



Regional Climate Change, Sea Level Rise & Water Resources

Jayantha Obeysekera, Ph. D., P.E., D.WRE_(Obey)
Hydrologic & Environmental Systems Modeling

APA Florida 2011 Conference
September 8, 2011

Role of SFWMD in SE Climate Compact

- **Membership in:**
 - **Steering Committee**
 - **Several Subcommittees**
 - **Working group for developing unified Sea Level Rise Projections**
- **Provide technical assistance in regional-scale issues**
- **Address regional-scale implications of climate variability, change, and sea level rise on our mission (vulnerability & adaptation)**
- **Monitor evolution of “Science”**

Geographical Scope of Climate Change



“Actionable” science is more and more desirable

Intergovernmental Panel on Climate Change (IPCC)

The IPCC formed in 1988 under auspices of the United Nations

Governments require information on climate change for negotiations

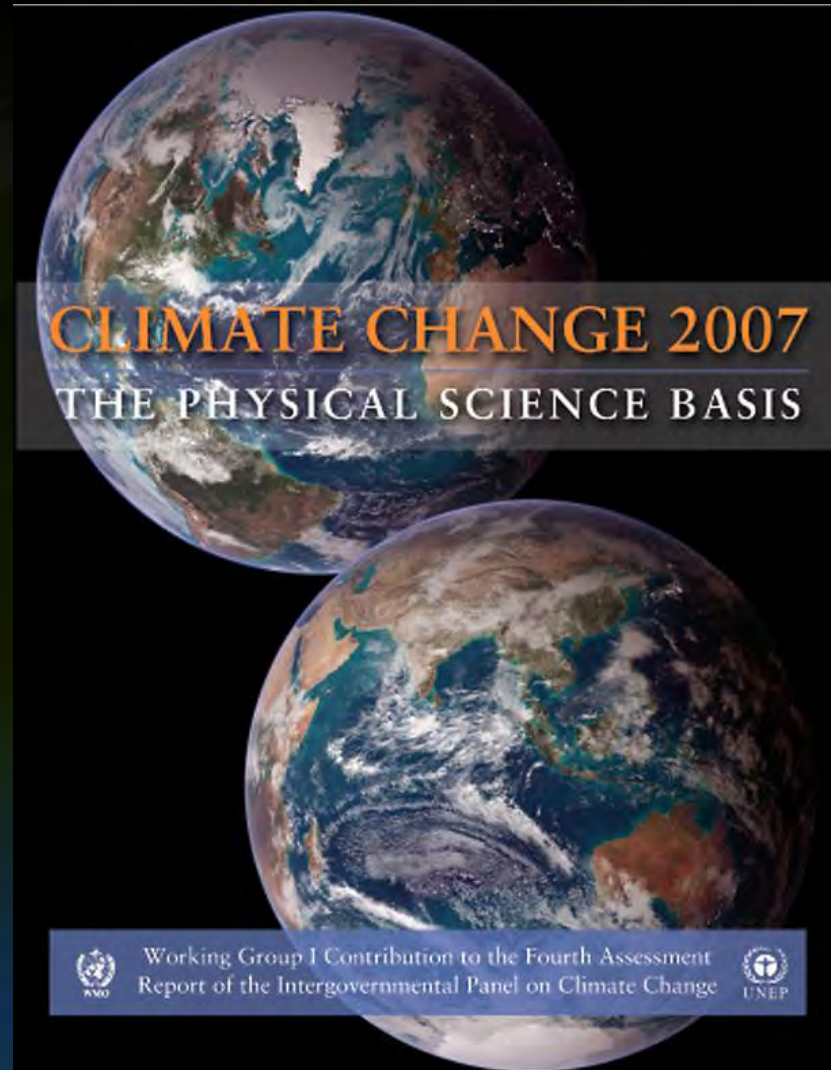
Function is to provide assessments of the science of climate change

Last report: AR4 (2007)

Next report: AR5 (2013-2014)

Changes in Climate can be due to both natural variability and human activity

www.ipcc.ch



IPCC Projections

Phenomenon and direction of trend	Likelihood that trend occurred in the late 20th century (typically post 1960)	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights	Very likely (>90%)	Virtually certain (>99%)
Warmer and more frequent hot days and nights	Very likely	Virtually certain
Warm spells/heat waves.	Likely	Very likely
Heavy precipitation events	Likely	Very likely

IPCC Projections (cont.)

Phenomenon and direction of trend	Likelihood that trend occurred in the late 20th century (typically post 1960)	Likelihood of future trends based on projections for 21st century using SRES scenarios
Areas affected by drought increases.	Likely (in many regions since 1970's)	Likely
Intense tropical cyclone activity increases	Likely (in some regions since 1970)	Likely
Increased incidence of extreme high sea level	Likely	Likely

Current & Evolving Climate Conditions: World

Aug 2010 Pakistan



Russia



China



Current & Evolving Climate Conditions : United States

Holy Heat Wave! Thermometer-Continue in U.S.

...o relief from heat wave in the South, North

Scott Thompson, CNN
15, 2011 3:12 a.m. EDT



(CNN) -- It's truly the dog days of summer in the South.

The heat wave that has encompassed many Southern states this week is not expected to loosen its grip in the coming days.

Scorching high temperatures are in the forecast over the weekend in the North.

Jul 12, 2011 2:12 PM ET

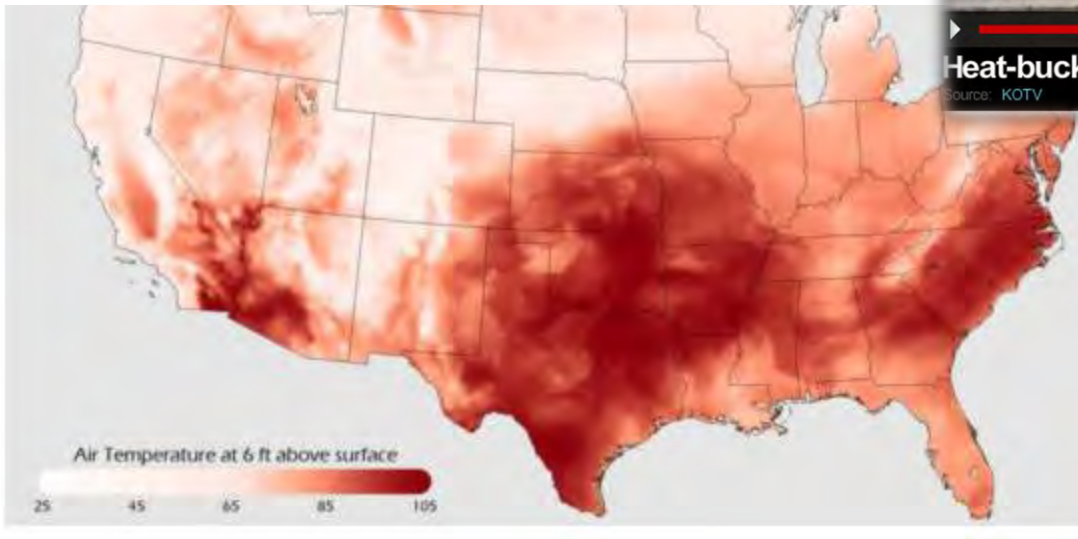
By Brett Israel, OurAmazingPlanet Staff Writer



Record temperatures seen as heat wave plagues 23 states

By Jacqui Jeras, CNN

July 11, 2011 8:30 p.m. EDT



Heat-buckled highway blamed for crash

Source: KOTV

Oklahoma Turnpike Authority

CNN



AP

More closer to home!



Miami-Dade County
Credit: Miami-Dade DERM

More closers to home (cont.)

IT'S OFFICIALLY... OUR HOTTEST SUMMER EVER

■ In the West Palm Beach area, the daily high reached or exceeded 90 degrees on 79 days

■ Those 79 days tied for the third most number of really hot days

■ Lows hovered above 80 degrees on 25 days to set a record

Water cycle seems out of whack, experts find

18 percent more water fed into oceans in 2006 than in 1994, satellite data show

10/7/2010 MSNBC

Steaming in South

Average summer 2010 hottest days in South

PALM BEACH

84.6°

2.4 degrees above normal

Previous record: 84.2° (1998)



Will warming debate reheat

Downtown Los Angeles bakes at record 111°

By JOHN ANTCAZAK, Associated Press Writer
Mon Sep 27, 6:14 pm ET

After South Florida's driest October on record, water district urges conservation



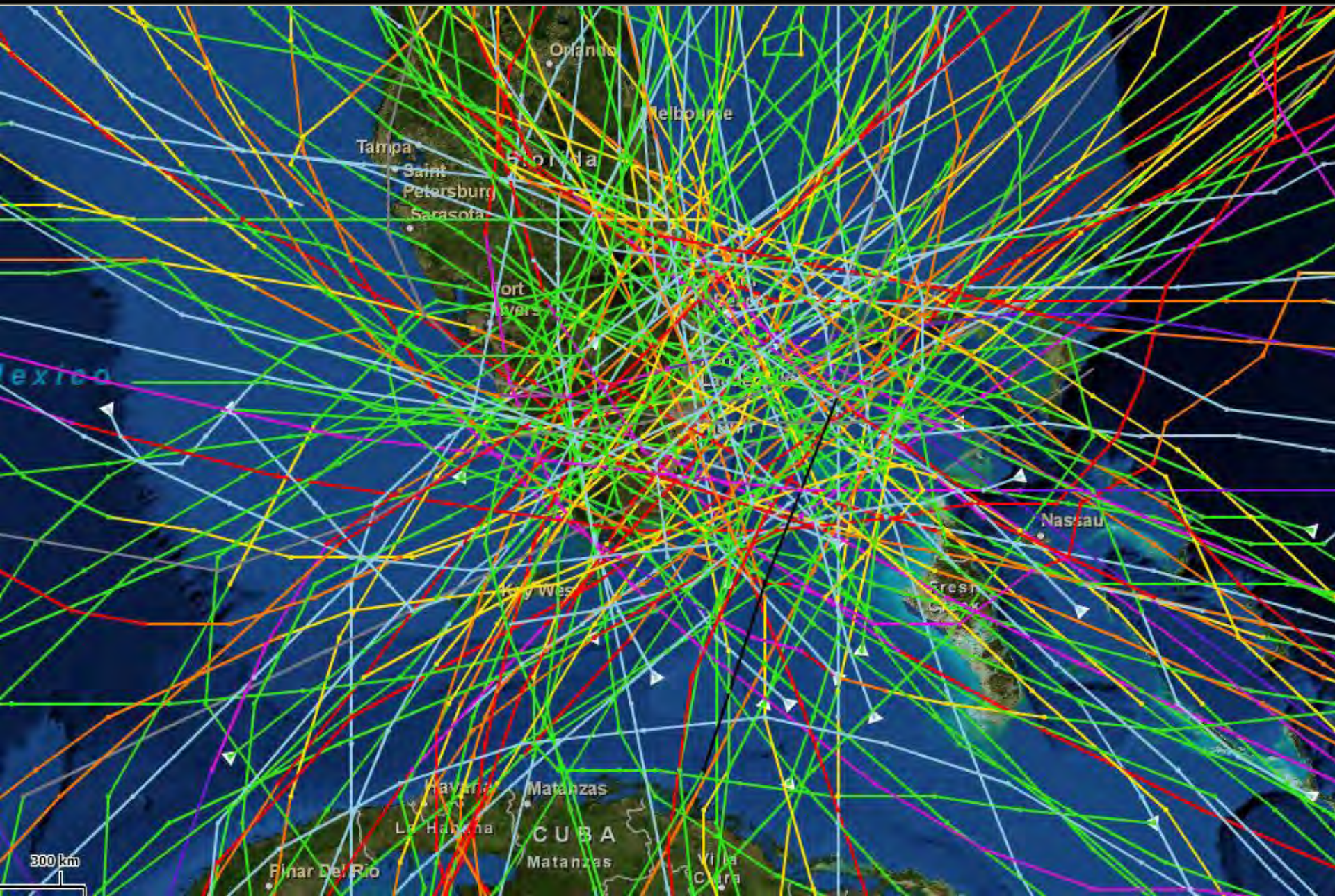
By ANDREW MARRA
Palm Beach Post Staff Writer

Posted: 7:54 p.m. Monday, Nov. 1, 2010

Post a Comment | E-mail | Print |

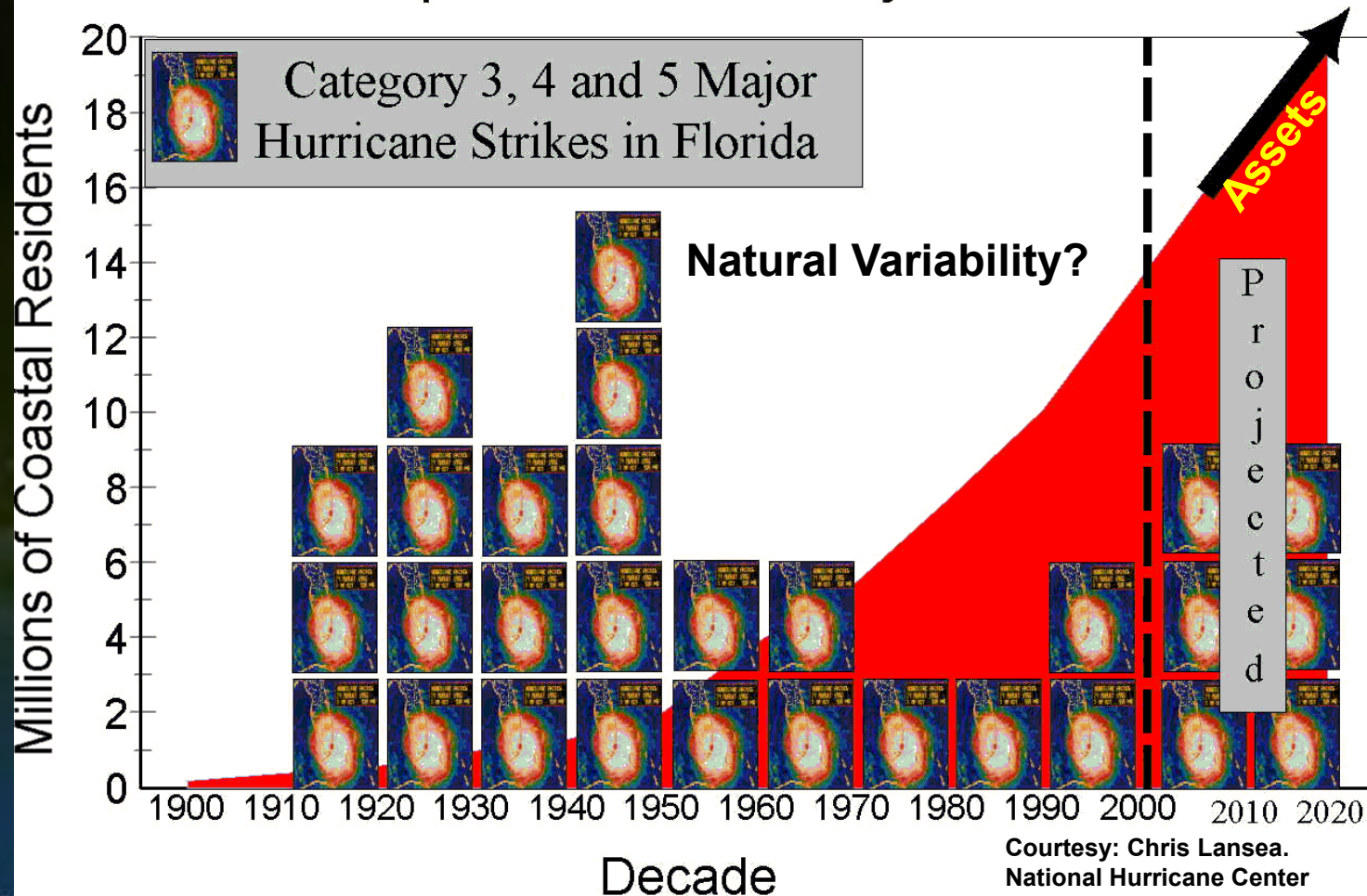
Last month was the driest October on record in South Florida, meteorologists said, underscoring concerns about local water shortages this winter.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT



Tropical Storms: Natural Variability versus Anthropogenic Effects?

Florida Population and Major Hurricanes





The National Climate Assessment

Name

Jayantha Obeysekera

Event

APA Florida 2011 Conference

<http://assessment.globalchange.gov>



NCADAC Members (Non-Federal)

- **Daniel Abbasi**
Mission Point Capital Partners
- **E. Virginia Armbrust**
University of Washington
- **T. M. Bull Bennett**
Kiksapa Consulting, LLC
- **Rosina Bierbaum**
PCAST, University of Michigan
- **Maria Blair**
American Cancer Society
- **Lynne Carter**
Louisiana State University
- **F. Stuart Chapin III**
University of Alaska
- **Camille Coley**
Florida Atlantic University
- **Jan Dell**
CH2MHill
- **Plácido dos Santos**
Arizona Department of Water Resources
- **Paul Fleming**
Seattle Public Utilities
- **Guido Franco**
California Energy Commission
- **Mary Gade**
Gade Consulting
- **Aris Georgakakos**
Georgia Institute of Technology
- **David Hales**
College of the Atlantic
- **Mark Howden**
Australian Commonwealth Scientific and Industrial Research Organization
- **Anthony Janetos**
Joint Global Change Research Institute
- **Peter Kareiva**
The Nature Conservancy
- **Rattan Lal**
Ohio State University
- **Arthur Lee**
Chevron Corporation
- **Diana Liverman**
University of Arizona and Oxford University
- **Edward Maibach**
George Mason University
- **Rezaul Mahmood**
Western Kentucky University
- **Michael McGeehin**
RTI International
- **Philip Mote**
Oregon State University
- **Jayantha Obeysekera**
South Florida Water Management District
- **Marie O'Neill**
University of Michigan
- **John Posey**
East-West Gateway Council of Governments
- **Sara Pryor**
Indiana University
- **Richard Schmalensee**
Massachusetts Institute of Technology
- **Henry G. Schwartz**
HGS Consultants, LLC
- **Joel Smith**
Stratus Consulting

