Ice Supersaturation in the Operational Global Model GME

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Global Model GME

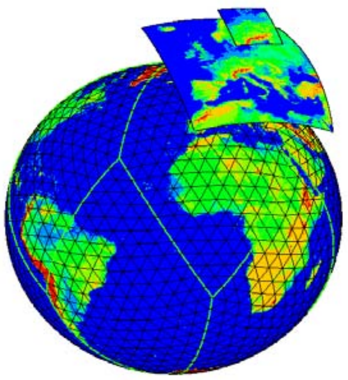

Fig. 1: Structure of GME grid and model domains of nested non-hydrostatic models COSMO-EU and COSMO-DE.

- Operational hydrostatic global model
- Icosahedral-hexagonal grid (Majewski et al. 2002)
  - Mesh size ~ 40 km, 368642 grid points/layer
  - 40 layers hybrid sigma/pressure coordinates
  - top layer at 10 hPa
  - Increased resolution of 30 km mesh size and 60 layers planned
  - Time step $\Delta t = 133$ s
- 3D-Var Data Assimilation
- Physical Parameterizations:
  - Tiedtke (1989) convection scheme
  - Ritter and Geleyn (1992) radiation
  - Prognostic ice microphysics with explicit supersaturation
- Daily operational forecasts:
  - 00 and 12 UTC + 174 hours
  - 06 and 18 UTC + 48 hours

Global RHi Distribution

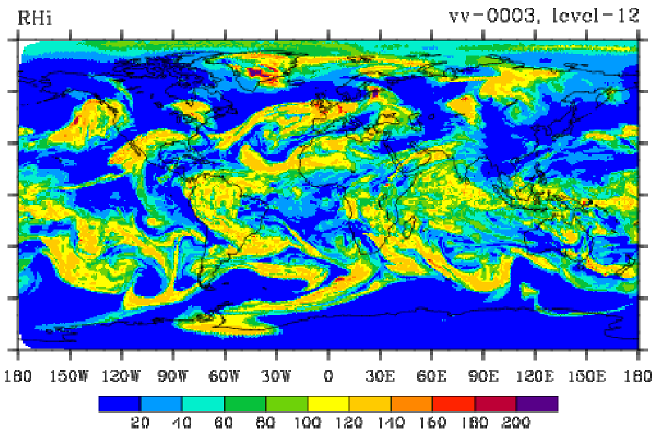

Fig. 2: Example of the spatial distribution of relative humidity with respect to ice in %. The GME is able to predict explicit ice supersaturation but ibt is presumably depleted too quickly, probably due to overestimation of ice nucleation and depositional growth.

Prognostic Cloud Ice Microphysics

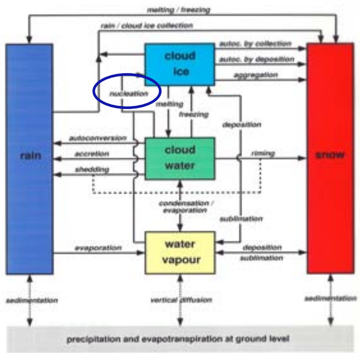

Fig. 3: Illustration of various micro-physical processes in GME.

- Includes cloud water, rain, cloud ice and snow. Currently rain and snow are treated diagnostically, i.e., advection is neglected.
- Prognostic treatment of cloud ice, i.e., non-equilibrium growth by deposition. No a-priori assumption made about liquid/ice fraction.
- Empirical temperature dependent parameterization of ice number concentration and homogenous freezing of cloud water.

$$n_i(T) = e^{(0.2(T_{melt}-T))}, \quad T_{melt} = 273.15\,\mathrm{K}$$

Ice Nucleation Modes

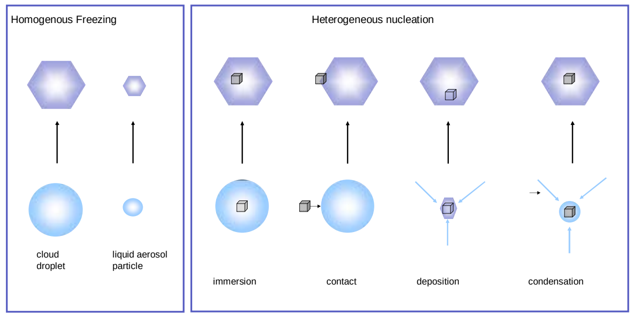

Fig. 4: Processes for ice cloud formation. The operational scheme do not include the important homogeneous freezing of liquid aerosol particles. (Figure from a presention by Thomas Leisner, with modifications)

Parcel Model

Input

w = cst.

T < 235 K

p < 350 hPa

→ **Parcel Model for Ice Nucleation and Depo-sitional Growth** →

Output

n_i – number density

m_i – mass number density

↑ Homogeneous and Heterogenous Nucleation

- Currently only temperature dependent parameterizations used for ice nucleation processes
- Parcel model:

  - Homogeneous parameterization following Kärcher et al. 2006 takes competition of het. and hom. freezing into account

  - Heterogeneous parameterization based on Phillips et al. 2008. Depends on concentrations of dust, soot and organic substances in the atmosphere

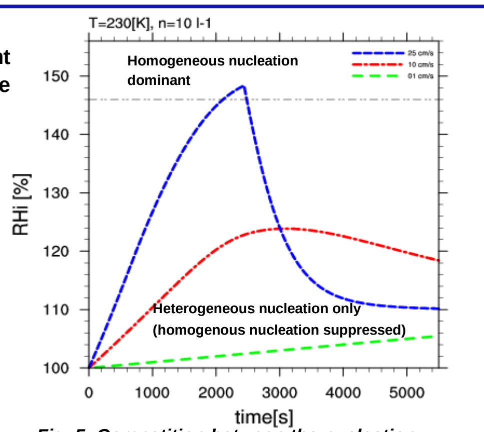

Fig. 5: Competition between the nucleation processes during cirrus cloud formation.

Conclusions and Future Work

- Approach needed in order to capture mesoscale fluctuations in temperature and vertical velocity to trigger homogeneous nucleation.
- Link aerosol climatology to heterogenous nucleation.
- Implementation of new ice nucleation schemes into GME, COSMO-EU and COSMO-DE Models and analyze scale dependencies.
- Perform validation with in-situ and satellite data.

References

Kärcher,B., J. Hendricks, U. Lohmann, 2006: Physically based parameterization of cirrus cloud formation for use in global atmospheric models, *J. Geophys. Res.*, **111**

Phillips, V., P. DeMott, C.Andronache, 2008: An empirical parameterization of heterogeneous ice nucleation for multiple chemical species of aerosol. *J. Atmos. Sci.*, **65**, 2757-2783

Majewski, D., and co-authors, 2002: The Operational Global Icosahedral–Hexagonal Gridpoint Model GME: Description and High-Resolution Tests, *Monthly Weather Review*, **130**, 319–338