Evaluation of Tb sensitivity to snowpack parameters using existing snow microwave radiative transfer models

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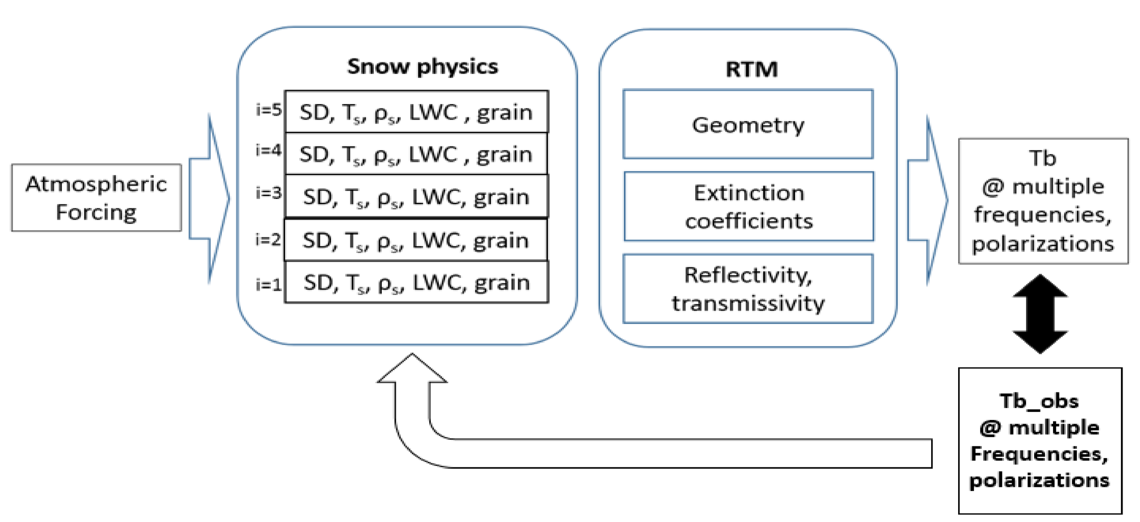
Abstract

Applying microwave radiative transfer models (RTM) to predict brightness temperatures of snowpacks is an essential element in microwave remote sensing of terrestrial snowpack. An RTM solves radiative transfer equations to compute the upward emission, i.e., the brightness temperature (Tb), from the multi-layered snowpack. Among many microwave forward models, three of them are to be examined in the paper, namely, i) the Microwave Emission Model of Layered Snowpacks (MEMLS), ii) the Dense Media Radiative Transfer based on the Quasi-Crystalline Approximation of Mie scattering of densely packed Sticky spheres (DMRT-QMS), and iii) the Helsinki University of Technology (HUT) models. Interestingly, these models can yield quite different Tb responses when driven by the same physical parameters of snowpack. These differences are to be examined in this paper for better choice and deployment of RTM in the snowpack retrieval framework. Understanding these differences also helps to establish better physical representations of layered snowpack.

In this paper, we first compare the brightness temperature prediction from the 3 RTMs as a function of snow grain sizes and densities. While Tb from all 3 RTMs decreases with the increase of the snow grain size, it is found that the scale factor is required to have the same amount of the Tb attenuations due to the grain size. With the variation of snow density, MEMLS shows the snow depth effect owing to the increase of density is not well represented. However, with the same increase of snow density, HUT and DMRT-QMS both produce increasing Tb due to decrease of the snow depth to represent less microwave attenuation attributed by the smaller length of microwave path. However, DMRT-QMS has more complicated Tb responses until 100 kg/m^3 with enhancement of the forward scattering due to the increasing snow density.

