Joint Variable Spatial Downscaling

A New Statistical Downscaling Approach

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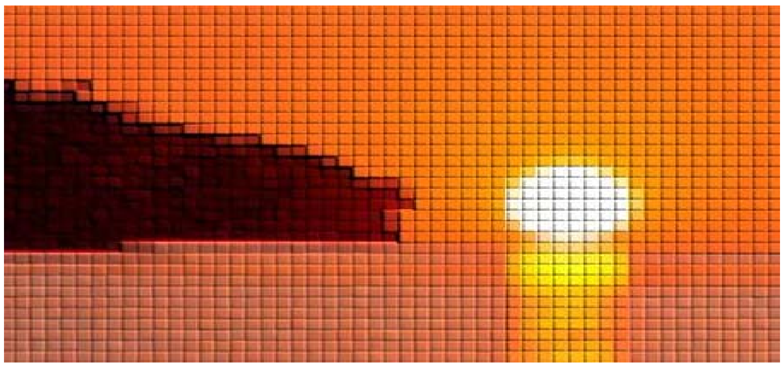
Everglades Workshop, Florida, 29 March 2012



- Downscaling Methods
- Comparison of BCSD and JVSD
- Southeast Climate Assessment
- Assessing Change
- Summary

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Statistical Downscaling Methods
Existing Methods

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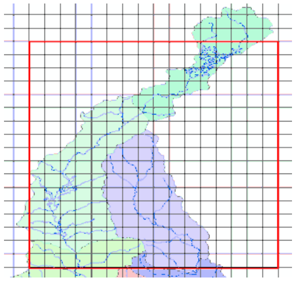
- Downscaling methods are based on relationships between coarse and high resolution historical data, and between observed and simulated variables;

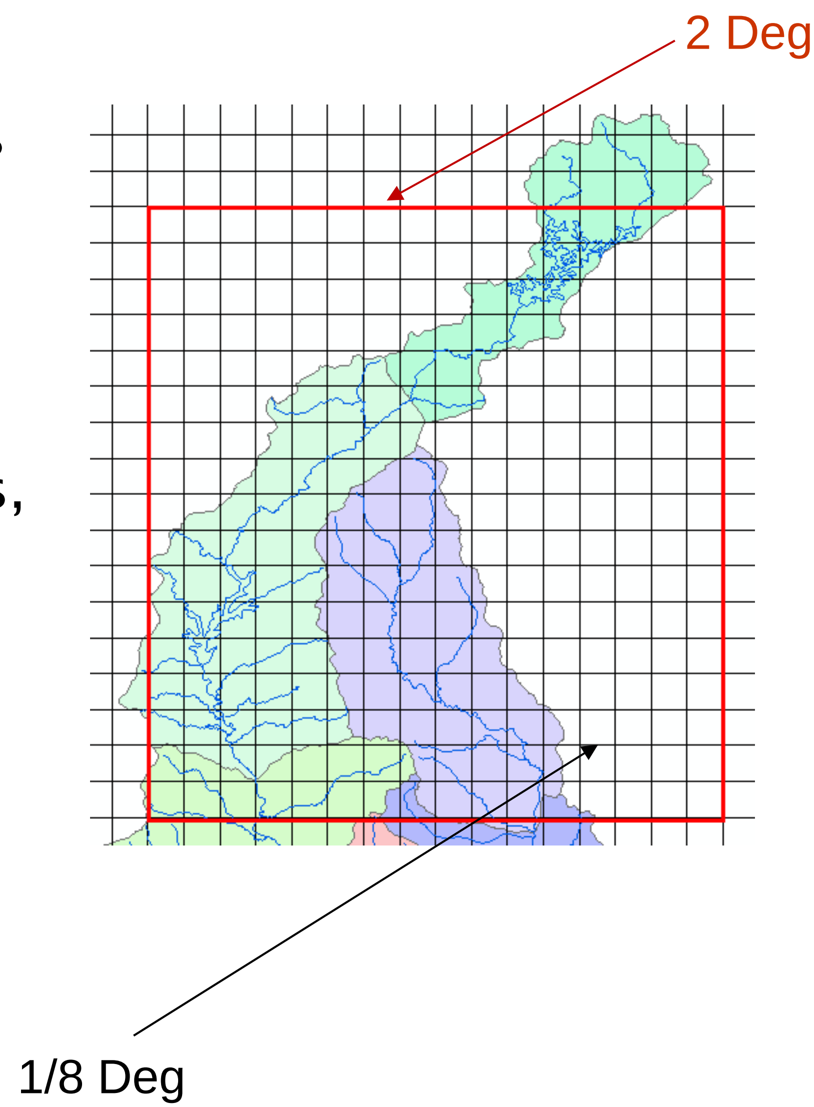


- Time and resource efficient;
- Bias Correction;
- Examples:
  - Regression Methods (Huth, 1999);
  - Weather Generators (Wilks and Wilby, 1999);
  - Changing Factor Methods (Beniston *et al.*, 2003);
  - Statistical Downscaling Model (SDSM; Wilby *et al.*, 2001);
  - Bias Correction and Spatial Downscaling (**BCSD**; Wood *et al.*, 2004);
  - Weather Typing Methods (WTM; Vrac, 2007);
  - Constructed Analogues (CA; Hidalgo *et al.*, 2008);
  - Joint Variable Spatial Downscaling (**JVSD**; Zhang and Georgakakos, 2011).

Bias Correction and Spatial Downscaling – BCSD (1)

Wood *et al.*, 2004

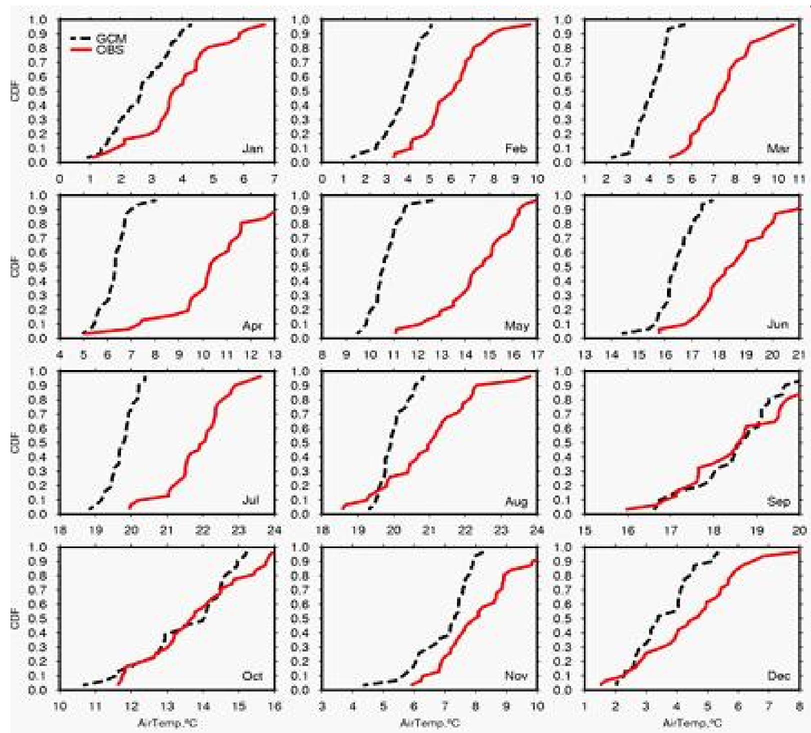
- **Bias Correction** – *quantile to quantile* association of GCM output to up-scaled observations (i.e., spatially averaged, temporally aggregated);
- **Spatial Downscaling** – interpolation of *monthly GCM anomalies* from 2 to 1/8 degrees, and addition to long term observed means;
- **Temporal Disaggregation** – resampling of observed daily sequences.

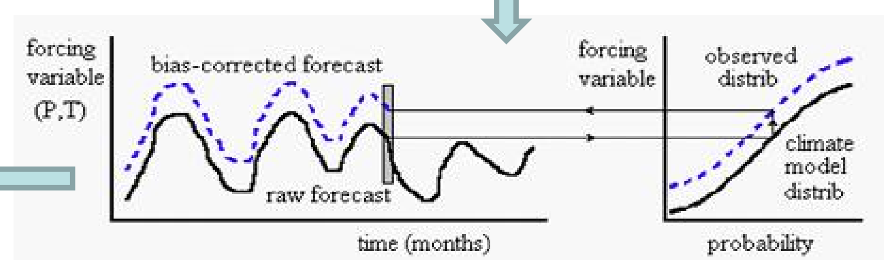


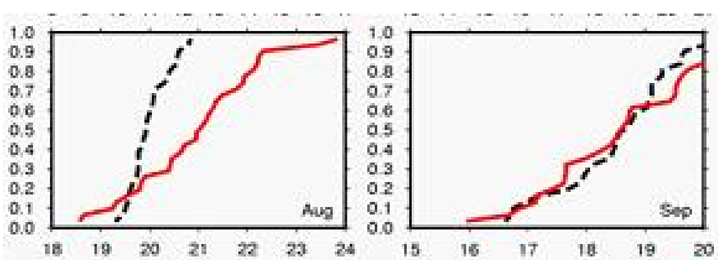
Bias Correction and Spatial Downscaling – BCSD (2)

Bias Correction

1. Generate monthly cumulative distribution functions (CDFs) of P and T for GCM and OBS data;
2. Identify T_{avg} GCM future trend;
3. Adjust P or T **individually** using the quantile to quantile association;
4. Add back the T_{avg} GCM trend to the adjusted GCM values.







Bias Correction and Spatial Downscaling – BCSD (3)
Spatial Disaggregation

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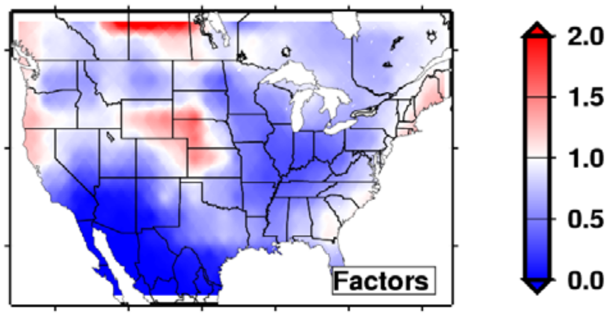
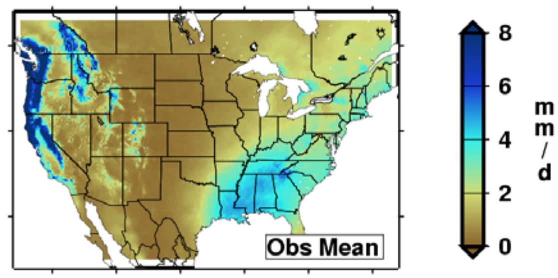
1. Compute factors (for the adjusted GCM P and T values) at each 2 degree grid cells in the domain (factors: P/[Domain P_{avg}]; T – [Domain T_{avg}]);
2. Interpolate the 2 degree factor values to 1/8 degree resolution using the SYMAP algorithm (Shepard, 1984), a modified inverse-distance-squared interpolation;
3. Apply the interpolated factors to the original 1/8 degree resolution OBS data.



1/8D

X



1/8D

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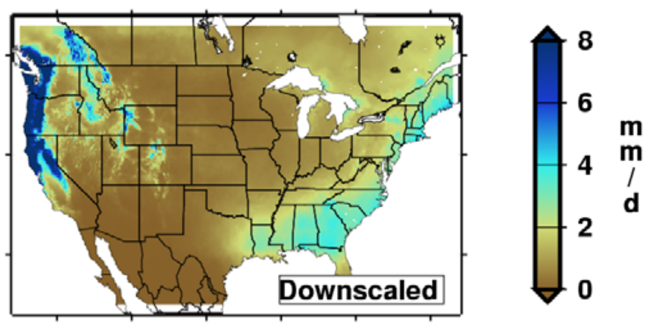

1/8D

Joint Variable Spatial Downscaling – JVSD (1)

Zhang and Georgakakos, 2011

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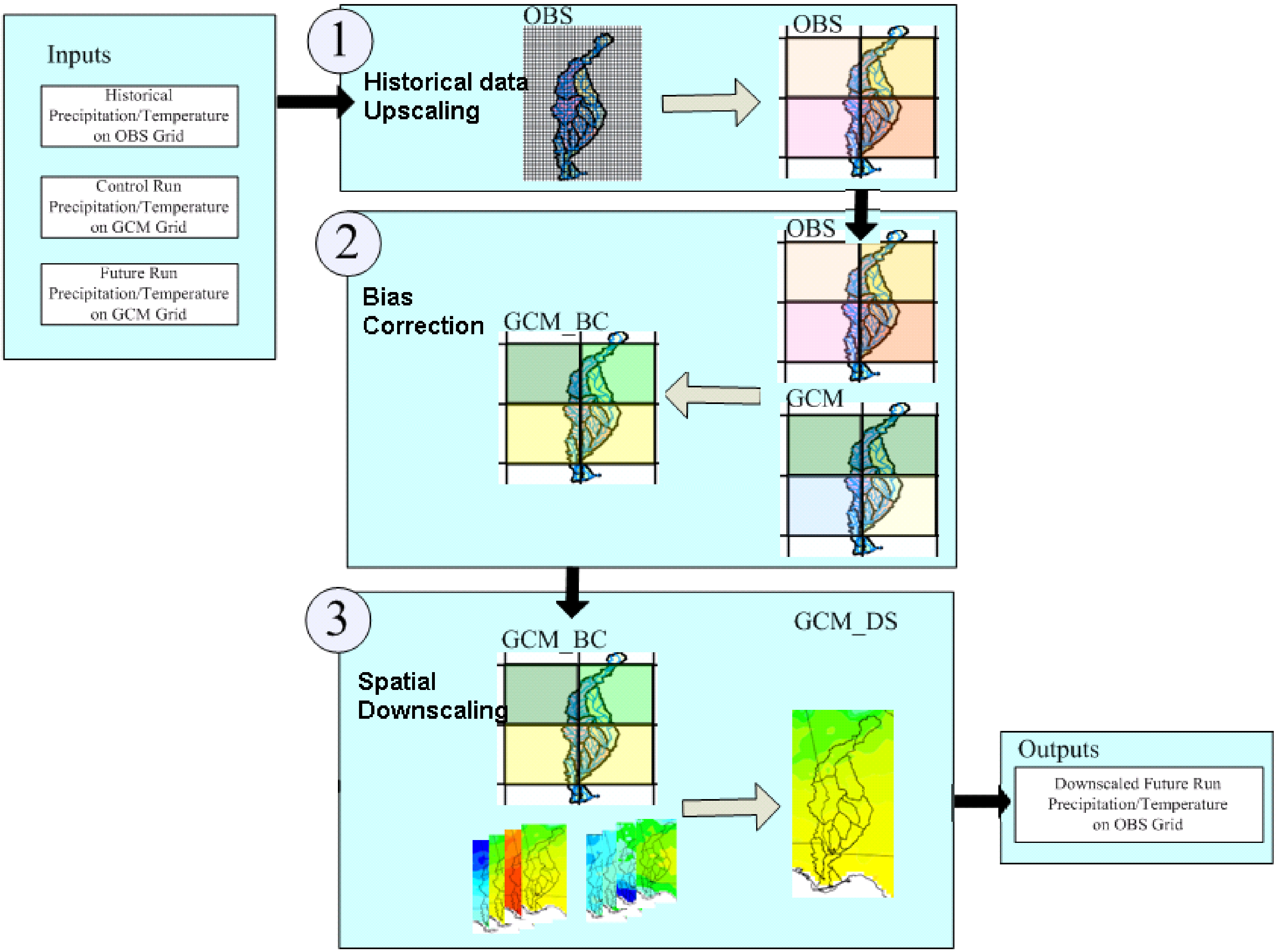
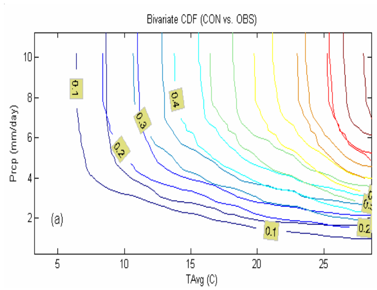


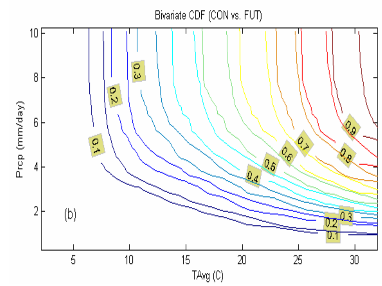
Joint Variable Spatial Downscaling – JVSD (2)

