# An 8 Year Lightning Climatology of North Carolina


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## Introduction

Cloud-to-ground (CG) lightning is one of the leading causes of weather-related fatalities in the United States, second only to flooding (Curran et al. 2000). Data from the publication "Storm Data" (NOAA/National Weather Service 2011) ranks North Carolina sixth in the United States for the number of lightning fatalities between 1995 and 2010 and fifth during this study period of 2003-2010. Lightning climatologies have shown a broad maximum of CG flash density over the southeastern United States (Orville and Huffines 2001; Orville et al. 2011), but these studies have not closely examined the lightning distribution over North Carolina. This climatology explores the influences of the season, time of day, various geophysical features, and mesoscale processes on the spatial and temporal distribution of CG lightning across the state. This project provides a context and initial dataset to support complementary lightning related projects.

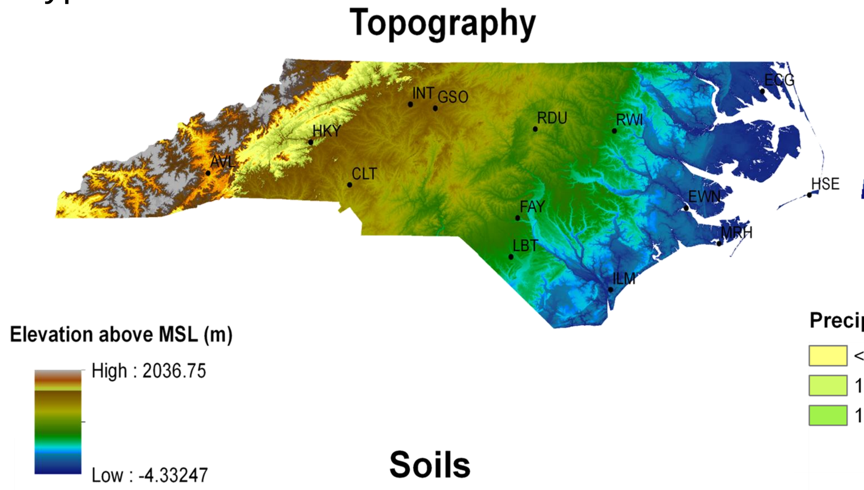
## Methodology

An eight year data set (2003-2010) of National Lightning Detection Network (NLDN) CG lightning data was constructed from local archives of AWIPS data. The data was quality controlled to remove positive flashes less than 15 kA. The point data, constructed with latitudinal and longitudinal pairs, were then ingested into ArcGIS software where the "Point Density" tool was used to create a 5 km$^2$ analysis. Statistical point data for eight selected cities were derived using a 25 km$^2$ grid box centered over the associated airport location (AVL, CLT, ECG, EWN, FAY, GSO, ILM and RDU).

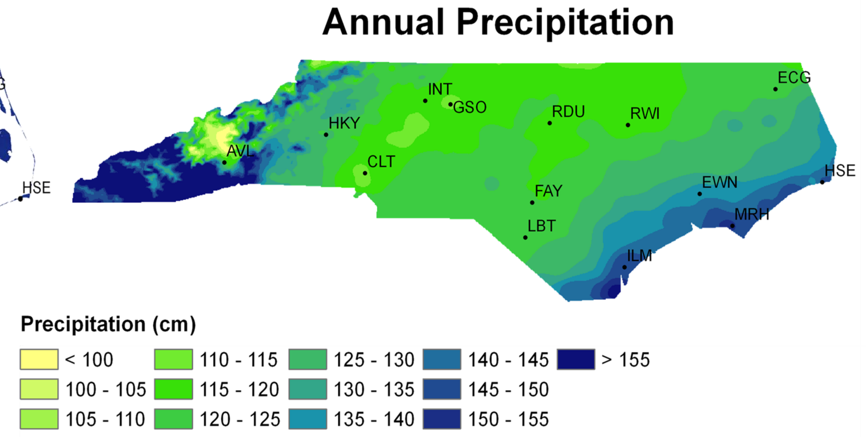
## Background

North Carolina's convective weather is heavily influenced by a unique and diverse set of geophysical features, including the southern Appalachian Mountains, the Atlantic Ocean, the Gulf Stream, the rolling terrain of the Piedmont, the gently sloping Coastal Plain, the sand based soil of the Sandhills region, the complex land-sea interfaces, as well as wide variations in soil types and land uses.

