# UNIFIED SEA LEVEL RISE PROJECTION

## SOUTHEAST FLORIDA

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*Prepared by the*

*Sea Level Rise Work Group*

## CONTENTS



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## EXECUTIVE SUMMARY

The Southeast Florida Regional Climate Change Compact reconvened the Sea Level Rise Work Group for the purpose of updating the unified regional projection based on global projections, guidance documents and scientific literature released since the original regional projection in 2011 (Compact, 2011). The objective of the unified sea level rise projection for the Southeast Florida region remains consistent that the projection is for use by the Climate Compact Counties and partners for planning purposes to aid in understanding of potential vulnerabilities and to provide a basis for developing risk informed adaptation strategies for the region. For the 2015 update, the starting point for all sea level rise projections has been shifted from 2010 to 1992. This allows for direct use of local tide station information to convert projections into local water surface elevations for flood vulnerability studies, and is consistent with current guidance from the U.S. Army Corps of Engineers (USACE) and the National Oceanographic and Atmospheric Agency (NOAA). The Unified Sea Level Rise projection for Southeast Florida has also been extended to 2100 in recognition of the need for longer range guidance for major infrastructure and other long term investments now being planned.

In the short term, sea level rise is projected to be 6 to 10 inches by 2030 and 14 to 26 inches by 2060 (above the 1992 mean sea level). In the long term, sea level rise is projected to be 31 to 61 inches by 2100. For critical infrastructure projects with design lives in excess of 50 years, use of the upper curve is recommended with planning values of 34 inches in 2060 and 81 inches in 2100. The National Aeronautics and Space Administration Jet Propulsion Laboratory (2015) has reported the average global sea level has risen almost 3 inches between 1992 and 2015 based on satellite measurements. Sea level rise in South Florida has been of similar magnitude over the same period (NOAA, 2015) but is anticipated to outpace the global average due to ongoing variations in the Florida Currents and Gulf Stream.

Projected sea level rise, especially by 2060 and beyond, has a significant range of variation as a result of uncertainty in future greenhouse gas emissions and their geophysical effects, the incomplete quantitative understanding of all geophysical processes that might affect the rate of sea level rise in climate models and the limitations of current climate models to predict the future. As such, the Work Group recommends that the unified sea level rise projection include three curves, in descending order, the NOAA High Curve, the USACE High Curve and a curve corresponding to the median of the IPCC AR5 RCP8.5 scenario, with specific guidance as to how and when they should be used in planning. This guidance document describes the recommended application of the projection as it relates to both high and low risk projects and short and long-term planning efforts. Also, the Work Group recommends that this guidance be updated every five to seven years because of the ongoing advances in scientific knowledge related to global climate change and potential impacts.

## INTRODUCTION

### WHO SHOULD USE THIS PROJECTION AND GUIDANCE DOCUMENT?

The Unified Sea Level Rise Projection for Southeast Florida is intended to be used for planning purposes by a variety of audiences and disciplines when considering sea level rise in reference to both short and long-term planning horizons and infrastructure design in the Southeast Florida area.

### HOW SHOULD THE REGIONAL PROJECTION BE APPLIED?

The projection (*Unified Sea Level Rise Projection for Southeast Florida)* contains a graph and table describing the rise in sea level from 1992 through the turn of the current century. The projection can be used to estimate future sea level elevations in Southeast Florida and the relative change in sea level from today to a point in the future. *Guidance for Application* contains directions and specific examples of how the projection can be used by local governments, planners, designers and engineers and developers. This regional projection is offered to ensure that all major infrastructure projects throughout the Southeast Florida region have the same basis for design and construction relative to future sea level.

### WHAT ARE THE IMPACTS ASSOCIATED WITH SEA LEVEL RISE?

The consequences associated with sea level rise include direct physical impacts such as coastal inundation of inland areas, increased frequency of flooding in vulnerable coastal areas, increased flooding in interior areas due to impairment of the region's stormwater infrastructure i.e. impacts to gravity drainage systems and features in the regional water management canal system, saltwater intrusion into the aquifer and local water supply wells, and contamination of the land and ocean with pollutants and debris and hazardous materials released by flooding. Consequences also include cascading socio-economic impacts such as displacement, decrease in property values and tax base, increases in insurance costs, loss of services and impaired access to infrastructure. The likelihood and extent to which these impacts will occur is dependent upon the factors influencing the rate of sea level rise such as the amount of greenhouse gases emitted globally, rate of melting of land-based ice sheets, the decisions and investments made by communities to increase their climate resilience and the many interconnected processes described in the ***Appendix B: State of Science Update***. One of the values of this sea level rise projection is the ability to perform scenario testing to better understand the potential impacts and timeline of sea level rise within the Southeast Florida community.

## WHO DEVELOPED THE UNIFIED SEA LEVEL RISE PROJECTION FOR SOUTHEAST FLORIDA?

In 2010, the Southeast Florida Regional Climate Change Compact Steering Committee organized the first Regional Climate Change Compact Technical Ad hoc Work Group (Work Group). Their objective was to develop a unified sea level rise projection for the Southeast Florida region for use by the Climate Compact Counties and partners. Its primary use was for planning purposes to aid in understanding of potential vulnerabilities and to provide a basis for outlining adaptation strategies for the region. The Work Group reviewed existing projections and scientific literature and developed a unified regional projection for the period from 2010 to 2060 (Compact, 2011). The projection highlighted two planning horizons: 1) by 2030, sea level rise was projected to be 3 to 7 inches above the 2010 mean sea level and 2) by 2060, sea level rise was projected to be 9 to 24 inches above the 2010 mean sea level. In anticipation of the release of the United Nations Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC, 2013), the Sea Level Rise Work Group recommended a review of the projection four years after its release in 2011.

In September 2014, the Sea Level Rise Work Group was reconvened for the purpose of updating the unified regional projection based on projections and scientific literature released since 2011. This report released in October 2015 contains a summary of the projections and publications reviewed and discussed, the methodology for deriving the projection, the recommended unified regional projection and additional recommendations from the Sea Level Rise Work Group.

# UNIFIED SEA LEVEL RISE PROJECTION FOR SOUTHEAST FLORIDA

## PROJECTION AND SUMMARY

This Unified Sea Level Rise projection for Southeast Florida updated in 2015 projects the anticipated range of sea level rise for the region from 1992 to 2100 (Figure 1). The projection highlights three planning horizons:

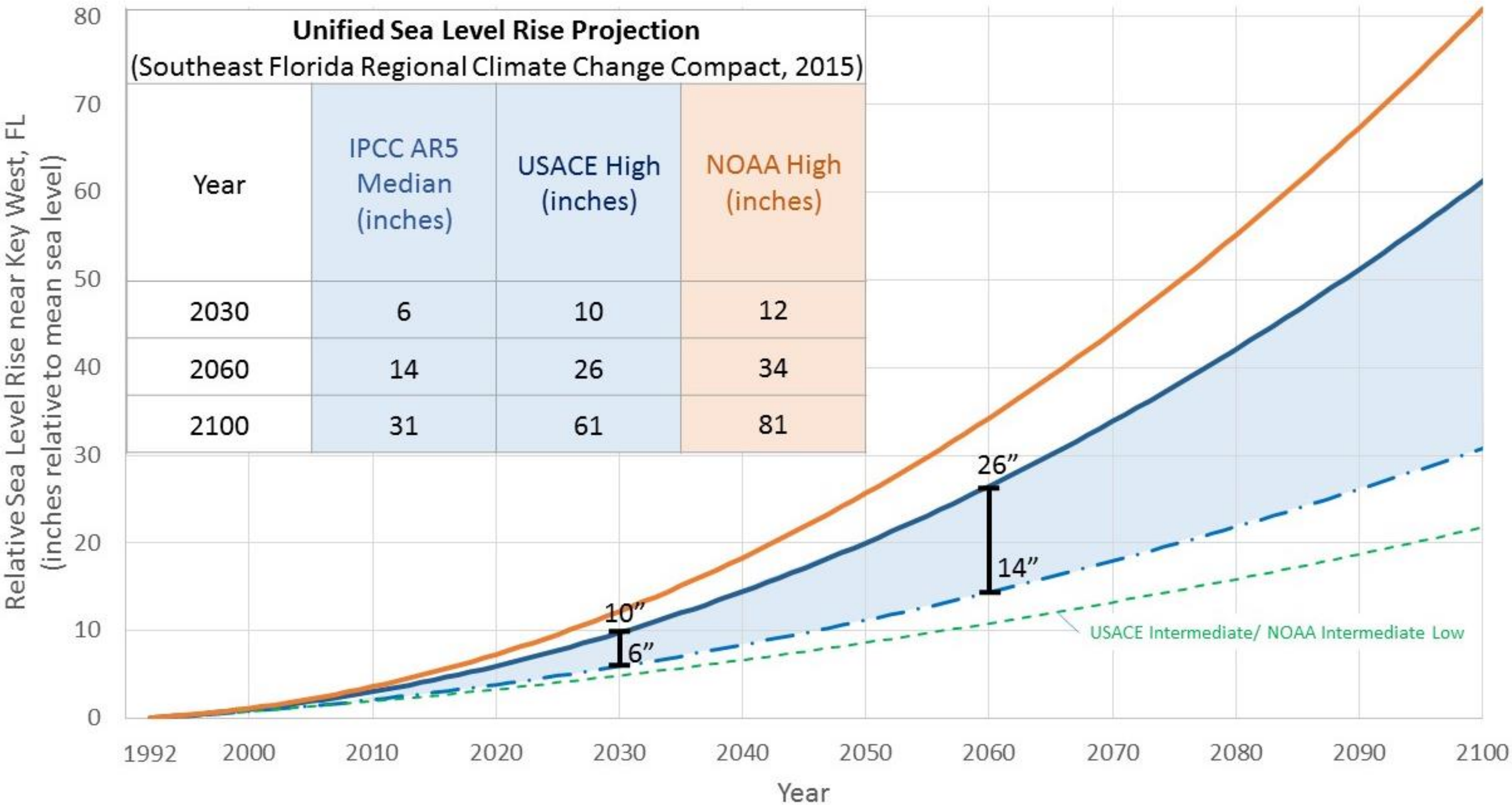
1) short term, by 2030, sea level is projected to rise 6 to 10 inches above 1992 mean sea level,

2) medium term, by 2060, sea level is projected to rise 14 to 34 inches above 1992 mean sea level,

3) long term, by 2100, sea level is projected to rise 31 to 81 inches above 1992 mean sea level.

Projected sea level rise in the medium and long term has a significant range of variation as a result of uncertainty in future greenhouse gas emissions and their geophysical effects, the incomplete quantitative understanding of all geophysical processes affecting the rate of sea level rise in climate models and current limitations of climate models to predict the future. As such, the Work Group recommends that the unified sea level rise projection include three global mean sea level rise curves regionally adapted to account for the acceleration of sea level change observed in South Florida. The titles of the global mean sea level rise curves were retained for simplicity of referencing source but the curves have been adjusted from the global projections to reflect observed local change. The projection consists of the NOAA High Curve, the USACE High Curve (also known as the NOAA Intermediate- High) and the median of the IPCC AR5 RCP8.5 scenario, with specific guidance as to how and when they should be used in planning.

- The lower boundary of the projection (blue dashed line) can be applied in designing low risk projects that are easily replaceable with short design lives, are adaptable and have limited interdependencies with other infrastructure or services.
- The shaded zone between the IPCC AR5 RCP8.5 median curve and the USACE High is recommended to be generally applied to most projects within a short -term planning horizon. It reflects what the Work Group projects will be the most likely range of sea level rise for the remainder of the 21$^{st}$ Century.
- The upper curve of the projection should be utilized for planning of high risk projects to be constructed after 2060 or projects which are not easily replaceable or removable, have a long design life (more than 50 years) or are critically interdependent with other infrastructure or services.




| Year | IPCC AR5 Median (inches) | USACE High (inches) | NOAA High (inches) |
|---|---|---|---|
| 2030 | 6 | 10 | 12 |
| 2060 | 14 | 26 | 34 |
| 2100 | 31 | 61 | 81 |

**Figure 1: Unified Sea Level Rise Projection. These projections are referenced to mean sea level at the Key West tide gauge. The projection includes three global curves adapted for regional application: the median of the IPCC AR5 RCP8.5 scenario as the lowest boundary (blue dashed curve), the USACE High curve as the upper boundary for the short term for use until 2060 (solid blue line), and the NOAA High curve as the uppermost boundary for medium and long term use (orange solid curve). The incorporated table lists the projection values at years 2030, 2060 and 2100. The USACE Intermediate or NOAA Intermediate Low curve is displayed on the figure for reference (green dashed curve). This scenario would require significant reductions in greenhouse gas emissions in order to be plausible and does not reflect current emissions trends.**

## PROJECTION DEVELOPMENT METHODOLOGY

### PROJECTION UPDATE

The key components of the methodology used to develop the unified sea level rise projection are as follows:

- *Planning Horizon of 2100:* In response to the release of climate scenarios extending to year 2100 from the Intergovernmental Panel on Climate Change (IPCC), projections through year 2100 by federal agencies including the US Army Corps of Engineers (USACE) and the National Oceanographic and Atmospheric Administration (NOAA) and the need for planning for infrastructure with design lives greater than 50 years, the unified sea level rise projection time scale has been extended to 2100.

- *Starting in 1992*: The year 1992 has been selected as the initial year of the projection because it is the center of the current mean sea level National Tidal Datum Epoch of 1983-2001. A tidal datum epoch is a 19 year period adopted by the National Ocean Service as the official time segment over which tide observations are used to establish tidal datums such as mean sea level, mean high water etc. The National Tidal Datum Epoch is revised every 20-25 years to account for changing sea levels and land elevations.

- *Tide gauge selection:* The Key West gauge (NOAA Station ID 8724580) was maintained as the reference gauge for calculation of the regional projection as was used in the original projection. In addition, appropriate conversion calculations are provided in Section 4: Guidance for Application in order to reference the projection to the Miami Beach gauge (NOAA Station ID 8723170) or the Lake Worth Pier gauge (NOAA Station ID 8722670). The Key West gauge has recorded tidal elevations since 1913. Tidal records from Miami Beach and Lake Worth Pier are available since 2003 and 1996, respectively.

- *Review of existing projections:* Global projections released since 2011 were reviewed and considered for interpretation for the unified sea level rise projection including those developed by USACE (2011; 2013), NOAA (Parris et al., 2012), IPCC (IPCC, 2013), Bamber and Aspinall (2013), Horton et al. (2014), Jevrejeva et al. (2014), and Kopp et al. (2014). Review criteria included comprehensiveness of datasets and models used to develop the projections, standing in the scientific community, and applicability to the Southeast Florida region.

