

# Potential Impacts of Climate Change on Water Resources in South Carolina and across the United States

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Southern Research Station  
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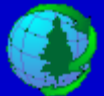
*Oct 14, 2008, Charleston, SC Water Conference*

SGCP



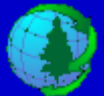
# Outlines

- Review U.S. water resources issues under multiple stressors.
- Water Supply Stress Index modeling (WaSSI) to evaluate the potential impacts on water supply and demand relations.

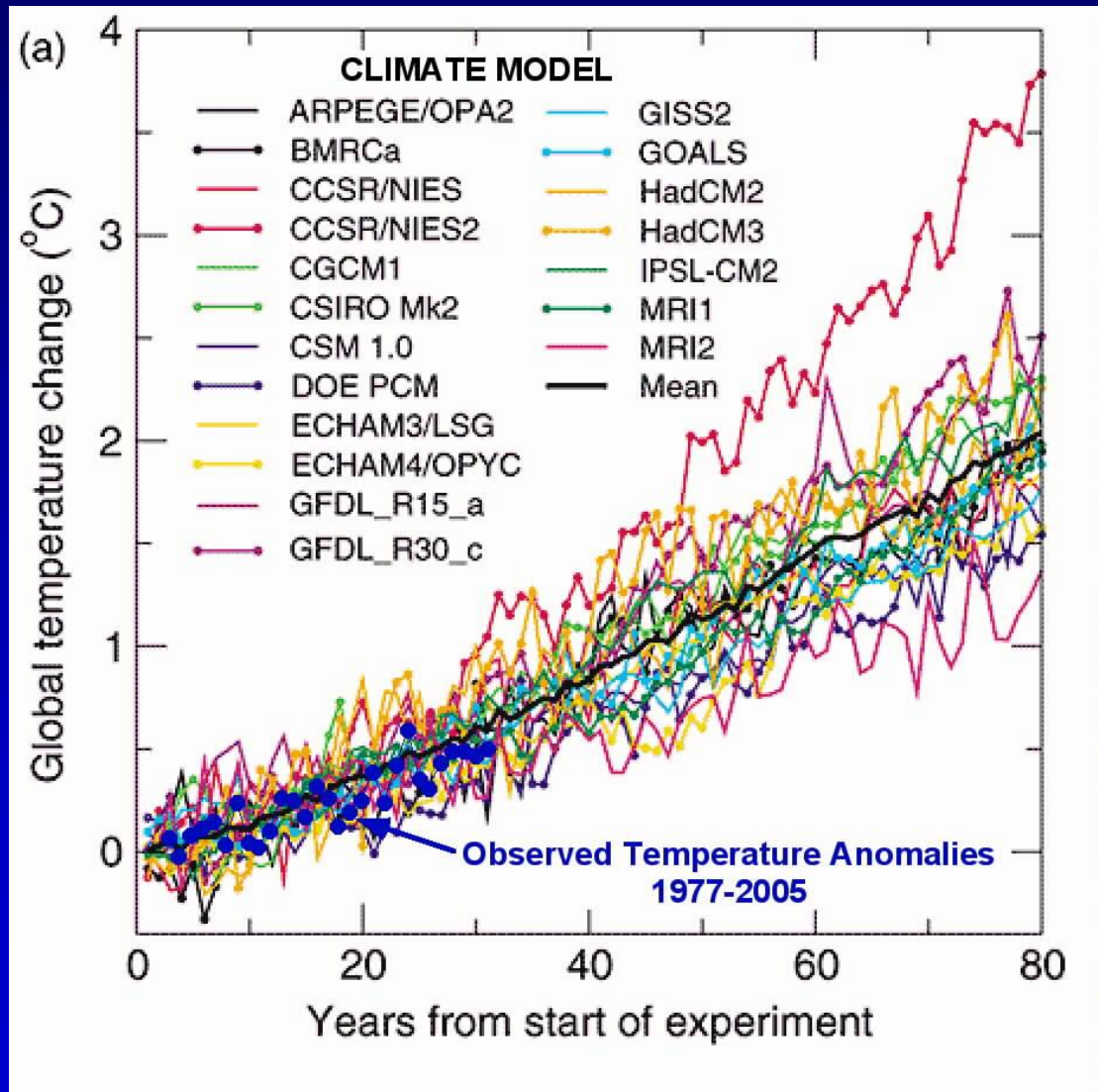


# Why Forest Service interested in Water and Climate Change ?

- Forests provide the best water quality among all land uses
- Forest lands (30% of land area) provide 50% of water supply in the US.
- Climate change has direct and indirect impacts on water supply and demand
- Population growth, urbanization and land use change
- Fire, Hurricanes
- Biofuel development



