SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Screening analysis of Climate Scenarios

Jayantha Obeysekera , Jenifer Barnes, Moysey Ostrovsky
Hydrologic & Environmental Systems Modeling

Predicting Ecological Change in the Florida Everglades in a Future Climate Change Scenario
Florida Atlantic University
February 14-15, 2013

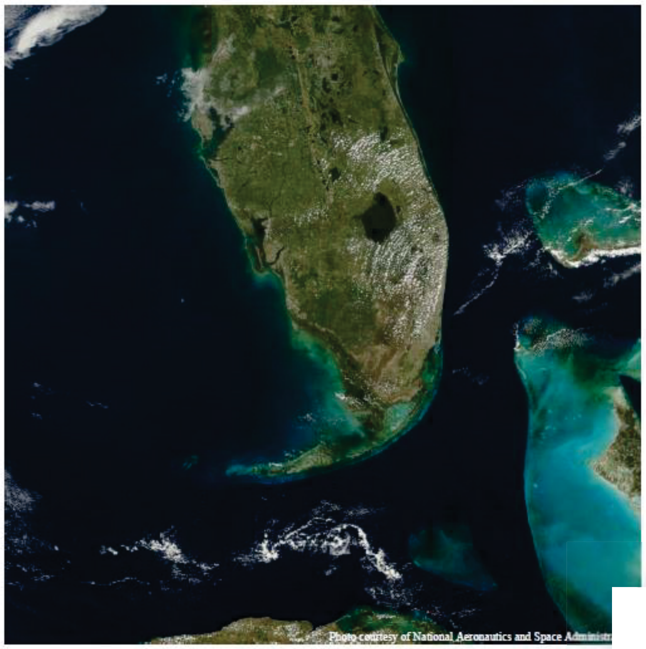
sfwmd.gov

Outline

- Rationale for scenario selection
  - Temperature
  - Precipitation
  - Sea Level Rise
- Scenario simulation using SFWMM (a.k.a. 2x2 model)
  - Peek at results

Research publications

Past and Projected Trends in Climate and Sea Level for South Florida



Hydrologic and Environmental Systems Modeling

Technical Report

July 2011

Reg Environ Change
DOI 10.1007/s10113-013-0411-0

ORIGINAL ARTICLE

Validating climate models for computing evapotranspiration in hydrologic studies: how relevant are climate model simulations over Florida?

Jayantha Obeysekera

Journal of Coastal Research	29	1	1–7

Scenario-Based Projection of Extreme Sea Levels

Jayantha Obeysekera[†] and Joseph Park[‡]

Michelle M. Irizarry-Ortiz[1]*, Jayantha Obeysekera[1], Joseph Park[1], Paul Trimble[1], Jenifer Barnes[1], Winifred Park-Said[1], Erik Gadzinski[2]

Probabilistic Projection of Mean Sea Level and Coastal Extremes

Jayantha Obeysekera, P.E., M.ASCE[1]; Joseph Park, P.E.[2]; Michelle Irizarry-Ortiz, P.E.[3]; Jenifer Barnes[4]; Paul Trimble[5]

David B. Enfield, Alberto M. Mestas-Nuez and Paul J. Trimble

Revised: 28 May 2010 – Accepted: 2 June 2010 – Published: 15 June 2010

Potential Impacts on Water Resources Management in South Florida

Climate Change Drivers

Natural Cycles
Inter-annual
(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

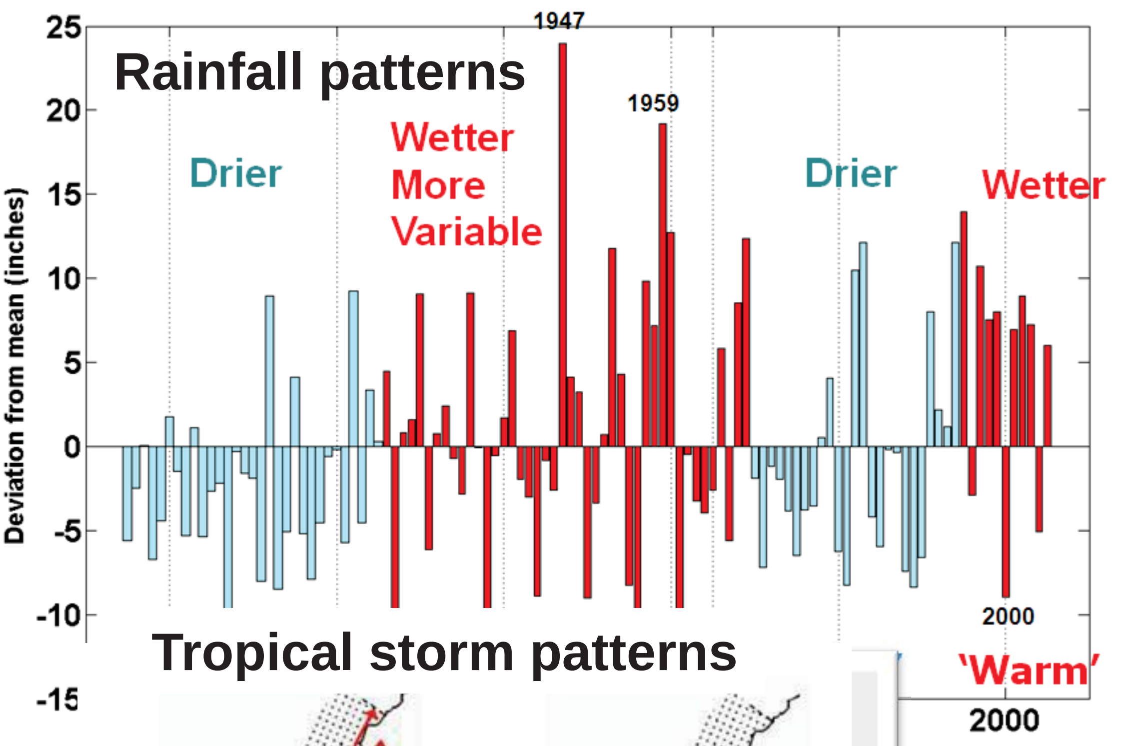
- **Rising Seas**
- **Temperature**
- **Rainfall (both average & extremes)**
- **Tropical Storms & Hurricanes**

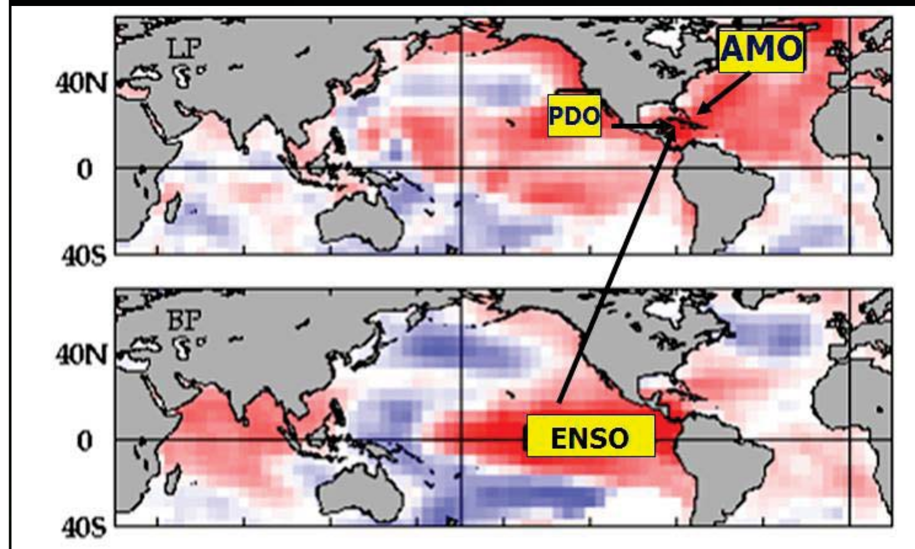
Water Management Impacts

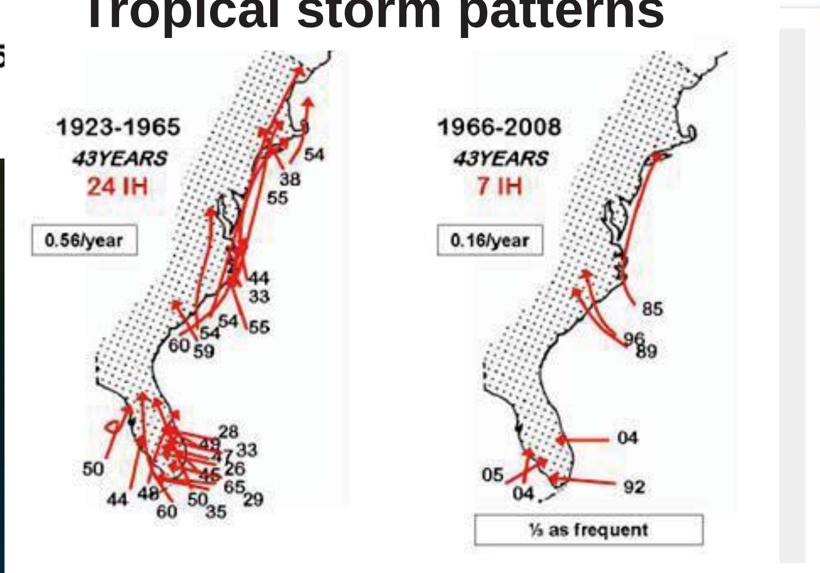
- **Direct landscape impacts (e.g. storm surge)**
- **Water Supply (e.g., saltwater intrusion)**
- **Flood Control (e.g. urban flooding)**
- **Natural Systems (e.g. ecosystem impacts, both coastal and interior)**

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

Natural Variability (Teleconnections)

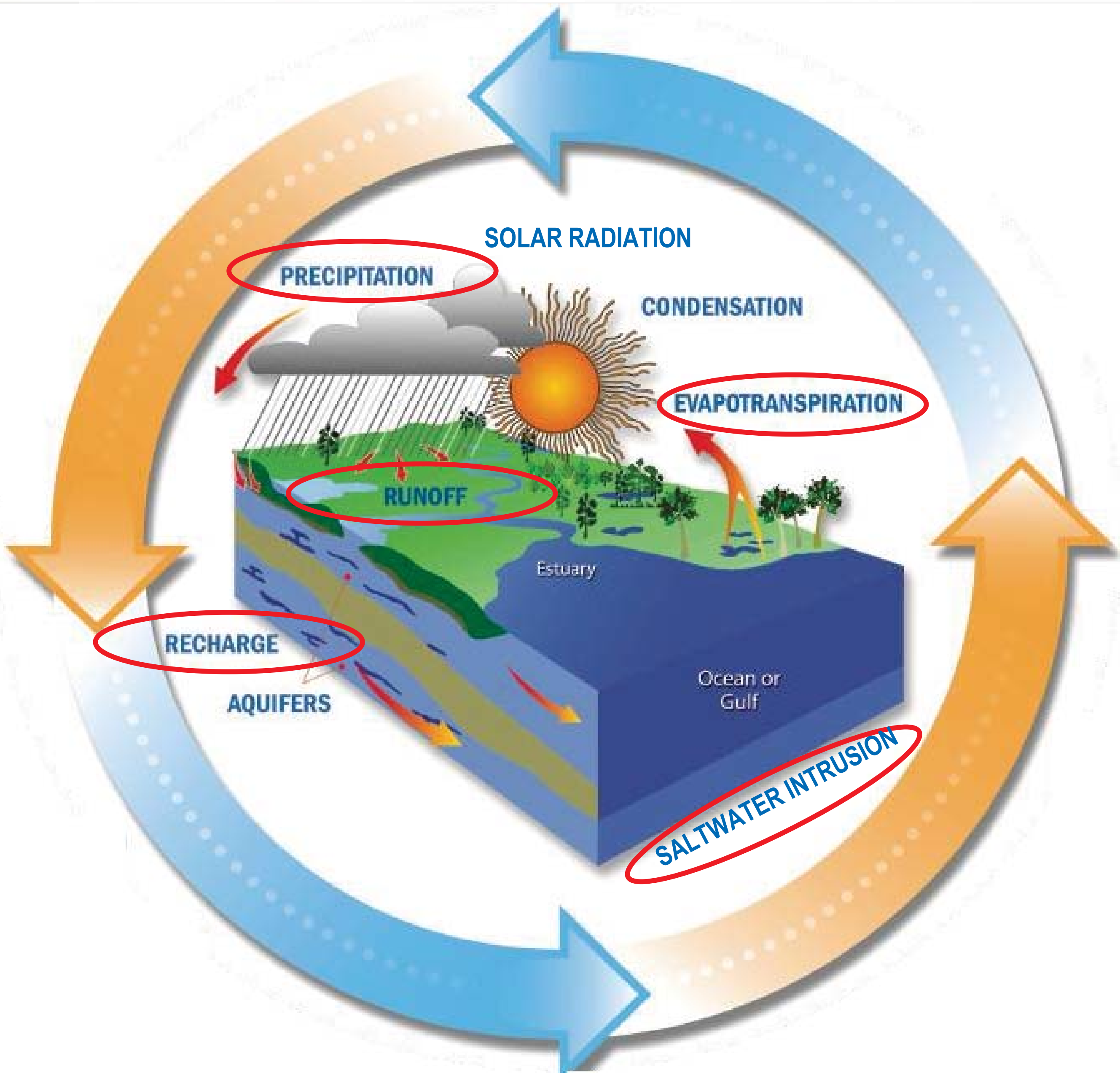






Lake Okeechobee
Inflow

Hydrologic Cycle – will it remain stationary under climate change?

