Implications of Changing Hydrologic Statistics for Water Management

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('Obey')

Chief Modeler

27th Annual Southwest Florida Water Resources Conference
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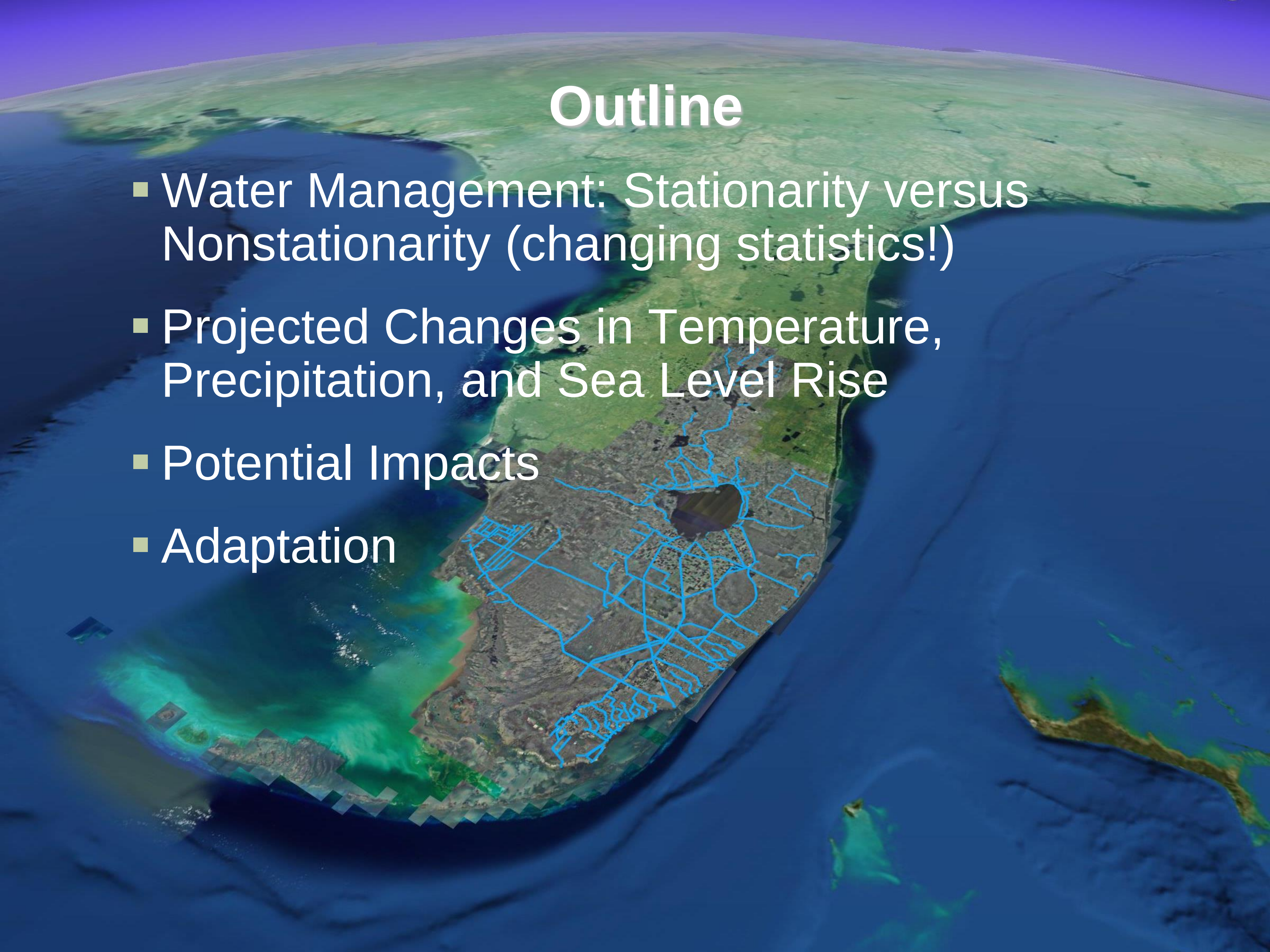


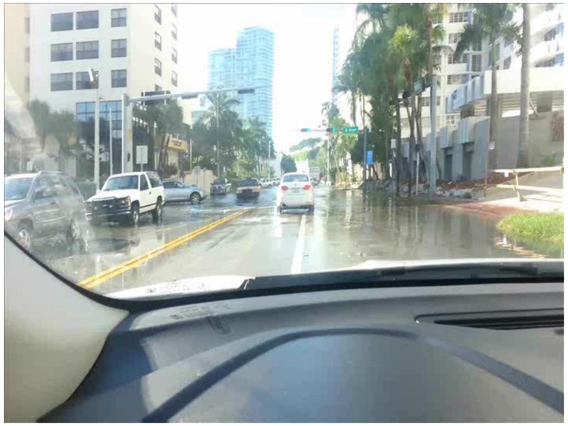
Outline

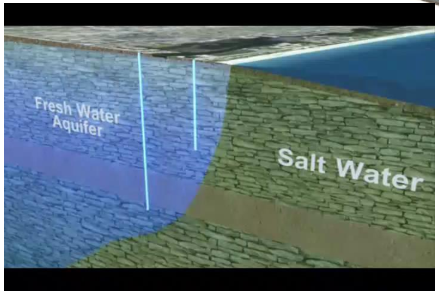
- Water Management: Stationarity versus Nonstationarity (changing statistics!)
- Projected Changes in Temperature, Precipitation, and Sea Level Rise
- Potential Impacts
- Adaptation

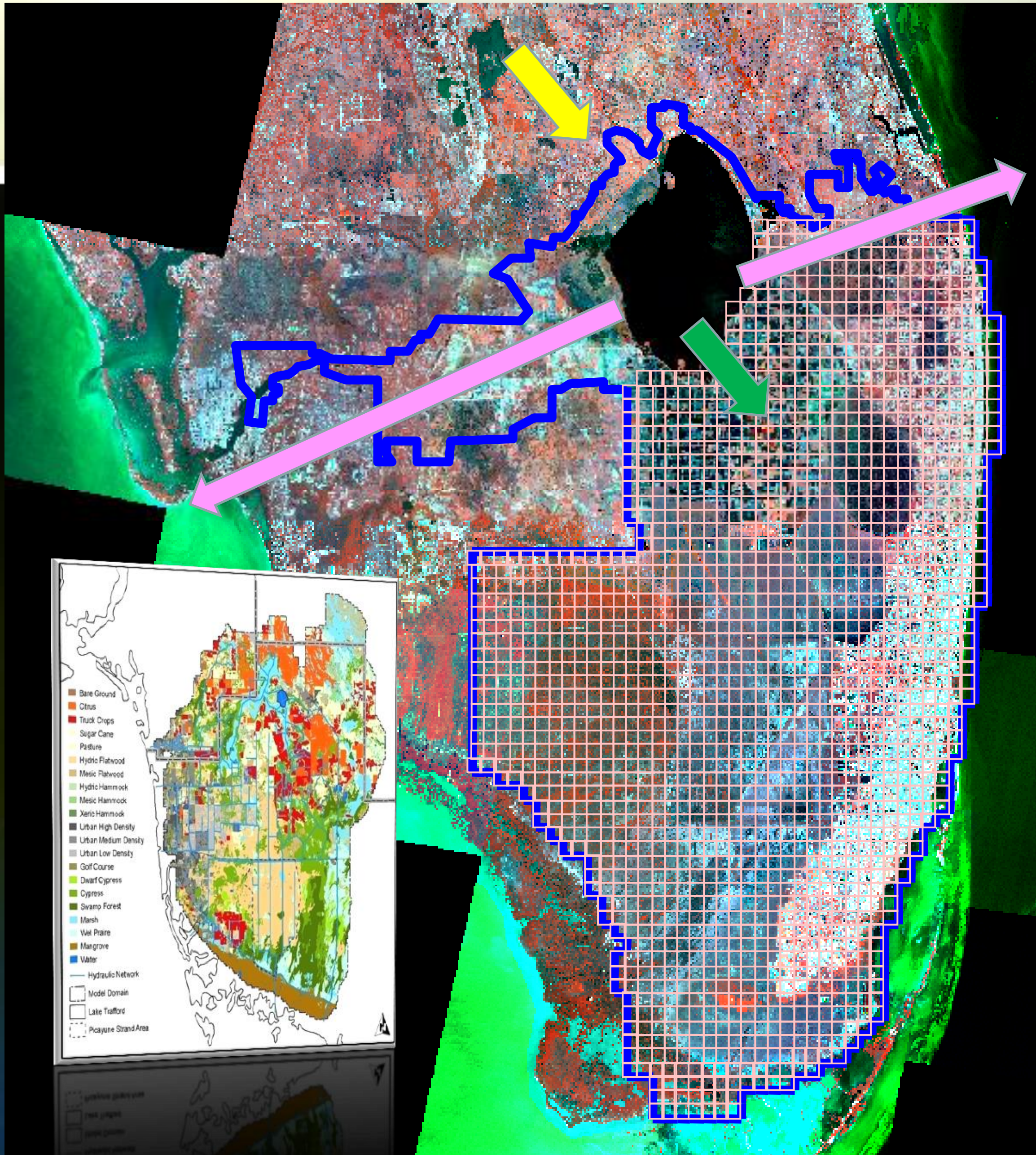
Impacts of Changing Climate and Rising Sea Levels

Drivers/Stressors:

- **Rising Seas**
- Increasing Temperature
- Change in rainfall patterns
- Changes in frequency and strength of hurricanes





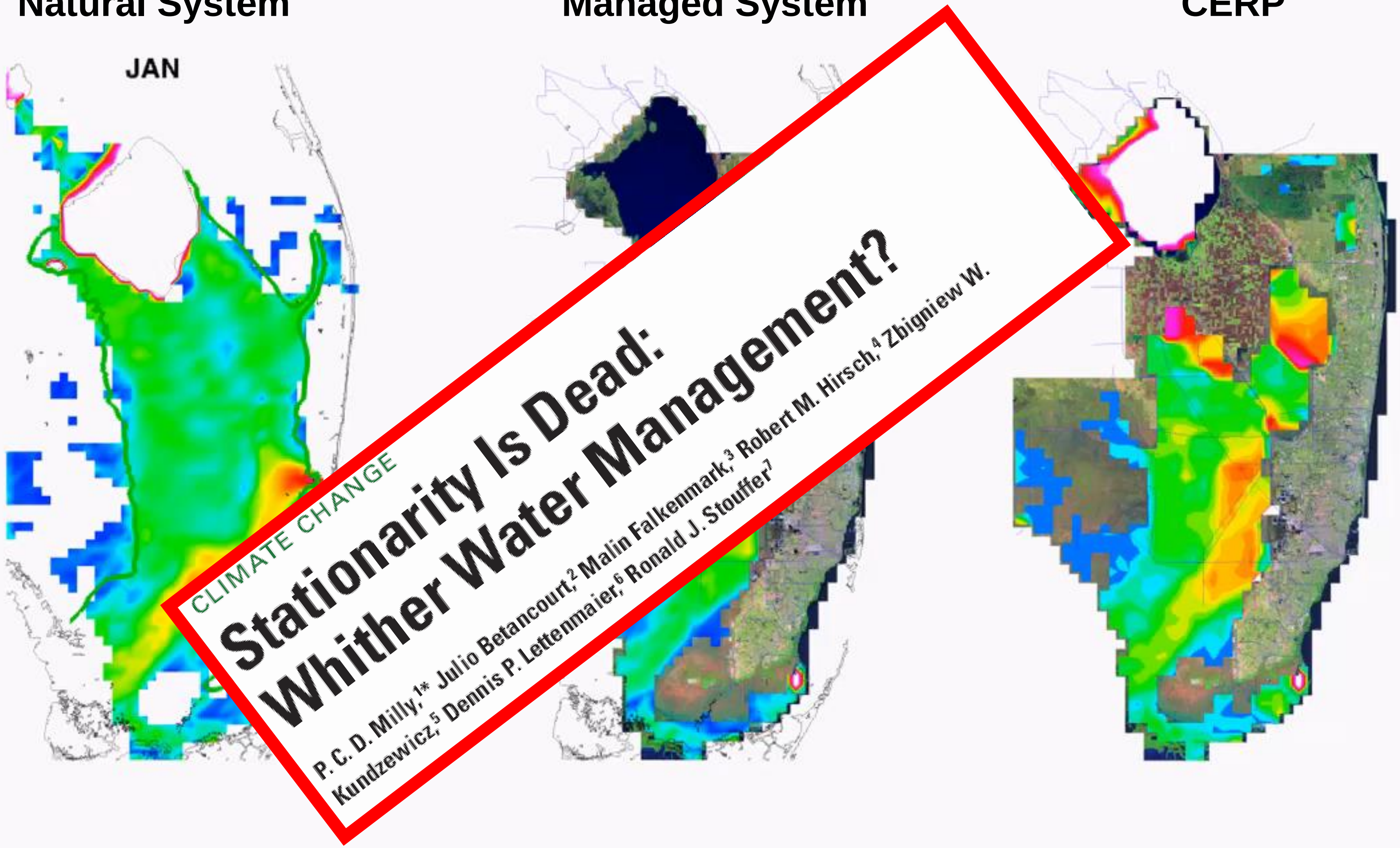


South Florida Water Management Model

- Integrated surface water groundwater model
- Regional-scale 2 mi x 2mi grid, daily time step
- Major components of hydrologic cycle
- Overland and groundwater flow, seepage
- Operations of C&SF system
- Water shortage policies
- Agricultural demands simulated
- Provides input and boundary conditions for other models

