Snow Cloud Characteristics Determined by Both Active and Passive Microwave Satellite Observations - Implications to Snow Detection and Retrieval

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Objectives

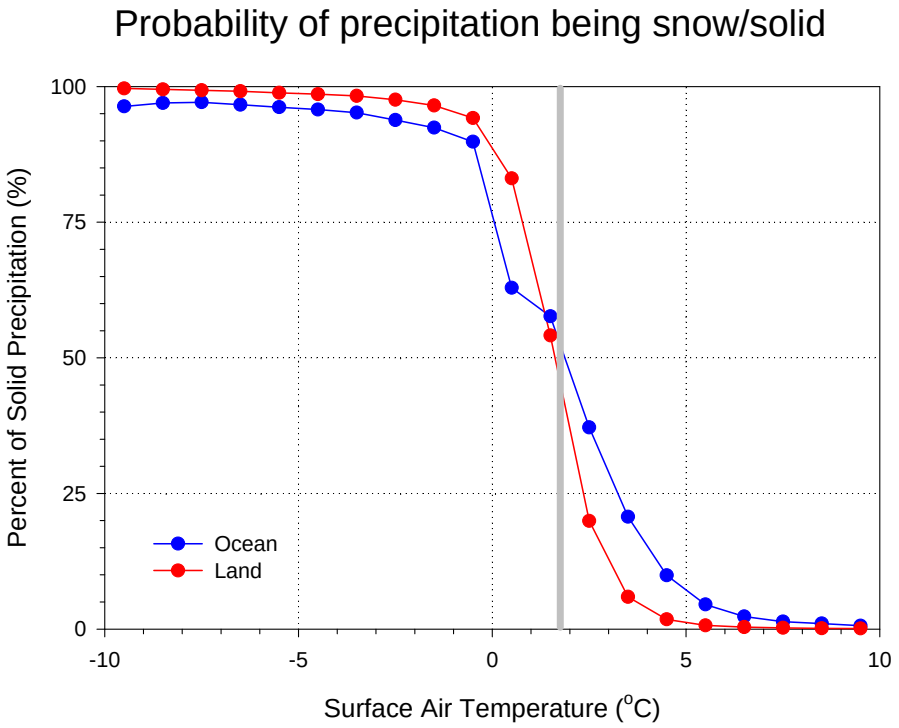
The ultimate goal of this study is to develop algorithms to detect and retrieve snowfall by high-frequency satellite passive microwave observations. To do so, we need to how microwave radiation responds to snow clouds.

Therefore, as the First Step:

We use combined Active (CloudSat) and Passive (AMSR-E/AMSU-B/MHS) microwave data to study the microphysical and radiative properties of snow clouds. In particular,

- Cloud Liquid Water in snowing clouds & its impact;
- Snowfall Rate Vertical Distributions

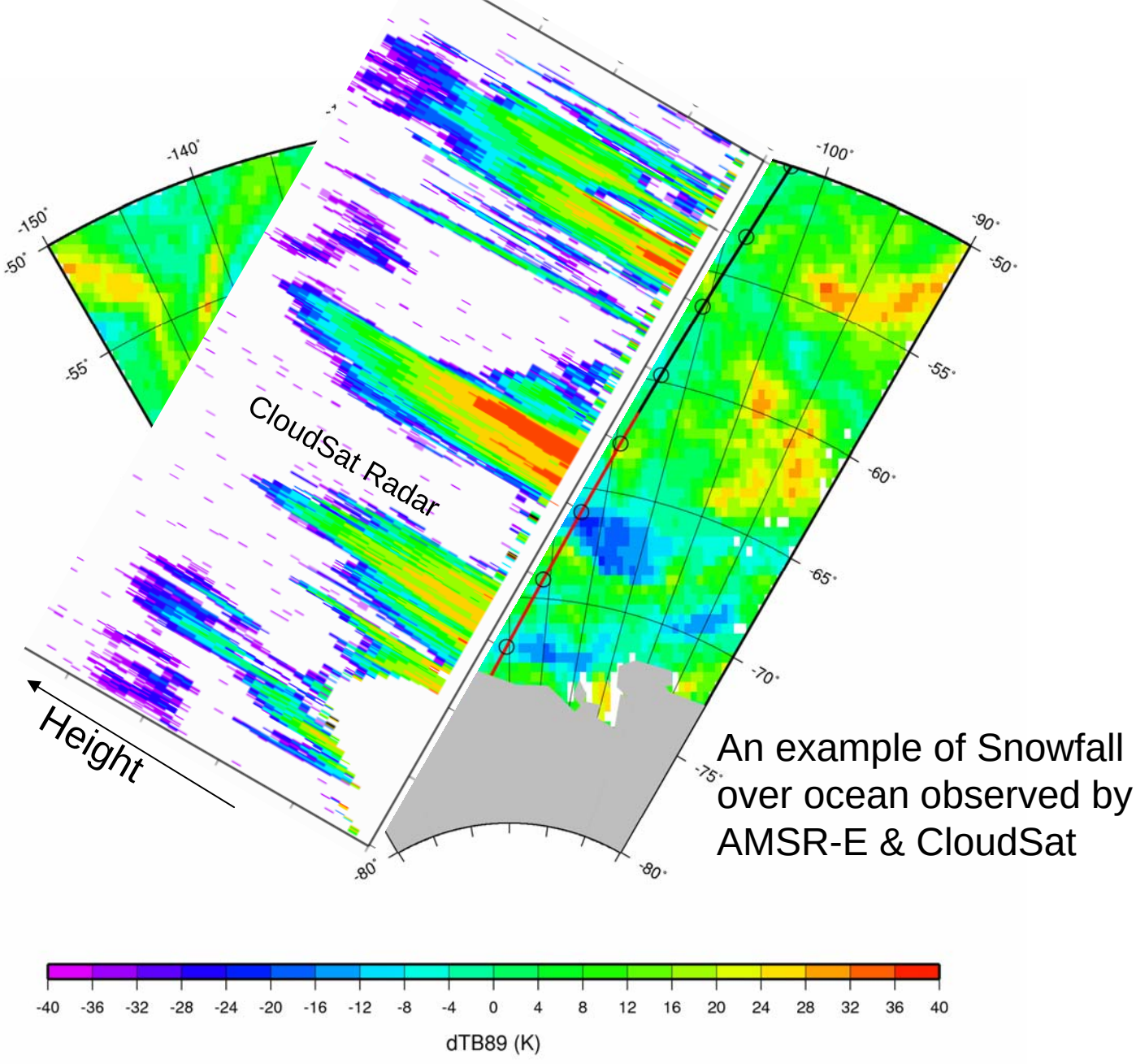
“Decide” whether or not it is a snowfall environment (not a rainfall …)