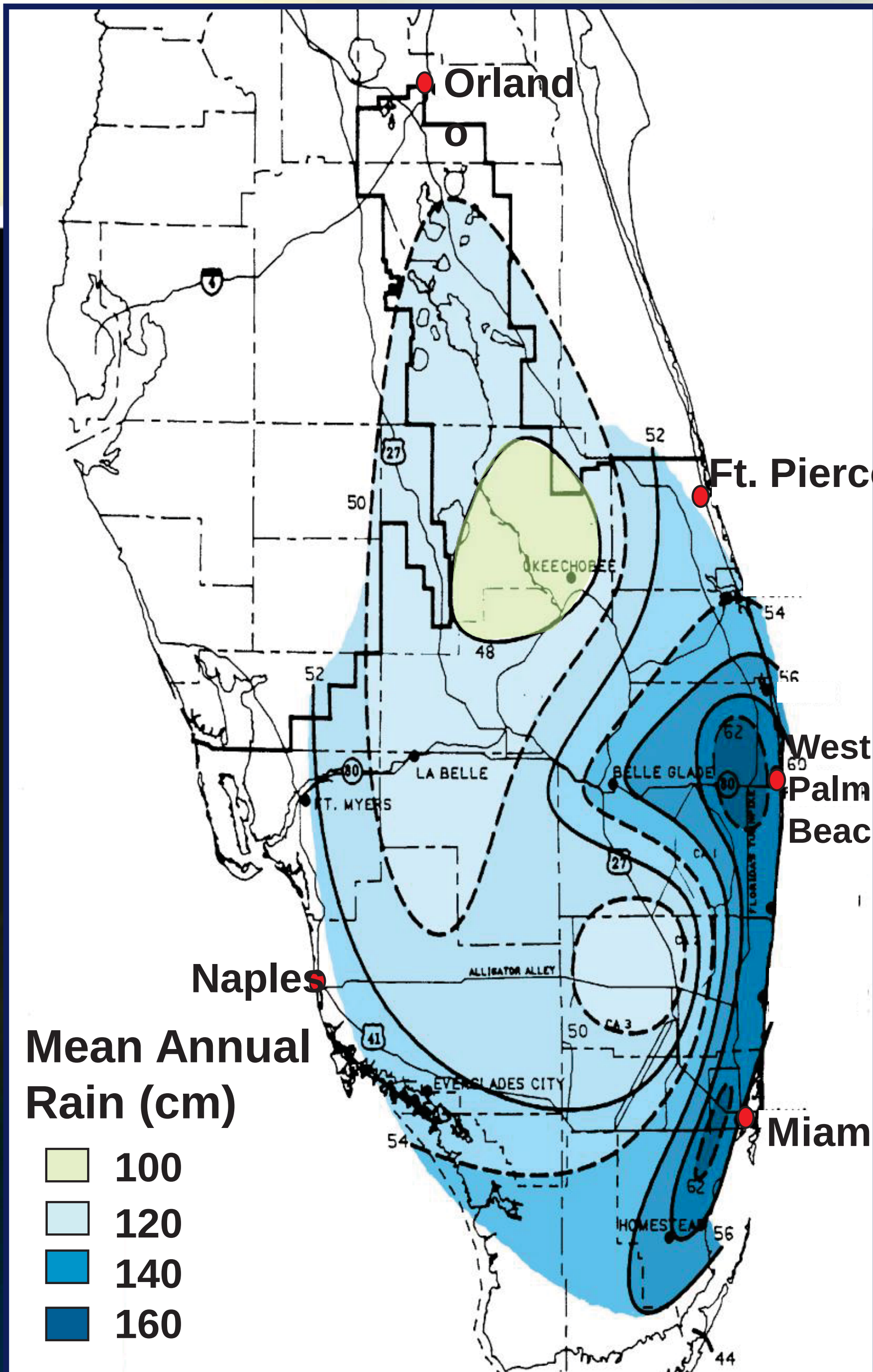


Primary Variables of interest:

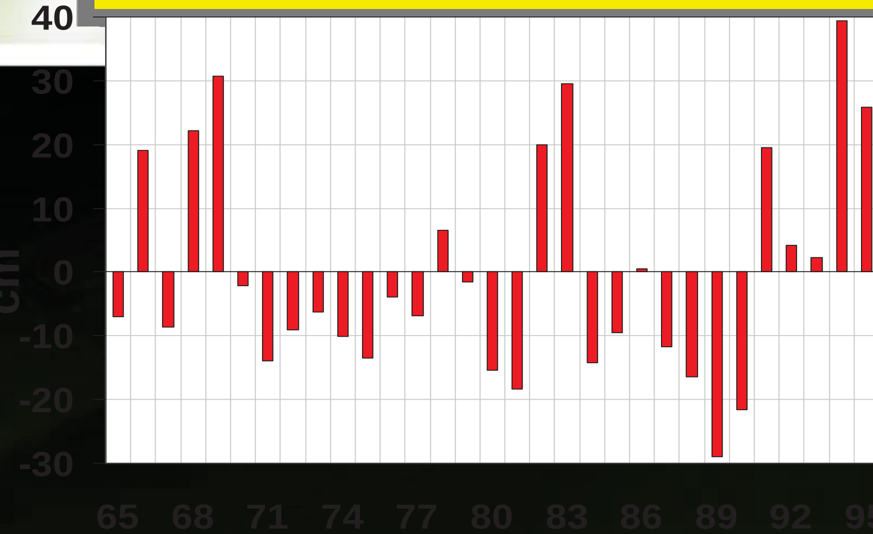
- Temperature
- Precipitation
- Evapotranspiration
- Saltwater Intrusion

Implications for:

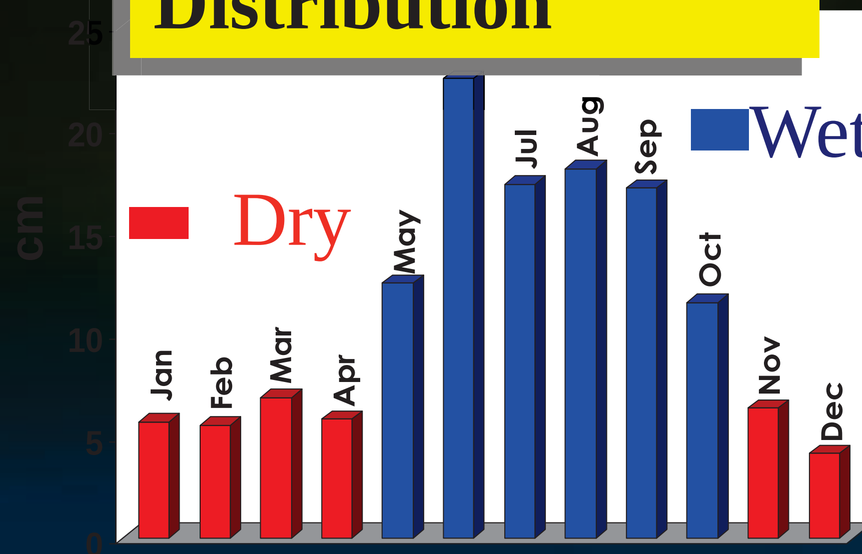
- **Water Management**
- Energy
- Agriculture
- Tourism
- Health

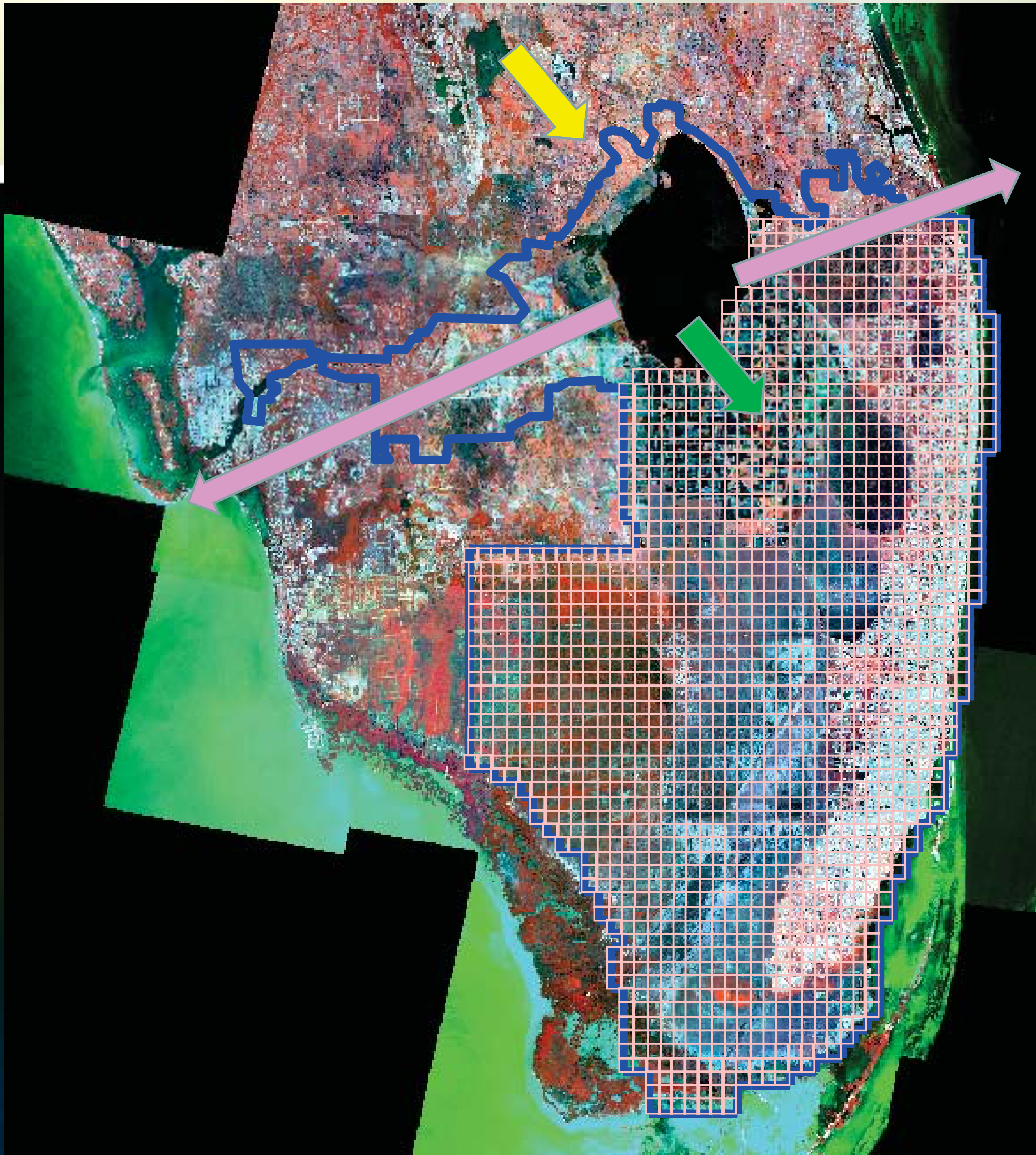


Rainfall Deviations from Mean of 133 cm



Monthly Distribution





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

Regional Modeling Approach

- Climatic Input
  - Rainfall
  - ET
- Boundary Conditions

SFWMM Model

Scenario

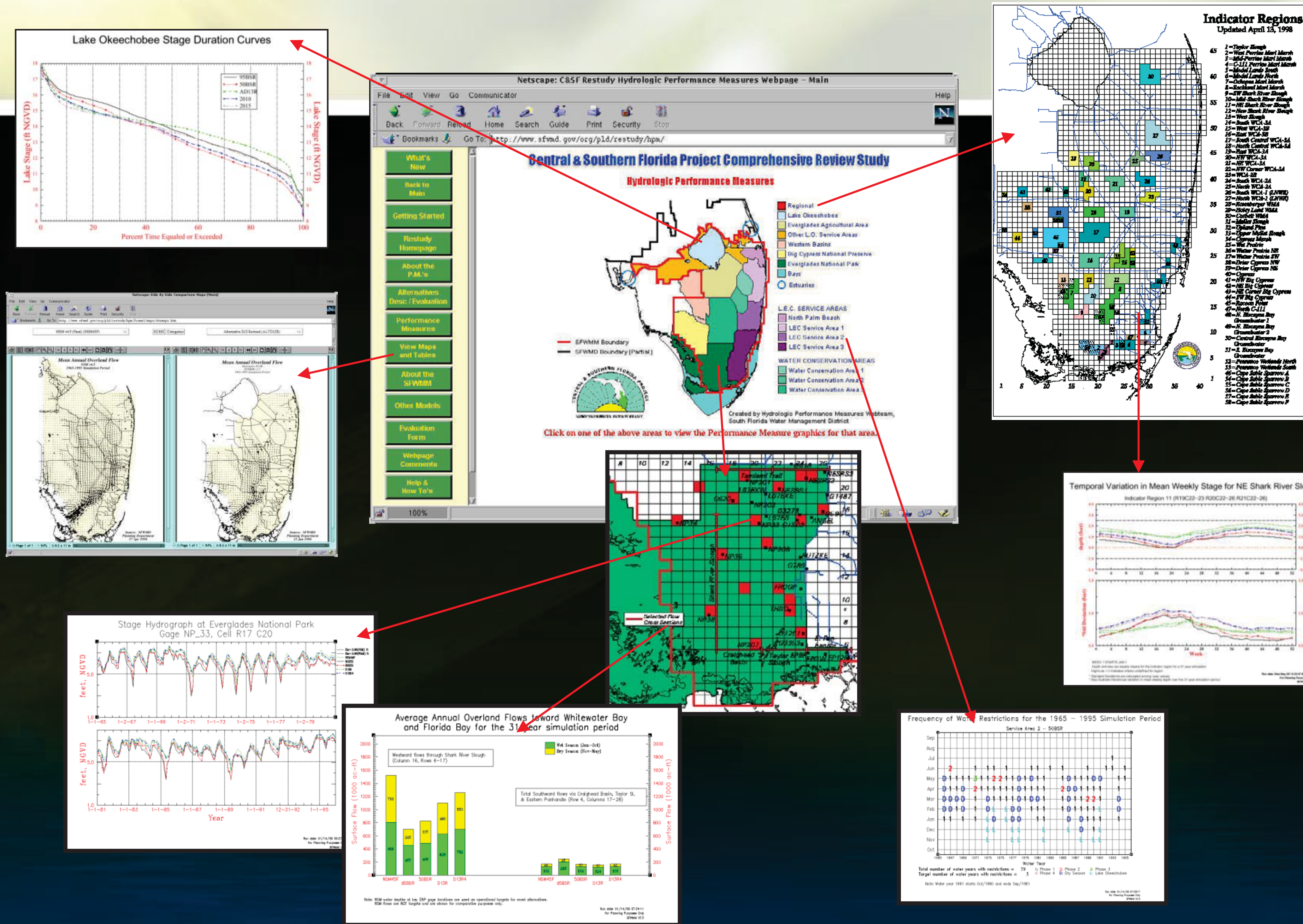
- Land Use/Land Cover
- Water Demands
- Operating Criteria

