

# *Atlantic Coastal Impacts of Global Warming*

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**Past 6000-8000 Years:** Ocean height roughly steady.

**Recent decades:** global warming & thermal expansion of ocean, & melting sea and land ice.

**Future:** If all ice sheets and glaciers in the world melt, sea level 212 ft (65 m) higher.

Sea level expected to continue to rise for at least 1,000 years.

High tides, storms, and erosion can rapidly change shoreline.

Today's extreme tide = tomorrow's routine high tide.

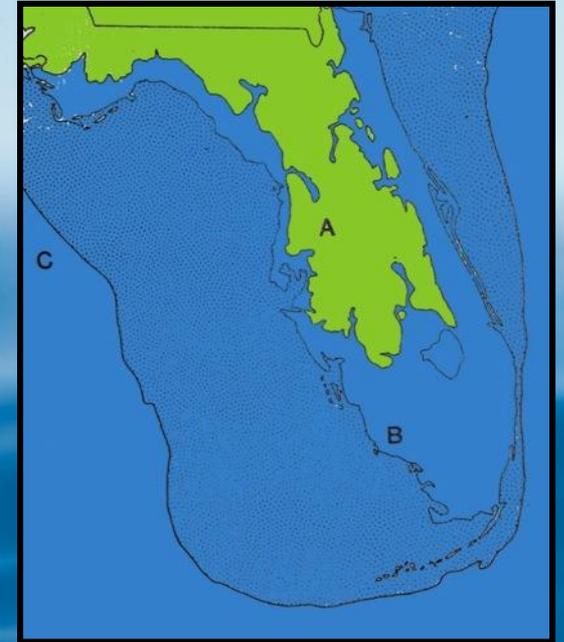
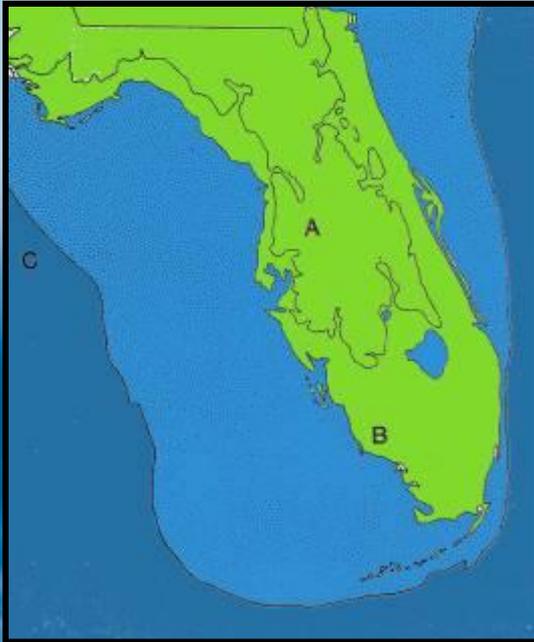
**Next few decades** → routine tidal flooding in many US east coast cities (& NASA centers).

Storm surge + high tide, as in Hurricane Sandy → extreme coastal flooding.

**Today**

**20,000 yrs ago**

**120,000 yrs**



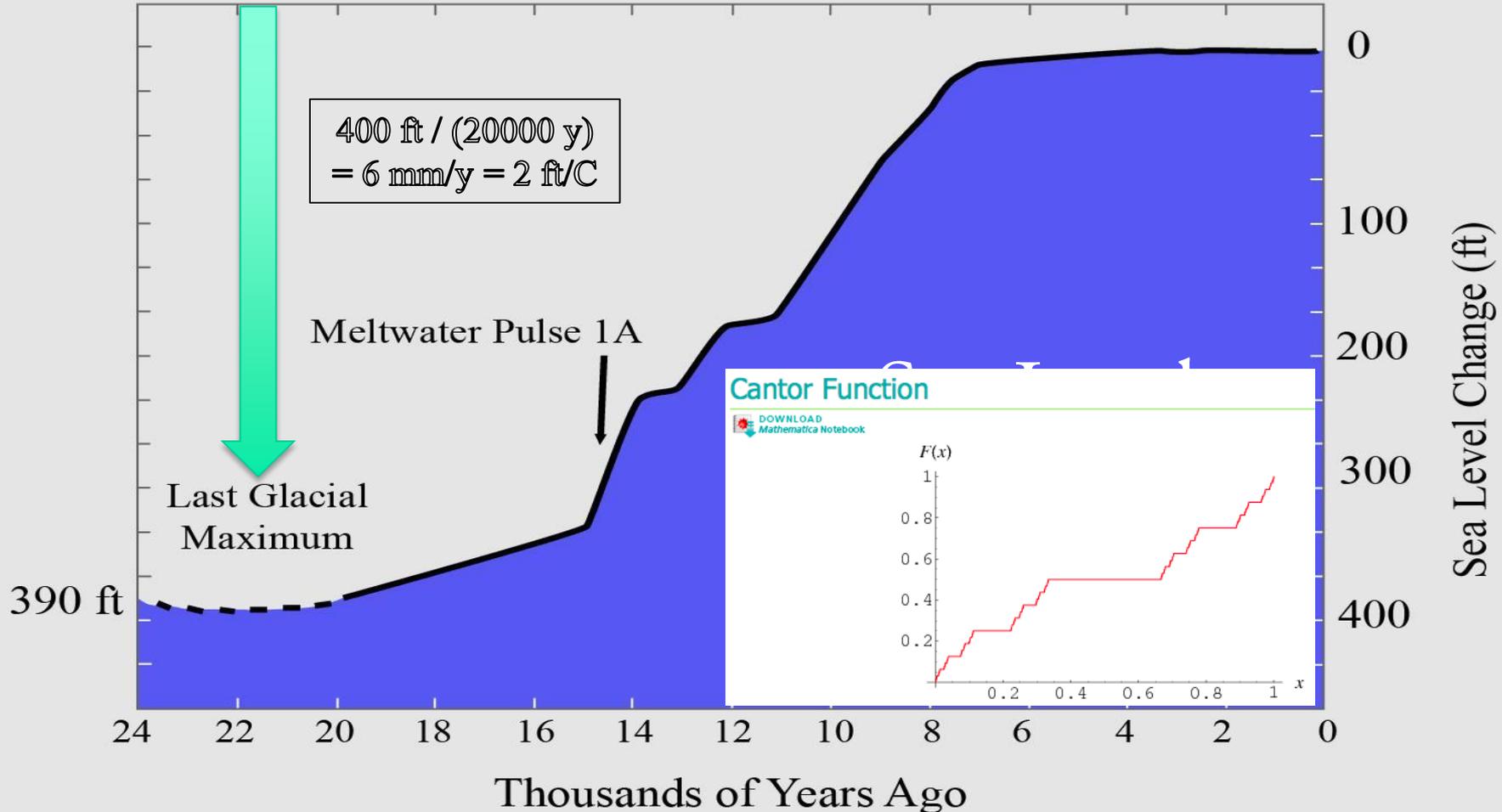
20,000 years ago, at the peak of the last ice age cycle, sea level was 390 feet (120 m) lower than present and Florida was roughly twice the current size.

