

A Coastal Flood Climatology for Charleston, SC and the Development of a Climatology Based Forecast Tool

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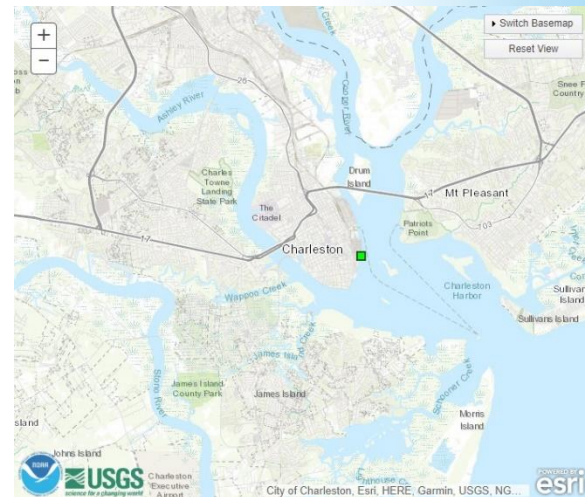
NOAA/National Weather Service

Charleston, SC

What is coastal flooding?

Coastal Flooding

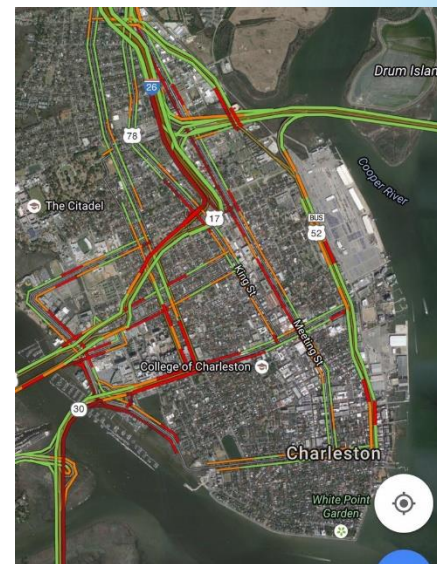
- Flooding of low lying, vulnerable areas near the coast due to elevated high tides
- Typically occurs in the absence of rain, “sunny day” flooding
- Impacts range from:
 - Minor: flooding of parking lots, roads, low lying coastal areas, with some minor beach erosion possible
 - Major: Significant, damaging flooding with numerous road closures, flooding of structures, and even isolating some communities
- Coastal flooding threshold for Charleston is 7.0 ft MLLW at the Charleston Harbor National Ocean Service (NOS) tide gauge



Why does coastal flooding matter?

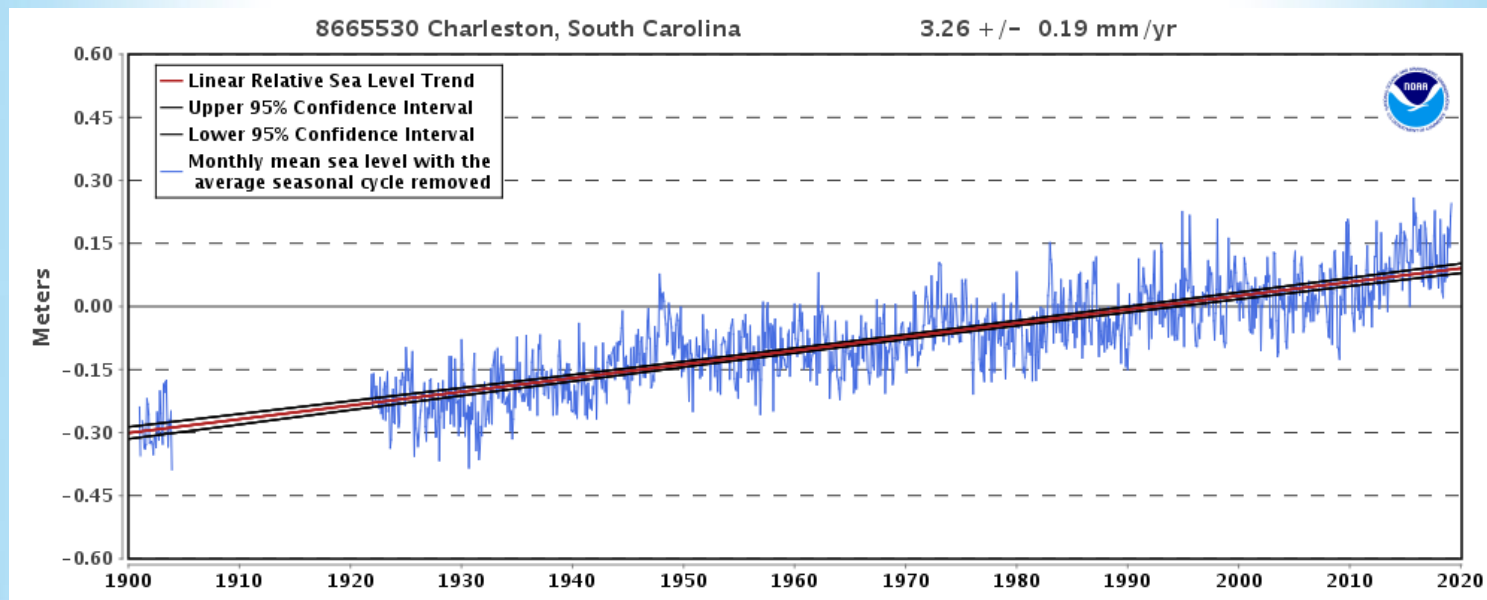
Coastal Flooding

- Coastal flooding is repetitive flooding
- Short term: Flooded roads can cause significant traffic issues, at higher tide levels some communities can become isolated
 - Disruptive to life and commerce
- Long term: repetitive flooding causes damage to property and infrastructure (roads, bridges, drainage systems)
- Numerous studies in recent years regarding population, land, and property at risk due to sea-level rise
 - Estimated cumulative cost of property damage due to 1.2-2.1 ft SLR through 2050, \$287-360 billion (Rhodium Group, American Climate Prospectus 2014)
 - Along the Eastern Seaboard, nuisance tidal flooding threatens ~7,500 miles of roadways including over 400 miles of interstate roadways (Jacobs et al. 2018)