Model Output

- Daily time series of water levels, flows
- Demands not met

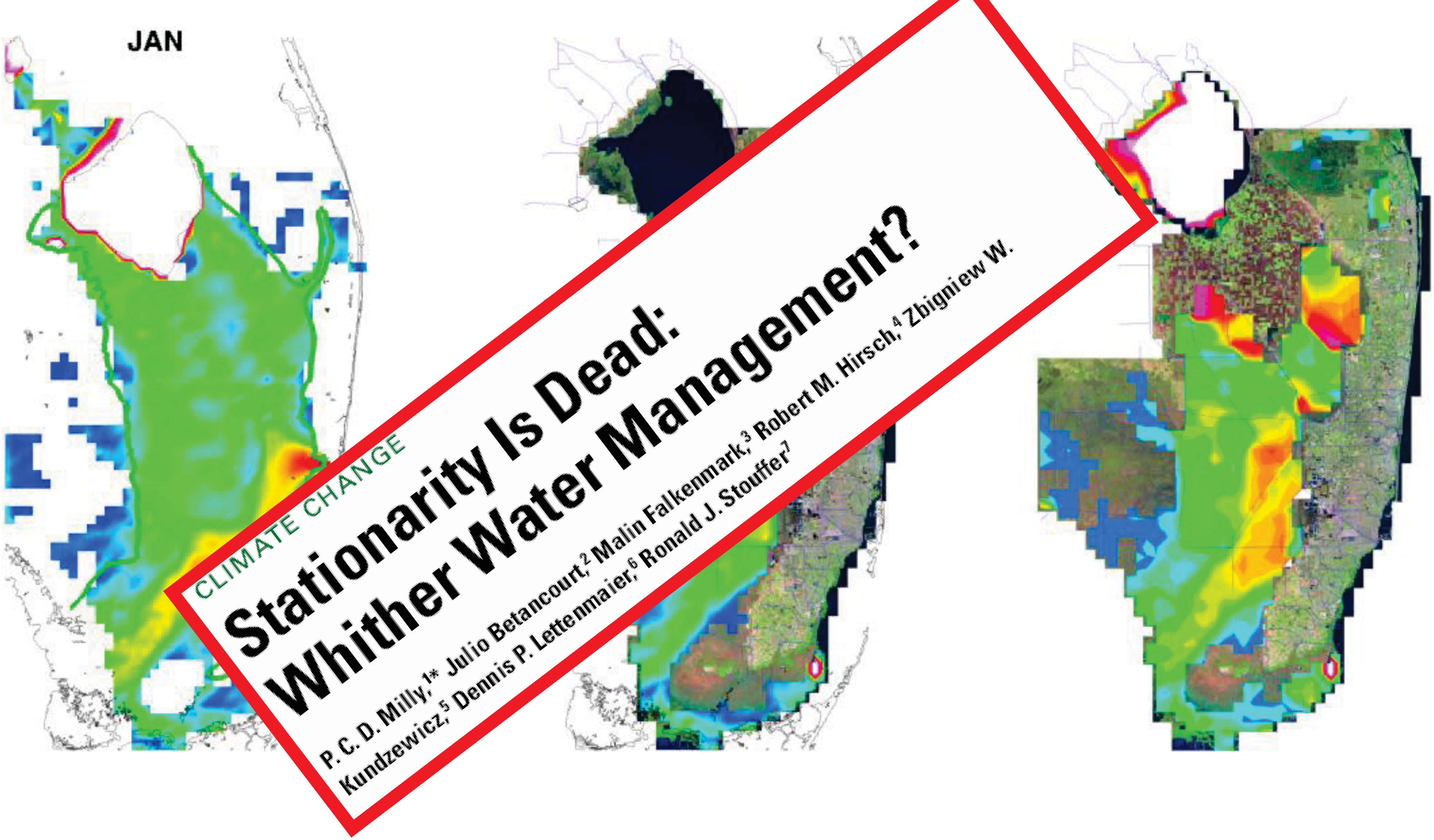
Performance Measures (Ag, Env, Urban)

Hydrologic Performance Measures



Everglades Restoration – Will traditional planning approach work?

Natural System | Managed System | CERP



Spatio-Temporat Rainfall Dataset

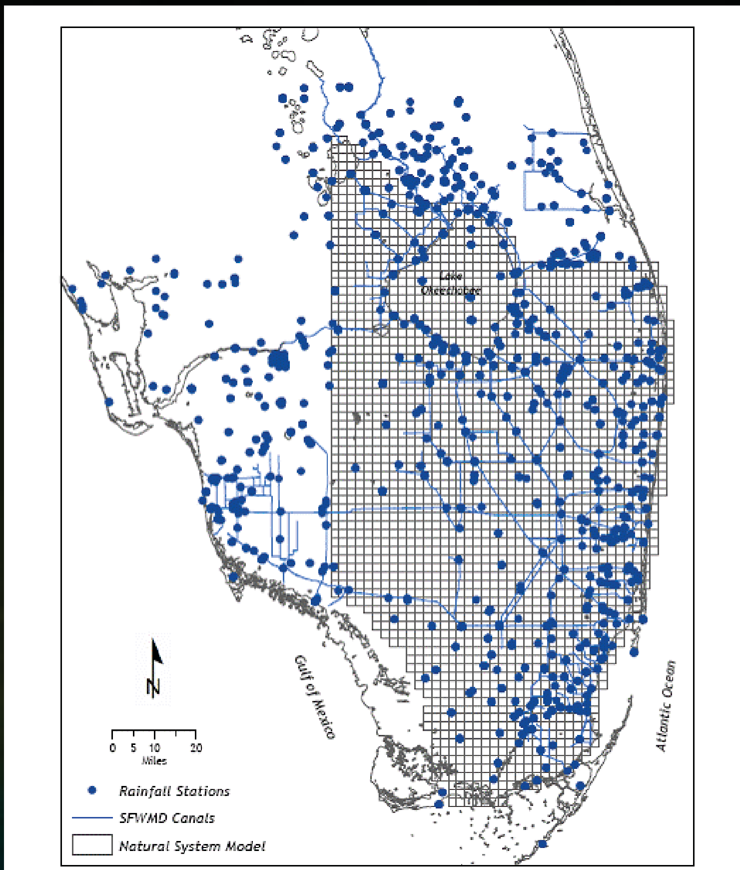


Figure 2.2.1.1 Location of Rainfall Stations

- Daily Rainfall (1965-2005)
- Spatially interpolated to create a spatial dataset for each day
- Future Rainfall Scenarios?

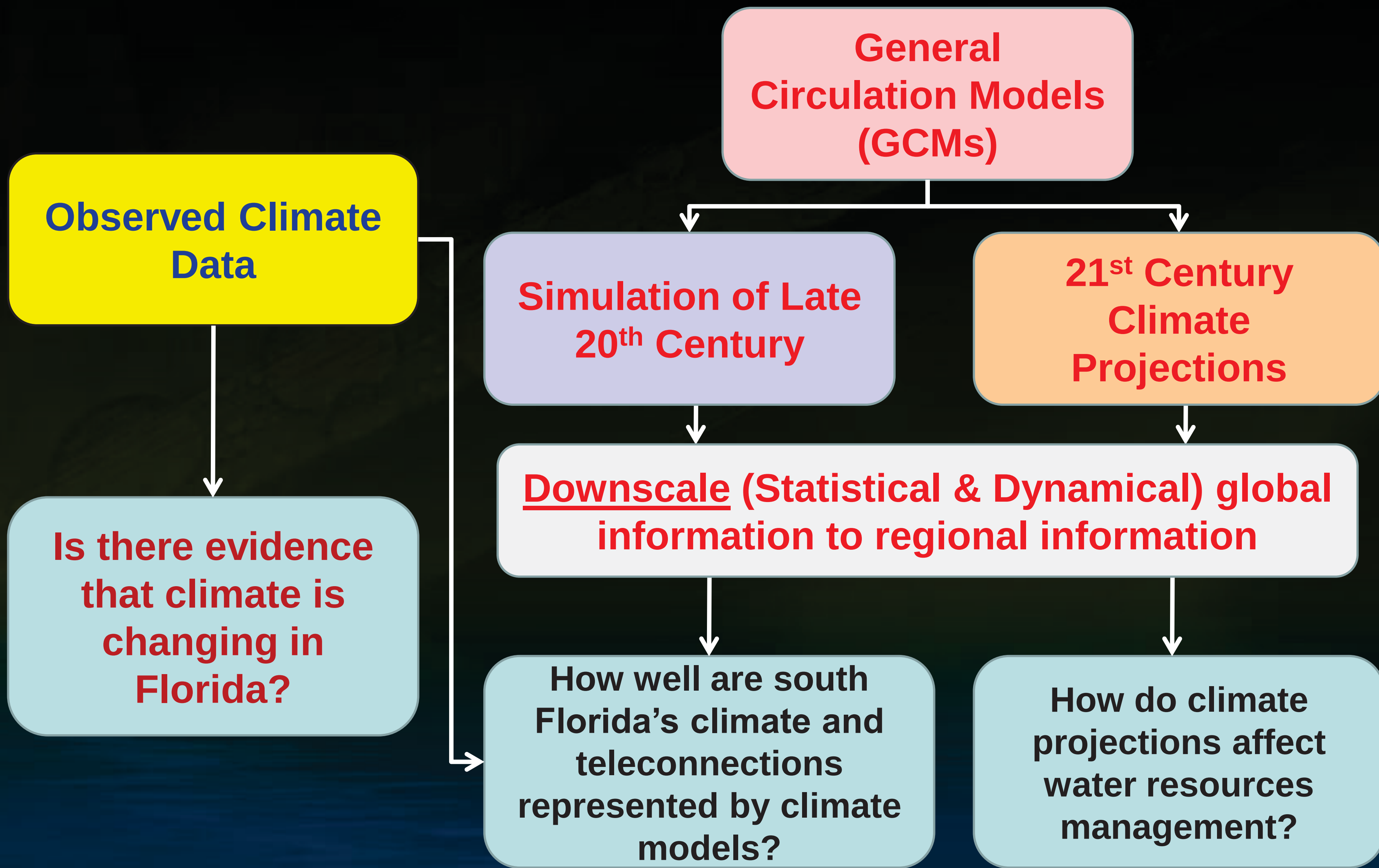
Reference Evapotranspiration (RET) – for this exercise

$$ET_p = \frac{K_1 * R_s}{\lambda}$$

$$R_s = \tau R_a = K_r (T_{max} - T_{min})^{0.5} R_a$$

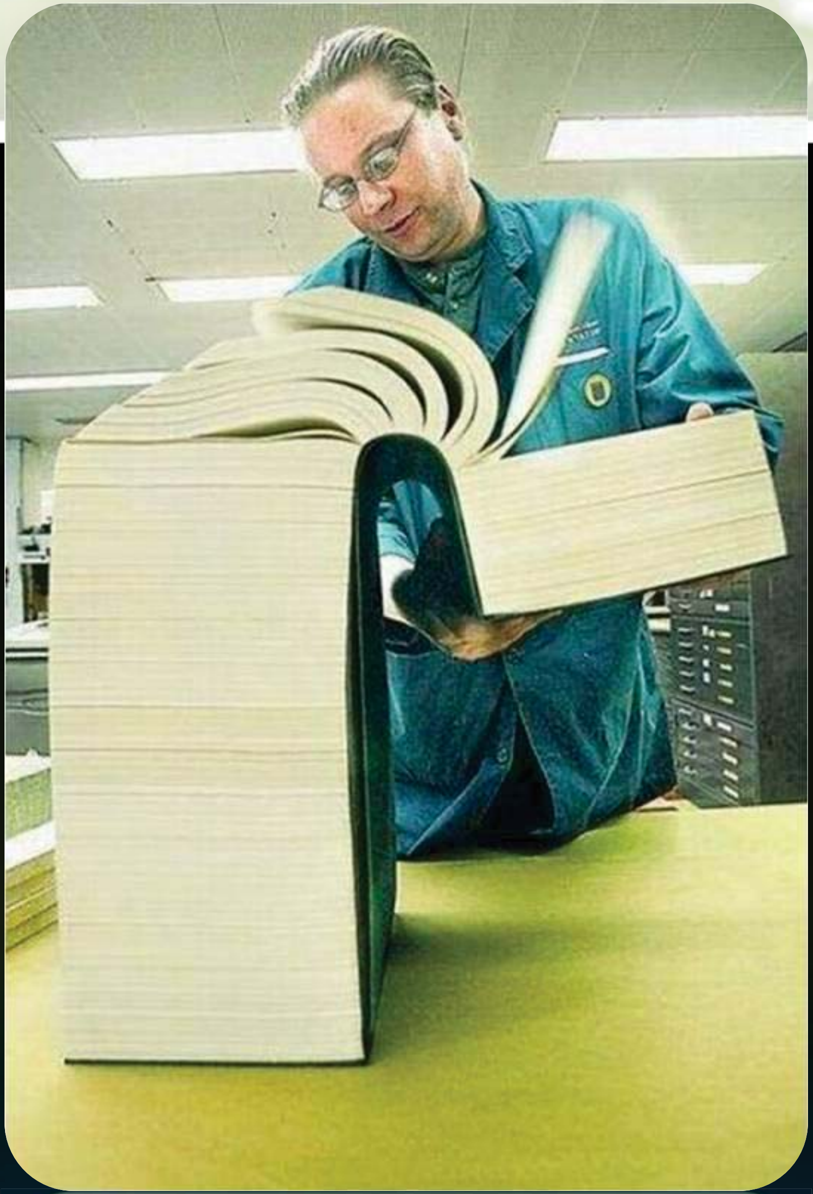
- R_s = Incoming solar radiation
- R_a = Solar radiation at the top of the atmosphere
- T_{max} and T_{min} are daily max and min temperature

