Solid Precipitation Retrieval Algorithm for AMSR3

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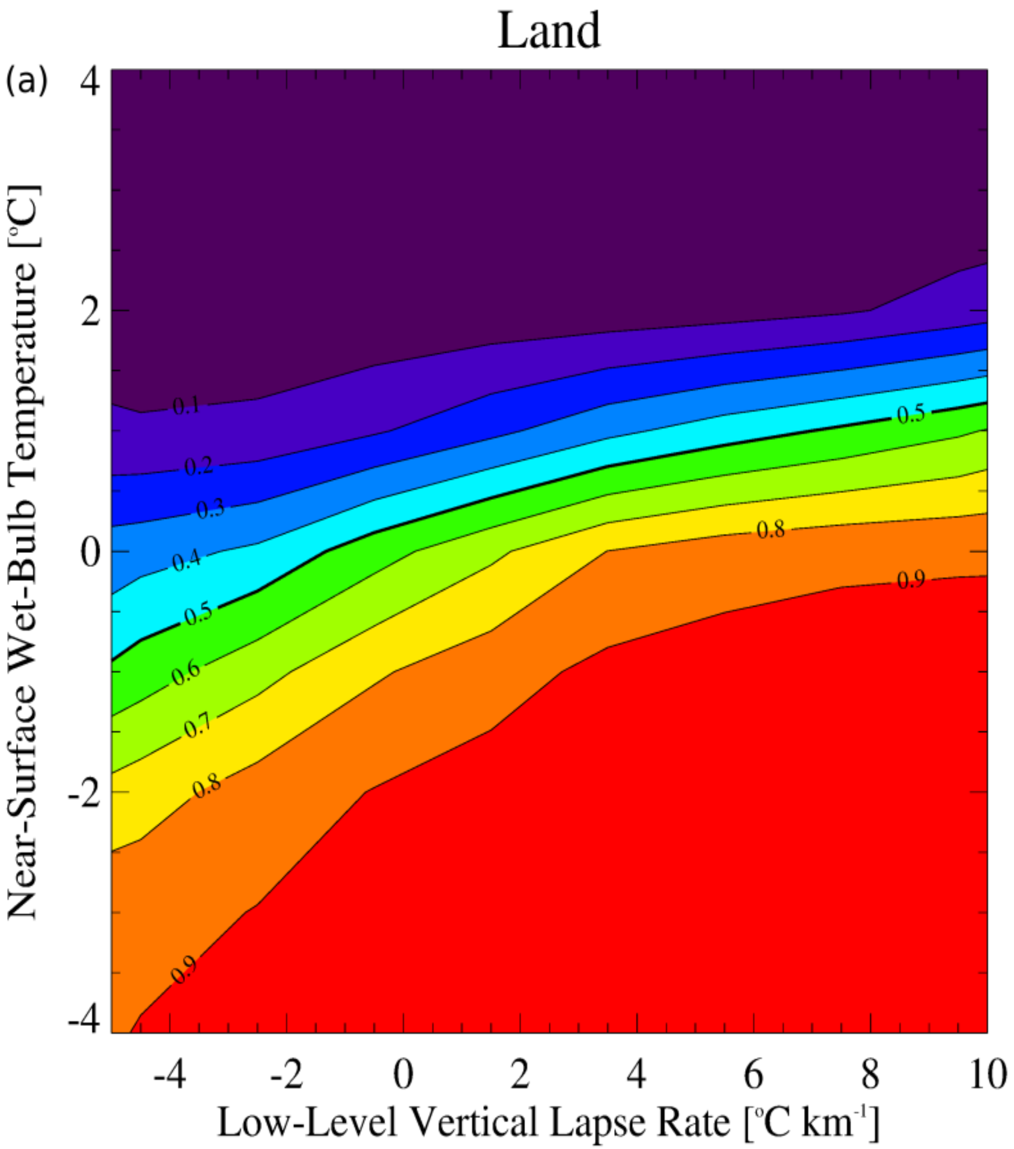
Algorithm Structure and History

- Snowfall retrieval is done following 3 steps:
  - Snowfall rate vs. brightness temperature database based on CloudSat (+DPR) snow and GMI TBs; Divide database into 7 (or more) categories;
  - Determine snowfall possible condition using environmental variables (Sims and Liu, 2015);
  - Inversion of TBs to snowfall using lookup table (or Bayesian …) method (Liu et al., 2013)
- Since AMSR3 will have similar channels to GMI's, we are currently using GMI data for testing
- A version of this algorithm is operating at JAXA for GSMaP.
- Algorithm improvement will be conducted in coordination with JAXA GPM solid precipitation algorithm PI, Dr. Nobuyuki Utsumi.

What We have Done in the Past Year

- Add DPR snowfall retrieval to the primarily CloudSat data based a priori database;
- Develop validation dataset from SNOTEL and GHCN-D (Global Historical Climatology Network – Daily) data over U.S. for comparison of "climatological means" of snowfall (satellite vs. surface measurements)
- Try different inversion methods, e.g., Bayesian, …

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)

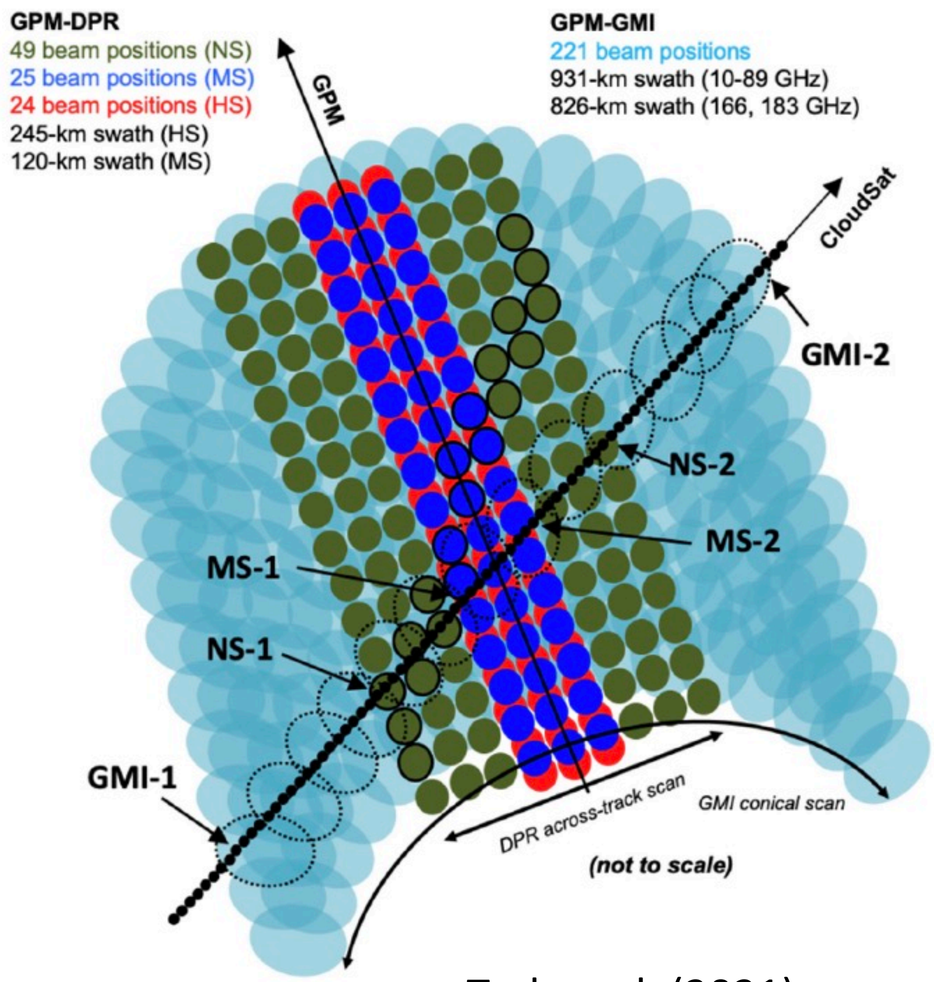
Sensitive Variables

- Air temperature (2 m)
- Humidity (2 m)
- Low-level (0 - 500 m) lapse rate
- Surface skin temperature
- Land or ocean