Stationarity is Dead-Nonstionarity is deeply uncertain

Natural System | Managed System | CERP



Climate Projection Uncertainties

Natural Variability

General Circulation Model

GCM (IPCC, 2007)

- BCM2
- CGHR
- CGMR
- CNCM3
- CSMK3
- ECHOG
- FGOALS
- GFCM20
- GFCM21
- GIAOM
- INCM3
- IPCM4
- MIHR
- MIMR
- MPEH5
- NCCCSM
- NCPCM

Downscaling

Statistical

- Constructed Analogues (CA)
- Bias Correction and Spatial Downscaling (BCSD)
- Weather Generators

Dynamical

- Regional Climate Models (RCMs)

Ice Sheet Dynamics

Model Uncertainty and Spread

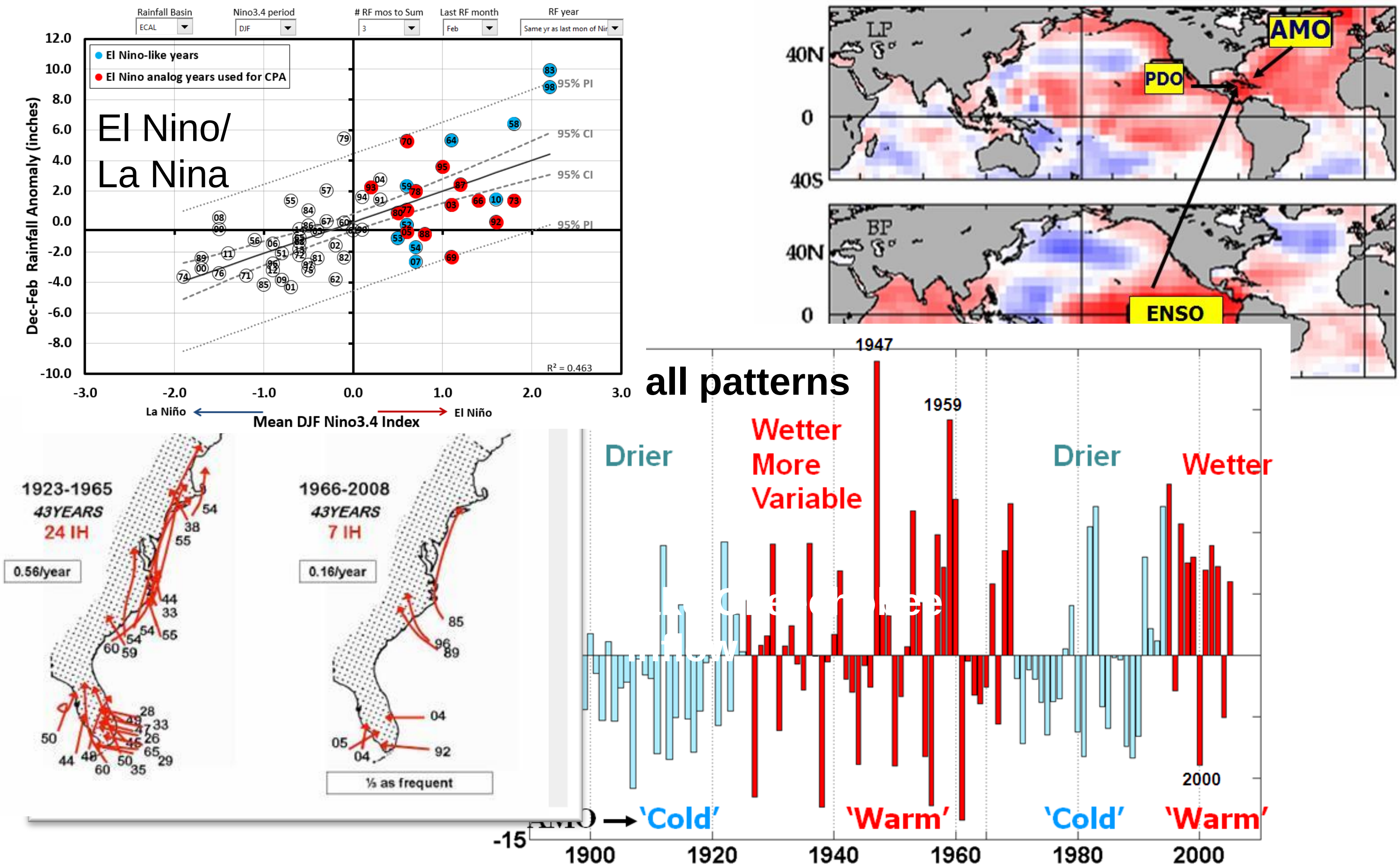
Scenarios (2081-2100)			
RCP2.6	RCP4.5	RCP6.0	RCP8.5
0.3-1.7 (°C)	1.1-2.6 (°C)	[illegible]	2.6-4.8(°C)
0.26-0.55 (m)	[illegible] (m)	0.33-0.63 (m)	0.45-0.82 (m)

Scenario Uncertainty

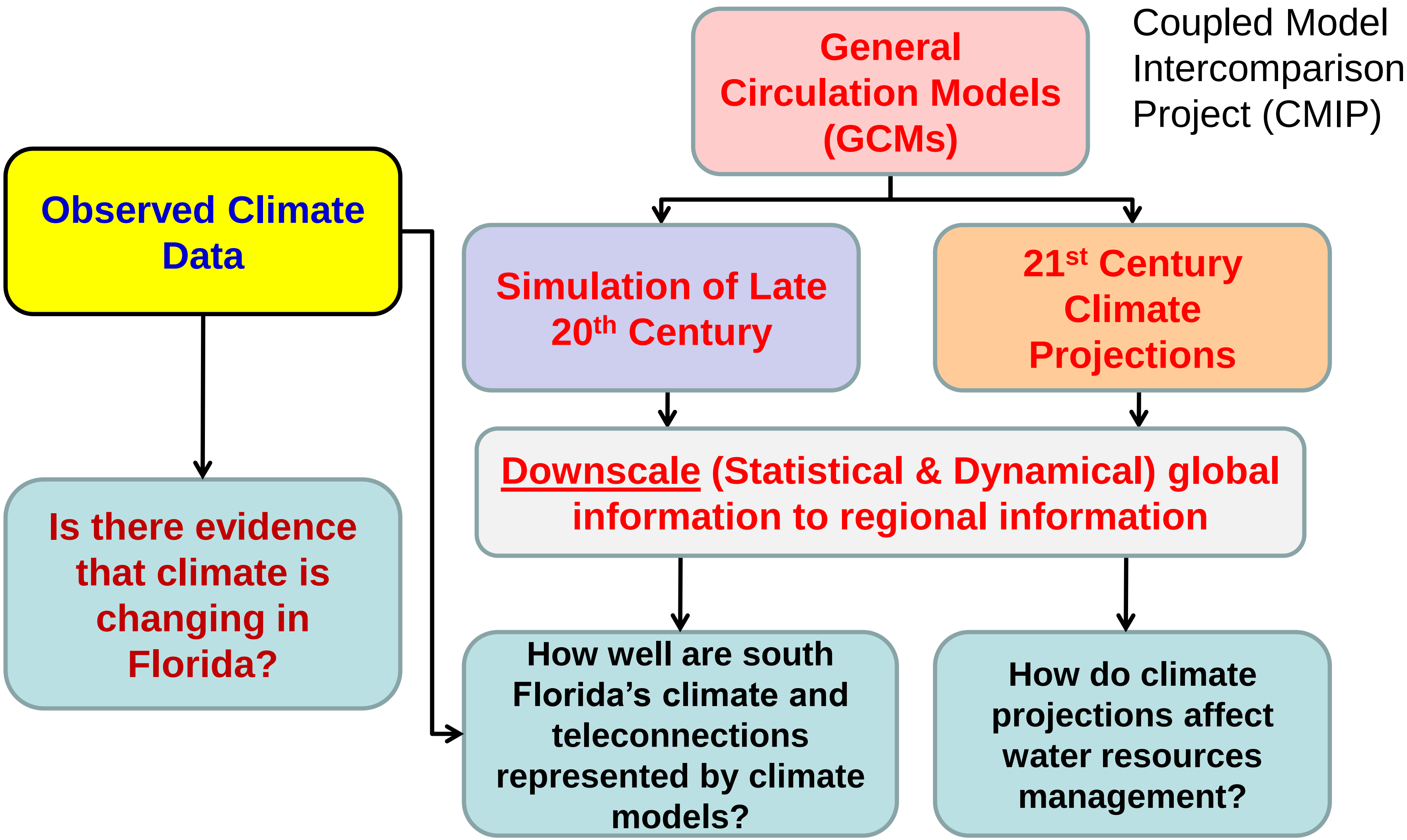
Climate Change Implications in Water Resources Investigations:

- Scenario based approaches
- Use all models
- Model Culling?

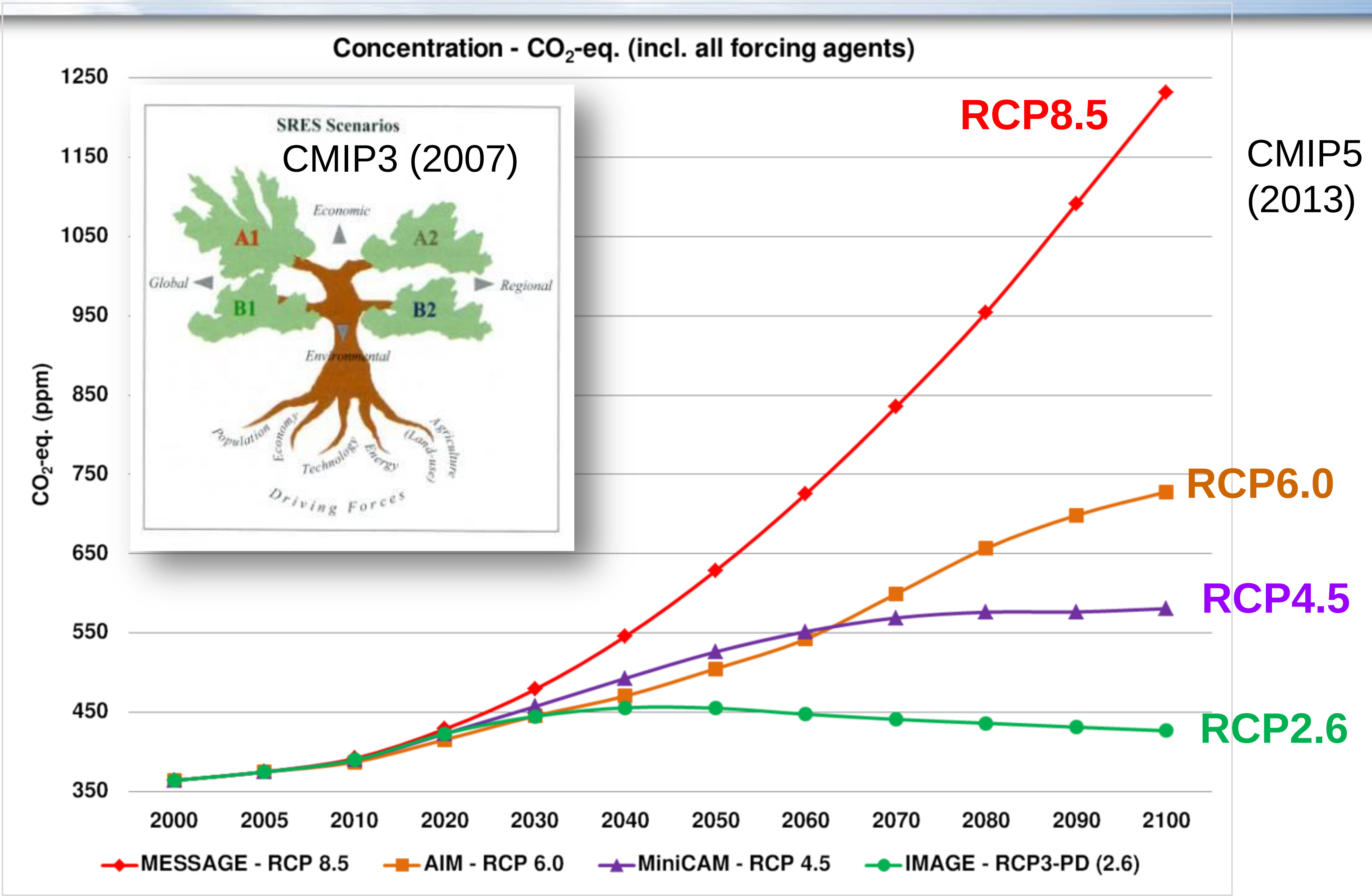
Natural Variability (Teleconnections)



