



CLIMATE  CENTRAL

FLORIDA AND THE SURGING SEA

A vulnerability assessment with projections for
sea level rise and coastal flood risk

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FLORIDA AND THE SURGING SEA

A VULNERABILITY ASSESSMENT WITH PROJECTIONS FOR SEA LEVEL RISE AND COASTAL FLOOD RISK

ABOUT CLIMATE CENTRAL

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Princeton: One Palmer Square, Suite 330 Princeton, NJ 08542

Phone: +1 609 924-3800

Toll Free: +1 877 4-CLI-SCI / +1 (877 425-4724)

www.climatecentral.org

REPORT AUTHORS

BEN STRAUSS, PhD, Lead

Vice President for Climate Impacts and Director of the Program on Sea Level Rise, Climate Central

Dr. Strauss directs Climate Central's Program on Sea Level Rise. He has published multiple scientific papers on sea level rise, testified before the U.S. Senate, and led development of the SurgingSeas.org coastal flood risk tool, leading to front-page coverage in the New York Times and Washington Post, appearances on NBC, ABC, CBS, PBS and NPR national programming. He holds a Ph.D. in Ecology and Evolutionary Biology from Princeton University, an M.S. in Zoology from the University of Washington, and a B.A. in Biology from Yale University.

CLAUDIA TEBALDI, PhD

Project Scientist, National Center for Atmospheric Research and Science Fellow, Climate Central

Dr. Tebaldi is a climate statistician at the National Center for Atmospheric Research and collaborates with the Climate Science and Impacts groups at Climate Central. Her research interests include the analysis of observations and climate model output in order to characterize observed and projected climatic changes and their uncertainties. She has published papers on detection and attribution of these changes, on extreme value analysis, future projections at regional levels, and impacts of climate change on agriculture and human health and she is currently a lead author for the IPCC Assessment Report, within Working Group 1. She has a Ph.D. in statistics from Duke University.

SCOTT KULP

Senior Developer and Research Associate, Climate Central

Scott Kulp serves as Senior Developer and Research Associate for Climate Central's Program on Sea Level Rise. Most recently he has worked on the development of Climate Central's Surging Seas 2.0 Analysis System and Risk Finder web toolkit. Previously, at Rutgers, he published several papers on the topic of 3D blood flow simulations as well as worked for the U.S. Department of Defense on several research projects. Scott holds an M.S. and is finishing a Ph.D. in Computer Science at Rutgers University, and holds a B.S. in Computer Science from Ursinus College.

CONTRIBUTORS

SUSAN CUTTER, PhD

Hazards and Vulnerability Research Institute, University of South Carolina

CHRIS EMRICH, PhD

Hazards and Vulnerability Research Institute, University of South Carolina

DANIEL RIZZA

Climate Central

DANIEL YAWITZ

Climate Central

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EXECUTIVE SUMMARY

Sea levels are rising at an accelerating rate, and the scientific community is confident that global warming is the most important cause. Higher sea levels translate to more and higher coastal floods. Using local sea level projections based on global scenarios from the U.S. Army Corps of Engineers, and also used by the four-county Southeast Florida Regional Climate Change Compact, this analysis finds that floods rising 3 ft above the high tide line at Key West are near certain this century under any sea level rise scenario. Six-foot floods range from very unlikely under slow rise, to 80% likely under fast rise. Key West has statistically the lowest flood levels of all eight water level stations analyzed in this study, from Pensacola to Tampa to Fernandina Beach, and thus makes a convenient least common denominator.

2120 square miles of land lie less than 3 feet above the high tide line in Florida. Some \$145 billion in property value, and 300,000 homes, sit on that land. These figures jump to \$544 billion and 1.4 million homes on 4660 square miles of land under 6 feet. Every inch of sea level rise within these ranges will be more damaging than the previous inch. This escalating risk, considered together with recent acceleration in sea level rise and projections for that trend to continue, places Florida in double jeopardy. Damage from sea level rise and coastal flooding is likely to turn sharply upward during the course of this century.

\$71 billion of Florida property sits on land less than two feet above the high tide line. Within less than the term of a 30-year mortgage, sea level rise could cause floods this high to occur once every five years, or even every year, depending on location within the state.

Florida has 2,555 miles of road below 3 feet, 35 public schools, one power plant, and 978 EPA-listed sites such as hazardous waste dumps and sewage plants. At 6 feet, these numbers grow to more than 16,000 miles of road, 300 schools, 14 power plants, and 5,509 EPA-listed sites.

This updated report is being released as a summary of findings coincident with the upgrade of a Florida Surging Seas Risk Finder online tool, accessible at <http://sealevel.climatecentral.org/ssrf/florida>

The tool includes:

- Interactive local projections of sea level rise and increasing coastal flood risk from 1-10 feet by decade;
- A zooming, zip-searchable map of low-lying areas threatened, plus layers showing social vulnerability, population density and property value;
- Detailed assessments of populations, property, infrastructure and contamination sources exposed, for each implicated county, city, town, zip code and more; and
- State- and county-wide heat maps facilitating high-level vulnerability comparisons.

Detailed knowledge of vulnerability is a critical tool for communities seeking to build resiliency to the climate challenges of today and the future.

01. INTRODUCTION

IN BRIEF

In March 2012, Climate Central released its first analysis of sea level rise and coastal flood threats in the United States. We published two [scientific papers](#) in a peer-reviewed journal; a [national report](#); fact sheets for each coastal state; and an interactive online map called [Surging Seas](#). About [800 stories](#) in local to national media covered our findings, and a [U.S. Senate committee](#) invited Climate Central to testify about the research in April 2012 – six months before Hurricane Sandy.

This report represents a major update to our 2012 analysis for Florida, using the same essential methods as our original work, but incorporating greatly improved and expanded data. The report summarizes major themes and findings taken from a much larger body of results accessible via a new interactive online tool, the [Florida Surging Seas Risk Finder](#).

RESEARCH IMPROVEMENTS

Our 2012 analysis used the best available national coverage elevation dataset at the time. This analysis uses far more accurate laser-based (lidar) elevation data. Our 2012 research assessed land, population and housing vulnerable to sea level rise and coastal flooding. This research assesses over 100 additional variables, including socially vulnerable populations, populations by racial and ethnic group, property value, roads, rail, airports, power plants, sewage plants, hazardous waste sites, schools, churches, and hospitals. Our 2012 analysis tabulated exposure at state, county, and city levels. This analysis adds zip codes, congressional districts, planning districts, state legislative districts, county commission districts, city council districts, and more.

For sea level rise projections, this analysis uses updated scenarios for future emissions of carbon pollution, as developed by the global climate research community. We use updated models of the global warming expected from these emissions, and a selection of global sea level rise models, instead of just one. We then factor in local effects, such as sinking land, to develop local sea level rise projections, employing the same methods as in our original peer-reviewed research.

We also carry forward the same methods we previously used to characterize storm surge risk, and integrate it with projected sea levels, to develop projections of overall local flood risk by decade. However, we have updated analysis inputs to include the full available record of hourly water levels at each water level station through the end of 2012. This means decades more data for most stations than the standard 30-year period used in the original analysis, increasing the robustness of our findings, providing a richer basis for our flood risk projections.

01. INTRODUCTION

FLORIDA SURGING SEAS RISK FINDER: A NEW ONLINE TOOL

The Surging Seas Risk Finder is searchable by geography, and offers easy navigation and visualization of analysis results from hundreds of thousands of combinations of location, water level, and risk element. The Risk Finder is divided into four components:

- Map: Interactive zooming map of sea level and flood risk zones
- Forecast: Projections of sea level rise and flood risk
- Analysis: Detailed analysis of exposed population, assets and infrastructure by individual location, from zip to state level
- Comparison: Comparisons of exposure across the whole state or selected county

02. A TIMELINE OF GROWING RISKS

Long before sea level rise permanently submerges new land, it will make its presence felt through higher and more frequent coastal floods, because higher seas raise the launch pad for storm surge.

In fact, every coastal flood today is already wider, deeper and more damaging because of the roughly 8 inches (IPCC 2013) of warming-driven global sea level rise that has taken place since 1900. This analysis finds that this rise has already increased the annual chance of extreme coastal floods threefold at Key West, a proxy for Southeast Florida more generally, and by 40% at St. Petersburg. Assuming medium or fast sea-level-rise scenarios, we estimate that historically unprecedented flooding would be certain this century at Key West and St. Petersburg alike, with a roughly 1-in-2 chance by midcentury at St. Petersburg. Three-foot floods at Key West are near certain under any scenario, but 6-ft floods this century range from very unlikely under slow rise, to 80% likely under fast rise.

This section explores projected sea level rise and how it aggravates coastal flooding.

SEA LEVEL RISE PROJECTIONS

This analysis projects a main range of local sea level rise from 0.6-1.3 feet by 2050, and 1.7-4.7 feet by 2100, at Key West, using sea level in 2012 as the baseline. End-of-century projections at the seven other water level stations analyzed around the state range from about 3 inches lower (Apalachicola) to about 2 inches higher (Vaca Key). Projections align closely with the unified sea level rise projections of the Southeast Florida Regional Climate Change Compact (2011).

02. A TIMELINE OF GROWING RISKS

Global Sea Level Rise Projections

The Earth's average temperature has warmed by more than one degree Fahrenheit over the last century, and scientists overwhelmingly agree that most or all of this warming comes from human influence (IPCC 2013). This influence comes mainly through the burning of fossil fuels and resulting accumulation of carbon dioxide in the atmosphere.

Global sea level rise is one of the scientifically best-established consequences of this warming. Warming shrinks glaciers and ice sheets, adding water to the ocean; and also heats up the ocean, expanding it. Over the past two decades, global sea level has risen roughly twice as fast as it did during the 20th century.

Projecting future sea level is a difficult scientific challenge, not least because it will depend upon how much more carbon humans put into the atmosphere. For global sea level rise projections, this analysis relies on scenarios developed by the National Research Council (1987) as adapted by the U. S. Army Corps of Engineers (USACE 2011) and the Southeast Florida Regional Climate Change Compact (Compact 2011). We focus on the low, intermediate, and high sea level rise scenarios from USACE, which point to 1.6 ft, 3.3 ft, or 4.9 ft of sea level rise globally by 2100, from a 1992 starting point. For simplicity, we call these scenarios "slow," "medium" and "fast." The slow and fast scenarios correspond to the range for global sea-level rise used in the Compact's unified projections.

These projections are similar in approach and within the range of those provided more recently by the National Oceanic and Atmospheric Administration (NOAA) and collaborating agencies for the U.S. National Climate Assessment (Parris et al 2012).

The Intergovernmental Panel on Climate Change recently released its Fifth Assessment Report on climate science (IPCC 2013). IPCC's sea level projections range from 0.9-3.2 feet by 2100, but explicitly do not include a potential rapid ice sheet breakdown scenario. The "fast" scenario in this report based on USACE guidelines is intended to reflect such a possibility, although it is not as high as the maximum plausible rise included among NOAA scenarios.

Surging Seas Risk Finder, the interactive web tool accompanying this report, includes projections based on all three USACE scenarios; four NOAA scenarios; IPCC projections; semi-empirical projections developed by Vermeer and Rahmstorf (2009); and a no-global-warming scenario for comparison. We will add additional global sea level rise projections over time.

Local Sea Level Rise Projections

Local sea level rise can differ from global sea level rise for many reasons. The ocean is not flat, and shifting currents and sea surface temperatures can alter local sea level trends over years or decades. In addition, landmasses are slowly sinking or (more rarely) rising in many coastal areas, augmenting or diminishing local sea level rise. Such vertical land motion is not a major concern in Florida.

