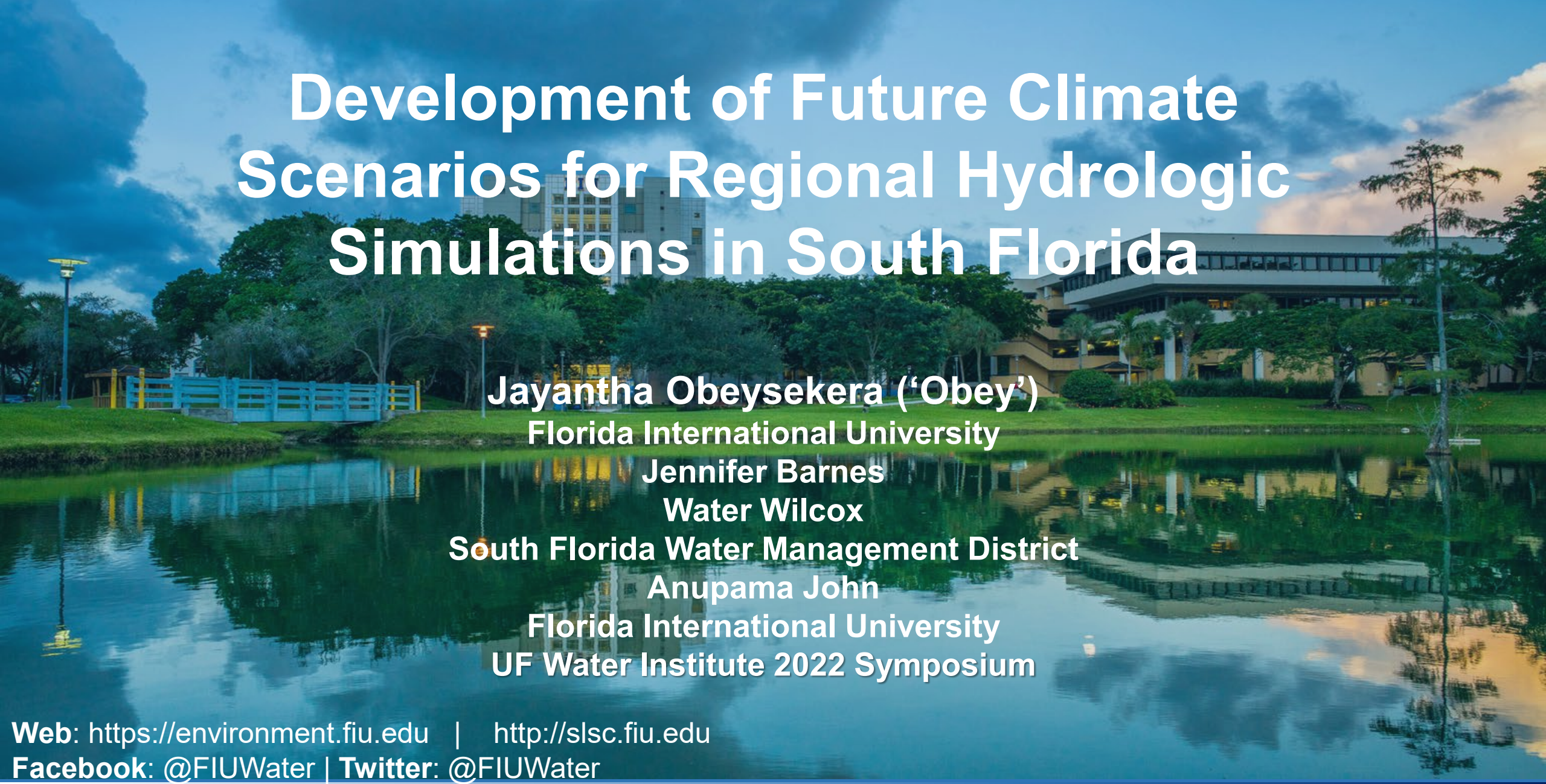


Development of Future Climate Scenarios for Regional Hydrologic Simulations in South Florida

Jayantha Obeysekera ('Obey')
Florida International University
Jennifer Barnes
Water Wilcox
South Florida Water Management District
Anupama John
Florida International University

UF Water Institute 2022 Symposium

Web: https://environment.fiu.edu | http://slsc.fiu.edu
Facebook: @FIUWater | **Twitter**: @FIUWater

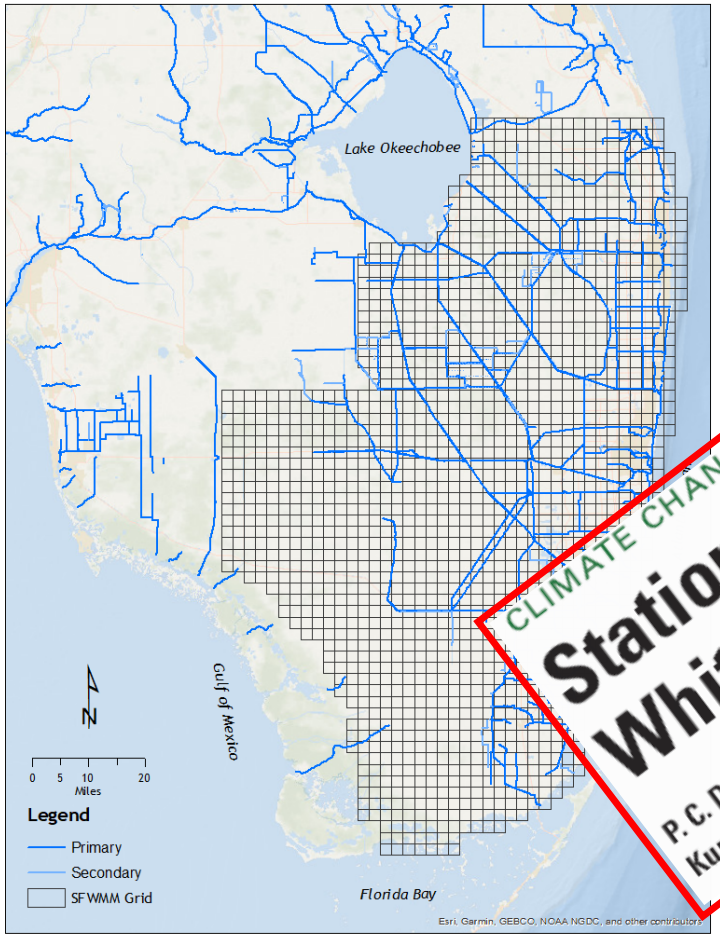
FIU Sea Level Solutions Center
Florida International University