- Land: Surface station data 1997.03 – 2007.02 (NCAR DS464.0)
- Ocean: ICOADS 1995.01 – 2007.05 (NCAR DS540.0)

- Totally liquid precip $T_{A}surf > 5$ ºC
- Totally solid precip $T_{A}surf < -2$ ºC
- 50% line around 2 ºC
- Sharp change within 5-degree range (-1 ºC to 4 ºC)
- Similar pattern for land and ocean

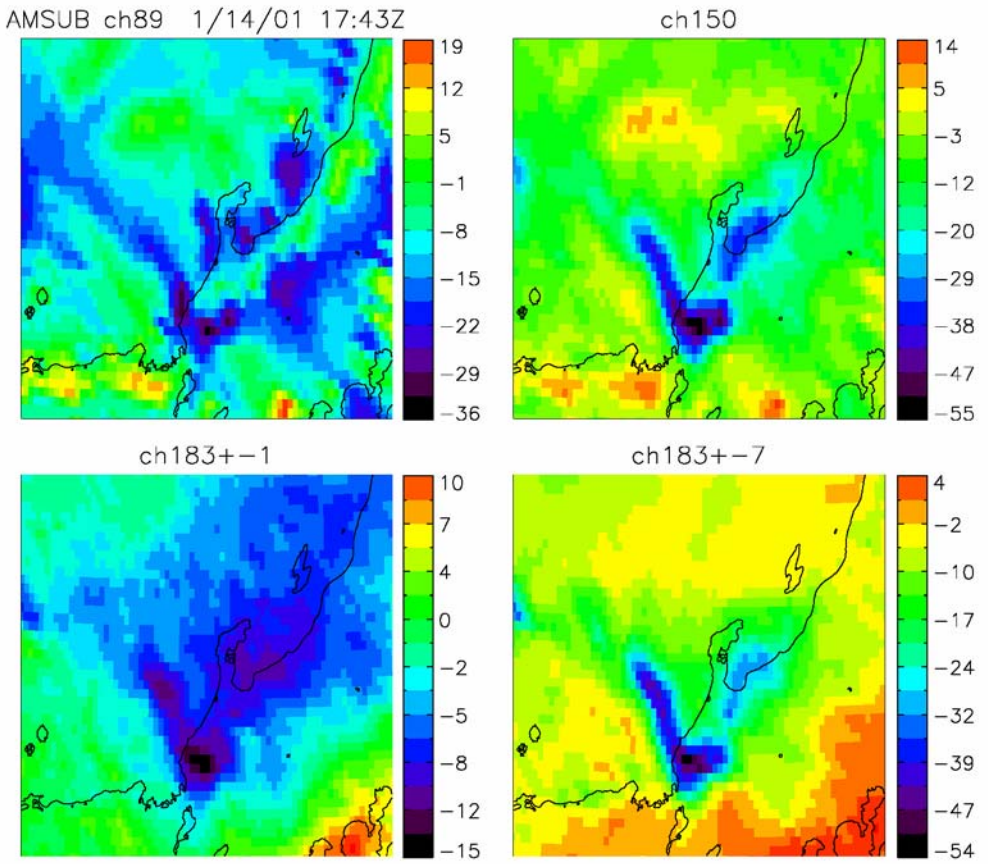
Use 2ºC Air Temp at 2 m (ECMWF analysis) to separate rain and snow



