Evaluation of dynamically and statistically downscaled climate model results

for use with Tampa Bay Water's Integrated Hydrologic Modeling Tool

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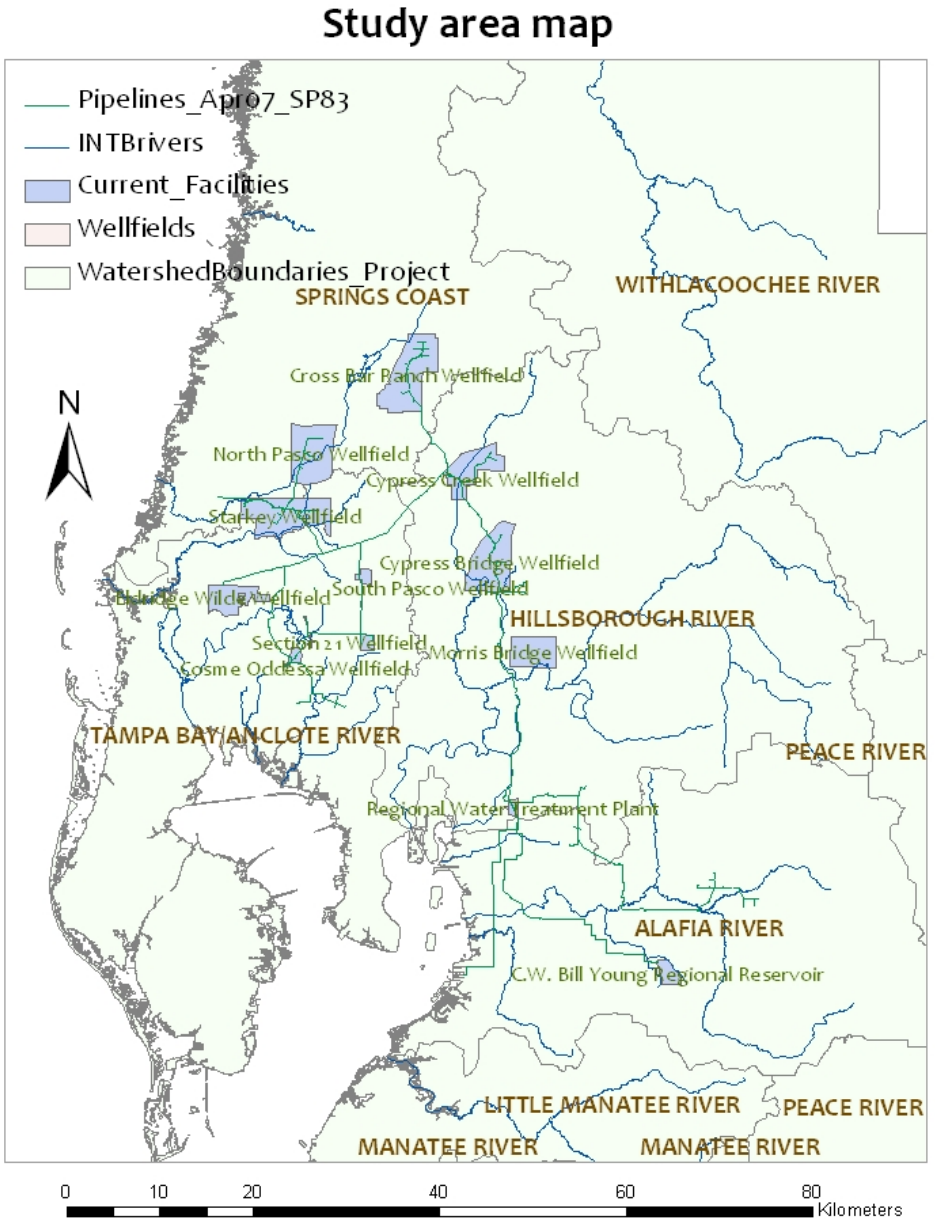
Project Goals

…. Evaluate the utility of using dynamically and statistically downscaled climate model output to drive hydrologic models in the Tampa Bay region. ..

…. Explore potential impacts of climate variability and climate change on water availability and water allocation decisions

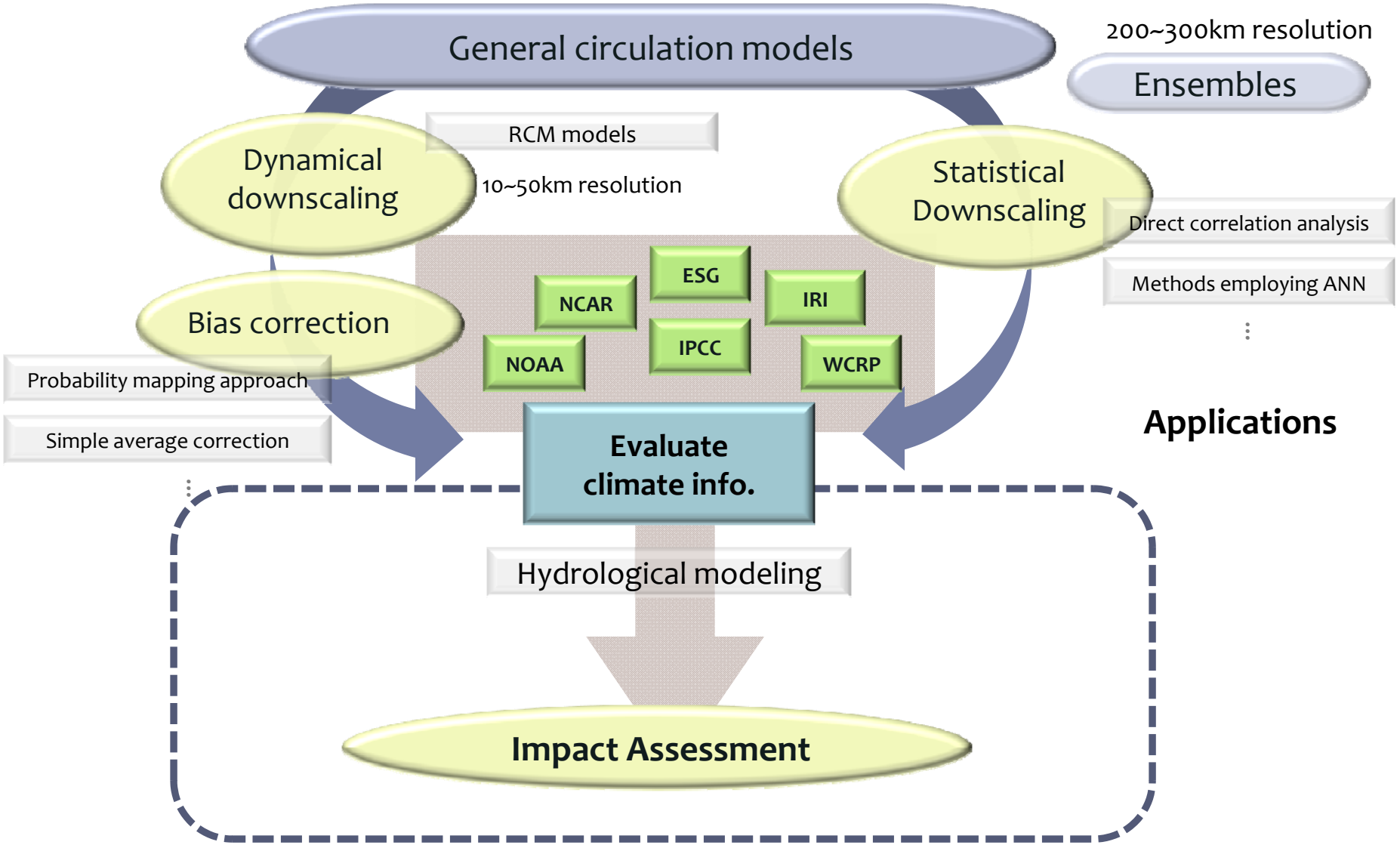


Project Partners

- Primary Partners
  - Tampa Bay Water
  - University of Florida Water Institute
  - Southeast Climate Consortium/ Florida Climate Institute

- Secondary Partners: Water Utilities Climate Alliance
  - Other Water Utilities: Seattle, Portland, San Francisco, New York City
  - Other Regional Integrated Sciences and Assessment Programs
    - Pacific Northwest Climate Decision Support Consortium — Oregon State University
    - California-Nevada Applications Project: Scripps Institution of Oceanography
    - Consortium on Climate Risk in the Urban Northeast — Columbia University

METHODS: BIG PICTURE



Available Downscaled Climate Modeling Results for the Tampa Bay Region

- **Bias corrected MM5** (1986-2008) **… completed**
  - Dynamically downscaled by UF using NCEP-NCAR reanalysis as Boundary Conditions
  - 3 spatial resolutions (3km, 9km, and 27km) over the Tampa Bay region
  - Bias corrected using 172 point and 12kmx12km gridded observations in the region

- **BCSD WCRP CMIP3** (1950-1999 & 2000-2099) **… results to be discussed today**
  - 16GCM predictions: bias corrected and statistically downscaled
  - Bias corrected data available at monthly timescale, 12km resolution
  - Raw data available at daily timescale, 12 km resolution
  - Available for download in NetCDF data format or ASCII text format

- **NARCCAP** (1971-2000 & 2041-2070) **… future**
  - 4GCM*6RCM combinations
  - Daily time scale, 50km resolution
  - Available for download in NetCDF data format (as completed)

