DIURNAL AND SPATIAL VARIABILITY OF TORNADOGENESIS AND FORECASTING IN TROPICAL CYCLONES

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Overview & Motivation

Landfalling tropical cyclones generate many hazards like storm surge, heavy rainfall, potential for flash flooding, and tornadoes. Tropical cyclone tornadoes (TCTORs) are extremely challenging to forecast given there being less clarity in environmental parameters and radar attributes of their parent convective cells. This uncertainty, coupled with high demands on forecasters, often leads to a higher false alarm rate for TCTORs.

In 2018, there were 71 TCTORs from 4 named storms (2 major hurricanes and 2 tropical storms). Hurricane Florence accounted for nearly 62% of all TCTORs.

Research Goals:

1. Determine the relative location and timing of TCTORs.
2. Identify differences in near-storm environments associated with tornadic and nontornadic cells.
3. Analyze the diurnal cycle's impact on near-storm environmental conditions.
4. Determine the variability in forecasting skill scores spatially and temporally relative to the diurnal cycle.

Methods

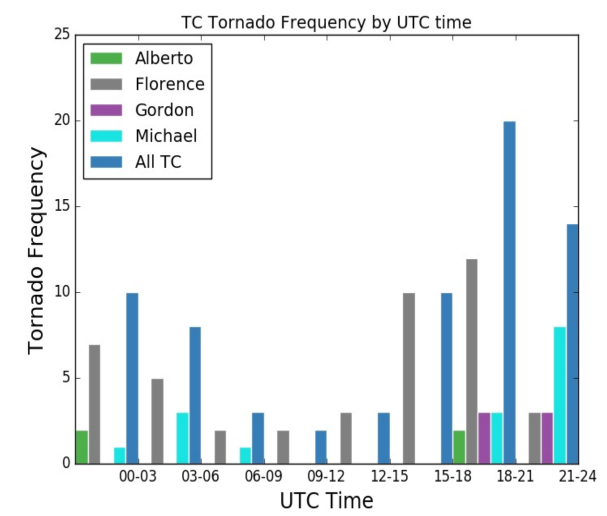
- This study targets TCTORs and nontornadic cells (false alarms) across the entire 2018 hurricane season in storms that made landfall in the United States.
- We examined all the CWAs within an 800 km radius of the NHC TC track for tornado warnings.
- Tornado warnings were collected from the Iowa State COW database, and TCTORs were obtained from the TCTOR database maintained by Roger Edwards at the SPC.
- Cells that produced multiple warnings and/or TCTORs were considered as one cell and classified as tornadic or nontornadic.
- TCTORs were also classified as warned or nonwarned based on whether the TCTOR had a warning associated with it.
- Total number of events in each category for 2018:
    - NONTOR: 63
    - TOR: 43
    - NONWARN: 19
    - WARN: 51

Near-Cell Environments:

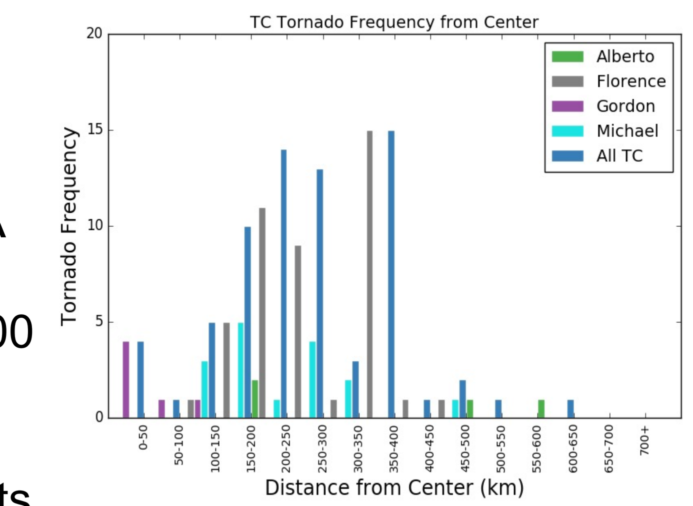
- Proximity soundings were gathered for each cell via the Rapid Refresh (RAP) numerical model analyses.
- They were gathered as close to the temporal midpoint of each warning and closest to the time of the TCTOR.
- Soundings were taken as close as possible to the cell location, but in cases where the location was also an area of heavy precipitation, the nearest alternative gridpoint was selected to limit convective contamination.
- Relevant environmental variables were calculated from the information in these soundings.

