Snowfall Detection and Retrieval from Passive Microwave Satellite Observations

Guosheng Liu

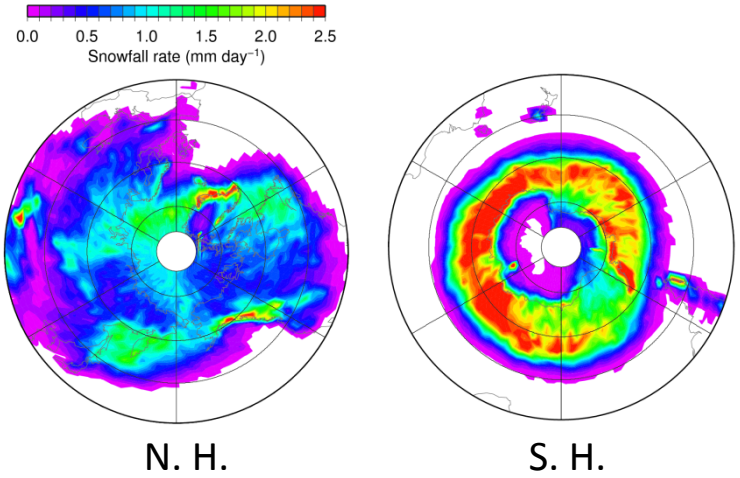
Florida State University

Collaborators: Eun-Kyoung Seo, Yalei You

Snowfall Retrieval: Active vs. Passive

CloudSat CPR:

- High Sensitivity (-30 dBZ), Able to most snow events
- Able to derive vertical distribution
- Lack of spatial/temporal coverage (1.5 km curtain)



Snowfall "climatology" derived from 4.5 years of CloudSat CPR data (2006.7-2010.12), based on Liu (2008)

High-Frequency Passive Microwave:

Satellite sensors w/ high frequency microwave observations

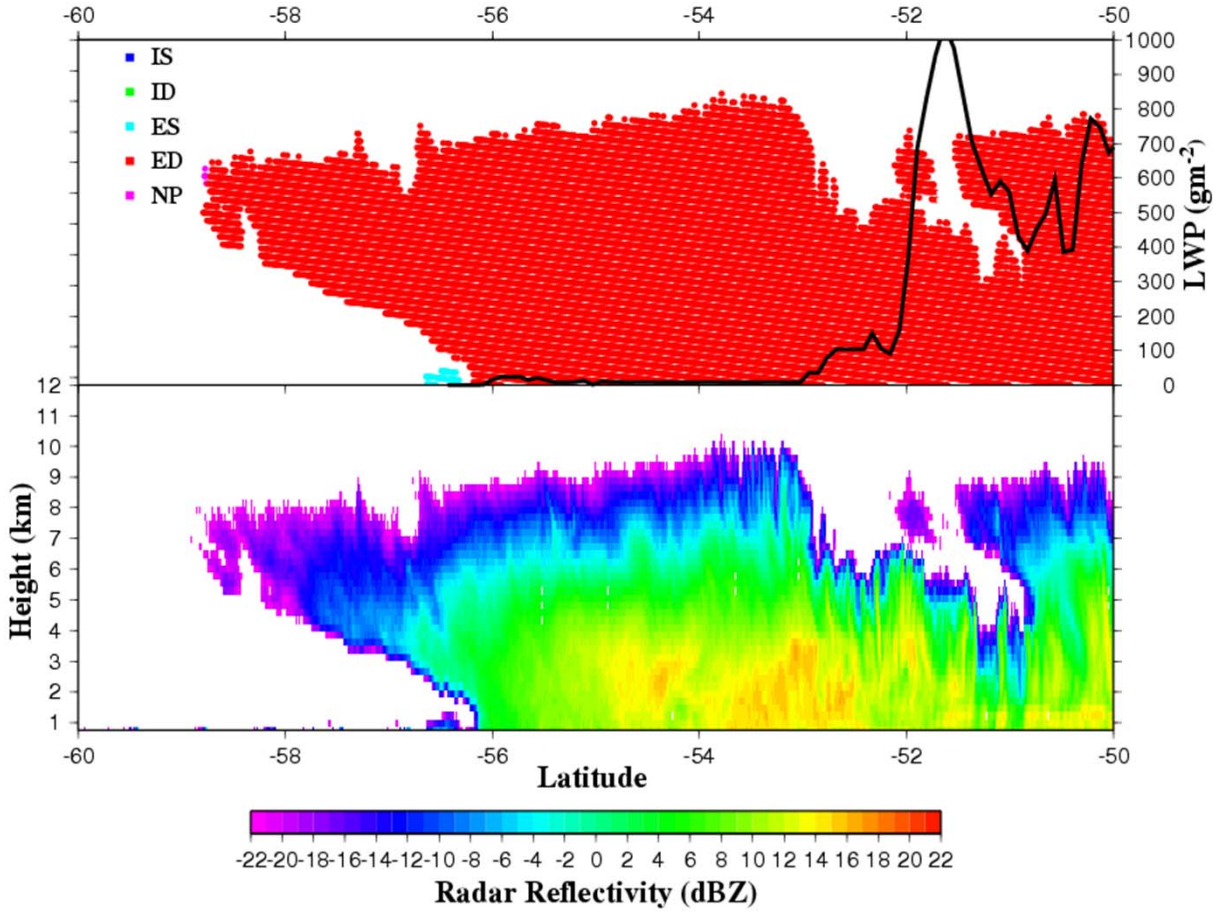
Satellite	*Sensor*	*Launch Date*
NOAA-15 (K)	AMSU-B	05/13/1998
NOAA-16 (L)	AMSU-B	09/21/2000
NOAA-17 (M)	AMSU-B	06/24/2002
NOAA-18 (N)	MHS	05/20/2005
NOAA-19 (N')	MHS	02/06/2009
EUMET-SAT MetOp-A	MHS	10/19/2006
DMSP F16	SSMIS	10/18/2003
DMSP F17	SSMIS	11/04/2006
DMSP F18	SSMIS	11/18/2009
NPP	ATMS	10/28/2011

AMSU-B: Advanced Microwave Sounder Unit – B
MHS: Microwave Humidity Sounder
SSMIS: Special Sensor Microwave Imager Sounder
ATMS: Advanced Technology Microwave Sounder

- Low sensitivity
- No established algorithm yet to detect/retrieve snowfall globally

➔ Merging Active with Passive

Cloud Liquid Water (08/26/2006)

