Climate Change Assessments for Georgia

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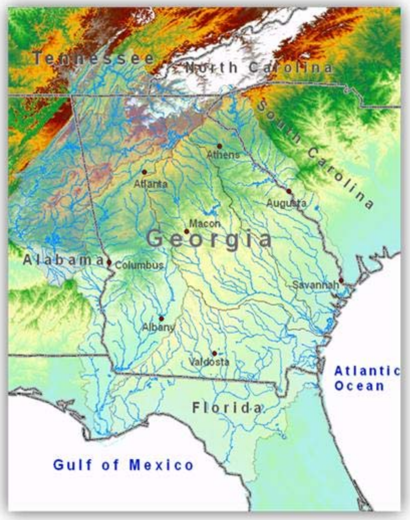
Everglades Workshop, Florida, 29 March 2012



(Sponsored by GA EPD, NOAA, and USGS)

- **Climate Change Impact Assessment Framework**
- **Climate Change Impacts for Major Georgia Basins**
- **ACF Water Resources Assessment**
- **Key Messages**

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Integrated Water Resources Assessment/Planning Framework

Climate - Hydrology - Water Resources - Environment - Energy…

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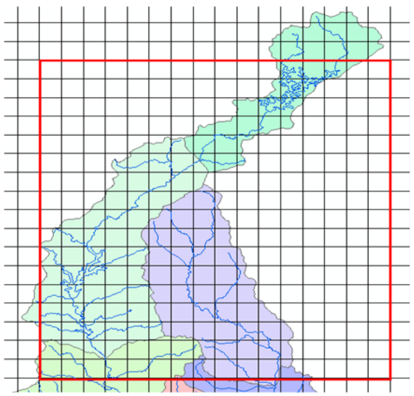
Climate - Sea Level Rise Scenarios & Downscaling
(Historical, Future)

Rainfall, temperature, PET, etc., sequences.

Land Use/Cover Scenarios

Demographic & Socio-Economic Scenarios



OBS Cells (~12 x 12 km^2):
- Monthly & Daily
- 1950-1999 (50 Years);
- Temperature, Precipitation

GCM Cells (~250 x 250 km^2):
- Monthly & Few Daily
- A1B: 2001-2100; (100 Years)
- A2: 2001-2100; (100 Years)

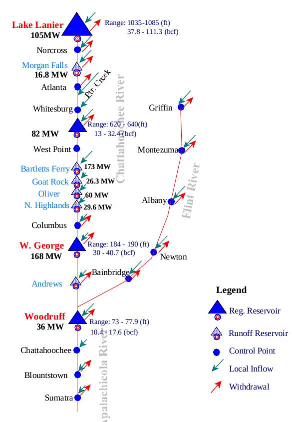
Hydrologic Response
Surface/Ground/WQ

Soil moisture, ET, runoff, aquifer recharge, WQ, etc.

Sectoral Demand Targets, Metrics
WS (urbn/ag/ind), Enrgy, Fisheries, Nav, Env.…
Mgt./Adapt. Options

River-Reservoir-Aquifer-Estuary Response

Actual water use levels, recreation, hydro-thermal enrgy, env. flows, lake/aquifer levels, fisheries, …



Environ. - Socioeconomic Impact Assessments

Risks/Vulnerabilities/Tradeoffs
(by sector and region)

Stakeholder Processes
Consensus Building
Shared Vision Mgt. Policies, Adaptation Measures, Indicators

Georgia Basins

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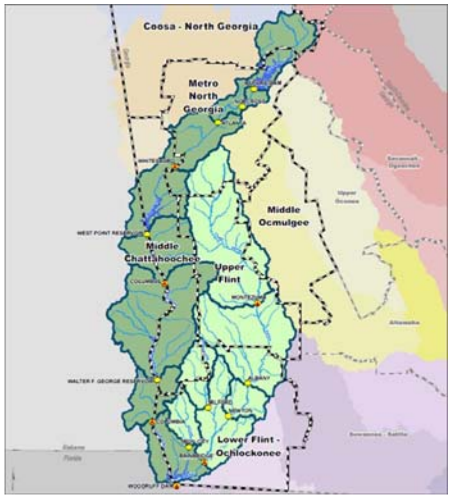
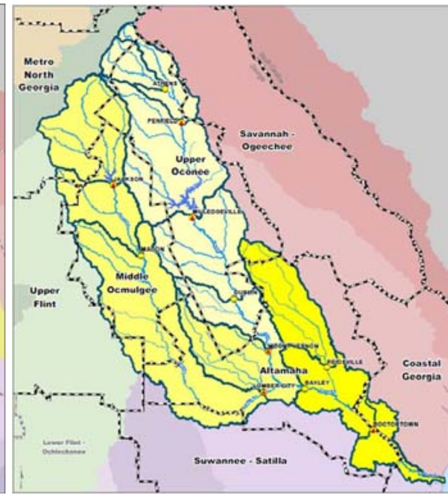
Tennessee

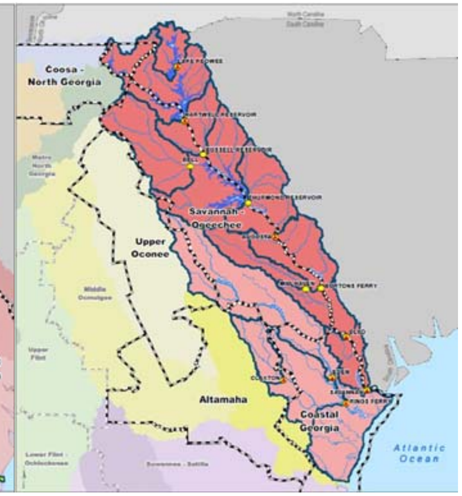
Etowah - Upper Coosa



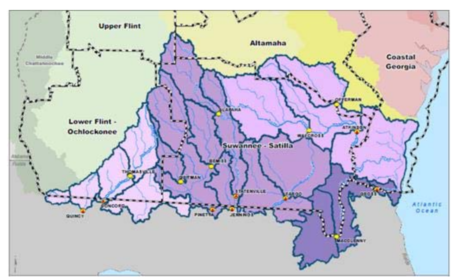
Apalachicola - Chattahoochee - Flint



Oconee - Ocmolgee - Altamaha



Savannah - Ogeechee



Ochlocknee - Suwannee - Satilla - St Mary's

Focus on ACF, OOA, SO, and Upper ACT

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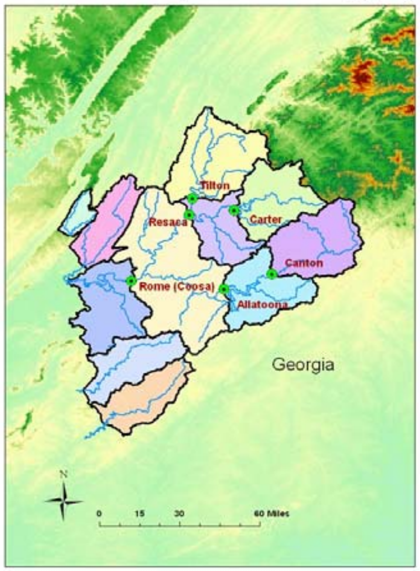
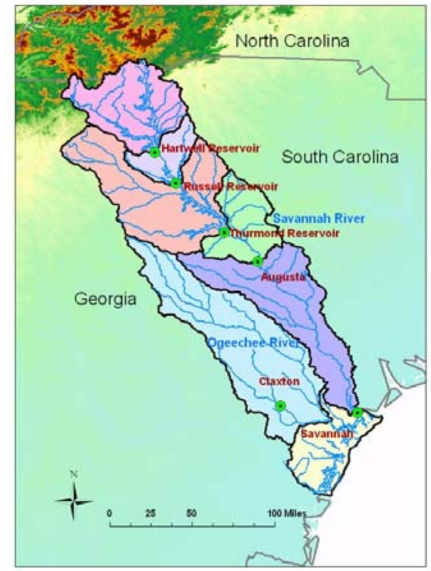
Alabama/Coosa/Tallapoosa River Basin (Upper)



Apalachicola/Chattahoochee/Flint River Basin

Ocmulgee/Oconee/Altamaha River Basin

Savannah/Ogeechee River Basin



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Global Circulation Models and Scenarios

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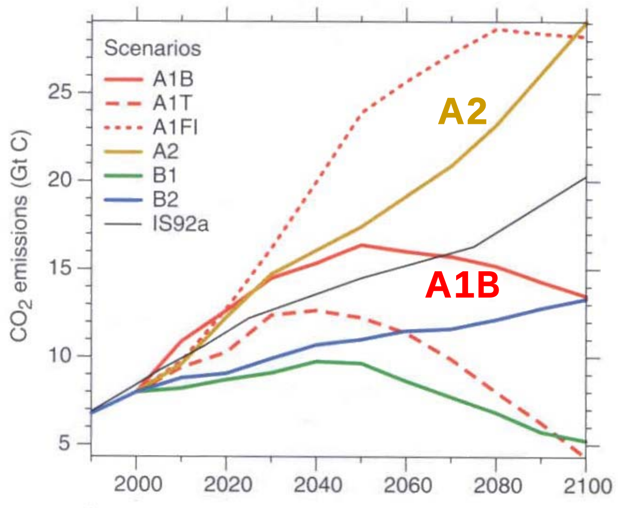
GCMs

Model	Contributor	Atm. Resolution	Ocean Resolution
BCCR-BCM2.0, Norway	Bjerknes Centre for Climate Research	T63L31	1.5 x1.5°, L31
CGCM3.1(T63), Canada	Canadian Centre for Climate Modeling and Analysis	T63L31	1.4°x0.9°, L29
CNRM-CM3, France	Centre National de Recherches Meteorologiques	T63L45	2.0°x1.2°
CSIRO-Mk3.5, Australia	CSIRO, Australia	T63L18	1.875°x0.84°
ECHAM5/MPI-OM, Germany	Max Planck Institute for Meteorology	T63L31	1.5°x1.5°, L40
GFDL-CM2.1, USA	Geophysical Fluid Dynamics Laboratory, NOAA	2.5°x2.5°	1°x1°
GISS-AOM, USA	NASA Goddard Institute for Space Studies	4°x3°, 12L	4°x3°, L16
MIROC3.2(hires), Japan	CCSR/NIES/FRCGC, Japan	T105L56	0.28°x0.19°, L47
CCSM3, USA	National Center for Atmospheric Research (NCAR),	T85L26	1.125°x(0.27° -1.0°)
PCM, USA	NCAR, NSF, DOE, NASA, NOAA	T42L26	1.125°x0.469°, L40
UKMO-HadCM3, UK	Hadley Centre for Climate Prediction and Research	2.75°x2.75°	1.25°x1.25°
MIUB ECHO-G, Germany/Korea	Meteorological Institute of the University of Bonn	T30L19	T42
INM-CM3.0, Russia	Institute for Numerical Mathematics	N.A.	N.A.

Emission Scenarios



13 GCMs x 2 Emission Scenarios = 26 Future Climates

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Downscaling

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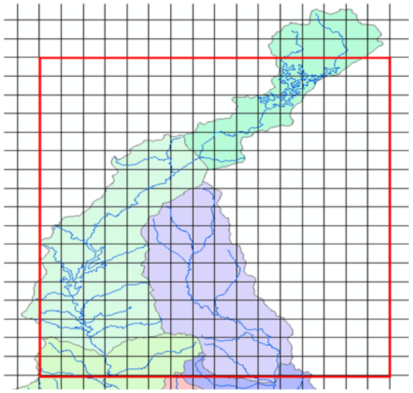
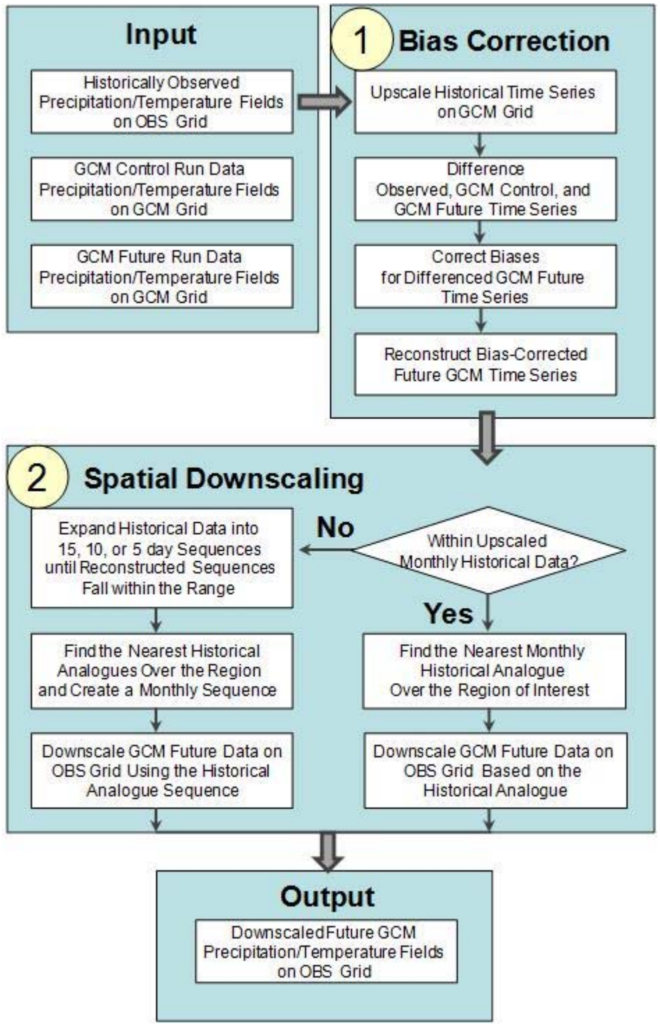
Need



OBS Cells (~12 x 12 km^2):
- Monthly & Daily
- 1950-1999 (50 Years);
- Temperature, Precipitation

GCM Cells (~250 x 250 km^2):
- Monthly & Few Daily
- A1B: 2001-2100; (100 Years)
- A2: 2001-2100; (100 Years)

Approach – JVSD



Key Features

- **Joint downscaling of P and T.**
- **Simultaneous downscaling of all sub-basins within a major basin.**
- **Represents spatial/temporal variability relationships**
- **Compares favorably against existing statistical and dynamic downscaling methods.**

Zhang, F. and A. P. Georgakakos (2012): "Joint Variable Spatial Downscaling," *Climatic Change*, 111(3), Page 945-972. Also, on line reference doi.org/10.1007/s10584-011-0167-9, 2011.

