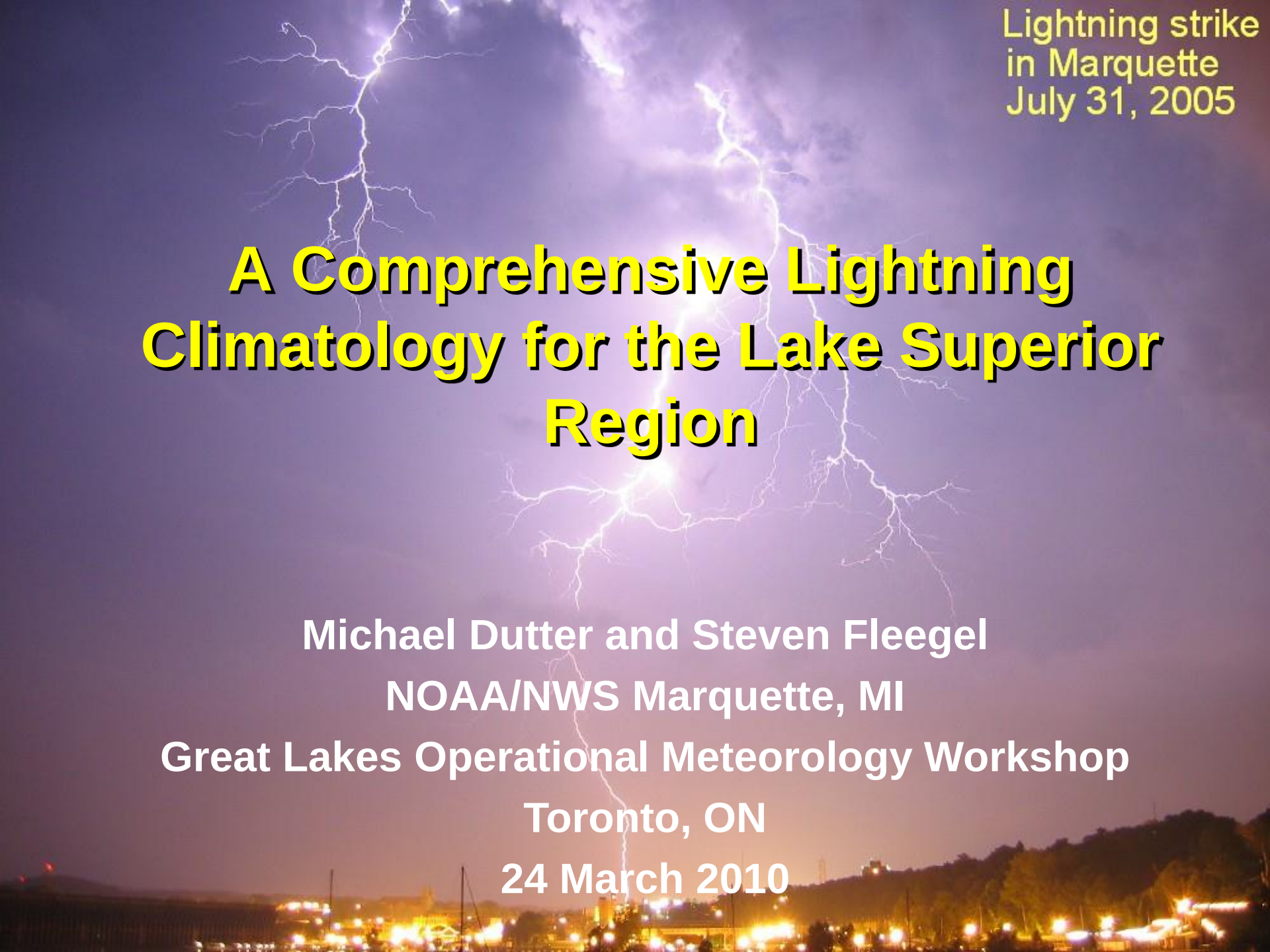


A Comprehensive Lightning Climatology for the Lake Superior Region

Michael Dutter and Steven Fleegel

NOAA/NWS Marquette, MI

Great Lakes Operational Meteorology Workshop

Toronto, ON

24 March 2010

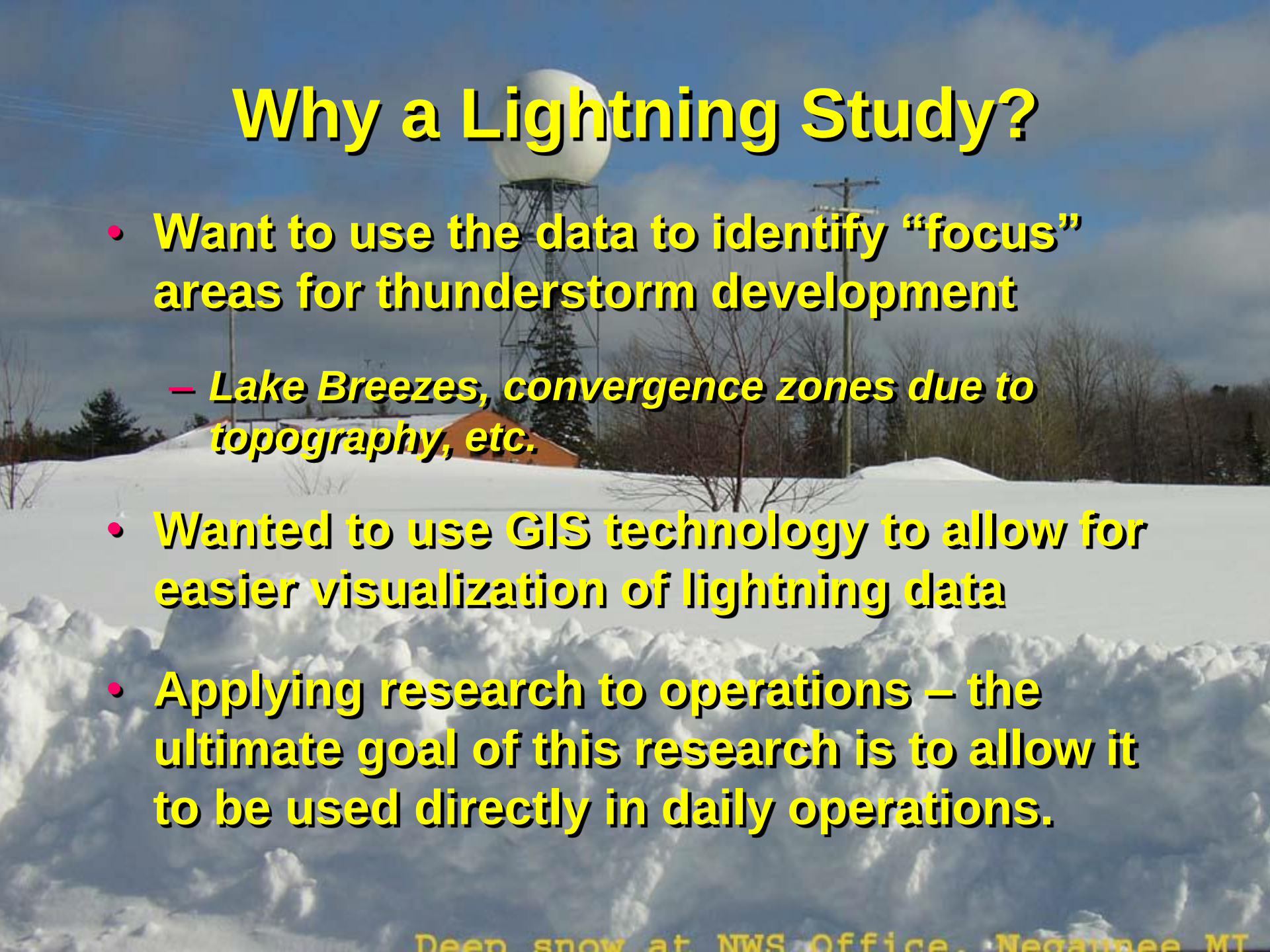
Why a Lightning Study?

- Let's face it, the northern Lakes are known for their snow storms…much more than thunderstorms and vigorous lighting. However, due to the numerous outdoor activities, thunderstorm and CG lightning detection/prediction is also very important.
  - *However, not a great amount of research on CG lightning climatology in the Great Lakes Region*
    - Cook et al. conducted a CG lightning climatology for the Upper MS valley, which included the western lakes.
- Wanted to take the "traditional" lightning climatology one step further and create "flow regime" lightning climatology for the 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.

Ice ridge just offshore on Lake Superior

Why a Lightning Study?

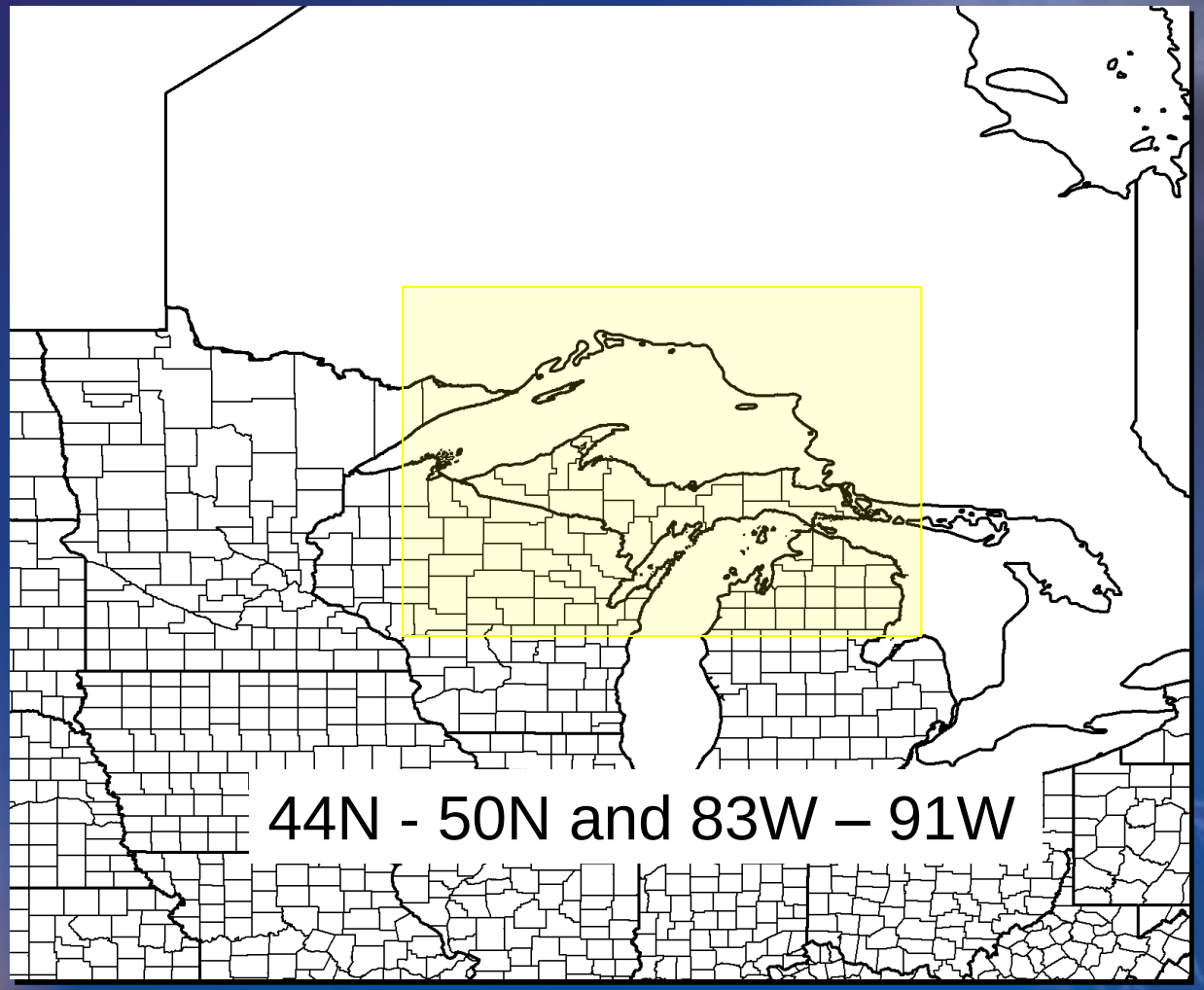
- Want to use the data to identify “focus” areas for thunderstorm development
  - *Lake Breezes, convergence zones due to topography, etc.*
- Wanted to use GIS technology to allow for easier visualization of lightning data
- Applying research to operations – the ultimate goal of this research is to allow it to be used directly in daily operations.



Outline

- **Methodology and Data**
  - *Quick refresher on the NLDN*
  - *How we conducted the research*
- **Results**
  - *Traditional CG Lightning Climatology*
  - *"Flow based" CG Lighting Climatology*
- **Applications (i.e. Research to Operations)**

Study Area



More areas will be completed in the future to cover the entire Great Lakes Region.

The National Lightning Detection Network (NLDN) (Cummins et al. 1998)

- Real Time Operations of the NLDN Started in 1989
- 106 sensors across the United States
- Dataset includes flash time, location, polarity, strength and strokes (multiplicity)
  - *We are mainly concerned with flash time and location.*
  - *Stroke information may be used in the future*
- NLDN generally has a detection efficiency of ~30-85% across the study area and is accurate to with 0.5-1 km.
  - *Efficiency and accuracy decreases to the north and especially into Canada.*

Accuracy and Efficiency of the NLDN

Median Location Error (km) (from Cummins et al 1998)

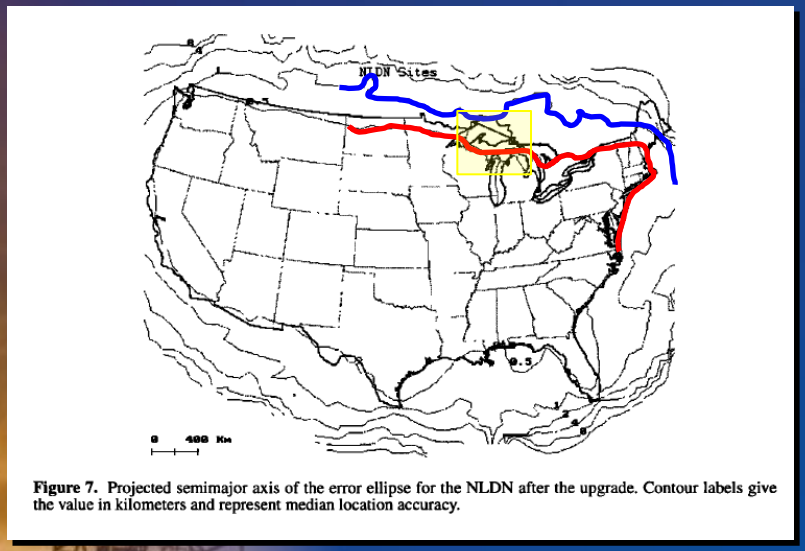


Figure 7. Projected semimajor axis of the error ellipse for the NLDN after the upgrade. Contour labels give the value in kilometers and represent median location accuracy.