120,000 years ago, at the last warm point in the natural climate cycle, sea level reached approximately 25 feet (8 m) higher than present, making the state less than half its current size.

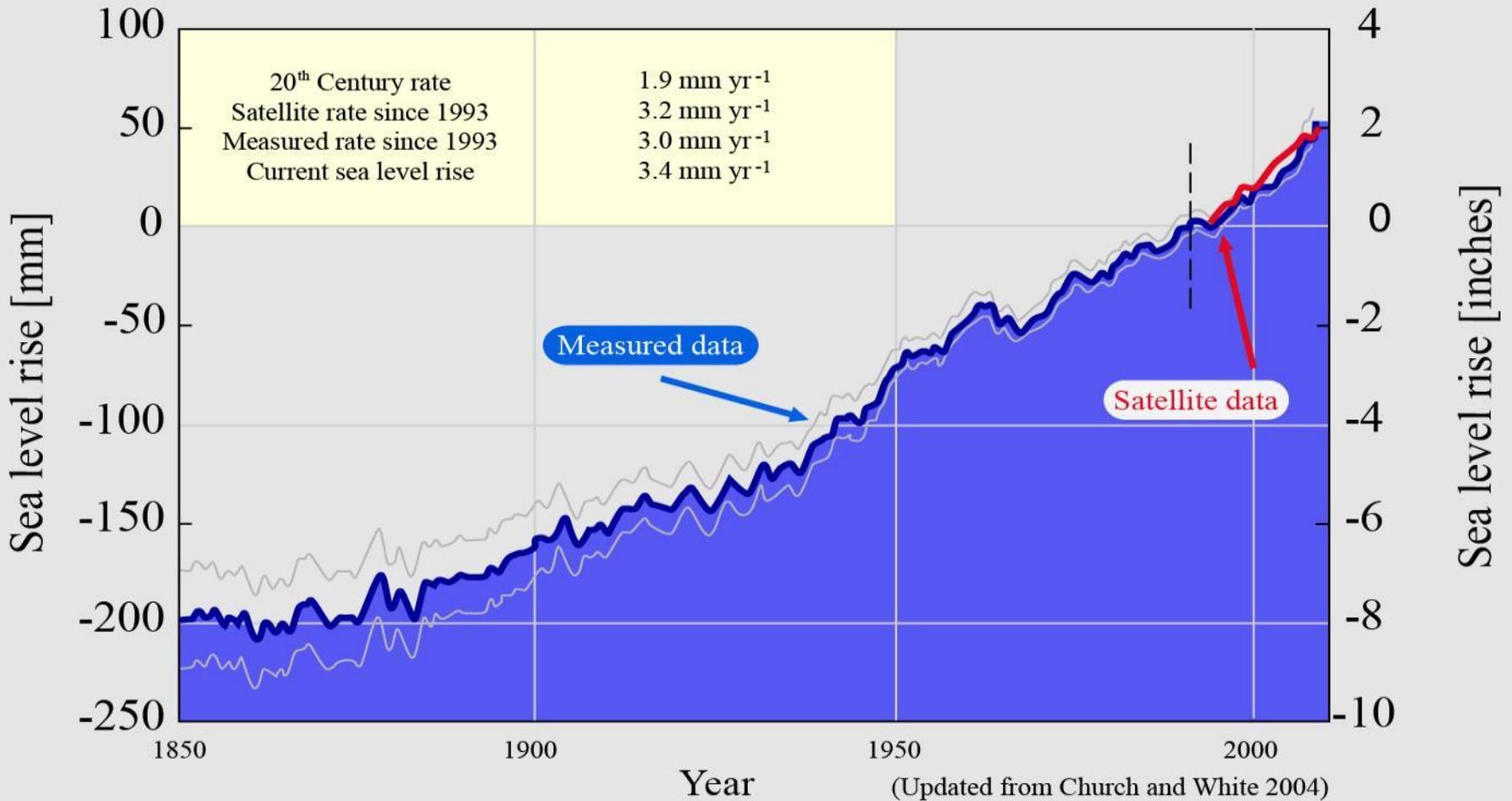


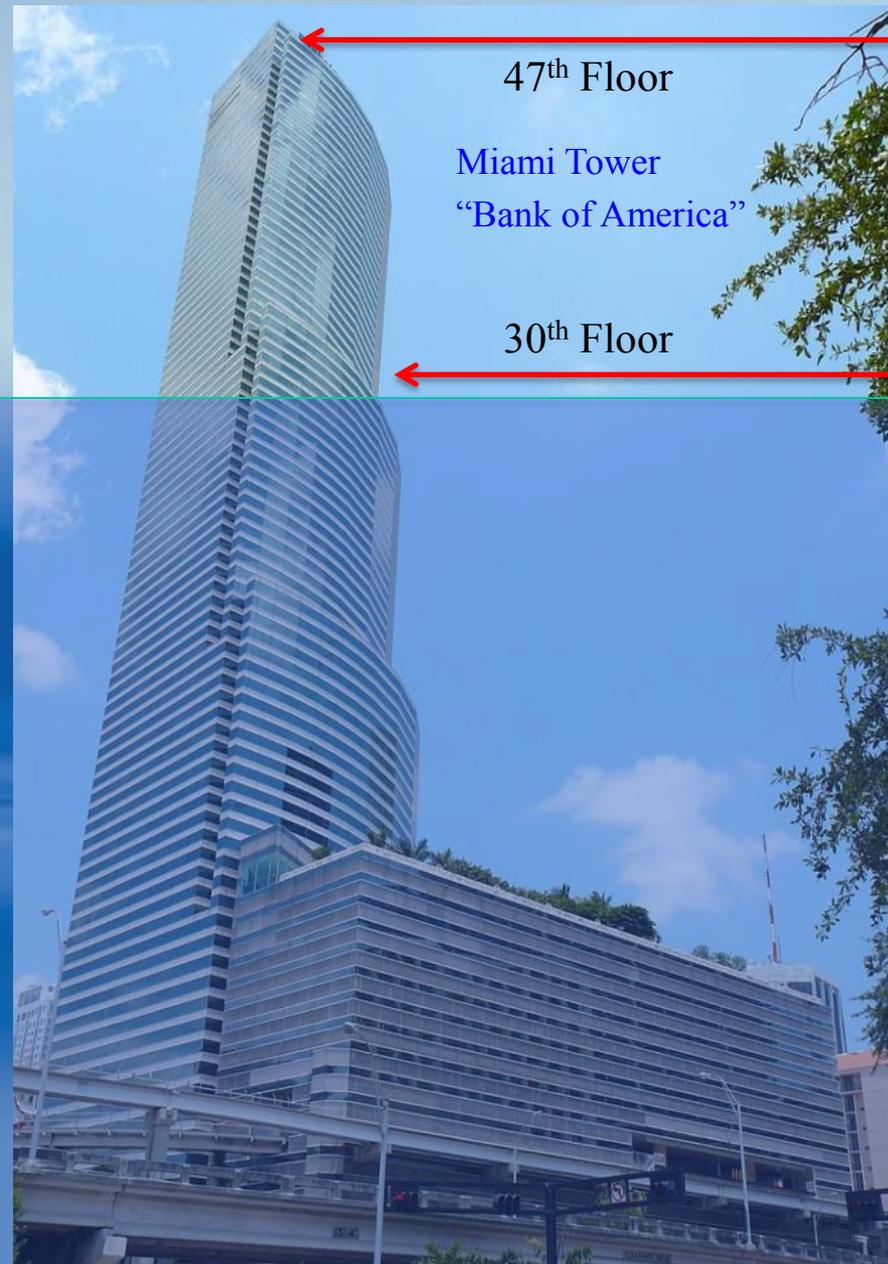
20,000 Years Ago

Last Ice Age