FIU Institute of Environment
Florida International University

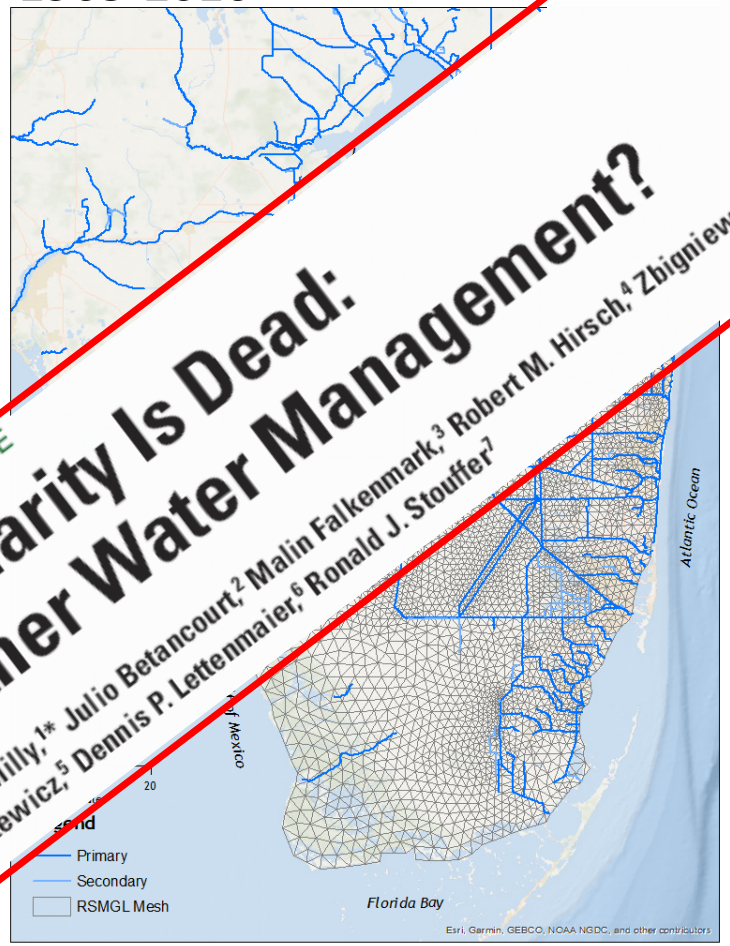
February 22-23, 2022

Regional Modeling based on the Stationarity Concept

SFWMM (a.k.a. 2x2)
1965-2016



Regional Simulation Model
1965-2016

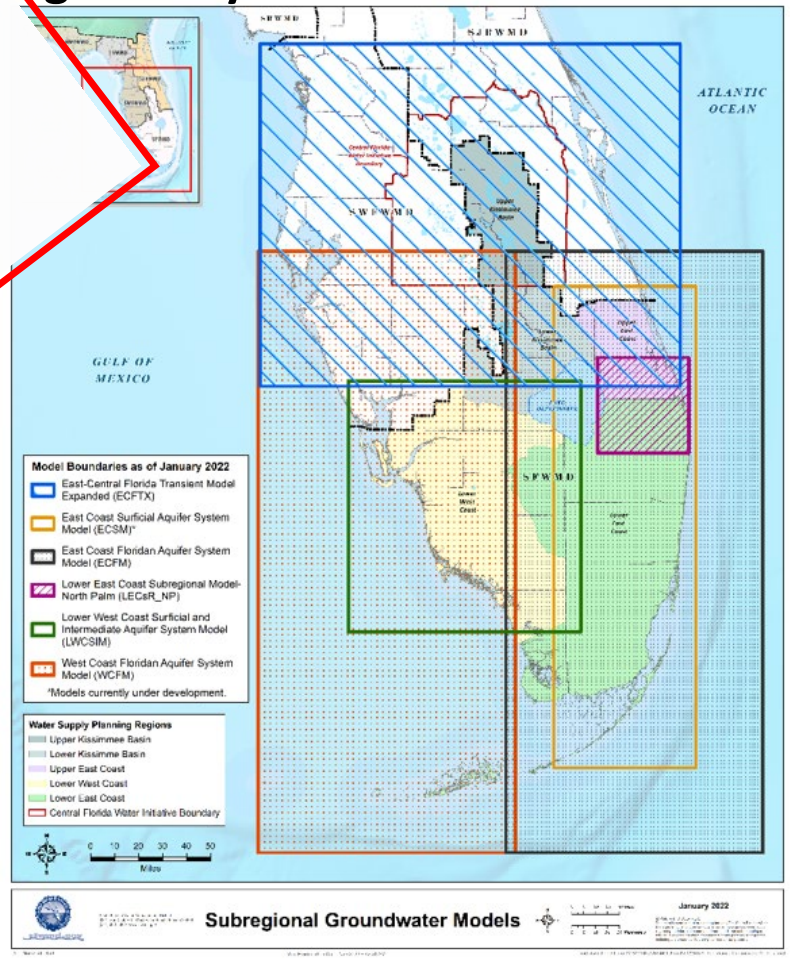


CLIMATE CHANGE

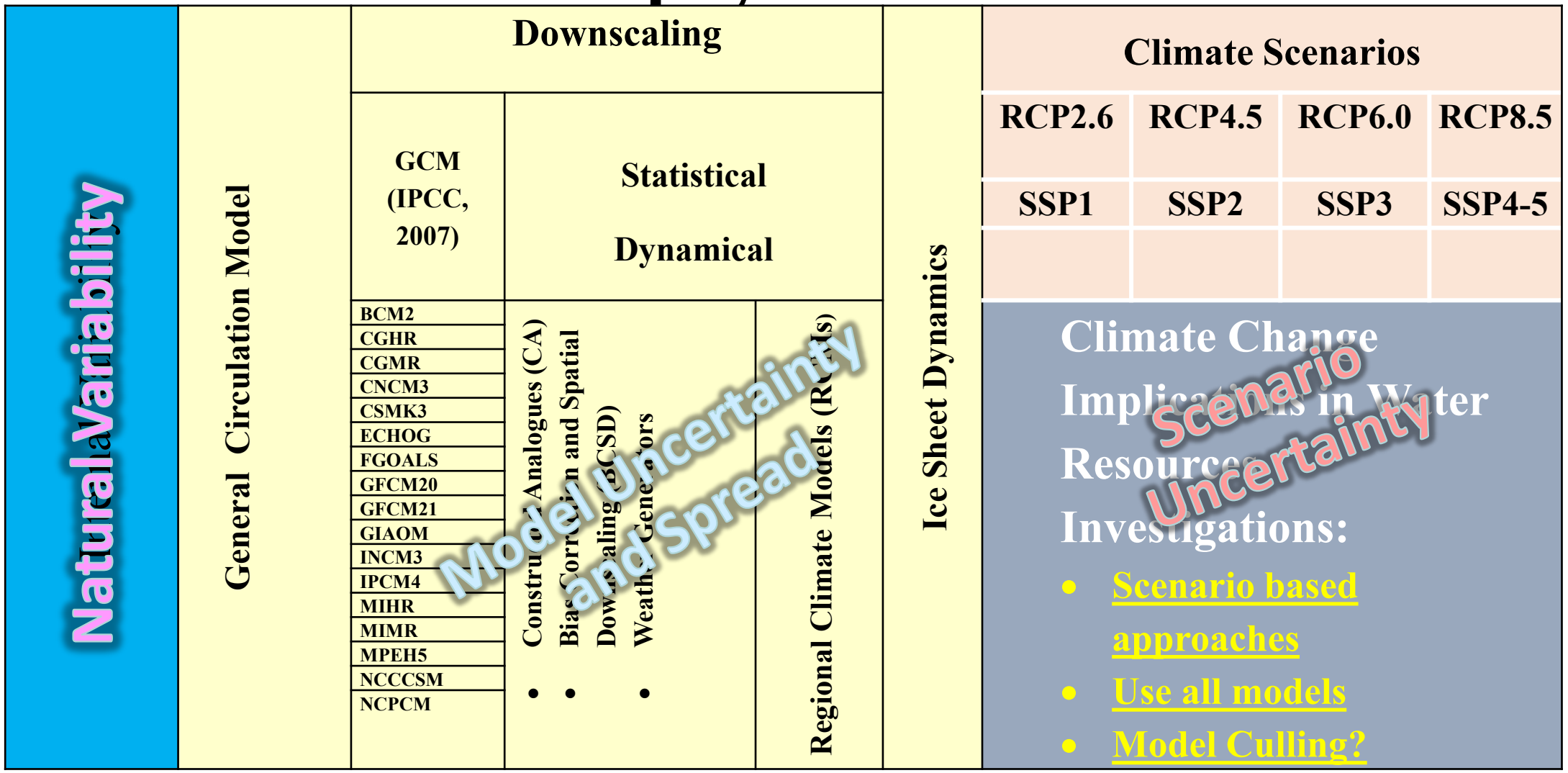
Stationarity Is Dead: Whither Water Management?

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]

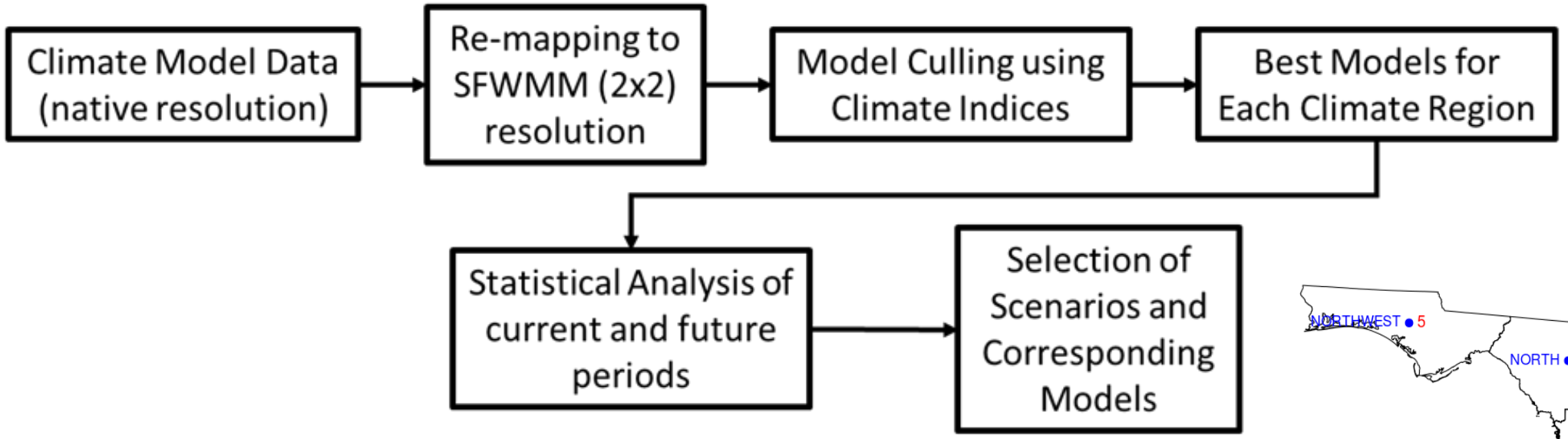
