



Scenario-based, Integrated Assessment of the Greater Everglades System to Climate Change

Jayantha Obeysekera

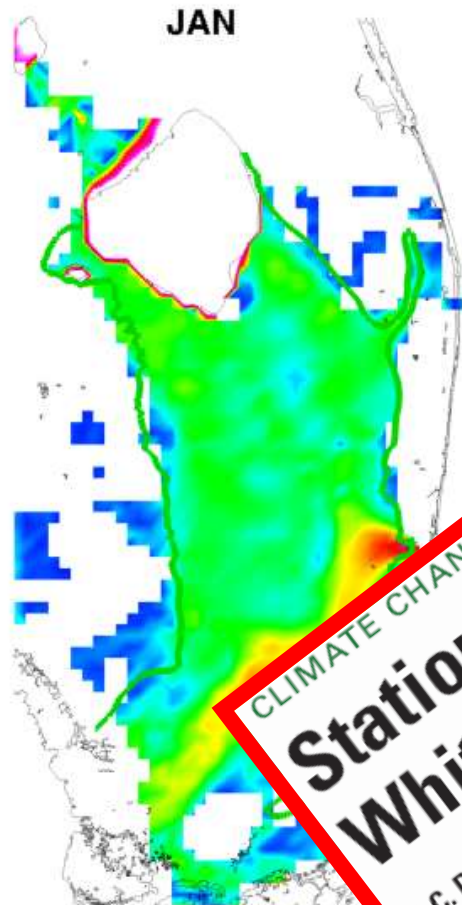
Jenifer Barnes

Martha Nungesser

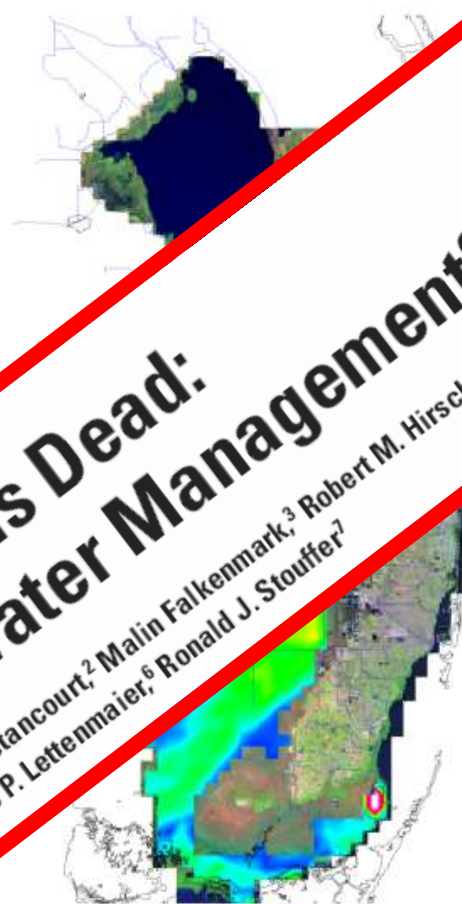
4th UF Water Institute Symposium
Gainesville, Florida, February 11-12, 2014

Everglades Restoration – Do we need a new paradigm?

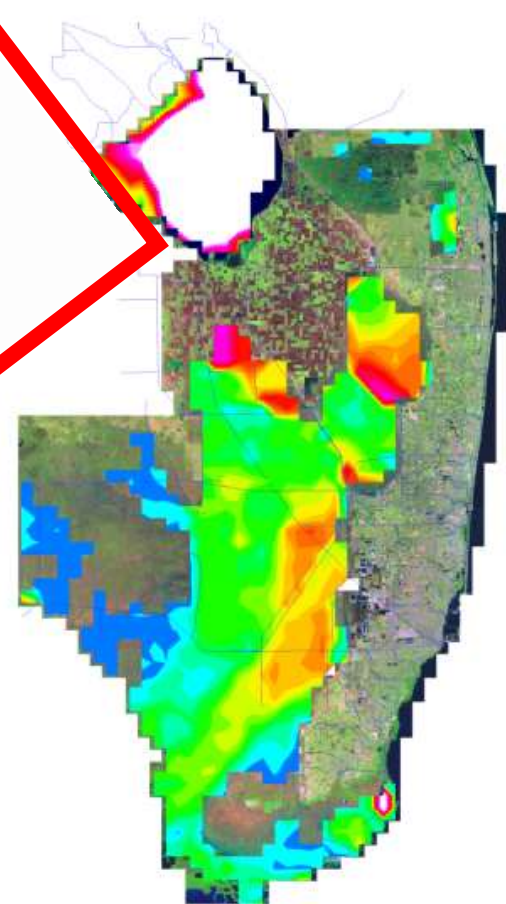
Natural System



Managed System



CERP

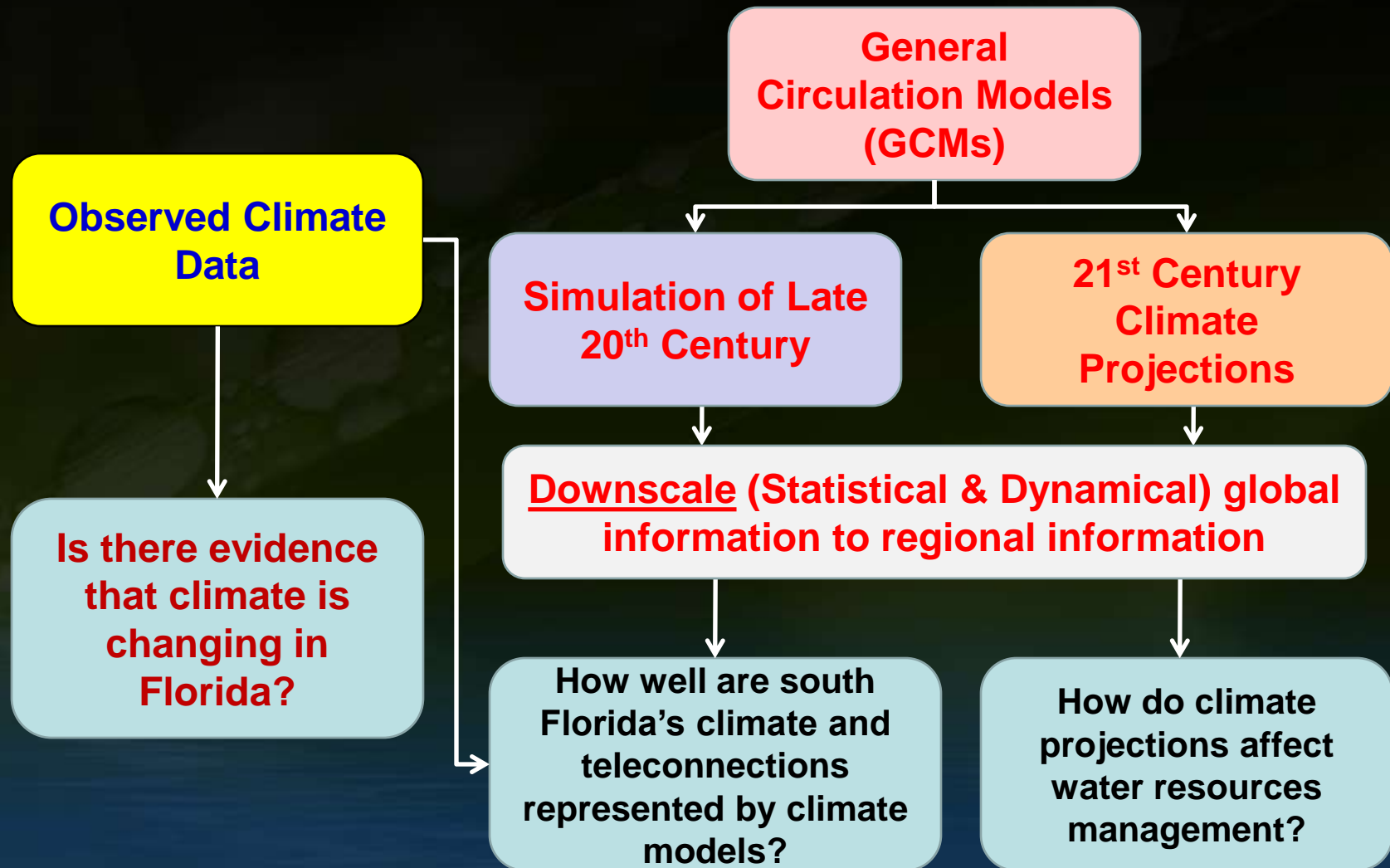


**Stationarity Is Dead:
Whither Water Management?**

CLIMATE CHANGE

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Using Climate Change Information (Lessons from California's Experience!)



Climate Projection Uncertainties

Natural Variability

General Circulation Model

	Downscaling
GCM (IPCC, 2007)	Statistical Dynamical
BCM2 CGHR CGMR CNCM3 CSMK3 ECHG ECHM20 GFCM21 GIAOM INCM3 IPCM4 MIHR MIMR MPEH5 NCCCSM NCPCM	• Constructed Analogues (CA) • Bias Correction and Spatial Downscaling (BCSD) • Weather Generators

Regional Climate Models (RCMs)

