P2.8 IDENTIFICATION AND RETRIEVAL OF SNOWFALL FROM THE ADVANCED MICROWAVE SOUNDING UNIT (AMSU)

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1. INTRODUCTION

In mid-to high latitudes, a substantial portion of precipitation occurs in the form of snow. Thus, snowfall retrievals are extremely important for obtaining accurate estimates of precipitation on a global scale. Additionally, these retrievals on both local and global scales have important implications for winter weather forecasting and monitoring and climate applications.

The retrieval of global precipitation from microwave remote sensing satellites has almost exclusively been limited to rainfall. A few studies have dealt with identification of snowfall over oceans (e.g., Katsumata et al., 2000; Liu and Katsumata, 2002). To our knowledge, the potential for global microwave snowfall retrievals over land has not yet been explored. It is important to emphasize that snowfall retrievals over land represent an enormous challenge, mainly from the presence of snow cover on the ground. However, several recent studies suggest that there is potential in using higher frequency channel measurements for precipitation as well as snowfall identification. Studies using AMSU data by Grody et al. (2000) and Ferraro et al. (2000) showed that the addition of the 150 GHz to the 89 GHz microwave channel greatly improved the ability to detect precipitation above desert and snow-covered surfaces. Using radiative transfer calculations (Liu and Katsumata, 2002) and aircraft measurements in the Japan Sea (Katsumata et al., 2000), it was shown that the brightness temperature decrease at 150 GHz was twice as large as at 89 GHz, and that the 150 GHz channel was superior to the 89 GHz for detecting and retrieving snowfall. A similar finding was reported by Bennartz and Petty, (2001), Liu and Curry (1997), and Ferraro and Grody (2001). Studies by Bauer and Grody (1995), Wang et al. (2001), Staelin et al. (2000) and Ferraro and Grody (2001) have also shown the advantage of using frequencies higher than 150 GHz. These channels may be particularly important to improve the ability of discriminating precipitation from snow cover. Grody (2002) has shown that fresh, finely grained snow can significantly decrease brightness temperatures at 150 GHz, more than the 89 GHz channel.

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This paper introduces a new snowfall retrieval algorithm based on Advanced Microwave Sounding Unit (AMSU) measurements of local winter storms over the US Great Plains using mainly frequencies at 150 GHz and higher and sounding channel measurements near the oxygen band at 52.8 and 53.6 GHz. The greatest advantage of the AMSU instrument is that it contains window (e.g., 23, 31,150 GHz) as well as atmospheric (e.g., 50-60, 176, 180, and 182 GHz) channels. These channels can be used for discriminating the scattering features over land surfaces (especially snow cover) and that of the atmosphere (ice crystals due to precipitation).

The algorithm was dynamically tested over the United States for two storm systems, and was able to retrieve a substantial portion of snowfall over a wide area and under changing weather conditions with great success. Below we describe the datasets, followed by a description of the algorithm and its validation. The next step in this study is to further test, improve the retrieval rate and expand the algorithm to represent other climatologies. The ultimate objective is to develop a global snowfall detection algorithm.

2. DATA AND METHOD OF ANALYSIS

Snowfall observations from two winter storm systems over the US Great Plains were analyzed: The first storm started on November 25 and ended on November 29, 2001 (Fig. 1).

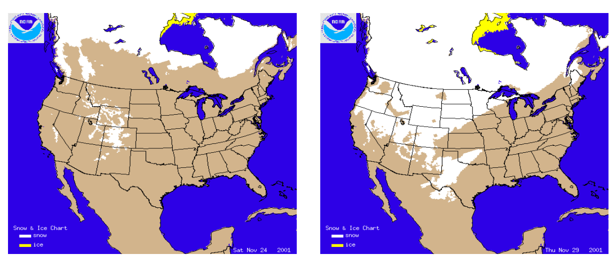

Figure 1. Snow cover before (left panel) and after (right panel) the first storm.

The second storm started on January 29, 2002 and ended on February 1, 2002 (Fig. 2). Both these storms had wide coverage, depositing appreciable amounts of snow over extended areas.

