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Parameterization of snowpack grain size for global satellite microwave estimates of snow depth

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Abstract- For accurate estimation of global snow depth or snow water equivalent on the Earth's surface using passive microwave instruments, knowledge of the snow pack's physical properties is important. It is known that the bulk snow grain size distribution exerts an important control over the microwave response from snow between 3mm and 300 mm wavelengths. In the absence of high quality snowpack data at a global scale, we show how the grain size distribution can be estimated using a general empirical model of grain growth. This information is used to parameterize a dense media radiative transfer model (DMRT) to estimate the radiometric response from a snow pack as a function of changing grain size distribution. The DMRT equations are based on the quasi-crystalline approximation (QCA) for densely distributed moderate sized particles in a medium such as a snow pack. The model snow depth estimates from the DMRT are used to calibrate a Special Sensor Microwave Imager (SSM/I) snow depth retrieval algorithm which is based on the brightness temperature difference between 19 and 37 GHz with the SWE. The method is tested using meteorological data from the WMO global network. Results show that using the DMRT model coupled with a grain size model improved estimates of snow depth are obtained.

I. Introduction

Remote sensing has been used to monitor continental-scale snow cover area in the northern hemisphere for almost 25 years [1]. With the improvement in satellite microwave instrumentation, regional and local scales can now be mapped effectively. However, passive microwave (PM) retrieval methods of snow water equivalent (SWE) and/or snow depth (SD) are less mature with large errors often resulting from retrievals at the global scale. One of the key reasons for these large errors is because instantaneous parameterization of snowpack properties at the global scale is not straightforward. Studies have shown that snowpack models can be used successfully to quantify changes in propereties of the pack (e.g. average grain size) [2]. These models often require intensive-scale observations of meteorological surface conditions that are usually not available in a high quality globally distributed form. Thus, to overcome this problem, we implement a simple statistical model of snow pack grain growth and couple it to a microwave emission model and passive microwave observations to estimate snow depth.

III. Testing of the Model and Conclusions

The model is tested on snow depth time series (1992-1993, 1993-1994 and 1994-1995) for two locations, one in north Sweden (67° 13' N, 23° 24' E) and the other in north America (56° 39' N, 111° 13' W). The original algorithm of

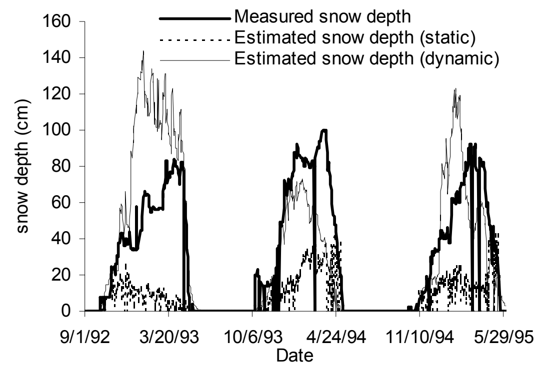

Fig. 2 Comparison of measured snow depth with estimated snow depth from the static and dynamic algorithms for north Sweden.

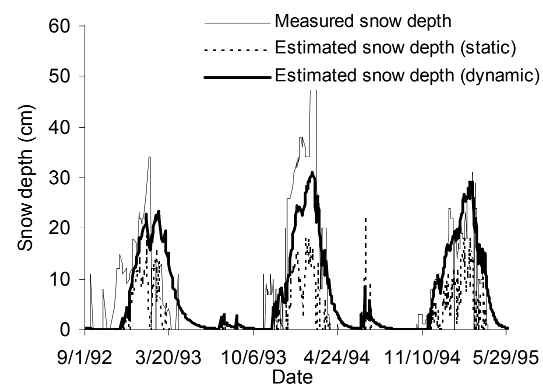

Fig. 3 Comparison of measured snow depth with estimated snow depth from the static and dynamic algorithms for north America.

[1] is compared with the newer algorithm and the results are shown in Figs. 2 and 3 for Sweden and north America respectively. Generally, the original static algorithm underestimates snow depth systematically for both sites. For the north Sweden site, however, there is overestimation in the 1992-1993 winter season but for the other two years the results are good. Overall, the correlation between the static algorithm and measured snow depth over the accumulated three winter seasons for north Sweden is 0.61 and for the dynamic model it is 0.77. For the north American site, the correlation for the static model is 0.71 while for the dynamic model it is 0.87. Thus, the dynamic model shows improvement over the original static algorithm.