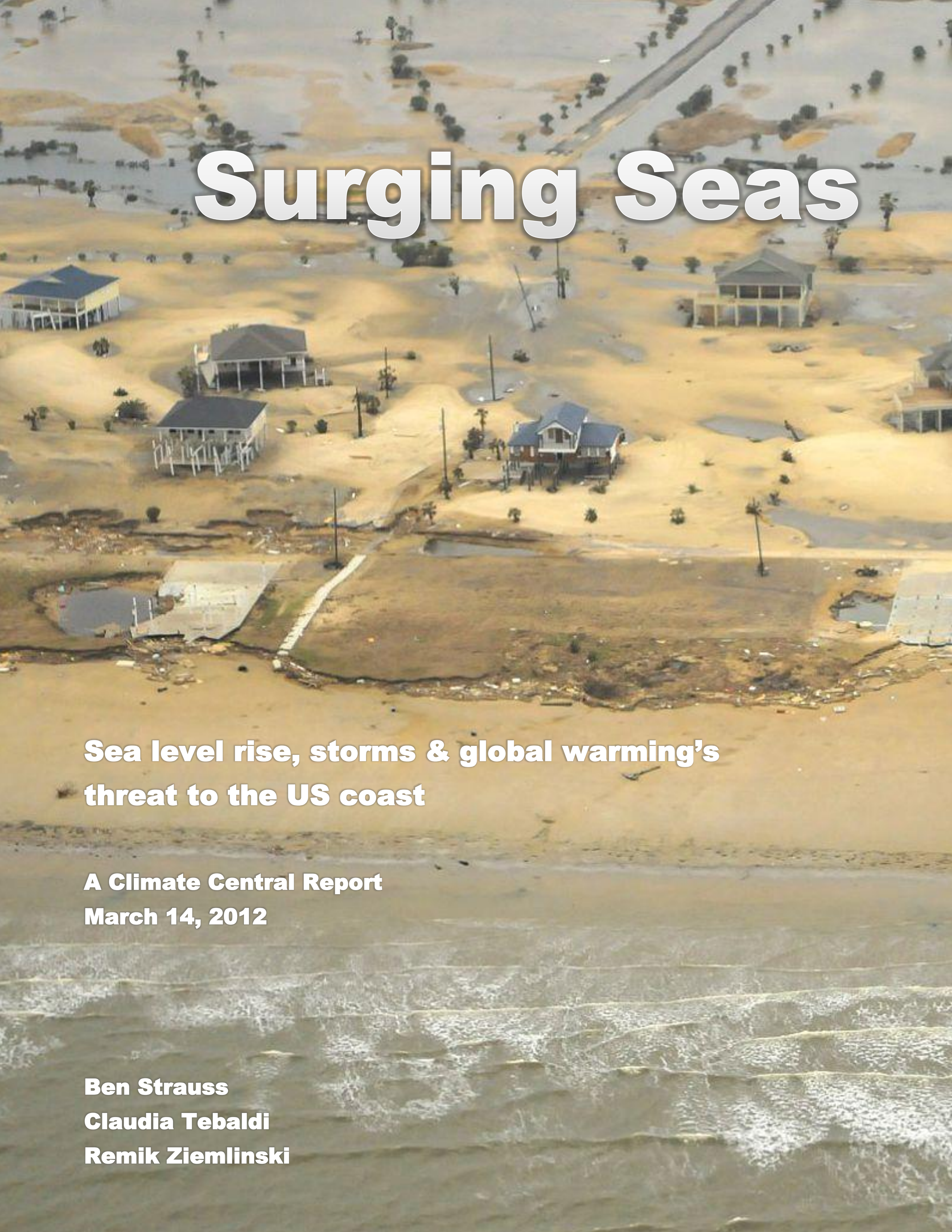

Surging Seas

Sea level rise, storms & global warming's threat to the US coast

A Climate Central Report
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Executive Summary

Global warming has raised sea level about 8 inches since 1880, and the rate of rise is accelerating. Scientists expect 20 to 80 more inches this century, a lot depending upon how much more heat-trapping pollution humanity puts into the sky. This study makes mid-range projections of 1-8 inches by 2030, and 4-19 inches by 2050, depending upon location across the contiguous 48 states.

