Towards revised cloud radiation coupling for the COSMO Model

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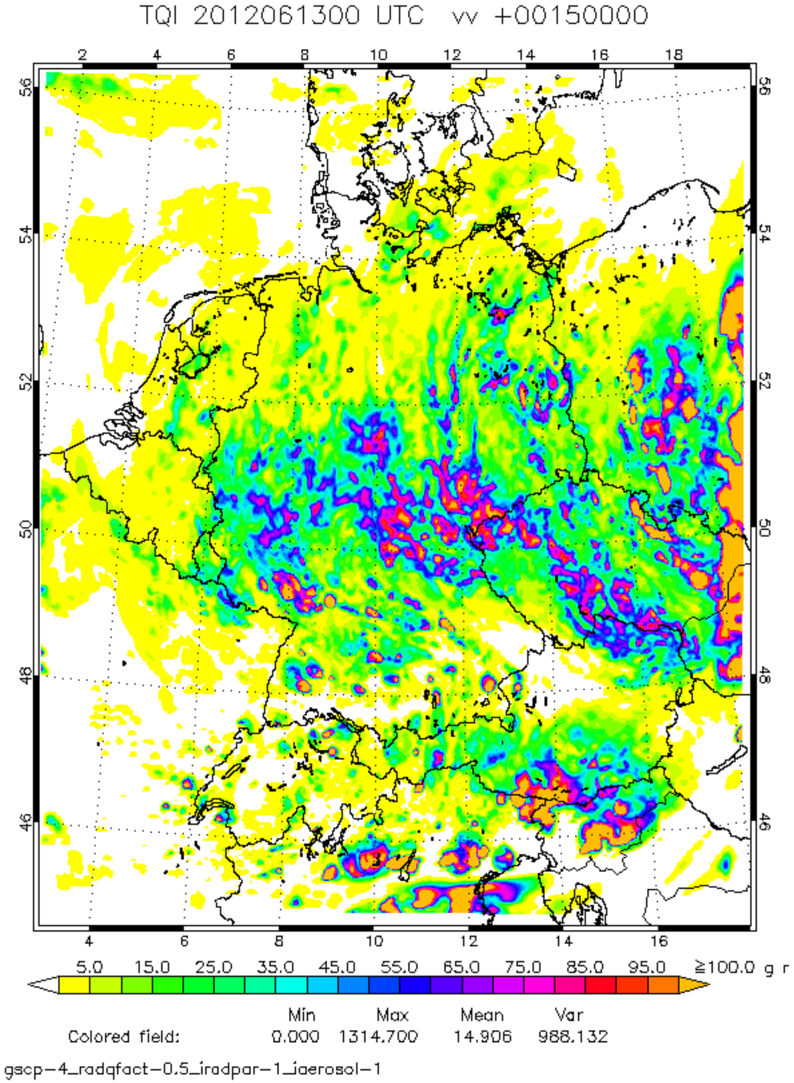
Motivation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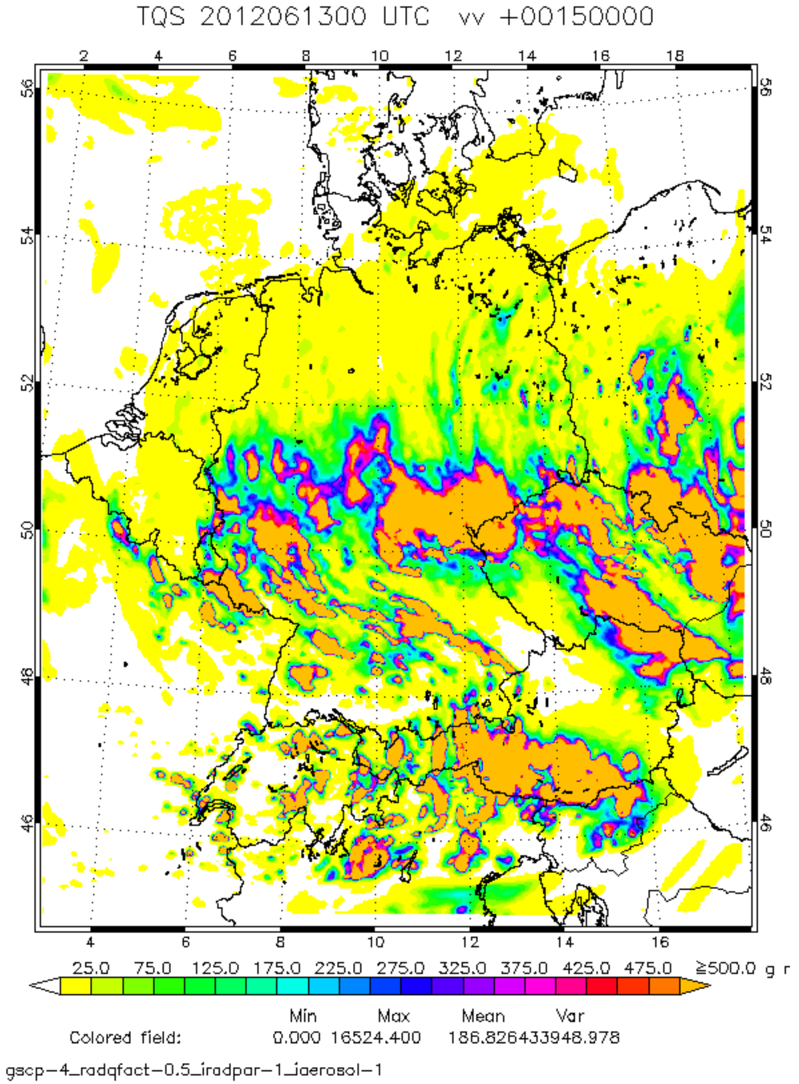
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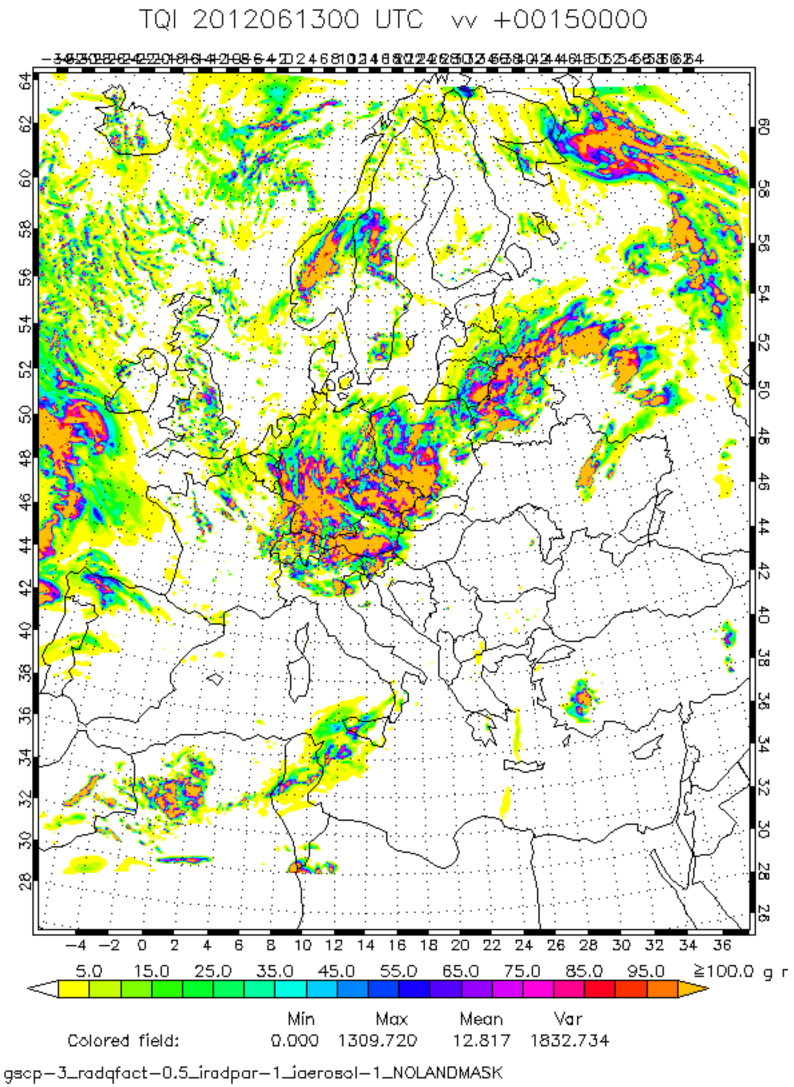
Motivation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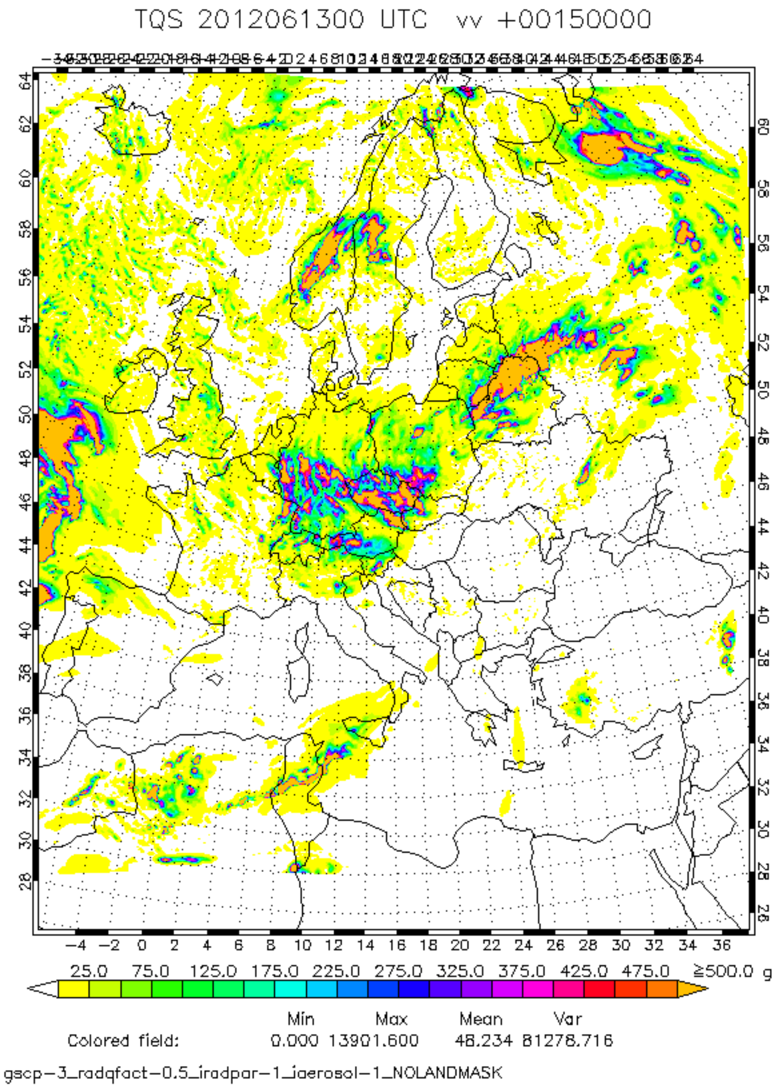
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Some issues in cloud-radiation coupling

