

## The Coming Reality of Sea Level Rise: Too Fast Too Soon

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The reality of accelerating rates of sea level rise as the result of human-induced global warming is becoming more and more clear and increasingly dire. In 2012, NOAA published the most recent US Government sea level rise projections as a part of the National Climate Assessment. The projections, which included limited to maximum anticipated ice melt from Greenland and Antarctica, were for 4.1 to 6.6 feet of sea level rise by 2100. That would be 2 feet by 2048-2066 and 3 feet by 2063 to 2085. A two to three foot rise of sea level will make nearly all the barrier islands of the world uninhabitable, result in inundation of a major portion of the world's deltas, and make low-lying coastal zones like southeast Florida increasingly challenging communities in which to maintain infrastructure and assure protection of life and property during hurricanes and other extreme events.

Most of the models projecting future sea level rise assume a gradual acceleration of sea level rise through this century and beyond as ice melt gradually accelerates. Our knowledge of how sea level rose out of the past ice age paints a very different picture of sea level response to climate change. At the depth of the last ice age, about 18,000 years ago, sea level was some 420 feet below present level as ice was taken up by large continental ice sheets. Subsequent ice melt was not a gradual acceleration and then deceleration process. Rather it was a series of very rapid pulses of sea level rise followed by pauses. These rapid pulses of rise, from three to thirty feet, were fast enough to leave drowned reefs, sandy barrier islands, tidal inlet deltas, and other coastal deposits abandoned across the continental shelf. That is what happens when climate change warms enough to destabilize some ice sheet sector. It rapidly disintegrates, resulting in a rapid rise.

We have significantly warmed atmospheric climate and that is resulting in an accelerated ice melt of the surface of the Greenland Ice Sheet. Much of the surface of the Ice Sheet is darkening as the dust and black carbon in the ice concentrates on the melting surface. This accelerates heat adsorption further accelerating surface ice melt.

More importantly, warmed ocean water is accelerating ice melt in both polar regions. The warming North Atlantic Ocean and Arctic Ocean have been accelerating ice melt all around Greenland since about 1995 as this dense, 'warm' ocean water enters the deep outlet glacial fjords that penetrate far in under the Ice Sheet. 'Warm' water from upwelling because of increased wind shear around Antarctica is also penetrating in under outlet glaciers to the West Antarctic and East Antarctic Ice Sheets. Each of these 'warm' waters are only 2-4 degrees Celsius, but that are doing a powerful amount of warming, and we are creating a basically unlimited supply of warmth to the oceans.

The beginnings of polar Ice Sheet melt are showing positive reinforcing feedbacks which are rapidly accelerating the rate of melt far beyond anything originally anticipated. Water on the melting ice surface adsorbs more heat accelerating surface melt; melt water percolating down through the ice lubricates the base permitting faster motion, which results in more extensive fracturing. Water percolating through the fractured ice accelerates ice melt and warms the ice resulting in softening of the ice and further acceleration. And so on. With the rapid melting of the Arctic Ocean pack ice and warming of the Arctic Ocean, release of additional carbon dioxide and methane from decaying organics in the melted permafrost and melting of methane hydrates on the Arctic continental shelf, this melt is accelerating and seems irreversible. We are most certainly witnessing the onset of a rapid pulse of sea level rise.

In the spring of 2014 NASA, JPL, Cal Tech, and University of California Irvine have come out with documentation showing that ice melt at the margins of the West Antarctic Ice Sheet is much less constrained by underlying bathymetry than previously considered AND that the numerous fjords penetrating in from the Greenland coast are deeper and extend much further in under the Ice Sheet than previously thought. Both of these findings mean that warmed ocean water will more easily penetrate further under the ice sheets and that accelerating ice melt will be happening significantly faster than previously thought.

Last summer, we had the opportunity to witness this, flying about 50 miles onto the Greenland Ice Sheet following the deep channel of the Jacobshaven Icefjord in western Greenland. We reached an elevation on the Ice Sheet of over 6,000 feet. It was like flying up a large, meandering, fractured stream bed in the ice surface. The channel was some 500 feet below the level of the ice sheet and dramatically fractured from the accelerated ice flow. This was created by melt at the base from deeply penetrating 'warmed' ocean water. As a result of the fracturing and detachment from the bottom, the forward velocity of the ice has accelerated from a couple of miles per year to over twenty. Overall, a spectacular but most disturbing experience.

In light of our improving understanding of ice melt, we probably should be looking at AT LEAST 7 to 10 feet of global sea level rise by the end of the century.