Summaries of the existing global projections are included below:

- *USACE Guidance: There was no update to the projections since 2011 (USACE, 2011). The range of global mean sea level change projected by USACE was approximately 0.2 to 0.6 meters (9 to 25 inches) by 2060 and 0.5 to 1.5 meters (20 to 59 inches) by 2100. Existing guidance and the online USACE Sea Level Change Calculator were used to adapt the global mean sea level change curves for the unified South Florida projection.*
- *IPCC AR5 Projections: The 5$^{th}$ Assessment Report (AR5) included four scenarios based on predicted greenhouse gas concentration trajectories (Regional Concentration Pathways, RCPs). The global mean sea level change projected in these scenarios ranged from 0.17 to 0.38 meters (7 to 15 inches) by years 2046 to 2065 and 0.26 to 0.82 meters (10 to 32 inches) by 2081 to 2100.*
- *NOAA Projections produced for the National Climate Assessment (NCA): For the 2014 NCA, four global mean sea level rise scenarios were defined in a manner allowing the user to select the appropriate curve based on risk of concern, uncertainty tolerance and type of application. The global mean sea level rise projected in these scenarios ranges from 0.2 meters to 2 meters (8 to 80 inches) by 2100.*
- *Recent Probabilistic Projections: Recently, several authors have quantitatively and qualitatively approached determining the likelihood or percent chance that the global mean sea level rise projections will occur by 2100. For example, based on a probability density function, Jevrejeva et al. (2014) concluded that there is only a 5% chance global mean sea level rise will be larger than 1.8 meters (71 inches) by 2100. Using an alternate method, Kopp et al. (2014) concluded there is only a 5% chance global mean sea level rise will be larger than 1.76 meters (69 inches). These studies represent examples of possible methods of further explaining applicability of projections for future use.*
- *Science Community Polling: Several polls have been conducted amongst groups within the scientific community to understand the experts' opinions on the level of uncertainty associated with existing global mean sea level rise projections. These surveys have yielded reported likely ranges of global mean sea level rise of 0.4 to 1.2 m (16 to 42 inches) depending on warming scenarios (Horton et al., 2014) and 0.29 m to 0.84 m (11 to 33 inches) (Bamber and Aspinall, 2013) by 2100.*

*Projection confidence:* The understanding of past sea level changes has improved since the Work Group's last review due to additional observations and analyses of processes driving thermal expansion, loss of ice from ice sheets and glaciers and terrestrial water storage by the scientific community. Despite this improved understanding, the development of complex climate models is evolutionary and many processes and responses are yet to be incorporated. The numerous ice melt accelerating feedbacks not in the models are especially of concern as they are speeding up ice melt and sea level rise well beyond model projections. Models do continue to offer useful approximations of trends and order of magnitude of rates of change and acceleration based on climate data input and are suitable for determining projected future ranges for planning and design efforts. Additionally, as noted in Parris et al. (2012), the quadratic curves comprising the projection were selected by the some of the scientific community for simplicity. Sea level will not rise in the smooth manner illustrated by the quadratic curves but, may be punctuated by faster and slower rates (Parris et al., 2013).

## GUIDANCE FOR APPLICATION

### INCREASE IN RECURRENT FLOODING AND REDUCED DRAINAGE CAPACITY

Recent analyses of tide gauge records acquired along the US Atlantic coast indicate a rapid acceleration in the rate of sea level rise since 2000, which was attributed to possible slowing down of the Atlantic Meridional Overturning Circulation (AMOC) (Ezer et al., 2013; Sallenger et al., 2012; Yin et al., 2009). The higher sea level resulted in increasing flooding frequency in several coastal communities, e.g., Boston, Norfolk, and Miami Beach (Ezer et al., 2013; Kirshen et al., 2008; Kleinosky et al., 2007; Wdowinski et al., 2015). These frequent flood events, often termed "nuisance flooding", occur mainly due to heavy rain during high tide conditions but sometimes occur due to high tide alone and are termed "King tides", "lunar flooding" or "sunny sky flooding". Recently, Ezer and Atkinson (2014) used tide gauge data to calculate accumulated flooding time in twelve locations along the Atlantic coast and showed a significant increase in flooding duration over the past twenty years. They suggested that flood duration is a reliable indicator for the accelerating rate of sea level rise, which is often difficult to estimate on a regional-scale.

On the national scale, NOAA (2014) published an assessment of nuisance flooding finding that the duration and frequency of these events are intensifying around the United States. Subsequently, Sweet and Park (2014) demonstrated that coastal areas are experiencing an increased frequency of flood events (an acceleration) over the last few decades, and that this acceleration in flood occurrence will continue regardless of the specific rate of sea level rise.

A detailed analysis of nuisance flooding occurrence in Miami Beach was conducted by Wdowinski et al. (2015), who used a variety of data sources (tide gauge, rain gauge, media reports, insurance claims, and photo records) from the past 16 years (1998-2013). They found that most flooding events occur after heavy rain (> 80 mm, 3 inches) during high tide conditions, but also after the fall equinox tides regardless of rain events. An analysis of flooding frequency over the past 16 years revealed that since 2006, rain-induced events increased by 33% and tide-induced events quadrupled, from 2 events during 1998-2005 to 8-16 events in 2006-2013. Wdowinski et al. (2015) also analyzed the nearby Virginia Key tide gauge record and found a significant acceleration in the rate of sea level rise since 2006. The average rate of regional sea level rise since 2006 is 9±4 mm/yr, significantly higher than the global average rate of 2.8±0.4 mm/yr estimated from in-situ data (Church and White, 2011). Although the Work Group notes that continued analysis of changes in trends over time is necessary to determine long-term significance of this recently observed uptrend, studies have already begun to correlate the regional sea level rise to the slowing down of the Gulfstream. A comparison between sea level variations near Miami with high-resolution global climate model simulations (Kirtman et al., 2012) revealed a strong correlation between increasing sea level rise in the Miami area and a weakening of the Florida Current-Gulf Stream system. This finding confirmed concurs with other studies that relate sea level rise acceleration along the US Atlantic coast with weakening of the Gulf Stream (e.g., Ezer et al., 2013; Park and Sweet, 2015).

### STORM SURGE AND SEA LEVEL RISE

Storm surge and sea level rise are independent coastal processes that when occurring simultaneously lead to compounded impacts. Sea level rise will increase the inland areal extent inundated by surges, the depth of flooding and power of the surge and the extent and intensity of damage associated with storm surge and waves. As a result, severe storms of the future will cause more damage than storms of equal intensity occurring at today's sea level. Tebaldi et al. (2012) estimate a 100-year magnitude surge flooding (by today's standards) will begin to occur every 20 years at the projected mean sea level in 2050. Regional hazard mapping does not yet include the combined effects of sea level rise and surge but the impacts are anticipated to be significant.

Historically, the sea level extremes have increased along with the increase in mean sea level at locations along the coasts. Using this as the basis, one can relate the sea level extremes to mean sea level which allows the determination of future extremes and return periods (Obeysekera and Park, 2013). Another approach is to use the non-tidal residuals (component of storm surge and waves above the tidal variations), NTR, and determine their probabilistic characteristics. Assuming future sea level rise scenarios and the tidal variations, one can then superimpose extreme storm surge of NTR for a given return period to determine total sea level extreme for a given time epoch in the future. Return period for a given scenario can be determined using methods outlined in Salas and Obeysekera (2014). Both approaches assume there is no change in future "storminesss" although with higher sea levels, magnitude of storm surge may change at some locations along the coasts.

### NATURAL RESOURCE DEGRADATION

As sea level rise increasingly inundates coastal areas, there is the potential for degradation of natural resources and loss of their services to the surrounding environment. Ecosystems will transition either by retreat and migration, adaptation, or elimination of functions and certain species. Shallow water habitats may transition to open water, forcing ecological changes in coastal wetlands and estuaries affecting nesting, spawning and feeding locations and behavior. Intrusion of saltwater inland, into inland water bodies and within the aquifer is negatively impacting freshwater resources, and these impacts will worsen or accelerate with further sea level rise. Inundation of shorelines will increase the extent and severity of beach erosion and previously stable coastal areas. In combination, these impacts will cascade throughout the region's ecosystems even if they are not immediately adjacent to open water areas.