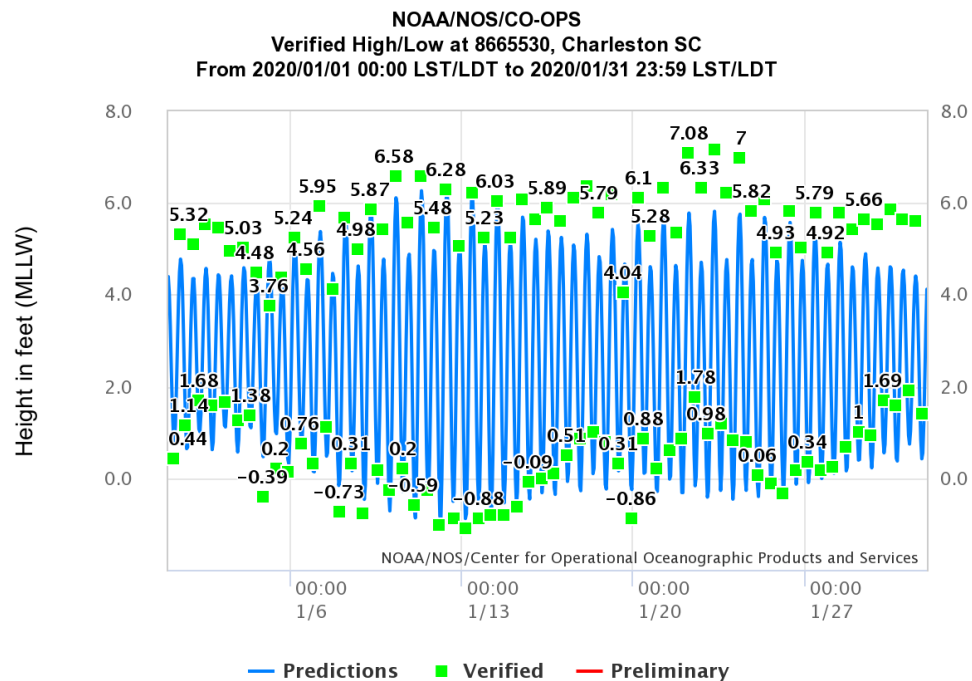
Coastal Flooding

- Sea-level rise points to an increasing coastal flooding threat
- Observations from the Charleston Harbor tide gauge show sea-level increase of 1.07 feet over 100 years
- Increase appears to be accelerating over the last decade

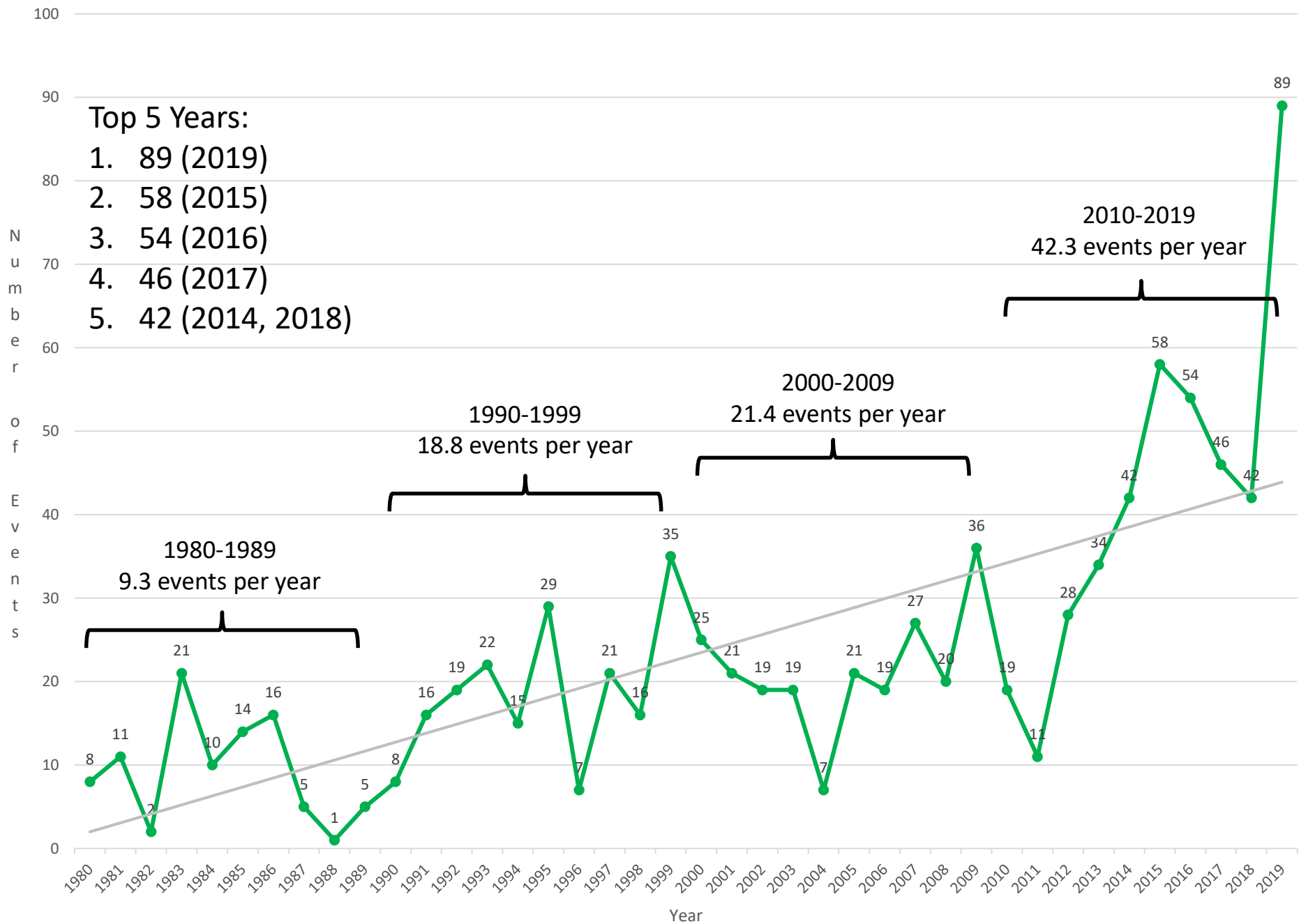


Charleston Coastal Flood Event Database

- Need a resource to monitor trends on a monthly, yearly time scale
- Provide information for media requests and to place flooding in a temporal context
- Document the date, time, and peak value of all tides that reach or exceed 7.0 ft MLLW
- Able to build a comprehensive database back to 1/1/1980
 - 1/1/1980 to 11/30/1995 used NOS verified high/low water level
 - 12/1/1995 to present used NOS verified 6-minute water level
- Identified 918 total tides of 7.0 ft MLLW or higher from 1/1/1980 through 12/31/2019