Rising seas dramatically increase the odds of damaging floods from storm surges. For over two-thirds of the locations analyzed (and for 85% of sites outside the Gulf of Mexico), past and future global warming more than doubles the estimated odds of "century" or worse floods occurring within the next 18 years—meaning floods so high they would historically be expected just once per century. For over half the locations analyzed, warming at least triples the odds of century-plus floods over the same period. And for two-thirds the locations, sea level rise from warming has already more than doubled the odds of such a flood even this year.

These increases are likely to cause an enormous amount of damage. At three quarters of the 55 sites analyzed in this report, century levels are higher than 4 feet above the high tide line. Yet across the country, nearly 5 million people live in 2.6 million homes at *less* than 4 feet above high tide. In 285 cities and towns, more than half the population lives on land below this line, potential victims of increasingly likely climate-induced coastal flooding. 3.7 million live less than 1 meter above the tide.

About half of this exposed population, and eight of the top ten cities, are in the state of Florida. A preliminary independent analysis suggests about $30 billion in taxable property is vulnerable below the *three*-foot line in just three counties in southeast Florida, not including the county with the most homes at risk in the state and the nation, Miami-Dade. Small pockets or wide areas of vulnerability, however, exist in almost every other coastal state.

The population and homes exposed are just part of the story. Flooding to four feet would reach higher than a huge amount of dry land, covering some 3.0 million acres of roads, bridges, commercial buildings, military bases, agricultural lands, toxic waste dumps, schools, hospitals, and more. Coastal flooding made worse by global warming and rising seas promises to cause many billions of dollars of damage over the coming decades.

This report and its associated materials, based on two just-published peer-reviewed studies, is the first major national analysis of sea level rise in 20 years, and the first one ever to include:

- Estimates of land, population and housing at risk;
- Evaluations of every low-lying coastal town, city, county and state in the contiguous US;

- Localized timelines of storm surge threats integrating local sea level rise projections; and
- A freely available interactive map and data to download online (see SurgingSeas.org).

Summaries of these findings at a state-by-state level are available in fact sheets at SurgingSeas.org/factsheets. The original peer-reviewed studies can be found via SurgingSeas.org/papers. All findings reflect best estimates from the research; actual values may vary.

This report focuses on new research and analysis, not recommendations; but it is clear from the findings here that in order to avoid the worst impacts, the United States must work to slow sea level rise by reducing emissions of heat-trapping gases, and work to diminish the remaining danger by preparing for higher seas in coastal cities and counties everywhere. SurgingSeas.org/plans lists a selection of existing resources, plans and efforts to prepare, from local to national levels.

Sea level rising

Background

Global average sea level has increased over 8 inches since 1880,[1] and global warming has caused the great majority, if not all, of that rise.[2] Warming has acted in two main ways: by heating up and thus expanding the global ocean; and by attacking glaciers and polar ice sheets, pouring meltwater and icebergs into the sea.[3] The planet has heated by more than one degree Fahrenheit over the last century, rising faster as we have burned coal, oil and gas faster, and so sent ever more heat-trapping gases into the air.[4] Scientists overwhelmingly agree that these building gases are responsible for most of the warming observed thus far.[5]

Warming and sea level rise[6] are both accelerating, as is the rate of decay of ice sheets on Greenland and Antarctica.[7] Loss of ice from these sources has the potential to raise sea level by many tens of feet over centuries. In the warm period before the last Ice Age – when the planet was as warm as we expect it to become by 2100 or sooner, at least without deep and immediate cuts to pollution – global sea level very likely reached over 20 feet higher than it is today,[8] an eventual sea level we could be *committing* to within decades[9] if not already.[10] That rise would be enough to drown many major coastal metropolises.

Projections

This century, scientists expect about 20 to 80 more inches of global sea level rise, depending significantly on how much more heat-trapping pollution humankind puts into the sky.[11] The amount also depends on just how strongly pollution translates into warming, and just how strongly warming translates into sea rise. The analysis presented in this report, based on a paper by Tebaldi and others,[12] takes a wide range of possibilities into account. It also factors in the gradual sinking or rising of coastal land around much of the U.S., which leads to faster or slower rates of local sea level rise, compared to global rates.

This study's middle-of-the-road projections for 2030 range from one inch of local sea level rise in the northwest corner of Washington State, where the land is slowly rising, to 8 inches near New Orleans, where it is sinking. By 2050, these projections increase to 4 and 19 inches, respectively. Best- and worst-case projections range from lower to considerably higher values. Table 1 shows findings for all 55 locations studied, plus regional and national summaries.