Natural infrastructure is critical to the resilience of the urban environment, in that it provides many benefits related to storm protection, water and air purification, moderating urban heat effects, and socio-economics. South Florida's tourist economy is heavily dependent on these natural resources. The region must prioritize providing space for habitat transitions and focus on reducing anthropogenic pressures that would compound the degrading effects of sea level rise.

## GUIDANCE IN APPLYING THE PROJECTIONS

### AUDIENCES

The Unified Sea Level Rise Projection for Southeast Florida is intended to be used for planning purposes by a variety of audiences and disciplines when considering sea level rise in reference to both short and long-term planning horizons as well as infrastructure siting and design in the Southeast Florida area. Potential audiences for the projections include, but are not limited to, elected officials, urban planners, architects, engineers, developers, resource managers and public works professionals.

One of the key values of the projection is the ability to associate specific sea level rise scenarios with timelines. When used in conjunction with vulnerability assessments, these projections inform the user of the potential magnitude and extent of sea level rise impact at a general timeframe in the future. The blue shaded portion of the projection provides a likely range for sea level rise values at specific planning horizons. Providing a range instead of a single value may present a challenge to users such as engineers who are looking to provide a design with precise specifications. Public works professionals and urban planners need to work with the engineers and with policy makers to apply the projection to each project based on the nature, value, interconnectedness, and life cycle of the infrastructure proposed.

Finally, elected officials should use the projections to inform decision making related to issues such as adaptation policies, budget impacts associated with design features which address planning for future sea level rise, capital improvement project needs especially those associated with drainage and shoreline protection, and land use decisions.

### APPLYING PROJECTION CURVES TO INFRASTRUCTURE SITING AND DESIGN

When determining how to apply the projection curves, the user needs to consider the nature, value, interconnectedness, and life cycle of the existing or proposed infrastructure. The blue shaded portion of the projection can be applied to most infrastructure projects, especially those with a design life expectancy of less than 50 years. The designer of a type of infrastructure that is easily replaced, has a short lifespan, is adaptable, and has limited interdependencies with other infrastructure or services must weigh the potential benefit of designing for the upper blue line with the additional costs. Should the designer opt for specifying the lower curve, she/he must consider the consequences of under-designing for the potential likely sea level condition. Such consequences may include premature infrastructure failure. Additionally, planning for adaptation should be initiated in the conceptual phase. A determination must be made on whether or not threats can be addressed mid-life cycle via incremental adaptation measures, such as raising the height of a sluice gate on a drainage canal.

Forward thinking risk management is critical to avoiding loss of service, loss of asset value and most importantly loss of life or irrecoverable resources. An understanding of the risks that critical infrastructure will be exposed to throughout its life cycle such as sea level rise inundation, storm surge and nuisance flooding must be established early on in the conceptual phase. If incremental adaptation is not possible for the infrastructure proposed and inundation is likely, designing to accommodate the projected sea level rise at conception or selection of an alternate site should be considered. Projects in need of a greater factor of safety related to potential inundation should consider designing for the upper limit of the blue-shaded zone. Examples of such projects may include evacuation routes planned for reconstruction, communications and energy infrastructure and critical government and financial facilities.

Due to the community's fundamental reliance on major infrastructure, existing and proposed critical infrastructure should be evaluated using the upper curve of the projection, the orange curve (Figure 1, NOAA High). Critical projects include those or projects which are not easily replaceable or removable, have a long design life (more than 50 years), or are interdependent with other infrastructure or services. If failure of the critical infrastructure would have catastrophic impacts, it is considered to be high risk. Due of the community's critical reliance on major infrastructure, existing and proposed high risk infrastructure should be evaluated using the upper curve of the projection, the orange curve (Figure 1, NOAA High). Examples of high risk critical infrastructure include nuclear power plants, wastewater treatment facilities, levees or impoundments, bridges along major evacuation routes, airports, seaports, railroads, and major highways.

For low risk infrastructure projects, the lowermost curve of the projection (Figure 1, IPCC AR5 RCP8.5 curve) may be applied. Low risk projects include infrastructure expected to be constructed and then replaced within the next 10 years, projects that are easily replaceable and adaptable or projects with limited interdependencies and limited impacts when failure occurs. An example of such a project may be a small culvert in an isolated area.

Additionally, planning for adaptation should be initiated in the conceptual phase. A determination must be made on whether or not risk can be addressed mid-life cycle via incremental. If incremental adaptation is not possible for the type of high risk infrastructure proposed and inundation is likely, designing to accommodate the projected sea level rise at conception or selection of an alternate site should be considered. To ensure an appropriately conservative design approach is used, the upper limit of the projection (Figure 1, NOAA High) should be used for projects with design lives of more than 50 years.

### AVAILABLE VULNERABILITY ASSESSMENTS

The Southeast Florida Regional Climate Change Compact and the individual Compact Counties have developed region-wide and county-wide sea level rise inundation vulnerability assessments available for public use (Compact, 2012). These assessments spatially delineate areas of inundation correlating to 1 foot, 2 feet and 3 feet of sea level rise. In addition, the Compact website hosts a multitude of sources of information, tools and links in support of adaptation and mitigation planning for use by the Compact communities.

## SUMMARY

The Work Group recommends the use of the NOAA High Curve, the USACE High Curve (USACE, 2015) and the median of the IPCC AR5 RCP8.5 scenario (IPCC, 2013) as the basis for a Southeast Florida sea level rise projection for the 2030, 2060 and 2100 planning horizons. In the short term, sea level rise is projected to be 6 to 10 inches by 2030 and 14 to 26 inches by 2060 (above the 1992 mean sea level). Sea level has risen 3 inches from 1992 to 2015. In the long term, sea level rise is projected to be 31 to 61 inches by 2100. For critical infrastructure projects with design lives in excess of 50 years, use of the upper curve is recommended with planning values of 34 inches in 2060 and 81 inches in 2100. Sea level will continue to rise even if global mitigation efforts to reduce greenhouse gas emissions are successful at stabilizing or reducing atmospheric $CO_2$ concentrations; however, emissions mitigation is essential to moderate the severity of potential impacts in the future. A substantial increase in sea level rise within this century is likely and may occur in rapid pulses rather than gradually.

The recommended projection provides guidance for the Compact Counties and their partners to initiate planning to address the potential impacts of sea level rise on the region. The shorter term planning horizons (through 2060) are critical to implementation of the Southeast Florida Regional

Climate Change Action Plan, to optimize the remaining economic life of existing infrastructure and to begin to consider adaptation strategies. As scientists develop a better understanding of the factors and reinforcing feedback mechanisms impacting sea level rise, the Southeast Florida community will need to adjust the projections accordingly and adapt to the changing conditions. To ensure public safety and economic viability in the long run, strategic policy decisions will be needed to develop guidelines to direct future public and private investments to areas less vulnerable to future sea level rise impacts.

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## APPENDIX A: STAND ALONE GUIDANCE DOCUMENT AND PROJECTION

The Southeast Florida Regional Climate Change Compact's 2015 Unified Sea Level Rise Projection is presented below showing the anticipated range of sea level rise for the region from 1992 to 2100 (Figure 1). The projection highlights three planning horizons:

1) Short term, by 2030, sea level rise is projected to be 6 to 10 inches above 1992 mean sea level;

2) Medium term, by 2060, sea level rise is projected to be 14 to 26 inches above 1992 mean sea level with the less likely possibility of extending to 34 inches;

3) Long term, by 2100, sea level rise is projected to be 31 to 61 inches above 1992 mean sea level with the less likely possibility of extending to 81 inches.