Charleston Harbor, SC Coastal Flood Events by Year (7.00 ft MLLW or higher)



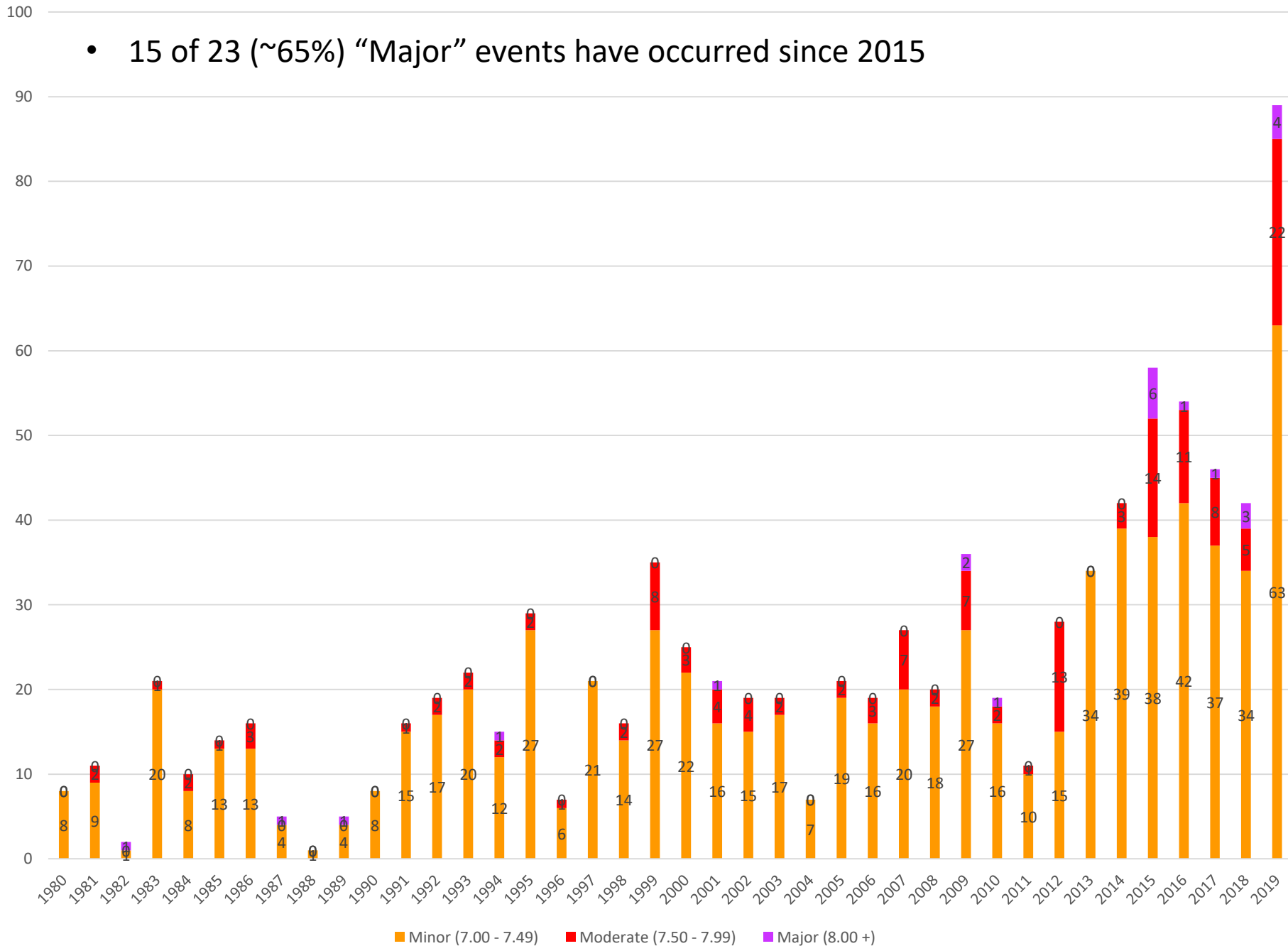
Charleston, SC Coastal Flood Events by Category