Using Climate Change Information

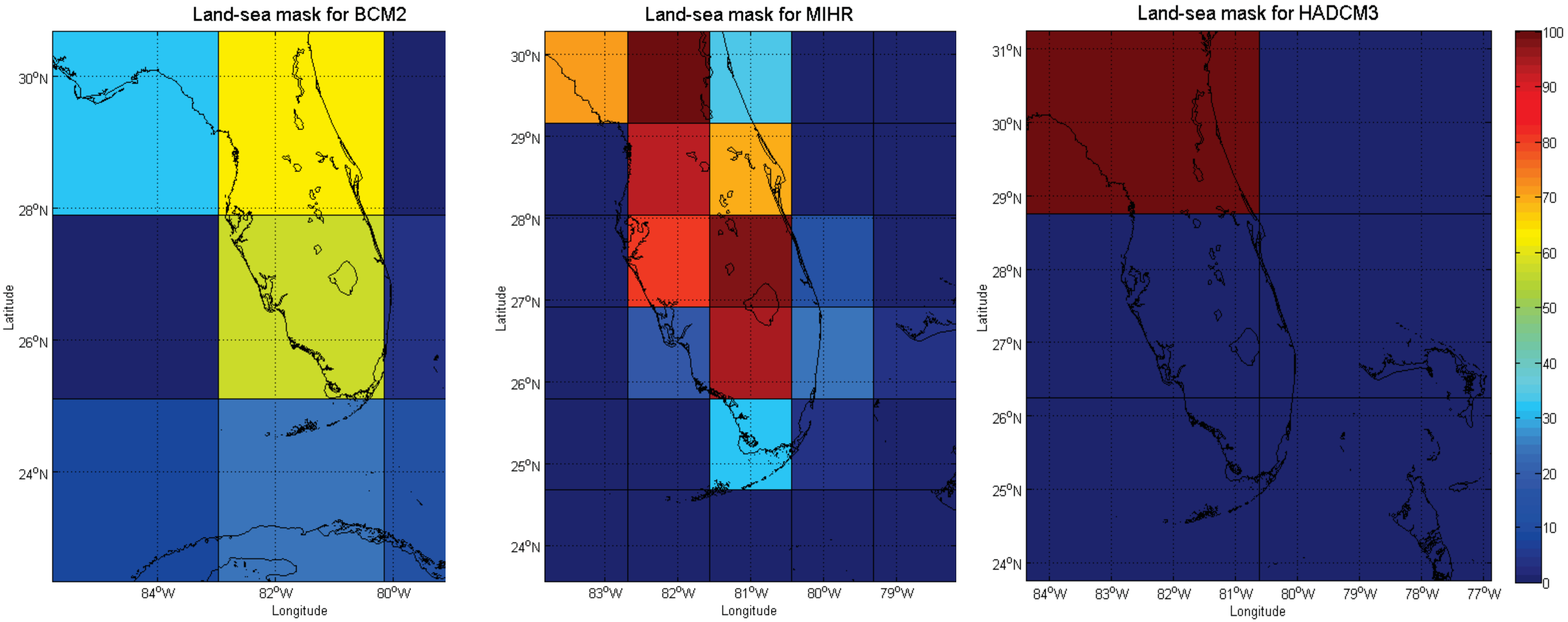


Book of Climate Output

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.

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

Dynamical

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

Regional Climate Models (RCMs)

Ice Sheet Dynamics

Model Uncertainty

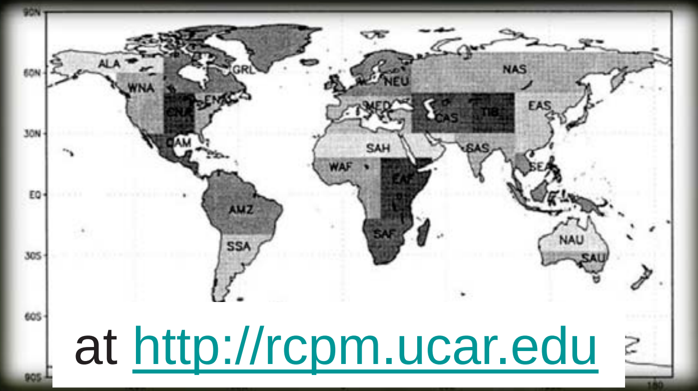
Scenario Uncertainty

Scenarios					
B1	A1T	B2	A1B	A2	A1FI
1.1-2.9 (°C)	1.4-3.8 (°C)	1.4-3.8 (°C)	1.7-4.4 (°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 Planning:

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

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

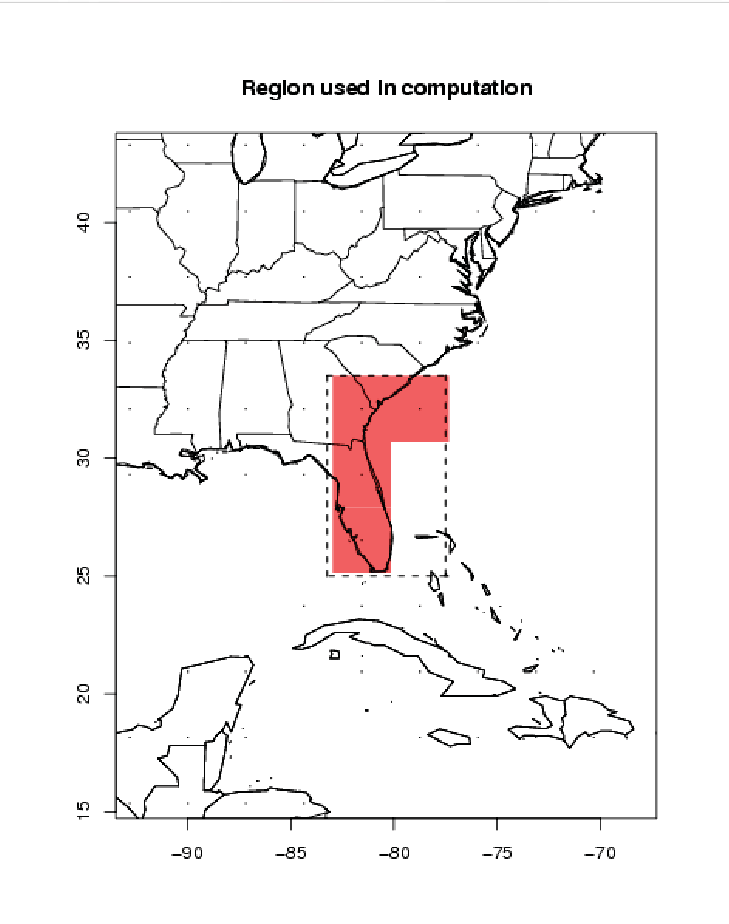
Priors:

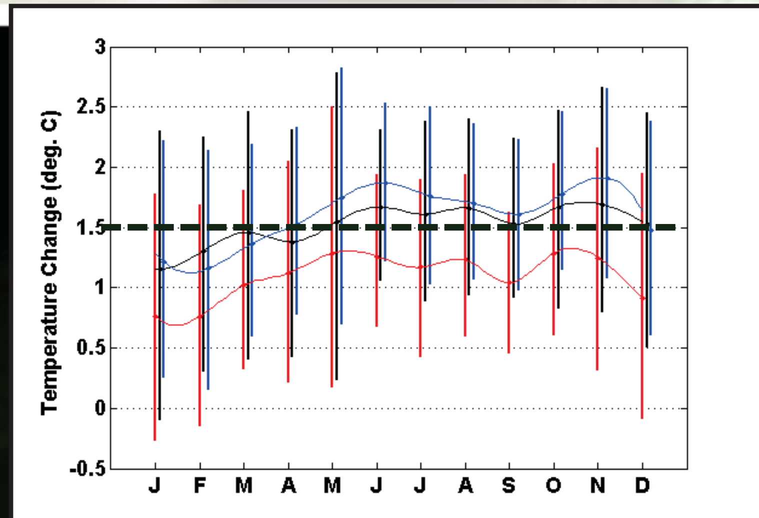
$\mu, \nu \sim U(-\infty, +\infty)$

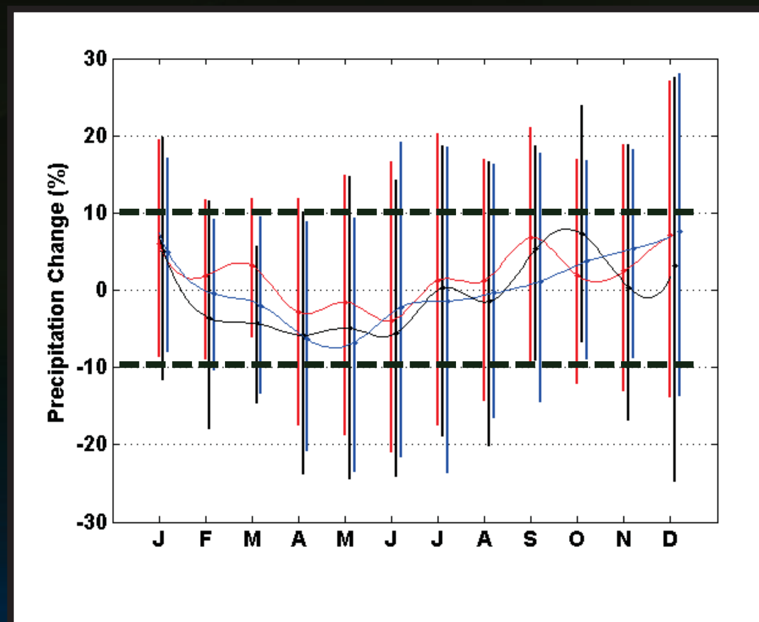
$\lambda_i \sim \Gamma(a,b)$, $\theta_i \sim \Gamma(c,d)$

- 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

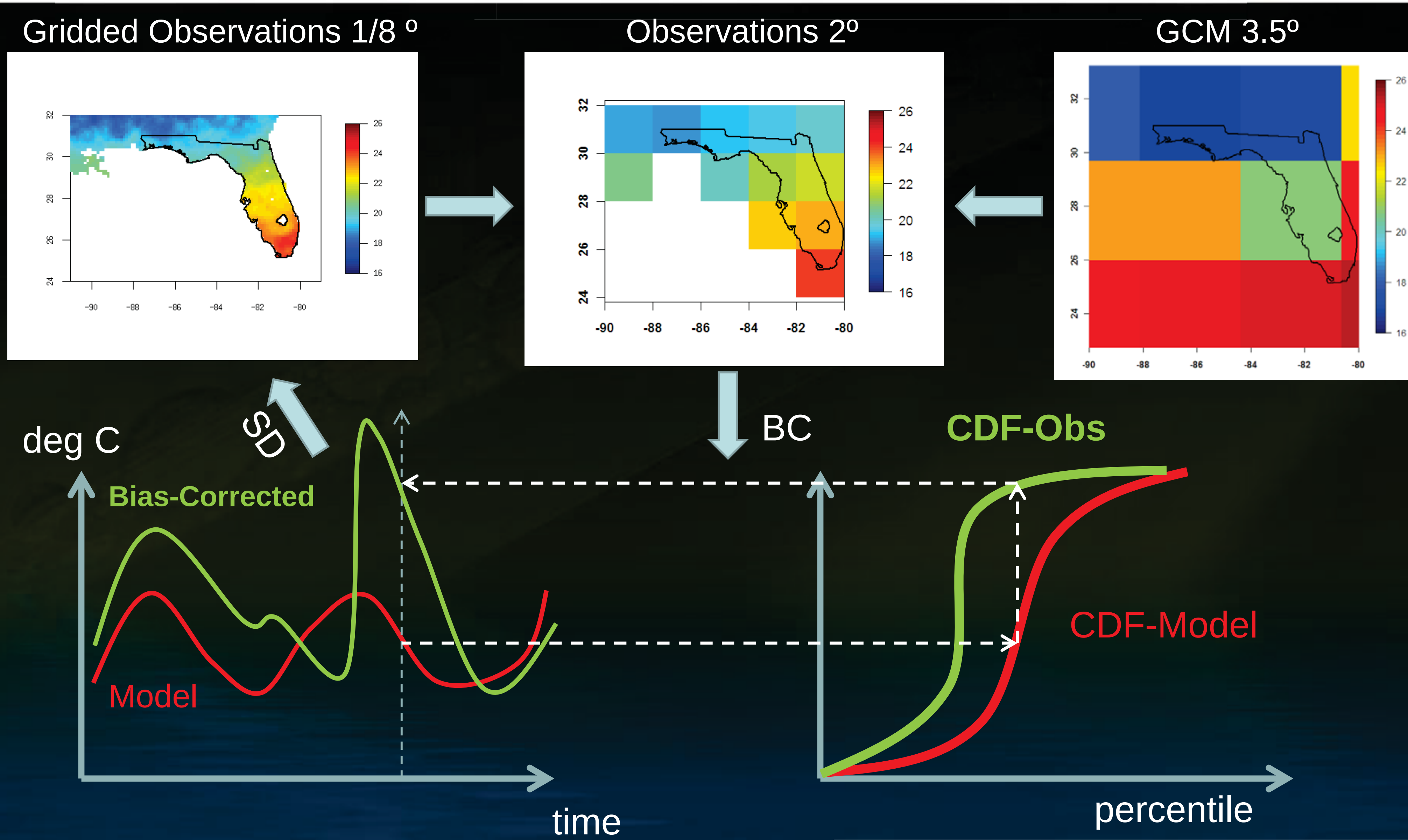






•The vertical bars correspond to the percentiles, 5% and 95% of the posterior distributions of temperature change for b1,a1b, and a2 scenarios (red, black and blue)

