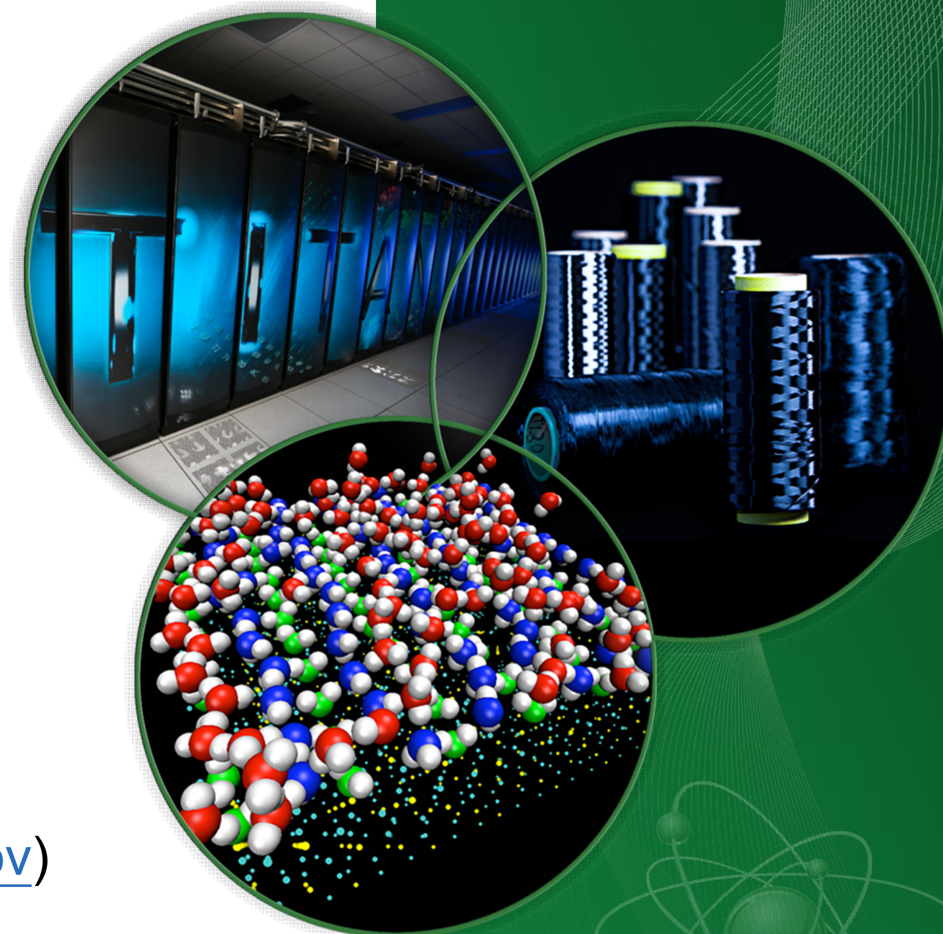
# Simulation of Probable Maximum Precipitation and Flood in a Warming Climate



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# Increasing Risk in a Warming Climate

**2009 flood near Atlanta**


**Increasing Extreme Precipitation**

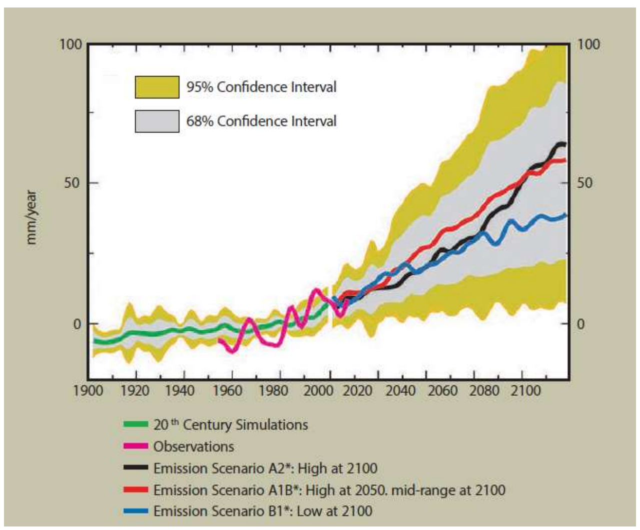
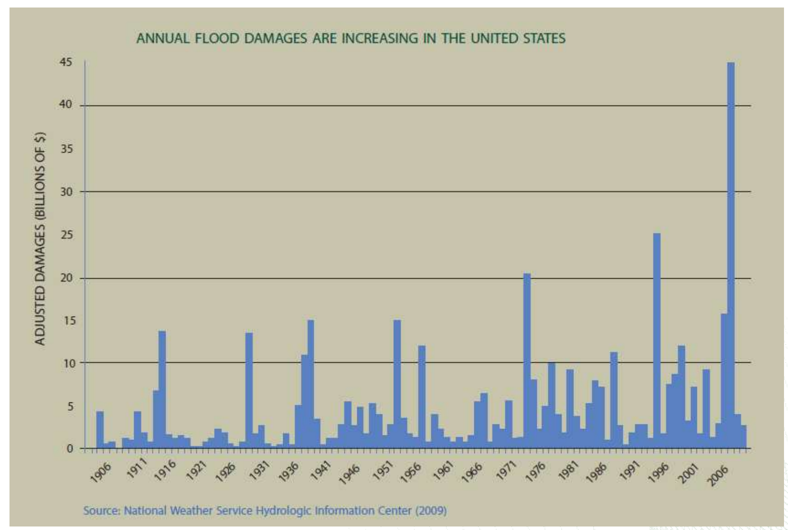



