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Scientific Report MeteoSwiss No. 104
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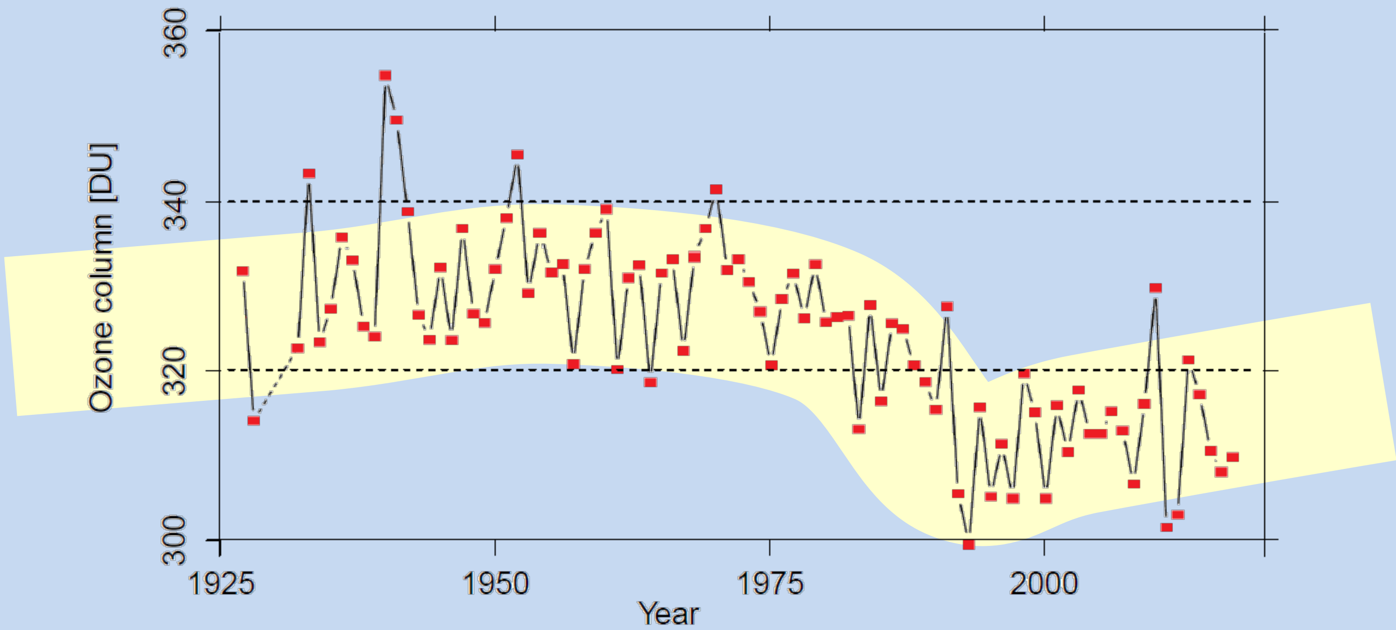
The Light Climatic Observatory Arosa

The story of the world's longest atmospheric ozone measurements

Johannes Staehelin and Pierre Viatte



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Foreword by Petteri Taalas, Secretary General of WMO

The history of the world longest series of total ozone of Arosa demonstrates several significant aspects of environmental monitoring. Total ozone measurements performed at the Light Climatic Observatory (LKO) provide a unique data set of continuous reliable measurements going back to the early 1930s. From the present report, we learn that in 1921 the municipality of Arosa (as "Kur- und Verkehrsverein") employed Dr. F. W. Paul Götz with the task to study the Radiation Climate of Arosa. Soon Götz became convinced of the necessity to measure total atmospheric ozone, i.e. the sum of all ozone in the stratosphere and troposphere, to understand climatology of ultraviolet radiation (UV), which was suspected to be essential for healthy alpine climate. Prior to treatment with modern antibiotics, lung tuberculosis (LTB) was a major factor for human mortality, and it was believed that a rest cure in the alpine climate strongly improved chances of recovery from LTB. In the years following World War II, when antibiotics became generally available, regular total ozone measurements of LKO needed a new justification for society. In looking back, it appears that the continuous high quality measurements of total ozone at LKO is a result of lucky circumstances, but mainly of the strong engagement of several personalities. In this context, it is of importance to highlight the merit of Prof. H.U. Dütsch, an earlier student of Götz, who played a key role in continuing the total ozone measurements.

The history of the LKO, though of local nature, reveals important features for reliable global monitoring. Satellite measurements of ozone begun in the late 1970s with continuous measurements assuring quasi-global coverage. However, reliable ground-based measurements remain crucial to date in order to guarantee and validate the long-term stability of the satellite data. When Molina and Rowland published their work on chlorine catalysed ozone destruction in 1974, they needed numerical modelling to quantify the effect of anthropogenic chemicals destroying stratospheric ozone (termed ODS, Ozone Depletion Substances). Continuous improvement of the numerical simulations led at the beginning of the 1980 to the conclusion that emissions of ODS could indeed lead to substantial damage of the ozone layer with detrimental health effects for the global population, unless world-wide emissions were curbed to stabilise ODS at levels of the 1970s. The measurements at the LKO, as longest reliable total ozone series, played a key role to show that the ozone loss in northern mid-latitudes, where the largest fraction of the global population lives and is exposed to changing UV-doses, was substantially larger than the chemical theory at this time predicted.

The total ozone measurements at the LKO had a stake in paving the way towards the signature of "The Montreal Protocol on Substances that Deplete the Ozone Layer" in 1987. The LKO observations are an integral part of the worldwide Global Atmosphere Watch network of the World Meteorological Organisation, in which the authors of this report were engaged for many years. The Montreal Protocol is an international success story, as catastrophic ozone loss could be avoided. Numerical simulations indicate that the extrapolated unlimited increase in ODS emissions would have led to large stratospheric ozone loss, with more than 50% of the stratospheric ozone lost in the second half of this century. However, the careful measurements need to be continued and they are expected to be substantially more challenging as the models predict an increase about three times slower than the decrease in the 1980s, requiring extreme long-term stability of the monitoring data. Recent studies provided evidence that the healing of ozone in certain layers of the stratosphere might be slower than expected, like due to climate change, further highlighting the importance of reliable monitoring. May this report contribute to the awareness of our responsibility for the ozone layer and for continuous measurements ensuring its preservation!

Prof. Dr. Petteri Taalas
Secretary-General
World Meteorological Organization
Geneva

Abstract

This document reports on the history of the Light Climatic Observatory (LKO) at Arosa, which spans nearly a century. The LKO was founded in 1921 by F. W. Paul Götz who became a leading scientist in ozone research. After his premature death in 1954, the continuation of the ozone measurements was highly uncertain and Hans Ulrich Dütsch, a former graduate student of Götz, eventually found a solution to continue the measurement activities at Arosa. He became responsible for the measurements of the LKO in 1962 maintaining and expanding their scope as professor at ETH Zürich (1965-1985). After his retirement (1985) the continuation of the long-term ozone measurements was in danger again until MeteoSwiss assumed overall responsibility for the long-term ozone measurements[1] of the LKO at Arosa in 1988. Only this decision enabled the world's longest total ozone measurement series to be kept alive. From the beginning until today the Arosa total ozone series proved to be particularly valuable to the global ozone community. In addition to total ozone, other valuable (long-term) ozone measurements are available from the LKO, such as the Umkehr series starting in 1956 as well as useful and representative surface ozone measurements[2].

The operational performance of long-term measurements needs support and hence justification. In the beginning the measurements at the LKO were justified by the search for environmental factors supporting therapy for tuberculosis in the mountains. This justification was obsolete a few years after World War II when modern antibiotic became available. In the 1940s Götz justified measurements of air pollution (surface ozone) by arguing that air quality is an important "natural resource" of resort areas. In the 1950s the scientific purpose of stratospheric ozone measurements at the LKO was connected to the improvement of weather forecasting. In the first part of the 1970s, reliable long-term stratospheric ozone measurements became important in the context of anthropogenic stratospheric ozone depletion. Since the middle of the 1990s, the focus lies on documentation of the recovery as expected from the 1987 Montreal Protocol. While the regulation of the Montreal Protocol saved the ozone layer from catastrophic loss recent studies suggest that climate change might significantly affect the further evolution of the ozone layer which require further studies and underlines the political relevance of continuation of high quality ozone measurements such as the longest total ozone measurements of Switzerland.

Looking back it appears rather accidental that the Arosa total ozone measurements have continued until the present day, especially that they were not discontinued in the early 1960s. The history of the almost century-long LKO demonstrates that the world longest total ozone series would not exist without the efforts of dedicated scientists and their involvement in the international scientific community and networks.

1 The long-term ozone measurements also include the ozonesondes that are regularly launched from Payerne by MeteoSwiss since 1968.

2 Representative surface ozone measurements of the LKO include data of the 1950/60s as well as continuous data since 1989.

Contents

1 Introduction

1.1 Aims of the report

This report is the result of a common effort of ETH Zürich and MeteoSwiss to provide a "historical LKO Ozone study" providing an overview of the eventful history of the Light Climatic Observatory[3], which was located at different sites in Arosa (see Figure 1). Arosa is famous in the ozone science community because the measurements, which started in 1926, led to the world's longest series of total ozone. Furthermore, the first reliable ozone profile data using the Umkehr method were performed at Arosa in 1932/1933 and began to be performed on a routine basis from 1956. In addition, surface ozone measurements were conducted based on long path UV absorption techniques in the 1930s, based on chemical methods in the 1950s and using modern analyzers since 1989.

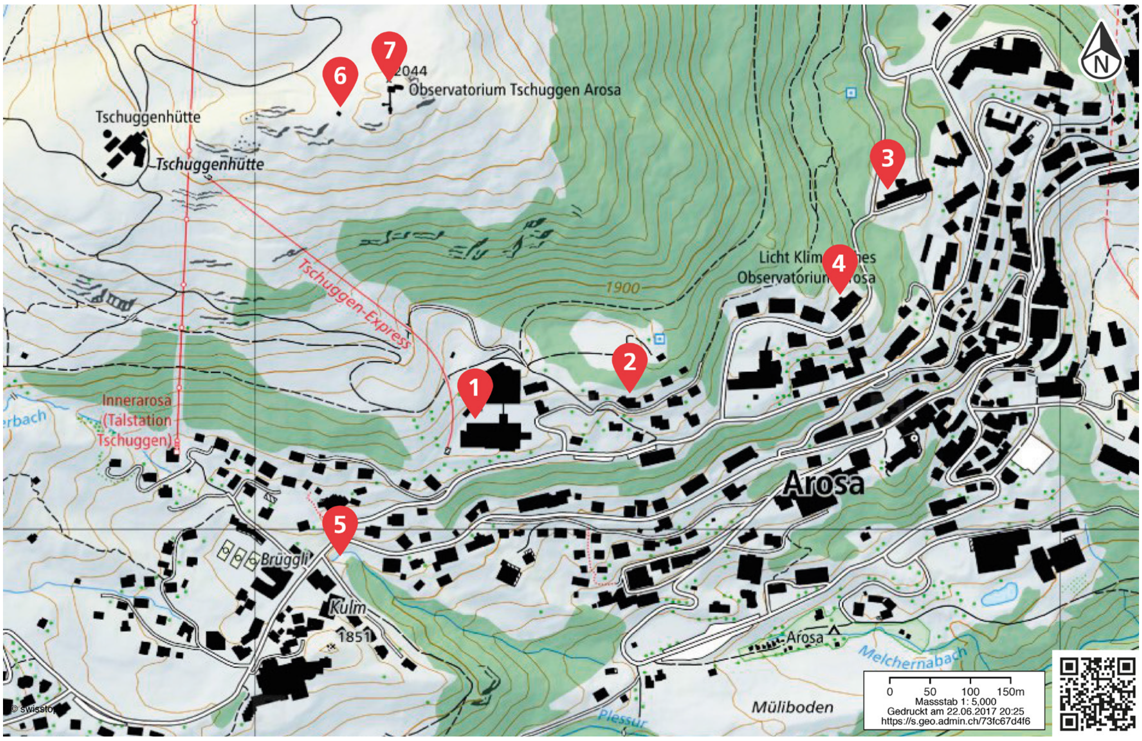

Figure 1: Map of important locations in Arosa relevant to the LKO (refer to text). LKO measurement sites: 1) Sanatorium Arosa 1921-1926; 2) Villa Firnelicht 1926-1953; 3) Florentinum 1954-1973; 4) Haus Steinbruch (since 1973). Other sites: 5) Götzbrunnen (fountain in honor of Götz); 6) Hut where Götz made his nighttime measurements at Tschuggen; 7) Astrophysical observatory at Tschuggen. With permission of swisstopo (Swiss digital maps, geo.admin.ch, from Staehelin et al., 2018a).

This report aims at demonstrating the key importance of the ozone measurements performed in Arosa to the international ozone research. The idea of the "historical LKO ozone study" goes back to

3 Lichtklimatisches Observatorium (LKO). From 1921-1926 the Light Climatic Observatory was designated as the Light Climatic Station (Lichtklimatische Station (LKS)).

the contribution of the authors to a publication highlighting the important contributions of Swiss scientists to international ozone science (Staehelin et al., 2016). In this chapter of a book published to celebrate the 100 years of the Swiss Society for Meteorology (Willemse and Furger, 2016) we underscored the many important contributions of Swiss scientists to ozone science. F. C. Schönbein, who discovered ozone in Basel in 1839, F. W. P Götz and H. U. Dütsch were named as "Swiss ozone pioneers". It is easy to put their scientific contributions in the proper context of international ozone research. However, it appeared that the historical background of the ozone measurements including their societal justification and institutional support – at least for the first decades – has not yet been well documented. As much material was available for such a study, the authors of the report (retired ozone scientists from ETH Zürich and MeteoSwiss, encouraged by Prof. Dr Thomas Peter (IACETH, refer to footnote 12 on page 4) and Prof. Dr Bertrand Calpini (Deputy Director of MeteoSwiss), were motivated to continue the efforts to unveil the early periods of the LKO. Bertrand Calpini came up with a proposal to present in a book the most attractive part of this material to the public (see below).

This report constitutes the basic document and summarizes the main results of the "historical LKO ozone study". It contains valuable information for different types of readers, ranging from ozone scientists to people interested in the history of environmental science. Particular emphasis is given to the development of atmospheric ozone measurement techniques. Nonetheless, this report is not meant to be used as an atmospheric ozone textbook. Given how little has so far been published about the first years of the LKO, the report gives special attention to the early history including the life of Götz and the developments around the observatory. In addition, it provides a comprehensive summary of all measurements performed at the LKO in Arosa, and an overview of all persons involved in the instrument operation and analysis of these measurements. Furthermore, it documents the evolution of the costs related to running the LKO as well as of the means dedicated to the activities of Swiss scientists making use of the data, which can be considered as part of the added value generated thanks to the measurements.

This report also serves as documentary basis for a book written by Martin Läubli [4] entitled "Licht, Luft, Ozon" (to be published in summer 2019), which presents the ozone history in a way attractive for interested laypersons. The book follows the same idea as this report, demonstrating the historical motivation of scientists to start, maintain and utilize these reliable ozone measurements: the early days in Arosa, the health-related and medical aspects of ozone, the task of demonstrating the success of the 1987 Montreal Protocol, and finally the ozone-climate interactions (1987).

Parts of the report have been published in the specialized scientific literature (Staehelin et al., 2018a). The paper focuses on the justification of the ozone measurements and its changes over the decades in the context of the history of international ozone research. The international ozone science community shows particular interest in some results of the study, as the community is facing increasing problems to continue the high-quality ozone station measurements worldwide. Indeed, continuous measurements as in Arosa require financial support. Staehelin et al. (2018a) reported that the MeteoSwiss Management Board decided in 2015 to explore the possibility of moving the Arosa measurements to the Physical Meteorological Observatory Davos (PMOD). Such a move would have the advantage to combine the excellent technical infrastructure and expertise available at the PMOD in Davos with a reduction of the measurement costs. Presently simultaneous total ozone measure-

4 Martin Läubli, Science Editor and Geographer ments of Brewer instruments of Davos and Arosa have been analyzed and presented (Stübi et al., 2017a). Nevertheless, before stopping the measurements at Arosa, it is essential to study a currently ongoing multiannual period of overlapping measurements also with Dobson spectrophotometers at both sites (Arosa and Davos). A break in the world's longest total ozone time series would be very unfortunate. As Staehelin et al. (2018a) also point out, a relocation is particularly challenging as stratospheric recovery from ODS is expected to be slow, meaning that ozone changes will be small, and thus very high-quality measurements are required.

1.2 Information sources

The early history of the LKO is strongly based on the information in the LKO Archives [5] where the many letters received by Götz are stored [6]. Other important sources of information are the annual reports (AR) of the Kur- und Verkehrsverein Arosa (KVV Arosa) [7], articles in the newspaper of Arosa [8] and our own investigations, e.g. by visiting federal, cantonal and municipal archives. Among others, we had the help of Renzo Semadeni and several experts as the historian Peter Bollier [9] and the science historian Brigit Bischof [10]. The personal views, discussions and further documents provided by the children of Dütsch were very helpful. The many persons providing invaluable assistance are named in the acknowledgments.

1.3 Structure of the report

The first chapters of the report generally follow the different phases of the LKO. In Chapter 2 we describe the historical factors important for the establishment of the LKO in Arosa. In the following chapters we attempt to describe the evolution of the LKO in the context of international ozone research. Chapter 3 (1921-1954) covers the period spanning from the founding of the LKO to Götz's death (1954). These first decades were basically determined by F. W. Paul Götz who founded the LKO. He became one of the world leading ozone scientists and this publication intends to put the scientific merits of Götz in an historical perspective, e.g. by describing the scientific arguments and reflections behind Götz's expedition to Svalbard [11] in 1929, which led to the discovery of the Umkehr method providing the first reliable atmospheric ozone profile measurements. Chapter 4 (1954-1962) describes a period during which Gertrud Perl was in charge of the measurement of the LKO and

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5 At the time of publication of this report the correspondence is located at MeteoSwiss in Payerne whereas the data sheets are stored in the Federal Archives in Bern.

6 As Götz generally did not make a copy of the letters he wrote, the number of letters written by Götz in the LKO archive is very limited. If a letter is (solely) referenced by (sender) name and date, this means that the respective letter was found in the LKO archives. Unfortunately, many key documents of Götz such as contracts and others are missing.

7 The "Kur- und Verkehrsverein Arosa" (KVV Arosa) was legally registered as a cooperative; the name of the present (subsequent) organization is "Arosa Tourismus". It had a considerable budget, mainly sponsored by the "tourist tax" (Kurtaxe, i.e. a fee to be paid by foreigners/guests staying in Arosa), which was used to cover the costs of various activities, some of them currently falling under the responsibility of the municipality. For more information see Section 3.1.

8 "Fremdenblatt Arosa". Newspaper published twice a month for pulmonary tuberculosis (TB) patients and tourists of Arosa (Sect. 2.1) covering a calendar of events, articles of public interest and a list of names of patients and other foreigners living in the individual sanatoria of Arosa.

9 Peter Bollier is a well-known expert of history from Davos who worked as teacher at the Schweizerische Alpine Mittelschule Davos. Bollier wrote two books about Gustloff, a former coworker of Dorno, and the Nazis in Davos (Bollier, 2016 and 2018).

10 Brigitte Bischof, Mag.a rer. nat., physicist and science historian, University of Vienna.

11 Götz speaks of "Spitzbergen" (Spitsbergen), the largest and only permanently populated island of the archipelago Svalbard in northern Norway.

when the continuation of measurements was highly uncertain. Chapter 5 (1962-1985) is devoted to the period in which Hans Ulrich Dütsch (professor at ETH Zürich and head of IACETH[12]) was responsible for measurements at the LKO. Chapter 6 (1985-1987) corresponds to an intermediate period following the retirement of Dütsch in which the continuation of the LKO was not guaranteed for about three years before a re-orientation occurred. In 1988 the LKO became part of MeteoSwiss[13] and a joint leadership with the ETH Zürich was established (Chapter 7, from 1988 to 2014[14]). Chapter 8 covers the time since 2015 including remarks on the future and the observatory's anticipated move to Davos. In the Chapters 6-8, we describe the international scientific evolutions and related requirements in the first sections before presenting the Swiss contributions in the subsequent sections. Chapter 9 proposes an inventory indicating the development of the LKO as a synopsis (overview of measurements and instruments used, listing of coworkers and the scientists involved as well as the budget situation). Chapter 10 consists of the summary and outlook.

The report ends with several appendices and annexes[15]. Appendix 1 includes a short description (in German) of the life of Margarethe Karoline Götz-Beversdorff, the wife of Götz and Appendix 2 documents the naturalization of Götz and his wife in 1946 whereas the different annexes contain the (travel)-journal (in German) written by Götz during his expedition to Svalbard, the publication lists of Götz, Perl and Dütsch as well as the common publications[16] of ozone researchers of ETH Zürich and MeteoSwiss and finally an inventory of the correspondence of Dorno respectively Dobson with Götz.

12 IACETH: Institute for Atmospheric and Climate Science of ETH Zürich since 2001; earlier LAPETH: Laboratory for Atmospheric Physics of ETH Zürich.

13 MeteoSwiss: Federal Office of Meteorology and Climatology (Bundesamt für Meteorologie und Klimatologie MeteoSchweiz), earlier: Schweizerische Meteorologische Anstalt (SMA), before: Meteorologische Zentralanstalt (MZA).

14 This period ends in 2014 when the scientific partner at IACETH (Staehelin) retired.

15 We distinguish between appendix (part of the main text) and annex (independent document).

16 Beginning in 1989.

2 Important factors for the founding of the Light Climatic Observatory (LKO)

The world famous total ozone measurements were performed at the alpine resort area Arosa. We start this chapter with a short section on the demographic evolution of Arosa and the nearby Davos since several important connections relevant in this context exist between the two famous alpine resort villages. After this, we present a short section about the medical treatment of pulmonary tuberculosis (TB) before modern antibiotics became available and a short introduction of the Observatory Dorno, the institution preceding the Physical Meteorological Observatory Davos (PMOD)[17], ending with a section of the life of Götz before he founded the Light Climatic Observatory at Arosa in 1921.

2.1 Davos and Arosa around the beginning of the 20th century

Davos[18] was first populated in the High Middle Age by Rhaeto-Romans[19] followed by a German speaking Walser population that were allowed to immigrate from the Canton of Valais starting in 1280. Until the middle of the 19th century Davos was a rather small village and the population lived primarily from agriculture. In 1850 the population size was 1,680 (see Table 1). After around 1865 Davos grew rapidly because it became a famous place for therapy in pulmonary TB (e.g. Virchow, 2004). In 1910, 26,656 patients stayed in Davos (SFI, 1997). It appears that the patients needed to pay by themselves (at least in earlier time) and therefore mostly rich patients coming from all over Europe stayed in Davos (and Arosa) to recover from pulmonary TB. Many sanatoria were built and the "Fremdenblatt Arosa"[20] was produced. This implies that the sanatoria were also important economic factors for Davos (e.g. Schürer, 2017).

The period of the World War I was an economic challenge for Davos as it became much more difficult for the rich clients to travel to Davos for treatment against TB. But according to Bollier the national border between Germany and Switzerland was much more permeable in World War I than in World War II and many Germans and French stayed in Switzerland (Bollier, oral communication, 2016). A particular program was set up for internees who were military persons injured in war or suffering from health problems. Even before start of World War I, a program was negotiated under the auspices of the Swiss Federal Council[21], the Red Cross and the pope in order to enable internees to recover from their health problems. In Davos, the Swiss tradition of Red Cross probably was important in this context as well as the possibility to fill the beds of hotels and sanatoria during the war. The most challenging part of this program was how to deal with those internees who recovered

17 Physikalisch-Meteorologisches Observatorium Davos (PMOD). Since 1971 the PMOD serves as World Radiation Center (WRC) of the World Meteorological Organization (WMO) (refer to http: www.pmodwrc.ch).

18 The information about Davos mainly originates from Wikipedia.

19 The main population of the Canton of Grisons (Graubünden) at this time.

20 Refer to footnote 8 on page 3.

21 Bundesrat

rather soon and therefore could be sent to the front again. This required a diplomatic agreement. In this agreement Davos played an important role as center for German internees with special programs for different types of internees and multiple courses and education programs were organized. Fridericianum in particular (Sect. 2.4) was important in this program for internees, offering special courses in addition to regular courses for young adults.

Table 1 indicates that population growth in Davos between 1900 and 1930 was rather moderate and the population was approximately stable thereafter.

Table 1: Population size of Davos and Arosa (from Wikipedia Davos and Arosa).

Year	Population Davos	Population Arosa
1850	1,680	52
1870		61
1888	3,891	88
1900	8,089	1,071
1930	11,164	3,366
1950	10,433	
1970		2,717
1980		2,782
2010	11,166	2,251

Arosa is located in the valley adjacent to Davos (see Figure 2) and was always less populated than Davos (see Table 1). Arosa was first inhabited by people coming from Davos around 1300. The settlers also belonged to the (German speaking) Walser population passing from Davos using the Strela pass, which was the main route to reach Arosa for many centuries. Arosa was part of the political community of Davos until 1851 and the number of inhabitants was very small (52 in 1850, see Table 1). This changed rapidly when a road was constructed in 1875 allowing direct connection from Chur to Arosa through the Plessur valley.

In 1877, the first guesthouse was opened and in 1888 the first sanatorium for TB patients started – it was argued that Arosa could be an even more suitable village for this type of therapy (see below) than Davos because of its special topography (see Figure 2 and Figure 3) [22]. Until the end of the 19th century the population growth was very fast and around 1900 a first economic maximum was reached. In that period the population grew from 61 in 1870 to 1,071 in 1900. Thereafter the growth of Arosa remained rapid, i.e. the population grew to 3,466 in 1930 [23]. The construction of the railway from Chur to Arosa (1912-1914) enhanced the accessibility of Arosa. However, World War I and the economic depression in the 1930s were also difficult times for Arosa.

22 Figure 2 shows clearly that the Plessur valley makes a sharp turn at Langwies and ends upwind from Arosa in the plain (“dead end”) causing low wind speed (Dütsch, 1973 and Sect. 3.5.2), whereas the Landwasser valley containing Davos is a rather straight valley and therefore more directly exposed to higher wind speed.

23 https://www.gemeindearosa.ch/portrait/geschichte.html

Figure 2: Map of Arosa and surroundings (Swiss digital maps, geo.admin.ch).

Figure 3: Aerial view of Arosa giving an idea of the topographical position (F=Villa Firnelicht, S=Haus Steinbruch) (Photo Reportair).

2.2 Treatment of tuberculosis prior to antibiotics

TB was a very serious sickness often leading to death before treatment with modern antibiotics was available. This happened a few years after World War II in Switzerland and surrounding countries. The state-of-the-art medical treatment of patients suffering from TB in Switzerland was the rest cure according to Turban[24]. Virchov (2004) includes a short summary of the medical treatment of TB until 1912. The patients were asked to move to an alpine site and they rested staying outside (on balconies) during the day (mostly not directly exposed to sun) (see Figure 4). In the following we describe the achievements of two medical doctors most relevant in the context of our report. For more details on important medical doctors and other aspects of this type of therapy refer to Bergamin (2017) and Schürer (2017) and also compare with Läubli (2019).

Figure 4: The photography illustrates the concept of rest cure according to Turban (see text), which was viewed as the best therapy against TB before antibiotics became available. (Photo Davos-Klosters website, Thomas Mann & der Zauberberg).

An important pioneer for medical treatment of pulmonary TB was Turban [25] (Bergamin, 2017). He first worked as a general practitioner in Weinheim (Germany) before hearing from the discovery of the TB bacillus by Robert Koch (1882). Thereafter he was an assistant of Koch in Berlin where he himself became sick from TB. After recovering he was asked to move to Davos to take the medical lead of a planned sanatorium. After having seen the medical treatment in Sanatoria in Davos he was shocked by the way the pulmonary TB patients behaved in the hotels in Davos – seriously ill patients were sent to walking tours in the high mountains, going to concerts in Davos, drinking beer and dancing –

24 Heliotherapy was discovered by Dr Oscar Bernhard (1861-1939), a medical doctor from Samedan (Engadin valley in the Grisons, Switzerland) (Hoffman, 2011). He applied heliotherapy to bone TB. Davos and Arosa were famous rest cure destinations for patients suffering from pulmonary TB.

25 Dr Karl Turban (1856-1935), physician in Davos. For information concerning Turban refer to Bergamin, 2017.

under the eyes of medical doctors. Turban opened in 1889 the first closed large sanatorium in Davos (Sanatorium Turban) and he introduced the rest cure in closed sanatoria. He combined very strict rules for hygiene and the typical rest cure treatment, namely the patients lying outside all day. He was convinced that the high alpine climate was a very important factor for recovery. Turban had an excellent reputation and many lung TB patients from all over the world travelled to Davos for treatment.

Amrein[26] was a very active medical doctor in Arosa – he originally suffered from TB as a young man and recovered from it in Arosa. He subsequently studied medicine but he was again infected with TB when he was working as an assistant doctor in Wald (Zürich area). He then applied to work as assistant doctor under Turban in Davos, which was not feasible at that time, but worked instead as a medical doctor in Davos. Finally, when the possibility was offered to him in 1900 to work directly under Turban, he was simultaneously asked to work in Arosa as a general practitioner. Faced with these two options, he ultimately decided to move to Arosa. Once there, he was more and more involved in medical treatment of TB patients and he became internationally famous, attracting patients from all over Europe to recover from TB. In order to avoid (re)infection by TB, Amrein (along with other medical doctors) was able to introduce a law concerning hygiene in Arosa. Subsequently he was involved in the construction of the large sanatorium Altein in Arosa (1914-1916) where he treated clients from all over Europe (many came from the UK), essentially following the concept used by Turban in Davos. He also was successful in organizing private sponsoring for destitute clients so that they could recover from TB in Arosa. But in the 1930s international clients could no longer afford to come to Arosa because of the Great Depression. The Sanatorium Altein was closed in 1931, subsequently reopened as a Sport Hotel before becoming a clinic once again.

Amrein was an internationally famous medical expert in the treatment of TB. Already in 1902, two years after starting as a general practitioner in Arosa, Amrein gave a presentation at an international conference in London. In 1908, he travelled to the US, first as a delegate at an assembly of delegates in Philadelphia. Subsequently he gave an oral presentation at an international congress about TB in Washington and at the end of this trip he was among the delegates invited to meet President Roosevelt in the White House. In the following years Amrein participated regularly in international congresses. He also contributed to research for about 60 publications. In 1917, he published a comprehensive book on pulmonary TB (Amrein, 1917). The book was written for practical doctors and students and is notable for Amrein's excellent overview of all important aspects relevant to pulmonary TB. It contains a brilliant review of the knowledge of TB stretching back to ancient times[27]. The book contains detailed instructions about diagnosis, the different stages of pulmonary TB and the various types of therapy including Pneumothorax[28]. After the discovery of the bacillus of TB by R. Koch in 1882 it was clear that infection was required to become ill from TB. It was also known that a large fraction of population had contact with the bacillus but never exhibited symptoms of the sickness. Infection (and reinfection) needed to be avoided as best as possible. The most important pathway of TB bacteria was believed to be through infected sputum if the water of the sputum evaporated. The last chapter of the book lists in detail the attempts to avoid infection in the public area by

26 Dr Oscar Amrein (1874-1935), physician in Arosa, Director of the Sanatorium Altein Arosa (1916-1931); President of the Medical Doctors Association of Arosa, member of the board of the KVV Arosa. The information concerning Amrein is taken from Gartmann (2007).

27 In ancient times pulmonary tuberculosis (TB) was called "Phtisis pulmonum".

28 Air was injected in the neighborhood of the infected part of the lung to allow the tissue to recover.

pointing out the key role of public hygiene and discusses the possibility of mandatory registration of persons found to be suffering from pulmonary TB. It was noted that the evolution of TB differed strongly among individuals and that for the best treatment an early diagnosis was thought to be crucial. For therapy the patients needed to rest (both physically as well as mentally) and were urged to no longer live in the family and environment where they become ill. The clients should move to special hospitals (Heilstätte) and sanatoria. The patients with fever needed to stay in bed. Consequently, the careful observation of fever was viewed as a very important indicator of the evolution of TB. The rest, implying to stay all the days on balconies in outside air, was regarded as the most successful therapy.

Amrein believed that an alpine area provided the best environment for recovery from TB – he proposed that the only reason not to follow this type of therapy was if the general health condition of the patient was too bad to travel to a high alpine site. He was aware that some medical doctors did not agree with the important role of climate for recovery from TB and supported the idea of a large international study. This was proposed but not feasible during World War I. Being convinced that the alpine climate was superior to others for recovery from pulmonary TB, he listed the following environmental factors as potentially relevant: low pressure and dryness of air, absence of large temperature differences, weak winds, absence of air pollution (fog, dust and smoke), presence of ozone and an abundance of natural light and sunshine.

Two textbooks for medical students that were published around 1940 (Assmann et al, 1939 and von Domarus, 1941[29]) detail the medical view of pulmonary TB and its medical treatment approximately a decade before modern antibiotics were available. The description of the medical knowledge history is very similar to that written by Amrein. Assmann et al. (1939) state that mortality from TB as described by statistics of the German Empire was large in 1885 but followed a strong downward trend until 1930. The number of cases per 10,000 dropped from 25 per year in 1895 to approximately 8 in 1930 with a strong intermittent increase again during World War I. The general decrease was probably caused by increasing public awareness of the bacillus being transferred by sputum, confirming that proper public hygiene was important. The intermittent increase during World War I was attributed by Assmann to bad nutrition among the population. In the 1930s, reliable diagnostics were available by bacteriological assay as well as by using X-ray.

The textbooks were state-of–the-art until World War II and highlight the importance of nutrition; otherwise there is no obvious difference to Amrein's book, which was published in 1917[30]. It appears that the rest therapy was considered to be most effective in supporting the body's recovery from lung TB (prior to availability of antibiotics). However, the beneficial effect of high altitudes for therapy of TB was never demonstrated by scientific studies (Schürer, 2017).

Suffering from TB and the death of young people was the subject of several masterpieces[31]. In the famous book the "Magic Mountain"[32] by Thomas Mann, the male hero visits Davos where he gets infected by pulmonary TB. According to Virchow (2004), Thomas Mann came to Davos for four

29 The textbook of Assmann et al. (1939) contains more details than von Domarus (1941) but essentially the same information.

30 Including reinfection, relaxation, hygienic conditions and alpine environment.

31 For example, the opera "La Bohème" of Giacomo Puccini (1896) and the book "Drei Kameraden" of Erich Maria Remarque (first published in 1937).

32 The "Magic Mountain" (Der Zauberberg) is a novel by the German writer Thomas Mann, first published in German in November 1924.

weeks in May/June 1912 to visit his wife who was staying there to recover from pulmonary TB[33]. The reactions of Davos' medical doctors to Mann's book were mostly negative when it was published more than 12 years after his visit to Davos as it contained, in their view, heavy criticism regarding the treatment of TB patients. One of the criticisms was Mann's descriptions of personal characteristics of doctors and other sanatoria staff in a way that they could be recognized, but the treatment of pulmonary TB patients was only part of the book's main history. Nevertheless, the occasional indecent behavior of pulmonary TB clients in closed sanatoria was subject to criticism, as the concept of the rest cure consisted of staying quiet on balconies for many weeks without many possibilities of distraction, as mentioned by several experts (Virchow, 2004), raising the question of whether the psychological wellbeing of TB patients was adequate. In contrast to the majority of the doctors of Davos, Amrein (1928) published in the medical literature in May 1928 a statement that TB patients as described by Mann indeed existed, stating that it is the duty of the medical doctors to protect the patients against the negative influence of the "Magic Mountain" environment. We might speculate that the distinctly different public statement of Amrein might be viewed as an indicator of possible problems in the medical communities of Davos and Arosa as they were competing for TB clients. This might have played some role in the collaboration between Davos and Arosa in medical and climatological research (Sect. 3.2).

2.3 Observatory Dorno and institute for tuberculosis research

Though the rest cure was well established in TB therapy, direct evidence for its success was lacking and some debates took place among medical doctors questioning the benefit of high alpine locations (Pischinger, 1927). As early as 1905, Turban (Sect. 2.2) made a proposal to establish an institute in Davos to study the effectiveness of this type of lung therapy (SFI, 1997). But because of different opinions and a lack of consensus among the medical doctors such an institute was finally established only in 1922 under the leadership of Erhard Branger[34], Mayor of Davos. On 22 March 1922, a decision was taken at the municipality assembly to establish a foundation for supporting a new institute for high altitude physiology and tuberculosis research[35] (SFI) in Davos. The financial resources for the foundation were provided from different sponsors and it was decided that all foreigners living in Davos that needed to register had to pay a small tax (0.05 CHF) per night to support the institute (for more details refer to SFI, 1997). For the proper study of the effectiveness of rest cure therapy at alpine sites, knowledge about the environmental conditions of an alpine area was undoubtedly important.

Dorno[36] founded in 1907 an observatory in Davos using his own resources, aiming to study the environmental factors important for the recovery from TB at alpine sites (SFI, 1997). Dorno first financed his observatory using his own means. He originated from a rich family from Königsberg (Germany). However, he lost most of his financial resources during World War I and the subsequent period of inflation. The community assembly of Davos decided on 18 February 1923 to support the Observato-

33 Though the diagnosis was wrong according to Virchow (2004).

34 Erhard Branger (1881-1958), PhD, Mayor (Landamman) of Davos (1920-1936), Director of the Rhaetian Railway (1936-1949).

35 Schweizerisches Forschungsinstitut für Hochgebirgsphysiologie und Tuberkuloseforschung (SFI), today: Schweizerisches Forschungsinstitut für Hochgebirgsklima und Medizin (SFI) (Swiss Research Institute for High Altitude Climate and Medicine).

36 Carl Dorno (1865-1942), PhD, professor, originally came to Davos in 1904 because his daughter suffered from TB. Although she passed away a few years after arriving in Davos, Dorno stayed at Davos until he died in 1942.

ry Dorno. When Dorno retired as director in 1926, the observatory was integrated and financed as an independent department of the SFI [37]. After full retirement in 1928, Dorno continued to contribute to research (for more details refer to SFI, 1997). Though the community of Davos provided additional financial resources to support the part of the Observatory Dorno, the problems of SFI with funding shortages remained, particularly for medical research (SFI, 1997). Dorno's observatory was the nucleus of the PMOD.

2.4 Götz's life before the founding of the LKO

Friedrich Wilhelm Paul Götz [38] was a German scientist who was working with Dorno in Davos in 1919-1920 (see Table 2) before founding the LKO in Arosa (Sect. 3.1). Regarding the life of Götz prior to the founding of the LKO the following important obituaries written by Trenkel [39] (1954), Waldmeier [40] (1955), Dütsch [41] (1954a, 1954b, 1954c and 1955) and a publication of Dütsch (1992) are available (see Figure 5). A CV written by Götz exists but is incomplete. Since none of these documents describe this period of Götz's life comprehensively, we complemented the published information with our own research in various public and private archives.

Götz grew up in Göppingen, a village near Stuttgart in Germany (see Figure 5), where his father Paul was running a hardware store. According to Trenkel (1954) his father expected him to continue his business, but Götz decided to study astrophysics. Waldmeier (1955) writes that Götz started his studies in physics and mathematics in 1910 in Heilbronn and that he originally intended to achieve a high-school teaching [42] degree for mathematics and physics. However, Götz had already started his scientific education in astronomy in 1912, receiving a "good education" in photometry in Tübingen under Rosenberg [43] and "excellent training" under Wolf [44] in Heidelberg in astronomical photography. This work led to his PhD dissertation titled "Photographische Photometrie der Mondoberfläche" [45], which was accepted in 1919.

In agreement with Trenkel we were able to document that Götz first stayed in Davos for health reasons (see Table 2). In the "release book" [46] of the patients leaving the German Sanatorium [47] the

37 The name of the medical department (Tuberculosis Research Institute) was changed in 1988 to Swiss Institute of Allergy and Asthma Research (SIAF) (Schweizerisches Institut für Allergie- und Asthmaforschung).

38 Note that F.W. Paul Götz is obviously not the same person as Paul Götz (1883-1962) who, by pure coincidence, was almost of the same age and (also) graduated in astronomy under M. Wolf at the university of Heidelberg in 1907 (refer to Wikipedia Paul Götz astronomer) as confirmed by a letter found in the LKO archives.

39 Heinrich Trenkel, PhD, was a medical doctor at Arosa and a personal friend of Götz.

40 Max Waldmeier (1912-2000), PhD, Professor for Astronomy at ETH Zürich (1945-1979) and University Zürich (1945-1982), Director of the Swiss National Observatory (Semper Observatory) (1945-1979) (Christian Bartsch, Swiss Lexicon).

41 Hans Ulrich Dütsch refer to Section 5.1.

42 "Gymnasium" is often translated in English as "high school". This translation is, however, not completely correct as a Gymnasium includes part of the college and is not designed as an integrated school.

43 Hans Oswald Rosenberg (1879-1940), Director of the Astronomical Observatory in Tübingen, professor at the University of Kiel (1926-1934), University of Chigaco (1934-1937) and University of Istanbul (1937-1940).

44 Maximilian Franz Joseph Cornelius Max Wolf (1863-1932), Professor of Astronomy and Director of the Astronomical Observatory of Heidelberg-Königsstuhl (1902-1932).

45 "Photographic photometry of the lunar surface". Translated by the authors.

46 Entlassungsbuch Deutsche Heilstätte, Davos Wolfgang.

47 Deutsche Heilstätte, today: Hochgebirgsklinik Davos. The German Sanatorium belonged to the type of Sanatoria called "Heilstätte" designating a public institution for indigent and needy residents (Bergamin, 2017).

name of Paul Götz is listed twice[48]. The German Sanatorium in Davos was famous for therapy in pulmonary TB and therefore we believe that Götz indeed suffered from this widespread serious illness[49]. The information of the "release book" also contains the periods of his stays; the first lasted from 27 March to 10 August 1914, the second from 27 October 1914 to 26 May 1915. At the end of the curative stays Götz was declared fit for work. It is interesting to note that Götz travelled to Davos for the first time before World War I started[50].

Table 2: Götz in Davos.

Deutsche Heilstätte [a)]	**Information from municipality: residence permit** duration (profession and permit)	**Fridericianum** [b)] **Annual report** (temporal coverage)
20.3.1914-10.8.1914 27.10.1914-26.6.1915		
	Permit from municipality: 4.2.1916-1.2.1917 (teacher, Fridericianum) (date of arrival: not found at municipality, probably close to date of start for permit) date of departure: 13.10.1916	1916/17: until beginning Oct. 1916 [c)]
	Permit from municipality: 9.7.1918-1.7.1919 (teacher, Chalet Derungs) date of arrival: 9.7.1918	1917/19: until 15.11.1919 [d)]
	Permit from municipality: 12.9.1918-1.9.1919 (teacher, Chalet Derungs and Villa Sonnenhof) date of arrival: 9.7.1918 Change in legal status: 29.9.1919 [e)]	Not listed in later Annual Reports of Fridercianum
	Permit from municipality in the form of [e)]*:* 29.9.1919-21.10.1924 (teacher, Sonnenhof) Coworker of PMOD according to Dütsch, 1973 Date of departure: April 1920	

[a)] From book of patients leaving sanatorium Deutsche Heilstätte ("Entlassungsbuch")
[b)] German school in Davos
[c)] Jahresbericht über das Fridericianum zu Davos, Militärberechtigte deutsche Auslandschule, Gymnasium mit Realabteilungen (Schulsanatorium); XXXIX. Schuljahr 1916/17, Herausgegeben im August des Kriegsjahres 1917
[d)] Jahresbericht über das Fridericianum zu Davos, Deutsche Ausland-Vollanstalt, Gymnasium mit Realabteilungen (Schulsanatorium); XXXX und XXXXI: Schuljahr 1917/19, Herausgegeben im September 1919
[e)] Change into a longer residence permit ("Niederlassung")

About half a year after his treatment ended at the German sanatorium, Götz stayed in Davos again, namely in the German school Fridericianum [51] (see Table 2). From the inquiry of Bollier we know that Götz was a teacher at the Fridericianum in Davos. From the Annual Report of Fridericianum 1915/16

48 We do not question the identity of Götz as he is listed as "cand. math." originating from Württemberg, Germany.

49 Note that patients of the German Sanatorium did not need to register in the municipality.

50 28 July 1914.

51 "Fridericianum zu Davos was a military approved German Foreign school". Translated by the authors. Original designation: „Fridericianum zu Davos, Ausland-Vollanstalt, Gymnasium mit Realabteilung. Berechtigung zur Ausstellung von Zeugnissen über die Befähigung für den einjährigen–freiwilligen Militärdienst."

(p.10-11) [52] we learn that teacher trainee Paul Götz from Göppingen, formerly assistant of the observatory of Königstuhl near Heidelberg, replaced another teacher at the end of October 1915 who joined the army. Götz took the responsibility of giving lectures in chemistry and physics (first grade) as well as lectures in mathematics and natural sciences for the senior grade [53]. In the Annual Report of 1916/17, it is noted (p. 22-23) that Götz resigned from his employment at the end of October 1916. Götz was teaching again, presumably from July 1918 until 15 February 1919 (see Table 2). This information is confirmed by documents found at the municipal administration of Davos [54] (see Table 2). However, apparently Götz started to teach in 1916 about six months before he was registered in the municipality. His health had obviously recovered sufficiently to teach several classes in mathematics and physics at the Fridericianum, which is believed to be a rather challenging job [55]. A publication of Götz in a journal for teachers [56] (Götz, 1922) seems to be related to his engagement as a teacher at the Fridericianum.

Götz stayed altogether a little more than half of the time from 1914 to 1919 intermittently in Davos. We do not know where he spent the rest of the time. Götz writes in a letter to Amrein on 19 January 1926 (Sect. 3.2) that his life's plans were disturbed [57] by World War I, and he writes that he needed to serve in military ancillary service. However, there is no evidence that Götz did serve among the combat troops of the German army. We might speculate that he was not very patriotic as he avoided using the first given names Friedrich Wilhelm, the first names of the German Emperors given by his parents but preferred to be called Paul (the third given name). In the scientific literature he always appears as F. W. Paul Götz. It seems most plausible that Götz was working at least partially on his PhD thesis in Germany in the meantime when he was not present in Switzerland, as otherwise he most probably would not have been able to finish his PhD within one year after the war ended.

Götz also had a permit to stay in Davos for the period 29 September 1919 - 21 October 1924 (see Table 2). For this period Götz is not listed as a teacher in Fridericianum. Apparently Götz was working some time as assistant at the Observatory Dorno in 1919-1920 before he went to Arosa (Casti, 1971 and Dütsch, 1973; Figure 5) [58]. In this collaboration Götz (Götz, 1925, see also Sect. 9.1.2.a) studied the spectrograms of the UV spectrum recorder of Davos with the microphotometer of the astronomical observatory of Tübingen [59] using light detection by photographic plates. But he was not satisfied with the results of this study [60], documenting differing views of Dorno and Götz regarding instrumental requirements and design. Götz left Davos on April 1920 (see Table 2) four years before the permit ended and one and a half year before the founding of the LKO (Sect. 3.1) in Arosa.

52 The school year started in August and ended in June.

53 Of one department (Realabteilung der Oberprima).

54 Kindly provided by Susanne Wernli, Municipality of Davos.

55 Götz was never an internee as shown by Wernli in the documentation of the municipality of Davos.

56 Schweizerische Lehrerzeitung

57 Letter Götz, 19 January 1926. Original text: „aus seiner Laufbahn herausgerissen wurde".

58 We do not know any details about the job conditions, i.e. the level of employment, duration and salary.

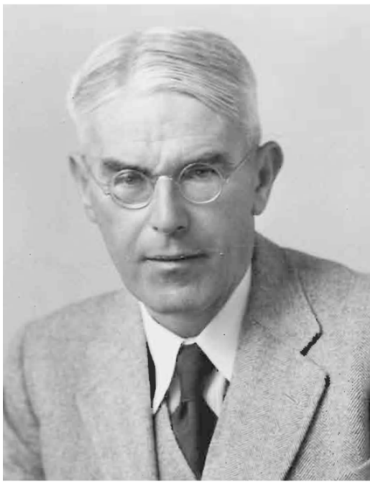
59 Götz, 1925. Translated by the authors. Original text: „Spektrogramme des Davoser Dauerspektrographen am Tübinger Mikrophotometer".

60 Götz wrote (Götz, 1925, p. 191, bottom) *"The results did not match the efforts because of [instrumental] stray light problems"*. Translated by the authors. Original text: „Der Erfolg entsprach nicht den Bemühungen, da sich der Dauerspektrograph infolge Überfülle diffus zerstreuten Lichtes als für Intensitätsbestimmungen am kurzwelligen Ende als unbrauchbar erwies.". In Fröhlich (2016) the problems with the UV spectrum recorder of Davos were rather attributed to problems with the sensitivity of the used films.

3 1921-1954: Period of F. W. Paul Götz

3.1 Founding of the LKO

In Arosa, the founding of the Light Climatic Observatory[61] was connected to the cure of pulmonary TB (Sect. 2.2) as well as the promotion of Arosa as a (winter) sport resort area (Just et al., 2007).



Friedrich Wilhelm Paul Götz

1891	Born on 20 May in Heilbronn (Germany).
1891-1910	Childhood in Göppingen, near Stuttgart (Germany).
1910	Start of studies in mathematics, physics and astronomy in Heilbronn (Germany).
1914-1915	Davos: recovery from pulmonary tuberculosis at the «Deutsche Heilstätte».
1916-1919	Intermittently high school teacher at the Fridericianum (German School) in Davos, Switzerland.
1919	Dissertation at the University of Heidelberg (Germany), thesis on the photometry of the lunar surface.
1919-1920	Part-time coworker of Dorno in Davos.
1921	Founding of the Light Climatic Observatory (LKO) at Arosa (called Light Climatic Station until 1926).
1931	Habilitation and lecturer at the University of Zürich, Switzerland.
1932	Marriage with Margarete Karoline Beverstorff (27 December).
1940	Promotion to «Titularprofessor» at the University of Zürich, responsible for teaching courses in meteorology.
1950-1954	Physical and mental illness (arteriosclerosis).
1954	Died on 29 August in Chur (Switzerland).

Figure 5: Biography of Friedrich Wilhelm Paul Götz (from Staehelin et al., 2018a) [62].

here is evidence that Götz approached the Medical Doctors Association of Arosa on his own initiative when looking for a job after he left Davos with the proposal of starting with atmospheric measurements at Arosa (letter of 19 January 1926 from Götz to Amrein, see Sect. 3.2). In March 1921, the Medical Doctors Association of Arosa made a request to the board of the KVV Arosa[63] to extend the

61 Refer to footnote 3 on page 1.

62 The information is confirmed by a questionary submitted by Götz on 29 July 1952 to the «Schweizer Biographisches Archiv (SBA)» (Redaktionsbüro, Lugano, Postfach 102). The SBA is a biographical reference book published from 1952 to 1958.

63 Refer to footnote 7 on page 3.

usual meteorological observations[64] with more detailed atmospheric observations (Sect. 9.1.3), particularly to study in a systematic way the biologically active solar radiation (Maron, 1934)[65].

The KVV Arosa accepted the request of the Medical Doctors Association at the meeting of the General Assembly on 20 August 1921 (Maron, 1934 p. 170-172; Maron, 1960, pp. 43-44; Fremdenblatt Arosa, 11, Nr. 9, 27 August 1921). Following the proposal of Jacobi[66], Götz was mandated by the KVV Arosa as scientist to found and run the LKO.

According to Danuser (1998a), Jacobi argued that the financial burden would be rather small as Götz asked only for a modest salary and Sanatorium Arosa (see Figure 1) would offer space for these measurements and for housing. A letter written by the lawyer Bernet[67] on 25 August 1921 on behalf the KVV Arosa (see Figure 6) shows that Götz was invited to start radiative climatic studies. In this letter he was asked to clarify the working program in more detail and some other points before the contract was signed. It was also suggested that Götz start his work by 1 November 1921. Götz obviously accepted this invitation and began working at Arosa[68]. In December 1921 and January 1922, he wrote three articles in the newspaper of Arosa[69] describing the concept and planned measurements in a form readily understood by educated laymen. We do not know the details of the contract between Götz and the funding institution. Ostensibly Götz did not obtain a long-term contract[70].

The measurements of the LKO were performed on the roof of the Sanatorium Arosa[71] (see Figure 7 and Figure 8).

64 The climatological meteorological observations by the national weather service (MeteoSwiss) in Arosa go back to 1889 (Sect. 9.1.1.a).

65 Fitz Maron (1891-1965), architect, President of the KVV Arosa from the the early 1930s until 1949.

66 Dr Ernst Jacobi, physician, President of the Medical Doctors Association of Arosa and Director of Sanatorium Arosa (one of the oldest and important sanatoria of Arosa).

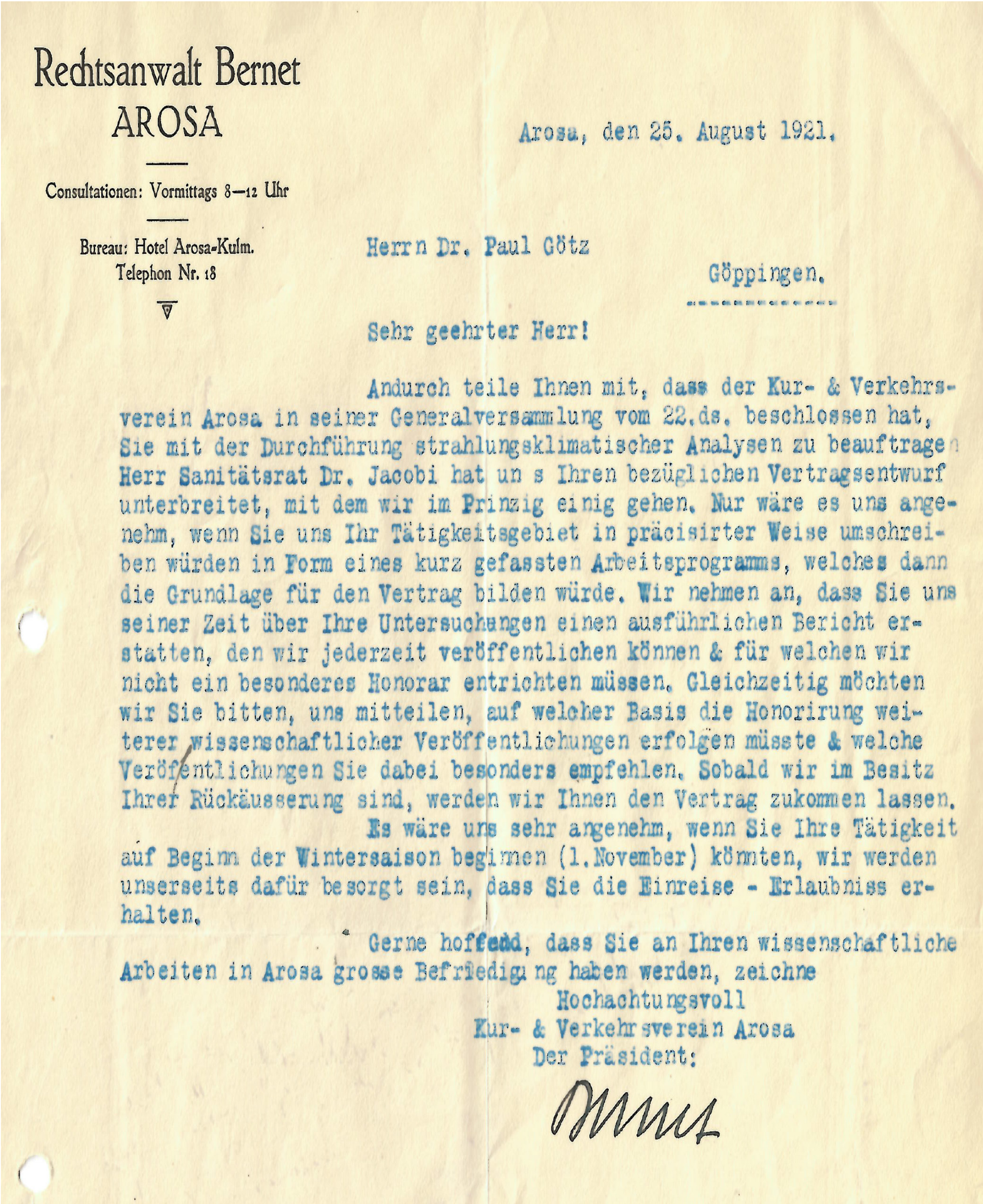
67 Hermann Bernet (1880-1930), lawyer, member of the parliament of the Canton of Grisons, President of the KVV Arosa.

68 Götz's name is listed as foreigner (Fremder) of Sanatorium Arosa in the "Fremdenblatt Arosa" in 1922.

69 Refer to footnote 8 on page 3.

70 This is also suggested from some remarks in the correspondence Dorno-Götz (Dorno, 27 and 30 December 1922).

71 First called Sanatorium Berghilf. The Sanatorium Arosa transformed itself into the winter sports oriented Tschuggen Grand Hotel (see Figure 1) in 1929.



Rechtsanwalt Bernet
AROSA

Consultationen: Vormittags 8—12 Uhr

Bureau: Hotel Arosa-Kulm.
Telephon Nr. 18

Arosa, den 25. August 1921.

Herrn Dr. Paul Götz

Göppingen.

Sehr geehrter Herr!

Andurch teile Ihnen mit, dass der Kur- & Verkehrsverein Arosa in seiner Generalversammlung vom 22.ds. beschlossen hat, Sie mit der Durchführung strahlungsklimatischer Analysen zu beauftragen. Herr Sanitätsrat Dr. Jacobi hat uns Ihren bezüglichen Vertragsentwurf unterbreitet, mit dem wir im Prinzig einig gehen. Nur wäre es uns angenehm, wenn Sie uns Ihr Tätigkeitsgebiet in präcisirter Weise umschreiben würden in Form eines kurz gefassten Arbeitsprogramms, welches dann die Grundlage für den Vertrag bilden würde. Wir nehmen an, dass Sie uns seiner Zeit über Ihre Untersuchungen einen ausführlichen Bericht erstatten, den wir jederzeit veröffentlichen können & für welchen wir nicht ein besonderes Honorar entrichten müssen. Gleichzeitig möchten wir Sie bitten, uns mitteilen, auf welcher Basis die Honorirung weiterer wissenschaftlicher Veröffentlichungen erfolgen müsste & welche Veröffentlichungen Sie dabei besonders empfehlen. Sobald wir im Besitz Ihrer Rückäusserung sind, werden wir Ihnen den Vertrag zukommen lassen.

Es wäre uns sehr angenehm, wenn Sie Ihre Tätigkeit auf Beginn der Wintersaison beginnen (1.November) könnten, wir werden unserseits dafür besorgt sein, dass Sie die Einreise - Erlaubniss erhalten.

Gerne hoffend, dass Sie an Ihren wissenschaftliche Arbeiten in Arosa grosse Befriedigung haben werden, zeichne

Hochachtungsvoll
Kur- & Verkehrsverein Arosa
Der Präsident:

Bernet

Figure 6: Letter of Bernet, president of the KVV Arosa, informing Götz about his mandate to perform atmospheric studies in Arosa (see text) (Letter LKO archives).

Figure 7: First measuring site of the LKO: Measuring platform on top of Sanatorium Arosa (from Just et al., 2007, Photo courtesy of Heimatmuseum und Kulturarchiv Arosa-Schanfigg).

With its support of Götz's idea, Arosa was the first resort village to support research in climatology. It is particularly notable that it predated Davos, a fact which was stressed by Götz several times. Dorno's observatory was older but a private undertaking. This historical evolution is confirmed by three letters from Mörikofer[72] and Götz of January 1935 in which Götz clarifies that it was his idea and initiative to contact the medical doctors of Arosa to support "light climatic studies". Götz informed Dorno only when the negotiations with the medical doctors were more or less settled[73]. Subsequently Dorno did his best to support establishing the LKO.

72 Walter Mörikofer (1892-1976), PhD, Director of PMOD (1929-1966).

73 Letter Götz, 26 January 1935. Translated by the authors. Original text: „[….] nachdem meine Verhandlungen mit dem hiesigen Ärzteverein so gut wie unter Dach waren."

Figure 8: First measuring site of the LKO: Sanatorium Arosa, prior to replacement by Hotel Tschuggen (from Just et al., 2007, Photo courtesy of Heimatmuseum und Kulturarchiv Arosa-Schanfigg).

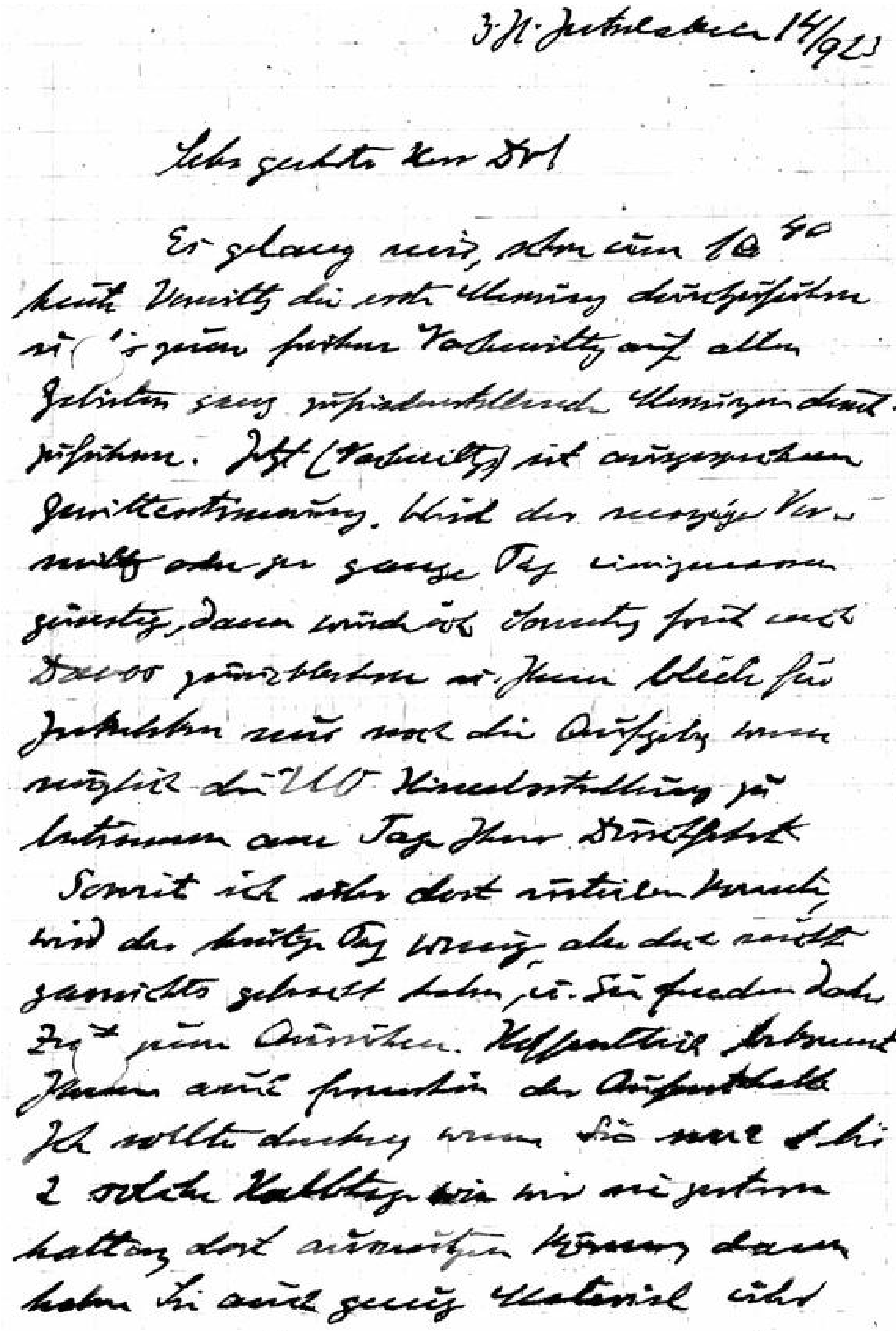
3.2 Initial years and relationship between Götz and Dorno (PMOD)

In the first years (1921-1924) Götz measured ultraviolet (UV-B) radiation using a photoelectric cell with a cadmium cathode as detector (Cd-cell)[74]. This instrument was property of the Observatory Dorno. Götz obtained training from Dorno in 1921 to use the instrument before starting measurements in Arosa. In 1924 Götz returned the Cd-cell (and other borrowed instruments) to the Observatory Dorno.

Many letters from Dorno to Götz stored at the LKO Archives show that in the first years they had common measurements projects and were looking positively forward to a closer collaboration between Davos and Arosa (see Figure 9 and Figure 10). Several letters suggest that Dorno, who was 26 years older than Götz, viewed himself as a mentor of Götz. Quite a few remarks of Dorno were related to Götz's well-being including recommendations to be careful with his health[75].

74 For a comprehensive description refer to Levi (1932).

75 Though Götz had completed his treatment in the German Sanatorium (Deutsche Heilstätte) of Davos more than 5 years earlier.



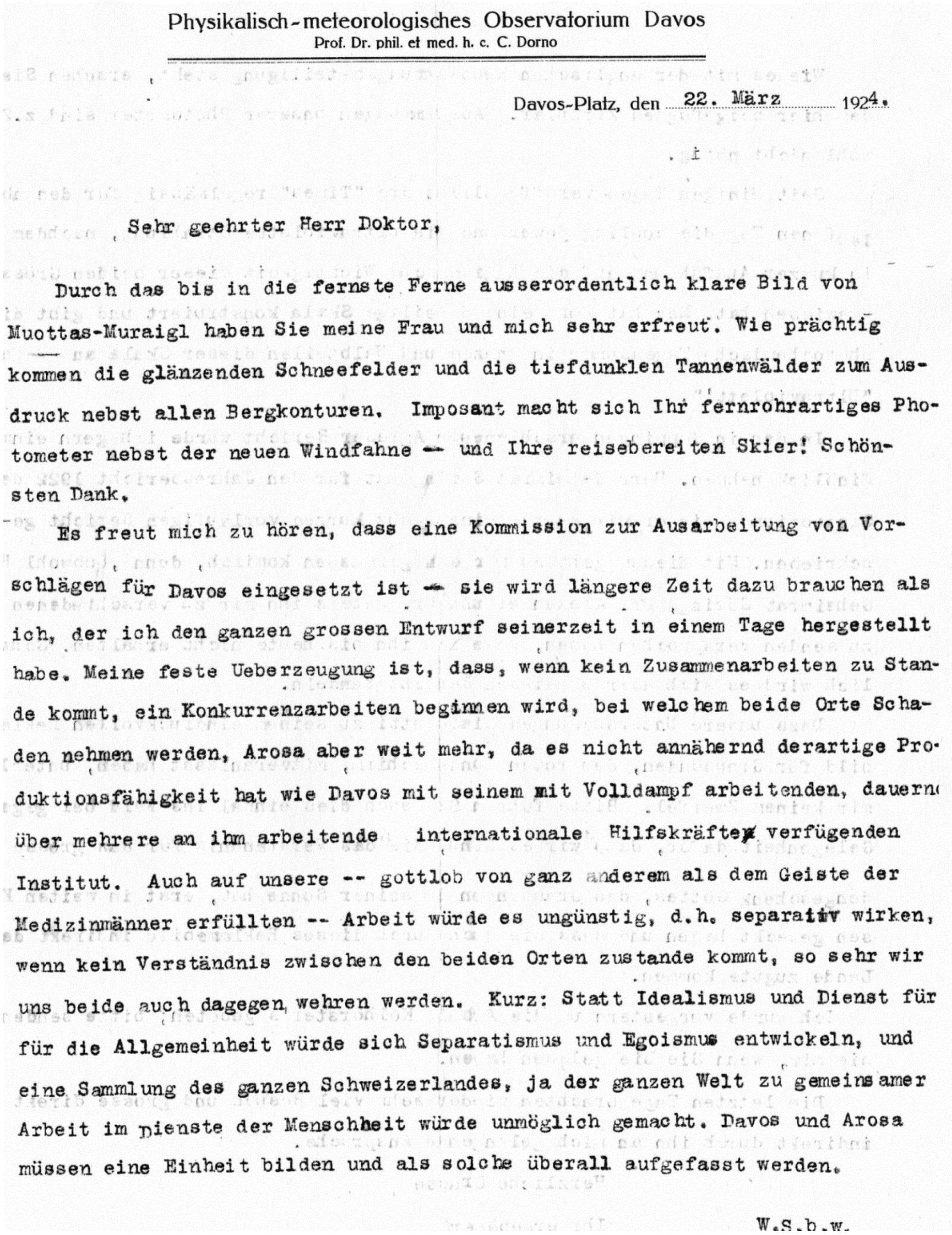
[illegible] 14/9 23

Sehr geehrter Herr Dr!

Es gelang mir, schon um 10^{40}
heute Vormittag die erste Messung durchzuführen
und bis zum frühen Nachmittag auf allen
Gebieten ganz zufriedenstellende Messungen durch-
zuführen. Jetzt (Nachmittags) ist ausgesprochene
Gewitterstimmung. Wird der morgige Vor-
mittag oder der ganze Tag einigermassen
günstig, dann werde ich Sonntag früh nach
Davos zurückkehren u. Ihnen bleibt für
[illegible] nur noch die Aufgabe wenn
möglich die UV Himmelsstrahlung zu
bestimmen am Tag Ihrer Durchfahrt.
Soweit ich aber dort urteilen konnte
wird der heutige Tag wenig, aber doch nicht
garnichts gebracht haben, u. Sie fanden daher
Zeit zum Ausruhen. Hoffentlich bekommt
Ihnen auch der Aufenthalt.
Ich sollte denken wenn Sie nur 1 bis
2 solche Halbtage wie wir sie gestern
hatten dort ausnützen können, dann
haben Sie auch genug Material über

Figure 9: Letter from Dorno to Götz of 14 September 1923 [76]. Only two of the 209 letters/cards addressed by Dorno to Götz from 10 July 1921 to 1 April 1926 are written by hand (there are almost no copies of the letters sent by Götz). (Letter LKO Archives).

76 Sehr geehrter Herr Doktor, Es gelang mir schon um 10^{40} heute Vormittag die erste Messung durchzuführen und bis zum frühen Nachmittag auf allen Gebieten ganz zufriedenstellende Messungen durchzuführen. Jetzt (Nachmittags) ist ausgesprochene Gewitterstimmung. Wird der morgige Vormittag oder der ganze Tag einigermassen günstig, dann werde ich Sonntag früh nach Davos zurückkehren und Ihnen bleibt für (….) nur noch die Aufgabe wenn möglich die UV Himmelstrahlung zu bestimmen am Tage Ihrer Durchfahrt. Soweit ich aber dort urteilen konnte, wird der heutige Tag wenig, aber doch nicht ganz nichts gebracht haben und sie fanden daher Zeit zum Ausruhen. Hoffentlich bekommt Ihnen auch …. der Aufenthalt. Ich sollte denken wenn Sie nur 1 bis 2 Halbtage wie wir sie gestern hatten dort ausnützen können, dann haben Sie auch genug Material über …



Physikalisch-meteorologisches Observatorium Davos
Prof. Dr. phil. et med. h. c. C. Dorno

Davos-Platz, den 22. März 1924.

Sehr geehrter Herr Doktor,

Durch das bis in die fernste Ferne ausserordentlich klare Bild von Muottas-Muraigl haben Sie meine Frau und mich sehr erfreut. Wie prächtig kommen die glänzenden Schneefelder und die tiefdunklen Tannenwälder zum Ausdruck nebst allen Bergkonturen. Imposant macht sich Ihr fernrohrartiges Photometer nebst der neuen Windfahne -- und Ihre reisebereiten Skier! Schönsten Dank.

Es freut mich zu hören, dass eine Kommission zur Ausarbeitung von Vorschlägen für Davos eingesetzt ist -- sie wird längere Zeit dazu brauchen als ich, der ich den ganzen grossen Entwurf seinerzeit in einem Tage hergestellt habe. Meine feste Ueberzeugung ist, dass, wenn kein Zusammenarbeiten zu Stande kommt, ein Konkurrenzarbeiten beginnen wird, bei welchem beide Orte Schaden nehmen werden, Arosa aber weit mehr, da es nicht annähernd derartige Produktionsfähigkeit hat wie Davos mit seinem mit Volldampf arbeitenden, dauernd über mehrere an ihm arbeitende internationale Hilfskräfte verfügenden Institut. Auch auf unsere -- gottlob von ganz anderem als dem Geiste der Medizinmänner erfüllten -- Arbeit würde es ungünstig, d.h. separativ wirken, wenn kein Verständnis zwischen den beiden Orten zustande kommt, so sehr wir uns beide auch dagegen wehren werden. Kurz: Statt Idealismus und Dienst für für die Allgemeinheit würde sich Separatismus und Egoismus entwickeln, und eine Sammlung des ganzen Schweizerlandes, ja der ganzen Welt zu gemeinsamer Arbeit im Dienste der Menschheit würde unmöglich gemacht. Davos und Arosa müssen eine Einheit bilden und als solche überall aufgefasst werden.

W.S.b.w.

Figure 10: Letter from Dorno to Götz (first page) of 22 March 1924 concerning the collaboration between them respectively between the Observatory Dorno and the LKO (Letter LKO archives).

The correspondence between Dorno and Götz also shows that they were aware of the touristic aspects and that their studies would convincingly contribute to the promotion of Davos resp. Arosa and the Grisons region. Referring to the advertisement poster painted (see Figure 11) by Giacometti [77], Dorno writes to Götz: "There is no doubt that our investigations have brought Giacometti to paint the poster with the red umbrella. Please, if you have the opportunity, do not forget to mention that it is our merit to have raised the attention of a broad community on this God-given gift of grace that the

77 August Giacometti (1877-1947), a famous painter of the Grisons.

sunshine represents for the Grisons, and that, through this poster, the whole country is benefitting indirectly from them [i.e. our investigations]"[78].

Figure 11: Advertisement poster painted by the famous painter Augusto Giacometti, from the Grisons (Switzerland), and mentioned in the letter from Dorno from 22 March 1924 pointing to the important role of the light climatic investigations made in Davos and Arosa (Photo Museum für Gestaltung Zürich, Plakatsammlung, ZHdK).

Despite everything, the relationship between Götz and Dorno was becoming gradually more and more difficult as the paternalistic behavior of Dorno seems to have increasingly irked Götz.

We also do not know whether the personal relationship was affected by the unclarified situation between their institutes. Dorno wrote to Götz in several letters that the close cooperation between the

78 Letter Dorno, 22 March 1924. Translated by the authors. Original text: „Dass unsere Untersuchungen Giacometti zu seinem eindrucksvollen Bild veranlasst haben, unterliegt mir keinem Zweifel. Bitte führen Sie auch dies einmal ins Feld bei gegebener Gelegenheit dafür, dass wir es sind, die das Verständnis für das grosse Gnadengeschenk Gottes, das Graubünden in seiner Sonne hat, erst in weiten Kreisen geweckt haben und dass sie durch dieses Reklamebild indirekt dem Lande zugutekommen.".

LKO Arosa and the Observatory Dorno had very high priority for him. Ostensibly Dorno was supporting the idea of a partnership based on the principle of "equal duties, equal rights". However, letters suggest that Davos (Dorno) did not agree with a proposal of Arosa (KVV Arosa, Medical doctors) in terms of "equal duties", possibly because Arosa was not ready to provide the expected financial support. On the other hand, it seems evident that the medical doctors of Arosa also wanted to increase visibility of the work supported by Arosa (see below).