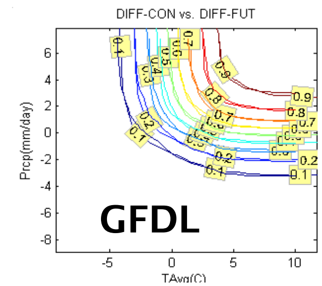
Bias Correction

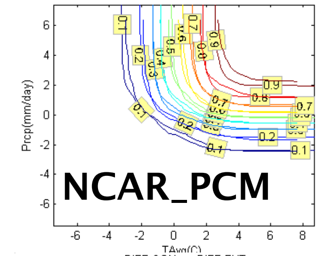
OBS vs. CON



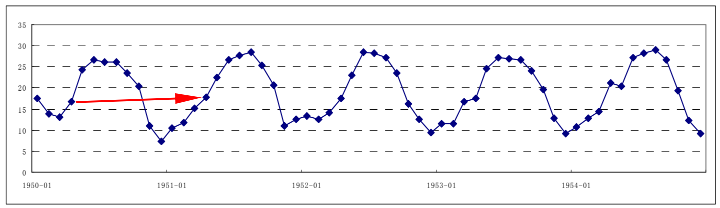
CON vs. FUT



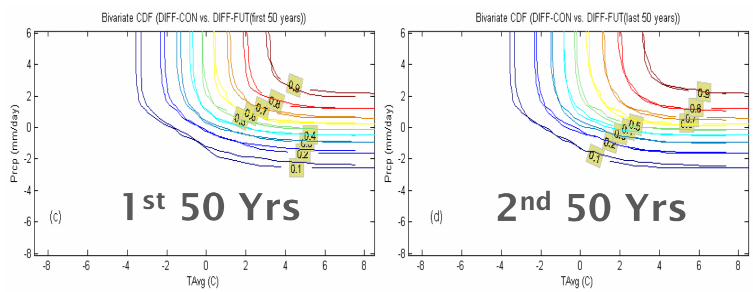


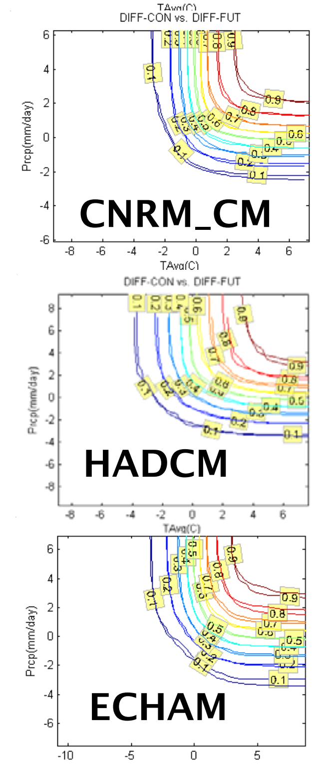


12-Month Differencing



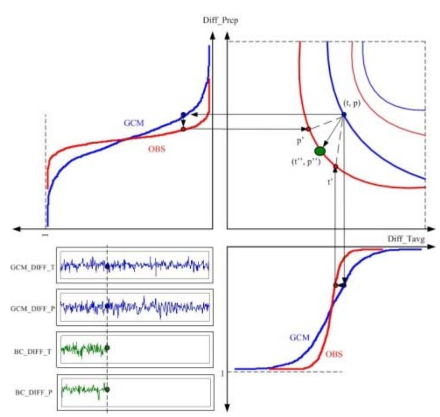
$D_{12}CON$ vs. $D_{12}FUT$





$D_{12}FUT$ → $D_{12}CON$ → $D_{12}OBS$

Nearest Neighbor in ($F_{T,P}$, F_T, F_P)



Reconstruction through **Integration**

Joint Variable Spatial Downscaling – JVSD (3)
Spatial Disaggregation

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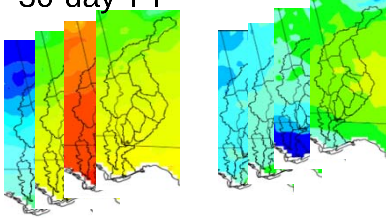
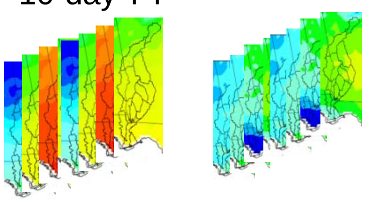
- **Historical Analog Approach**
- **Contemporaneous for all Basin Area**

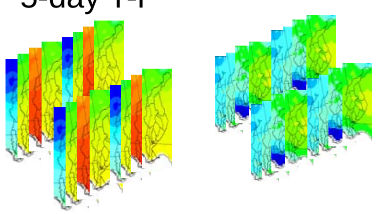
30-day T-P



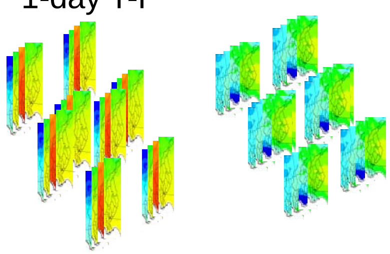
10-day T-P

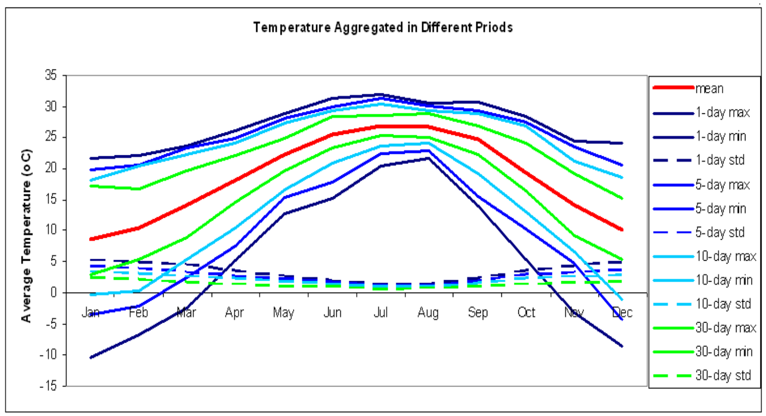


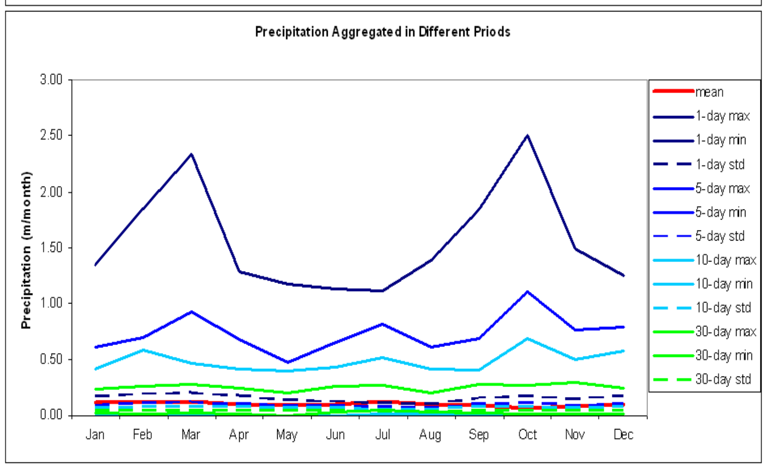
5-day T-P



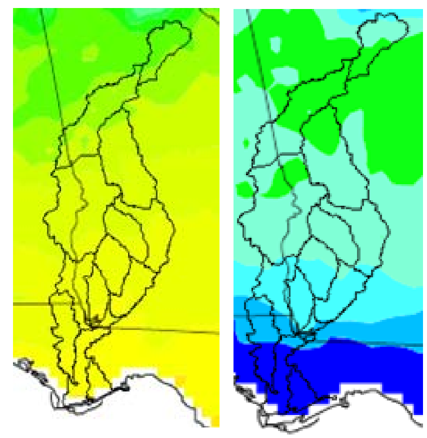
1-day T-P







Spatially Downscaled T-P Fields



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JVSD – BCSD Tests and Comparisons

Seasonal Joint CDFs (Buford Watershed, GA)

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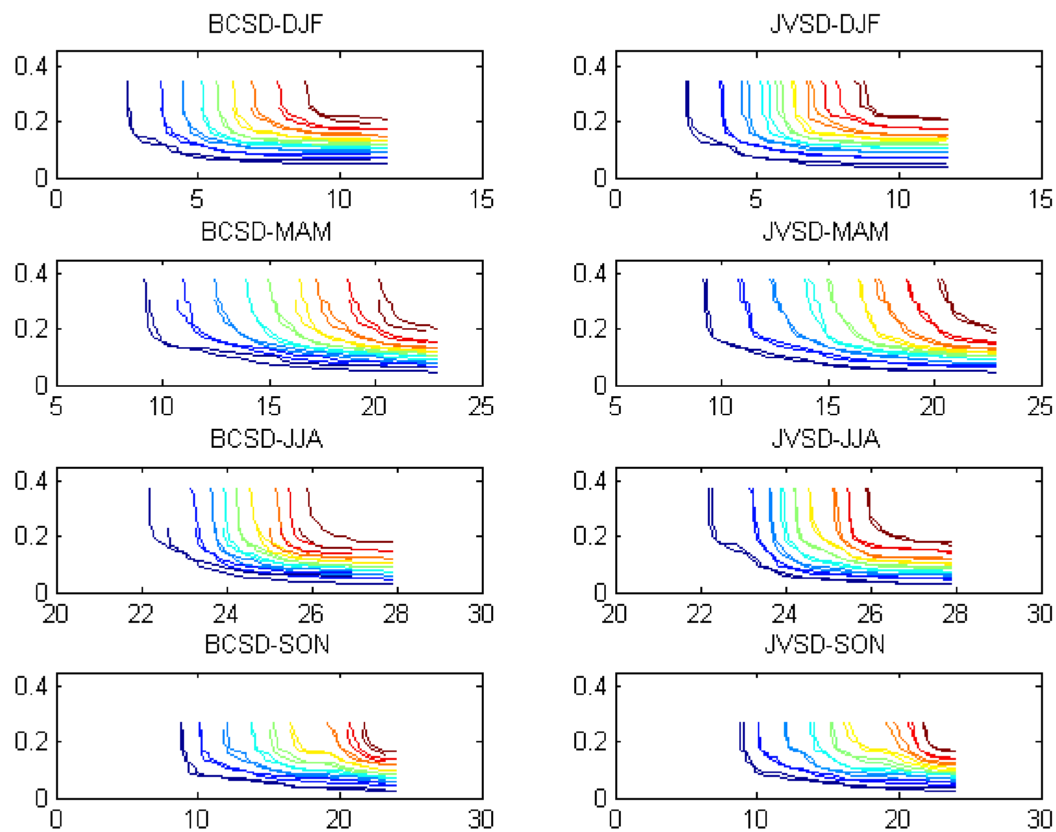
(OBS vs. BCSD) (OBS vs JVSD)

Control Run
1950 - 1999



P (vertical axes, meters/month) - T (horizontal axes, ^{o}C)

- **JVSD corresponds well with OBS in all seasons**
- **BCSD exhibits discrepancies in MAM and JJA**
- **BCSD under-estimates extremes**

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JVSD – BCSD Tests and Comparisons

P-T Seasonal Correlation

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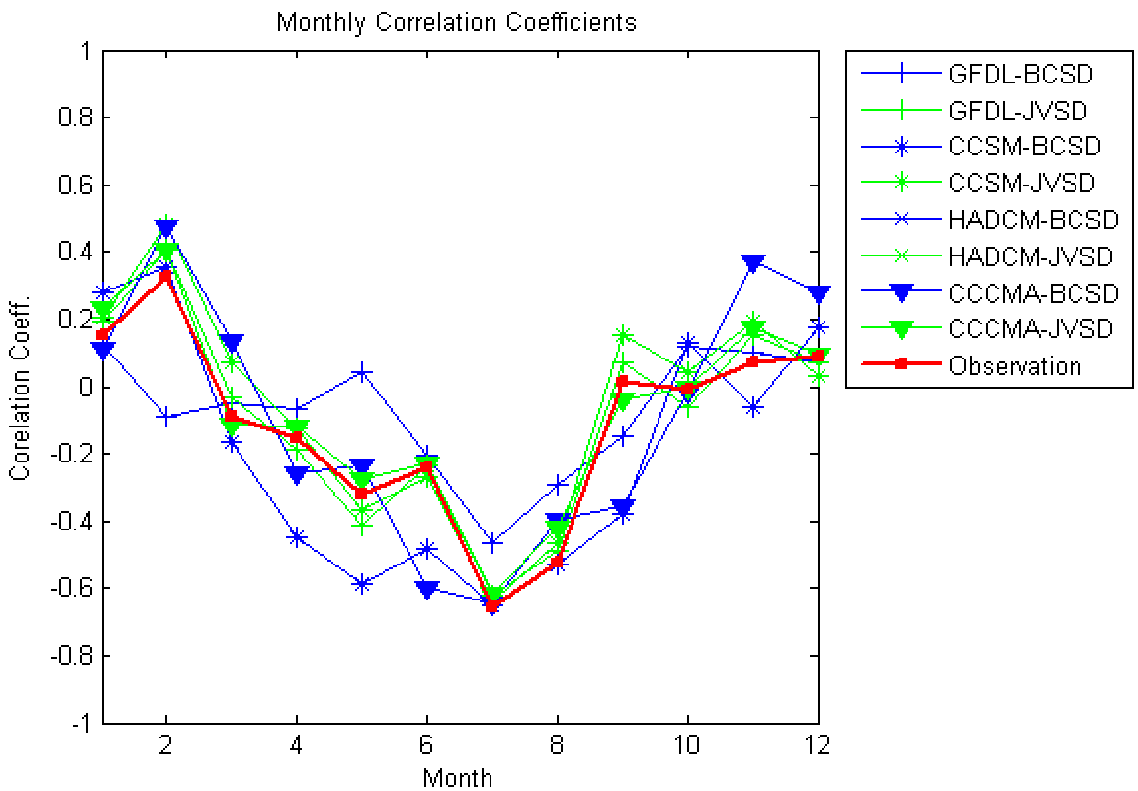
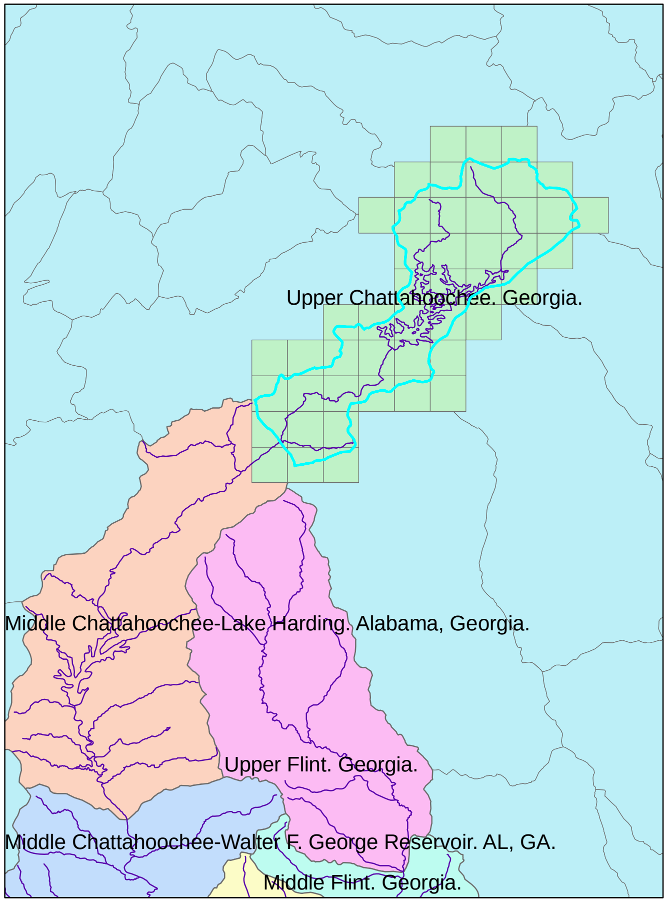


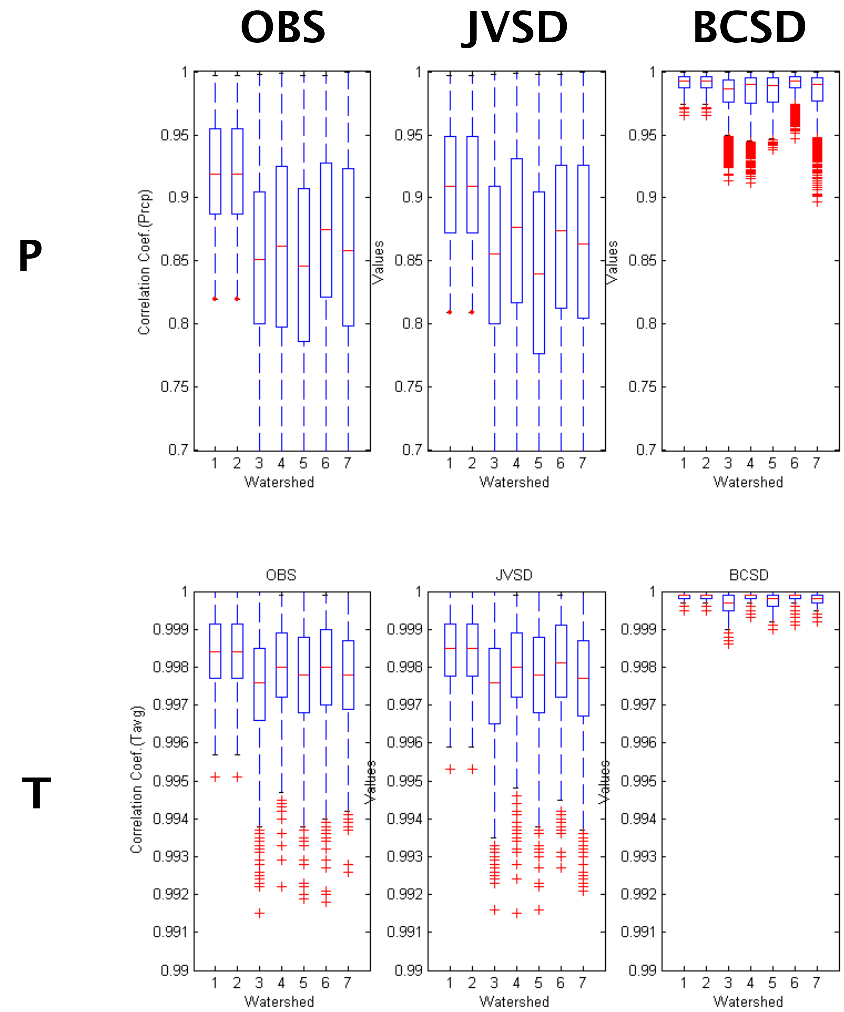
OBS (red), **BCSD** (blue), **JVSD** (green)