Red = 0.5 km
Blue = 1.0 km

Flash Detection Efficiency (from Cummins et al. 1998)

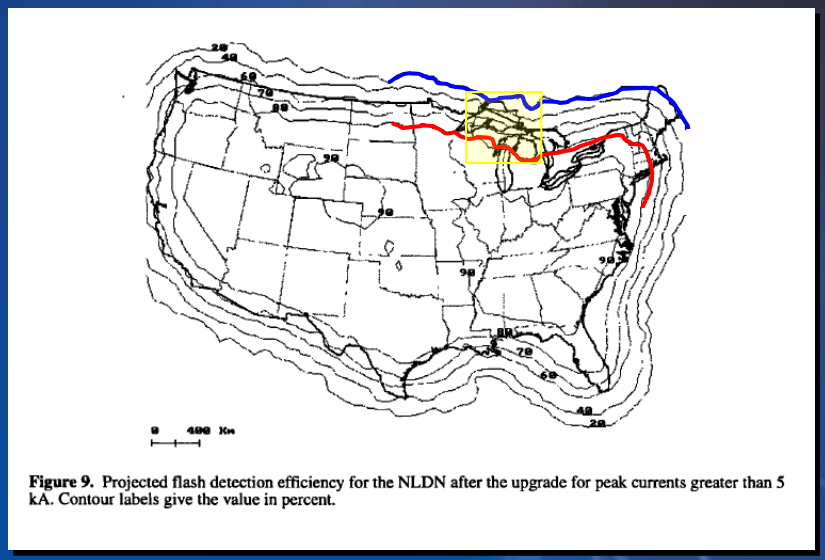


Figure 9. Projected flash detection efficiency for the NLDN after the upgrade for peak currents greater than 5 kA. Contour labels give the value in percent.

Red = 80%
Blue = 20%

Upgrade in 2003 likely helped improve some errors, especially on the fringes.

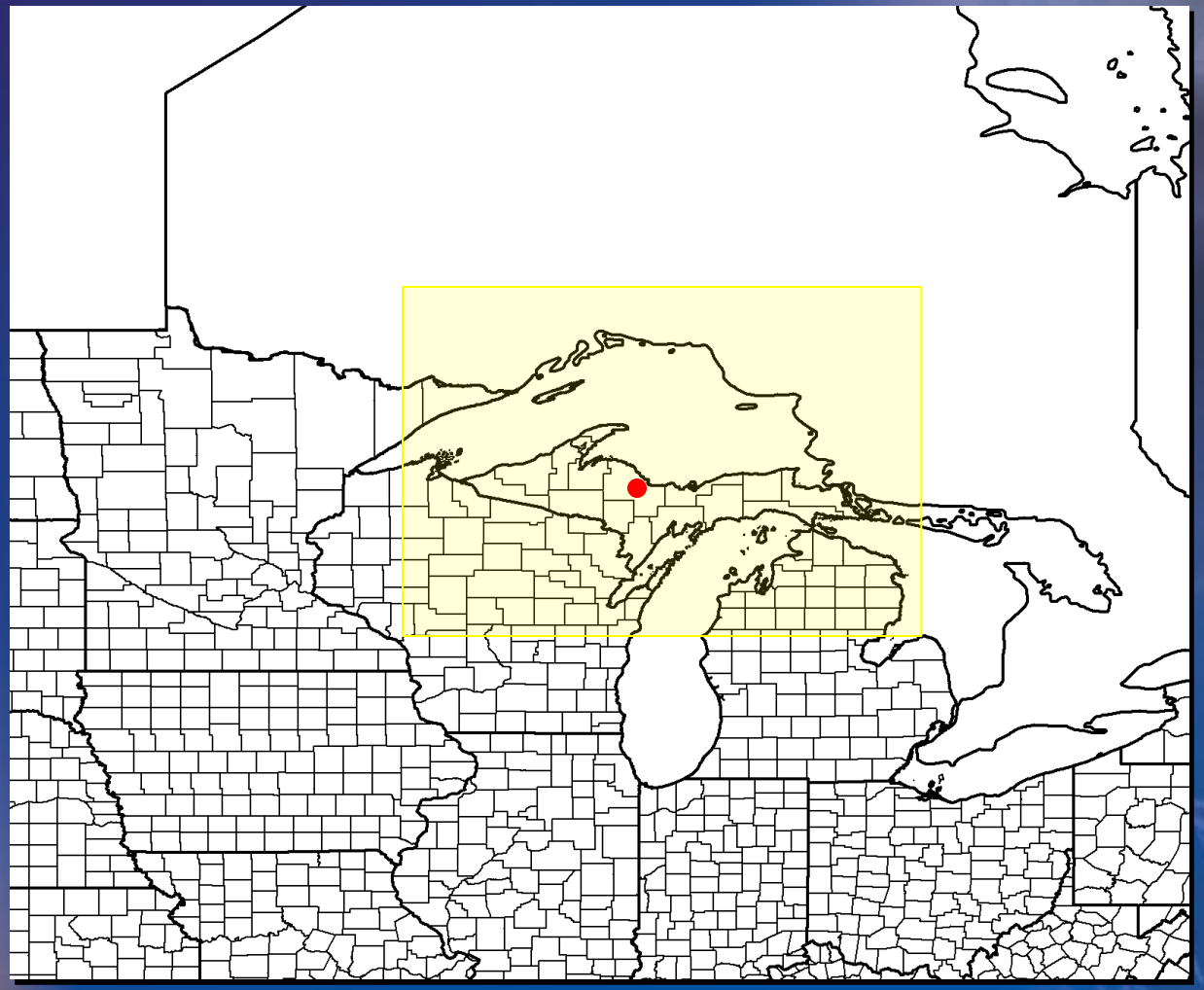
Methodology

1. Gathered complete regional lightning dataset from the NLDN from 2002-2008 (thanks to Visalia and Florida State).
   - *Made no corrections for accuracy or detection efficiency.*
2. Placed each lightning strike in a MySQL database
   - *28+ million entries -- Allows each lighting strike to have it's own set of "attributes"*
   - *Also allows for easy access to data*

Methodology

3. Using the North American Regional Reanalysis (NARR) (Mesinger et. al, 2006) , meteorological data was “assigned” to each lightning strike in the study area.
   - *700 hPA wind was used as a proxy for mean flow*
   - *Data point near Marquette, MI was used as the representative point for our study.*
4. Using ArcGIS, high resolution 1km^2 lightning density plots were developed for the region using the database.

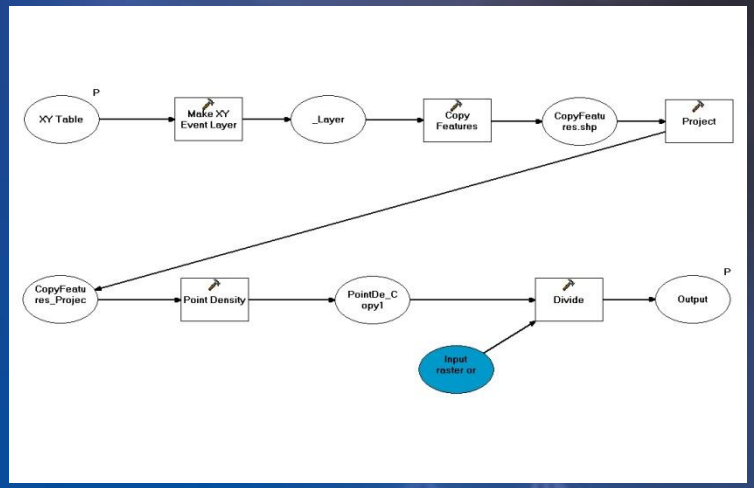
Study Area



NARR Data Point used for 700 hPA wind data

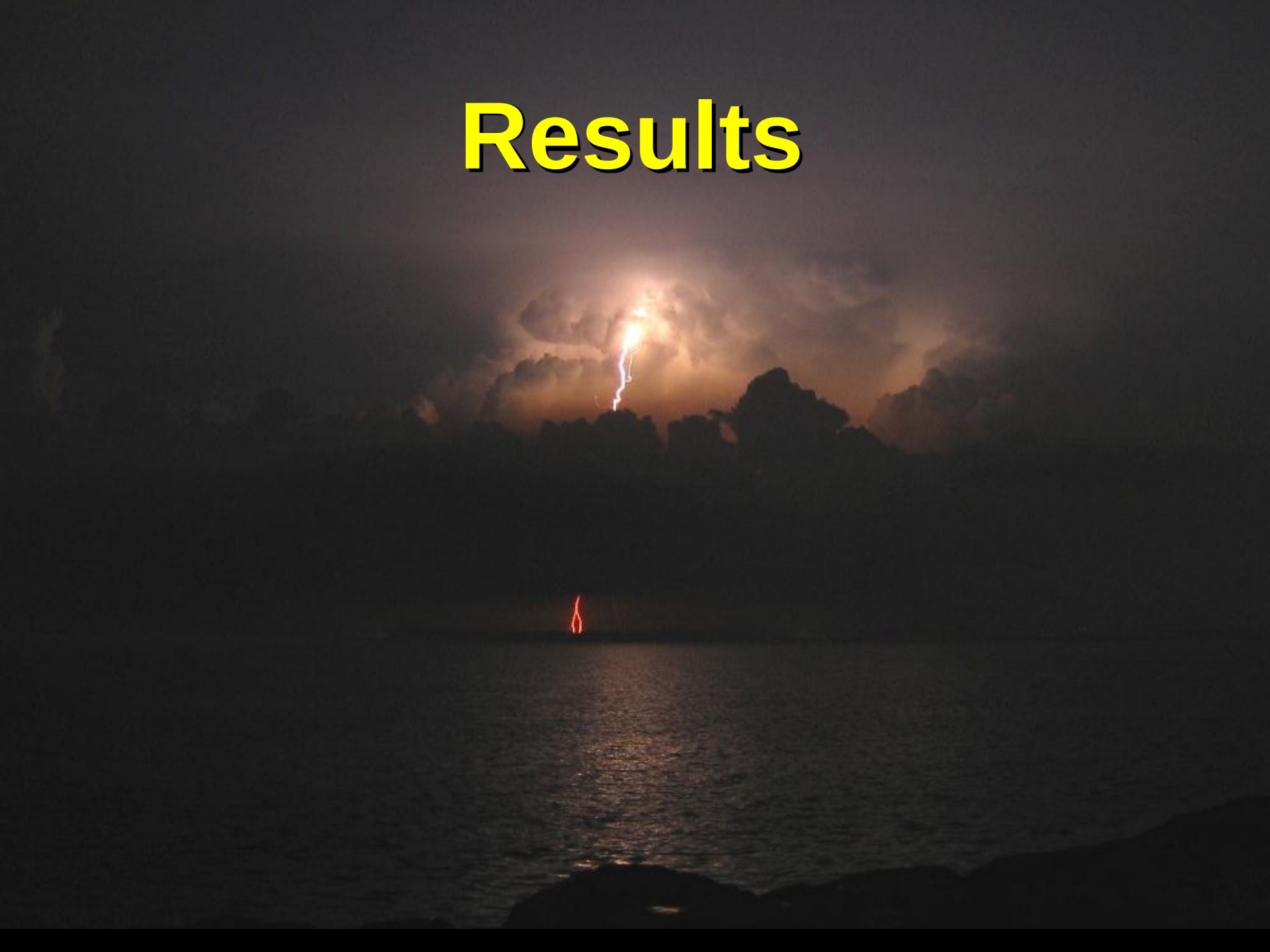
A little more about using ArcGIS in this project

- Exported CSV files from MySQL database
- Created a Toolbox/Model , which allowed the redundant processes to be scripted
  - *Imported Data to shapefile*
  - *Converted Projection from NAD83 to UTM16N*
  - *Point Density*
    - 1km by 1km grid
    - Only looked at the 1 sq. km grid to create density raster
  - *Raster Divide (by # of years)*
- Generated Point Density Raster datasets
- Created uniform layout to display the rasters