Figure Source : National Wildlife Federation, 2009, Data Sources: U.S. Climate Change Science Program (CCSP),2008

**Annual Flood Damages in US**




National Weather Service Hydrologic Information Center (2009)



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# For Critical Energy Infrastructures

- **Probable Maximum Precipitation (PMP) and Flood (PMF)**
  - Design basis for major dams and nuclear power plants.
  - **In theory**, the greatest extreme event that could occur
  - Return period $10^5 – 10^9$ years (National Research Council, 1994)


**Fort Calhoun nuclear plant, Nebraska, June 2011**

# Current PMP Needs to be Updated

- **HRM 51 and other NWS reports (published ~1980)**
  - Historic storms with moisture maximization
- **Issues**
  - No new update by NWS
  - Based on several key simplifications
  - Do not consider long-term climatic trends

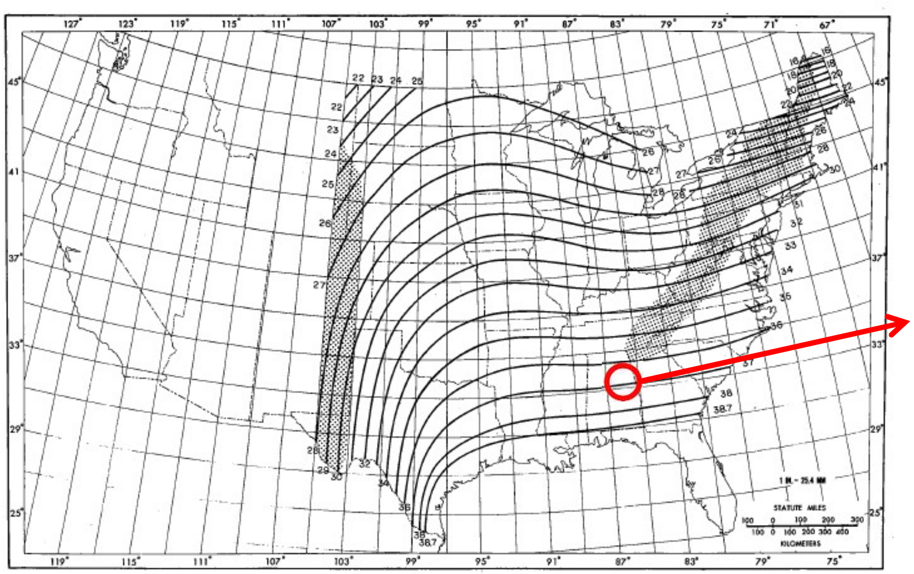
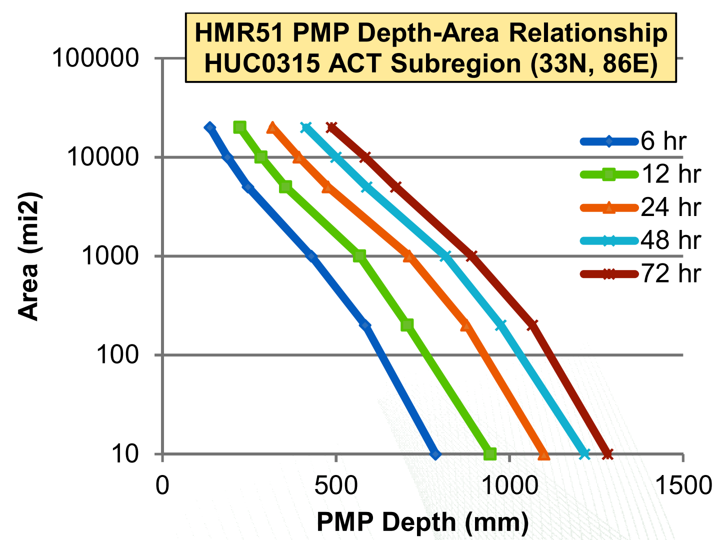
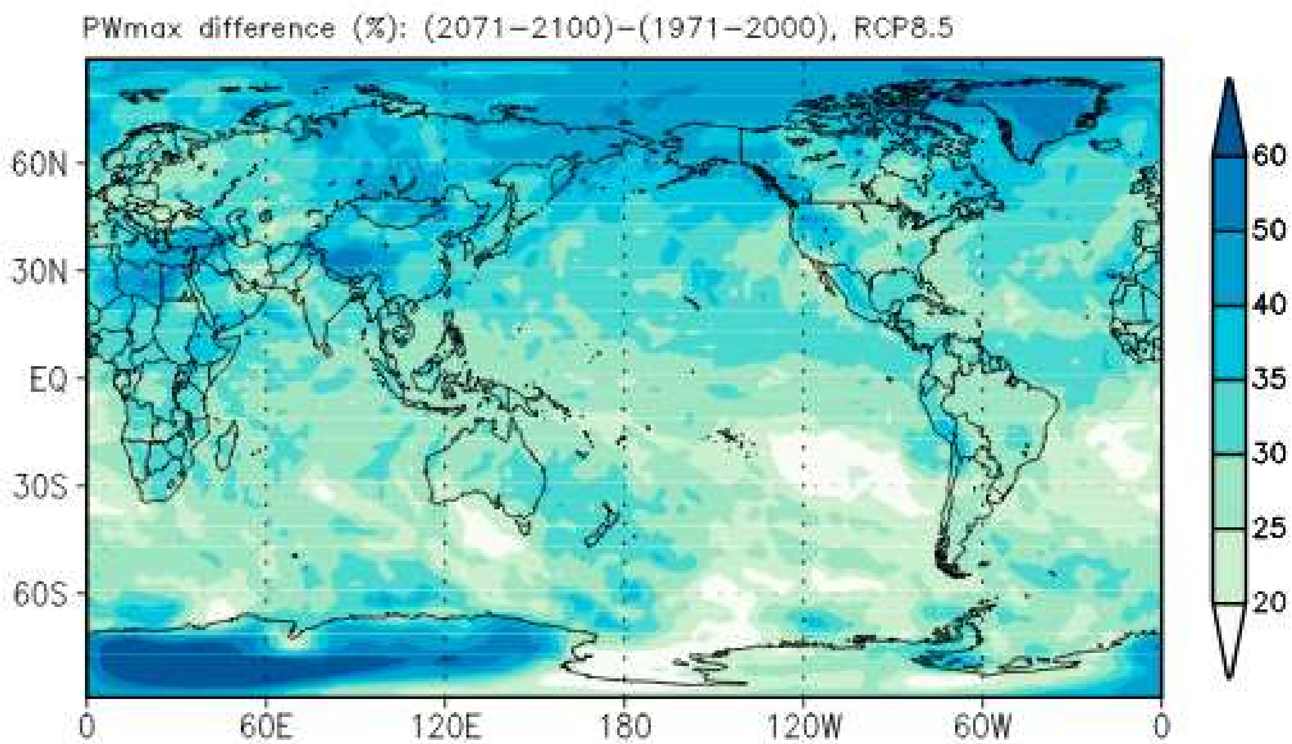