- **JVSD represents historical P-T correlations better**

JVSD – BCSD Tests and Comparisons
Spatial Correlations

Pair-wise correlation box plots for all ACF Watersheds (OBS vs. JVSD vs. BCSD)





- BCSD over-estimates spatial correlations

JVSD – BCSD Tests and Comparisons
Spatial Correlations (2)

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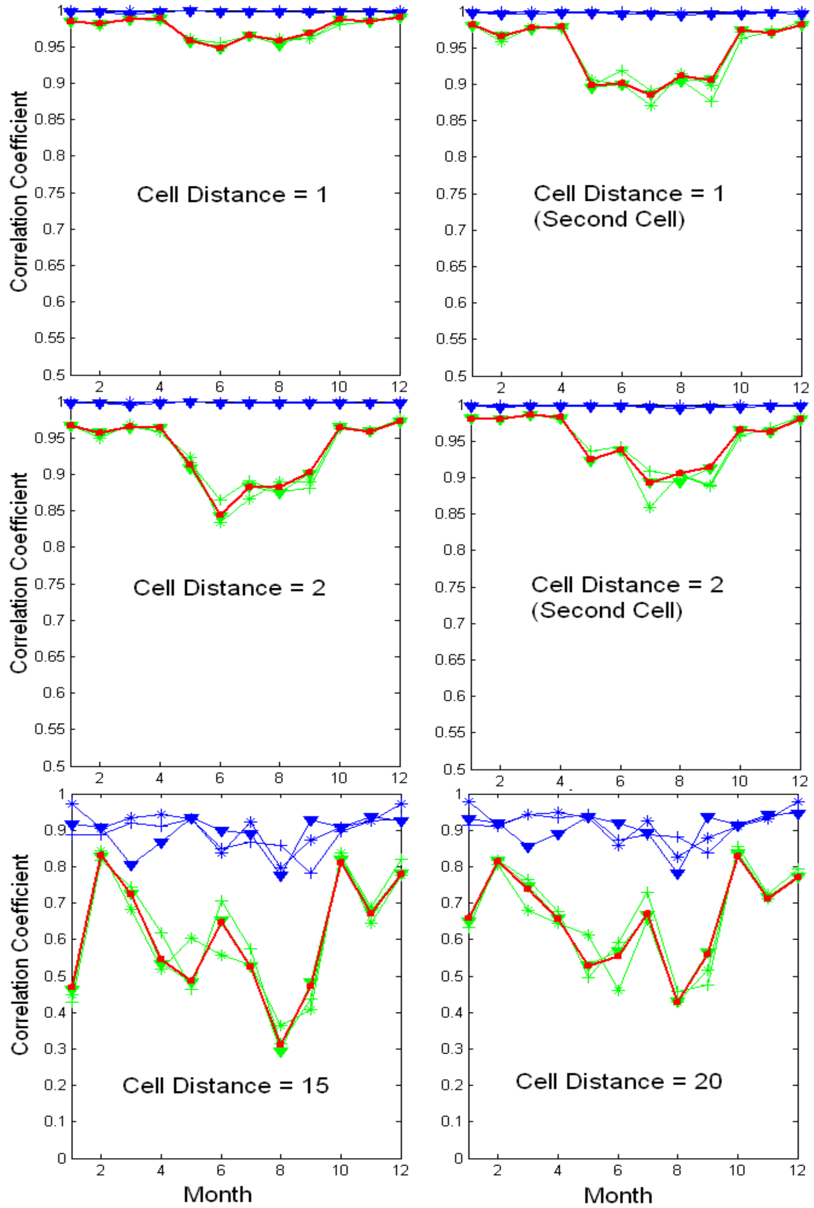


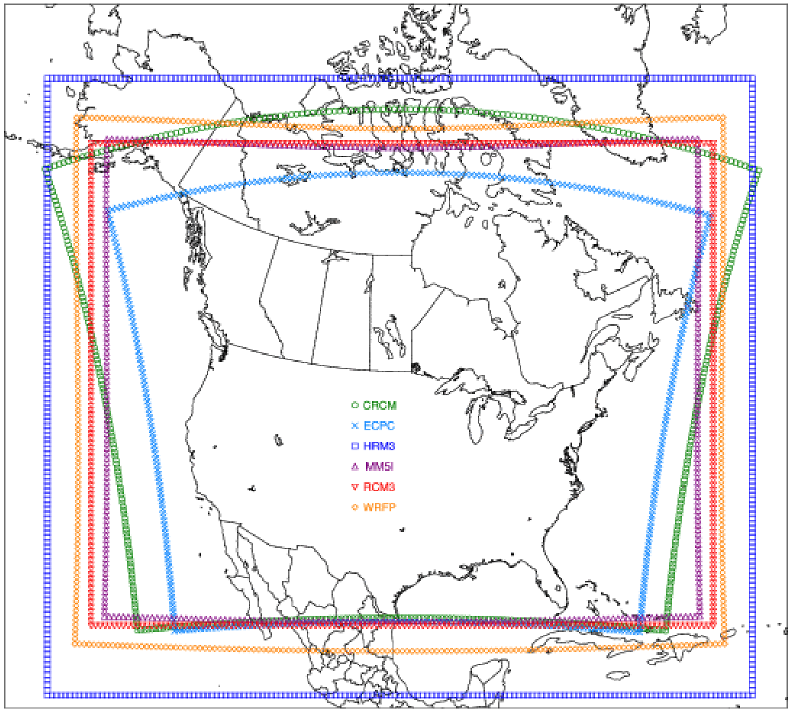
OBS (red), **BCSD** (blue), **JVSD** (green)

- **BCSD** exhibits spatial correlation biases

Comparison of Dynamic/Statistical Downscaling

North America Regional Climate Change Assessment Program (NARCCAP)

NARCCAP RCM Domains



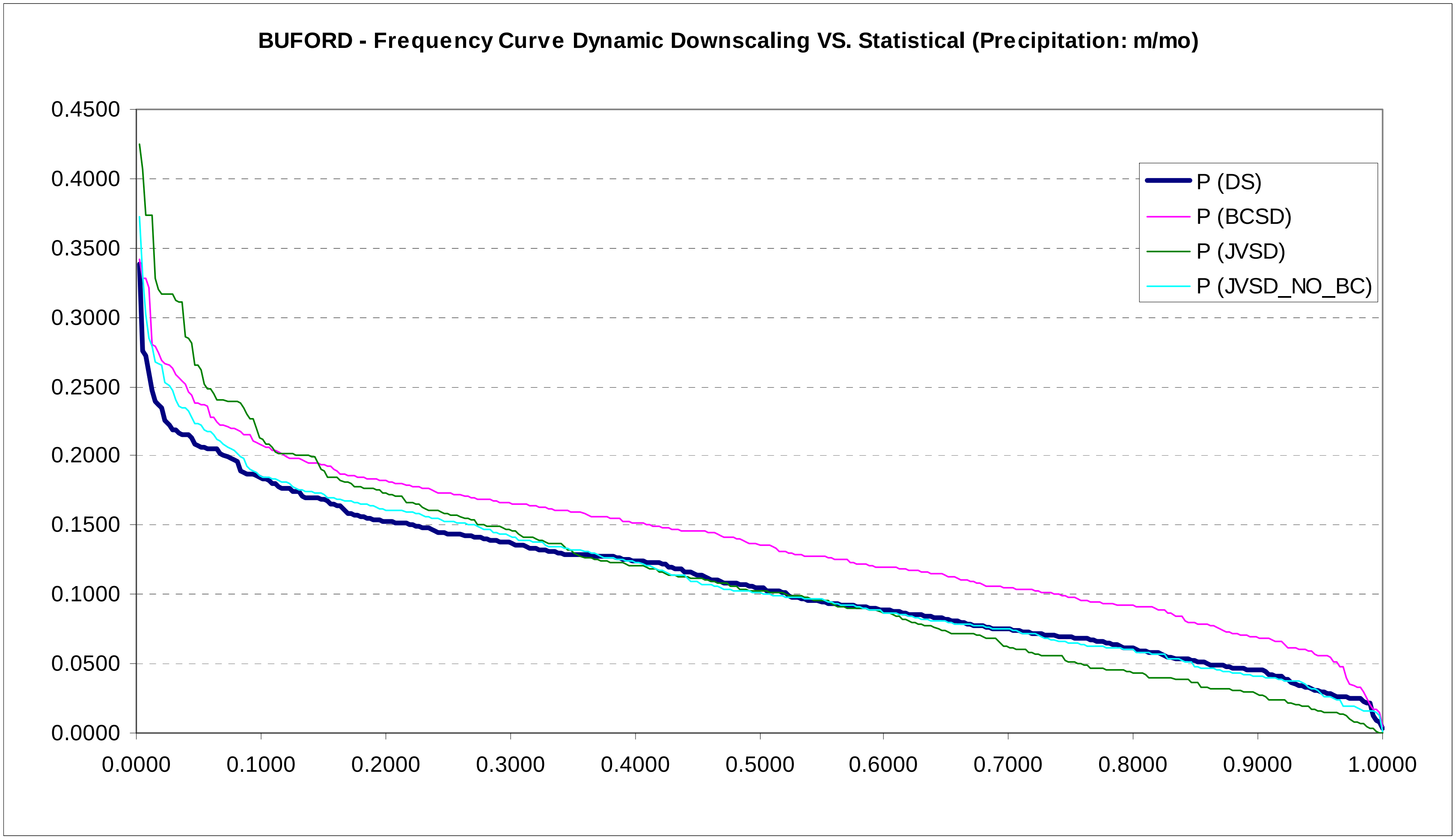
RCM / GCM combinations

	Phase I	Phase II			
	NCEP	GFDL	CGCM3	HADCM3	CCSM
CRCM	X		1		2
ECPC	X	1		2	
HRM3	X	2		1	
MM5I	X			2	1
RCM3	X	1	2		
WRFP	X		2		1
timeslice		X			X

1: First pairing to be run
2: Second pairing to be run

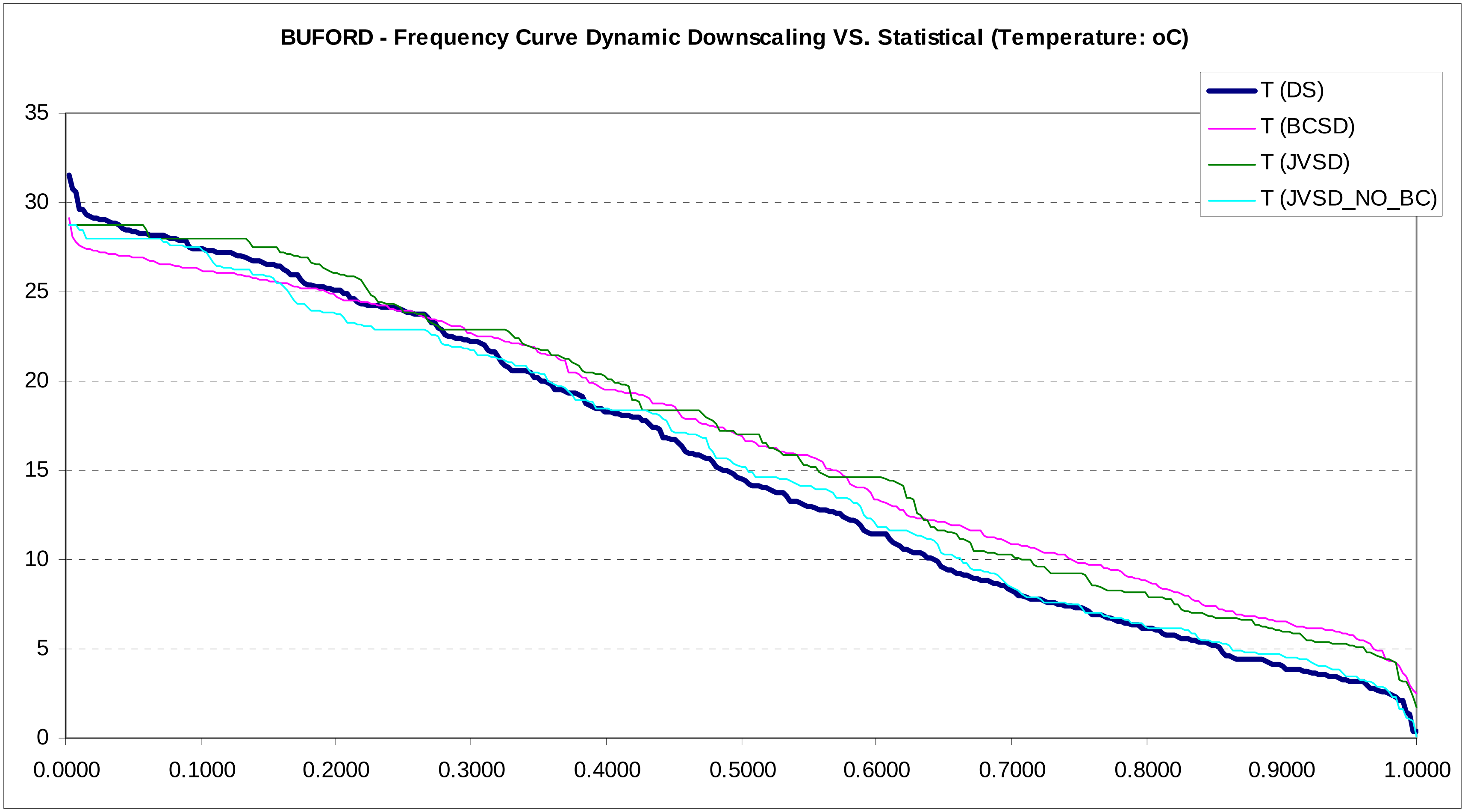
2041 - 2070

Comparison of Dynamic/Statistical Downscaling
Precipitation, Buford



- **Dynamic Downscaling is comparable to JVSD without bias correction**
- **BCSD under-estimates both precipitation extremes with respect to JVSD**

Comparison of Dynamic/Statistical Downscaling
Temperature, Buford



- **Dynamic Downscaling is comparable to JVSD without bias correction**
- **BCSD and JVSD perform comparably for temperature**

Summary
Downscaling Method Differences

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- Single vs. joint variable downscaling
- Spatial and temporal relationships
- Representation of extremes
- Select approach based on assessment features and requirements

Climate Assessment

Knowledge Gaps, Further Research/Information Needs

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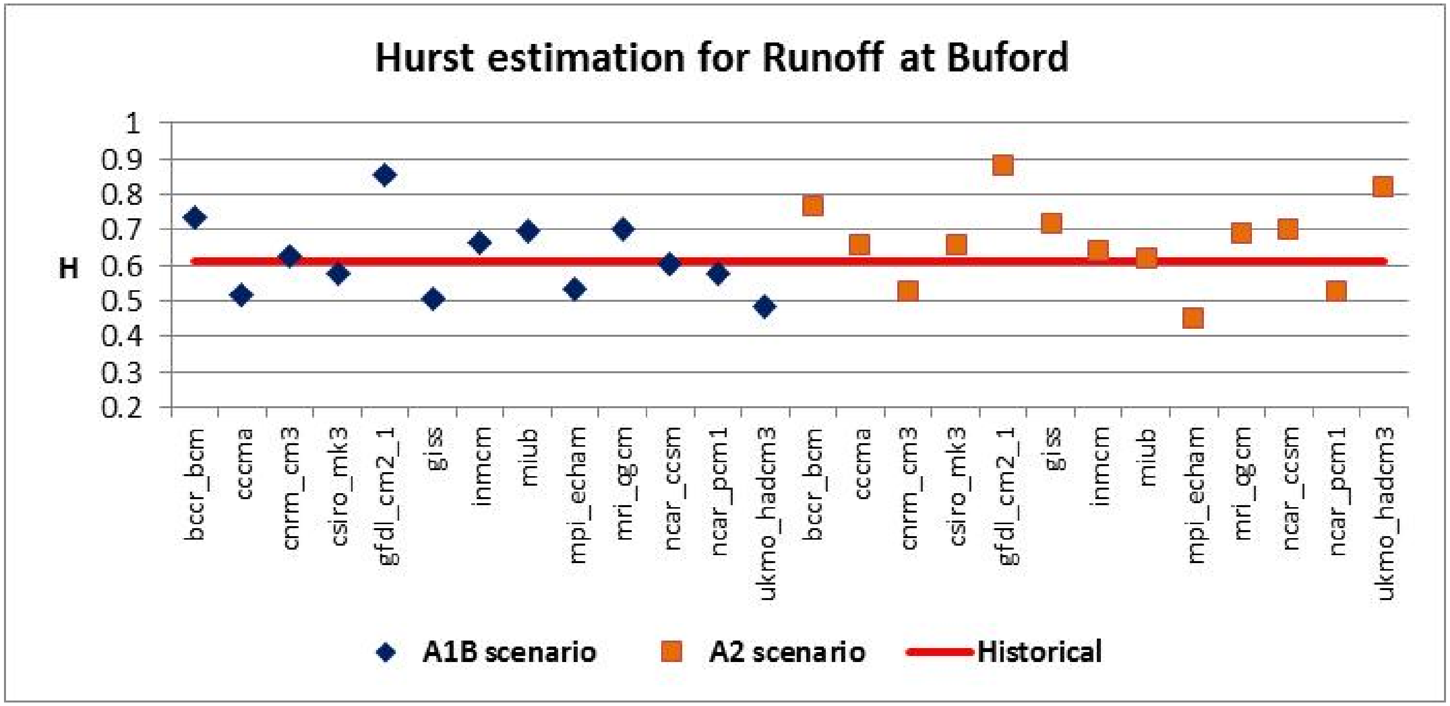
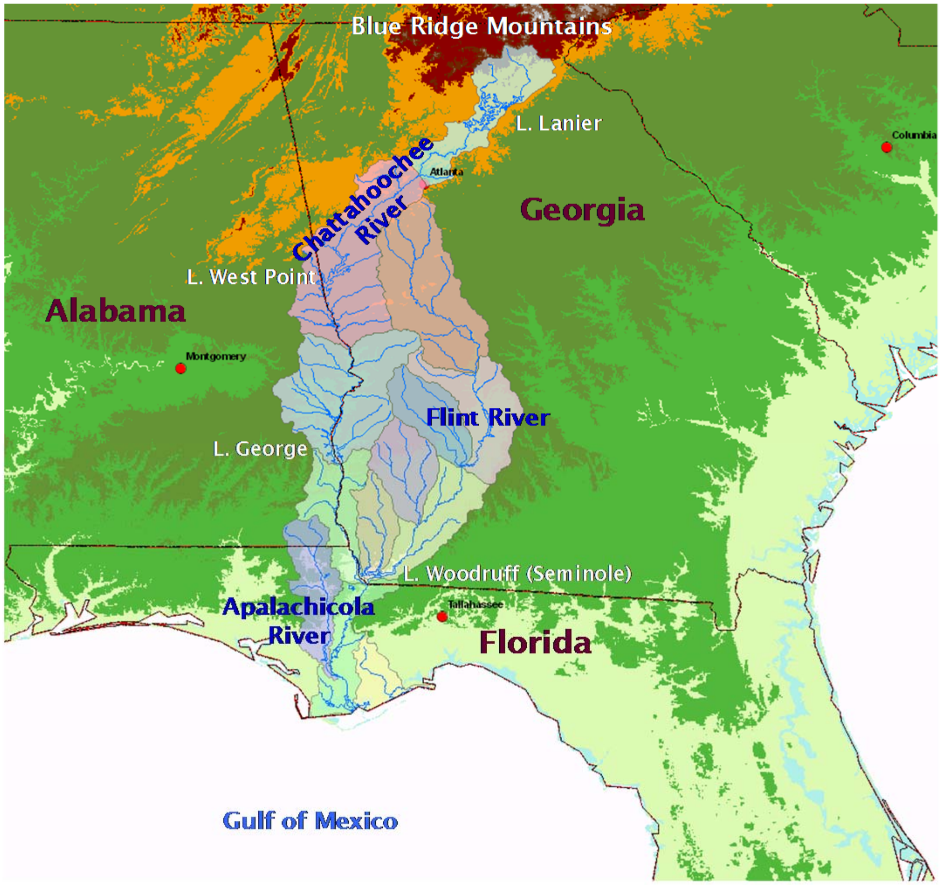
- **Do GCMs/Downscaling procedures preserve long process memory (Hurst)?**