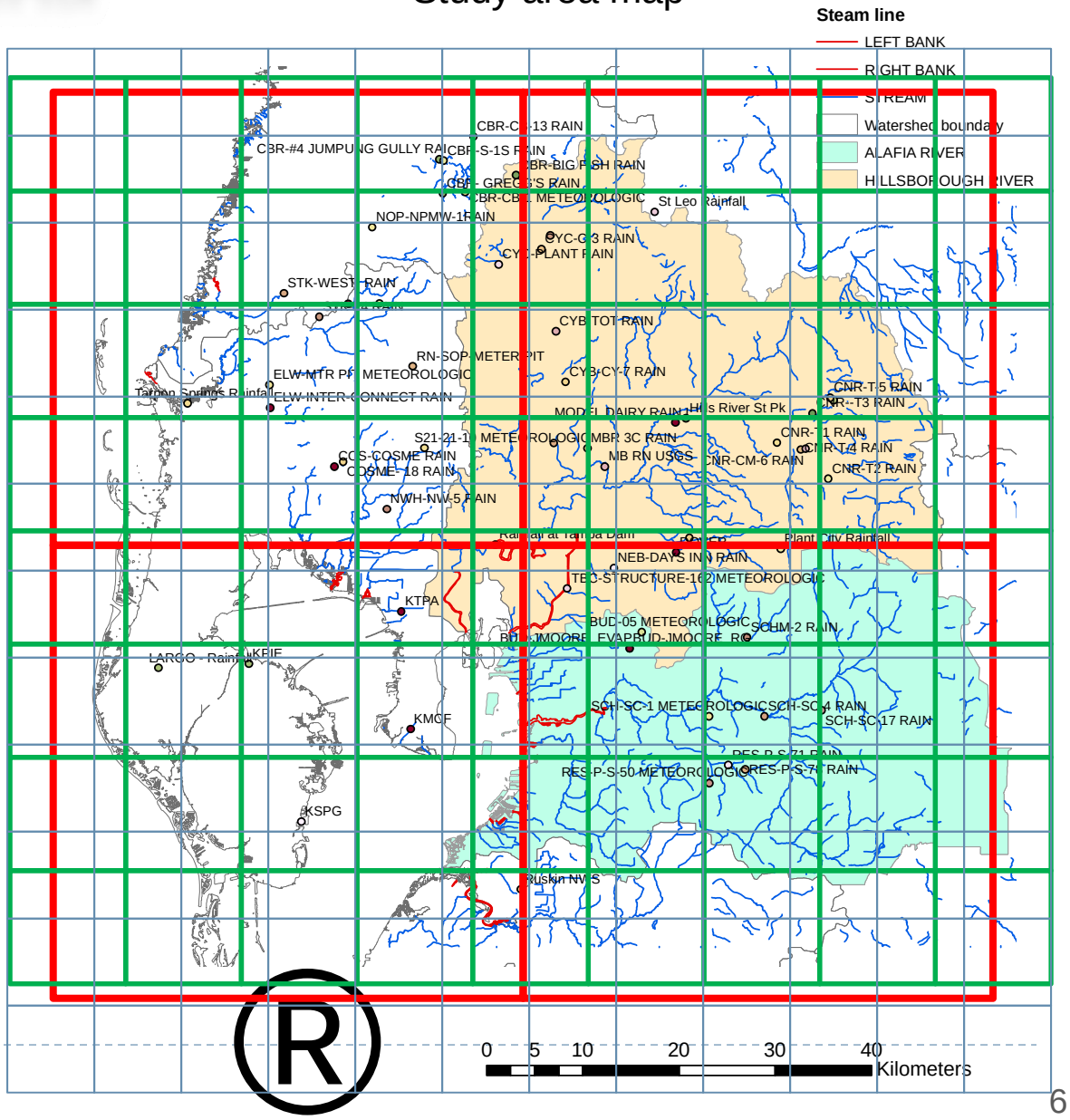
SPATIAL RESOLUTION

MM5
downscaled results
(9km× 9km)

BCSD CMIP3 data
(12km × 12km)

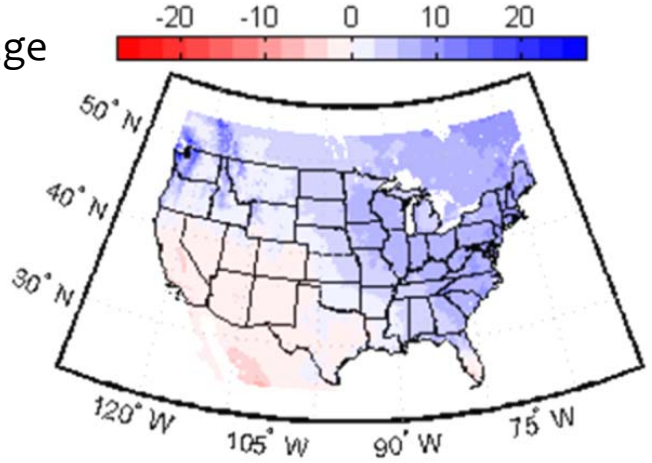
NNARCCAP data
(50km × 50km)

Study area map



WCRP CMIP3

Spatial Coverage



- 16 GCMs (1950~1999 & 2000~2099)
- 3 scenarios for future greenhouse gas emissions
- Bias correction
  - probability mapping approach
    - Wood et al. (2004)
- Statistical downscaling
  - 1/8° grid =12km resolution
    - Maurer, E.P. (2002).

RECLAMATION
Santa Clara University
CLIMATE CENTRAL

Bias Corrected and Downscaled WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer (IE) 6., IE 7.*, and Firefox 2.*.*
Requires JavaScript to be enabled.

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Click on the sub-tabs below for information on how this archive relates the WCRP CMIP3 effort, the scope of archive contents, dataset attributes (e.g., variables, spatial-temporal coverage and resolution), and methodology used to convert WCRP CMIP3 projections into bias-corrected and spatially downscaled translations.

Background | Scope | Attributes | Methodology | References

Climate modeling groups have produced hundreds of simulations of past and future climates for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). The WCRP Working Group on Coupled Modelling helped to coordinate these activities through the CMIP3 effort (see Meehl et al. 2007) and worked to co-locate these simulations within a single archive, hosted by the Lawrence Livermore National Laboratory (LLNL) Program for Climate Model Diagnosis and Intercomparison (PCMDI). The conversion of all simulation results to a common data format has made probabilistic, multi-model projections and impacts assessments practical.

One issue not solved by the AR4 archive development is that the spatial scale of climate model output is too coarse for most impacts studies and decision-support purposes. Multiple downscaling approaches exist for deriving regional climate from coarse resolution model output (Giorgi et al. 2001, Wilby and Wigley 1997). One method of statistically downscaling spatially continuous fields, developed for hydrologic impact studies (Wood et al. 2004), is computationally efficient enough to be easily applied to ensembles of projections (e.g., Maurer 2007), and has compared favorably to other downscaling techniques. Downscaled data developed by this method have been used in the study of potential climate change impacts on various resource systems, including watershed hydrology, reservoir systems, wine grape cultivation, habitat migration, and air quality.

Motivated by a common interest to establish data access for climate change impacts analysts, the U.S. Department of Interior's Bureau of Reclamation (Research and Development Office) and LLNL, through support from the U.S. Department of Energy's National Energy Technology Laboratory and the U.S. Army Corps of Engineers Institute for Water Resources, have teamed with Reclamation's Technical Service Center, Santa Clara University Civil Engineering Department, Climate Central, and The Institute for Research on Climate Change and its Societal Impacts to develop this public-access archive. Archive content and services are hosted by LLNL Green Data Oasis. Downscaling was performed using the technique described in (Wood et al. 2004, Maurer 2007) and summarized on the "Methodology" tab here. Users are offered "Standard" and "Custom" data-retrieval options, along with retrieval tutorials and data analysis tools. The "Custom" data-retrieval option permits the user to select subsets of projection data corresponding to particular climate models, emissions pathways, time periods, projected variables, and/or geographical areas.

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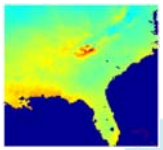
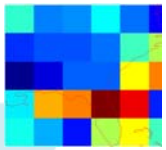
Privacy and Legal Notice Comments/Questions

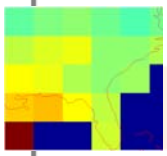
BCSD CMIP3 (Daily downscaling method)



Observationally based daily gridded dataset: spatial resolution of 1/8° (~12 km)



GCM's daily simulation of 20th century climate : spatial resolution of 2.8°



Aggregate to 2° spatial resolution

Compute factor values at each 2° grid point in the domain
Factor= 2° GCM/aggregated 2° monthly mean

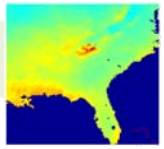
2° GCM factor

Interpolate the 2° GCM factor values to 1/8° resolution using a modified inverse-distance-squared interpolation

Multiply 1/8° GCM factors by observed 1/8° observed mean

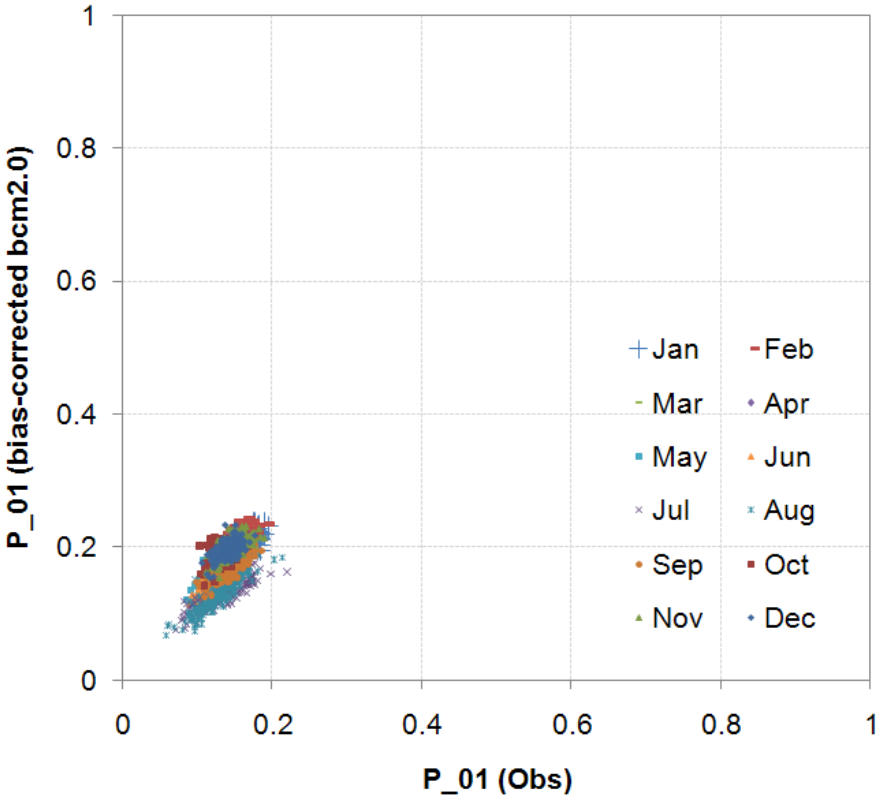
calculate given month's 1950-1999 mean from the observational dataset (2° resolution)

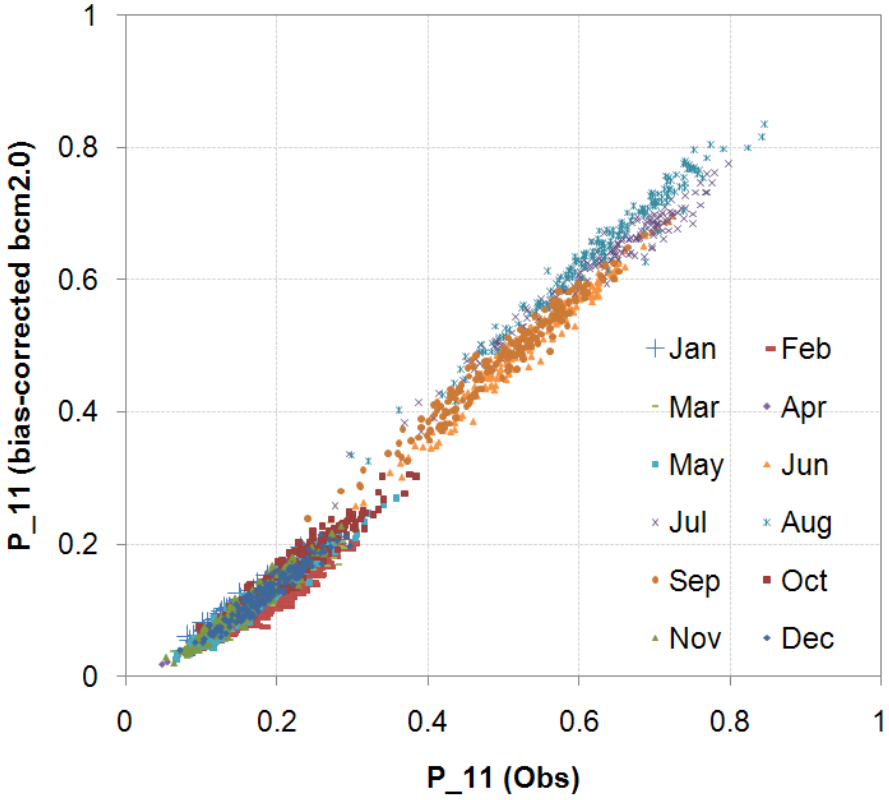
Bias correction: CDF construction & matching