The Unified Sea Level Rise Projection for Southeast Florida include three curves, named after the global sea level rise curves from which they were derived: the NOAA High Curve (orange solid), the USACE High Curve (blue solid) and the median of the IPCC AR5 scenario (blue dashed). The blue shaded area represents the *likely* range of sea level rise for our region. The orange curve represents a condition that is possible but less likely. The USACE Intermediate or NOAA Intermediate Low curve is displayed on the figure for reference (green dashed curve). This scenario would require significant reductions in greenhouse gas emissions in order to be plausible and does not reflect the impact on sea level from the current emissions trends.

When determining how to apply the projection curves, the user needs to consider the nature, value, interconnectedness, and life cycle of the infrastructure in question. The following guidance is provided for using the projection.

- The shaded zone between the IPCC AR5 median curve and the USACE High is recommended to be generally applied to most projects within a short to long-term planning horizon, especially those with a design life expectancy of less than 50 years. The designer of a type of infrastructure that is easily replaced, has a short lifespan, is adaptable, and has limited interdependencies with other infrastructure or services must weigh the potential benefit of designing for the upper blue line with the additional costs. Should the designer opt for specifying the lower curve, he must consider the consequences of under designing for the potential likely condition.
- The uppermost boundary of the projection (orange curve) should be utilized for planning of critical infrastructure to be constructed after 2060 or projects with a long design life (more than 50 years) as a conservative estimate of potential sea level rise. Critical projects include those which are not easily replaceable or removable, have a long design life (more than 50 years), or are interdependent with other infrastructure or services. If failure of the infrastructure would have catastrophic impacts on the economy, community or environment, it should be considered critical.

To reference the projection to the current year i.e. 2015, simply subtract the values listed in the table below from the projected sea level rise. For example, based on the projection, sea level rise in 2030 will be 6 to 10 inches above 1992 mean sea level. In order to determine how much rise will occur relative to the current year, 2015, the values listed in the table below for the IPCC AR5 median and USACE High curves can be subtracted from the projected range i.e. 6-3=3 inches for the lower end of the range and 10-4.3=5.6 inches for the upper end of the range, respectively. The projection can be restated as such: sea level will rise 3 to 5.6 inches from this year (2015) to 2030.

| Current Year | IPCC AR5 Median (Blue Dashed Line) | USACE High (Blue Solid Line) | NOAA High (Orange Line) |
|---|---|---|---|
| **2015** | 3 | 4.3 | 5.3 |
| **2016** | 3.1 | 4.7 | 5.6 |
| **2017** | 3.4 | 4.9 | 6 |
| **2018** | 3.5 | 5.3 | 6.4 |
| **2019** | 3.7 | 5.5 | 6.8 |

To convert local relative sea level rise datum from mean sea level to a topographic reference point used in surveying land elevations (NAVD 88), add the number listed in the table below to projected sea level rise:

| | To convert relative sea level rise datum from mean sea level to feet NAVD 88*, add the number below to value from projection | To convert relative sea level rise datum from mean sea level to inches NAVD 88, add the number below to value from projection | Mean High Water (MHW) | Mean Low Water (MLW) |
|---|---|---|---|---|
| | Mean Sea Level in feet NAVD 88 | Mean Sea Level in inches NAVD 88 | Inches NAVD 88 | Inches NAVD 88 |
| Key West | -0.87 | -10.4 | -5.6 | -14.2 |
| Vaca Key | -0.83 | -10 | -5.6 | -14.2 |
| Miami Beach | -0.96 | -11.5 | 3.0 | -26.5 |
| Lake Worth Pier | -0.95 | -11.4 | 4.9 | -27.8 |

*North American Vertical Datum of 1988 (NAVD 88) is the topographic reference point used in surveying land elevations. By definition it is the vertical control datum of orthometric height established for vertical control surveying in the United States of America based upon the General Adjustment of the North American Datum of 1988.

Alternatively, the USACE Sea Level Change Curve Calculator (Version 2018.88) (USACE, 2015) found at this website http://www.corpsclimate.us/ccaceslcurves.cfm can be used to change datums, reference years and tide gauge locations. The projection curves were generated using this tool.

The equations used for the curves comprising the unified sea level rise projection are as follows:

- NOAA High Curve (Parris, 2012) and USACE High Curve (USACE, 2013):

$$E(t_2) - E(t_1) = a(t_2 - t_1) + b(t_2^2 - t_1^2)$$

where $E(t_2) - E(t_1)$ = Eustatic sea level change (m) with reference year of 1992;

$t_1$ = difference in time between current year or construction date and 1992 e.g. 2015-1992 = 23 years;

$t_2$ = difference in time between future date of interest and 1992 i.e. 2060-1992 = 68 years;

where $a$ is a constant equal to 0.0017 m/yr, representing the rate of global mean sea level change, and *b* is a variable equal to $1.56 x 10^{-4}$ for the NOAA High Curve; $1.13 x 10^{-4}$ for the USACE high curve, representing the acceleration of sea level change.

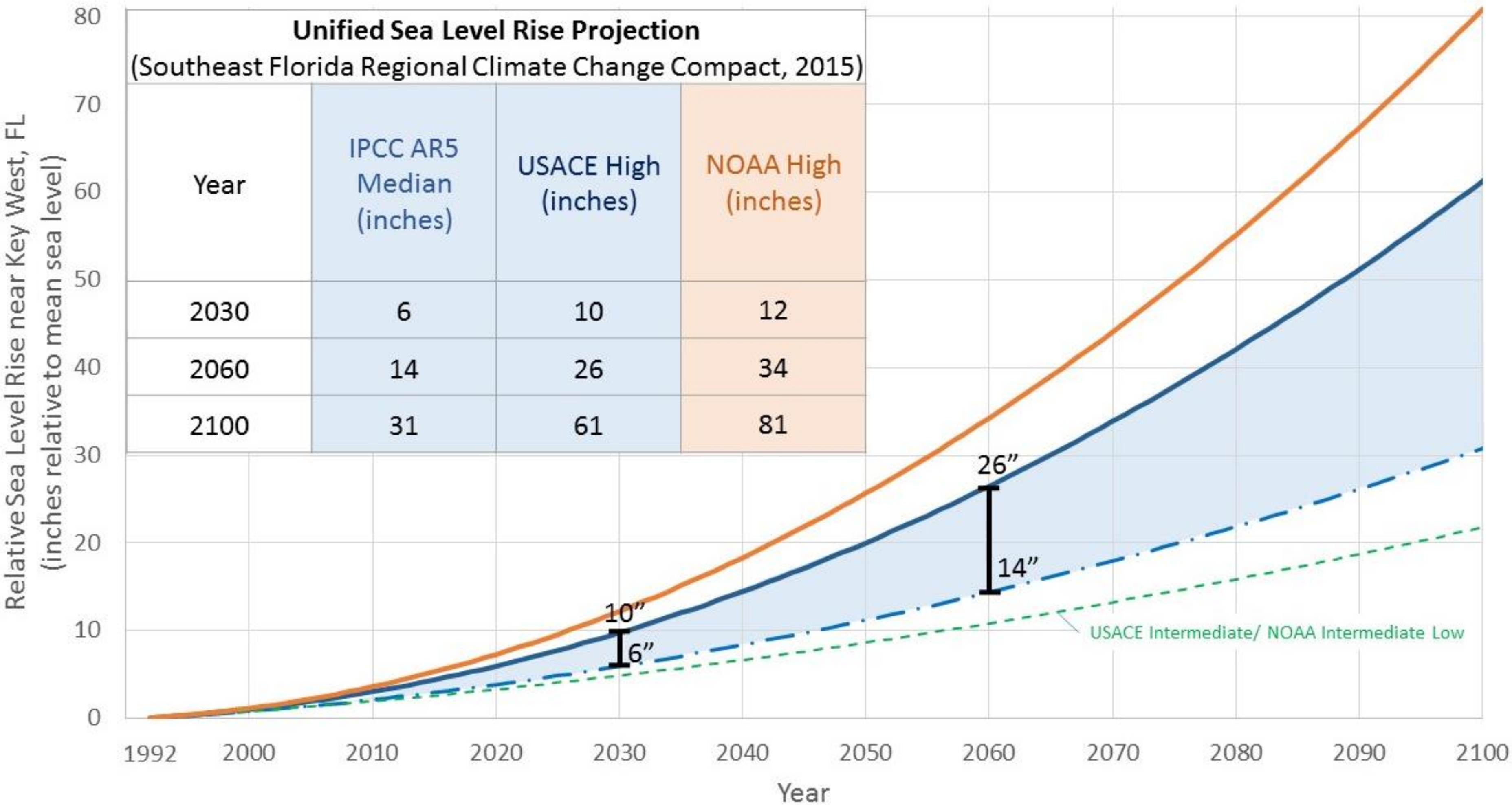
- IPCC AR5 RCP8.5 Median Curve (IPCC, 2013):