Ice Sheet Dynamics

Scenarios

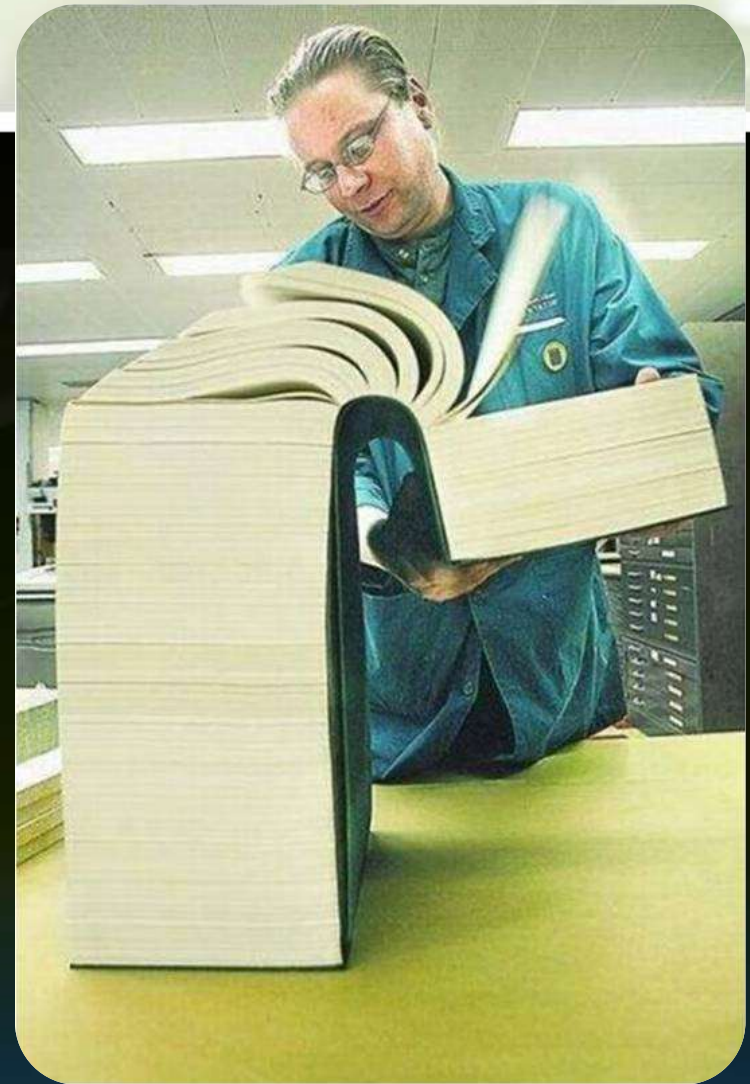
B1	A1T	B2	IS92a	A2	A1FI
1.1-2.9 (°C)	1.4-3.8 (°C)	1.4-3.8 (°C)	1.4-3.8 (°C)	2.0-5.4 (°C)	2.4-6.4 (°C)
0.18-0.38 (m)	0.20-0.45 (m)	0.20-0.43 (m)	0.21-0.48 (m)	0.23-0.51 (m)	0.26-0.59 (m)

Climate Change
Implications in Water
Resources Investigations:

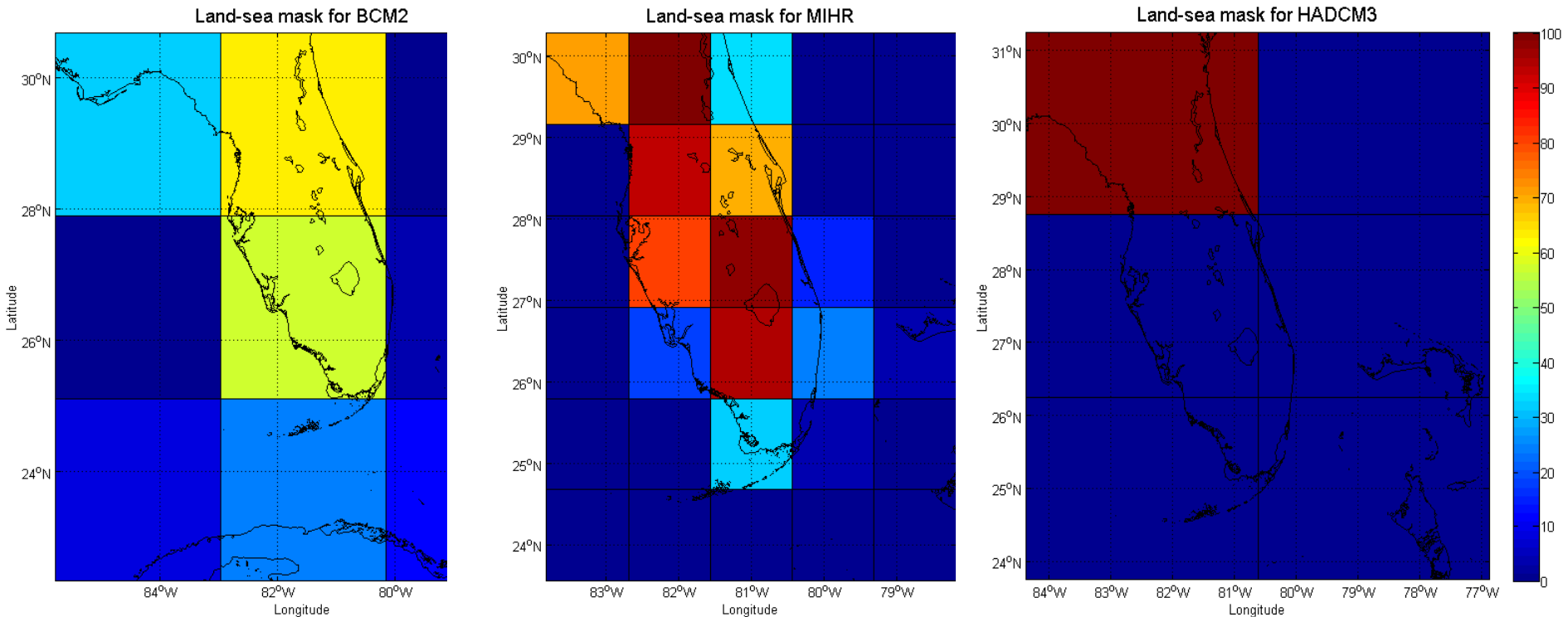
- Scenario based approaches
- Use all models
- Model Culling?

Book of Climate Output

What exactly we
find for Florida?



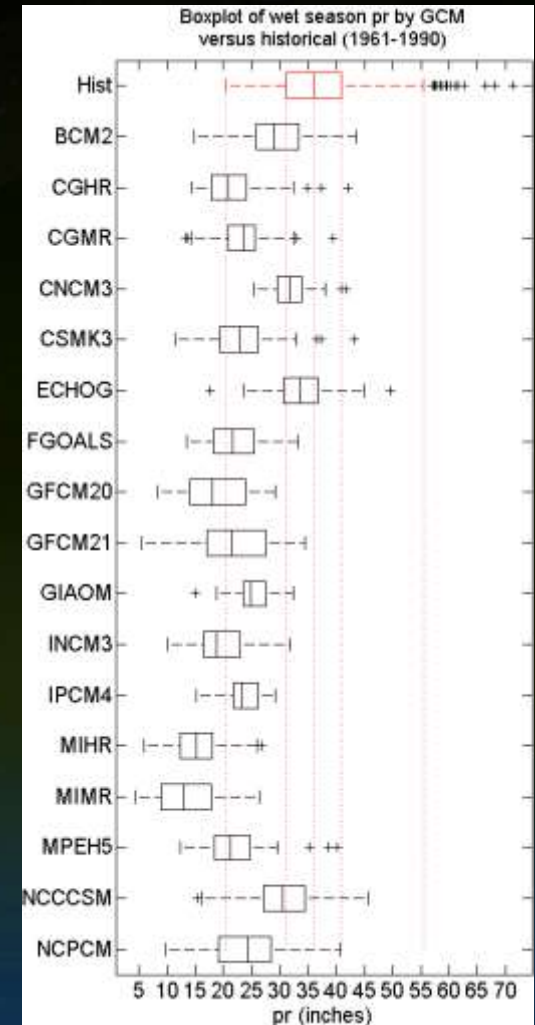
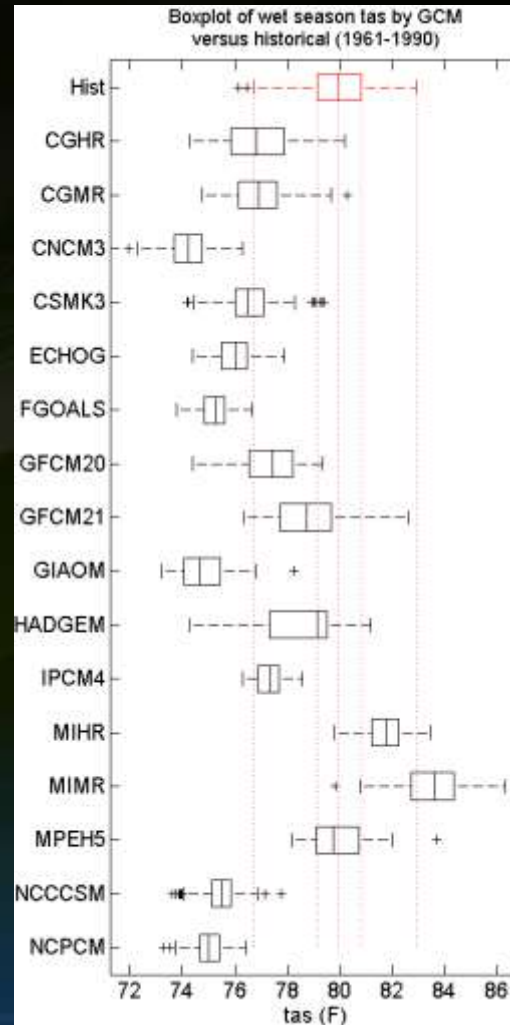
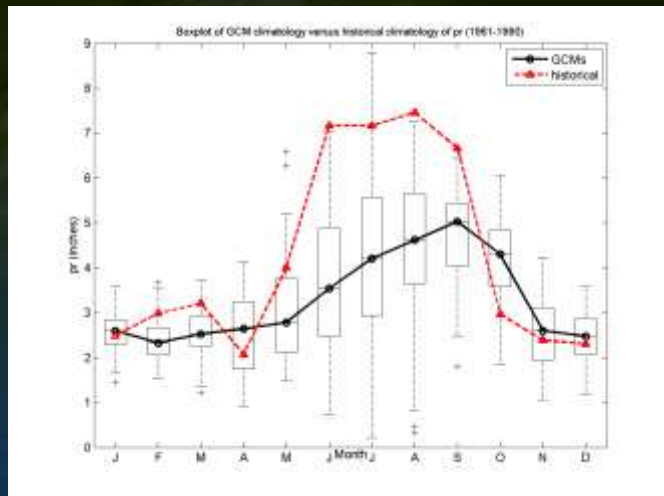
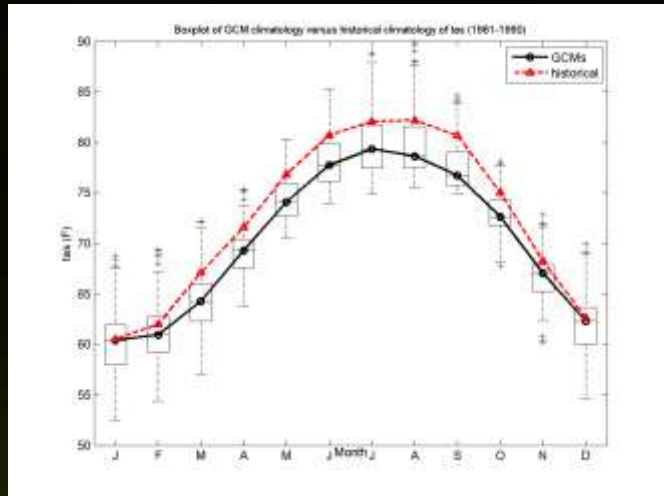
GCM Resolution in Florida



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.

