Investigation of Extreme Lightning Days in North Carolina

Gail Hartfield and Jonathan Blaes -- NOAA/National Weather Service, Raleigh, North Carolina

Gary Lackmann, Michael Graves, and Lindsey Anderson -- North Carolina State University, Raleigh, North Carolina

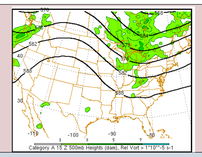
Overview: Lightning is a significant threat to life and property. Highly active lightning days, in particular, can be extremely hazardous. To gain a better understanding of such events, researchers at North Carolina State University and forecasters at the National Weather Service in Raleigh, NC, have partnered to study past lightning in events in NC, with a focus on prolific lightning-producing convection.

How it was done: Using a 10-year cloud-to-ground (CG) lightning database, surface and upper-air patterns for prolific events (defined as > 7000 CG strikes in 24 hours) were examined and categorized. These were contrasted with less-prolific convective events. Anomalies were also computed. Composite maps and soundings were created for each category, and through these, key signals were identified.

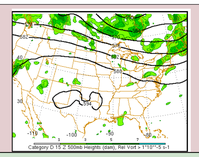
Here is some of what we have learned:

(1) Prolific events could be categorized into four main synoptic patterns.

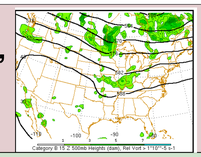
"Eastern Trough" (31 events)



"Zonal" (9 events)

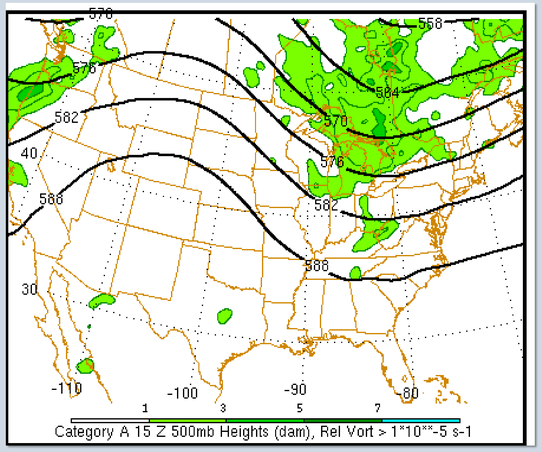


"Central Trough" (7 events)

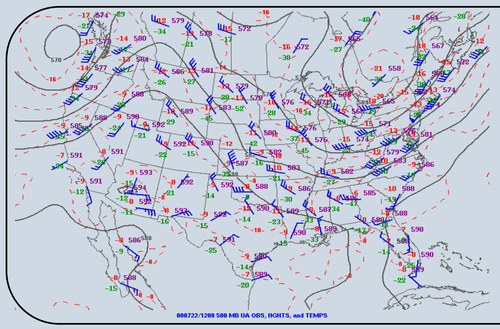


"Eastern Ridge" (only 3 events) (not shown)

(2) Most prolific events featured a long wave trough over eastern North America.



Composite 500 hPa map of "Eastern Trough" cases. Contours depict height lines; shading shows relative vorticity.



Example of prolific "Eastern Trough" case, 500 hPa analysis, from 1200 UTC on 22 July 2000.

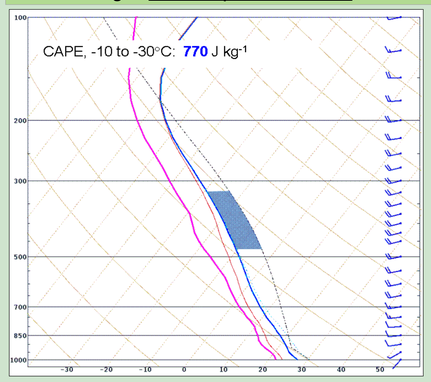
Around 60% of prolific lightning-producing events fell into a category termed "Eastern Trough." It is thought that the contribution by dynamic forcing for ascent helps to increase and organize convection. This, along with strong instability to facilitate strong updrafts, may serve to increase the number of cells generating nearly continuous lightning strikes. This agrees with established research which has found that strong updrafts favor rapid charge separation and support lightning production. Also, a stationary surface front was often present over NC, serving to focus convection.

(3) Prolific events possessed greater instability in the -10°C to -30°C "mixed phase" layer as compared to non-prolific events.

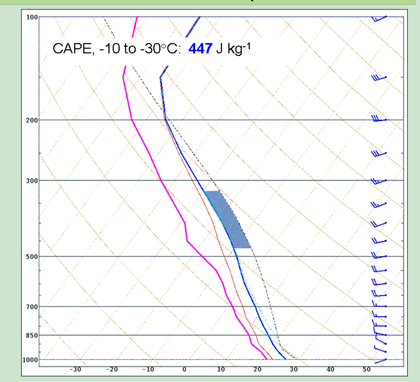
A popular theory of lightning production is based on the non-inductive charging (NIC) mechanism. Charging occurs when ice crystals and graupel collide in the presence of supercooled water -- termed the "mixed phase" region of the storm. Updrafts carry lighter particles with positive charge aloft, and heavier particles with negative charge sink to bottom of storm, while the ground becomes positively charged. Charge separation leads to buildup of electric potential gradient and eventual electrical discharge.

