The Vertical, Horizontal, and Temporal Characteristics of Tropical Mesoscale Convective Systems

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BACKGROUND

Mesoscale Convective Systems (MCSs) are a common precipitative feature in the world's tropical regions and are responsible for over 50% of annual rainfall in these regions. They serve as a critical link between our understanding of atmospheric convection and large-scale circulation, and they are an integral part of the global radiation budget [1]. Yet numerous gaps remain in our knowledge of the characteristics of MCSs in the tropical regions. In particular, more work is needed to understand how their vertical and horizontal structure evolve as a function of time, geography, and atmospheric conditions.

SCIENCE QUESTIONS

How do the characteristics of MCSs' horizontal and vertical structure vary over land and ocean during different lifecycle stages globally?

DATA

Using IMERG, Russell et al [2] temporally tracked global MCSs from $30°\ N$ to $30°\ S$ for the years 2014-2020, creating The Tracked IMERG Mesoscale Precipitation Systems (TIMPS) dataset. Within this dataset, the lifecycle stage (growth, mature, decay) of an MCS was determined at each timestamp using volumetric rain rate and area rate of change. TIMPS MCSs were then collocated with the University of Washington's Convective Feature (UWCF) Dataset, which provides information regarding echo types. Criteria for classification of echo type in the moderate and strong thresholds are derived from Houze et al. [3]:

	Reflectivity Thresholds	Height Thresholds	Horizontal Area Thresholds
Deep Convective Cores (DCCs)	30 (40) dBZ	8(10) km	-
Wide Convective Cores (WCCs)	30 (40) dBZ	-	$800\ km^2\ (1{,}000\ km^2)$
Deep and Wide Cores (DWCs)	30 (40) dBZ	8(10) km	$800\ km^2\ (1{,}000\ km^2)$
Broad Stratiform Regions (BSRs)	-	-	$40{,}000\ km^2$ $(50{,}000\ km^2)$
Shallow Isolated Cores (SHI)	-	At least 1km below 1°C	-