*Figure 19.--All-season PMP (in.) for 12 hr 10 mi² (26 km²).*



# PMP is Projected to Increase

- **Increasing trend of maximum precipitable water ($PW_{max}$)**
  - Increasing trend of observed dew point (Robinson, 2000)
  - CMIP5 multi-GCM trend (Kunkel et al., 2013)




Kunkel et al. (2013)



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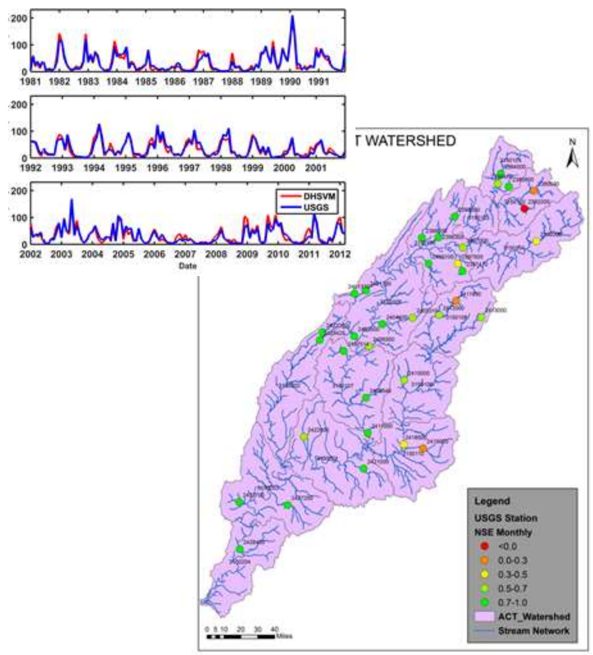
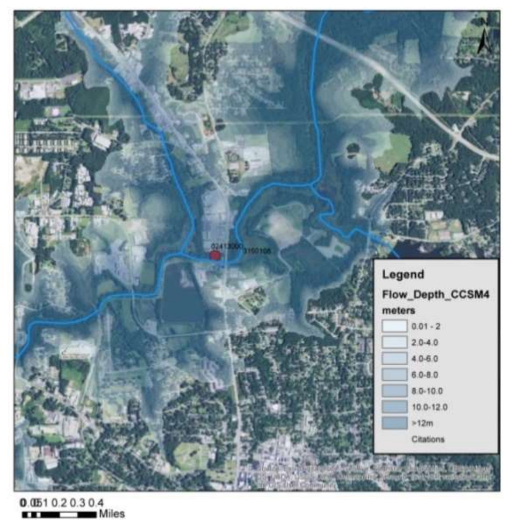
# Simulation Framework

