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Flow Regime Based Climatologies of Lightning Probabilities for Spaceports and Airports

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Matthew Volkmer, David Sharp, and Scott Spratt
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Richard A. Lafosse
Spaceflight Meteorology Group, Houston, TX

Applied Meteorology Unit  http://science.ksc.nasa.gov/amu
Outline

- Project objectives
- Data and period of record
- Flow regime definitions
- Methodology
- Taming the data for the forecaster
- Summary
Project Objectives

- Provide forecasters with "first guess" warm season climatological lightning tool
- Create climatologies of lightning probabilities based on flow regime
  - 5-, 10-, 20-, and 30-n mi circles around the Shuttle Landing Facility and seven airports within Melbourne National Weather Service (NWS) Forecast Office CWA for TAF support
  - 1-, 3-, and 6-hour increments
- Develop a forecaster tool to display the data with an easy to use GUI
Data and Period of Record (POR)

- NWS in Tallahassee provided National Lightning Detection Network (NLDN) gridded data of cloud-to-ground (CG) lightning strikes
  - Spatial resolution: 2.5 X 2.5 km
    - 24°–32.5° N and 78°–88° W
    - 405 x 377 grid boxes
  - Temporal resolution: 1 hour
- Warm season months of May through September in the 16-year period 1989–2004
Flow Regime Definitions

- Florida State University (FSU) identified large-scale flow regimes over Florida
  - Found strong relationship between regimes and spatial distribution of CG lightning
  - Average wind directions in 1000 – 700 mb layer from the 1200 UTC soundings Miami (MFL), Tampa (TBW), and Jacksonville (JAX)
  - Studies yielded 7 distinct flow regimes

<table>
<thead>
<tr>
<th>Flow Regime Name</th>
<th>Definition</th>
<th>Days in Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW-1</td>
<td>Ridge from Atlantic High South of MFL</td>
<td>271</td>
</tr>
<tr>
<td>SW-2</td>
<td>Ridge from Atlantic High North of MFL and South of TBW</td>
<td>241</td>
</tr>
<tr>
<td>SE-1</td>
<td>Ridge from Atlantic High North of TBW and South of JAX</td>
<td>309</td>
</tr>
<tr>
<td>SE-2</td>
<td>Ridge from Atlantic High North of JAX</td>
<td>225</td>
</tr>
<tr>
<td>NE</td>
<td>Overall Northeast Flow</td>
<td>174</td>
</tr>
<tr>
<td>PAN</td>
<td>Ridge from Central Gulf Coast High over Panhandle</td>
<td>109</td>
</tr>
<tr>
<td>NW</td>
<td>Overall Northwest Flow</td>
<td>94</td>
</tr>
<tr>
<td>Other</td>
<td>Undefined Regime</td>
<td>827</td>
</tr>
</tbody>
</table>
Methodology

- FSU provided code which AMU modified to:
  - Output 1-, 3-, and 6-hourly grids for each day of each flow regime in the POR
  - Read the output from the first program to create files with twenty-four 1-, eight 3- and four 6-hourly climatological lightning probabilities at 5-, 10-, 20- and 30- n mi circles for each site and flow regime
- Resulting 36 new programs handled various combinations of time interval and site location
Methodology

- AMU modified code to convert the gridded data to latitude/longitude for each site
- Center point of each runway was not always in the center of a grid box or at an apex of a grid box
  - Picked closest 2.5 km X 2.5 km grid box to runway center
  - Determined corner grid boxes at 5-, 10-, 20-, and 30-n mi from center square
  - Had to use area of square instead of area of circle due to design of code
Methodology

- 529 grid boxes instead of 30-n mi circle
  - Area of purple square is 27% larger than area of purple circle
- 225 grid boxes instead of 20-n mi circle
  - Area of green square is 23% larger than area of green circle
- 49 grid boxes instead of 10-n mi circle
  - Area of red square is 13% larger than area of the red circle
- 9 grid boxes instead of 5-n mi circle
  - Area of blue square is 16% smaller than area of the blue circle

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Taming the Data

- Generated 864 spreadsheets in Excel from the FORTRAN output which contained the climatological probabilities of lightning for:
  - 9 sites
  - 3 time intervals
  - 4 different size circles
  - 8 flow regimes
- Contained climatological probability of lightning for:
  - each hour of the day rounded to the nearest integer
  - corresponding UTC time
  - number of CG strikes for each hour
  - number of flow regime days in the POR

