9.5 SATELLITE OBSERVATIONS OF POLAR PRECIPITATION USING AQUA

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1. ABSTRACT

Polar precipitation (snowfall) has been observed in 13-km resolution multispectral passive microwave imagery from the Advanced Microwave Sounding Unit (AMSU) and Humidity Sounder for Brazil (HSB) aboard the Aqua satellite. For example, on 20 July 2002, Aqua observed at ~100-minute intervals a precipitation event approximately 200 × 1000 km in size moving from near the North Pole toward northern Canada with features moving as fast as 100 km/h. Several smaller, rapidly moving precipitation events have also been observed between June and September. Sensors similar to AMSU/HSB, i.e. AMSU-A and AMSU-B, are currently operating on the NOAA-15, NOAA-16, and NOAA-17 satellites. Each of these four polar-orbiting satellites repeatedly observes suitably located polar precipitation events at intervals of ~100 minutes using sensors that image the earth at 19-20 frequencies between 23 and 191 GHz. The polar precipitation images are produced by an algorithm developed for mid-latitude regions (Staelin and Chen, 2000; Chen and Staelin, 2003); it utilizes microwave channels in the opaque oxygen and water vapor absorption bands near 54 and 183 GHz, respectively. Because these bands are opaque near the surface, scattering of cold cosmic radiation by large ice particles aloft has a unique signature related to particle size and indirectly related to surface precipitation rate. This signature is more stable for convective precipitation than for stratiform events.

2. INTRODUCTION

The Aqua satellite was launched on May 4, 2002, and has been collecting information that will help in the study of the earth's water cycle. The Advanced Microwave Sounding Unit (AMSU) and Humidity Sounder for Brazil (HSB) are two of the instruments aboard Aqua. Together, they measure thermal radiation at 19 frequency bands, most of which are near oxygen and water vapor resonant frequencies. These measurements are useful for estimating precipitation rate as well as atmospheric temperature and humidity profiles. The 19 channels aboard Aqua AMSU/HSB are also on AMSU-A and AMSU-B of the NOAA-15, NOAA-16, and NOAA-17 satellites.

3. ESTIMATING PRECIPITATION RATE USING MICROWAVE CHANNELS

Some of the most important degrees of freedom involved in precipitation estimation include the water vapor profile, temperature profile, cloud-top altitude, and particle size distribution. The algorithm developed by Chen and Staelin involves feeding AMSU/HSB-derived information about these degrees of freedom into a neural network trained using data collected over the eastern U.S. by the ground-based NEXRAD radar system (Staelin and Chen, 2000; Chen and Staelin, 2003). This algorithm has also detected mid-latitude snow (Chen and Staelin, Jan. 2002, June 2002, and 2003). Skofronick-Jackson et al. (2002) also have demonstrated that Aqua HSB data is useful for detecting snow.

4. EXAMPLES OF POLAR PRECIPITATION

Fig. 1 shows relative precipitation rate estimates for four consecutive observations inside the Arctic Circle at ~100-minute intervals on July 20, 2002. The four images in this figure show the evolution of a precipitation system about 200 km wide and 1000 km long with features moving as fast as 100 km/h. Fig. 2 shows similar images for two storms on July 4-5, 2000. In 5 hours, the storm beginning near 74° N, 150° W moved approximately 450 km, and the storm beginning near 73° N, 170° W moved approximately 350 km.

These figures suggest that these precipitation rate estimates are not likely to have resulted from surface variations because such rapid morphological changes in surface features are unlikely.

Additional evidence that these images reveal precipitation can be seen in radiometric data from specific channels. For example, the 52.8-GHz brightness temperature image exhibits perturbations that cannot be the result of surface

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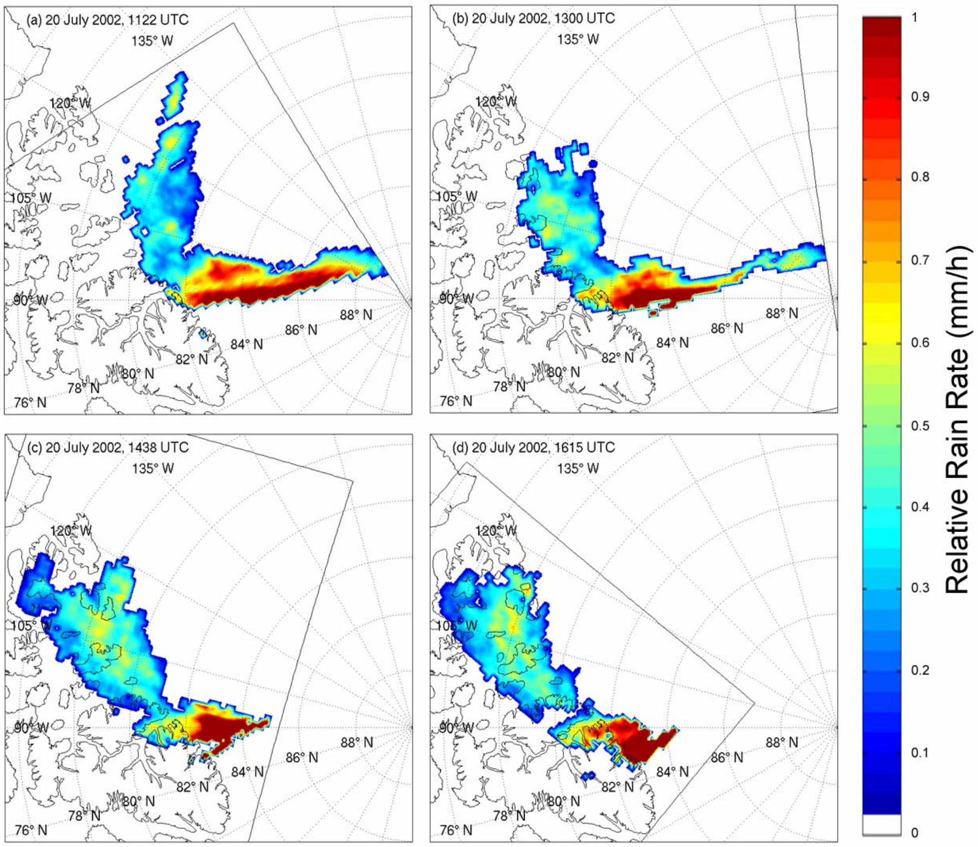