2018 Hurricane Season

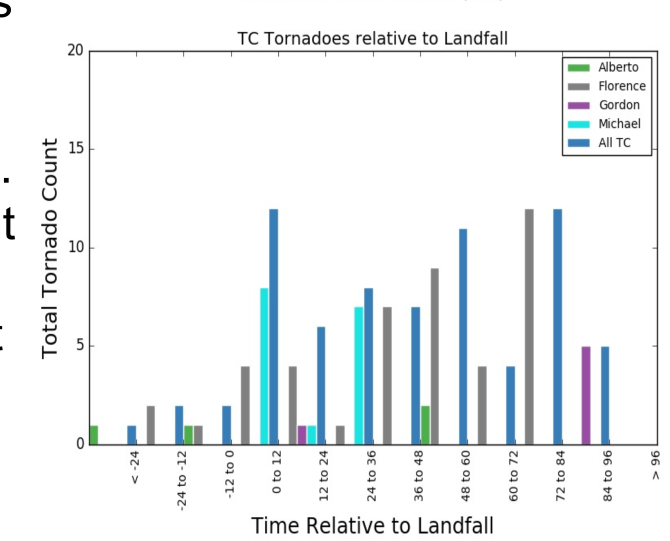
- The distribution by time of day for TCTORs in 2018 is consistent with Edwards (2012). We see a general increase starting at 1500 UTC with the highest number of TCTOR occurring between 1800 and 2400 UTC.



- The radius of the TCTORs also agrees with Edwards (2012). A majority of TCTOR occur within the 150-400 km range.

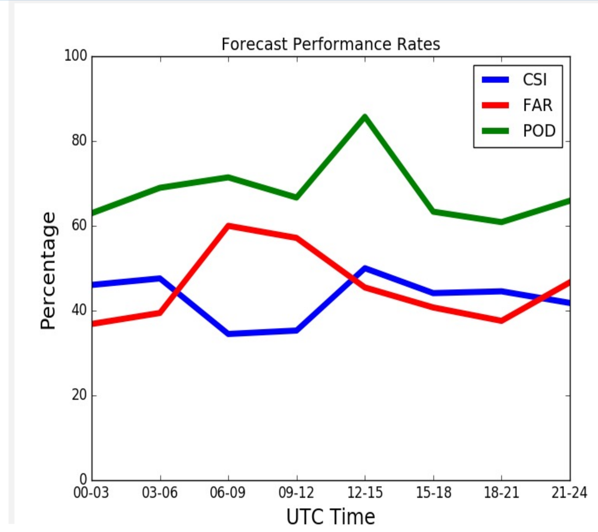


- McCaul (1991) suggests most tornadoes occur between -12 and 36 hours relative to landfall. That is true for 2018, but there are a significant number of TCTORs that occurred between 36 and 84 hours after landfall.