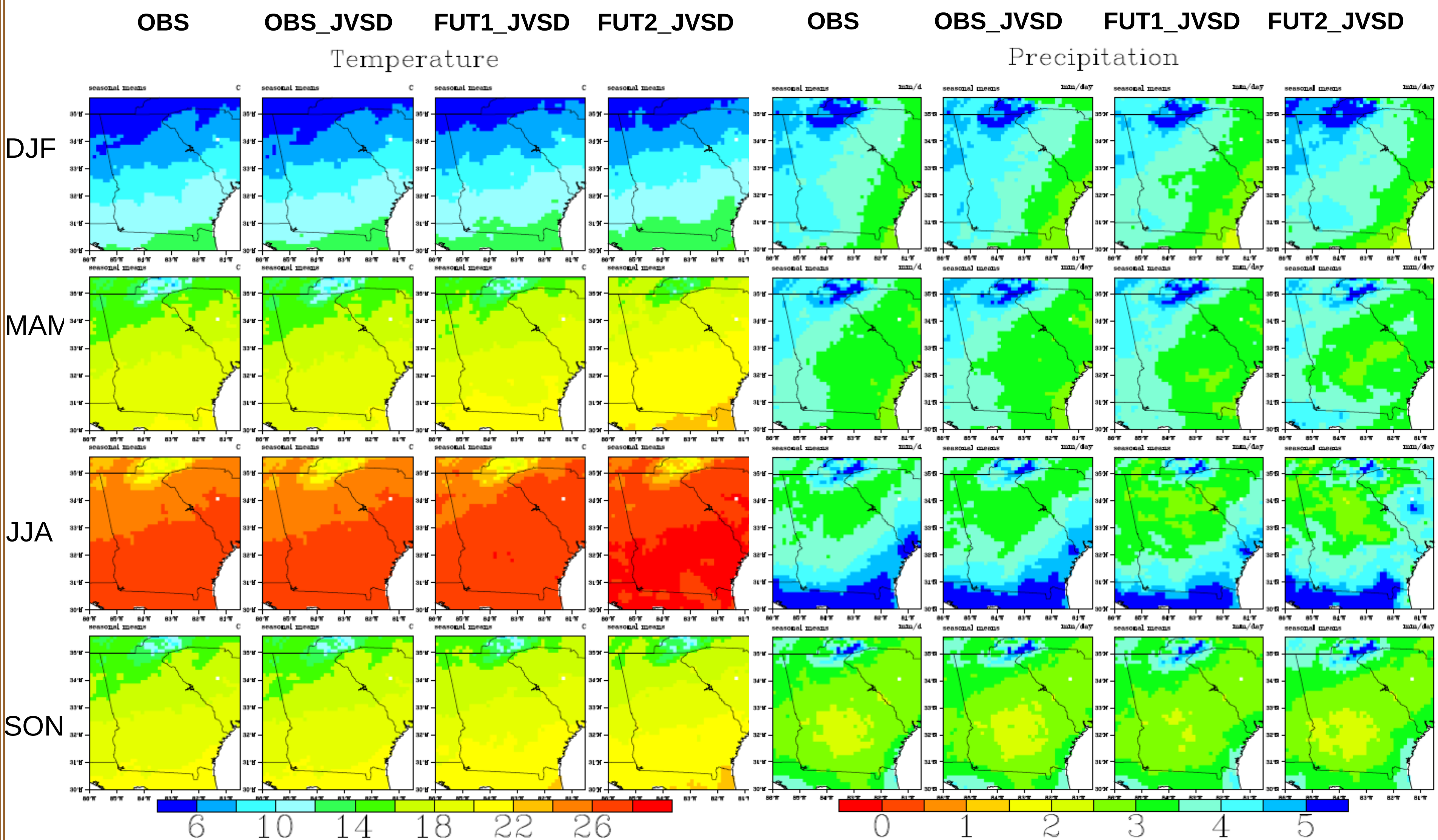


- **Very significant implications for water management**
- **Do GCMs preserve long process memory?**
- **Can downscaling methods be developed to preserve H?**

Climate Assessment
Southeast US, ACF

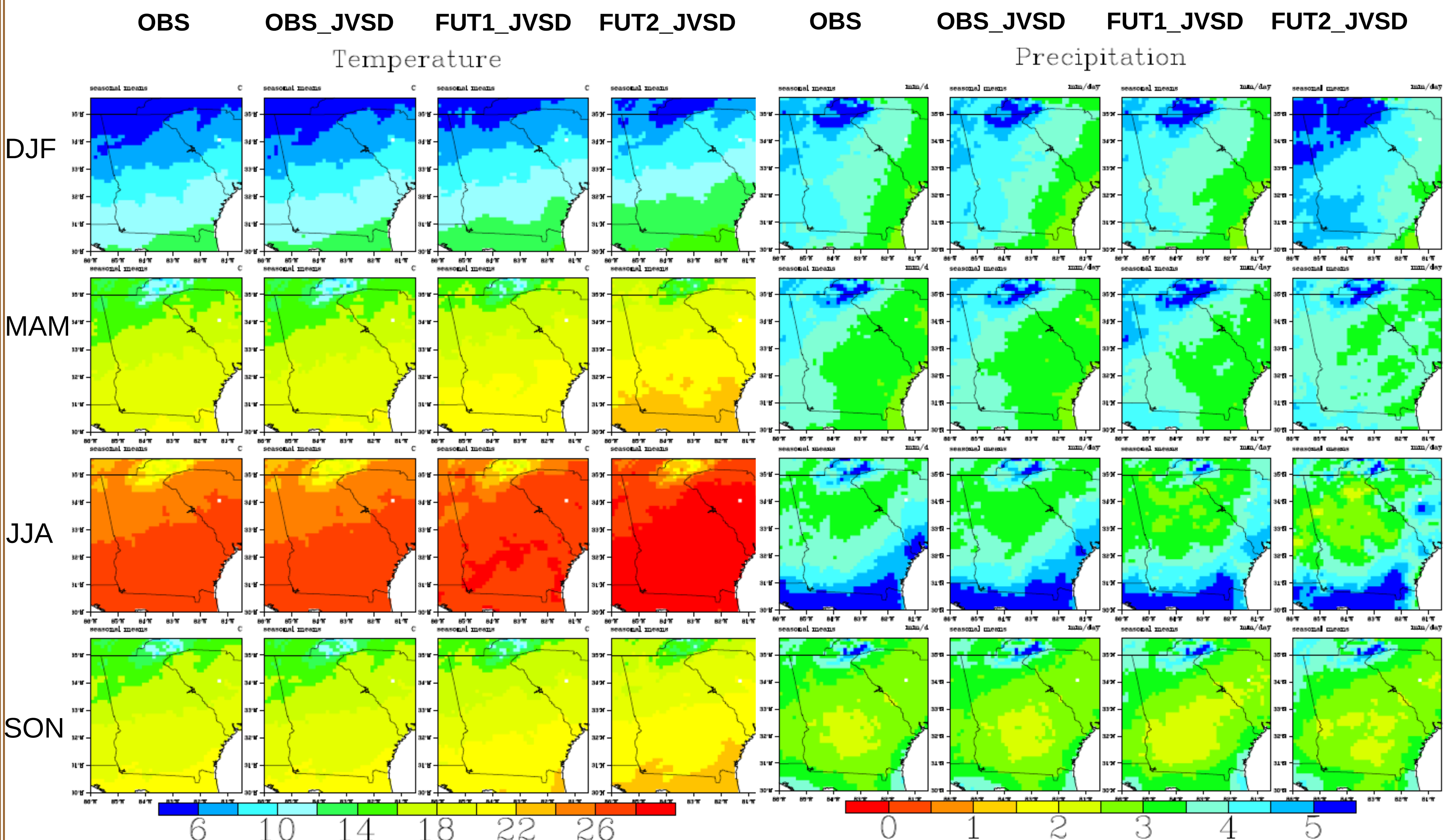


JVSD Results
CCCMA CGCM3.1 – SRESA1B



- Warmer MAM, JJA, and SON
- Wetter DJF

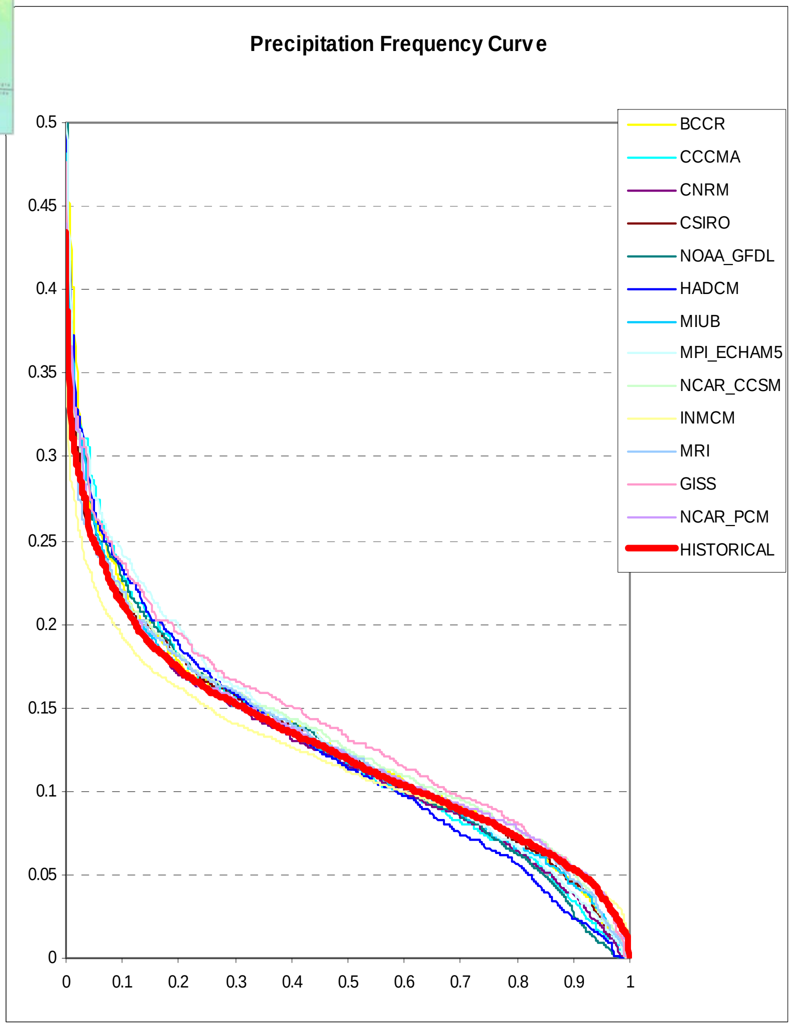
JVSD Results
CCCMA CGCM3.1 – SRESA2

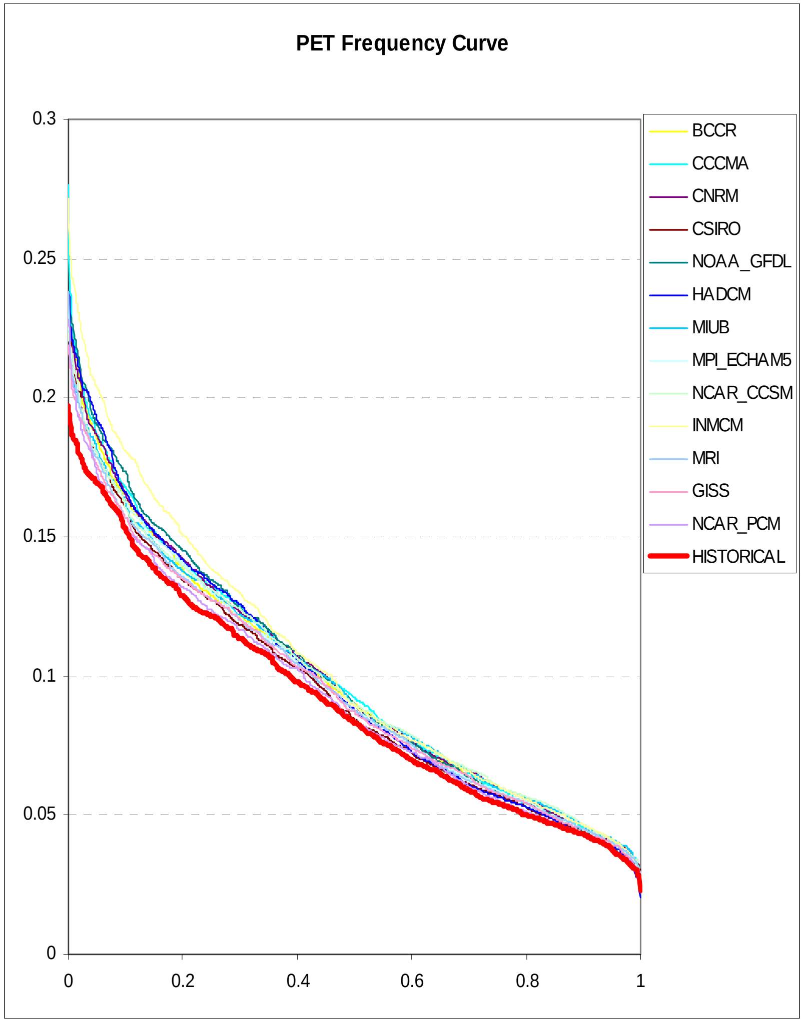


- Warmer DJF, MAM, JJA, and SON
- Wetter DJF, MAM

Climate Assessment

Buford: Historical and Future Precipitation, PET (**A2**)