Look-Up-Table Version: Sims & Liu 2015 , Equation Version: Yin & Liu 2018

Training database for T_B to snowfall conversion

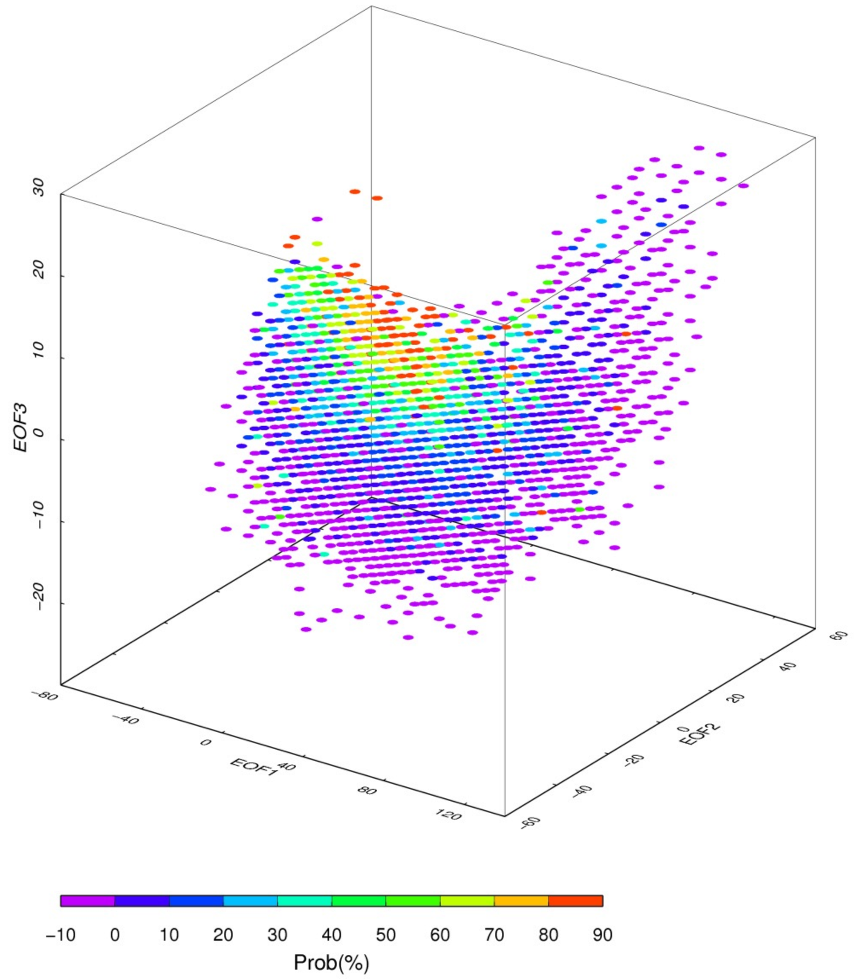
- Currently: CloudSat vs. GMI matchups (Ocean and Land)
- Working on:
  - Add DPR when snowfall is heavy enough (DPR Ku > 14 dBZ) (Ocean and Land)
- Planned:
  - Add beam-height corrected surface radar obs. (NexRad) (Land only)



Turk et al. (2021)

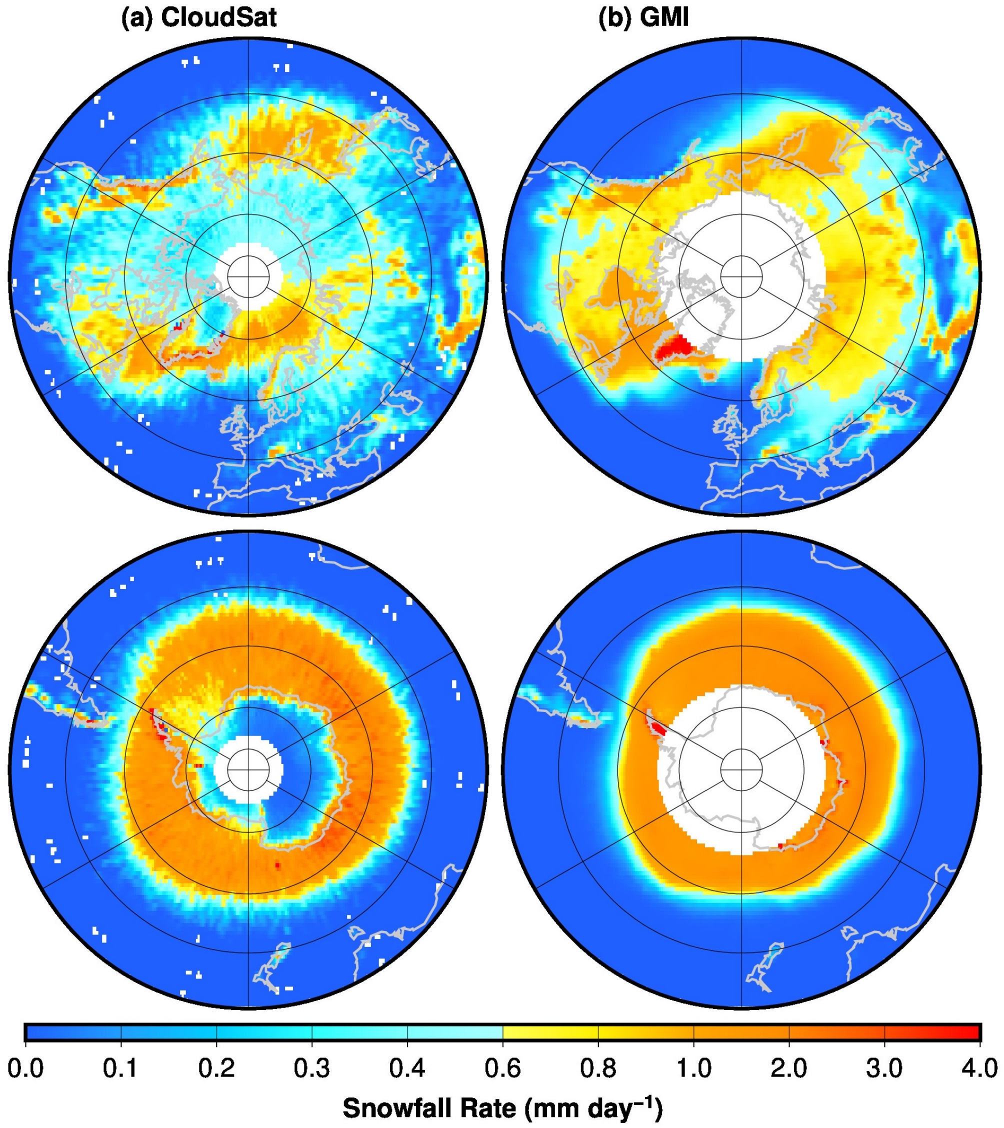
Brightness Temperature to Snowfall Rate Conversion

- Currently: 3D lookup table in TB's EOF space, 7 regimes based on surface type and water vapor;
- Working: Bayesian, 7 regimes based on surface type and water vapor
- Planned:
  - Add "synoptic type" in subsetting Databases, for example, for shallow "cold air outbreak" snowfall



(Liu&Seo, 2013)

