EMBRY-RIDDLE Aeronautical University METEOROLOGY

A New Metric to Diagnose Precipitation Distribution in Transitioning Tropical Cyclones

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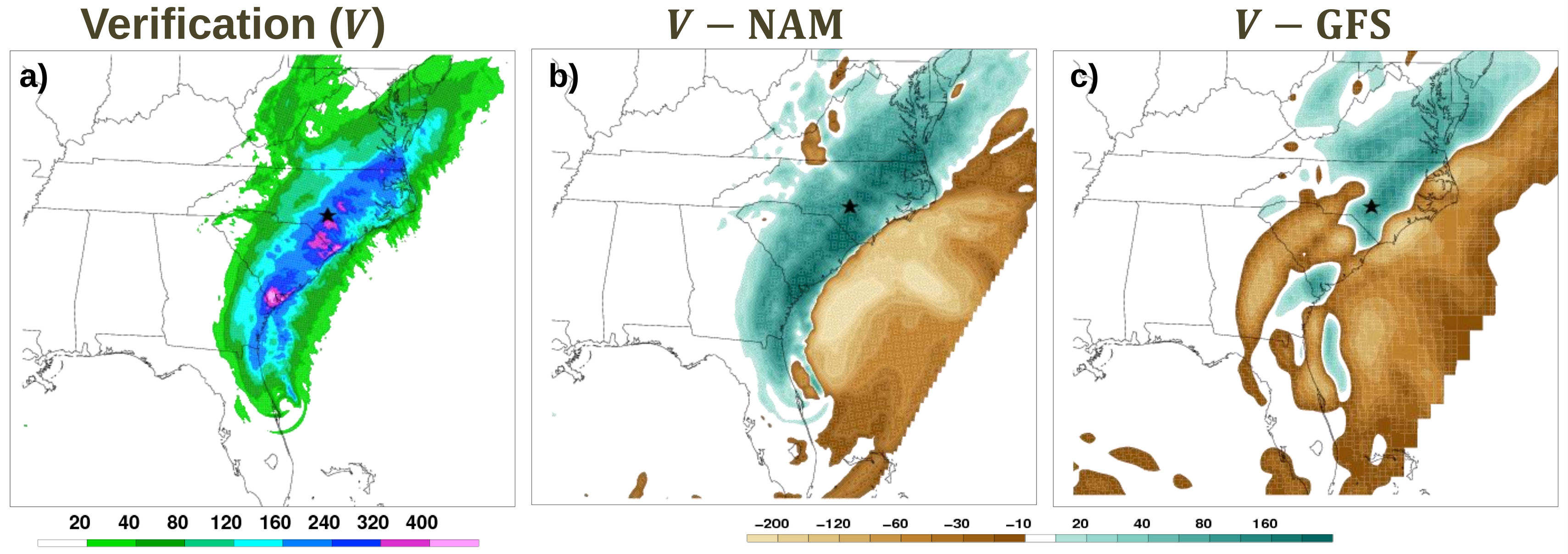
1. Motivation: QPF and the ET of Hurricane Matthew

- Extratropical Transition (ET) can result in reduced forecast skill in numerical weather prediction (NWP) models
- Quantitative Precipitation Forecasting (QPF) remains a challenge, especially during extreme events; NWP models exhibit less skill for QPF than for mass fields (e.g., wind, height)
- During high-impact ET cases, precipitation distribution shifts left-of-center (LOC). Therefore, transitioning TCs such as Irene (2011), Sandy (2012), and Matthew (2016) that tracked along the east coast of the U.S. caused severe flash flooding well inland



48-h total accumulated precipitation (mm, shaded) from 1200 UTC 7 October–1200 UTC 9 October during Hurricane Matthew. Fayetteville, NC is marked with a black star. a) Observed precipitation from NCEP Stage-IV dataset. Differences between observed and NWP 48-h QPF using the b) ***NAM*** and c) ***GFS*** model run initialized at 1200 UTC 6 October.

