Snowfall Detection and Retrieval for GPM

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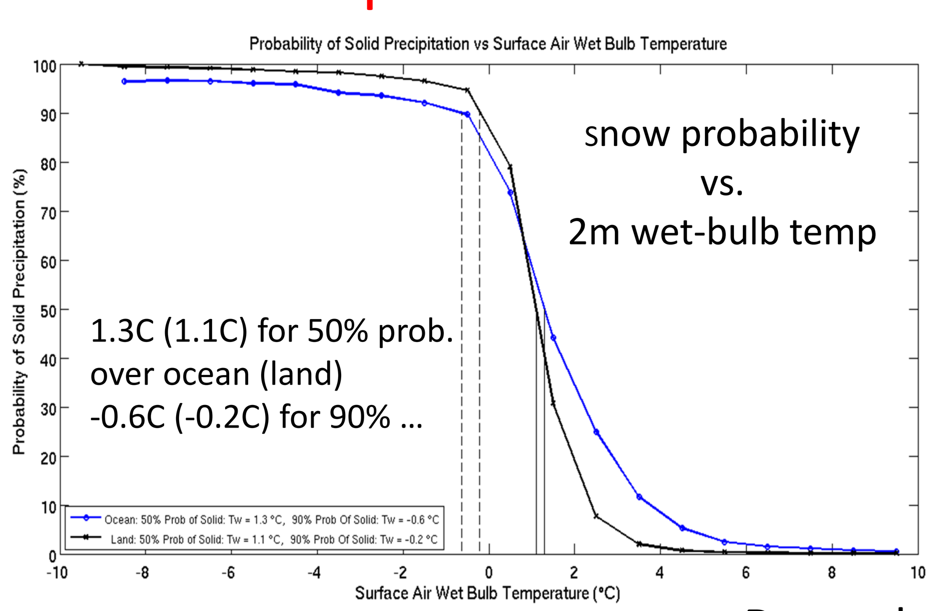
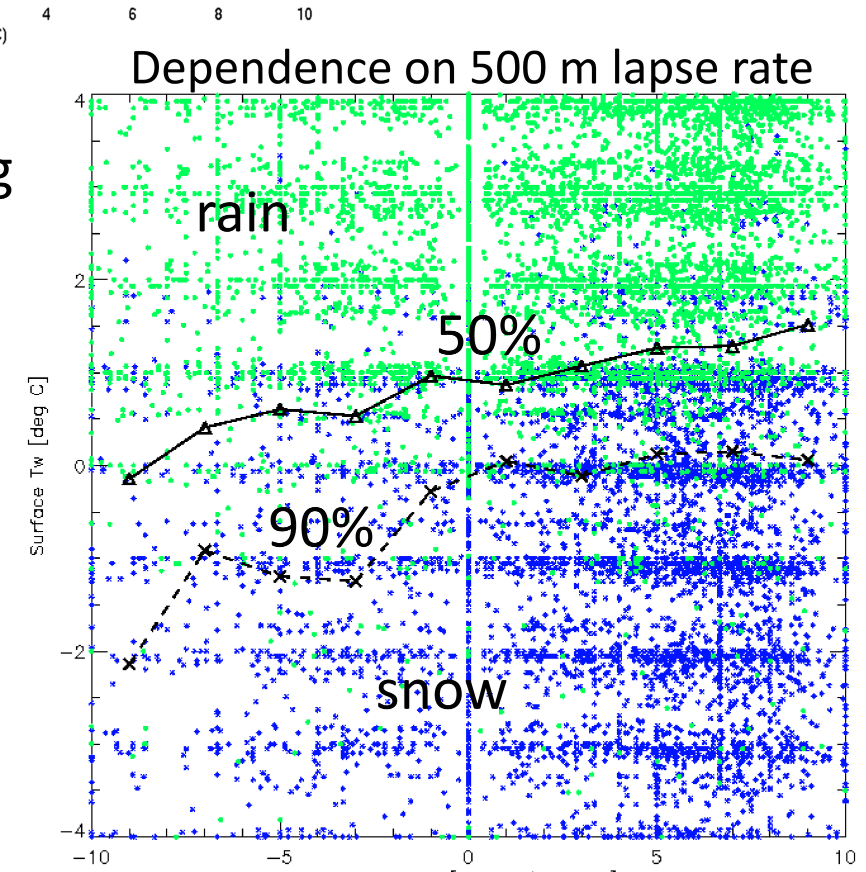
Introduction: The goal of this research is to develop algorithm components for snowfall detection and retrieval using GPM high-frequency microwave observations. Toward this goal, currently we are working on the following components: (1) a snow-rain separation algorithm based on surface-based observations, (2) understanding the microphysical properties of snow clouds, in particular, how cloud liquid water in snow clouds affects snowfall detection and retrieval by microwave observations, (3) scattering properties of aggregate snowflakes, and (4) snowfall detection algorithm based on high-frequency microwave brightness temperatures.