02. A TIMELINE OF GROWING RISKS

Sea Level Rise Multiplies Flood Risk at Key West: Projections

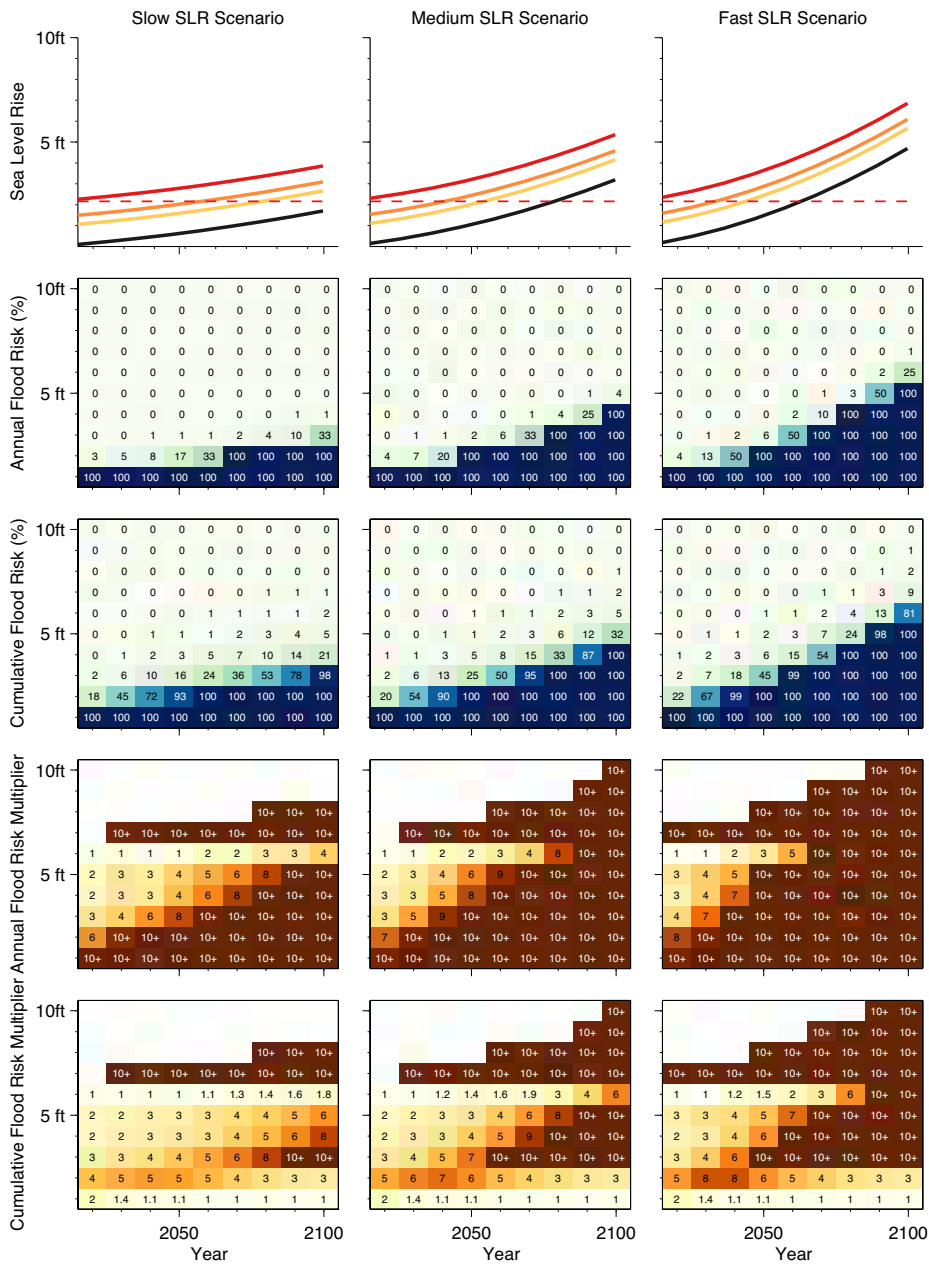


Figure 1. Sea Level Rise Multiplies Flood Risk at Key West: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

02. A TIMELINE OF GROWING RISKS

This analysis employs the same method as Tebaldi et al (2012) to develop projections for each location studied. In essence, we compare global sea level rise to local sea level rise measured at a water level station over a 50-year period. We use the difference to define a local component of sea level rise, and assume that the local component rate will continue unchanged into the future. This is a reasonable assumption at least for the effects of sinking or rising land, effects important enough to account for most or all of the long-term local component in most places (Tebaldi et al 2012). (See Appendix A or Tebaldi et al (2012) for more detail.)

This peer-reviewed method is very similar to the approach recommended by the USACE and used by the Compact for adapting global projections locally. Our results fall within 1-2 inches of Compact unified projections for 2060 at Key West.

Overall, we developed projections at water level stations at 8 water level stations around Florida. Projections across these locations varied only slightly. Our analysis projects a main range of local sea level rise from 0.6-1.3 feet by 2050, and 1.7-4.7 feet by 2100, at Key West, using sea level in 2012 as the baseline. End-of-century projections at the seven other water level stations range from about 3 inches lower (Apalachicola) to about 2 inches higher (Vaca Key).

The lower numbers are our “slow” projections and correspond to the Compact’s lower projections. The higher numbers are our “fast” projections and correspond to the Compact’s upper projections. Our “medium” projections fall almost exactly between slow and fast, amounting to 0.9 ft for 2050 and 3.2 ft for 2100 at Key West. For projection plots, see the top row of Figure 1 (for Key West), or Figures B1-7 (for the remaining stations).

The projections given in this analysis should be taken as indicative of long-term trends, and not as precise projections for specific years. Global and local sea level experience natural ups and downs over years and decades that may temporarily obscure the underlying trend, but which will balance out over time.

02. A TIMELINE OF GROWING RISKS

Table 1. Stations Data and Basic Analysis

	Fernandina Beach	Vaca Key	Key West	Naples	St. Petersburg	Clearwater	Apalachicola	Pensacola
Start of historic record used for storm surge analysis	1897	1979	1913	1979	1946	1979	1979	1923
Extreme flood level based on statistical analysis of historic record (ft)	3.1	2.6	2.2	3.2	4.9	5.4	12.3	7
Highest observed flood during historic period (ft)	6.9	5.8	3.1	3.1	4	4.1	6.4	7.4
Year of highest observed flood	1898	2005	2005	1972	1985	1993	2005	1926
Observed local sea level rise during historic record (ft)	0.8	0.4	0.8	0.4	0.6	0.3	0.2	0.6
GW multiplier: How much past sea level rise from global warming has already multiplied the annual chances of topping extreme flood level	7	1.8	3	3	1.4	1.3	1.1	1.2
Sea level rise projections, 2050 (ft)	0.5 - 1.3	0.6 - 1.4	0.6 - 1.3	0.5 - 1.3	0.6 - 1.3	0.6 - 1.3	0.4 - 1.2	0.5 - 1.3
Sea level rise projections, 2100 (ft)	1.6 - 4.6	1.9 - 4.9	1.7 - 4.7	1.6 - 4.6	1.8 - 4.7	1.7 - 4.7	1.4 - 4.4	1.6 - 4.6

Extreme flood level is defined as the water level with a 1% annual chance of being exceeded, commonly referred to as a “100-year” flood. All heights are relative to the Mean Higher High Water (MHHW; the high tide line). All station records run through the end of 2012...

02. A TIMELINE OF GROWING RISKS

COASTAL FLOODING: HISTORY AND PROJECTIONS

Rising seas raise the launch pad for storm surge, driving coastal floods higher. This study projects future flood risk by superimposing sea level rise projections onto historical patterns of flooding. In other words, we assume that coastal storm statistics remain constant – the same frequency and intensity of coastal storms – while sea levels rise. There is evidence that storm surges have been increasing with global warming (Grinsted et al 2013). If such a trend were to continue, it would mean that our assumption makes our risk estimates lower than they should be.

Historical Analysis to Define Extreme Floods

The first step in this approach is to characterize historical coastal flood risk at each study site – in this case, the eight water level stations assessed around Florida. We apply standard methods to estimate the precise relationship between a flood’s height and its annual likelihood (the higher the rarer), based on a long historical record of hourly water levels. For example, we estimate that a flood with a 1% annual chance – what we call an “extreme” flood in this study, and commonly referred to as a “100-year” flood – reaches 2.2 feet above the high tide line at Key West. For reference, this level has been exceeded just once at Key West station (3.1 ft) since it began operation in 1913.

In Southeast Florida, tides and coastal floods are very mild – generally except in the rare instance of a hurricane track falling nearby to a location.

We apply the same methods as Tebaldi et al (2012) for this analysis (see Appendix A for a brief summary). However, we update our previous findings by now including water level records through the end of 2012, and back to the earliest year with reliable records at each water level station. Table 1 provides details and findings for each station, including the highest observed flood in the record of each station. This allows us to project future risks of “unprecedented” floods as well as statistically “extreme” ones.

In this report, we give all flood heights and water levels in elevations relative to Mean Higher High Water (MHHW), or what we more simply call today’s “high tide line,” defined based on tide levels during NOAA’s standard 1983-2001 tidal “epoch.” Our purpose is to give a good sense of how high floods might reach above normal local high water lines. Different sources use different reference frames, so Appendix C provides tables for converting to and from a variety of them, including Mean Lower Low Water (MLLW) and standard modern map elevation (North American Vertical Datum 1988, or NAVD88).

Flood level (or storm tide) is the sum of the tidal level at a given time, plus the storm surge (the extra water driven by a storm), plus the extra baseline component contributed by sea level rise.

02. A TIMELINE OF GROWING RISKS

Coastal Flood Projections

As sea levels rise, they increase the chances of extreme floods by today's standards. For example, an extreme flood reaching 2.2 feet above the present high tide line at Key West would today require a 1%-annual-chance combination of storm surge and tide. But after 9 inches of sea level rise, a flood reaching the same absolute elevation would only require a 9-inch-lesser combination of storm and tide, coming with a roughly 10% annual chance. After 14 inches of sea level rise, a flood to 2.2 ft would be an annual event.

Table 2 shows how different rates of sea level rise affect the annual and cumulative chances for floods that exceed the 2.2-foot extreme flood level at Key West in the decades ahead. We find a roughly 40% cumulative chance of at least one flood this high by 2030, and a 50% annual chance of such a flood by midcentury, given a medium rate of sea level rise. Tables B1-7 give the equivalent flood risk projections for other stations around the state.

We conducted the same analysis for water levels from 1-10 ft above the high tide line, computing probabilities for each level by decade. Findings are shown for Key West in Figure 1, and for other stations in Figures B1-7. The results indicate a roughly 80% chance for a 6-ft flood at Key West by the end of the century given fast sea level rise, or a 2% chance given slow sea level rise. Three-foot floods (or permanent submersion at that level) are near certain under any scenario. Assuming medium rise, local floods unprecedented in the station record (5 ft) have a roughly 1-in-2 chance in St. Petersburg by midcentury.

A critical feature of these projections is how, at many water levels, annual flood risk may increase from near-negligible levels to near-certain ones within a few decades, even within the life of a thirty-year mortgage. Such a flood risk cliff would swiftly transform a property that seemed safe to one that may be untenable. For example, the annual risk of a flood to 2 ft at Key West jumps from 4% in 2020, to 100% in 2050 (or about 1.5% today, to 20% by 2040).

While sea level rise projections are quite similar for each of the water level stations studied, the local flood risk profiles vary more substantially. In general, flood risk by elevation can vary significantly across short distances, depending upon local geography. Thus the escalating flood risks computed for each station may be taken as *indicative* of increasing risk in its wider area, but should not be interpreted as providing *predictions* for nearby areas.

02. A TIMELINE OF GROWING RISKS

Global warming multiplies extreme flood risk

Since sea level rise multiplies extreme coastal flood risk, and global warming contributes to sea level rise, global warming multiplies flood risk. This effect is independent of any potential warming influence on storm frequency or intensity. We assessed the sea level driven global warming multiplier by comparing flood probabilities with and without the global component of sea level rise (leaving out local components that might come from sinking or rising land).

We found that global warming has already multiplied the likelihood of extreme floods in Florida by factors ranging from 1.1 (Apalachicola) to 7 (Fernandina Beach). Multipliers for the annual chances of extreme and higher floods are quite high throughout the century for all sea level rise scenarios at most Florida stations, quickly exceeding 10X in most cases – see Tables 2 and B1-7, and the second-to-last row of Figures 1 and B1-7. The multipliers generally grow more slowly at stations with higher extreme flood levels.