Bias corrected and spatially downscaled 1/8°prediction

RESULTS: CMIP3 vs Observed Transition Probabilities

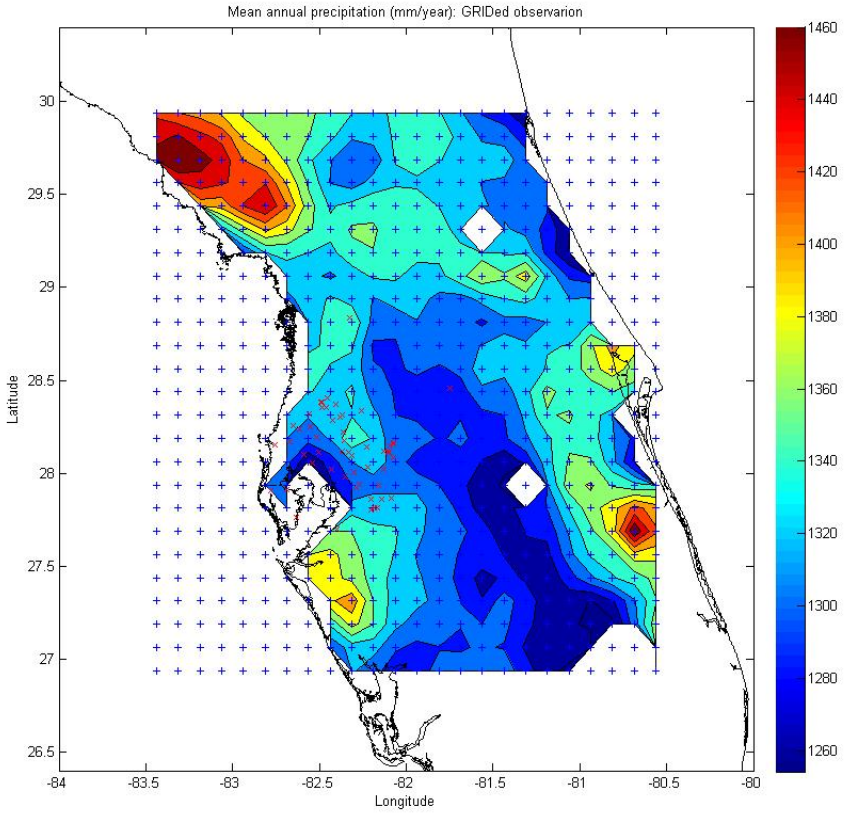




RESULTS: Mean Annual Precipitation (1961-1999)

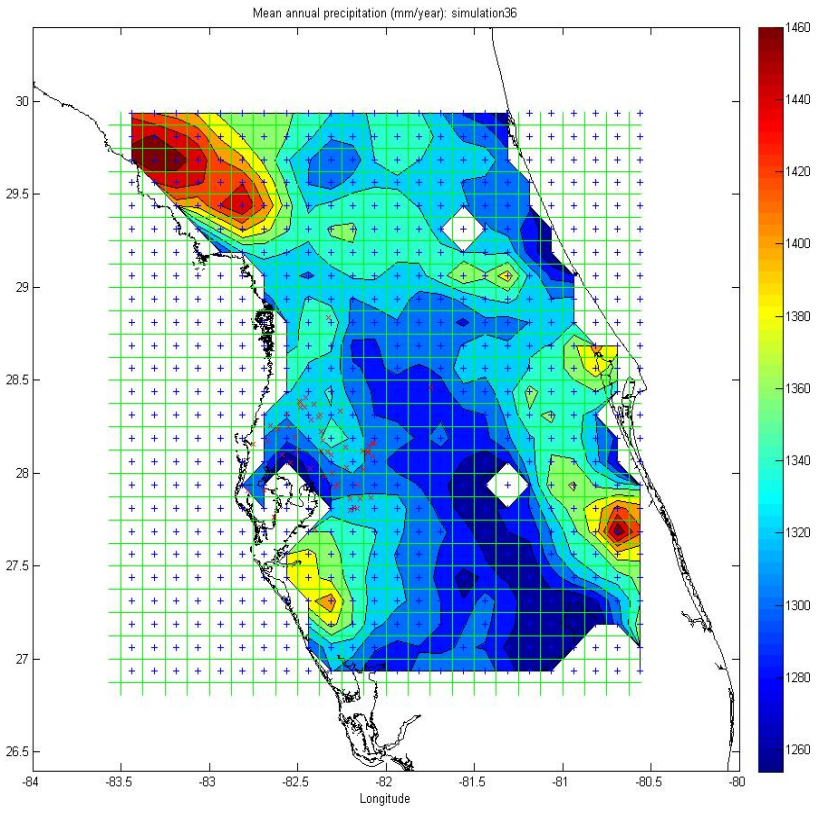
Gridded observation

1260~1460 mm



BCSD CMIP3 BCM2.0

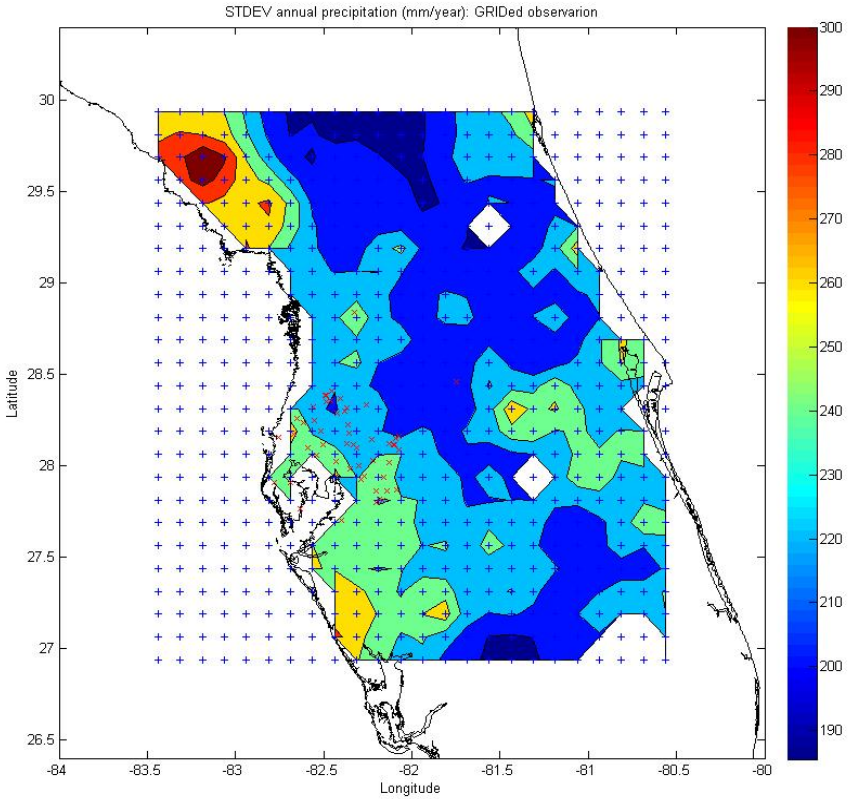
1260~1460 mm



RESULTS: Std Dev Annual Precipitation (1961-1999)