Regional Groundwater Models
generally 1985-2014

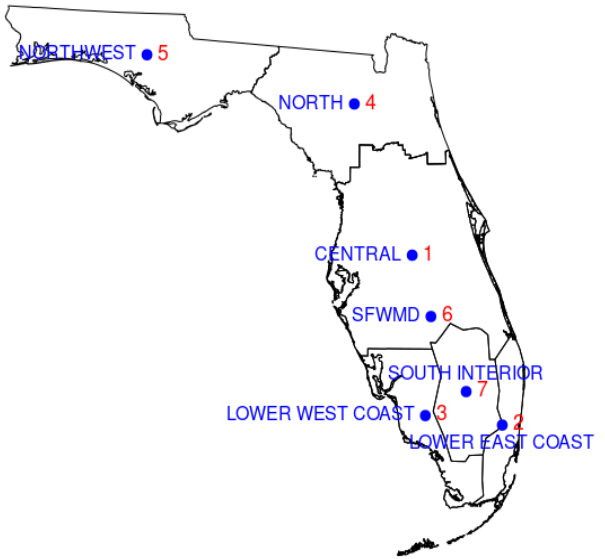


Nonstationarity Projections may be Deeply Uncertain



Scenario Development Approach





Acquisition and assessment of climate model data for future periods

- GCM resolution is too coarse
- Downscaled data available for Florida:
  - Statistical Downscaling
  - Dynamical Downscaling
- Available for future potential atmospheric scenarios Representative Concentration Pathways (RCPs). RCP4.5 and RCP8.5