Multipliers for cumulative flood probabilities (last row of Figures 1 and B1-7) behave more complexly, because the cumulative risk for an extreme flood becomes substantial when accumulated across many decades, even in the absence of global sea level rise. This puts a cap on multiplier values: for example, a background 50% cumulative risk cannot have a multiplier any greater than 2X.

02. A TIMELINE OF GROWING RISKS

Table 2. Extreme Flood Projections at Key West

Extreme flood level is based on statistical analysis of historic record at the station: 2.2 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	3%	8%	100%	3	9	10+
Medium	4%	50%	100%	5	10+	10+
Fast	7%	100%	100%	7	10+	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	16%	30%	56%	-	-	-
Slow	31%	76%	100%	1.9	2	1.8
Medium	38%	100%	100%	2	3	1.8
Fast	47%	66%	100%	3	3	1.8

03. PEOPLE, PROPERTY AND INFRASTRUCTURE IN HARM'S WAY

2120 square miles of land lie less than 3 feet above the high tide line in Florida. Some \$145 billion in property value, and 300,000 homes, sit on that land. These figures jump to \$544 billion and 1.4 million homes on 4660 square miles of land under 6 feet. Every inch of sea level rise within these ranges will be more damaging than the previous inch. This escalating risk, considered together with recent acceleration in sea level rise and projections for that trend to continue, places Florida in double jeopardy. Damage from sea level rise and coastal flooding is likely to turn sharply upward during the course of this century.

Florida has 2,555 miles of road below 3 feet, 35 public schools, one power plant, and 978 EPA-listed sites such as hazardous waste dumps and sewage plants. At 6 feet, these numbers grow to more than 16,000 miles of road, 300 schools, 14 power plants, and 5,509 EPA-listed sites.

LAND

Florida has about 2120 square miles of land at less than 3 feet MHHW, more than doubling to 4660 square miles less than 6 ft above the tide line. Miami-Dade, Monroe, Broward and Collier Counties account for about half of this land at the higher level (and 40% at 3 ft).

These totals are based on analysis of high-resolution land and tidal elevation data from NOAA, after screening out areas classified as saltwater wetlands by the U.S. Fish and Wildlife Service (see Appendix A for more detailed methodology).

We further analyzed how much low-lying land might be protected by levees, sea walls, or natural features such as ridges: 16% of the total area below both 3 and 6 feet. We used levee data from FEMA's Midterm Levee Inventory, the most complete levee data publicly available. This analysis assumes levees are always high enough and in good condition; the inventory does not report these data. Much of the levee system is known to be in poor repair; but the inventory does not yet include most levees (American Society for Civil Engineers 2013).

In general, the connectivity of a specific area to the ocean at a given flood or water level can be difficult to assess. Areas that appear connected may not be connected, due to unmapped levees, seawalls or other protections. Areas that appear protected may not be protected, due to faulty levees, or connections via ditches, culverts or sewer lines. Elevation data error may also influence results.

In many areas of Florida, especially south Florida, the bedrock is highly porous limestone, meaning that levees or ridges will not be able to hold back water in the long run: it will penetrate through the ground underneath them.

Because of these complications, and because of the relatively small percentage of area that might be protected, this analysis follows Strauss et al (2012) and focuses on the simple metric of

03. PEOPLE, PROPERTY AND INFRASTRUCTURE IN HARM'S WAY

how much land falls below different threshold elevations. Further analysis addresses how much population, property and infrastructure sits on that land.

Our approach does not take into account, and also avoids complications from, future erosion as sea levels rise, and the uneven surfaces of floodwaters driven by individual storms, and influenced by details of local geography

Overall, the maps and analyses here should not be taken as precise predictions or flood emergency guides. Rather, we present them as risk indicators in a world of rising sea levels and increasing floods.

PEOPLE, PROPERTY AND INFRASTRUCTURE

Once maps of land below different threshold elevations are established, it is relatively straightforward to account for the populations, property and infrastructure exposed within these zones. The Surging Seas Risk Finder presents hundreds of thousands of combinations of analysis results by geography, water level, and variable. Here we present some of the major categories and highlights, with a focus on exposure below 3 and 6 feet.

We estimate that in Florida, \$35 billion in property value and 65,000 homes sit on land less than one foot above the local high tide line. \$71 billion and 136,000 homes sit below 2 feet, and \$145 billion and 300,000 homes below 3 ft. The numbers double with every vertical foot in this range.

More than \$544 billion and 1.4 million homes are on land below 6 ft.

The increasing density with every vertical foot suggests that the current pattern of development may reflect attempts to steer clear of historic flood risk. Housing density is 61 units per square mile between 0 and 1 ft above MHHW; 128 units per square mile between 1 and 2 ft; and 322 units between 2 and 3 ft. Similarly, property value density jumps from \$42,000 per acre to \$102,000 to \$227,000 across the same three vertical bands. (Both sets of calculations consider all land, not just owned or developed land.)

However, the same increasing density indicates that every inch of sea level rise in Florida will inflict more damage than the previous inch. And each foot could inflict twice the damage of the previous foot.

When considered together with the fact that sea level rise is already accelerating, and is projected to continue accelerating, the implication is that Florida faces double jeopardy. Damage from sea level rise, and the flooding it aggravates, appears likely to turn sharply upward during the course of this century.

\$71 billion of Florida property sits on land less than two feet above the high tide line. Within less than the term of a 30-year mortgage, the medium sea level rise scenario in this report would cause floods this high to occur once every five years, or even every year, depending on location within the state.

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Nonresidential buildings and infrastructure are widely at risk as well. All told, 2,555 miles of road in the state lie on land below 3 feet; 133 houses of worship; 35 public schools; two power plants; and 978 EPA-listed sites, screened to include mostly hazardous waste sites, facilities with significant hazardous materials, and wastewater generators. At 6 feet, these numbers grow to more than 16,000 miles of road, 458 houses of worship, 300 public schools, 14 power plants, and 5,509 EPA-listed sites.

Table 3 gives percentage exposure in these and further categories, with breakdowns by county. The Surging Seas Risk Finder presents complete analysis results, including many more categories and subcategories, tallied by city, town and zip code, as well as county, congressional district and statewide.

Exposure to sea level rise and coastal flooding is spread throughout the entire state of Florida. But while it is most pronounced in Southeast Florida, the counties Collier, Lee, Franklin, Charlotte, Pinellas, and St. Johns – in addition to Miami-Dade, Broward and Monroe – all have property and housing exposure rates disproportionately higher than the statewide averages.

Despite this widespread exposure, at a more granular level, a lot of risk is concentrated into a small number of zip codes – particularly at the lowest elevations. For example, 14% of the property value sitting on land less than 3 ft falls inside 5 zip codes, whereas 9% of property below 6 ft falls inside the top 5 zip codes at that level. Similar patterns hold for other variables such as population, housing and road miles, as shown in Table 4.

This analysis simplifies most facilities as points with a single latitude and longitude. It also evaluates exposure by evaluating the height of the land that structures sit upon. It takes into account neither the full footprint of a facility; nor the potential elevation of structures or equipment above ground; nor the possibility of unsealed basement areas. We regard such analysis as useful for assessing the general exposure of different facility types across different geographies, and as useful for screening the possible exposure of individual facilities. However, authoritative assessments for individual facilities are best served by on-the-ground measurement.

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Table 3. County and State Percentages of People, Property and Infrastructure on Land Below 3 Feet.

Table shows select (most affected) counties. Figures in the county columns reflect percentages of totals within each county. Figures in the 'Statewide' column reflect percentages of totals within the state as a whole (including unlisted and unaffected counties). *Note that statewide percentages for property value are not included, due to missing data for higher elevation (unlisted) counties.*

Land	4	3	8	7	2	6	13	17	1	4	2	1	25	74	7	0	9	8	1	1	4
Property value	12	7	7	6	3	6	10	4	5	7	12	5	11	42	7	5	9	10	4	8	
Homes	7	5	5	5	1	3	8	4	2	4	8	2	7	43	4	2	5	8	2	3	3
Population	6	4	3	4	1	3	3	1	2	3	5	2	5	45	4	1	5	7	1	2	3
High social vulnerability population	4	5	4	3	0	2	0	0	4	3	4	1	4	53	0	1	2	2	0	1	2
Population of color	4	2	2	3	0	1	1	0	1	1	3	1	4	46	3	0	3	5	1	1	2
EPA listed sites	5	6	3	7	1	3	8	2	2	2	3	3	5	38	4	2	3	7	4	1	2
Roads	4	2	3	3	0	1	1	1	1	1	3	1	4	33	1	1	4	3	1	2	1
Railroads	1	0	0	1	1	0	0	1	0	0	2	0	2	0	0	0	0	0	0	0	1
Passenger stations	9	0	0	50	0	0	0	0	0	25	0	0	6	29	0	0	0	0	0	0	5
Power plants	0	0	0	0	0	0	0	0	0	0	0	0	17	0	100	0	0	0	0	0	2
Sewage plants	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	4
Hospitals	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1
Public schools	1	0	4	3	0	0	0	0	0	2	1	0	4	8	0	0	1	2	0	0	1
Houses of worship	6	4	3	10	1	0	0	8	1	3	3	0	5	44	0	4	5	17	1	0	2
	Broward	Charlotte	Citrus	Collier	Escambia	Flagler	Franklin	Gulf	Indian River	Lee	Manatee	Martin	Miami-Dade	Monroe	Nassau	Palm Beach	Pinellas	Sarasota	St. Johns	St. Lucie	Statewide

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Table 4. Top Zip Codes At Risk, 3 Feet and 6 Feet.

Florida statewide and top zip code totals for people and property on land less than **3 ft** above the high tide line.

Variable	State Total Below 3 ft	Top Five Zip Codes Affected	% of Total < 3ft	Top Zip Codes (Most to Least Affected)
Land (acres)	1,357,195	280,737	21%	34141 (Ochopee), 33034 (Homestead), 32465 (Wewahitchka), 34114 (South Naples), 32328 (Eastpoint)
Population	489,925	75,383	15%	33139 (Miami Beach), 33141 (Ochopee), 33040 (Key West), 33027 (Pembroke Pines), 33160 (North Miami Beach)
Property Value (\$ Billions)	145	20.8	14%	33139 (Miami Beach), 33480 (Palm Beach), 33040 (Key West), 33140 (Miami Beach), 33050 (Marathon)
Housing Units	300,041	46,911	16%	33139 (Miami Beach), 33141 (Ochopee), 33040 (Key West), 33140 (Miami Beach), 33009 (Hallandale Beach)
Road Miles	2,555	305	12%	33040 (Key West), 33042 (Hollywood), 33043 (Big Pine Key), 33050 (Marathon), 34448 (Homosassa)
EPA-listed sites	978	140	14%	33040 (Key West), 33139 (Miami Beach), 33004 (Dania Beach), 32084 (St. Augustine), 33050 (Marathon)

Florida statewide and top zip code totals for people and property on land less than **6 ft** above the high tide line.

Variable	State Total Below 6 ft	Top Five Zip Codes Affected	% of Total < 6ft	Top Zip Codes (Most to Least Affected)
Land (acres)	2,983,907	492,583	17%	34141 (Ochopee), 33034 (Homestead), 33194 (Everglades National Park), 32465 (Wewahitchka), 34114 (South Naples)
Population	2,655,967	211,241	8%	33012 (Hialeah), 33025 (Miramar), 33024 (Hollywood), 33027 (Pembroke Pines), 33139 (Miami Beach)
Property Value (\$ Billions)	544	51.4	9%	33139 (Miami Beach), 33480 (Palm Beach), 34145 (Marco Island), 33040 (Key West), 33140 (Miami Beach)
Housing Units	1,444,827	113,494	8%	33139 (Miami Beach), 33160 (North Miami Beach), 33009 (Hallandale Beach), 33141 (Ochopee), 33012 (Hialeah)
Road Miles	16,022	955	6%	33981 (Port Charlotte), 33914 (Cape Coral), 33950 (Punta Gorda), 33024 (Hollywood), 33993 (Cape Coral)
EPA-listed sites	5,509	565	10%	33166 (Miami Springs), 33311 (Fort Lauderdale), 33178 (Miami), 33142 (Doral), 33138 (Miami Shores)

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THE MOST VULNERABLE

Social vulnerability is a broad term that describes the sensitivity of populations to the impacts of environmental risks and hazards, including coastal flooding. Social vulnerability helps explain why some places can experience hazards differently even without differences in exposure. The Social Vulnerability Index is a tool that synthesizes socioeconomic characteristics of populations – characteristics known to influence a community's ability to prepare for, respond to, and recover from hazard events like floods (see e.g. Emrich and Cutter 2011; Finch et al 2010; Cutter et al. 2013).

