Using GPM and IMERG to Explain Interactions between Dynamics and Precipitation in Cyclones

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INTRODUCTION: Extratropical cyclones (ETCs) produce the majority of total and extreme midlatitude precipitation. The dynamical strength of ETCs (e.g., their vorticity; relative or potential) can be boosted by latent heating due to ETC generation of precipitation. This boost can be understood in terms of potential vorticity (PV):

$$\frac{\partial PV}{\partial t} \approx PV \frac{\partial Q_{HEAT}}{\partial z}$$

Q_{HEAT} is the diabatic heating. The largest source of Q_{HEAT} in ETCs is usually condensation. The equation shows that the vertical distribution of latent heating is a key factor, and therefore, it is important to understand the mechanisms that generate vertical motion in the ETCs. Here, we present 3 distinct analyses related to this issue. **Analysis 1**:ETC life cycles in terms of precipitation and vorticity. **Analysis 2:** the relative contribution of upright convection to ETC precipitation. **Analysis 3**: comparing precipitation for hurricanes, extratropical-transition (ET) events, and ETCs. Analysis 2 is preliminary work that will soon incorporate GPM data. Analysis 3 is the starting point for a PhD work on projecting future changes in hurricane, ETC, and ET precipitation.

1. Precipitation and Vorticity Life Cycles (Booth et al. GRL 2018)

Methods: IMERG precipitation, ERA-Interim PWV and vorticity in a cyclone-centered compositing analysis. KEY: Cyclones are sorted by life cycle age, and then subsample the cyclones such that the distribution of cyclone-PWV for the age groups are all equal. Cyclones per life cycle age: ***allPWV***: 1336; ***matchPW***: 1006.

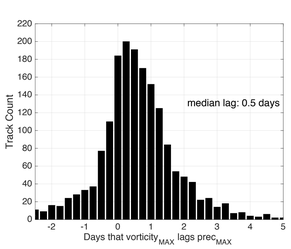


Fig. 1: Differences in timing of vorticity and precip maxima: Per cyclone track, we compare the timing of the max in vorticity and max in precipitation. For most ETCs, precipitation peaks before the vorticity.

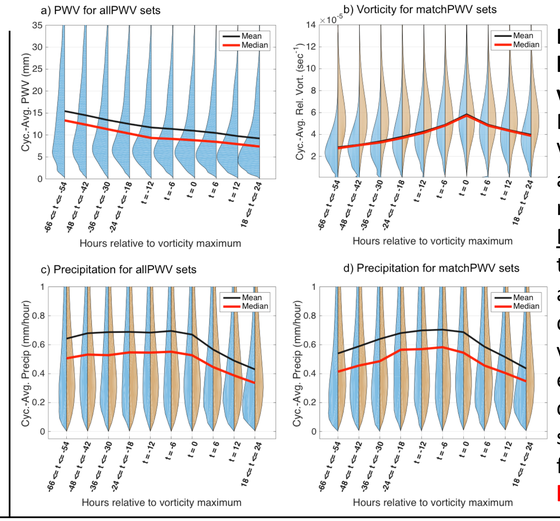


Fig. 2: Sorting Cyclones based on precipitation and vorticity life cycles. (a) PWV for all cyclones, (b) Vorticity for matchPWV, (c and d) precipitation in the range from 0 to 1 mm hr^{-1}, Blue shows distribution at time indicated on the x-axis. Orange shows distribution for time of vorticity max (repeated on every timestep for comparison). **Black line** shows multi-cyclone mean for each time step and **red line** shows median.

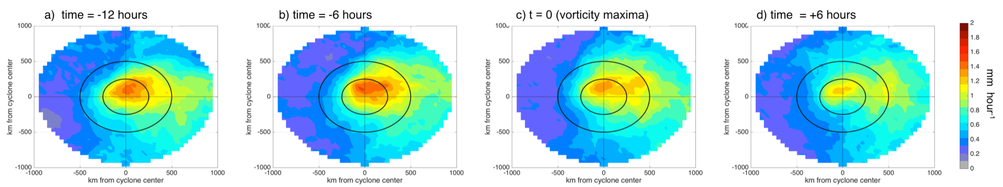
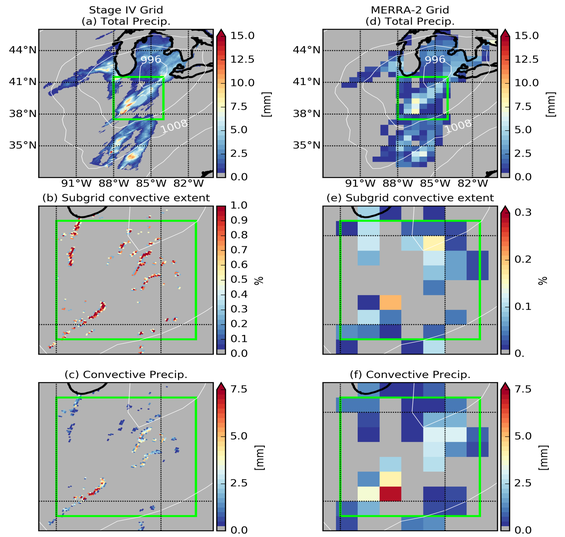