**Weather Simulation**
- WRF
- RegCM4

**Hydrologic Modeling**
- DHSVM
- VIC

**Flood Simulation**
- Flood2D-GPU

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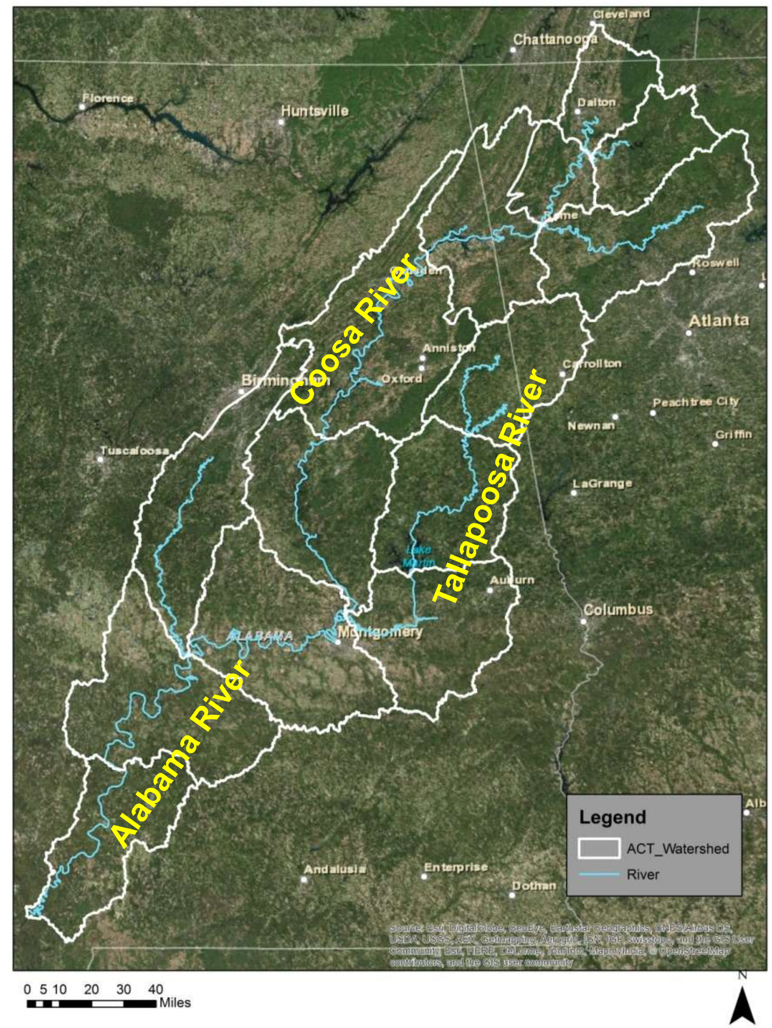
# Study Area and Forcing Scenarios

- **Alabama-Coosa-Tallapoosa (ACT) River Basin**
- **Climate Forecast System Reanalysis (CFSR) forcing**
  - CFSR-CT: 30 historic storms (1981–2011)
  - CFSR-T1: CT +1°C
  - CFSR-T2: CT +2°C
- **Community Climate System Model version 4 (CCSM4)**
  - CCSM4-BL: 30 storms (1981–2005 baseline & 2006–2010 RCP8.5)
  - CCSM4-F1: 30 storms (2021–2050 RCP8.5)
  - CCSM4-F2: 30 storms (2071–2100 RCP8.5)