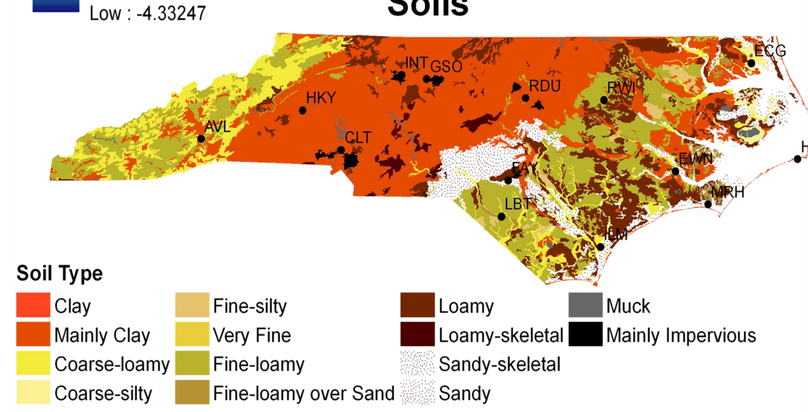
Topography



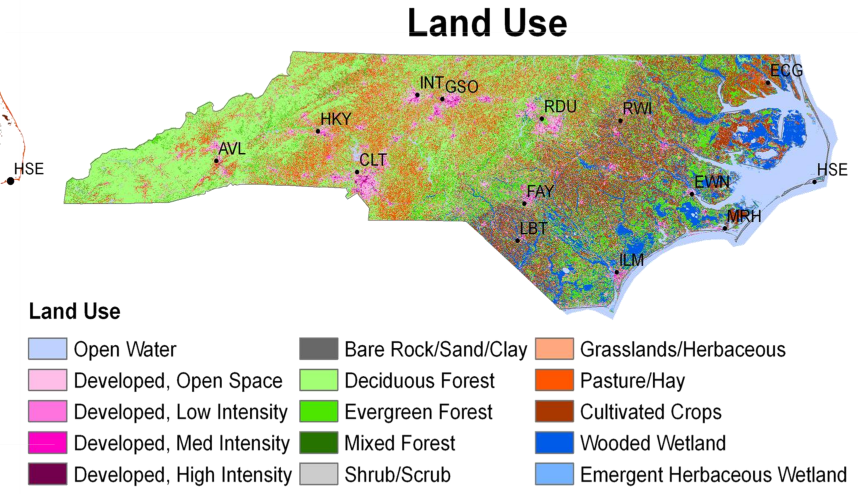

Annual Precipitation




Soils

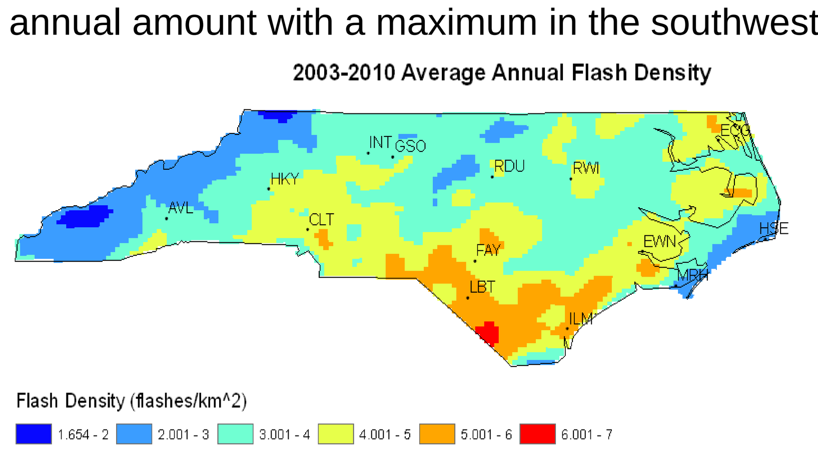


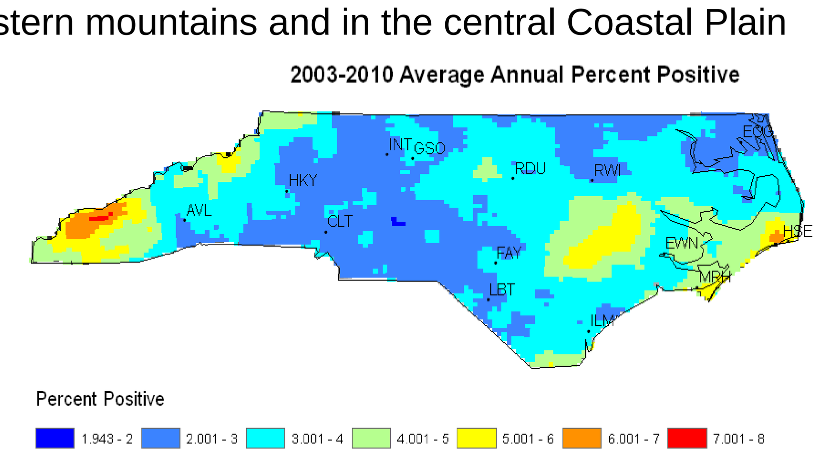

Land Use




## Annual Flash Density Maps

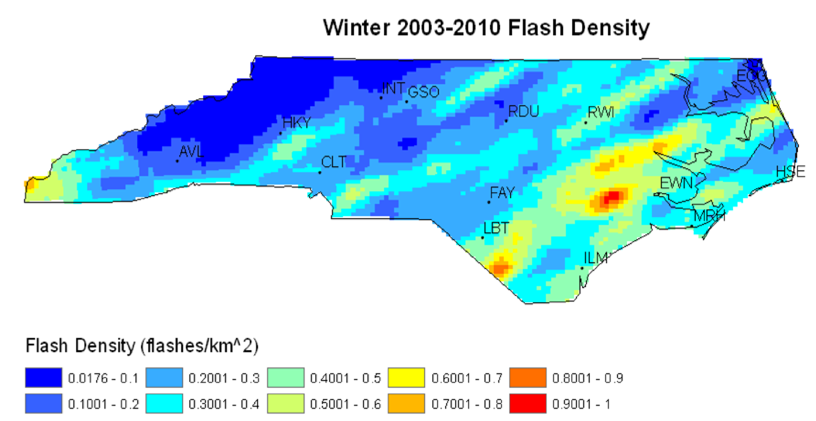
- High annual flash densities in the Sandhills, southern Coastal Plain, and the coastal regions are likely due to the juxtaposition of multiple regions of favored convective development
- The southern coastal region max likely results from coastline orientation that promotes inland penetration and collisions of sea breeze boundaries
- The Sandhills region max likely results from enhanced surface convergence along the clay-sand soil transition zone on the western perimeter of the region (Wootten et. al 2010)
- Northeast-southwest max/min pair across the Piedmont region likely results from enhanced convergence and convection associated with the Piedmont trough (Koch and Ray, 1997)
- Other flash density maxima located across the coastal region are separated by the westward extension of the Albemarle and Pamlico Sounds
- Most of NC experiences very few positive flashes, generally between 2% and 5% of the total annual amount with a maximum in the southwestern mountains and in the central Coastal Plain

