The Convective Nature of the Tropical Cyclone Lifecycle via GLM and GPM Observations

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Paper 5.1

Background: Lightning in Tropical Cyclones (TCs)

- Previous ground-based and satellite-based sensor studies
  - Ground-based (e.g., WWLLN, NLDN)
    - Confined to ~500 km buffer of the US coast
    - Primarily detect cloud-to-ground (CG), which is an incomplete depiction of the total lightning flash rates (CG + IC)
  - Satellite-based (e.g., OTD, TRMM-LIS)
    - Short-duration snapshots; do not allow temporally continuous analysis of electrical activity for an individual tropical cyclone (TC)
    - Insight into vertical structure of TC precipitation; electrical, kinematic, microphysical processes during TC lifecycle equatorward of 35º
- Lightning is frequent in the inner core/eyewall region and can be even more frequent in the outer rainbands (i.e., bimodal distribution; Molinari et al., 1999; Abarca et al., 2011; Stevenson & Corbosiero, 2016; Fierro et al., 2018)
- More lightning during weaker TC phases (e.g., tropical storms) than during more intense TC phases (e.g., major hurricanes) (DeMaria et al., 2012; W. Zhang et al., 2015).

- **No observed total lightning trends poleward of 35º, during phases such as the post-tropical cyclone (PTC) phase after extratropical transition**

✮ **<u>Relative intensity of lightning-producing convective features seems driven more by the number of lightning producing cells, rather than systematic storm-relative intensity differences between those cells</u>**

Data & Methodology

- GLM-16 Flashes
- GPM Precipitation Features (Liu et al 2008, Heuscher et al 2022)
  - GPM Core Observatory; GCOMW-1
  - Dual-Frequency Precipitation Radar: rPFs; cPFs;
  - Microwave-radiometer defined: 1CPFs
- 2018-2021 Atlantic Basin hurricane seasons
  - Tracks from the International Best Track Archive for Climate Stewardship (IBTrACS); Extended by tracking sea level pressure minimum, vorticity maximum through ERA5 reanalysis
  - TCs divided into life cycle phase; Saffir-Simpson scale used for Tropical Storm (TS), Category 1-2 hurricanes (CAT12), Category 3-5 hurricanes (CAT35); Asymmetry factor (Evans and Hart 2003, Hart 2003) PTC phases
  - Divided into 3-hourly individual time periods (ITPs)