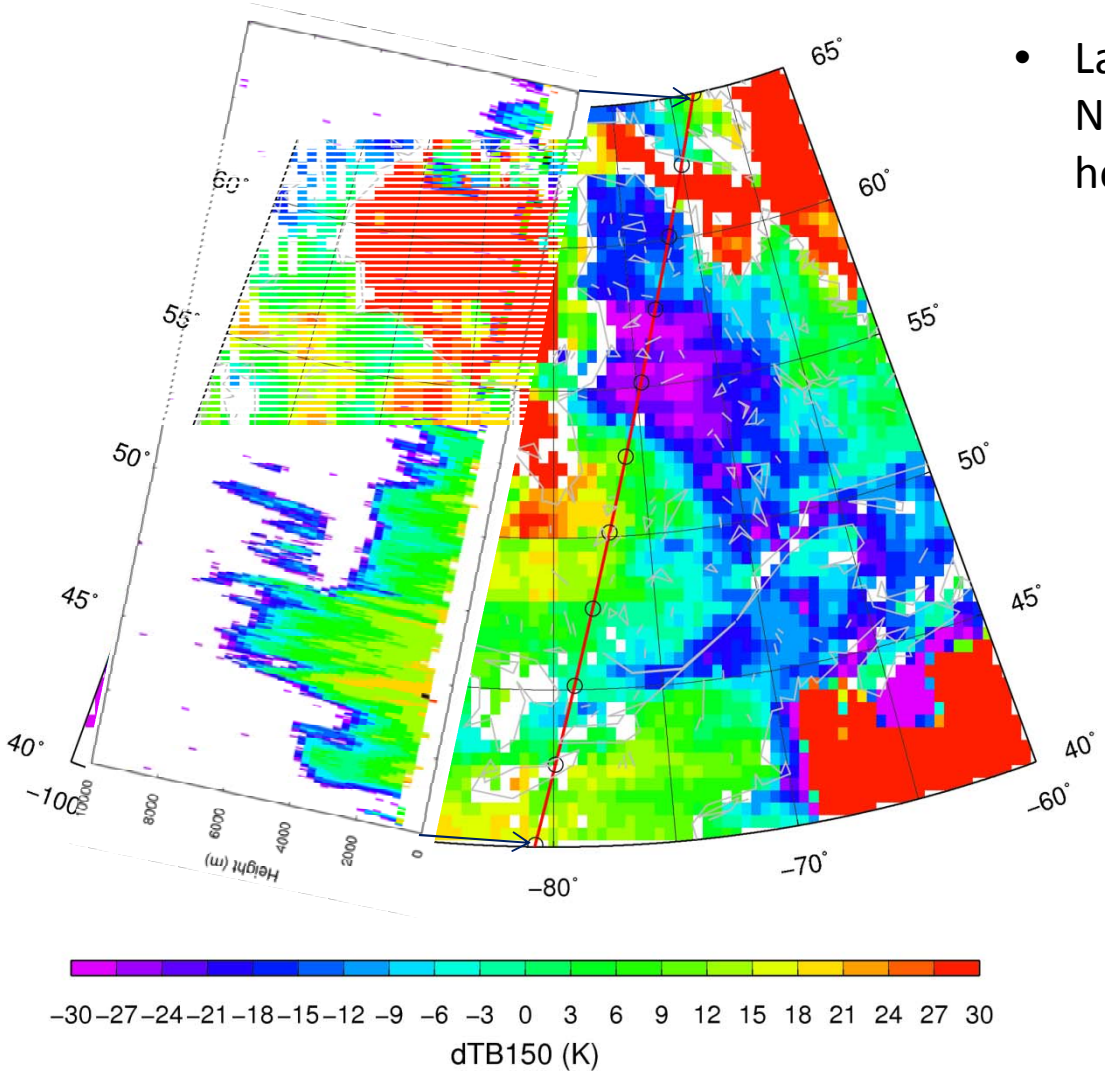


LWP

g m^{-2}

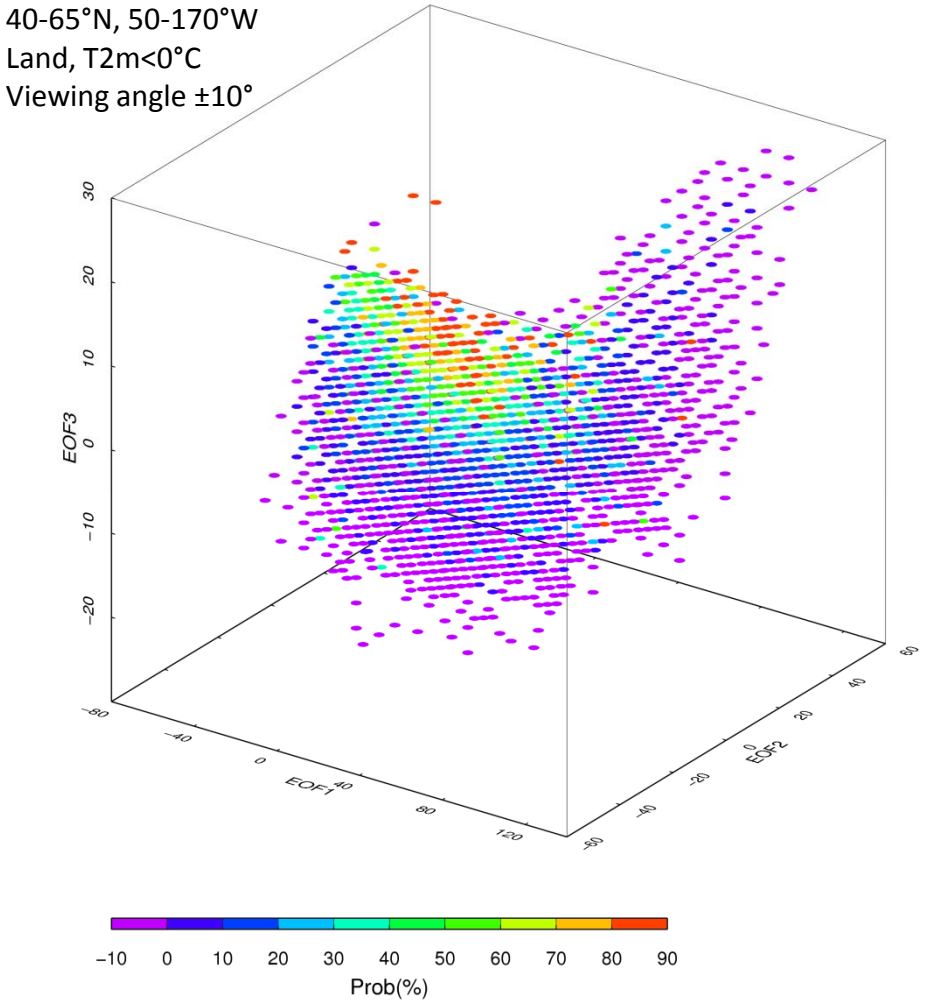
CloudSat dBZ & AMSR-E LWP

The Jan 22 2007 case w/CloudSat Over Pass



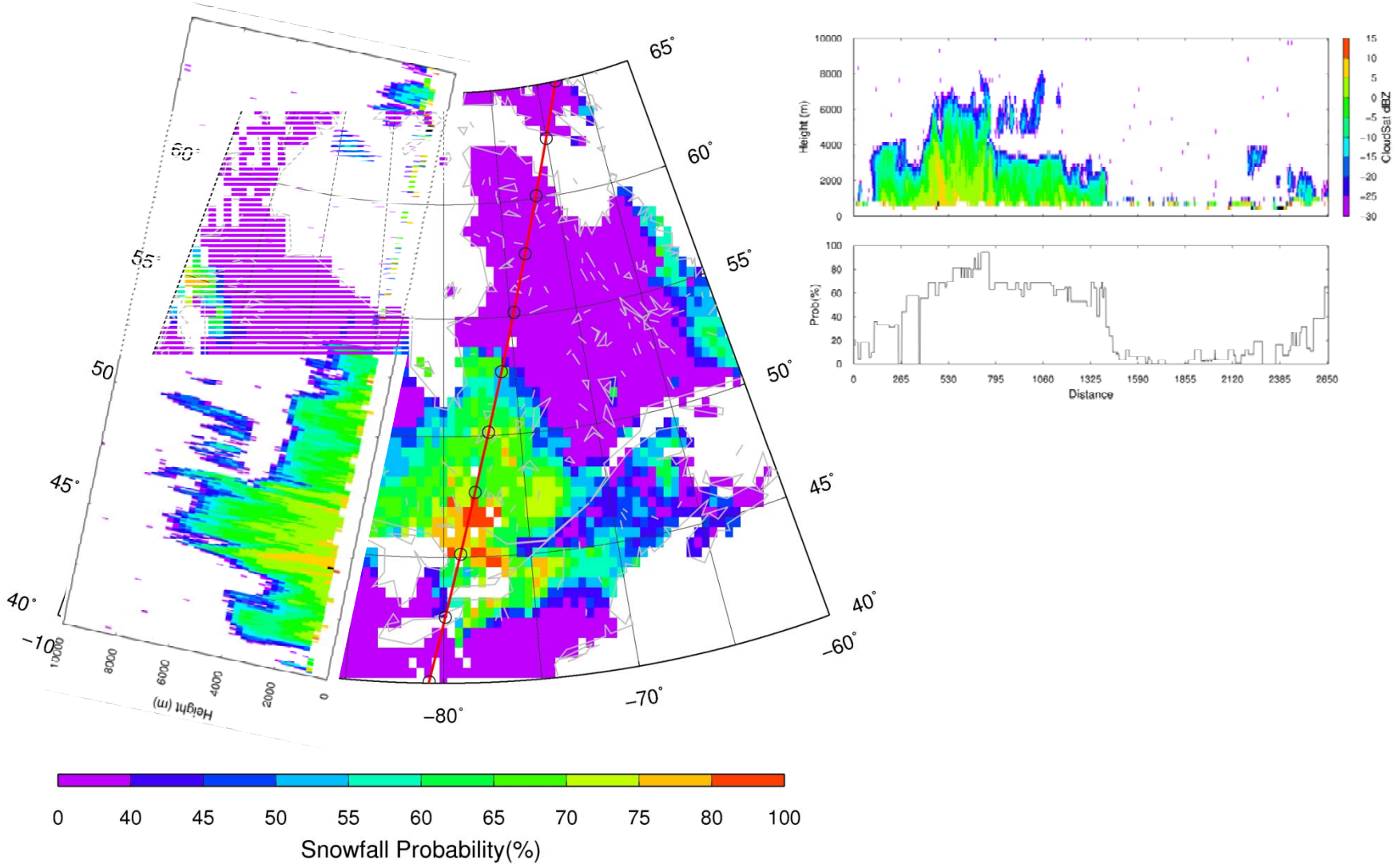