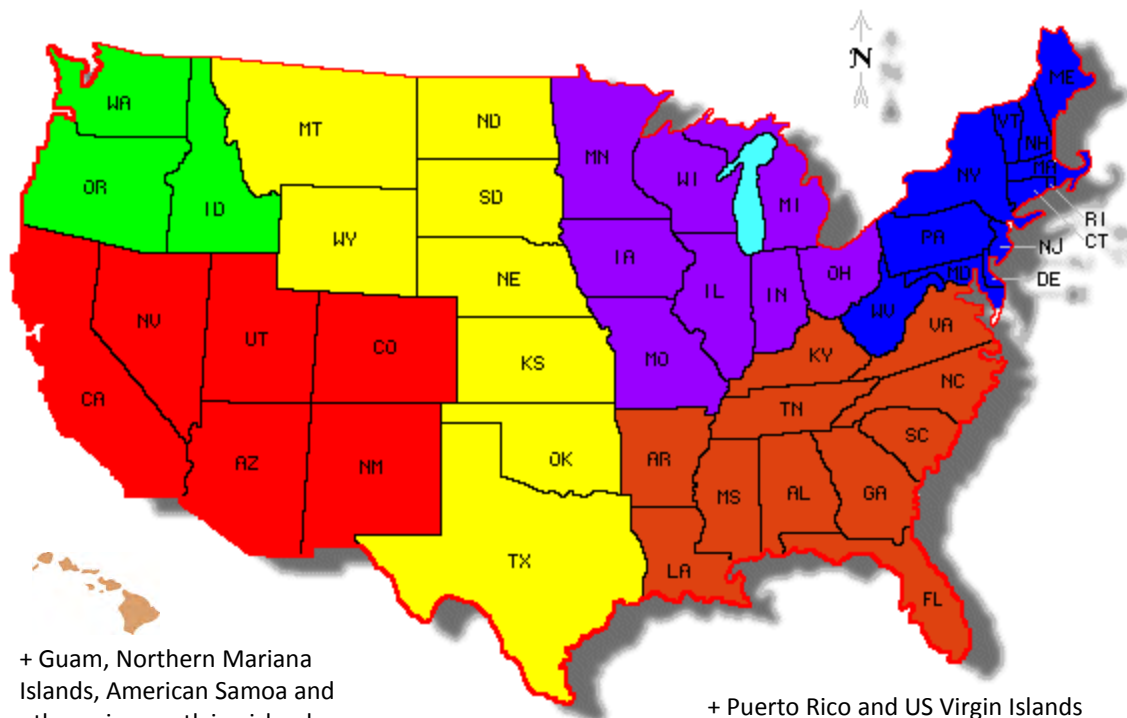


**National
Climate
Assessment**

U.S. Global Change Research Program

Regions

- Northeast
- Southeast and Caribbean
- Midwest
- Great Plains
- Northwest
- Southwest
- Alaska and Arctic
- Hawaii and Pacific Islands



+ Guam, Northern Mariana Islands, American Samoa and other minor outlying islands

+ Puerto Rico and US Virgin Islands

Potential Impacts on Water Resources Management in South Florida

Climate Change Drivers

Natural Cycles

Interannual
(e.g. El Nino and La Nina) to
Multi-decadal
(e.g. AMO*)
Solar, Volcanos



Human Induced

Land use changes
Greenhouse gases

Quartet of change: Stressors

- **Rising Seas**
- **Temperature**
- **Rainfall, floods, and droughts**
- **Tropical Storms & Hurricanes**

Water Management Impacts

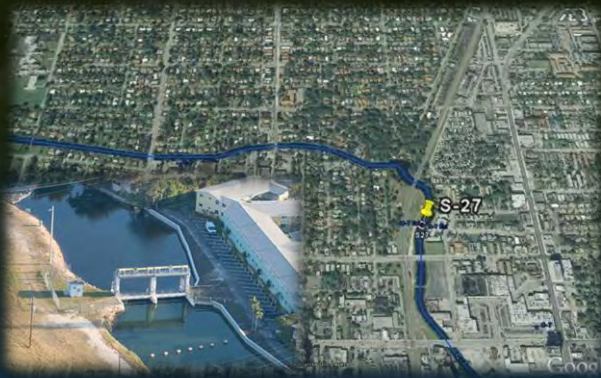
- Direct landscape impacts (e.g. storm surge)
- Water Supply (e.g. droughts, saltwater intrusion)
- Flood Control (e.g. urban flooding, hurricanes)
- Natural Systems (e.g. ecosystem impacts, both coastal and interior)

*Atlantic Multi-decadal Oscillation of temperature in the Atlantic Ocean

Water Management – Potential Sea Level Rise Impacts



- Direct impacts on the coastal belt (storm surge)
- Flood Protection (urban flooding, hurricanes)
- Water Supply (saltwater intrusion)
- Natural Systems (ecosystems along the coast)



SFWMD White Paper, Technical Paper & Strategy



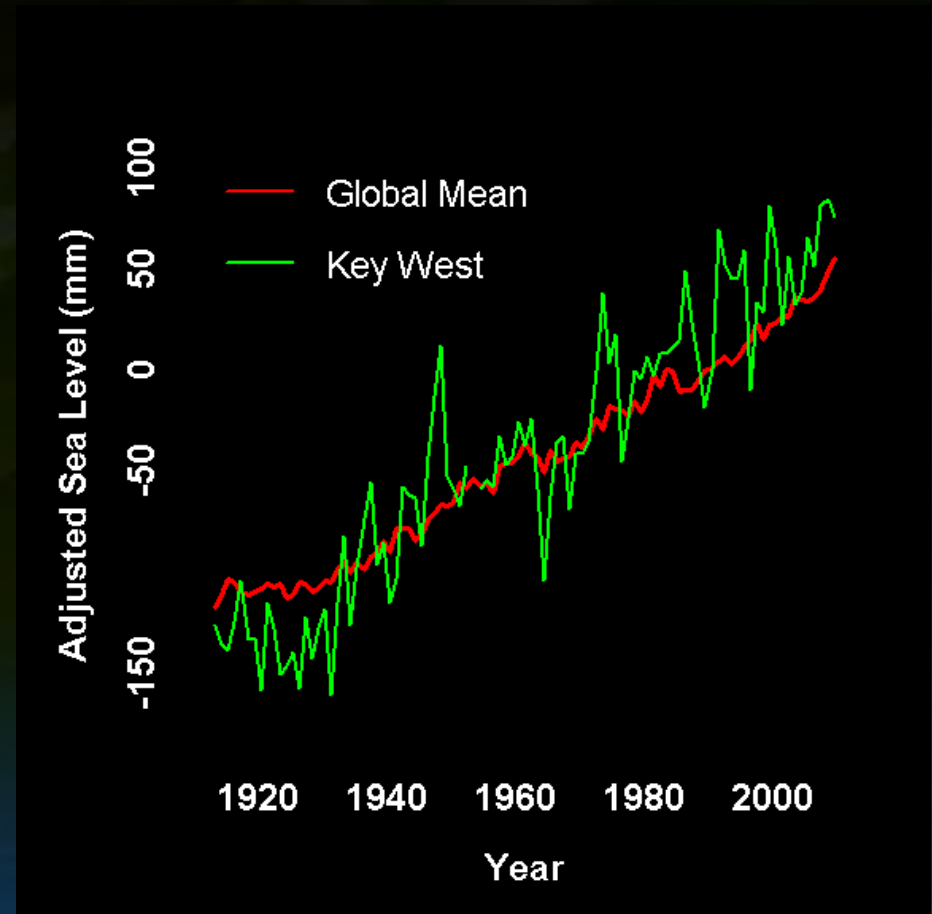
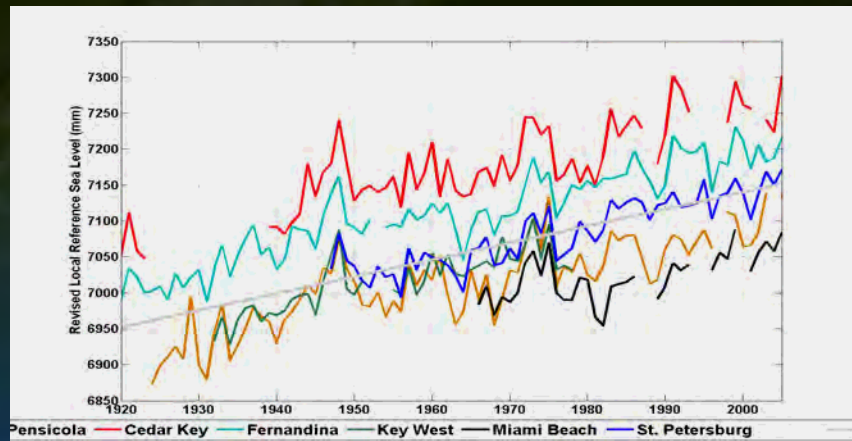
■ Two Important Questions:

- Which decisions are likely to be affected and could benefit from adaptation strategies (**Type I**) in the short term?
 - “No Regret Strategies”
- Which decisions are likely to be affected but for which adaptation strategies (**Type II**) could be deferred without serious consequences?

Sea Level Rise

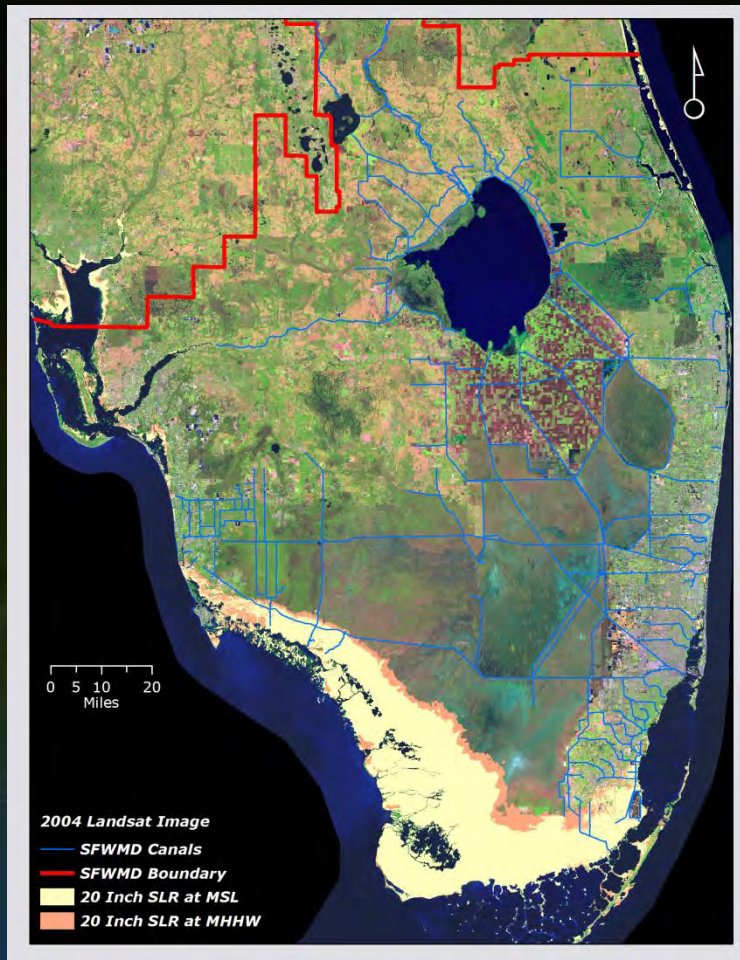


Rising Seas – Historical Data



Sea Level Rise Environmental Impacts

- Relocation and possible reduction of mangrove forests
- Forced migration of wading birds north
- Potential peat collapse, coastal erosion, and redistribution of sediments
- Salinity intrusion into freshwater marshes can: discharge toxic hydrogen sulfide, cause coastal fish kills, and increase habitat loss



Impacts of Rising Seas: Flood Control

Coastal Structure

Ocean Side
(tailwater)

Land Side(headwater)



Impacts of Rising Seas: Flood Control

Coastal Structure

**Ocean Side
(tailwater)**

Land Side(headwater)

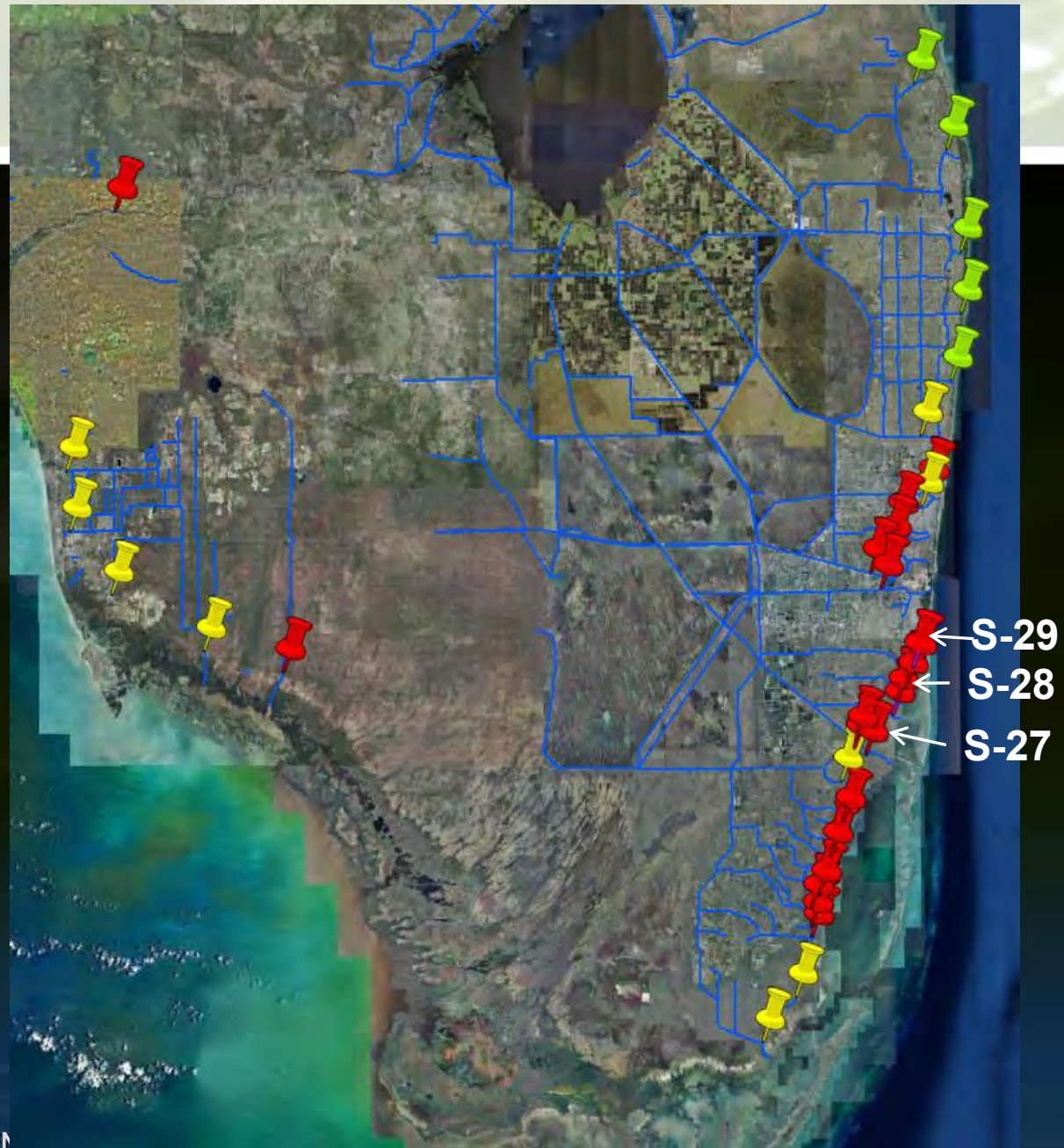


Area Surrounding S-27 Structure

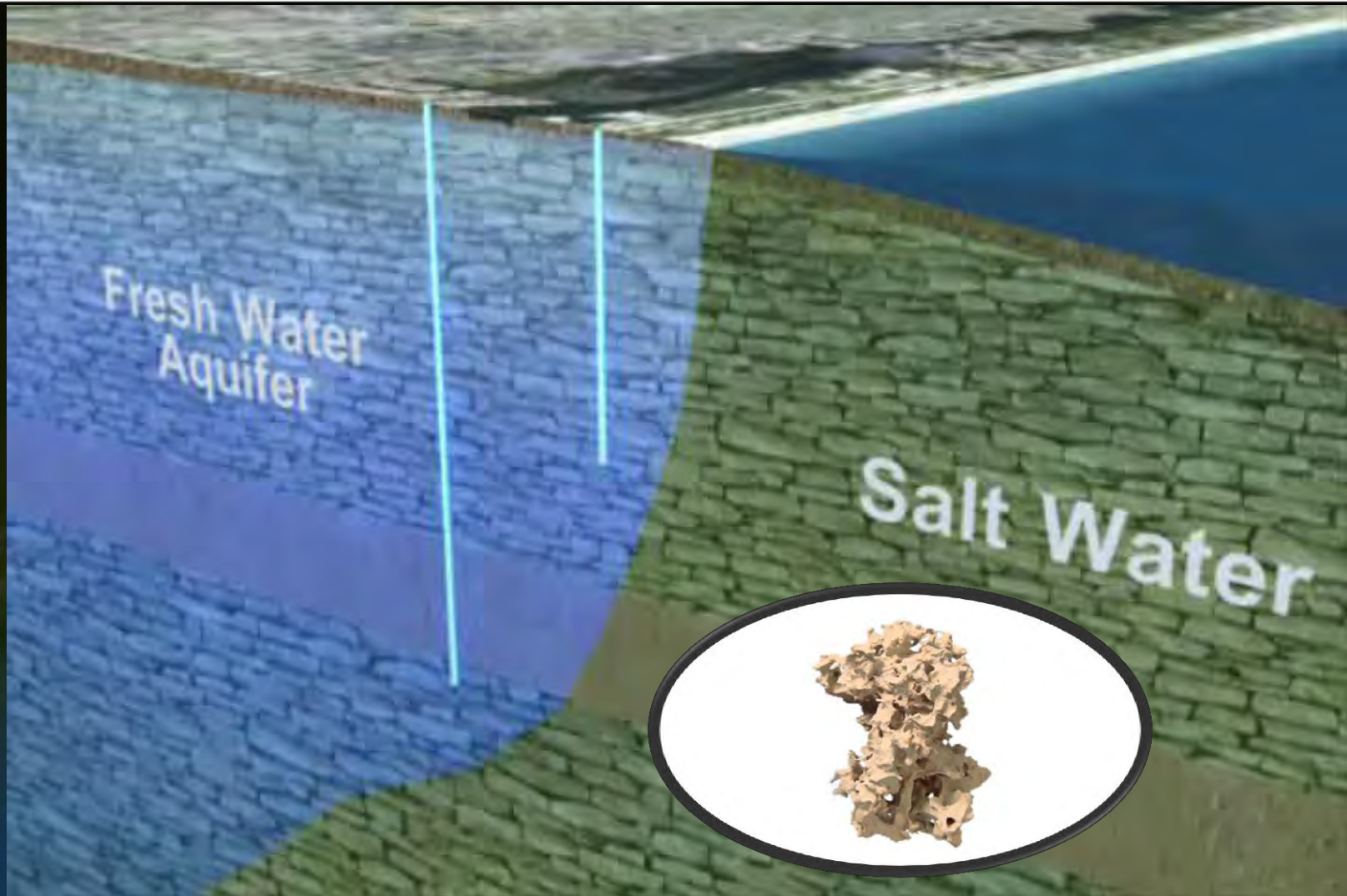


Vulnerable Structures

- Preliminary review based on original designs
- 28 gravity structures on the East Coast
- Six gravity structures on the west coast
- Most vulnerable structures are in Miami-Dade and Broward counties
 - Prioritized 3 structures

