Encroaching Tides

*How Sea Level Rise and Tidal Flooding Threaten U.S.
East and Gulf Coast Communities over the Next 30 Years*
www.ucsusa.org/encroachingtides

Appendix: Technical Background Document

Union of Concerned Scientists

Introduction

The Union of Concerned Scientists' coastal inundation analysis and accompanying report "Encroaching Tides" evaluates the potential impact of sea level rise on the frequency and severity of tidal flooding. While sea level rise stands to inundate significant stretches of the U.S. coastline by the end of this century, many places will be effectively inundated much earlier—within the next 30 years—as coastal flooding conditions begin to be met simply during the daily high tide.

Through our analysis of current conditions, we have identified places that are already coping with frequent minor coastal flooding. These floods are typically associated with a National Weather Service Coastal Flood Advisory that advises about disruptions to, for example, transportation or beach access, that do not pose risk to life and property. We then use localized sea level rise projections based on the National Climate Assessment scenarios to calculate flood frequency for two time horizons: 2030 and 2045.

Our analysis demonstrates that at least 40 of the 59 locations investigated up and down the East and Gulf Coasts would undergo a doubling (or more) in the number of coastal flooding events by the year 2030 in an Intermediate-High sea level rise scenario. By 2045, the majority of the locations we evaluated are projected to experience a 10-fold increase in flood frequency.

In addition to becoming more frequent, coastal floods are projected to become more severe. By 2045, nearly half of the locations we evaluated will be experiencing moderate coastal floods from the tidal fluctuations that cause only minor coastal floods today. Moderate coastal floods today are associated with National Weather Service Coastal Flood Warnings about imminent or immediate flooding which could pose a serious risk to life and property.

The majority of tidal flooding events today are limited in extent and duration, which is why the National Weather Service categorizes these events as "minor" flooding. In this report, we also refer to these events as "nuisance" flooding. While these floods typically do not pose a direct risk to life or property, they can–and do–present challenges to daily life.

This document outlines the methods and tools we have used for our coastal flooding project:

1. NOAA's National Ocean Service Tide Gauges
2. Flooding Thresholds from NOAA and National Weather Service Weather Forecast Offices
3. Calculating and confirming current flood frequency using the NOAA Center for Operational Oceanographic Products and Service's (CO-OPS) Inundation Analysis tool
4. Global sea level rise scenarios from the U.S. National Climate Assessment
5. Local, tide-gauge specific sea level rise projections from Climate Central
6. Calculating future flood frequency using NOAA's Inundation Analysis Tool
7. Calculating historical flood frequency using historical NOAA tide gauge data
8. Calculating when high tides reach the flooding threshold and when minor floods become moderate Floods
9. Estimates of uncertainty in the analyses

1. NOAA'S NATIONAL OCEAN SERVICE TIDE GAUGES: THE BASIS FOR ANALYSIS

Tide gauges maintained by NOAA's National Ocean Service form the basis of our analysis. To be included in the analysis, a gauge must have a defined flooding threshold for minor coastal flooding and be available within NOAA's online Inundation Analysis tool (NOAA Tides and Currents 2013b). Fifty-nine gauges along the East and Gulf coasts meet these requirements and serve as the basis for our analysis (see Figure 1). Throughout the report, we refer to some tide gauges by the name of the more recognizable nearby town. The gauges we do this for are: Sewells Point, VA (Norfolk); Springmaid Pier, SC (Myrtle Beach); Ft. Pulaski, GA (Savannah); Mayport, FL (Jacksonville); Virginia Key, FL (Miami); and Bay Waveland Yacht Club, MS (Bay St. Louis). In addition, we use the nearest available gauge to discuss changes in nearby areas that lack National Ocean Service tide gauges (e.g. using the tide gauge at The Battery, NY, to discuss flooding in Jamaica Bay, NY).

2. FLOODING THRESHOLDS FROM NOAA/NATIONAL WEATHER SERVICE WEATHER FORECAST OFFICES

When flood conditions are possible, imminent, or occurring, official statements are issued by Weather Forecast Offices, which are a component of the National Weather Service and NOAA. Using observations from tide gauges in their regions and working with local emergency managers, public safety officials, and citizen scientists, Weather Forecast Office officials have determined threshold water levels that are associated with flooding conditions in local areas. For each gauge, officials have defined a minor flooding threshold referenced to the Mean Lower Low Water (MLLW) tidal datum that corresponds to a water level that, when exceeded, will translate to on-the-ground flooding in a given area. Minor coastal flooding is typically associated with the issuance of a Coastal Flood Advisory, which alerts residents to minor, or nuisance, level flooding conditions that do not pose a serious risk to life and property (NWS 2009a).

Many Weather Forecast Offices have also defined thresholds for moderate flooding for the gauges in their area. Moderate coastal flooding, which results from higher water levels than minor coastal flooding, usually occurs when a high tide combines with a storm system that brings rain and forces wind and/or seawater onshore. This type of flooding is associated with a Coastal Flood Warning, which alerts residents to imminent or immediate flooding that could pose a serious risk to life and property (NWS 2009b).

It is important to note that these minor and moderate flooding thresholds are determined observationally rather than statistically. The statistical method defines floods by their return period and uses terms such as "100-year flood" or "10-year flood". In this analysis, we use observational flooding thresholds because they reflect water levels associated with observed local flooding.

For each tide gauge used in this analysis, a flooding threshold was obtained from the National Weather Service Advanced Hydrologic Prediction Service website. Each threshold was verified by contacting the appropriate Weather Forecast Office. In a few instances where the thresholds could not be confirmed, we relied on thresholds used within the NOAA Sea Level Rise Viewer (see Flood Frequency View) and provided by the NOAA Coastal Services Center (NOAA n.d.).