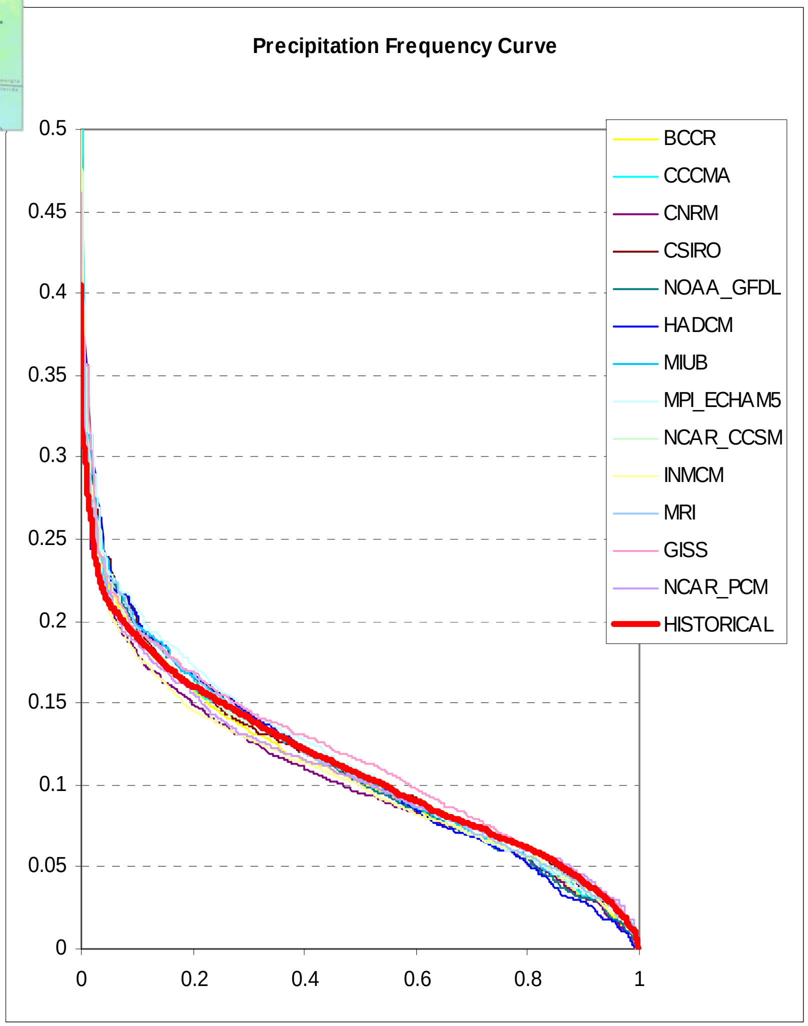


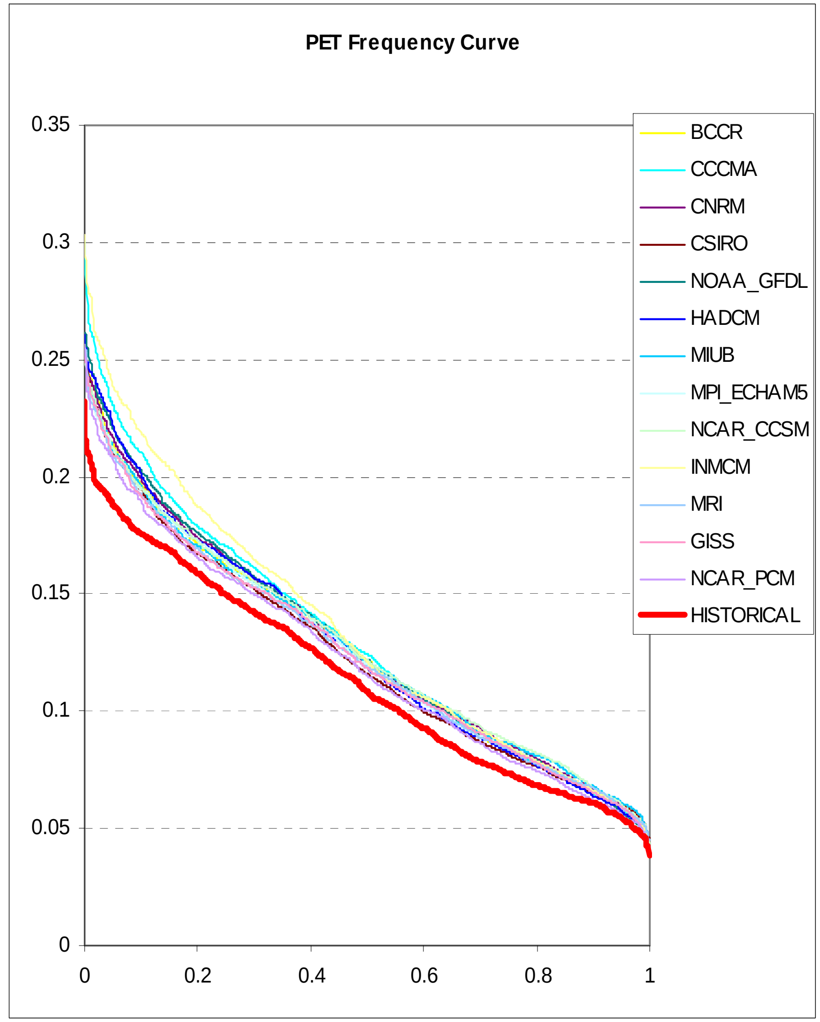


- **Future precipitation extremes (wet and dry) are expected to increase**
- **Future PET will be higher than historical**

Climate Assessment

Woodruff: Historical and Future Precipitation, PET (A2)





- **Future precipitation extremes (wet and dry) are expected to increase**
- **Future PET will be higher than historical; the difference increases with latitude**

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Climate Assessment

Buford: Monthly Historical and Future P, PET (**A2**)

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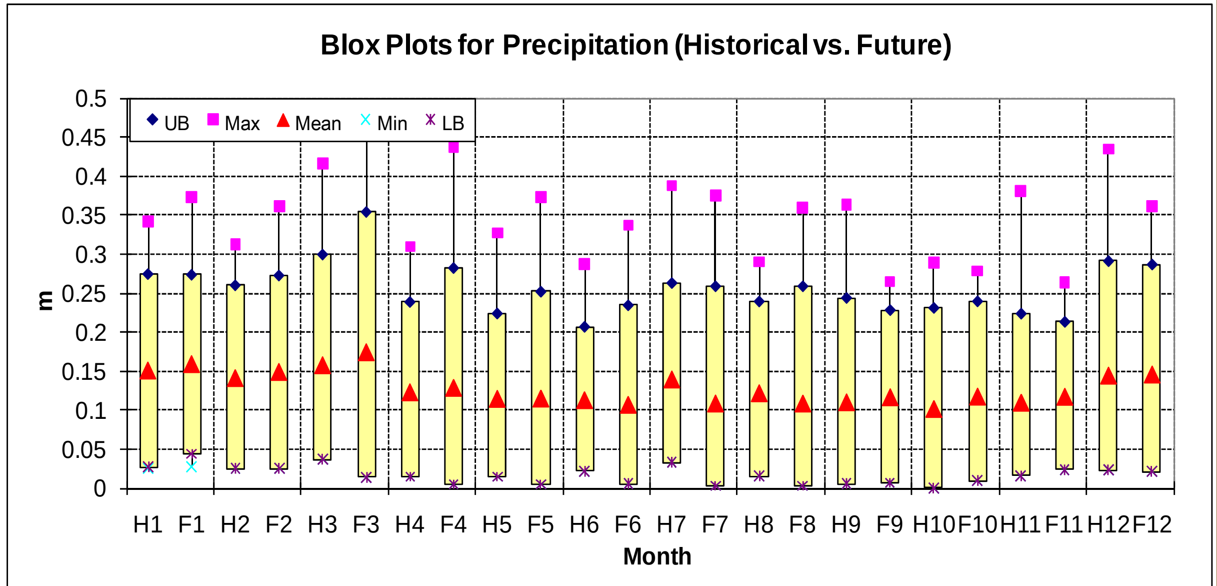
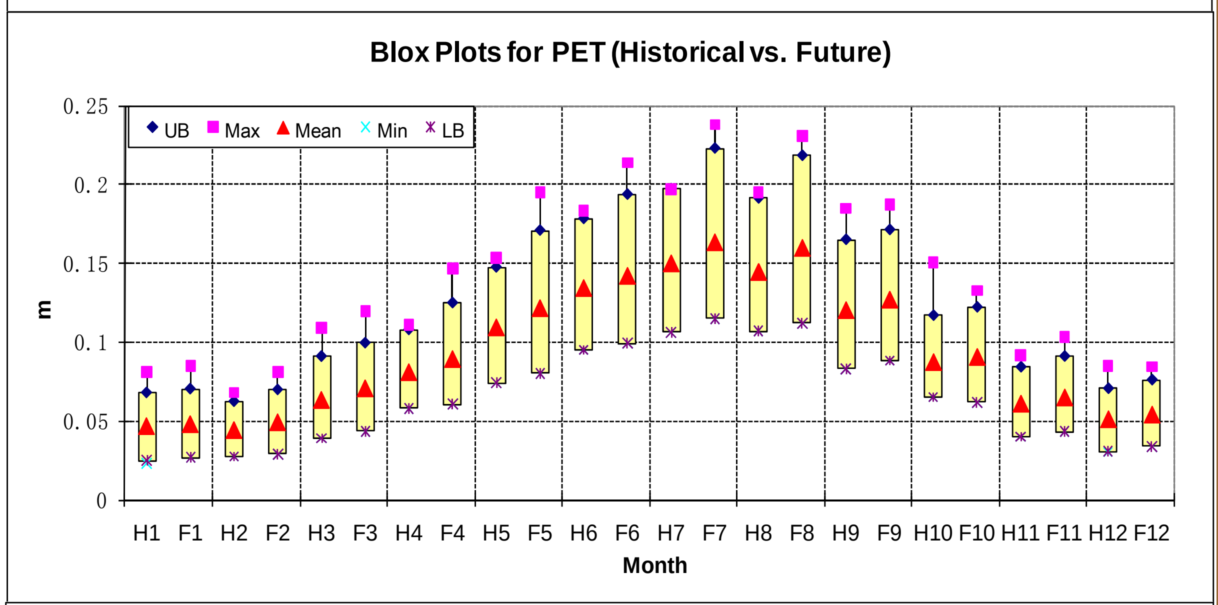
- **Precipitation:**
  Wetter Jan, Feb, Mar, Apr
  Drier June, July, August



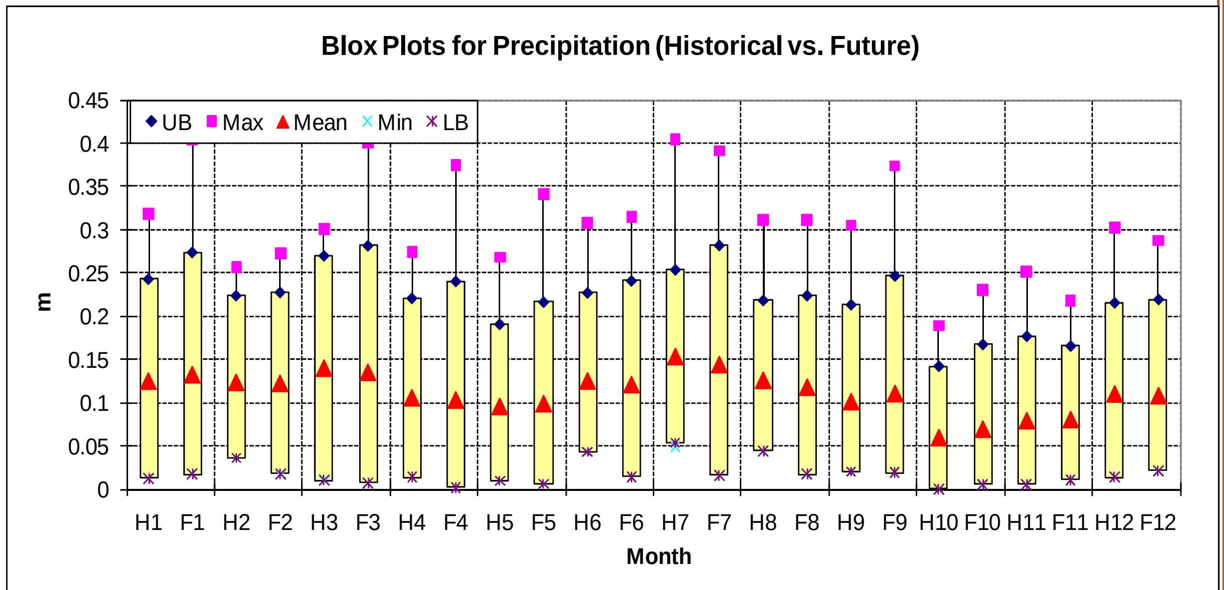
- **PET:**
  Future > Historical from
  April through September

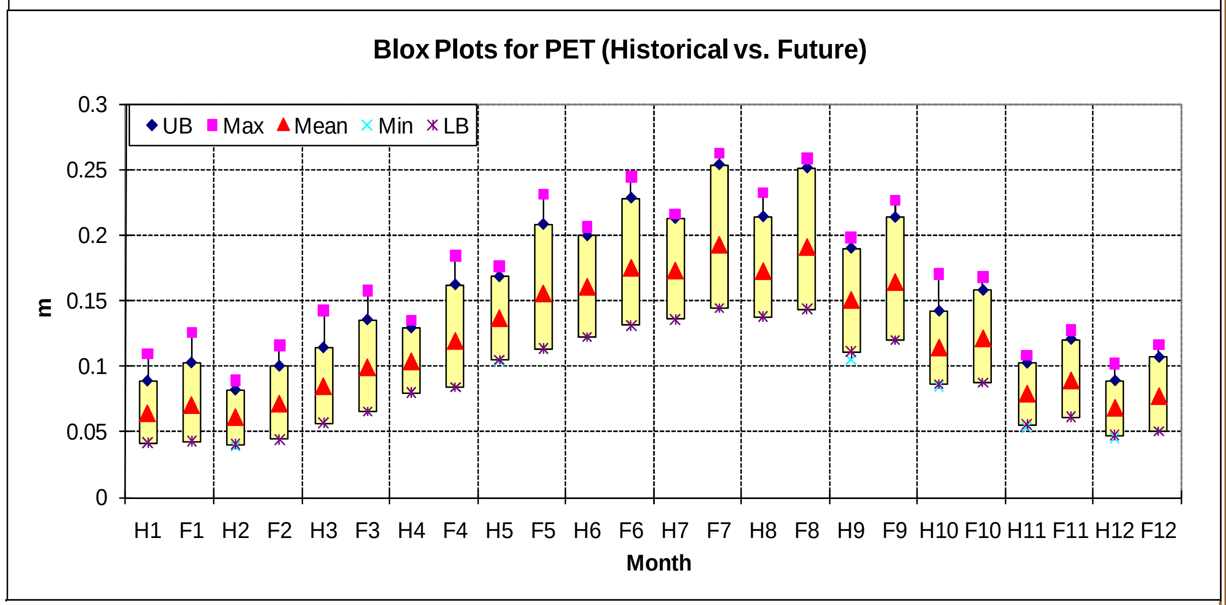


Climate Assessment

Woodruff: Monthly Historical and Future P, PET (A2)

- **Precipitation:**
  Wetter Jan, Sep, Oct
  Drier June, July, Aug





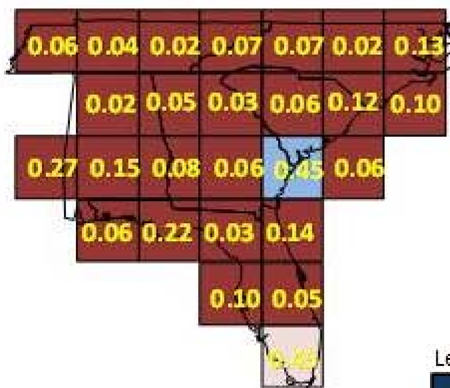
- **PET:**
  Future > Historical from
  January through December

Assessing Change

J. Reagan and A. Georgakakos

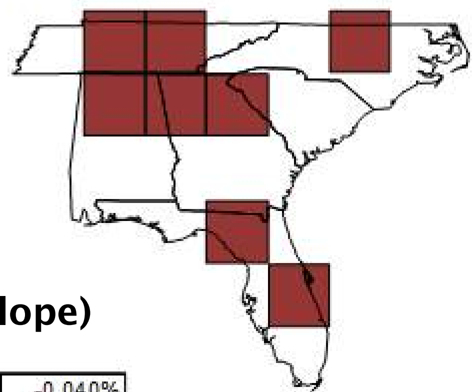
1986 - 2010 T_{min} Trends
(p-values in yellow)

October



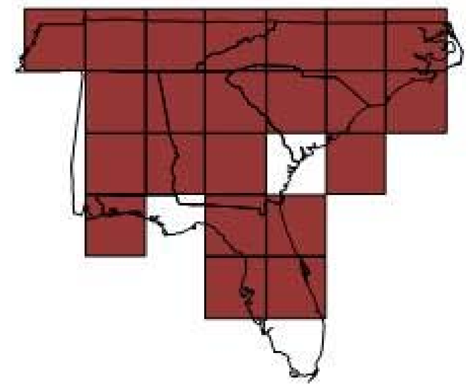
Significant Trends
(Individual Cells: p<0.05)

October



Significant Trends
(Cell Groups)

October



Trend (Slope)

Legend

| --- | --- | --- |
dark blue		-0.040%
blue	-0.040%	-0.020%
light blue	-0.020%	0.000%
light pink	0.000%	0.020%
pink	0.020%	0.040%
dark red	0.040%	

- **Apparent climatic change may or may not be *statistically significant*.**
- **Statistical significance is different for individual cells and cell groups.**