A letter from 13 November 1924 written by Götz to Dorno and the reply of Dorno (15 November 1924) illustrate serious problems in their relationship mixing personal and professional aspects. Götz had obviously made a presentation at the Swiss Society of Natural Sciences [79] in Lucerne without informing Dorno, who was upset about the content of the talk. In the letter of 13 November 1924, Götz apologized for his presentation not being based on a written manuscript [80]. He agreed that coordination of research with Davos would be important, but he clarifies that he did not feel comfortable regarding his role vs. the Observatory Dorno and the medical doctors at Arosa: "it is not fair to level accusations at me when I refer to what I committed myself to, at Arosa" [81] (Sect. 3.1). Finally, he clearly defended himself against the accusation of dishonorable behavior [82] made by Dorno in an earlier phone call. The letter from Dorno of 15 November 1924 starts with criticism that Götz presented measurements of shortwave solar radiation with the Cd-cell instrument as being reliable for geophysical studies (i.e. for stratospheric ozone) and Dorno claims that he did not use the instrument properly. It is hardly feasible for us today to judge whether Götz used the instrument in a proper way; nevertheless, these measurements were subsequently published and discussed in the reviewed literature (Götz, 1925 and 1926a). Dorno argued that he has much more experience with this instrument and claimed that other scientists using such an instrument did not view his remarks for the purposes of scientific rigor as criticism but more as an aid for publishing the results. Dorno repeated several times that Götz did not point out in a proper way all the merits of the Observatory Dorno, e.g. that he used an instrument, which was property of the Observatory Dorno and that he obtained training in the instrument at his institute.

The contention between Götz and Dorno culminated in January 1926 when a debate took place between the medical doctors of Arosa and Davos. Obviously, the medical doctors of Arosa under the leadership of Amrein, successor of Jacobi as president of the Medical Doctors Association of Arosa in 1925, sent a letter on 8 January to the medical doctors of Davos with the proposition to merge the activities of the LKO and the Observatory Dorno and to establish a new joint observatory in Arosa. This letter could not be found in the LKO Archives but is referred to in other documents.

This proposal is possibly related to the fact that Dorno was near retirement and the future of the Observatory Dorno at that time was considered by the medical doctors of Arosa to be still open. There was an immediate and vigorous response from the medical doctors of Davos, signed by its president Georg Michel, sent to Amrein on 12 January 1926. From the phrasing of this letter it is likely that it was drafted or written by Dorno. The reply of the doctors of Davos started with the clarification that the Observatory Dorno was much more than a Light Climatic Station and that the light climatic obser-

79 Schweizerische Naturforschende Gesellschaft.

80 Which could have been sent to Dorno prior to the presentation.

81 Letter Götz, 13 November 1924. Translated by the authors. Original text: „Es darf mir kein Vorwurf gemacht werden, wenn ich [.....] mich auf das beziehe, worauf ich mich Arosa verpflichtet habe.".

82 Ibid. Translated by the authors. Original text: „unehrenhaftes Verhalten".

vations counted only for a small part of the scientific activities of the observatory. It was also asserted that all light climatic studies had been started by the Observatory established by Dorno. The letter contains a short history of the Observatory and states that a contract already existed for the future (Sect. 2.3). The letter then claims that the Light Climatic Station in Arosa only existed because of the engagement of Dorno, not only because Götz could use instruments (Cd-cell) from Davos and obtained extended instructions to use these instruments. The letter goes as far as to claim that Dorno originally only agreed with the measurements at Arosa in order to help Götz get an opportunity to stay in the alpine environment to recover from his health problems and that, in Dorno's view, these health concerns had higher priority than any other arguments, including scientific arguments. Furthermore, the fact that Götz's results were yet to be published was criticized. In the end, the options of moving the light climatic activities or the entire Observatory Dorno to Arosa were rejected. It was made clear that the activities of Davos were internationally acclaimed and that the proposed extension of the institute's name to "Schweizerisches Institut für Hochgebirgs-Physiologie und Tuberkuloseforschung in Davos und Arosa" would be not acceptable as the institute was located in Davos and Arosa's contribution was merely the Light Climatic Station. The letter concludes with the remark that an earlier proposal of a cooperation proposed by the Davos' doctors to those of Arosa based on "equal rights and equal duties" had obviously not been accepted by the Arosa's partners [83].

Apparently, Götz was not involved prior nor informed about the letter sent by Amrein on 8 January 1926 because he stayed in Göppingen due to urgent family reasons, possibly because of his father's serious health problems (Sect. 3.3). Amrein asked Götz for comments on the reply from Davos doctors. In the letter sent to Amrein on 19 January 1926, Götz was upset and expressed that the letter from 12 January 1926 by Davos' medical doctors to Amrein described his role in a false and very unfair way. For example, he clarified that it was his own idea to start measurements at Arosa (Sect. 3.1, last para.), and that the training he obtained at the PMOD was funded by the KVV Arosa etc.

In summary, it seems quite striking that the relation between the doctors of Arosa and Davos was obviously difficult [84]. These debates appear not only to reflect competition between the two medical societies but also between the resort areas Davos and Arosa (Sect. 2.1).

Dorno also disagreed with Götz in scientific analysis (Sect. 2.4, last para.). Götz's publications (Götz, 1925 and Götz, 1926a and 1926b) cover the analysis of the measurements with the Cd-cell. In his analysis Götz found an indication of the seasonal variation in total ozone, with a maximum in spring and a minimum in the fall. This publication was earlier than the more famous paper from Dobson and Harrison published 1926. In 1927, Dorno criticized Götz's publication concerning the Cd-cell results in the open literature (Dorno, 1927a [85]). The scientific arguments were discussed more thoroughly by Levi, a scientific employee from the PMOD (Levi, 1932).

83 Unfortunately, all our efforts to find more documents on the dispute between the medical societies of Davos and Arosa were unsuccessful (including the Documentation Library (Dokumentationsbibliothek) of Davos and the Cantonal Archives of the Grisons (Staatsarchiv Graubünden).

84 One might argue that in case of good relations, Amrein might have first discussed orally with his colleague from Davos to find an appropriate solution for cooperation in atmospheric studies before writing a letter.

85 The paper also includes a reply from Götz.

After 1926, private correspondence between Götz and Dorno seems to have been reduced to cards thanking for reprints. Despite that, there was obviously scientific exchange between Mörikofer [86] and Götz. In the LKO Archives we found a letter dated 13 December 1932 from Mörikofer starting with a sentence that he contributed to an annex to the protocol of the Radiation conference as suggested by Götz. In the following paragraph of this letter Mörikofer informs Götz that Levi (see above) was leaving the PMOD without having a new job. Furthermore, Mörikofer emphasizes that this should be viewed as information (and not as tentative to pressure him) in case it might be useful for him. It is not clear whether this information was an invitation for Götz to apply for an open position in the PMOD, possibly with the implication for Götz to move from Arosa to Davos, or a mere suggestion to consider employment of Levi at the LKO [87]. Both options are informative as they express that Götz, as seen on many other occasions, was not thoroughly happy with the situation at the LKO [88].

Maron [89] wrote in his book (Maron, 1960, 43ff.) that attempts to coordinate research work with Davos started after founding of the LKO and were continued after death of Dorno but failed (Sect. 3.6.4) because of lack of interest from Davos [90].

3.3 Construction of Villa Firnelicht, Tschuggen and personal matters

3.3.1 Villa Firnelicht

Year 1926 was important in Götz's career. In early 1926, the confrontation between Götz and Dorno reached a peak (Sect. 3.2) and Götz continued his research on his own. In the same year Götz started a close collaboration with Dobson [91] (Sect. 3.7) and had the opportunity to use in Arosa a Féry type spectrograph constructed by Dobson (see Figure 16 and Sect. 9.1.2).

In the same year, Götz's father died and we find the personal dedication to his father [92] in the book "Das Strahlungsklima von Arosa" (Götz, 1926b).

Another important step in 1926 was the completion of the construction of his own house (Villa Firnelicht, see Figure 12), which is located close to the Sanatorium Arosa (see Figure 1). We obtained information from the administration of the Arosa municipality that Götz bought the land of Villa Firnelicht on 20 November 1924 from the civic community [93] of Chur. The "transfer of the observatory into its own premises occurred" when the construction of the house was finished in early 1926 [94].

86 Refer to footnote 72 on 18.

87 Although the financial situation of LKO under Götz was difficult.

88 For further contacts of Götz with Mörikofer refer to Section 3.6.4.

89 Refer to footnote 65 on page 16.

90 Maron, 1960. Translated by the authors. Original text: „In den nächsten Jahren und besonders nach Dorno's Tod versuchte man eine Zusammenarbeit, auch unter Teilung der Aufgaben, die aber für Davos kein Interesse hatte, so dass die Verhandlungen bald zu Ende waren.".

91 Gordon Miller Bourne Dobson (1889-1975), PhD, University Lecturer in Meteorology at the Oxford University, UK, and famous ozone scientist (Sect. 3.7).

92 Götz, 1926b. Translated by the authors. Original text: „Ich widme die Schrift dem Gedächtnis meines naturliebenden Vaters, Paul Götz, Kaufmann in Göppingen, 1859-1926.".

93 Bürgergemeinde.

94 Götz, 1926b. Translated by the authors. Original text: „Die Verlegung des Observatoriums in eigene Räume zu Anfang 1926 [….].".

Figure 12: Villa Firnelicht where measurements were performed from beginning of 1926 until end of 1953 (for location see Figure 1) (Photo LKO Archives).

The house was property of Götz (and his wife, see Sect. 3.11) and we could speculate that he used the resources of his family heritage to finance the large house (Sect. 2.4).

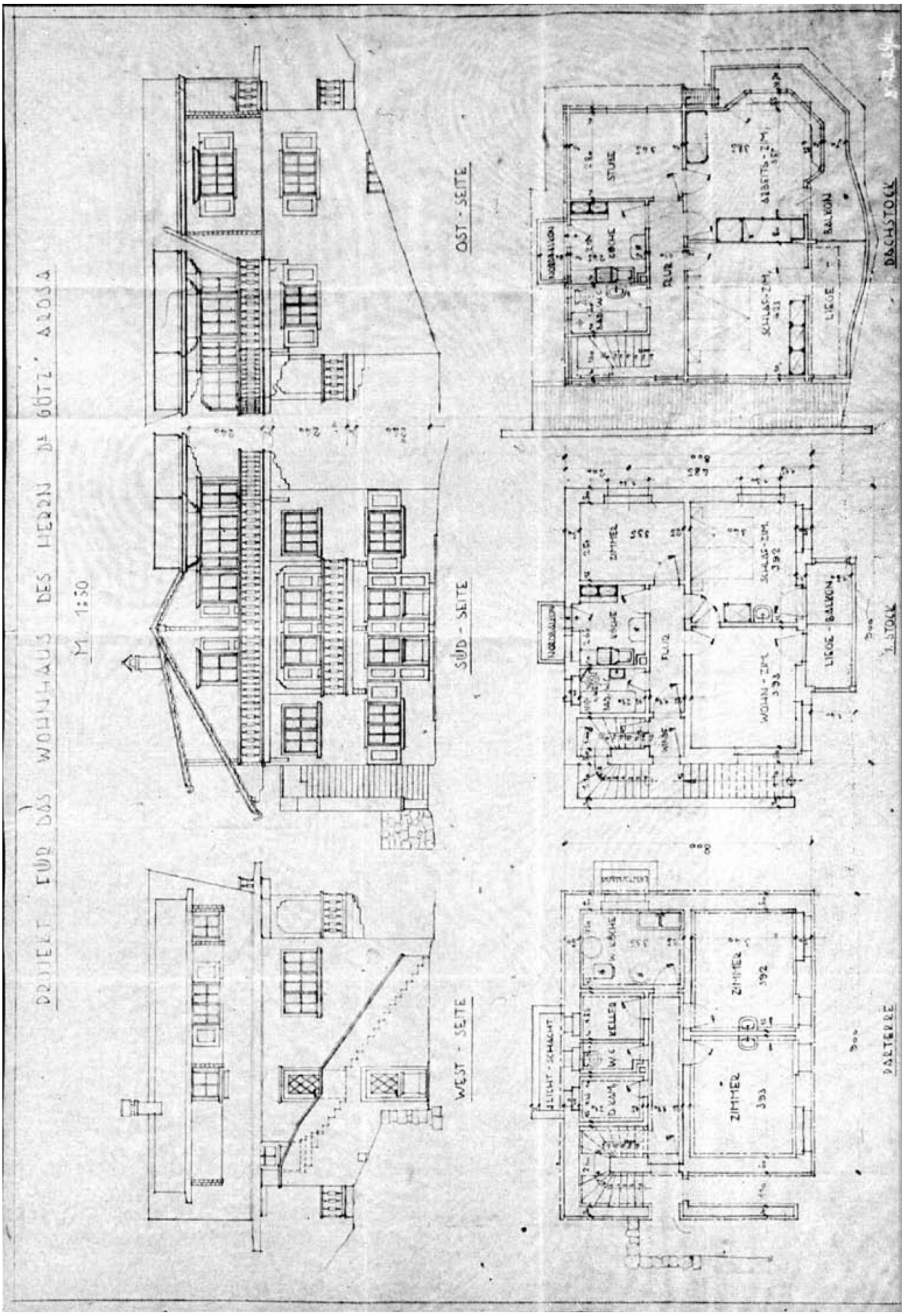


Figure 13: Construction plans of Villa Firnelicht (obtained from the administration of the community of Arosa, see text).

The house was designed by Ferdinand Zai, a famous architect from Arosa who had constructed several houses in the area (Just et al., 2007). The building was constructed along the slope of the hill (see Figure 1) and had three floors (see Figure 13 for the plans submitted by Götz to the municipality of Arosa). On the roof and on the balcony of the third floor [95], instruments were installed to perform atmospheric observations. All three floors contained a kitchen, bedrooms, and toilets. Villa Firnelicht was rather large as a home for just two people. Götz obviously invited many colleagues to stay at Villa Firnelicht (see Table 3 in Sect. 3.4). It was also an opportunity for him to generate additional income. Obviously, rooms or apartments at Villa Firnelicht were also (occasionally) rented to other persons as deduced from the newspaper of Arosa [96] (Sect. 3.10).

3.3.2 Hut at Tschuggen

At the beginning of 1930, Götz was looking for an observation place outside of the village of Arosa suitable for night time observations, allowing interference in the signal from disturbing light sources in night time observation to be overcome [97]. His choice fell on a hill at the top of Tschuggen [98], a site free from light pollution. On 28 February 1933, he addressed a request to the civic community of Chur, which was the owner of the land. On 3 April 1933, the citizen's council of the city of Chur agreed, in principle, to make a land parcel on the mountain available, initially on loan for 30 years. The choice of the concrete location and the entry in the cadastral register were settled the following year. In a letter from 16 July 1934, the KVV Arosa confirmed that the credit for the construction of a measuring station on this lot was fully granted. The date when the new hut became operational is not exactly known, but in the LKO activity survey 1931-34, published by Götz in the annals of the Swiss Society of Natural Sciences [99] (Götz, 1934), a photograph (taken on 2 November 1934) of the newly constructed hut is reproduced (see Figure 14).

In the following decades Götz spent many nights at Tschuggen, alone or with an assistant (e.g. Dütsch, see Section 5.1), to carry out observations, e.g. of aurora borealis and of air glow phenomena. The hut served for all kinds of additional measurements during the different periods of the LKO (Sect. 9.1.3). The site is still used by the LKO in current times. The arrangements with the citizen's council of Chur for the land and with the KVV Arosa for the hut have been renewed regularly, the operation and maintenance costs being borne by the LKO.

95 "Dachstock" in Figure 13.

96 Refer to footnote 8 on page 3.

97 The scientific background for the construction of this hut is described in Section 3.5.1.

98 A hilltop near Arosa situated at an altitude of 2040 m a.s.l., about 250m above the village of Arosa (see Figure 1 for location and Figure 14).

99 Refer to footnote 79 on page 23.

Figure 14: House in the mountain pasture on Tschuggen above Arosa used by Götz for specific activities, especially for observations of aurora and air glow as well as for measurements of surface ozone (Photo LKO Archives).

In 1938, an astrophysical observatory of ETH Zürich was constructed under Waldmeier [100] close to the Tschuggen hut. The observatory [101] served as a platform for the famous studies on the eleven-year solar sunspot number by Waldmeier.

3.3.3 Personal matters

On 27 December 1932 Götz married Margarete Karoline Beverstorff [102]. She had been registered in Arosa since 7 January 1923. Trenkel (1954) noted that Margarete Beverstorff moved to Villa Firnelicht together with Götz in 1926. According to Rösli Aeschbacher, wife of Kurt Aeschbacher [103], Margarete Götz admired her husband and strongly supported his work. She assisted Götz to perform meteorological measurements and observations. Seemingly she took care of the many scientific guests that visited Arosa to perform measurements and for scientific exchange (see Table 3 in Sect. 3.4). Appendix 1: contains a short description (in German) about the life of M. Götz-Beverstorff.

Götz and his wife obtained Swiss citizenship on 28 May 1946 (Appendix 2). The first attempt of naturalization failed because the representatives of the Canton of Grisons were suspicious about whether Götz was collaborating with the Nazi regime as Götz and his wife traveled several times to Germany during World War II. In the second and successful attempt Götz and his wife had justified every trip to Germany and Austria during World War II. Appendix 2 shows that Götz and his wife actively supported several persons threatened by the Nazis, which is also shown by his commitment to Hedwig Kohn (Sect. 3.6.2). Renzo Semadeni, who was living mostly in Arosa, also thinks that Götz did not count

100 Refer to footnote 40 on page 12.

101 The observatory served until 2002 (refer to Section 7.3).

102 She was born on 20 February 1903 and was therefore 12 years younger than Götz.

103 Kurt Aeschbacher, local station manager of the LKO (1964-2001), retired in 2001 (for more details refer to Section 9.2.1.b).

among the Germans living in Arosa during World War II with sympathies for the Nazi Regime as testified by Ladenburg[104] in a letter of June 1946[105].

3.4 The LKO as research institute under Götz

The LKO under Götz can be viewed as a small research company (basically a one-man company) with similarities to modern small private research consulting companies[106].

Götz's very successful scientific career (Sect. 3.10) was based on the following factors:

- Götz obtained continuous but modest support, first solely from the KVV Arosa, later also from the Railway Company Chur-Arosa (Sect. 3.6.1) and other institutions (Sect. 9.3.1) in order to assure the LKO's core program of measurements[107]. Götz obviously performed most of the observations himself with UV spectrophotometers (on loan from Dobson) and others (Sect. 9.1.2). The income was probably sufficient to finance his and his wife's basic living costs[108]. It seems that he already had part time assistants in the first years[109].
- Götz made a large investment in constructing Villa Firnelicht (Sect. 3.3) enabling him to ask leading scientists to perform (together with him) cutting-edge research by observations performed at Villa Firnelicht. The most outstanding example is the campaign of Umkehr measurements, which were performed in Arosa in 1932-1933 (Sect. 3.8.5; for other examples refer to Section 9.1.3). In addition, Götz invited colleagues to take short sabbaticals in Villa Firnelicht (see Table 3).
- LKO's budget was always tight, making it very difficult to buy state-of-the art instruments. This made it necessary for him to look for joint projects with other scientist or institutions. Götz began his studies in partnership with Dorno with an instrument that was property of the Observatory Dorno (Sect. 3.2). He then started a collaboration with Dobson, and this gave him the opportunity to use three types of spectrophotometers constructed by Dobson (Sect. 3.7)[110].
- He needed to apply for external grants. The first example is the grant of the German Research Foundation[111] to finance his expedition to Svalbard in 1929 (Sect. 3.8). Others are mentioned in Section 9.3.2.

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104 Rudolf Ladenburg (1882-1952), PhD, a well-known German physicist, accepted the appointment as professor at Princeton University (USA) in 1932 because his family was Jewish.

105 In a letter (copy) of 7 June 1946 signed by Ladenburg as a Research Professor of Princeton University we read: "This is to testify that I have known Professor Doctor F. W. Paul Götz very well for many years. I know that he had never any connection with the German Nazis, nor any inclination for them. As a matter of fact, he refused a call as Professor of the University of Frankfurt A/M, Germany, on account of his disapproval of the Nazi government." This letter was written in order to facilitate the naturalization of Götz and his wife, but in fact they obtained Swiss citizenship around 10 days prior to this letter.

106 In the sense that research scientists earn their income not as employees of a governmental laboratory nor a university but with their own company, also being responsible for infrastructure, e.g. a house in the case of Götz.

107 Measurements of total ozone and solar radiation (Sect. 9.1.3.a) complementing the observations of the climatological station of MeteoSwiss (Sect. 9.1.1.a).

108 Considering that they did not need to pay for housing.

109 Although little is known about the assistants working at the LKO in the 1920s and 1930s (Sect. 9.2.1.a).

110 Besides these instruments the Arosa ultraviolet spectrograph was constructed with resources of the KVV Arosa on a design supervised by Götz (Sect. 9.1.2.a).

111 Deutsche Forschungsgemeinschaft (DFG), earlier: Notgemeinschaft der Deutschen Wissenschaft (NDW).

While only limited information is available for the years 1921-1924, we can rely on short annual activity reports existing since 1925. These LKO reportings were part of the annual reports from the Kur- und Verkehrsverein Arosa (KVVA, 1921-77) subsequently termed AR. The books relating to the years 1930-1933 could not be found. The activity AR are usually a half to one page and devoted to the work of the LKO. An appendix contains the balance of the previous year's budget and that for the coming year (excluding external grants, Sect. 9.3.1.a). These reports usually contain: (1) a list of publications published in the last year, (2) a short overview of the measuring program, (3) names of staff members, (4) listing of external visitors (see Table 3 [112]) and (5) information of presentations (see Table 4), demonstrating Götz's many attendances to conferences inside and outside Switzerland and the travel restrictions during World War II.

Table 3: Visitors (scientists spending extended time) at the LKO in Arosa between 1929 and 1952 (H.K. means Hedwig Kohn, see Sect 3.6.2; AR: Annual Report of the KVV Arosa).

Dr Challonge, Physics Institute, Paris	AR, 1929
Götz and Meetham (extended Umkehr measurements)	1932 [a)]
Cand. phys. Mayer-Leibnitz, Dr Dauvillier (Paris), Dr Challonge (Paris), Dr Vassy (Paris), Dr Barbier (Marseille)	AR, 1934
Coworkers of «Nordlichtobservatorium Tromso, colleagues of the Physics Institute of the University Zürich, one researcher obtained stipendium for research for 2-3 months from American grant	AR, 1935
Dr H.G. (Görlitz), Frl. P.D. Dr. H. K.	AR, 1936
Dr Glawion, Prof. Störmer (Oslo) (instrumental support for night time observations)	AR, 1937
Prof. Cario (Braunschweig), Dr Penndorf (Leipzig), Dr Nicolet (Brussels)	AR, 1939
Dr Dobson (Oxford), Prof. Regener (Friedrichshafen), Dr Nicolet (Brussels) (others were not able to come because of World War II, including members of International Radiation Commission)	AR, 1940
Dr med. M. Curry (American Bioclimatic Research Institute, among others)	AR, 1948
Prof. Dr Dobson and coworkers	AR, 1950
Dr Tscheng-Mao-Lin, guest from Belgium (Institut Royal Météorologique)	AR, 1951
Dipl. Phys. F. Volz	AR, 1951

[a)] Annual Reports of years 1930-33 are missing, see Section 3.8.5

AR 1925 states that the goal of the LKO was the systematic study of the "power of light" [113] and the climatology of Arosa. It also specifies that a book by Götz was expected to appear in fall 1925, based on extensive studies [114]. The instruments provided by Dorno of Davos are acknowledged, but it emphasizes that *"better instrumentation is required to reach the scientific goals"* [115] (Sect. 2.4, last para).

112 Covering only those visitors which stayed for several weeks at the LKO as part of a sabbatical.

113 Lichtkraft.

114 Some parts were published in scientific literature.

115 AR 1925 (KVVA, 1921-1977). Translated by the authors. Original text. „Das notwendige Instrumentarium […...] muss immer noch ergänzt werden, um die verschiedenen Untersuchungen zu ermöglichen und zu präzisieren.".

Table 4: Presentations of Götz extracted from the Annual Reports of the KVV Arosa (AR, year).

AR 1928	followed many requests from Switzerland and abroad
AR 1929	First results of the new ultraviolet spectrograph presented at the Internat. Ozone Conference, Paris; Première Conférence Internationale de la lumière, Lausanne-Leysin; meeting of "Royal Institute of Public Health" and presentations at other places
AR 1930-1933	Not available
AR 1934	among others: Meteorologen Kongress, Hamburg; Internationale Kommission zur Erforschung der freien Atmosphäre, Friedrichshafen; International Society of Medical Hydrology, St. Moritz.
AR 1935	presentations at several meetings
AR 1936	Internationaler Astronomen Kongress, Bern; Meteorologen Tagung, Danzig; Universität Frankfurt; Naturforschende Gesellschaft Graubünden, Chur.
AR 1937	among others: Dritter internationaler Kongress für Lichtforschung, Wiesbaden; Second Conference for Atmospheric Ozone, Oxford; Meeting of Internat. Radiation Commission
AR 1938	In AR 1938 reporting on the LKO is missing
AR 1939	invitations rejected (e.g. Liege, Berlin) because of need to make measurements
AR 1940	problems because of war, e.g. cancelling of meeting of the International Rad. Comm. in Arosa
AR 1941	Presentations restricted (war): Jahresversammlung Schweiz. Naturf. Gesellschaft, Locarno; Naturforschende Gesellschaft Graubünden. In Arosa: Tagung Schweiz. Erziehungsdirektoren; Sportärztliche Wochen der Zürcher Klinikerschaft; Sommerprogramm.
AR 1942	In addition to other presentation explicitly only mentioned: Schweiz. Naturf. Gesellschaft, Basel
AR 1943	In addition to presentations in Arosa: Jahresversammlung der Schweiz. Naturf. Gesellschaft Sitten; Physikalische Gesellschaft, Zürich; two invitations (University of Göttingen and Leipzig) needed to be cancelled because the visa to re-enter Switzerland could not be organized in time
AR 1944	Schweiz. Naturf. Gesellschaft Schaffhausen; on invitation in (Tharandt) Germany.
AR 1945	restricted to Switzerland: 100-year anniversary of discovery of ozone: presentation at the Naturforschende Gesellschaft Basel; Jahresversammlung der Schweiz. Naturf. Gesellschaft (Sils-Maria)
AR 1946	among others: Jahresversammlung Schweiz. Naturf. Gesellschaft, Freiburg (Schweiz); Physikalisches Kolloquium, Basel; Sportmedizinischer Kurs der Zürcher Klinikerschaft; first time outside Switzerland after war: meeting in St. Louis, Alsace
AR 1947	No presentation mentioned
AR 1948	among others: Conference on "Relations entre les Phénomènes Géophysiques", Lyon (invitation from Centre National de la Recherche Scientifique); guest seminars in Technical University Darmstadt and Frankfurt a. M. (supported by American military authority)
AR 1949	Kolloquium Universität Freiburg (Schweiz); Schweiz. Naturf. Gesellschaft Winterthur; Conference Internat. Union of Geodesy and Geophysics, Oslo.
AR 1950	among others: Naturf. Gesellschaft Zürich; Schweiz. Gesellschaft für Balneologie und Klimatologie Bern (title: Die Atmosphäre als Organismus).
AR 1951/1952	as delegate of Schweiz. Naturf. Gesellschaft in August 1951: two presentations in Brussels at the two weeks meeting of Internat. Union of Geodesy and Geophysics: (1.) (together with F. Volz) at Symposium sur le rayonnement "title: The blue sun of September 1950" and (2.) at Symposium on Atmospheric Ozone on "Vertical Distribution of Ozone"
AR 1953 and later	No presentation listed

International research cooperation was very important for Götz. He participated in the important international Ozone Conferences (see Table 5). A letter in the LKO Archives (Götz to Bernet, 27 December 1928) shows that Arosa had been foreseen as venue of the first ozone conference. However, as the necessary guarantees by the authorities of Arosa were delayed, Paris was chosen as meeting place[116]. The conference in Tharandt (Germany) took place in 1944 (see Table 5) and was supported by the German Meteorological Service[117]; the results were published after the World War II in reports from the German Weather Service in the US Zone (Weickmann, 1949).

Götz is listed as a member of the International Radiation Commission of IMO[118] (1932-1936) and of IAMAS (1948-51) (Internat. Rad. Com., 2008). Götz was a member of the Committee on Ozone established in September 1933 within the Radiation Commission of IAMAS as requested by Charles Fabry[119] and recommended by the Fourth Assembly of the International Union of Geodesy and Geophysics (IUGG)[120] at Stockholm in 1930 (Bojkov, 2012). He also was a member of the International Ozone Commission (IO_3C)[121] from 1948 until 1954. In the AR 1941 (KVVA, 1921-1977) we learn that Götz was elected as member of the Academy of Sciences Leopoldina[122] honoring his excellent research. In AR 1949, it is indicated that Götz was a member of the following international commissions: Commission for Solar-Terrestrial Relations, Radiation Commission, Northern Light Commission, Ozone Commission and UNESCO Commission for High Alpine Research Institutes.

Table 5: Participation of Götz in early international ozone conferences (from Bojkov, 2012, also refer to IO_3C website).

Conference on Atmospheric Ozone	Paris	15-17 May 1929
Conference on Atmospheric Ozone	Oxford	9-11 Sep 1936
Special meeting on Ozone	Tharant	17-18 Apr 1944
Symposium on Ozone	Oslo	30-31 Aug 1948
Symposium on Atmospheric Ozone	Brussels	30-31 Aug 1951
Symposium on Ozone	Oxford	2-4 Sep 1952

In addition, Götz reported at least four times to the Society of Natural Sciences of the Grisons (Götz, 1931a, 1934, 1938 and 1948); these surveys summarized his studies and results in a rather general way. He also wrote articles in the local newspaper[123] and produced occasional articles in other newspapers.

116 Later on, Götz undertook a second attempt and wanted to organize the ozone conference of 1936 in Arosa, obviously without successful realization (refer to Section 3.9.1).

117 Deutscher Reichswetterdienst.

118 International Meteorological Organization (1853-1950), the predecessor to the World Meterological Organization (WMO).

119 Charles Fabry (1867-1945), PhD, physicist, Professor of General Physics at Sorbonne, Paris (1921-1945), Director of the "Institut d'optique théorique et appliquée".

120 The International Union for Geodesy and Geophysics (IUGG), with its International Association for Meteorology (IAM) (now International Association of Meteorology and Atmospheric Sciences (IAMAS)), was the only relevant international organization that could appropriately host such a group of scientists interested in the atmospheric ozone. The IAMAS had only one permanent scientific commission on solar radiation formed in Madrid in 1924. At the Lisbon assembly in 1933, the Radiation Commission, "in recognition to the importance of ozone research for better understanding of the stratosphere", established a Committee on Ozone; the members were Dobson, Fabry and Götz. At that meeting two papers related to ozone: "Report on Ozone Research" by G. M. B. Dobson and F. W. P. Götz and "On the progress of the methods for study of atmospheric ozone" by Ch. Fabry were presented.

121 The International Ozone Commission (IO_3C) was established in 1948 at the Seventh Assembly of the International Union of Geodesy and Geophysics (IUGG) as one of the special commissions (see Table 5). For more information on the early IO_3C history refer to Bojkov (2012).

122 The "Deutsche Akademie der Naturforscher Leopoldina" has been the German National Academy of Sciences since 2008.

123 Refer to footnote 8 on page 3.

Götz communicated with many colleagues by letter. The correspondence of Götz available in the LKO Archives is very extensive including as many as 35 folders covering scientific and technical as well as personal matters. The correspondence also demonstrates the capability and effectiveness of Götz in networking. He had extensive correspondence with Dobson[124] (Sect. 3.7), Maurer[125], later Lugeon[126], Linke[127] his former PhD advisor Wolf[128] (Sect. 2.4), Chalonge[129] and many others.

3.5 Scientific studies

3.5.1 Key scientific questions

At the end of the 1920s the following questions were in the center of the scientific debate of the young atmospheric ozone research.

The first network of Féry instruments (Sect. 3.7.1) produced by Dobson in Oxford provided measurements of northern extratropics. At the most northern site of Abisko[130] data from the end of April until end of September were obtained, showing a tendency for an increase from the tropics to the High North (Dobson et al., 1929; Götz, 1929a). Concerning the higher stratospheric ozone concentration in the winter months in the northern latitude as compared to the summer season[131] Ladenburg (1929) reflects the discussions at the International Ozone Conference in 1929 in Paris in the following way: *"Is it possible that sunlight is not the main determining factor in the generation of ozone[132]? Perhaps the radiation, to which we owe the polar lights, contributes to the ozone formation, and the sun, which is very effective during the long days of the summer in the northern latitudes, induces primarily the destruction of the ozone. Therefore, special high ozone values should be measured in the High North in the autumn and a great dependence of these values on the polar lights be detected"*[133]. Götz (1929a) addressed these basic scientific questions in a similar way including more instrumental questions.

Ladenburg underlines in his summary that data should be collected concerning these questions during Götz's Svalbard expedition in the summer of 1929[134] (Sect. 3.8). Indeed, one of the main aims

124 Refer to footnote 91 on page 25.

125 Julius Maurer (1857-1938), PhD, physicist, Director of MeteoSwiss (1905-1934), President of the International Radiation Commission (1912-1932).

126 Jean Lugeon (1898-1976), PhD, professor at the University of Zürich, Director of MeteoSwiss (1943-1963).

127 Karl Wilhelm Franz Linke (1878-1944), PhD, Director and Professor of the Institute for Meteorology and Geophysics, Goethe-University of Frankfurt a. M., 1908-1944) (see also Section 3.6.3).

128 Refer to footnote 44 on page 12.

129 Daniel Chalonge (1895-1977), French astronomer, one of the founders of the "Institut d'astrophysique de Paris".

130 Sweden, 68.2 N, 18.5 E.

131 Ladenburg, 1929. Translated by the authors. Original text. „Warum aber findet man z. B. in Abisko, im nördlichsten Schweden, nach monatelangem niedrigstem Sonnenstand gerade die höchsten Ozonwerte?".

132 Note that photolysis of molecular oxygen (O_2) by solar light determines ozone production in the theory of Chapman (1930) providing the well accepted chemical theory for stratospheric ozone for many decades and the basis of the calculations of the PhD thesis of Dütsch (Sect. 5.1).

133 Ladenburg, 1929. Translated by the authors, Original text: „Ist etwa das Sonnenlicht gar nicht der wesentlichste Bildungsfaktor des Ozons. Vielleicht wirken die Strahlen, denen wir das Polarlicht verdanken, auch ozonbildend, und die Sonne, die im dauernden Tag des Nordlichtsommers besonders stark wirken kann, ruft vornehmlich eine Zerstörung des Ozons hervor. Dann müssten im hohen Norden im Herbst besonders kleine Ozonwerte und eine starke Abhängigkeit dieser Werte von Polarlichtern gefunden werden.".

134 Ladenburg, 1929. Translated by the authors. Original text: „Für diese wichtige Frage soll von einer durch Unterstützung der Notgemeinschaft nach Spitzbergen entsandten Expedition in diesem Sommer Beobachtungsmaterial gesammelt werden.".

justifying the Svalbard measurements of Götz described in Section 3.8 was the confirmation about the stratospheric ozone amount near the North Pole during the arctic summer. The measurements of Götz from Svalbard in 1929 confirmed and extended the mean seasonal variation as well as the general increase of total ozone from the tropics toward the polar latitudes (see Dobson et al., 1930[135]). However, the increase from the tropics to the High North was puzzling when accepting the general view of ozone production by shortwave (UV) solar light (Götz, 1929a and 1933) as relatively short time to reach the equilibrium between ozone formation and destruction was assumed and nothing about transport of ozone was know at this time[136]. To solve this scientific problem, Götz assumed that additional processes are required and polar particles might be involved in stratospheric ozone depletion.

One other key question was the atmospheric ozone profile. In this context Götz started surface ozone measurements (Sect. 3.5.2) and in Section 3.8 entire atmospheric ozone profiles obtained by the Umkehr method and extending up to the upper stratosphere are described.

Upon returning from Svalbard it was Götz's intention to further investigate these topics and to extend the studies already underway in Arosa. Therefore, in collaboration with the Auroral Observatory of Tromsø[137], he completed night time measurements of the ozone absorption made there with a quartz spectrograph with similar photo plates taken during full moon nights in March in Arosa (Götz, 1935a).

Several articles show that the northern lights visible from Arosa were one key topic of his research at this time; Götz published papers on such phenomena every year between 1938 and 1942 (as well as in 1947) (Annex 2). Encouraged by a proposal from Carl Stoermer[138] entitled *"The Importance of height determination of northern lights in central Europe"*[139], Götz designed an observational network composed of three stations[140] to take simultaneous pictures and determine the height of the polar lights by triangulation. Besides this, Götz expanded the observations to all kind of phenomena occurring in the sky; in a description summarizing his research topics (Götz, 1935b) he then emphasized that the observation of air glow was considered as a new important research topic for the LKO as started in the 1930s[141].

Götz endeavoured to procure the adequate instruments for the planned observations and submitted a request to the University of Zürich. In a response of 13 February 1933, the Foundation for Scientific Research at the University of Zürich[142] agreed to finance the acquisition of a quartz spectrograph to

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135 The measurements of Götz from Svalbard are included in Figure 1a on p. 417 of Dobson et al. (1930) underlining the high importance of the data measured by Götz.

136 Similar questions were addressed by the PhD thesis of Dütsch (Sec. 5.1) and they were finally solved by the detection of the Brewer Dobson circulation (Brewer, 1949), i.e. showing transport of ozone mainly formed in the tropics most of it being transported as inactive tracer into the extra tropics in the winter hemisphere.

137 Today: Tromsø Geophysical Observatory.

138 Carl Störmer (1874-1957), PhD, professor at the University Blindern (near Oslo), Norway, chairman of the Northern Light Commission of the IUGG.

139 Document Störmer, 193? (date not on the document). Translated by the authors. Original title: „Über die Wichtigkeit von Höhenmessungen der Nordlichter in Mitteleuropa".

140 The three stations were: Arosa (CH), Zugspitze (D), Oberhilfenswil (CH). During the World War II the Zugspitze was replaced by the Jungfraujoch (Letter von Muralt, 6 October 1941).

141 Today it is well established that different types of cosmic rays connected with northern light phenomena such as aurora can affect stratospheric ozone (Krivolutski, 2003 summarizes the present knowledge on the involved processes); however, these events usually do not have a strong effect on ozone at latitudes like Arosa.

142 Stiftung für wissenschaftliche Forschung an der Universität Zürich.

support the "*investigations [of Götz] on the highest layers of the atmosphere"* [143]. Concomitantly the astronomical observatory of University of Göttingen was ready to start observations at Arosa with a specially developed instrument ("interference disc" [144]). Cario [145] of the Physics Institute of the Technical University of Braunschweig also came to Arosa with his own spectrograph to make night time observations.

A series of documents suggest that Götz was originally even more ambitious. At the end of the 1920s he approached Brunner [146] of the astronomical institute of ETH Zürich with the idea of defining common research fields focused on solar observation. Brunner showed great interest (Brunner, 30 October 1929) but ultimately stayed behind [147]. A few years later, Linke [148] assisted him in the tentative plan to establish an international "solar station" [149] at Arosa; Buisson [150] and probably other well-known scientists were contacted to start an international collaboration [151]. According to Götz [152], preliminary commitments of the federal authorities existed to support the operation of a federal research institute in Arosa through a TB foundation, but the initiative for obtaining financial support from the TB foundation was unsuccessful (Sect. 3.6.1).

Note that the effect of the solar cycle on stratospheric ozone addressed by Götz was also studied by Dütsch (Sect. 5.1) and is still discussed today [153].

3.5.2 Selected scientific studies

For estimating tropospheric ozone amount (surface ozone), measurements were made in the surroundings of Arosa in the 1930s by Götz and Ladenburg (1931) and Götz and Maier-Leibnitz (1933b) [154]. Surface ozone measurements at Jungfraujoch (see also Section 9.1.3.h) extended the surface ozone measurements up to the elevations of 3466 m a.s.l.

The investigations from Peppler (1930) and Peppler and Götz (1931) underline the efforts of Götz to study the environmental factors of Arosa in an extended and comprehensive way. From 4 November 1929 to 15 March 1930, 105 pilot balloons were launched [155] from Arosa and their paths were fol-

143 Letter/Form University of Zürich, 14 February 1933. Translated by the authors. Original text: „Anschaffung eines Quarzspektrographen zur Untersuchung der höchsten Atmosphärenschichten.".

144 „Eine Interferenzplatte zur Untersuchung der Intensitätsverteilung der grünen Nordlichtlinie am Nachthimmel" (Author unknown).

145 Günther Cario (1897-1984), PhD, professor at the Technische Hochschule Braunschweig (1936-1968?).

146 William Otto Brunner (1878-1958), PhD, had a joint appointment as Professor for Astronomy (1926-1945) of the University of Zürich and ETH Zürich.

147 With respect to the unsuccessful tentatives of a collaboration with Brunner at the end of the 1920s, it can be seen as irony that in 1938 the new astrophysical observatory of the Institute for Astronomy of the ETH Zürich was built in close proximity to Götz's Tschuggen hut (see Section 3.3.2).

148 Refer to footnote 127 on page 34.

149 Letter Linke, 1 May 1931. Translated by the authors. Original text: „Wie Sie wissen, halte ich Arosa für die günstigste Stelle eines Strahlungsobservatoriums und überlege zur Zeit, ob man in internationaler Zusammenarbeit Ihr Observatorium nicht zu einer Solarkonstanten-Station ausbauen sollte."

150 Henri Buisson (1873-1944), PhD, physicist, professor at the University of Marseille (1914-1944).

151 Letter from Linke dated 21 May 1931 (copy) to Buissson.

152 Letter from Götz dated 28 February 1933 to Mr Metz, Mayor of the city of Chur (Bürgermeister der Stadt Chur).

153 The knowledge of the magnitude of the influence of the solar cycle on ozone is important in the context of the long-term trend determination (Sect. 6.1; Dütsch et al., 1991). Furthermore, the effect of cosmic rays on ozone is also discussed in the context of the variance of the solar cycle as described by chemical climate models (Funke et al., 2017).

154 For further information concerning surface ozone measurements in Arosa refer to Section 9.1.3.b.

155 At following hours: 10am - 11am and 2pm - 3pm.

lowed by telemetry. The aerological studies were justified by bioclimatology as well as by requirements of air traffic including gliders. Arosa, situated at the end of the Schanfigg valley, is surrounded by high mountains (see Figure 2), which shield the village from the higher wind speeds that prevail at higher altitudes[156].

3.6 Evolution of the LKO under Götz

3.6.1 LKO support by the Rhaetian Railway and the Swiss tuberculosis fund

As the financial situation of the LKO under Götz was always difficult (Sect. 9.3), he tried to obtain additional support. The Railway Company Chur-Arosa (ChA Bahn) was sponsoring the LKO[157]. Searches of Florian Ambauen (Rhaetian Railway Company) show how Götz was able to obtain support for the LKO from the ChA Railway. Götz approached Gustav Bener[158], Director of the Rhaetian Railway Company. Bener who was member of the board committee of the ChA Railway Company proposed that the ChA Railway Company support the LKO[159]. The minutes of the 123rd board committee meeting, which took place on 3 December 1931, document that funding of the LKO by the ChA Railway Company was finally approved. Nevertheless, the protocol of the board committee meeting also documents that this financial contribution by the Railway Company was controversial at the 122nd meeting that took place on 24 October 1930[160]; the documentation also includes a letter from the medical doctors of Arosa of 5 November 1930 supporting the request and underlining the strong need for the support. This shows that Götz was a skilled networker as Bener obviously strongly supported the LKO[161].

Documents obtained from the Swiss Federal Archives[162] demonstrate another initiative to obtain support for the LKO, namely from the Swiss tuberculosis fund. In a letter from 2 April 1932, Götz reports to Vital[163] of the Federal Department of Home Affairs about a meeting with Carrière[164] of the Office of Public Health, stating that it might be possible to obtain such support if the value of the LKO investigations to TB research could be demonstrated. However, Carrière suggested first adapting the organization of the LKO to fulfill the formal prerequisites for such support. A draft of a deed of foundation was written. In a letter from the Department of Home Affairs (11 November 1932) we learn that the federal government was eventually ready to supervise the foundation. However, the proposed deed of foundation would require adaptions, e.g. related to capital and increase of capital of foundation as well as to memberships. Gähwiler, president of the Medical Doctors Association of

156 Refer to footnote 22 on page 6.

157 The Chur-Arosa Railway Company merged with the Rhaetian Railway Company on 1 January 1942.

158 Gustav Bener (1873-1946), Director of the Rhaetian Railway Company (1918-1936), member of the board committee of the ChA Railway Company.

159 Letter Bener, July 1930. "Your request of 27 June 1930 would be most probably accepted at the board committee meeting of the ChA Railway Company and I am willing to support your request." Translated by the authors. Original text: „Ihre Anfrage vom 27. Juni fände jedenfalls beim Verwaltungsratsausschuss der Chur-Arosa-Bahn volles Verständnis und ich würde dort im Verwaltungsrat der ChA Bahn Ihren Plan gerne empfehlen.".

160 The annual support varied between 1,333 and 4,000 CHF/y in the period 1932-1957 (Sect. 9.3.1.1).

161 Götz was furnished with free train tickets for the travels of himself and of many scientists visiting the LKO Arosa.

162 Schweizerisches Bundesarchiv (BAR) Bern.

163 Fritz Vital, PhD, Secretary of the Federal Department of Home Affairs (Eidgenössisches Departement des Innern) in Bern.

164 Henri Carrière, PhD, Director of the Swiss Federal Office of Public Health (Gesundheitsamt) in Bern.

Arosa, replied only on 31 August 1934 stating that the involved persons in Arosa were very motivated to realize the project, but that times were evolving so badly that every initiative would a priori lead to a failure. The initiative was temporarily stopped (but never resumed).

3.6.2 Hedwig Kohn at the LKO

PD Dr Hedwig Kohn is abbreviated as H.K in Table 3. This was a precautionary measure because, being Jewish, she was being hounded by the Nazi regime (refer to https://de.wikipedia.org/wiki/Hedwig_Kohn). According to Winnewisser (2003 and 2016) Hedwig Kohn[165] was among the youngest female physicists following a research career in Germany, attaining a habilitation[166] on 5 May 1930. However, she could not pursue her university career because she was Jewish. She was removed from the university teacher list in 1933 but was still able to continue advising PhD students. She stayed at the LKO for 3 months in 1935 supported by a grant from an American organization of ex-Germans (German Scientists Relief Fund). We found about a dozen letters[167] written by Kohn to Götz from June 1935 to July 1939. Only one copy of the many letters addressed by Götz to Kohn is in the LKO Archives. The first letters include scientific and logistic planning of her stay in Arosa. The topic of the study was UV sky measurements using the Arosa ultraviolet spectrograph (Sect. 9.1.2.a). When Kohn returned home, some photographic plates were sent to her institute in Breslau and she informed Götz about the analysis work, but apparently the progress was not as originally expected. In the letter dated 30 December 1936, we read that she obtained support from a grant to continue the study in Arosa, allowing her to stay there for 5 months, but that she only could travel to Arosa in the second part of 1937 due to other commitments. We do not know the reason why Kohn did not continue research at the LKO. According to a remark in Götz and Schönmann (1948), she worked on an error analysis related to the Arosa ultraviolet spectrograph, but the study was not finished due to emigration[168].

The letters demonstrate Kohn's continuous trials to get an opportunity to emigrate and her feelings alternating between hope and disappointment. She was obviously personally very grateful for the help and support from Götz and his wife and the letters (after return to Germany) are very warmly written, always containing greetings to Götz's wife. Götz seems to have been moved by the Kohn's plight and seems to have taken care of her beyond the professional aspects. In a letter from 8 March 1939, Dobson mentioned that he got a letter from the Refugee Committee of the International Federation of University Women with the request "to advise them whether she [Hedwig Kohn] is likely to get scientific work here or in the Dominions". He therefore asked Götz about Hedwig Kohn as she was working for three months at the LKO in 1935. Hedwig Kohn was eventually able to emigrate to Sweden and subsequently to the USA in 1940 (Winnewisser, 2003) when World War II had already started. Her brother died in the Holocaust. Her emigration was initiated by Ladenburg[169]. In the USA, Kohn first taught at the Women's College of North Carolina for a year and a half, and then from 1942 to her retirement in 1954 she was teaching at Wellesley College in Massachusetts (Wikipedia).

165 Hedwig Kohn (1887 - 1964), born in Breslau (Germany).

166 For description of the "habilitation" refer to Section 3.9.2.

167 Exclusively handwritten.

168 Götz und Schönmann, 1948. Original text: „Eine 1935 am Lichtklimatischen Observatorium mit einem Quarzspektrographen in Angriff genommene Arbeit von P.-D. HEDWIG KOHN kam infolge ihrer Auswanderung nicht zum Abschluss.".

169 He was the first unofficial PhD adviser of Kohn in Breslau before he became professor first in Breslau and later in Berlin. See also footnote 104 on page 30 and Section 3.5.2.

3.6.3 Plans to leave Arosa

Two (confidential) letters[170] show that Götz considered options to leave Arosa in the 1930s. Linke was informed by Knoch[171] about the interest of Götz in the planning of a German high alpine institute related to climate research. Linke wrote to Götz discussing options for employment at a university institute connected to an astronomical observatory. Götz acknowledged Linke's proposal in his reply and mentions that his position at Arosa was still not secured and that German nationality might become a difficulty concerning his expectations in Zürich[172]. However, Götz also appreciated his opportunities in Arosa having an autonomous (small) institute allowing him to earn income for his own survival and to perform his independent research. The letter ends with him stating that he would consider moving to Germany, but only if the new position were permanent and offer him the possibility of continuing his professional work[173].

However, in 1940 it was not clear to Götz whether he should continue to work in Arosa, which is also reflected in the correspondence between Dobson[174] and Götz (Sect. 3.7) and is surely due largely to diminishing finances during World War II (refer to Section 9.3.1.a). A letter from 14 Aug 1940 written by Götz to Zuber[175] describes Götz's contacts with Colonel Isler[176], who suggested constructing an airport for gliders in Arosa. Obviously, such a project would have allowed Götz to obtain additional support at least for instrumentation. In a letter to Colonel Isler at the end of 1940 we learn that Zuber was planning to meet him (Colonel Isler) in Bern, but Götz expressed his disappointment that the LKO's budget had reached a minimum and that his wishes to obtain support for employees assisting him in the analysis of the measurements seemed unrealistic in the near future. In the last sentence of this letter we find that Götz rejected an offer from the University of Frankfurt to succeed Linke because he preferred to stay in the Alps[177].

In a letter from 7 March 1940, Linke mentions that he got the impression that Götz and his wife wished to leave Arosa when he visited them. Already in an earlier letter (5 January 1939) Linke regrets that the University of Zürich did not offer Götz a full professorship[178], which he felt would be appropriate, because in Switzerland "nobody cares" about Götz[179]. In the same letter Linke writes about his attempts to find a position for Götz in his group at the University of Frankfurt. However, the

170 Letters Linke, 5 September 1935 and Götz, 17 September 1935.

171 Karl Heinrich Knoch (1983-1972, PhD, professor, Director of the German Weather Service (Reichswetterdienst) (1935-1945).

172 Certainly the University of Zürich is meant; however, this concern obviously turned out to be wrong at least concerning his promotion to honorary professor that took place in in July 1940 (Sect. 3.9.2).

173 Letter Götz, 17 September 1935. Translated by the authors. Original text: „Ich möchte so vorläufig nur dann an einen Wechsel denken, wenn es sich nicht um ein Sprungbrett, sondern um eine definitive Stellung meiner Arbeitsrichtung handeln würde.".

174 Refer to footnote 91 on page 25.

175 Paul Zuber, Director of the KVV Arosa (1934-1942).

176 Arnold Isler (1882-1941), Director of the Air Traffic Authority (erster Direktor des Eidgenössischen Luftamts) in Bern (1920-1941).

177 Letter Götz, 30 December 1940. Translated by the authors. Original text: „ […..] habe ich 1940 eine Berufung an die Universität Frankfurt ausgeschlagen, wo Prof. Linke, Direktor des Universitätsinstituts für Meteorologie und Geophysik [mich] als Nachfolger haben möchte; - ich hänge zu sehr an den Bergen."

178 Letter Linke, 5 January 1939. Original text: „Wäre es nicht möglich, dass der Lehrauftrag sich in eine Professur für Meteorologie und Geophysik umwandeln lässt?".

179 Ibid. Translated by the authors. Original text: „Ich bedauere immer, dass Sie nicht den Platz einnehmen, der Ihnen gebührt, weil die Schweiz sich nicht um Sie kümmert.".

original plan apparently turned out to be unfeasible because, unexpectedly, Möller[180] was able to join his institute after working at the German Weather Service[181]. Linke also brings up his intention to create a new institute with a strong emphasis on astrophysics and geophysics, which, however, would need additional resources that might have become available in 1939.

It is clear that Linke made an offer to Götz during 1939, which is not available to us, but Götz asked Cario[182] for his opinion and advice about Linke's offer. Cario[183] pointed out that Linke's offer was problematic because of the following points: (1) the position offered by Linke was one of a senior assistant with a rather modest salary and retirement funds were not mentioned (which would need clarification); (2) it was felt that the institute should, at least, offer Götz a position of an extraordinary professorship; (3) the possibility, obviously included in the offer, that Götz could follow Linke as professor at the university of Frankfurt was considered to be too uncertain. Cario suggested to Götz to be careful about this promise as it would not be feasible to give Götz any formal certainty on this important point. Cario suggested that Götz should insist that the new institute[184] would be formally independent and chaired by Götz[185]. Only in this case Götz could avoid possible difficulties if another younger colleague would obtain Linke's professorship[186].

Ostensibly Götz wrote[187] to Linke informing him of his decision not to leave Arosa because he wanted to continue to stay in the Alps, as acknowledged by Linke on 7 March 1940 (see above). Linke was also in discussion with Götz about another option for a professorship (letter of Götz to Linke, 22 August 1942): Wagner[188], professor at the University of Innsbruck, had passed away and seemingly Götz was interested in getting this professorship. We do not know whether this was pursued. Linke died on 23 March 1944 from a stroke while helping to extinguish a fire caused by a bomb attack. From the information of naturalization (Appendix 2) we learn that Götz also obtained the offer of a professorship at the University of Vienna.

3.6.4 Medical development of the resort areas

In 1942, in a letter to Maron[189], Götz was referring to a newspaper article probably describing the success of the construction of the new observatory for the Institute of Snow and Avalanche Research[190] at Weissfluhjoch[191] and compared the situation between Davos and Arosa. The letter

180 Fritz Möller (1906-1983) completed his PhD at the University of Frankfutt in 1928, "Observator" at the Universities of Frankfurt and Leipzig (1938-1948), Professor of Meterology and Geophysics at the University of Mainz (1948-1960), Professor at the University of Munich (1960-1972).

181 Reichsamt für Wetterdienst (see Wikipedia).

182 Refer to footnote 145 on page 36.

183 Letter Cario, 28 February 1940. Translated by the authors. Original text: „[…..] vor allem gefällt mir nicht, dass man Ihnen Hoffnung macht, in einigen Jahren Linkes Nachfolger zu werden. Eine verbindliche Zusage kann und will Ihnen niemand geben.".

184 Planed in Königstein (im Taunus), part of the Frankfurt Rhein-Main urban area.

185 Letter Cario, 28 February 1940. Translated by the authors. Original text. „Sie müssten deshalb auf alle Fälle darauf dringen, dass das Institut in Königstein selbstständig würde und ausschliesslich Ihnen unterstellt wird.".

186 Ibid. Translated by the authors. Original text: „Nur so würden Sie [.…] vermeiden können, dass aus einer eventuellen Besetzung der Linkeschen Professur mit einer jüngeren Kraft Unannehmlichkeiten erwachsen könnten.".

187 Letter not available to us.

188 Artur Wagner (1883-1942), PhD, professor at the University of Innsbruck (1927-1942) and Director of the Institute of Cosmic Physics.

189 Refer to footnote 65 on page 16.

190 Schweizerisches Institut für Schnee-und Lawinenforschung (SLF) at Weissfluhjoch (Davos).

shows his disappointment: *"Is it normal that I need to think after 21 very successful years whether it would be acceptable to stay here in Arosa further or whether it would be more appropriate to move to another place where I receive an acceptable salary and some safety to survive when I am old?"*[192]. He complains that the community of Davos was able to obtain much better support for the SFI[193] and claiming that in Davos all actors including the public community, medical doctors etc. worked together. In the letter from 22 September 1942, he proposed to reconsider the proposal of 1924, namely the fusion of the institutes of Davos with Arosa (Sect. 3.2). Götz argues that in 1942 the condition for such a merger would be much better for Arosa than in 1924 when the doctors of Arosa stopped further negotiations. He also remarked that it could be useful to strengthen the institute of Davos, though did not know about the possible reaction of Davos. The institute could be renamed from "Schweizerisches Forschungsinstitut in Davos" to "…. und Arosa" and include the following four parts (1) an observatory with a focus on geophysical research, located in Arosa and run by Götz; (2) an observatory with a focus on bioclimatology, located in Davos and run by Mörikofer[194]; (3) a bacteriological-anatomical institute, located in Davos and run by Berblinger; and (4) an institute for physiology, located in Davos, which needed to be restarted again. Götz also pointed out that he was teaching at the University of Zürich and his colleague Mörikofer at the University Basel. We do not know whether this idea was discussed further.

Götz was obviously not satisfied with the financial support for his research[195]. This can be documented in many cases. In the short reports written for the KVV Arosa (Sect. 3.4), it is also indicated several times that the research activities at the LKO were limited because of restrained financial support to hire assistants both for performing field observations as well as for interpreting the many measurements. In AR 1935 we read: *"In neighboring countries the research of climate of resort areas obtains strong national support whereas the observatory [LKO] does not even obtain cantonal support"*[196]. In the surveys intended to the Society of Natural Sciences of the Grisons (Götz, 1938), Götz also stressed the need for more appropriate financial resources to afford assistance in performing the measurements, which were already well known in the international scientific community.

In the second part of World War II a rather broad program aimed at the medical development of the resort areas[197], dubbed "climatological action"[198] for short, was prepared in Switzerland with the main goal of supporting scientific activities to put the Swiss alpine health and touristic resorts in a good position for the time when the war would end. The funding originated from the Swiss Federal Office for Transport[199] and a commission[200] prepared the decision about the support of the individual

191 Test field of SLF established in autumn 1936 at the Weissfluhjoch (2693 m a.s.l.) above Davos.

192 Letter Götz, 21 September 1921. Translated by the authors. Original text: „Oder finden Sie es als normal, wenn man sich nach 21-jähriger erfolgreicher Arbeit allmählich ernstlich die Frage stellen muss, wie lange man noch zusehen kann, wenn man nicht die Jahre versäumen will, in denen man anderwärts ein der Ausbildung und Leistung einigermassen entsprechendes Einkommen und eine Sicherung für das Alter erhalten kann?".

193 Namely amounting to 60-80'000 CHF annual budget (which was approximately four times the budget of the LKO at that time) (Sect. 9.3.1.1).

194 Refer to footnote 72 on page 18.

195 In Section 3.6.3, the plans of Götz to leave Arosa are put in a more general perspective.

196 AR 1935 (KVVA, 1921-1977). Translated by the authors. Original text: „[….] während im Ausland die Kurortsklimaforschung neuerdings grosszügige staatliche Förderung findet, hat das Aroser Observatorium auch nicht einmal kantonale Unterstützung.".

197 Medizinischer Ausbau der Kurorte

198 Klimaaktion.

199 Bundesamt für Verkehr.

200 Fachausschuss für den medizinischen Ausbau der schweizerischen Kurorte.

contributions. We found relevant documents in the Swiss Federal Archives[201]. In a document from 30 April 1943 sent to the Federal Office for Transport, Maron asked for annual support for the LKO of 5,000 CHF for several years, pointing out the scientific merits of Götz and the strong demand for support.

In a letter from 2 October 1943, Götz informed Trenkel[202] about a phone call from von Neergard[203] declaring that the decision about the proposal would be taken on 14 October and that Mörikofer from Davos had applied for three assistants, adding to the 7 assistants and other staff already available. Von Neergard also wanted to discuss whether the medical doctors of Arosa would be interested in contributing to the studies of the "climatological action".

Götz wrote two letters on 15 October, one to Maron and the other to Trenkel. He informed Maron that he obtained, in another phone call from von Neergard, confidential information from the meeting in Bern that Götz's proposal (formally proposed by the KVV Arosa) for contribution to the "climatological action" was rejected because of Mörikofer's vote arguing that Götz's work was not related to the climatology of Arosa; von Muralt[204], the only expert in the commission who could have corrected Mörikofer's view, was not present at the meeting and von Neergard was even unsuccessful in asking for an external review of a neutral expert. In the same letter, we learn that Davos made a proposal for 2,000,000 CHF with plans to get a very large institute and that in the following week the governing council of the Grisons was planning to travel to Davos; von Neergard recommended that a representative of Arosa should travel immediately to Gadient[205] in Chur so that Arosa could also have a chance to receive some support. The letter sent to Trenkel contains the same information including the remark that he was informed about ten years ago by Bener[206] (Sect. 3.6.1), that he (Bener) rebuffed Mörikofer after a meeting in Davos in which a Federal Councillor[207] from Bern was present about the statement that the observatory at Arosa was superfluous as this work could be done by his institute in Davos. Götz added that Mörikofer might like to get rid of him as he probably had problems comparing himself with him; Mörikofer might have been a brilliant agitator but not a successful scientist[208] with modest scientific results when considering he had 10 assistants[209].

In the official minutes of the meeting[210] we find that Cottier[211], the president of the committee, declared that the proposal from Arosa could not be decided in this meeting, but that he would like to

201 Refer to footnote 162 on page 37.

202 Refer to footnote 39 on page 12.

203 Kurt von Neergard (1887-1947), PhD, Professor of Physical Therapy at the University of Zürich (1940-1947) treating problems of lung pressure.

204 Alexander Ludwig von Muralt (1903-1990), PhD, Professor of Physiology of the University of Bern (with an education in medicine and physics), President of the International Foundation of the High Altitude Research Stations Jungfraujoch and Gornergrat HFSJG (1937-1973), founder of the Swiss National Science Foundation (SNSF) in 1952.

205 Andreas Gadient (1892-1976), member of the governing Council of the Canton of Grisons (Regierungsrat des Kanton Graubünden) (1939-1947).

206 Refer to footnote 158 on page 37.

207 Bundesrat.

208 Letter Götz, 15 October 1943 (to Trenkel). Translated by the authors. Original text: „[…..] als Wissenschaftler aber sehr unter Mittelmass ist."

209 We were not able to confirm by independent source the number of collaborators of PMOD during World War II.

210 Summarisches Protokoll der dritten Sitzung des Fachausschusses für den medizinischen Ausbau der schweizerischen Kurorte" of 14 October 1943.

211 Raphaël Cottier (1891-1974), Director of the Federal Office of Transport (Schweizerisches Bundesamt für Verkehr (BAV)) (1940-1949).

hear the opinions from members of the commission. Mörikofer spoke about the excellent scientific reputation of Götz, however, it appears not obvious to him how to include Götz in the program as his expertise was in astronomy. Nevertheless, one could discuss this with Götz in order to give him an opportunity to contribute to the study program. In a letter from 26 November 1943 to Cottier, Mörikofer states that he had asked Götz to discuss the matter with him; however, he believed that it would be difficult to coordinate his own research activities with Götz's project due to financial and psychological aspects.

In the letter from 11 November 1943 written to the KVV Arosa (to be sent to the Director of the Federal Office for Transport) Götz presented a new concept to justify measurements at the LKO for society. Götz writes about priorities of research of resort areas (illustrated by his publications) and compares this research to the study of "natural resources" by an industrial company as the climate should be viewed as the "natural resource" of resort areas. Remarkable in this letter are investigations of pilot balloons (Sect. 3.5.2) to study the wind conditions indicating the strong protection of the alpine wind field by the orography of Arosa[212] and the high value of air quality for the comparison of resort areas. Götz argued that the low air quality in cities goes along with low ozone concentration whereas the high air quality of resort areas is characterized by high ozone values as it was believed at this time that ozone originates exclusively from the stratosphere[213].

Cottier asked von Muralt in a letter from 6 December 1943 about his opinion to support the LKO based on the proposal from 11 November 1943. Cottier clarifies that he originally found it feasible to include the LKO's activities in Mörikofer's project, also possibly with respect to financial matters, but that he changed his opinion thinking that such an approach would be hardly practical due to personal as well as financial aspects. The written review of von Muralt, which is included in the protocol of the fourth meeting of the commission of 16 December 1943, indicates that von Muralt supported the proposal of the KVV Arosa (LKO) because of Götz's internationally well-known research in climate research. Götz presented two programs, namely a minimal version asking to analyze measurements of Arosa including additional measurements of wind flow and radiation and a maximal program including additional studies of air pollutants and UV transparency. Von Muralt strongly favored the maximal program. It was discussed whether the Swiss Academy for Medicine could be interested in financing the program, which had been denied. The commission eventually supported the proposal unanimously[214]. Mörikofer recommended that the program should not be defined too narrowly as the progress might depend on the availability of capable employees and that the KVV Arosa should not be allowed to reduce the support for the LKO.

The decision was communicated in a letter dated 5 January 1944, which was sent from the Federal Department of Post and Railways[215] to the KVV Arosa. This was forwarded to Götz by Zuber on 14 January 1944. This support had been very important for a reorientation of the LKO as it enabled several staff members to be employed (see Table 20 in Sect. 9.3.2). The well-known surface ozone measurements of Arosa (Götz and Volz, 1951, Staehelin et al., 1994), that were continued by Perl

212 And other aspects concerning synoptic meteorology such as foehn.

213 Note that ozone concentration is lower in polluted areas due to reaction with nitrogen oxide (NO) and dry deposition (decomposition at the Earth's surface).

214 For financial amount refer to Section 9.3.2.

215 Eidgenössisches Post- und Eisenbahndepartement, today: Eidgenössisches Departement für Umwelt, Verkehr und Kommunikation (UVEK).

(1965), were therefore performed (Sect. 9.1.3.b) and measurements of atmospheric electricity were undertaken, in collaboration with the University of Fribourg, Switzerland (Sect. 9.1.3.c).

Götz subsequently made continuous attempts to obtain additional funding from other (external) sources.

3.7 Collaboration between Götz and Dobson (University of Oxford, UK)

The close collaboration of Götz with Dobson[216] was very important for Götz's career. The following section starts with a short overview of the basics of ground-based instruments to measure total ozone[217].

3.7.1 Sun spectrophotometers for total ozone measurements in the Huggins band

The intensity of the solar light at the surface with an approximate wavelength between 300 and 350 nm is diminished through (i) absorption by atmospheric ozone (see Figure 15) (ii) Rayleigh scattering[218] and (iii) scattering and absorption by atmospheric aerosols. Total ozone determination is based on measuring the difference between the intensity at two wavelengths (wavelength pairs) because the strong decrease in ozone absorption cross sections with increasing wavelength (see spectrum in Figure 15, left side) allows precise ozone measurements.

The design of instruments to measure column ozone[219] differs by (i) wavelengths pairs used, (ii) the dispersive element to separate the wavelengths and (iii) the detection system. Dobson was very successful in constructing sun spectrophotometers for reliable (stratospheric) ozone measurements (Walshaw, 1989). He first designed and constructed the Féry spectrometer (see Figure 16, top). Ozone was determined from three different wavelength pairs (see Figure 15, right side) and the signal was detected by photographic plates.

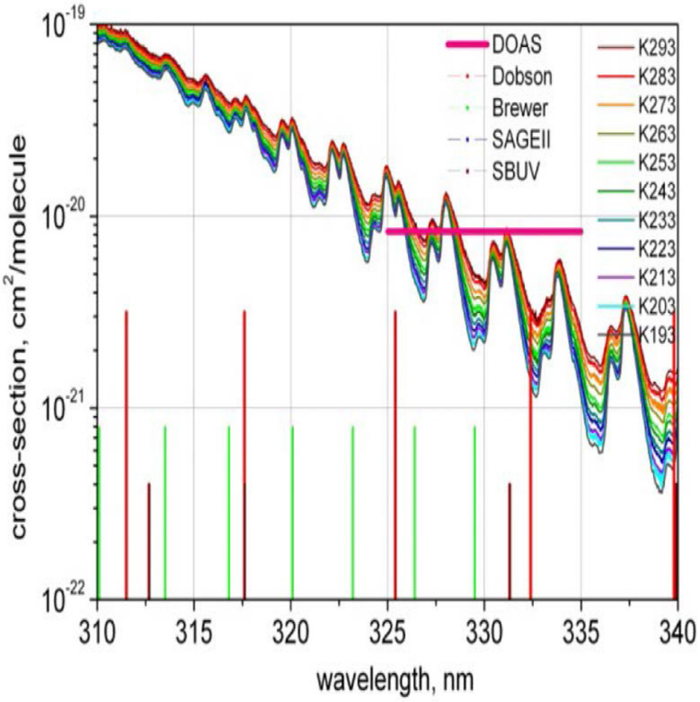
Dobson improved the measurement technique with a novel optical design leading to the Dobson spectrophotometers containing two dispersive elements (see Figure 16). This minimized interference by internal stray light.

216 Refer to footnote 91 on page 25.

217 Such instruments are also used to measure ozone vertical distribution by the Umkehr method, refer to Section 3.7.1.

218 Elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the radiation. These particles may be individual atoms or molecules.

219 Fabry and Buisson (1921) first presented precise total ozone measurements. In 1926, Götz ordered an ozone instrument based on the Fabry-Buisson design from the company Schmidt-Haensch (Berlin), which was delivered in 1928 and which he called the "Aroser Ultraviolett Spektrograph" (Götz, 1929b) (Sect. 9.1.2.a).



Fery spectrograph
(photographic detection)
3 wavelengths pairs:
306.2/326.4; 305.2/323.2; 302.2/326.4
Dobson instrument
(with photoelectric detection)
311.0/330.0
(with photomultiplier)
A: 305.5/325.4
B: 308.8/329.1
C: 311.45/332.4
D: 317.6/339.8
Since IGY (1958): AD

Figure 15: Ozone observations made by ground-based sun photometers (operated in the wavelength region 300-350 nm). Ozone absorption spectrum in the Huggins band (left, ACSO, 2015, Figure 3) and wavelengths used in total ozone observation; AD wavelengths pairs used to minimize aerosol interference (from Staehelin et al., 2018a).

The Dobson spectrophotometers are consecutively numbered, e.g. D15 means Dobson spectrophotometer (fabrication) number 15. The signals were first detected by photoelectric devices, which were replaced by photomultipliers when available[220]. Most precise total ozone measurements are obtained by direct sun observation. The retrieval of total ozone needs to take into account the ozone absorption cross section at the wavelengths used (pairs) and improved knowledge from laboratory measurements of ozone absorption cross section, which increase accuracy in total ozone data[221]. Rayleigh scattering needs to be included in the ozone retrieval depending on atmospheric pressure at the site of measurement. In addition, aerosols (besides sulfur dioxide[222]) can falsify total ozone measurements, which can be important in polluted urban areas such as Oxford. Several wavelength pairs were tested for ozone determination before the AD wavelength pairs (see Figure 15, right side) were selected as the World standard for total ozone measurement in the International Geophysical Year (IGY)[223] in 1957/58 in order to minimize aerosol interference[224]. The basic methods of the present network of Dobson instruments and some data series go back to IGY (Staehelin, 2008; Dlugokencky, et al., 2010). Note that the Dobson network still forms a basis for global stratospheric ozone monitoring.

220 Around the end of World War II.

221 The ozone absorption cross section in the Huggins band (see Figure 15) depends on temperature (Sect. 7.6.2).

222 Note that the interference by SO_2 is also important but cannot be removed by AD measurements.

223 The International Geophysical Year (IGY) was an international project that lasted from 1 July 1957 to 31 December 1958. Marcel Nicolet (Belgian physicist and meteorologist, who stayed at the LKO for several months in the 1930s, Sect. 9.1.3.g) was secretary general of the associated international organization (see Wikipedia). Lugeon was responsible of the Swiss contribution.

224 Note that aerosol absorption and scattering only weakly depend on wavelength in this wavelength range and therefore its effects can be minimized when using two wavelengths pairs.

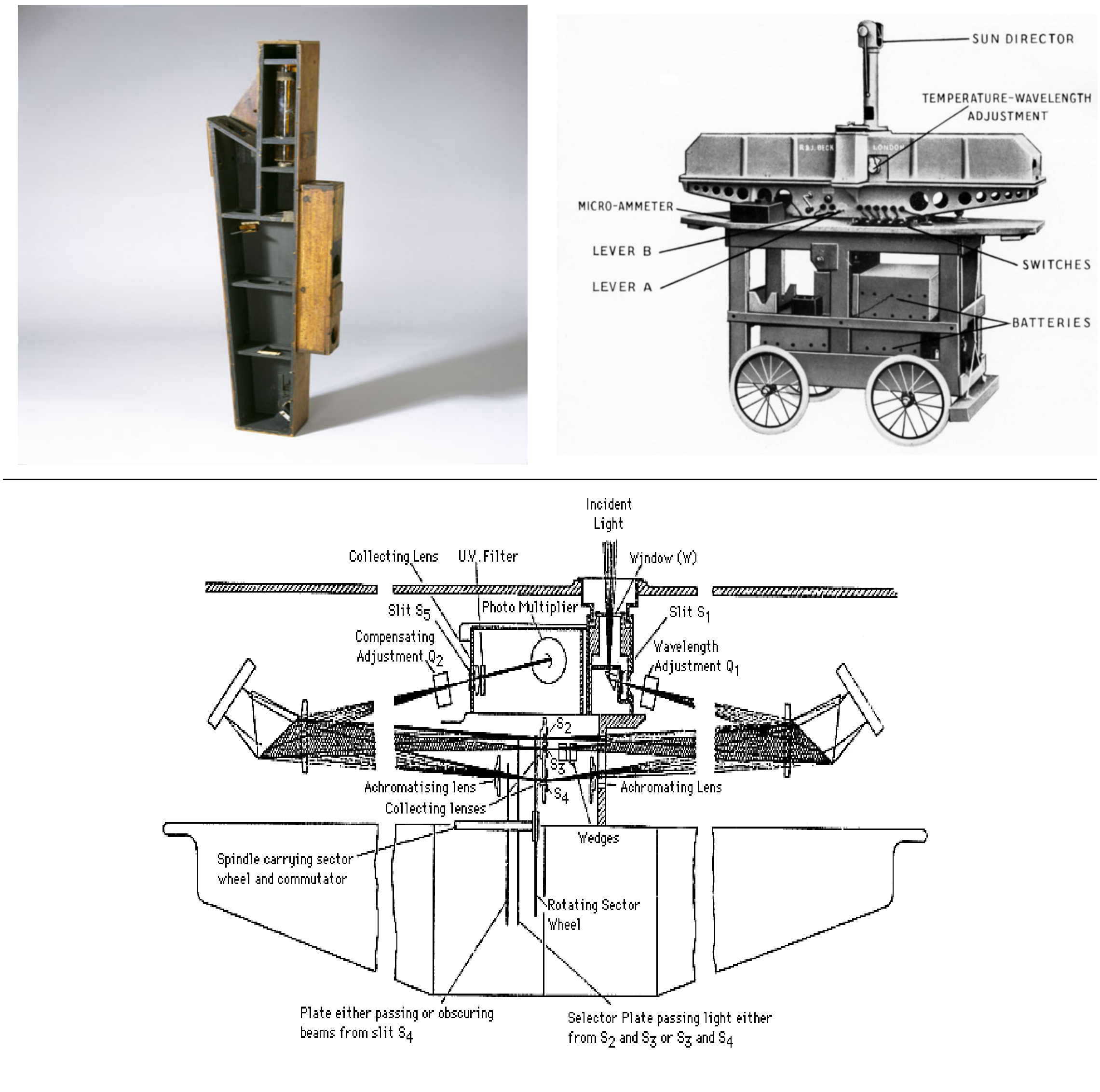


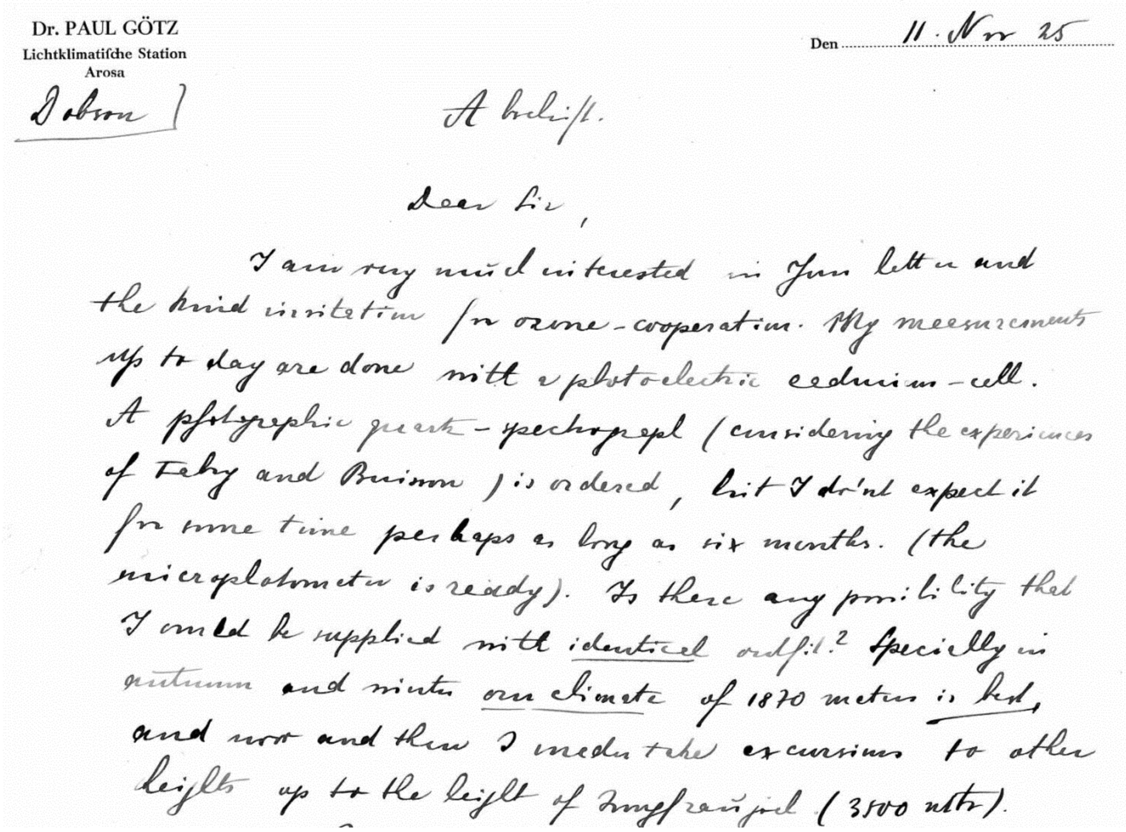
Figure 1. Optical system of the Dobson spectrophotometer.

