SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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

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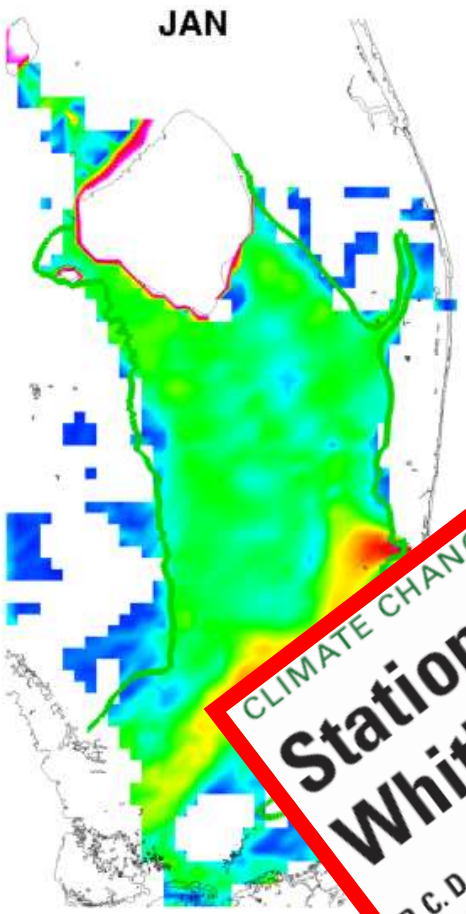
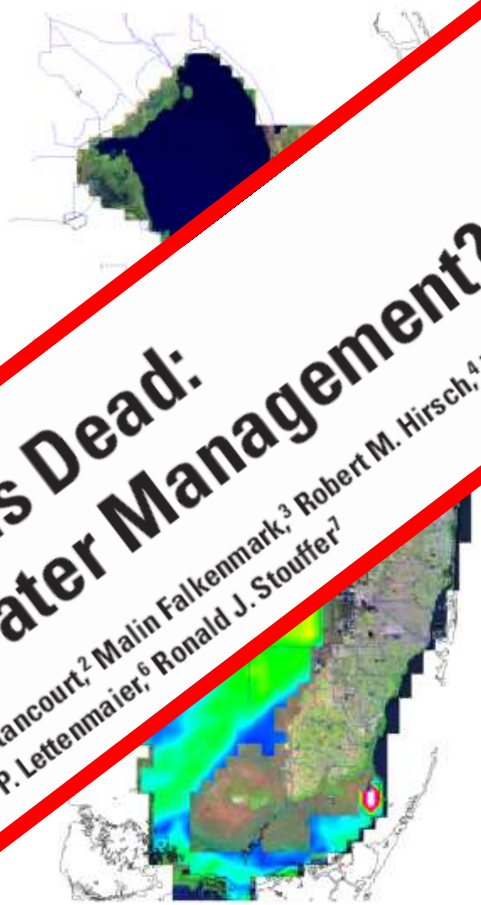
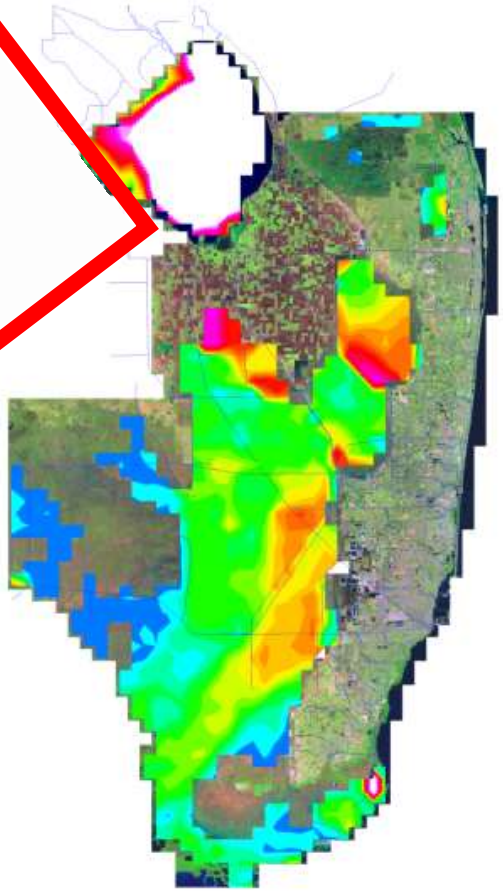
sfwmd.gov

Everglades Restoration – Do we need a new paradigm?

Natural System | **Managed System** | **CERP**





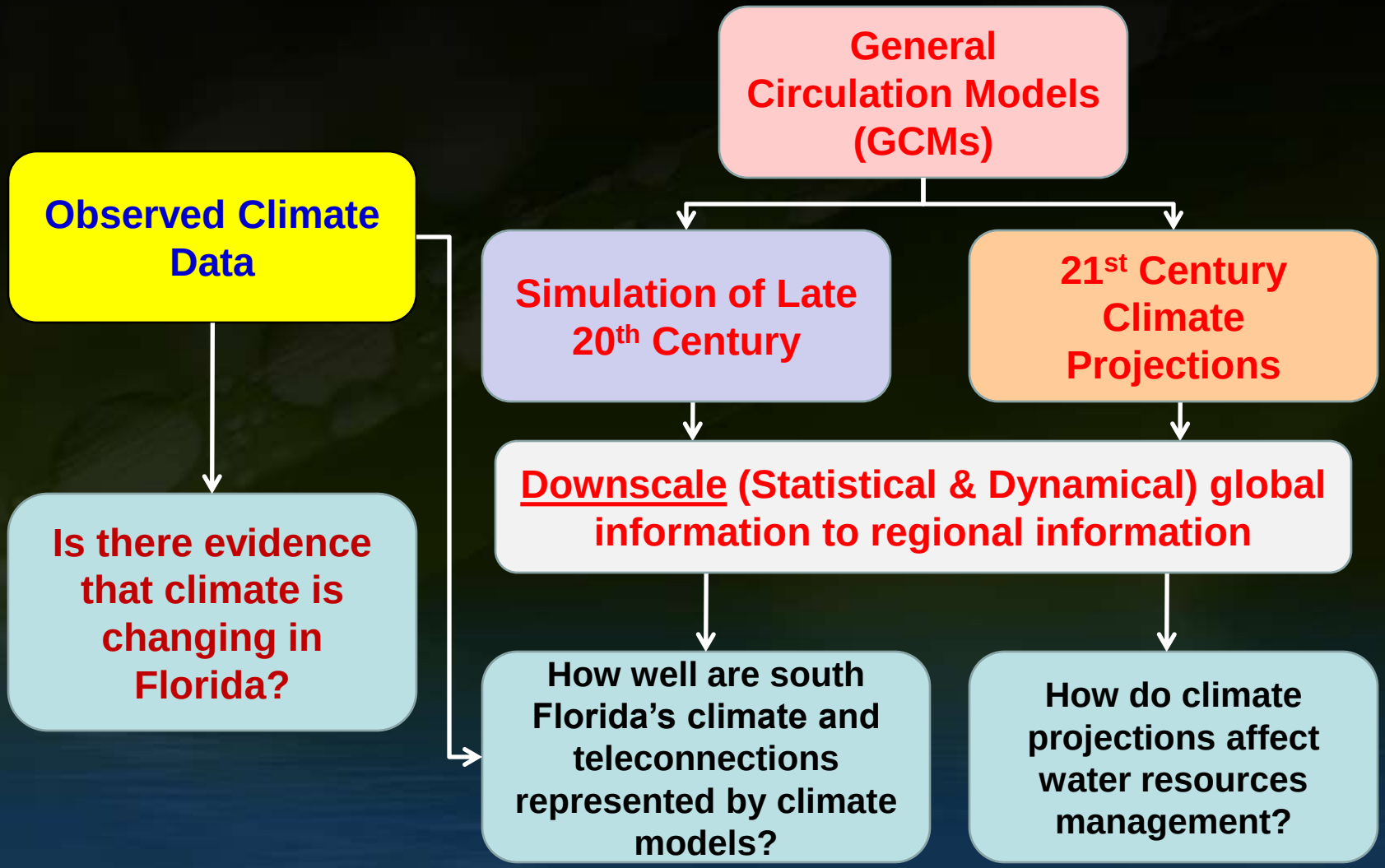


CLIMATE CHANGE

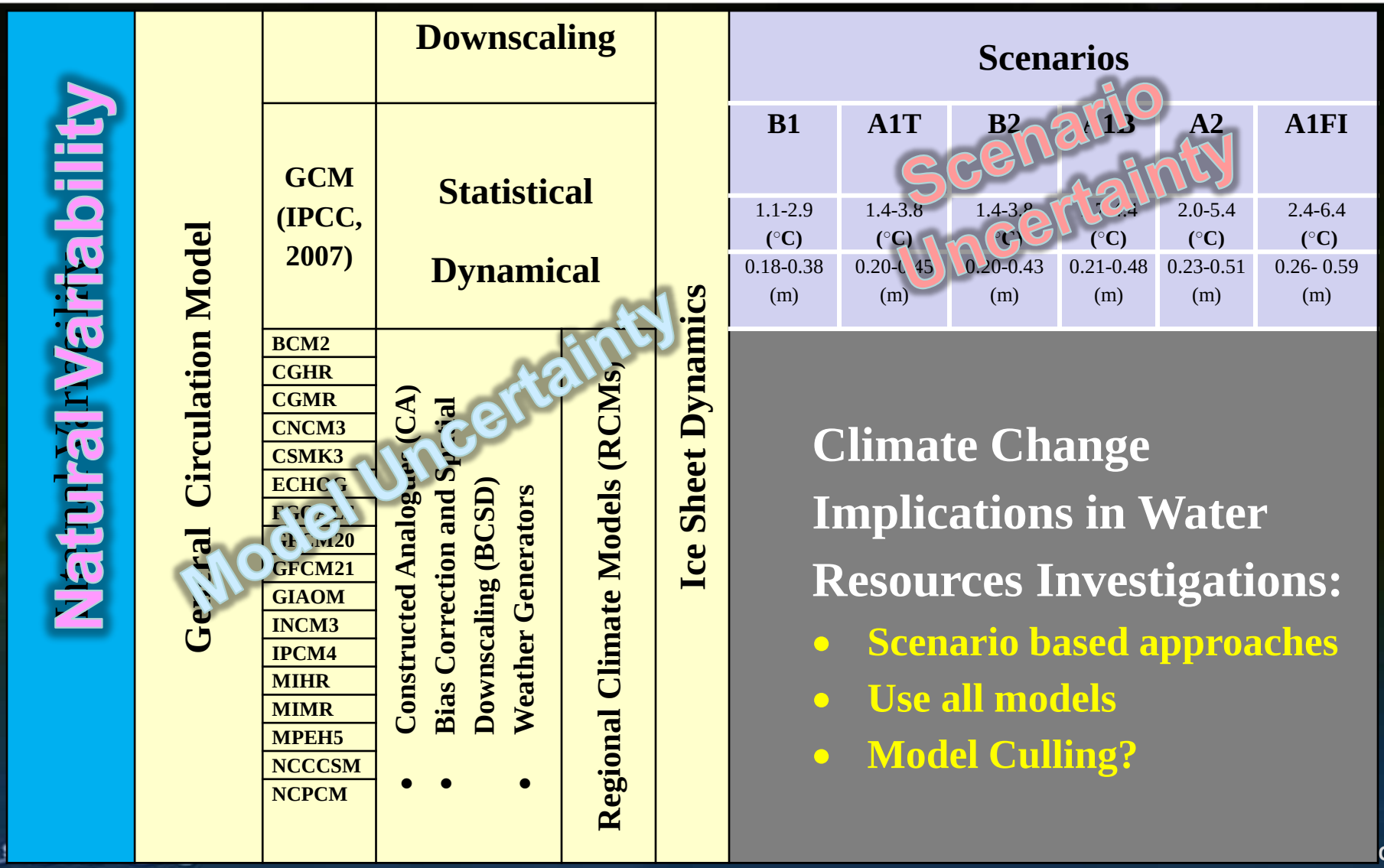
Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