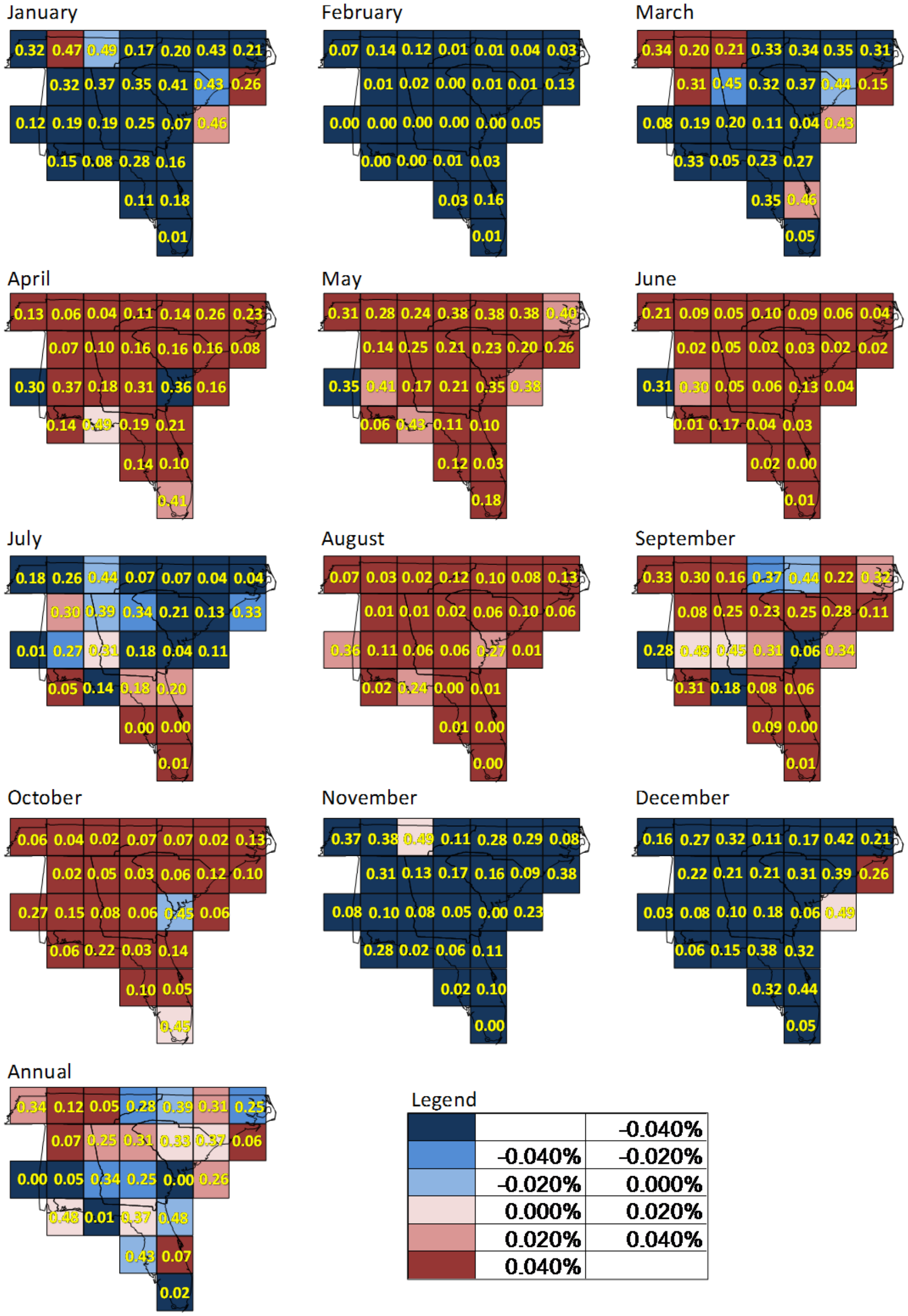
Individual Cells

- Reorder period of trend for each cell or basin randomly.
- Estimate sampling distribution of trend.
- Data was reordered 2000 times to find 2000 random trends.
- Test the null hypothesis that the actual trend is not significantly different than zero.
- Reject the null hypothesis if $p < 0.05$.

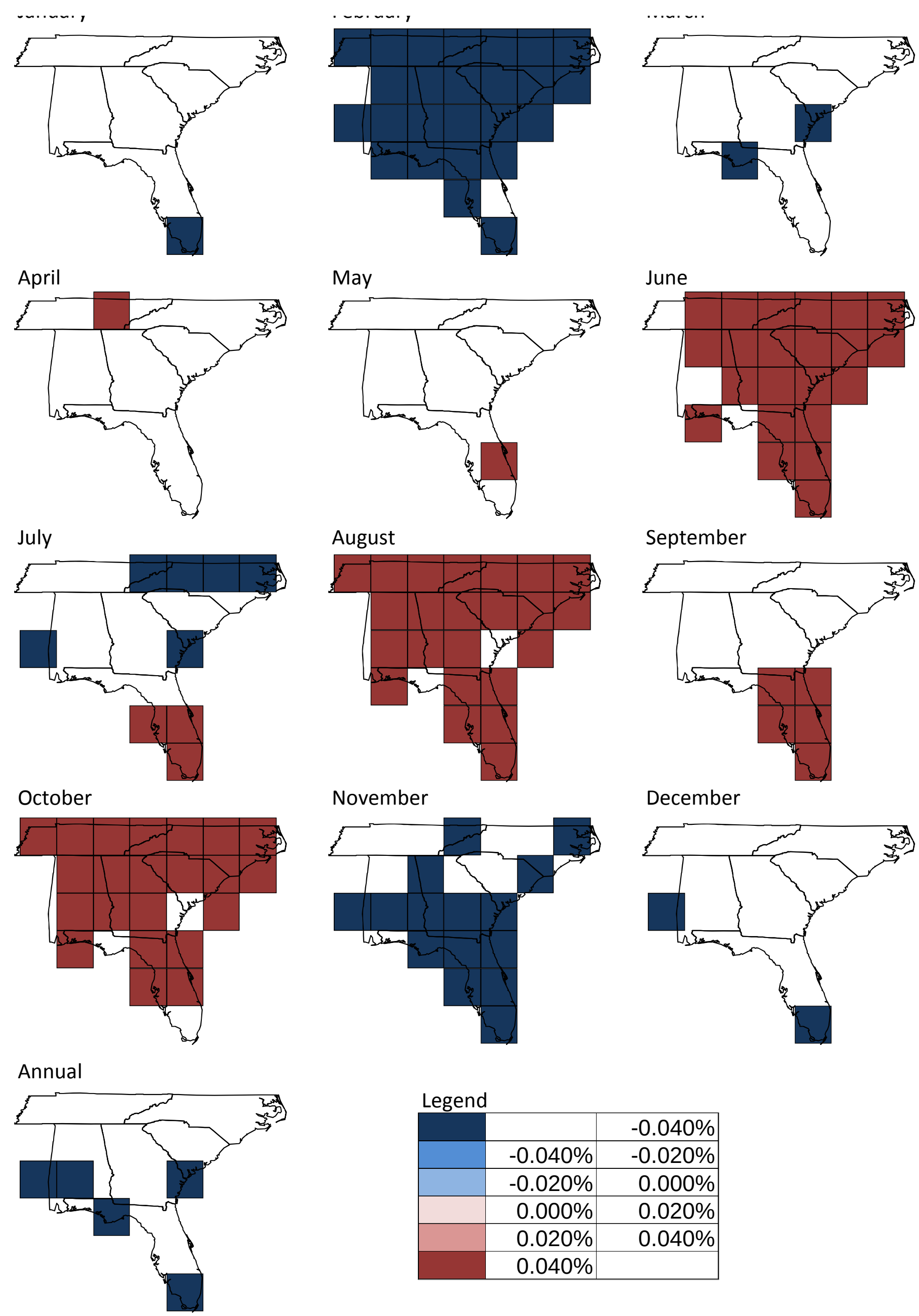
Groups of Cells

- Each cell or basin is tested as a group with its neighbor cells or basins.
- An average observed trend is found for the group and compared with the average randomly generated trends.
- Reject the null hypothesis if the p-value of the group trend is less than 0.05.
- Add new neighbors to the group until the p-value becomes greater than 0.05.