Figure 16: Instruments designed by Dobson for stratospheric ozone observation. Top left: Féry Spectrograph; Top right: Dobson Spectrophotometer; Bottom: light path and optical scheme of Dobson instruments (refer to https://www.esrl.noaa.gov/gmd/ozwv/dobson/index.html).

Ozone determination is based on Lambert Beer's law requiring knowledge of the solar radiance outside the atmosphere at the wavelengths used. The Langley plot method used for calibration of Dobson instruments and information on the calibration of the world-wide Dobson network is described in Section 7.5. For a recent review of the ground-based Dobson network see Staehelin et al. (2018b).

3.7.2 Friendship and collaboration between Dobson and Götz

The first letters that Götz and Dobson exchanged go back to November resp. December 1925 (see Figure 17 and Figure 18). From this date onwards Götz and Dobson corresponded extensively, covering scientific, technical and also personal topics until Götz's death in 1954. About 350 letters and cards (mostly addressed from Dobson to Götz[225]) (Annex 6, Table 2) are in the LKO Archives. The exchange is always characterized by a profound respect and great confidence. When Götz started to



Dr. PAUL GÖTZ
Lichtklimatische Station
Arosa

Den 11. Nov 25

Dobson !

Abschrift.

Dear Sir,

I am very much interested in your letter and the kind invitation for ozone-cooperation. My measurements up to day are done with a photoelectric cadmium-cell. A photographic quartz-spectrograph (considering the experiences of Fabry and Buisson) is ordered, but I don't expect it for some time perhaps as long as six months. (the microphotometer is ready). Is there any possibility that I could be supplied with identical outfit? Specially in autumn and winter our climate of 1870 meters is best, and now and then I undertake excursions to other heights up to the height of Jungfraujoch (3500 mtr).

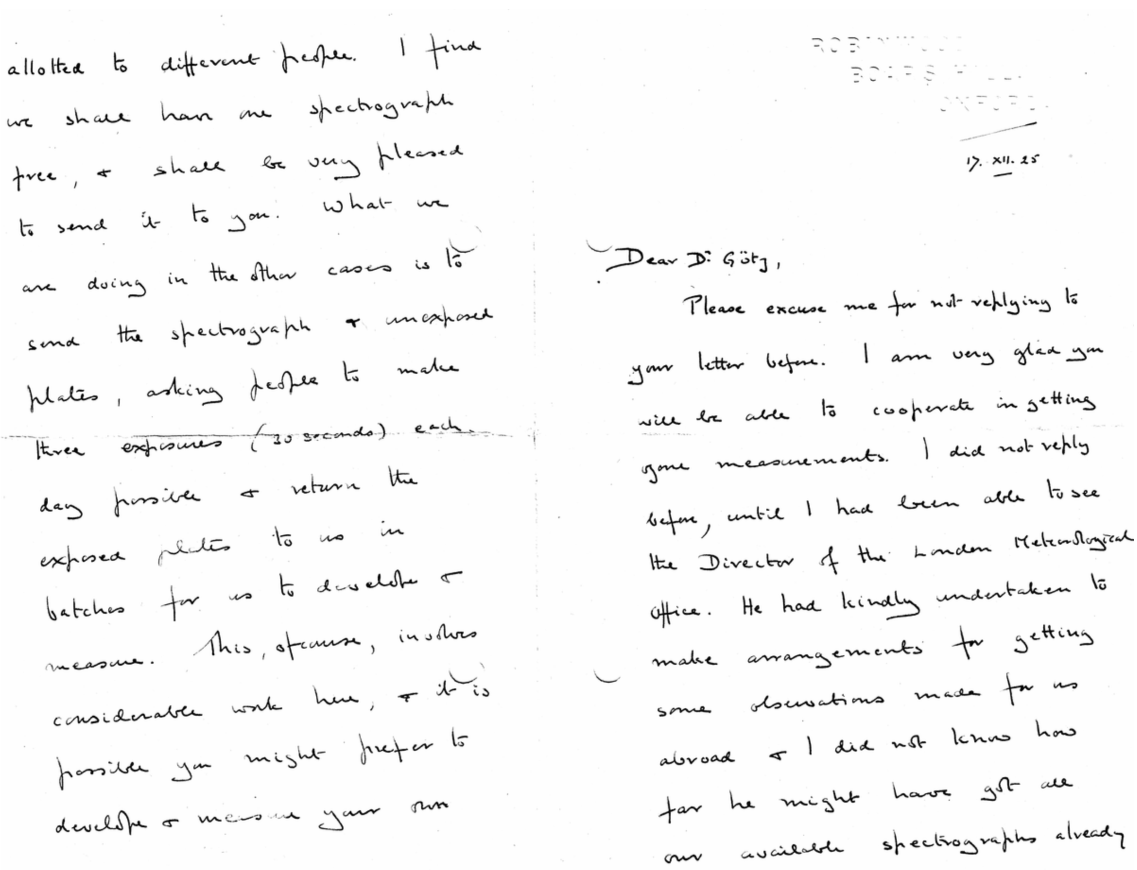
Figure 17: First letter Götz sent to Dobson on 11 November 1925 about a possible collaboration concerning ozone measurements with spectrophotometers [226] (one of the few letters from Götz to Dobson existing in the LKO Archives).

use instruments developed by Dobson (Sect. 9.1.2.b) for measuring total ozone in Arosa[227], he was allowed to evaluate the photographic plates by himself when other stations in the European and later worldwide networks established by Dobson still had to send the measurement recordings to Oxford for analysis.

225 Refer to footnote 6 on page 3.

226 Text of the letter of 11 November 1925 (Götz to Dobson:) "Dear Sir, I am very much interested in your letter and the kind invitation for ozone-cooperation. My measurements up to day are done with a photoelectric cadmium-cell. A photographic quartz-spectrograph (considering the experience of Fabry Buisson) is ordered. But I don't expect him for some time perhaps as long as six months (the micro-photometer is ready). Is there any possibility that I could be supplied with identical outfit? Specially in autumn and winter our climate of 1870 meters is best, and now and then I undertake excursions to other heights up to the height of Jungfraujoch (3500 meters). ….. I shall communicate your letter also to Prof. Maurer Zürich. Awaiting your detailed proposal and hoping, we may agree on an arrangement. Yours very sincerely….".

227 The following instruments from Dobson were used for total ozone measurements at the LKO Arosa: A Féry spectrograph ("D2") from 1926 to 1939, a photoelectric spectrophotometer (D7) from 1939 to 1949 and photomultiplier systems after 1949: D15 in the period 1949-1992, D101 since 1966 and D62 since 1992 (for details see Section 9.1.2.b).


17. XII. 25

Dear Dr Götz,

Please excuse me for not replying to your letter before. I am very glad you will be able to cooperate in getting your measurements. I did not reply before, until I had been able to see the Director of the London Meteorological Office. He had kindly undertaken to make arrangements for getting some observations made for us abroad & I did not know how far he might have got all our available spectrographs already

allotted to different people. I find we shall have one spectrograph free, & shall be very pleased to send it to you. What we are doing in the other cases is to send the spectrograph & unexposed plates, asking people to make three exposures (30 seconds) each day possible & return the exposed plates to us in batches for us to develop & measure. This, of course, involves considerable work here, & it is possible you might prefer to develop & measure your own

Figure 18: Response (first part) of Dobson from 17 December 1925 to Götz's letter (11 November 1925, see Figure 17 above) making available a spectrophotometer to the LKO in the context of a European network established by Dobson [228]. This led to the total ozone series which started in Arosa on 23 July 1926 [229]. (Letter LKO Archives).

Many times, Dobson emphasizes in the letters to Götz (i.e. 31 December 1947) the most favorable measuring conditions of Arosa. He was also very much impressed by the remarkable skill of Götz in the performance of the measurements [230]. For these reasons Dobson considered Arosa to be an ideal place not only to perform ozone measurements but also to make instruments calibrations or to test measuring methods (Sect. 9.1.2.b). He visited Arosa several times, alone or with an assistant or with his wife, where he was a guest in Götz's Villa Firnelicht (Sect. 3.3.1). Some remarks in letters from Dobson to Götz indicate that he was well informed about the LKO's very critical situation at the beginning of World War II [231] (Dobson, 13 April & 13 June & 2 October 1940) and that Götz considered leaving Arosa at that time (Sect. 3.6.3).

228 Text (part) of the letter of 17 December 1925 (Dobson to Götz): "Dear Dr Götz, Please excuse me for not replying to your letter before. I am very glad you will be able to cooperate in getting your measurements. I did not reply before, until I had been able to see the Director of the London Meteorological Office. He had kindly undertaken to make arrangements for getting some observations made for us abroad & I did not known how far he might have got all our available spectrographs already allotted to different people. I find we shall have a spectrograph free & I shall be very pleased to send it to you. […….]".

229 Only 31 of the 368 letters/cards/notes addressed by Dobson to Götz from 9 November 1925 to 31 December 1954 (found in the LKO archives) are written by hand.

230 Document of IUGG – Sub-Committee on Atmospheric Ozone, drafted by Dobson, President of the Sub-Committee, 1929. Original text: "Dr. Götz obtained good results [on moonlight] with of our Féry type instruments at Spitzbergen during the summer, but there is great doubt whether an observer without Dr. Götz's experience of this type of instrument would obtain good result."

231 Letter Dobson, 13. April 1940. "I sincerely hope that your observatory will not be closed down.".

The cooperation was particularly close regarding Götz's Svalbard expedition and the Umkehr measurements of Arosa (Sect. 3.8).

However, Figure 40 in Section 7.4.1 shows Dobson's team was not infallible.

The many letters from Dobson to Götz also demonstrate the personal friendship between the two men. As an example, Dobson also asked Götz whether his son Desmond could come to Arosa. He was barely 20 years old [232] and his father encouraged him to learn German. This plan to all appearances couldn't be realized, but Götz arranged that Dobson's son could finally stay in Zürich together with Meyer [233] (Sect. 3.9). It appears that Dobson also approached Götz to help Regener [234] to emigrate from Germany.

3.8 Expedition to Svalbard and Umkehr measurements

One of the most outstanding findings of Götz's exceptional scientific career was determining the first realistic atmospheric ozone profiles using an experimental approach based on the Umkehr effect (Götz et al., 1934a), also called the Götz effect in some earlier publications (ref. e.g. Vassy, 1965). Götz discovered the Umkehr effect by analyzing measurements collected during an expedition in Svalbard (Götz, 1931b and Dütsch, 1992).

3.8.1 Open scientific questions in the late 1920s

In the late 1920s, ozone profile determination (Sect. 3.5.1) was one of the open key scientific questions in atmospheric ozone research as confirmed by many letters exchanged between Dobson and Götz between 1927 and 1929 [235]. Information on the height of the ozone layer was derived in these years from direct sun measurements at low sun elevation angles. Using this method, Götz and Dobson determined an averaged altitude of about 40-50 km above mean see level for Arosa (Götz and Dobson, 1928). Because of the difficulty of direct sun observations when the sun is near to the horizon, due to increased scattering, Cabannes and Dufay (1927) suggested a more appropriate approach. The proposed method was designed to allow determination of the height of the ozone layer by measuring the zenithal light at different sun elevation angles near to sunrise or sunset.

As discussed in Section 3.5, it was important to obtain more information on the thickness and the height of the ozone layer at high latitudes. In the correspondence between Dobson and Götz, the name of Svalbard (more precisely Spitsbergen) in Norway appears as early as 1927 (Dobson, 18 May 1927). Svalbard is mentioned as one possible place where ozone measurements should be performed in the worldwide network [236] planned by Dobson after the accomplishment of the Europe-

232 Exact date of birth not known to us. Dobson married in 1914 and he had three children, 1 daughter and two sons (in this sequence); Desmond was the elder son.

233 Edgar Meyer (1879-1960), PhD, Professor of Physics of the University Zürich (1916-1949).

234 Erich Regener (1881-1955), atmospheric scientist, Professor for Experimental Physics at the University of Stuttgart. Regener's wife originated from a Jewish family and therefore his son (Victor) needed to emigrate from Germany whereas Regener himself was able to stay in Germany.

235 Among others: Dobson, 9 September 1927 & 17 March 1928 & 7 May 1929.

236 In addition to Table Mountain in California, Helwan in Egypt, Kodal Kanal in India and Christchurch in New Zealand besides Arosa in Switzerland and Oxford in the UK.

an Campaign in 1926-1927 [237] (Dobson, 1968; Dobson and Harrison, 1926; Dobson et al., 1927). Dobson tried to establish an operational station in Svalbard in collaboration with the Norwegian Weather service. In a letter from 23 January 1928, Dobson reported to Götz that the Norwegian Weather Service had given a positive answer to his request, but the project was very uncertain because of organizational and technical problems. The intention was therefore expressed by Götz as early as 1927 to conduct an expedition to Svalbard; this was supported by Dobson as follows (Dobson, 23 January 1928): "it will be very much satisfactory if you can go there as you hope".

3.8.2 Scientific goals and objectives of Götz's expedition to Svalbard

The general motivation and scientific objectives of the Svalbard expedition (for organization and realization refer to Section 3.8.3) can be found in different documents [238].

Based on studies by Kestner (1927) who stressed the analogy between the climates of the short polar summer and the summer in the Alps, reflected in the existing physiological similarities between the life forms in both environments [239], Götz was convinced of the need for more research studies in the High North. He concluded (Götz, 1929a) that it would be highly desirable to complement the planned distribution of Dobson spectrophotographs over the world by conducting measurements in Svalbard [240].

In the application letter of his funding request concerning the Svalbard expedition (Götz, 24 November 1928 [241]) Götz was referring to an article published earlier (Götz, 1927) with observations based on Dobson's first ozone measuring network showing for the first time that the thickness of the ozone layer, which is increasing from the equator towards the north decreased from the 60° latitude on to the pole (Sect. 3.5.1). Götz claimed that according to Dobson the observations in the High North would be one of the most urgent contributions for the ozone problem at that time [242]. A declared goal of Götz for the Svalbard expedition was to perform, besides radiation measurements, mainly observations of the atmospheric ozone, covering both total ozone content and the height of the ozone layer.

Götz described some key elements of the measuring program of the Svalbard expedition in a letter to Dobson (27 December 1928). There he points out that May and June and the second half of August would be favorable for the application of the method of Cabannes and Dufay concerning the determination of the height of the ozone layer. In his publication of the Svalbard results (Götz, 1931b) it is mentioned that prior to the expedition he performed some trials to test the applicability of this method

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237 Dobson, 1967: "The British Meteorological Office was helpful in allowing measurements to be made at Valentia, Ireland, and Lerwick, Shetland, and also by arranging with other meteorological services for measurements to be made at Abisko, Sweden, and Lindenberg, Germany. Dr. Götz kindly undertook to operate an instrument at Arosa, Switzerland.".

238 We could not find any detailed research plan as it is common practice in a modern research proposal.

239 It was postulated that this parallelism could be related to the fact that the transparency of UV light in summer time in the High North is closer to the conditions of Jungfraujoch than of Hamburg.

240 Götz, 1929a. Original text: „Es dürfte so erwünscht sein, dass der neue Verteilplan der Dobson-Spektrographen [….] durch eine geplante Messreihe des Lichtklimatischen Observatoriums Arosa in Spitzbergen ergänzt werde.".

241 Only a stenographic draft version of the proposal submitted to the German Research Foundation is available; the information provided is based on a transcription by an expert on stenography.

242 Letter Götz, 24 November 1928 (stenographic draft): „Auch Dr. Dobson, mit dem ich zusammenarbeite und der neuerdings auch über dem Äquator messen lässt, stimmt mit mir überein, dass Ozonmessungen im hohen Norden der zurzeit dringlichste Beitrag zum Ozonproblem sei.".

in Arosa. From this it is quite obvious that Götz went to the Svalbard with the idea of using Cabannes' and Dufay's method (1927) for the determination of the ozone layer height.

3.8.3 Planning and realization of the expedition

In 1927, Götz contacted the German Research Foundation[243] asking for the possibility of funding his Svalbard expedition. On 24 November 1928 Götz wrote an official request to this institution. Although verbal acceptance was signified earlier by the German Research Foundation, he received the definitive positive response to his application with a letter from 6 March 1929, which agreed with the proposed budget[244].

Quite a number of letters in the LKO Archives demonstrate that the preparation for the expedition was rather laborious and time-consuming. Götz prepared everything very conscientiously and systematically. He contacted a number of experts (in Germany, Norway and Svalbard) who could assist him in organizing the travel, finding an appropriate place for the measurements[245] and providing him support on site. With the permission of the Kings Bay Kul Company[246] he was able to install the instruments in the cabin of the Nobile expedition from 1928, close to the airship hall (see Figure 19).

Figure 19: Cabin and instruments used by Götz during his measurements at Svalbard. Götz is adjusting the Arosa (Fabry-Buisson type) spectrograph. The Féry spectrograph is in the center. The instruments on the shelf (right hand side) are a Michelson actinometer (left) and a silver disk pyrheliometer (right). (Photo LKO Archives).

243 Refer to footnote 111 on page 30.

244 Of 4,000 Reichsmark (RM), approximately 5,000 CHF (according to the historical effective exchange rates), corresponding to roughly 34,000 CHF in 2015 (according to the consumer price index of Swistoval, www.swistoval.ch, state of 14.1.2019 (Pfister and Studer, 2019) (Information on exchange rates and inflation adjustment made available by Tobias Straumann, Professor of Economic History of the University of Zürich).

245 Because of the free horizon at Ny-Ålesund in Kings Bay this location was finally preferred to Ny-London.

246 A coal mining company.

Initially, Götz planned to travel to Svalbard by airship early in the year because of the ice still present at this time. Although it seems that he had some assurance concerning such a flight (Götz, 24 August 1928), the Zeppelin trip could not be realized, and he was obliged to reach Svalbard by train and ship. He left Arosa on 12 June 1929 and arrived in Ny-Ålesund on 30 June 1929 [247]. The departure in Tromsø was delayed because of ice still present on the route to Svalbard. At the end of the stay, Götz had to leave Svalbard on 5 September due to early winter conditions; he was back in Arosa on 21 September 1929. He therefore spent much less time in Svalbard than initially anticipated. Götz was accompanied in this expedition by Emil Henssler, who was already meteorological assistant in the previous years at Arosa [248].

Götz performed different kinds of field measurements at Svalbard. Several instruments were transported and set up (Götz, 1931b). Two systems were used for the ozone observations. Dobson initially intended to offer a special instrument for the campaign to prevent interruption of the measurements in Arosa during summer. However, a spectrograph lent by Dobson to Professor Pontremoli was out of service as it was damaged in the crash on of the Nobile airship Italia in Svalbard during the polar expedition of Nobile in 1928 [249]. The spectrograph returned to Oxford during 1929 but had to be refurbished and was therefore not available for Götz's Svalbard campaign. Finally, the following instruments for ozone measurements were used: a spectrograph of Féry type for total ozone observations [250] and a spectrograph of the Fabry-Buisson type for the zenith sky measurements (Götz, 1931b) [251]. The instruments were back in Arosa by 28 September [252].

Götz was writing a diary [253] during the travel and his stay in Svalbard; the report contains (for almost every day) remarks on the measurements, the many meetings with other persons, the weather conditions and the various excursions on the island. This travel diary covering the whole expedition shows Götz as a well-educated scientist and an excellent observer interested in a large range of aspects, in the style of many scientists of the 19th century. Although the information in this diary about the measurements is rather limited, it can be concluded that the weather conditions were quite challenging, especially for the zenith observations at sun elevation angles near sunrise resp. sunset, and furthermore that the presence of smoke in Kings Bay was interfering with the measurements. Götz relied on these extensive notes to write the two travel reports (Götz, 1929c and 1929d) printed in the newspaper of Arosa [254] during the summer in which the conditions of the expedition are described with a note of irony and a good sense of humor. He also noted in the diary that he reported twice to the German funding institution [255] of the expedition [256].

247 For travelling route see Läubli 2019.

248 It could not be established how long and in which years Henssler was meteorological assistant.

249 Umberto Nobile (1885-1978), an Italian arctic explorer, reached the pole with his airship Italia on 24 May 1928. On the way back the ship ran into a storm and crashed onto the pack ice on 25 May 1928. Nobile and nine members of the crew were thrown to the ice as the gondola was smashed and survived; the six others were trapped in the buoyant superstructure and disappeared definitively (Wikipedia). Götz was accommodated in the hut occupied by Nobile at Ny-Ålesund.

250 This was the Féry instrument ("D2") made available by Dobson and normally operated in Arosa.

251 The Arosa ultraviolet spectrograph designed by Götz (Götz, 1929b) with a much higher sensitivity (Sect. 9.1.2).

252 The Féry spectrograph had suffered damage during transit and required repair in Oxford.

253 A typed transcript of the handwritten text is presented in Appendix 2.

254 Refer to footnote 8 on page 3.

255 Refer to footnote 111 on page 30.

256 These reports could unfortunately not be found.

3.8.4 Description of the scientific results of the Svalbard expedition

The scientific results of the expedition to Svalbard are presented in a publication that was the thesis of Götz's habilitation (Götz, 1931b) accepted by University of Zürich in 1931 (Sect. 3.9). During his stay in Svalbard Götz was able to perform total ozone observations on roughly 75% of the days [257]. From the notes in the journal it is evident that the sky was very often at least partially overcast and that measurements with the sun near to the horizon where height determination was possible were only feasible on a limited number of days [258]. Because of lack of sensitivity, such measurements were normally almost impossible with the first-generation spectrographs (even with the Arosa UV-spectrograph). At the latitudes of Svalbard, the slow move of the sun at midnight helped to compensate for this drawback [259]. However, he stressed the risk of atmospheric ozone changes during the long measuring times.

As proposed by Cabannes and Dufay (1927), a series of observations at 3 (sometimes 2) sun elevation angles near to the horizon (typically 21°, 9° and 1°) were realized by Götz. The plates were analyzed [260] when Götz returned back from the expedition [261].

The fact that the observed intensity ratio of two pairs of adjacent elevation angles (with the higher angles above) is decreasing at short wavelengths and that they are intersecting each other lets Götz conclude (Götz, 1931b) *"the lower the position of the sun and the shorter the wavelength (i.e., the stronger the absorption), the more light is capable to prevail relative to the strongly reduced beam, finding the way through the ozone layer not totally but partially in the short zenithal pathway."* [262]. Götz called the features of this finding Umkehr (inversion) effect (see Figure 20), although this does not yet correspond to the Umkehr curves (see Figure 22) resulting from the so-called Umkehr method (Sect. 3.8.5).

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257 Total ozone could be measured on 46 of 63 measuring days.

258 Data for determination of the height of the ozone layer were available for 16 days, half of them were considered to be satisfactory. Götz used three methods for height determination in the thesis of habilitation. It is not specified on how many days the method of Cabannes and Dufay could be applied. Only two cases are presented in Götz (1931b).

259 From comments of Götz (1931b) it can be assumed that in the planning of the expedition, he must have been aware of this advantage: „Infolge der flachen Sonnenbahn konnte immerhin relativ länger exponiert und so zu tieferen Sonnenständen herabgegangen werden als mit der gleichen Apparatur in Arosa.".

260 With the aid of a microphotometer of Hartmann type.

261 This explains why almost no information on the measurement results is contained in the diary.

262 Götz, 1931b. Translated by the authors. Original text: „Je tiefer der Sonnenstand, je kürzer die Wellenlänge (das heisst je stärker die Absorption) desto mehr vermag dann gegen den stark geschwächten Strahl solches Licht aufzukommen, das seinen Weg durch die Ozonschicht wenn nicht ganz, so doch teilweise in der kurzen zenitalen Wegstrecke findet.".

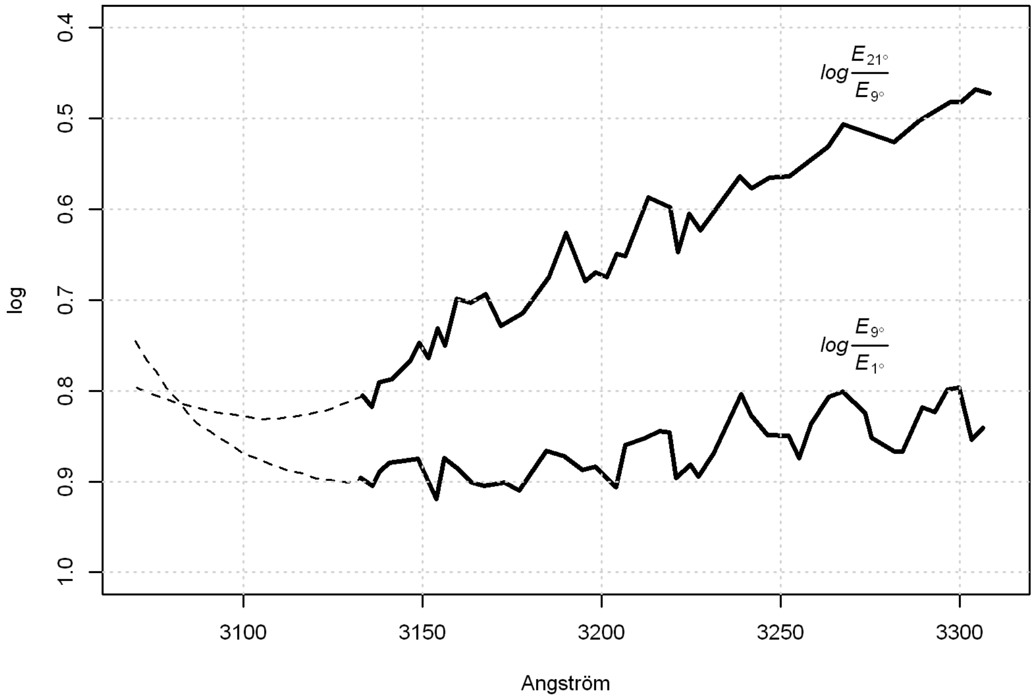


Figure 20: Intensity ratio of the zenithal light at 21°:9° and 9°:1° sun elevation measured on 26 August 1929 on Svalbard (figure adapted and data extracted from Figure 9 of Götz, 1931b).

It was the deep scientific understanding of atmospheric short-wave radiation combined with his insight that allowed Götz to realize that the sequence of zenith sky observations contains valuable information for determining the vertical distribution of ozone (Götz, 1931b and 1931c).

3.8.5 Development and results of the Umkehr method

Götz mentions in his habilitation thesis (Götz, 1931b) that he communicated his results to Dobson in September 1930 (one year after being back from Svalbard). According to Dobson's paper on ozone history (Dobson, 1968) Götz was suggesting that the intensity ratio of two wavelengths, as measured by the new photoelectric spectrophotometer under development by Dobson in Oxford at that time, should show comparable behavior at low sun elevation angles. Dobson was rather skeptical. Nevertheless, the strongly improved sensitivity of the new photoelectric system gave Dobson the opportunity to make such zenith sky measurements near to the horizon, even in the Oxford location, and he tested Götz's suggestion on a clear morning at the beginning of January 1931. Dobson commented on the results to Götz in a letter in the following days (Dobson, 8 January 1931) and confirmed Götz's hypothesis (see Figure 21).

8th Jan ~~1931~~ 1931.

Dear Götz,

You will have noticed that in the ozone results with very high values of sec Z (and light from the zenith sky) of which I sent you a rough copy a day or two ago, the ozone value decreases with increasing sec Z. It appears that this decrease is not due to assuming a wrong height for the ozone, since it would indicate a very great height (80 kms or so). I have made further observations today also using the light from the clear zenith sky & have continued them till the sun was nearly setting. These show that at very large values of sec Z the ratio of 3110 Å/ 3265 Å increases again! The only explaination that I can see is the same as you found in some of your results viz. that at great values of sec Z Cabanne's assumption is not true, & a large part of the light which is seen at the zenith has been scattered above the ozone layer & so has a shorter path through the layer than if it were scattered below it. The value of the ratio 3265 Å/ 4435 Å did not increase again as the sun got very low but the decrease was much slower than when the sun was higher. Evidently we shall have to be careful in calculating ozone from zenith sky readings when the sun is low, & it seems doubtful if they are at all trustworthy for deducing the height of the ozone layer. Fortunately nothing is likely to affect the readings on the direct sunlight so that we can use these to check the others. I have not yet taken any with

Figure 21: Letter from Dobson to Götz (first page) from 8 January 1931 commenting on the results of the first Umkehr observation performed in Oxford one or two days earlier with the new photoelectric spectrophotometer developed by Dobson at that time (Letter LKO Archives).

Thus, the classical Umkehr curve was born representing the behavior of the intensity ratio of two wavelengths against the solar elevation angle near to sunrise resp. sunset. Dobson repeated this experiment and performed a series of 4 such measurements on 25-27 January 1931 in Oxford. These Umkehr curves, as presented in the paper of Walshaw dedicated to Dobson and his work (Walshaw, 1989), are shown in Figure 22 [263].

263 There is no evidence for additional Umkehr observations made in Oxford.

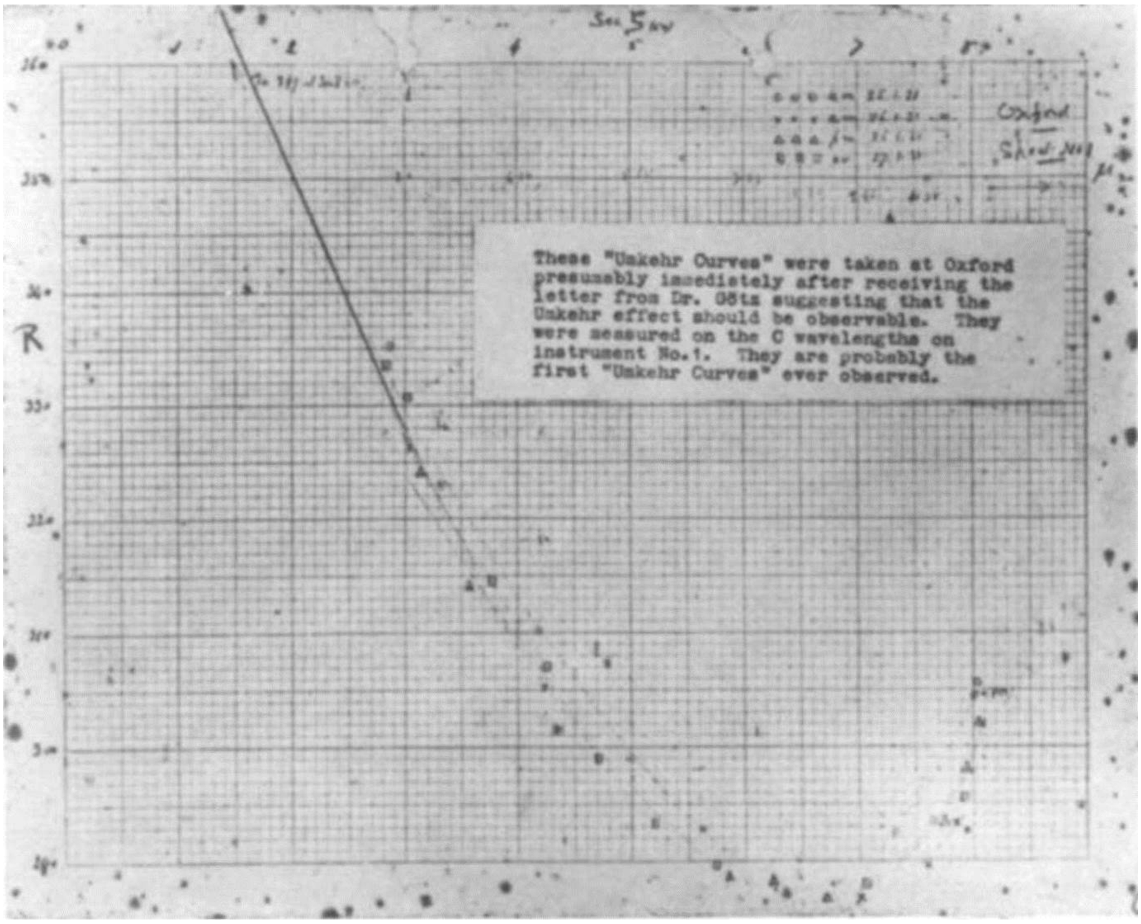


Figure 22: Dobson's first Umkehr observations in January 1931 (4 observations from 25-27 January) at Oxford (Figure 6 of Walshaw, 1989).

In 1932, Dobson and his coworker Meetham brought two newly designed Dobson instruments with photoelectric detection to Arosa to perform such Umkehr observations at the LKO and to develop the required retrieval to obtain ozone profile information (see Figure 23). One instrument was used to measure Umkehr curves, the other for total ozone (direct sun) observations. Because of unfavorable weather conditions only a few measurements could be performed in the two months of Dobson's stay in Arosa. However, after Dobson returned to Oxford with one instrument in August 1932, Götz continued to make Umkehr observations until June 1933 with the second instrument (the instrument was shipped back to Oxford in summer 1933). In total, 46 valuable Umkehr curves distributed over the whole year resulted from this campaign. Already in August 1933, the key results were published in Nature (Götz et al., 1933a) indicating that the ozone maximum (in partial pressure) at midlatitudes was at an altitude of around 22 km above sea level and therefore much lower than previously believed. The key paper on Umkehr (Götz et al., 1934a) with the presentation of the first methods used to retrieve the ozone profile has been published based on the results of these measurements. Two methods, one developed by Götz and the other by Dobson, have been applied for the ozone profile retrieval. In the same year ozone profile measurements determined from spectrographs on balloons were published by Regener [264] (1934) that supported the findings of Götz et al. (1934a) [265].

264 Refer to footnote 234 on page 49.

Figure 23: Dobson and Meetham (behind) taking measurements on the first Umkehr campaign during summer 1932 at the LKO in Arosa (Photo LKO Archives).

3.8.6 Concluding remarks concerning the Svalbard expedition and Umkehr

We might note the following points that were important for the success of the Svalbard expedition, and typical for the whole career of Götz (Sect. 3.4 and 3.10):

- Götz managed to organize the Svalbard expedition by acquiring external funding through the German Research Foundation [266].
- His excellent skills in instrumental design allowed him to develop the Arosa spectrograph designed on his own expertise.
- Thanks to his excellent scientific collaboration with Dobson, Götz was able to use the best quality sun spectrophotometers developed in Oxford.
- Already in the second half of the 1920s, Götz was an outstanding and very innovative atmospheric physicist in the international ozone research community. Though few zenith sky data were at disposal from the Svalbard campaign he interpreted the results the right way.

265 The 50 historical Umkehr curves (Oxford and Arosa) have recently been digitalized and reprocessed with more sophisticated retrieval algorithms in current use (Maillard et al., 2008); 40 ozone profiles could be retrieved. Among these, 10 of them fulfilled the convergence criteria which are required by the World Ozone and UV Data Center (WOUDC) in the case of the actually submitted data. This gives an idea on the reduced quality of the Umkehr curves obtained by the photoelectric photometers (compared to the instruments with photomultiplier).

266 Refer to footnote 111 on page 30.

– Because of the normally favorable climatic conditions in Arosa, the LKO served as a measuring platform to assess the measurements of the famous Umkehr curves suggested by the results from the Svalbard expedition in 1929 and based on the first trials in Oxford in 1931[267].

3.9 Collaboration of Götz with Meyer and the University of Zürich

3.9.1 Collaboration with Meyer

Meyer[268] had broad interests in physics (refer to Wikipedia) including atmospheric ozone. His PhD thesis was on the subject of absorption of ultraviolet light by ozone[269] and a PhD student of Meyer provided new additional laboratory measurements of ozone absorption cross sections (Läuchli, 1928). Meyer also studied measurements with the Cd-cell of the PMOD (Sect. 3.2) and he found that the measurements of the Cd-cell could be understood when a column ozone amount of around 300 DU was assumed (Meyer, 1925). Götz maintained close contact with Meyer in all the years he was teaching at the University of Zürich and arranged meetings between Dobson and Meyer (at the request of Dobson, 8 December 1939). Meyer refers in a letter to Götz from 22 December 1934 to an initiative of Götz offering to organize an ozone conference either in Zürich or Arosa[270]. Meyer argued that he would prefer to go Edinburgh as originally proposed by Dobson as a conference location (Table 5 shows that the ozone conference finally took place in Oxford in September 1936). In addition to the large burden of work organizing the conference, he also pointed out serious financial problems in a bid to gain financial support for the invited speakers as the Great Depression brought severe economic problems during the 1930s.

3.9.2 Götz's teaching career

Götz was teaching at the same faculty[271] as Meyer. The milestones of the teaching career of Götz are shown in Table 6[272]. His teaching career started with the habilitation degree furnishing him with the title of "Privatdozent" (PD)[273]. To obtain this degree, the habilitation thesis[274] was required, demonstrating the candidate's capability to conduct appropriate research. Furthermore, the candi-

267 It seems that after this campaign no more Umkehr measurements were performed in Arosa until 1949 when the spectrophotometer D15 equipped with a photomultiplier arrived. A request of Götz to IAMAS (Prof. J. Bjerknes, 24 September 1949) indicates "that Dobson hoped extended observations to be done in the favorable high altitude climate of Arosa in order to tackle again the important problem of the vertical distribution of ozone with the improved system". Translated by the authors. Original text: "Ausserdem hofft Dobson, dass in unserem günstigen Höhenklima ausgedehnte Messreihen gemacht werden, […..,], damit das wichtige Problem der vertikalen Ozonverteilung mit der besseren Apparatur erneut aufgegriffen werden kann.". From a letter of Perl (Sect. 4.1) of 7 November 1950 we learn that there were several days "where the Umkehr effect was measured". These data were apparently not analyzed nor published.

268 Refer to footnote 233 on page 49.

269 "Die Absorption von ultraviolettem Licht in Ozon" (Meyer, 1903).

270 Remember that Götz had already attempted to organize the first ozone conference in Arosa in 1929 (Sect. 3.4).

271 Philosophical faculty II.

272 We acknowledge the important support of Hans-Ulrich Pfister and Verena Rothenbühler to derive the documents from the State Archives of the canton of Zürich (Staatsarchiv des Kantons Zürich).

273 "Privatdozent (PD)" - viewed as equivalent to senior lecturer- was a common degree in German speaking universities. The qualification paves the way for appointment as full professor at (German speaking) universities and includes the right and obligation to give regular lectures at the home university (which was called "Venia Legendi").

274 Habilitationsschrift.

date had to give a rehearsal presentation[275] to demonstrate his teaching capability. After approval of the habilitation thesis and the rehearsal presentation by the faculty, the documents were submitted by both the candidate and the faculty to the political authority for acceptance, which required a decision from the Education Department of the Canton of Zürich[276]. In spring 1931 Götz obtained the degree of "Privatdozent" including the "Venia Legendi", which needed to be renewed regularly (see Table 6). Table 7 lists the lectures given by Götz.

Table 6: Götz at the University of Zürich: formal documents.

Relevant parts of protocols of decisions of political authorities of Kanton Zürich.
30 April 1931: Decision of directorate of education (Erziehungsrat) of acceptance of **Habilitation** (promotion to **Privatdozent** ("senior lecturer"), submitted by Dr F. W. Paul Götz of Arosa and on request of Philosophical Faculty II (natural sciences) of University of Zürich) and **Venia Legendi** (permission and obligation for giving regular lectures), starting in WS 1931/1932, for 6 semesters
27 June 1934: (on request of Philosophische Fakultät II) **renewal of Venia Legendi** (starting in WS 1934/35)
25 May 1937: (on request of Philosophische Fakultät II) **renewal of Venia Legendi** (for 6 semesters, starting in WS 1937/38)
24 May 1940: (on request of Philosophische Fakultät II) **renewal of Venia Legendi** (for 12 semesters, starting in WS 1940/41
11 July 1940: decision of governing council of Kanton Zürich (Regierungsrat) proposed by education department (Erziehungsdirektion) and education department (Erziehungsrat)): promotion of Privatdozent to **Titularprofessor** ("honorary professor"): Justification: Very good performance in teaching *("seine Lehrtätigkeit wird sehr günstig beurteilt, seine Vorlesungen und Übungen erfreuen sich guter Frequenz")* and high scientific productivity *(" Dr. Götz entfaltet eine reiche publizistische Tätigkeit, die nach dem Bericht des Dekanates allgemeine Anerkennung findet").*
12 August 1946: (on request of Philosophische Fakultät II) **renewal of Venia Legendi**, starting WS 1946/47
31 August 1949: reimbursement of travel costs Arosa/Zürich: 250 CHF per semester (starting in WS 1949/50)
1 September 1952: **renewal of Venia Legendi** (starting WS 1952/53)
31 August 1954: Note of death of Götz

Götz needed to overcome several problems before he obtained the degree of habilitation. In order to obtain the habilitation, the lectures needed to be attributed to a particular field of specialization and to be integrated in the ordinary lecture program of the university. Götz (who graduated in astronomy, see Figure 5) first approached Brunner[277] (Waldmeier, 1959). A letter of Brunner from 22 April 1930[278] explains that there was no demand for additional lectures in the field of astronomy as the number of students interested in attending such lectures at University of Zürich as well as ETH Zürich was very small. Instead he suggested geophysics as a field of specialization for the habilitation. Brunner offered to discuss this with his colleague Meyer. Meyer, who was acting as dean of the faculty, informed Götz in the letter from 17 May 1930 that he and all professors concerned at the faculty supported Götz's habilitation. However, Meyer agreed with Brunner that astrophysics would not be the appropriate discipline for habilitation but proposed cosmic physics or, better still, atmospheric

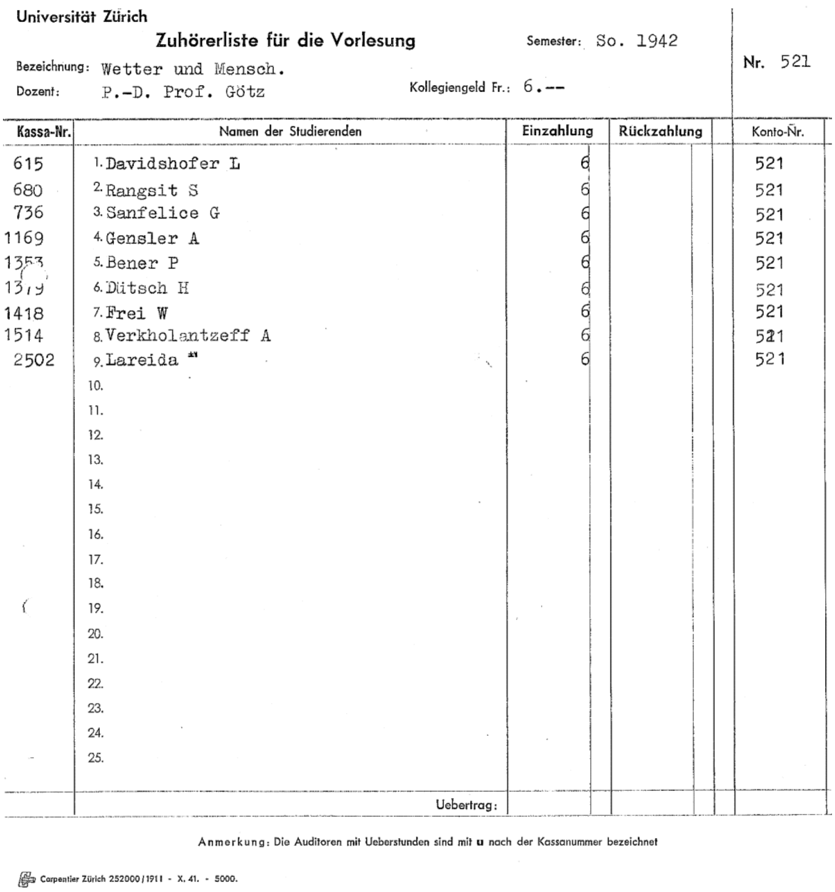
275 Probevortrag.

276 Erziehungsratsbeschluss.

277 Refer to footnote 146 on page 36.

278 Less than one year after the Svalbard expedition of 1929, which was the basis of his habilitation thesis and published as scientific journal article (Götz, 1931b) (see Section 3.8).

physics with a strong emphasis on meteorology. Finally, he asked Götz to come for a meeting together with Brunner, Wehrli [279] and himself for discussion. Götz obviously asked Wolf [280], one of his former PhD advisors (Sect. 2.4), for advice about the field of his habilitation and Wolf agreed in his letter from 25 April 1930 with the view of Brunner, namely that Götz should accept the possibility of obtaining specialization in the field of cosmic physics or geophysics. In a letter from 16 July 1930, Meyer informed Götz that the faculty could not reach an agreement about the field of specialization, implying that this question would be decided after receipt and discussion of the habilitation thesis, with the consequence that his lecture might not be included in the university's lecture list for the summer semester of 1931 (which was obviously true, see Table 7). Meyer (personal letter, 17 April 1931; as dean of the faculty, 23 February 1931) informed Götz that the topic "Lichthaushalt der Erde" [281] was selected for his rehearsal talk by the faculty and that the date of the rehearsal talk was fixed for 23 April.



Universität Zürich

Zuhörerliste für die Vorlesung — Semester: So. 1942 — Nr. 521

Bezeichnung: Wetter und Mensch.

Dozent: P.-D. Prof. Götz — Kollegiengeld Fr.: 6.--

Kassa-Nr.	Namen der Studierenden	Einzahlung	Rückzahlung	Konto-Nr.
615	1. Davidshofer L	6		521
680	2. Rangsit S	6		521
736	3. Sanfelice G	6		521
1169	4. Gensler A	6		521
1353	5. Bener P	6		521
1379	6. Dütsch H	6		521
1418	7. Frei W	6		521
1514	8. Verkholantzeff A	6		521
2502	9. Lareida	6		521
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Anmerkung: Die Auditoren mit Ueberstunden sind mit u nach der Kassanummer bezeichnet

Carpentier Zürich 252000/1911 - X. 41. - 5000.

Figure 24: List of students who participated in the lectures of Götz in the Summer Semester 1942. Note that this list was the basis for determination of Götz's salary as lecturer at the University of Zürich. (Document LKO Archives).

279 Hans Jakob Wehrli (1871-1945), Professor for Geography of the University of Zürich (1913-1940).

280 Refer to footnote 44 on page 12.

281 *"Light budget of the earth"*. Translated by the authors".

In a letter of 1 May 1931 from Linke[282] we learn that Götz was concerned that his habilitation might not be accepted by the political authority after the faculty's approval because of lack of demand for lectures. Linke tried to reassure him by saying that this would be very unlikely and that he would be willing to help but that such assistance would need to be formally requested. Götz's habilitation was obviously accepted by the political authority on 30 April 1931 (see Table 6).

The lists of participants[283] (see an example in Figure 24) show that the number of students who attended Götz's lectures varied between four and sixteen. However, Table 7 shows that lectures were moved in between astronomy, astronomy and meteorology as well as physics several times on the university's lecture list, suggesting that the faculty changed its opinion several times. Only after the summer semester of 1939, when meteorology was accepted as a minor at the University of Zürich, did Götz's lectures consistently appear in the category of astronomy and meteorology.

In 1940, Götz was promoted from a "Privatdozent"[284] to a "Titularprofessor"[285]. As "Titularprofessor", he was able to act as main adviser of PhD theses (Sect. 5.1) and meteorology was introduced as a minor[286] at the University of Zürich. The basis for this minor was a 4-semester lecture cycle of Götz (see Table 7). Beginning in WS 1939/40 Götz was teaching together with Lugeon[287] (see Table 7).

Table 7:Lectures of Götz at the University of Zürich (from the lecture list of the University (Vorlesungsverzeichnis)).

WS 31/32[a)]: *Sonnenstrahlung und Himmelslicht* (Dr. Brückmann: Einführung in Meteorologie)
SS 32[b)]: *Aufbau der Atmosphäre*; (Dr. Brückmann: Grundlagen der wissenschaftlichen Wettervorhersage)
WS 32/33[c)]: *Atmosphärische Optik*
SS 33[c)]: *Klimatologisch-medizinische Grenzprobleme und Höhenklima*
WS 33/34[c)]: *Die Stratosphäre*
SS 34[a)]: *Geophysikalische Einflüsse auf Lebensvorgänge; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner); (Dr. Brückmann: Meteorologische Übungen)
WS 34/35[a)]: *Sonnenstrahlung und Strahlungsklima; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
SS 35[a)]: *Hochgebirgsklima; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
WS 35/36[a)]: *Die hohe Atmosphäre; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
SS 36[a)]: *Physikalisch-meteorologische Grundlagen des Klimas; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
WS 36/37[a)]: *Ozon der Atmosphäre und verwandte Probleme; Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
SS 37[a)]: *Die Sonne und ihre Wirkung auf Erde und Mensch (für Hörer aller Fakultäten); Kolloquium für Astronomie und Geophysik* (together with Prof. W. Brunner)
WS 37/38[a)]: *Meteorologische Optik*
SS 38[a)]: *Aufbau der Atmosphäre*
WS 38/39[a)]: *Bioklimatologie und Hochgebirgsklima*
SS 39[b)]: *Einführung in die Meteorologie (Physik der Atmosphäre) mit Übungen*
WS 39/40[b)]: *Meteorologie: Dynamik der Atmosphäre*; (Lugeon: Allgem. Meteorologie mit Rücksicht auf das Flugwesen)
SS 40[b)]: *Meteorologische Optik*; (Lugeon: Übungen zur allgemeinen Meteorologie mit Rücksicht auf das Flugwesen; Praktische Meteorologie)

282 Refer to footnote 127 on page 34.

283 Zuhörerliste.

284 Senior lecturer.

285 Honorary professor.

286 Prüfungsfach.

287 Refer to footnote 126 on page 34.

WS 40/41[b)]: *Das Nordlicht*; (Lugeon: Allgem. Meteorologie mit Rücksicht auf das Flugwesen; Übungen in praktischer Meteorologie)
SS 41[b)]: *Meteorologie, I. Teil: Einführung (Physik der Atmosphäre)*; (Lugeon: Praktische Meteorologie; Übungen zur allgemeinen Meteorologie mit Rücksicht auf das Flugwesen)
WS 41/42[b)]: *Meteorologie, II. Teil: Dynamik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 42[b)]: *Wetter und Mensch*; (Lugeon: Übungen zur Allgemeinen Meteorologie (mit Rücksicht auf das Flugwesen))
WS 42/43[b)]: *Die hohe Atmosphäre*; (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 43[b)]: *Meteorologie, I. Teil: Einführung (Physik der Atmosphäre; Übungen dazu)*; (Lugeon: Übungen zur Allgemeinen Meteorologie (mit Rücksicht auf das Flugwesen))
WS 43/44[b)]: *Meteorologie: Dynamik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 44[b)]: *Meteorologische Optik*; (Lugeon: Übungen zur Allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen; Praktische Meteorologie)
WS 44/45[b)]: *Gesetzmässigkeit und Zufall in meteorologisch-geophysikalischen Beobachtungen (mit Übungen);* (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 45[b)]: *Einführung in die Meteorologie (Meteorologie, I. Teil)*; (Dr. Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 45/46[b)]: *Meteorologie: Dynamik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 46[b)]: *Meteorologische Optik*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 46/47[b)]: *Das Nordlicht* (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 47[b)]: *Einführung in die Meteorologie (Meteorologie, I. Teil)*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 47/48[b)]: *Einführung in die Meteorologie, II. Teil: Dynamik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
SS 48[b)]: *Optik der Atmosphäre*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 48/49[b)]: *Physik der hohen Atmosphäre*; (Lugeon: Allgemeine Meteorologie mit Rücksicht auf das Flugwesen)
SS 49[b)]: *Einführung in die Meteorologie, I. Teil* (Lugeon: Übungen zur allgemeinen Meteorologie mit Rücksicht auf das Flugwesen)
WS 49/50[b)]: *Meteorologie, II. Teil: Dynamik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
SS 50[b)]: *Optik der Atmosphäre* (Lugeon: Übungen in allgemeiner Meteorologie, mit Rücksicht auf das Flugwesen; Pahlen: Gleichgewichtsfiguren rotierender Flüssigkeit und Gase)
WS 50/51[b)]: *Physik der hohen Atmosphäre*; (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
SS 51[b)]: *Einführung in die Meteorologie, I. Teil*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 51/52[b)]: *Meteorologie, II. Teil: Dynamik der Atmosphäre*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
SS 52[b)]: *Meteorologie, I. Teil: Zusammensetzung und Statik der Atmosphäre*; (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
WS 52/53[b)]: *(Götz on leave (beurlaubt); lecture entrusted to H. U. Dütsch)*; (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
SS 53[b)]: *(Götz on leave (beurlaubt))*; (Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen)
WS 53/54[b)]: *Götz on leave (beurlaubt)* (Lugeon: Allgemeine Meteorologie, mit Rücksicht auf das Flugwesen)
SS 54[b)]: Götz on leave (beurlaubt), no meteorology lecture
WS 54/55[b)]: Götz on leave (beurlaubt)
SS 55[b)]: Götz no longer listed
In the following semesters: Lugeon: Übungen zur allgemeinen Meteorologie, mit Rücksicht auf das Flugwesen

The lectures are listed under "Philosophische Fakultät II" (natural sciences), in the following categories: a) Astronomy, b) Astronomy and meteorology, c) Physics;
title of lectures of Götz in italic; lectures of other teachers in meteorology in brackets.
WS: Winter Semester; SS: Summer Semester.
According to Waldmeier (1955): Introduction of meteorology as minor (Promotionsfach) in 1939, subsequently the lectures of Götz were organized as a cycle covering four semesters.

Götz was no longer capable of giving regular lectures from the spring of 1951 because of serious health problems. He became member of a student association[288] called "Falkenstein"[289] in order to maintain contact with young persons[290] and to overcome his isolation in Arosa.

3.10 Overview of scientific achievements and character of Götz

Götz started his extraordinary scientific production in 1925 (Annex 2). In 1926, his book "Das Strahlungsklima von Arosa"[291] was published (Götz, 1926b). It shows the very broad scientific interests of Götz and a tendency to encyclopedic comprehensiveness. The book covered sunshine duration, total solar radiation, thermal radiation, atmospheric transmission, ultraviolet solar radiation (including studies of the Cd-cell, Sect. 3.2) and (stratospheric) ozone as well as the synoptic weather conditions.

From the beginning, Götz was especially interested in UV-B radiation at the surface and at different altitudes (Nicolet, 1992). However, he was not satisfied by measurement of UV-climatology. In a presentation to the Royal Institute of Public Health in May 1929 he explained his scientific approach, which clearly differed from Dorno's view (Sect. 3.2). *"From the beginning the measurements of UV light in Arosa are not only designed on a statistical basis but are also driven by the desire to understand the variability. The observed higher UV-levels in the autumn with respect to the spring observed in the series 1921 to 1924 can only be explained by the weaker ozone layer in the autumn. The variations of the ozone layer first observed quantitatively by Fabry and Buisson are essential for the comprehension of the behavior of UV radiation, which is essential for life"*[292].

Götz's most important scientific achievement was probably the discovery of the Umkehr or Götz effect based on measurements he made during his expedition to Svalbard in summer 1929 and the Umkehr measurements made at Arosa. These provided the first reliable measurements of the atmospheric ozone profile (Sect. 3.8). Götz was already one of the most prominent scientists in ozone research in the 1930s, remaining so until his early death, and wrote several review articles about the subject (Dütsch, 1992). He was also interested from the very beginning in the study of the effect of the solar cycle on ozone (Götz, 1926a and 1926b; see Section 3.5.1).

However, Götz was not only interested in the UV-part of but also in the visible and thermal (infrared) part of solar radiation. In addition, he studied ozone in ambient air (surface ozone, see Sections 3.5.2 and 9.1.3.2) and was convinced that ozone can be used as an indicator for air quality (Götz, 1954; Götz and Volz, 1951). He used first spectroscopic devices (long path ultraviolet spectroscopy, Götz and Ladenburg, 1931; Götz and Maier-Leibnitz, 1933b) before applying a chemical method in the 1950s that allowed him to obtain representative measurements (Götz and Volz., 1951).

288 Studentenverbindung.

289 Götz was able to become a member of "Falkenstein" because this student association was affiliated with the "Studentenverbindung Wingolf" joined by Götz when he was a student in Germany (Sect. 2.4; Trenkel, 1954).

290 i.e. students of the University of Zürich when teaching in Zürich.

291 "*Radiation climate of Arosa"*. Translated by the authors.

292 Royal Institute of Public Health, 1929: Translated by the authors. Original text: „Die Messungen der ultravioletten Strahlung in Arosa sind von Anfang an nicht lediglich statistisch angelegt, sondern auch aus dem Wunsch heraus eines Verständnisses der Schwankungen. So erklären die Reihen 1921-1924 den grösseren Ultraviolettreichtum der Herbstsonne gegenüber der Frühjahrssonne durch die im Herbst schwächere Ozonschicht der Atmosphäre. Die Schwankungen der quantitativ 1920 erstmals von Fabry und Buisson gemessenen Ozonschicht sind entscheidend für das Verständnis des Lichthaushalts des lebenswichtigen Ultravioletts.".

His productivity was outstanding (Götz's publication list includes about 170 publications, including all types of articles, see Annex 2) particularly keeping in mind that (i) he made most of the measurements himself and (ii) he contributed to a large variety of scientific topics.

In the following we try to describe some features of the character of Götz from studying the many documents available to us. We read many times about his humble spirit defining his personal behavior and character (e.g. Trenkel, 1954; Dütsch, 1992). His behavior was very friendly and open but reserved in social life. Persons not familiar with atmospheric research (such as the ones living in Arosa) would never realize they were speaking with a world renowned (ozone) scientist. Waldmeier (1955) described Götz in the following way: *"He was very busy adding scientific studies, one after another, and dedicated his life almost exclusively to science [….] everybody who came into close contact with Götz felt that he was very happy pursuing his scientific studies"*[293].

Even in the first years of his career, there is evidence that Götz was strongly fighting for his point of view as shown in the controversy with Dorno in the years 1924-1926. In several documents related to Götz we find complaints about inappropriate support for his work (e.g. lack of assistants for analyzing the data and helping to perform measurements), or complaints that the situation of the colleagues in Davos was much better than in Arosa, etc. (Sect. 3.6.3 and 3.6.4). Apparently, he felt deprived of the support, which would be appropriate for his merits. These complaints could potentially be viewed as a consequence of his dissatisfaction that he was unable to realize part of his scientific visions and plans[294].

The correspondence reveals that Götz was not always an easy person and that he did not always behave diplomatically in his relationships. We found two letters detailing an emotional confrontation between Götz and Carl Brandt, the owner of a photography shop in Arosa. Götz needed a photograph of a front page of a famous book for a talk and made an appointment. In the letter from 29 July 1943, Götz mentioned that the daughter informed him that her father was at Tschuggen when he came to the shop. He immediately left, slamming the door so hard that they were afraid the glass might break. Brandt wrote in his letter from 30 July that Götz's reaction was completely unexpected and so emotional that his wife and daughter were unable to clarify that the photographer would be back in a few minutes. Brandt also complained that Götz immediately decided to give his work to the competing shop in Arosa and that he refused several times to greet him on the street in Arosa, although, as Brandt claimed, up to five times more hours were required than charged for Götz's earlier assignments. Another example shows that Götz could sometimes be very unforgiving. From a decision of the Swiss Federal Supreme Court of 28 October 1938[295] regarding matter of Albert Bougeant-Urien from Amiens (France) against Dr Friedrich Wilhelm Paul Götz (Arosa) and the district office of Chur (Switzerland) we learn that Götz was convinced that Bougeant owed him 300 CHF for the rent of an apartment at his house in Arosa. Götz tried to obtain the money by going to the police and the district office of Chur, which decided on 11 August and 6 September 1938 to issue an arrest warrant for Bougeant. Bougeant subsequently presented a constitutional appeal at the Federal Su-

293 Waldmeier, 1954. Translated by the authors. Original text: "Mit unermüdlichem Fleiss hat er (sein umfangreiches und geschlossenes) Lebenswerk zusammengetragen, er hat rastlos Arbeit an Arbeit gereiht und mit fast ausschliesslicher Hingabe der Wissenschaft gedient. Aber jeder, der mit dem liebenswürdigen und bescheidenen Verstorbenen in Berührung kam, fühlte auch, wie restlos ihn die Hingabe an die Forschung beglückte."

294 Remember the project of an international collaboration for a network for observatories for measurements of the solar constant, which was internationally discussed in 1931 (Letter Linke, 1 May 1931 (see Sect. 3.5.1)).

295 Bundesgerichtsurteil 1038.

preme Court arguing that the court in France (residence district of Bougeant) would be responsible for decision in this matter. The Federal Supreme Court came to the conclusion that international laws did not allow the responsible court to be determined in this case. In the end Götz was not able to obtain the money and probably lost much more than 300 CHF to pay the lawyer besides many hours of his time. This story shows that Götz contained a stubborn trait indicating that he had difficulties accepting defeats.

In 1958, the community of Arosa and the KVV Arosa constructed (Danuser, 1998b) a fountain to honor F. W. P. Götz and his work [296] (see Figure 25 and for location in Arosa see Figure 1). On the fountain, we read: GEMEINDE UND KURVEREIN AROSA: DEM VERDIENTEN ERFORSCHER DES AROSER KLIMAS PROF F.W. PAUL GÖTZ 1891-1954[297].

Figure 25: Götzbrunnen (see text above) (Photo Franziska Keller MeteoSwiss).

3.11 Götz's untimely death

Götz's health had been steadily declining since the beginning of the 1950s. Perl (refer to Section 4.1) was Götz's most important collaborator from 1947 assuring the operation of the LKO during these years. Götz's suffering is impressively described in the obituary written by Trenkel (1954). He writes that it was very difficult for Götz to accept that he had to give up teaching at the University of Zürich (Sect. 3.9) and he was sad he could no longer accept invitations and give presentations at interna-

296 Called "Götzbrunnen" in Arosa.

297 Community and Kurverein Arosa: "Devoted to the honorable researcher of the Climate of Arosa Prof. F.W. Paul Götz 1981-1954". Translated by the authors.

tional conferences. His suffering from progressive arteriosclerosis, which started several years before his death, as well as physical ageing increasingly diminished his strength. According to Waldmeier (1955), Götz was no longer capable of giving regular lectures at the University of Zürich starting in the winter semester (WS) of 1952/53 and his name appears in the list of lectures [298] of the University of Zürich as on leave (beurlaubt) up to the WS 1954/55. The Education Department [299] of Kanton Zürich renewed the “Venia Legendi” on 1 September 1952 (see Table 6) [300]. A letter from the Education Department of 23 April 1953 shows that Götz asked for leave from his lectures for the summer semester (SS) 1953 due to health problems. This was accepted and, in a letter from June 1953, we learn that Götz was no longer expected to teach in the WS 1953/54 due to health reasons.

It appears that Götz was less and less capable of fulfilling the duties of leading the LKO starting around 1952. Because of health problems, Götz was replaced by Perl in a meeting on 9 February 1952 in which studies by both the physics institute of the University of Fribourg (Switzerland) and the LKO relating to measurements of ions at the LKO were discussed. Perl wrote in a letter to Niggli [301] on 23 October 1952 that Götz suffered from serious heart problems preventing him from regular work and that he had to move to Göppingen (Germany), his mother’s home town, following the advice of his doctor who suggested staying for several weeks at a lower elevation in the hope for recovery. In a letter from Perl [302] we learn that Götz’s wife (Margarete, see Appendix 1) also contributed to meteorological observations at the LKO, but it seems clear that Perl was the person most deeply involved in the LKO’s activities. Unfortunately, Margarete Götz and Perl did not get along with each other. A commission [303] was created by the KVV Arosa to look after the problems of the LKO and to evaluate its future.

In 1953, Perl asked to obtain a new contract: she was employed by Götz (formally the LKO) but insisted on being engaged directly by the KVV Arosa, an option which was supported by Grob [304] and Huber [305], whereas Ms. Götz, assisted by Trenkel [306], wished to continue as before. In a meeting on 12 August 1953, the research council of the Swiss National Science Foundation (SNSF) [307] approved, following an initiative of Huber, a substantial contribution to the salary of Perl (5,000 CHF for 3 years) under the condition that the KVV Arosa and other co-sponsors [308] continued support for the LKO. In addition, a pension [309] (Sect. 9.3) was allotted to Götz to be paid for 6 years by the KVV Arosa. However, during these months the personal problems between Perl and Margarete Götz were

298 Vorlesungsverzeichnis.

299 Erziehungsrat.

300 The lecture Meteorology III, for the WS 1951/53 (Atmospheric Optics) was scheduled, but the Education Department (following the suggestion of the “Hochschulkommission”) transferred the lecture to Dütsch, his earlier graduate student (Sect. 5.1) (letter of the Education Department of 18 October 1952).

301 Paul Niggli (1888-1953), PhD, Professor of Mineralogy and Petrography of ETH Zürich (1920-1953).

302 To Max Schüepp, professor at the University of Zürich, head of research of MeteoSwiss.

303 “Studienkommission für die Observatoriums Angelegenheiten”. Members: Werner Grob (see footnote 304), Paul Huber (see footnote 305) and Heinrich Trenkel (see footnote 39).

304 Werner Grob, Director of the KVV Arosa (1950-1970).

305 Paul Huber (1910-1971), PhD, Professor and Director of the Institute of Physics of the University of Basel (1942-1971) and important person in the Swiss National Science Foundation (SNSF).

306 Refer to footnote 39 on page 12.

307 Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung (SNF).

308 These are: the Rhaetian Railway Company, the Community of Arosa and the Canton of Grisons.

309 Ruhegehalt.

escalating and Perl was no longer allowed to access the rooms of Villa Firnelicht [310] on 30 November 1953, which rendered further measurements at the location impossible. New premises therefore needed to be found rapidly to ensure the sustainability of the measurements of the LKO. In a letter from 1 December 1953, Huber instructed Perl to accelerate the search for new premises for the LKO in Arosa (already started before) mentioning that support of SNSF could not be taken as guaranteed if measurements could not be continued. At that time, the KVV Arosa was very hesitant and considered completely stopping support for the LKO, or at least asked to obtain a substantial relief of the financial burden [311].

In December 1953, the Sanatorium Florentinum (a health institution held by a catholic monastic organization [312] agreed (after having first refused) to offer space for the LKO including one room [313] and a cabin [314] with access to the roof (see Figure 27). Perl describes these rooms in a letter to Huber [315] : *"[The measurement instruments are] actually housed in a room in the 5th floor, [….], approximately 20 m above ground. Therefore, the influence originating from the ground should be completely discarded. Interference in the measurements by smoke and dust from the neighborhood is also impossible because the house is not surrounded by other buildings and the roof is higher than the surroundings trees. Furthermore, the house's furnace of the house is located in a position favorable for us"* so that the observations were not affected. This was particularly important for the measurements of the ions as well as the other chemical compounds. The Florentinum is no longer owned by the monastic organization and the available documentation provided by Markus Näpflin [316] is very sparse. In a chronicle entry of the monastery, the transport of the equipment to the Florentinum is mentioned and it appears that Perl finally needed to convince the responsible Reverend Mother to obtain acceptance for making measurements at Florentinum.

Considering these new facts and the obvious support of the scientific community, the KVV Arosa changed its earlier intentions and agreed to continue support for the LKO but only under the condition that its support would stop after 3 years [317]. This enabled continuation of the LKO Arosa measurements until the International Geophysical Year (IGY) [318]. Based on the support of SNSF Perl obtained a contract from the KVV Arosa (starting retroactively on 1 November 1953). The move of the instruments to the Florentinum took place on 28-31 December 1953 (as decided by the KVV Arosa) under the supervision of Waldmeier [319]. A complete inventory of the LKO was established on this occasion. For this move all instruments and documents belonging to Götz were excluded. This was

310 Villa Firnelicht was property of the family Götz.

311 Minutes from the meeting of the advisory committee for the Light Climatic Observatory of 2 April 1958 at MeteoSwiss in Zürich (Protokoll der Sitzung des Patronat Komitees für das Lichtklimatische Observatorium Arosa vom 2. April 1958 in der Meteorologischen Zentralanstalt in Zürich).

312 Monastery at Ingenbohl in the Canton of Schwyz (Barmherzige Schwestern vom Hl. Kreuz in Ingenbohl/SZ).

313 Nordzimmer

314 Liegekabine

315 Letter Perl to Huber, 11 January 1954. Translated by the authors. Original text: "Sie ist hier in unserem Dachzimmer untergebracht, d.i. im Haus die 5. Etage, [….] also ca 20 m über dem Erdboden.[….] Damit sollte der Einfluss des Bodens doch ganz ausgeschaltet sein !? Eine Störung du

316 Markus Näpflin, archivist of the monastery at Ingenbohl.

317 Letter Perl of 23 December 1953 announcing to Huber the decision of a meeting of the board of the KVV Arosa held a day before.

318 Refer to footnote 223 on page 45.

319 Refer to footnote 40 on page 12.

also the case for the private property at Tschuggen, which was part of the LKO. On 31 December 1953, the meteorological station was likewise moved from Villa Firnelicht to Florentinum [320].

The last publication of Götz was his book “Klima und Wetter in Arosa” [321]. This book contains a personal dedication to his mother [322]. It covers a comprehensive overview of 50 years of meteorological observations in Arosa, such as temperature, humidity, the relationship between ozone and air quality, cloudiness and transport of aerosols by Saharan dust events etc. The production of the book was supported by the SNSF with 5,000 CHF (letter of SNSF secretariat, 22 July 1953). During the process of producing the book Götz was already seriously ill, which resulted in publication being delayed. Both Margarete Götz and Perl assisted in the production of this book (in addition to Honegger [323]). A debate took place as to whether Ms. Götz or Perl would be responsible for the final approval of the manuscript [324]. Finally, Huber decided (on behalf of SNSF), that Margarete Götz was in charge of giving final approval of the manuscript for production, arguing that the book was a private item of Götz. This decision can be interpreted such that the weather observations were not considered a central part of the core observations supported by the KVV Arosa and Huber potentially made a pragmatic decision to overcome the obvious problems. The book was published in 1954 and the introduction shows that the book indeed appeared before Götz’s death (Sect. 3.10). Götz died on 29 August 1954 at the age of 63 in the hospital [325] in Chur.

320 The costs of the move and the installation of the instruments at the new site (excluding move of the meteorological station) amounted to 3692 CHF, which were shared between the KVV Arosa (2/3) and the University of Fribourg (1/3, as part of the scientific project related to the measurements of atmospheric ions).

321 “Climate and weather in Arosa” (Götz, 1954).

322 Götz, 1954. „Gewidmet meiner Mutter, Frau Marie Götz, geb. 10 November 1866, als Gruss aus ihrem geliebten Arosa.“.

323 Hans Honegger, a former student of Götz (proposal of thesis found in the LKO Archives), teacher at an academic high school and friend of Dütsch.

324 Gut zum Druck.

325 Kreuzspital.

4 1954-1962: Period of Gertrud A. Perl

Hereinafter, we present results of our recent investigations on the career of Gertrud Anna Perl (Sect. 4.1) who played a key role in the continuation of the measurements of the LKO (Sect. 3.11 and 4.2).

4.1 Scientific career of Perl

Gertrud Anna Perl

1908	Born on 17 March in Grein/Donau in Austria.
	Elementary school in Linz (1914-1917), continuing school in Vienna (1919-1927).
1933	Degree for teacher of mathematics and physics for gymnasium level.
1935	PhD accepted ("*On the knowledge of solar radiation at different latitudes*").
1937	Assistant of W. Schmidt (1937-1939).
1941	On 15 January registration at Davos, scientific coworker (assistant) of PMOD.
1948	On 12 March signing off from Davos.
	LKO Arosa: Scientific assistant of Götz (1948-1953), Leadership (1953-1962).
1962	Move to Bern because of health problems.
	Contributions to scientific publications related to medical studies.
1966	Employment (60%) by the Swiss National Science Foundation as scientific collaborator in the Swiss National Library (Landesbibliothek).
1974	Death on 6 July.

Figure 26: Biography of Gertrud Anna Perl (Photo Markus Näpflin, Kloster Ingenbohl).