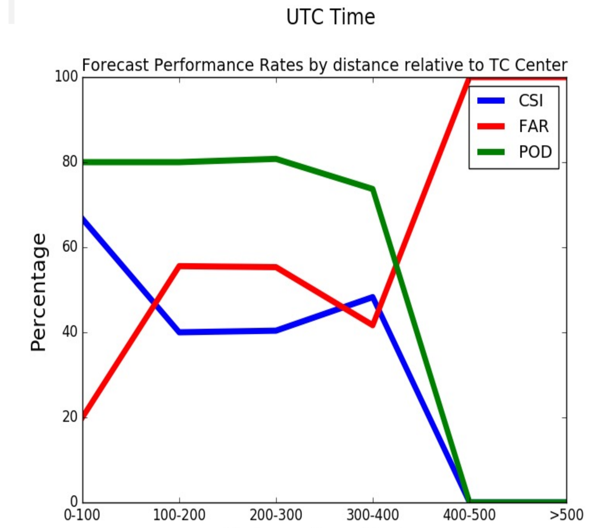


Forecast Skill Scores

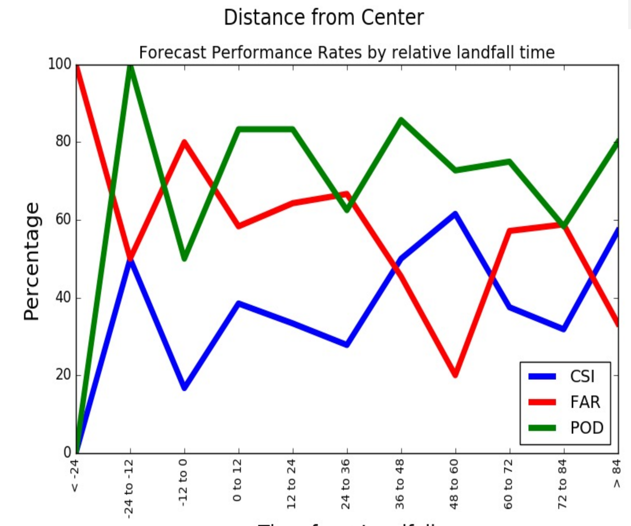
- Forecasters struggled more in the overnight hours (0600-1200 UTC) as we see an increase in false alarms and a lower Critical Success Index (CSI) value.



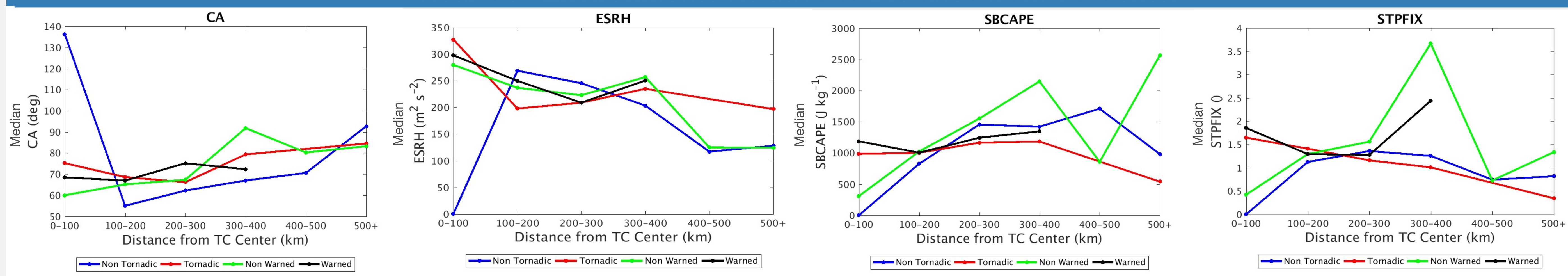
- There is a slight cyclical nature to the Probability of Detection (POD) as forecasters tend to be better during the daytime.
- Forecaster struggled to predict cells outside of 400km away from the TC center, though few tornadoes occurred at this range.



- There is a general increase in CSI after the storm makes initial landfall. This is accompanied by a decrease in false alarms.