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

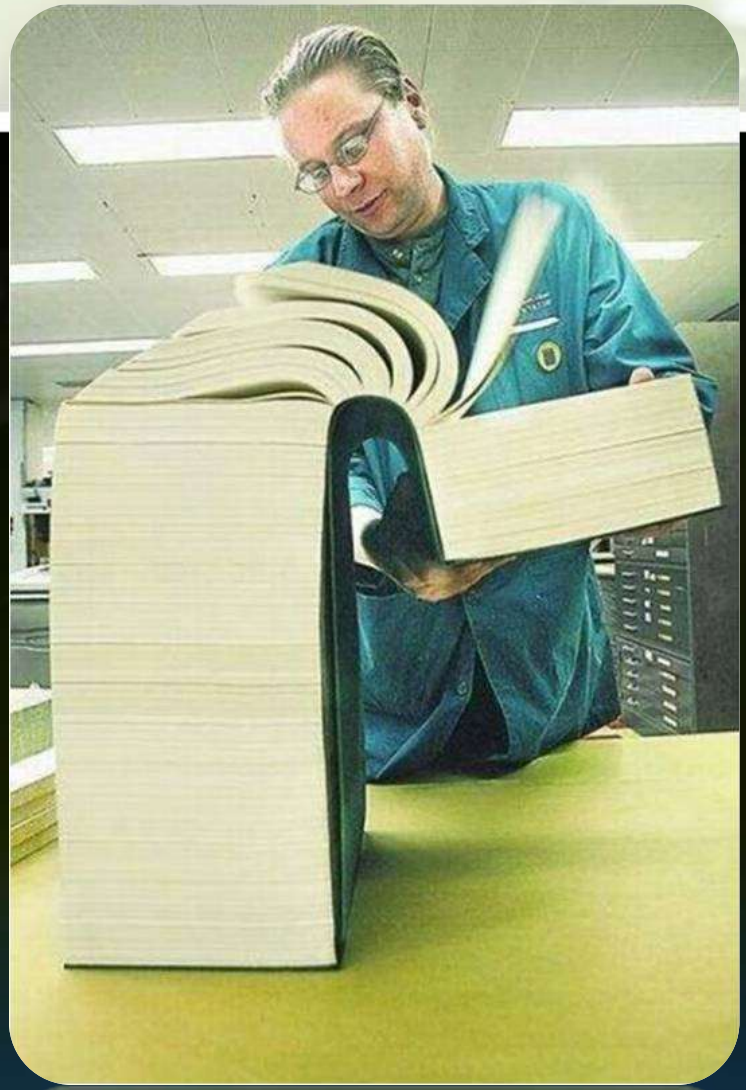


Climate Projection Uncertainties

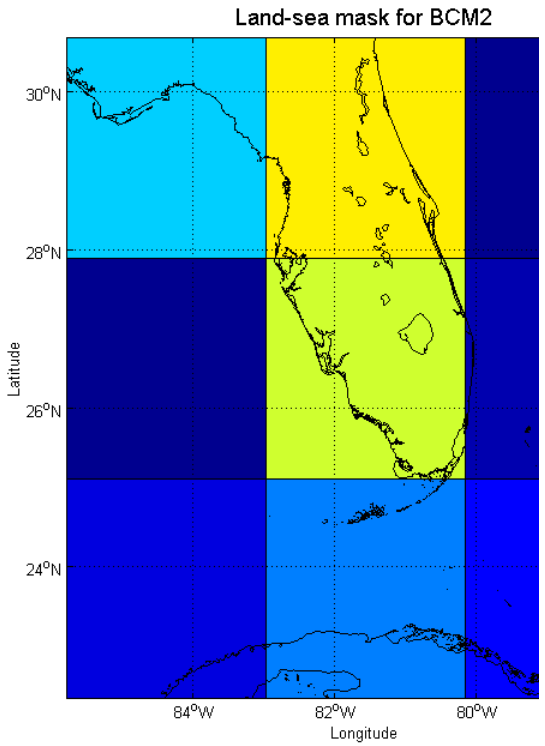


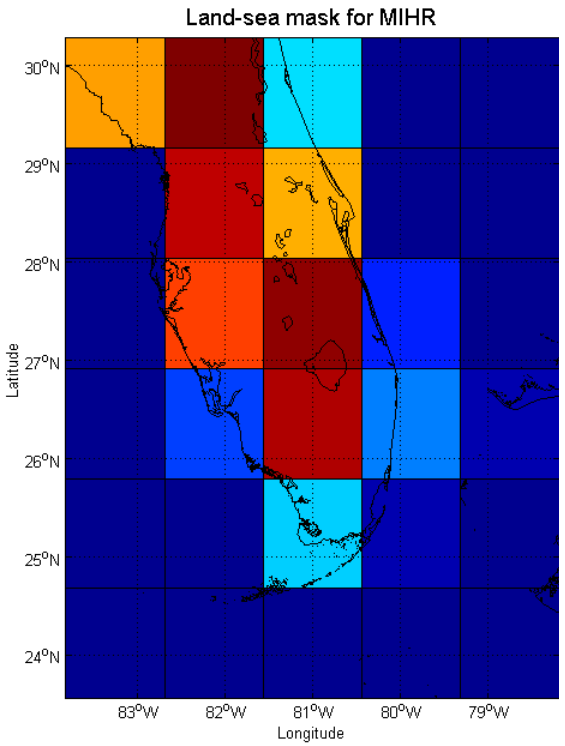
Book of Climate Output

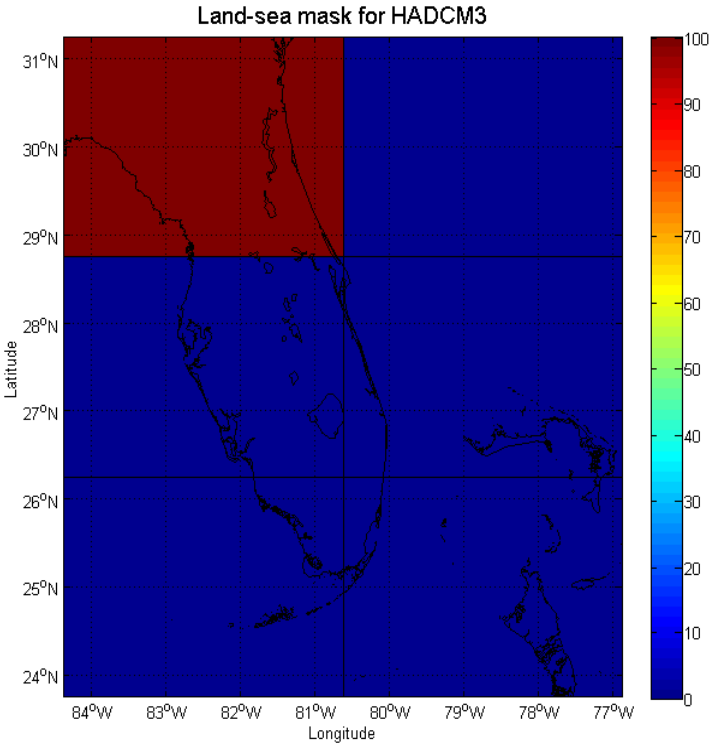
What exactly we find for Florida?