GCM Skill for Florida



Regional Climate Change Projections from Multi-Model Ensembles (Tebaldi et al., 2008)



MODEL

Likelihood:

Observed: $X_0 \sim N[\mu, -\lambda_0^{-1}]$

GCM (current): $X_i \sim N[\mu, -\lambda_i^{-1}]$

GCM(future): $Y_i \sim N[v, -(\theta\lambda_i)^{-1}]$

Priors:

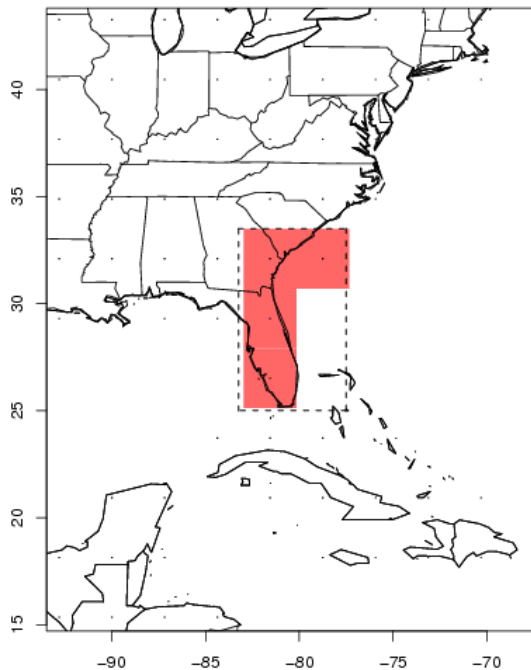
$\mu, v \sim U(-\infty, +\infty)$

$\lambda_i \sim \Gamma(a, b), \theta_i \sim \Gamma(c, d)$

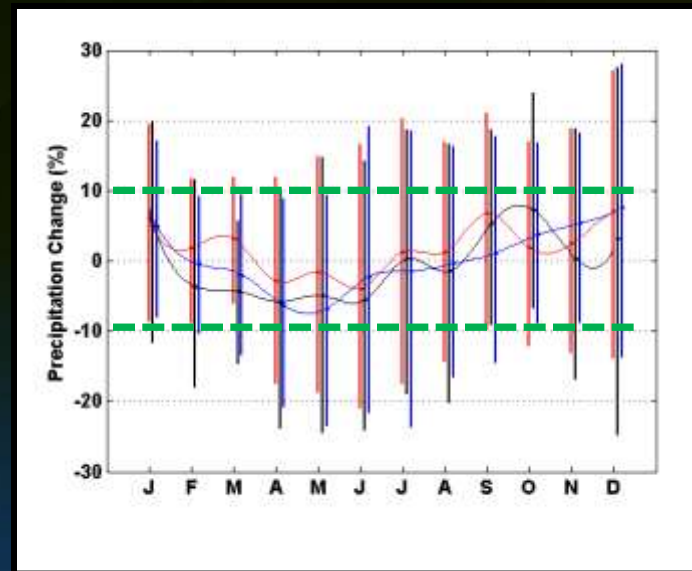
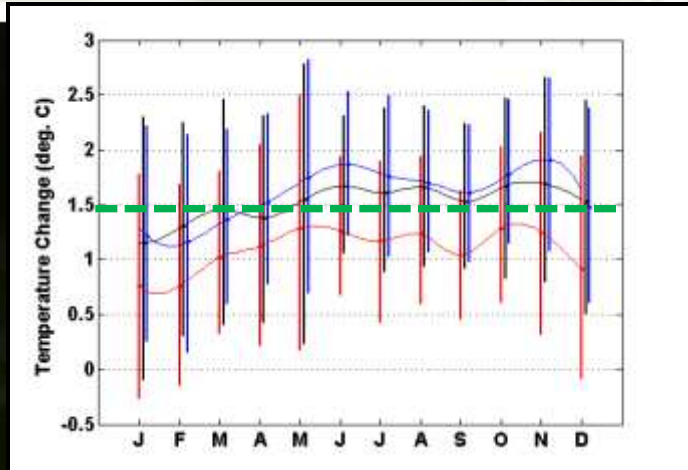
- A Bayesian approach
- Reward models with respect to BIAS (w.r.t. current climate) and CONVERGENCE (consensus on future projections)
- 23 Models, SRES scenarios A2(high), A1B (midrange), B1(low)
- Posterior distribution of precipitation & temperature for each season & future decades

Projected Temperature Change from AOGCMs (for 2050) – Posterior Distribution

Region used in computation



- The vertical bars correspond to the percentiles, 5% and 95% of the posterior distributions of temperature change for b1,a1b, and a2 scenarios (red, black and blue)



Downscaling CMIP3 GCM Climate Projections

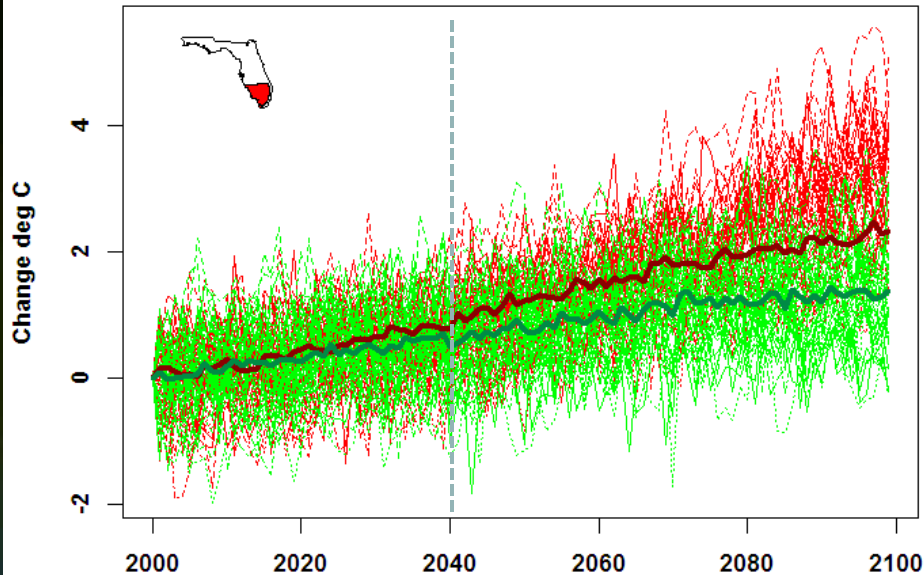
- Statistical Downscaling
 - BCSD (Bias-Corrected, Spatially-Downscaled)
 - BCCA (Bias-Corrected, Constructed Analogs)
 - Others are being developed
- Dynamical Downscaling (using Regional Climate Models)
 - NARCCAP (from NCAR)
 - FSU – Regional Spectral Model (RSM) (Not used in our study yet but others have)

Future Projections – Temperature & Precipitation (Statistical Downscaling)

