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Determining Snow Cloud Characteristics by Both Active and Passive Microwave Satellite Observations

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The goals of the this study are two-fold: (1) understanding the structure and microphysical characteristics of snow-producing clouds using multiple years of satellite data (primarily CloudSat radar and Aqua AMSR-E radiometer data), and (2) developing snowfall detection and retrieval algorithms for high-frequency microwave satellite observations using the knowledge on snow clouds derived in step (1). While its spatial coverage is very limited, the cloud radar on CloudSat provides the opportunity to study the vertical structure of snow-producing clouds. On the other hand, passive microwave observations by AMSR-E can be used to derive liquid water amount in snow clouds. In our data analysis, we first classified snow clouds into several different types according to their horizontal and vertical extents. Then, their frequency of occurrence, their abundance of cloud liquid water, their contribution to surface snowfall and their typical snowfall vertical profiles are studied. Because currently there is no suitable liquid water retrievals for the cold environment (standard AMSR-E algorithm has been developed for environment warm than 0°C), we have developed a new algorithm that specifically applicable to cold temperatures. This algorithm takes the advantage of CloudSat-detected clear-sky area and uses actual AMSR-E observations at the clear-sky area to dynamically calibrate no-cloud background radiation. It also determines the cloud height (and therefore cloud temperature) using CloudSat observations. Results based on this algorithm showed that liquid water in snow clouds is abundant, occasionally several hundreds of g m-2, depending on cloud types. An interesting finding is that cloud liquid water is abundant (100 $\sim$ 200 g m-2) in shallow, isolated snow clouds, while deep snow clouds associated with low pressure systems are relatively "dry" (low liquid water path) although they produce heavy snowfall. Radiative transfer simulation indicated that from time to time this high liquid water amount masks scattering signature by snowflakes, and very frequently, the liquid water emission signature becomes greater than the ice scattering signature. Therefore, liquid water in snow clouds is a very important factor needed to be considered in retrieval algorithms.

For passive microwave snowfall retrieval, we take different approaches for snowfall over land and over ocean. Over land, using CloudSat radar data as truth, we are studying the possibility to detect snowfall from high frequency microwave (AMSU-B or MHS) observations. One of the ideas we are testing is: first representing the covariance of the multichannel brightness temperatures by EOFs and assessing the probability of snowfall in EOF space. Our preliminary results showed that high snowfall probability concentrates at a certain area in two-EOF (first and second EOFs) space, implying that observations fallen in this area are most likely snowing data. For snowfall retrieval over ocean, we are developing a snow-cloud-radiation database, which can be used to retrieve snowfall in a Bayesian framework. To build the database, we obtain atmospheric temperature and moisture information from numerical weather prediction model reanalysis data, snow and ice water profiles from CloudSat radar data and cloud liquid water (path) information from retrievals based on AMSR-E data. These geophysical parameters are then inputted into a radiative transfer model to compute upwelling brightness temperatures. In the radiative transfer model, the single-scattering properties of ice/snow particles are computed using Discrete Dipole Approximation.