- Largest TB depression does NOT necessarily correspond to heavy snowfall
  - Why ?
    Scattering by snowflakes competes with emission from cloud liquid.

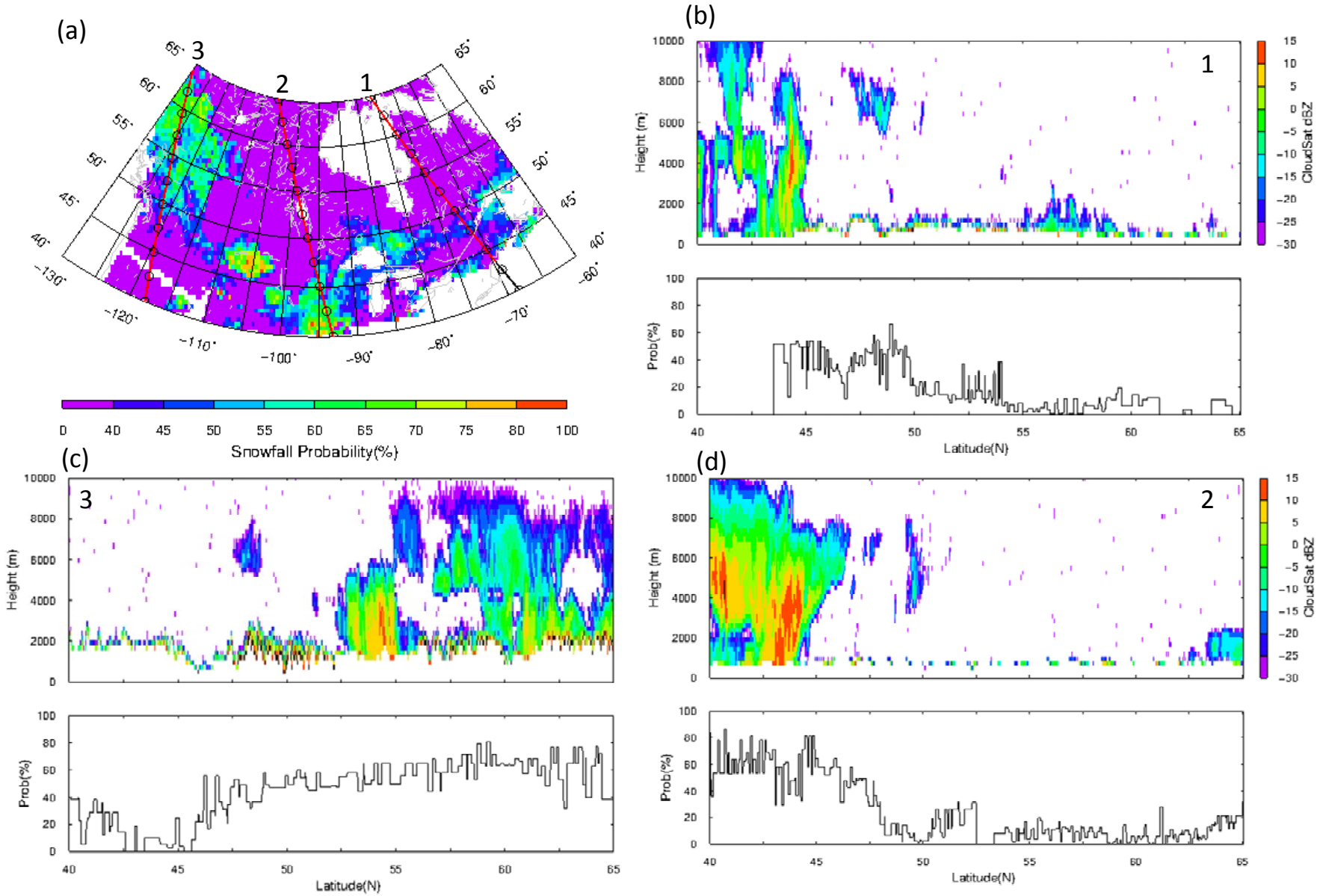
Lookup Table based on MHS-CloudSat Matchups – 4.5 years data, North America

