Intense / Severe Convective Systems: Climatologies and Precipitation Retrievals

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Infer severe thunderstorms based on their TRMM signatures

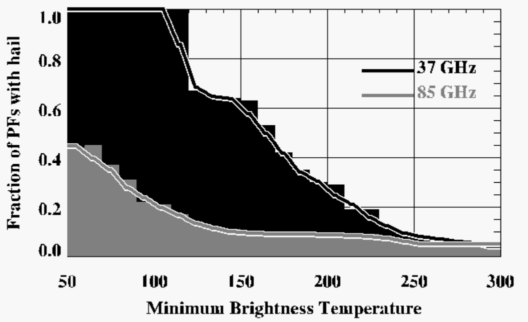
Following approach from Cecil (2010) JAMC, match reports of large hail (at least 1 inch diameter) in the U.S. to TRMM Precipitation Features

For a given TMI brightness temperature or PR reflectivity, what is the likelihood large hail was reported nearby?

Have to use a large time window to search for reports, since TRMM only sees short instances in time

Have to use a large space window to search for reports, since Precip Feature centroid location is used (not necessarily the location of the strongest convective signature)

The approach is purely empirical, with the parameters chosen based on physical reasons.



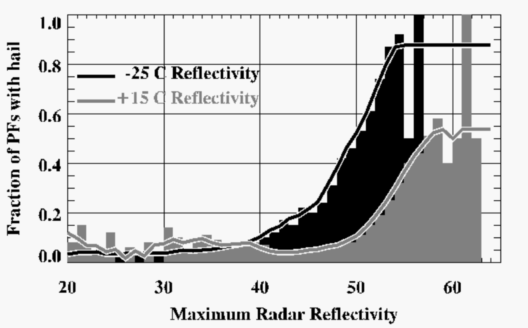
Lower brightness temperature is increased with a greater likelihood of large hail, because larger hailstones scatter more of the upwelling radiation. A few large hailstones woud also usually be accompanied by a large concentration of smaller (but radiometrically significant) hailstones within the satellite footprint.

37 GHz channel is more responsive to large hail than 85 GHz, because its longer wavelength is less influenced by the smaller particles.

To estimate hail climatologies, we use features with:

37 GHz < 200 K - count each storm as a fraction of an occurrence, with that fraction weighted as the value in the figure above. E.g., if the storm has ~190 K at 37 GHz, it counts as ~ 0.3 hail storms. If the storm has 100 K at 37 GHz,, it counts as 1.0 hail storms. Limit at 200 K to lessen the influence of numerous weaker storms. The hail probability becomes significant below ~200 K, and large below ~160 K.

85 GHz < 90 K - same procedure as above, except the probabilities from 85 GHz never get very large, topping out at 0.45. A deep column with high concentrations of large graupel and small hail can give an extremely low 85 GHz temperature.



Global maps of estimated hailstorms (right):

To first order, all these approaches show similar distributions of likely hailstorms, with hotspots in:

Central and West Africa

Subtropical South America

Subtropical North America (especially south central U.S.)

Bangladesh

Pakistan

South Africa

They differ in the details, especially concerning the tropics versus subtropics.

TMI-based estimates put many more storms over tropical land, especially Central Africa, the Amazon Basin, northern Colombia, and the Maritime Continent.

PR-based estimates drastically reduce the count over oceans, the Amazon, Colombia, and Maritime Continent.

Total count in each plot depends on the cutoff threshold used to limit the influence of the numerous weaker storms. Such tuning makes differences in the number of storms over the oceans and the peak values from the continents especially noticeable. The thresholds used in these plots were chosen based on the 30% probability of hail from the figures at left.

Radar reflectivity should be a more direct measure, since it resolves particular altitudes instead of responding to a column-integral. Numerous methods for identifying hail from ground-based radars (especially WSR-88D NEXRAD) have been developed. But large liquid drops are also highly reflective.

