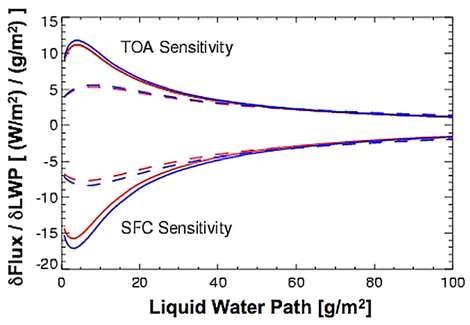
Assessment of refractive index models at super-cooled temperatures and microwave frequencies

Redl[1], S., S. Kneifel[1], U. Löhnert[1], and S. Crewell[1]
[1] *Institute for Geophysics and Meteorology, University of Cologne*

1. Motivation

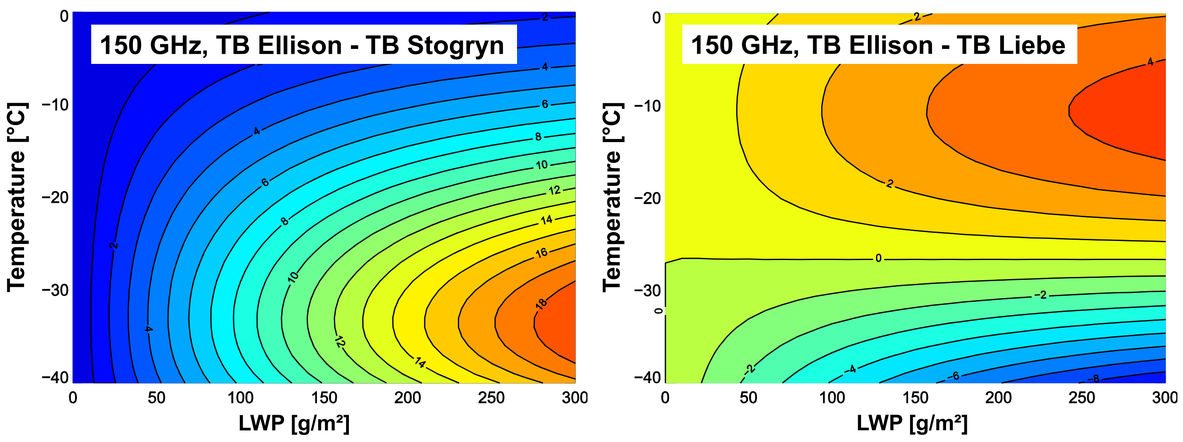
- Liquid water droplets in natural clouds can exist down to -38°C.
- This so called super-cooled liquid water (SLW) plays an essential role in cold cloud microphysics.
- Even small amounts of SLW (<30g/m²) in clouds dramatically change their radiative effect (radiative forcing).
- Passive microwave (MW)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



Sensitivity of the shortwave flux at the surface (SFC) and top of atmosphere (TOA) to cloud liquid water path (LWP) (Turner et al., 2007).

2. How large are the model discrepancies?

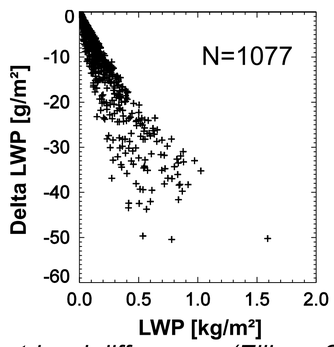
- While the sensitivity of the MW channel to SLW increases with (frequency)², also the uncertainty in the refractive index models increases with frequency.
- Including high frequency channels (e.g. 90/150 GHz) in SLW retrievals greatly enhances their sensitivity/accuracy. However, this implies that current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



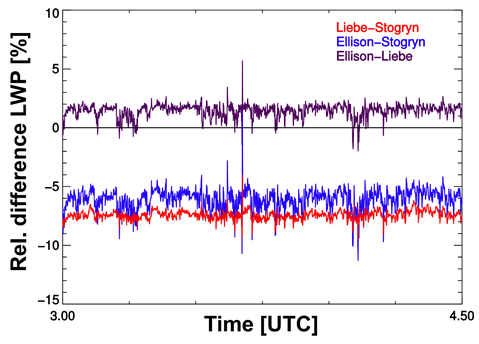
The SLW refractive index models considered in this study, **Ellison (2006)**, **Liebe et al. (1991/93)**, **Ray (1972)**, and **Stogryn et al. (1995)**, show different behavior depending on frequency, temperature, and LWP value.

3. What is the impact on retrieved LWP?

- LWP retrievals for 9 frequencies (22.24 - 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.



LWP retrieval differences (Ellison-Stogryn) as a function of LWP (Ellison) for clouds with a mean temperature between 0°C and -20°C.