Storm surge: The risk multiplier

Rising seas dramatically increase the odds of damaging floods from storm surges. For over two-thirds of the 55 locations analyzed (and for 85% of sites outside the Gulf of Mexico), past and future global warming more than doubles the estimated odds of "century" (or worse) floods occurring by 2030—meaning floods so high they would historically be seen with only a one percent (or less) chance per year. For over half the locations analyzed, warming at least triples the odds of century-plus floods. Figure 1 illustrates these changes around the nation, and Table 2 shows results at all flood study sites. Additionally, for two-thirds of the locations, sea level rise from warming has *already* at least doubled the annual risk of century-plus floods (see Table 2 and footnote 18). These calculations all incorporate the assumption that 90% of historic sea level rise has stemmed from warming.

The increases in odds come despite the fact that sea level rise from warming, over the next two decades and over the last century, is better measured in inches than in feet. In many places, only inches separate the once-a-decade flood from the once-a-century one; and separate the water level communities have prepared for, from the one no one has seen. Critically, a small change can make a big difference, like the last inch of water that overflows a tub. Sea level rise is raising the launch pad for storms and high tides, and being experienced by the ever-more frequent occurrence of extreme high water levels during these events – long before the ocean reaches damaging heights permanently.

Flood waters will reach different levels in different places on different schedules. Part of these differences will come from uneven local rates of sea level rise, part will come from chance, and part will come from how big local storm surges tend to be, which can vary a lot. Mostly because of this last factor, expected heights above high tide are generally about a foot higher than the national average in the Gulf of Mexico, and a foot lower than average in southern California and the southern Atlantic coast. But lower heights do not necessarily imply lower risk. For example, two feet of sea level rise should make an enormous difference in places where two-foot surges are rare extremes, and relatively less in places where ten-foot surges are sometimes seen.

This study found that at over half the sites examined, there is a one-in-two or better chance of water reaching at least 4 feet higher than the average local high tide by 2030, at least once. 85 percent of stations have at least one-in-six odds. By 2050, many locations should experience 5-foot or higher floods, with at least one-in-two odds at nearly half of stations, and at least one-in-six odds at nearly two-thirds. In all cases, sea level rise caused by global warming increases the odds, usually doubling or tripling them or more. Table 2 provides details for each site studied.

U.S. vulnerability

Floods exceeding these levels are likely to cause an enormous amount of damage. Across the country, nearly 5 million people live in 2.6 million homes on land less than 4 feet above high tide. In 285 cities and towns, more than half the population lives below this line, potential victims of increasingly likely climate-induced coastal flooding. And nationwide, over 6 million people live on land less than 5 feet above average high tide. Based on a paper by Strauss and others,[13] this study estimated the land, housing and population less than 1-10 feet above local high tide levels, for every coastal town, city, county and state in the contiguous 48 states. SurgingSeas.org presents full results in a searchable, interactive map and in tables. 3.7 million live on land less than 1 meter above the local high tide.

About half of the exposed population under 4 feet, and eight of the top ten cities, are in the state of Florida. A preliminary independent analysis suggests about $30 billion in taxable property lies below the *three*-foot line in just three counties in southeast Florida, not including the county with the most homes at risk in the state and the nation, Miami-Dade.[14]

Small pockets or wide areas of vulnerability, however, exist in almost every other coastal state, as Figure 2 makes clear. Table 3 shows the top ten states, counties and cities by total population living less than 4 feet above local high tide. State fact sheets at SurgingSeas.org/factsheets provide more summary information at a state level. The map at SurgingSeas.org links each city displayed with the nearest flood analysis site used in this study, as an indicator for when and with what chances a given water height might be achieved in the area. Actual odds may vary over even small distances.

The population and homes exposed are just part of the story. Flooding to four feet would reach higher than a huge amount of dry land, covering some 3 million acres of roads, bridges, commercial buildings, military bases, agricultural lands, toxic waste dumps, schools, hospitals, and more. Coastal flooding made worse by global warming and rising seas promises to cause many billions of dollars of damage over the coming decades. This report focuses on population, housing and land, but future analyses will address infrastructure, landmarks, and property threatened.