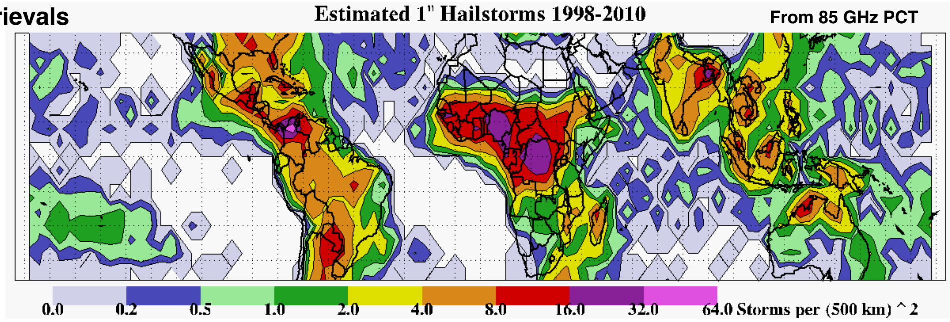
To eliminate warm rain cases, we first require 40+ dBZ @ -5 C temperature level (from NCEP reanalysis).

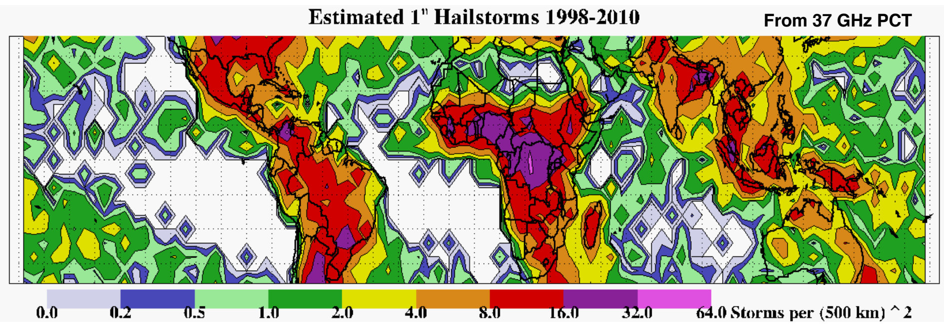
Using TRMM PR, attenuation is an issue. A hail core generally has a deep column of high reflectivities, attenuating the 2.2 cm signal. Even with 2A25 attenuation correction, how much can the low levels be trusted?

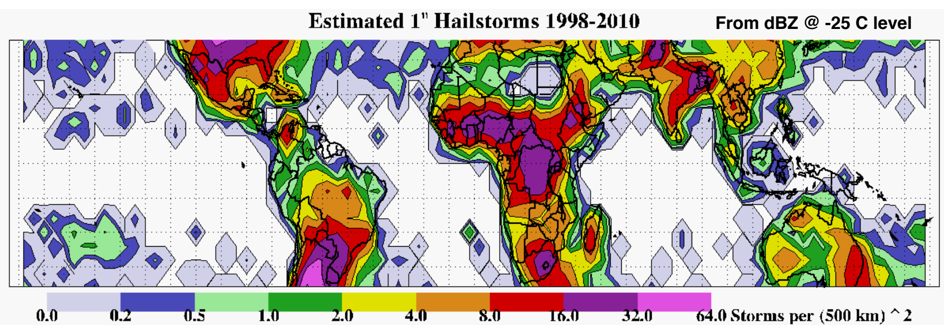
To estimate hail climatologies, we use features with:

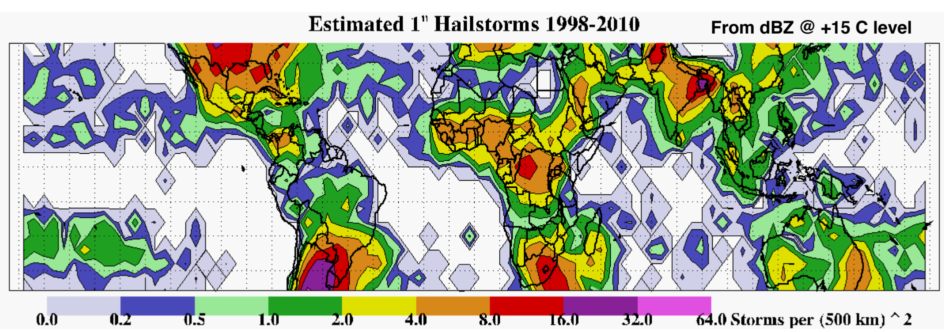
45+ dBZ @ -25 C temperature level - Except in the most extreme cases, there should not be much attenuation this high. If *large* hail stones exist aloft, they should not lose much diameter to melting because they have large terminal velocities and large mass. Hail probabilities become large as reflectivities exceed 50 dBZ. This correlates with even greater reflectivities at lower altitudes.

54+ dBZ @ +15 C temperature level - A simple approach is to look at low levels with the radar. But will problems with attenuation or contamination of the signal by large liquid drops overwhelm the hail signal? The hail probability doesn't get very high. Only 32 / 58 cases exceeding 58 dBZ were associated with hail reports in the training sample.

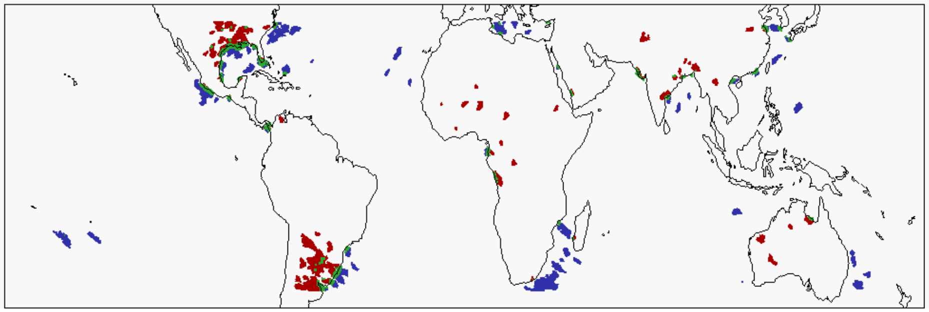








Top 100 Land and Ocean PFs by lowest 37 GHz
2A12 V7 Surface Types



ABOVE: Locations of Intense Precipitation Features used in this analysis. From the top 100 over-land precipitation features and top 100 over-ocean precipitation features, ranked by their coldest 37 GHz PCTs.

Red: Land Pixels in 2A12 V7

Blue: Ocean Pixels in 2A12 V7

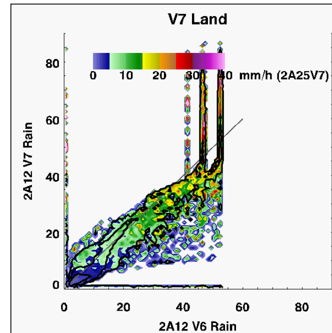
Green: Coast Pixels in 2A12 V7

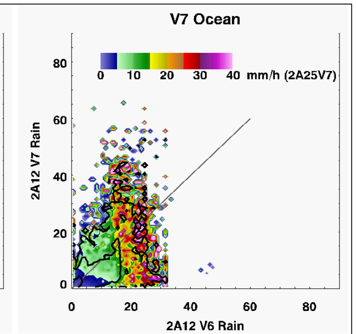
Pixels are selected based on Version 6:

2A25 Near Surf Z ≥ 20 dBZ or

1B11 85 GHz PCT ≤ 250 K

Changes from Version 6 to Version 7 for Intense Convective Systems



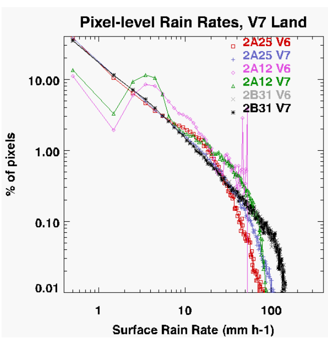


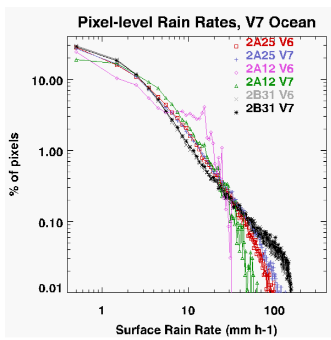
Color shading above: Mean 2A25 Version 7 Surface Rain Rate for pixels with the specified combination of 2A12 surface rain rates.

