Retrieval Algorithm Development for Falling Snow Detection and Estimation over Land:

Thresholds of Detection for Satellite-borne Active and Passive Sensors

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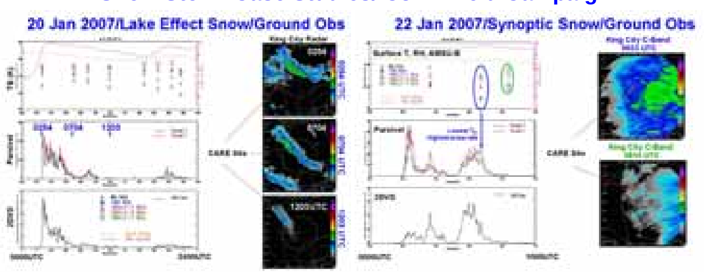
Introduction

The GPM mission has a requirement to detect falling snow to assist in obtaining the global precipitation water cycle and to help in understanding the Earth's energy and radiation budgets. Since falling snow from space is the next precipitation measurement challenge from space, information must be determined in order to guide retrieval algorithm development for current and future missions. This information includes thresholds of detection for various sensor channel configurations, snow event system characteristics, snowflake particle assumptions, and surface types.

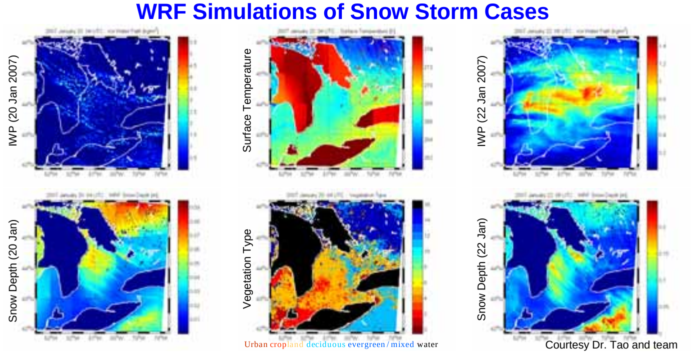
What are the thresholds of detection in terms of IWP or IWC? For example, can a lake effect snow system with low (~2.5 km) cloud tops having an ice water content (IWC) at the surface of 0.25 g m^{-3} and dendrite snowflakes be detected? If this info is known, we can focus retrieval efforts on detectable storms and concentrate advances on achievable results.

This research focuses on determining the thresholds of detection for various falling snow events for both active and passive sensors. We use all GMI channels, emphasizing the use of high frequency passive microwave channels (85-200 GHz) since these are more sensitive to the ice in clouds. For the radar, an analysis is performed for Ku, Ka, and W-band. The results rely on simulated Weather Research Forecasting (WRF) simulations of falling snow cases. The micro and macro structure (e.g., snowflake shape, PSD, IWP, cloud depth) of the underlying cloud scene was found to affect the results, producing different thresholds for the lake effect, and synoptic snow events.

Snow Storm Case Studies/ C3VP Field Campaign



WRF Simulations of Snow Storm Cases



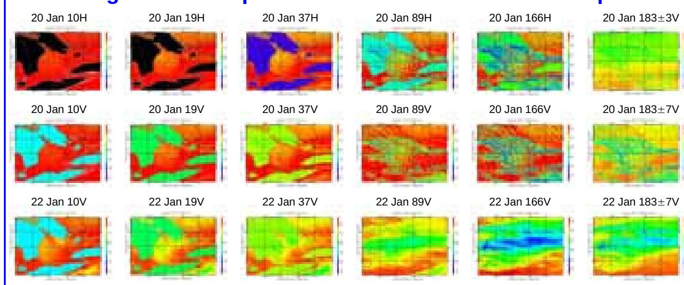
Courtesy Dr. Tao and team

Radiative Transfer Calculations: Active and Passive

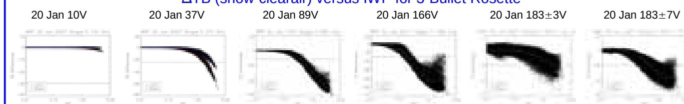
The radiative transfer equations rely on the planar-stratified, multiple scattering based model described in [*Skofronick-Jackson et al.*, 2004]. These calculations are performed at the native resolution of the simulations (1 km) and for each of the 207,000 profiles in the WRF domain. **TBs at the GMI channels were computed.** For the Z computations, we use the reflectivity eqns found in Meneghini et al., [1997]. Reflectivity range gates are the WRF vertical layers. **Zs were computed for Ku, Ka, and W-bands.**

For the snow and graupel particles, randomly oriented, non-spherical particles from G. Liu's database [2004] are used. Liu's database provides absorption, scattering, asymmetry, and backscattering parameters over a fixed range of non-spherical radii for 11 different shapes (see below). Size distributions for these frozen particles are determined by the fixed range of the Liu particle calculations along with the combined IWC as prescribed by WRF using the methodology described in Skofronick-Jackson and Johnson (2011). **TBs and Z were computed for all 11 snowflake shapes.**

