Properties of Global Extreme Rainfall Events Identified Using the GPM Precipitation Radar

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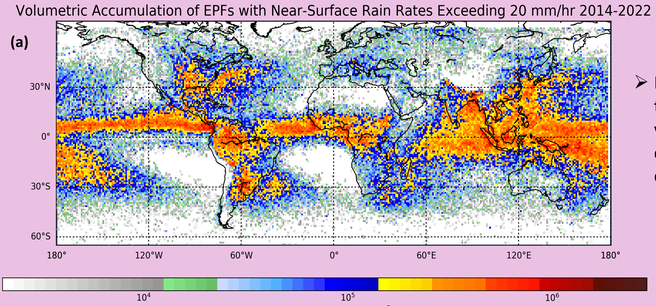
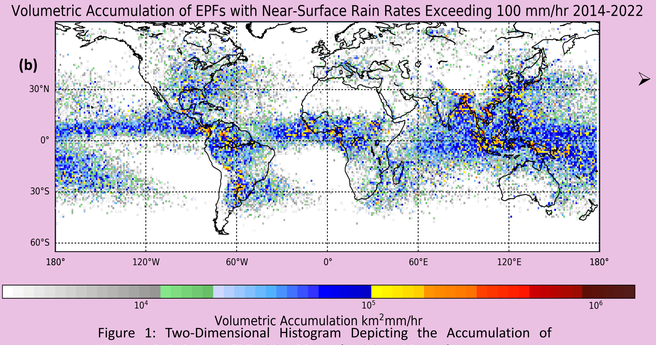
Volumetric rain from extreme rain rates:

Volumetric Accumulation of EPFs with Near-Surface Rain Rates Exceeding 20 mm/hr 2014-2022



- EPFs over the ocean typically exhibit higher volumetric precipitation compared to events occurring over land.

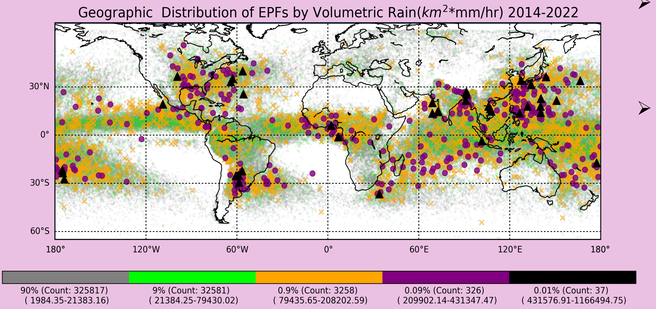
Volumetric Accumulation of EPFs with Near-Surface Rain Rates Exceeding 100 mm/hr 2014-2022



- Regions such as the Amazon Argentina Central/West Africa, and South Asia experience significant volumetric accumulations from extremely severe events

Figure 1: Two-Dimensional Histogram Depicting the Accumulation of Volumetric Rain from EPFs. (a) > 20 mm/hr, (b) > 100 mm/hr

Geographic Distribution of EPFs by Volumetric Rain(km^2*mm/hr) 2014-2022



- The top 1% of EPFs exhibit volumetric precipitation amounts ranging up to 1,116,494 km² *mm/hr.
- Many of the most extreme cases are found near previously mentioned regions as well as Argentina, the United States and the Indian Ocean. Some of them are tropical cyclones

Figure 2: Geographic Distribution of EPFs Categorized by Percentiles Based on Their Volumetric Rain Contributions.

2D Histogram of MAXNSPRECIP vs. Log(VOLRAIN_KU)

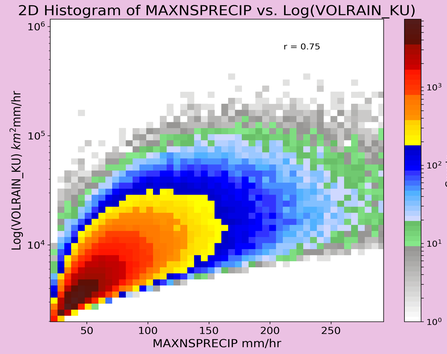


Figure 3: Two-Dimensional Histogram Depicting the relationship between Maximum NS rain rate and Volumetric rain coming from EPFs with a NS rain rate exceeding 20 mm/hr

- There is a strong correlation between maximum near-surface rain rates and volumetric accumulations. Higher rain rates are typically associated with higher volumetric precipitation amounts, and lower rain rates with decreased amounts.