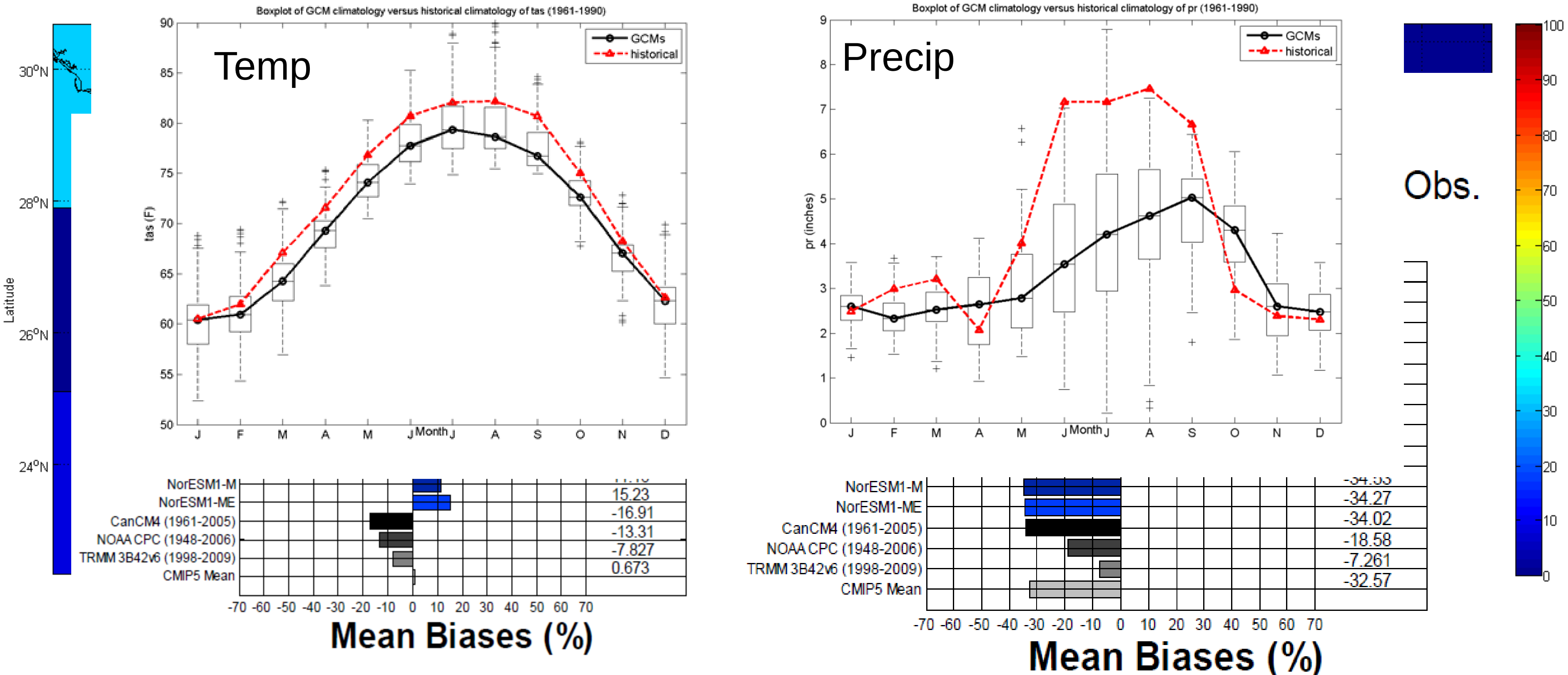
Using Climate Change Information



Climate Scenarios: Representative Concentration Pathways (RCPs)



GCM Skills in Florida



Credit: Cespedes (2012)

Downscaling CMIP3 & CMIP5 GCM Climate Projections

- **Statistical Downscaling** (~12 km)
  - BCSD (Bias-Corrected, Spatially-Downscaled)
  - BCCA (Bias-Corrected, Constructed Analogs)
  - SOM method: Penn State (FIU-WCS project)
  - LOCA (not analyzed yet)(apparently better for extremes!)
- **Dynamical Downscaling** (using Regional Climate Models)
  - NARCCAP (from NCAR) (~50km)
  - FSU – Regional Spectral Model (~10km)
  - WCRP CORDEX (not analyzed yet)

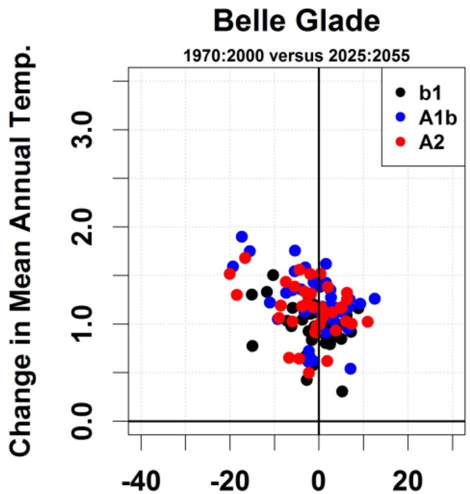
Initial Vulnerability Assessments

Environmental Management
DOI 10.1007/s00267-014-0315-x

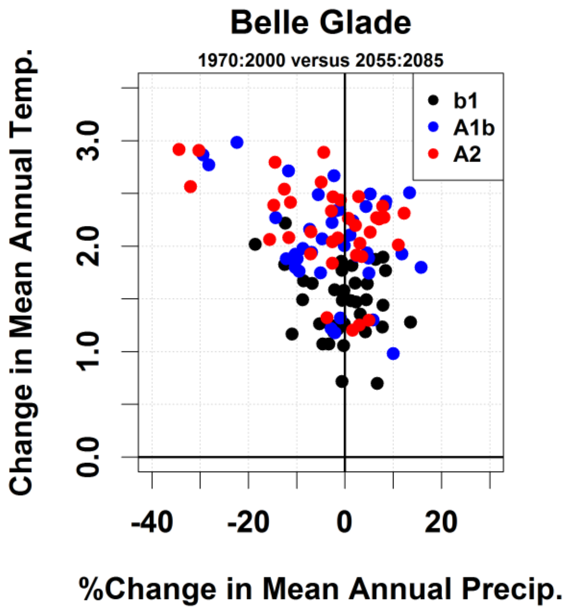
Climate Sensitivity Runs and Regional Hydrologic Modeling for Predicting the Response of the Greater Florida Everglades Ecosystem to Climate Change