# Sea Level Rise: 20<sup>th</sup> Century





47<sup>th</sup> Floor

Miami Tower  
"Bank of America"

30<sup>th</sup> Floor

**When all ice melts**

**212 ft (65 m)**

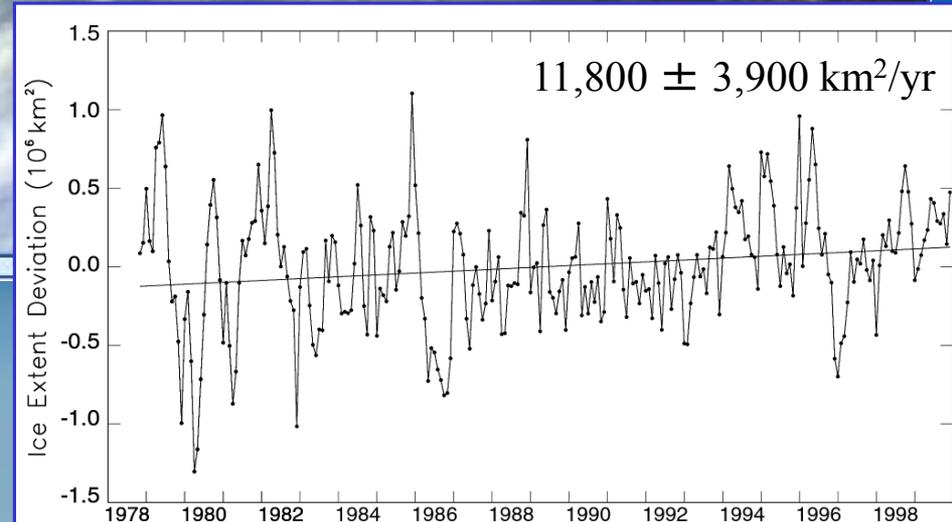
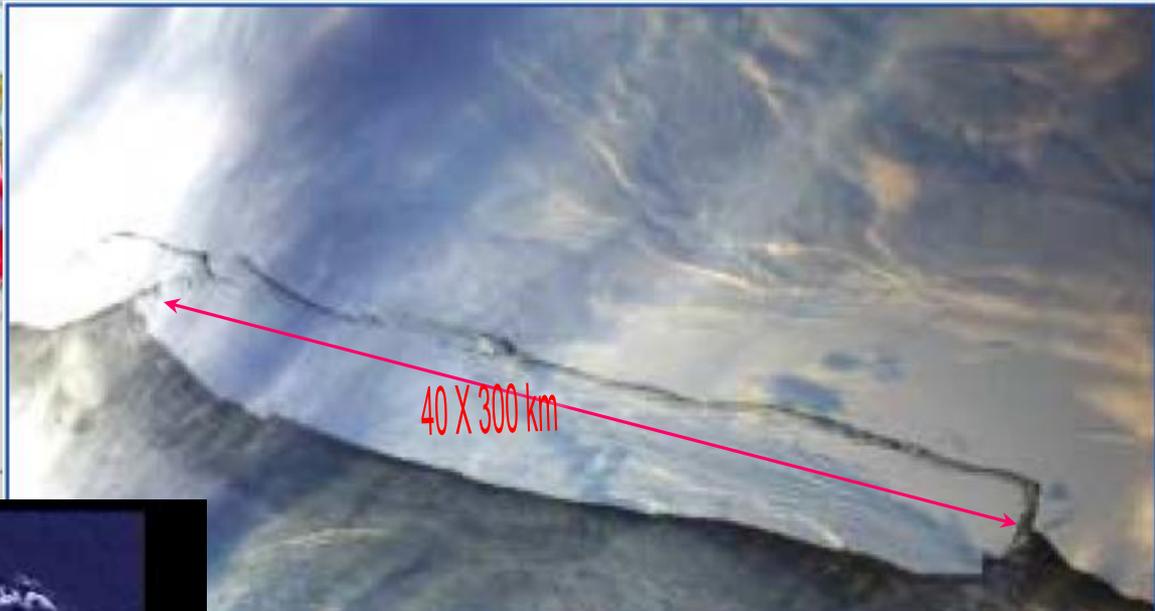
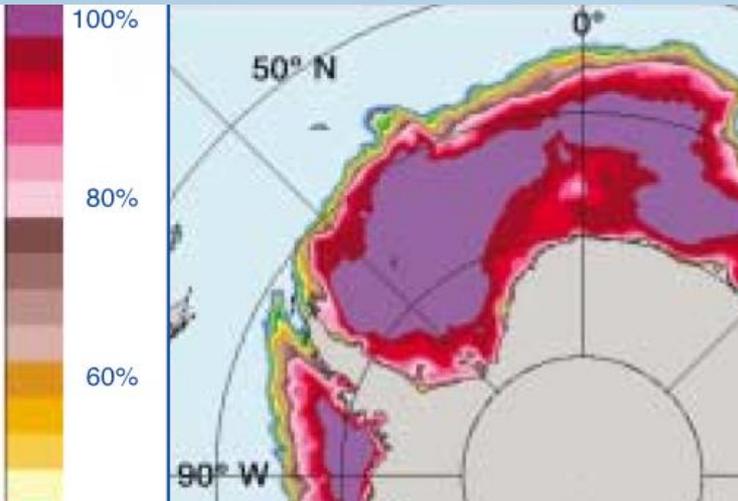
**Present Sea Level**