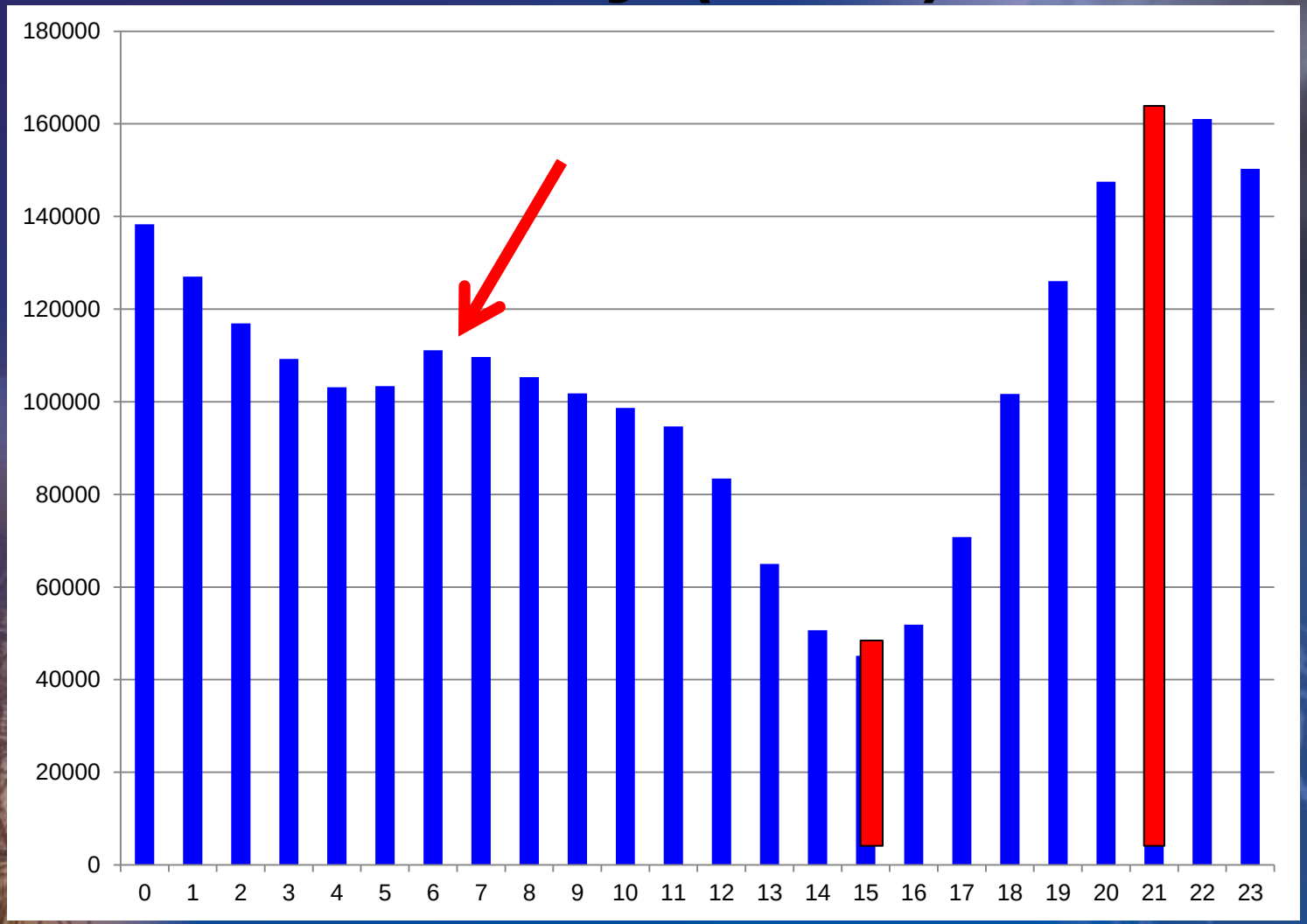


ArcGIS Modelbuilder

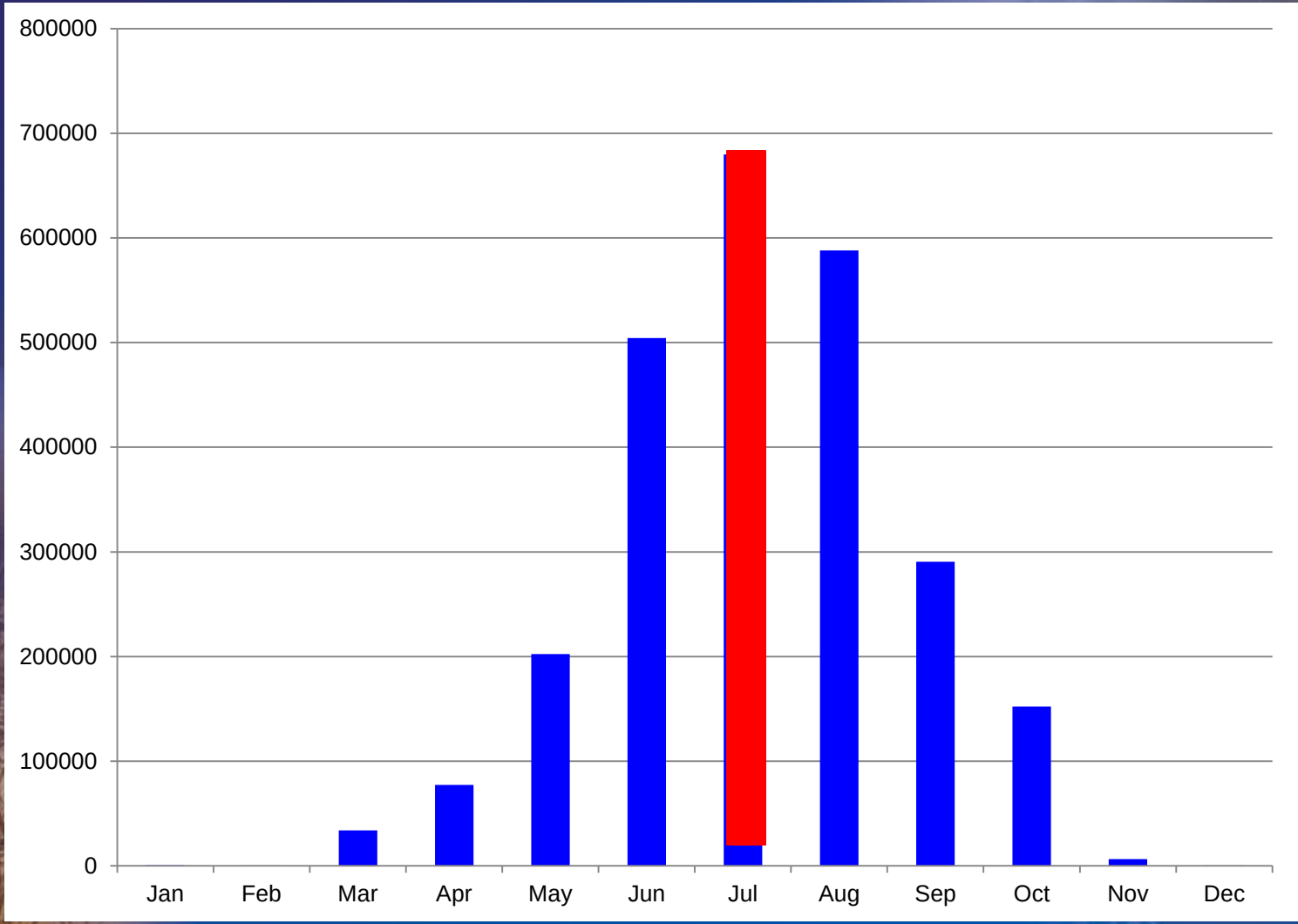
Results



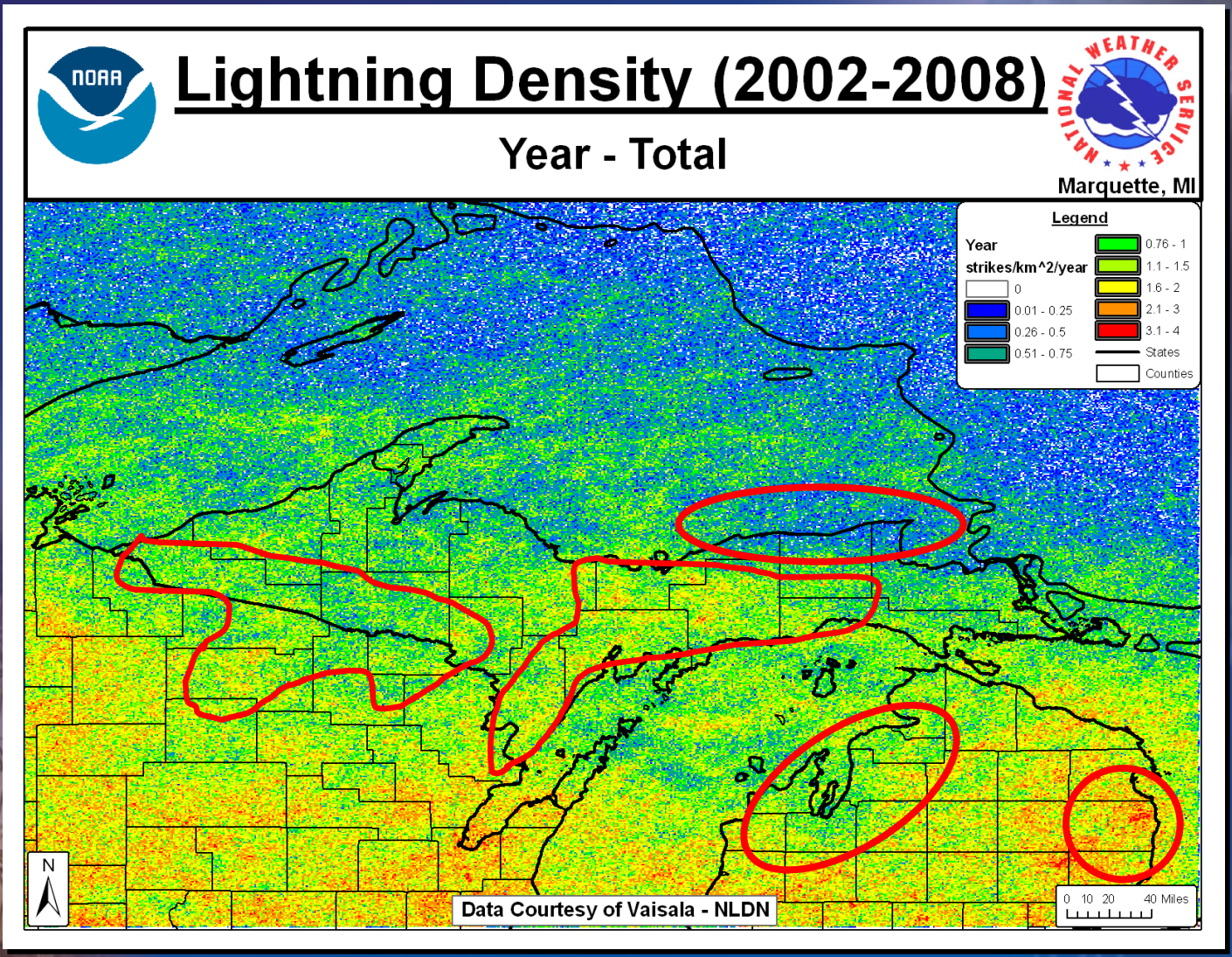
CG Lightning Strikes By Hour of Day (GMT)



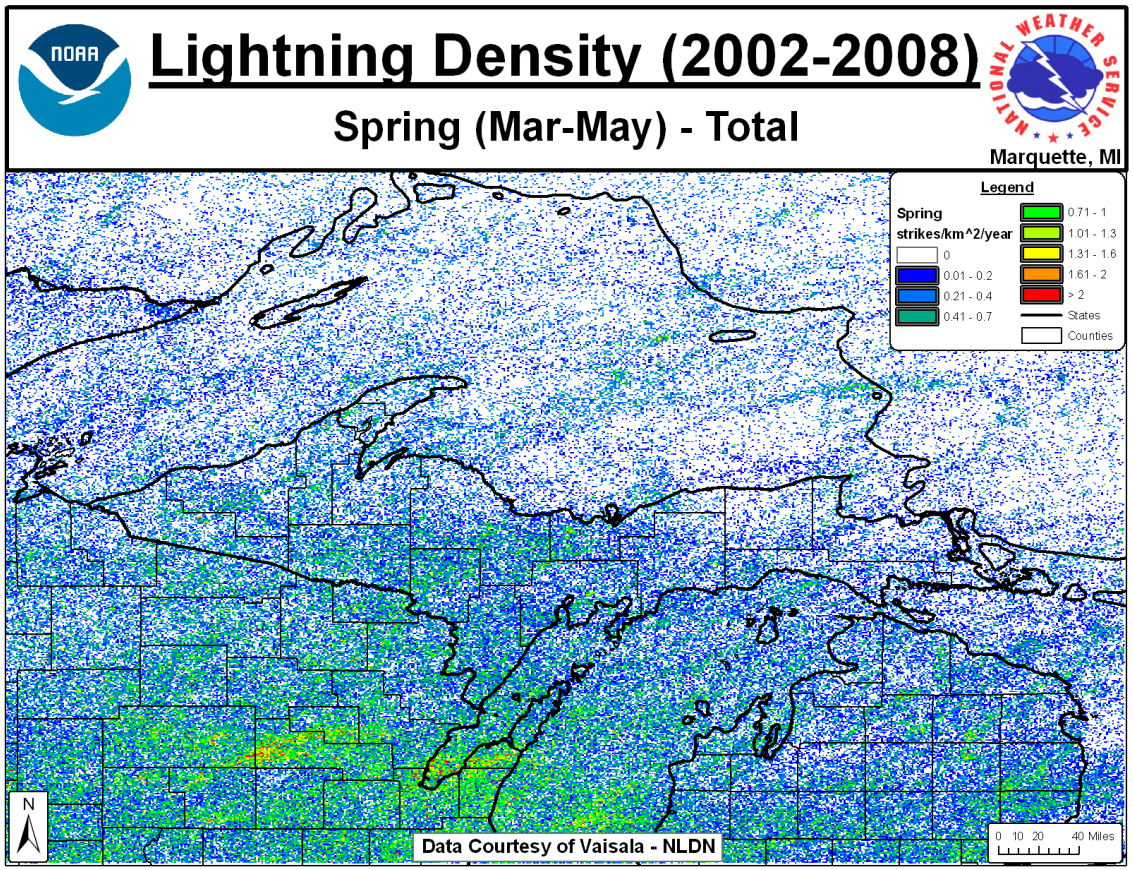
Lightning Strikes by Month



Yearly Lightning Density

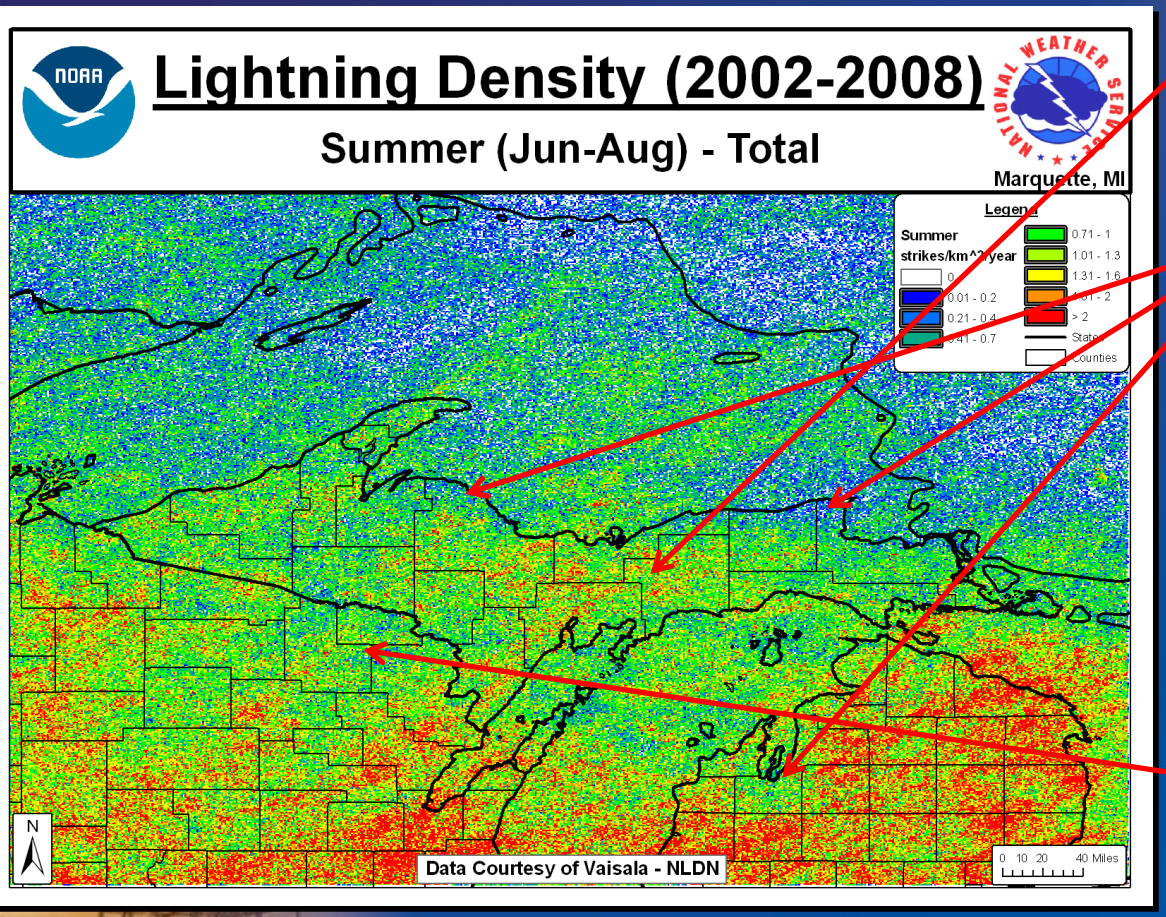


Spring Lighting Density



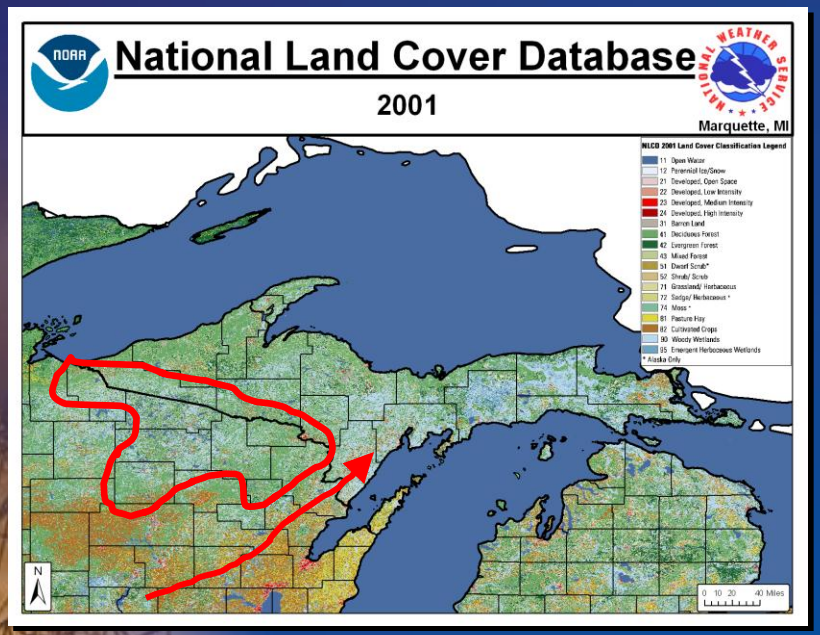
- Note the lack of significant organization over the lake
- Highest density across the south.
- Hints of “organized”, single cell convection
  - *Much lower likelihood of MCS type activity*