We are in for it. Even if we stopped burning fossil fuels tomorrow, the greenhouse gases in the atmosphere will keep warming the atmosphere for at least another 30 years. And most of this global warming heat is really ending up in the oceans which have the capacity to capture and store and use this heat for centuries. As a result, ice melt and sea level rise will continue for centuries. Most all projections show sea level rise accelerating through this century and the next. When we are talking about 4-6 feet by the end of the century, this will not be some new fixed sea level. It is an acceleration of sea level rise because of accelerating ice melt. If we are at 5 feet at the end of the century, sea level will be rising at a foot per decade. Think about trying to maintain a port facility anywhere with that.

Several recent papers, including one from the National Research Council, have pointed out that we now have greenhouse gas levels sufficient to cause a 79 foot sea level rise. We just have no

experience in knowing exactly how fast destabilized ice sheet sectors can disintegrate. Indications from the past and the present are that pulses of sea level rise can happen very fast.

It is truly amazing to me to watch the very aggressive building boom underway again in south Florida – on the beaches and barrier islands, throughout downtown and in the low western areas bordering the Everglades. They are building like ‘there is no tomorrow.’ Unfortunately, they are right.

Even with the current projection of 6.6 feet by the end of the century, it is beyond sobering to consider the risk in the present investments. Just think it through. With a further two feet of rise (possibly before 2048) most of the barrier islands (of south Florida and the world) will be abandoned and the people relocated; at the same time low places like Sweetwater and Hialeah bordering the Everglades will become more and more frequently flooded and difficult places to live. We will be losing our freshwater resources, be living in a community with a failing and disconnected infrastructure, and be at increasing risk from catastrophic storm surges and flooding from hurricanes. Counties should be aggressively and transparently planning for their future – working with elevation and infrastructure maps to determine the timing, costs and economic feasibility for maintaining a functional infrastructure, viable insurance, and human health and safety. There are already areas that will be unlivable and properties that will be unsellable within a 30-year mortgage cycle. The 4-county Compact on climate change in southeast Florida has some 1,200 action items to help insure the stability of the people and the communities. It is time to truly act within a framework of the reality before us. Every day we put it off, we are warming the ocean further and making it more and more difficult to reverse - and making the inevitable climate changes and sea level rise worse and worse.

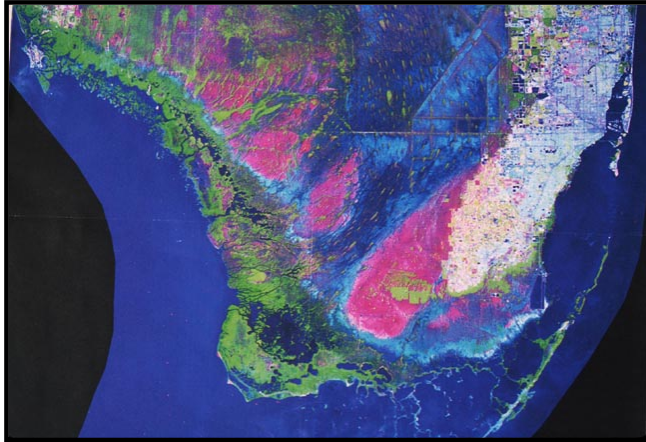
If communities use the 2012 NOAA projections (\*) for planning (4.1-6.6 feet by 2100), they will quickly realize that very serious problems will be occurring very soon and that serious evaluation must be made of the reality/unreality of maintaining functional infrastructure in different community sectors as each step of inundation occurs. And for south Florida, forget the levees and dikes. They may be fine for New Orleans and the Netherlands, but not here. Our limestone and sand substrate is much too porous and permeable.

Many top scientists have concluded that global sea level may rise 15-20 feet by the end of the century. If you are planning for 4-6 feet, it will not be hard to then plan for something higher and faster. Without planning, there will come a point where society will collapse into chaos. We can prevent this scenario with serious planning and effort. Our children and future civilization deserve much better than we are presently doing.

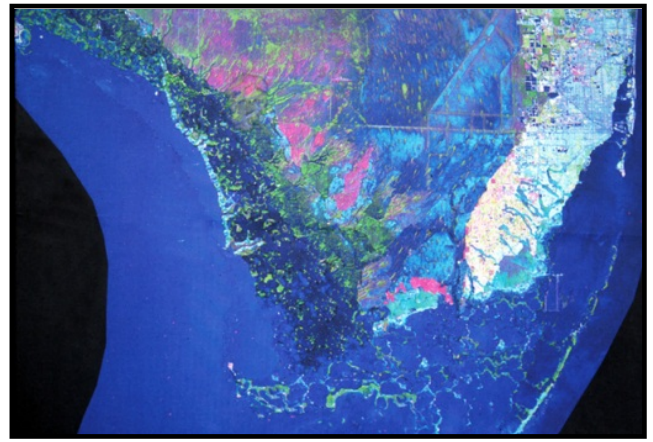
The Synthesis of the UN’s Intergovernmental Panel on Climate Change 5<sup>th</sup> Report came out the beginning of November 2014. Statements in the draft of that are on the last page. For the first time it focuses on irreversibility and the centuries of effect that human-induced climate change will now cause,

\* NOAA, 2012. Global Sea Level Rise Scenarios for the United States National Climate Assessment.