GCM Resolution in Florida



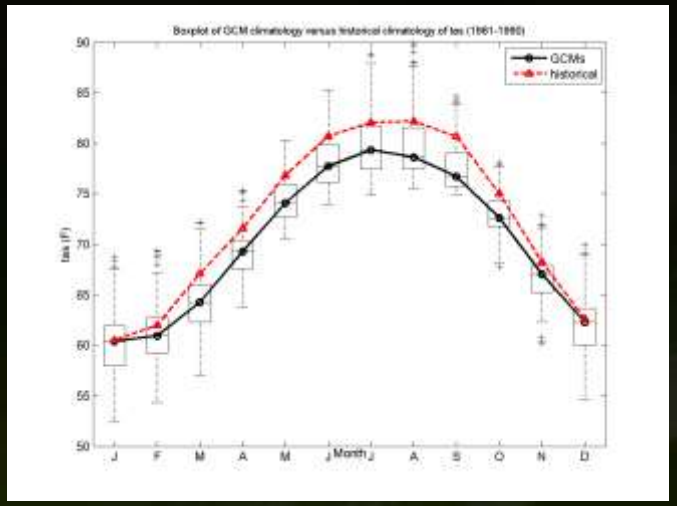


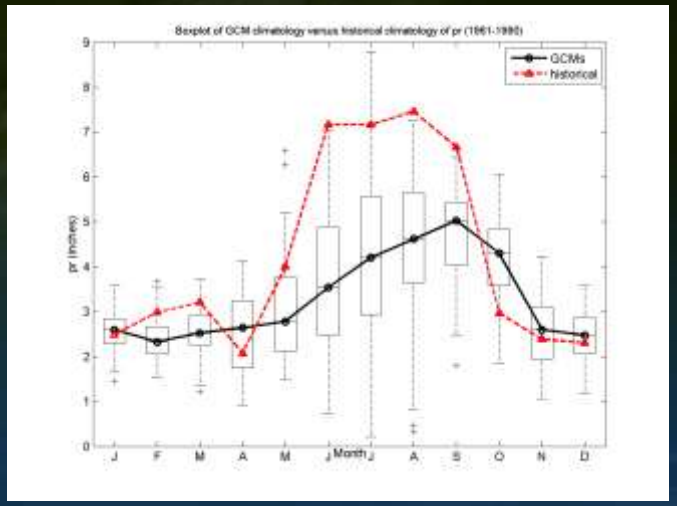


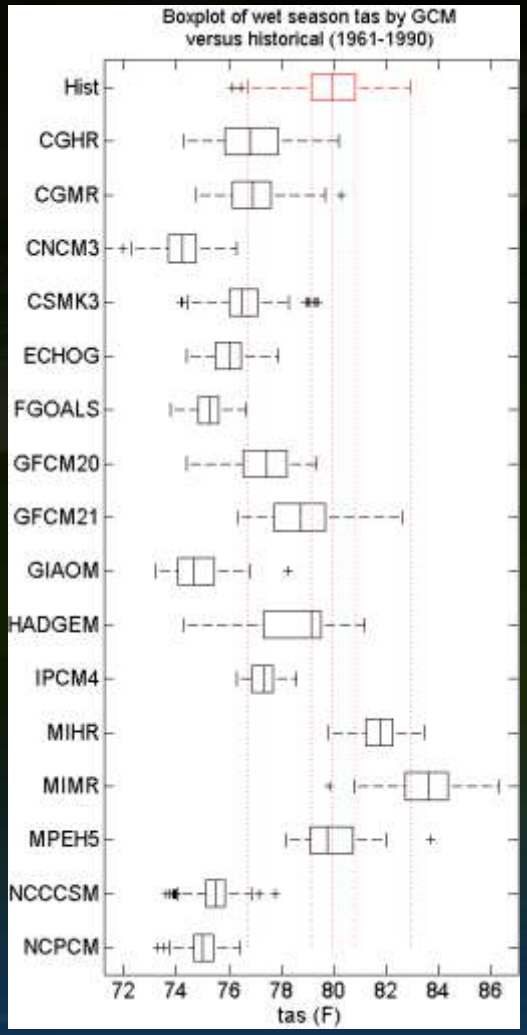
Uncertainties in GCM predictions due to:

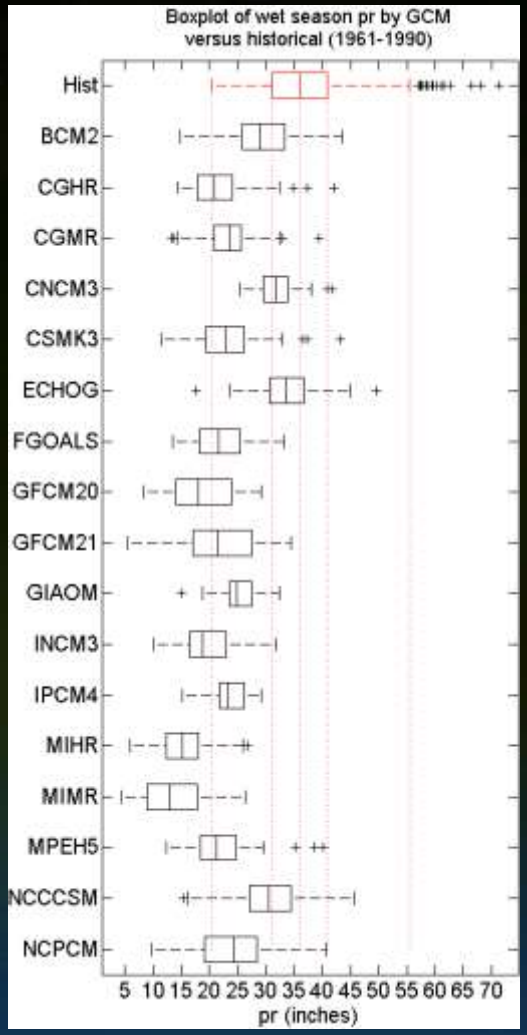
- **Poor resolution** – South Florida not even modeled in some GCMs; greater errors at smaller scales
- From IPCC AR4-WG1, Ch. 8 - Simulation of tropical precipitation, ENSO, clouds and their response to climate change, etc.

GCM Skill for Florida









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

at http://rcpm.ucar.edu

MODEL

Likelihood:

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

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

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

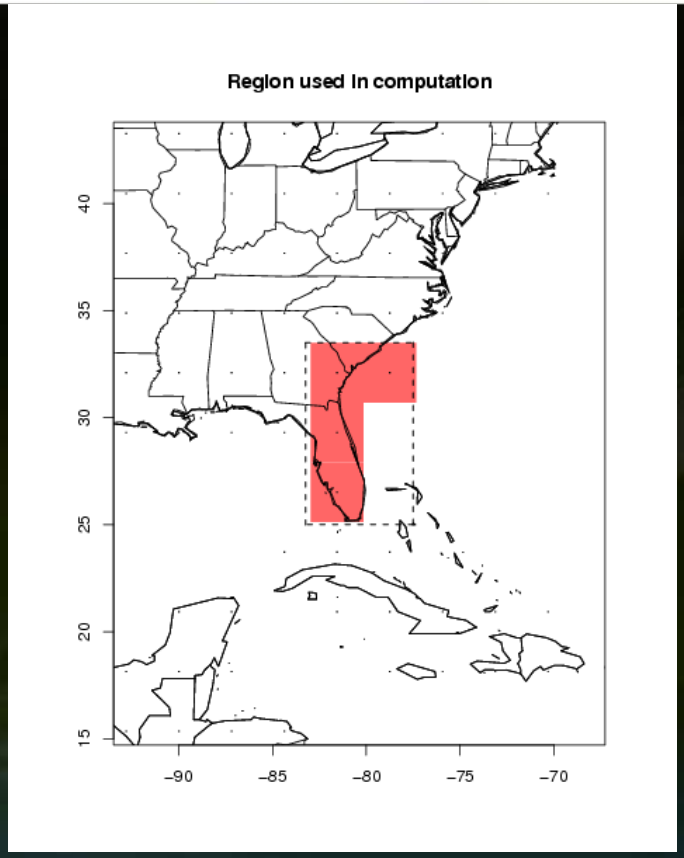
Priors:

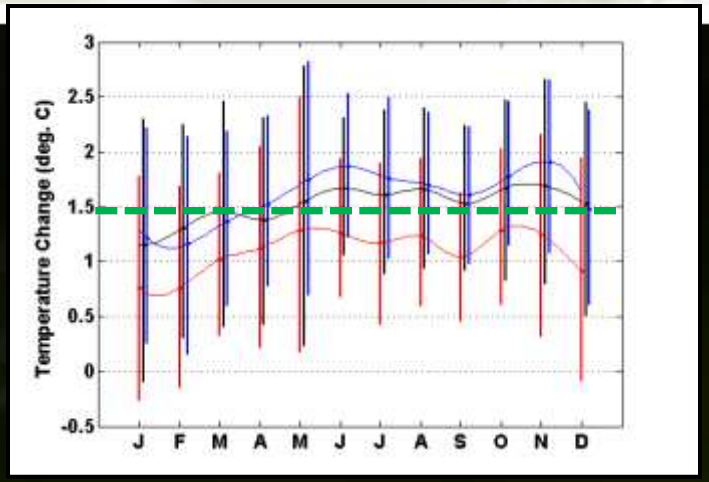
$\mu, \nu \sim U(-\infty, +\infty)$

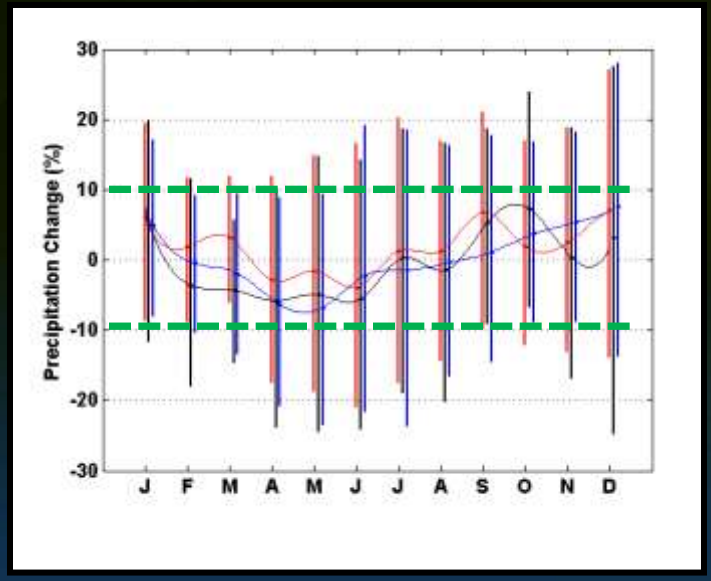
$\lambda_i \sim \Gamma(a,b)$, $\theta_i \sim \Gamma(c,d)$

- 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







•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)

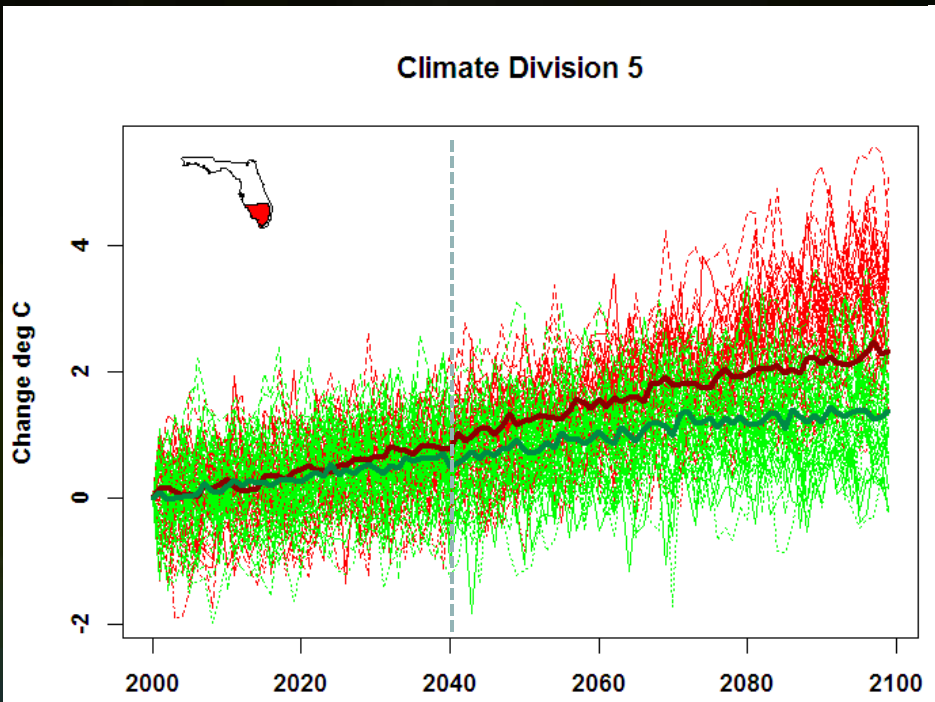
Downscaling CMIP3 GCM Climate Projections