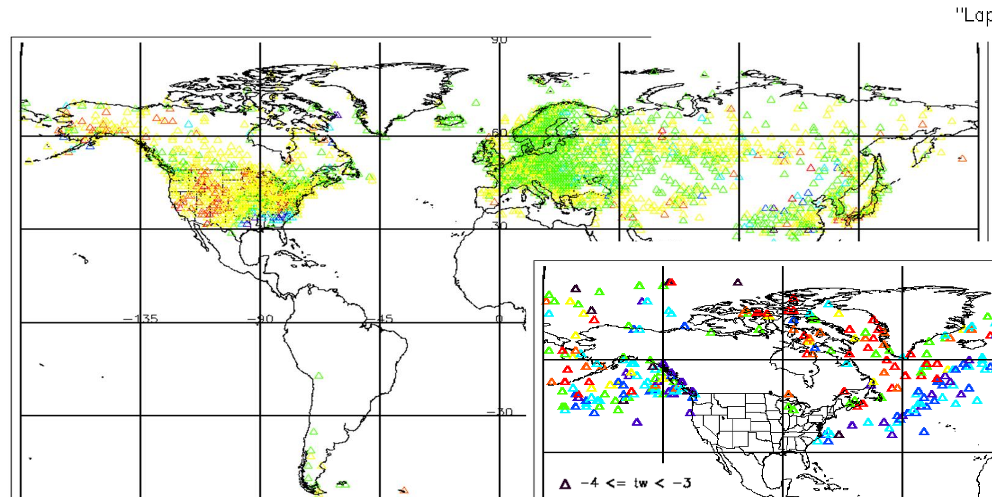
Snow-Rain Separation:

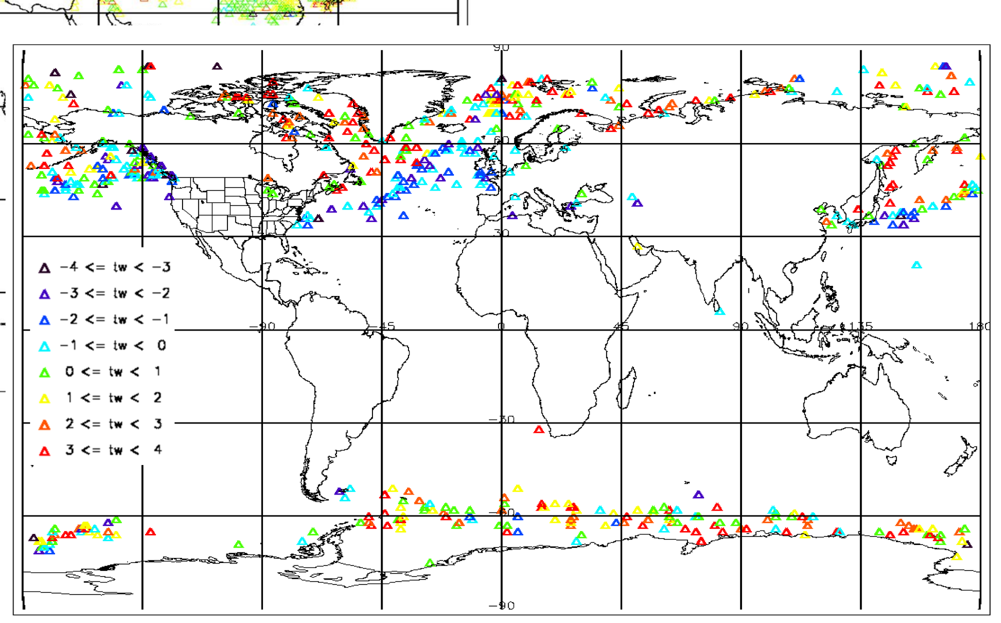


Data Used:
Land: NCEP ADP Operational Global Surface Observations, 1997-2007
Ocean: International Comprehensive Ocean-Atmosphere Data Set (ICOADS), 1995-2007
Upper Air: Integrated Global Radiosonde Archive (IGRA)

The criteria for separating snow vs. rain conditions seems to depend on:
-surface air temperature,
-humidity,
-low-level lapse rate,
- surface features
(elevation, temperature,