Gertrud Perl (see Figure 26; see also Korotin and Stupnicki, 2018 and Bischof, 2019) was born on 17 March 1908 in Grein, a small rural municipality by the Danube in Austria. Her parents (Augusta Perl, maiden name Bock, and Karl Franz Perl) originated from Tropau, a city belonging to the Austria-Hungarian Empire [326]. The grandfather of Gertrud was director of an industrial factory producing cables and wires, illustrating the higher middleclass family background. Gertrud had one older brother and two older sisters (Bischof, 2019). Her sister Edith never left Vienna, which probably also holds for her sister Ilse (at least until 1940). The family moved during World War I to Linz and later to Vienna. After starting primary school in Linz, Perl continued primary school in Vienna. Subsequently, she continued her school education at the reformed school for girls [327], one of the academic high schools

326 Presently part of the territory of Czech Republic

327 Reformgymnasium

for girls in Vienna[328]. She finished her general education (gymnasium level) in June 1927 with a "Matura" degree qualifying for entering University. She studied for nine semesters at University of Vienna mathematics and physics[329] and graduated with a diploma for teaching of mathematics and physics. She spent a test year for teaching at a well-known school[330] and finished her exams in January 1933. Perl submitted her PhD thesis in July 1934[331] with the title "Zur Kenntnis der Sonnenstrahlen in verschiedenen geographischen Breiten"[332], which was accepted in 1935. The two "referees" (advisors) accepting the PhD were Wilhelm Schmidt[333] and Gustav Jäger[334]. Perl was the first female teaching assistant when subsequently employed by the University of Vienna at the professorship of physics of the Earth working until August 1938[335]. After the death of Schmidt in November 1936 the contract was continued. She was not only involved in teaching, but she was continuing her scientific work as shown by the scientific publications with Steinhauser[336] (Annex 3). After occupation of Austria by Germany in March 1938, the law of the third (German) Reich for employment in public positions (including former Austrian Universities)[337] required for all employees to be in line with the racial law of the National Socialism implying that none of their parents nor grandparents were of Jewish origin[338]; this did not hold for Perl[339]. The documents found by Bischof[340] show that the persons such as the new responsible Professor von Ficker[341] were able to delay the treatment of administrative matters so that the contract expired for Perl finally August 1938. Bischof (2019) found a note that Perl was subsequently living in England; this was corrected by handwriting that she found a position to work as meteorologist in the Netherlands[342]. Since 1939, she lived in Switzerland[343] were she continued her successful career as atmospheric scientist as she published peer-reviewed articles. She was first employee at PMOD in Davos and continued to publish (Annex 3). She was registered in Davos from 15 January 1941 until 12 March 1948[344].

328 The attendance of an excellent school underlines the high priority for education in upper middle class families.

329 Philosophische Fakultät.

330 Mädchengymnasium Albertgasse 8 in Vienna.

331 It seems that Perl was working on her PhD thesis in parallel with applying for the qualification as teacher.

332 "*On the knowledge of solar radiation at different latitudes*". Translated by the authors. Kindly provided by Harald Rieder, Univeristy of Natural Resources and Live Science, Vienna.

333 Wilhelm Schmidt (1883-1936), PhD, professor, meteorologist belonging to the professorship physics of the Earth of the University of Vienna (Kleine Lehrkanzel für Physik der Erde der Universität Wien); Director of the Meteorological Service of Austria (ZAMG) (1930-1936).

334 Gustav Jäger (1865-1938), PhD, Physicist, Professor and Director of the second Institute of Physics of the University of Vienna (1920-1934).

335 Wissenschaftliche Hilfskraft an der Lehrkanzel für Physik der Erde bei Professor Wilhelm Schmidt.

336 Ferdinand Steinhauser (1905-1991), PhD, Professor of Terresterial Physics of the University of Vienna (1953-1976), Director of the Meteorological Service of Austria (ZAMG) (1952-1976).

337 In German: „Reichsbeamtengesetz" und „Neuordnung des Berufsbeamtentums".

338 Original formulation: „Es musste ein sogenannter „Ariernachweis"' erbracht werden, insbesondere, dass sich bis zur Generation der Großeltern keine Personen jüdischer Herkunft befanden.".

339 Although Perl was obviously baptized as Roman Catholic (whereas her mother as well as her father belonged to the Lutherian confession).

340 Refer to footnote 10 on page 3.

341 Heinrich von Ficker (1881-1957), PhD, German-Austrian meteorologist and geophysicist, Professor of the University of Vienna and Director of the Meteorological Service of Austria (ZAMG) (1936-1952).

342 Original text: „Die Notiz, dass sich Perl in England aufhalten würde, wurde handschriftlich korrigiert in: „...soll die Gertrude Perl seither in Holland als Meteorologin in Verwendung stehen.".

343 Information from the Swiss Federal Archives, Bern.

344 Information provided by Susanne Wernli, Municipality of Davos (15 September 2018). The available documents provide contradictory information concerning the home country (Deutsches Reich, Germany and later Austria) and roman-catholic is indicated as religion.

On 1 March 1948, Perl moved to the LKO (letter of Mörikofer to Götz of 12 February 1948; see Table 20). The reason of this move is not known, but we might speculate that Perl was interested in contributing to the rather new area of atmospheric electricity, which Götz was ready to start in the framework of the "climatological action" in collaboration with the University of Fribourg (Switzerland) (Sect. 9.1.3.c). She stayed for training at the University of Fribourg (November 1950-May 1951). Obviously, her brother was living in Pratteln (Switzerland) at that time, since she mentioned in a letter to Götz having visited him during her training in Fribourg (Perl, 10 December 1950). It seems that she had already some health problems as she noted in a letter to Götz that she booked a room in the Clinique Garcia obtaining suitable food for her health (Perl, 7 November 1950).

Perl played a key role for continuing the measurements at LKO in the period after the death of Götz (Sect. 4.2). For the atmospheric ozone community, the measurements of surface ozone were very important (Perl, 1965)[345]. She had to leave Arosa for health reasons in April 1962 and continued to work at Bern with von Muralt[346] (Aroser Zeitung, 1962), first contributing to a publication related to high altitude effects on physiology (Weihe, 1964)[347] and later as scientific collaborator in the library of the Swiss National Science Foundation[348] starting on 26 April 1964 (employment at 60%) until her death on 6 July 1974[349] .

It is worth to point out (i) that graduation by PhD was exceptional for female scientists in the 1930s and (ii) we are convinced that the publication record of Perl (ten papers in reviewed literature) shows that Perl would have been capable to write a habilitation qualifying for a university.

4.2 Continuation of the measurements of the LKO

Perl started the measurements at the Florentinum (see Figure 27) in early 1954. There was a delay in the continuation of total ozone observations after the move to the Florentinum (Sect. 3.11) because the galvanometer was badly damaged during transport and the repair in which Dobson was also involved (as consultant) took considerable time. A close collaboration with Dobson[350] was also established. Every ten days, Perl sent the retrieved total ozone values to Dobson. The measurements of ions were continued in collaboration with the University of Fribourg including registrations of "fast air movements"[351]. Other measurements performed by Perl covered meteorological measurements, surface ozone measurements (Perl, 1965), the intensity of solar radiation and wind registration. Measurements at Tschuggen were also continued and extended. On 19 October 1954, Saxer (later professor at the academic high school Aarau) installed an instrument for the measurement of ions at this site.

345 Her work was supported by Dütsch as the author acknowledges (partial) financial support by the Office of Aerospace Research of the U.S. Air Force and thanks Prof. Dr. H. U. Dütsch for making use of the "complete" ozone series.

346 Refer to footnote 204 on page 42.

347 In the acknowledgment we find: "The editor wishes to express his gratitude to Dr. Gertrud Perl and to his wife Dr. Patricia A. Weihe, M.B.B.Chir. (Cantab.), D.C.H., for their invaluable assistance in editing this book.".

348 Information provided by Pascal Fischer of Swiss National Science Foundation (SNSF), Division II: Mathematics, Natural and Engineering Sciences on 24 August 2018.

349 Result of Internet search: Historischer Kalender oder der hinkende Bote, 249, 1976: Gedenktafel; im Dienst der ETH Bibliothek Zürich digitalisiert https://www.e-periodica.ch/cntmng?pid=hib-001:1976:249::162 (11 December 2018).

350 Refer to footnote 91 on page 25.

351 We did not find any publication of these measurements (see also Richner, 2016).

Figure 27: The Florentinum (a health institution held by a catholic monastic organization (Barmherzige Schwestern vom Hl. Kreuz in Ingenbohl/SZ)) hosted the Light Climatic Observatory from 1954 to 1973 (for the location see Figure 1). From 1996 to 2012 the former sanatorium was run as Backpacker Mountain Lodge, since 2012 as Arosa Mountain Lodge. (Photo Franziska Keller MeteoSwiss).

After the death of Götz in August 1954 (Sect. 3.11), measurements at the LKO, partially supported by SNSF [352], were continued. In the period 1953-1956, the KVV Arosa lost interest in the LKO and attempted finding a new sponsor to take over its obligations. However, the situation changed when MeteoSwiss came in as an additional sponsor. The Federal Commission of Meteorology (EMK) [353] was informed by Lugeon [354] about the situation of the LKO. He was responsible for the Swiss contribution to the IGY [355] and was well aware of the importance of the measurements at the LKO [356]. The members of the EMK were convinced that ozone measurements at the LKO should be continued, even after the IGY, according to the protocols of the EMK meetings. The EMK decided to create an

352 As documented by a letter of SNSF of 20 August 1953 sent to the KVV Arosa (with a copy to Perl)

353 Eidgenössische Meteorologische Kommission (EMK). The Federal Commission of Meteorology was an extra-parliamentary commission and existed until the early 2000's. The commission had the task to advise the Federal Council, the Federal Department of Home Affairs and MeteoSwiss on issues related to Meteorology and Climatology.

354 Refer to footnote 126 on page 34.

355 Refer to footnote 223 on page 45.

356 Remember that Lugeon was also teaching together with Götz at the University Zürich (Sect. 3.9).

advisory committee [357] to take care of the future of the LKO. The first meeting took place on 2 April 1958 and annual meetings were planned [358]. It is not known when this committee was dissolved.

In the Geophysical Year (1957/58) and in the following years, the LKO obtained substantial support (Sect. 9.3.1.a) from MeteoSwiss on initiative of Lugeon (letter of Lugeon to Perl of 23 July 1956). However, the contribution of MeteoSwiss needed annual approval preventing longer planning. For other contributions refer to Section 9.3.1.

Dütsch (Sect. 5.1 and Figure 28) became more and more active at the LKO in this period. He was at that time teacher at an academic high school (Gymnasium) in Zürich but obviously still strongly interested in ozone research. He introduced Umkehr observations into the LKO's regular measuring program in 1956.

After Perl had left (because of health problems, see Section 4.1), the measurements were performed by students on their own for several months. In this critical phase, Dütsch wrote a letter to the Federal Councillor Hans Peter Tschudi [359] on 5 June 1962 in order to find a proper long-term solution for continuing the measurements at the LKO. In the answering letter from 27 June 1962, signed by the Councillor Tschudi, it is noted that ozone measurements can be viewed as part of regular measurements of meteorological institutes according to several resolutions of the WMO [360] and therefore MeteoSwiss was allowed to continue its support for the salary of the person in charge of routine measurements at the LKO (Sect. 9.3.1.a). From the letter we also learn that the EMK decided in its meeting of 11/12 May 1962 to form a sub-committee to jointly study the problems of the observatories of Davos (PMOD) and Arosa (LKO) to find the most suitable solution. The options discussed were either to make the LKO part of MeteoSwiss (the solution which was chosen later on in 1988, refer to Chapter 7) or to move the measurements of the LKO to Davos, making the LKO part of the PMOD. However, no protocol of the meeting in which these issues were discussed (23 November 1962) exists.

Lugeon opined that MeteoSwiss should not assume responsibility for the ozone measurements at the LKO leading to an additional burden [361]. Dütsch was clearly against the move of the LKO to Davos. He argued that move's consequences would probably be moderate for total ozone [362], however, there would be a clear negative effect on the Umkehr measurements because of additional air pollution by aerosols at Davos - in addition, he argued that the total ozone series should be continued at Arosa because it was (even at that time) the longest record in the world [363].

357 Patronat Komitee. Members: Lugeon [126], Paul Huber [305], Kreis [564], Dütsch (Sect. 5.1) and Grob [304]. This committee replaced the Commission (Studienkommission) which existed during Götz's illness respectively after his death and which managed the relocation of the LKO to the Florentinum.

358 Protocols of only 3 meetings are available (2 April 1958, 9 March 1966 and 19 May 1967).

359 Hans Peter Tschudi (1913-2002), PhD, Swiss Federal Councillor, head of the department of Home Affairs of the Swiss Federal government (Eidgenössisches Departement des Innern), responsible for the Office of Meteorology and Climatology (MeteoSwiss).

360 Refer to footnote 118 on page 33.

361 Minutes of the ordinary annual meeting of the Federal Commission of Meteorology, 11 and 12 May 1962 in Zürich. Original text: « M. Bider ne verrait pas d'inconvénient à incorporer Davos, voire Arosa, à la MZA. M. Lugeon pense qu'il ne faut pas surcharger la Confédération de dépenses supplémentaires, si ces observations sont déjà faites ailleurs. ».

362 Note that at that time long-term trend of stratospheric ozone caused by anthropogenic activities was not a research topic.

363 Minutes of the meeting of the Advisory Committee for the Light Climate Observatory Arosa (Patronat Komitee, refer to footnote 357 on page 73), 23 October 1963, MZA Zürich. Original text: „[….] dass eine solche [Verlagerung] für Gesamtozon vielleicht ohne grösseren Schaden möglich wäre, für die Umkehrmessungen infolge der atmosphärischen Trübung in Davos nicht verantwortet werden können, ganz abgesehen davon, dass darauf gehalten werden sollte, die Aroser Messreihen als die längsten zur Verfügung stehenden in Arosa selbst fortzuführen.”.

5 1962-1985: Period of Hans Ulrich Dütsch

5.1 Scientific career of Dütsch in the context of international research

Hans Ulrich Dütsch

1917	Born on 26 October in Winterthur (Switzerland) Childhood in Winterthur.
1936-1942	Studies in Physics and Chemistry at the University of Zürich with a minor in meteorology, including degrees for teaching at two different levels.
1943-1946	Graduate student of Götz; thesis on the photochemical theory of atmospheric ozone.
1948	Marriage with Ursula Müller (children: Ursula, Hansrudolf, Annemarie).
1947-1962	Academic high school (Gymnasium) teacher in physics in Zürich, continuing ozone research.
1950	Visitor at the Massachusetts Institute of Technology (MIT) in Cambridge (MA, USA).
1959-1960	Researcher at the High Altitude Observatory (HAO) in Boulder (CO, USA).
1962-1964	Head of the Ozone Research Programme at the newly founded National Center for Atmospheric Research (NCAR) in Boulder (CO, USA).
1965-1985	Professor of Atmospheric Physics of ETH Zürich.
2004	Died on 27 December in Zürich (Switzerland).

Figure 28: Biography of Hans Ulrich Dütsch (from Staehelin et al., 2018a) [364].

Hans Ulrich Dütsch (see Figure 28) [365] studied physics, mathematics and chemistry, including meteorology as minor [366], at the University of Zürich. He was inspired by Götz's lectures [367] (Sect. 3.9). Subsequently he became a graduate student of Götz (see Figure 29; Dütsch, 1946, title of PhD thesis: "Photochemische Theorie des atmosphärischen Ozons unter Berücksichtigung von Nichtgleichgewichtszuständen und Luftbewegungen" [368]. The thesis was based on the chemical theory of Chapman (1930) and the ozone measurements of Arosa including total ozone and profile information derived by the Umkehr method (Sect. 3.8). After extended calculations, he reached the conclusion that the knowledge deduced from the Chapman theory was not sufficient to explain the ozone

364 For more details see Läubli, 2019.

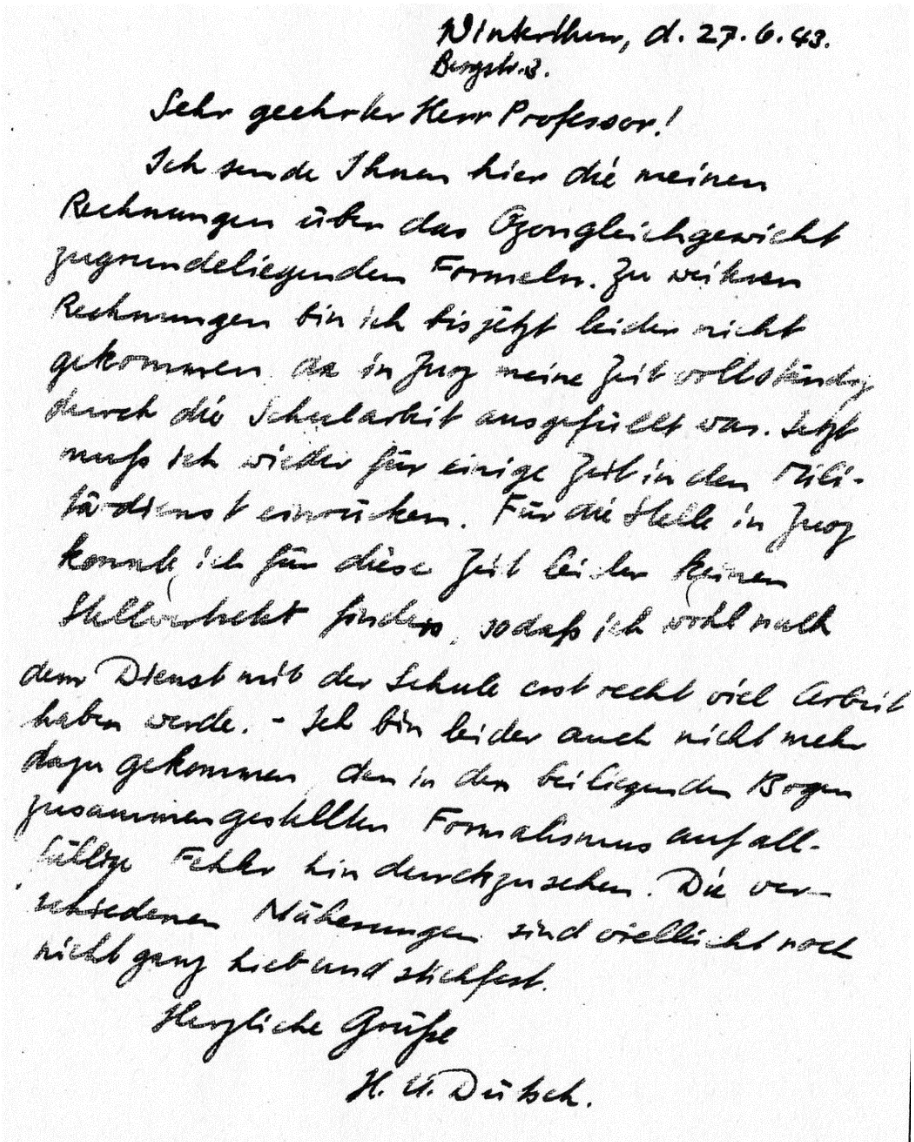
365 The information about the career of Dütsch is also based on the valuable information of Dütsch, 2002, kindly provided by his children.

366 Dütsch also finished two teaching degrees for natural sciences (regular high school (Sekundarschule), 1940) and physics (academic high school (Gymnasium), 1942), which was particularly demanding as he needed to make regular military service during World War II.

367 We note a number of similar features in the scientific career of Dütsch and Götz, among education and experience as class room teachers.

368 "Photochemical theory of atmospheric ozone under consideration of non-equilibrium states and air movements". Translated by the authors.

measurements available from Arosa (particularly regarding seasonal cycle) and he therefore indirectly concluded that other important processes, which were not known at that time, had to play a significant role. Only four years later Brewer published his paper (Brewer, 1949) showing that transport processes are indeed relevant in the stratosphere, transporting ozone from the tropical source region into midlatitudes, which is currently known as Brewer-Dobson circulation.



Winterthur, d. 27.6.43.
Bergstr. 3.

Sehr geehrter Herr Professor!

Ich sende Ihnen hier die meinen Rechnungen über das Ozongleichgewicht zugrundeliegenden Formeln. Zu weiteren Rechnungen bin ich bisjetzt leider nicht gekommen, da in Zuoz meine Zeit vollständig durch die Schularbeit ausgefüllt war. Jetzt muß ich wieder für einige Zeit in den Militärdienst einrücken. Für die Stelle in Zuoz konnte ich für diese Zeit leider keinen Stellvertreter finden, sodaß ich wohl nach dem Dienst mit der Schule erst recht viel Arbeit haben werde. – Ich bin leider auch nicht mehr dazu gekommen, den in den beiliegenden Bogen zusammengestellten Formalismus auf allfällige Fehler hin durchzusehen. Die verschiedenen Näherungen sind vielleicht noch nicht ganz hieb und stichfest.

Herzliche Grüße

H. U. Dütsch.

Figure 29: Letter of Dütsch of 27 June 1943 telling Götz about his problems finding time to conduct research for his doctoral thesis as he was teaching at the academic high school in Zuoz and needed to perform military service as 1943 was during World War II [369] (Letter LKO Archives).

369 Text of letter of 27 June 1943: „Sehr geehrter Herr Professor! Ich sende Ihnen hier die meinen Rechnungen über das Ozongleichgewicht zugrundliegenden Formeln. Zu weiteren Rechnungen bin ich bis jetzt leider nicht gekommen, da in Zuoz meine Zeit vollständig durch die Schularbeit ausgefüllt war. Jetzt muss ich wieder für einige Zeit in den Militärdienst. Für die Stelle in Zuoz konnte ich leider keinen Stellvertreter finden, so dass ich wohl nach dem Dienst mit der Schule recht viel Arbeit haben werde. – Ich bin leider auch nicht mehr dazu gekommen, den in den beiliegenden Bogen zusammengestellten Formalismus auf allfällige Fehler hin zu durchsuchen. Die verschiedenen Näherungen sind vielleicht noch nicht genug hieb und stichfest. Herzliche Grüsse, H. U. Dütsch.".

Dütsch finished his important and comprehensive PhD thesis within three years, which was very challenging. These problems are illustrated in a letter (see Figure 29) where he apologizes for slow progress in his scientific work as he was simultaneously teaching at the Alpine academic high school in Zuoz in the Grisons and intermittently needed to perform military service because it was during World War II [370].

After his PhD Dütsch was mostly working as a teacher at the "Oberrealschule Zürich", an academic high school. In 1948, he married Ursula Müller. She always supported him as when moving with the growing family to the United States and back to Switzerland (see below) [371]. In 1950, Götz arranged for Dütsch a 9-month post-doc position at MIT in Boston in order to build contacts with the international ozone science community [372]. Dütsch replaced Götz as lecturer during one semester at the University of Zürich when Götz was already seriously ill (Sect. 3.11). Though he could not continue to give lectures at the University of Zürich he still was interested in ozone research (Sect. 4.2). He also started to produce weather forecasts [373] for the newspaper "Neue Zürcher Zeitung" (NZZ). Sent to a conference in Rom in 1954 by the NZZ, Dütsch met Harry Wexler [374] who suggested to him to apply to the Geophysics-Research-Directorate of US Air Force to obtain the required financial support to continue the ozone observations at the LKO when it became clear that Götz no longer was able to perform the measurements (Sect. 3.11) [375]. With this contract, Dütsch became involved in the analysis of Umkehr measurements [376]. Dütsch was one of the first applying modern computers for retrieval of Umkehr profiles [377]. Using the finances of the Air Force grant, Dütsch organized in 1958 as well as in 1961 and 1962 important profile intercomparison campaigns (Sect. 9.1.3.g). In 1959-1960, he had the opportunity to spend a year with his family in Boulder CO, USA, evaluating data of the IGY at the High Altitude Observatory (HAO). In order to follow a professional career in ozone research, Dütsch and his family emigrated for him taking a new position [378] in Boulder at the newly formed National Center for Atmospheric Research (NCAR) in 1962 (see Figure 28). However, he also took the full responsibility for continuation of the ozone measurements at the LKO after the departure of Perl (Sect. 4.2 and 5.2).

According to Dütsch (2002) he gave a lecture at ETH Zürich about stratospheric ozone at the occasion of one of his regular trips to Switzerland (required to oversee the ozone measurements at LKO,

370 From Dütsch (2002) we learn that he quit his employment at the school at Zuoz in spring 1945 in order to be able to finish the very time-consuming calculations (without computer, only with side rules).

371 We found Ursula Dütsch-Müller open minded and very helpful also assisting his husband when he was travelling after his retirement.

372 Dütsch claims that he found (without publication) fast (winter) stratospheric warmings (SSW: Sudden Stratospheric Warming) before (independent) discovery and publication by Scherhag (1952).

373 The strong interests in meteorology can be viewed as another common interest with Götz.

374 Harry Wexler (1911-1962) was a famous meteorologist, Chief of the Scientific Services division of the US Weather Bureau (US National Weather Service) (1946-1962) (see Wikipedia).

375 The successful grant allowed starting with the continuous Umkehr series of Arosa (Sect. 9.1.2.b, Umkehr measurements) and the study of the relationship between ozone vertical distribution and weather.

376 Another research continuing activity of Götz.

377 At that time, Dütsch travelled regularly to Paris because the IBM 704 in Paris was the fastest computer allowing for efficient treatment of the complex and time-consuming Umkehr retrieval. He continued with Carl Mateer the use of modern computers to retrieve ozone profiles from Umkehr measurements.

378 Dütsch took this decision when the Director of the "Oberrealschule" (Gymnasium emphasizing mathematics and science) was no longer willing to reduce the numbers of teaching lectures (as it was accepted when he took the responsibility of the Air Force grants mentioned above).

see Sect. 5.2), which was attended by ETH president Pallmann [379], and he obtained the position [380] of full professor [381] at ETH and head of the IACETH [382] in autumn 1964 [383]. The main science topic of Dütsch was ozone research and therefore ozone measurements at the LKO were continued as part of IACETH's [384] research (Sect. 5.2). Dütsch was interested both in total ozone as well as in ozone profile measurements (Sect. 4.2). Furthermore in 1966, he started ozone balloon measurements, first launched in Thalwil [385] and from 1968 onwards performed operationally by MeteoSwiss at the Aerological Station in Payerne [386]. With this data, he derived ozone profile climatologies (Dütsch, 1978). Dütsch and coworkers compared ozone climatologies as deduced from ozonesondes launched from Boulder, CO, USA, Thalwil, Switzerland (Dütsch et al., 1970), and Payerne (Dütsch, 1974a). Results were first published as technical reports.

Improving the knowledge of the circulation in the upper atmosphere (particularly at the tropopause altitude) was believed to be valuable for improvement of weather forecasts. Breiland (1964) showed that the relation between the ozone vertical distribution and synoptic meteorological conditions was a research topic in the 1960s. Publications of the observatory of Hohenpeissenberg [387] show results of careful analyses of the relations between ozonesonde measurements and synoptic weather type [388] (Hartmannsgruber, 1973; Attmannspacher and Hartmannsgruber, 1973 and 1975). Dütsch justified the ozone measurements of the LKO with atmospheric physics research as written in a letter on 19 September 1961 [389] to Vaterlaus [390]. The letter starts by referring to the Ozone symposium that took place in August 1961 in Arosa and then specifies: *"Ozone is a tracer to study [vertical] stratospheric air movement that cannot be directly measured and important results are expected regarding unresolved problems of stratospheric circulation (from small to largest scales). This gas is not only a tracer for such movements but actively contributes to them […] for such reasons activities in ozone measurement have strongly increased over the last decade and significant progress has been achieved regarding determination of the vertical distribution of this trace gas* [391]. Thereafter, he re-

379 Hans Pallmann (1903-1965), PhD, Professor and Director of the Institute of Agriculture Chemistry of ETH Zürich, Rector of ETH 1947-1949, President of the ETH School Board 1949-1965.

380 It appears that Pallmann suggested to Dütsch to apply for the open position (personal communication Hans Richner, February 2019).

381 Note that Dütsch was just the right person to introduce an (extended) new teaching program in meteorology (Vertiefungsrichtung in Physik) which did not exist in Switzerland (in contrast to Germany).

382 Refer to footnote 12 on page 4.

383 Evidently the return to Switzerland was viewed with mixed feelings by Dütsch and his family: "although we all found it difficult to leave the inspiring atmosphere of Boulder". Translated by the authors. Original text:"obschon es uns allen schwer fiel, die inspirierende Atmosphäre von Boulder zu verlassen" (Dütsch, 2002).

384 Refer to footnote 12 on page 4.

385 Close to Zürich.

386 Located in the western part of the Swiss plateau.

387 Located in Bavaria, Southern Germany.

388 Weather type classifications aim at identifying recurrent dynamical patterns for particular regions; the resulting weather types can then be used to describe weather and climate conditions (Weusthoff, 2011).

389 Written by Dütsch on letter head of the ozone commission (IO_3C).

390 Ernst Vaterlaus (1891-1976), PhD, Member of Swiss Parliament (1951-1963), President of the Swiss Council of States (Ständerat) (1961-1962).

391 Letter Dütsch (to Vaterlaus), 19. Sept. 1961. Translated by the authors. Original text: „Einmal erweist sich dieses Spurenelement als geeigneter "Tracer" für nicht direkt nachweisbare stratosphärische Strömungsvorgänge (wie etwa Vertikalbewegungen), und man hofft mit seiner Hilfe wesentliche Aufschlüsse über die noch keinesfalls gelösten Probleme der stratosphärischen Zirkulation (vom kleinen bis zum allergrössten Massstab) zu gewinnen. Dies umso mehr, als das Gas nicht nur zum Nachweis solcher Strömungsvorgänge verwendet werden kann, sondern aktiv auf deren Entstehung mitwirkt ….. Aus solchen Gründen sind die Anstrengungen zur Ozonbeobachtung ported on ozone variations at higher altitudes (30 km) that might be attributable to the 11-year solar cycle and pointed out the need for continuation of such studies as circulation changes in the stratosphere are expected to propagate to lower atmospheric layers that might have a direct effect on weather. The letter ends with the statement that such analyses are considered to be important for reliable long-term meteorological weather prediction. This letter can also be viewed as a case for supporting Umkehr measurements.

Besides ozone research, Dütsch was strongly and continuously interested in (synoptic) meteorology and meteorological weather forecast. For 51 years he produced weather forecasts for the famous newspaper Neue Zürcher Zeitung (NZZ, 9 January 2001), a task he continued more than 15 years after his retirement as professor of ETH Zürich.

At the beginning of the 1970s, a paradigm change took place in stratospheric ozone research. The study of the effect of anthropogenic emissions in the lower stratosphere was a new topic that received very high priority (e.g. Staehelin et al., 2016). First the effect of anthropogenic nitrogen emissions from civil aircraft planned to operate with supersonic speed [392] were discussed (Johnston, 1971 and Crutzen, 1970). Only a few years later, Stolarski and Cicerone (1974) and independently Molina and Rowland (1974) found that ClO_x can destroy stratospheric ozone; the latter postulated chlorofluorocarbons as source gas of ClO_x[393].

Figure 30: Presentation during the Quadrennial Ozone symposium in 1961 at Arosa (Protestant church parish hall) (Photo LKO Archives).

im letzten Jahrzehnt stark gesteigert worden, und es wurden vor allem in Bezug auf die Bestimmung der vertikalen Verteilung des Gases beträchtliche Fortschritte erzielt.".

392 Super Sonic Transporter (SST).

393 In 1995 the Nobel Prize in Chemistry was awarded to Paul Crutzen, Mario Molina and F. Sherwood Rowland for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

Dütsch was one of the leading scientists in stratospheric ozone research and one of the few ozone experts involved in ozone research both in the time before anthropogenic ozone destruction was debated and in the decades when ozone destruction by ozone depleting substances (ODS, such as chlorofluorocarbons) was in the focus of stratospheric ozone research. He contributed to the IO_3C [394], serving as member from 1957 to 1975, as secretary for 15 years (1959-1975), before being elected as president in the period 1975-80. In 1988, he was awarded as an honorary member of the IO_3C. He was also the main organizer of two important ozone symposia (Quadrennial Ozone Symposium (QOS), organized for the IO_3C) that were held in Arosa in 1961 (with 75 participants) and 1972 (with 90 participants) [395] (Bojkov, 2012). These symposia took place in the Protestant church parish hall of Arosa (see Figure 30).

In the QOS of 1972 in Arosa, the topic of anthropogenic ozone depletion was new in the community. The quantification of the effect of anthropogenic emissions required the development of numerical simulations, which were becoming more and more sophisticated over time (refer to Section 6.1). During the 1970s, many features of state-of-the-art stratospheric knowledge needed to be developed. The theory of Molina and Rowland (1974), i.e. the destruction of the ozone layer by manmade chlorofluorocarbons releasing ClO_x radicals in the upper stratosphere, was questioned by the chemical industry that supported additional research. Furthermore, satellite instruments were launched to monitor the ozone layer from space.

Dütsch provided valuable information for the community, e.g., to assess numerical simulations describing anthropogenic ozone depletion with ozone climatologies (Dütsch 1974b; Dütsch, 1978). For more information on Dütsch's publications see Annex 4 [396]. Toward the end of his career several employees in his group were involved in air pollution research (e.g., Graber, 1984).

Very high data quality and reliability (see Sect. 6.1) in the ground-based total ozone measurements also became a political issue. Du Pont, the market leader in production of chlorofluorocarbons in the 1970s made an advertisement in New York Times, 1975: *"Should reputable evidence show that some fluorocarbons cause health hazard through depletion of the ozone layer, we are prepared to stop production of the offending compounds".* Indeed, negative long-term ozone trends were viewed as "reputable evidence" for stratospheric ozone destruction by chlorofluorocarbons. Note, that long-term calibration stability of ground-based instruments need to be very high since anthropogenically caused long-term trends in stratospheric ozone at midlatitudes are in the order of several percent change per decade whereas day to day variability of ozone can be as large as ± 20% (Sect. 6.1 and 7.5).

394 Refer to footnote 121 on page 33.

395 In 1972, Arosa was chosen as symposium venue allowing to celebrate the 50th anniversary of the LKO and to honor its founder F. W. Paul Götz.

396 Dütsch was the main advisor of several PhD theses relevant in this context: Piaget (1970) studied stratospheric intrusions, Züllig (1973, 1975) looked at the relation between the intensity of stratospheric polar vortex and the ozone content of the winter hemisphere; the PhD thesis of Birrer (1975a and b) focused on the homogeneity of the total ozone record at Arosa, whereas that of Braun (1980) was devoted to studying the effect of stratospheric warmings on ozone at mid latitudes (see also Table 16 in Sect. 9.2.3).

5.2 Measurements at the LKO 1962-1973

When Perl had to leave Arosa in 1962, Dütsch assumed scientific leadership of the LKO (Sect. 4.2). At the same time, he went to Boulder (NCAR) to pursue research in the field of atmospheric ozone. Honegger [397] was helping to manage the program of measurements at the LKO during the leave of Dütsch (1962-1964, see Sect. 5.1). Dütsch defined an "extended ozone program" covering the following measurements: (i) routine observation of total ozone; (ii) measurements of atmospheric electricity; (iii) continuation of climatological measurements[398]; (iv) ozone profile measurements by the Umkehr method. Several Dobson spectrophotometers were in use at the LKO during the Dütsch period [399].

Five total ozone measurements per day were submitted to Toronto for publication by WMO starting in 1962; they were also published in the annals of MeteoSwiss[400] in 1961 and in the following years.

The observations were now performed by a technician[401] who acted as station manager (for more information refer to Section 9.2.1.a). The KVV Arosa still continued to support the LKO and the station manager received his salary from the KVV Arosa for 10 years.

Measurements at the roof of the Florentinum were difficult because the space was limited. As the nurse working at night in the sanatorium had her sleeping room at the same floor, some problems with noise complicated work as well.

A letter from 13 April 1967 provided by Näpflin[402] from the documentation of the monastery Ingenbohl signed by Grob[403] and the Reverend Mother in charge of the Florentinum describes a new regulation for the rooms of the LKO at the Florentinum. As 3 rooms were now available, the monthly rent was increased and other organizational details were discussed that obviously needed clarification.

Dütsch used the statistical Langley plot method [404] to update the instrumental constants; this requires a large number of measurements at different sun elevations (Dütsch, 1984). The observer therefore had to make measurements over the entire day looking for the required weather conditions as only direct sun observations (at different wavelength pairs, refer to Staehelin et al., 1998a) were performed for total ozone measurements at Arosa. To ensure the highest data quality Dütsch applied the statistical Langley plot calibration every year to check and update the instrumental constants of the Dobson instruments operated at the LKO Arosa (Dütsch, 1984). For this purpose, Dütsch went to Arosa every year for several days or even weeks and checked all total ozone measurements before deriving updates from the instrumental constants, which also were applied backwards for every year (see Sect. 7.5) leading to small changes in each total ozone value.

397 Refer to footnote 323 on page 68.

398 Observations of the climatological station of MeteoSwiss.

399 For more information concerning measurements and instruments refer to Section 9.1.2.

400 Annalen der Meteorologischen Zentralanstalt (today MeteoSwiss).

401 The employment of the technician was based on the letter of the Councillor Tschudi of 27 June 1962 (Sect. 4.2) in which ozone measurements were viewed as part of the duties of a Meteorological Office.

402 Refer to footnote 316 on page 67.

403 Refer to footnote 304 on page 66.

404 The statistical Langley plot method is described in Section 7.5.

5.3 Move of the LKO to the Haus Steinbruch and first Dobson intercomparison at Arosa

According to a document from Näpflin[405], the LKO was forced to leave the Florentinum by the end of 1972 with the justification that the rooms used by the LKO were needed for the employees of the Florentinum. The measurements were moved from the roof of the sanatorium Florentinum to the roof of another building nearby, the "Haus zum Steinbruch" [406] (see Figure 1 for location and Figure 31), at the beginning of 1973. On that occasion, the local station manager (Aeschbacher [407] at that time) became an employee of IACETH. The new place offered much better working and measuring conditions (see legend of Figure 31); however, the running costs were considerably higher (Sect. 9.3.1). The rent for the new measuring platform as well as for the related apartments was also paid by ETH Zürich through the Federal Office for Buildings and Logistics[408]. One apartment was reserved for the station manager and his family, the other one for external people working at the LKO or visitors (see legend of Figure 31).

Figure 31: Building Haus zum Steinbruch (see Figure 1 for site in Arosa) where the LKO was located since 1973. Measurements are performed on the roof, in the permanent construction of the roof (behind) the measurements are analyzed (the other parts installed on the roof were constructed after 1988 by MeteoSwiss (on the left: Umkehr hut and rotating Spectrodome)). Two apartments in the floor below the measurements are used (1) for housing of the technician and (2) housing of visiting technicians and scientists as well as for data analysis. (Photo René Stübi MeteoSwiss).

405 Refer to footnote 316 on page 67.

406 Haus Steinbruch in this report.

407 Refer to footnote 103 on page 29.

408 Eidgenössisches Bundesamt für Bauten und Logistik.

The high data quality of the worldwide Dobson network is achieved by regular side by side comparison with reference instruments that are regularly compared with the primary world (Dobson) standard instrument [409] (for more details refer to Section 7.5). In 1978, such an intercomparison organized by Dütsch was held in Arosa. It was one of the first international Dobson intercomparison exercises and the results were debatable [410] (for more information refer to Staehelin et al., 1998a; Basher, 1995). They were not applied to the Arosa record and Dütsch continued to use the statistical Langley plot method [411] for the update of the instrumental constants of D15 until it was replaced by D101 [412] as the main instrument at the LKO Arosa (Sect. 9.1.2.b).

409 Dobson Spectrophotometer D83.

410 It turned out that a debate took place which of the instruments should be used as standard instrument (Basher, 1995).

411 The statistical Langley plot method is described in Section 7.5.

412 Refer to footnote 227 on page 47.

6 1985-1988: Period of re-orientation

6.1 Arosa measurements and International Ozone Trend Panel Report

Around 1984-85, the global stratospheric ozone problem appeared to be much less severe than believed in the late 1970s. Global models are required to quantify the effect of ODS emission on stratospheric ozone. In 1974, only 1-dimensional models were available, which were continuously improved. Furthermore, stratospheric ozone chemistry involves dozens of chemical species connected via many chemical reactions[413]. Chemical ozone depletion (in the gas phase) is limited by the formation of key reservoir species such as $ClONO_2$ staying in a chemical equilibrium with ClO and NO_2, both of them destroy ozone. However, in the publication of Rowland and Molina in 1975 the reaction rate of the formation of $ClONO_2$ could only be estimated from laboratory measurements made at physical conditions (temperature and pressure) very different from the stratosphere. Beginning in the second part of the 1970s, key reaction rate constants were measured (often supported by the chemical industry) for physical conditions more typical of the stratosphere[414]. This caused very large changes (see Figure 32) in the global ozone destruction projected to be reached after 50 to 100 years (i.e. after reaching steady state) assuming always the same emissions of ODS, namely those of the 1970s. The first numerical results for 1974 described in Rowland and Molina (1975) [415] indicate a global ozone decrease of 15%; the largest ozone depletion by ODS was expected to be 19% in 1979, whereas the ozone decline was predicted to be only about 3% in 1983. This result suggested that anthropogenic ozone depletion would become only a serious environmental problem in case of continuous increase in worldwide ODS emission.

On the political side, the international discussion on anthropogenic ozone depletion resulted in the Vienna Convention for the Protection of the Ozone layer in 1985 [416]. However, the Vienna Convention did not contain any formal commitment for emission reductions of individual countries.

The view of the stratospheric ozone depletion changed dramatically in the second part of the 1980s. The Antarctic Ozone hole was detected in 1985 (Farman et al., 1985), a phenomenon which was completely unexpected. Farman et al. (1985) speculated in their paper that the Antarctic ozone hole could be caused by increasing emission of CFCs; however, this explanation was speculative at this time and strongly questioned. This led to large aircraft campaigns and within a few years it became clear that the rapid Antarctic ozone depletion was caused by manmade emissions of ODS (Rowland, 1991; Peter, 1997; Solomon, 1999).

413 State-of-the-art stratospheric chemistry models include more than hundred compounds.

414 Reliable determination of such reaction rate constants needs special expertise and equipment.

415 Refer to footnote 393 on page 79.

416 The treaty of the Vienna Convention came into force on 22 March 1985 when signed by more than 20 countries.

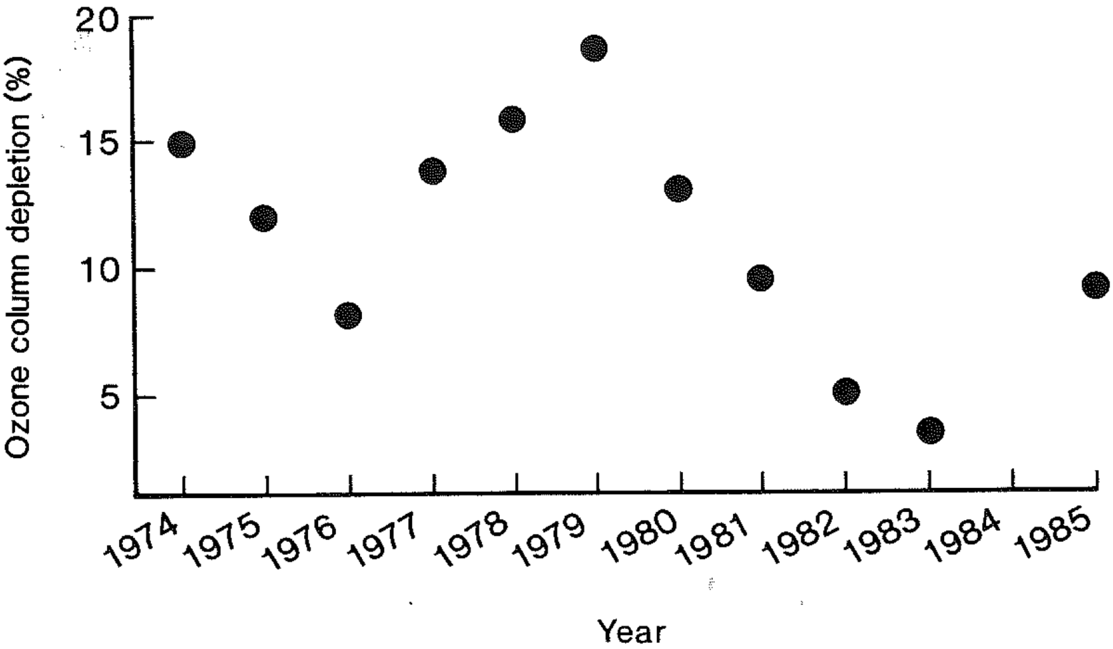


Figure 32: Prediction of decrease in global stratospheric Ozone (see text) (from Benedick, 1991, p. 13).

The change in the assessment of the ozone layer threat was also the result of the report from the International Ozone Trends Panel (IOTP, 1988, chaired by Robert T. Watson) documenting significant ozone reduction in the more populated (northern) midlatitudes. Continuous ozone satellite observations by the instruments TOMS and SBUV on board the Nimbus 7 satellite started in 1979 (e.g. Staehelin et al., 2001). The first trend analyses of the (relatively) short TOMS record suggested a strong decrease in total ozone in northern midlatitudes (Heath, 1988). These findings started a debate, since the ground-based total ozone measurements did not confirm the large decrease reported from the satellite measurements. In the IOTP (1988) (among other topics) satellite and ground-based measurements were reviewed. The IOTP (1988) reached the conclusion that ground-based measurements were more reliable concerning the long-term stability, while satellite data provide global coverage. The lack of long-term stability of the satellite calibration was caused by inappropriate description of the degradation of the diffuser plate radiance reference[417].

Chapter 4 of Vol. I of the IOTP (1988)[418] contains a comparison between ground-based Dobson and TOMS overpass measurements. The quality of most of the ground-based total ozone data available at the World Ozone Data Center (WODC)[419] was not sufficient for reliable trend analysis and TOMS data[420] were used as transfer standards in order to detect sudden changes in ground-based measurements attributed to calibration problems in the Dobson data. Only the Arosa total ozone data were

417 After the publication of IOTP (1988), the TOMS and SBUV-satellite data sets were treated by a new retrieval algorithm making use of measurements at different wavelengths overcoming the problem of diffuser plate degradation (Hermann et al., 1991). This led to the TOMS/SBUV version 7 (e.g. Stolarski et al., 1992) and more recently version 8 series (Bhartia et al., 2004).

418 Entitled "Trends in Total Column Ozone Measurements" (chaired by F. S. Rowland).

419 Presently World Ozone and Ultraviolet Data Center (WOUDC) operated by Environment and Climate Change Canada at Toronto.

420 Satellite measurements are called overpass data when matching best individual ground-based ozone measurements regarding space and time.

used as provided by Dütsch. For the other stations the observations corrected by TOMS-overpass data as provided by Bojkov[421] were used[422].

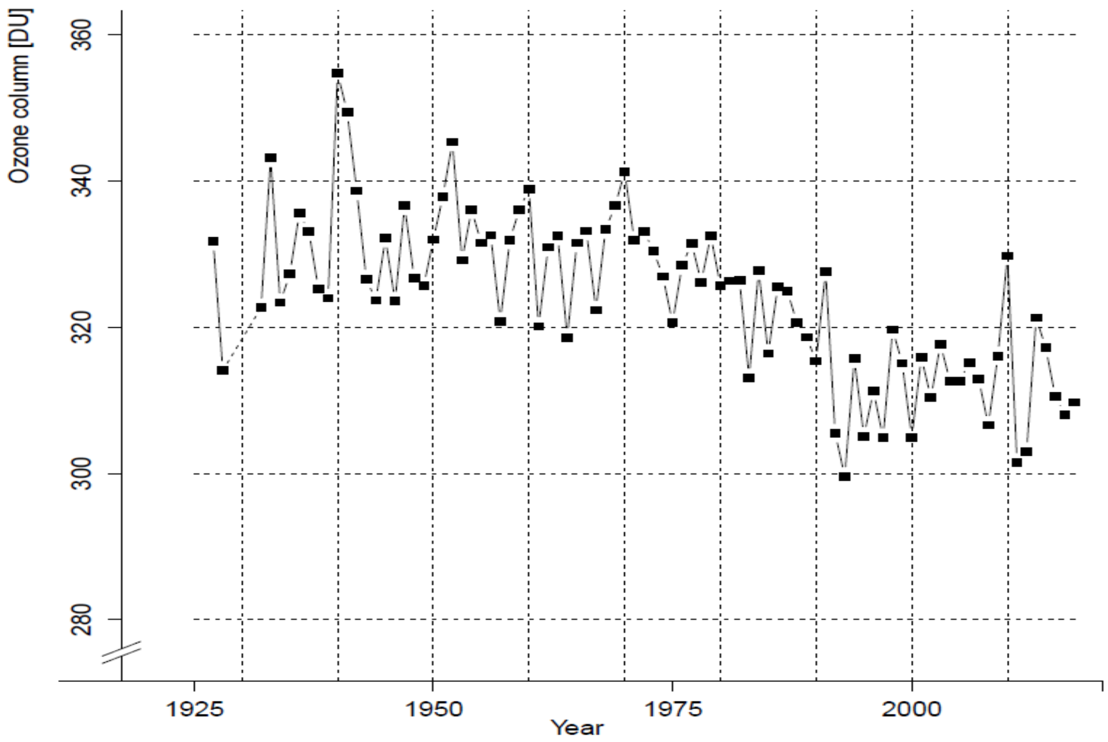


Figure 33: Annual means of the total ozone series of Arosa (Chart René Stübi MeteoSwiss).

The results of trend analysis of ground-based total ozone measurements presented in IOTP[423] can be found in the PhD thesis of Harris (1989)[424], which was performed under the supervision of Rowland[425]. Harris developed a statistical time series model accounting for seasonal variation and including a long-term trend component depending on calendar month[426]. Other terms described the noise and were used for determining uncertainties of trend magnitude. Furthermore, the model included three proxies (or explanatory variables) for the description of natural variability such as the Quasi

421 Rumen Bojkov, PhD, Former Special Advisor to the Secretary-General of WMO on Ozone and Global Environmental Issues and Secretary of IO_3C (1984-2000).

422 The data provided by Bojkov were named "provisionally revised data".

423 In the IOTP, 27 Dobson records of sufficient length of the northern hemisphere (most of them located in midlatitudes, 11 sites with measurements that went back to the 1950s) were available whereas there were only 4 suitable records from the southern hemisphere. A debate evolved around the "provisionally revised data", as in urban areas, tropospheric SO_2 can significantly deteriorate O_3 column measurements of Dobson instruments. Therefore, changes in local SO_2 pollution can lead to false ozone trends in Dobson series as documented in the total ozone series of Uccle, a station close to Brussels (De Muer and De Backer, 1992).

424 The thesis of Harris contains a comprehensive overview of earlier studies of trend analyses of total ozone that did not show significant trends (e.g. Reinsel et al., 1981). Harris (1989) used two approaches to deduce and confirm significant negative winter ozone long-term trends at northern midlatitude stations. In the simple approach, he compared monthly mean values of two approximately equal periods of the individual station data with measurements starting in 1965 and ending in 1985 finding in most cases lower winter ozone values for the measurements 1970-1985 than the earlier data.

425 Refer to footnote 393 on page 79.

426 The trends were assumed to start at the beginning of 1970 (using a ramp function), but the selection of the exact year did not significantly change the conclusion.

Biennial Oscillation, the 11-year sunspot cycle and a term derived from numerical simulations to describe the effect of nuclear bomb tests[427]. Harris (1989) was the first to show negative winter downward trends in northern midlatitudes.

Harris (1989)[428] used two versions of the Arosa data. Data based on AD-double wavelength[429] (Sect. 3.7.1) observations were used for trend analysis of total ozone measurements after the IGY. In addition, he also utilized the C-wavelength pair measurements of Arosa (Staehelin et al., 1998a), which were available from 1931[430]. Arosa is located at an alpine site where the effect of aerosols is expected to be very small and therefore the trends of the two data sets were similar.

The Arosa series (see Figure 33) played a key role in the IOTP 1988 (and the thesis of Harris) because (a) it was the only series that did not need correction by TOMS overpass data[431] and because (b) of its unique length.

DuPont, the market leader in ODS production, during the 1970s strongly opposed to a limitation of ODS chemical production (Sect. 5.1), rather suddenly changed its position supporting global regulation in 1986 (Grundmann, 1999, p. 257 ff.). DuPont was probably afraid of being confronted with compensation claims due to skin cancer: in a study of EPA of 1986 800,000 “additional” deaths from skin cancer within the coming 88 years were projected and therefore documentation of negative ozone trends at midlatitudes might have been important in the decision of the DuPont company to stop production of chlorofluorocarbons as significant ozone decrease might have been viewed as “reputable evidence” (Sect. 5.1).

The same type of statistical model was used in the WMO/UNEP Ozone Assessments (Sect. 7.1), with the only difference that the proxy of nuclear bomb tests used by Harris was ignored in the later studies.

6.2 Measurements at the LKO (1985-1988)

When Dütsch retired in 1985, measurements at the LKO were at first continued as described in 5.2. The second international Dobson intercomparison at Arosa took place in 1986, organized by Dütsch on behalf of the World Meteorological Organization. One of the Dobson instruments used at Arosa[432] (D101) was recalibrated by comparison with the world primary Dobson instrument (D83, see Sect. 7.5) whereas the instrumental constants of the other Dobson instrument (D15) were not changed (Sect. 7.4.1).

427 The nuclear bomb tests mainly occurred in the first half of the 1960s and might have caused stratospheric ozone depletion by release of nitrogen oxides.

428 Harris (1989) compared the results of long-term trend analysis with the results of a (2-dimensional) numerical simulation. The numerical models also showed downward trends strongest in winter, however, much smaller than those obtained by the statistical analysis. Harris (1989) argued that the numerical simulations did not contain heterogeneous chemical reactions.

429 Remember that AD measurements allow the effects of aerosols to be minimized and were introduced in the Dobson network in IGY (see Figure 15). Reliable C and AD data is available only at Arosa.

430 After homogenization of the earliest measurements (Birrer, 1975a and b).

431 Refer to footnote 420 on page 86.

432 Refer to footnote 227 on page 47.

6.3 Search for a solution to continue observations at the LKO

Upon the retirement of Dütsch in 1985, the continuation of long-term stratospheric ozone measurements at Arosa (namely total ozone and Umkehr) was uncertain as the new Professor and new Director of IACETH [433] succeeding to Dütsch had other research priorities and was not interested in atmospheric ozone research. Bruno Hoegger [434] played an important role in finding a proper solution. Dütsch, Rieker [435] and Hoegger participated in a meeting on 25 June 1985 at Payerne [436] to discuss the ozonesondes launched at Payerne, where also an inspection of the Dobson instruments at Arosa was planned for spring 1986. At a meeting of Richner (IACETH), Rieker and Hoegger in Payerne on 10 January 1986, the future of the ozone measurements at Arosa was discussed when it was clear that neither IACETH nor the Geographic Institute of ETH Zürich [437] were willing to continue the measurements [438]. In the minutes (written by Hoegger) it was suggested to ask the PMOD in Davos to continue the LKO measurements as trained personnel suitable for this task would be available. Furthermore, MeteoSwiss argued that it was not useful to perform the ozonesonde measurements and to take over the responsibility of the ozone observations in Arosa without a qualified scientist in Switzerland responsible for scientific analysis and interpretation of the ozone data [439] since the scientific research based on the measurements was believed to be very important for data quality. It was also argued that this problem could not be solved by hiring a research scientist at MeteoSwiss because a long-term commitment for such a scientist was required, which was not possible for MeteoSwiss as no permanent position was available and it was deemed inappropriate to hire a qualified scientist on a non-permanent position.

Dütsch took [440] the initiative by writing a letter to the responsible Federal Councillor Cotti [441]. Based on this letter the Swiss Federal Office for the Environment [442] was charged to analyze the situation of the ozone activities in Switzerland. The Office came to the conclusion that Swiss research in stratospheric as well as tropospheric ozone needed to be continued because the scientific expertise in stratospheric as well tropospheric ozone was required to support decisions related to international cooperation such as the Vienna Convention [443] (Sect. 6.1). This led to a request from Böhlen [444] of the Swiss Federal Office for the Environment to Oeschger [445] to coordinate the evaluation of the fu-

433 Refer to footnote 12 on page 4.

434 Bruno Hoegger, PhD, responsible of the Measurement Technics of MeteoSwiss at the Aerological Station in Payerne (1984-2002) (Sect. 9.2.2.b), retired in 2002.

435 Jean Rieker, PhD, responsible of the Upper Air Measurements of MeteoSwiss at the Aerological Station in Payerne

436 Minutes available at the Aerological Station of Payerne.

437 Atsumu Ohmura, PhD, Professor (Emeritus) of Physical Geography at the Geographic Institute of ETH Zürich (1983-2001) and IACETH (2001-2007).

438 ETH Zürich argued that regular ozone measurements routinely performed at the LKO do not fall under the responsibility of a university.

439 As it was the case at the time when Dütsch was working as scientist at ETH Zürich.

440 As in the first phase of uncertainty concerning the continuation of the LKO after the death of Götz (Sect. 3.11 and 4.2).

441 Flavio Cotti, Swiss Federal Councillor (1986-1999), Head of the Swiss Federal Department of Home Affairs in Bern (Vorsteher des Eidgenössischen Departements des Innern) (1986-1993).

442 Bundesamt für Umwelt (BAFU) since 2006, earlier: Bundesamt für Umwelt, Wald und Landschaft (BUWAL) (1989-2005), before: Bundesamt für Umweltschutz (BUS) (1971-1989).

443 Refer to footnote 416 on page 85.

444 Bruno Böhlen (1930-2011), PhD, professor at the ETH Zürich, Director of the Swiss Federal Office for the Environment (1985-1992).

445 Hans Oeschger (1927-1998), PhD, Professor of Climate and Environmental Physics at the Physics Institute of the University of Bern (1963-1992), chairmen of the Commission for Climate and Atmosphere (CCA) (Kommission für Klima und Atmosphäre), a commission of the Swiss Academy of Sciences (Schweizerische Akademie der Naturwissenschaften SCNAT).

ture of ozone research in Switzerland, leading to an expert meeting on 27 May 1986 with the participation of the interested administrative bodies and the Swiss scientists active in ozone research in order to make a valuable proposal to find a solid basis for the continuation of the Swiss ozone measurements in Arosa (and Payerne). Different institutional options and various locations were analyzed to host the measurements. At that time, the move of the LKO to Davos was also considered.

Finally, the evaluation ended in the following arrangement. On 12 March 1987, Primault [446] submitted a request to the management board of MeteoSwiss to take over the measurements of the LKO in which the budget for operations and investments for renewal of the station was included. The management board of MeteoSwiss, under the direction of Junod [447], agreed to continue the ozone soundings by MeteoSwiss at the Aerological Station in Payerne and to take the responsibility for regular performance of the ozone measurements of the LKO in Arosa (total ozone and Umkehr). The Department of Home Affairs approved that the number of permanent positions at MeteoSwiss could increase by one personal unit [448] allowing moving the observer (station manager) of the LKO (occupied by Aeschbacher [449]) to MeteoSwiss[450]; MeteoSwiss obtained the new position by 1 January 1988 and the LKO [451] was integrated into MeteoSwiss[452]. At the same time, the former position of the observer of the LKO at IACETH [453] was converted into a scientific position in order to continue (among other tasks) the scientific support of the Swiss ozone measurements[454].

446 Bernard Primault, PhD, head of the Measurement and Data department of MeteoSwiss (Bereich Messungen und Daten) (1983-1987).

447 André Junod, PhD, physicist, Director of MeteoSwiss (1983-1992).

448 Despite a hiring freeze existing in the federal administration.

449 Refer to footnote 103 on page 29.

450 Confirmed by the letter of 2 July 1987 of the responsible Federal Department of Home Affairs (Eidgenössisches Departement des Innern) to the Director of MeteoSwiss.

451 At that occasion a change of the official name of the LKO was introduced: Light Climatic Observatory – Ozone Measuring Station of MeteoSwiss (Lichtklimatisches Observatorium – Ozonmessstation der MeteoSchweiz abbreviated LKO, as previously).

452 The LKO was becoming part of the Aerological Station of Payerne and integrated into the division in charge of the Upper Air measurements of MeteoSwiss (for the responsible persons refer to Table 14 in Section 9.2.2.a) which was also operating the measurements of the ozonesondes at Payerne. Technical aspects (renewal and maintenance of the instrumentation) fall under the responsibility of the Measurement Techniques division of Payerne (for the responsible persons refer to Table 15 in Section 9.2.2.b).

453 Refer to footnote 12 on page 4.

454 By 15 April 1988, Johannes Staehelin (one of the authors of the report) started his position at IACETH taking care (among other duties) of the scientific activities related to the ozone measurements and being data quality advisor for the ozone measurements of MeteoSwiss.

7 1988-2014: Period of MeteoSwiss and IACETH

7.1 International development

The Montreal Protocol (MP) [455] is justifiably viewed as a milestone in the global environmental regulation allowing for legally binding reduction of the anthropogenic emissions of ODS. The MP was subsequently strengthened several times (see Figure 34) and strongly dominated the agenda in ozone research in the following decades.

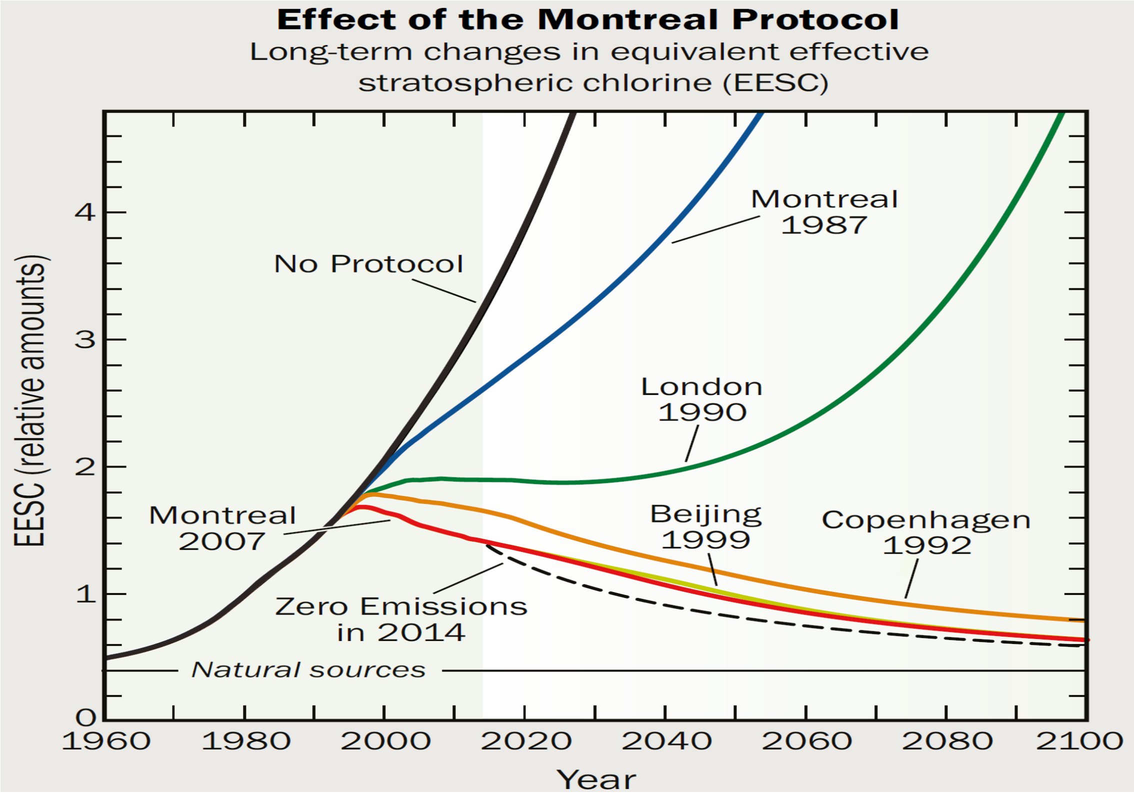


Figure 34: Montreal Protocol and its strengthenings. The worldwide emissions of ozone depleting substances are shown as equivalent effective stratospheric chlorine. (From Hegglin et al., 2015).

The atmospheric loading of ozone depleting substances is often described by the metric "Equivalent Effective Stratospheric Chlorine". Its evolution is shown in Figure 34. The peak loading was reached

455 The Montreal Protocol (MP) was prepared on 16 September 1987 by the parties of the Vienna Convention and went into force on 1 January 1988.

in the second half of the 1990s. Stratospheric ozone measurements were therefore required to document the “turn-around” of the negative stratospheric ozone trends and the expected subsequent recovery. Documenting the recovery of the ozone layer is also viewed as an important task as the aim of the MP is the protection of the global ozone layer (Sect. 8.1) [456].

7.2 Collaboration between MeteoSwiss and IACETH

The following partnership between MeteoSwiss and IACETH was established in the subsequent period of measurements at the LKO. MeteoSwiss was in charge of the operational performance of the ozone measurements whereas IACETH was mainly responsible for scientific analysis of the measurements and contributing to data quality assurance and control (QA/QC) (Sect. 7.5). In this cooperation, it was attempted to make best use of the different strengths of the two types of institutions. MeteoSwiss has (i) the required budget and technical capability for renewal of the equipment (see below) and (ii) the possibility to hire professionally trained personnel in permanent positions necessary for high quality measurements. These two requirements can hardly be fulfilled by universities today. Conversely, the strength of a university such IACETH is scientific research, which benefits from the analysis of the Swiss ozone measurements. Research at universities is strongly based on the work of PhD students, which requires publishing papers in peer reviewed literature. This in turn requires an element of new innovative research. The PhD advisor has the duty to provide the PhD candidate with a research topic allowing completion of the PhD thesis within about three years and to discuss with the student the progress of his/her research. By this cooperation, the Swiss long-term ozone measurements were analyzed and published in the reviewed literature, which assured the scientific use of these data and enhanced the visibility of the measurements performed by MeteoSwiss. The close cooperation between MeteoSwiss and IACETH also helped strengthen the motivation of the MeteoSwiss employees performing the operational measurements, which can be viewed as an important element in QA/QC since very high data quality data is required as a basis for research published in the reviewed literature. At the beginning [457] of the working relationship between MeteoSwiss and IACETH, the roles needed to be defined including an adequate interface.

7.3 Measurements at the LKO (1988-2014)

Dobson instruments were previously located on trolleys (see Figure 36). During night and adverse weather conditions (precipitation) they were located in a hut and needed to be positioned in a proper way for measurements. Instrument readings were written by hand on paper sheets and the total ozone values were subsequently calculated [458].

456 The relevant scientific results were subsequently summarized within three to four years in the WMO/UNEP Ozone Assessments that were produced for the states that signed the MP.

457 Refer to footnote 14 on page 4.

458 A PhD student under Dütsch started in the 1970s to automate a Dobson spectrophotometer for total ozone observation, however, the work was not successfully completed (refer to Section 9.1.2.b Total Ozone observations for more details).

Figure 35: Hans Ulrich Dütsch (on the left) together with Bruno Hoegger (MeteoSwiss), who was responsible for the renewal of the LKO in 1987-1989, staying in front of the hut in which the automated Dobson instrument (D51) was located for the Umkehr observations (Photo Bruno Hoegger).

Figure 36: Two Dobson instruments as operated at the Haus Steinbruch before the renewal in 1987-1989. The instruments were located on trolleys enabling transport to the huts (left), where the instruments stayed during night and in case of precipitation. (Photo Kurt Aeschbacher).

Hoegger[459] (see Figure 35) invested considerable efforts to initiate and realize the renewal of the infrastructure. A spectrodome was constructed (see Figure 37) in which the two Dobson instruments were located. At the roof, a window could be opened for measurements and the spectrodome could be rotated for proper position of total ozone (direct sun) measurements. Furthermore, the position of the wedge of the instruments providing the instrument's signal was recorded electronically and the signal transferred electronically to the PCs inside the building, enabling much easier and more reliable operation of the Dobson spectrophotometers (Hoegger et al., 1992). PC-programs were written to derive total ozone amount and graphics were developed, e.g., to compare the individual total ozone values of the two Dobson instruments (e.g. for one day) allowing easy detection of suspicious data.

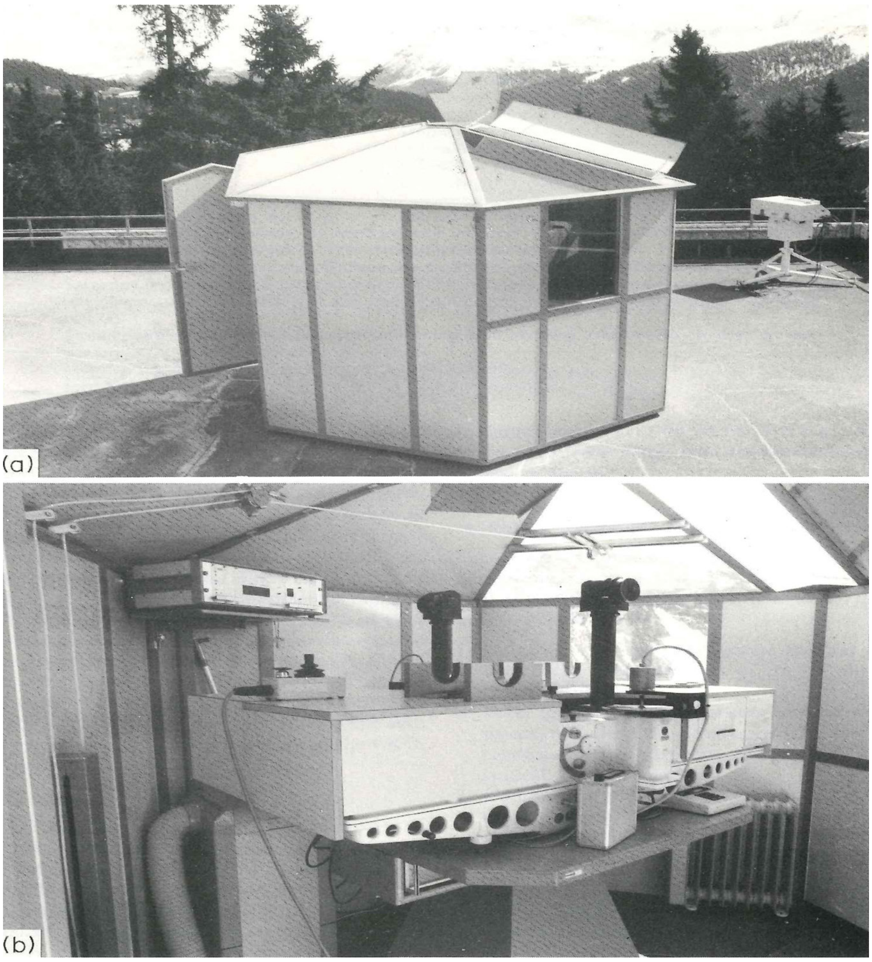


Figure 37: Spectrodome installed by MeteoSwiss for housing of the (semi-automated) Dobson instruments (from Hoegger et al., 1992).

At the same time, one Dobson instrument was completely automated for the Umkehr measurements[460] and placed in a special hut (visible in Figure 35). Cloud screening algorithms were developed to process and analyze the automated Umkehr measurements[461].

459 Refer to footnote 434 on page 89.

460 To avoid a scenario where an employee was required for Umkehr observations.

461 For more information on the Dobson measurements refer to Section 9.1.2.b)

At that time, fully automated Brewer sun spectrophotometers, which were commercially available from the beginning of the 1980s, were also installed at the LKO with the aim of introducing new measuring technologies to extend the measurement capabilities (spectral UV) and to improve the reliability of ozone measurements (total ozone and Umkehr) at Arosa by redundancy (for more information refer to Hoegger et al., 1992; see also Section 9.1.2.c).

On the other hand, Müller [462] and Rieker were focused to restructure the organization and to define new operational procedures[463]. The students were replaced by part-time auxiliary staff (more details can be found in Section 9.2.1.a).

Three large Dobson intercomparisons (Sect. 7.5) took place in 1990, 1995 and 1999 in Arosa (involving 10-15 instruments, see Figure 38). After 2000, smaller Dobson intercomparisons were organized, normally in Hohenpeissenberg. Nevertheless, important intercomparison campaigns continued to be organized in Arosa, such as a regional Dobson intercomparison in 2003 (including 6 Dobson instruments), and the LKO specific intercomparisons in 2006 and 2010 (with 4 Dobson instruments).

Figure 38: Dobson intercomparison at the roof of the Haus Steinbruch (Photo Bob Evans, formerly NOAA, Boulder).

Additionally, the first Brewer workshop was held at Arosa in 1990. Brewer Regional Calibration campaigns were carried out in 2008, 2006; maintenance/calibration campaigns with the European Brewer Calibration Center (RBCC-E) traveling reference instrument have taken place in 2012, 2014 and 2016 (Stübi et al., 2017a). Scientific meetings during the Dobson and Brewer intercomparisons were held in the meeting room of the Catholic Church community of Arosa.

462 Gerhard Müller, former acting Director of MeteoSwiss (2010-2011), Deputy Director (1998-2011), Head of the Measurement and Data department (1987-2012), retired in 2012.

463 As documented by a series of notes found in the archives.

In November 2001, Aeschbacher[464], the local station manager, retired. Before a replacement was decided, Viatte[465] produced a strategy paper requested by the management board of MeteoSwiss to review the situation of the observatory with the aim of analyzing if the LKO was on the right track and if operation could be optimized. Once again, the question of a merger with the PMOD in Davos was a topic of discussion. As the expected recovery of the ozone layer due to a diminished loading of ozone depleting substances in the atmosphere was not yet confirmed in the data it was concluded that it was not the moment to endanger the long total ozone measurement series and that a rapid move to another place was not possible but would require a good preparation with an extended period of parallel measurements (Sect. 8.2).

In 2002, the astrophysical observatory (Sect. 3.5.1; see Figure 39), which had been built by ETH Zürich in 1938 at Tschuggen near Götz's hut was closed. MeteoSwiss was asked if there would be some interest to take over the building for the purpose of the LKO. The possibility to use it as new LKO measurement platform was envisaged and the scientific as well as the technical and financial aspects were evaluated. However, the idea was ultimately abandoned.

Figure 39: The hut of Götz (build in 1934, on the right) and the astrophysical observatory of ETH Zürich (build in 1938, on the left) at Tschuggen (Photo LKO Archives).

464 Refer to footnote 103 on page 29.

465 With the support of all people involved in the ozone activities of the LKO (Hoegger, Aeschbacher, Stübi, Schill and Staehelin) (Sect. 9.2).

7.4 Homogenization of the ozone measurements of the LKO

7.4.1 Homogenization of Arosa's total ozone series

Since the beginning of the ozone measurements with Dobson spectrophotometers, different instruments were operated at the LKO [466] (Sect. 9.1.2.b). The careful inspection of the instrument in summer 1992 indicated that the standard Dobson instrument used between 1949 and 1992 (D15) was not operated in proper optical alignment (Sect. 9.1.2.b). Dütsch regularly applied the statistical Langley plot [467] method to correct small changes in the instrumental constants (Sect. 5.2 and 7.5) for determination of total ozone (Staehelin et al., 1998a). The correspondence of Götz with Dobson shows (Staehelin et al., 1998a) that Götz was never satisfied with the performance of the new instrument D15 when operated at the LKO and results of comparisons of measurements between the old Féry Spectrophotometer ("D2") and D15 from April-June 1950 showed pronounced differences (see Figure 3 in Staehelin et al., 1998a). This provided evidence that D15 was always operated in optical misalignment, but most probably in stable condition as Dütsch always used the statistical Langley plot correction. The instrument was carefully inspected several times, but no particular problem in D15 was found; in one report we found the remark that everything on D15 was tested except the optical alignment because of a lack of suitable instrumentation (Staehelin et al., 1998a). Figure 40 shows the results of the calibration of instruments performed in Oxford in the late 1940s including those of D15. The remarkable difference of D15 against the standard instrument ("D1") (see data around 09.50) provides independent evidence that D15 had an instrumental problem before being transported to Arosa, most probably the optical misalignment detected by the inspection in 1992. It was decided to use a statistical approach for correction (homogenization), which was based on daily mean measurements of D15 and D101 during the period 1986-1991, D101 being calibrated against the world primary Dobson instrument (D83) in the Dobson intercomparison in 1986 (Sect. 6.2). The Dobson intercomparison of Arosa in 1990 confirmed that D101 was stable against the standard instrument from 1986-1991.

The homogeneity of the time series before 1949 was obtained by a statistical approach as well. The measurements prior to 1930 should not be used for trend analysis [468]. In the Dobson intercomparison of Arosa in 1995, a substantial shift between the Arosa instrument D101 against the reference instrument was found. The applied correction to obtain a homogenous series is described by Staehelin et al. (1998). The findings were basically confirmed by the Arosa Dobson intercomparison of 1999 (for more information refer to Scarnato et al., 2010). Brönnimann and Compo (2012) confirmed by comparison with meteorological data the reliability of the homogenized Arosa Dobson series back to the start of the measurements. In Staehelin et al. (1998b) total ozone trends based on the homogenized Arosa total ozone series were published.

