Diagnostic cloud number concentration based on Tegen climatology and Segal/Khain aerosol activation parameterization

Ulrich Blahak (DWD)

Motivation

- ➔ Implemented as one of two options to diagnose the cloud number concentration in the revised cloud radiation coupling scheme (the other is a constant number via namelist, similar to the 1-moment microphysics). Currently applies for grid-scale clouds only (SGS clouds are more difficult)
- ➔ Idea: if we can do it in the radiation, why not also in the 1-moment microphysics? Influence on autoconversion process.
- ➔ This idea has been tested and is reported in this presentation.

Outline of the talk:

- ➔ General description of the method
- ➔ Effects in 1-moment microphysics (idealized + real case studies)

Tegen aerosol climatology

- Tegen et al. (1997): total optical thickness for 5 different aerosol categories: sea salt, SO4, mineral dust, black carbon, organics (incl. black carbon)
- Because black carbon is included in organics, we can exclude it for our purpose
- Paper gives some informations on assumed specific extinction coefficients that allow an approximate back-calculation of grid-column total aerosol mass / m^2.
- Assumptions about aerosol mean mass radius and bulk density allows computation of total number / m^2:

sea salt:	0.5 µm		3000 kg/m^{-3}
mineral dust:	1.0 µm		1000 kg/m^{-3}
SO4	0.08 µm	(sensitive!)	2000 kg/m^{-3}
organics:	0.08 µm	(sensitive!)	2000 kg/m^{-3}

- From this, assumption about vertical profile (exponential decrease above a well-mixed PBL) allows diagnosis of cloud nuclei number density (ncn) in $1/m^{-3}$ (see next slide)
- Assumption about soluble fractions:

sea salt:	1.0
mineral dust :	0.1
SO4:	1.0
organics:	0.9

Tegen aerosol climatology

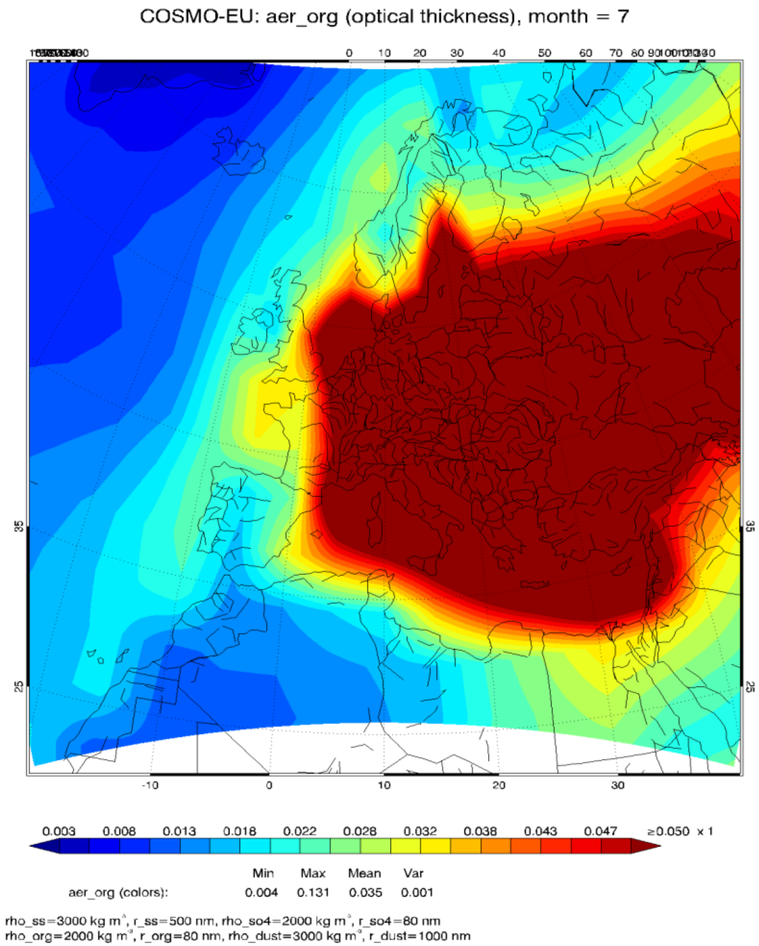
➔ **Vertical profile:**

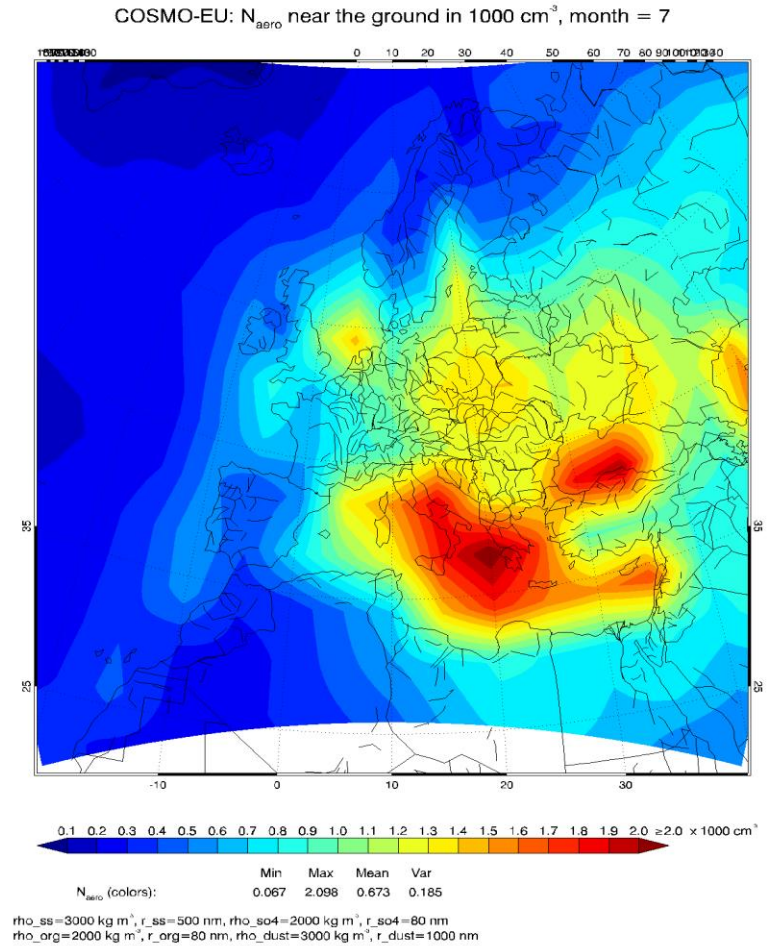
$$N_{NC}(z) = \rho(z)\, Q_{NC}(z) = N_{NC,0} \begin{cases} 1 & z \leq z_t \\ \exp\left(\frac{(z-z_t)\,\ln 2}{6000\text{ m}}\right) \exp\left(\frac{z-z_t}{z_{1/e}}\right) & z > z_t \end{cases}$$

with $N_{NC,0}$ in such a way that $\int_{z_{surf}}^{12\,\text{km}} N_{NC}(z)\, dz = N_{tot}$, N_{tot} derived from τ_{aero}