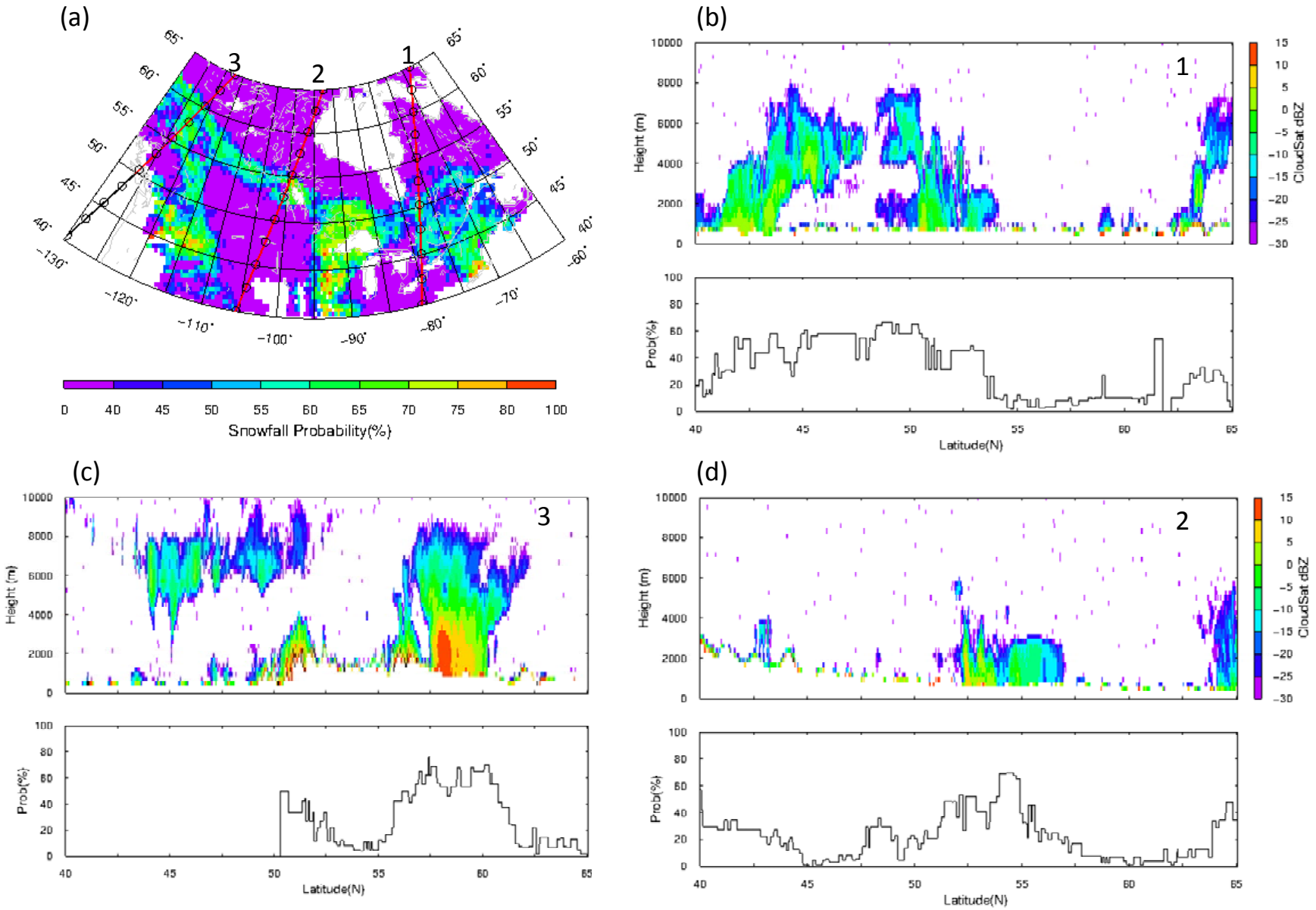


- EOF analysis to MHS data:
  - First 3 PCs – 88.6%, 8.2% and 2.1% of variances
  - PC3 had the best correlation Coeff to CloudSat reflectivity
- Lookup Table:
  - Project observed TBs to the first 3 PCs
  - In the 3-d EOF space, using MHS-CloudSat matchups, compute the probability of snowfall (CloudSat 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

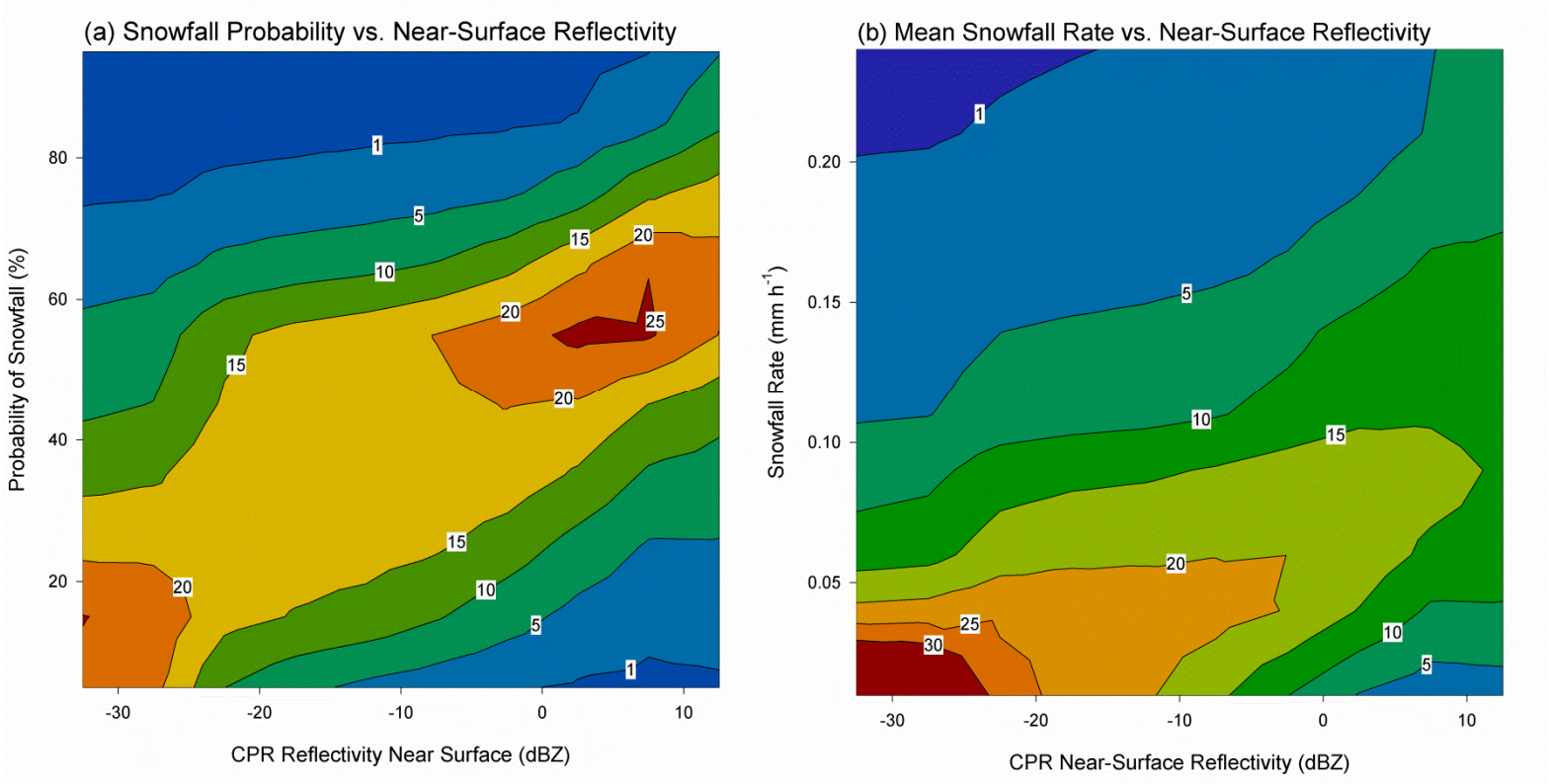
Apply to C3VP Case – 2007.1.22




(a)
3
2
1
0 40 45 50 55 60 65 70 75 80 100
Snowfall Probability(%)
(b)
1
Height (m)
Prob(%)
Latitude(N)
CloudSat dBZ
(c)
3
Height (m)
Prob(%)
Latitude(N)
(d)
2
Height (m)
Prob(%)
Latitude(N)
CloudSat dBZ


