Modelling mixed-phase clouds with large-eddy model UCLALES-SALSA

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Outline

Motivation

Model description: UCLALES-SALSA

Model verification base on the ISDAC campaign

Prognostic ice simulation

Conclusions
Motivation

- Better understanding of aerosol-cloud interactions and their impact on the climate
- Shallow clouds are hard to model with General Circulation Models but are important for the climate
  - Earth’s albedo depends highly on shallow marine clouds
Model description: UCLALES-SALSA

- Large-eddy simulation (LES) model UCLALES $^{1,2}$ for atmospheric turbulence
- Bin microphysics description with SALSA $^{3}$
- coupled UCLALES-SALSA first introduced in Tonttila et al., 2017 $^{4}$

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Bin microphysics description

- **Dry aerosol particle diameter from 3 nm to 10 μm**
- **Nucleation modes**: Aitken & Accumulation, Coarse
- **Ice nucleation & melting**
- **Drizzle/rain**
- **Cloud droplets**
  - Explicit modeling of growth in supersaturated conditions
  - Evaporation, release of aerosol
- **Droplet diameter from 50 μm to 2 mm**
- **New implementation**: 1a, 2a, 2b

Aerosol

Cloud droplets

Drizzle/rain

Ice
Model verification base on the ISDAC campaign

ISDAC Arctic case study (Ovchinnikov et al. 2014.\textsuperscript{5})

- Comparisons between LES models of mixed phase cloud simulations
- 11 models
  - 2 models with bin microphysics, 9 models with bulk 2-moment microphysics

Model intercomparison

We confirmed the accuracy of newly implemented ice microphysics with a comparison to the ISDAC mixed-phase cloud model intercomparison study.
Prognostic ice simulation

To see the difference between fixed and prognostic droplet freezing, we made a prognostic ice simulation that was targeted to have similar IWP during the first 8 hours as in the simulation with ice number concentration of \(4 \, (L^{-1})\) (ICE4). This ICE4 simulation was selected for comparison because it is close to the tipping point where cloud either stabilises or glaciates.
The simulation demonstrated how larger droplets froze first.

Figure: Relative portions of hydrometeors at each time step in the cloud layer. Cloud layer is defined when both cloud liquid water and ice mixing ratios are over 0.001 ($g \text{ kg}^{-1}$). Black line represents relative change of the total number concentration in each bin.
The model captured the typical layered structure of Arctic mixed-phase clouds: a liquid layer near cloud top and ice within and below the liquid layer. Moreover, the simulation showed realistic freezing rates of droplets within the vertical cloud structure.

Figure: Vertical profiles of liquid water and ice and freezing rate of droplets (nucleation rate) UCLALES-SALSA simulation with prog-nostic droplet freezing
Conclusions

- New cloud model with explicit ice description (warm cloud microphysics implemented 2017)
- Matches well with other models
- The implemented detailed sectional ice microphysics with prognostic aerosols is essential in reproducing the characteristics of mixed-phase clouds.
- The prognostic simulation showed the importance of the self-adjustment of ice nucleation active particles.
- The manuscript describing this study is under review.\(^6\)

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