**390 ft  
(120 m)**

**20,000 years ago  
Last Ice Age**

Location	Feet	Meters
East Antarctic	169	51.6
West Antarctic	15	4.5
Antarctic Peninsula	2	0.5
Greenland	24	7.3
Other glaciers, etc	2	0.6
<b>Total Ice melting</b>	<b>212</b>	<b>64.5</b>

# Antarctic Melt-down ?



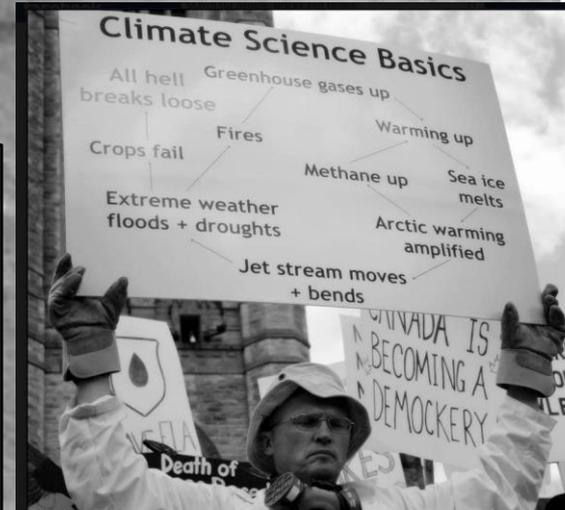
Ash Wednesday Storm, March 6-8, 1962

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"50 years ago, Ocean City was washing away"  
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– Baltimore Sun, March 5, 2012

Visit [baltimoresun.com](http://www.baltimoresun.com) at <http://www.baltimoresun.com>

"My 2011-2012 VT winter season, when the ground was frozen, was a mere 67 days, instead of 150 days. Watch what is happening to the Arctic ice - and here is the June snow record looking like terminal collapse."  
"





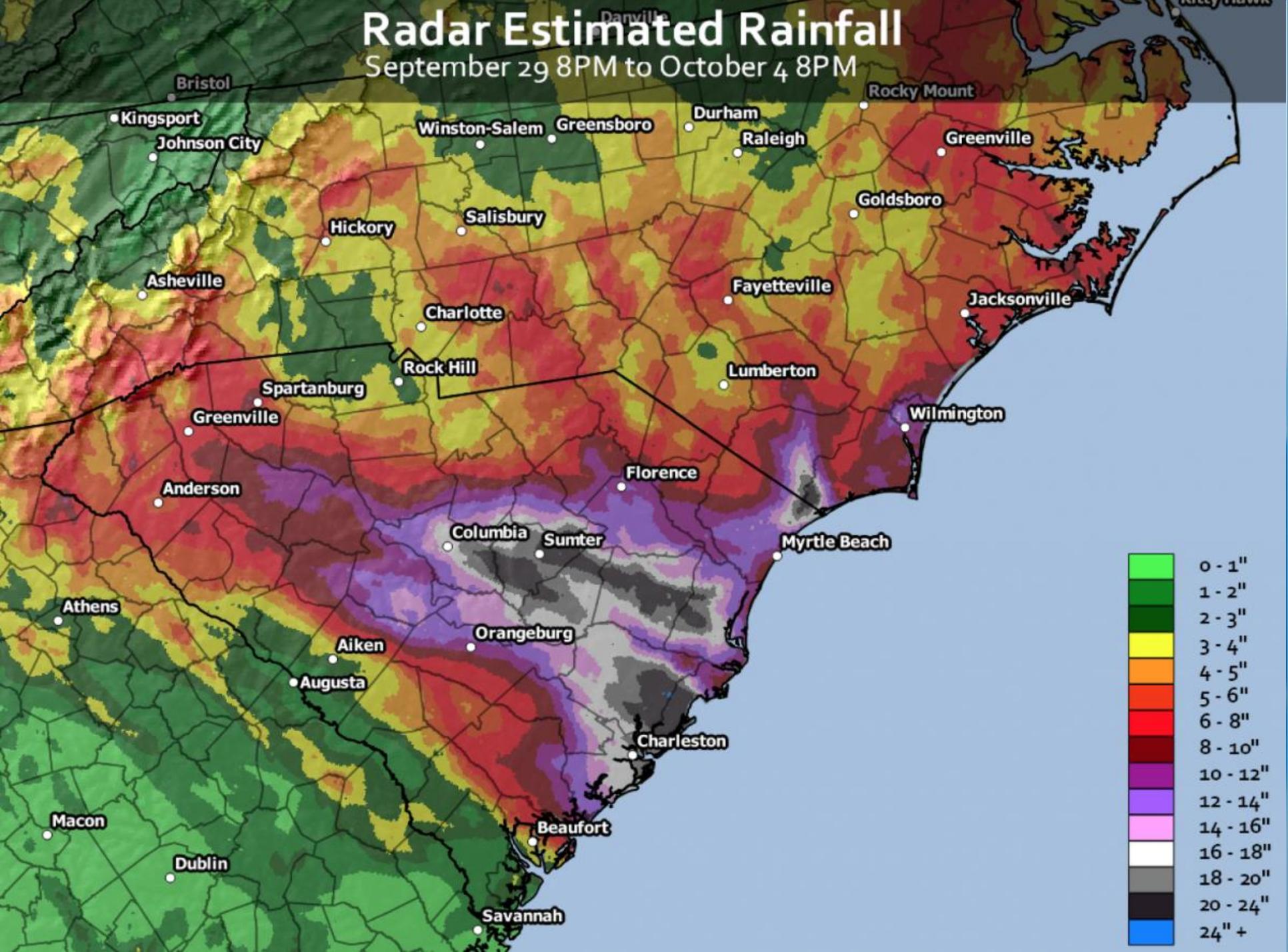
**Holland Island** The last house on Holland Island in the Chesapeake Bay as it stood in October 2009. It fell into the bay a year later. The owners held on until almost the last possible minute.