Data & Methodology

- GLM lightning flashes matched to PFs

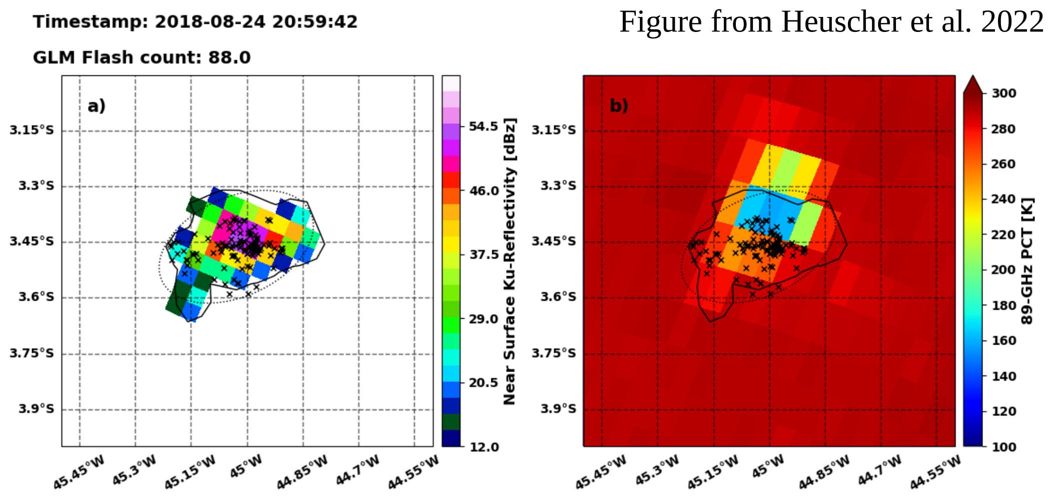
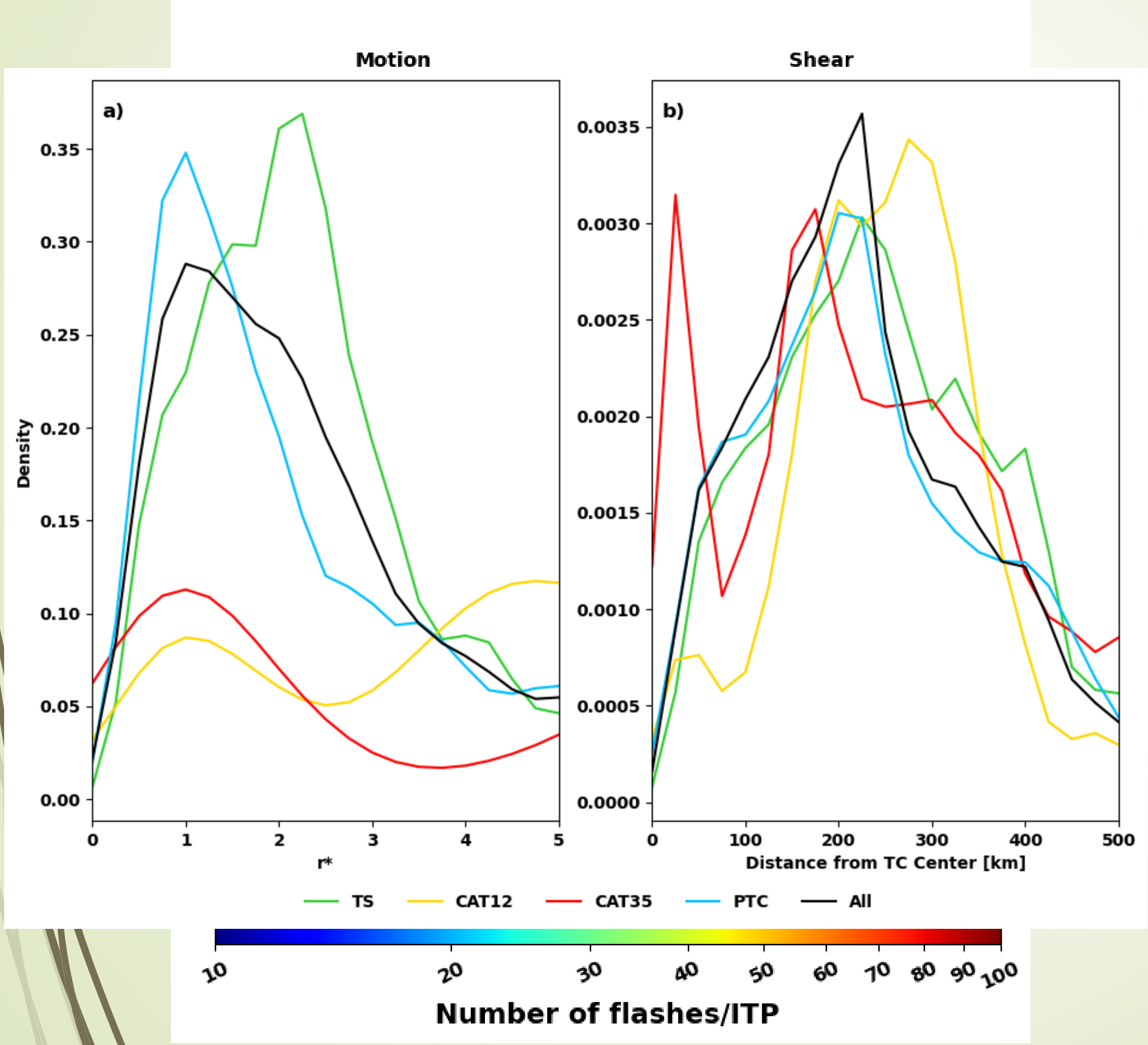


Figure from Heuscher et al. 2022

- QC
  - PFs constrained to have all pixels within GLM field of view
  - GLM flashes with a quality flag = 0 used to remove sun glint (over the ocean.
  - Transitional ITPs removed
- Angle relative to motion/shear vector calculated
- RMW-scaled distance: $\boldsymbol{r^* = \frac{r}{RMW}}$