- ➔ In the COSMO radiation scheme (Ritter & Geleyn 1992), the optical properties (extinction coeff., single scattering albedo, asymmetry factor) only depend on qc respectively qi.
  - ➔ Nowadays more modern parameterizations based on an effective radius R_e are available.
  - ➔ From inherent assumptions about N(D) and particle shapes in state-of-the-art microphysical models R_e can be deduced.
  - ➔ Then: optical properties = fct (qx, R_e)
- ➔ For the gridscale clouds, only a fraction k=0.5 of qi and/or qc is considered in the radiation scheme („tentative“ effective factor to take into account subgrid ρ_c scale variability).
- ➔ Radiation scheme is only aware of cloud droplets and cloud ice!

1) Revised optical properties

➔ σ_{ext}, ω, $g = \mathrm{fct}(R_e, q_x, \lambda)$

➔ For cloud droplets:
Parameterisation of Hu and Stamnes (1993), spectrally remapped to the 8 spectral intervals of RG92 (3 visible, 5 infrared).

➔ For cloud ice:

- ➔ Visible spectral region: optionally
  Key et al. (2002), assuming horizontally aligned hexagonal plates or
  Fu et al. (1998), assuming randomly oriented hexagonal needles
- ➔ Infrared region:
  Fu et al. (1996), assuming randomly oriented hexagonal needles

1a) Cloud droplets (Hu & Stamnes)

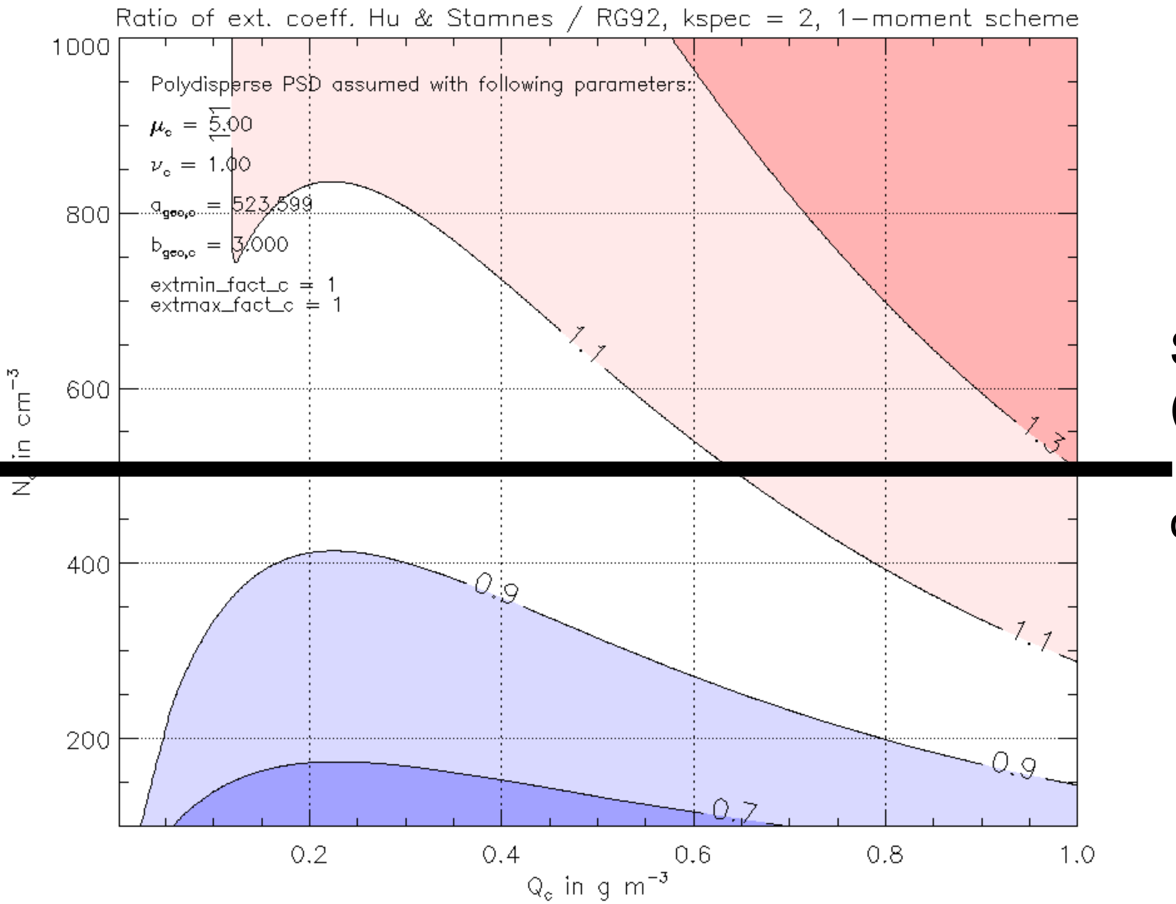
- ➔ If grid scale qc > 0: from cloud microphysics:

$$f(D) = N_0 \, D^{\mu} \, e^{-\lambda D}$$

$$\mu = 5.0$$

$$N_c = \texttt{cloud\_num}$$

q_c prognostic



Spectral interval „2“ (visible range)

