Assessment of refractive index models at super-cooled temperatures and microwave frequencies

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1. Motivation

- Liquid water droplets in natural clouds can exist down to -38°C.
- This so called super-cooled liquid water (SLW) plays an essential role in cold cloud microphysics.
- Even small amounts of SLW (<30 g/m²) in clouds dramatically change their radiative effect (radiative forcing).
- Passive microwave (MW) retrievals of SLW depend on accurate models of the SLW refractive index.
- Current models are mainly extrapolations based on laboratory data with T_water > 0°C.

2. How large are the model discrepancies?

- While the sensitivity of the MW channel to SLW increases with (frequency)^2, also the uncertainty in the refractive index models increases with frequency.
- Including high frequency channels (e.g. 90/150 GHz) in SLW retrievals greatly enhances their sensitivity/accuracy. However, this implies that current refractive index models are improved.

3. What is the impact on retrieved LWP?

- LWP retrievals for 9 frequencies (22.4 - 31.4, 90, 150 GHz) have been created using the Ellison, Liebe, and Stogryn models.
- LWP values can differ by 40 g/m² and more depending on the refractive index model used.

4. Validation approach using RT simulations and observations

Long-term observations of passive and active MW radiometers and additional instruments as a ceilometer (Löhnert et al., 2011) from the environmental research station Schneefenernahe (UFS) at 2650m have been used to select ideal cases (thin single layer clouds) for model - observation comparison of the different SLW refractive index models.

Concept:

TB observations, not used for estimate of atmospheric state
Best estimate of the atmospheric state

NWP analysis (COSMO-DE): Vertical profiles: Temperature, Press., Humidity

Assume realistic LWP range (e.g. 0 – 200 g/m²)

Radiative Transport (RT) applying different SLW refractive index models

Comparison of observed TB with simulated TB range (using the four different SLW refractive index models)

RT model – observation residuals 31.4 vs. 90 GHz

RT model – observation residuals 31.4 vs. 150 GHz

References:


Liebe et al., 1992: Propagation modeling of moist air and suspended water/ice particles at frequencies below 1000 GHz. AGARD. Atmospheric propagation effects through natural and man-made obstacles for visible to mm-wave radiation.