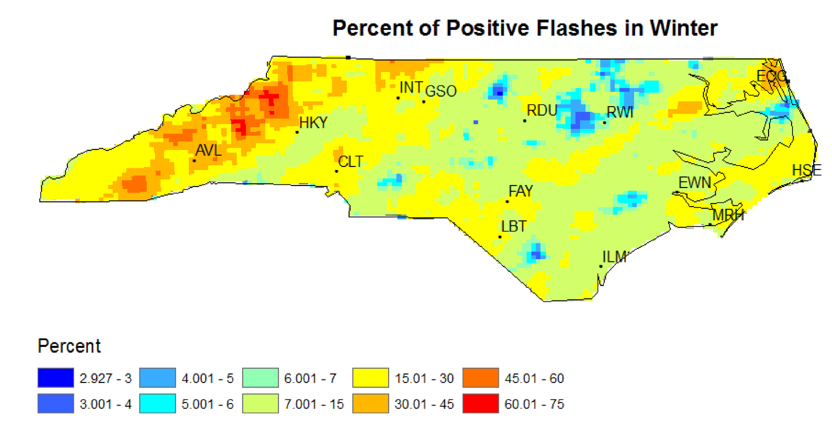


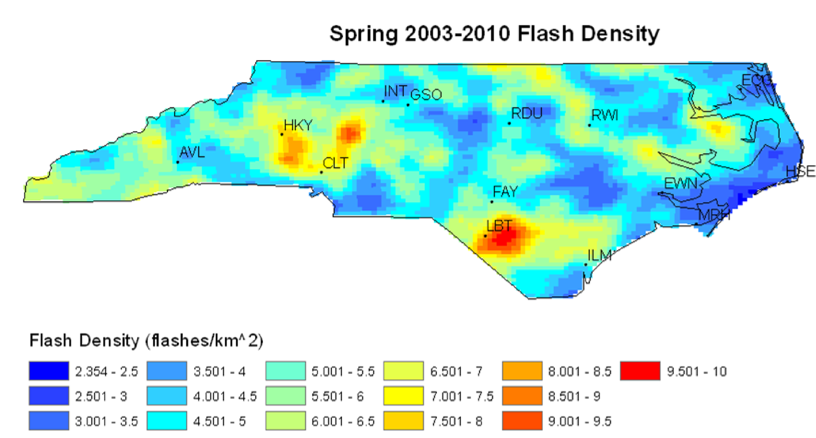



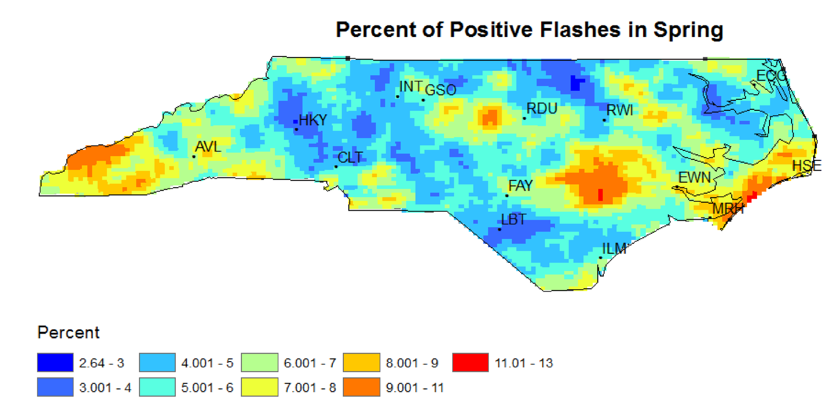

## Seasonal Flash Density Maps

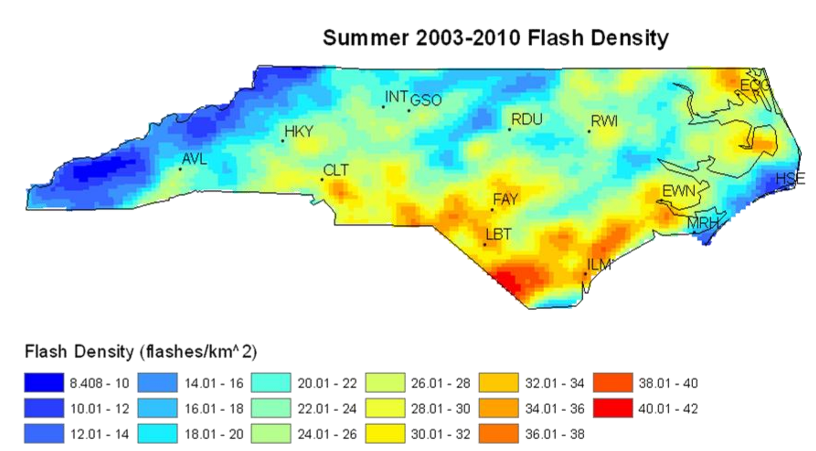
- Higher flash densities in the winter along the southeastern coast likely result from enhanced low level instability resulting from a modification of the low level air mass from the Gulf Stream
- Lower flash densities in northeastern NC compared to the rest of eastern NC likely result from cooler near shore waters
- Given the predominance of lightning in the summer, the summer flash density map displays a very similar pattern to the annual flash density map and highlights the location of sea breeze interactions and the Piedmont trough
- The average percent of positive flashes for the eight locations during winter was 20.0%, spring 6.0%, summer 2.4%, and fall 5.8%