σ_{ext} ratio HS / RG92

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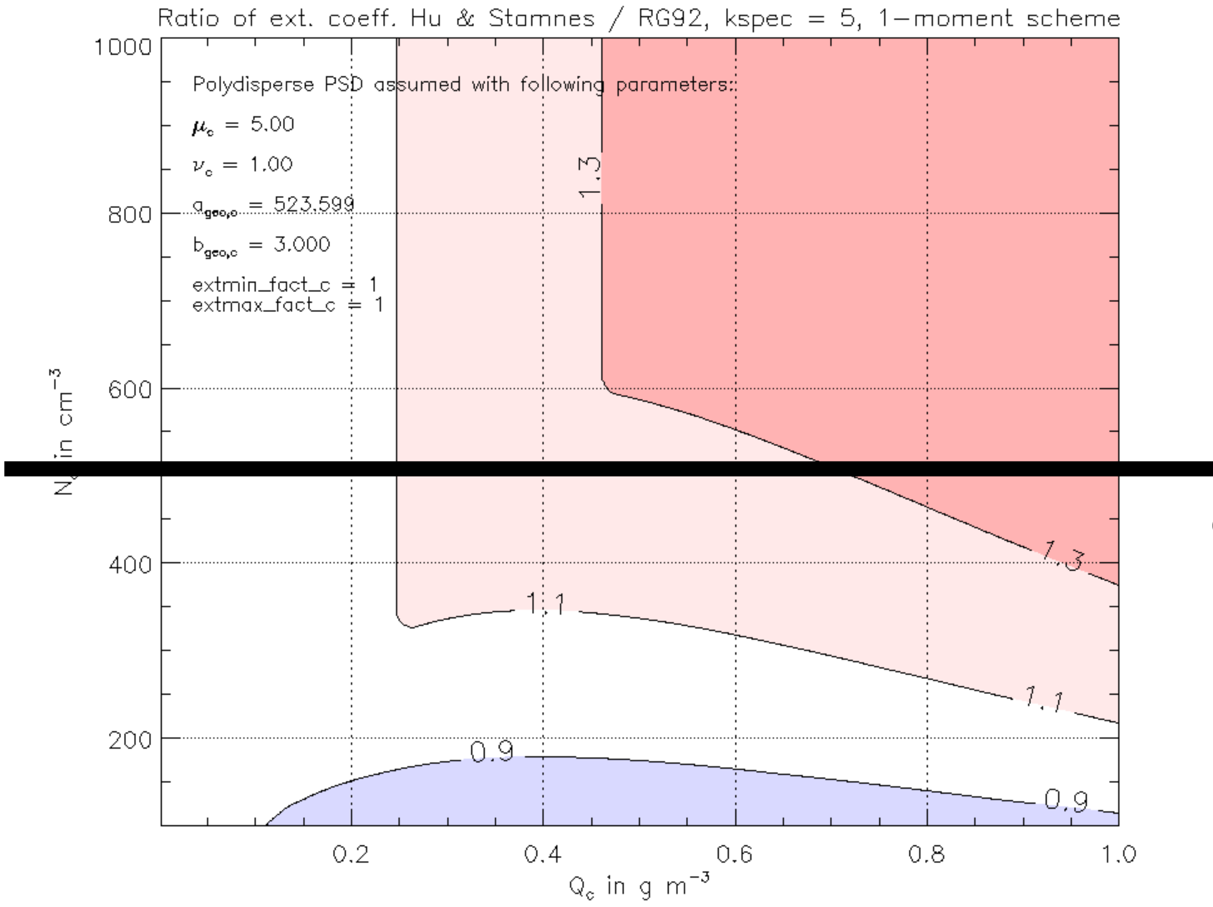

Spectral interval „5“
(infrared range)

σ_{ext} ratio HS / RG92

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1a) Cloud droplets (Hu & Stamnes)

➔Pure subgrid scale clouds ??? → R_e = 10 µm

1b) Cloud ice (visible; Fu et al.)

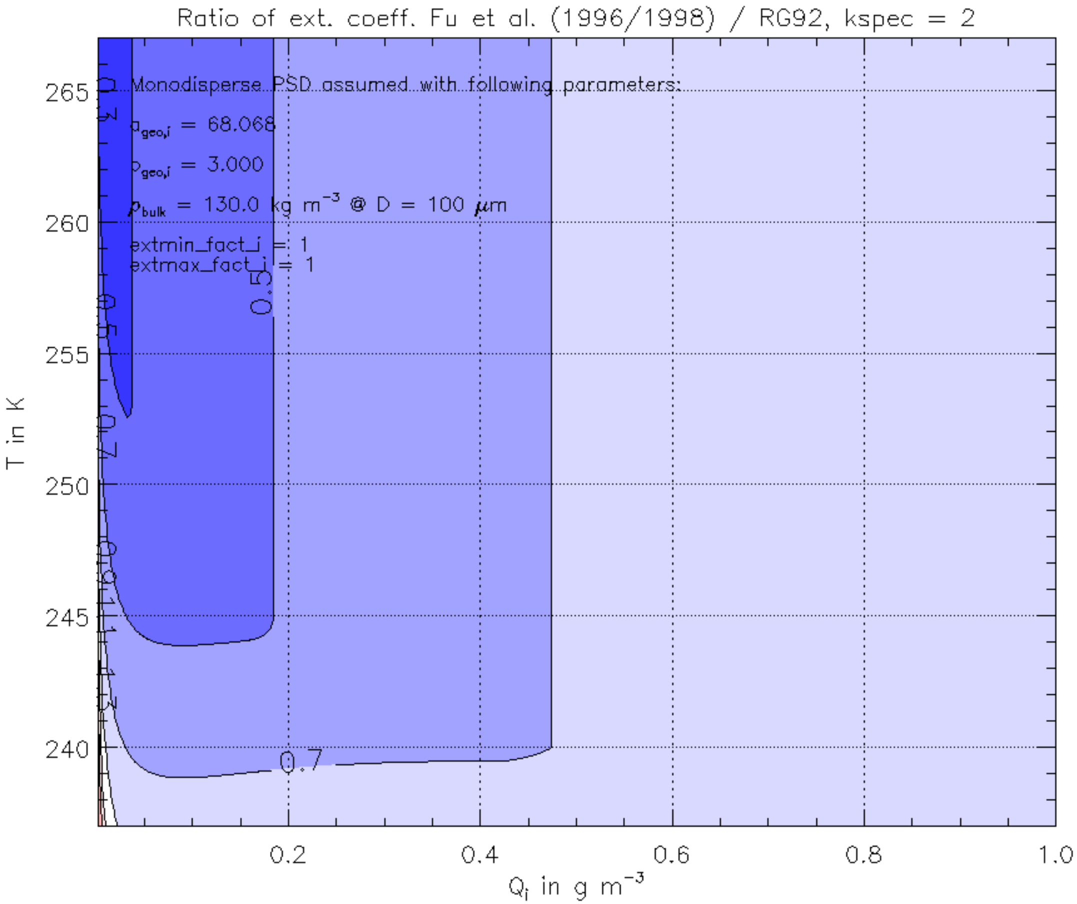
➔ If grid scale qi > 0: from cloud microphysics:

$$f(D) = \text{monodispers}$$

$$N_i(T) = a \exp\left(b\left(T_3 - T\right)\right)$$

q_i prognostic

$$m_i = 130\, D^3 \quad \text{(SI-units)}$$



Spectral interval „2“ (visible range)

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1b) Cloud ice (infrared; Fu et al.)

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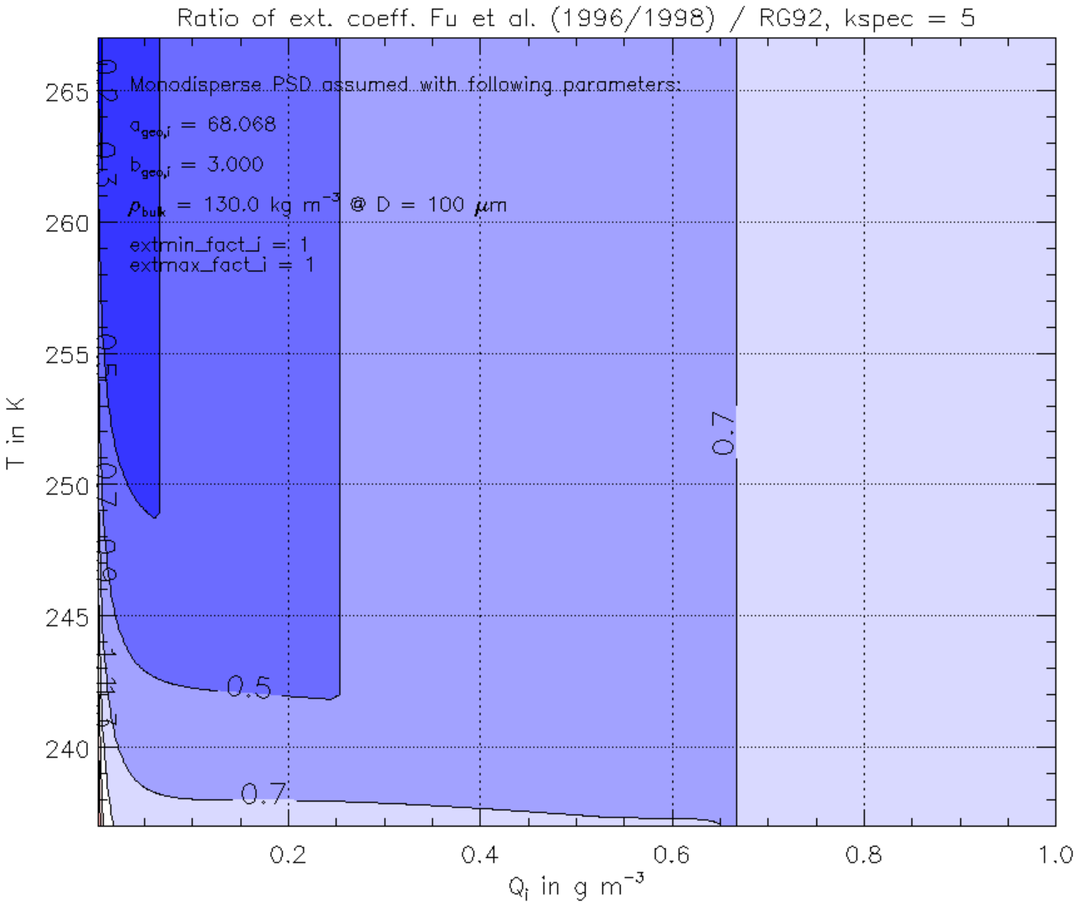


Spectral interval „5“
(infrared range)

σ_{ext} ratio Fu / RG92

1b) Cloud ice (infrared; Fu et al.)