3. CALCULATING AND CONFIRMING CURRENT FLOOD FREQUENCY USING NOAA'S INUNDATION ANALYSIS TOOL

To calculate how frequently the minor coastal flooding threshold is currently exceeded at a particular gauge, we have used NOAA's Inundation Analysis tool (NOAA Tides and Currents 2013b). The Inundation Analysis tool allows the user to set a specific water level—for example the level required to exceed the minor or moderate flooding thresholds--and a specific date range. The tool then analyzes 6-minute water level observations for the specified date range and returns each event during which the flooding threshold was exceeded. The tool provides basic statistics about each event, such as its elevation above the specified water level and its duration. For example data from Boston in 2012, see Table 1.

To define a current flood frequency, we used a 5-year period from 2009 through 2013. We then calculated an average flood frequency per year over those 5 years to even out seasonal and short-term variability. However, this does not remove longer-term influences such as the multi-year and multi-decadal ocean cycles.

To confirm that the exceedances of the flooding threshold are consistently associated with the issuance of Coastal Flood Advisories, we went through every flood event identified by the Inundation Analysis method for each tide gauge for the two-year period 2012-2013 and determined whether it was correlated to a specific Coastal Flood Advisory. The 2012-2013 two-period was chosen because Weather Forecast Offices do adjust flooding thresholds over time based on observations. By using the most recent two year period available, we ensure that the threshold being used to issue Coastal Flood Advisories is the same as that used in the Inundation Analysis. It should be noted that the state of the El Nino Southern Oscillation was in weakly negative Southern Oscillation Index in 2012, followed by a weakly positive Southern Oscillation Index in 2013 (NCDC 2014).

Records of the issuances were accessed via the Iowa State Mesonet VTEC Browser (Iowa Environmental Mesonet 2014). For completeness – and because statements are issued differently in different situations – we also collected and checked Coastal Flood Statements, Warnings, and Watches, as well as Hurricane and Tropical Storm Statements, Warnings, and Watches in our analysis.

Fifty-two of the 59 tide gauges analyzed had a correlation of greater than two thirds (66%) between events identified by the Inundation Analysis and Coastal Flood Advisories or other statements (see Figure 2). That is, for these gauges, a Coastal Flood Advisory (or other statement) is issued at least 2 out of 3 times when water levels exceed the flooding threshold. We used this as a measure of whether the threshold at a particular tide gauge is a useful indicator of local flooding. Several of the tide gauges had no basis for evaluation (due to zero coastal flood events occurring during the evaluation period) and these have been included in the analysis after ensuring that no Coastal Flood Advisories were issued during the evaluation period either.

Most gauges also have instances of Coastal Flood Advisories being issued in the absence of an event that exceeds the flooding threshold. There are instances, for example, of Weather Forecast Offices issuing an advisory based on tidal predictions that do not manifest as being above the flooding threshold. A large number of issued Coastal Flood Advisories without correlative events in the Inundation Analysis would suggest a mismatch between threshold recorded at the tide gauge and the coastal flood advisories as inferred from the number of Coastal Flood Advisories. In such instances, our analysis would be a conservative estimate of current and future flood frequency.

There are many potential reasons why exceedances of the flooding threshold might not be associated with a Coastal Flood Advisory. In some locations, advisories are not issued if the tide is predicted to be just slightly above the flooding threshold for a very short period of time. In less populated regions, the tide may technically exceed the flooding threshold, but the Weather Forecast Office may not receive any on-the-ground reports of flooding. In other locations, such as coastal New Hampshire, the National Ocean Service tide gauge may be located in a different tidal environment than the nearby areas that are most flood-prone, making recorded tidal levels disconnected to the experience of flooding. Wind and wave height can also play into whether or not a Coastal Flood Advisory is issued, which may affect the correlation between tide height and advisories.

4. GLOBAL SEA LEVEL RISE SCENARIOS FROM THE NATIONAL CLIMATE ASSESSMENT

Three scenarios from the National Climate Assessment provide the backbone for the sea level rise projections used in this analysis. We have chosen the Intermediate-Low, Intermediate-High, and Highest scenarios. These scenarios rely on different projections of future global warming emissions. The primary differences between them, however, arise from the potential response of ice sheets to warming temperatures (Parris et al. 2012; Table 2). In addition, the projections include a local component of the sea level rise developed by Tebaldi, Strauss, and Zervas 2012 and obtained from Climate Central (Climate Central n.d.).

5. LOCAL, TIDE-GAUGE SPECIFIC SEA LEVEL RISE PROJECTIONS FROM CLIMATE CENTRAL

Climate Central has worked with a nearly identical set of tide gauges as the basis for their second generation Surging Seas tool. Using a set of three global sea level rise projections from the National Climate Assessment as a basis, Climate Central has calculated a localized sea level projection for each tide gauge on a decade-by-decade basis through 2100.

These projections are currently unpublished by Climate Central, but the methodology is similar to the group's earlier, published work using a different global sea level rise projection (Tebaldi, Strauss, and Zervas 2012). To generate local projections, Climate Central has evaluated the historical rate of sea level rise at each gauge and separated out a local component (i.e. the difference between the global average rate and the rate at that gauge). They then add that local component (keeping it steady) to a global sea level rise projection to calculate a gauge-specific sea level rise projection. They have used the Intermediate-Low, Intermediate-High, and Highest National Climate Assessment scenarios and have calculated the amount of sea level rise projected at each gauge for each decade through the end of this century (see Table 3).

Using a similar method to Climate Central in their Surging Seas tool, we have plotted the decadal projections for each gauge. We then fit a polynomial to the data (see Figure 3). We examined two time periods in our analysis: 2030 and 2045. Climate Central provided projections for sea level rise for 2030, and we calculated sea level rise for 2045 based on the polynomial fit to the data.

