



SEA LEVEL

RISE

*Tips for Adaptation Planning*

**When the low tide becomes the high tide...  
where will the high tide be?**

# SEA LEVEL RISE

*Tips for Adaptation Planning*

The purpose of this publication *Sea Level Rise - Tips for Adaptation Planning* is to provide information to local community leaders, planners, resource managers and concerned individuals about basic considerations and tools to help adapt to climate-related sea level rise.

The focus is on adaptation for the impacts of sea level rise so that critical human systems (such as communities, economies, and culture) and natural systems (including wetlands, coastal ecosystems and fisheries) can continue to function effectively and be resilient in the face of climate change. The tools and tips offered in this brochure are also broadly applicable to many other climate-related impacts, such as more temperature extremes, heat waves and heavy precipitation periods, increased drought in some areas, and more extreme weather events.

This publication was produced in partnership by  
Sarasota Bay Estuary Program and Mote Marine Laboratory, Marine Policy Institute.



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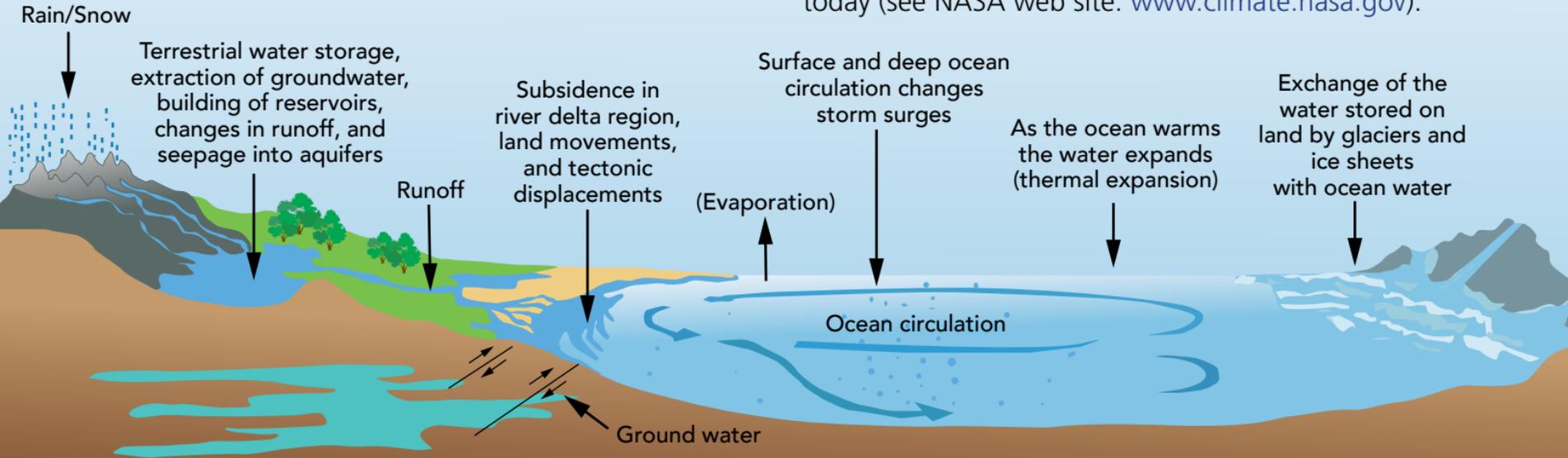
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# SEA LEVEL RISE

## WHAT CAUSES SEA LEVELS TO CHANGE

**Sea levels** on Earth change with the climate. Global sea levels have fluctuated throughout our planet's history as it goes through cooling and warming spells. Some scientists estimate the range of change by as much as +/- 300 feet from the present level (Donoghue, 2011).

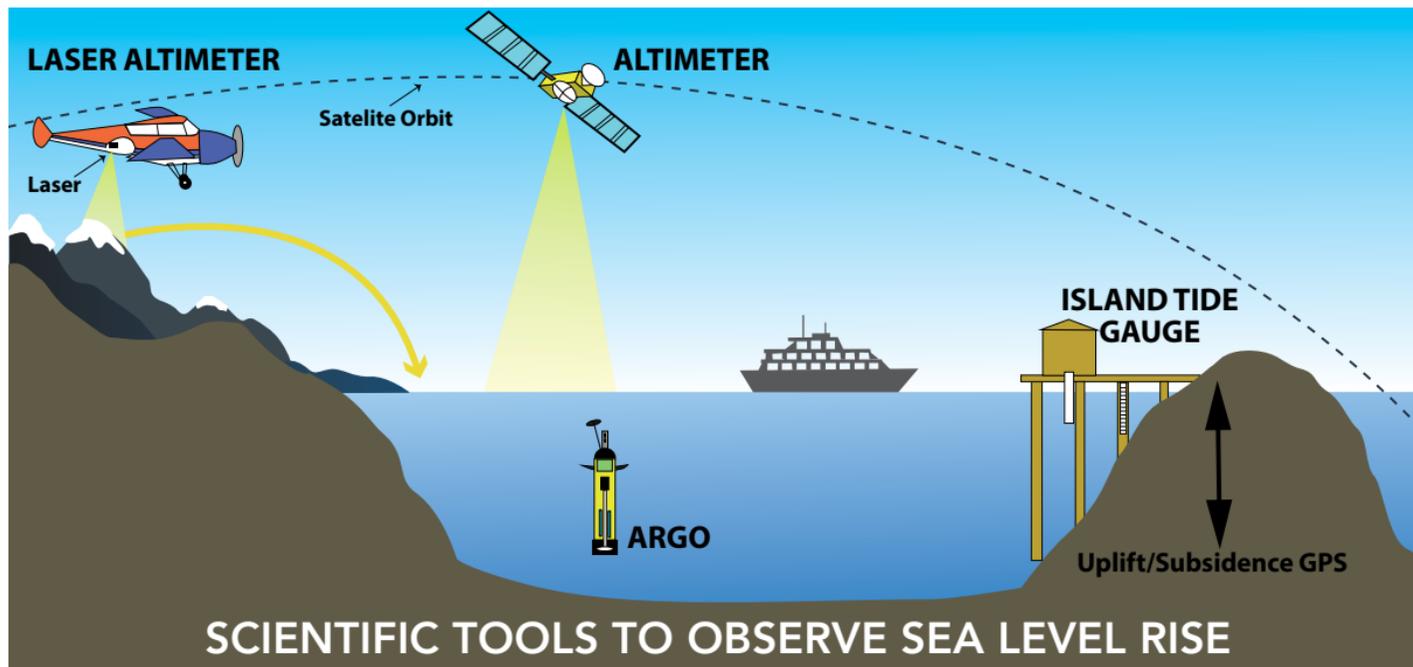
According to NASA scientists, during the last ice age (about 18,000 years ago) global average sea levels were as much as +/-350 feet below today's levels. During the last warm interval (about 125,000 years ago) global average sea levels were 9 feet to 18 feet higher than today (see NASA web site: [www.climate.nasa.gov](http://www.climate.nasa.gov)).



