Building and Testing a GPM Passive-Microwave Hail Retrieval and Climatology

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Global Threat of Hail

Hail is at the top of the intensity spectrum of precipitation, and therefore:

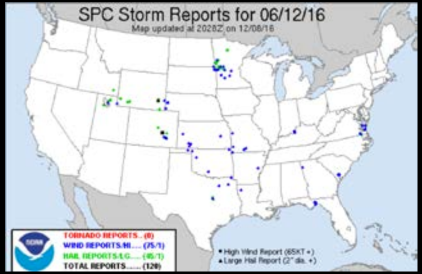
- constitutes ~70% of nearly $65 billion in annual insured losses
- is difficult to measure *in situ*
- can result in strong attenuation and multiple scattering in radar data, leading to errors in retrievals
- is seldom retrieved by the large scale satellite precipitation algorithms

Aon Benfield, 2018; Bataglia et al., 2015

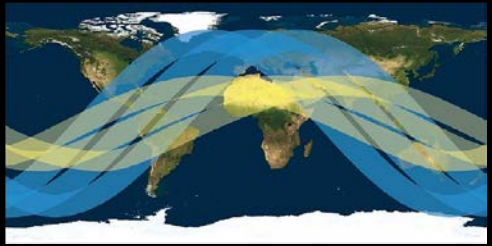
Climatologies of Hail

Hail Climatologies:

- Can be made using ground radar, surface reports



- For consistency, uniformity and to avoid geographic bias, satellite datasets are the best option



NASA's TRMM & GPM Missions

Tropical Rainfall Measuring Mission

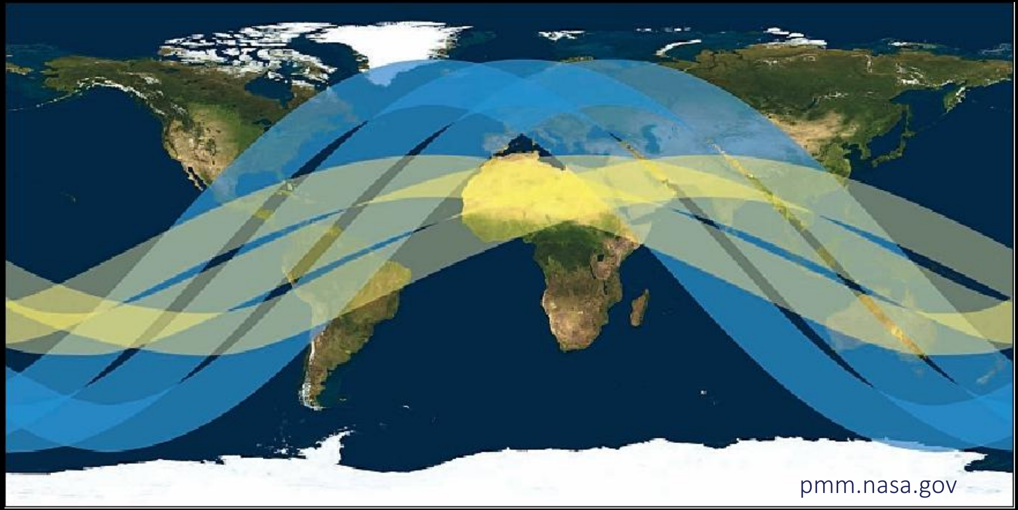
1997 – 2014

- TRMM Microwave Imager (TMI)
  - 9-channels, 10-85 GHz

Global Precipitation Measurement

2014 - present

- GPM Microwave Imager (GMI)
  - 13-channels 10-183 GHz



Constellation Partners:

- JAXA, NOAA, DOD, EUMETSAT, CNES, ISRO
- Cross-calibrate passive microwave observations

Passive Microwave, specifically:

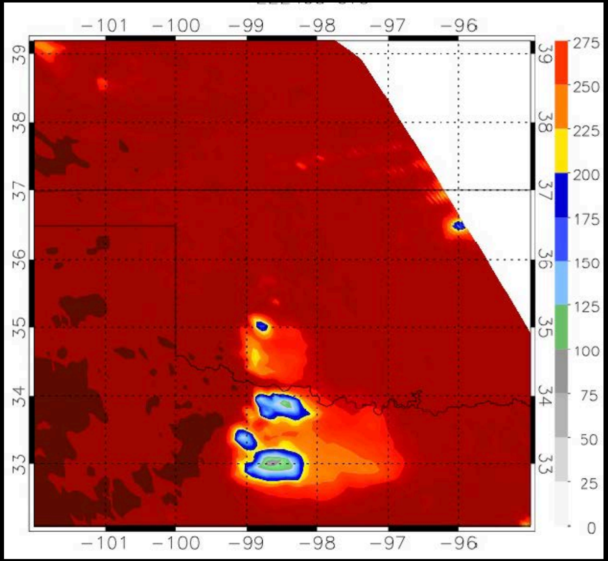
- Excellent global coverage
- Long legacy in space

Kummerow et al., 1998; Hou et al. 2014

Building and Testing

Building

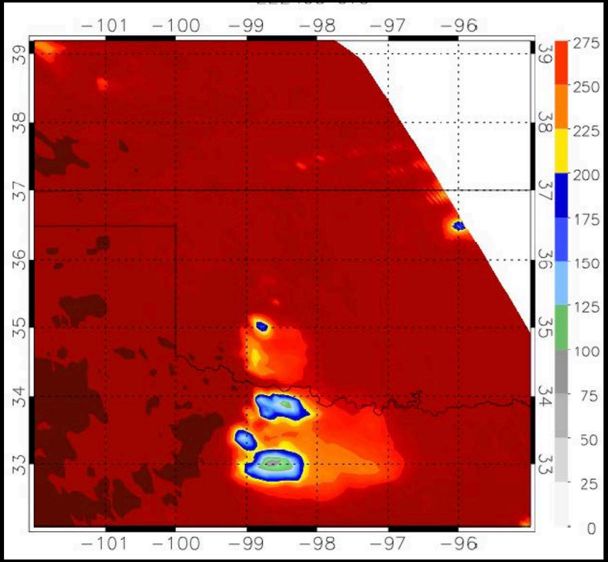
Passive-Microwave Signatures in Hail

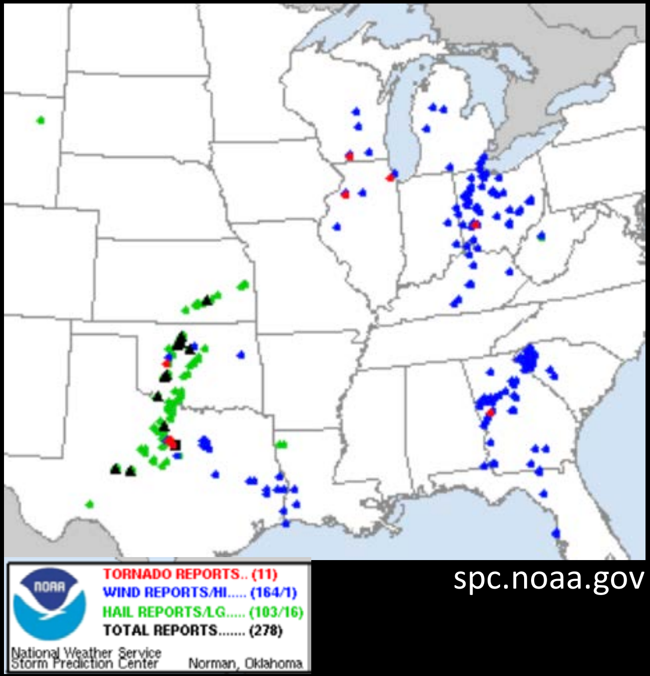


Minimum 89 GHz PCT

- Hailstorms register depressed T_bs due to scattering of upwelling microwave radiation