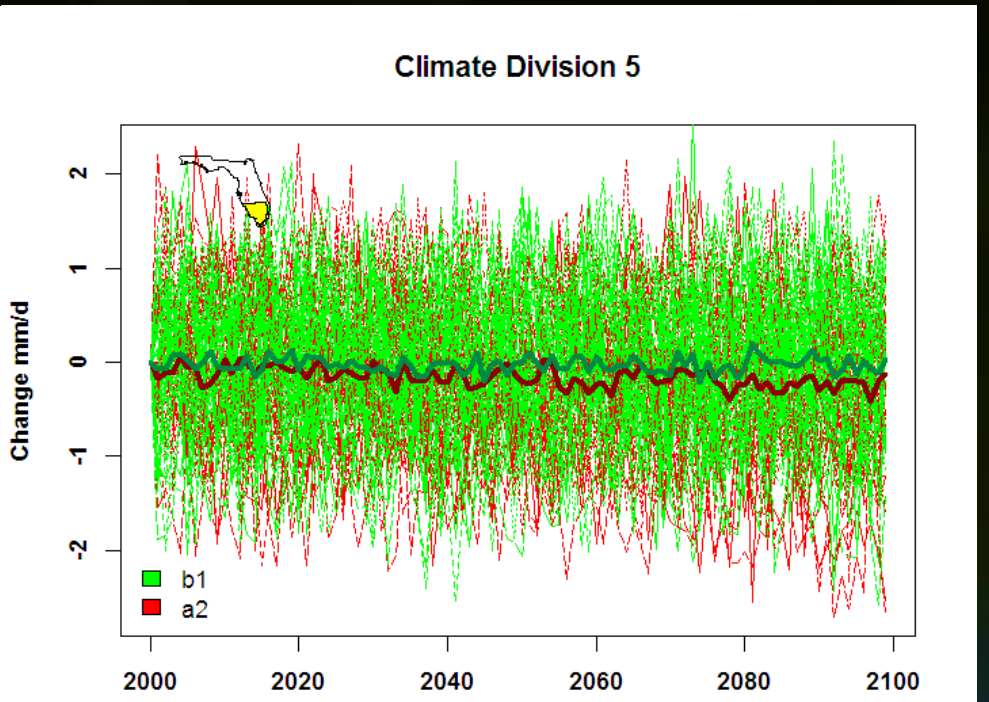
- Statistical Downscaling
  - BCSD (Bias-Corrected, Spatially-Downscaled)
  - BCCA (Bias-Corrected, Constructed Analogs)
  - Others are being developed
- Dynamical Downscaling (using Regional Climate Models)
  - NARCCAP (from NCAR)
  - FSU – Regional Spectral Model (RSM) (Not used in our study yet but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

Future Projections – Temperature & Precipitation (Statistical Downscaling)

