Improving Supercooled Liquid Water Absorption Models in the Microwave Using Multi-Wavelength Ground-based Observations

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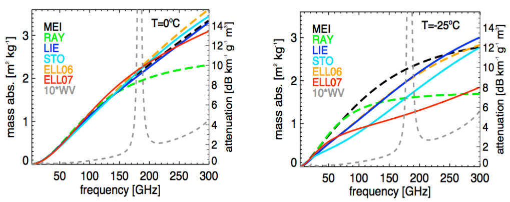
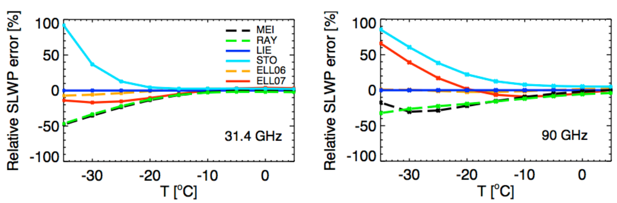
(1) Background

- Microwave radiometers are primary tool used to quantify liquid water path (LWP) in atmosphere
- MWRs measure T_b, and algorithms retrieve LWP from T_b obs
- Liquid water absorption models are critical, but all are tuned using lab data at T_{cloud} > -2ºC
- Huge (as large as 70%) uncertainties in LWP when T_{cloud} < 0ºC using different models



Mass absorption coefficients at two different temperatures from 6 popular models

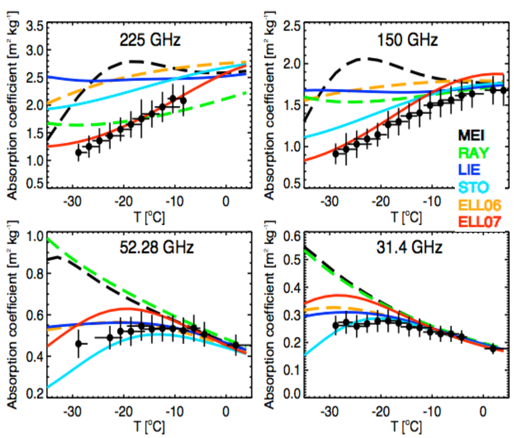
Differences in retrieved LWP using the different models (relative to Liebe91 model)



Liebe91 model is perhaps the most commonly used model (ARM uses it operationally)

(3) Opacity Ratios to Evaluate Current Absorption Models

- Atmospheric opacity easily derived from T_b obs
- Total opacity is sum of (dry gas opacity) + (water vapor opacity) + (liquid water opacity)
- Liquid water opacity has the highest variability in time, thus easily separated out
- Can easily compute opacity ratios between different channels and remove calibration artifacts



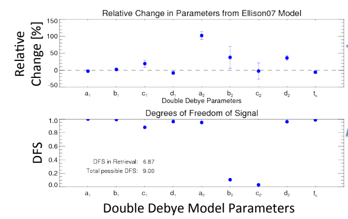
- Opacity ratio measurements from all 3 sites are consistent
- Previous work (Cadeddu and Turner 2011, Mätzler 2010) demonstrated Stogryn95 is "ok" at 90 GHz
- Stogryn model used to turn observed opacity ratios into absorption coefs at other freqs, which are compared to models
- None of the current suite of commonly used absorption models fits the field data at supercooled temps well
- Stogryn95 seems to be best model for f ≤ 90 GHz, Ellison07 seems best for f > 90 GHz

(2) Datasets Used

- AMF Deployment, Black Forest, Germany, 511 m MSL: 31, 52, 90, and 150 GHz
- UFS, Zugspitze Site, 2650 m MSL: 31, 52, 90, and 150 GHz
- ICECAPS, Summit Station, Greenland, 3250 m MSL: 31, 52, 90, 150, and 225 GHz

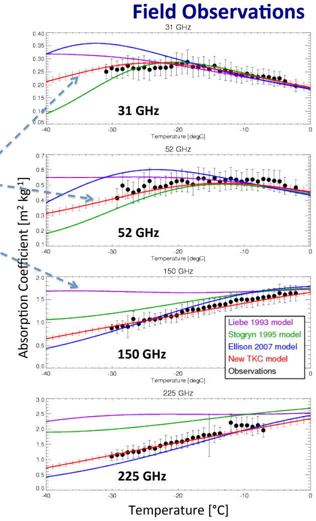
(4) Development of a New Absorption Model

- Assumed a double Debye model, as is common with most of the current models
- Retrieved the model coefs using an optimal estimation approach so uncertainties are produced
- Used historical lab data (compiled by Ellison) and our field data to empirically determine coefs



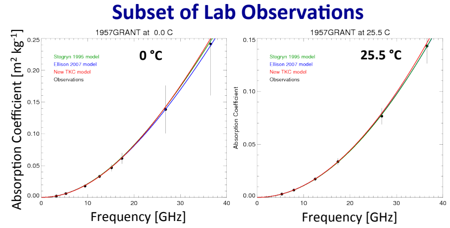
- Compared retrieved model parameters to Ellison07 model – some big changes
- Degrees of freedom for signal indicates (lab+field) obs have ~7 pieces of information (out of 9)

Field Observations



- New "TKC" model fits the supercooled field data at all frequencies very well
- Error bars on new TKC model (red) are quite small
- ARM's current model (Liebe) is particularly bad for T_{cloud} < -20ºC for f < 60 GHz and for f > 60 GHz
- TKC model fits lab data well also

Subset of Lab Observations



(5) Future Work

- Primary assumption here is that Stogryn is accurate at 90 GHz at supercooled temperatures
- Will use AERI-retrieved LWP at Summit and FKB to provide additional validation

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