Tegen aerosol climatology

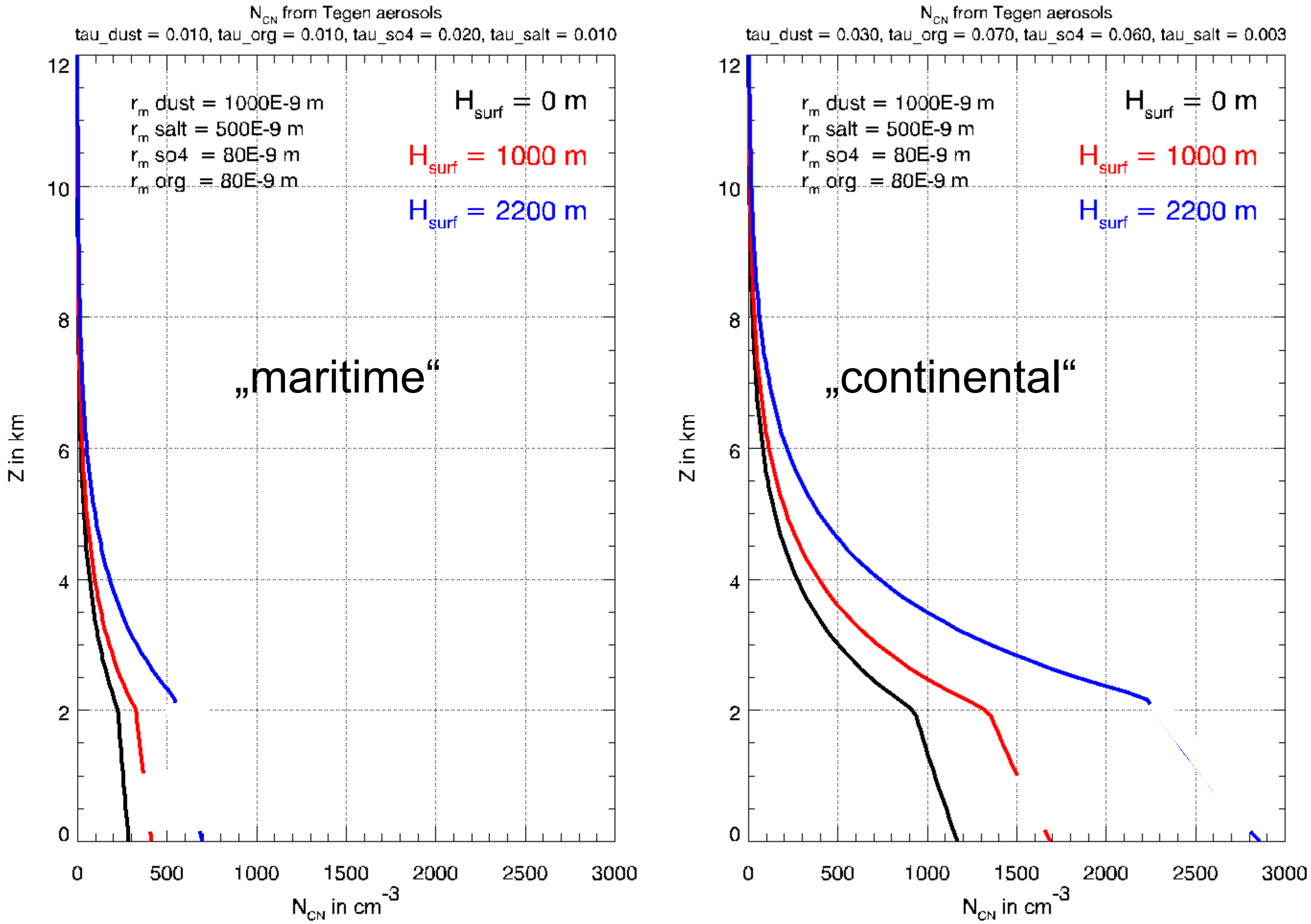
➔ example: **ave. opt. thickn.** of organics and resulting PBL-value of N_{cn0} for July:





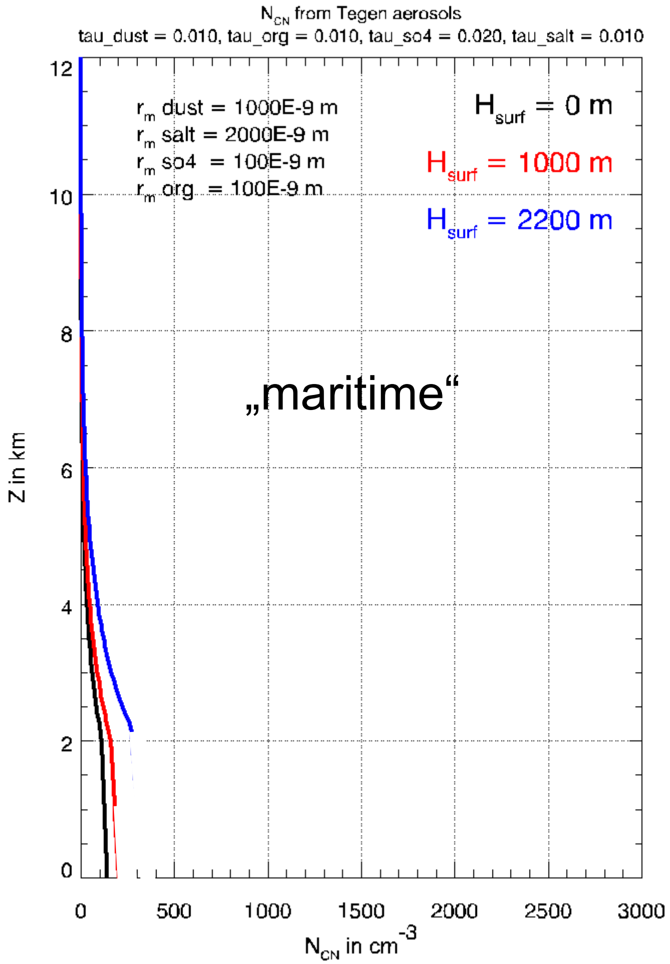
Tegen aerosol climatology

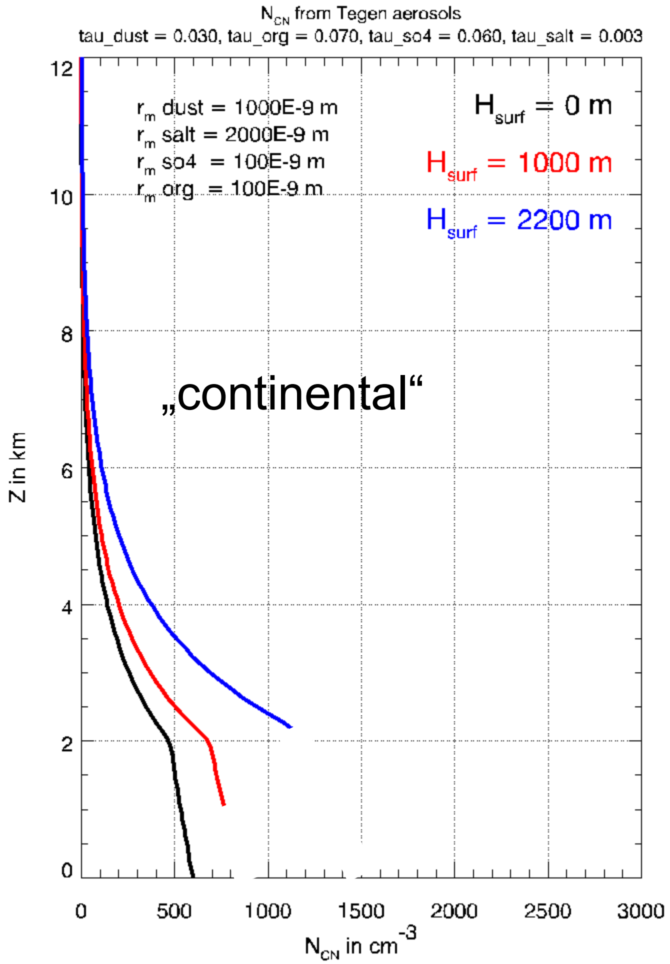
➔ Vertical profiles and their dependencies: **standard settings**



Tegen aerosol climatology

➔ Vertical profiles and their dependencies: **larger mean radii** (most sensitive: organics + SO4)



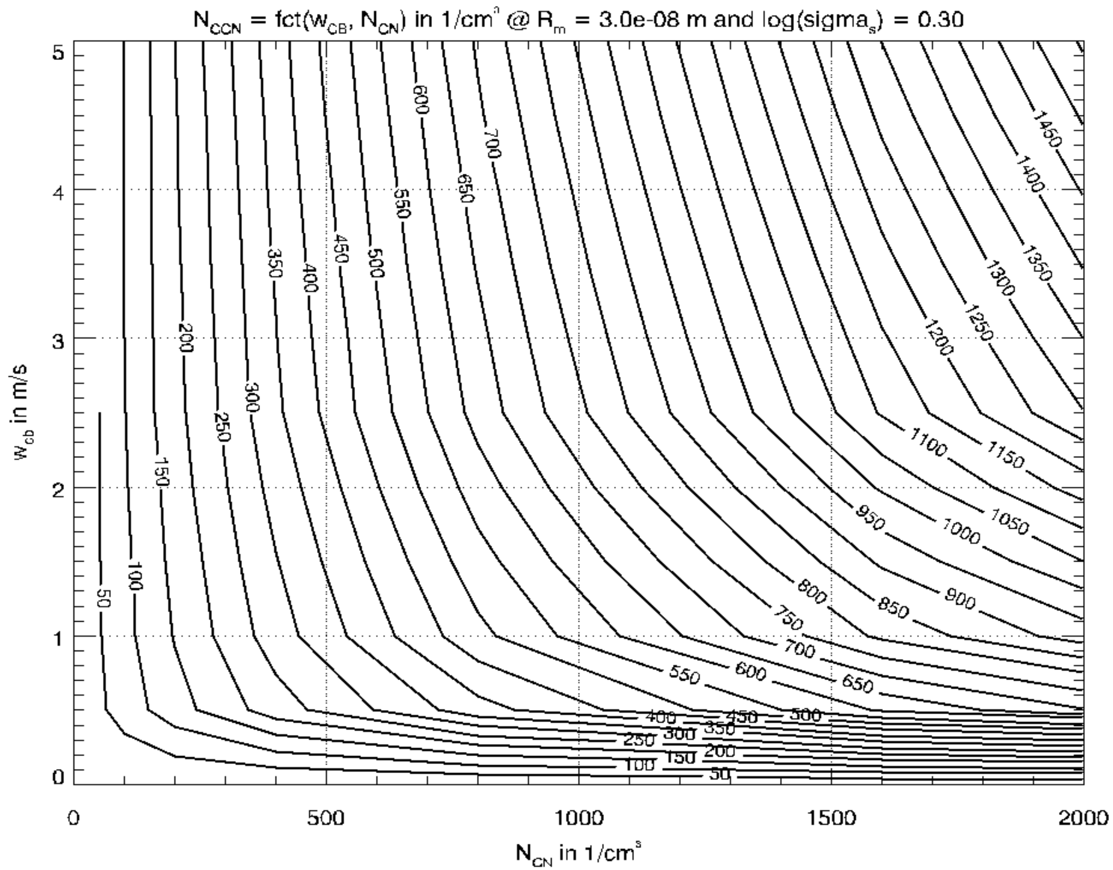


Tegen aerosol climatology

qnc = Tegen + …

… Segal/Khain activation parametr.

- ➔ Segal and Khain (2006) lookup-table, efficient bi-linear interpolation as function of cloud-base updraft speed (w_{cb}) and aerosol number density (N_{CN}).
- ➔ Involves vertical cloud-base search in continuous cloud layers and vertical exponential decrease within „active“ clouds, parameterizing autoconversion, selfcollection and riming.