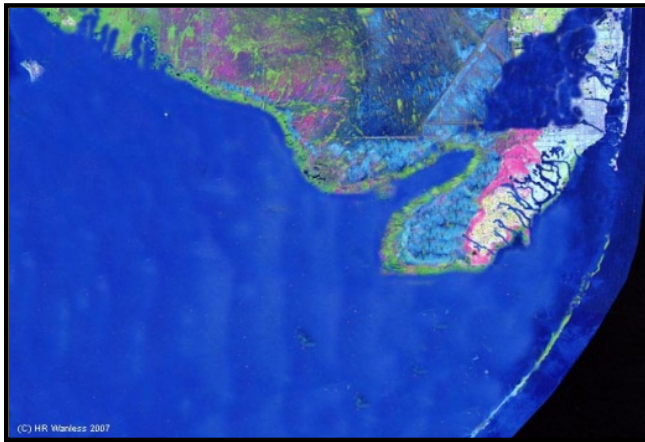
## PROJECTED INUNDATION FOR SOUTH FLORIDA



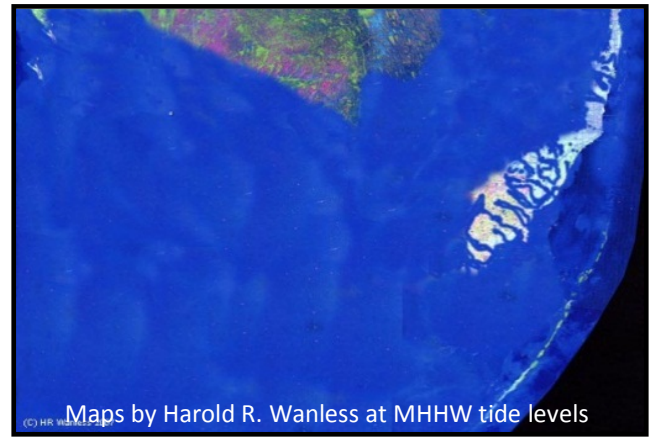
TODAY



+2 feet (by 2048 to 2066)



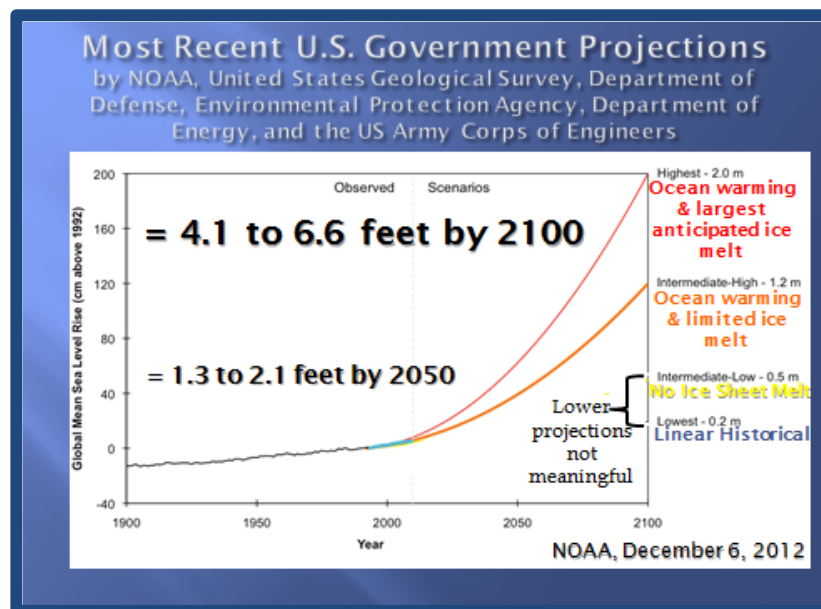
+ 4 FEET (by 2074 to 2100)



Maps by Harold R. Wanless at MHHW tide levels

+ 6 FEET (by 2094 to 2122)

Projected inundations dates below are from NOAA, 2012: *Global Sea Level Rise Scenarios for the United States National Climate Assessment*.