In the most exposed areas, below 3 feet, our analysis found essentially no difference in relative exposure to sea level rise and coastal flooding when comparing populations with high scores on the Social Vulnerability Index against the population as a whole, across the coastal and low-lying counties of Florida taken as a whole. However, individual communities vary, and analyses for each town, city, county and congressional district in the state are available via the Risk Finder.

The Social Vulnerability Index compares places based on their relative levels of social vulnerability. For this analysis, vulnerability was assessed at the Census tract level for all of Florida, using 27 variables from the 2010 Census and the 2006-10 American Community Surveys (see Appendix A for further methodological details). The online [Submergence Risk Map](#) that accompanies this report includes a feature visualizing social vulnerability levels in areas that are physically vulnerable to coastal flooding and sea level rise.

The Social Vulnerability Index shows where there is uneven capacity for preparedness and response and where pre and post-event resources might be most effectively used to reduce pre-existing vulnerability and increase resilience post-disaster. The index is also a useful indicator in understanding spatial differences in disaster recovery. It has been used in combination with other disaster data to provide emergency responders with a much clearer understanding of disaster impacts, thus providing decision makers with an objective comparison of damages sustained across the full spectrum of affected communities (see <http://webra.cas.sc.edu/hvri/products/SoVapplications.aspx>).

04. CONCLUSION

Long before rising seas redraw local maps, they will result in more coastal floods reaching higher. They are already having this effect.

The research in this report underscores the high concentration and wide range of populations, property, infrastructure, buildings, and potential contamination sources in low-lying coastal areas. In the densest areas, the most socially vulnerable populations are exposed the most. Patterns vary from place to place.

It will not require hurricanes to cause extensive economic damage and suffering in the future. Knowledge of vulnerabilities can lead to better preparation for the next inevitable flood, and the ones after. Higher floods in the future are certain, but how much damage they inflict is not -- and will depend on the measures coastal communities take.

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APPENDIX A: METHODS

PROJECTING LOCAL SEA LEVEL RISE

To project future sea levels, we followed the same essential methods as Tebaldi et al (2012). In that study, we added “semi-empirical” projections of global sea level rise to separate local sea level change components developed for 55 water level stations around the contiguous U.S. For the Florida Surging Seas Risk Finder, we also use global sea level rise projections from the Army Corps of Engineers (2011), and make these our focal point, with projections given for eight stations throughout Florida. We begin here, however, with a description of our overall method using the example of projections built on top of a semi-empirical model, as in Tebaldi et al.

For the global component in our semi-empirical approach, we used projections from Vermeer and Rahmstorf (2009). Their approach, based on the recent historic relationship between global sea level and global average temperature, has successfully hind-casted sea level rise over the last century and millennium with great fidelity. The relation estimated over the past observed records of sea level rise and global warming can be applied to projections of future temperature change produced by climate models. By this approach, therefore, future global sea level rise is not directly derived from the output of climate models, but is projected on the basis of the future temperature projections of these models. As projections based on historical observed relationships generally do, this approach assumes that the dynamics captured by the past relation will remain the same for the projected future period. If the ongoing increase in global temperatures leads ice sheets to unravel in ways not experienced during the model’s twentieth century calibration period, then this approach may understate the problem.

Use of Vermeer and Rahmstorf’s approach allowed this analysis to take into account a wide range of possible futures, from ones where humanity continues to send great amounts of heat-trapping gasses into the atmosphere, to ones where we sharply reduce these emissions. Through Vermeer and Rahmstorf’s method we were also able to incorporate a range of possible relationships between emissions and global temperature increases (by using a range of climate model parameters and thus exploring the dimension of model uncertainty), and a range of possible relationships between temperature and sea level (by considering the uncertainty in the parameters of the empirical model). Our analysis rolled all of these factors together to produce one set of best estimates, and a range of potential outcomes around them.

For the Florida Surging Seas Risk Finder, we updated our semi-empirical projections to employ the most recent carbon emissions scenarios (“Representative Concentration Pathways”) and warming models being used by the global scientific community (Moss et al 2010).

In addition to future SLR estimates based on the empirical relation fitted between global temperature projections and SLR, we have implemented a range of three scenarios of global sea level rise as described by a U.S. Army Corps of Engineers (2011) circular and adapted by the Southeast Florida Regional Climate Change Compact. The USACE approach assumes a relation between time (year) and sea level that is quadratic of increasing magnitude for three scenarios (low, intermediate and high).

Any global sea level rise projection, such as these, can be adapted to help make a local projection.

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Changes in local sea level come not only from changes in global sea level, but also from local effects such as the slow rising or sinking of coastal land, driven largely by the ancient retreat of massive ice sheets across North America. To determine local effects, we removed global rise from the total observed local sea level increase over a 50-year period (1959-2008) at each of the 55 nationwide stations we analyzed in our original study. The difference between the total observed local component and global rise during the same period (both of them expressed as linear trends of sea level change per year) is what we call the local component, and, in our projections, we assumed that each local component will continue as a constant rate into the future that offsets or adds on to the global component as an additive term. A detailed analysis using multiyear data from high-precision continuous GPS stations showed that vertical land motion can explain most or all of these local components. The forces behind such motion generally stay constant for thousands of years.

Our projections should not be interpreted as precise predictions for specific years, but rather best estimates that indicate overall trends, because of all of the factors that could lead to a range of outcomes (for example, different emissions futures) and because of natural year-to-year and decade-to-decade variability. For this reason, we present projections at the decade scale only.

PROJECTING COASTAL FLOOD RISK

In Tebaldi et al (2012) and here, to project the probabilities of reaching different high water levels in the future, through combinations of storms, tides and sea level rise, we developed statistics based on patterns of historical extreme water levels, and then superimposed projected sea level rise onto these. For this report, we used local statistics and local sea level projections for each of the eight Florida water level stations analyzed.

We used statistical methods specialized for handling extreme values to analyze records of hourly data. We expanded our analysis from the fixed standard 30-year period (1979-2008) used in Tebaldi et al, to use the maximum available high quality data for each water level station through the end of 2012 (utilizing 34-116 year records, depending on the station – see main report Table 1).

We estimate the parameters of a Generalized Pareto Distribution at each station, characterizing the probability density of extreme water levels at that location, and on the basis of those parameters we derive what is called a “return level curve” for each water level station. Our return level curves relate water heights (in MHHW) to their annual probability (given sea level in 2012): for example, heights with a 1% chance of being reached in any given year (“100-year” or “century” or “extreme” floods) are higher than heights with a 10% chance (“decade floods”), and so forth. We filtered out the effects of ongoing historic sea level rise at each station by estimating a linear trend over the length of the record and subtracting it out, in order to calculate baseline return level curves influenced only by tides, storms, and seasonal shifts in water level.

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Once we establish a curve for the baseline period (that we can think of as today in most cases), it is easy to modify it for a given time in the future, on the basis of the effects of sea level rise alone. For example, if at that future time sea level has risen by one foot, an event reaching 5 feet of elevation will have at that future time the same probability of occurring as a minor event reaching 4 feet has today. Thus, sea level rise will make rare high water events of today more likely in the future.

These considerations allow us to compute the chance that a particular height H will be reached in some future year (say, for example the chance that an event reaching 5 feet will happen in 2030). All that is needed is the amount of sea level rise, say L , between today (the baseline) and that target year, and the return level curve for the baseline: we then take H , subtract L and find, on the curve, the probability associated to the event of size $H-L$.

Slightly more complex is the computation of the cumulative risk of at least one such event by some future year, i.e., the estimate of the chance that a particular height H will be reached or exceeded by some future year. The way to think of this is as the complement of (i.e., one minus) the probability that such event will never be reached by that year. As an example, let's say the event H is currently a "100-year" event. That means that this year it has 0.01 chances of occurring, and therefore 0.99 chances of not occurring. Next year, if nothing changed, the chance of it not occurring would be the same, therefore the probability of H not occurring this year or next year would be $0.99 \times 0.99 = 0.98$; its complement, that is the chance of H occurring by next year, would be $1 - 0.98 = 0.02$.

The same calculation applies for any number of years until the target year. We simply multiply the chances of the event H not occurring every year for the entire period, and then take its complement.

Critically, however, sea level rise makes the chance of any event higher—at least on average decade after decade. Therefore we compute changing probabilities over the years, taking into account the effect of sea level rise. To do so, we incorporate local projections of sea level rise decade by decade, not just the total rise projected by the target year.

More specifically, we used the return level curve for each decadal year, e.g. 2040, incorporating sea level rise projected through that year, and applied the same curve for the five preceding and four succeeding years as well. We then used the probability of exceeding H each year between 2011 and the target year to compute the overall odds of exceeding H at least once during the period.

To continue with the example of H as the 100-year event of today one can imagine that for a target year far enough in the future the multiplication will involve values sooner or later (depending on the pace of sea level rise at this station and on the shape of its return level curve) significantly smaller than 0.99, therefore producing a significantly larger value of the complement, by the target year, compared to that computed under the assumption of no sea level rise.

As with our projections of sea level rise, and for similar reasons, we limit our presentation to odds of reaching different flood levels at decade resolution. Any given year, even within a steady long-term trend of sea level rise, may see dips and jumps in the actual value of sea level rise at a given location. Our estimates of sea level rise are appropriate only as long-term average trends, decade after decade.

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Note that the same type of calculation performed for a detailed range of values and years in the future allow us to answer a question mirroring the one above. We can search among our results for which size event will become, say, at least Q% likely by the next 20 years, rather than starting with a given size event and ask what its likelihood of occurring at least once in the next 20 year will be. Similarly we can ask questions about waiting times, looking for the number of years it will take for a given size event to occur with at least an Q% chance.

Our calculations all concern flood levels reaching elevations relative to a stable baseline, the average high tide level during a fixed historic reference period at each station, the so called tidal datum epoch (the current standard epoch is 1983-2001). This way of measuring flood levels is different than pure storm surge, which is calculated as the extra water height above the predicted tidal water level for the very same moment in time. Our focus was not storm surge, but rather how high water actually gets, due to storm surge, plus tide, plus sea level rise.

This analysis assumed that historic storm patterns will not change; in other words, it did not address the possibility that storms might become more or less frequent or severe due to climate change.

This analysis was based on data taken at water level stations. Tides, storm surge, and the resulting statistics vary from place to place, sometimes over short distances, due to factors including land and ocean geometry and storm directions. On the other hand, in our national analysis (Tebaldi et al 2012), results for distantly spaced water level stations within the same region were often similar. Therefore, results from stations may be taken as rough indicators but not precise estimates for their neighborhoods and regions, and the quality and coverage of indication will vary.

ESTIMATING GLOBAL WARMING FLOOD RISK MULTIPLIERS

To estimate how global warming is shifting the odds of high storm surges, through sea level rise, we calculated the odds of extreme events in a hypothetical world with no past or future global sea level rise due to warming, to compare against our original calculations, which included warming. We did this comparison at each water level station in the study. The approach basically translated to subtracting out the roughly 8 inches of historical global sea level rise measured from 1880-2009, and then also assuming no future global sea level rise, for the no-warming scenario at each station (a scenario viewable in the Surging Seas Risk Finder). The no-warming scenarios still included local sea level rise from factors other than warming, such as sinking or lifting land — the full local component of sea level rise.

We made one further adjustment, which was to add back 10% of the historic global sea level rise (10% of 8 inches), in the event that some of the observed historic rise has come from factors other than warming. Research on the sea level budget assigns the great majority of the 8 inches to warming-caused effects: expansion of the ocean as it has warmed, and the melting and calving of glaciers and ice sheets. Small fractions of global sea rise unaccounted for are widely viewed to come at least in part from additional ice loss. We assume 90% of the 8 inches are due to global warming, and thus deduct this amount for our comparison.