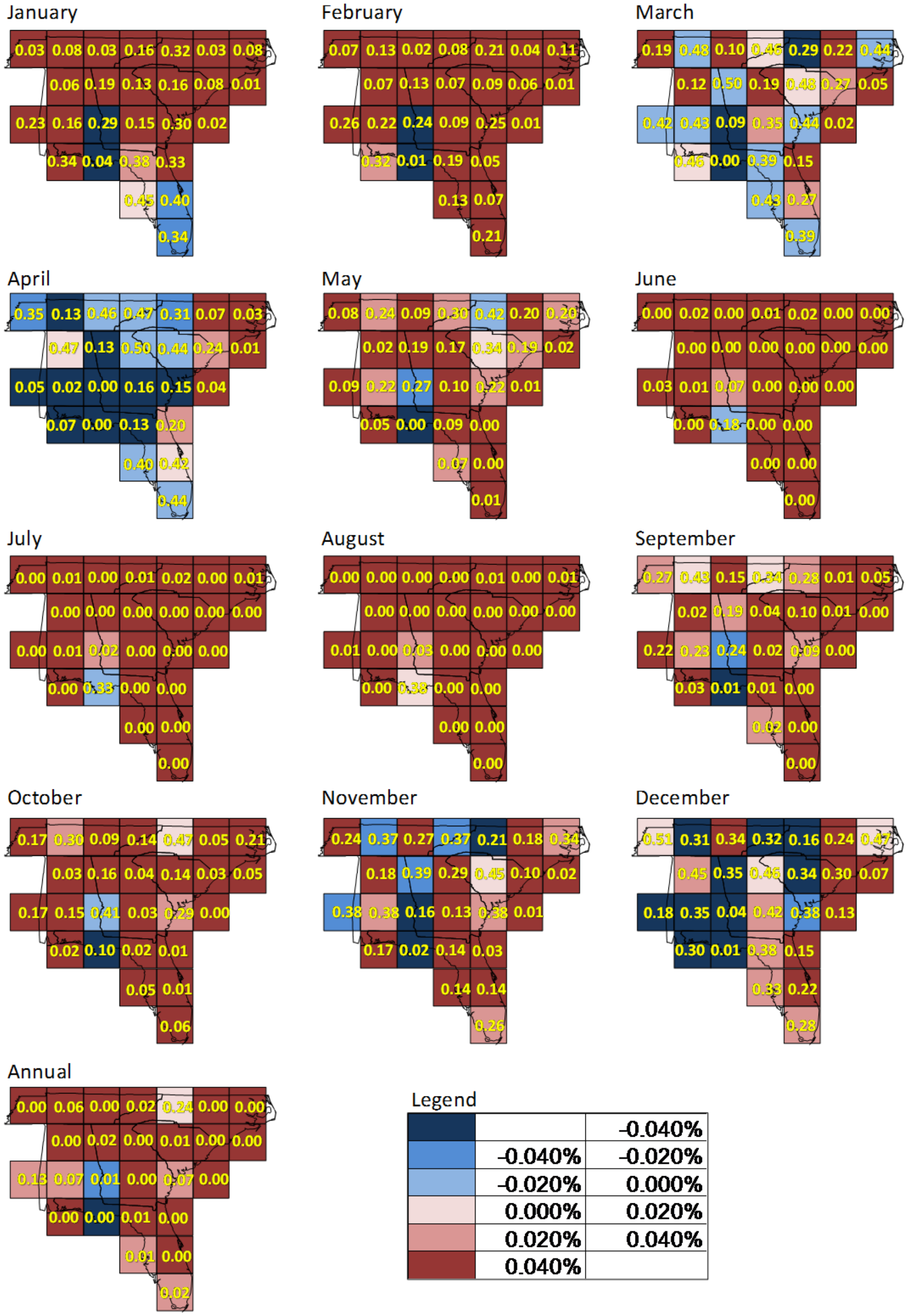
Tmin 1986-2010 Trends



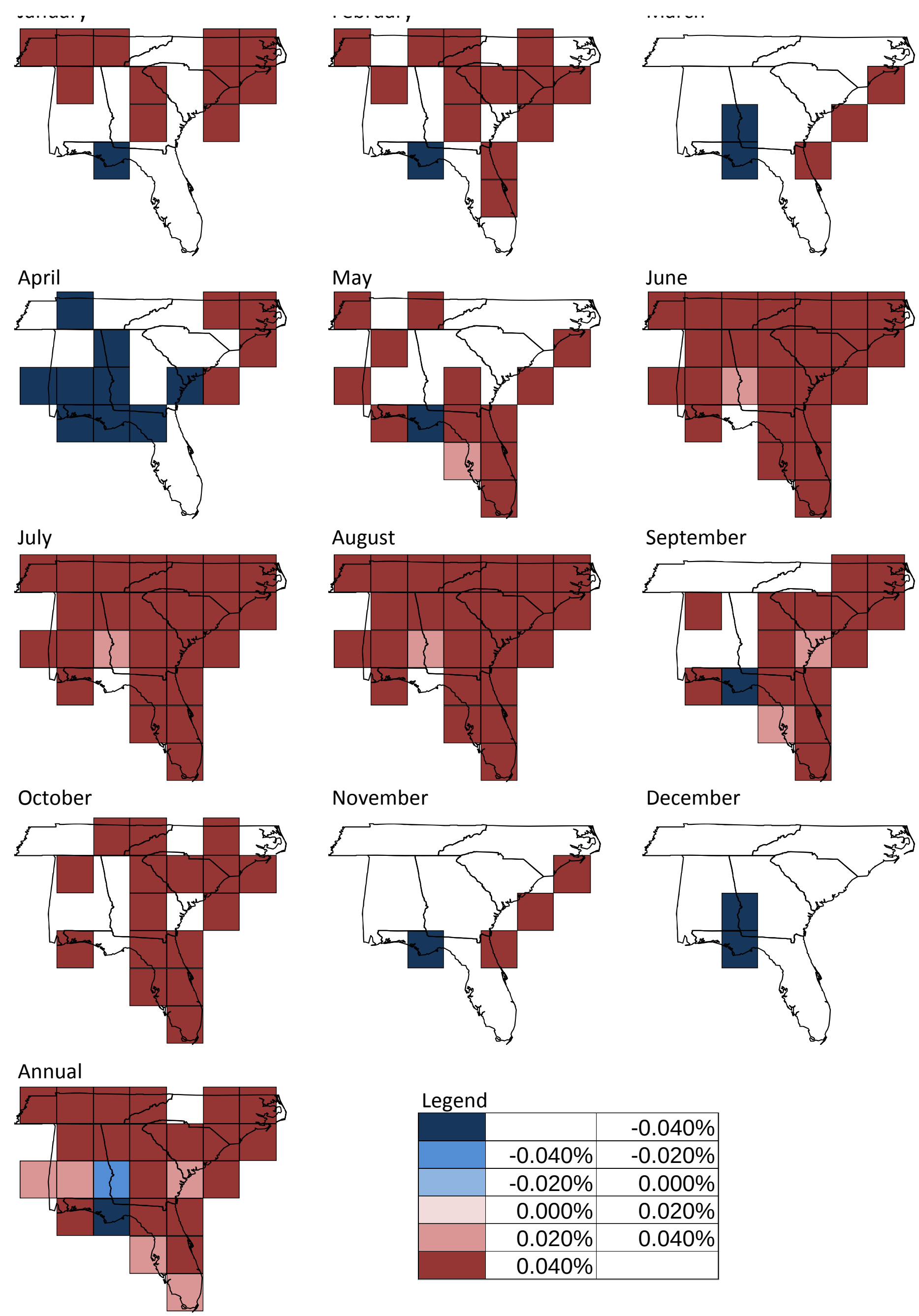
Tmin 1986-2010 Sig Group Trends



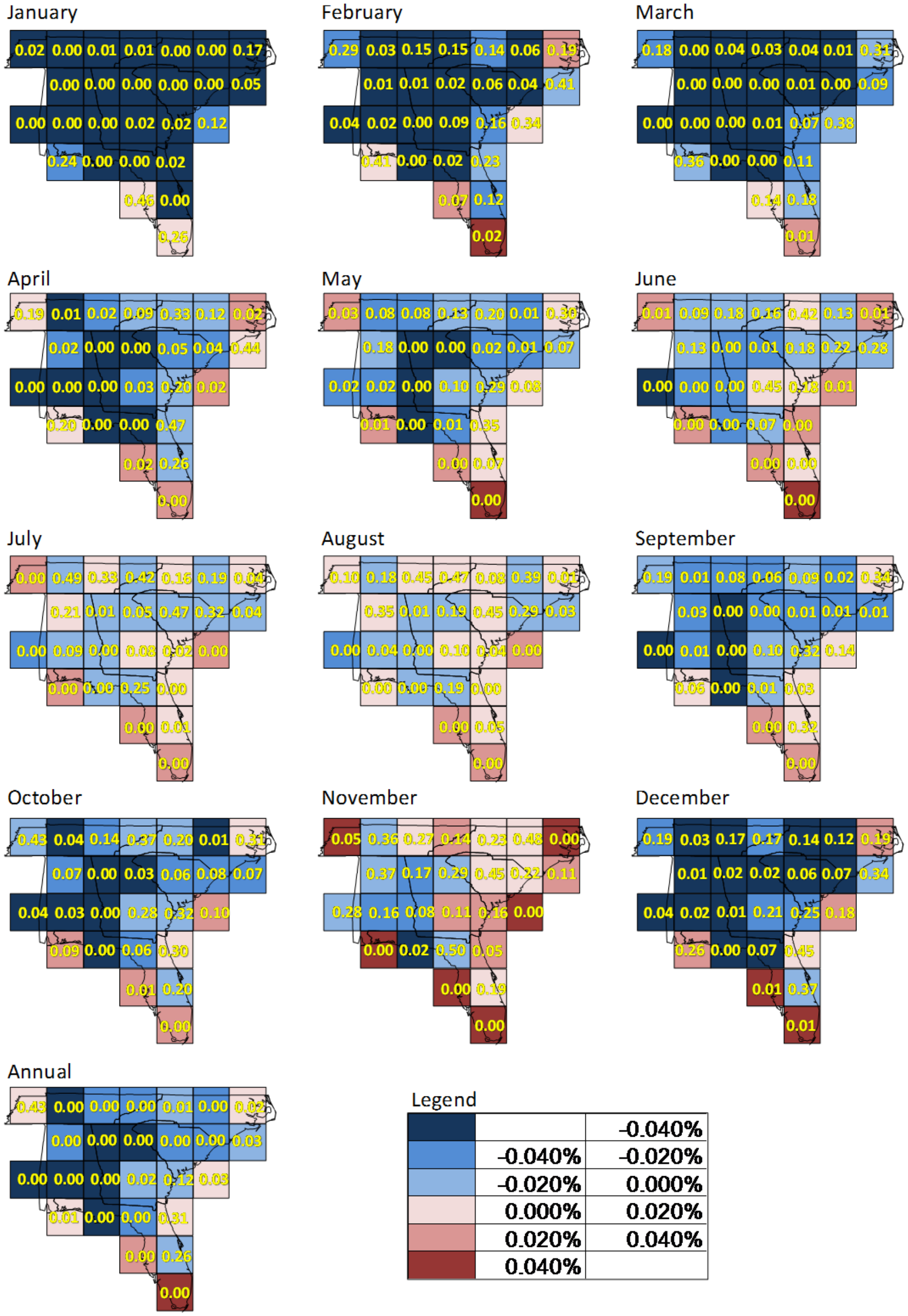
Tmin 1961-2010 Trends



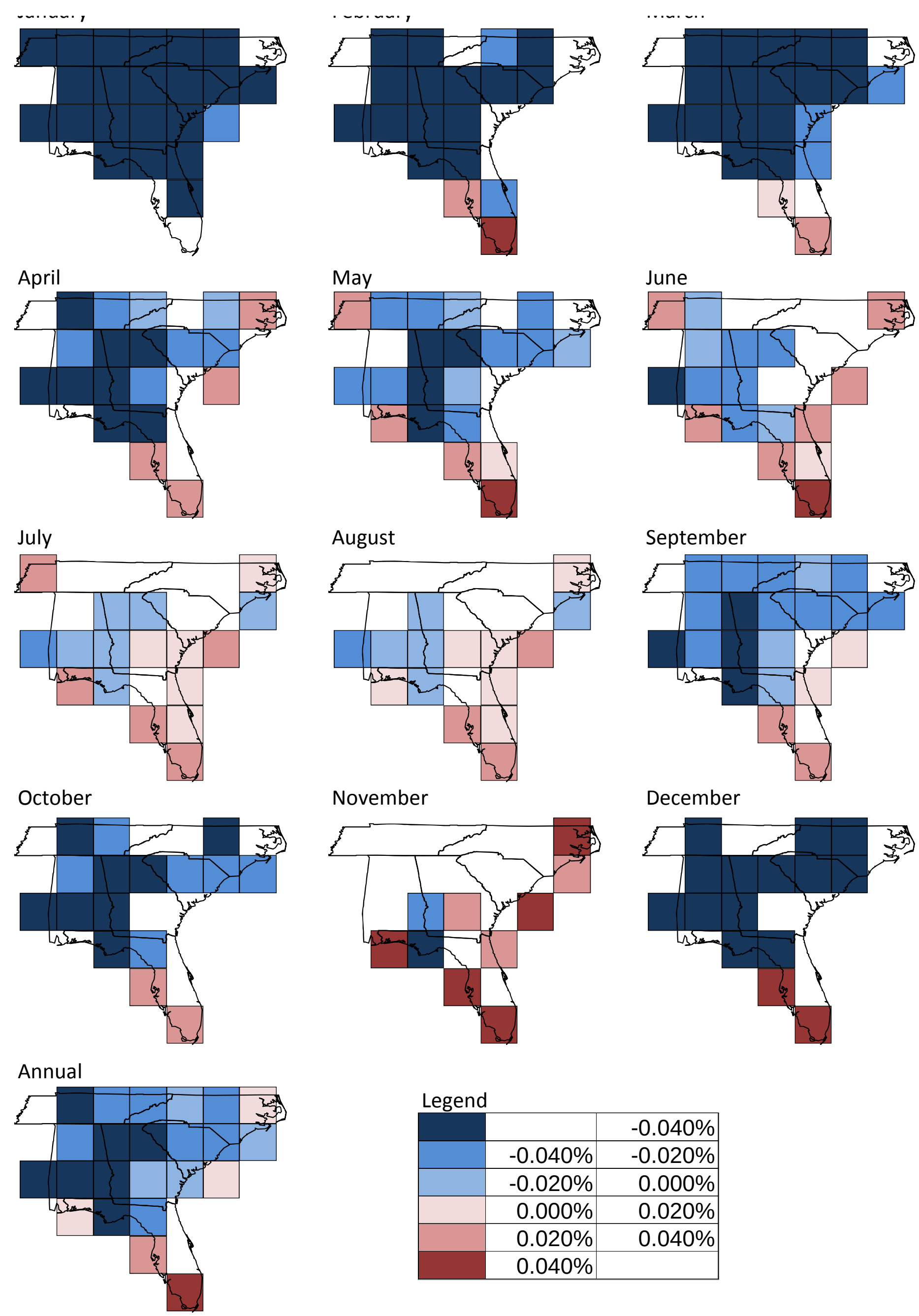
Tmin 1961-2010 Sig Group Trends



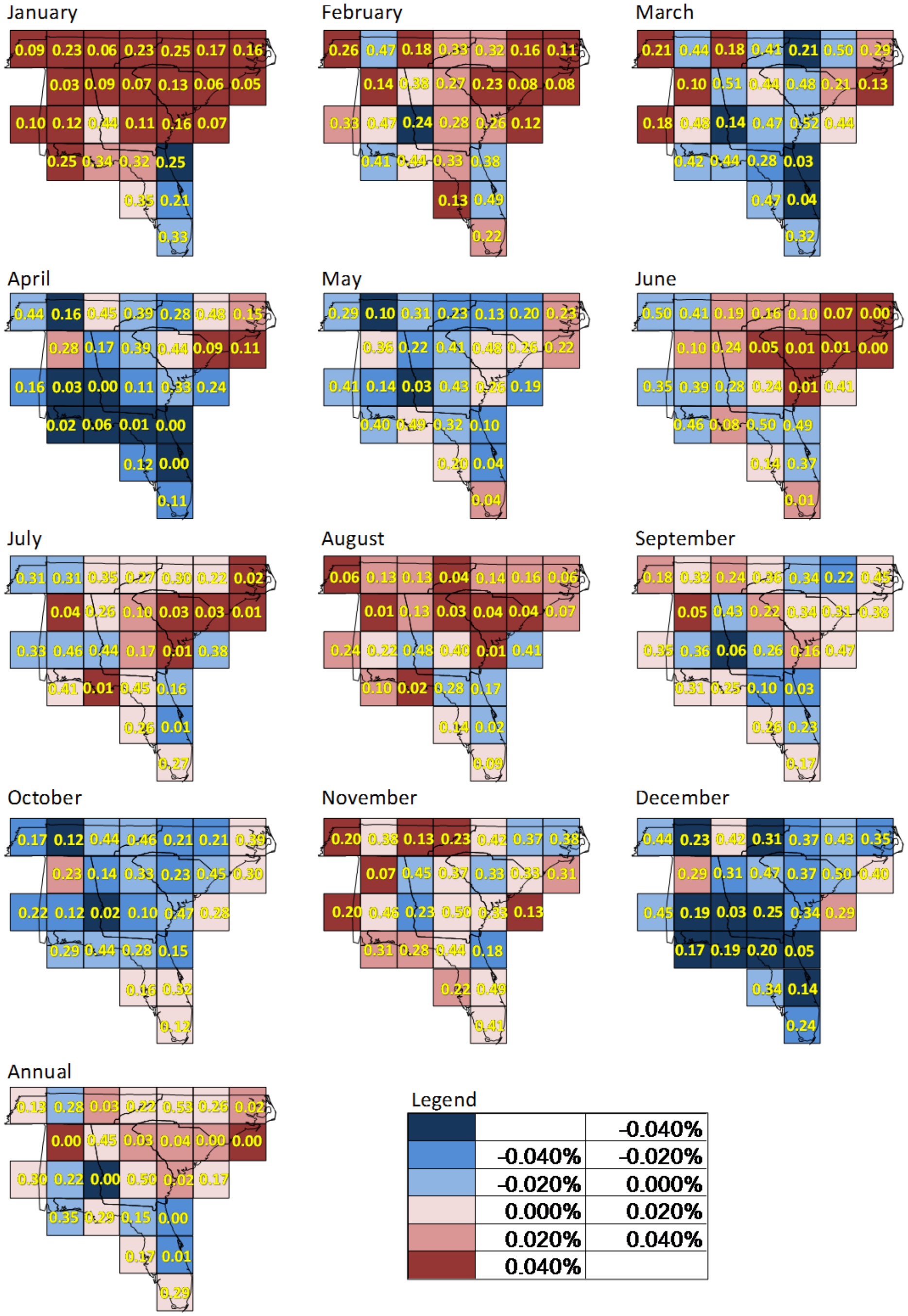
Tmin 1901-2010 Trends



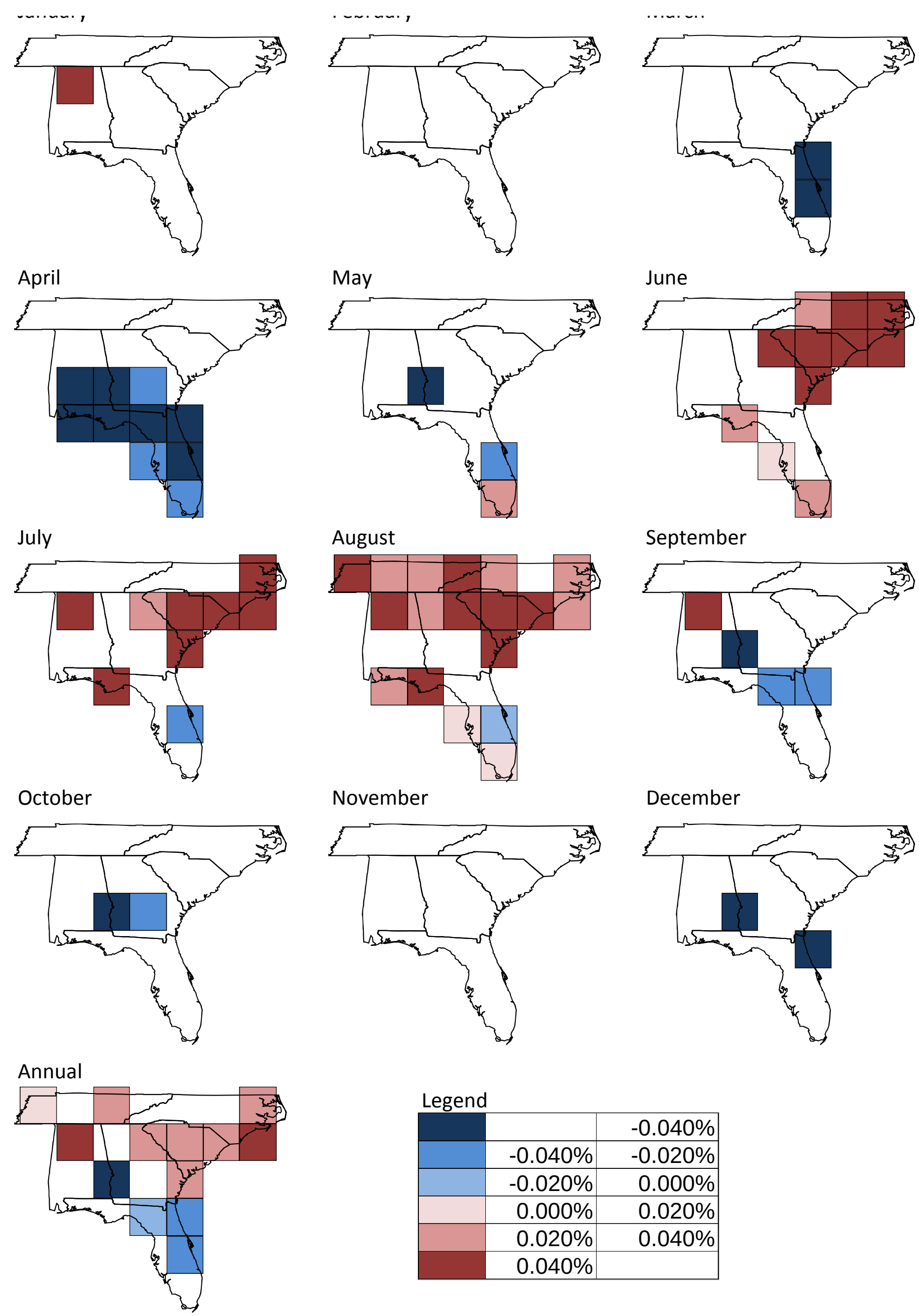
Tmin 1901-2010 Sig Group Trends



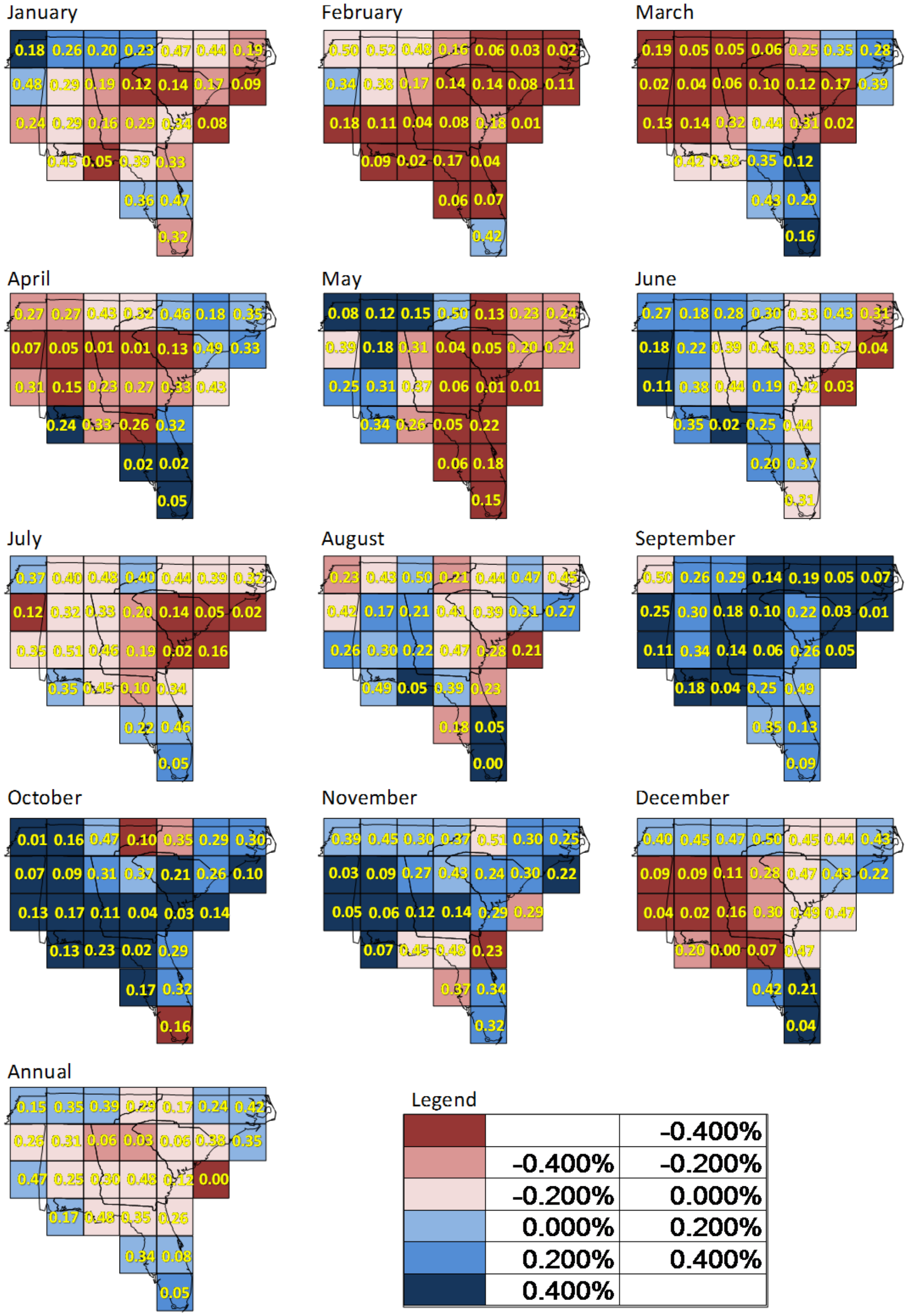
Tmax 1961-2010 Trends



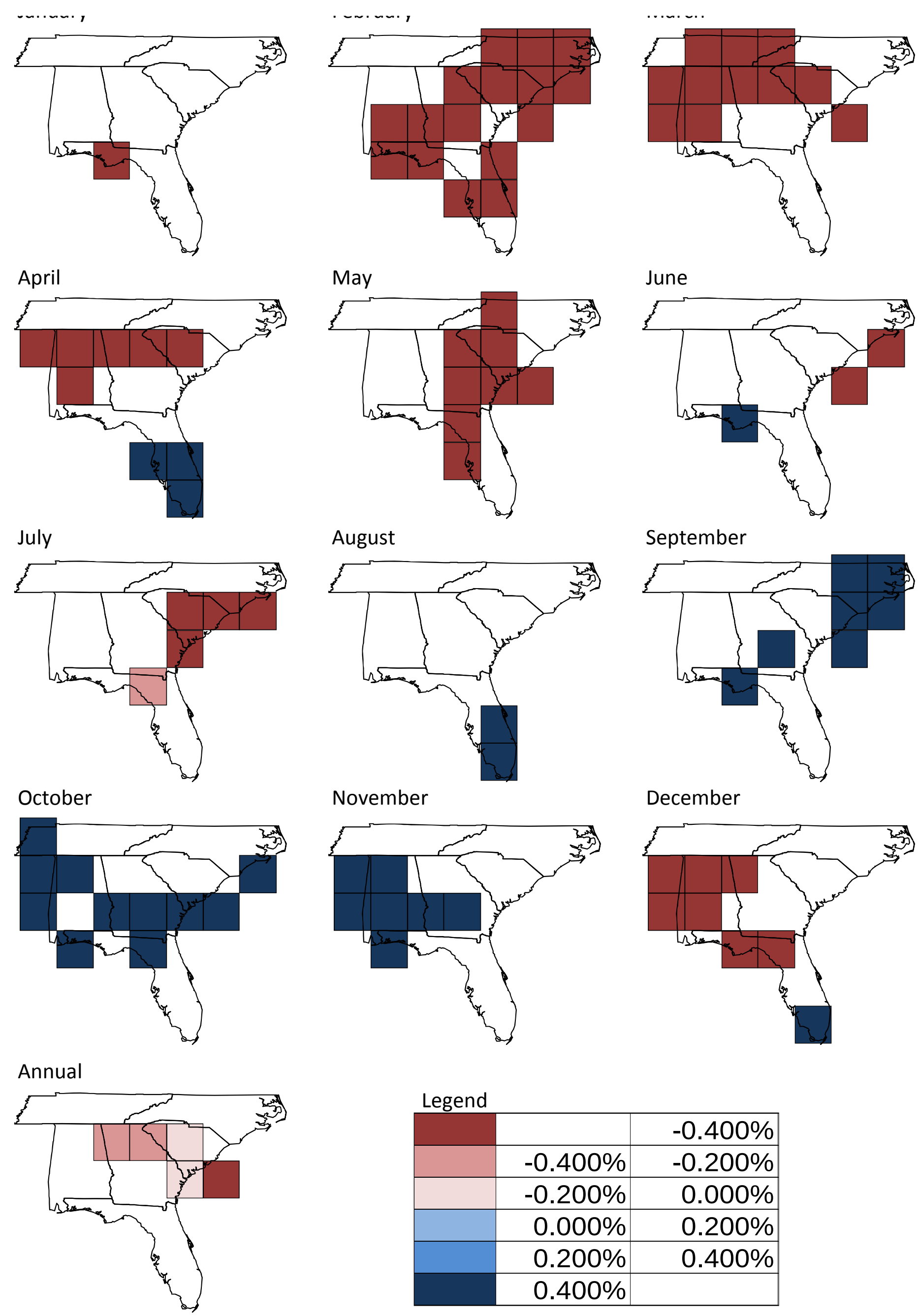
Tmax 1961-2010 Sig Group Trends



Prec 1961-2010 Trends



Prec 1961-2010 Sig Group Trends

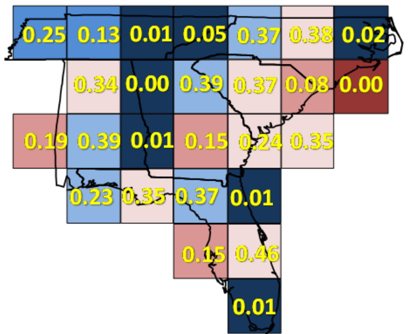


Increase in Number of Consecutive Days over 95 Degrees

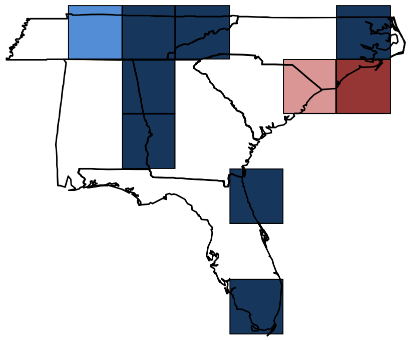
		-0.040%
	-0.040%	-0.020%
	-0.020%	0.000%
	0.000%	0.020%
	0.020%	0.040%
	0.040%	

1901-2010

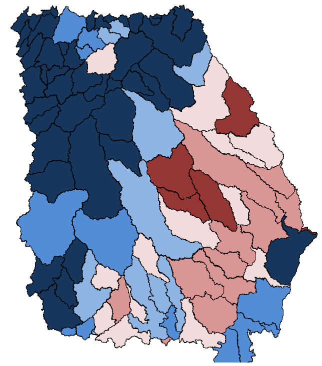
Annual



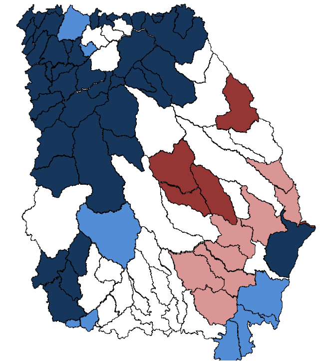
Annual



Annual

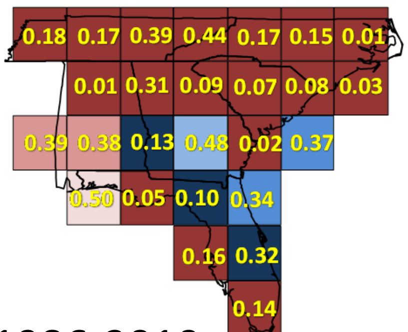


Annual



1961-2010

Annual



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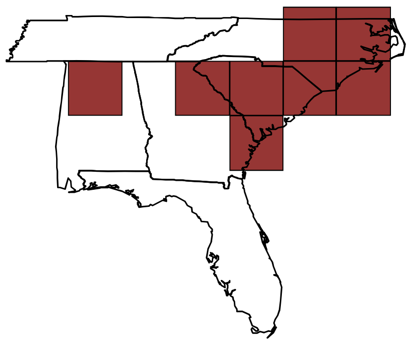

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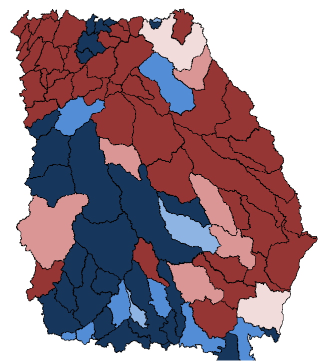
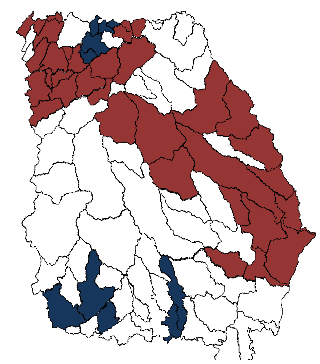
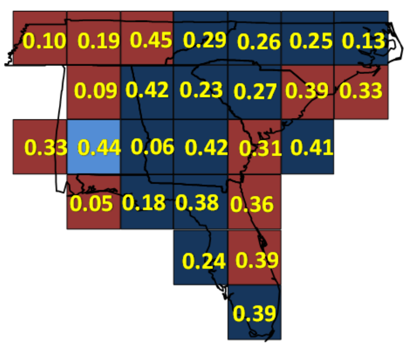


Annual