Local projections from Climate Central are not available for all of the gauges for which we have flooding thresholds and reliably associated Coastal Flood Advisories. In these instances, we have used Climate Central's nearest available local sea level rise projection to calculate future and past flood frequency (see Table 4).

6. CALCULATING FUTURE FLOOD FREQUENCY USING INUNDATION ANALYSIS

As sea level rises due to global warming, it becomes easier to reach the flooding threshold because the base water level increases while the flooding threshold remains constant. In essence, the height of the tide required to reach the flooding threshold is lower. To simulate this effect, we subtracted the projected amount of sea level rise for a gauge from the height required to reach the current flooding threshold and used the Inundation Analysis Tool for this new threshold for the 2009-2013 time period. A "future flood events" analysis typically returns both (i) the same events as the current flooding analysis – though with a longer duration, and (ii) additional events that did not meet the flooding threshold today, but would if sea level were higher. Matt Pendleton of the NOAA Coastal Services Center outlined this method in a blog post (Pendleton 2013), and we have had several conversations with Matt Pendleton, Doug Marcy, and Billy Sweet (all from NOAA) to confirm this methodology.

We have done this calculation for 2030 and 2045 for all three National Climate Assessment scenarios (Intermediate-Low, Intermediate-High, and Highest), though, for the purposes of the report, we have focused our attention primarily on the Intermediate-High scenario (see Figure 4).

7. CALCULATING HISTORICAL FLOOD FREQUENCY USING INUNDATION ANALYSIS

Records of the frequency of coastal flooding events in decades past are sparse, and the National Climatic Data Center only archives records of Coastal Flood Advisories, Warnings, etc. back to 1983 (Wall 2014). We have therefore calculated historical flood frequency directly from tide gauge data from 1970 to the present for a small subset of gauges. While the Inundation Analysis tool used to calculate current flood frequency relies on tide gauge data collected every 6 minutes, such data did not become available until the 1990s. In order to maintain consistency in our analysis from 1970 to the present, we have used hourly data archived on the NOAA Tides and Currents webpages (NOAA Tides and Currents 2014).

We analyzed the hourly tide gauge data to determine the number of hours per year when the current flooding threshold was exceeded and the total number of days with flooding annually.

In several instances, we have been able to compare our analysis of the hourly historical data to somewhat analogous records provided by external sources. For example, records from The Hague, a neighborhood in Norfolk, VA, show more than a quadrupling in the number of flooded hours annually since the 1970s (VIMS 2013). Our historical analysis for the Sewells Point tide gauge in Norfolk shows a roughly 5-fold increase in the number of days with flood events since the 1970s, a comparable change. Our results also align well with two recently published studies that calculate historical flood frequency at a larger set of NOAA tide gauges (Nelson, Wilson, and McNeill 2014; Sweet et al. 2014).

8. CALCULATING WHEN HIGH TIDES REACH THE FLOODING THRESHOLD AND WHEN MINOR FLOODS BECOME MODERATE FLOODS

To highlight the impact of rising seas in the short term, we calculated the year in which sea level rise would raise the high tide level up to today’s minor flooding threshold. In essence, this is the timeframe in which minor flood events become a nearly daily high tide occurrence. We used the Mean Higher High Water (MHHW) level—the mean of all the highest daily tides in a location over a year—to define high tide.

For this calculation, we first determined the difference between the current Mean Higher High Water level and the current minor flooding threshold. Then, using the sea level rise projections for each location, we calculated in what year that amount of sea level rise would take place. For instance, if “today” (using the baseline year of 2012) Mean Higher High Water level is 12 inches below the Flooding Threshold at a particular tide gauge, and the projections show that sea level will rise by 12 inches in 35 years’ time, then minor flood conditions will occur at Mean Higher High Water in 35 years’ time, in the year 2047 (see Figure 5).

Similarly, we wanted to know when sea level rise would cause tides that, today, cause only minor floods (with a Coastal Flood Advisory issued currently) but that would reach as high as a present-day moderate flood (one that has a Coastal Flood Warning issued). To do this we calculated the difference between the present day minor and moderate flood levels and again used the projections of sea level rise to determine how many years from now sea level would increase by that amount. For example, if there is currently a six inch difference between a minor and moderate flood in a particular location, and that location will see 6 inches of sea level rise in 20 years’ time, then by 2032 what would have been a minor flood today will be a moderate flood instead.

9. ESTIMATES OF UNCERTAINTY IN THE ANALYSES

In estimating the uncertainty of the projected flood frequency statistics we identify possible contributions from the following three analytical steps and discuss them below: (I) use of sea level rise projections, (II) use of NOAA tide gauge data and the NOAA Inundation Analysis tool, and (III) the correlation statistics between Coastal Flood Advisories and local flooding. There are inherent assumptions in our analysis, such as that land use, coastal morphology, and tidal ranges will continue to be predictable in each location for the short term future (15-30 years), though there is evidence that sea level rise will alter coastal morphology (e.g. FitzGerald et al. 2008) and may also increase tidal range (Flick, Murray, and Ewing 2003).

(I) SEA LEVEL RISE PROJECTIONS

In our main report, we chose to use the National Climate Assessment Intermediate-High scenario as a representative future pathway. Because this scenario is a potential one of many possible futures, there are many different assumptions connected with it: firstly, the emissions pathway that the global community follows, secondly the thermal expansion of the ocean, and thirdly the response of the land-based ice sheets. Sea level rise will affect stretches of our coastline in different ways depending on how land use and coastal morphology evolve in response to rising water levels. Because of the nature of these contributions, it does not make sense to explicitly quantify a resulting uncertainty from the use of this scenario in the context of our analysis but simply to be clear in the discussion as to the nature of the assumptions. We do not include uncertainties from the use of the projections. See more detailed analysis in Parris et al. 2012 and Tebaldi, Strauss, and Zervas 2012.

