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STUDIES ON SNOWFALL RETRIEVALS FROM SATELLITE HIGH FREQUENCY MICROWAVE OBSERVATIONS

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1. INTRODUCTION

In mid- and high latitudes, a substantial portion of precipitation falls in the form of snow during winter. Thus, precipitation from snowfall becomes important in the mid- and high-latitudes for obtaining accurate estimates of precipitation on a global scale. Additionally, measuring snowfall has important social and scientific implications including detection of hazardous snowfall weather events, assessment of the impact of snowfall on ocean surface buoyancy fluxes and hydrological applications. Observation of snowfall from satellite was hampered by the lack of contrast between snowfall (floating ice particles) signature and its background for most of the remote sensors used in current satellites. In this study, we investigate the snowfall signature in high frequency microwaves (85 GHz and above) by both analyzing available observational data and conducting radiative transfer modeling. Because of the strong scattering by ice particles, observation at high frequency microwaves provides a potential opportunity to detect snowfall. The ultimate goal of the study is to quantitatively develop a snowfall retrieval algorithm using satellite high frequency microwave data. At the initial stage of the study, we focus snowfalls over ocean.

2. SNOWFALL SIGNATURE OBSERVED BY AIRCRAFT MEASUREMENTS

Fig.1 shows simultaneous observations of a shallow snowfall event by a ground-based radar and an airborne microwave radiometer at 89 GHz (Katsumata et al., 2000). The maximum radar reflectivity is about 25 dBZ, which translates to a liquid equivalent precipitation rate of ~1.5 mm/h. The brightness temperature (dashed line in the top figure) decreases by ~15 K at the convective cell center compared to clear-sky regions. Because of the small horizontal scale of the convective cells, the brightness temperature contrast could be much smaller if the snow clouds were observed by satellite radiometers.

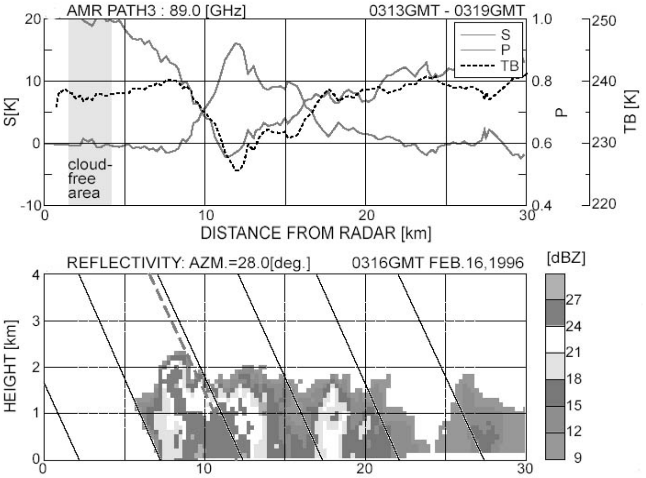

Fig.1 Top: 89 GHz brightness temperature (hashed line) observed over the cloud by an airborne radiometer. Bottom: height-distance (in km) cross-section of radar reflectivity.

Using the same atmospheric and cloud conditions, we conducted a radiative transfer model simulation to investigate how different frequencies respond to this snowfall event. The simulation result is shown in Fig. 2 for 37, 89, 150 and 183±7 GHz. It is seen that 37 GHz brightness temperatures almost do not respond the snow cloud at all while at 150 GHz the microwave scattering signature is the strongest. The magnitude of the brightness temperature decrease at 150 GHz is twice as large as that at 89 GHz, particularly when the snowfall rate is small. Therefore, 150 GHz is much superior over 89 GHz for detecting and retrieving snowfall. Brightness temperature at 183±7 GHz does not have strong response to snowfall for this case. The reason is that its weighting function peaks above the shallow snow cloud layer, so that the snow scattering signature is

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masked by water vapor in the boundary layer. For deeper snow cloud layer, the 183±7 GHz would also have a strong response.

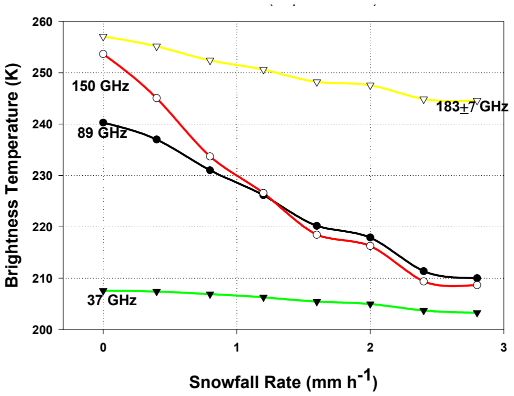

Fig. 2 Radiative transfer model simulated response to shallow snow clouds for brightness temperatures at 37, 89, 150 and 183±7 GHz.

3. SNOWFALL SIGNATURES OBSERVED BY SATELLITE SSM/T-2

The SSM/T-2 onboard DMSP satellites has channels at 90 GHz, 150 GHz, and three frequencies near 183 GHz. Although it was designed for water vapor sounding, we may use its 150 GHz for snowfall detection. As mentioned earlier, brightness temperature at 150 GHz is much more sensitive to snow scattering than the other channels.

Fig.3 shows snowfall index retrieved from SSM/T-2 150 GHz (top) for the 1992-93 winter months over North Atlantic compared to the snowfall frequency of occurrence derived from current weather report by ship observers (COADS data) for the same time period (Liu and Curry, 1997). It is seen that the patterns of the two measurements compare well with heavier snowfalls occurring along the east coast of N. America and Greenland. Further studies showed that those snowfalls are associated with cold air outbreaks from the continent, which create very unstable atmospheric conditions when flow over the warmer ocean surface. It is also found in Liu and Curry (1997) that rainfall maximum (retrieved from SSM/I) in this region is along the warm water of Gulf Stream – North Atlantic Drift, which has distinctly different pattern from the snowfall distribution, and is believed to be largely resulted from the passage of storms. The good correspondence between SSM/T-2-retrieved snowfall and shipboard observations suggests that the 150 GHz scattering signature reasonably resembles snowfall event and may be used for quantitative snowfall estimation.

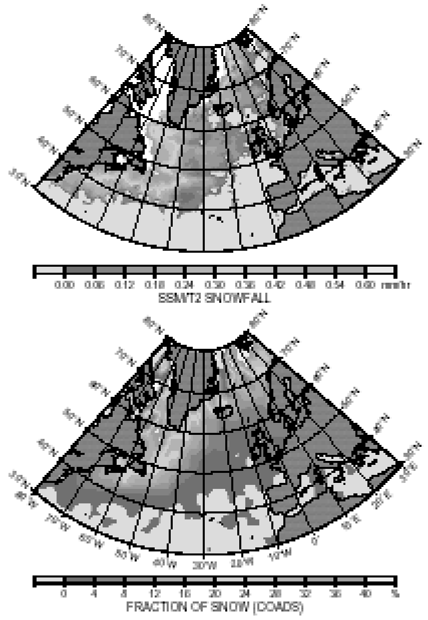

Fig.3 Horizontal distributions of SSM/T-2 derived snowfall index (top) and snowfall frequency derived from COADS data for the 1992-93 winter months.

4. CONCLUDING REMARKS

Observational evidence and model results showed that snowfall could be retrieved over oceanic regions by using high frequency microwave measurements (e.g. at 150 GHz). Further studies on the snow vertical distribution, density, etc. are needed for more quantitative estimation. Additionally, investigation of the snowfall possibility over more complicated surfaces (land, sea ice) is needed.

References

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