Sea Level Rise in South Florida: Causes, Consequences and Opportunities

Dr. Todd A. Crowl
Director, Institute of Water & the Environment
Director, Southeast Environmental Research Center
Co-Founder, Sea Level Solutions Center
Florida International University

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FIU Sea Level Solutions Center
FLORIDA INTERNATIONAL UNIVERSITY

Develop new interdisciplinary solutions through partnerships and collaboration

The SLSC is a university-wide center for:

1) *conducting, facilitating, and synthesizing research and education to advance understanding of sea-level rise and its impacts on the well-being of both human and natural systems, and*
2) *converting this knowledge into actions for the benefit of society*

Knowledge → **Action**

Threat → **Opportunity**

Create interdisciplinary, solution-oriented science and training opportunities that are policy-relevant

Sea Level Solutions Center Interdisciplinary Studio

Taking a holistic, system-oriented approach - that integrates evaluation of future scenarios - to realize a new and resilient Miami while training the next generation of innovators.

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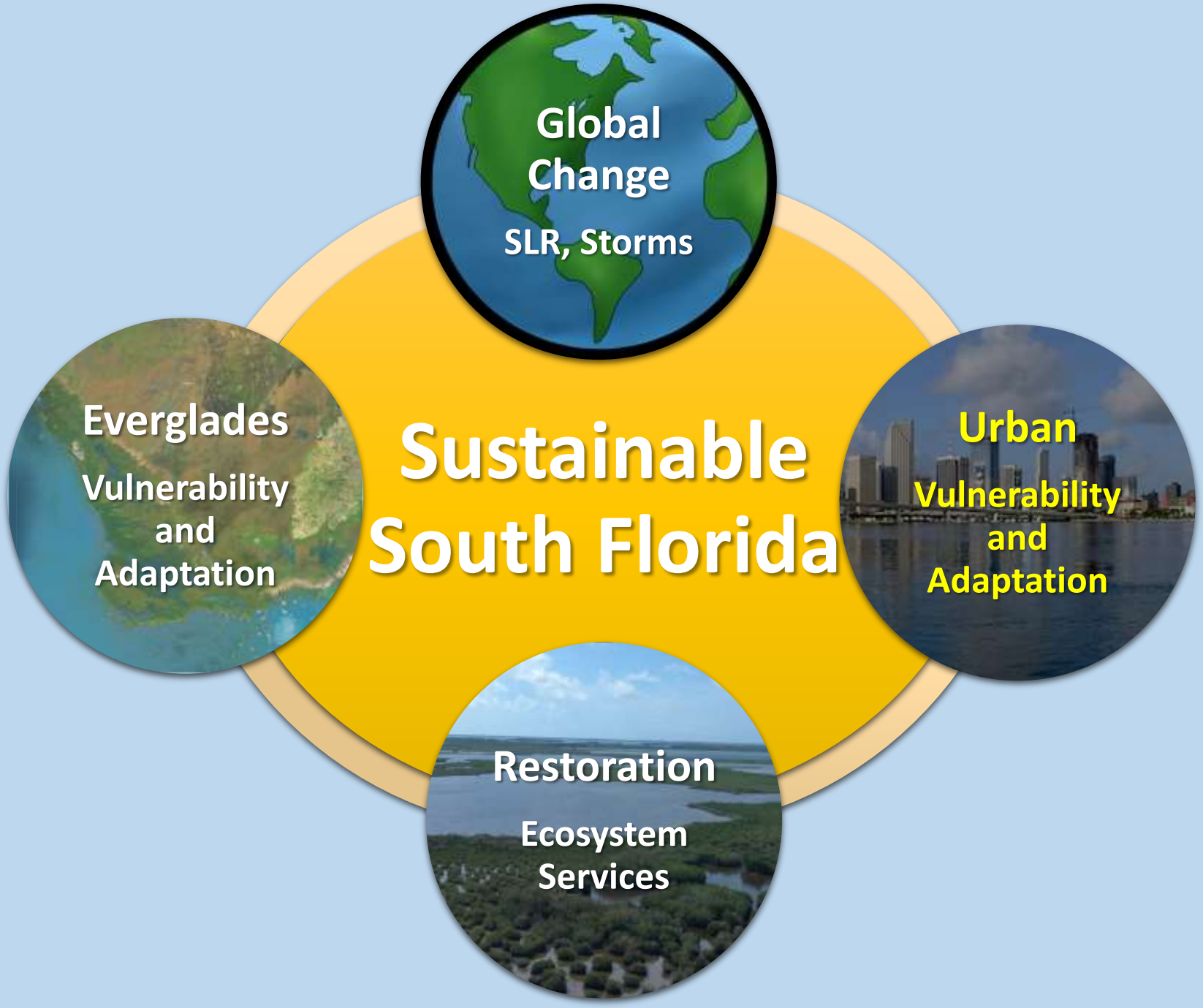
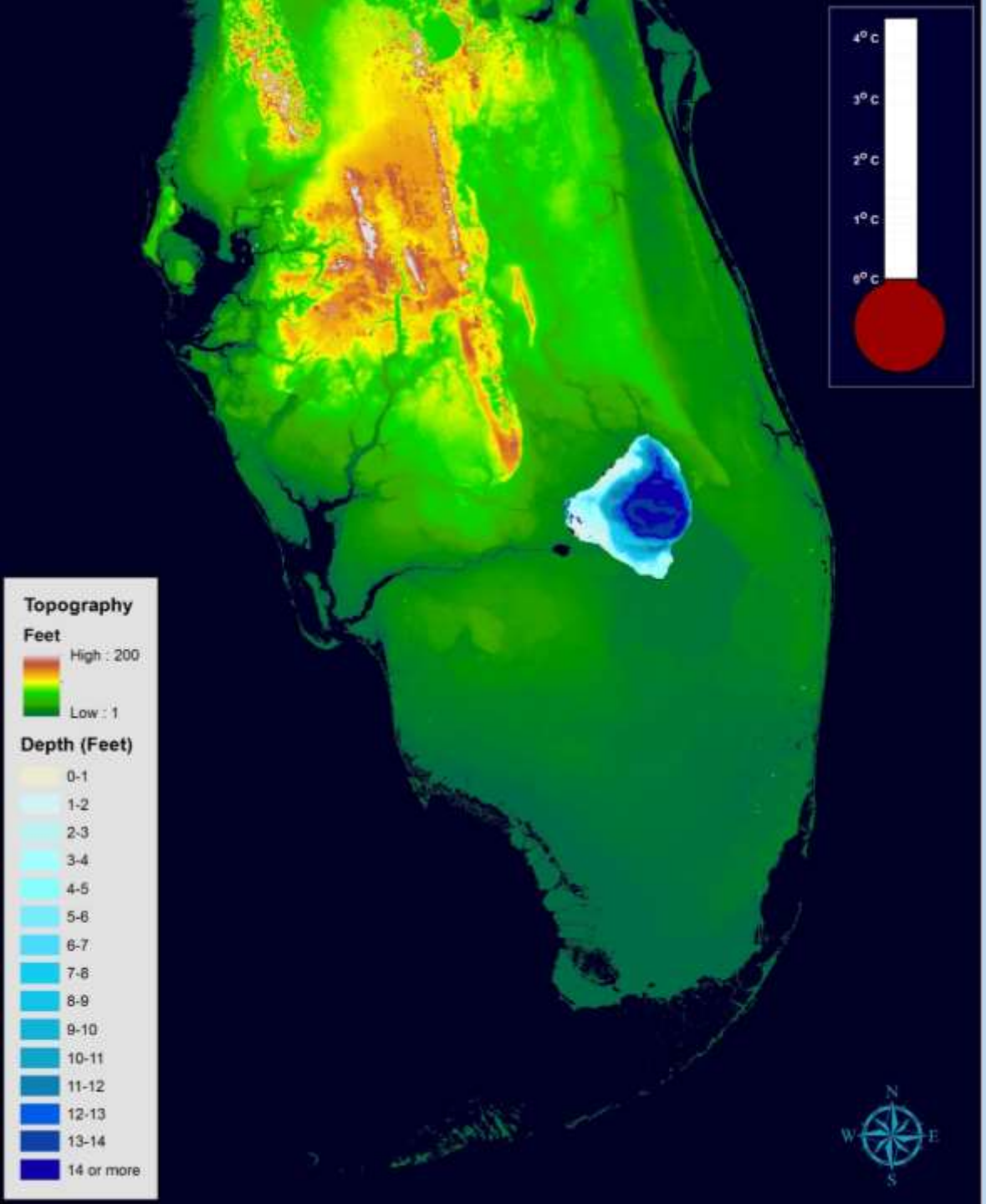

Global Change
SLR, Storms
Everglades
Vulnerability and Adaptation
Sustainable South Florida
Urban
Vulnerability and Adaptation
Restoration
Ecosystem Services

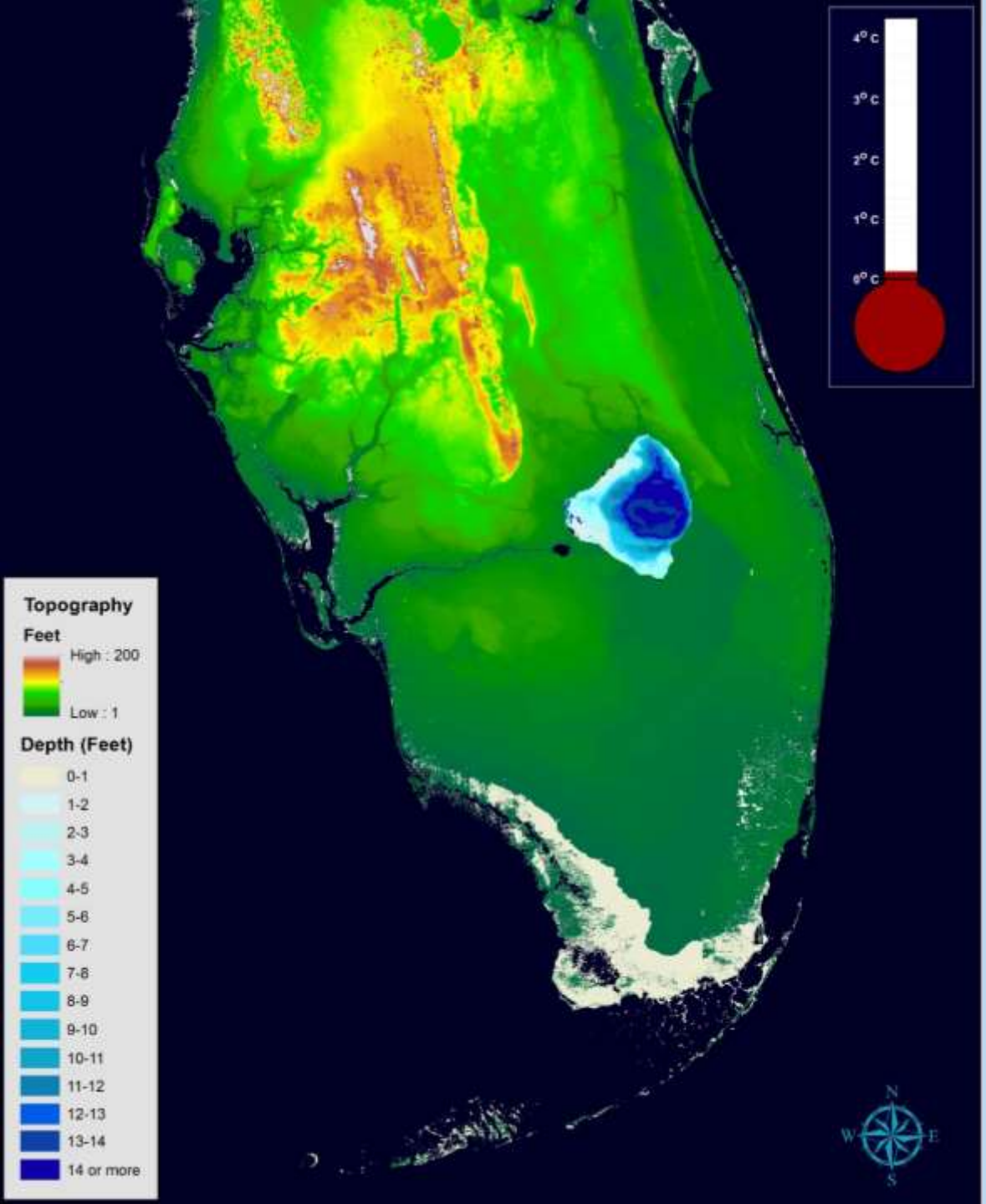
Flooding in Miami

Alton Rd between 8th and 10th streets has been flooding every year for the past 7 years at least.



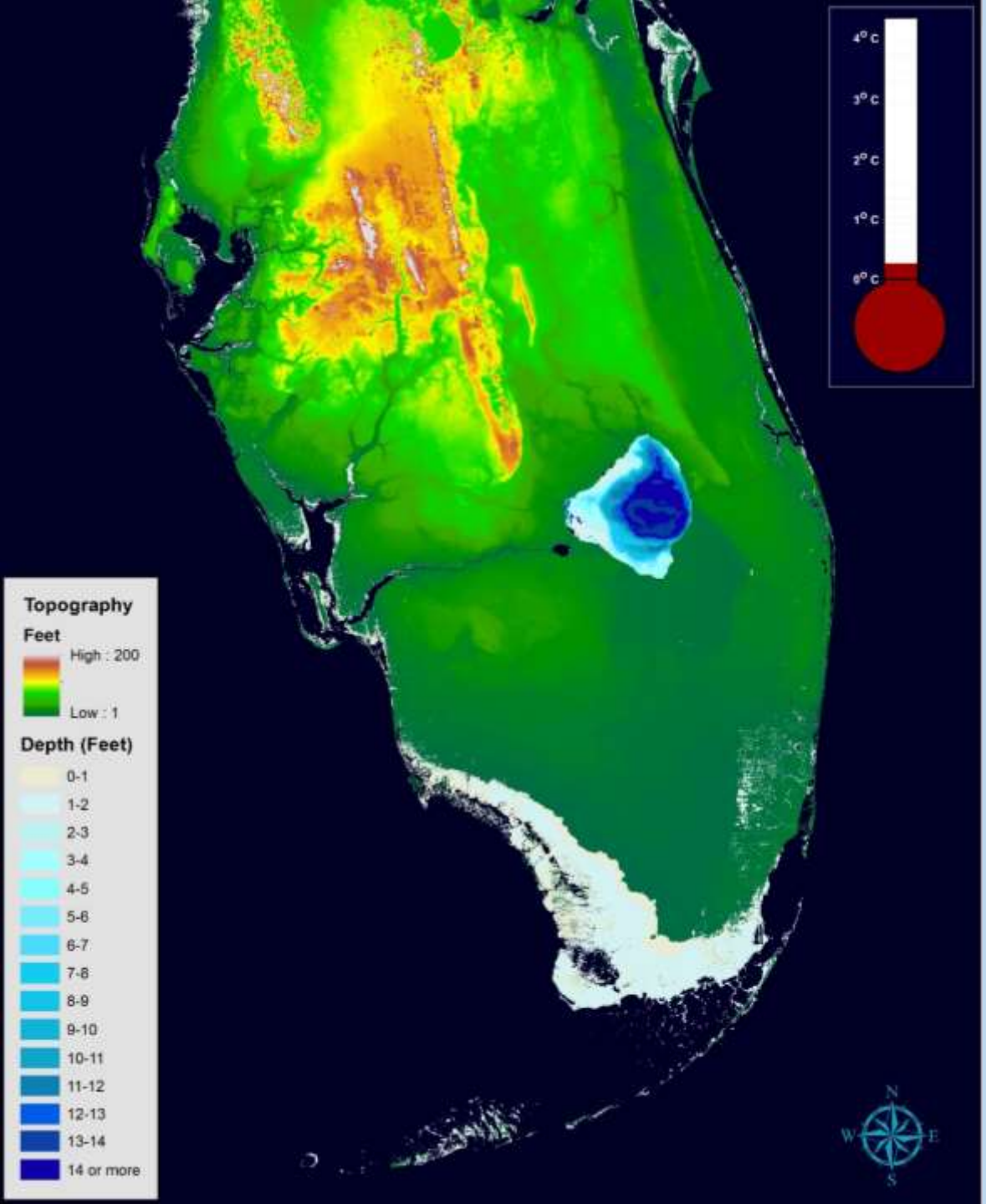
Southern Florida Topography

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



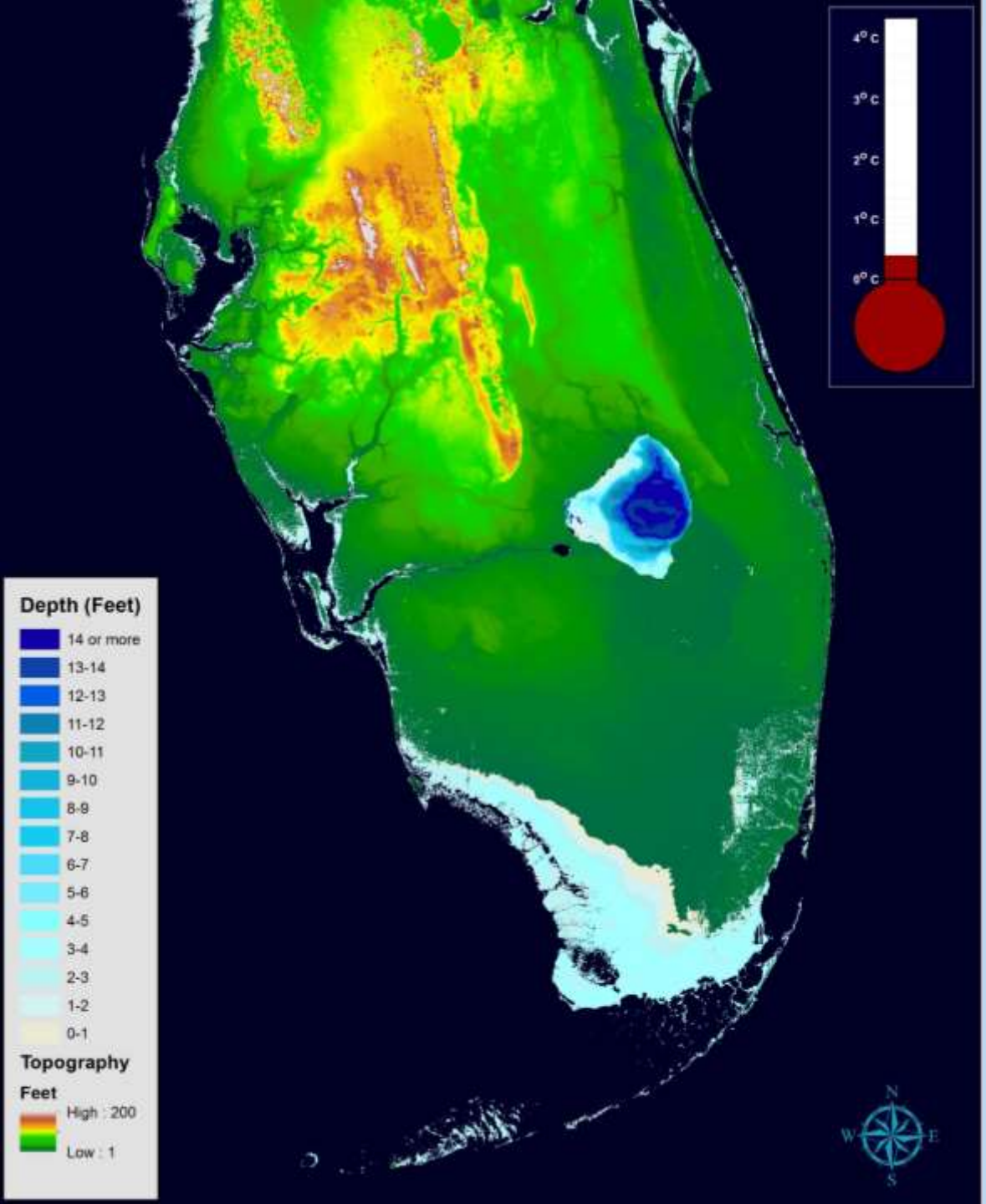
Southern Florida with 1 foot of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



