A Revised Version of the Cloud Microphysical Parameterization of COSMO-LME

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Motivation:

- Well known problems of COSMO-LME regards wintertime precipitation:
  - Overestimation of orographic precipitation
  - Too little precipitation in the lee of mountains
  - Maybe too low condensate content (cloud water, cloud ice, snow)
  - General overestimation of precipitation amounts during winter

- The COSMO-LME microphysics scheme is somewhat outdated as it is mainly based on the scheme of Rutledge and Hobbs (1983).

  Can recent observations or new parameterizations improve the precipitation forecasts of COSMO-LME?

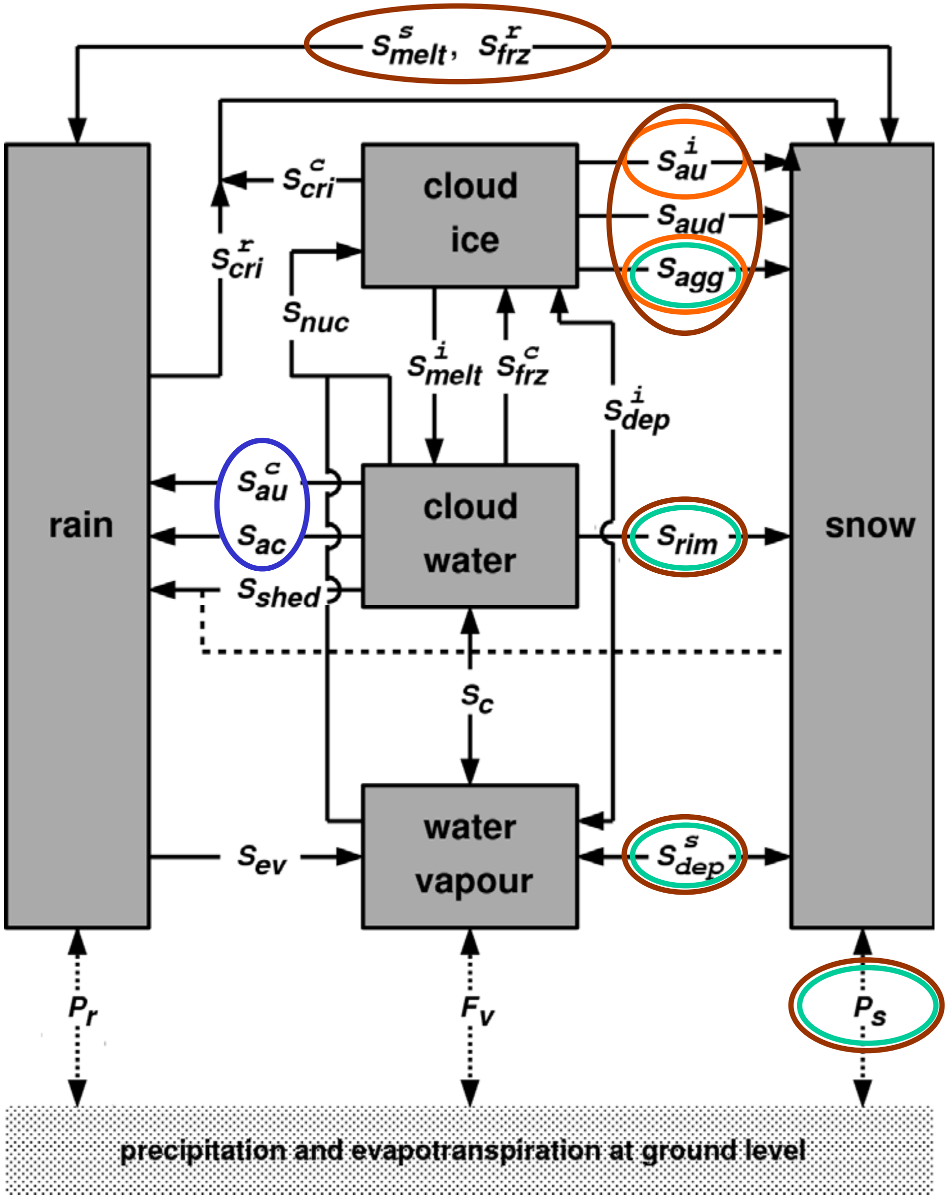
LME cloud ice scheme:

Changes with 3.22:

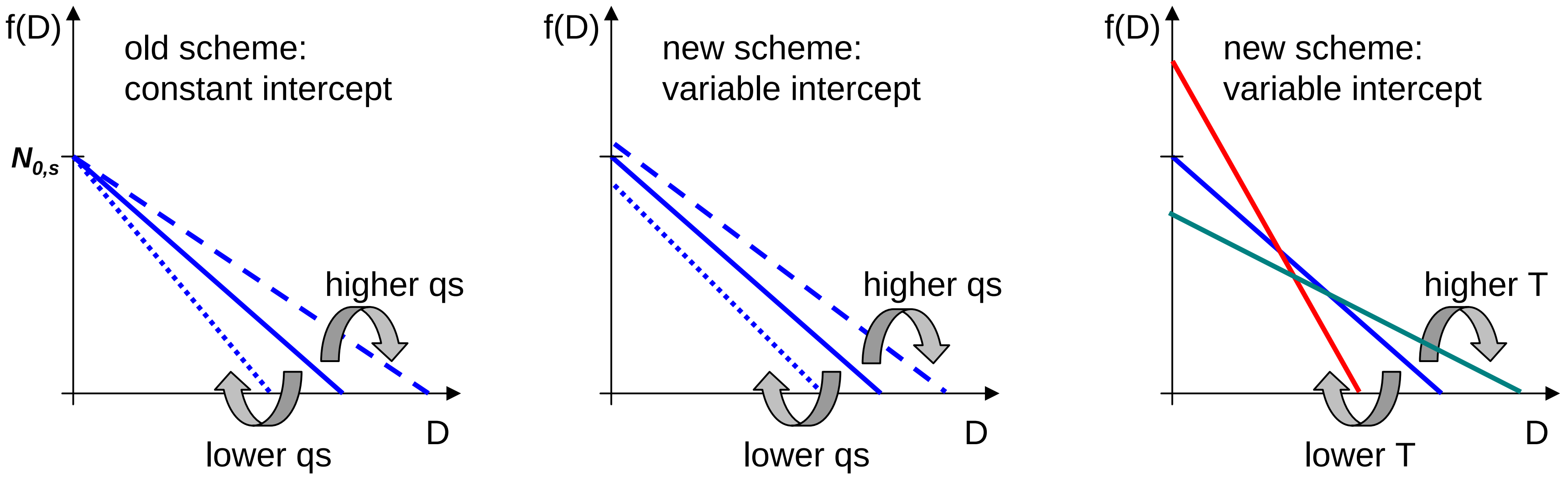
- Sticking efficiency (O)
- Fall speed of snow (O)
- Intercept parameter and geometry of snow (O)
- Warm rain scheme (O)

Overall effect?

- Precipitation formation much slower, especially at cold temperatures.
- On average higher mixing ratios of cloud water, cloud ice and snow.



Variable snow intercept parameter: What's that?



- The snow size distribution can now adjust to different conditions as a function of temperature and snow mixing ratio.
- This will (hopefully) give more accurate estimates of the various microphysical process rates.

Variable snow intercept parameter: An empirical parameterization

Using a parameterization of Field et al. (2005, QJ) based on **aircraft measurements** all moments of the snow PSD can be calculated from the mass moment:

$$\mathcal{M}_n = a(n, T_c)\mathcal{M}_2^{b(n,T_c)}$$

Assuming an exponential distribution for snow, $\boldsymbol{N_{0,s}}$ can easily be calculated using the 2nd moment, proportional to $\boldsymbol{q_s}$, and the 3rd moment:

$$N_0 = \frac{27}{2}\,\frac{\mathcal{M}_2^4}{\mathcal{M}_3^3} = \frac{27}{2}\,a(T)\,\mathcal{M}_2^{4-3b(T)}$$

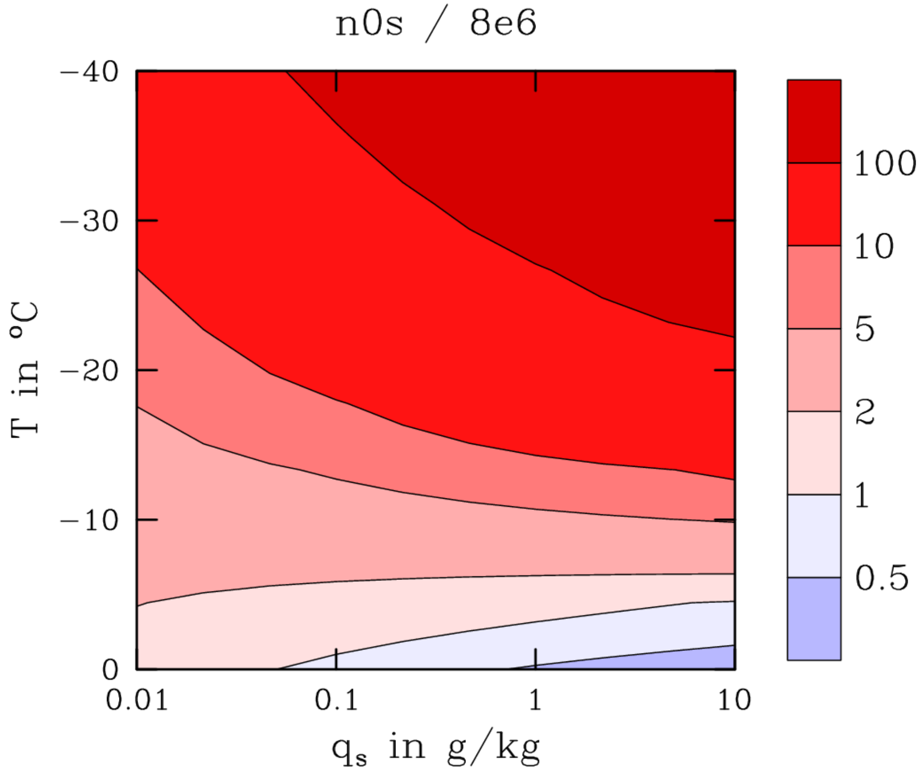
Now we have parameterized $\boldsymbol{N_0}$ as a function of temperature and snow mixing ratio.