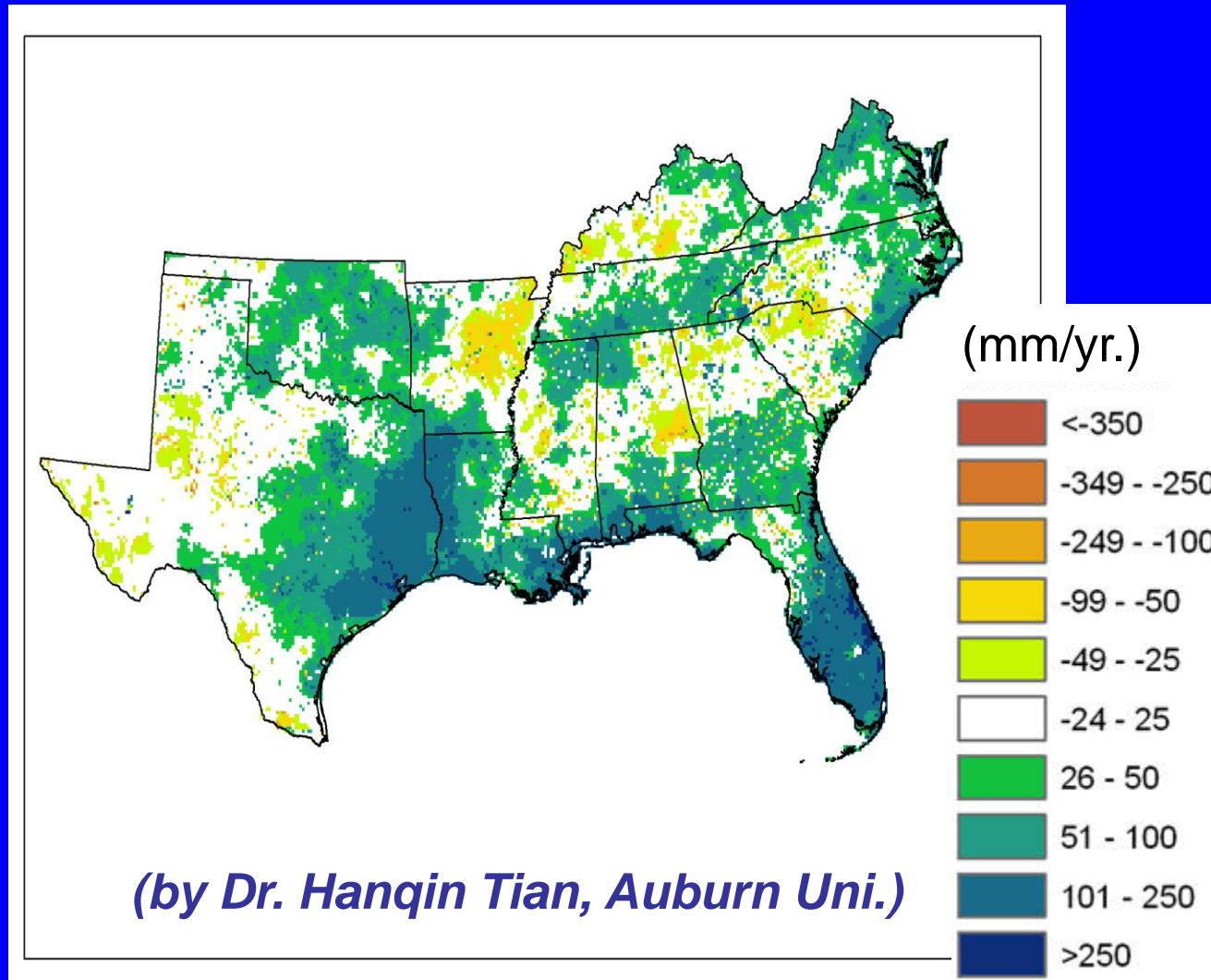
# Climate change is happening and will continue ....