A number of state and local governments are beginning to plan or even take action against the challenge of sea level rise. SurgingSeas.org/plans presents a list and further resources.

Research methods

To make maps of low and vulnerable coastal land, this study used the highest-resolution nationwide coastal elevation data publicly available, from the National Elevation Dataset (US Geological Survey; cells ca. 30 feet on a side). We adjusted elevations to indicate heights compared to the nearest average high tide levels, because these can vary by several feet from place to place. Tidal information came from VDatum, a tool created by the National Oceanic and Atmospheric Administration. We then removed from consideration all wetland area as defined by the National Wetlands Inventory, and overlaid the remaining map elevation zones against high-resolution data from the 2010 Census to extract population and housing estimates. SurgingSeas.org/LandAnalysis provides more detail.

To analyze future high water levels from sea level rise plus storm surge and tides, we studied 55 water level gauges around the US. We combined local factors, such as sinking land, and global future sea level rise estimates, to make local sea level rise projections at each site. We then used historic patterns of local extreme water levels to forecast future probabilities of extremes assuming the same patterns continue, but augmented by the projected local sea level rise. Our analysis also included developing confidence intervals around best estimates. SurgingSeas.org/FloodAnalysis provides more detail.

To estimate how global warming shifts the odds of high storm surges, we computed extreme event probabilities in a hypothetical world with no warming-induced sea level rise, past or future, and then compared the results with our first calculations including warming. We retained local sea level change from vertical land movement in the no-warming scenario. Based on a review of scientific literature, we assumed that 10% of the global average sea level rise observed since 1880 came from factors other than warming, and so also retained this 10% of global rise in the no-warming scenario.

For more detail, visit SurgingSeas.org/research, which includes links to fuller descriptions of our methods, and the two core scientific papers upon which this report is based:

Tebaldi C, Strauss B H and Zervas C E 2012. Modelling sea level rise impacts on storm surges along US coasts. *Environmental Research Letters*.

Strauss B H, Ziemlinski R, Weiss J L, and Overpeck J T 2012. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. *Environmental Research Letters*.

Limitations

The results presented here should be interpreted with certain limits in mind. One set of limits comes from the elevation data used. Like almost any dataset, it includes errors – so any point classified as below a given height, may in fact be above it; and any point classified as above a height, may be below it. These potential errors should cancel out when evaluating the totals of what is affected over larger areas like towns, cities and counties. However, elevation error should be kept in mind when looking at any individual point on the map that accompanies this analysis (SurgingSeas.org/map).

Another issue from the elevation data concerns their horizontal resolution. Cells 30 feet on a side are too large to completely capture fine features like levees or seawalls, which may protect land even when it is below the water level, such as in the New Orleans area. Therefore, this analysis quantifies the land, housing and population *below* different threshold elevations – amounts not affected by built protection – but does not evaluate how much would be *inundated*, given each water level. Of course, many areas are not protected; protected areas are protected only to limited heights; and being below water level poses challenges for storm water drainage, increasing the risk of rain-driven flooding.

The analysis of flood odds and timing applies strictly only at the 55 water level gauge sites studied, and can only be considered general indicators for the surrounding areas. This is mainly because storm surge patterns can vary from place to place, even over short distances, due to geography and storm directions. Statistics among gauges sometimes correspond well over wide areas, suggesting wide applicability. But they also sometimes vary greatly over short distances, suggesting the opposite.

This report assumes that recent historic storm patterns do not change in the future. However, global warming may change the frequency or intensity of storms that affect coastal flooding. This analysis also leaves out projected changes in Atlantic circulation expected to add several extra inches of sea level rise along the Northeast Corridor by mid-century;[15] and projected changes in the "gravity fingerprint" of global oceans,[16] which may partly counteract the first change.[17]

Most broadly, this report presents our best estimates for the quantities analyzed, given the underlying data and our assumptions. True values are likely to fall above or below our estimates.

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Table 1. Projected sea level rise with 90% confidence intervals.