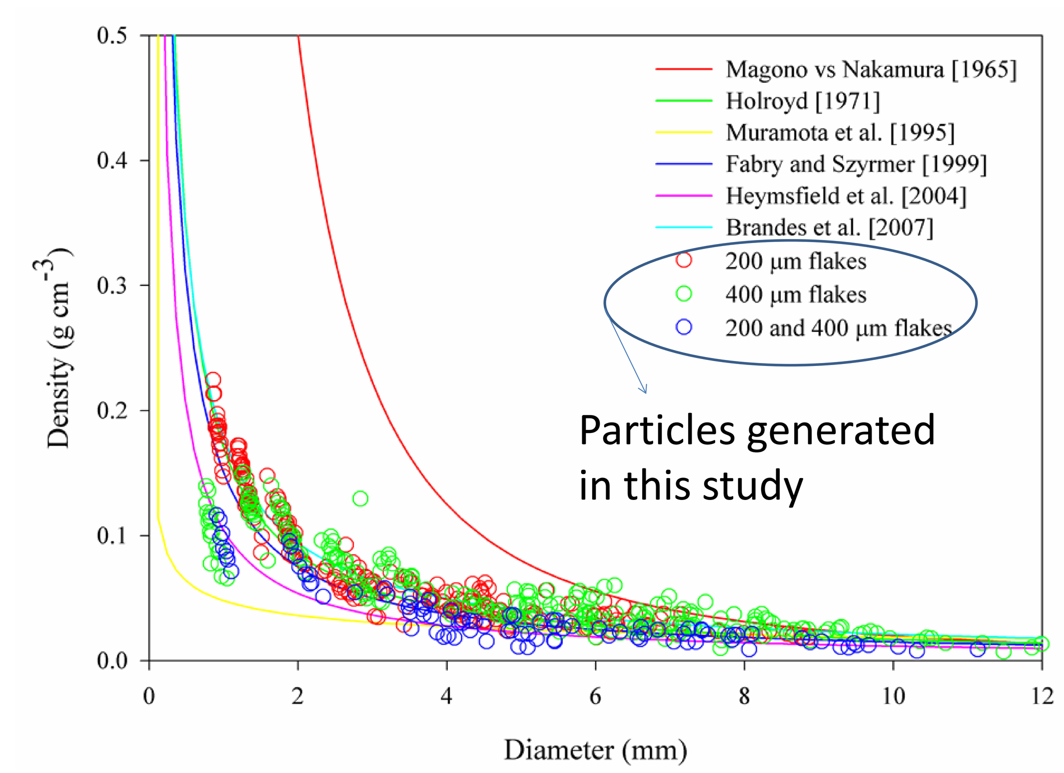


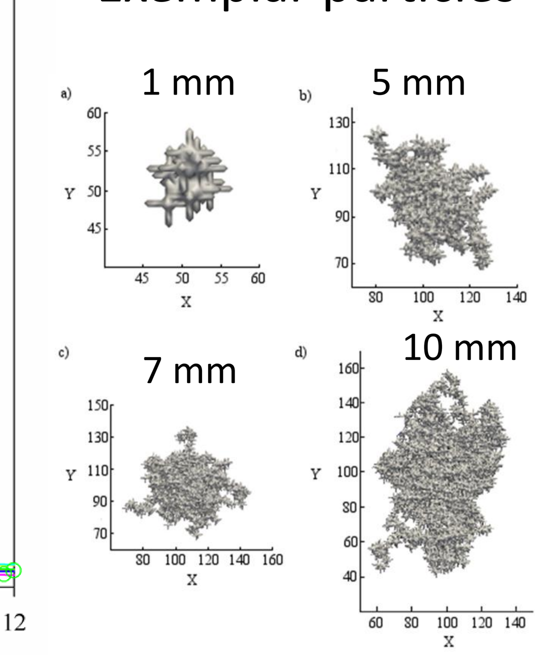


Warm surface (high elevation) seems to have low (high) separation threshold (wet-bulb) temperature

Scattering Table by Aggregates:

Aggregate snowflakes have been created with their dimension-mass/density relation constrained by consensus of observations (Figure below). Their scattering properties have been calculated using DDA and scattering table is archived on the web. With the addition of table to the earlier table for crystal type particles, we now have the scattering table for full range of ice/snow particles. The scattering table is downloadable from cirrus.met.fsu.edu.





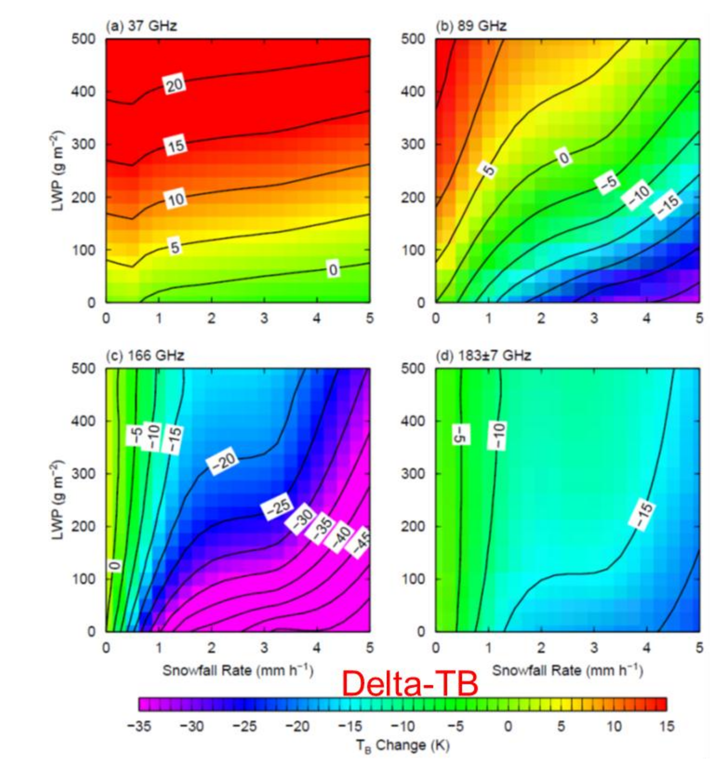
Liquid water in snowing clouds and its masking effect on scattering signatures:

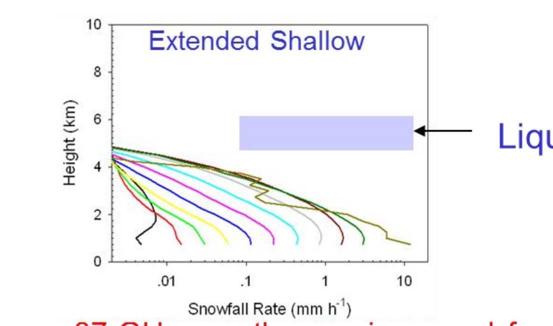
Retrievals from AMSR-E shows that liquid water is abundant in snowing clouds, which masks ice scattering signatures by snowflakes.