# Then, what are the consequences....

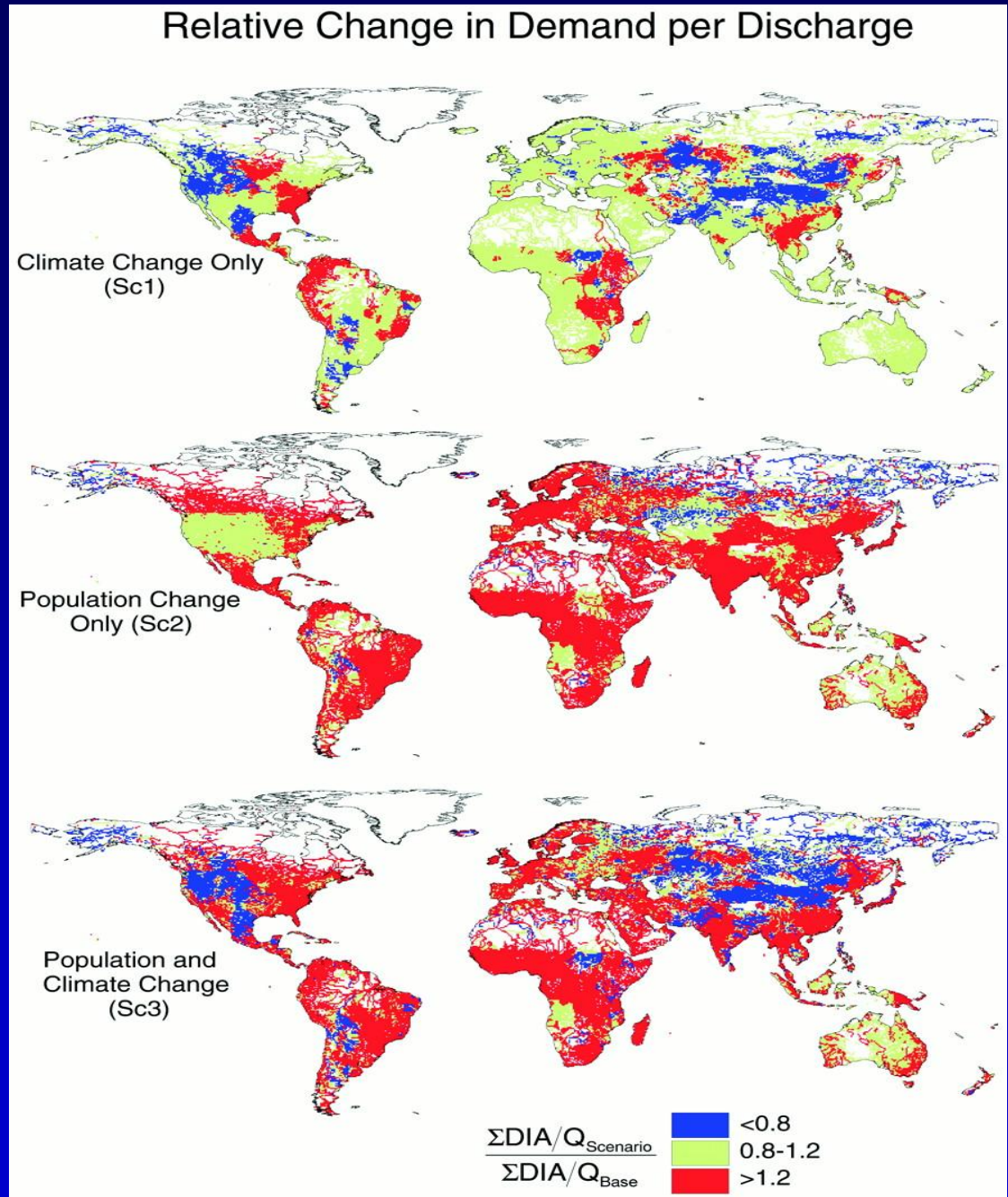


# Modeled Runoff Anomaly for 1991-2005 Compared to 1961-1990



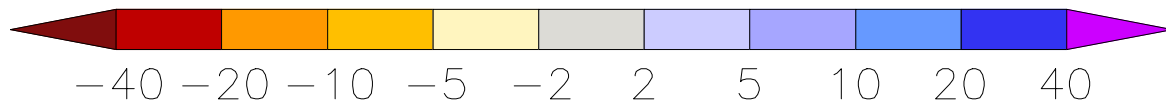
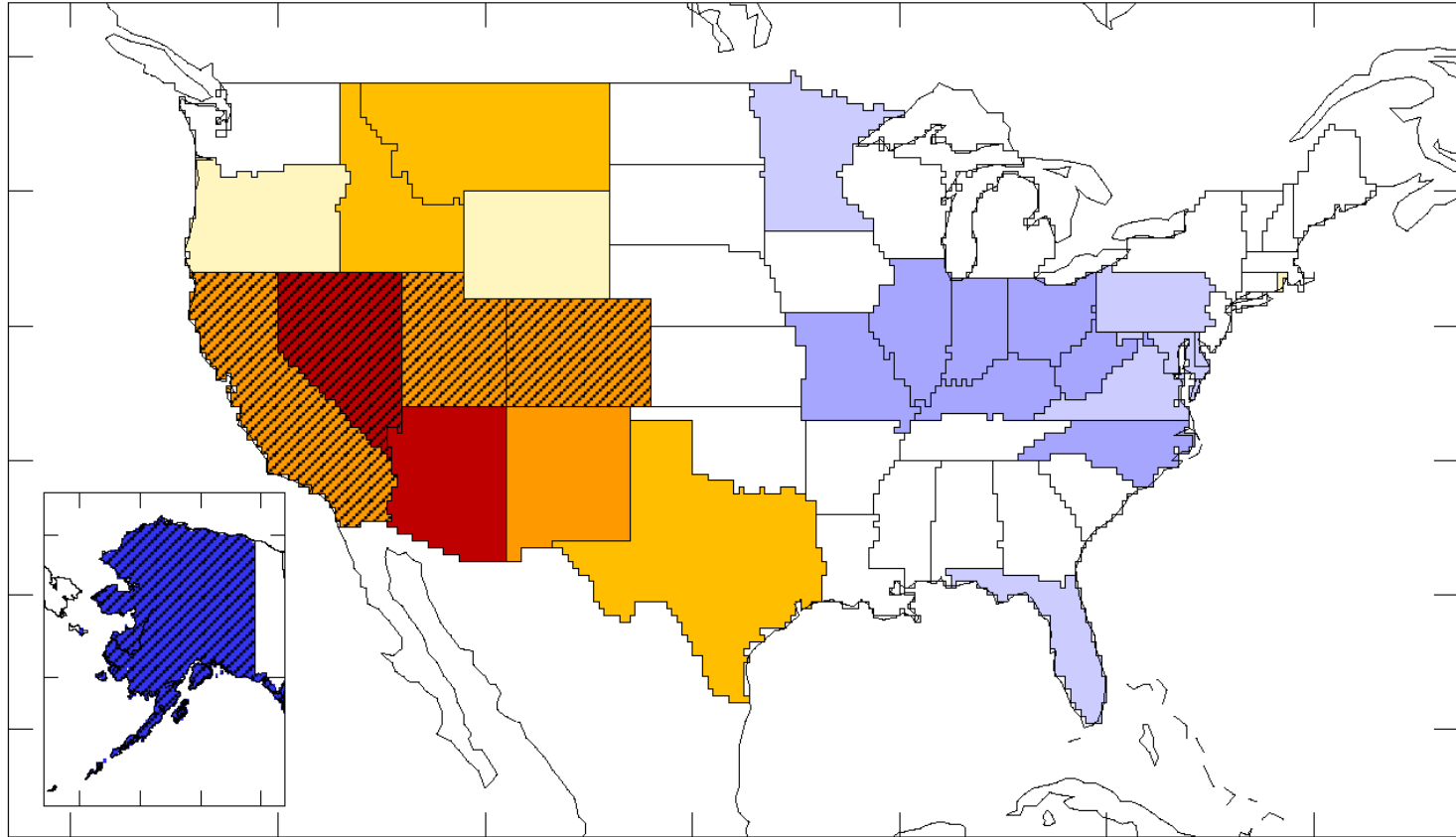
# Global Impacts of Climate Change and Population Growth on Water

Source: Vörösmarty et al., 2000 (Science 289: 284-288)



# Model-Projected Changes in Annual Runoff, 2041-2060

Relative to 1900-1970 (Curtsey of Milly Congressional briefing April 2007)