- 15 of 23 (~65%) “Major” events have occurred since 2015

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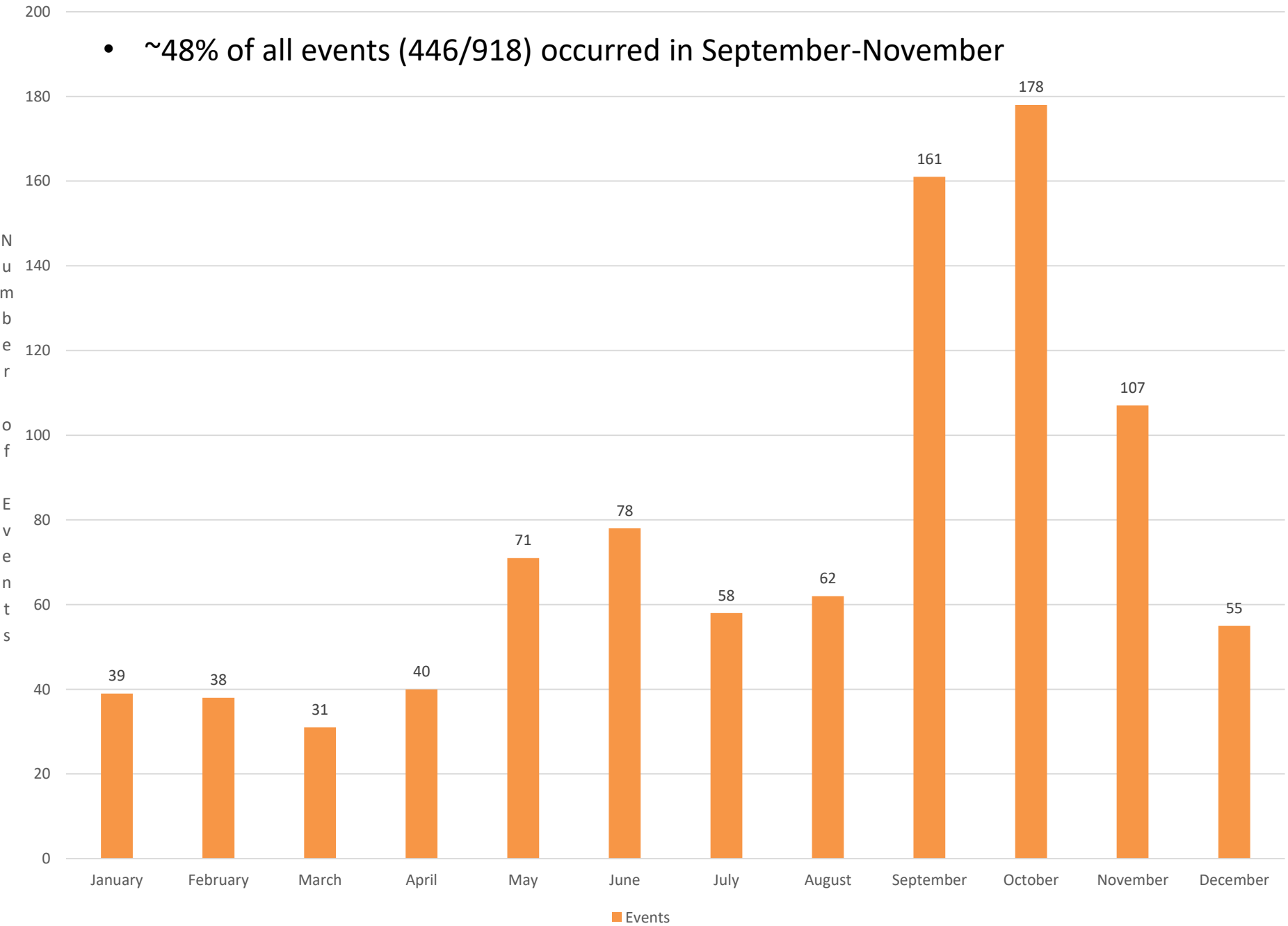
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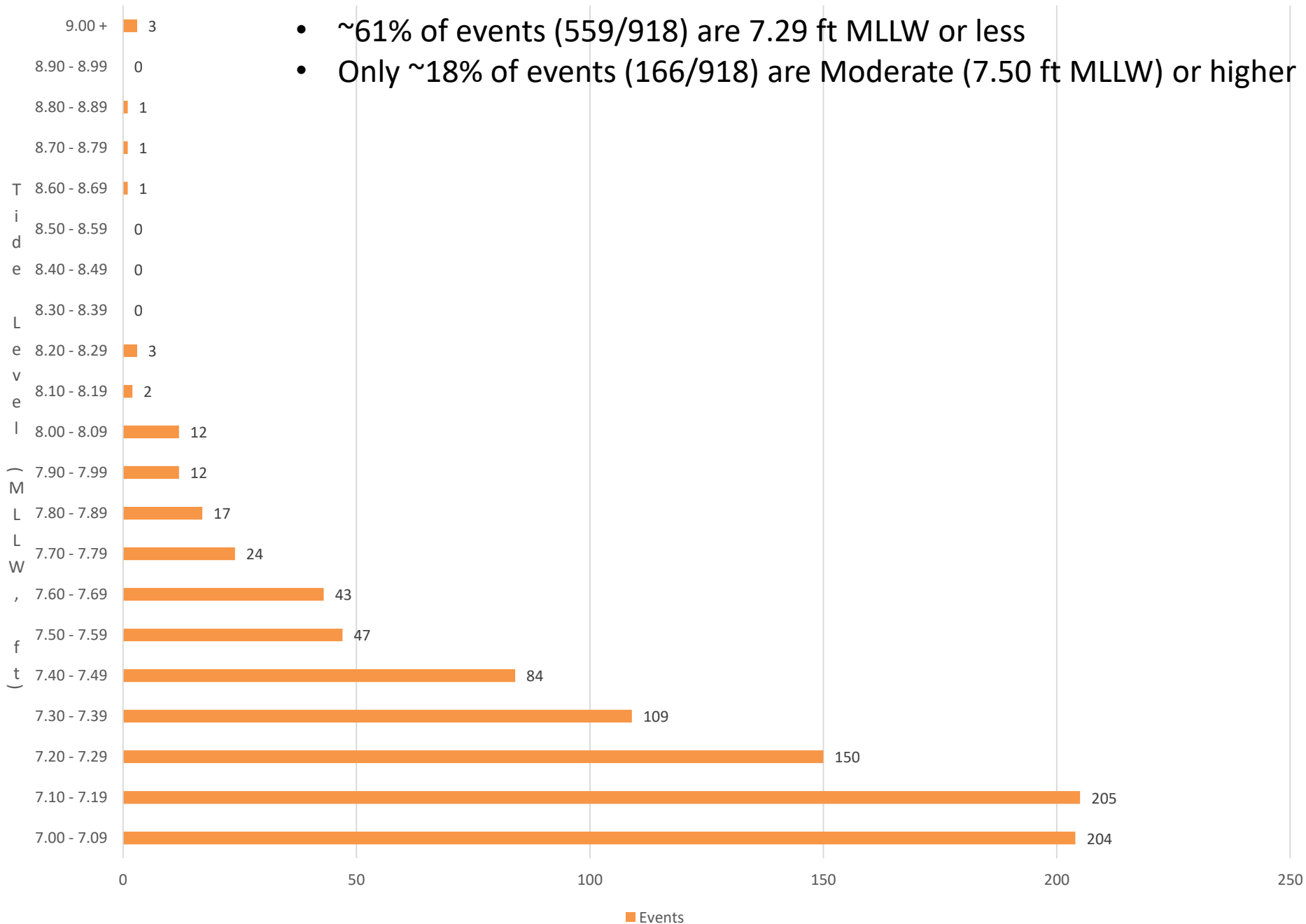


Charleston, SC Coastal Flood Events by Month (1/1/1980 to 12/31/2019)