## Conclusions from the 5<sup>th</sup> report Synthesis of the IPCC:

The continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems.

Many aspects of climate change and its impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases cease. The risk of abrupt and irreversible change increases as the magnitude of the warming increases.

**Climate change represents a substantial multi-century commitment, effectively irreversible over a period of many human generations.** Stabilization of radiative forcing would result in an ongoing global warming for many centuries. Warming would continue beyond 2100 under nearly all model scenarios. (p. 78)

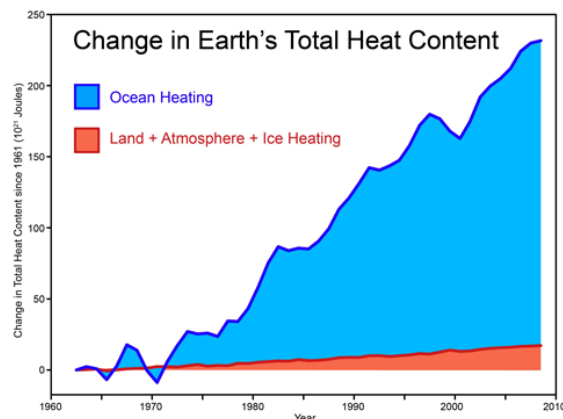
**The anthropogenic contribution to surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of net anthropogenic CO<sub>2</sub> emissions.** (p. 78)

**Stabilization of global average surface temperature does not imply stabilization for all aspects of the climate system.** Shifting biomes, re-equilibrating soil carbon, ice sheets, ocean temperatures and associated sea level rise all have their own intrinsic long timescales that will result in ongoing changes for hundreds to thousands of years after global surface temperature has been stabilized. (p. 78)