## FACTORS AFFECTING SEA LEVELS AND SEA LEVEL CHANGE

**Laser Altimeter:** An instrument that uses light and radar to learn about the topography, or the shape of the surface, of the planet. In the commercial sector, laser altimetry is commonly referred to as 'lidar' mapping (from the combined words of light and radar). A laser altimeter can be operated from a plane, a helicopter, or a satellite. It determines the distance to the earth surface by measuring the time-of-flight of short flashes of laser light which travel to the surface and are reflected back.

**Argo:** a global array of free-drifting floats that measures the temperature, salinity, and velocity of the upper 2000 meters of the ocean. This technology allows continuous monitoring of the physical state of the upper ocean so it can be systematically measured and the data assimilated in near real-time into computer models. Argo has grown to be a major component of the ocean observing system.

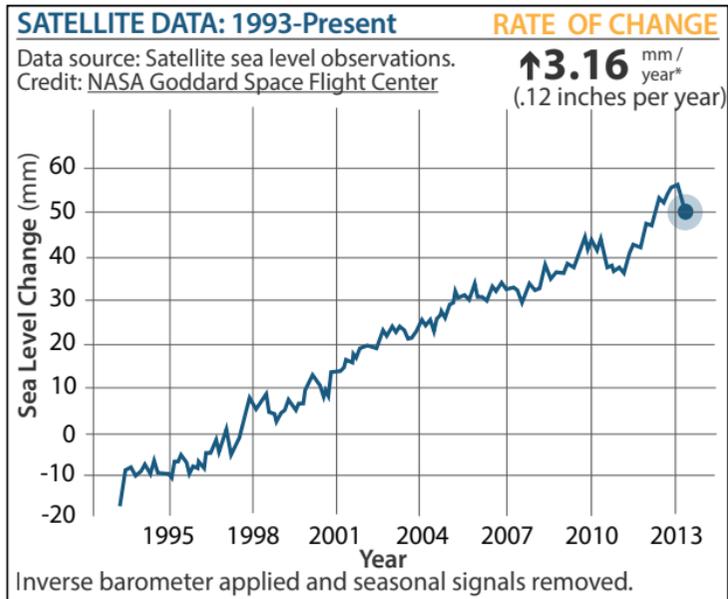
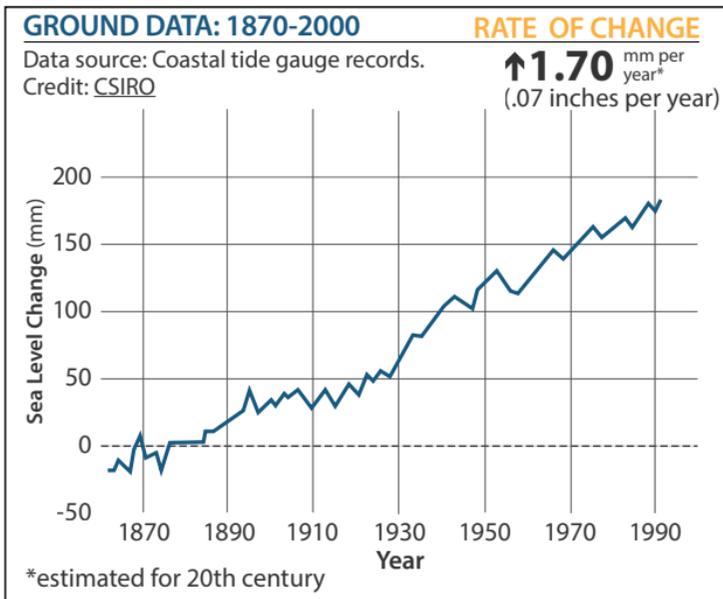


## IS SEA LEVEL RISE ACCELERATING?

Scientific evidence indicates that **global average sea levels** were stable for the last 2,000 to 3,000 years and did not change significantly until the late 19th century.

The most recent satellite and ground-based observations show that the global average sea level has been accelerating since the early 1990s, nearly doubling the rate of the previous century.

A 2013 international scientific assessment finds that global average sea level will continue to rise at a faster rate than we have experienced over the past 40 years (IPCC 2013).

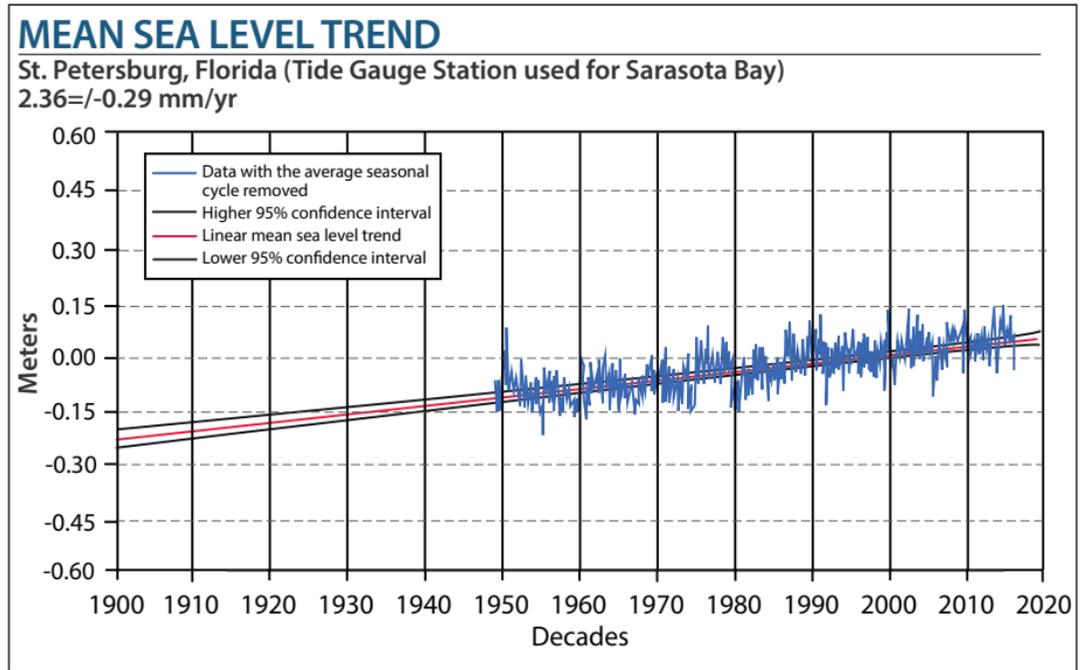


*Sea level rise is caused by two factors related to global warming: the added water coming from the melting of land ice and the expansion of sea water as it warms up. The above graphs show how much sea level has changed since about 1880 (left, coastal tide gauge data) and since 1993 (right, satellite data record).*