$$E(t_2) – E(t_1)= 0.0017(t_2 – t_1) + (4.684499 x 10^{-5})(t_2^2 – t_1^2)$$

- The NOAA Intermediate Low/ USACE Low curve that is not part of the projection but included on the graph for reference (green dashed line) can be derived as follows:

$$E(t_2) – E(t_1)= 0.0017(t_2 – t_1) + (2.71262 x 10^{-5})(t_2^2 – t_1^2)$$

The equations above are global mean sea level rise projections. In order to adapt the curves for regional use, the average rate of mean sea level rise or "*a*" value is adjusted. For example, to reference the above equations to the Key West tide gauge, *a* equals 0.0022 m/yr.




| Year | IPCC AR5 Median (inches) | USACE High (inches) | NOAA High (inches) |
|---|---|---|---|
| 2030 | 6 | 10 | 12 |
| 2060 | 14 | 26 | 34 |
| 2100 | 31 | 61 | 81 |

**Figure A-1: Unified Sea Level Rise Projection. These projections are referenced to mean sea level at the Key West tide gauge. The projection includes three global curves adapted for regional application: the median of the IPCC AR5 scenario as the lowest boundary (blue dashed curve), the USACE High curve as the upper boundary for the short term for use until 2060 (solid blue line), and the NOAA High curve as the uppermost boundary for medium and long term use (orange solid curve). The incorporated table lists the projection values at years 2030, 2060 and 2100. The USACE Intermediate or NOAA Intermediate Low curve is displayed on the figure for reference (green dashed curve). This scenario would require significant reductions in greenhouse gas emissions in order to be plausible and does not reflect current emissions trends.**

## APPENDIX B: STATE OF SCIENCE UPDATE

### ACCELERATION OF SEA LEVEL RISE

A statistically significant acceleration of sea level rise has been documented in the latter half of the 20th century continuing through recent years (Church and White, 2011; Calafat and Chambers, 2013; Hay et al. 2015; IPCC, 2013; Watson et al., 2015). Hay et al. (2015) reported the global sea level rise rate from 1901 to 1990 to be 1.2 +/- 0.2 mm/yr (a value which had been overestimated in previous studies). Since 1993, an increase in the average global mean sea level rise rate has been observed (Hay et al., 2015; Watson et al., 2015). Watson et al. (2015) has most recently reported the average global mean sea level rise rate to be more than double the rate of the previous century, indicating an acceleration; the observed rate was 2.6+0.4 mm/yr from 1993 to 2015 with an acceleration of 0.04 mm/yr$^2$. This acceleration indicates sea level will rise more rapidly in the future than it has historically. The global and regional processes driving sea level rise and its acceleration are discussed in the following sections.

### FACTORS INFLUENCING SEA LEVEL RISE

#### GLOBAL PROCESSES

In 2011, the Work Group noted studies describing a variety of reinforcing (positive) feedbacks that are accelerating ice sheet melt in Greenland and Antarctica and also accelerating Arctic pack ice melt, permafrost thaw and organic decay, and methane hydrate release from the warming Siberian Shelf, in addition to other global processes affecting sea level rise i.e. increasing greenhouse gas concentrations, changes in volcanic forcing and tropospheric aerosol loading (Compact, 2011). Since then, numerous additional reinforcing feedbacks have been documented and previously recognized feedbacks have intensified.

#### ACCELERATION OF ICE MELT

Accelerated melting of the ice sheets on Greenland and Antarctica (Rignot et al., 2011; Talpe et al., 2014) is expected to be the predominant factor affecting sea level rise acceleration during the 21st Century. Melting is caused by increasing temperatures and warming of the atmosphere, warm currents moving along the coast of Greenland, and warm ocean water moving under and up into ice sheets through deep outlet glacial fjords in Antarctica. Recent observations have indicated ice sheets are more vulnerable to melting than previously realized due to the extent of deep valleys within the ice sheets connecting warmer ocean water to the internal areas of the ice sheets thus causing rapid melting and peripheral thinning (Jenkins et al., 2010; Jacobs et al., 2011; Morlighem et al., 2014; Rignot et al., 2014; Greenbaum et al., 2015). Accelerated melting results in large discharges of fresh water which raises the local sea level near the ice sheets (8 inches around Antarctica over past 20 years) (Rye et al., 2014). This release of freshwater has resulted in a seasonal increase in the amount of sea ice in the Antarctic (Bintanja et al., 2013; Rye et al., 2014) and slower circulation of North Atlantic surface water, also known as Atlantic Meridional Overturning Circulation (Rahmstorf et al., 2015). The slowdown in circulation may contribute to increased local sea level rise along the Florida coast, as discussed in the ***Regional/ Local Processes*** section. The IPCC projections do not include the factors related to acceleration of ice melting processes described above, and as a result are likely an underestimate of future sea level rise (Rignot et al., 2011).

### ICE SHEET DISINTEGRATION

Indicators of ice sheet disintegration include retreat of the ice sheet's outer boundary and rapid thinning. Lateral flow of the Greenland Ice Sheet margin, the outer boundary, has dramatically accelerated in the past two decades in response to surface melt waters penetrating fractures in the ice and warming and softening the ice (Bell et al., 2014). In addition to retreat, the ice sheets have initiated a rapid thinning process due to basal melt (Pritchard et al., 2012), signaling the initiation of prolonged ice sheet degradation based on historic analysis (Johnson et al., 2014). Joughin et al. (2011) have used numerical models to look at the sensitivity of the outlet glaciers of the West Antarctic Ice Sheet to ocean water melt and have concluded that the West Antarctic Ice Sheet collapse is already underway; the extent of the collapse in the future is not yet known. As part of the Gravity Recovery and Climate Experiment (GRACE) satellite monitoring program, ice sheet mass loss has been quantified as 280±58 gigatons per year (Gt/yr) from Greenland and up to 180±10 Gt/yr in Antarctica (Velicogna et al., 2014). As a reference for the magnitude of a gigaton, one could estimate one gigaton to equal the mass of over one hundred million elephants. In addition, significant recent work was completed to verify the estimated contribution of ice sheet disintegration to sea level rise using satellite data (Jacob et al., 2012; King et al., 2012; Gardner et al., 2013) with the conclusion that ice sheet melt accounted for 29±13% of sea level rise from 2003 to 2009 (Gardner, 2013). In order to further refine the estimates and projections of the magnitude of ice sheet degradation and their contribution to sea level rise, the complex dynamics driving ice sheet melt need to be better understood, in particular the mechanisms driving interactions between ice sheets and warm currents.