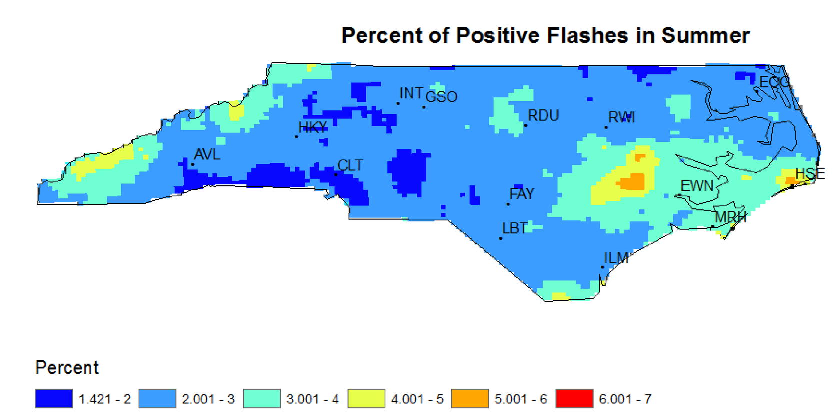


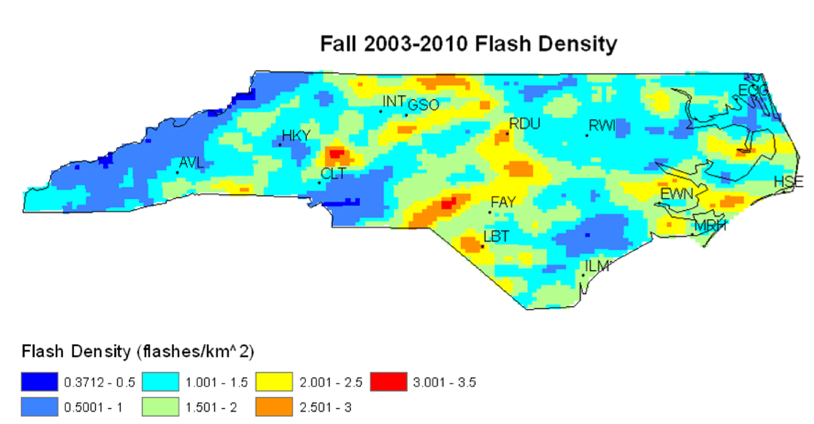



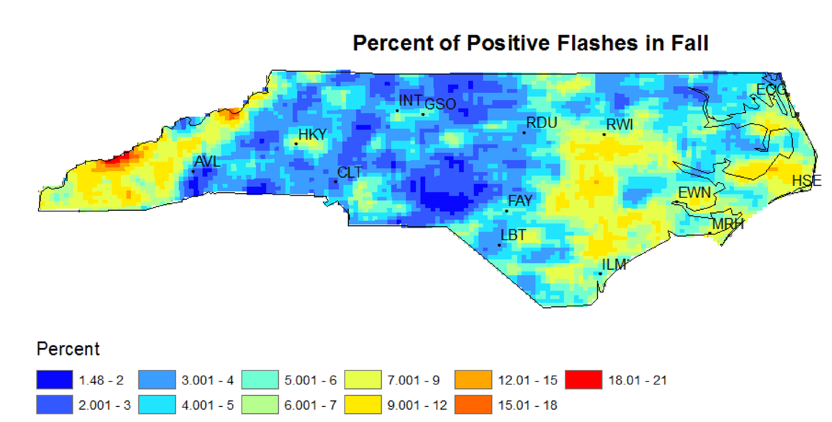



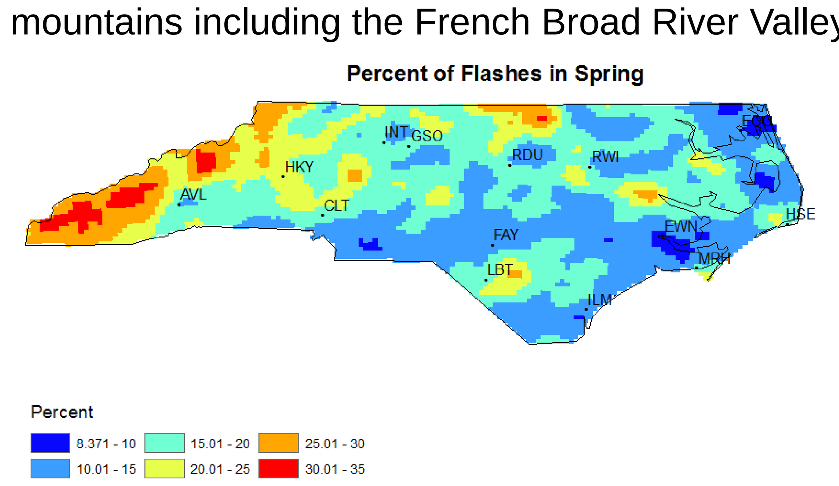



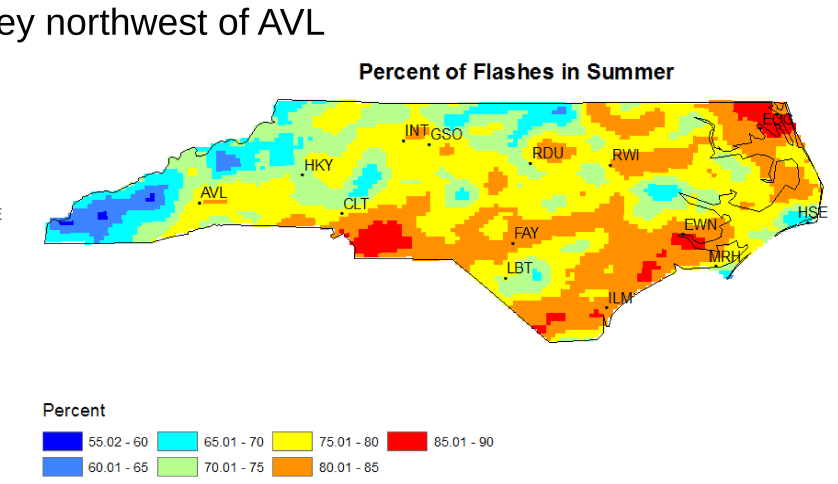




- A very large majority of all flashes occur during the spring and summer which explains the complementary distribution pattern between the percentage of spring and summer maps
- The maximum in percent of flashes in the spring across the mountains likely results from convection and MCS activity developing upstream and moving into this region
- The general minimum in percent of flashes in the spring across the coastal region likely results from the negative impact cooler water temperatures have on instability
- The inland progression of sea breeze boundaries is evident across the southern coastal region
- The distribution of the percent of flashes in western NC detail the complex terrain in the mountains including the French Broad River Valley northwest of AVL