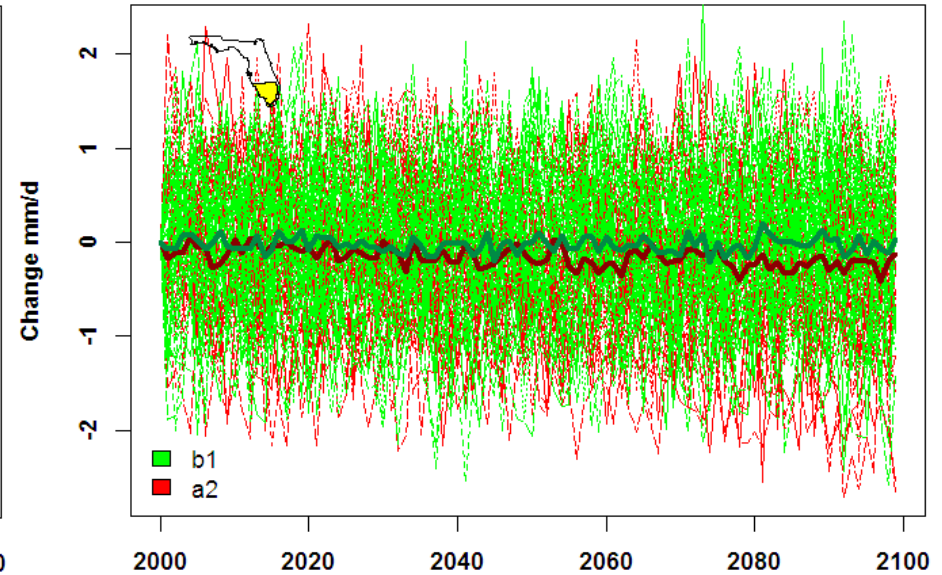
T_o
all models

ensemble P mean

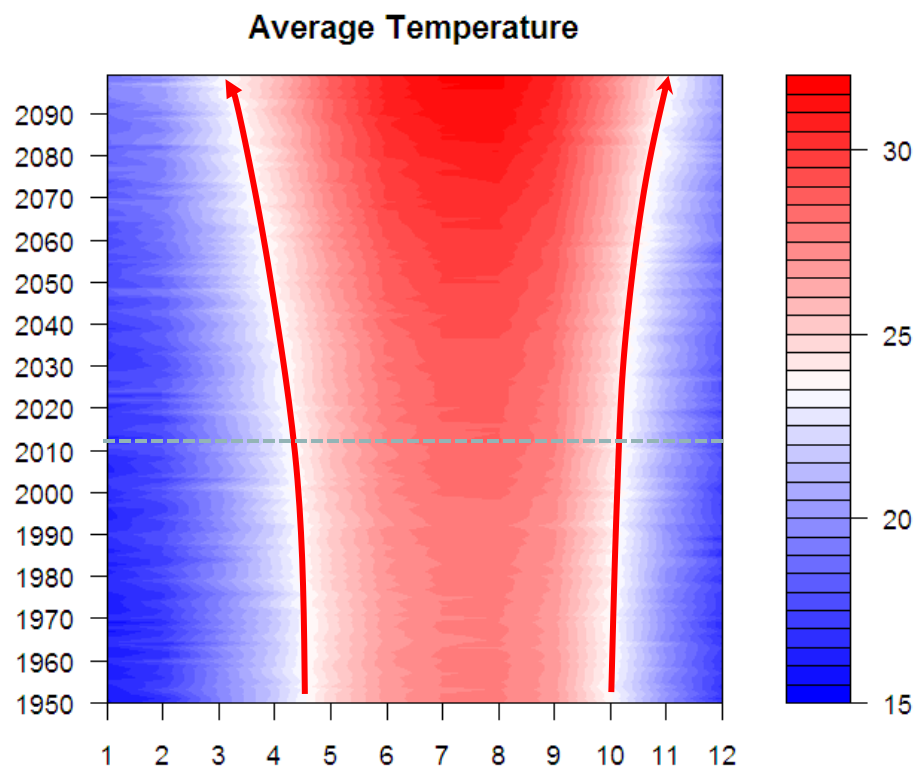
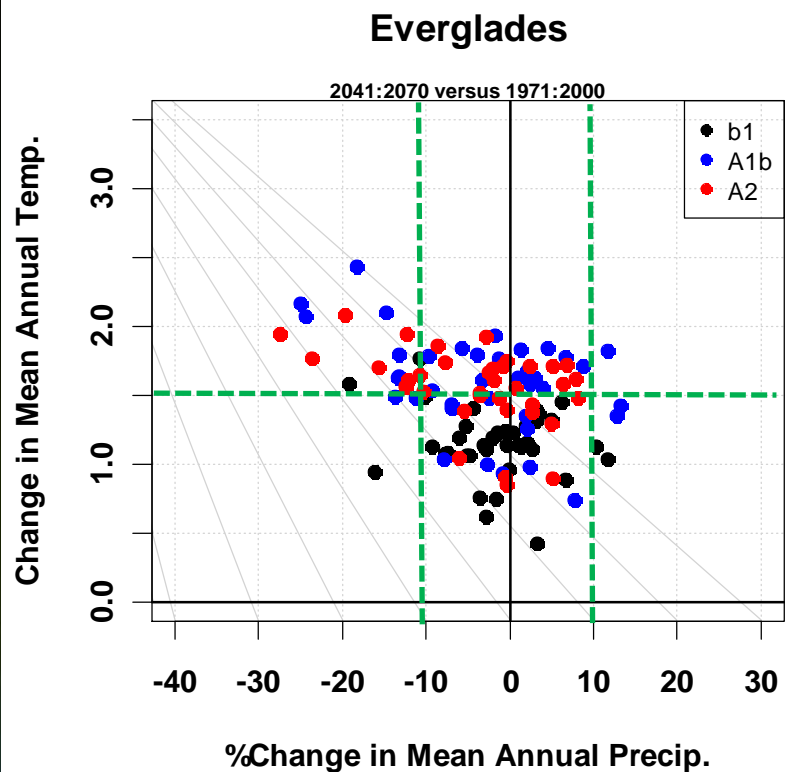
Climate Division 5