Black Contours: Probability Density Function of version 6 and version 7 rain rate combinations, at levels 10^{-5} and 10^{-4} of entire sample.

2A12 Land: Version 7 decreases rain rates compared to Version 6, and generally agrees better with 2A25 surface rain.

2A12 Ocean: Version 6 is more reliable at identifying high rain rates (if taking 2A25 as accurate). Version 7 is more reliable with the lowest (but most common) rain rates.





LEFT:

Histograms of surface rain rates from the various algorithms, for all pixels in the selected intense convective systems. This includes stratiform rain, and is conidtioned on Version 6 Precipitation Features:

20+ dBZ Near Surface Reflectivity (2A25 V 6) or

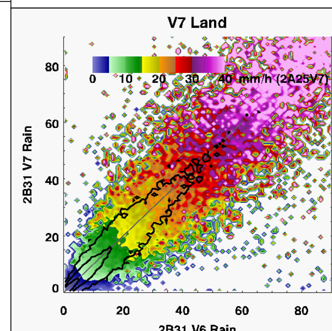
250 K or lower 85 GHz PCT (1B11 V 6)

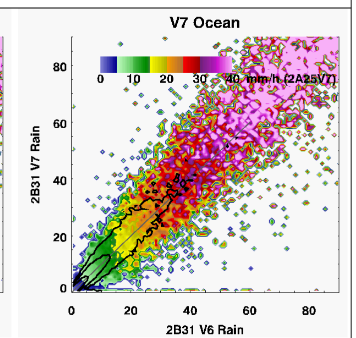
BOTTOM LEFT:

Subset of pixels with strong convective signatures from either PR or TMI:

30+ dBZ Reflectivity at 8 km (2A25 V7) or

220 K or lower 37 GHz PCT (1B11 V7)

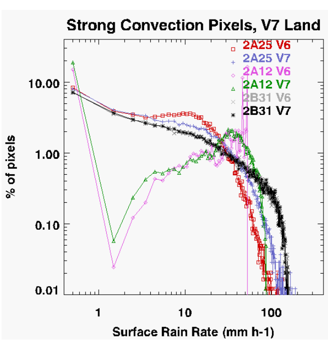


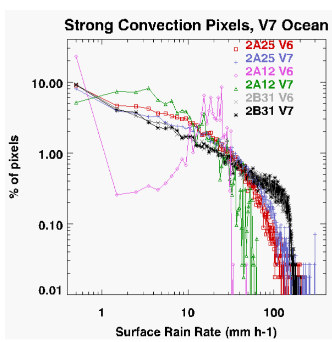


Color shading above: Mean 2A25 Version 7 Surface Rain Rate for pixels with the specified combination of 2B31 surface rain rates.

Black Contours: Probability Density Function of version 6 and version 7 rain rate combinations, at levels 10^{-5} and 10^{-4} of entire sample.

2B31 surface rain rates do not appear to have large systematic differences between Versions 6 and 7, and 2B31 rain rates are strongly consistent with 2A25 surface rain rates.





Right:

Color shading: Mean 1B11 Version 7 85 GHz Polarization Ocrrected Temperature for pixels with the specified combination of 2A25 surface rain rates.

Black Contours: Probability Density Function of version 6 and version 7 rain rate combinations, at levels 10^{-5} and 10^{-4} of entire sample.

Where Version 6 and Version 7 2A25 differ, Version 7 tends to correlate with the 85 GHz scattering signature - a lower 85 GHz goes with a higher 2A25 V 7 surface rain rate, compared to 2A25 V6.