Jayantha Obeysekera · Jenifer Barnes · Martha Nungesser

CMIP3 vs. CMIP5



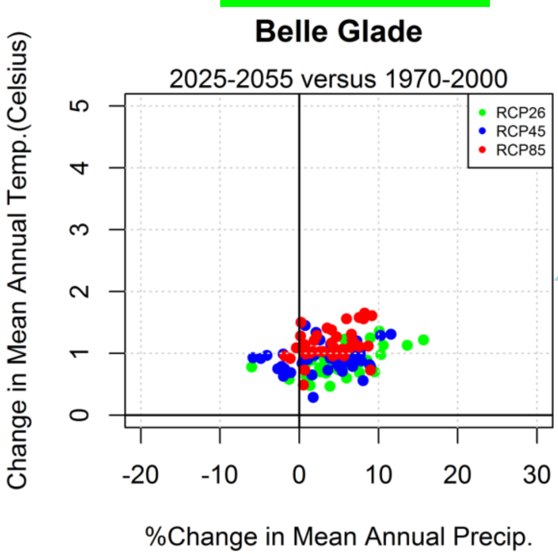
Near Future

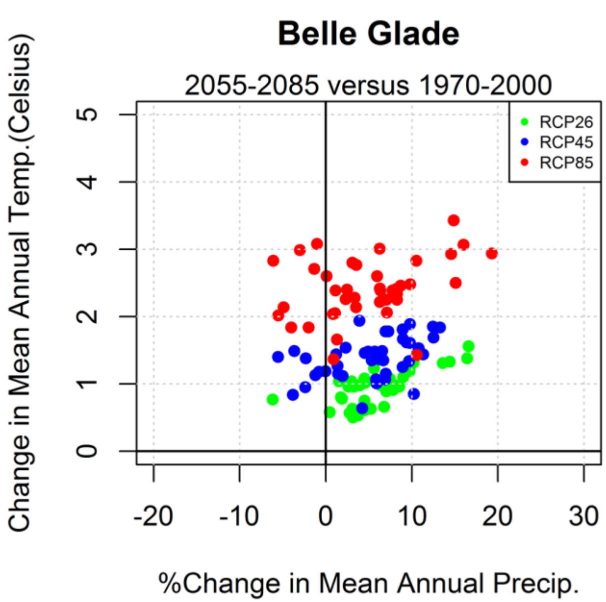


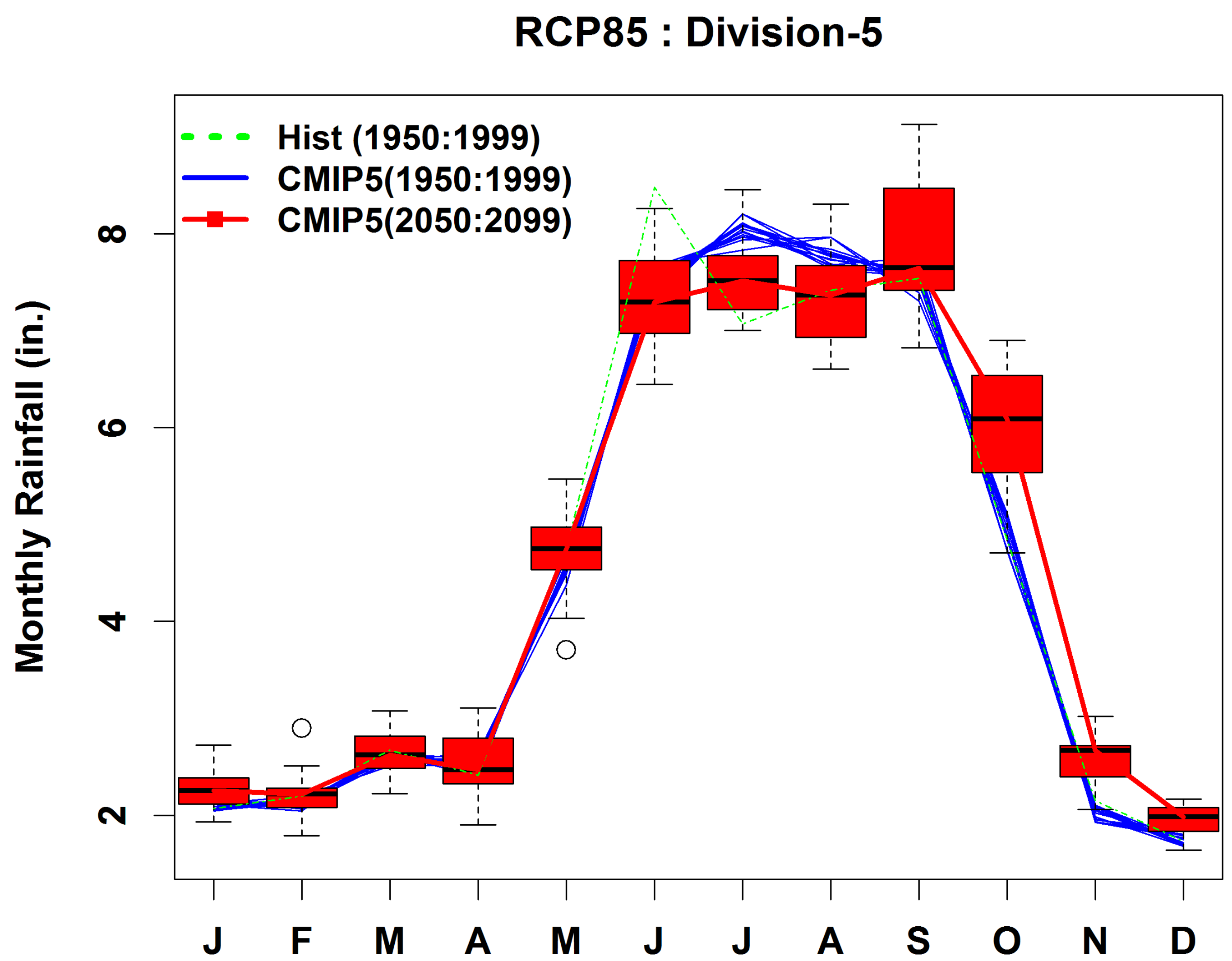
Far Future

CMIP3

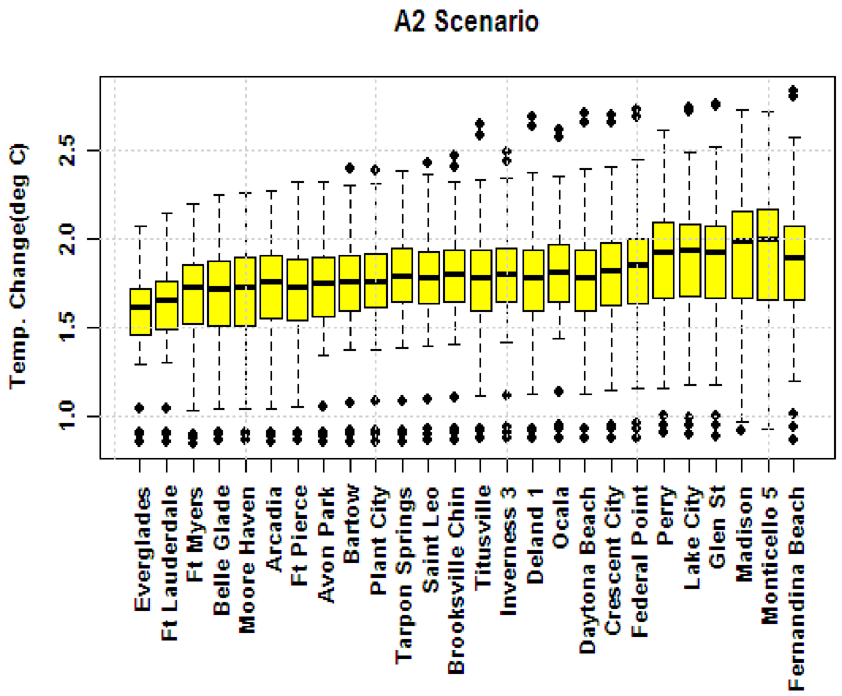
CMIP5



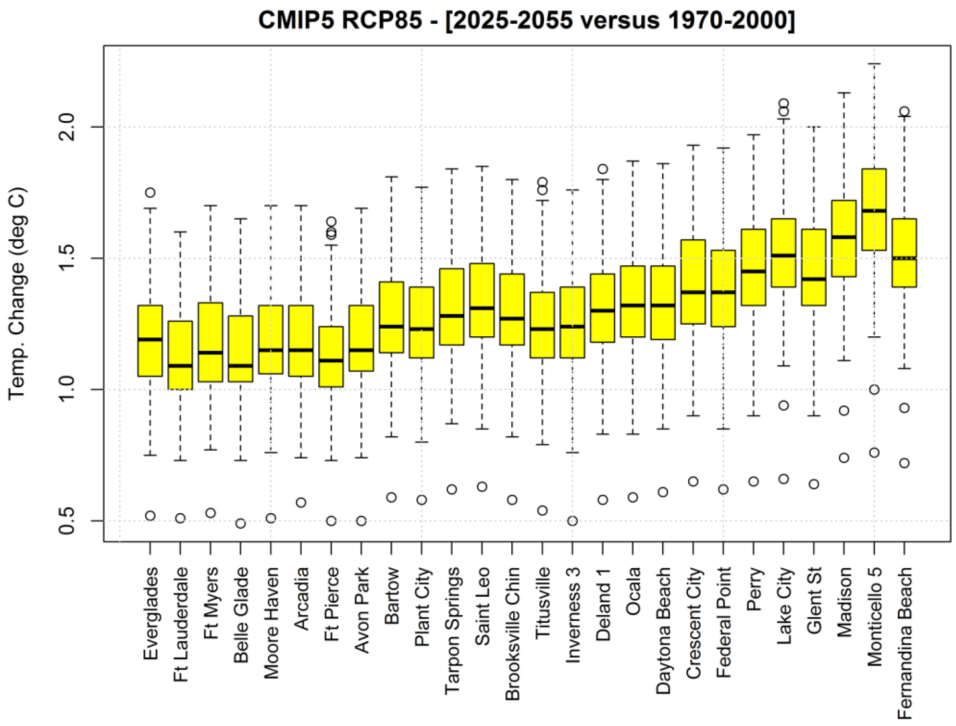



RCP85 : Division-5
Hist (1950:1999)
CMIP5(1950:1999)
CMIP5(2050:2099)
Monthly Rainfall (in.)
2
4
6
8
J
F
M
A
M
J
J
A
S
O
N
D

Spatial Trends in Florida (Temperature)

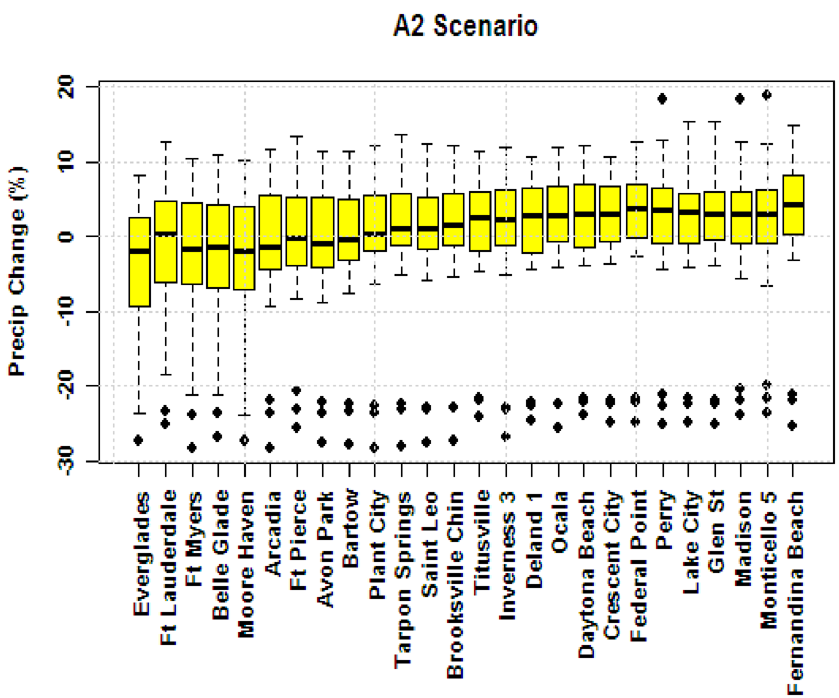


CMIP3

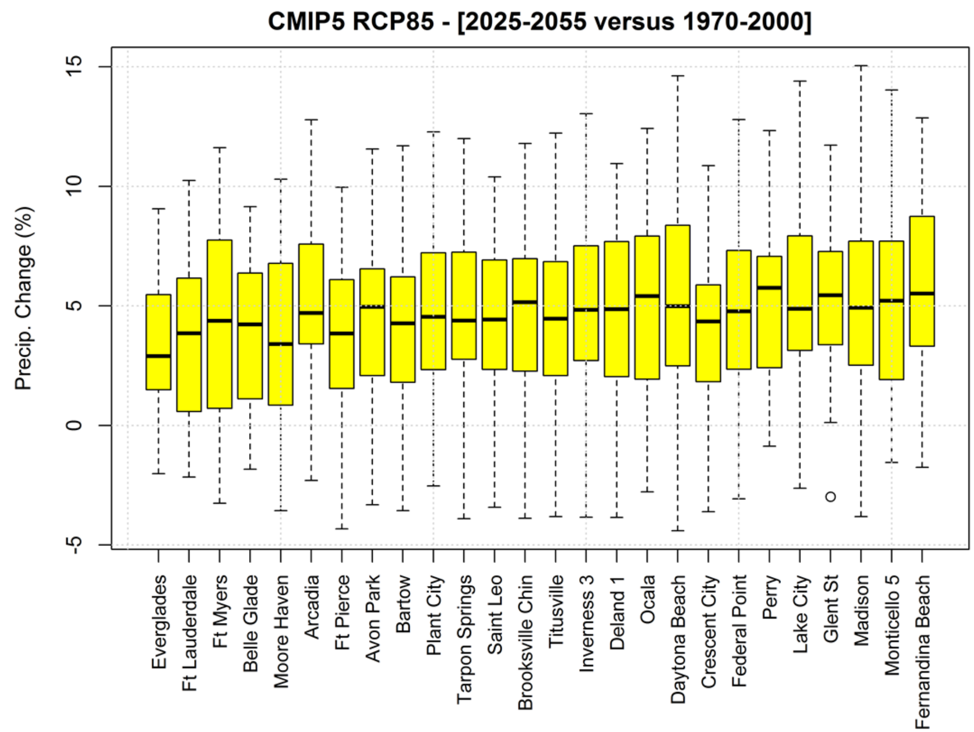


CMIP5

Spatial Trends in Florida (cont.) – Rainfall



CMIP3



CMIP5

Sensitivity Investigations: Scenario Assumptions for 2060

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
Sea Level Rise	1.5 feet		

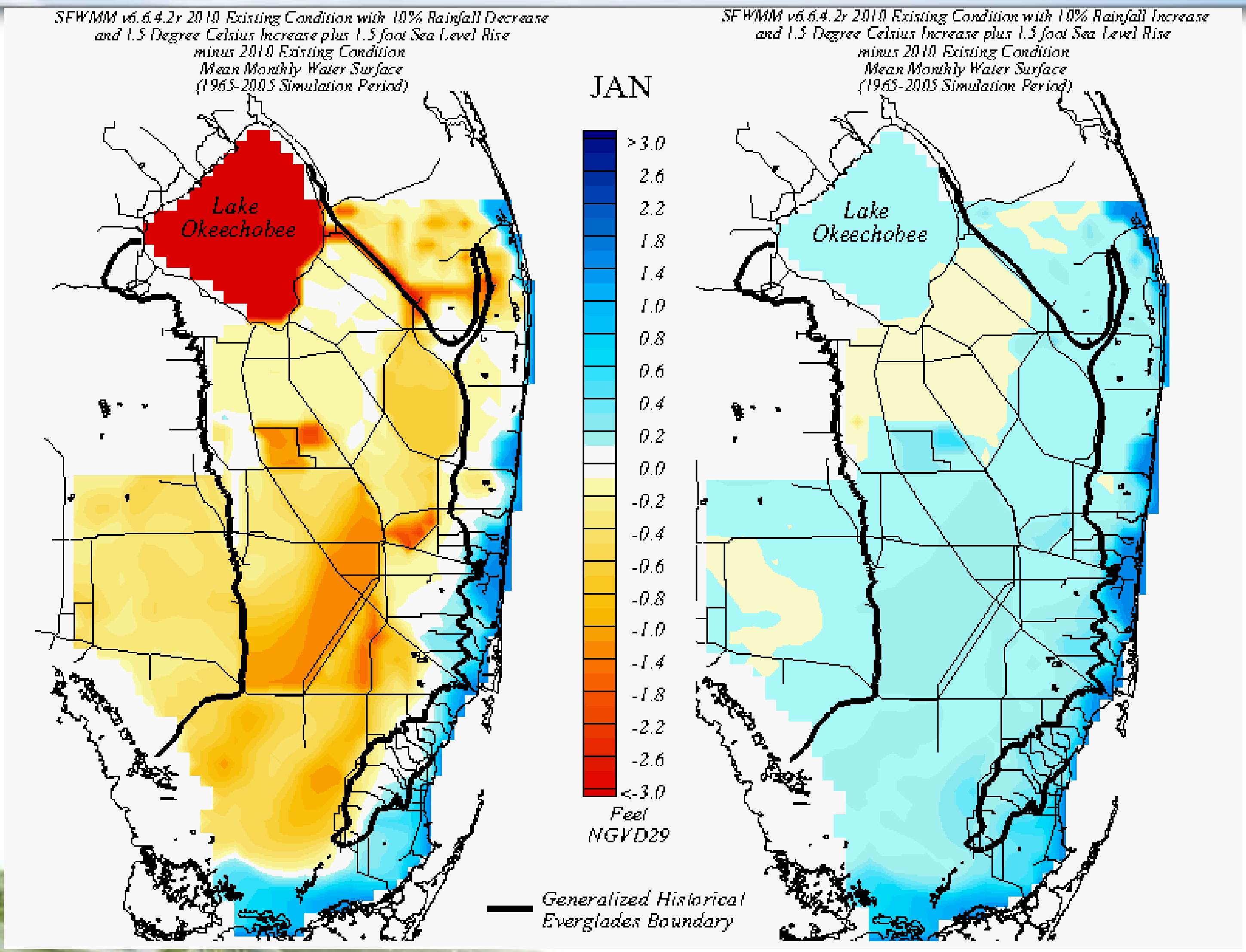
Climate Sensitivity Runs and Regional Hydrologic Modeling for Predicting the Response of the Greater Florida Everglades Ecosystem to Climate Change