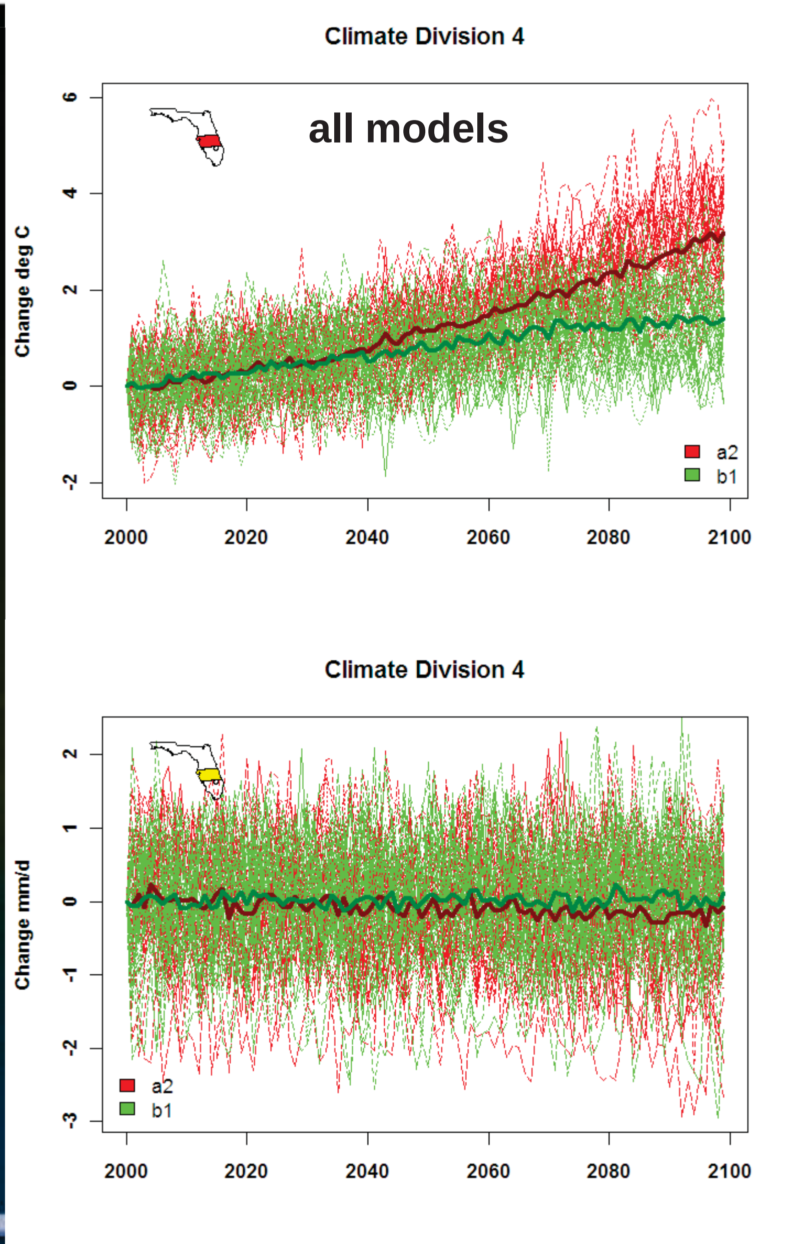
Statistical Downscaling – Example (Bias Correction-Spatial Disaggregation)

