Seismology at Croatian Seismological Survey

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CROATIAN SEISMOLOGICAL SURVEY

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Introduction - Seismicity of Dubrovnik Area

- Wider Dubrovnik area is one of the most seismicaly active in Croatia

1667 April 6,Dubrovnik M=7.4, I=X^{o}
MCS, tsunami, 3000 dead, 4000 missed

- Several very strong events in the past
- Most devastating event occured in 1667, all the city was destroyed

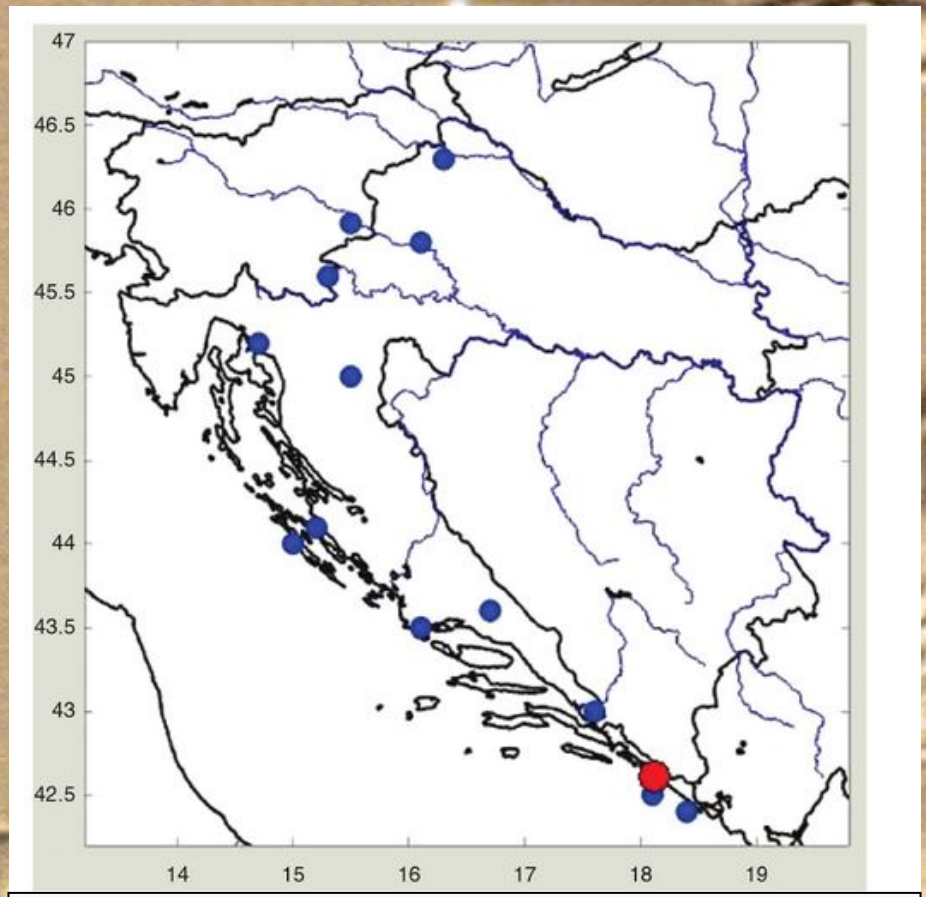
Introduction - Seismicity of Dubrovnik Area

- More strong earthquakes (1979 Montenegro (~70 km SE from Dubrovnik, Mm =6.9), Dubrovnik 1995 M=5.0, Ston-Slano 1996

Ston 1996, M=6.0, epicenter about 35km NW from Dubrovnik

1979, Montenegro

Introduction - Historical erthquakes in Croatia



Epicentres of earthquakes with Intensities ≥ 9 MCS for the period before 20 St.

- Zagreb 1880 (VIII °MCS)

Remete (part of Zagreb)

Kraljev Vrh (near Zagreb)

Introduction - Begining of Seismology in Croatia

- On Croatian territory of Austria-Hungary, there were 2 seismological stations:

  - Pula (1900, the at the Hydrographic Institute),
  - Rijeka (1901, Maritime Academy)

- After the end of Austro-Hungaria, they both stopped working

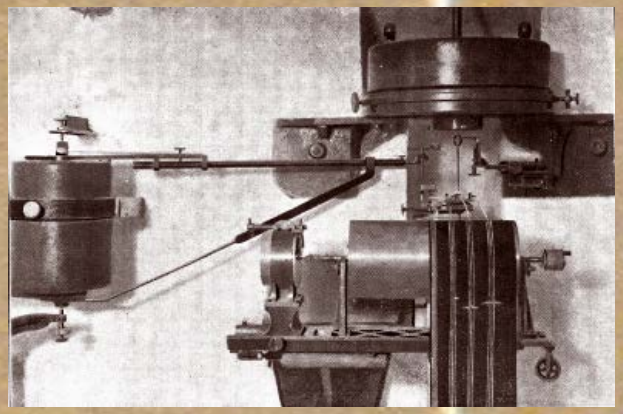
Introduction - Begining of Seismology in Croatia

- Begining of Seismometry at 70's of 19th century when I.Stozir installs first vertical ***Pendulum*** (120 cm) that writes on the dust during the earthquakes

- In 1901 M.Kispatic and A.Mohorovicic purchased first electrical ***Seismoscope*** (*Agamennone*)

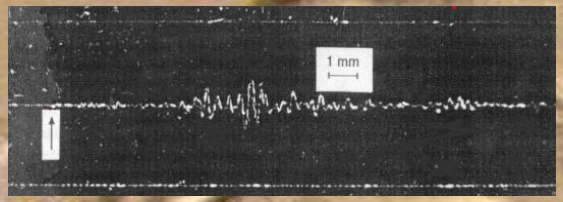
- 1905 Mohorovicic in Budapest borrows the first ***Seismograph*** (type *Vicentini*). It arrives in Zagreb in October, but is put into work after strong earthquakes in december **1905** and january **1906**, on the 4th of April

Introduction - Begining of Seismology in Croatia

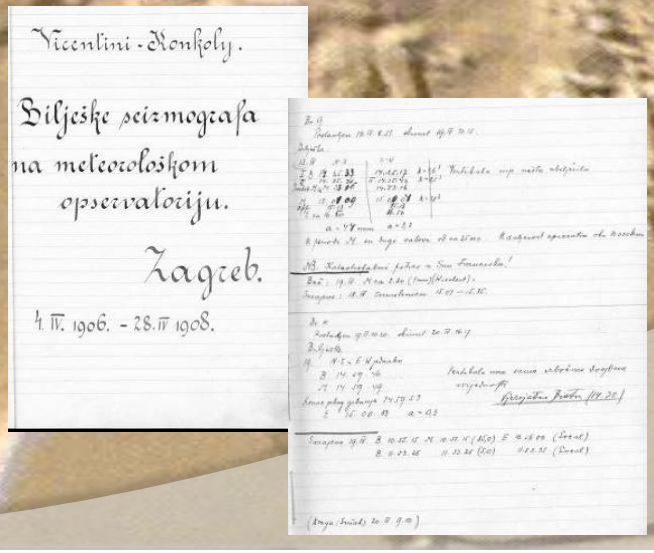


Vicentini – Konkoly Seismograph

- After only 12 days, it recorded a well known earthquake that happend on the 18th of April, and hardly devastated San Francisco