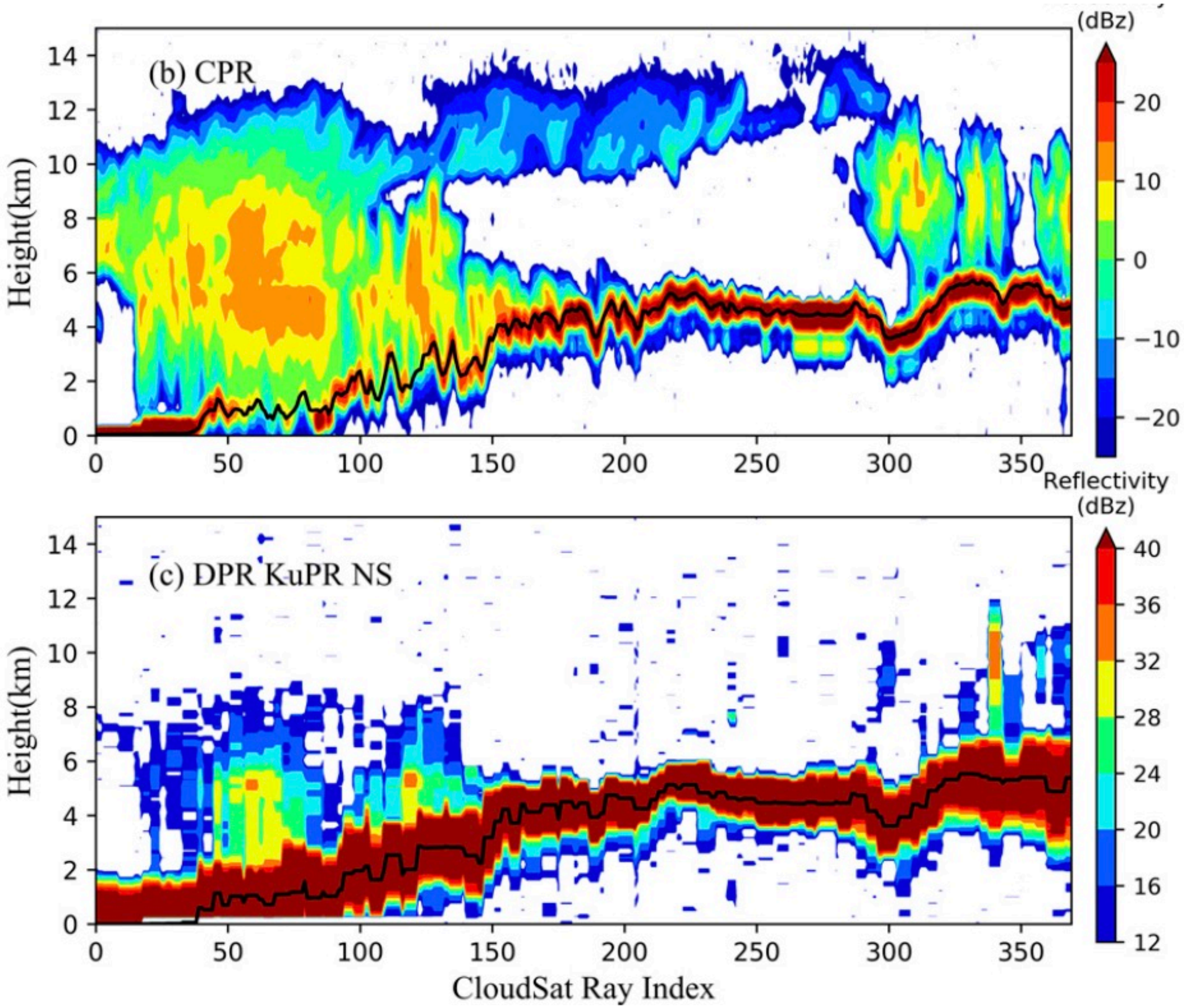
Global Snowfall Distribution



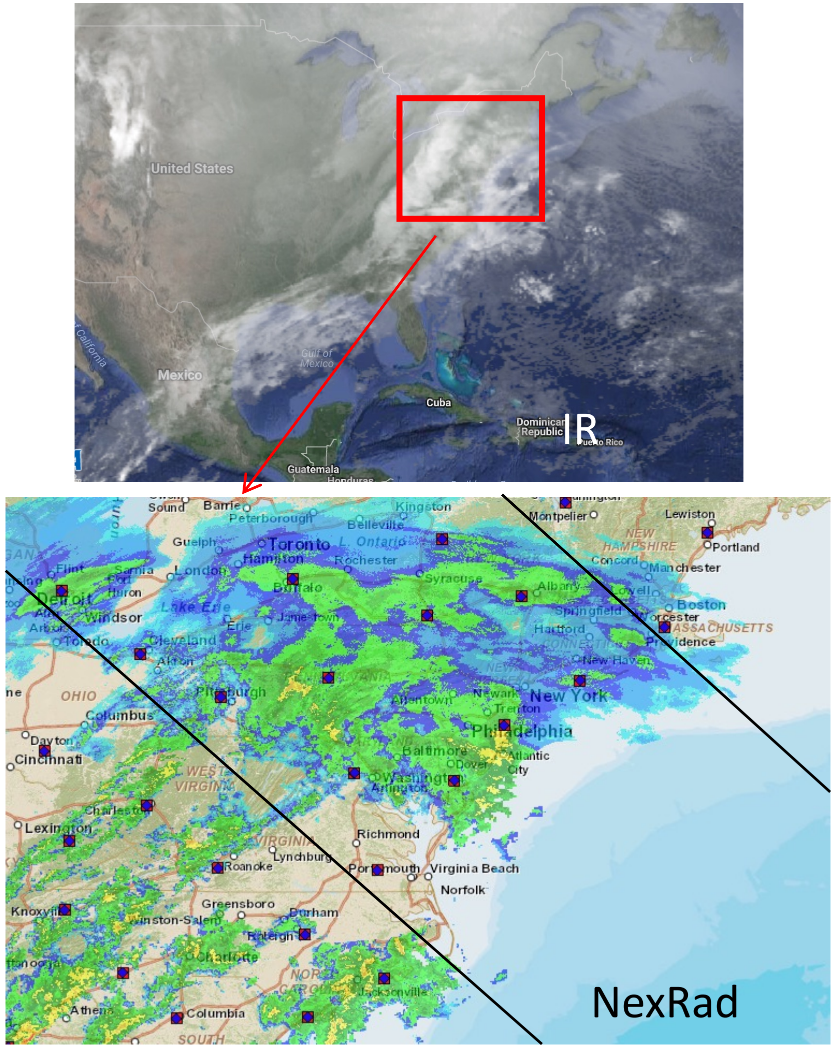
- CloudSat 2C-SNOW-PROFILE 2006-2017 (Daytime only since 2011)
- GMI (2014-2019): Using CloudSat-GMI matchups as training dataset
- General pattern similar; GMI problem over Greenland

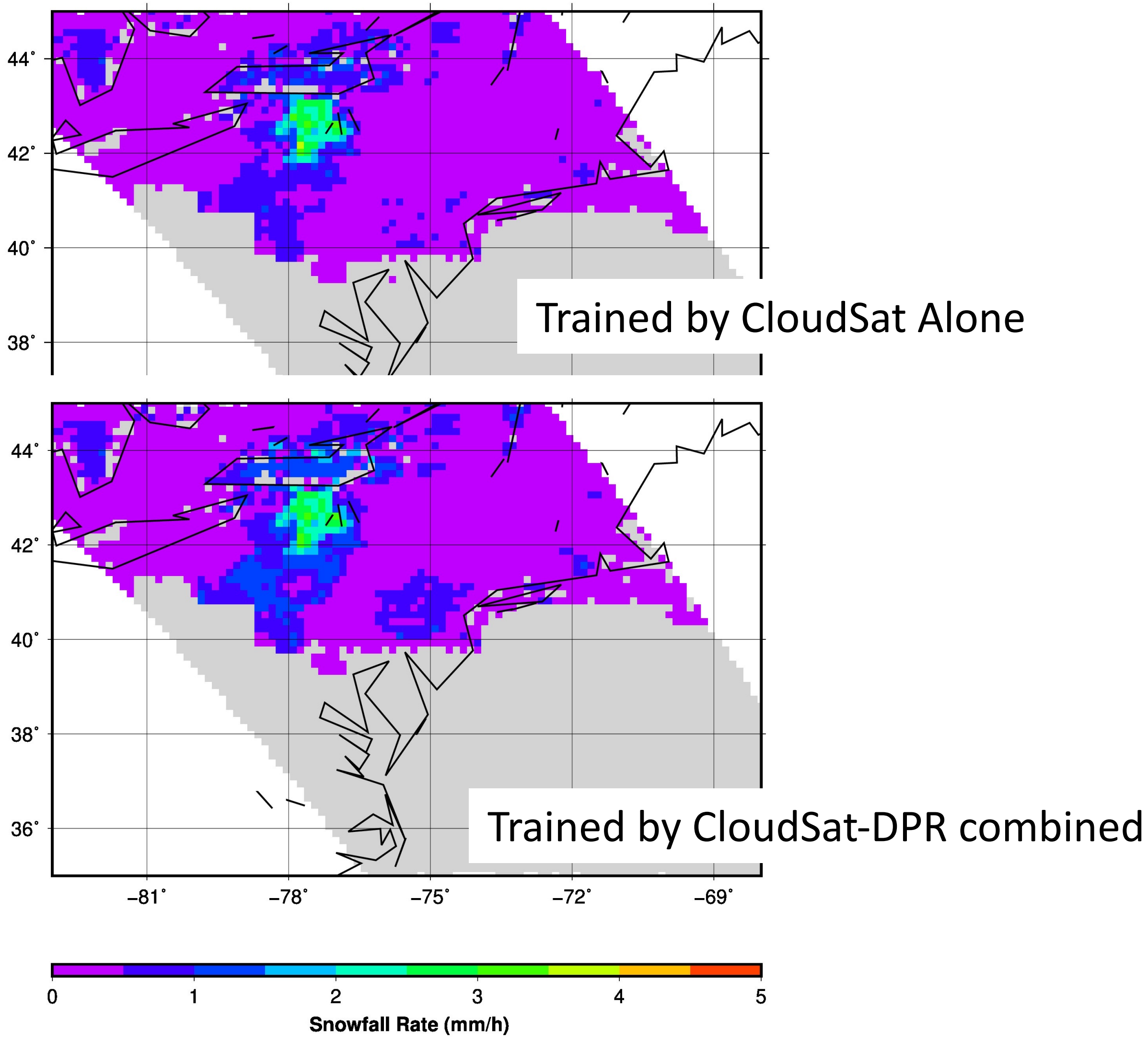
Tests on Adding DPR in the Training Dataset