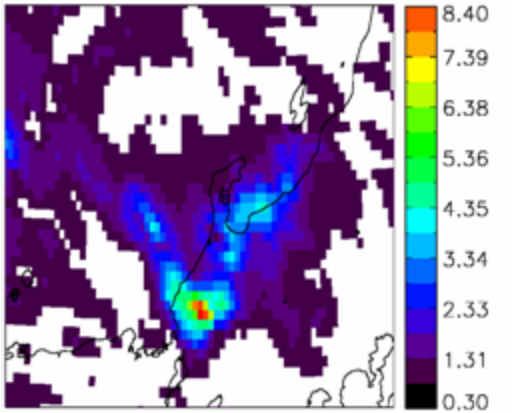
An example of Snowfall over ocean observed by AMSR-E & CloudSat

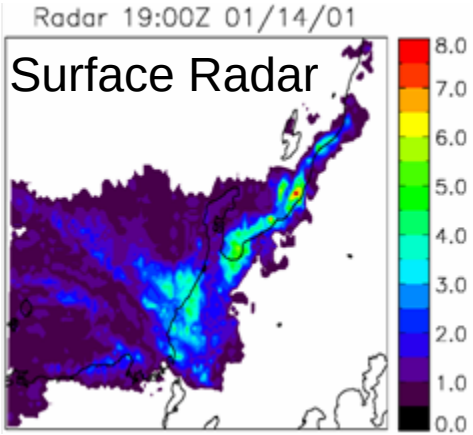
Examples of Snow Retrieval over Ocean

AMSU-B OBS

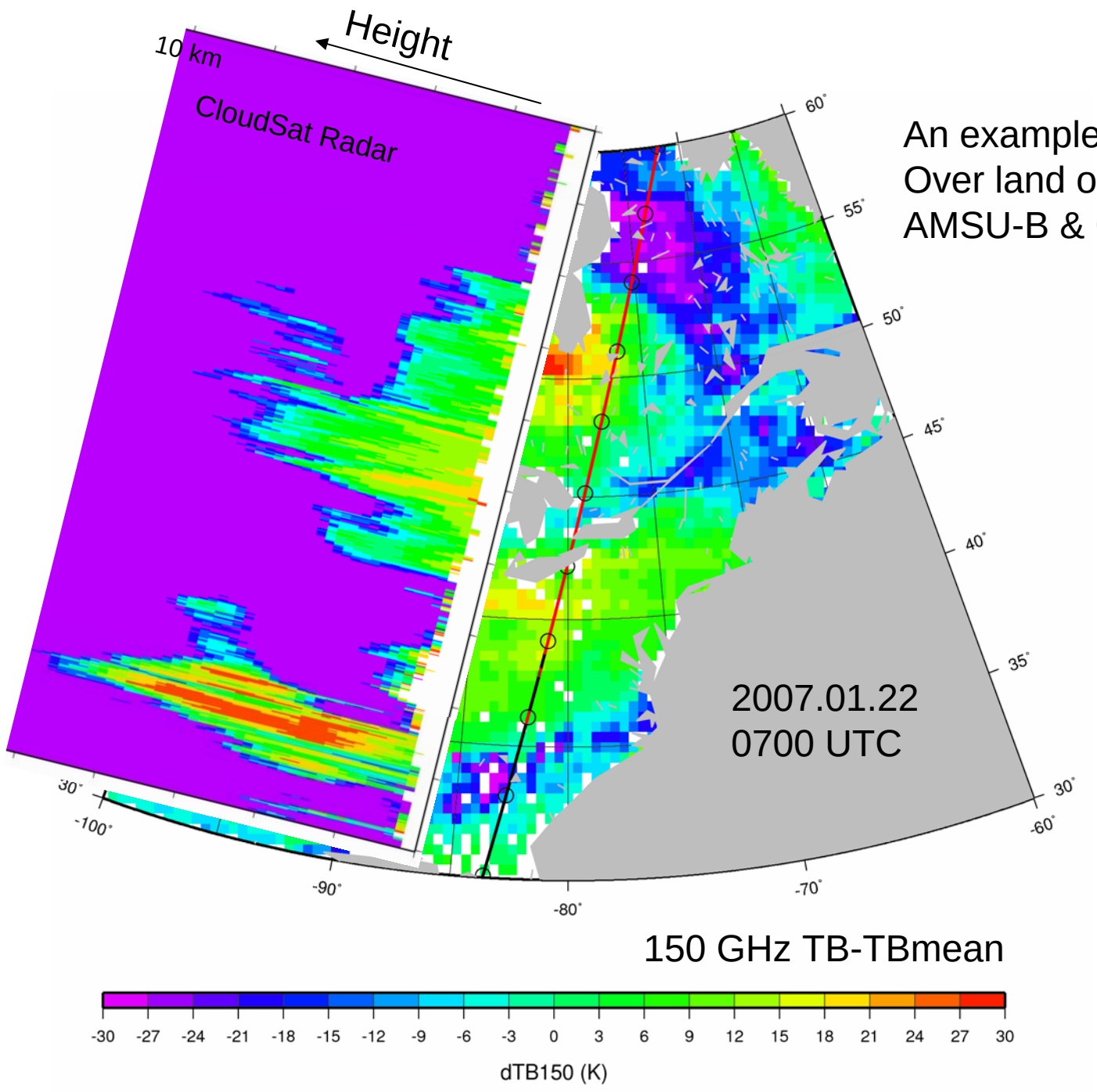


