Investigating Environmental Controls on Tropical Mesoscale Convective System Lifecycles

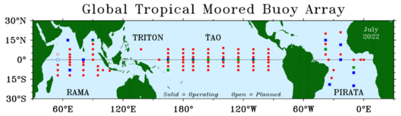
Sayali R. Kulkarni[1], Kathleen A. Schiro[1], Gregory Elsaesser[2], , Piyush Garg[3]
University of Virginia[1], NASA Goddard Institute of Space Studies/Columbia,University[2], Argonne National Laboratory[3]
Email: ejb6nj@virignia.edu

Motivation

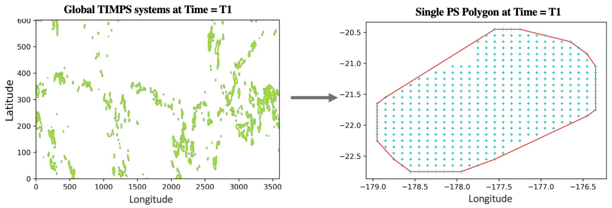
- Tropical mesoscale convective systems (MCS) are some of the most intense and frequent precipitating systems occurring throughout the year >75% of the annual rainfall across tropics (Maranan *et al* 2018).
- Thermodynamic, dynamic, and microphysical feedbacks affect the MCS lifecycle.
- We attempt to improve the existing knowledge of dominant rain- producing systems in the tropics to better recognize MCS-associated processes and amend the current parametrization schemes. Bulk estimates like total column water vapor (CWV) and buoyancy are explored to quantify conditional instability and their relationships to the convective lifecycle.
- Cold pools are also thought to significantly influence the convective lifecycle. We preliminarily quantify cold pool characteristics across MCS lifecycle stage.

Data

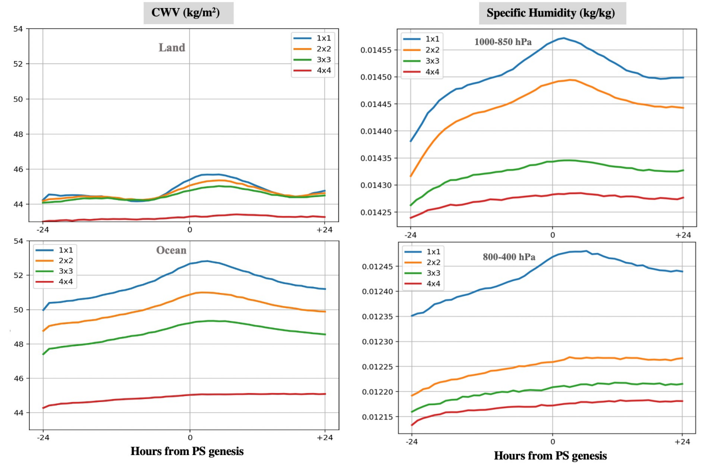
- NASA GPM-derived IMERG product at 0.1° spatial and 30-min temporal resolution is used to create the Tracked IMERG Mesoscale Precipitation System database (*TIMPS*; Russell *et al.* 2022).
- Systems > 3000 km² area and >10 mm hr⁻¹ max precipitation are identified as precipitating systems (PS), further segregated into *growth*, *mature*, and *decay* stages of convection based on volumetric rain rate and size.
- Scatterometer wind-derived cold pool dataset, employed using ASCAT and RapidScat surface wind-vector retrievals provide us with gradient features (GF; Garg *et al.* 2020).
- CWV and buoyancy-related variables are utilized from ERA5 reanalysis.
- In-situ buoy data is acquired from NCAR Tropical Moored Buoy System:



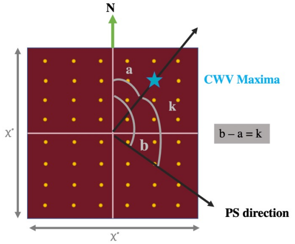
- PS polygons created using convex hull technique to collocate with buoy data and identify system overlap with new high-resolution NASA AIRS single footprint retrievals of temperature and moisture profiles (Irion *et al.* 2018):