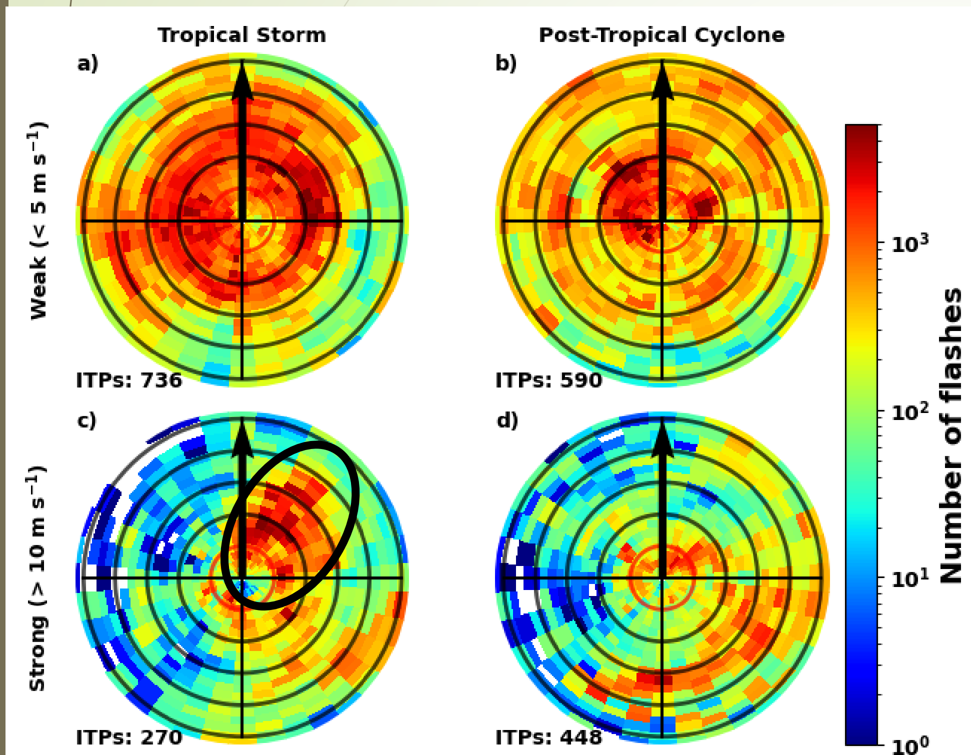
Results – Lightning Distribution



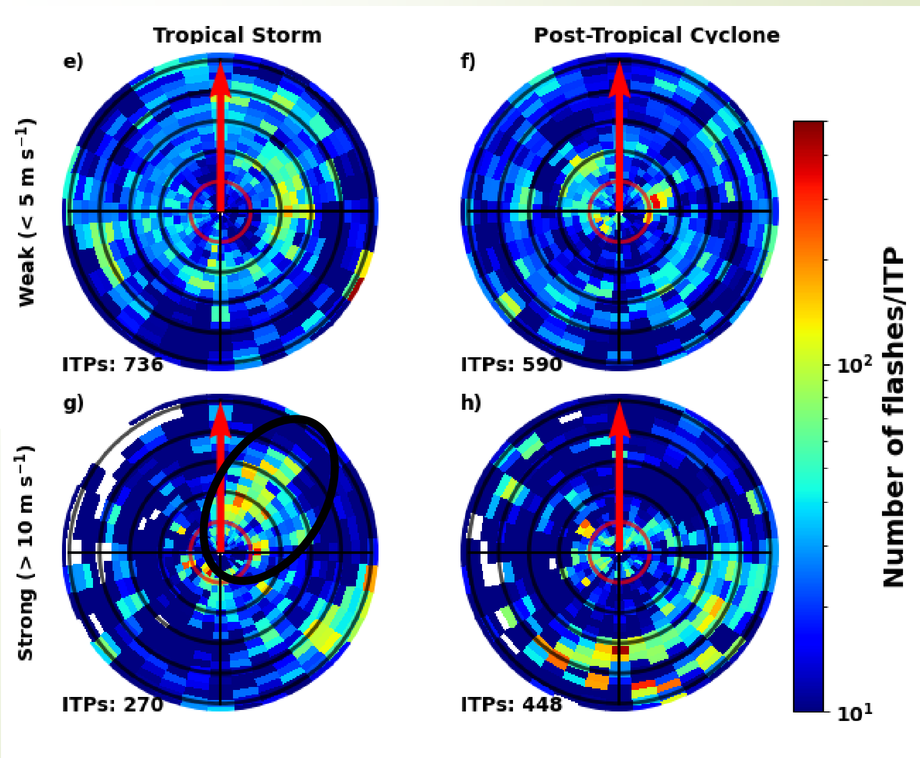
- Bimodal distribution not found as in previous studies; peak near 1-2r* (i.e., the RMW)

- Lightning maxima are found downshear and in forward flanks (Abarca et al 2011; Corbosiero and Molinari, 2002, 2003; Matyas 2010)