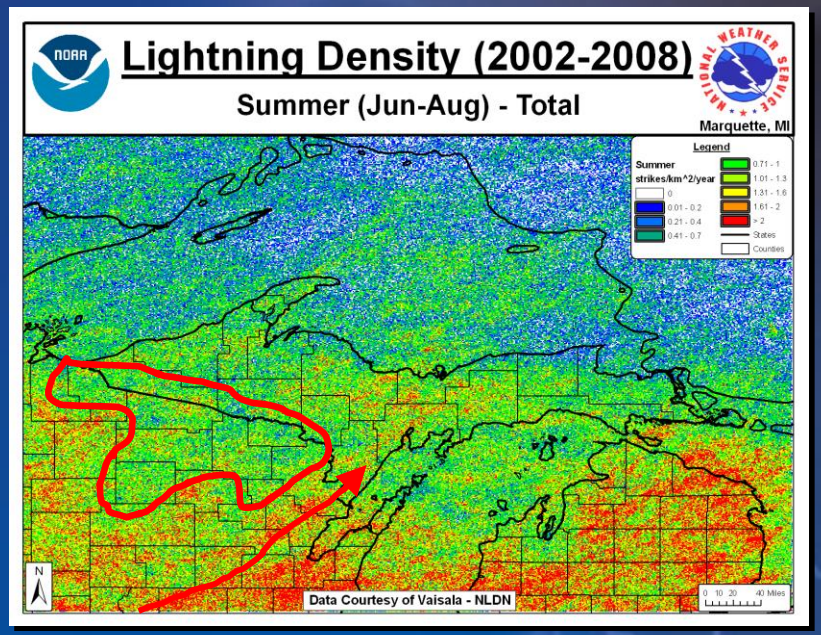
Summer Lighting Density



- Lake Breeze "maximum" is seen.
  - *As are "lake shadows"*
- Highest density remains across Central WI and into Northern Lower MI
- What about this minimum in lightning over NC WI and SW Upper MI?

Is land use important in modulating thunderstorm/CG lightning?

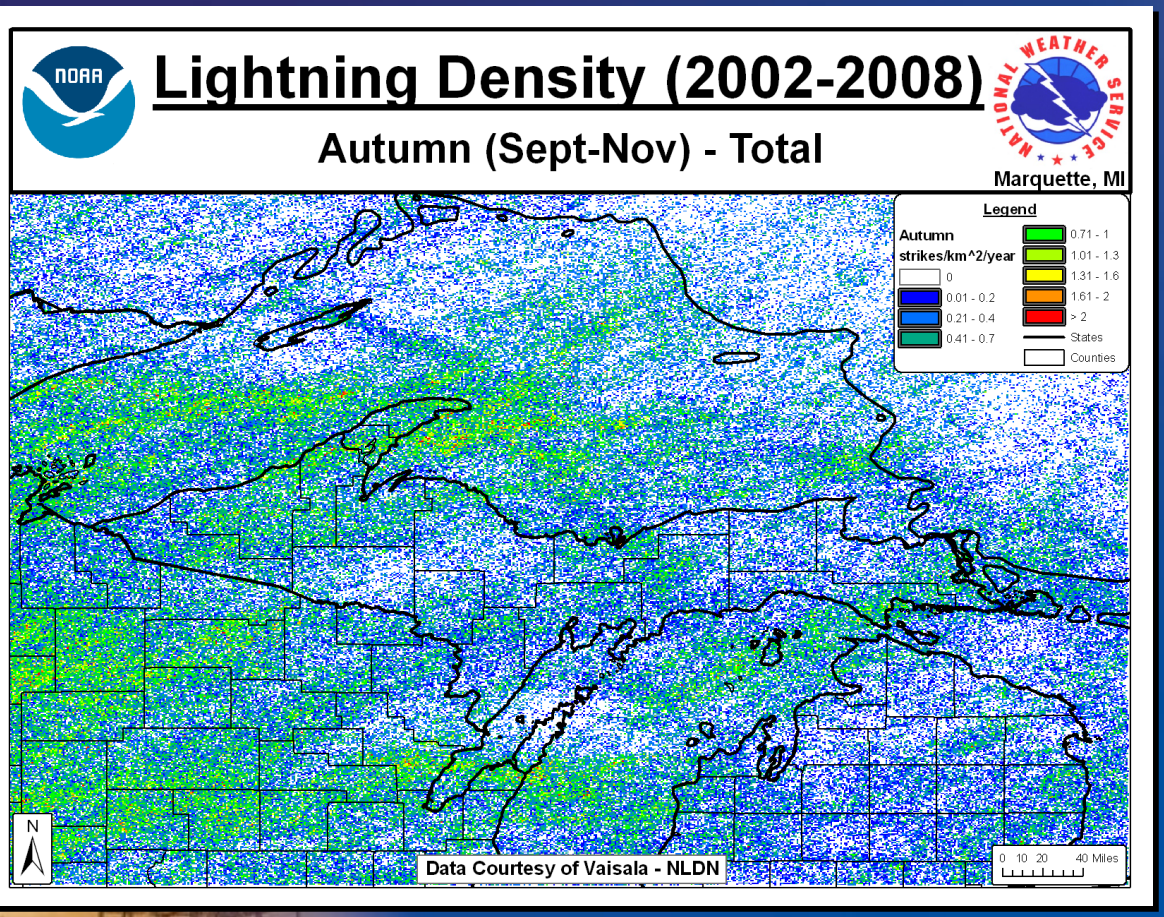




Green = Forested Area
Blue = Wetlands
Brown = Agriculture

Is the forested and/or wetland area causing the minima in lighting (compared to agricultural areas?

Autumn Lighting Density

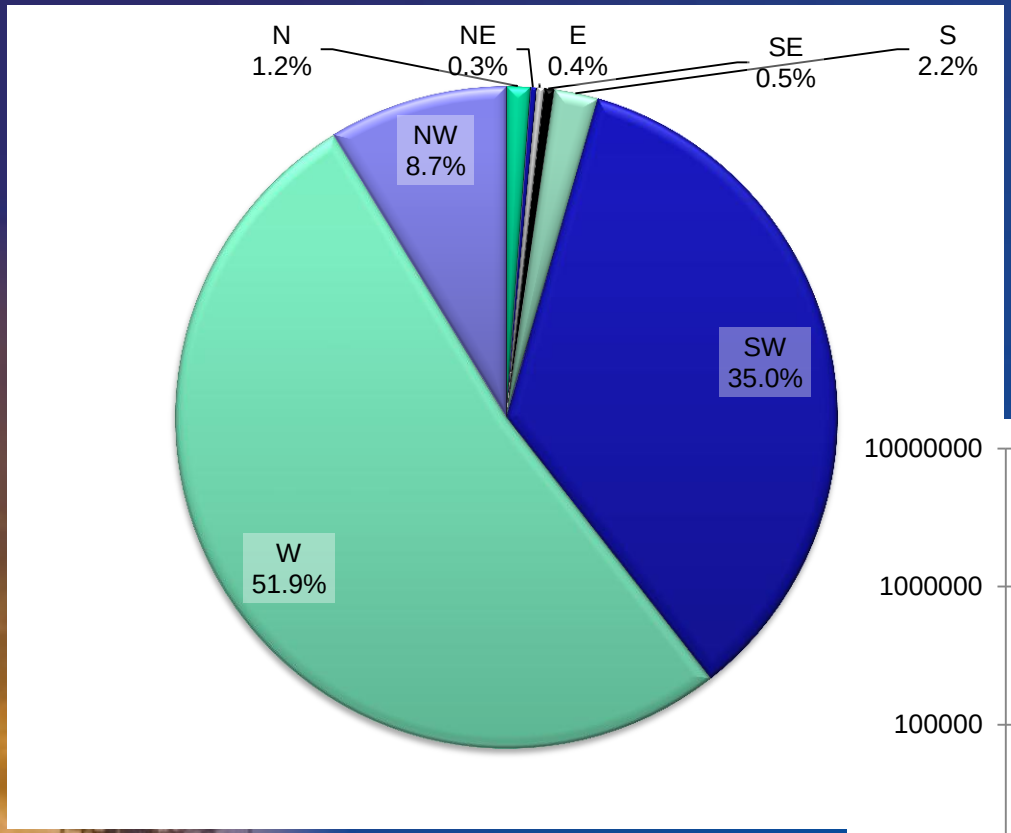


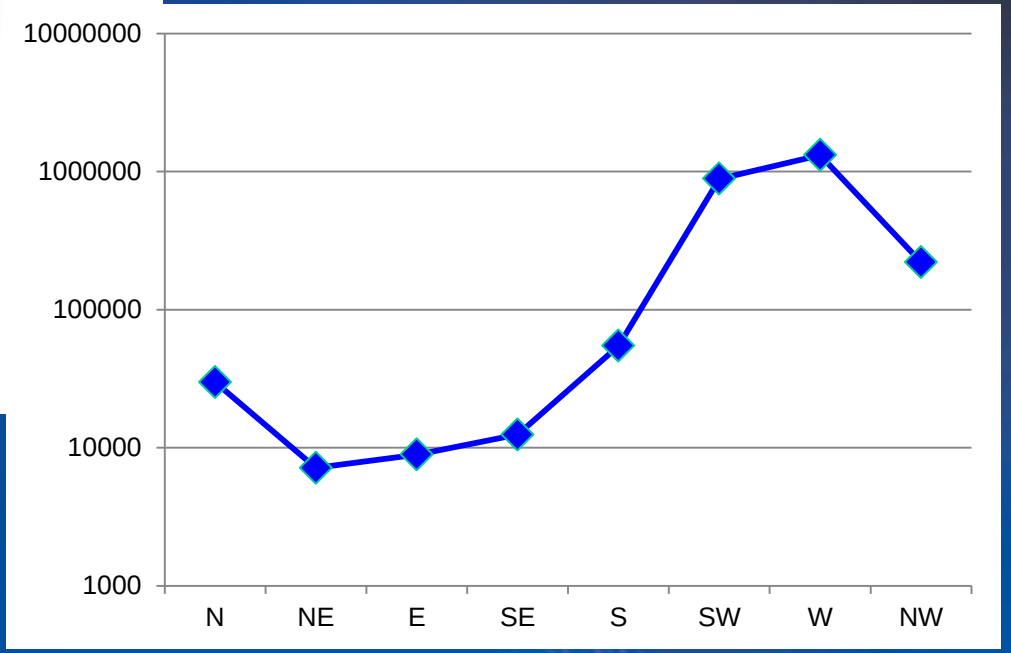
- **Highest concentration of activity is over western Lake Superior, Lake Michigan and northern WI.**
  - ***Thunderstorms are more dynamic this time of year – and lakes are at their warmest in Sept.***

Flow regime strike climatology

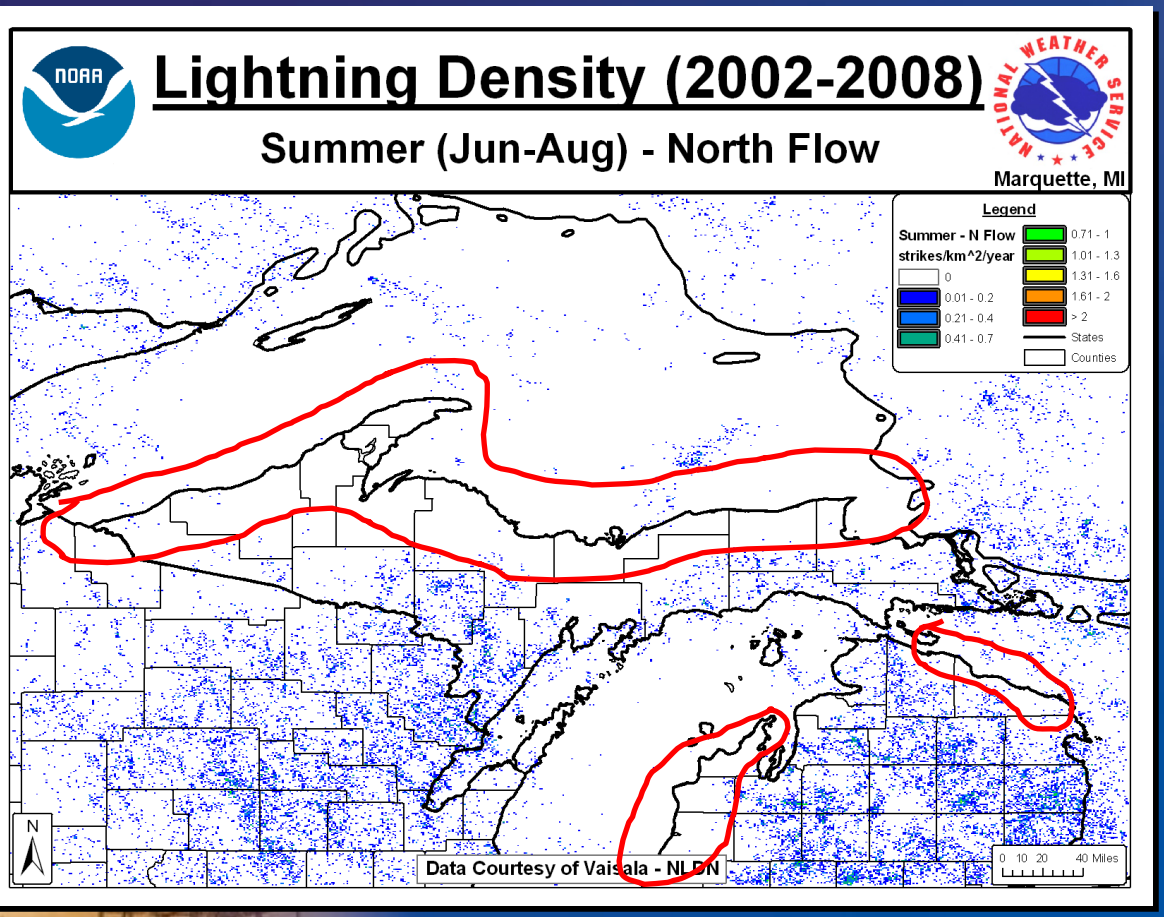
- Can hopefully identify where thunderstorm activity is maximized (and minimized) given a flow regime.
- Information can be used to help daily forecasts, especially in the gridded era.
- Will focus on the summer months since the majority of lightning strikes in this region comes during the summer.