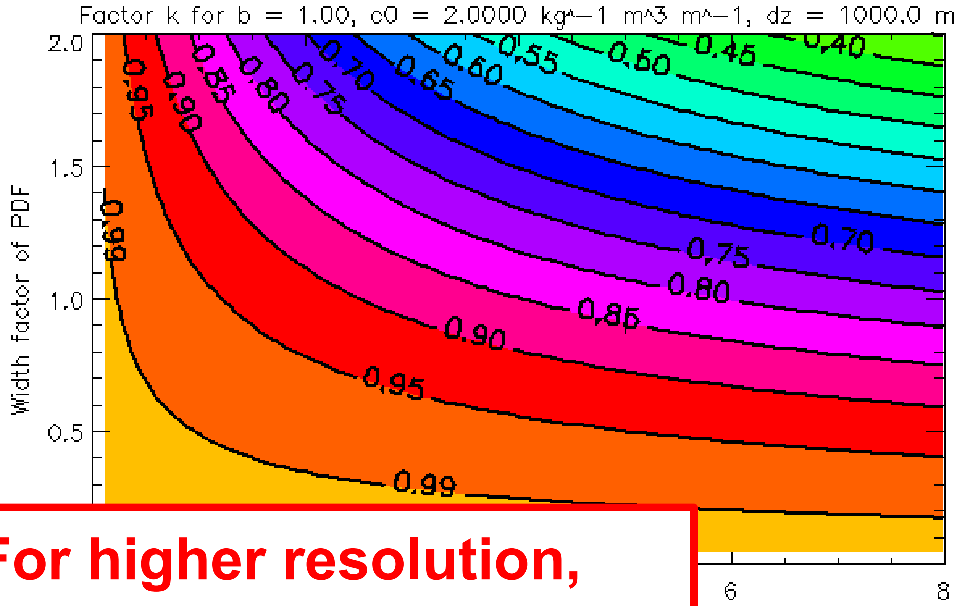
➔Pure subgrid scale ice clouds ??? → $R_e = 20\ \mu m$

2) Subgridscale variability, factor k

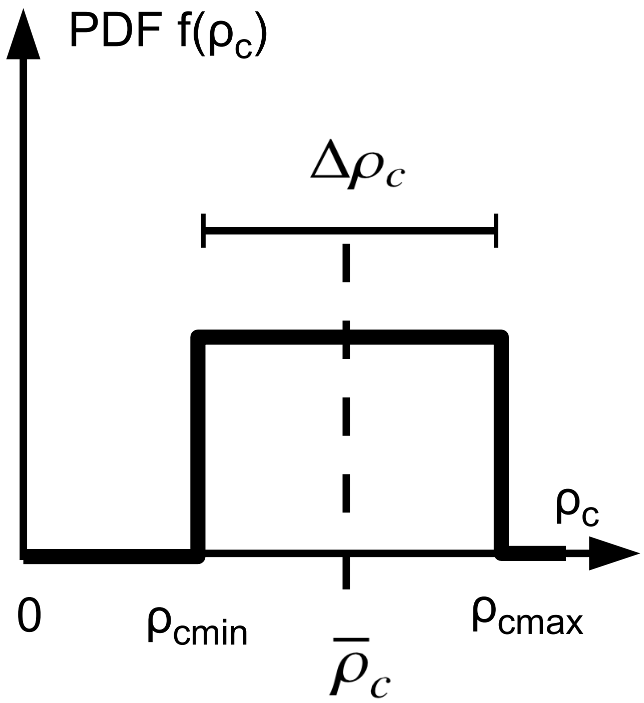
$$e^{(-k\, c_0\, \bar{\rho}_c\, \Delta z)} \overset{!}{=} \int_0^\infty PDF(\rho_c)\, e^{(-c_0\, \rho_c\, \Delta z)}\, d\rho_c$$

$$k = \frac{1}{\underbrace{c_0\, \bar{\rho}_c \Delta z}_{\bar{\tau}}} \ln\left[\frac{\Delta\rho_c\, c_0\, \Delta z}{\exp(-c_0\, \rho_{cmin}\, \Delta z) - \exp(-c_0\, \rho_{cmax}\, \Delta z)}\right]$$

cloudy grid box ρ_c



For higher resolution,
k = 0.5 seems too low!



$$\text{width factor} = \frac{\Delta\rho_c}{\bar{\rho}_c} \leq 2$$

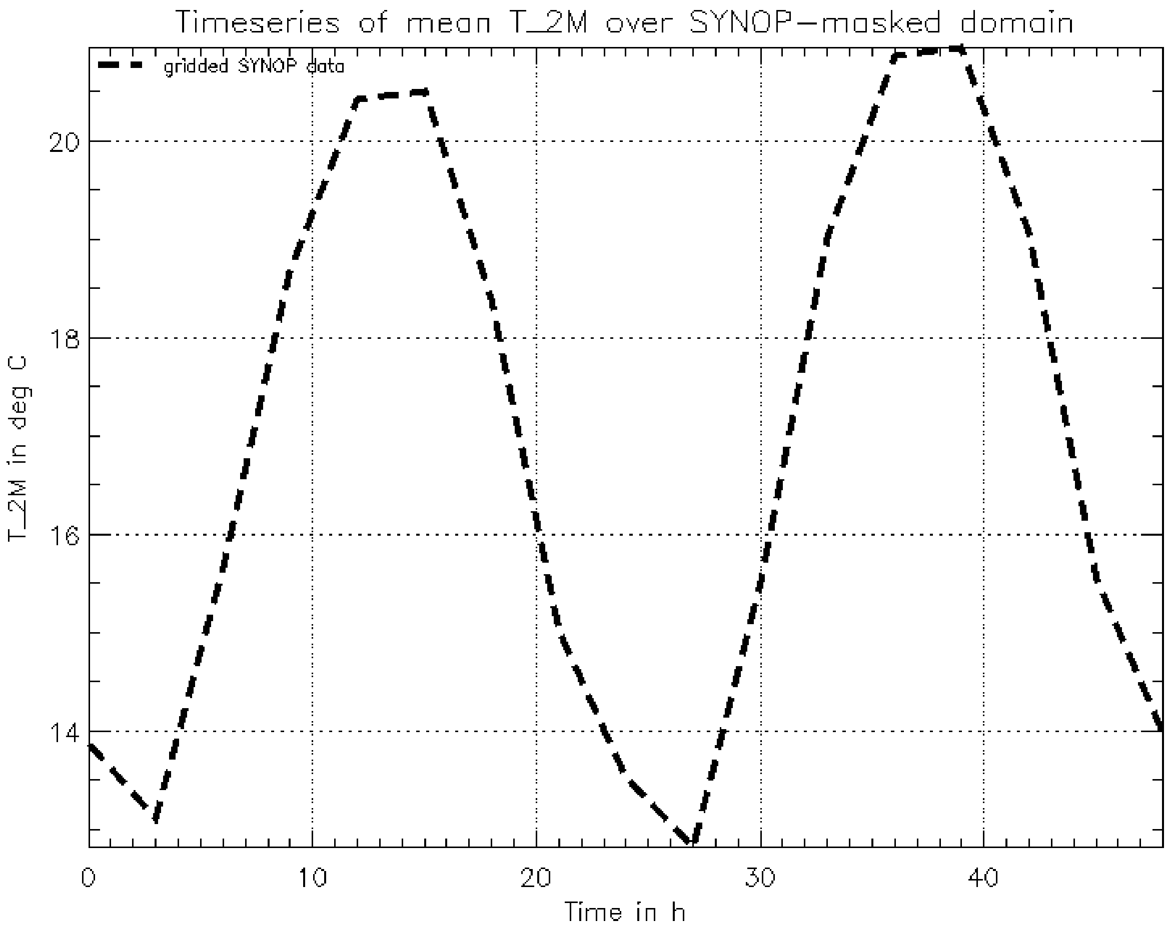
3) Include grid scale qs, qg into radiative calculations

- Very simplistic methodology:
  - Treat qs and qg exactly the same way as qi, except that for R_e, the maximum value of the validity range of the parameterizations is used, which is 70 µm.