Satellite Retrieval



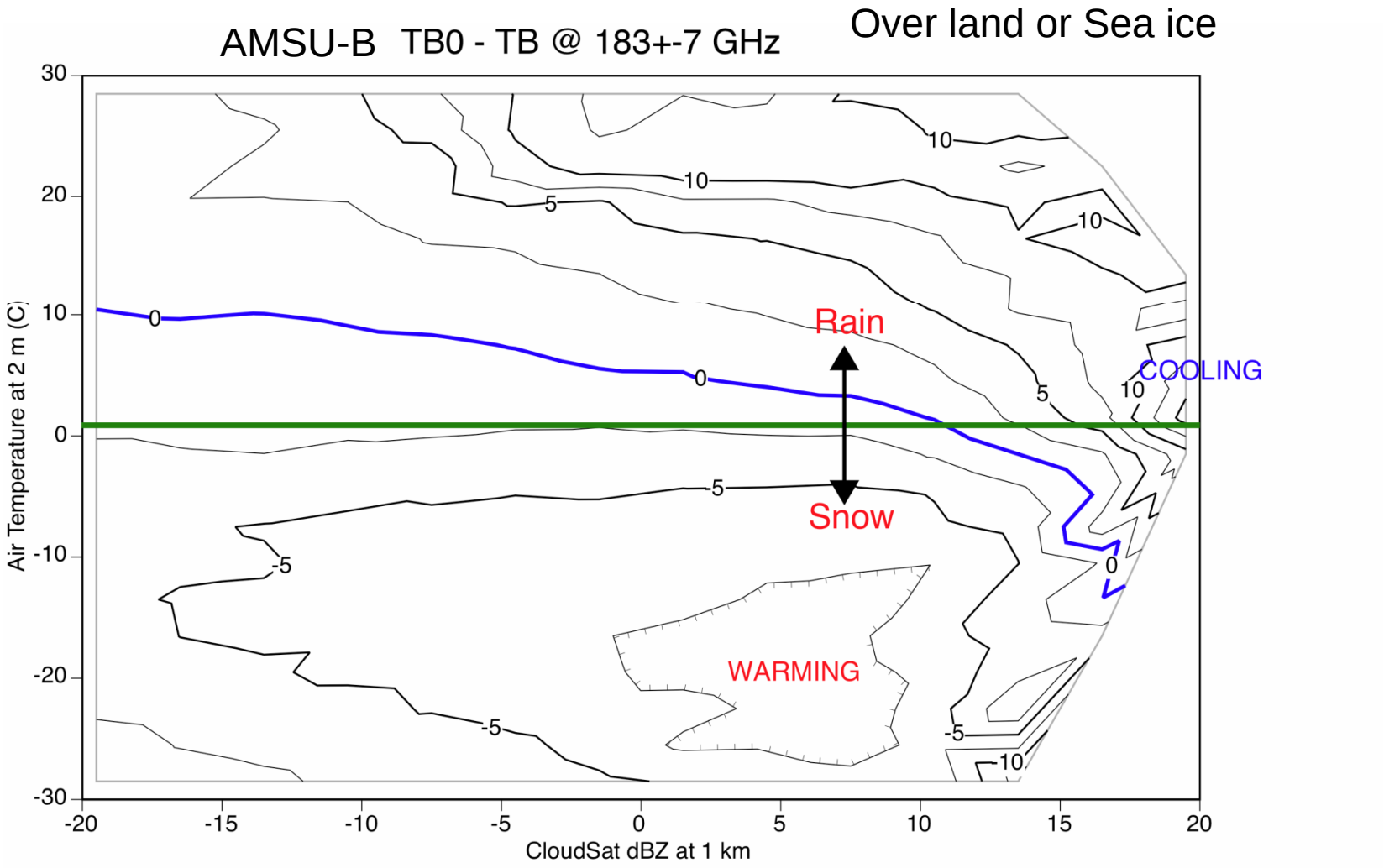


Noh et al. 2006 JGR

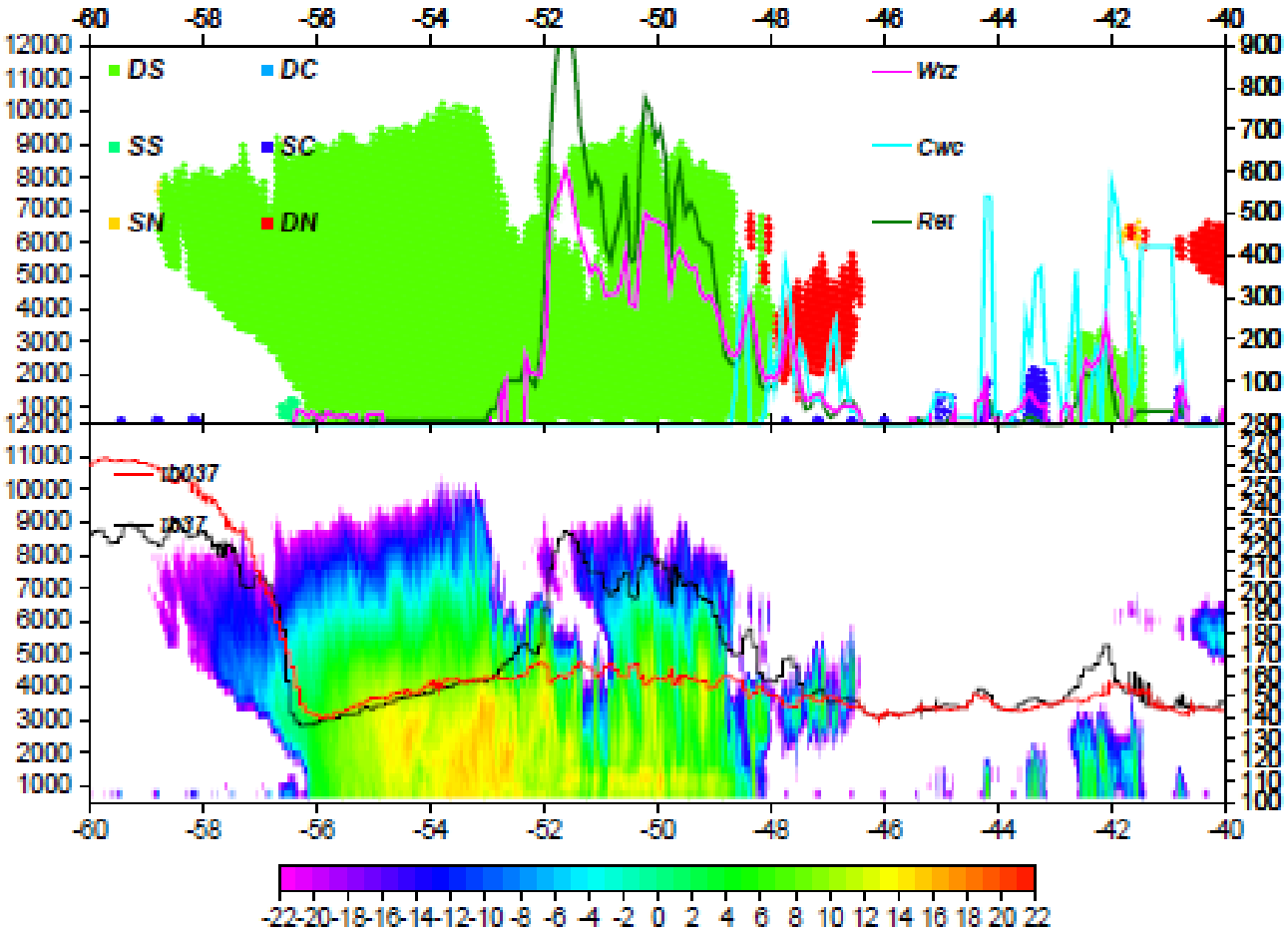


An example of snowfall
Over land observed by
AMSU-B & CloudSat

176 GHz TB's Response to Snowfall