Jayantha Obeysekera · Jenifer Barnes · Martha Nungesser

Modeling Scenarios (using 2x2)

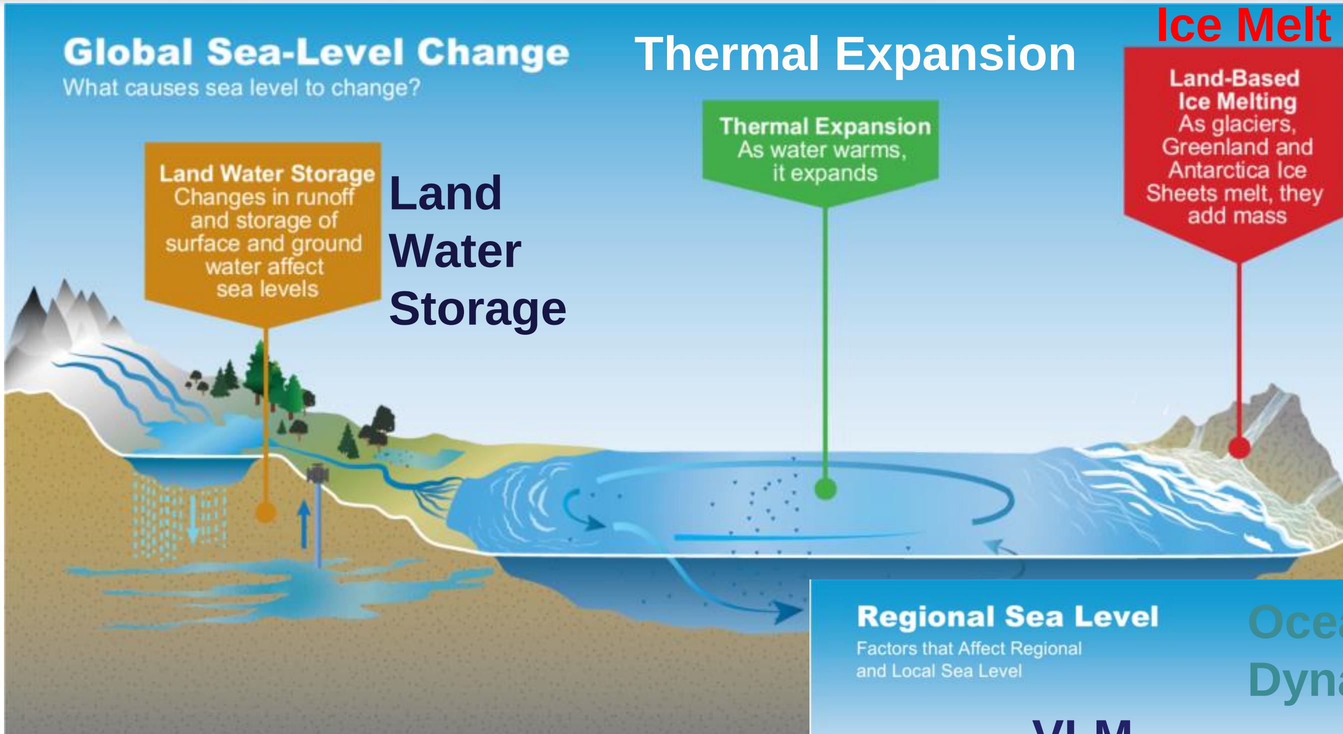
- 2010 Baseline (demands and landuse corresponding to 2010 simulated with the 1965-2005 rainfall & ET (**BASE**)
- 2010 Baseline with 10% decrease in rainfall (**decRF**)
- 2010 Baseline with 10% increase in rainfall (**incRF**)
- 2010 Baseline with 1.5° Celsius increase and 1.5 foot sea level rise with increased coastal canal levels (**incET**)
- 2010 Baseline with 10% decrease in rainfall, 1.5° Celsius increase and 1.5 foot sea level rise with increased coastal canal levels (**decRFincET**)
- 2010 Baseline with 10% decrease in rainfall, 1.5° Celsius increase and 1.5 foot sea level rise with no increased coastal canal levels (**decRFincETnoC**)
- 2010 Baseline with 10% increase in rainfall, 1.5° Celsius increase and 1.5 foot sea level rise with increased coastal canal levels (**incRFincET**)

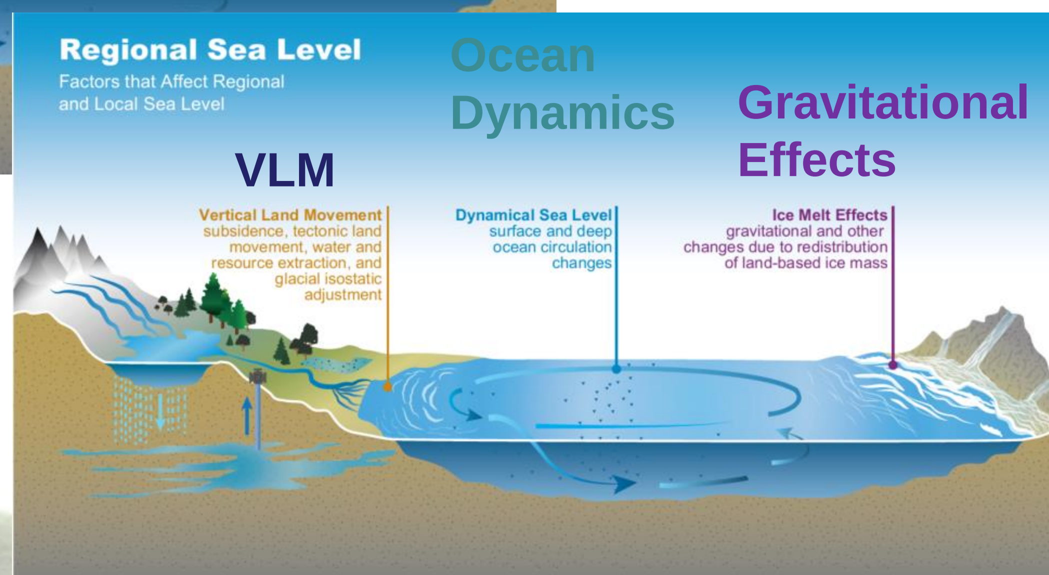
DecRFincET versus IncRFincET



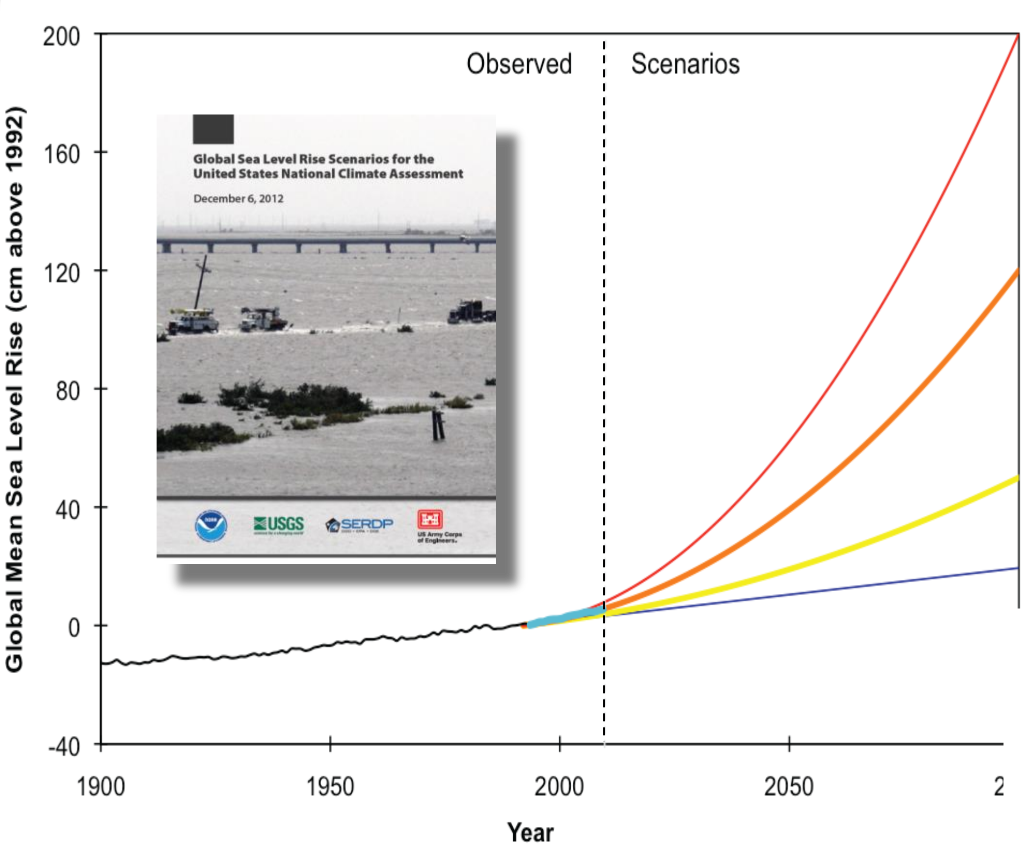
Global, Regional, and Local Sea Level Projections

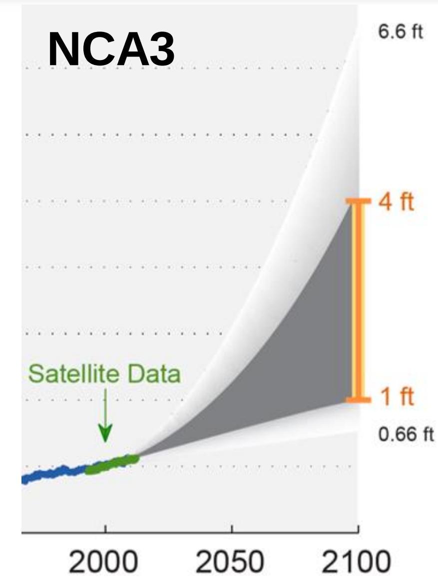
Sources of Global and Regional Sea Level Change