Relative difference of LWP time series for a super-cooled cloud case.

References:

Löhnert et al., 2011: A multi-sensor approach towards a better understanding of snowfall microphysics: The TOSCA project, Bull. Amer. Meteor. Soc., 92(5).

Turner et al., 2007: Thin liquid water clouds: Their importance and our challenge, Bull. Amer. Meteor. Soc., 88(2).

Ellison, 2006: Dielectric properties of natural media, in Thermal Microwave Radiation: Application for remote sensing, Editor C. Mätzler, IET Publisher.

Liebe et al., 1991: A model for the complex permittivity of water at frequencies below 1 THz, Int. J. Infrared Millimeter Waves, 12(7).

Liebe et al., 1993: Propagation modeling of moist air and suspended water/ice particles at frequencies below 1000 GHz. AGARD, Atmospheric propagation effects through natural and man-made obscurants for visible to mm-wave radiation.

Ray, 1972: Broadband complex refractive indices of ice and water, Appl. Opt., 11(8).

Stogryn et al., 1995: The microwave permittivity of sea and fresh water, GenCorp Aerojet, Azusa, CA, Aerojet Rep.

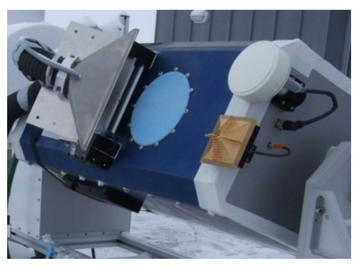
4. Validation approach using RT simulations and observations

Long-term observations of passive and active MW radiometers and additional instruments as a ceilometer (Löhnert et al., 2011) from the environmental research station Schneefernerhaus (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

HATPRO
22 - 60 GHz



DPR
90 / 150 GHz

Best estimate of the atmospheric state

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

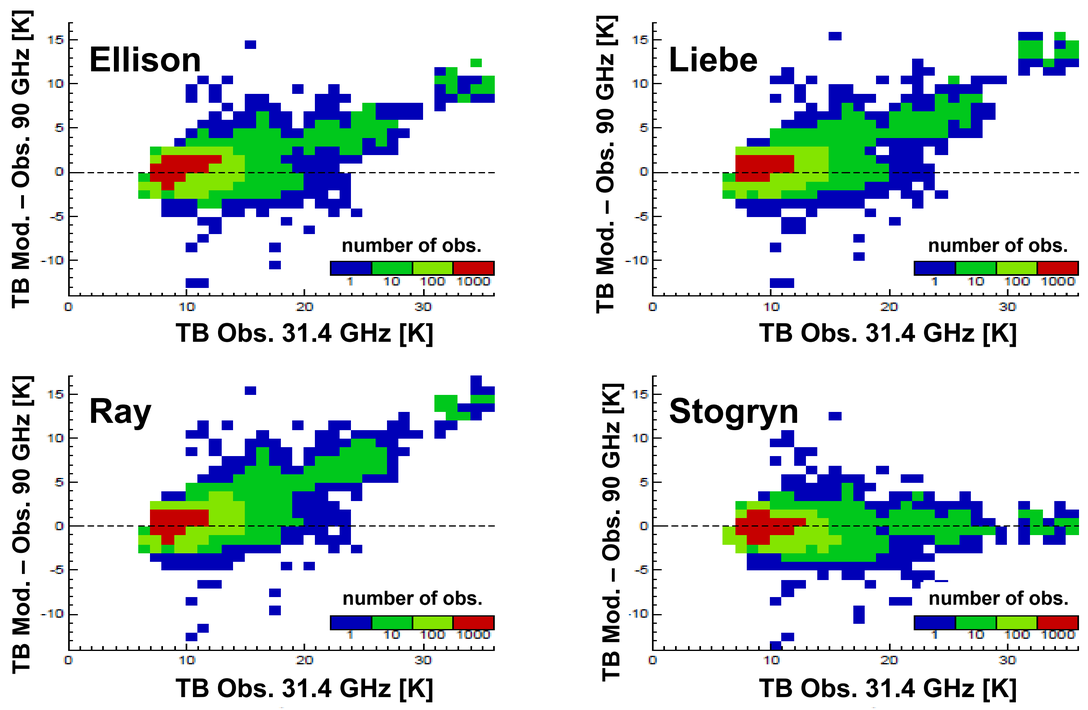
Assume realistic LWP range (e.g. 0 – 200 g/m²)

Ceilometer: Cloud base height

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

Radiative Transport (RT) applying different SLW refractive index models

RT model – observation residuals 31.4 vs. 90 GHz



RT model – observation residuals 31.4 vs. 150 GHz