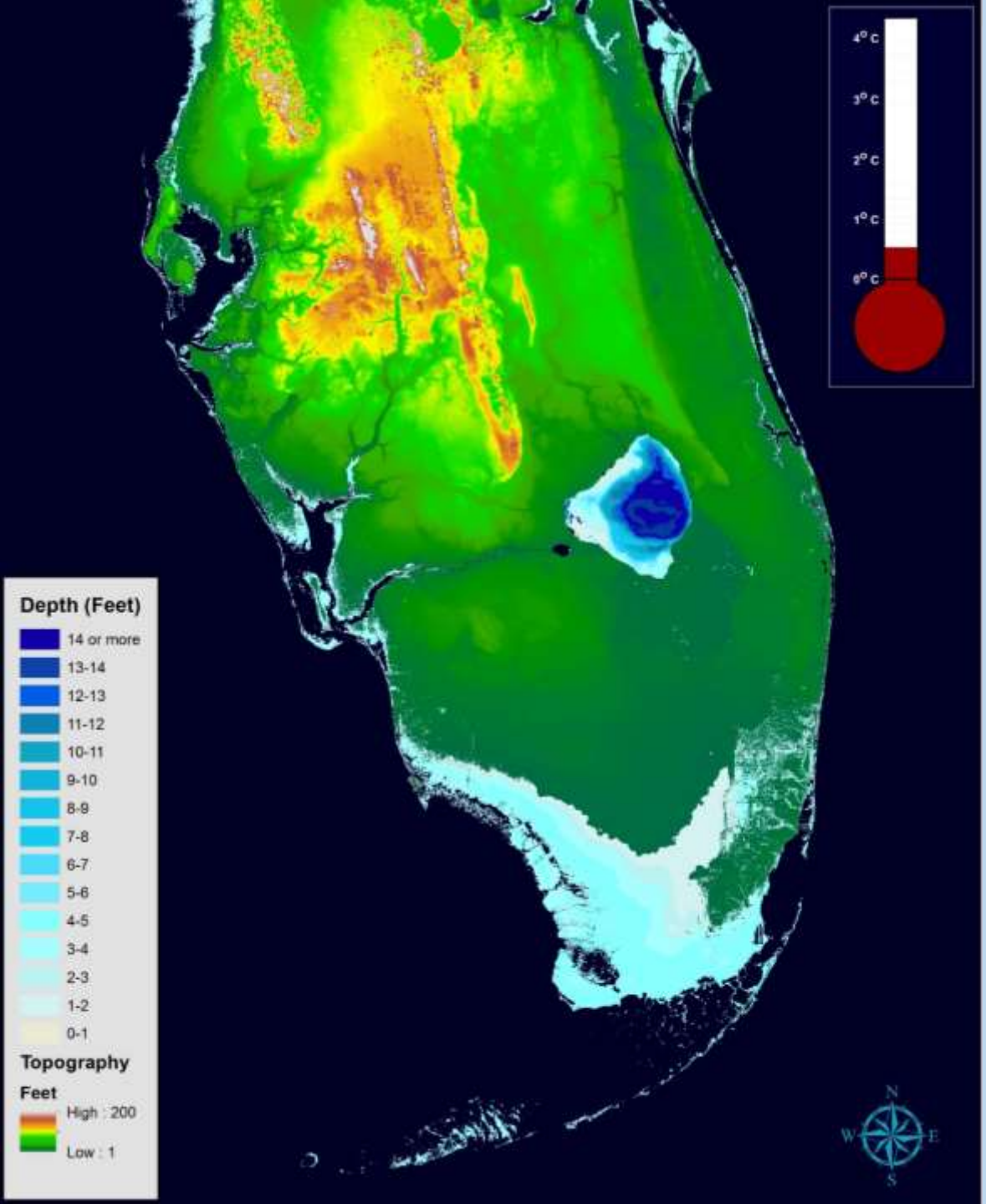
Southern Florida with 2 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



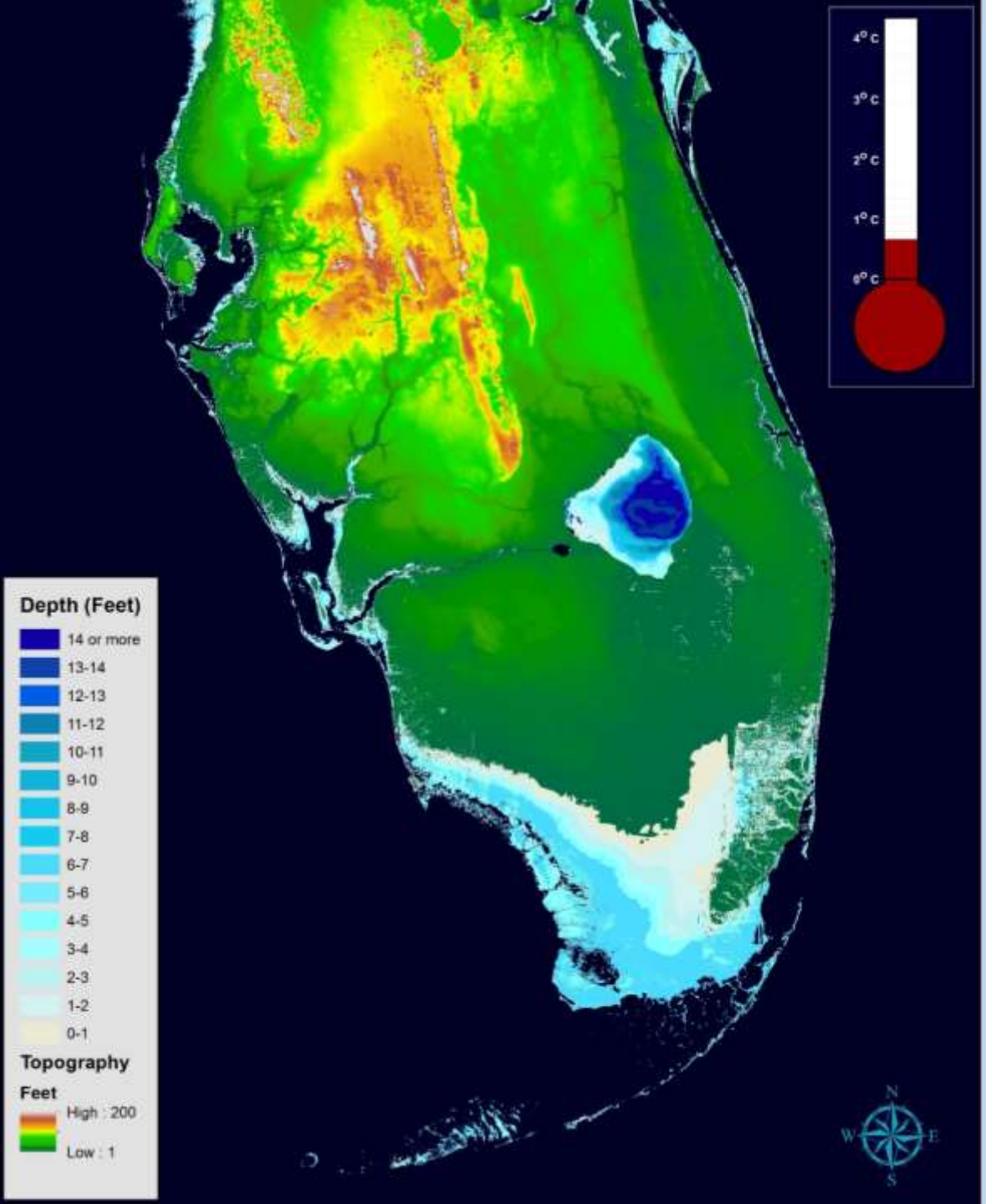
Southern Florida with 3 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



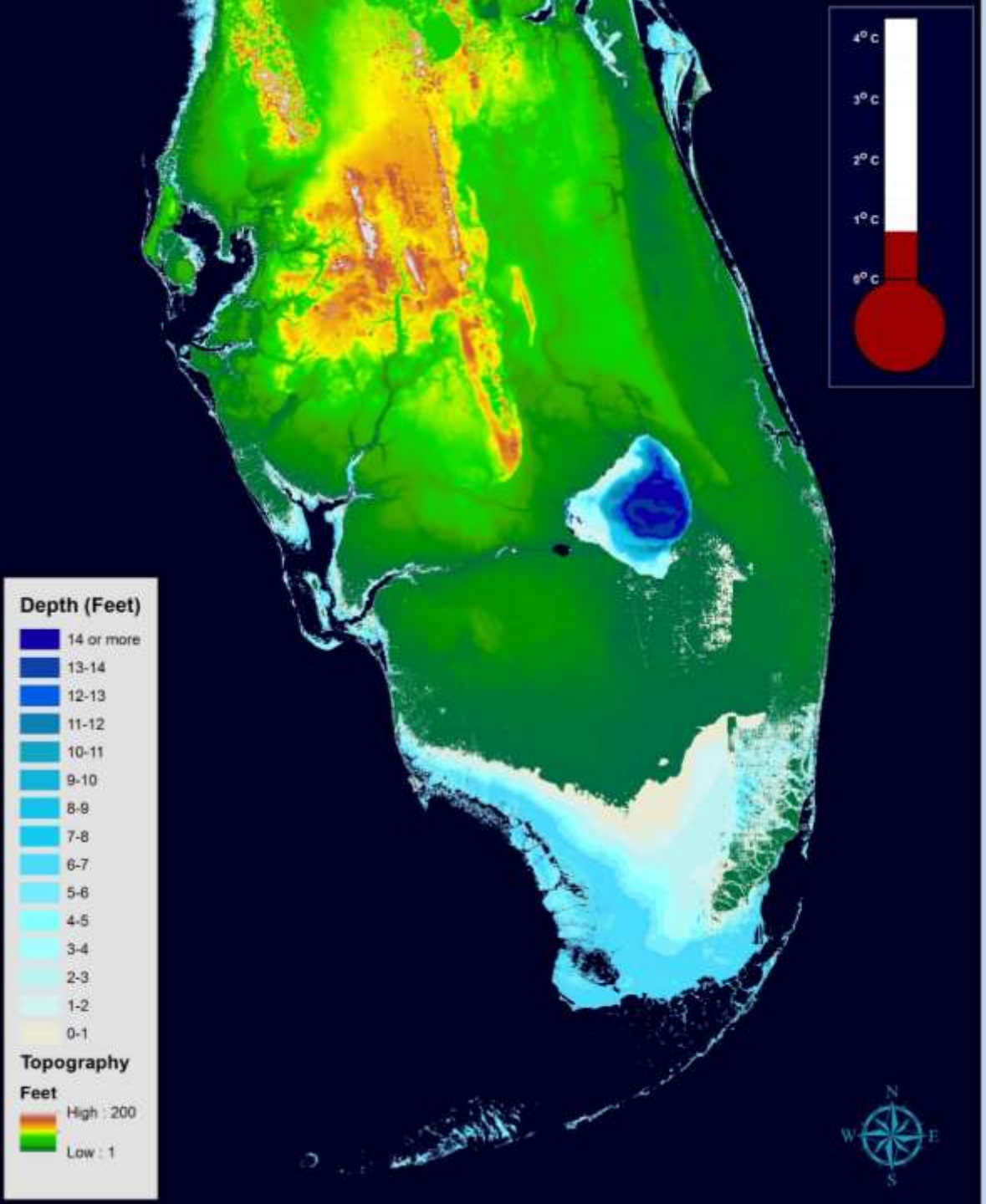
Southern Florida with 4 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



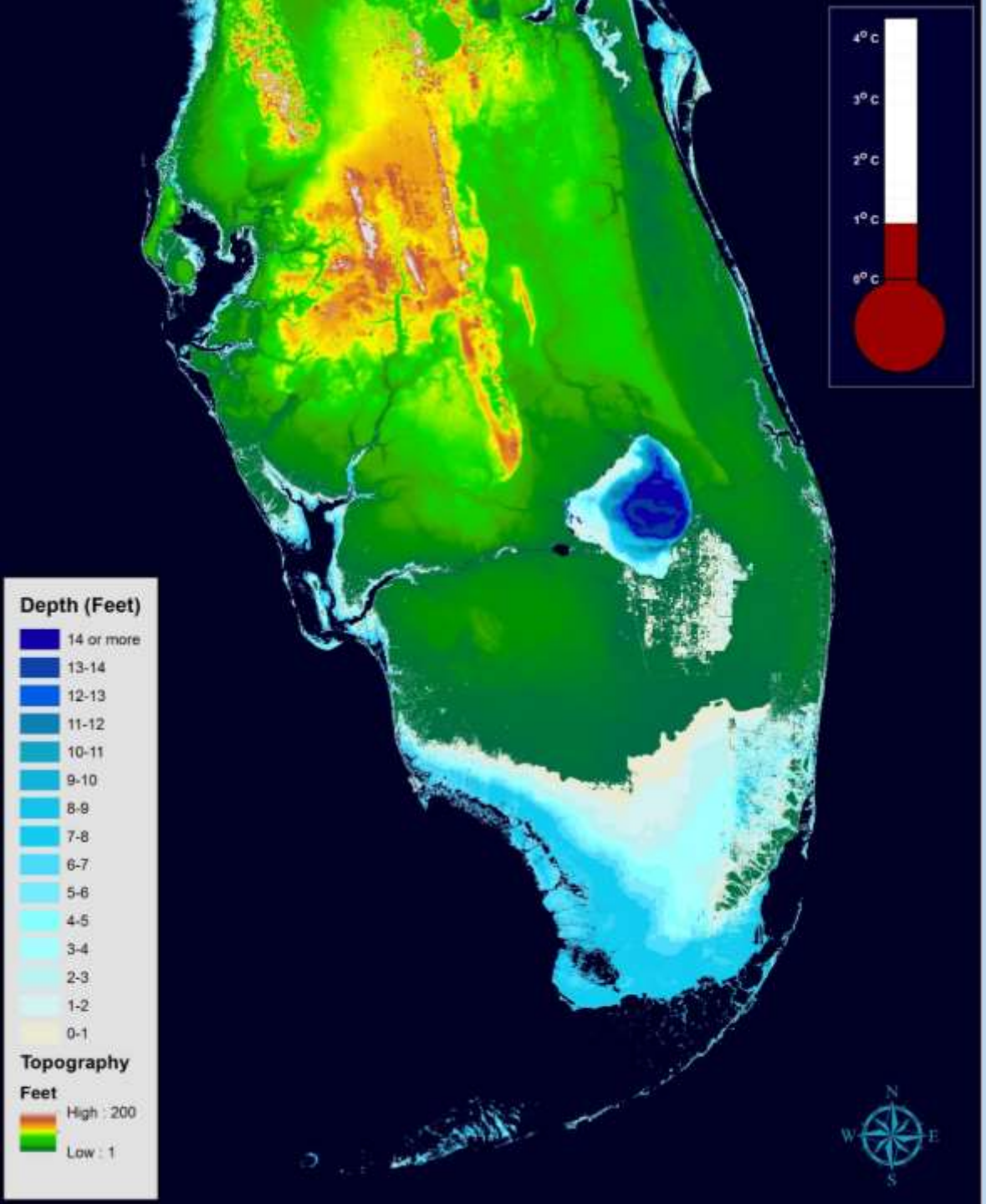
Southern Florida with 5 feet of Sea Level Rise !

