THE DMRT-ML MODEL: NUMERICAL SIMULATIONS OF THE MICROWAVE EMISSION OF SNOWPACKS BASED ON THE DENSE MEDIA RADIATIVE TRANSFER THEORY

Ghislain Picard[1], Ludovic Brucker[2], Alexandre Roy[3] , Florent Dupont[1,3], Michel Fily[1], Alain Royer[3], Nicolas Champollion[1], Samuel Morin[4]

[1] Univ. Grenoble Alpes / CNRS, Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE), UMR5183, 38041 Grenoble, France
[2] NASA Goddard Space Flight Center, Cryospheric Sciences Laboratory, code 615, Greenbelt, MD USA
[3] Centre d'applications et de recherches en télédétection (CARTEL), Université de Sherbrooke, Sherbrooke, Canada
[4] Météo-France – CNRS, CNRM-GAME, Centre d'Etudes de la Neige, Grenoble, France

1. INTRODUCTION

Microwave radiometer observations have been used to retrieve snow depth and snow water equivalent on both land and sea ice, snow accumulation on ice sheets, melt events, snow temperature, and snow grain size. Modeling the microwave emission from snow and ice physical properties is crucial to improve the quality of these retrievals. It also is crucial to improve our understanding of the radiative transfer processes within the snow cover, and the snow properties most relevant in microwave remote sensing. Our objective is to present a recent microwave emission model and its validation. The model is named DMRT-ML (DMRT Multi-Layer), and is available at http://lgge.osug.fr/~picard/dmrtml/.

2. THE DMRT-ML MODEL

DMRT-ML is a physically-based model to compute the thermal microwave emission of a given snowpack for passive microwave remote sensing applications. The model is based on the Dense Media Radiative Transfer Theory (DMRT; Tsang et al., 2000, 2007) for the computation of snow scattering and absorption properties. The radiative transfer equation is accurately solved using the DIscrete Ordinate Radiative Transfer Method (DISORT). The DMRT-ML model was initially designed for semi-infinite snowpacks as found in inner Antarctica (Brucker et al., 2010). Recently, it was extended and applied to Arctic and sub-Arctic seasonal snowpacks on tundra and ice-cap environments (Roy et al., 2013; Dupont et al., 2014).

The snowpack is described as a stack of horizontal snow layers and an optional underlying interface representing either the soil or the ice. The atmospheric down-welling contribution can be optionally taken into account. DMRT-ML is designed to work for most snow-covered surfaces, and can account for both dry and wet snowpack conditions over soil (e.g. Alpine or Arctic seasonal snow) and over ice (e.g. on ice sheet or lake).

3. MODEL VALIDATIONS

The DMRT-ML model was validated against satellite observations at Dome C, East Antarctica, using in-situ snow grain size, density and temperature profile measurements (Brucker et al., 2011). It was also validated for sub-Arctic seasonal snowpacks (Roy et al., 2013), using a set of 20 detailed snowpit measurements and surface-based microwave radiometer observations. In addition, the model was applied to snowpacks overlying ice, as found on the Canadian Barnes ice cap and on the ablation areas of ice sheets. Accounting for the ice properties (bubble size and density) appeared to be important to reconcile the model simulations and the ground-based radiometer observations (Dupont et al., 2014).

4. CONCLUSION

We will present the DMRT-ML model, which accurately simulates snow brightness temperature over a wide range of cryospheric environments (e.g. seasonal snow, ice sheet, superimposed ice). Such results are of particular interest for the assimilation of satellite passive microwave data in snow models and for improving simulations of snow properties. The model can take input from a detailed snowpack model such as Crocus, or SNOWPACK. It is entirely written in Fortran90 which makes its integration in numerical weather prediction land surface assimilation schemes as seamless as possible.

5. REFERENCES

Brucker, L., Picard, G., and Fily, M.: Snow grain size profiles deduced from microwave snow emissivities in Antarctica, J. Glaciol., 56, 514–526, doi:10.3189/002214310792447806, 2010.

Brucker, L., Picard, G., Arnaud, L., Barnola, J., Schneebeli, M., Brunjail, H., Lefebvre, E., and Fily, M.: Modeling time series of microwave brightness temperature at Dome C, Antarctica, using vertically resolved snow temperature and microstructure measurements, J. Glaciol., 57, 171–182, doi:10.3189/002214311795306736, 2011.

Dupont, F., Picard, G., Royer, A., Fily, M., Roy, A., and Champollion, N.: Modeling the microwave emission of ice; Applications to the Cap Prud'Homme Blue Ice Area in Antarctica and to the Barnes Ice Cap superimposed ice in Arctic, IEEE Trans. Geo. Remote Sens., in press, 2014.

Picard, G., Brucker, L., Roy, A., Dupont, F., Fily, M., Royer, A., and Harlow, C.: Simulation of the microwave emission of multi-layered snowpacks using the Dense Media Radiative transfer theory: the DMRT-ML model, Geosci. Model Dev., 6, 1061-1078, doi:10.5194/gmd-6-1061-2013, 2013.

Roy, A., Picard, G., Royer, A., Montpetit, B., Dupont, F., Langlois, A., Derksen, C., Champollion, N., 2013. Brightness temperature simulations of the Canadian seasonal snowpack driven by measurements of the snow specific surface area. IEEE Trans. Geo. Remote Sens., 51 (9) : 4692-4704. DOI: 10.1109/TGRS.2012.2235842.

Tsang, L., Chen, C. T., Chang, A. T. C., Guo, J., and Ding, K. H.: Dense Media Radiative Transfer Theory Based on Quasicrystalline Approximation with Application to Passive Microwave Remote Sensing of Snow, Radio Sci., 35, 741–49, 2000.

Tsang, L., Pan, J., Liang, D., Li, Z. X., Cline, D., and Tan, Y. H.: Modeling active microwave remote sensing of snow using dense media radiative transfer (DMRT) theory with multiple scattering effects, IEEE Trans. Geo. Remote Sens., 45, 990–1004, 2007.