Table 1. Statistics of Over Ocean Snowing Clouds*

Cloud Type	N_{Total}	$N_{LWP>0}/N_{Total}$	LWP (g m^{-2})	σ_{LWP} (g m^{-2})	$MaxZ_e$ (dBZ)	$SurfZ_e$ (dBZ)	T_{2m} (°C)
IS	4,732,498	75%	50	63	-6	-8	-9.4
ID	12,944	83%	53	69	5	-2	0.4
ES	10,510,966	84%	98	96	-3	-5	-14.2
ED	11,628,358	67%	73	117	3	0	-13.9
NP	3,380,035	55%	32	59	-9	-	-6.4
ALL	29,904,801	72%	74	94	-1	-4	-13.1

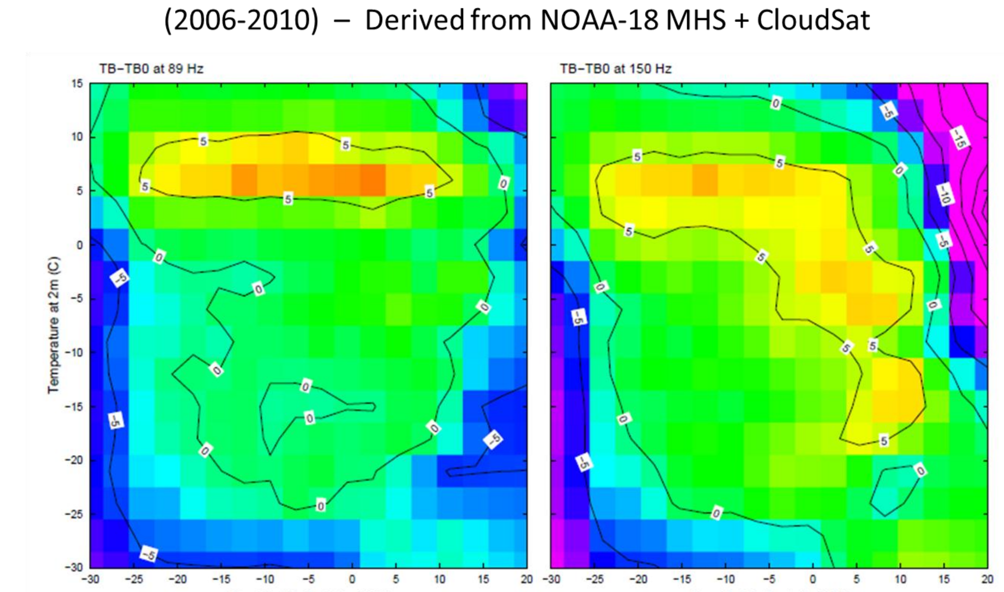
* N_{Total}: total number of observations (pixels), $N_{LWP>0}$: number of observations that have retrieved liquid water path greater than 0, LWP: mean liquid water path, σ_{LWP}: standard deviation of liquid water path, $MaxZ_e$: the maximum value in the mean radar reflectivity factor profile, $SurfZ_e$: mean of radar reflectivity factors near the surface, T_{2m}: mean of 2-m air temperatures.





- 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

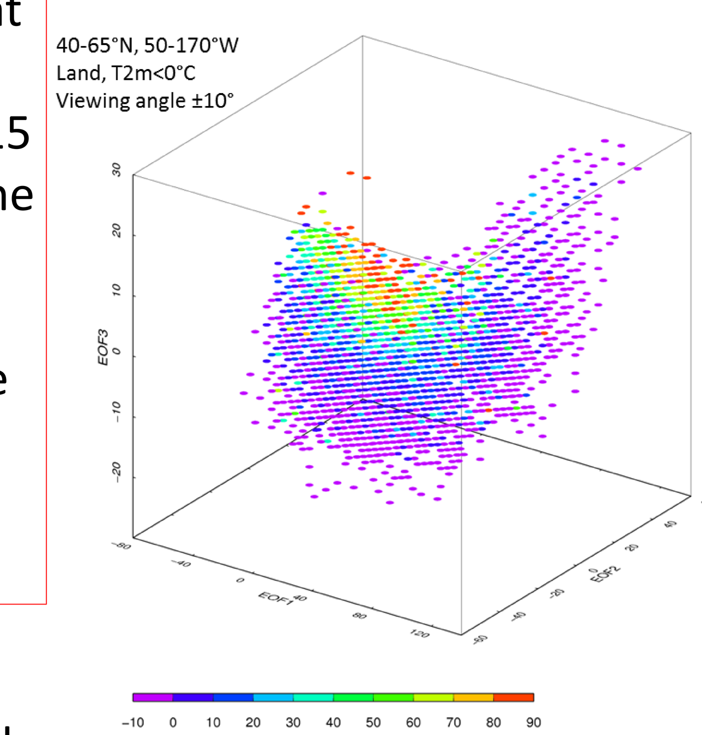
Empirical method for snowfall detection:



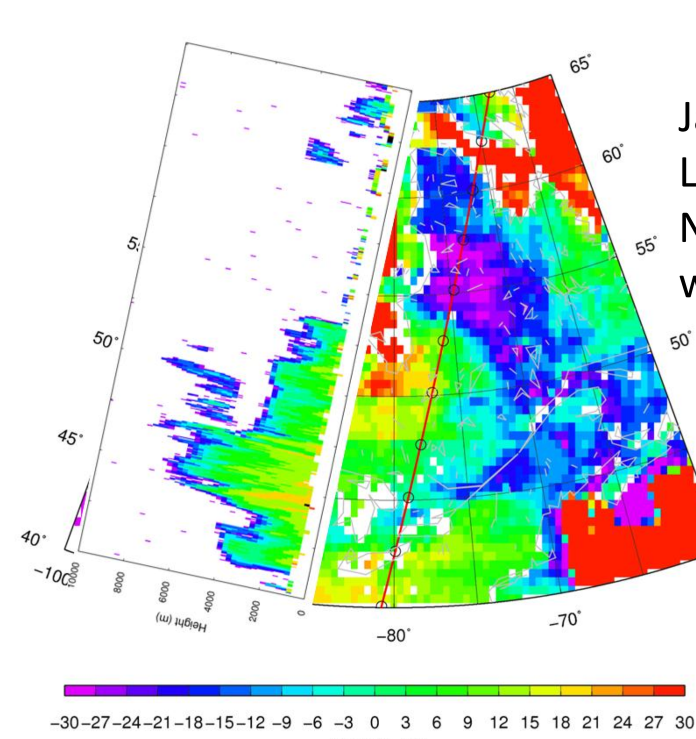
Due cloud liquid emission, TB under snowing conditions often warmer than that under clear conditions. Therefore, simple threshold method has difficulties to detect snowfall.

The detection algorithm is based on a lookup-table that is generated using coincident MHS and CloudSat data pairs. Using CloudSat near-surface reflectivity greater than -15 dBZ as an indication of snowfall, the lookup-table gives snowfall probability in 3-D brightness temperature EOF space. The figure on the right is an example of one such lookup-tables for near nadir viewing observations..