Climate Division 5



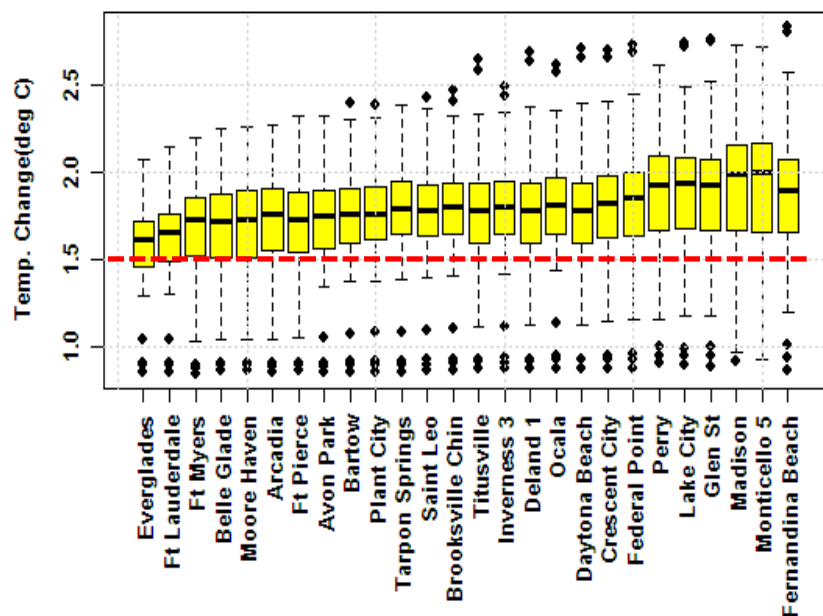
Change: Magnitude & Seasonality



a2 scenario

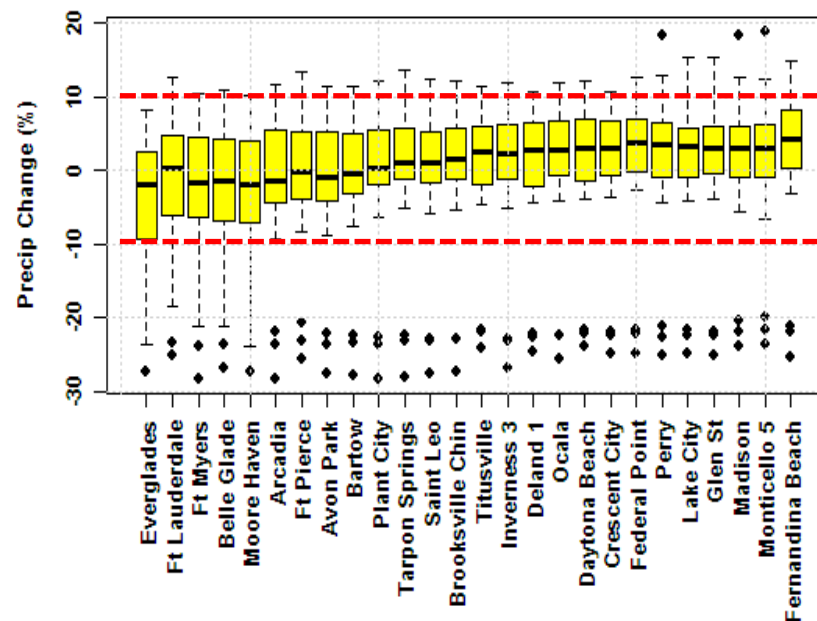
Spatial Trends

A2 Scenario



Temperature

A2 Scenario

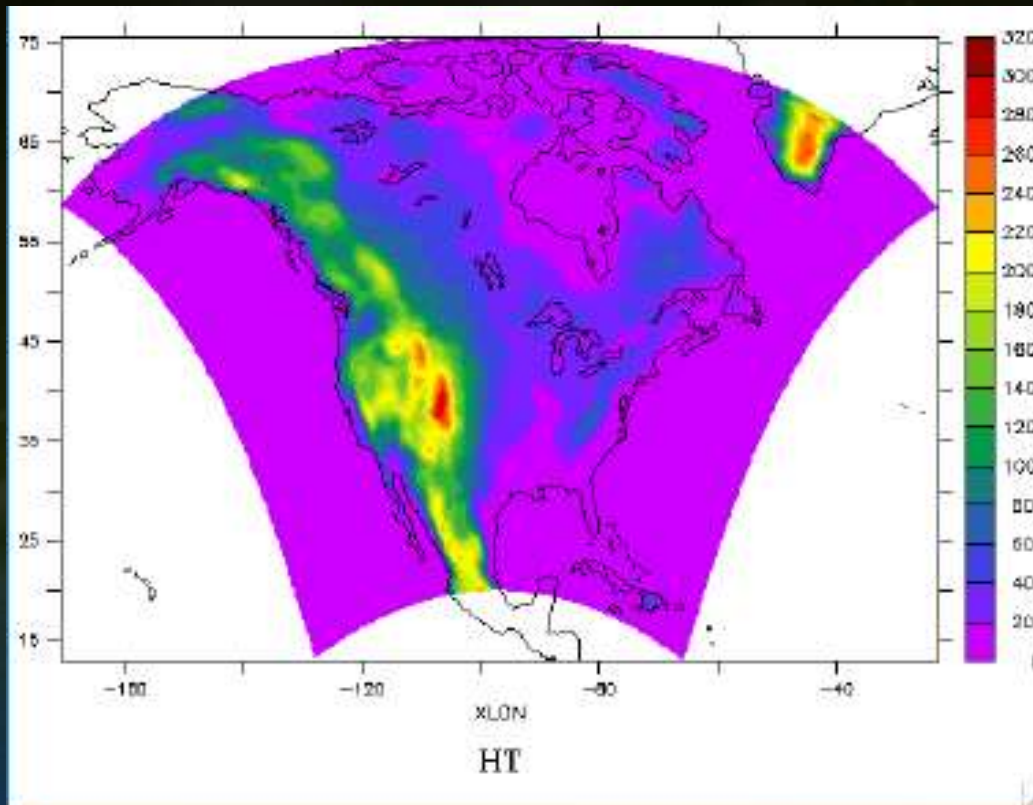


Precipitation

Dynamical Downscaling

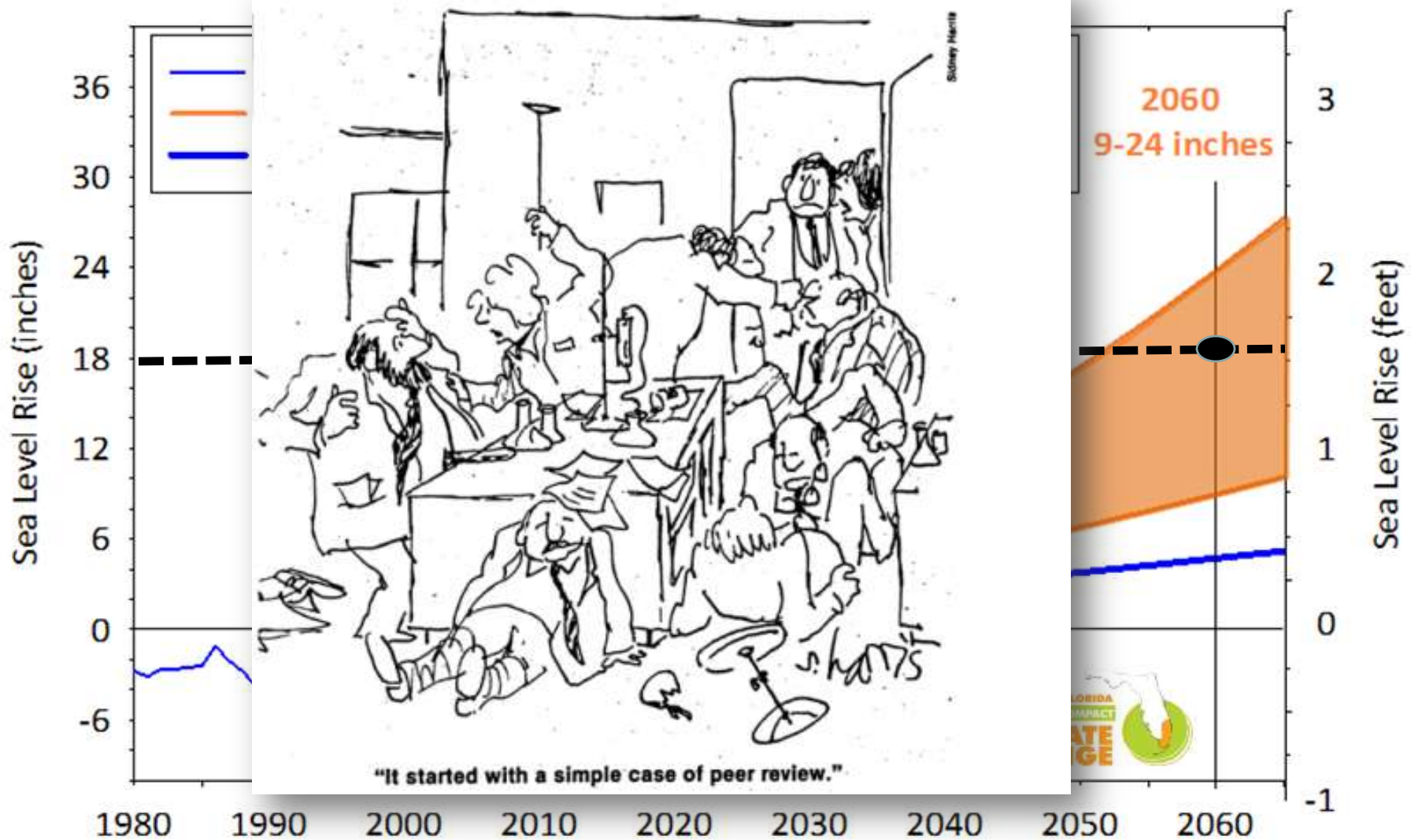
North American Regional Climate Change Assessment Program

NARCCAP

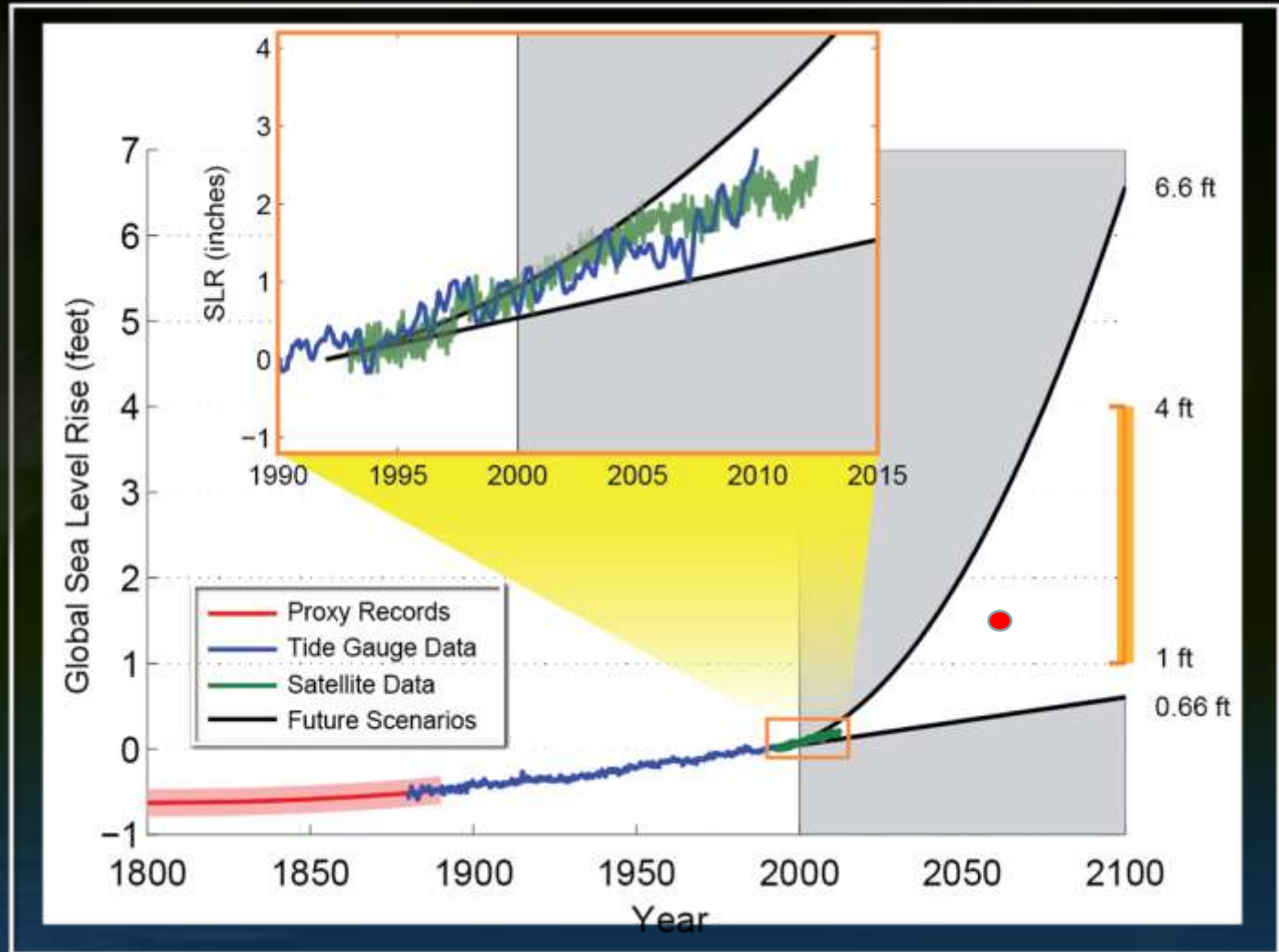


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NARCCAP is funded by the National Science Foundation (NSF), the U.S. Department of Energy (DoE), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency Office of Research and Development (EPA)."

Unified SE FL Sea Level Rise Projection



Projected range of sea level rise (National Climate Assessment, 2013)