(II) TIDE GAUGE DATA, INUNDATION ANALYSIS TOOL – NOAA

The Inundation Analysis Tool uses frequency and inundation statistics from observed NOAA tide gauge data. The tide gauge data have a +/- 1-2cm uncertainty in high and low water measurements and a +/- 1-5cm uncertainty in the tidal datum elevation mark listed in the User Guide. While there are data gaps in the tide gauge records, only a single gauge included in our analysis is missing more than 3.5% of its data for our 2009-2013 evaluation period – Virginia Key, FL, at 6.4%. All the rest have 3.5% or less of the data missing.

The Inundation Analysis tool employs verified 6-minute data to determine whether a threshold was crossed. We presume that this means the data derived from the Inundation Analysis tool do not have an inherent uncertainty associated with them per se – flooding either occurred or it did not according to the verified records. Other than those quoted above, we have thus not included an uncertainty in our use of the statistics for calculating current flood frequency and duration.

We did however conduct a sensitivity analysis to the specified input flooding threshold by rounding the flooding threshold estimates to the nearest millimeter and estimate that this small change in flood threshold altered the calculated flood frequency by less than 1%. Because of the simplistic nature of the sea level projections we have used, the future flood frequency analysis should be considered an indicator of things to come rather than a predictor.

For further detail, see the online manuals for the NOAA Inundation Analysis Tool (CO-OPS 2013a; CO-OPS 2013b; CO-OPS 2008).

(III) COASTAL FLOOD ADVISORY CORRELATION

The use of Coastal Flood Advisories in this study was used to verify that – in a location where a flood threshold is exceeded – local flooding does in fact occur. It was used as a tool to select robust sites. We have chosen to include places that show a good correlation (at least two-thirds, 66.6% or better, with most locations showing 80% or better), not as a predictive tool but as a measure of the existence of local flooding. The projections of flooding for 2030 and 2045 reflect the rise in sea level at each location and are based on the current NOAA tide gauge data and the associated local sea level rise projections. The projected numbers of future floods are not based on the current correlation of Coastal Flood Advisories. For this reason, we do not see it as necessary to include an uncertainty in the projections based on the correlation with Coastal Flood Advisories, but rather we note that there is uncertainty inherent in the sea level rise projections and the NOAA tide gauge data.

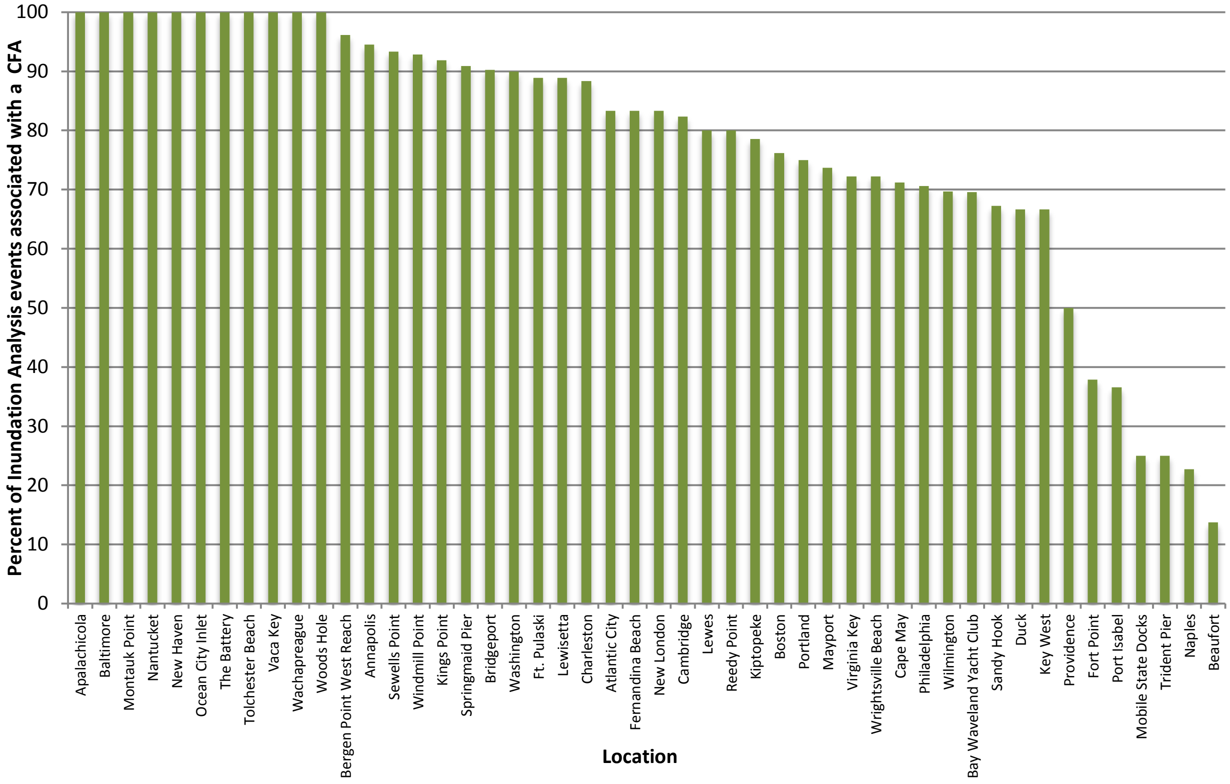
[FIGURES]

FIGURE 1. **East and Gulf Coast Locations in This Analysis**

Location of tide gauges on the East and Gulf coasts that were used in this analysis. Starred locations are profiled in the main report.