- This is certainly too simple and has to be improved in in the future! (Careful) extrapolation of the fits, taking into account correct (asymptotic) large-size limit behaviour

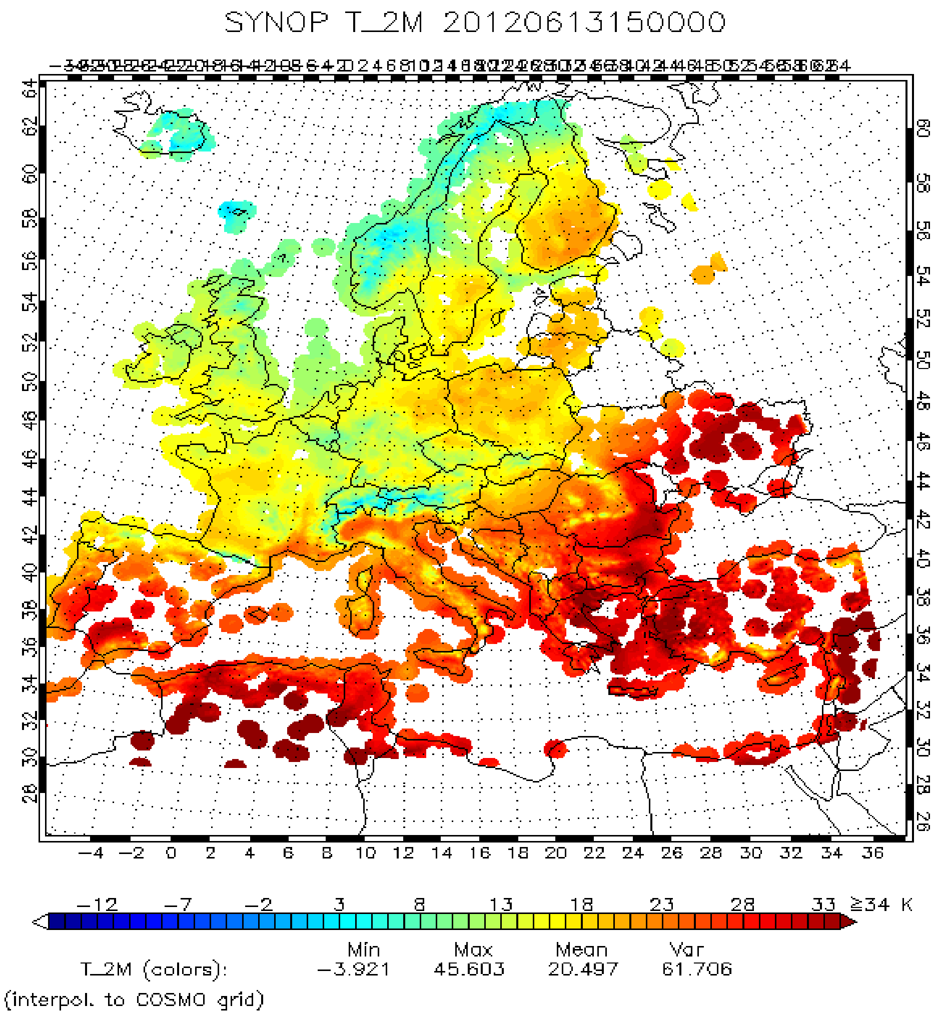
Case study: 13.6.2012 (C-EU)

Cloudy day in central Europe, cf. pictures from the beginning of the talk!



Gridded synop

Gridded T_2M from synop station data (COSMO-EU)



Voronoi-interpolation, based on triangulation.

Height correction using standard atmosphere gradient.

Max. distance from the next synop station 70 km.

⇨ Synop data on the model grid, suitable for computing, e.g., bias and rms.

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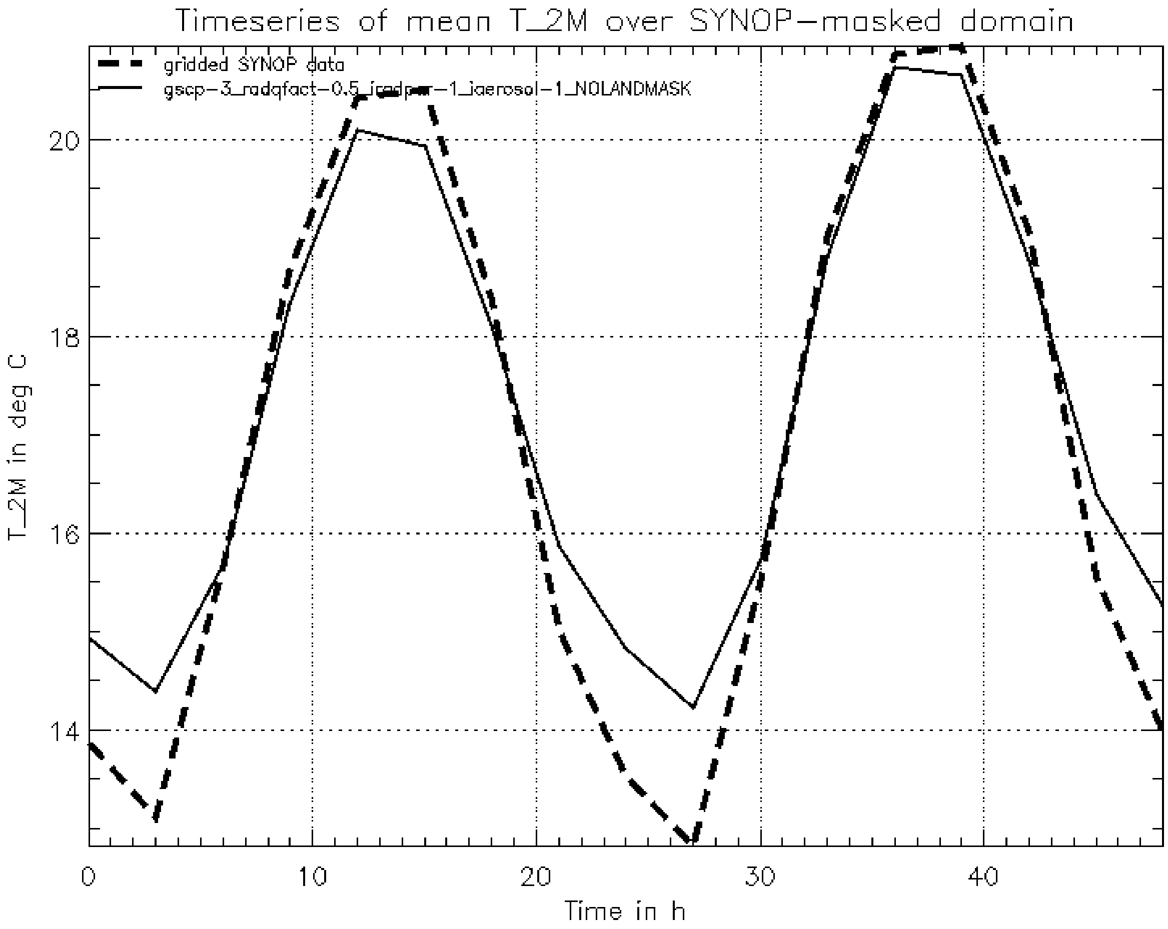

control

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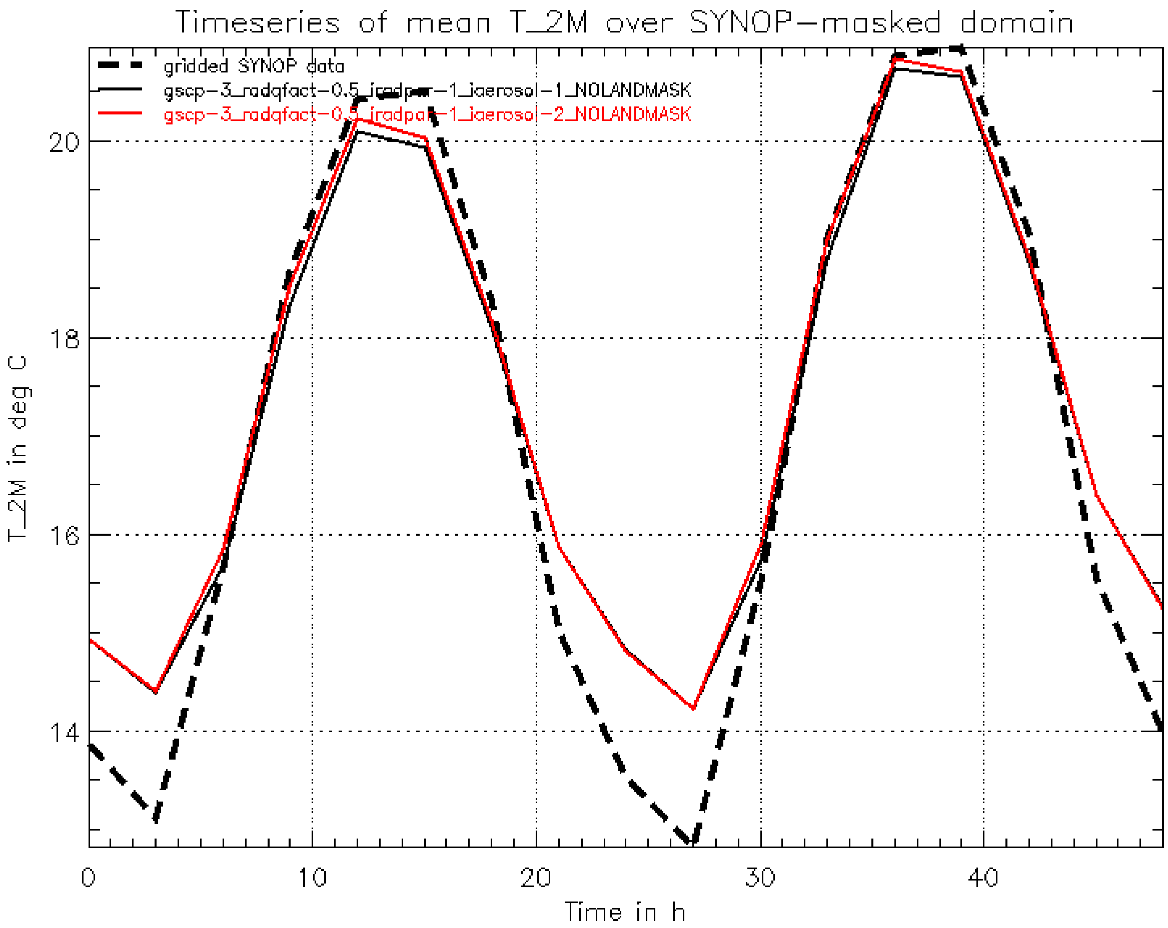
Case study: 13.6.2012 (C-EU)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Cloudy day in central Europe, cf. pictures from the beginning of the talk!