### WARM CURRENTS

In 2011, the Work Group acknowledged the effects of warm ocean water currents accelerating summer pack ice melt and causing melting beneath the outlet glaciers. Recent work has further clarified the compounding mechanisms driving the flow and temperature changes of warm currents. Spence et al. (2014) analyzed the poleward shift in direction of the southern hemisphere westerly winds since the 1950's and simulated the intense warming of coastal waters associated with such a shift in order to explain and forecast the significant temperature increase in ocean waters interacting with the base of ice sheets and floating ice shelves. This study serves to validate the projection of the persistence of this wind trend and the resulting melting due to warm current interaction. Separate from wind forcing, an increase in ocean surface stress due to thinning of the formerly consolidated sea-ice cover near Antarctica is proposed to result in a redirection of warm ocean currents into submarine glacial troughs and further expediting melting of the deep ice-shelf base based on ocean-ice modeling (Hellmer et al., 2012). Ice sheet melt as a result of interaction with warm currents is one of the dominant factors contributing to recent global sea level rise (IPCC, 2013); however, as discussed in the next section, land based contributions to global warming may further exacerbate sea level rise in the future.

### THAWING PERMAFROST

The potential for significant additional emissions of carbon dioxide and methane from thawing permafrost and the rate of occurrence continues to be investigated. The intricate feedback mechanisms associated with permafrost are not well understood; as such, the IPCC did not include permafrost thaw in its projections (Collins et al., 2013). This deficiency was criticized publicly due to the theorized potential for permafrost carbon emissions to exceed emissions from fossil fuel use.  Schuur et al. 2013 conducted a survey of experts to quantify permafrost change in response to four global warming scenarios and found despite risk for significant contributions of emissions from thawing, fossil fuel combustion was likely to remain the main source of emissions and climate forcing until 2100 based on the proposed warming scenarios.

Following the release of the IPCC (2013) report, demand for research to understand the dynamics of the physical and chemical permafrost processes has increased in order to confirm the estimates of emissions from thawing. As an initial step, the occurrence of significant submarine permafrost thawing was confirmed by Overduin et al. (2014) when 8 to 10°C of warming within the permafrost layer was observed in less than 1,000 years, resulting in a degradation of ice-bearing permafrost at the rate of 3 cm/yr. In addition, seawater seeping through soil pores was identified as the source of sulfate necessary to oxidize methane in the upper layer of the thawing permafrost. Although site specific, studies such as Overduin et al. (2014) will begin to provide the information necessary to incorporate permafrost thawing into models and projections in the near future.

## REGIONAL/ LOCAL PROCESSES

### VERTICAL LAND MOVEMENT

Vertical earth movements, which regionally and locally modify the globally averaged rate of sea level change, result in a relative rate of change that varies from one location to another. These land motions have been inferred from historical tide data and geodesic measurements. When added to projected rates of global mean sea level rise, they result in a perceived change ranging from increased rise in regions of subsidence (e.g., New Orleans) to falling sea levels where the land is being uplifted (e.g., along the northern border of the Gulf of Alaska). Other regions are geologically stable and have only small differences with respect to the global rate of change. In South Florida, in general, coastal land elevations are considered to be relatively stable meaning that the land is not experiencing significant uplift nor subsidence. It is also important to note, the vertical land movement that is occurring is non-uniform across South Florida and movement measured at specific monitoring stations sites may not reflect vertical land movement in adjacent areas.

The Continuously Operating Reference (COR) network of permanent Global Positioning System (GPS) receivers provides precise measurements of vertical land movement in four locations throughout Southeast Florida (Key West, Virginia Key, Pompano Beach, and Palm Beach) over periods of nine to eleven years. Additional continuous GPS measurements have been acquired in eight other sites in the region over various time periods (two to eleven years). Precise analysis of these data reveals negligible vertical movements at most stations (less than 1 mm/yr) (Snay et al., 2007; Santamaría-Gómez et al., 2012; NGL, 2015). However, some stations show 1 to 6 mm/yr of subsidence, reflecting mostly local unstable conditions of the GPS antenna monument (e.g., local building movements) (e.g., Bock et al., 2012).

National Geodetic Survey has operated continuous GPS stations at Key West, Fort Lauderdale, Miami and Palm Beach Gardens. The GPS data of these sites were processed by the Nevada Geodetic Laboratory, who presents the results at GPS time series (http://geodesy.unr.edu/index.php). The rates of vertical land movement at these stations are shown in Table 1 (Blewitt et al., 2015). It should be noted vertical land movement is non-uniform across South Florida as a result of geology variations and the non-uniform compaction of fill placed during development of the region. Subsidence at tide stations is closely monitored to ensure the accuracy of sea level rise measurements. The regional rate of sea level rise is affected by such localized subsidence and is accounted for in the regional sea level rise acceleration variable incorporated in the projections adapted for the region.

**Table 1: Continuous GPS Operation in Southeast Florida (Blewitt et al., 2015)**

| Site | Location | Duration | Vertical rate (mm/yr) |
|---|---|---|---|
| KYW1 | Boca Chica Key | 1997-2008 | -0.5 ± 0.1 |
| KYW5 | Boca Chica Key | 2007-present | 0.1 ± 0.1 |
| KYW6 | Boca Chica Key | 2007-present | 1.0 ± 0.1 (uplift) |
| KWST | Key West airport | 2003-present | -1.5 ± 0.1 |
| CHIN | Key West, 500 m south of tide gauge | 2008-presnt | -1.6 ± 0.5 |
| LAUD | Fort Lauderdale Executive Airport | 2005-2014; 2014-2015 | -0.5± 1.1 |
| ZMA1 | Miami Airport | 2004-2008; 2008-present | 0.2± 0.9 |
| FLC6 | Florida City | 2009-present | -1.8± 1.2 |
| PBCH | North Palm Beach County Airport | 2005-present | 1.0± 1.0 (uplift) |

Additionally, in some regions, the effects of changing ocean currents can further modify the relative local rate of sea level rise. Such is the case of the east coast of Florida, as is discussed in the next section, **Ocean Dynamics, Gulfstream/ Circulation**

## OCEAN DYNAMICS, GULFSTREAM/ CIRCULATION

Ocean circulation has changed little during the current period of scientific observation, but in the future it can considerably alter the relative rate of sea level rise in some regions, including Southeast Florida. A slowing of the Florida Current and Gulf Stream will result in a more rapid sea level rise along the east coast of North America. By 2100, these circulation changes could contribute an extra 8 inches of sea level rise in New York and 3 inches in Miami according to Yin et al. (2009). Most of the global climate models used by the IPCC (IPCC, 2007; 2013) project a 20-30% weakening of the Atlantic Meridional Overturning Circulation (AMOC), of which the Gulf Stream and Florida Current are a part. Measurements of the AMOC have yet to conclusively detect the beginning of this change, however there has been a report of a recent decline in AMOC strength by Smeed et al. (2014) that coincides with the mid-Atlantic hotspot of sea level rise reported by Ezer et al. (2013) and Rahmstorf et al. (2015). Recent analysis of the Florida Current transport has detected a decrease in circulation over the last decade, which appears to account for 60% of South Florida sea level rise over the decade and contribute to a positive acceleration (Park and Sweet, 2015). If a long-term slowdown of the AMOC and Florida Current. Rahmstorf et al. (2015) use a proxy method also suggesting that a slowdown of the AMOC has begun. If a long-term slowdown of the AMOC does occur, sea level rise along the Florida east coast could conceivably be as much as 20 cm (8 inches) greater than the global value by 2100.

According to the most recent estimates by the IPCC (IPCC 2013, FigureB-1), the combined differential due to regional ocean heating and circulation change along the Southeast Florida coast would be in the range of 10%-20% greater than the globally averaged rise by 2090. For a median (50% probability) sea level rise of one meter by 2100, this would give about 10-20 cm (4-8 inches) of additional rise along the Southeast Florida coast, which is within the range of estimates by Yin et al. (2009). However, the IPCC models do not have the horizontal resolution required to effectively estimate these changes at the scale of the Florida Current and more research with higher resolution ocean models will be required. As such, it is prudent to add ~15% to the global mean sea level rise values projected by the IPCC in order to use them for Southeast Florida planning. This adjustment is accounted for in the regional sea level rise coefficients incorporated in the projections adapted for the region.