Coupled Model



Snow Grain Size

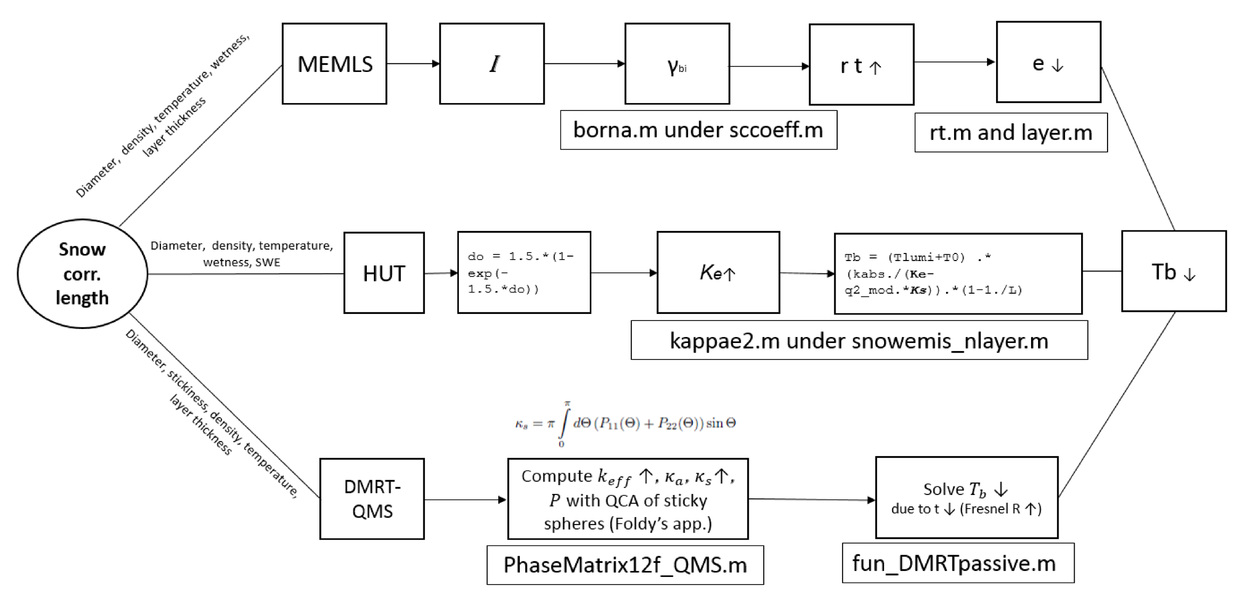


Fig. 2 **Schematic view of 3 RTMs governed by gradual changes in snow correlation lengths.**

- **MEMLS:** Integration constant in a bistatic scattering coefficient increases with the correlation length with a power of 3. 1.8 multiplication factor.
- **HUT**: ke = 2 × (f^4 × $\mathbf{d}^6$)$^{0.2}$ followed by Roy et al. 2004
- **DMRT-QMS**: the effective scattering loss has a peak as you increase the grain size..
- **DMRT-QMS** has a lower Tb than MEMLS because its scattering loss has a stronger correlation length dependence. 0.4 multiplication factor.