466 Refer to footnote 227 on page 47.

467 The statistical Langley plot method is described in Section 7.5.

468 Remember, that Götz used the Féry spectrometer (Sect. 9.1.2.b Total Ozone observations) operated at the LKO for his expedition to Svalbard (Sect. 3.8), but the instrument was damaged in transit back to Switzerland and the instrument was subsequently shipped to the laboratory in Oxford for repair (Sect. 3.8.3). This resulted in a substantial number of months of missing data at the LKO in 1930 and 1931 and most probably introduced a break in the early part of the Arosa series.

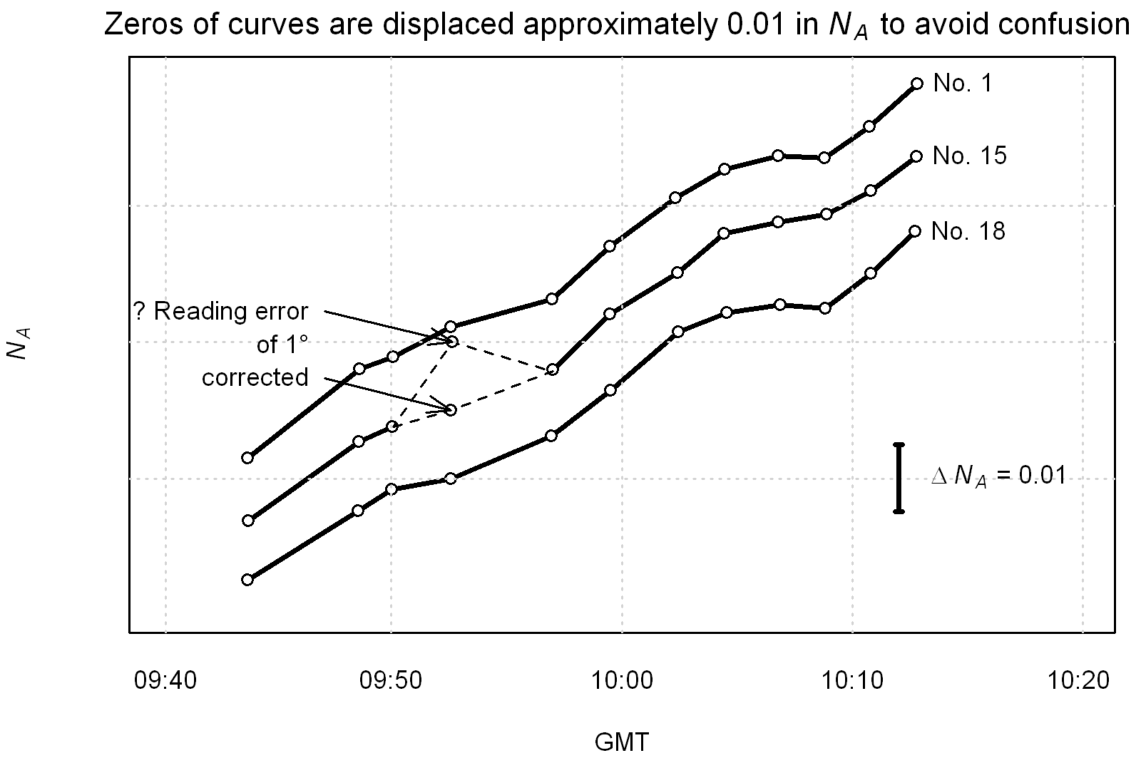


Figure 40: Calibration of new Dobson instruments (D15 and D18) by comparison with "D1" in Oxford prior to transport to Arosa (figure adapted and data extracted from Dobson and Normand, 1962).

7.4.2 Homogenization of Arosa's Umkehr series

The Arosa Umkehr series also needed homogenization. Irina Petropavlovskikh discovered [469] two breaks in the Umkehr series of Arosa (Petropavlovskikh et al, 2001; see Figure 1 in Zanis et al., 2006). The long-term Umkehr series is based mainly on measurements of the Dobson instruments D15 (1956-1988, manual) and D51 (1989-today, automated, see Section 9.1.2.b). After 1988, manual Umkehr measurements with D15 were continued but much less frequently. In September 1992, D15 was replaced by D62 [470]. The first break, which occurred in 1988, was caused by the instrumental change from D15 to D51. The overlap between D51 and the less frequent D15 measurements from 1 January 1988 to 30 January 1989 were used for homogenization. The second break in the Umkehr measurements occurred in 1992. It was caused by the replacement of the chopper-motor in D51, which was required because of a strong lightning stroke in August 1992. Apparently, the new settings led to a misalignment of the shaft recorder. A note in the logbook of the data was used for the correction. For more details and trend analysis results refer to Zanis et al. (2006).

469 As part of her contribution to the EU-project REVUE.

470 For the Umkehr measurements performed with D101 refer to Section 9.1.2.b Umkehr measurements.

7.5 Contribution of Swiss Scientists to the Scientific Advisory Group of GAW/WMO

Atmospheric ozone measurements are crucial for determining long-term changes in (stratospheric) ozone as caused by manmade emissions of ozone depleting substances (Sect. 5.1 and 6.1). Ground-based long-term series such as the total ozone record of Arosa are key measurements in all WMO/UNEP Ozone Assessments[471]. Furthermore, ground-based total ozone measurements are also very important for evaluation of the long-term stability of satellite ozone measurements, which allow obtaining quasi global stratospheric ozone trends (Sect. 6.1 and Sect. 10.5).

Since the 1970s, the WMO coordinates the world-wide network of ground-based stratospheric ozone stations first through the Global Ozone Observing System (GO_3OS) and thereafter through the Global Atmosphere Watch (GAW) Programme (WMO, 1997, 2001 and 2004; Staehelin, 2008; Dlugokencky et al., 2010). The responsible body in GAW is the Scientific Advisory Group (SAG) for ozone. SAG-Ozone is mainly responsible for overseeing the network of stratospheric ground-based

Figure 41: Annual meeting of the Scientific Advisory Group for Ozone (SAG-Ozone) held in October 2005 at the Aerological Station of MeteoSwiss at Payerne (Switzerland) (third person from the left: Johannes Staehelin, second person from the right: Pierre Viatte – the authors of this report) (Photo MeteoSwiss).

471 Refer to footnote 456 on page 92.

ozone measurements that include ground-based sun photometers such as Dobson and Brewer instruments used for regular total ozone, as well as Umkehr measurements and ozonesondes. SAG-Ozone is also mandated to provide SOPs (Standard Operation Procedures) enabling institutions like weather services to perform high quality measurements, to evaluate the quality of the measurements, to promote instruments calibration and to oversee the work of the WOUDC [472]. Both authors of this report [473] acted as members of SAG-Ozone (see Figure 41).

Determination of total ozone amount from Dobson and Brewer spectrophotometers requires knowledge of the intensity of solar radiation outside the atmosphere at the respective wavelengths as described in Section 3.7.1. This information was not directly available when Dobson instruments were introduced, but it can be obtained indirectly by plotting the values at different solar zenith angles by extrapolation to an air mass of zero, providing the "instrumental" constants that cover the extraterrestrial constants. This procedure is called the Langley plot method. This method is regularly applied to the world primary Dobson and Brewer spectrophotometers. Within the present networks the individual station instruments are regularly compared [474] with the primary instruments. The absolute calibration of the world primary Dobson instrument D83 is achieved by the Langley plot method based on measurements performed at the Mauna Loa Observatory at Hawaii (Komhyr et al., 1989). The application of the Langley plot method requires measurements of at least one half-day during which (besides clear sky and low aerosol content) total ozone remains constant. At midlatitude stations, total ozone often varies which is caused by changing meteorological conditions and it is very difficult to confirm stability in total ozone for a particular half-day. However, a similar type of method can be applied to a large collection of measurements by a statistical approach called statistical Langley plot method, which was originally proposed by Dobson and Normand (1962). The valid measurements are plotted against solar elevation for every individual half-day. In the next step the results of the extrapolation are finally averaged to derive an averaged value of the instrumental constants. This approach provides reliable results if it can be assumed that no systematic diurnal variation of column ozone exists when measurements are averaged over a large collection of measurements, e.g. of one year. If this assumption can be viewed as fulfilled and if a large collection of data including a large variety of solar zenith angles is available, the statistical Langley plot method allows updating the instrumental constants of Dobson instruments without relying on intercomparisons. (Dütsch, 1984). Dütsch applied this method [475] for the Arosa series until 1986 and for D15 until 1992 (Sect. 7.4.1) [476].

In the worldwide network of Dobson measurements, the systematic comparison of individual Dobson instruments by Dobson intercomparisons was introduced in the 1970s and was formalized in the 1980s and 1990s (e.g. Staehelin et al., 2018a). Intercomparisons of stations' Dobson instruments were planned to take place approximately every 4 years from the 1990s [477]. This continuously improved the data quality of the world-wide Dobson network (Komhyr et al., 1989; Köhler et al., 2004, Staehelin et al., 2019b).

472 Refer to footnote 419 on page 86.

473 Viatte from 1996 to 2007 (replaced by Stübi of MeteoSwiss in 2007) and Staehelin from 2004-2013 (2005-2013 as chairperson).

474 Indirectly, namely by comparing with regional standard instruments which are regularly compared with the world standard Dobson spectrophotometer D83.

475 Note that the statistical Langley plot method was also used in the Antarctic ozone measurements published by Farman et al. (1985).

476 The new instrumental constants were applied for the past year as well, yielding small chages for the total ozone values.

477 Because of the extraordinary stability of Dobson instruments the interval for intercomparison of station instruments was increased (in absence of particular concern) to 5 years by the SAG-Ozone in 2013 (Ulf Köhler).

7.6 Joint scientific achievements

7.6.1 The role of the Swiss Programme GAW-CH

In the period since 1988, the collaboration between MeteoSwiss and ETH Zürich has been successful, which is reflected in the large number of common publications (and possibly) including close to 50 articles published in peer reviewed journals (Annex 5). In the first years Dütsch, although retired, was still active in scientific research, e.g. studying Umkehr measurements and the effect of solar cycle on total ozone.

On an initiative of Müller [478], the Swiss GAW Programme (GAW-CH) (Müller, 1994) was established and started in the beginning of 1995 (based on a decision of the Swiss Federal Council [479] of 25 November 1994) as the contribution of Switzerland to the worldwide GAW Programme of WMO, covering services [480] and operational monitoring. Concerning the latter, the goal of GAW-CH is to coordinate as well as to maintain and extend the measurements of Switzerland contributing to GAW including ozone, radiation, aerosols and greenhouse gases (Müller and Viatte, 2005). The Swiss Federal government allocated 3.8 million CHF to the build-up of the GAW-CH Programme during the years 1995-1998, as well as a regular contribution of more than 1 million CHF per year for the follow-up activities. The GAW-CH Programme aims to facilitate scientific and technical experiments in the above-mentioned fields as well as to support the use of GAW measurements in scientific research by financing projects. For support by these grants the Swiss atmospheric scientists are invited, every 3-4 years, to submit proposals to MeteoSwiss to conduct scientific research related to GAW. Since 1995, the authors of this report were member of the steering group of GAW-CH [481], which meets twice a year, providing a platform for information exchange and discussion of activities relevant in the context of GAW. Among the supported projects, four PhD theses in atmospheric ozone were financed by GAW-CH at IACETH (see Table 16). In one of the projects supported by GAW-CH the Institute of Applied Physics of the University (IAP) of Berne was commissioned to develop an Ozone microwave radiometer to be deployed at the Aerological Station in Payerne [482]. Dobson and Brewer Intercomparisons were also funded.

7.6.2 Research foci

It was well known since the middle of the 1980s that Dobson and Brewer instruments show small but systematic differences in seasonal variation in total ozone, which is particularly relevant if automated Brewer should replace manual Dobson spectrophotometers. The unique Arosa total ozone time series from Dobson and Brewer instruments allowed studies of the differences between the two instrument types (Staehelin et al., 1998a; Scarnato, 2008; Scarnato et al., 2009 and 2010) as well as their

478 Refer to footnote 462 on page 95.

479 Refer to footnote 21 on page 5.

480 One aim of GAW-CH is to support services in favor of the activities of the International GAW Programme (i.e. World Calibration Centers, ozone soundings in Kenya).

481 GAW Landesausschuss.

482 A measurement series of ozone profiles was started in Payerne in 1999 with the microwave radiometer SOMORA in order to complement the ozone soundings from Payerne and the Umkehr profiles in Arosa. This was a follow up to the measurements performed by the IAP in 1989 at the LKO with the OGOS instrument (Sect. 9.1.3.7) and later on in Bern with the GROMOS system.

long-term behavior/trends (Stübi et al., 2017b) since they are calibrated in different networks (Sect. 9.1.2).

The unique series of quasi-simultaneous total ozone measurements of Dobson and Brewer instruments of the LKO were very valuable in quantifying the effect of temperature dependence of the different wavelengths used in the two types of instruments (Redondas et al., 2014). This result was important in the context of the project ACSO in which the effects of ozone absorption cross section on different atmospheric ozone measurements techniques were studied (ACSO, 2015; Orphal et al., 2015).

Quantification of the downward ozone trends was a key focus for making long-term stratospheric measurements in the late 1980s and the first part of the 1990s (Sect. 6.1; Staehelin et al., 1998b and 2001). These trends were viewed as a consequence of increasing stratospheric ODS concentrations. Subsequent studies were devoted to quantify the contribution of other processes enhancing the observed downward trends, such as long-term climate variability, which were viewed in connection with tropopause altitude (Steinbrecht et al., 1998) and the North Atlantic Oscillation (NAO) or Arctic Oscillation (AO) (Appenzeller et al., 2000; Steinbrecht et al., 2001; Weiss, 2001; Weiss et al., 2001). Brönnimann et al. (2000) studied the effect of Eurasian climate indices on total ozone at Arosa; the long total ozone series of Arosa played a key role in studying the effect of El Niño on stratospheric ozone over Europe and the effect on El Niño on Eurasian climate in the 1940s (Brönnimann et al., 2004a and 2004b). Koch used backward trajectory modeling to study stratospheric ozone variability at midlatitudes making use of the ozonesonde measurements of Payerne (Koch, 2003; Koch et al., 2002 and 2005).

The long-term total ozone and Umkehr series were also important in the EU project CANDIDOZ [483] (Zanis et al., 2006; Brunner et al., 2006; Harris et al., 2008). Documentation of the "turnaround" in stratospheric ozone trends became more and more important as time went on (e.g. Maeder, 2004; Maeder et al., 2007; Maeder et al., 2010). The Arosa time series was also used to introduce the concept of extreme value theory in ozone science (Rieder, 2011; Rieder et al., 2010a and b) and ozonesonde measurements were compared with regular aircraft measurements (Staufer, 2013; Staufer et al., 2013 and 2014) [484].

483 CANDIDOZ: Chemical and Dynamical Influences on Decadal Ozone Change.

484 For other related studies see Table 16.

8 Recent years and future of the LKO

8.1 Scientific requirements

Since around the second half of the 1990s, the Montreal Protocol (MP) resulted in slow decreases in stratospheric concentrations of ODS and therefore the ozone recovery from ODS is expected to proceed at a moderate rate, as predicted in numerical simulations (e.g. Chipperfield et al., 2016 and 2018).

Recently Hossaini et al. (2017) showed that a continued large increase in emission of dichloromethane, a chemical used as solvent belonging to the class of very short-lived substances (VSLSs), might possibly delay the effect of the MP on the recovery of the ozone layer by several years[485]. However, in the future N_2O will become the dominant anthropogenic source gas for stratospheric ozone loss depletion.

Climate change influences stratospheric ozone in several ways. Greenhouse gas increase leads to stratospheric cooling (particularly pronounced in the upper stratosphere), which affects ozone chemistry by changing the reaction rates, which in turn leads to higher stratospheric ozone concentrations (other effects expected for polar ozone depletion are not discussed here). Chemistry climate models (CCMs) predict an enhancement of the Brewer-Dobson circulation as a consequence of climate change, caused by increasing greenhouse gas emissions such as carbon dioxide (Butchart, 2014). By this enhancement of the Brewer Dobson circulation, ozone is transported more rapidly from its source region over the tropics to midlatitudes, leading to higher ozone amounts in extra tropics (the so-called "super recovery") and leaving ozone reduced over the tropics. It appears that today the enhancement of the Brewer Dobson circulation cannot be demonstrated by any atmospheric measurements. According to CCMs the enhancement of the Brewer Dobson circulation is expected to become dominant over the recovery from ODS in the extra tropics in the second part of this century.

Appropriate CCMs are used to describe the expected evolution of stratospheric ozone as influenced by the decrease in ODS and the ongoing climate change (for a recent update, see e.g. Dhomse et al., 2018). Results of such (stratospheric) CCMs presented earlier suggest a return of total ozone at northern mid-latitudes to the 1980 levels around 2020 (see Figure 42 and Hegglin, 2015). However, the measurements of Arosa (see Figure 42) show a different tendency.

485 Implying limited effects on the recovery of the ozone layer.

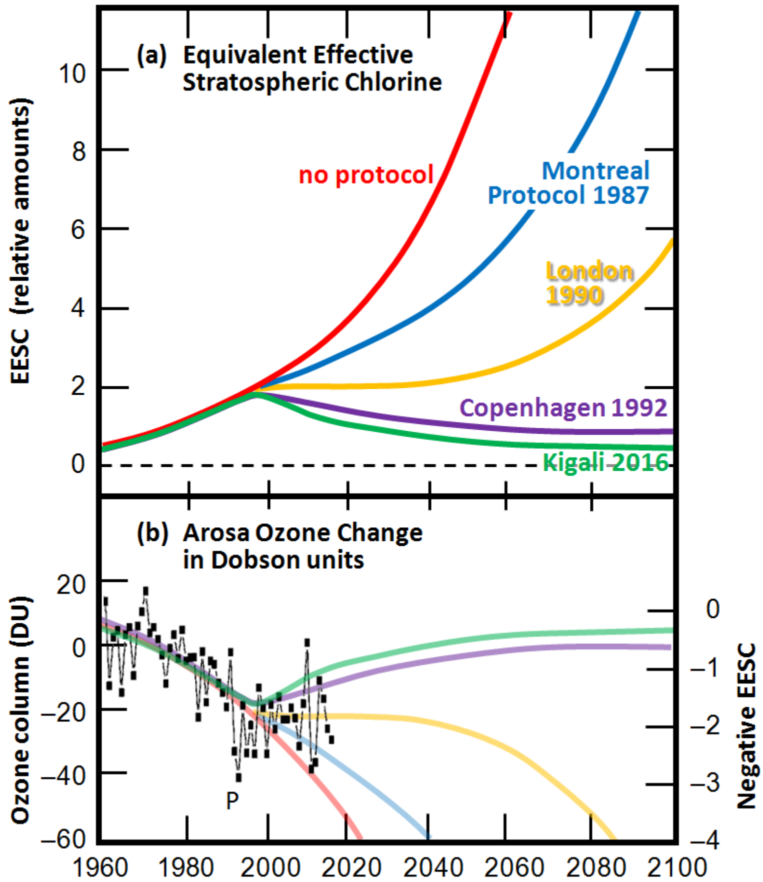


Figure 42: (a) Relative abundance of Ozone Depleting Substances (ODS, i.e. volatile halocarbons) expressed as equivalent effective stratospheric chlorine (EESC) for the midlatitude stratosphere, shown for various scenarios (demonstrating the impact of the Montreal Protocol and its subsequent Adjustments and Amendments). EESC can be viewed as a measure of chemical ozone depletion by ODS and takes into account the temporal emission of the individual ODS species as well as their ozone depleting potential as presented in Hegglin et al. (2015). (b) Arosa annual mean ozone columns (black symbols, as presented in Figure 33) in comparison with the scenarios in (a). “P” marks the eruption of Mt. Pinatubo in 1991, which has aggravated the ozone loss. (From Staehelin et al., 2018a).

Dhomse et al. (2018) presented an updated analysis of CCM future projections using the new suite of CCM runs within CCMI, an update of the CCMVal-2; in additional to CCM developments over the intervening period, updates also included revised historical and future boundary conditions. Their study points out the strong dependence of return time of stratospheric ozone on greenhouse emissions concluding that the most likely return date will be at least one decade later than presented in Figure 43 [486].

486 Here and in the following we restrict the discussion to Northern midlatitudes as this report focuses on the total ozone series of Arosa.

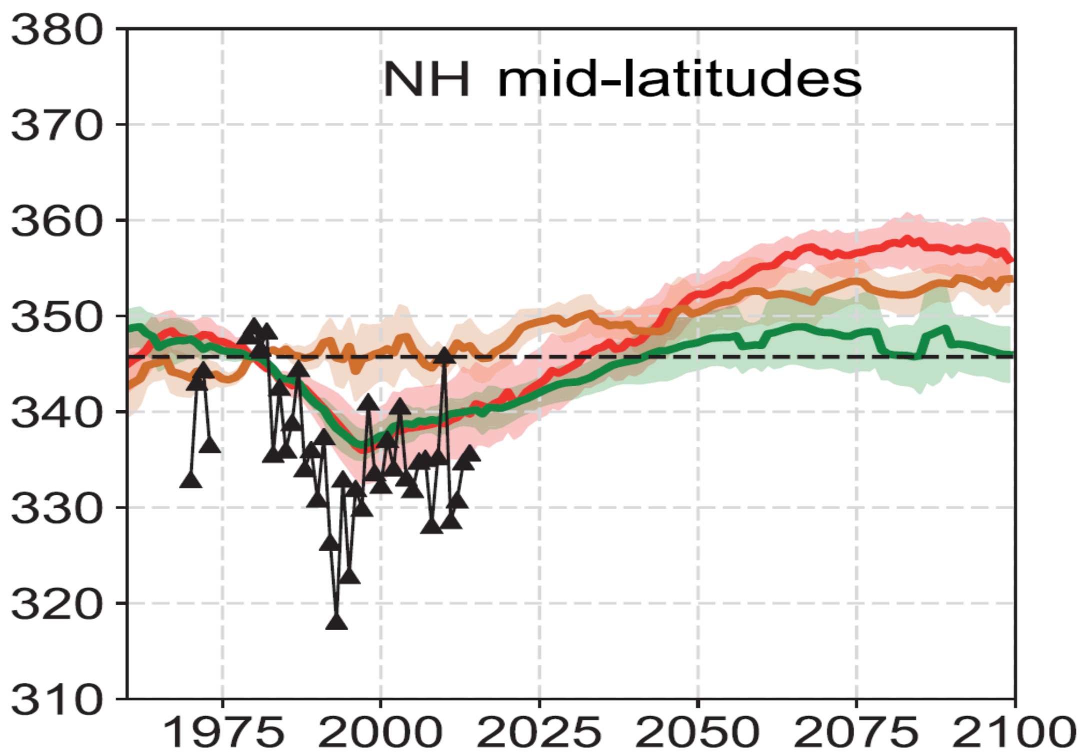


Figure 43: Total ozone annual mean values extracted from Chemistry Climate models including prediction compared with satellite measurements (see Figure 3 of Dhomse et al., 2018). The red (REF-C2) curve includes ODS and greenhouse gases (RCP6.0), the dark green (SEN-C2-fGHG keeps greenhouse gases fixed to the 1960 level and the brown curve (SEN-C2-fODS) assume fixed ODS emissions. The triangles denote total ozone measurements from satellite (merged SBUV).

Stratospheric ozone depletion by ODS most directly affects the upper stratospheric ozone where photolysis leads to the release of halogen radicals. It is therefore expected that early signs of ozone recovery from ODS will be found here as an increase of upper stratospheric ozone at midlatitudes. Extended data analysis as provided by SI2N [487], which was a common activity supported by SPARC [488], failed to show a significant increase of ozone in upper stratosphere in the extra-tropics [489] (Harris et al., 2015). The SPARC activity LOTUS [490] can be viewed as continuation of SI2N, namely, to improve the knowledge on data quality of the related measurements.

487 SI2N means the IO_3C, IGACO-O_3/UV (Integrated Global Atmospheric Composition Observations) and NDACC (Network for Detection of Atmospheric Composition Change).

488 Stratosphere-troposphere Processes and their Role in Climate (SPARC).

489 Refer to the special issue jointly organized between Atmospheric Chemistry and Physics (ACP), Atmospheric Measurement Techniques (AMT) and Earth System Science Data ESSD: Changes in the vertical distribution of ozone, SI2N report by Bhartia et al. (2012).

490 LOTUS: Long-term Ozone Trends and Uncertainties in the Stratosphere, subproject of SPARC.

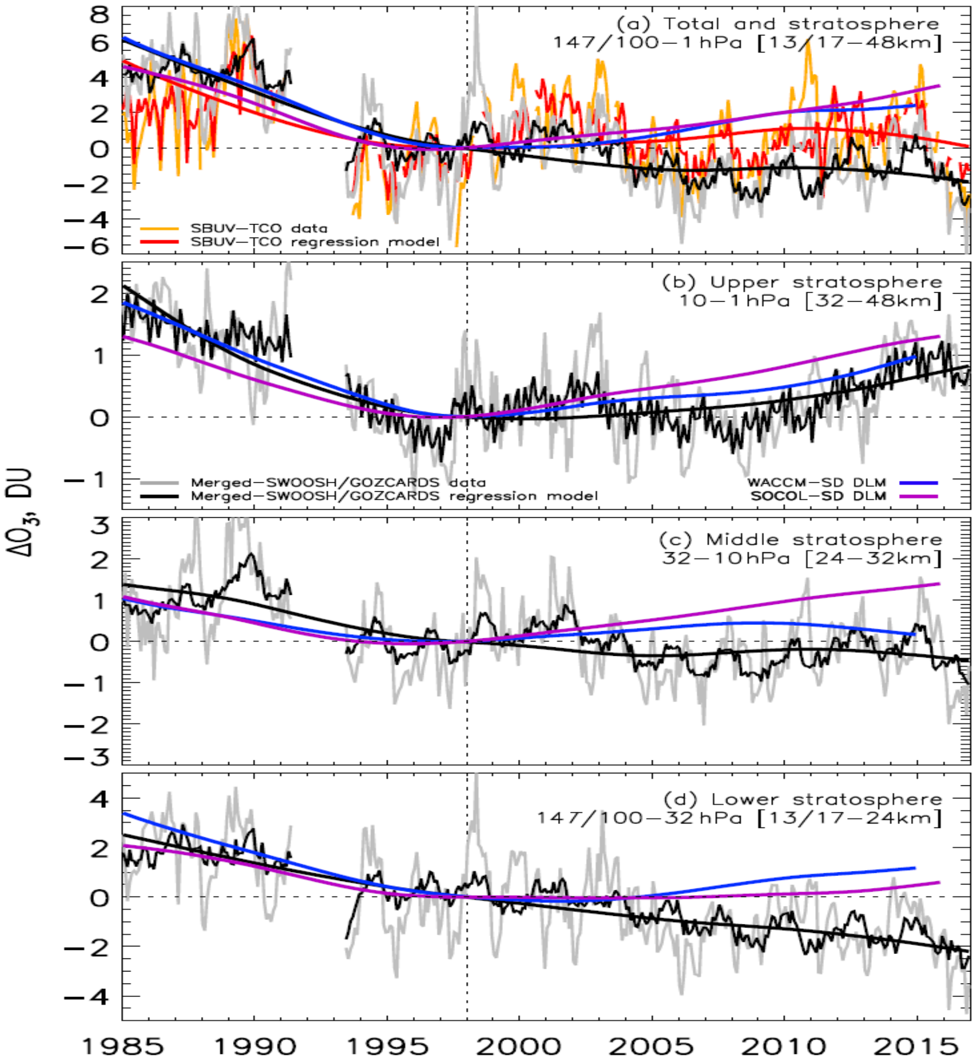


Figure 44: Total and partial column ozone anomalies integrated for 60°S to 60°N between 1985 and 2016 (see figure 3 from Ball et al., 2018). Deseasonalised and regression model time series are given for the Merged-SWOOSH/ GOZCARDS composite (grey and black, respectively) for (a) the whole stratospheric column and (b) upper, (c) middle, and (d) lower stratospheric partial column ozone. The DLM nonlinear trend is the smoothly varying thick black line. In (a), the deseasonalised SBUV total column ozone is also given (orange), with the regression model (red) and the non-linear trend (thick, red). Data are shifted so that the trend line is zero in 1998. DLM results for WACCM-SD (blue) and SOCOL-SD (purple) are also shown; model results in (a) are for the stratospheric column.

Designing suitable approaches for merging satellite ozone time series has turned out to be a serious problem. Satellite ozone instruments (e.g. Hassler et al., 2014) have limited life times, the overlap between satellite series is often limited or non-existent, observing properties differ between instruments, thus the method for merging is a challenge (e.g. Tummon et al., 2015; Ball et al., 2017). It is therefore not only very important to find a solution to the merging problem but also to continue high quality stratospheric ozone measurements to follow the slow recovery of the ozone layer from the burden of stratospheric anthropogenic halogens (chlorine and bromine).

Ball et al. (2018) made use of Bayesian statistical methods[491] to merge satellite measurements and performed time series analysis; they confirmed the increase in stratospheric ozone in the upper stratosphere (panel (b) in Figure 44) that started around the middle of the 1990s in good agreement with the expected increase as shown by the two numerical models and other studies (see SPARC activity LOTUS 2). Ozone measurements of the middle stratosphere (panel (c) in Figure 44) do not show any clear tendency, but a significant and continuing downward trend was found in the satellite measurements in the lower most stratosphere (panel (d) in Figure 44). This decreasing trend (though rather small in absolute amount) strongly affected total ozone at midlatitudes to the extent that the upward trend expected from the successful reduction in ODS by the MP (1987) has remained undetected (for more details see Ball et al., 2018). The trend analysis based on five long-term LIDAR data series presented by Zerefos et al. (2018) are consistent with Ball et al. (2018) with respect to the unexpected lower stratospheric ozone decrease. However, the results of two numerical simulations shown on panel (d) of Figure 44 show an increasing tendency in lower stratospheric ozone that contrasts the presented measurements. The recent numerical simulations presented by Chipperfield et al. (2018) show good agreement with the measurements (see Figure 45) indicating a remarkable increase in 2017. The high values predicted by the numerical simulations for 2017 (see Figure 45) need confirmation by ozone measurements and measurements of the coming years will indicate whether they can be viewed as a beginning of the expected "ozone recovery" or not.

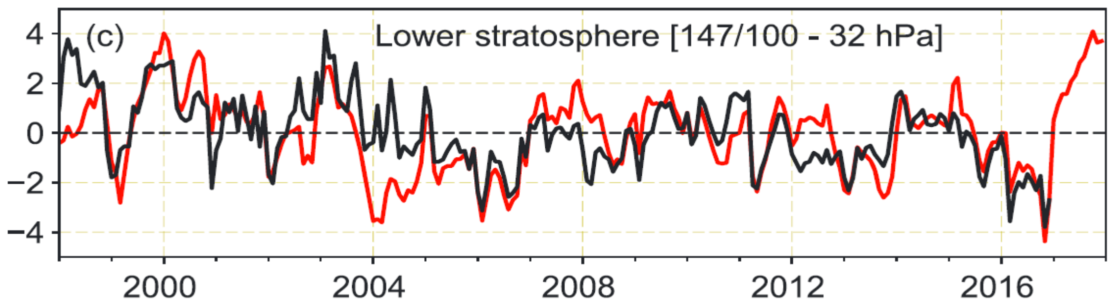


Figure 45: Lower stratospheric ozone variability for Norther midlatitudes presented in Figure 1c of Chipperfield et al. (2018) using a Chemistry Transport Model (red) compared with the observational data from Ball et al., 2018 (black).

The unexpected decrease in the lower most stratospheric ozone found at northern midlatitudes might also be connected to the enhancement of the Brewer-Dobson circulation (see above), however, the documentation of an enhanced Brewer-Dobson circulation from measurements still has high priority.

The total ozone series of Arosa is expected to be in future[492] a particularly attractive dataset allowing to demonstrate the predicted enhancement of the Brewer Dobson circulation because of its unique length, including several decades of measurements prior to start of the anthropogenic disturbances (caused by ODS and climate change); this is important for describing natural variability in an anthropogenically undisturbed atmosphere.

In the 1990s, the rule of thumb to be considered for reliable long-term (stratospheric) ozone monitoring implied to be able to detect trends in the order of 1% (3 DU) per decade considering the down-

491 Typically employed as a standard in other fields.

492 See Chapter 10.

ward trends observed in northern midlatitudes (see 6.1) - having the consequence that the uncertainty of the total ozone monitoring needs to be considerably smaller[493][494]. Today, we are looking to trace the “recovery”, but the requirements might be derived from the analysis of Ball et al. (2018) (see Figure 44), which are more difficult to reach as the unexpected and scientifically unexplained changes in the lower stratosphere are approximately 3 times smaller (1 DU per decade).

8.2 Move of the LKO from Arosa to Davos

As the justification for founding of the PMOD and the LKO was similar and occurred almost at the same time (as support of the community is concerned), and as the study field was partially overlapping while they are at very close geographical location, it is not surprising that the idea of a collaboration between both observatories seemed obvious. However collaboration only took place in the first two years of the LKO, between 1921 and 1923, through the use of the Cd-Cell at Arosa and joint measurement campaigns (i.e. at Muottas Muragl); after this, the cooperation was disrupted due to scientific disagreements, personal and external factors as explained in Section 3.2. Later on, throughout the different periods of the LKO, the collaboration was only occasional and limited.

However, the question of a common institute at two places or of a merge respectively a move has been raised several times as shown in Table 8. Although this solution was considered, analyzed and discussed on at least six occasions in in the past, with the aim to generate synergies and related to financial shortage or retirements, it was never realized for different reasons as described in the Chapters 3-7.

Beginning of the 2010s, in order to assure the long-term continuation of the ozone monitoring activities as well as to improve data quality and availability, MeteoSwiss decided to start two projects with the aim of enhancing the technical and scientific support of the ozone program as well as of taking benefit of the synergies between the ozone observations of MeteoSwiss at Arosa and the UV measurements performed by the PMOD/WRC in Davos, with the perspective of a possible relocation of the LKO from Arosa to Davos.

In an initial project (AutoDob), completed between 2012 and 2014, the Dobson instruments were upgraded from manual to completely automated operation. A second project (A2D4O3) was started in September 2014 with the goal to carry out a study quantifying the effect of the LKO’s potential move from Arosa to Davos on the ozone measurements and to analyze the feasibility of such a relocation concerning the organizational structure and the observation programs.

493 Please keep in mind that the long-term monitoring stability is not the same as the uncertainty of an single measurement.

494 The use of several instrument and different different instrument types (two Dobsons and three Brewers) was important to fulfill these requirements.

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Table 8: Summary of discussion regarding cooperation and merger of the LKO Arosa and the PMOD Davos as deduced from the current historical study (for more details see the information as given in the referenced sections). Some information was deduced from indirect sources lacking independent information.

Year	Initiative	Documents	Context	Refer to.	Comments
1922	Discussions between physicians of Davos and Arosa	Several letters of Dorno mention these ongoing discussions	Founding of SFI in Davos in March 1922	Sect. 3.2	Arosa not ready to bring in the expected finances → no follow-up
1926	Proposal of physicians of Arosa	Letter Michel to Amrein of 19 January 1926 (letter Amrein 8 Jan. 1926 not available)	Retirement of Dorno; Integration of PMOD in SFI	Sect. 3.2	Proposal to transfer PMOD from Davos to Arosa → rejected flatly by Davos
1942	Proposal of Götz	Letter of Götz to KVV Arosa (Maron) of 22 Sept. 1942	Financial restraints during World War II	Sect. 3.5	Proposal to merge LKO and PMOD remaining at 2 sites; discussions with PMOD not known → no action
1962	Federal Meteor. Commission (EMK) supported by Tschudi (Head Dep. of Home Affairs)	Letter of 27 June 1962 cited in minutes of meeting LKO Advisory Group of 23 Oct. 1962	Unstable period after Götz's dead	Chapter 4	Subcommission of EMK (see footnote 353) created "to study the problems of both observatories" → no action
1987	Federal Environm. Office; Swiss Acad. of Natural Sciences	Minutes of expert meeting 2 July 1987	Retirement of Dütsch	Sect. 6.3	Consultation resulting in MeteoSwiss-ETHZ collaboration → move considered - not retained
2001	MeteoSwiss	P. Viatte: Konzept zur Weiterführung des LKO, 2001	Retirement of Aeschbacher	Sect. 7.3	Organisation analysis on behalf of directory board MeteoSwiss → site of Arosa maintained
2015	MeteoSwiss	R. Stübi: Description Project A2D4O3	Measurement improvements	Sect. 8.2	Feasability study / comparison of O3 measurements Arosa-Davos → decision of move in June 2018

8.2.1 Complete automation of the Dobson measurements

The complete automation of the Dobson spectrophotometers allows not only a reduction in manpower costs compared to the semi-automated mode as used at the LKO since the early 1990s (Sect. 7.3) but also leads to lower uncertainties of the individual measurements since the operators no longer need to be trained and the operators' skills are no longer relevant for the uncertainties of the operational measurements (although they are still important in case of intercomparisons). The Dobson instruments were fully automated by MeteoSwiss under Stübi [495] allowing for the measurement of both total ozone as well as Umkehr quasi simultaneously with the same system.

In the period 2012-2014, the different Dobson instruments (D62, D51 and D101; for the dates of modifications see Table 9) were updated for fully automated use. The spectrodome was no longer

495 René Stübi, PhD, Senior scientist of the Upper Air division of MeteoSwiss at the Aerological Station in Payerne (refer to Section 9.2.3).

appropriate for fully automatic operation and a new housing was designed and constructed allowing for the entry of the direct solar beam, through a small quartz dome in the roof of the container, into the Dobson instrument.

8.2.2 Simultaneous Brewer and Dobson measurements at Arosa and Davos

As the great value of the total ozone series of Arosa lies in its length (unique in the world), the high data quality of the measurements and its homogeneity, it is crucial that the impact of a “move” be minimized. This is important in the context of long-term trend determination. Indeed, the distance between the stations at Arosa and Davos is only 13 kilometers and the synoptic meteorological conditions are the same at both sites. However, particularly challenging at the present time is the tracing of the systematic upward trends predicted to be particularly small during the slow recovery phase, as expected from the steadily decreasing stratospheric ODS (refer to Sect. 8.1). In order to prepare the final decision of relocating the LKO’s total ozone measurements from Arosa to Davos, simultaneous ozone measurements were planed extending over several annual cycles. Simultaneous total ozone measurements between Brewer total ozone measurements at the two sites have been performed since 2011. The differences in total ozone values between the sites are usually small and systematic effects are probably at least partially attributable to a stray light bias and the altitude difference between the two sites (Stübi et al., 2017a and b). On rare occasions, a time lag due to transport effects was found (Egli and Gröbner, 2016) and its quantitative influence requires further study. Simultaneous Dobson observations at Arosa and Davos are conducted since 2016 to get a suitable basis for an optimal transfer function when moving the instruments from Arosa to Davos.

Based on the results of these projects, the management board of MeteoSwiss took on 12 June 2018 the decision to transfer the observations of the LKO Arosa to the PMOD in Davos on 1 January 2019. The monitoring activities were thus outsourced to the PMOD, but MeteoSwiss keeps the ownership of the instruments and the responsibility of the data collected.

On 28 September 2018, two additional spectrophotometers were transferred to Davos (D51 and Br156) in addition to the systems already installed there. Since this date the center of gravity of the ozone activities switched to Davos. Two spectrophotometers (D62 and Br40) remain in Arosa until the end of 2020 in order to reach almost 10 years of simultaneous Brewer and 5 years of simultaneous Dobson measurements at both sites[496]. Before this operation the Brewer spectrophotometers of the LKO participated to an intercomparison held in Arosa in July 2018 in order to validate these systems against the standard instrument Br185 of Izaña. At the same time, the Dobson spectrophotometers of the LKO were compared with the D64, the regional standard for Europe.

496 This goes beyond the requirements (3 years) of the Global Climate Observing System (GCOS) of WMO which apply in the case of relocation of measurement sites.

9 Overall development of the LKO

Looking at the evolution of the LKO since 1921 (Chapt. 2 to 8), it is clear that not only the justifications for the ozone measurements at the LKO in Arosa have changed during its existence, but also the organizational aspects have undergone quite drastic changes. The continuation of Dütsch after the "one-man show" of Götz allowed the embedding of the LKO in an institute of a technical university, providing the opportunity to situate the LKO in a much more stabilized and research-oriented environment. The transfer to MeteoSwiss later on brought the advantage for the LKO to be integrated into an institute, which has the task of guaranteeing optimal operational conditions favoring long-term measurements, the research still being covered by an institute of ETH Zürich (IACETH). In the following chapter the aim is to look at the history of the LKO with a comprehensive view concerning the measurements (Sect. 9.1), the personnel involved (Sect. 9.2) as well as the budget available (Sect. 9.3). This brings in a new perspective allowing comparison of the different periods.

9.1 Measurements

From the preceding chapters it is obvious that the LKO's reputation is primarily based on the long-term stratospheric ozone measurements; the measuring program leading to the world's longest total ozone and Umkehr series will be synthesized in Section 9.1.2. However, we start with the presentation of the meteorological measurements because these go back to 1889 and were relevant for the establishment of the LKO (Sect. 9.1.1). In the course of time, the basic measuring program has been extended by a series of additional measurements at the LKO and at Tschuggen[497] (see Figure 1 for the locations) being the subject of Section 9.1.3. An important source of information was the station history by Aeschbacher and Schill (2016).

9.1.1 Meteorological measurements

Most of the climatological information used by Götz in his studies on the (radiation) climate of Arosa (Götz, 1926b and 1954) was based on the data of the official climatological station of MeteoSwiss (Sect. 9.1.1.a) complemented by special radiation components (Sect. 9.1.3.a). Also during the Dütsch era, the meteorological observations used for the purpose of the LKO were mostly those of the MeteoSwiss station. But in all periods, especially since the 1990s, supplementary meteorological measurements were performed at the LKO platform and at Tschuggen (Sect. 9.1.1.b).

497 Refer to footnote 98 on page 28.

9.1.1.a) Climatological station of MeteoSwiss in Arosa

Meteorological measurements[498] in Arosa were started by the national weather service MeteoSwiss[499] on 1 November 1889[500]. First, the measurements were performed in the villa Frisia[501] at Innerarosa. On 1 October 1900, the station was moved to the Sanatorium Arosa (see Figure 1) where Götz started on 1 November 1921 with his own measurements. Because of the problems related to the frequent change of the meteorological observers[502], Götz agreed to take care of the observational program of MeteoSwiss from 1 February 1926 onwards. When Götz moved to his own house (Villa Firnelicht) on April 1926, the meteorological station still remained at Sanatorium Arosa for four more years and was installed at Villa Firnelicht later on 1 April 1930.

At the beginning of 1954, the LKO moved to the Florentinum (see Figure 1; see also Section 3.11 and 4.2) and the meteorological station was transferred simultaneously to this location and installed in due distance of the Florentinum building. When the LKO was installed in the Haus Steinbruch nearby in 1973 (Sect. 5.3), the instrument shelter remained near the Florentinum until 1996, while part of the instruments (like anemometer and sunshine duration meter) was directly displaced on the new LKO platform. On 26 November 1996, a Stevenson screen[503] was installed in the vicinity of the Haus Steinbruch[504]. Towards the end of 2015, the measurements of the climatological station of MeteoSwiss were completely automated and moved to a new location at the alp Maran.

Between 1926 and 1953, the meteorological measurements were operated by Götz (with some assistance of other persons such as his wife Margarethe Götz). After Götz's death, the meteorological observations continued to be part of the regular duties of the LKO and were handled by the LKO staff[505]. When the station was automated and moved to Maran in 2015, the LKO staff was released from the observational work-related climatological station of MeteoSwiss in Arosa.

9.1.1.b) Additional meteorological measurements at the LKO and at Tschuggen

There are some hints that special meteorological measurements were performed at Tschuggen during the Götz and Dütsch eras, although probably only for short periods[506].

In order to assure an optimal meteorological embedding of the ozone observations as well as other measurements done by MeteoSwiss and the guests, completely separate meteorological measure-

498 The parameters pressure, wind, temperature, air humidity, sunshine duration, precipitation as well as snow height and cloud cover were measured.

499 Refer to footnote 13 on page 4.

500 Since 1884 climatological observations performed by Dr O. Herwig, physician in Arosa, are available in written form.

501 The Villa Frisia was a "dependence" of the Villa Dr. Herwig; the meteorological station was managed by Dr. Janssen, private teacher and guesthouse owner (Götz, 1926b).

502 As mentioned in the station history of the climatological station Arosa at MeteoSwiss (Stationsgeschichte (STAGE) der Klimastation Arosa der MeteoSchweiz) (Internal document MeteoSwiss).

503 Stevenson screen is an enclosure to shield meteorological instruments against precipitation and heat from direct radiation.

504 The old screen remained near the Florentinum up to 31 May 1999 for more than 2.5 years of parallel measurements.

505 Until 1973, MeteoSwiss paid financial compensation for the work accomplished (see Figure 51); there is no information available about such a compensation concerning the period 1973-1987 (when the LKO was integrated in the IACETH).

506 It is rather difficult to be more precise on these measurements as they were not clearly documented.

ments were continuously performed at the LKO platform from 4 June 1992 [507] and at Tschuggen from 5 August 1994 [508] in addition to the measurements of the official climatological station of MeteoSwiss.

Intensive cloud observations going beyond the needs of the climatological station of MeteoSwiss were part of the measurement program of the LKO throughout the different periods of the LKO. In normal operation, each manual Dobson reading was accompanied by a visual cloud observation. Ideally, also the time between the readings was documented when changes in the cloud cover occurred. Intensive cloud cover observations at the LKO were maintained after the complete automatization of the meteorological station of MeteoSwiss and the move of this station to Maran [509]; they were abandoned in 2018 when the center of gravity switched to Davos.

9.1.2 Ozone measuring program and instruments used

Götz had started measurements of stratospheric ozone with sun spectrophotometers as early as 1926 [510]. In this section we provide detailed information on the type of instruments used at different stages, the detection techniques involved as well as the kind of measurements performed (direct sun – zenith sky) and the operation mode of the systems (redundancy, observation frequency and degree of automation). These measurements are summarized in Figure 46 and Table 9. A synthesis on the number of observations carried out with each of the systems operated at the LKO is given in Table 10 for the total column ozone measurements and in Table 11 for the Umkehr measurements.

9.1.2.a) Arosa ultraviolet spectrograph

Götz submitted a request to Bernet [511] asking for financial support to build a spectrograph as early as October 1923 (Götz, 2 October 1923). In January 1924, he contacted (Götz, 21 January 1924) the company Carl Zeiss (Jena), which had already developed the spectrograph used by Dorno at the PMOD in Davos (Fröhlich, 2016). Based on the experience with this instrument [512] Götz was obviously convinced that an instrument with crossed prisms like the design proposed by Fabry and Buisson (Fabry and Buisson, 1921) was a prerequisite. A letter of Zeiss Jena (Zeiss, 30 January 1926) seems to imply that there was competition with Dobson at that time in constructing an operational spectrograph [513]. However, the progress of Zeiss Jena turned out to be very sluggish.

507 Including pressure, air temperature, relative humidity, wind speed and wind direction, sunshine duration, precipitation, brightness, UV- and global radiation.

508 Covering air temperature, relative humidity, wind speed and wind direction as well as UV- and global radiation.

509 The cloud cover gives an indication on the changing sky conditions and therefore on the quality of the ozone and radiation measurements.

510 Remember that on the basis of his early experiences with the Cd-Cell (Sect. 3.2) between 1921 and 1923, Götz was convinced that it was more appropriate to study ozone which determines UV-B radiation at the Earth's surface than to extend UV-B radiation climatology (Sect. 3.10).

511 Refer to footnote 67 on page 16.

512 Götz, upon request of Dorno, tried in 1920 to characterize the instrument of Dorno at the astronomical observatory in Tübingen, with disappointing results. Letter Götz, 7 April 1925 (to Carl Zeiss (Jena)). Original text: „Ein dauerregistrierender Apparat ist unnötig, ausserdem käme Ihr Instrument nach Dorno, so reiche Früchte es im Übrigen gehabt hat, aus dem Grunde nicht in Betracht, weil er für die kürzesten Wellenlängen mit falschem Licht überlegt wird (ich habe 1920 verschiedene solche Filme mit negativem Ergebnis am Tübinger Mikrophotometer durchphotometriert)." (Sect. 2.4, last Para.).

513 Letter Carl Zeiss (Jena), 30. January 1926. Original text: „Jedenfalls ist dies der schnellste Weg, auf dem Sie in den Besitz eines gebrauchsfertigen Spektrographen kommen; hoffentlich haben die Engländer nicht einen Vorsprung vor Ihnen.".

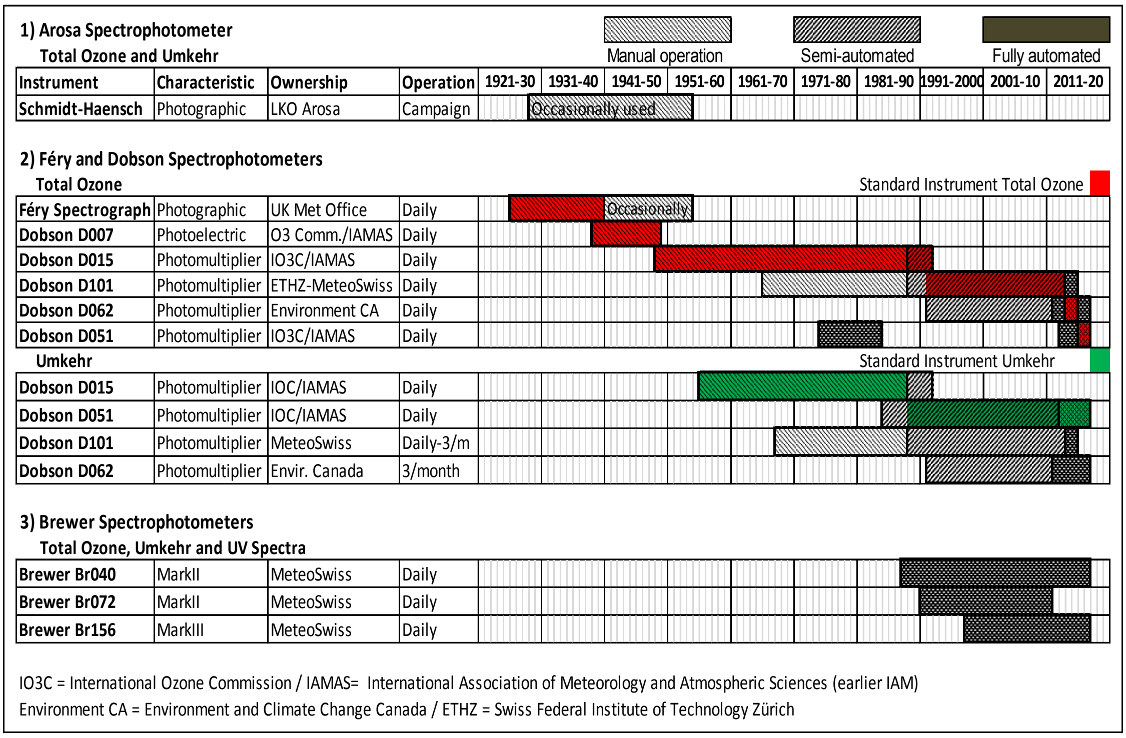

Figure 46: Observational periods of the spectrophotometers used at the LKO Arosa from 1926 to 2017 (from Staehelin et al., 2018a).

Götz was therefore not satisfied with the time response and the conditions offered by Zeiss and addressed a similar request to Schmidt and Haensch (Berlin) (Götz, 29 March 1926). This company finally produced the desired instrument based on a design initiated resp. supervised by Götz (Schmidt and Haensch, 29 June 1926) and financed by the KVV Arosa (Götz, 1927). The many letters exchanged with this company show that the development process was also rather complex and time-consuming (Schmidt and Haensch, 21 March 1928; Bernet, 2 May 1928). It took two and a half years to build the instrument, which was finally delivered in October 1928 [514]. Götz presented the design of this instrument at the first International Conference on Ozone [515] (Götz, 1929b) and he used this instrument in Svalbard (Sect. 3.8). Two publications making use of the measurements taken with this instrument are available (Götz, 1931b; Götz and Schönmann, 1948), but no data could be found in the LKO archives. The spectrograph was viewed by Götz as a universal instrument and too time-consuming to be used in the daily work. The system was still in the LKO inventory when Perl took over the LKO on 1 November 1953 (Sect. 3.11). In 1954, discussions were held on how to deal with a request from the Meteorological Institute of the University of Mainz asking to buy the instrument for half of the original price. The KVV Arosa supported selling the instrument, but Huber [516] refused the deal. There is no trace of this instrument now.

514 The costs (Schmidt-Haensch, 11 October 1928) amounted to nearly 10,000 Reichsmark (RM), approximately 12,500 CHF (according to the historical effective exchange rates), corresponding to roughly 86,000 CHF in 2015 (according to the consumer price index of Swistoval, www.swistoval.ch, state of 14.1.2019 (Pfister and Studer, 2019) (Information on exchange rates and inflation adjustment made available by Tobias Straumann, Professor of Economic History of the University of Zürich).

515 The first International Ozone Conference took place in Paris on 15-17 May 1929.

516 Refer to footnote 305 on page 66.

9.1.2.b) Dobson spectrophotometers

The main spectrophotometers used at the LKO for measurements of stratospheric ozone were instruments designed by Dobson (Walshaw, 1989) [517].

The realization of the spectrographs developed by Dobson in the early 1920s turned out to be very rapid and successful such that a series of five instruments was already operational at the beginning of 1926. In establishing his first European Network (Dobson, 1968), Dobson submitted a proposal of collaboration to Götz with the idea that the latter would join the network with his own system (Dobson, 9 November 1925). Götz was very much interested in Dobson's invitation for ozone cooperation, but as he was aware that the development of his own instrument was delayed, he asked to be supplied with one of Dobson's spectrographs (Götz, 11 November 1925). Dobson who expressed interest in including the site of Arosa regretted that Götz was not able to bring in an additional instrument but otherwise saw the advantage of obtaining uniform measurements and therefore agreed to reserve one of his instruments for the LKO (Sect. 3.7.2).

Total Ozone observations

The Féry spectrograph No.2 ("**D2**") [518] based on photographic detection, was sent to Götz on 26 April 1926. The first observation at Arosa was made on 23 July 1926. Dobson incidentally proposed that the spectra obtained in Arosa could be evaluated by Götz himself, which was not the usual way of cooperation as noted by Dobson in the letter from 17 December 1925 (see Figure 18) [519].

The instrument "D2" was the standard instrument of the LKO from 23 July 1926 until July 1939 [520], when it was replaced by spectrophotometer D7, a new generation instrument. "D2", which stayed in Arosa until 1954, was then used (Staehelin et al., 1998a) to make quasi-simultaneous measurements with the new generation instruments [521] and it was operated if problems arose with the instruments used in routine operation. At the request of Dobson, "D2" was returned to Oxford by March 1954 (several months before the Götz's death), after the LKO moved to the Florentinum in December 1953 (Sect. 3.11).

Another Féry spectrograph No.3 (termed "D3") [522] was sent to Arosa in February 1930. Dobson made this second instrument available to Götz for "simultaneous observations at high & low stations" (Dobson, 27 June 1930). According to the data inventory (see Table 10) 100 measurements were taken with this instrument.

517 The concepts of total ozone spectrophotometers designed by Dobson are summarized in Section 3.7.1.

518 The Féry instrument No.2 was termed "D2" in the LKO measuring sheets (also used in Birrer, 1975a und b). Please note, that we do not recommend using this abbreviation "D2" for the Féry instruments because it is not used internationally and only leads to unnecessary confusion; refer to Section 3.7.1 for common use of abbreviations of the Dobson spectrophotometers (Dx).

519 Letter Dobson (to Götz), 7 December 1925. "What we are doing in the other cases is to [….] send unexposed plates [….] asking people to return the exposed plates [….] it is possible you might prefer and measure your own plates.".

520 This instrument was also used by Götz during the Svalbard expedition (Sect. 3.8) for the direct sun (total ozone) measurements, together with his own instrument, the Arosa ultraviolet spectrograph described in Section 9.1.2.a, for the zenith sky observations.

521 First with D7 between 1939 and 1945 and then with D15 from April to June 1950 (20 measurements, according Staehelin et al. 1998a).

522 The instrument No.3 (termed "D3" in the LKO measuring sheets) came back from Egypt and was sent by Dobson to Arosa together with the repaired No.2 ("D2") after the Svalbard expedition (Sect. 3.8.3).

Table 9: Spectrometers used at the LKO Arosa between 1926 and 2018.

Name	Characteristic	Ownership	Frequency	Manual Operation	Semi-automated Operation	Fully automated Operation	Standard Instrument TO and UM
1) Arosa UV-Spectrograph [a]							
	Photographic	LKO Arosa	Campaign [b]	Oct. 1928-(1954) [c]			

[a] Fabry-Buisson type spectrograph, build by Schmidt-Haensch (Berlin) from Mar. 1926 to Oct. 1928 on a design supervised by Götz, financed by the Kurverein (Tourismus) Arosa. [b] Instrument operated in Svalbard 1929 (with D2). [c] Instrument removed of operation after 1954 (exact date not known).

Name	Characteristic	Ownership	Frequency	Manual Operation	Semi-automated Operation	Fully automated Operation	Standard Instrument TO and UM
2) Dobson Spectrophotometers							
a) Total Ozone Measurements							
D002 [b]	Photographic	Univ. Oxford	Daily [a]	**Jul. 1926-Mar. 1954** [f]			Jul. 1926-Jul. 1939
D007	Photoelectric	IMA	Daily [a]	**Jul. 1939-Aug. 1949** [g]			Jul. 1939-Aug. 1949
D015	Photomultiplier	IO_3C / IMA	Daily [a]	**Aug. 1949-Jul. 1989**	**Aug. 1989-Aug.1992** [h]		Aug. 1949-Aug. 1992
D101 [c]	Photomultiplier	MeteoSwiss	Daily [a]	**Apr. 1966-Jul. 1989**	**Aug. 1989-Sep. 2013**	**Jul. 2014-Jan. 2016**	Aug. 1992-Sep. 2013
D062	Photomultiplier	Envir. Canada	Daily [a]		**Sep. 1992-Mar. 2012**	**Apr. 2012-today**	Oct. 2013-today
D051	Photomultiplier	IO_3C / IMA [d]	Daily [a]		**Jan. 1975-Jun. 1985** [e]	**Mar. 2013-today**	2014-18 short periods

[a] In favorable weather conditions. [b] Féry type spectrograph / name D2 given by Dütsch (not internationaly used) / operated in Spitsbergen 1929 (with Arosa spectrograph). [c] Since Jan. 2016 operated at PMOD in Davos. [d] Intern. O3 Comm. / Intern. Met. Association. [e] From Jan. 1975 to Jun. 1985 test operation in fully automated mode. [f] Instrument occasionally operated from 1939 to 1954 (comp. with D7 and D15) / back to Oxford in Mar. 1954. [g] Instrument back to Oxford probably in 1949. [h] Instrument refurbished and transferred to Botswana in Apr. 2000.

Name	Characteristic	Ownership	Frequency	Manual Operation	Semi-automated Operation	Fully automated Operation	Standard Instrument TO and UM
b) Umkehr Measurements							
D015	Photomultiplier	IO_3C / IMA	Daily [a] [b]	**Dec. 1955-Jul. 1989**	**Aug. 1989-Aug. 1992**		Dec. 1955-Jan. 1989
D051	Photomultiplier	IO_3C / IMA	Daily [a]		**Jul. 1985-Jan. 1989**	**Feb. 1989-today** [d]	Feb. 1989-today
D101 [c]	Photomultiplier	MeteoSwiss	Daily [a] [b]	**Jan. 1968-Jul. 1989**	**Aug. 1989-Sep. 2013**	**Jul. 2014-Jan. 2016**	
D062	Photomultiplier	Envir. Canada	3 / m [b]		**Sep. 1992-Mar. 2012**	**Aug. 2012-today**	

[a] In favorable weather conditions. [b] Since Mar. 1989 only 3 times per month [c] Since Jan. 2016 operated at PMOD in Davos. [d] In Mar. 2006 renewal of turning table and acquisition part ; in Jan.-Febr.2012 full upgrade of control and acquisition system.

Name	Characteristic	Ownership	Frequency	Manual Operation	Semi-automated Operation	Fully automated Operation	Standard Instrument TO and UM
3) Brewer Spectrophotometers (Total Ozone, Umkehr and UV Spectra [a])							
Br040	MarkII [b]		Daily			**Oct. 1988-today**	
Br072 [c]	MarkII		Daily			**Jun. 1991-Nov. 2011**	
Br156	MarkIII		Daily			**Jul. 1998-today**	

[a] Up to 2005, Br40 mainly devoted to Total Ozone and Umkehr, Br72 to Total Ozone and Br156 to Total Ozone and UV spectra; in 2005 begin with uniformisation of measuring programmes (Total Ozone, Umkehr und UV Spectra). [b] MarkII: Single monochromator / MarkIII: Double monochromator. [c] Nov. 2011-Mar. 2013 and since July 2015 instrument operated in Davos.

Table 10: The LKO Arosa Total Ozone Data Availability 1926 – 2017 [a].

Year	D2 [b]	D3	D7	D15	D101	Year	D15	D101	D62	D51 [c]	Br40	B72	Br156
1926	*117*					**1972**	1,268	1,137		x			
1927	*302*					**1973**	1,223	1,144		x			
1928	*259*					**1974**	1,172	874		x			
1929	*116*					**1975**	1,396	1,345		x			
1930	*12*					**1976**	1,302	1,276		x			
1931	68	64				**1977**	1,242	1,267		x			
1932	178	46				**1978**	1,308	859		x			
1933	234					**1979**	1,269	1,203		x			
1934	245					**1980**	1,158	1,212		x			
1935	206					**1981**	1,218	1,150		x			
1936	217					**1982**	1,401	1,363		x			
1937	194					**1983**	1,533	1,573		x			
1938	228					**1984**	1,384	1,347		x			
1939	184		345			**1985**	1,394	1,383		x			
1940	89		478			**1986**	1,384	1,358					
1941	102		467			**1987**	1,111	1,060					
1942	108		171			**1988**	1,194	958			1,300		
1943	111		278			**1989**	1,277	1,218			13,811		
1944	150		226			**1990**	1,434	1,437			10,234		
1945	15		406			**1991**	1,479	1,342			7,499	2,238	
1946			530			**1992**	923	1,487	556		9,150	5,890	
1947			388			**1993**		1,621	1,490		9,477	4,974	
1948			429			**1994**		1,568	1,469		9,468	6,131	
1949			223	492		**1995**		1,543	1,439		9,165	6,119	
1950				1,116		**1996**		1,573	1,509		9,498	6,761	
1951				429		**1997**		1,728	1,707		11,392	9,068	
1952				138		**1998**		1,728	1,688		10,747	8,702	2,802
1953				160		**1999**		1,606	1,535		9,943	8,454	7,001
1954				93		**2000**		1,558	1,617		10,937	8,910	7,107
1955				186		**2001**		1,735	1,731		11,055	8,901	6,958
1956				1,481		**2002**		2,141	1,924		10,545	8,788	7,019
1957				1,341		**2003**		3,006	2,965		15,089	13,315	9,868
1958				1,402		**2004**		2,684	2,687		13,594	13,928	8,236
1959				843		**2005**		2,617	2,218		14,669	14,474	10,908
1960				752		**2006**		2,425	2,371		15,255	14,950	13,094
1961				1,746		**2007**		1,900	1,994		14,935	13,946	14,310
1962				2,139		**2008**		2,075	2,097		12,703	12,720	13,401
1963				2,263		**2009**		1,981	1,977		12,901	11,629	14,069
1964				1,735		**2010**		1,669	1,875		12,534	11,151	11,007
1965				1,378		**2011**		1,467	1,521		15,665	13,809	11,505
1966				844		**2012**		2,418	5,818		12,485	11,431	9,750
1967				1,593	831	**2013**		3,631	11,074	5,592	11,589	10,553	7,932
1968				1,399	1,121	**2014**		4,163	15,749	8,096	11,144	10,724	8,069
1969				1,130	1,225	**2015**		15,911	25,596	556	15,680	15,762	15,450
1970				1,191	1,144	**2016**		22,682	17,555	15,695	14,416	16,290	15,124
1971				1,511	1,316	**2017**		18,876	24,365	15,324	16,347	16,801	17,562

[a] Number of obs. / y (only unflagged events included)
[b] 1926-30: number of meas. days / y
[c] Automated total ozone observations of D51 during 1972-1985 no more available

From 7 July 1939 onwards, the Dobson spectrophotometer **D7** with photoelectric detection[523] was in operation at the LKO in Arosa. This instrument was made available by the International Association of Meteorology and Atmospheric Sciences (IAMAS) through Dobson (president of the Ozone Sub-Committee). Dobson's objective in placing such an instrument with photoelectric detection at the LKO was to determine reliable data of the extraterrestrial or instrumental constants (Sect. 7.5 and Dütsch, 1986) in the favorable climate conditions of Arosa, as formulated in a letter to Götz (Dobson, 17 May 1939): "I therefore wondered whether you would be willing to have an instrument at Arosa and to make some of the necessary measurements" [524]. Dobson came to Arosa from 18 July to end of July 1939 [525] to install and set up the new spectrophotometer. The instrument D7, which was the standard instrument of Arosa until 26 August 1949, was obviously given back after having served at the LKO (date of shipping unknown) as it was subsequently deployed at other stations in the Dobson network (in Singapore since 1970).

Dobson spectrophotometers with photomultipliers were in operation at the LKO from 1949 onwards. When Dobson was ready with a photomultiplier version of the spectrophotometer, Arosa was again considered by him to be the first-choice place to determine the new instrumental constants of the updated instruments (Dobson, 31 December 1947): "Now as regards your instrument, that is what I am going to suggest: We should get one instrument here [Oxford] into as good order as possible fitted with multiplier etc. and send it to you. We should use this instrument to make a re-determination of the extraterrestrial values and on this re-determined value all the other instruments will be calibrated. The instrument should also be used for an entirely new determination of the vertical distribution of the ozone [526]. What do you think about this programme? It would mean asking you a great deal of observing work. On the other hand, your climate is so very much better than we are likely to get elsewhere that it would be a great advantage to get the work done in Arosa". Dobson arranged for the Ozone Sub-Committee of IAMAS (Sect. 3.4) to make the new Dobson spectrophotometer available for deployment at the LKO. Dobson himself installed the instrument D15 at the LKO; he stayed in Arosa from 23 August to 11 September 1949 [527]. Spectrophotometer **D15** went into operation on 27 August 1949 and was run at the LKO for several decades. However, some problems of D15 were known; Dütsch believed that they were caused by internal stray light (Staehelin et al., 1998a). In summer 1989, D15 was equipped with an electronic system which allowed semi-automated handling and was operated from 2 August 1989 in a rotating spectrodome (Sect. 7.3). Unfortunately, it was damaged by a lightening stroke in August 1992. The instrument D15 was replaced with the Dobson spectrophotometer D62 (see below). When D15 was removed from operational measurements Archie Asbridge inspected the D15 very carefully finding that the instrument was not operated in proper optical alignment (Sect. 7.4.1; for more details including the required homogenizations see Staehelin et al., 1988a) [528]. D15 was subsequently completely refurbished (25 July - 6 August 1994).

523 The Féry spectrographs and the Dobson spectrophotometers were numbered according two distinct lists. Dobson numbered the Féry instruments (No. x) whereas all Dobson spectrophotometers obtained subsequent numbers independent of the detection device (Dx) (Sect. 3.7.1). The official WMO list of Dobson spectrophotometers does not include instruments with photographic detection.

524 Note that Dütsch used this method to update regularly the instrumental constants of the instruments of Arosa (Dütsch, 1984).

525 Letters Dobson, 11 July & 2 August 1939.

526 This can be understood as an invitation of Dobson to undertake Umkehr measurements in Arosa. with the new instrument D15 equipped with a photomultiplier. Such measurements were indeed performed (letter of Perl, 7 November 1950) but apparently never published (nor analyzed). Regular Umkehr measurements were introduced by Dütsch in 1956.

527 Letters Dobson, 14 August & 14 September 1949.

528 After this finding, Dütsch confirmed that the optical alignment of D15 was never changed. Figure 40 provides evidence of a problem of D15 before it was shipped to Arosa when assuming that the value measured around September 1955 was not a reading error.

The repaired instrument was then sent to Botswana in April 2000 [529]. Dobson D15 served as the standard instrument of the LKO Arosa from 27 August 1949 to 3 August 1992.

On 16 April 1966, a secondary instrument, Dobson spectrophotometer **D101**, was unveiled at the LKO. This instrument had been purchased by IACETH on a project basis [530] in the first year when Dütsch became professor at ETH Zürich (Sect. 5.1). This system was manually operated on a routine basis as a redundant instrument, in parallel to Dobson D15. In summer 1989, D101 underwent the same modifications as D15 and was also operated in the spectrodome in a semi-automated fashion (Sect. 7.3).

After a complete renewal of the electronic and acquisition system in the period from September 2013 to July 2014, the system was operated fully automatically in Arosa. On 13 January 2016, Dobson spectrophotometer D101 was placed in new housing at the PMOD in Davos in order to compare the results obtained at both sites based on multiannual observations and to underpin experimentally that the decision of a transfer of the LKO platform from Arosa to Davos was feasible (Sect. 8.2). Since August 1992 when D15 was removed, D101 served as the new standard instrument of Arosa until its full automation in September 2013.

Spectrophotometer **D51** [531] arrived in Arosa in the late 1960s. This instrument was upgraded in early 1970s in order to perform automatic column measurements of ozone (Räber, 1973). The automation of this Dobson instrument was the subject of the PhD thesis of Jost Räber, which, however, was never submitted. The instrument was operated intermittently between January 1975 and December 1984, but apparently these data were never sent to WOUDC [532]. The project was officially discontinued in June 1985 [533].

The Dobson spectrophotometer **D62** [534] was installed at the LKO on 6 September 1992 in order to replace D15 and became the new secondary instrument. When arriving in Arosa, D62 was equipped with the same electronic system as D101 in order to be operated in a semi-automated mode in the spectrodome. Thanks to an upgrade of the electronic and the acquisition system in March 2012 the measurements were performed thereafter in a completely automated manner in a new housing. It was planned that D62 would replace D101 as standard instrument at Arosa from September 2013 to December 2015 due to the upgrade works on D101.

Umkehr measurements

The Dobson spectrophotometers presented above were also used for the zenith sky measurements regularly performed at the LKO Arosa in order to obtain Umkehr profiles.

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529 As decided by the SAG-Ozone which supervises the global network of WMO/GAW (Sect. 7.5).

530 This SNSF project had the main goal of introducing ozonesoundings in Switzerland, first in Thalwil (1966-68), later in Payerne (since 1968) (refer to Jeannet et al., 2007) aiming to get complementary ozone profiles.

531 The Dobson instrument D51 came to Arosa on long-term loan from the IO_3C around 1970. It was initially lent by the IO_3C to Aarhus, then in 1964/1965 to the Belgian-Dutch Antarctic base.

532 The total ozone values of the automated Dobson spectrophotometer D51 were compared in 1976 for one month with the measurements of the two other manually operated Dobson instruments in Arosa (Räber, 1976). Statistics for 11 months from November 1983 to December 1984 are available from the diploma thesis of Thomas Moser (Moser, 1985).

533 D51 was then updated in order to perform automated Umkehr measurements and used as the standard Umkehr instrument at Arosa since the late 80's (see below Section 9.1.2.b Umkehr measurements).

534 The Dobson spectrophotometer D62 was provided on a long-term loan basis by the Environment and Climate Change Canada in 1992.

Table 11: The LKO Arosa Umkehr Data Availability 1956-2017 [a)].

Year	D15	D101	Year	D15/D62	D101	D51	Br40	Br72	Br156
1956	173		**1987**	104	128	104			
1957	226		**1988**	132	74	132	87		
1958	250		**1989**	299	26	299	52		
1959	85		**1990**	311	23	311	224		
1960	0		**1991**	124	33	124	177		
1961	237		**1992**	0	0	0	0		
1962	297		**1993**	0	0	0	0		
1963	253		**1994**	0	0	0	0		
1964	254		**1995**	18	17	328	551		
1965	215		**1996**	12	13	330	554		
1966	134		**1997**	25	24	393	567		
1967	238		**1998**	16	15	357	557		
1968	202	226	**1999**	17	16	329	509		
1969	163	192	**2000**	20	23	340	558		
1970	148	181	**2001**	26	25	325	458		
1971	184	198	**2002**	34	38	360	538		
1972	150	182	**2003**	74	73	402	552		
1973	150	165	**2004**	46	45	348	556		
1974	130	144	**2005**	44	45	359	548	69	52
1975	197	233	**2006**	44	44	363	547	322	313
1976	185	202	**2007**	48	47	395	556	312	314
1977	122	195	**2008**	47	44	396	513	288	291
1978	122	102	**2009**	39	39	439	562	293	306
1979	143	174	**2010**	38	38	411	461	266	216
1980	147	179	**2011**	10	10	316	618	280	288
1981	122	143	**2012**	76	31	146	526	229	254
1982	46	188	**2013**	64	28	226	560	235	268
1983	0	232	**2014**	46	19	92	488	344	310
1984	0	190	**2015**	102	143	359	447		
1985	130	187	**2016**	53	3	400	452		
1986	157	166	**2017**	183	19	458	419		

[a)] Number of Umkehr profiles / y:
- D15, D51, D62 and D101 (since 1989): valid profiles (no rain, sunshine)
- Br40: retrieved profiles; Br72 and Br156: days with retrieved profiles (not necessarily valid)

The years 1983-84 and 1992-94 are disturbed by volcanic eruptions (El Chichon, Pinatubo).

Two spectrophotometers with photoelectric detection (Dobson Instruments D1 and D2 [535]) were brought by Dobson to Arosa in June 1932 in order to realize the very first Umkehr measurement campaign [536] (Sect. 3.8.5). One instrument was used for the Umkehr observations, the second for the

535 These are the instruments termed No.1 and No.2 in Figure 11 of Dobson (1968). Note that the latter is obviously different from the instrument “D2” corresponding to the Féry spectrograph used in Arosa (see 9.1.2.b Total Ozone observations).

536 Before this campaign, only four Umkehr curves were recorded in Oxford in January 1931 (Sect. 3.8.5).

total ozone measurements performed during the Umkehr readings [537]. The data from this campaign was analyzed in Götz et al. (1934a).

A number of Umkehr measurements were later on undertaken with the Dobson spectrophotometer D15 (equipped with photomultiplier) in 1950 (Perl, 7 November 1950), but the results were apparently never published (nor analyzed) [538].

After a series of trials in December 1955, Dütsch [539] initiated in January 1956 Umkehr observations with D15 on a routine basis (Sect. 4.2 and 5.1), thereby laying the foundation of the long-term Umkehr series of Arosa. From January 1968 onwards, redundant Umkehr measurements were also performed on a regular basis with D101, with the same observational frequency as with D15 up to August 1992, but D15 was considered as the standard instrument for the Umkehr observations from January 1956 to January 1989.

The D51 system was progressively modified [540] between summer 1985 and January 1989 allowing first semi-automated Umkehr measurements (exclusively Umkehr observations on the C wavelength pair) and fully automated Umkehr measurements since February 1989. The fully automated spectrophotometer D51 served now as the standard instrument for the Umkehr measurements, but manual readings were still performed 3-6 times per month with D15 and D101 in parallel with D51, thereby assuring a redundancy with instrument D51. When D15 was taken out of service (see above) it was replaced by D62 so that there were still two redundant manual Umkehr readings.