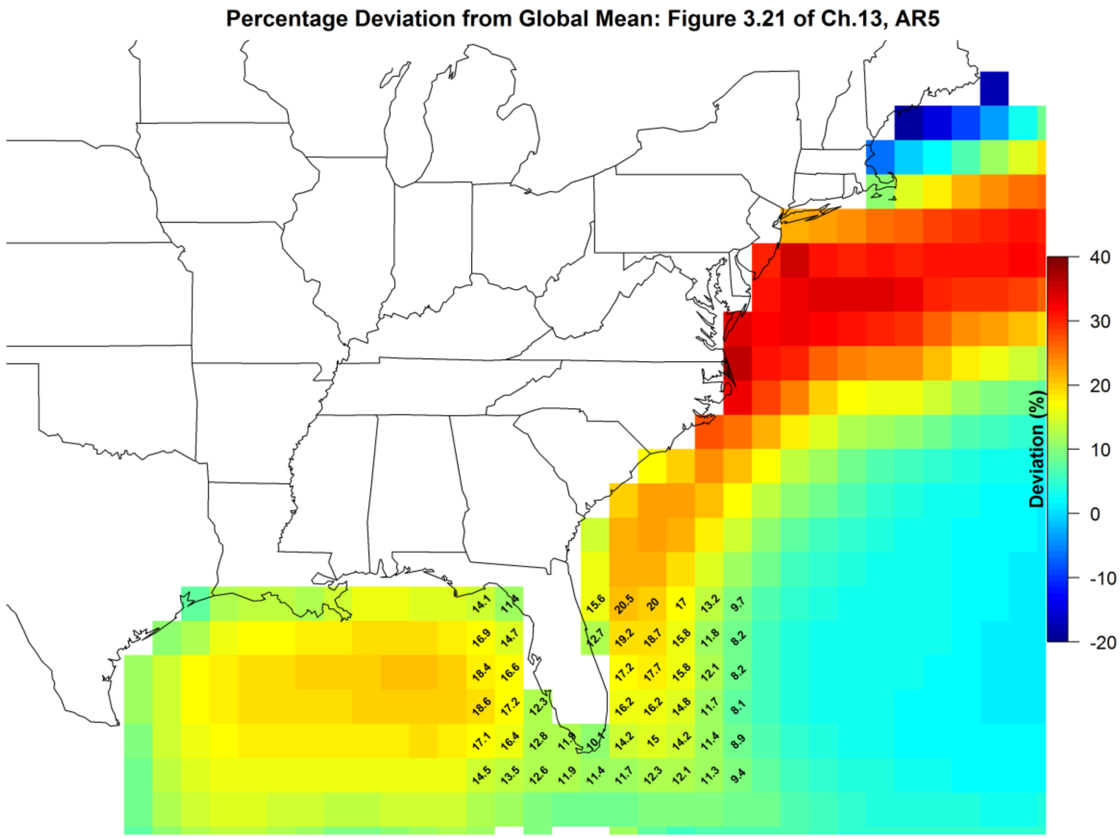



**Figure B-1. Percentage of the deviation of the ensemble mean regional relative sea level change between 1986-2005 and 2081-2100 from the global mean value, based on Figure 13.21, IPCC (2013). The figure was computed for RCP4.5, but to first order is representative for all Representative Concentration Pathways (RCP). RCPs are the four greenhouse gas concentration trajectories adopted by the IPCC for its fifth Assessment Report (AR5).**

## APPENDIX C: WORKGROUP COMMENTARY AND RECOMMENDATIONS

The following are recommendations made by the Work Group for consideration by the Southeast Florida Regional Climate Compact Steering Committee to be used by the Compact Counties as part of the implementation of the Regional Climate Change Action Plan.

a. The unified SE FL sea level rise projection will need to be reviewed as the scientific understanding of ice melt dynamics improves. The projection should be revised within five years of final approval of this document by the Southeast Regional Climate Change Compact Steering Committee. This timing is consistent with the release of Intergovernmental Panel on Climate Change Sixth Assessment Report which will provide a synthesis of the major findings in climate science to date.

b. Users of the projection should be aware that at any point of time, sea level rise is a continuing trend and not an endpoint.

c. The planet is currently on a high emissions trajectory for which committed sea level rise is probably near the high end of the ranges. It should also be noted that the attenuation of impacts through mitigation will not likely be sufficient to overcome the inertia of the climate system prior to 2060.

d. Full and complete transparency of the projection and its implications should be promoted across the communities in order to encourage and guide effective and realistic planning, obtain realistic economic realities for maintaining functional infrastructure, insuring social and economically sound further development, and necessary adaptation.

e. Further work to develop projections for the occurrence of extreme events in tandem with sea level rise may be necessary to assist communities in planning for storm drainage adaptation.

## APPENDIX D: ACKNOWLEDGEMENT OF PARTICIPANTS

The Southeast Florida Regional Climate Change Compact Counties (Monroe, Miami-Dade, Broward and Palm Beach Counties) and their partners wish to acknowledge the Work Group participants and members of the SE FL Regional Climate Change Compact Steering Committee for participating in meetings to support the development of the Unified Sea Level Rise Projection and the guidance document. The following members contributed to the development and refinement of the projection:

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## APPENDIX E: DEVIATION FROM 2011 PROJECTION

The updated unified sea level rise projection includes the range projected by the 2011 unified sea level rise projection with three enhancements. As described in previous paragraphs, the year the projection begins was shifted from 2010 to 1992. Since the projection now references the sea level rise that has occurred since 1992 instead of 2010, the values in the projection are larger as a result of the sea having 8 more years to rise. For example, at the lower boundary of the projection, by 2030, sea level rise is projected to be 5 inches above the where mean sea level was in 1992. This is the exact same projected elevation as 3 inches above where the mean sea level was in 2010, just a different elevation datum. Table 1 shows the adjustment of values from the 2011 Unified Projection with a reference (starting) year of 1992. Please note the lower boundary is the same in both the 2011 and 2015 projections. The second enhancement to the projection was the extension of the projection past 2060 continuing to 2100. The third enhancement to the projection was the addition of the NOAA High Curve as the upper boundary after Year 2060. For critical infrastructure projects with design lives in excess of 50 years, use of the upper curve is recommended with planning values of up to 34 inches in 2060 and up to 81 inches in 2100.

**Table 2: Comparison of Unified Projection in 2011 and 2015 at Key West**

| Year | 2011 Unified Projection (referenced to Year 2010) (inches above msl) | | 2011 Unified Projection (adjusted to reference Year 1992) (inches above msl) | | 2015 Proposed Unified Projection (referenced to Year 1992) (inches above msl) | | | |
|---|---|---|---|---|---|---|---|---|
| | NRC Curve I (1987) | NRC Curve III (1987) | NRC Curve I (1987) | NRC Curve III (1987) | NOAA Int.- Low | IPCC AR5 Median | USACE High | NOAA High |
| **1992** | | | 0 | 0 | 0 | 0 | 0 | - |
| **2030** | 3 | 7 | **5** | **10** | **5** | 6 | **10** | - |
| **2035** | | | | | 6 | 7 | 12 | - |
| **2060** | 9 | 24 | **11** | **26** | **11** | 14 | **26** | 34 |
| **2075** | | | | | 15 | 20 | 38 | 49 |
| **2100** | | | | | 22 | 31 | 61 | 81 |