Passive-Microwave Signatures in Hail

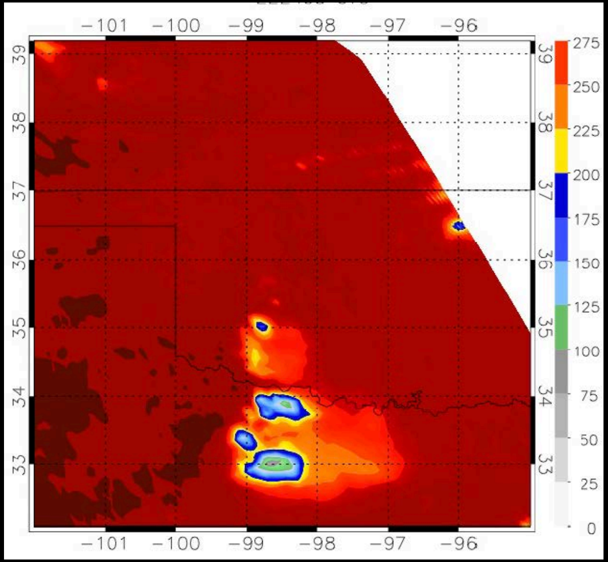


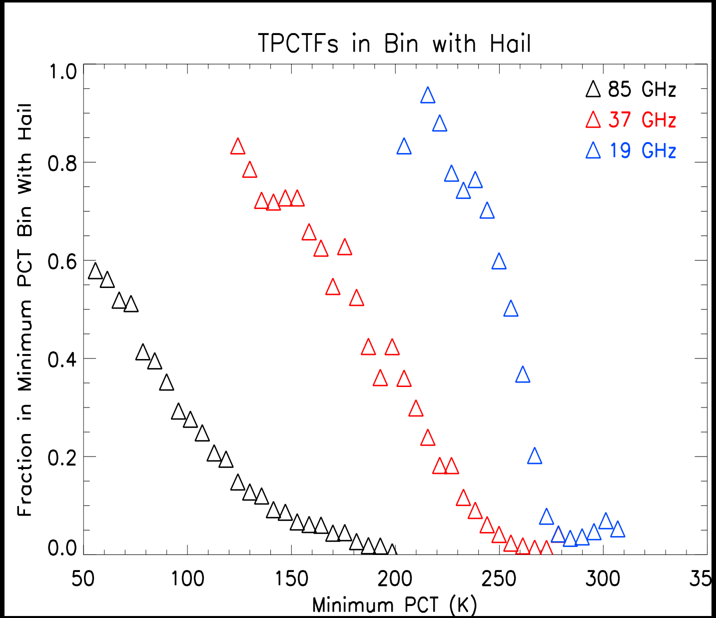


spc.noaa.gov

- Hailstorms register depressed T_bs due to scattering of upwelling microwave radiation
- To train the retrieval, we pair TRMM PCTFs (Polarization Corrected Temperature Features) with USA hail reports
  - Severe (>25mm) hail at the ground

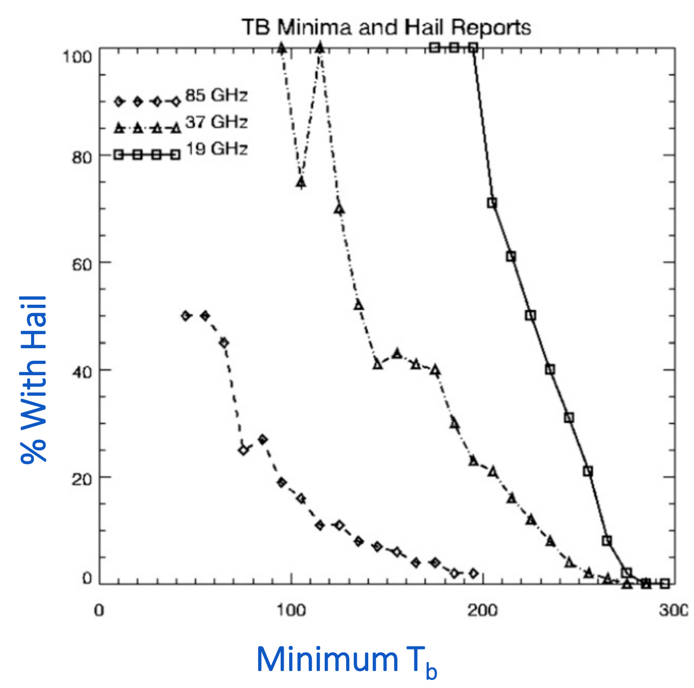
Passive-Microwave Signatures in Hail





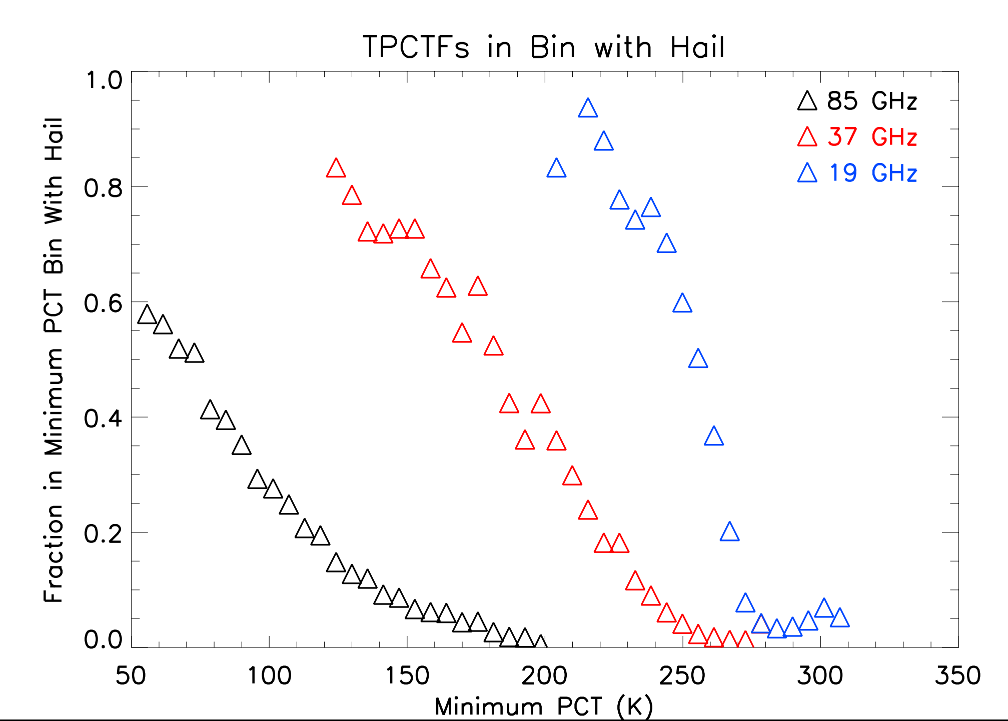
- Hailstorms register depressed T_bs due to scattering of upwelling microwave radiation
- To train the retrieval, we pair TRMM PCTFs (Polarization Corrected Temperature Features) with USA hail reports
- Visible relationship between decreasing T_b and likelihood of hail

Passive-Microwave Detection of Hail in the Literature



Cecil, 2009

Based on Spencer et al., 1987



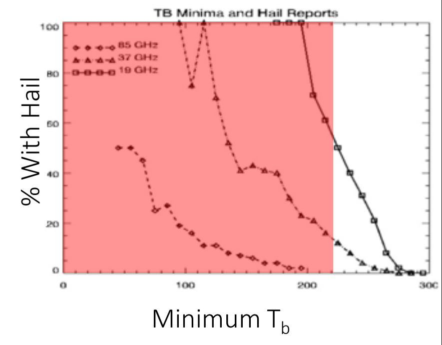
Bang and Cecil, 2019

Passive-Microwave Detection of Hail in the Literature

37 GHz PCT Threshold:

- Cecil (2009), Cecil (2011), Ni et al. (2017)

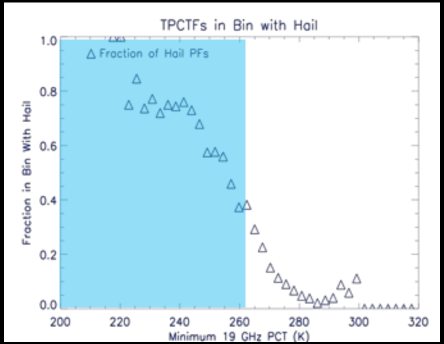
37 GHz PCT < 230K



19 GHz PCT Threshold:

- Mroz et al. (2017)

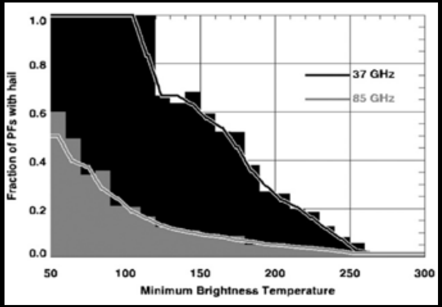
19 GHz PCT < 261K



37 GHz PCT Lookup Table:

- Cecil and Blankenship (2012)