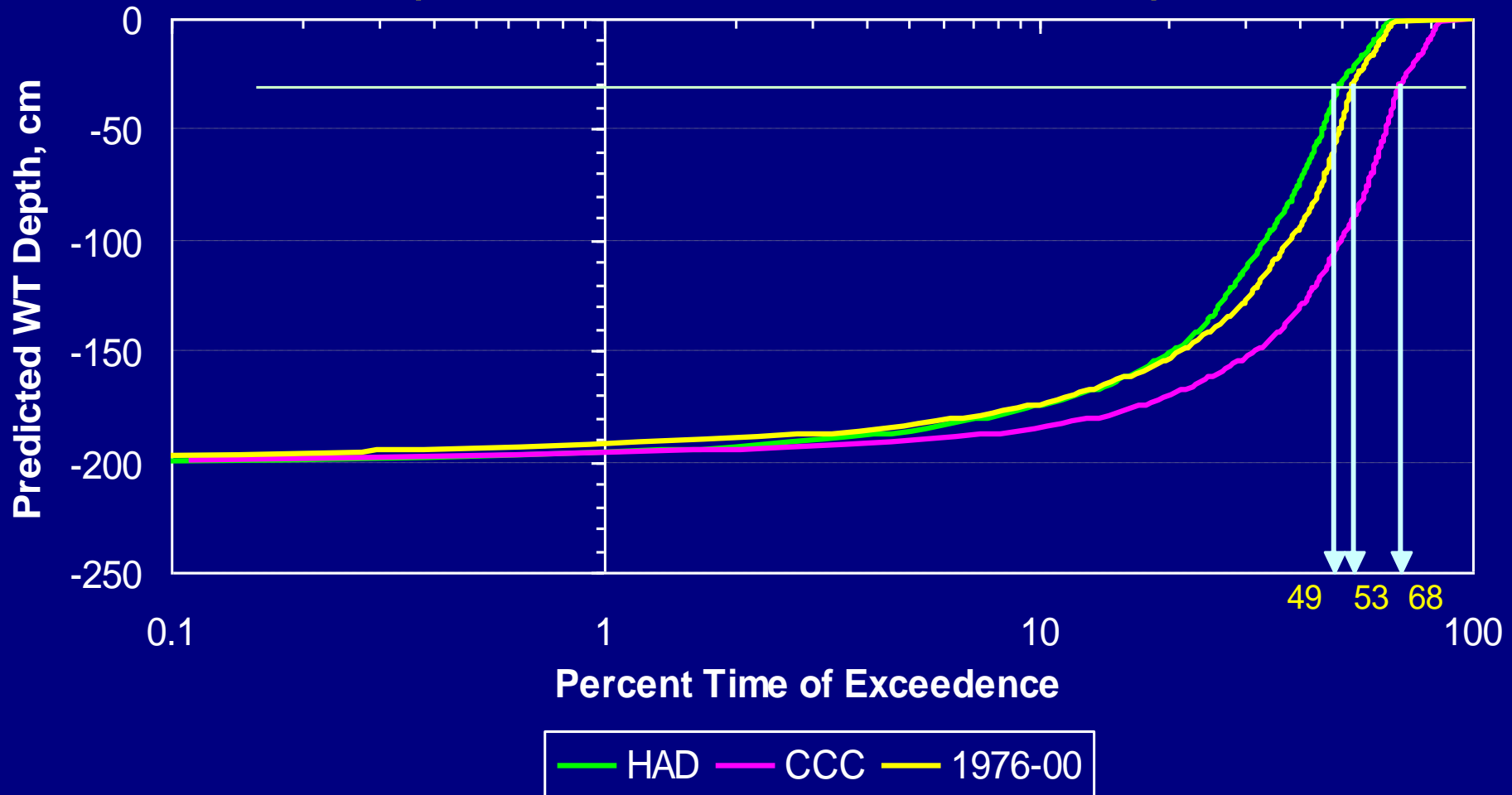
(After Milly, P.C.D., K.A. Dunne, A.V. Vecchia, Global pattern of trends in streamflow and water availability in a changing climate, *Nature*, **438**, 347-350, 2005.)





# Watershed Impacts (*Amatya et al. 2006*)

## Predicted Daily Water Table Depth Frequency Curves S4 (2001-25 GCM & 1976-00 Historic)



# Impacts on U.S. Water Resources: Basic Consensus

- Increase of air temperature and precipitation likely, but distribution uncertain;
- Drought and flood severity increases;
- Water supply change
- Sea level rise affecting coastal ecosystems
- Water quality degradation (warming temperature, stormwater runoff);

# Case Study



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## IMPACTS OF MULTIPLE STRESSES ON WATER DEMAND AND SUPPLY ACROSS THE SOUTHEASTERN UNITED STATES<sup>1</sup>

*Ge Sun, Steven G. McNulty, Jennifer A. Moore Myers, and Erika C. Cohen<sup>2</sup>*

