Developing Cloud-Radiation Database for Snowfall Retrieval Using High-Frequency Microwave Observations

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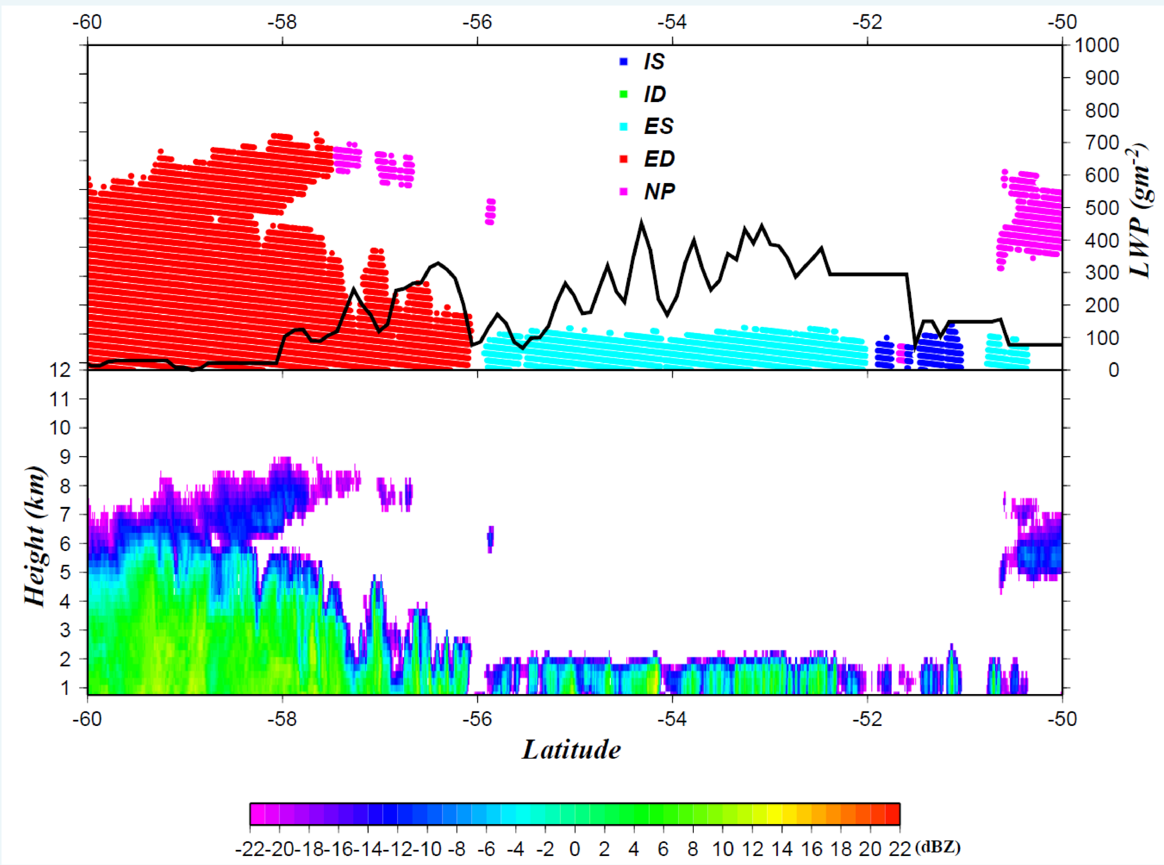
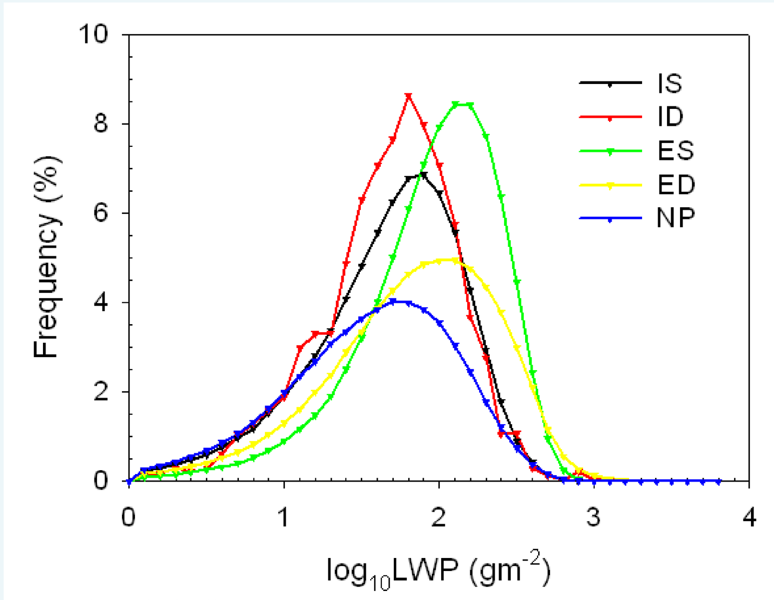
Introduction:

The ultimate goal of this research is to develop a snowfall detection technique over land and a snowfall retrieval algorithm over ocean using GPM high-frequency microwave observations. Toward this goal, currently we have been working on: (1) understanding microphysical properties of snow clouds based on observations, including the vertical distribution of snow particles and the liquid water characteristics; (2) simulating scattering properties of snowflakes; (3) over land snowfall detection based on EOFs of AMSU-B/MHS observed brightness temperatures, and (4) over ocean empirical database based on ECMWF and SSMIS data.

Microphysical Properties of Snowing Clouds:





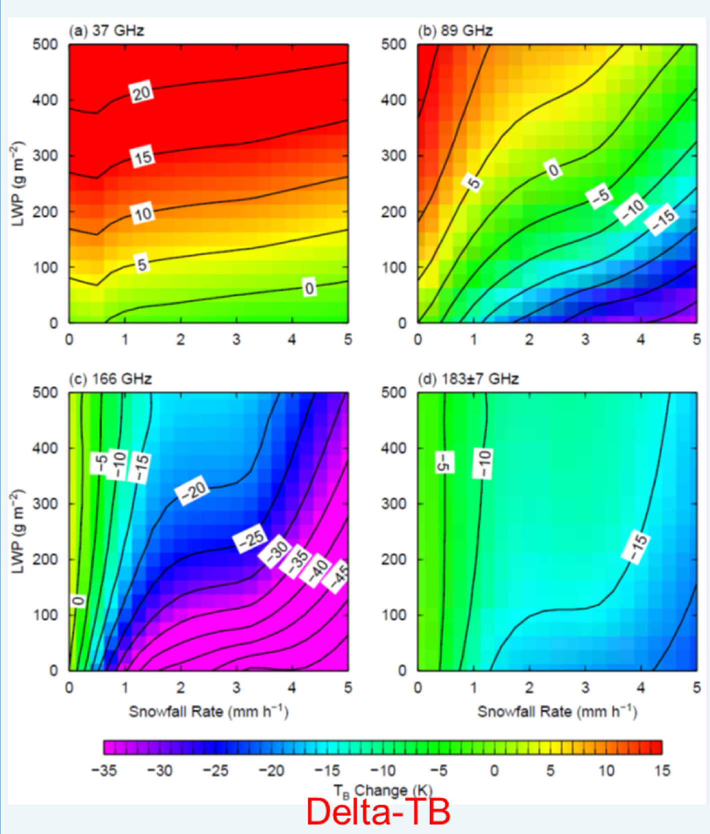
IS: Isolated Shallow
ID: Isolated Deep
ES: Extended Shallow
ED: Extended Deep
NP: Non-Precipitating