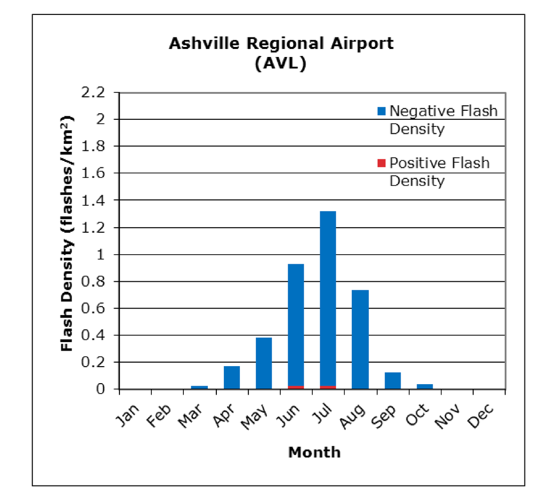

## Annual Flash Count

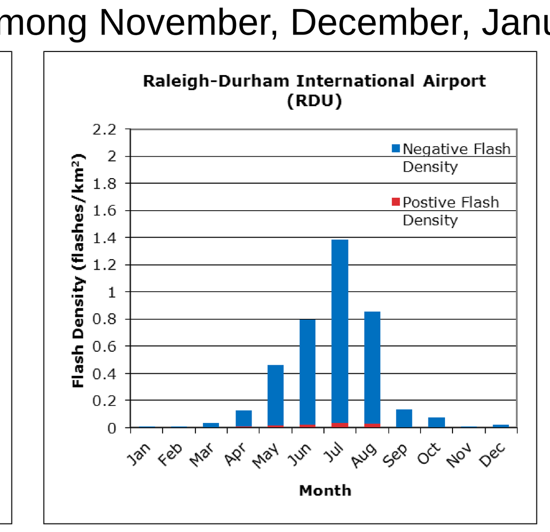
- ILM has the greatest number of strikes per year, 13% more than the second greatest location (FAY) while GSO has the fewest.
- The top three locations in number of strikes per year, ILM, FAY, and EWN are located in southeastern NC where sea breeze boundaries, the Sandhills convergence zone, and the Piedmont trough can complement one another and produce convection.
- AVL has the greatest number of days with strikes (nearly 57) and the second fewest number of strikes per year.
- All 8 locations experience days with excessive lightning with 50% of the total annual lightning occurring on just 4 to 6 days.

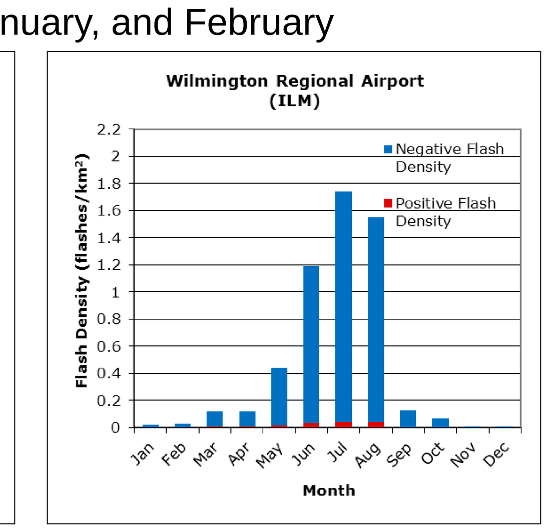
| Site | Total strikes | Avg strikes per year | Avg days with strikes | Avg days to exceed 50% of annual | Avg days to exceed 75% of annual | Avg days to exceed 90% of annual | Days with 50 strikes | Days with 250 strikes |
|---|---|---|---|---|---|---|---|---|
| AVL | 18572 (7) | 2322 | 56.8 (1) | 5.6 (8) | 12.8 (8) | 22.4 (8) | 13.0 (4) | 1.4 (8) |
| CLT | 23173 (4) | 2897 | 48.9 (3) | 5.0 (7) | 10.1 (7) | 17.9 (7) | 14.0 (2) | 2.5 (5) |
| ECG | 22866 (5) | 2858 | 41.6 (8) | 4.1 (2) | 8.6 (1) | 15.5 (1) | 12.6 (6) | 3.1 (2) |
| EWN | 23587 (3) | 2948 | 47.6 (4) | 4.0 (1) | 9.4 (3) | 16.6 (3) | 12.9 (5) | 3.0 (3) |
| FAY | 23961 (2) | 2995 | 47.3 (5) | 4.6 (5) | 9.6 (5) | 17.5 (6) | 13.6 (3) | 2.8 (4) |
| GSO | 18359 (8) | 2295 | 41.8 (7) | 4.8 (6) | 10.0 (6) | 16.9 (4) | 11.8 (7) | 2.3 (6) |
| ILM | 27076 (1) | 3385 | 51.5 (2) | 4.3 (3) | 8.9 (2) | 15.9 (2) | 14.4 (1) | 4.0 (1) |
| RDU | 19435 (6) | 2429 | 44.1 (6) | 4.3 (3) | 9.4 (3) | 16.9 (4) | 10.8 (8) | 2.1 (7) |

## Monthly Flash Density

- July has the most flashes out of any month for all eight sites closely examined
- The percent of flashes during July at the eight sites ranged from 44% to 29% and the average was 36.0%
- A dramatic decline in flashes from August to September reflects the climatologically drier fall
- The minimum month varied among November, December, January, and February