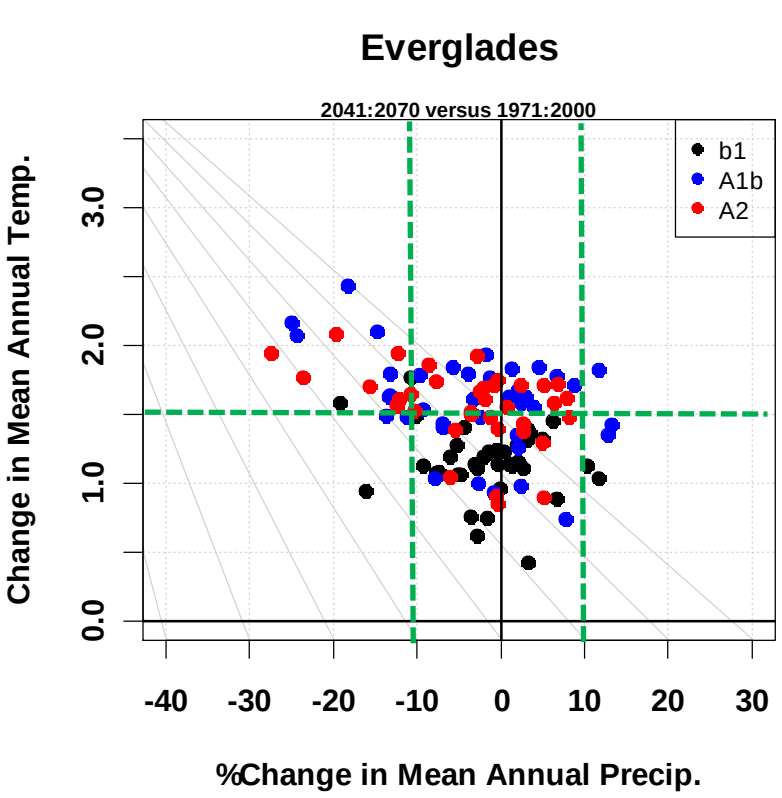
T° all models

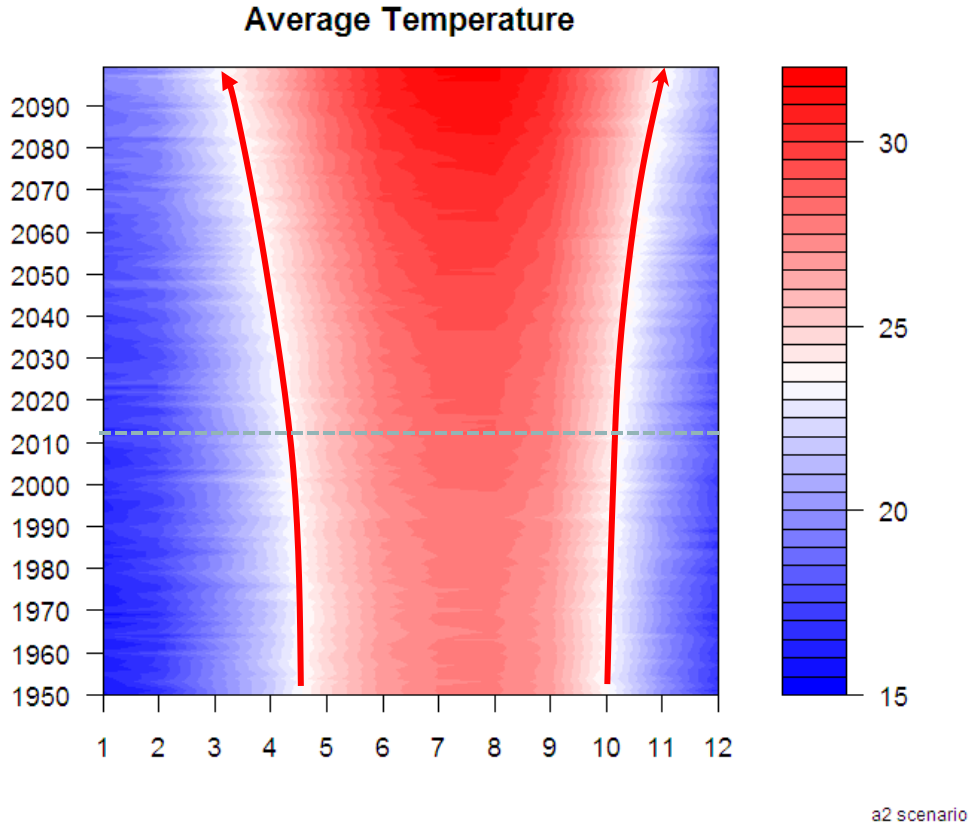
P ensemble mean



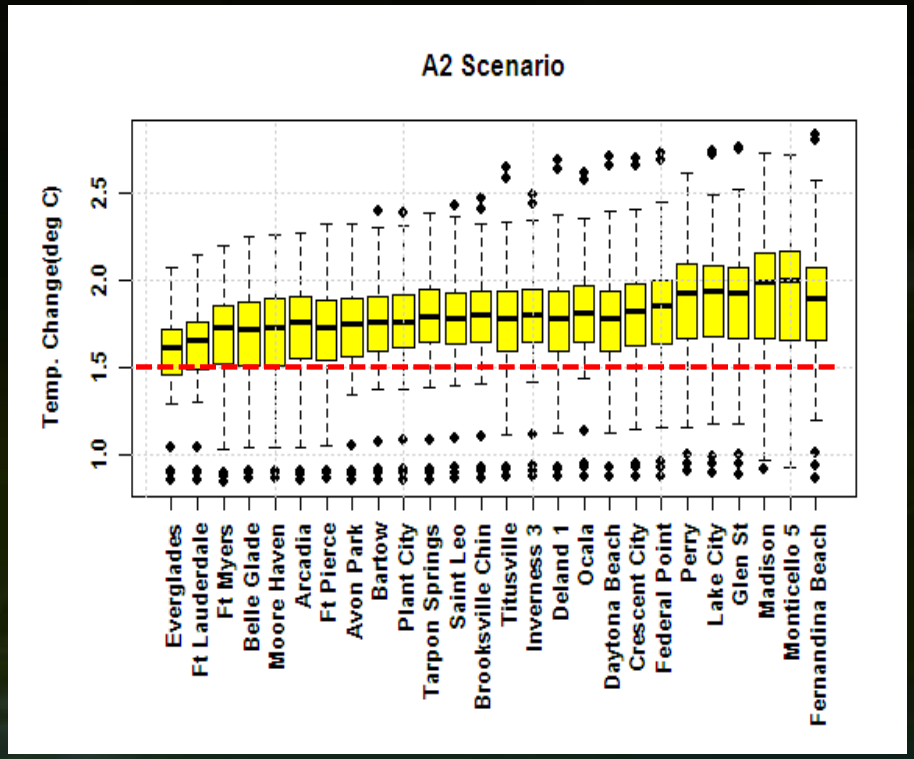


Change: Magnitude & Seasonality

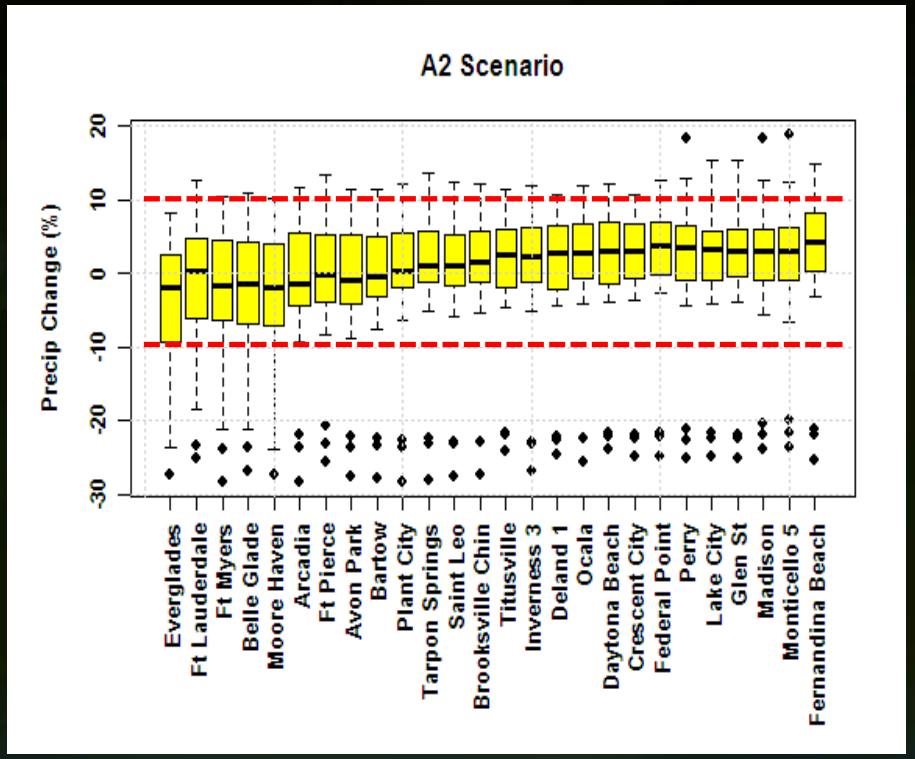




Spatial Trends



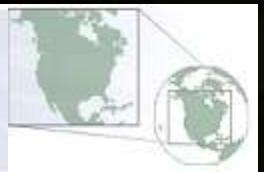
Temperature

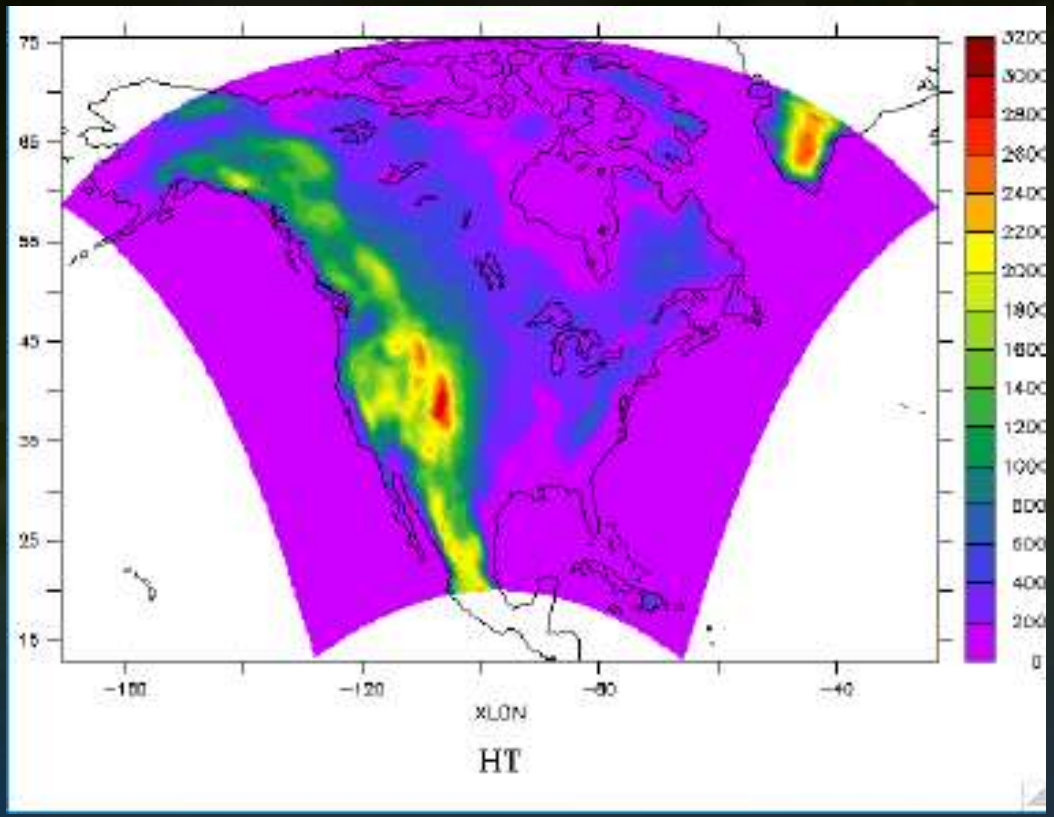


Precipitation

Dynamical Downscaling
North American Regional Climate Change Assessment Program

NARCCAP

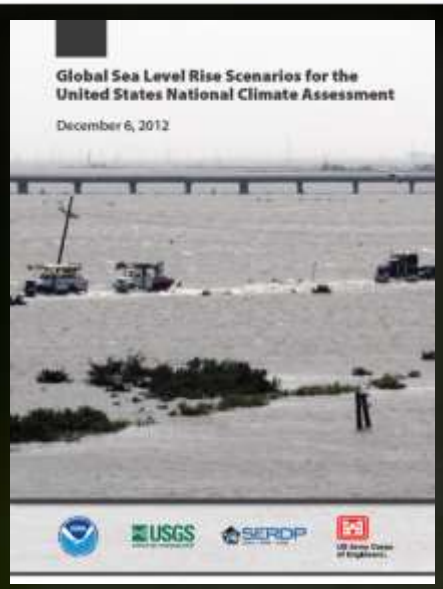


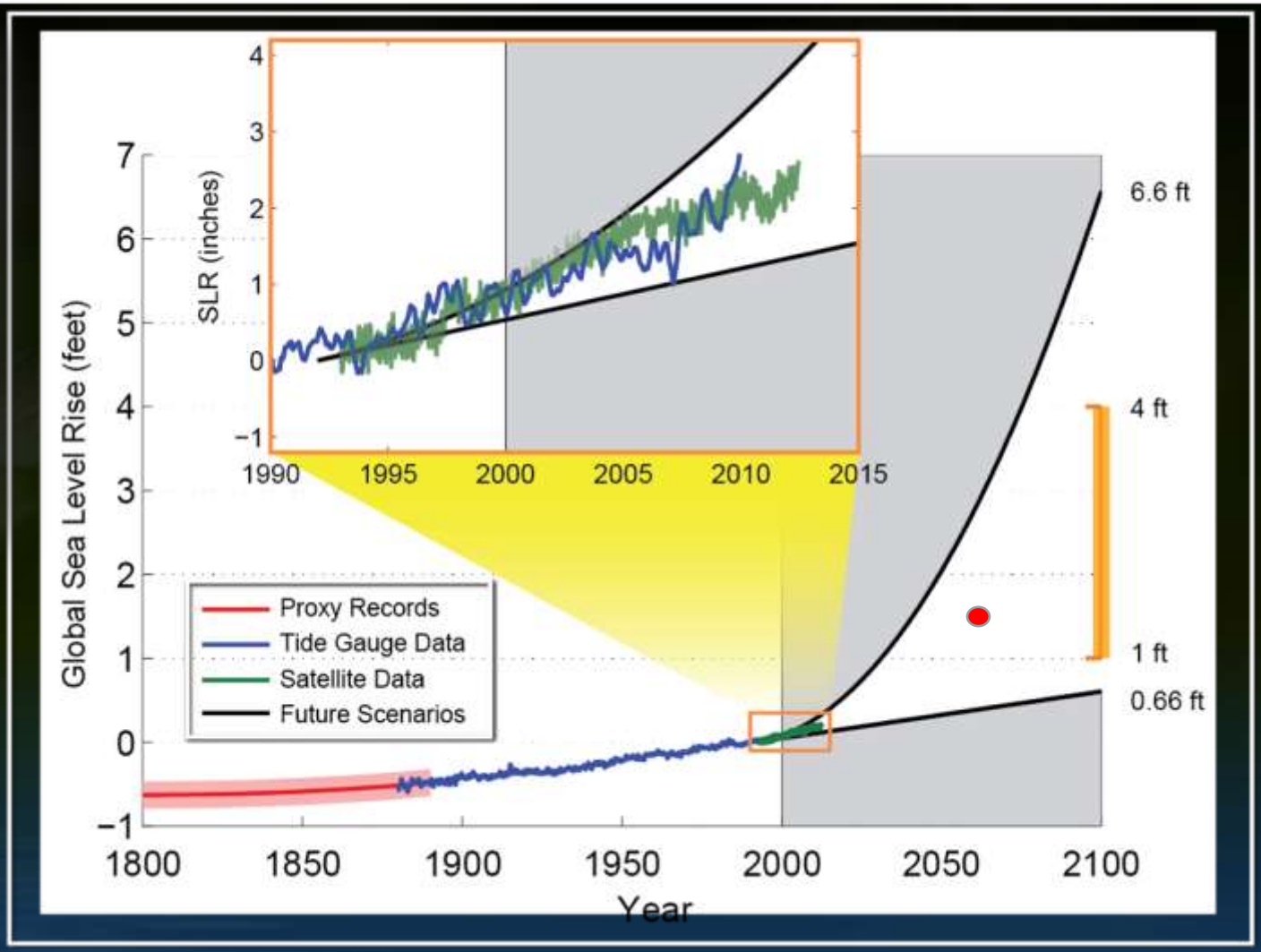


<u>Acknowledgement:</u>
NARCCAP is funded by the National Science Foundation (NSF), the U.S. Department of Energy (DoE), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency Office of Research and Development (EPA)."