Total Lightning Strikes by Wind Direction



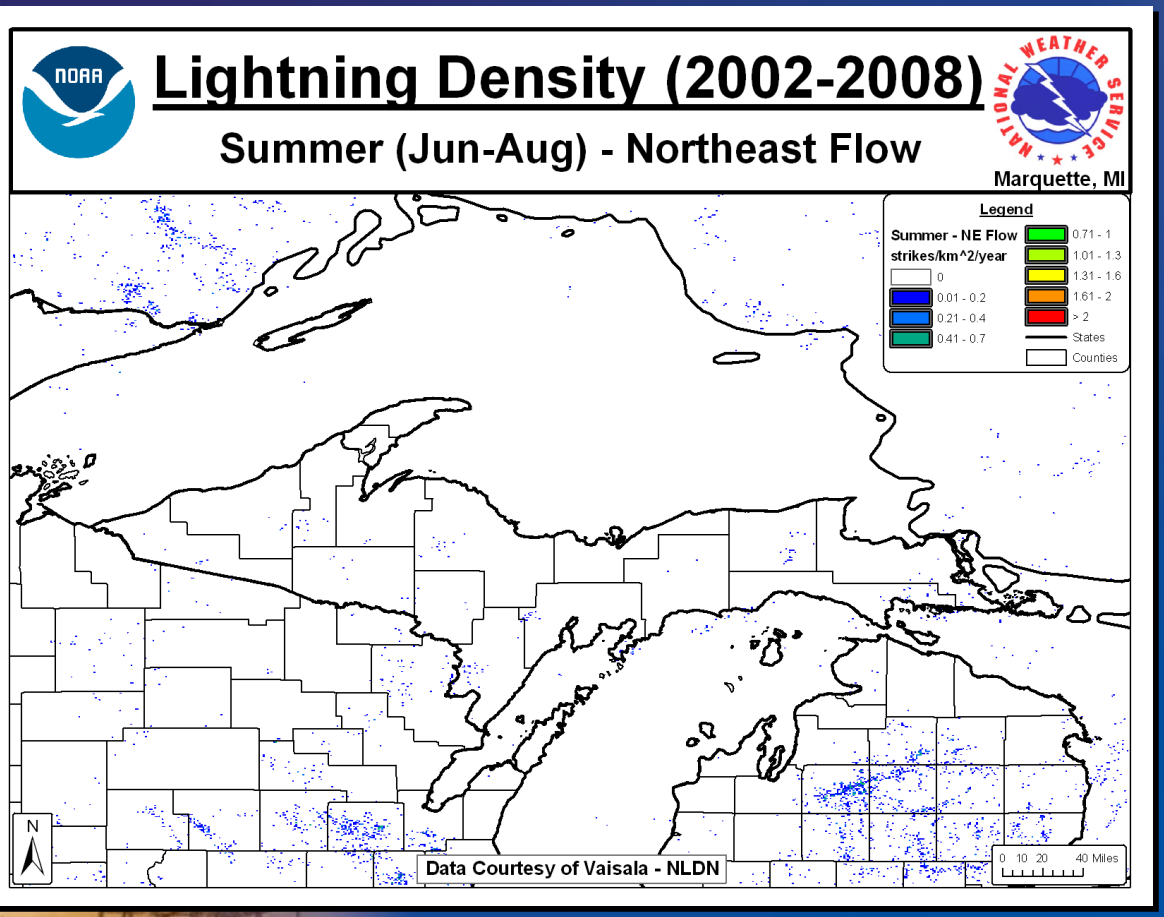


Summer North Flow Lighting Density

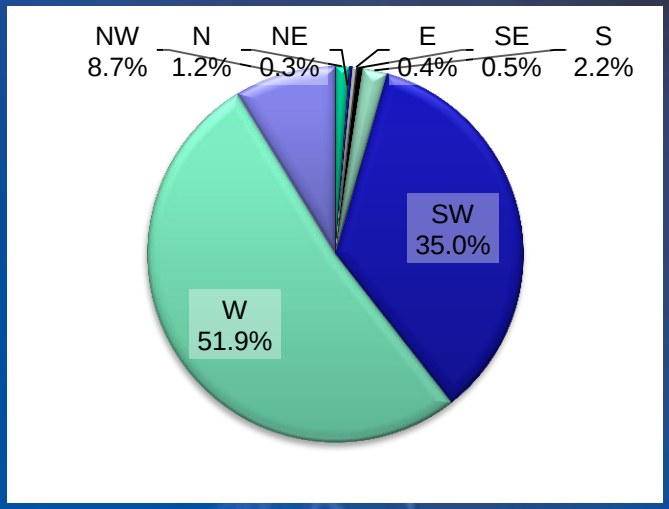


- Little if any activity along the Michigan downwind shoreline of Great Lakes
- Diurnally driven afternoon and early evening storms.

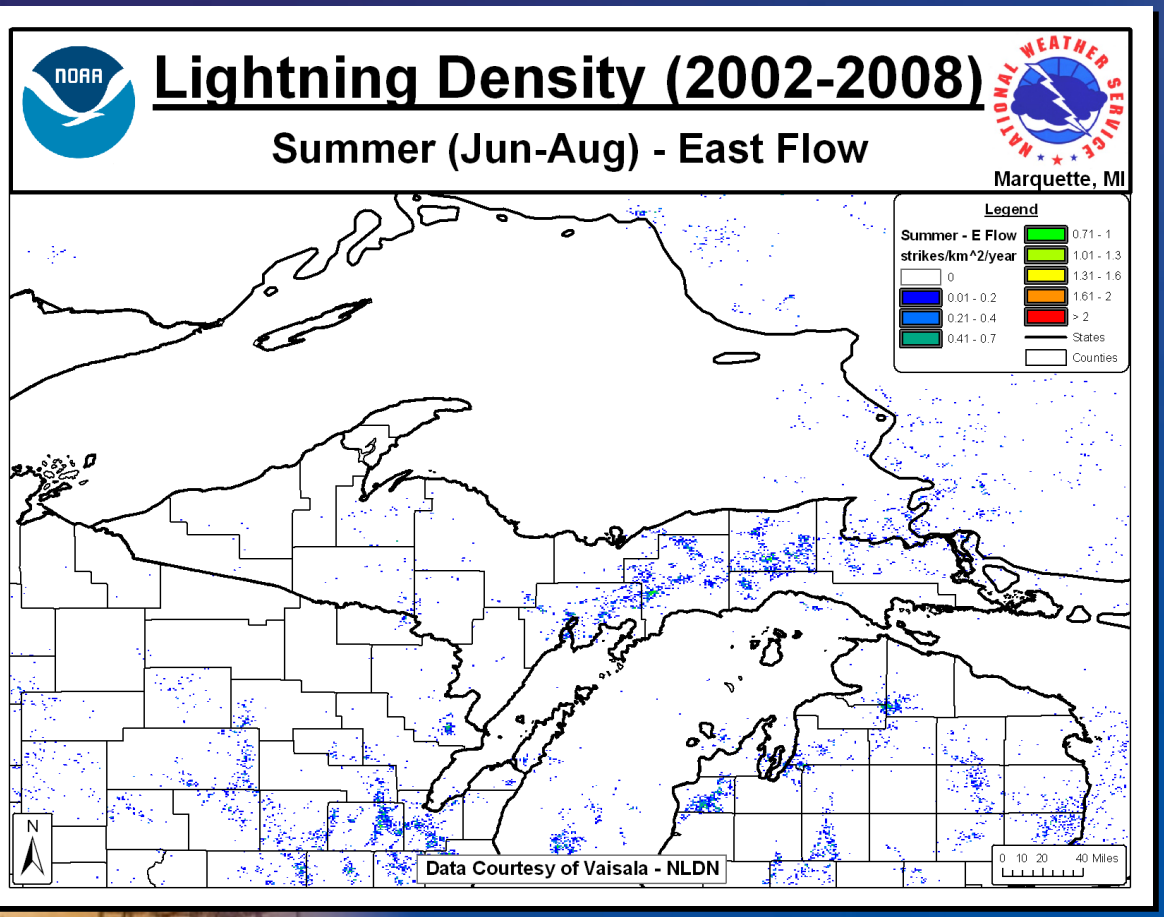
Summer Northeast Flow Lighting Density



- Least CG lightning strike activity of any wind direction

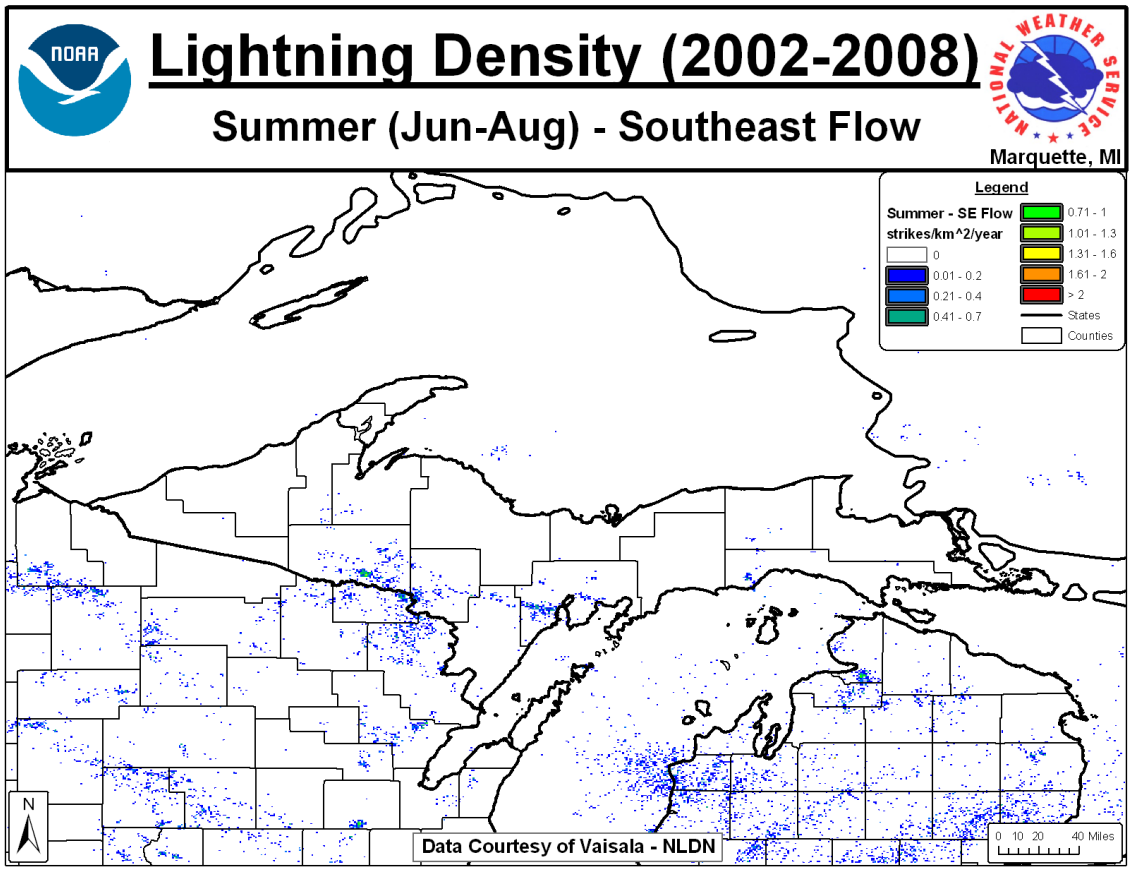


Summer East Flow Lighting Density



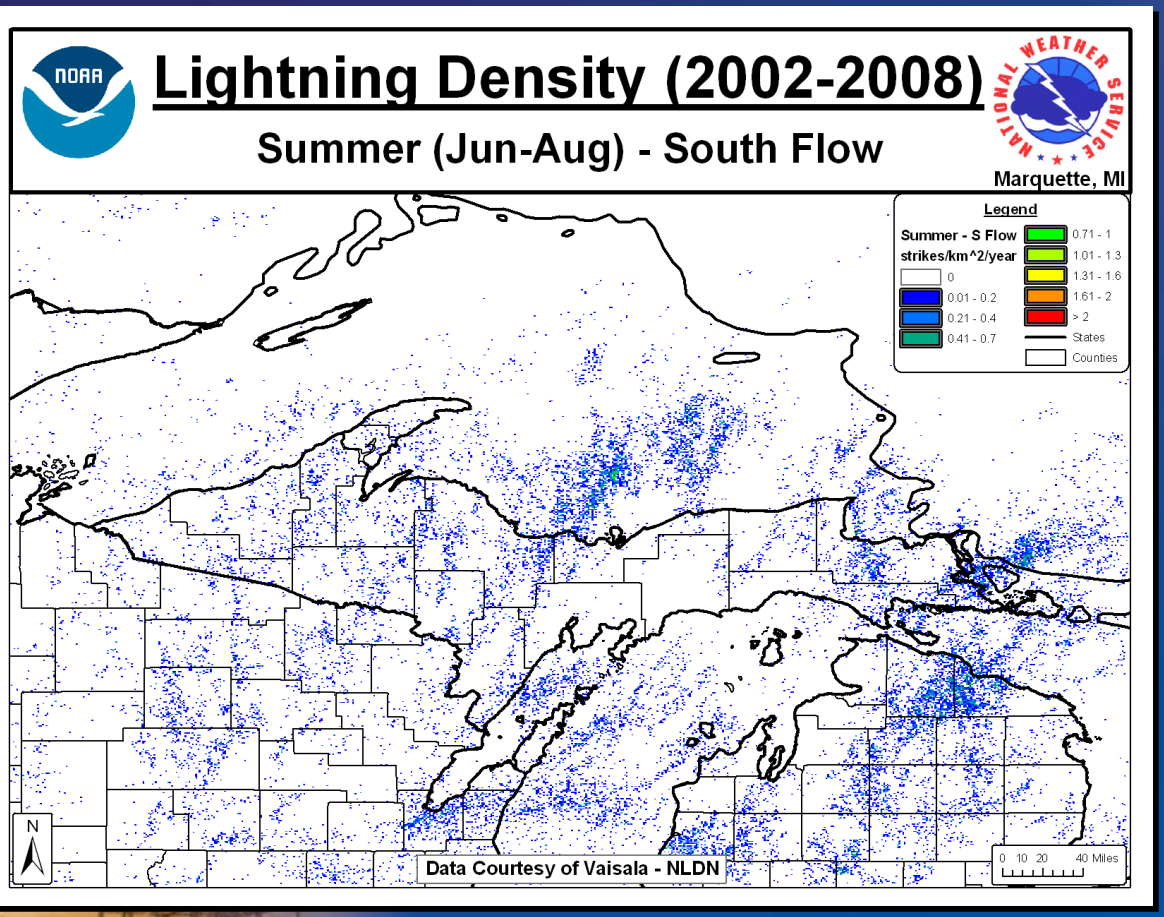
- Tough to get thunderstorm activity in east flow as well
- Relative maximum over the eastern U.P. are from numerous events.