… and updraft speed

- Equivalent updraft speed for aerosol activation accounts for:
  - grid scale updrafts
  - mean turbulent SGS updrafts
  - radiative cooling

$$w_{cb}^{k} = w_{grid}^{k+1} + \alpha \sqrt{\frac{\mathrm{TKE}^{k+1}}{3}} - \frac{c_{pd}}{g} \left.\frac{\partial T^{k}}{\partial t}\right|_{radiation}$$

$\alpha = 0.7$ (tentative factor due to skewed updraft PDF)

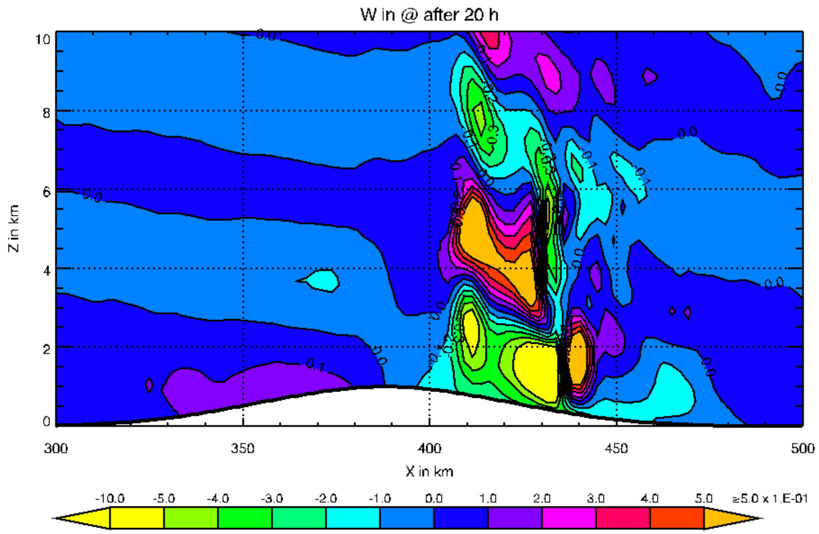
Effect on pure orographic warm rain

- ➔ Moist mountain wave flow simulation with idealized COSMO:
  - ➔ U = 10 m/s, H_{hill} = 1000 m, $D_{1/2}$ = 80 km, dTdz ~ 0.6 K/100m
  - ➔ initially 4-layered atmosphere:
    - ➔ dryer PBL (RH=80 %, dTdz = 0.6 K/100 m)
    - ➔ moist layer (1 - 5 km, RH = 95 %, dTdz = 0.5 K/100 m)
    - ➔ dryer mid-troposphere (RH = 50 %, dTdz = 0.6 K/100 m)
    - ➔ stable and dry tropopause layer from 12 km up to model top = 15 km
- ➔ Control run: standard graupel scheme, qnc = cloud_num = 500 kg^{-3}
- ➔ Experiment: qnc from Tegen and Segal/Khain for a maritime aerosol scenario

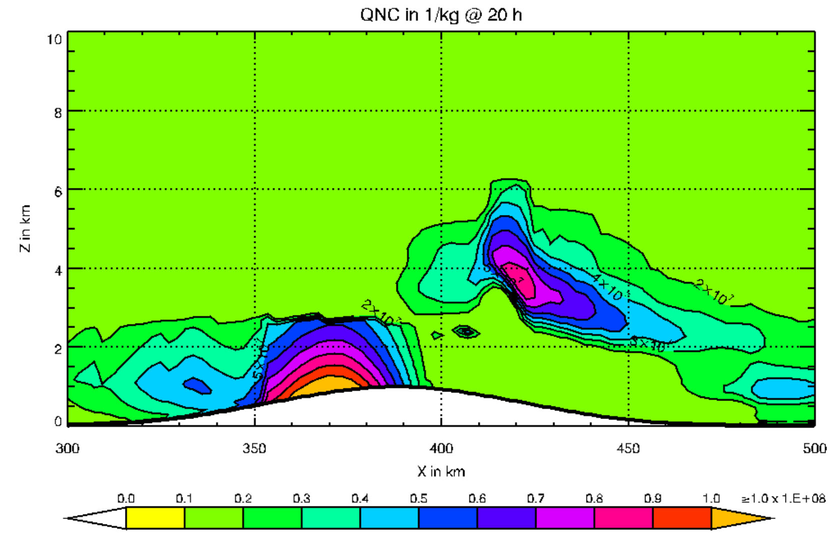
Effect on pure orographic warm rain

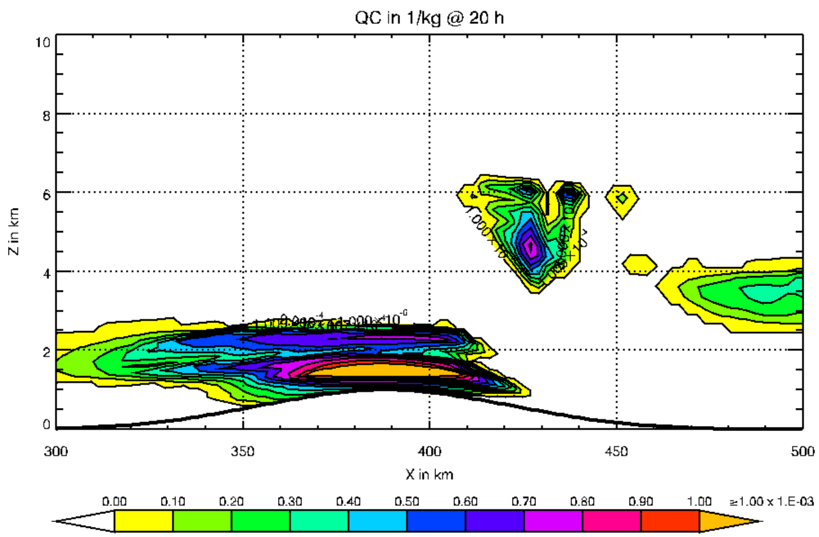
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