In March 2006, a first renewal of the turning table and the electronics took place. The electronic and acquisition system of D51 was completely changed and upgraded in January-February 2012. Umkehr measurements [541] at different wavelengths could now be collected with this instrument, since November 2016 in a new housing. These modifications will make necessary a new homogenization of the Umkehr series in the future.

9.1.2.c) Brewer spectrophotometers

When fully automated Brewer spectrophotometers were introduced at the LKO in 1988 and in the following years (Sect. 7.3), the expectation was to compare Brewer and Dobson instruments by parallel measurements for a few years in order to replace the still partly manually operated Dobson instruments and therefore to reduce manpower costs (Sect. 7.6.2) as well as to measure UV-B at the Earth's surface. An initial system (Br40) was installed in September 1988, a second system (Br72) in June 1992 and a third one (Br156) in July 1998. In the first years, the measurement schedules of these three systems were defined in such a way that Br40 was focusing on total ozone measure-

537 Dobson returned to Oxford in August 1932 with one of the instruments; the second one was shipped back in October 1933, more than one year after the end of the campaign in June 1933. After one instrument returned to Oxford the spectrographic instrument "D2" routinely operated at the LKO was used for the total ozone measurements during the Umkehr observations.

538 Refer also to footnote 526 on page 118.

539 Remember that Umkehr measurements were a key subject in Dütsch's career (Sect. 4.2 and 5.1).

540 MeteoSwiss (Hoegger [434]) was already strongly involved in these transformations since 1986. This technical upgrading was started in the context of a diploma work of the University of Applied Sciences (Fachhochschule) of Fribourg (Switzerland), then managed and realized by the company Hengartner in Chur.

541 Ozone column data can now also be recorded with D51 in addition to the Umkehr measurements.

ments, Br72 [542] was primarily taking Umkehr measurements and Br156 was run with emphasis on UV spectra. The measurement program of all three instruments was unified between 2008 and 2010 [543].

9.1.3 Additional measurements

The LKO was always considered as a privileged place for studies concerning the particular climate of alpine stations. The following section is devoted to the manifold measurements which were collected at the LKO, in addition to the stratospheric ozone measurements.

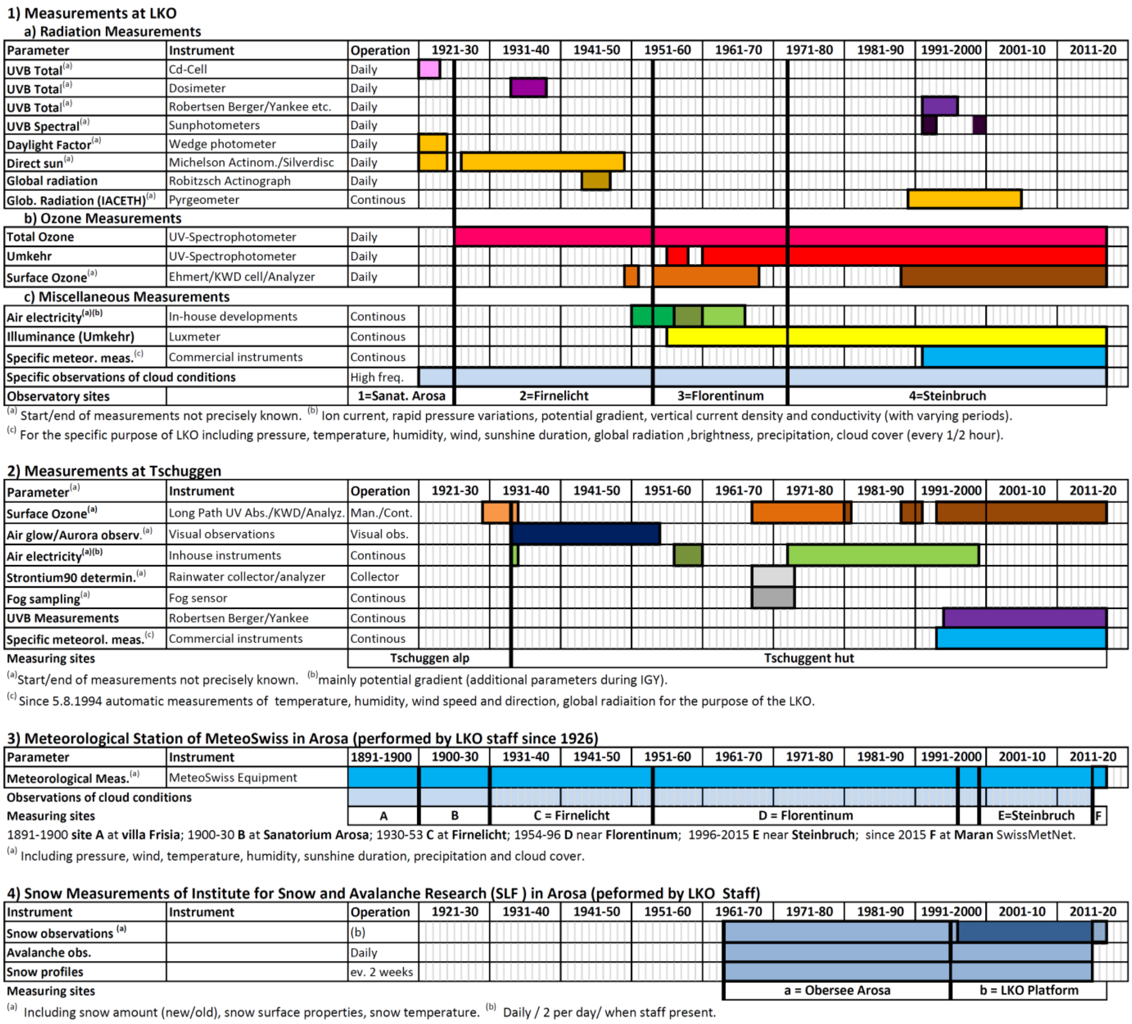

Figure 47: Atmospheric measurements performed at Arosa between 1921 and 2017.

Figure 47 gives an overview of the measurements performed at Arosa, at the LKO platforms (see Figure 1 for the locations) and at Tschuggen [544] (Sect. 3.3.2), for longer periods and operated by the

542 Since November 2011 Br72 was run at Davos with the purpose of investigating the comparability between the two sites when considering a relocation of the LKO from Arosa to Davos (Stübi et al., 2017a) (Sect. 8.2).

543 The Brewer spectrophotometers can be considered as a very valuable complement to guarantee the quality of the ozone observations at the LKO. However, as the Arosa series is based on the Dobsons spectrophotometers which are still the backbone of the GAW network, the report focusses mainly on the Dobson systems.

LKO staff. The temporary measurements performed at Arosa by invited scientists and the observations made by persons of the LKO (Götz and others) outside of Arosa are treated at the end of this section.

9.1.3.a) Radiation measurements

The measurement of the direct component of solar radiation and the biologically active UV-B radiation were part of the specific mandate of the KVV Arosa when the LKO started its activities in 1921 [545]. The measurement of these parameters continued, with some interruptions, almost through the entire history of the LKO.

- **Biologically active UV-B radiation**
  After recording of the UV-B radiation in the starting phase of the LKO [546], Götz established a small network measuring the biologically active UV-B radiation in the 1930s with dosimeter instruments manufactured by I.G. Farbenindustrie (KVV Arosa Annual Report 1935), a development initiated by Götz.

  Only much later UV-B measurements were resumed in Arosa. From 14 August 1992 to 15 June 1999 UVB radiation was registered at the LKO platform with instruments of different types (Macam, Robertson-Berger, Yankee and Kipp&Zonen); UV-B radiation has been continuously measured at Tschuggen since 2 May 1995.

- **Direct component of solar radiation and global radiation**
  The direct component of the total solar radiation was measured at the LKO with a Michelson actinometer, which was calibrated with silver disc pyrheliometers (in the first years on loan from Dorno and later from MeteoSwiss). The measurements of the first years from October 1921 to March 1925 were presented in the publication covering the radiation climate of Arosa (Götz, 1926b). The measurements of the direct sun intensity were then continued for an extended duration beyond the starting period, as the intensity of the midday sun is given for the entire period lasting from 1927 to 1948 in the second book on Arosa's climate (Götz, 1954).
  This data supplemented the measurements of the global radiation collected with a Fuess-Robitzsch actinograph at the climatological station of MeteoSwiss at Arosa from 1901 to 1939. Again, during the years 1944-1947 global radiation has been registered in the framework of the "climatological action" [547] (for more details refer to Section 3.6.4 of this report).
  After an interruption of more than 40 years, different radiation components were again measured at the LKO under the auspices of a program supervised by Atsumu Ohmura [548] from January 1990 to March 2007.
  The global radiation is also part of the automatic meteorological measurements installed at the LKO platform since 1992 (for the LKO's own purposes).

544 Refer to footnote 98 on page 28.

545 For this reason, they are treated outside of the climatological parameters presented in Section 9.1.1.a.

546 Remember, that the biologically active UV-B radiation was determined by Götz from November 1921 to May 1923 with a Cadmium cell (on loan from Dorno; for details refer to Section 3.2) allowing for estimation of stratospheric ozone.

547 Refer to footnote 198 on page 41.

548 Refer to footnote 437 on page 89.

9.1.3.b) Surface Ozone

Here we provide additional information about the methods of the surface ozone measurements mentioned in Section 3.5.2 (see Staehelin et al. 2017 for further information and present use of the measurements). Götz performed optical measurements of the ozone content near the ground with a UV spectrograph and a mercury lamp installed at a certain distance (Götz and Ladenburg, 1931). A letter (Ladenburg, 1 May 1931) and other documents found in the LKO Archives show that performing chemical measurements as done in Montsouris [549] was also considered for Arosa at this time. But ultimately the long path method was preferred, the chemical method being considered as too complicated and too uncertain.

Surface ozone became again a topic of interest at the LKO in the context of the program aimed at the medical development of the resort areas ("climatological action", refer to Section 3.6.4). First measurements were performed with the electrochemical method of Ehmert at the beginning of the 1950s (Götz and Volz, 1951). Regular measurements of surface ozone were performed after the move in the Florentinum, covering 144 days from 29 April 1954 to 18 October 1958 at the LKO (Perl, 1965; Staehelin et al., 1994). According to the LKO activity report AR 1969 (KVVA, 1921-1977), measurements of surface ozone continued at Florentinum up to the end of the 1960s although little is known on the techniques used and the frequency of the measurements. At the end of the 1960s and the beginning of the 1970s (AR 1969-1971), measurements are also mentioned at Tschuggen. During winter 1980/81 and summer 1981 surface ozone (as well as CO and NO_x) was measured at different places in Arosa (Graber, 1984).

Since the beginning of the 1990s, surface ozone is again continuously monitored with analyzers at the LKO platform and at Tschuggen with the goal of supplementing the total ozone and profile measurements with the ozone conditions near the ground [550].

9.1.3.c) Atmospheric Electricity

In the framework of the "climatological action", Götz entered a cooperation with the University of Fribourg (Switzerland) in order to extend the investigation of the local climate conditions to atmospheric electricity. Under the direction of Dessauer [551] a program was started at the beginning of the 1950s comprising measurements of ion current and rapid pressure variations.

These measurements were continued after the retirement of Dessauer in 1951 and Götz's death in 1954. Leonhard Saxer and Werner Siegrist, both scientists of the University of Fribourg and later teachers of physics at the High School of Aarau [552], took over the responsibility of the investigations concerning atmospheric electricity. A special 3-year project, granted by the Swiss National Science Foundation, was started in 1956 in the context of the activities related to the IGY [553]: The measure-

549 At the Parc de Montsouris, near Paris, Albert Lévy conducted quantitative ozone measurements from 1876-1910 (Calvert et al., 2015).

550 The measurements at the LKO are operated by Oekoscience (Chur) mandated by the Environment department of the Canton of Grisons (from summer 1991 to March 1996 the equipment was placed on the Florentinum platform, later on in a special hut on the LKO terrace).

551 Friedrich Dessauer (1881-1963), Professor and Director of the Physics Institute of the University of Fribourg (1937-1951).

552 Kantonsschule Aarau.

553 Refer to footnote 223 on page 45.

ments of the ion current were stopped whereas those of the rapid pressure variations maintained; in addition, measurements of potential gradient, vertical current density and conductivity became part of the program, and this not only on the LKO platform but also at Tschuggen (2050 m a.s.l.) and at the top of the Weisshorn (2650 m a.s.l.) (Saxer and Siegrist, 1961). The activities were discontinued at Tschuggen and at the Weisshorn after the IGY (probably in February 1960) but were maintained at the LKO for a while. In 1963, the program at the LKO was scaled back, maintaining only the recordings of the potential gradient and of the rapid pressure variations. The registration of the atmospheric electricity parameters at the LKO platform was then completely suspended in 1966 for several years.

According to Saxer (1983), atmospheric electricity parameters, mainly air conductivity and electric potential gradient were again registered at Tschuggen from 1973 onwards as a complement to the measurements performed at the lowland station established in Aarau in 1964 (Saxer and Siegrist, 1966; Saxer, 1983). These measurements, which were supervised by Saxer and Siegrist and supported by the staff of the LKO, continued almost 30 years and were stopped on 3 September 1999 (in Aarau the data acquisition ended in 2002).

9.1.3.d) Miscellaneous measurements

From the LKO activity report AR 1972 (KVVA, 1921-1977) it turns out that fog measurements were performed at the Tschuggen at the beginning of the 1970s. In the same period, precipitation samples were collected at this place in order to determine the Strontium-90 content, presumably related to studies of the fallout originating from the high altitude nuclear explosions occurring mainly in the years 1958-1962. Nothing is known about the originator and the users of these measurements.

Primary air pollutant concentrations were continuously measured in the framework of the PhD theses of M. Campana (Campana et al., 2005) and Y. Li (Li et al., 2005) for more than a year at Tschuggen.

9.1.3.e) Air glow and Aurora observations

As brought up earlier, Götz was very much interested in all kinds of optical phenomena in the atmosphere, especially those arising in the upper atmosphere (also emphasized in Dütsch, 1992). The scientific motivations behind this curiosity are presented in Section 3.5.1. As can be seen from his publication list (Annex 2) many publications on halos, light pillars, air glow and auroras prove his great devotion to all these light phenomena. Götz spent many nights during the second half of his career in the hut (built in 1934) at Tschuggen documenting as many interesting features as possible.

9.1.3.f) Snow measurements of the Institute for Snow and Avalanche Research (SLF)

Since the winter 1964/65, the LKO served as a reference station of the institute of snow and avalanche research (SLF) [554] of Davos. From the first snow of the winter up to the thaw period, a daily message (from winter 1997/98 onwards, 2 messages/day) of new and total snow amount were generated at a fixed time. In the middle and at the end of the month a profile of the snow cover was established. In addition, observed avalanches were promptly reported. At the winter season 2015/16, the program has been considerably reduced, with only one determination of the new snow and total

554 Refer to footnote 190 on page 40.

snow amount per day, measured not at fixed hours but at any time when the staff is present at the observatory. The snow observations for the SLF at the LKO were stopped after the winter season 2017/18.

9.1.3.g) Special observations at the LKO Arosa

Because of its location and climate, Arosa was considered by many scientists as an ideal place to conduct atmospheric investigations and the LKO offered good infrastructure to support invited activities[555].

As mentioned in Sect. 3.4, Götz was networking very efficiently and was very open-minded about hosting invited guests in his house. Although the list is surely not exhaustive, Table 3 of this report gives an idea of the great number of scientists who often came with their proper instruments to perform complementary studies at the LKO. Only few examples of the 1930s (not included in Figure 47), which Götz explicitly emphasized in the LKO activity reports AR (KVVA, 1921-1977), shall be mentioned here: in addition to Peppler's balloon measurements[556], Schein and Stoll of the University of Zürich started applying photomultipliers to atmospheric investigations at the LKO (Götz et al., 1934b), Glawion examined Sahara dust events during a project of one and a half years (Glawion and Götz, 1937, Glawion, 1937a, 1937b, and 1938) and Nicolet (Brussels) stayed for 6 months in Arosa to study the mechanism of excitation of the forbidden lines of oxygen and nitrogen in the spectra of the aurora and the night sky with the special spectrograph (Sect. 3.5.1) acquired in 1933 for the observations at Tschuggen (Sect. 3.3.2) (Nicolet, 1938a, 1938b, 1939a and 1939b).

During the Dütsch and the MeteoSwiss/ETH eras, the LKO continued to serve as measuring platform for the ozone community, mainly during the Dobson intercomparisons[557].

In connection with the Umkehr measurements, Migeotte[558] came to Arosa in the years 1956-1959 (IGY) to measure the vertical ozone distribution by means of infrared measurements, which were analyzed by Ernest Virgroux.

Based on Migeotte's Air-Force contract, an intercomparison of four different methods for determining the vertical ozone distribution was held at Arosa in July-August 1958[559]. Additional intercomparisons of the same type took place in 1961 (in conjunction with the Ozone Symposium) and 1962.

In addition, research groups from Switzerland[560] and abroad[561] were regularly hosted at the LKO and at Tschuggen.

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555 "Invited activities" meaning measurements performed by colleagues invited for special campaigns.

556 Peppler explored the wind circulation in the Arosa valley with pilot balloons (Sect. 3.5.2) (Peppler and Götz, 1931).

557 Remember the international Dobson intercomparisons organized at LKO on behalf of WMO (Sect. 7.5, last Para.): 1978 (Sect. 5.3); 1986 (Sect. 6.2) as well as 1990, 1995 and 1999 (Sect. 7.3). Later on, Regional Brewer Calibrations Campaigns for Europe took place in 2008, 2010 as well as maintenance/calibration campaigns with the European Brewer Calibration Center (RBCC-E) traveling reference instrument in 2012, 2014 and 2016 (Sect. 7.3).

558 Marcel Migeotte (1912-1992), PhD, astrophysicist, professor at the University of Liège (Belgium).

559 Indirect methods corresponding to infrared emission and absorption (Vigroux) and Umkehr (Dütsch) were compared to direct methods based on optical radiosondes (Paetzold) and chemical ozonesondes (Brewer).

560 E.g. Ozone profile measurements with a microwave radiometer were made by Hans-Jürg Jost of the Applied Physics group of the University of Bern in 1989; from 15 July 1999 to 10 October 2000, a sun photometer was installed at the LKO by Alain Heimo of MeteoSwiss in the framework of the CHARM project of the Swiss GAW-CH Programme.

9.1.3.h) Götz's scientific measurement campaigns outside of Arosa

Besides the broad list of fields covered by Götz at Arosa (at the LKO platform and at Tschuggen) it should be mentioned here that Götz extended his observational activities to being involved in projects with measurement programs at sites other than Arosa. It would go too far to enter in the details of all these various campaigns, but the list of his publications (Annex 2) gives an idea concerning all the different studies Götz initiated or participated in, outside of Arosa. A few examples shall be mentioned here: In the 1920s, Götz was involved in a project of Dorno in performing radiation measurements at Muottas-Muraigl in the Engadin (Dorno, 1927b). In this period, he also provided some support to Alfred Gockel [562] concerning radiation measurements in Montana (Switzerland) (Gockel, 19 September 1926 and 2 February 1927). A grant attributed by the IUGG in 1933 enabled the study of surface ozone conditions at Jungfraujoch and Lauterbrunnen in collaboration with Chalonge and Vassy and with the support of cand. phys. Maier-Leibnitz (Chalonge et al., 1934, Götz and Maier-Leibnitz, 1933). Observations with Dobson spectrophotometers at Jungfraujoch and Lauterbrunnen in the 1930s (in collaboration with Dobson) are mentioned in the AR 1934 (KVVA, 1921-1977); the results were submitted to WOUDC. Following the tests with UV-dosimeters [563] at the LKO, Götz established a small network comprising the sites of Arosa, Chur, Zürich and Jungfraujoch allowing the comparison between the different locations in Switzerland (Götz und Kreis, 1937); this happened in collaboration with Alfred Kreis [564] who supported Götz in many other investigations [565]. The expeditions complete the picture of these activities engaged outside of Arosa: besides the Svalbard expedition (Sect. 3.8) Götz participated in 1930 in an aircraft expedition to Iceland [566] (Götz, 1930) and in 1936 he made a trip to Tripoli [567] (Götz, 1936; Dütsch, 1992).

9.2 Personnel

During the existence of the LKO, more than 170 persons participated in the operation and analysis of the measurements summarized above (Sect. 9.1). In the following, an overview of the persons who played a role in the destiny of the LKO will be presented thereby distinguishing the specific aspects related to the operational and management tasks (Sect. 9.2.1 and 9.2.2) and the scientific activities (Sect. 9.2.3). An important concern of this part is also to give credit to all the persons involved in the guidance, performance and enhancement of the measurements at the LKO for their conscientious and qualitatively convincing work.

561 E.g. the Max Planck Institute of Chemistry from Mainz (Johnsons, Arlander, Parchatka and Bergens as well as Roth and Klüpfel) performed measurements for almost half a year, from 4 November 1991 to 8 April 1992, at Tschuggen and at the Obersee in Arosa.

562 Alfred Gockel (1860-1927), PhD, Professor at the Physics Department of the University of Fribourg (Switzerland), Director of the Institute of Cosmic Physics.

563 Produced by I.G. Farbenindustrie Aktiengesellschaft, Ludwigshafen.

564 Alfred Kreis (1885-1964), teacher at the Academic High School of Chur (Switzerland), honorary doctor of ETH Zürich.

565 Among others, Götz and Kreis followed the stratospheric flight of August Piccard on 18 August 1932 with theodolites from the ground (Ganz et al., 1932).

566 From 16 July to 18 July 1930, Götz had the opportunity to participate to the first expedition of the airship "Graf Zeppelin" to Iceland; in around 60 hours the airship went from Friedrichshafen over Hamburg to Bergen, then crossing the sea to the eastern side of Iceland, longing the souths coast of Iceland until Reikjavik; the airship flew back on the Atlantic sea to the western coast of France (Nantes) and back to Friedrichshafen. It is amazing to note that one of the others guests on board was Umberto Nobile whose hut Götz occupied during his expedition in Svalbard (Sect. 3.8).

567 To describe the course of the total solar eclipse which occurred on 19 June 1936.

9.2.1 Operation

9.2.1.a) Measurement and operational tasks during the Götz period

From 1921 to 1944, Götz was mostly working alone and most of the long observational records of the LKO were taken by himself (for more details concerning this period refer to Chapter 3 of this report). Only occasionally did he have some help from other persons (see Table 12). In the first two years of the measurements with the Féry instrument of Dobson (1926-27) he noted that he had to reduce his holidays in order to continuously ensure reliable measurements in Arosa, performed at first in the framework of the European measuring project [568] initiated by Dobson. As stated in the annual reports of the KVV Arosa, (AR 1926/27) he had the opportunity to hire a university assistant in 1927 (NN. Ferenez [569]) to replace him during the weeks he was on a study trip in Holland and England. During his expedition to Svalbard in 1929 he was accompanied by Emil Henssler who had previously worked as an observer of the climatological station of MeteoSwiss in Arosa. It can be assumed that from 1921 to 1926 [570] the observer(s) of the MeteoSwiss station (Sect. 9.1.1) probably also provided some assistance to Götz in accomplishing the measurements of the LKO.

As described in Section 3.6.4, Götz referred several times in the activity reports, as e.g. in AR 1938/39 (KVVA, 1921-1977), to the high work load he was facing and complained about the lack of assistants. Cand. phys. Zünti (Götz, 1938) is the only person cited in the activity reports or in any other documents [571] as having assisted him in this period with the ozone measurements.

Nevertheless, although no concrete proof could be found, it can be taken for granted that Götz had some assistance in performing total ozone observations in the 1930s. This can be judged from the large number of days with direct sun observations in Arosa in some years (see Table 10 in Sect. 9.1.2.b) and Table 1 in Staehelin et al. 1998a). This would mean that measurements had to be taken on most fair days, while Götz needed to teach once per week during academic semesters in Zürich (Sect. 3.9) and was regularly travelling to conferences (Sect. 3.4). This seems to be confirmed by a remark in the activity survey 1935-1938 (Götz, 1938) [572], where it is noted that in the absence of permanent collaborators, he was dependent on the help of some occasional auxiliary persons (not cited by name) [573].

In this decade, Götz invited a large number of scientists to Arosa in order to perform measurements at the LKO for weeks or even months (Sect. 9.1.3.g). The annual report AR 1939 mentions 25 visiting scientists. It is reasonable to consider that these visitors helped Götz to overcome the shortages in manpower during this period in some way.

568 Refer to footnote 237 on page 50.

569 First name not known.

570 After 1926, the climatological station was run by Götz.

571 Cand. phys. Maier-Leibnitz (from Göttingen) was hired in 1936 on a project concerning surface ozone at Jungfraujoch (Sect. 9.1.3.h).

572 Addressed to the Society of Natural Sciences of the Grisons.

573 As Margarethe Götz, the wife of Götz, was involved in the observational program of the meteorological station of MeteoSwiss in Arosa (Sect. 3.11) we might speculate that she also assisted him occasionally in the ozone activities of the LKO (although this is not clearly stated in any document).

It was only in the 1940s that Götz applied intensively for grants[574] allowing him to hire a series of collaborators (as can be seen from Table 16 in Sect. 9.2.3). These collaborators were mainly involved in projects or particular studies, but at least with Perl it is clearly known that she also participated in the regular ozone measurements.

Table 12: Local station managers and measuring staff of the LKO including period of employment and employer (or grant).

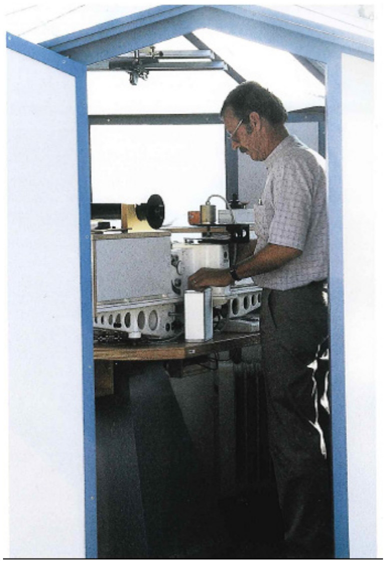
Person	Period	Affiliation/employer
Station management and measurements		
Paul Götz, PhD, Prof.	Nov. 1929 - Oct. 1953	KVV Arosa (†1954)
Gertrud Perl, PhD	Nov. 1953 - Apr. 1962	KVV Arosa (leave due to health problem)
Werner Frick	May 1962 - Dec. 1963	KVV Arosa (†1964)
Rosmarie Frick	Jan. 1964 - Sep. 1964	KVV Arosa (manag. without observations)
Kurt Aeschbacher	Oct. 1964 - Nov. 2001	KVV Arosa / ETH Zürich / Meteoswiss Arosa
Rudolf Burren	Sep. 2002 - Feb. 2011	MeteoSwiss Arosa (†2011)
Werner Siegrist	May 2011 - today	MeteoSwiss Arosa
Observational assistance		
Margarethe Götz	1926 - 1953	KVV Arosa
Emil Henssler	May 1929 - Oct. 1929	MeteoSwiss/KVV Arosa (Svalbard)
Student Assistants		
X students (see footnote 575)	1956 - 1965	KVV Arosa (US Army grants)
81 students from 1964-1988	1965 - 1973	KVV Arosa
(names see Table 13)	1973 - 1988	ETH Zürich
Auxiliary observation staff		
Christine Schawalder	Jan. 1988 - Jun. 1991	MeteoSwiss Arosa 20%
Rosina von Dach	Jul. 1988 - Dec. 1989	MeteoSwiss Arosa 20%
Ursula Schurtenberger	Sep. 1989 - Jul. 1996	MeteoSwiss Arosa 20%
Rosina von Dach	Apr. 1990 - Dec. 1993	MeteoSwiss Arosa 20%
Heidi Caminada	Oct. 1991 - Jun. 1999	MeteoSwiss Arosa 20%
Josef Steiner	Feb. 1995 - Mar. 1995	MeteoSwiss Arosa 20%
Armin Urech	Jan. 1996 - Apr. 2006	MeteoSwiss Arosa 20%
Barbara Kipfer	Aug. 1996 - Jun. 1999	MeteoSwiss Arosa 20%
Barbara Hüppi	Apr. 1999 - Jul. 1999	MeteoSwiss Arosa 20%
Maud Neininger	May 1999 - Nov. 2008	MeteoSwiss Arosa 20%
Beatrice Meister	Oct. 1999 - Apr. 2011	MeteoSwiss Arosa 20%
Beatrix Rehli	May 2006 - Jun. 2017	MeteoSwiss Arosa 20%
Evelyne Caluori	Nov. 2008 - Feb. 2011	MeteoSwiss Arosa 20%
Rebekka Herger	Mar. 2011 - Oct. 2015	MeteoSwiss Arosa 20%
Verena Danuser	Mar. 2011 - Oct. 2015	MeteoSwiss Arosa 20%
Housekeeping staff		
Rösli Aeschbacher	Jan. 1988 - Nov. 2001	MeteoSwiss Arosa 10%
Verena Burren	Dec. 2001 - Mar. 2011	MeteoSwiss Arosa 10%

574 E.g. in the framework of the "climatological action" from the Swiss Federal Office of Transport, for more details refer to Section 3.6.4.

In November 1953, Perl was charged by the KVV Arosa with replacing Götz and assuring the transfer of the LKO to the sanatorium Florentinum (Sect. 3.11 and 4.2). It seems that she was alone in the two first years at Florentinum (1955-1956) to cover all the observational tasks; at least no persons supporting Perl can be found in any document. When Dütsch started the Umkehr program (Sect. 4.2 and 5.1) in Arosa in 1956, students were employed and specifically trained (one or two students at once) to perform these tedious and time-consuming measurements as they require mainly cloud free conditions starting before sunrise[575]. They stayed at Arosa usually for several (generally 3-6) months. As can be learned in a letter from Dütsch to Tschudi[576] (Dütsch, 5 June 1962), the students working for the Umkehr program were also employed in providing some assistance in the routine work of the LKO; they conducted total ozone measurements, particularly over the weekend, to relieve the observer.

9.2.1.b) Local operational responsibility after 1962

When Perl left Arosa in spring 1962 (Sect. 4.2) Oswald Frick[577], a technician, was hired on 1 May 1962 as local station manager and observer to perform and analyze the measurements. Frick died on 5 January 1964 after having worked for 13 months at the LKO. Subsequently, Rosmarie Frick (the widow of Oswald Frick) ran the LKO from January until 30 September 1964[578]. Aeschbacher, also a technician, then succeeded to Frick as local station manager.



Kurt Aeschbacher

1945	Elementary school (6 years) and secondary school (3 years).
1954	Apprenticeship as machine fitter.
1959	PMOD Davos: Technical coworker.
1964	LKO Arosa: Station Manager. Employee of KVV Arosa (1964-1973), of IACETH. (1973-1987) and of MeteoSwiss (1988-2011).
2001	Retirement on 30 November.

Figure 48: Biography of Kurt Aeschbacher, station manager and observer of the LKO from 1964 to 2001 (Photo Kurt Aeschbacher).

575 In Dütsch (1959) the following 9 students are acknowledged: H. Heer, U. Gasser, W. Züllig, K. Schönenberger, W. Schulthess, W. Aellig, R. Keller, J. Himmelsbach and H. Obergfell, "who did their work carefully under not always agreeable conditions (very low temperatures in winter; very early start of work in summer)".

576 Refer to footnote 359 on page 73.

577 Oswald Frick (1930-1964), station manager of the LKO (1962-1963), was previously working for an extended time at the PMOD under Mörikofer.

578 To all appearances Rosemarie Frick was mainly involved in mapping Umkehr curves; it must therefore be assumed that the measurement work was mostly performed by the students during this period.

Kurt Aeschbacher (see Figure 48) deserves a special mention with regard to the long time he was in charge of the operational responsibility of the LKO. His work is viewed by the authors of the report to be essential for obtaining the extraordinary high quality of the stratospheric ozone measurements required for reliable long-term trend analysis. From 1959 to 1964, he worked at the PMOD in Davos as technical coworker before he joined the LKO in Arosa on 1 October 1964. He was first hired by the KVV Arosa and worked as station manager under the scientific leadership of Dütsch. According Aeschbacher, he obtained his first training to perform the measurements from students when Dütsch was not present [579]. In 1973, when the LKO moved to the Haus Steinbruch, Aeschbacher was salaried by IACETH [580]. Since the move to the Haus Steinbruch he stayed with his family [581] in the service apartment which was just under the platform of the observatory; this was important in order to more easily perform the Umkehr measurements, which were done manually until 1989 on cloudless days. Students continued to be employed at the LKO to assist the station manager, primarily to perform the Umkehr measurements but also to replace the station manager during weekends and holidays as before. Aeschbacher was responsible to initiate and train the 81 students [582] who spent several months for observing work in Arosa at the LKO between 1964 and 1988 (a list of the names of all these students is given in Table 13). It is his merit having been able to train and motivate these young people and to enable them to provide high quality data. In the later time, he was assisted increasingly by Schill [583] when automation was becoming more and more important.

On 1 January 1988, he became an employee of MeteoSwiss. At that time, a new operational solution was introduced with three part time auxiliary assistants as backup for the station manager during weekends and holidays instead of the students. By this way the employment periods were longer, thus bringing more experience and a greater stability, although a certain rotation of the personnel involved could not be avoided [584]. The names of the 15 part-time observers (20-30%) who were working at the LKO in the period 1988-2014 are listed in Table 12.

Aeschbacher was also very important in the large international instrumental ozone intercomparison campaigns taking place at the LKO (Sect. 5.3, 6.2 and 7.3). Aeschbacher retired in November 2001 after more than 37 years of service at the LKO in Arosa.

Rudolf Burren [585] replaced Aeschbacher as station manager. He started to work at the LKO on early September 2001 and during a three month overlap he was introduced by Aeschbacher to all the tasks of the observatory. When Rudolf Burren died in 2011, Werner Siegrist succeeded as the local responsible observer.

579 During this period, Dütsch was employed in Boulder and visited Arosa only occasionally (during holidays) (Sect. 5.2).

580 Refer to footnote 12 on page 4.

581 Rösli Aeschbacher, his wife, was in contact with Margarethe Götz, the widow of Götz, taking care of her in the last years of her life; she provided much of the information presented in Appendix 1.

582 Most of these students served only once at the LKO. Herbert Schill, nowadays station scientist at the LKO, began as one of these students and was engaged eight times in the years from 1977 to 1982.

583 Refer to Section 9.2.3 and to footnote 582 on 131.

584 The average employment time of an assistant was approximately 5.5 years.

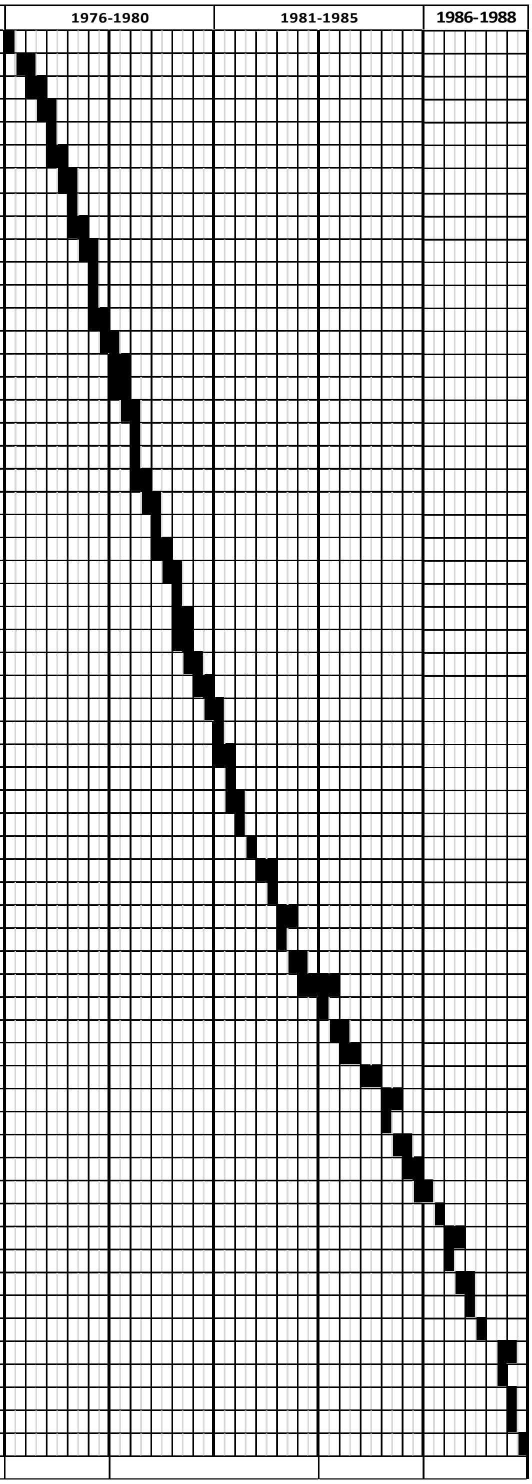
585 Rudolf Burren (1950-2011), station manager of the LKO (2001-2011), previously the responsible technician at the Hotel Tschuggen Arosa.

Table 13: From November 1964 to July 1988, 81 students (corresponding to 115 tenures) assisted the local station manager (names provided by Aeschbacher). The colors indicate multiple tenures. Part 1: Period 1964-1975.

Name	Begin	End	Mths	Empl.	Birth	1962-1965	1966-1970	1971-1975
Casparis	20.11.1964	10.04.1965	4.7	1.	1944			
Ryf	05.04.1965	15.07.1965	3.4	1.	1944			
Frösch D.	29.06.1965	05.08.1965	1.2	1.	1943			
Frösch Walter	26.07.1965	15.10.1965	2.7	1.	1944			
Oechslin Hanspeter	04.10.1965	31.03.1966	5.9	1.	1946			
Kind Seraina	25.03.1966	25.04.1966	1.0	1.	1942			
Risch Christian	30.04.1966	09.05.1966	0.3	1.	1942			
Rösli Hanspeter	13.05.1966	26.05.1966	0.4	1.	1942			
Kind Alba	15.06.1966	13.07.1966	0.9	1.	1944			
Grebner Dietmar	01.08.1966	03.10.1966	2.1	1.	1942			
Diebold Walter	01.10.1966	31.01.1967	4.1	1.	1946			
Rüdiger Greil	09.02.1967	28.04.1967	2.6	1.	1942			
Eichler Ralph	13.04.1967	30.06.1967	2.6	1.	1947			
Schädler Bruno	10.06.1967	08.10.1967	4.0	1.	1948			
Doumer Hansjörg	01.02.1968	03.03.1968	1.0	1.	1942			
Diebold Walter	04.03.1968	21.04.1968	1.6	1.	1946			
Favarger Daniel	06.05.1968	05.06.1968	1.0	1.	1945			
Schaffitz Werner	23.09.1968	28.02.1969	5.3	1.	1948			
Favarger Daniel	01.02.1969	28.02.1969	0.9	2.	1945			
Schädler Bruno	01.03.1969	12.04.1969	1.4	2.	1948			
Wiesmann Thomas	14.04.1969	29.08.1969	4.6	1.	1952			
Schaffitz Werner	05.06.1969	30.06.1969	0.8	2.	1948			
Schädler Bruno	30.08.1969	15.10.1969	1.5	3.	1948			
Angst Peter	01.10.1969	30.01.1970	4.0	1.	1950			
Albani Carlo	01.03.1970	18.04.1970	1.6	1.	1947			
Meier Walter	04.05.1970	31.07.1970	2.9	1.	1944			
Wullbrandt Harry	20.07.1970	30.09.1970	2.4	1.	1948			
Schaffitz Werner	01.10.1970	17.10.1970	0.5	3.	1948			
Schoch Rudolf	06.10.1970	30.01.1971	3.9	1.	1950			
Schädler Bruno	01.04.1971	19.04.1971	0.6	4.	1948			
Hügli Ulrich	13.04.1971	30.06.1971	2.6	1.	1942			
Hügli Andreas	23.06.1971	06.08.1971	1.5	1.	1949			
Trefzger Charly	21.07.1971	17.10.1971	2.9	1.	1947			
Möckli Benedikt	04.10.1971	24.01.1972	3.7	1.	1952			
Bosonnet Marcel	21.02.1972	30.06.1972	4.3	1.	1952			
Hügli Ulrich	15.07.1972	15.09.1972	2.1	2.	1951			
Bobst Jean Pierre	05.09.1972	21.10.1972	1.5	1.	1940			
Schmid Wilhelm	16.10.1972	31.01.1973	3.6	1.	1949			
Oettli Bernhard	05.03.1973	12.04.1973	1.3	1.	1951			
Widmer Kurt	09.04.1973	31.05.1973	1.7	1.	1952			
Schürch Peter	25.07.1973	30.09.1973	2.2	1.	1952			
Hügli Ulrich	29.07.1973	19.08.1973	0.7	3.	1951			
Gunzenhauser Jürg	08.10.1973	28.11.1973	1.7	1.	1954			
Rinderknecht Stefan	12.11.1973	30.04.1974	5.6	1.	1952			
Leutwyler Dieter	08.04.1974	30.06.1974	2.8	1.	1955			
Jenny Lukas	01.07.1974	07.10.1974	3.3	1.	1954			
Werder Martin	20.09.1974	27.01.1975	4.3	1.	1955			
Blabol Jiri	16.01.1975	30.04.1975	3.5	1.	1954			
Neidhart Martin	10.04.1975	11.08.1975	4.1	1.	1956			
Widmer Richard	15.07.1975	25.10.1975	3.4	1.	1956			
		1 employment				2 employments		4 employments
						3 employements		>4 employements

Table 13 (cont.): From November 1964 to July 1988, 81 students (corresponding to 115 tenures) assisted the station manager (names provided by Kurt Aeschbacher). The colors indicate multiple tenures. Part 2: Period 1976-1988.

Name	Begin	End	Mths	Empl.	Birth
Häseli Urs	06.10.1975	20.01.1976	3.5	1.	1956
Kaspar Martin	05.04.1976	07.08.1976	4.1	1.	1955
Häseli Urs	15.07.1976	05.10.1976	2.7	2.	1956
Zingg Ernst	01.10.1976	22.01.1977	3.8	1.	1956
Oettli Bernhard	09.02.1977	24.02.1977	0.5	1.	1951
Blabol Jiri	27.02.1977	20.04.1977	1.7	1.	1954
Kalt Peter	06.04.1977	06.07.1977	3.0	1.	1957
Blabol Jiri	13.07.1977	13.08.1977	1.0	2.	1954
Prantel Toni	18.07.1977	15.10.1977	3.0	1.	1955
Schill Herbert	01.10.1977	28.02.1978	5.0	1.	1957
Graber Werner	31.01.1978	11.02.1978	0.4	1.	1951
Blabol Jiri	25.02.1978	24.03.1978	0.9	3.	1954
Walker Andreas	23.03.1978	03.04.1978	0.4	1.	1960
Hafner Hans Peter	05.04.1978	05.08.1978	4.1	1.	1959
Schill Herbert	10.07.1978	15.10.1978	3.2	2.	1957
Wegmüller Andreas	02.07.1978	07.10.1978	3.2	1.	1959
Weidmann Staefan	23.10.1978	14.01.1979	2.8	1.	1959
Häseli Urs	05.02.1979	10.03.1979	1.1	3.	1956
Walker Andreas	19.02.1979	24.02.1979	0.2	2.	1960
Laumann Joachim	26.02.1979	16.04.1979	1.6	1.	1960
Widmer Rudolf	17.04.1979	14.07.1979	2.9	1.	1958
Schill Herbert	11.07.1979	11.08.1979	1.0	3.	1957
Wider Adrian	11.07.1979	06.10.1979	2.9	1.	1958
Billeter Daniel	10.10.1979	27.01.1980	3.6	1.	1960
Häseli Urs	01.02.1980	29.02.1980	0.9	4.	1956
Schill Herbert	25.02.1980	07.04.1980	1.4	4.	1957
Weiss Lukas	07.04.1980	30.06.1980	2.8	1.	1960
Billeter Daniel	01.07.1980	10.10.1980	3.4	2.	1960
Montigel Markus	01.10.1980	24.01.1981	3.8	1.	1960
Wachter Daniel	15.10.1980	24.01.1981	3.4	1.	1961
Blabol Jiri	01.02.1981	28.02.1981	0.9	4.	1954
Schill Herbert	01.03.1981	20.04.1981	1.7	5.	1957
Schill Herbert	14.05.1981	20.05.1981	0.2	6.	1957
Meier Christoph	06.04.1981	20.09.1981	5.6	1.	1962
Billeter Daniel	15.07.1981	02.08.1981	0.6	3.	1960
Häseli Urs	10.10.1981	25.10.1981	0.5	5.	1956
Heikkinen Tauno	18.01.1982	15.04.1982	2.9	1.	1946
Steiner Mathias	13.04.1982	12.06.1982	2.0	1.	1960
Heuberger Renate	01.06.1982	15.10.1982	4.5	1.	1962
Schill Herbert	14.07.1982	11.08.1982	0.9	7.	1957
Tempus Martin	04.10.1982	22.01.1983	3.7	1.	1963
Heuberger Renate	24.01.1983	15.10.1983	8.8	2.	1962
Frei Christoph	01.08.1983	30.09.1983	2.0	1.	1962
Delius Christian	03.10.1983	31.01.1984	4.0	1.	?
Heuberger Renate	25.02.1984	30.04.1984	2.2	3.	1962
Mürset Urs	16.04.1984	15.07.1984	3.0	1.	1964
Mayer Jörg	01.07.1984	15.10.1984	3.5	1.	1964
Heuberger Renate	14.07.1984	15.08.1984	1.1	4.	1962
Siegenthaler Alex	01.10.1984	21.01.1985	3.7	1.	1965
Bantle Stefan	10.06.1985	06.10.1985	3.9	1.	1964
Rüegg Willi	15.11.1985	31.03.1986	4.5	1.	1962
Heuberger Renate	08.04.1986	08.06.1986	2.0	5.	1962
Rösch Andreas	09.06.1986	11.10.1986	4.1	1.	1965
Bantle Stefan	14.07.1986	04.08.1986	0.7	1.	1964
Uebersax Hans Peter	01.10.1986	31.01.1987	4.1	1.	1965
Häseli Urs	24.02.1987	28.03.1987	1.1	6.	1956
Saltzmann Partick	08.04.1987	30.06.1987	2.8	1.	1967
Roos Christian	07.10.1987	31.01.1988	3.9	1.	1968
Schill Herbert	17.10.1987	02.11.1987	0.5	8.	1957
Häseli Urs	01.01.1988	31.01.1988	1.0	7.	1956
Hauenstein Jürg	07.03.1988	31.03.1988	0.8	1.	1966
Schaffner Michael	15.04.1988	10.07.1988	2.9	1.	1967
Colors see first part above					



9.2.2 Management

During the Götz and Dütsch eras, the administrative and technical management of the observatory was clearly concentrated in the same hands. In the MeteoSwiss period the responsibilities were divided; thus, these functions will be presented distinctively in the following.

9.2.2.a) Administrative management

During the period he was active at the LKO (1921-1954), Götz not only took most of the long observational records by himself (for more details see Section above) but also assumed all the management functions related to the operation of the observatory, preparing the working plans, reporting to the KVV Arosa on the activities of the LKO and presenting the annual cost statements (see Figure 50 in Section 9.3.1.a). From 1954 to 1962, Perl covered these activities as Götz's successor (Sect. 4.2).

After Perl left Arosa, the LKO administrative supervision of the LKO was assumed entirely by Dütsch, with the assistance of the station managers handling the local conditions. It is interesting to note that this was also the beginning of a new era where the leading persons were no longer personally involved in taking measurements and no longer resident at Arosa.

Table 14: Persons involved in the administrative management of the LKO.

Person	Period	Affiliation/employer
Administrative supervision		
Paul Götz, PhD, Prof.	Nov. 1929 - Oct. 1953	KVV Arosa
Gertrud Perl, PhD	Nov. 1953 - Apr. 1962	KVV Arosa (under LKO advisory board)
Hans Ulrich Dütsch, PhD, Prof.	May 1962 - Dec. 1987	Professor IACETH Zürich
Jean Rieker, PhD	Jan. 1988 - Mar. 1991	MeteoSwiss Payerne
Pierre Viatte, PhD	Apr. 1991 – May 2008	MeteoSwiss Payerne
Dominique Ruffieux, PhD	Jun. 2008 – May 2018	MeteoSwiss Payerne
Alexander Haefele, PhD	Aug. 2018 - today	MeteoSwiss Payerne
Logistic support		
Jean-Michel Clerc	1991 - 2015	MeteoSwiss Payerne

In 1988, under the leadership of MeteoSwiss, the LKO was integrated in the Upper Air Division at the Aerological Station in Payerne (for the responsible persons see Table 14), which assumed henceforth the responsibility and administrative management of the ozone measurements in Arosa in addition to the ozone soundings already performed at Payerne since 1968.

9.2.2.b) Technical management and automation

As for the operational work, Götz was left on his own for the technical aspects; at least we could not find any person or any service which was involved in the technical management of the LKO during this period. However, the correspondence with Dobson as well as the exchange with the company Schmidt-Haensch concerning the development of the Arosa Spectrograph reveal that Götz possessed a solid experimental background enabling him to face the technical problems mostly alone. Occasionally, he had the support from the technical service of the University of Zürich. More critical problems were addressed with Dobson's help [586].

During the Dütsch period, at least from 1973 onwards, the LKO was part of the IACETH. The institute's infrastructure could therefore be used for technical assistance and repairs. Donat Hoegl, a technician of IACETH, was helping to cover the maintenance and development works in order to face instrumental problems of the spectrophotometers used. Dütsch was quite aware of the instrumental problems as he was applying the statistical Langley plot to the measurements series of Arosa by himself (Sect. 5.2, 7.4.1 and 7.5). He was very much concerned with assuring a high data availability; with the purchase of the Dobson spectrophotometer D101 in 1966, a complete redundancy for both the direct sun (total ozone) and the zenith sky (Umkehr measurements) was implemented. In 1975, he started a project aiming to perform automated measurements with the instrument D51 [587].

Table 15: Persons involved in the technical management of the LKO.

Person	Period	Affiliation/employer
Technical Responsability		
Paul Götz, PhD, Prof.	Nov. 1929 - Oct. 1953	KVV Arosa
Gertrud Perl, PhD	Nov. 1953 - Apr. 1962	KVV Arosa (with external assistance)
Hans Ulrich Dütsch, PhD, Prof..	May 1962 - May 1988	IACETH Zürich
Bruno Hoegger, PhD	(Jan. 1988) - Feb. 2002	MeteoSwiss Payerne
Bertrand Calpini, PhD, Prof.	May 2002 - Dec. 2011	MeteoSwiss Payerne, Deputy director
Yves-Alain Roulet, PhD	Dec. 2011 - today	MeteoSwiss Payerne
Technical staff		
Donat Högl	1985	IACETH Zürich
Gilbert Levrat	1987 - 1994	MeteoSwiss Payerne
Franz Herzog	1994 - today	SLF Davos (Mandate Meteoswiss)
Reto Wetter	1994 - 2006	SLF Davos (Mandate MeteoSwiss)
Andi Moser	2006 - 2019	SLF Davos (Mandate MeteoSwiss)
Serge Brönnimann	2006 - 2006	MeteoSwiss Payerne
Jean-Marc Aellen	2006 - 2006	MeteoSwiss Payerne
Jean-Michel Cornuz	2011 - 2015	MeteoSwiss Payerne

When MeteoSwiss came into the picture (in fact as early as 1986), the LKO could fully benefit from the technical infrastructure and services existing at the meteorological office in order to ensure the operation of its various measurement networks and activities. The technical responsibility was assumed since then by different persons as can be seen from Table 15.

586 This was the case when the Féry spectrograph Nr. 2 ("D2") was damaged during the Svalbard expedition and had to be refurbished in Oxford (Sect. 3.8 and 9.1.2.b).

587 First for the direct sun (total ozone) and in 1985 for zenith sky (Umkehr) observations (Sect. 9.1.2.b). The development was finally brought to operational maturity by MeteoSwiss.

Based on a cooperation agreement between MeteoSwiss and the Institute of Snow and Avalanche Research (SLF) in Davos, the maintenance tasks of the technical systems at the LKO were accomplished by collaborators of this institute from 1994 onwards (see Table 15). But several collaborators from the Measurement Techniques division of MeteoSwiss in Payerne were also involved in the installation, maintenance and repair as well as technical upgrading work (see Table 15).

Two automation steps[588] were realized by the Measurements Techniques division:

- Hoegger was the linchpin of the large technical renewal of the LKO in 1986-1989, which resulted in completely automated Umkehr and semi-automated total ozone measurements. This enabled an increase in the number of total ozone observations per day and ensured the optimal number of Umkehr observations because of easier operating conditions. The redundancy was also considerably reinforced in the 1990s with the introduction of the automated Brewer systems.
- The full automation of all Dobson systems occurring between 2011 and 2015 was realized at the initiative of Calpini with Stübi [589] as project leader. This again brought a quantum leap as now direct sun and zenith sky measurements could be performed quasi-simultaneously with each system at different wavelengths and the total ozone could be measured in a very stable mode at a much higher frequency [590].

9.2.3 Scientific activities

The impressive publication list of Götz (Annex 2) shows that he was scientifically very productive and assumed the scientific leadership in a very comprehensive manner during the entire time he was active at the LKO (Sect. 3.10). The Perl period was much shorter and only a few publications based on her LKO activities are available (Annex 3).

Under the scientific leadership of Dütsch, the LKO not only survived in the uncertain times following Götz's death but regained a leading role in ozone research (Chapt. 5).

In 1988, Staehelin started to contribute to ozone research at IACETH and made sure that the world's longest ozone series at Arosa could make a valuable contribution to the debate on the anthropogenic ozone depletion (Sect. 7.6.2). For more than 27 years (from April 1988 to August 2014) he acted as scientific advisor of MeteoSwiss; his contribution to SAG-Ozone (Sect. 7.5) can also be viewed as a contribution to QA/QC.

Altogether eleven PhDs dedicated to the ozone measurements of Arosa were completed (one under the lead of Götz at the University of Zürich, four under the supervision of Dütsch and seven under the

588 Details for the different instruments are given in Section 9.1.2.b.

589 Refer to footnote 495 on page 109.

590 However, the switch from direct sun to zenith sky measurements (or back) still needs manual interaction (setting/removing of the ground quartz plate and the sundirector).

Table 16: Scientists involved with the activities and the data of the LKO.

Person	Period	Affiliation/employer
Scientific leadership		
Paul Götz, PhD, Prof.	Nov. 1929 - Oct. 1953	KVV Arosa, Professor University Zürich
Gertrud Perl, PhD	Nov. 1953 - Apr. 1962	KVV Arosa
Hans Ulrich Dütsch, PhD, Prof.	May 1962 - Mar. 1988	IACETH Zürich
Johannes Staehelin, PhD, Prof.	Apr. 1988 - Aug. 2014	IACETH Zürich
Research, QA/QC and scientific support		
René Stuebi, PhD	1998 - today	MeteoSwiss Payerne, senior scientist
Eliane Maillard, PhD	2001 - today	MeteoSwiss Payerne, senior scientist
Herbert Schill	(1987) - today	MeteoSwiss Arosa, station scientist
Scientific assistance / projects		
NN. Ferenez	1926, period unknown	Replacement during study trip of Götz
NN. Meyer-Leibnitz, cand.phys.	1933, period unknown	Grants (IUGG)
NN. Zünti, cand.phys.	1936, period unknown	Grant (Giacomi Foundation)
Philippe Casparis, PhD	Apr. 1941 - May 1947	Grant (mainly Climat. Action) Intermitt.
Gian Gensler	May 1944 - Jan. 1945	Grant (mainly Climatological Action)
Ike Duninowski	Mar. 1946 - Jul. 1946	Grant (mainly Climatological Action)
Ernst Schönemann, PhD	Jul. 1946 - Feb. 1948	Grant (mainly Climatological Action)
E. Günewald	Aug. 1947 - Oct. 1948	Grant (mainly Climatological Action)
Gertrud Perl, PhD	Mar. 1948 - Oct. 1953	Grant (mainly Climat. Action) Intermitt.
Frits Weil	May 1948 - Apr. 1949	Grant (mainly Climatological Action)
Friedrich Volz	Mar. 1950 - Sep. 1951	Grant (mainly Climatological Action)
Work on LKO archives and homogenization of ozone series		
Veronique Bugnion	1995 - 1996	MeteoSwiss Payerne, project work
Marianne Giroud	1995 - 1996	MeteoSwiss Payerne, project work
PhD and Diploma Thesis		
Hans Ulrich Dütsch, PhD	PhD Thesis 1946	University of Zürich
Alexandre Piaget, PhD	PhD Thesis 1970	IACETH Zürich
Walter Züllig, PhD	PhD Thesis 1973	IACETH Zürich
Walter Birrer, PhD	PhD Thesis 1975	IACETH Zürich
Walter Braun, PhD	PhD Thesis 1984	IACETH Zürich
Thomas Moser	Diploma Thesis 1985	IACETH Zürich
Anne Renaud, PhD	PhD Thesis 1988	IACETH Zürich
Andrea Weiss, PhD	PhD Thesis 2000	IACETH Zürich Grant (GAW-CH)
Gisela Koch, PhD	PhD Thesis 2003	IACETH Zürich
Jörg Mäder, PhD	PhD Thesis 2004	IACETH Zürich Grant (GAW-CH)
Barbara Scarnato, PhD	PhD Thesis 2008	IACETH Zürich Grant (GAW-CH)
Rieder Harald, PhD	PhD Thesis 2011	IACETH Zürich Grant
Johannes Staufer, PhD	PhD Thesis 2013	IACETH Zürich Grant (GAW-CH)

direction of Staehelin[591] at LAPETH resp. IACETH[592]) in relation to the long-term ozone measurements of Arosa (Sect. 7.6.2)[593]. Anne Renaud (IACETH) also significantly contributed to the homogenization of the Arosa total ozone record. In addition, there were also quite a number of diploma theses accomplished (number not known).

MeteoSwiss was also supporting the ozone measurements in Arosa (and Payerne) at the scientific level since 1994 (as part of the Swiss GAW Programme). Several persons were/are concerned (see Table 16):

- Stübi and Maillard were covering a broad spectrum of activities including QA/QC as well as data processing and analyses. Stübi was leading the automation project of the Dobson instrument and is strongly involved in the planning of the move of the LKO from Arosa to Davos (for more details refer to Section 8.2). Maillard contributed to the processing and analysis of the Umkehr measurements as well as of the ozone profile measurements performed with the microwave radiometer SOMORA at the Aerological Station in Payerne (Sect. 7.6.1).
- Schill, already involved as a student and assistant of Dütsch at the LKO between 1977 and 1982 (see Table 13 and refer to footnote 582 on page 131), worked at the LKO on mandates from MeteoSwiss from 1987 to 2002 (especially accompanying the station staff during the phase of introduction of computer based processes as well as on QC and data handling problems) and was hired by MeteoSwiss as (part-time) station scientist in 2002.
- Specific contributions were accomplished by Giroud and Bugnion in 1995-1996 investigating and classifying the LKO Archives concerning the total ozone and Umkehr data of Arosa stored in Payerne.

9.3 Budget

In this section, the budget of the LKO during the entire duration is presented. For some specific periods detailed information was available whereas for others some approximate estimates were required.

In Section 9.3.1, the expenses related to the operation of the LKO over the entire period have been compiled. Whereas in Section 9.3.1.a) the values are given as nominal numbers in Swiss Francs (CHF) including charges as practiced in the successive periods (see Table 17), an attempt is made in Section 9.3.1.b) to present a consistent overview on the evolution of the costs of the LKO based on numbers corrected for inflation to allow a direct comparison of the expenses in the different phases[594]. In Section 9.3.2, the means devoted to scientific activities (including QA/QC, analysis and research) are estimated. These numbers might be more questionable as less direct information was available and therefore additional assumptions were required. Nevertheless, they are believed to provide valuable estimates for the efforts made on scientific work throughout the lifetime of the LKO.

591 Note that only those PhD's accomplished with Dütsch and Staehelin at LAPETH resp. IACETH are listed here which were in close connection to LKO or with financial support from GAW-CH.

592 Refer to footnote 12 on page 4.

593 For the names see Table 16 and for the titles see the References.

594 Following common terminology, we use here "nominal" for the values in the currency used at the time and "real" for values adjusted for inflation.

9.3.1 Operational costs

9.3.1.a) Operational budget based on nominal values

From the outset to the early 1930s, the KVV Arosa was the only institution supporting the LKO based on an annual budget [595]. At the very beginning, the study of the climatological conditions of Arosa was planned for a short period [596] and the budget was rather modest. The costs for the first 6 months amounted to 1,563 CHF; the budget for the first full financial year was of 4,000 CHF. In the first years, when the LKO was located at the Sanatorium Arosa (see Sect. 3.1 and Figure 1), we might assume that no cost was required for renting rooms. After 1926, when the LKO moved to Götz's own house (Villa Firnelicht), the continuation of the activity of the LKO was considered on a longer time scale and the budget was increased significantly. As can be seen from Figure 49, the KVV Arosa paid during the period 1924-1930 on average 8,000 CHF/y in order to support the core program of the measurements, including total ozone and radiation measurements [597].

Table 17: Approximated charges applied to the staff costs (a simplified scheme is used).

Period	Years	Social contributions	Overhead costs	Total
Götz KVV Arosa	1921-1975	2%	5%	7%
Dütsch ETHZ	1976-1985	7%	10%	17%
MeteoSwiss/ETHZ	1986-2015	15%	20%	35%

In the second decade, beginning in 1932 [598], the Railway Company Chur-Arosa [599] began to support the activities of the LKO, first with approximately 2,500 CHF/y in the 1930s and then with 4,000 CHF/y in the 1940s. At the same time the community of Arosa also started contributing on a regular [600] basis with 2,000 CHF/y. The yearly spending of the LKO therefore grew on average to roughly 12,500 CHF/y during the decade 1932-1940.

595 As mentioned in Section 3.4, budget information could be found in the annexes of the annual reports of the Kur- und Verkehrsverein Arosa which were published annually (KVVA, 1921-1977).

596 Initially for one year, extended in December 1922 as can be concluded from comments in the correspondence Dorno-Götz of 27 and 30 December 1922.

597 This contribution represented about 2.8% of the mean annual budget (291,334 CHF) of the KVV Arosa in the years 1924-1929.

598 The Annual Reports of the KVV Arosa for 1930-1933 are missing (Sect. 3.4).

599 Refer to footnote 157 on page 37.

600 Note that "regular sponsor" covers different types of sponsors that allowed to finance the operational measurements excluding specific research proposals.

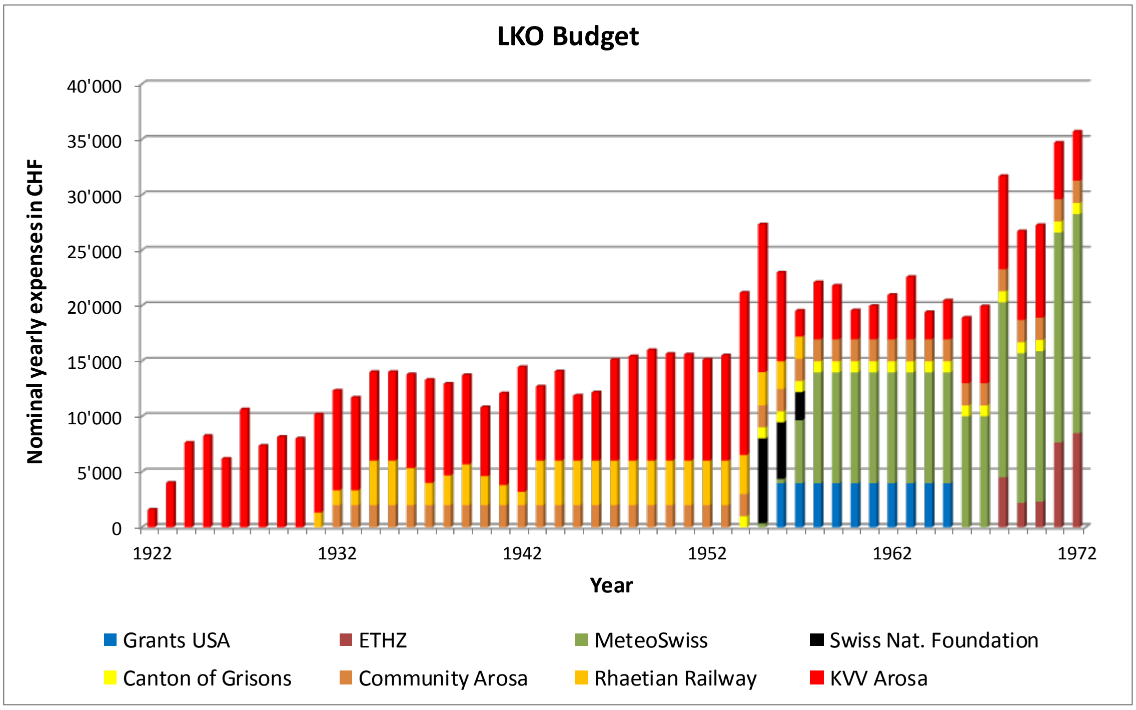


Figure 49: Annual expenses of the LKO in Swiss Francs (CHF) for the period 1921–1972 paid by the "regular sponsors" including the KVV Arosa (1921-1972), the Rhaetian Railway Company (1932-1957), the Community Arosa (1932-1972), the Canton of Grisons (1953-1972), Swiss National Foundation (1955-1957), MeteoSwiss (1956-1972) and ETH Zürich (1969-1972) (the numbers are nominal, not inflation-adjusted).

At the beginning of World War II, the KVV Arosa as well as Rhaetian Railway Company reduced their funding intermittently and the budget of the LKO dropped down to lower levels during the first years of the war (approximately CHF 10'000 in 1940), which seriously threatened the activities of the LKO [601].

For the period 1944-1953, the values of the budget are derived from the detailed monthly accounts of the LKO expenses (see Figure 50) as submitted by Götz to the KVV Arosa [602].

Figure 51 gives an overview of the size of the different budget items, as defined by Götz, based on averaged monthly values for the last 10 years of Götz's working life. In this period, the operating budget (mainly dedicated to running costs) covered by the "regular sponsors" amounted on average to 13,900 CHF/y [603].

601 Remember that Götz seriously considered leaving Arosa around 1940 (Sect. 3.6.3).

602 Found in the LKO Archives.

603 Note that the expenses concerning externally financed project staff (grants) are not included in this cost breakdown, they are part of the scientific means (Sect. 9.3.2).

Kur- und Verkehrsverein
Arosa
Postcheckrechnung X 1649

Rechnung *für* Dezember 1946

BUCHDRUCKEREI A.-G., AROSA

A)LICHTKLIMATISCHES OBSERVATORIUM AROSA					
Gehalt Prof. Götz mit Teuerungszulage	807.	50			
abzüglich 2% Lohnausgleichskasse	16.	15	791.	35
Miete Observatorium Anteil Obs.-Rechg.			180.	00
Apparate -Unterhalt Sendung Prof.Kreis			2.	00
Studienkosten				
Fixiersalz etc 1.35 1.00	2.	35		
Copien 1.30 0.46	1.	76		
1 Leihbatterie (Koller)	10.	00	14.	11
Allg.Unkosten				
Porto	16.	70		
Auslagen bei Besuch Prof.Volochine	12.	00		
Millimeterp. 1.87 Kohlepap.etc4.21	6.	08		
Auslagen Hauswart Wiederkehr Jungfraujoch	18.	00	52.	78
			1040.	24
B) KLIMATOLOGISCHE AKTION				
Gehalt Assistent Caparis 400.–				
abz.2% 8.–	392.	00		
Gehalt Assistent Schönmann				
(bei 6 Std. Arbeitszeit) 300.–				
abz.2% 6.–	294.	00		
Teilbetrag Miete Observatorium	100.	00	786.	00
C)Meteorologische Station Arosa				
Telefon Abonnementstaxe	9.	50		
Schneepegel- Reparatur (Flüeler)	9.	10		
1 Batterie (Hold)	1.	19		
1 Uebernachten Zürich zwecks Vornahme von Auszügen an der Meteor.Zentralanst.	10.	00	29.	79
Gesamtbetrag von A) B) B)			1856.	03

Den Empfang von Frs 1856.03
bestätigt Arosa, den 20. Dezember 1946

Der Leiter des Observatoriums:

Zahlbar innert 30 Tagen an unserer Kasse oder auf Postcheckrechnung X 1649.
Nach Verfall werden 5% Verzugszins berechnet.

Figure 50: Expenses of the LKO in December 1946. Detailed monthly accounts (established by Götz) are available for the period 1944-1953). (Document LKO Archives).

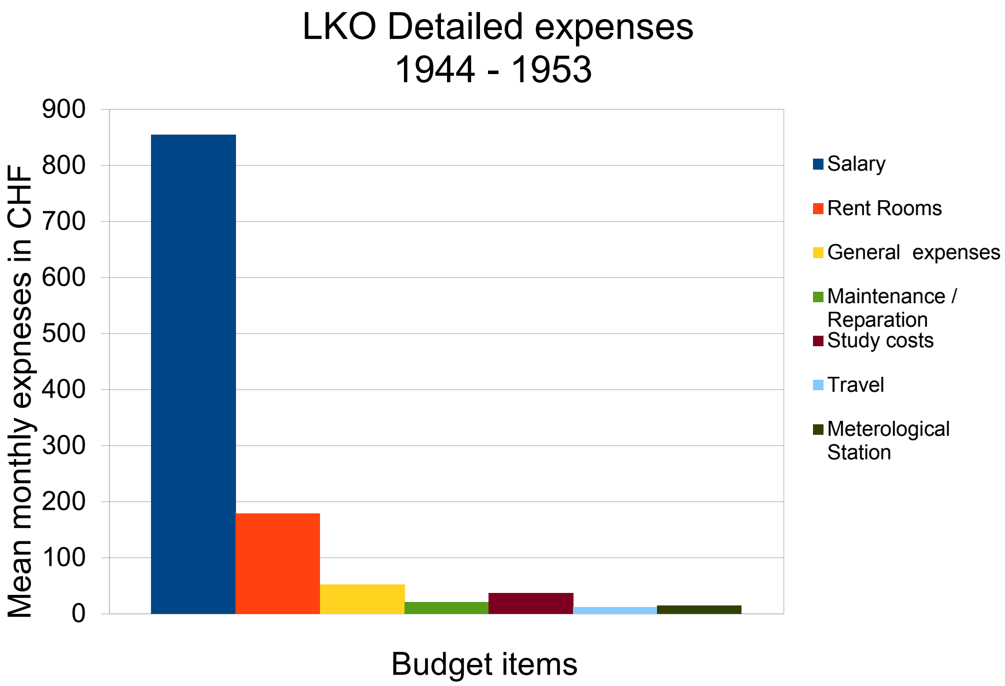


Figure 51: Averaged monthly budget of the LKO in Swiss Francs (CHF) for the period 1944-1953 categorized according to different budget items as defined by Götz (based on detailed monthly invoices as in Figure 50).

During these years, Götz's salary represented approximately ¾ of the regular budget; the part including salary as well as the rent of the observatory rooms corresponded to nearly 90%. No investments are specified during the whole period 1944-1953. The 3% expenses for "*study costs*" [604] paid on the regular budget are very low and correspond exclusively to expenditures such as paper, pencils and stamps; they do not include the time Götz needed to analyze and publish the results of his research[605].

It is interesting to follow the evolution of the salary of Götz during his career at the LKO. In the first year, it must have been no more than 330 CHF/m. It can be established that the salary part of the budget was 660 CHF/m in 1944. The last monthly settlements from October 1953 indicate that the salary component reached 915 CHF/m in the last year before death; this is still rather modest keeping in mind his extraordinary efforts (Sect. 3.10) [606].

When it became clear in 1953 that Götz, who was seriously handicapped since 1951-1952 (Sect. 3.11), would not recover from his illness and could no longer sustain the operational measurements, a pension was awarded by the KVV Arosa to him and his wife. This explains the higher level of the budget in 1954 and the following years (see Figure 49). Furthermore, a solution had to be

604 Götz called this „Studienkosten".

605 As shown in Chapter 3, Götz was a very productive scientist.

606 This corresponded to annual salaries of 4,000 (1922), 7,920 (1944) and 10,980 (1953) CHF/y in nominal values. When adjusted for inflation (real values), annual incomes of respectively 27,000, 43,000 and 54,000 CHF/y would guarantee the same purchasing power in 2015 (Consumer price index (Konsumentenpreisindex KPI)). But taking into account the wage index (Historischer Lohnindex HLI) instead of the consumer price index, this would rather correspond to wages of respectively 59,000, 105,000 and 109,000 CHF/y in 2015 (both indices according to Swistoval, www.swistoval.ch, state of 14 January 2019 (Pfister and Studer, 2019)) (Information made available by Tobias Straumann, Professor of Economic History of the University of Zürich). Thus, the increase of salary between 1922 and 1944 was quite significant, but the values were still modest compared to actual wages.

found for the continuation of the LKO (Sect. 3.11 and Sect. 4.2). During this period, the SNSF made an important contribution to allow continuation of the measurements of the LKO, deciding at the request of MeteoSwiss [607] to support the LKO with 5,000 CHF/y for three years, thereby allowing Perl, who had been Götz's assistant since 1948, to be paid a salary. Prior to this she had been funded with external grants [608].

At the end of Götz's career the long-term continuation of the LKO became very uncertain [609]. As president of the committee for the Swiss activities of the IGY [610], Jean Lugeon [611] was greatly interested by the prospect that ozone measurements from the LKO could be part of the Swiss contribution to the IGY and arranged financial funding (10,000 CHF/y beginning in 1956) from the budget of MeteoSwiss for the operation of the LKO before and during IGY. The support by MeteoSwiss was crucial as from 1953 onward the Rhaetian Railway Company began to gradually reduce its funding [612]; it completely stopped in 1958. This funding was partly replaced by financial support from the Canton of Grisons of 1,000 CHF/y beginning in 1954, while the subsidizing of 2,000 CHF/y by the community of Arosa was still ongoing. MeteoSwiss did not abandon the financing of the LKO after the IGY and its financial contribution was maintained at the same level up to 1973 when ETH Zürich took over complete financial responsibility for the LKO.

The ozone profile measurements with the Umkehr method introduced by Dütsch in 1956 into the observational program of the LKO were first based on US grants [613]. Although the precise amount of these grants is not known, it can be reasonably assumed that they must have been in the order of 8,000 – 10,000 CHF/y enabling him to finance the assistance from the students [614] throughout these years (Sect 9.2.1.a). These new resources were important to guarantee the continuation of the activities in the uncertain times after the death of Götz.

As Perl had to leave Arosa in 1962, Dütsch undertook the scientific leadership of the LKO (Sect. 4.2) and assumed full responsibility for the LKO in 1965 when he became professor at ETH Zürich. At first there were no significant changes in the funding of the LKO (Sect. 5.2). The main support still came from MeteoSwiss (10,000 CHF/y). The funding of the KVV Arosa (5,000 CHF/y on average), the community of Arosa (2,000 CHF/y) and the canton (1,000 CHF/y) were also continued. Financial contributions of ETH Zürich appear in the accounts of the annual reports of the KVV Arosa from 1968 onwards, with 5,000 CHF/y on average in the following years, thus allowing the budget of the LKO to reach 24,000 - 27,000 CHF/y in the years 1968-1972. When the US grants ceased in 1965, the students were paid out of the regular LKO budget and SNSF grants.

The complete financial integration of the LKO in ETH Zürich was only achieved in 1973 when the LKO moved to the Haus Steinbruch (Sect. 5.3). The budget situation then evolved in the following

607 Minutes from the meeting of the Federal Meteorological Commission (Eidgenössische Meteorologische Kommission, EMK) of 27 March 1953.

608 The SNSF support is here included as "regular sponsor" as its support for salary of Perl allowed continuation of regular ozone observations.

609 In December 1953, the KVV Arosa agreed to extend its financial contribution for only three more years.

610 Refer to 223 on page 45.

611 Refer to 126 on page 34.

612 From 4,000 CHF/y before 1954, the funding dropped to 2,000 CHF/y in 1957.

613 Grants from the US Air Force (1956-59, 1961-1963) and later from the National Center of Atmospheric Research (NACR) (1963-65); refer also to Section 5.1).