Summer Southeast Flow Lighting Density



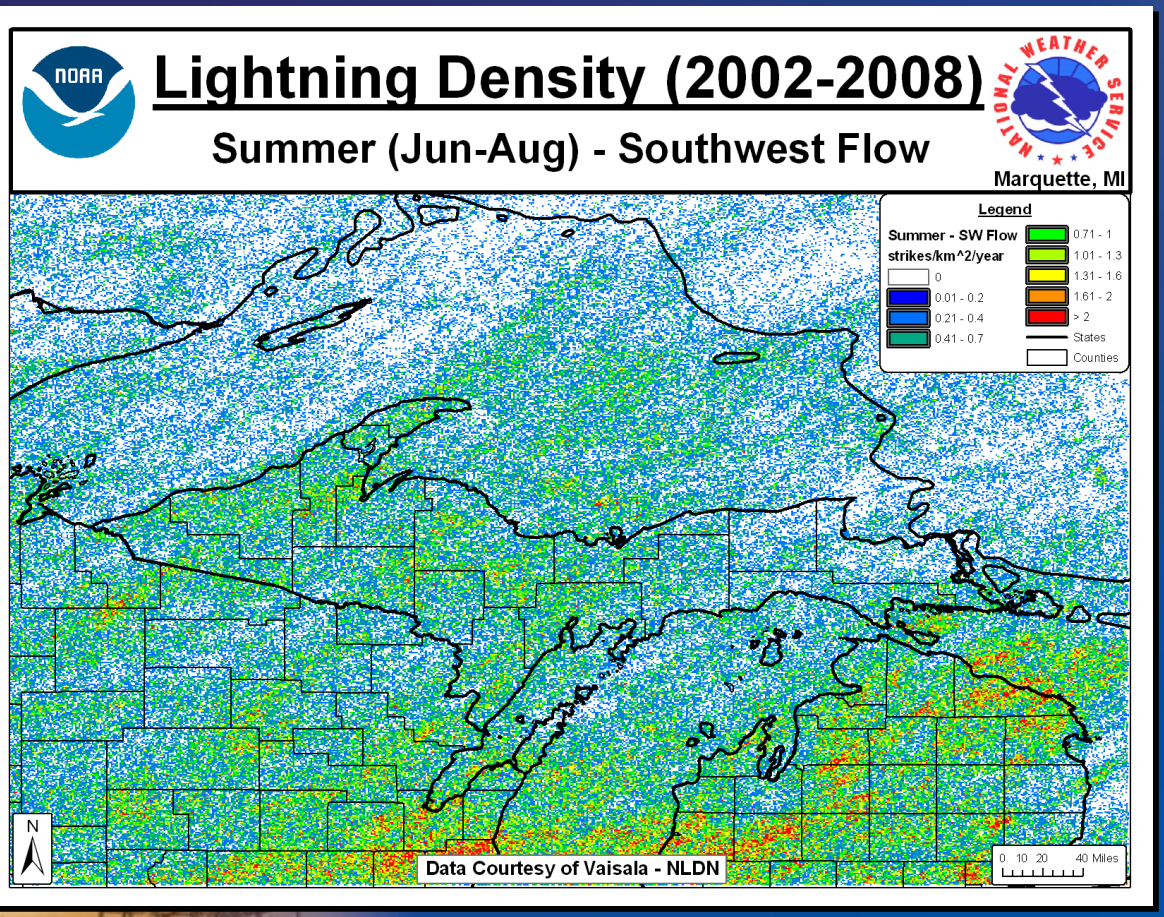
- Unlike east flow, the southeast flow showed a void in lightning activity in the eastern U.P.

Summer South Flow Lighting Density



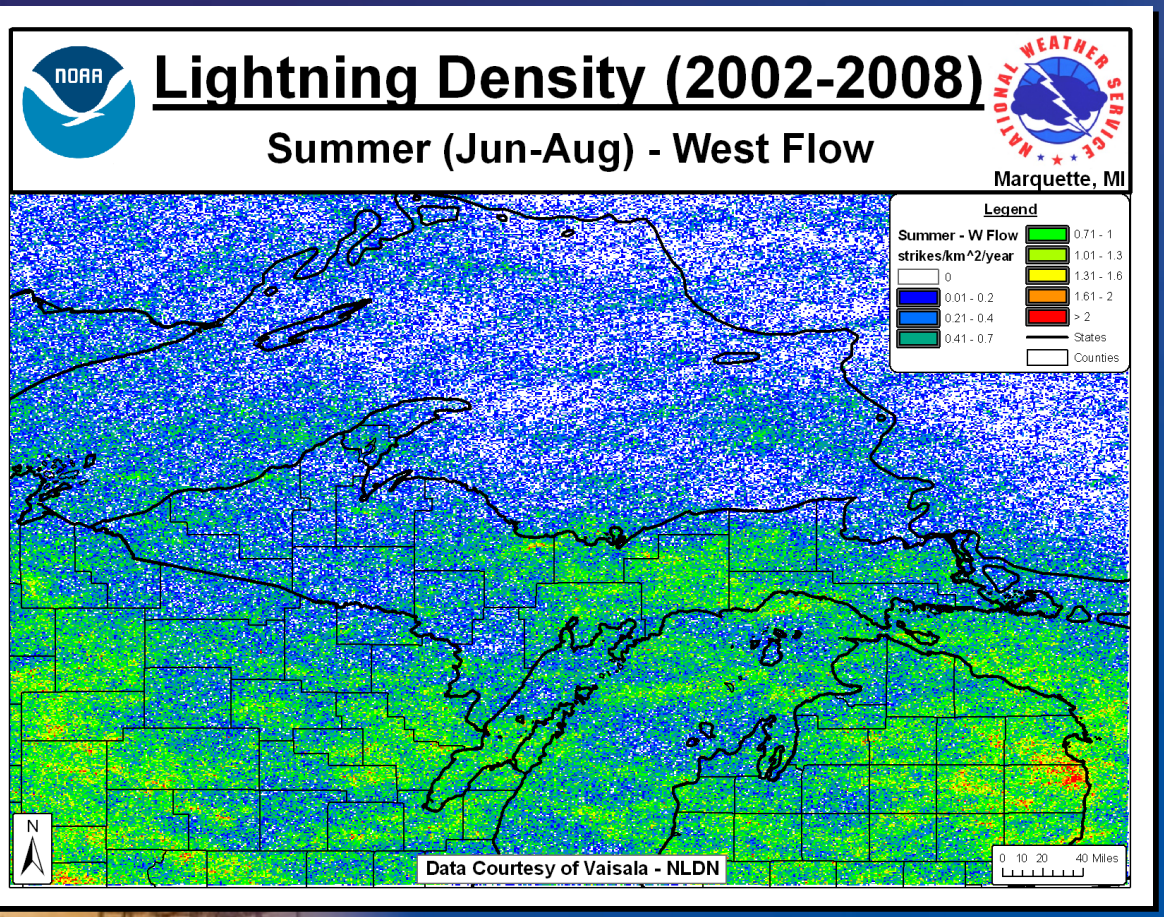
- Surprising that more is not seen in south flow.
- May be just be too dry and stable.
  - *"Return flow" just starting*

Summer Southwest Flow Lighting Density



- Void of activity noted across eastern Upper MI
- Higher activity across northern Lower MI
- "Single cell" look of lightning. Can pick out individual tracks.

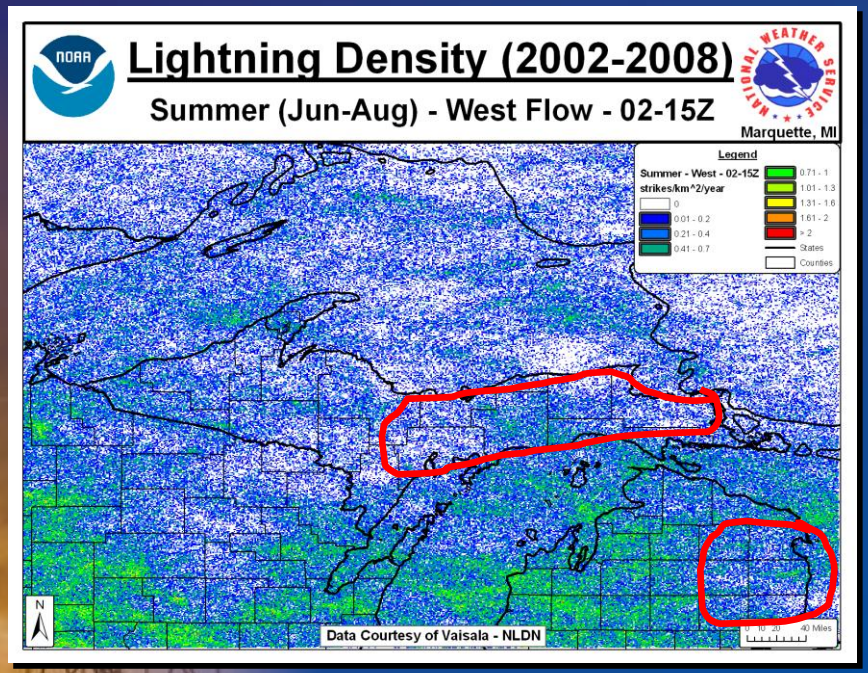
Summer West Flow Lighting Density



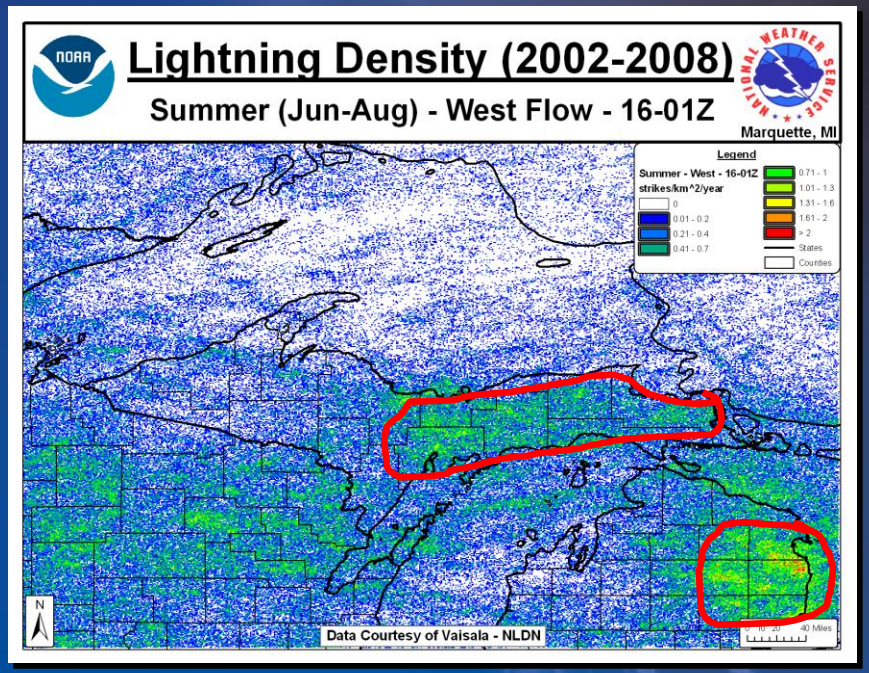
- Density much more consistent across the entire region.
  - *Perhaps due to more MCS activity.*
- Minimum across western upper MI and northern WI
- Relative max in lake breeze circulation region of eastern Upper MI.

Summer West Flow

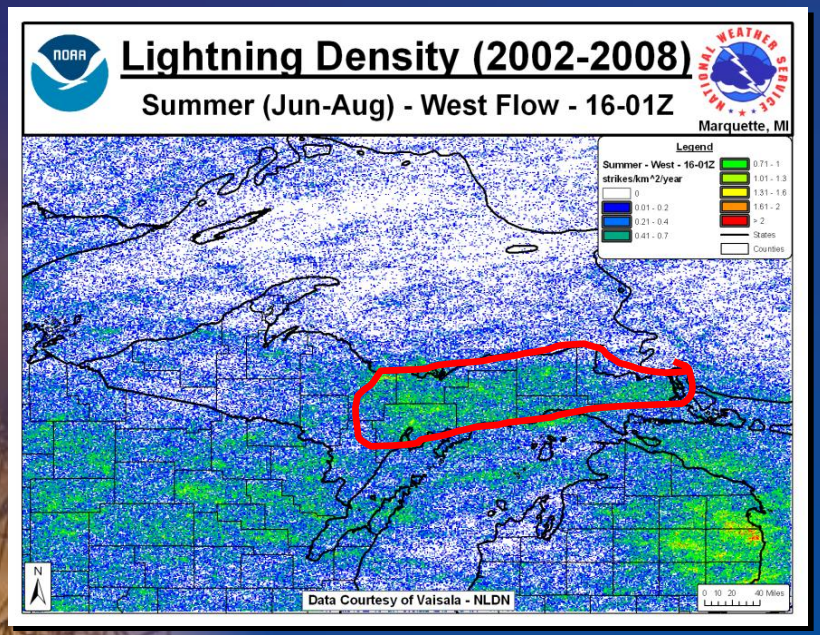
Night (02z-15z)



Day (16z-01z)

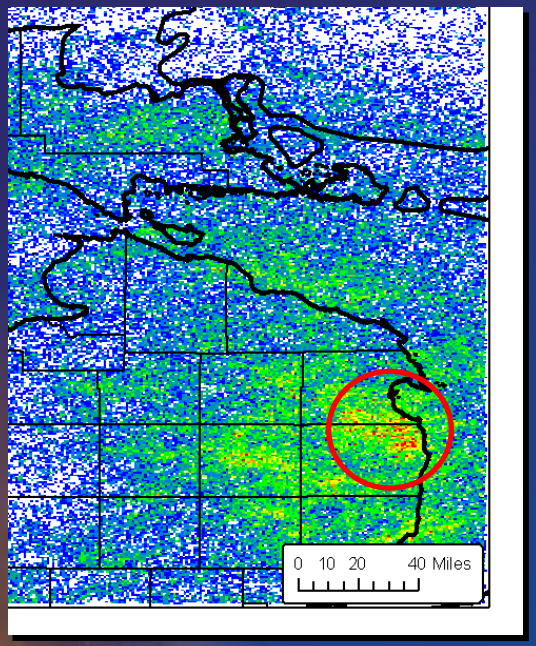


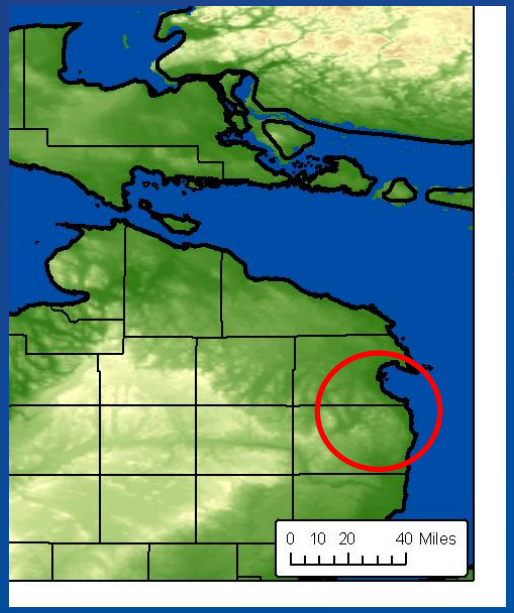
Summer West Flow and Lake Breezes



- Likely confirms that lake breezes (and the convergence of) across the eastern U.P. allows for increased thunderstorm probabilities
  - *Higher CAPE, less ambient air from the cooler Great Lakes*
- Numerous studies (Sills et. al 1994, King et al. 1999, and others) have studied the mergers of lake breezes across the southern Lakes.
- Finding will likely spawn additional research into this feature.