Monthly Distribution of EPFs Based on Volumetric Precipitation (km^2*mm/hr)

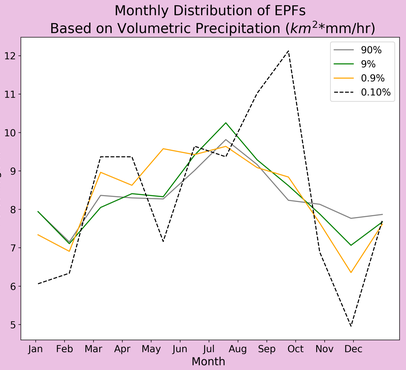


Figure 4: Histogram Depicting the Seasonal Distribution of EPFs by Volumetric Rain Contribution Percentile Categories.

- The frequency of EPFs increases in the spring and reaches a peak during the summer months, aligning with the height of the hurricane season as well as the monsoon season in South East Asia and South West United States.

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Objectives:

- This study aims to comprehensively analyze the properties of extreme rainfall events globally, utilizing data from the Global Precipitation Measurement (GPM) satellite spanning 2014-2022
- What is the global geographical distribution of extreme rainfall events, and how do their volumetric contributions from extreme rain rates compare across different regions?
- What distinctions in land and ocean properties are observed during extreme rainfall events

Data and methodology:

- Extreme Precipitation Features (EPFs) are defined by grouping contiguous pixels with at least 20 mm/hr. precipitation rate as derived by the GPM Ku band radar. From the defined criteria, 362,019 such events were identified in 8+years.
- The characteristics of the EPFs, emphasizing their geographical locations, maximum heights of 20, 30, 40 dBZ echo tops, and volumetric rain are summarized, and seasonal variations are analyzed.

Geographic Distribution of EPFs based on Maximum Near Surface Rain Rate 2014-2022

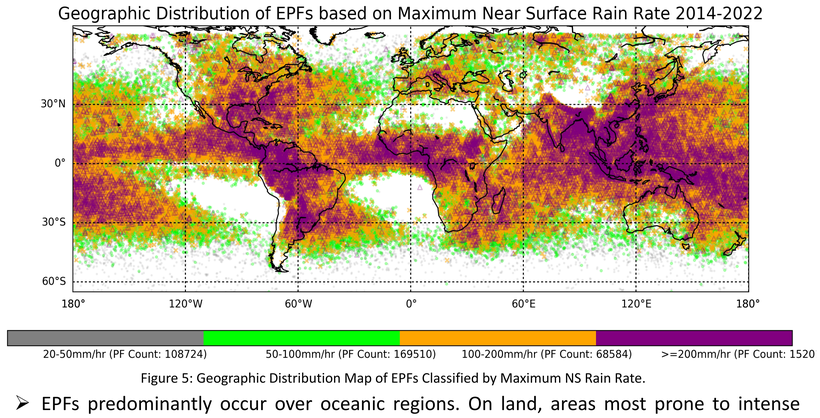
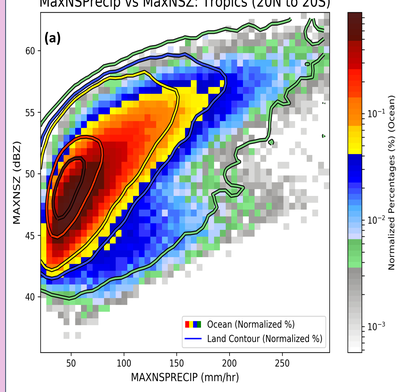


Figure 5: Geographic Distribution Map of EPFs Classified by Maximum NS Rain Rate.

- EPFs predominantly occur over oceanic regions. On land, areas most prone to intense rainfall, where events with maximum near-surface rain rates can surpass 200 mm/hr—include the Amazon, Argentina, Central Africa, and Southeast Asia.