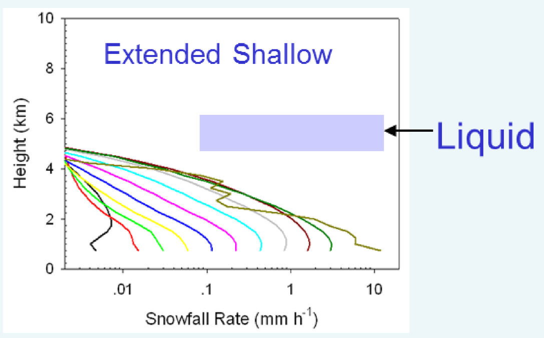
Shallow < 5km < Deep
Isolated < 40km < Extended

Liquid water path (LWP) is retrieved from AMSR-E data over ocean based on a newly developed algorithm that is suitable for snowing clouds. LWP characteristics for different types of snowing clouds (as determined by collocated CloudSat radar data) are studied. It is found that liquid water is abundant in snowing clouds, while deeper clouds do not necessarily have more liquid water.

Impact on Brightness Temperatures – RT Model Runs

(GMI Frequencies, 53 degree Viewing Angle, High-Lat Winter Atmosphere, Ocean)



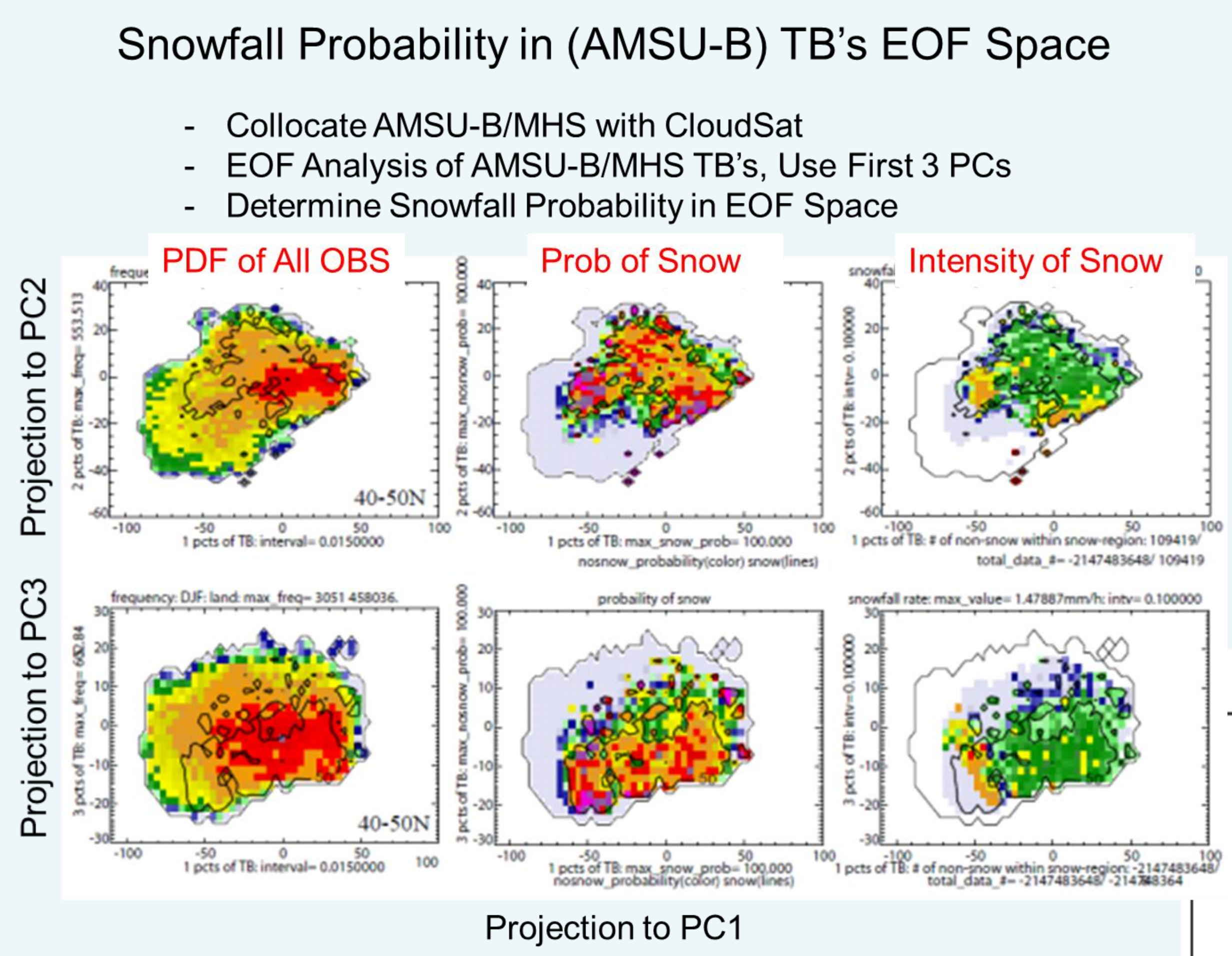


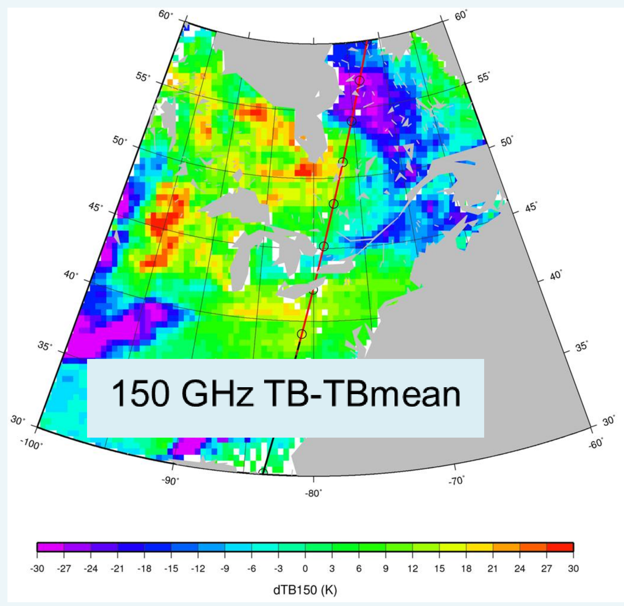