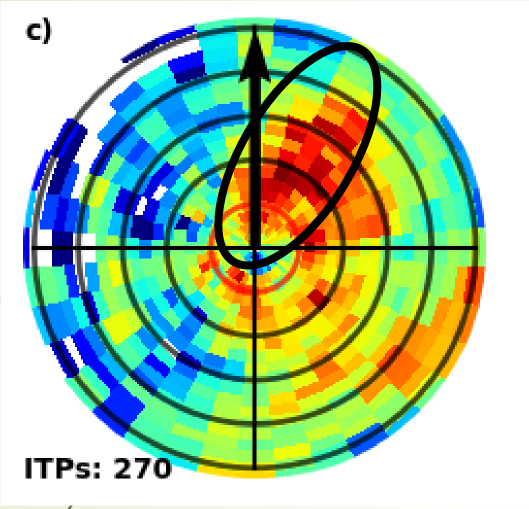
Results – Shear

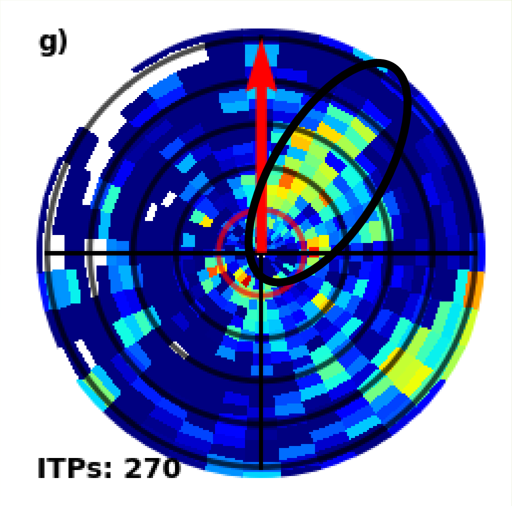


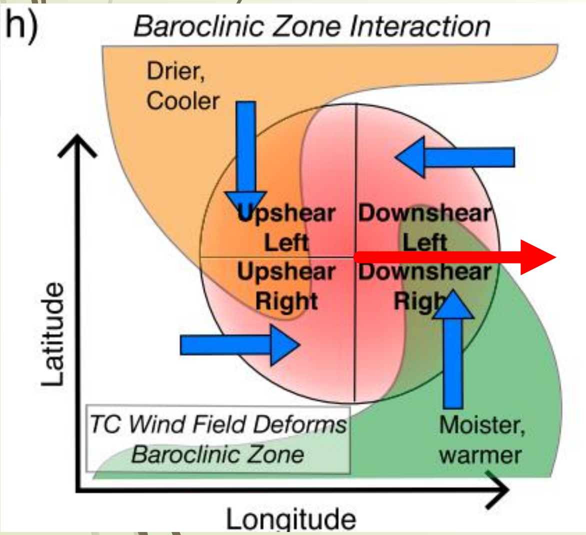
- Strongly sheared TCs in TS and PTC phases have a lower amount of lightning flashes
- Lightning maxima within strongly sheared TS phases can be physically explained (next slide).

