FALLING SNOW RETRIEVAL ALGORITHM DEVELOPMENT WORK FOR GPM

Gail Skofronick-Jackson[1], Benjamin Johnson[2], James R. Wang[3]
[1]Mesoscale Processes Branch, Code 613.1, NASA Goddard Space Flight Center,
Greenbelt, MD Gail.S.Jackson@nasa.gov
[2]University of Maryland Baltimore County (JCET/GEST)
[3]SSAI, Lanham, MD

Submitted for the TRMM/GPM Special Session or the Clouds and Precipitation Session

Retrievals of falling snow from space represent one of the next important challenges for the atmospheric, hydrological, and energy budget scientific communities. Estimates of falling snow must be captured to obtain the true global precipitation water cycle, snowfall accumulations are required for hydrological studies, and without knowledge of the frozen particles in clouds one cannot adequately understand the energy and radiation budgets. The Global Precipitation Measurement (GPM) mission has a requirement to detect falling snow. Historically, retrievals of falling snow have been difficult due to the relative insensitivity of satellite rain-based channels as used in the past. We emphasize the use of high frequency passive microwave channels (85-200 GHz) since these are more sensitive to the ice in clouds (e.g., [1], [2], [3], [4], [5]). Our work ensures a physical consistency between the underlying cloud and atmospheric state and the brightness temperature observations. Three of the major challenges associated with falling snow retrievals include: (1) assessing the effects of land surface signatures and environmental state variables that obscure falling snow signatures in brightness temperature observations; (2) adequately modeling the physical characteristics of precipitating snow in radiative transfer calculations for database construction; and (3) ensuring that the retrieval database is representative of falling snow events. Here we focus on testing the sensitivity of the detection and estimation results to surface emission, particle shape, and environmental state to help assess uncertainty in the retrievals based on these input variables. This work also allows for an improved understanding of the relationships between radiative properties associated with radar reflectivities, brightness temperatures (TB), and the physical properties of frozen precipitation within a cloud.

This analysis relies on data from the Canadian CloudSat/CALIPSO Validation Program (C3VP) field campaign held from October 31, 2006 through March 1, 2007. The

C3VP field campaign provided an opportunity for the CloudSat/CALIPSO and GPM mission teams to participate in cold-season northern latitude data collection activities. It was located 80 km north of Toronto, in a rural agricultural and forested region and had regular CloudSat and AMSU-B overpasses [6]. The field campaign was heavily instrumented on the ground (Parsivel, 2-Dimensional Video Disdrometers, etc), with aircraft (4 intensive operating one-week operating periods of in-situ sampling of cloud microphysics) and with CloudSat and AMSU-B satellite overpasses.

With the C3VP data we performed both long-time series analysis for satellite footprints over the C3VP site and single overpass 5^ox5^o views. The process is to

[1] obtain initializing environmental parameters such as surface temperature and vertical profiles of T and water vapor,
[2] estimate surface emissivity for clear air overpasses,
[3] interpolate emissivity for cloud and precipitating overpasses,
[4] adjust an initial vertical profile for clear air cases such that overpass TB at selected channels match computed clear air TB (using the surface emissivity and surface T).

Once the clear air environmental conditions are determined, we move to the non-clear-air cases. Here we use the interpolated emissivity and surface temperature and adjusted vertical profile to compute clear air TB. These clear air TBs are compared to the observed TB for the non-clear air cases. (We use ISCCP to prescribe cloud cover, when ISCCP [7] says cloud cover is <= 16% we assume that we are in clear air conditions.) When the differences deviate significantly from zero (zero is expected under clear air conditions), then precipitation is considered detected.

In step one above, initializing environmental parameters come from a variety of sources including for example, land data assimilation systems, ISCCP, and WRF [8]. In step two, the retrievals of emissivity are obtained [9]. In step 3, we use a smart interpolation procedure, while in step 4 the adjustment to the RH and T profiles is done by iterating over a large (40,000) set of possible choices and minimizing the difference between the computed clear air TB and the observed clear air TB at 183±1 and 183±3 GHz as obtained from the NOAA AMSU-B or MHS instruments that have channels at 89, 150, 183±1, 183±3, and 183±7. The 89, 150, and 183±7 are much less sensitive to the T and RH profile, but more sensitive to the surface. In this way we can also use the 183±1 and 183±3 GHz channels for precipitating cases since for the shallow snow clouds at C3VP the 183±1 and 183±3 GHz channels will not “see” the surface.

We have found that the surface emission (~emissivity*Tsurf) contributes to the TB seen from space [10]. This surface emission (if not accounted for) can contaminate the TB signal from the atmospheric falling snow and cause errors in the retrievals. Our work shows that there are difficulties in adequately estimating the surface emission and environmental profiles, however, falling snow detection retrievals are making progress. The C3VP data set is especially challenging since the climatology supports shallow snow cloud events and light synoptic frozen precipitation. These shallower/light storms do not necessarily provide enough signal to noise ratio between the atmospheric snow signal and the surface emission/environmental profile noise. We will show how we validate our results using CloudSat data and other C3VP observations. This preliminary work to understand the relationships between high frequency passive microwave observations of falling snow and the microphysics of falling snow are important areas of research to prepare for the upcoming GPM mission.

Bibliography:

[1] Liu, G., 2004: Approximation of Single Scattering Properties of Ice and Snow Particles for High Microwave Frequencies. *J. Atmos. Sci.*, **61**, 2441–2456.

[2] McCollum, J. R., and R. R. Ferraro (2003), Next generation of NOAA/NESDIS TMI, SSM/I, and AMSR-E microwave land rainfall algorithms, *J. Geophys. Res.*, 108(D8), 8382, doi:10.1029/2001JD001512.

[3] Skofronick-Jackson, G. 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, May 2004.

[4] Noh, Y.-J., G. Liu, E.-K. Seo, and J. R. Wang 2006: Development of a snowfall retrieval algorithm at high microwave frequencies, *J. Geophy. Res.*, **111**, D22216, doi:10.1029/2005JD006826.

[5] Chen F. W. and D. H. Staelin, “AIRS/AMSU/HSB precipitation estimates,” *IEEE Trans. Geosci. Remote Sens.,* 41, pp. 410-417, 2003.

[6] See the website: http://www.c3vp.org/

[7] Rossow, W.B., and R.A. Schiffer, 1991: ISCCP Cloud Data Products. *Bull. Amer. Meteor. Soc.*, **72**, 2–20.

[8] J. J. Shi, W. –K. Tao, T. Matsui, R. Cifelli, A. Hou, S. Lang, A. Tokay, C. Peters-Lidard, G. Skofronick-Jackson, S. Rutledge, and W. Petersen, "WRF simulation of

the 20-22 January 2007 snow events over Eastern Canada: Comparison with in-situ and satellite observations," submitted to J. Applied Meteor. Climatol., May 1, 2009.

[9] J. R. Wang, G. Skofronick-Jackson, and B. Johnson, Submitted to IGARSS 2010 and paper in preparation.

[10] G. Skofronick-Jackson and B. Johnson, Surface and Atmospheric Contributions to Passive Microwave Brightness Temperatures, submitted ot JGR-Atmospheres, December 2009.