+ Tegen aerosol climatology instead of Tanre

Case study: 13.6.2012 (C-EU)

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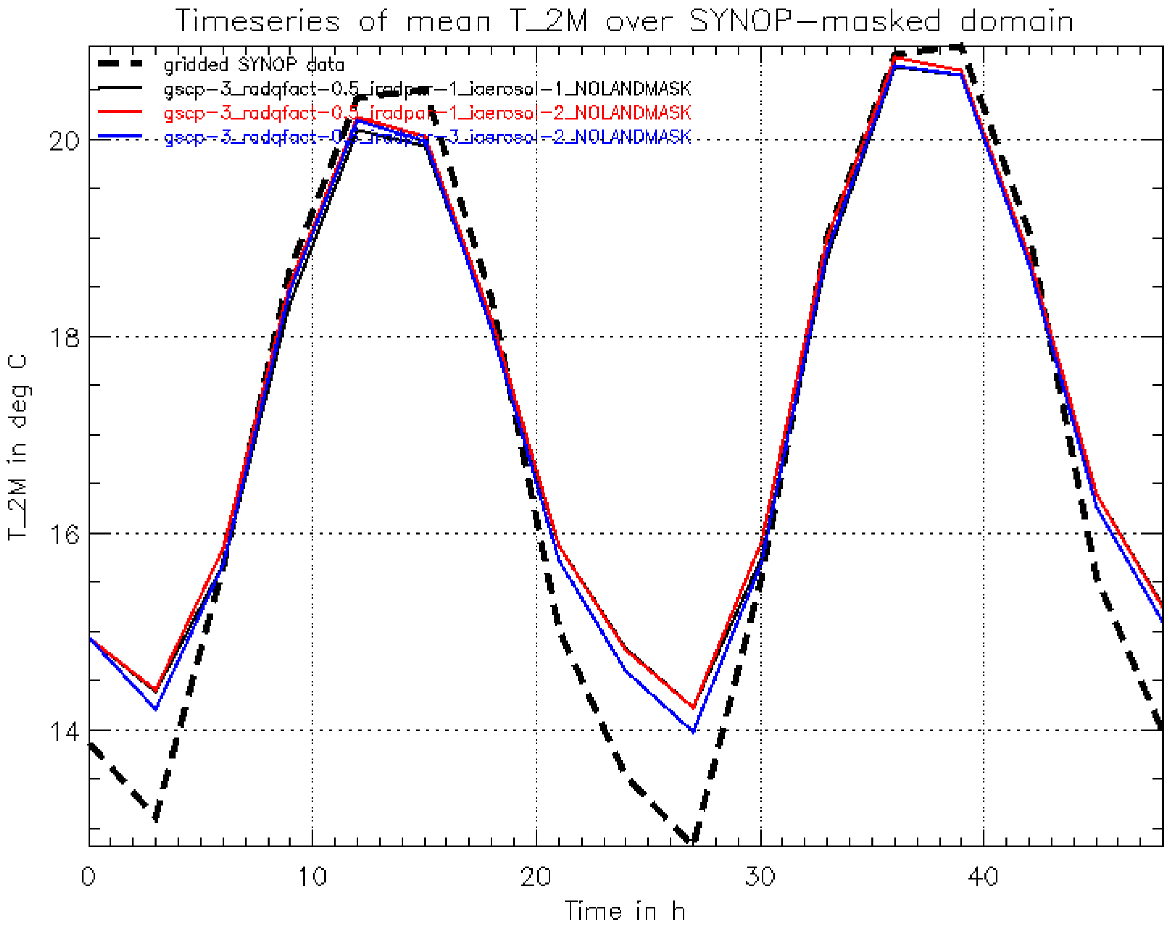

+ new optical properties

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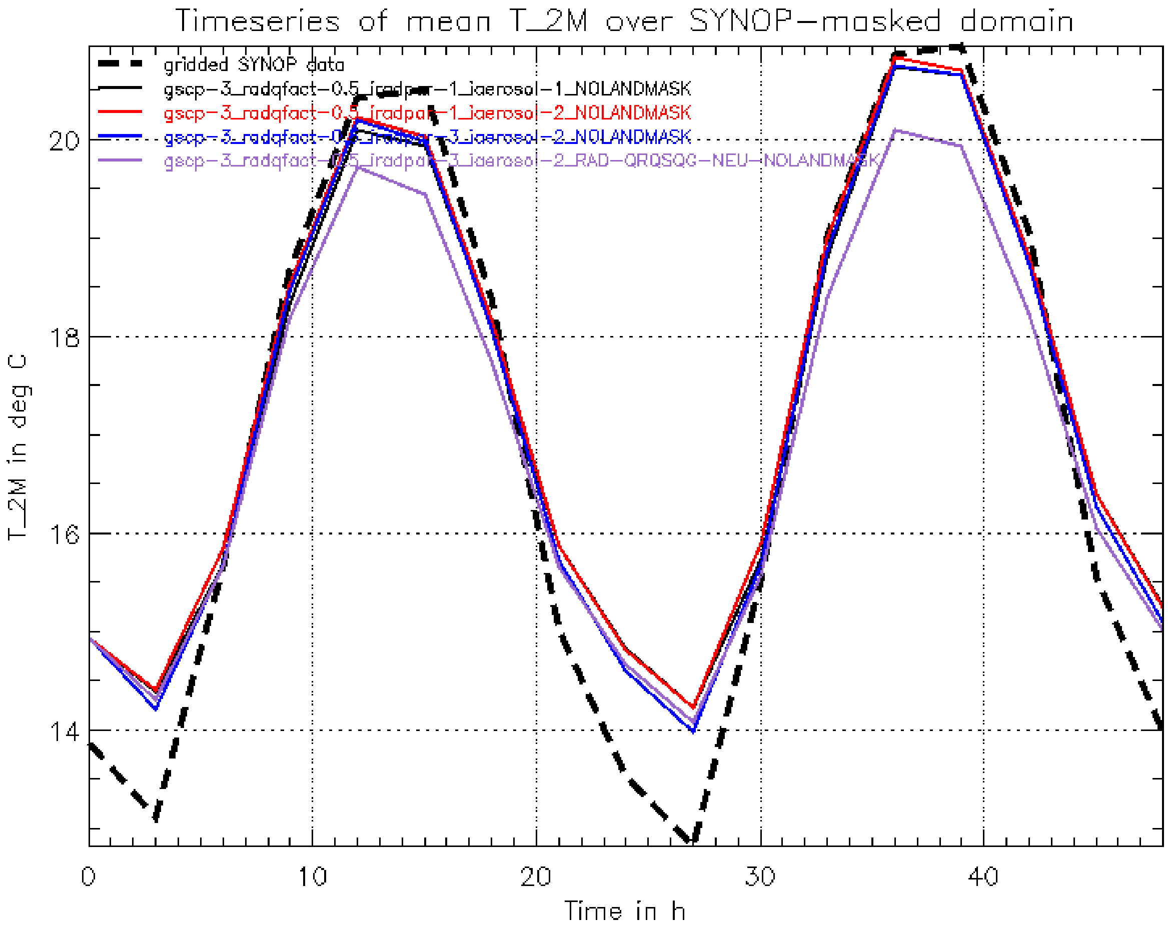