***37 GHz PCTs adjusted by region**

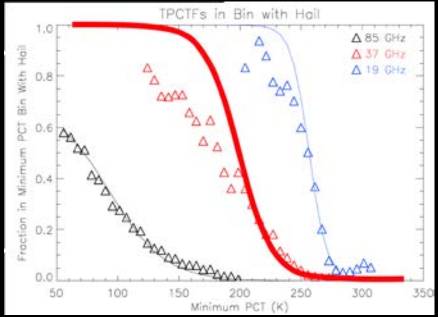


Cecil and Blankenship, 2012

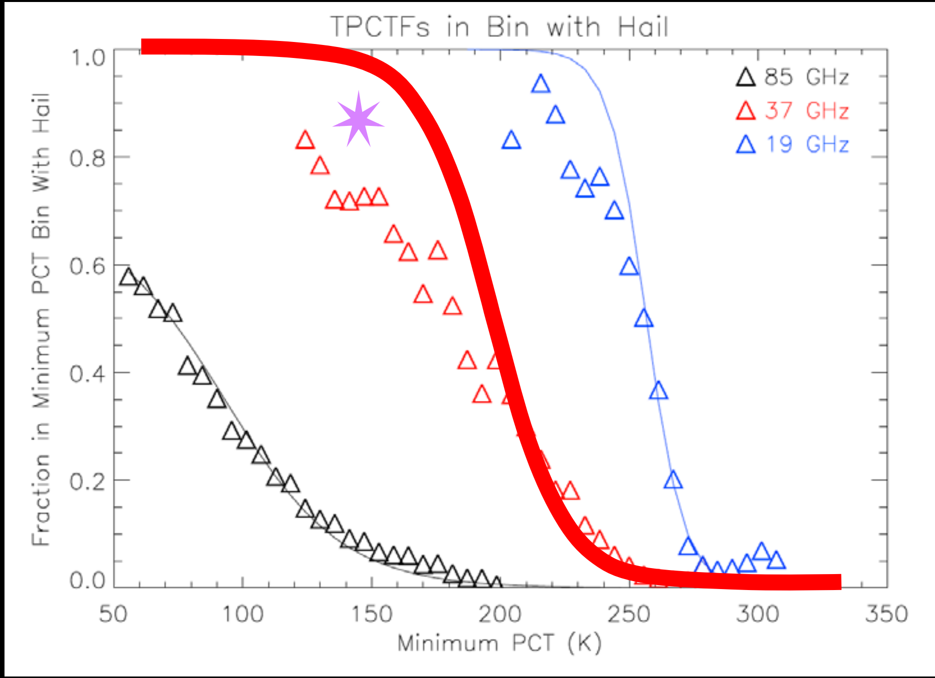
Function of 37 & 19 GHz PCT

- Bang and Cecil (2019)

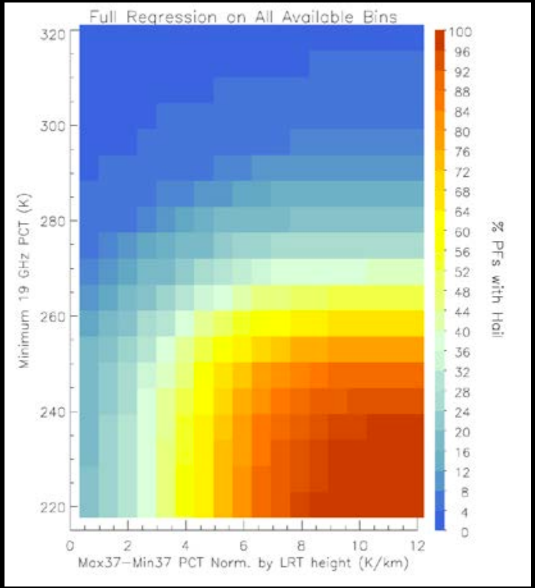
37 GHz Depression / LRT Minimum 19 GHz PCT



Hail Probability "Function" of 37 and 19 GHz PCT



$$f(x) = \frac{L}{1 + e^{-k(x-m)}}$$

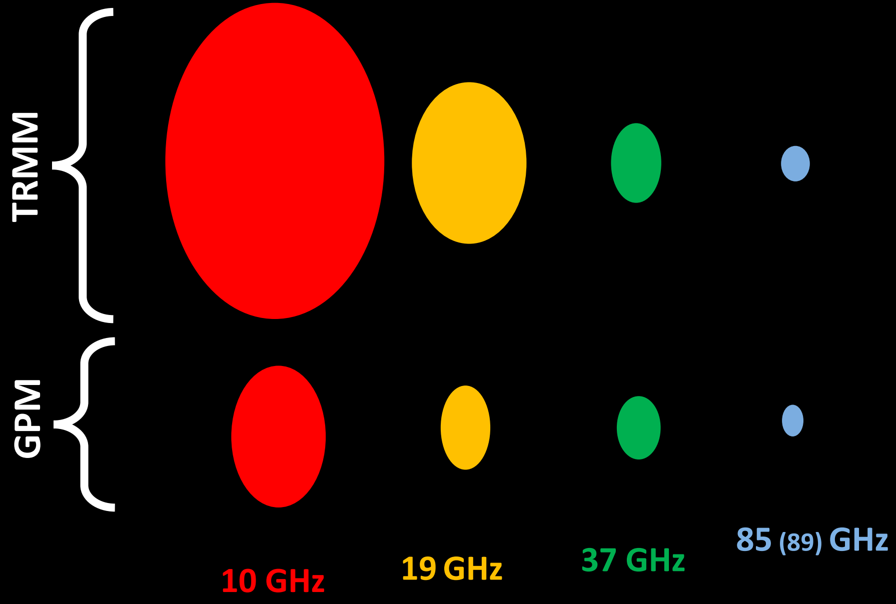


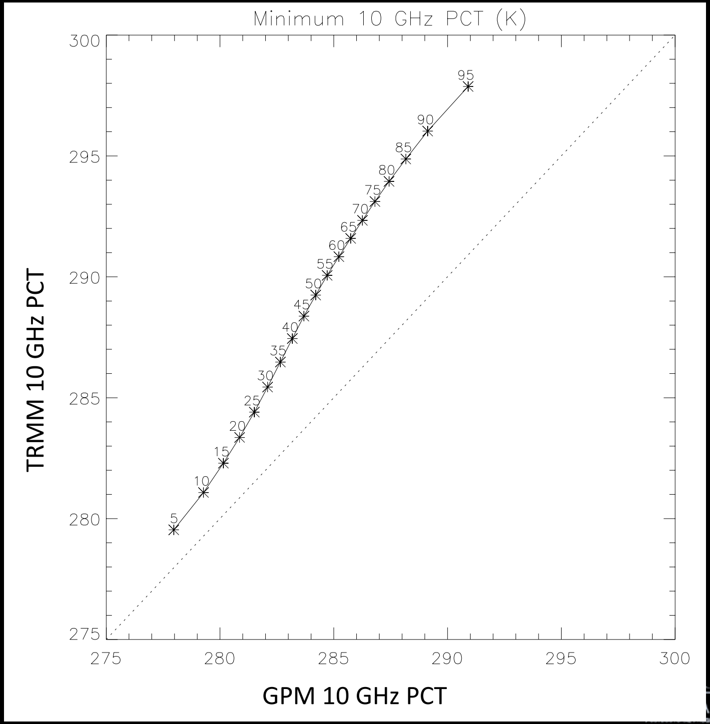
*Purposely higher, as we suspect underreporting.

(see Allen and Tippett, (2015) for more on hail reporting issues)

Caveats / Challenges / Things to Consider

#1: Adjusting for Different Footprint Size



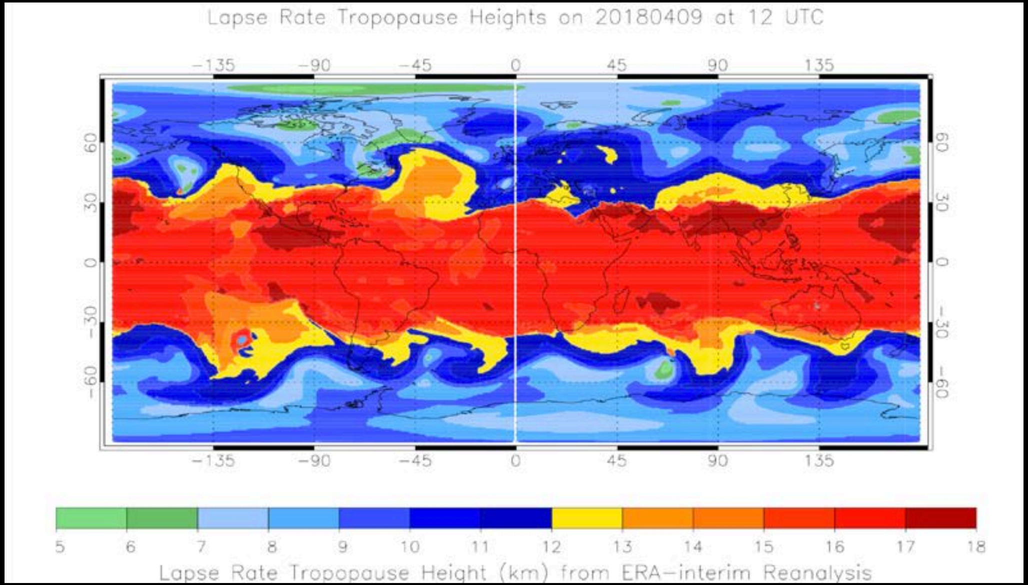


10 December 2019

Caveats / Challenges / Things to Consider

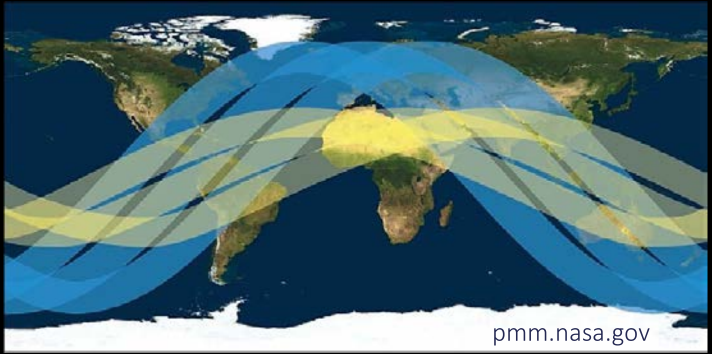
#2: Changes in tropopause depth with latitude