Variable snow intercept parameter: (continued)

$$N_0 = \frac{27}{2}\,\frac{\mathcal{M}_2^4}{\mathcal{M}_3^3} = \frac{27}{2}\,a(T)\,\mathcal{M}_2^{4-3b(T)}$$

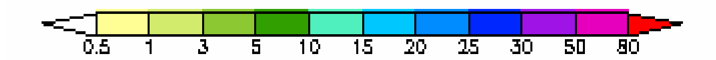
The dominant effect is the temperature dependency, which represents the size effect of aggregation, i.e. on average snow flakes at warmer temperature are larger.

This dependency has already been pointed out be Houze et al. (1979, JAS) and is parameterized in many models using ***$N_{0,s}(T)$.***

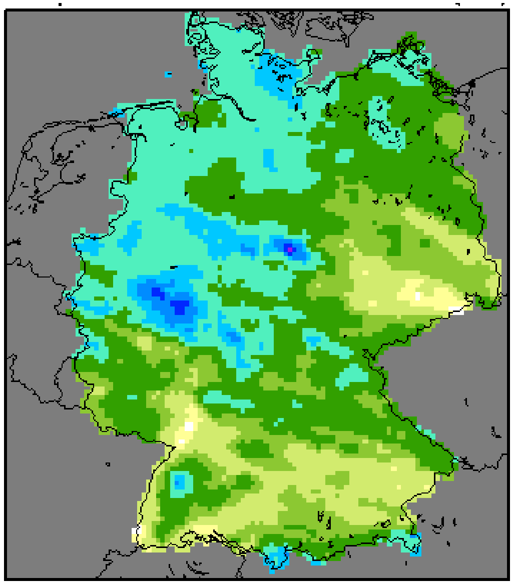


Accumulated precipitation
11.01.07 00 UTC, 06h - 30h

accumulated precipitation in mm

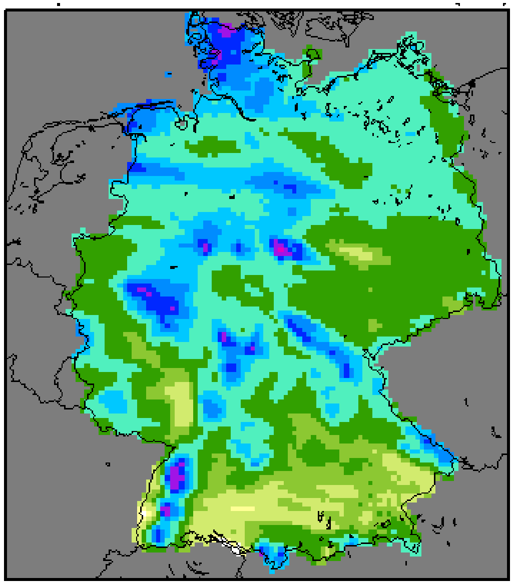


Surface observations



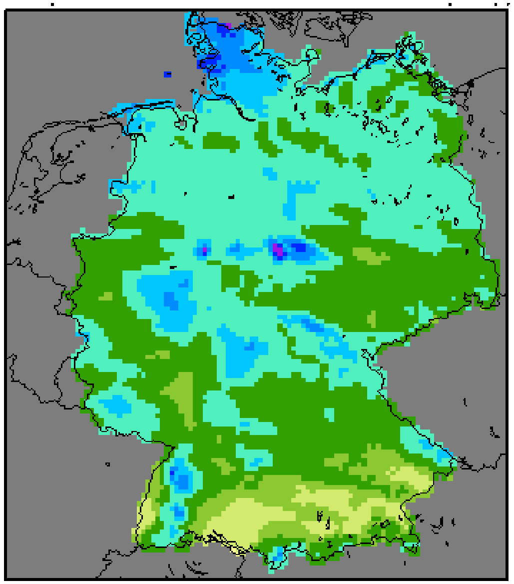
mean: 8.1 mm
max: 31.5 mm

LME, old microphysics



mean: 11.5 mm
max: 50.7 mm

LME, new microphysics

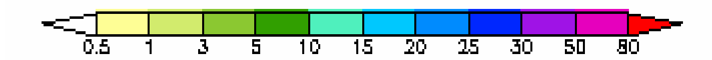


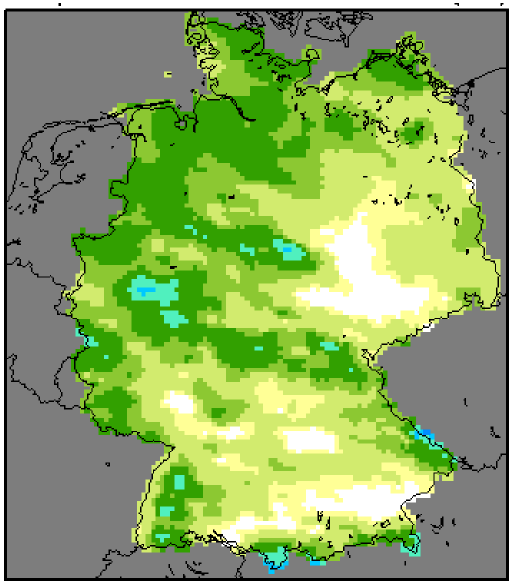
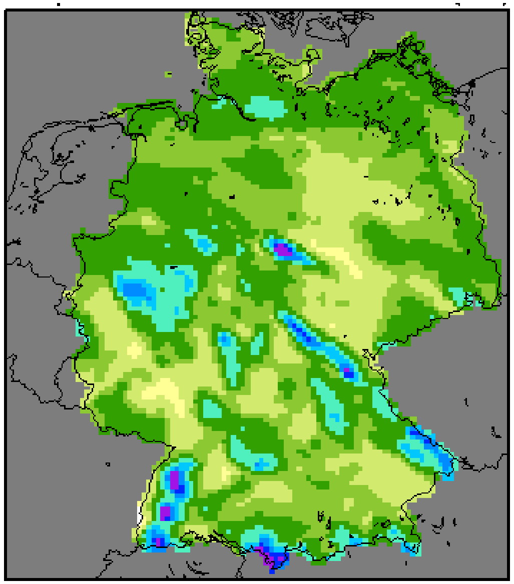
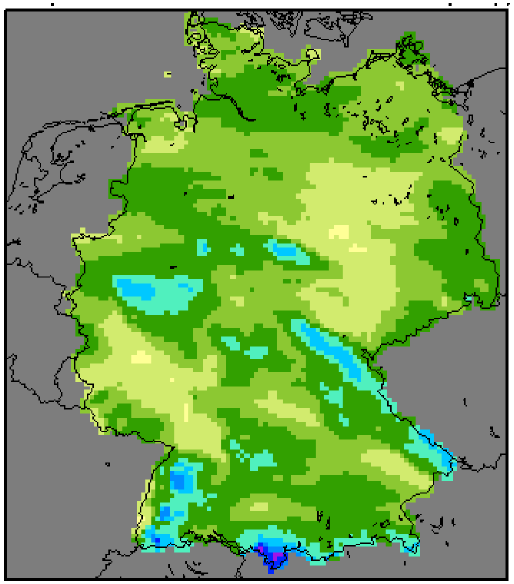
mean: 10.3 mm
max: 36.7 mm

- Orographic precipitation falls out slower leading to decreased precip amounts at mountain tops and more horizontal advection into the lee