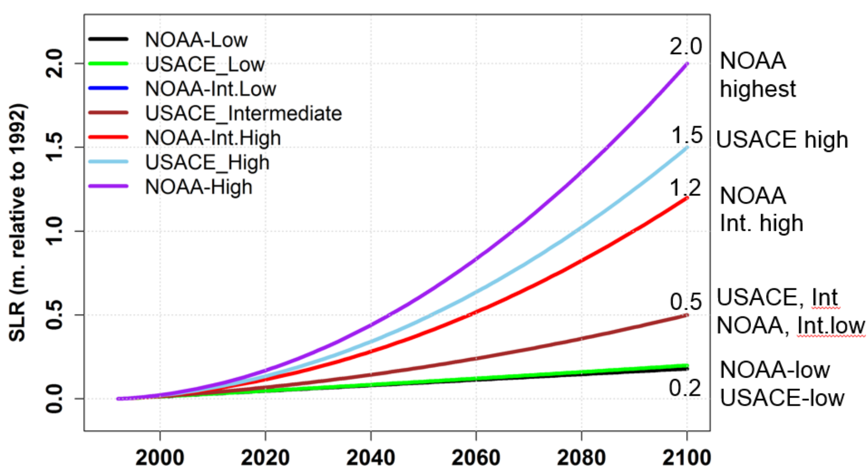




Scenario approach (NOAA, 2012) for 3rd National Climate Assessment

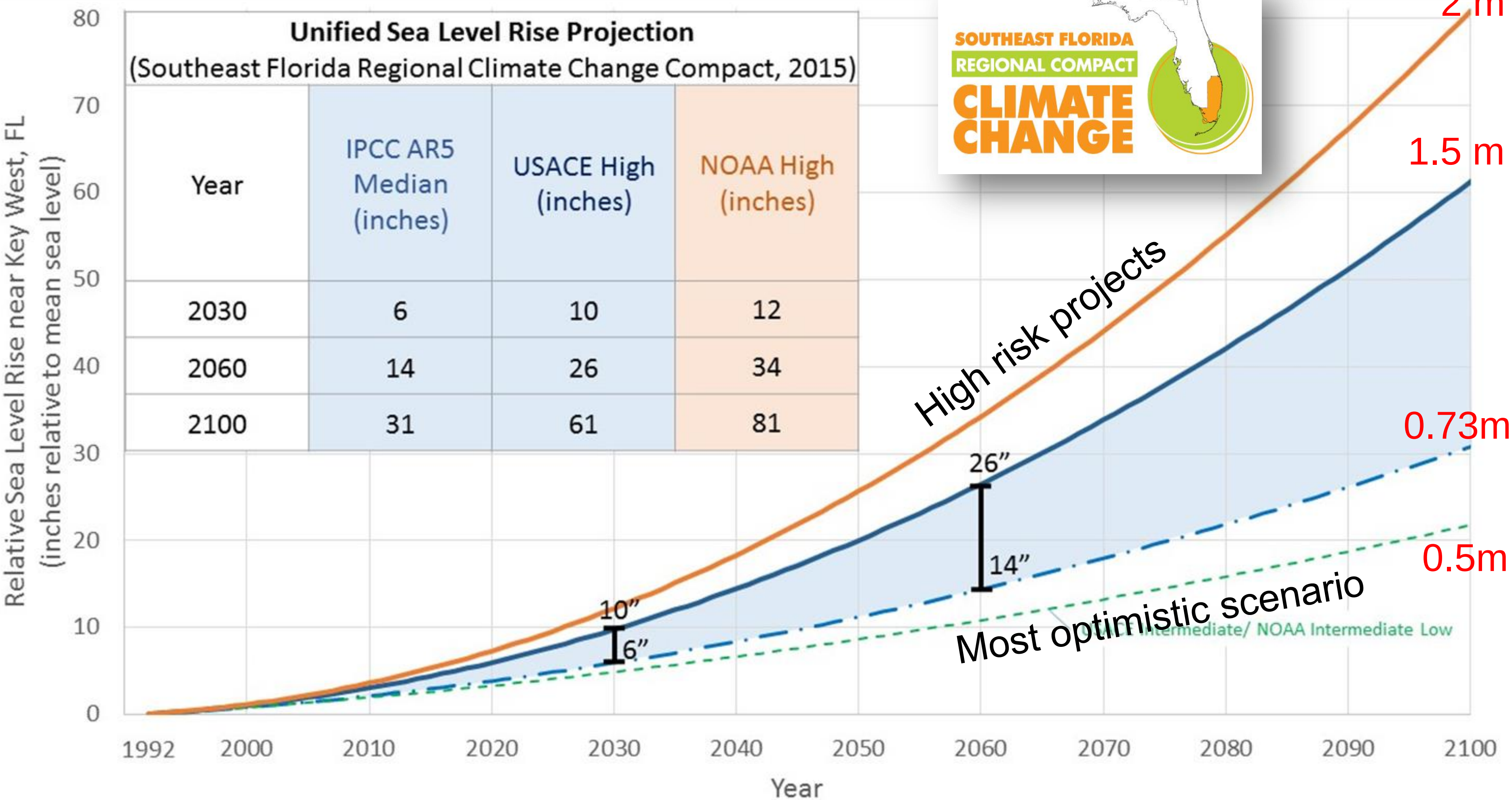






Confidence (>90%) was assigned to the range as bounding possible futures, with no likelihoods assigned to individual scenarios.

Unified SLR Projections (Climate Compact)



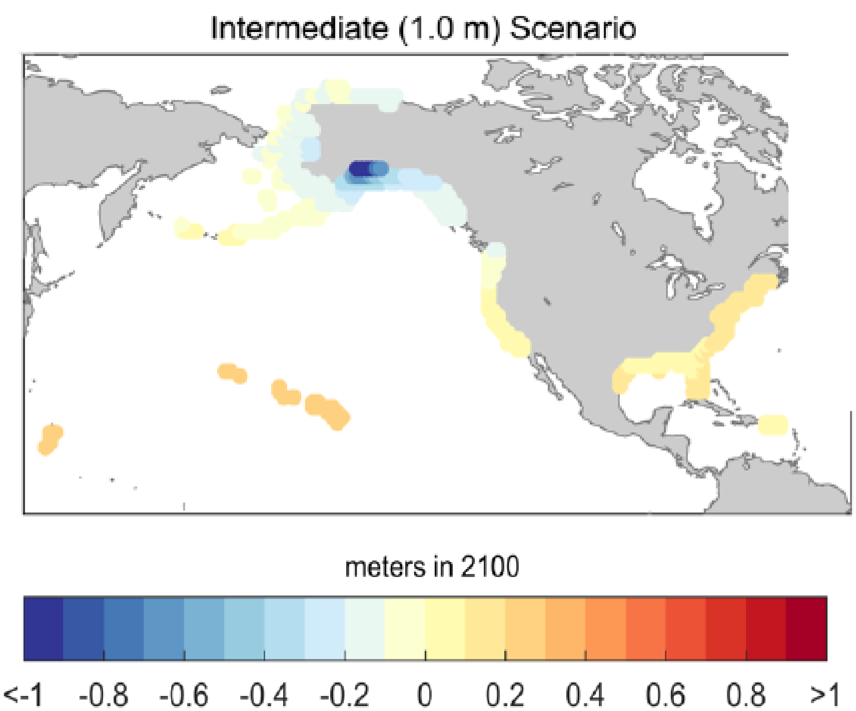
Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2015)

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

SOUTHEAST FLORIDA REGIONAL COMPACT CLIMATE CHANGE

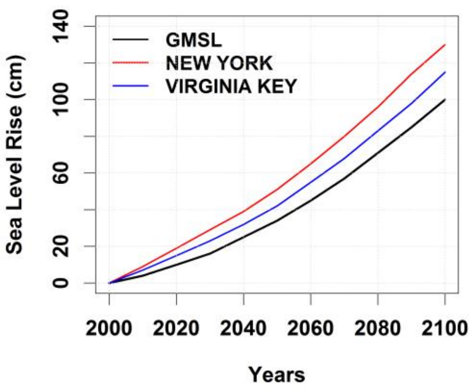
Regional Sea Level Projections

- Both Hall et al. (DoD 2016) and Sweet et al. (NOAA 2017) accounted for all components



Florida

Regional Sea Level Curves



SLR Dimensions in south Florida

Physical

- Global, Regional, Local Mean Sea Level
- Tides, Storm Surge (storminess), Waves
- Teleconnections (e.g. El Nino, AMO)

Impacts

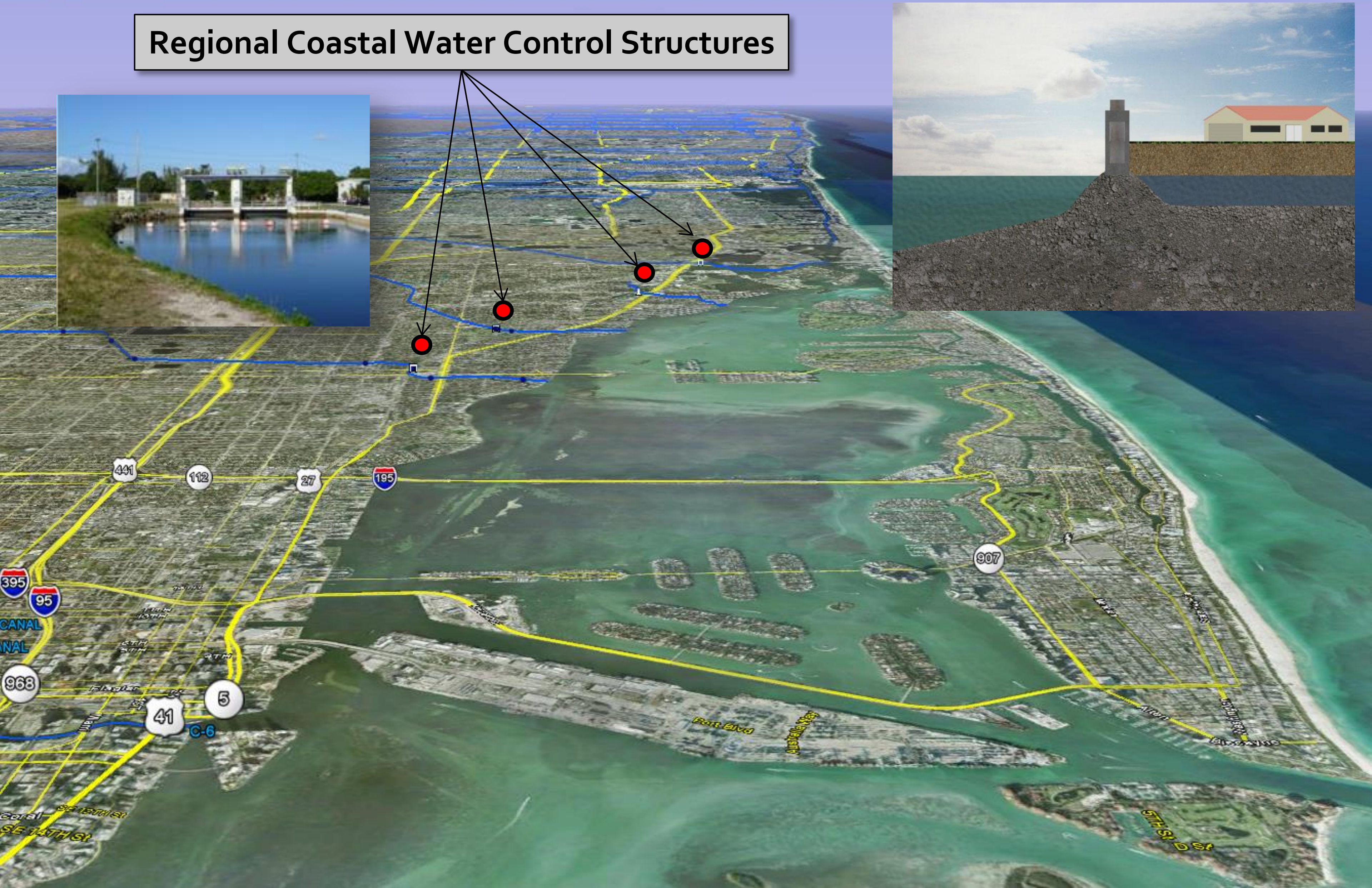
- Flooding, Water Supply, Environment
- Local versus Regional
- Socio-economic (e.g. infrastructure, population, economy, insurance)

Response

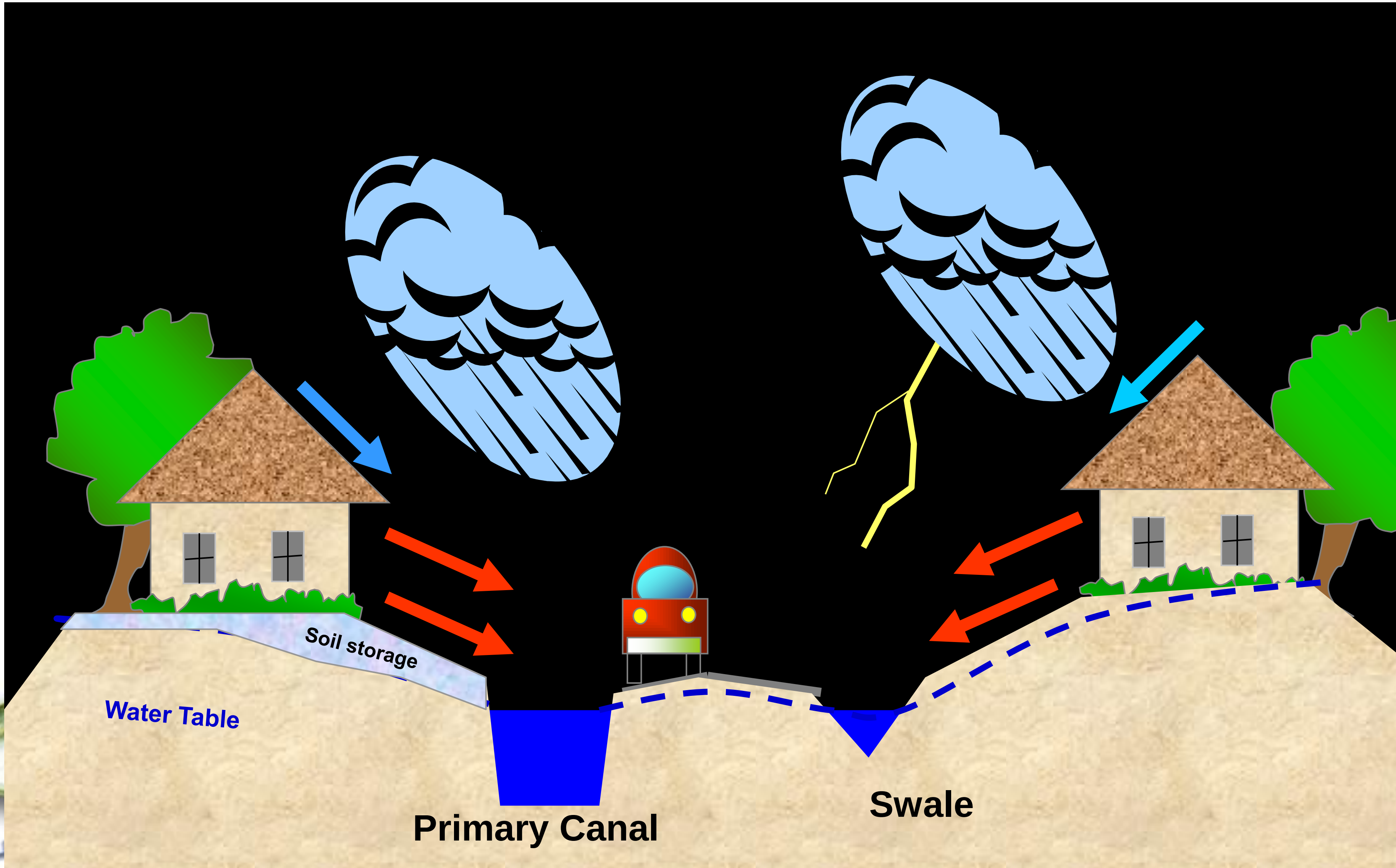
- Science
- Adaptation, Resilience
- Governance (local, state, federal)
- Outreach