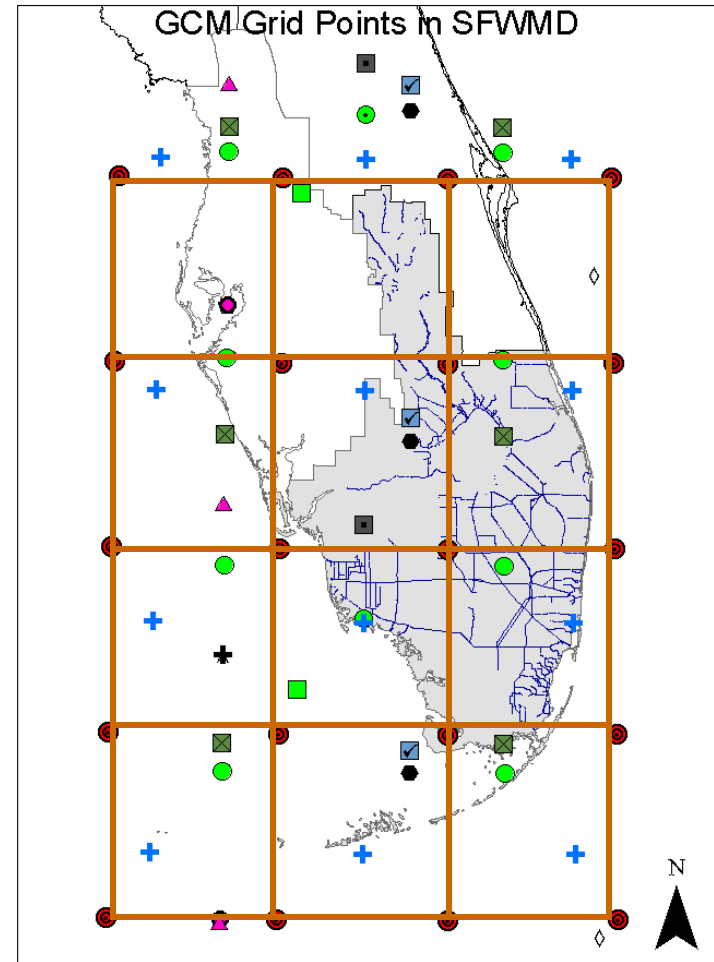
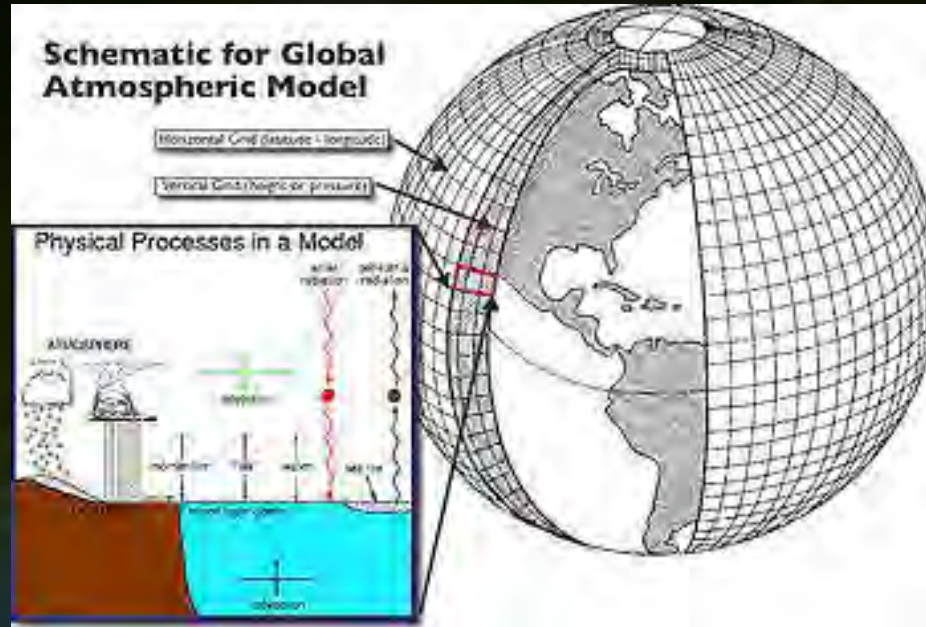


Rising Seas - Water Supply: Saltwater Intrusion



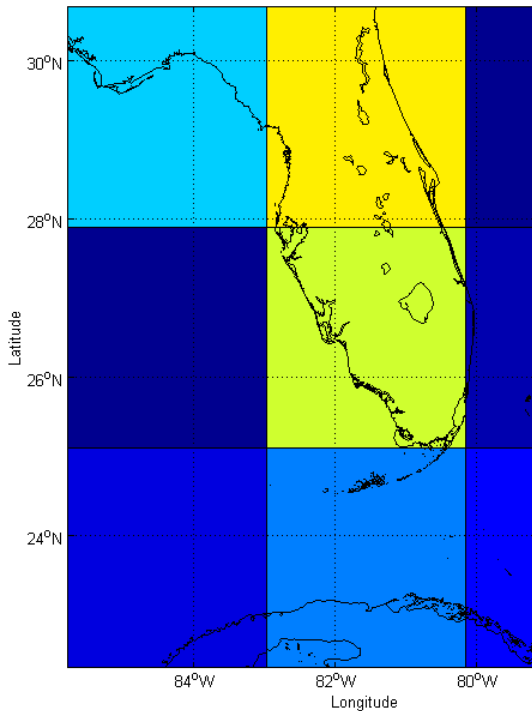
Coupled Atmosphere-Ocean General Circulation Models (AOGCMs)

Over 20 different models

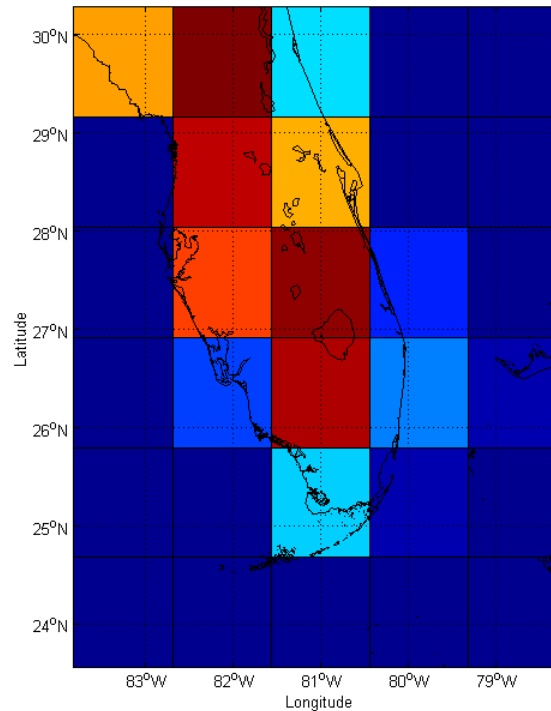


Concerns about global models

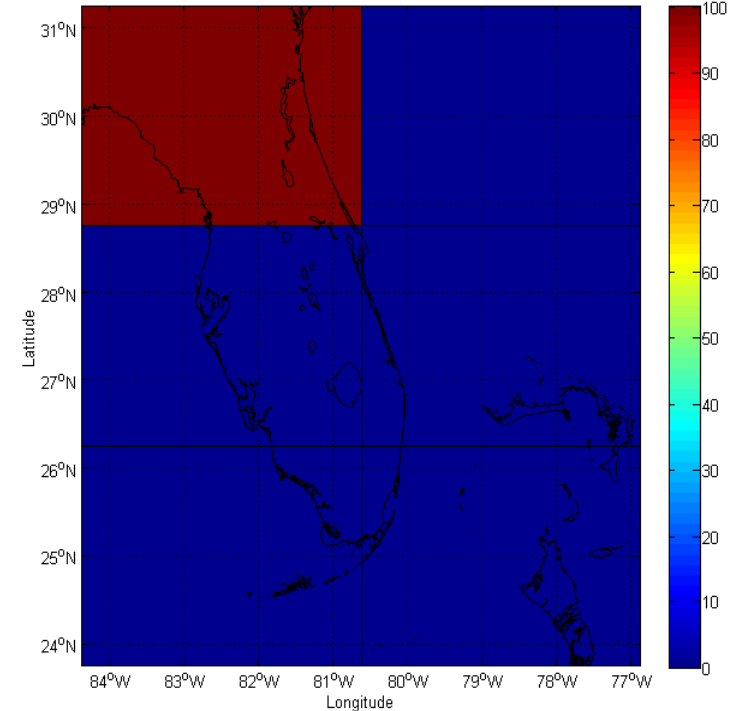
Land-sea mask for BCM2



Land-sea mask for MIHR



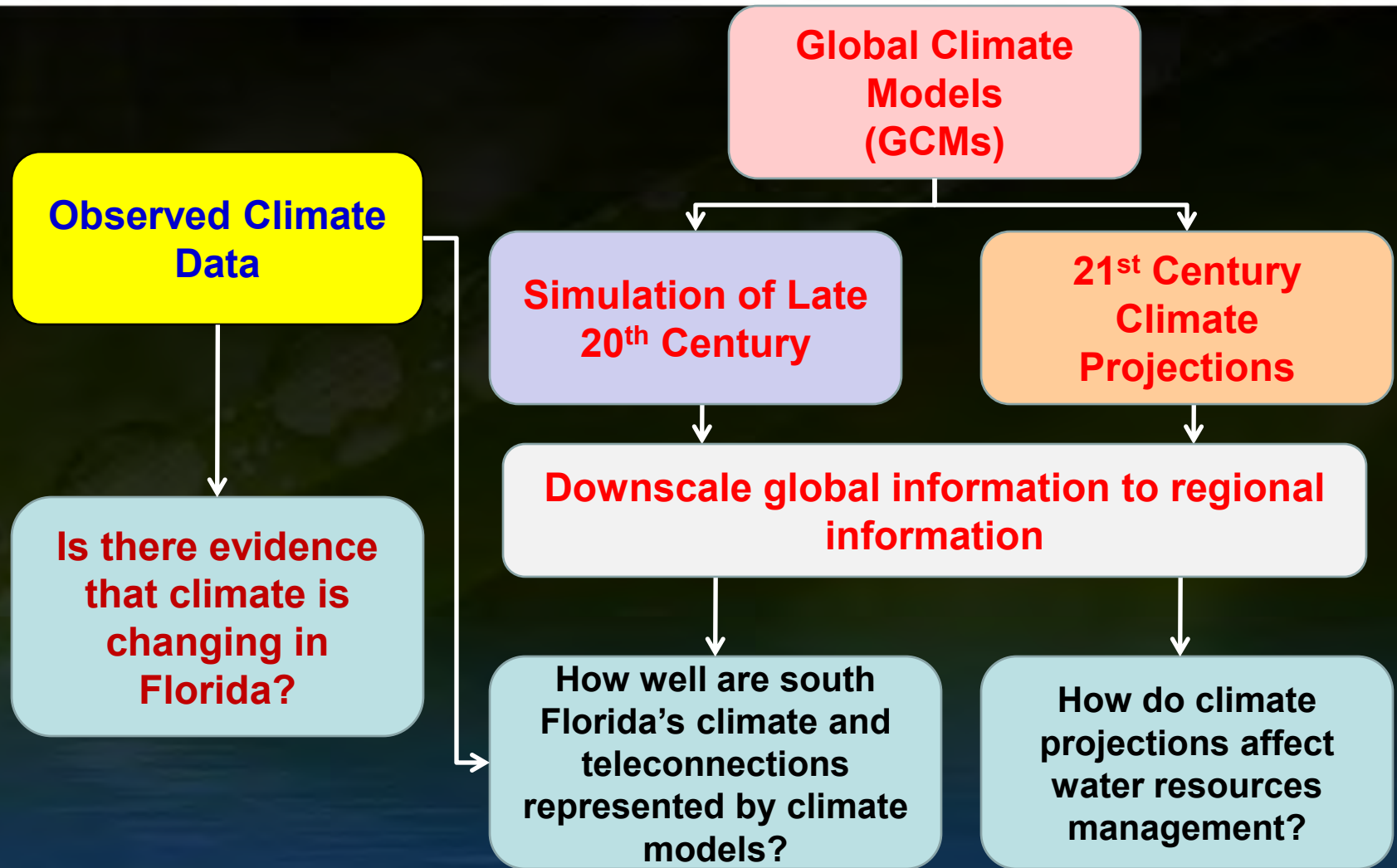
Land-sea mask for HADCM3



Uncertainties in GCM predictions due to:

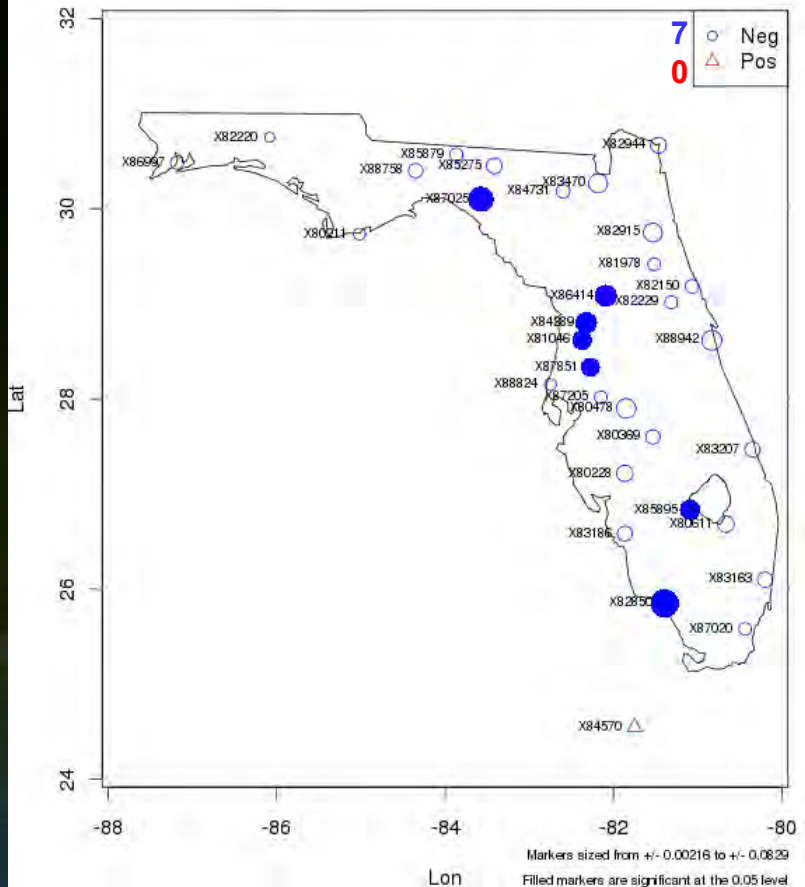
- **Poor resolution** – South Florida not even modeled in some GCMs; greater errors at smaller scales
- From IPCC AR4-WG1, Ch. 8 - Simulation of tropical precipitation, ENSO, clouds and their response to climate change, etc.

A systematic approach for using climate model data



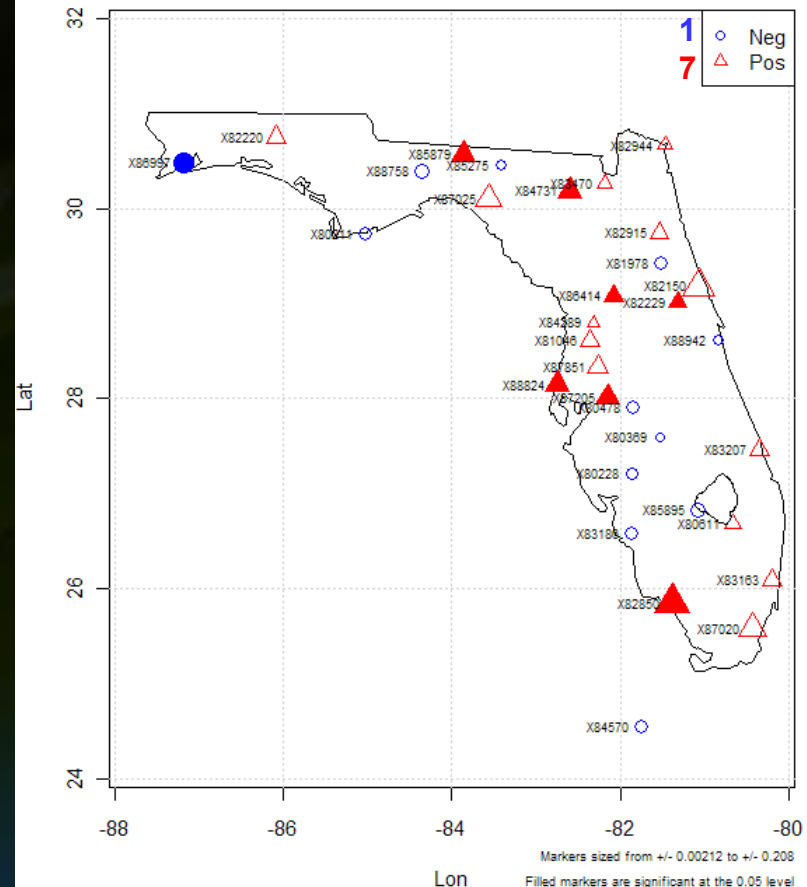
Historical Trends

May Precipitation – post-1950



Historical decrease in wet season precipitation, which is most evident for the month of May.

of Wet Days Dry Season - POR



Historical increase in the number of wet days during the dry season, especially during NDJ.