- ~48% of all events (446/918) occurred in September-November



Charleston, SC Coastal Flood Events by Value Range (1/1/1980 to 12/31/2019)



Charleston Coastal Flood Event Database

- Available on our web page
 - <https://www.weather.gov/chs/coastalflood>
- Includes monthly and annual data, records, various charts and graphs
- Same data also available for the Fort Pulaski, GA tide gauge
- Will be updated each month

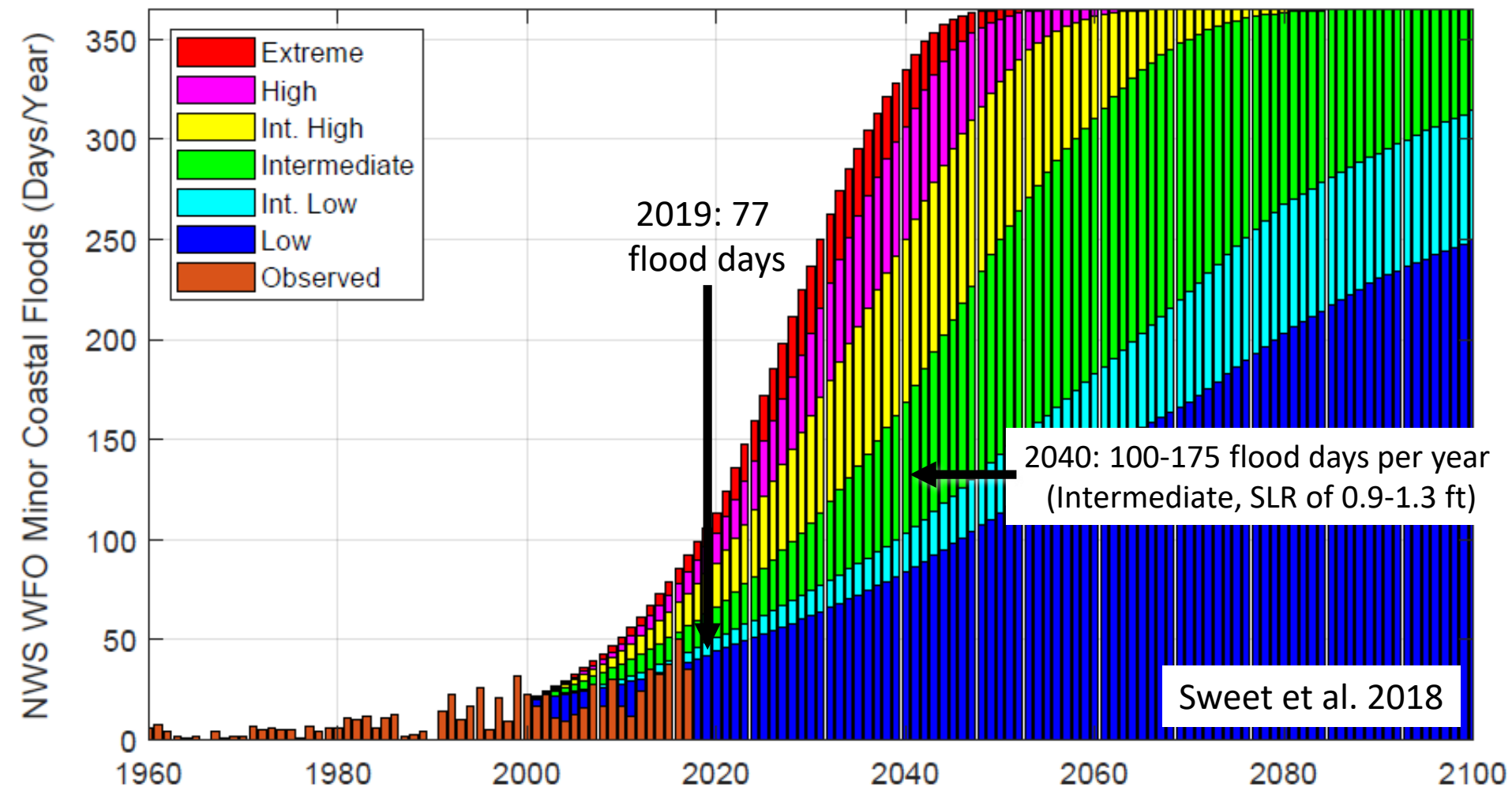
Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1980	1	0	0	0	2	2	0	0	2	1	0	0	8
1981	0	0	0	0	4	0	0	0	0	2	5	0	11
1982	0	0	0	0	0	1	0	0	0	0	0	1	2
1983	4	3	2	0	0	4	4	0	0	3	1	0	21
1984	1	0	1	1	0	0	0	1	0	3	3	0	10
1985	0	0	0	0	1	0	0	0	4	9	0	0	14
1986	1	0	0	1	3	3	1	0	1	0	4	2	16
1987	1	2	0	0	0	0	0	0	2	0	0	0	5
1988	0	0	0	0	0	0	0	0	1	0	0	0	1
1989	0	0	2	0	1	1	0	0	1	0	0	0	5
1990	0	0	1	0	3	0	0	0	0	1	3	0	8
1991	0	0	0	0	2	0	4	1	3	3	3	0	16
1992	0	0	0	0	0	6	0	0	10	1	2	0	19
1993	3	4	0	5	0	1	0	1	1	4	2	1	22
1994	0	0	0	0	3	0	0	0	1	7	0	4	15
1995	1	0	2	0	3	2	4	5	6	2	1	3	29
1996	0	0	0	0	2	2	1	1	0	1	0	0	7
1997	1	1	0	0	1	4	1	3	4	4	1	1	21
1998	2	8	0	1	2	0	0	0	0	1	2	0	16
1999	4	1	0	1	6	4	3	1	6	1	5	3	35
2000	3	0	1	0	1	5	5	3	2	0	4	1	25
2001	1	0	1	0	1	0	3	0	6	5	4	0	21
2002	0	0	2	1	1	0	0	5	2	6	1	1	19
2003	0	0	1	5	2	0	0	0	6	2	3	0	19
2004	0	0	0	0	0	0	1	3	3	0	0	0	7
2005	0	5	0	0	2	1	0	2	2	9	0	0	21
2006	0	0	0	1	0	0	0	1	8	5	3	1	19
2007	0	0	0	2	3	7	1	0	3	6	2	3	27
2008	0	0	0	3	3	0	0	0	7	3	3	1	20
2009	0	0	0	0	0	5	2	3	11	4	9	2	36
2010	1	0	0	0	2	0	0	3	4	7	2	0	19
2011	0	0	0	0	1	2	2	1	0	3	1	1	11
2012	0	0	0	4	4	5	2	0	0	3	7	3	28
2013	0	0	2	1	5	5	0	3	3	9	3	3	34
2014	3	3	3	4	2	1	2	6	9	3	0	6	42
2015	2	1	7	2	1	0	2	3	12	22	6	0	58
2016	4	1	0	0	4	9	2	1	5	15	8	5	54
2017	1	0	2	5	2	2	3	1	12	8	3	7	46
2018	3	2	1	0	0	3	6	3	8	7	7	2	42
2019	2	7	3	3	4	3	9	11	16	18	9	4	89
2020	3												3
Total	42	38	31	40	71	78	58	62	161	178	107	55	921