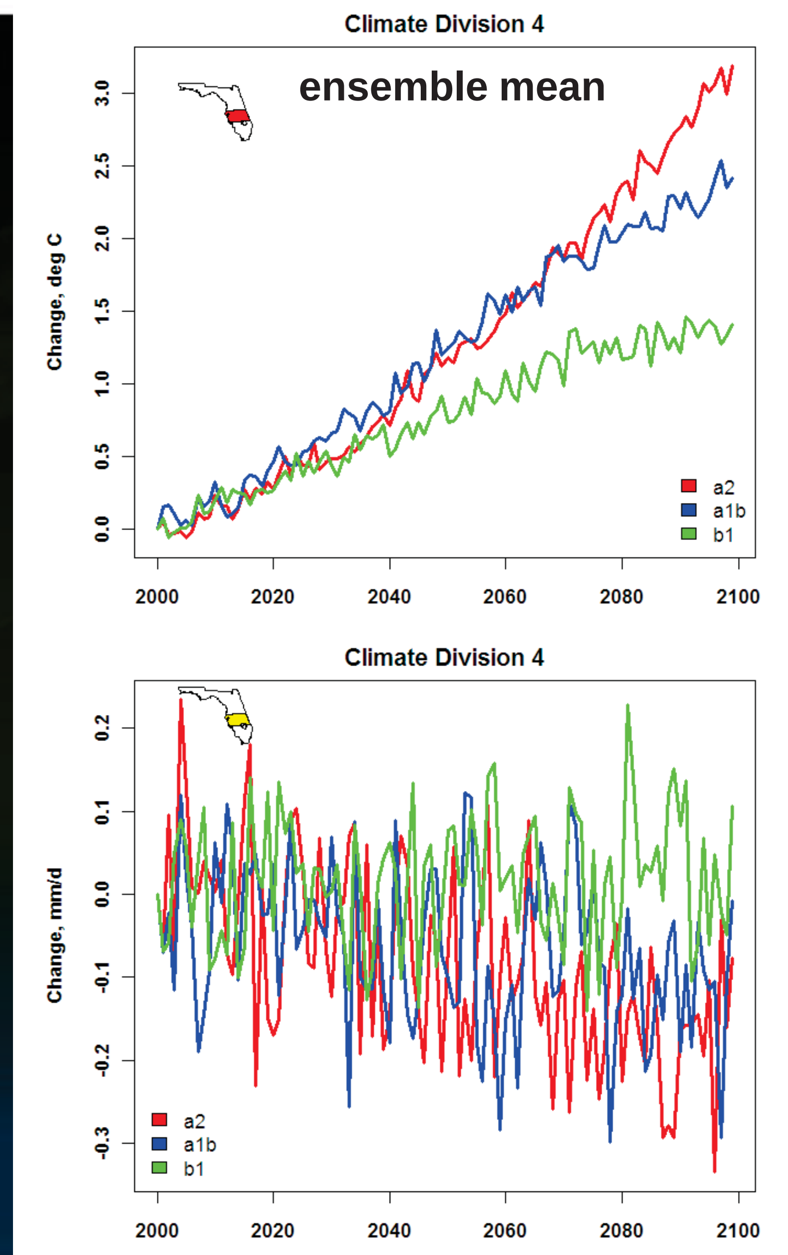


Future Projections – Temperature & Precipitation

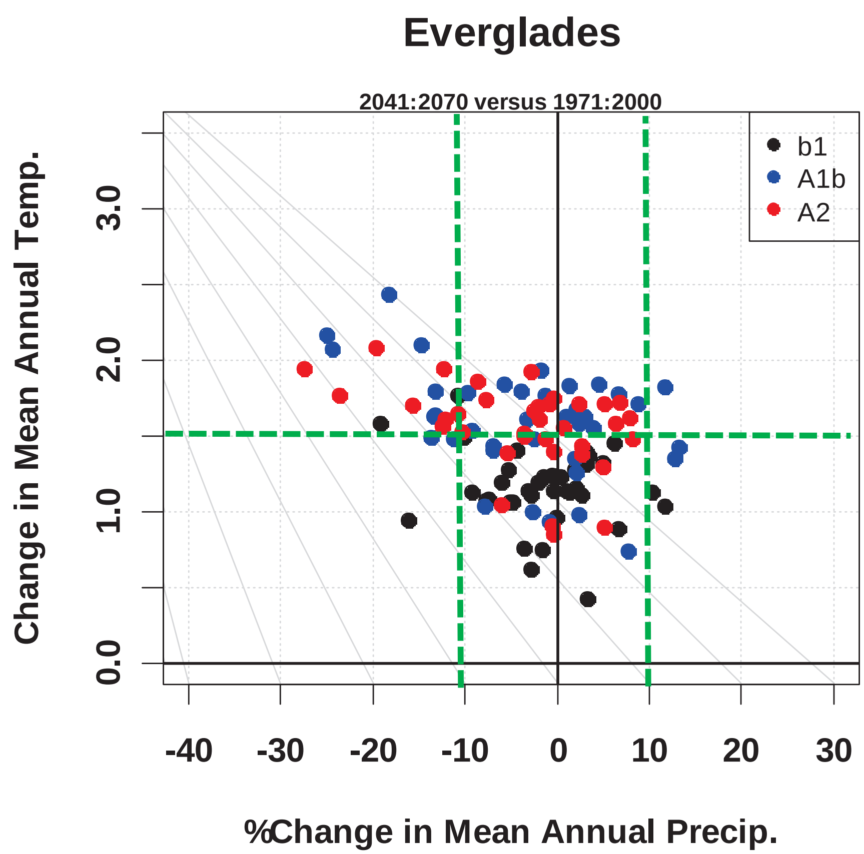
T°

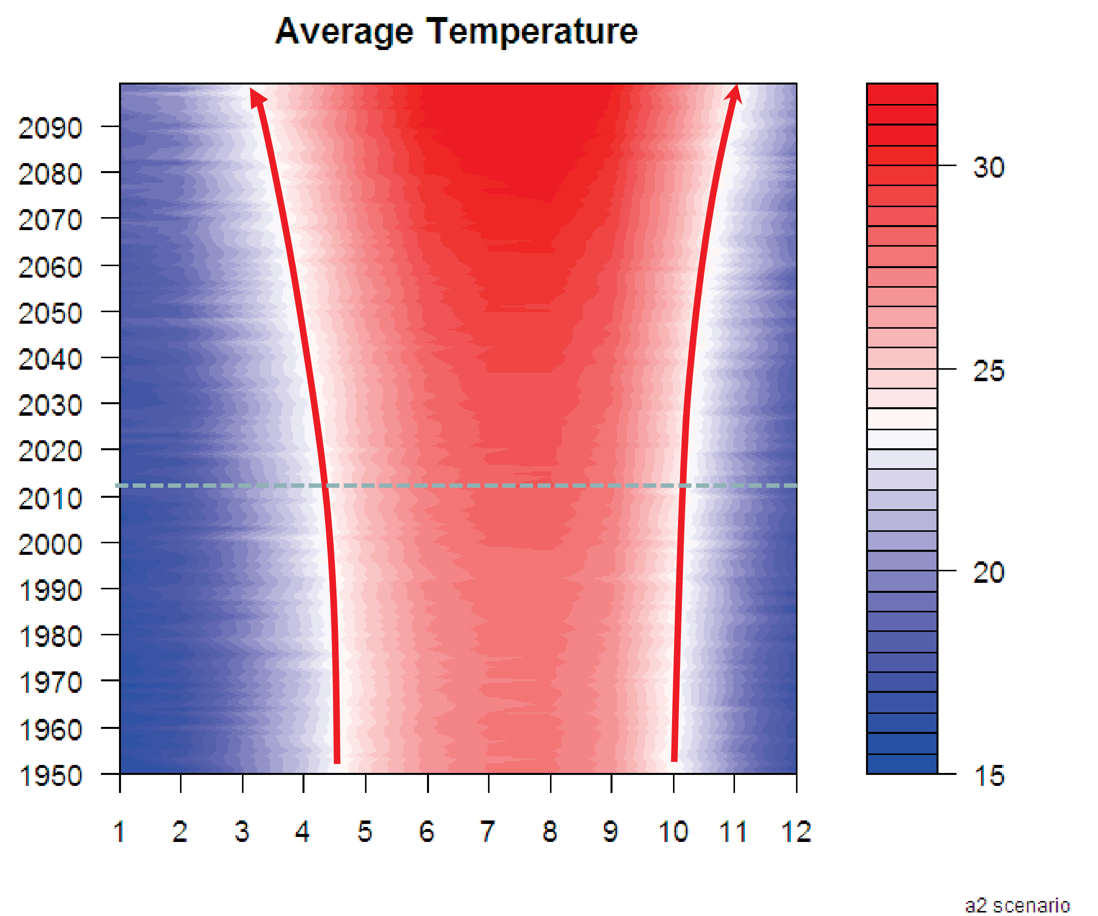
P



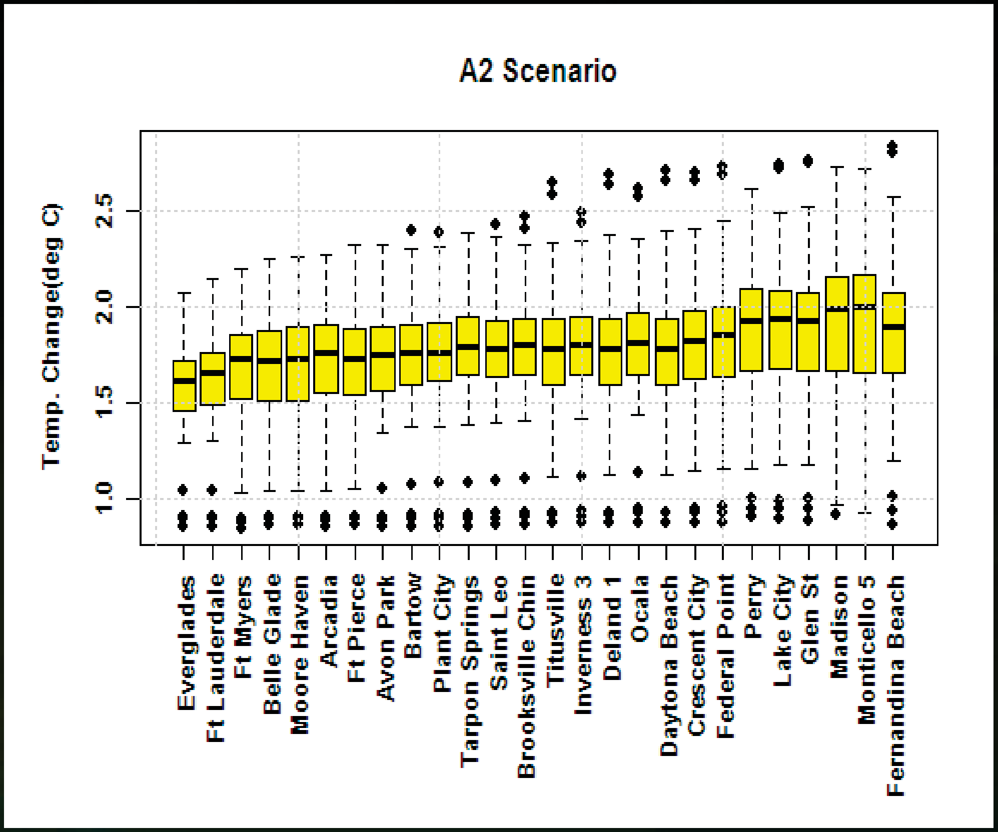


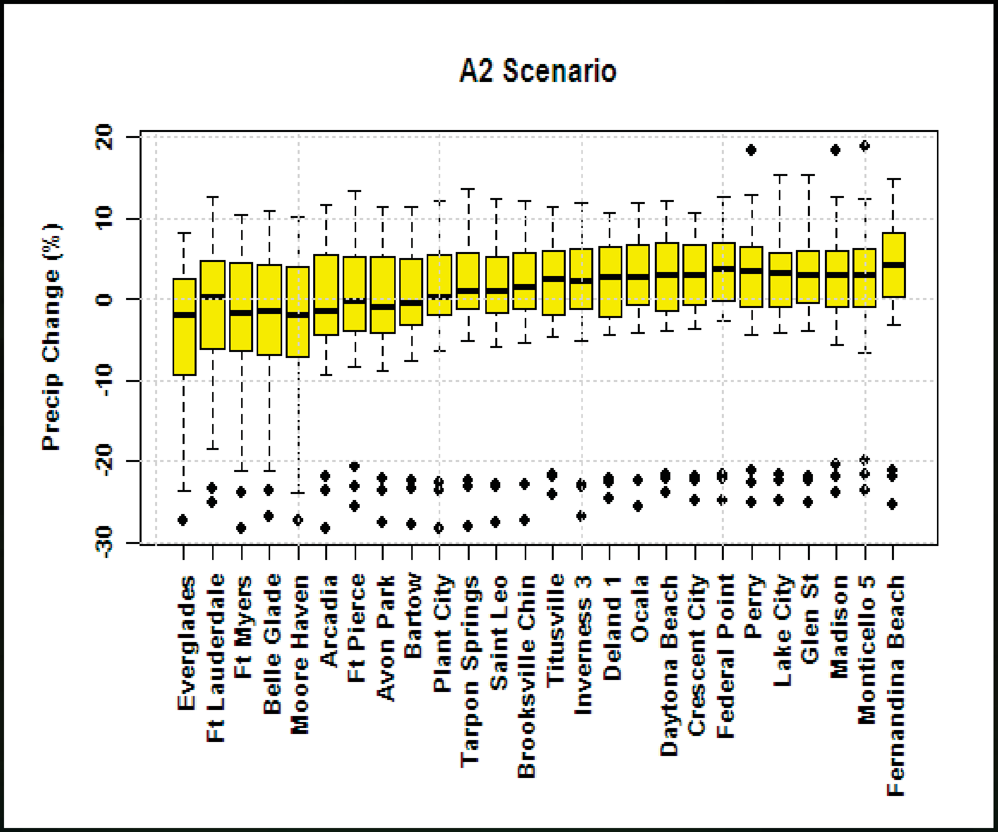
Change: Magnitude & Seasonality





Spatial Trends

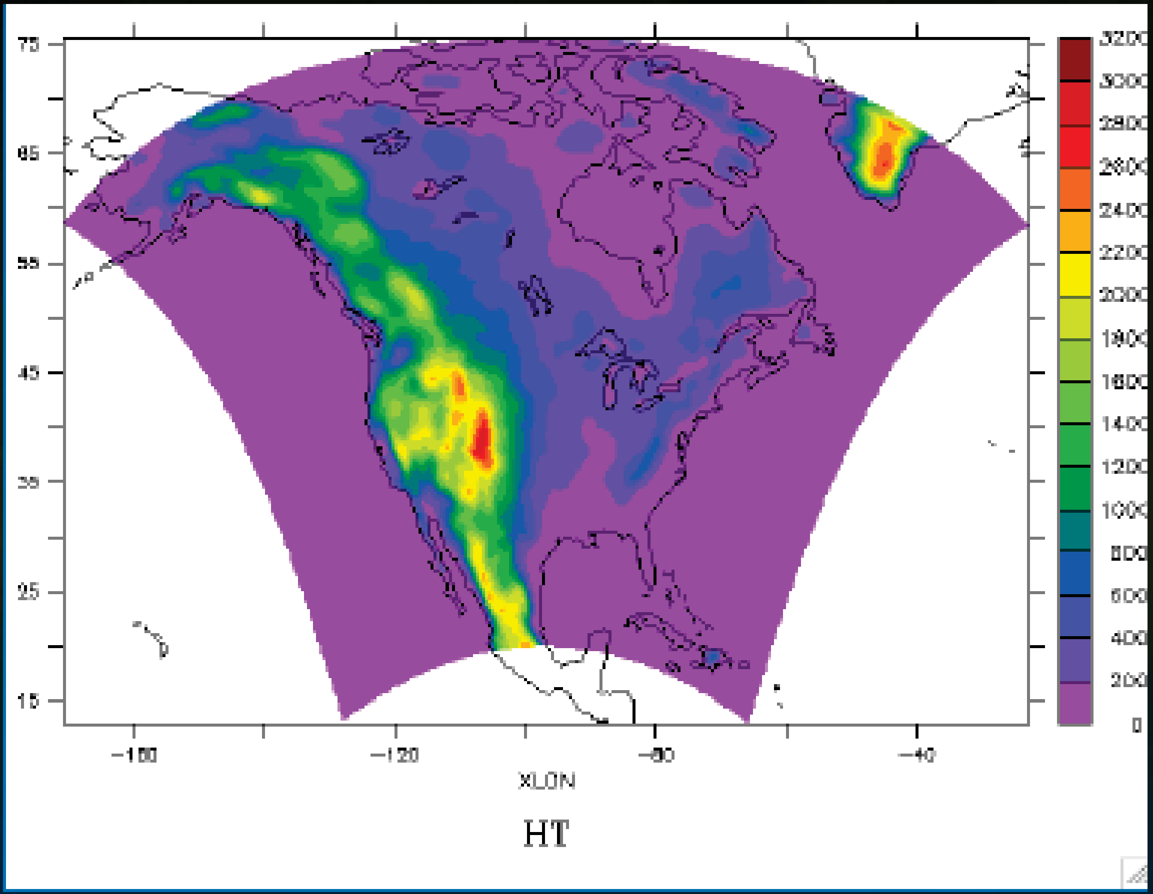




Temperature **Precipitation**

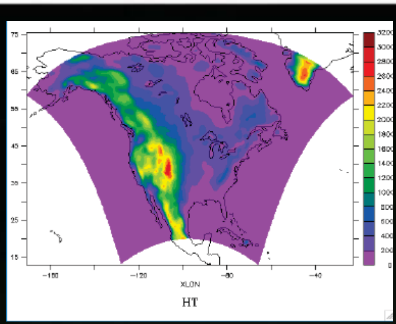
Dynamical Downscaling
North American Regional Climate Change Assessment Program

NARCCAP



__Acknowledgement:__
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)."

NARCCAP Scenario & Model Suite



A2 Emissions Scenario

GFDL Time slice 50 km

GFDL

CGCM3

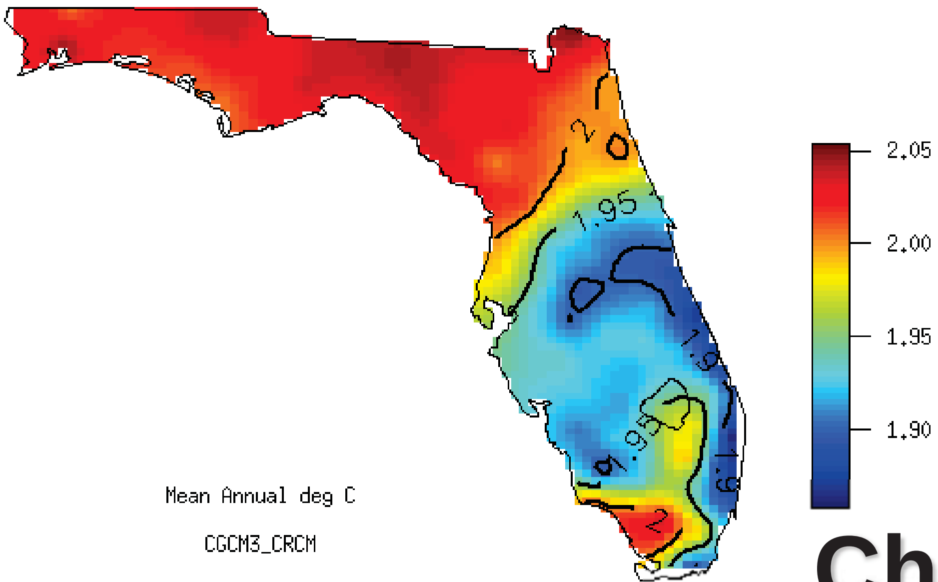
HADCM3
link to European Prudence

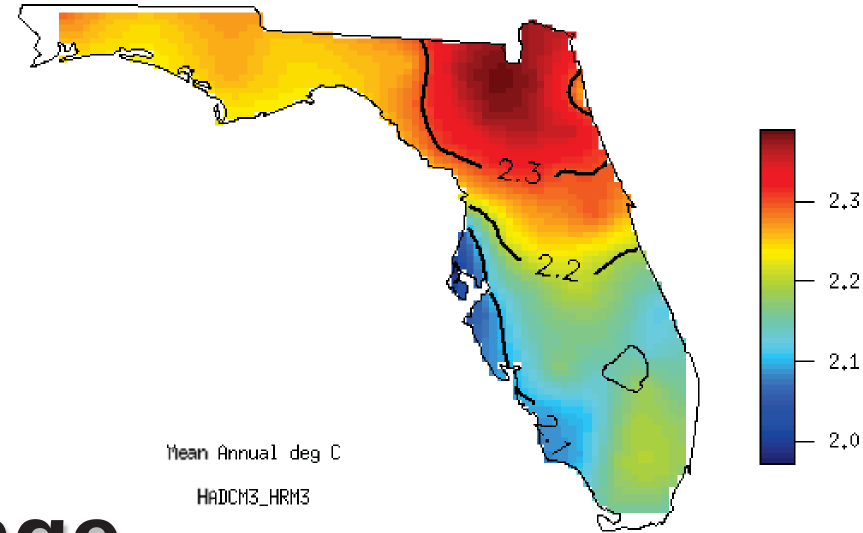
CCSM

CAM3 Time slice 50km

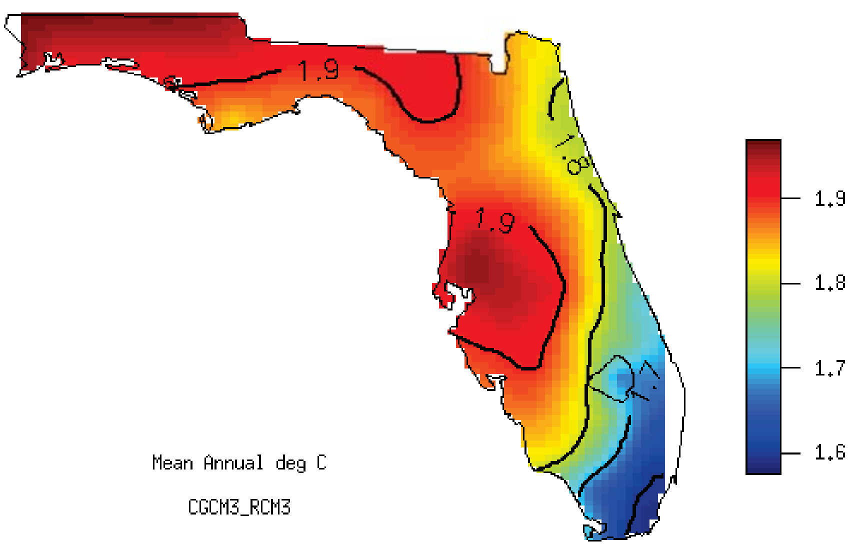
1971-2000 current — **Provide boundary conditions** — 2040-2070 future