Source: [www.climate.nasa.gov/key\\_indicators](http://www.climate.nasa.gov/key_indicators)

Sea level rise for Florida can, for most practical societal purposes, be considered to be essentially similar to global average sea level rise throughout the state's coastal areas (Merrifield et al., 2009). When national and international reports give projections on global average sea level change, those numbers can generally be used for local planning here in Southwest Florida.

For the last 100 years, Florida sea level rise has been similar to the global average of 6 to 8 inches, or roughly .06-.08 inches/year (EPA and Merrifield). The latest global projections for sea level rise by the year 2100 are based on various scenarios for future greenhouse gas emissions and changes in ocean warming and land ice melt. The projections range from as little as 10 inches of sea rise under the most optimistic emissions reduction to a bit more than 3 feet in the worst case scenario (IPCC 2013).



*The mean sea level trend is 2.36 millimeters/year with a 95% confidence interval of  $\pm$ 0.29 mm/yr based on monthly mean sea level data from 1947 to 2006 which is equivalent to a change of 0.77 feet in 100 years. Source NOAA.*

## RECENT SEA LEVEL RISE

There is general **scientific consensus** that the global climate is changing as global average air and sea surface temperatures continue to rise largely due to increased concentrations of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases in the atmosphere. As explained by the Florida Ocean and Coastal Council, the increase in the rate of global sea level rise in the

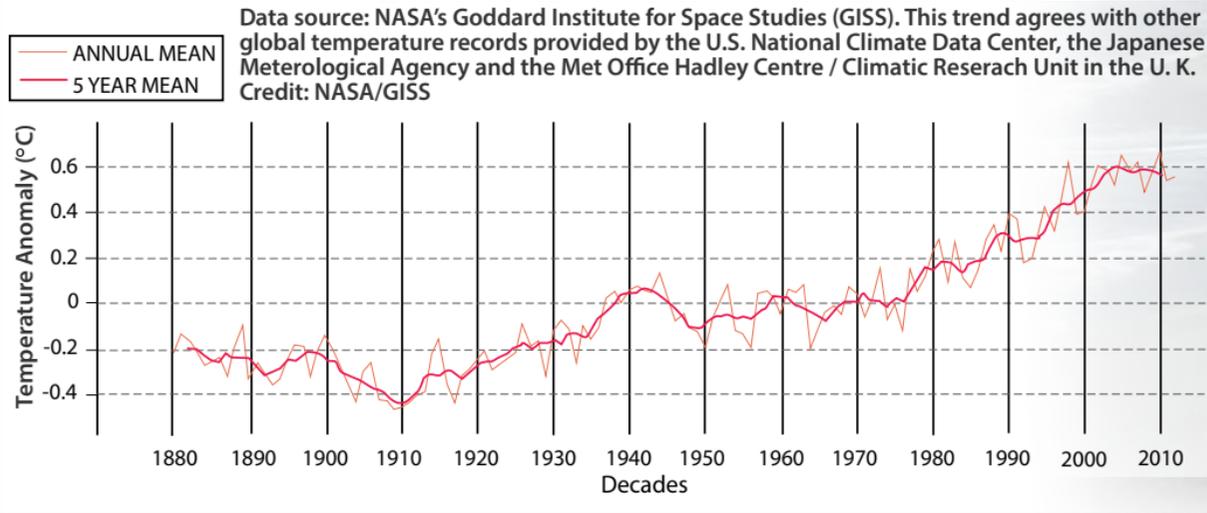
past century is due to both ocean warming and the contributions from land-based ice melt from glaciers and the ice sheets of Greenland and Antarctica.

Sea levels are already rising in many places and are forecasted to continue to rise long after 2100 even if greenhouse gas

concentrations are stabilized well before the end of this century (IPCC 2013).

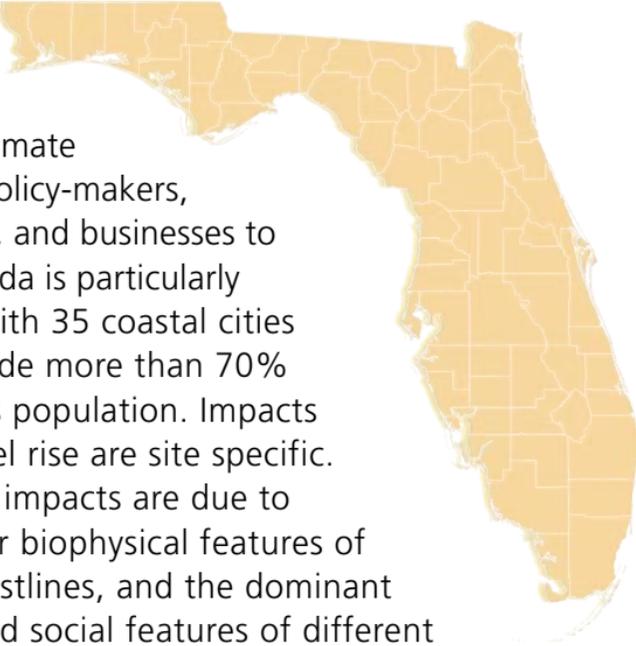


### GLOBAL LAND-OCEAN TEMPERATURE INDEX



## RESPONDING TO SEA LEVEL RISE

Sea level rise is one of the most visible impacts of climate change for policy-makers, communities, and businesses to address. Florida is particularly vulnerable with 35 coastal cities in which reside more than 70% of the state's population. Impacts from sea level rise are site specific. Variations in impacts are due to the particular biophysical features of different coastlines, and the dominant economic and social features of different coastal communities.