DATA SOURCE: NOAA TIDES AND CURRENTS 2014

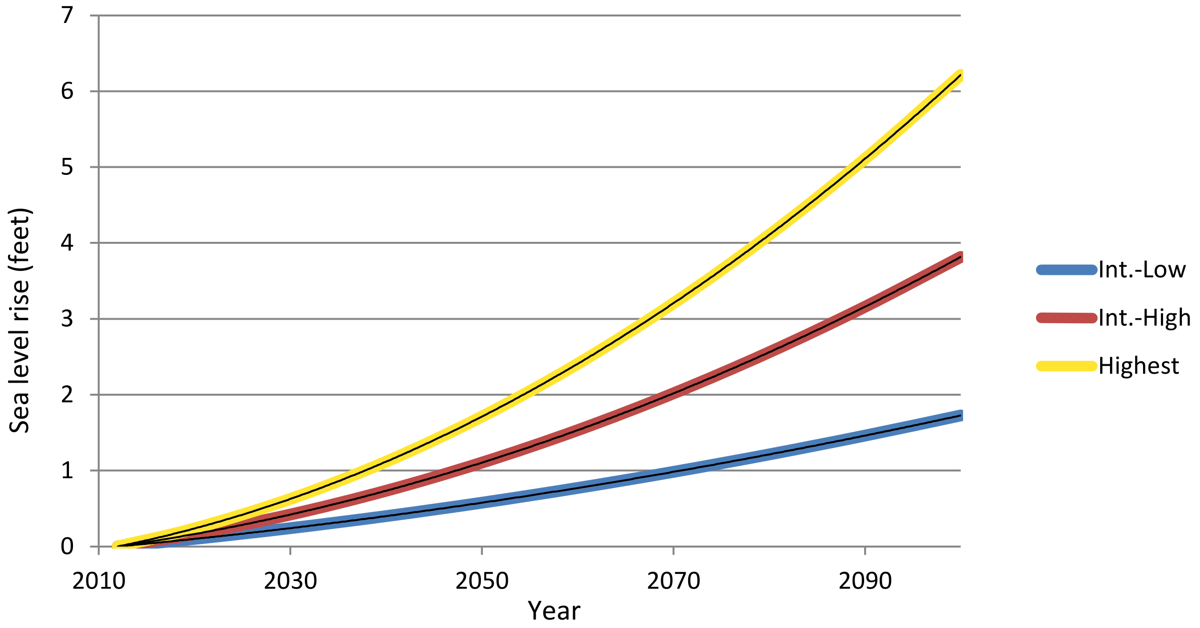
FIGURE 2. **Percent of Inundation Analysis Events Associated with a Coastal Flood Advisory 2012-2013**



Percent of events identified by the Inundation Analysis tool that are associated with a Coastal Flood Advisory for the years 2012 and 2013. Gauges with a correlation of less than 66.6% were excluded from further analysis.

DATA SOURCE: IOWA ENVIRONMENTAL MESONET 2014; NOAA TIDES AND CURRENTS 2013A

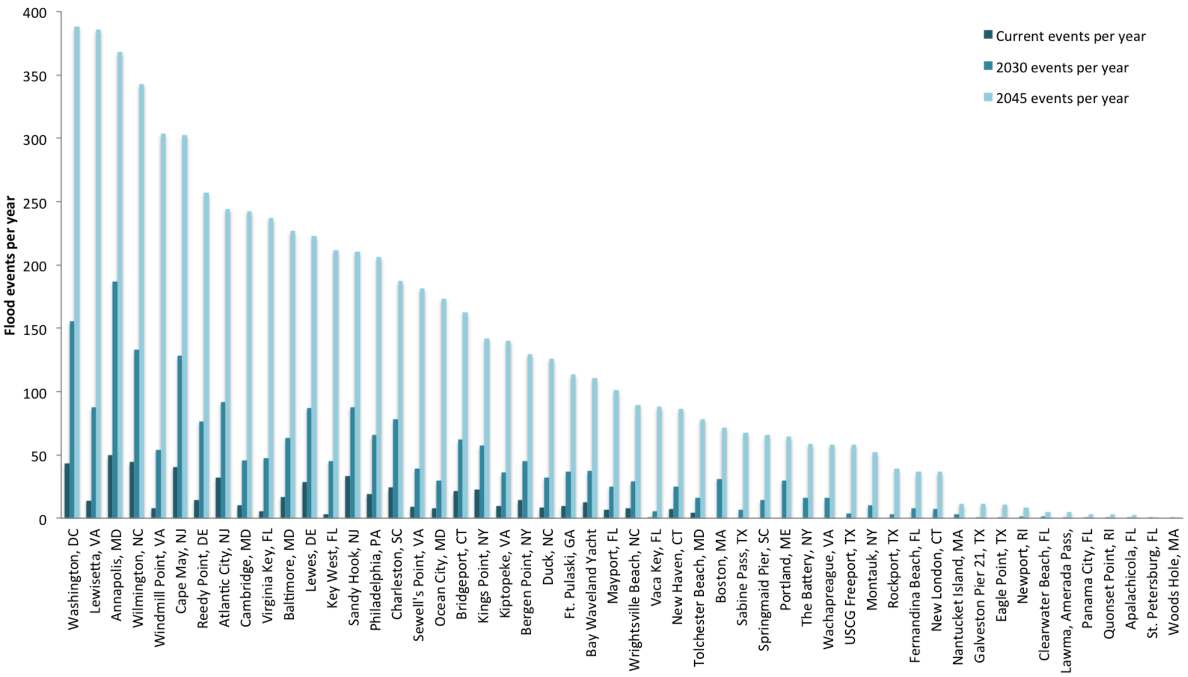
FIGURE 3. **Example of Projected Local Sea Level Rise**



Example of local sea-level rise projections from Climate Central. Localization is performed on top of the NCA Intermediate-Low (blue), Intermediate-High (red), and Highest (yellow) scenarios. Second order polynomials (black) are fit to each projection.

