A Cloud to Ground (CG) Lightning Climatology for the Lake Superior Region

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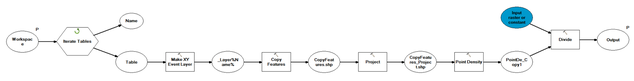
Why a Lightning Study?

- Not a great amount of research on CG lightning climatology in the Upper Great Lakes Region
  - Cook et al. conducted a CG lightning climatology for the Upper Mississippi Valley, which included the western lakes.
  - Burrows et. al (2002) conducted a lightning climatology on the Canadian Lightning Detection Network, which included the Great Lakes
- However, none of these studies were mesoscale in nature.
  - We wanted to take the "traditional" lightning climatology one step further and create "flow regime" lightning climatology for the Upper Great Lakes.
    - Attempt to find mesoscale features associated with lake breezes, convergence zones, etc.
    - Similar to Smith et al. (2005) study over northern Gulf of Mexico Coast.

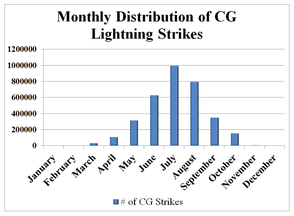
Methodology

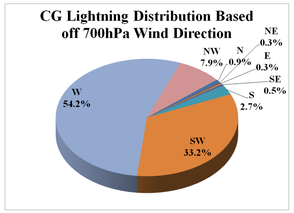
1. Gathered complete regional lightning dataset from the National Lightning Detection Network (NLDN) from 2002-2008 (thanks to Vaisala and Florida State) and supplemented with local archive from 2009-2011.
   - Made no corrections for accuracy or detection efficiency.
2. Placed each lightning strike in a MySQL database
   - 36+ million entries -- Allows each lighting strike to have it's own set of "attributes"
     - Also allows for easy access to data
3. Using the North American Regional Reanalysis (NARR) (Mesinger et. al, 2006) , meteorological data was "assigned" to each lightning strike.
   - 700 hPa wind was used as a proxy for mean flow
4. Using ArcGIS, high resolution 1 km^2 lightning density plots were developed using the Model Builder (example below).

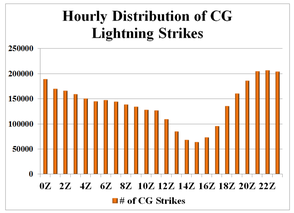


General Lightning Climatology

- Hourly: small peak towards 6Z
  - Likely due to MCS activity coming out of the Northern Plains
- Lightning defined by 700hPa flow
  - Upper Great Lakes region dominated by west and southwest flow
    - Over 87% of lightning strikes







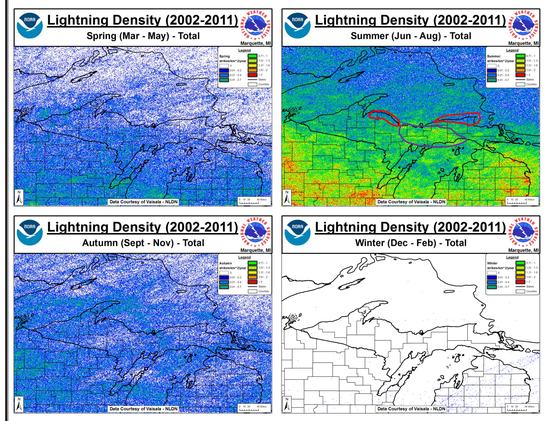
Seasonal Lightning Climatology

Spring
- Lake Superior shadow with cool water temperatures
  - 1992-2011 Average of 1.8º C during March-May (GLSEA*)

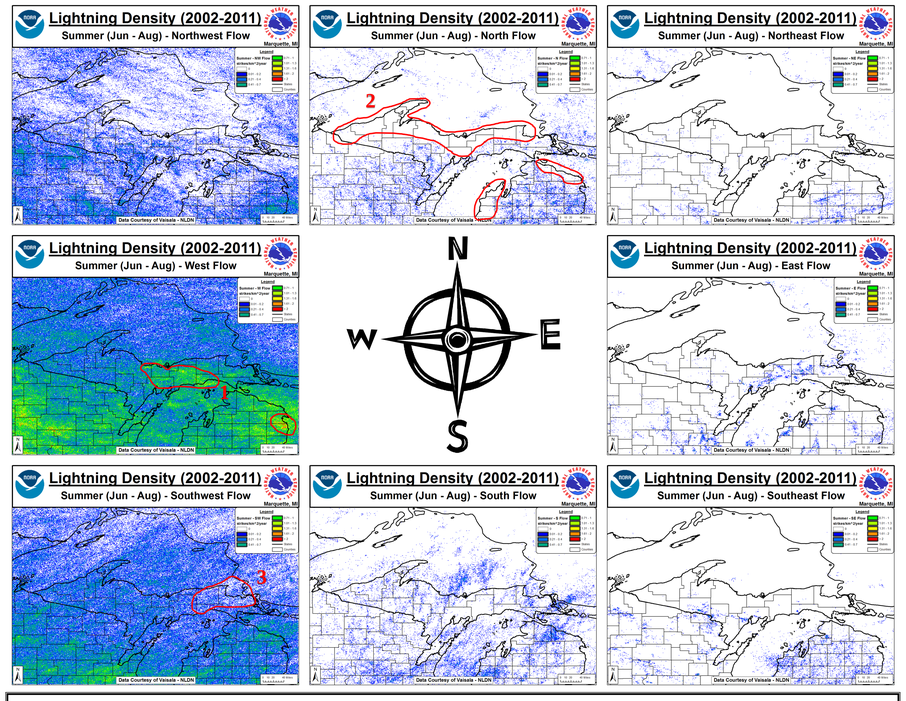
Summer
- Lake shadows remain (noted in red)
- Lake breeze circulation maximum (noted in purple)