Draft report: <http://ncadac.globalchange.gov>

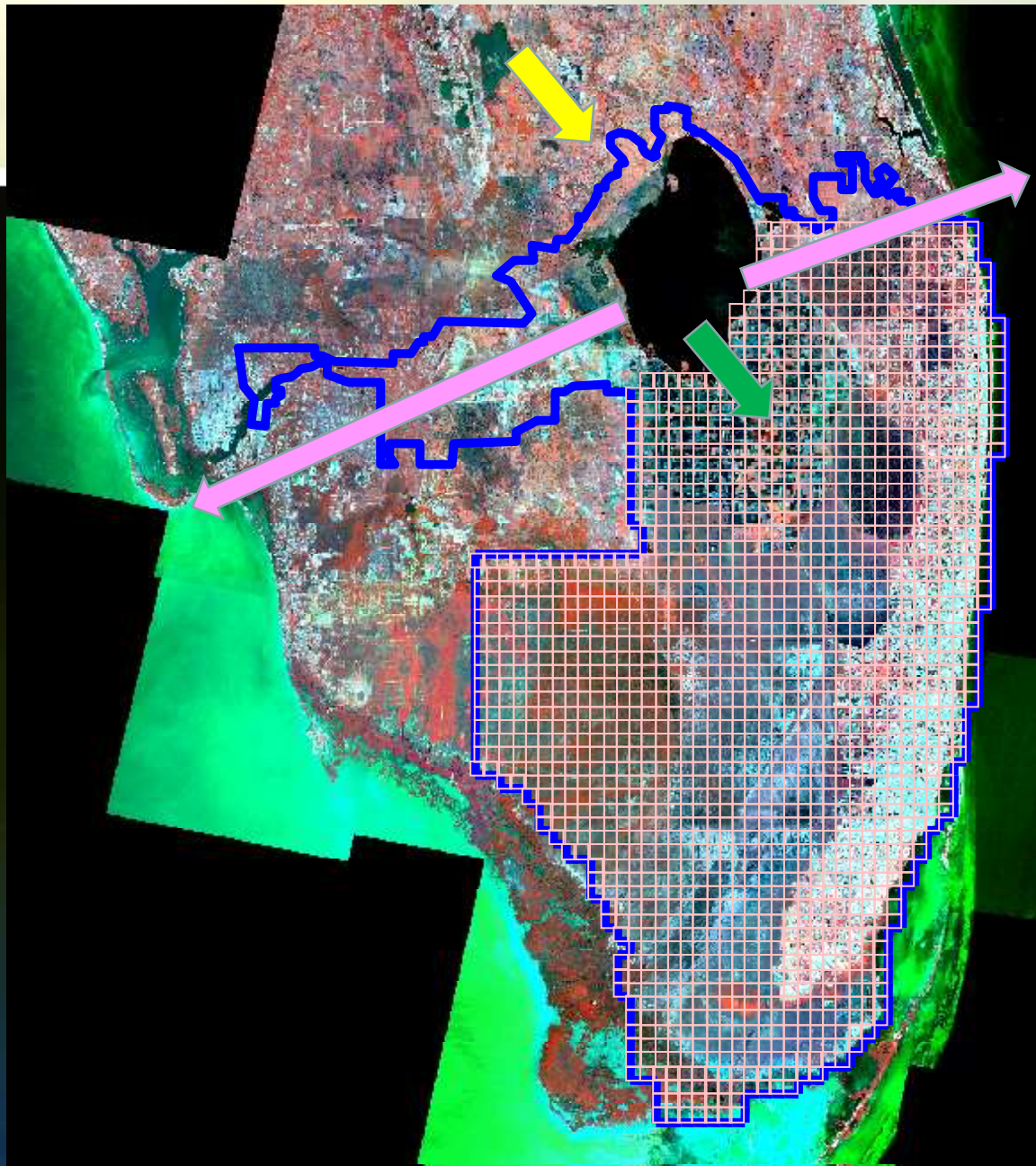
Summary of Projections for 2060

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		

Modeling Scenarios

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

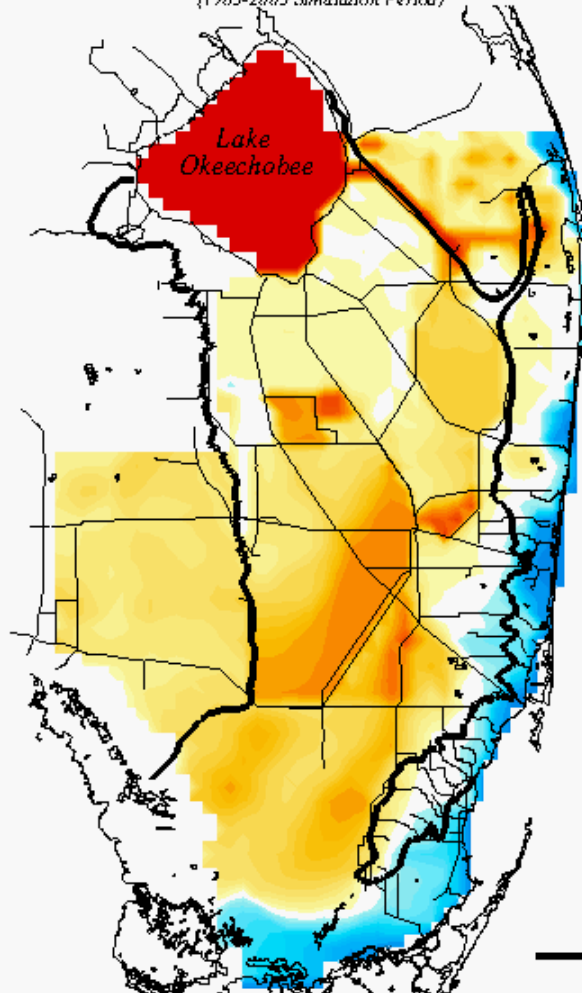
South Florida Water Management Model



- 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

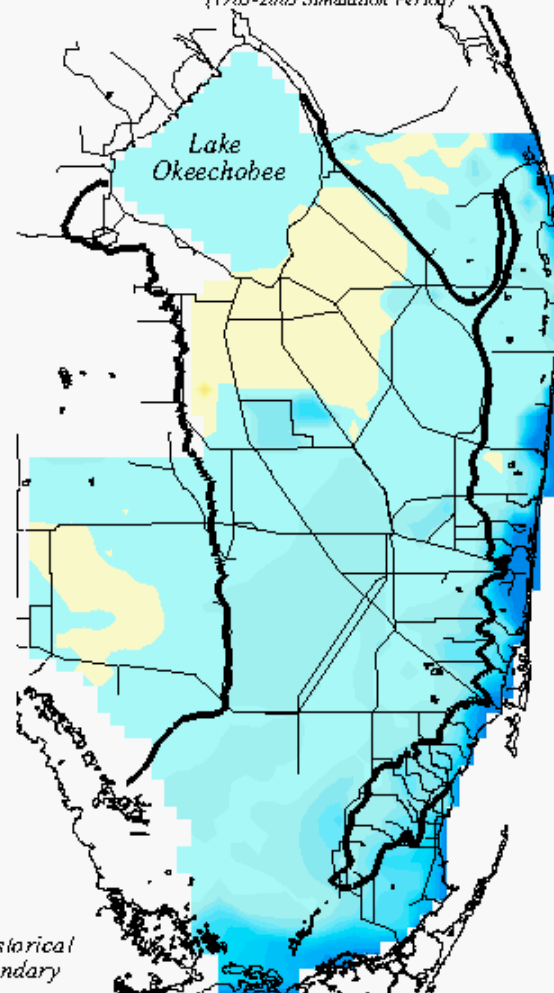
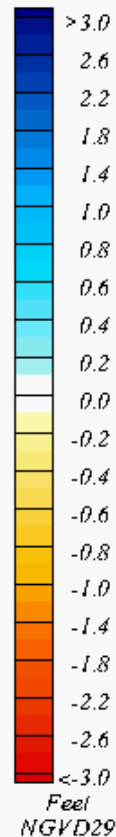
-RF+ET versus +RF+ET

SFWMM v6.6.4.2r 2010 Existing Condition with 10% Rainfall Decrease and 1.5 Degree Celsius Increase plus 1.5 foot Sea Level Rise minus 2010 Existing Condition Mean Monthly Water Surface (1965-2005 Simulation Period)



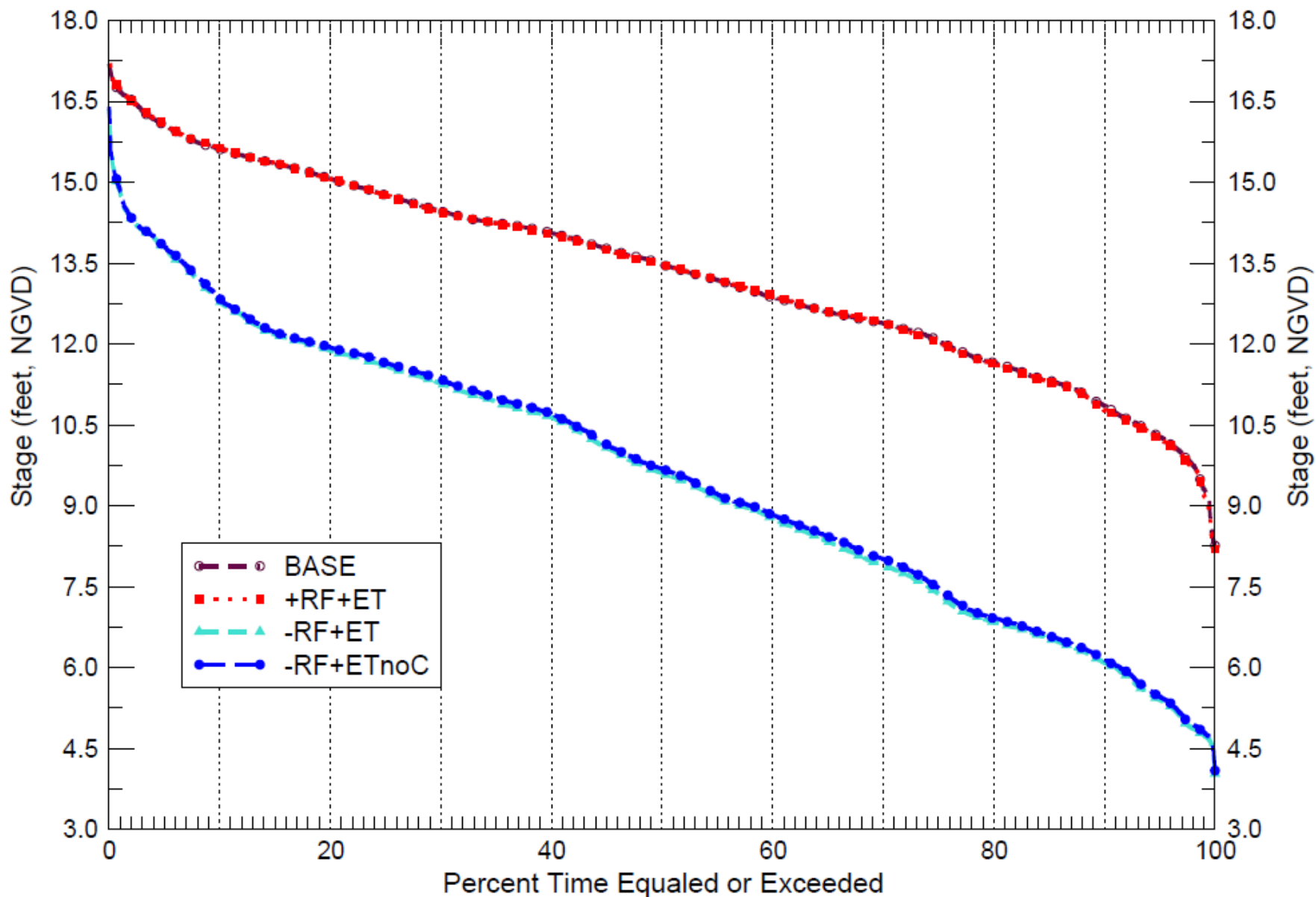
SFWMM v6.6.4.2r 2010 Existing Condition with 10% Rainfall Increase and 1.5 Degree Celsius Increase plus 1.5 foot Sea Level Rise minus 2010 Existing Condition Mean Monthly Water Surface (1965-2005 Simulation Period)