Signals in composite soundings, showing high CAPE indicative of possible vigorous updrafts for the prolific events, support this theory.

Both of these soundings are composites for events with an "Eastern Trough", valid at 1500 UTC. But the sounding on the left represents prolific lightning events, while the right sounding is for non-prolific events. Note the stark difference in "mixed phase" CAPE.

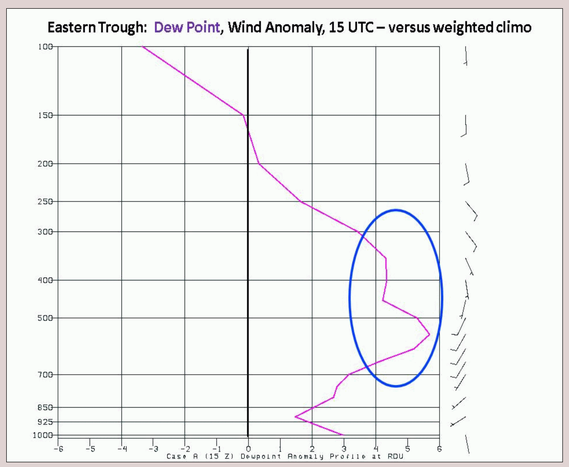


Composite 1500 UTC RUC sounding at Raleigh-Durham (KRDU) for "Eastern trough" prolific lightning events. Shading represents estimated swath of "mixed phase" CAPE.



Composite 1500 UTC RUC sounding at Raleigh-Durham (KRDU) for non-prolific "Eastern trough" lightning events. Shading represents estimated swath of "mixed phase" CAPE.

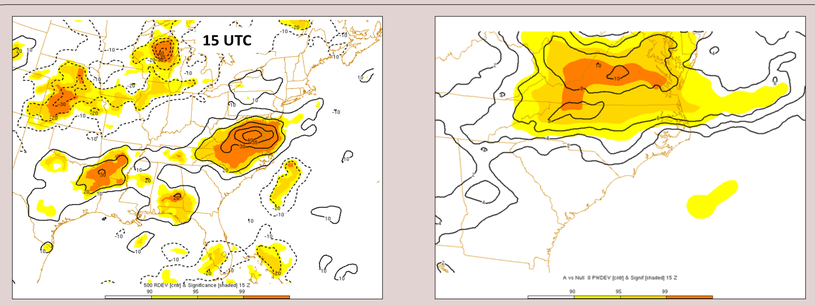
(4) Greater moisture in the -10°C to -30°C "mixed phase" layer was also found with prolific events.



Composite dew point trace (vs. weighted climatology) for 1500 UTC, at Raleigh-Durham (KRDU), from RUC gridded data, for prolific "Eastern Trough" cases. Note the positive moist anomaly in the mid levels, around 650 to 450 hPa, encompassing the "mixed-phase" region.

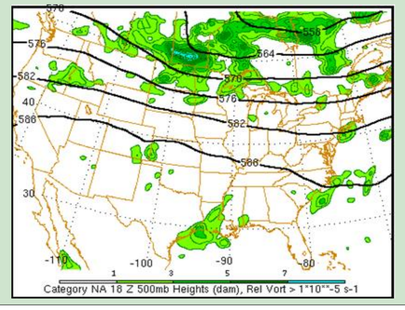
Past lightning research conducted with total lightning data has demonstrated a high correlation between high total lightning activity and ice mass flux in the so-called "mixed phase" layer. Links have also been established between active lightning days and high precipitable water content.

Composite dew point traces for the "Eastern Trough" cases support these theories, showing a statistically significant moist anomaly in the mid levels, encompassing this "mixed phase" region. Composites of non-prolific events revealed much drier air aloft, consistent with research findings.



Contours show the 500 hPa relative humidity anomaly (left) and precipitable water anomaly (right) for "Eastern Trough" cases compared to non-prolific events, valid at 1500 UTC; shading shows statistical significance from a two-tailed Student T test.

On right: Composite 500 hPa map of all non-prolific cases. Contours depict height lines; shading shows relative vorticity. Note the relative flat nature of the flow as compared to the prolific "Eastern Trough" events.



Non-prolific lightning events were defined as cases featuring lightning and convection over central NC, but with < 500 CG strikes.

Goals and Future Work

- Expand composite sample sizes with more cases
- Develop real-time diagnostics for mid-level humidity and -10°C to -30°C CAPE anomalies; test as predictors
- Analyze days with anomalously large percentage of positive CG polarity
- Train operational forecasters, with the goal of improving pattern recognition and situational awareness
- Incorporate into WFO Raleigh experimental lightning activity forecasts

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Contact : gail.hartfield@noaa.gov