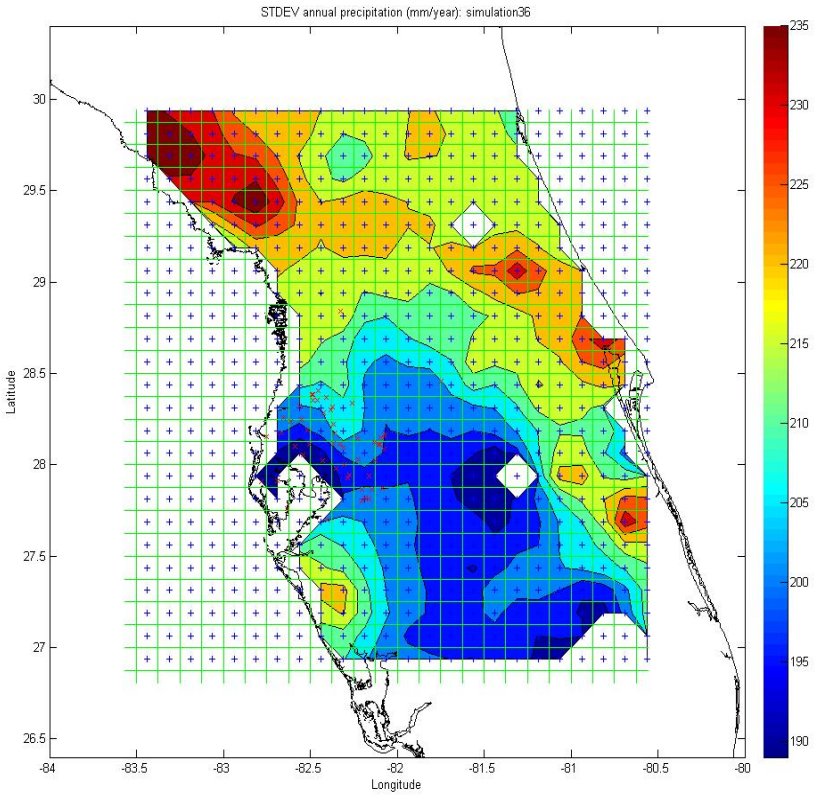
Gridded observation

190~300 mm

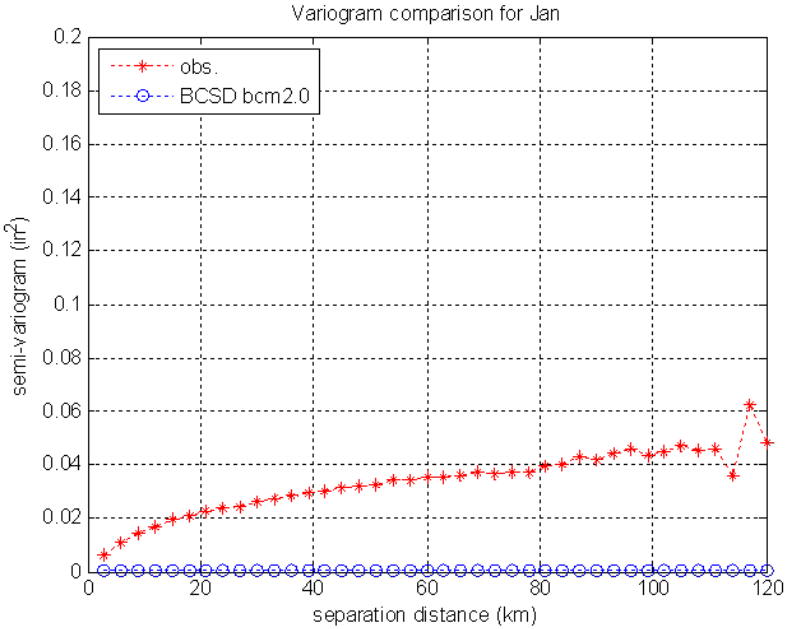


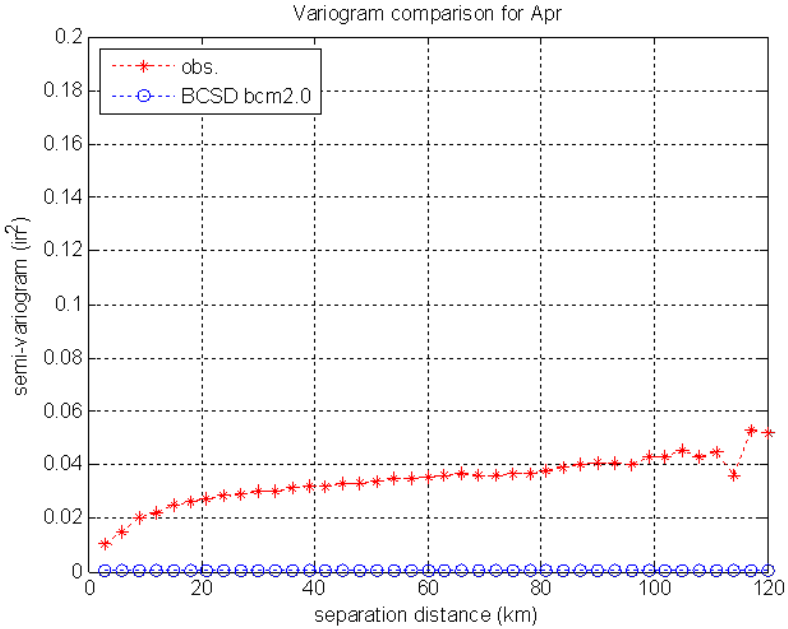
BCSD CMIP3 BCM2.0

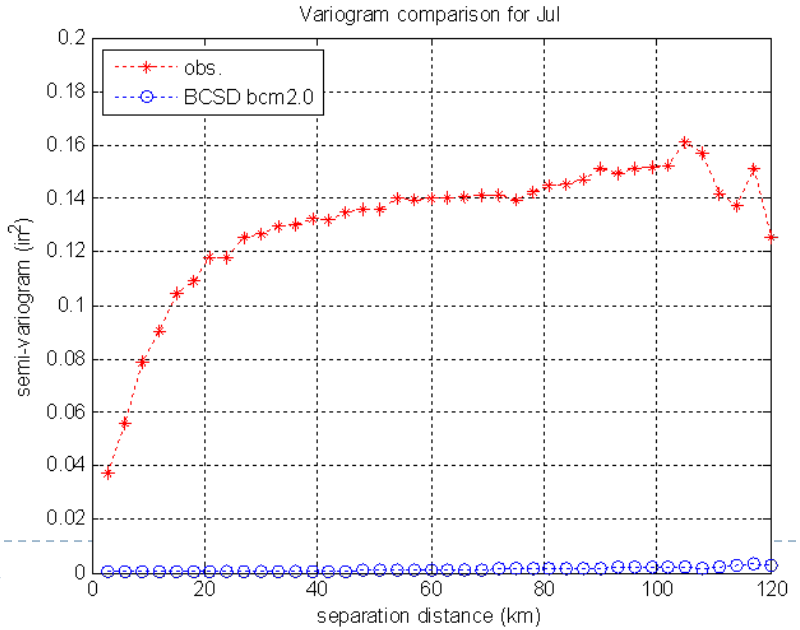
190~230 mm

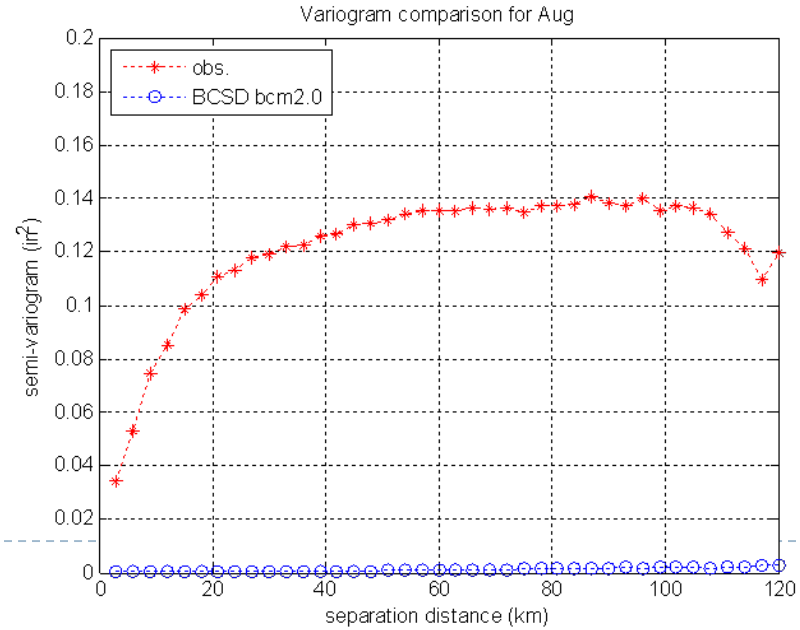


RESULTS: Variogram Comparison

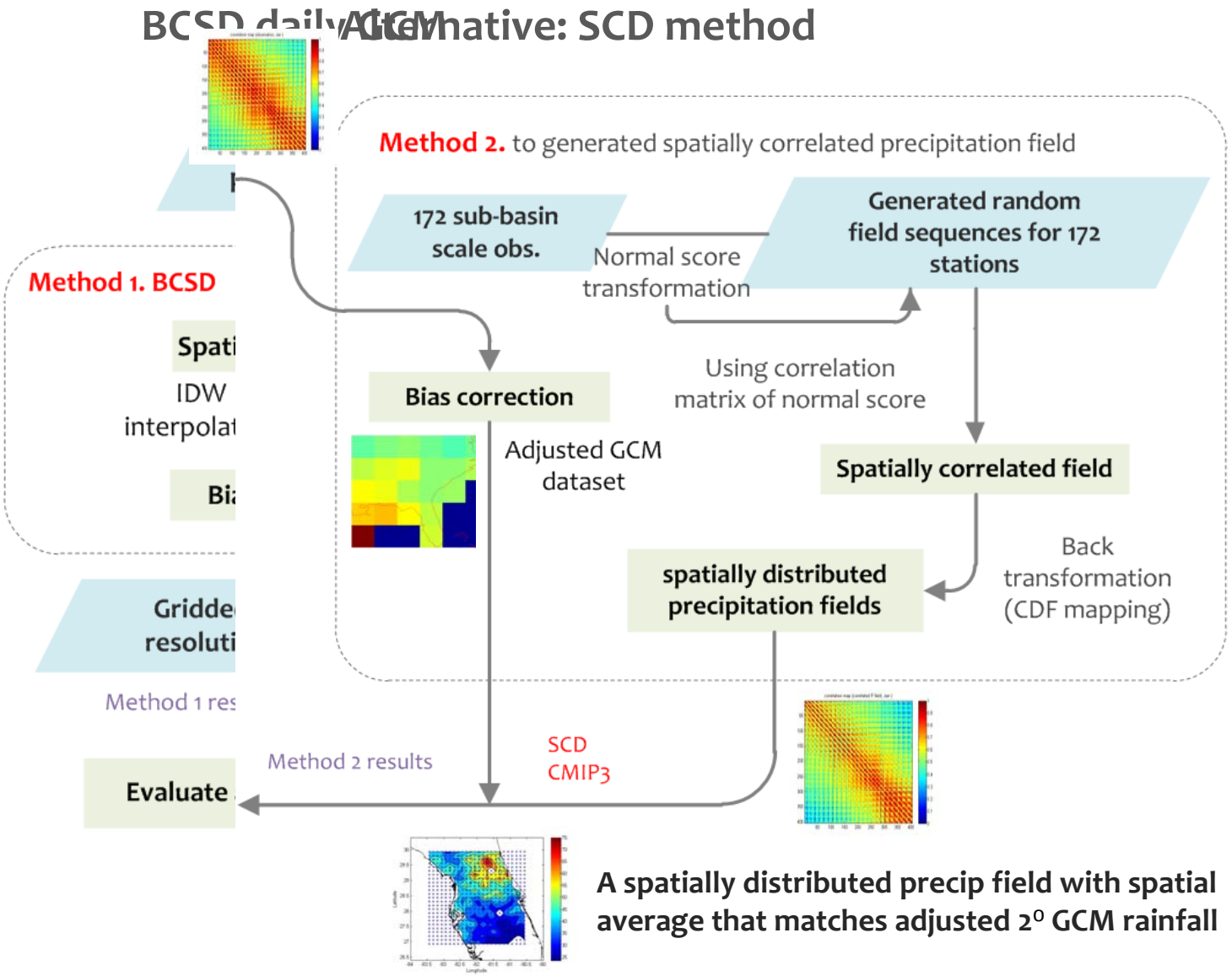






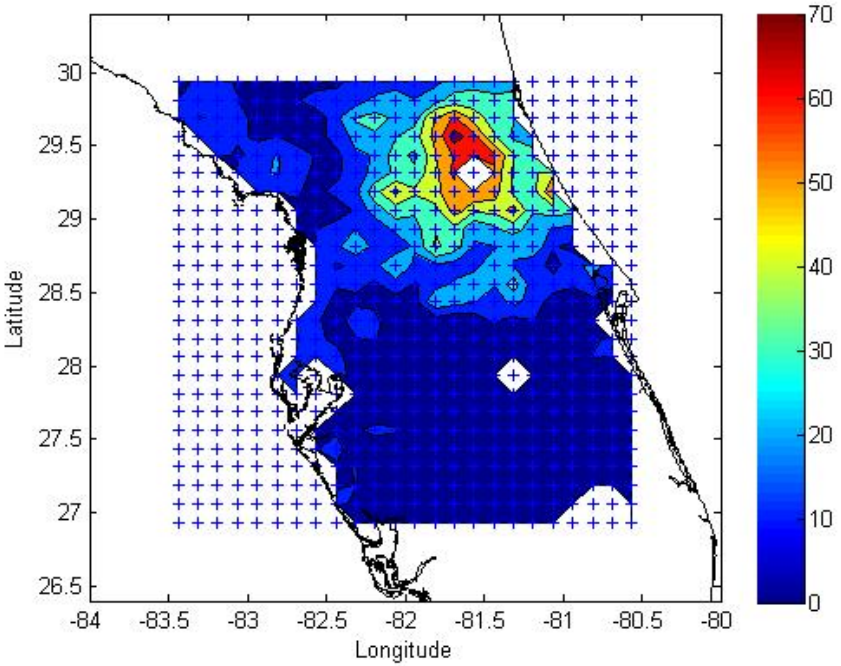


Alternative Method: Spatially Correlated Disaggregation

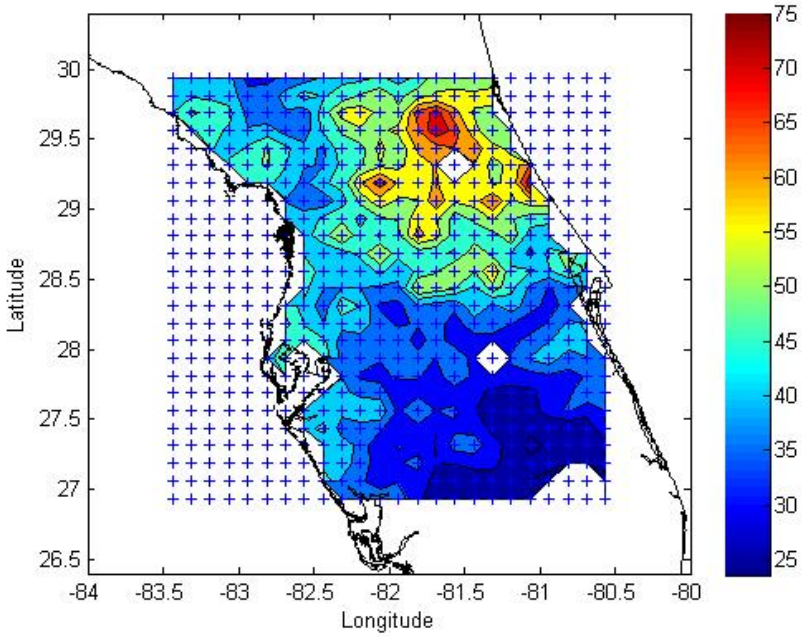


A spatially distributed precip field with spatial average that matches adjusted 2⁰ GCM rainfall

