Falling Snow Retrieval Algorithm Development Work

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Introduction:

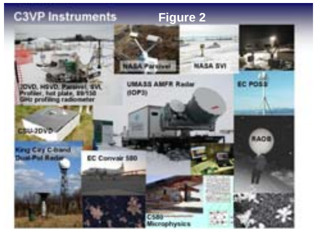
The precipitation science community is in great need of high-quality data sets for developing falling snow detection and estimation algorithms. In the past, the retrieval community has used a number of approximate models for the frozen atmospheric particles and the surface emission, all giving different results based on choices of parameters and assumptions. The field campaign data set described in this poster can help the snowfall retrieval algorithm community develop a better understanding of the relationships between non-spherical snowflakes and their radiative properties, surface emission (especially over snow covered surfaces), and the impact environmental conditions (e.g., profiles of T and RH) can have on falling snow estimates.

A database linking radar and radiometer signals with the falling snow physical state would be a useful tool that can be developed using field campaign data. Since high frequency channels (89 to 183 GHz) are particularly sensitive to precipitating snow, these channels must be included in the database. Thus we are generating a High Frequency Active Passive (HFAP) database for use in Bayesian retrievals of falling snow. This HFAP dbase is one part of the proposed work for falling snow retrievals.

Field Campaign:

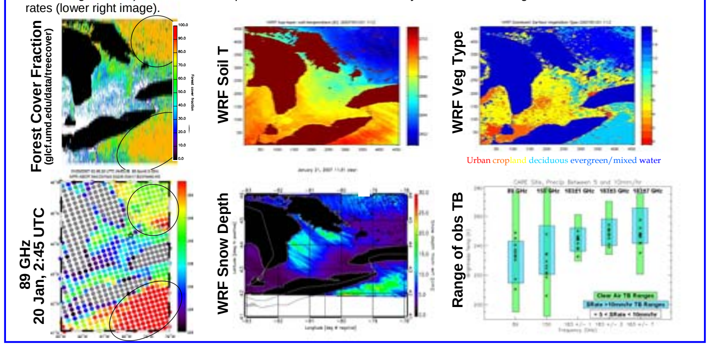
The Canadian CloudSat/CALIPSO Validation Program (C3VP) was a field campaign held from Oct. 31, 2006 through March 1, 2007. The C3VP field campaign provided an opportunity for the CloudSat/CALIPSO and Global Precipitation Measurement (GPM) mission teams to participate in cold-season northern latitude data collection activities. Our interest in this experiment was to collect data for developing falling snow detection and snow rate retrieval algorithms. The C3VP field campaign was held at the Centre for Atmospheric Research Experiments (CARE) research facility operated by the Air Quality Research Branch of the Meteorological Service of Canada. It is located 80 km north of Toronto, in a rural agricultural and forested region (Fig. 1) and has regular CloudSat and AMSU-B overpasses and was heavily instrumented (See Fig. 2 and http://www.c3vp.org/).

Figure 1: Location of the CARE site and two CloudSat overpasses.



TB Ambiguity due to Surface Features (near CARE site)

Surface emission (~emissivity*Tsurf) contributes to the TB seen from space. This surface emission (if not accounted for) can contaminate the TB signal from the atmospheric falling snow and cause errors in the retrievals. The 89 GHz image shows differing TB in the upper right and lower right likely due to the differences in soil temperature and vegetation type (as shown in the images below). Surface snow depth also affects surface emissivity. The result is a range of TB for various snowfall rates (lower right image).



Retrieved Emissivity from AMSU-B/MHS Observations

Oct'06 to March'07 at CARE site

Results courtesy James R. Wang

Retrieved from multiple overpasses per day

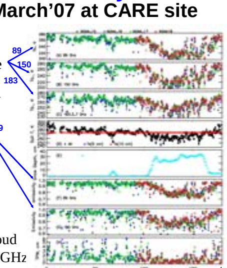
Retrieved emis. directly over the C3VP site

Used TP3000 to obtain IWP

Used Egbert GS for surface T

Future work:

1) Use a multi-layer cloud model to obtain 183 GHz emissivities



21 Jan 07 11:31 UTC

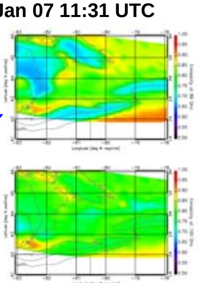
5°x5° Box

Used GOES to obtain IWP

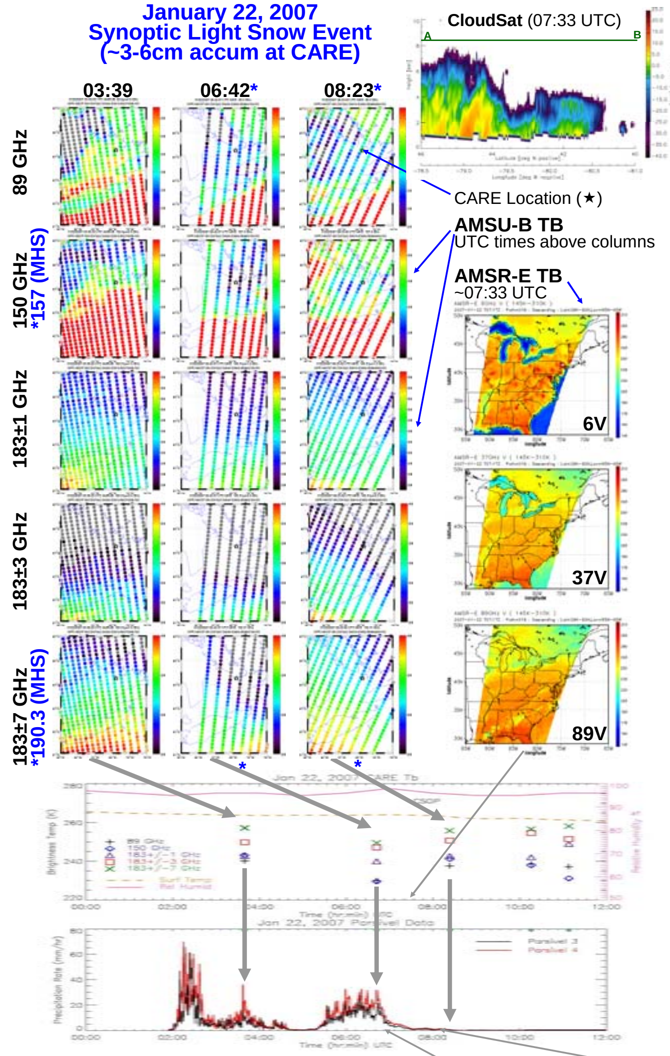
Used WRF for Surface T

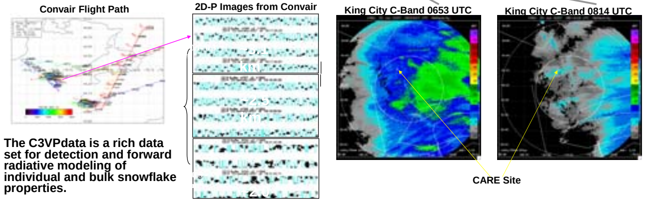
89 GHz

150 GHz



January 22, 2007
Synoptic Light Snow Event
(~3-6cm accum at CARE)





The C3VPdata is a rich data set for detection and forward radiative modeling of individual and bulk snowflake properties.

Acknowledgments:

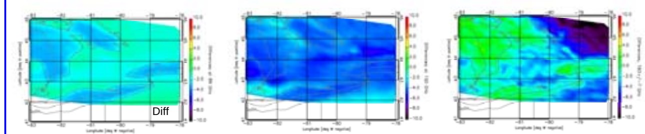
We thank all the team members and PI's of the C3VP experiment, especially Dave Hudak of Environment Canada (overall C3VP PI), Ali Tokay (for the Parsivel data), Dr. Tao, Roger Shi and Tao's team (for the WRF model data), and Steve Nesbitt (for the King City images and data). Funding for this work comes from NASA Headquarters and PI (Skofronick-Jackson) for CloudSat (Hal Maring) and PMM (Ramesh Kakar) grants.