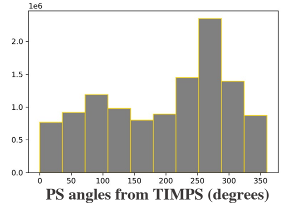


MCS Thermodynamic Evolution



- CWV upsurge can be noticed ~ 6 hours prior to MCS genesis over both land and ocean
- A gradual increase in CWV is seen within the 24-hour period before MCS genesis over ocean; no signal is detected before 6-8 hours prior to MCS genesis over land
- A clear signal in specific humidity ~ 6 hours prior to MCS genesis; increase in free tropospheric humidity more gradual
- Beyond 2° x 2°, the signal in water vapor is significantly reduced

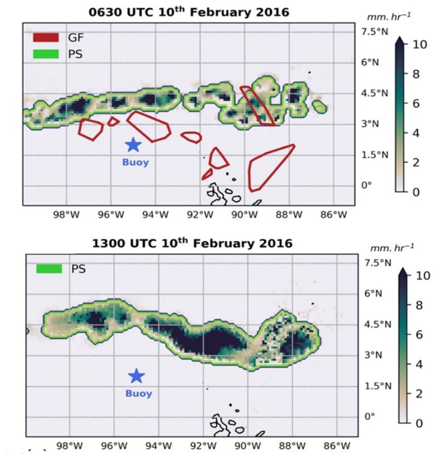


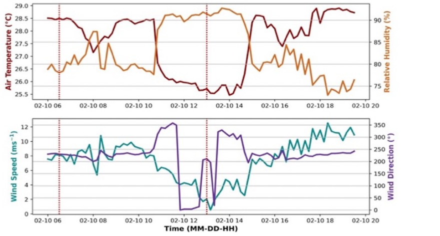


Key Science Question: How does the thermodynamic environment affect MCS propagation direction and organization?

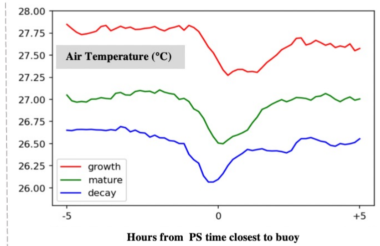
Methodology: CWV is analyzed over a PS-centric grid box at T_i for the PS lifecycle $T_1 \ldots T_n$. After detecting the spatial location of CWV maxima (blue), we find its angle with respect to north (*angle a*). Differences between *angle a* and PS-direction (*angle b*) could offer us an insight into how moisture and buoyancy contribute to MCS propagation and organization.

How do cold pools interact with MCSs?





- Case study illustrates a strengthening MCS seemingly uninhibited by its own cold pool(s) between 0630 and 1300 UTC.
- Environment recovers quickly with passage of weaker (t=02-10-08) and stronger (t=02-10-14) cold pools



- Buoys capture thermodynamic evolution of environment following the passage of cold pools and MCSs
- Data can be compared for growth, mature, and decay phase convection as it passes near buoy
- Example of methodology shown above, where environmental air temperature decreases from growth to mature to decay phases, while ~0.5°C decrease in T the same across stages.
- Decrease in T detected ahead of MCS for mature and decay phases – indicative of cold pool expansion

Key Science Question:

- Do thermodynamic and/or size thresholds exist whereby cold pools limit future growth of convection?

What's next?

1. Composite integrated buoyancy to quantify the spatio-temporal evolution of growth, mature, and decay MCS stages.
2. Explore bulk estimates like buoyancy and CWV to find out how environment could steer the MCS direction and contribute to convective clustering.
3. Investigate buoy-detected cold-pool thermodynamic thresholds, and further segregate them associated to *living* and *decaying* MCSs.