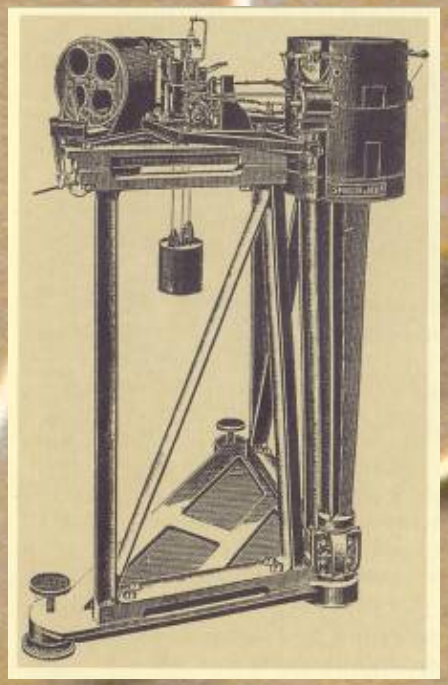


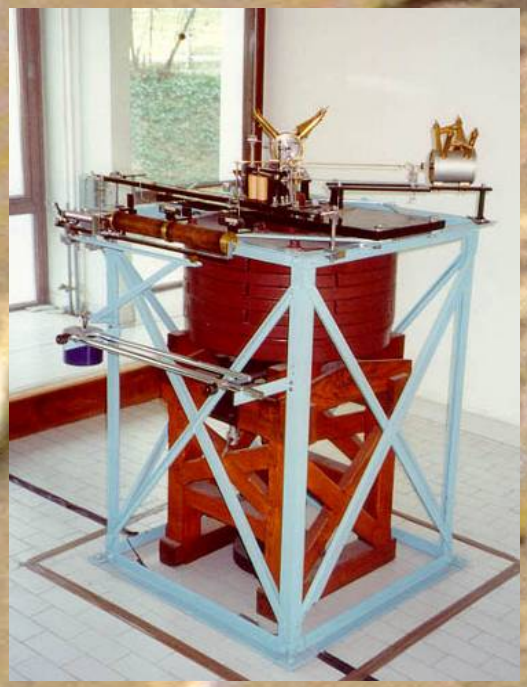
Pictures present that seismograph, and Mohorovicic notes on that earthquake

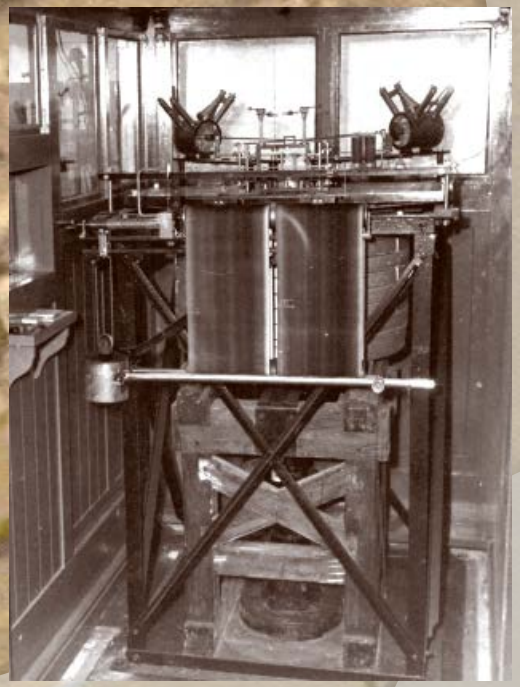


Introduction - Begining of Seismology in Croatia

- Mohorovicic was not very happy with that seismometer, so he purchases the newest and the best he could get – Wiechert seismograph (first just horizontals (80 kg, January 1908), 1000 kg (March, 1909).



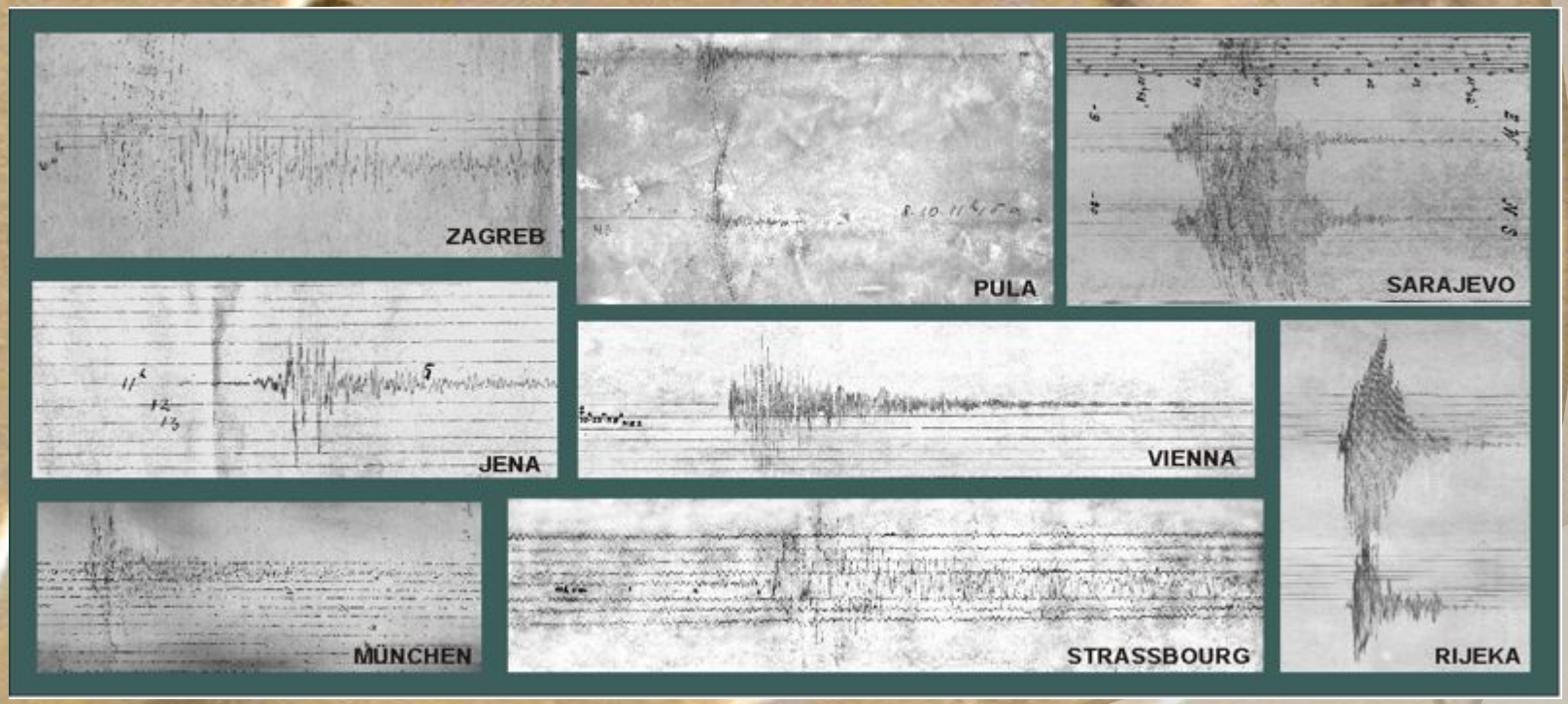




http://www.gfz.hr/sobe-en/exhibition.htm

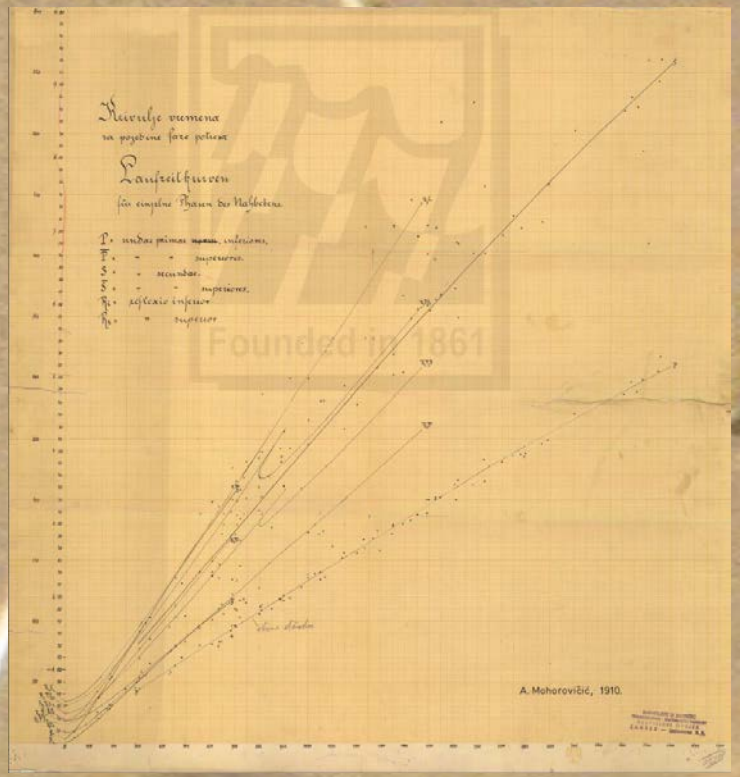
Introduction - Begining of Seismology in Croatia

- After the Pokupje 1909 earthquake, comes the Discovery of the discontinuity (1910)



Introduction - Begining of Seismology in Croatia

- Little bit of original calculation..