DATA SOURCE: CLIMATE CENTRAL N.D.

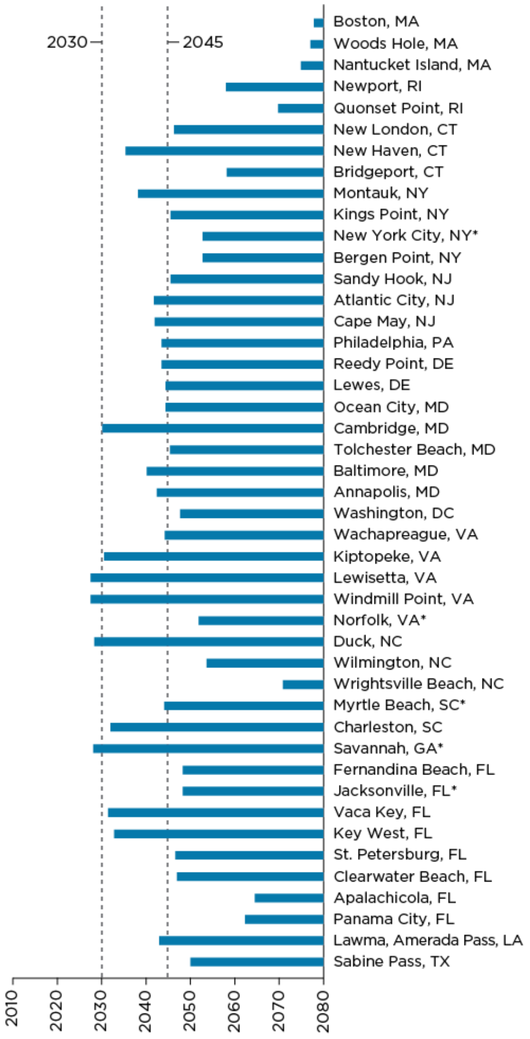
FIGURE 4. **Tidal Flooding Today, in 2030, and in 2045**



Projected number of minor flooding events per year for NOAA tide gauges selected for use in this study. Projections use the National Climate Assessment Intermediate-High scenario. Events that reach the minor flooding threshold initiate a Coastal Flood Advisory.

DATA SOURCE: SPANGER-SIEGFRIED, FITZPATRICK, AND DAHL 2014

FIGURE 5. **Year When Nuisance Floods Become Extensive**



Tides that cause minor, or nuisance, flooding today will be rolling in on higher seas in the future. The year when those tides begin to cause moderate, or more extensive, flooding, varies with the location. The time frame reflects the difference between today's minor and moderate flooding thresholds in each location, as determined by the National Weather Service, and the projected pace at which local sea level rise will lose the gap between the two. (Some locations included in our analysis, like Miami, do not have a defined threshold for moderate flooding. Locations are shown from north to south by state, wrapping around Florida to the Gulf Coast.)

DATA SOURCE: SPANGER-SIEGFRIED, FITZPATRICK, AND DAHL 2014

TABLE 1. **Sample Data Returned by the Inundation Analysis tool**

Period Start	Period End	Time of High Tide	Elevation (Meters) Above Datum	Tide Type	Duration (Hours)
2012-01-12 17:30	2012-01-12 18:42	2012-01-12 18:00	0.084	HH	1.2
2012-06-03 01:42	2012-06-03 02:24	2012-06-03 02:00	0.036	HH	0.7
2012-06-04 01:54	2012-06-04 04:06	2012-06-04 02:54	0.298	HH	2.2
2012-06-05 02:48	2012-06-05 05:00	2012-06-05 03:54	0.329	HH	2.2
2012-06-06 04:06	2012-06-06 05:30	2012-06-06 04:48	0.151	HH	1.4

Sample data returned by the Inundation Analysis tool. Example taken from the Boston tide gauge using the minor flooding threshold (12.5 feet above MLLW) for the year 2012.

DATA SOURCE: NOAA TIDES AND CURRENTS 2013A

TABLE 2. **Assumptions for Emissions, Ice Loss, and Ocean Warming for the National Climate Assessment Sea Level Rise Scenarios**

Scenario	Global Average SLR by 2100 (meters)	Global Average SLR by 2100 (feet)	Scenario Assumptions			
			Emissions Scenario	Ice	Oceans	Notes
Highest Scenario	2.0	6.6	A1B	Maximum loss on land ice.[a]	Warm as projected by IPCC AR4	This scenario combines maximum ice loss and a level of ocean warming associated with a middle-of-the-road emissions scenario (A1B) to calculate future sea level rise.
Intermediate-High Scenario	1.2	3.9	Models employ a range of IPCC AR4 SRES scenarios.[b]	Ice loss increases throughout the 21st century comes to dominate total sea level rise. Ice loss is simulated as a response within climate models.	Thermal expansion is simulated as a response within climate models. Its contribution to total sea level rise over the 21st century gradually declines.	This scenario represents the average of the high end of semi-empirical models that use observed data to extrapolate into the future.[c] Models rely on the existing observed relationships between global temperature and the rate of sea level rise, ice loss, and thermal expansion to project how future warming will affect Earth systems and, ultimately, cause sea level rise.
Intermediate-Low Scenario	0.5	1.6	B1	Minimal ice sheet loss	Warming as per IPCC AR4 B1	This scenario assumes aggressive decreases in GHG emissions. Sea level rise is primarily driven by thermal expansion, with minimal ice loss.