NOAA water level station	State	Projected sea level rise (inches) By 2030 Best estimate	By 2030 90% range	By 2050 Best estimate	By 2050 90% range
National average		5	2-9	12	6-22
Atlantic average		6	2-10	13	6-23
Gulf average		6	3-9	13	8-23
Pacific average		4	0-8	9	2-20
Eastport - Passamaquoddy Bay	ME	4	1-8	9	2-20
Portland - Casco Bay	ME	4	1-8	10	3-20
Boston - Boston Harbor	MA	5	2-9	12	5-22
Woods Hole - Buzzards Bay	MA	5	2-9	12	5-22
Nantucket Island, Nantucket Sound	MA	5	2-10	13	6-23
Newport - Narragansett Bay	RI	5	2-9	12	5-22
Providence - Providence River	RI	5	2-9	11	4-22
New London - Thames River	CT	5	2-9	12	5-22
Bridgeport - Bridgeport Harbor	CT	5	2-9	12	5-22
Montauk - Fort Pond Bay	NY	6	2-10	13	6-23
The Battery - New York Harbor	NY	5	2-9	13	6-23
Atlantic City - Atlantic Ocean	NJ	7	4-11	15	8-25
Cape May - Cape May Canal	NJ	6	3-10	15	8-25
Reedy Point - C&D Canal	DE	6	3-10	14	7-24
Lewes - Ft. Miles	DE	6	3-10	13	6-24
Cambridge, Choptank River	MD	6	2-10	13	6-23
Baltimore - Fort McHenry	MD	5	2-10	13	6-23
U.S. Naval Academy - Severn R.	MD	6	2-10	13	6-23
Solomons Island - Patuxent River	MD	6	3-10	14	7-25
Washington - Potomac River	DC	6	2-10	13	6-23
Kiptopeke - Chesapeake Bay	VA	6	3-10	14	7-24
Lewisetta - Potomac River	VA	7	4-11	16	9-26
Sewells Point - Hampton Roads	VA	7	4-11	16	9-26
Chesapeake Bay Bridge Tunnel	VA	8	5-12	17	10-28
Beaufort, Duke Marine Lab	NC	6	2-10	13	6-23
Wilmington - Cape Fear River	NC	5	2-9	11	4-22
Springmaid Pier - Atlantic Ocean	SC	6	3-10	14	7-25
Charleston - Cooper River Entrance	SC	5	2-10	13	6-23
Fort Pulaski - Savannah River	GA	6	3-10	13	6-24
Fernandina Beach - Amelia River	FL	5	2-9	12	5-22
Vaca Key - Florida Bay	FL	5	2-10	13	6-23
Key West	FL	5	2-9	12	5-22
Naples - Gulf Of Mexico	FL	5	1-9	11	4-22
St. Petersburg, Tampa Bay	FL	5	2-9	12	5-23
Clearwater Beach - Gulf Of Mexico	FL	5	2-9	12	5-22
Apalachicola - Apalachicola River	FL	4	1-8	10	3-20
Pensacola - Pensacola Bay	FL	5	1-9	11	4-21
Grand Isle, East Point	LA	8	7-12	19	14-27
Sabine Pass North	TX	5	3-8	11	7-20
Galveston Pier 21 - Galveston Channel	TX	7	5-10	16	12-24
Galveston Pleasure Pier - Gulf Of Mexico	TX	8	6-11	18	14-26
Freeport, Dow Barge Canal	TX	6	4-9	14	9-22
Rockport - Aransas Bay	TX	6	4-9	14	10-22
Port Isabel - Laguna Madre	TX	6	4-9	13	9-21
La Jolla - Pacific Ocean	CA	5	2-9	11	4-22
Los Angeles - Outer Harbor	CA	4	1-8	10	3-20
Port San Luis - Pacific Ocean	CA	3	0-7	9	2-19
Monterey - Monterey Harbor	CA	4	1-8	10	3-20
San Francisco - San Francisco Bay	CA	4	1-9	11	4-21
Charleston - Coos Bay	OR	4	0-8	9	2-20
South Beach - Yaquina River	OR	5	2-9	12	5-22
Astoria - Tongue Point	OR	3	-1-7	7	0-18
Toke Point - Willapa Bay	WA	4	1-8	10	3-20
Neah Bay - Strait of Juan De Fuca	WA	1	-2-5	4	-3-15
Seattle - Puget Sound	WA	4	1-9	11	4-21

Table 2. Increase in flood odds driven by sea level rise from global warming.[18]