JAN



Generalized Historical Everglades Boundary

Stage Duration Curves for Lake Okeechobee



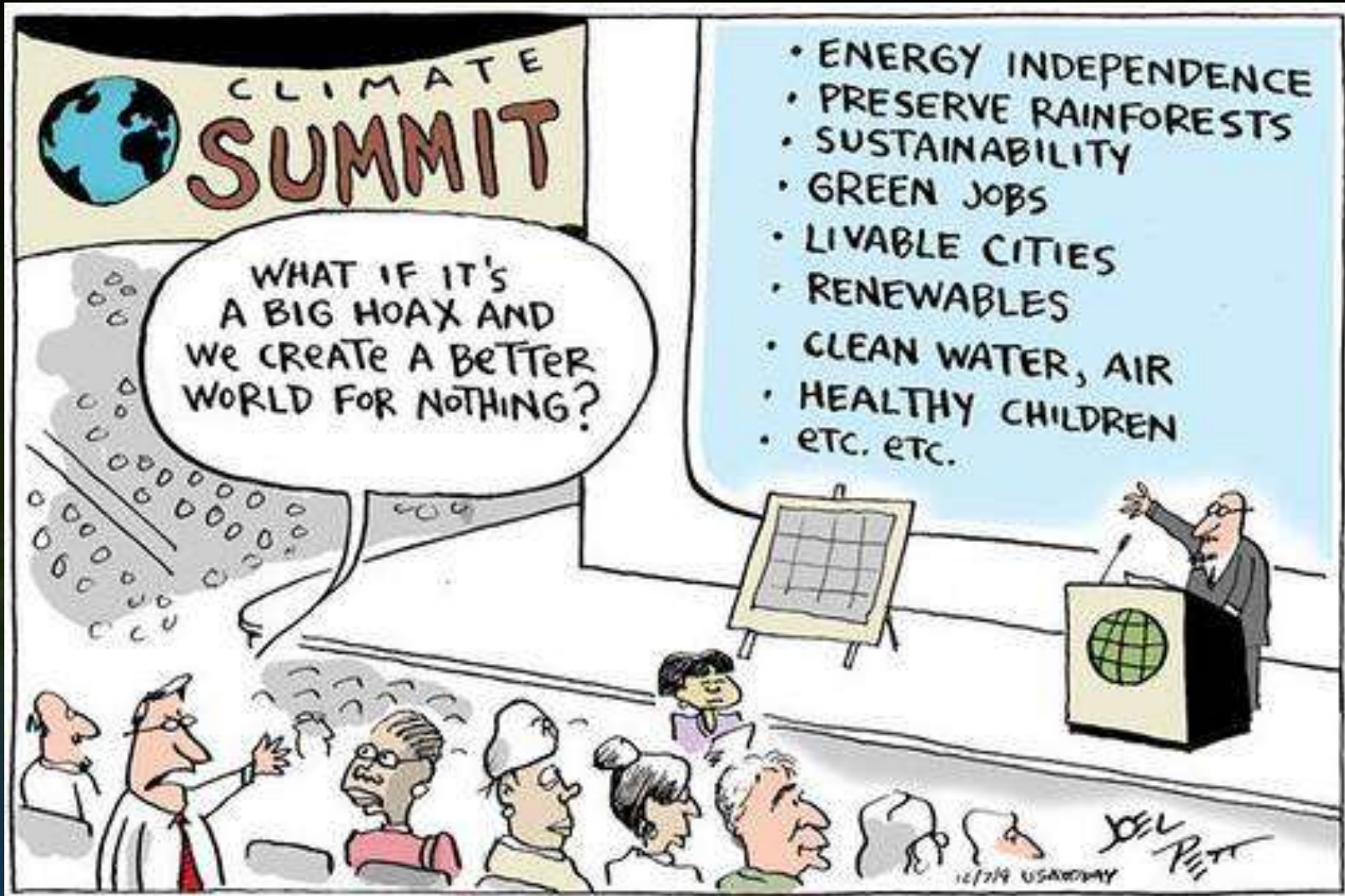
CONCLUSIONS

Climate change scenarios suggest that with increased ET and -10% rainfall:

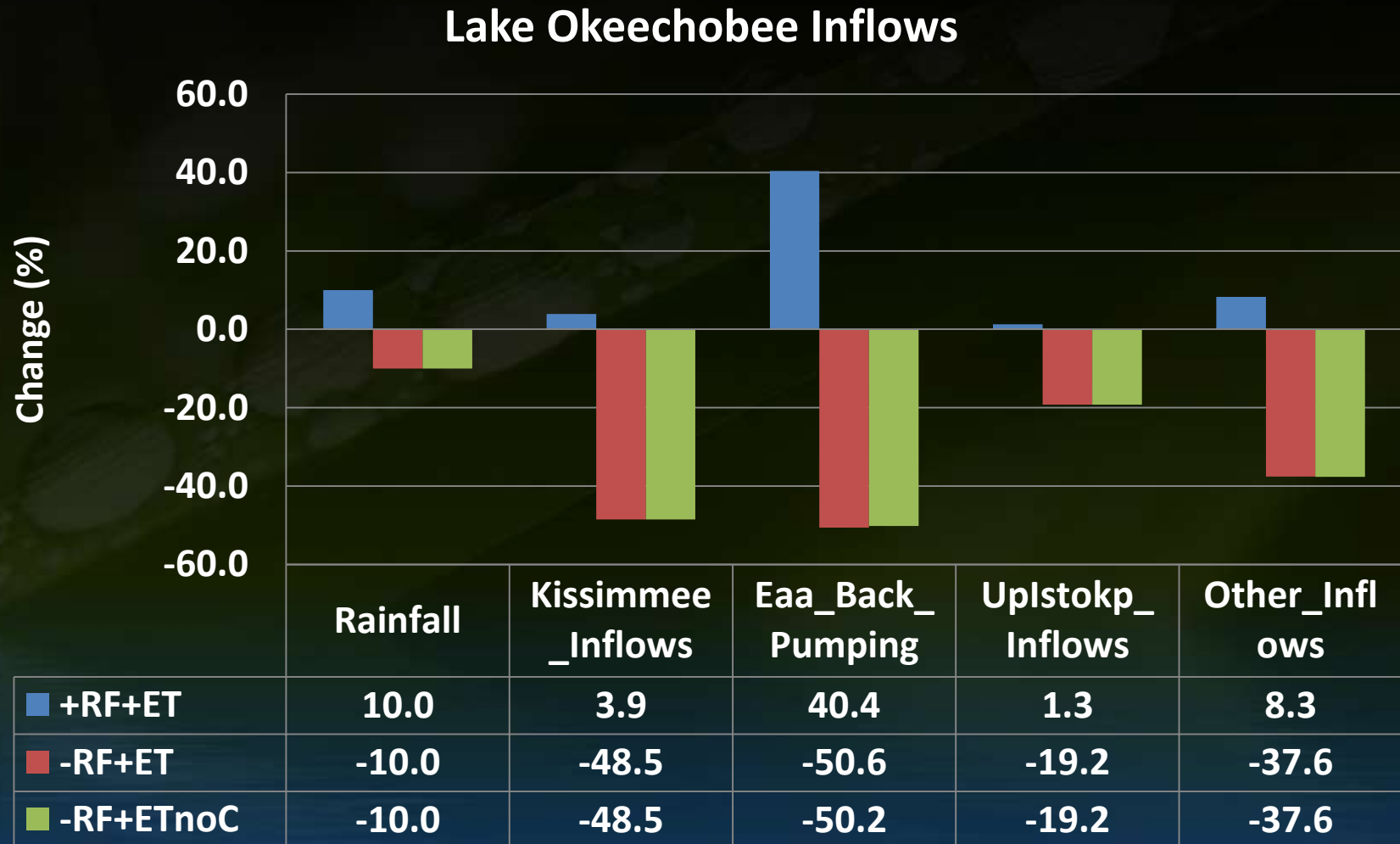
- Water levels will decrease -0.5 to -3.0+ feet
- Annual surface water inundation decreases by 10-50% across Everglades
- Novel conditions for Everglades over last 5000 years



Questions?