Florida - Main Observations

- Precipitation and temperature statistics at 32 stations in Florida analyzed for trends using non-parametric techniques
- ↑ number of wet days during the dry season – POR
- ↓ May precipitation throughout the state – POR and especially post-1950. May be linked to changes in start of the wet season.
- Urban heat island effect – urban (and drained) areas
 - ↑ Tave and ↑ number of dog days for wet (warm) season especially post-1950
 - Decrease in DTR (↑ Tmin > ↑ Tmax)
 - ↑ Annual maximum of Tave and Tmin for all seasons in POR and especially post-1950

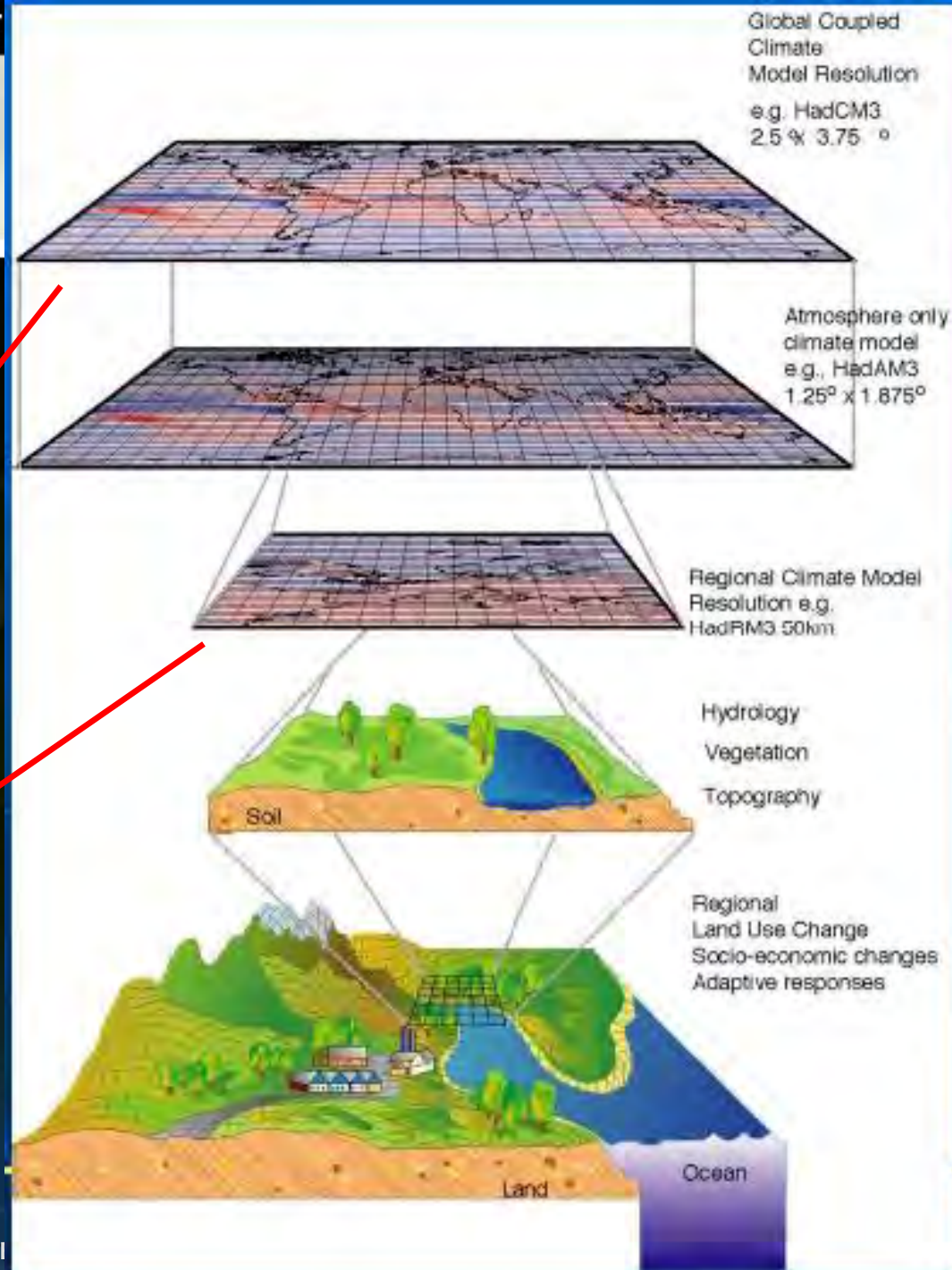
Downscaling

■ “Downscaling

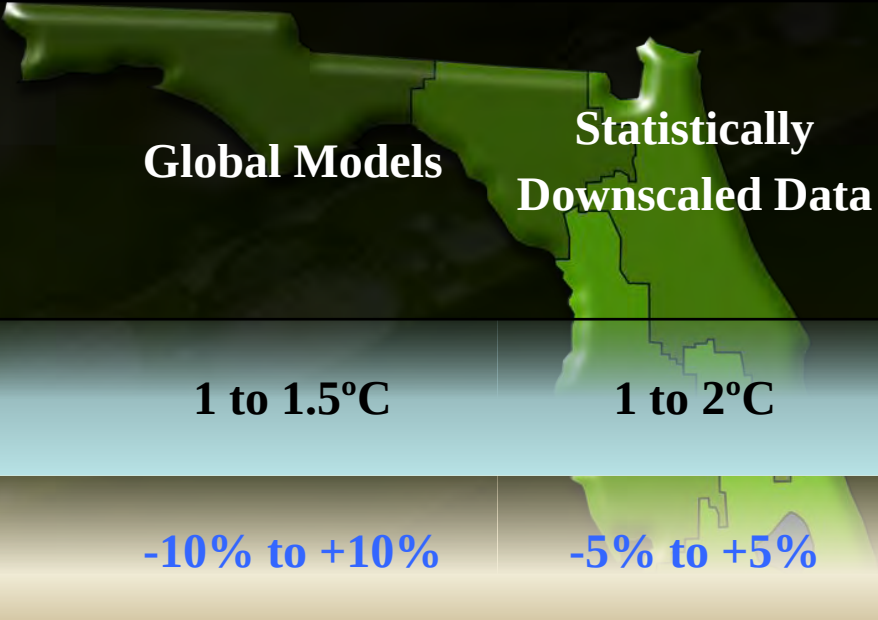
Atmosphere-Ocean
General Circulation
Models (AOGCM)



Regional Climate
Models (RCM)

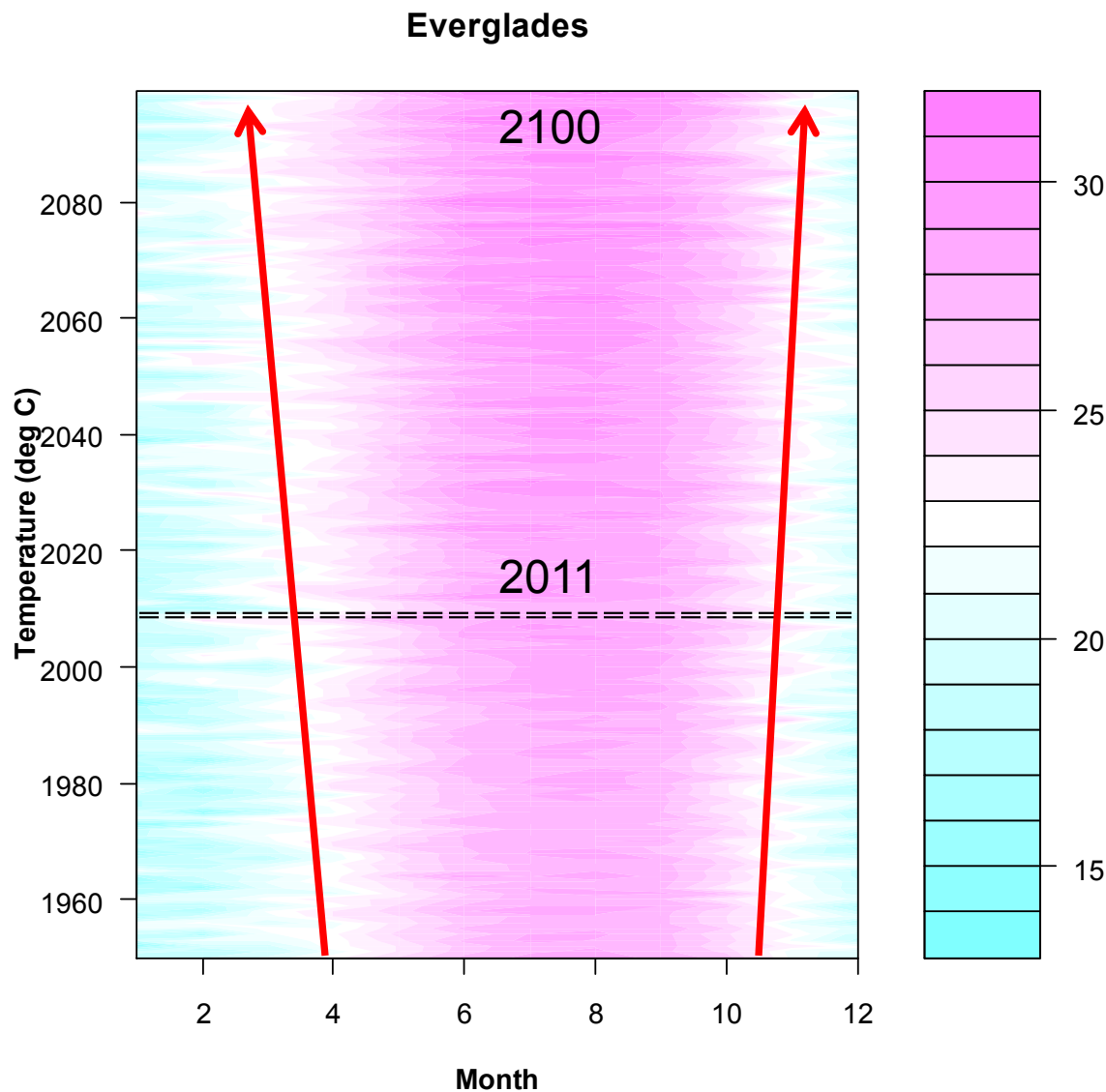


By 2050 (findings to date - may change as science evolves)



Variable	Global Models	Statistically Downscaled Data	Dynamically Downscaled Data
Average Temperature	1 to 1.5°C	1 to 2°C	1.8 to 2.1°C
Precipitation	-10% to +10%	-5% to +5%	-3 to 2 inches
Reference Crop Evapotranspiration			3 to 6 inches

Hotter and Longer Summer?



Sources of Sea Level Rise

What causes the sea level to change?

Terrestrial Water Input

Terrestrial water storage, extraction of groundwater, building of reservoirs, changes in runoff, and seepage into aquifers

Land-based Ice (Glaciers, Ice Sheets in Greenland, Antarctica)

Exchange of the water stored on land by glaciers and ice sheets with ocean water

Surface and deep ocean circulation changes, storm surges

As the ocean warms, the water expands

Thermal Expansion

Subsidence in river delta region, land movements, and tectonic displacements

Vertical Land Movement

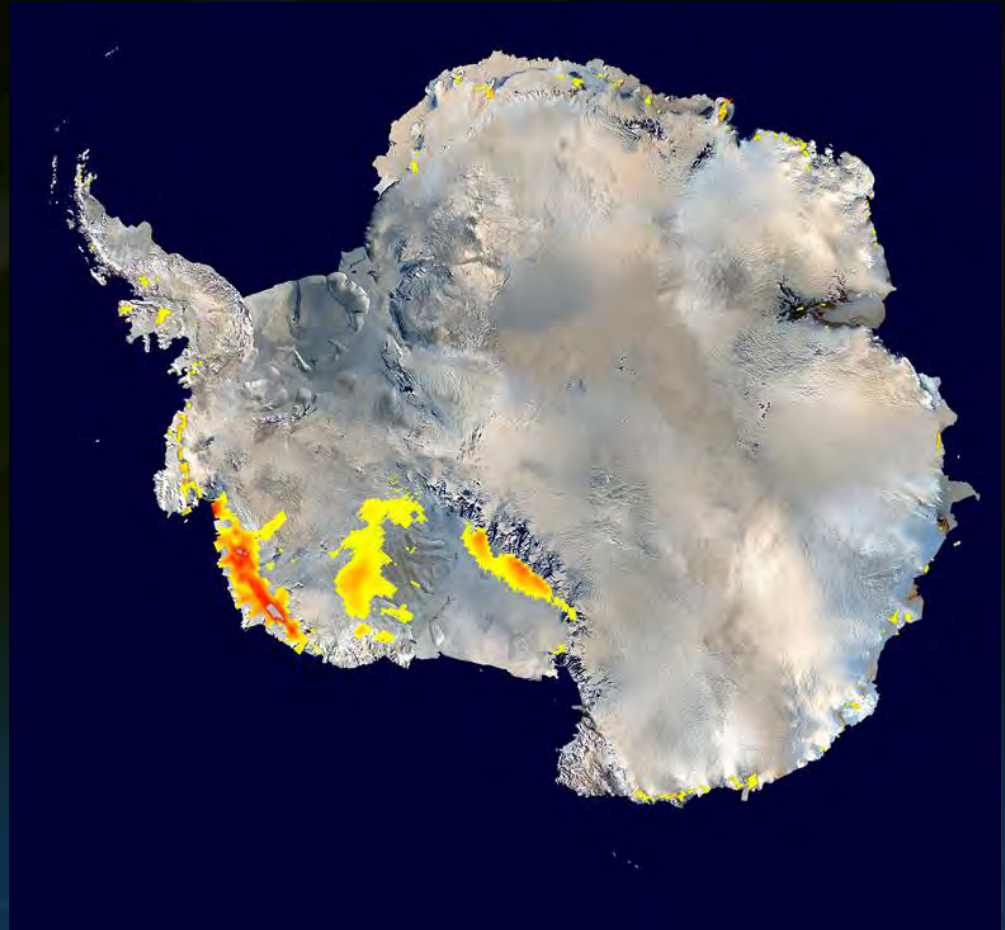
SYR - FIGURE 3-4

Future Projections of Sea Level Rise: Polar Ice Uncertainty

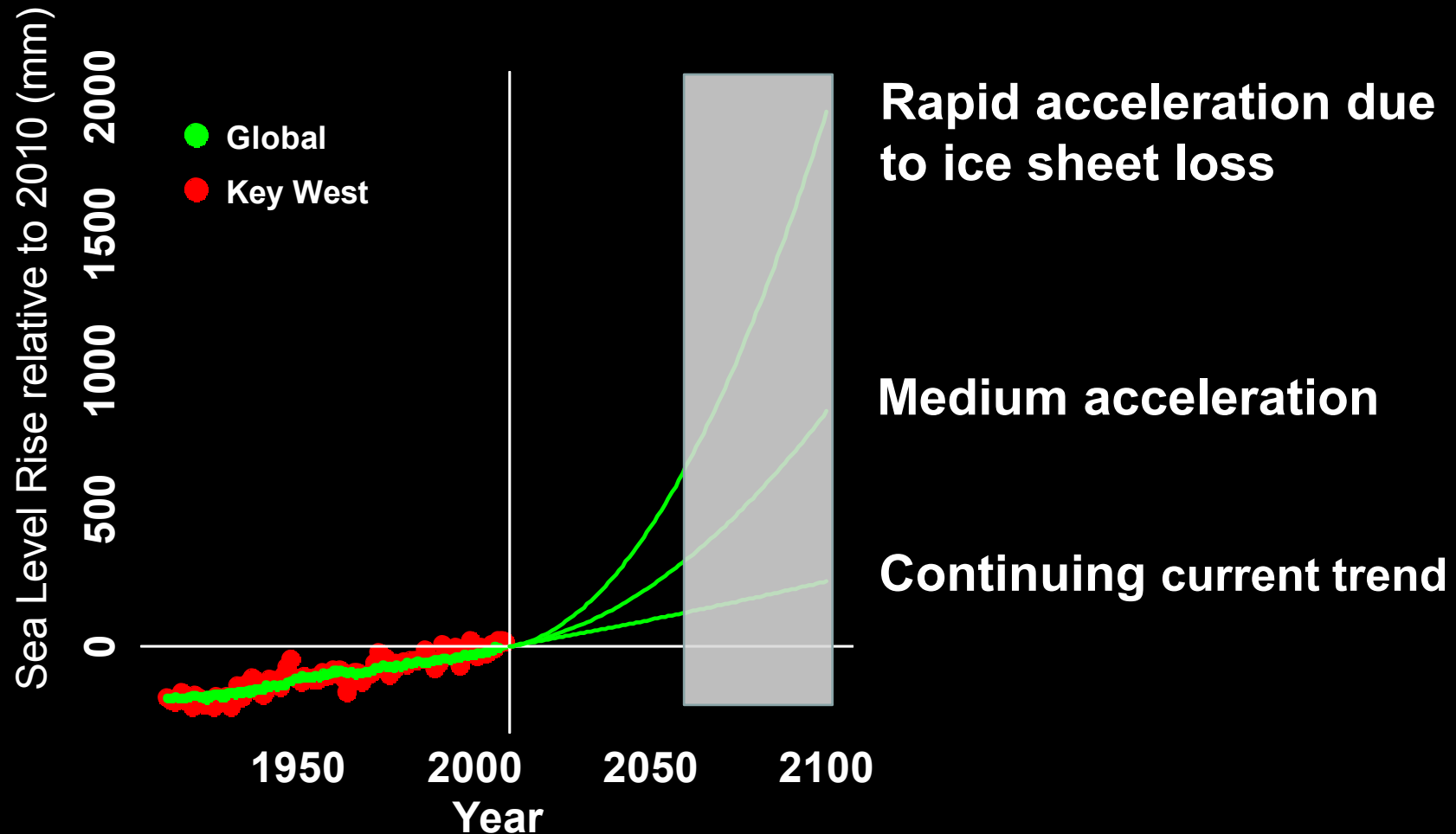
Greenland
(~ 2 million sq.km.)

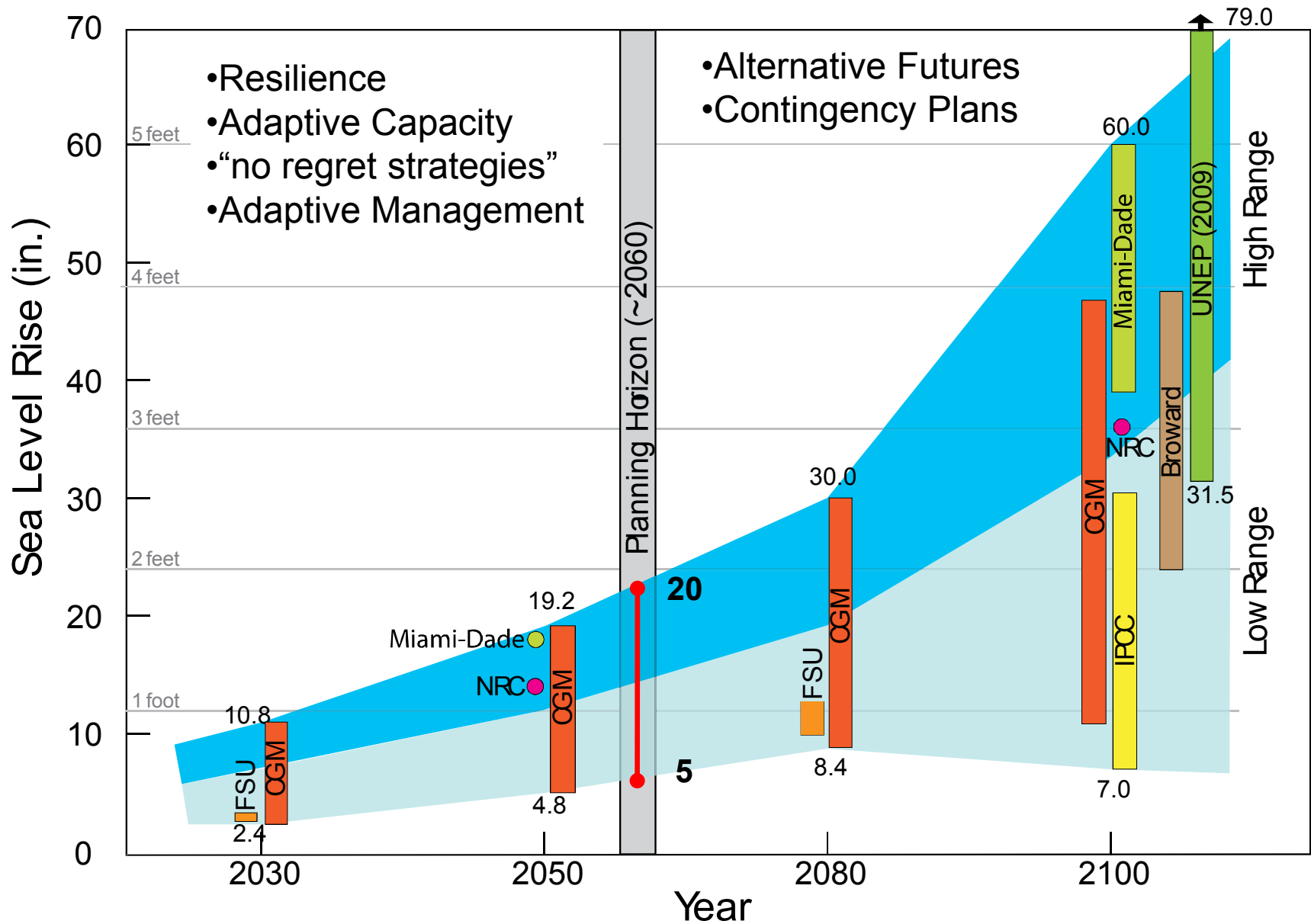


Antarctica
(~5.4 million sq. km.)