a: as modeled by Pfeffer, Harper, and O'Neel 2008
b: Vermeer and Rahmstorf 2009; Jevrejeva, Moore, and Grinsted 2010
c: i.e. Vermeer and Rahmstorf 2009; Horton et al. 2008; Jevrejeva, Moore, and Grinsted 2010

DATA SOURCE: ADAPTED FROM PARRIS ET AL. 2012

TABLE 3. **Excerpt of Data for Projected Local Sea Level Rise**

Boston, MA										
Year	2012	2020	2030	2040	2050	2060	2070	2080	2090	2100
Years from 2012	0	8	18	28	38	48	58	68	78	88
Int-Low	0	0.10	0.24	0.40	0.58	0.77	0.98	1.21	1.46	1.73
Ing-High	0	0.16	0.42	0.73	1.10	1.53	2.02	2.56	3.16	3.82
Highest	0	0.24	0.63	1.12	1.71	2.41	3.21	4.11	5.11	6.21

Excerpt of data from a local sea level rise projection from Climate Central. Data are for the Boston tide gauge and are in feet relative to 2012.

DATA SOURCE: CLIMATE CENTRAL N.D.

TABLE 4. **Full Data Set from this Analysis**

					Intermediate-Low Scenario				Intermediate-High Scenario				Highest Scenario					
State	**Tide Gauge**	**Gauge #**	**Record Start**	**Events Today**	**SLR 2030 (in)**	**Events 2030**	**SLR 2045 (in)**	**Events 2045**	**SLR 2030 (in)**	**Events 2030**	**SLR 2045 (in)**	**Events 2045**	**SLR 2030 (in)**	**Events 2030**	**SLR 2045 (in)**	**Events 2045**	**Nearest Projection**	**Miles to Projection**
CT	Bridgeport	8467150		21.6	3.0	42.0	6.0	73.2	5.1	62.0	11.3	162.4	7.6	93.2	16.8	295.2		
CT	New Haven	8465705	1964	7.2	3.0	15.2	6.0	30.8	5.1	25.2	11.3	86.4	7.6	45.2	16.8	199.4	Bridgeport	27
CT	New London	8461490		2.2	3.0	4.2	6.1	9.8	5.2	7.2	11.4	36.6	7.6	15.0	16.9	135.6		
DC	Washington, DC	8594900	1938	43.2	3.3	94.8	7.1	208.2	5.4	155.4	11.9	388.2	7.9	241.0	17.4	544.4		
DE	Lewes	8557380	1924	28.4	3.6	55.6	7.0	106.4	5.7	87.2	12.4	222.6	8.2	127.2	17.9	372.6		
DE	Reedy Point	8551910	1919	14.6	3.8	41.8	7.5	109.4	5.9	76.4	12.8	256.8	8.4	128.8	18.3	441.4		
FL	Apalachicola	8728690	1956	0.6	2.1	1.0	4.5	0.8	4.3	0.8	9.7	2.8	6.8	1.2	15.3	13.0		
FL	Clearwater Beach	8726724	1967	0.2	2.9	0.2	5.8	1.6	5.0	1.4	11.1	5.2	7.5	2.4	16.6	43.0		
FL	Fernandina Beach	8720030	1973	1.8	2.6	4.0	5.3	10.6	4.7	8.0	10.5	36.8	7.2	16.6	16.1	105.6		
FL	Key West	8724580	1987	3.0	2.8	19.0	5.7	57.2	5.0	45.2	11.0	211.6	7.4	95.2	16.5	435.4		
FL	Mayport	8720218	1913	6.6	2.6	13.0	5.3	29.8	4.7	25.2	10.5	101.2	7.2	50.0	16.1	242.6	Fernandina Beach	19
FL	Panama City	8729108		0.0	2.1	0.0	4.5	0.4	4.3	0.2	9.7	3.4	6.8	0.6	15.3	21.8	Apalachicola	51
FL	St. Petersburg	8726520		0.0	3.0	0.2	6.0	0.6	5.1	0.6	11.2	1.0	7.6	0.6	16.8	2.6		
FL	Vaca Key	8723970	1947	0.4	3.3	1.4	6.5	11.2	5.4	5.6	11.8	88.0	7.9	21.2	17.3	263.6		
FL	Virginia Key	8723214	1971	5.8	3.3	23.6	6.5	66.4	5.4	47.6	11.8	237.2	7.9	94.6	17.3	510.8	Vaca Key	92
GA	Ft. Pulaski	8670870		9.6	3.3	21.2	6.6	45.0	5.4	36.8	11.9	113.4	7.9	63.0	17.4	220.4		
LA	Lawma, Amerada Pass	8764227	1935	0.0	7.4	0.2	14.1	1.0	9.6	0.4	19.4	5.0	12.0	0.8	24.9	21.2	Grand Isle	84
MA	Boston	8443970		11.2	2.9	21.8	5.8	33.8	5.0	31.2	11.1	71.8	7.5	45.0	16.7	136.0		
MA	Nantucket Island	8449130	1921	0.6	3.5	1.6	6.9	3.8	5.6	3.0	12.2	11.6	8.1	4.8	17.7	53.6		
MA	Woods Hole	8447930	1965	0.2	3.0	0.2	6.1	0.2	5.2	0.2	11.4	0.4	7.7	0.2	16.9	2.2		
MD	Annapolis	8575512	1932	49.8	3.4	122.0	6.7	224.0	5.5	186.8	12.0	368.4	8.0	262.8	17.5	380.8		