Cloud Liquid Water



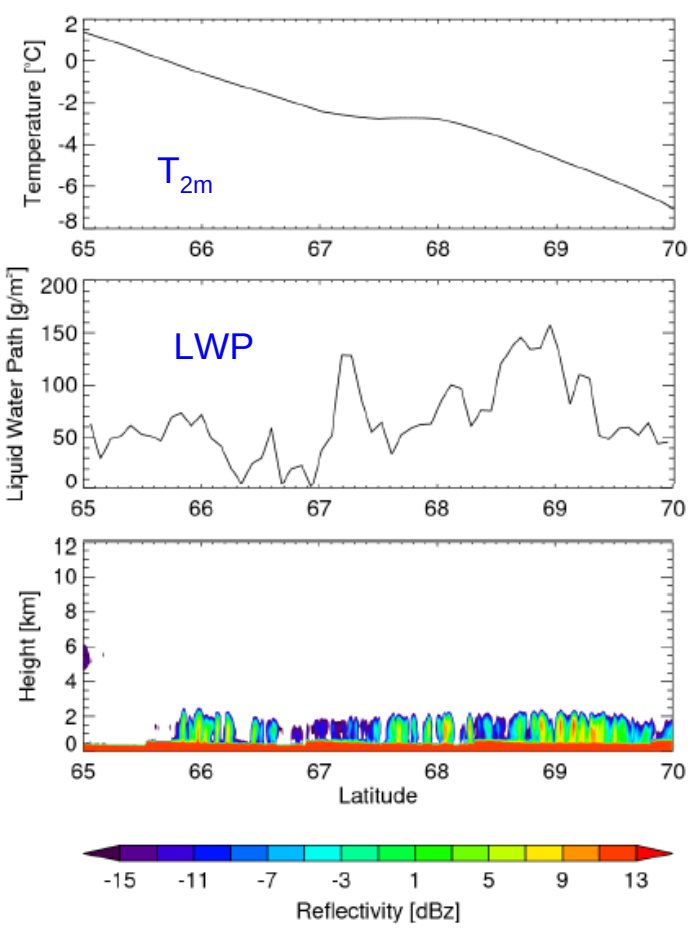
LWP

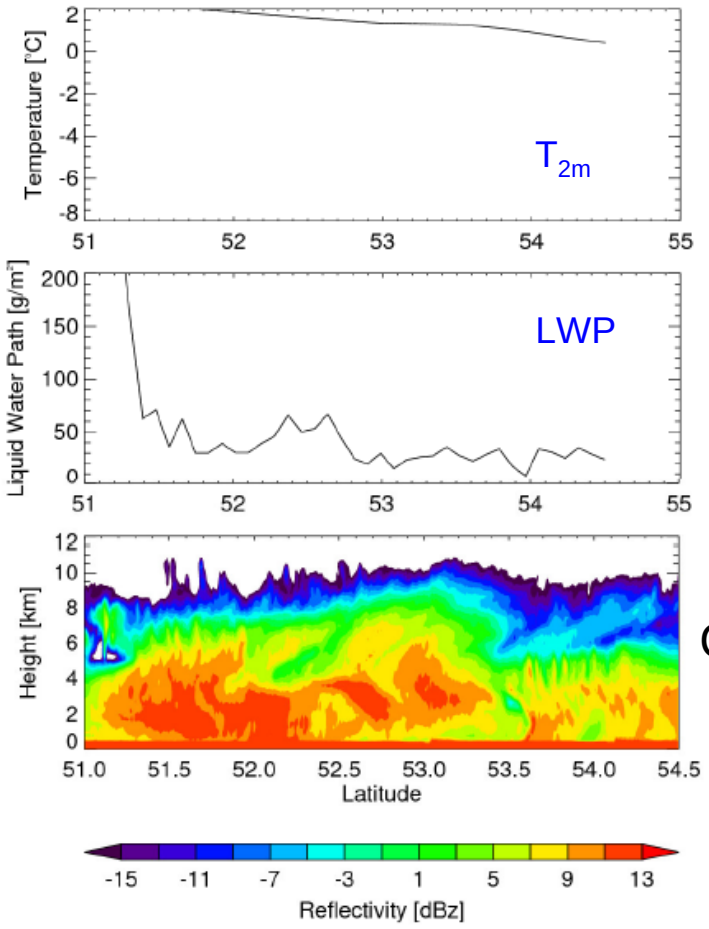
g m^{-2}

T2m<2C

CloudSat dBZ & AMSR-E LWP

Liquid Water in Snow Clouds



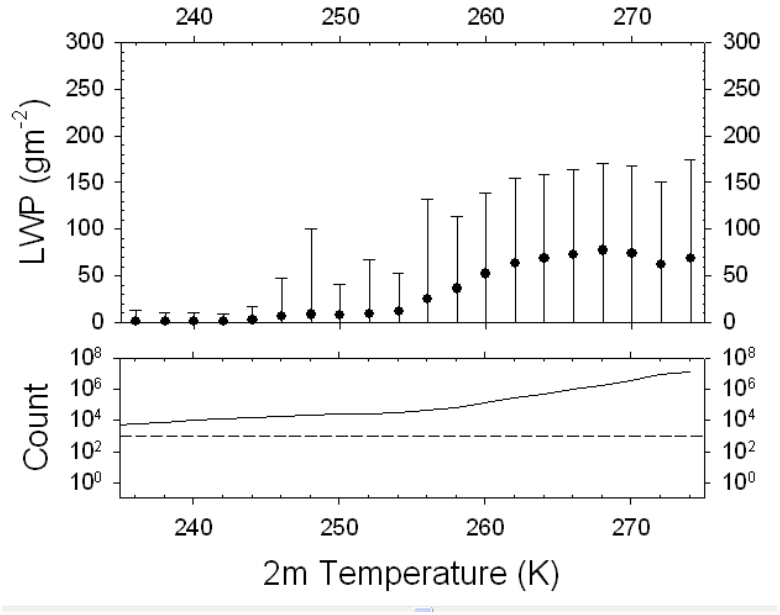


