A Recent Climatological Look at Tornado Events Relative to Sunset

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INTRODUCTION

- Climatologically, tornadoes are most frequently observed in the afternoon and early evening hours during spring and summer in association with convection forced by solar heating.
- Sunset and disappearance of solar heating typically yields the collapse and stabilization of the boundary layer, and usually, the demise of tornadoes. Occasionally, tornadoes persist after sunset or even first occur after sunset.
- Nocturnal tornadoes pose an elevated hazard due to difficulty in visualizing, communication, and response; it is thus particularly important to understand and be conscientious of nighttime threats (e.g. Ashley et al. 2008).
- This research serves to quantify the distribution and climatology of tornado events relative to sunset. Further, it investigates the synoptic and mesoscale factors that distinguish between tornado events that begin in the afternoon and continue after sunset, those that start and end before sunset, and those that initiate after sunset. Lastly, a case observed during the PECAN field campaign will be examined.

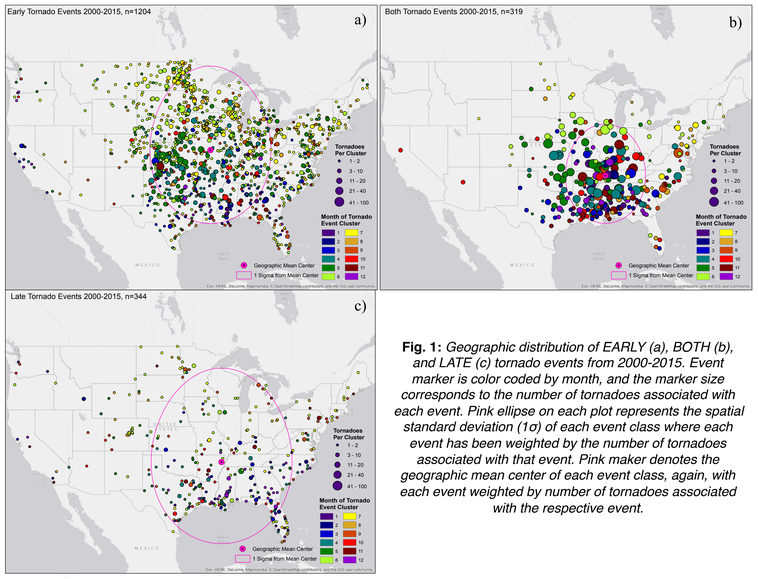

Fig. 1: *Geographic distribution of EARLY (a), BOTH (b), and LATE (c) tornado events from 2000-2015. Event marker is color coded by month, and the marker size corresponds to the number of tornadoes associated with each event. Pink ellipse on each plot represents the spatial standard deviation (1σ) of each event class where each event has been weighted by the number of tornadoes associated with that event. Pink maker denotes the geographic mean center of each event class, again, with each event weighted by number of tornadoes associated with the respective event.*

DATA AND METHODS

- The record of United States tornado tracks from the SPC SVRGIS database from 2000 to 2015 were classified relative to sunset based upon the geographic location and tornado start time
- Tornadoes, using a clustering algorithm, were classified into tornado events that occur exclusively before sunset (EARLY), exclusively after sunset (LATE), and events had tornadoes occur both before and after sunset (LATE) based upon a buffer of 2 hours relative to sunset and 3 hours relative to sunrise
- The synoptic and mesoscale environmental characteristics between each event class were examined using the North American Regional Reanalysis (NARR; Mesinger et al. 2006), especially vertical profile of kinematic and thermodynamic data following Potvin et al. (2010)
- This data was supplemented by using the SPC Storm Mode dataset (Smith et al. 2012) to examine the distribution of specific severe weather parameters over each event class
- Radiosondes obtained by mobile assets of the PECAN field campaign (Geerts et al. 2017) on July 2nd, 2015 of a BOTH event will also be examined and compared to the bulk event characteristics.

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Environmental Characteristics of EARLY, BOTH, and LATE events

Questions to investigate:

What environmental factors, both synoptically and on the mesoscale, distinguish these different event classes?