Unified SE FL Sea Level Rise Projection

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





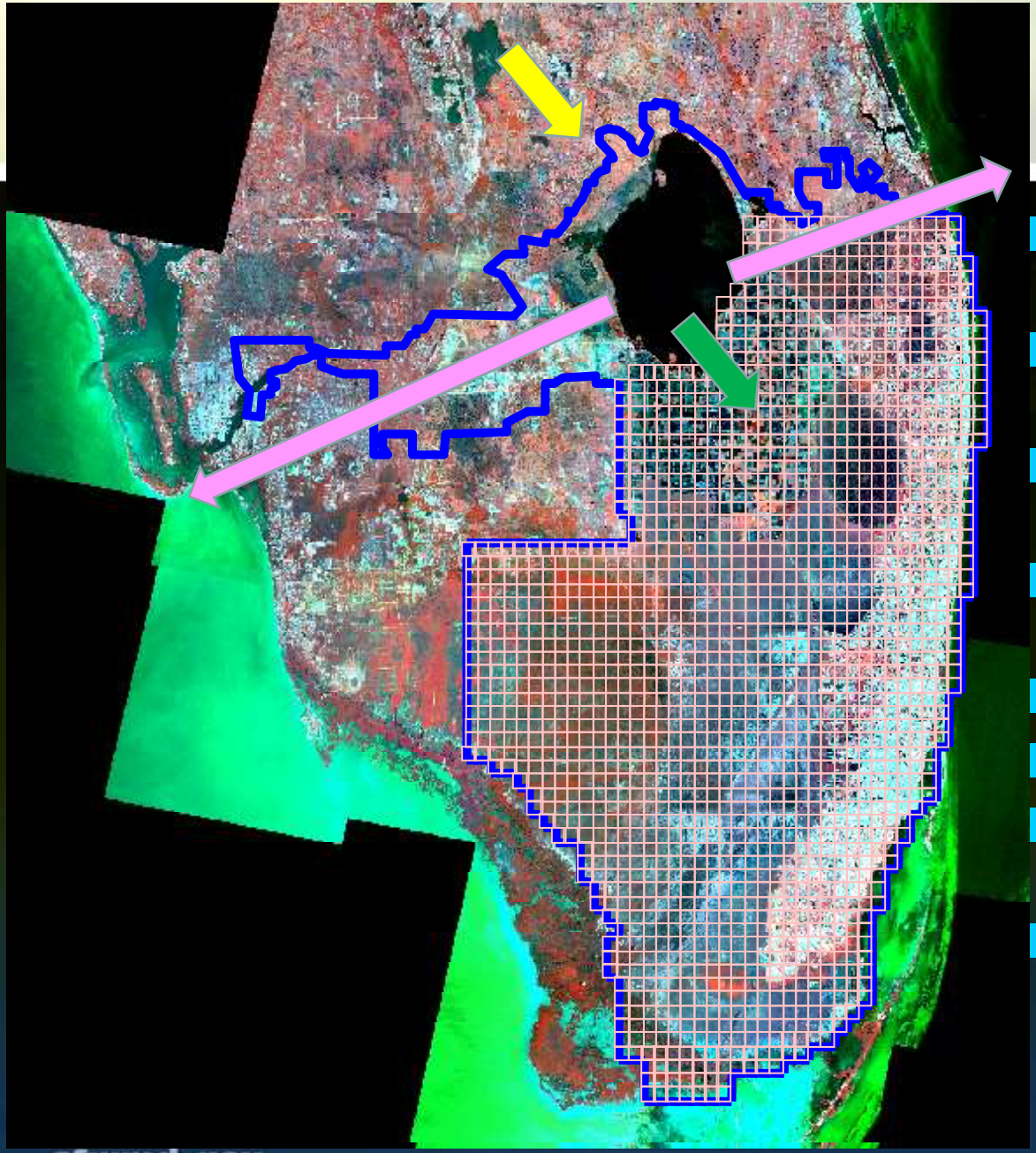
Draft report: http://ncadac.globalchange.gov

Summary of Projections for 2060

Variable	Global Models	Statistically Downscaled Data	Dynamically Downscaled Data
Average Temperature	1 to 1.5ºC	1 to 2ºC	1.8 to 2.1ºC
Precipitation	-10% to +10%	-5% to +5%	-3 to 2 inches
Sea Level Rise		1.5 feet	

Modeling Scenarios

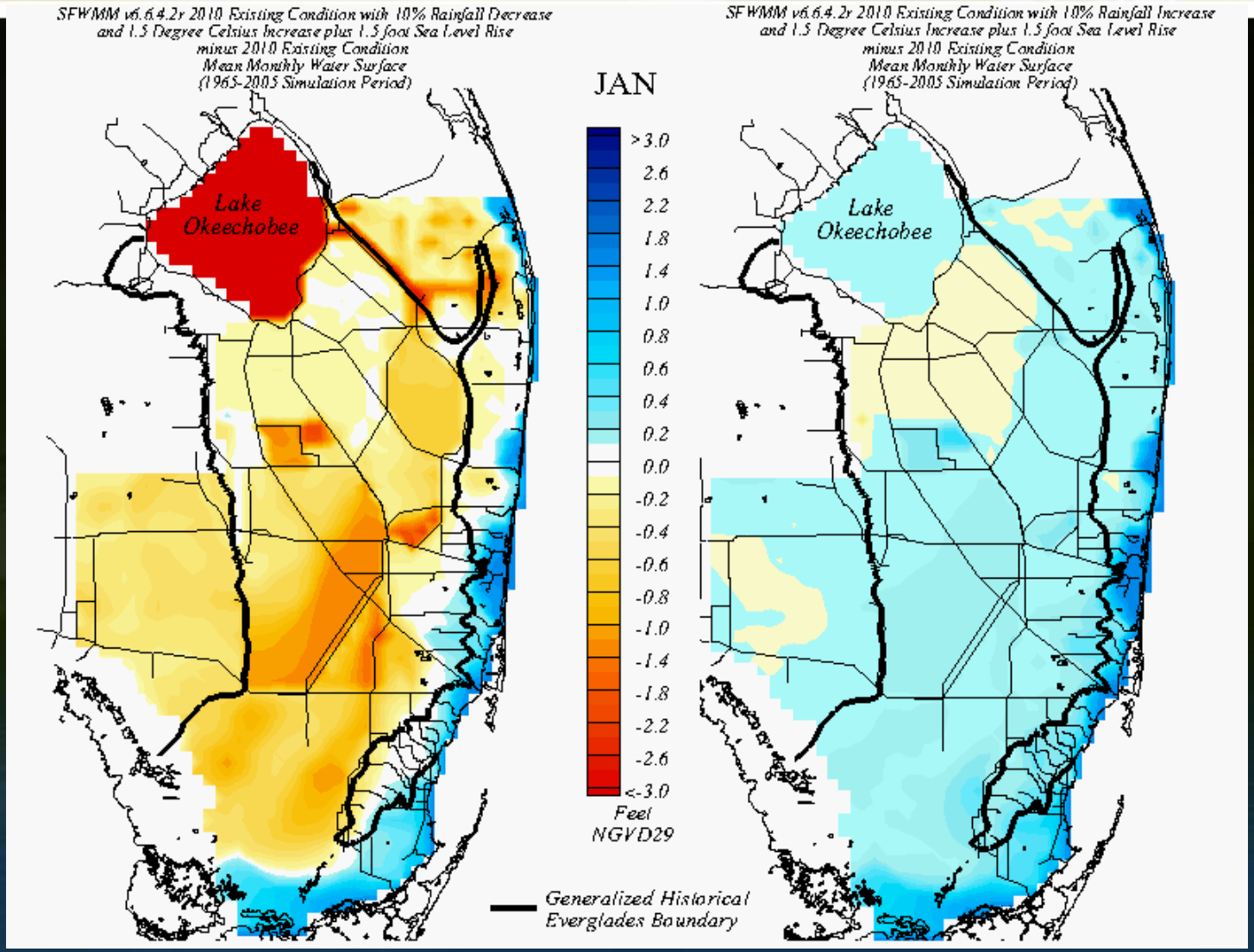
- 2010 Baseline (demands and landuse corresponding to 2010 simulated with the 1965-2005 rainfall & ET (**BASE**)
- 2010 Baseline with 10% decrease in rainfall (**-RF**)
- 2010 Baseline with 10% increase in rainfall (**+RF**)
- 2010 Baseline with 1.5° Celsius increase and 1.5 foot sea level rise with 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**)