Coastal Flooding and Sea Level Rise

- NOAA Technical Report 083
 - Global and Regional Sea Level Rise Scenarios for the United States
- Charleston scenarios by 2040
 - Low: 0.5-0.9 ft
 - Int. Low: 0.6-1.0 ft
 - Intermediate: 0.9-1.3 ft
 - Int. High: 1.1-1.7 ft
 - High: 1.5-2.1 ft
 - Extreme: 1.4-2.3 ft
- How would this impact coastal flooding?

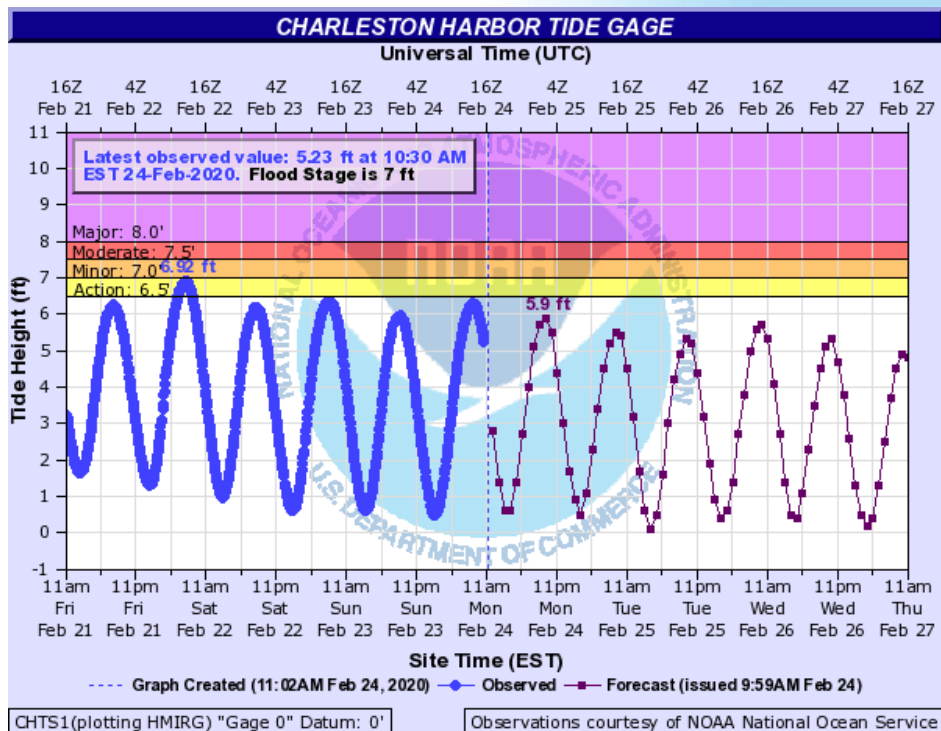


NOAA Tide Gauge Charleston, SC (7' above MLLW)



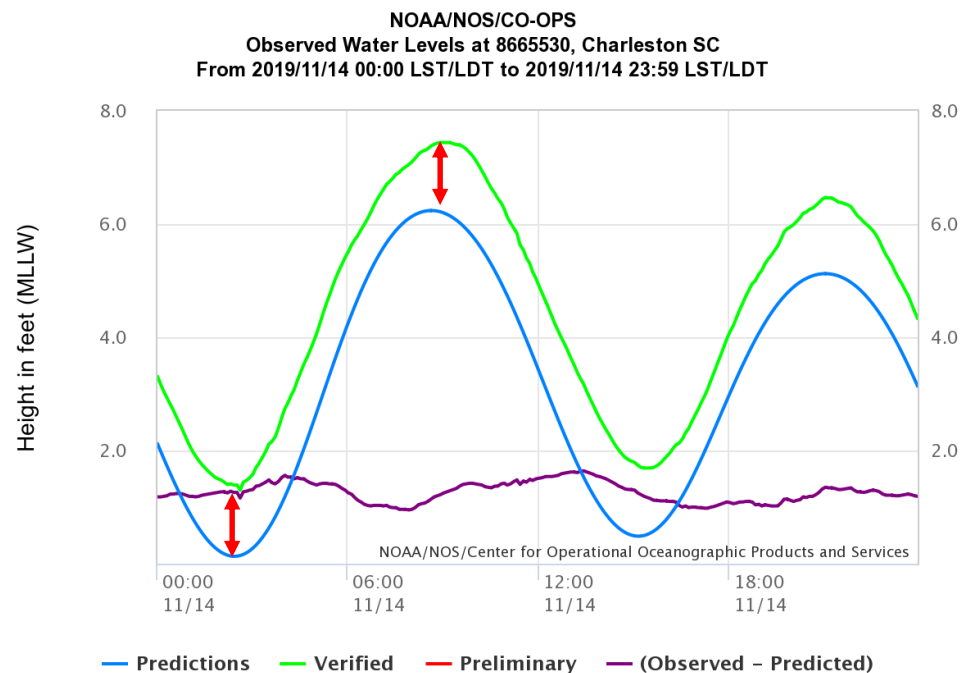
Total Water Level Forecasts

- Forecasts issued at least twice a day
- Forecast takes into account the astronomical tide, tide model output, pattern recognition, and forecaster input
- Forecast used to make Watch/Warning/Advisory decisions
 - At or above 7.0 ft MLLW, Coastal Flood Advisory for the southeast South Carolina coast
 - At or above 8.0 ft MLLW, Coastal Flood Watch/Warning for the southeast South Carolina coast
- How can we improve these forecasts?