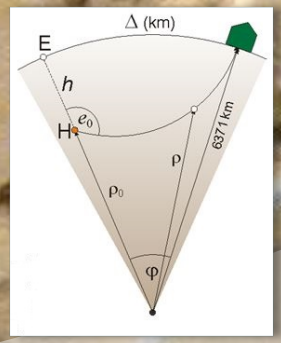
+ $c = c_0 (r_0 / r)^k$

+

$$t = \frac{s}{(k+1) c_0 r^k} \left[\sqrt{1 - r^{2(k+1)} \sin^2 i_0} - r^{k+1} \cos i_0 \right]$$

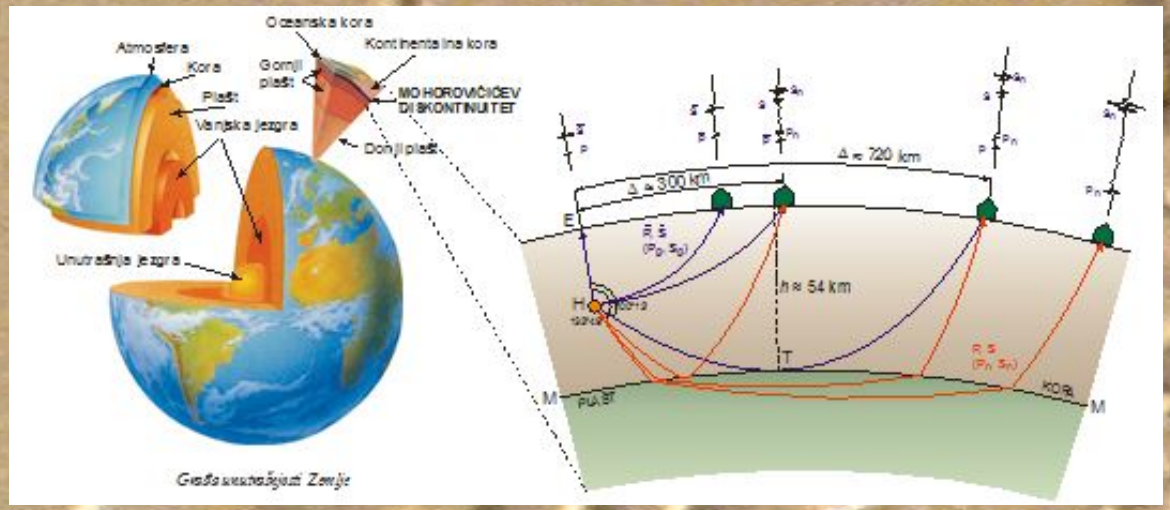
$$\int = \frac{c_0}{k+1} - \frac{1}{k+1} \arccos \left[\left(\frac{s_0}{s} \right)^{k+1} \sin i_0 \right]$$

+

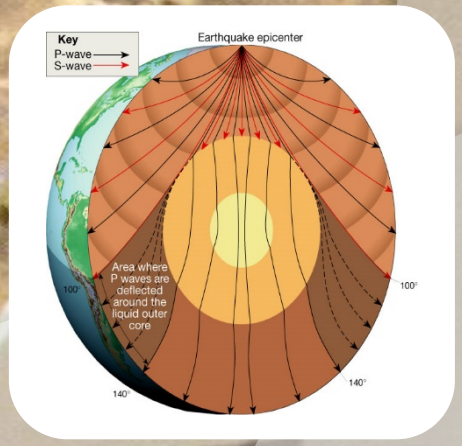


Introduction - Begining of Seismology in Croatia

- *Mohorovicic's discontinuity (Moho)*



- Later on, using the same methods, other discontinuities were explained (Inge Lehmann, Guttenberg, ...)



Seismology at CSS

- 1985 Croatian government brought the „Law on Seismology" and founded The ***Croatian Seismological Survey***, within the Geophysical Institute of Faculty of Science
- At that time, it had 8 Seismologists
- 3 Stations (ZAG, PTJ, HVAR)
- That was the bone of the Network, that started to grow with time
- 1989 Modern digital seismographs were deployed for stations ZAG, HVA, and DBK

Seismology at CSS

- ***11 Seismologists*** *working in* ***Croatia today*** (pure seismology) !!

- CSS – 6 seismologists + 1 el.engineer
- Faculty of Science, Geophysical Dept. – 5 seismologists (2 Professors, 1 Assistant proferssor, 2 assistents)
- CSS included in the Faculty work (science and teaching)

- ***CSS*** operates, completely (installing, maintaince, communications, etc...) the ***Seismograph network*** and the ***Accelerograph Network*** in Croatia and does all the usual seismological tasks
  - archiving the data
  - analysing the data
  - macroseismic field work and analyses
  - bulletins, cataloguing, ...

Seismology at CSS

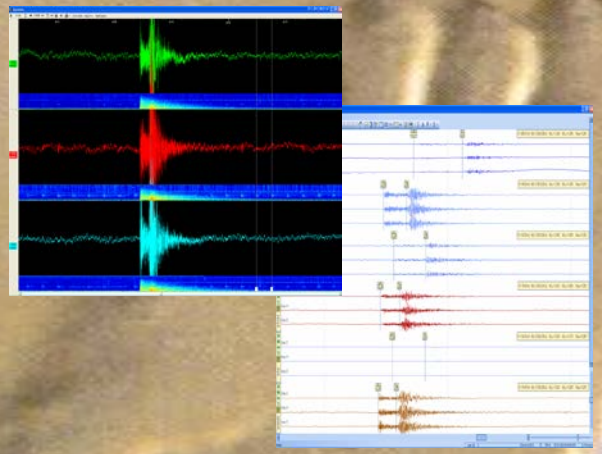
- Head of the Survey is a memeber of the *State Headquarters for Protection and Rescue (Civil Defense)*
- Representatives of the CSS are members of the City Headquarters for Emergency Situations, and other State and local authorities for Crises Management
- Responsible for almost all other seismological issuses (seismic hazard and risk, etc) on the State and local levels

- 24 /7 /365 Seismologist on duty
  - Mon - Friday 7am - 9 pm , Sat 07 am - 2 pm in the office
  - the rest of the day „on Standby”