What is the future rate of acceleration?





Source	Reference Year	SLR Projection (inches)			
		2030	2050	2060	2100
Historic South Florida Trend (2.37 mm/yr)	2000	2.8	4.7	5.6	9.3
Southeast Florida Regional Climate Change Compact (2011)	2010	3-7		9-24	
Miami-Dade Climate Change Advisory Task Force (Miami- Dade County, 2008)	2000		>18		36-60
Broward County Climate Change Advisory Task Force (Broward County, 2010)	2000	3-9		10-20	24-48
South Florida Water Management District (SFWMD, 2009)	1990			5-20	

Tropical Storms & Climate Change

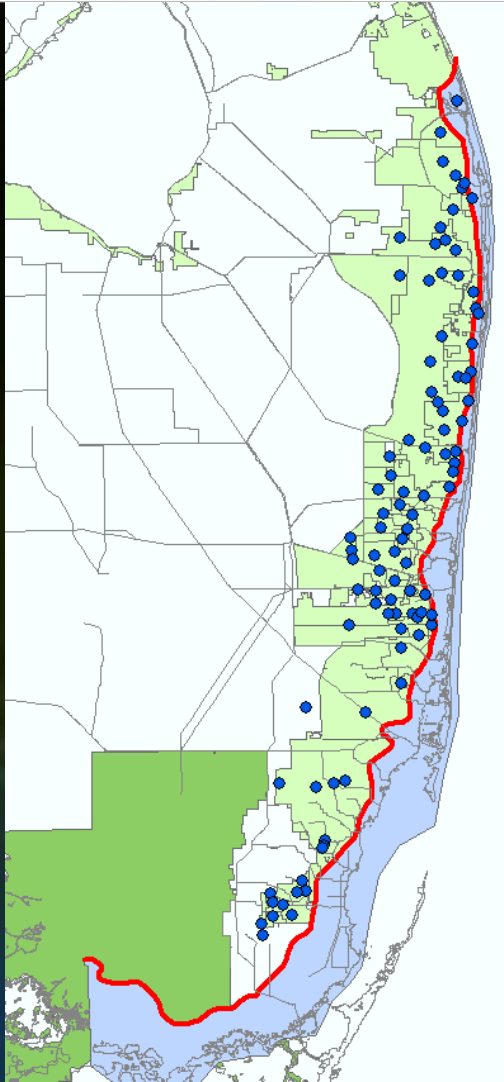
- Tropical cyclones to shift towards stronger storms (2-11% intensity increase by 2100)
- Decrease in global frequency of tropical cyclones (6-34%)
- Increase in the frequency of the most intense cyclones
- Increase in rainfall rate, 20% within 100 km of storm center

Adaptation to Rising Seas

Example: Forward Pumping at S-26 Structure



Saltwater Intrusion: Adaptation



- Determine saltwater/ freshwater interface
- Update saltwater intrusion monitoring network
- Identify utilities at risk
- Implement water conservation
- Alternatives sources of water Supply
- Incorporate sea level rise in planning efforts
- Regional coordination

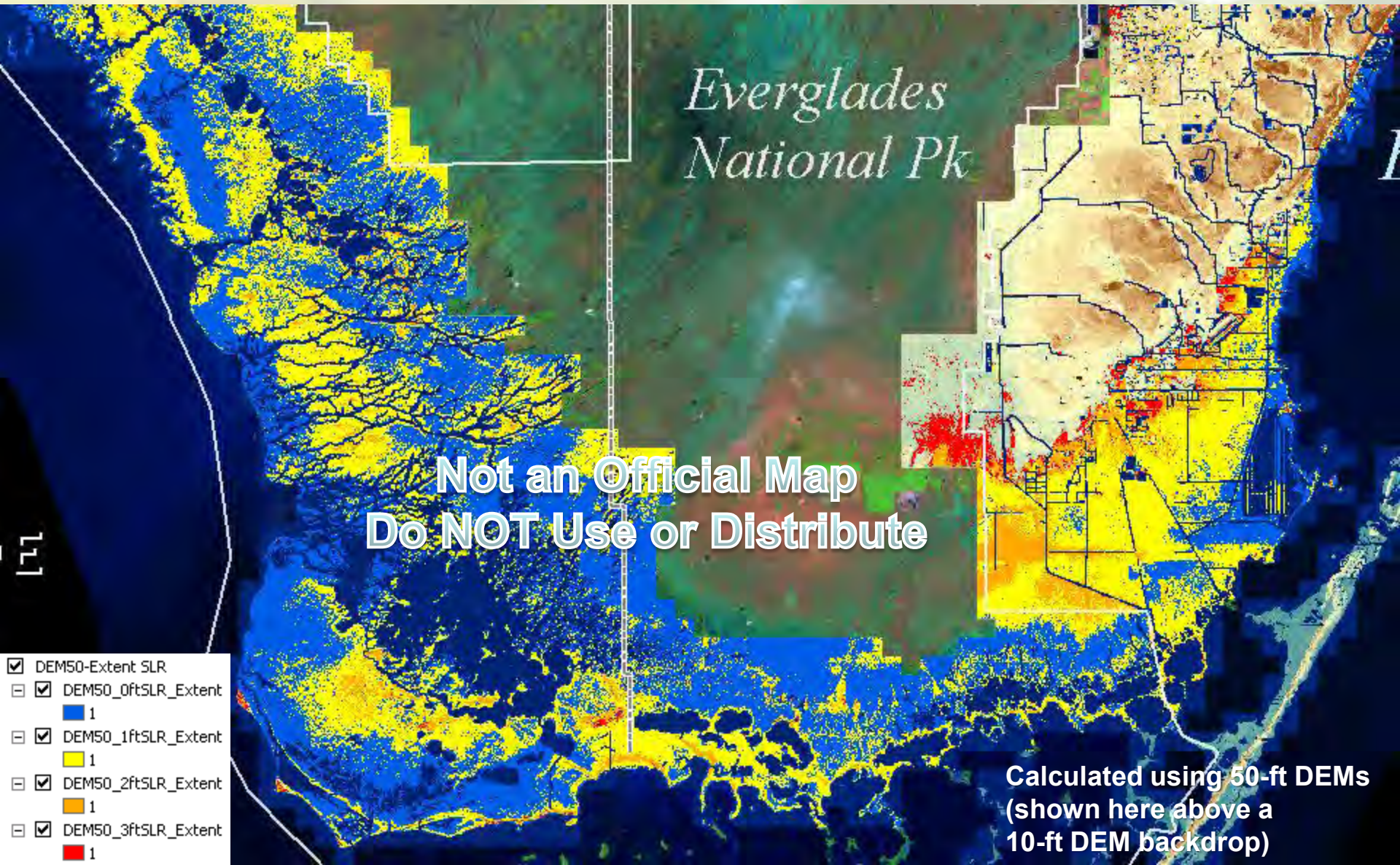
Water Supply and Water Conservation

- Continue looking at opportunities and technologies to reduce amount of additional freshwater needed for water supply
- Look at opportunities to use reuse as a hydraulic barrier
- Implement water conservation measures
- Develop alternative water supply options



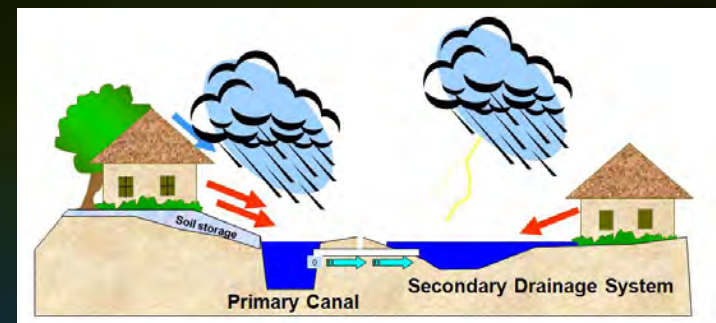
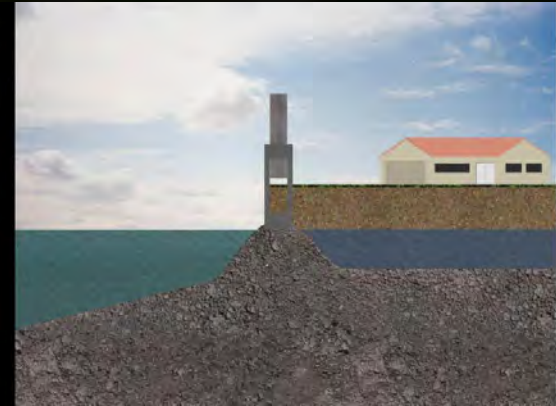
Inundation Mapping

Areas $\leq$ MHHW + SLR Scenario

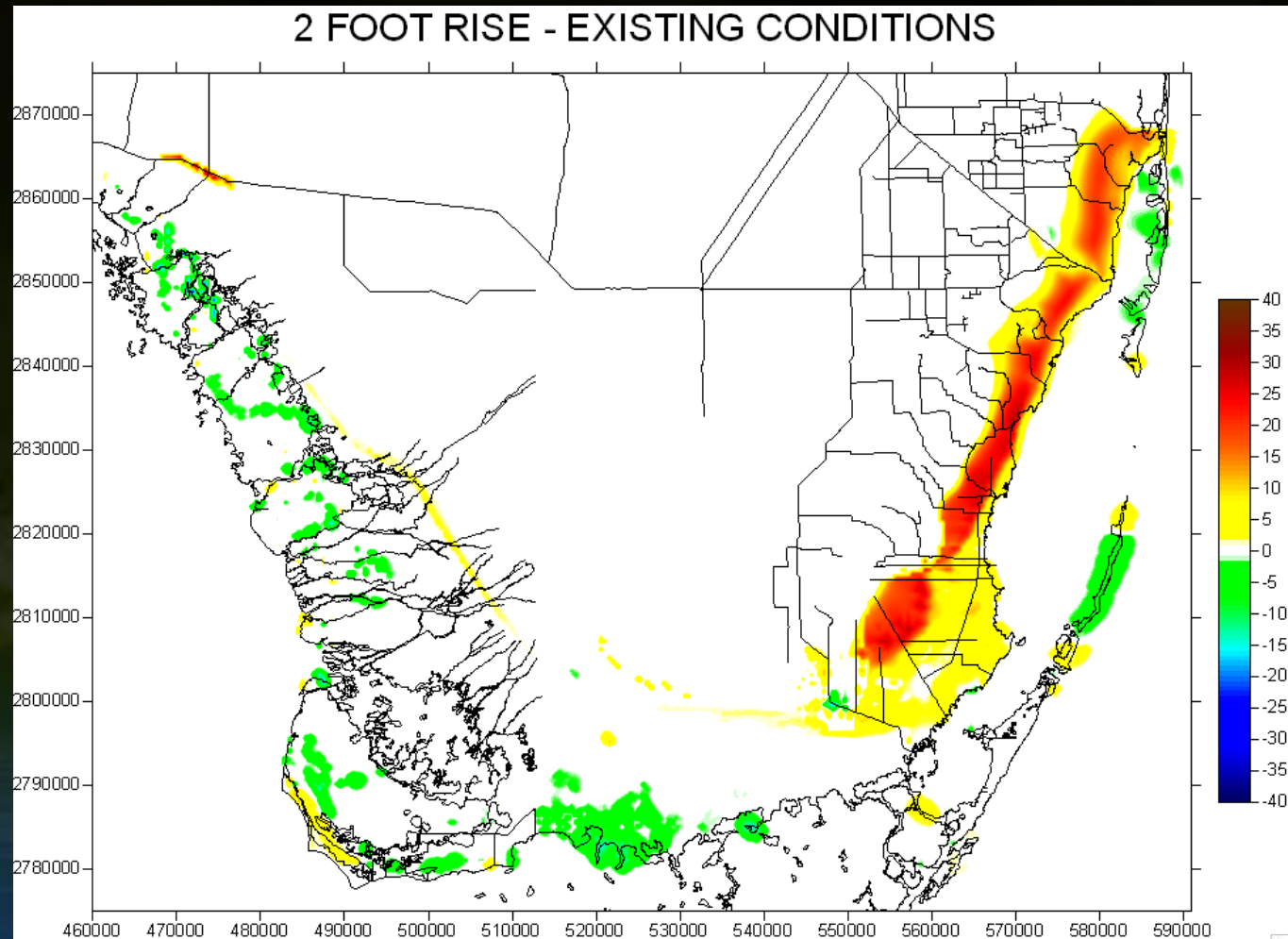


Flood Event Model Development

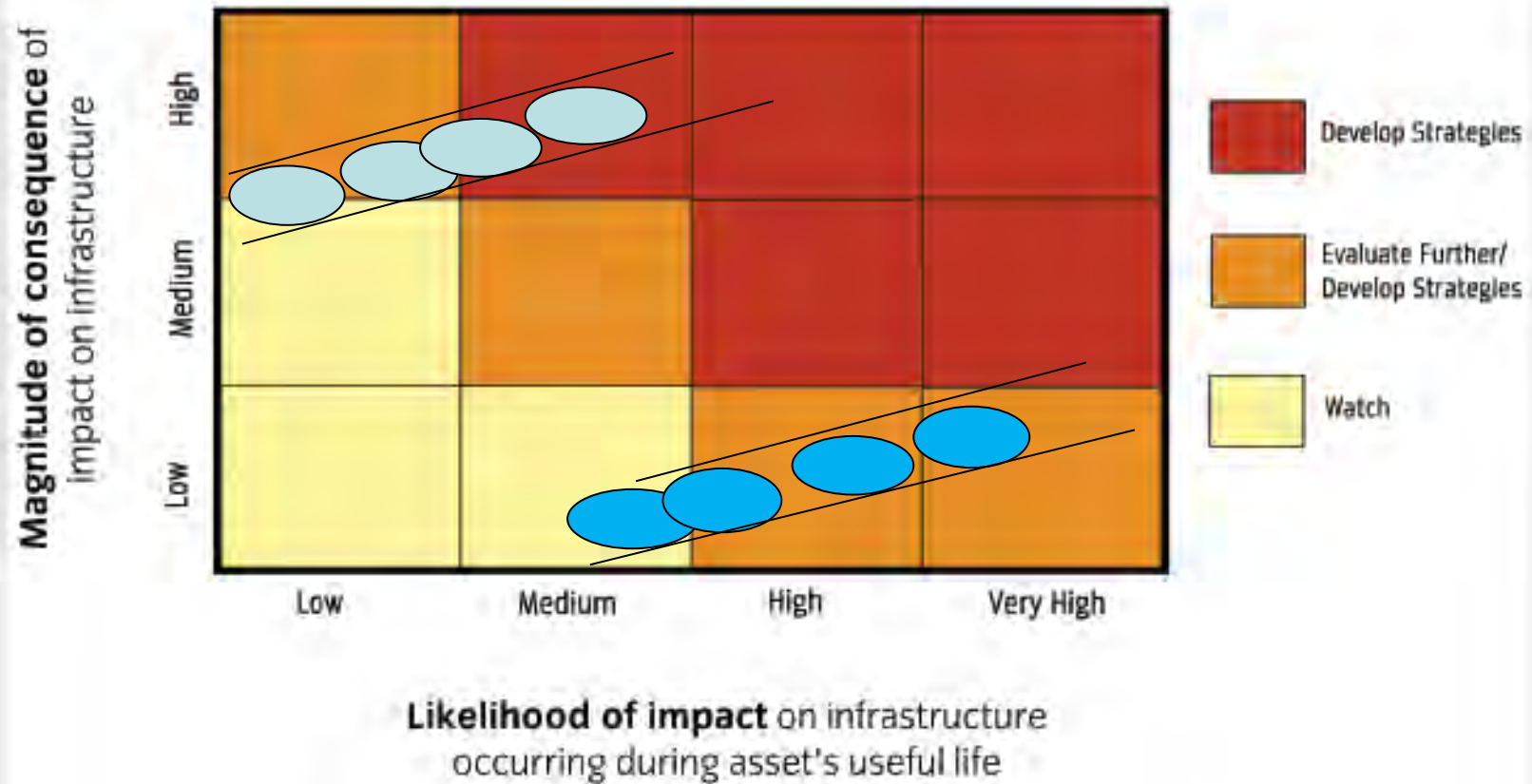
- Collaboration with Hydrologic Engineering Center (\$75K for 3 years)
- Accelerate planned development linking:
 - MODFLOW (groundwater)
 - RAS (canal network model)
- Linkage facilitated through OpenMI (Open Modeling Interface)
- Initial testing in C-4 Basin



Groundwater salinity difference with two-foot sea-level rise



Risk Management

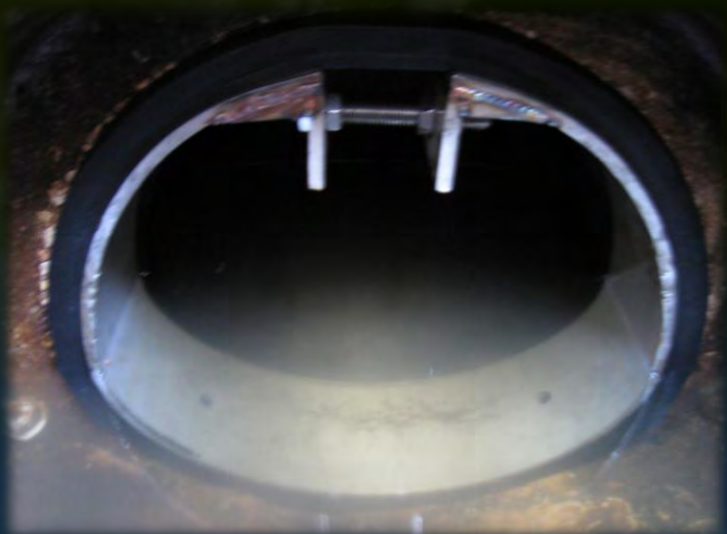
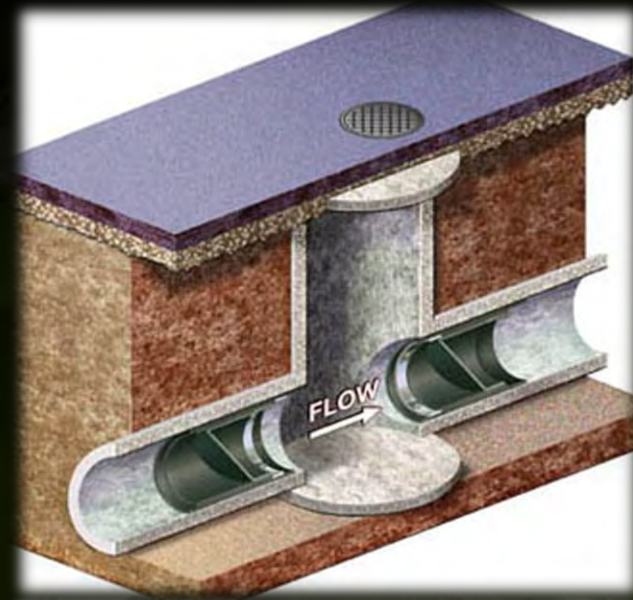
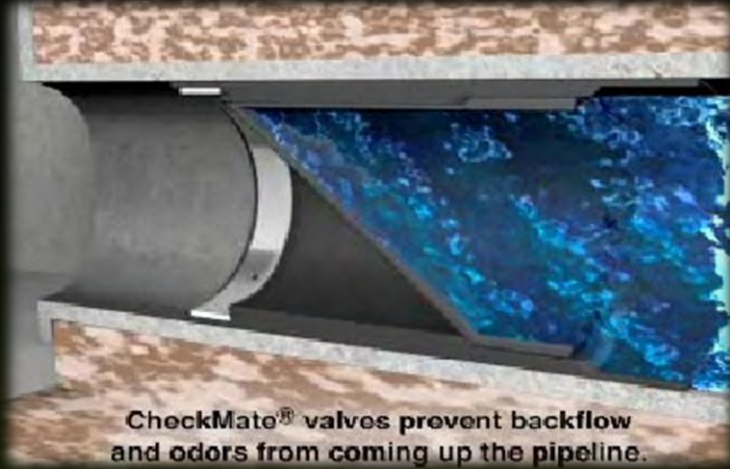


Questions!