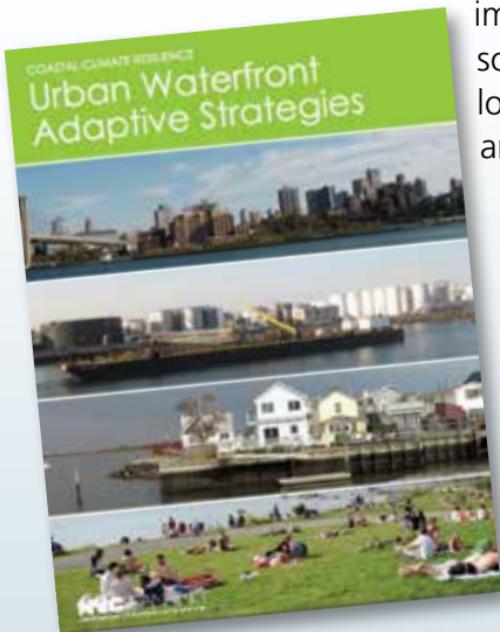
South and southeastern Florida ecosystems and infrastructure are already being affected by sea level rise, and many communities there are presently responding. In contrast, affects from sea level rise are so far less of an issue in the Panhandle of Florida. Importantly, scientists advise that many impacts can be addressed through early planning and well-designed adaptive responses. Many coastal communities and states already have started to plan for climate-related sea level rise. The next 20 to 30 years are critical for taking action to build coastline resilience to the impacts of sea level rise.



## IMPORTANCE OF PLANNING FOR ADAPTATION

Adapting to sea level rise will be essential for Florida's most vulnerable coastal communities in order to safeguard local livelihoods and qualities of life. It is important that planning be based on projected local impacts and support solutions that reflect local values, capacities and priorities.

This requires local leadership and community-wide involvement to build awareness about local threats and to assess and understand local vulnerabilities. In this process, coastal communities taking steps for sea level rise adaptation can take advantage of the growing body of available scientific information and support tools.



*New York City planning for sea level rise adaptive strategies.*  
Download report: [www.nyc.gov](http://www.nyc.gov)





## HOW TO FIND CREDIBLE AND EASY-TO-UNDERSTAND SCIENTIFIC INFORMATION

There are many credible, easy-to-access and easy-to-understand sources of information available on current and projected sea level rise for planners, resources managers, and the general public.

NASA scientists explain that Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture by collecting many different types of information about our planet and its climate on a global scale.

Important national government sites for tracking the latest scientific data and projections include the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA),

U.S. Environmental Protection Agency (EPA), and U.S. Geological Survey (USGS). These and nine other federal agencies make up the U.S. Global Change Research Program created in 1990.

At the international level, the U.S. also is a major scientific contributor and leading force in the work of the United Nations Intergovernmental Panel on Climate Change (IPCC).



National Aeronautics and Space Administration  
[www.climate.nasa.gov](http://www.climate.nasa.gov)



**Climate.gov**  
science & information for a climate-smart nation



**EPA**  
[www.epa.gov](http://www.epa.gov)

**USGS**  
science for a changing world  
[www.usgs.gov](http://www.usgs.gov)

**ipcc**  
[www.ipcc.ch](http://www.ipcc.ch)

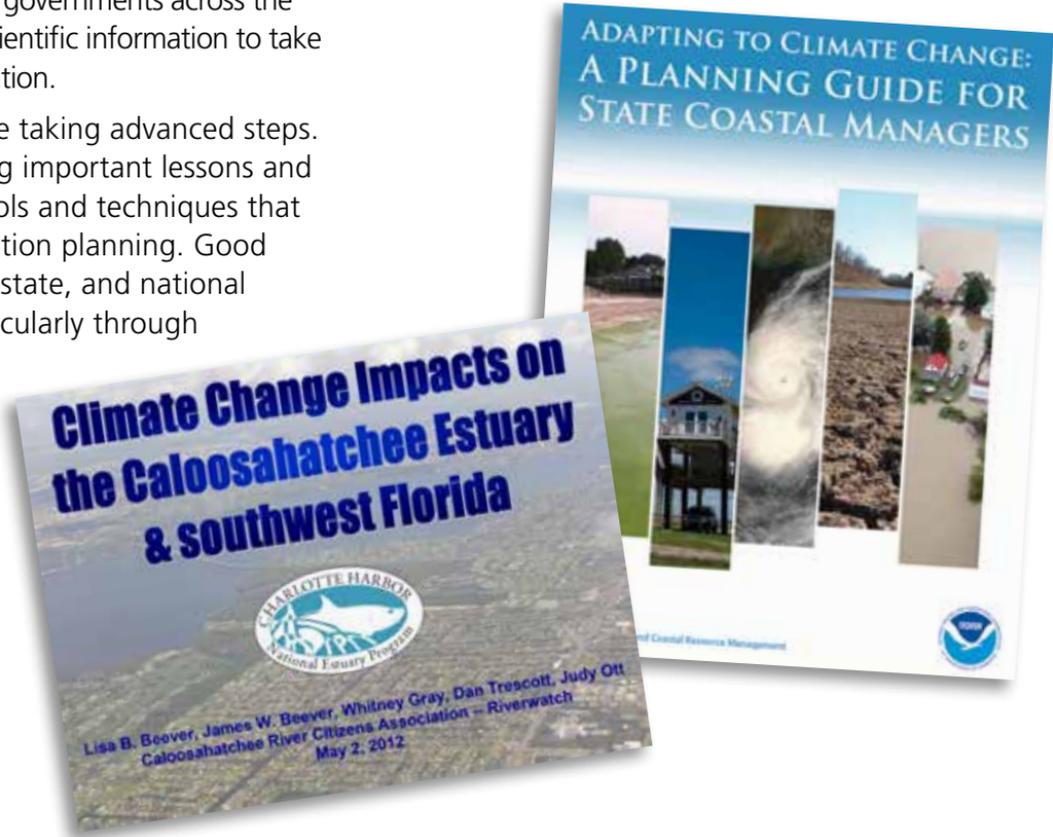
## SOURCE OF SCIENTIFIC INFORMATION

## HOW TO LEARN WHAT OTHER COMMUNITIES ARE DOING

Communities and local and state governments across the coastal United States are using scientific information to take steps toward sea level rise adaptation.

