

Spaceborne Passive-Microwave Hail Detection: Global Climatologies, Validation, and Challenges Going Forward

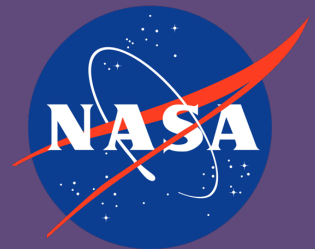
Sarah D. Bang and Daniel J. Cecil

NASA Marshall Space Flight Center

Huntsville, AL

September 20, 2022

North American Hail Workshop • Boulder, Colorado



Spaceborne Hail Observation/Detection



(I know not to hold it in my hand now!)

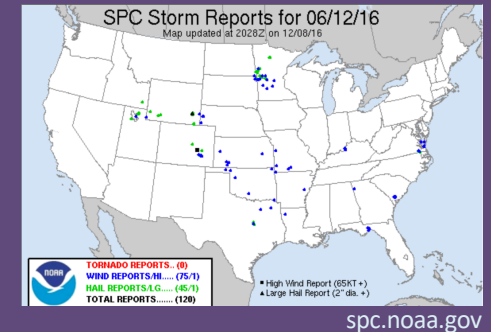
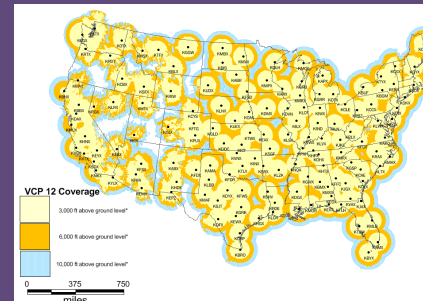
Severe Hail (> 25 mm) poses threats to life, property, infrastructure and agriculture

- Tens of billions of USD in insured loss each year from severe storms
 - Hail constitutes ~70% of these losses
- Hail can cause attenuation in radar observations, multiple scattering, and lead to errors in retrievals
- Seldom retrieved in large-scale satellite precipitation algorithms

Aon Benfield, 2018; 2020; Bataglia et al., 2015

Hail climatologies can be made using ground radar, surface reports

- Spotter reports suffer from nonmeteorological bias
- Radar coverage is not available everywhere



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

Can observe remote, data-sparse, and oceanic regions

Passive-Microwave Hail Detection

Spaceborne Passive-Microwave Radiometers:

- Excellent global coverage
- Long legacy in space



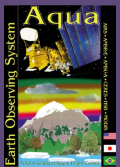
Tropical Rainfall Measuring Mission

- TRMM Microwave Imager (TMI), 1997 - 2014



Global Precipitation Measurement

- GPM Microwave Imager (GMI), 2014 - present



Aqua

- Advanced Microwave Scanning Radiometer for EOS (AMSR-E), 2002 - 2011

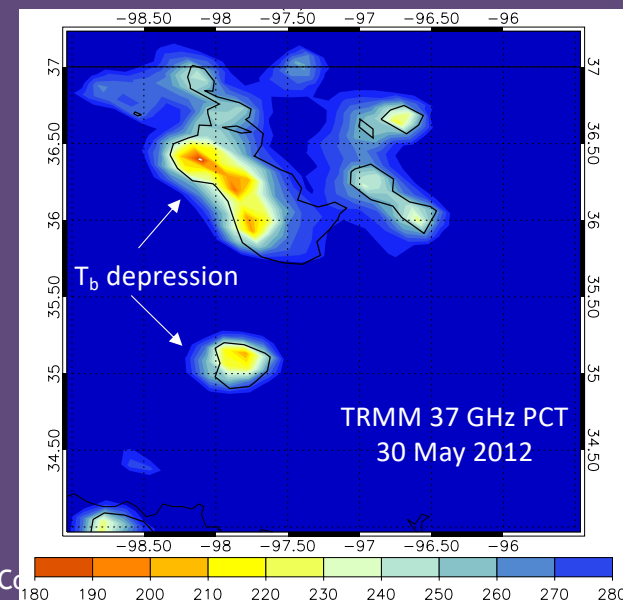
GCOM-W1



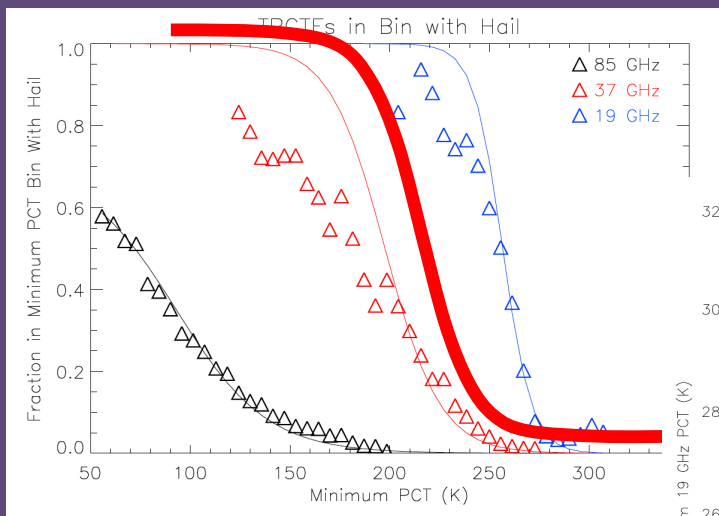
- Advanced Microwave Scanning Radiometer 2 (AMSR2), 2012 - present

