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EXPERIMENTAL AND MODELING STUDIES OF MICROWAVE REMOTE SENSING OF SEASONAL SNOW

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An extensive set of microwave radiometer measurements of snow cover was made at Kirkkonummi, southern Finland, over the whole snow season from January to April in 1985. The radiometer data include brightness temperatures at 1 GHz, 16.5 GHz and 37 GHz, vertical and horizontal polarization. Continuous recording was done at an incidence angle of 50 degrees off nadir. Daily data collection was conducted as a function of incidence angle with 10-degree steps from 10 degrees to 60 degrees. Aluminium sheets covered the ground near the observation tower, thus providing an opportunity to observe microwave emission from snow only (eliminating ground contribution) for small incidence angles.

Detailed ancillary data for snow were collected including water equivalent, depth, temperature, layering, and surface roughness and grain size (photographs). A special effort was made to obtain information on the extinction and dielectric properties of snow vs. depth. Numerous homogeneous snow samples were taken from various depths in the snow pack and measured using free-space transmission systems resulting in dielectric and extinction properties of snow. The free-space systems were operated at 12 GHz (providing snow dielectric properties) and 35 GHz (extinction values) and, occasionally, at 18 GHz (dielectric properties). The results were further transformed into extinction coefficients (dry snow) and wetness values (wet snow), thus providing layered information on the whole snow pack. Equations from [1] were used for computing wetness from the complex dielectric constant.

Two emission models were planned to be used for comparison of experimental data against theoretical values: the TKK model and the MEMLS model. Both models can be used between 5 and 90 GHz. The TKK model [2] is a single-layer radiative transfer model, which assumes scattering being concentrated mostly in the forward direction and includes experimental characterization of the snow extinction coefficient [3]. The Microwave Emission Model of Layered Snowpacks (MEMLS) [4] [5] is a radiative multiple-scattering model, based on experimental characterization of snow over a broad frequency range. In this model snow is assumed to consist of numerous horizontal layers with each layer characterized electrically and physically. The TKK model employs mean snow grain size (measured in the campaign), whereas the MEMLS model employs snow correlation length; this handicap has been reported in [6] .

Our IGARSS'08 presentation [7] summarized the arrangements for and technical details of the campaign and an overview of results from radiometer measurements. Especially, the measured brightness temperatures at 16.5 and 37 GHz were compared against those obtained from the TKK snow emission model [2] for three cases using experimental average snow pack density values: (1) early and mid-winter dry snow (January through mid-March, snow depth 7 to 39 cm), incidence angle 30 to 60 deg (10 deg steps), (2) refrozen dry snow (late March through mid-April, depth 15 to 30 cm) on top of wet snow (depth 5-17 cm), incidence angle 30 to 60 deg, and (3) dry snow (January through mid-March, depth 7 to 39 cm) on top of aluminium sheets, incidence angle 10 deg. The comparison was done by optimizing the value of the snow grain size to best fit

experimental brightness temperatures. For Case 1 the optimized snow grain size values were fairly stable and realistic at 37 GHz and more variable and slightly too high at 16.5 GHz. For Case 2 mostly realistic values were obtained again at 37 GHz; however, there was little experimental data available for 16.5 GHz. For Case 3 the model somewhat underestimated the increase of the brightness temperature vs. time. Our IGARSS'08 presentation [7] included no comparisons using the MEMLS model.

This paper presents a comparison of selected experimental values against the MEMLS model output including cases with (1) substantial dry snow layering and (2) wet/dry snow layers on top of each other. Experimental data on the physical and extinction/dielectric characteristics vs. snow depth for each case are used. Additionally, time series from a detailed 24-hr monitoring effort of a strong melt/freeze cycle are compared against the MEMLS model. During the 24-hr period the snow pack included (top layer mentioned first): dry/wet snow, (2) wet/dry/wet snow, (3) dry/wet/dry/wet snow, and (4) dry/wet snow. The feasibility of retrieval of snow parameters from microwave radiometer data in the case of partially wet snow pack is discussed; this topic is important for the development of realistic algorithms for retrieval of snow water equivalent from satellite radiometer data especially for areas where no snow/air temperature and snow wetness reference data are available.

Our preliminary results from the comparisons suggest that the MEMLS model produces satisfactory agreement between theoretical and experimental results for layered snow packs. Work is in progress in order to make further comparisons.

[1] M. Hallikainen, F.T. Ulaby, M. Abdelrazik: Dielectric properties of snow in the 3 to 37 GHz range, IEEE Trans Antennas and Propagation, vol. AP-34, no. 11, pp. 1329-1340, November 1986.

[2] J. Pulliainen, J. Grandell, M. Hallikainen, HUT snow emission model and its applicability to snow water equivalent retrieval, IEEE Trans Geosci Remote Sensing, vol. 37, no. 3, pp. 1378-1390, 1999.

[3] M. Hallikainen, F.T. Ulaby, T.E. Van Deventer, Extinction behavior of dry snow in the 18 to 90 GHz range, IEEE Trans Geosci Remote Sensing, vol. GE-25, no. 6, pp. 737-745, November 1987.

[4] A. Wiesmann and C. Mätzler, Microwave emission model of layered snowpacks, Remote Sensing of the Environment, vol. 70, no. 3, pp. 307-316, 1999.

[5] C. Mätzler and A. Wiesmann, Extension of the Microwave Emission Model of Layered Snowpacks to coarse-grained snow, Remote Sensing of the Environment, vol. 70, no. 3, pp. 317-325, 1999.

[6] M. Tedesco, E. Kim, Intercomparison of electromagnetic models for passive microwave remote sensing of snow, IEEE Trans Geosci Remote Sensing, vol. 44, no. 10, pp. 2654-2666, 2006.

[7] M. Hallikainen, P. Lahtinen, T. Piepponen, A. Schäfer, Results from microwave campaign of seasonal snow and comparison with emission models. Proceedings of IEEE 2008 International Geoscience and Remote Sensing Symposium (IGARSS'08), Boston, MA, USA, July 7-11, 2008.