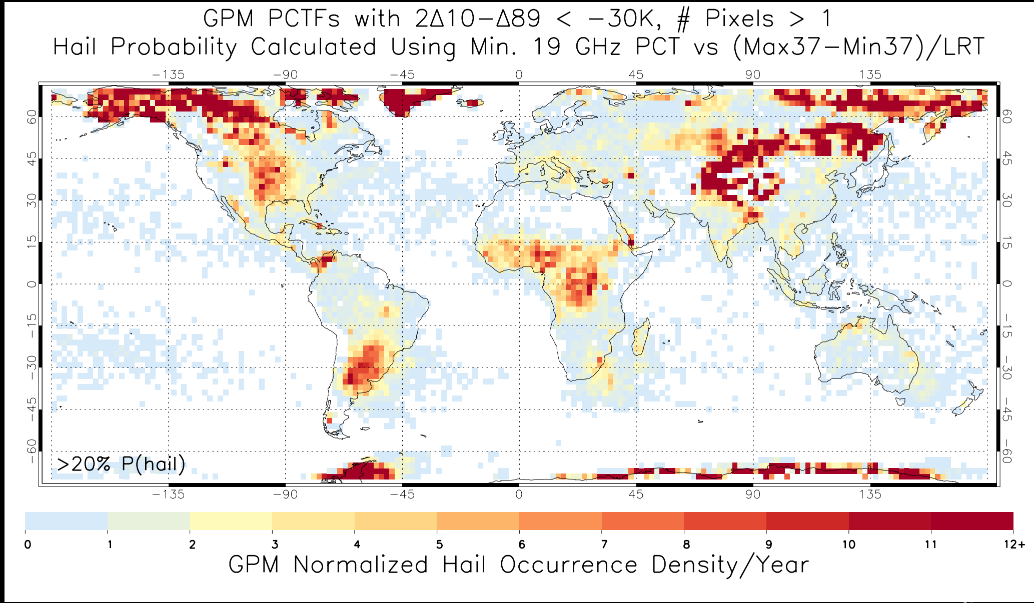
$$\text{Normalized 37 GHz PCT Depression} = \frac{MAX37PCT - MIN37PCT}{(LRT)}$$



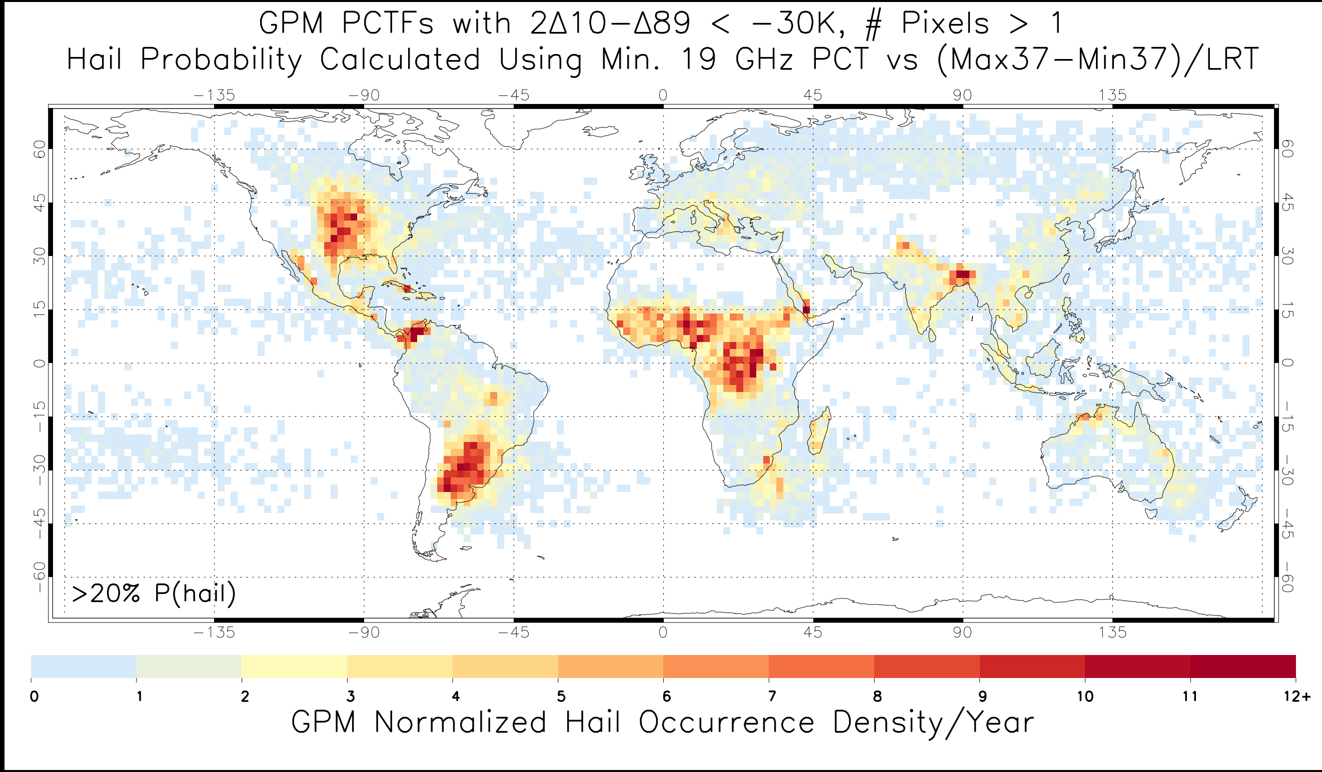
Caveats / Challenges / Things to Consider