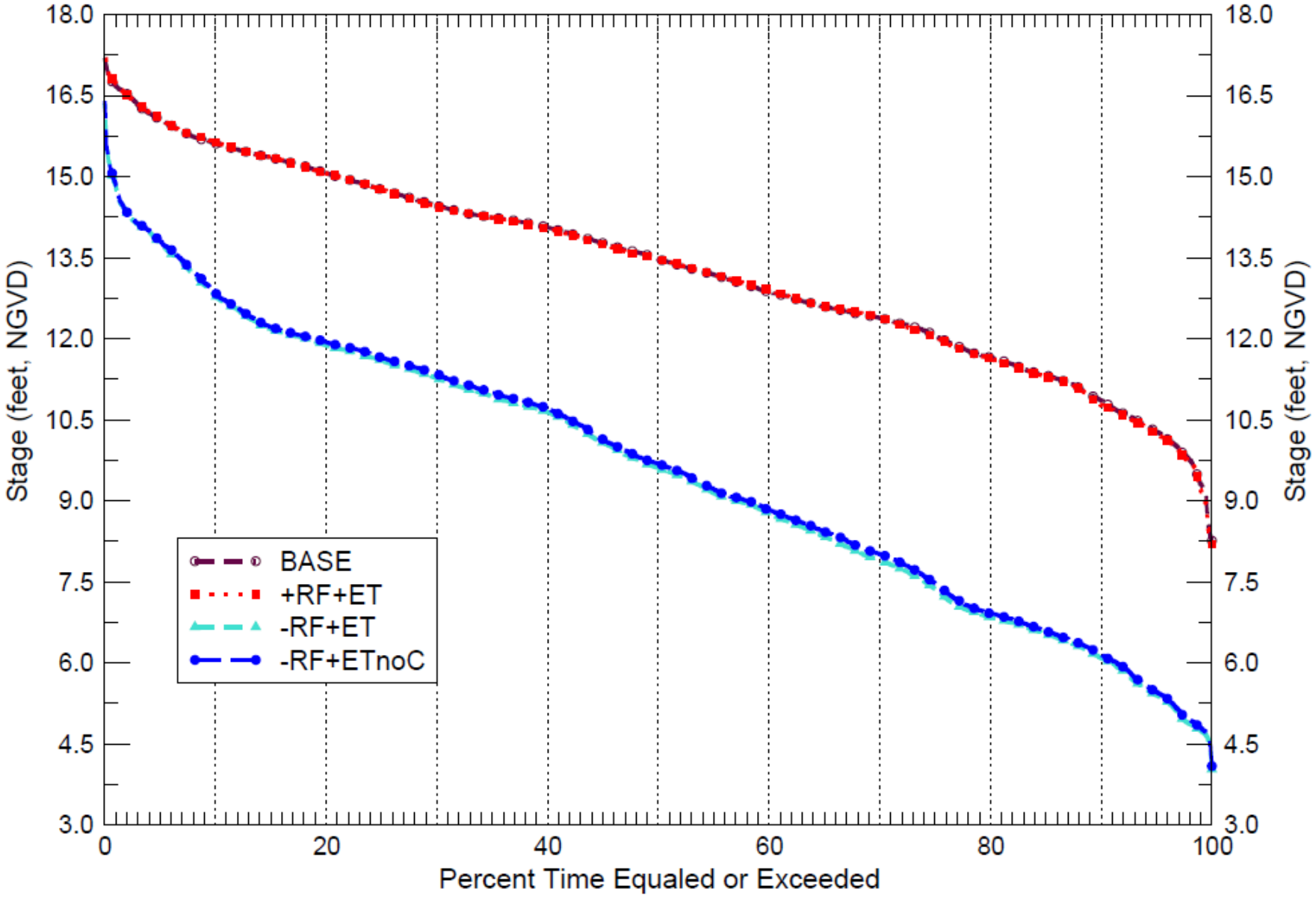
South Florida Water Management Model

- 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



Stage Duration Curves for Lake Okeechobee

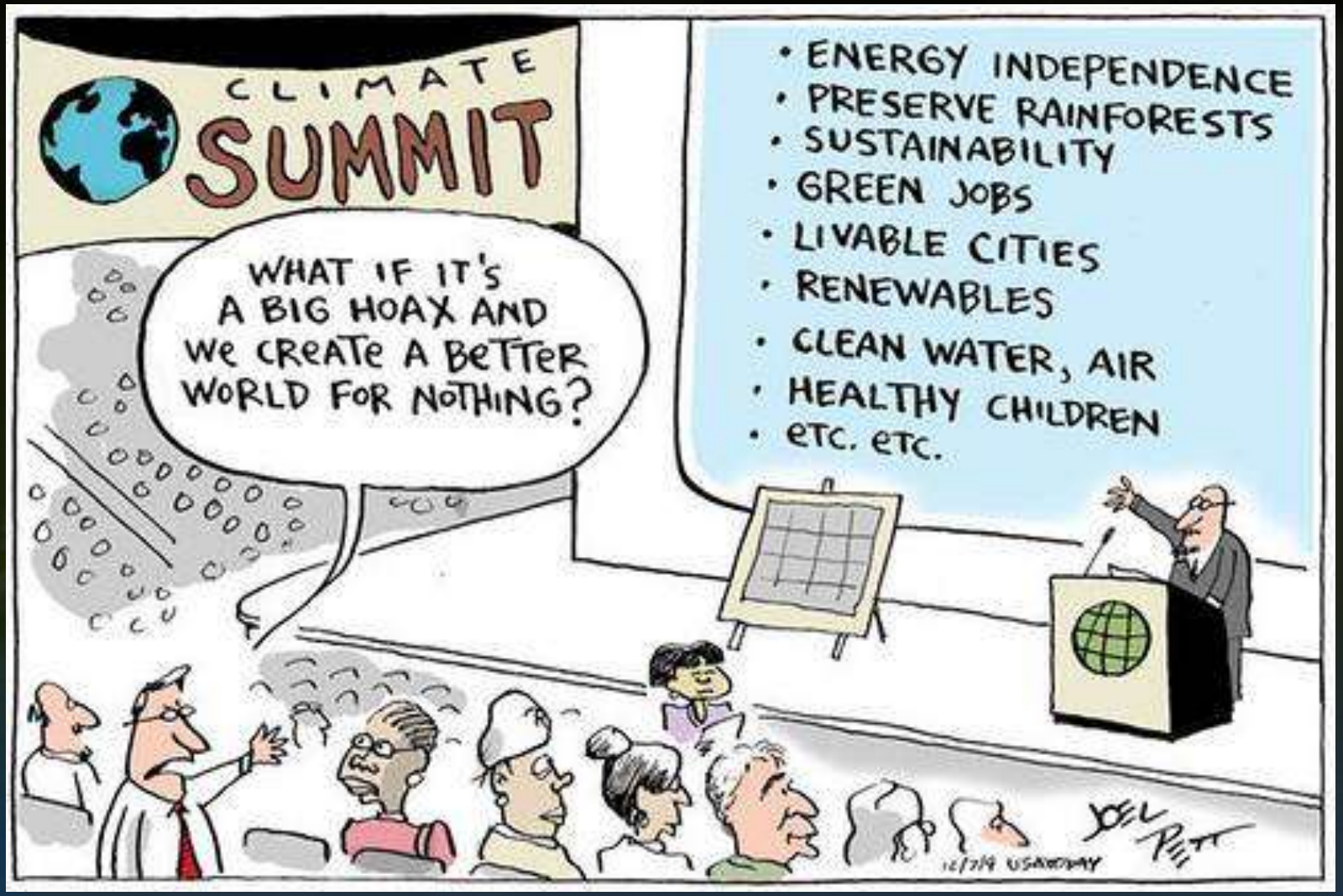


CONCLUSIONS

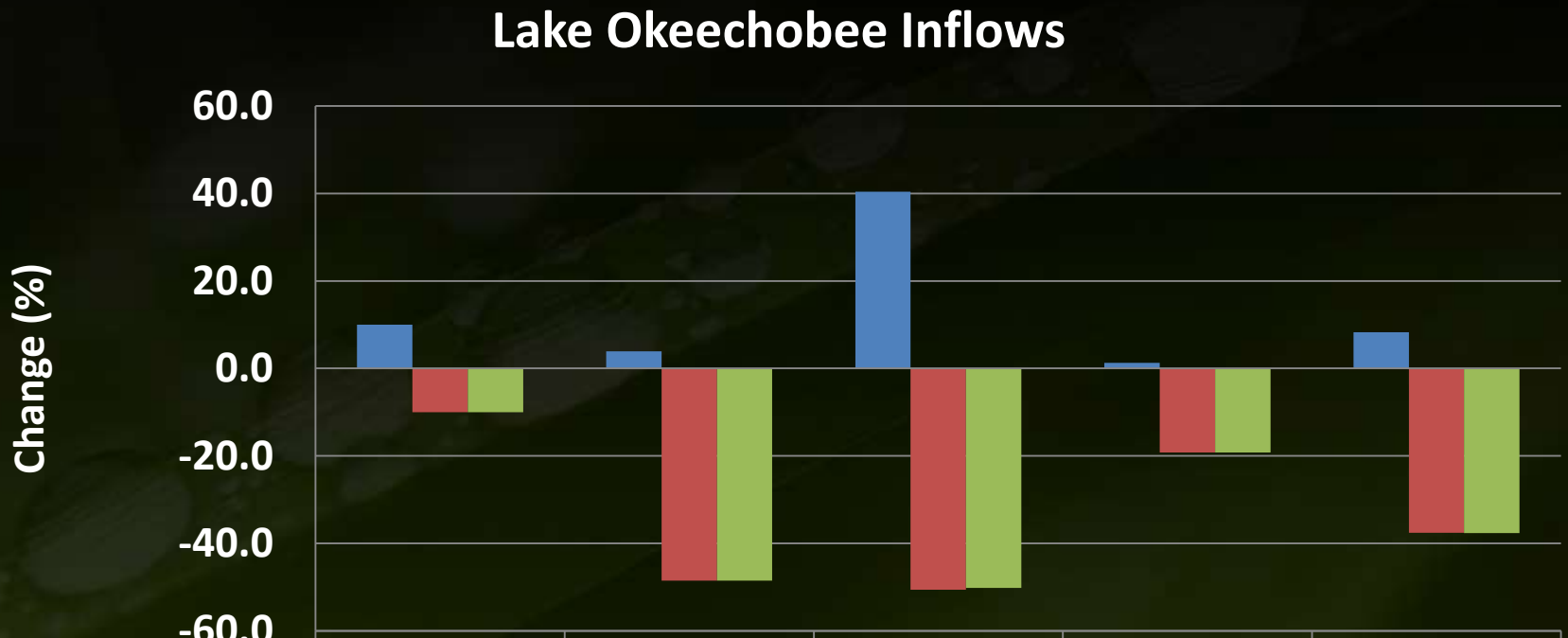
Climate change scenarios suggest that with increased ET and -10% rainfall:

- 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?

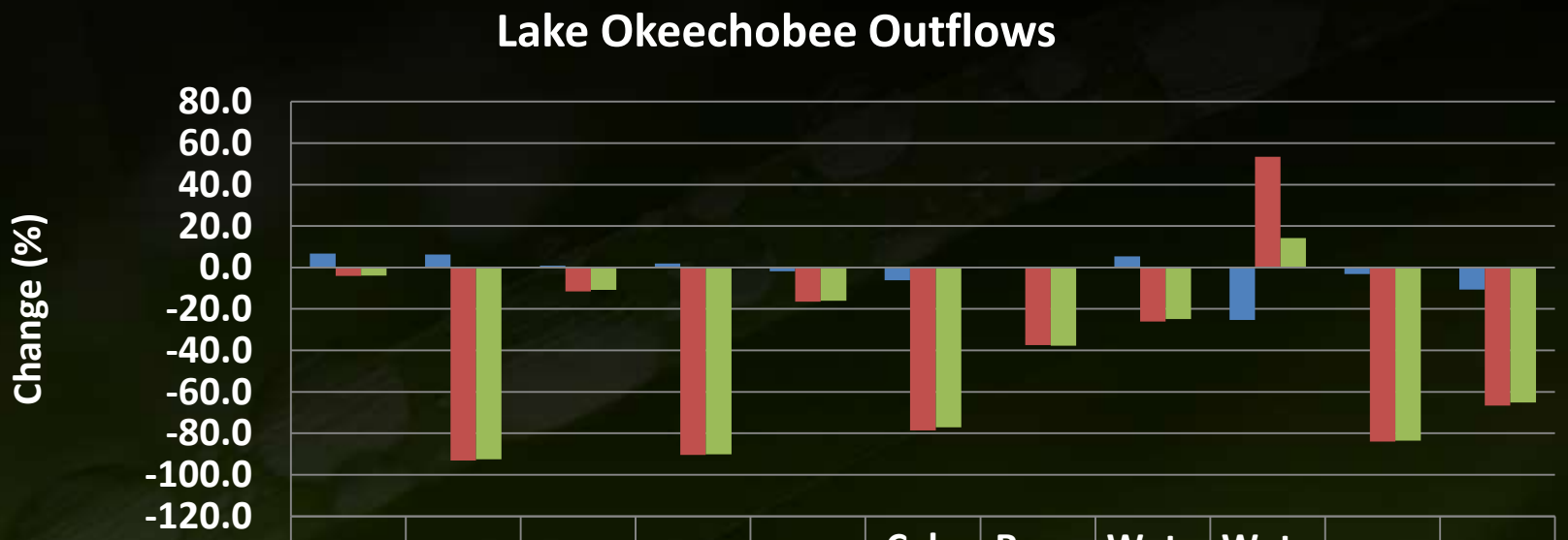

CLIMATE
SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• ETC. ETC.

