A Climatology-based Forecast Tool for Coastal Flooding in the Lowcountry

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Coastal flooding and its impacts

What is it?

- A coastal flood is the inundation of land areas along the coast as a result of higher than average high tide.
- Coastal floods can be worsened by heavy rainfall or onshore winds.
- Defined in Charleston as a high tide that exceeds 7.0 feet mean low low water (MLLW).

What are the impacts?

- HEAVY TRAFFIC
- Negative health effects (mold)
- Power outages
- Storm water backup
- Delayed emergency response
- Disruption of business and commerce
Measuring tides in Charleston, SC

Photograph of tide station 8665530 Charleston, Cooper River Entrance, SC.

Location of tide station 8665530 Charleston, Cooper River Entrance, SC.
Coastal flooding in Charleston has increased by an order of magnitude.

<table>
<thead>
<tr>
<th>Years</th>
<th>Number of tidal cycles &gt; 7.0 ft above MLLW</th>
<th>Yearly Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950–1959</td>
<td>22</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Flooding categories and NWS products

**Categories**
- Minor flooding – greater than or equal to 7.0 feet MLLW
- Moderate flooding – greater than or equal to 7.5 feet MLLW
- Major flooding - greater than or equal to 8.0 feet MLLW

**NWS Products**
- Advisory – level expected to be at least 7 ft MLLW but below 8 ft MLLW
- Watch – level might get to at least 8 feet MLLW, but not sure yet.
- Warning – Level expected to get to at least 8 feet MLLW
The current number of statistical tools available to the NWS for predicting nuisance (minor) level events is limited.

- The following forecast tool will not only help NWS forecasters better predict the occurrence of nuisance level coastal flooding events, but also it will allow them to more accurately issue coastal flood advisories.
Data and Methods

- Study site – Charleston
- Study period – 1996-2014
- Identification of coastal flood events (high tides greater than 7.0 ft above MLLW)
- Separation of events into type-based categories (anticyclonic, cyclonic, frontal, neutral, and tropical).
- Determination of climatological anomalies for flood tides (observed – predicted) for both high tides and previous low tides.
  - The creation of sigma high and sigma low
- Creation of composite weather maps for each category
- Sigma high vs. sigma low scatterplots
- Identification and analysis of outliers
Results

Percentage of Non-tropical Coastal Flood Events by Category (1996-2014)

- Anticyclonic: 34.5%
- Cyclonic: 32.0%
- Neutral: 18.3%
- Frontal: 14.7%

Number of Non-Tropical Flood Events by Category Per Year (Total Tide > 7.0 feet above MLLW)
Anticyclonic cases

3-day panel for anticyclonic event composite mean maps for surface level pressure (mb)
Anticyclonic cases

3-day panel for anticyclonic event composite mean anomaly maps for surface vector wind (m/s)
Ekman spiral

- Wind
- Surface current
- Net water transport
- 100 meters

45°
3-day panel for cyclonic event composite mean maps for surface level pressure (mb)
Cyclonic cases

3-day panel for cyclonic event composite mean anomaly maps for surface vector wind (m/s)
Scatterplots

**Anticyclonic Cases**

Sigma High Anticyclonic = 0.2074 + 0.7428 Sigma Low Anticyclonic

<table>
<thead>
<tr>
<th>Regression</th>
<th>95% CI</th>
<th>95% PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.205033</td>
<td></td>
</tr>
<tr>
<td>R-Sq</td>
<td>69.0%</td>
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</tr>
<tr>
<td>R-Sq(adj)</td>
<td>68.5%</td>
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</tr>
</tbody>
</table>

**Cyclonic Cases**

Sigma High Cyclonic = 0.1180 + 1.019 Sigma Low Cyclonic

<table>
<thead>
<tr>
<th>Regression</th>
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<th>95% PI</th>
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</thead>
<tbody>
<tr>
<td>S</td>
<td>0.331632</td>
<td></td>
</tr>
<tr>
<td>R-Sq</td>
<td>71.4%</td>
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</tr>
<tr>
<td>R-Sq(adj)</td>
<td>70.9%</td>
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</table>
November 24, 2018: A recent case study
Surface vector wind anomaly (m/s)
Anticyclonic Cases

$\text{Sigma High Anticyclonic} = 0.2074 + 0.7428 \times \text{Sigma Low Anticyclonic}$

- **Regression**: $S = 0.205033$
- **R-Sq**: 69.0%
- **R-Sq(adj)**: 68.5%
<table>
<thead>
<tr>
<th>Date</th>
<th>Time (GMT)</th>
<th>Astronomically predicted height (ft MLLW)</th>
<th>Model predicted height (ft MLLW)</th>
<th>Verified height (ft MLLW)</th>
<th>Model predicted - Verified</th>
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</thead>
<tbody>
<tr>
<td>11/22/18</td>
<td>12:00</td>
<td>6.39</td>
<td>7.28</td>
<td>7.06</td>
<td>0.217776</td>
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<tr>
<td>11/23/18</td>
<td>0:18</td>
<td>5.55</td>
<td>6.63</td>
<td>6.69</td>
<td>0.060096</td>
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<tr>
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<td>8.09</td>
<td>8.14</td>
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<tr>
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<td>1:24</td>
<td>5.53</td>
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<td>7.23</td>
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<td>0.04362</td>
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</tbody>
</table>

RMSE and MAE were calculated as 0.18 and 0.15, respectively.
Flooding events are increasing by an order of magnitude
Not enough tools available to make accurately issue coastal flood advisories
Chronic impacts cause long term issues
Mitigation is expensive (pump stations, raising seawalls, boots on the ground, etc.)
This tool will help forecasters, which in turn will help emergency managers and public officials.
Public outreach
Acknowledgements

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COMET
NOAA/NWS

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