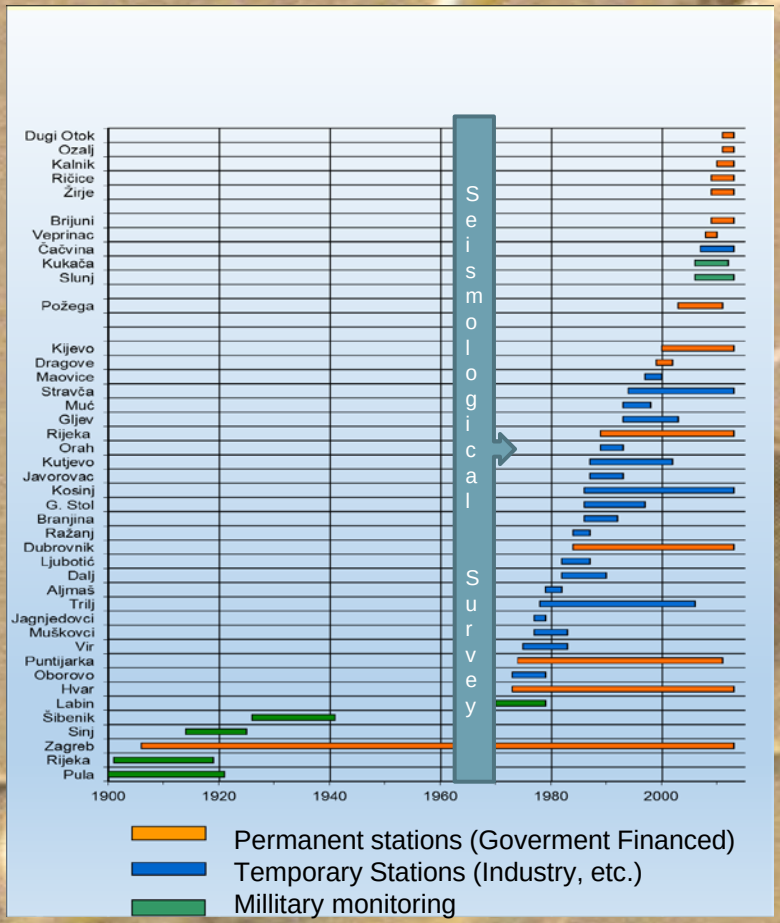
Seismology at CSS

- Reporting Earthquakes to

  - Public, Media, Relavant State and local Institutes
  - National Protection and Rescue Directorate (112)
  - City Office of Imergency Management
  - Other Important Offices or Institutes