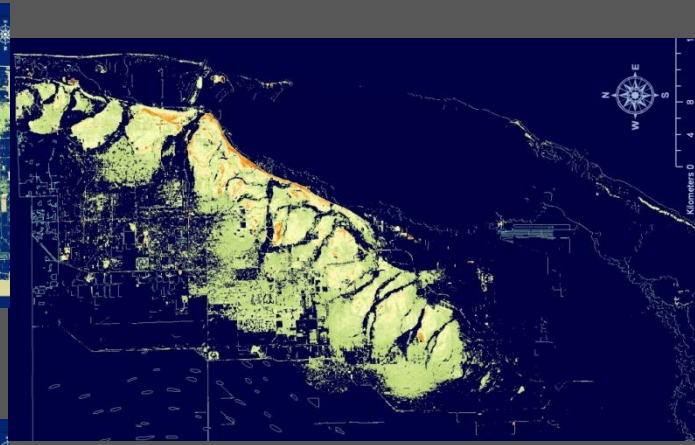
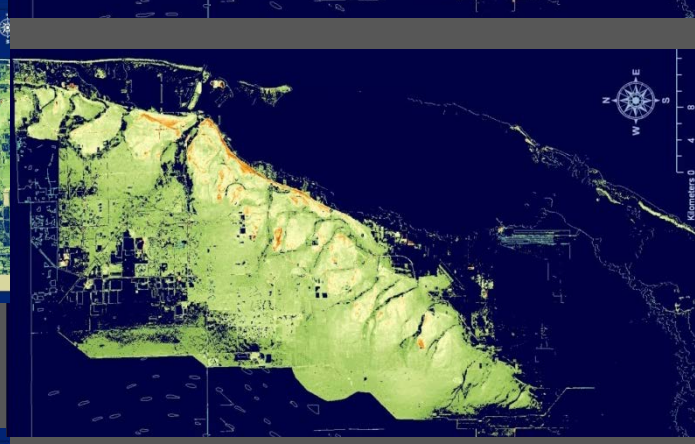
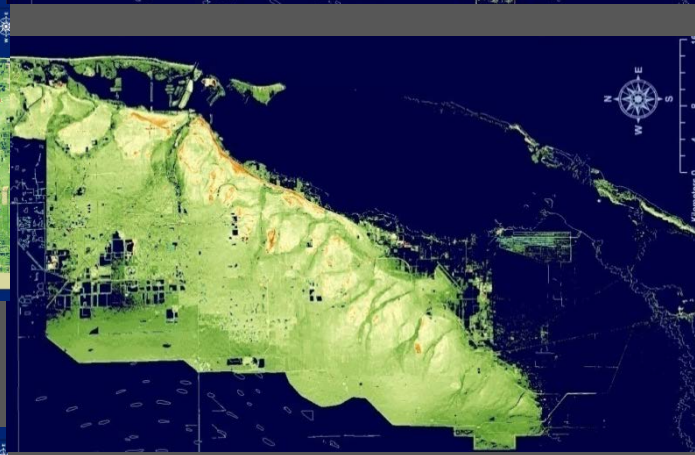
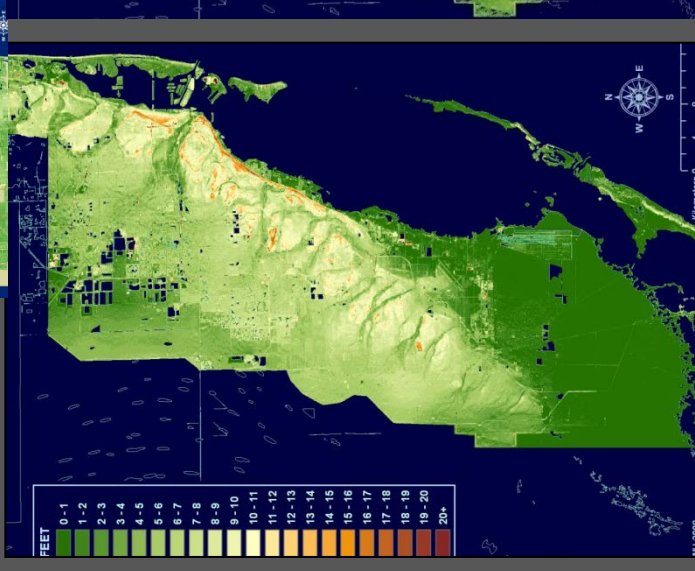
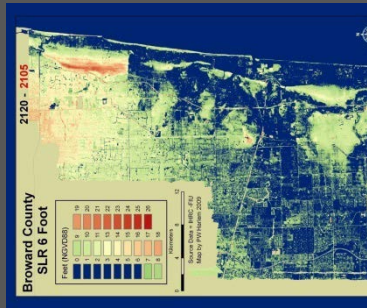
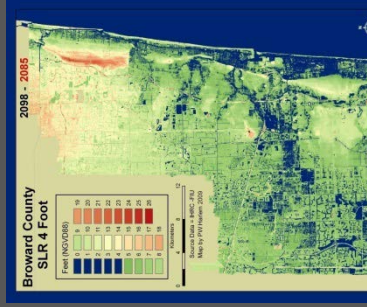
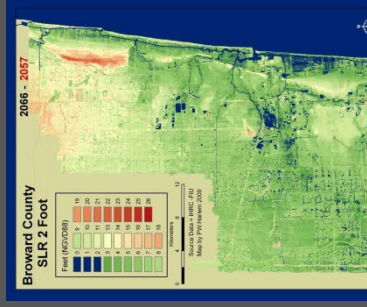
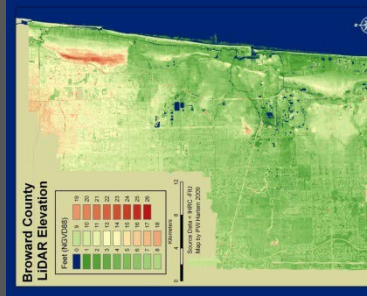
**Global mean sea level rise, caused by ocean thermal expansion and the loss of mass from ice sheets, will continue for many centuries beyond 2100.** (p. 79)

**Sustained mass loss by ice sheets would cause larger sea level rise, and part of the mass loss might be irreversible.** There is *high confidence* that sustained global mean warming greater than a threshold would lead to the near-complete loss of the Greenland ice sheet over a millennium or more, causing a sea level rise of up to 7 m. Current estimates indicate that the threshold is greater than 1 °C (*low confidence*) but less than about 4 °C (*medium confidence*) with respect to pre-industrial temperatures. Abrupt and irreversible ice loss from a potential instability of marine-based sectors of the Antarctic ice sheet in response to climate forcing is possible ... (p. 81)

Global mean surface temperature increases by 2100 are from about 3.7 to 4.8 °C (range based on median climate response; the range is from 2.5 °C to 7.8 °C when including climate uncertainty). (p. 87)



# MIAMI-DADE AND BROWARD COUNTIES THIS CENTURY



Present topography

+2 FEET

+4 FEET

+6 FEET

**(2048-2066)**

**(2074-2099)**

**(2093-2121)**

**WHAT WE WILL LOSE**

Freshwater Resource

Airports

Storm Protection

Sewage Plants

Road connectivity

Tax Base

MAPS BY PETER HARLEM, FIU