- 37 GHz: mostly warming, good for liquid water retrieval
- 89 GHz: competing between liquid-warming and snow-cooling
- 166 GHz: snowing cooling dominates, but liquid significantly reduces the scattering signature
- 183+/-7 GHz: vapor effect strong. Because viewing at 53 degree, vapor effect much stronger than that so-far-seen at MHS channels

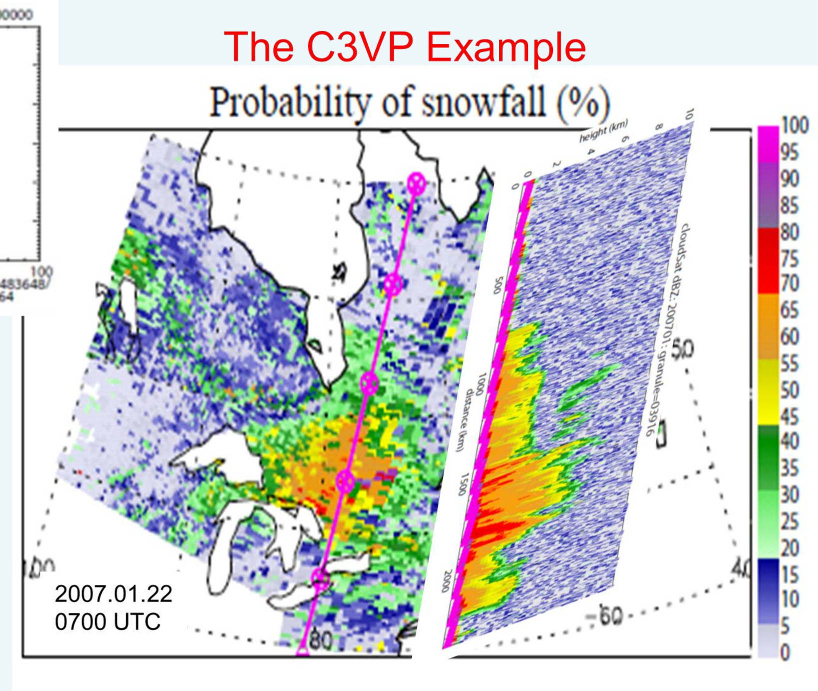
The masking effect on snow scattering signatures at GMI frequencies is simulated using a RT model with CloudSat derived snowfall vertical profiles. At high frequencies (>80 GHz), the masking effect is quite large, and must be taken care of in snowfall detection and/or retrieval algorithms, which is particularly true for shallower clouds.