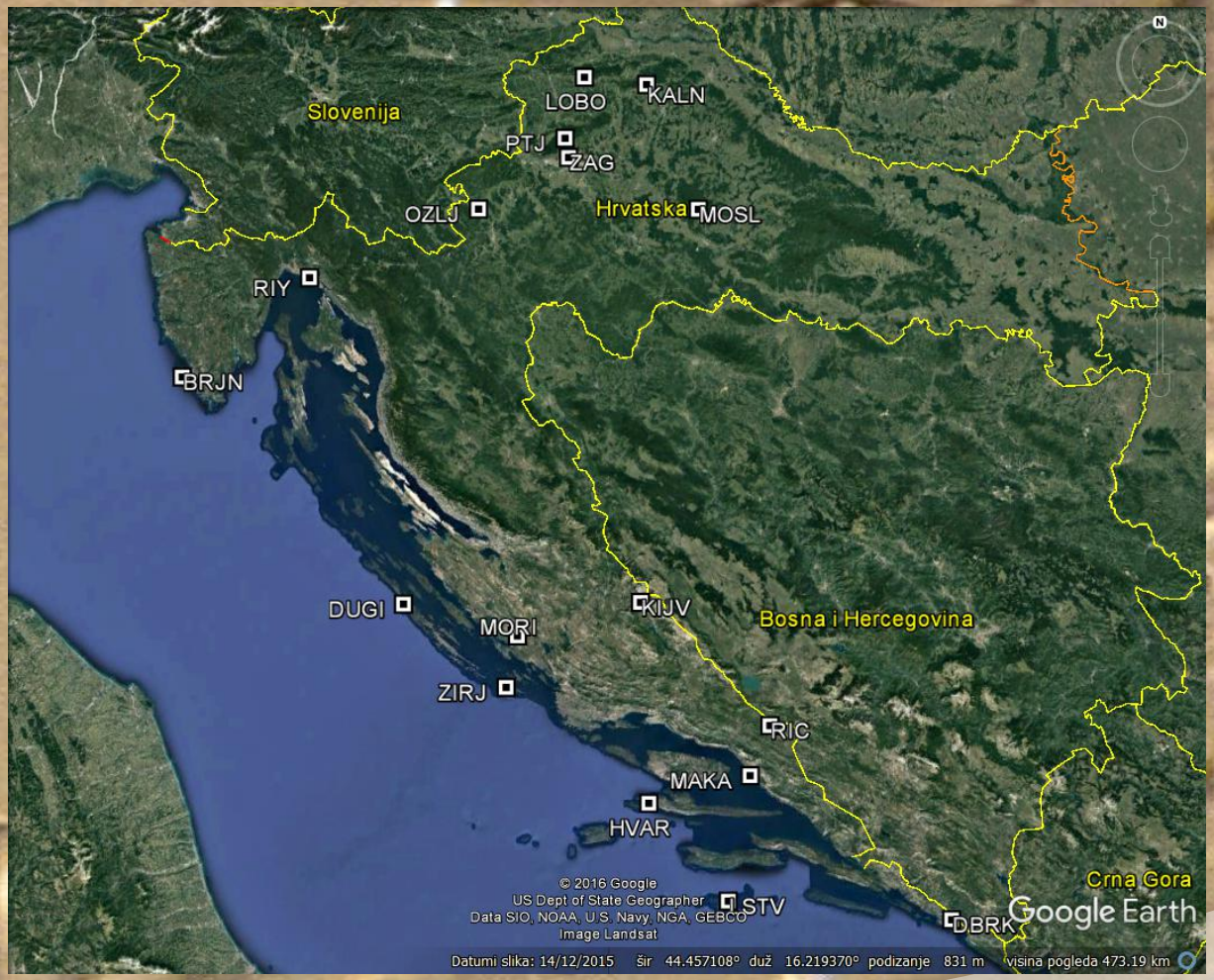
Seismology at CSS



Deployment of Seismological stations

Spatial distribution of permanent stations

Seismology at CSS

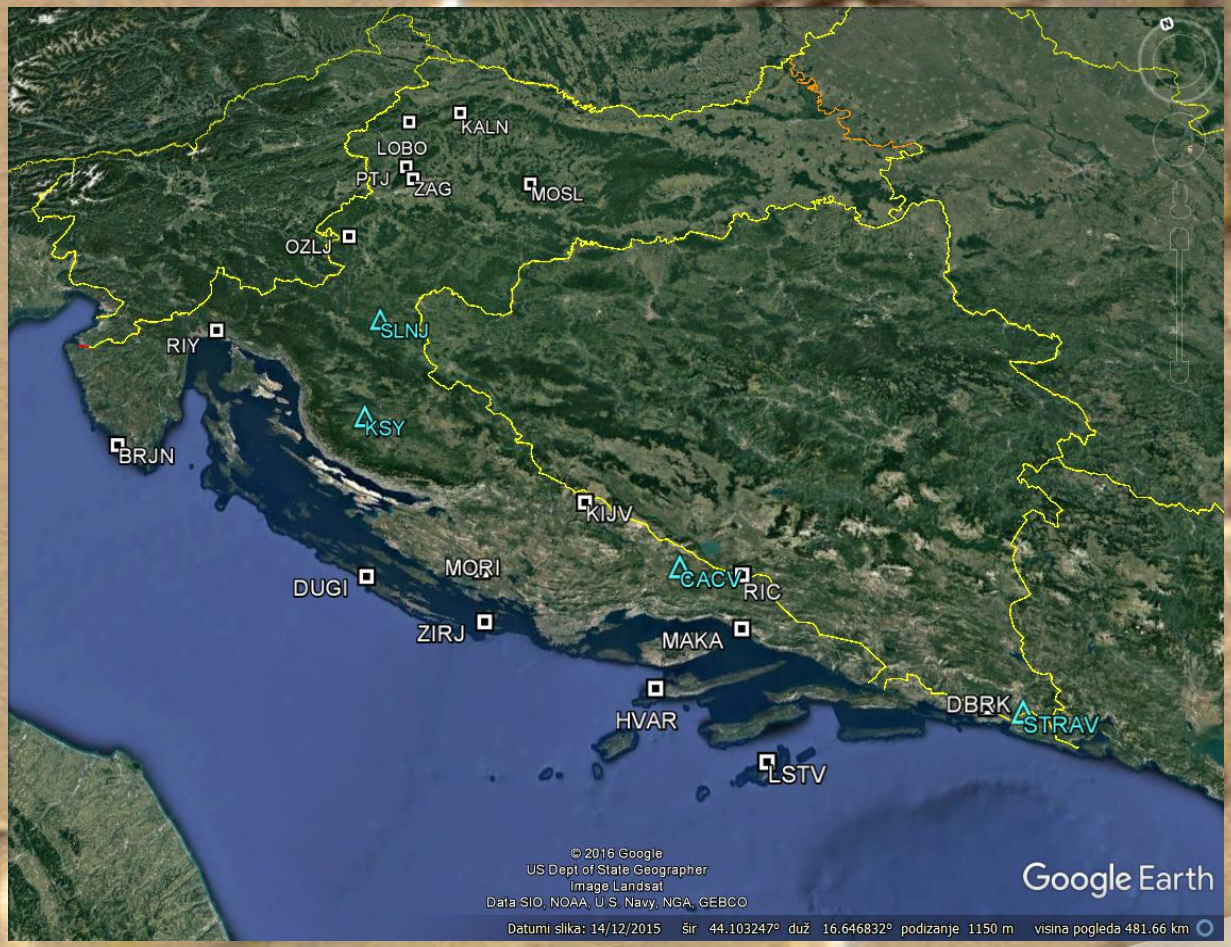


17 permanent stations (seismographs)

4 temporary stations (Millitary, Industry)

Moslavacka g. Station

Seismology at CSS



17 permanent stations
(State Network)

4 Temperary stations
(Millitary, Industry)

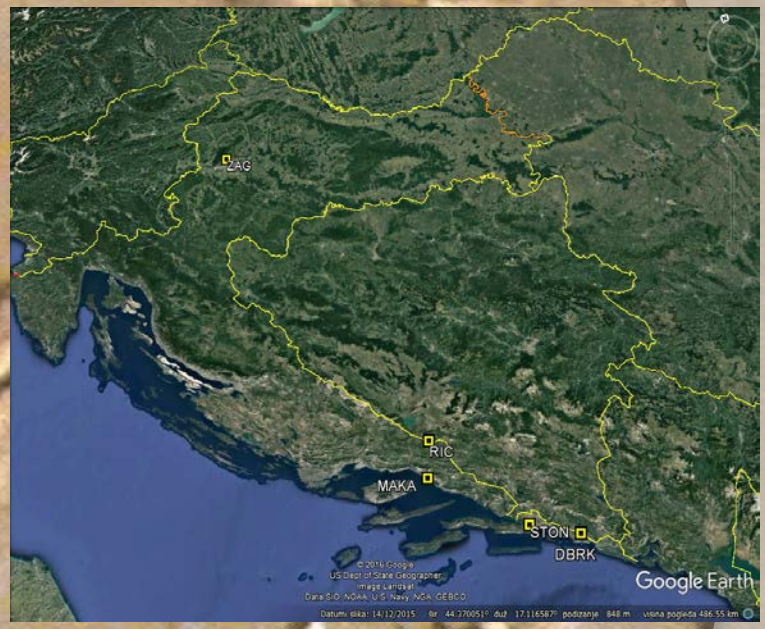
-STS 2
-CMG 3T, CMG 3ESP, CMG40T(D),
CMG 6TD
- Lennartz (20 s)
- Q330
- CMG24, S3, EAM, ...

Seismology at CSS

Accelerographs

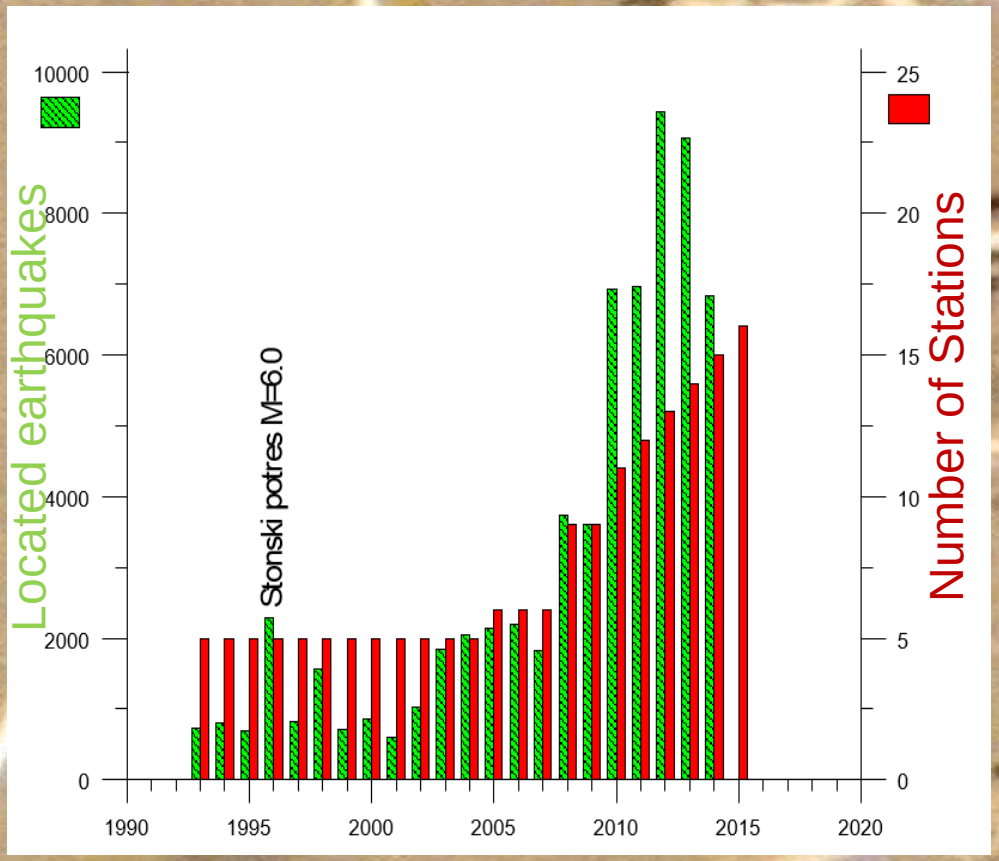
- Only 8 Accelerographs
  - 1 in Zagreb (CMG5T)
  - 1 in Makarska (Etna)
  - 1 in Ston (Etna)
  - 2 in Ricice (SSA2)
  - 3 in Dubrovnik (GeoSIG)

- 4 more CMG5TDE to be installed in Zagreb



Accelerographs

Seismology at CSS



Graphical presentation of located earthquakes per year (left axes)

Number of Stations (of the State Network) (right axes)

Seismology at CSS

- Communications – Different methods of data-transfer
  - CARNet (best quality, highest speed, bandwidth, but not available at field stations
  - SATTELITES (VSAT)
  - 3G, 4G Networks (mobile-providers)
  - ADSL

- 2 'Seismological Platforms' working parallel

  - Guralp based (SCREAM)
  - SEISComP

Seismology at CSS

- DATA EXCHAGE
  - The real-time data exchange with different Institutions in the region

-And Project CEERN

- Italy (INGV (Roma, Milano), Udine Univ., Trieste Univ.
- ZAMG (Austria)
- ARSO (Slovenia)
- Seismological Survey of Serbia
- Bosnia and Hercegovina (Banja Luka)
- Montenegro (?)
- Czech Republic
- GFZ Potsdam
- Orfeus (ALPARRAY, ..)
- ...