Passive-Microwave Hail Detection:

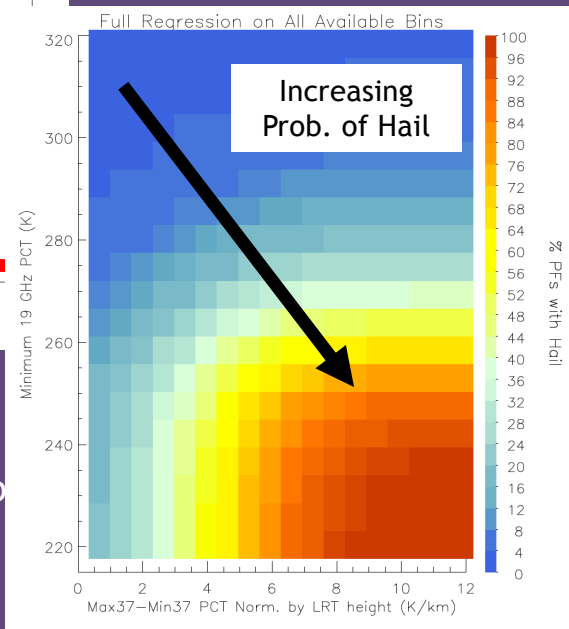
- Upwelling microwave radiation is scattered by hail, resulting in a T_b depression
- The hail size, concentration, depth, and the frequency determine the magnitude of the depression



Bang and Cecil (2019) Passive-Microwave Algorithm



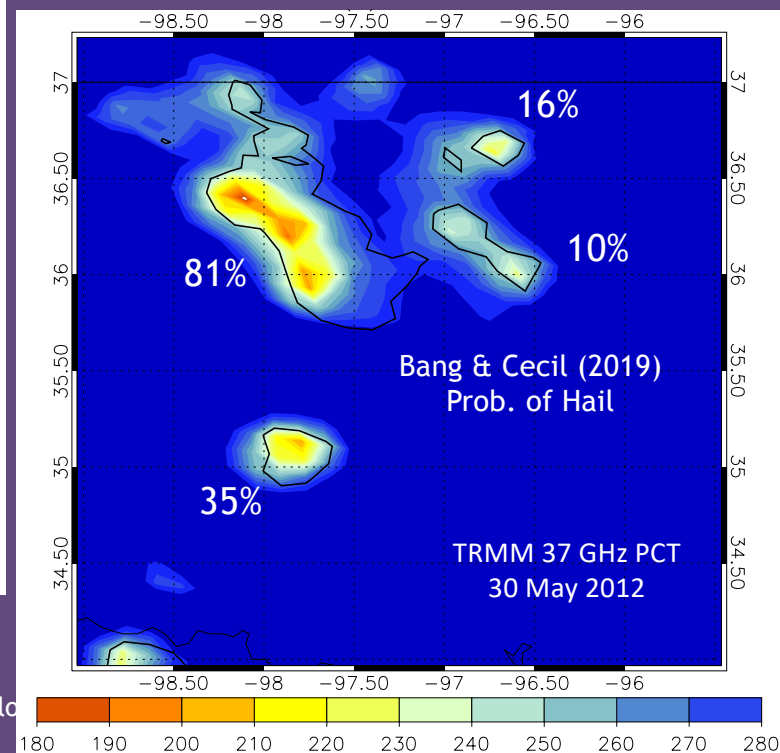
$$f(x) = \frac{L}{1 + e^{-k(x-m)}}$$



Passive-microwave hail-detection algorithms leverage the relationship between decreasing T_b and increasing probability of hail.