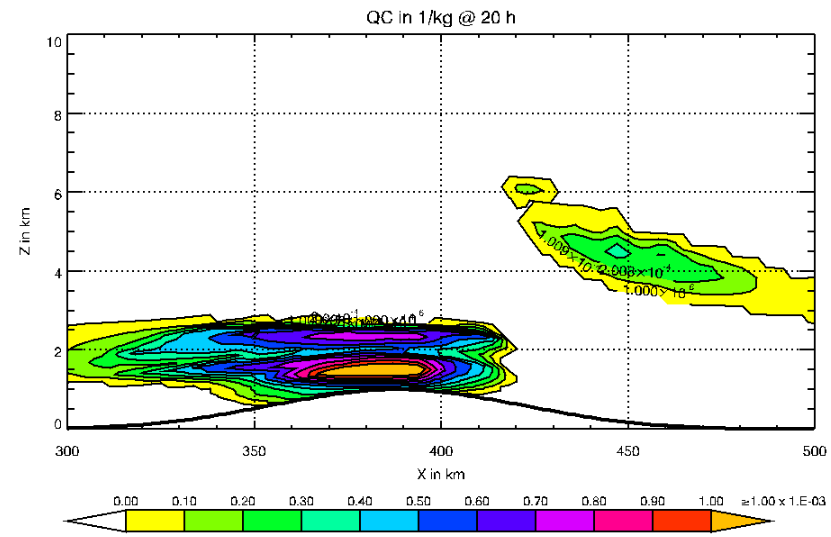
Control



Experiment

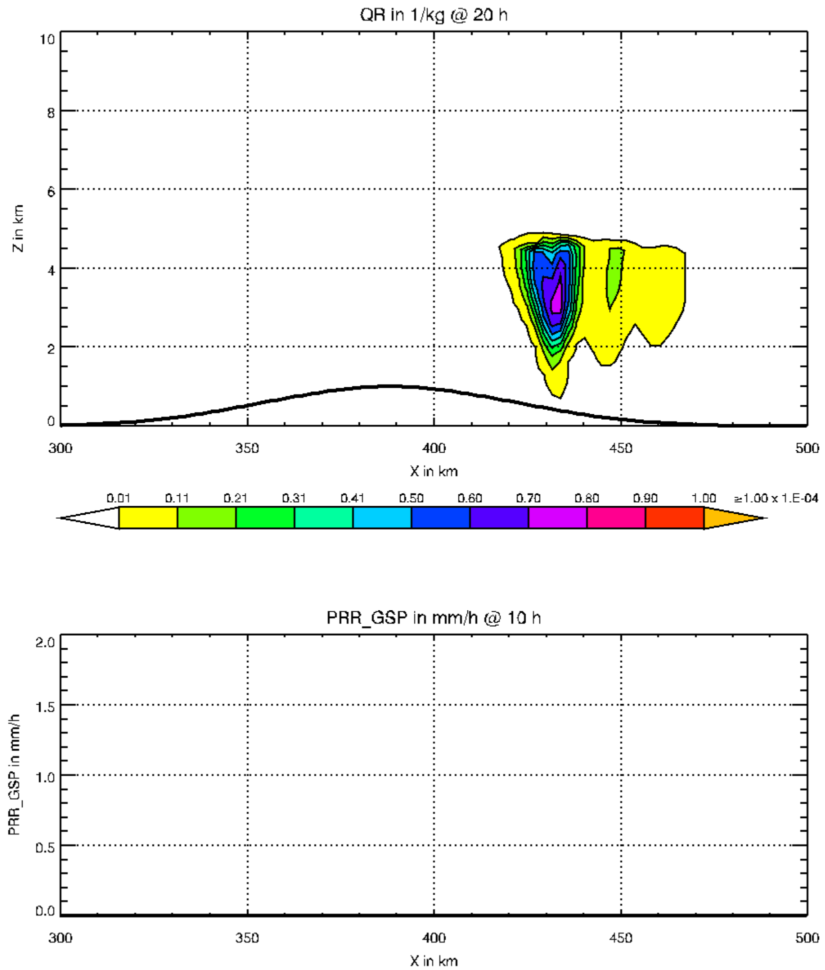




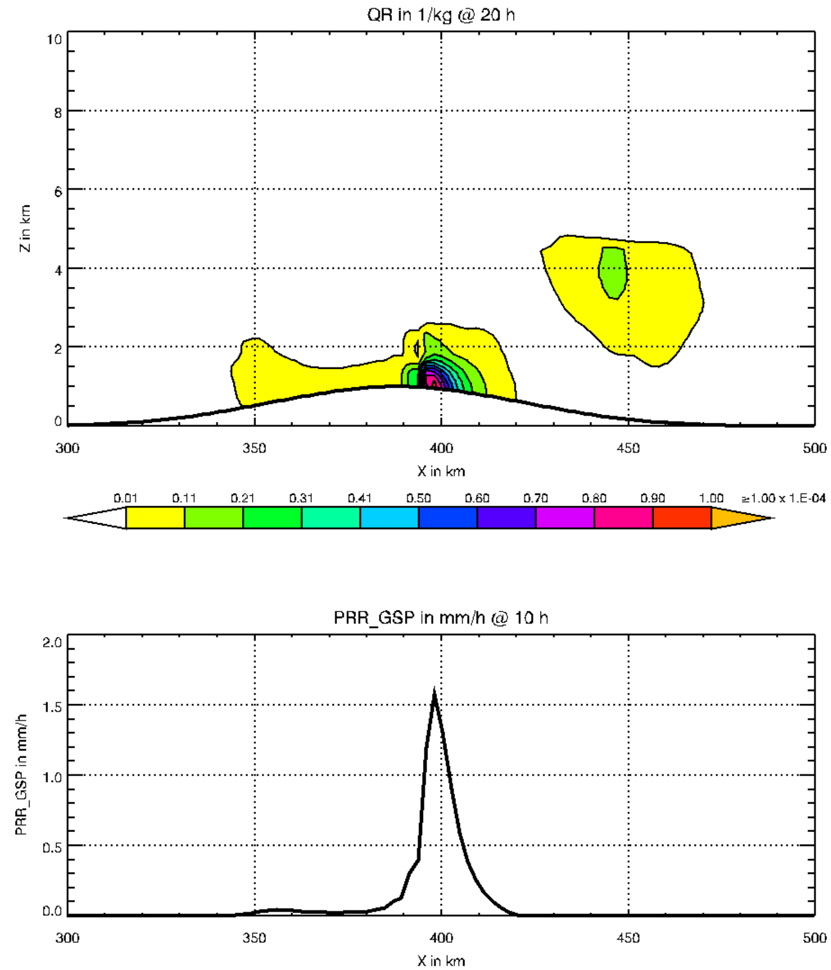


Effect on pure orographic warm rain

Control



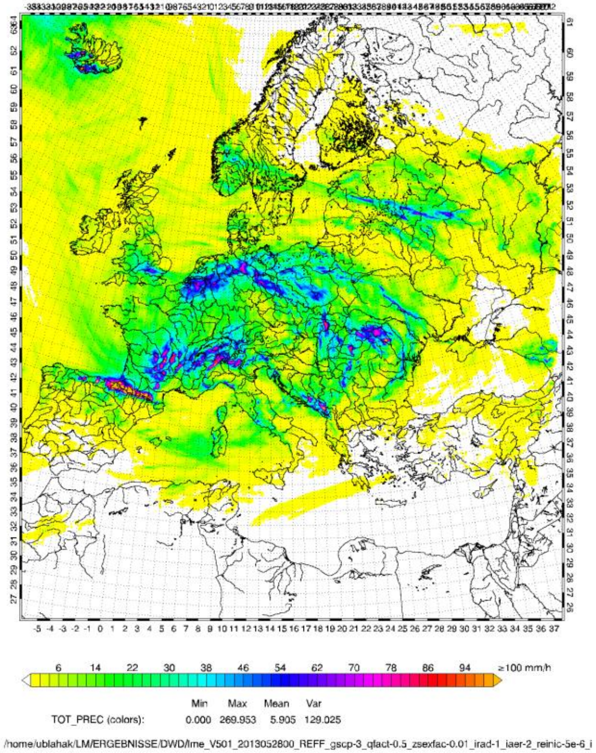
Experiment



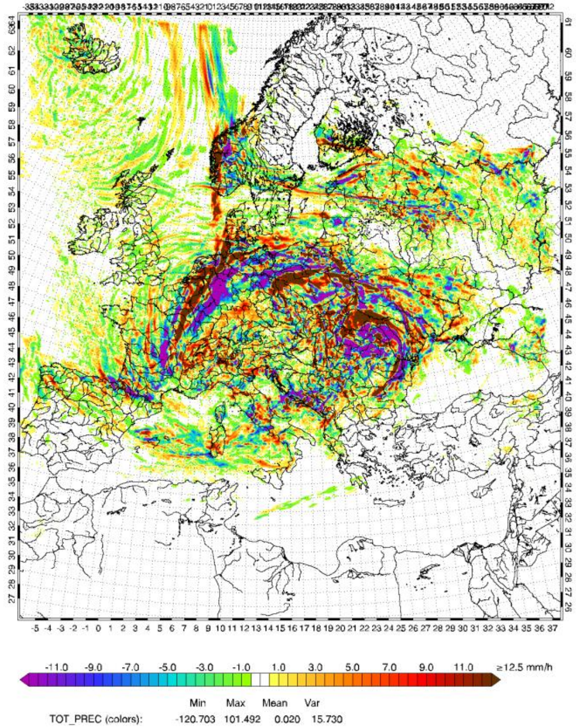
Effect in a real case (summer)

➔ COSMO-EU 28.05.2013