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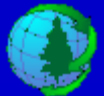
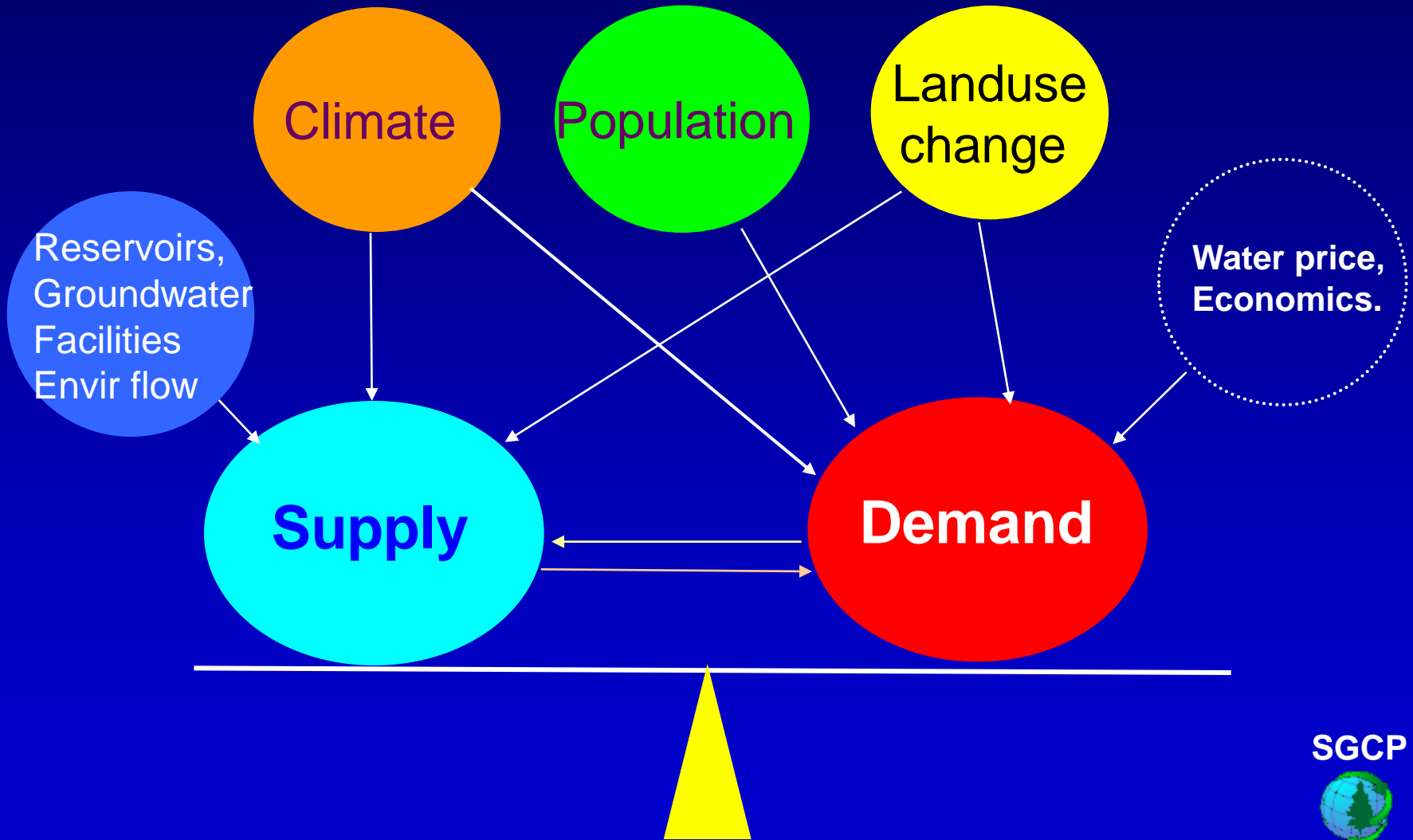


# Water Supply Stress Index (WaSSI):

$$\text{WaSSI} = \frac{\text{Water Demand}}{\text{Water Supply}}$$



# Water Supply and Demand



# Definitions

**Water Supply** at Hydrologic Unit Code (HUC)  
Scale (Watersheds)

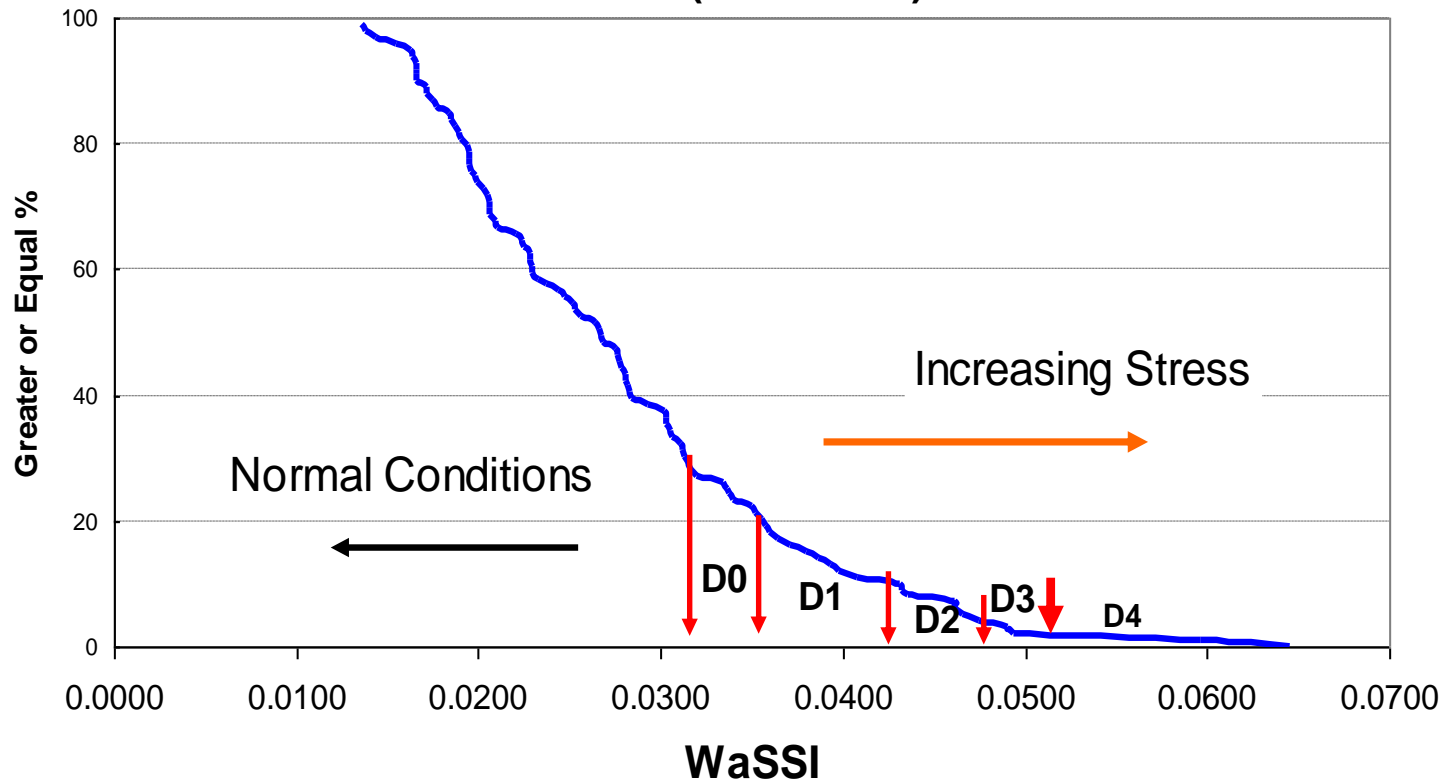
= Precipitation - Evapotranspiration +  
Groundwater Supply + Returnflow from Water  
Users