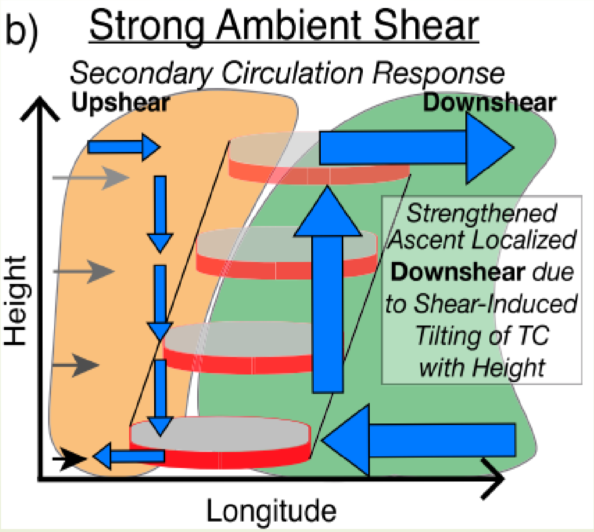


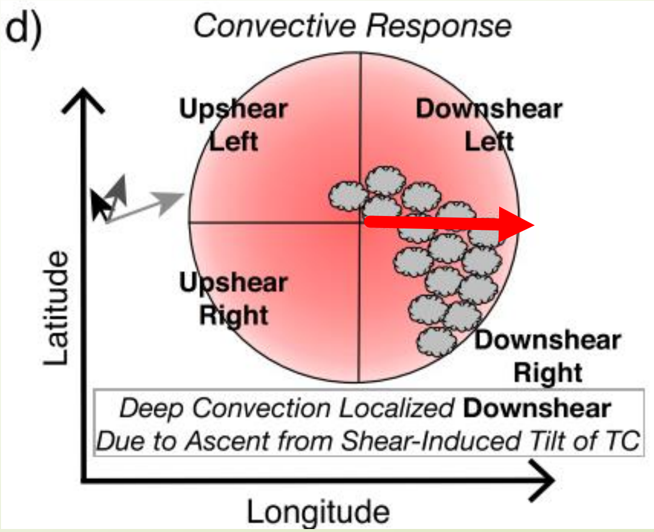
Results – Strongly sheared TS





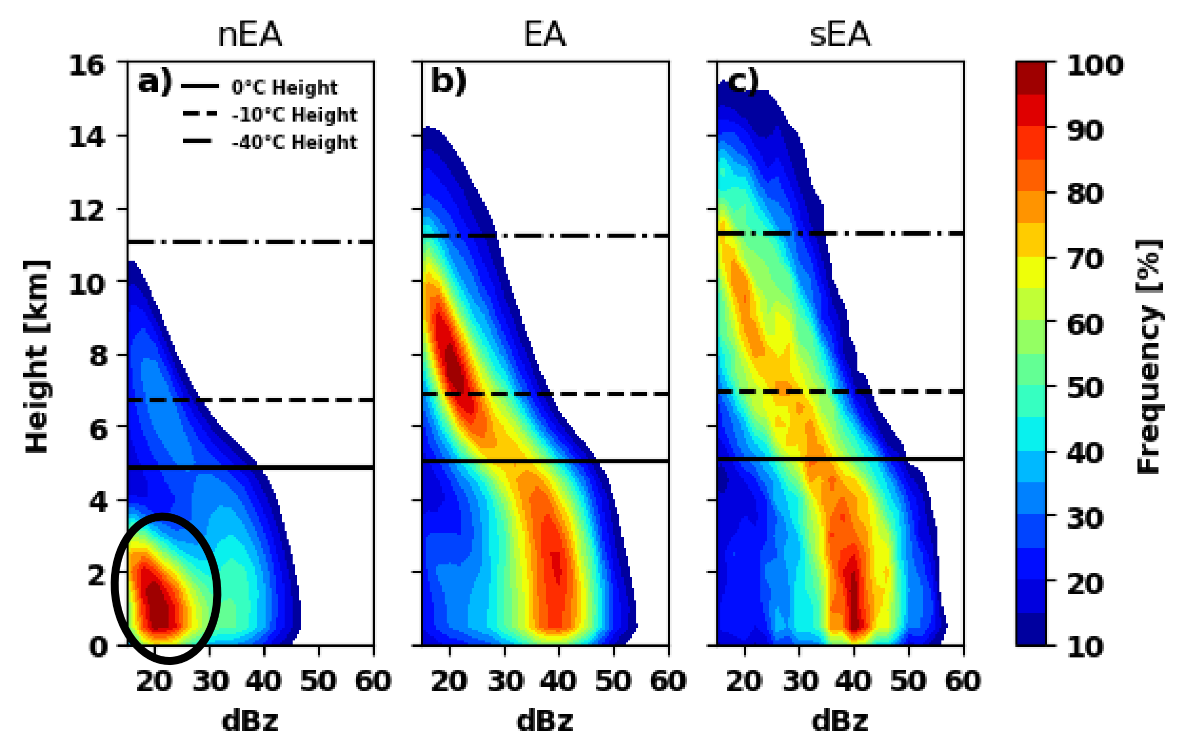






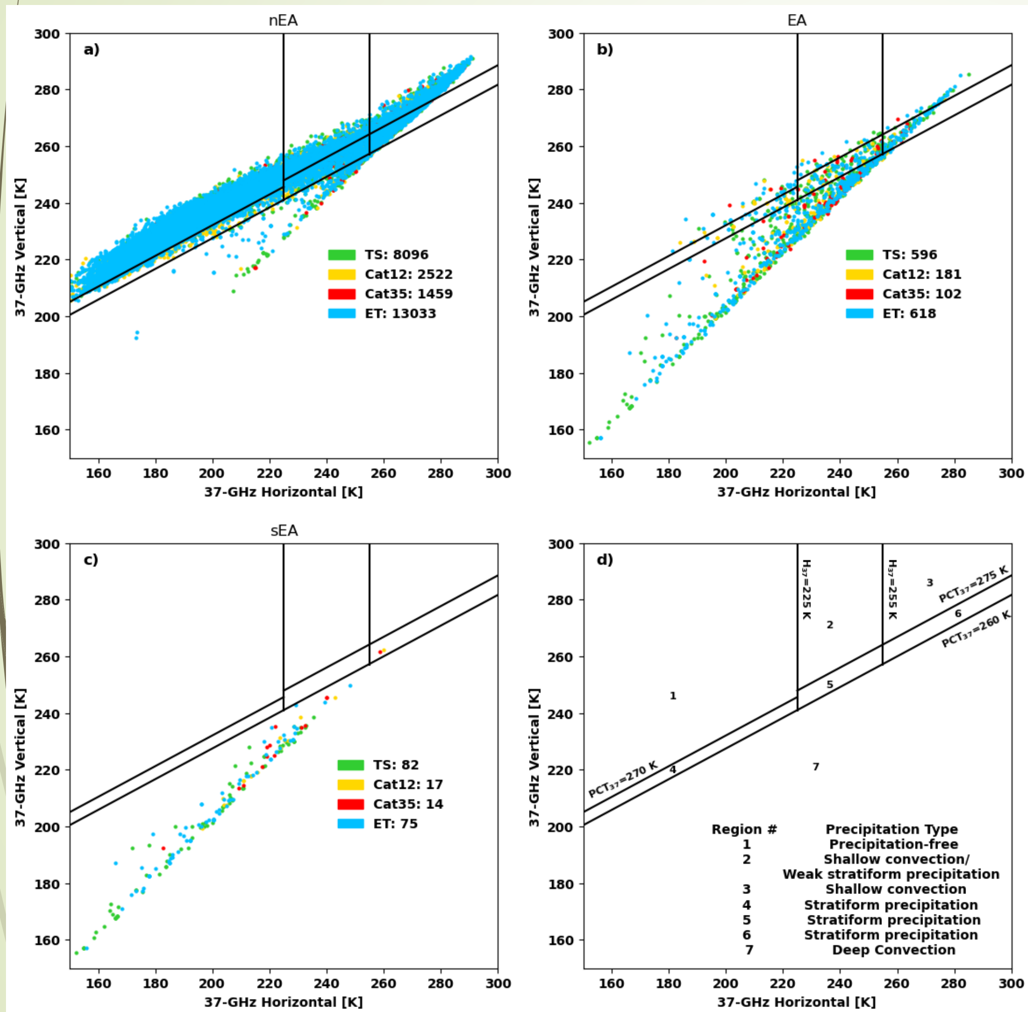
Figures modified from Schenkel et al. 2020

Results – cPF Reflectivity



- cPFs divided by electrical activity:
  - Non electrically active (nEA)
  - Electrically active (EA)
  - Super electrically active (sEA); > 100 flashes
- EA cPFs are deeper, with higher reflectivity in the mixed phase zone for a given height
- Two different convective modes most pronounced within nEA cPFs

Results – PF Passive Microwave



- rPFs, cPFs, and 1CPFs all utilized
- Precipitation type (lower left) determined by methodology in Jiang et al 2018.

- Point is placed at 37_H and 37_V of minimum $PCT_{37\text{-GHz}}$

- **Passive microwave precipitation classification at 37 GHz can reveal relative presence of electrical activity (EA or sEA) in TCs, but not necessarily TC phase.**

Conclusions

- Storm-relative character of feature lightning occurrence (e.g., downshear etc.): relative intensity of lightning-producing convective features seems driven more by the number of lightning producing cells, rather than systematic storm-relative intensity differences between those cells
- Non electrically active (nEA), electrically active (EA), and super electrically active (> 100 flashes; sEA) cPFs have different reflectivity profiles
  - EA cPFs: larger reflectivity gradient within mixed phase zone; shift towards higher reflectivities at all heights; deeper than nEA cPFs
  - Some differences can be teased out by TC phase
- Passive microwave precipitation classification at 37 GHz can reveal relative presence of electrical activity (EA or sEA) in TCs, but not necessarily TC phase.

Future Work

- Addition of more Atlantic Basin hurricane seasons
- Expansion to Pacific Basin
- Importance of in-situ microphysical, electrical, environmental TC observations

Questions??

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