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



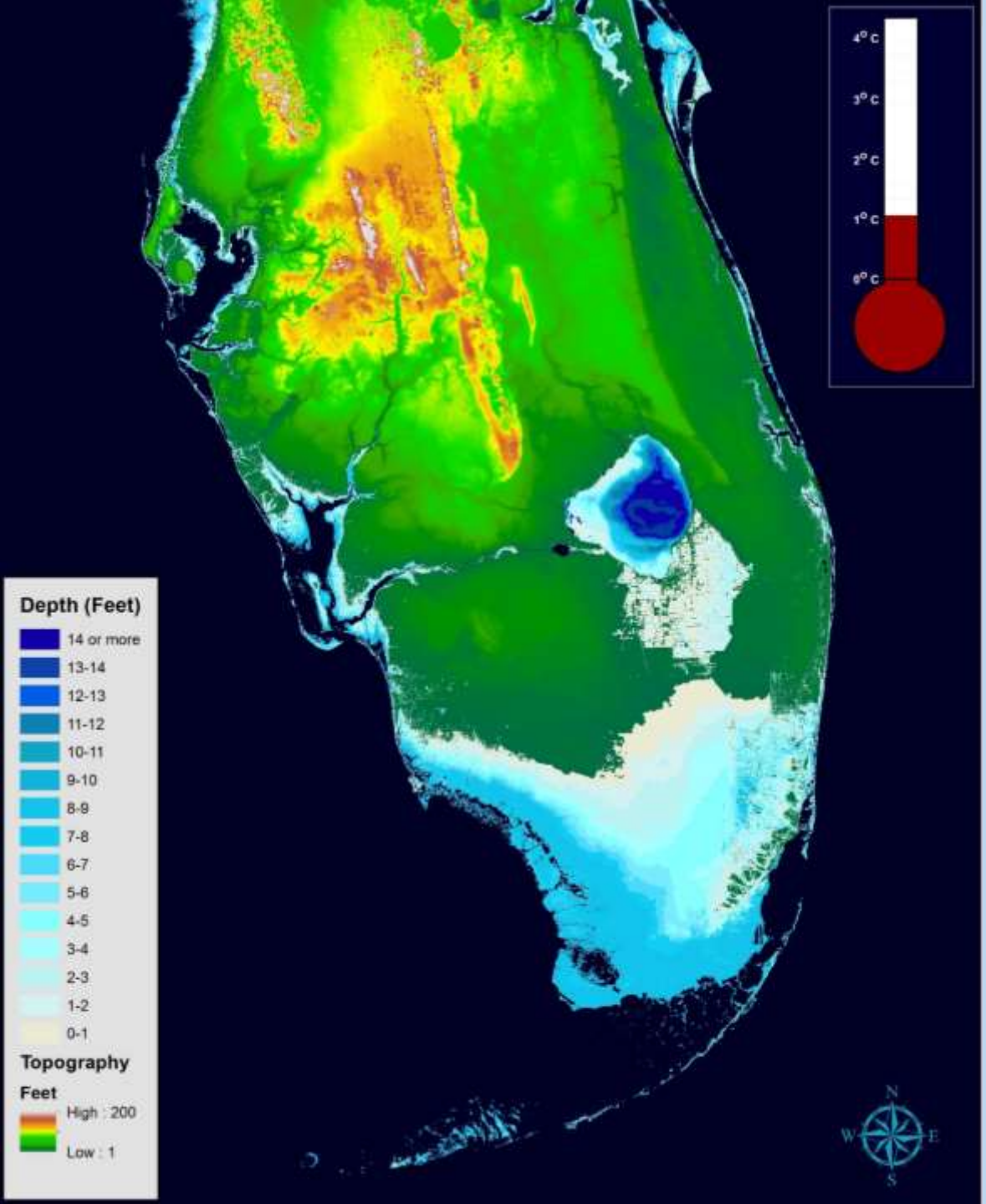
Southern Florida with 6 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



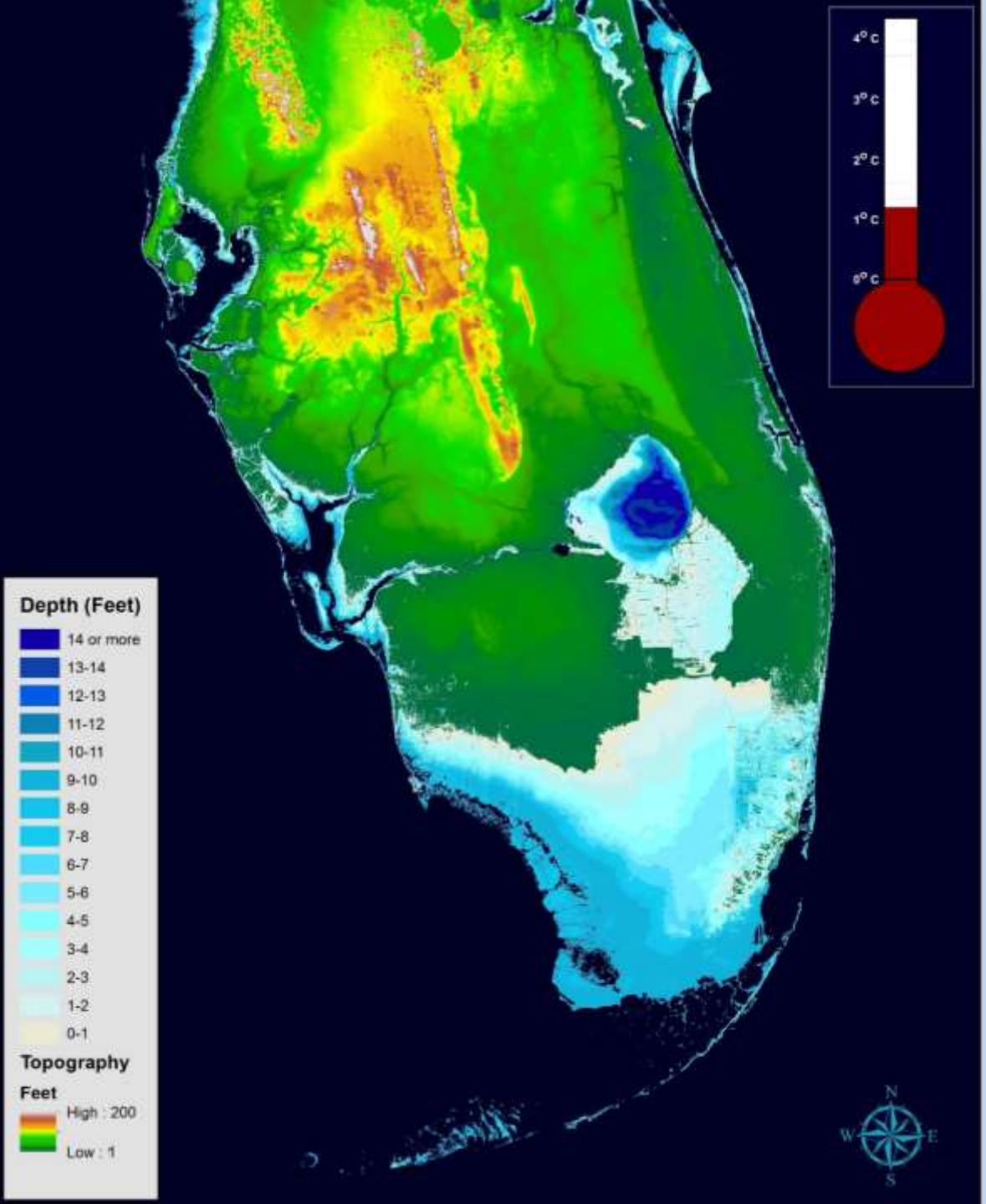
Southern Florida with 7 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



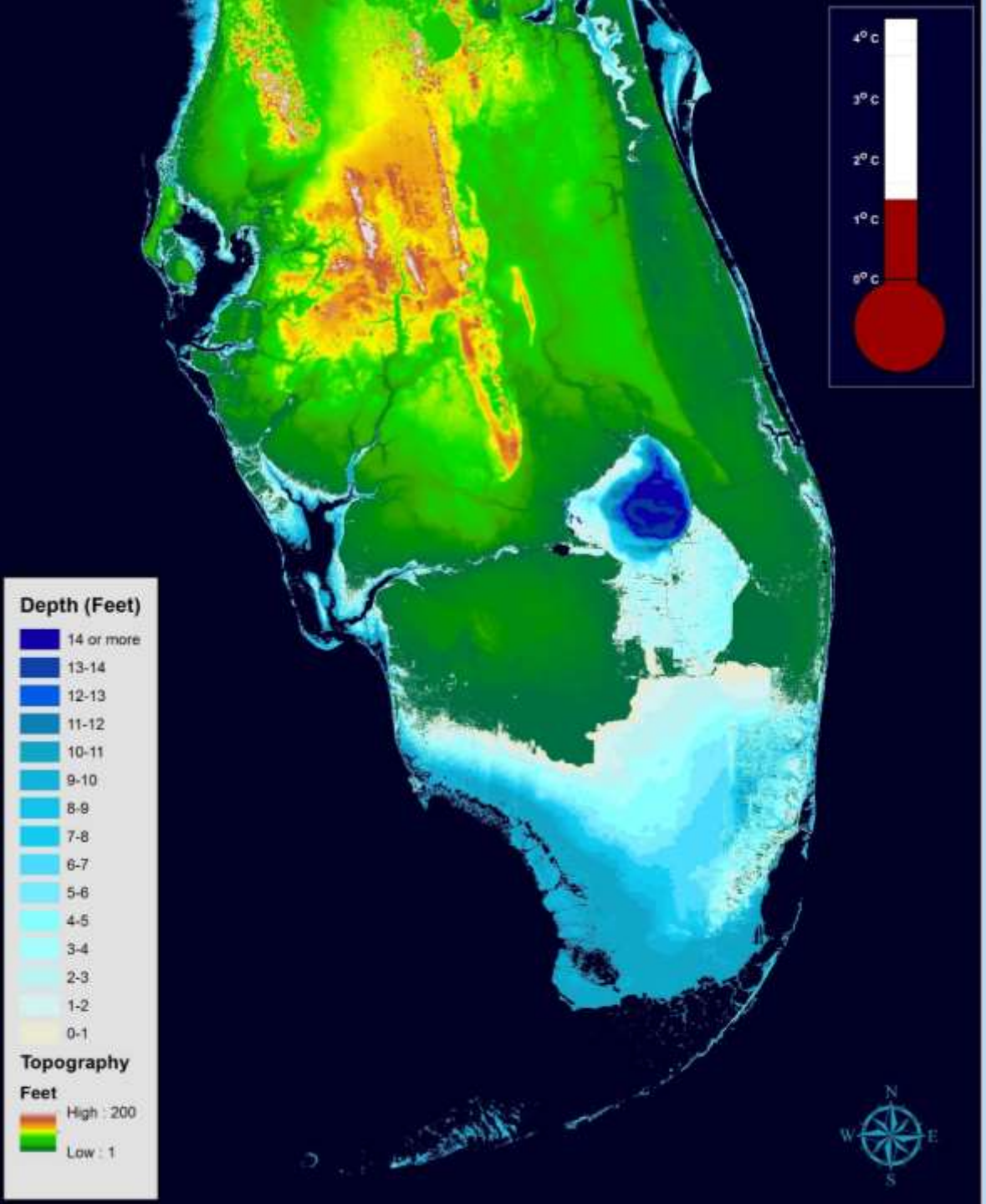
Southern Florida with 8 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



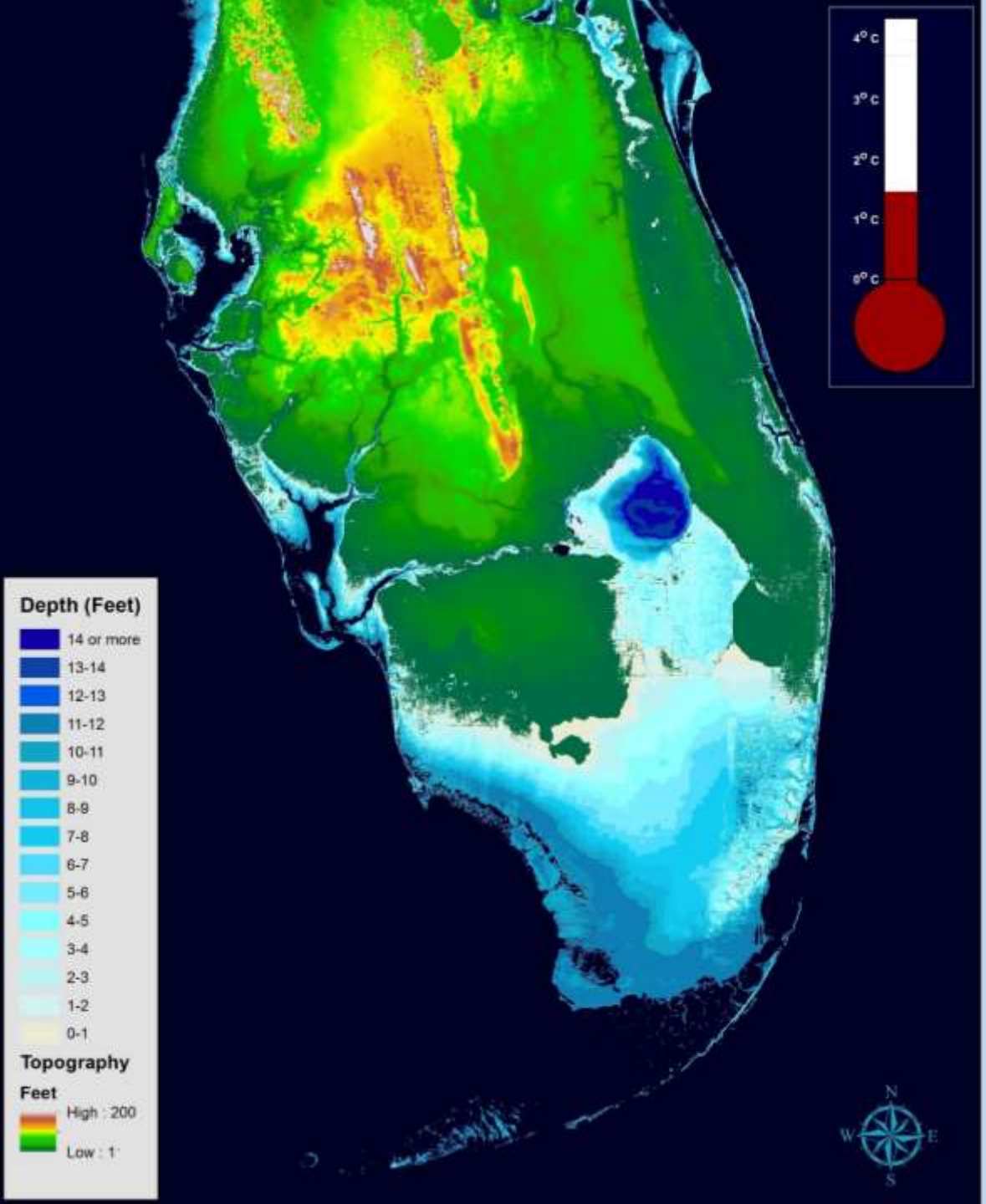
Southern Florida with 9 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



Southern Florida with 10 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015



Southern Florida with 11 feet of Sea Level Rise

Map by Peter W. Harlem
GIS-RS Center and SLSC,
FIU, 2015

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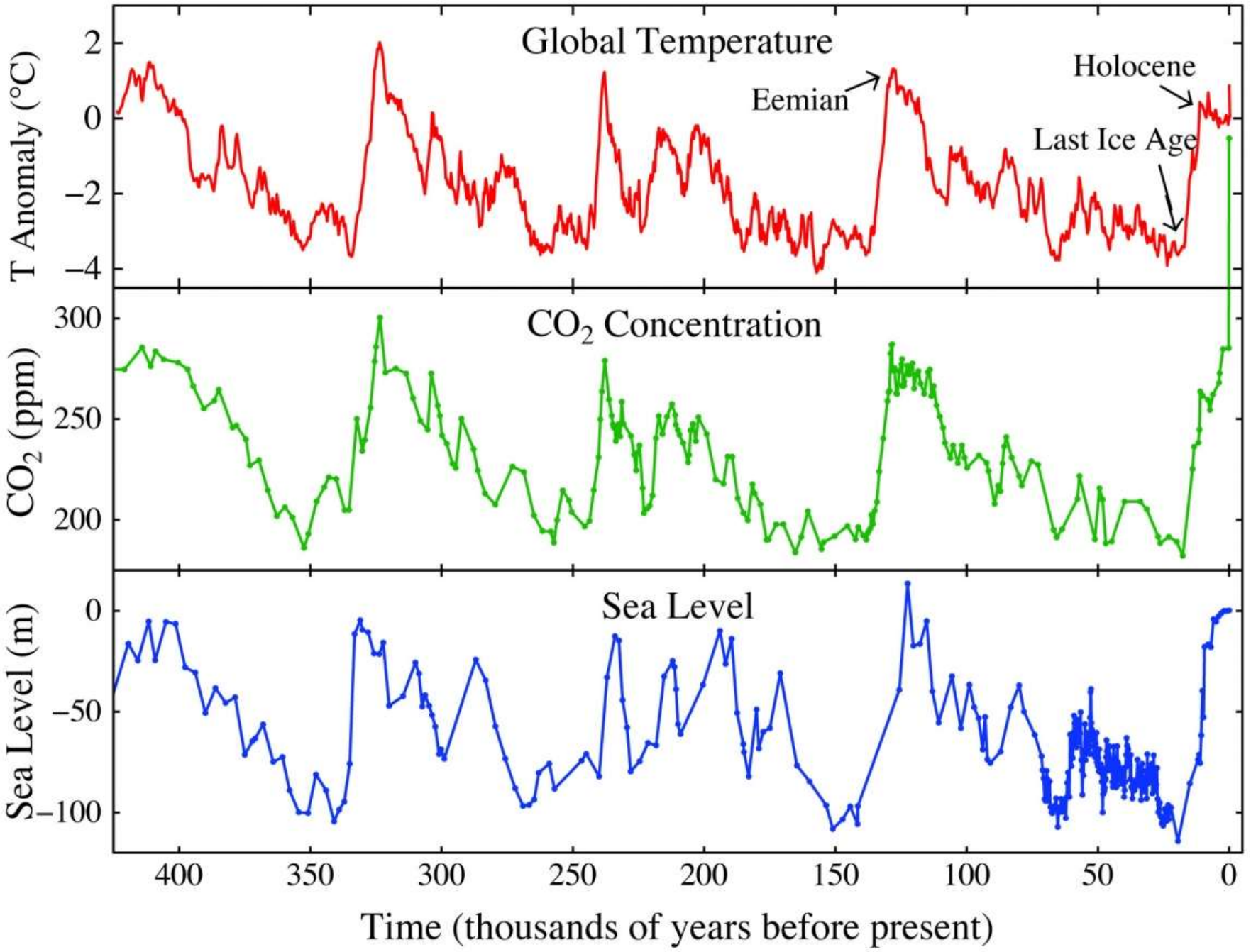
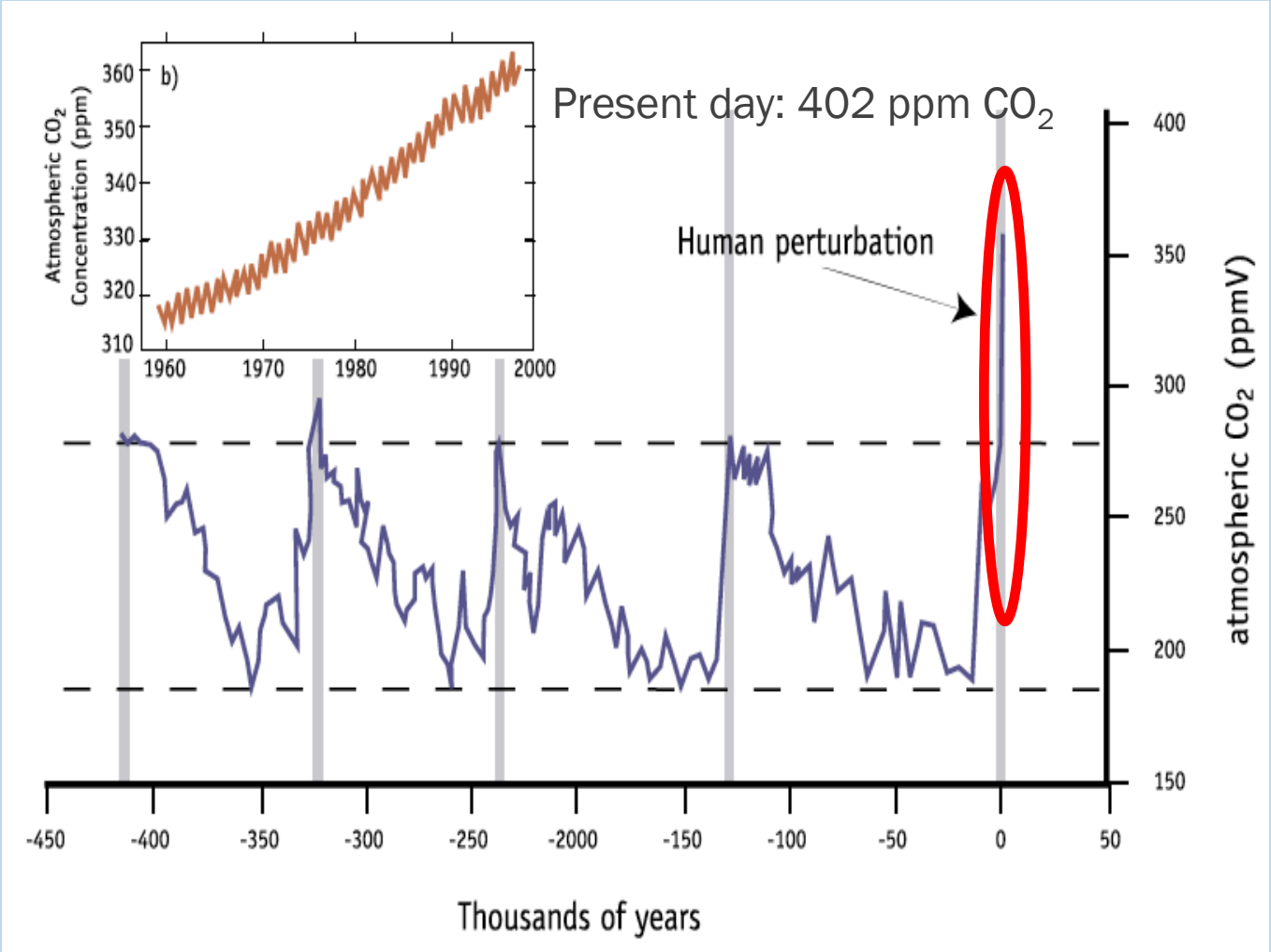
Understanding the Science and Data Behind the Maps:

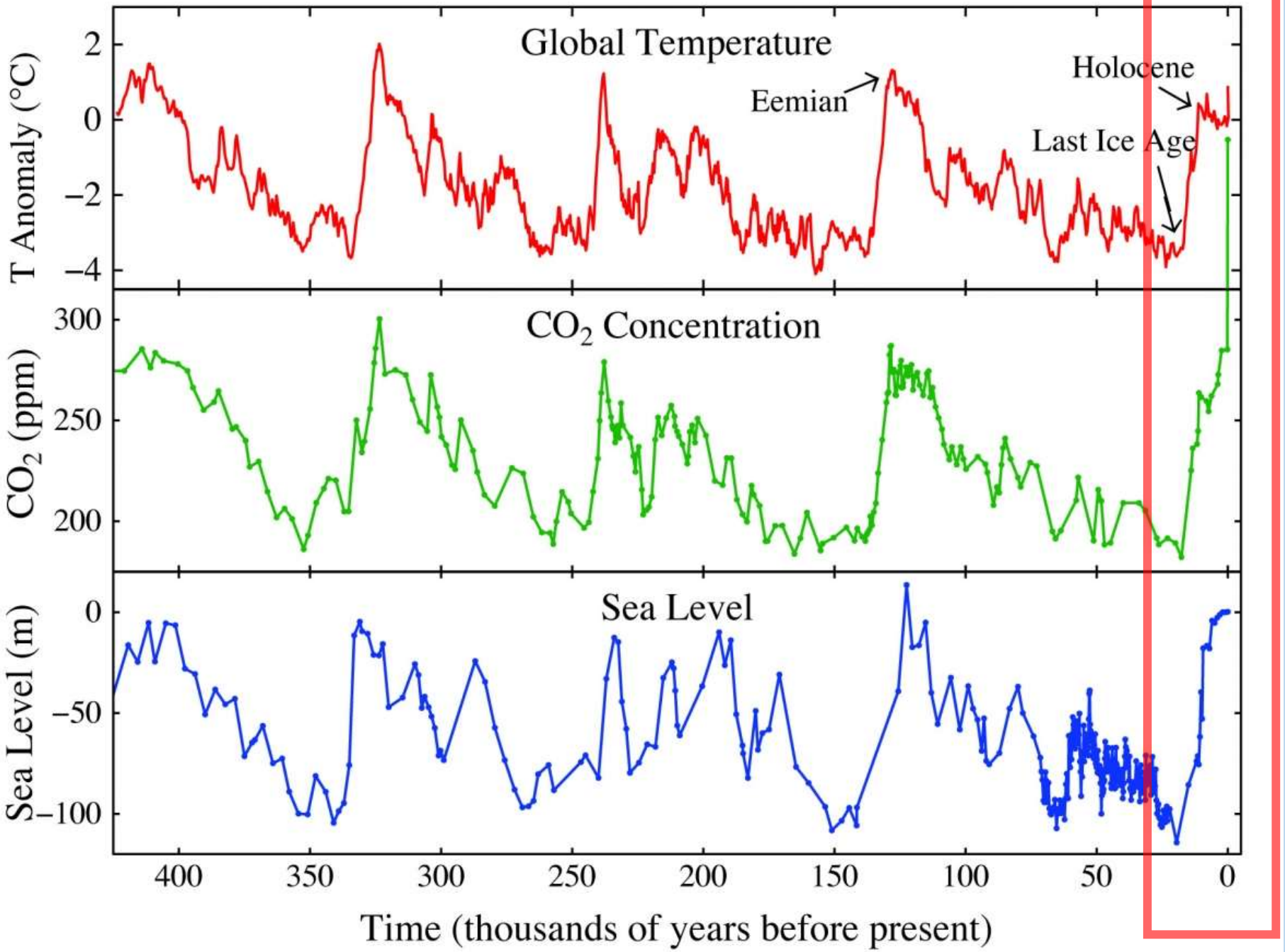
1) Historic patterns
2) Observations
Tide Gauges (1807-)
Satellites (1950-)
3) Models



courtesy Hansen and Sato; JohnEnglander.net

It’s not a natural cycle

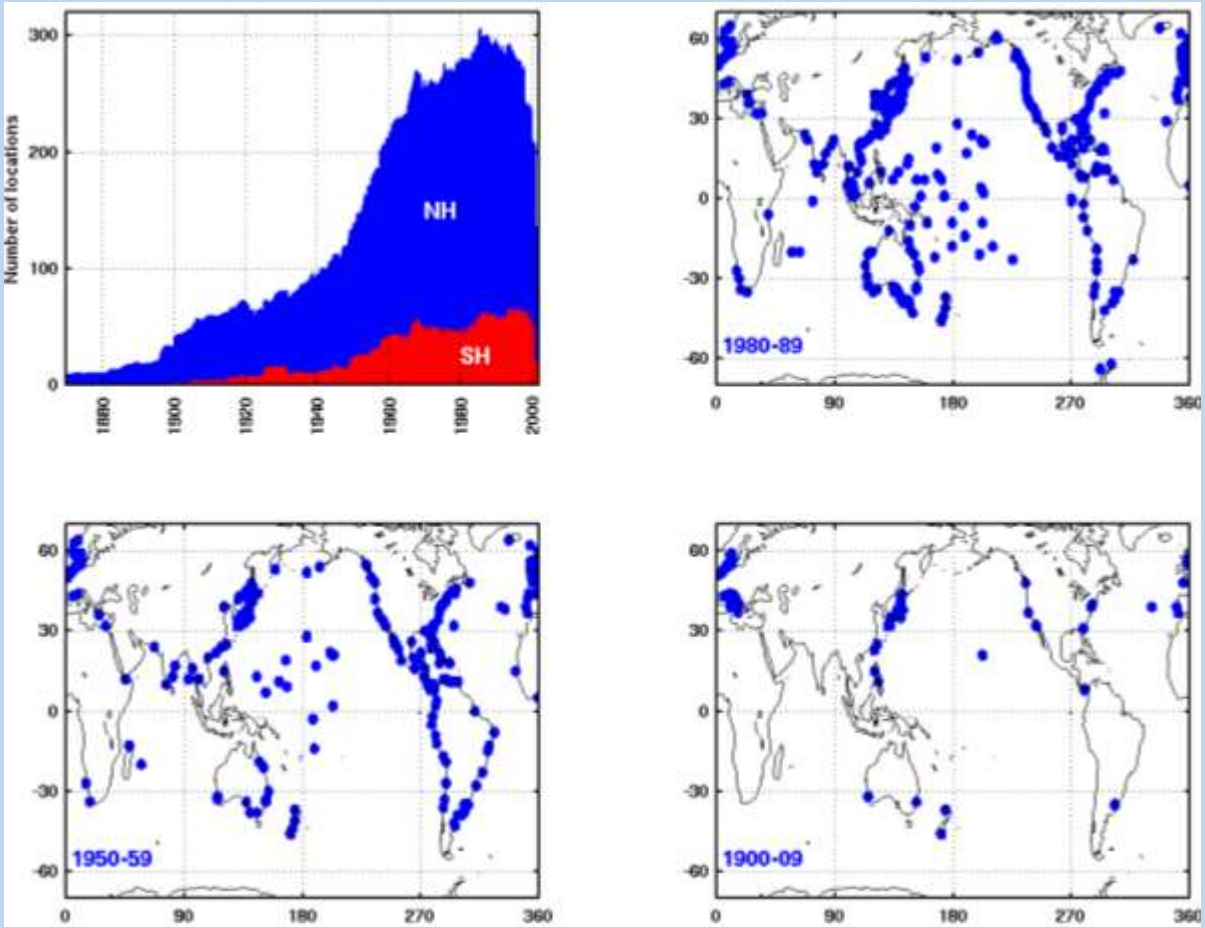




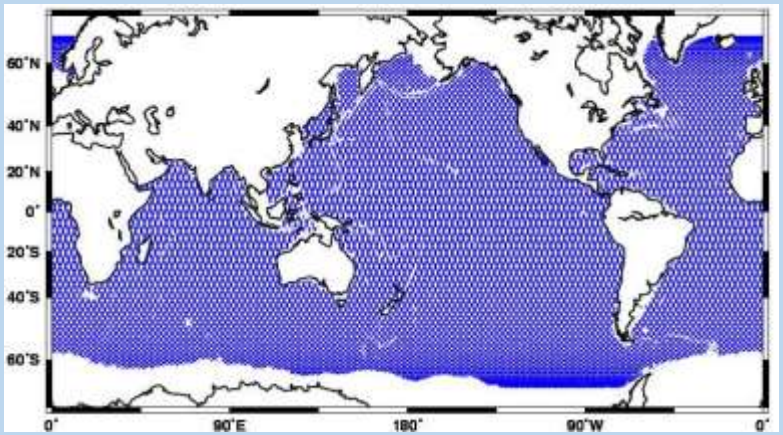
courtesy Hansen and Sato; JohnEnglander.net

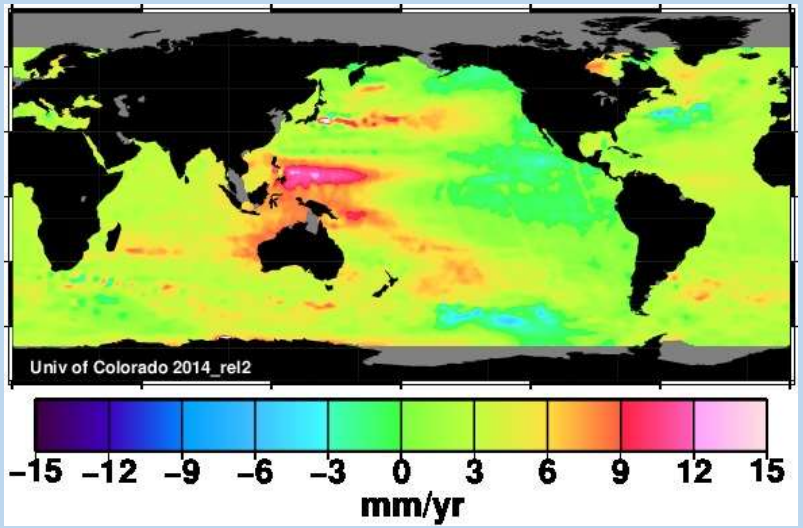
Tide Gauges

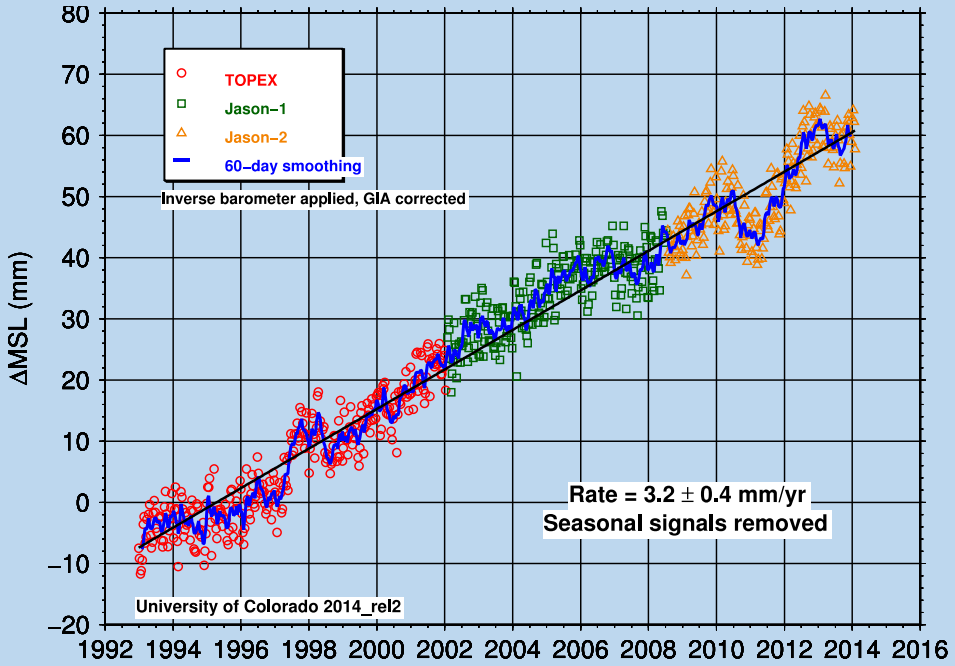
Tide gauge record – long record (1800s-), but poor spatial coverage.