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For comparison of odds with and without warming, we used standard “100-year” or “century” floods as our reference, meaning water station water levels high enough that they have just a 1% chance of occurring in any given year. We calculated the elevations 100-year floods reach when starting on top of baseline 2012 sea level at each station, using the same data and methods as for our overall water level probability projections. Elevations were relative to average local high tide (MHHW) during a fixed past reference period (the 1983-2001 tidal epoch), as with all elevations in related studies.

In comparing the probabilities of flood levels with and without global warming, we cut ratios off at ten, because higher ratios start to lose a sense of meaning. We also do not compute ratios at all when the chance of flooding is very close to zero without global warming. These situations create very large ratios whose exact values are meaningless: tiny changes in near-zero odds (odds without global warming) would lead to enormous changes in the ratio value.

This analysis did not address the possibility that storms might become more or less frequent or severe due to climate change. We also limited ourselves to looking at the total effects of global warming, and did not aim to separate fractions caused by humans versus natural variations. The strong scientific consensus points to people as causing most, if not all, of the average warming observed over the last century, and to being the dominant cause of future warming.

MAPPING LOW COASTAL AREAS

To develop our maps of at-risk areas, we used high-resolution, high-accuracy laser-based (lidar) elevation data provided by NOAA. These data have a roughly 5 m (16.5 ft) horizontal resolution. In order to achieve complete coverage for the state, we supplemented these data with the following sources in descending priority order: U.S. Geological Survey Airborne Height Finder data (for the Everglades); 1/9 arc-second data from the National Elevation Dataset (NED); and University of Florida Geoplan elevation data. The great majority of low-lying area outside the Everglades is covered by NOAA’s lidar data.

For general discussion of the accuracy of elevation data and what it means for our maps and statistics, see Strauss et al (2012), which used 1/3 arc-second NED data exclusively, as lidar data were not sufficiently available. This discussion concluded that NED quality data are sufficient for the types of analysis conducted here. Nonetheless, the reported vertical accuracy (root mean square error) of lidar data, as used in this analysis, is roughly ten times more accurate than NED.

We began our process by classifying all cells as ocean (ocean, bay, estuary or saltwater wetland) or land (land or freshwater wetland), because ocean or saltwater marsh misclassified as land would lead to overestimates of susceptible total land area. We admitted cells as land according to a conservative consensus of three independent data sets. First, the cells had to be designated as land within the elevation data itself. Second, we included only cells with centers landward of NOAA’s Medium Resolution Digital Vector Shoreline. Finally, we eliminated cells with centers inside areas classified in the National Wetlands Inventory (NWI) as estuarine or marine wetland or deepwater. In computing total land area susceptible, we included NWI freshwater wetlands.

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Next, we adjusted the elevation of each cell to be in reference to the nearest average high tide line, instead of a standard zero. For example, if a cell's elevation were five feet, but the local high tide reached three feet, then we would compute an elevation of two feet relative to the tide line. Clearly, sea level rise or a storm surge would need to reach only two feet above high tide to threaten this cell with inundation. Sea level and tidal amplitude vary sometimes widely from place to place, and therefore also the average height of high tide. For local high tide elevations, we used values of Mean Higher High Water from VDatum, a NOAA data product and tidal model.

Based on these elevations adjusted relative to MHHW, we identified the set of cells beneath each water level threshold from one to ten feet above local high tide, and drew maps of each area.

Finally, we distinguished areas connected to ocean at a given water level, versus isolated areas, to use in different exposure analyses, and for differential display in our online mapping application. We included levees from the Midterm Levee Inventory in this analysis of connectivity, assuming each levee to be of sufficient height and condition to offer protection at every water level. Additional discussion can be found in the main body of this report (see "Land" in Table of Contents).

ASSESSING SOCIAL VULNERABILITY

The Social Vulnerability Index for 2006-10 marks a change in the formulation of the SoVI[®] metric from earlier versions (see e.g. Emrich and Cutter 2011). New directions in the theory and practice of vulnerability science emphasize the constraints of family structure, language barriers, vehicle availability, medical disabilities, and healthcare access in the preparation for and response to disasters, thus necessitating the inclusion of such factors in SoVI[®]. Extensive testing of earlier conceptualizations of SoVI[®], in addition to the introduction of the U.S. Census Bureau's five-year American Community Survey (ACS) estimates, warrants changes to the SoVI[®] recipe, resulting in a more robust metric. These changes, pioneered with the ACS-based SoVI[®] 2005-09, carry over to SoVI[®] 2006-10, which combines the best data available from both the 2010 U.S. Decennial Census and five-year estimates from the 2006-2010 ACS.

The table below gives a complete list of the 27 variables used in SOVI[®] 2006-10 for Census tract level analysis.

APPENDIX A: METHODS

Table A1. Variables Used in Social Vulnerability Analysis

VARIABLE	DESCRIPTION
QASIAN	Percent Asian
QBLACK	Percent Black
QHISP	Percent Hispanic
QNATAM	Percent Native American
QAGEDEP†	Percent of Population Under 5 Years or 65 and Over
QFAM†	Percent of Children Living in Married Couple Families
MEDAGE	Median Age
QSSBEN	Percent of Households Receiving Social Security
QPOVTY	Percent Poverty
QRICH200K	Percent of Households Earning Greater Than \$200,000 Annually
PERCAP	Per Capita Income
QESL†	Percent Speaking English as a Second Language with Limited English Proficiency
QFEMALE	Percent Female
QFHH	Percent Female Headed Households
QNRRES	Percent of Population Living in Nursing and Skilled-Nursing Facilities
QED12LES	Percent with Less Than 12th Grade Education
QCVLUN	Percent Civilian Unemployment
PPUNIT	Per Unit
QRENTER	Percent Renters
MDHSEVAL†	Median House Value
MDGRENT†	Median Gross Rent
QMOHO	Percent Mobile Homes
QEXTRCT	Percent Employment in Extractive Industries
QSERV	Percent Employment in Service Industry
QFEMLBR	Percent Female Participation in Labor Force
QNOAUTO†	Percent of Housing Units with No Car
QUNOCCHU	Percent Unoccupied Housing Units

For this analysis, we assessed Social Vulnerability Index scores by Census tract across all of Florida. We then assigned tracts high, medium, or low social vulnerability scores, based on whether they fell within the top 20%, middle 60%, or bottom 20%, respectively, of vulnerability for the whole set.

More information on the Social Vulnerability Index is available at <http://webra.cas.sc.edu/hvri/products/sovi.aspx>

APPENDIX A: METHODS

ESTIMATING EXPOSURE OF PEOPLE, PROPERTY, AND INFRASTRUCTURE

To calculate potential risks at each water level within areas such as zip codes, cities or counties, we used boundaries provided by the 2010 U.S. Census to overlay against our maps of land beneath different water level thresholds. We then computed the amount of land below each threshold in each place. For denominators in percentage calculations, we used our own computations of land area for each place, because our definitions of coastline differed slightly in places from that of the Census.

To tabulate population and housing potentially affected, we used block-level data from the 2010 U.S. Census, and assumed development on dry land only (neither freshwater nor saltwater wetland). For each Census block, we divided the population and number of housing units by the number of dry land cells with centers inside the block. We assigned the resulting per-cell density values back to each cell, creating new datasets for population and housing unit density. To estimate the population or housing at risk for a particular water level, we simply added up population and housing densities of land cells affected under the specification. Our analysis considered the elevation of land upon which housing stands, and made no special provision for elevated or multi-story buildings.

We followed the same essential approach for property value, but using Census block group geometry from the 2000 Census, in order to match with property value data from Neumann et al (2010) and (for Miami-Dade County) the Florida Department of Revenue. The property value is derived almost exclusively from individual parcel assessed just values, evaluated in 2008 (2009 for Miami-Dade), which we adjusted using the Consumer Price Index to 2012 dollars. The data include residential, commercial, industrial, institutional and government property, both taxable and tax-exempt.

For analysis of linear features such as roads and rail, we computed the length of each feature on land below the water level in question, and made totals by feature type (e.g. total roads, federally-owned roads, or mainline rail).

For airports, we used linear runway data, and determined the percentage of runway length on land below each water level. We counted an airport as vulnerable at a given level when this percentage exceeded a threshold of 25%.

APPENDIX A: METHODS

For point features, we simply use latitude/longitude coordinates overlaid onto our MHHW elevation map to evaluate whether a building, site or facility falls below a given water level. This approach does not take into account the actual footprint of a structure, nor the possibility that critical features may be elevated above the ground (or stored in an unsealed basement).

The first step in each type of analysis is to properly filter and de-duplicate records for the feature class or subclass of interest from a source dataset – for example, sewage treatment plants from among all EPA listed sites. Feature data came from latest available versions of the U.S. Census’s TIGER lines database (roads), DOT’s National Transportation Atlas Database (rail, passenger stations), DOE’s Annual Electric Generator Report (power plants), EPA’s Facilities Registry Database (EPA listed sites, sewage plants), the Department of Education’s National Center of Education Statistics (public schools), and USGS’s Geographic Names Information Service (hospitals, houses of worship). The Florida Surging Seas Risk Finder “Comparison” and “Analysis” modules give more detail about these data sources and the many additional sources for data analysis presented online only.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Fernandina Beach: Projections

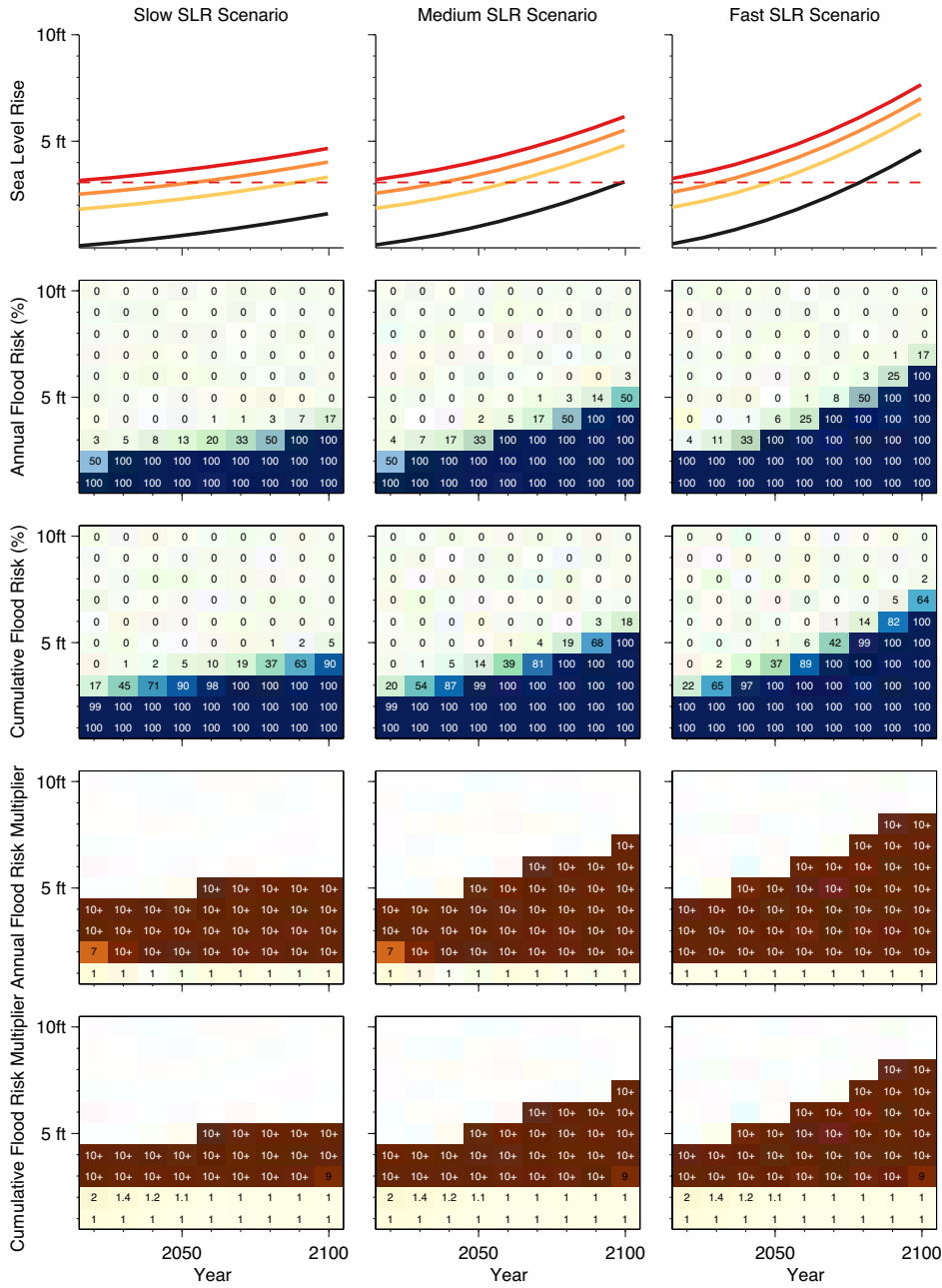


Figure B1. Sea Level Rise Multiplies Flood Risk at Fernandina Beach, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Vaca Key: Projections

