First evaluation of Greenland clouds in RACMO2.4 using EarthCARE observations

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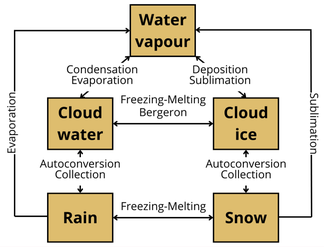
Modelling Greenland clouds using RACMO2.4

- Clouds affect Greenland ice sheet melt through precipitation and surface radiation
- The physical representation of clouds in regional climate models comes with large uncertainties
- We use observations from the EarthCARE satellite, launched in May 2024, to evaluate cloud representation in the regional atmospheric climate model RACMO v. 2.4p1
  - ECMWF integrated forecast system cycle 47r1
  - Prognostic cloud liquid, ice, snow and rain
  - Single-moment scheme



Cloud observations from EarthCARE

- 2D and 3D cloud and aerosol profiles based on four instruments
- Here, we focus on the atmospheric lidar (ATLID) and cloud profiling radar (CPR) observations
  - Level 1 backscatter and reflectivity products
  - Level 2 derived cloud properties and classification
- For comparison, we compute co-located RACMO cloud profiles on EarthCARE trajectories and simulate lidar level 1 backscatter for these profiles

Case study

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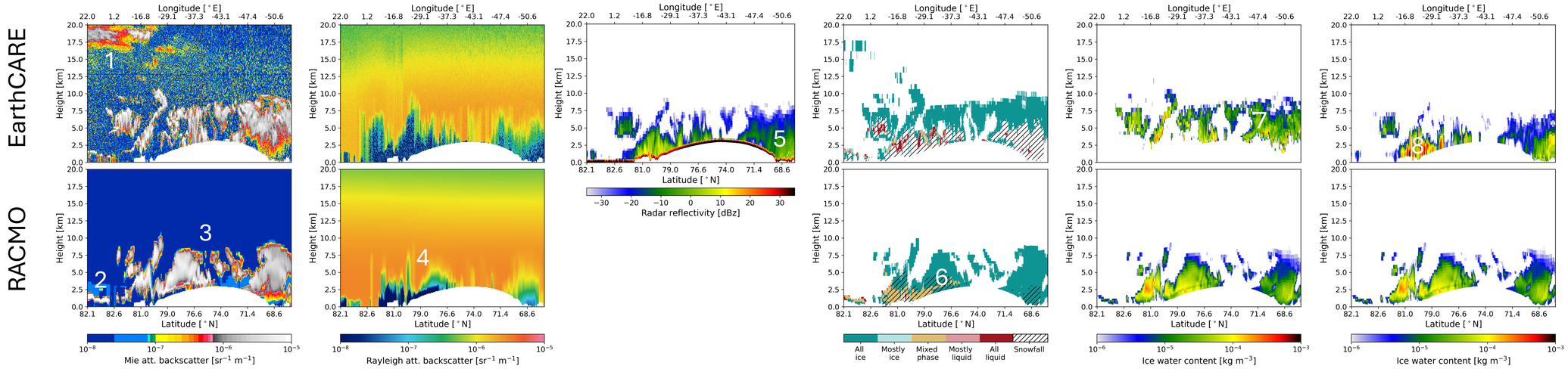
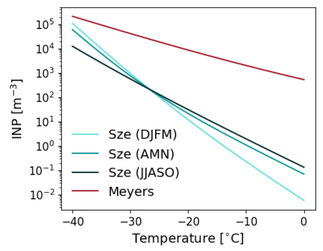
Lidar - ATLID Mie backscatter | Lidar - ATLID Rayleigh backscatter | Radar - CPR Radar reflectivity | Lidar + Radar Classification (AC-TC) | Lidar - ATLID Ice water content | Radar - CPR Ice water content



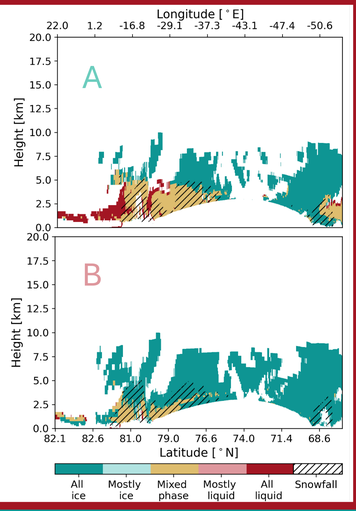
1) RACMO does not model stratospheric clouds
2) Both EarthCARE and RACMO show a liquid layer over the ocean
3) RACMO captures the complex structure of these ice clouds well
4) In RACMO, thick ice clouds and liquid layers are at too low heights
5) The radar can observe clouds at locations where the lidar signal is fully attenuated – using both lidar and radar gives a more complete cloud profile
6) RACMO sometimes misses liquid clouds
7) RACMO misses some thin ice clouds at higher elevations
8) In RACMO, some of the ice clouds contain too little ice water content

Can we improve cloud representation by tuning the microphysics?

- **Test A**: more realistic treatment of Arctic aerosols
  - Tune Bergeron process: **Ice nucleating particle parameterization** based on Greenland observations of Sze et al. (2023) instead of the Meyers et al. (1992) parameterization
  - Tune autoconversion of cloud liquid water to rain: **Cloud condensation nuclei concentrations** over the ice sheet equal to ocean concentrations ($50\ cm^{-3}$ instead of $300\ cm^{-3}$)
  - More overlap in liquid and mixed phase clouds compared to EarthCARE, but now there is too much liquid cloud
    - Polar aerosol measurements are limited, resulting in large uncertainties
- **Test B**: Tune autoconversion of cloud ice to snow
  - **Critical threshold of cloud ice** needed for generation of snow increased from $5{\cdot}10^{-7}$ to $1{\cdot}10^{-4}$ kg/kg
  - Improves representation of ice clouds as delayed snowfall results in a longer cloud lifetime



		Probability of detection	False alarm rate
Default	Ice	**37%**	**30%**
	Liquid	**6%**	**85%**
A	Ice	35%	28%
	Liquid	63%	91%
B	Ice	67%	30%
	Liquid	5%	85%



To conclude: How well can we model Greenland clouds?

- We made a first comparison between RACMO model simulations and the first available EarthCARE observations
- RACMO represents ice clouds better than liquid clouds, but underestimates both
- Using more realistic aerosol concentrations for polar regions can improve liquid cloud representation, but estimates of polar aerosols remain uncertain
- Slower generation of snowfall can improve ice cloud representation

What is next?

- RACMO evaluation on growing dataset of EarthCARE observations
- Comparison with EarthCARE multi-instrument retrieval products
- Evaluating microphysical assumptions for generation of cloud ice, water, snow and rain
- Comparing radiation estimates of EarthCARE observations and RACMO model results

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References
Meyers et al. (1992). New primary ice nucleation parameterization in an explicit model.
Sze et al. (2023). Ice-nucleating particles in northern Greenland: annual cycles, biological contribution and parameterizations.