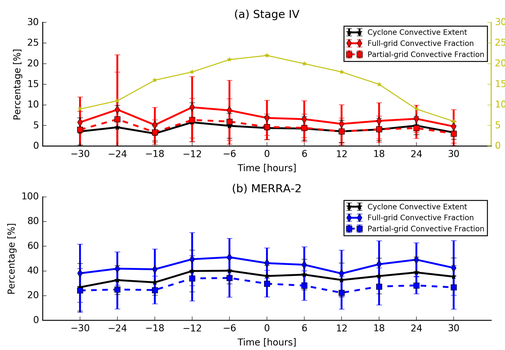
Fig. 3:Cyclone-centered composites sorted by age: for NH and SH, 2014-2017. In each panel, the inner black circle indicates a radius of 250 km. The outer black circle is 500 km. There are 1006 cyclones per composite.

2. Upright Convection in Extratropical Cyclones

Methods: Composites of 3-D NEXRAD obs. for 2014- 2016 are used to identify convection (Starzec et al., MWR, 2017).Stage IV data is used to identify the precipitation. Flagged precipitation is then analyzed on the Stage IV 4-km grid, akin to a NWP model grid and the MERRA-2 0.5 X 0.625 grid, akin to a GCM grid. An example is shown at right. ETCs are tracked in the reanalysis.
NEXT STEPS: Comparing with GPM-CMB and then a global analysis.

Example Case: March 24, 2016





Time index 0 is the time step of maximum PR$_{AA}$

Fig. 4: Cyclone convective spatial extent and convective fraction vs. life cycle of 42 ETCs. Yellow line in (a) shows number of cyclones included for each time step. Dotted colored lines show the partial-grid convective fraction accounting for the subgrid convective extent. Solid colored lines show the full-grid convective fraction when the grid cell is considered as entirely convective.

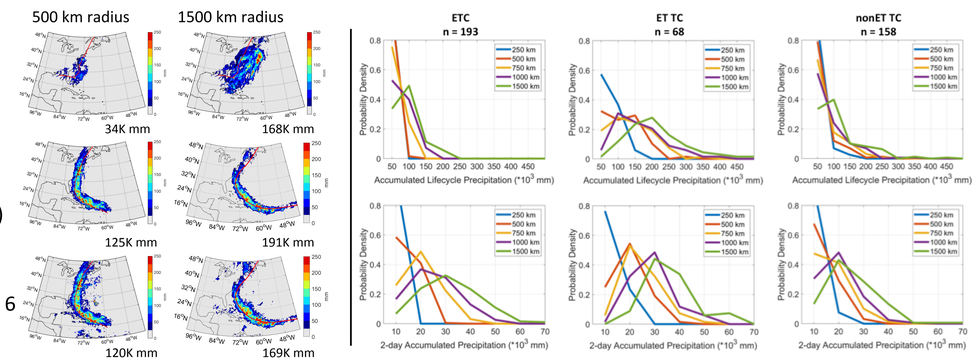
3. Precipitation in Hurricanes, Extratropical Transitions (ET), and ETCs

Methods: Using the TMPA data, we compare cyclone life cycle total accumulated and 48-hour precipitation and analyze the sensitivity of the result to the search radius used in associating precipitation with a cyclone.

ETC: Jan 24 – 27 2000

ET: Aug 21 – 30 2011 (Irene)

Hurricane: Aug 24 – Sept 6 2011 (Earl)



4. Discussion

- For individual ETCs, precipitation max often precedes vorticity max. However, the timing difference is most likely related to ETC PWV content, rather than a delay in the process of diabatic heating impacting vorticity.
- Upright convection occurs sparingly in ETCs over the US. The signal appears larger than it is on a GCM grid.
- Extratropical-Transitioning hurricane generate more life-time total precipitation than ETCs and TCs.
- ETCs generate more of the strongest 48-hour precipitation events