MD	Baltimore	8574680	1928	17.0	3.3	36.2	6.5	84.2	5.4	63.2	11.8	226.8	7.9	115.6	17.3	381.0		
MD	Cambridge	8571892	1902	10.0	3.7	27.4	7.4	70.2	5.9	45.8	12.7	242.4	8.4	90.2	18.2	456.0		
MD	Ocean City	8570283	1943	7.6	3.6	18.2	7.0	42.6	5.7	29.6	12.4	173.4	8.2	59.6	17.9	411.6	Lewes	31
MD	Tolchester Beach	8573364	1975	4.4	3.3	9.0	6.5	20.8	5.4	16.2	11.8	78.4	7.9	29.4	17.3	226.4	Baltimore	45
ME	Portland	8418150		11.2	2.1	19.6	4.3	30.2	4.2	30.0	9.6	64.6	6.7	42.4	15.2	124.6		
MS	Bay Waveland Yacht Club	8747437	1912	12.8	2.5	22.0	5.2	41.2	4.7	37.4	10.5	110.4	7.1	60.2	16.0	223.4	Pensacola	83
NC	Duck	8651370		8.2	4.5	19.0	8.8	48.4	6.7	32.2	14.1	126.0	9.1	51.0	19.6	265.2	Sewells Point	62
NC	Wilmington	8658120	1978	44.4	2.5	88.6	5.1	145.2	4.6	133.2	10.4	343.0	7.1	209.8	15.9	557.8		
NC	Wrightsville Beach	8658163	1935	8.0	2.5	17.0	5.1	32.0	4.6	29.0	10.4	89.6	7.1	50.0	15.9	185.6	Wilmington	10
NJ	Atlantic City	8534720		31.8	4.3	67.8	8.3	125.2	6.4	92.0	13.7	244.2	8.9	134.6	19.2	391.0		
NJ	Cape May	8536110	1911	40.6	4.2	92.0	8.3	167.2	6.4	128.4	13.6	302.4	8.9	179.2	19.1	454.4		
NJ	Sandy Hook	8531680	1965	33.0	3.2	59.4	6.4	103.4	5.4	87.8	11.7	210.6	7.8	127.0	17.3	356.4	The Battery	16
NY	Bergen Point	8519483	1932	14.2	3.2	30.8	6.4	53.2	5.4	45.2	11.7	129.8	7.8	71.4	17.3	258.6	The Battery	8
NY	Kings Point	8516945		22.4	3.2	40.2	6.4	67.6	5.4	57.2	11.7	142.0	7.8	82.4	17.3	264.0	The Battery	15
NY	Montauk	8510560		3.0	3.5	6.4	6.9	14.8	5.6	10.2	12.2	52.2	8.1	19.0	17.7	168.8		
NY	The Battery	8518750	1947	5.4	3.2	9.4	6.4	20.8	5.4	16.2	11.7	58.8	7.8	28.6	17.3	148.4		
PA	Philadelphia	8545240	1856	19.0	3.8	39.8	7.5	95.4	5.9	66.0	12.8	206.2	8.4	112.8	18.3	367.0	Reedy Point	35
RI	Newport	8452660		0.0	3.0	0.8	6.1	1.8	5.2	1.4	11.4	8.4	7.6	2.4	16.9	33.6		
RI	Quonset Point	8454049	1930	0.0	3.0	0.0	6.1	0.6	4.9	0.4	10.8	3.2	7.3	1.0	16.3	13.8	Newport	7
SC	Charleston	8665530		24.2	3.1	50.4	6.2	94.0	5.2	78.2	11.5	187.4	7.7	114.8	17.0	347.0		
SC	Springmaid Pier	8661070	1921	3.6	3.6	8.4	7.2	21.0	5.8	14.6	12.4	65.6	8.2	26.4	18.0	139.4		
TX	Eagle Point	8771013	1957	0.0	5.5	0.2	10.7	2.2	7.7	0.8	16.0	10.8	10.2	2.2	21.5	40.8	Galveston Pier 21	14
TX	Galveston Pier 21	8771450		0.0	5.5	0.2	10.7	2.4	7.7	1.0	16.0	11.6	10.2	2.4	21.5	53.6		
TX	Rockport	8774770	1908	0.8	5.4	2.0	10.4	9.0	7.6	3.4	15.8	39.0	10.0	6.6	21.3	106.8		
TX	Sabine Pass	8770570	1948	0.2	4.9	2.6	9.6	15.2	7.1	6.6	14.9	67.4	9.6	15.2	20.4	217.0		
TX	USCG Freeport	8772447	1958	0.2	7.0	2.0	13.4	13.0	9.1	3.6	18.7	58.0	11.6	58.0	24.2	6.0	Freeport	1
VA	Kiptopeke	8632200	1954	9.6	3.6	20.4	7.1	46.2	5.7	36.0	12.4	140.4	8.2	60.2	17.9	336.6		
VA	Lewisetta	8635750	1951	14.0	4.9	48.8	9.6	162.2	7.1	87.6	14.9	386.0	9.6	159.8	20.4	533.6		
VA	Sewells Point	8638610	1974	9.0	4.5	27.0	8.8	64.4	6.7	39.2	14.1	181.6	9.1	70.8	19.6	389.4		
VA	Wachapreague	8631044	1927	5.0	3.6	11.0	7.1	20.6	5.7	16.0	12.4	58.2	8.2	25.4	17.9	154.4	Kiptopeke	35
VA	Windmill Point	8636580		7.8	4.9	27.6	9.6	95.2	7.1	54.0	14.9	303.8	9.6	95.0	20.4	500.2	Lewisetta	28

Sea-level rise projections courtesy of Climate Central.

DATA SOURCE: CLIMATE CENTRAL N.D.

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