2. EMBGR Metric and Data

$$\sigma_{BI} = 0.31\, f \,\frac{\partial \vec{v}}{\partial z} N^{-1}$$

Eady Baroclinic Growth Rate — *Eady 1949 and Hoskins and Valdes 1990*

$$N_m^2 = \frac{g}{T}\left(\frac{dT}{dz} + \Gamma_m\right)$$

Moist Brunt-Vaisala Frequency (N_m) — *Durran and Klemp 1982*

$$EMBGR = 0.31\, f \,\frac{\partial v}{\partial z} N_m^{-1}$$

Eady Moist Baroclinic Growth Rate (EMBGR)

Advantages

- Better evaluation of baroclinicity and moist thermodynamics
- Relies on Environmental Flow Characteristics and not TC Structure
  (*Relatively Well Forecast*) (*Difficult to Forecast*)

Objectives

- Use the EMBGR as a mass field proxy metric for precipitation during ET
- Evaluate utility of EMBGR in
  a) Reanalysis-based climatology in the North Atlantic basin
  b) Various operational deterministic and ensemble numerical model systems

Data

- NCEP 0.5° Climate Forecast System Reanalysis (CFSR) for case and composite analyses
- HURDAT2 for TC track information
- NCEP 0.5° GFS and 12-km NAM NWP models

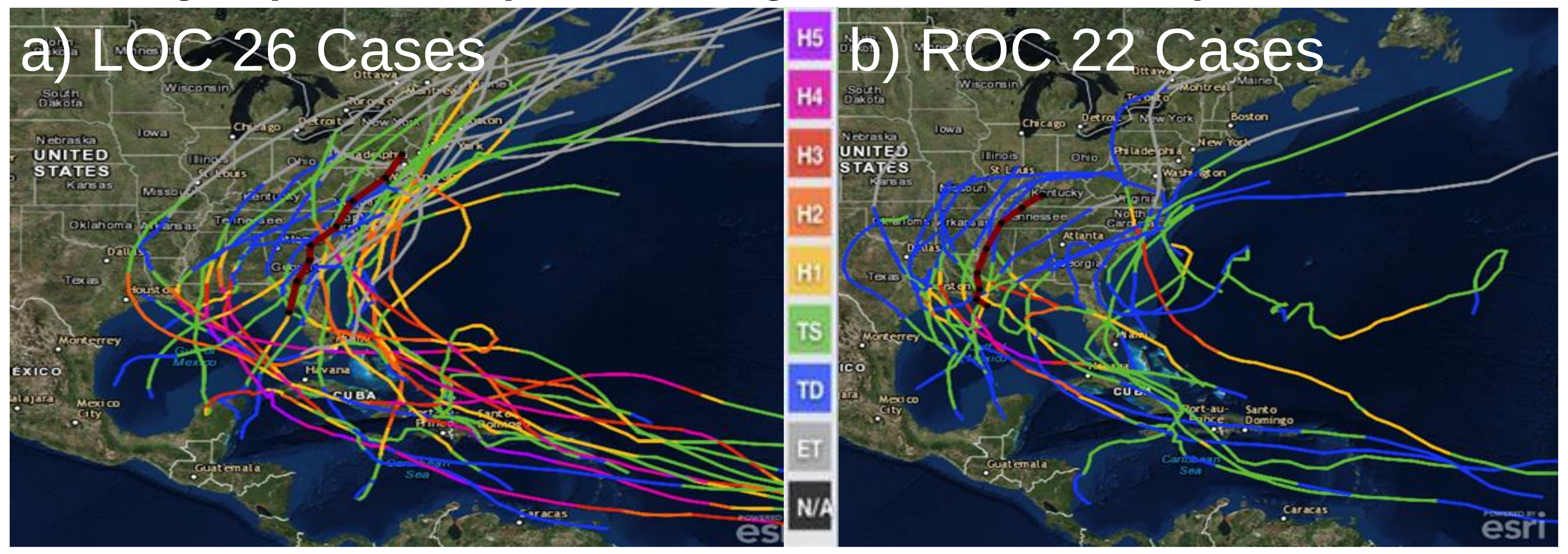
3. Methods

Case identification

- Atlantic basin TCs that made landfall in the CONUS from 1979–2014
- Precipitation shift to LOC or ROC had to occur during or after the TC had moved 500 km poleward after landfall (*removed pure tropical cases*), and last a minimum of 12 h (*two CFSR time steps*)
- To be classified as LOC or ROC, > 50% of the total CFSR areal precipitation within a 5° × 5° box around the TC center at a given 6-h time step had to be LOC or ROC