MaxNSPrecip vs MaxNSZ: Tropics (20N to 20S)



MaxNSPrecip vs MaxNSZ: Mid-Latitudes (23.5N to 66.5N)

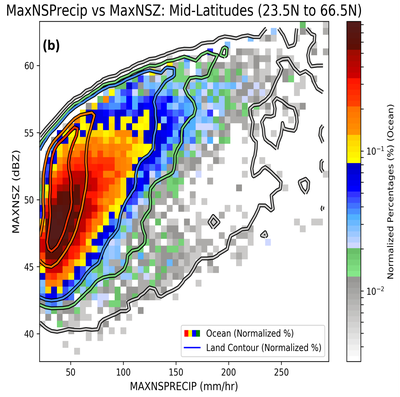


Figure 6: Normalized two-dimensional histograms and contours between MAXNSPRECIP and MAXNSZ in different geographical zones. (a) Depicts the distribution for tropical regions, spanning 20°N to 20°S (b) Depicts the distribution for mid-latitude regions, from 23.5°N to 66.5°N. The histograms represent oceanic data, indicated by normalized percentages of the total counts, while the blue contour lines delineate land data, smoothed using a Gaussian filter for clarity.

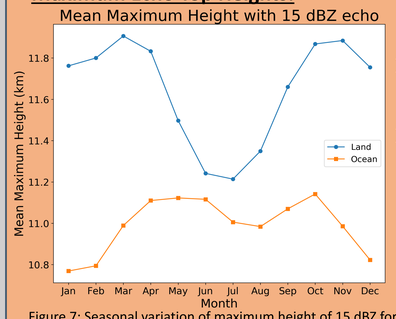
- The figure indicates a shift between land and ocean, revealing that even with equivalent maximum near-surface rain rates, the reflectivity is generally higher over land compared to over the ocean.
- A secondary peak is observed over the ocean, predominantly observed in the tropics, especially in the Atlantic and Pacific Ocean. These events occur most frequently during the spring and summer months, aligning with the hurricane season.

Summary:

- EPFs occur most frequently over the ocean and have a higher volumetric precipitation amounts than events over land
- Land EPFs are taller than ocean EPFs but ocean EPFs exhibit higher rain rates.
- Areas most susceptible to extremely severe rain events include the Amazon, Argentina, Africa, and Asia..
- Over land, EPFs frequently occur at higher latitudes during the summer months, whereas ocean EPFs occurring in mid-latitudes peak in the fall.
- Taller/Stronger storms do not always equate to higher rain rates as seen in Africa and Asia

Maximum Echo Top Heights:

Mean Maximum Height with 15 dBZ echo



- A seasonal pattern shows a peak in Max Height in early spring, a decline during summer, and a second peak during fall and winter.
- On average, land EPFs reach greater heights (11.5 km) compared to ocean EPFs (10.9 km). Both areas exhibit their tallest average maximum heights in the fall, with land EPFs at 11.79 km and ocean EPFs at 11.07 km during this season.

Figure 7: Seasonal variation of maximum height of 15 dBZ for land and ocean EPFs

Max NS Rain Rate vs Max Height of 40 dBZ (km): Land and Ocean

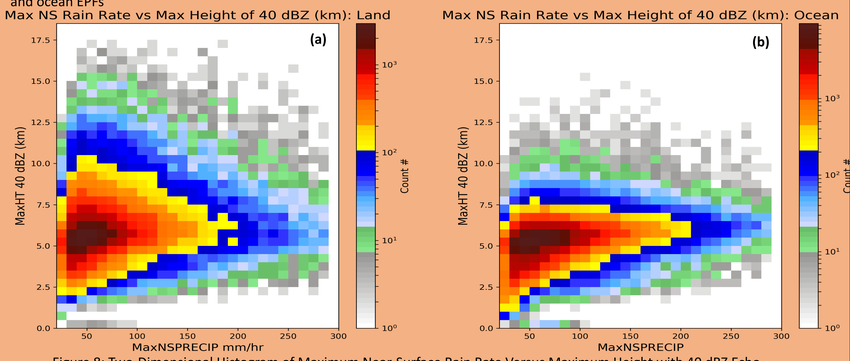
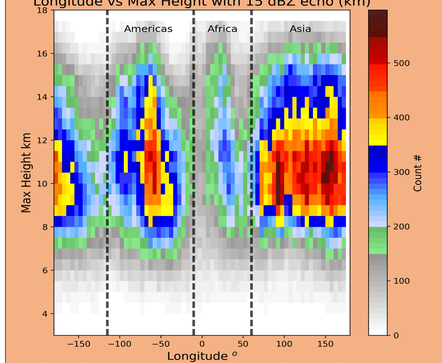