614 One or two students at a time hired on a 3-6 months-basis.

way: the Canton of Grisons stopped its contribution in 1974, while the community of Arosa and the KVV Arosa continued to support the LKO until 1977, the first maintaining its contribution of 2,000 CHF/y and the second reducing the amount to 2,000 CHF/y.

Thereafter, the costs of the LKO were (formally) covered by the budget of IACETH. Despite rather sparse information available for this period, the annual costs of the LKO paid on the budget of ETH in 1980, can be estimated to be in the order of 130 kCHF/y (see Table 18). The main contributions were the salaries (71 kCHF/y) and the rent of the platform as well as the apartments and the office rooms in the Haus Steinbruch (49 KCHF/y) [615].

The mean annual operational costs (nominal) grew to averaged levels of roughly 400 kCHF/y (Viatte, 2001; Ruffieux, 2011 and 2016) in the decades 1995-2015 [616] when MeteoSwiss was fully in charge of the LKO, as can be seen from Table 18. The renewal and upgrading of the technical equipment (Sect. 7.3) generated considerable investment (amortization) costs [617]. Furthermore, the technical maintenance was now carried out by a technical group from the Institute for Snow and Avalanche Research [618] in Davos, paid from the MeteoSwiss instrumental budget (Sect. 9.2.2.b). In addition, the operation of the measurements was organized with the assistance of salaried employees (instead of students on a more or less volunteer basis) (Sect. 7.3 and 9.2.1.b), which represents a remarkable financial charge when taking into account the performance specifications with extended working hours on a daily basis (week-ends included).

Table 18: Mean annual expenses (nominal and real) averaged per decade concerning the operation of the LKO between 1926 and 2015 (in kCHF/y) according to different budget items, charges included according to Table 17 (information for breakdown into different budget items is not available for the years in which only the total amount is given).

LKO Budget 1925 – 2015							
Years	**Salary**	**Expandables**	**Maintenance**	**Investments**	**Rent**	**Total nominal**	**Total Infl.-adj.**
1926-34						9.3	65.3
1936-45						12.1	78.2
1946-55	7.2	1.2	0.3		2.2	11.3	75.7
1956-65						20.5	81.6
1966-75						38.0	107.9
1976-85	70.6	2.0	5.0	5.0	48.5	131.1	239.9
1986-95	148.4	5.0	30.5	25.0	46.0	254.8	341.1
1996-2005	227.7	7.0	36.1	30.0	48.8	349.5	388.4
2006-2015	305.1	7.2	38.1	29.8	54.1	434.3	446.5

615 For comparison, during the decade 1944-1953 the KVV Arosa paid nominally 2,160 CHF/y (180 CHF/m) to Götz in order to cover the costs of the measuring platforms at Villa Firnelicht (see Figure 51), while in the Florentinum period (1954-1973) the yearly rent was nominally 2,040 CHF/y (170 CHF/m). In real values, the rent costs were approximately 10,000 CHF/y in 1950 (Firnelicht), 7,000 CHF/y in 1965 (Florentinum) and 90,000 CHF/y in 1980 (Steinbruch).

616 Concerning the averaged value of the decade 1986-1995 in Table 18, it must be taken into account that this corresponds to the period where the transition from ETH Zürich to MeteoSwiss took place.

617 With respect to the estimated investment costs of about 625 kCHF for this renewal (including the acquisition of the three Brewer systems), an amortization of 25 kCHF per year for 25 years has been taken into account.

618 Refer to footnote 190 on page 40.

9.3.1.b) Evolution of operational budget based on real values

For an appropriate overview of the evolution of the costs of the LKO (covered by the "regular sponsors") over the whole duration it is necessary to compare real values, i.e. values after adjustment for inflation [619]. The inflation-adjusted values, averaged over 10 year periods, are shown in Table 18 and Figure 51. Three distinct cost levels corresponding to the different periods (Götz KVV Arosa, Dütsch ETHZ [620] and MeteoSwiss/ETHZ) can clearly be distinguished.

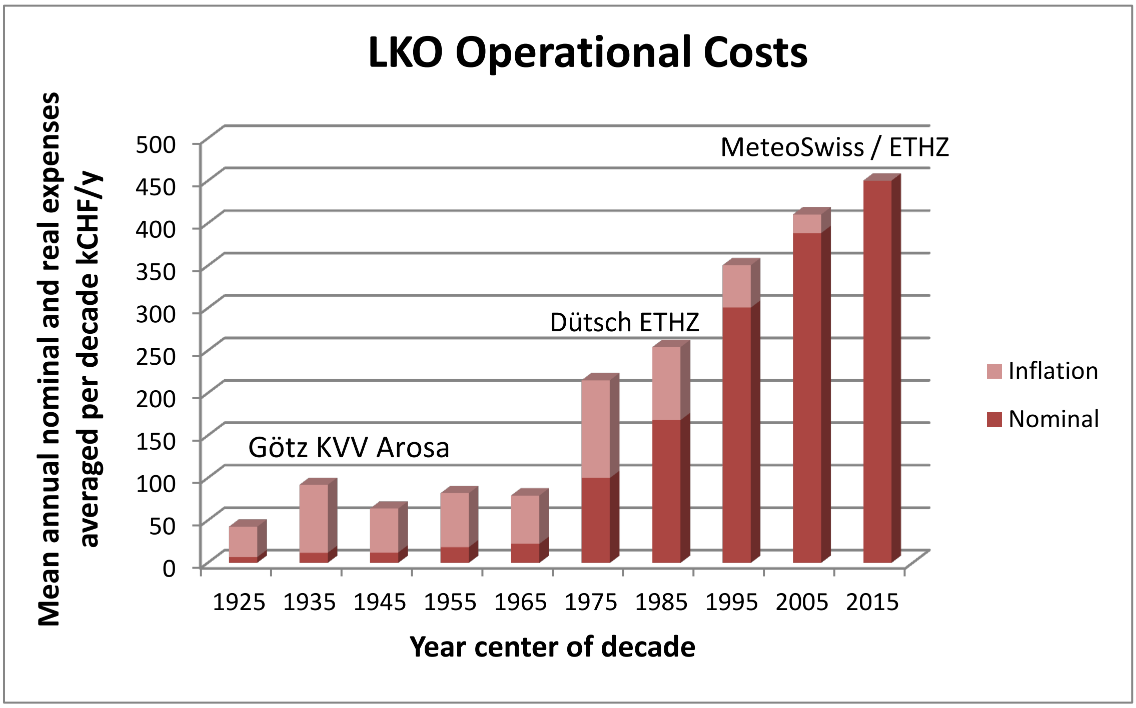


Figure 52: Mean annual expenses (nominal and real (inflation-adjusted)) averaged per decade in Swiss Francs (kCHF/y) concerning the operation of the LKO between 1925 and 2015 ("real" means taking into account inflation (2015=100%). For 2015, the value of this particular year is shown.

In the first 50 years, the real costs (inflation-adjusted) were approximately 70 kCHF/y on average (see Figure 52) [621]. As pointed out in Section 3.4, in this period the LKO under Götz can be viewed as a one-man research company, with continuous but rather modest support mainly from the KVV Arosa (and other "regular sponsors" [622]). Only in one exceptional case were costs required for instrumentation (Arosa ultraviolet spectrograph see Section 9.1.2.a); the rest of the time Götz used spectrophotometers made available by Dobson (Sect. 3.7 and 9.1.2.b). He clearly performed nearly all of the observations with Dobson spectrophotometers and other instruments himself, at least in the 1920s

619 This has been completed based on the Swiss consumer price index (annual average, base being December 2015 = 100) published by the Swiss Federal Statistical Office (Eidgenössisches Bundesamt für Statistik (BFS)) Neuchâtel (Switzerland).

620 Corresponding to the period after move of the LKO into the Haus Steinbruch.

621 It has to be noted that the peak in terms of buying power observed in the decade 1935 (1931-1940) seems to be accentuated by the inflation adjustment (deflation).

622 Note that the "regular sponsors" also supplied Götz's income for the time which he devoted to the analysis of the measurements as well as to the many publications and attendance of conferences and meetings (see Table 4 in Section 3.4). Therefore only 70 % of the support of the "regular sponsors" were attributed to the operational costs whereas 30% were attributed to research and publication.

and 1930s; it was only in the late 1940s that he could benefit from the support of young scientists [623] who also helped with the operational measurements. His salary and the income from renting rooms [624] in Villa Firnelicht were rather small (see Figure 51).

During the period in which the operational costs of the LKO were fully covered by ETH Zürich, i.e. after the move to the Haus Steinbruch in 1973, the real (inflation-adjusted) value of the annual budget was in the order of 240 kCHF/y (see Table 18 [625]). The increase in expenses compared to the former period is clearly visible, even if strongly attenuated by the inflation adjustment. The raise was partly due to the higher salary of the professional observer as the station manager was now paid with ETH remuneration, important for the long-term perspective. Furthermore, the market price was now paid for the observatory rooms as the Haus Steinbruch was a private building; the rent was therefore significantly higher than in the previous periods [626]. As the working conditions at Florentinum were very difficult it was an important step for the LKO to move to the Haus Steinbruch, which offered a working environment for the employees in charge of the measurements corresponding to modern standards.

When MeteoSwiss took over responsibility for the LKO in 1988, reliable ozone trend determination became of particular interest. As the long-term ozone evolution related to the MP and its strengthening's was more and more in the focus (see Figure 34), the requirements concerning long-term stability of the ozone measurements were higher than in earlier times (Sect. 7.1). MeteoSwiss addressed this challenge by consolidating the infrastructure and upgrading the measurement capabilities, by professionalizing the maintenance services and by reinforcing the operational staff. This corresponded to a financial commitment which had never been made before and explains the jump of the expenses visible in Figure 52 (compared to the previous periods) with the annual operational real costs of the LKO in inflation-adjusted terms rising on average as high as 420 kCHF/y [627] in the years 1995 to 2015 [628].

9.3.2 Scientific financial resources

The purpose of this section is to estimate the financial resources dedicated to scientific work and value-added activities concerning the data gathered at the LKO (and at Tschuggen) during the different periods. The amount of support for scientific work is of a different nature compared to the operational costs described in Section 9.3.1. Here we included both QA/QC activities allowing enhancement of the potential of the measurements for data analysis as well as scientific studies aimed at getting articles published in peer reviewed journals. The latter might be viewed as a sort of indicator

623 Engaged on external research grants (not shown in the cost breakdown of Figure 51).

624 Refer to footnote 615 on page 144.

625 The decade 1976-1985 gives the most representative value.

626 Refer to footnote 615 on page 144.

627 The increase still visible in Figure 52 from 1995 to 2015 is the sign that the inflation adjustment does not fully compensate the evolution of the charges during this period. This indicates that that the consumer index does not reflect the progression of the salaries occurring in this period as the other charges have not changed significantly during these years (see Table 18).

628 The value of 450 kCHF in 2015 constitutes a peak in the operational expenses of the LKO. With the reduction of the observations since 2015 (meteorological and snow observations abandoned) the costs were already reduced. Substantial savings (all in all almost 1/3 of the costs) are particularly expected to be realized with the move to Davos taking into account the elimination of the renting costs, taking advantage of the automation of the spectrophotometers and benefiting from the synergy with the PMOD for the operational and technical aspects. It is to precise that the costs of the full automation of the Dobson spectrophotometers realized in 2010-2015 were not included here.

of the scientific attractiveness of the measurements in that the greater the investments for scientific activities the more valuable the data generally is for the scientific community [629]. Only funding spent by Swiss institutions were considered in this overview, although very valuable studies using Swiss ozone data have been realized by scientists from other countries [630].

Table 19 presents an estimate of the costs related to the scientific work based on approximate nominal and real (inflation-adjusted) numbers; they demonstrate the constant efforts in manpower (PU) which have been made in the different specific periods to enhance the quality and exploit the added value of the data obtained at the LKO by treating the scientific aspects related to these measurements.

Numbers for the 1920s and 1930s are very difficult to determine and might be underestimated: without direct information available from the early periods of the LKO to precisely assess the time devoted by Götz to the analysis of the measurements and publication, this part is estimated to be in the order of 30% (see Table 19). Götz started his extraordinary scientific production at the beginning of the 1920s (Annex 2), but before the period 1944-1953 the budget covered by the "regular sponsors" gave him the opportunity to engage assistants only occasionally (Sect. 9.2.1.a).

Table 19: Estimated mean annual manpower costs (nominal and real) averaged per decade dedicated to scientific work (covering QA/QC, analysis and research) related to the LKO measurements between 1926 and 2015 (in Personal Units (PU) and Swiss Francs (kCHF/y)). (MeteoSwiss is mainly in charge of QA/QC whereas the ETH contribution covered scientific analysis and publication to a large extent).

Annual costs of scientific activities devoted to LKO measurements											
	KVV Arosa / ETHZ [a)]					MeteoSwiss		SNSF + GAW [b)]			
	Scient. Assistant		Senior Scientist			Senior Scientist		PhD student			
Years	**PU**	**Costs [c)]**	**PU**	**Costs [c)]**	**Total**	**PU**	**Costs [c)]**	**PU**	**Costs [c)]**	**TOTAL**	**TOTAL Infl.-adj.**
1926-34			***0.30***	***1.3***	***1.3***					1.3	9.24
1936-45			***0.30***	***2.5***	***2.5***					2.5	16.01
1946-55	***1.36***	***6.0***	***0.30***	***3.2***	***9.2***					9.2	44.54
1956-65	***1.00***	***4.0***	***0.10***	***8.9***	***12.9***					12.9	51.29
1966-75			***0.10***	***9.4***	***9.4***			1.0	21.0	30.4	86.32
1976-85	0.15	2.6	0.15	36.7	39.3			1.0	27.0	66.3	121.43
1986-95			0.25	60.5	60.5	0.10	15.8	1.0	35.0	111.2	148.87
1996-2005			0.30	71.6	71.6	0.30	64.4	1.0	44.0	180.0	199.98
2006-2015			0.30	90.8	90.8	0.45	102.1	1.0	53.0	245.9	252.87

[a)] Upper part = KVVA (italic/bold) - lower part: = ETHZ (normal)
[b)] SNSF=Swiss National Science Foundation; GAW=Swiss GAW project (trough MeteoSwiss)
[c)] Costs including social charges and overhead

629 The priority of ozone science in the international science agenda is also important in the context of the number of scientific articles. However, when the number of publications is considered, one also should take into account that the topic of ozone research might lose its attractiveness when the political problem is considered solved by the MP.

630 One of the most significant contribution directly deduced from the Arosa total ozone series was the result of the PhD thesis of Harris dedicated to the issue of ozone depletion (Harris, 1989; Sect. 6.1).

Götz had been looking for external support since the late 1920s. He financed his expedition to Svalbard with a grant from the German Research Foundation [631] (Sect. 3.8) of 4,000 Reichsmark [632]. Because of serious financial restrictions at the beginning of World War II, Götz began applying intensively for grants in order to tackle new projects and to ensure an optimal scientific evaluation of the data. He prospected the private industry [633] and public institutions in Switzerland [634] as well as outside of Switzerland [635]. From 1944 onwards he had the opportunity to participate in a "climatological action" of the Swiss government (Sect. 3.6.4). From this action, he obtained 10,000 CHF/y for four years; on average the different grants represented 6,000 CHF/y in the years between 1944 and 1953. He therefore had the possibility of hiring 8 collaborators during this period, from some months to several years as summarized in Table 20 [636]. As the regular budget covered by the "regular sponsors" (mainly dedicated to operational activities) amounted to about 15 kCHF/y, the external grants of 6 kCHF/y represented in the last period of Götz's career practically 30% of the total budget of 21 kCHF/y. When adjusted for inflation, the mean annual resources devoted to scientific work in the period 1946-1955 can be estimated at amounting to 45 kCHF; for the decade 1956-1965 they were in the order of 50 kCHF (see Table 19).

Table 20: External grants (in CHF) obtained by Götz during the period April 1944 to October 1953 and collaborators hired at the LKO on these grants.

LKO Grants and collaborators during the period April 1944 - October 1953									
Name	**Begin**	**End**	**MTH**	**CA (CHF)**	**UZH (CHF)**	**IO_3C (CHF)**	**IRC (CHF)**	**HR (CHF)**	**TOTAL**
Ph. Casparis	Apr. 1944	May 1947	37	12,864					12,864
G. Gensler	May 1944	Jan. 1945	9	2,280					2,280
I. Duninowski	Mar. 1946	July 1946	5	1,372					1,372
E. Schönmann	July 1946	Feb. 1948	21	5,691					5,691
E. Grünewald	Aug. 1947	Oct. 1948	3	412					412
G. Perl	Mar. 1948	Oct. 1953	54	8,085	2,799	467		13,500	24,850
F. Weil	May 1948	Apr. 1949	12	3,222					3,222
F. Volz	Mar. 1950	Sep. 1951	19	6,672			1,862		8,534
TOTAL			160	40,597	2,799	467	1,862	13,500	59,224

CA Climatological Action, UZH University Zürich, IO_3C Internat. Ozone Commission, IRC Internat. Radiation Commission, HR Hofmann La Roche

631 Refer to footnote 111 on page 30.

632 Approximately 5,000 CHF, corresponding today to 30,000-32,000 CHF (when adjusted for inflation).

633 Hoffmann-La Roche, Basel (Switzerland).

634 University of Zürich and the Swiss Federal Office of Transport.

635 International Commission for Ozone (IO_3C) and the International Radiation Commission.

636 However, it is difficult to quantify how much these collaborators contributed to the analysis resp. publication of the data and how much also to the performance of the measurements. Here the work load of the collaborators funded by external grants is exclusively attributed to their scientific analysis (wich is probably not a completely realistic assumption).

During the period 1965-1985, when Dütsch was professor at ETH Zürich, the LKO could benefit from the infrastructure and services of ETH not only to support the operation of the observations but also to promote scientific studies based on the data [637]. With the contribution of Dütsch himself to the processing and interpretation of the LKO's measurements and the PhDs funded in this period, the real expenses dedicated to the scientific work were approximately 85 kCHF/y for the decade 1966-1975 and 120 kCHF/y for the decade 1976-1985, when adjusted for inflation (see Table 19) [638].

Justified by the observed decline of the ozone layer and the MP (Sect. 7.1), with the start of the collaboration MeteoSwiss-ETH Zürich in 1988, a great effort was devoted not only to the technical and operational aspects of the LKO but also to QA/QC and scientific studies. Staehelin on the ETH side as well as Stübi (since 1998) and Maillard (since 2001) at MeteoSwiss dedicated an important part of their time to scientific activities related to the LKO ozone measurements [639] (Sect. 9.2.3). The work devoted to SAG-Ozone (see details in Section 7.5) can also be viewed as a substantial contribution of MeteoSwiss as well as ETH Zürich to QA/QC matters. Furthermore, financial support for PhD theses was available in all the years from 1988 onwards [640]. With these facts in mind, it can be assumed that the yearly contributions for scientific work during the period 1996-2015 amounted on average to 225 kCHF/y when inflation is taken into account (see Table 19 and Figure 53).

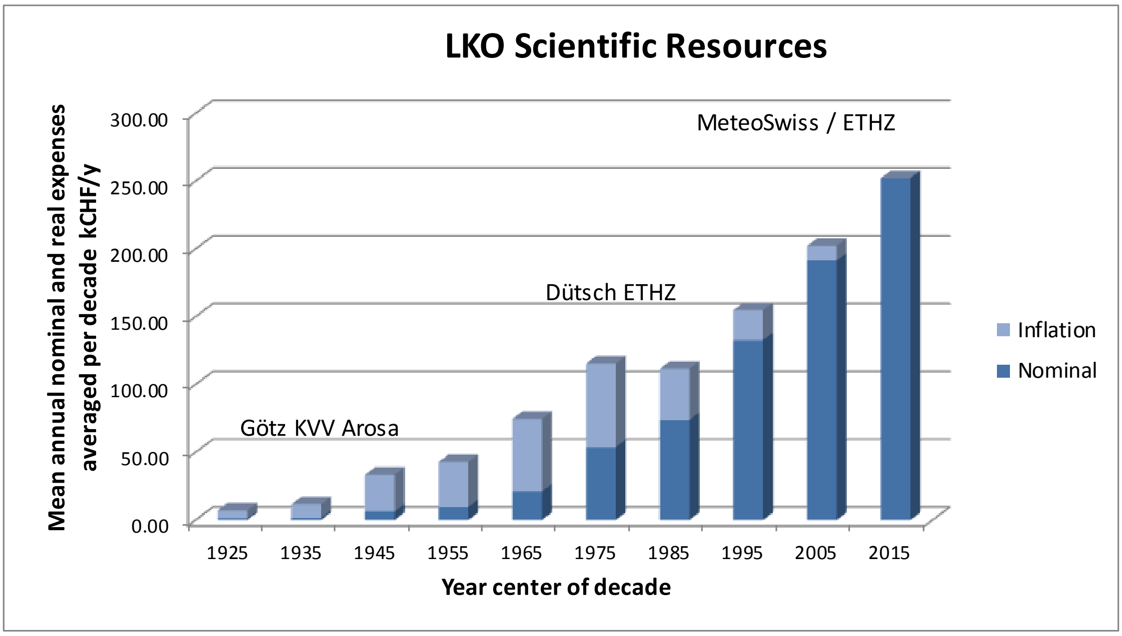


Figure 53: Mean annual expenses (nominal and real (inflation-adjusted)) averaged per decade in Swiss Francs (kCHF/y) concerning the scientific work (covering QA/QC, analysis and research) related to the LKO measurements between 1925 to 2015 ("real" means taking into account inflation (2015=100%). For 2015, the value of this particular year is shown.

637 Several PhD theses (mainly supported by the SNSF and GAW-CH) were dedicated to the analysis of the ozone data (Sect. 9.2.3).

638 This is probably a rather conservative estimate.

639 Note that QA/QC was mainly covered by MeteoSwiss.

640 Not only in the framework of the GAW-CH-Ozone project but also financed by other institutions (Sect. 9.2.3).

The real (inflation-adjusted) financial budget values, as displayed in the graphical representation of Figure 53, clearly show the increasing levels of the annual expenses spent on scientific work (including QA/QC, analysis and research) for the different periods of the LKO as explained in the text above.

The means dedicated to research resp. scientific work (see Table 19 and Figure 53) represent the efforts invested to exploit the measurements added value. Figure 54 allows the comparison of the scientific resources with the operational costs. Since the 1940s [641], they are estimated to be most of the time [642] at a level corresponding to approximately half of the operational costs, independent of the organizational and financial regime at the LKO [643]. The means, although substantial, may appear somehow moderate when trying to make full use of the potential of the LKO observations. But it should be made clear that we only included here Swiss research contributions, in the last decades mainly of MeteoSwiss and ETH Zürich. In fact, as demonstrated by the preceding chapters, the measurement activities of the LKO have to be seen in a larger, internationally oriented context, which

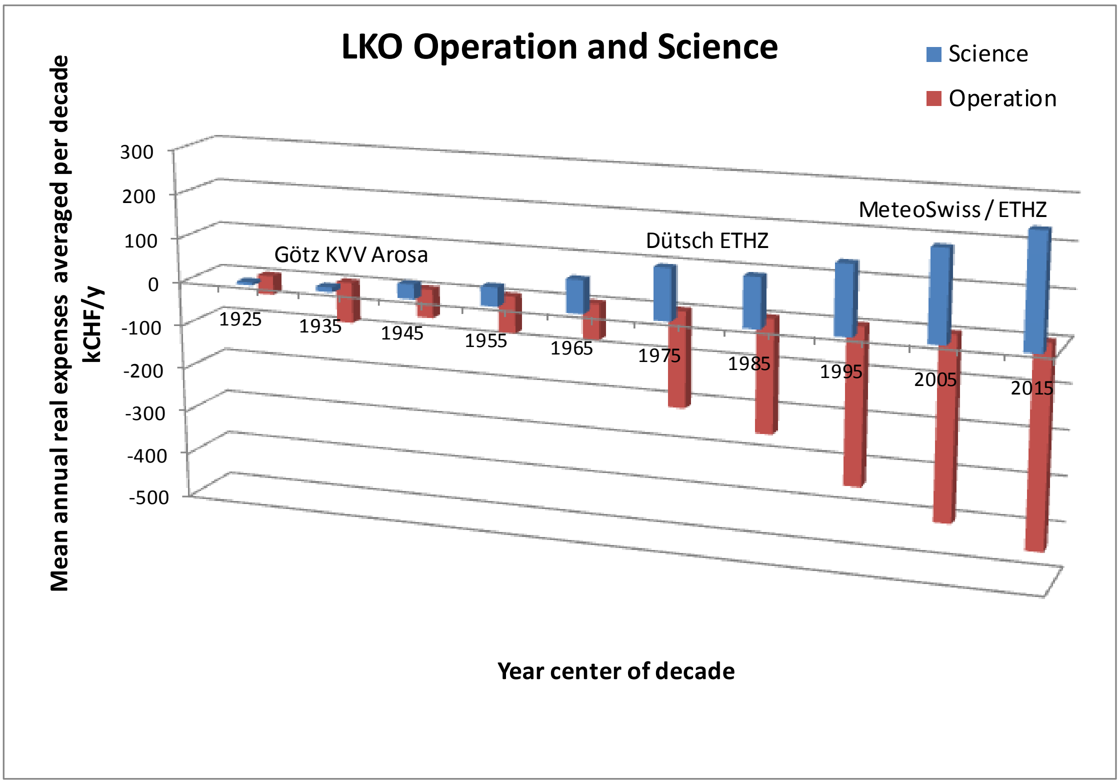


Figure 54: Mean annual real (inflation adjusted) expenses averaged per decade in Swiss Francs (kCHF/y) concerning the operational and scientific work related to the LKO measurements (for definition see text) between 1925 and 2015. For 2015, the value of this particular year is shown.

641 Because of the difficulty to properly assess the part of operational resp. scientific work of Götz, the values of the first two decades are of limited relevance.

642 In the decade centered on 1965 the ratio is higher (almost 95%) which may be due to the fact that the operational budget was still at the same level as before, but research projects initiated by Dütsch at ETH Zürich were already started.

643 Corresponding to the specific periods: Götz KVV Arosa, Dütsch ETHZ and MeteoSwiss/ETHZ.

existed all the time as shown by the many visiting scientists at the LKO. In particular, the ozone measurements were (and still are) mainly aimed as a contribution to the world wide ozone monitoring in the framework of the GAW Programme of WMO. They are also very useful for the calibration of the satellite measurements as the Arosa platform include both reliable Dobson as well as Brewer data. Most of the added value is therefore realized through the use in global trend reports, the satellite ground truthing as well as analyzes made by scientists all over the world. But, nevertheless, the studies resp. scientific activities financed at the national level are crucial to control and maintain the high quality of the data and to give a rapid feedback to the persons in charge of the performance of the observations.

9.3.3 Overall expenses

From the real values presented above we can roughly estimate the total expenses of the LKO over the entire duration. In inflation-adjusted terms, the cumulated operational costs correspond approximately to an amount of 18 million CHF and the amount spent by Swiss institutions for related scientific activities represent nearly 10 million CHF. The estimated total expenses related to the LKO for the period 1921-2015 are therefore in the order of 28 million CHF.

In 2017, the annual costs dedicated to Data and Climate [644] in the budget of MeteoSwiss amounted to 28.6 Million CHF [645]; the expenses for the LKO during almost 100 years therefore correspond nearly to the annual expenses of MeteoSwiss for activities related to the measurements.

The overall LKO expenses might not seem especially high compared to the costs of satellite missions [646] when considering the benefit these ground-based measurements, among others, bring to the satellite systems.

644 This corresponds to the Product Group 1 (PG1) of MeteoSwiss.

645 MeteoSwiss Report „Fakten und Zahlen“ of 2017.

646 In 2017, the Swiss contribution to EUMETSAT (from the MeteoSwiss budget) was 18.8 Million CHF.

10 Summary and outlook

Here we summarize the key results of the historical Swiss long-term ozone study (see Sect. 1.1).

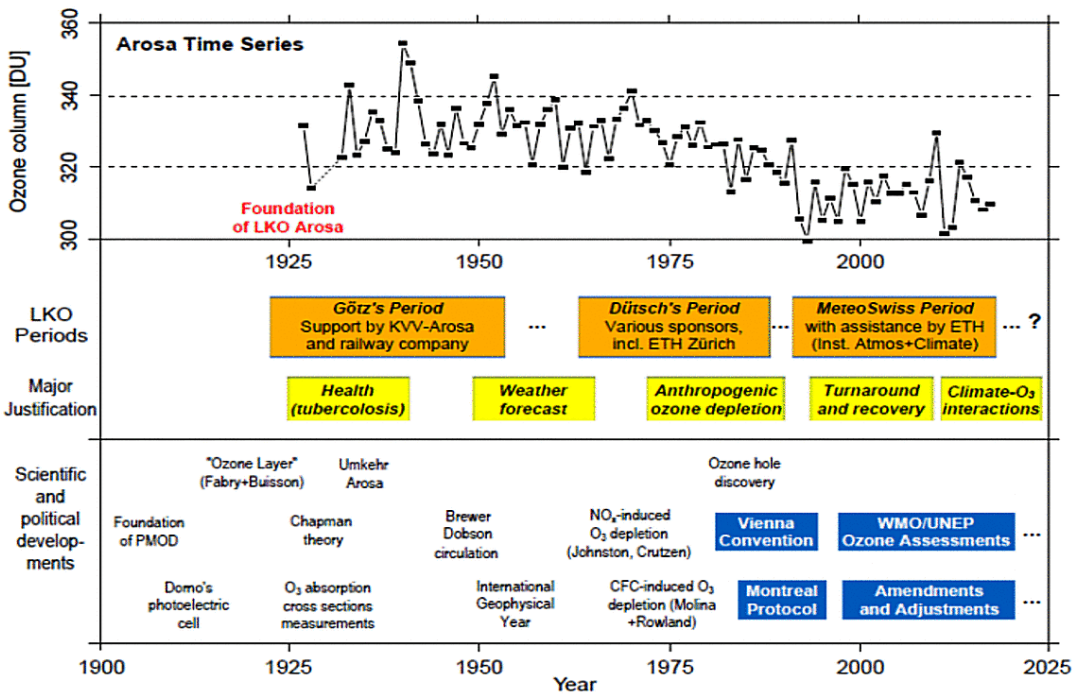


Figure 55: Historical overview of the successive periods of the Light Climatic Observatory of Arosa (LKO). Total ozone measurements (top, annual means); different phases during the history of the LKO including main sponsors (in orange); justification of measurements for society (in yellow); milestones in international ozone research and international legislation (in blue) (from Staehelin et al., 2018a).

10.1 Overview of LKO history

The founding of the LKO in 1921 and the continued support for the first decades of measurements by the KVV Arosa and other institutions was initially justified by its medical application (i.e. therapy of lung TB). The relationship between Götz in Arosa and Dorno in Davos, which was important in the starting phase of the LKO, was quite friendly and characterized by mutual respect but apparently became difficult in the period from 1924-1926. It seems that Dorno, whose institute, created in 1907, provided the nucleus for the PMOD in Davos, developed a more and more difficult relationship with his former colleague Götz. Available documents suggest that personal characters of both Dorno and

Götz (Sect. 3.10) made mutually beneficial collaboration difficult for both partners. The search for a proper collaboration may have also been complicated by a possible competition between medical doctors in Arosa and Davos and/or by competition of the health resort authorities of Arosa and Davos.

With the availability of modern antibiotics a few years after World War II, justifiying the measurements of the LKO with the therapy of lung TB became obsolete. Towards the end of World War II, Götz started justifying the continuation of measurements at the LKO and further studies including surface ozone by means of more general arguments related to air quality and comparison of environmental factors among resort areas – arguments however not directly applicable to the continuation of total ozone measurements. At the same time, Götz published annually in the peer-reviewed literature. He was a brilliant scientist who became a world-leading expert in atmospheric ozone research. He obviously was also very careful in performing and overseeing the quality of the measurements, so that we can still today make use of the measurements of this period, despite the fact that long-term trend analysis had not been a topic of concern prior to the 1970s.

If Götz had decided to leave Arosa in 1940 (Sect. 3.6.3) when funding was significantly reduced while he was in discussion for several offers of professorship positions, the total ozone series of Arosa most probably would have been terminated after having delivered reliable measurements of about a decade.

After the early death of Götz in 1954 at the age of 63, the continuation of the measurements of the LKO was highly uncertain. Dütsch and Perl, among others, were strongly involved in securing the continuation of ozone measurements at the LKO (total ozone and Umkehr). When Dütsch became professor at ETH Zürich his interests were first in ozone climatology, circulation in the atmosphere and its consequences for weather forecasting. In the 1970s, Dütsch was able to integrate the LKO into IACETH. Discussions about anthropogenic ozone depletion, which started in the first part of the 1970s, provided a new motivation to continue long-term ozone measurements at the LKO. Significant efforts were needed to reach the very high long-term calibration stability required for reliable long-term trend analysis.

The decreasing total ozone trends documented by the end of the 1980s (see below) was probably important for the decision of the DuPont company – the market leader in production of chlorofluorocarbons – to stop the production of these ozone depleting substances (Sect. 6.1).

After the retirement of Dütsch in 1985, it was again unclear whether the measurements at the LKO could be continued because ETH Zürich argued that such long-term measurements should be continued by other institutions more oriented to operational measurements. In 1988, MeteoSwiss took over the responsibility for performing the long-term measurements at the LKO. The study of the effectiveness of the Montreal Protocol and its amendments was the basic motivation for society to continue supporting long-term ozone measurements at Arosa and Payerne at that time. In the period 1988-2014, scientific research and QA/QC activities with these measurements were pursued at IACETH, which can be viewed as continuation of the earlier scientific work of Dütsch. This collaboration between IACETH and MeteoSwiss was successful in exploiting the measurements in the context of international research, e.g. by PhD theses funded through GAW-CH and other research agencies.

The Montreal Protocol (1987) was very successful in limiting the emissions of manmade Ozone Depleting Substances (such as chlorine and bromine containing organic compounds). Chemical ozone depletion as determined by the time evolution of anthropogenic emissions of ODS was peaking around the second part of the 1990s at midlatitudes.

Climate change caused by the increasing anthropogenic emissions of greenhouse gases (such as carbon dioxide[647]) not only affects the tropospheric climate such as mean temperature, precipitation, rise of ocean level, melting of glaciers but also is expected to change the dynamics of the stratosphere. Numerical simulations based on state-of-the-art CCMs predict changes in the stratospheric dynamics, namely in the so-called Brewer-Dobson circulation that transports stratospheric ozone from the source region of the tropical stratosphere to midlatitudes. The enhancement of the Brewer-Dobson circulation is predicted to lead to larger total ozone amounts at midlatitudes as compared to the level before anthropogenic ozone depletion started (around the beginning of the 1970s), which is also called “super-recovery”. This process is expected to become dominant over the recovery from ODS in the second part of this century. These changes (particularly large at northern midlatitudes) should be viewed as part of Earth's system changes as caused by climate change. This implies that high-quality ozone measurements are needed to document these changes that are presently only predicted by numerical simulation.

Since around the middle of the 1990s the scientific community tries to document the recovery of the ozone layer from the recovery of the ozone depleting substances, a discussion which is still ongoing.

The costs of running the LKO strongly increased over time (Sect. 9.3). The costs were very low at the beginning because of Götz's commitment. He not only worked very hard but also spent his family inheritance in constructing Villa Firnelicht, allowing him to run his own small research institute. We also have to point out that an important part of the large increase in costs, especially during the MeteoSwiss-ETH period, resulted from the demand of reliable trend analysis, a challenge which led to quasi simultaneous total ozone measurements by two Dobson and three Brewer instruments. This led to additional investment costs for instruments and further expenses for automation.

10.2 Funding of ground-based long-term monitoring

The reasons for continuing the Arosa measurements have changed many times over past decades and it was never imagined that such a long record could be established. The justifications for the LKO measurements for society can be summarized (see Figure 55) as

1. to study environmental factors potentially important for the medical recovery from pulmonary TB (relevant from the beginning until around World War II),
2. to investigate air quality as an important “natural resource” in resort areas (as discussed in the second half of World War II),
3. to improve our understanding of atmospheric physics for improved weather forecasts (important in the 1960s and early 1970s),
4. to quantify anthropogenic ozone destruction by ODS (mid-1970s to mid-1990s),
5. to document the effectiveness of the Montreal Protocol in saving ozone (since around the middle of the 1990s),

647 Note that ODS and its substitutes are strong greenhouse gases.

6. to understand the mutual relationship between climate change and global ozone depletion and the effectiveness of the Montreal Protocol (this century).

“It is difficult to obtain funding for continuous observations through normal science funding agencies such as the Swiss National Science Foundation (SNSF), since an additional few years of measurements usually do not result in novel scientific conclusions. This is the experience within other networks as well, for example NDACC. The success of the Montreal Protocol measures probably contributed to the decrease in the number of ozone measurements submitted to the World Ozone and Ultraviolet Data Center (WOUDC, presently operated by Environment and Climate Change Canada) over the past few years (Geir Braathen, personal communication). This might be exacerbated in the future as monitoring costs come under further pressure in many countries. However, we believe that such routine measurements making an important contribution to environmental monitoring are the responsibility of developed countries. Institutions like national meteorological services, although they also may experience financial shortfalls, are ideally suited to carry out these types of measurements since they are (in contrast to universities) capable of making long-term commitments and have the possibility to hire permanent staff. On the other hand, universities have the advantage of being able to focus on particular issues (e.g. through PhD theses) for a limited time, resulting in articles in peer-reviewed journals. It is important to stress the relevance of scientific activities using long-term observations. Excellent collaboration has existed between MeteoSwiss and ETH Zürich for the past three decades. However, this particular type of cooperation will be less feasible in future, as the required permanent scientific positions will typically no longer be available at universities. In other countries the research aspects are often integrated in the same institution (e.g. the German Weather Service (DWD) in Germany or the “Centre National de la Recherche Scientifique (CNRS)” in France).” [648]

10.3 Intercomparison with standard instruments

The Dobson series of Arosa needed homogenization, but the long-term stability of the record was hardly affected because of the careful application of the statistical Langley plot calibration by Dütsch (Staehelin et al., 1998a).

Over the last decades the calibration of the network for ground-based monitoring of the ozone layer was gradually improved. The success of the regular intercomparisons for increasing the reliability of the Dobson network is shown in Figure 56.

The experience of the Arosa series suggests that the application of such intercomparisons should be assessed critically for special instruments/stations such as Arosa. Particularly since the transfer of the calibration of one to another Dobson instrument by side by side calibration is within ±1% uncertainty and in the regular Dobson intercomparison the World Dobson scale (D83) needs to be transferred to the regional standard instrument before calibrating the station instruments. In the 1995 Dobson intercomparison at Arosa, a correction of the Arosa Dobson instrument (D101, for AD-wavelength and operational µ-range (1-2.5)) and the regional standard instrument of 2.1% was suggested, which was believed to be inconsistent with other total ozone measurements of the station (for more detail see Staehelin et al., 1998a). The deviation of the Arosa instruments from the standard instrument were much smaller in the subsequent intercomparisons suggesting that the 1995 inter-

648 Note that this passage and the following texts in quotes originate from Staehelin et al. (2018a).

comparison should not be applied (Scarnato et al., 2010, Table 2). Therefore, the information of the redundant measurements of two Dobson and three Brewer instruments should be considered in the Swiss total ozone series.

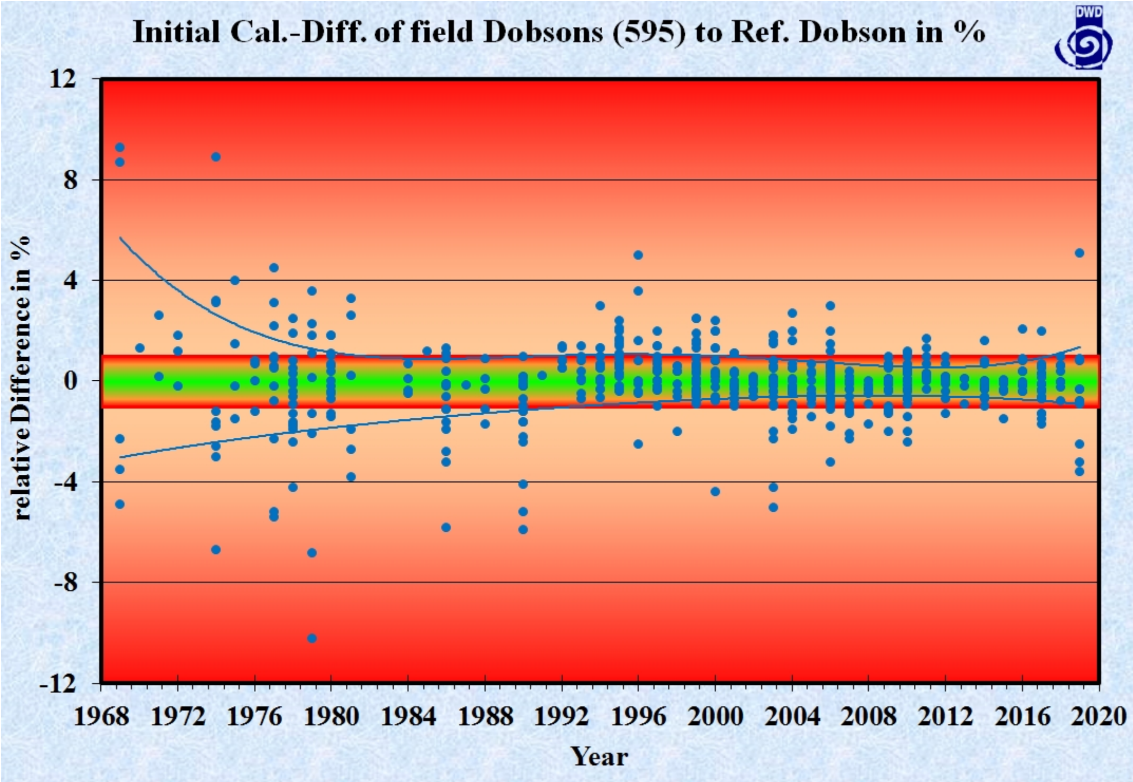


Figure 56: Improvement of the calibration of the Dobson network by regular intercomparison with Dobson standard instruments. The individual points show the deviation of the calibration of station instruments from the standard instruments prior to recalibration. (Provided by coutesy of Ulf Köhler, DWD, Hohenpeissenberg).

10.4 Scientific value of the LKO ozone measurements

"Homogenous long-term records such as the world's total ozone series from Arosa are very valuable for trend analyses in climate science. Reliable long-term, ground-based total ozone measurements are crucial for validation of ozone observations from space, particularly in terms of validating the long-term stability of merged satellite datasets (e.g. Labow et al., 2013) [649]. Furthermore, they serve as a baseline for evaluating numerical simulations such as Chemistry Climate models (CCMs), which are used to make projections of future ozone evolution (see e.g. Eyring et al., 2013; Dhomse et al., 2018; see Section 8.1). The extraordinary length of the Arosa record was important for a wide range of studies, including the analysis of stratospheric ozone related to long-term climate variability such as the NAO/AO (Appenzeller et al., 2000) and El Nino Southern Oscillation (Brönnimann et al., 2004a and b). Furthermore, the measurements have been very valuable for the evaluation of the (early part of the) Twentieth Century Reanalysis Project (Compo et al., 2011; Brönnimann and Com-

649 Satellite instruments measure ozone from space allowing for quasi-global ozone monitoring (continuous ozone monitoring from space started in 1978).

po, 2012)" [650]. The possibility of such studies might be viewed as a "secondary scientific benefit" of the measurements as they were not anticipated when the measurements started in Arosa in 1926.

Because of its high data quality, the Arosa ozone data series played a key role in the 1988 International Ozone Trends Panel report (IOTP, 1988, see Sect. 7.1). At that time significant downward ozone trends were viewed as key evidence for effectiveness of the causal relationship between ozone depletion and the emissions of chlorofluorocarbons as first suggested by the theory of Molina and Rowland (1973) but questioned particularly by chemical industry for many years. However, subsequent analysis indicated that part of the decreasing downward trend as measured by Arosa was attributable to changes in meteorological transport as described by NAO/AO condition. In the early 1990s, changes of the order of ± 1 % (3 D.U.) per decade were believed to be required (rule of thumb) for long-term ozone trend detection [651] both for ground-based as well as satellite measurements, compare Dobson and TOMS total ozone series (Labow et al., 2013).

"From our experience the following issues were most relevant for the successful operation of LKO over the last decades:

- Redundancy allows for increased credibility of measurements, which is particularly important for reliable long-term trend analysis. At Arosa, three Dobson and three Brewer spectrophotometers were simultaneously operated since 1998, which helps to obtain important scientific results regarding Dobson and Brewer spectrophotometers relevant within the broader context of atmospheric ozone measurements.
- Regular comparison of station instruments with standard spectrophotometers operated under the WMO umbrella is important for high-quality measurements and consistency of ozone measurements within a particular network.
- Scientific analysis and use of stratospheric ozone measurements in scientific publications and model intercomparisons not only enhances visibility of the measurements within the community but is also a quality assessment, which might motivate scientists and technicians operating the measurements.
- Reliable techniques are important for high quality stratospheric ozone measurements including automation to reduce manpower costs and to make measurements less dependent on the skills of an individual operator."

It is also remarkable that several times in the history of the LKO (especially when continuation of measurements was highly uncertain, namely in the period 1954-1965 after the death of Götz and during 1985-1988 when Dütsch retired) the move of the measurements of the LKO (total ozone as well as Umkehr) from Arosa to Davos was considered. Now the transfer of the measurements from Arosa to Davos (Sect. 8.2) was decided after automation of the Dobson spectrophotometers and several years of parallel measurements, thus improving the synergies between MeteoSwiss and the PMOD.

"From the very beginning, the ozone measurements from Arosa (initiated by the fruitful collaboration between Götz and Dobson) have been an important contribution both to the global network of ozone measurements and to ozone research. During the early part of the record, the International Ozone

650 Note that this passage and the following texts in quotes originate from Staehelin et al. (2018a).

651 Remember, that the precision of individual total ozone measurements of Dobson instruments are around ± 0.5% and the day to day meteorological variability ± 20%.

Commission (IO_3C) of IAMAS coordinated the ozone measurements. Since the 1970s, WMO has taken the lead, first in the framework of the Global Ozone Observing System (GO_3OS), later the Global Atmosphere Watch (GAW) programme (SAG-Ozone) became responsible for overseeing and coordinating stratospheric ozone measurements to obtain and maintain high quality data suitable for long-term trend analysis. GAW might continue these activities in collaboration with other networks, such as NDACC, the present Brewer COST network, and the IO_3C in order to (i) maintain and extend high quality records of ground-based ozone stations and (ii) to continue comparisons of Dobson and Brewer measurements with other/new instruments such as SAOZ and PANDORA." [652]

10.5 Scientific challenges

As pointed out above, high reliability of measurements in the future needs to continue as the rates in stratospheric ozone increase attributable to the recovery of the ozone layer from ozone depleting substances is considerably smaller than the decrease in the 1980s. Additionally the effect of climate change on ozone is still uncertain and the projections based on complex climate chemistry models need very careful evaluation with long-term measurements.

Beyond any doubt the Montreal Protocol (including its strengthenings) has been very successful for the protection of the ozone layer over densely populated areas, avoiding large damage by manmade chemicals as shown by extended numerical simulations (Newmann et al., 2009). Montzka et al. (2018) found for the first time clear deviation between monitoring measurements of CFC-11 and emissions as expected by the Montreal Protocol, which needs further study [653]. The recent study of Ball et al. (2018) failed to confirm an upward trend in total ozone as expected from numerical simulations for northern mid-latitudes despite increases in upper stratospheric ozone indicating that the Montreal Protocol is indeed "working" as expected. In order to compare merged satellite series in the future, when the stratosphere is expected to gradually recover from the decreasing burden of ODS, continued observations will not only be required to document the expected increase in stratospheric ozone; they will also be necessary for documenting the effects of climate change on stratospheric ozone, as predicted to happen by CCMs, i.e. through enhancement of the Brewer Dobson Circulation and possible other effects connected with climate change, which need further study. For reliable documentation of such trends long-term measurement stability of 1 D.U. per decade should be envisaged (Ball et al., 2018, 2019).

10.6 Move of instruments from Arosa to Davos and homogenization of the series

The following information was presented at a meeting at Davos in February 2019 attended by persons of PMOD, IACETH and MeteoSwiss. The automation of the Dobson spectrophotometer was successfully completed [654]. The complete automation of Dobson instruments allows dissociating the measurement quality from the skills of the operators and significantly increasing the number of measurements. In order to filter the measurements with low data quality (as caused by cloudy condition) new procedures for data quality assessments needed to be introduced and tested.

652 Note that this passage and the following texts in quotes originate from Staehelin et al. (2018a).

653 Hegglin (2018) showed that the unaccunted amount of CFC-11 is small.

654 Paper in preparation.

All instruments (three Brewer and three Dobson) are now running in automated mode. For both types of instrument, the total ozone column is monitored by the direct sun method and the ozone profile by the Umkehr method.

Until recently two Dobson and two Brewer instruments were operated at Arosa and one Dobson and one Brewer at Davos for parallel measurements. Since autumn 2018 the opposite configuration has been implemented with two Brewer instruments (B072, B156) and two Dobson instruments (D101, D051) operational at Davos, while one Brewer (B040) and one Dobson (D062) are continuing operational measurements at Arosa. This Davos - Arosa parallel measurement period will be extended until 2021. The difference between Davos and Arosa measurements is maximal during the summer (~0.5% higher in Davos than Arosa) based on almost six years of parallel Brewer measurements in the period 2010-2016 (Stübi et al., 2017a).

New results from the project ATMOZ [655] are now available and can be used to better understand existing differences between measurements performed with Brewer and Dobson instruments. The goal of this project was the improved characterization and calibration of the Brewer- and Dobson-spectroradiometers to gain a deeper knowledge of the measurement uncertainties of these instruments (e.g., slit functions of individual Dobson measurements were measured).

All Brewer and Dobson instruments were successfully calibrated in 2018 in intercomparisons performed at Arosa, including the official Dobson and Brewer traveling references. Before interpreting the parallel measurements, these calibration results will have to be analyzed carefully in order to determine to what extent the station instruments should be adjusted.

As the world longest total ozone series is based on Dobson instruments, it will be important as a next step to carefully study the comparison of the Dobson measurements at Arosa and Davos. The homogenization of the Dobson series will be important since detecting changes in the order of 1.5 D.U. will be required in the present recovery phase (Ball et al., 2019, submitted).

Differences and changes in the measurements at the two sites, possibly considering tropospheric flows at the two sites have to be further investigated. Finally, the use of independent data from total satellite overpass data and from the measurements of Hohenpeissenberg will allow testing the homogenized Swiss alpine total ozone series for homogeneity. Statistical methods as used by Ball et al. might be applied in this context. Obviously, the skills and resources are available to make the best effort to homogenize the Dobson series.

655 ATMOZ: Joint Research Project “Traceability for atmospheric total column ozone” (with PMOD/WRC as JRP coordinator) within the European Metrology Research Progamme (EMRP) of the European Association of National Metrology Institutes (EURAMET).

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Abbreviations

A2D4O3	Arosa to Davos for Ozone
ACP	Atmospheric Chemistry and Physics (Journal of the European Geoscience Union)
ACSO	Atmospheric Cross-Sections of Ozone
AMT	Atmospheric Measurement Techniques (Journal of the European Geoscience Union)
AR	Annual Report (of KVV Arosa)
ATMOZ	Traceability of Atmospheric Total Ozone
AutoDob	Automated Dobson
BAFU	Bundesamt für Umwelt
BAR	Schweizerisches Bundesarchiv
BAV	Bundesamt für Verkehr
BFS	Bundesamt für Statistik
BUS	Bundesamt für Umweltschutz
BUWAL	Bundesamt für Umwelt, Wald und Landschaft
CA	Climatological Action
CANDIDOZ	Chemical and Dynamical Influences on Decadal Ozone Change
CCA	Commission for Climate and Atmosphere
CCM	Chemistry-Climate Model
CCMI	Chemistry-Climate Model Initiative
CCMVal	Chemistry-Climate Model Validation
CFC	Chlorofluorocarbon
ChA	Chur-Arosa (Bahn)
CHARM	Swiss Atmospheric Radiation Measurements
CNRS	Centre National de la Recherche Scientifique
CO	Colorado
COST	European Cooperation in Science and Technology
DFG	Deutsche Forschungsgemeinschaft
DLM	Dynamic Linear Model

D.U.	Dobson Units
DWD	Deutscher Wetterdienst
EESC	Equivalent Effective Stratospheric Chlorine
EMRP	European Metrology Research Programme
EPA	Environment Protection Agency
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EURAMET	European Association of National Metrology Institutes
ETH	Eidgenössische Technische Hochschule
GAW	Global Atmosphere Watch
GAW-CH	Swiss GAW Programme
GCOS	Global Climate Observing System
GO_3OS	Global Ozone Observing System
GOZCARDS	Global Ozone Chemistry and Related Datasets for the Stratosphere
GROMOS	Ground-based Millimeter-wave Ozone Spectrometer
HAO	High Altitude Observatory
HFSJG	Hochalpine Forschungsstationen Jungfraujoch-Gornergrat
HLI	Historischer Lohnindex
IACETH	Institut für Atmosphäre und Klima
IAMAS	International Association of Meteorology and Atmospheric Sciences
IGY	International Geophysical Year
IMO	International Meteorological Organization
IAM	International Association of Meteorology
IAP	Institute of Applied Physics
IGACO	Integrated Global Atmospheric Compositions Observations
IO_3C	International Ozone Commission
IOTP	International Ozone Trend Panel
IRC	International Radiation Commission
IUGG	International Union of Geodesy and Geophysics
JRP	Joint Research Project
KVV	Kur- und Verkehrsverein (Arosa)
KPI	Konsumentenpreisindex

LAPETH	Laboratorium für Atmosphärenphysik der ETH
LIDAR	Light Detection And Ranging
LKO	Lichtklimatisches Observatorium
LKS	Lichtklimatische Station
LOTUS	Long-term Ozone Trends and Uncertainties in the Stratosphere
MA	Massachusetts
MIT	Massachusetts Institute of Technology
MP	Montreal Protocol
MZA	Meteorologische Zentralanstalt
NAO/AO	North Atlantic Oscillation / Arctic Oscillation
NCAR	National Center for Atmospheric Research
NDACC	Network for the Detection of Atmospheric Composition Change
NDW	Notgemeinschaft der Deutschen Wissenschaft
NOAA	National Oceanic and Atmospheric Administration
NZZ	Neue Zürcher Zeitung
ODS	Ozone Depleting Substances
PANDORA	Pandora Sun photometer
PD	Privatdozent
PG	Product Group
PMOD	Physikalisch-Meteorologisches Observatorium Davos
QA/QC	Quality Assurance / Quality Control
QOS	Quadrennial Ozone Symposium
RBCC-E	Regional Brewer Calibration Center - Europe
REVUE	Reconstruction of Vertical Ozone Distribution from Umkehr Estimates
RhB	Rhätische Bahn
RM	Reichsmark
SAG	Scientific Advisory Group
SAOZ	Système d'Analyse par Observation Zénithale
SBUV	Solar Backscatter Ultraviolet (Radiometer)
SCNAT	Schweizerische Akademie der Naturwissenschaften
SIAF	Schweizerisches Institut für Allergie und Asthmaforschung
SFI	Schweizerisches Forschungsinstitut

SI2N	SPARC/IO$_3$C/IGACO-O3/NDACC
SLF	Schweizerisches Forschungsinstitut für Lawinenforschung
SMA	Schweizerische Meteorologische Anstalt
SNF	Schweizerischer Nationalfonds
SNSF	Swiss National Science Foundation
SOCOL	Solar Climate Ozone Links
SOMORA	Stratospheric Ozone Monitoring Radiometer
SPARC	Stratosphere-Troposphere Processes and their Role in Climate
SWOOSH	The Stratospheric Water and Ozone Satellite Homogenized (database)
TB	Tuberculosis
TOMS	Total Ozone Monitoring System
UNEP	United Nations Environment Programme
USA	United States of America
WACCM-SD	Whole Atmosphere Community Climate Model – Specified Dynamics
WCC	World Calibration Center
WMO	World Meteorological Organization
WRC	World Radiation Center
WODC	World Ozone Data Center
WOUDC	World Ozone and UV Data Center
ZAMG	Zentralanstalt für Meteorologie und Geophysik

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Appendix 1 Margarethe Karoline Götz-Beversdorff (1903-1994)

Margarethe Beversdorff, geboren am 20. Februar 1903, wurde am 7. Januar 1923 in der Gemeinde Arosa registriert. Es ist uns nicht bekannt, weshalb die junge Frau nach Arosa kam, ob sie in einem Sanatorium angestellt war (wir konnten ihren Namen in den Listen von „Fremden" in den Fremdenblättern des Jahres 1923 nicht finden) und welche Berufsbildung sie hatte. Am 27. Dezember 1932 haben M. Beversdorff und F.W. Paul Götz geheiratet. Das Paar wurde am 28. Mai 1946 eingebürgert. Im Nachruf auf F. W. Paul Götz schreibt Dr. med. Trenkel „ …. Der junge Gelehrte ….. begann seine Arbeit im früheren Sanatorium Arosa, um dann das Institut nach seiner Verheiratung in sein selbst erbautes Haus zu verlegen". Götz bezog zu Beginn des Jahres 1926 die „Villa Firnelicht", in welchem das Lichtklimatische Observatorium Arosa (LKO) untergebracht wurde, wobei die meteorologische Station am 1. April 1930 in die Villa Firnelicht verlegt wurde. Frau Götz hat meteorologische Beobachtungen und Ablesungen durchgeführt wohingegen anspruchsvollere atmosphärische Messungen wie mit Dobsonspektrophotometer von ihrem Gatten oder AssistentInnen des LKOs gemacht wurden.

Schwierigkeiten ergaben sich in den letzten Lebensjahren von F.W. Paul Götz (er verstarb am 29. August 1954), als dieser in zunehmendem Masse an Arteriosklerose litt und auch körperlich an einem schweren Herzleiden erkrankte. Frau Prof. Götz stellte offenbar höhere finanzielle Forderungen an den Kur- und Verkehrsverein Arosa (KVV Arosa) für die Miete der Räume des Hauses „Villa Firnelicht", das Eigentum des Ehepaares Götz war und in welchem die Messungen durchgeführt wurden. Sie wollte damit möglicherweise Teile ihres Lebensunterhaltes nach dem zu erwartenden Tode ihres Mannes sichern. Gemäss Schreiben von Kurdirektor W. Grob vom 3. August 1956 an Nationalrat A. Schirmer betrug die Jahresmiete für die Benutzung des LKOs, die vom KVV Arosa bezahlt wurde, CHF 2'160, wohingegen Frau Götz CHF 4'000 forderte, eine Summe die (auch nach Inflationsbereinigung) als Jahresmiete für die Benutzung von zwei Räumen, einem Balkon und einer Dachterrasse nicht sehr hoch scheint. Für eine derartige Erhöhung wäre offenbar eine Bewilligung der Kantonalen Mietzinskontrollstelle nötig gewesen, für welchen Schritt Frau Götz die erforderliche Zusammenarbeit verweigerte. Frau Dr. Gertrud Perl war langjährige wissenschaftliche Mitarbeiterin von F. W. P. Götz, die seit 1947 als Mitarbeiterin des LKOs angestellt war. In seiner Sitzung vom 12. August 1953 bewilligte der Forschungsrat des Schweizerischen Nationalfonds zur Förderung der Wissenschaftlichen Forschung für die Weiterführung der Ozonbeobachtung in Arosa als Saläranteil von G. Perl CHF 5'000 pro Jahr (für drei Jahre). Es scheint, dass Frau Perl vom damaligen Kurdirektor beauftragt wurde zu evaluieren, an welchen Orten in Arosa die atmosphärischen Messungen durchgeführt werden könnten, falls eine Weiterführung der Messungen in der Villa Firnelicht nicht mehr möglich wäre. Ein Schreiben von G. Perl vom 2. Dezember 1953 (wahrscheinlich an Prof. Huber) beschreibt die Ergebnisse dieser Suche nach alternativen Standorten für die Weiterführung der Messungen in Arosa, wobei sich zeigte, dass nur das Sanatorium Florentinum in Frage kam, da andere mögliche Hotels nicht ganzjährig geöffnet waren oder die Dachterrassen für Touristen offenstanden was die Durchführung von atmosphärischen Messungen verhinderte. Als der Entscheid über den Ort der zukünftigen Messungen noch in der Schwebe war, verschlechterte sich die zwischenmenschliche Beziehung zwischen Frau Götz und Frau Perl in dramatischer Weise. Am 30. November 1953 konnte Frau Perl die atmosphärischen Messungen nicht durchführen und eine direkte Kommunikation zwischen den beiden Frauen war offenbar nicht mehr möglich. Frau Götz sagte zu Frau Perl: „Sie hinterhältige Person, hinter unserem Rücken setzen Sie sich mit anderen Leuten in Verbindung“. Frau Götz verfolgte Frau Perl in ihr Zimmer in der Pension Montana, wo Frau Götz offenbar noch hörte, dass Frau Perl mit dem Kurdirektor telefonierte, worauf Frau Götz in derartige Erregung kam, dass Frau Perl fürchtete, mit dem Schlüsselbund von Frau Götz verletzt zu werden. Darauf folgte Frau Perl der Aufforderung von Frau Götz und gab ihr den Hausschlüssel der Villa Firnelicht. Am nächsten Morgen sprachen Dr. med. Trenkel und am Abend der protestantische Pfarrer von Arosa mit Frau Götz um sie zu einer Zusammenarbeit zu bewegen, doch erwiesen sich beide Versuche als erfolglos. Frau Götz kündigte am 9. Dezember 1953 per Jahresende. Damit war entschieden, dass ein neuer Ort für die atmosphärischen Messungen gefunden werden musste. Zuerst wurde die Durchführung von Messungen auf dem Flachdach des Florentinum abgelehnt, doch konnte (dank externer Vermittlung) die Leitung des Florentinums umgestimmt werden. Zwischen 28. und 31. Dezember wurde dann unter Leitung von Prof. M. Waldmeier, mit welchem Götz in seiner Tätigkeit an der Universität Zürich ein freundschaftliches Verhältnis aufgebaut hatte, die Messinstrumente und die anderen Gegenstände, die nicht Eigentum von Götz waren, aus der Villa Firnelicht entfernt und ins Florentinum gebracht, wo die Messungen des LKOs von Frau Perl weitergeführt wurden.

Wir wissen nicht, wie Frau Prof. Götz in der Zeit nach dem Hinschied ihres Gatten im August 1954 ihr Leben gestaltete. Sie erhielt wohl das „Ruhegeld“ von 30‘000, das F. W. Paul Götz vom Kur- und Verkehrsverein Arosa zugesprochen wurde und das während sechs Jahren ausbezahlt wurde. Herr Renzo Semadeni, der heute das Kulturarchiv Arosa-Schanfigg leitet, war Nachbar von Frau Götz von 1977 bis 1985. Er sagt, dass sie „eine alte Dame“ gewesen sei mit wenig Kontakt zu anderen Leuten. Sie lebte zurückgezogen in ihrem Haus. Sie hat ihn gelegentlich zu einem Kaffee eingeladen in ihre Stube. Es ist uns nicht bekannt, ob Frau Götz Teile der Villa Firnelicht als Ferienwohnungen vermietete (R. Semadeni kann sich nicht daran erinnern) oder ob sie andere Wege fand, ihren Lebensunterhalt zu finanzieren.

Frau Rösli Aeschbacher hat Frau Götz als schwer demenzkranke Frau im Altersheim Surlej in Arosa ehrenamtlich begleitet (die folgenden Informationen entstammen einem längeren Interview, das die Autoren des LKO-Berichtes mit Frau Aeschbacher, der Ehegattin von Kurt Aeschbacher, dem langjährigen Leiter des LKOs, in ihrem Haus in Müllheim (TG) am 11. Februar 2016 führten). Nach Angaben von Frau Aeschbacher lebte Frau Götz nach dem Hinschied ihres Gatten sehr zurück gezogen in der „Villa Firnelicht“, sie war in der Bevölkerung nicht integriert und sie wurde eher verachtet. Sie vertrat die Ansicht, dass die Verdienste von ihrem Ehegatten Götz in der Bevölkerung nicht gebührend gewürdigt würden.

Später zeigten sich bei Frau Götz Zeichen von fortschreitender Demenz; so sei sie vom Nachtportier des Hotels Tschuggen verwirrt im Nachtkleid auf dem Höhenweg gefunden worden. Schliesslich wurde sie in die kantonale psychiatrische Klinik Beverin in Cazis eingeliefert, nachdem sie offenbar nicht mehr in ihrem Haus in Arosa leben konnte. Frau Herwig, die Frau eines Arztes von Arosa, erkannte, dass die Klinik Beverin nicht geeignete Bedingungen für die Pflege von Frau Götz bieten konnte und veranlasste, dass Frau Götz in das kommunale Altersheim Surlej in Arosa verlegt wurde.

Frau Aeschbacher hat sie im Surlej während etwa 5 Jahren (vor ihrem Ableben) mindestens einmal wöchentlich (für etwa 30-60 Minuten) besucht und es gelang ihr, ein persönliches Vertrauensverhältnis mit Frau Götz auf zu bauen. Zu Beginn war Frau Götz extrem verwirrt. So traf Frau Aeschbacher Frau Götz in falscher Lage im Bett (mit den Füssen auf dem Kopfkissen), sie war offenbar auch oft aggressiv gegen das Betreuungspersonal. Sie besass keine eigenen Besitztümer mehr und hatte nur noch wenige Zähne, die dank der Initiative von Frau Aeschbacher bei einem Zahnarzt bestmöglich repariert werden konnten. Langsam öffnete sich Frau Götz und erzählte aus ihrem Leben. Sie insistierte, dass sie mit „Frau Professor“ Götz angeredet wurde, was zeigt, dass sie ihr Leben vollständig in den Dienst ihres Mannes gestellt hatte, den sie auch sehr stark verehrte. So erzählte sie, dass sie ihrem Mann drei Uhr in der Nacht sagen musste, er solle endlich schlafen gehen, weil er am nächsten Morgen nach Zürich fahren musste um dort Vorlesungen zu geben (was auch den extremen Arbeitseinsatz von Götz zeigt, vgl. Nachruf von Waldmeier). Götz präsentierte alle seine Vorträge und Vorlesungen zuerst seiner Gemahlin als Probehörerin. Frau Götz erzählte auch von den „Hoheiten“, die sie in der Villa Firnelicht bewirtete. Mit den „hohen Gästen“ sind offensichtlich die vielen berühmten Wissenschaftler gemeint, die in der Villa Firnelicht zu Forschungsaufenthalten weilten. Sie freute sich, als Frau Aeschbacher ihr erzählte, dass die Messungen ihres verstorbenen Mannes weitergeführt wurden und sie wusste, dass H. U. Dütsch, der seit Mitte der 60er-Jahre die Messungen des LKOs wissenschaftlich leitete, Schüler von ihrem verstorbenen Mann gewesen war. Obwohl das Altersheim Surlej in Arosa liegt, erkannte Frau Götz nicht, dass sie (wieder) in Arosa lebte, wahrscheinlich wegen ihres (wohl zwangsweisen) vorherigen Aufenthaltes in der psychiatrischen Klinik in Cazis. Als Frau Aeschbacher ihr erzählte, dass die Christrosen im Garten der Villa Firnelicht blühten, freute sich Frau Götz und erinnerte sich, dass sie diese Blumen früher selber gepflanzt hatte. Frau Götz freute sich auch, als sie von Frau Aeschbacher auf das Grab ihres verstorbenen Ehemannes geführt wurde, sie wusste aber nicht mehr, dass dieses sich in Arosa befand.

In der Aroser-Zeitung vom 14. Januar 1994 erschien die oben wieder gegebene Todesanzeige – es scheint, dass Frau Götz eine sie überlebende Nichte hatte (lediger Name: Grünewald), die wahrscheinlich mit Dr. Ismail Izzet-Hassan (angeheiratet) verwandt war.

In der Aroser-Zeitung wurde am 21. Januar 1994 ein Artikel publiziert (gemäss Angaben von R. Semandeni verfasst von Danuser) mit dem Titel „Margarete Götz-Beversdorff†: Wir nehmen Abschied“. Dabei werden das Leben und die Verdienste von F.W. Paul Götz beschrieben, die Angaben über die Verstorbene erschöpfen sich darin, dass sie die Ehefrau von Götz war – was als weiteres Zeichen gesehen werden kann, dass Frau Götz ihr Leben ganz in den Dienst ihres Mannes stellte.

Ende März 2016, J. Staehelin, und P. Viatte

Appendix 2 Naturalization of F. W. P. Götz and M. Götz

For naturalization in Switzerland, support from the local, the cantonal (small council of the Canton of Grisons in case of naturalization of the couple Götz) as well as the federal authorities (Police Office of the Federal Justice and Police Department in Bern) is required (the information below originates from documents available at the Swiss Archives (Bundesarchiv) in Bern.

The first attempt of naturalization of Götz and his wife failed because the cantonal authority rejected the application. Götz and his wife travelled several times to Germany and Austria during the World War II, and this made the cantonal authority suspicious (document of 8/17 October 1945 of small council of the Canton of Grisons) ("*Obwohl die erhaltenen Auskünfte mit Bezug auf Charakter usw. sehr günstig lauteten, konnte sich der Kleine Rat nicht entschliessen, das Gesuch zu befürworten, da das Ehepaar Götz noch rege Beziehungen mit Deutschland unterhielt und noch in den Kriegsjahren verschiedene Reisen dorthin unternahm*"). This implies between the lines the accusation that the applicants might have collaborated with the Nazi regime.

The second trial for naturalization was sent to the police department of the federal government in Bern by Dr. Hans Schmid, lawyer in Arosa and president of the political community of Arosa, on 5 March 1946 which included forms filled out by Götz and the following documents:

(a) The reply of Götz regarding travelling (report of our travelling to Germany, 26 February 1946) starts by explaining that international travelling is very important for scientific communication (congresses, meetings illustrated by many examples) for his professional activities working in an isolated institute in Arosa. He also points out that he offered the opportunity to Hedwig Kohn (Sect. 3.6.2) to work at LKO when she was fleeing from the Nazi regime because of her Jewish family background, illustrating that he did not care about politics. During World War II he needed to travel to Austria in 1938 to support his colleague Prof. Conrad who needed to emigrate to USA, a further trip to Austria was required to explain to Prof. von Ficker in a personal meeting why he did not follow the call to become professor in Vienna (which was not feasible by written communication). In 1943, he accepted the invitation to a seminar in Frankfurt which was difficult for him to refuse as Prof Linke had twice offered him a job in Frankfurt. He visited Germany in spring 1943 and he travelled in spring 1944 to a conference near Dresden (obviously the ozone conference in Tharant, see Table 5) offering him the possibility to promote the new results of his PhD student Dütsch (Sect. 3.4, see Table 6), who graduated in February 1946 at the University of Zürich (Sect. 5.1). In addition to these scientific justifications to travel to Germany, he took the opportunity to visit (for only one to two days) his 80-years-old mother who had visited Arosa annually before World War II (later she was not able to obtain a permit to visit Switzerland). Private motivations were the reasons for his wife Margarete Götz to travel to Frankfurt: her sister living in Frankfurt was married to a Jewish husband (family name Grünewald) who needed help emigrating to Uruguay. The situation was particularly dramatic when she was informed in spring 1944 that her relatives in Frankfurt suffered from bomb attacks, her sister was sick and her niece was under direct threat because she was half Jewish. In this difficult time in the final phase of World War II (which finally ended in 2 September 1945) she traveled to Germany without a valid return visa which was impossible to obtain from the Swiss government. However, by electing to travel to Germany at her own risk (as suggested from some "persons in Bern") the stay in Germany needed to be extended, against her will, to a longer duration.

(b) The declaration written and signed by Maron, president of the KVV Arosa, of 14 February 1946 starts by describing the scientific merits of Götz as a world renown leading scientist in ozone research, pointing out Götz's outstanding role and his invitations to scientific meetings, even during World War II, and stating that these invitations should be viewed as important for tourism in Arosa as the research of Götz is important for promoting Arosa and the Swiss Alps as a resort area (particularly mentioning the research of LKO in the "climatological action" see Sect. 3.6.4). The letter continues that through knowing Götz since 1921 he (Maron) is aware that Götz is a scientist exclusively interested in his science but who never had any sympathy with the Hitler regime as his political attitude is very democratic. A remark emphasises that because of Götz's concentration on science, he might not be perfectly integrated in the community in Arosa. The letter ends pointing out that the naturalization is important for the continuation of the scientific research of Götz and therefore he strongly recommends naturalization for Mr and Mrs Götz which should be viewed as an honor for Switzerland.

(c) A declaration from Schmid on 2 March 1946 states that Götz was never active in politics, describes the scientific merits of Götz and mentions that Götz rejected several job offers from German and Austrian universities, standing by his decision to stay in Arosa. He declares that Götz has an excellent reputation among the population of Arosa, this being the reason that the citizens' community of Arosa is keen to accommodate Götz as a new member.

(d) The list of references for the application of Prof. Götz contains 21 names, including three medical doctors of Arosa, other names from the Canton of Grisons (including (among others) Erhard Branger, Director of the Rhaetian Railway company, Adolf Nadig, member of the Swiss parliament and Alfred Kreis, teacher at the Academic High School Chur), several persons from the Canton of Zürich (among others) Prof. Edgar Meyer, Director of the Physics Institute of the University of Zürich, Prof. Dr med. Kurt von Neergard, Robert Billwiler, Director (1941-1943) of MeteoSwiss (at that time Eidgenössische Meteorologische Zentralanstalt), from Bern (among others) Prof. Dr med. Alexander von Muralt from the University of Bern, Raphaël Cottier, Director of the Federal Office for Transport and from Basel (Prof. Paul Huber, Director of the Physical Institute of the University of Basel). (No name of PMOD is included in the reference list, for Davos only Dr med. Rudolf Wolfer is listed who was living in the Canton of Zürich at that time but who had previously lived in Davos). The reconsideration request was sent to Bern and checks were made as to whether Götz and his wife were registered in any criminal records. No such entries were found (11 March 1946).

On 23 March 1946 a letter from the naturalization office in Bern was sent to the member of the governing council of the police department of the Canton of Grisons writing that Schmid was asking for reconsideration of its negative decision. In the same letter it also states that the responsible offices in Bern support the naturalization of the couple Götz. The additional information convinced the small council of the Canton of Grisons to reverse its decision and to support the naturalization of Götz and his wife. In its letter dated 4 April 1946 we read that the small council were convinced that the many travels to Germany during World War II only served scientific purposes and therefore gave its support for the naturalization. This finally led to the approval of the naturalization of Mr and Mrs Götz sent from the Justice and Police Department of the Federal Government in Bern dated 18 April 1946.

Annex 1 Expedition Spitzbergen vom 12. Juni bis zum 28. September 1929

Reisetagebuch von F. W. P. Götz

Bemerkungen der Autoren des Berichts:

Der nachfolgende Text beruht auf einer Transkription handschriftlicher Notizen von Götz, die nicht für eine Veröffentlichung editiert wurden und stilistische Fehler enthalten, die wir nicht korrigiert haben. Es gibt verschiedene unleserliche Stellen im handschriftlichen Text:

- *Wörter, die als ---- bezeichnet sind, konnten nicht entziffert werden*
- *Wörter (ganz oder teilw.), die in grau und Kursivschrift stehen, sind unsicher*

Stellen in Fettschrift beziehen sich auf die Beobachtungstätigkeiten.
Die am 8. September angeführten Kosten sind in Reichsmark (das lässt sich durch andere Dokumente belegen).