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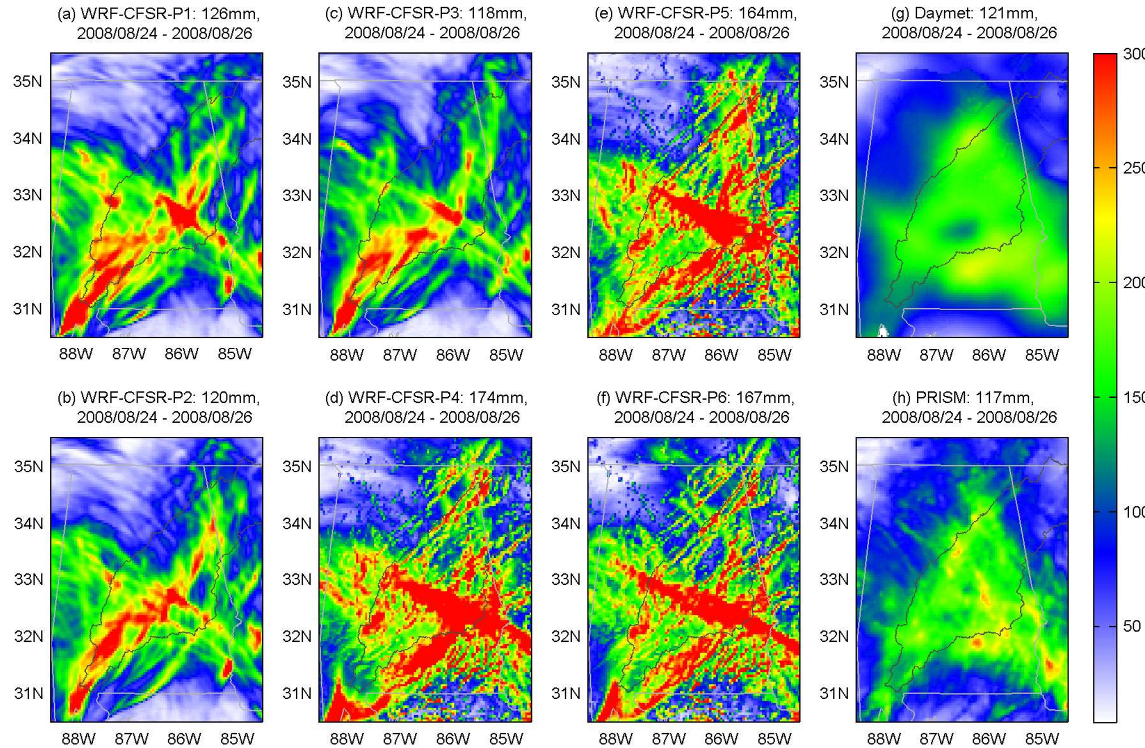
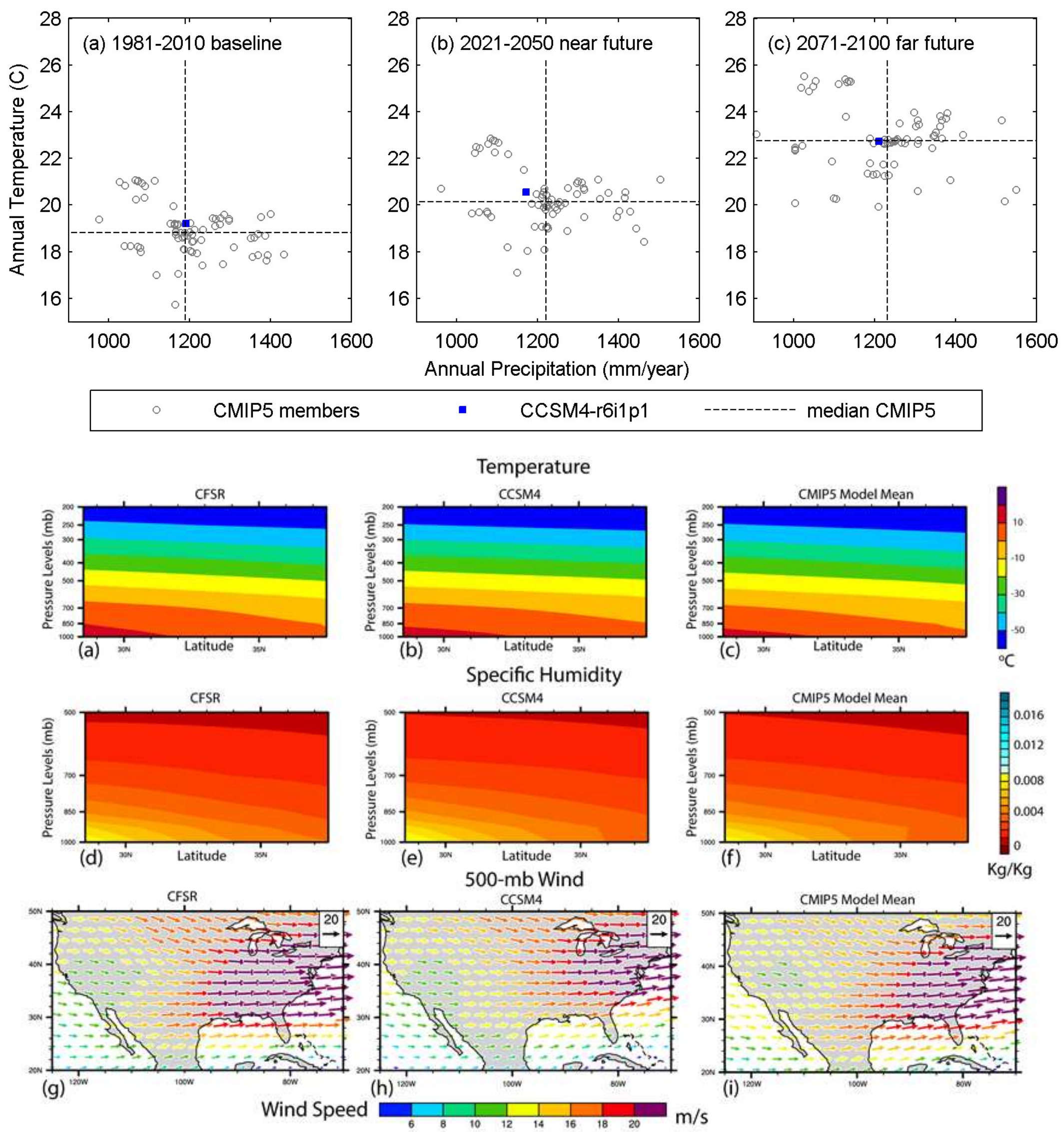
# WRF Model Tuning

- Conduct for 30 CFSR storms for 6 sets of parameter schemes
- Evaluate by both Daymet and PRISM 3-day rainfall




| | Cumulus par. | Cloud microphysics | $R^2$ – Daymet | $R^2$ – PRISM | RMSE (mm) – Daymet | RMSE (mm) – PRISM |
|---|---|---|---|---|---|---|
| **P1** | **Grell-Devenyi** | **Lin et al.** | **0.725** | **0.704** | **19** | **19** |
| P2 | Grell-Devenyi | Single Moment 5-class | 0.703 | 0.683 | 22 | 22 |
| P3 | Grell-Devenyi | Thompson scheme | 0.706 | 0.681 | 25 | 25 |
| P4 | Kain-Fritsch | Lin et al. | 0.620 | 0.580 | 26 | 28 |
| P5 | Kain-Fritsch | Single Moment 5-class | 0.626 | 0.595 | 21 | 22 |
| P6 | Kain-Fritsch | Thompson scheme | 0.605 | 0.558 | 24 | 26 |

# GCM Selection




- Relative performance to other CMIP5 models
- Reasonable synoptic features of temperature, specific humidity, and 500-mn wind
- Good performance suggested by other studies



