Improve Microwave Snow Emissivity Model using Dense Media Radiative Transfer Theory Based on the Quasicrystalline Approximation (QCA/DMRT)

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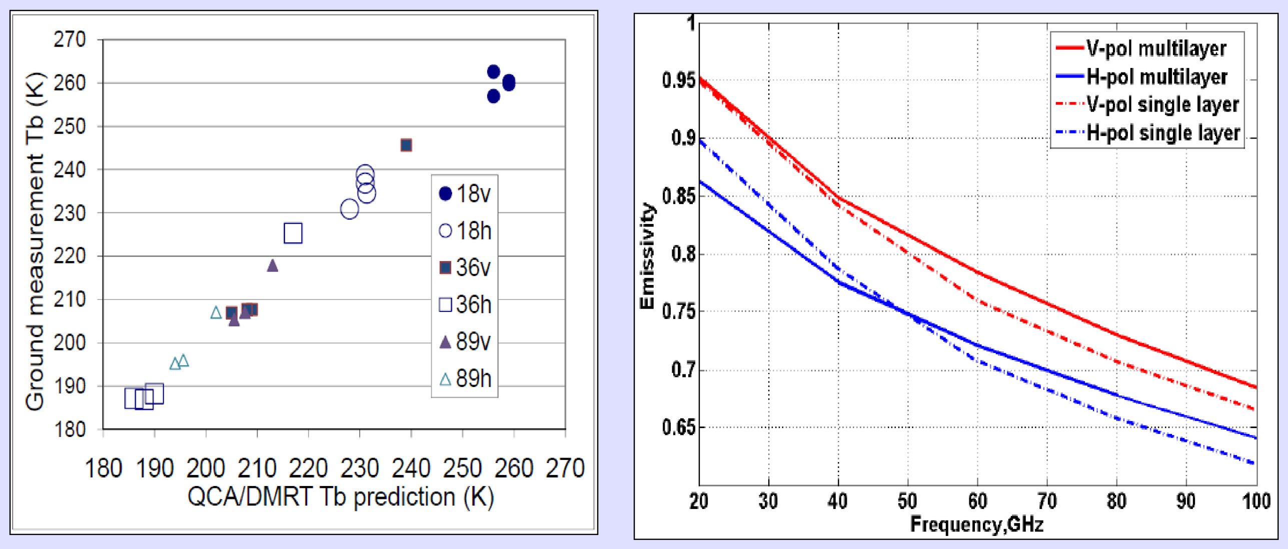
Abstract

Accurate land emissivity information will increase the assimilation of satellite microwave data in numerical weather prediction (NWP) models. The current Land Emissivity Model at Microwave frequencies (LEMM) was used in the US Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) which is now being used in several NWP models. This model works well over snow at frequencies less than 30 GHz. However, the model often underestimates snow emissivity at higher frequencies, especially for newly formed snow.

To improve the capability of simulating snow emissivity at high frequencies, the Dense Media Radiative Transfer theory based on the Quasicrystalline Approximation (QCA/DMRT) is being applied to develop a fast but accurate multi-layer snow emissivity model. The QCA/DMRT model is a physical model, which takes into account the collective scattering effects of the particles by including the wave interactions among the particles. Input parameters include frequency, snow grain size, snow density and snow depth. The NASA Land Information System (LIS) and NOAA Land -Surface Model (LSM) outputs will be used as input parameters to QCA/DMRT model. An algorithm will be developed to estimate snow grain size and density required in the emissivity models using NASA LIS and NOAA LSM snow types.