#3: Snow/Surface Ice Artifact Filter

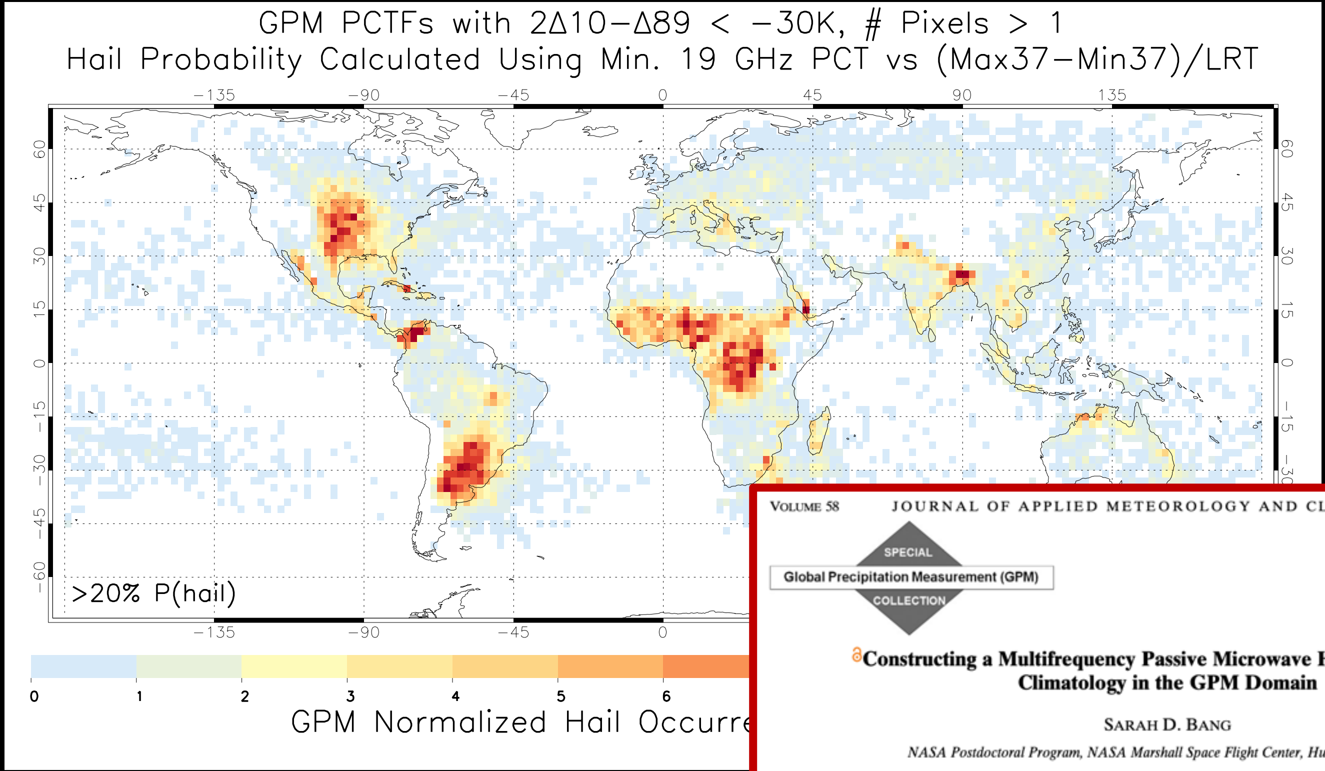




GPM Passive-Microwave Hail Climatology



GPM Passive-Microwave Hail Climatology



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SPECIAL
Global Precipitation Measurement (GPM)
COLLECTION

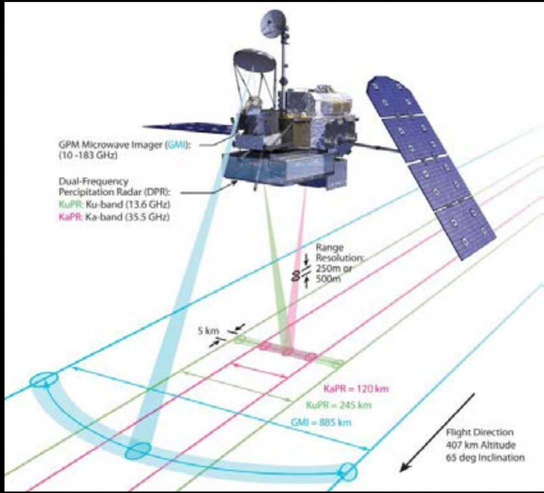
Constructing a Multifrequency Passive Microwave Hail Retrieval and Climatology in the GPM Domain

SARAH D. BANG
NASA Postdoctoral Program, NASA Marshall Space Flight Center, Huntsville, Alabama

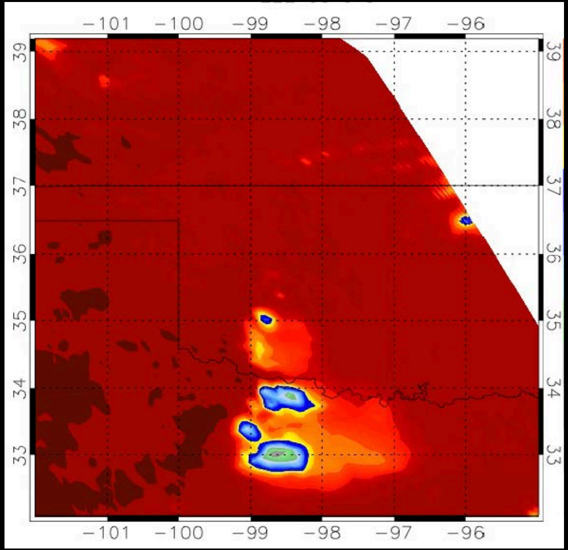
DANIEL J. CECIL
NASA Marshall Space Flight Center, Huntsville, Alabama

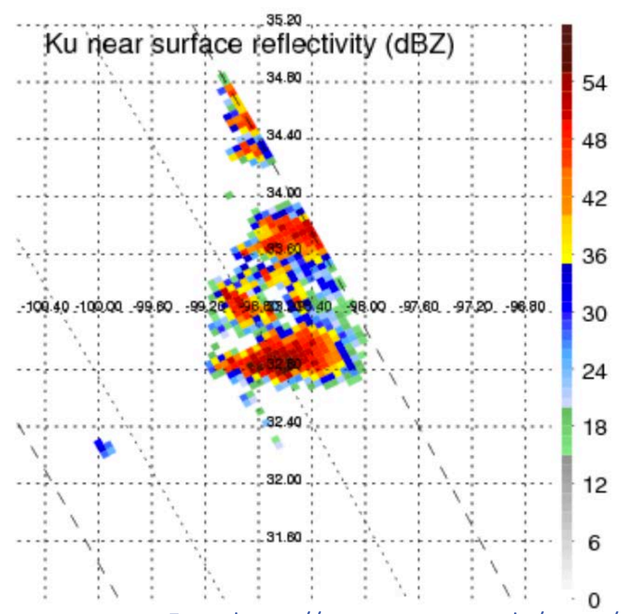
Testing

Testing our retrieval with GPM DPR Ku-band radar



pmm.nasa.gov





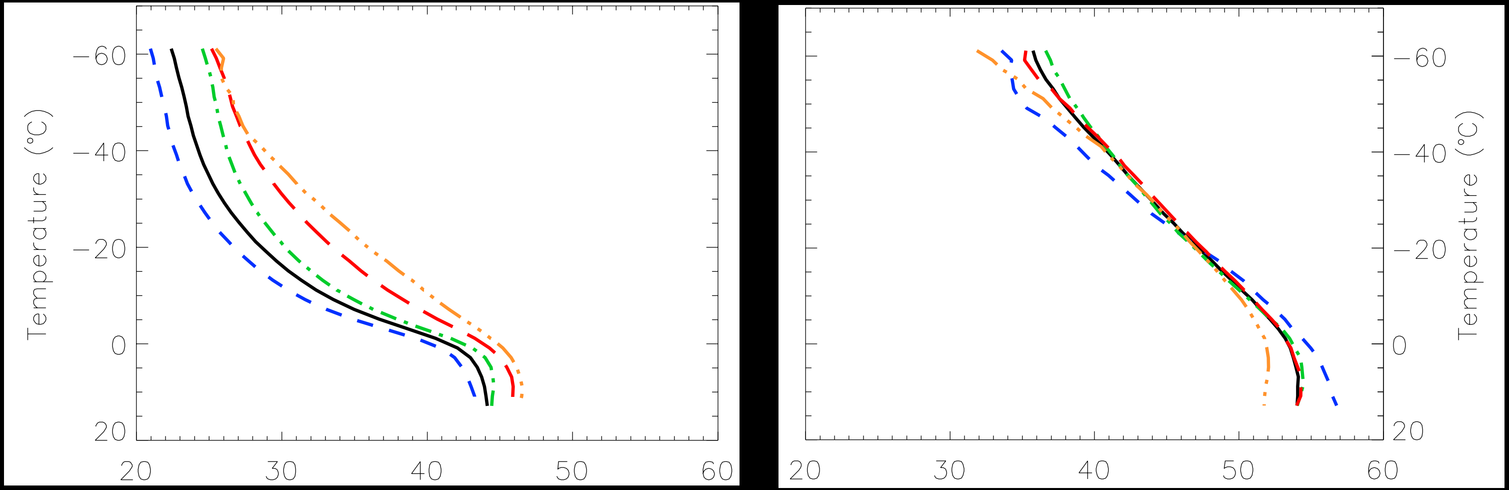
From https://atmos.tamucc.edu/trmm/

Testing with Ku-band Radar: Profiles

“Poor Performing” Algorithm
(none)

“Well Performing” Algorithm
(Must have 50 dBZ +/- 5 dB at -20 °C)