NOAA water level station	State	Historic "century" floods: Height (feet)	Historic "century" floods: Projected Odds by 2030	Historic "century" floods: Global Warming Multiplier	Floods to 4 feet: Projected Odds by 2030	Floods to 4 feet: Global Warming Multiplier	Floods to 5 feet: Projected Odds by 2050	Floods to 5 feet: Global Warming Multiplier
Median, all listed stations		4.7	25%	>3	55%	1.9	41%	2.8
Median, listed Atlantic stations		4.7	27%	>3	43%	2.1	39%	2.9
Median, listed Gulf stations		6.6	20%	1.4	68%	1.4	71%	1.4
Median, listed Pacific stations		4.1	39%	>3	66%	>3	11%	>3
Eastport - Passamaquoddy Bay	ME	5.4	28%	>3	100%	1.2	98%	>3
Portland - Casco Bay	ME	4.0	36%	>3	24%	>3	2%	>3
Boston - Boston Harbor	MA	5.6	23%	2.5	90%	1.7	76%	2.5
Woods Hole - Buzzards Bay	MA	4.8	25%	>3	55%	2.4	41%	>3
Nantucket Island, Nantucket Sound	MA	4.4	28%	>3	37%	2.9	24%	>3
Newport - Narragansett Bay	RI	4.7	24%	2.7	47%	2.3	37%	2.9
Providence - Providence River	RI	8.5	20%	1.3	93%	1.2	94%	1.2
New London - Thames River	CT	4.1	37%	>3	35%	>3	10%	>3
Bridgeport - Bridgeport Harbor	CT	5.6	23%	2.6	86%	1.7	75%	2.4
Montauk - Fort Pond Bay	NY	4.2	36%	>3	39%	>3	16%	>3
The Battery - New York Harbor	NY	5.2	26%	>3	81%	2	65%	>3
Atlantic City - Atlantic Ocean	NJ	5.2	30%	>3	87%	1.8	74%	>3
Cape May - Cape May Canal	NJ	4.7	32%	>3	65%	2.7	45%	>3
Reedy Point - C&D Canal	DE	3.9	33%	>3	18%	>3	11%	>3
Lewes - Ft. Miles	DE	5.4	28%	>3	92%	1.7	78%	>3
Cambridge, Choptank River	MD	4.1	27%	>3	23%	2.4	19%	2.9
Baltimore - Fort McHenry	MD	5.7	22%	1.8	66%	1.7	63%	1.8
U.S. Naval Academy - Severn R.	MD	5.3	22%	1.9	53%	1.7	51%	1.9
Solomons Island - Patuxent River	MD	4.4	24%	2.1	28%	1.8	28%	2
Washington - Potomac River	DC	10.1	19%	1.2	95%	1.2	97%	1.1
Kiptopeke - Chesapeake Bay	VA	3.9	42%	>3	19%	>3	6%	>3
Lewisetta - Potomac River	VA	4.2	29%	2.9	25%	2.1	23%	2.7
Sewells Point - Hampton Roads	VA	5.4	29%	>3	89%	1.6	81%	2.6
Chesapeake Bay Bridge Tunnel	VA	4.8	45%	>3	79%	2.4	61%	>3
Beaufort, Duke Marine Lab	NC	4.9	22%	1.8	39%	1.7	40%	1.8
Wilmington - Cape Fear River	NC	4.0	24%	2.6	19%	2.2	17%	2.5
Springmaid Pier - Atlantic Ocean	SC	4.1	36%	>3	25%	>3	14%	>3
Charleston - Cooper River Entrance	SC	5.1	22%	1.9	50%	1.8	46%	2
Fort Pulaski - Savannah River	GA	3.3	83%	>3	0%	>3	0%	n/a
Fernandina Beach - Amelia River	FL	3.3	55%	>3	1%	>3	0%	>3
Vaca Key - Florida Bay	FL	3.0	25%	2.6	7%	1.7	8%	1.9
Key West	FL	3.1	24%	2.4	8%	1.7	9%	1.7
Naples - Gulf Of Mexico	FL	3.9	25%	>3	19%	2.9	12%	>3
St. Petersburg, Tampa Bay	FL	6.5	20%	1.5	69%	1.5	71%	1.5
Clearwater Beach - Gulf Of Mexico	FL	6.6	20%	1.4	67%	1.4	71%	1.5
Apalachicola - Apalachicola River	FL	15.0	19%	1.1	95%	1.1	98%	1.1
Pensacola - Pensacola Bay	FL	14.0	19%	1.1	85%	1.1	93%	1.1
Grand Isle, East Point	LA	9.2	20%	1.2	78%	1.3	89%	1.2
Sabine Pass North	TX	6.3	20%	1.4	61%	1.5	65%	1.5
Galveston Pier 21 - Galveston Channel	TX	7.0	21%	1.5	81%	1.3	86%	1.4
Galveston Pleasure Pier - Gulf Of Mexico	TX	11.3	20%	1.2	96%	1.1	99%	1.1
Freeport, Dow Barge Canal	TX	5.2	23%	2.1	62%	1.9	59%	2.3
Rockport - Aransas Bay	TX	6.1	20%	1.3	47%	1.5	56%	1.4
Port Isabel - Laguna Madre	TX	5.9	20%	1.4	45%	1.4	53%	1.5
La Jolla - Pacific Ocean	CA	3.2	89%	>3	0%	n/a	0%	n/a
Los Angeles - Outer Harbor	CA	3.2	83%	>3	0%	n/a	0%	n/a
Port San Luis - Pacific Ocean	CA	3.5	32%	>3	4%	>3	0%	>3
Monterey - Monterey Harbor	CA	3.4	39%	>3	2%	>3	0%	>3
San Francisco - San Francisco Bay	CA	4.1	27%	>3	28%	>3	14%	>3
Charleston - Coos Bay	OR	4.4	38%	>3	85%	>3	16%	>3
South Beach - Yaquina River	OR	4.6	42%	>3	94%	>3	42%	>3
Astoria - Tongue Point	OR	4.5	43%	>3	99%	>3	11%	>3
Toke Point - Willapa Bay	WA	6.5	24%	>3	100%	1	100%	1.2
Neah Bay - Strait of Juan De Fuca	WA	4.7	21%	>3	100%	>3	28%	>3
Seattle - Puget Sound	WA	4.1	65%	>3	66%	>3	2%	>3