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Downscaling Example

Canadian GCM – A1B Emission Scenario

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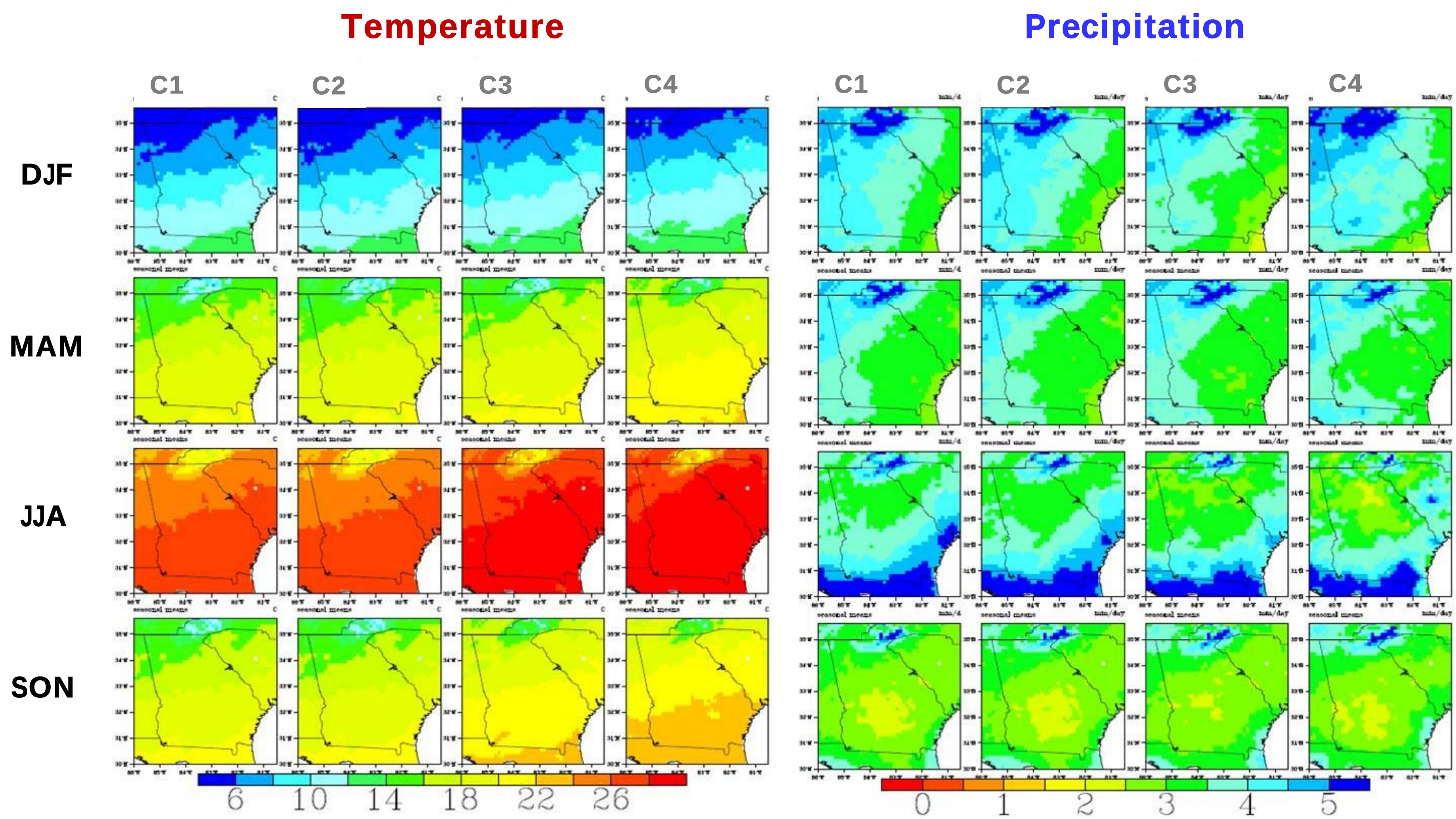

C1: Observations for the period 01/1950 - 12/1999;
C2: JVSD downscaled data using input from the period 01/1950 - 12/1999;
C3: JVSD downscaled data using input from the CGCM3.1-run1-A1B Scenario for the period 01/2000 - 12/2049;
C4: JVSD downscaled data using input from the CGCM3.1-run1-A1B Scenario for the period 01/2050 - 12/2099.

GWRI Watershed Model

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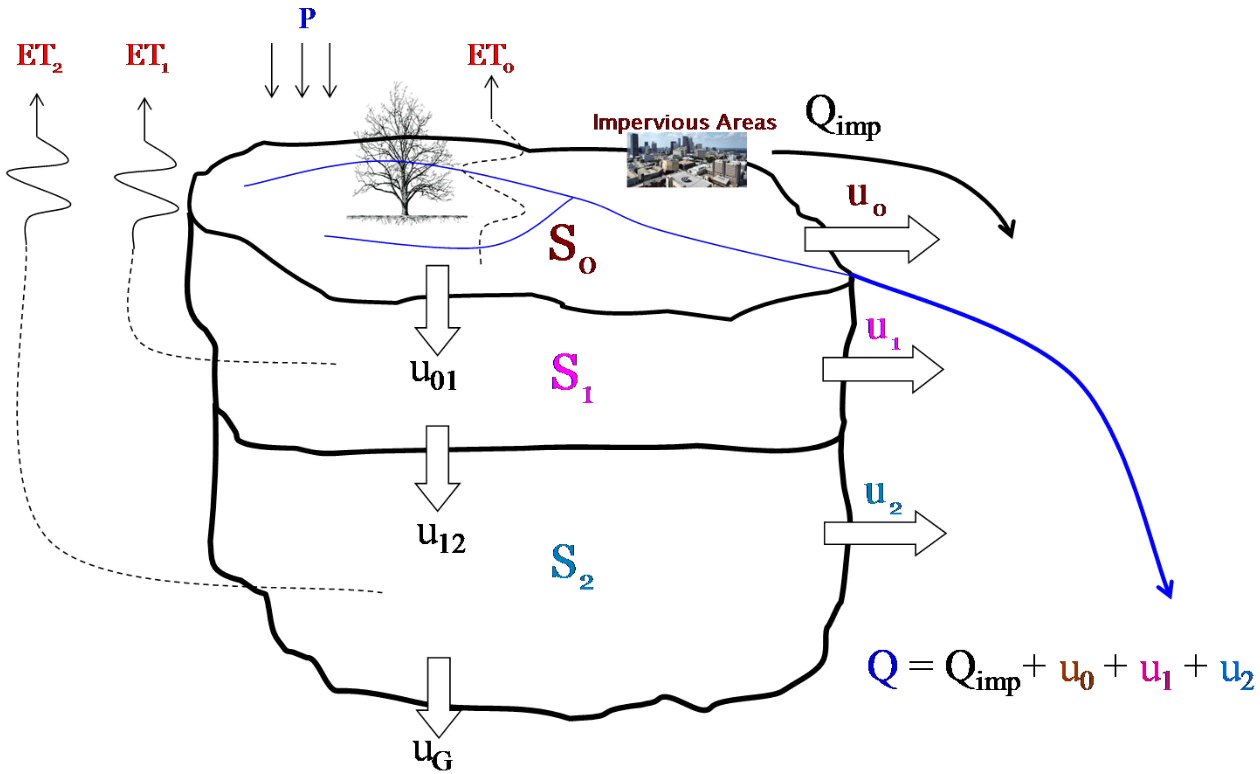

Available Observations: P, T, PET, Q, Area, Terrain, Land Cover.
Model Calibration: Storage capacities, runoff functions, and percolation functions.
Model Outputs: S_0, S_1, S_2, ET_0, ET_1, ET_2, u_0, u_1, u_2, Q.

- **Primary Parameters: Storage Capacities, Impervious Area**
- **Storage-Release and Percolation Functions Inferred from Data**
- **New Parameter Estimation Procedure Based on Control Theory** (*Georgakakos et al., 2011, Appendix B*).

Watershed Model Calibration Results for Buford

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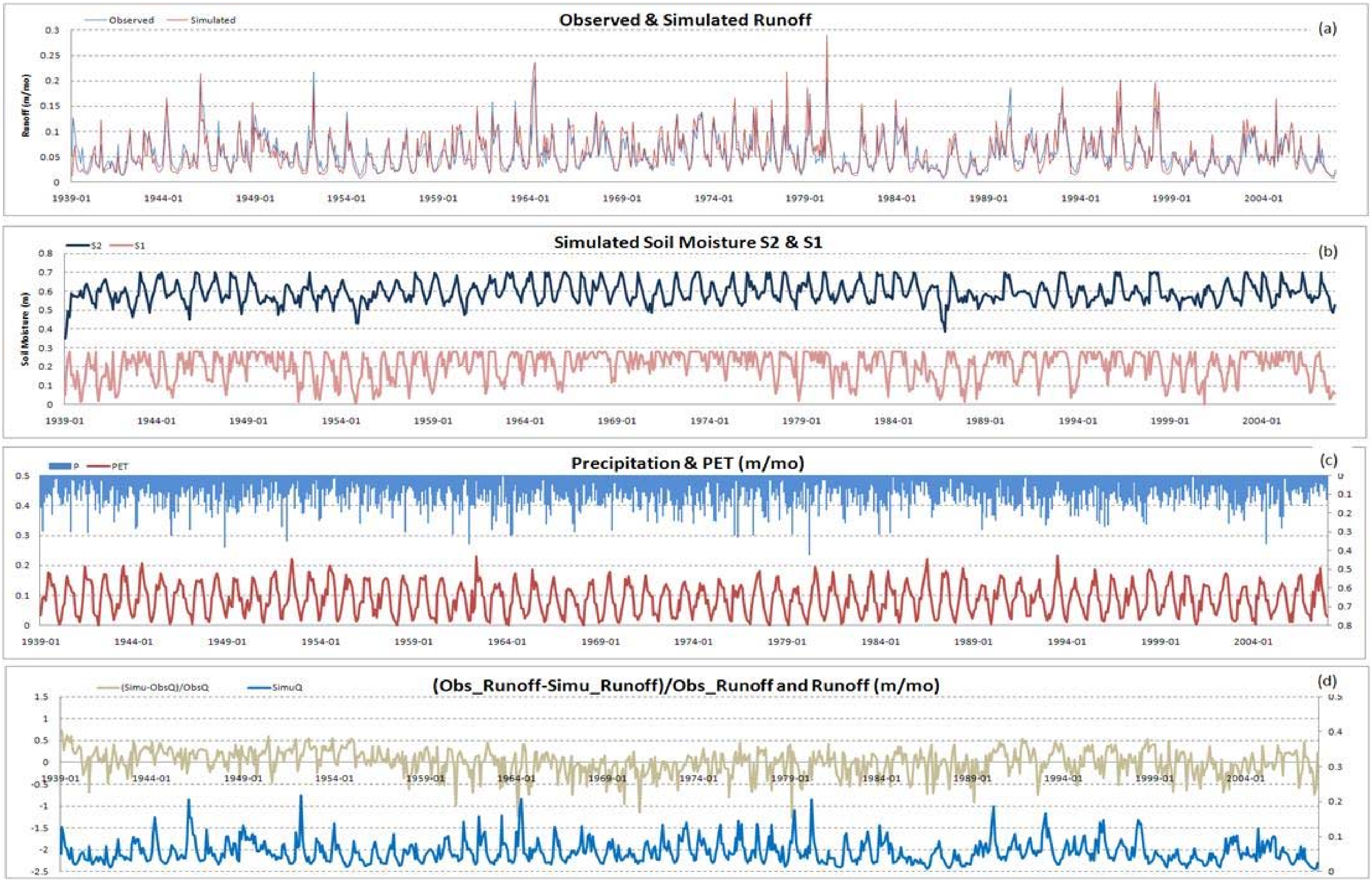

Figure B-16: Hydrological Simulation for Buford Watershed: (a) Observed Versus Simulated Runoff, (b) Simulated Soil Moisture for the Lower and Upper Storages, (c) Precipitation and PET as Inputs, and (d) Normalized Runoff Simulation Errors.

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Improvement of Monthly PET Estimation Approach

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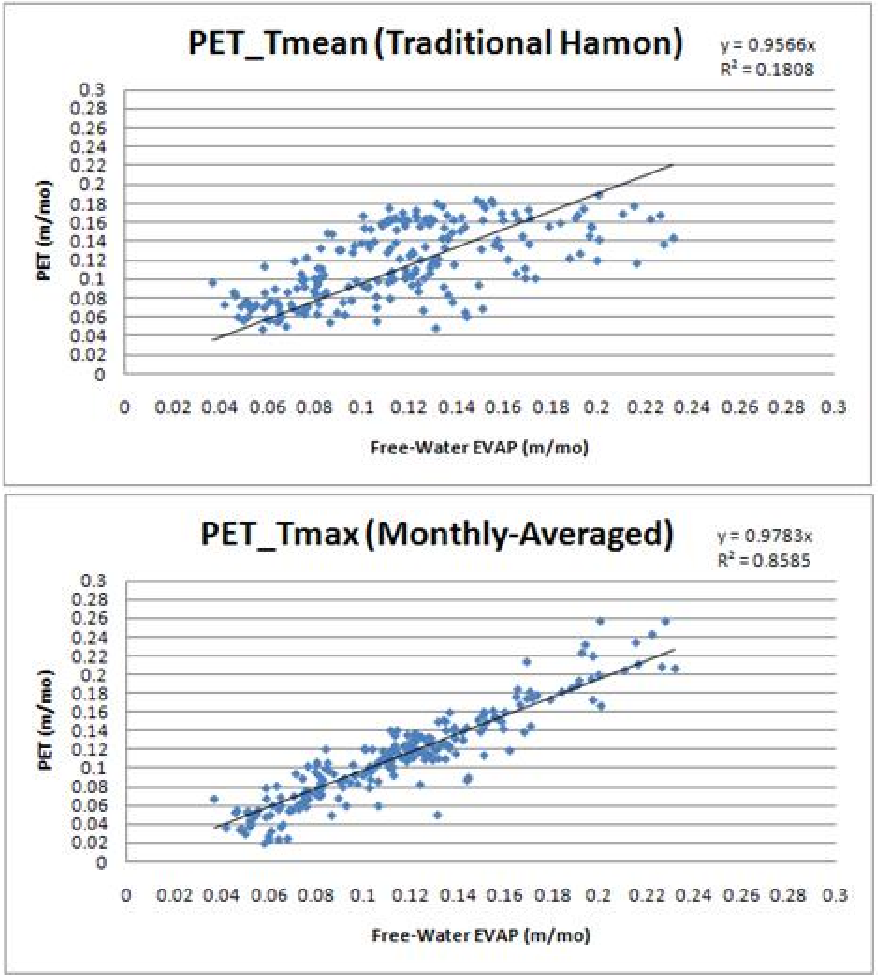

Figure B-11: Comparison of Two PET Calculation Approaches for Station 381770: (1) Using the Traditional Hamon's Equation (top), and (2) Using the Modified Hammon's Method (bottom). (Georgakakos *et al.*, 2011).