Summer West Flow and Lake Breezes

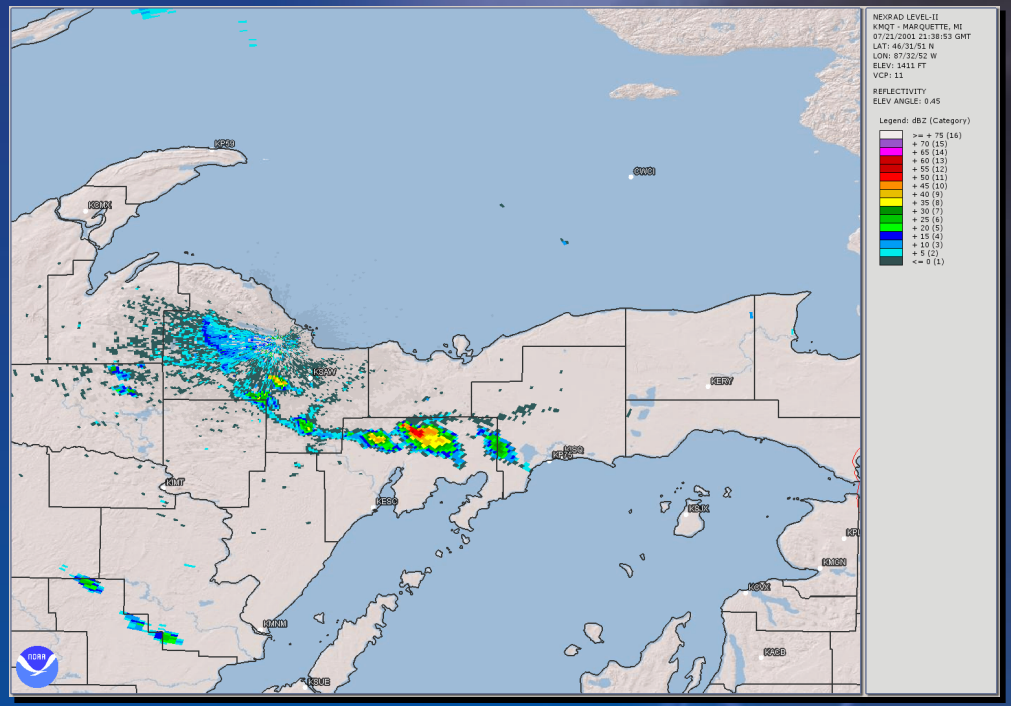




- Maximum over far northeast Lower MI is likely due to stronger lake breeze circulation in the westerly synoptic flow (as seen in Arritt 1993) and convergence of the lake breezes from Thunder Bay to the north and Lake Huron to the east.
- This area is also a region relative high terrain helping to enhance updraft strength.

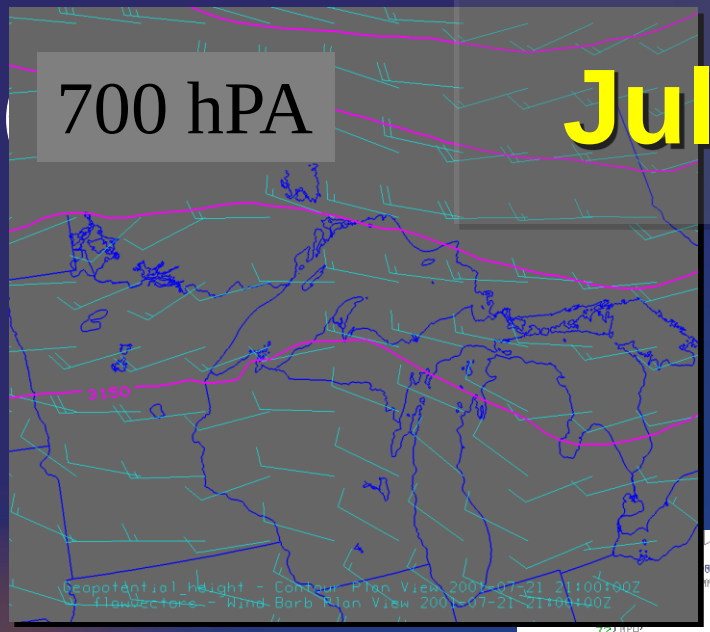
July 21, 2001

- Classic lake breeze day
- Weak to moderate W-NW flow aloft
  - *May have helped to push the Superior breeze further inland , but weaker while helping to keep the Michigan breeze closer to the shoreline, but stronger (i.e. Arritt ,1993)*
- Warm temps (above 80F) across the interior

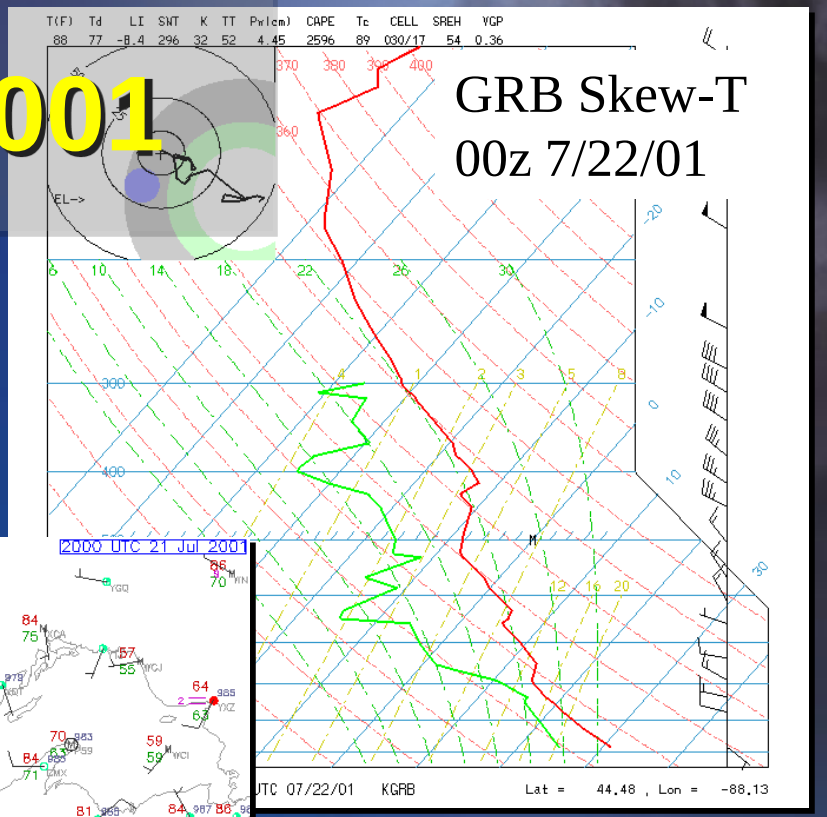


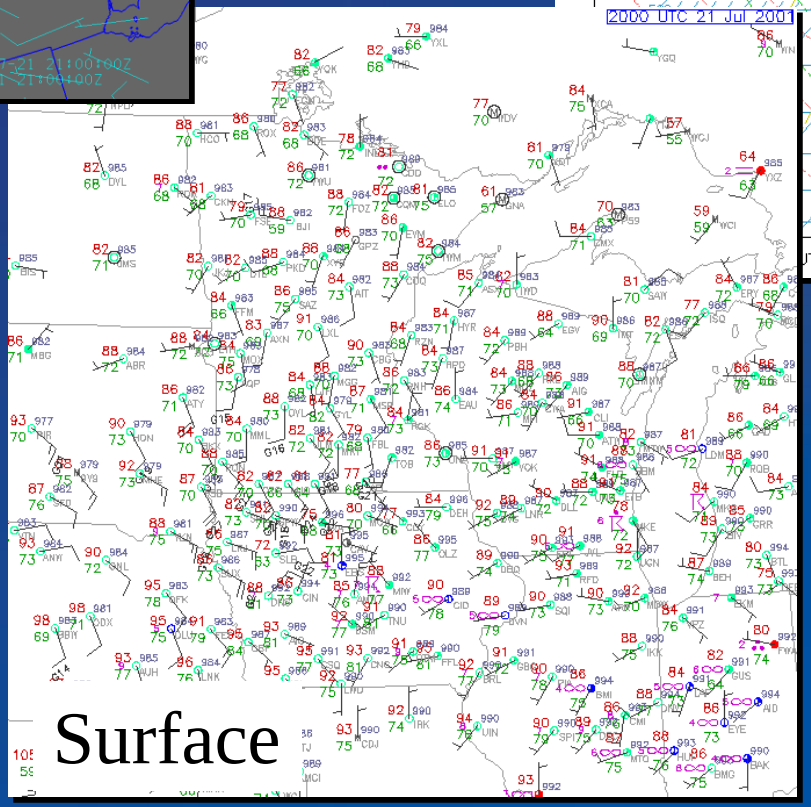
July 21, 2001

700 hPA



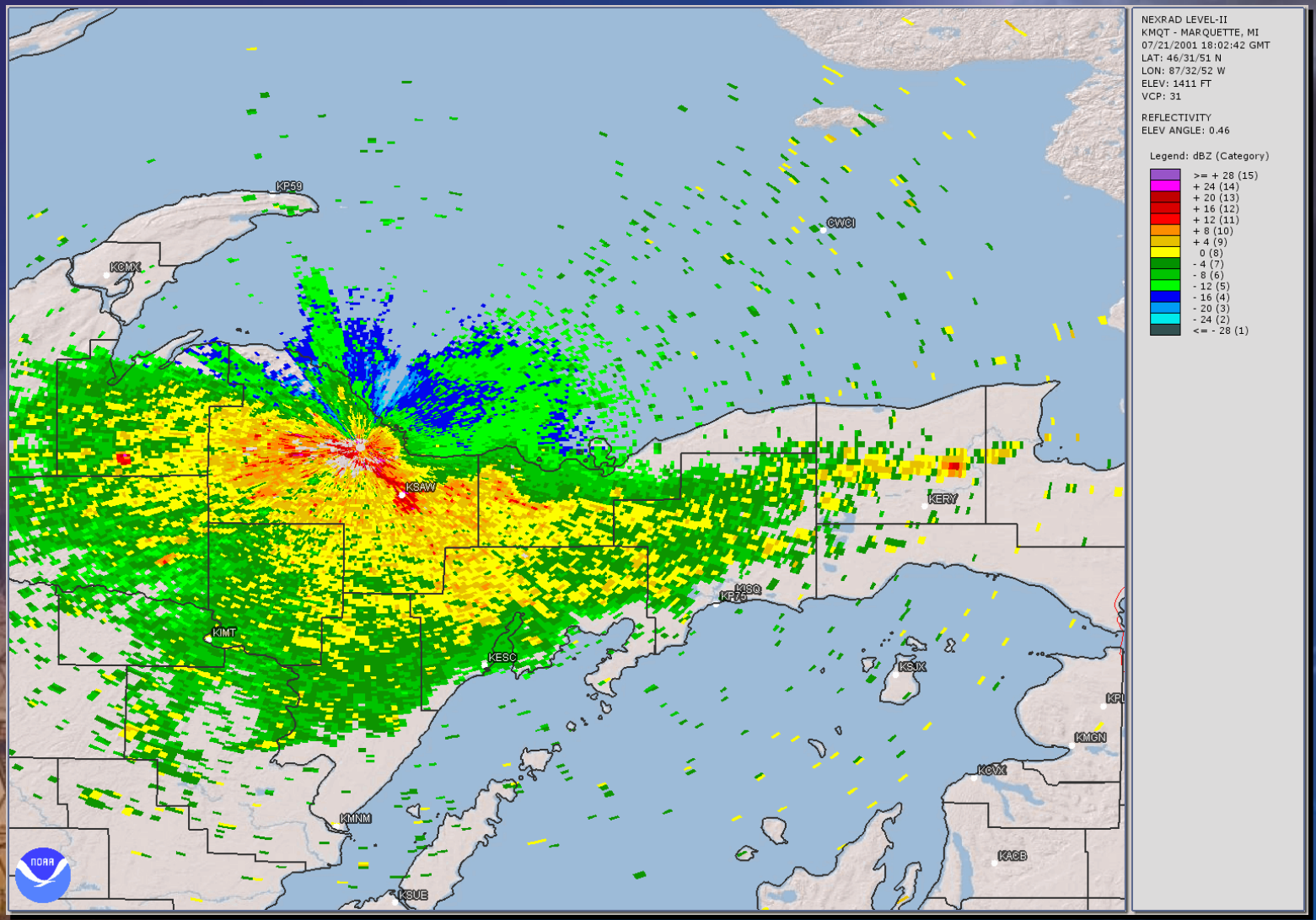
GRB Skew-T
00z 7/22/01



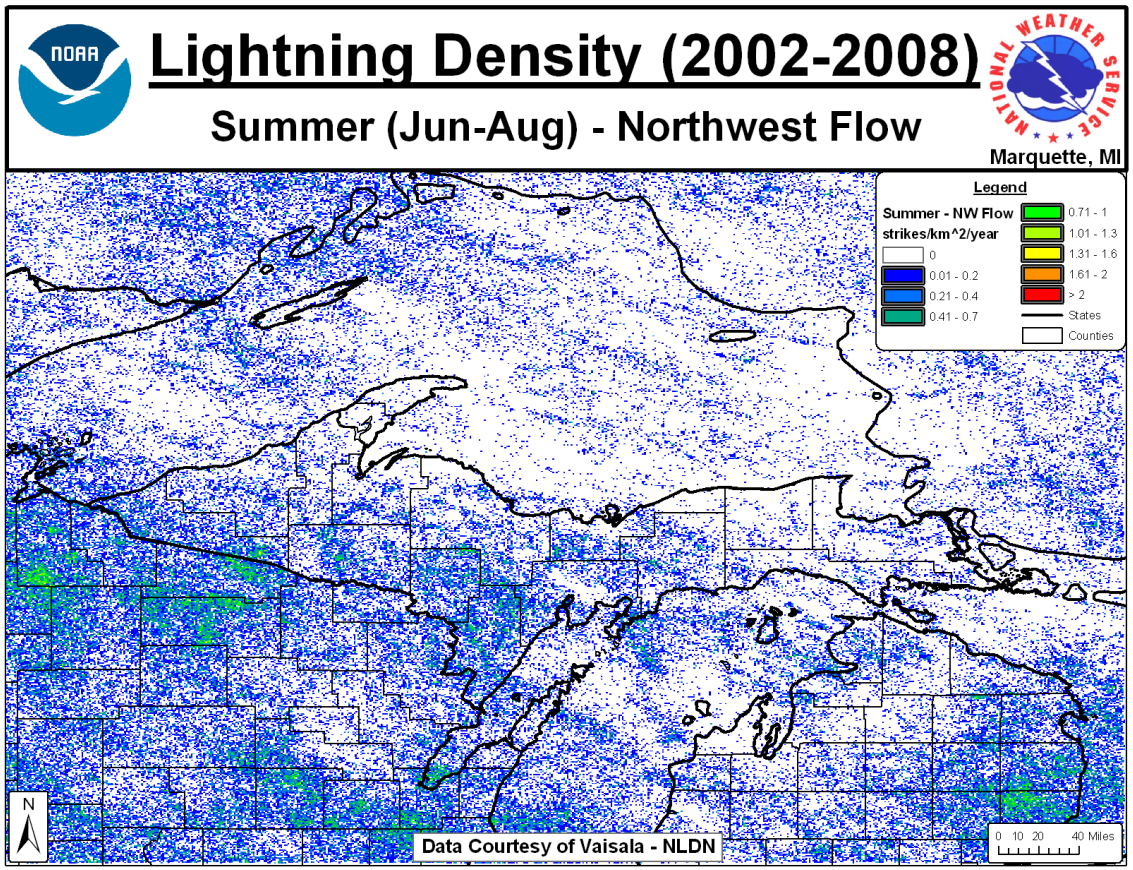


Surface

July 21, 2001


NEXRAD LEVEL-II
KMQT - MARQUETTE, MI
07/21/2001 18:02:42 GMT
LAT: 46/31/51 N
LON: 87/32/52 W
ELEV: 1411 FT
VCP: 31
REFLECTIVITY
ELEV ANGLE: 0.46
Legend: dBZ (Category)
>= + 28 (15)
+ 24 (14)
+ 20 (13)
+ 16 (12)
+ 12 (11)
+ 8 (10)
+ 4 (9)
0 (8)
- 4 (7)
- 8 (6)
- 12 (5)
- 16 (4)
- 20 (3)
- 24 (2)
<= - 28 (1)
KP59
KCWI
KCMX
KSAW
KERY
KMQT
KIMT
KESC
KSIX
KMQN
KCVX
KMNM
KABE
KSUE