Some of these communities are taking advanced steps. These experiences are providing important lessons and information about different tools and techniques that are helpful for sea level adaptation planning. Good information comes from local, state, and national government publications, particularly through official web sites.

The National Estuary Programs (NEPs) have special initiatives, many supported by EPA's Climate Ready Estuary program, to synthesize lessons being learned. Many private foundations, universities, research institutes, and non-profit organizations also are undertaking similar efforts.



In our region, the Gulf of Mexico Alliance (GoMA), a regional governmental organization for the five Gulf states, maintains an online network to exchange information about sea level rise adaptation initiatives at community and state levels. This network is called StormSmart Coasts.



An example of a very informative government online information source is the EPA Climate Ready Estuary program which provides regular progress reports of climate change actions being taken by the network of 28 organizations that are part of the National Estuary Program.

At the NGO level, **Climate Adaptation Knowledge Exchange (CAKE)** is one of the most active online networks for climate change information. Founded in 2010, CAKE is an interactive online source that provides the latest information available on what communities are doing to plan for climate change, manages a directory of practitioners, and includes information about data and tools available on other sites ([www.cakex.org](http://www.cakex.org)).



[www.gulfofmexicoalliance.org](http://www.gulfofmexicoalliance.org)

## WHAT TYPES OF TOOLS EXIST

Communities throughout the coastal United States are gaining experience with new tools to help assess sea level rise threats and vulnerabilities of their infrastructure and ecosystems. While the field of sea level rise **adaptation planning** is still relatively new, much is being learned about the potential to make increased use of existing planning processes and policies, and to take advantage of new tools being developed for specialized analysis.



*Sarasota County Comprehensive Planning website. Such plans address issues that need to take into account sea level rise.*

## Comprehensive Plans

Most communities in Florida and in many other states have processes in place to produce long-range comprehensive plans. In Florida these plans are legally binding and provide a key tool for incorporating current and projected sea level rise into government decision making about future development and investment.

## Hazard Mitigation Plans

Many communities also undertake hazard planning and post disaster redevelopment planning in order to analyze potential losses from floods, hurricane winds, and coastal storm surges, and minimize these losses through controls on existing and future development. These planning tools provide an opportunity for many communities to assess potential losses due to sea level rise.

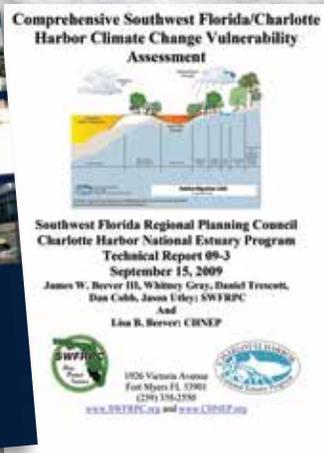
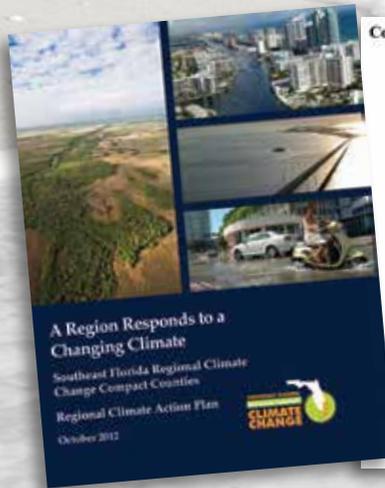


# PLANS AND PLANNING PROCESSES

## Climate Change Plans

Many coastal communities are developing adaptation plans specifically for climate change and sea level rise. Sometimes these are called action plans, for example, the Southeast Florida Regional Compact Climate Change Action Plan adopted by the four counties of Broward, Miami-Dade, Monroe, and Palm Beach. Some are called climate change vulnerability assessments, such as in the Charlotte Harbor National Estuary Program. The city of Punta Gorda, Florida is using that region-wide assessment to develop its own plan where a central focus is sea level rise.

These initiatives are valuable for the processes they use to fully engage scientists, the community, and policy makers in developing consensus solutions. They provide important inputs to comprehensive development plans and other plans, such as hazard plans, emergency management plans, and post disaster redevelopment plans.



*Manatee County Comprehensive Planning website.*

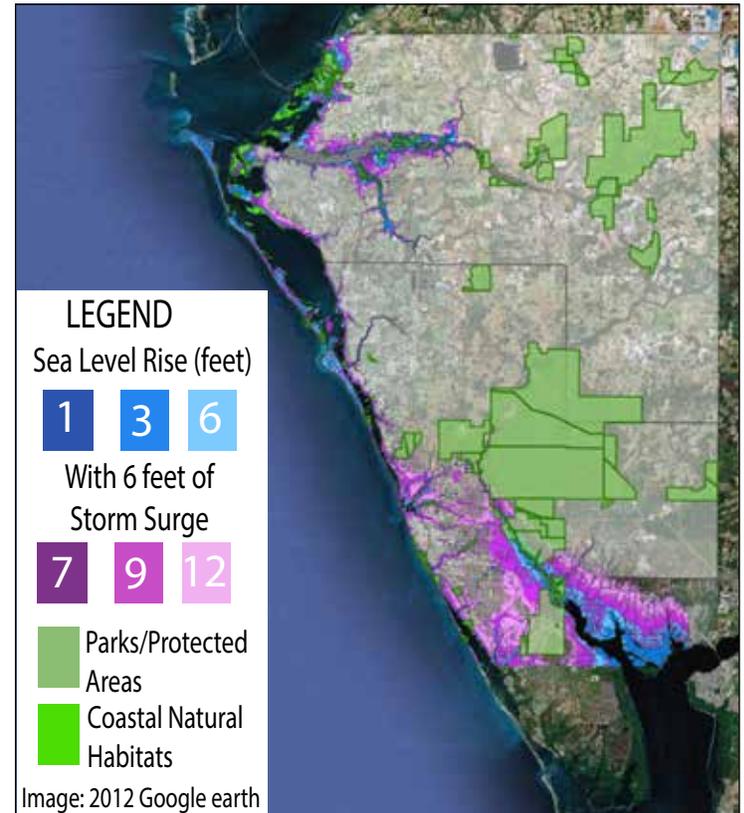
# TOOLS FOR ADAPTATION PLANNING

## ANALYTICAL AND SUPPORT TOOLS

A variety of new analytical and support tools are being used by communities working on sea level rise adaptation planning. These tools focus especially on software and web-based applications and are grouped in three main types by the functions they serve: visualization, modeling, and decision support. Different tools may be most useful at different points in a planning process or for particular sectors. Therefore, it is important to select the appropriate tool for the specific need. (Coastal Tools Network, 2013)

### VISUALIZATION TOOLS

Visualization tools can help users see potential consequences of different scenarios of sea level rise. They are especially useful for stakeholder engagement, taking inventories, and assessing vulnerabilities. An example of a visualization tool is the Sea Level Rise and Coastal Flooding Impacts Viewer developed by the NOAA Coastal Services Center and available to everyone on the internet. The viewer uses the latest digitized elevation data which covers the entire coast of Florida and most of the Gulf of Mexico.