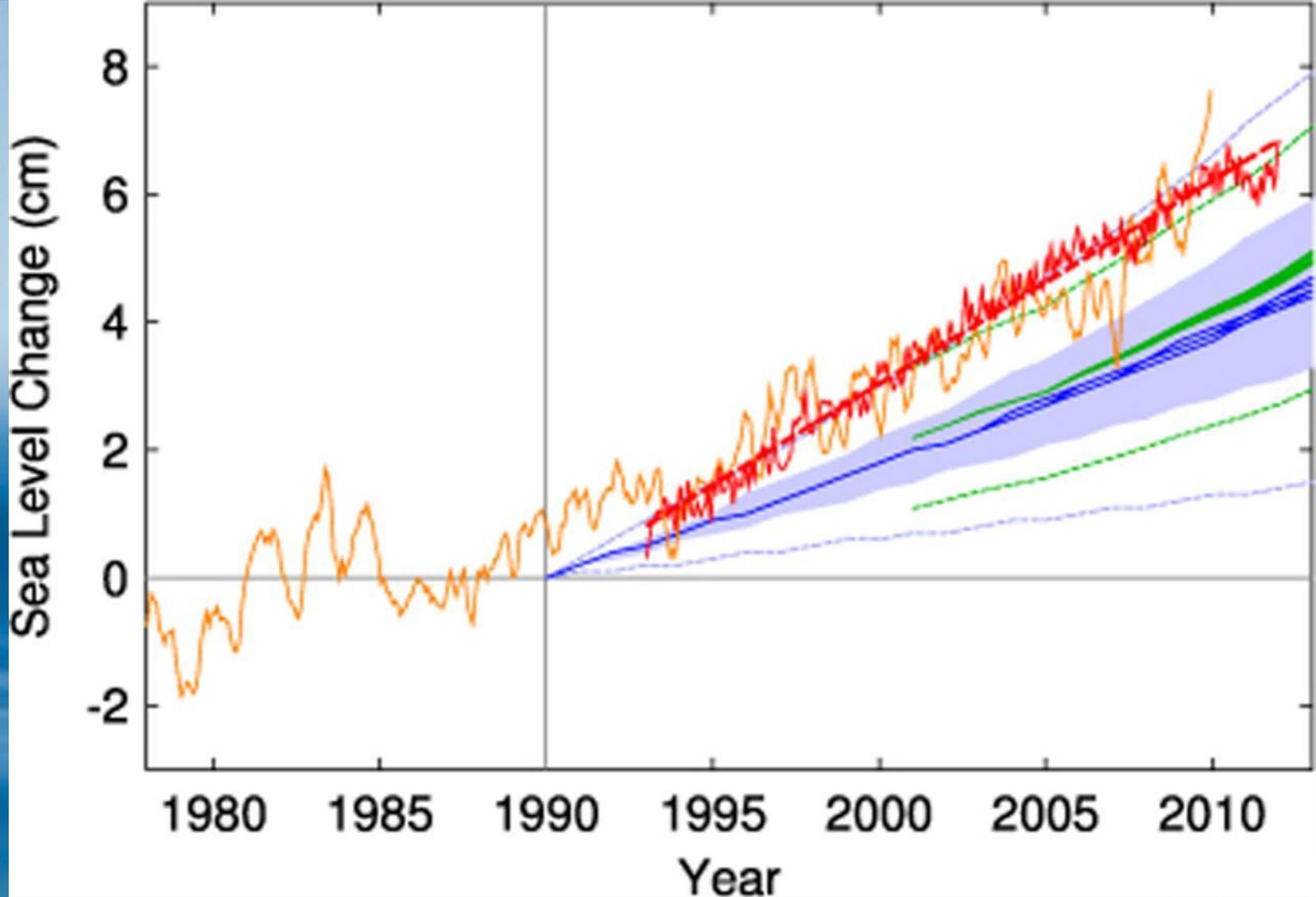


**Far Rockaway, NY** The top image shows Far Rockaway, NY before Hurricane Sandy. The bottom image shows the same neighborhood after Hurricane Sandy hit.