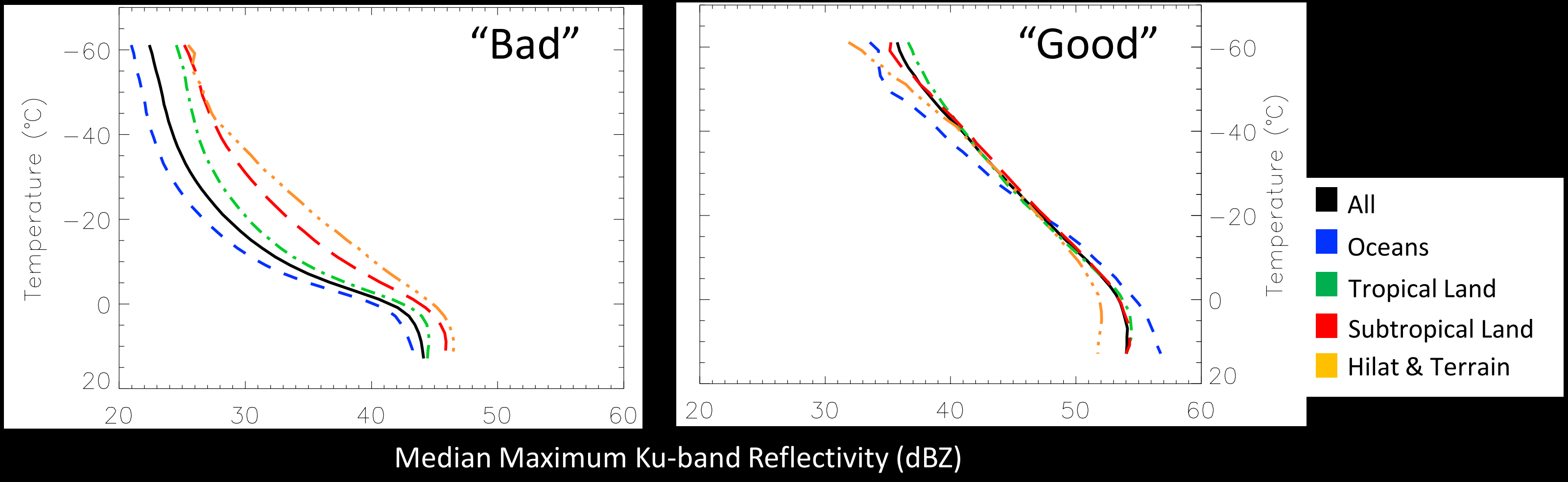
Temperature



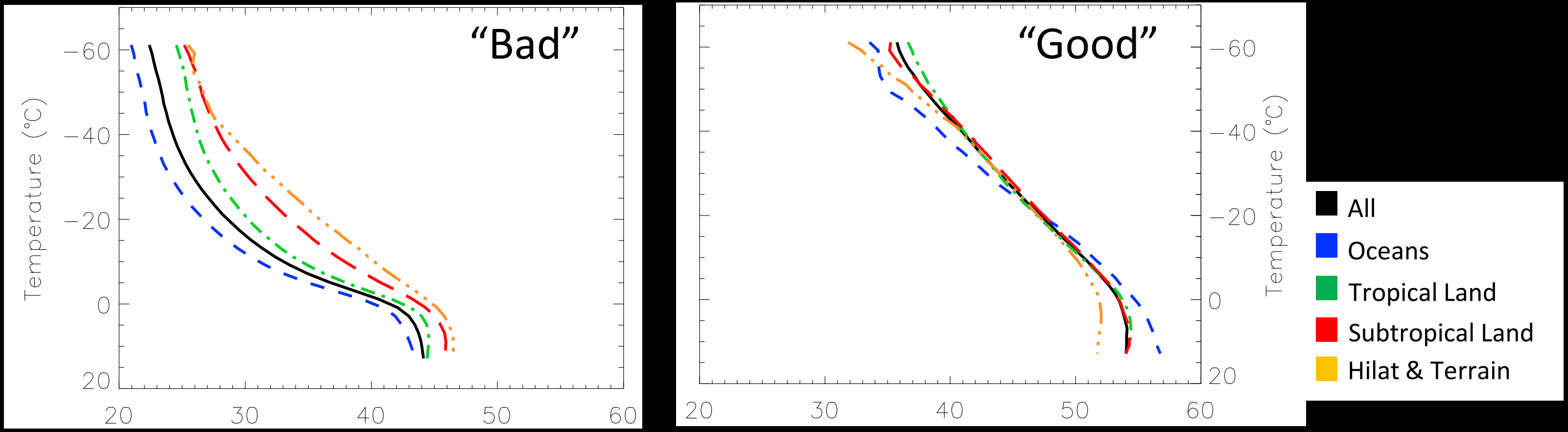
Median Maximum Ku-band Reflectivity (dBZ)

- All
- Oceans
- Tropical Land
- Subtropical Land
- Hi-lat Land & Terrain

Testing with Ku-band Radar: Profiles

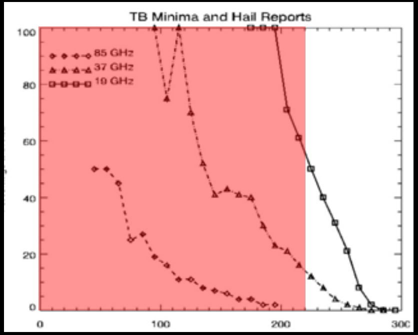


Testing with Ku-band Radar: Profiles

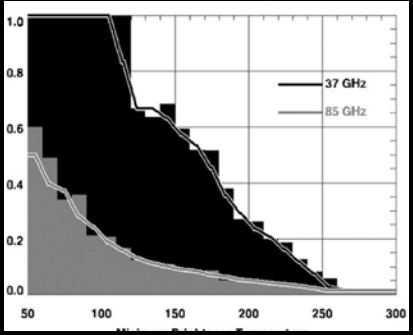


Median Maximum Ku-band Reflectivity (dBZ)

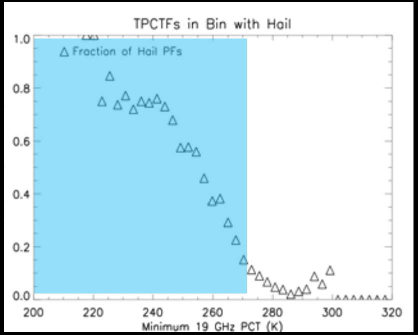
Ni et al. (2017)
37 GHz Cutoff



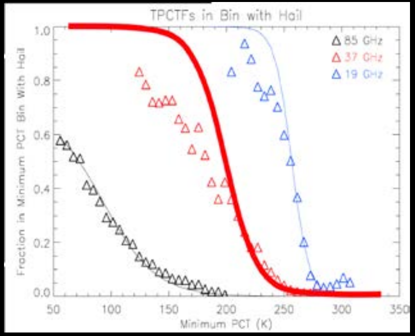
Cecil and Blankenship (2012)
37 GHz Lookup Table



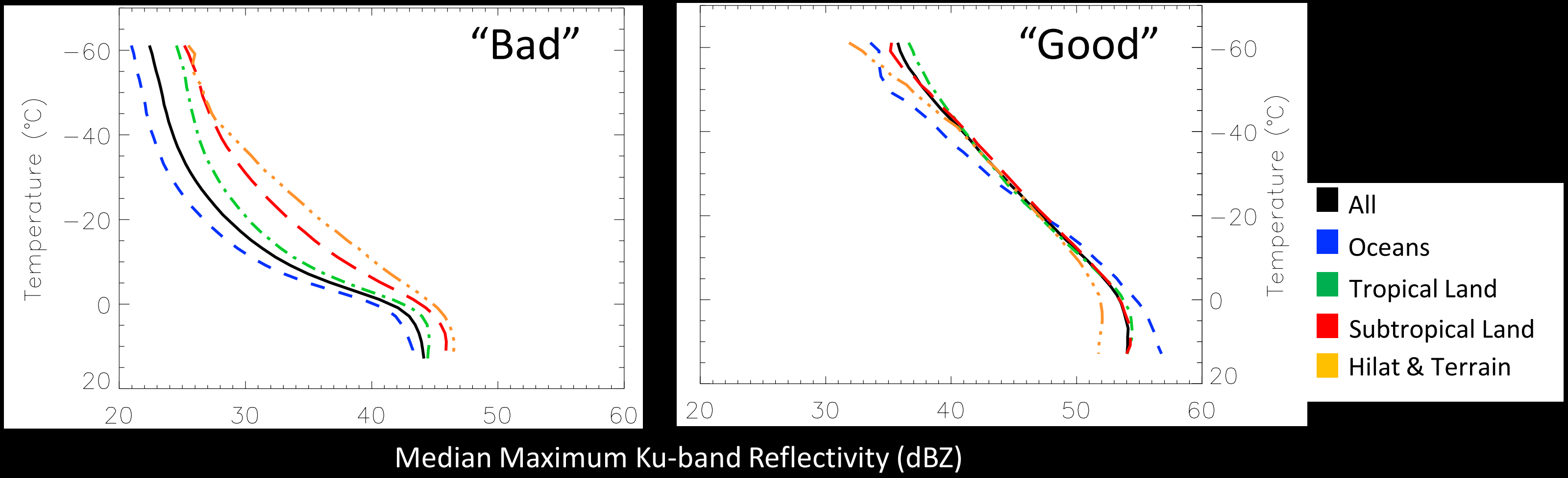
Mroz et al. (2017)
19 GHz Cutoff



Bang and Cecil (2019)
37 & 19 GHz Function



Testing with Ku-band Radar: Profiles



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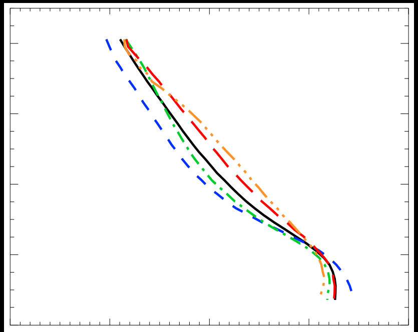