TOT_PREC, itype_clnum_gscp = 1, 2013052800 +0412 ddhh



Diff. TOT_PREC, itype_clnum_gscp = 2 minus 1, 2013052800 +0500 ddhh



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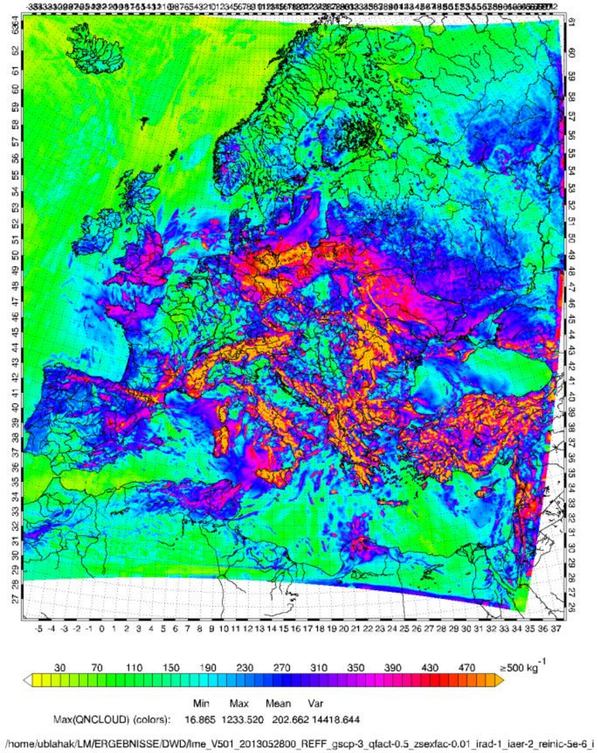
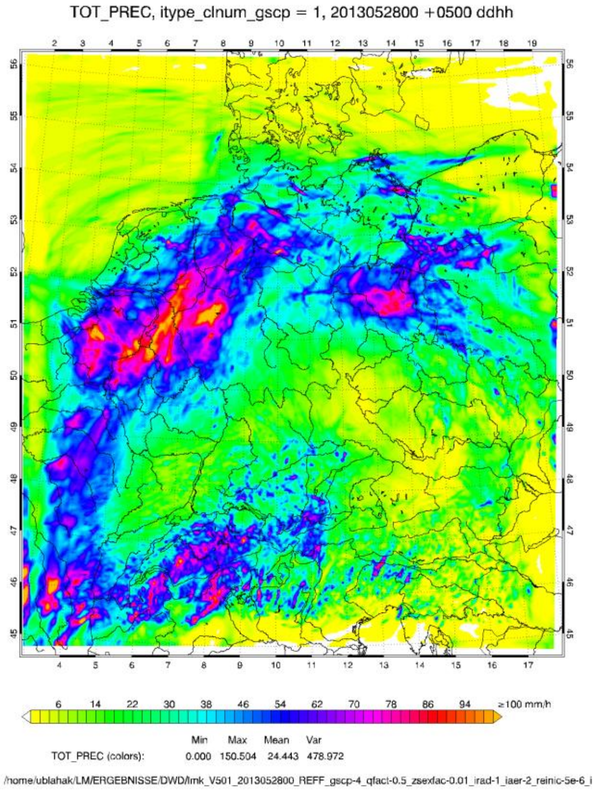
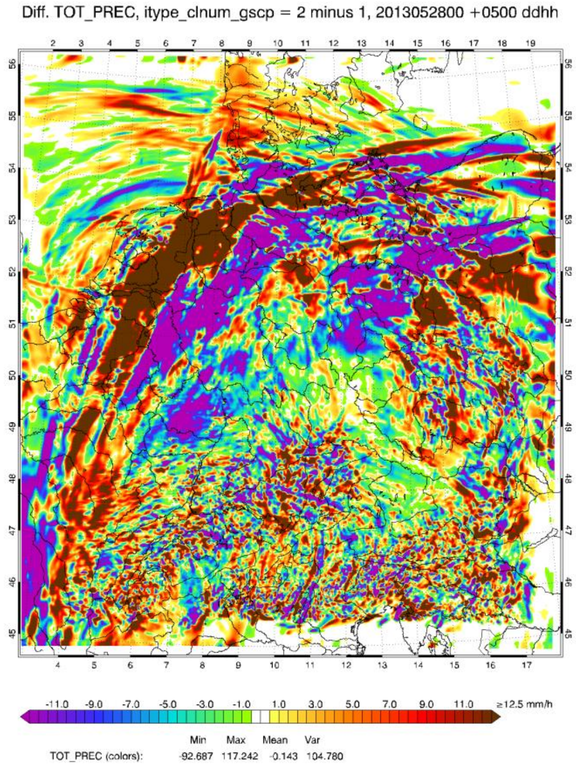
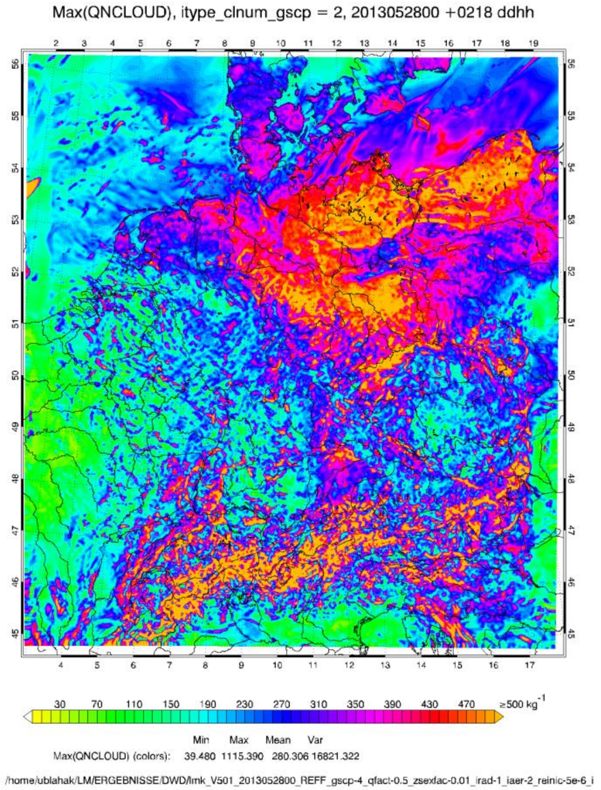