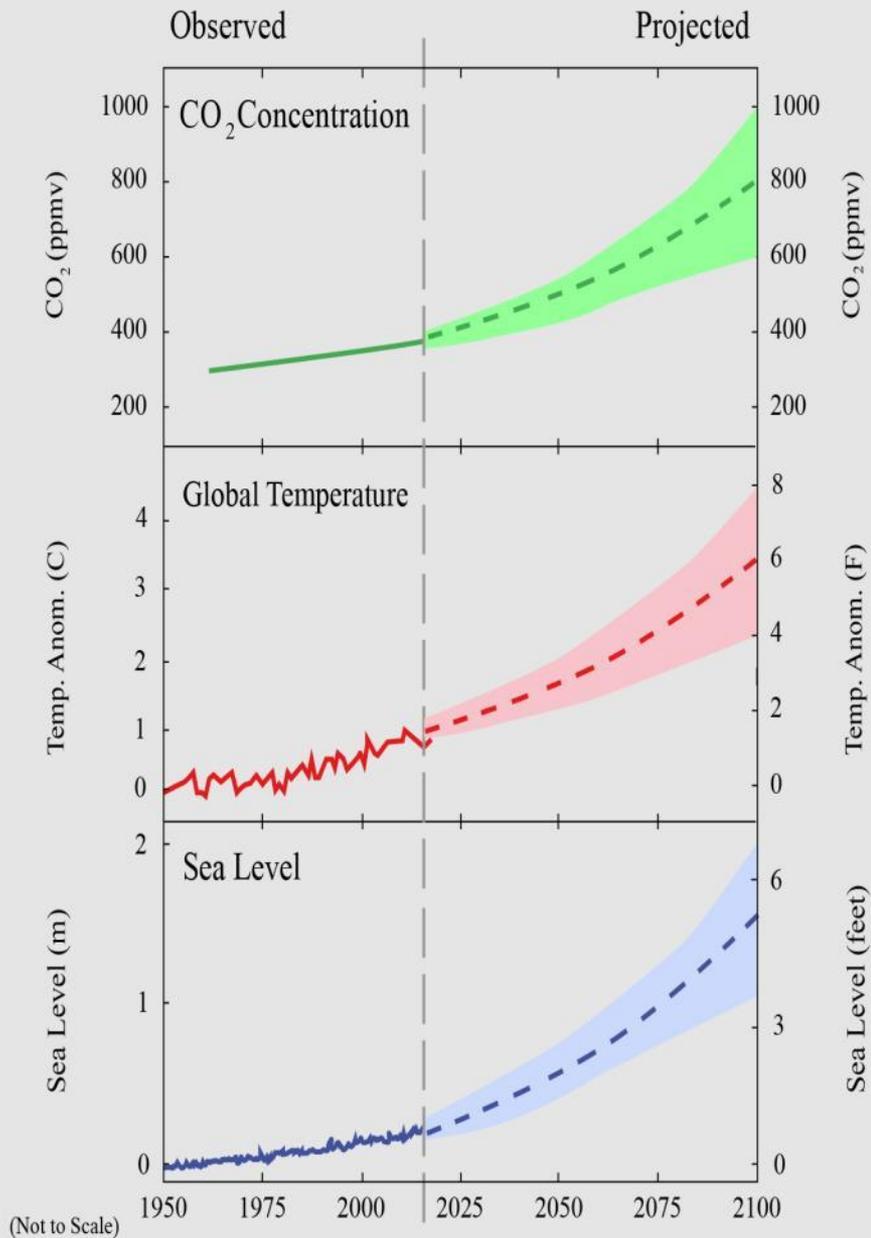
# Radar Estimated Rainfall

September 29 8PM to October 4 8PM





**Sea Level Change: Projections v. Actual** How good are SLR projections? IPCC published SLR projections in 1990 and in 2002, shown above as the fairly straight upper and lower boundary lines starting in 1990 and 2002. The yellow squiggly line starting on the far left is sea level measured by tide gauges. The red line running through that from the mid 90's is satellite altimeter data. The highest projections barely include the actual sea level rise. The IPCC projections for SLR are consistently low, a good indicator that future projections will continue the same pattern. (From Rahmstorf, 2012.)



Last half century continues the pattern:

CO<sub>2</sub>, global temperature, and sea level are all rising

# Encroaching Tides

How Sea Level Rise and Tidal Flooding Threaten U.S. East and Gulf Coast Communities over the Next 30 Years



## Savannah and Tybee Island, GA

*These historic coastal communities are taking steps to tackle tidal disruption.*



Savannah is a major port city that also boasts one of the nation's most extensive National Historic Landmark Districts. The waterfront is in many ways the engine behind the city's past and present prosperity. Founded as a major cotton export town, Savannah's picturesque cobbled streets and old warehouses draw millions of visitors each year and provide a popular hub for recreational fishing. However, the city is entering a new era as riverfront buildings increasingly flood at high tide.

Neighboring Tybee Island, at the mouth of the Savannah River, was once known as Savannah's beach. The island has a permanent population of around 3,000, which swells to 30,000 during the summer. Georgia's most densely developed barrier island and a tourist destination, Tybee Island has a colorful past as the haunt of the notorious pirate Blackbeard.

Like Savannah, this vacation town knows that it sits on the front line of sea level rise and is already taking steps to adapt. These efforts include raising the elevation of electronic controls for city wells, placing tide gates on storm-sewer outflows, raising roads, and nourishing eroding beaches.

Floods in the Savannah area, including Tybee Island, now occur about 10 times a year—up from an average of just five or fewer some 40 years ago (Sweet et al. 2014). The island is served by a single highway, Highway 80, which has become particularly prone to tidal flooding during a full or new moon. When water floods this and other roads, residents often contend with standing water, and downtown parking lots become inaccessible. Conditions are worse during higher spring tides, which occur twice a month when sun, moon, and Earth align. At these times, flooding can affect many sections of downtown, as well as stretches of the railway to the Port of Savannah.

Onshore winds and low-pressure systems off the coast often aggravate flooding by pushing water against the shore and allowing successive tides to build up. On those occasions sewer pipes on parts of Tybee Island fill with seawater and cannot drain into the ocean, so backflow occurs. Such events leave cars stuck and properties flooded.

Projections show that by 2030, just 15 years from now, Savannah could see more than 30 tidal floods a year—a threefold increase compared with today. And sea level rise of almost half a foot will transform today's nuisance tidal flooding into more dangerous and damaging ones, with conditions that now occur only during the worst tidal floods.

Projections for 2045 are stark: Savannah could see a foot of sea level rise and a 10-fold increase in tidal flood events—to more than 100 annually. Each year, about 10 of those floods would fall into the extensive category, affecting highways, houses, businesses, infrastructure, and parks, across an expanded area of the city and region.

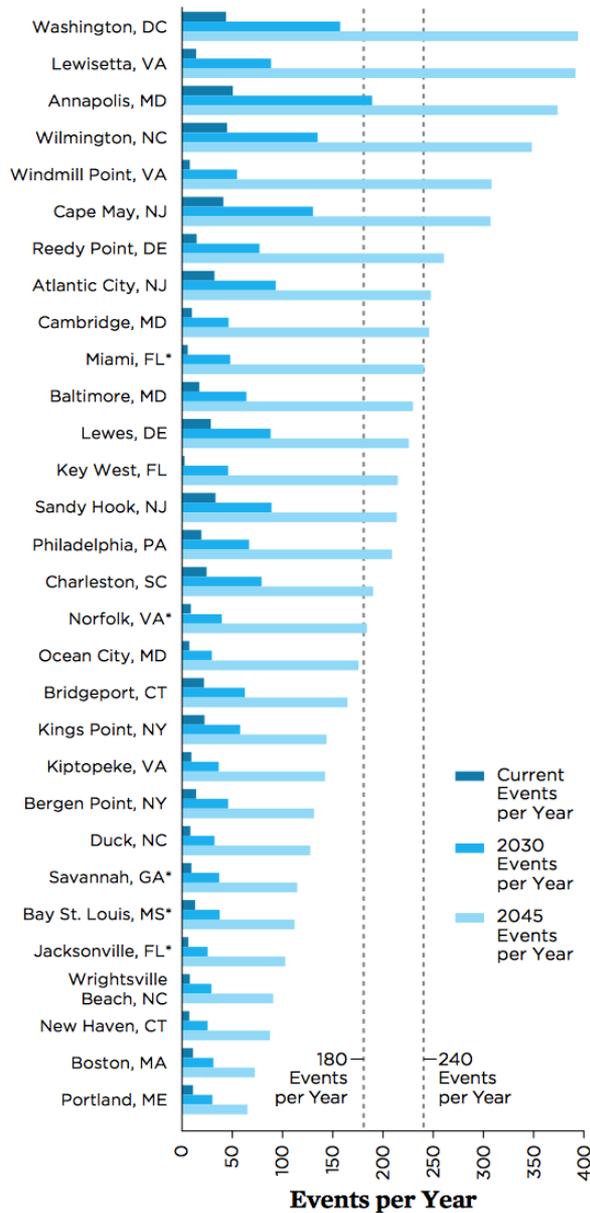
According to Jason Evans of the Carl Vinson Institute at the University of Georgia, "With a foot of sea level rise, you'd expect to see tidal flooding on the order of 100 days a year, rather than just four to five times a year as we do now." Observes Paul Wolff, Tybee Island's longest-sitting city council member, "Now is the time to plan and budget for infrastructure that we'll need 20, 50, and 100 years from now to deal with the impacts of sea level rise."