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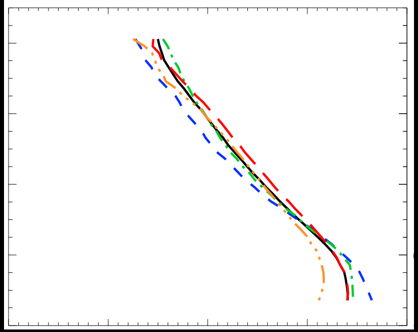

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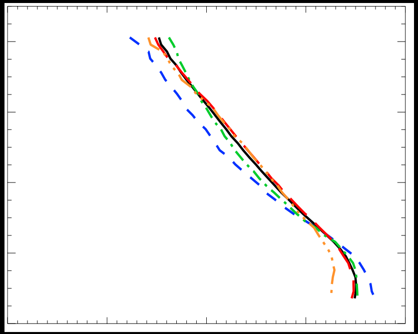
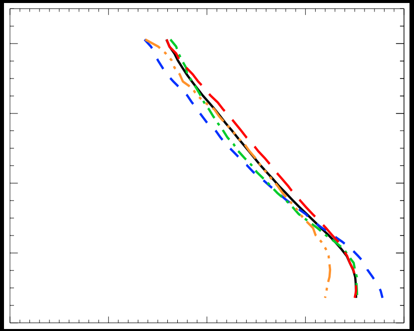
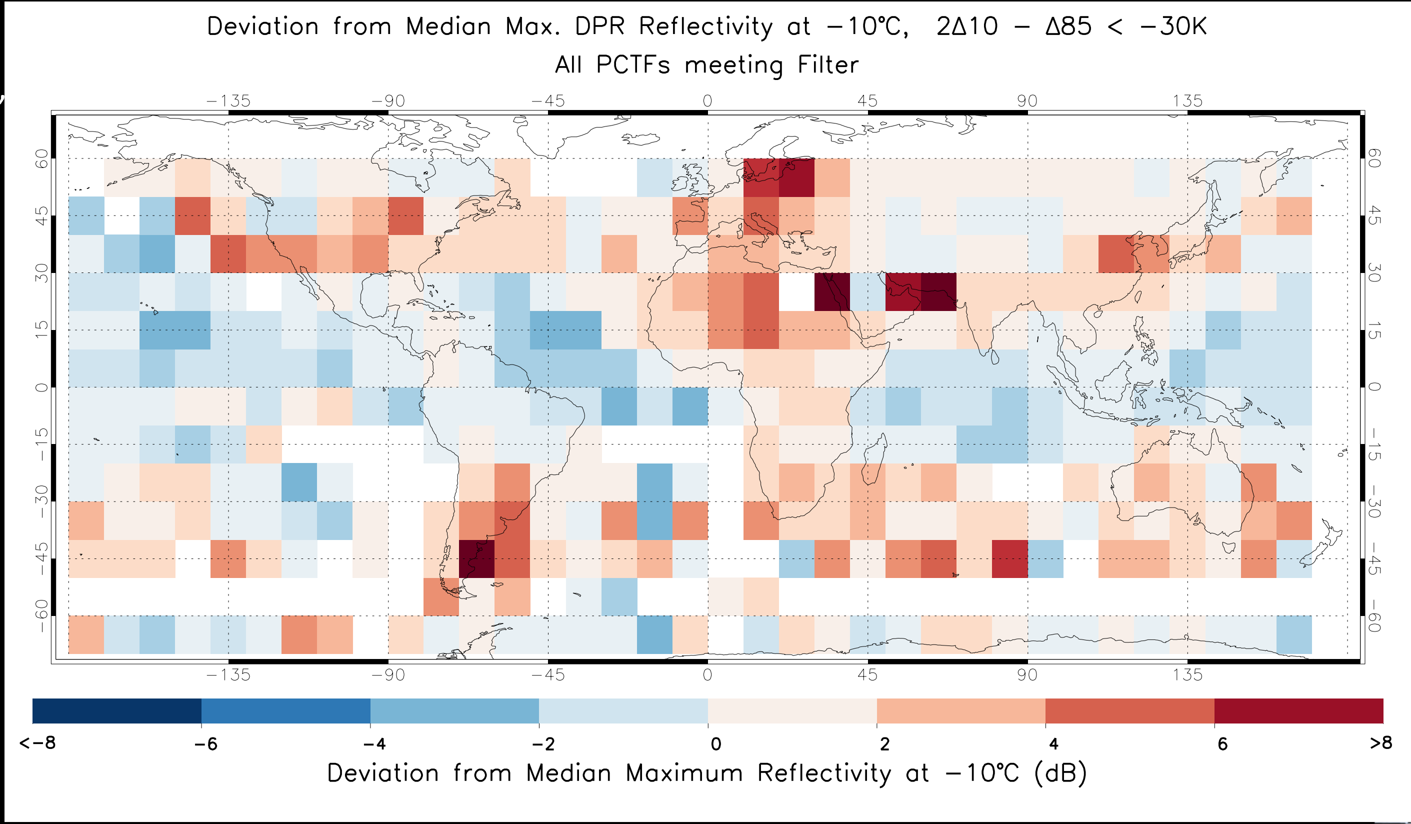