RESULTS: Example of spatial distribution

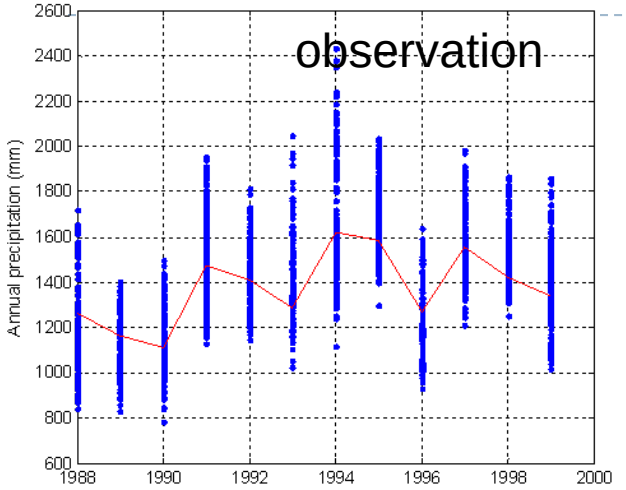


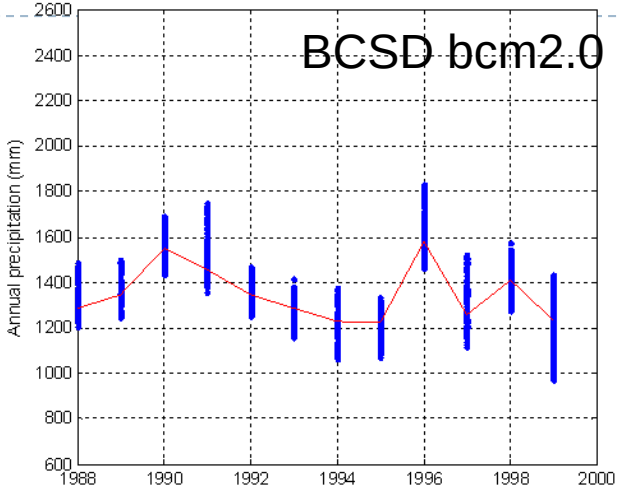
Spatial distribution of **BCSD CMIP3** rainfall field