Recent cabinet meeting of the island nation, Maldives

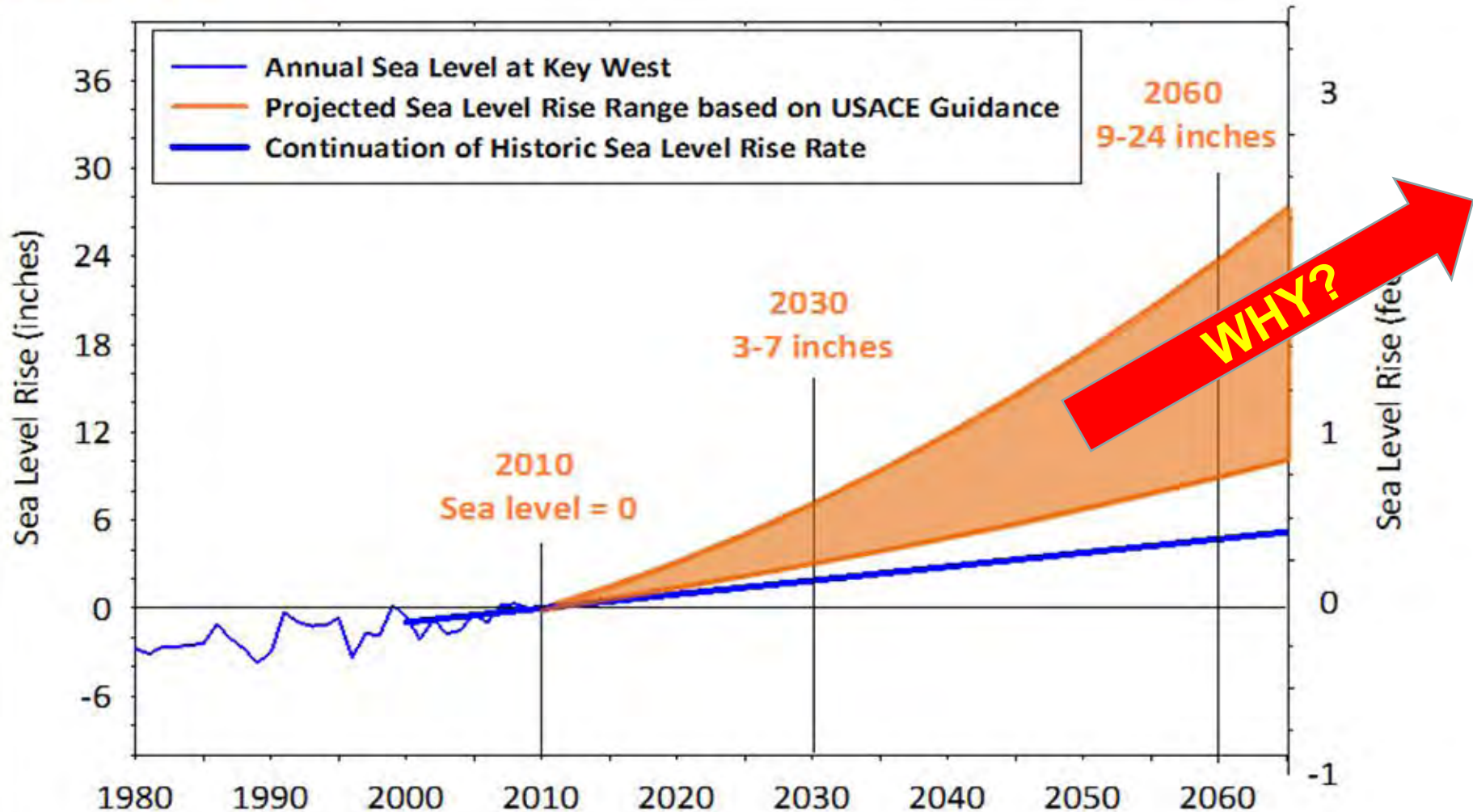


Reverse flow during high-tide: A simple adaptation strategy





SE Florida SLR Projection

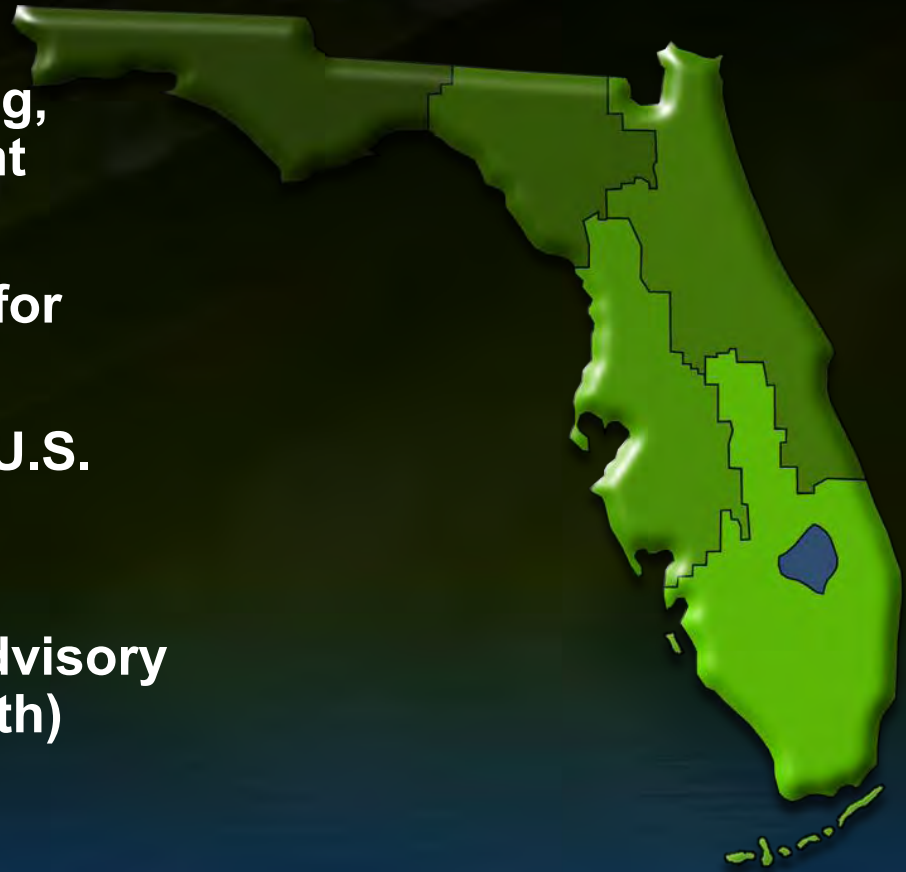


PAST: 8-10 inch/century

FUTURE: 1 foot rise by 2040-207

SFWMD & I

- Chief Modeler, Hydrologic & Environmental Systems Modeling, South Florida Water Management District
- Technical lead, Climate Change for SFWMD
- Member, two committees of the U.S. National Academy of Science
- Member, U.S. National Climate Assessment Development & Advisory Committee (appointed this month)



Four-County Climate Change Planning Post-Disaster Redevelopment

**2011 APA FLORIDA
ANNUAL CONFERENCE**

September 7-10, 2011
The Breakers, Palm Beach

Post-Disaster Redevelopment Plans

- A Concurrent State Effort of Pilot Projects guiding local solutions
- Funded by a grant from FEMA
- Applicable in Adaptation Action Areas and wherever natural hazard strikes
- Should be coordinated with the Regional Action Plan

Post-Disaster Redevelopment Recent Initiatives

- 2006 PBC Adopts a Countywide PDR Plan
- 2007 state-wide pilot projects based on PBC's PDR Plan
- State Publishes Guidebook: "Post-disaster Redevelopment Planning: A Guide for Florida Communities"

Post-Disaster Redevelopment Project Next Phases

- Phase IV: Implementation, maintenance & updates of adopted plans
- Phase V : Incorporation of climate change factors – PBC selected as Pilot Community
- Expected completion time end of 2011

Palm Beach County PDRP

- Comprehensive Guideline for Pre- and Post Disaster Actions
- Involves working groups from public and private sectors, homeowners and businesses, from planning through implementation and activation
- Incorporates detailed Pre-Disaster & Post-Disaster actions for the short and long terms for several disaster levels

PDRP Action Plan Matrix

- PDRP Action Plan is comprised of multiple, complex matrix series organized by the factors mentioned above and identifying:
 - Responsible working group
 - Issue or Topic areas
 - Specific Action(s)
 - Disaster Level
 - Jurisdictions involved
 - Funding Considerations and timeframes

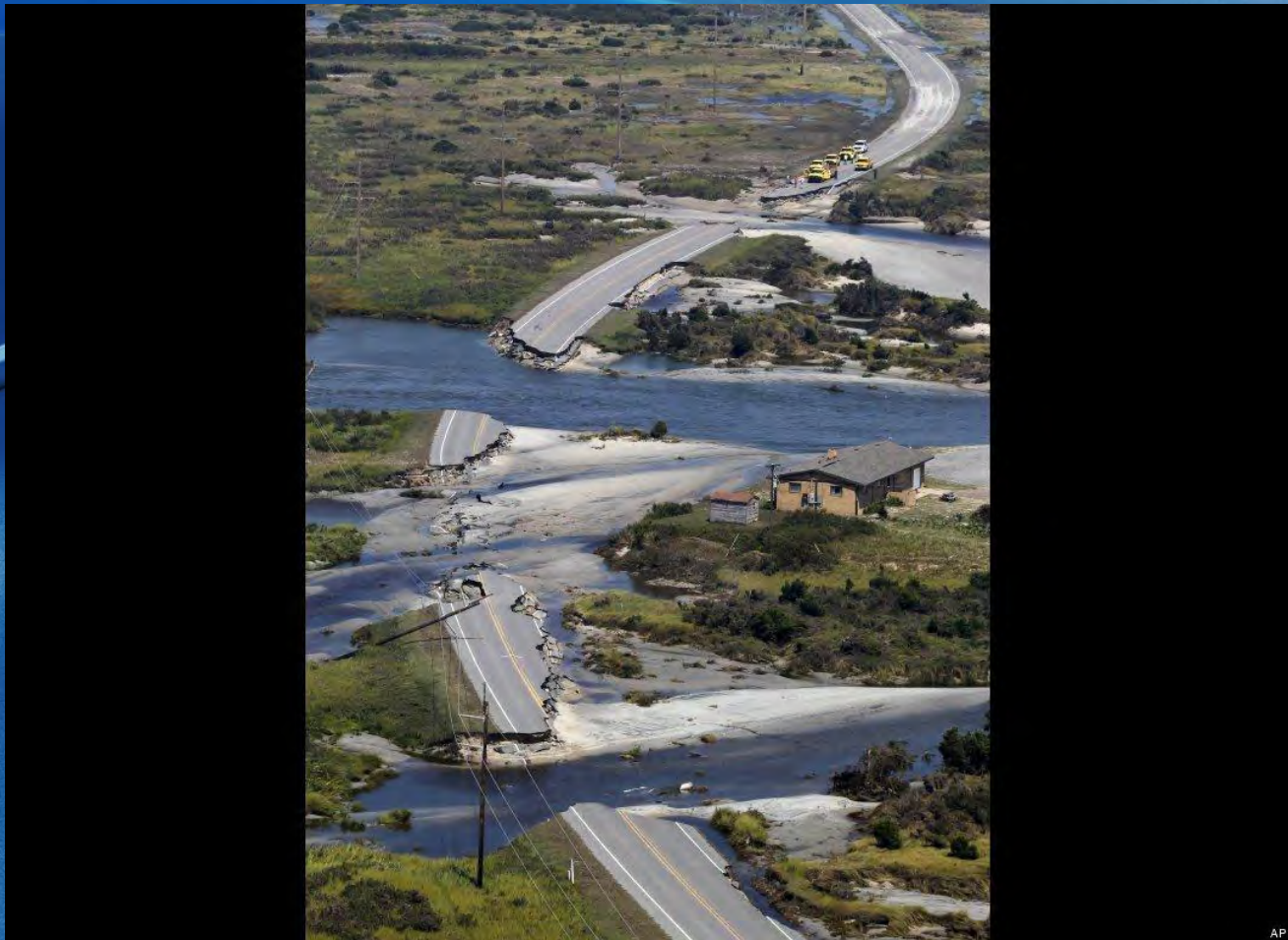
Incorporating Climate Change into PDRP

- Joint effort of Palm Beach, Broward, Miami-Dade and Monroe counties
- Regional Climate Change Action Plan
- Adaptation Action Areas

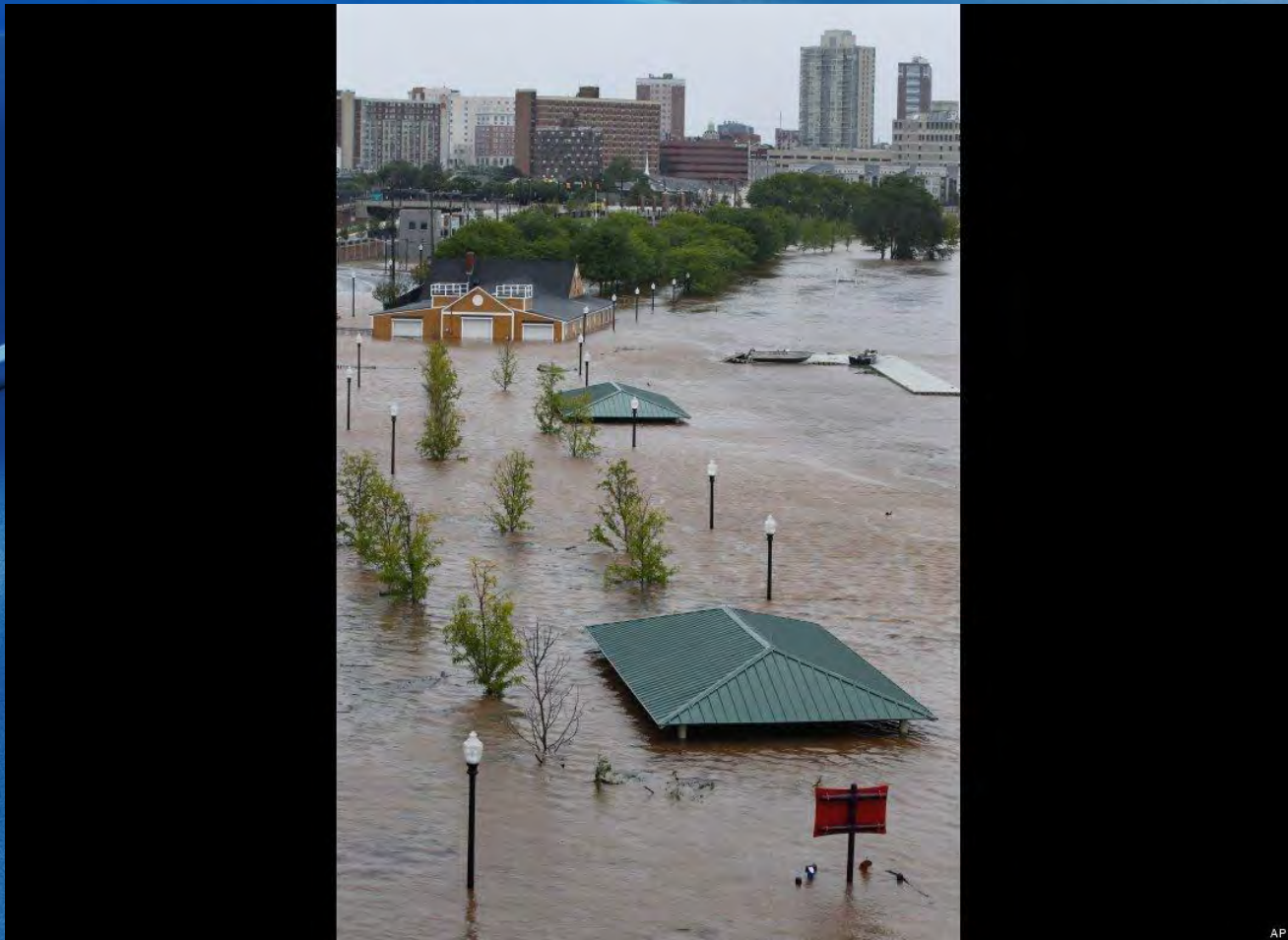
Climate Change Factors to consider in PDRPs

- Sea Level Rise (SLR) with dramatic long-term implications for coastal communities
- Heightened Cyclonic activity
- Severe droughts and extended rainy seasons

Irene – NC Aug 2011



Irene – NJ Aug 2011



Irene – Soho/Manhattan Aug 2011



Irene – Mass. Aug 2011



Irene – Conn. Aug 2011



Typhoon Talas – Japan Sep 2011



Tohoku –Earthquake & Tsunami



Missouri Tornadoes - 2010



Tennessee Flooding 2010



Colombia Floods – Early 2011



La Nina Floods – S. Africa

Early 2011



Venice, Italy Flooding



Texas Wildfire – Sep 2011



Tropical Storm Lee Hits New Orleans- Sep 2011



Linking Climate Change Issues and Opportunities

- Short and long-term approach of PDRPs an opportunity to address SLR and other hazardous events
- Ideal to incorporate climate change factors after regional action plan is unveiled
- PDRPs should have consistent implementation throughout the region