Figure 8: Two-Dimensional Histogram of Maximum Near-Surface Rain Rate Versus Maximum Height with 40 dBZ Echo. (a) Land comparison, (b) Ocean comparison

- Over land, Extreme Precipitation Events (EPFs) tend to exhibit higher 40 dBZ echo top heights, whereas oceanic EPFs generally have lower 40 dBZ heights. There is no clear relationship between the 40 dBZ echo top height and near surface precipitation rate

Longitude vs Max Height with 15 dBZ echo (km)



Longitude vs Max Near Surface Rain Rate (mm/hr)

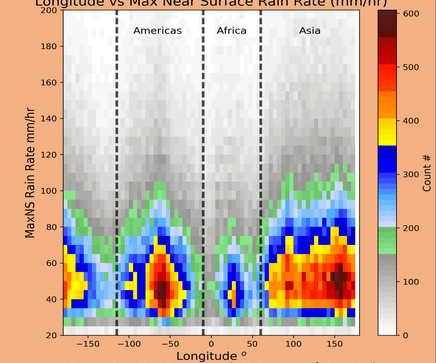


Figure 9: Two-Dimensional Histogram of Longitude Versus Maximum Height with 15 dBZ Echo.

Figure 10: Two-Dimensional Histogram of Longitude Versus Maximum Near Surface Rain Rate.

- Africa's systems are on average the tallest, with a mean maximum height of 12.04 km, while Asia's systems are shallower, with an average maximum height of 11.72 km. The mean maximum height with a 40 dBZ echo is also higher in Africa at 6.21 km compared to Asia's 5.64 km (not depicted in figure 9)
- Despite having the taller systems, Africa exhibits a lower maximum near-surface rain rate on average at 83.22 mm/hr, compared to Asia where it is higher at 86.20 mm/hr despite having shallower systems.
- Taller Storms ≠ Higher rain rates (Hamada et.al 2015)

Seasonal Comparison of EPF frequency across Latitudes: Land and Ocean

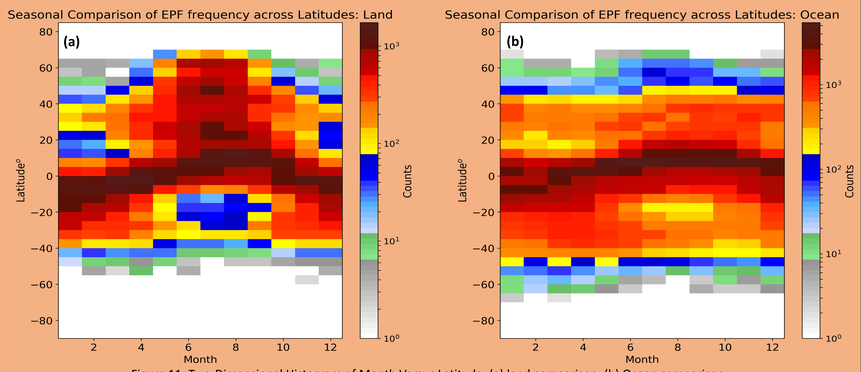


Figure 11: Two-Dimensional Histogram of Month Versus Latitude. (a) land comparison, (b) Ocean comparison

- Land-based EPFs often occur in tropics, summer monsoon, and mid-high latitude summer.
- Ocean EPFs, however, most commonly occur in tropics and peak from late summer into the fall.