*Sarasota Bay Estuary Program Sea Level Rise visualization tool - a simplified version of the NOAA viewer.*

The Sarasota Bay Estuary Program, working with the Marine Policy Institute of Mote Marine Laboratory, has developed a local sea level rise web viewer covering the Sarasota Bay Estuary (Sarasota and Manatee Counties). This viewer can be accessed through the Sarasota Bay Estuary Program web site ([www.sarasotabay.org](http://www.sarasotabay.org)). It is a simplified version of the NOAA viewer that uses the latest digitized elevation data for this area. It allows the user to see how far inland sea water is likely to go with 1, 3, or 6 feet of sea level rise based on land elevation, and can help identify which areas are most vulnerable. In addition, the user can see these different sea levels with an addition of 6 feet of storm surge, which might occur with a hurricane or a strong tropical storm.



SLAMM vulnerability analysis.

## MODELING TOOLS

Modeling tools are more technical, often requiring GIS software. This set of tools can be especially helpful with analyses and risk assessment. For example, HAZUS-MH (Hazards-United States-Multi-Hazard) is a model developed by Federal Emergency Management Agency (FEMA) to analyze potential losses from floods, hurricane winds, coastal surge, and earthquakes. FEMA has begun to take into account sea level rise in its emergency work. Many communities have used this FEMA modeling tool to project potential losses due to sea level rise.

Another important modeling tool is SLAMM (Sea Level Affecting Marshes Model). This tool is directed to natural resources and simulates wetland conversion and shoreline modification resulting from long-term sea level rise. It can be used to provide best/worst case scenarios and takes into account uncertainties in future sea level rise and other factors. It is relatively technical and GIS expertise is required to produce outputs. The Tampa Bay Estuary Program has used this tool to simulate coastal habitat changes under different land management and sea level rise scenarios.



## WAYS TO TAKE ACTION

Sea level impacts and solutions are site specific. Therefore, it is important to take advantage of local and regional experience and scientific expertise when assessing local threats and planning adaptation actions. Also, as experiences are showing, local communities stand to gain far more by starting to adapt today rather than by waiting or not taking action at all.

Experiences with sea level rise adaptation planning across the United States provide helpful tips on things that coastal communities can begin to do now:

- Create specialized groups, task forces, and committees to monitor and do outreach on climate change and local sea level rise threats and options for action. For example, SBEP and its Citizens Advisory Committee created a Sea Level Rise/Subcommittee in 2012.
- Build awareness by learning about local tides — today's high tide is tomorrow's low tide. Participate in the King Tide Project, where local residents volunteer to become "Tide Watchers" to document vulnerability during "King Tides."
- Encourage local governments to play a catalytic and convening role in adaptation planning.
- Learn about new analytical and support tools such as some of the tools described here, and work with partners to develop customized local versions of these tools.



*Sarasota Bay Estuary Program is working with its sister Tampa Bay Estuary Program to promote participation of local residents in an annual King Tide photo competition. King tides are extremely high tides which occur typically two times per year. The pictures above took first place in the 2012 competition, showing a dock at a residence in Siesta Key during a King Tide (left) and low tide (right).*

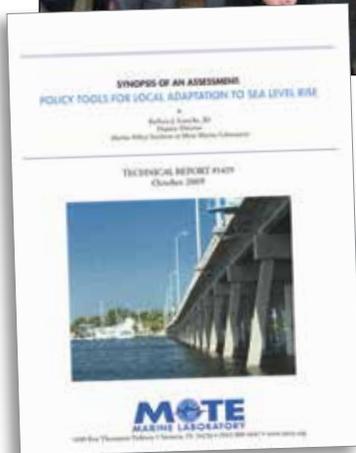
## OPPORTUNITIES TO TAKE ACTION

## WAYS TO TAKE ACTION

- Promote efforts to use existing policy and planning tools to strengthen planning to include sea level rise adaptation. Several existing policy tools for local adaptation to sea level rise were identified in a recent publication by Mote Marine Laboratory.



*SBEP Management Board 2014.*



*A 2009 Mote publication on local policy tools to begin to address sea level rise adaptation.*

- Promote a community-wide conversation about sea level rise threats and options for dealing with the most serious risks.
- Use Post Disaster Redevelopment Plans to provide opportunities for adaptation. Is it appropriate to rebuild?
- Draw on local and regional organizations and scientific experts to provide technical advice on sea level rise trends, projections, options for adaptation, and provide updates as scientific understandings advance.



*Members of the SBEP Citizens Advisory Committee – Sea Level Rise/Subcommittee, meeting in November 2013 to discuss latest reports and projections on sea level rise.*

## **SARASOTA BAY ESTUARY PROGRAM – WORKING WITH SEA LEVEL RISE**

In Southwest Florida, the Sarasota Bay Estuary Program shares experiences and cooperates with two other National Estuary Programs on the west coast of Florida – the Tampa Bay Estuary Program and the Charlotte Harbor National Estuary Program, each of which have initiatives related to sea level rise tailored to their communities.

Within Sarasota Bay, the Sarasota Bay Estuary Program has had a long-standing collaboration with the Mote Marine Laboratory. In recent years, this has expanded to joint activities in community awareness and education about sea level rise and adaptation planning.