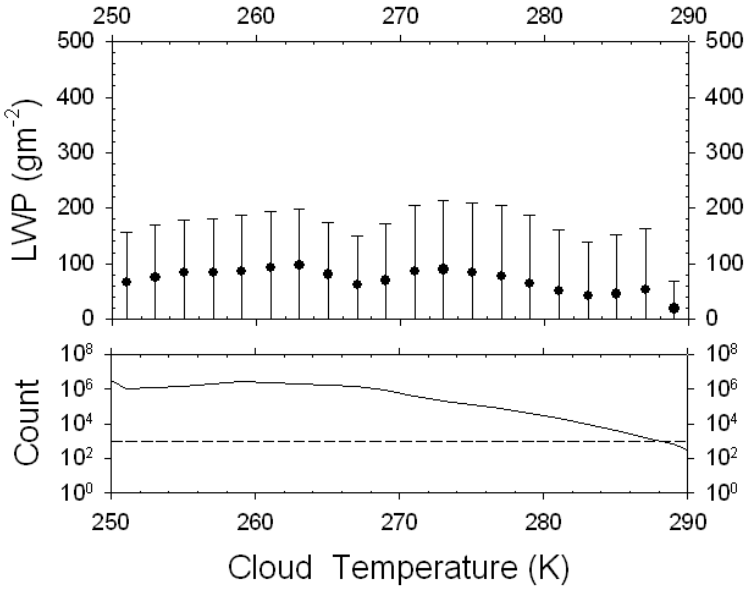
ECMWF

AMSR-E

CloudSat

Cloud Water in Snow Clouds
- in relation to temperature based on 4-year data



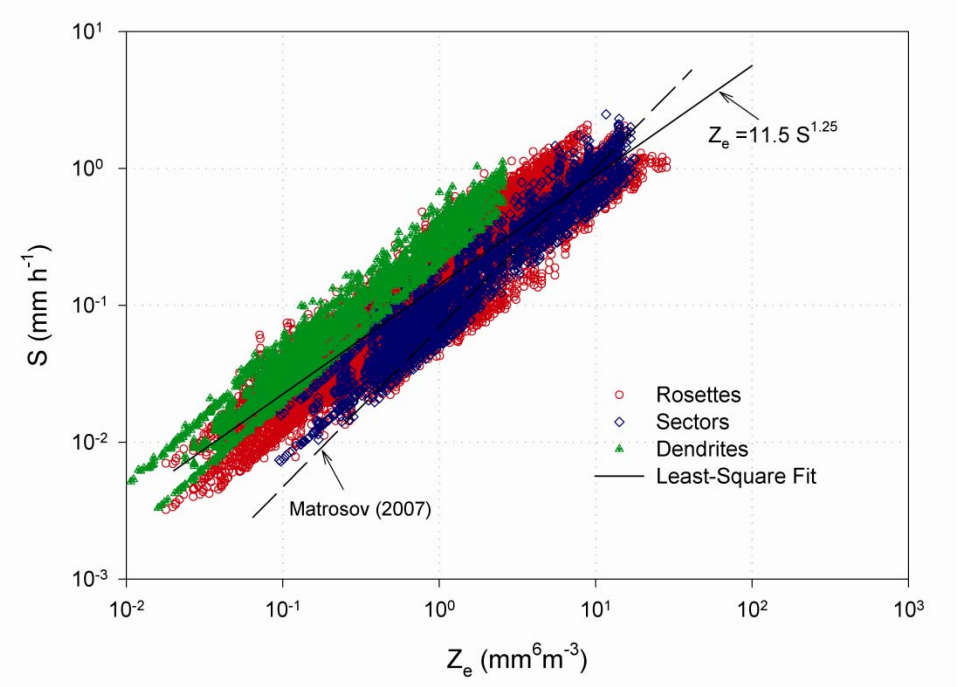


- When surface is warmer, snow clouds tend to have more liquid.