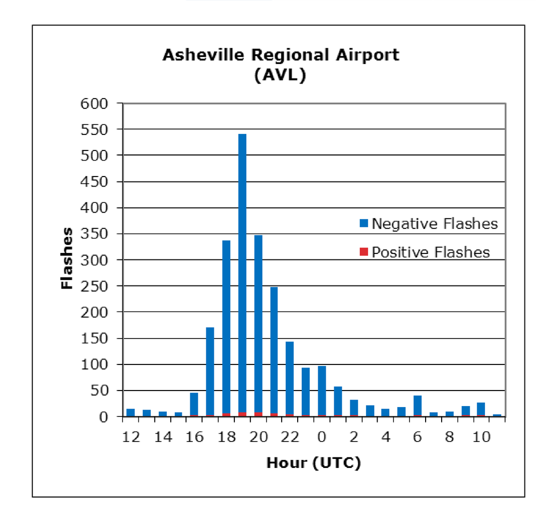



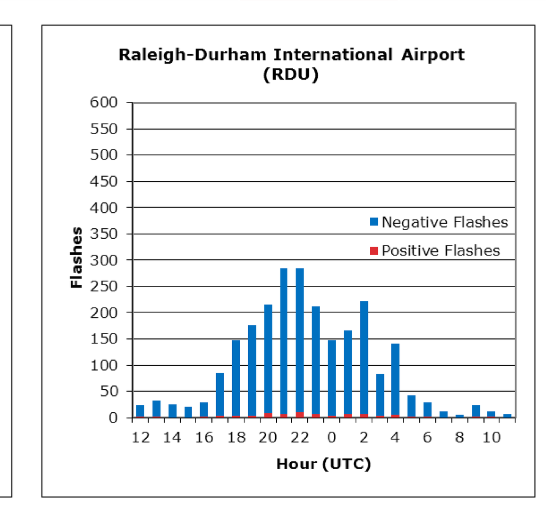



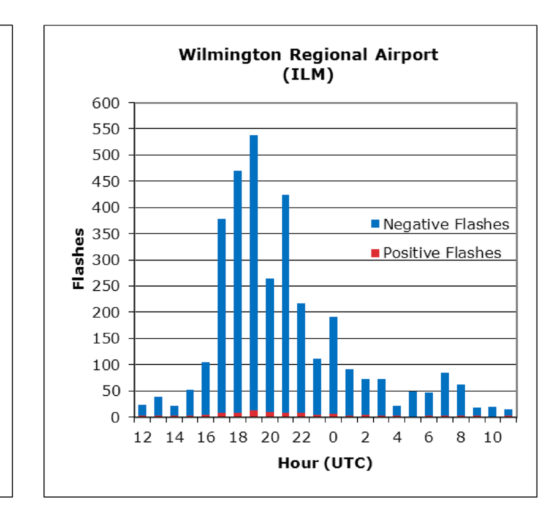

## Hourly Flash Count

- Earlier peak at AVL and ILM, likely results from stronger geographical forcing mechanisms
- On average, 23% of flashes at AVL occur during the peak hour, 16% at ILM, and 12% at RDU
- The three sites in central NC, CLT, GSO, and RDU had the latest peak time, 22Z

| Site | Peak hour | Minimum hour | Percent of strikes in peak hour | Percent of strikes 10Z-14Z | Percent of strikes 16Z-20Z | Percent of strikes 18Z-22Z | Percent of strikes 20Z-24Z |
|---|---|---|---|---|---|---|---|
| AVL | 19Z | 11Z | 23.3 (1) | 2.88 (4) | 62.1 (1) | 69.7 (1) | 40.1 (7) |
| CLT | 22Z | 13Z | 18.6 (2) | 1.19 (8) | 25.2 (7) | 54.6 (4) | 65.6 (1) |
| ECG | 21Z | 15Z | 18.3 (3) | 2.57 (5) | 36.1 (4) | 60.9 (2) | 52.7 (3) |
| EWN | 20Z | 14Z | 11.7 (8) | 2.52 (6) | 40.9 (3) | 53.0 (5) | 44.0 (6) |
| FAY | 20Z | 14Z | 12.0 (6) | 3.08 (3) | 28.0 (5) | 44.5 (8) | 47.5 (4) |
| GSO | 22Z | 13Z | 17.3 (4) | 2.52 (7) | 24.8 (8) | 51.4 (6) | 60.4 (2) |
| ILM | 19Z | 11Z | 15.9 (5) | 3.45 (2) | 51.8 (2) | 56.5 (3) | 35.6 (8) |
| RDU | 22Z | 8Z | 11.7 (7) | 4.29 (1) | 26.8 (6) | 45.5 (7) | 47.0 (5) |





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