Historical Watershed Response – ACF Watersheds

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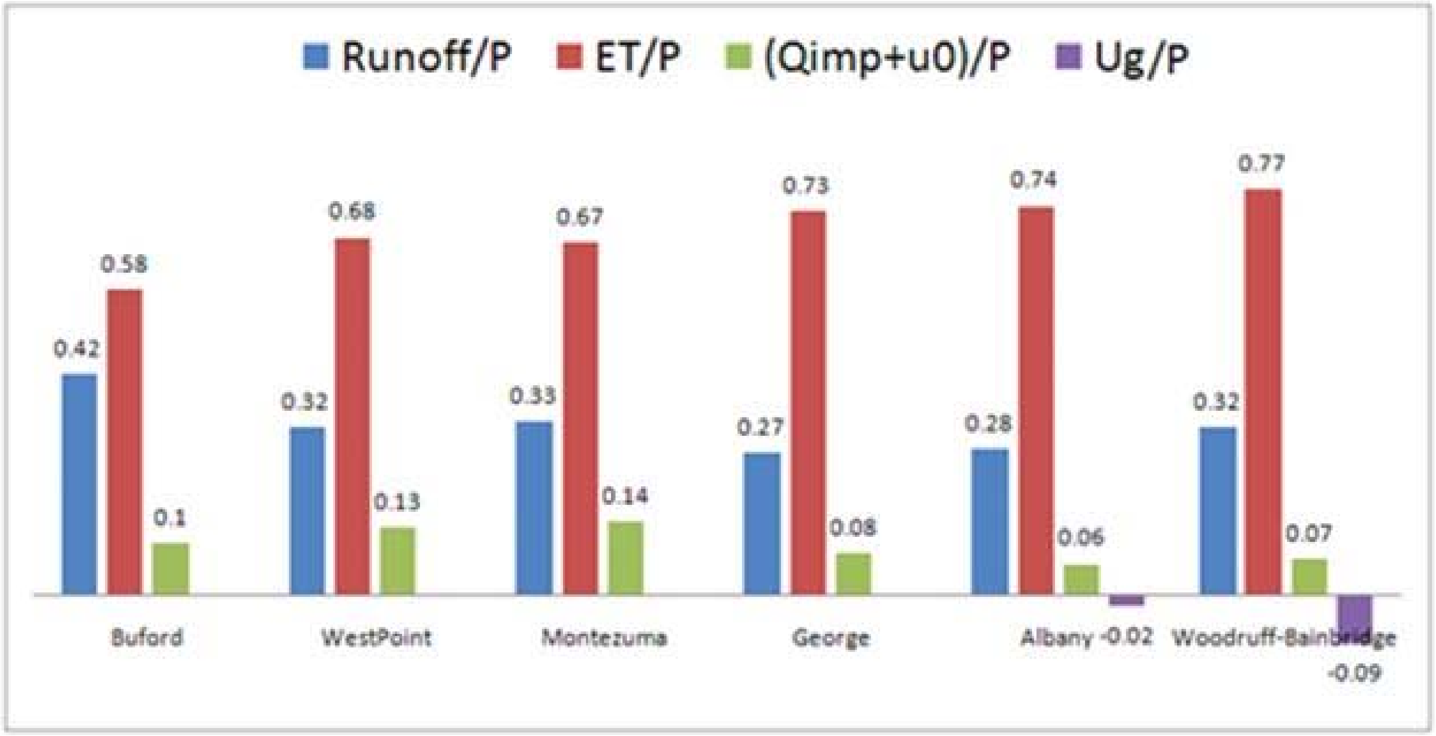

Figure B-26: Average Hydrologic Response by Watershed (1901 - 2009) with including Groundwater Recharge flux Ug.

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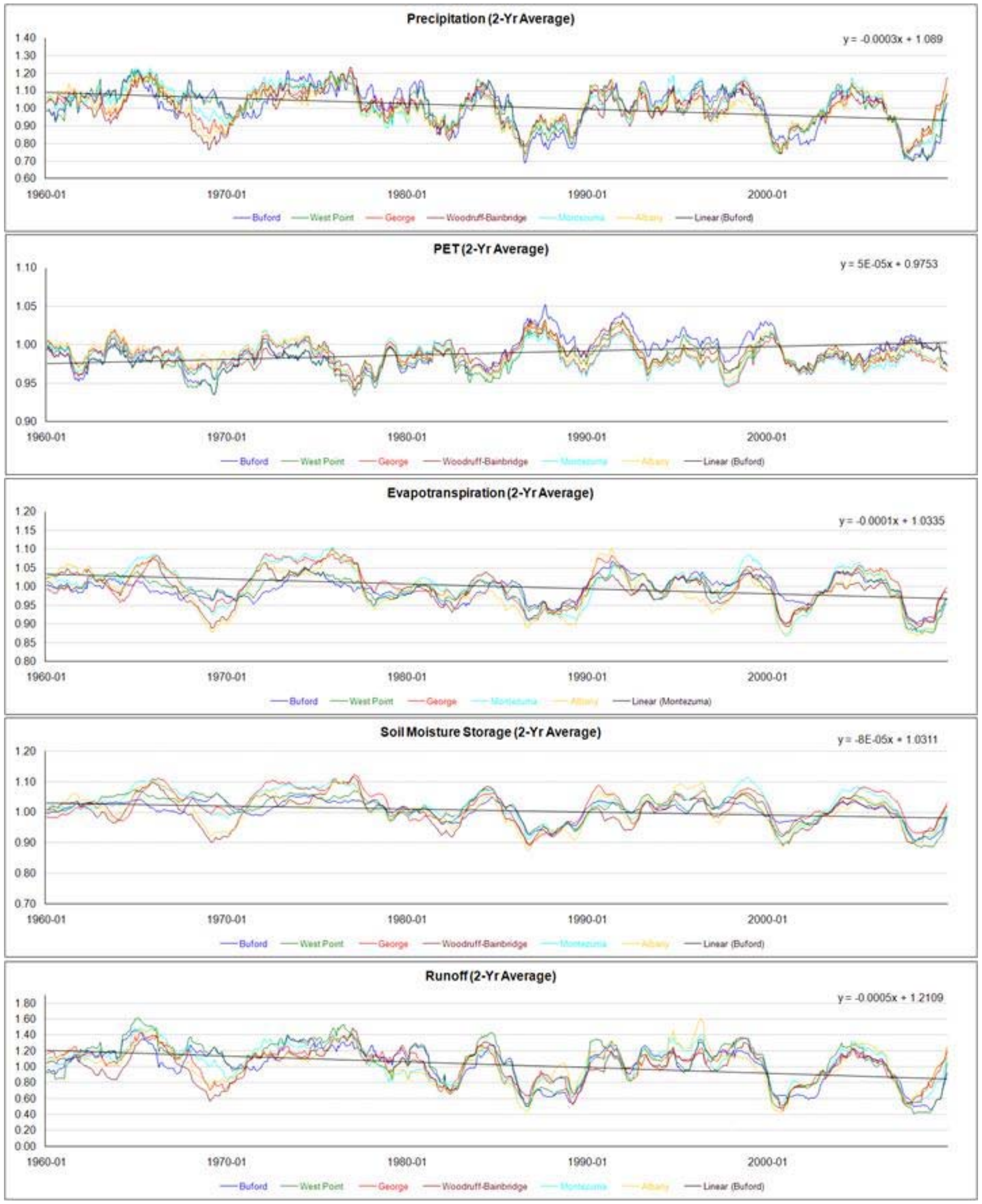
Historical Climate Assessments - ACF



Key Findings

- **Precipitation exhibits a declining trend of about 9% - 16% across all ACF watersheds;**
- **PET exhibits an increasing trend of about 1% - 3% across all ACF watersheds (except for George where it decreases by about 0.8%);**
- **Soil moisture declines by about 3% - 6% across all watersheds; and**
- **Runoff declines by about 16% - 27% across all watersheds.**

Figure 3.3: ACF Normalized, 2Yr Average Hydrologic Response (1960 - 2009).

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Future Climate Assessments – ACF/Buford-Annual

Key Findings

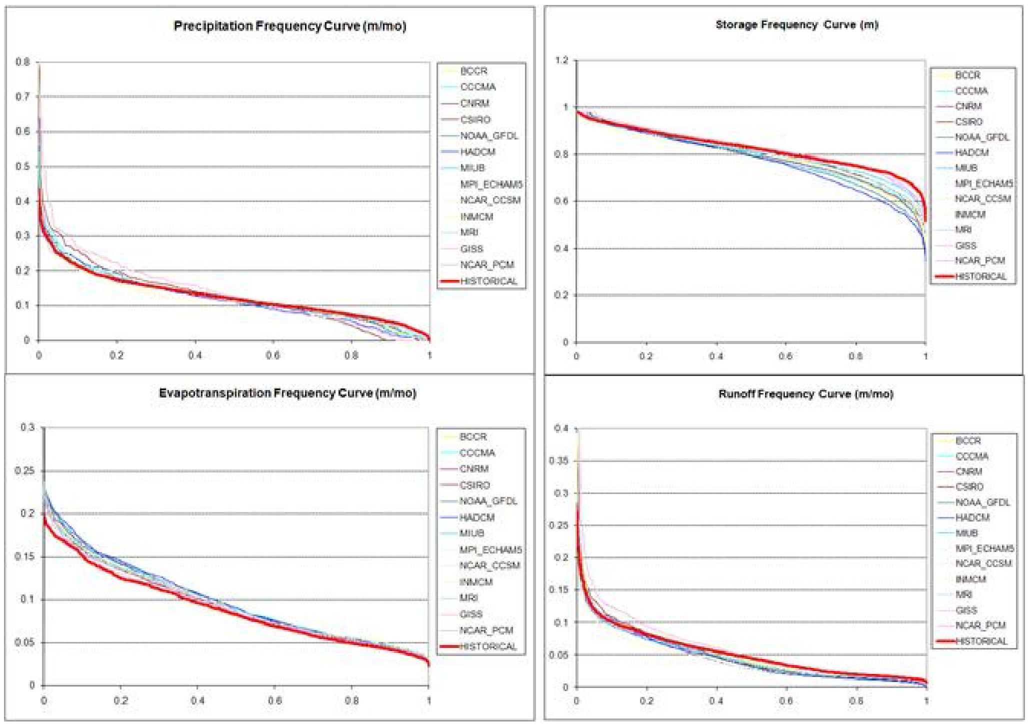

Figure 3.5: A2 Climate Scenarios (2000-2099), Buford, Frequency Curves.

- **Average precipitation is not expected to change significantly.**
- **The precipitation distribution is expected to "stretch" becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 15% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, Buford future floods and droughts will be more severe than those experienced in the historical past.**

Future Climate Assessments – ACF/Buford-Monthly

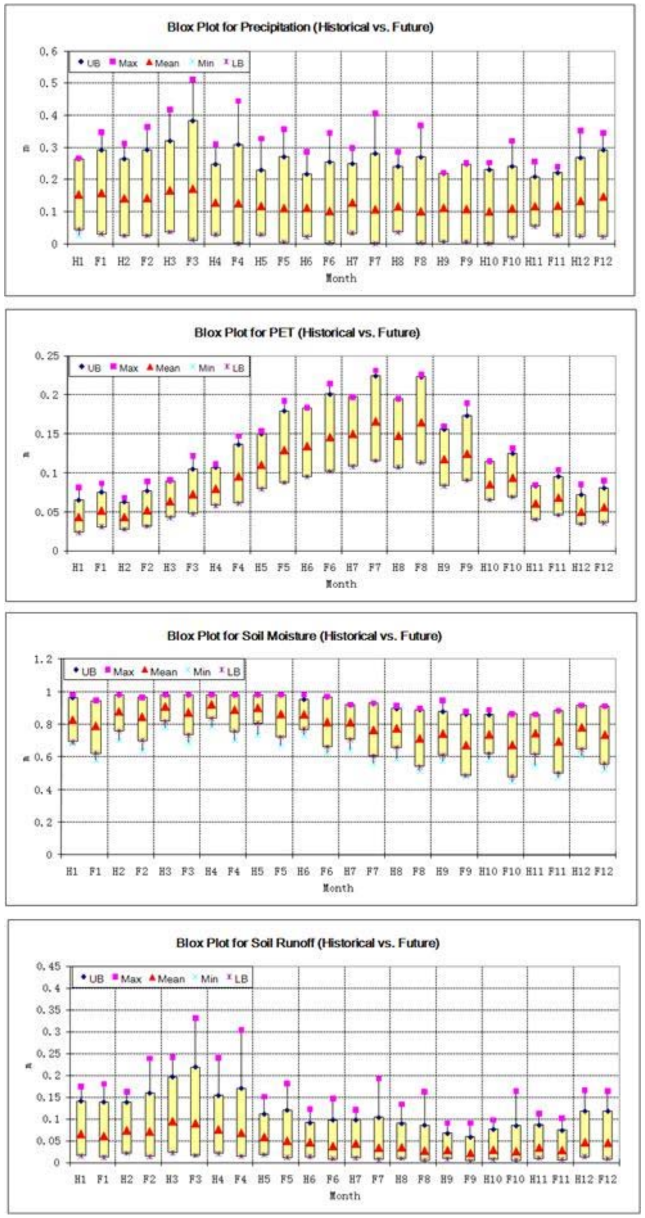

Figure 3.7: Monthly Historical vs. Future (A2) Watershed Response, Buford. (P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

Key Findings

- **Mean watershed precipitation shows clear decline trends in June, July, and August, but it does not show any appreciable change for the other months of the year. However, the precipitation distributions for January through September are considerably extended (toward both ends) in comparison to the historical distributions.**

- **Future PET exhibits higher mean and wider range than historical PET from February to September, with the largest change observed in July and August. For these two months, the future mean PET is higher than the historical PET by up to 12%, while the quartile range of the future distribution exceeds that of the historical by nearly 20%.**

- **Future soil moisture is clearly lower than its historical levels in almost all months. The decline is more pronounced in late summer and fall months (exhibiting a 6% - 10% declining trend).**

- **Future Buford runoff is drier that historical in all months of the year (A2 scenarios).**