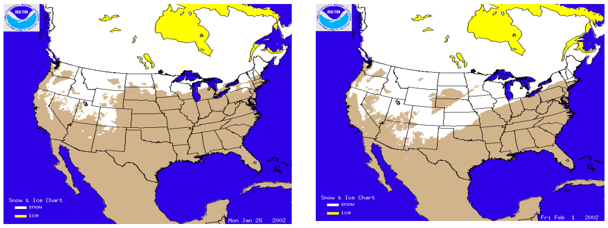

Figure 2. Snow cover before (left panel) and after (right panel) the second storm.

Snowfall versus non-precipitation areas were identified using NEXRAD radar images in combination with the hourly weather reports from the “First Order” stations of the National Weather Service (NWS). These reports contain hourly present weather observations and hourly measurements of equivalent water depth. Non-precipitation areas sampled were with or without snow on the ground, during the storm and after the storm had ended. Snow on the ground (Figs. 1 and 2) was identified using NOAA’ s operationally daily snow cover product (Satellite Services Division). Next, NOAA-15 and -16 AMSU measurements in the 23 to 182 GHz range were matched with the identified events on a pixel-by pixel basis (1/4 degree resolution) as ground-truth. Specifically, the following AMSU channels were included in the analysis: 23, 31, 52.8, 53.6, and 89 GHz (AMSU-A), and 89, 150, 176, and 180 GHz (AMSU-B). The 52.8 and 53.6 GHz channels along with the AMSU beam position were used to compute the limb-corrected brightness temperature (TB) at 53.6 GHz. Only match-ups for areas located between latitudes 30 and 50 north, and longitudes 84 and 104 degrees west were analyzed. As shown on Figures 1 and 2, both storms deposited snow on the ground as far south as Texas, Oklahoma and Nevada.

3. RESULTS AND DISCUSSION

3.1 Data Analysis and Algorithm Development

Figure 3 shows the histogram of brightness temperatures (TB) of 53.6 GHz limb-corrected channel for snowfall and non-snowfall pixels. Note that the number of snowfall pixels is less than the number of non-precipitation ones because the non-precipitating areas were larger than those covered by the storms. Additionally, a number of snow cover conditions were sampled. The 53.6 channel is a sounding channel near the oxygen band, and therefore is surface-blind. Its brightness temperature is an approximate measure of atmospheric air temperature at about 700 hPa. As shown, most of the snowfall events were associated with brightness temperatures between 245 and 250 K. This corresponded to observed near-surface air temperature between –6 and 0 ^{0}C. TB54 below 245 K indicates non-precipitation events with colder air temperature and snow on the ground.

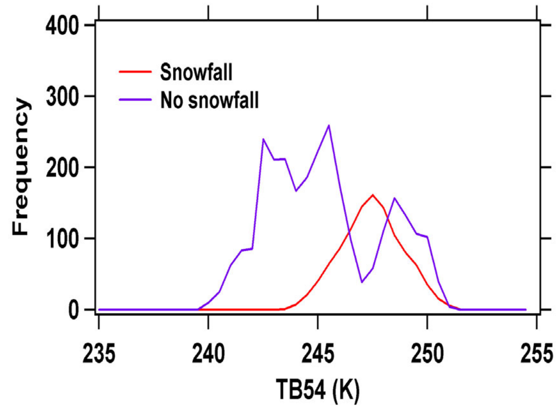

Figure 3. Histograms of limb-corrected TB54 for snowfall and non-snowfall pixels for both storm systems. Non-snowfall pixels were sampled with or without snow on the ground.

Discrimination between snowfall signatures and snow on the ground was achieved by computing the linear combinations: TB176-TB180 (Fig.4) and TB150-TB180 (Fig. 5). As shown, for TB176-TB180 values less than –20 K (Fig. 4) or TB150-TB180 values less than –40 K (Fig.5) no snowfall occurs. Snow cover observations suggested that values lower than the above thresholds were associated with specific weather conditions: snow on the ground with clear, cold weather (TB176-TB180 < -20 K), or freshly-fallen, finely grained snow cover on the ground (TB150-TB180 < -40 K).