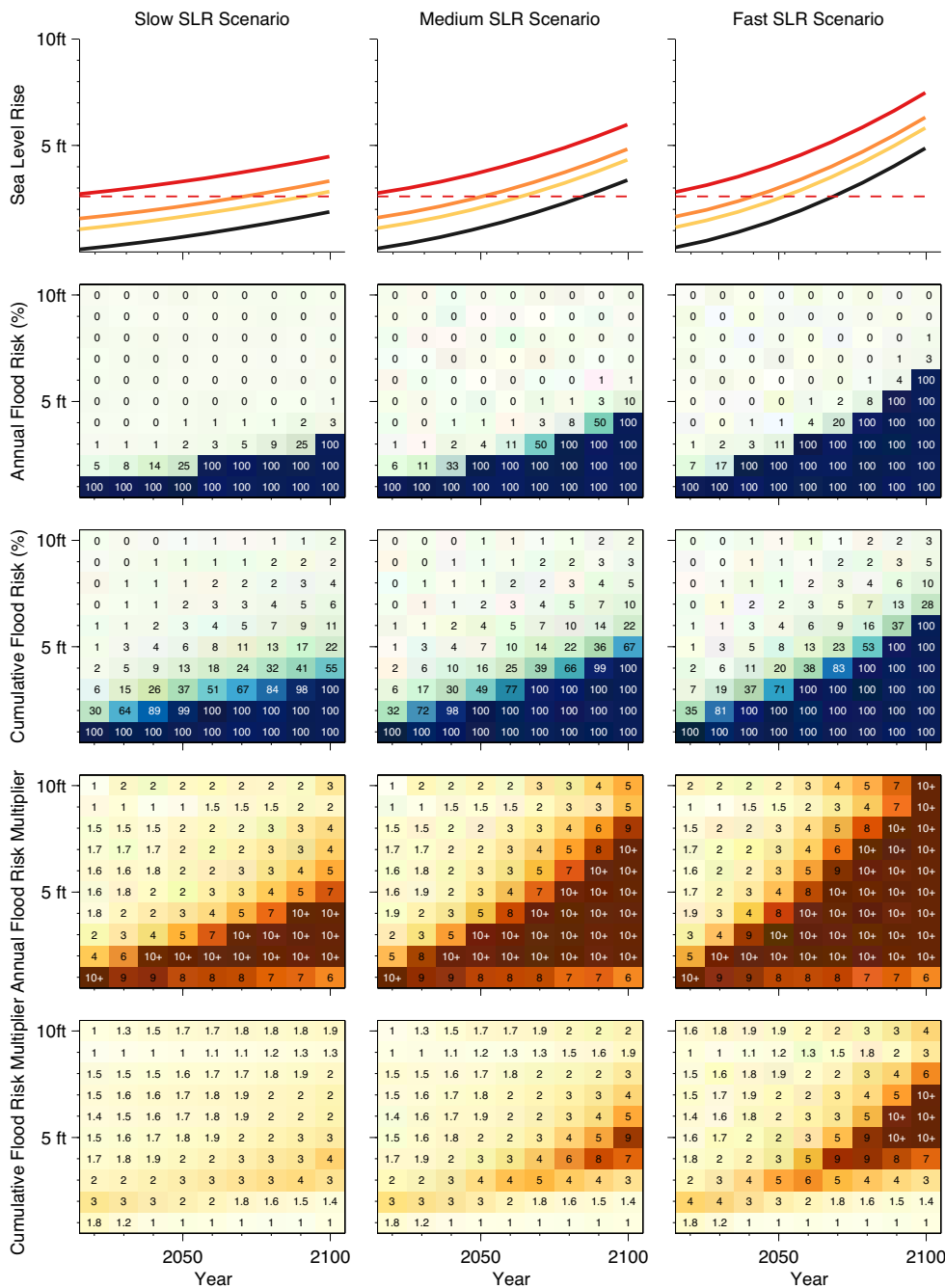


Figure B2. Sea Level Rise Multiplies Flood Risk at Vaca Key, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Naples: Projections

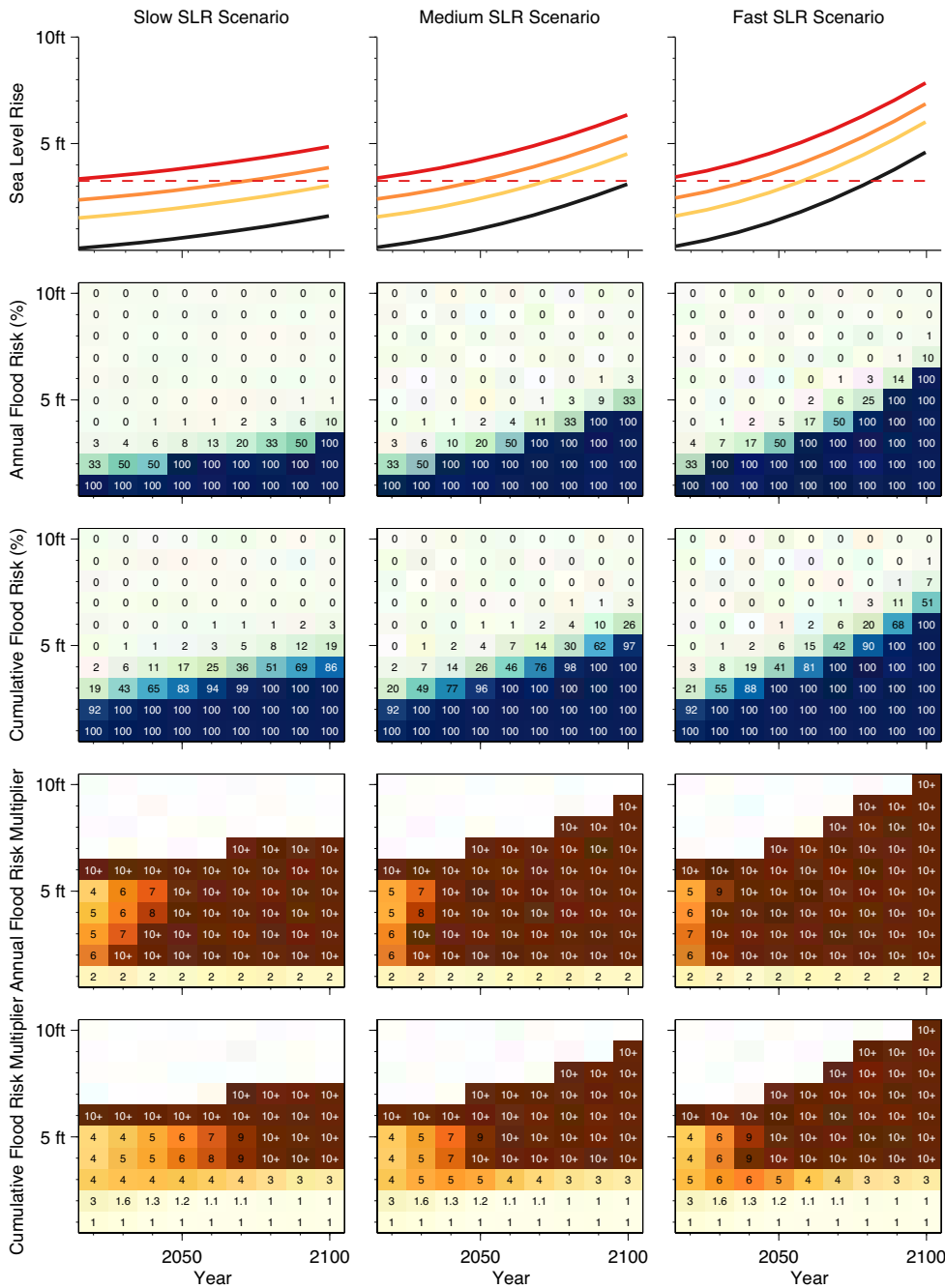


Figure B3. Sea Level Rise Multiplies Flood Risk at Naples, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at St Petersburg: Projections

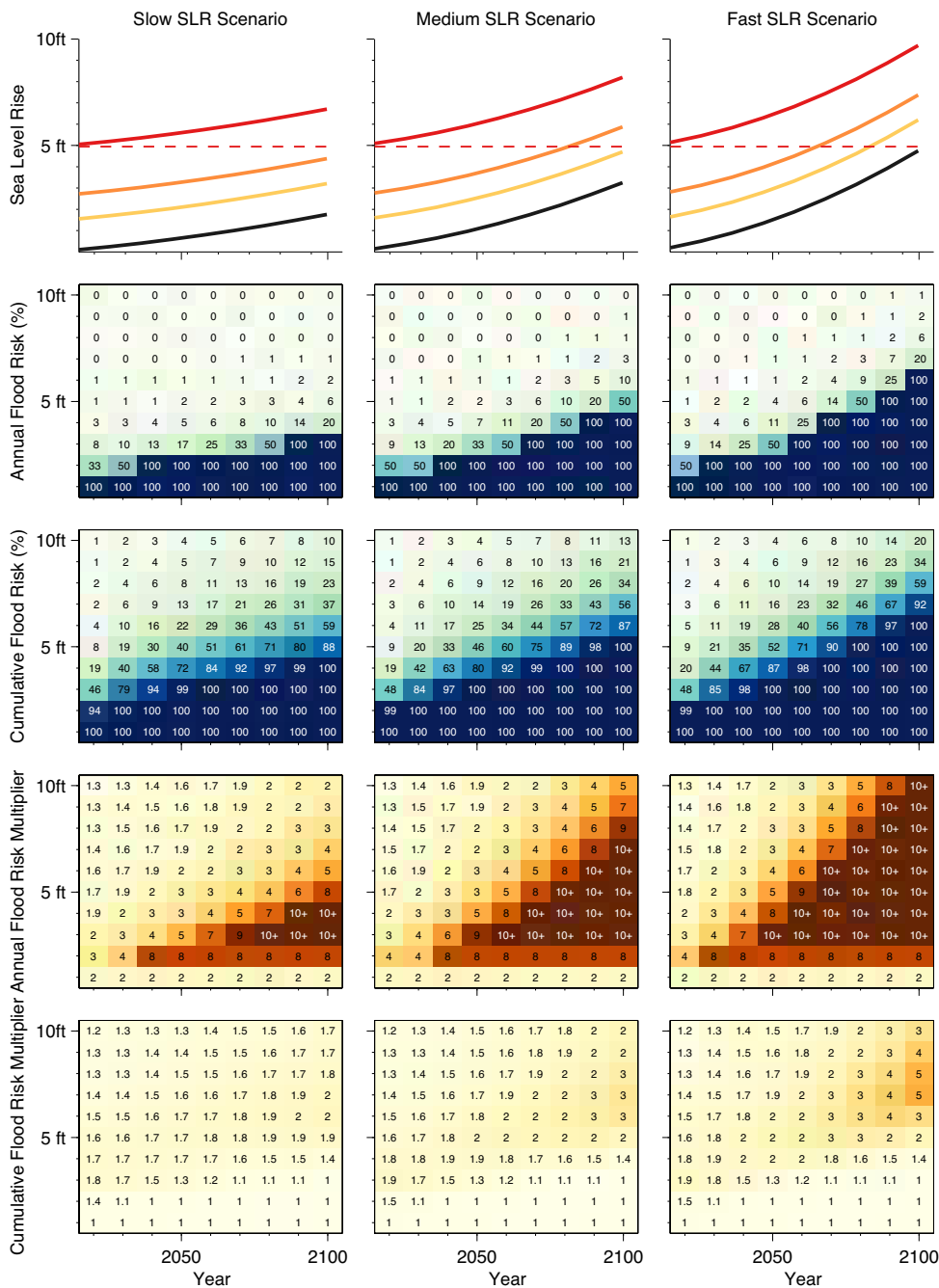


Figure B4. Sea Level Rise Multiplies Flood Risk at St. Petersburg, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Clearwater Beach: Projections