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Future Climate Assessments – ACF/Woodruff-Annual

Key Findings

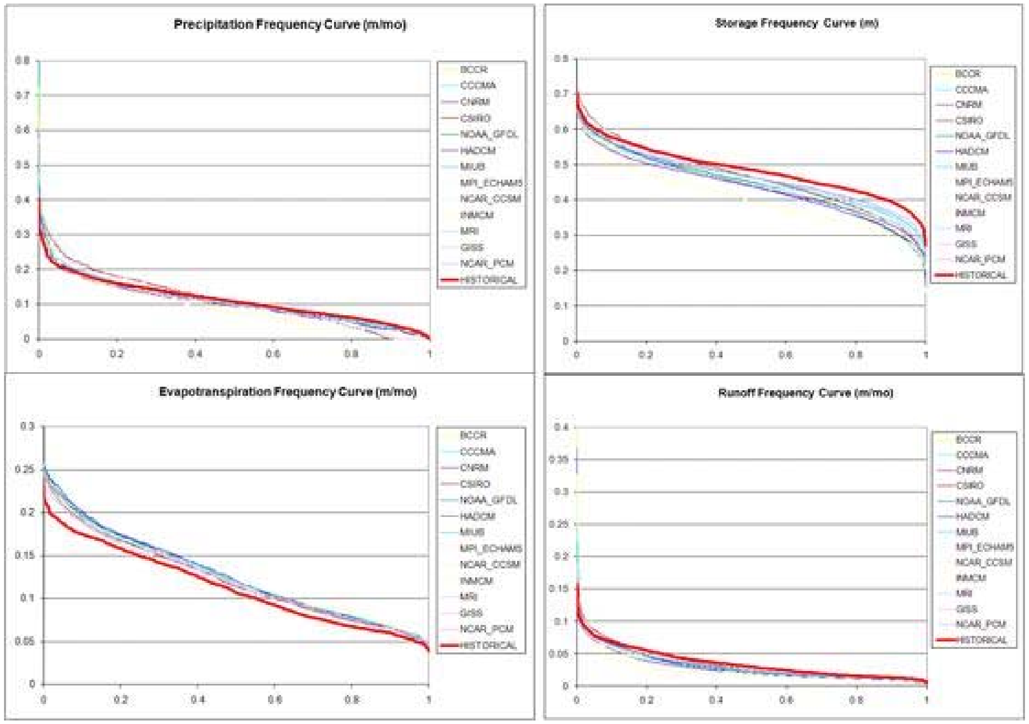

Figure 3.25: A2 Climate Scenarios (2000-2099), Woodruff-Bainbridge, Frequency Curves.

- **Average precipitation is not expected to change significantly.**
- **The precipitation distribution is expected to "stretch" becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 8% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, Woodruff-Bainbridge future floods and droughts will be more severe than those experienced in the historical past.**

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Future Climate Assessments – ACF/Woodruff-Monthly

Key Findings

- **Mean precipitation exhibits a decreasing trend in early spring (January, February, and March) and summer (June, July, and August) of about 9%. (Buford did not show such significant trends in early spring.)**

- **Future PET exhibits higher mean and wider range than historical PET with the largest change observed in July and August. For these two months, the future PET is higher than the historical PET by up to 15%. (This trend is somewhat larger than that of Buford.)**

- **Future soil moisture is lower than historical in most months. This change is more pronounced for summer and fall, and it is larger than in Buford. The average soil moisture reduction reaches up to 11%. Even more critical is the significant decline of the future low soil moisture levels (as indicators of agricultural droughts). Summer months are particularly impacted, with implications that cannot be ignored for the southeast economy.**

- **Noticeable mean runoff reductions begin in January and extend through July. In spring and early summer, the mean runoff reduction is 9 -16%. (More severe reduction than Buford). In late summer and fall months, the runoff reduction is about 6% - 16%. (Larger than Buford).**

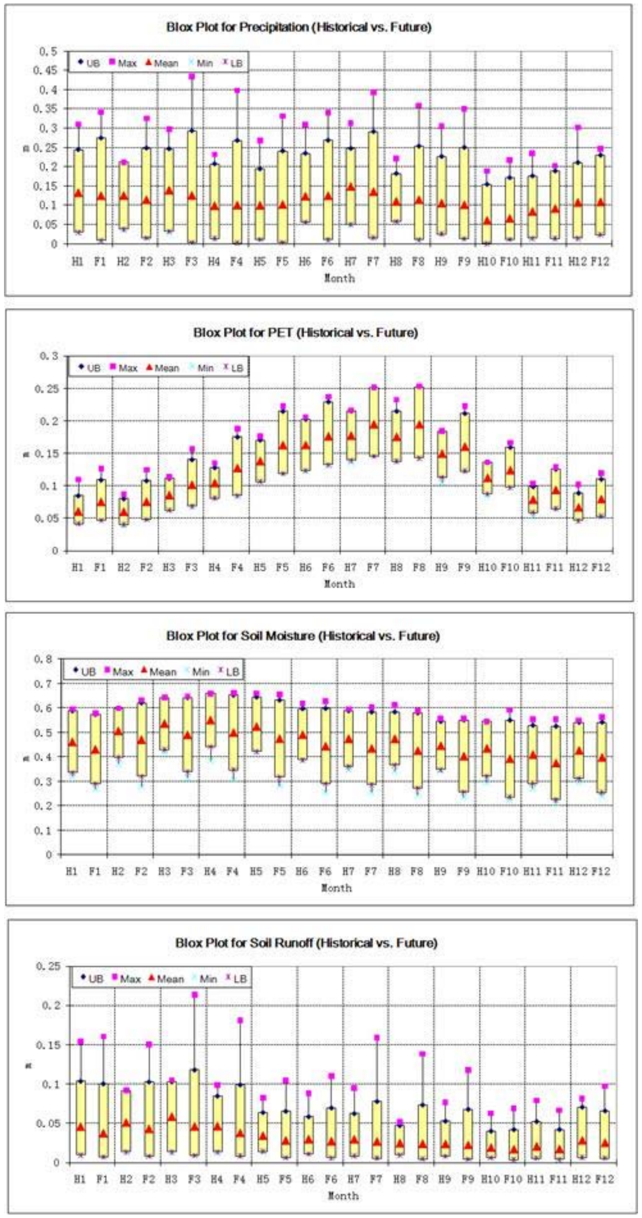
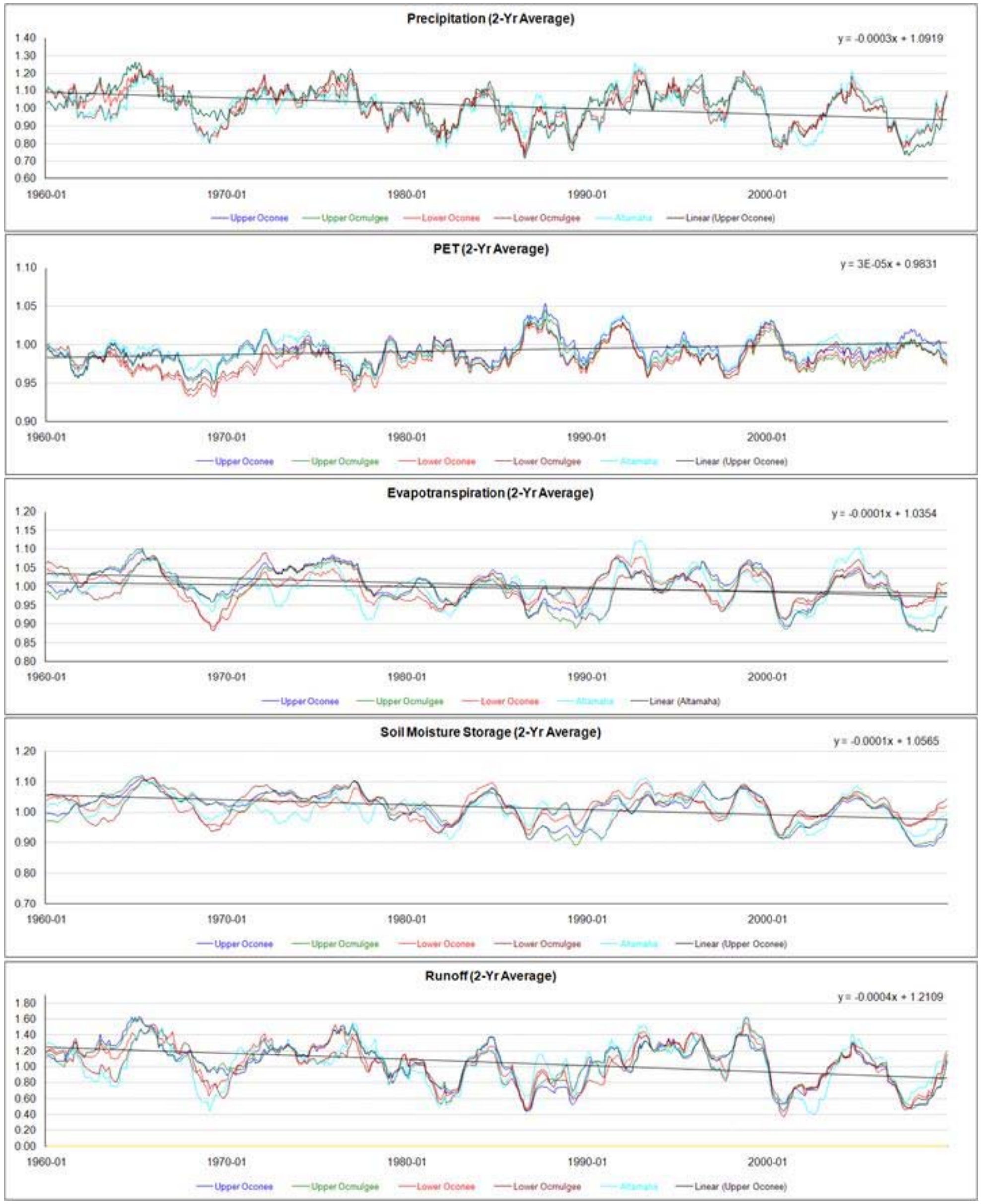


Figure 3.27: Monthly Historical vs. Future (A2) Watershed Response, Woodruff-Bainbridge. (P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

Historical Climate Assessments - OOA



Key Findings

- **Precipitation exhibits a declining trend of about 6% - 16% across all ACF watersheds, with the decline being steeper in the upstream watersheds;**
- **PET exhibits an increasing trend of about 1% - 3% across all ACF watersheds (except for George where it decreases by about 0.8%);**
- **Soil moisture declines by about 3% - 6% across all watersheds; and**
- **Runoff declines by about 25% - 28% in the upstream watersheds, and by 5% - 20% in the downstream watersheds.**

Figure 3.30: OOA Normalized, 2Yr Average Hydrologic Response (1960 - 2009).

Future Climate Assessments – OOA/Up. Oconee-Annual

Key Findings

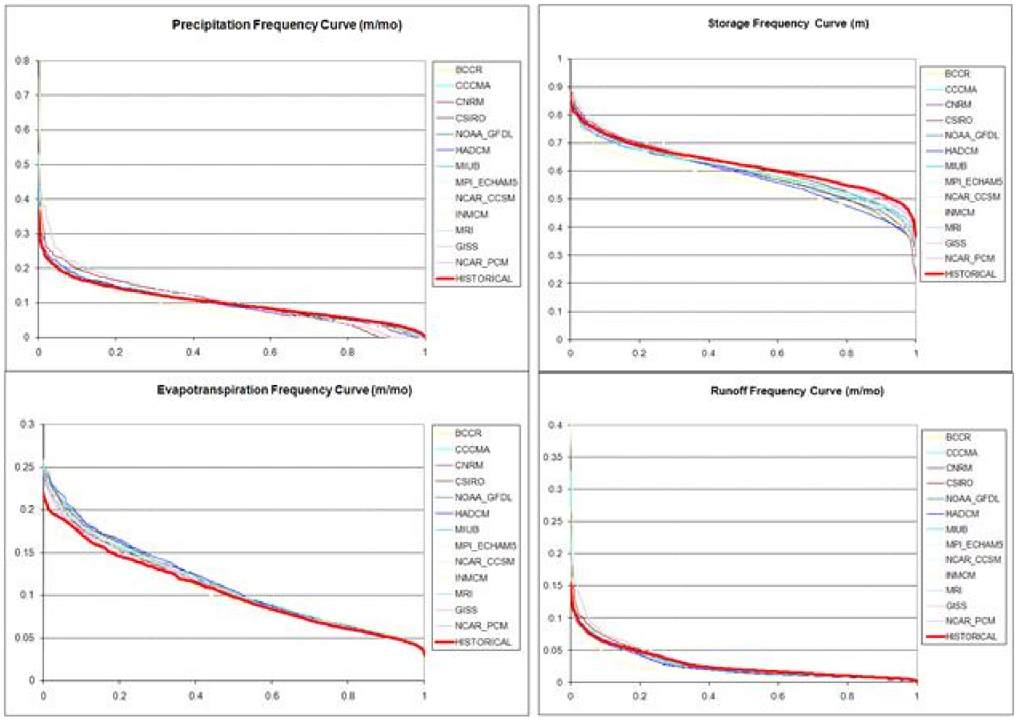


Figure 3.32: A2 Climate Scenarios (2000-2099), Upper Oconee, Frequency Curves.