Figure 1. Arctic precipitation observed by Aqua AMSU/HSB on July 20, 2002

features and that suggest convective activity within the cores of some storms. Finally, numerical weather predictions of precipitation rate using the MM5 model and based on ECMWF initializations (Bai and Bromwich, personal communication, 2003) exhibited excellent morphological agreement with these microwave observations over several hours as the storm evolved. As a result, it can be concluded that the signatures revealed by the observed brightness temperature spectrum are indeed associated with precipitation and are not, for example, due to patches of dry air that reveal low microwave emissivity surfaces.

5. FUTURE WORK

This algorithm for estimating precipitation rate was trained only on convection-rich data over the eastern U.S. and has not yet been calibrated to accurately estimate stratiform snowfall. As a result, it has shown weaknesses in other climates. For example, in Figs. 1 and 2 the retrieved precipitation indexes exceeded 18 and 50 mm/h, respectively, precipitation rates that far exceed plausible limits for typical Arctic temperatures and humidity profiles. In contrast, the MM5 estimates for Figure 1 peak near 1 mm/h. Further studies and algorithmic improvements are in progress.

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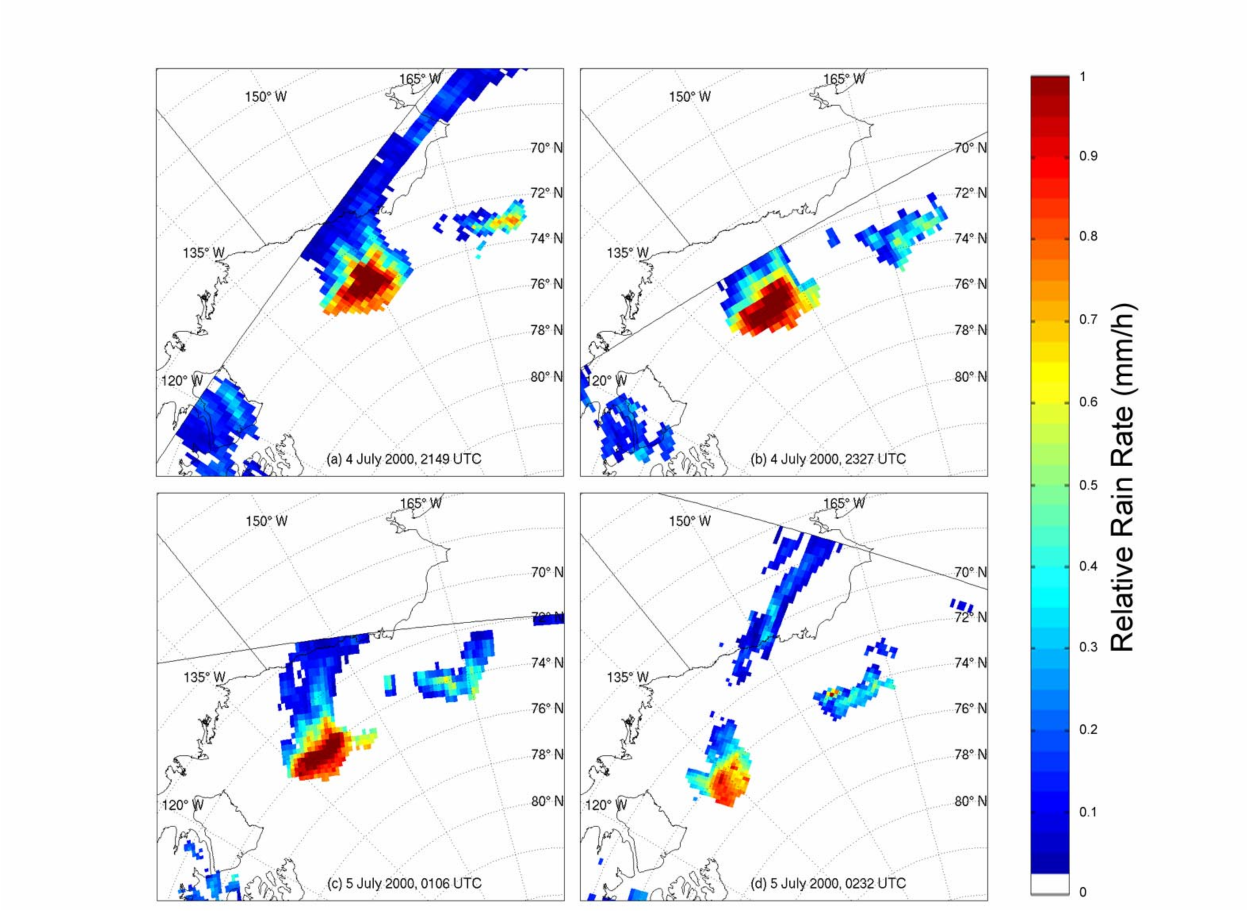

Figure 2. Precipitation north of Alaska on observed by NOAA-15 AMSU on July 4-5, 2000

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