Development of Snowfall Retrieval Algorithm by Combining Measurements from CloudSat, AQUA and NOAA Satellites for the Korean Peninsula

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Abstract: Cloudsat satellite data is sensitive to snowfall and collected during each month beginning with Dec 2007 and ending Feb 2008. In this study, we attempt to develop a snowfall retrieval algorithm using a combination of radiometer and cloud radar data. We trained data from the relation between brightness temperature measurements from NOAA’s Advanced Microwave Sounder Unit-B (AMSU-B) and the radar reflectivity of the 2B-GEOPROF product from W-band (94 GHz) cloud radar onboard Cloudsat and applied it to the Korea peninsula. We use a principal components analysis to quantify the variations that are the result of the radiometric signatures of snowfall from those of the surface. Finally, we quantify the correlation between the higher principal component (orthogonal to surface variability) of the microwave radiances and the precipitation-sensitive CloudSat radar reflectivities. This work summarizes the results of applying this approach to observations over the East Sea during Feb. 2008. The retrieved data show reasonable estimation for snowfall rate compared with Cloudsat vertical image.

Key Words: Snowfall, CloudSat, Advanced Microwave Sounding Unit (AMSU), Microwave Humidity Sounder (MHS).

1. Introduction

Snowfall in the Korean region is a very important component in the climate system that plays a key role in the hydrological cycle. To monitor this snowfall, snowfall gauges and radar on the ground have been used, but these monitoring systems are difficult to implement and are sparsely distributed.

A satellite-based monitoring system is more effective for measuring snowfall over the Korean region. Passive microwave imaging radiometers operating at frequencies in which the atmosphere is relatively transparent have been available since 1978. Measurements onboard the EOS-Aqua satellite provide information about environmental parameters such as the areal extent of snow cover. Unfortunately,
it is quite difficult for an AMSR-E sensor to measure the snowfall rates at a low frequency on the land area. In addition, there is little to be gained by incorporating passive visible or infrared measurements of Korean regions, since their effectiveness is limited to distinguishing clouds from bright surface ice during daytime viewing conditions. They would also introduce much ambiguity in many cases, such as when there are ice clouds over snow and sea ice, let alone in night time conditions. In recent years, researchers have shown an increased interest in developing an accurate snowfall rate from passive microwave measurements between 89-190 GHz from a NOAA AMSU-B sensor. The operational microwave radiometric sounders with “opaque” channels at frequencies in which the atmosphere absorbs radiation (such as the 183-GHz water vapor rotational absorption line) include the Microwave Humidity Sounder (MHS) and its predecessor, the Advanced Microwave Sounding Unit (AMSU-B), onboard the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting platforms. The fact that the atmosphere obscures emissions from the underlying surface at these frequencies makes it plausible to try to use these channels to measure snow as it is falling in the atmosphere to use these channels to measure snow as it is falling in the atmosphere (Chen and Staeline, 2003; Jee and Lee, 2010; Kim et al., 2008; Kim and Park, 2002; Kongili et al., 2003; Liu, 2004; Noh et al, 2006; Shofronick-Jackson et al., 2004).

The 94-GHz CloudSat Cloud profiling Radar (CPR) was launched in 2006 (Stephens et al, 2002). It can offer the first opportunity to date to provide systematic profiles of precipitation over Korean regions. The only polar-orbiting instrument that is directly sensitive to snowfall, the CPR has been collecting data over the Korean peninsula since June 2006. Its vertical profiles of radar reflectivity permit the systematic detection of any snowfall occurring within the instrument’s field of view. Because the CPR has no scanning capability, it can only capture snow events that are directly beneath the track of CloudSat and this severely limits its sampling utility. This is why it is highly desirable to use direct CPR estimates to train the opaque-channel AMSU-B and MHS instruments in order to make estimates of snowfall within their wide 2300-km swaths. A priori, a passive radiometer alone is somewhat less than ideal for the estimation and monitoring of snowfall because its channels are only indirectly sensitive to the vertical distribution of any precipitation within its field of view. However, recent studies have confirmed that the measurements of these radiometers can indeed be used to detect such precipitation (Kongili et al., 2003) and that their opaque and scattering channels are sensitive to falling snow (Bennartz and Bauer, 2003).

One can therefore expect that the best results would be obtained by selectively combining the measurements of all the passive channels, using the radar measurements to determine the most judicious combination, and to then estimate the column of condensed water, if not its detailed vertical profile, and to quantify the uncertainty of the estimates. The number and wide swath of the radiometers would then provide the sampling capability that CPR lacks. Our approach is to try to achieve this goal by correlating observed radiances with nearly-simultaneous radar profiles measured by the CloudSat radar.

2. Datasets and Procedures

The highest 3 channels of the AMSU-B sensor on board the NOAA satellite constitute the strongly water vapor absorption line. This is the operational humidity sounder on the NOAA-15, 16 and 17 spacecraft. Beginning with the launch of the NOAA-