CEERN Central Eastern Europe Earthquake Research Network

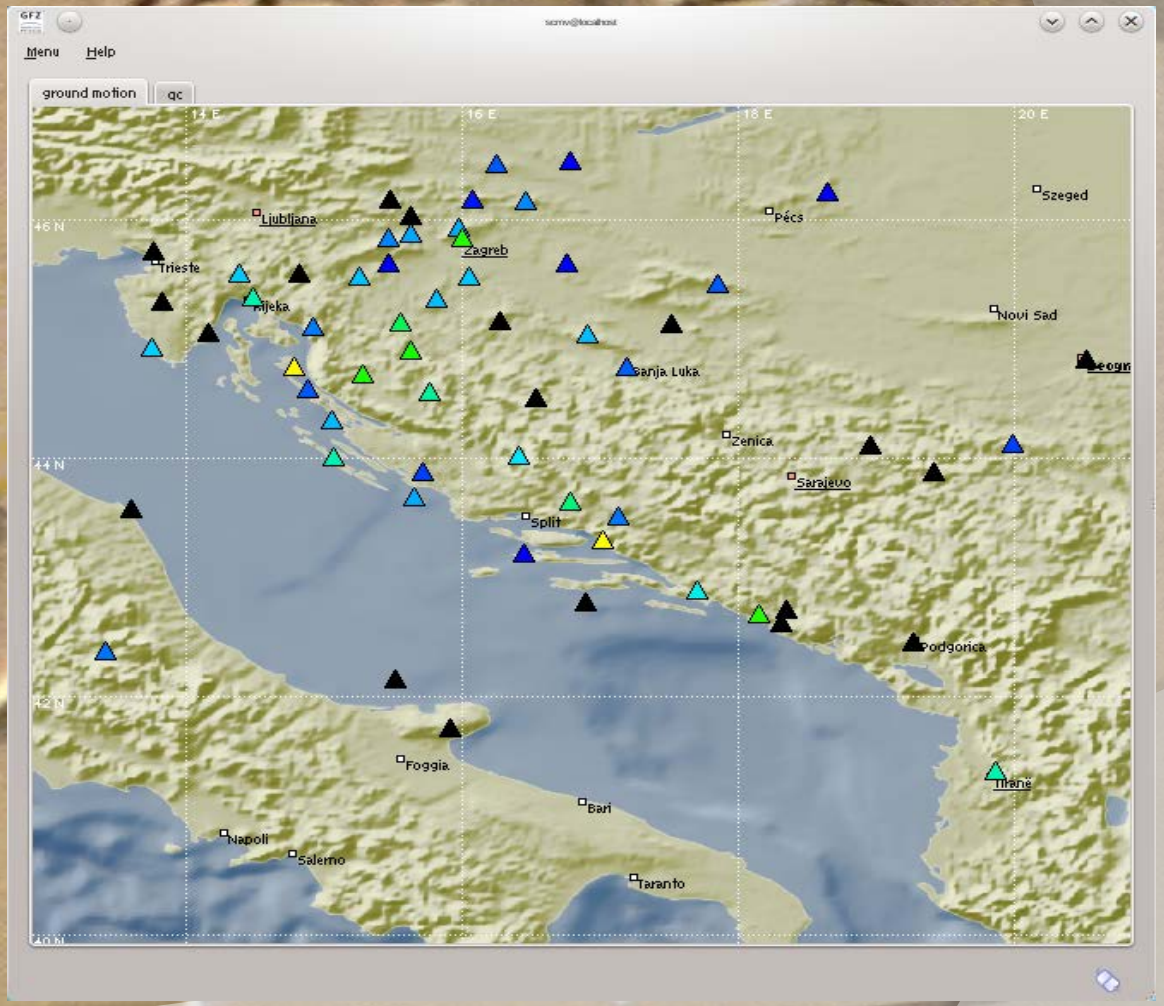
Seismology at CSS

FULL NETWORK

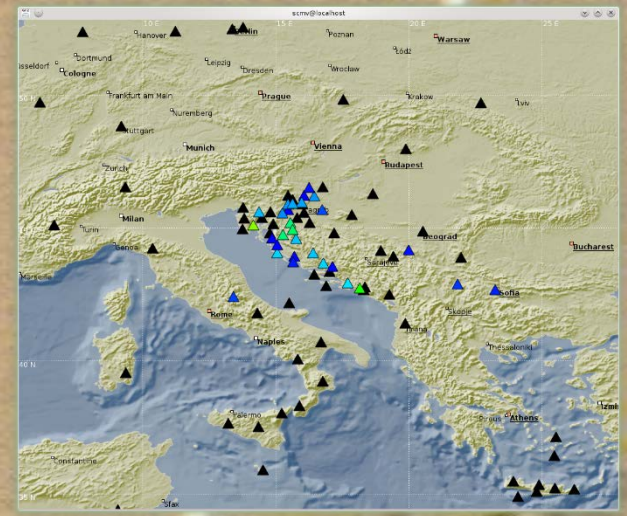
- State Network
- Industry and Military
- Univ. Projects (VELEBIT, ...) ALPARRAY

and

- Foreign stations (through real-time data Exchange)

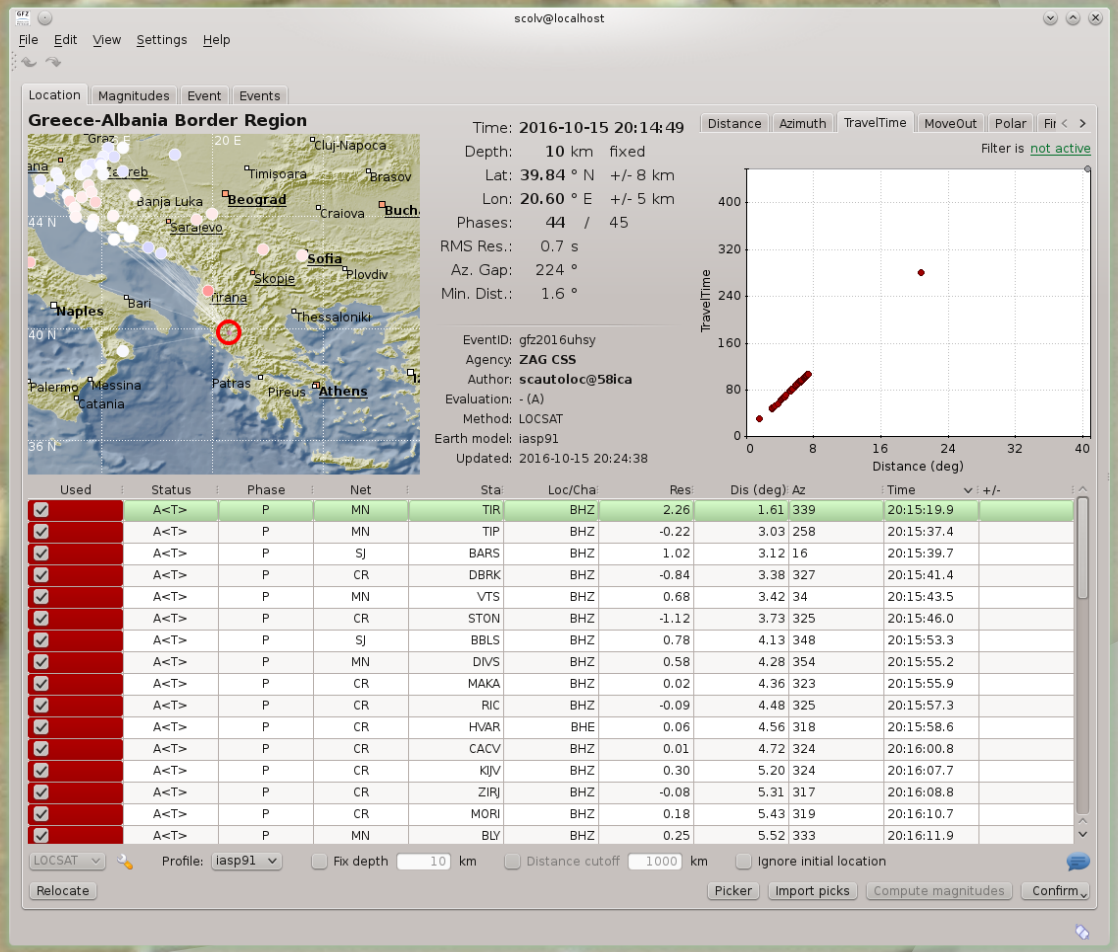


Seismology at CSS



VIRTUAL NETWORK

- *Local Network(s) and foreign Stations*



Seismology at CSS

Example of good colaboration – mobile pool (?) CSS (Cro) + ARSO (Slo)