**Water Demand** by Humans at HUC Watershed  
Scale

= Water Use by Sector (Thermoelectric,  
Commercial, Domestic, Irrigation, Livestock,  
Industrial, Mining, Public Supply Use/Loss)

# WaSSI Classification

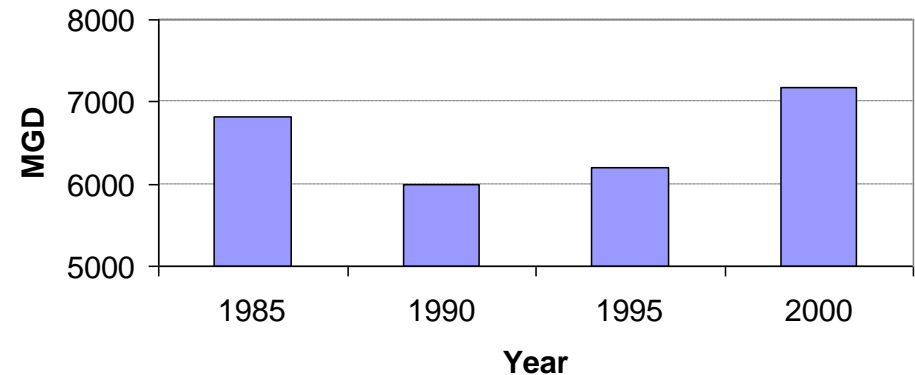
WaSSI Frequency Distribution for Raleigh NC  
(1895-1993)



# Databases: Water Demand

- Historic annual water withdrawal data by HUC (USGS)
- Monthly summary by sector, states, 18 Water Resource Regions

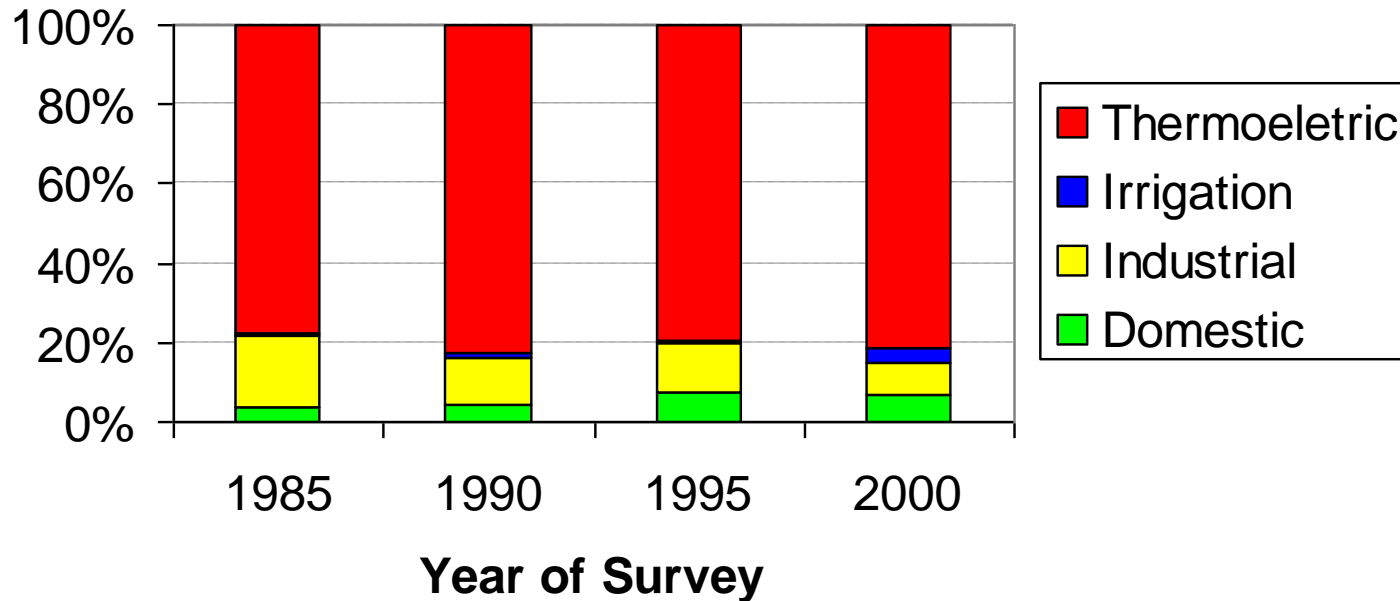
**Total Water Withdrawal  
in South Carolina (USGS)**



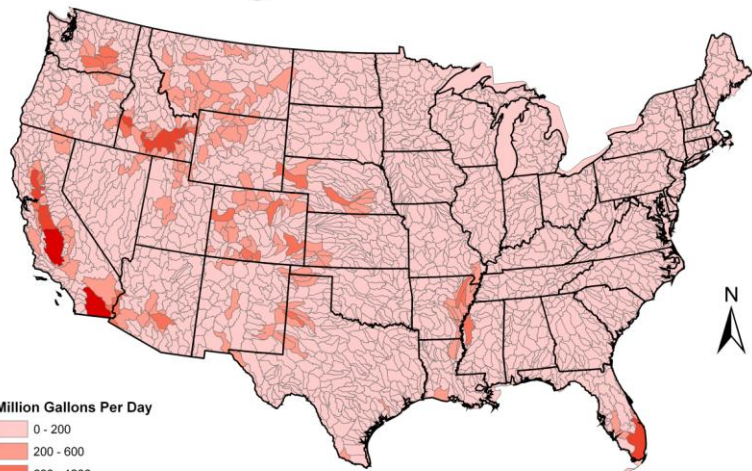


# Water Withdrawal by Sector

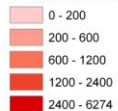
**Water Use by Sectors  
in South Carolina (USGS)**