Datasets Assembled:

- Coordinated Regional Downscaling Experiment (**CORDEX**), dynamically-downscaled (World Climate Research Program) (25 and 50 km scales, gridMET and Daymet datasets for bias-correction)
- Localized Constructed Analogues (**LOCA**), statistically downscaled (SCRIPPS Institute of Oceanography) (1/16 deg~6 km, Livneh dataset)
- Multivariate Adaptive Constructed Analogs (**MACA**), statistically downscaled (University of California, Merced) (1/16~6 km, Livneh and gridMET datasets)

LOCA Data

Dataset	Scenarios(#)	Global Climate Models	
Localized Constructed Analogues (LOCA)	**Historical** (30)	ACCESS1-0	GFDL-ESM2M
	RCP45 (30)	ACCESS1-3	GISS-E2-H
	RCP85 (30)	bcc-csm1-1-m	GISS-E2-R
		CanESM2	HadGEM2-AO
		CCSM4	HadGEM2-CC
		CESM1-BGC	HadGEM2-ES
		CESM1-CAM5	IPSL-CM5A-LR
		CMCC-CM	IPSL-CM5A-MR
		CMCC-CMS	MIROC5
		CNRM-CM5	MIROC-ESM
		CSIRO-Mk3-6-0	MIROC-ESM-CHEM
		EC-EARTH	MPI-ESM-LR
		FGOALS-g2	MPI-ESM-MR
		GFDL-CM3	MRI-CGCM3
		GFDL-ESM2G	NorESM1-M

MACA Data

Dataset	Scenarios (#)	Global Climate Models	
Multivariate Adaptive Constructed Analogs (MACA)	**Historical** (20)	bcc-csm1-1	HadGEM2-ES365
	RCP45 (20)	bcc-csm1-1-m	inmcm4
	RCP85 (20)	BNU-ESM	IPSL-CM5A-LR
		CanESM2	IPSL-CM5A-MR
		CCSM4	IPSL-CM5B-LR
		CNRM-CM5	MIROC5
		CSIRO-Mk3-6-0	MIROC-ESM
		GFDL-ESM2G	MIROC-ESM-CHEM
		GFDL-ESM2M	MRI-CGCM3
		HadGEM2-CC365	NorESM1-M

CORDEX Data

Dataset	Scenarios (#)	Global Climate Models	
Coordinated Regional Downscaling Experiment (CORDEX)	**Historical** (54) **RCP85** (54)	CanESM2.CanRCM4, CanESM2.CRCM5-UQAM CanESM2.RCA4 EC-EARTH.HIRHAM5 EC-EARTH.RCA4 GEMatm-Can.CRCM5-UQAM GEMatm-MPI.CRCM5-UQAM GFDL-ESM2M.RegCM4	GFDL-ESM2M.WRF HadGEM2-ES.RegCM4 HadGEM2-ES.WRF MPI-ESM-LR.CRCM5-UQAM MPI-ESM-LR.RegCM4 MPI-ESM-LR.WRF MPI-ESM-MR.CRCM5-UQAM
	RCP45 (14)	CanESM2.CanRCM4 (2) CanESM2.CRCM5-UQAM CanESM2.RCA4	EC-EARTH.HIRHAM5 EC-EARTH.RCA4 MPI-ESM-LR.CRCM5-UQAM

Model Culling: Metrics

ID	Indicator Name	Definition	Units
PRCPTOT	Annual total precipitation	Annual total, days > 1mm	inches
PMMEAN	Seasonal Pattern	Mean monthly rainfall	inches
WSTART	Wet Season Start Date	Start of the Wet Season	days
R10mm	Heavy precipitation days	# of days with > 10mm	days
R20mm	Heavy precipitation days	# of days with > 20mm	days
SDII	Daily intensity index	Ratio Annual precipitation / #wet days	inches /day
CDD	Consecutive dry days	#max. consecutive days < 1 mm	days
CWD	Consecutive wet days	#max. consecutive days > 1 mm	days

ID	Indicator Name	Definition	Units
RX1day	Max 1-day precipitation amount	Annual maxima of 1-day precipitation	inches
R95p	Very wet days	Annual precip from days > 95%	inches
R99p	Extreme wet days	Annual precip from days > 99%	inches
RX3day	Max 3-day precipitation amount	Annual maxima of 3-day precipitation	inches
RX5day	Max 5-day precipitation amount	Annual maxima of 5-day precipitation	inches
RX7day	Max 7-day precipitation amount	Annual maxima of 7-day precipitation	inches
RX10day	Max 10-day precipitation amount	Annual maxima of 10-day precipitation	inches

Model Culling: Evaluation using indices

- Climate indices defined by Expert Team on Climate Change Detection and Indices (**ETCCDI**) (Sillman et al 2013; Srivastava et al. 2020)
- Root Mean Square Error(RMSE of an index I for model m:

$$RMSE_{m,I} = \left[\frac{1}{N}\sum_{n=1}^{n=N}\left(\overline{I_{m,n}} - \overline{I_{o,n}}\right)^2\right]^{1/2}$$

- $\overline{I_{m,n}}$ = Average of the index for model m, and cell n (1:N)
- $\overline{I_{o,n}}$ = Average of the index for the reference data set, o, and cell n

Evaluation using indices (Cont.)