(a)
3
2
1
Snowfall Probability(%)
(b)
1
Height (m)
Prob(%)
Latitude(N)
CloudSat dBZ
(c)
3
Height (m)
Prob(%)
Latitude(N)
(d)
2
Height (m)
Prob(%)
Latitude(N)
CloudSat dBZ

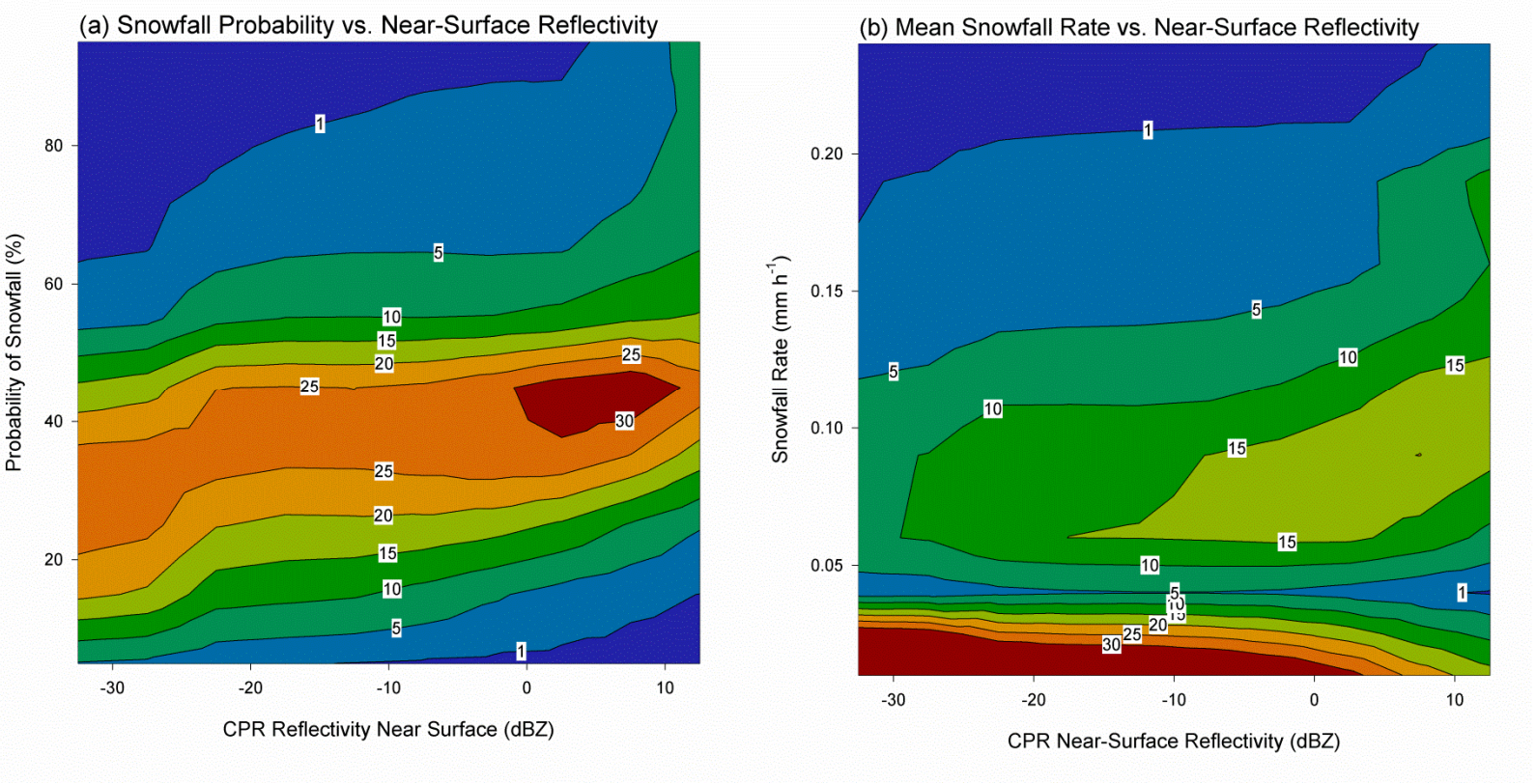
CloudSat vs. MHS – Global/MultiYear



Collocated CloudSat and AMSR-E Data

- 2006.06-2010.12, global
- Select snow-possible data points: T_{2m}<0C
- Similarly to the AMSU-B/MHS + CloudSat analysis, use the leading 3 EOFs to generate snowfall probability/rate look-up-tables, and perform retrievals

CloudSat vs AMSR-E

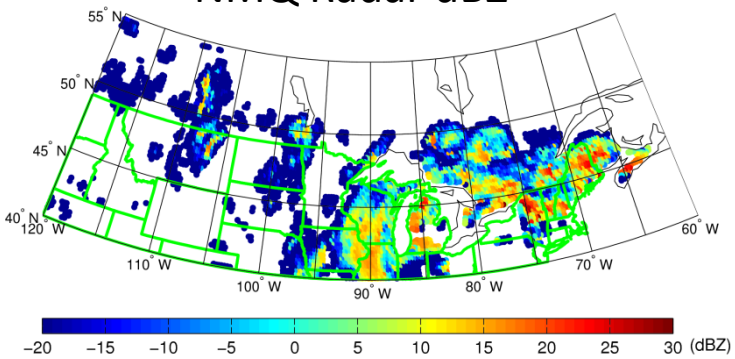


What are the best frequency-combinations for snowfall retrieval ?