Bang and Cecil, 2019

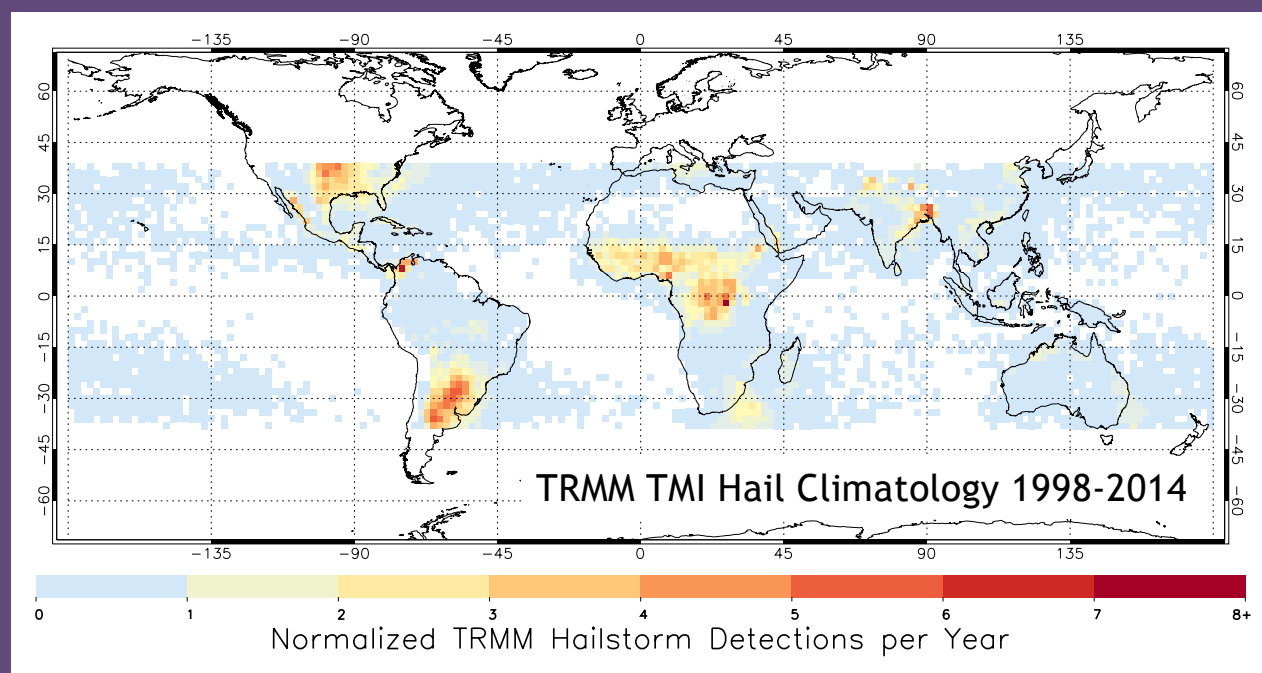
The Bang and Cecil (2019) algorithm was constructed using 17 years of TRMM TMI data paired with SPC severe hail reports. It leverages the 19 and 37 GHz channels.



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Building [near] Global Climatologies