+ qs, qg

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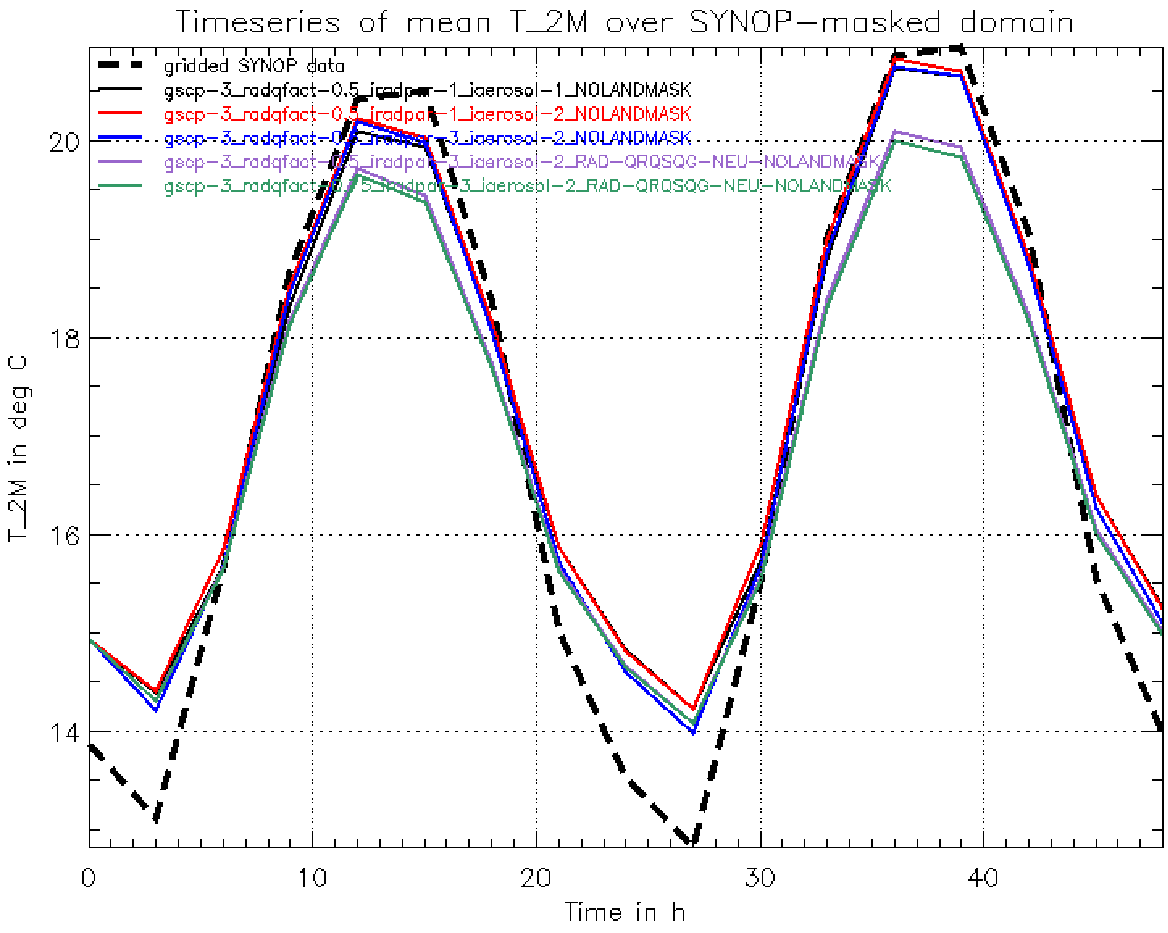

k = 0.75
instead of 0.5

Case study: 13.6.2012 (C-EU)

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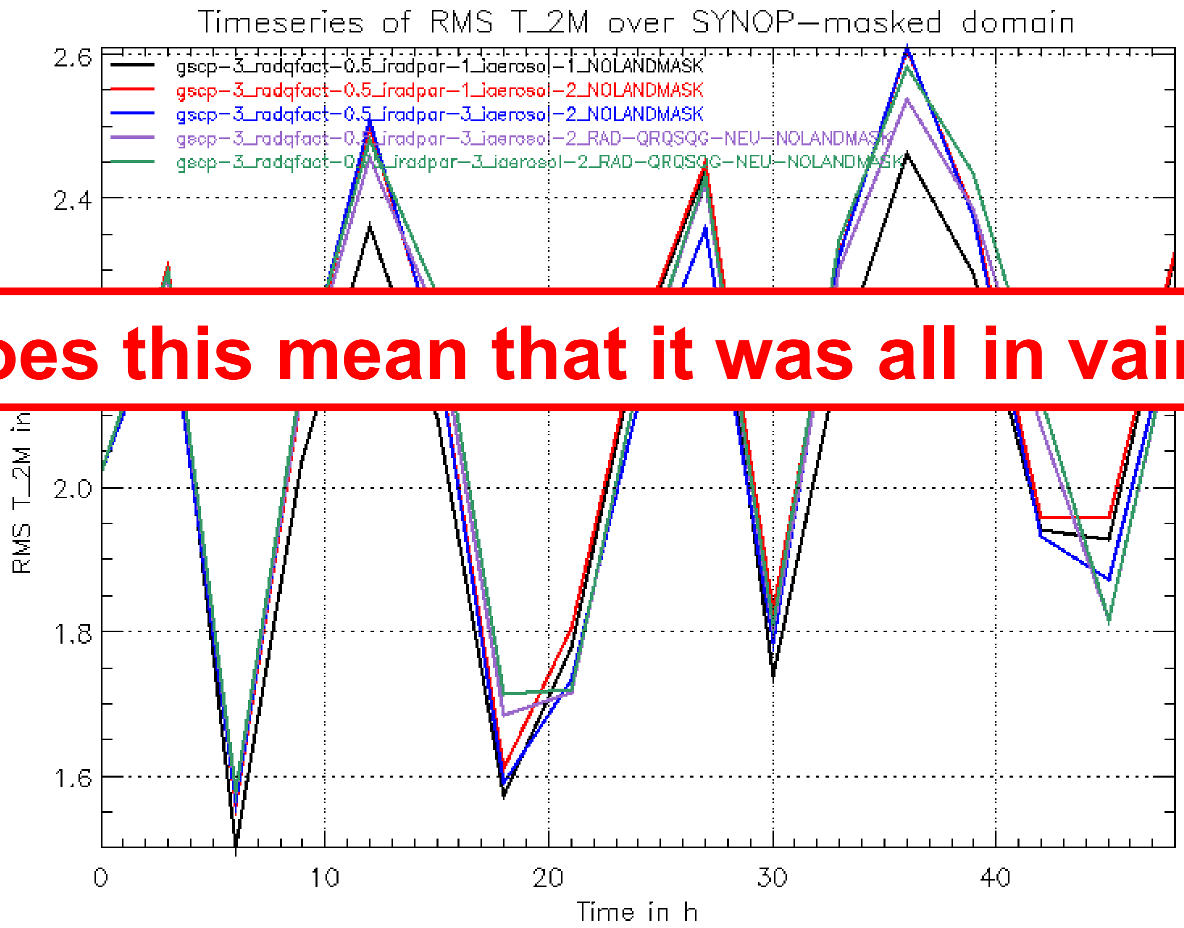

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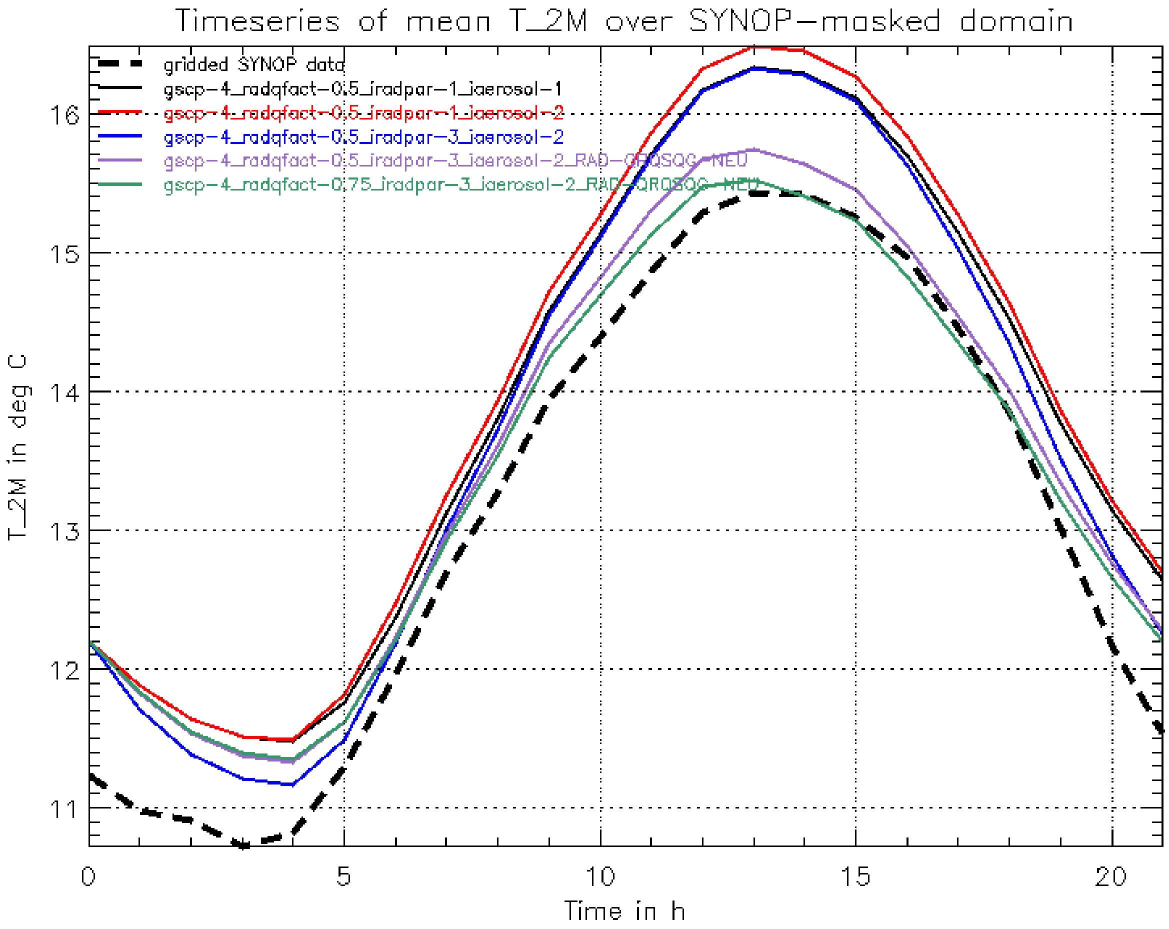
Does this mean that it was all in vain?