- While CloudSat CPR sees more light precip, it saturates/attenuates as precip gets heavier.
- Combine both: Whenever DPR/Ku > 14 dBZ and CPR > 0 dBZ, replace CPR snowfall by DPR "snowfall" (Using a Z-S relation given by Heymsfield et al. (2018)



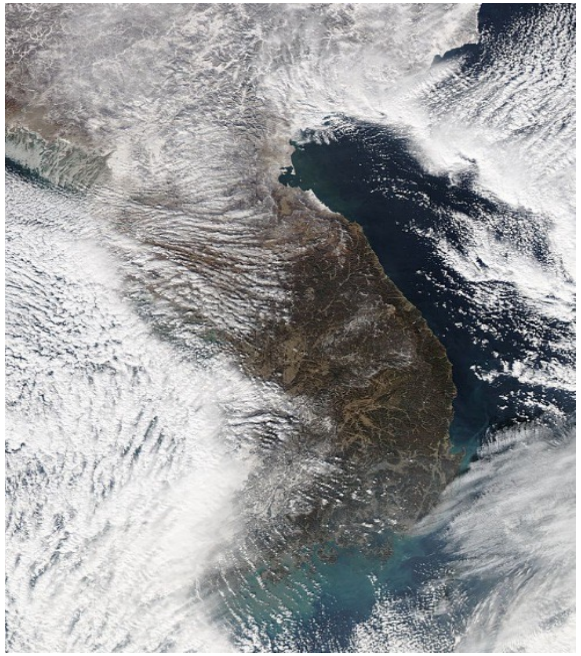
Feb. 2, 2015 North American Blizzard

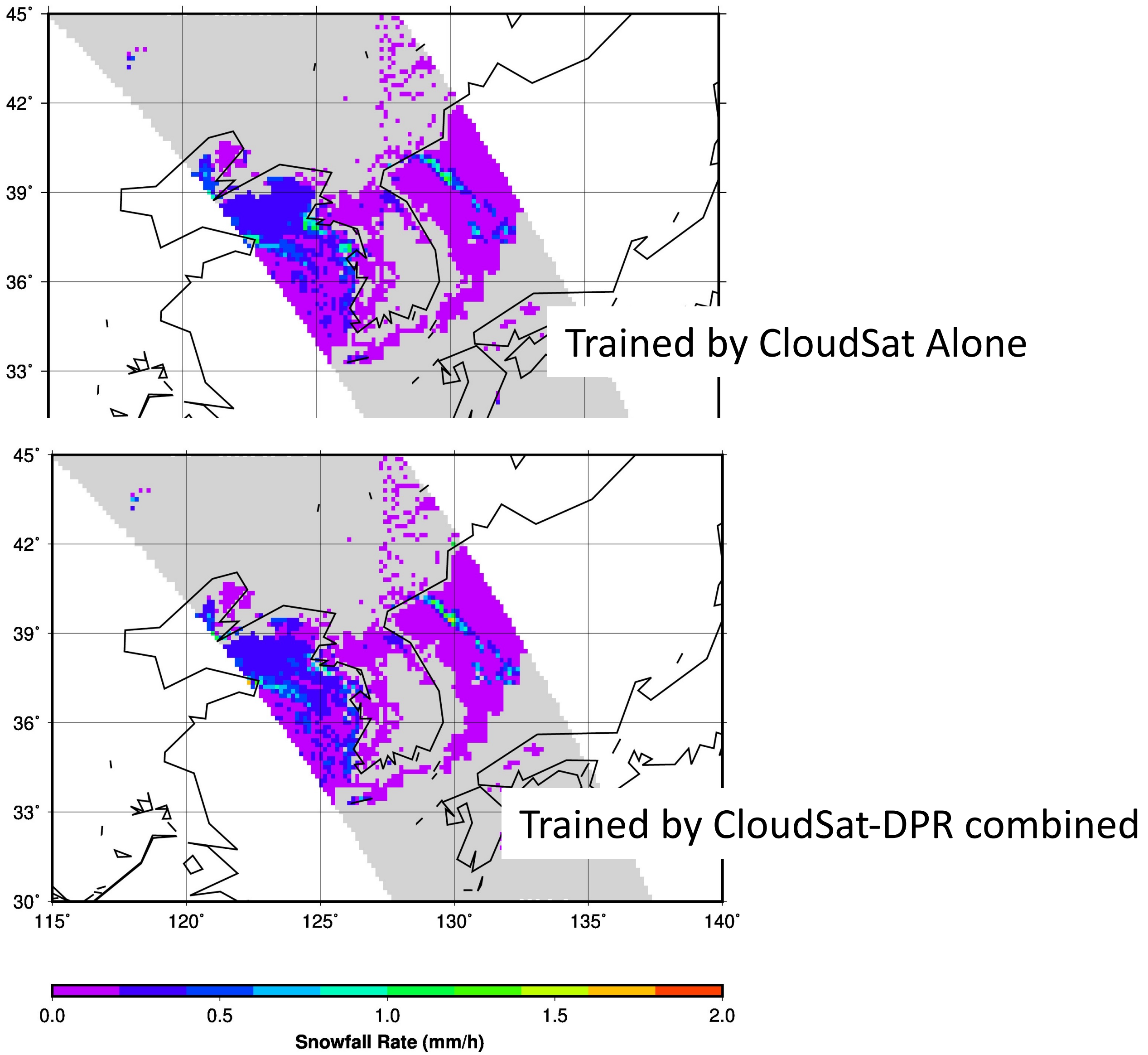




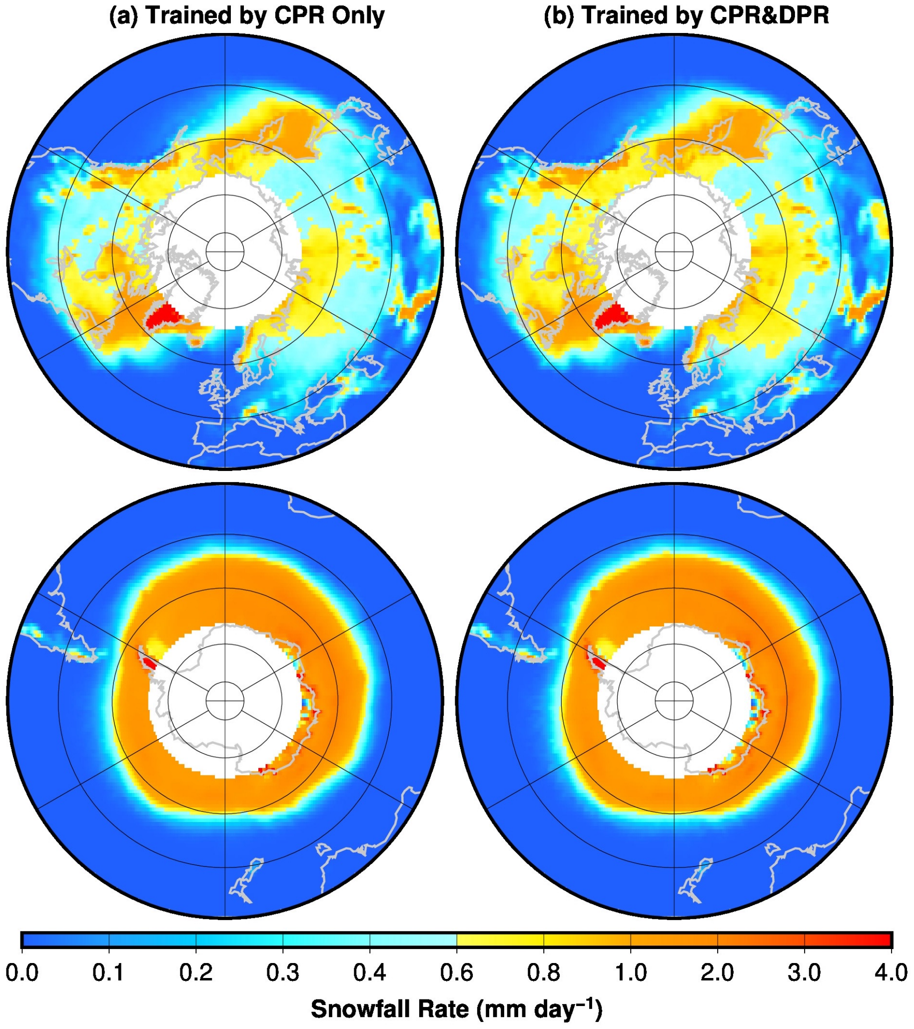
Jan 23, 2016 Cold Air Outbreak