Snow Detection Over Land:

Use collocated AMSU-B/MHS and CloudSat data, find the snowfall probability in brightness temperature EOF space (using the first 3 PCs currently) assuming CloudSat detected near-surface snowfall as true. This is done on a region-by-region basis. The following is an example for Canadian region; higher snowfall probability occurs at certain "locations" in the EOF space.







We use this empirical probability-in-EOF-space as a lookup table to "retrieve snowfall probability".

Empirical Database for High-Frequencies Over Ocean:

Data

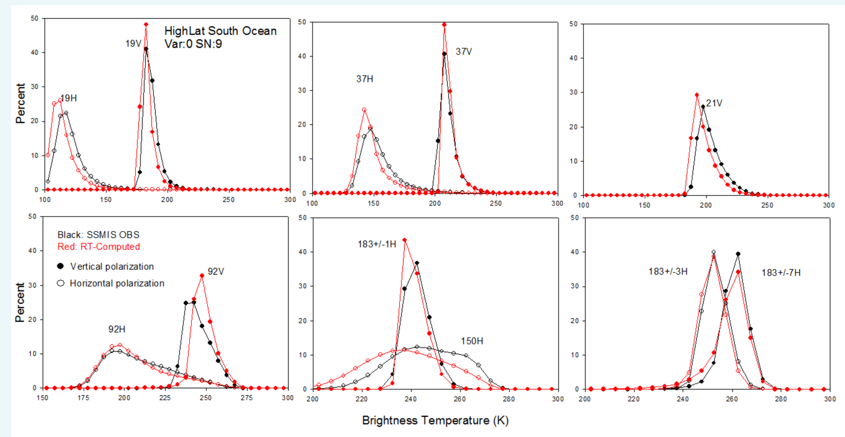
2005.11.01 – 2006.6.30

ECMWF (provided by Greg Elsaesser, CSU)
- Original resolution:
  - T799: ~25km (?)
  - 4 forecasts/day
- Thinned Data
  - Sample every 5th latitude and every 5th longitude
  - Sample every 10th day
- Variables
  - Cloud liquid, cloud ice, rain, snow, cloud fraction, T, Ts, T2m, q, p, …

SSMIS (L1C from CSU)
- 92V, 92H, 150H, 183+/-1H, 183+/-3H, 183+/-7H
- 14x13, 14x13, 14x13, 14x13, 14x13

Radiative Transfer Model (Liu, 1998)
- Gas absorption: Rosenkranz (1998)
- Sea Surface Emissivity: Guillou et al. (1998) ocean + Schluessel and Luthardt (1996) wind adjustment
- Fresnel reflection
- Delta-4 Stream
- Water Species: cloud water, cloud ice, rain, snow, graupel (did not use in this study)
- Ice/snow shapes: rosettes, sectors, dendrites (scattering properties from DDA)

Histogram HighLat (50S-60S)



We are developing an empirical database based on high-resolution ECMWF runs and radiative transfer models with nonspherical ice scattering included. Histograms show the simulated TBs are well compared with SSMIS observations for all sky conditions. But for precipitating conditions, sub-pixel variability must be taken into account in the radiative transfer simulation, to match the simulated TB histogram with that of observed.