Satellite Altimetry

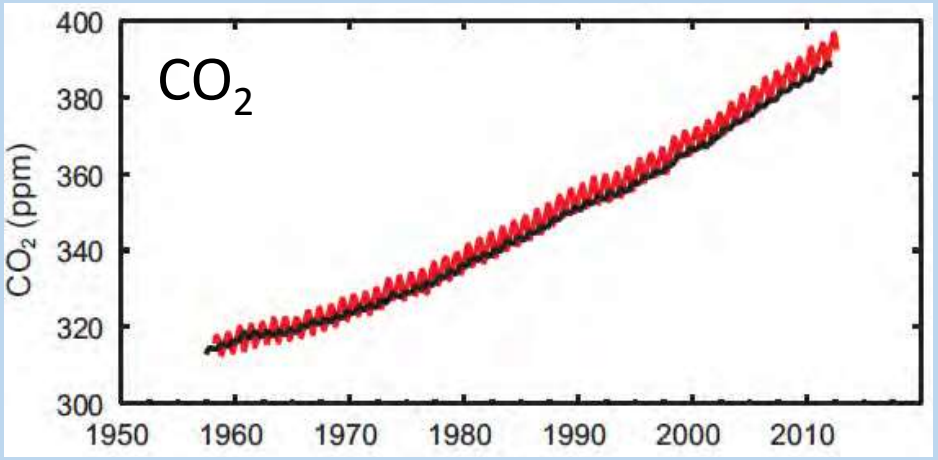


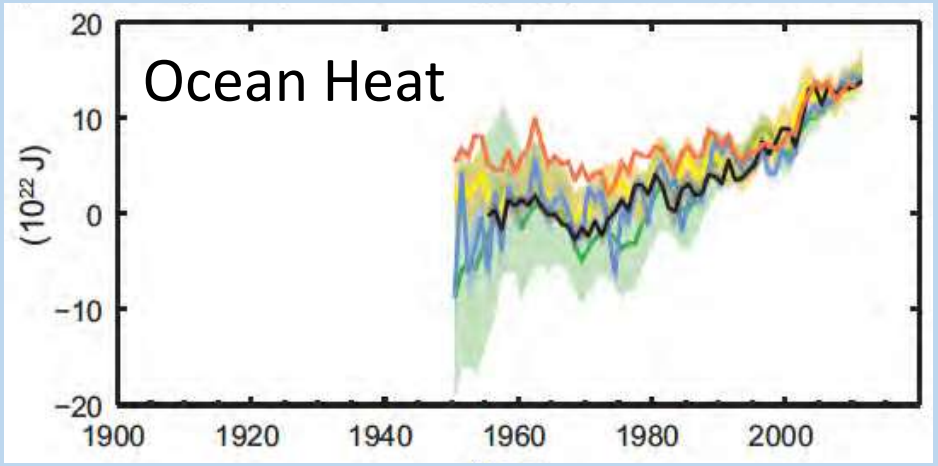


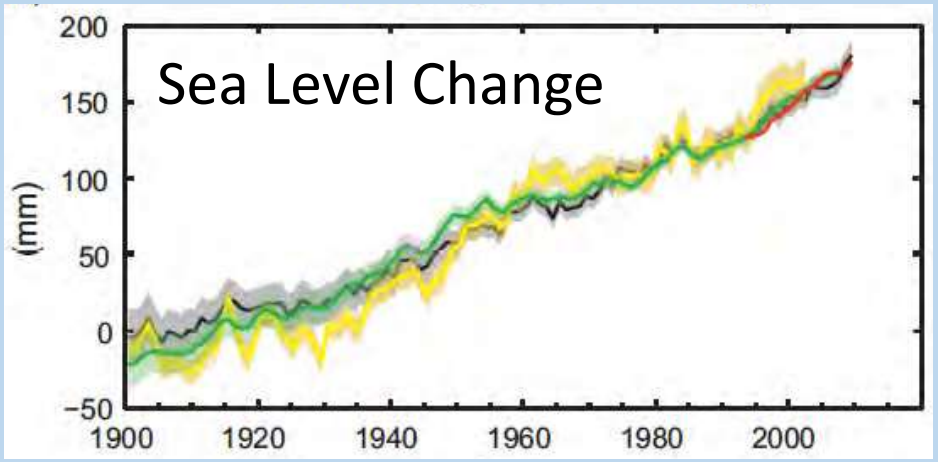


Satellite altimetry record – near-global coverage, but short record length (1993-)

Climate Change drives sea level rise







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Understanding the Science and Data Behind the Maps:

Models

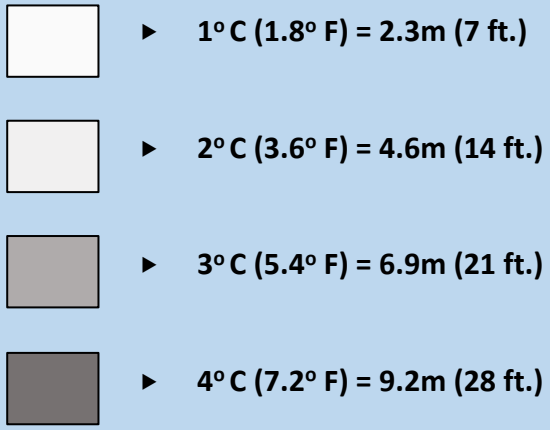
1. *Carbon dioxide increases temperature*
2. *Increased temperature increases ice melting*
   but also, thermal expansion
   and land subsidence due to agriculture, thawing, flooding

Temperature Anomaly vs. Sea Level Rise Commitment

Commitment levels are achieved when the ocean equilibrates to the combined effects of an expanding warming ocean, melting of land ice primarily at the poles, and other smaller drivers.

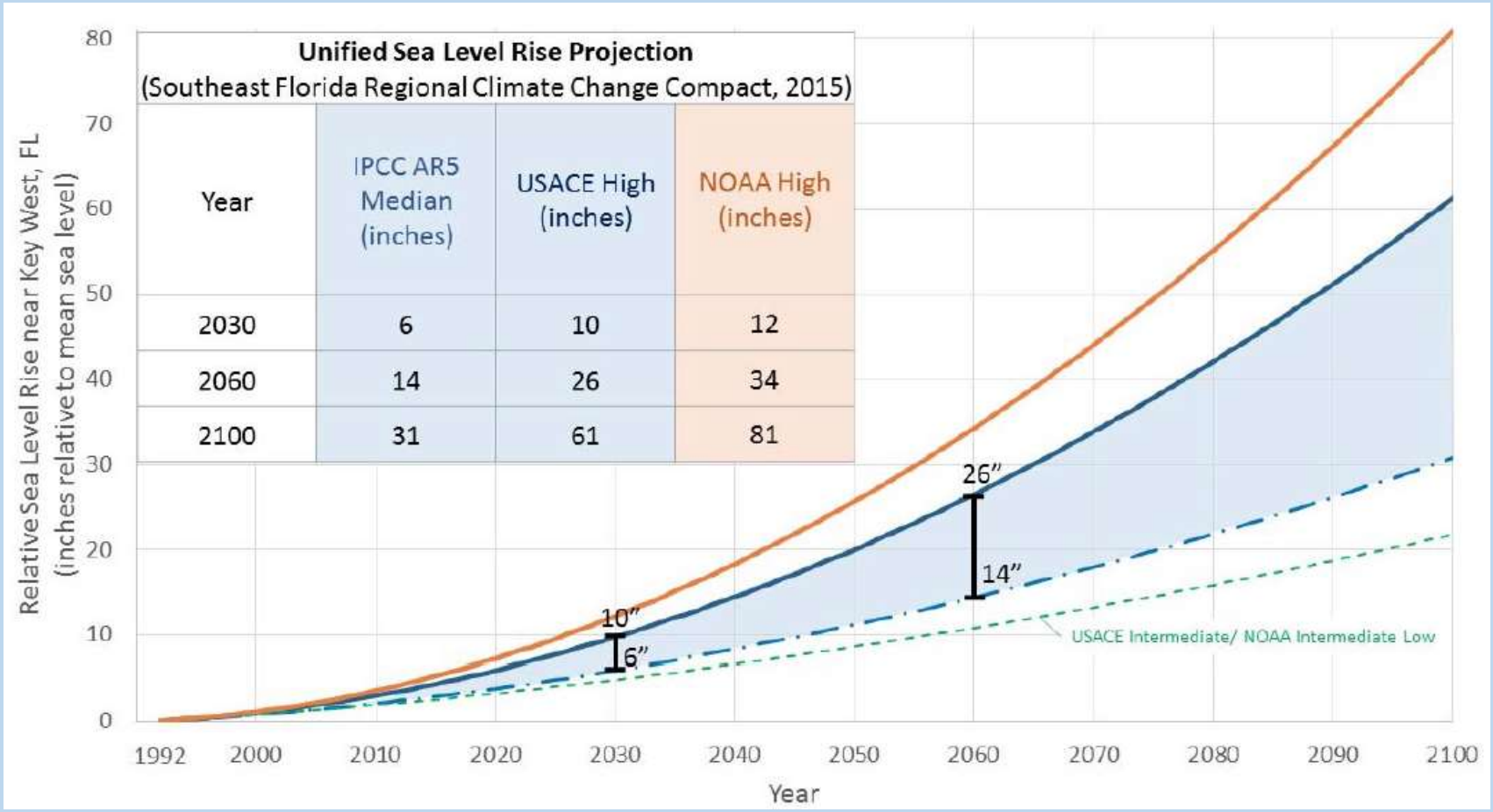
Levermann et al. in 2013 calculated that the commitment level relationship is:

1º C = 2.3 meters (7.5 feet) of committed SLR

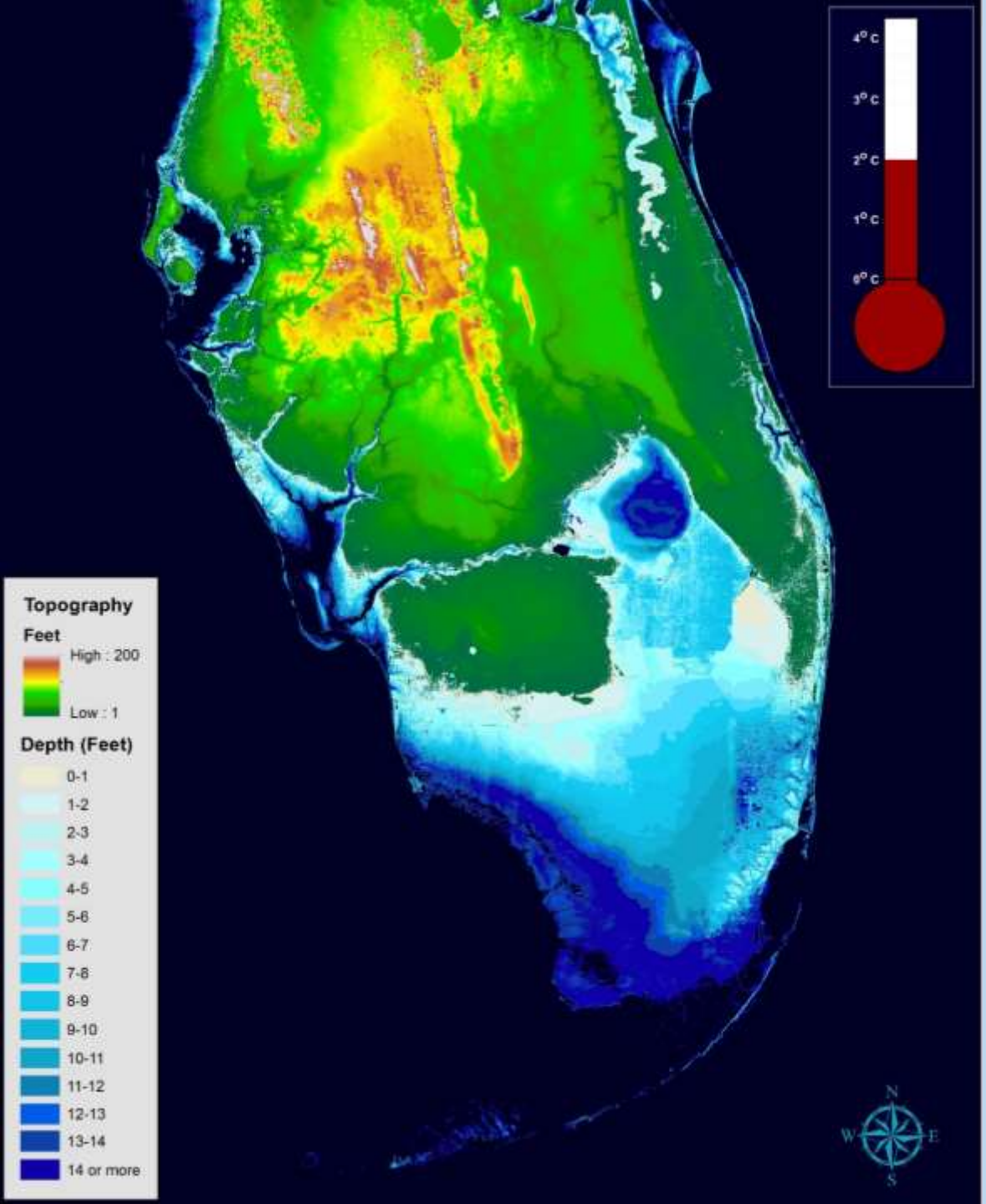


South Florida projections for SLR

Unified Southeast Florida Sea Level Rise Projection for Regional Planning Purposes



Compact 2015

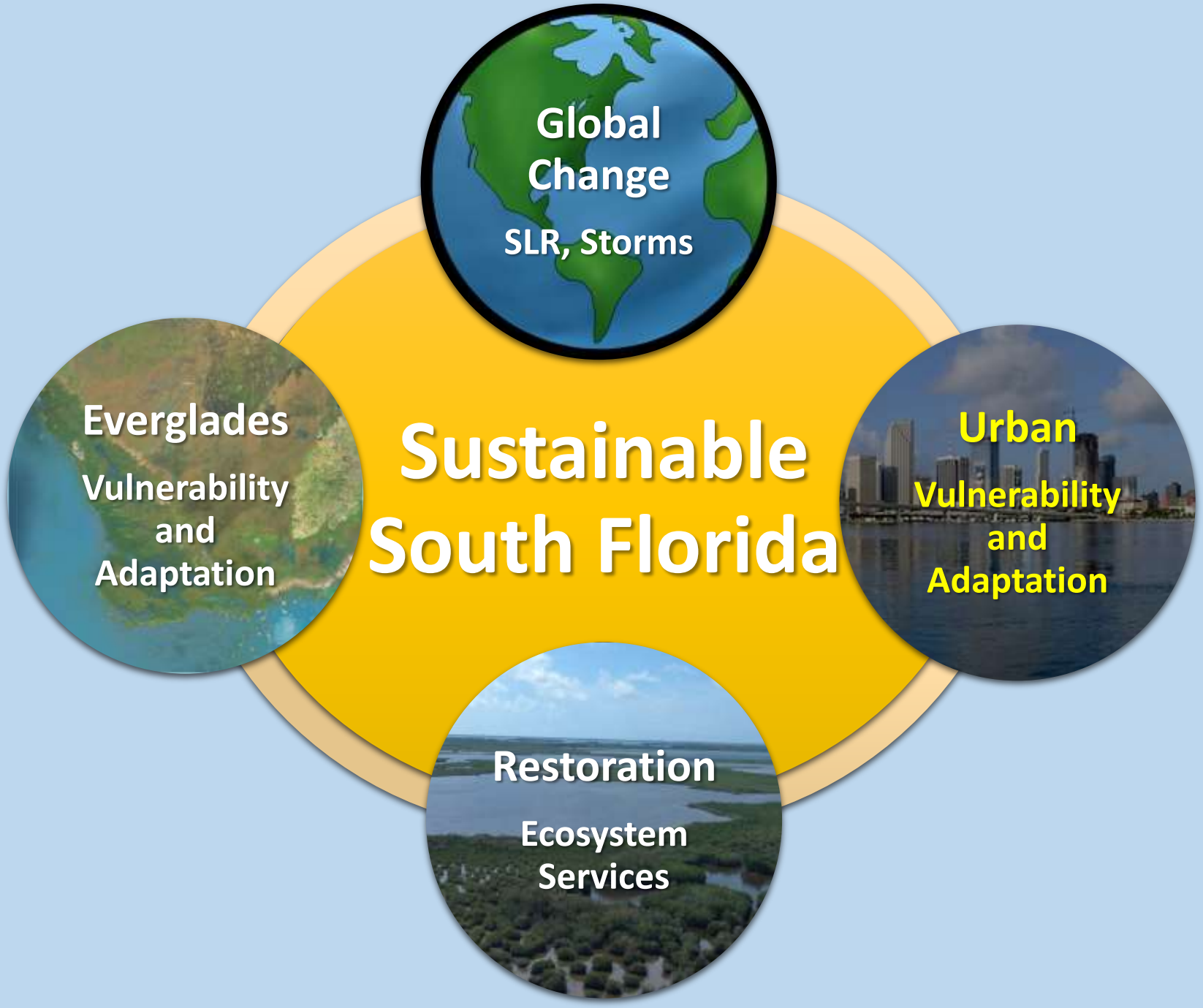


Southern Florida with 15 feet of Sea Level Rise

This is the estimated commitment level for a temperature rise of 2.0 degrees C.

This level will take a long time to realize because warming (expanding) the ocean and melting of polar ice to equilibration are much slower processes.

Map by Peter W. Harlem
GIS-RS Center and SLSC,
Florida International University
2015