Earthquake Sequence near Krsko Nuklear Power Plant (2015)

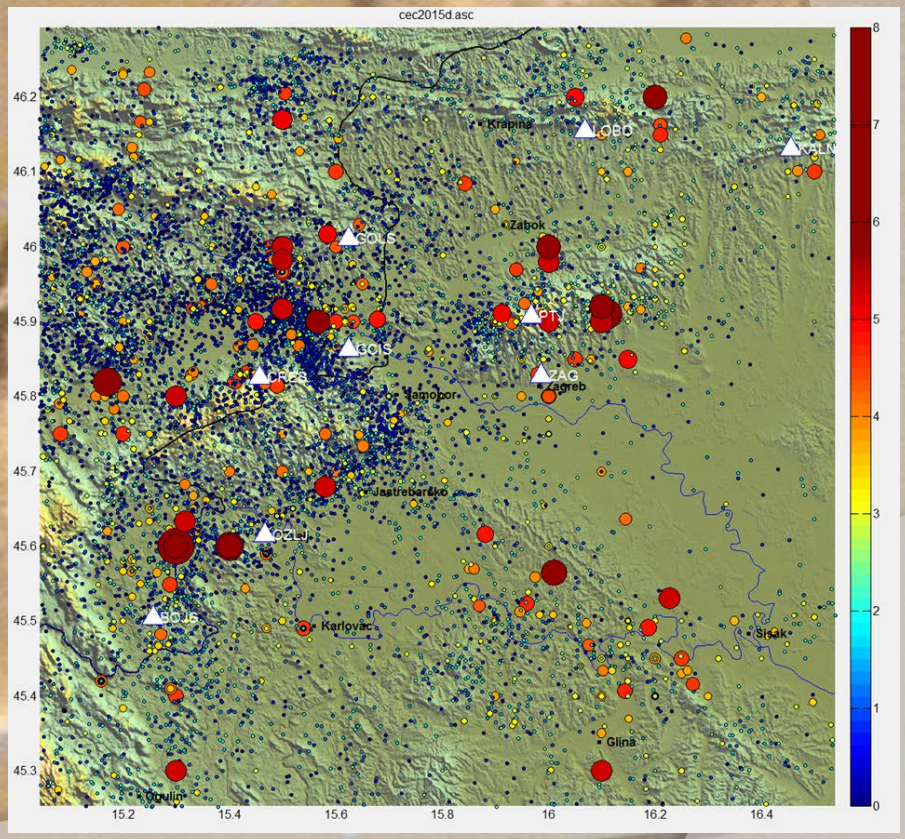
Main shock

4.3 magnitude earthquake 5 km from Brežice, Slovenia

12 months ago

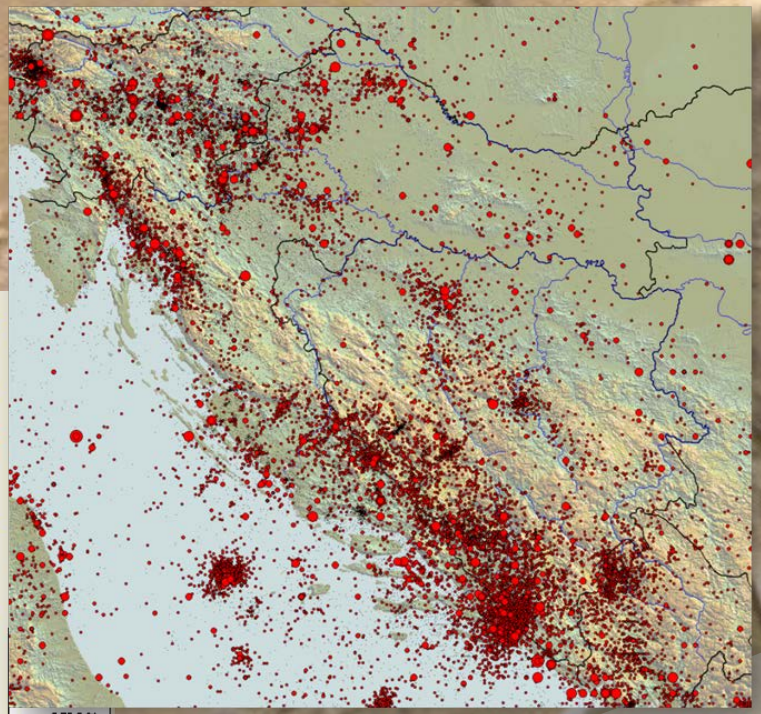
UTC time: Sunday, November 01, 2015 07:52 AM
Your time: Sunday, November 1 2015 8:52 AM
Magnitude Type: mb
USGS page: M 4.5 - 4km W of Brezice, Slovenia
USGS status: Reviewed by a seismologist
Reports from the public: 19 people

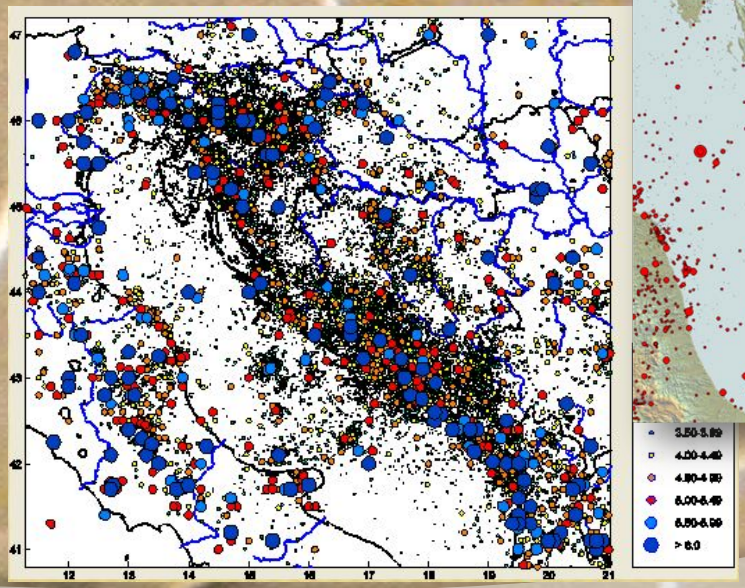
4 Hours after Main shock, 2 temporary stations in Croatia, and the same in Slovenia
Hundreds of Earthquakes in next month



Outcomes of Seismology

- As the result of 135 years of croatian seismology, there are more then 90000 earthquakes since
  373 bC
  in croatian catalogue