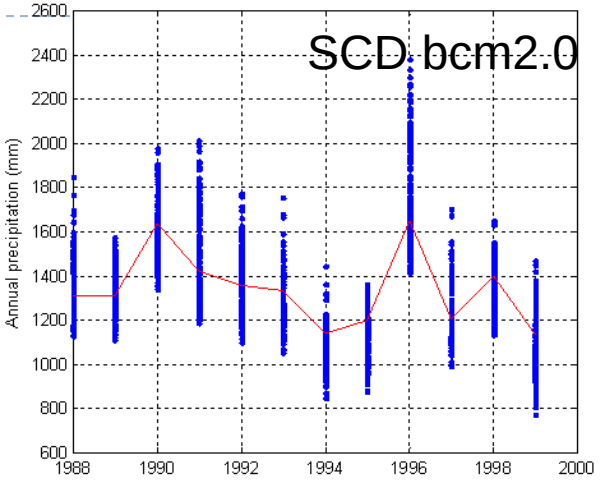


Spatial distribution of CMIP3 rainfall field disaggregated with **SCD** method

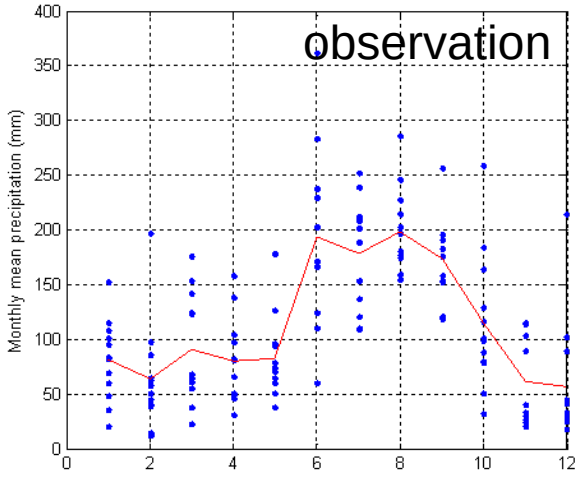
Results: Annual total precipitation

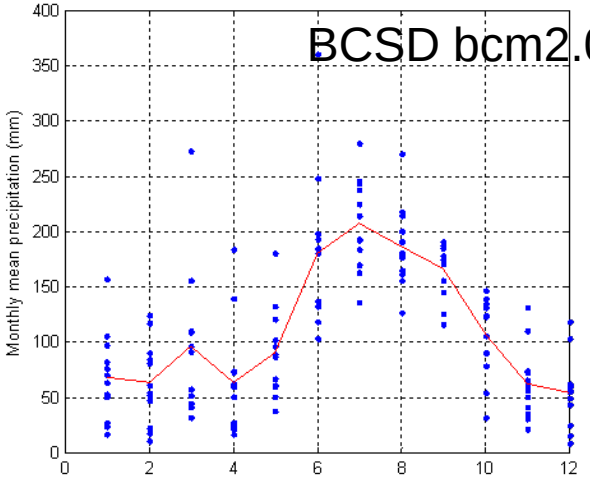


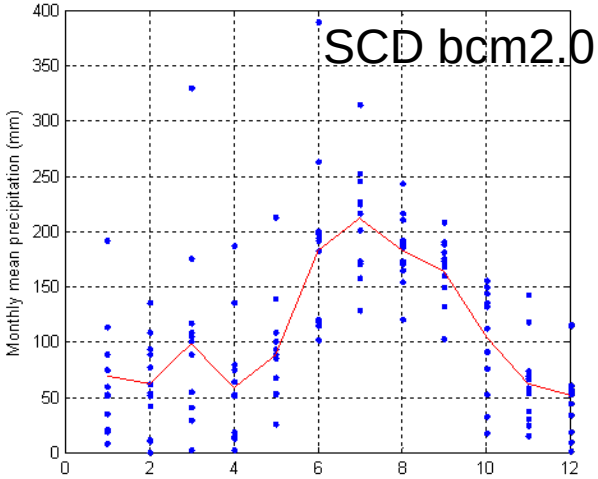




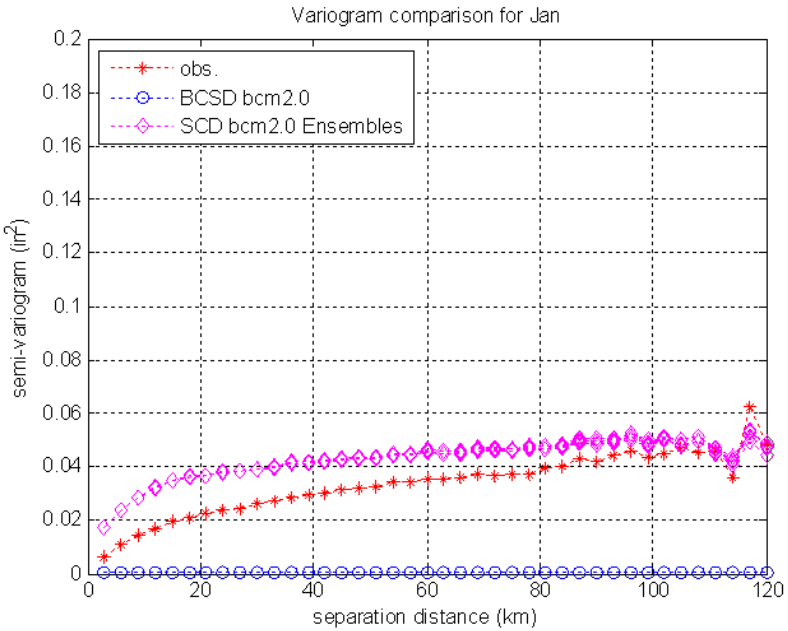
Results: Monthly mean precipitation

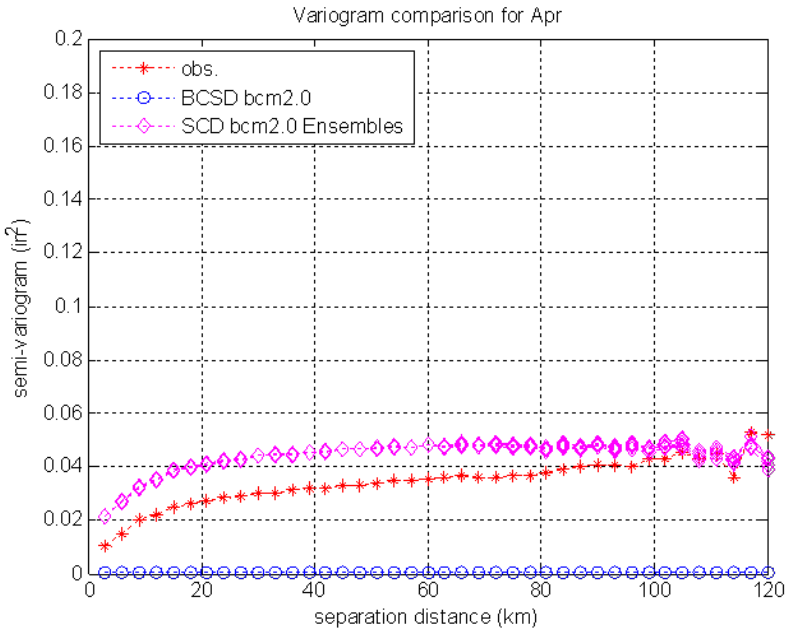


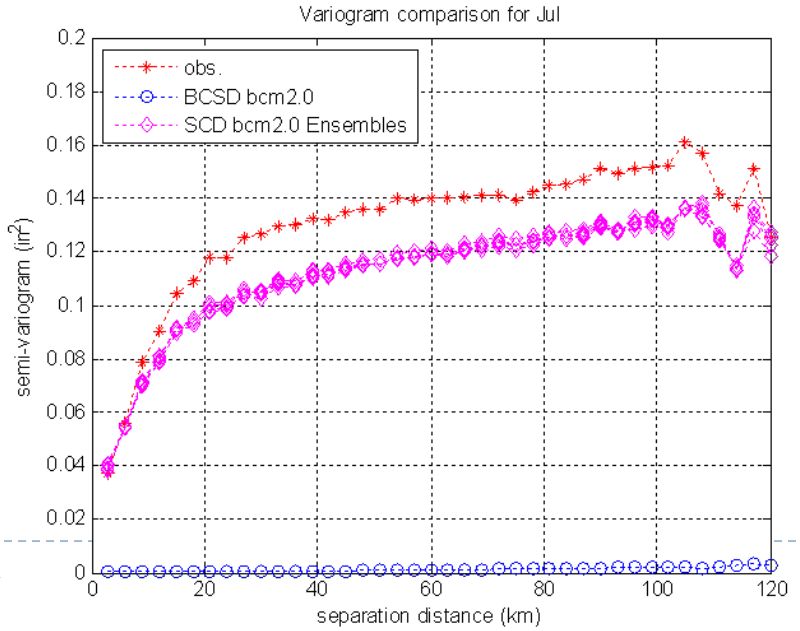


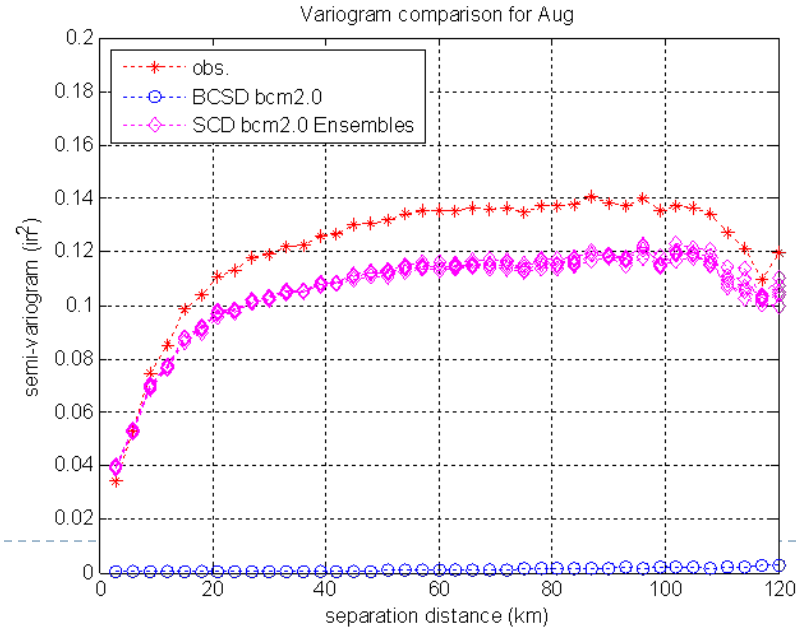


Results: Variogram Comparison







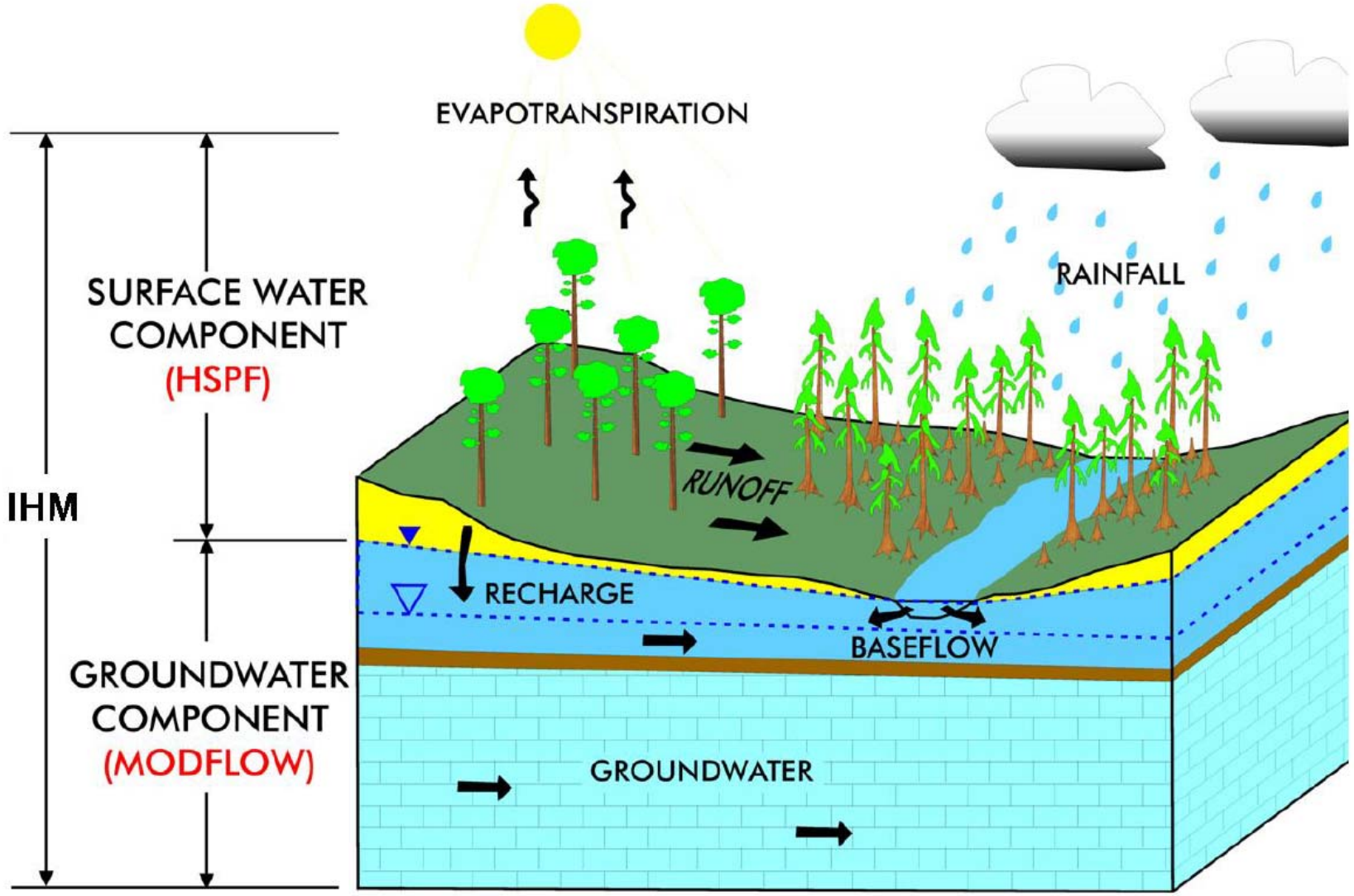


Lessons Learned: Precipitation Analysis

- BCSD
  - Reproduced daily transition probabilities and mean climatology
  - Underestimated interannual variability in annual rainfall
  - Underestimated spatial variance and overestimated spatial correlation of precipitation
- Alternative spatial correlated disaggregation (SCD) method
  - Improved interannual variability in annual rainfall
  - Improved spatial variance and spatial correlation structure

IHM simulation results

Conceptual View of HSPF & MODFLOW within IHM



The overall goals are to…

- Evaluate hydrologic importance of accurately representing the spatiotemporal characteristics of precipitation fields using Tampa Bay Water's Integrated Hydrologic Model (IHM)
- Evaluate the ability of bias-corrected and spatially-disaggregated GCM retrospective simulations (CMIP3 and NARCAAP) to reproduce observed hydrologic behavior using IHM
- Evaluate changes in hydrologic behavior that result from driving the IHM with bias-corrected and spatially disaggregated GCM future predictions

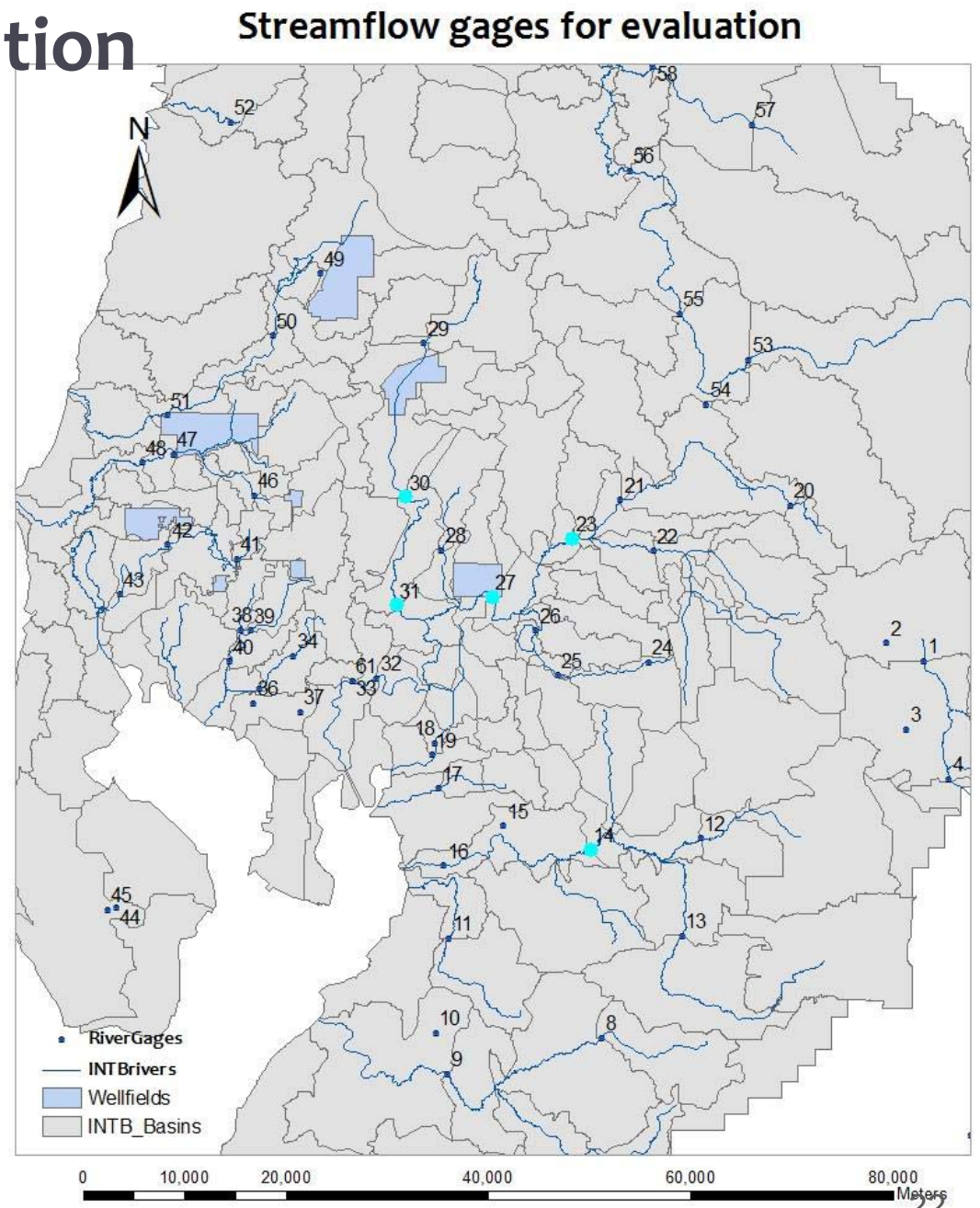
IHM modeling Plans

		Precipitation	Temperature	Production	Diversion	Irrigation	Status
Task 1	1	Obs. (1986-2008)	Obs.	Obs.	Obs.	Obs.	complete
	2	MM5 (1986-2008)	MM5	Obs.	Obs.	Obs.	complete
Task 2	**3**	**BCSD_GCM (1950-1999)**	**BCSD_GCM**	**Obs.**	**Obs.**	**Obs.**	**4 of 16 GCMs complete**
	4	BCSD_GCM (2000-2009)	BCSD_GCM	Scenario	Scenario	Scenario	Near term
Task 3	5	NARCCAP (1950-1999)	NARCCAP	Obs.	Obs.	Obs.	future
	6	NARCCAP (2000-2009)	NARCCAP	Scenario	Scenario	Scenario	future