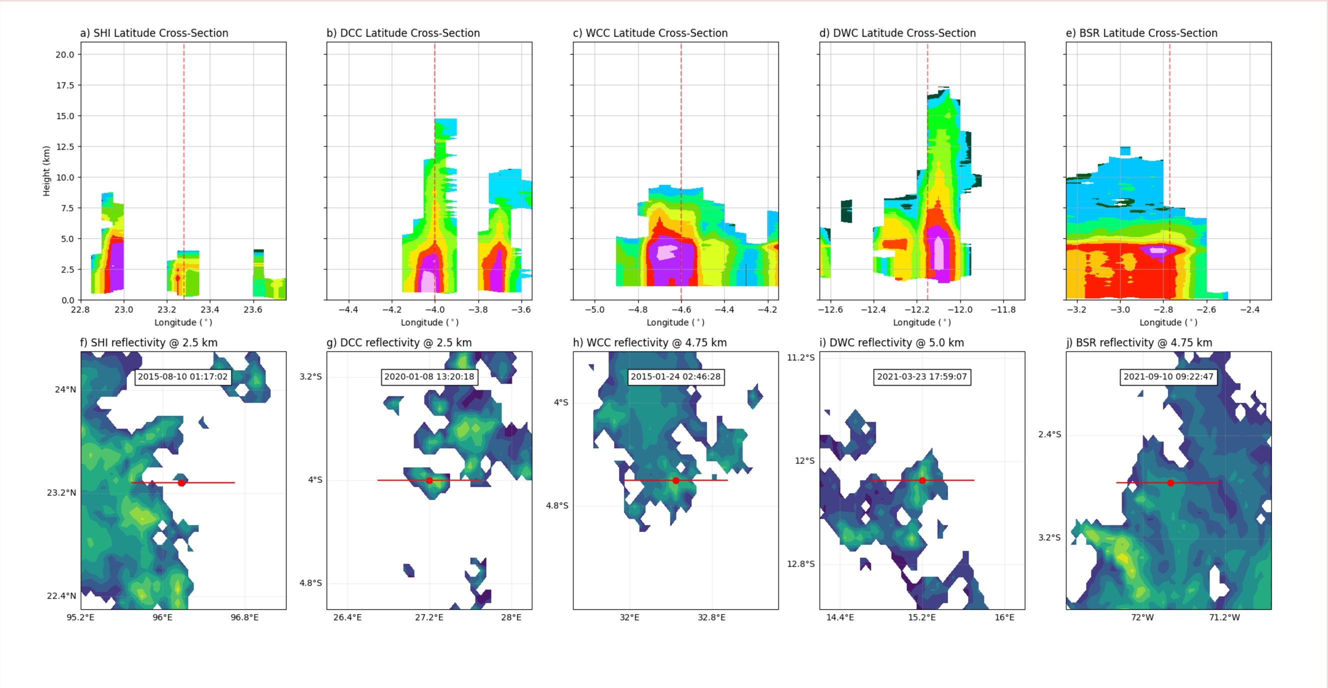

Figure 1. The cross-section of the echo types is obtained, where each echo type is existing in an MCS's mature stage

CHARACTERISTICS OF ECHO TYPES GLOBALLY AND IN DIFFERENT LIFECYCLE STAGE:

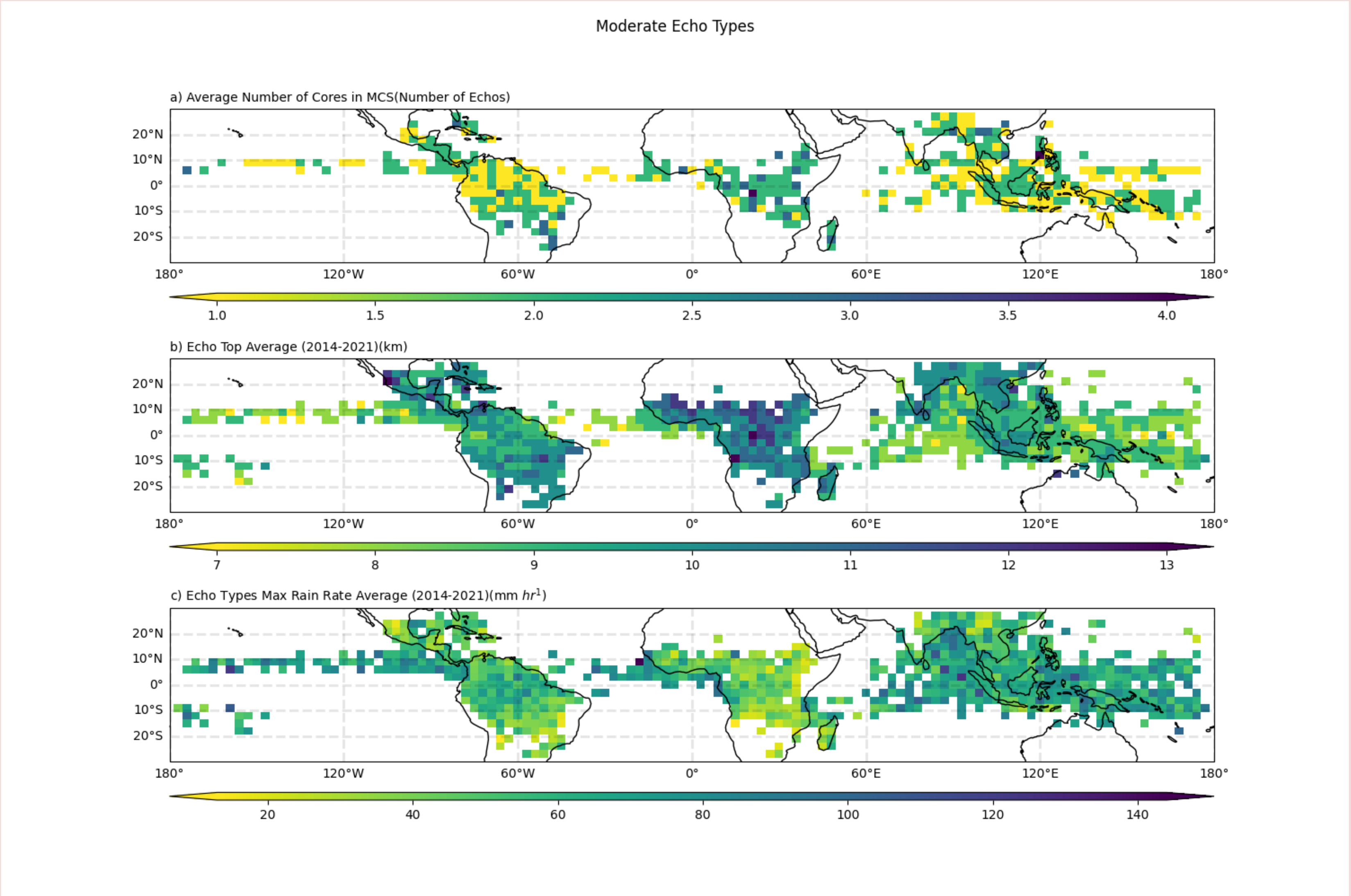

Figure 2. Global analysis of echo type characteristics is demonstrated on a 3° × 3° grid

On average, MCSs over land will have at least 2 echo types, except in northern South America. Echo top heights are deepest in continental Africa, and generally deeper over land.
The strongest maximum rain rates occur over ocean. The weakest max rain rates are observed along the Great Rift Valley in central Africa.

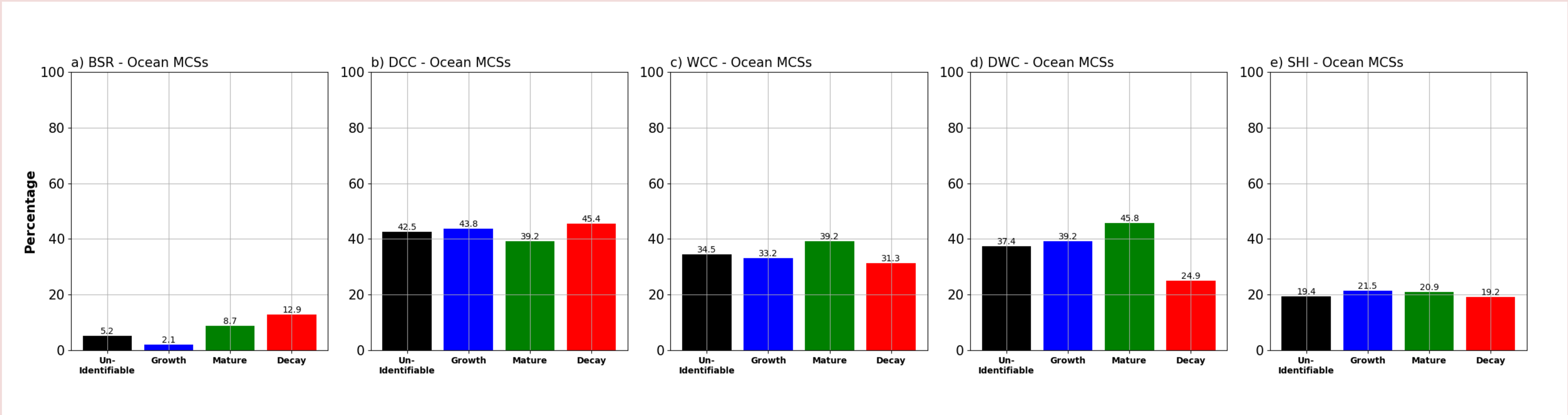

Figure 3. Echo types were sub-categorized based on the lifecycle stage of the ocean MCS it existed in. This was normalized by the total number of ocean MCSs that observed echo types in that same lifecycle stage