Autumn
- Warm water temperatures have limited influence on convective activity

Winter
- Eastern Lake Superior: Lake Effect Snow Bands in 12/05



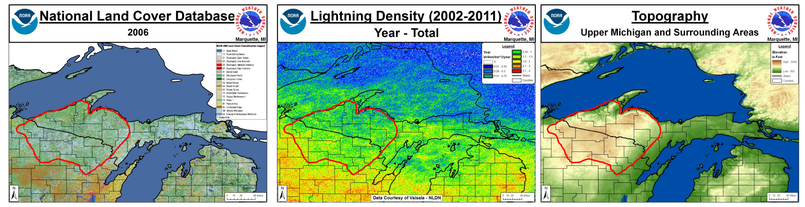
Summer 700 hPa Flow Climatology



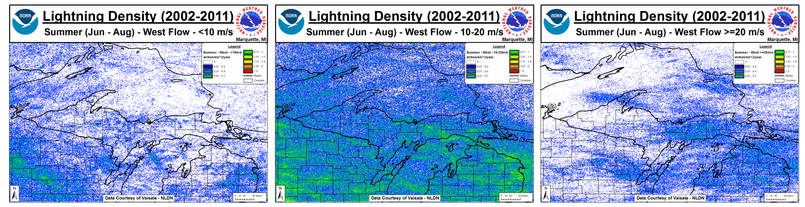
1. Highest concentration of elevated lightning density occurs over east central Upper Michigan.
   - Produced by the westerly flow providing more time to become convectively unstable and interact with afternoon Lake Breezes. Similar influences can be seen on the east and southeast flows.
2. Lake Superior shadow over northern Upper Michigan
   - North flow generally provides a more convectively stable atmosphere and when it flows across the cooler Lake Superior temperatures, it casts a large shadow over much of Upper Michigan.
   - Can also be seen off Lake Michigan and Lake Huron in northern Lower Michigan.
3. Southwest flow off Lake Michigan produces a shadow over Luce and Chippewa Counties
   - Can you find any other Lake Shadows?

Terrain and Land Use

Lightning void is highlighted in red. This can be attributed to a combination of features:
- Terrain: Limits inland push of lake breezes and also provides a slightly cooler environment
- Land Use / Soil Type: Transition from crops to more of a coniferous forest limits length/intensity of convective development (J.O. Adegoke et al, 2007)



Summer West Flow – Speed



< 10 m/s
- 16.7% of Summer west flow lightning flashes
  - Blotchy appearance due to limited storm motion

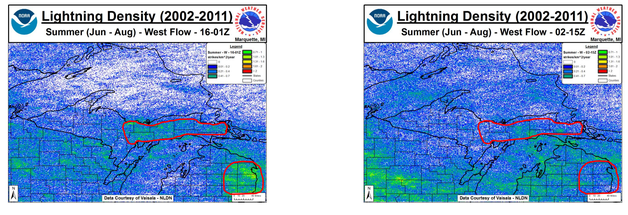
10-20 m/s
- 68.8% of Summer west flow lightning flashes

> 20 m/s
- 14.5% of Summer west flow lightning flashes
  - Events dominated by bow echoes

Summer West Flow – Day vs. Night

Day
- Likely confirms that lake breezes (and the convergence of) across eastern Upper Michigan allows for increased thunderstorm probabilities during the Afternoon hours
  - Higher CAPE, less ambient air from the cooler Great Lakes

Night
- Fairly uniform across the region
  - Still higher locations over Western Lake Superior
  - Also, maximum over eastern Upper Michigan, due to lingering thunderstorms from afternoon heating.



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* GLSEA: Great Lakes Surface Environmental Analysis