Aqua MODIS true color image for a snowfall case on 23 Jan 2016 (from *NASA/EOSDIS*)



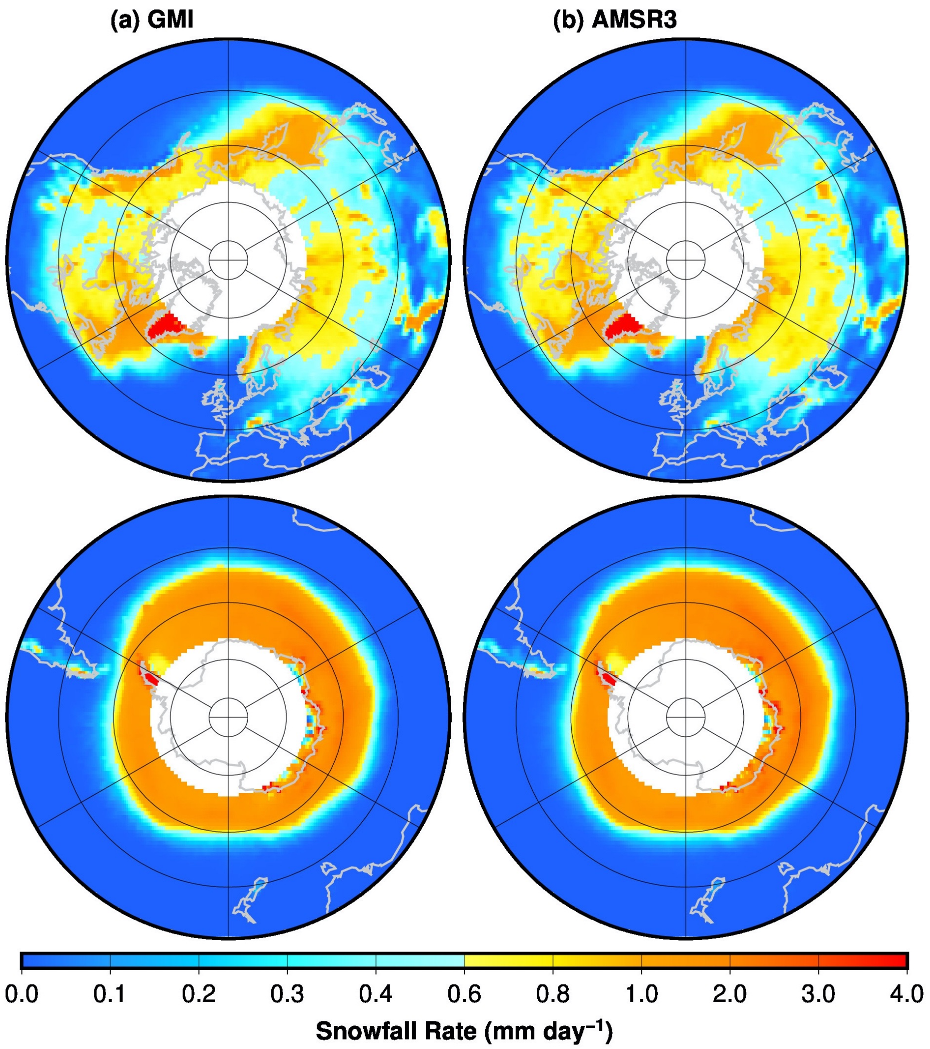


Global Average (2018)



- Adding DPR snowfall only slightly increases mean snowfall
- Pattern of global distribution remains the same
- Still have problem over Greenland
- Will study whether the dBZ-to-snowfall conversion from DPR-Ku is adequate

What if using AMSR3



- Use GMI minus 166 H to mimic AMSR3
- Small impact for global averages (at least when using the lookup table method)