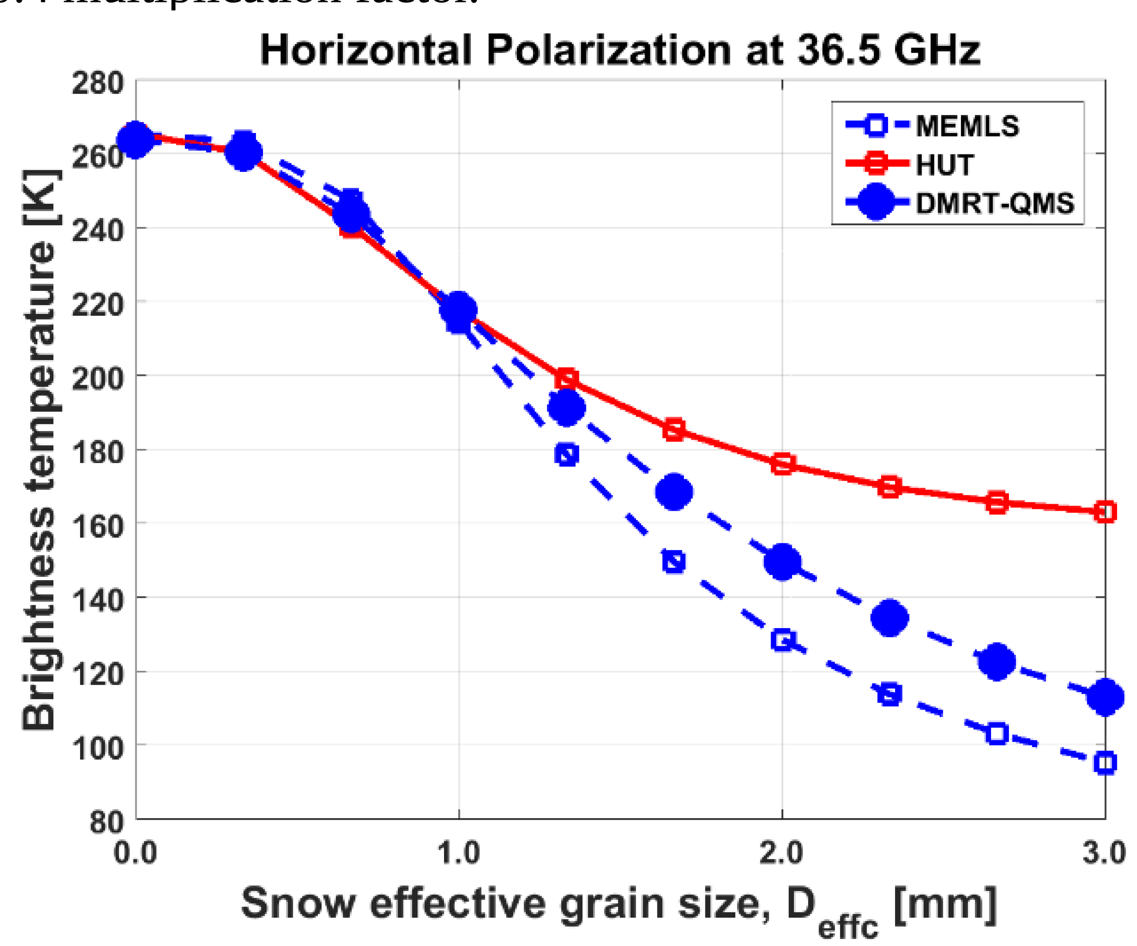


Figure 3. Horizontally polarized Tb responses at AMSR-E frequencies such as 36.5 GHz, evaluated by MEMLS, HUT, and DMRT-QMS with increasing snow density (in case of fixed parameters, snow temperature = 270 K, snow grain correlation length = 0.21 mm, snow water equivalent=0.06 m, density = 50.0~400.0 kg/m^3, ground dielectric constant = 6+1*i* only for HUT, ground temperature = 270 K and the incidence angle = 53.1°).