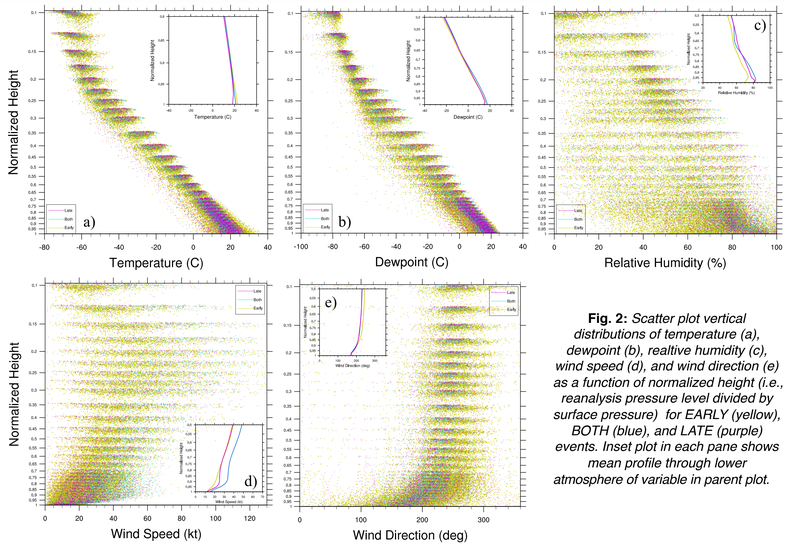

Fig. 2: *Scatter plot vertical distributions of temperature (a), dewpoint (b), realtive humidity (c), wind speed (d), and wind direction (e) as a function of normalized height (i.e., reanalysis pressure level divided by surface pressure) for EARLY (yellow), BOTH (blue), and LATE (purple) events. Inset plot in each pane shows mean profile through lower atmosphere of variable in parent plot.*

- BOTH events are associated with more tornadoes per event and are generally confined to the Mississippi Valley (Fig. 1b). EARLY events are common east of the Rockies and often have fewer tornadoes per event, compared to BOTH events (Fig. 1a). LATE events are most common in the coastal regions and are not typically associated with outbreaks (Fig. 1c)
- The spread of environmental conditions over which EARLY (yellow markers) events occur is much larger than BOTH (blue) and LATE (purple) events (Fig. 2)
- Largest differences between the sub-classes are seen in wind speed (Fig. 2d), relative humidity (Fig. 2c), low-level temperature profiles (Fig. 2a).
- The increase in wind speed in BOTH and LATE events points to the importance of the nocturnal low-level jet and wind shear profile in initiation or maintenance of tornadoes after sunset (Fig. 2d).

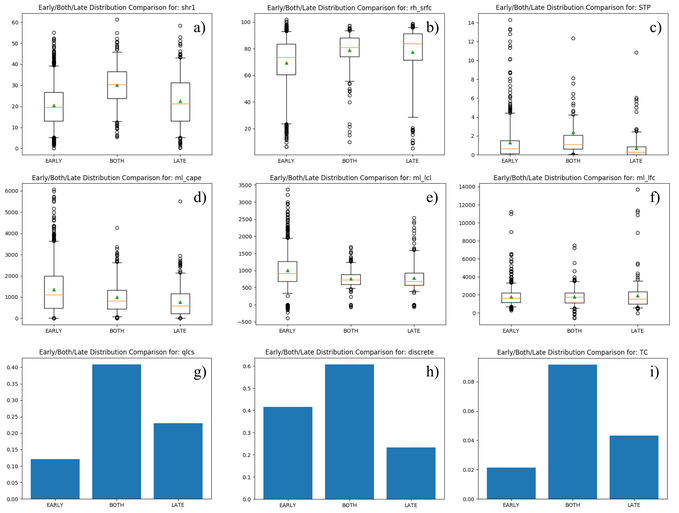

Fig. 3: *Box and whisker plots with green triangle representing the mean for all event classes of (a) 0—1 km shear (kt), (b) surface RH (%), (c) STP, (d) MLCAPE (j/kg), (e) ML-LCL (m), (f) ML-LFC (m), (g) frequency of occurrence in QLCSs (%), (h) Discrete storms (%), (i) and Tropical Cyclones (%) from SPC Storm Mode Dataset.*