Accumulated precipitation
04.01.07 00 UTC, 06h - 30h

accumulated precipitation in mm

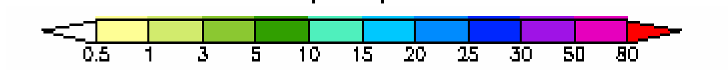


Surface observations	LME, old microphysics	LME, new microphysics
		
mean: 3.7 mm max: 21.2 mm	mean: 6.0 max: 43.4	mean: 5.6 max: 32.9

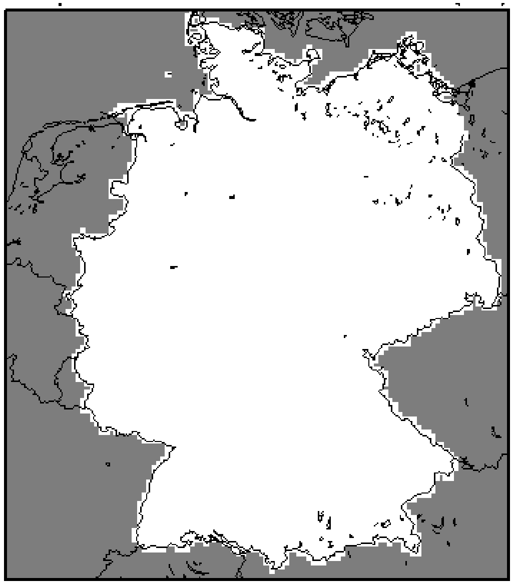
- Orographic precipitation falls out slower leading to decreased precip amounts at mountain tops and more horizontal advection into the lee