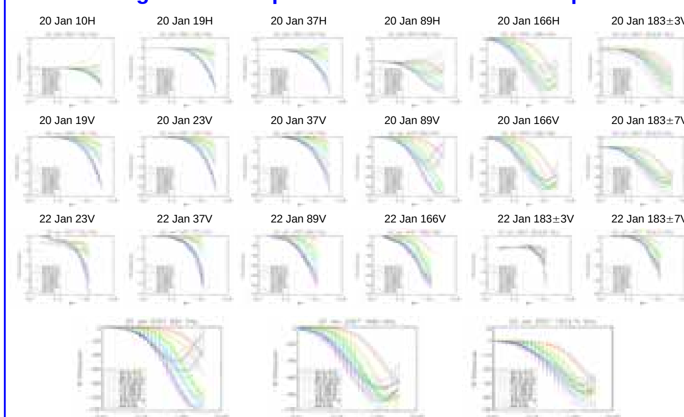
Brightness Temperatures: 3-Bullet Snowflake Shape



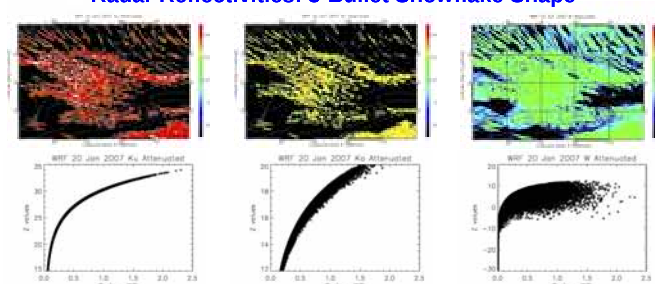
ΔTB (snow-clearair) versus IWP for 3-Bullet Rosette



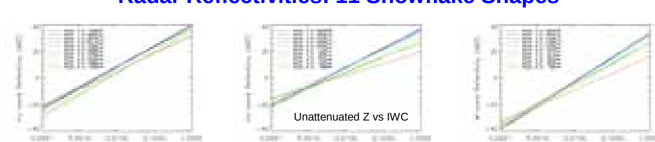
ΔBrightness Temperatures: 11 Snowflake Shapes



Radar Reflectivities: 3-Bullet Snowflake Shape



Radar Reflectivities: 11 Snowflake Shapes



Thresholds of Detection for Falling Snow Events

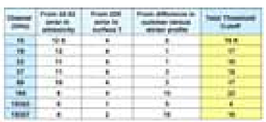
Radar Perspective

We use the unattenuated WRF simulations and the minimum detectable reflectivity from GPM DPR (Ku at 18 dBZ, Ka at 12dBZ) and CloudSat W-Band at -15 dBZ (for precipitating snow, not the minimum signal of CloudSat). The IWC amounts detected vary considerably for Ku, Ka, W-bands and for the different shapes. They will also vary dependent on the attenuation correction through different profiles. The IWC are converted to melted surface snow rates using the Marshall-Palmer related conversion of SR = $19.9 \cdot IWC^{1.19}$ mm hr^{-1}.

Snowflake Shape (#)	Ku-Band	Ka-Band	W-Band
Long Hexagonal Col. (0)	0.037 g m^{-3}	0.020	0.0020
Short Hexagonal Col. (1)	0.037	0.020	0.0019
Block Hexag. Col. (2)	0.039	0.020	0.0020
Thick Hexagonal Plate (3)	0.035	0.019	0.0019
Thin Hexagonal Plate (4)	0.033	0.018	0.0022
Three Bullet Rosette (5)	0.062	0.038	0.0018
Four Bullet Rosette (6)	0.065	0.052	0.0026
Five Bullet Rosette (7)	0.062	0.047	0.0022
Six Bullet Rosette (8)	0.063	0.101	0.0023
Sector Snowflake (9)	0.077	0.049	0.0018
Dendrite Snowflake (10)	0.079	0.145	0.0032
Average	0.054	0.048	0.0022
Melted SR (mm hr^{-1})	0.617	0.537	0.0137

Radiometer Perspective

In a similar manner we explored potential thresholds of detection for passive radiometers at 53deg. Because retrieval algorithms are not mature enough for fully accurate detection, we use a simple differencing ΔTB = TBsnow-TBclearair. Based on how accurate we expect the Tbclearair to be, we set threshold cutoffs:

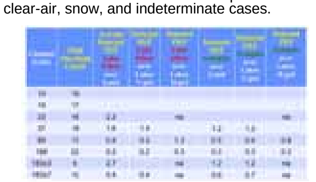


To convert IWP (kg m^{-2}) to surface IWC, we divide by the thickness of the cloud layer. To estimate snow rate we use the expression used in the radar analysis.

22 Jan 2007: Synoptic Snow Case

Conclusions

Passive microwave retrievals over land are challenging due to the contamination from surface emission, but falling snow detection is achievable. **The results show that for active sensors, the minimum detectable reflectivity of the radar drives the detection level of falling snow. For passive sensors, the results show that indeed large IWP values are more easily detected and that the higher cloud tops also increases detectability of falling snow clouds. We note that the detection capabilities of the 166V channel are comparable to the Ku and Ka on the GPM DPR radar with both able to detect a little better than1 mm hr^{-1} melted.** Additional efforts will constrain the process to further improve the process and to distinguish rain, clear-air, snow, and indeterminate cases.



Future Work

Our next steps include: (1) incorporating our observational and simulated Bayesian database into the official GPM radiometer database, (2) in an operational-sense knowing how to obtain the "TBclearair" or another measure using ancillary data, & (3) verifying that ice scattering above rain does not contaminate these falling snow retrievals.

Relevant References

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Acknowledgments

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