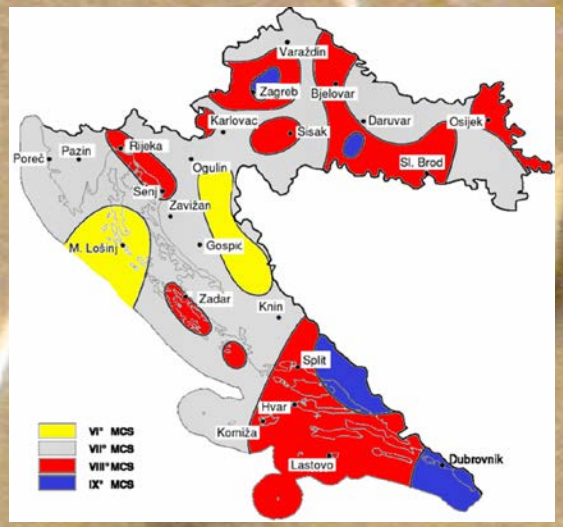


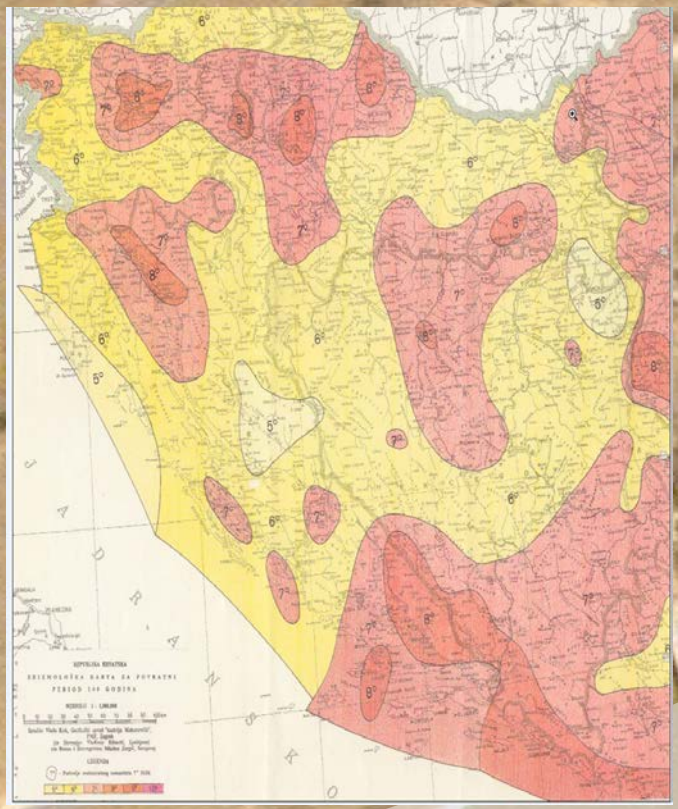


Outcomes of Seismology

The maps that were widely used:

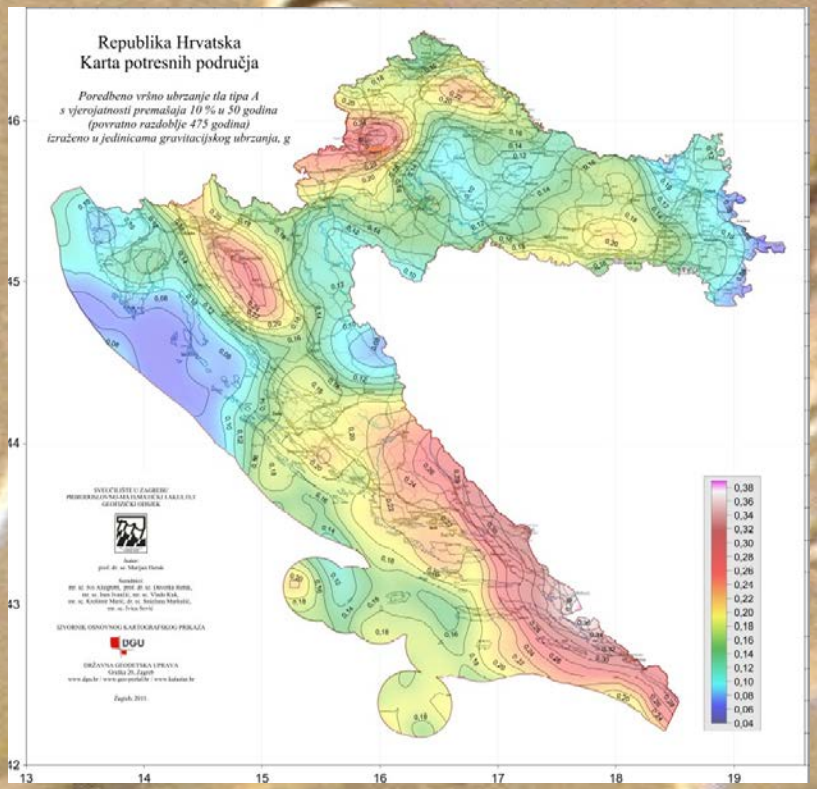
Former Maps of Maximal Expected Intensity for the return period of 100 years (right), and 475 years (down)



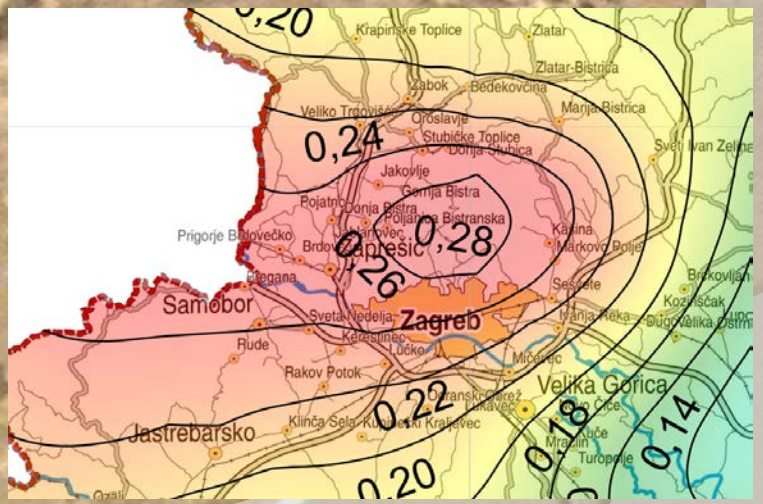


Outcomes of Seismology

- A new map has been done (2011), respectively to Eurocode regulations, using acceleration:



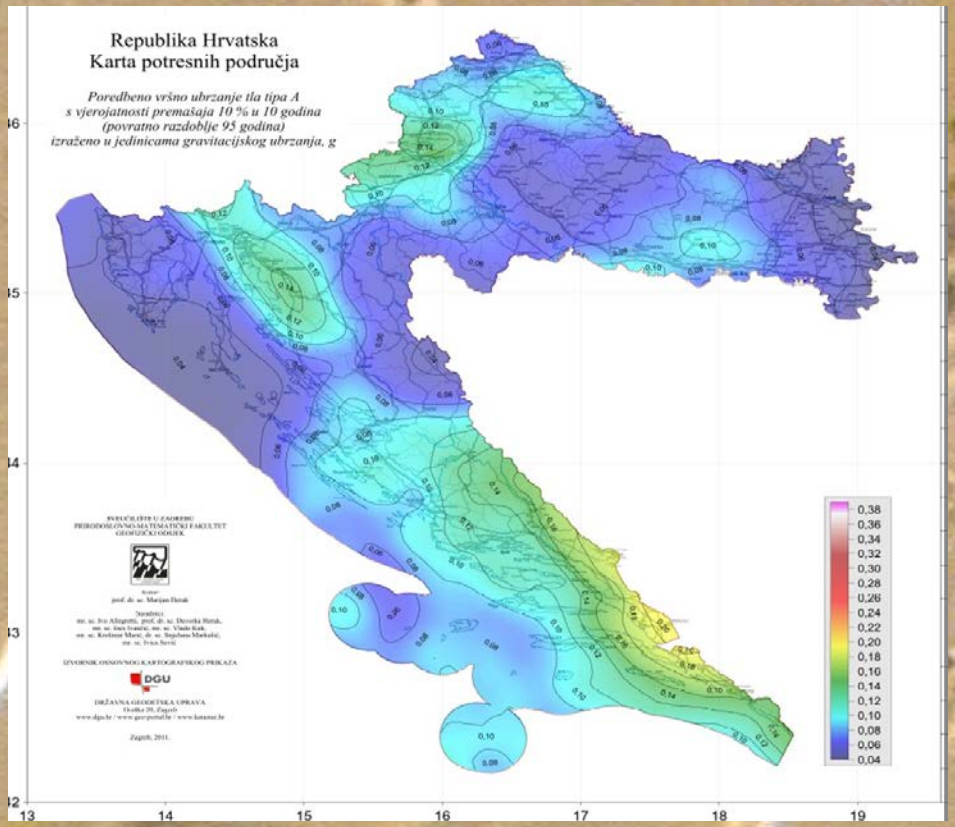
Peak ground horizontal Acceleration (in terms of *g*) for the return period of 475 years



Seismic Hazard for City of Zagreb

Outcomes of Seismology

- And the same for the Return Period of 95 years



Peak ground horizontal Acceleration (in terms of *g*) for the return period of 475 years (for the soil type A)

All Croatian Seismology

Croatian Seismological Service
and
Geophysical Dept. of
Faculty of Science


THANK YOU !