Accumulated precipitation
22.12.06 00 UTC, 06h - 30h

accumulated precipitation in mm

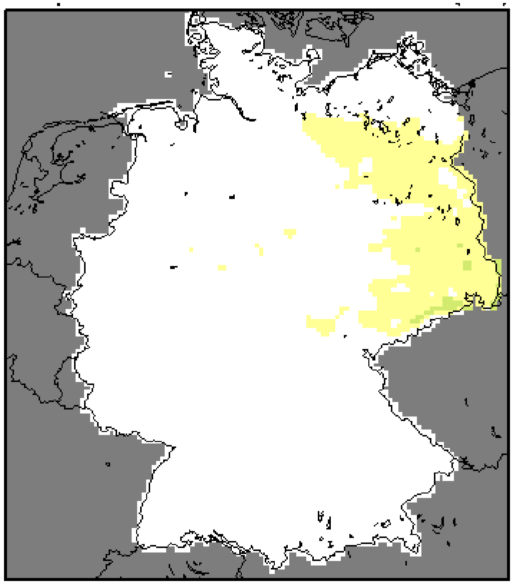


Surface observations



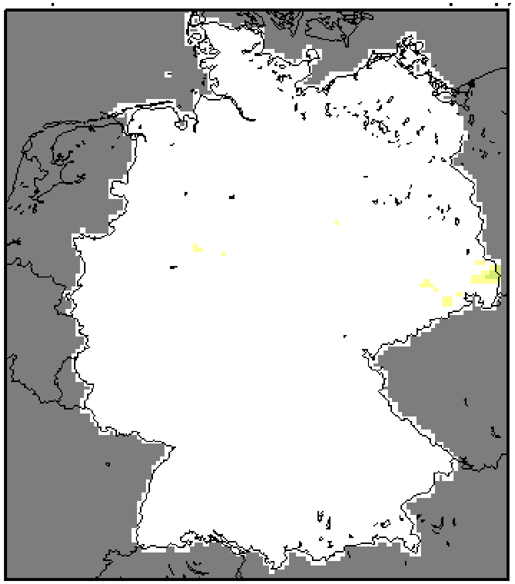
mean: 0.002 mm
max: 0.45 mm

LME, old microphysics



mean: 0.17 mm
max: 2.1 mm

LME, new microphysics

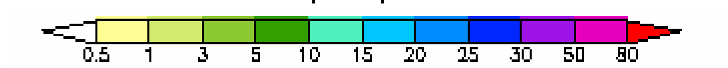


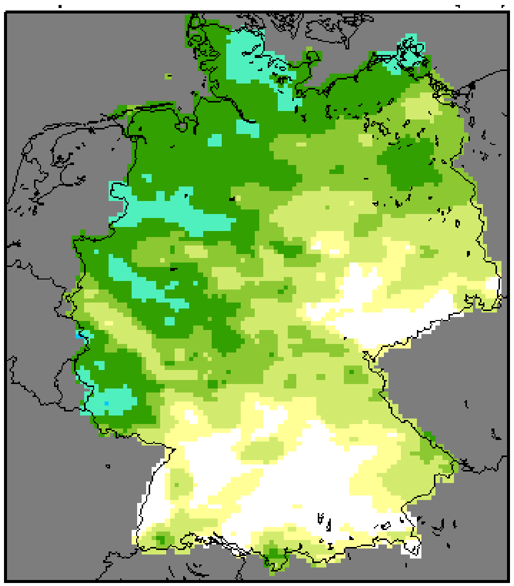
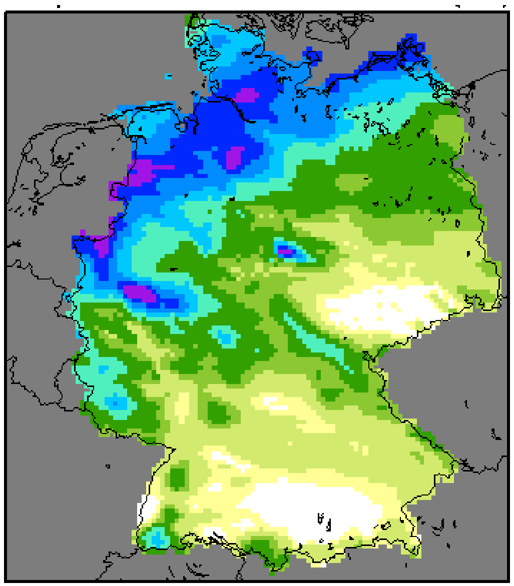
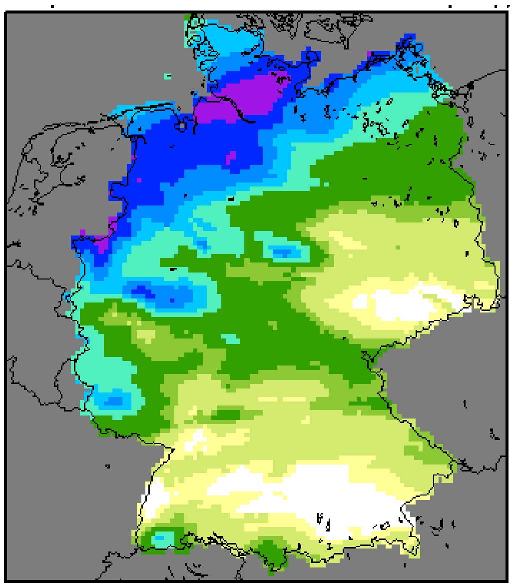
mean: 0.01 mm