- Normalize RMSE for model m and index I:
  - $NRMSE_{m,I} = \frac{RMSE_{m,I} - RMSE_{median,I}}{RMSE_{median,I}}$ where median is across all models
  - $Model\ Climate\ Performance\ Index, \boldsymbol{MCI} = Average\ of\ all\ NRMSEs\ over\ all\ indices$

- Inter-annual Variability Skills Score (IVSS):

$$IVSS_{m,I} = \left[\frac{1}{N}\sum_{n=1}^{n=N}\left(\frac{\sigma_{m,n,I}}{\sigma_{o,n,I}} - \frac{\sigma_{o,n,I}}{\sigma_{m,n,I}}\right)^2\right]$$

$\sigma_{m,n,I}$: Interquartile range for model m (o for reference data), cell n, and index I

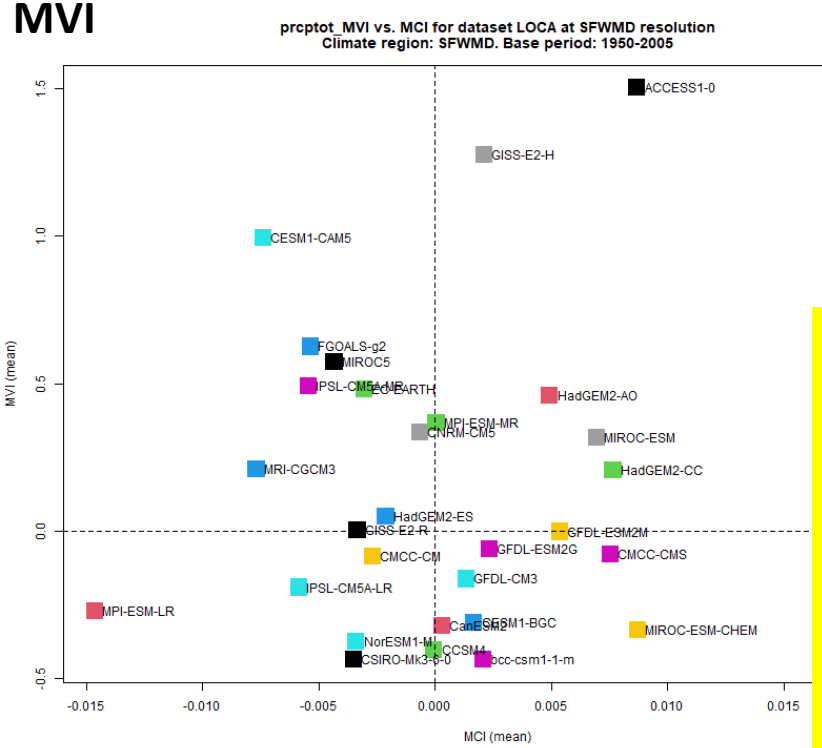
  - Normalized IVSS

$$NIVSS_{m,I} = \frac{IVSS_{m,I} - IVSS_{median,I}}{IVSS_{median,I}}$$

  - $Model\ Variability\ Index, \boldsymbol{MVI} = Average\ of\ all\ NIVSS\ over\ all\ indices$

Model Culling

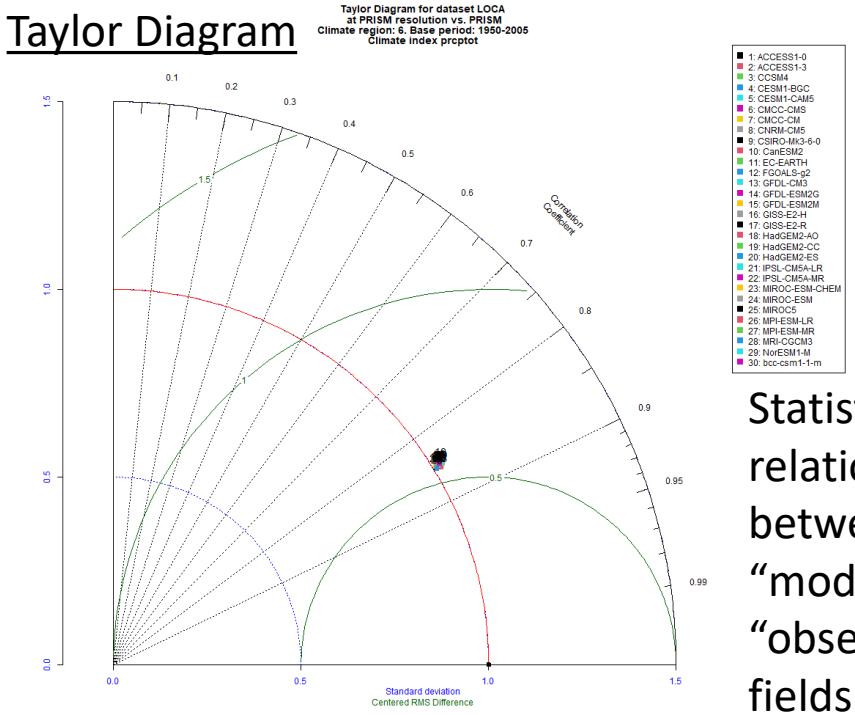
MVI



MCI

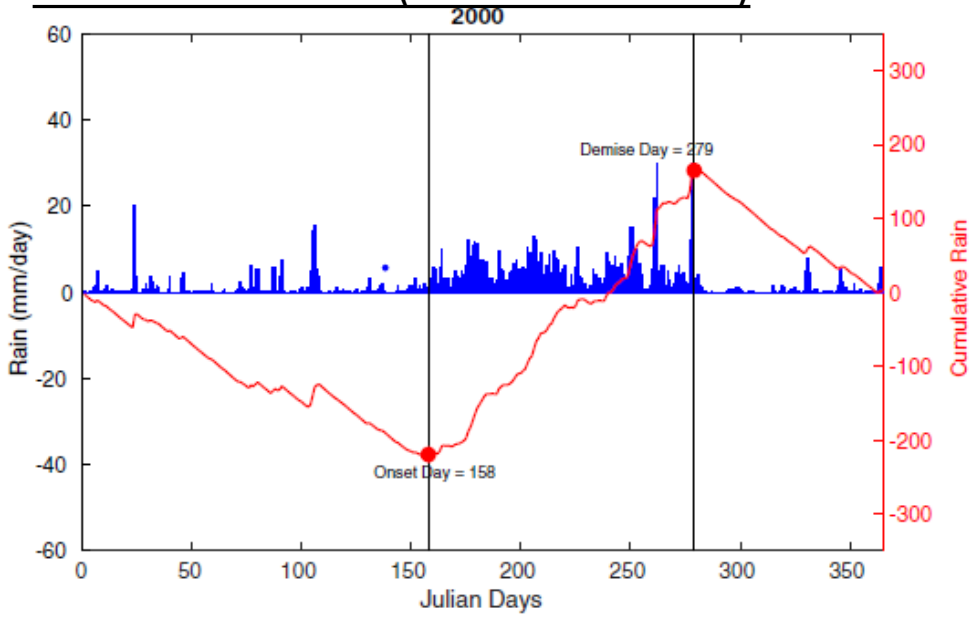
"..models that lie in the bottom-left quadrant have performance better than median performance in simulating both the climatologies and interannual variability of the indices"
Srivastava et al. (2020)