Linking Climate Change Issues and Opportunities

- PDRPs provide redevelopment guidelines but need to be supported by specific local policies
- County coordination with local governments critical challenge
- PDRPs must balance the immediate need to rebuild homes and businesses on site with decisions to relocate them out of vulnerable areas

Links

Post Disaster Redevelopment:

DCA: <http://www.dca.state.fl.us/fdcp/dcp/PDRP/index.cfm>

PBC:

<http://www.pbcgov.com/publicsafety/emergencymanagement/programs/planning/postdisredev.htm>

Climate Change Compact:

Palm Beach: <http://www.pbcgov.com/gogreen/>

Broward:

<http://www.broward.org/NATURALRESOURCES/CLIMATECHANGE/Pages/SoutheastFloridaRegionalClimateCompact.aspx>

Miami-Dade: <http://green.miamidade.gov/climatechangesummit.htm>

Monroe: <http://fl-monroecounty.civicplus.com/index.aspx?nid=386>



The Southeast Florida Regional Climate Change Compact

***Jennifer Jurado, Ph.D., Director
Broward County
Natural Resources Planning and Management Division***

***Presented to:
Florida APA
September 8, 2011***

Overview



- Background
- Elements of the Compact
- Compact Implementation
- Next Steps

Characteristics Across Borders



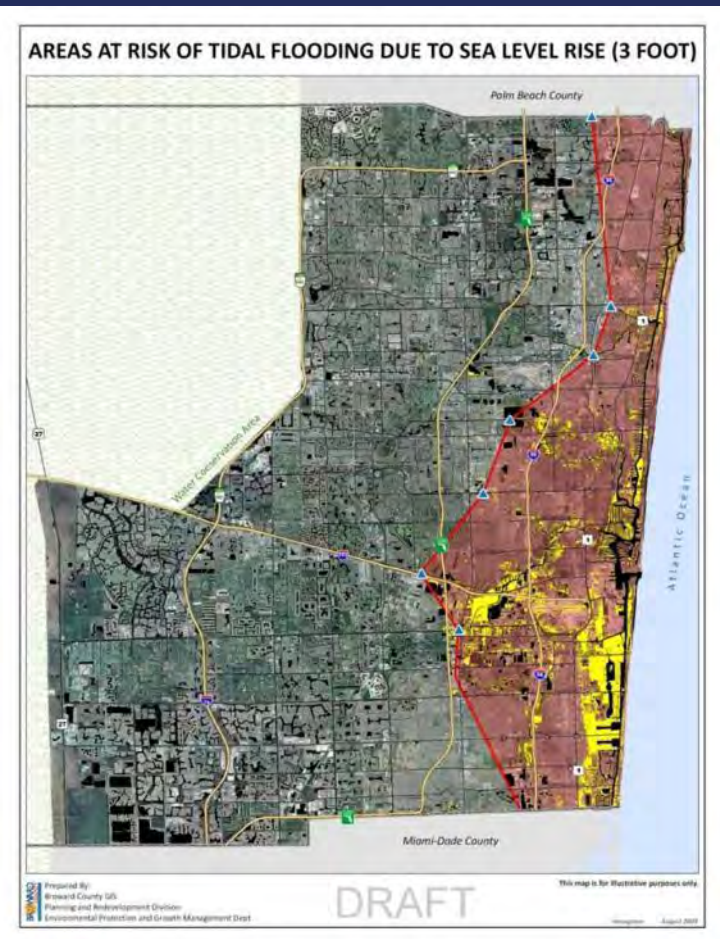
- Low lying coastal community
- Tourist-based economy
- Natural resources of national significance
 - Everglades ecosystem
 - Biscayne National Park
 - Coral reefs including Florida Keys National Marine Sanctuary
- Common airshed, watershed, and climate
- Regional transportation system

Common Region/Different Approaches

e.g. Vulnerability Analysis

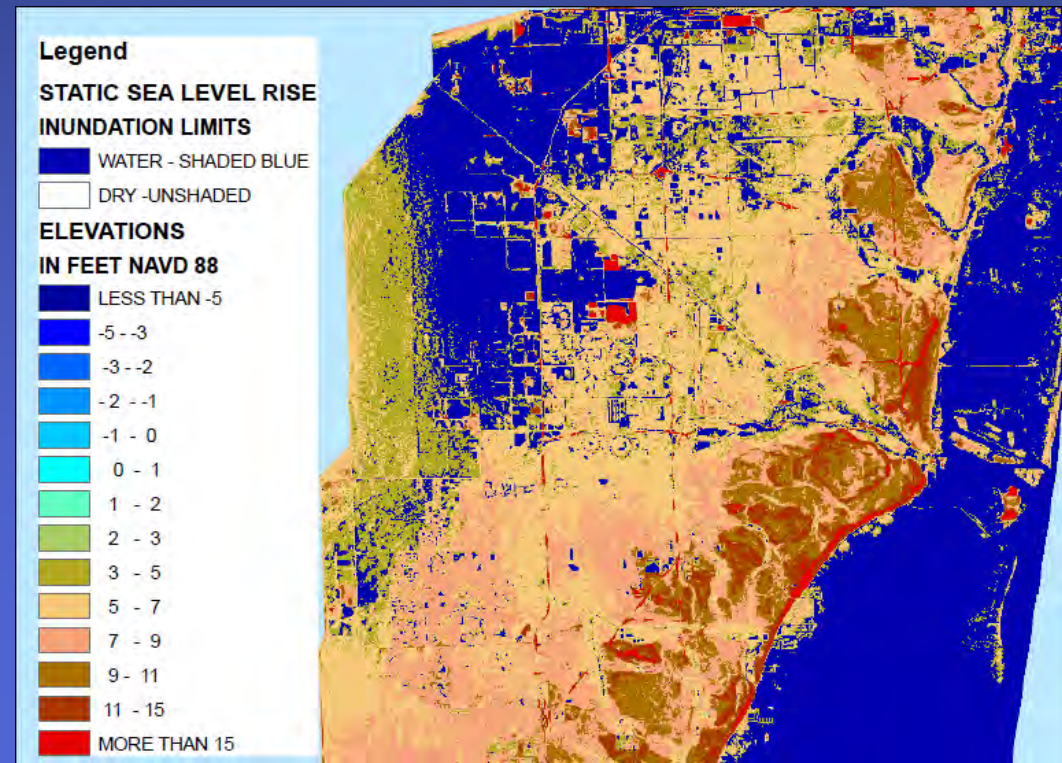
Miami-Dade

- Impacts reviewed based on land elevation
- 1, 2 and 4 foot scenarios used

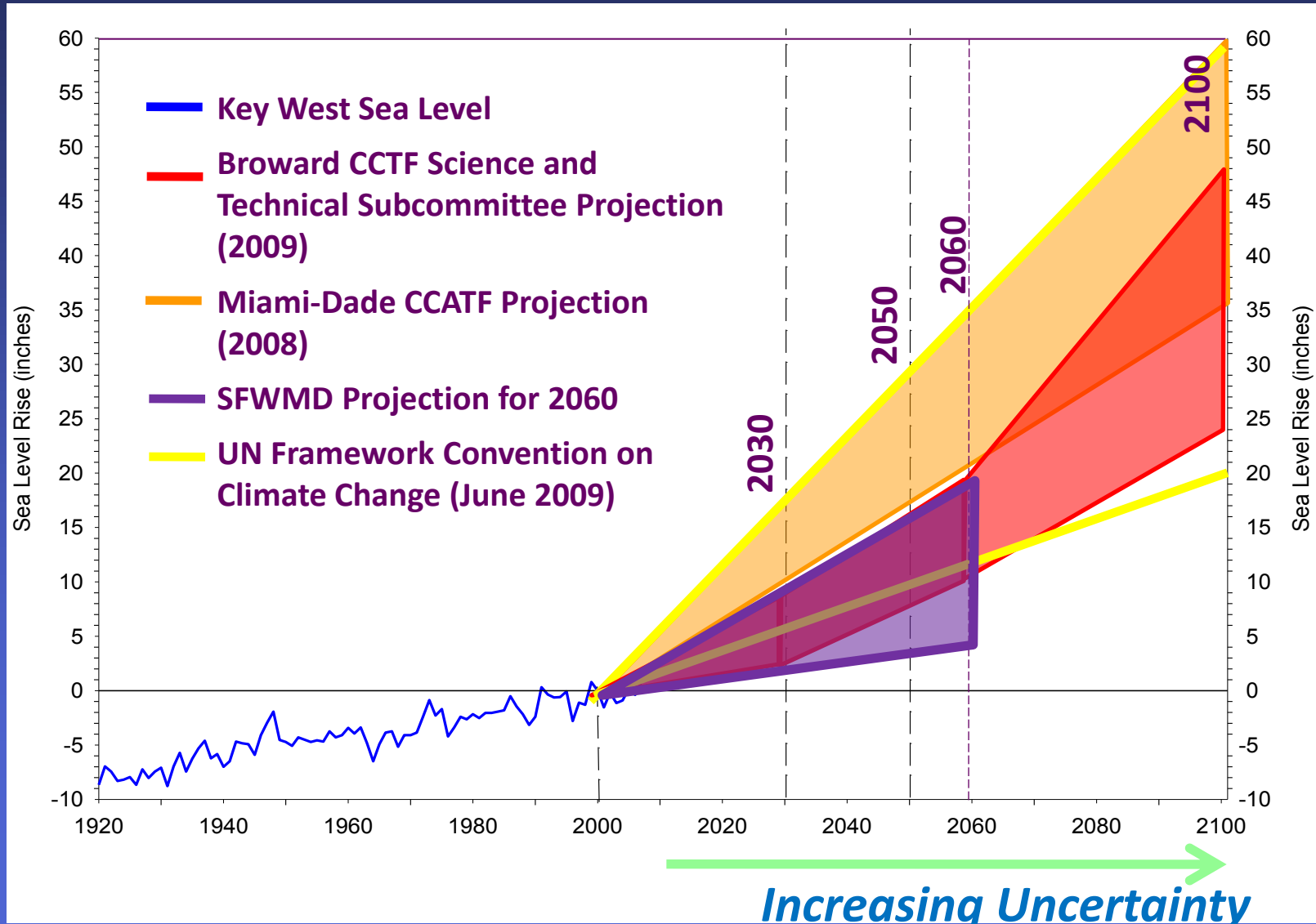


Broward

- Impacts reviewed for tidal area
- 1, 2 and 3 foot scenarios used



Common Region/Different Approaches e.g. Sea level Rise Projections





Southeast Florida Regional Climate Leadership Summit

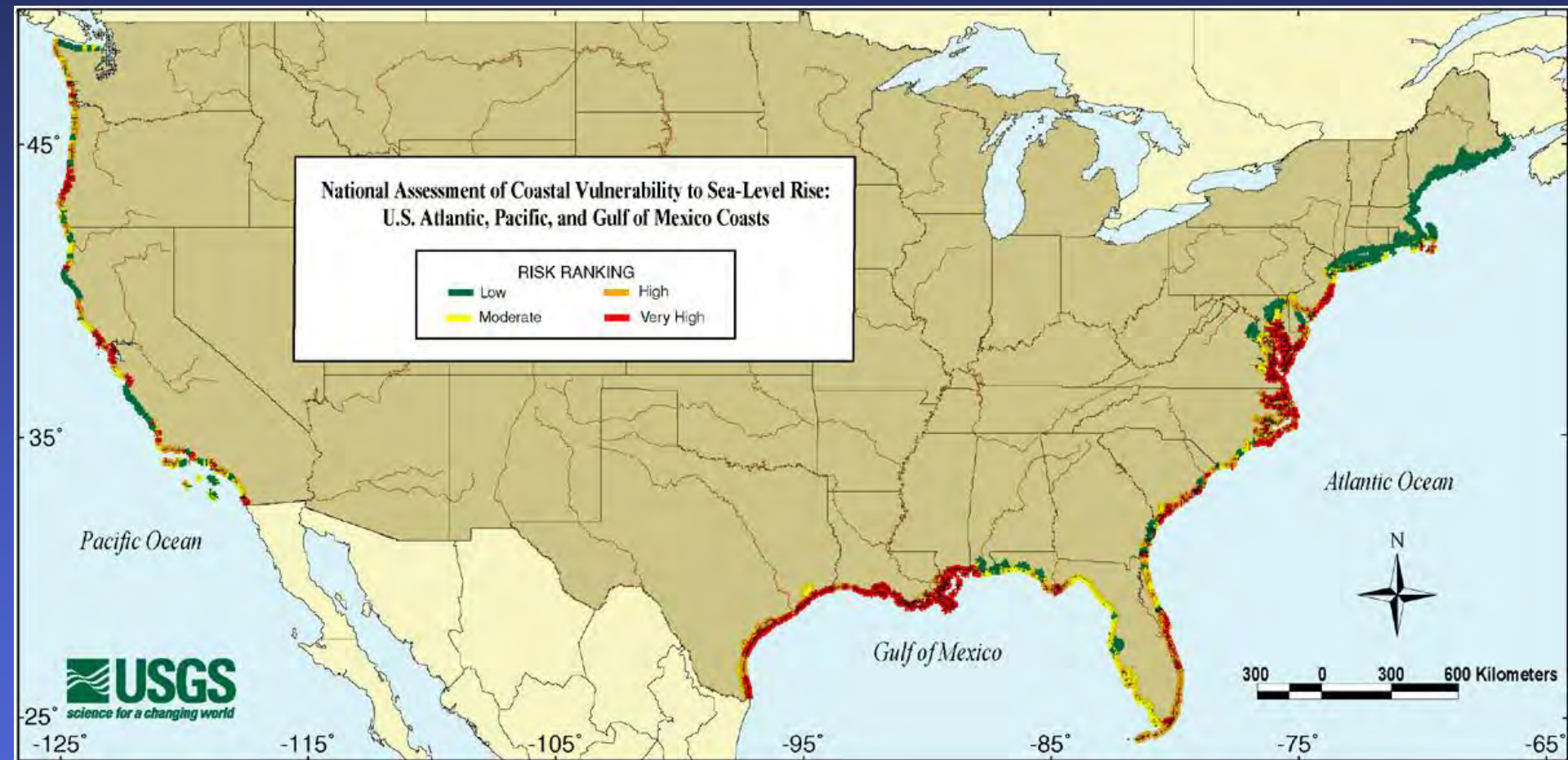
Friday, October 23, 2009



Coordination of a Summit

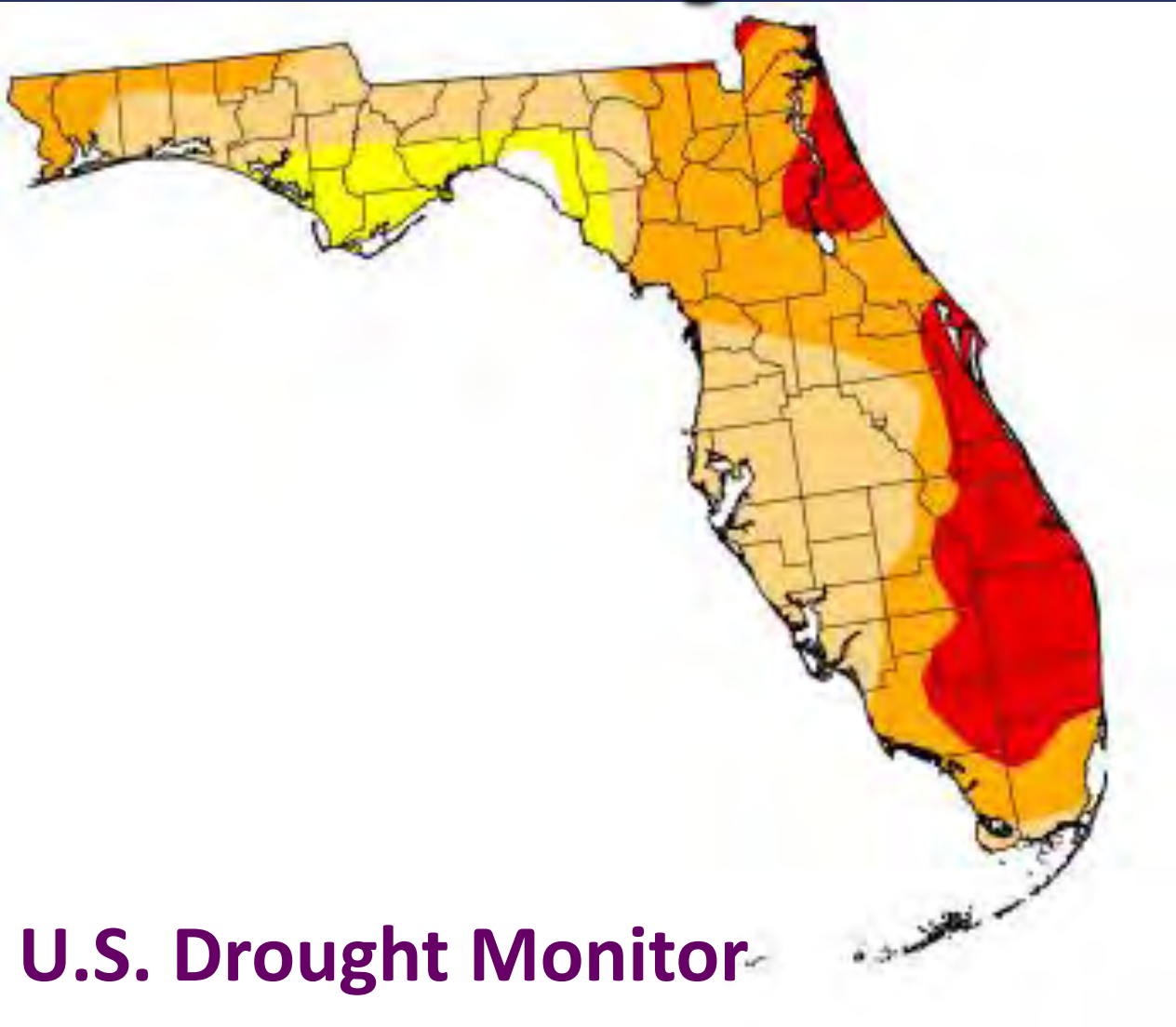
- 300 participants
- Elected officials
 - Federal
 - State
 - County
 - Municipal
- 34 municipalities
- Members of green teams & task forces

Water Resources and Climate Change



Red zones indicate high vulnerability to sea level rise.