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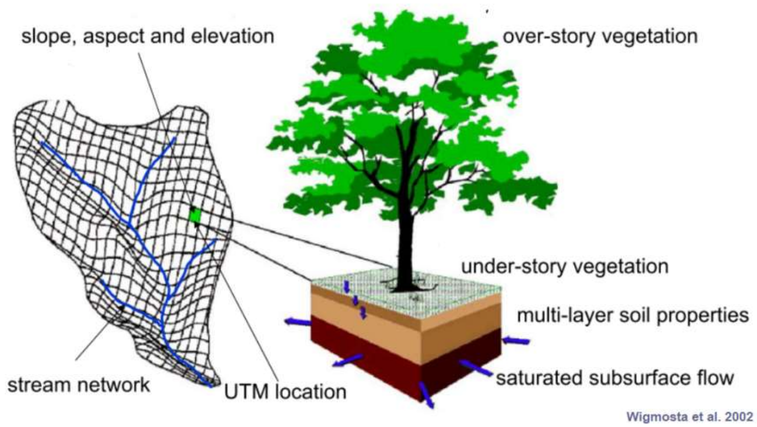
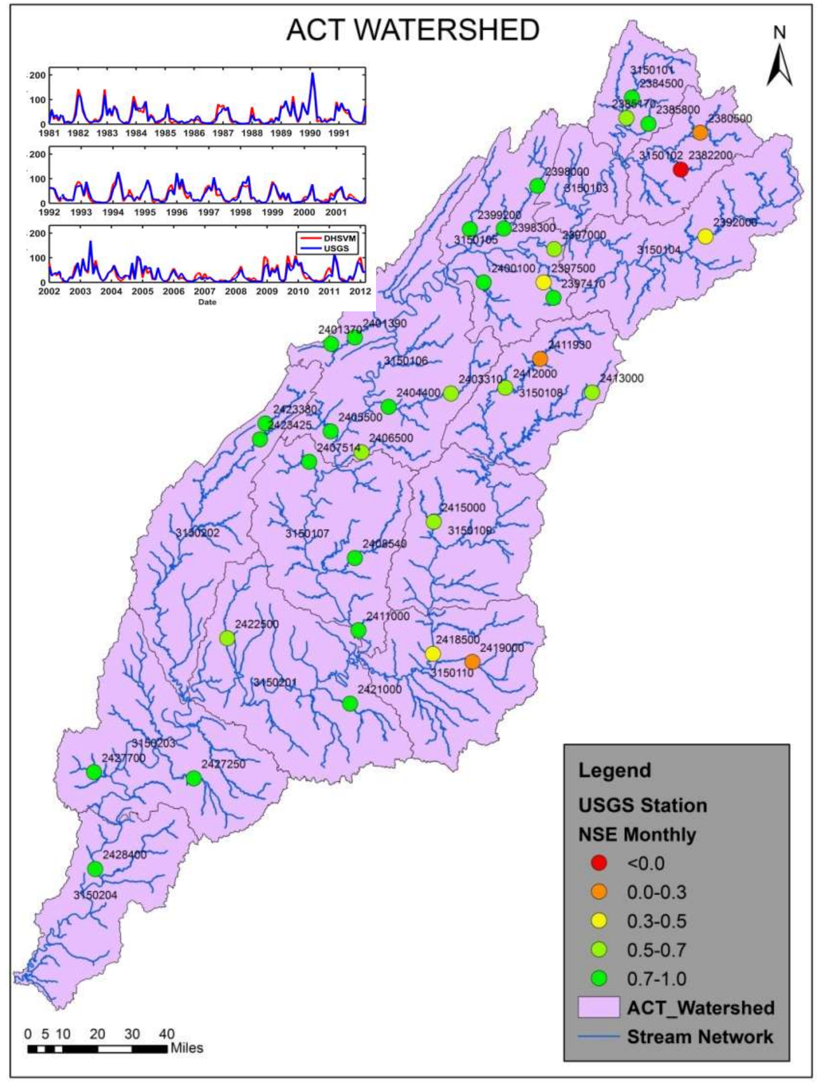
# Hydrologic Modeling and Calibration

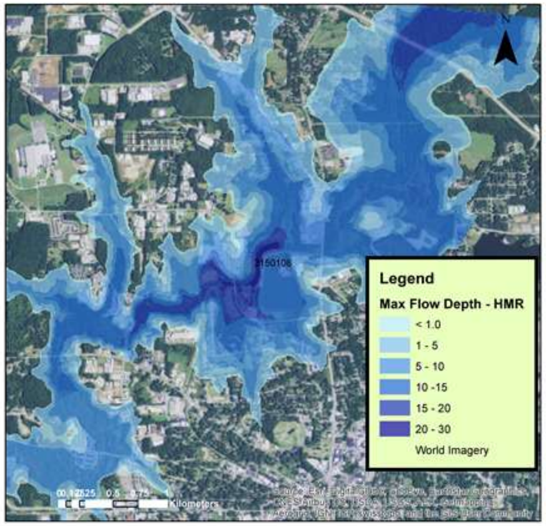
- **DHSVM – Distributed Hydrology Soil Vegetation Model**
  - High-resolution (90m)
  - Driven by Daymet or WRF meteorology
  - Model calibration to reproduce historic obs