Taylor Diagram



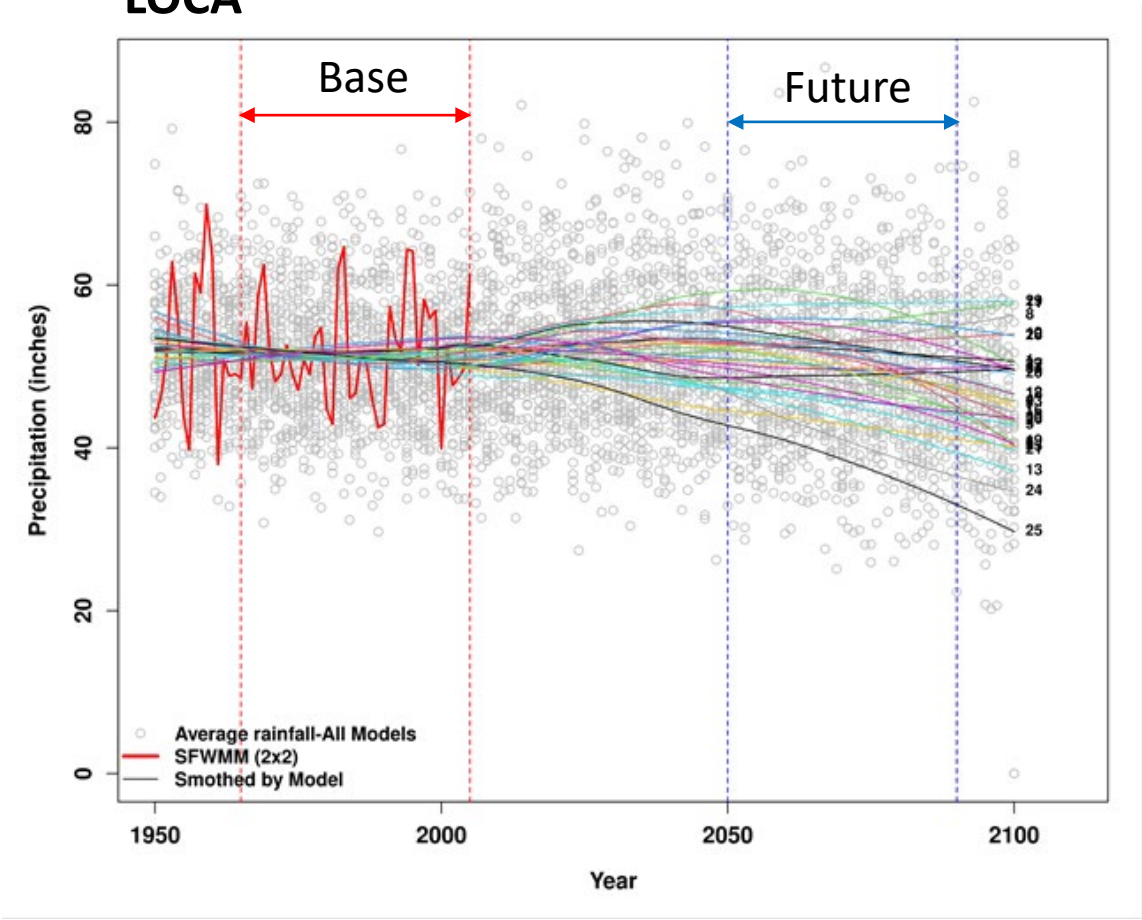
Statistical relationship between "model" and "observed" fields

West Season Start (Misra et al. 2017)