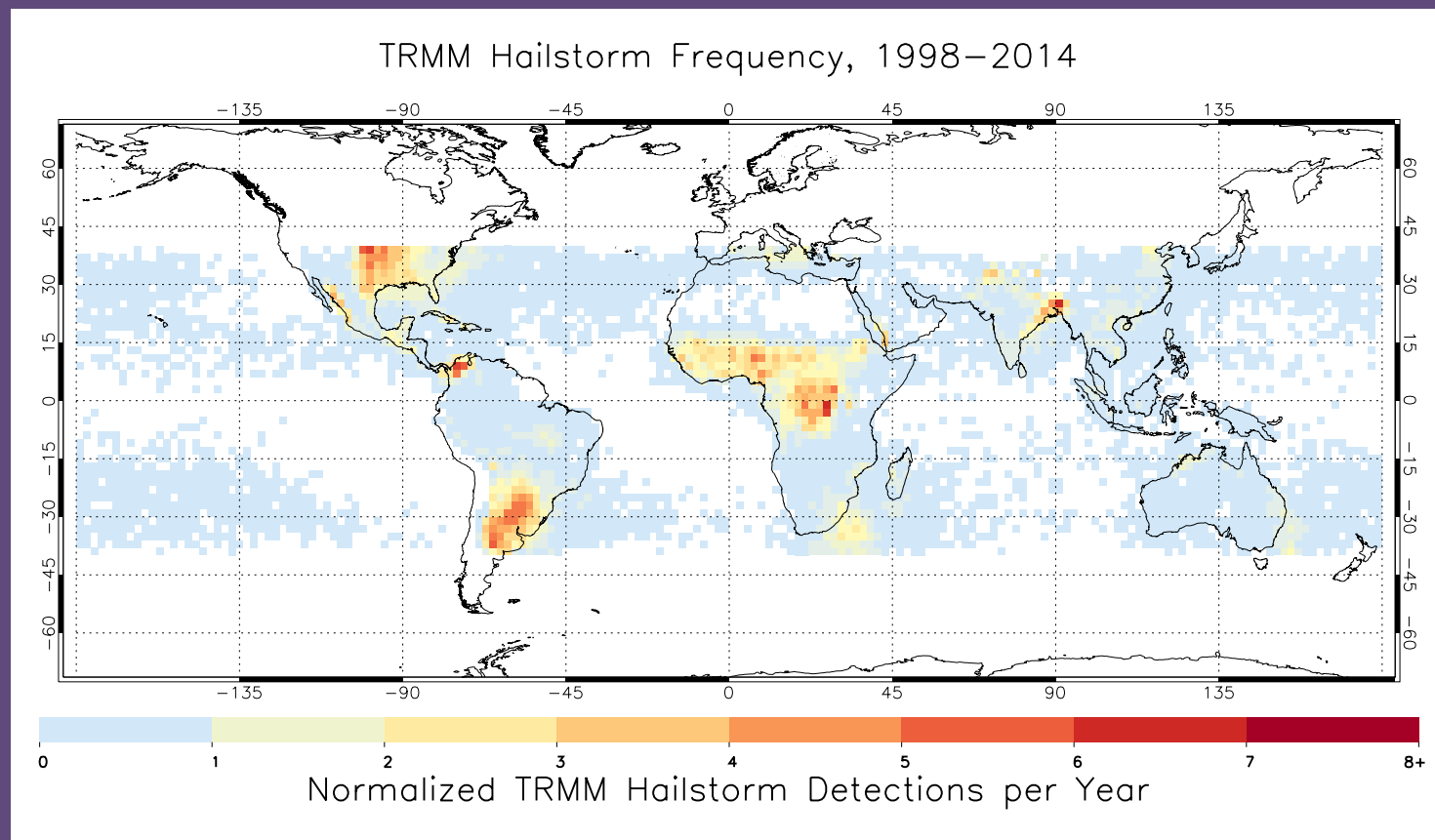


We can now estimate a probability of hail for any precipitating feature given a set of T_b s in the same frequencies and tally them to make a hail climatology.

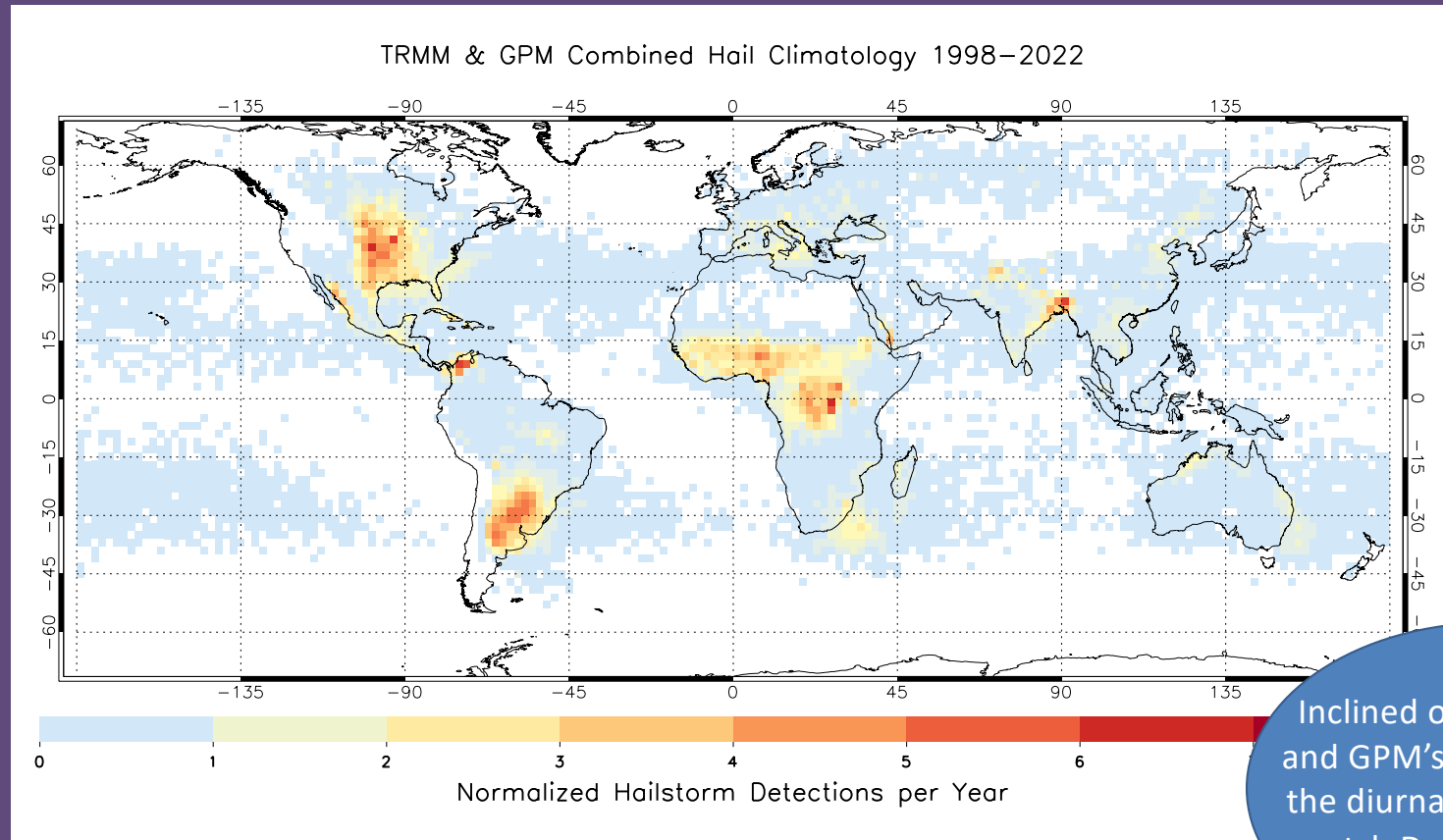


To apply the BC2019 algorithm to other sensors, we first need to adjust the T_b s to account for different footprint sizes.