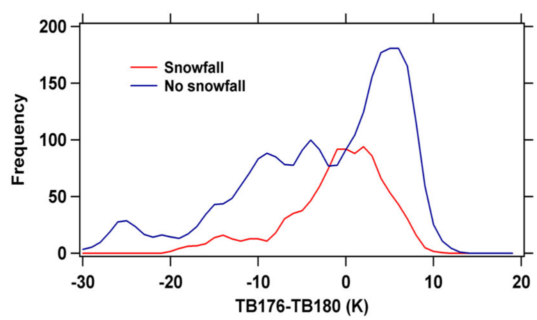

Figure 4. Histograms of TB176-TB180 for snowfall and non-snowfall pixels for both storm systems. Non-snowfall pixels were sampled with or without snow on the ground.

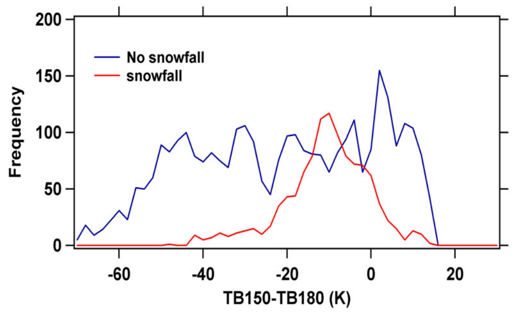

Figure 5. Histograms of TB150-TB180 for snowfall and non-snowfall pixels for both storm systems. Non-snowfall pixels were sampled with or without snow on the ground.

Therefore, linear combinations of TB176-TB180 and TB150-TB180 were employed as filters for removing snow cover signatures under snowfall conditions. Figure 6 is a scatter plot of brightness temperatures (TB) at 176 and 180 GHz after applying these filters, and for TB54 greater or equal to 245 K. Decreased brightness temperatures at 176 and 180 GHz are clearly identified as snowfall. For TB176 and TB180 less than or equal to 255 K, approximately 65 % of snowfall is retrieved with false signatures less than 5%.

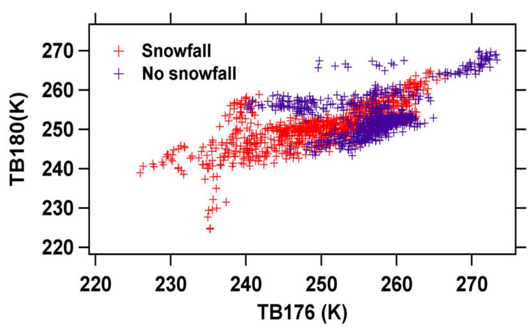

Figure 6. Scatter plot of TB176 and TB180 after the following conditions have been met: TB176-TB180 >= -20, TB150-TB180 >= -40, and TB54 >= 245

3.2 Algorithm Validation

Figure 7 is a flow diagram of the snowfall retrieval algorithm developed on the two case studies described above. In order to retrieve precipitation in the form of snow, the AMSU rain rate algorithm (Weng et al., 2002) is applied when conditions derived from Figures 3-6 are met and the rain rate algorithm reports no rainfall signal. It is important to note that these thresholds (Figs.3-6) empirically