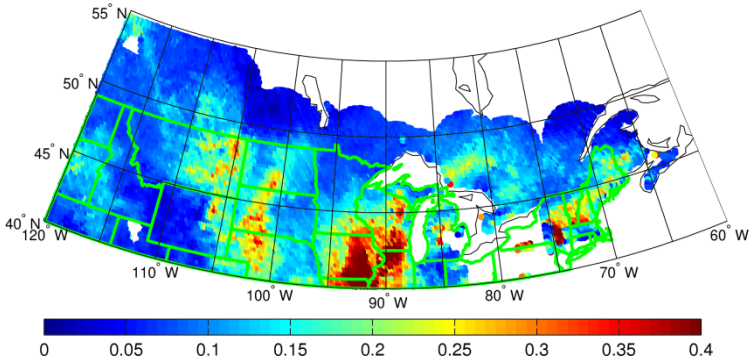
- Collocate SSMIS and NMQ
  - SSMIS: 19, 22, 37, 50-60, 92, 150, 183±1,3,7 GHz
  - NMQ: U.S.+Canada Radar networks
  - MERRA: reanalysis
- Select cold-only (T_{2m}<0°C) dataset, Create snow probability lookup table
- Analyze the correlation between retrieved vs. observed snowfall probability

Case Study: NMQ radar vs. SSMIS retrievals
- use different number of channels

NMQ Radar dBZ

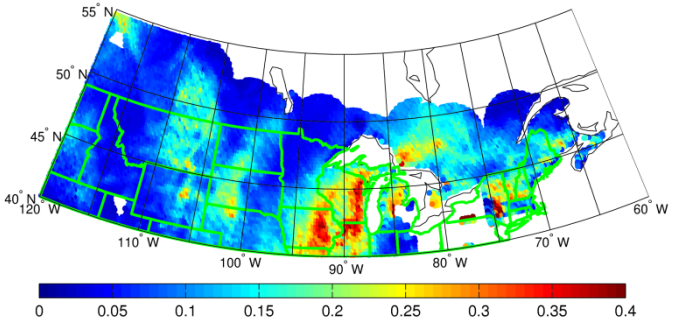


Snow Prob by 11 SSMIS channels

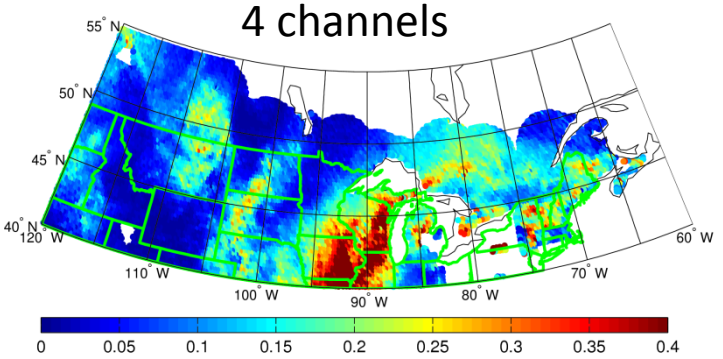


Snowfall probability

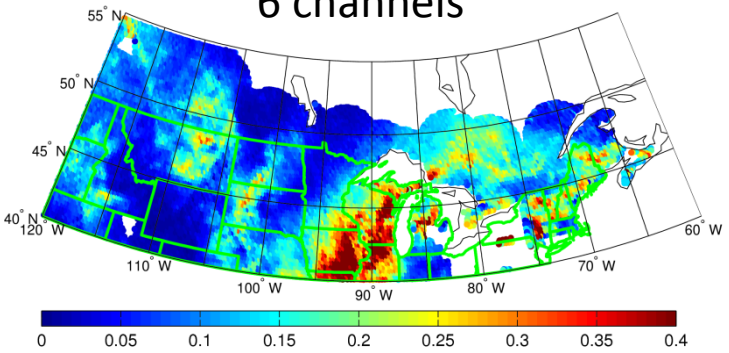
Use 2 channels (37 & 183±3 GHz)