Results

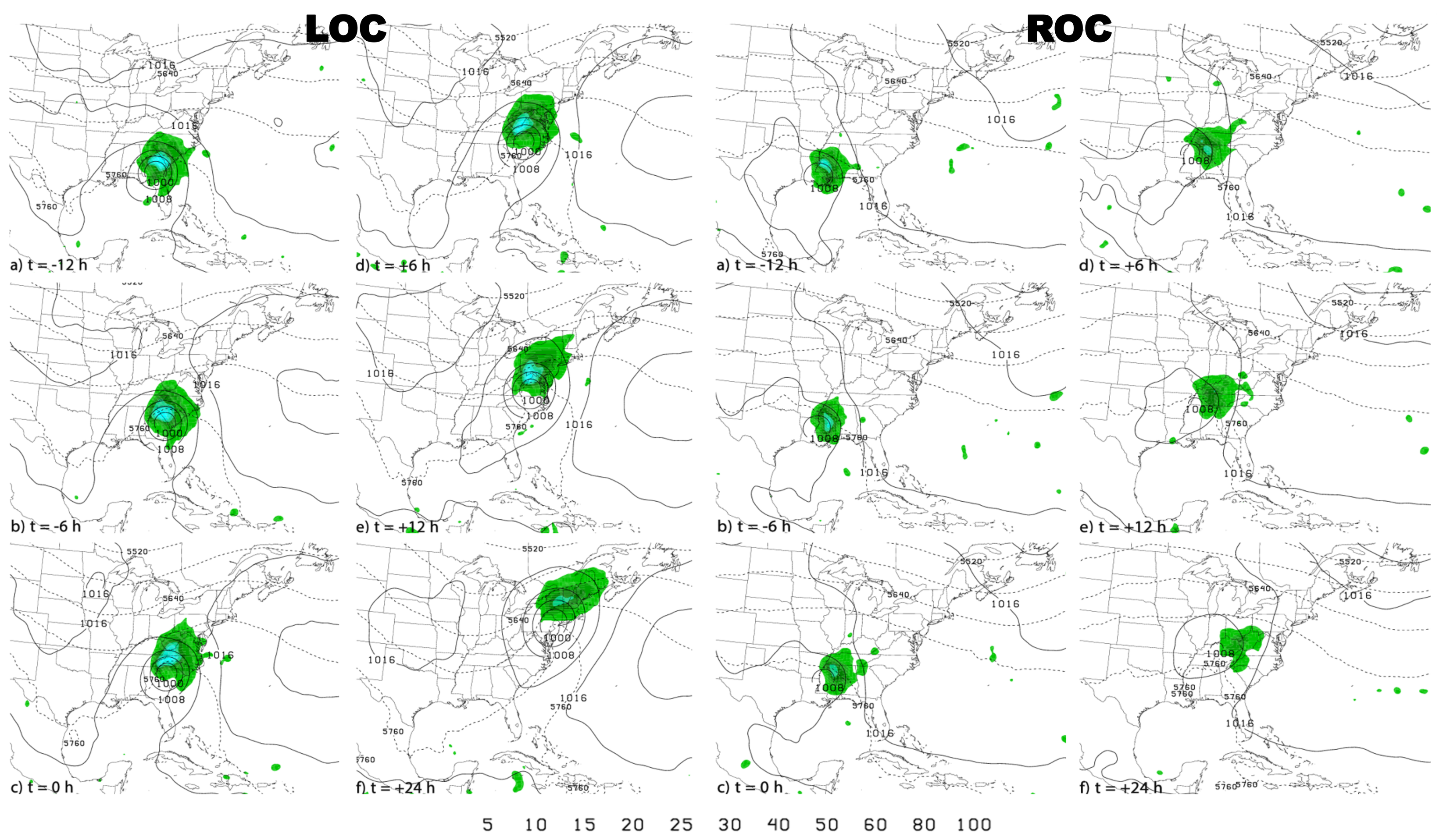
- 26 LOC cases, 22 ROC cases
- Each group then composited using storm-relative composite method



Storm tracks of the a) LOC and b) ROC cases. The dark red line in each panel represents the median track used for the storm-relative composite technique, from t = -24 h to t = +24 h with black dots every 6 h.