Table 3. Top ten nationally-ranked states, counties and cities for largest total populations living on land less than four feet above local high tide.

Rank		Top 10 States		Top 10 Counties		Top 10 Cities
1		Florida		Miami-Dade, FL		New Orleans, LA*
2		Louisiana*		Broward, FL		New York, NY
3		California		Jefferson, LA*		Hialeah, FL
4		New York		Orleans, LA*		Metairie, LA*
5		New Jersey		Lee, FL		Pembroke Pines, FL
6		Virginia		Pinellas, FL		Cape Coral, FL
7		Texas		Nassau, NY		Miami Beach, FL
8		North Carolina		San Mateo, CA		Plantation, FL
9		South Carolina		Collier, FL		Miramar, FL
10		Massachusetts		Hillsborough, FL		Fort Lauderdale, FL

* includes significant populations on land already under the local high tide line, and protected by levees

Figure 1. Odds of century or worse floods by 2030, with and without sea level rise from global warming, at select sites. Table 2 provides detail for all sites studied.

Figure 2. City populations on land less than four feet above local high tide for 2,206 American cities. Nonlinear scale used.

Notes

[1] Church J A and White N J 2011. Sea-level rise from the late 19th to the early 21st century. *Surveys in Geophysics*
[2] Moore J C, Jevrejeva S and Grinsted A 2011. The historical global sea-level budget. *Annals of Glaciology.* Also Church J A, White N , Konikow L F, Domingues C M, Cogley J G, Rignot E, Gregory J M, van den Broeke M R, Monaghan A J, and Velicogna I 2011. Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. *Geophysical Research Letters.* Also Shum C K and Kuo C-Y 2011. Observation and geophysical causes of present-day sea-level rise. In *Climate Change and Food Security in South Asia*, R. Lal *et al*, eds.
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[7] Rignot E, Velicogna I, Van den Broeke M R, Monaghan A, and Lenaerts J 2011. Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise. *Geophysical Research Letters.*
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[18] Odds are for floods *by* given years, not within given years. Flood heights measured relative to local high tide. Century flood levels estimated using historic flooding patterns and assuming 2009 sea level as a baseline. Global warming multipliers indicate how much sea level rise from global warming has multiplied flood odds, compared to a world without warming, to reach the projected odds shown. 90% of historic global average sea level rise since 1880 is assumed to come from warming. Historic century flood odds have *already* doubled at all sites with multipliers >2 by 2030, except for at Solomons Island, MD and Freeport, TX, where odds have increased by 90% or more.

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