Global Change
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Sustainable South Florida
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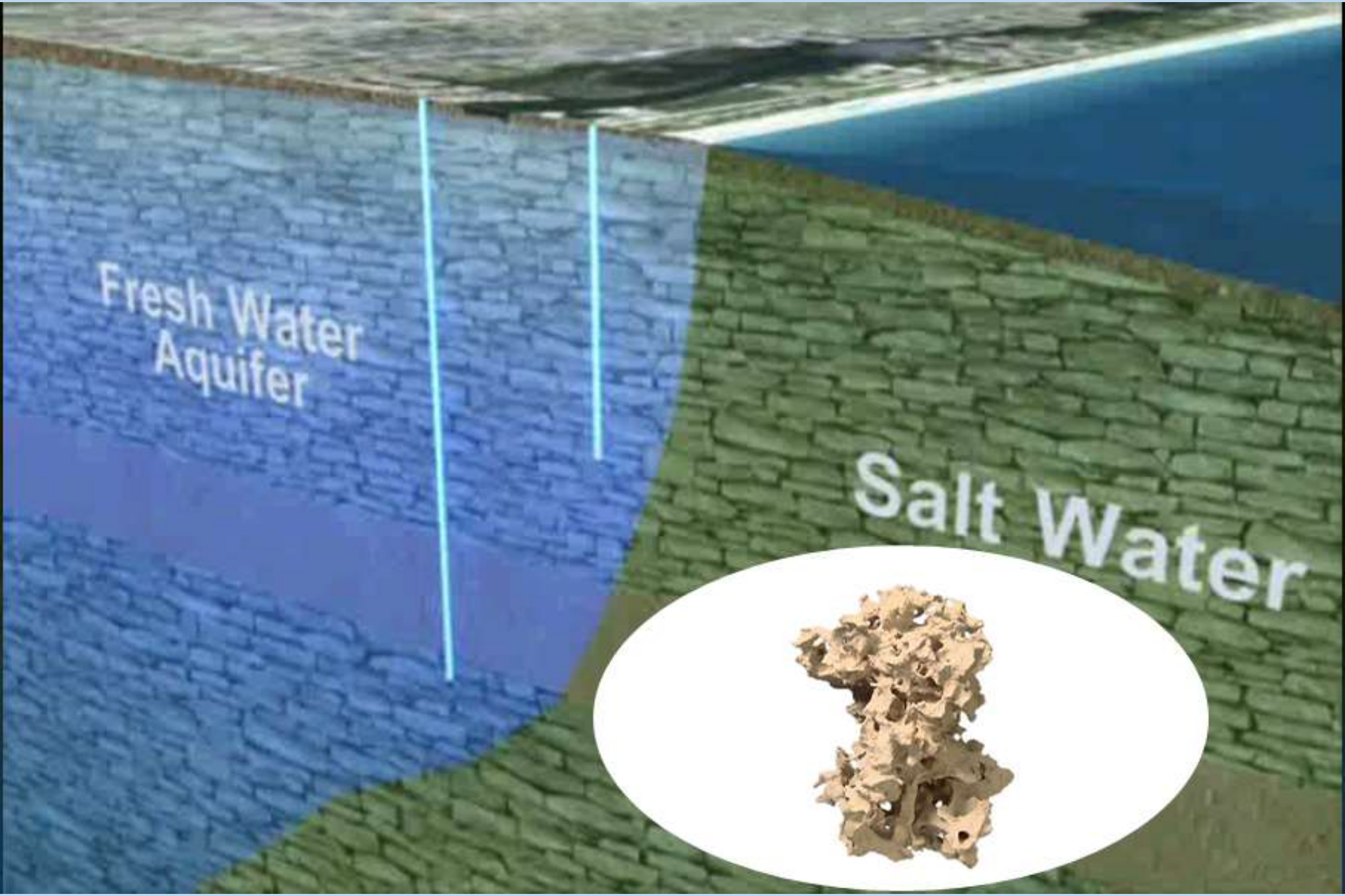
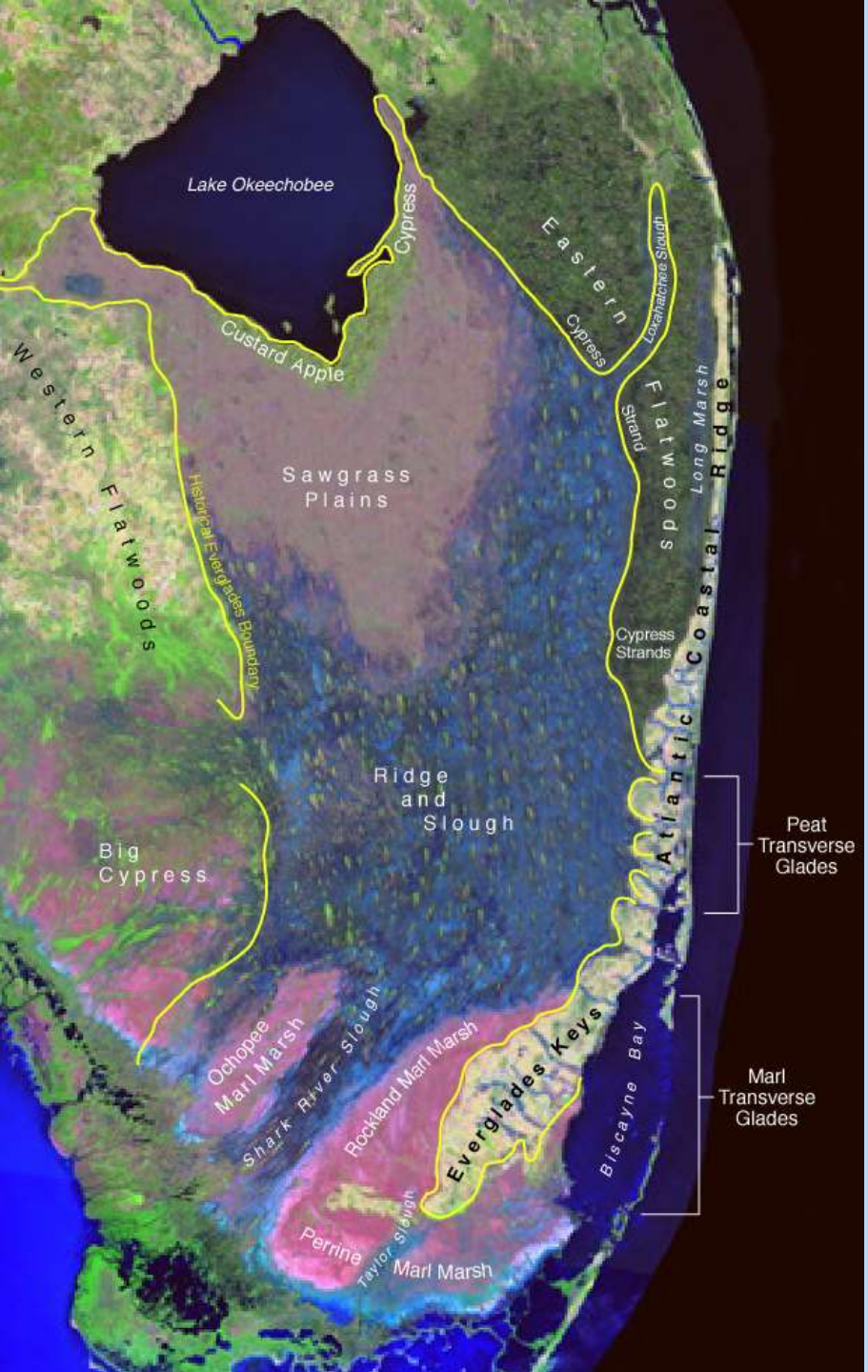
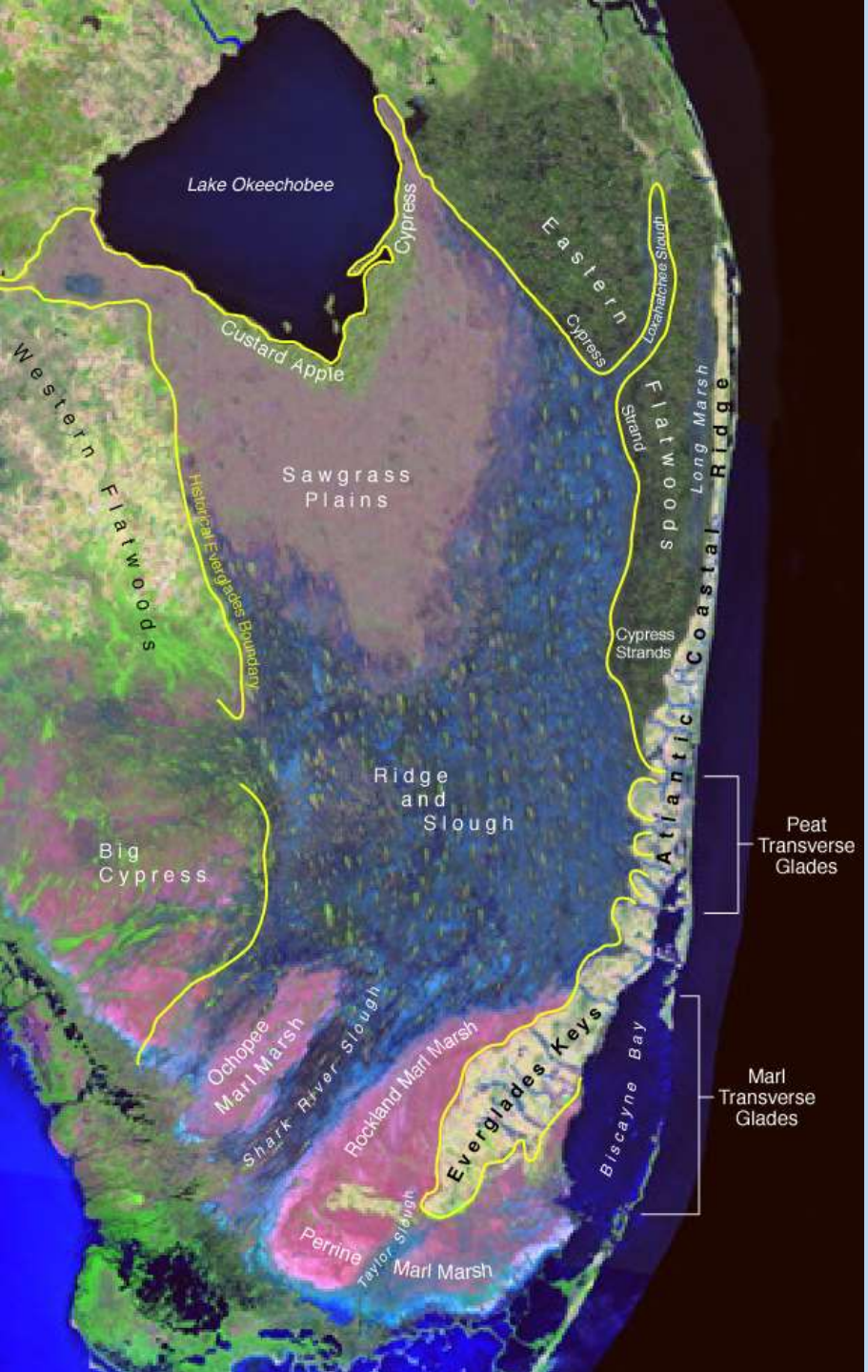
Restoration
Ecosystem Services


Fresh Water
Aquifer
Salt Water


Lake Okeechobee
Cypress
Eastern Cypress
Loxahatchee Slough
Custard Apple
Western Flatwoods
Sawgrass Plains
Historical Everglades Boundary
Strand
Flatwoods
Long Marsh
Atlantic Coastal Ridge
Cypress Strands
Ridge and Slough
Big Cypress
Peat Transverse Glades
Ochopee Marl Marsh
Shark River Slough
Rockland Marl Marsh
Everglades Keys
Biscayne Bay
Marl Transverse Glades
Perrine Marl Marsh
Taylor Slough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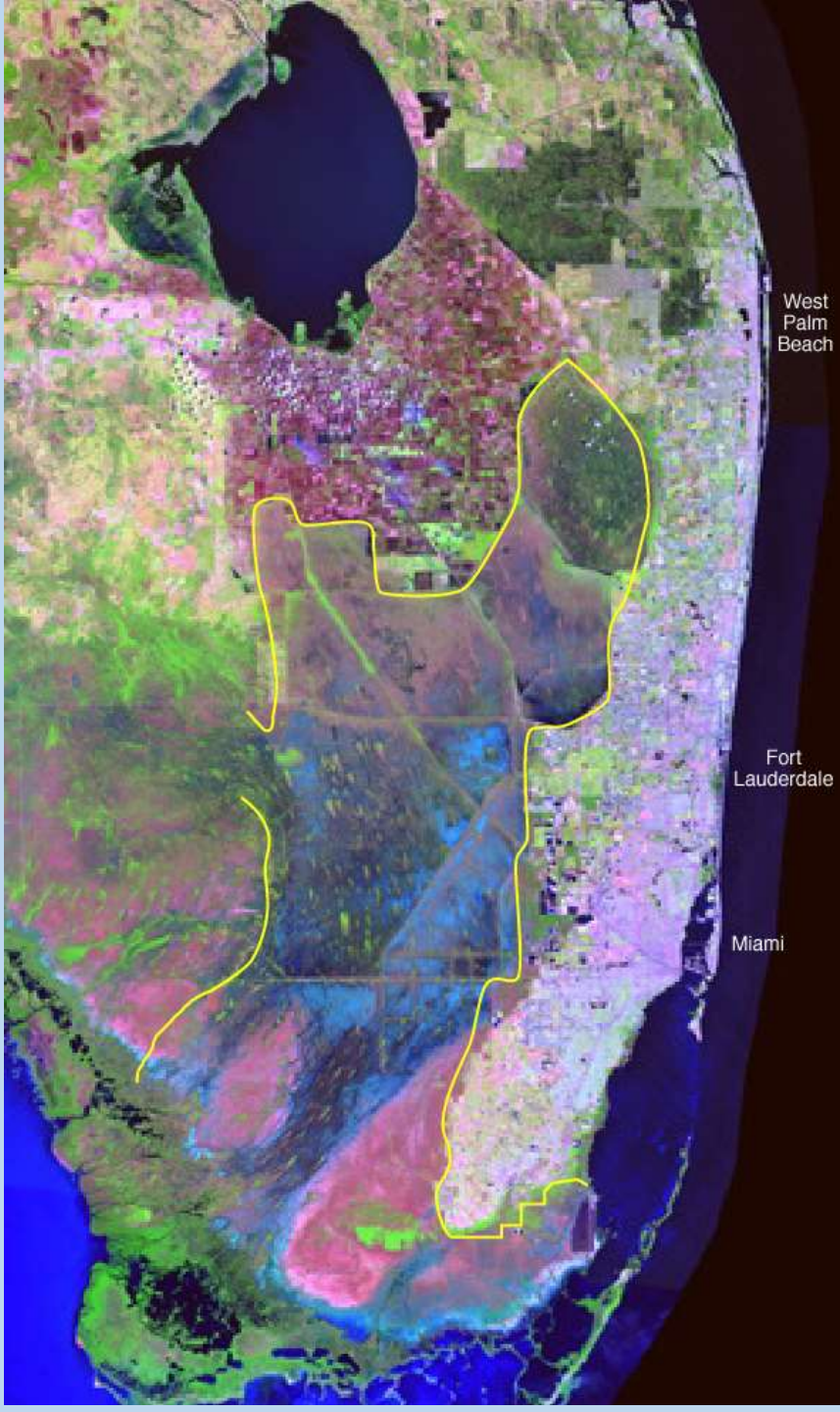
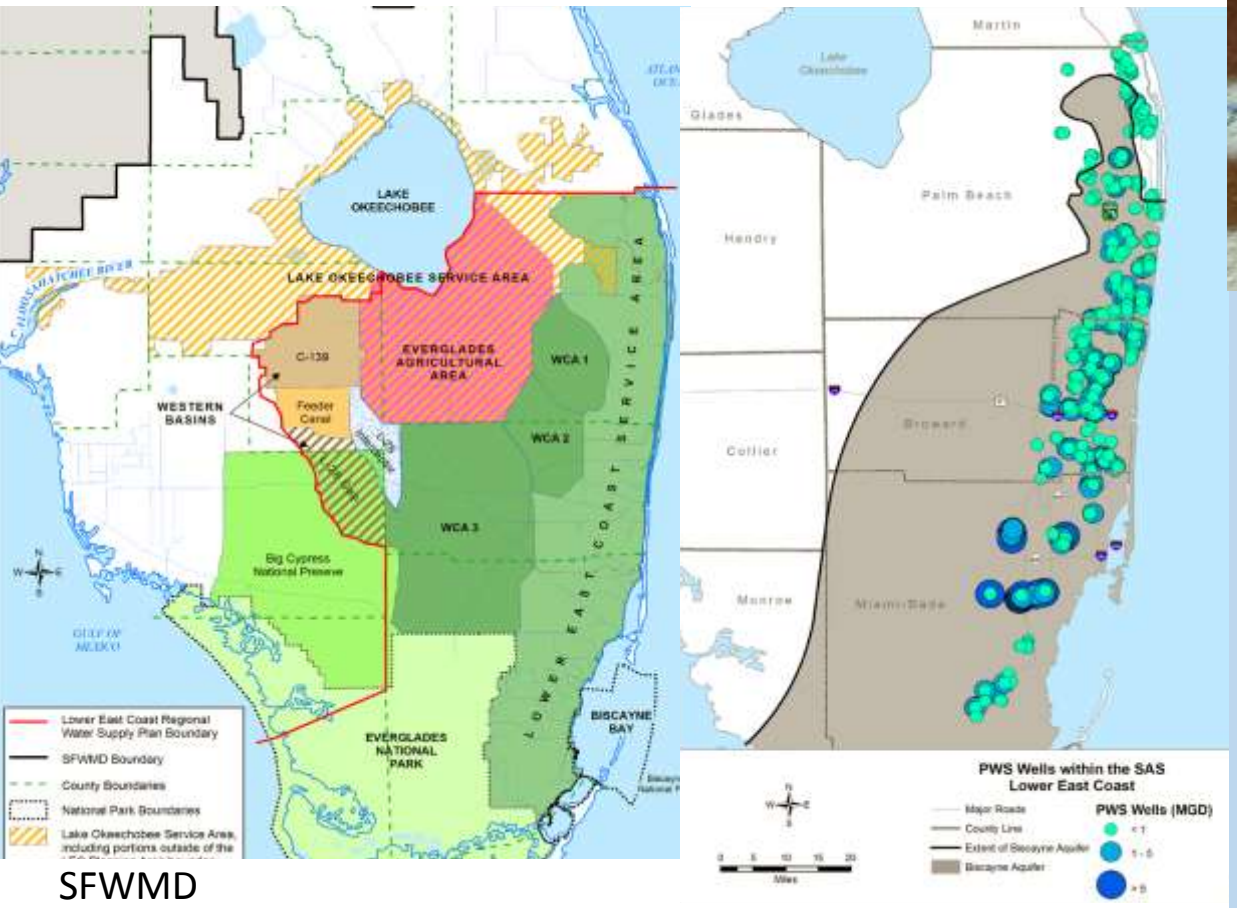
Marl Marsh

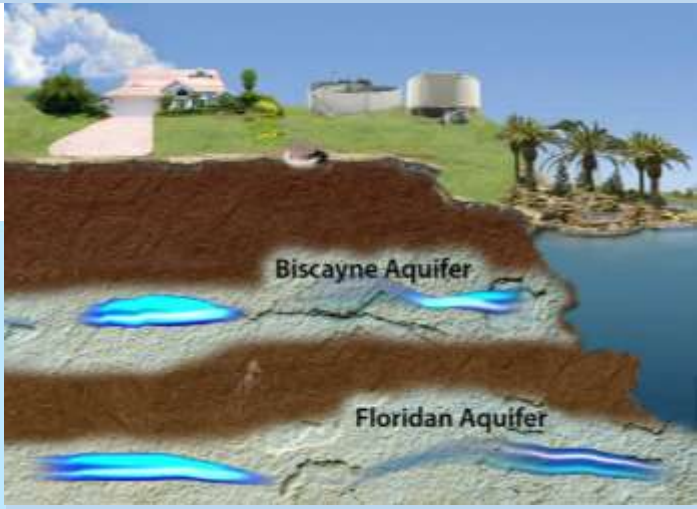

West Palm Beach
Fort Lauderdale
Miami

Implications for drinking water in south Florida

Water from Lake Okeechobee, the Water Conservation Areas (WCAs) and the C&SF Canals recharge the Biscayne Aquifer