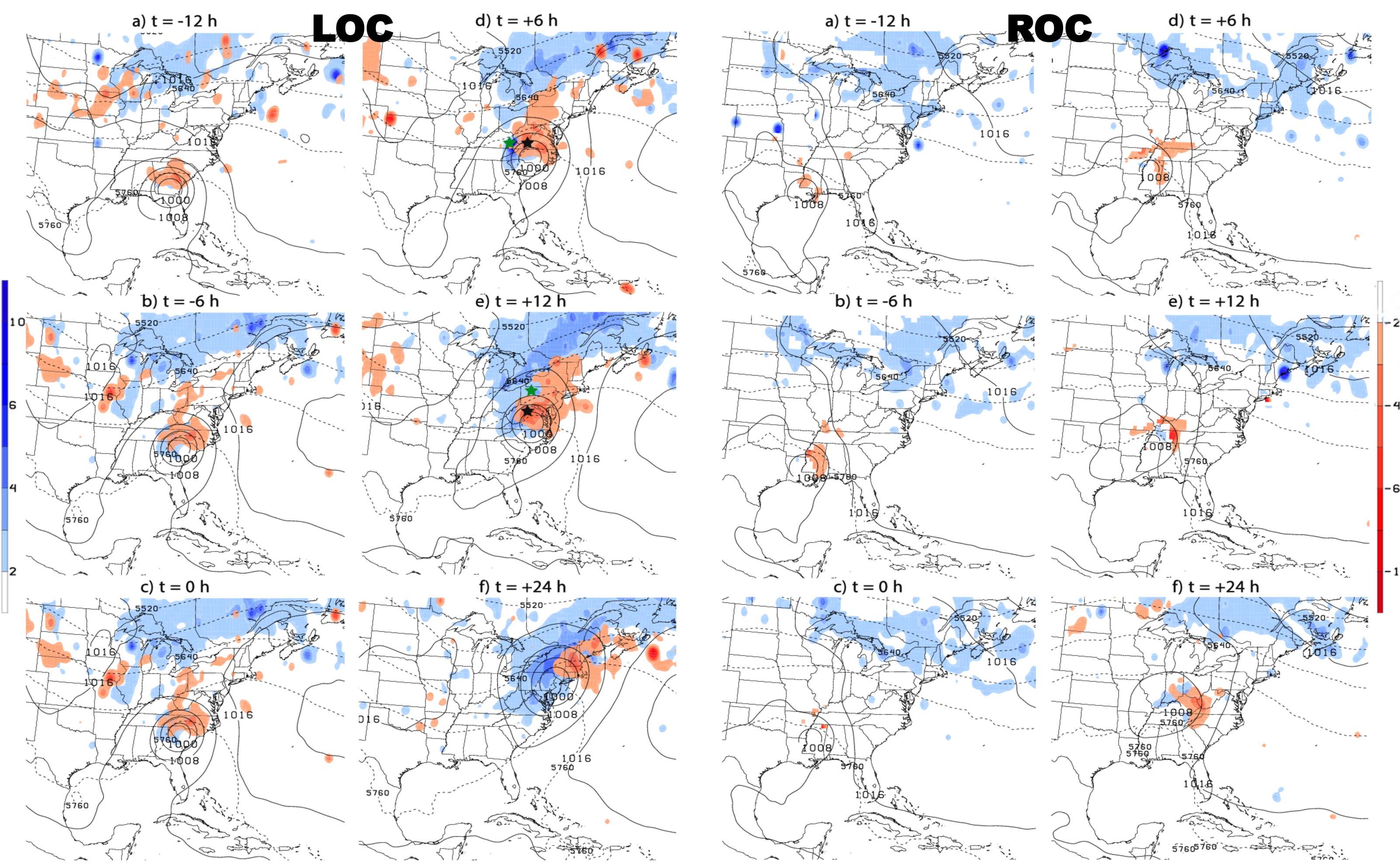
4. Storm-relative Composites for LOC and ROC cases