Lookup Table based on MHS-CloudSat Matchups – 4.5 years data, North America

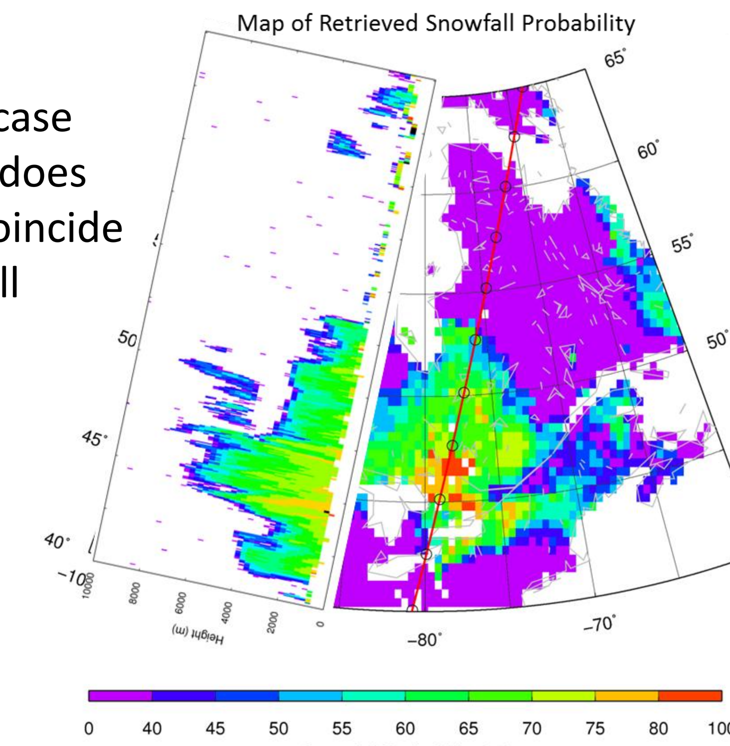


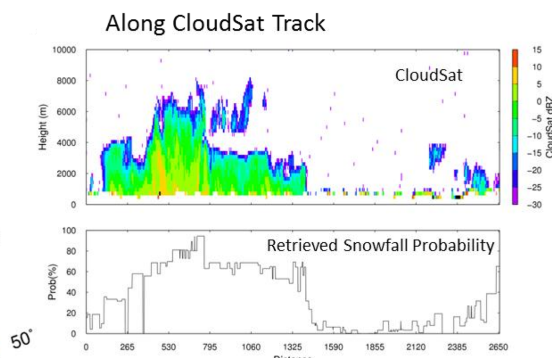
- EOF analysis to MHS data:
  - First 3 PCs – 88.6%, 8.2% and 2.1% of variances
  - PC3 had the best correlation Coeff to CloudSat reflectivity
- Lookup Table:
  - Project observed TBs to the first 3 PCs
  - In the 3-d EOF space, using MHS-CloudSat matchups, compute the probability of snowfall (CloudSat near-surface dBZe>-15)
  - Lookup tables for different MHS viewing angles
- Retrieve snowfall probability using the above lookup table; Use a Z-S relation, we can retrieve snowfall rate as well



Jan 22 2007 C3VP case
Large TB decrease does NOT necessarily coincide with heavy snowfall

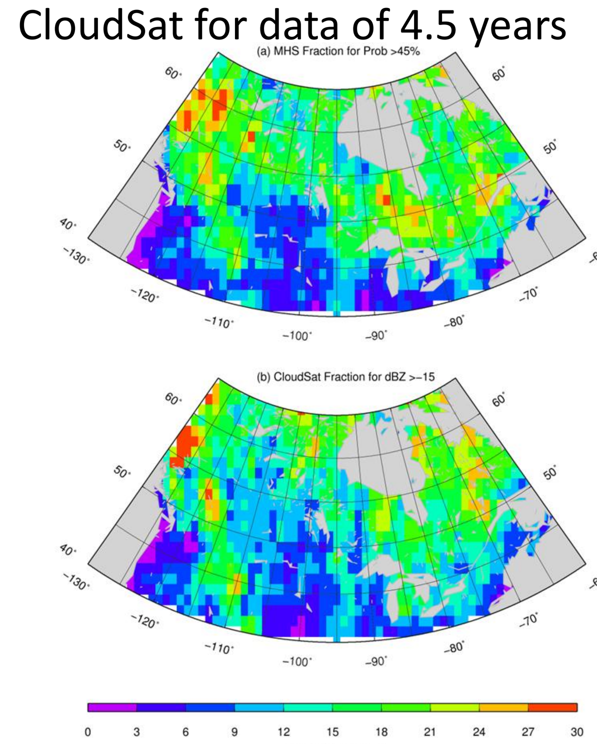
Results of this detection algorithm

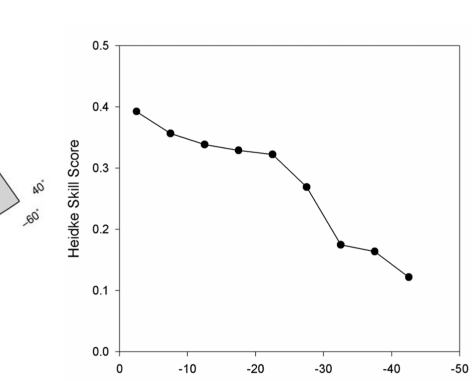




Use CloudSat to train passive microwave observations (done MHS, working on AMSR-E/AMSR2) for snowfall detection. This example shows that the trained passive microwave algorithm correctly identified snowfall area, and is potentially able to estimate snowfall intensity as well.

Snowfall frequency compared well with CloudSat for data of 4.5 years





However, skills seem to depend on surface temperature /latitude/weather