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Retrieval of Snow Depth in Boreal Forests using Microwave Radiometer Data

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A new technique to retrieve snow depth (SD) information from time series of passive microwave radiometers is presented. The technique is based on Bayesian (statistical) inversion of an analytical brightness temperature model, and it enables the assimilation of remote sensing data to other information, such as ground-based snow depth measurements. Both the data assimilation and stand-alone SD retrieval are demonstrated for the boreal forests and sub-arctic regions of Eurasia using SSM/I observations from 22 test stations around Russia, covering a time period from November 1993 to beginning of April 1994. The results indicate that the inversion approach yield a performance higher than that of empirical algorithms, especially when large areas and long time spans are considered. However, regional and temporal biases remain a problem. This handicap can be eliminated by the use of reference information available from a sparse weather station network. The estimates obtained by the new algorithm are compared with the results of commonly used empirical (regression) algorithms.

The SWE/SD retrieval algorithm employed is based on the semi-empirical HUT snow emission model. It is a constrained Bayesian optimization procedure that estimates both the SWE and the effective snow grain size. Temporal variations in SWE estimates are limited by restricting the day-to-day changes of estimates. The inversion approach also enables the assimilation of remote sensing data with other sources of information. The algorithm testing is carried out as an automatic procedure. Only one parameter in the inversion procedure is adjusted regionally, the *a priori* mean value of the effective

grain size (the mean value around which the estimated grain size varies).

The test results indicate a superior performance of the new algorithm when compared with empirical algorithms. For Canada, the algorithm was tested using 216 discrete SWE observations from 22 stations (snow courses) as reference. The RMSE of retrieval results was ranging from 25 to 36 mm as all data from November -93 to April -94 were included in analyses. In case of Canada, the successful employment of the algorithm required that the *a priori* mean grain size was slightly different for three geographical regions (Quebec, Ontario/Manitoba and North West Canada). As the algorithm was tested for a 51.000 km^2-sized river basin in Finland, the RMSE of yearly estimation results was ranging from 17 to 46 mm as the *a priori* mean grain size was kept constant. In case of Russia, the SD estimation results showed a RMSE range from 12 cm to 18 cm as the algorithm was tested for four regions (Europe, Western, Central and Eastern Siberia) applying a constant *a priori* mean grain size. The number of Russian test stations was 11 and the total number of observations from the time period of November –93 to April –94 was 1689.

The accuracy of current empirical algorithms was found to be quite poor (also when testing restricted to cold mid-winter conditions). These algorithms require regional and seasonal tuning of empirical parameters in order to produce satisfactory estimates. The new adaptive algorithm tested here improves this deficiency by reducing the number of regionally tuned parameters into one, which is the *a priori* mean effective snow grain size