- **Average precipitation is not expected to change significantly.**
- **The precipitation distribution is expected to “stretch” becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 15% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, Upper Oconee future floods and droughts will be more severe than those experienced in the historical past.**

Future Climate Assessments – OOA/Up. Oconee - Monthly

Key Findings

- **Mean watershed precipitation shows clear decline trends in June and July, but it does not show any appreciable change for the other months of the year. However, the precipitation distributions for January to August are considerably extended (toward both ends) in comparison to the historical distributions.**

- **Future PET exhibits higher mean and wider range than historical PET from February to September, with the largest change observed in July and August. For these two months, the future mean PET is higher than the historical PET by up to 15%.**

- **Future soil moisture is clearly lower than its historical levels in almost all months. The decline is more pronounced in September and October (exhibiting a 11% declining trend).**

- **Future runoff is drier that historical in all months of the year (A2 scenarios). The highest decreases are in June, July, August and September by 10% - 25%.**

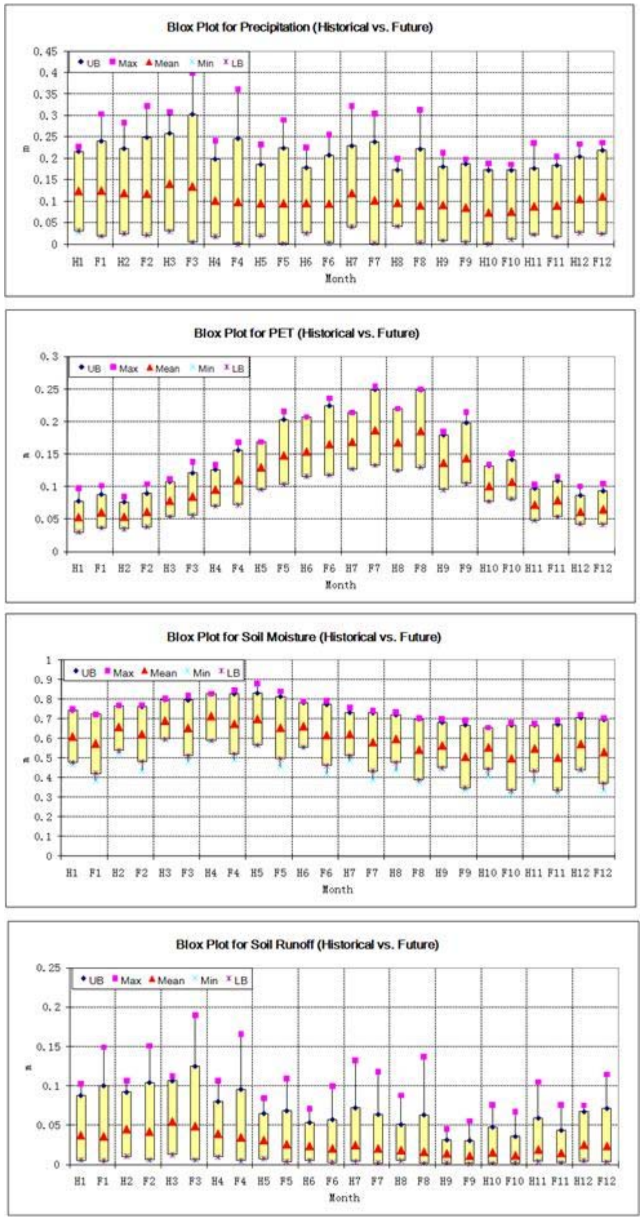


Figure 3.34: Monthly Historical vs. Future (A2) Watershed Response, Upper Oconee. (P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

Future Climate Assessments – OOA/Altamaha-Annual

Key Findings

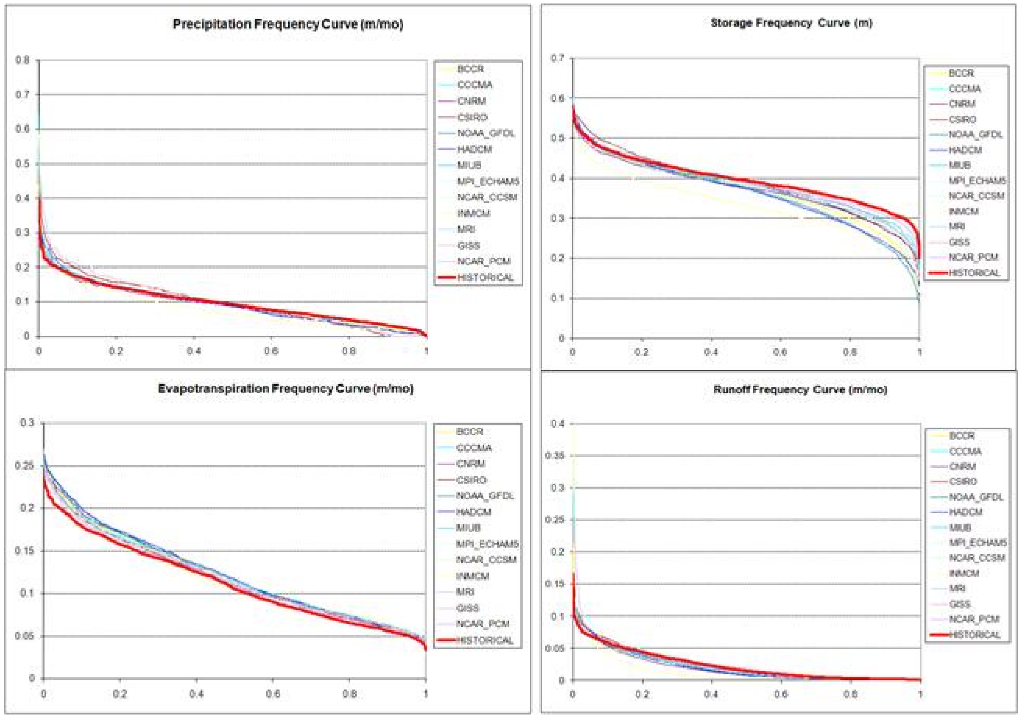
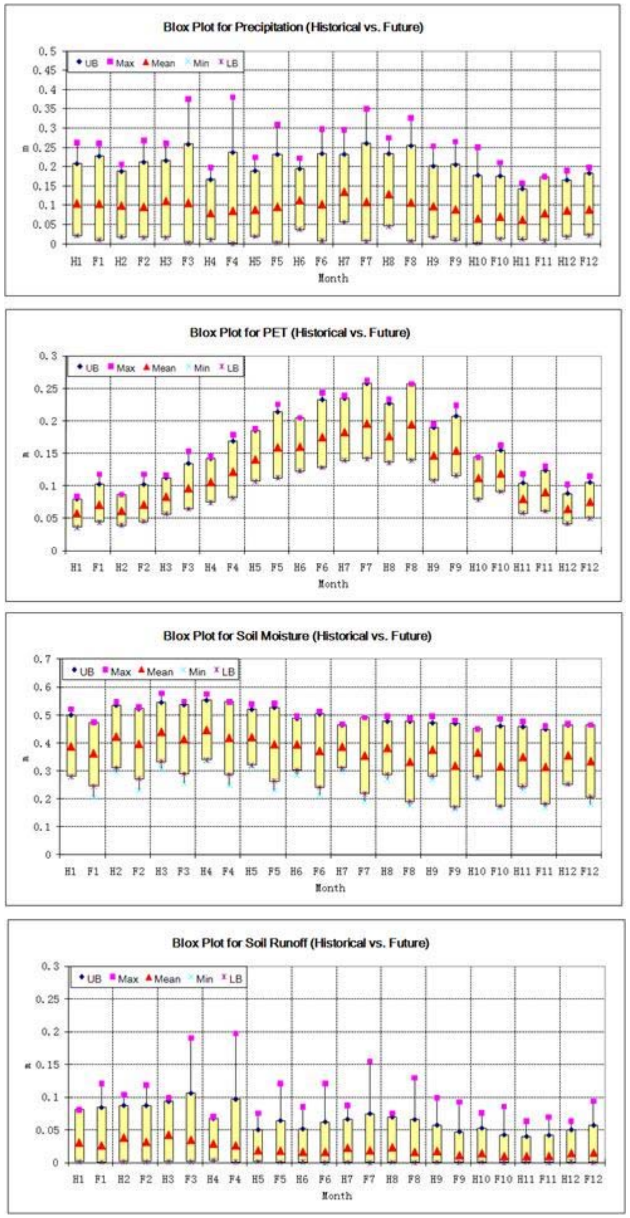


Figure 3.36: A2 Climate Scenarios (2000-2099), Altamaha, Frequency Curves.

- **Average precipitation is not expected to change significantly.**
- **The precipitation distribution is expected to "stretch" becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 8% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, Altamaha future floods and droughts will be more severe than those experienced in the historical past.**

Future Climate Assessments – OOA/Altamaha-Monthly



Key Findings

- **Mean watershed precipitation shows clear decline trends in June and July, but it does not show any appreciable change for the other months of the year. However, the precipitation distributions for January to August are considerably extended (toward both ends) in comparison to the historical distributions.**
- **Future PET exhibits higher mean and wider range than historical PET from February to September, with the largest change observed in July and August. For these two months, the future mean PET is higher than the historical PET by up to 15%.**
- **Future soil moisture is clearly lower than its historical levels in almost all months. The decline is more pronounced from July to November (exhibiting a 15% declining trend).**
- **Future runoff is drier that historical in all months (by 10% - 25%), except in November and December (when it exhibits an increase of 2% - 3%).**

Figure 3.38: Monthly Historical vs. Future (A2) Watershed Response, Altamaha. (P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

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Historical Climate Assessments - SO

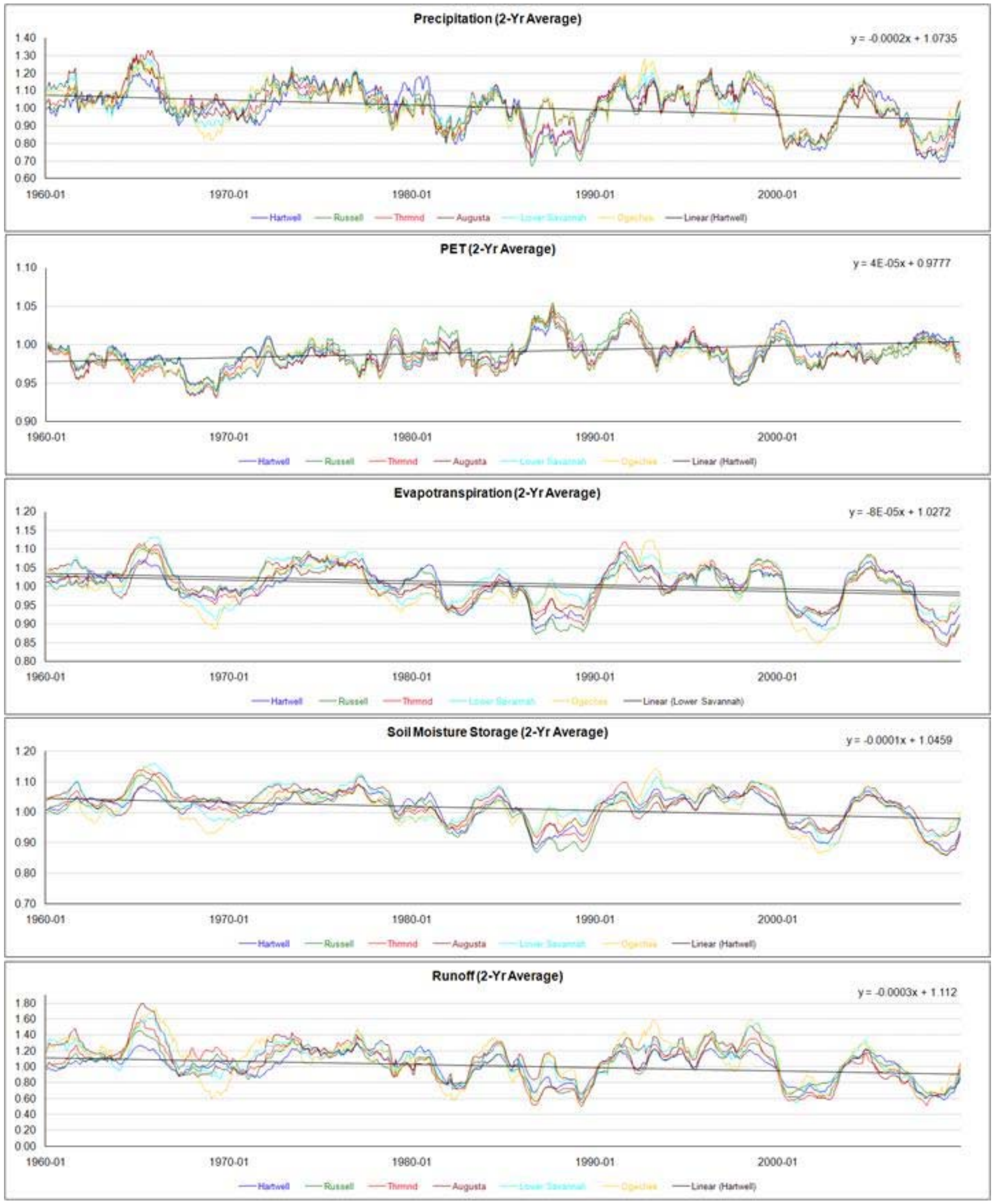


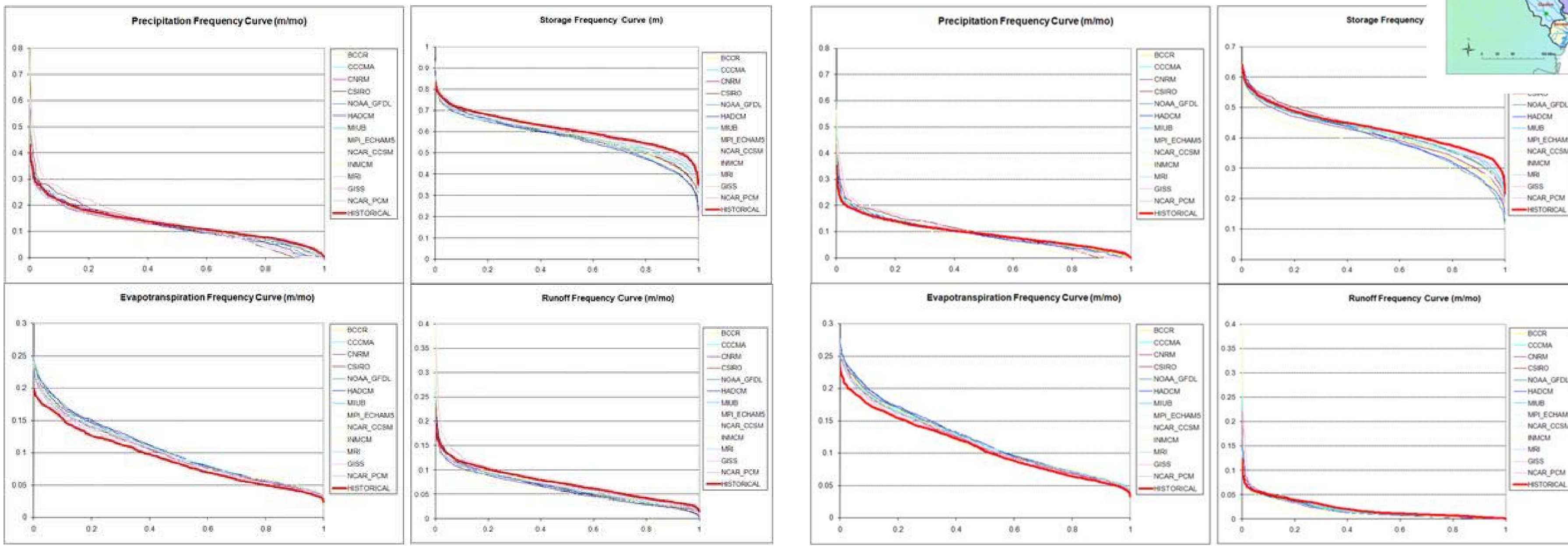
Figure 3.41: SO Normalized, 2Yr Average Hydrologic Response (1960 - 2009).