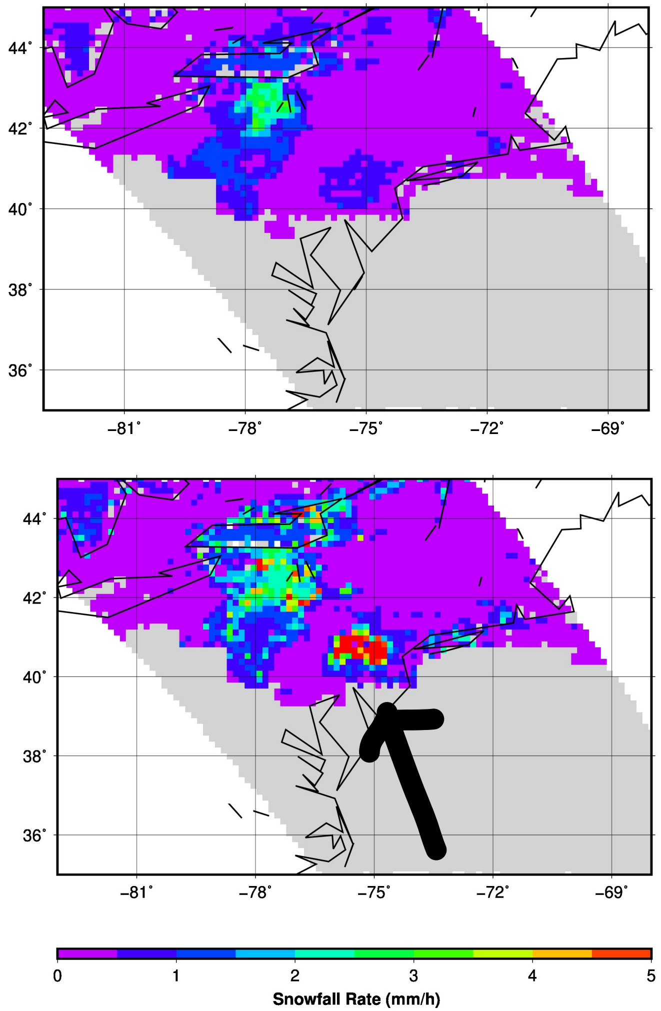
Lookup Table vs. Bayesian

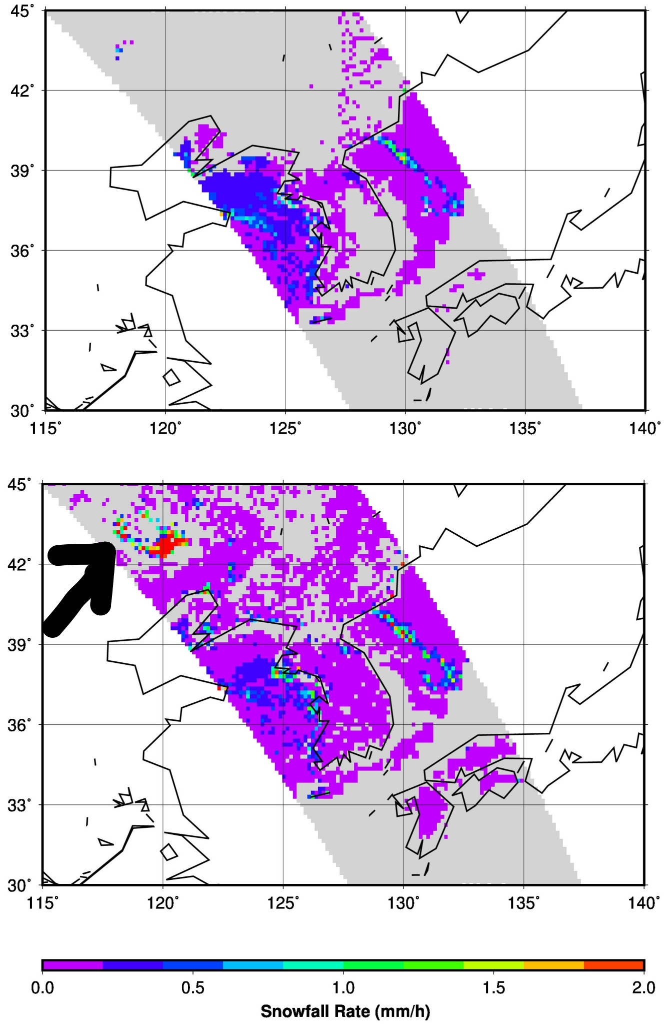
N.A. Winter Storm

Cold Air Outbreak

Lookup Table

Bayesian





Find Surface References

SNOTEL

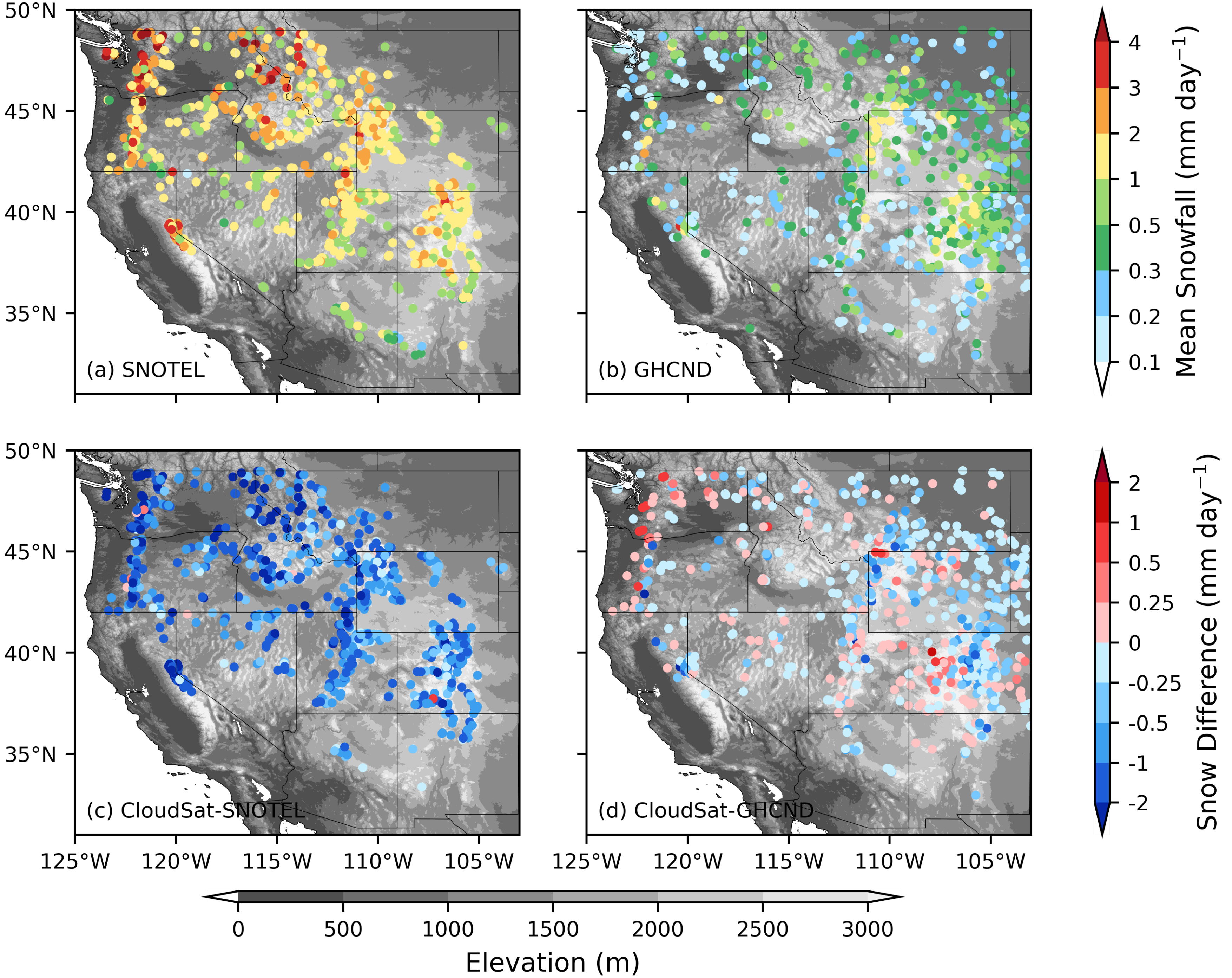
- SNOw TELemetry
- West U. S., remote area
- We used Daily difference of Snow Water Equivalence to compute daily snowfall
- We used 2014 – 2020 mean

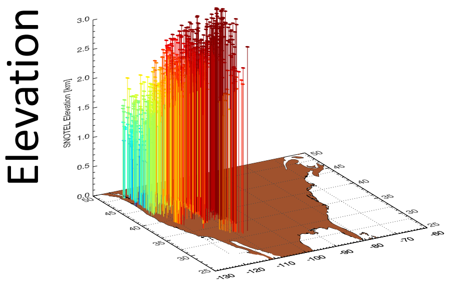
GHCND

- Global Historical Climatology Network - Daily
- Global, but here we used U.S. data only, conventional stations
- Daily snow depth, x0.1 to convert to liquid equivalent depth
- We used 2014 – 2020 mean

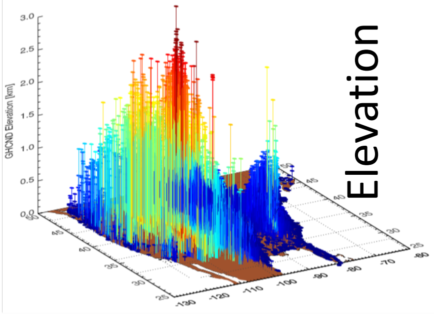
How the two references compare with each other

SNOTEL: 2014 – 2020
GHCND: 2014 – 2020
CloudSat: 2006-2017
1°x1° centered at stations