Other Climatologies and Combination



Other Climatologies and Combination

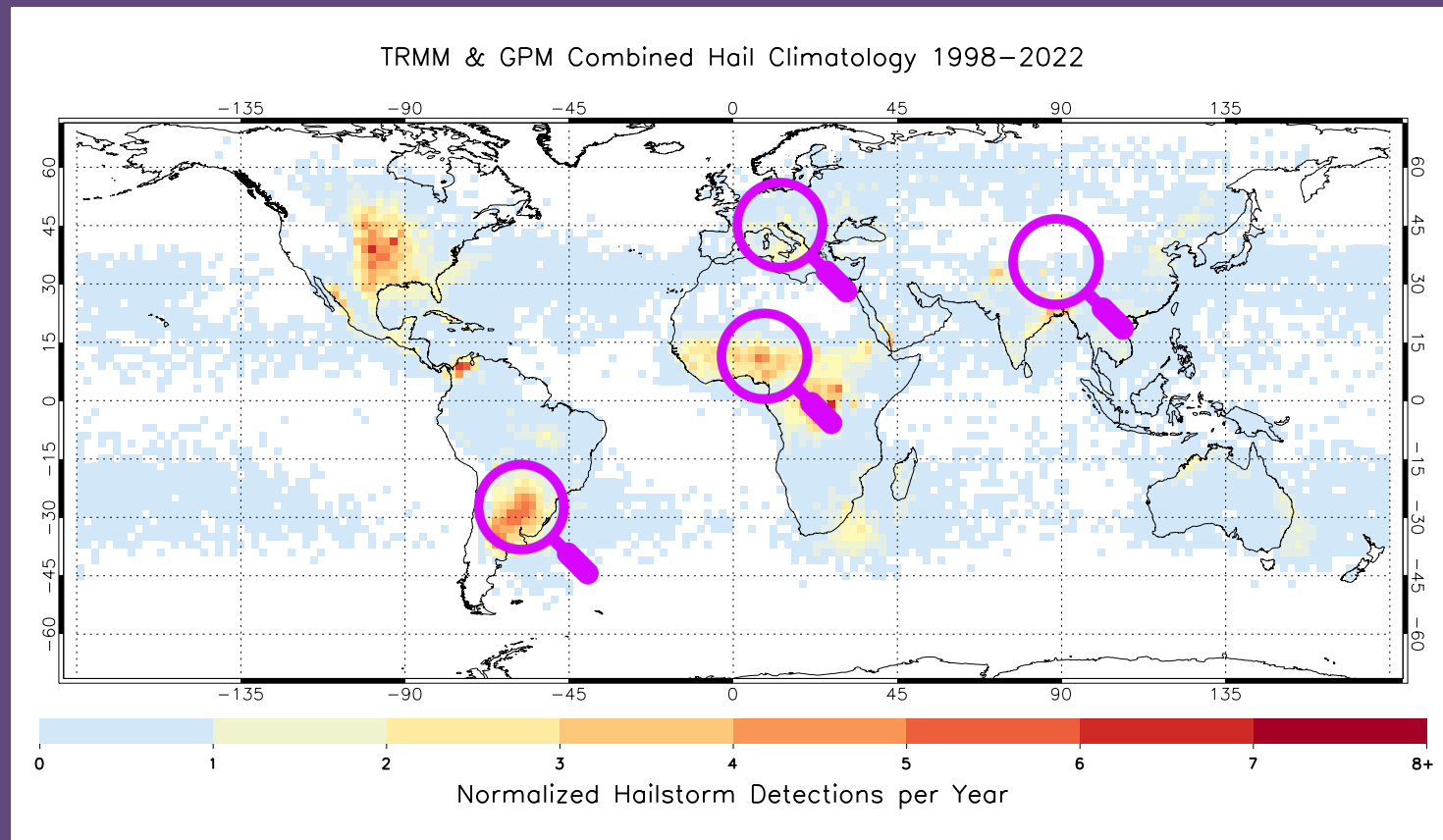


Inclined orbits like TRMM and GPM's make analysis of the diurnal cycle possible – catch Dan Cecil's talk on Thursday at 4:30pm