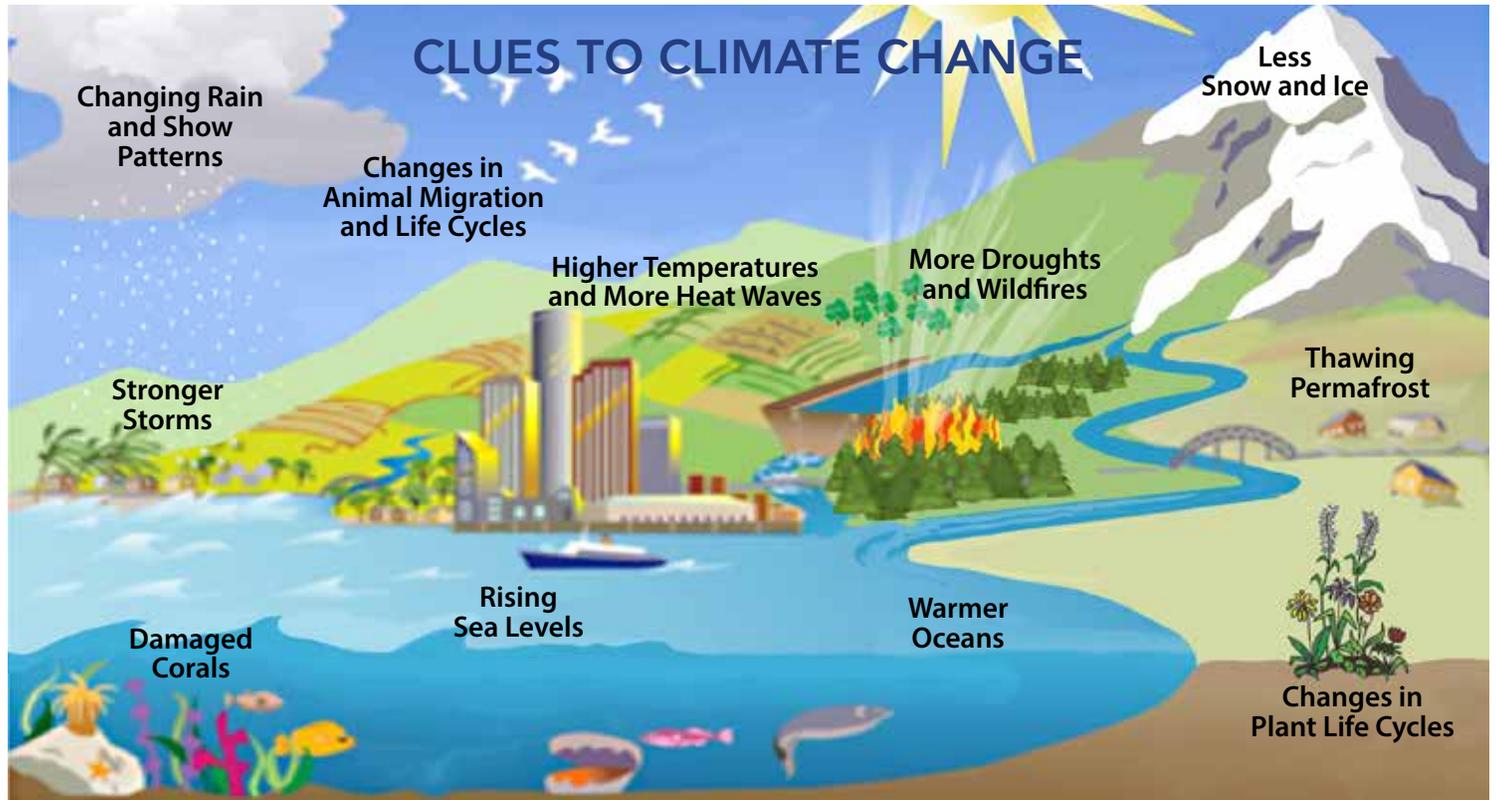
## GLOSSARY & FACTOIDS

### *Adaptation Planning:*

As defined by experts of coastal climate adaptation planning, adaptation planning is planning that seeks to reduce the negative impacts of potential climate effects by reducing exposure, promoting resilience and accommodating adaptation of ecosystems, species, communities, and infrastructure to the changing conditions.

### *Climate Change:*

Climate change refers to any significant and lasting change in weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Impacts from climate change include major changes in temperature, precipitation, vegetation, wind patterns, sea level rise, ocean acidification, and ocean currents.



### ***Climate versus Weather:***

Climate is the average weather in a place over more than 30 years. With modern satellite observation techniques, scientists can accurately look at patterns over 50 years, and “paleoclimatology” techniques allow them to look further back 1000s of years ago into earth’s climatic history.

### ***Sea Level:***

The term ‘sea level’ has different meanings depending on the context. The level of the sea (as measured by satellites) is expressed relative to a hypothetical calm state. Tide gages measure variations in sea level near land and define “zero depth” for navigation charts. Land elevations are tied to a national reference system that reflects long-term changes in sea level, but “zero” for land elevations has no intrinsic meaning relative to mean sea level, mean high water, or other water-level measurements. “Sea level” is most often taken as the average height of the sea, but this changes according to tides, monthly temperatures, weather, and other conditions. A height averaged over a year is used often to describe sea level for that year. Sea level rise can be calculated using average-daily to average-yearly data. As sea level rises, so does the location of mean high tide, ‘king tides,’ and storm surge.

### ***Global Average Sea Level:***

Because sea levels relative to local land surfaces vary depending on land motion and other factors, scientists use the term eustatic or global average sea level to represent the actual level compared to the level of water in the oceans as if it was contained in a single calm basin. Changes in this level are calculated from measurements through time, and scientists compare the changes to calculations of total ocean mass or volume (e.g., from land ice sheet run off) and changes in density of the water (e.g., warm water expands and cool water contracts). Increases in global average sea level are mostly due to runoff from land ice melt and thermal expansion as the oceans warm.