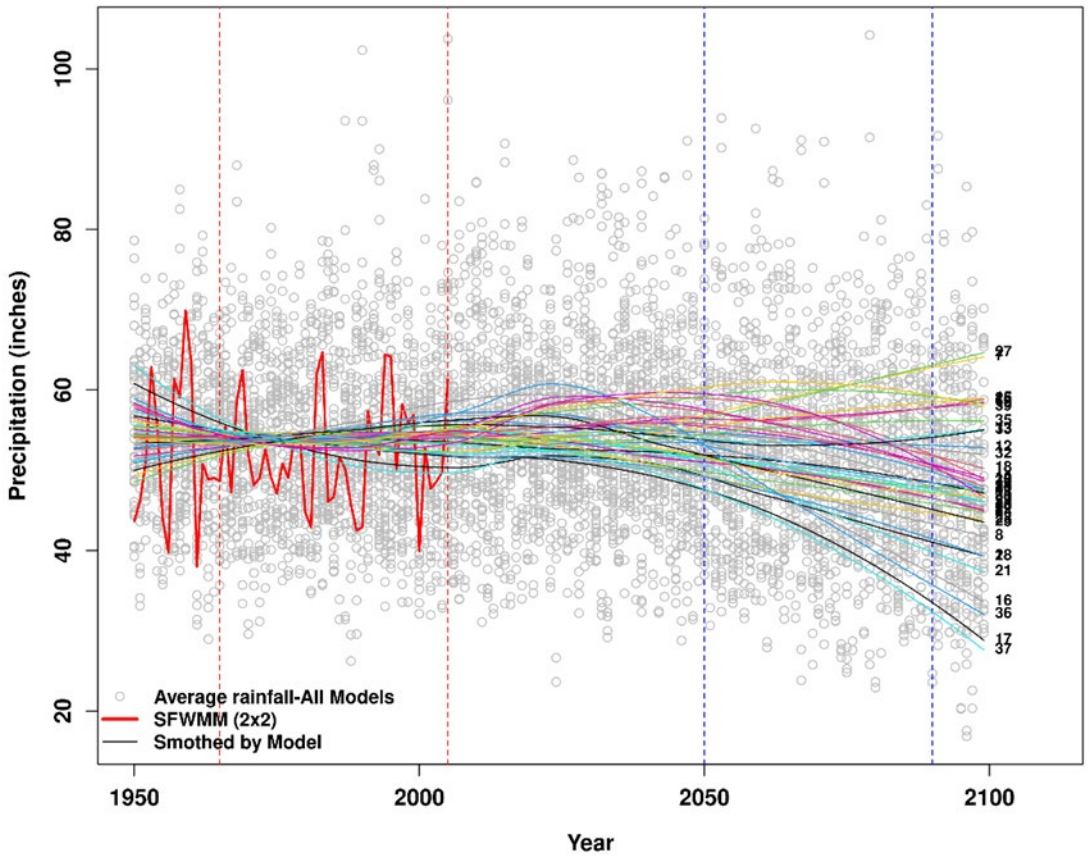


Total Precipitation (Entire SFWMD Region)