Key Findings

- **Precipitation exhibits a declining trend of about 10% - 18% across all ACF watersheds, with the decline being steeper in the upstream watersheds;**
- **PET exhibits an increasing trend of about 2% - 3% across all ACF watersheds (except for George where it decreases by about 0.8%);**
- **Soil moisture declines by about 5% - 8% across all watersheds; and**
- **Runoff declines by about 11% - 23%.**

Future Climate Assessments – SO-Annual

A2 Scenarios (2000-2099), Hartwell (left) Ogeechee (right).



Key Findings

- **Average precipitation is not expected to change significantly. (Harwell: 1-2% decline.)**
- **The precipitation distribution is expected to "stretch" becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 5% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, SO future floods and droughts will be more severe than those experienced in the historical past.**

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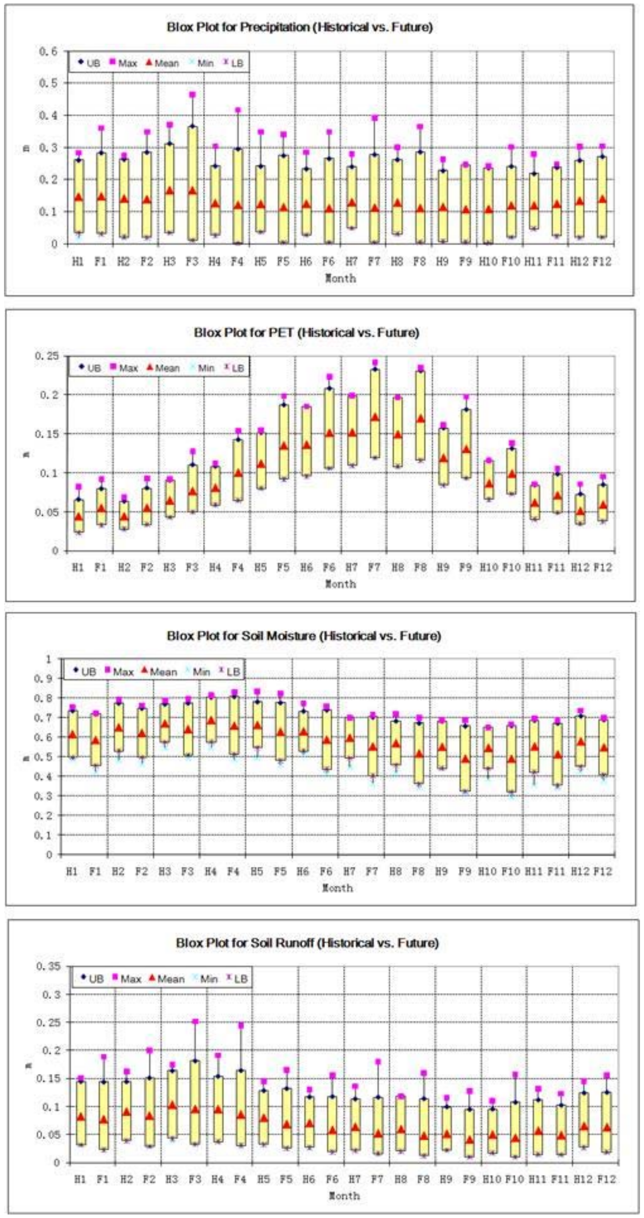
Future Climate Assessments – SO/Harwell-Monthly



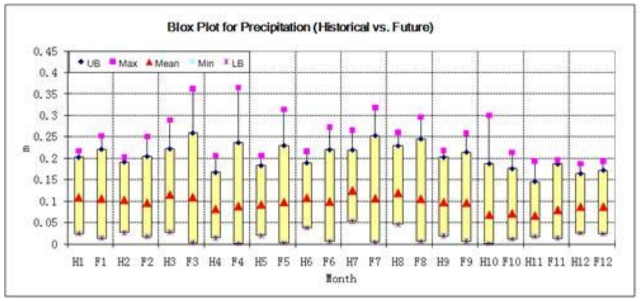
Key Findings

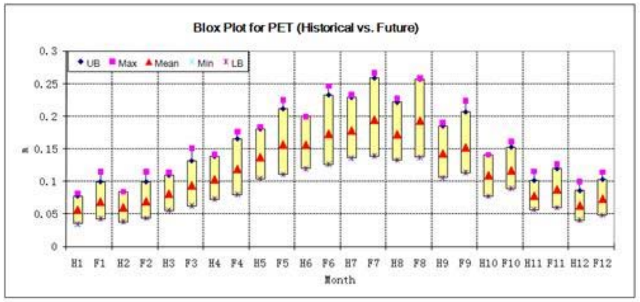
- **For Hartwell, mean watershed precipitation exhibits clear decreasing trends in June, July, and August (up to 15%), and clear increasing trends in October and December (up to 10%). In addition, the precipitation distributions for almost all months are considerably extended (toward both ends) in comparison to the historical distributions.**
- **Future PET exhibits higher mean and wider range than historical PET from January to September. For these two months, the future PET is higher than the historical PET up to 20% for Hartwell.**
- **Future soil moisture is clearly lower than historical in almost all months. The change is more pronounced from August to October. For Hartwell, the largest reduction is up to 11%.**
- **Future runoff is generally drier for all SO watersheds. For Hartwell, the largest runoff reduction is from May to November. Runoff reductions are more pronounced in Hartwell (northern watershed) than in Ogeechee (southern watershed).**

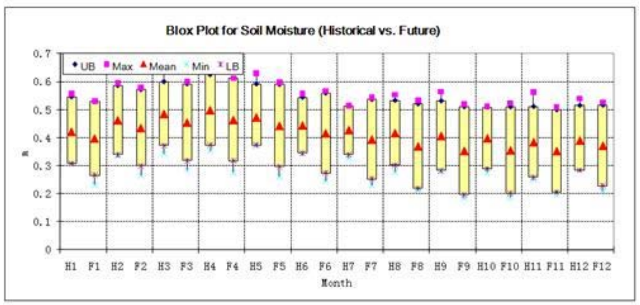
Figure 3.45: Monthly Historical vs. Future (A2) Watershed Response, Hartwell.
(P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

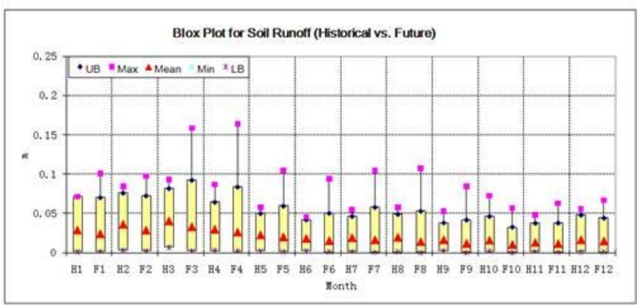
Future Climate Assessments – SO/Ogeechee - Monthly

Key Findings









- **For Ogeechee, precipitation decreases in February, March, June, July and August (with the highest reduction occurring in July and August of up to 13%), and increases in April, May and from September to December (up to 15%). In addition, the precipitation distributions for almost all months are considerably extended (toward both ends) in comparison to the historical distributions.**

- **Future PET exhibits higher mean and wider range than historical PET from January to September. For these two months, the future PET is higher than the historical PET up to 15% for Ogeechee basin.**

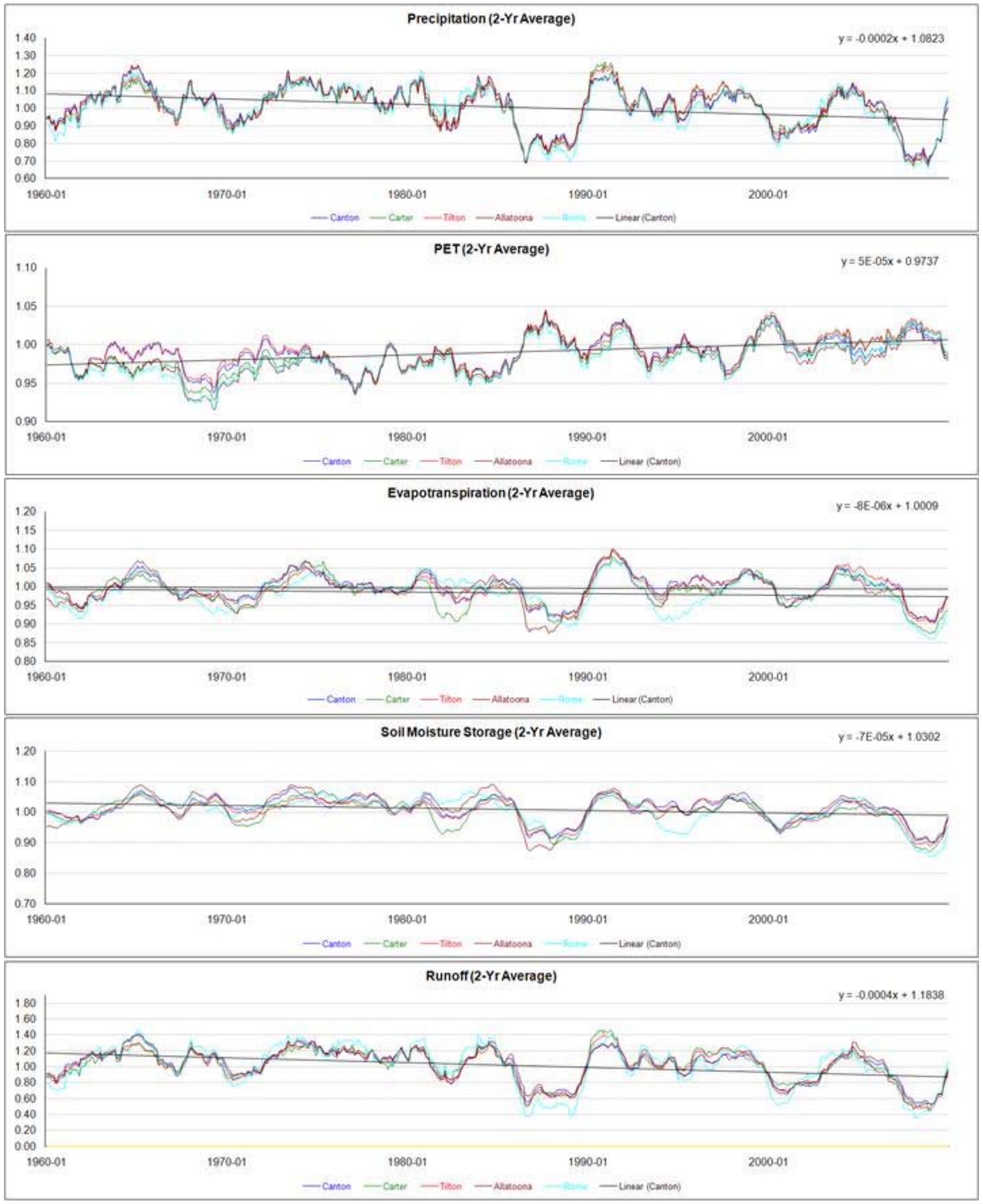
- **Future soil moisture is clearly lower than historical in almost all months. The change is more pronounced from August to October. For Ogeechee, the largest reduction is up to 13%.**

- **Future runoff is generally drier for all SO watersheds. For Ogeechee, the largest runoff reduction is from June to October. Runoff reductions are more pronounced in Hartwell (northern watershed) than in Ogeechee (southern watershed).**

Figure 3.49: Monthly Historical vs. Future (A2) Watershed Response, Ogeechee. (P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

Historical Climate Assessments - ACT

GWRI



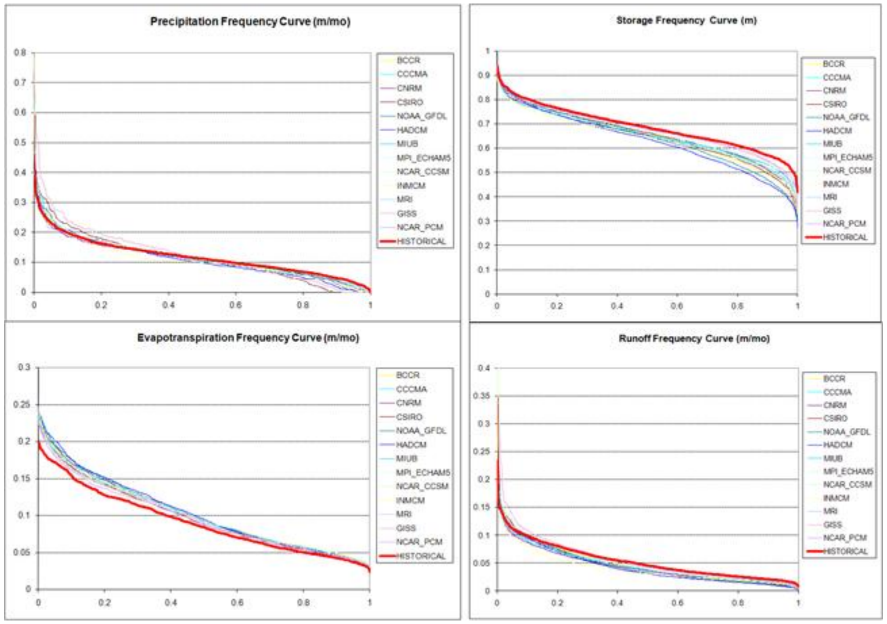
Key Findings

- **Precipitation exhibits a declining trend of about 11% - 15% across all ACF watersheds, with the decline being steeper in the upstream watersheds;**
- **PET exhibits an increasing trend of about 3% - 5% across all ACF watersheds (except for George where it decreases by about 0.8%);**
- **Soil moisture declines by about 4% - 5% across all watersheds; and**
- **Runoff declines by about 20% - 23%.**

Figure 3.52: ACT Normalized, 2Yr Average Hydrologic Response (1960 - 2009).