- However, this does not translate to “warmer clouds having more liquid”.

From Z to S
- need more works

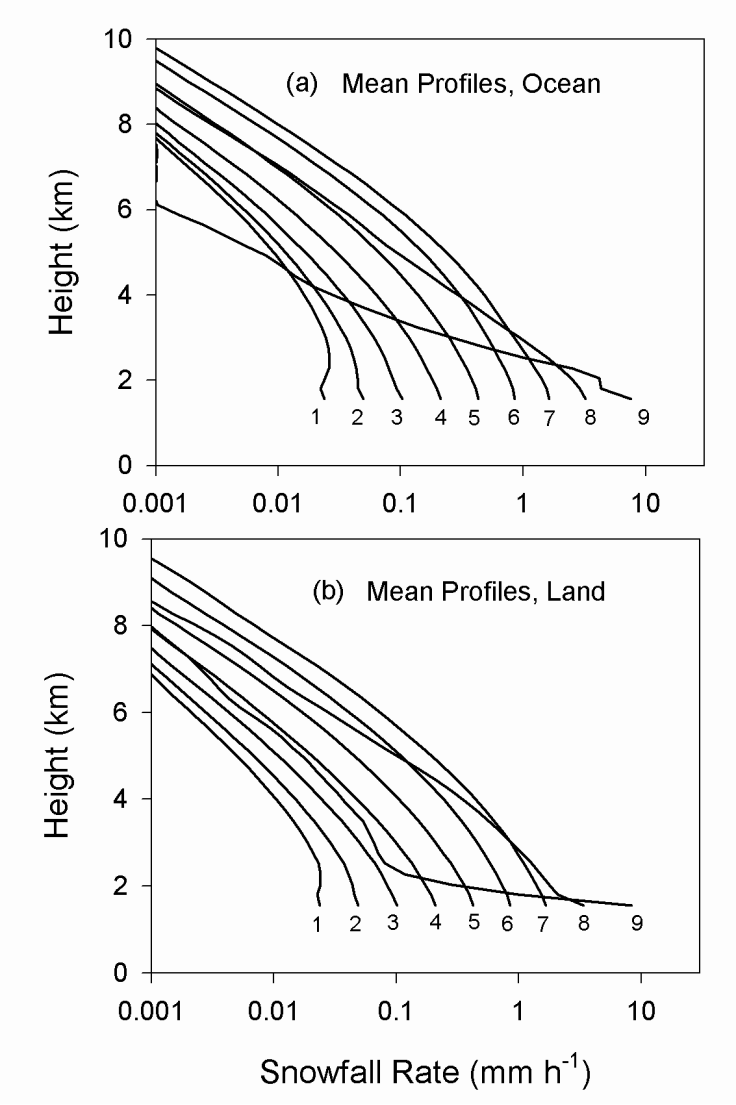
- CloudSat Radar: 94 GHz
  - spherical approximation for backscattering unacceptable