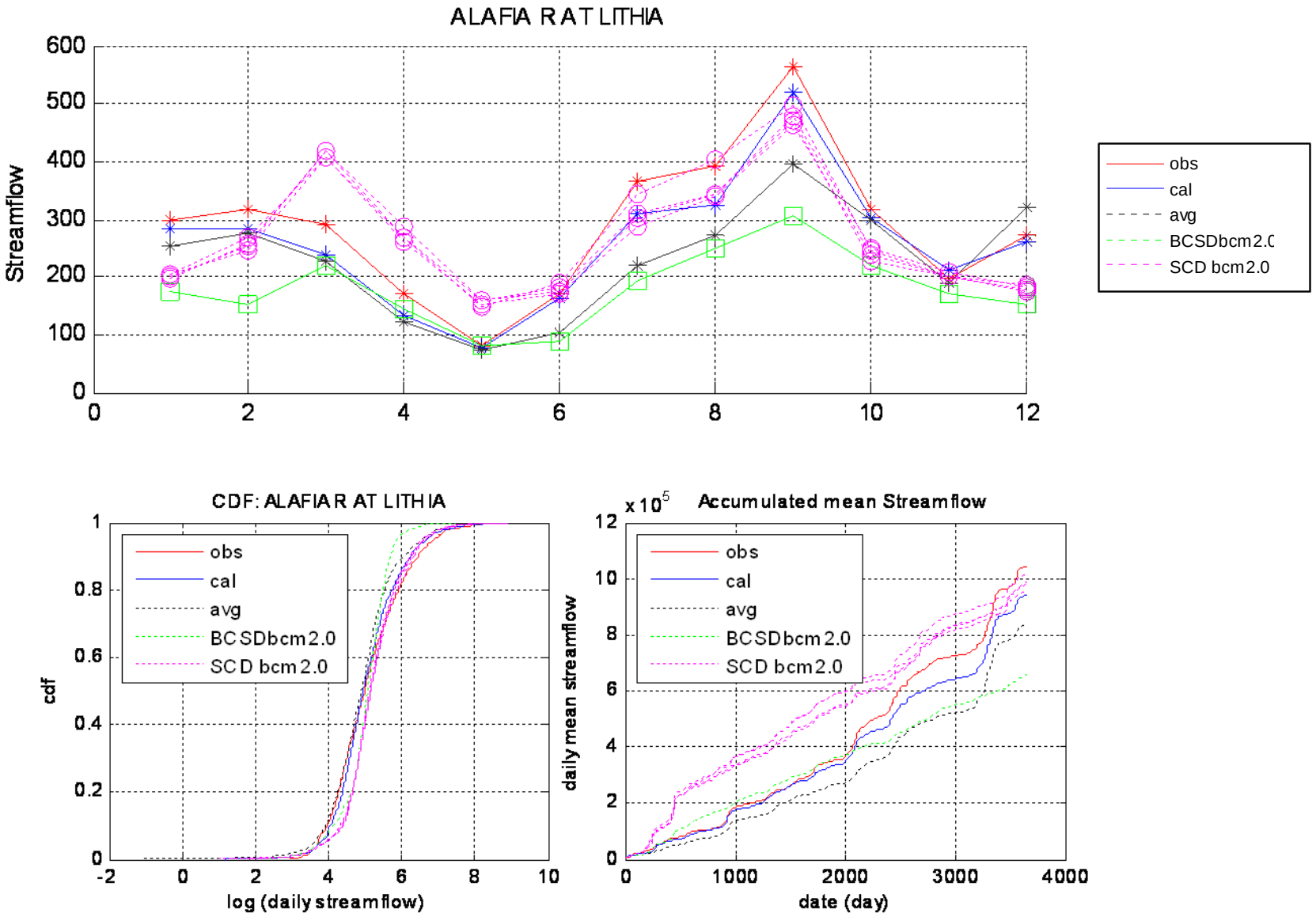
1. Streamflow evaluation

- Target stations

1. Alafia at Lithia (14)
2. Cypress Creek at Worthington (30)
3. Hillsborough river at Zephyrhills (23)
4. Anclote river near Elfers



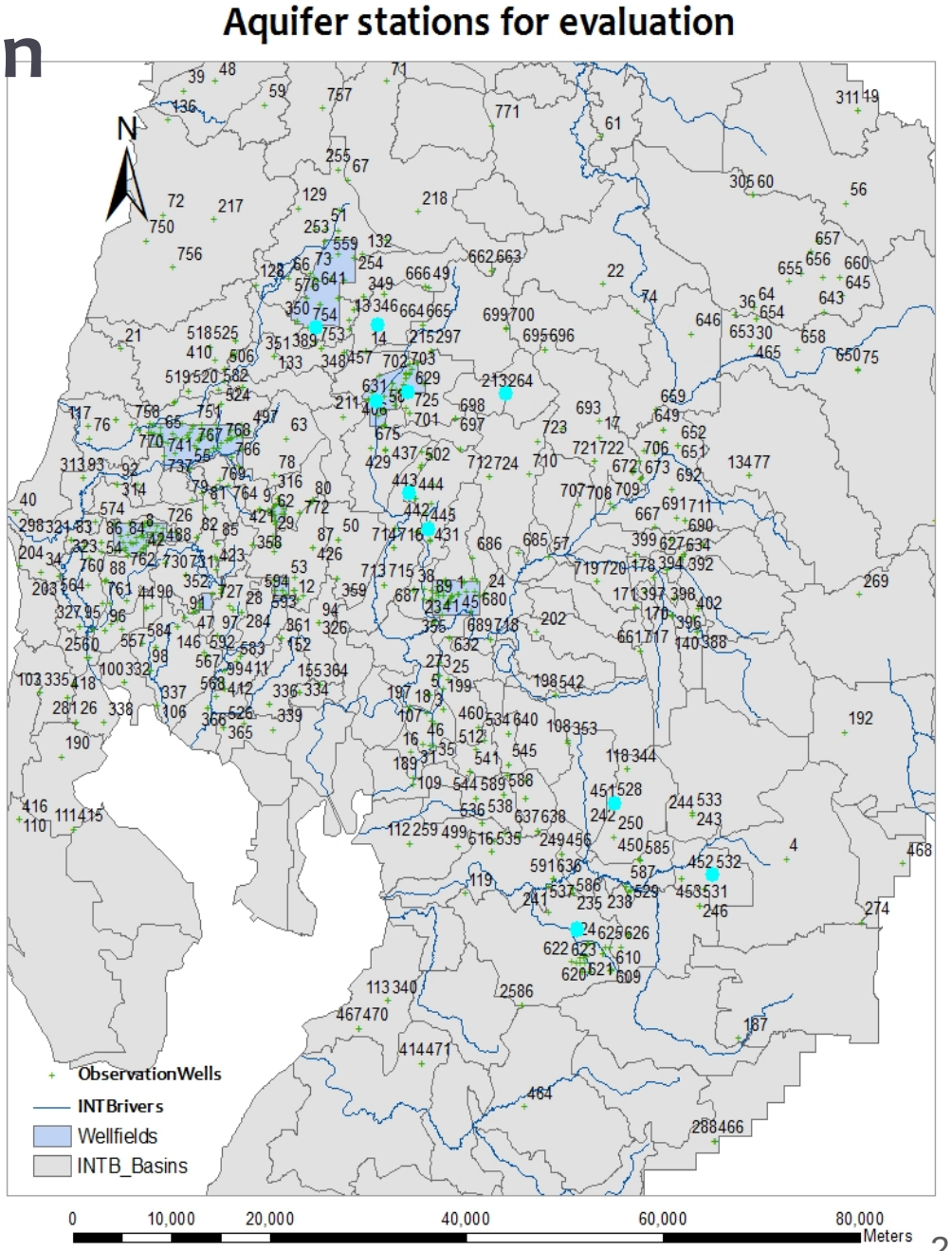
Results for Alafia at Lithia



2. Aquifer evaluation

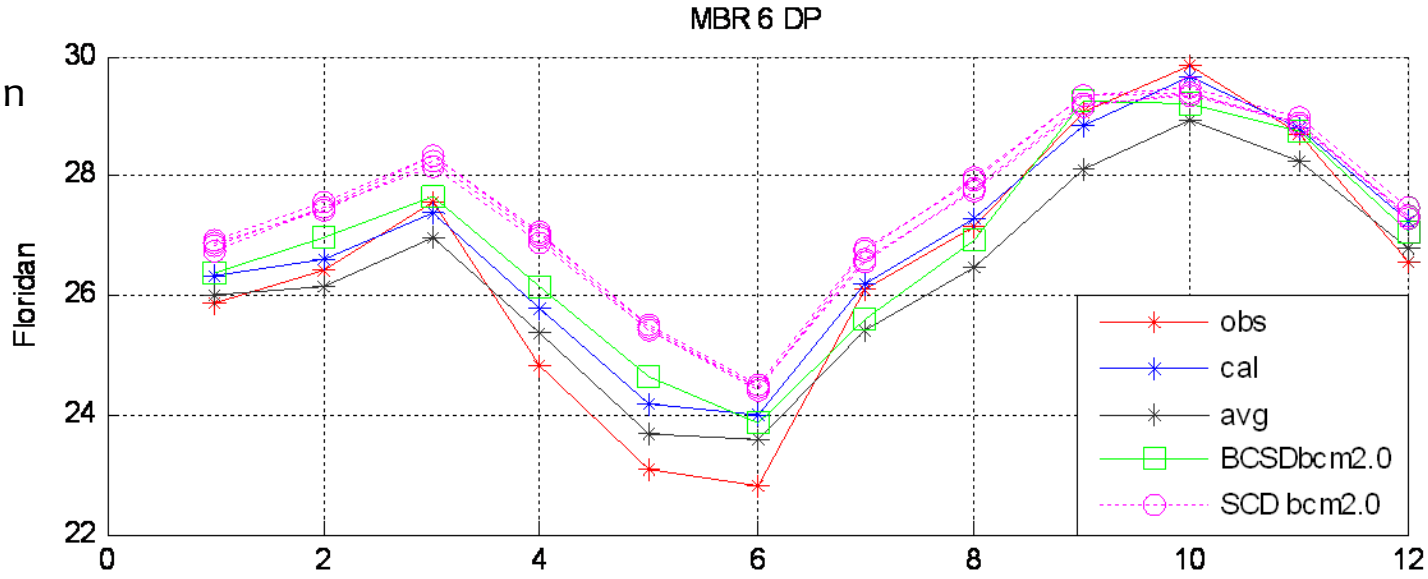
- Target stations

4 pairs of groundwater level stations for Floridan and Surficial aquifer near each of four TBW wellfields. Both unconfined and semi-confined Floridan conditions are represented.