Bang and Cecil (2019)
37 & 19 GHz Function



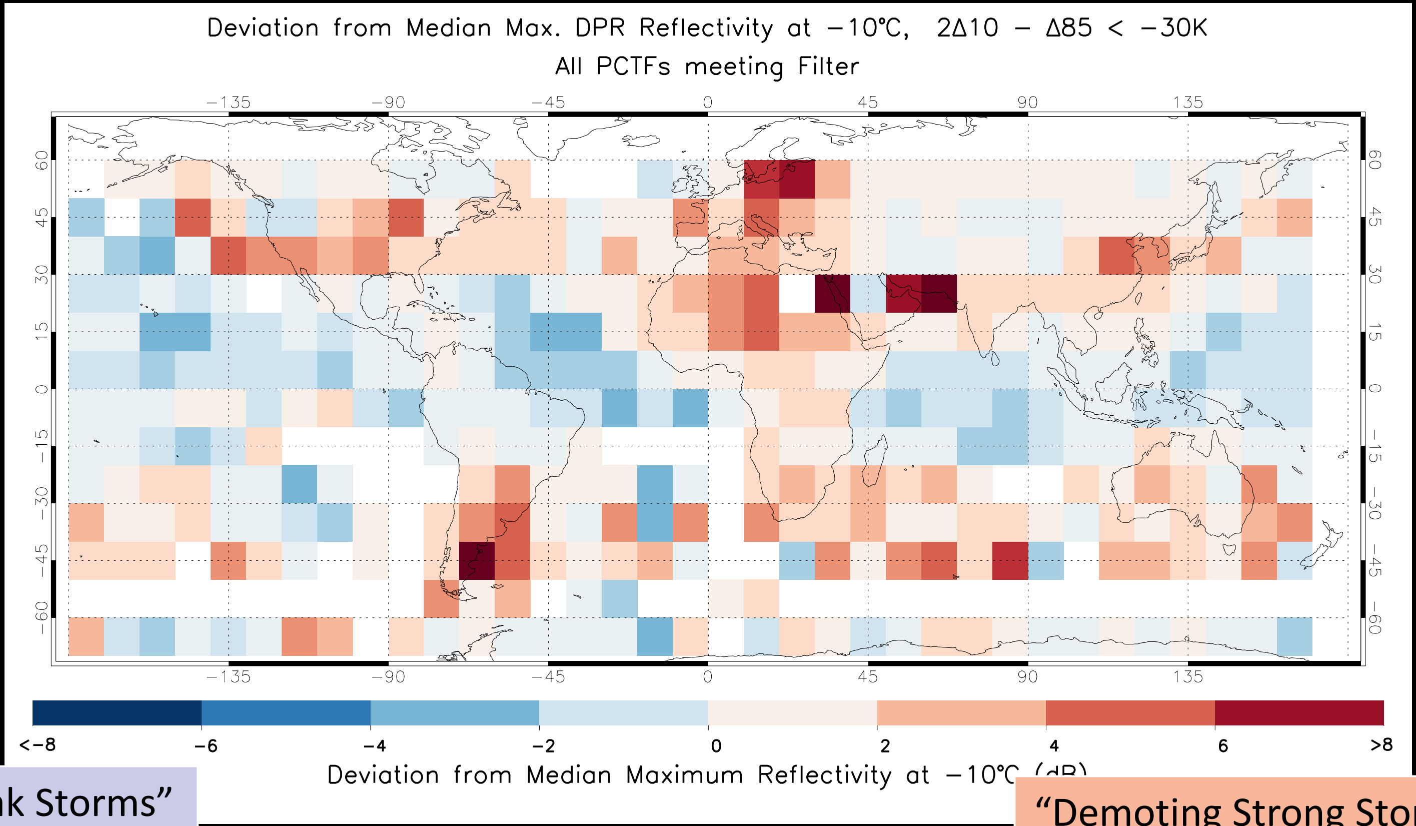
Testing with Ku-band Radar: Bias Maps

The "poor performing" algorithm



Testing with Ku-band Radar: Bias Maps

*A “perfect” map, with no regional bias, would have no color

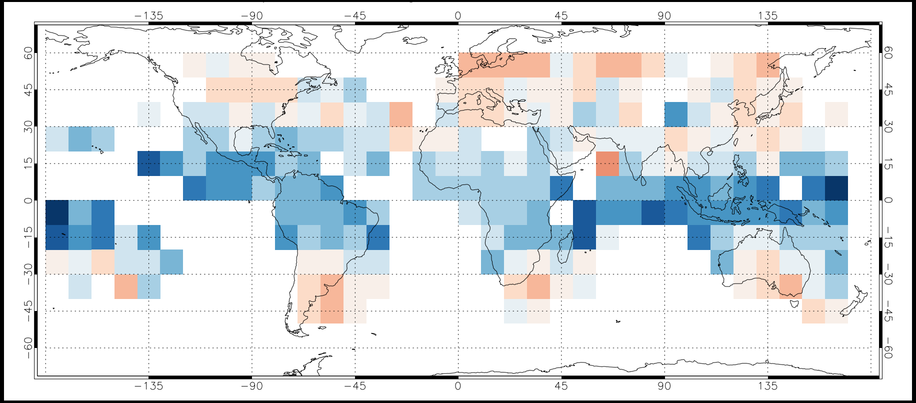


“Boosting Weak Storms”

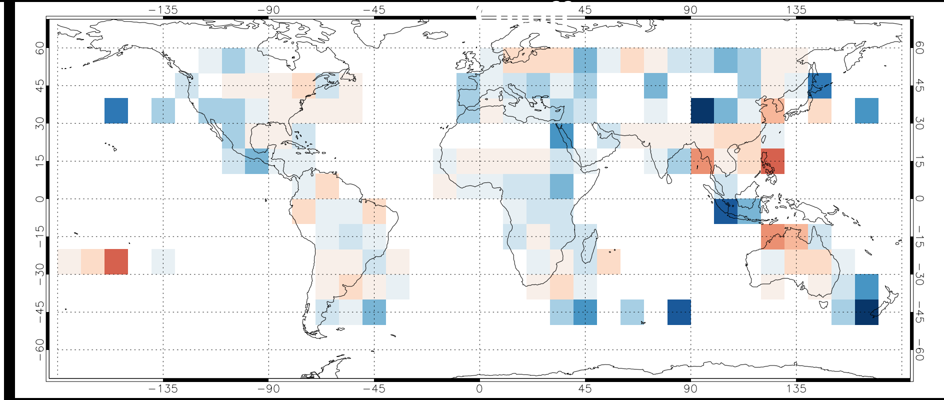
“Demoting Strong Storms”

Testing with Ku-band Radar: Bias Maps

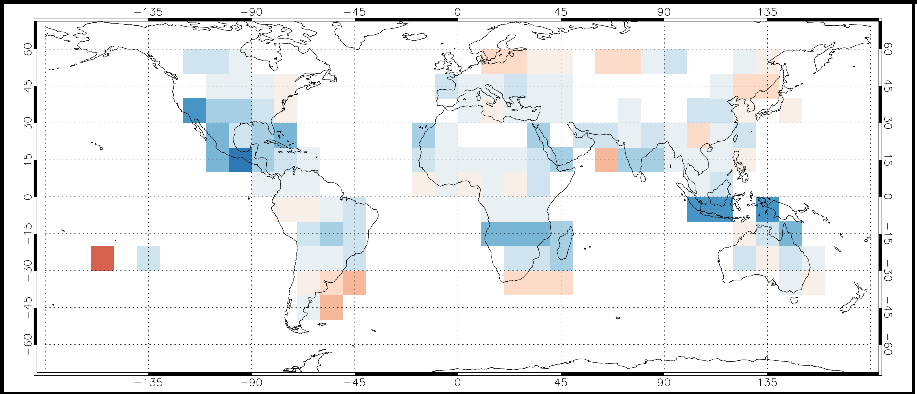
Ni et al. (2017) • 37 GHz Cutoff



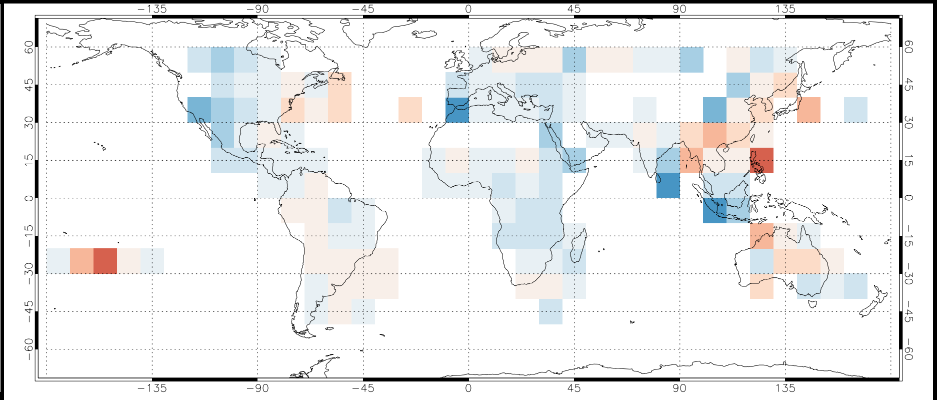
Mroz et al. (2017) • 19 GHz



Cecil and Blankenship (2012) • 37 GHz Lookup Table

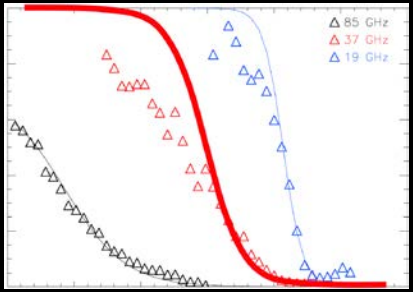


Bang and Cecil (2019) • 37 & 19 GHz Function

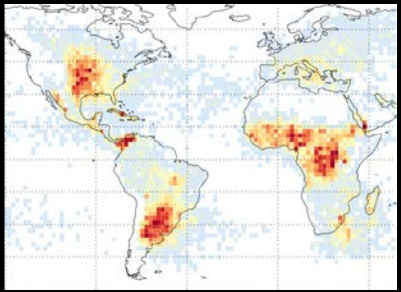


Summary

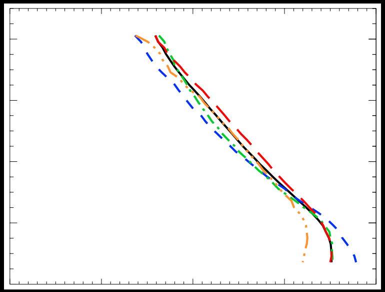
Train a hail detection algorithm on a TRMM feature database paired with surface hail reports.
Create a P_{hail} function based on both 37 & 19 GHz PCTS



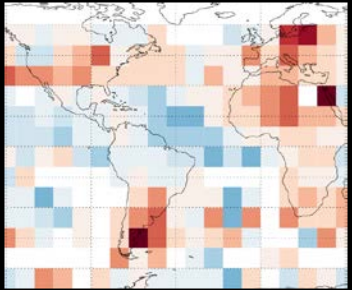
After adjusting for footprint size and surface snow and ice, apply that algorithm to features in the GPM domain to build a near-global climatology of hail.



Test the performance of the retrieval using concurrent DPR Ku-band radar profiles in different geographic regimes, and against other retrieval techniques.



Test the regional bias of our retrievals (and others in the literature) by looking at radar deviations over the entire GPM domain



Building

Testing

NASA

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Testing a Passive Microwave-based Hail Retrieval and Climatology using GPM DPR Ku-band Radar

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2NASA Marshall Space Flight Center, Huntsville, Alabama, USA

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Thank You!

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