### ***Scientific Consensus about Climate Change (IPCC):***

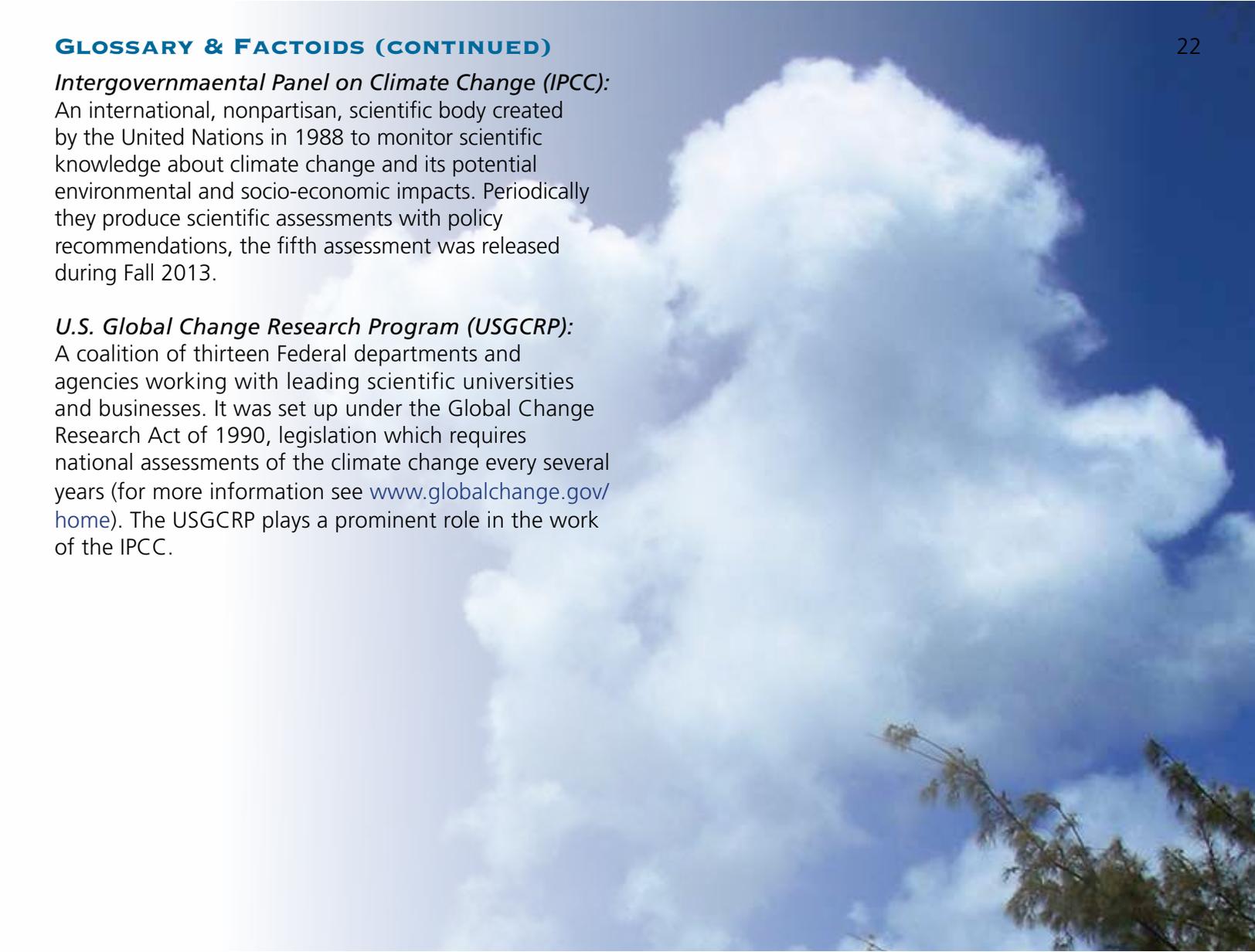
Ninety-seven percent of climate scientists agree that climate-warming trends over the past century are very likely due to human activities and most of the leading scientific organizations worldwide have issued public statements endorsing this position. These organizations include: American Association for the Advancement of Science, American Chemical Society, American Geophysical Union, American Medical Association, American Meteorological Society, American Physical Society, The Geological Society of America, U.S. National Academy of Sciences, U.S. Global Change Research Program (comprised of 13 U.S. Government departments and agencies), and the Intergovernmental Panel on Climate Change. [www.climate.nasa.gov/scientific-consensus](http://www.climate.nasa.gov/scientific-consensus); accessed July 2013]

### ***Intergovernmental Panel on Climate Change (IPCC):***

An international, nonpartisan, scientific body created by the United Nations in 1988 to monitor scientific knowledge about climate change and its potential environmental and socio-economic impacts. Periodically they produce scientific assessments with policy recommendations, the fifth assessment was released during Fall 2013.

### ***U.S. Global Change Research Program (USGCRP):***

A coalition of thirteen Federal departments and agencies working with leading scientific universities and businesses. It was set up under the Global Change Research Act of 1990, legislation which requires national assessments of the climate change every several years (for more information see [www.globalchange.gov/home](http://www.globalchange.gov/home)). The USGCRP plays a prominent role in the work of the IPCC.



## KEY REFERENCES

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Climate Change and Sea-Level Rise in Florida: An Update of “Effects of Climate Change on Florida’s Ocean & Coastal Resources.” Tallahassee, FL.  
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***Coastal-Marine Ecosystem-Based Management Tools Network (Coastal Tools Network). 2013:***  
Tools for Coastal Climate Adaptation Planning: A guide for selecting tools to assist with ecosystem-based climate planning. NatureServe. Arlington, Va.  
Available online at: [www.natureserve.org](http://www.natureserve.org)

***Merrifield, M.A., C.T. Merrifield, and G.T. Mitchum.***  
2009: An anomalous recent acceleration of global sea level rise. *Journal of Climate* 22: 5772-5781. Cited in FOCC, 2010, p. 3.

## USEFUL WEBSITES

**United States Environmental Protection Agency (EPA):**

EPA climate website: [www.epa.gov/climatechange](http://www.epa.gov/climatechange)  
EPA Climate Ready Estuary

**National Oceanic and Atmospheric Administration (NOAA):**

NOAA climate: [www.climate.gov](http://www.climate.gov)

**National Aeronautics and Space Administration (NASA):**

NASA climate: [www.climate.nasa.gov](http://www.climate.nasa.gov)

**U. S. Geological Survey (USGS):**

[www.usgs.gov](http://www.usgs.gov)

**Intergovernmental Panel on Climate Change (IPCC):**

[www.ipcc](http://www.ipcc)

**Climate Adaptation Knowledge Exchange (CAKE):**

[www.cakex.org](http://www.cakex.org)

**StormSmart Coasts Network:**

[www.stormsmartcoasts.org](http://www.stormsmartcoasts.org)

**Gulf of Mexico Alliance (GoMA):**

[www.gulfofmexicoalliance.org](http://www.gulfofmexicoalliance.org)

**U.S. Global Change Research Program (GCRP):**

[www.globalchange.gov/home](http://www.globalchange.gov/home)

**Sarasota Bay Estuary Program (SBEP):**

[www.sarasotabay.org](http://www.sarasotabay.org)

**Mote Marine Laboratory (MOTE/MPI)**

[www.mote.org/mpi](http://www.mote.org/mpi)



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