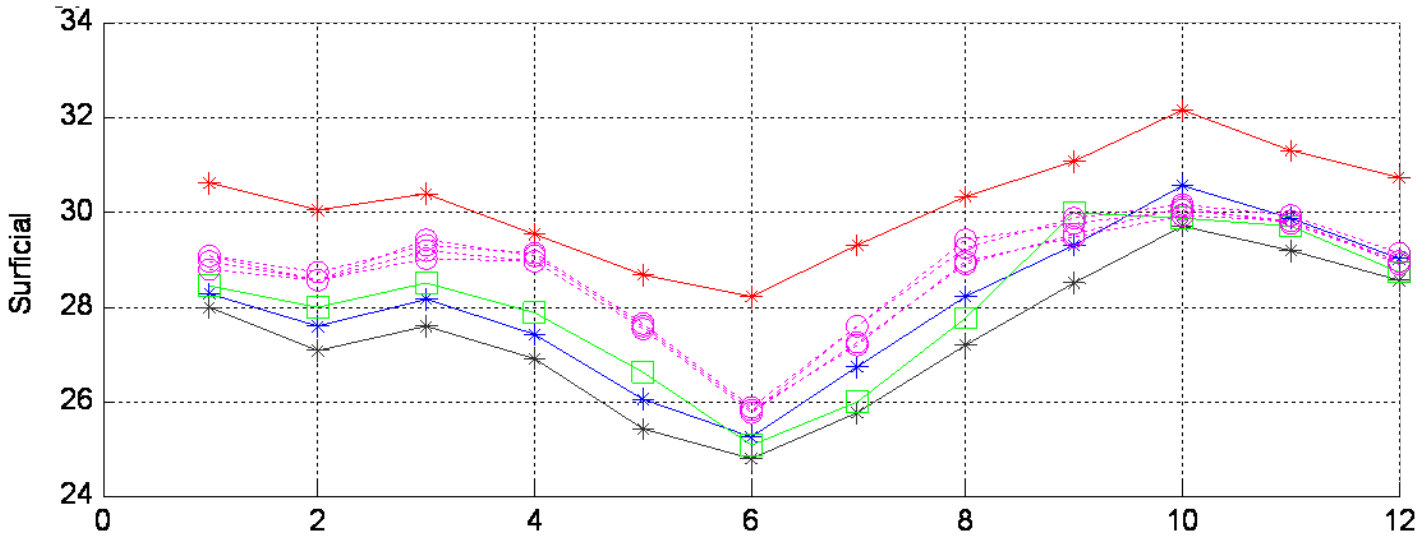


Comparison of the monthly mean groundwater level

1. Floridan



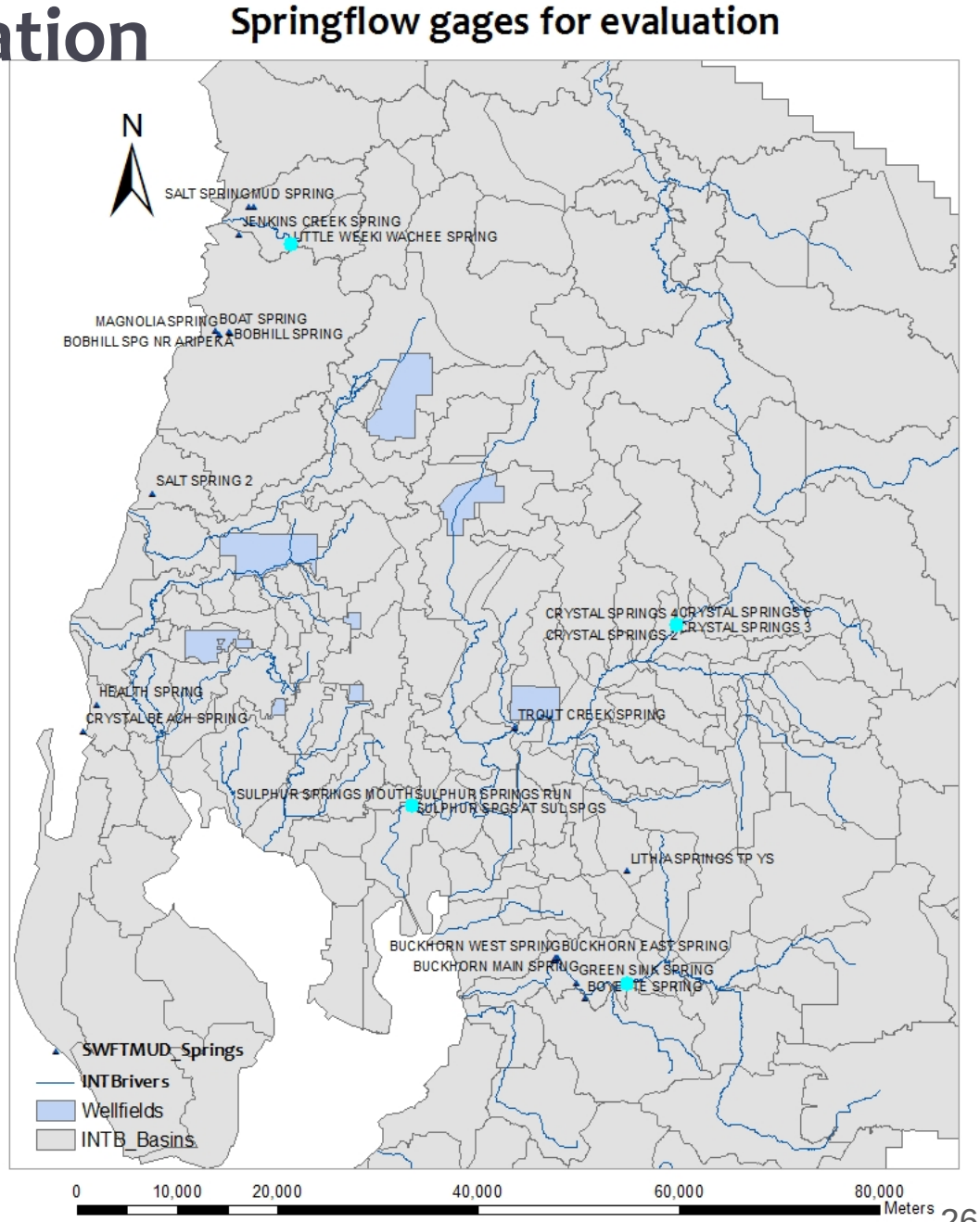
2. Surficial



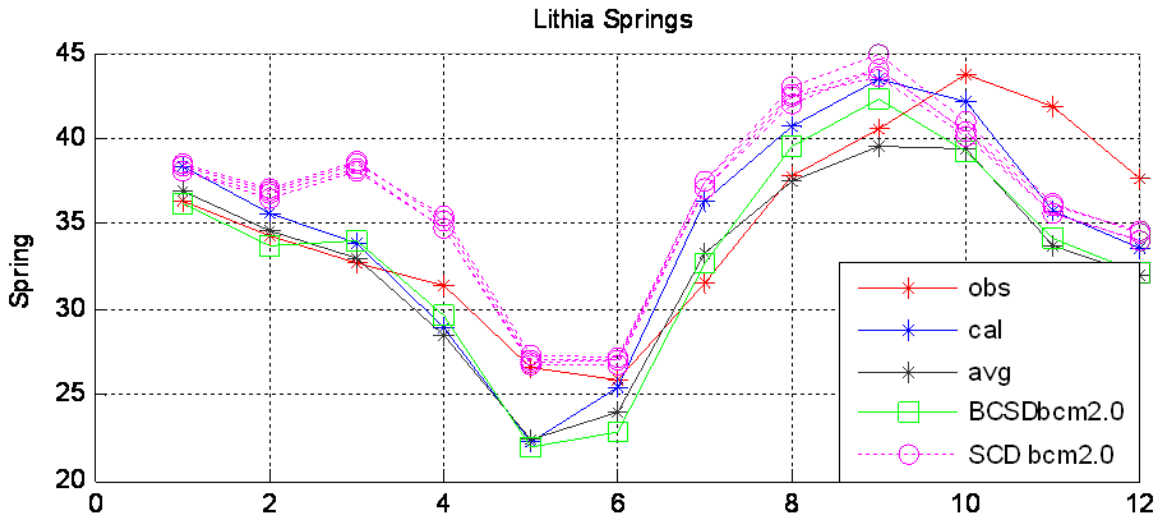
3. Springflow evaluation

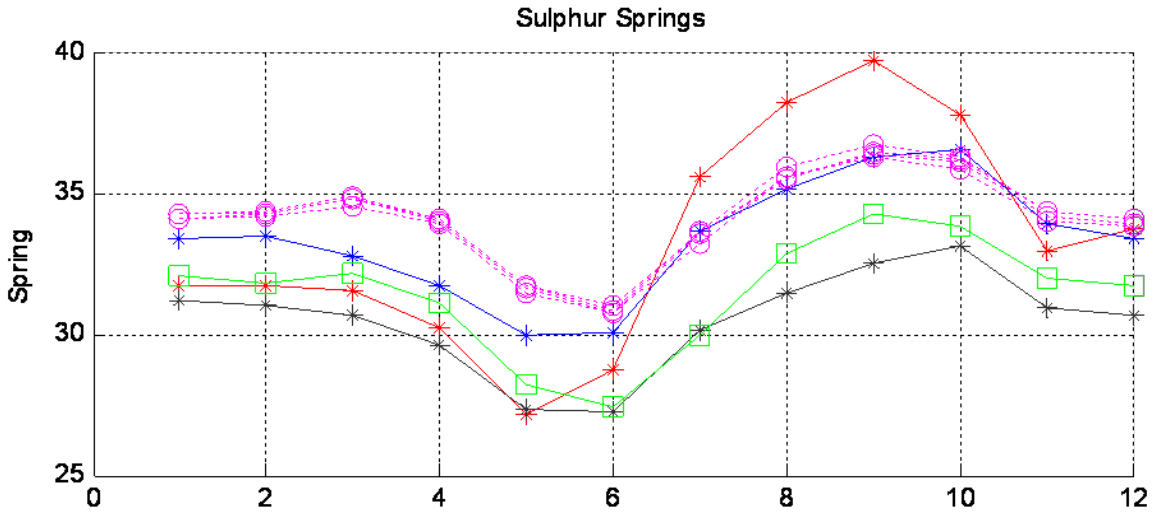
- Target stations

1. Crystal springs
2. Weeki Wachee springs
3. Sulphur springs
4. Lithia springs



Springflow simulation results for two stations





Lessons learned:

- The calibrated IHM model adequately reproduces observed streamflow, springflow, ground water level, and water balance over the domain for '89-'97.
- SCD BCM2.0 results generally reproduce observed hydrologic behavior (i.e. average monthly streamflow, springflow and groundwater levels and accumulated streamflow) compared to observed and calibrated IHM results.
- Due to low spatial variability of precipitation, IHM simulations with spatially averaged precipitation and BCSD BCM2.0 results tend to
  - Predict higher average annual ET compared to calibrated and SCD BCM2.0 results
  - Predict lower streamflow, springflow compared to calibrated and SCD results.
  - Predict significantly lower total surface water availability (i.e., low accumulated streamflow predicted over simulation period)

Relevance to CWIG community:

- Nationally available downscaled products (CMIP3 and NARCAAP) may reproduce long-term climatology but not necessarily small-scale spatial correlation structure and spatiotemporal distribution of precipitation events in Florida.
- Low intensity, low spatial variability precipitation scenarios may overpredict ET and recharge and underpredict streamflow, leading to errors in surface and groundwater availability estimates for Florida
- Geostatistically based as well as historical analog disaggregation methods can be used to improve small-scale spatiotemporal characteristics of nationally available GCM products at least for retrospective simulations
- High resolution (3-10km) dynamically downscaled results with high fidelity climate physics (ie. CLARReS10) should also improve the small-scale spatiotemporal distribution of precipitation

Questions?