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Climatology Notes



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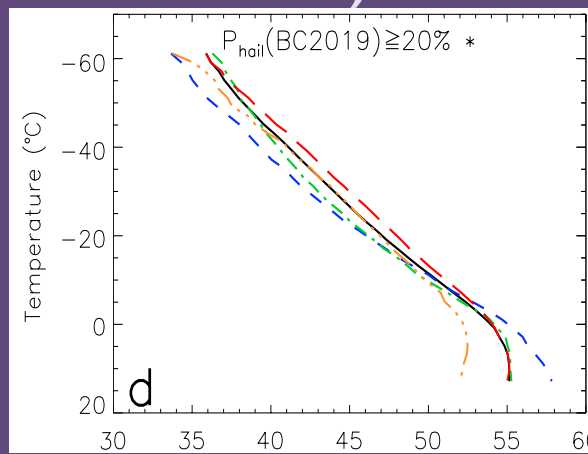
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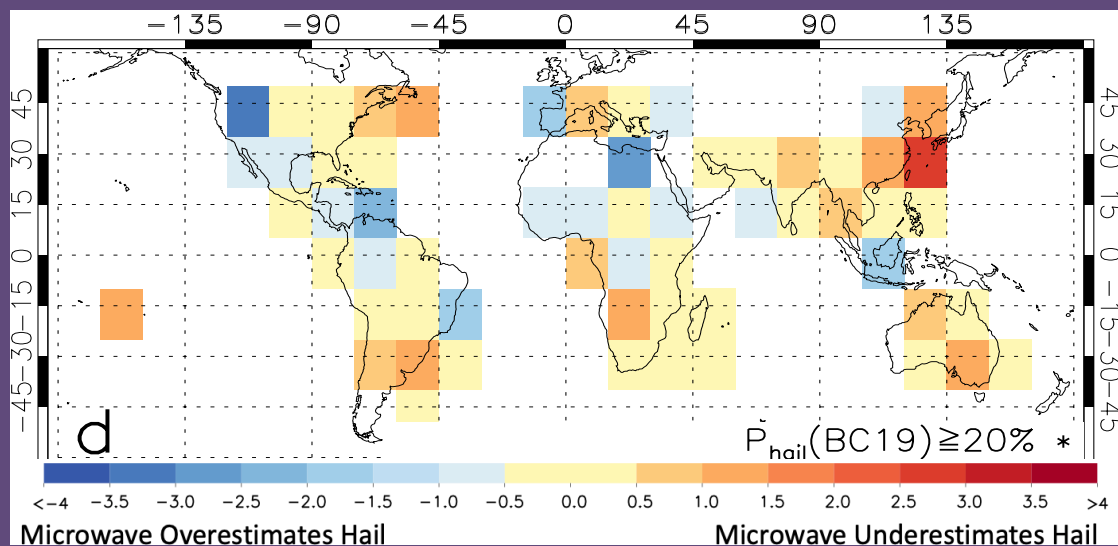
TRMM & GPM (PR & DPR) Validation

- TRMM and GPM both had (have) precipitation radars onboard: the TRMM PR and GPM DPR.
- Precipitation radar (an active sensor) can observe hydrometeors throughout the column and mapped to specific altitudes
- Passive-microwave T_b is a measure of the integrated scattering and results in one temperature, not a profile, as in radar.
- There are well-known relationships between hail and radar reflectivity that we can leverage to examine the passive-microwave based algorithms.



We used the precipitation radars to examine the radar characteristics of what the BC2019 passive-microwave algorithm calls “hailstorms.”

The reflectivity profiles of did not show wide disparities geographically, and high reflectivities (~45 dBZ) near -20°C. Especially compared to others in the literature!



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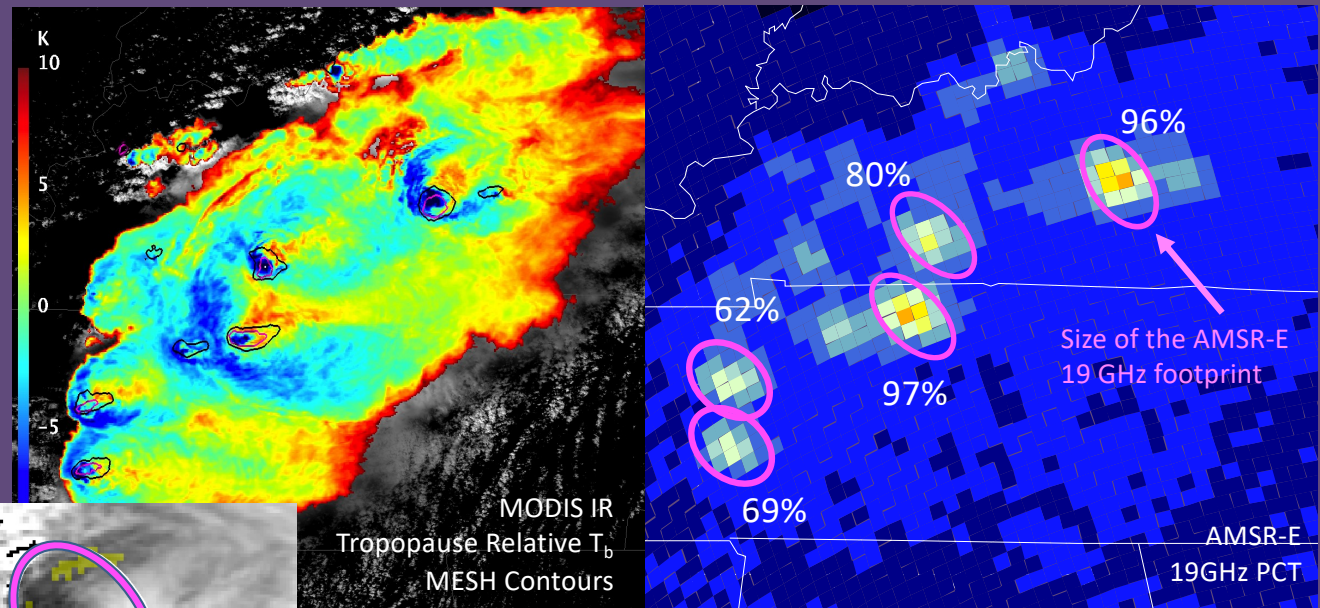
Concurrent, Subsequent and Parallel Work:

Looking at passive-microwave signatures of severe convection using Aqua MODIS and AMSR-E

Sarah Bang, Dan Cecil (NASA MSFC)
Kris Bedka (NASA LaRC)
with: Kyle Itterly, Ben Scarino (SSAI)
Frank LaFontaine (Jacobs), Michael Solomon (UAH)
John Allen (MTSU), and Cameron Homeyer (OU)

Recently funded work in the NASA Science of Terra, Aqua, and Suomi-NPP program includes using fine resolution Aqua MODIS visible/IR observations to assess the non-uniform beam filling in large footprint AMSR-E passive-microwave observations of severe weather phenomena.

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The size of a deep convective core is small relative to a passive-microwave footprint, and therefore the scattering will be non-uniform throughout the FOV. The aim is to use fine resolution coincident MODIS data to tease out more detail about the characteristics of the convection and relate it back to the T_b .



Concurrent, Subsequent and Parallel Work:

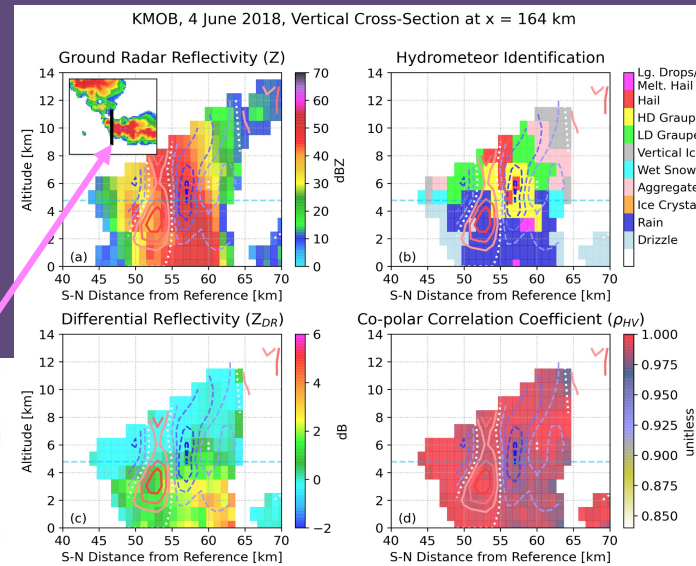
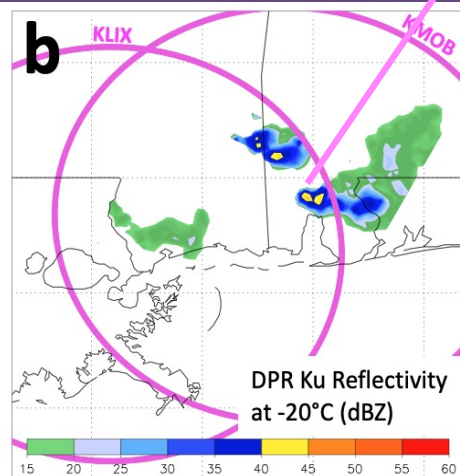
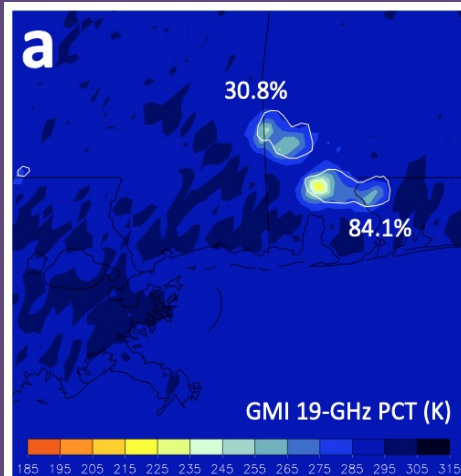
Looking at hail properties, trajectory and melting from satellite, ground-based radar, in-situ aircraft, and simulations

Sarah Bang (NASA MSFC), Becky Adams-Selin (AER)

Sarah Stough (UAH), Andy Heymsfield (NCAR)

with: Aaron Bansemer (NCAR), Andy Detwiler (UND)

Concurrent work in the NASA Precipitation Measurement Mission focuses on assessing hail size distributions, trajectories, melting, and how this is manifested in hail retrieval algorithms (like BC2019).