Case study: 13.6.2012 (C-DE)

Cloudy day in central Europe, cf. pictures from the beginning of the talk!

NO!



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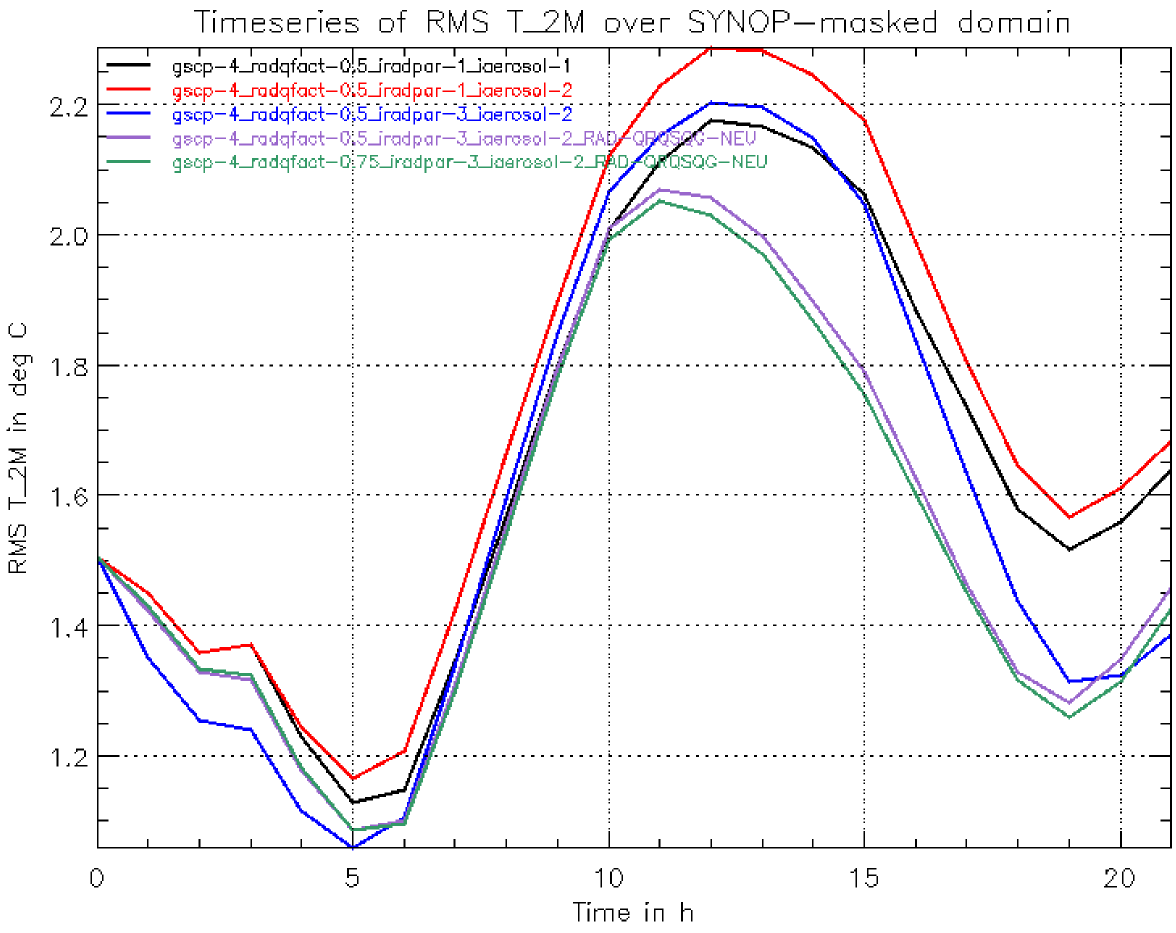

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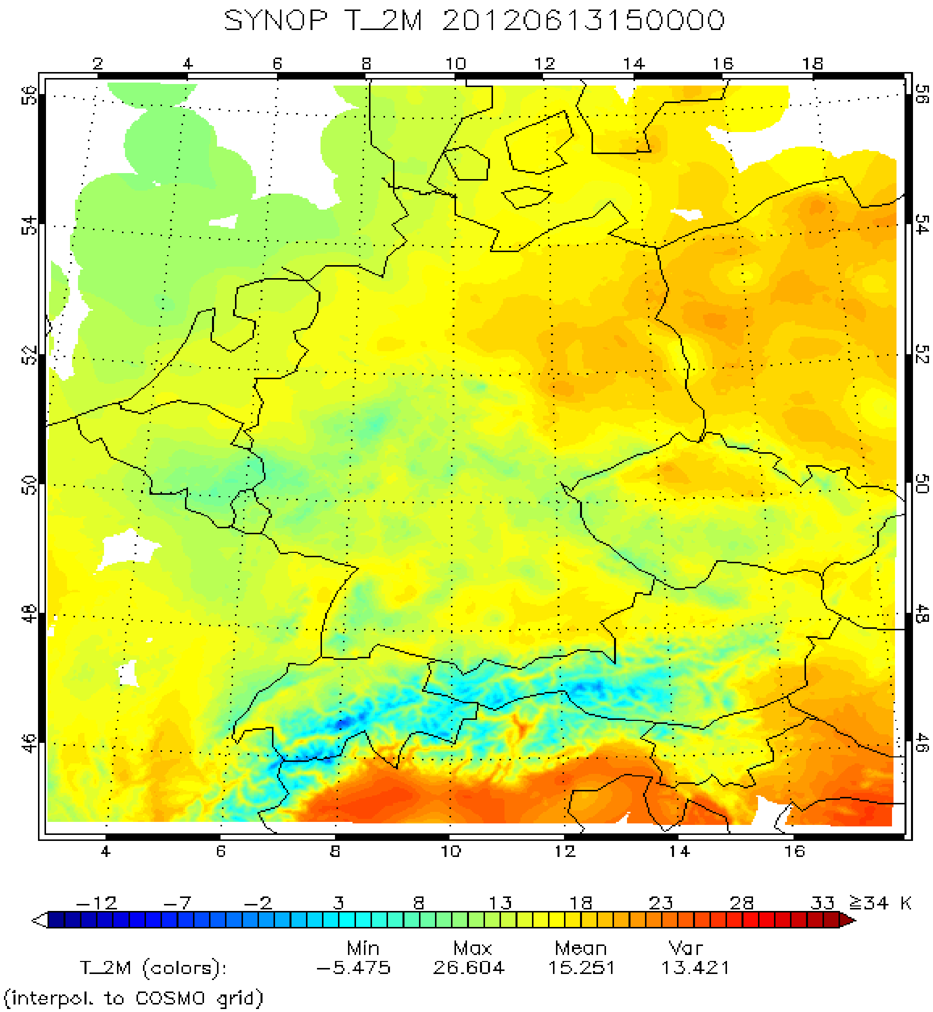
Conclusions

- ➔ Changes in cloud radiation coupling can lead to big changes of T_2M and possibly other model variables. This gives us a pretty big handle on the model!
- ➔ Sensitivities: The implemented R_e-parameterisations make the ice clouds optically thinner in the visible and infrared, therefore increased shortwave heating and longwave cooling in the presence of clouds. Including qs/qg and increasing factor k counteract, the clouds get optically thicker at all wavelengths, so Tmax during day is reduced.
- ➔ However, entire model currently tuned to the previous method of cloud radiation coupling (SGS cloud diagnostics, ...). Therefore, to uncover possible beneficial effects of the presented new method will require extensive re-tuning of the model!
- ➔ That will be a long process!

Gridded T_2M from synop station data (COSMO-DE)



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