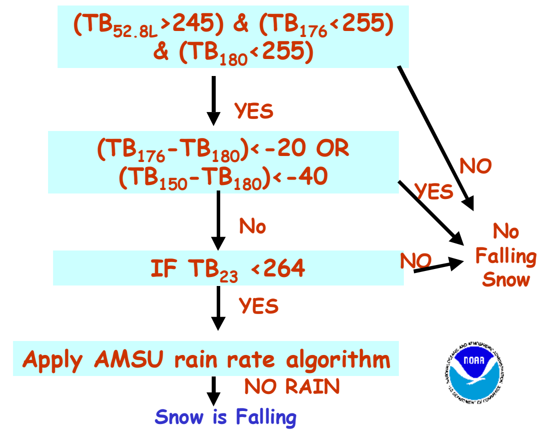

Figure 7. Preliminary snowfall retrieval algorithm

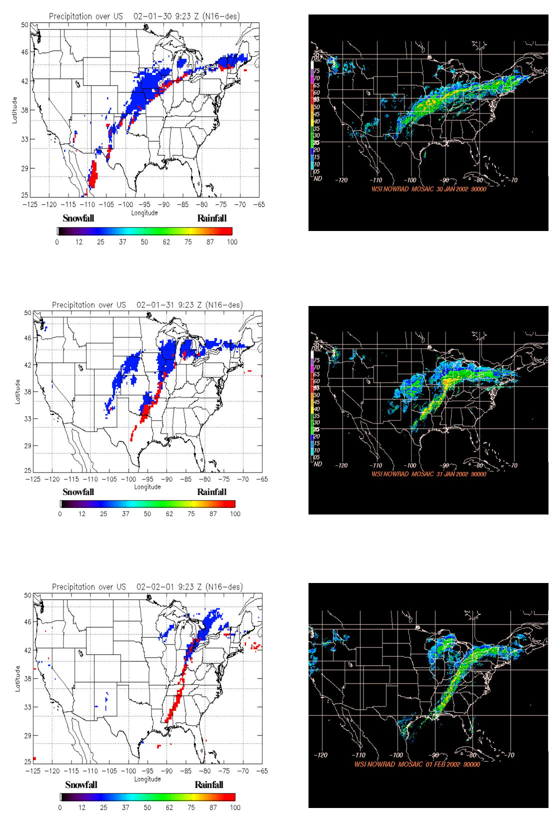

Figure 8. Dynamic retrievals of precipitation over the US in the form of rain and snow (left panels) for three consecutive days (January 30-February 1, 2002) versus measured precipitation by NEXRAD (right panels).

established from snowfall observations capture precipitation in the form of rain as well, so discrimination between rain and snow is necessary. The algorithm also uses 23 GHz channel measurements as an additional check to remove rainfall and possible non-precipitation signals from snowfall.

The robustness of the algorithm was tested by dynamically generating 6-hourly time series of precipitation (rainfall and snowfall) maps over the US territory for each storm system using NOAA-15 and NOAA-16 AMSU measurements, and comparing these maps with precipitation NEXRAD images and with observations recorded by weather stations. Shown in Figure 8 are precipitation retrieval (left panels) and NEXRAD (right panels) maps for three consecutive days, January 30-February 1, 2002. In the retrieval maps (left panels), the red depicts rainfall and the blue depicts snowfall occurrence, whereas NEXRAD colors reflect the precipitation intensity as measured by the instrument. Note that no discrimination between rainfall and snowfall is made by NEXRAD. As shown, most of the precipitation is accurately retrieved. Missing is only some portion of snowfall on January 30, 2002 (middle panel), falling outside the established thresholds. The algorithm captures the complex storm dynamics surprisingly well. Note also the large extent of snow cover deposited on the ground on February 1, 2002 (Fig. 2), which the algorithm is able to filter out. Additionally, the rain-snow transition from South to North is predicted reasonably well.

4. CONCLUSIONS

In this study, a preliminary snowfall retrieval algorithm over land using AMSU was developed and successfully tested with snowfall observations over the US territory. The preliminary algorithm uses mainly higher frequency channel measurements (150, 176 and 180 GHz) in combination with the measurements near 54 GHz. Linear combinations of brightness temperature of the 150, 176 and 180 GHz channels are used as filters to remove false signals resulting from snow on the ground under specific weather conditions. Primary retrieval channels are the 176 and 180 GHz. The 54 GHz channel captured the atmospheric snowfall conditions of two storms, representative of the snow climatology over the US territory and other parts of the globe. Discrimination between rainfall and snowfall was made using the operational NOAA/NESDIS AMSU rain rate product (Weng et al., 2002). The algorithm captured about 65 % of the snowfall with less than 5% misclassification. It also captured complex storm dynamics and rain-snow transition surprisingly well. Next step in our on-going research is to further test, improve the retrieval rate, and expand the algorithm to capture other climatologies. Ultimate objective is to develop a global snowfall retrieval scheme.

5. REFERENCES

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