Regional Water Control System

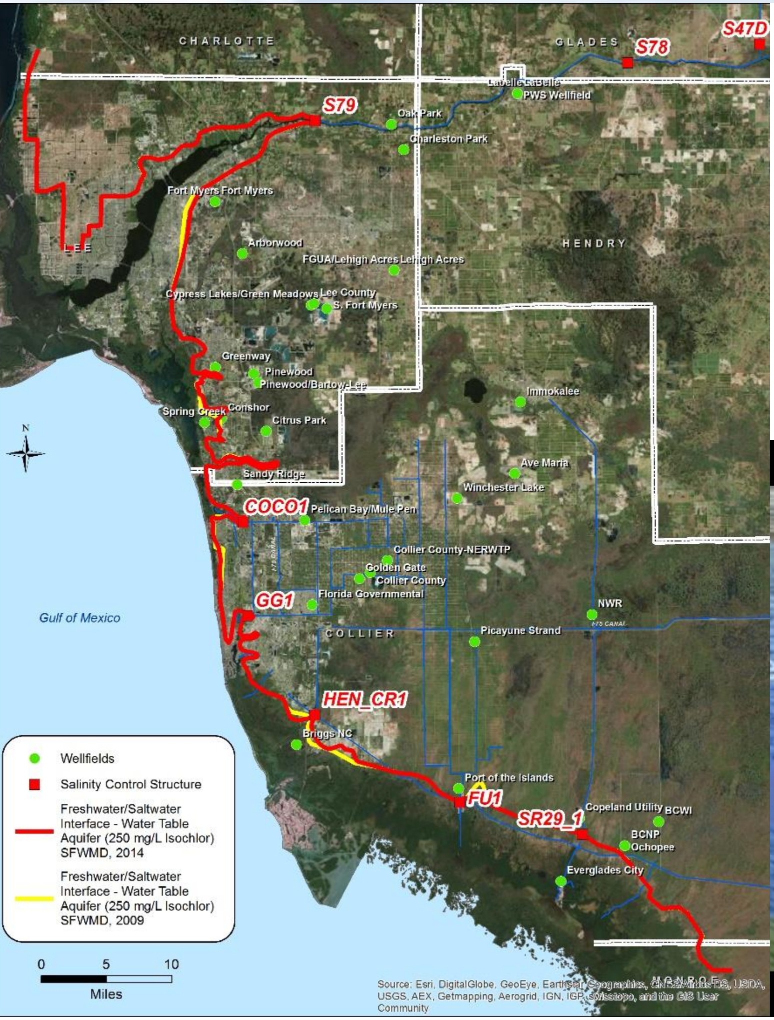
Regional Coastal Water Control Structures



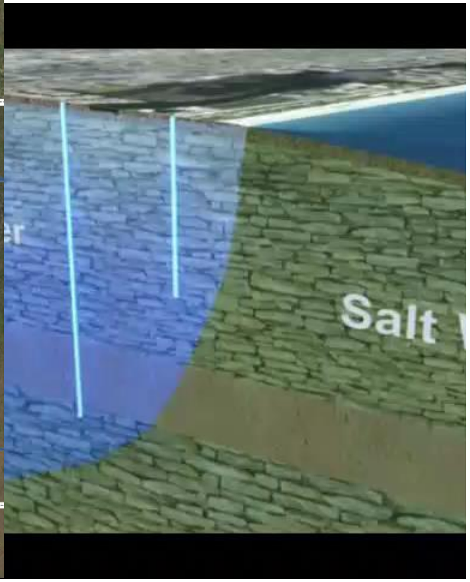
Effect of rising water table

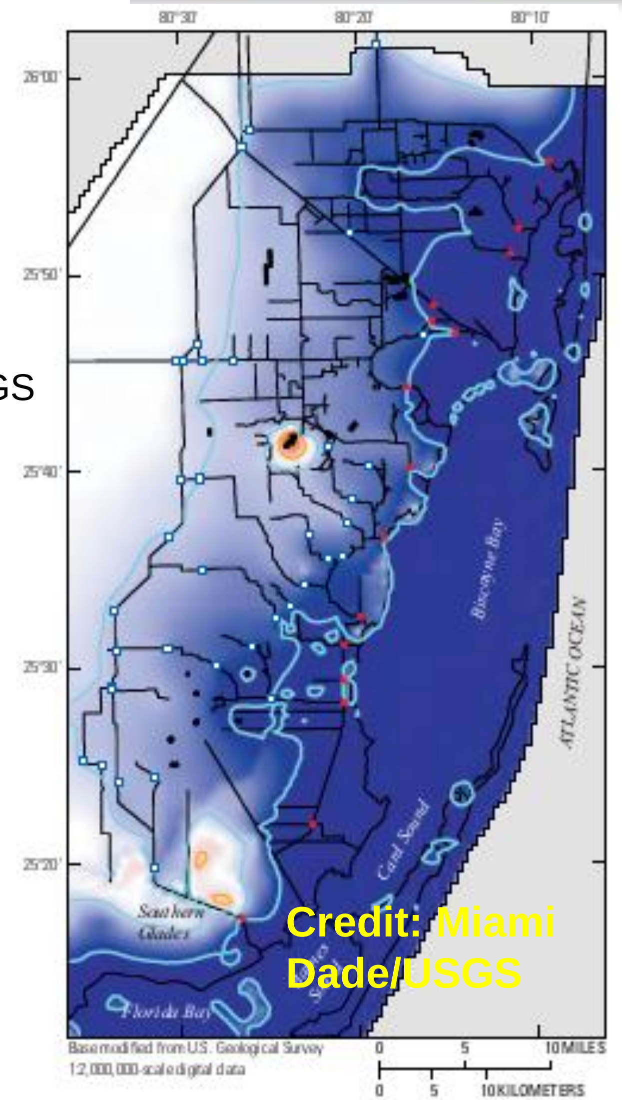


Acceleration of Saltwater Intrusion



Credit: K. Cunningham USGS





Credit: Miami Dade/USGS

Adaptation Portfolio

Everglades Restoration

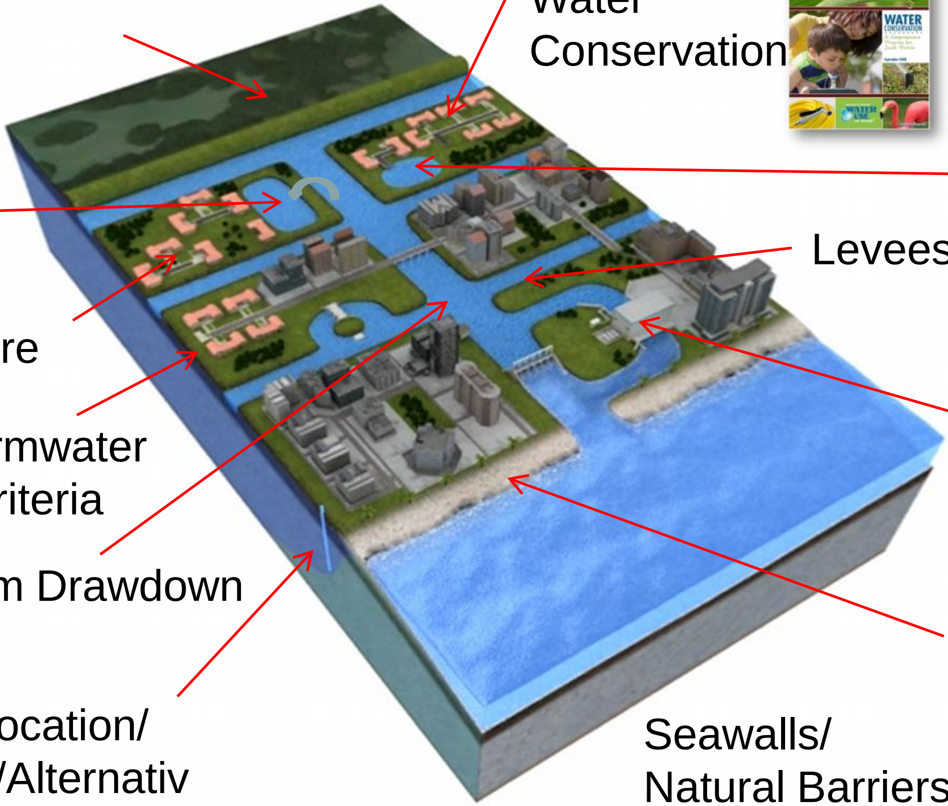
Impoundments & Pumps

Green Infrastructure

Revised Stormwater Permitting Criteria

Pre-storm Drawdown

Wellfield Relocation/ Interconnect/Alternative Water Supply (Reuse)