Future Climate Assessments – ACT - Annual

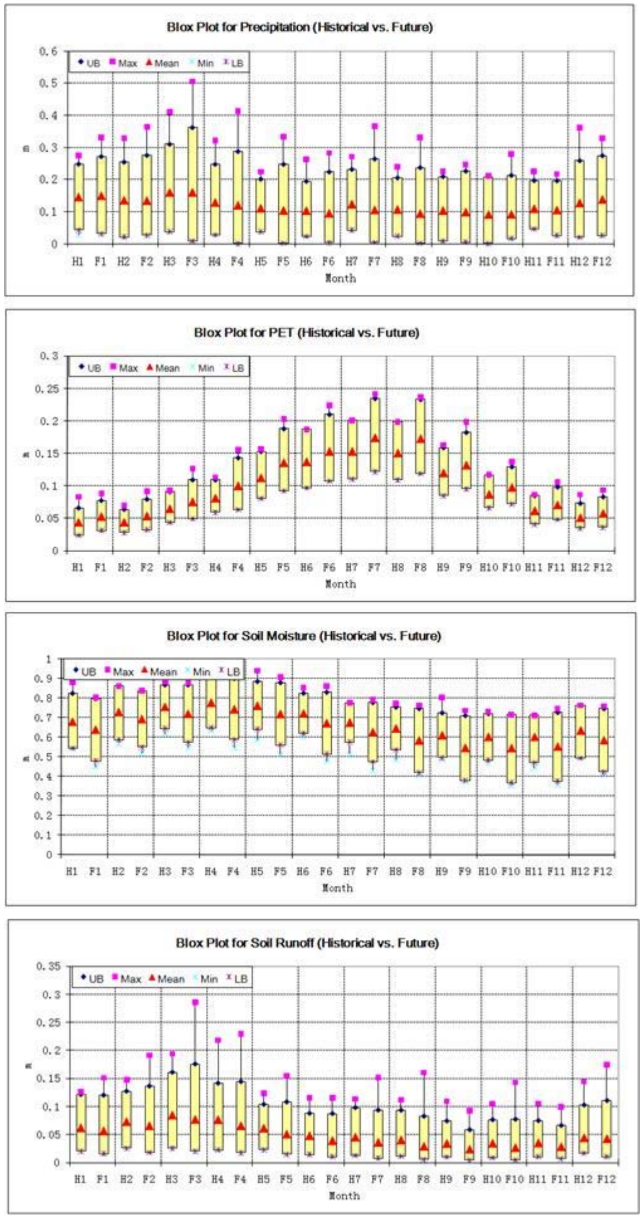
A2 Scenarios (2000 - 2099), Allatoona.



Key Findings

- **Average precipitation is expected to slightly decline (2 - 3%).**
- **The precipitation distribution is expected to “stretch” becoming wetter and drier than that of the historical climate.**
- **All future scenarios portend higher PET, higher ET, and lower soil moisture storage. This effect is especially pronounced in dry years (falling below 75% of the distribution values).**
- **In the 5% wettest years, runoff is expected to be higher than historical. However, the rest of the future distributions indicate drier than historical runoff conditions.**
- **Namely, ACT future floods and droughts will be more severe than those experienced in the historical past.**

Future Climate Assessments – ACT / Allatoona - Monthly



Key Findings

- **Mean watershed precipitation exhibits clear decreasing trends from April through September by about 7% - 14%. It also shows mild increasing trends from December to January.**

- **Future PET exhibits a higher mean and a wider range than historical PET from February to September, with the largest percentage changes observed in April and May. For these two months, the future mean PET is higher than the historical PET by up to 15% - 20%, while the quartile range of the future distribution exceeds that of the historical by nearly 10% - 20%.**

- **Future soil moisture is clearly lower than historical in almost all months. The change is more pronounced in August and September, reaching up to 10%.**

- **Future runoff is drier in most months. The change is more pronounced in August and September. Under the A2 scenario, the largest runoff reduction is up to 25%.**

Figure 3.56: Monthly Historical vs. Future (A2) Watershed Response, Allatoona.
(P – m/mo; PET – m/mo; Soil Moisture – m; Runoff m/mo.)

Climate/Hydrology Assessment Summary

Historical Climate Assessments

In the last 50 years, all major Georgia basins (Upper ACT, ACF, OOA, and SO) exhibit:

- **Precipitation declining trends;**
- **PET rising trends;**
- **Soil moisture and total runoff declining trends.**

Future Climate Assessments

The assessment findings for the major Georgia basins (Upper ACT, ACF, OOA, and SO) indicate:

- **Most watersheds in all four basins are expected to experience precipitation reductions during summer and early fall (June, July, August, and September);**
- **All watersheds show significant PET increases;**
- **Summer PET increases are larger than those of winter in absolute value;**
- **Upstream watersheds show higher PET increases in late spring (April and May);**
- **Runoff in all watersheds is expected to decrease in most months (and especially in summer).**

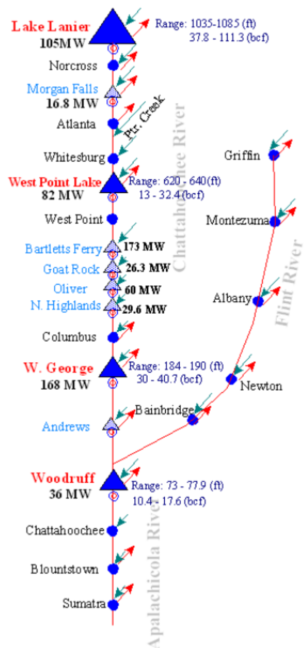
Key Messages

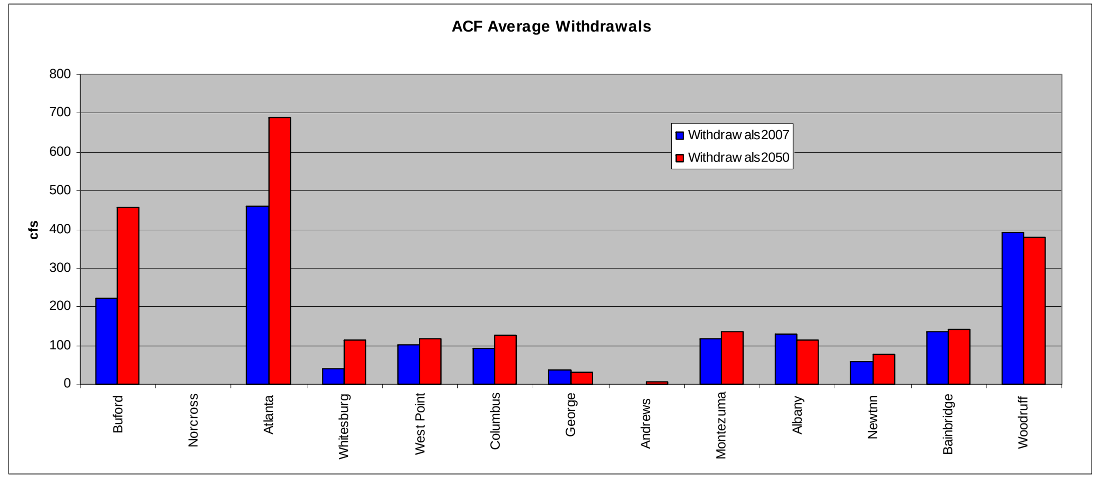
- **Historical and future (GCM) assessments demonstrate that significant climate change is occurring in Georgia and the southeast.**
- **Findings have direct implications for the development of water plans.**
- **Water planning should consider historical *and* future scenarios, and include adaptation strategies.**

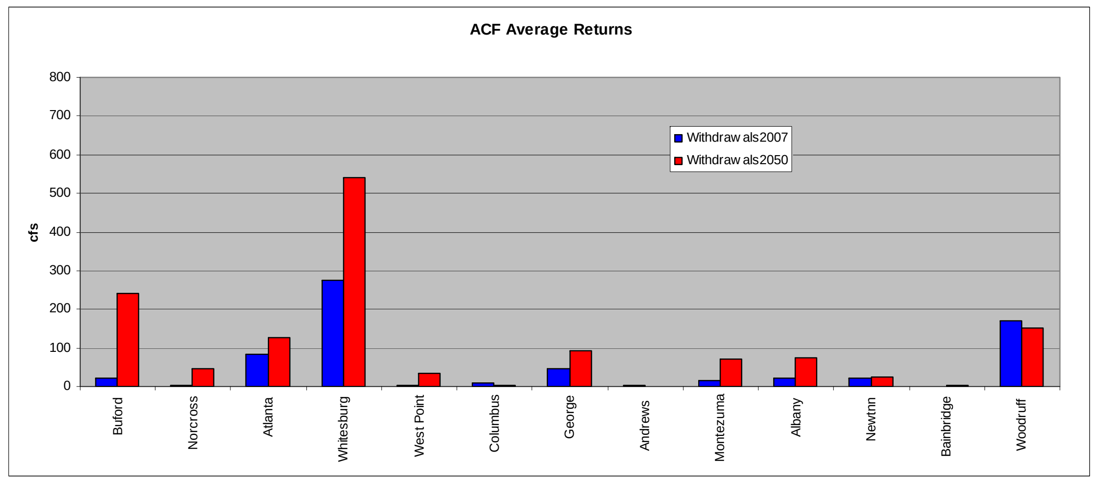
ACF Water Resources Assessment
Water Demand Scenarios 2007 and 2050

GWRI

Georgia Tech







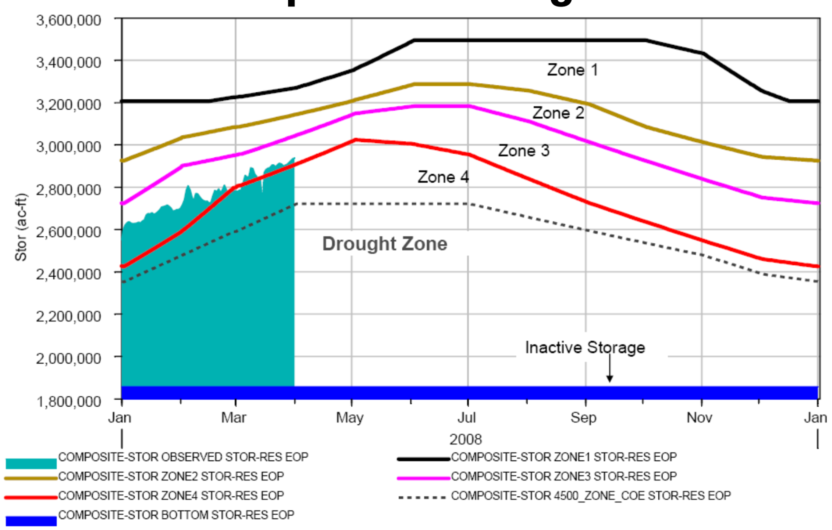
Future Agricultural Water Demand Projections Do Not Account for Climate Change.

Woodruff Release Requirements—Interim Operations Plan (RIOP)

Georgia Tech

Months	Composite Storage Zone	Basin Inflow (BI) (cfs)	Release (cfs)
March -May	Zones 1 and 2	>=34000	>=25000
		>=16000 and <34000	>=16000+50%*(BI-16000)
		>=5000 and <16000	>=BI
		<5000	>=5000
	Zone 3	>=39000	>=25000
		>=11000 and <39000	>=11000+50%(BI-11000)
		>=5000 and <11000	>=BI
		<5000	>=5000
June - November	Zones 1,2, and 3	>=24000	>=16000
		>=8000 and <24000	>=8000+50%(BI-8000)
		>=5000 and <8000	BI
		<5000	>=5000
December-February	Zones 1, 2, and 3	>=5000	>=5000
		<5000	>=5000
All Times	Zone 4		>=5000
All Times	Drought Zone		>=4500

Composite Storage Zones



Woodruff Release Limits

Release Range (cfs)	Max. Fall Rate (ft/day) at Chattahoochee Gage
>30000	No Restriction
>20000 and <=30000	1 to 2
>16000 and <=20000	.5 to 1
>8000 and <16000	0.25 to 0.5
<8000	<=0.25

Note: No restrictions in Composite Zone 4.

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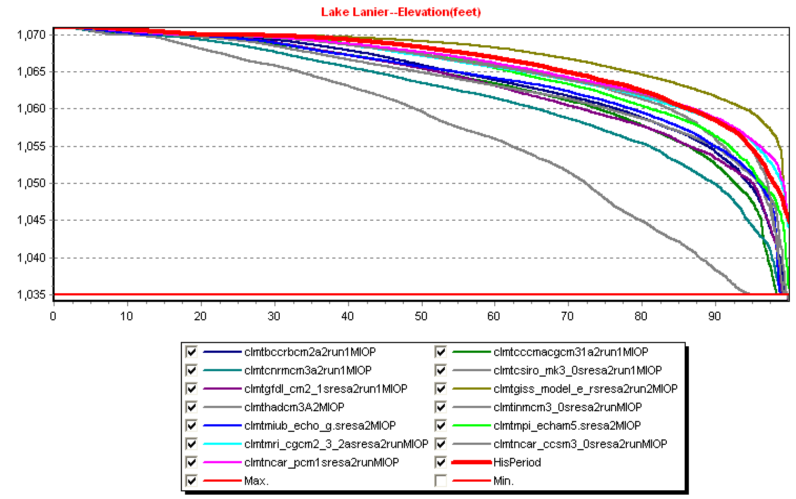
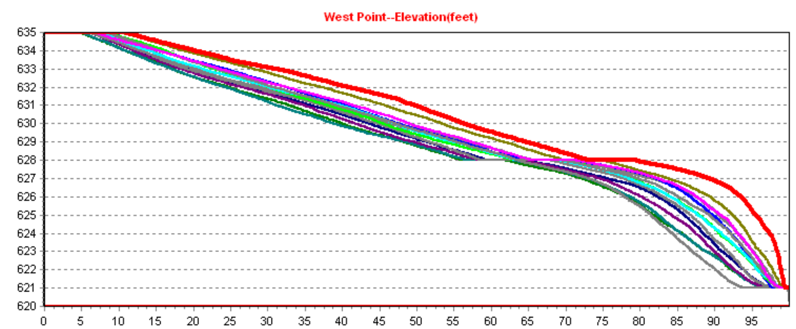
Lake Level Assessment