Summer Northwest Flow Lighting Density



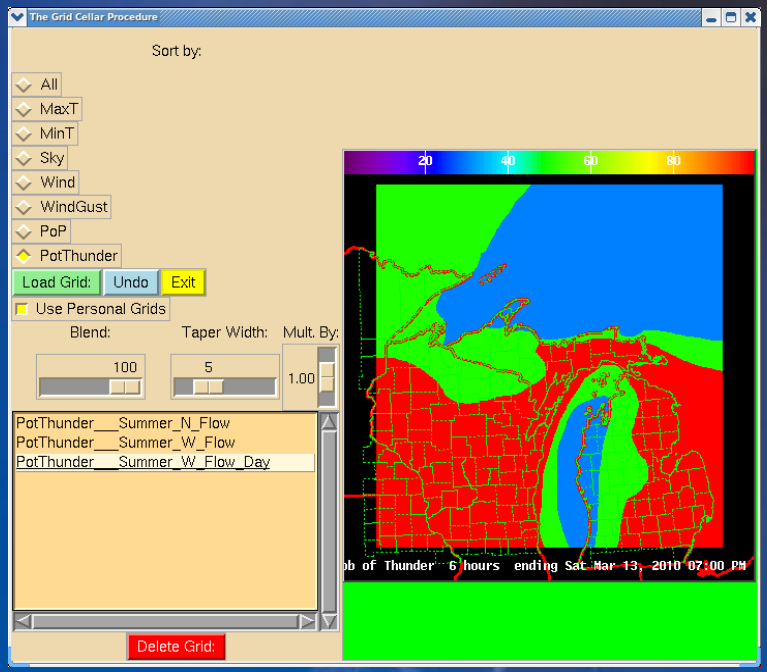
- Lake shadow is seen again downwind of the lakes.
- Highest density is well downwind of each Great Lake
  - *Although some convection does filter into the upstream areas of the Lakes*

Research to Operations

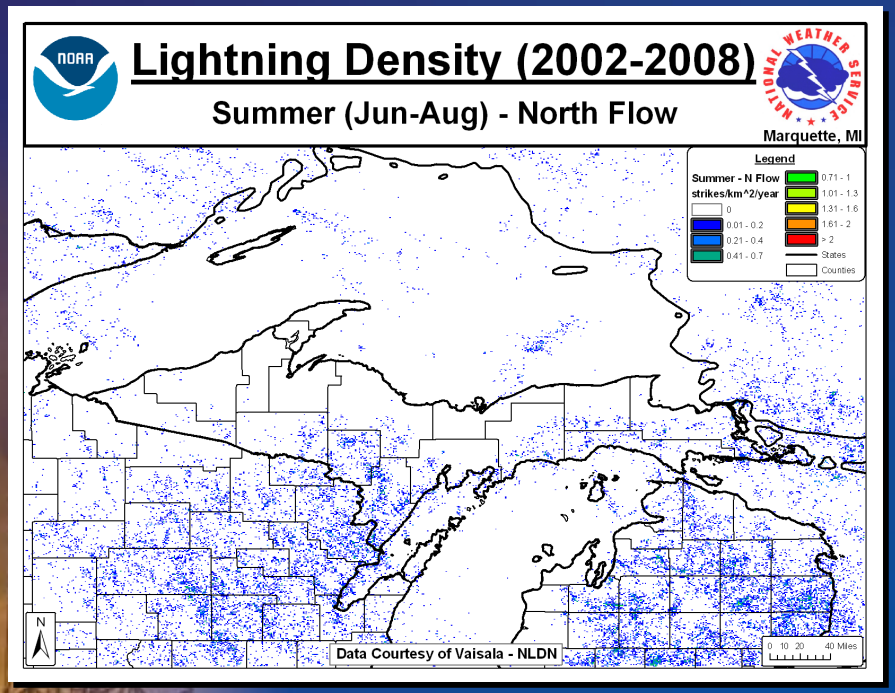
- Goal with all research is to help in operations.
- How can we use this data to support forecast operations in an easy and effective manner?

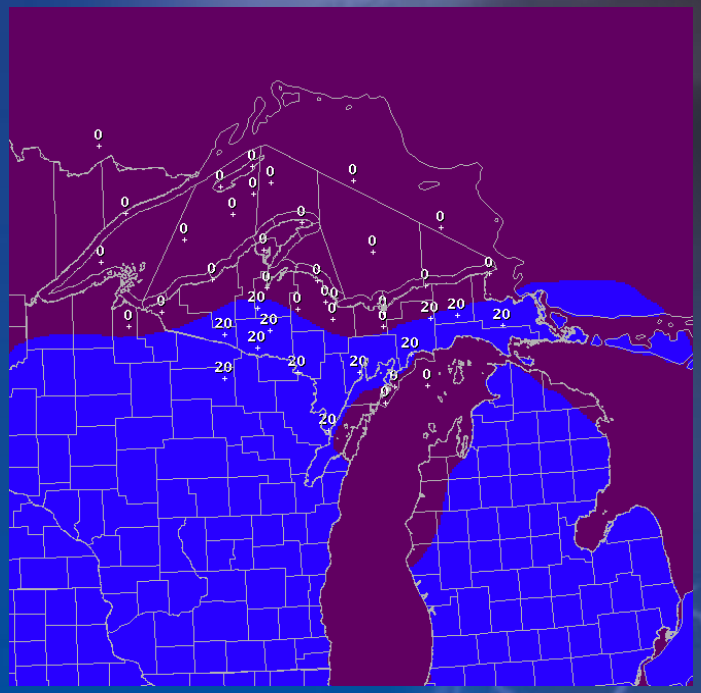
PoWT and Grid Cellar

- **Probability of Weather Type (PoWT)**
  - *A methodology for creating weather grids within the NWS Graphical Forecast Editor (GFE)*
  - *Developed by Andrew Just (WFO La Crosse)*
- **Grid Cellar**
  - *Used to store climatology grids for easy access by forecasters*
  - *Developed by Jonathan Wolfe (WFO Portland)*
  - *Currently used at WFO Marquette for Lake Effect Snow*
    - **PoP / Sky**



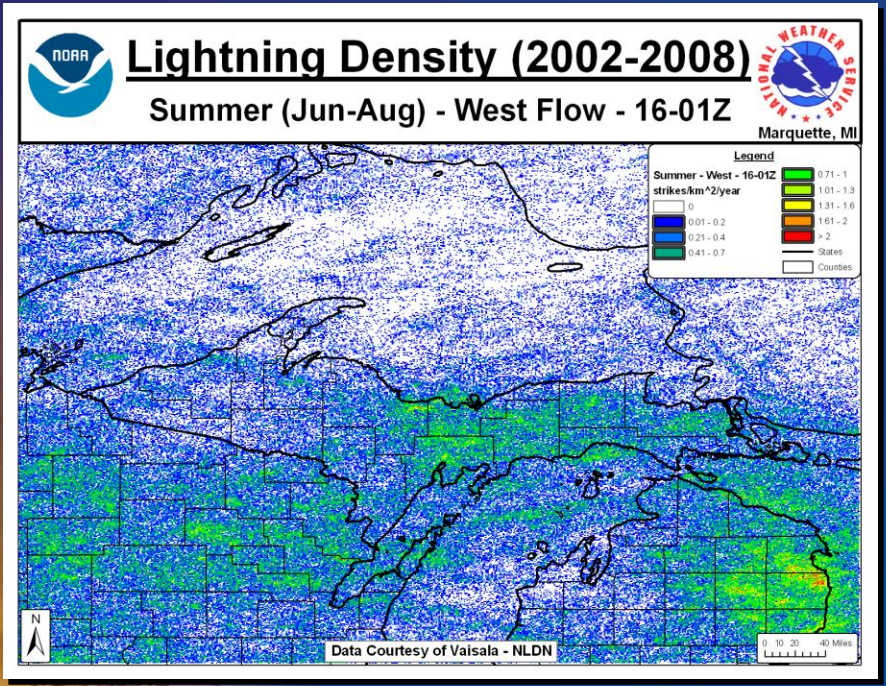
PoWT Grid – Summer North Flow

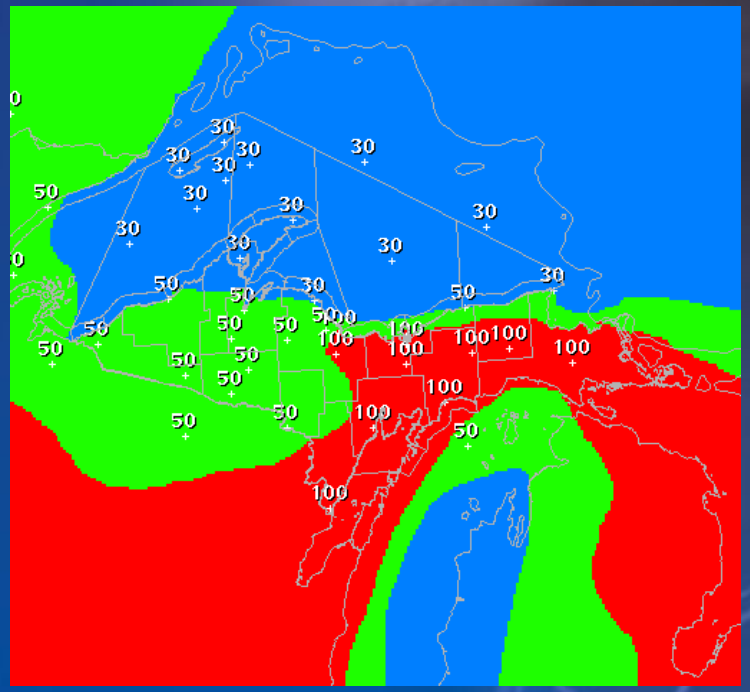




- Basic Example of a PoWT Thunder grid

PoWT Grid – Summer West Flow (Daytime)





- Can be useful in both Short and Long Term forecasts

Conclusions

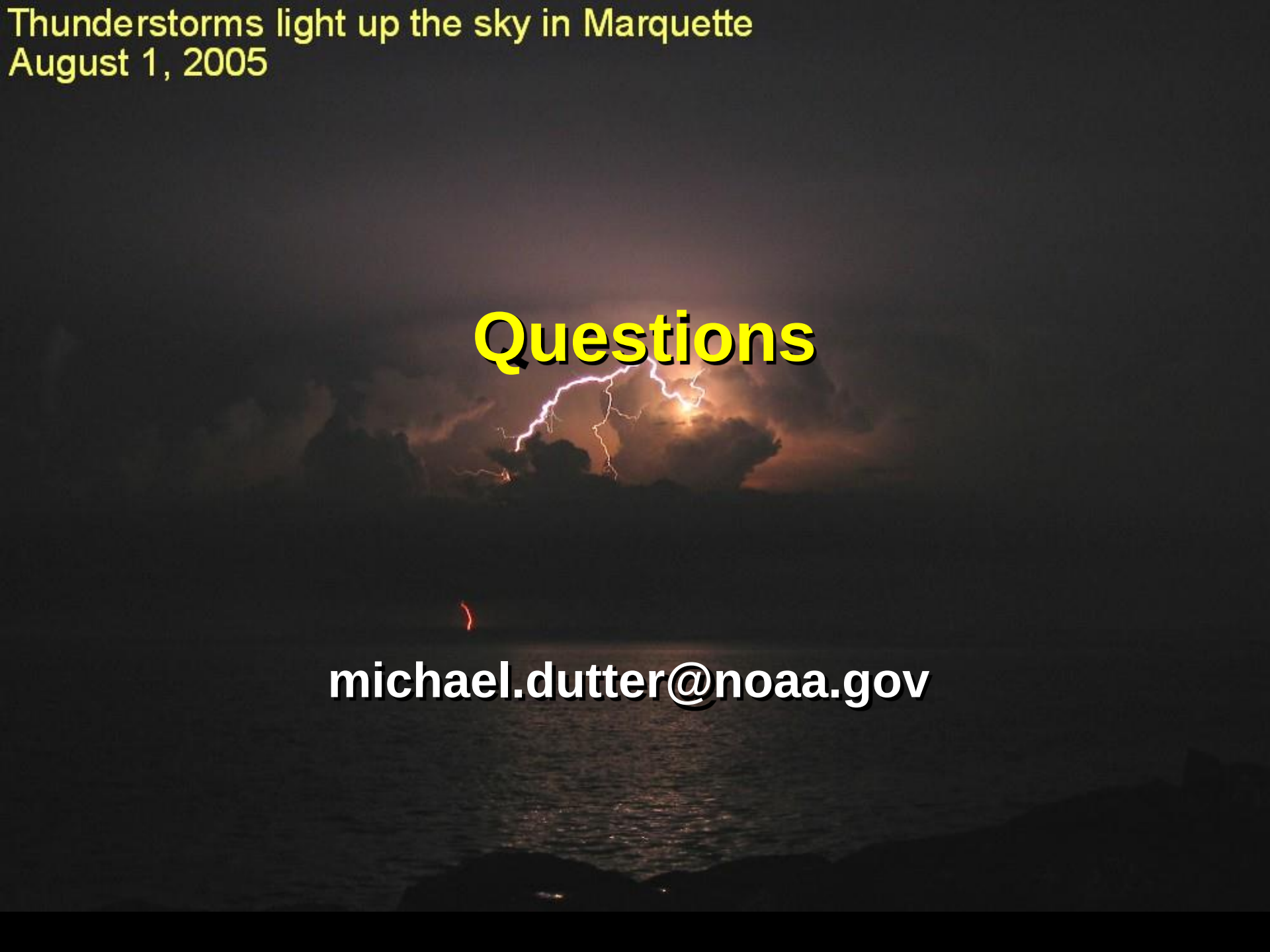
- **Many of the seasonal CG Lighting traits found in other studies (Cook et al., etc) are also found in our study**
  - ***Mid to Late afternoon diurnal max with a secondary max in the overnight***
- **Mesoscale aspects of the Great Lakes do play a heavy role in CG lightning**
  - ***Especially convergence zones, lake breeze areas, "lake shadows"***

Conclusions

- Westerly flow give the most lightning strikes during the year, and most evenly distributed
- West flow is also the best opportunity for lake breeze thunderstorms to develop (at least across eastern Upper and northeast Lower MI.
- Lake shadows can happen in nearly all flow regimes.

Future Work

- Use stability (CAPE) from the NARR to stratify dataset for each flow regime
  - *Would also like to look closer at wind speed CG lightning climatology.*
- Create similar datasets for other Great Lakes areas.
- Convert the Raster Datasets to KML
  - *Use in Google Earth/Map*
  - *Allow for a more interactive experience*



Questions

michael.dutter@noaa.gov