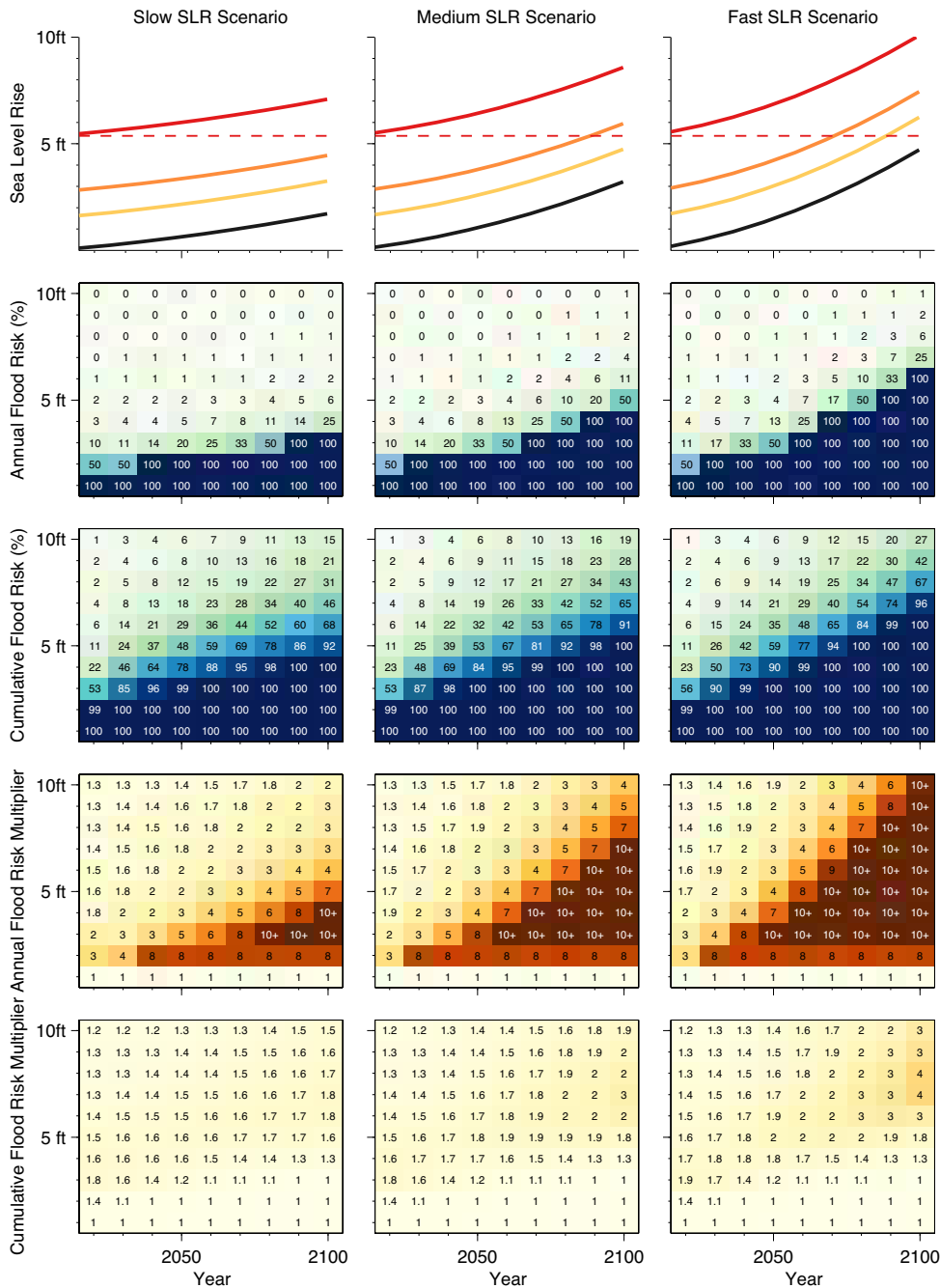


Figure B5. Sea Level Rise Multiplies Flood Risk at Clearwater, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Apalachicola: Projections

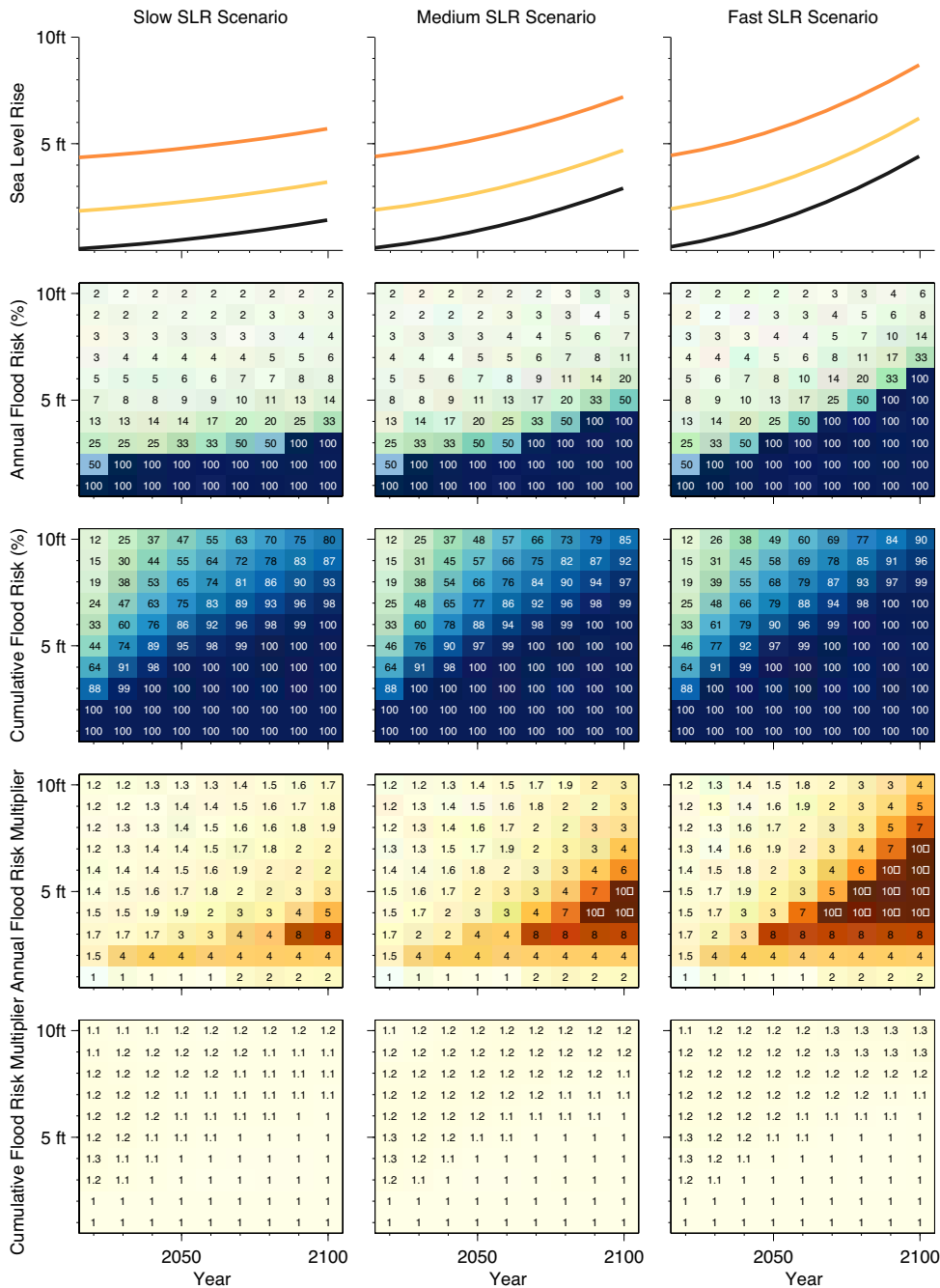


Figure B6. Sea Level Rise Multiplies Flood Risk at Apalachicola FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow) or 10-year (orange) floods. 100-year floods are estimated as too high (12.3 ft above MHHW) for showing on this scale. The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Sea Level Rise Multiplies Flood Risk at Pensacola: Projections

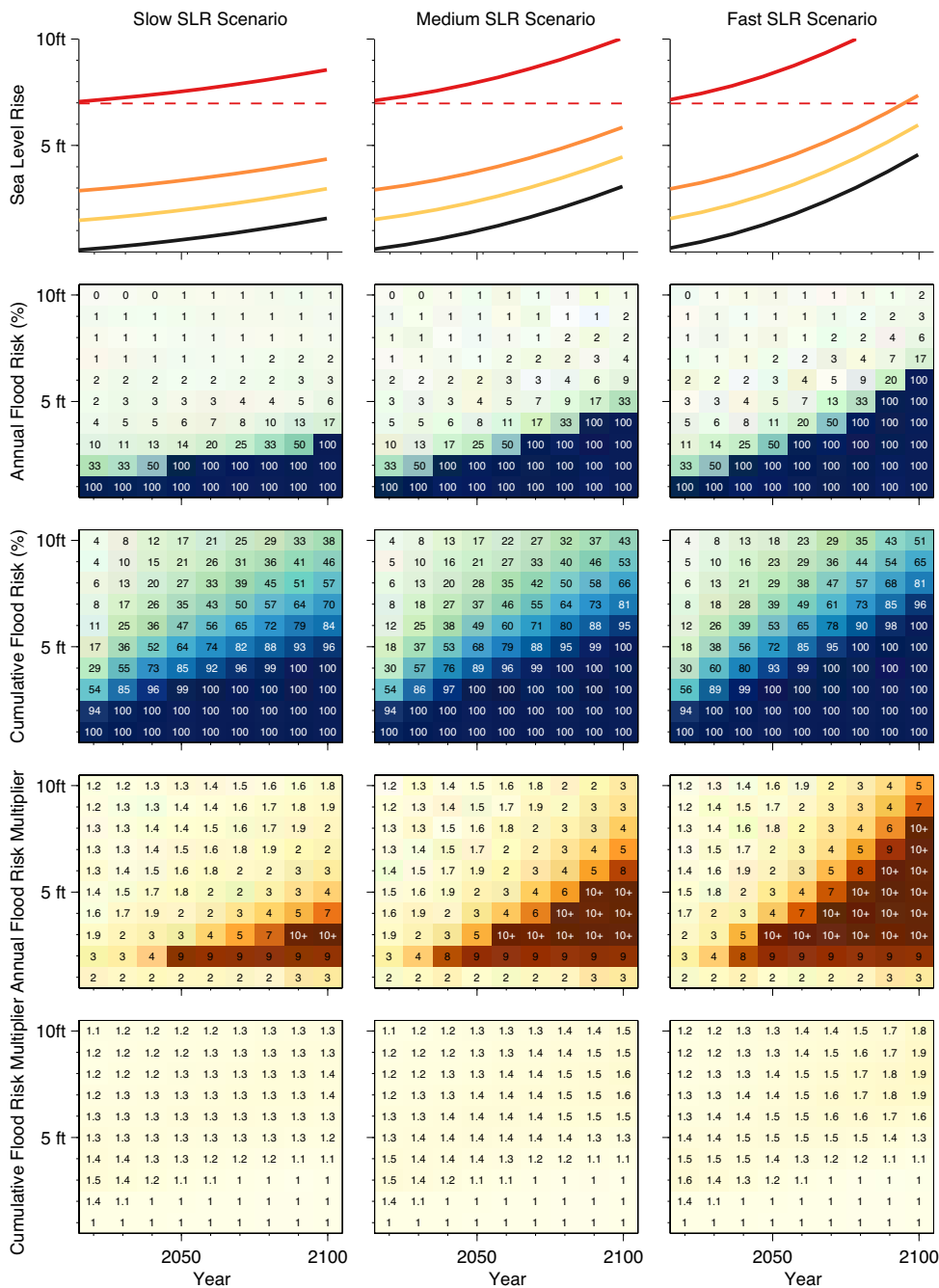


Figure B7. Sea Level Rise Multiplies Flood Risk at Pensacola, FL: Projections

The top row shows slow (left hand side) through fast (right hand side) scenario sea level rise projections (black lines), plus the height of 1-year (yellow), 10-year (orange) or 100-year (red) floods. The dashed red line shows the elevation of a 100-year (extreme) flood measured from today's high tide line (MHHW). The next two rows show projections for annual and cumulative percentage risk of floods reaching 1-10 ft MHHW by decade (2020-2100). The final two rows show how the global warming component of sea level rise is projected to multiply these risks, cell-by-cell.