Falling Snow Detection Procedure

Goal: Remove effects of Surface and Relative Humidity from AMSU-B data

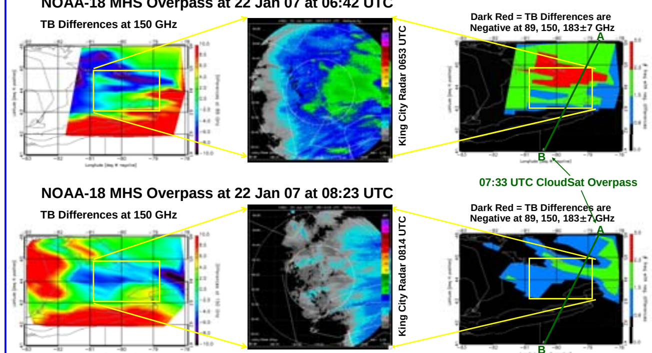
1) Use WRF modeled data or GOES derived data for surfT and profiles of T & RH
2) Estimate surface emissivity using AMSU-B/MHS data (see lower left of poster)
3) Verify surface emissivity during clear air overpasses (see block below)
4) Compute TB w/surf. emissivity and T&RH profiles & assuming clear air
5) Take the Difference: $TB_{AMSU\text{-}B} - TB_{computed}$
6) If 3 of 5 channels have a negative difference (scattering) then snow detected (see below).

Verify Surface Emissivity for Clear Air (21 Jan 2007 11:31 UTC)



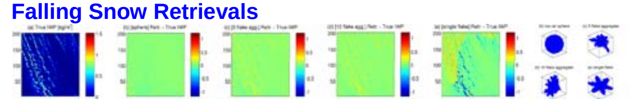
These images show the difference Observed minus Computed for 89, 150 and 183±7 GHz. We note that at 89 GHz the differences are between 0 and -2K showing that the AMSU-B estimated emissivity is accurate and vertical T & RH conditions do not affect that result. On the other hand for 150, the atmosphere T and RH are changing the derived TB by ~2K. For 183 GHz, the surface emission used in the calcs was from 150 GHz and the atmospheric T and RH are causing differences up to -10K. The 183 GHz emissivity retrievals need to be updated to a multi-level atmosphere.

Detection Results: Over 5°x5°



These images show the results of the falling snow detection procedure. The upper images are for 06:42 UTC and the lower panel is for 08:23 UTC. These two MHS overpass times sandwich the CloudSat overpass shown in the middle part of this poster. *The CloudSat image shows that the cloud tops go from ~6km to 3km (A->B) and that affects the ability to detect falling snow as shown in the 06:42 and 08:23 images* (and verified by the King City C-Band grnd radar).

Falling Snow Retrievals



Bayesian Retrievals of Ice Water Path (IWP) for various particle shapes. Panel (a) shows the "true" IWP derived from a WRF simulation. The retrieval database assumes spherical particles [shape (b)], and panel (b) shows good agreement when the "true" shapes are spheres as well. Panels (c)-(e) show the error incurred when the true particle shapes are non-spherical whereas the database still assumes spheres only. This highlights the uncertainty inherent in choosing the hydrometeor shape.

High Frequency Active Passive (HFAP) Database Develpmnt

We aim to create a database of physical profiles of precipitating snow clouds and associated simulated CPR reflectivity profiles for use in both CPR-only snowfall retrievals and in combined high frequency (>= 85 GHz) passive microwave / CPR snowfall retrievals. Using a broad set of microphysical assumptions, we will build an initial probability distribution of ice water content (IWC) and frozen particle characteristics at a given CloudSat radar range gate, for all vertical range gates down to the surface. From the IWC we will compute the associated vertical profiles of path-integrated attenuation (PIA), accounting for attenuation by hydrometeors. We will also compute the multiple-scattering (MS) contribution to the reflectivities, and add to the computed single-scattering reflectivities in the database. After retrievals from CloudSat, the updated profiles will be used to compute the forward modeled passive microwave brightness temperatures consistent with the sensor and scene being observed, and hence we will have updated the HFAP database. (See also Dr. Ben Johnson's poster.)

Conclusions

- Retrievals over land are challenging due to contamination from surface emission, but falling snow detection is achievable using basic surface and atmospheric profiles
- Radar on CloudSat will constrain process to further distinguish rain, clear-air, snow, and indeterminate cases.

1) Future Work: Check robustness of detection process using other data sets
2) Future Work: Generate HFAP Bayesian database using CloudSat Z, CloudSat retrieved snow & AMSU-B/MHS

Relevant References

1) G. M. Skofronick-Jackson, M.-J. Kim, J. A. Weinman, and D.-E. Chang, "A Physical Model to Determine Snowfall over Land by Microwave Radiometry," IEEE Trans. Geosci. Remote Sens, vol. 42, pp. 1047-1058, 2004.
2) Skofronick-Jackson, A Tokay, B Johnson, A Kramer, "Detection of Falling Snow and Cloud Ice Scattering over Land Surfaces from Spaceborne Radiometric Observations," to be submitted to JGR-Atmospheres, fall 2009.