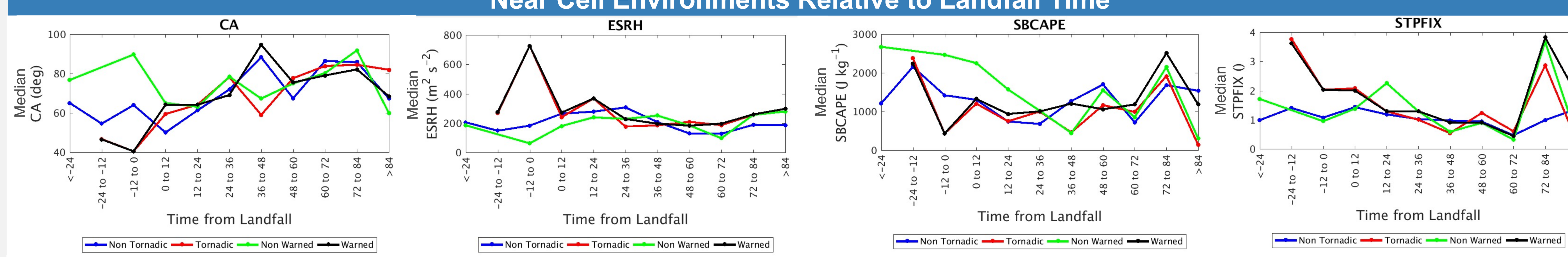


Near Cell Environments Relative to Distance from TC Center



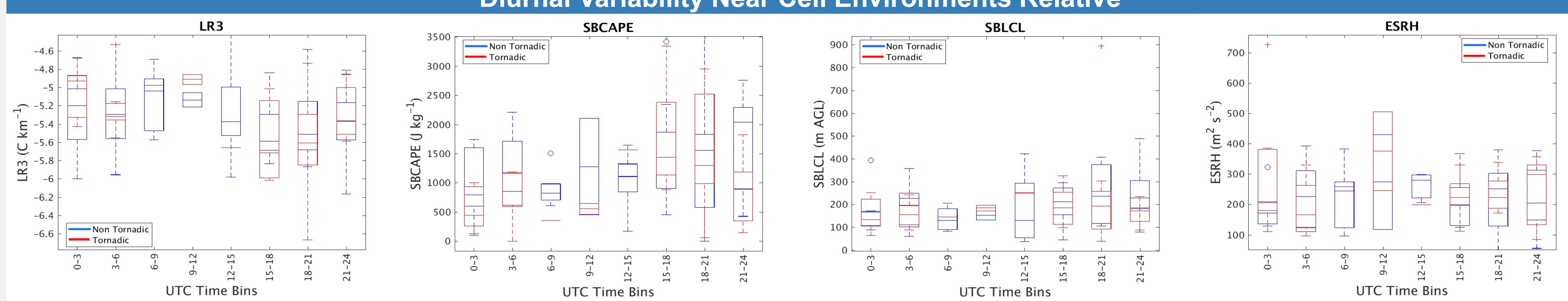
- The helicity (SRH1, SRH3, ESRH) in a cell's environment tends to decrease the farther away it is from the TC center.
- The critical angle (CA) has a general increase moving away from the TC center.
- The CAPE tends to increase away from the center. SBCAPE peaks at the radius where most tornadoes form.
- The STP index has its highest values in the distance range that produce the most tornadoes.
- Overall, near-storm environments are more favorable for tornadoes in the range where tornadoes are most common, but there is little discrimination between environments of tornadic and nontornadic cells, highlighting the difficulty in using cell environments to predict tornadoes.

Near Cell Environments Relative to Landfall Time



- The near-cell helicity decreases 24 hours after landfall. This is also associated with a rise in the critical angle.
- The CAPE decreases until 48 hours after landfall where it begins to increase.
- The STP decreases until the 72-hour mark, where it rebounds.

Diurnal Variability Near Cell Environments Relative



- The strongest lapse rates occurs later in the day, increasing instability.
- CAPE is highest in the late afternoon after a majority of solar heating has occurred.
- The lowest LCLs are in the evening and overnight hours, slightly delayed from when a majority of tornadoes occur.
- There is no clear diurnal signal in ESRH, as might be expected.

Conclusions

- 2018 TCTORs occurred at similar times and ranges as expected from prior studies, but the TCs continued to produce TCTORs longer after landfall than expected.
- Tornadic and nontornadic environments have their greatest differences when comparing distance instead of relative time.
- Variables affected by solar heating (CAPE, LCL, Lapse Rate) have a more pronounced diurnal cycle when farther away from the landfall time.
- Forecasters were slightly more accurate as a storm moved farther inland, but they struggled with cells greater than 400km away from the center.

Future Work

- Expand work to previous hurricane seasons.
- Examine the different environments produced by different levels of TCs (Major Hurricanes, Hurricanes, Tropical Storms, Tropical Depressions).
- Conduct radar analysis to help forecasters identify radar characteristics to decrease false alarms.

References

Edwards, R., 2012: Tropical cyclone tornadoes: A review of knowledge in research and prediction. *Electronic J. Severe Storms Meteor.*, **7** (6), 1–61.

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