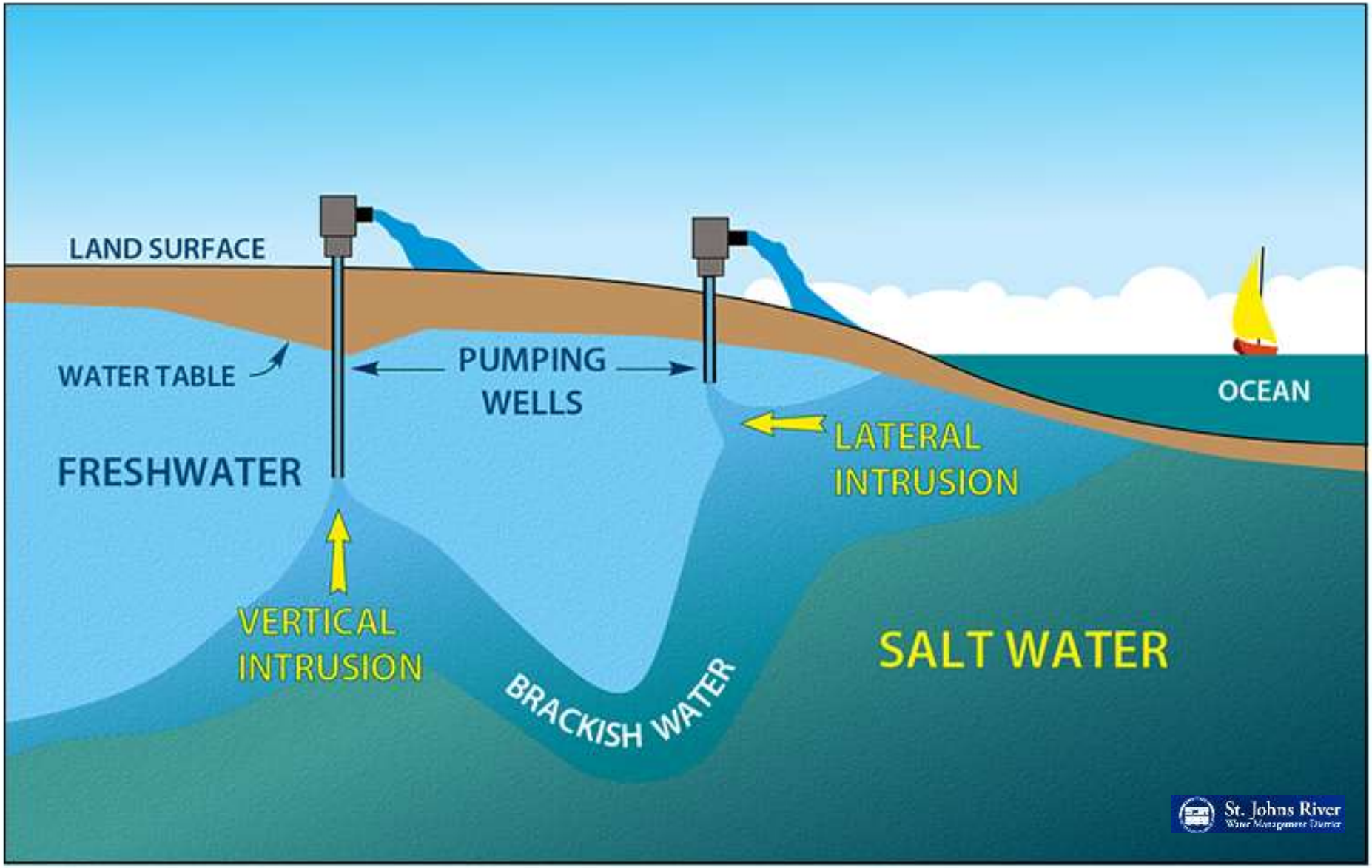


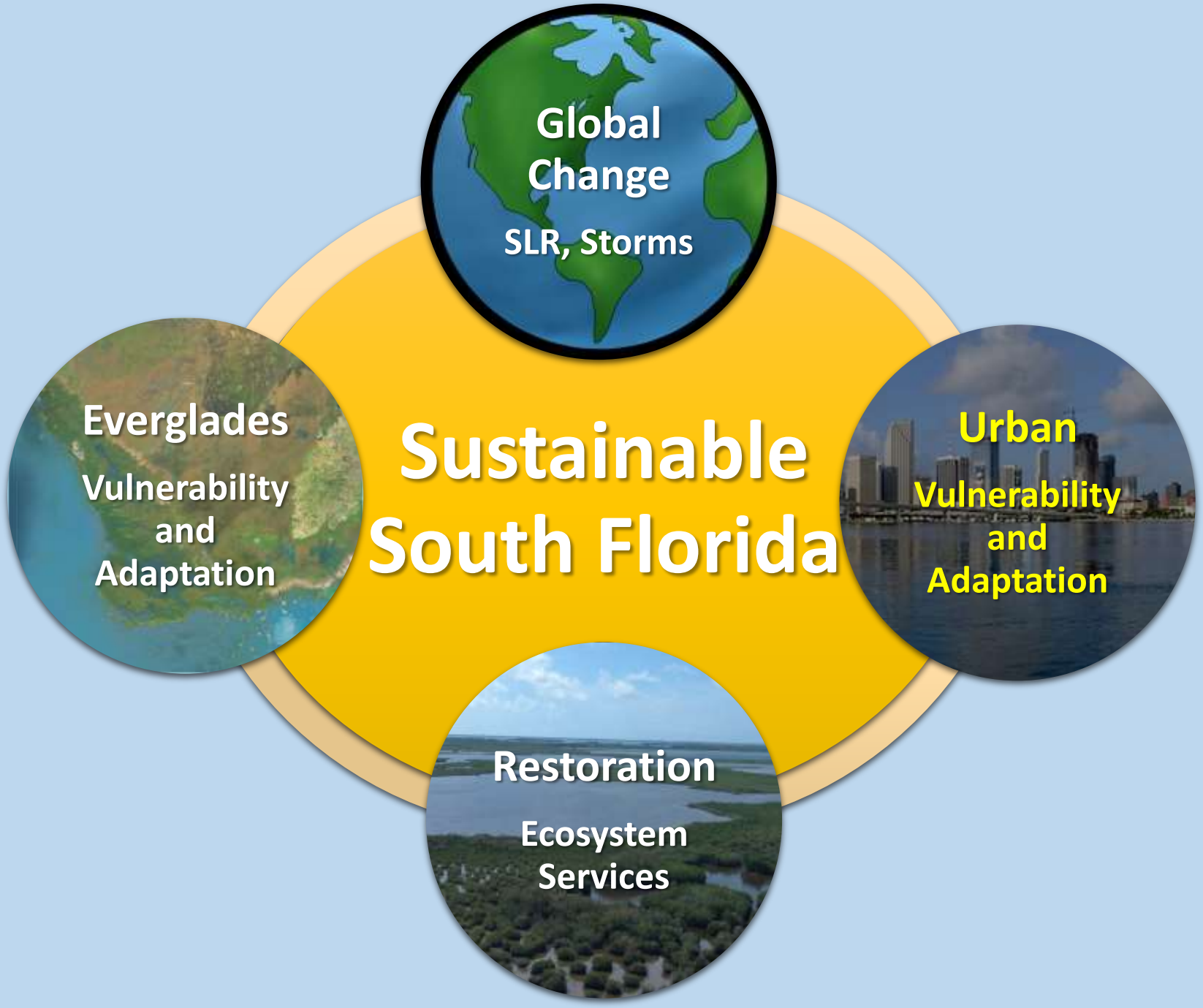
SFWMD



The Biscayne Aquifer supplies 90% of the south Florida's drinking water -- more than 8 billion gallons of water each day.

Saltwater intrusion from freshwater extraction




Global Change
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Two Levels of Response:

1. Mitigation - direct intervention such as reducing carbon emissions; Long-time frame

2. Adaptation - modifying infrastructure or behavior to adjust to rising temperatures and sea level, increased coastal flooding and perturbation of weather patterns; Immediate and short-time frame

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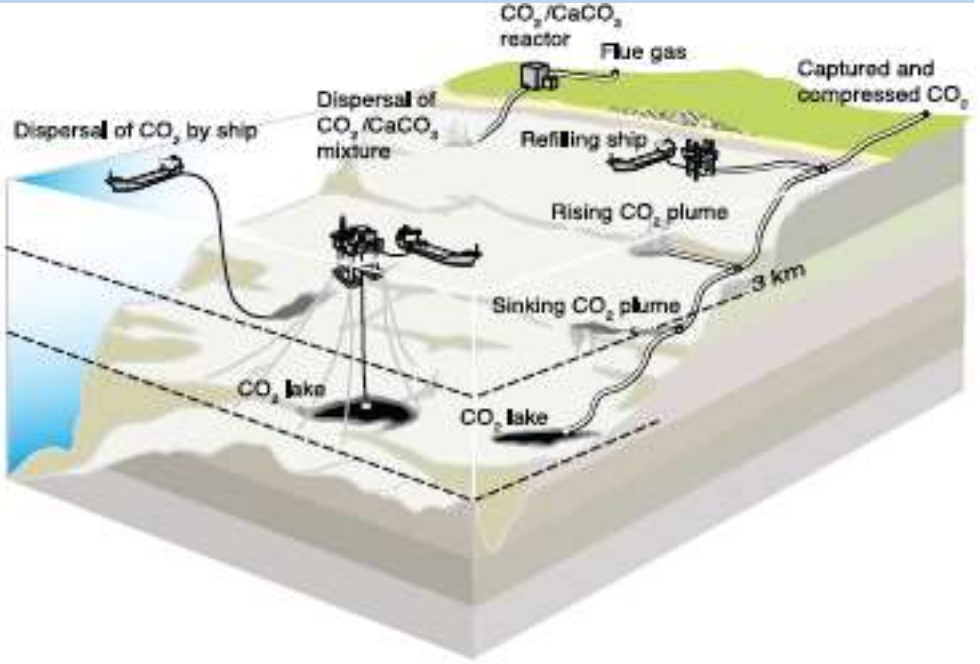
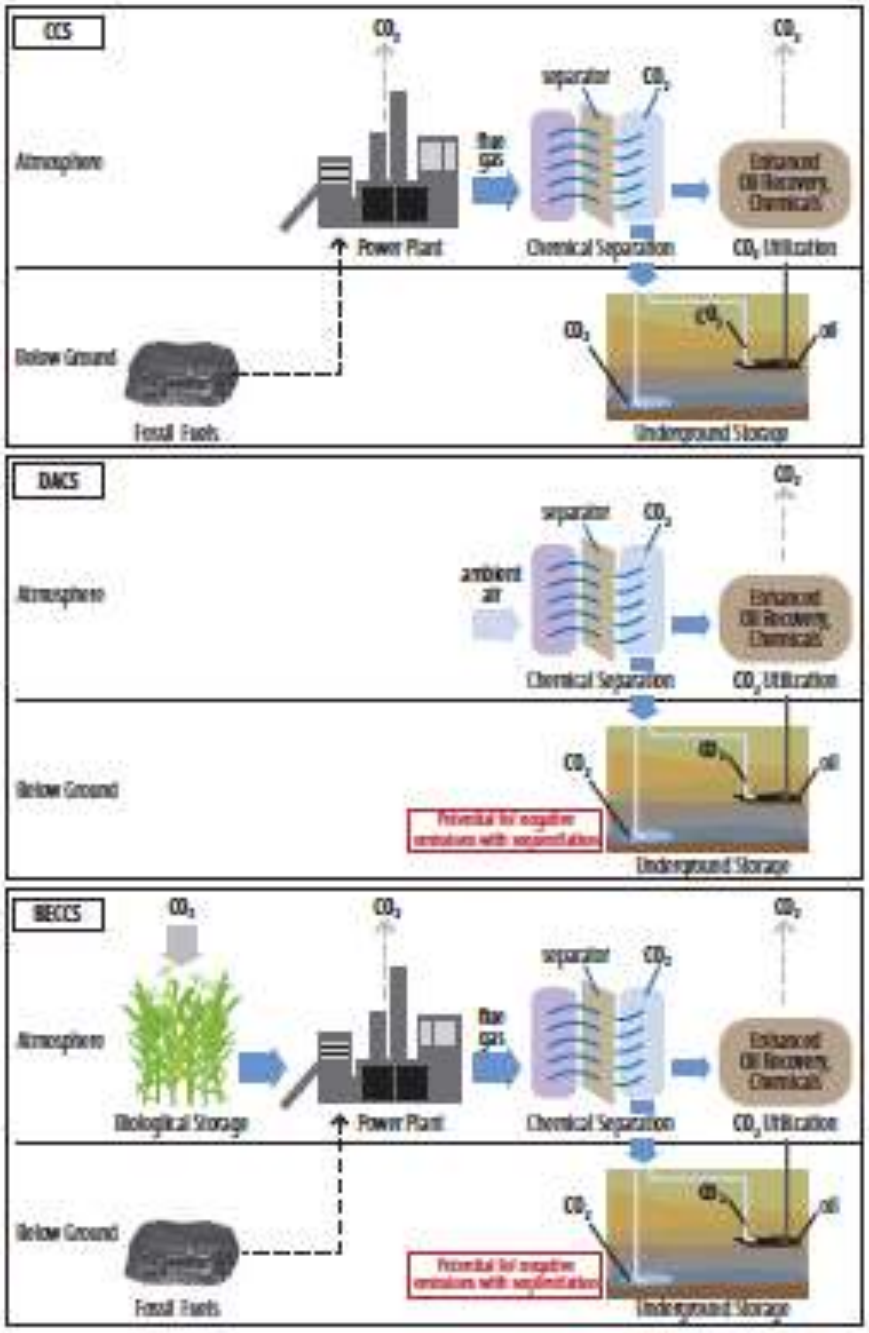

CO_2/$CaCO_3$ reactor
Flue gas
Captured and compressed CO_2
Dispersal of CO_2 by ship
Dispersal of CO_2/$CaCO_3$ mixture
Refilling ship
Rising CO_2 plume
Sinking CO_2 plume
3 km
CO_2 lake
CO_2 lake


CCS
Atmosphere
Power Plant
flue gas
separator
Chemical Separation
Enhanced Oil Recovery, Chemicals
CO_2 Utilization
Below Ground
Fossil Fuels
Underground Storage
DACS
ambient air
BECCS
Biological Storage

Coral Gables Proposed Sustainability Plan GOALS:

Goals by Focus Area

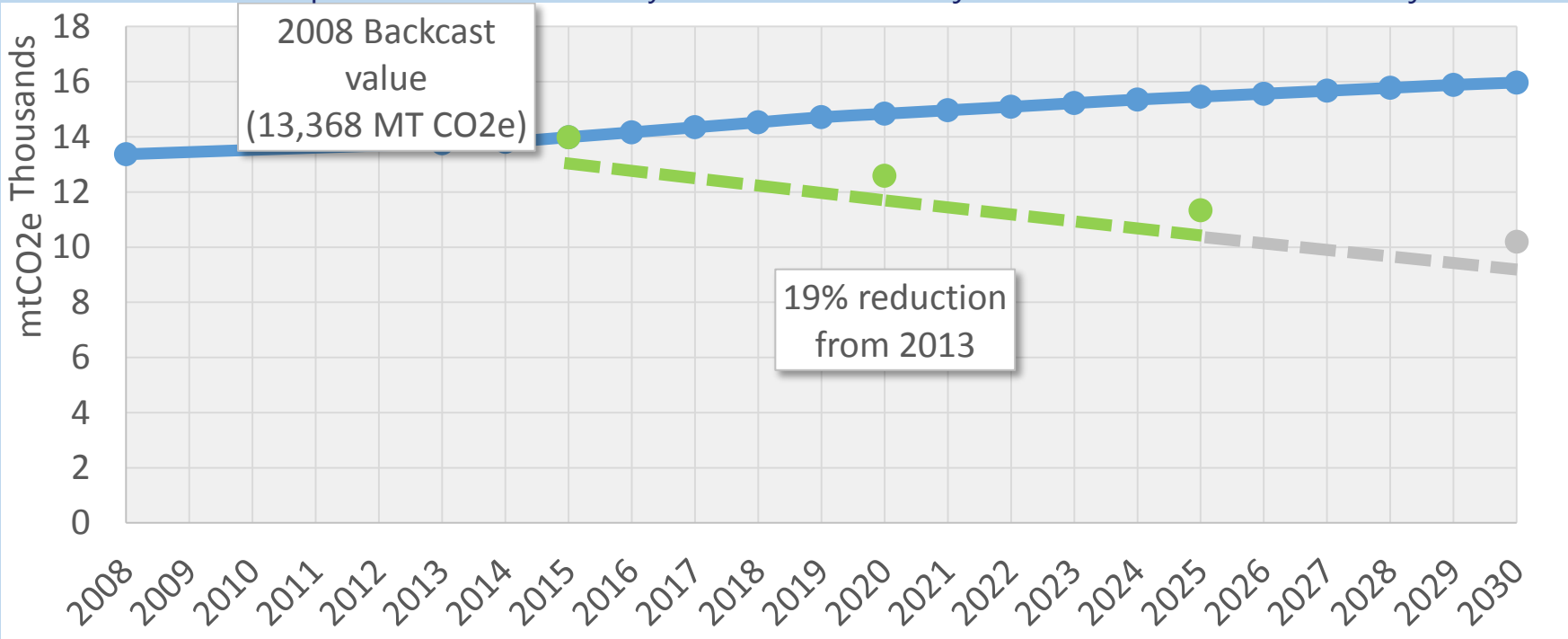
Focus Area	Action	Metric	Baseline	Completion
Energy	Reduce electricity use	20%	below 2013 levels	by 2025
Water	Reduce water consumption	20%	below 2013 levels	by 2025
Materials	Divert solid waste*	75%		by 2020
Fleet	Reduce fossil fuel use	20%	below 2013 levels	by 2025
Climate	Reduce greenhouse gas emissions	20%	below 2013 levels	by 2025
Others	Of total projects**, implement	100%		by 2025

**City operations and single family residential waste*

***as identified in the Coral Gables Sustainability Management Plan*

RESULTS: GREENHOUSE GAS EMISSIONS REDUCTIONS

Local Government Operations GHG Inventory and Forecast w/ Projected Reductions from Plan Projects



Two Levels of Response:

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2. Adaptation - modifying infrastructure or behavior to adjust to rising temperatures and sea level, increased coastal flooding and perturbation of weather patterns; Immediate and short-time frame