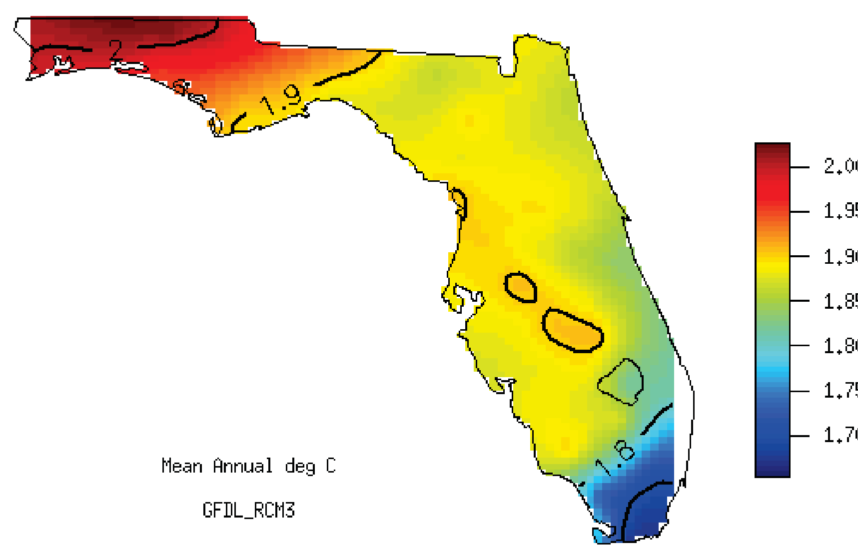
MM5	RegCM3	CRCM	HADRM3	RSM	WRF
Iowa State/ PNNL	UC Santa Cruz ICTP	Quebec, Ouranos	Hadley Centre	Scripps	NCAR/ PNNL



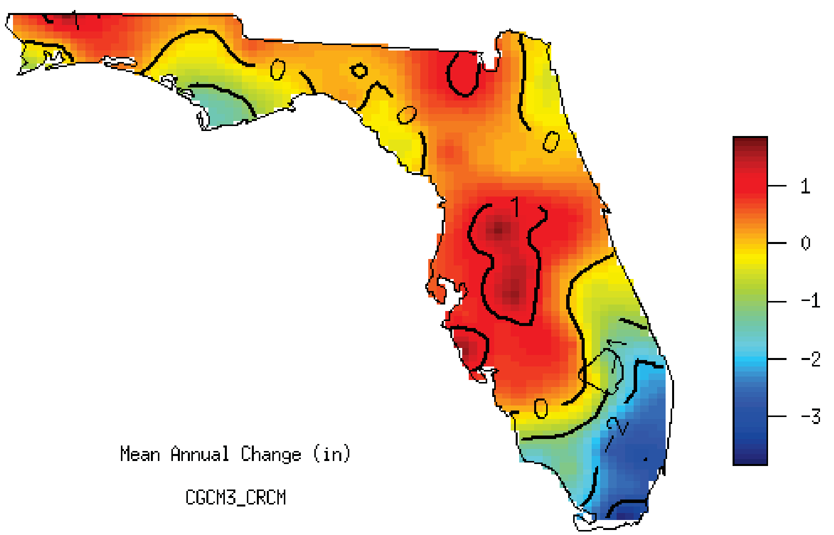


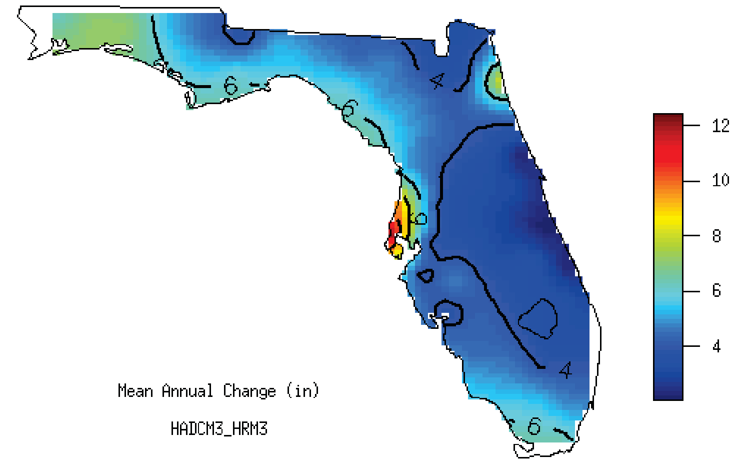
Change Temperature



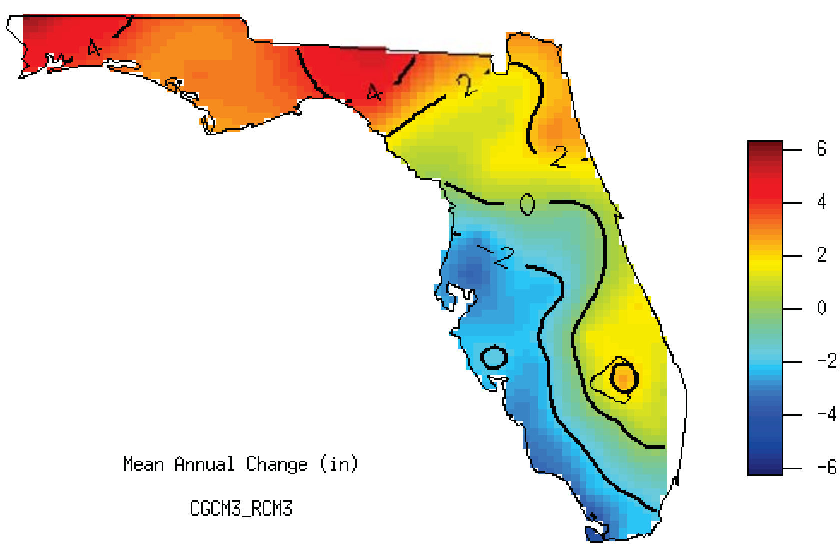


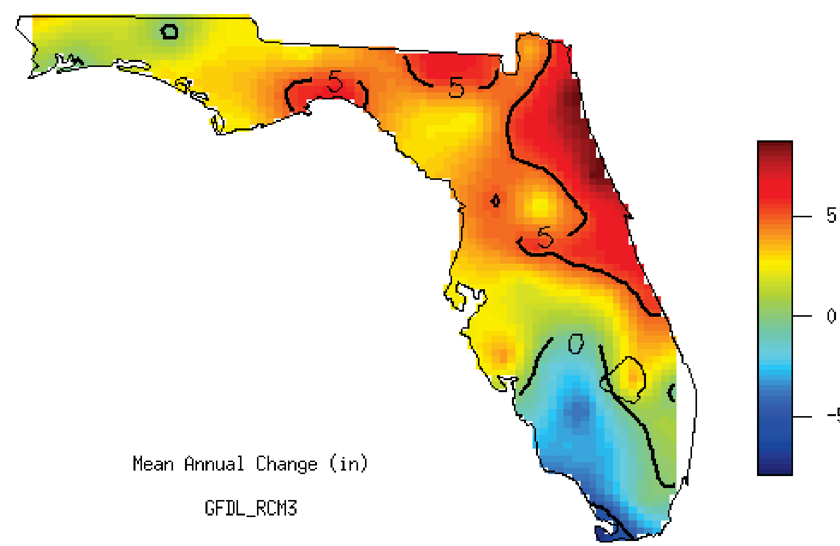
NARCCAP





Change Precipitation



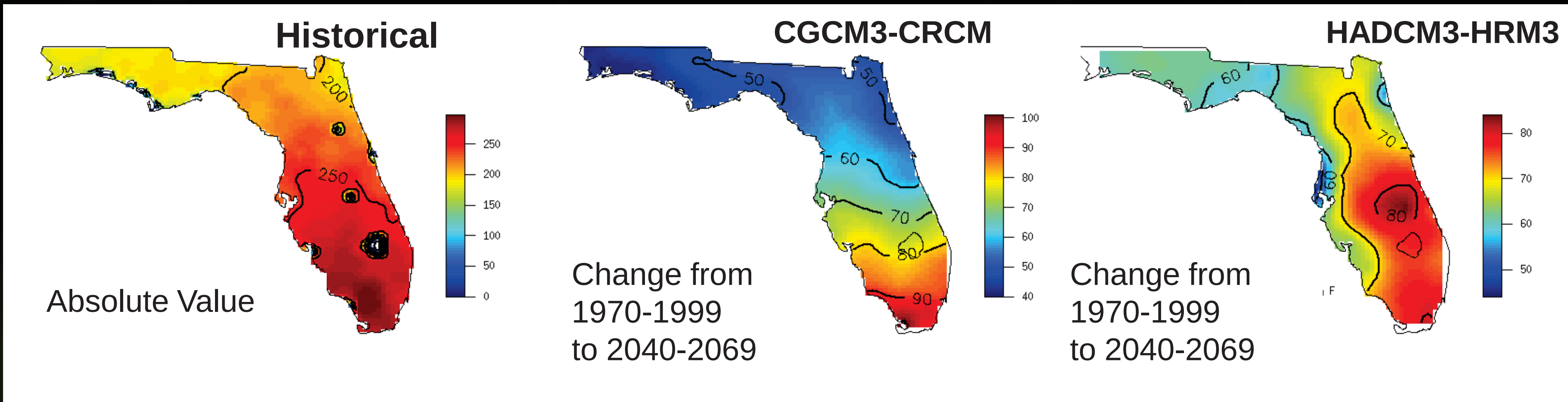


NARCCAP

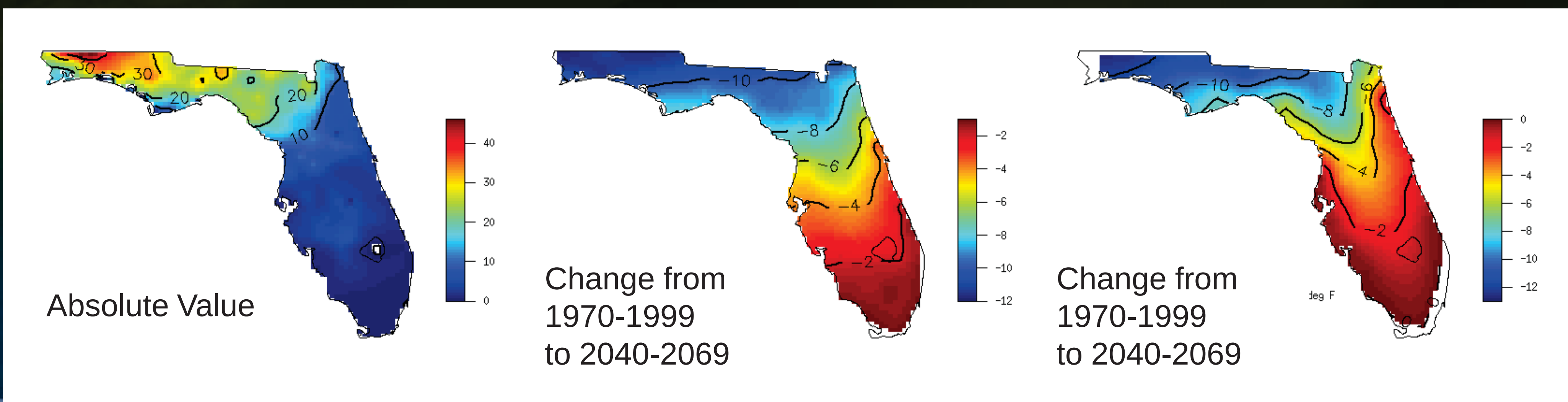
Changes in duration of "dog days" & "freezing temperatures"