## Irrigation Water Use

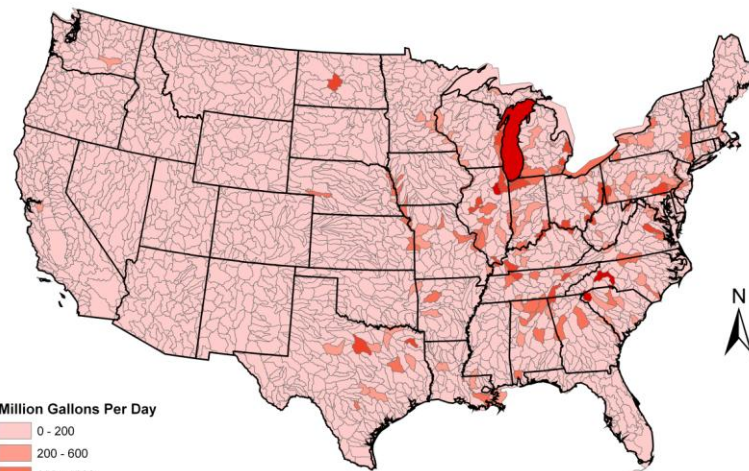


Million Gallons Per Day

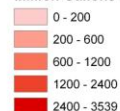


0 205 410 820 1,230 1,640 Kilometers

## Thermoelectric Water Use

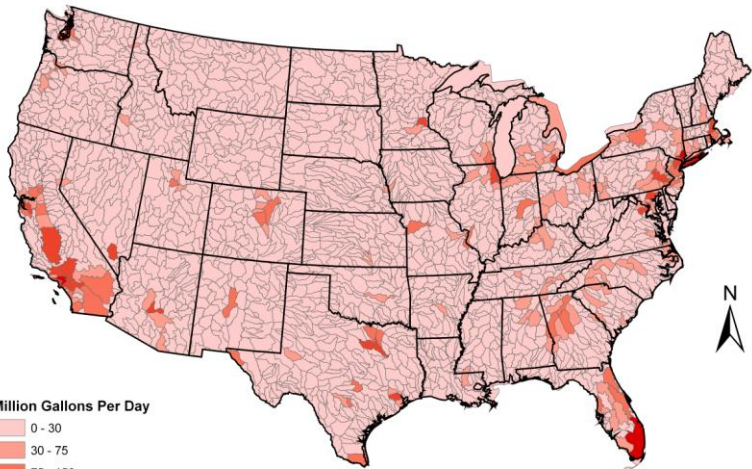


Million Gallons Per Day

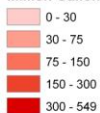


0 205 410 820 1,230 1,640 Kilometers