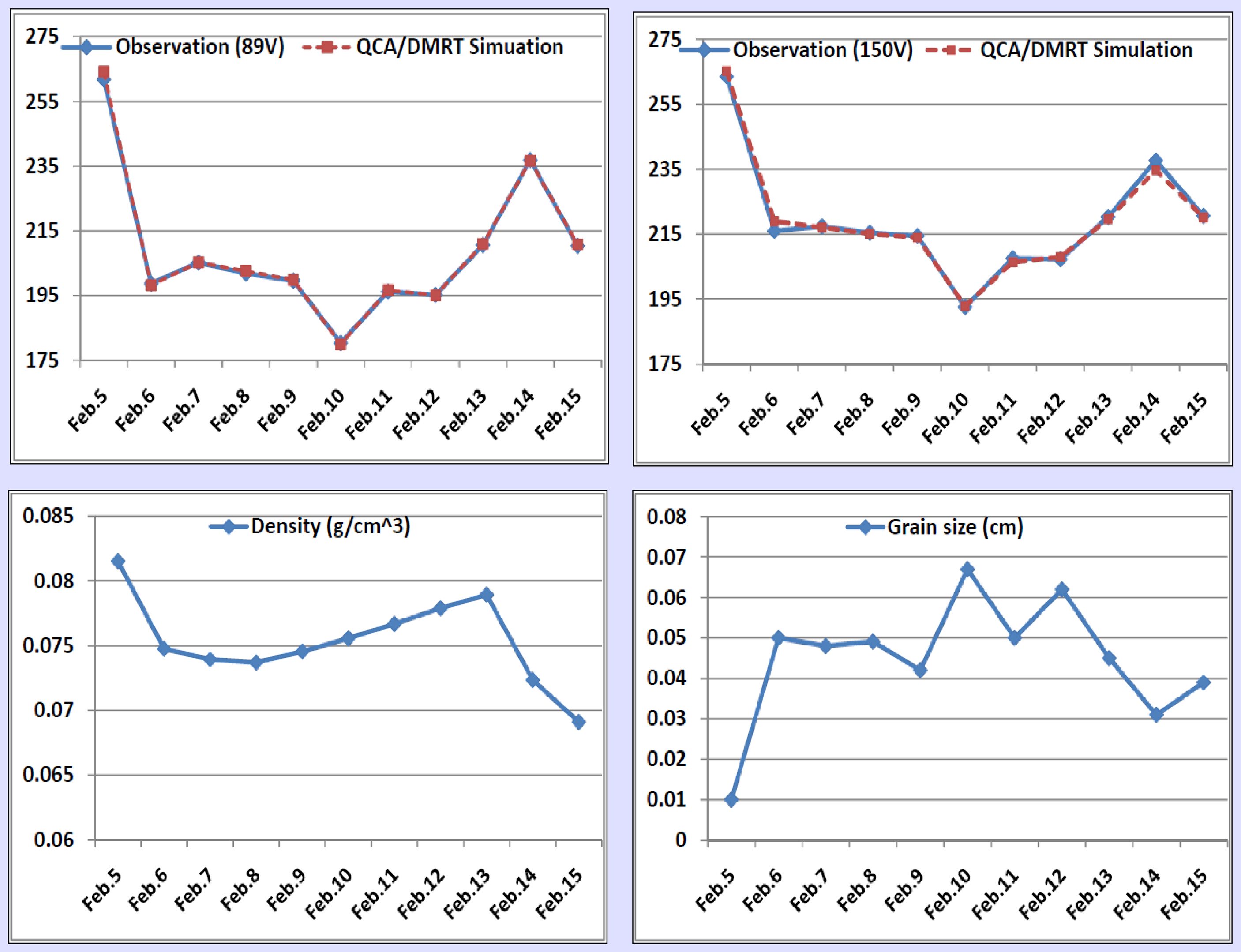
To speed the computation, look up table of snow optical properties based on QCA/DMRT simulations will also be developed.

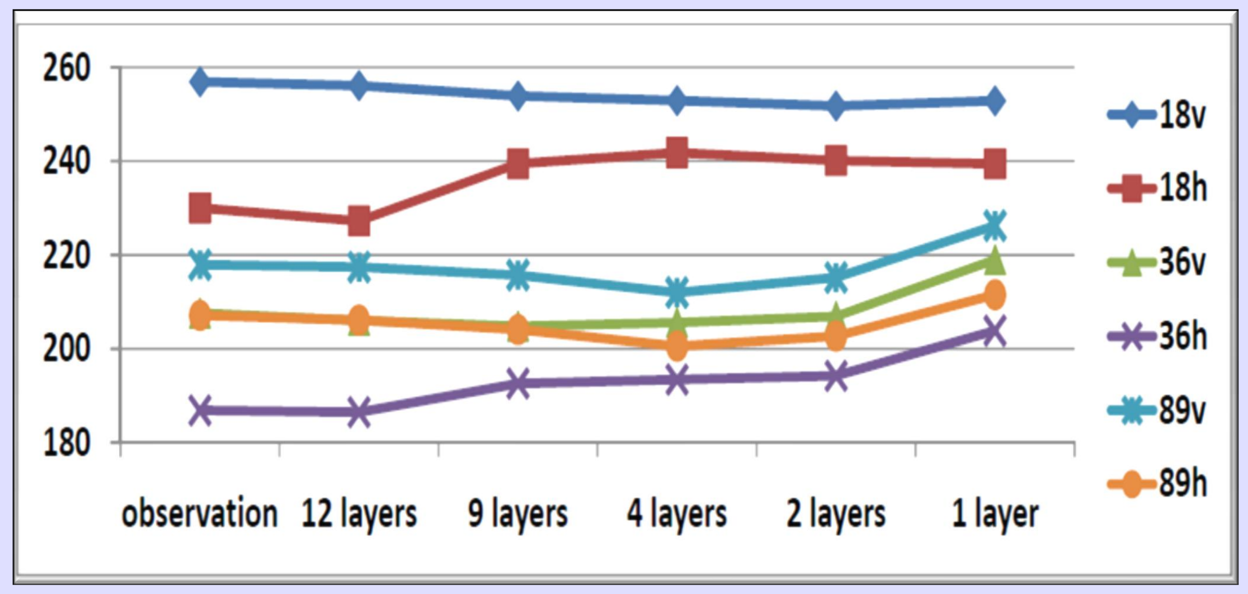
Comparison of GBMR Point Observations and DMRT Predictions