Scattering coefficient

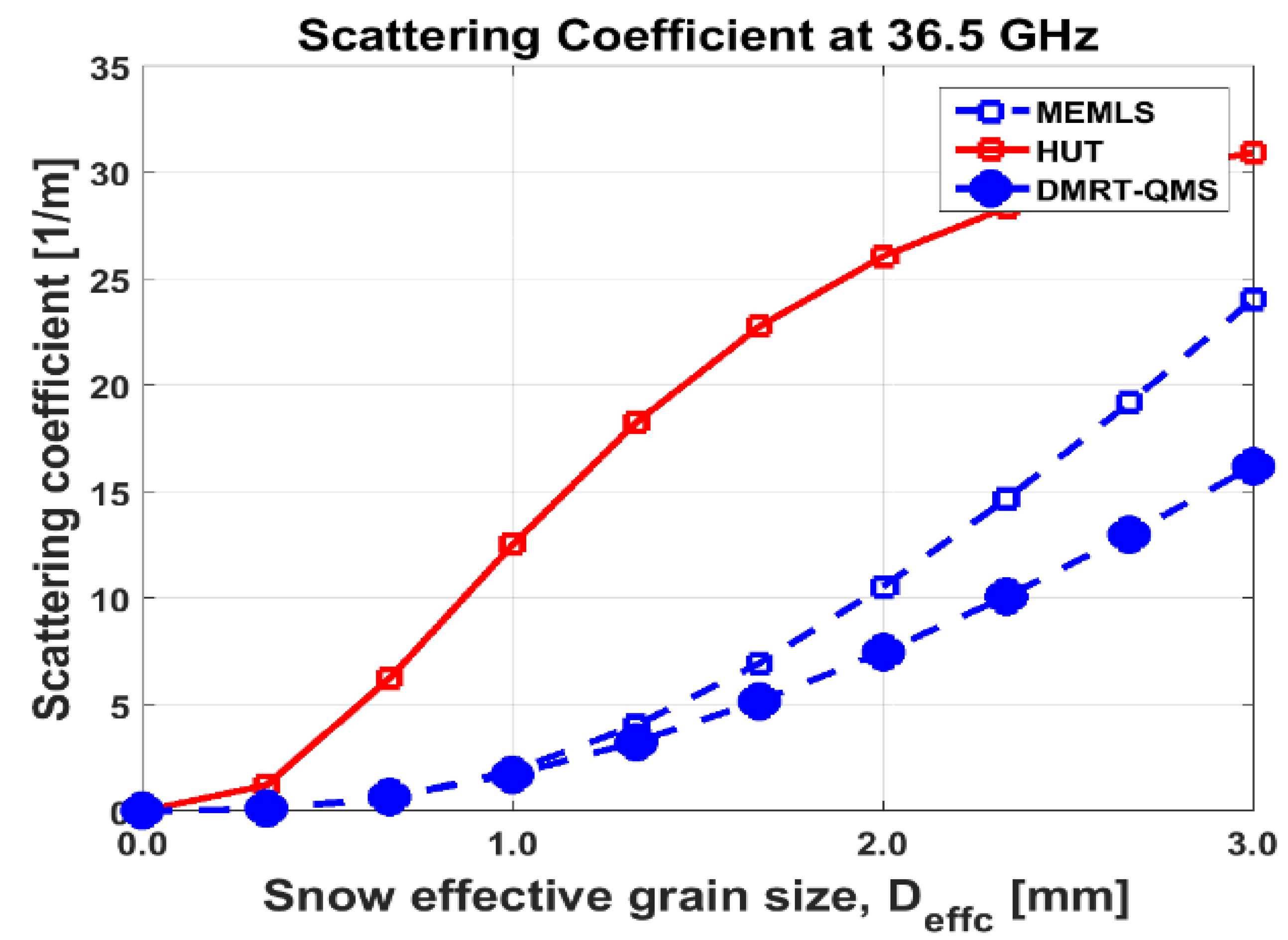


Fig. 4. Variations in scattering coefficient on snow grain size (**evaluated by MEMLS, HUT, and DMRT-QMS with increasing snow density (in case of fixed parameters, snow temperature = 270 K, snow grain correlation length = 0.21 mm, snow water equivalent=0.06 m, density = 50.0~400.0 kg/m^3, ground dielectric constant = 6+1*i* only for HUT, ground temperature = 270 K and the incidence angle = 53.1°).**

- **MEMLS:** backward scattering is dominant. Therefore, the resultant Tb became the lowest among 3 RTMs
- **HUT**: forward scattering is dominant as the snow grain size increases. While the scattering coefficient is the maximum among 3 RTMs, the leading Tb is higher than other 2 RTMs with the large snow grain size.
- **DMRT-QMS**: the scattering coefficient in DMRT-QMS is the lowest among 3 RTM, but the Tb itself behaves in a middle value of other 2 RTMs.