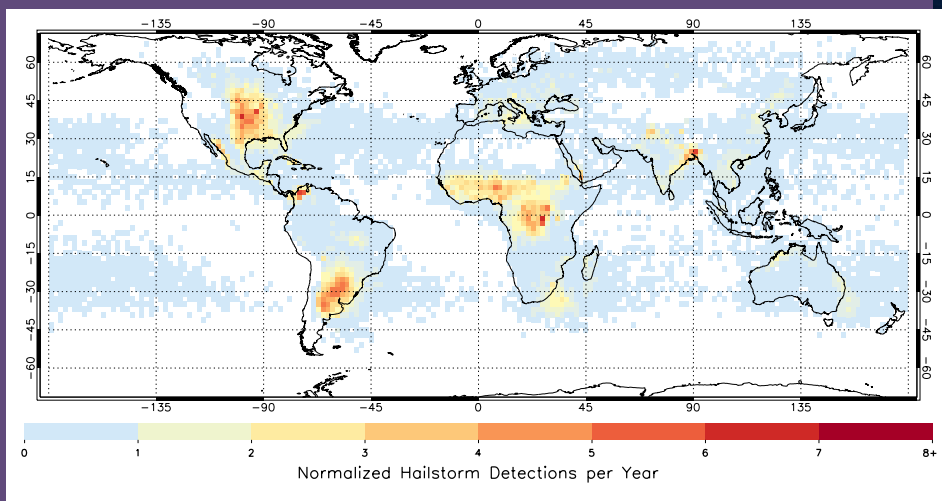


Using the GPM Validation network, we can examine the microphysical and kinematic characteristics of GMI-identified hailstorms. We will also examine PSDs derived in-situ from aircraft, radar-PSD relationships, and environmental characteristics, and then simulate the hailstones' trajectories and melting in HAILCAST to analyze and aim to tie those properties to the satellite signatures.

Possible disconnect between the hailstones aloft in the cloud when the satellite instrument detects them and what hailstones are reaching the ground where humans experience them

Graupel/small hail aloft may have low T_b but melt along its trajectory, leaving subsevere or no hail at the surface.

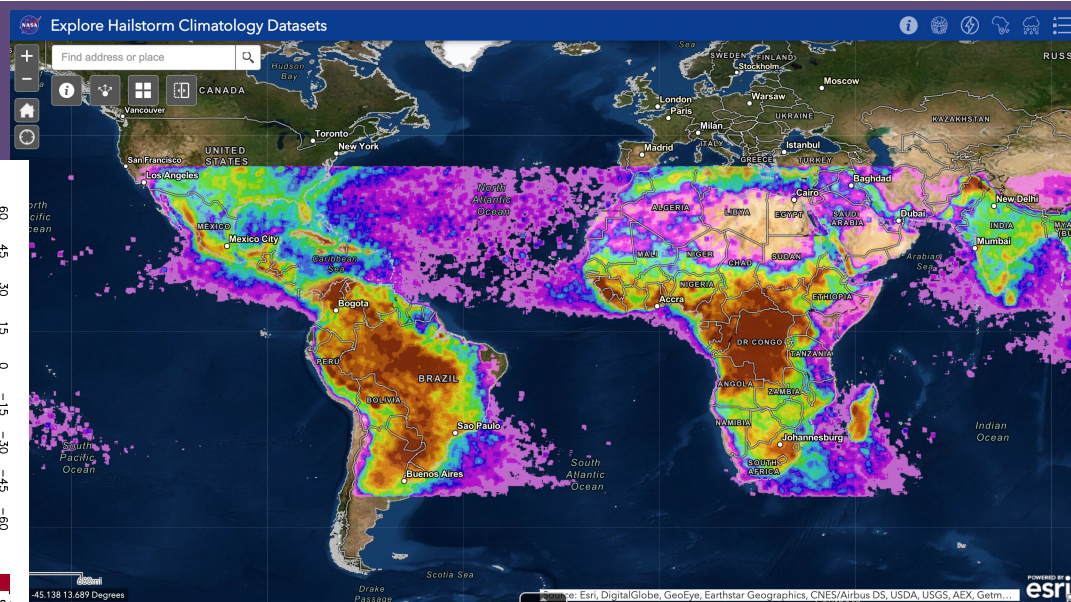
Data Access



Hail Climatologies
TRMM, GPM, TRMM + GPM
publicly available from the
NASA Global
Hydrometeorology Resource
Center (GHRC)

ghrc.nsstc.nasa.gov/pub/hail_climatology/data/

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ArcGIS Hailstorm Climatology Visualization Portal

<https://arcgis.is/0C8eXC>

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SPECIAL
Global Precipitation Measurement (GPM)
COLLECTION

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

Testing Passive Microwave-Based Hail Retrievals Using GPM DPR Ku-Band Radar

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- Aon Benfield, 2020: Weather, Climate & Catastrophe Insight: 2019 Annual Report. Aon Benfield Analytics and Impact Forecasting, 1-81 pp.
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