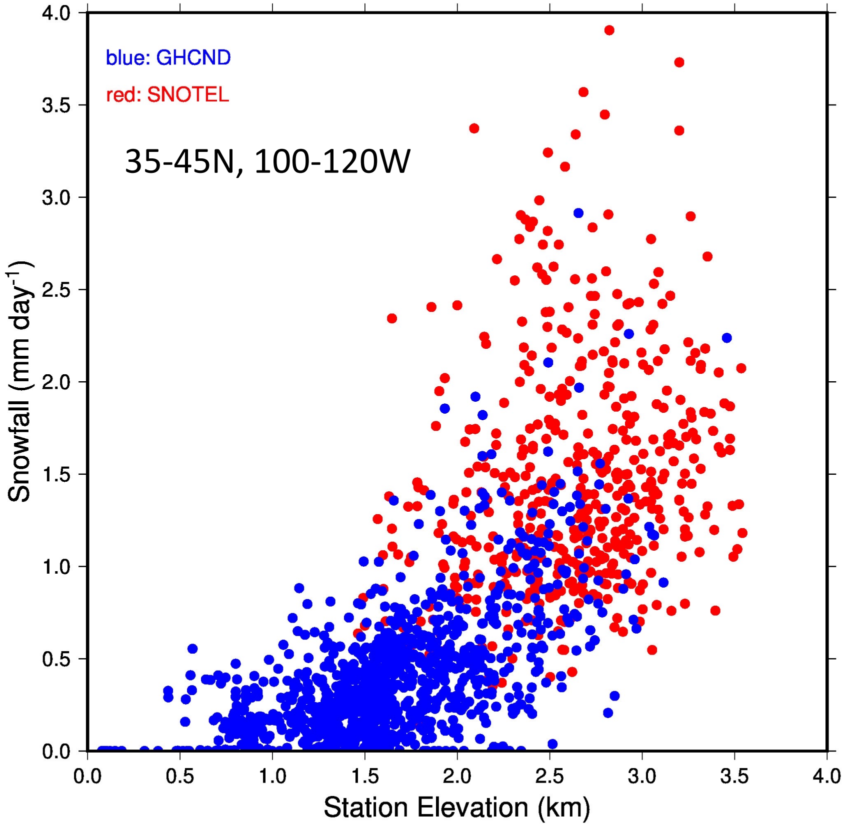


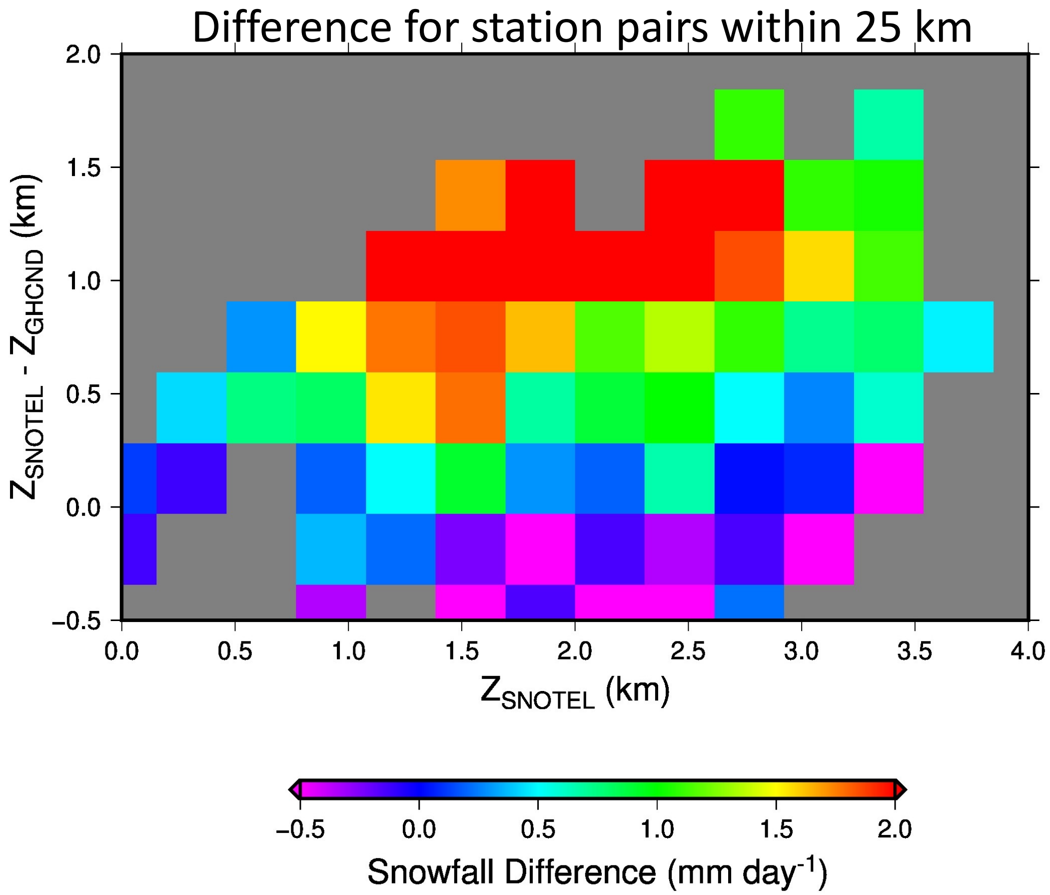


SNOTEL vs. GHCND



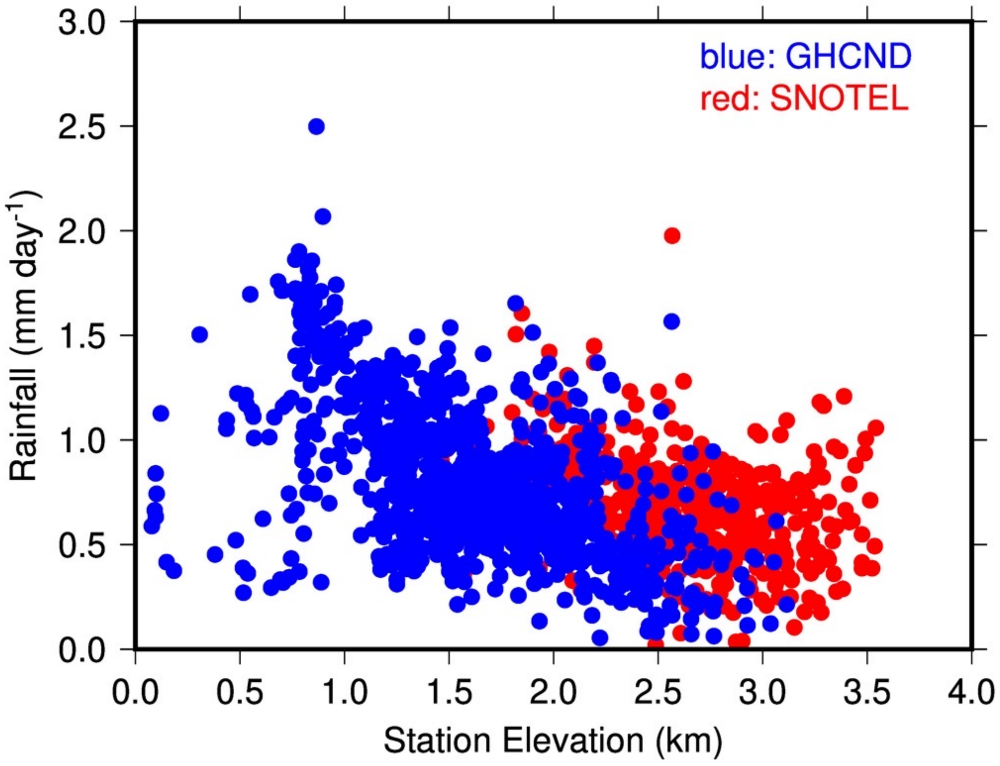
the systematic difference is largely due to elevation difference