The cost of flood insurance for residents of Tybee Island is set to increase, partly because of the growing flood risk to their homes from sea level rise (Wolff 2014). FEMA plans to redraw flood maps in 2016, putting even more pressure on residents—more than a third of whom own vacation rentals that bring summer income.



*Flooding on Tybee Island, associated with extreme tides, affects a neighborhood for hours on a November 2012 day.*

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



Of the 52 locations we examined, 30 (shown here) can expect at least two dozen tidal floods per year, on average, by 2030, and some of those can expect much more. (Note that some communities, such as Broad Channel in Jamaica Bay, NY, see roughly this much flooding today; however, this flooding is not captured by the closest tide gauge.) By 2045, one-third of the locations we analyzed can expect 180 or more

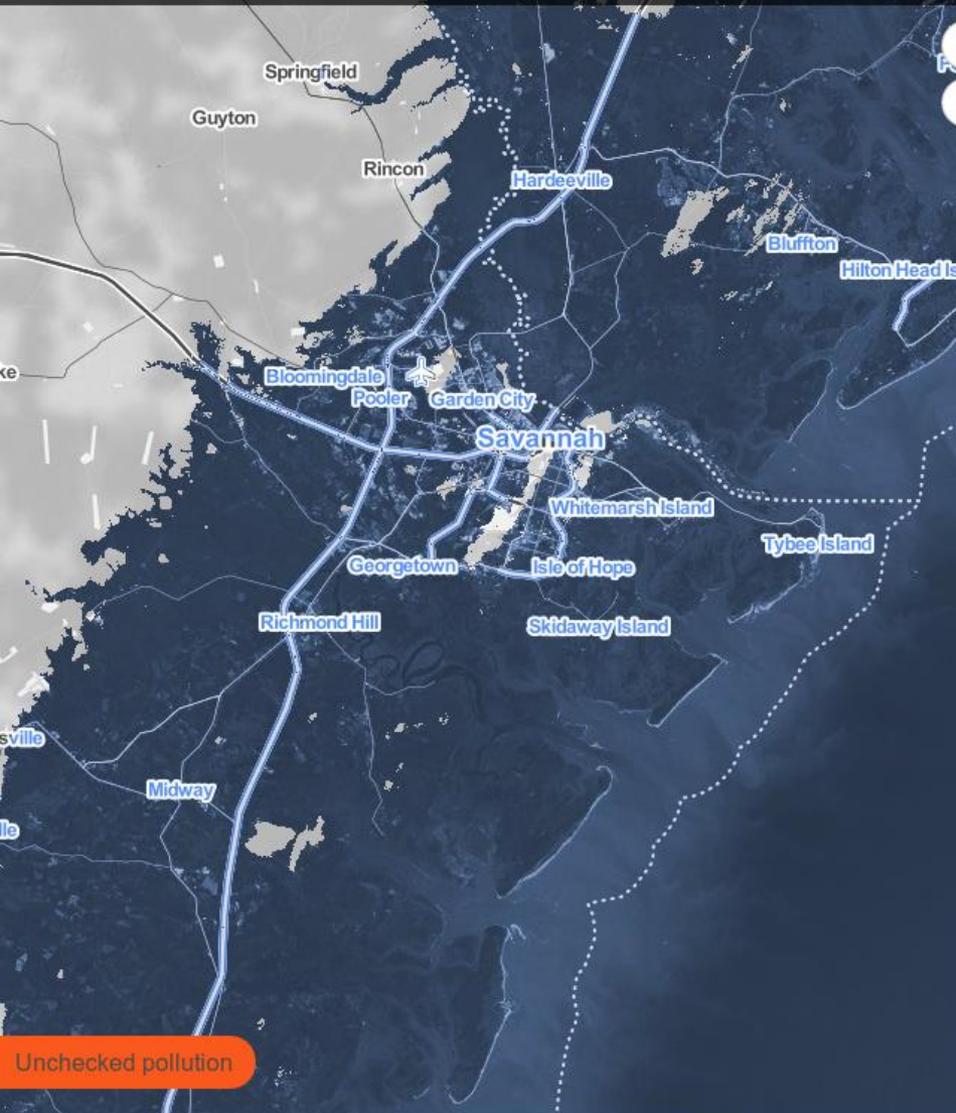


**Flooding in the famous St. Mark's Square, Venice, Italy on September 18, 2009** For the last three decades, these have become increasingly routine, known locally as *alta acqua*, or high water.