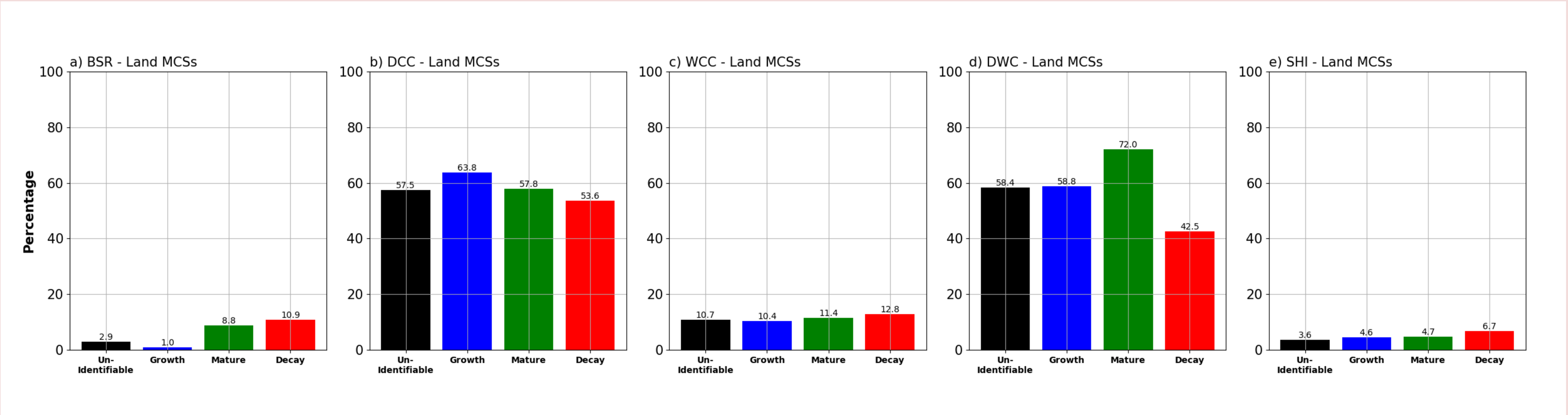

Figure 4. Echo types were sub-categorized based on the lifecycle stage of the land MCS it existed in. This was normalized by the total number of land MCSs that observed echo types in that same lifecycle stage

Convective echo types are the most common echo type in MCSs in both regions.
All echo types are observed in every lifecycle stage.

WCC and SHI are less frequent compared to other echo types in ocean MCSs, however they are more frequent than over land.

CHARACTERISTICS OF MCSs

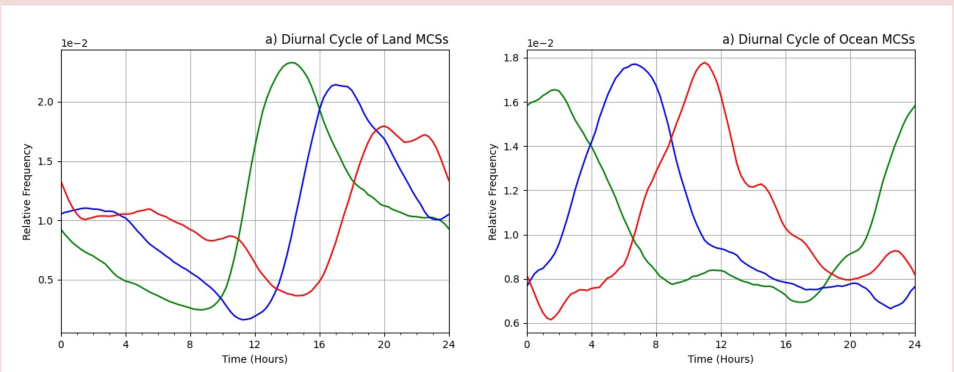

Figure 5. Diurnal Variability of different lifecycle stages of MCSs over land and ocean

Initiation of MCSs over land is most common shortly after noon, whereas initiation over oceans occurs during the late evening to early morning hours.