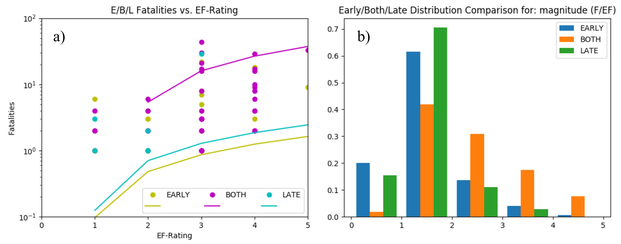

Fig. 4: *(a) tornado deaths versus EF rating for each of the three events classes. Dots represent the number of fatalities normalized by the number of tornadoes in an individual event. Lines represent mean. (b) frequency of a specific EF rated tornado occurring within each event class.*

- BOTH and LATE events tend to have higher 0—1km shear values and surface relative humidity values than EARLY events (Fig. 3a-b)
- EARLY events tend to be associated with the most MLCAPE (Fig. 3d); however, the corresponding LCL heights for BOTH and LATE events tend to be lower (Fig. 3e), which hints at a more boundary-layer moisture in the latter sub-classes
- MLLFC heights overall tend to be lowest in the LATE case and highest in the BOTH cases (Fig. 3f)
- The significant tornado parameter (STP) is often highest for BOTH events and struggles to identify LATE events (Fig. 3c)
- BOTH and LATE events have a higher frequency of producing QLCS tornadoes, compared to EARLY events (Fig. 3g), which hints there is often upscale evolution of convection in the prior classifications
- LATE events least frequently produce discrete tornadoes (Fig. 3h); however, BOTH events continue to produce discrete tornadoes at a high frequency
- Tropical cyclones, since the ingredients for tornado production generally do not depend on the diurnal cycle, are most frequently associated with BOTH and LATE events, but this is dependent on timing of landfall (Fig. 3i)
- BOTH events generally produce the strongest tornadoes, with EARLY and LATE events producing relatively similar frequency distributions of F/EF rating (Fig. 4b)
- More fatalities are associated with BOTH events, compared to the other sub-classes, for a give F/EF rating (Fig. 4a). Further, more deaths for a given F/EF rating are associated with LATE events than EARLY events (Fig. 4a)
- In situ soundings (Fig. 5) of a BOTH event during PECAN shows the presence of a developing nocturnal low-level jet, which enhances the 0—1km shear values. Nocturnal stabilization is still seen but is potentially overcome in this scenario by the increase in low-level shear in the presence of already existing storms.

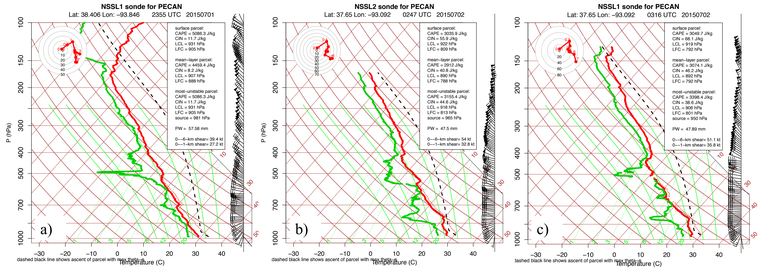

Fig. 5: *Mobile soundings taken by the OU (NSSL1) and NCSU (NSSL2) teams during a both event that occurred 1-2 July 2015 in Missouri. Soundings are valid at (a) 2355 UTC July 1st, (b) 0247 UTC July 2nd, and (c) 0316 UTC July 2nd.*

CONCLUSIONS and ACKNOWLEDGEMENTS

- BOTH events are associated with the strongest atmospheric forcing (in terms of instability and low-level shear), produce the highest number of tornadoes per event, are associated with most fatalities, are associated with both discrete and QLCS storm modes, and are tightly geographically clustered in the Mississippi Valley
- LATE events tend to have highest low-level moisture values, smallest thermodynamic instability, and generally are associated with embedded storm modes. However, they produce tornadoes of a similar strength to EARLY events and are associated with more fatalities per F/EF rating than EARLY events. Geographically they occur east of the Rocky Mountains, but tend to cluster along the Gulf and Atlantic coasts
- EARLY events are associated with a larger range of atmospheric conditions than LATE and BOTH events, mainly occur throughout CONUS east of the Rockies, and generally occur in discrete storm modes

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