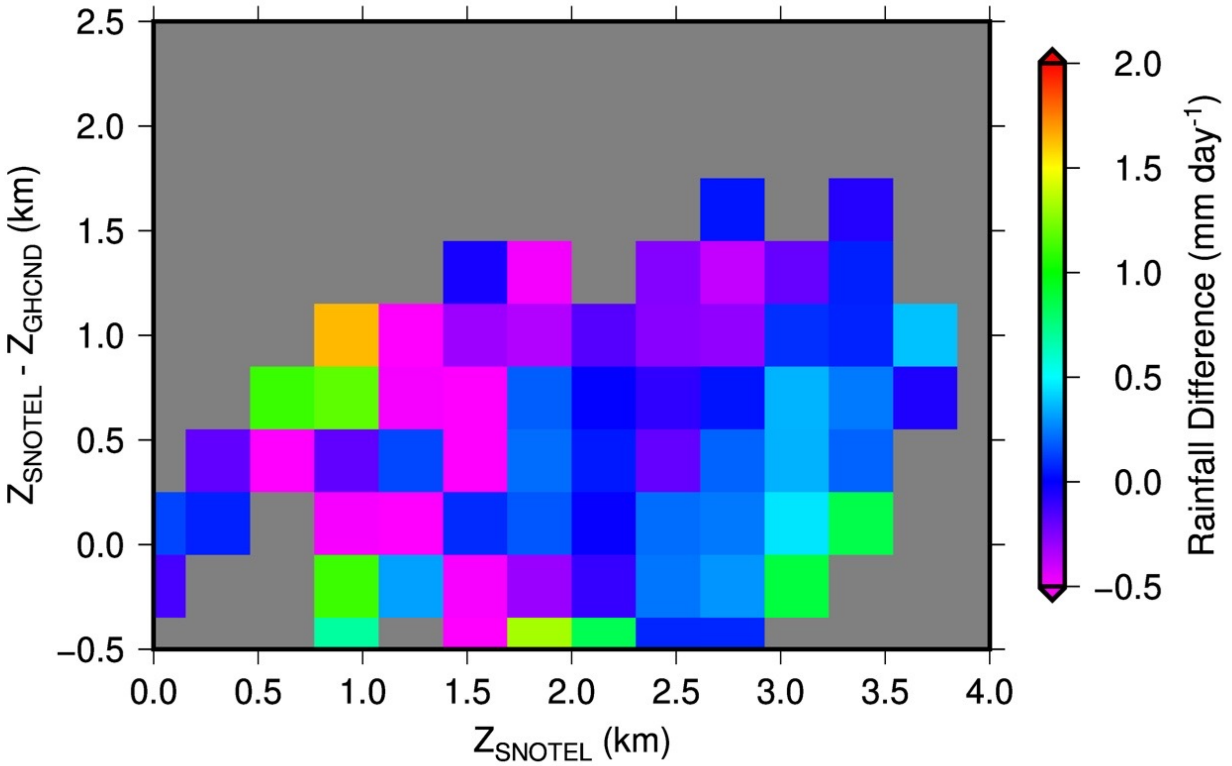


Hawaii

How about rainfall ?
- no clear elevation dependence (or slight negative)

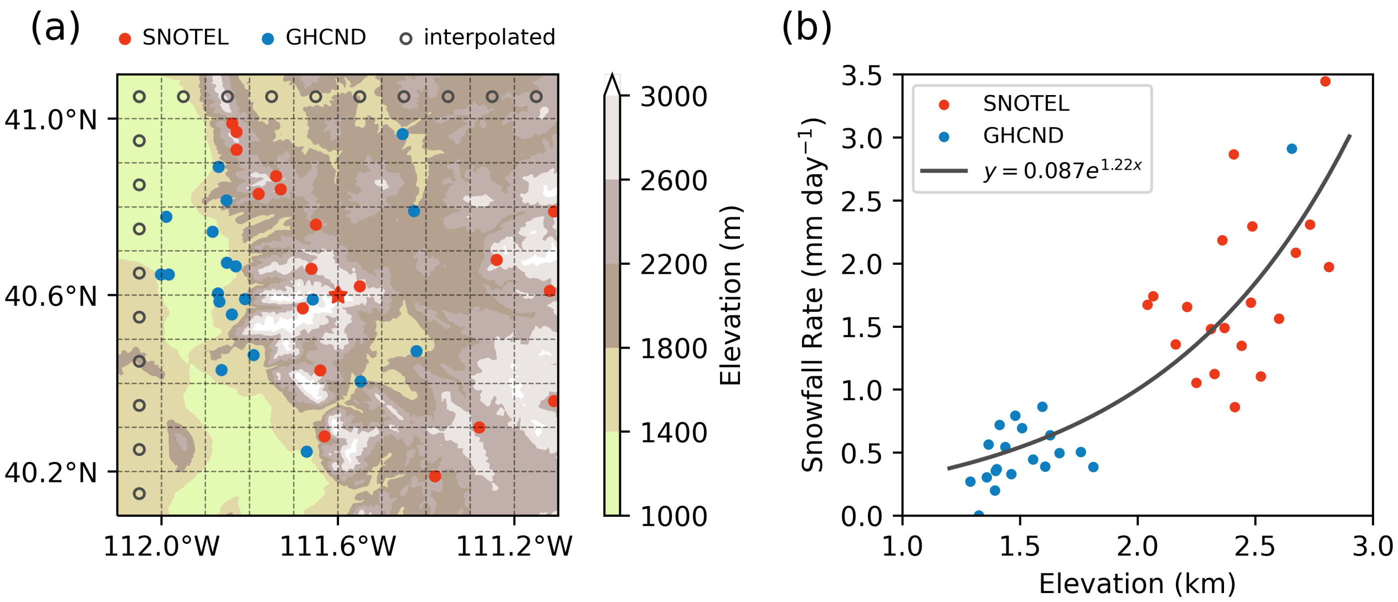


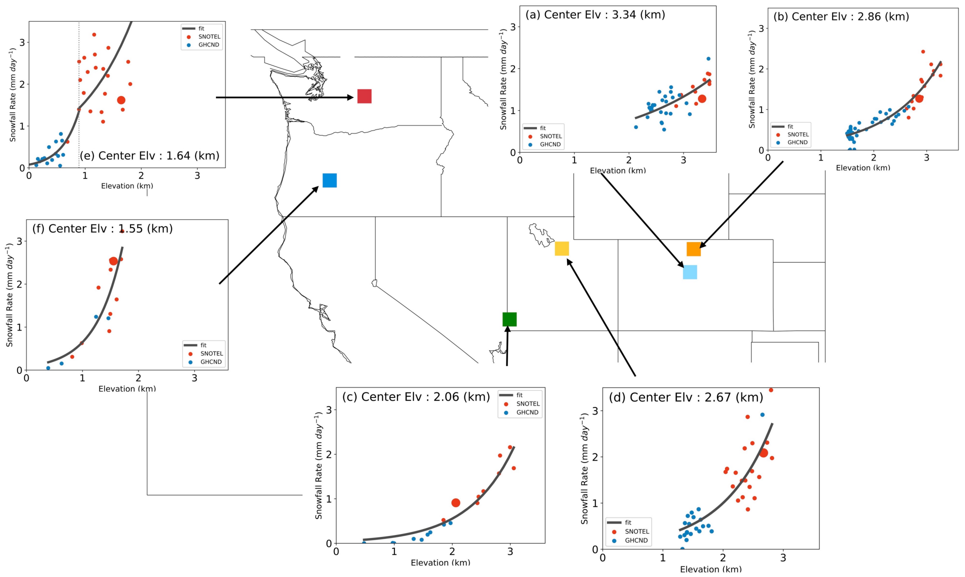
(a)



(b)

Create a Validation Dataset of mean snowfall in 1deg x 1deg boxes around SNOTEL stations





In each 1x1 deg box, find a snowfall-elevation relation. Use this relation to fill fill snowfall in sub-boxes where there is no surface obs. This method is to mimic "surface observations are available everywhere".

The snowfall vs. elevation relation is different at different locations. We manually examined/curve-fitted about 180 of them (one for each 1x1 box centered at SNOTEL station)

Summary

- Refining Training Database by combining CloudSat and DPR
  - Results in some increases in snowfall retrieval
  - Patterns similar
- Testing conversion methods, lookup table vs. Bayesian
  - Leads some significant changes
  - Continue to investigate
- Developing ground-based validation dataset
  - The significance of elevation dependence of snowfall
  - Proposed mitigation