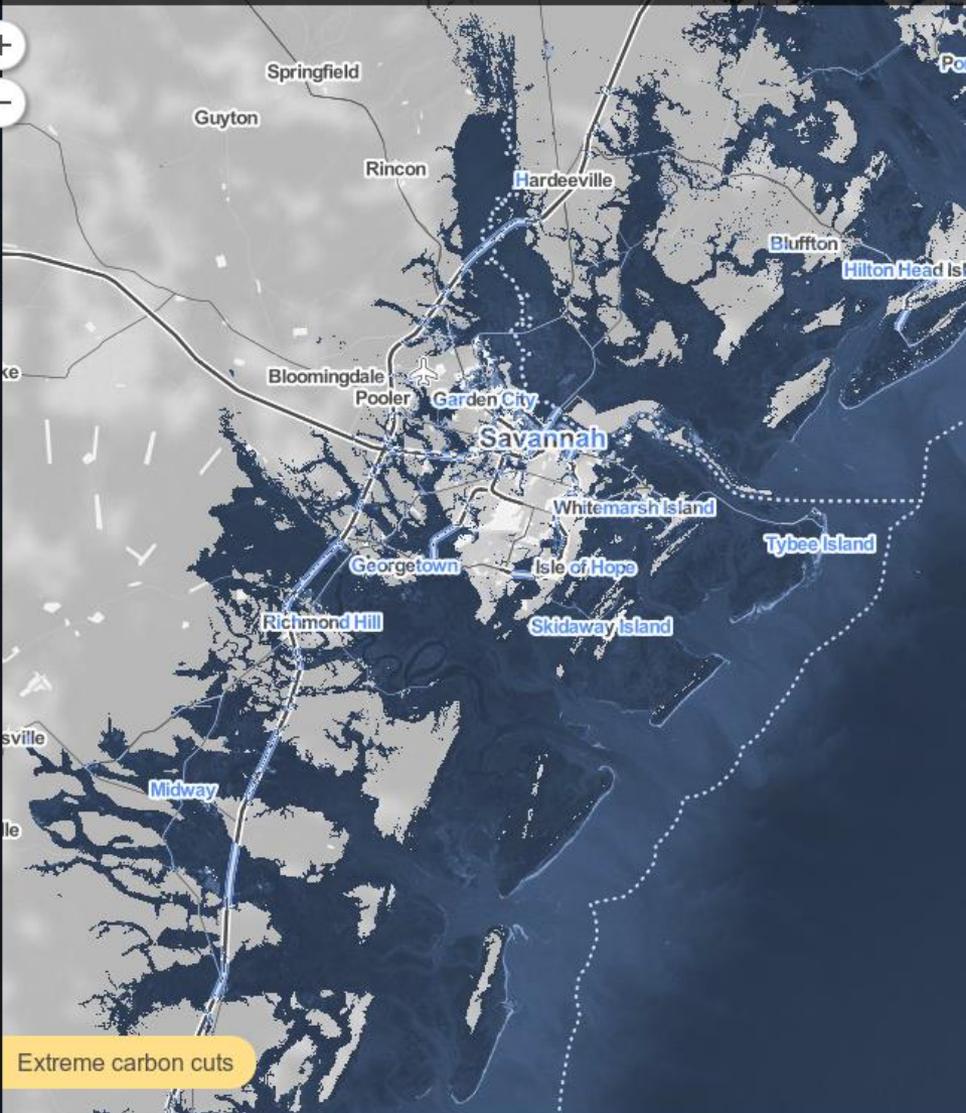
Enter a U.S. city or zip

Which sea level will we lock in?

When will this happen?



Unchecked pollution



Extreme carbon cuts

RISING SEA LEVEL  
AND THE COMING  
COASTAL CRISIS



**John Englander**

*Foreword by Bill McKibben*

*Chapter 6:*

**What We Can Do**



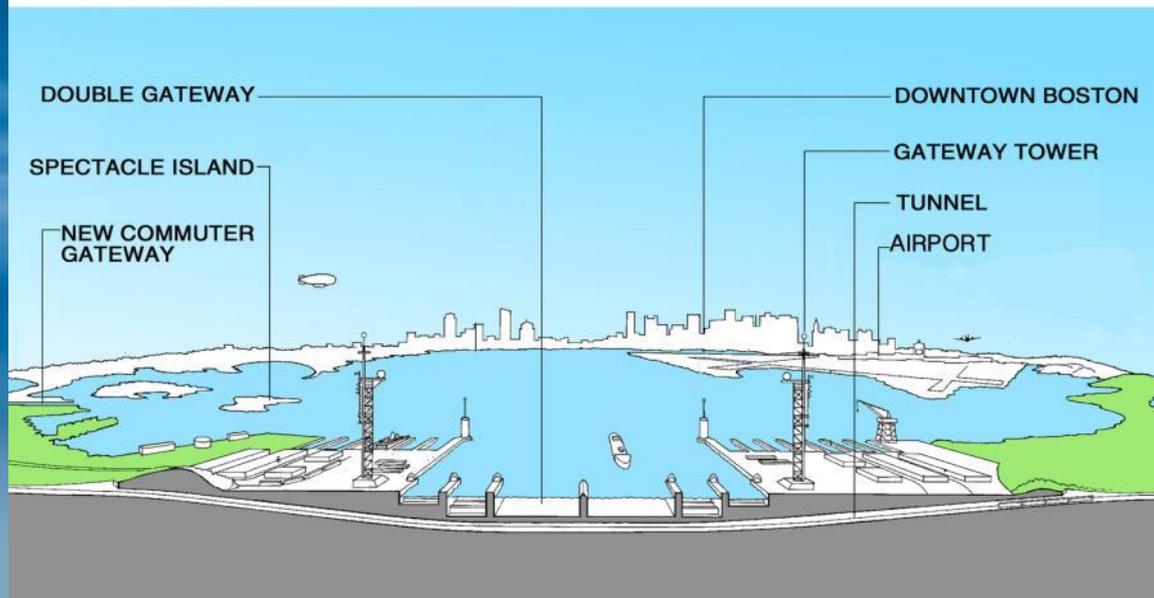
**Galveston Seawall** that lines Galveston's beaches is ten miles long and seventeen feet high.



**Rhode Island Hurricane Barrier** The Fox Point Hurricane Barrier is a tidal flood barrier spanning Providence River in Providence, Rhode Island. The barrier is 3,000 feet (915 m) long and 25 feet (8 m) high, consisting of gates, dikes, and a pumping station.



**Stiltville in Biscayne Bay** A group of houses built on stilts in Biscayne Bay off the coast of Miami.



**Boston's Safety Belt** an innovative solution to the problem of rising sea level in that highly vulnerable city. In spite of winning first place in a design competition in 1988, the plan gathers dust on a shelf.

# *What choices are being made?*

VIEW current and expected climate changes along our coasts:

<http://world.time.com/timelapse/>

<http://choices.climatecentral.org/>

Nature and human development is directly altering the landscape, and also now people are indirectly altering the landscape, via greenhouse gas emissions, causing Nature to respond in ways likely to make hundreds of millions or a billion humans homeless. Florida state government reportedly avoids use of the term 'sea level rise' in government documents. That's easy to understand, when you see the probable future of Florida: Within this century, Miami may become the "Drowned City." Within this millenium, Florida may become the "Drowned State." Stage 1: denial.

*A climate wave is arriving.*

*Will we wipe out ...*



*... or ride the wave?*