Percent Change in Lake Okeechobee Inflows



	Rainfall	Kissimmee _Inflows	Eaa_Back_ Pumping	UpIstokp_ Inflows	Other_Infl ows
+RF+ET	10.0	3.9	40.4	1.3	8.3
-RF+ET	-10.0	-48.5	-50.6	-19.2	-37.6
-RF+ETnoC	-10.0	-48.5	-50.2	-19.2	-37.6

Percent Change in Lake Okeechobee Outflows



	ET	StLucie_Regulatory	StLucie_Ag_Dmds	Caloos_Regulatory	Caloos_Ag_Dmds	Caloos_Estuary_Min	Regulatory_to_Wcas	Water_Supp_to_EAA	Water_Supp_to_LEC	Reg_L8_Tide	L8_Basin_Ag_Dmds
+RF+ET	6.7	6.2	0.8	1.9	-1.9	-6.2	0.2	5.4	-25.3	-3.1	-10.7
-RF+ET	-4.0	-93.1	-11.5	-90.4	-16.5	-78.5	-37.5	-26.1	53.4	-84.0	-66.6
-RF+ETnoC	-3.9	-92.6	-10.8	-90.1	-16.0	-77.1	-37.8	-24.8	14.3	-83.6	-65.1

EXPECTED CHANGES FROM CLIMATE CHANGE

Drought

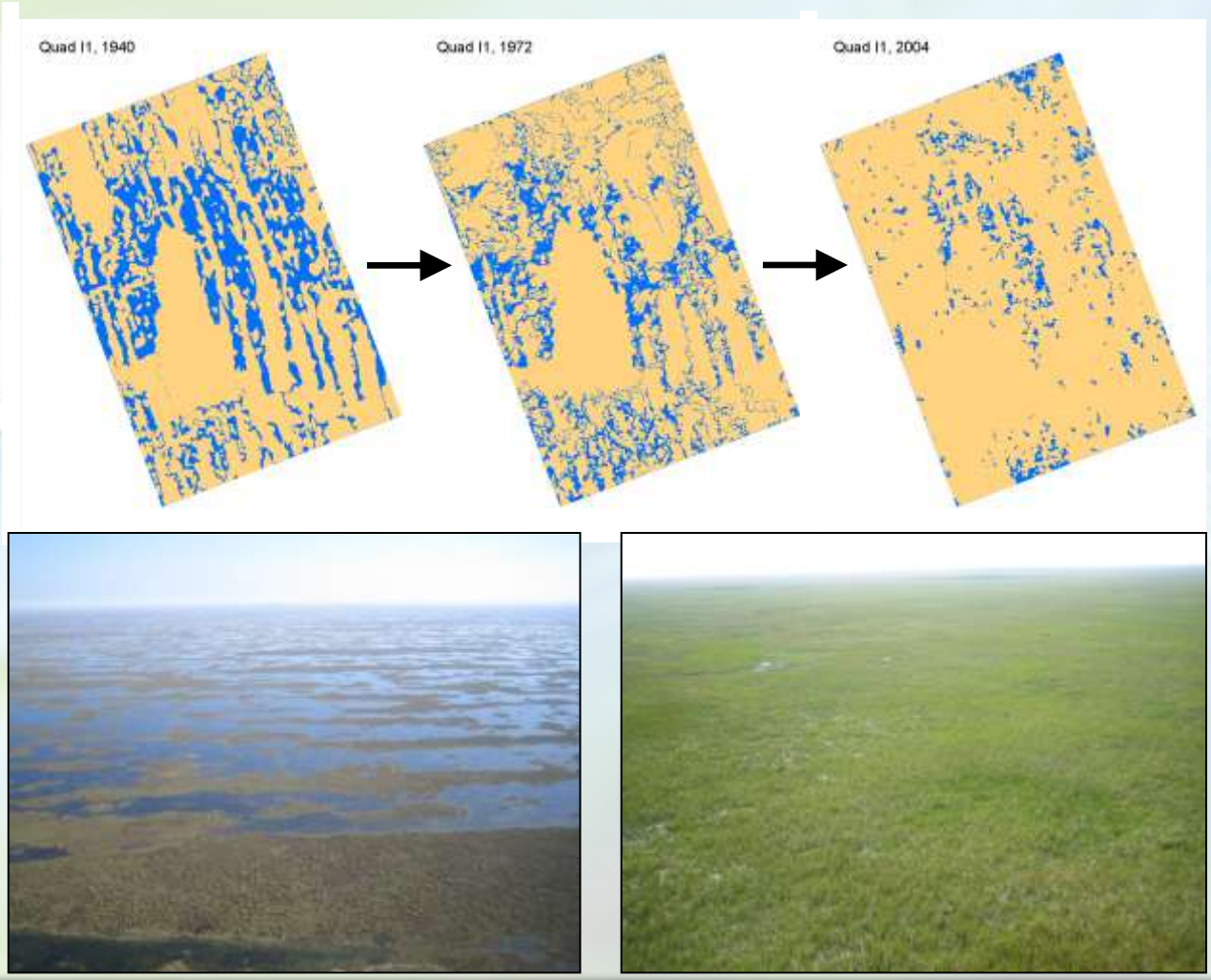
Recent droughts: Water 2-3 feet below peat surface (June 2011)

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):

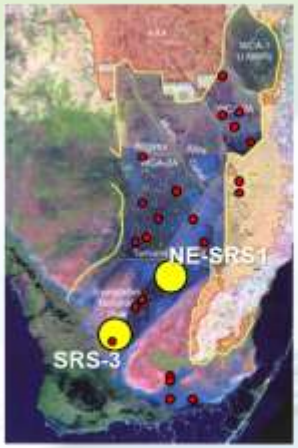
Lower water levels are likely to increase spread of *Lygodium* in the WCAs

Ascending forest canopy

Covering tree island

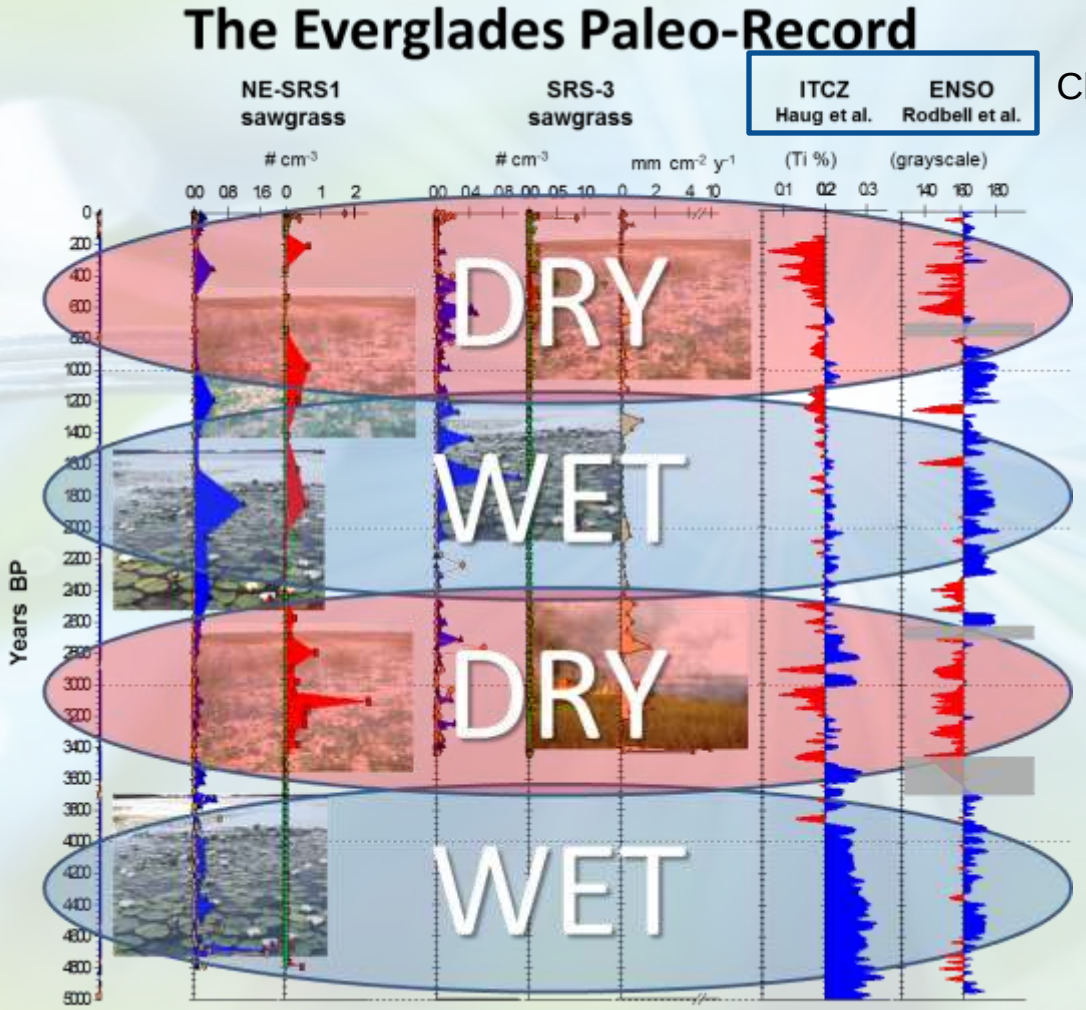
Paleoecology—nothing like it

Sample sites



Fossil seeds

Saunders et al., 2008 & in prep



Climate records

1200 year shifts of wet-dry climate cycles

Extra slides