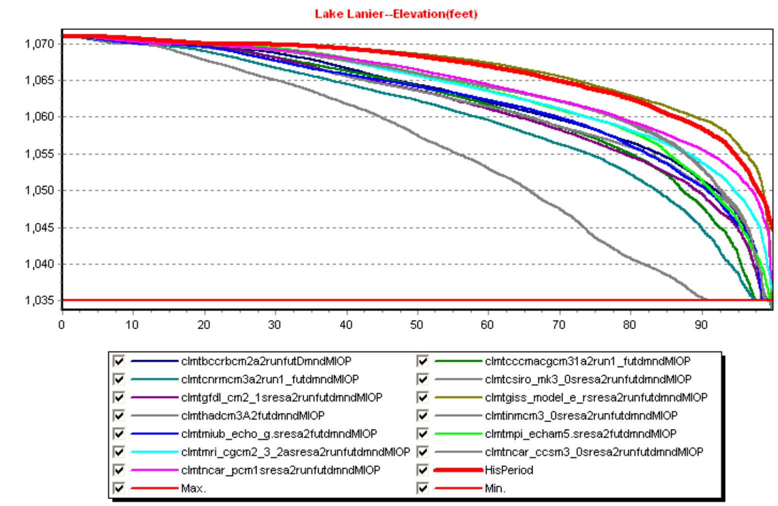
Georgia Tech

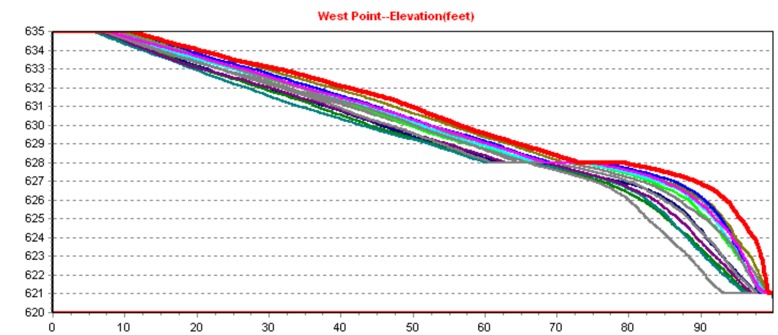
A2 – 2007 Dmnds





A2 – 2050 Dmnds



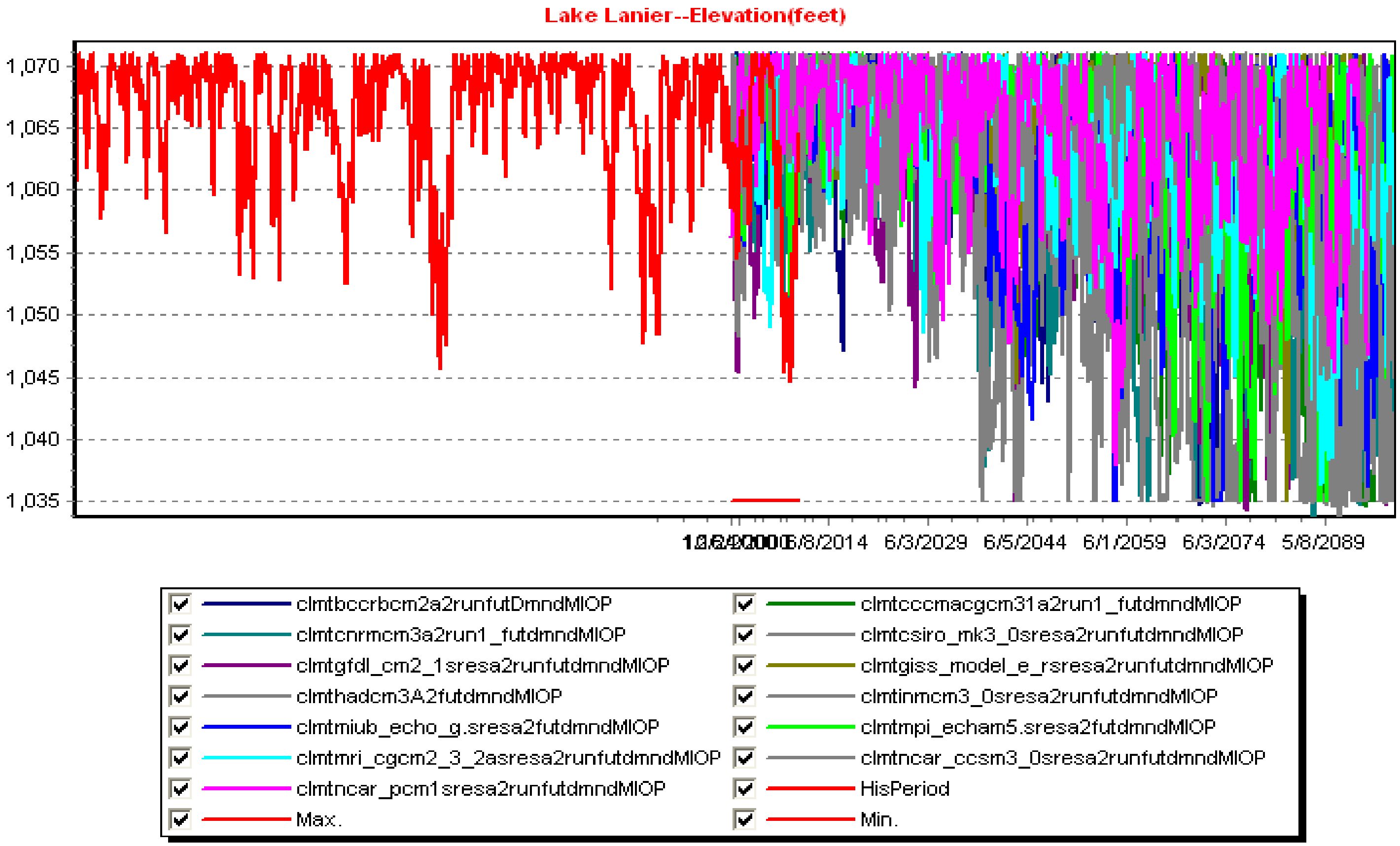


Key Messages

- **Future A2 climates portend deeper and more frequent lake drawdowns.**
- **2050 Demands exacerbate lake water stress.**

Lake Lanier Level Sequences

Historical and Future Climates (A2) and 2050 Demands



Key Messages

- **Drawdowns intensify beyond 2050.**

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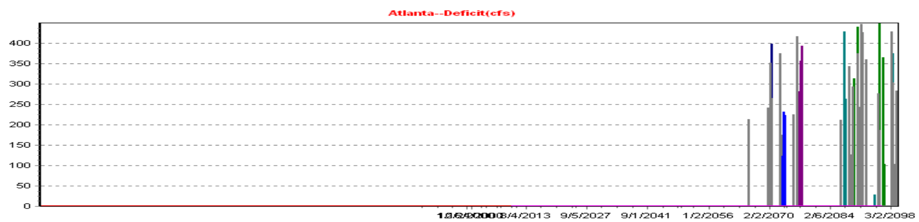
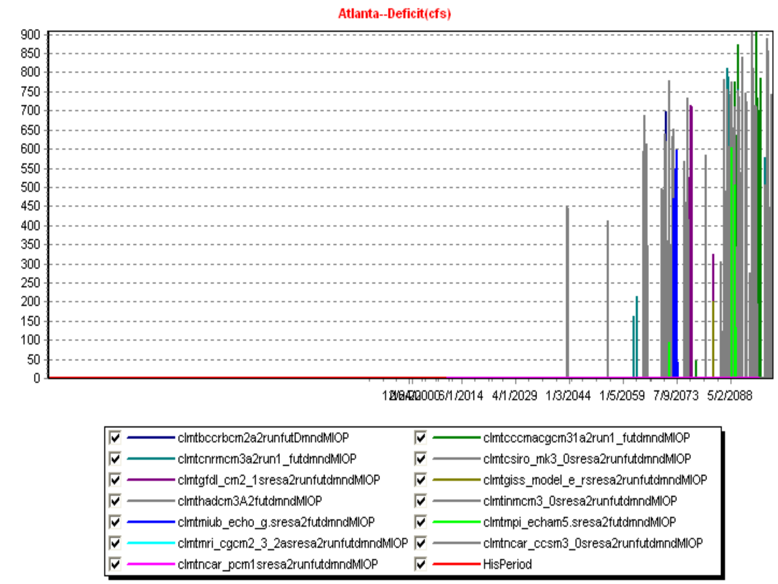
Water Supply Deficit Assessments—Atlanta

Georgia Tech

A2 – 2007 Dmnds



A2 – 2050 Dmnds



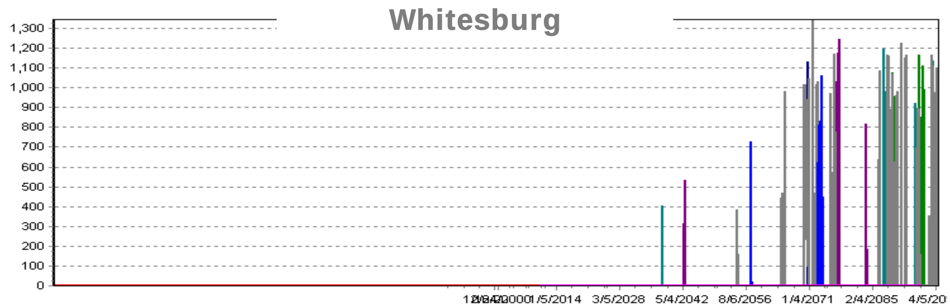
Key Messages

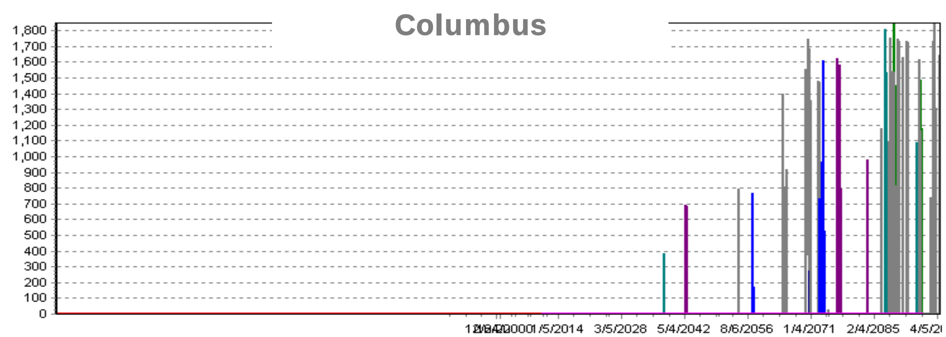
- **Future A2 climates indicate that Atlanta will be vulnerable to critical water supply deficits beyond 2060.**

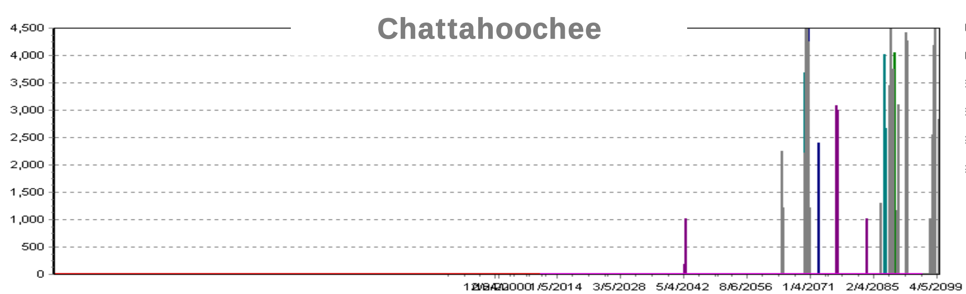
In-stream Flow Target Assessment

Georgia Tech

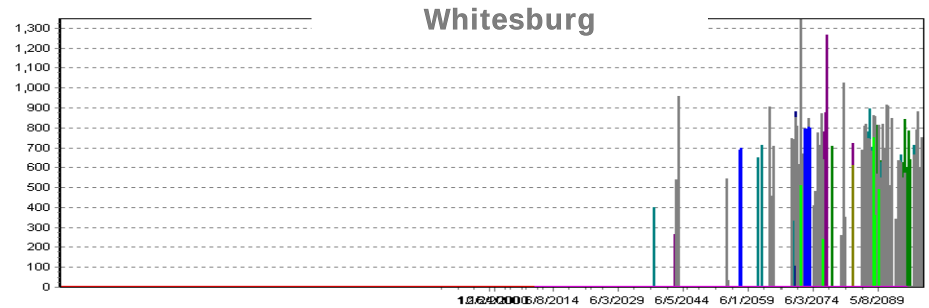
A2 – 2007 Dmnds

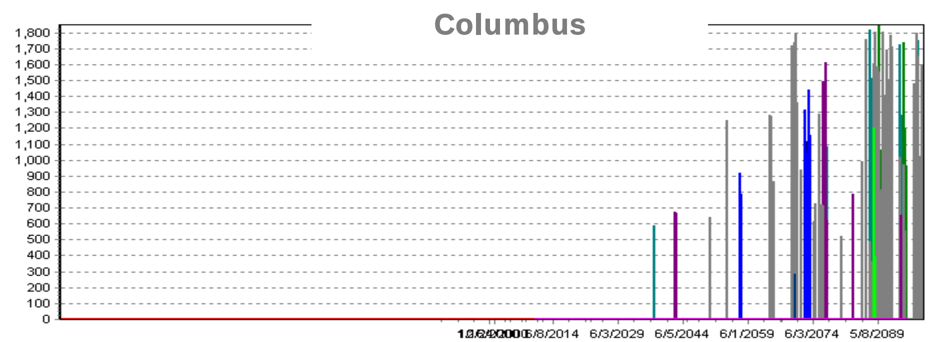


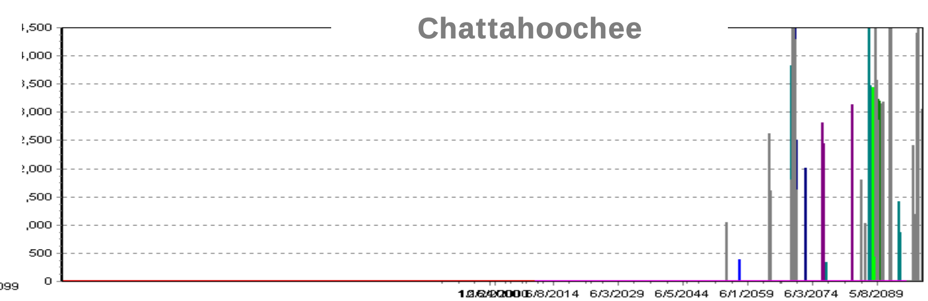




A2 – 2050 Dmnds







Key Messages

- **Future A2 climates are likely to impair ACF's capacity to meet instream flow targets, especially beyond 2060 and under increased demands.**

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Water Resources Assessment Summary

Georgia Tech

Key Messages

- **All indicators show that ACF (all water users and uses) will be increasingly vulnerable to water scarcity and stress beyond 2050-2060.**

- **It is imperative that water planning processes *recognize* the ACF vulnerability to climate change, and put in place appropriate adaptation measures (in infrastructure, conservation, regulation, and management).**