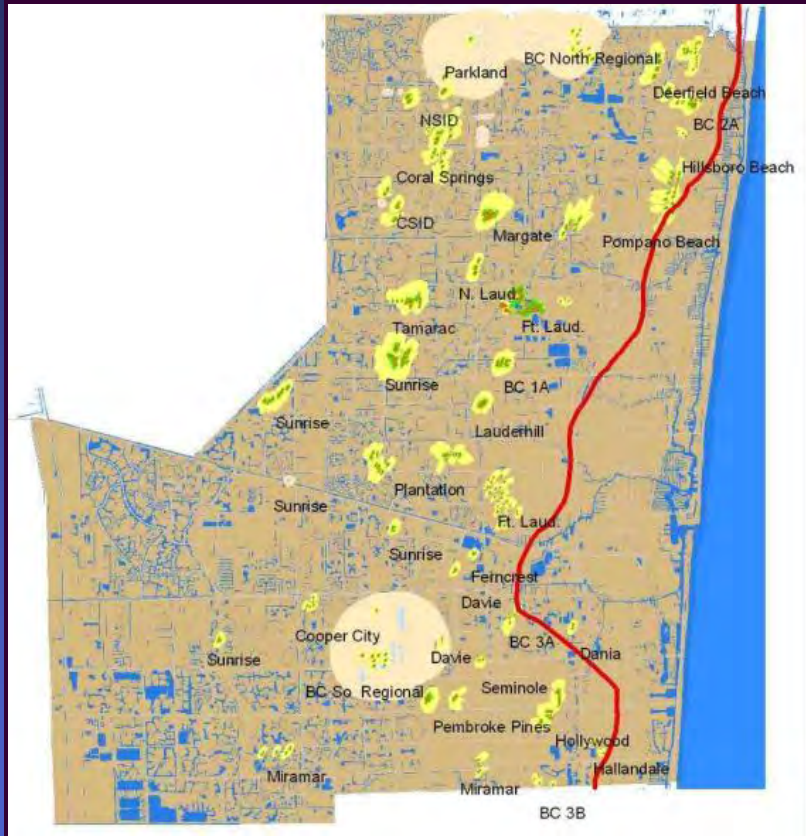
Extreme Weather Drought Conditions



- 4 droughts in last decade

U.S. Drought Monitor

Threatened Potable Water Supplies

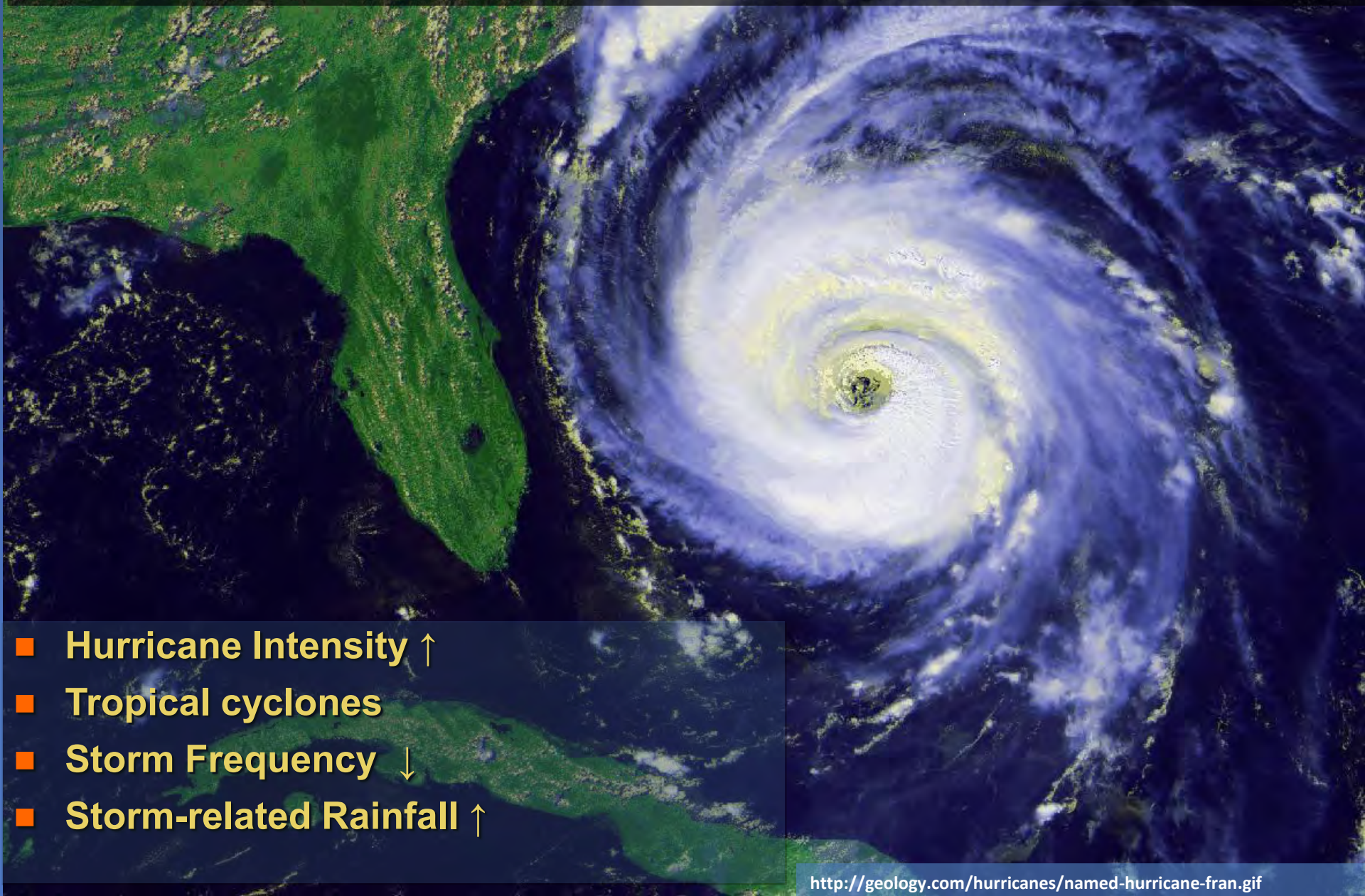


Saltwater
intrusion into the
aquifer

Regional drought



Extreme Storm Events



- Hurricane Intensity ↑
- Tropical cyclones
- Storm Frequency ↓
- Storm-related Rainfall ↑

Extreme Weather Rain Events



Photo: Sun
Sentinel

8-16 inches rainfall

Tidal Flooding

8 inches above average high tide



•Las Olas Isles



•Isle of Capri Drive



•Coral Way



Tidal Flooding





Tidal Flooding





Regional Summit Program



Exhibits by sponsors



Presentations by national experts



Panels on climate change initiatives



Panel on how to move forward regionally

Summit Deliverable

SE Florida Regional Climate Change Compact

- Adoption by the four County Commissions finalized by unanimous votes – January 2010
- Compact Commitments
 - Develop and further federal and state policies
 - Convene a Regional Climate Team
 - Develop a Regional Climate Change Action Plan
 - Regional Baselines
 - Mitigation and Adaptation Strategies
 - Host Annual Climate Summit



Compact Steering Committee and Collaborating Partners

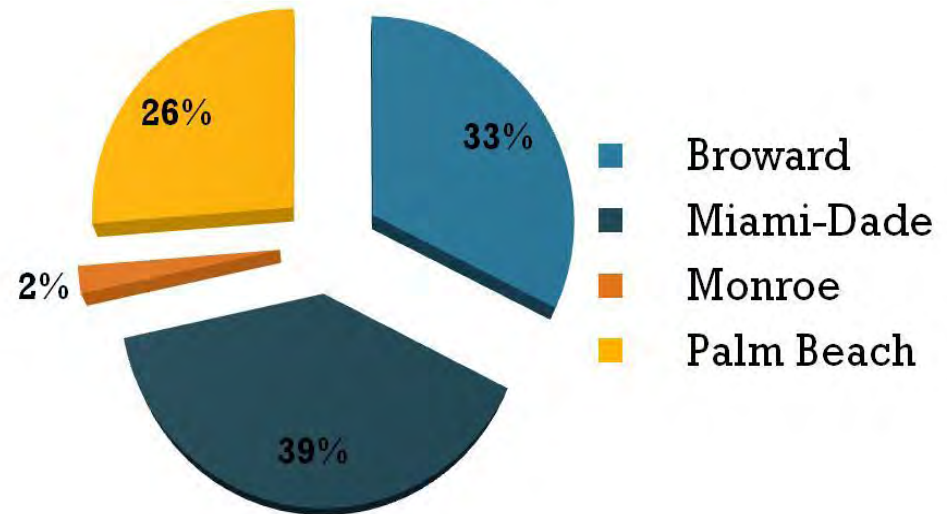


Regional GHG Emissions Inventory

GHG Work Group

- Cooperative Data Collection
- Summary for years 2005-2008
- Regional comparative analysis of emissions
- Create a baseline for planning efforts

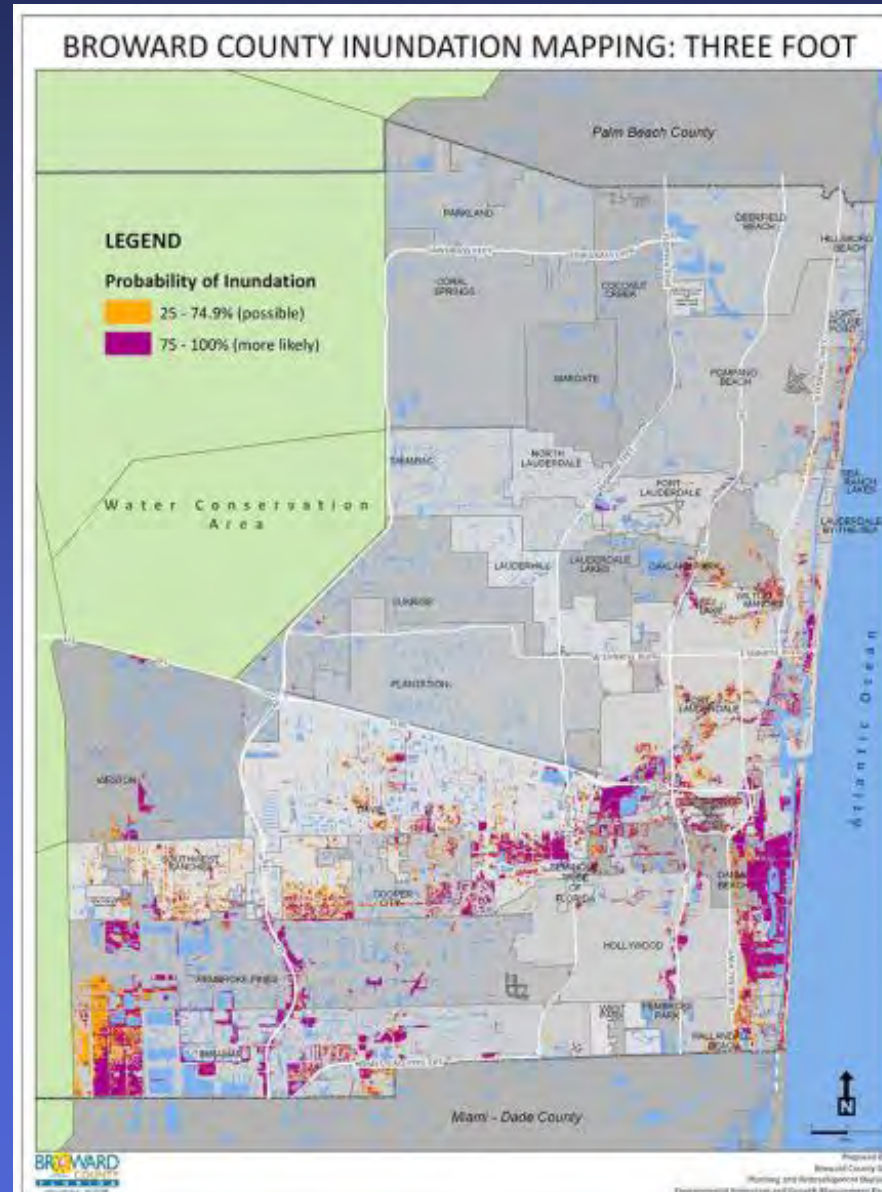
Regional Emissions – Residential Electricity Emissions (2008)



Regional Vulnerability Assessment

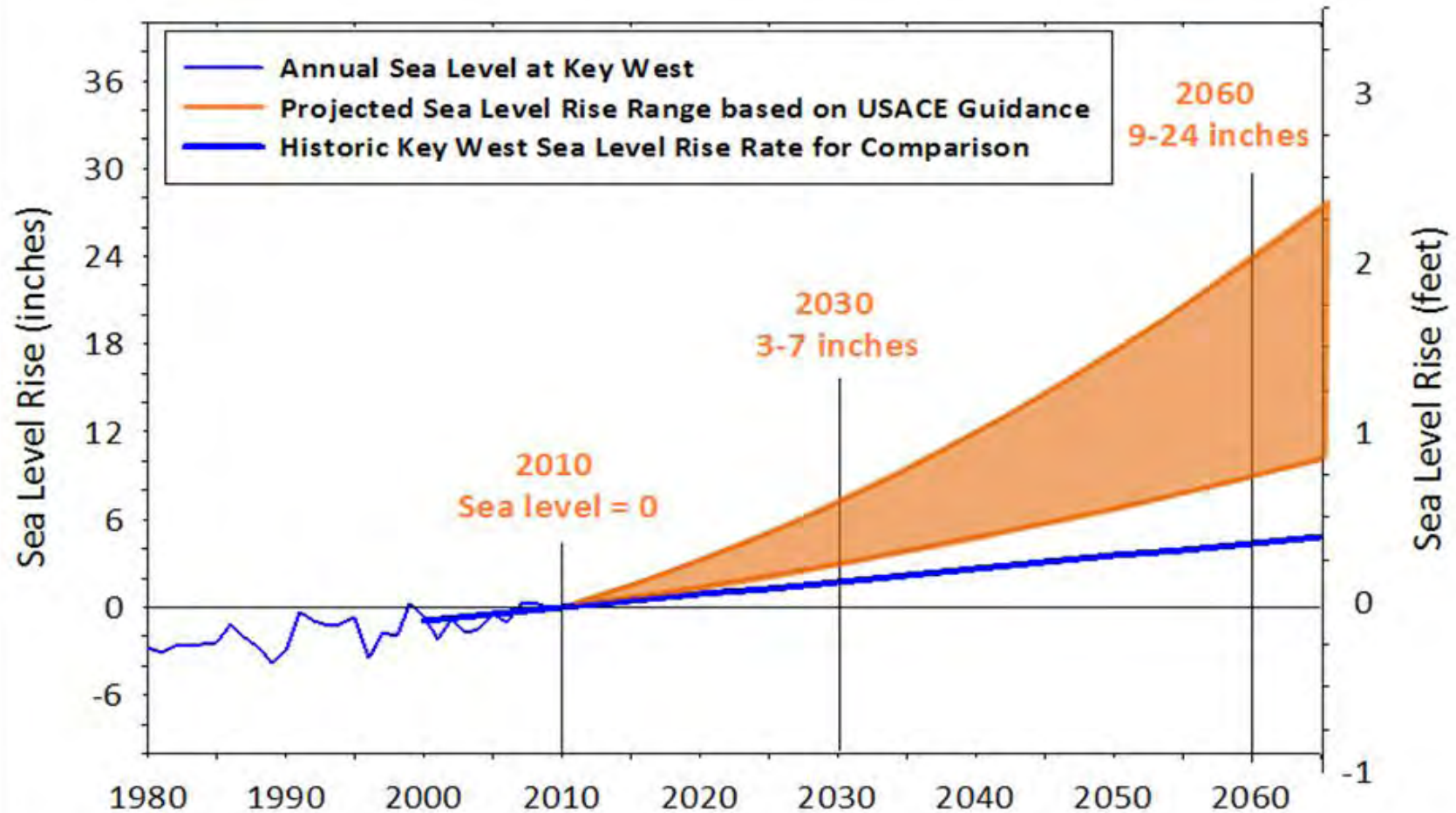
Vulnerability Work Group

- **Advances in the regional vulnerability analysis**
 - Completion of the digital elevation modeling
 - Agreement on assessment intervals (1, 2, and 3 feet)
 - Prioritization of infrastructure for analysis
 - Tested application of protocol by Broward
 - Regional presentations
 - Agreed upon refinements



Unified Sea Level Rise Projection

Sea Level Rise Work Group



Regional Policy Coordination and Advocacy

2011 Community Planning Act “Adaptation Action Areas”

Congress of the United States
Washington, DC 20515
May 13, 2011

The Honorable Rodney Frelinghuysen
Chairman
House Appropriations Committee
Subcommittee on Energy and Water
2362-B Rayburn House Office Building
Washington, DC 20515

The Honorable Pete Visclosky
Ranking Member
House Appropriations Committee
Subcommittee on Energy and Water
1016 Longworth House Office Building
Washington, DC 20515

Dear Chairman Frelinghuysen and Ranking Member Visclosky:

As you begin work on the Fiscal Year 2012 Energy and Water Appropriations bill, we respectfully request you to include language with the Army Corps of Engineers enabling at-risk, multi-county regions impacted by rising sea levels to develop long-term plans for adaptation.

Scientists around the world and within our most respected institutions note an alarming level in sea level rise, possibly by several feet over the next century. This will inundate low-lying coastal zones, impacting hundreds of millions of people worldwide and tens of millions of Americans here at home. Our states and local communities are just beginning to grapple with the possible effects of what this kind of massive, permanent flooding will mean. It is critical that local leaders be given the necessary tools to start planning now, so that our communities will have enough time to prepare for these life-altering effects.

We request that the following language be inserted into the Army Corps of Engineer's Operations & Maintenance account, or whichever account you feel is most relevant:

"Funds will be used to study, define and designate several "Adaptation Action Areas," which are at-risk, multi-county, regions of the country, uniquely vulnerable and significantly impacted by rising sea level."

We hope that this language will enable regional groups to begin effectively strategizing and planning for adaptation, to sea level rise. We thank you for your consideration of this important request.

Sincerely,



Alice L. Hastings
Member of Congress



Ted Deutch
Member of Congress



Debbie Wasserman Schultz
Member of Congress

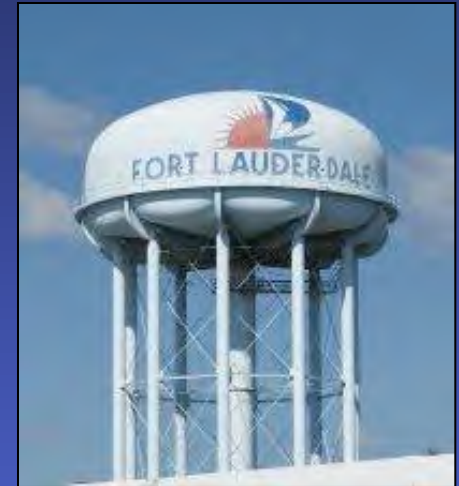


Frederica Wilson
Member of Congress

“...study, define and designate several “Adaptation Action Areas” which are at-risk, multi-county, regions of the country, uniquely vulnerable and significantly impacted by rising sea level.”

Regional Compact Work Groups

- Built Environment, Transportation, and Land and Natural Systems Workgroups
- Focus on areas where regional approach enhances efficiency and effectiveness
- Common Themes:
 - Priority Planning / Adaptation Action Areas
 - Water resources and drainage
 - Energy use, production, and distribution
 - Hazard mitigation
 - Economic development
 - Everglades restoration
 - Outreach and Education



Next Steps

- **September 2011 - Finalize priority recommendations**
- **December 8-9, 2011 - Present recommendations at 3rd Annual Summit**
- **February 2012 – Finalize and seek adoption of regional action plan**
- **Action Plan Implementation**
- **Compact Expansion**

Questions?