4 channels

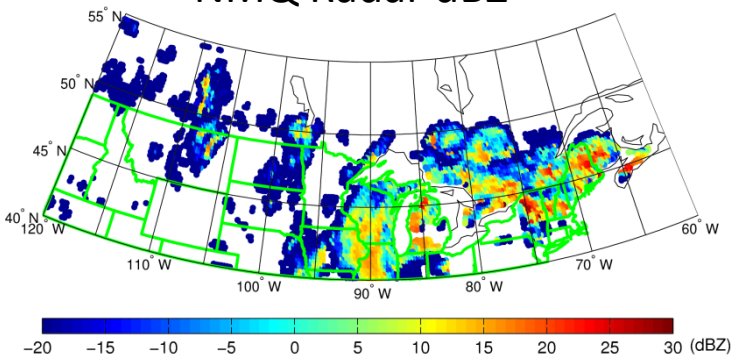


6 channels

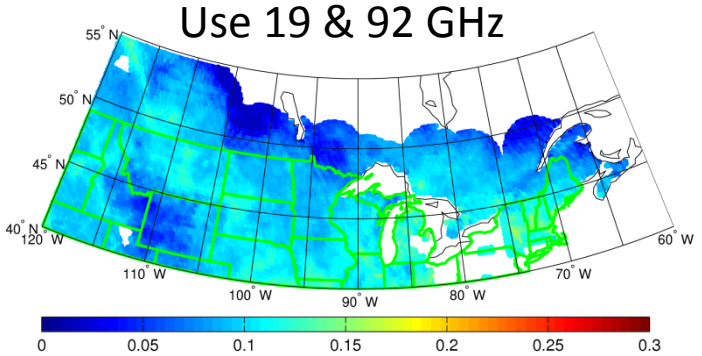


Case study: 2-channel combinations

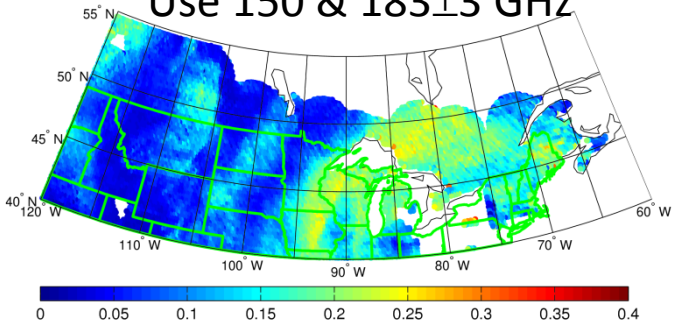
NMQ Radar dBZ



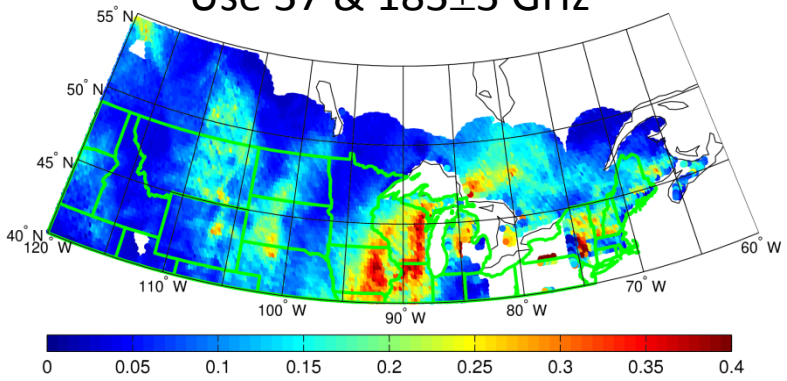
Use 19 & 92 GHz



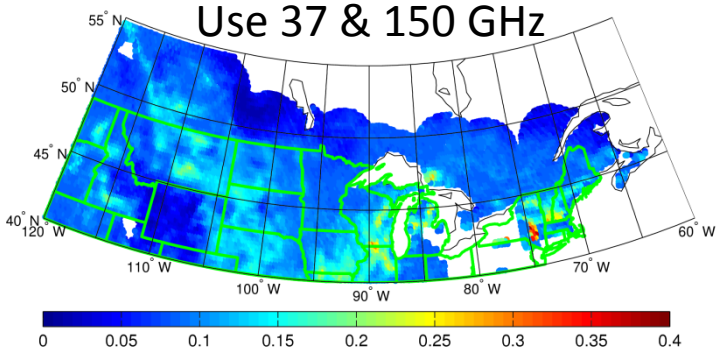
Use 150 & 183±3 GHz



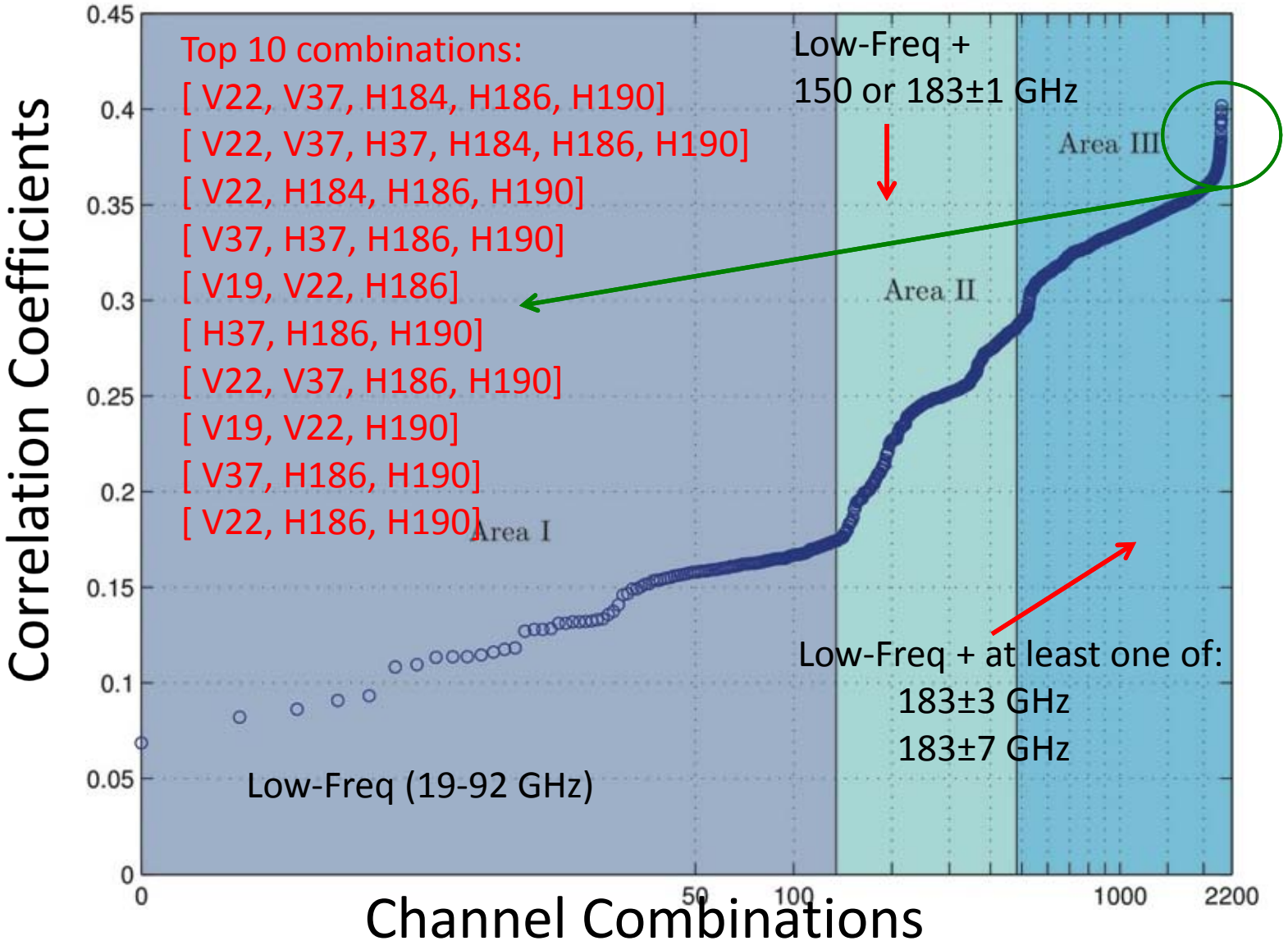
Use 37 & 183±3 GHz



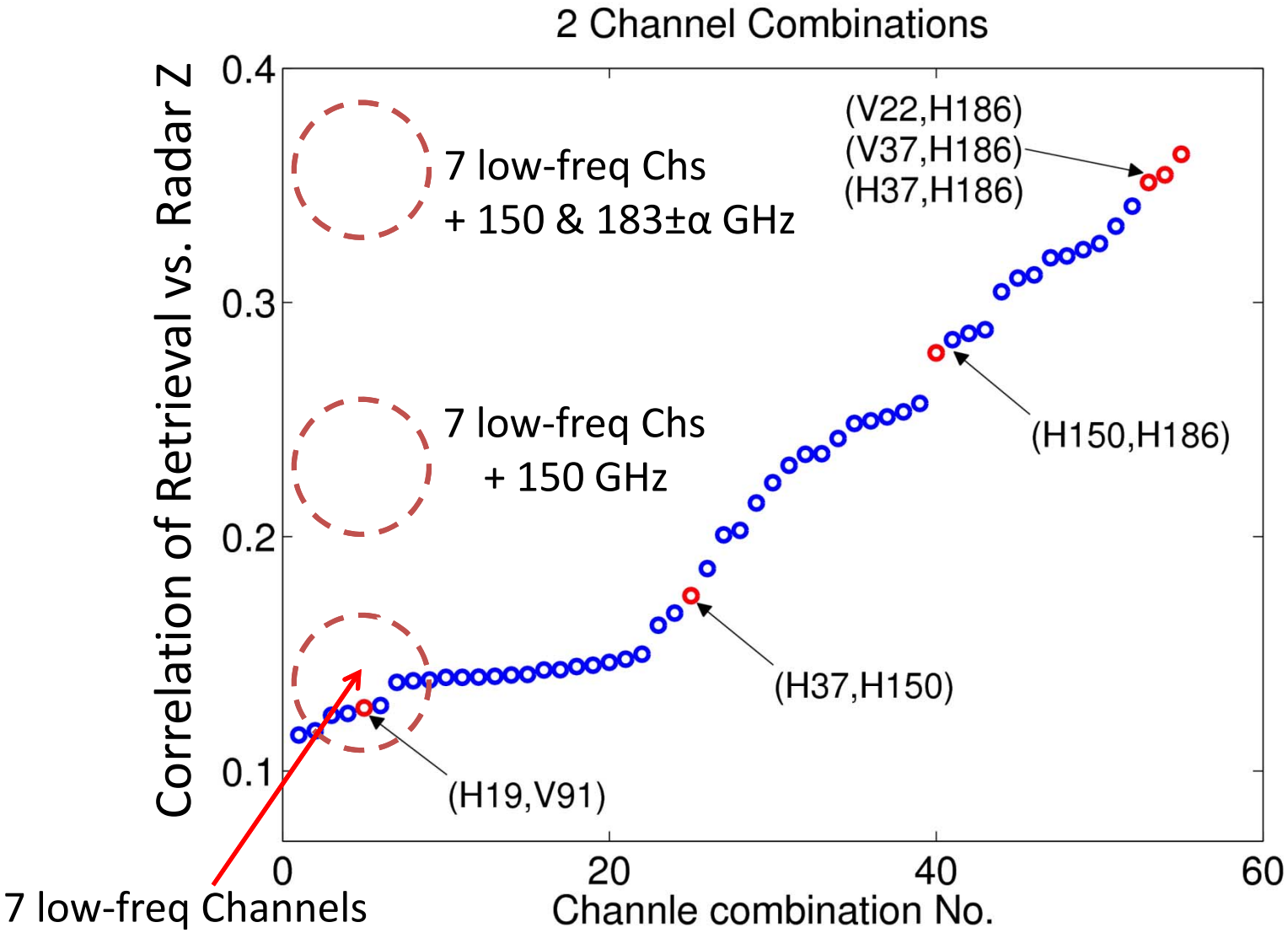
Use 37 & 150 GHz



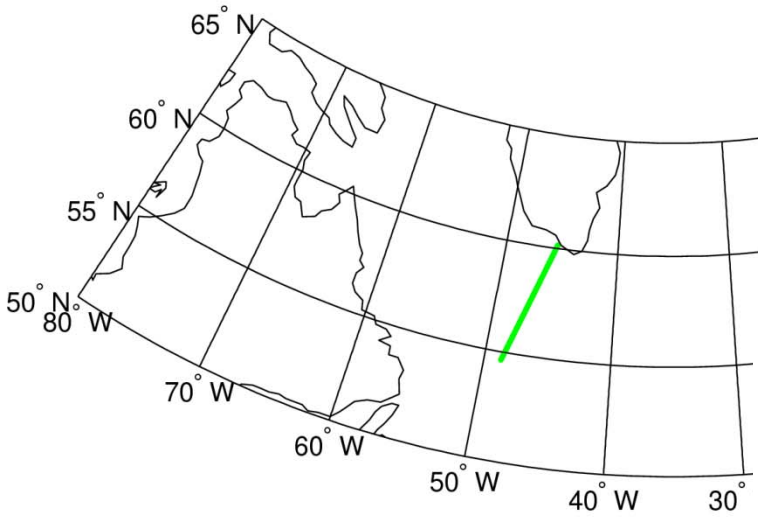
Correlation between NMQ Radar and SSMIS snow-probability retrieval for different 2-to-6-channel combinations

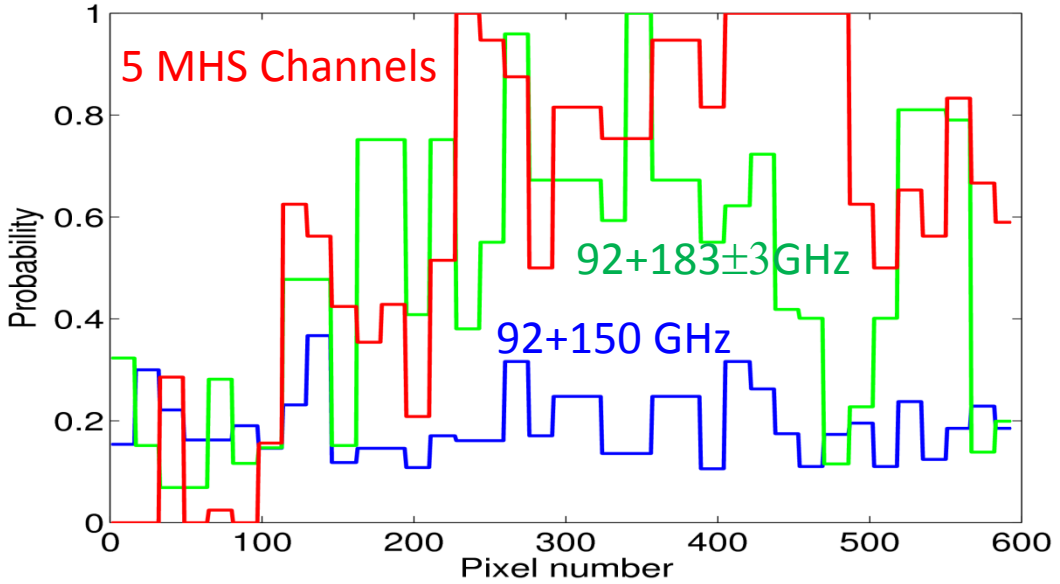


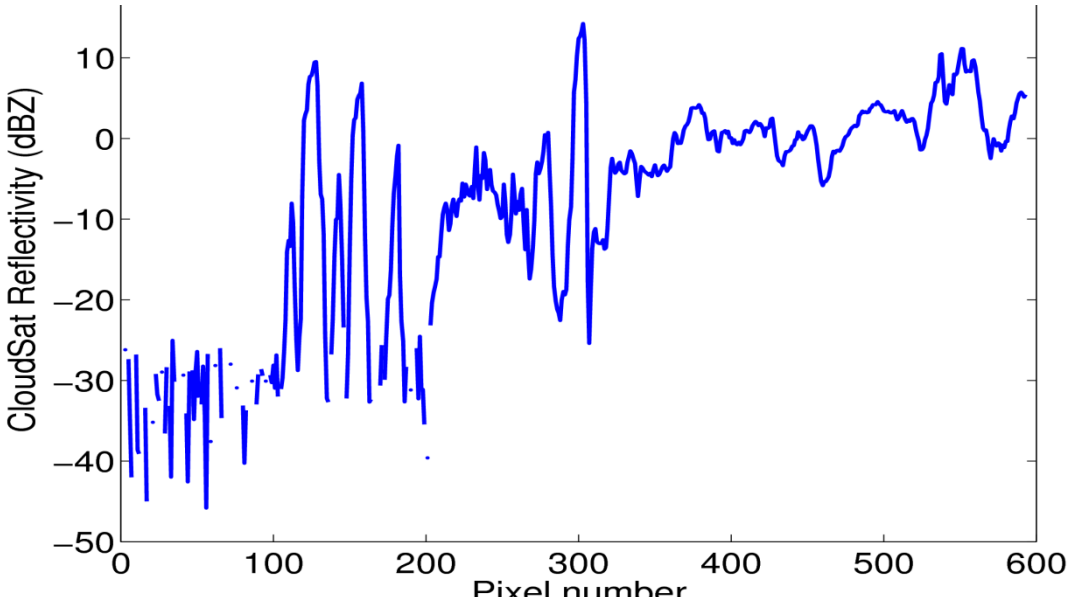
Which channels contain the most info



A MHS vs. CloudSat Case







150 vs. 183±3 GHz

- Fact: 183±3 GHz worked better than 150 GHz in snowfall retrieval
- Interpretations
  - Inferring snowfall by water vapor info
  - Water vapor masking surface variations
- A test using data only from a 5°x5° ocean area (less surface variation) showed the difference between using 150 GHz and using 183±3 GHz is small (still working on this)
  - Masking effect is important!

Important Findings

- With right frequency combinations, passive microwave satellite observations have the ability to estimate snowfall
- Low frequency observations alone, such as AMSR-E/2, are not enough
- Best frequency combinations are: low (19/22/37GHz) plus high (>150 GHz) channels; High-frequency channels alone (such as AMSU-B/MHS), while reasonably works, are also less favorable
- Between 150 and $183\pm\alpha$ GHz channels, $183\pm\alpha$ is preferable, since it (1) has scattering signal and (2) masks surface-induced variations

Microwave Sensing of Cloud & Precipitation