- QCA/DMRT model simulations agree with GBMR point Tb observations (left).
- Comparison of simulated emissivity by multilayer QCA/DMRT model and single layer QCA/DMRT model (right).

Comparison of AMSU-B Observations and DMRT Predictions

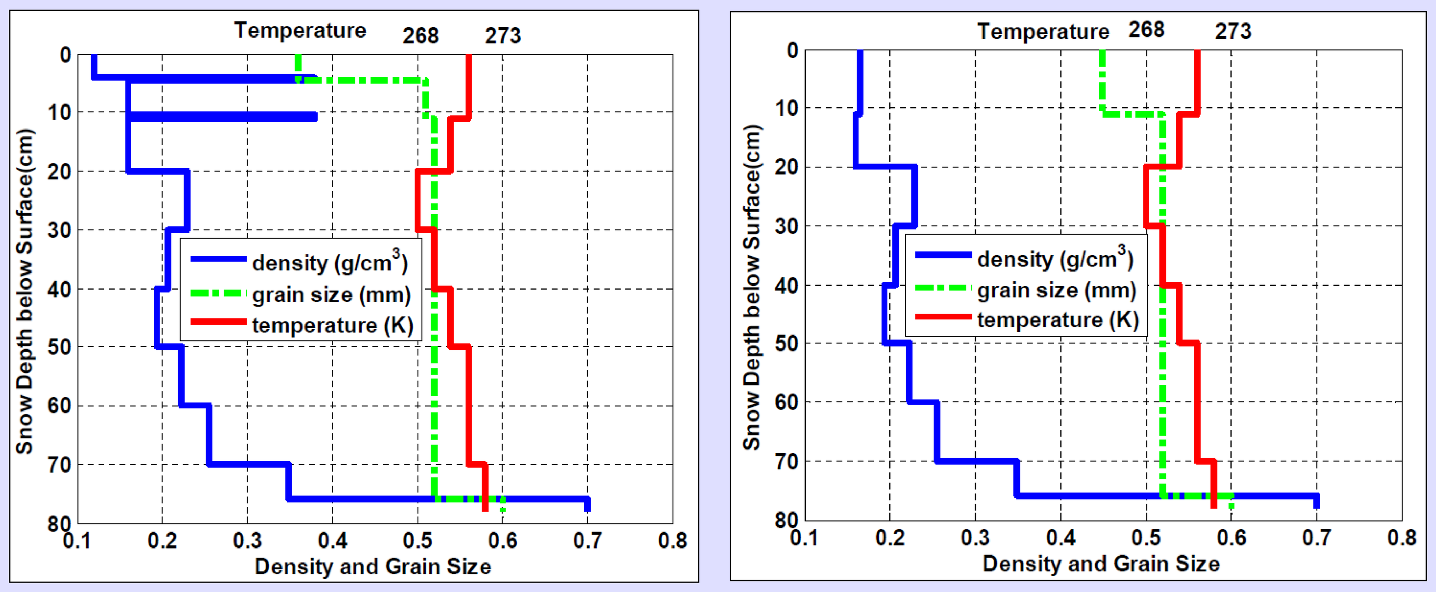




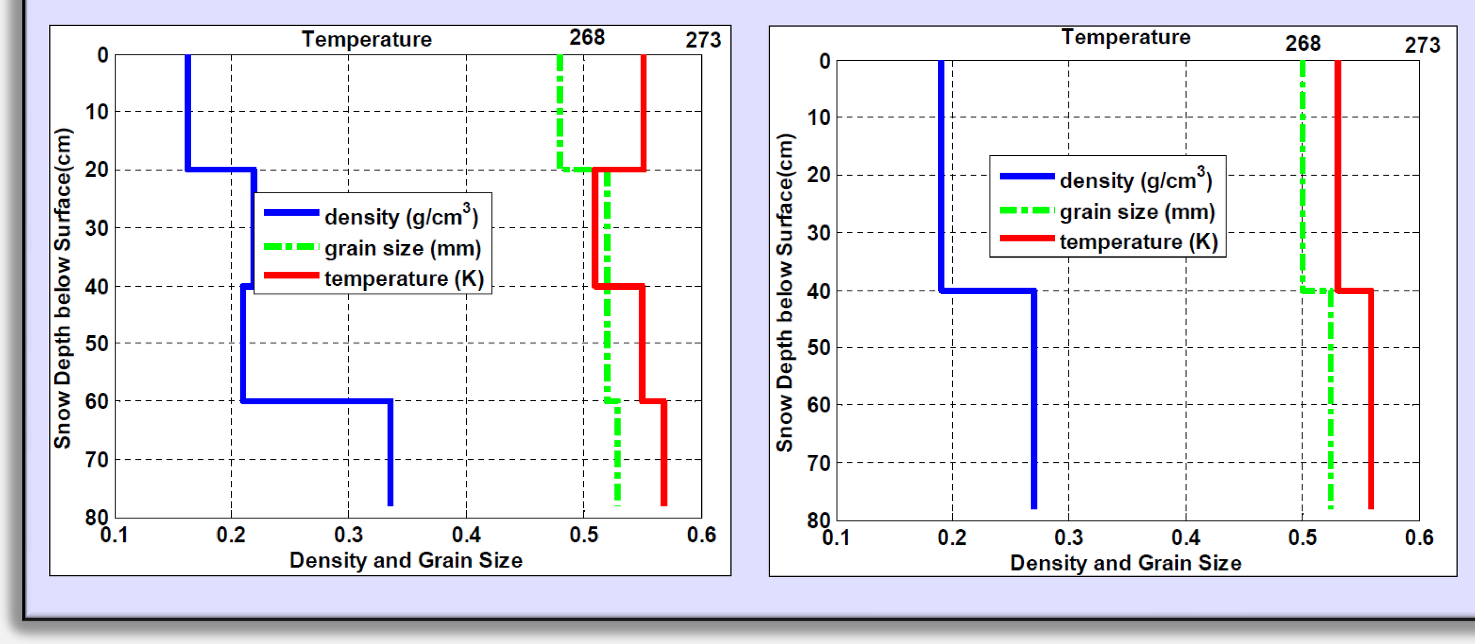
- 12-layer model predicts higher polarization difference at 18.7GHz and 36.5GHz than other models due to large snow density variance near surface.
- All models predict similar polarization difference at 89GHz .
- Single layer model predicts higher brightness temperature at 36.5GHz and 89GHz than multilayer model.

Multilayer QCA/DMRT Model Simulation Comparison

Model Input



12 layers 9 layers



4 layers 2 layers

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Look-up-table of Snow Emissivity Based on QCA/DMRT Model

- **Input:**
  - Frequency(GHz): 23.8, 31.4, 50.4, 89, 150
  - Fractional volume: 0.1, 0.12, 0.14, 0.145, 0.15, 0.155, 0.16, 0.165, 0.17, 0.175, 0.18, 0.2, 0.22, 0.24, 0.26, 0.28, 0.3, 0.32, 0.34, 0.36
  - Grain size (mm): 0.1, 0.2, … 1.4, 1.5
- **Output:**
  - Snow emissivity and permittivity

Summary

The information of snow emissivity at frequencies above 89 GHz play an important role in microwave remote sensing and satellite data assimilation systems since frequency channels at 89, 150 and 183 GHz are covered by Advanced Microwave Sounding Unit-B (AMSU-B), Microwave Humidity Sounder (MHS), Special Sensor Microwave Imager and Sounder (SSMIS), and Global Precipitation Measurement (GPM) Microwave Imager (GMI).

This study has explored the feasibility of simulating snow emissivity at frequencies above 89 GHz. The accurate snow emissivity will result in better utilization of the high frequency data in numerical weather prediction.

The improved microwave emissivity model will benefit the usage of JPSS and GOES-R satellite data and products in weather forecast.