<table>
<thead>
<tr>
<th>Probability (%)</th>
<th>UTC Time</th>
<th># Strikes</th>
<th># Flow Regime Days</th>
</tr>
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<tbody>
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<td>271</td>
</tr>
<tr>
<td>10</td>
<td>23</td>
<td>429330</td>
<td>271</td>
</tr>
</tbody>
</table>
Merged the data from multiple spreadsheets into data tables grouped by time interval and flow regime

Created graphs from the tables to provide a "quick look" tool for the forecasters
Tying it all together for the Forecaster

- Built a GUI using HTML
  - Easily navigable web site
  - Platform independent
- Navigation
  - Data and Definitions
    - View helpful information about data, methodology and flow regime definitions
  - Nine sites
  - By flow regime or time interval
- Displays both tables and corresponding graphs

Applied Meteorology Unit  http://science.ksc.nasa.gov/amu
Summary

- Objective: provide forecasters with a "first guess" climatological lightning probability tool
  - Focus on Space Shuttle landings and NWS TAFs
  - Four circles around sites: 5-, 10-, 20- and 30 n mi
  - Three time intervals: hourly, every 3 hr and every 6 hr
- Based on:
  - NLDN gridded data
  - Flow regime
  - Warm season months of May-Sep for years 1989-2004
- Gridded data and available code → squares, not circles
- Over 850 spreadsheets converted into manageable user-friendly web-based GUI
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Outline

- Project objectives
- Data and period of record
- Flow regime definitions
- Issues
- Problems
- Solutions
- Taming the data for the forecaster
- Summary
Project Objectives

- Provide forecasters with a warm season climatological probability of one or more lightning strikes within a circle at a site within a specified time interval.
- Create climatologies based on Florida flow regimes for TAFs and shuttle landings for:
  - 9 sites
  - 5-, 10-, 20-, and 30-n mi circles around the sites
  - 1-, 3-, and 6-hour increments
- Develop an easy to use GUI to display data.

Data and Period of Record (POR)

- NWS in Tallahassee provided NLDN grided data of cloud-to-ground (CG) lightning strikes
  - Spatial resolution: 2.5 X 2.5 km
  - Temporal resolution: 1 hour
- Warm season months:
  - May – Sep
  - 16-year period
  - 1989–2004
Flow Regime Definitions

- Florida State University (FSU) identified large-scale flow regimes over Florida
  - Found strong relationship between regimes and spatial distribution of CG lightning
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Flow Regime Definitions - Example

- Southwest (SW-1)
  - Atlantic high pressure ridge south of MFL
  - 1000-700 mb layer average wind direction is from the southwest across peninsula
  - CG lightning maximum along the east coast of Florida
Issues

• Needed to know:
  – Number of CG strikes in given period of time and distance from site

• Had to work with:
  – Code provided by FSU to read NLDN data in gridded format

• Needed to generate:
  – 1-, 3-, and 6-hourly grids for each day and each flow regime
  – 5-, 10-, 20- and 30- n mi circles for each site and each flow regime

Problems

• Data
  – Gridded format not individual CG’s

• Code designed for:
  – 24 hr intervals
  – Entire (rectangular) domain (343,000 n mi²)
  – Not lat/lon based
Solutions

- **Data**
  - No change
- **Changed code**
  - Multiple time intervals and smaller, multiple domains by lat/lon
- **Used area of square instead of circle**
  - 30-n mi circle:
    - 529 grid boxes: area of square is 27% larger than area of circle
  - 20-n mi circle
    - 225 grid boxes: area of square is 23% larger than area of circle
  - 10-n mi circle
    - 49 grid boxes: area of square is 13% larger than area of the circle
  - 5-n mi circle
    - 9 grid boxes: area of square is 16% smaller than area of the circle

Taming the Data

- Generated 864 spreadsheets in Excel® containing climatological probabilities of lightning for:
  - 9 sites
  - 3 time intervals
  - 4 different size circles
  - 8 flow regimes
- **Tables contained:**
  - Climatological probability of lightning
  - UTC time
  - Number of CG strikes for each hour
  - Number of flow regime days in the POR

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User Friendly Format

- Merged the data from multiple spreadsheets into data tables grouped by time interval and flow regime
- Created graphs from the tables to provide a "quick look" tool for the forecasters

![Graph of 1-Hour Intermittent SLF Southwest 5 Flow Regimes]

Tying It All Together for the Forecaster

- Built a GUI using HTML
  - Easily navigable web site
  - Platform independent
- Navigation
  - Data and Definitions
  - Nine sites
  - Flow regime or time interval
- Displays both tables and corresponding graphs

[Demo]
Summary

- Objective: provide warm season climatological probability of one or more lightning strikes within a circle at a site within a specified time interval
  - Focus on Space Shuttle landings and NWS TAFs
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