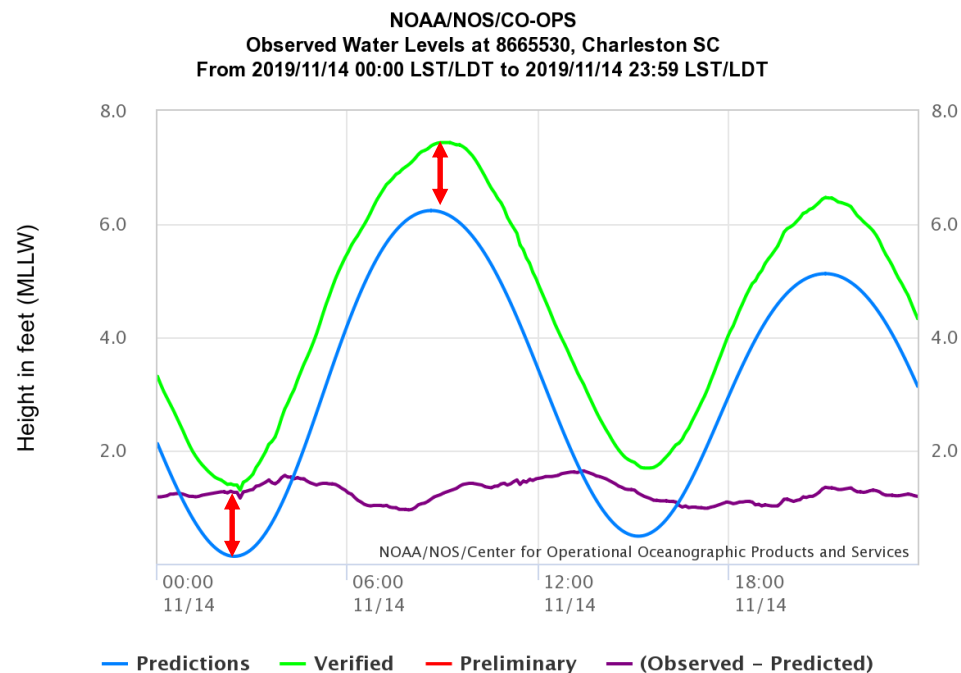
Forecast Tool Development

- College of Charleston graduate student project (Coz 2019)
 - Investigated the relationship between tidal departure at low tide and tidal departure at the next high tide
- Categorized events based on the ongoing weather features
 - Category A: Anticyclonic
 - Category B: Cyclonic
 - Category C: Frontal
 - Category D: Neutral
 - Category E: Tropical
- Included data from 1996-2014



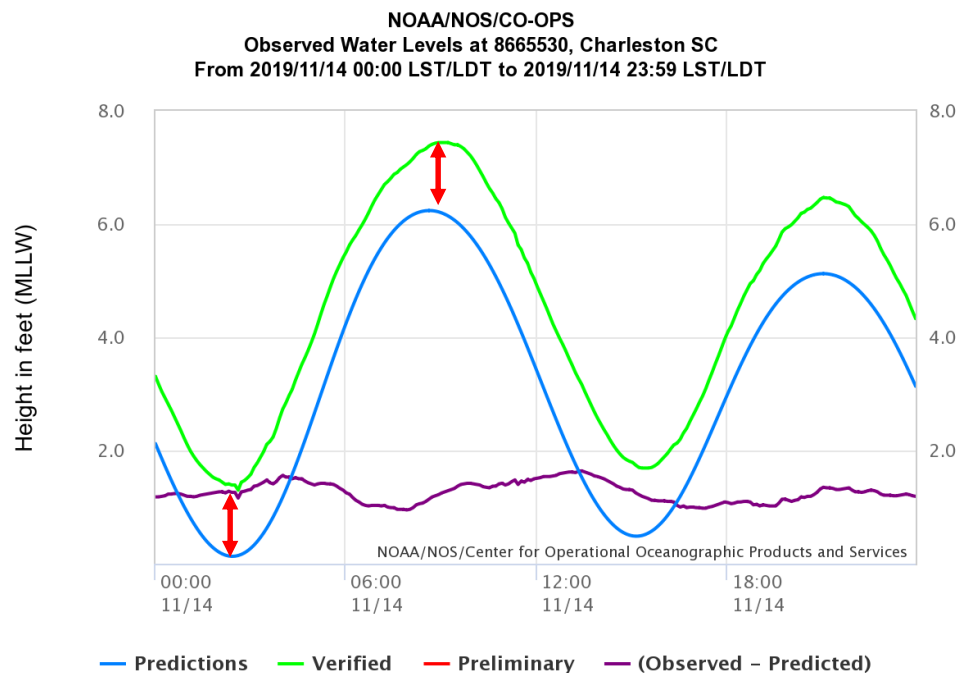
Forecast Tool Development

- Local project to extend the dataset through 2018
- Use 2019 events as a test case
 - Excellent opportunity with 89 events
- Linear regression analysis to provide a forecast tool used operationally
- Only utilized on the upcoming high tide, limits lead time
- But, could serve as a way to refine the forecast