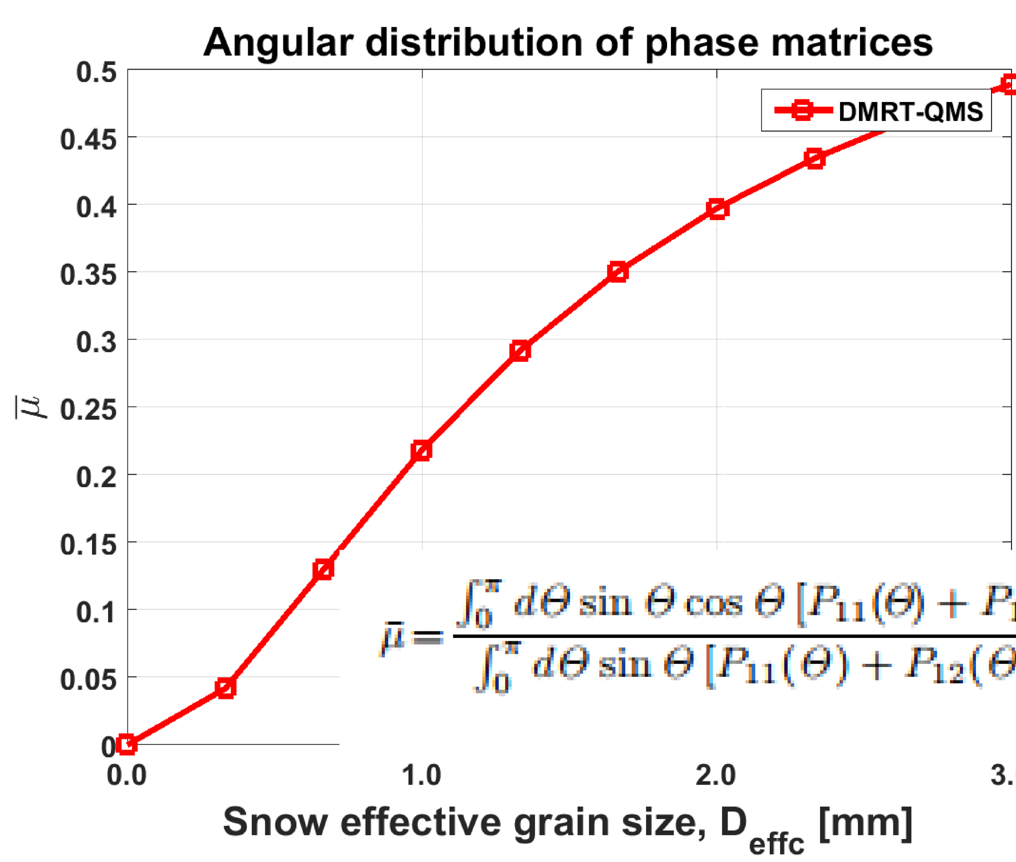


Figure 5. Angular distribution of phase matrices available in DMRT-QMS

$$\bar{\mu} = \frac{\int_0^{\pi} d\Theta \sin\Theta \cos\Theta \,[P_{11}(\Theta) + P_{12}(\Theta) + P_{21}(\Theta) + P_{22}(\Theta)]}{\int_0^{\pi} d\Theta \sin\Theta \,[P_{11}(\Theta) + P_{12}(\Theta) + P_{21}(\Theta) + P_{22}(\Theta)]}. \quad (4)$$

Realistic simulations

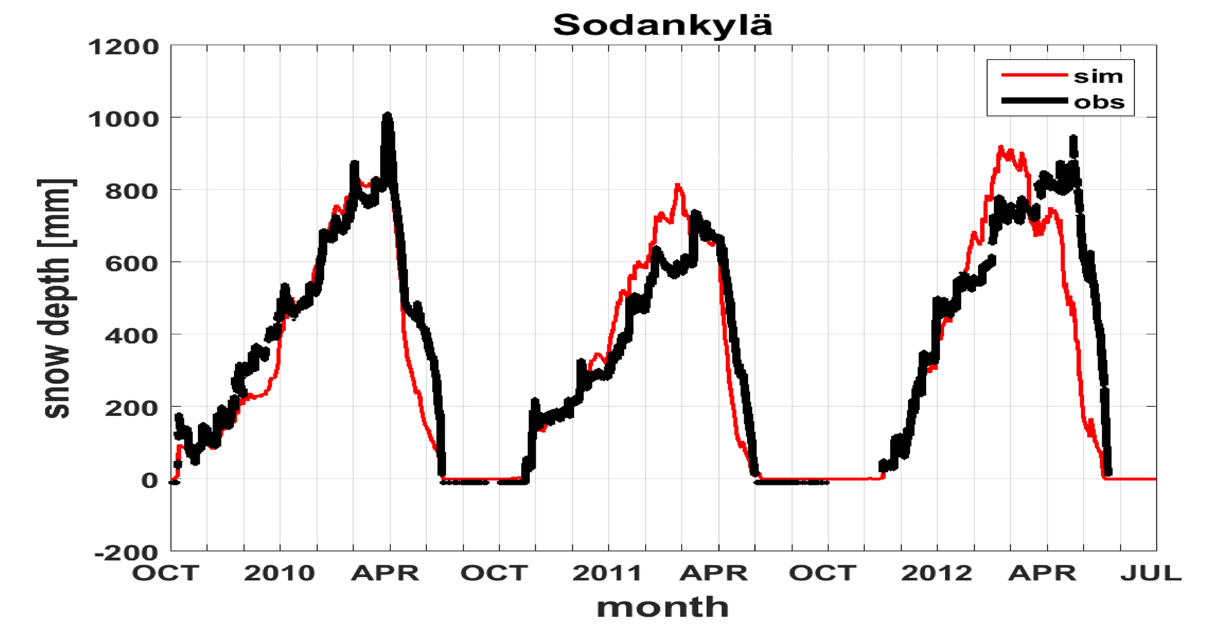


Figure 6. Simulated snow depth and number of layers compared with the observed snow depth from Oct 2009 to Sep 2012 at NoSREx I, II in Sodankylä, Finland.