Mittwoch 12. Juni
Arosa Göppingen

Donnerstag 13. Juni
Göppingen Aussichtsturm, Orientierung "Richtung Spitzbergen" Telgr. Prof. Krogness.

Freitag 14. Juni
"Von der *Eichel* bis zum Balt."

Samstag 15. Juni
3h vom *Hirbener*quai Ausfahrt mit Dampfer *Irma* "Monte Cervantes". Leewärts *Blau Konvektion*: "Cap Polognio (Buenos Aires), besonders von der Ferne feenhaft. Tüchtiger Wind. Mit den vielen Dampfern der Unterelbe in der Abendsonne ein überaus freundliches Bild; besonders 6h nach Passieren des Kaiser Wilhelm Kanals. Dampfer "*Freta Cuxhaven*", der Lotse verlässt das Schiff, Sonnenuntergang gegen 9h, wegen der untersten Himmelsschicht nicht bis zum Schluss zu beobachten, sonst windstill und wolkenlos. 101/4h Blitzfeuer Helgoland alle 5 Sekunden; 10 3/4h rechts unterhalb die sonstigen Lichter von Helgoland sichtbar.

Sonntag 16. Juni
Im Skagenakhöhe Regen. Nach kurzer Zeit ganz aufklärend. 17h B_{1-2}, Nach kräftigem ---- *Schauer* nun Sonne, Himmel *6,5. 18h30* norwegische Küste, die 19h00 immer näher kommt: der erste Fjord, die Brandungsstreifen an der Küste, Möwen, ein Segelboot - und Neptun beeilt sich, noch rasch ein Opfer zu finden. Emil (Begleiter: Emil Henssler) verzieht sich in die Kabine, ich selbst überschätze mit Einnahme des Abendessens an der leeren Tafel meine Kräfte. Es könnte schlimmer sein. 19h40 wird beim großen Leuchtturm Ekerö der Lotse an Bord genommen. 21h30 Stavanger; Regen.

Montag 17. Juni

Nun Bergen. Behäbige, gemütliche Stadt. Vorsichtige Gepäckträger. Hotel Victoria. Besuch bei Prof. Krogness (Krogness erinnert sich an Prof. Münd) im Det Geofysik Institut. Krogness beschäftigt sich speziell damit, aus den magnetischen Kurven das Nordlicht abzulesen, die Daten werden mir zur Verfügung stehen. Telegramm der Kingsbay Kul Company, dass Dampfer erst 1. Juli von Tromsö nach Spitzbergen geht. Abend im Landhause bei Krogness. **Photogr. von Mittelholzer.** ***Partikel*-licht**.

Dienstag 18. Juni

Krogness führt mich zu Srudsup, der in gleicher Weise freundlich. **Ansicht der Pyrheliometer Kurven von Greenharbour**; Mondexpedition. Srudsups Wunsch, (ich solle) das dortige Instrument (zu) eichen oder gar mitzunehmen nach Kingsbay*. Bjerknes d.J.. -* Als erstes am Morgen Besuch des hanseat. Museums, (Fischmarkt) Sehenswert! 7h Einschiffen auf der schönen, neuen "Dronning Maud", leider im üblichen Bergener Regen. Wir freuen uns, auf 4 Tage diese schöne *Ruhestille* zu fahren und die Instrumente wohl verstaut zu wissen.

Mittwoch 19. Juni

Das schöne Wetter der Morgenfrühe wird berechtigterweise voll verschlafen - es ist nicht die Schuld des "Bergen Ol". Trotz des sich verschlechternden Wetters sehr schöne Fahrt, viele an die Schweiz erinnernde Bergformen: Monte Generoso, Piz delle Margna. In Aalesund Besuch bei den Direktoren der Kingsbay Cul Company. Haus auf den Loom Inseln (Northern Exploration). Typische Einfahrt in den Molde Fjord. Molde. Trotz Regen prächtiger Blick in den *weiten* Fjord und die Schneeberge des Romsdal. Kapitän von Horsten bietet uns freundlicherweise an, ab Drontheim in die 1. Klasse überzusiedeln. Abends Kristiansund, im regnerischen Abend ein rechtes "Nest".

Donnerstag 20. Juni

Der Sonnenblick der Frühe wieder nicht von Dauer, seit Hamburg noch kein Tag ohne Regen. Drontheim (Trondheim), Dom, prächtige Mischung von romanischem und got(ischem) Stil, mit meist wein=dunkelvioletten und gelben Mauern; Erneuerungsarbeiten. Nordischer Frauentyp, sehr schlank, schmaler Gesichtsbau. Abends trotz tief liegender Bewölkung, sehr sichtige Luft. 21h00 vor Rörvik schönes Segelboot; in Rörvik Stockfischtrocknerei, grosse Massen an Gestellen aufgehängt; darüber eine Möwe als Vogelscheuche; ---- Fischhaufen unter einem hölzernen Hut.

Freitag 21. Juni

Fünf *Landmassen*, 7 Schwestern. In *Kvartoy*, ungedeckte Fischhaufen Schöner Blick auf die zackigen Hastmandö. Dort verkündet 10h48 ein Kanonenschlag das Passieren des Polarkreises. Prächtige Blicke auf die gebirgige Küste. Einlaufen an den Svartisengletscher. Wie im Berninagebiet, an Stelle der Arvenwälder Birkenwälder, eine Gletscherzunge geht bis herunter an die See (Besuch des Svartisen abweichend von der Route). Gronoy prächtig bewaldete Gebirgslandschaft, neben den Birken auch Kiefern. Nachmittags endlich die Sonne durchbrechend, schöner Abend in Bodo, wunderbar klarer Rückblick bei der Ausfahrt in den Westfjord. Und nun das Grossartigste, die Fahrt gegen die Lofoten bei wundervollen Abendfarben, klare Sonne bis zum Untergang hinter den Lofotenzacken. Mitternachtsspaziergang in Svolvaer. Das erste an Kultur dort ein grosses Schaufenster, das lediglich dem Buch gewidmet ist. "---- Nyt fra Vestfronten". Der Kapitän verschwindet auch hier wieder in der Apotheke.

Samstag 22. Juni

Sonnig! In Höhe Harstad zur Linken die prächtige Inselgruppe Senjen, das ein Mitreisender, der dort 14 Tage mit Zelt weilen will, als ein zweites Spitzbergen rühmt. Kleiner, netter Ausflug (Wagenplätze in angenehmer Weise ausgenützt) mit dieser Gesellschaft von Harstad zur alten mittelalterlichen Kirche Trondenes, in der Nähe der Volkshochschule. Bei der Weiterfahrt prächtig blaue See. Gelegentlich ein schwer beladenes Stockfischschiff. In der Gegend soll es Dörfer geben bis zu 70% Tuberkulose; ausser Fischfang eher arme Gegend. Ankunft Tromsö bei Regen 08h00, am Schiff Konsul Saether, und der vom Nordlichtinstitut beauftragte Besitzer des Hotels Jahnson.

Sonntag 23. Juni

Vormittags von Prof. Evjen und Herrang abgeholt, Besuch der Wetterwarte und des Nordlichtinstituts, beide in reizender Lage auf der Höhe der Tromsöinseln. Nachmittags mit denselben bei schönem Wetter Ausflug ins Tromsdal. Man könnte denken, im Dischma in Davos zu sein, wenn man an Stelle der dortigen Arven Birken setzt. Lappenlager schon bezogen (Frau und Kinder), Rentiere sind nicht da. Unterwegs viele Zeltlager aus Anlass des heutigen Sankt Hanstages (Johannisfest). Wir genießen die Mitternachtssonne bei wolkenlosem Himmel am Hafen, dort prächtige Bilder.

Montag 24. Juni

Der erste Spitzbergendampfer (abgesehen vom Expeditionsschiff Heimen) ist heute unverrichteter Weise wieder nach Tromsö zurückgekehrt, um Kohlen zu fassen. Es wird wohl nächste Nacht wieder in See gehen, wir bemühen uns um die Erlaubnis, mitfahren zu dürfen, obwohl er schon 150 Arbeiter führt. Ganz wolkenloser, wunderbarer Tag; Himmel blau bis zum Horizont, Dicke 10:8,5, Einkauf des Proviants. Konsul Saether, Konsul Jahns. Nachmittag bei D. Herrang, auch eine **Michelsonmessung vom Nordlichtobservatorium** aus. - Es ist erreicht, der Kapitän nimmt uns morgen mit. Provianteinkauf bei A. Sveen unter Beihilfe von *Henn Bohne*: Ganz **schwierige Einbringung der Instrumente auf das an dem Kohlenschuppen liegenden Schiff**, Gott sei Dank geht alles gut.

Dienstag 25. Juni

Ein Tag dauernden Zuwartens mit stetem Vorfragen auf der Reederei *(Hahn Roe*). Vielleicht ist er nicht der einzige! Besuch des Museums. Wetter noch schön, aber frischer. **Unfall mit der Mattscheibe**. Der Hotelier überbringt nach Mitternacht die Nachricht, das Schiff nach Kingsbay fahre 06h00 in der Frühe.

Mittwoch 26. Juni

5h30 Einschiffen bei wunderbar wolkenlosem Himmel (L.8) und spiegelnd ruhiger *Grund*. Heraufklettern an den Strickleisten an Bord. 6h15 wird der Anker eingeholt. 7h30 im Kielwasser des Schiffes junger Wal. 9h30 über der freien See gegen den blauen Himmel abgegrenzte Wolkenschicht bemerkbar, Eiswolke (----*)*. 11h00 kommt das Schiff auf die freie See. Zunehmende Bewölkung, später Hochnebel. Das Lager im "Jahrn" ist vergeben, wir werden uns mit zwei Schlafplätzen auf dem Boden begnügen müssen; die Hauptsache ist, dass es wieder vorwärts geht. Abends einige Sonnenblicke, zunehmender Seegang.

Donnerstag 27. Juni

Infolge des stärkeren Nordwests (öfters starke Sturmwellen) kommt Listo nur langsam vorwärts. Lektüre des Glöckners von Notre-Dame.

Freitag 28. Juni

Mittags bei klarer Sicht auf der Höhe der Bäreninsel, diese nicht sichtbar. 16h00 im Westen Eis, in der Sonne blitzend, dann Robbenfänger. Nach und nach der halbe Horizont bald "*Eisblind*", bald wie eng gezähnt mit Nadeln. Scharfe Kursänderung nach Westen. Bei durchbrochener Bewölkung prächtig klar. 9h00 abends ein schöner Blick auch zur Linken des Schiffs.

Samstag 29. Juni

Fahrt in nördlicher Richtung in Höhe Spitzbergen in weitem Abstand vom Land. Dauernd einzelne Felsblöcke *(florer)* in den phantastischsten Formen (Schwäne, Pilze, ….). Teilweise neblig. 20h00 Richtung ENE.

Sonntag 30. Juni

Seit dem frühen Morgen liegen wir an dem Vorland am Anker, und warten zur Einfahrt auf bessere Sicht, da es nebelt und schneit. Dann und wann ein Blick auf Land und Eis. Vor dem Schiff schwimmen die Möwen, manchmal aufgeschreckt die kleinen Taucher, die wie ein Stein ins Wasser klatschen. 11h00: Es geht langsam weiter. 13h00 bei durchdringender Sonne Nebellücke, mehr und mehr aufklärend, Sonne und Windstille, überwältigende Einfahrt, 03h00 in Ny-Ålesund am Ziel. Unbeschreiblich lichtes Farbenspiel, die Zinnen und Gletscher spiegeln sich in der mit Treibeis erfüllten Flut. Schon unterwegs hat uns Bergmester Merckoll hingewiesen auf die leere Hütte Nobiles bei der Luftschiffhalle. Eine erste Besichtigung des Orts Ny-Ålesund stellt uns vor die Alternative: diese (Rauchfragen) oder Ny-London (schwierig hinüberzukommen, ungünstige Mitternachtssonne, vollkommen auf sich selbst angewiesen). Abends und bei der prächtigen Mitternachtssonne **die ersten Messungen mit Michelson**.

Montag 1. Juli

Slater hat uns Nobiles Hütte zur Verfügung gestellt, Emil schreinert - ich denke wir sind fein heraus. Die Instrumente konnten mit einer Grubenlokomotive recht nahe herangefahren und von dort mit einem Ross vollends an die Hütte geschafft werden. Nach etwas Aufklärung am Vormittag mittags scharfer Westwind, prächtige Hinderniskappen über den Bergen. Emil will in der Hütte schlafen, ich diese Nacht nochmals auf "Listo". Spätabends Aufklärung".

Dienstag 2. Juli

Dunkelkammer, Ofen (Herd) Matratzengestelle. Erstes Mittagessen in der Hütte, **erste Dobsonaufnahme** (stark bewölkter Tag). Der Kapitän erzählt bei der Abrechnung, der Dampfer Hertha", der 17. Juni von Tromsö auslief, sei gestern unverrichteter Dinge nach Tromsö zurückgekehrt.

Mittwoch 3. Juli

Fertigstellung der **Dunkelkammer**, *....photometer* , Windmesser, Silondisk

Donnerstag 4. Juli

Ab heute die **meteorologischen Terminablesungen**. **Die Sonne vormittags verpasst**. "Listo" geht abends 7h wieder in See.

Freitag 5. Juli

In der Frühe fährt Dampfer Hertha ein. - In der Dunkelkammer *werden* 1 Dutzend Platten schwarz, fast *sämtliche* Platten des letzten Reisewegs! Als schuldig erweist sich eines der roten Osramdunkelkammerlämpchen, die auch grünes Licht abgibt. **Dann die Dobsonaufnahme während der kur-**

zen Gelegenheit am Vormittag des Stratustags wieder nicht erwischt. - Kein erfreulicher Tag! Fluchen gestattet.

Samstag 6. Juli

1. Dobsonplatte gut. Abends Spaziergang an die nahe Gletscherstirn, dann hinunter zur Zeppelinbucht und aufs Eis. ---- schöner Sulzschnee zum Skifahren ----.

Sonntag 7. Juli

Bergmester Merckoll gibt die heurige Winterproduktion auf 57000 t an, eine Dampferladung ist 3000 t. Er zeigt sein Schiff (2 Mann Besatzung). Zum Rücken liegt am Quai ein Fischdampfer aus Aelesund, der Haie (?) zur Gewinnung von Leberöl fischt. Besuch bei Slater, sehr komfortabel eingerichtete Wohnung; dort der Kapitän des Fischkutters, der von schönem Wetter auf offener See am Vormittag berichtet (eisfrei von Bellsund bis Düneninsel). Hier den ganzen Tag Schneetreiben, abends sehr schöne Kristallformen.

Montag 8. Juli

Beginn der Schreibarbeiten. Ebbe und Flut. Abends prächtige Strömung meerwärts. **In den wenigen Minuten Sonnenschein am Morgen eine Dobsonmessung erwischt** - es heisst hier aufpassen wie der Teufel auf eine arme Seele. Kein Wunder, dass man sich bei solchem Wetter an Seemannsgebräuche gewöhnt: Abends mehr Rum als Ruhm.

Dienstag 9. Juli

Fast der ganze Tag geht drauf mit dem Rauch in der Bude, infolge des *st....* Windes (offenbar Föhn).

Mittwoch 10. Juli

Der erste Tag mit halbwegs Sonne, leider nur getrübt durch den ersten Schnupfen im keimfreien Spitzbergen. Emil gibt am Giebel unserer Villa den Wimpel "Firnelicht". Es müsste heissen Ny-Firnelicht in "Ny-Arosa". Um Mitternacht krampfhafte Versuche, am **Dobson eine Exposition in einer Stunde Belichtungszeit** herauszuschinden. Nach Mitternacht Einlaufen des 3. Dampfers.

Donnerstag 11. Juli

S/S Strudsholm, für den wir ursprünglich bestimmt waren, bringt die erste Post (somit nach Tromsö adress)!

Freitag 12. Juli

Der erste Hapagdampfer, "Reliance" von Nuogenk her, macht schnöderweise des kräftigen Treibeises wegen vor der Königsbucht kehrt. Öfters Lawinenrollen vom fernen Königsgletscher. Abendspaziergang am Kohlenhafen, Eidenenten

Samstag 13. Juli

Ein dreizehnter, der Verschluss des Photoapparates ist nicht mehr brauchbar.

Sonntag 14. Juli

Emil geht in der Verzweiflung über den nebligen Sonntag auf die Eidenentenjagd und bringt als Beute 2-halb ausgebrütete Enteneier mit.

Montag 15. Juli

Im Hafen liegt an Stelle von „*Skogsik*" wieder "Listo", ferner ein Fischer, das Schiff des Bergmester und das Schiff des Sysselmend. Emil überrascht mit einem Lader (bzw. Ballonfüller)-Fauteuil von sicher bald historischem Wert. Darauf wird es sich sicher doppelt intensiv arbeiten lassen, scheint es.

Dienstag 16. Juli

Ich brings nach 3 Tagen wieder zu einer **Dobson-Aufnahme** und Emil zur ersten Eiderente. Jedem das Seine.

Mittwoch 17. Juli

Abends Eidenentenbraten, überhaupt den Eidenenten gewidmeter Tag. Vorm. photogr. Aufnahme von Gehegen: Teils Nester mit den grüngrauen Eiern und der brütenden Ente, teils schon Junge, die auch von der Mutter gedeckt sind; es tut einem Leid, die armen Viecher inmitten dieser harten Natur ihrer Damen zu berauben. - Im Hafen "Lovstakken" der mit Frau und Kind vorbei spazierende Schiffsherr erzählt, dass das Schiff eben von Süditalien mit Salz nach Norwegen gekommen sei. Die Besatzung von Listo erzählte, dass sie im Winter gewöhnlich mit engl. Kohle nach Spanien und Italien führen.

Donnerstag 18. Juli

Nachmittags fährt der Norddeutsche-Lloyd Vergnügungsdampfer "Sierra Ventana" ein und bootet ca. 200 Reisende aus. Der Fahrtenleiter würde mich gerne mit in die Mollenbucht mitnehmen, doch Risiko eines Landens in - Norwegen zu gross. Die Poststelle hat 1200 Ansichtskarten zu stempeln. - Übrigens erzählt uns der Schiffsherr von Lovstakken, dass innerhalb der letzten 14 Tage 2 Eisbären in der Bucht gesichtet worden seien.

Freitag 19. Juli

Über der offenen See liegt klarer Himmel, der Lloyddampfer, den wir abends ausfahren sahen, muss in der Mollenbucht einen schöneren Tag gehabt haben als wir. Nun auch hier Aufklärung.

Samstag 20. Juli

Emil hat auch seine Tage! Hätte heute Nacht gut etwas Hilfe brauchen können, **beide Apparate sind zur Mitternacht unmöglich zur selben Zeit zu bedienen. Schade, dass der Wetterumschlag einen Grossteil der Arbeit wieder zunichtemachte**. Wunderbar war ja bei der tiefen Mitternachtssonne der Abbruch des Königsgletschers in die See. Übrigens rückt die Mitternachtssonne schon etwas tiefer! 3 Grad tiefer als im Hochsommer, in Tromsö ist die Mitternachtsgemütlichkeit schon langsam zu Ende.

Sonntag 21. Juli

Wir machen Besuch auf der "Resolut" (Hapag), ein wunderbares Luxusschiff; Wintergarten, Schwimmbad, Tennisplatz, usw. usw. , **ich erhalte genaue Zeit**, die beiden mich führenden Offiziere machen hernach Gegenbesuch - eine holländische Familie nimmt bei uns Tee. Der Dampfer will die Magdalenenbai anlaufen, da dort zurzeit eine Walfischstation. Auch uns kommt die Lust, zumal Emil direkt am Landeplatz heute die ersten Robben sah. - Hoffentlich bleibt darüber noch Weiteres zu berichten.

Montag 22. Juli

Die erste direkte Post kam mit Dampfer Hertha. Besuch durch einen neuen Touristendampfer, den engl. "Arandora Star". Man muss leider konstatieren, dass das engl. Publikum einen feineren Ein-druck macht als das gemischte und teilweise stark aufgeputzte der deutschen Dampfer. Ein Herr, der auch in *Buckden* die Sonnenfinsternis beobachtet hat! Auch heute wieder Besuch von 2 Seeoffizieren. **Ich gebe Post für Dobson mit, von dem in der Frühe Brief kam. Erster Reise- und Tätigkeitsbericht an die Notgemeinschaft (13 Ozontage, Trübungsfaktoren bis 20.7)**. In der Bucht viel Eis.

Dienstag 23. Juli

Am 23. Juli (Dienstag) waren wir an der Stirn des Königsgletschers. Ungemein farbige Landschaft, die verschiedenen Grüns der Polster (Rentierflechte), das oft direkte Rot der Steine, Felsblöcke, die mit grell oranger gelber Flechte überwuchert sind. Alles mit dem weiten Blick schön abgestimmt und licht. Ich finde den ersten Vogelberg, zu vielen Hunderten besetzt mit Möwen und Alken. Wie in einem Hühnerstall. Eine Leiter in den Vogelberg verrät die nahe Siedlung - sonst ist, bis auf einige angeschwemmte Kisten der Citta di Milano am Heimweg - hier wirklich noch unberührtes Spitzbergen. Je mehr wir uns der Gletscherstirn nähern, desto feenhafter ragen die Eistürme, Dolmiten ins Eis - ein Eckpfeiler erinnert mich an die "Löwin" bei Eybeck. Von den Eisblöcken am Strand oft kurzer, scharfer Peitschenknall; in den firnartigen Schneeflächen am Strand ist der Schnee in langen Stäben und Säulen kristallisiert. (Luftblasen unter hohem Druck ins Eis eingepresst.) An der Gletscherstirn in einigen Eisbuchten unzählige Möwen, dicht gedrängt auch auf manchen Eisschollen, der Höhepunkt des Tages die im Wasser sich tummelnden Seehunde. Sonntag vor 8 Tagen waren auf den Loominseln sogar 4 Eisbären, die wir nicht zu Gesicht bekamen. Seit heute wieder, eine ungemeine Steigerung der Eindrücke, ich habe oft direkt Mühe, alles zu verarbeiten. Es ist eine feine Seele hier oben.

Mittwoch und Donnerstag 24/25. Juli.

Der erste richtig schöne Tag unseres Aufenthalts. Bin ja schon glücklich, wenn es einmal von Mittag bis Mitternacht oder von Mitternacht bis Mittag durchhält. Abends 25. eindrucksvoller Wetterumschlag und Sturm.

Freitag 26. Juli

Wieder Post, Emil sogar Zeitungen. An der neuen Radiostation ist das Richtzeichen aufgerichtet (Strohkranz und Bierkrug).

Samstag 27. Juli

Bis gegen Abend schöner wolkenloser Tag, das Schlechtmachen des Klimas in den **Berichten an die Notgemeinschaft** scheint gewirkt zu haben.

Sonntag 28. Juli

Der Tag geht herum im Warten auf die "Monte Cervantes" - gegen 7 Uhr abends fährt sie ein. Wie schreibt doch Saether: I suggest that he should be a philospher as well, knowing that in the Arctic patience is king among the virtues. "Monte Cervantes" fährt herein und legt wieder ab. Als ich sie anfunken lasse, antwortet sie, dass sie von Greenharbour aus direkt nach der Magdalenenbay gefahren und nun bereits auf der Rückfahrt (über die Kreuzbucht) nach Hammerfest sei. Und es war so schön ausgeklügelt, nach eintägigem Aufenthalt in der Magdalenenbucht von "*Oridveo*" nach Königsberg zurückgebracht zu werden. Abends gehn wir mit dem Telegrafisten zu einem Whisky: merke mir wie schwerfällig die Norweger offenbar sind: er ist überrascht, dass wir uns interessieren, dass Prof. Evjen auf Anfang August meinen Besuch angekündigt hat zwecks Verlegung der Meteorolog. Station von Greenharbour nach Kingsbay.

Montag 29. Juli

Ruhiger Arbeitstag. Abendspaziergang an die andere Seite des Kohlehafens (Quadehock zu), wo ein Fangmann an der Stelle eine Sommerhütte aufgeschlagen hat, die ich Prof. Hoel als besonders günstig bezeichnet hatte. Tüchtige Gymnastik (Weitsprung) über die Schmelzwasser, am Strand eine Walfischwirbel, eine Unmenge Holz, aufgeschwemmte Kisten der Citta di Milano, Chiantiflaschen. Prächtige gelbe Beleuchtung, fabelhafte Sicht – *kein* Vergleich mit den Sichtweiten etwa am Bodensee. **Nach Mitternacht noch eine Lenticularis-Aufnahme**.

Dienstag 30 Juli

Emil baut sich aus Nobile-Ballonstoff einen neuen Rucksack. Der übliche Abendbummel - 21-24h - diesmal nach Südwest; dort ganz grosse Steinnischen (Blockanhäufung), während ich *an kleineren* die schönsten bis jetzt direkt unter der Amundsen-Denksäule (Amundsen, Dietrichsen, Elsworth, Feucht, Omdahl, Riiser Larsen 21. Mai 1925) fand. *Alpenmohn*

Mittwoch 31. Juli

Ich lasse mir auf "Orinoco" die Haare schneiden. Er war in der Nacht zuvor auf 80°10' am Packeis. Ich lasse mir auf dem Schiff an den Karten die Lage des Walfischfanges in der Magdalenenbucht bezeichnen, der Herr antwortet: "He, sie sind doch auch ein Schwabe - ein Karlsruher, wohnhaft Basel, letzten Winter Arosa. Auf unserer Karte an der Tür finde ich nachher: "Ein Gruss von *Haufener*, ein Schweizer", und Emil hat sich auf dem Schiff mit dem Koch, einem Jugo, angebiedert. Interessanter sind für uns die Fangleute aus dem Nordostland. Wer hätte uns beispielsweise hier erzählt, dass in Ny-Ålesund Nordenskjölds Vega liege - das Schiff, auf dem der Holzkai fundiert ist, und das bald freiliegt, bald vom Wasser der Flut überflutet ist. Die Fangleute kommen den weiten Weg in einem primitiven "Robben", da ihnen ihr Schiff letzten Winter im Eis zerdrückt wurde, der Alte wartet auf ein neues Schiff aus Tromsö. Er war 4 Jahre selbst nicht in Norwegen, sondern kommt nur immer nach der Kingsbay, um sich für einen neuen Winter einzudecken. Der vergangene Winter sei ab Februar der Kälteste mit 1905 gemessen (bei Windstille dauernd -65°), für die Jagd sei darum auch im Süden bessere Zeit gewesen als so hoch im Norden (besonders gut an Blaufüchsen habe *Pedersen* in Ny London abgeschnitten). Er selbst bringt uns 8 Eisbärfelle. - Er zeigt uns, wo letztes Jahr die Zelte der "*Kressin*" lagen - noch viele russ. Zeitungen 1928. Einer der russ. Flieger habe ihnen am 2. Sept. gesagt, am 9. ist der letzte Tag, wo wir fliegen können, nachher kommt Schlechtwetterperiode, es habe fein gestimmt. Auch er lobt sehr den norwegischen Wetterdienst. Ganz in der Nähe des *Kressin*lagers ja auch die vielen Gräber, alte russ. Kolonie (Straflager), das letzte Grab 80 Jahre alt, die ältesten viel älter. Im März habe der Skorbut oft grauenhaft gewütet, da sie dann während der langen Fastenzeit gesalzenen Fisch gegessen hätten. Am Eck der Landungen, etliche neue Gräber, darunter das von Dr. Otto Stoll, Leiter der norwegischen geopl. Station auf Quadehoek 1920-23, geb. 11. März 1883 gest. 30. Juni 23.

Donnerstag 1. August

Schöner warmer und sonniger Sommertag, würdig eines schweiz. 1. August. Prächtiger Rundblick von der Höhe des Luftschiffmastes (Antennenmasts). Ob wohl - was gestern das neueste auf "Orinoco" war - Graf Zeppelin seine Amerikafahrt heute angetreten hat?

Freitag 2. August

Ich lerne den Chefingenieur kennen, der erzählt, dass mit "Listo" (die übrigens an der Küste wegen Nebel ankert) am Abend ein italienischer Professor komme. Dann besuchen uns die Fangleute - Bengson (der Alte Bengson nur gestern) und der auf der andern Seite des Kohlehafens wohnende, der oben auf den norwegischen Inseln sitzt - und laden uns auf den Sonntag zur Robbenjagd ein. Der Alte erzählt, dass er seit 4 Jahren das erste Glas Whisky trinke - früher war es in Norwegen verboten, in Svalbard erlaubt, und jetzt umgekehrt. Abends holt er mich nochmals, um seinen Sohn mit den heute erlegten 3 Robben zu photographieren.

Samstag 3. August

Die Post hat den "Hohenstaufen" von 15. bis 19. Juli, die Ersatz.... der ----; ein italienischer Journalist (Bennenio Broglieri) ist angekommen, ---- besucht schon in der Frühe Prof. Hojen, der die amtliche Station einrichten will (sogar Pilotballons) - und offenbar ähnliche Erfahrungen macht wie wir! Vom Fangmann Ben(g)son hören wieder vieles Interessantes. So hat er noch Rohgummisohlen - nur kosten sie ihn nichts - oft werde hier Rohgummi direkt aus Brasilien angetrieben, er zeigt uns ein grosses Stück. Er will nun morgen doch mit der Listo nach Norwegen zu ganz kurzem Aufenthalt, um dort ---- Hunde zu kaufen - seine eigenen vier musste er bei der Abreise erschiessen, es sei eine Schande gewesen, aber keine Möglichkeit sie mitzunehmen. Er will nun bei den Lappen im *Finnsdal* versuchen, *neue* zu erhalten. Sein Leben ist ein kleiner Roman: In der Jugend Jäger in Alaska, seit 1905 auf Spitzbergen, dann eigenes Geschäft und *Aussenden* von Schiffen in seiner Heimat Bergen, in der Inflationszeit durch Zusammenbruch der Landesbank Verlust des Vermögens - nun wieder Spitzbergen und diesen Winter Verlust des Schiffes.

Sonntag 4. August

Ein wundervoller Tag mit den beiden jungen Fangleuten auf der heute recht bewegten Bucht (bedeckt und windiges Wetter) und im Eise. Wir fahren erst Richtung Ny-London dann in *Ause Deer* dem *Blumstrand*gletscher entlang zum (rechten Arm des) Königsgletscher. Mit den beiden letzten Patronen schiesst Emil 2 Seehunde, aber beim Harpunieren der getöteten Tiere - sie schwimmen nur kurze Zeit an der Wasseroberfläche - stösst er beide mal das Tier in die Tiefe, da sind mir Felle sicherer, die der alte Benson mir geschenkt hat. Mit tun die Tiere leid und die beiden ---- Blutlachen in dieser wunderbaren Farbensymphonie von Grün, Weiss und Blau. Bei der Rückfahrt sind wir eine Zeitlang zwischen dem turmhohen Treibeis ziemlich in der Sackgasse, fahren dann hinüber nach Ny-London - reizende Anlage - und trinken bei Peders Pedersen Kaffee. Er hat sich eben Frau und Kind (Hanna?) aus Norwegen geholt, sie sollen den nächsten Winter mit ihm überwintern. Er hat die wunderbarsten Hunde, die ich in meinem Leben bislang gesehen habe, langes Fell, schwarz weiss und wie sie einem schon trauen und nicht genug bekommen, gestreichelt zu werden. Schon allein wegen dieses Hundes muss ich bald wieder hinüber nach Ny-London! Zurück fahren wir mit den vom Italiener geheuerten Motorboot, am freien Landesteg bei Ebbe sehen wir erstmals die "Vega" in der ganzen Länge, es ist das grosse Schiff durch diese Verwendung am besten durch Zerstörung von Eis geschützt, wie Abends der Direktor erzählte. 800 Tonnen Stein haben sie dazu verwendet. Abends gehe ich an eine Einladung zum Direktor. Er, Slater und der junge Arzt als Einheimische, Prof. Evjen, der ital. Journalist und ich als Gäste. Es gibt Wein, Bier und Whisky, der Italiener lädt mich ein, mit ihm morgen mitzufahren nach dem Nordosten, bei unserer Ausrüstung und dem kleinen Motorboot eine zu gewagte Sache. Im Direktorhaus gibt's kleine Spitzbergenbibliothek.

Montag 5. August, Nachts

Gegen Mitternacht kommt bereits der Italiener mit seinem Motorboot zur Reparatur zurück (Begl. Fengstmen Johannsen - Magdalenenbai). Gestern Abend brachte er übrigens das Gespräch darauf, er habe im Dorf zwei Frauen gesehen. Darauf der Direktor, hier sind 20 - und der Italiener in höchster Ekstase " - 20! - "; Allgemeines Gelächter, Slater fragt ob er ihm zeigen soll, wo sie wohnen. Im Übrigen heute Vormittag und Mittag in der ganzen Bucht Sonne, nur **bei uns "Hinderniswolken"** über den Zeppelinbergen, der Wind aus N. Mitternacht schön.

Dienstag 6. August und Mittwoch 7. August

Sonne und Arbeit, leider auch Ärger mit der Rauchplage.

Donnerstag 8. August

Bei wolkenlosem Himmel sehen wir uns heute mit dem Motorboot das Saethersche Haus auf den Loominseln an (sehr schlecht im Stand). Wunderbare Klarheit, auf der Insel selbst Farbensattheit, hier möchte man bleiben! Wir wollen nun wohl doch mal noch etliche Zeit nach Ny-London übersiedeln. Prof. Evjen hat die **meteor. Station bald eingerichtet und** ü**bt Pilotaufstiege ein**. - Hübsch übrigens, wie aufgeweckt heute der alte braune Spitzbergenhund, er fühlt sich ganz jung vor lauter Sommersonne - und sonst so philosophisch bedächtig allein durch die Nobilehütte.

Freitag 9. August

Im Motorboot von Enoksen (Sohn des Enok) machen wir Besuch bei Fangmann Oxos, um ihn wegen der Gelegenheit nach der Magdalenenbai zu fragen; er erzählt, dass er selbst mit den Burgmester nach oben fahre, 15. oder 20. August, und dass dann seine Hütte - ausgezeichnete Lage - zu unserer Verfügung stünde. Immerhin sehen (wir) uns nun nochmals Ny-London an. Befriedigende Unterkunft, aber die Ausmessung des Horizonts nicht so günstig. Enoksen lädt uns ein, heute Nacht nach Ebeltofthafen mitzufahren, wo er zu tun habe, wir sagen zu (Abfahrt 10 Uhr abends); bei der Rückfahrt ---- im Hafen ein Walfänger, mit sichtbarer Harpune, "Lopre“ aus Sandefjord.

Samstag 10. August

Mit der Abfahrt nach Ebeltofthafen wird's doch Samstag, nachts 1. Trotz mühsamer Verständigung ist Enoksen (Enok in Bibel) ein witziger Bursche - seine Hauptsprachkenntnisse sind "absolutely fine" und "feine Seele". Sprachunterricht: "RobbeTaucher". Er fängt in Ebeltofthafen im Winter hauptsächlich Blaufüchse (500.-, ein Eisbärfell um 200 Kronen). Prächtiges Bild des Blumstandgletschers, ---- des Vulands, beim Einbiegen in die Kreuzbucht schönes Mitternachtssommerbild. In Ebetlofthafen ein merkwürdiges ---- von alten Gräbern, dem Gerümpel zur ---- überhaupt die Fanghütte und den Spuren des alten "Deutschen Observatoriums Ebellofthafen - Spitzbergen". Da stehen noch alte Beobachtungsstühle, Winde und Rolle für die Drachenaufstiege, von den Gebäuden sind noch die Fundamente und gelbroten Ziegel sichtbar. Wir finden Briefumschläge an Dr. Kurt Wegener, mit Poststempel 1913 aus Tromsö. Hauptstempel Berlin (1912?), mit Trauerrand. Monatstabellen der Meteorologischen Landesanstalt von Elsass-Lothringen. Ein selbst angefertigter Abreisskalender für Januar. Kistendeckel adressiert an "Prof. Geheimrat Hergesell". Emil hilft Enoksen beim Erweiterungsbau der Hütte und verdient sich so sein Mittagsbrot - 3 Alke oder auch Eidenenten. Zum Schlaf natürlich etwas Alkohol. "Kognak immer gut" - wir hätten überhaupt das Dreifache des Quantums an Whisky mitnehmen sollen! Schwermütige Landschaft - ist es der nun ziemlich trübe Himmel, der nun doch sich geltend machende Schlafmangel? Spazierhang am Ufersteilrand nach Norden. Blick in die Mollenbai, wuchtige Bergwelt. Am Fuss des Grossen Vogelbergs mächtige grüne Polster. Bei der

Heimfahrt rufen öfters die papageiähnlichen *Lummen* mit rotem Schnabel, auch immer wieder mal eine Robbe.

Sonntag 11. August

Enoksen macht Abschiedsbesuch, Dr. Engels "Antrittsbesuch". Enoksen will heute Nacht mit Lovstakken nach Tromsö, und dann am 5. Sept. sein Winterquartier beziehen. Er bringt den alten braunen Polarhund mit, der ihm gehört. - "Wiggo" - der arme Kerl wird nicht mehr mitgenommen, und watet am Strand bis ins Wasser, wenn er das Motorboot löst.

Montag 12. August

6 Uhr früh fährt "Stella Polaris" ein, auf der ich mir wieder die **Uhrkorrektion geben lasse**. War in der Nacht bis 80°30' im Nebel, ohne Packeis zu treffen. Hauptsächlich Amerikaner und Franzosen, ich kann sogar ---- einen direkten Gruss nach Paris mitgeben. Die nette Sängerin des Schiffs erzählt von dem luxuriösen Schiffsbetrieb. Abends frage ich den Bergmeister wegen einer Fahrt nach Norden, es kommt zu einer Einladung auf morgen fünf mit dem Regierungsschiff der Sysselmannen, leider langt's nur für einen. Hoffentlich bleibt gut Wetter! An der Abendgesellschaft, in die ich hereinschneie, ist Stegrud, der als Leiter von 3 Studenten mit 4 Grönlandhunden Spitzbergen eben von Norden bis Königsberg auf dem Schlitten durchfahren hat. Evjen erzählt mir fachwissenschaftliches. Die met. Station auf ---- kostet jährlich 5000.-, auf den Băreninseln 20000.- Kronen. Mit den Sysselmannen übrigens noch niedliches Missverständnis: Bei Besprechung der Platzverhältnisse frage ich: "Wie lange bleiben sie denn weg" - er bezieht es auf die Füsse, wieweit sie von der Schlafbank abstehen und demonstriert.

Dienstag 13. August

Da der mitfahrende Dr. Engels noch zu einem Kranken auf Strudsfahrn gerufen wird, verzögert sich die Abfahrt etwas, bis etwa 11h. Unterwegs beim Whisky (ich frage, wie viel Flaschen einem Fangmann über den Winter erlaubt seien) ("arktischer Durst") allerlei Neues. Der Papageitaucher (schöner roter Schnabel) heisse bei den Fischern nun Amundsenvogel. Hoel bringe von Grönland ---- mit. Der Sysselmannen wolle auf Spitzbergen 20 Hasen aussetzen. Auf der "Stella Polaris" sei unter Führung eines auf Freibillet reisenden franz Journalisten Revolution gewesen, der Dampfer habe nochmals nordwärts gewendet und diesmal die Magdalenenbucht, Mittarnachtsonne und Packeis gesehen. Wir fahren in die Magdalenenbucht 17 Uhr ein. Interessant in der Landschaftsstimmung die rosa Färbungen auf dem Firnschnee. Viele offene Gräben. Gegenüber der lichten, weiten Königsbai düstere Landschaft. Weiterfahrt durch Südgat, an ein paar wuchtigen Eisbergen vorbei, vorbei auch an alter *....burg*, wo man auf der flachen Landzunge noch die Erhöhungen für die Feuerkessel sieht, zum Viagohafen, wo etwa 21 Uhr landen. Andrees Haus in Trümmern. Fundstücke "Wallmann 1906". **Ich komme zu einer Strahlungsmessung** und bleibe bis über Mitternacht hinaus im Freien. Der wolkenlose Himmel wird um diese Zeit durch eine niedrige Nebeldecke entzogen.

Mittwoch 14. August

Wir fahren etwa 9 Uhr durch's Dänengat in Sonne und offener See. Sehr warmer Tag, leichte Ci, schöne Einfahrt in die Königsbucht, gegen 6 Uhr wieder zu Hause und von Emil empfangen. Abends photographiere ich noch Prof. Evjen bei einem **Pilotaufstieg**.

Donnerstag 15. August

Der Sysselmann sieht vormittags vorbei - ich verspreche, mich mit Photos zu revanchieren (er wohnt in Kirkenes). Vor allem erzählt er im Tromsöerblatt sei gestanden, Albertini von der italienischen Hilfsexpedition sei von einem Eisbären erschlagen worden! Tragik von Anfang bis Ende auf der Nobileexpedition. Den ganzen Tag bunkert am Quai "Prinz Olav", der erste Touristendampfer übrigens, der mit Motorbooten gegen die Gletscher fährt. Vor den Passagieren machen wir diesmal "einen Bogen", das ist immer ein zu grosser Zeitverlust. Prof. Evjen, der nun in der Nacht leider abfährt, erzählt, dass er mit dem Motorboot mitgefahren sei, auf dem ....eis seien Seehunde gelegen - ein alter neugieriger bis auf etwa 8 Meter Distanz. - Auch "Prinz Olav" schlecht besetzt, etwa 50 Passagiere (Grund Barcelona?).

Freitag 16. August

Ich schwinge mich auf zum ersten "Expeditionsbrief" ans Aroser Fremdenblatt.

Samstag 17. August

"Monte Cervantes" mit ca. 1100 Passagieren; übrigens mehr ansprechendes Publikum, nicht nur wegen der dort vertretenen Stuttgarter, Reutlinger und Gislinger! An Bord hör ich von Dr. Ingels, dass in der Frühe ein Grubenunglück 2 Opfer gefordert habe. - Abends nochmals richtiggehende Mitternachtssonne, erst nach Mitternacht kurze Zeit unterbrochen.

Sonntag 18. August

Mit Photoarbeiten ausgefüllter Regentag. Abends im Kohlenschiefer ohne gerade grossen Erfolg nach Versteinerungen gesehen. Schöne Abdrücke von Laubblättern.

Montag 19. August

Bis abends Regenwolken, ich durchstöbere etwas die kleine Bibliothek im Direktorhaus, wissenschaftliche, insbes. geologische Spitzbergenliteratur. In Wilhelm ----, Quer durch Spitzbergen, Berlin 1911" ein gutes kleines einführendes Kapitel "Aus der Geschichte der Entdeckung und Erforschung Spitzbergens". 1596 Willen Barends auf einem der Suchen nach der nordöstlichen Durchfahrt, und zwar die Nordküste. Südliche Rückfahrt an der Westküste des neuen Landes, das "zum grössten Teil zerrissen und ziemlich ---- und nur aus Gebirgsketten und spitzen Bergen bestand, weshalb wir ihm den Namen Spitzbergen gaben (Barends). Hudson 1607 machte auf die reiche Tierwelt aufmerksam. Wal- und Robbenfängen; *Sonerenberg* 1764 erste Expedition *(Russen)*, ab 1806 Engländer. 1827 Darry, Vorstoss zum Pol. *Soren Loven* = Stockholm, der 20 Jahre später seine Landleute Torell und Nordenskiöld zu ihrer Spitzbergenexpedition anregte. Diese erste der seitdem in die Nordpolgebiete entsandten zahlreichen schwed. Expeditionen bedeutet die Einleitung der eigentlichen wissenschaftlichen Erforschung Spitzbergens und seit 1858 hat das schwedische Volk den grössten Anteil an der dort geleisteten Arbeit. 1868 erste deutsche Nordpolexpedition unter Kolderwey, 1870 v. Henglin. 1882/83 Internationales Polarjahr, schwed. Expedition bei Kap Thordson. "Da in den letzten Jahren die spitzbergische Westküste an einzelnen Punkten dem immer weiter um sich greifenden Touristenverkehr während den eigentlichen Sommerwochen erschlossen worden war, errichtete die *Vesten-aalm* Dampfschiffgesellschaft ein kleines Hotel auf *Admiral-Point*, zu dem sie einen wöchentlichen Dienst von Tromsö aus unterhielt. Allerdings mussten sie es schon nach dem zweiten Sommer wieder schliessen; immerhin.....(1896?). 11. Juni 1897 Andrees Aufstieg von der kleinen "Däneninsel" aus. 1898 schwedische Expeditionen unter *Nethorst* durchforschten einige Buchten an der Westküste ---- , ebenfalls 1898 erster Besuch des Fürsten von Monaco. Internationale ----messung ab 1898, Russen und Schweden bis 1902. Sommer 1906 Fürst von Monaco "in erster

Linie wurden ozeanographische Untersuchungen gefördert sowie Beobachtungen über die meteorologischen Verhältnisse in den höheren Luftschichten angestellt; daran anschliessend Isaksen sowie Karte 1910 erschienen. Kohlenabbau seit 1906.

Dienstag 20. August

Bis nach Mittag die grosse Bucht in Sonne, nur uns am Fuss des Zeppelinbergs gelingt heute nicht mal eine 1 **Dobsonaufnahme**! Nachmittags Aufnahme derselben Steinringe wie ---- , wiedergegeben in O. Stall, Veröffl. Heft 7 des Deutschen Observatoriums Ebellofthafen Spitzbergen. Abends erzählt Dr. Ingels uns sehr interessierendes; der Sysselmann sei nicht wegen des Unglücks zurückgekehrt, sondern weil der Eisfjord total von Eis blockiert sei; die Store Norske fabriziert einen täglichen Verlust von 7000 Kronen. Wegen des vielen Gases in den beiden Gruben an Königsbay stehe die Schliessung der Grube zur Erwägung, in diesem Falle ginge das letzte Schiff am 20. September, zumal die gute geförderte Kohle bereits fast abtransportiert sei.

Mittwoch 21. August

Zur Herausarbeitung der Müdigkeit eine Bergtour. Nach Mittag Aufstieg auf den Gletscher östlich des Zeppelinbergs. Bei Vorgehen zum Grat hübscher Blick auf Hafen und Bucht. Vor der Passscheide Gletschersee; sehr schön nun die Loomnische hervortrat und *leichter* Nebel, beim Anstieg zum Gipfel auch Schneefall. Mächtige brüchige Platten senkrecht zum Grat. Wir verzichten auf den Hauptgipfel und klettern die Schuttfelder auf dem Gletscher westlich herab. Heimkehr nach 9 Uhr bei richtigem Regenwetter. Feststellung zuhause: es dunkelt etwas!

Donnerstag 22. August

Seit gestern bunkern am Hafen 4 Kohlenschiffe (!) der "Store Norske" (darunter ein grosser griechischer „Petallis"). Auch 4 Eismeerfischer liegen am Anker, u.a. "Polaris". 9 Tage schon liegen die Kohlenschiffe in dem Eisfjord, der nun Packeis von Süden her. Soll mit Eis verstopft sein. Wir erhalten alles bei Besuch. - Das Regenwetter geht weiter, abends verschiedentlich Licht im Dorf. Emil, der letzthin schon einen Schnupfen hatte (Dampfbad oder Ebeltofthafen), will aber nicht wissen von Sympt.

Freitag 23. August

Bei Quadehoek auch schon an der Kingsbai das Eis? Dann wären wir ja auch glücklich in der Mausefalle. Abends über Ebeltofthafen Sonne prächtig rot vor Untergang, über dem Königsgletscher der blasse Mond. über der untergehenden Sonne rote Lichtsäule.

Samstag 24. August

Wir wollen nachmittags nach Quadehoek, auch des Eises wegen, das nun wirklich dort liegt. Wir kommen nicht über den grossen Bach vor Oxos' Hütte, da diesmal die Sandbänke nur den Fluss bedeckten. Bei Rückkehr in einem der *Teiche* 2 prächtige Wildgänse.

Sonntag 25. August

Nachts wie schon an den Vortagen starkes Donnern des Gletschers. **2. Bericht an die Notgemeinschaft**. Um Mitternacht schöne Spiegelung des gelben Himmels in der Bucht. *Durcharbeit.*

Montag 26. August

Nachmittags 1 Uhr kommt Dampfer "Hertha", um 7 Uhr früh ab durch Scholleneis! Im Hafen nun 6 Dampfer (5 der Store Norske). Der Direktor Skordahl bestätigt, dass die Grube über Winter geschlossen werde, sie müsse ganz neu organisiert werden, Gas und Wasser! Ca 7 Uhr Abends Mitternachtsmond. Der Sitz der Sysselmannen ("Sysselmann H. Thoresen, Kirkenes, Sör. Varanger) ist Greenharbour. Dorthin kommt nun auch die neue Telegraphenanlage, da eigener Strom in Königsberg diesen Winter zu teuer würde. Die holländische Grube Barentsburg seit 1925 still, 34 Millionen Kronen Kapital, 4 km von Greenharbour.

Dienstag 27. August

Ein kräftiger Ost und Wellengang seewärts. Am Mittag fahren 2 Kohlendampfer der Store Norske ab; auf "Hertha" werden abends die Bahren der beiden verunglückten Arbeiter gebracht.

Mittwoch 28. August

Wieder schönes Wetter - alles in allem also über Erwarten gut. Fangstmann Bengtssen Knud zum Kaffee, er erzählt für mich seien nun 10 Seehundsfelle in einem Fässchen eingepökelt. Er geht diesen Winter nicht nach Nordestland, sondern an den Vulandsund, da er weder den Bergmester noch den Sysselmann befehligen will. Dann erzählt er, wie er für mich Felle in Tromsö erhalte. Winterbär 250 Kronen, das grösste Fell dieses Winters hat er übrigens für 200 Kronen dem Doktor abgelassen; Blaufuchs ---- getrocknet 550 Kr., Weissfuchs 150 Kronen. Ich will mich für ihn in der Schweiz erkundigen, was er in der Schweiz erhielte (erneut Sch Verbindung über Greenharbour). Adresse Bergen: Karl. J. Bengtssen, Firmat Rosenlund, King Oskars gd., Bergen, Norge.

Donnerstag 29. August

Emil wird vom Telegrafisten gefragt, "wann eigentlich wir abreisen wollten". Der Direktor erzählt mir dann, dass bereits am Sonntag 170 Arbeiter wegführen. Er schlage uns vor, dann mit dem nächsten Dampfer am 3. oder 4. August abzureisen, da dann nur noch 2 Dampfer gingen (20. oder 25.), die überfüllt seien. So geht nun alles rascher als gedacht. Bengtssen fährt schon morgen zu seinem neuen Standort in Vulendsund, die Hütte muss er morgen in Quadehoek mitnehmen, vielleicht fahren wir bis dorthin mit. Wetter bei kräftiger Ostlage, abgesehen von Cirrusstörungen andauernd gut.

Freitag 30. August

Warte ab Mittag vergeblich auf Bengtssen, höre dann ganz zufällig abends, dass Bederssens Motorboot Defekt gehabt hätte (übrigens ein altes Rettungsboot des Kreuzers Berlin; wann, wo und wie?) Also morgen fünf Uhr vielleicht. Nach ---- nun recht frisch, Bewölkungswand zum Nordwesten hin.

Skognick (oder Strundholm) fährt vielleicht über Greenharbour, vorausgesetzt, dass die Eisverhältnisse Einfahrt in den Eisfjord erlauben; 2 der Store Norske Dampfer liegen noch immer hin ---- herum. Dr. Ingels meint, es sei gut für uns wegzukommen, auf dem Meer sei richtiges Polareis, 3 Meter hoch mit Süsswasserseen drauf, gesichtet, hoffentlich kämen sie am 20. oder 25., wie beabsichtigt, noch weg. (Adresse des jj. Telegrafisten: Regnar Schröder, Jvar Aasens gt 8, Aalesund).

Samstag 31. August

(in Worten einundreissigster August)

Man stellt sich so langsam innerlich auf Abreise ein. - "Wiggo" trottet vormittags durch die Nobilehütte, abends auf der flachen Abdeckung er Wasserleitung, der alte Kerl schätzt bequeme Promenaden.

Sonntag 1. September

Es geht nachts nun unter null. Wir sehen auch schon unterwegs an den Tümpeln und alten Schneeresten, auf denen das Schneewasser schon wieder gefroren ist. Wir gehen nachmittags nochmals an den geliebten Königsgletscher. Der Gletscher *kracht* mächtig, ganze Türme stürzen ein und erzeugen mächtige Brandungswellen, in der Bucht voll Eis, man sieht schon die Strömungen. Am Vogelberg waren nur Möwen, sämtliche Alken verschwunden.

Montag 2. September

Mittags fährt Studsholm, die 2 der "Store Norske" Schiffe liegen noch immer herum. Abends 11 Uhr fährt Lovstakke (so benennt nach einem der 7 Berge Bergens) und nimmt trotz voller Kohlenladung noch 170 Leute mit, von den 100 vorläufig Zurückbleibenden ist wohl alles am Quai. Unter den Zurückfahrenden auch verschiedene Familien, die beiden kleinen Zwillinge. Eines der Mädel mit Weissfuchspelz, dirndelhaftem Sommerkleidchen mit blossen Armen. Die Ziehharmonika täuscht nicht weg über die wehmütige Stimmung des Ganzen. Nachher fährt gleich Skognik, mit dem wir also auch "Greenharbour "das Westend von Spitzbergen" sehen wollen, an den Quai. Dieses ist, wie mir Thordal erzählt, 1920 erbaut, die "Vega" wurde von Norwegen hier herauf geschafft; die Grube wurde 1917 in Gang gebracht und im gleichen Jahr schon Kohle wegtransportiert (Kriegsverhältnisse), wobei an Stelle der Quais kleine ---- verwendet wurden. - Der Burgmester erzählt, dass im Eisfjord im August wenig gutes Wetter gewesen sei, nur hinten im Innern des Fjords habe man die Sonne durchschimmern sehen.

Dienstag 3. September

Der grosse Spektrograph ist nochmals kurz *aussen*; ich vermesse auch heute noch den Mitternachtshorizont, und verpacke die Platten. Donnerstag fünf geht's ja ab, sprach früh schon den Kapitän. Für Emil bin ich froh, dass es so *ist*. Er hockt bei blauem Himmel herum und hat "Langeweile" und wird immer verschlafener und maudiger. Hoffentlich wird er nicht noch krank auf der Reise.

Mittwoch 4. September

Eigentlich schon 5. September. Denn Mitternacht (um Mitternacht nun schon recht dunkel) ist vorbei; wir sind auf Skognik, die 2 Uhr früh in See soll. Das Hüttchen steht schon verlassen; wieder wurde das Gepäck erst in dem lustigen Pferdegespann, dann vom "Extrazug" an den Quai gebracht. Nun alles soweit ist, sind wir wohl zufrieden. Die Tonne mit Seehundsfellen wandert auch mit. Eine eigenartige Zeit liegt hinter uns. Dem Telegrafendirektor ist die Fahrt nach Greenharbour nicht ---- genug - er sendet nur die Apparate, er selbst will mit dem Burgmesterschiff nach Greenharbour - ja ja der Skat!

Donnerstag 5. September

Es wird wohl sichtlich 3 Uhr gewesen sein, dass die üblichen 3 Pfiffe - beantwortet *vom Werk und "nach Vermögen" auch der* ---- uns zum Bewusstsein brachten, dass es nun abging. In der Frühe ist der Nebel *durchstossen*, und wir sind beide - Ende gut, alles gut - in recht munterer Stimmung. 9h prächtiger Rückblick auf unsere Königsbay, die 7 Eisberge bis herauf zur Däneninsel, Kap *Mister* und Quadehock. Am Vuland entlang beginnt bald das Eis als langer Streifen der Küsten entlang, stets überlagert von niedrigem Nebel. Erst abends 7 Uhr - prächtige Beleuchtung - kommen wir *vor* dem Eisfjord selbst *an* die ersten Blicke. Immer wieder "Amundsenvögel"; prächtiger Sonnenuntergang.

Freitag 6. September

Früh 2 Uhr in Greenharbour, im Hafen nur Eis. Die 50 t Kohle für die Radiostation (, die) ausgeladen werden sollen, bleiben bis 7 Uhr liegen. Nach dem Frühstück lassen (wir) uns ausbooten. Alte Walstation; prächtige Hunde der Radiostation. Grosszügige Grubenanlage im 3/4 Std entfernten Barentsburg; dort *weisse* Polarhunde (----). Die Kohle wird *Tags* für *Tags* ausgekrant, am Nachmittags 4 Uhr geht's doch weiter. Auffallend klare Sicht in den grossen Eisfjord, bei der Ausfahrt ---- auch in den Bellsund. 7 Uhr abends schneidige Fahrt durchs Eis. Auf dem Schiff fühlen uns recht wohl, haben eigene vom Telegrafisten abgetretene Kabine, und über mangelnden Appetit gibt's auch nicht zu klagen; so ein klein bisschen *sind*, ohne Emils Kochkünsten nahe zu treten, nach dem vielen "Speck mit Bohnen" und "Bohnen mit Speck" doch ausgehungert. Der Kapitän präsidiert in sehr netter Weise die Tafel.

Samstag 7. September

Nachts erspähe ich durch die Luke vom *Lager* aus noch mehrmals Eis, morgens schon ruhiges Wetter und - Spitzbergen schon ausser Sichtweite. Gegen Abend macht sich's ein Eisfalke auf dem Schiff - als blinder Passagier - gemütlich, er ist gar nicht ängstlich und lässt sich auf 3 bis 4 Meter Distanz photographieren. Nach dem Abendbrot sitzt der Bursche wieder da, wollen mal sehen, ob gar morgen früh.

Sonntag 8. September

Ich schliesse für Arosa den 2. Quartalsbericht - Kingsbay 2. Sept. mit Briefstempel vom 4. Uebrigens meldet Kingsbay Schnee und Kälte. Wir haben bis jetzt bei nun etwas kräftigerem Seegang sehr günstiges Wetter zur Überfahrt. Um Mittag waren wohl auf Höhe Bäreninsel, wenn's so bleibt, Könnten am 10. früh in Tromsö sein; das wäre fein, da wir dann für die Weiterfahrt wieder die "Dronning Maud" hätten.

Montag 9. September

Gestern Abend etwas Regen, aber es geht gut weiter, heute Abend könnten (wir) schon Land sehen und morgen früh in Tromsö sein, meinte bei Tisch der Kapitän. Ich habe heute früh etwas abgerechnet. Wenn ich absehe vom Reiseanzug, Kauf einer Kamera (Mark 185.-), des Stutzens (Mark 50.-), so wäre die **Rechnung** etwa:

Ergänzung des Instrumentariums	567.00
Vorauslagen	870.00
Gepäcktransport	250.00
Dasselbe wohl zurück	250.00
Reise Arosa Spitzbergen 2P.	790.00
und wohl ebenso zurück	790.00
Aufenthalt Spitzbergen 2P.	815.00
	4332.00
Notgemeinschaft	4000.00
Defizit	332.00

welches eventuell noch durch Abnahme des Barometers durch Arne auf die Hälfte sich reduziert. Wir wären also zu zweit mit dem Voranschlag durchgekommen, der ursprünglich für mich allein aufgestellt worden war. 5 Uhr Nachmittags die beschneiten Berge Norwegens schon sehr schön sichtbar.

Dienstag 10. September 8h abends.

Die Lichter des nett erleuchteten (Kirchenuhr) Turms verschwunden, wir sitzen glücklich wieder auf der "Maud" und sogar in unserer alten Kabine. Prof. Evjen kommt zum Abschied aufs Schiff. Er erbat sich übrigens Arvensamen zu einem Versuch in Tromsö. B. Herrang war zum Kaffee, er zeigt mir eine prächtige Nordlichtaufnahme der vorangegangenen Nacht (10tel Bel.) Das Ausbooten der Instrumente in ein kleines Motorboot war wieder nicht so ganz einfach.

Kaum geschrieben, sehe ich selbst die schönsten Nordlichtentfaltungen (ca. 9 h) über dem ganzen Himmel, schöne intensive Linien im Taschenspektroskop. Das heisst Glück. Besonders schön dann 10h bei noch mehr vorgeschrittener Dunkelheit. In *Triesnes,* wo ich bei dem halbstündigen Aufenthalt um Mitternacht eine erstes Photo erhoffe, Himmel schon so gut wie bedeckt.

Mittwoch 11. September

Blauer Himmel in der Frühe, **Versuch einer Dobsonaufnahme nach Loednigen** , besserer Erfolg denn um Mittag in Svolver, In Svolver schon recht dichtes Laub. "---- ----". Fahrt an den Lofoten entlang bis Stamsund, dort ein ganzer Berg von Dorschköpfen.

Donnerstag 12. September

Früh Regen, erst abends lichter und in der Dämmerung bei Purpurlicht schöne Dämmerung.

Freitag 13. September

In der Frühe in Drontheim von Emil Trennung, der der Instrumente halber wieder nach Bergen, um dort mit "*Arnfinn Jarl*" nach Hamburg fahren wird, während ich mit der Bahn von Drontheim nach Oslo (550 Kronen) fahre (Drontheim ab 7 Uhr, Oslo an 22 Uhr). Trotz bedecktem Himmel schöne Fahrt durch urwüchsige Gebirgslandschaft, Fichten, Kiefer, zuletzt Birke, prächtige Himmelfarben, Rot der Heide, Gold der Birke, Grüngrausilber die Renntierflechte. Gegen Mittag an Erreichung der Passhöhe der *Doorfjeld* Hochnebel sich lichtend, Blick auf den Snehätte (2300m), wir erreichen die Passhöhe Hjerkinn 1017 Meter. ----. *Hinab*fahrt nach Dombaas, viele Höfe, selbst ein B----hof, eine Kapelle mit Rasen gedeckt, im übrigen statt der Holzmischung der Küstengegend nun mehr Blockbau, oft an Graubünden erinnernd, ich photographiere deswegen ein kleines Turistenhotel in Dombas (13h). *Hinab*fahrt durch das lange, historische Gudbrandsdal*,* nun Lillehammer (17h), dann Seenlandschaft des Mjösensees. - In Oslo fahre ich im Taxi von einem besetzten Hotel ins andere, der Besitzer vom "Westminster" vermittelt mir dann gute Unterkunft im Privathotel "St. Olav".

Samstag, 14. September

Besuch bei Dozent Hoel in seine stattlichen Büroräume; er erzählt mir, dass er 6 Wochen über die Vulkane der schwäb. Alb gearbeitet habe (Kirchheim). Prof. Rosselund ist in Amerika, Prof. Neuser in Genf, erzählt mir 11 Uhr Hoel. 12 Uhr geht der allwöchentlich einmal fahrende Dampfer nach Kiel. So verzichte ich auf Wikingerschiff und weiteres in Oslo, fahre mit Taxi ins Hotel, ohne Karte zum Anlegeplatz der *Söndenfjelds*-Norske Dampfer und komme 12 Uhr noch mit "*Krug Dag*" mit, die eine Nacht schlafe ich gerne wieder mal --- --- ! Nebel; Lektüre von d. Abs, über die Ernährung der Bassh.... von Barentsburg, ist hier nicht der Impuls des natürlichen Sonnenlichts unterschätzt?

Dozent Hoel fährt übrigens morgen nach Berlin an die Deutsche Versuchsanstalt für Luftfahrt (Abteilungs.... *Lakinen*) wegen der Frage photo*grammatischer* Spitzbergenaufnahmen, die die Versuchsanstalt nächsten Sommer ausführen will.

Sonntag 15. September

Am 15. Juni gingen in Hamburg in See, am 15. September, wollen zur gleichen Stunde in Kiel einlaufen - haarscharf ein Vierteljahr. Bei wolkenlosem Himmel in den grossen Balt, 9 Uhr (---- 6+) auf der Höhe Nyborg-Korsor; 9 Uhr begegnen dem Schwesterschiff "Kong Ring". Gegen Mittag an der Südspitze von Langeland, 1 Uhr die deutsche Küste sichtbar, Kieler Bucht, eine ganze Reihe grosser radial stehender Dampfer. Auf der ---- viele Segelboote. 3 am Quai.

Richtiger Sommer nochmals. Überhaupt soll das Wetter seit Wochen erstaunlich schön gewesen sein, wie mir dann Rosenberg erzählt, der oben ganz reizend sitzt. Bleibe oben zu Gast.

Montag 16. September

Weiterfahrt nach Hamburg. Besuch der Seewarte, bei Dr. Dammmeyer und seines Lichtforschungsinstituts des Eppendorfer Krankenhauses. Morgen wird "Graf Zeppelin" in Hamburg erwartet, und erster Begrüssung des von Amerika zurückkehrenden D. ---- .

Dienstag 17. September

Weiterfahrt in Göttingen unterbrochen; Besuch bei ---- und Prof. *Augenfeister.* Abends Weiterfahrt bis Heidelberg.

Mittwoch 18. September

Prächtiger Tag oben auf der Heidelberger Sternwarte bei Geheimrat Wolf. Die Eisbären Postkarte hatte er über seinem Schreibtisch befestigt; der Eisbär des Dr. Götz. Er erzählt, ich sei auf der Vorschlagsliste für die Frankfurter astron. Professur an dritter Stelle gestanden!! Weiterfahrt bis Stuttgart.

Donnerstag 19. September

Stuttgart-Göppingen. Noch keine telegr. Nachricht von Emil aus Hamburg.

Freitag 20. September.

Letzte Etappe. Mittags in Friedrichshafen Besuch von Frau Silerz; bei ihr wohnt nun *Eckenes* Direktionssekretärin, Frl. Brausewetter. Frau Silerz schenkt mir zur Erinnerung an Walter ein Buch aus seiner Bücherei.

Samstag 21. September

Kommt Emil erst in Hamburg an.

Freitag 27. September

Emil bringt die Instrumente bis Chur, wo ich sie durch den Zoll bringe. Das Fässchen mit Seehundsfellen ist bereits mehrere Tage in Göppingen.

Samstag 28. September

Früh 8h kommen noch die Instrumente wieder ins "Firnelicht". Unliebsame Überraschung beim "Dobson". Seit ein paar Tagen wunderbares Herbstwetter. **Im Aroser Fremdenblatt erschien heute "Reisebrief II".**

Annex 2 Publications of the LKO under F. W. P. Götz 1922-1954

Note:

Publication list established by Götz and extended by the report authors. Please note, that we did not complete and check all references.

The references (for articles in journals) are listed according to: author(s): title. journal, volume, (start) page, year.

Some papers included in this list by Götz (as LKO papers) do not contain the name of Götz as co-author.

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Annex 3 Publications of G. A. Perl 1937-1965

Note:

Publication list established by the report authors.

The list, which is not necessarily complete, covers the whole career of G. A. Perl.

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Annex 4 Publications of H. U. Dütsch 1946-1989

Note:

Publication list established by H. U. Dütsch. Minor adjustments made by the report authors.

The notation differs from that used in the other lists.

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Annex 5 Publications ETHZ - MeteoSwiss 1989- 2018

Note:

Publication list established by the report authors.

The list contains scientific papers based on the Swiss long-term ozone measurements (Light Climatic Observatory Arosa and Upper Air Station Payerne) written by ozone scientists at ETH Zürich and/or originating from the close collaboration between scientists of ETH Zürich and MeteoSwiss.

**: papers of PhD studies funded by GAW-CH; italic: Coworkers of MeteoSwiss*

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Johannes Staehelin, October 2015

Annex 6 Correspondence of Götz

Table 1: Correspondence **Dorno** (PMOD Davos) – Götz (LKO Arosa) 1921-1927
206 letters/cards/notes Dorno to Götz; only 3 letters Götz to Dorno found in the LKO archives

Year	Mth	Day	Letter Card	Year	Mth	Day	Letter Card	Year	Mth	Day	Letter Card	Year	Mth	Day	Letter Card
1921	10	7	L	1922	11	2	L	1923	9	28	C	1924		2	C
9		10	L			6	L			28	L			4	L
		26	C			8	L		10	1	C			7	L
	11	2	L			11	C			15	L			10	C
		9	L		12	7	L			17	L			12	L
		19	L			13	L			18	C			13	C
		30	L			15	L			22	L			14	L
	12	17	L			23	L			24	C		7	1	L
		27	L			27	L			24	L			2	C
1922	1	6	C			30	L			31	C			3	C
54		16	C	**1923**	1	10	L		11	2	L			5	C
		21	C	68		13	L			6	C			9	L
		31	C			20	C			15	L			11	L
	2	3	L			24	N			18	C		8	11	L
		4	L		3	6	L			20	C			21	C
		13	C			9	L			27	C			23	L
		23	L			21	L		12	3	C			25	C
		28	L			23	C			5	C			27	L
	3	4	L			28	C			8	L			30	L
		13	L			31	C			10	L		9	2	C
		19	L		4	10	L			11	L			4	L
		26	L			11	L			17	C			9	L
		27	C			18	L			18	C			10	L
		29	L			24	C			20	L			11	L
	4	14	L			27	L			27	L			23	C
		22	L		5	2	L	**1924**	1	8	L		10	21	L
	5	11	L			8	C	66		12	L			23	C
		12	L			15	L			30	L	Götz	11	13	L
		14	C			18	L		2	1	L			15	L
		17	L			24	L			2	L			16	L
		26	L			27	L			5	L			19	L
	6	7	L		6	3	C			7	C			20	L
		16	C			4	L			13	C			21	C
		27	L			29	C			15	C			22	L
	7	4	C		7	9	L			17	L		12	11	C
		10	L			16	L			18	C			15	L
		24	C			25	C			22	L			22	L
		27	L			26	C			27	L			30	C
		27	C			27	C			31	L	**1925**	2	2	L
	8	1	L			28	C		4	3	L	7		5	L
		22	L			30	C			7	L		3	24	L
		31	L		8	4	L			10	L			27	L
	9	6	L			7	L			11	C		5	27	C
		9	L			17	C			14	L		8	4	C
		16	L			16	L			21	C		9	9	C
		21	L		9	4	L		5	9	L	**1926**			
		23	L			5	L			12	C	3 Götz	3	26	L
		29	L			?	C			20	C			27	L
	10	3	L			?	C			22	L	Götz		28	L
		7	L			16	C			23	C	**1927**	7	2	L
		10	L			18	L			27	C	2	12	2	C
		14	C			20	L			30	L	correspondence stops			
		19	L			25	C		6	2	L				

Table 2: Correspondence **Dobson** (Oxford UK) – Götz/Perl (LKO Arosa) 1925-1954 Part 1: 1925-1935
346 letters/cards/notes Dobson to Götz/Perl, 13 Götz to Dobson and 9 Perl to Dobson (1953-54) in the LKO archives.

Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note
1925	11	9	L	1927	10	26	L	1929	7	2	L	**1933**	1	21	L
Götz		25	L		11	3	C			9	L	28	2	11	L
3	12	17	L			8	L		9	21	L			26	L
1926	3	8	N			14	L		10	1	L		3	7	L
31	4	16	N			19	L			20	L			8	L
		26	N		12	2	C		12	7	L			14	C
	5	9	C			12	L	**1930**	1	1	L			18	L
		25	N			15	L	14		30	L		4	8	L
	6	3	N			19	L		2	11	L		5	4	L
		7	N			31	C		3	15	L			20	L
		12	L	**1928**	1	5	L		4	21	L			27	C
		18	L	38		14	L		5	18	L		6	9	L
		24	N			23	L		7	9	L			17	L
	7	5	N			31	L		9	22	L			21	C
		19	N		2	20	L			29	C		7	14	L
		20	N			27	C		10	3	N			26	L
		22	N		3	17	L			13	L		8	5	C
	8	9	N			21	L		11	6	L			8	C
		16	N			29	L		12	7	L			31	L
		27	N		5	10	L			29	L		9	3	C
	9	3	N			19	L	**1931**	1	8	L			16	L
		24	C			29	C	12		29	L			19	L
		29	N		6	1	L		2	21	C			22	C
		?	C/N			18	L		4	14	C		11	8	L
	10	5	C		7	2	L		6	5	C			16	L
		26	N			19	C		8	13	L		12	3	L
	11	4	N			24	L			24	L			21	L
		8	N			25	C		10	31	C			27	L
		18	N			26	L		11	10	L	**1934**	1	16	L
	12	10	N			31				18	L	18		22	L
		20	N		8	9	L		12	1	C			27	L
		22	C			?	C			11	L			31	L
		?	C		9	4	L	**1932**	1	4	L		2	5	L
		31	C			12	L	22		27	L			12	L
1927	1	7	L			?	C		4	13	L		3	3	L
30		29	L		10	1	L			21	L			26	L
	2	9	L			9	C		5	9	C		4	3	C
		12	L			29	L			19	C		5	4	L
		28	L			30	L			20	L		6	4	C
	3	27?	C		11	3	C		6	4	C			18	C
	4	14	L			6	L			6	L		7	18	L
		23	L			10	C			8	L			28	L
	5	18	L		12	5	L		8	22	C		9	19	L
		20	N			13	L			30	C		10	1	L
		23	L			20	L		9	7	L			8	L
	7	16	L			22	L			8	C			24	C
	8	5	L	Götz		27	L			26	L	**1935**	1	10	L
		22	L			31	C		11	7	L	7	2	11	C
Götz	9	6	L	**1929**	2	3	L			11	L			?	L
		9	L	12		24	L		12	11	L		10	7	L
		16	L		4	8	L			13	L			25	L
	10	13	L			20	L			27	L		11	14	L
		14	C			24	L			30	C		12	31	L
		15	L		5	7	L			31	C				

Table 2 (cont.): Correspondence **Dobson** (Oxford UK) – Götz/Perl (LKO Arosa) 1921-1954 Part 2: 1936-1954
Total: 346 letters/cards/notes Dobson to Götz/Perl, 13 Götz to Dobson and 9 Perl to Dobson (1953-54) in LKO archives.

Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note	Year	Mth	Day	Letter Card Note
1936	1	16	L	1939	7	3	L	**1948**	1	5	N	1950	2	17	N
19	3	3	L			5	L	Götz		8	L	Götz		27	L
		17	L			11	L	5	3	15	L		7	9	N
	4	6	L		8	2	L		6	29	N		8	16	N
	5	13	L			3	L	Götz	11	25	N		11	1	N
	6	12	L			16	L	**1949**	1	29	N			6	N
		19	L			19	L	30	2	8	N			18	N
		23	L			26	L	Götz		14	L		12	2	N
	7	15	L		9	12	L			16	N			15	N
		16	L			23	L			17	N			18	N
		29	C		10	6	L		3	15	N	**1951**	1	23	N
	8	5	C		12	39	L	Götz		18	L	4	3	6	N
		12	C	**1940**	1	9	L	Götz		24	L			21	N
		21	L	14		16	L		4	4	L		10	3	N
		27	L		2	17	L			6	N	**1952**	6	11	N
	9	2	L		3	4	L	Götz	5	2	L	Götz	8	4	L
		14	L			13	L			14	N	3	8	7	N
	11	4	C			25	L	Götz		28	L	**1953**	5	27	N
	12	14	L		4	5	L		6	3	N	Götz	6	1	L
1937	1	14	L			13	L		7	12	N	Perl		16	L
8		24	L			26	L		8	5	N	Perl	10	13	L
	7	31	C			29	L			14	N			15	N
	9	9	L		6	13	L			24	N			22	N
		9	L		8	28	L		9	14	N	Perl	11	2	L
		25	L		10	2	L			21	L	Perl		10	L
	11	11	L		11	18	L			29	N	9	12	31	C
	12	25	L	**1941** Götz	4	10	L		10	11	N	**1954** Perl	1	8	L
1938	1	13	L	**1942**	1	27	C			29	N	13		15	N
3	12	19	L	2	11	22	C			31	N	Perl	2	24	N
	12	21	C	**1943**	8	13	L		11	5	N	Perl		25	N
1939	1	3	L	**1945**	11	29	L			15	L			24	N
20		5	L	**1946**	8	13	L			15	N			25	N
		16	L	3		23	L		12	2	N	Perl		27	L
		21	L		12	?	L			5	N		3	2	N
	3	8	L	**1947**	2	8	L			31	C	Perl		5	L
	5	17	L	4		11	L	**1950**	1	2	N			17	N
		27	L		6	11	L	13		6	N			26	N
	6	19	L		12	31	L		2	10	N	Perl	4	15	L
													12	31	C

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