Water Conservation

Water Storage

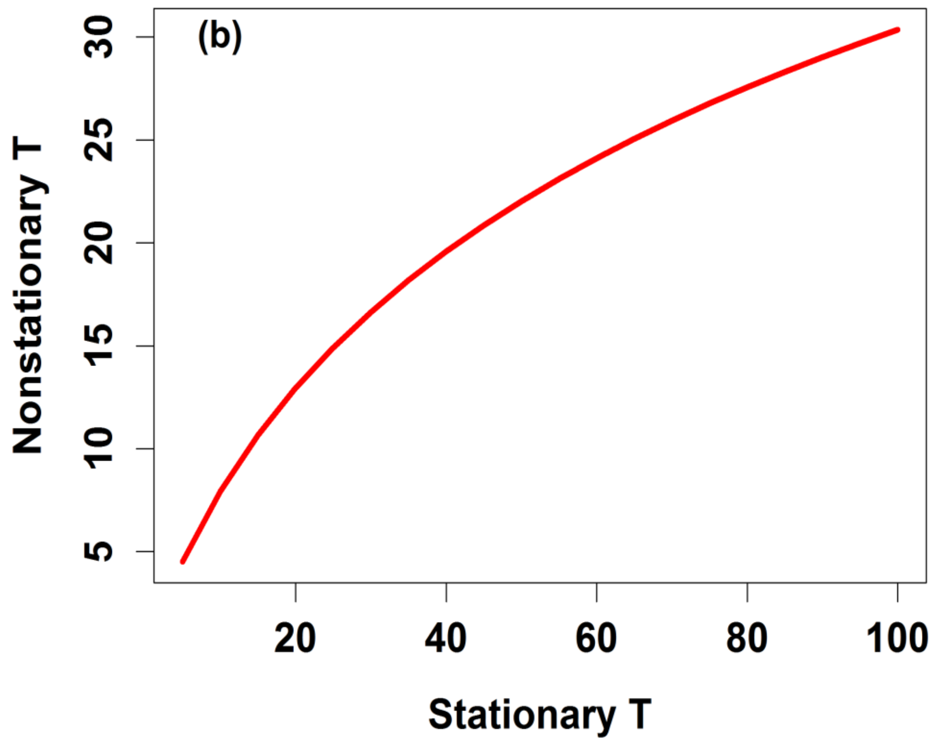
Levees/Elevated infrastructur

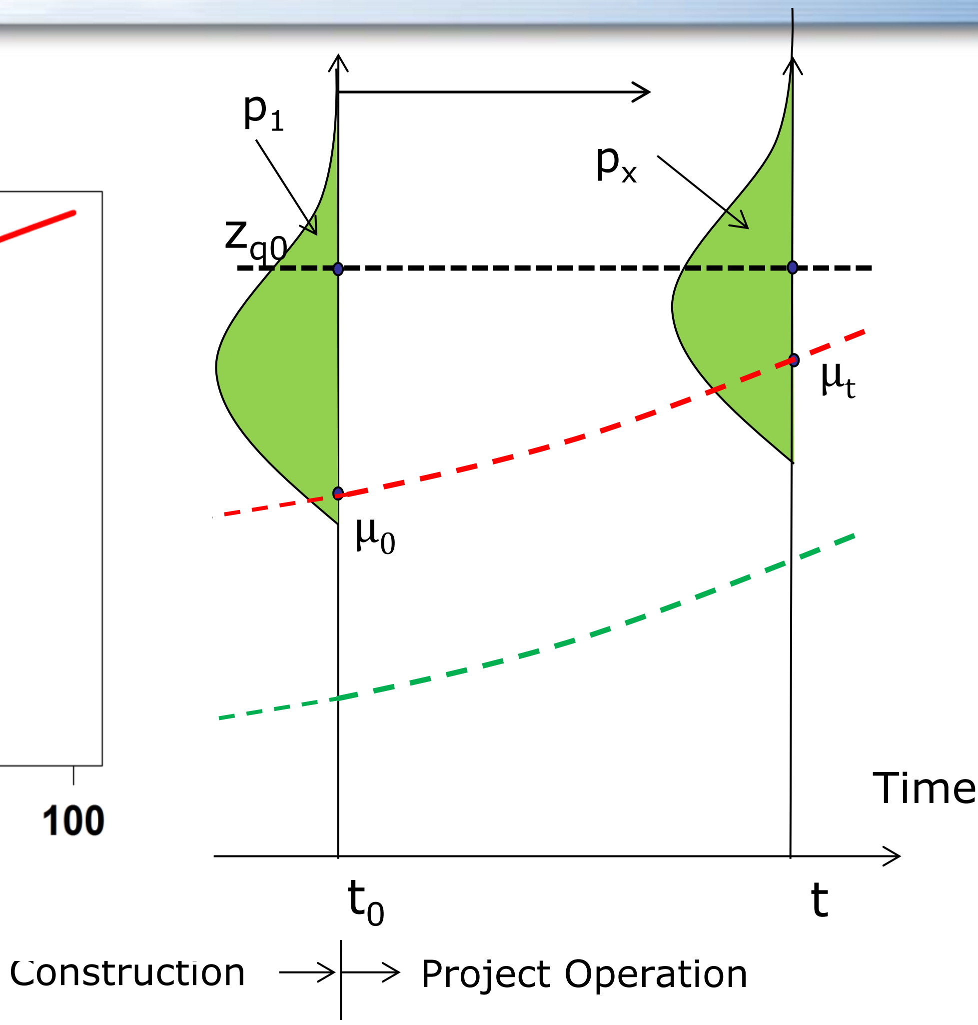
Forward Pumps

Seawalls/ Natural Barriers

Questions?

Concept of NONSTATIONARITY





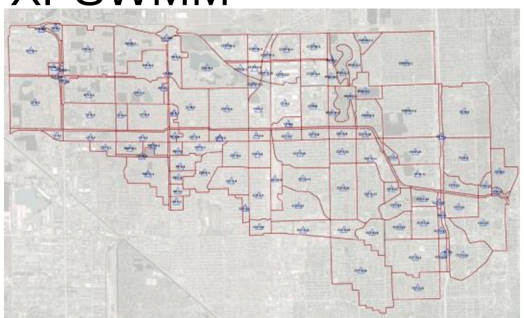
Revisiting the Concepts of Return Period and Risk for Nonstationary Hydrologic Extreme Events

Jose D. Salas, M.ASCE[1]; and Jayantha Obeysekera, M.ASCE[2]

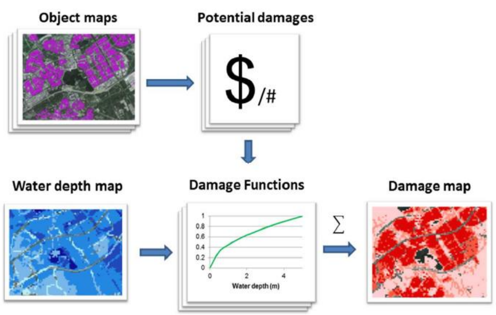
Flood Risk Management in Miami-Dade County (with Deltares) : C-7 basin

Hydrologic Drivers:
Rainfall; Storm Surge
Sea Level Rise

Hydrodynamic Model
XPSWMM



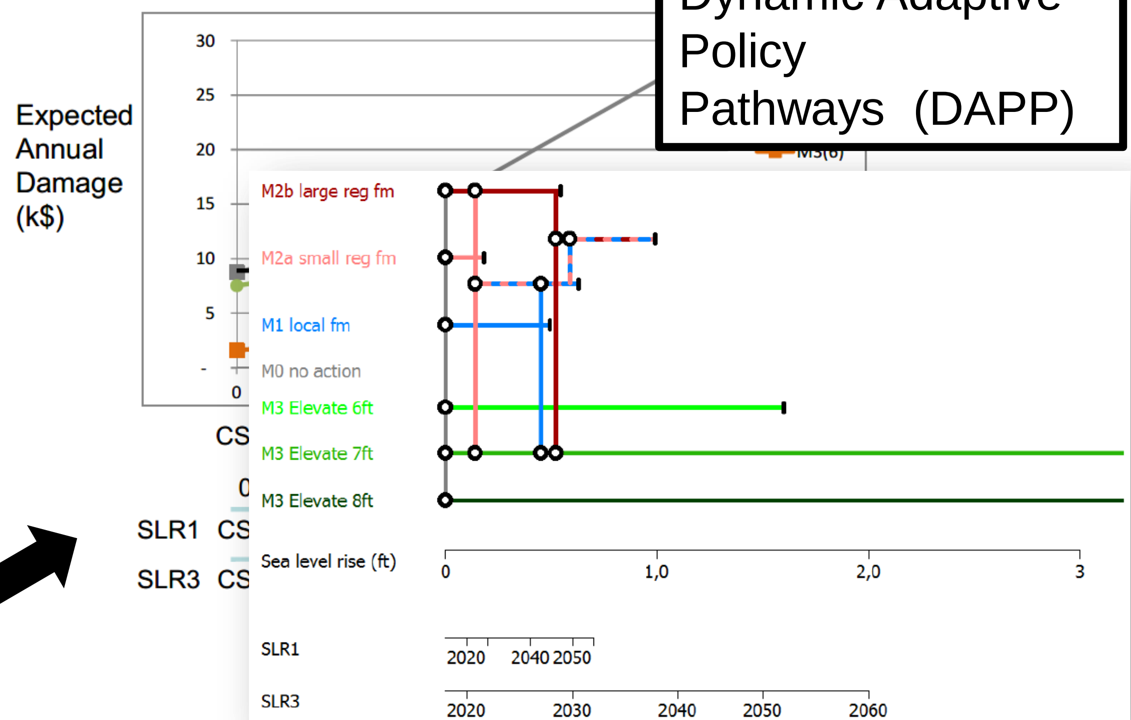
Delft-FIAT damage model



Adaptation Options:

- M1:Local Flood Mitigation (flood walls, pumps)
- M2:Regional Flood Mitigation (Forward pumping at outlet)
- M3:Land-use mitigation (elevate buildings, roads)

Dynamic Adaptive Policy Pathways (DAPP)



KEY Research papers

Revisiting the Concepts of Return Period and Risk for Nonstationary Hydrologic Extreme Events

Jose D. Salas, M.ASCE[1]; and Jayantha Obeysekera, M.ASCE[2]

Quantifying the Uncertainty of Design Floods under Nonstationary Conditions

Jayantha Obeysekera, M.ASCE[1]; and Jose D. Salas, M.ASCE[2]

J. Hydrol. Eng. 2014.19:1438-1446.

Frequency of Recurrent Extremes under Nonstationarity

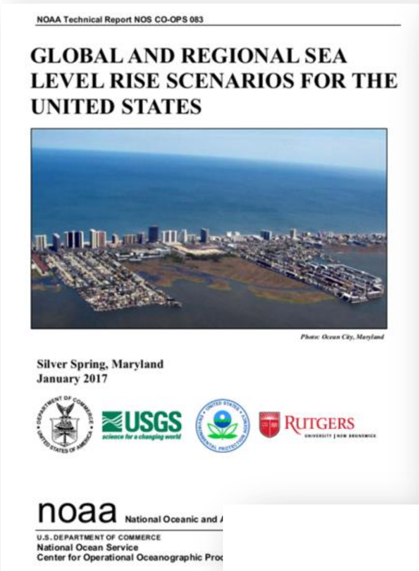
Jayantha Obeysekera, M.ASCE[1]; and Jose D. Salas, M.ASCE[2]

(paper published online: J. Hydrologic Engineering)

Techniques for assessing water infrastructure for nonstationary extreme events: a review

J.D. Salas[a], J. Obeysekera[b], and R.M. Vogel[c] (paper in review)

NOAA (Sweet et al. 2017) for 4th National Climate Assessment


NOAA Technical Report NOS CO-OPS 083

GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Photo: Ocean City, Maryland

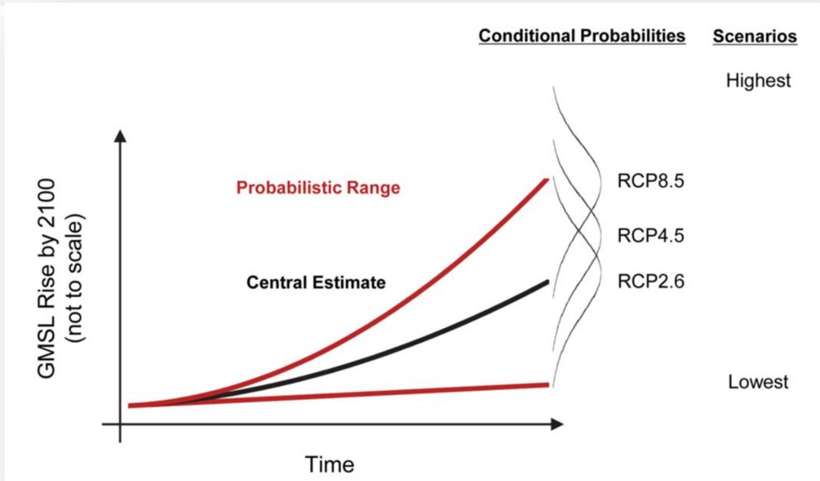
Silver Spring, Maryland
January 2017

USGS science for a changing world

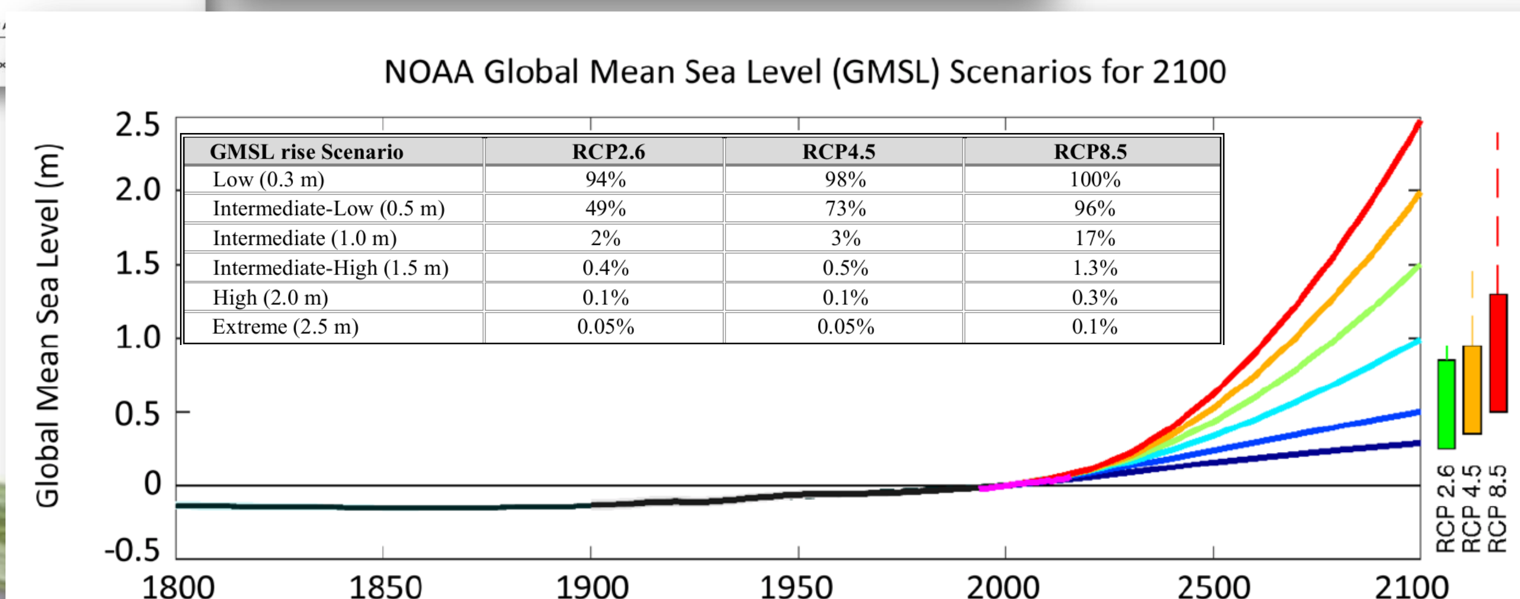
RUTGERS

noaa National Oceanic and A

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Proc



- Kopp et al. (2014)
- Bayesian Probabilities
- Expert elicitation to get the tails
- **DeConto & Pollard (2016):** Antarctica can contribute more, hence 2.5 m scenario



GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%