max: 1.65 mm

- Wrong forecasts of widespread drizzle are considerably reduced

Accumulated precipitation
03.01.07 00 UTC, 06h - 30h

accumulated precipitation in mm

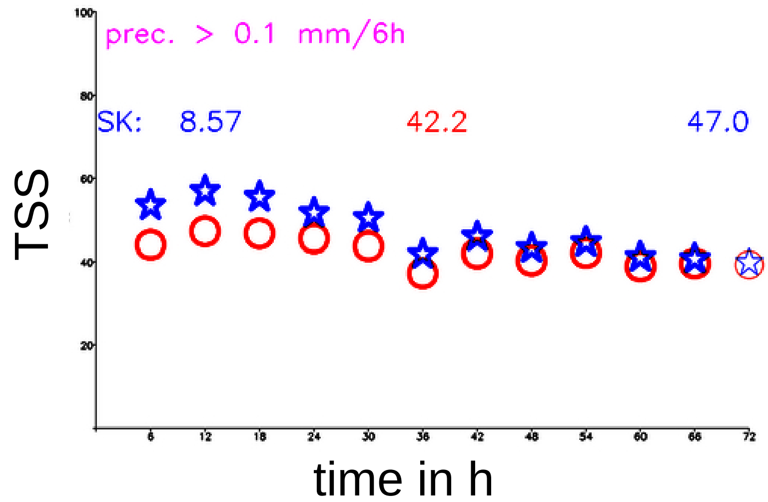


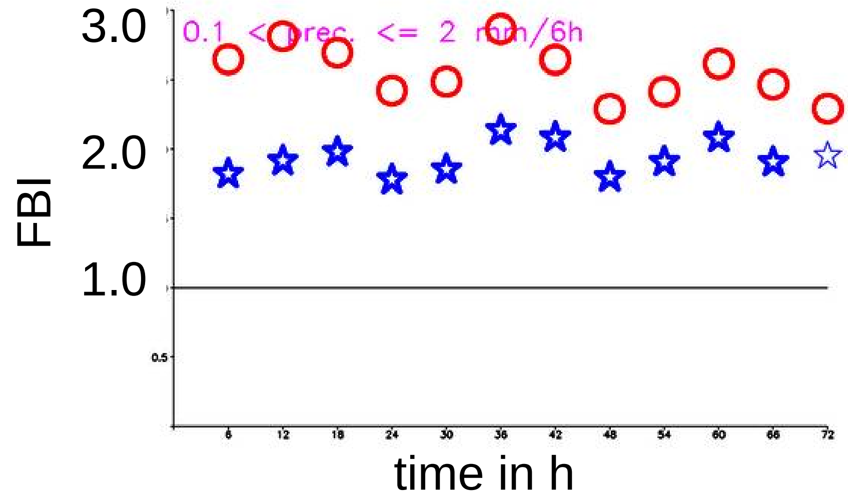
Surface observations	LME, old microphysics	LME, new microphysics
		
mean: 4.0 mm max: 15.9 mm	mean: 8.8 mm max: 37.6 mm	mean: 9.2 mm max: 35.6 mm

- The general problem of overestimation of precipitation during wintertime remains unsolved!