Precipitation



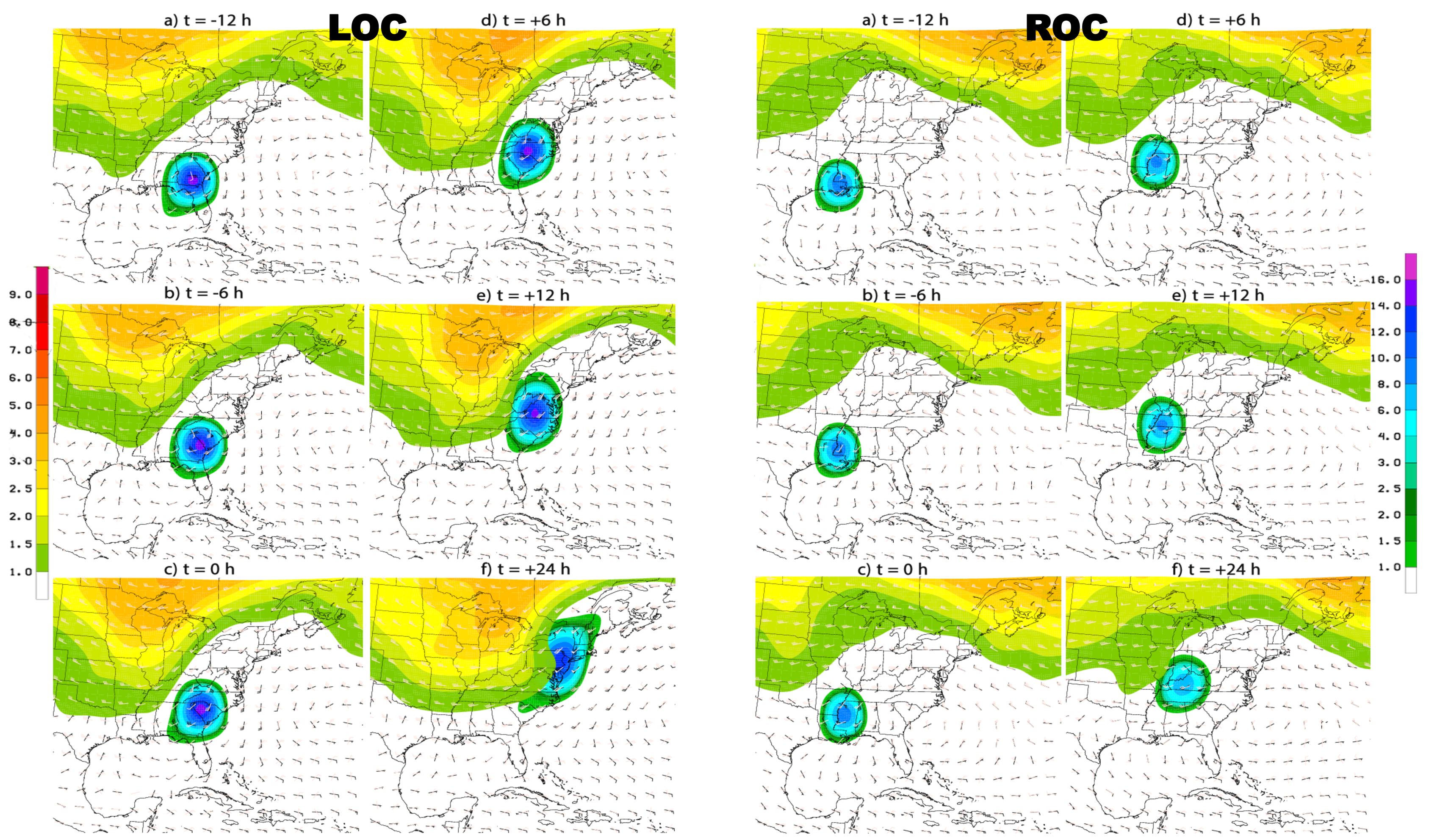
Composite 6-h precipitation (mm, shaded), mean sea-level pressure (hPa, solid black contours) and 1000–500-hPa thickness (dam, dashed black contours).

EMBGR



Composite EMBGR (x10^{-6} day^{-1}, stable EMBGR shaded in cool colors, MAUL EMBGR shaded in warm colors), mean sea-level pressure (hPa, solid black contours), and 1000–500-hPa thickness (dam, dashed black contours).

TC-Trough Interaction



Composite 300–200-hPa layer-averaged potential vorticity (PVU, shaded warm colors) and winds (kt, white barbs), 850–700-hPa layer-averaged relative vorticity ($\times 10^{-5}\ s^{-1}$, shaded cool colors) and winds (kt, black barbs).

5. Future Work

- Document predictability in real time NWP models Research-to-Operations (R2O)
- Reanalysis data vs. operational (deterministic and ensemble) models may not produce identical results
- Investigate cases in other basins (e.g., Western North Pacific)

6. References

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