BCCA

Dog days – Mean Number of days average above 80º F

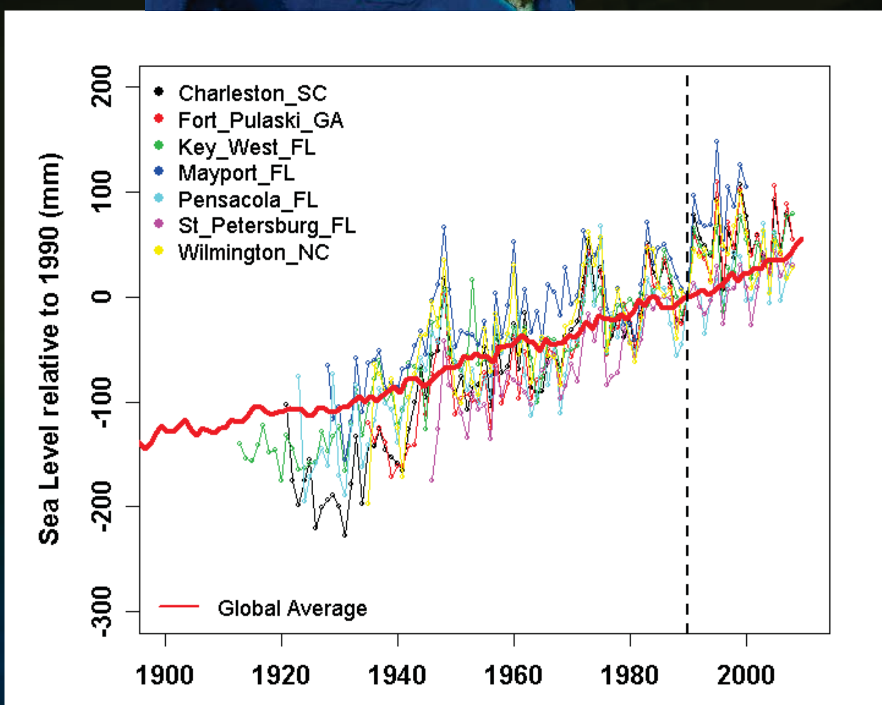


Freezing – Mean Number of days minimum below 32º F



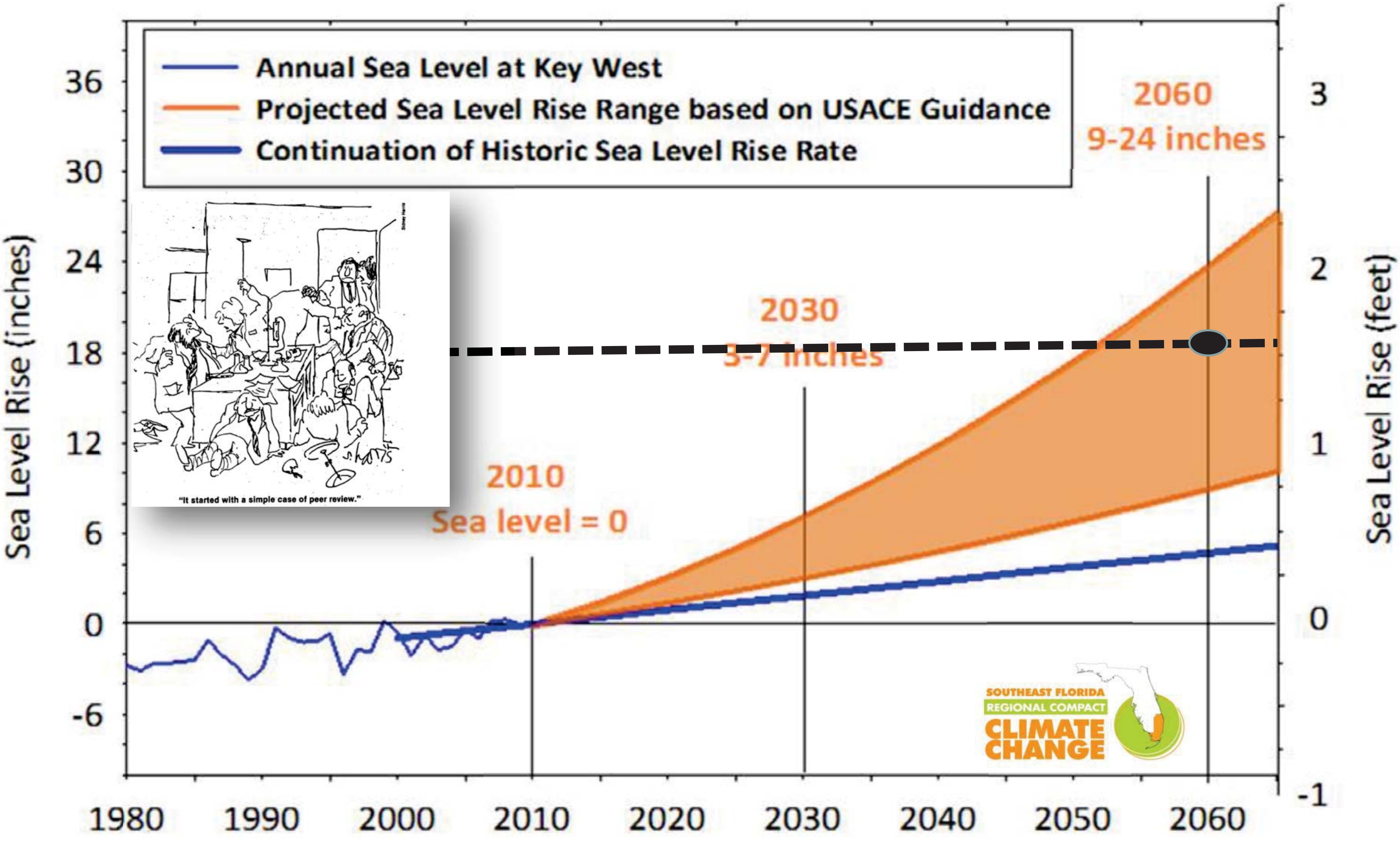
Sea Level Rise

Rising Seas – Historical Data

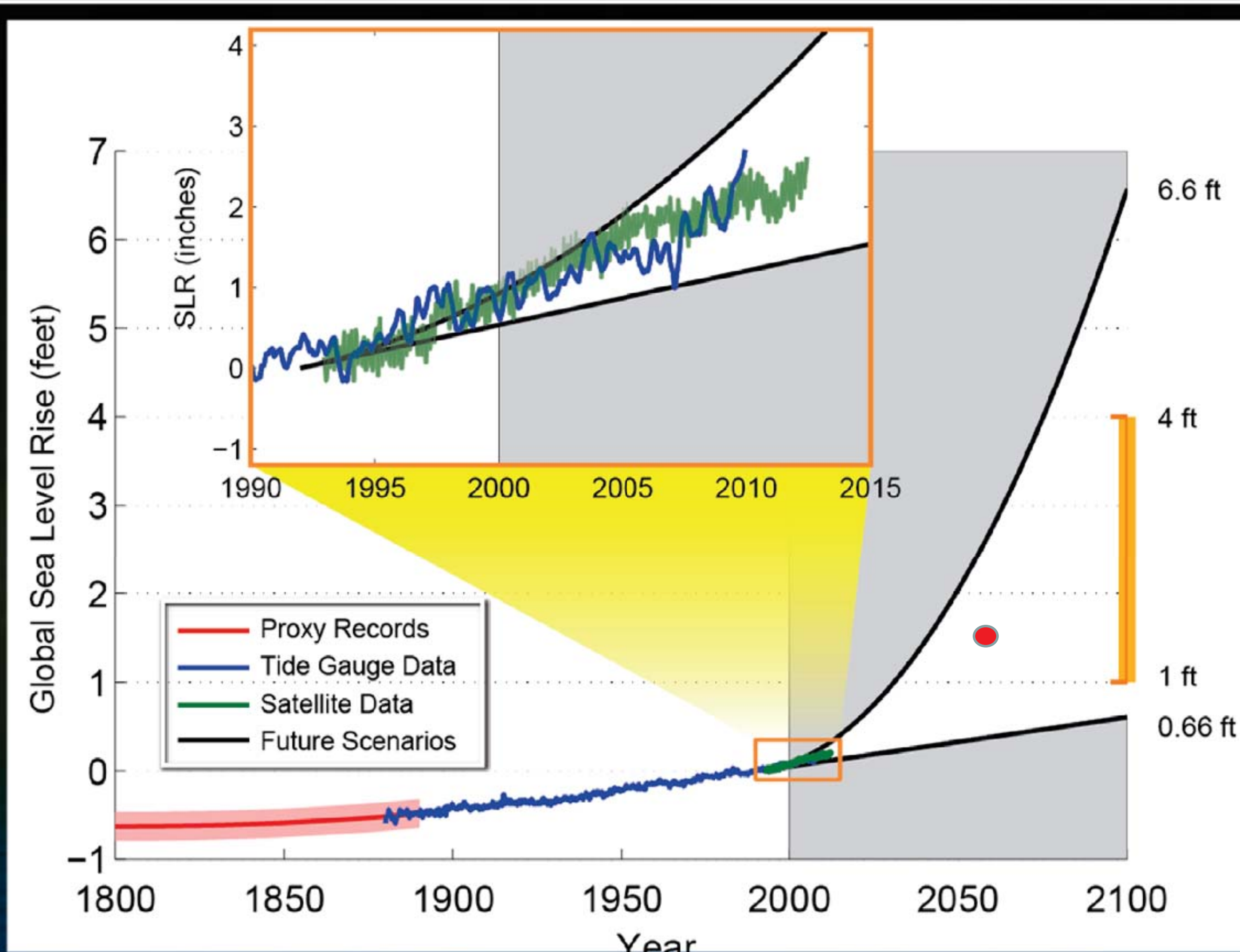


- Relative Sea Level (height above a local datum) depends on:
  - Global Mean Sea Level
  - Regional Variability
  - Vertical Land Movement (uplift/subsidence)

Unified SE FL Sea Level Rise Projection



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



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

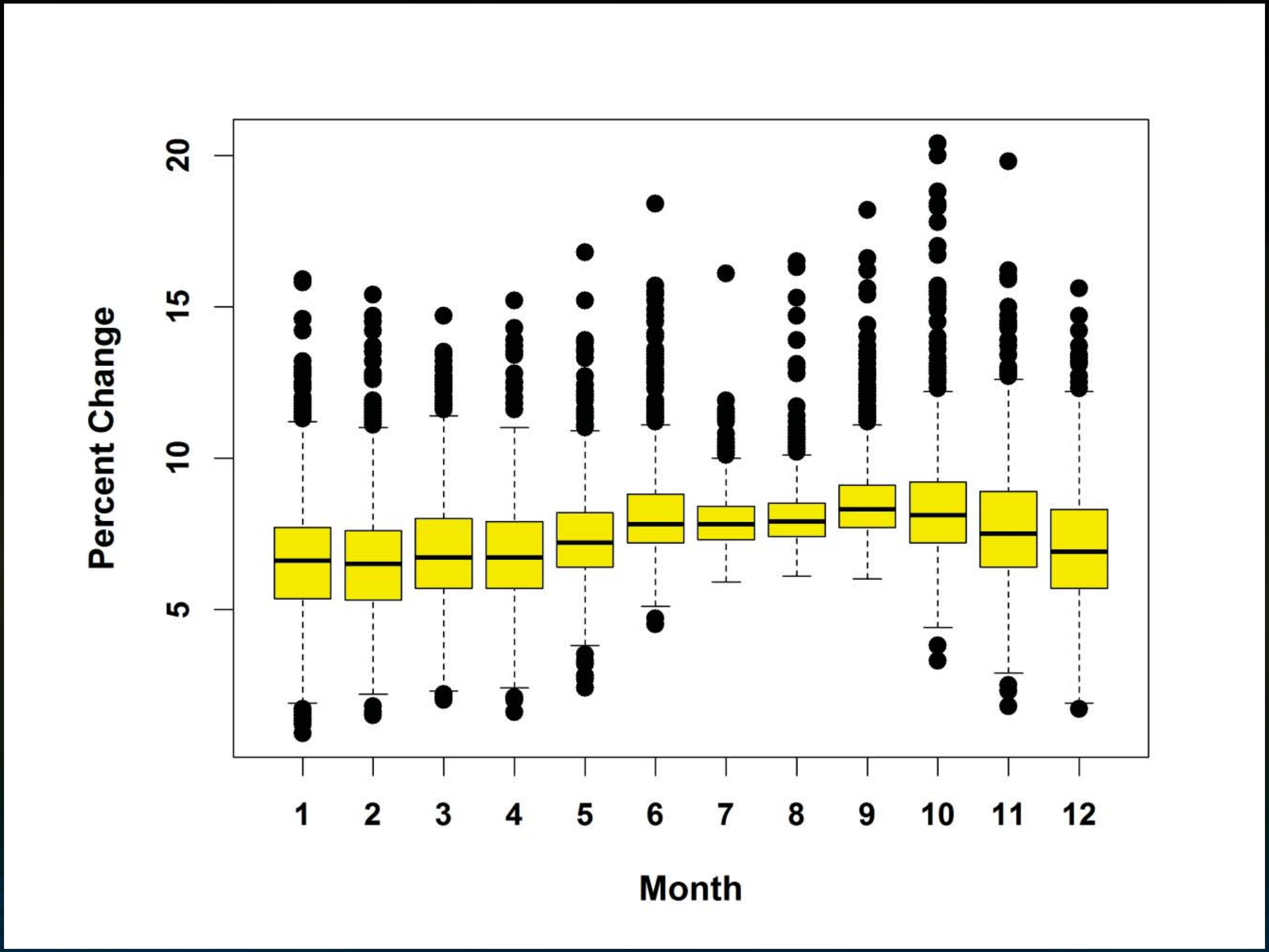
Summary of Projections for 2060

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 (**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**)

Potential ET change



Percent Change in Demand and Runoff (K ac-ft)

Type	BASE	decRF	incRF	incET	decRF incET	decRF incETnoC	incRF incET
Palm Beach County Irrigation	209	3	-6	-2	1	1	-8
Broward County Irrigation	161	3	-6	2	5	5	-5
Miami-Dade County Irrigation	231	4	-5	5	9	9	-1
EAA	309	20	-10	25	61	60	6
C-43 Demand	107	15	-14	14	31	31	-1
C-43 Runoff	713	-27	28	-11	-36	-36	17
C-44 Demand	24	21	-16	21	47	47	2
C-44 Runoff	166	-26	28	-12	-36	-36	15

Changes to boundary flows (Kissimmee Basin Example)