Objective Verification
(SYNOP-Stations, Germany, 20.12.06-19.01.07)

Weak precipitation (0.1 – 2 mm / 6h):



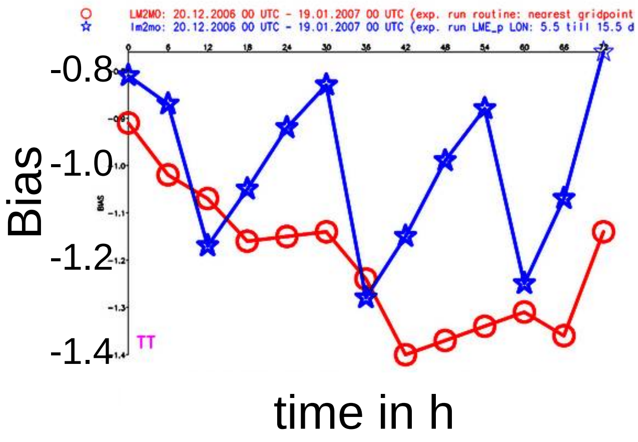


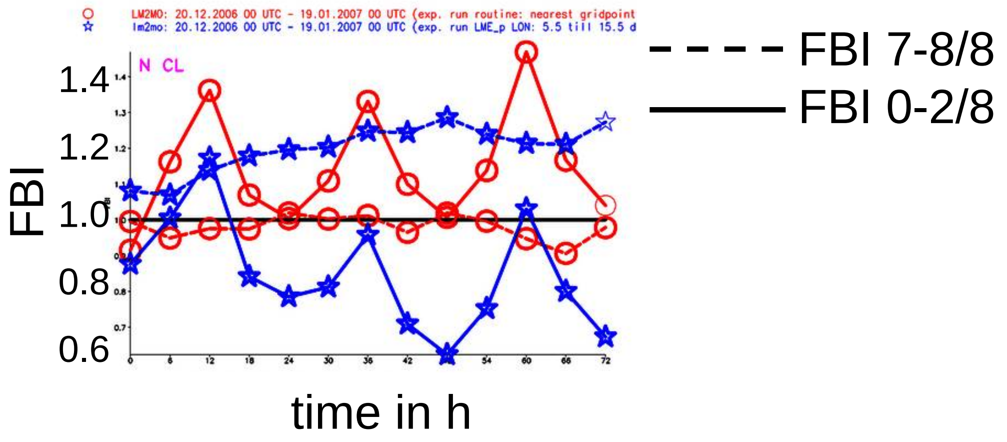
O LME, old microphysics   ☆ LME, new microphysics

- Forecasts of weak precipitation are significantly improved regarding TSS and FBI.

Objective Verification
(SYNOP-Stations, Germany, 20.12.06-19.01.07)

2m-temperature und low-level cloud cover:



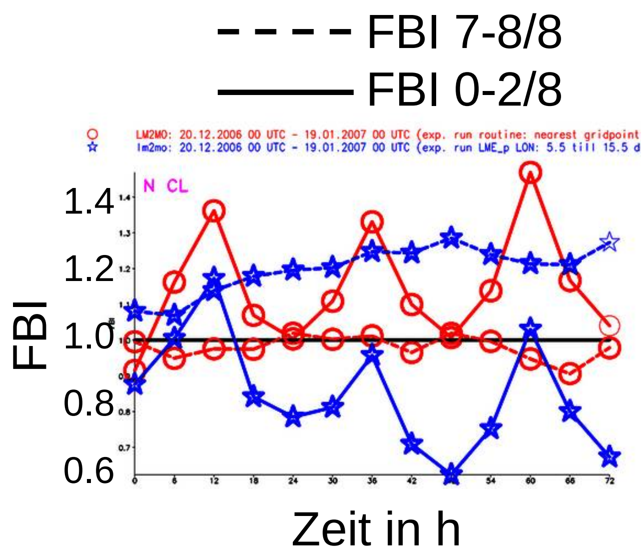


O LME, old microphysics ☆ LME, new microphysics

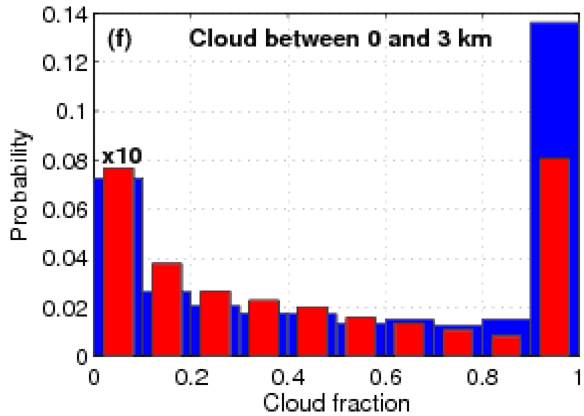
- Temperature bias slightly reduced, especially during night.
- High cloud cover now slightly overestimated, low cloud cover underestimated during night. During daytime reduced bias of 0-2/8 cloud cover.

How objective is objective verification?

Low-level cloud cover: Synop vs Lidar/Radar



Lidar/Radar (Lindenberg)



O LME, old ✰ LME, new

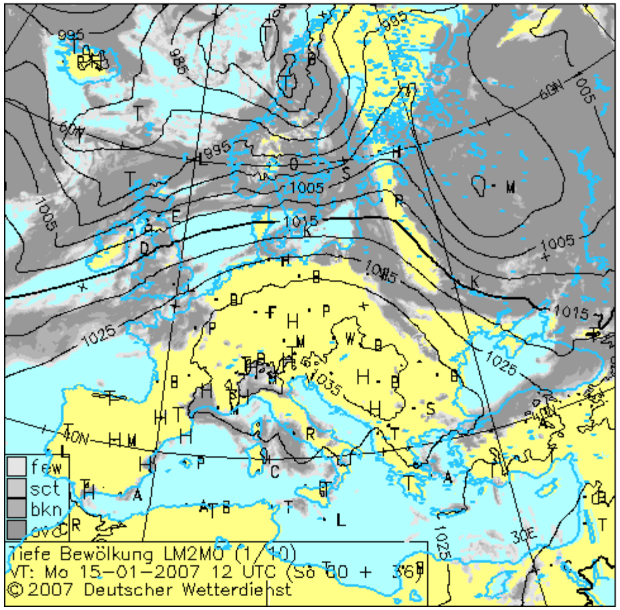
LME, old Obs

- Compared to SYNOP stations the old version of LME was bias-free regarding high cloud cover (7-8/8).
- Compared to radar/lidar measurements the old version understimates the frequency of overcast conditions.

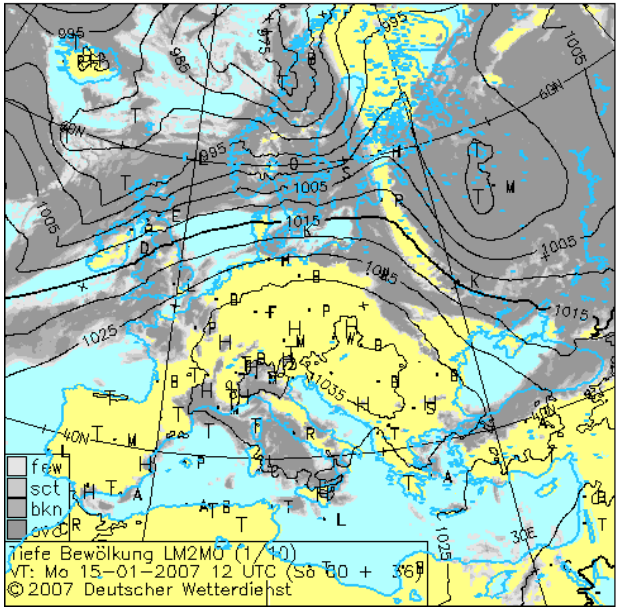
Subjective choice of the dataset for objective verfication!

Low-level cloud cover: An example

CLC 14.01.07 00 UTC + 36 h



LME, old microphysics



LME, new microphysics

In this example the cloud structures of frontal clouds are unchanged, but low cloud cover in high pressure areas is increased with the new microphysics scheme.

Summary:

The revised microphysics scheme, operational in COSMO-LME since 31.01.2007 12 UTC, aims to improve the forecasts in several ways:

- More realistic orographic wintertime precipitation
- Drizzle problem is significantly reduced
- Minor increase in cloud cover with a small positive effect on 2m-temperature

… and Outlook:

- The changes have to be transfered to the 'Graupel-scheme' of COSMO-LMK. A first version is currently being tested and will become operational soon.
- In general, the results show a significant effect of microphysical parameterizations on the mesoscale. For convection-resolving NWP, like COSMO-LMK, this might be even more important.
- Model validation is at least as difficult as model development!
  Who can measure IWC, PSDs or cloud cover accurately?