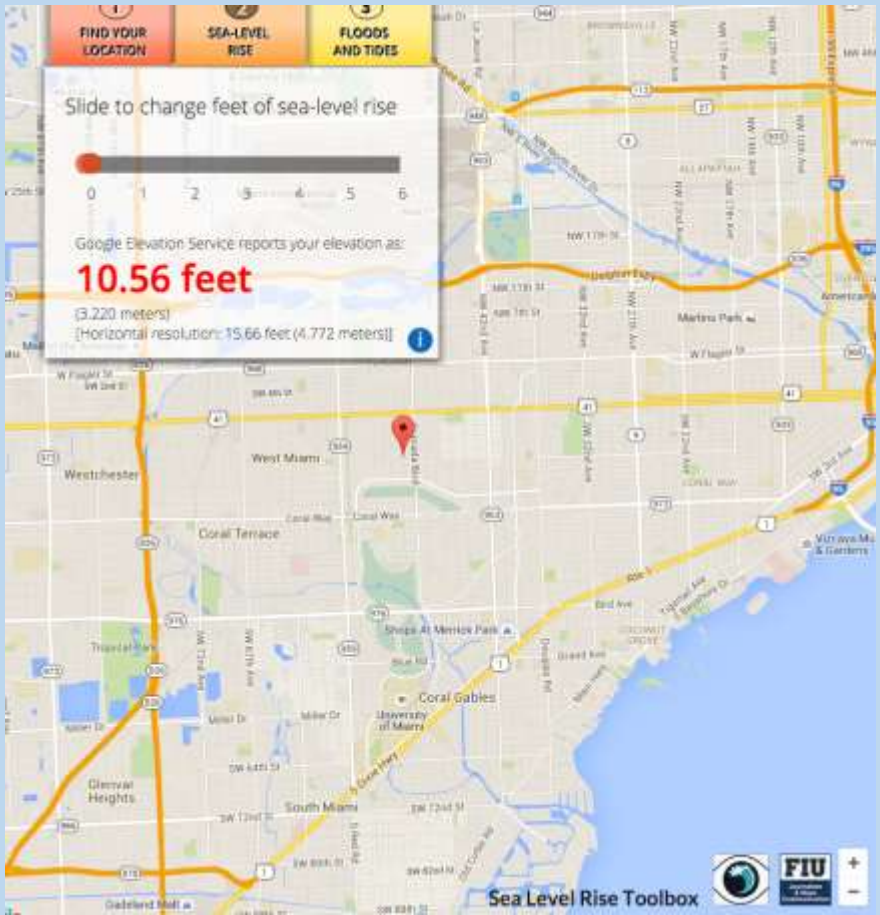
Eyes on the Rise

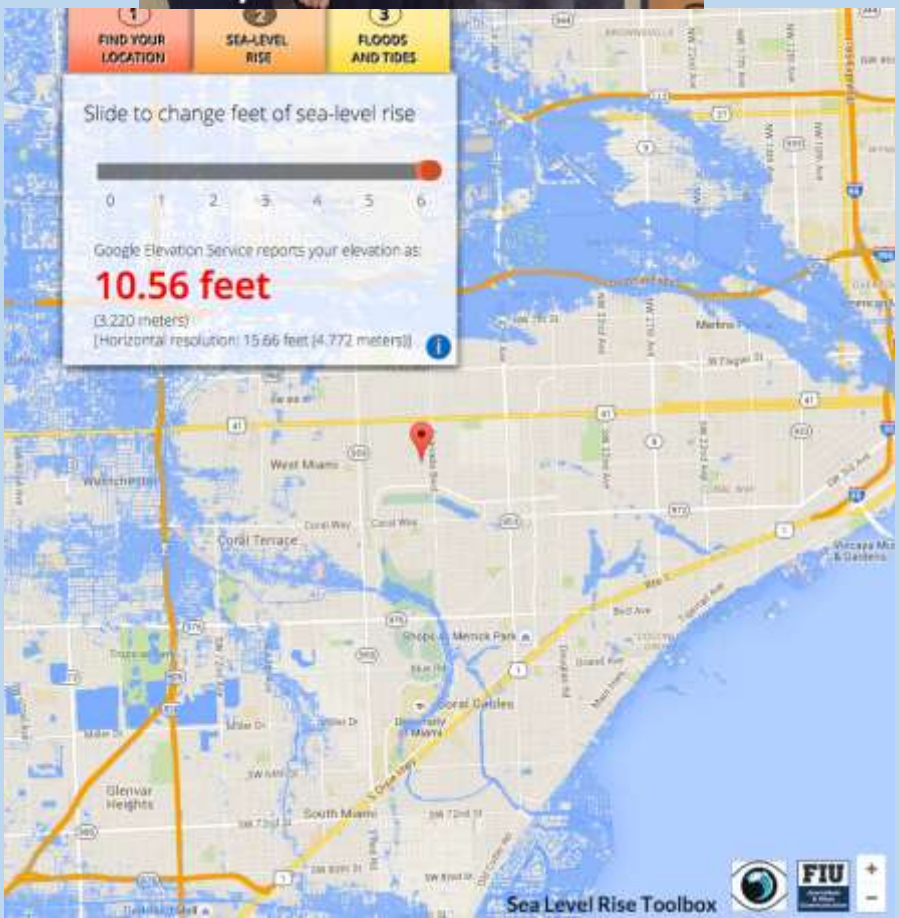
Sea Level Rise South Florida

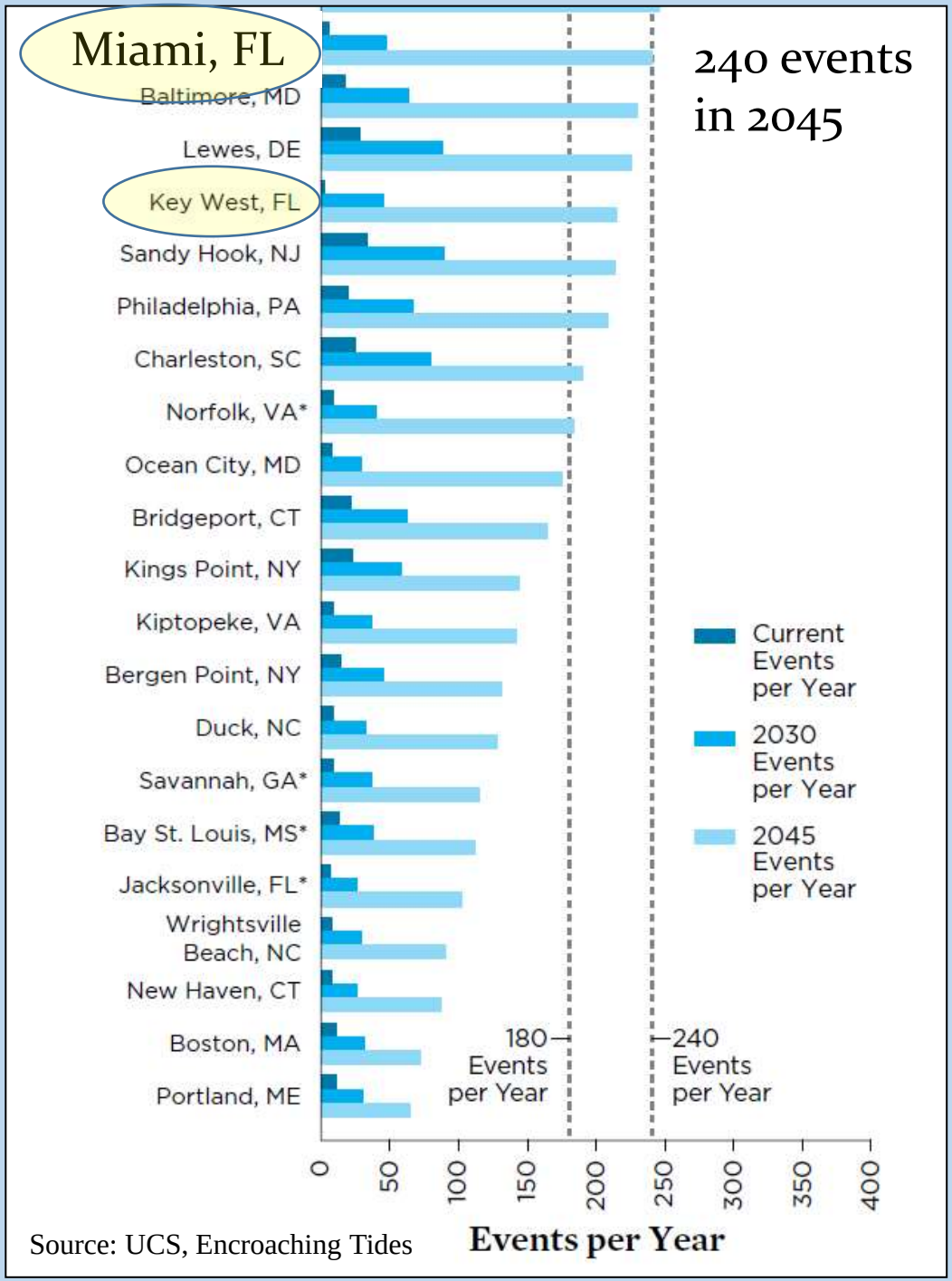
http://www.eyesontherise.org/

Juliet Pinto, Kate MacMillin, and Susan Jacobson

FIU Journalism & Mass Communication







Source: UCS, Encroaching Tides

Tidal Flooding today, in 2030 and in 2045

Southeast Florida will advance from

<10 events today

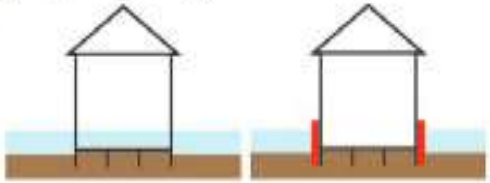
to

240 events in 2045

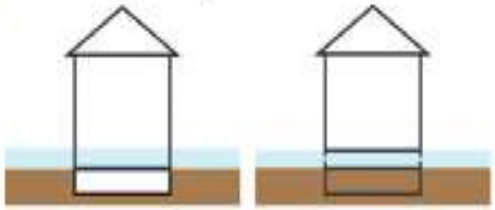
Retrofitting Existing Buildings

Before *After*

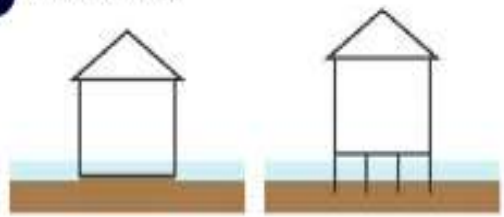
08 Dry Floodproofing



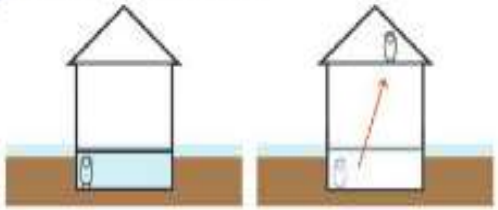
09 Wet Floodproofing

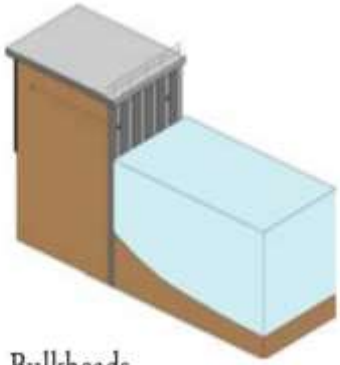


10 Elevate on Piles

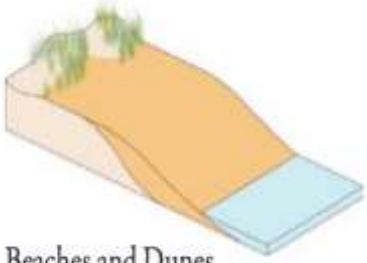


11 Protect Building Systems

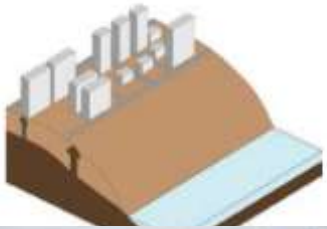




Bulkheads



Beaches and Dunes



MAKING ROOM FOR WATER IN THE CITY

PUBLIC SPACE

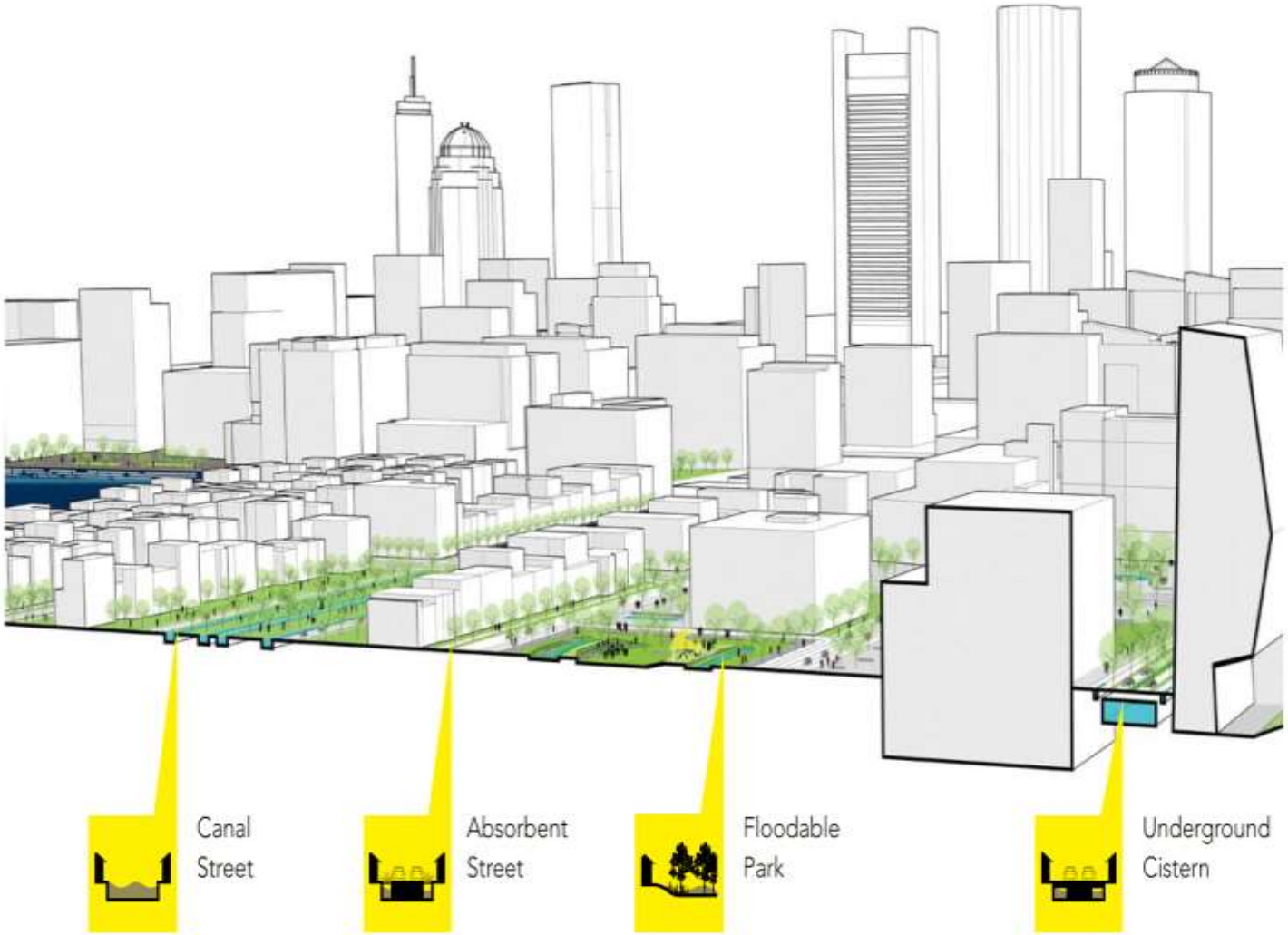


TABLE 6.1 SAMPLE OF CLIMATE HAZARDS AND ADAPTIVE RESPONSES ACROSS SECTORS

Projected Change in Climate Phenomena (Likelihood)	Drivers of Urban Exposure and Vulnerability	Consequences for Cities, if Unaddressed	Sectors Involved	Sample Adaptive Responses (not an exhaustive list)	Relative Investment Level / Cost
Warmer with fewer cold days and nights, more hot days and nights (virtually certain) Hot spells/heat waves—increased frequency (very likely)	Urban heat island effect. Lack of electricity and cooling systems, especially in many informal settlements.	Exacerbated air pollution Heat-induced illness and death	Transportation, housing, private sector building industry, public health	Green infrastructure, including improved vegetation and green building investments for natural cooling.	Medium to high with significant economic and sustainable development cobenefits
				Retrofit of existing bus fleet with white roofs to reduce solar heat gain and ventilation to ensure adequate air circulation. Undertaking public relations campaigns to encourage passengers to carry water with them to avoid heat stroke.	Low to medium
	Lack of diversified energy supply and substandard energy infrastructure.	Energy shocks and disruptions because of increased demand	Energy	Investment in clean energy and energy efficiency.	Low to high, depending on the specific energy investment; significant cobenefits for economic prosperity and "green growth."
Heavy precipitation events—increased frequency (very likely) Intensity of tropical cyclone activity increases (likely) Rising sea level (virtually certain) *(continued next page)*	Rapid urban growth leading to informal settlements on marginal land with no roads or drainage systems, or drains that are clogged with debris and silt.	Exacerbated flooding and landslides	Land use, housing, solid waste, public health, emergency management	Development and enforcement of a sound land use plan that a) is based on understanding of climate change vulnerabilities, b) effectively encourages dense, mixed-use development in resilient areas, and c) engages ecological planning approaches outside of city limits (for example, village-level watershed management on the outskirts of a city, protection of mangroves and wetlands on nearby coastline).	High, involving significant political and staff investment
		Contaminated waters and spread of disease in stagnant waters		Improved solid waste handling practices (for example, proximity to drinking water supply, corrosive-resistant containers) to prevent leakage and contamination.	Medium to high.
				Short-term clearance/disposal of solid waste from drains to prevent clogging.	Low
				Public health engagement and risk prevention around likely flood-related diseases.	Low
	Nonexistent or substandard transportation infrastructure.	Blockage of emergency routes because of road flooding, resulting in delayed emergency evacuations Losses in commercial activity	Transportation, emergency management, private sector	Investment in roads and other transportation choices for informal settlements.	Medium to high
				Green infrastructure.	Medium to high with significant economic and sustainable development cobenefits
				Relocation of storage yards for buses and train cars out of flood-prone areas to reduce the risk of damage or loss of this equipment.	High

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Current FIU Projects and Proposals:

1) Florida Coastal Everglades Program and SERC – Understanding Everglades ecology and hydrology for restoration

2) SERC research on water quality – coastal, canals, rivers and wetlands

3) Sustainable Built Environment and Informatics Program (SLSC/SBEI) - Development of 'big data' capabilities for 'Smart Cities'

4) SLSC-CAKE (Center for Advanced Knowledge Enablement)-US.DOT proposal – 'Smart Cities'; proposal to build next generation road and traffic system to minimize energy, carbon emisisons and adapt to sea level rise