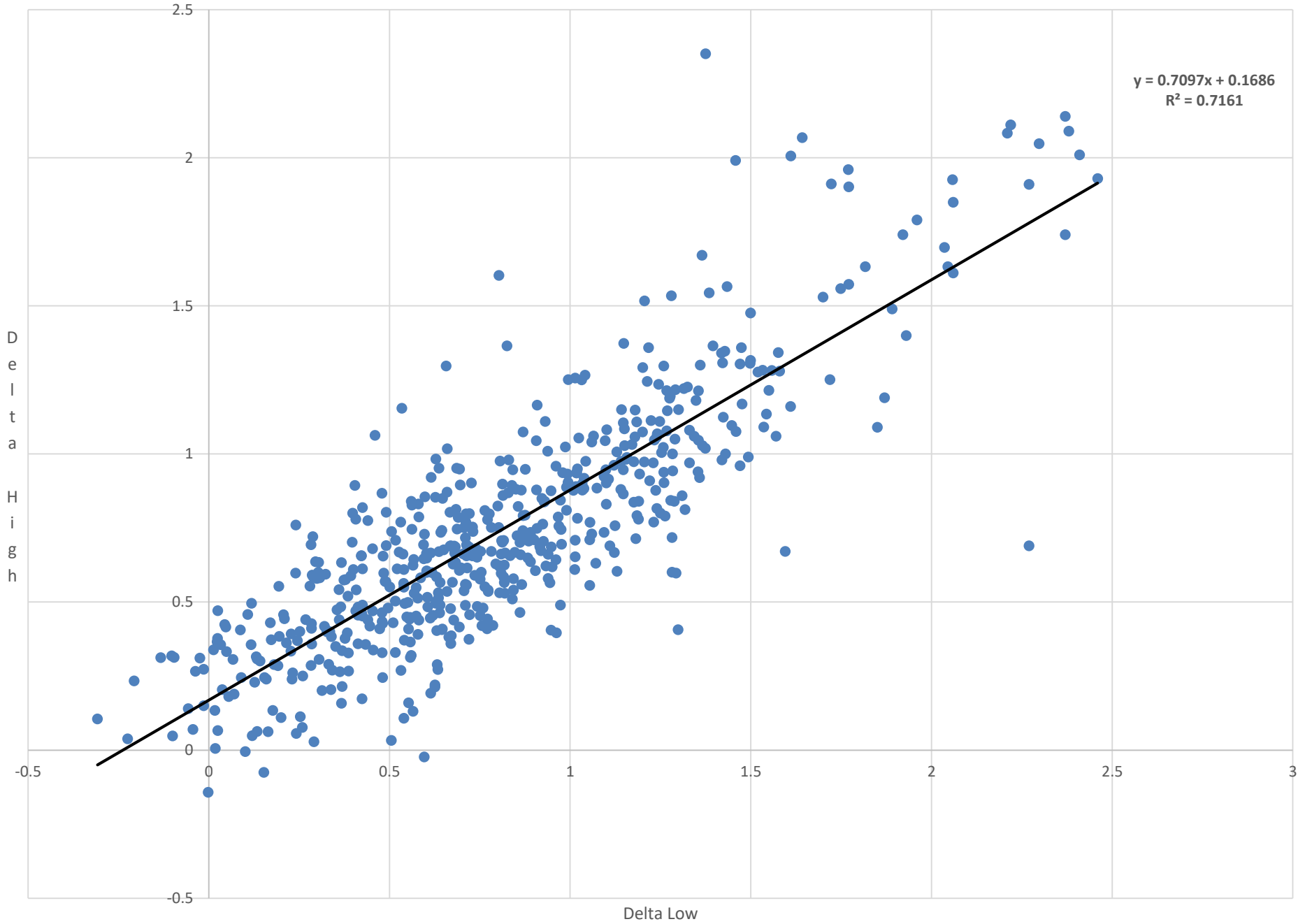


Forecast Tool Development

- Study included 627 total events from 1996-2018
 - Category A: 241 events (~38%)
 - Category B: 141 events (~22%)
 - Category C: 132 events (~21%)
 - Category D: 64 events (~10%)
 - Category E: 49 events (~8%)
- For analysis purposes, tropical events (Category E) are removed

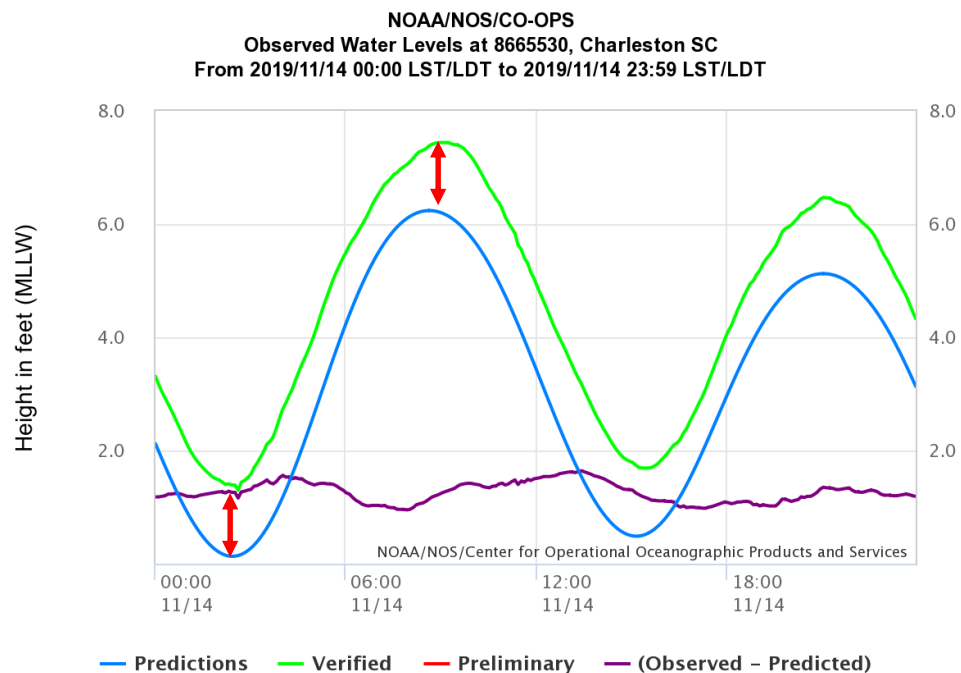


Delta Low vs. Delta High for All Non-Tropical Events 1996-2018



Preliminary Forecast Tool Performance

- 81 non-tropical events in 2019
- MAE = 0.16 ft
- For 34 events the forecast was within 0.10 ft (~42%)
- For 53 events the forecast was within 0.20 ft (~65%)
- Certainly shows some promise, but not a perfect tool
- Need to look at the specific events where the tool performs poorly to provide guidance to operational forecast staff



Conclusions

- Coastal flooding is repetitive and causes various short term and long term impacts to coastal communities
- A database of coastal flood events shows a distinct increasing trend over the last 40 years, with an acceleration over the last 5-10 years
- All sea-level rise scenarios show a sharp increase in coastal flooding over the next 20 years and beyond
- Tide forecasting is tricky, but there is an effort to develop new tools to improve forecasts and service