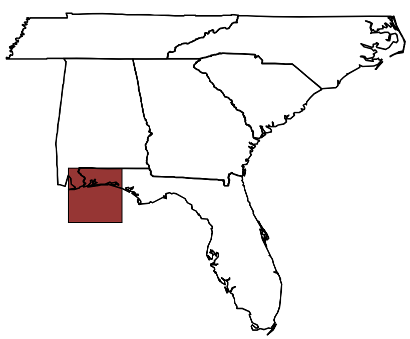


1986-2010

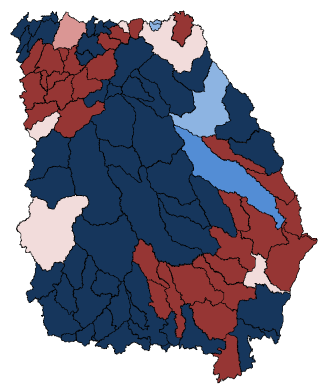
Annual



Annual



Annual



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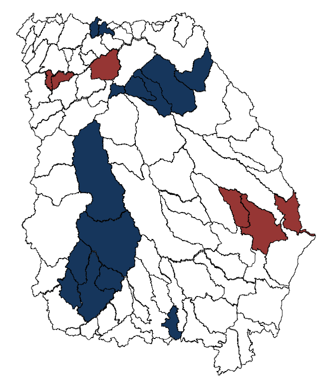
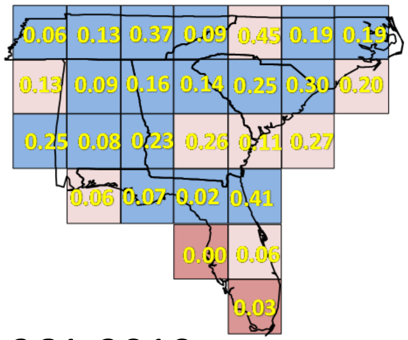


Increase in Number of Consecutive Days with Prec < 3 mm

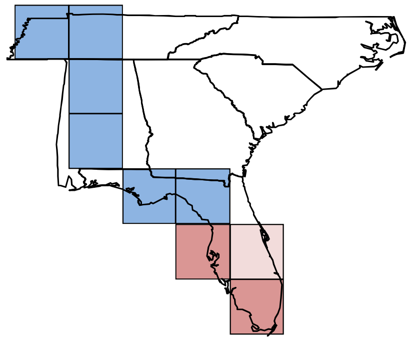
		-0.040%
	-0.040%	-0.020%
	-0.020%	0.000%
	0.000%	0.020%
	0.020%	0.040%
	0.040%	

1901-2010

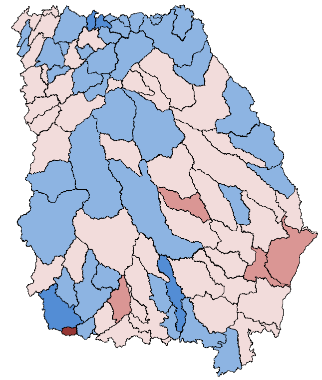
Annual



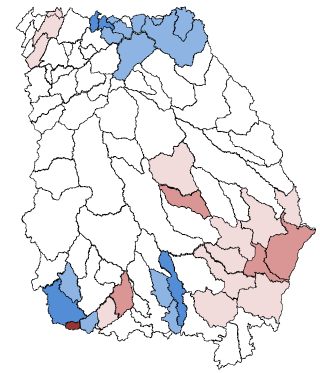
Annual



Annual

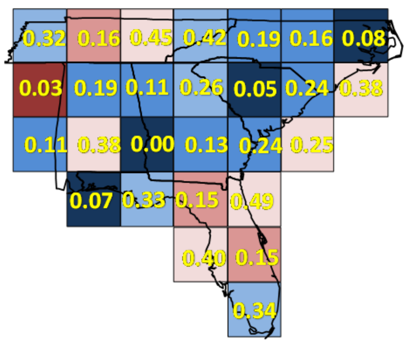


Annual

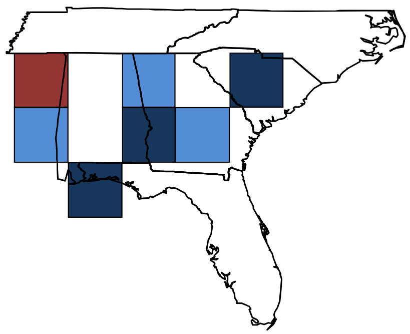


1961-2010

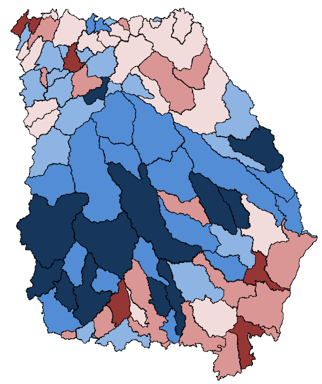
Annual



Annual



Annual



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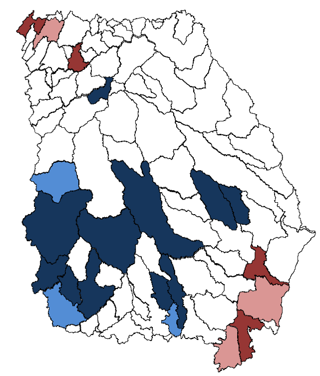
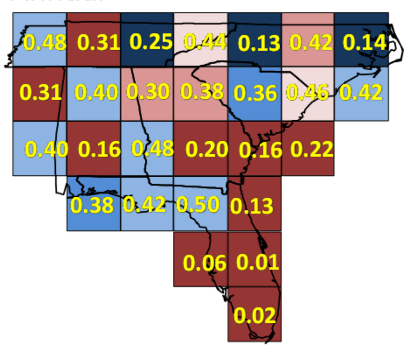


1986-2010

Annual



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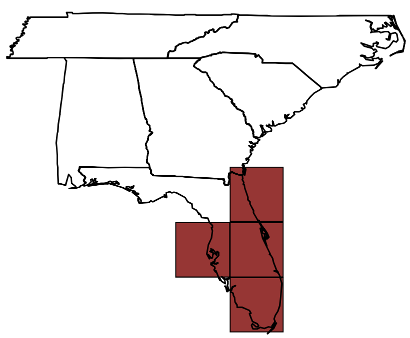

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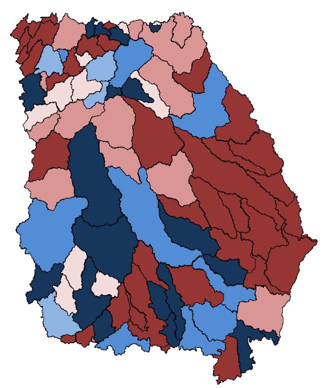

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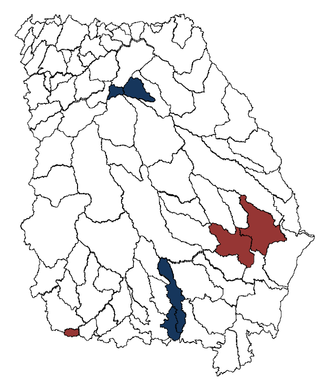
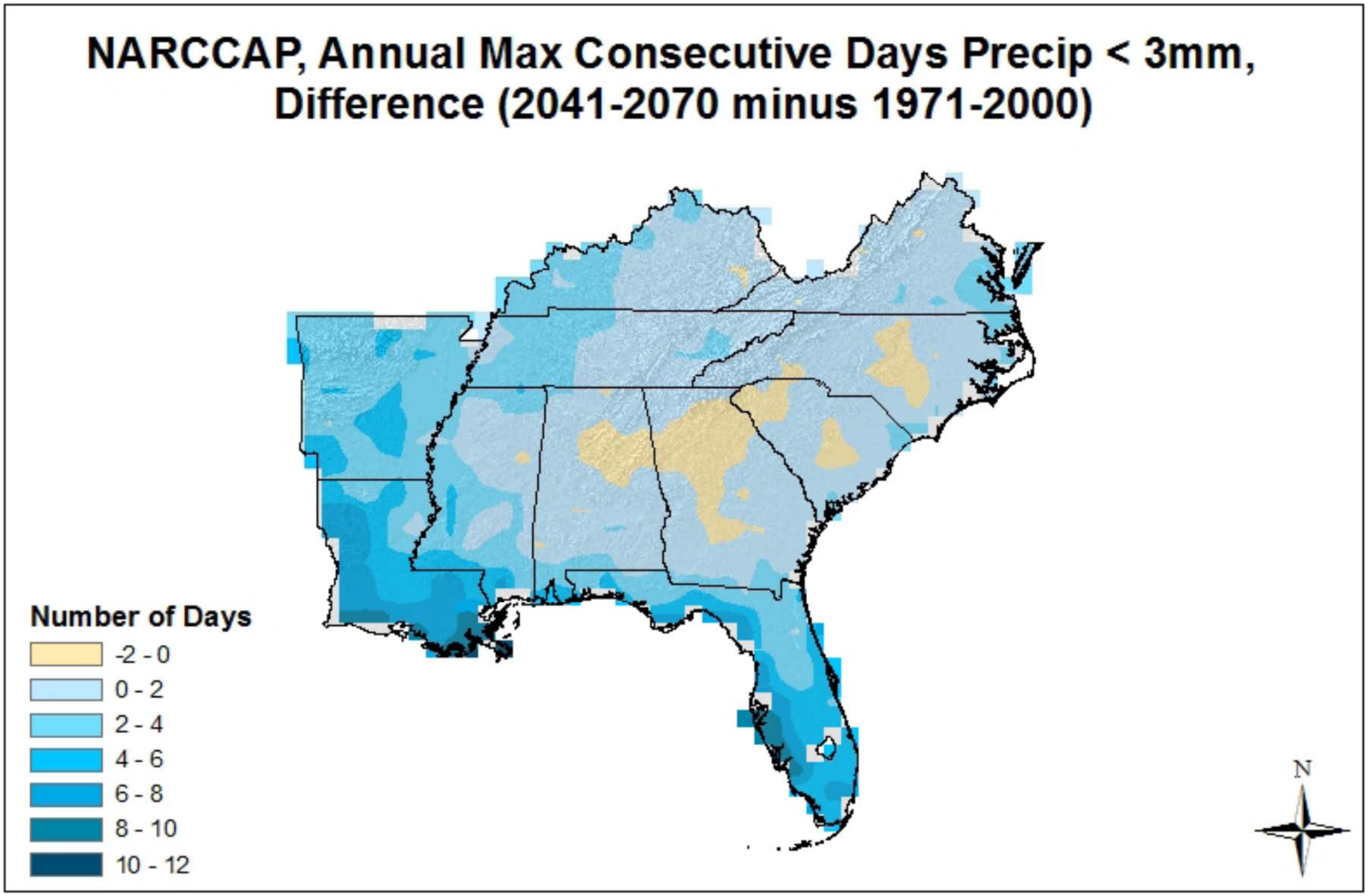


Are these changes significant?



Thank you!

Georgia Tech

The future ain't what it used to be!

Yogi Berra