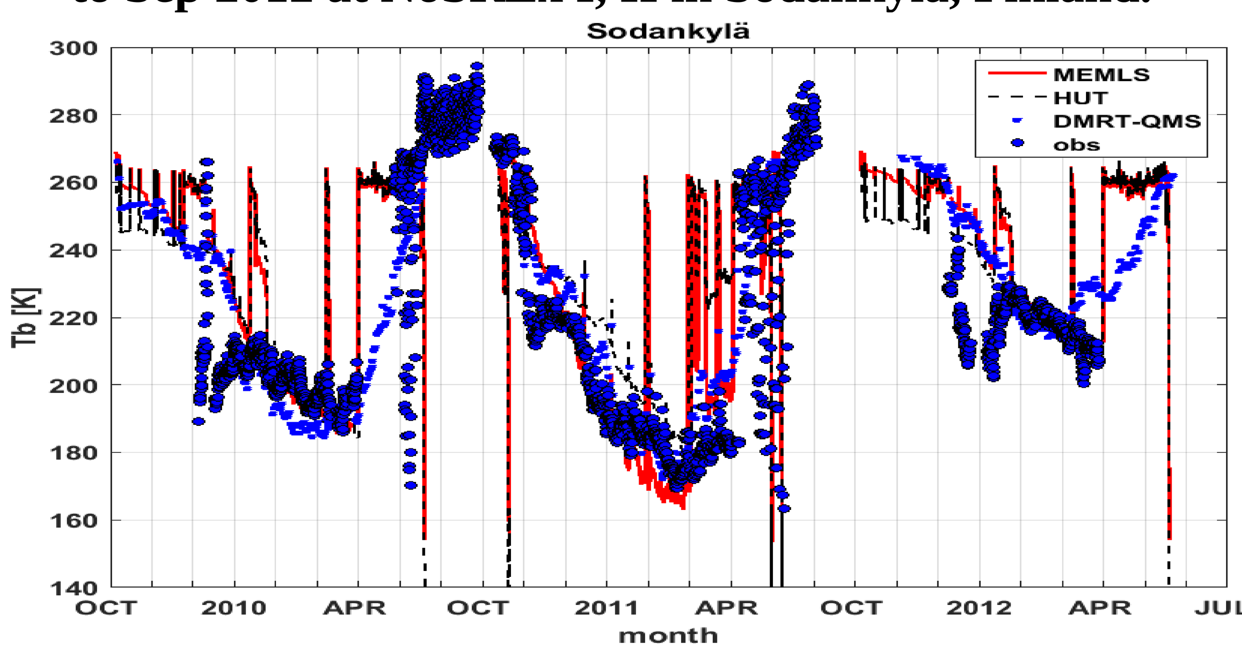


Fig. 7. Simulated Tb at 37.5 GHz from 3 RTMs, MEMLS, HUT, and DMRT-QMS, compared against the SODRAD Tb observation.

Summary

- ➢DMRT-QMS has the most sensitive response to the snow correlation length.
- ➢DMRT-QMS has a concave response to the snow density. The eigen vector calculation needs to be reviewed to resolve this issue.
- ➢The application of NoSREx by the coupled model shows a robustness of the performances of snow physics and microwave brightness temperature with all 3 RTMs.

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Reference & Acknowledgements

KANG, D., AND BARROS, A. P., "OBSERVING SYSTEM SIMULATION OF SNOW MICROWAVE EMISSIONS OVER DATA SPARSE RETIONS, IEEE TGRS

NoSREx I II datasets are provided by European Space Agency, 2011 Juha Lemmetyinen and et al. Finish Meteorological Institute