Effect in a real case (summer)

➔ COSMO-DE 28.05.2013

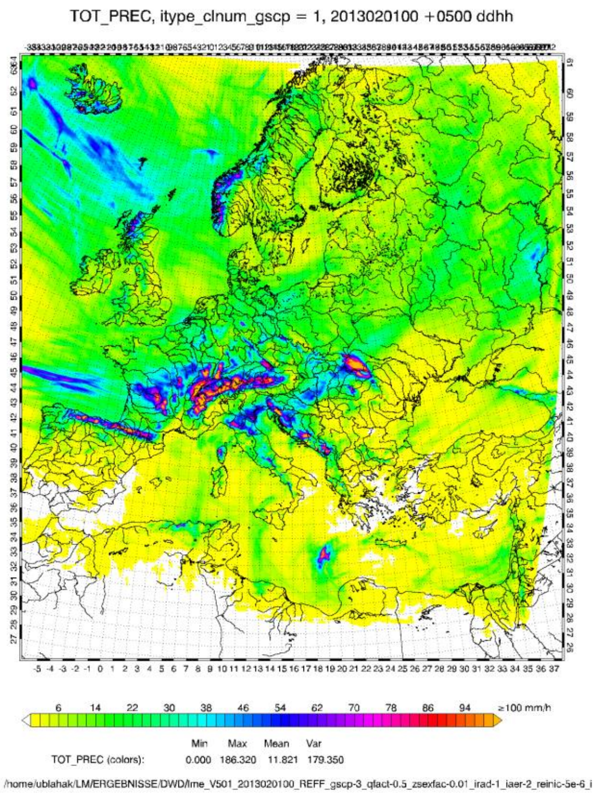


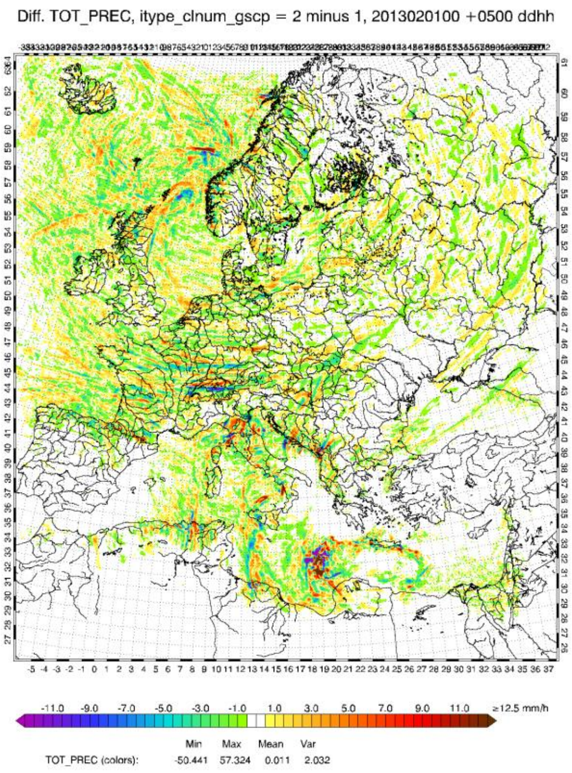


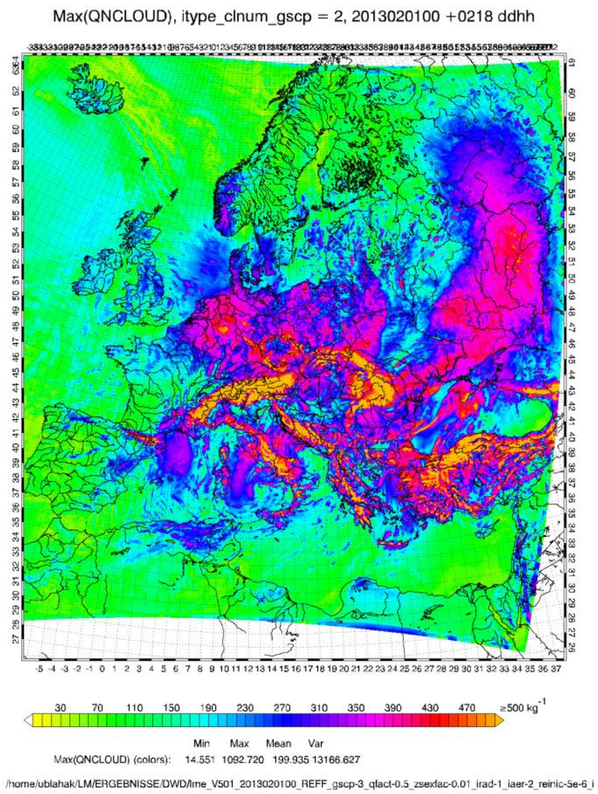


Effect in a real case (summer)