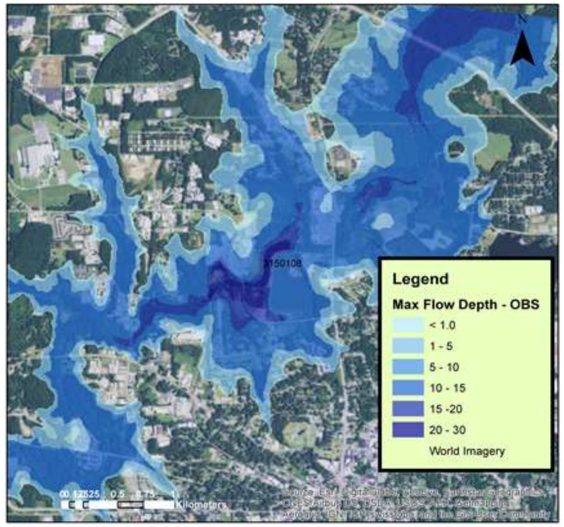



# Flood Simulation

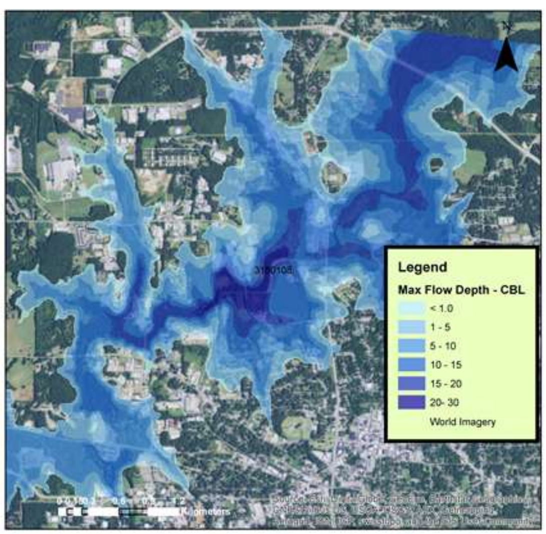
**HMR**



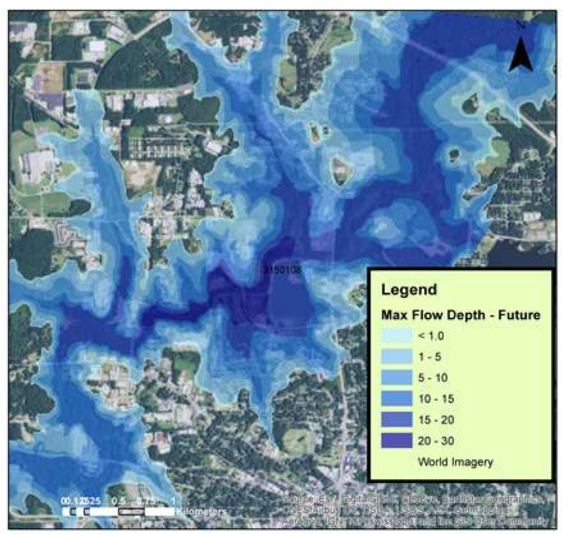

**CFSR**



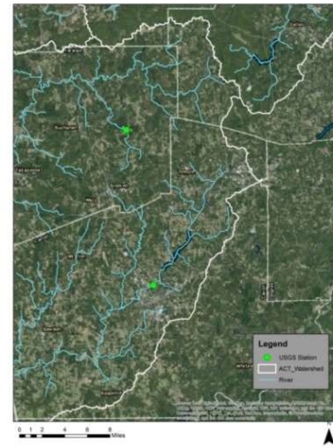

**CCSM4 Baseline**

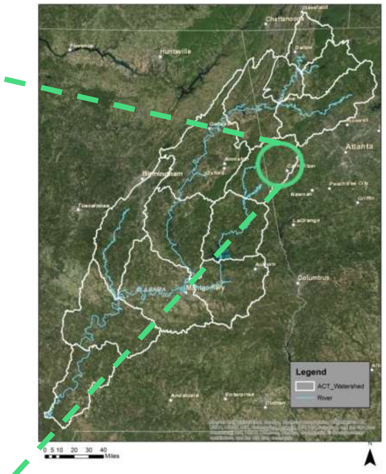


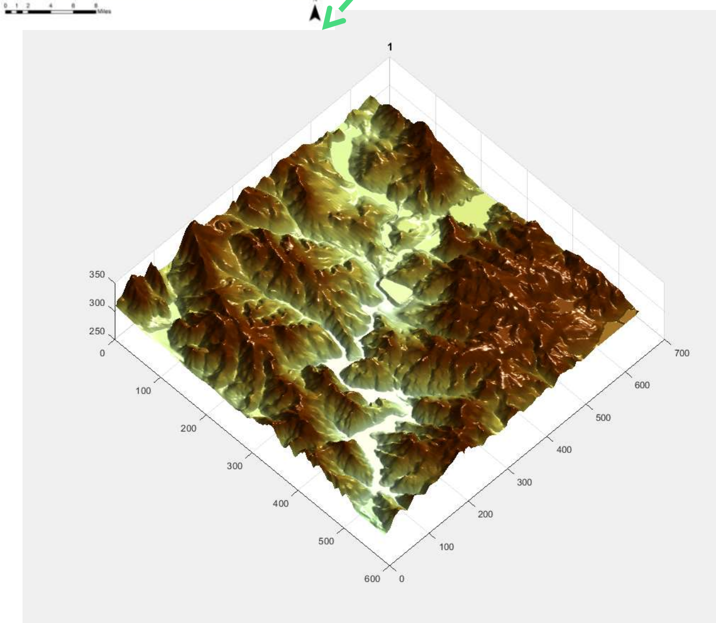

**CCSM4 Future**




**Carrollton, GA**



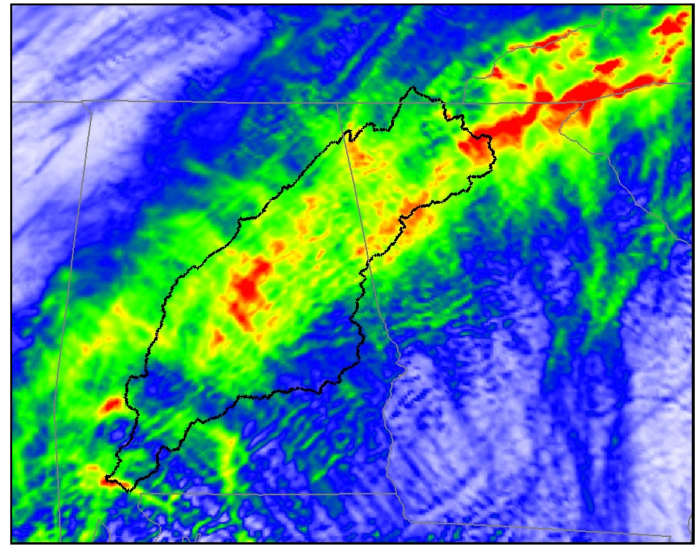



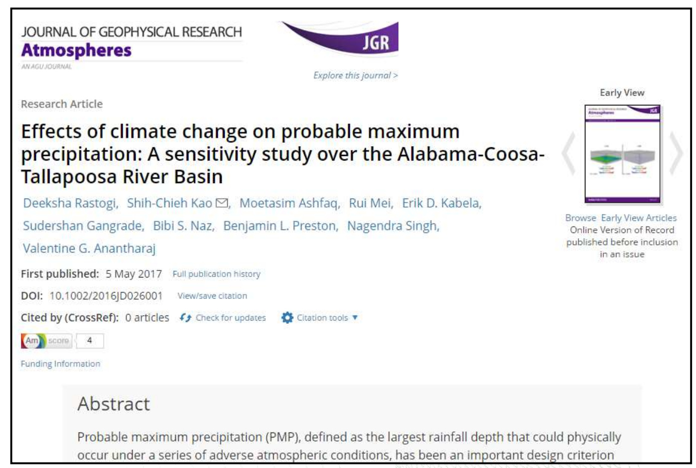




**Flood simulation using Flood2D-GPU (Prof. Al Kalyanapu, Tennessee Technology University)**

# Key Points

- **The deterministic PMP storm upper bound is projected to increase in a warming environment.**
  - Implications for our national energy-water security.