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table BI. Extreme Flood Projections at Fernandina Beach, FL

Extreme flood level based on statistical analysis of historic record at station: 3.1 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	4%	10%	100%	5	10+	10+
Medium	6%	33%	100%	8	10+	10+
Fast	9%	100%	100%	10+	10+	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	14%	26%	45%	-	-	-
Slow	37%	84%	100%	3	3	2
Medium	46%	99%	100%	3	4	2
Fast	57%	100%	100%	4	4	2

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B2. Extreme Flood Projections at Vaca Key, FL

Extreme flood level based on statistical analysis of historic record at station: 2.6 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	2%	4%	100%	1.9	4	10+
Medium	3%	13%	100%	2	10+	10+
Fast	3%	50%	100%	3	10+	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	17%	34%	64%	-	-	-
Slow	26%	60%	100%	1.5	1.8	1.6
Medium	29%	81%	100%	1.7	2	1.6
Fast	33%	99%	100%	1.9	3	1.6

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B3. Extreme Flood Projections at Naples, FL

Extreme flood level based on statistical analysis of historic record at station: 3.2 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	2%	5%	50%	3	6	10+
Medium	3%	11%	100%	3	10+	10+
Fast	4%	25%	100%	5	10+	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	15%	28%	51%	-	-	-
Slow	27%	62%	100%	1.8	2	2
Medium	31%	82%	100%	2	3	2
Fast	36%	96%	100%	2	3	2

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B4. Extreme Flood Projections at St. Petersburg, FL

Extreme flood level based on statistical analysis of historic record at station: 4.9 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	1%	2%	6%	1.4	1.8	6
Medium	2%	3%	500%	1.5	3	10+
Fast	2%	4%	100%	1.7	4	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	17%	32%	59%	-	-	-
Slow	20%	42%	89%	1.2	1.3	1.5
Medium	21%	47%	100%	1.3	1.5	1.7
Fast	22%	53%	100%	1.3	1.7	1.7

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B5. Extreme Flood Projections at Clearwater, FL

Extreme flood level based on statistical analysis of historic record at station: 5.4 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	1%	2%	4%	1.3	1.7	4
Medium	1%	2%	25%	1.4	2	10+
Fast	2%	3%	100%	1.6	3	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	16%	32%	58%	-	-	-
Slow	19%	40%	84%	1.2	1.3	1.4
Medium	20%	44%	99%	1.2	1.4	1.7
Fast	21%	49%	100%	1.3	1.5	1.7

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B6. Extreme Flood Projections at Apalachicola, FL

Extreme flood level based on statistical analysis of historic record at station: 12.3 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	1%	1%	1%	1.1	1.1	1.4
Medium	1%	1%	2%	1.1	1.2	1.9
Fast	1%	1%	3%	1.1	1.3	3

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	16%	31%	57%	-	-	-
Slow	17%	33%	63%	1	1.1	1.1
Medium	17%	34%	63%	1	1.1	1.2
Fast	17%	35%	73%	1.1	1.1	1.3

APPENDIX B: TABLES AND FIGURES FOR FERNANDINA BEACH, VACA KEY, NAPLES, ST. PETERSBURG, CLEARWATER, APALACHICOLA, AND PENSACOLA

Table B7. Extreme Flood Projections at Pensacola, FL

Extreme flood level based on statistical analysis of historic record at station: 7 ft above MHHW. GW Multiplier is how much the global warming component of sea level rise multiplies likelihoods, according to this analysis.

Annual likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	1%	1%	1%	-	-	-
Slow	1%	1%	2%	1.2	1.3	2
Medium	1%	1%	4%	1.2	1.5	5
Fast	1%	2%	17%	1.3	1.8	10+

Cumulative likelihood of exceeding history-based extreme flood level

Scenario	Likelihood			GW Multiplier		
	2030	2050	2100	2030	2050	2100
NoGW	16%	31%	57%	-	-	-
Slow	18%	35%	70%	1.1	1.1	1.2
Medium	18%	37%	82%	1.1	1.2	1.4
Fast	18%	39%	96%	1.1	1.3	1.7

APPENDIX C: ELEVATION AND TIDAL DATUM CONVERSION TABLES

Table C1: Flood Elevation Conversion Tables

For this analysis, we use elevation relative to Mean Higher High Water (MHHW) as the standard of comparison for all flood heights. Some other sources use different frames of reference for elevation. To compare across sources, use the conversion tables below. Note that there are different conversions at different water level stations because of different tidal regimes.

Examples: If the water level is 5 feet above the MHHW at Key West then it is 6.81 feet above the MLLW

If the water level is at a standard elevation of 4 feet (NAVD88) at Key West then it is also 3.95 ft above MHHW
 $(3.95 = 4 - 0.05)$

Fernandina Beach, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.35 ft	MHW - 0.35 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 2.74 ft	NAVD88 - 2.74 ft
MLLW	Mean Lower Low Water	MHHW + 6.56 ft	MLLW - 6.56 ft

Vaca Key, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.11 ft	MHW - 0.11 ft
NAVD88	North American Vertical Datum, 1988	MHHW - 0.36	NAVD88 + 0.36 ft
MLLW	Mean Lower Low Water	MHHW + 0.98 ft	MLLW - 0.98 ft

APPENDIX C: ELEVATION AND TIDAL DATUM CONVERSION TABLES

Table C1: Flood Elevation Conversion Tables (continued)

Key West, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.29 ft	MHW - 0.29 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 0.05 ft	NAVD88 - 0.05 ft
MLLW	Mean Lower Low Water	MHHW + 1.81 ft	MLLW - 1.81 ft

Naples, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.25 ft	MHW - 0.25 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 0.58 ft	NAVD88 - 0.58 ft
MLLW	Mean Lower Low Water	MHHW + 2.87 ft	MLLW - 2.87 ft

APPENDIX C: ELEVATION AND TIDAL DATUM CONVERSION TABLES

Table C1: Flood Elevation Conversion Tables (continued)

St. Petersburg, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.28 ft	MHW - 0.28 ft
NAVD88	North American Vertical Datum, 1988	n/a	n/a
MLLW	Mean Lower Low Water	MHHW + 2.26 ft	MLLW - 2.26 ft

Clearwater Beach, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.34 ft	MHW - 0.34 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 0.99 ft	NAVD88 - 0.99 ft
MLLW	Mean Lower Low Water	MHHW + 2.76 ft	MLLW - 2.76 ft

APPENDIX C: ELEVATION AND TIDAL DATUM CONVERSION TABLES

Table C1: Flood Elevation Conversion Tables (continued)

Apalachicola, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.1 ft	MHW - 0.1 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 0.85 ft	NAVD88 - 0.85 ft
MLLW	Mean Lower Low Water	MHHW + 1.61 ft	MLLW - 1.61 ft

Pensacola, FL

Datum	Description	To convert elevations from MHHW	To convert elevations to MHHW
MHHW	Mean Higher High Water	-	-
MHW	Mean High Water	MHHW + 0.03 ft	MHW - 0.03 ft
NAVD88	North American Vertical Datum, 1988	MHHW + 0.94 ft	NAVD88 - 0.94 ft
MLLW	Mean Lower Low Water	MHHW + 1.23 ft	MLLW - 1.23 ft

APPENDIX D: TABLES OF EXPOSURE AT 6 FEET MEAN HIGH HIGHER WATER

Table D1. County and State Percentages of People, Property and Infrastructure on Land Below 6 Feet.

Figures in the “State” column give percentages for the state as a whole (including all state counties). *Note that statewide percentages for property value are not included, due to missing data for higher elevation (unlisted) counties.*

Land	28	11	13	20	4	9	21	25	2	14	4	2	77	97	11	3	22	13	3	5	9
Property value	50	39	14	35	13	17	41	15	23	32	24	15	46	78	18	16	32	28	12	24	
Homes	43	33	11	29	4	10	26	15	14	25	16	12	43	84	12	8	22	24	10	13	16
Population	41	28	9	23	2	7	11	8	10	19	12	9	40	85	10	5	18	22	5	8	14
High social vulnerability population	32	25	11	24	0	7	0	0	19	21	10	5	41	96	0	3	11	7	0	7	18
Population of color	37	19	7	20	1	2	4	2	4	8	7	4	35	85	9	2	12	15	1	2	12
EPA listed sites	43	33	19	27	4	7	31	16	6	13	7	8	45	77	11	6	12	18	7	4	12
Roads	41	34	8	18	2	4	8	5	8	19	9	6	38	62	5	6	18	12	4	7	8
Railroads	14	0	0	70	11	0	0	1	0	0	15	0	25	0	0	4	0	0	0	0	8
Passenger stations	55	0	0	100	0	0	0	0	0	25	0	0	24	71	0	10	0	0	100	0	18
Power plants	40	0	0	0	0	0	0	0	100	0	0	0	33	100	100	0	0	0	0	0	11
Sewage plants	100	0	0	33	0	33	0	0	0	40	100	0	100	100	25	33	12	29	100	33	24
Hospitals	18	40	0	0	0	0	0	100	0	0	0	0	25	67	0	4	4	0	67	0	9
Public schools	24	8	11	16	0	0	20	0	3	3	1	0	26	42	5	1	3	30	0	0	7
Houses of worship	39	35	7	42	1	0	100	17	4	11	6	2	26	75	0	6	10	50	1	8	6
	Broward	Charlotte	Citrus	Collier	Escambia	Flagler	Franklin	Gulf	Indian River	Lee	Manatee	Martin	Miami-Dade	Monroe	Nassau	Palm Beach	Pinellas	Sarasota	St. Johns	St. Lucie	Statewide

APPENDIX E: GLOSSARY AND ABBREVIATIONS

EPA – U.S. Environmental Protection Agency

Extreme flood – As used in this report, a coastal flood height with a 1% or lower annual chance, assuming the sea level for 2012.

High tide line – see MHHW

IPCC – Intergovernmental Panel on Climate Change

Lidar – Light detection and ranging technology. A method of measuring distance that relies on firing laser beams and analyzing their returned, reflected light.

MHHW – Mean Higher High Water: a local frame of reference for elevation based on the elevation of the higher of the two high tides each day averaged across a reference period. The reference period used is the current tidal epoch, 1983-2001. This report uses “high tide line” as the equivalent of the height of MHHW.

MLLW – Mean Lower Low Water. See MHHW; MLLW is instead a frame of reference based on the elevation of the lower of the two low tides each day.

NCA – National Climate Assessment

NOAA – National Oceanic and Atmospheric Administration

NPCC2 – New York City Panel on Climate Change

Sea level rise, slow – In this report, the NCA intermediate low global sea level rise scenario

Sea level rise, medium – In this report, the NCA intermediate high global sea level rise scenario

Sea level rise, fast – In this report, the NCA fast global sea level rise scenario

SLR – Sea level rise

Social vulnerability - A broad term that describes the sensitivity of populations to the impacts of environmental risks and hazards, including coastal flooding; related to a community’s ability to prepare for, respond to, and recover from hazard events.

Storm tide – the height of tidal stage plus storm surge

Tidal epoch – Period over which tidal levels are defined. See definition for MHHW.

Princeton: One Palmer Square, Suite 330 Princeton, NJ 08542
Phone: +1 609 924-3800
Toll Free: +1 877 4-CLI-SCI / +1 (877 425-4724)
www.climatecentral.org