➔ COSMO-EU 01.02.2013

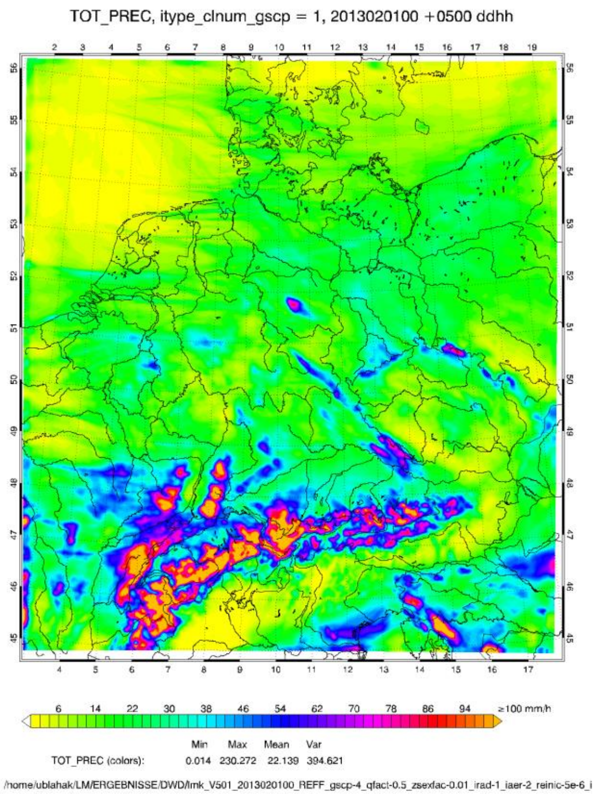


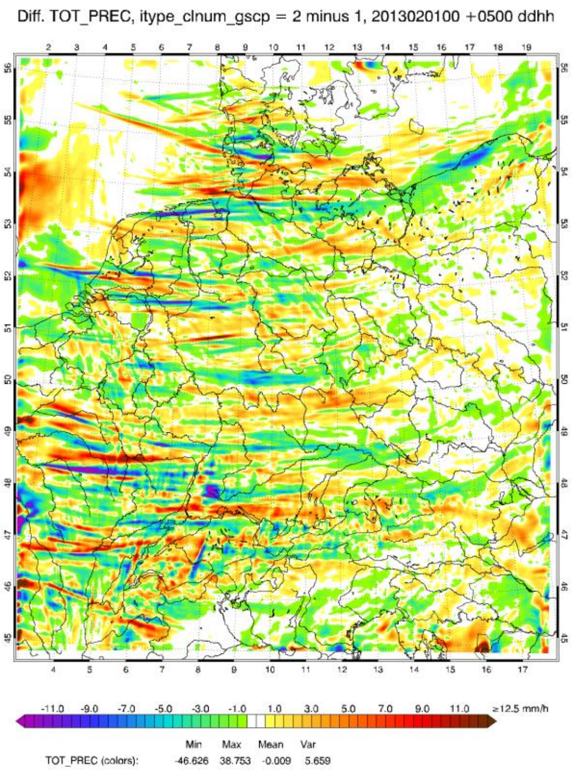


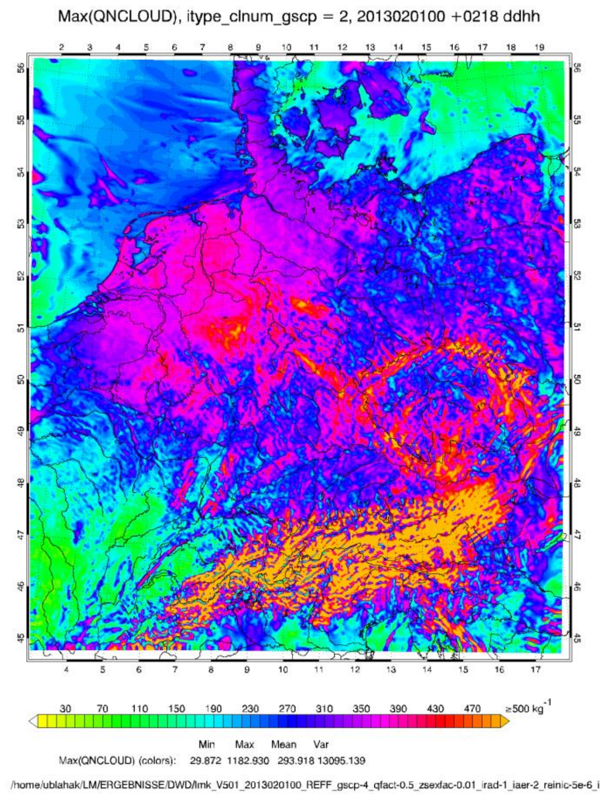


Effect in a real case (summer)

➔ COSMO-DE 01.02.2013







Summary and Conclusions

- Enables more realistic simulation of the warm-rain process. Previously, this process was nearly shut off by choice of a too large cloud_num.
- For maritime warm-rain dominated precipitation the precipitation singnificantly increases. Previously there were reports of much too low precipitation in such cases (e.g., coastal orographic rain at Salalah, Indian Ocean coast of Oman)
- For mid-latitudes: moslty upstream shift of precipitation. Previously, the warm rain process was virtually shut off, but precipitation was instead formed equally efficient via ice phase processes.
- If this cloud number concentration parameterization is used for cloud effective radii in the radiation, it can be as well used for the 1-moment microphysics at no additional cost.
- Code is currently only contained in the test version 5.1 for the revised cloud-radiation coupling.