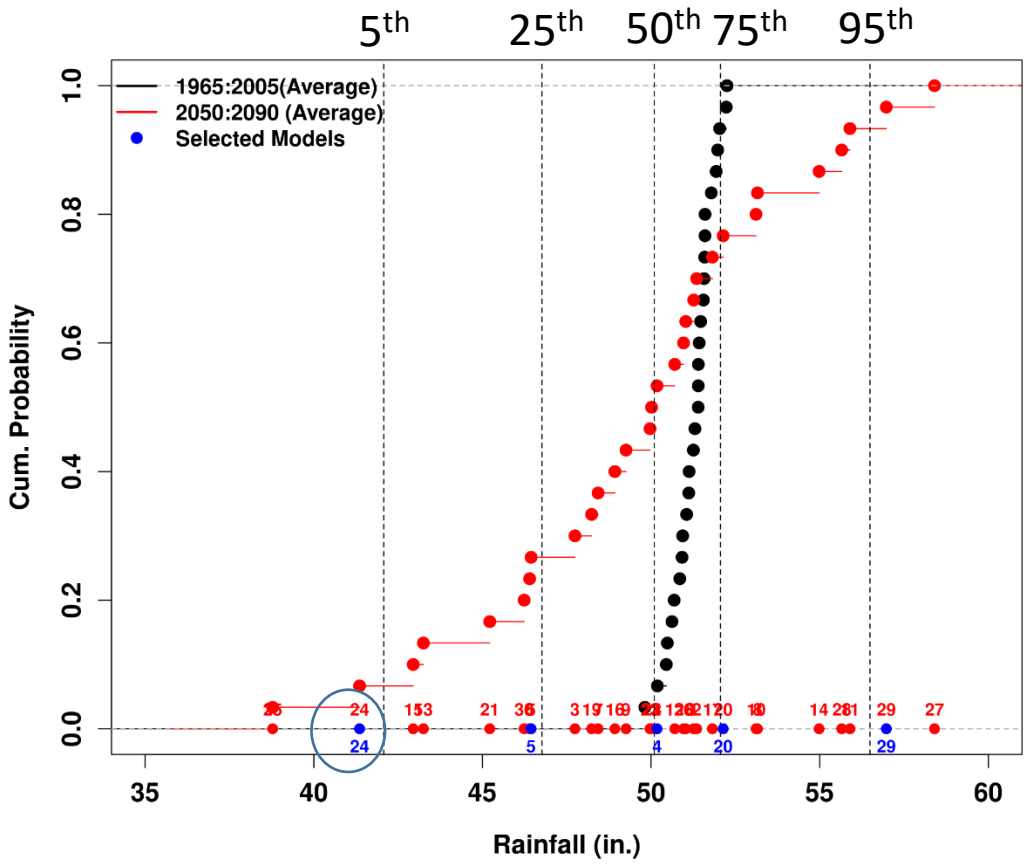
LOCA

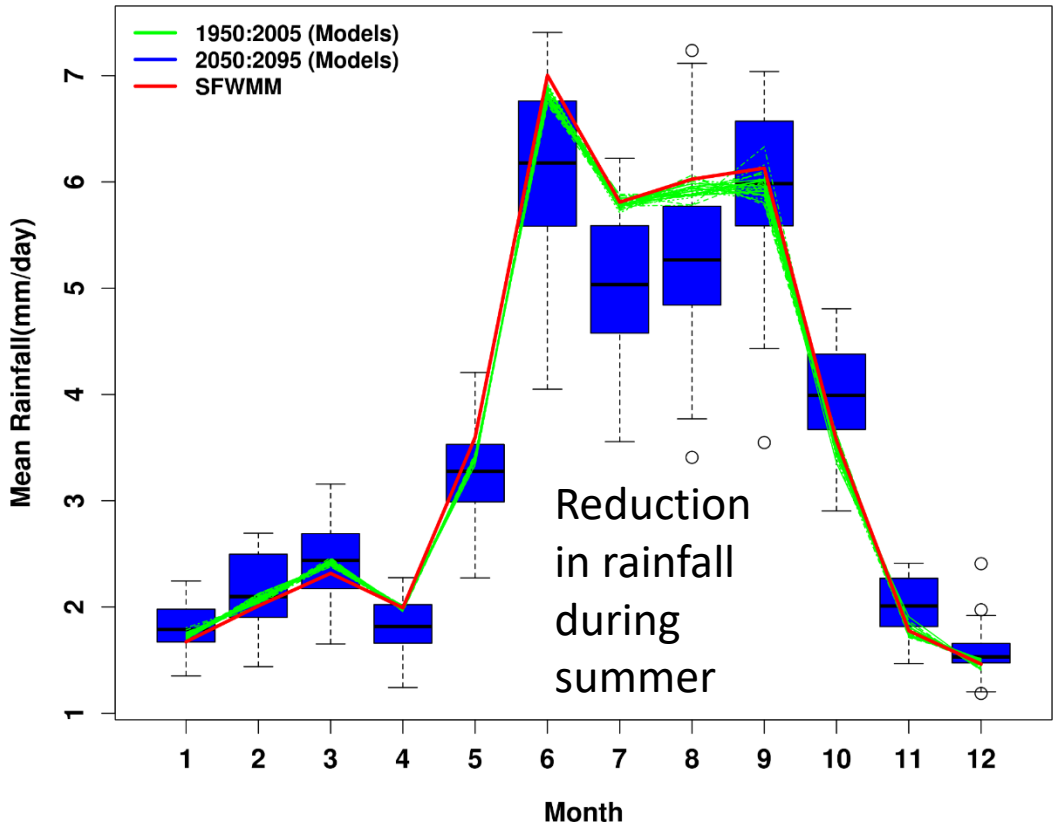


MACA



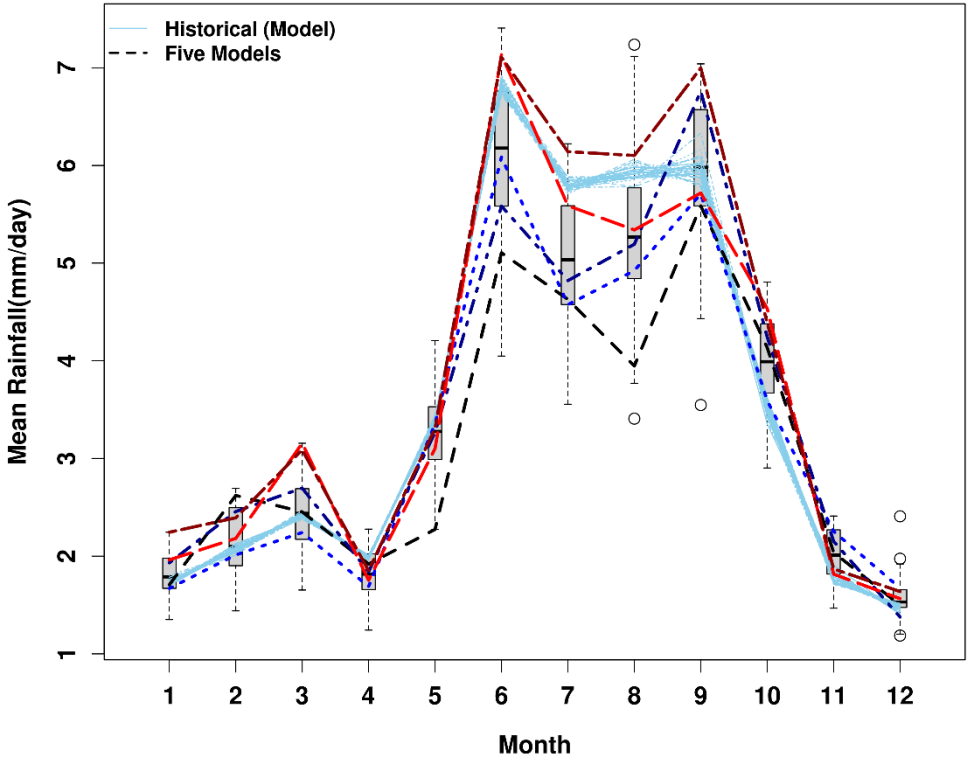
Model Selection – Seasonality (LOCA)





Five Models – and their seasonal patterns (LOCA)

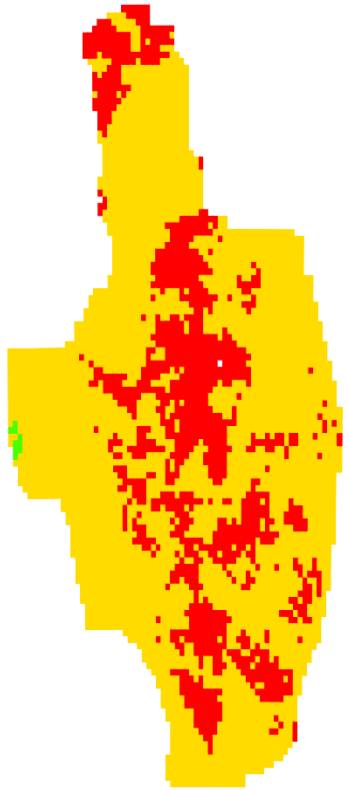
Scenario	Model #	Percentile	Average Rainfall (inches)	Model Name
1	24	5%	41.36	pr_MIROC-ESM_r1i1p1_rcp85_2006-2100
2	5	25%	46.44	pr_CCSM4_r6i1p1_rcp85_2006-2100
3	4	50%	50.18	pr_CanESM2_r1i1p1_rcp85_2006-2100
4	20	75%	52.14	pr_HadGEM2-CC_r1i1p1_rcp85_2006-2100
5	29	95%	56.97	pr_MRI-CGCM3_r1i1p1_rcp85_2006-2100

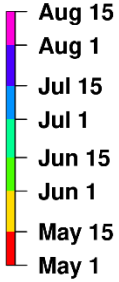


Wet Season Start Date (LOCA)

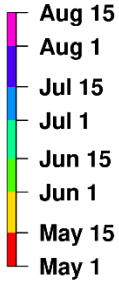
Base Period

Historical





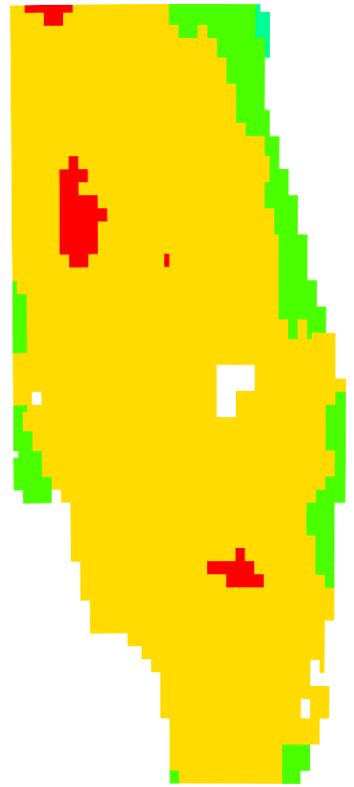
Models



Future

Historical (models)

Future



Concluding Remarks

- Best Models are not always consistent across metrics
- LOCA and MACA show similar results (more drier scenarios in the future)
- CORDEX showed a larger biases in the base period (preliminary observation – results are being finalized)
- Selected rainfall datasets may be used for “stress testing” in project planning
- A similar analysis was conducted for Temperature (to be included in the final report) and they may be used for computing future evapotranspiration