- *Present Study*:
  - six idealized shapes (Liu, 2004)
    - 3-,4-,5-,6-bullet rosettes
    - sector
    - dendrite
  - size distributions from field obs
    - Lo and Passarelli, 1982
    - Braham, 1990
  - random orientation
  - DDA simulations



Further improvements are being studied

Mean Snowfall Profiles
- grouped by surface snowfall rate

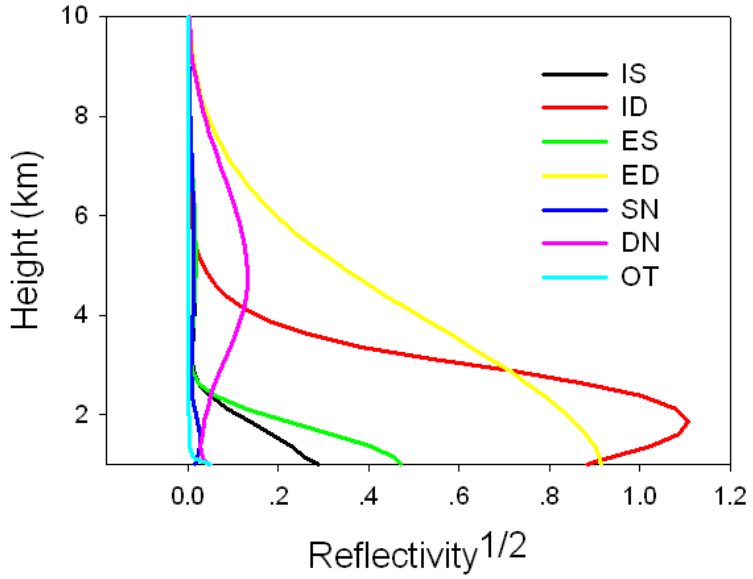


- Given a surface snowfall rate, how do the mean profiles look like ?

- Deeper snow layers for heavier surface snowfall, UNTIL snowfall rate reaches a few mm h^{-1}; BUT the two profiles for the heaviest snowfall reverse this trend:

➢ the shallow snow events produce the heaviest surface snowfall?

Vertical Profiles of Snow Clouds



IS: Isolated Shallow Clouds

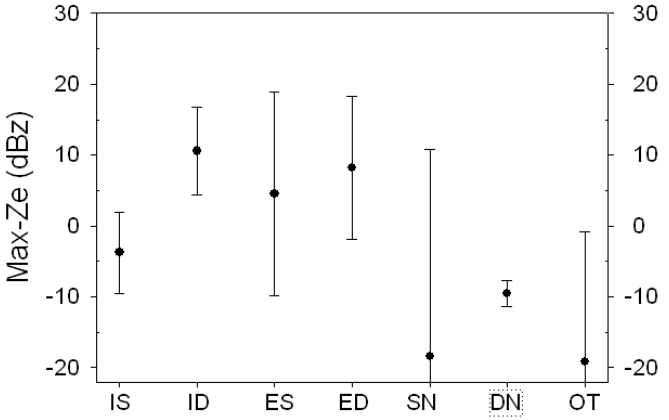
ID: Isolated Deep Clouds

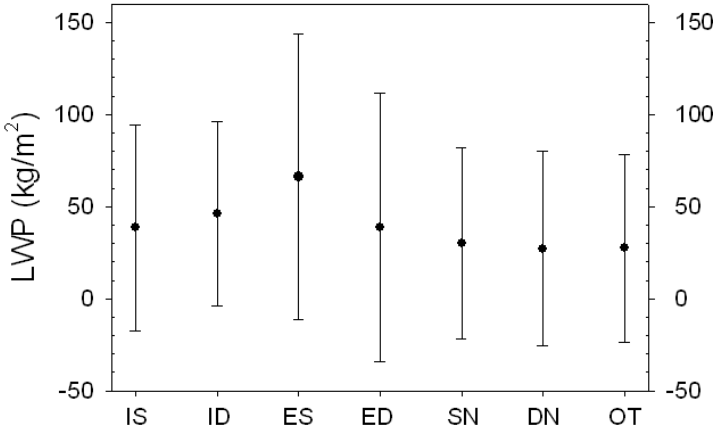
ES: Extended Shallow Clouds

ED: Extended Deep Clouds

Isolated: < 40 km, otherwise Deep

Shallow: < 3.2 km, otherwise Extended





Conclusions

- Substantial Liquid water in snowing clouds, which complicates snow detection/retrieval by passive microwave, particularly over land where polarization info can not be used
- Liquid water amounts depend on cloud types (e.g., warm or cold front); Over average, more liquid for warmer atmosphere, but it does not seem to have a systematic relation with cloud temperature
- Synoptic deep snow clouds: deeper cloud → heavier snowfall

  Isolated convection (e.g., lake-effect snow): very heavy snow but having a very shallow layer ← challenge for snow detection/retrieval