- **The conventional assessment can be largely improved by numerical models.**
- **Further thinking and understanding will be needed to develop modern PMP and PMF for engineering application.**



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Research Article

Effects of climate change on probable maximum precipitation: A sensitivity study over the Alabama-Coosa-Tallapoosa River Basin


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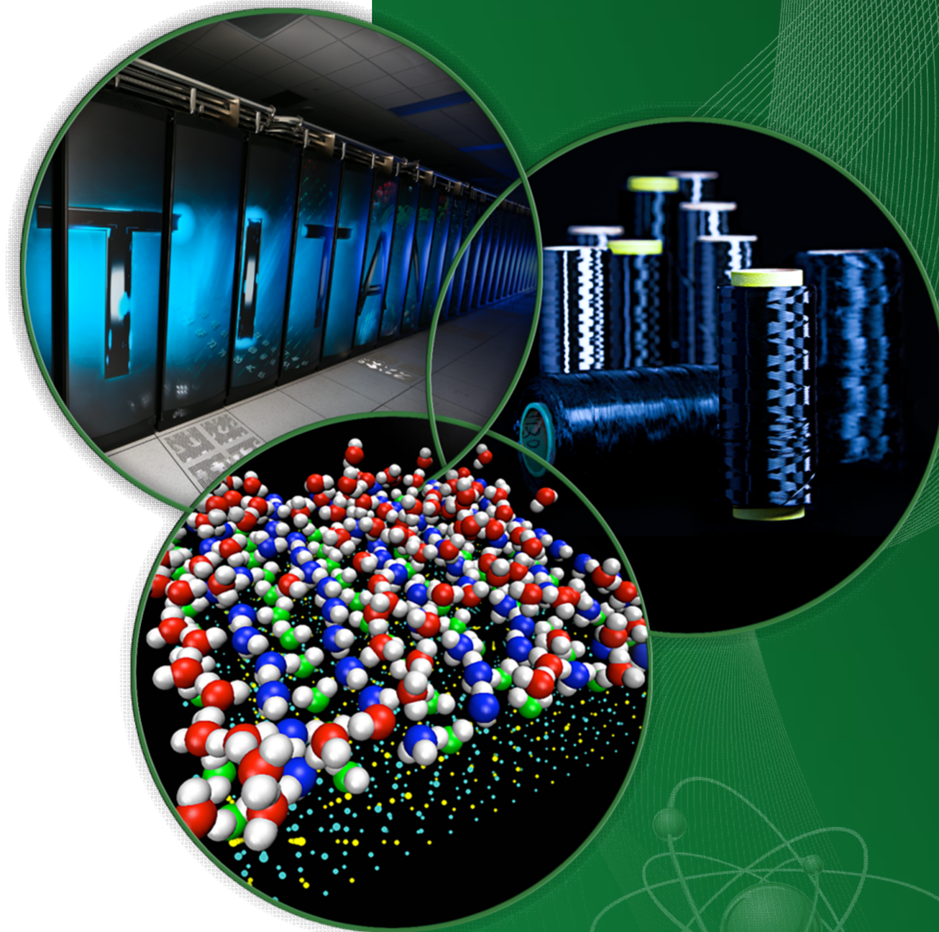
Abstract

Probable maximum precipitation (PMP), defined as the largest rainfall depth that could physically occur under a series of adverse atmospheric conditions, has been an important design criterion

# Thank you
# Questions?



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