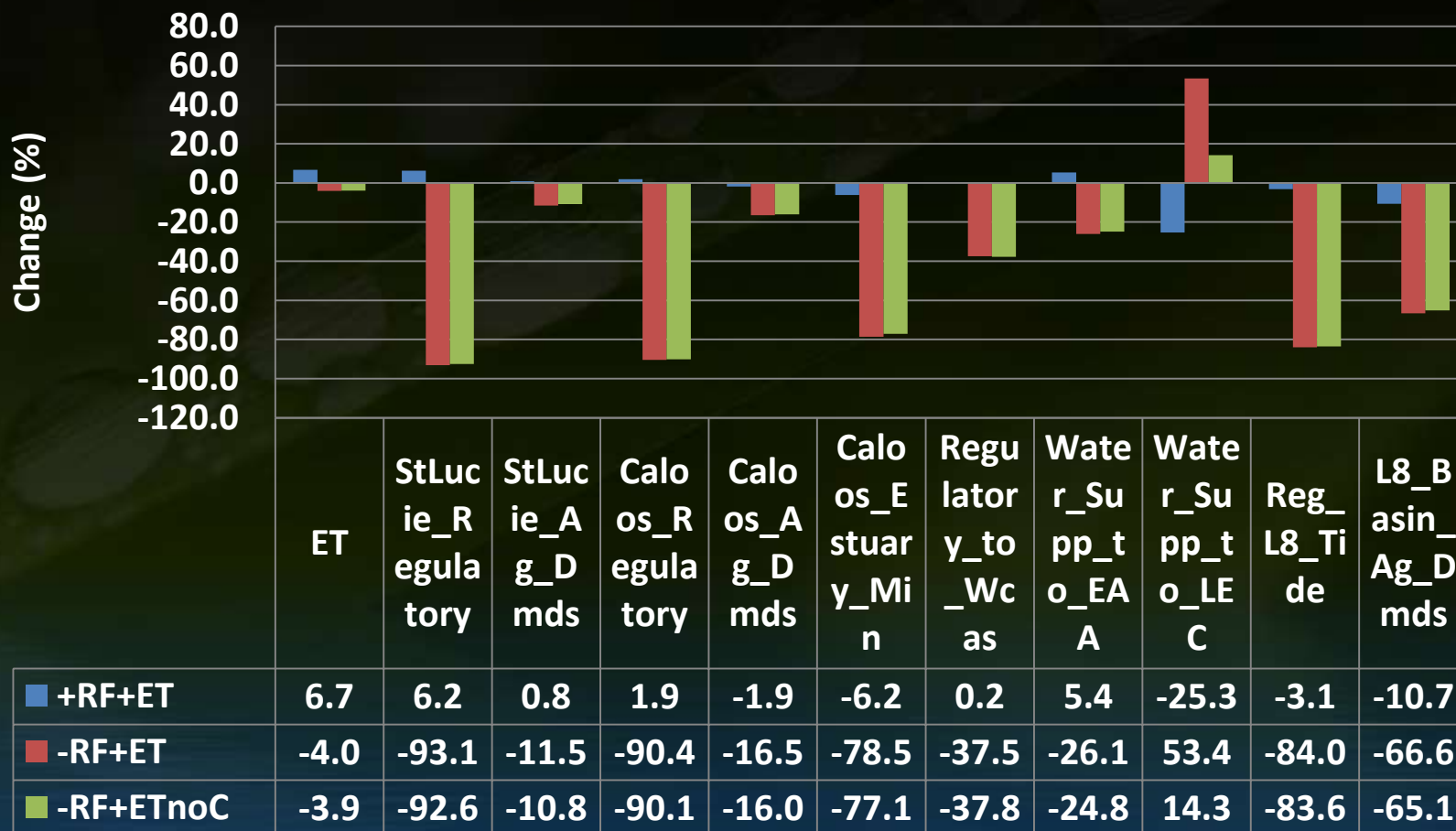


Percent Change in Lake Okeechobee Inflows



Percent Change in Lake Okeechobee Outflows

Lake Okeechobee Outflows





EXPECTED CHANGES FROM CLIMATE CHANGE

Drought

Recent droughts:
Water 2-3 feet
below peat
surface (June
2011)



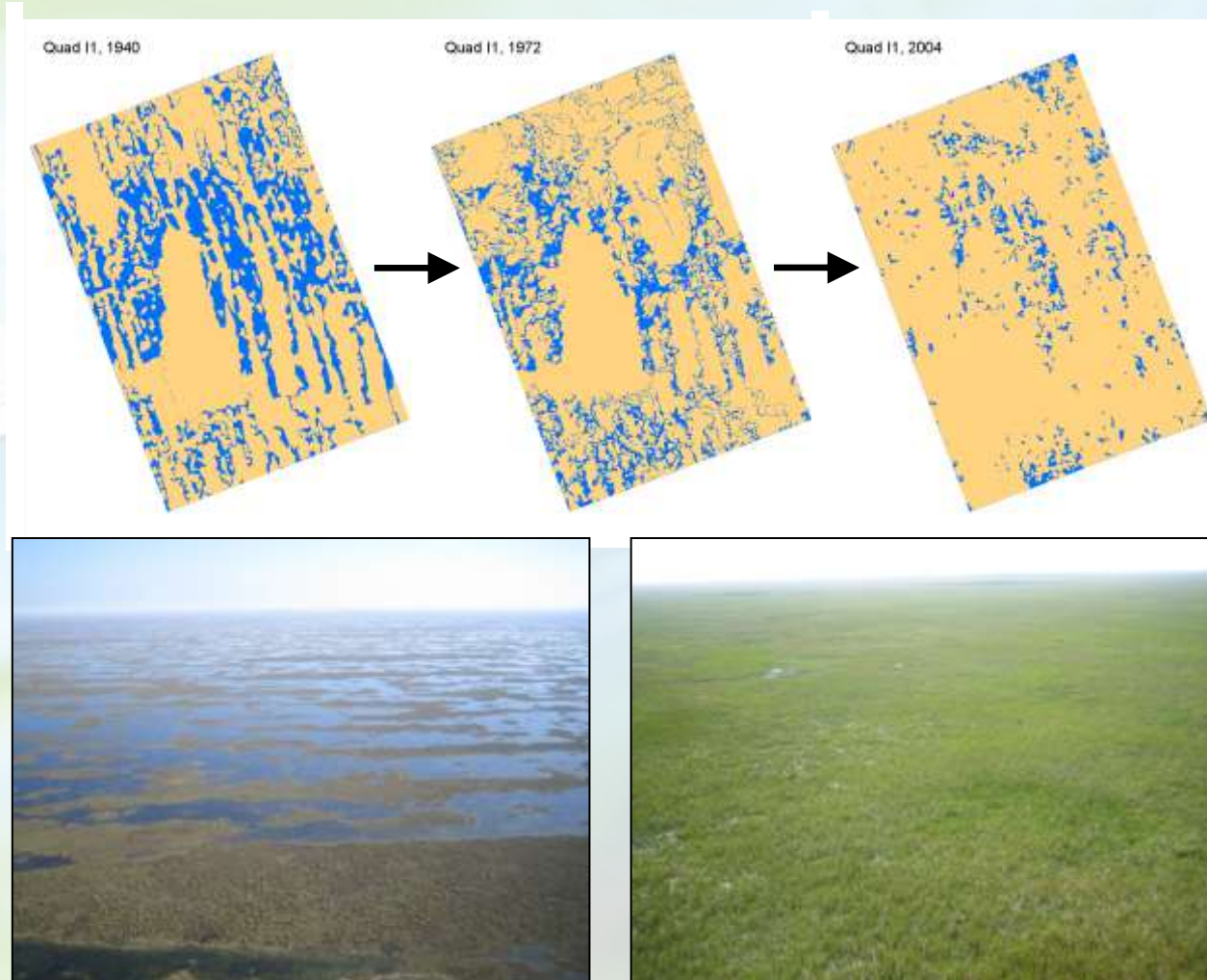
Large Wildfires



Peat flammability is similar across the Everglades: Lower organic content/dryer conditions similar to higher organic content/wetter conditions (Johnson 2013)

“Prairie Fire,” June 2011, WCA-3B: 68,300 acres (107 sq. mi.)

Pattern Loss



(Nungesser 2011)

Plant Community Changes



Tree islands in Everglades

Native Everglades tree species vary in moisture tolerance

Changing hydroperiods, shallower soils (peat loss), higher fire frequencies will:

- Favor more drought tolerant species
- Shift plant community composition and structure (Ewe and Coronado 2009)

Decrease in water availability in Everglades hammocks:

- Probable loss of tree hammock species
- Shifts to pineland and xeric communities (Saha 2009)

Pineland on rock outcrops



Invasive exotic species (*Lygodium microphyllum*)



Lygodium microphyllum

Tree islands with *Lygodium* had significantly lower and less variable water levels around them (Nungesser et al., submitted):

Lower water levels are likely to increase spread of *Lygodium* in the WCAs

Ascending forest canopy



Covering tree island



Paleoecology—nothing like it

Sample sites

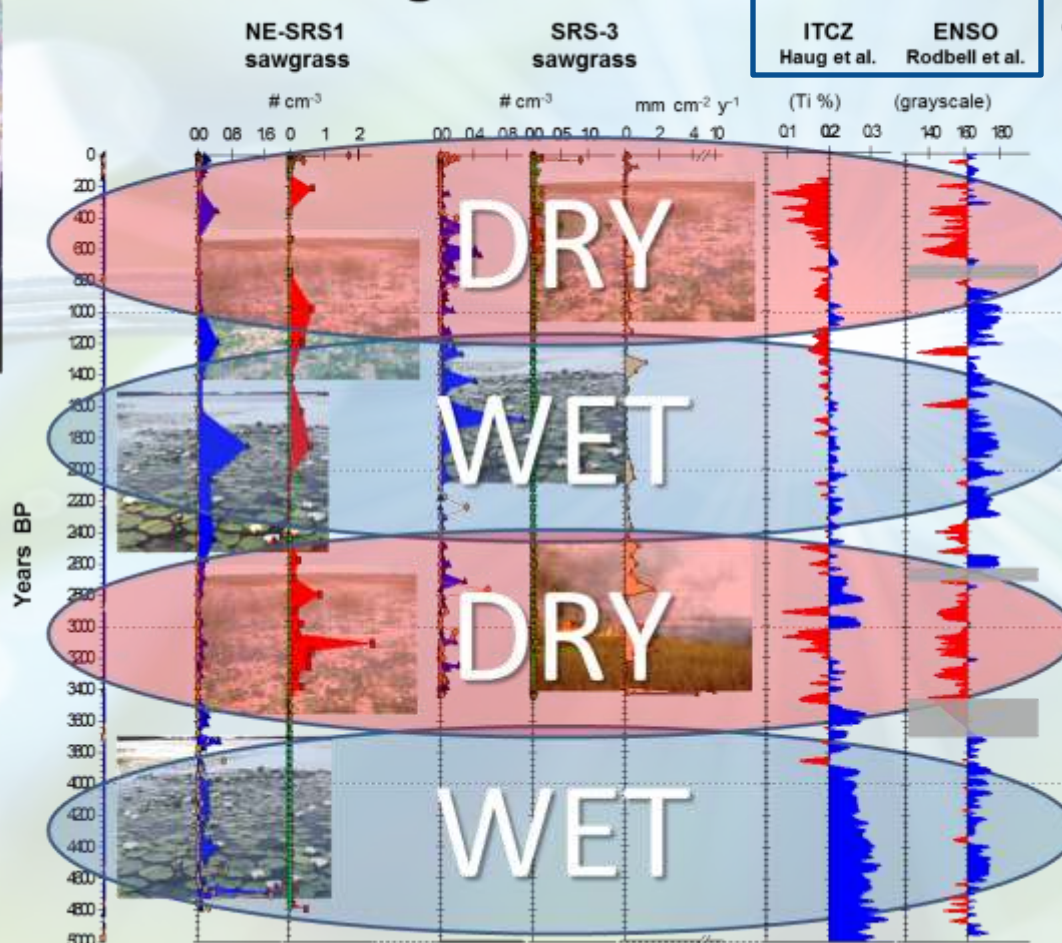


Fossil seeds

- ▲ Slough seeds
- Sawgrass seeds
- ▼ Wet Prairie seeds
- ◆ *Utricularia* spp. seeds
- Charophyte oospores
- ▲ Charcoal (SRS-3 only)
- gaps in ENSO record

Saunders et al., 2008 & in prep

The Everglades Paleo-Record



Extra slides