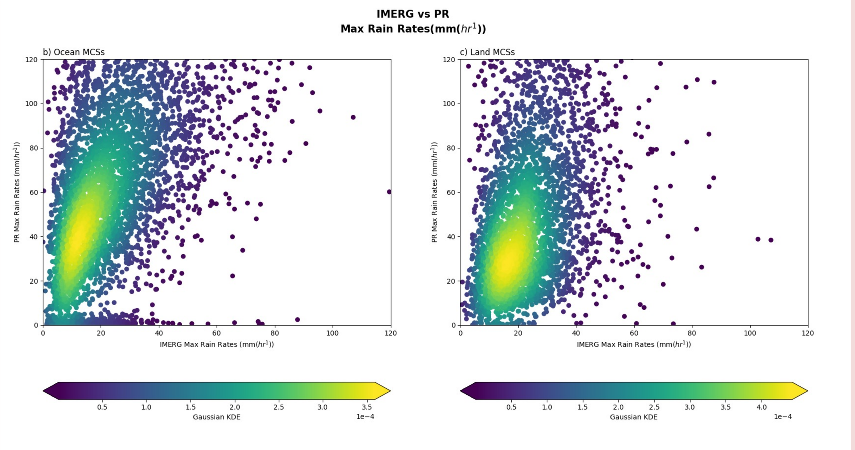

Figure 6. Scatter plot of the PR and IMERG max rain rates

For each MCS, the strongest echo type max rain rate from PR was compared to the max rain rate observed in the IMERG data. We found that a strong relationship exists between the two rain rates (Figure 8).

Echo types that exist over land reach taller heights, where a linear relationship exists between echo top height and PR max rain rate (Figure 9).

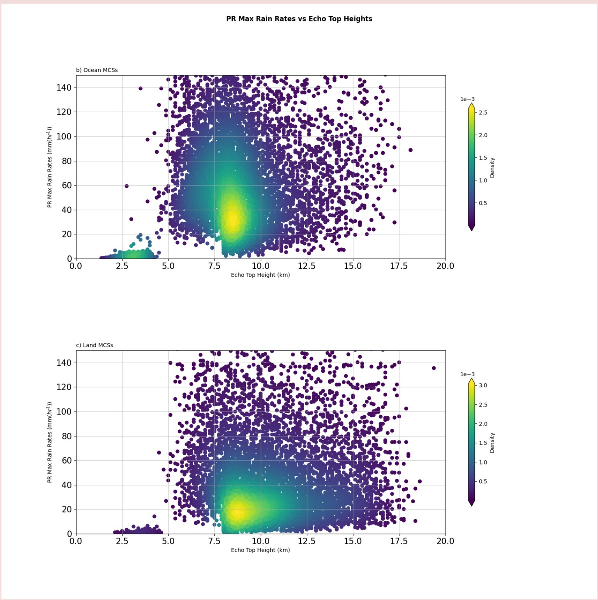

Figure 7. Scatter plot of PR max rain rates and echo top heights

SUMMARY

- Land MCSs on average have more echo types than ocean MCSs.
- MCSs that form over land are more likely to have deeper convection, while ocean MCSs have stronger rain rates.
- Convective echo types are the most common type observed in MCSs.
- WCCs, BSRs, and SHI occur more frequently in ocean MCSs.
- All analyzed echo types exist in every lifecycle stage and vary accordingly.
- A linear relationship exists between echo top heights and PR max rain rates. However, this is not as evident in ocean MCS.

REFERENCES

[1] Feng, Zhe, et al. "A global high-resolution mesoscale convective system database using satellite-derived cloud tops, surface precipitation, and tracking." *Journal of Geophysical Research: Atmospheres* 126.8 (2021): e2020JD034202.

[2] Russell, James, et al. "A Dataset of Tracked Mesoscale Precipitation Systems in the Tropics." *Geoscience Data Journal*. TBD

[3] Houze Jr, Robert A., et al. "The variable nature of convection in the tropics and subtropics: A legacy of 16 years of the Tropical Rainfall Measuring Mission satellite." *Reviews of Geophysics* 53.3 (2015): 994-1021.

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