## Domestic Water Use

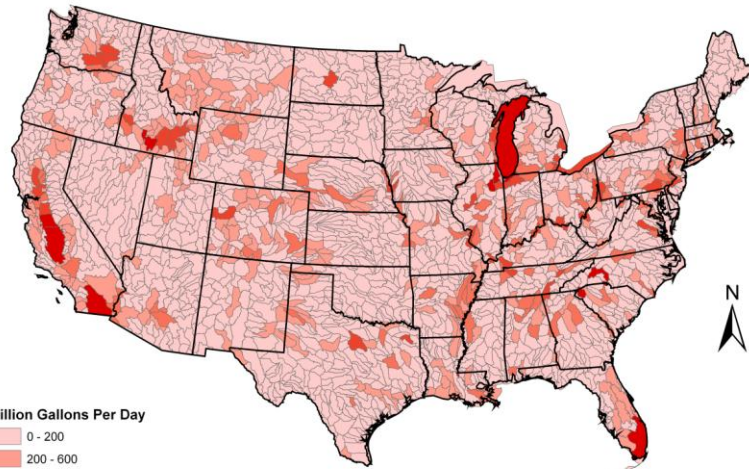


Million Gallons Per Day

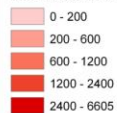


0 205 410 820 1,230 1,640 Kilometers

## Total Water Use

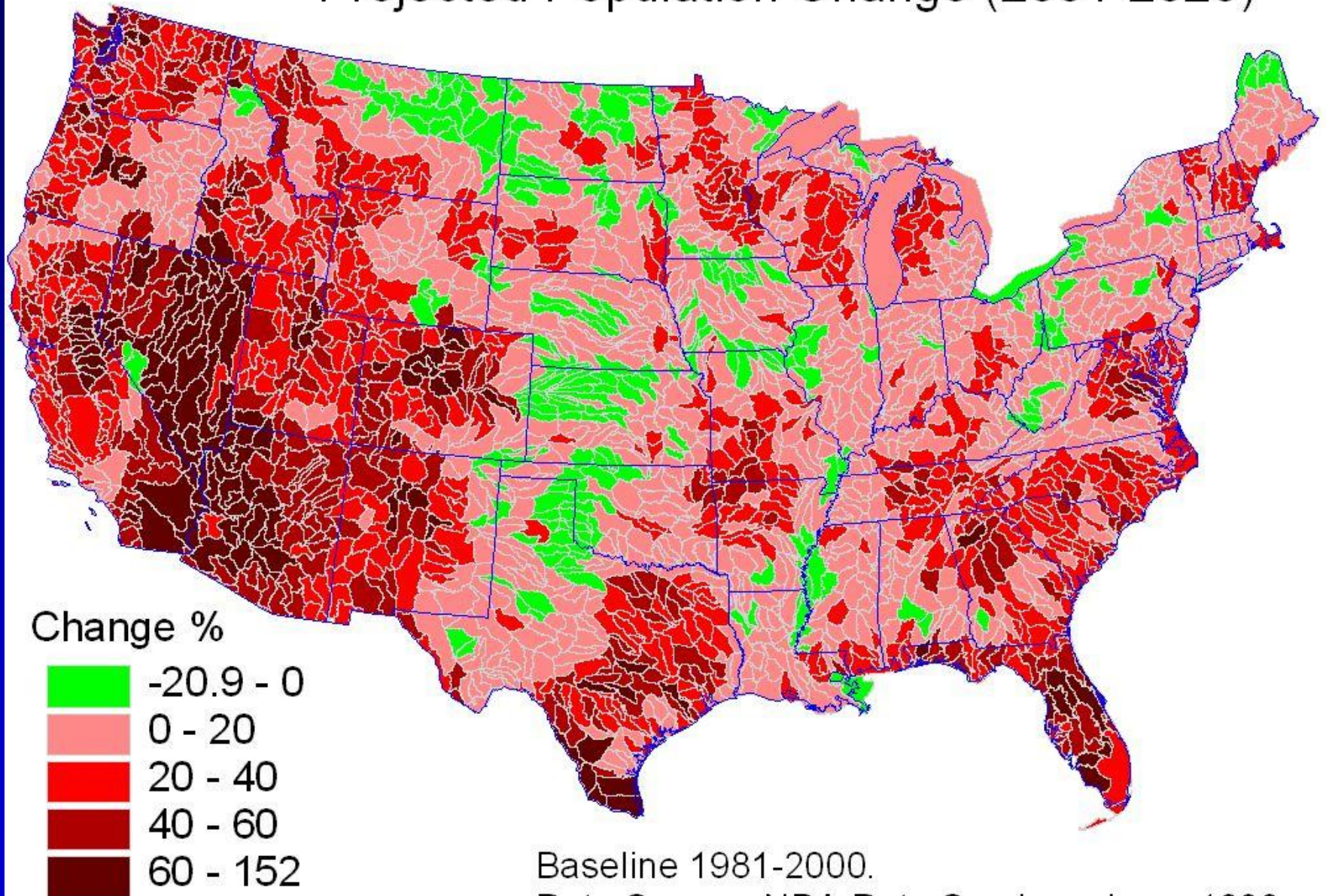


Million Gallons Per Day



0 140 280 560 840 1,120 Miles

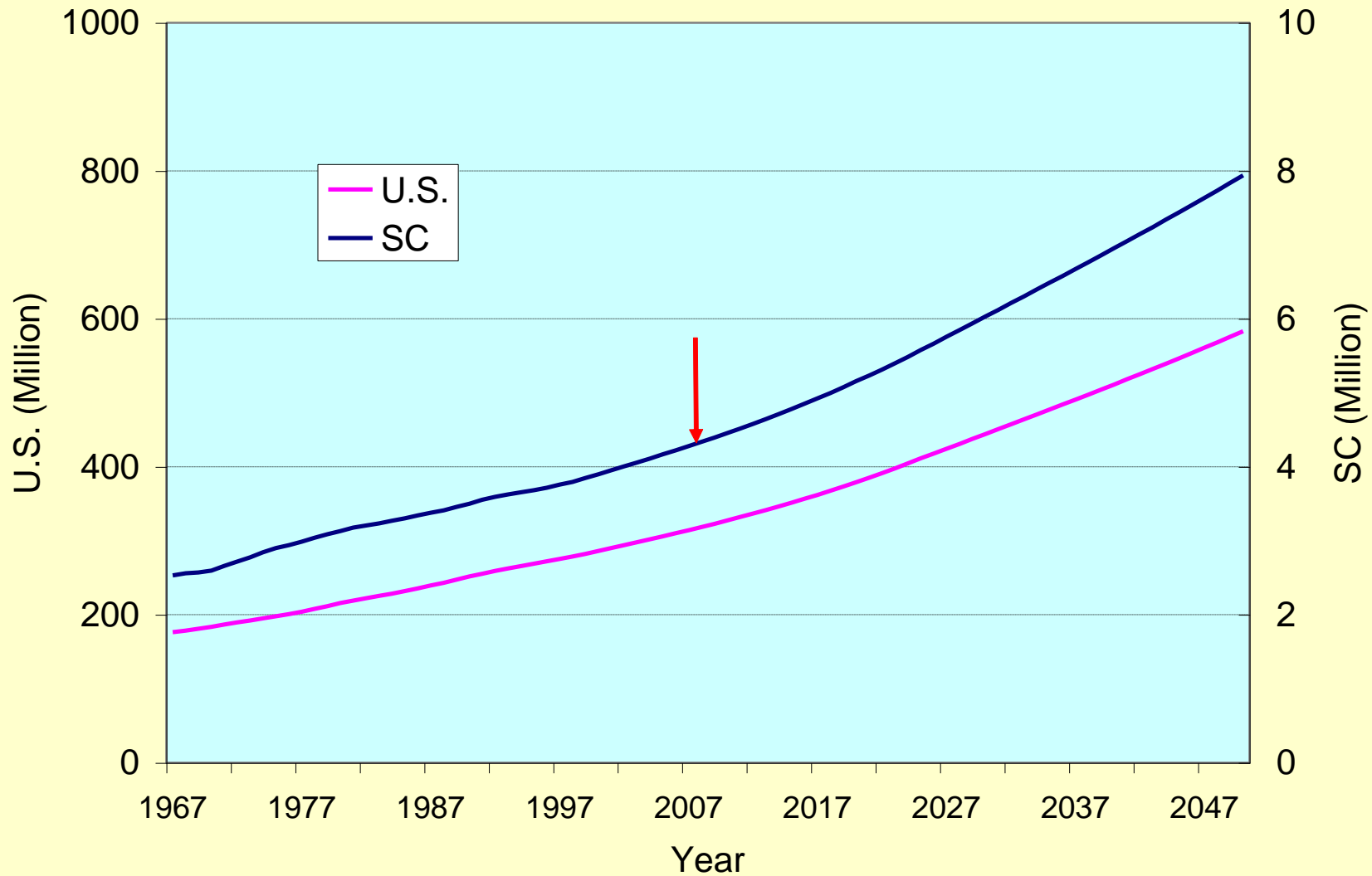
# Projected Population Change (2001-2020)



Baseline 1981-2000.

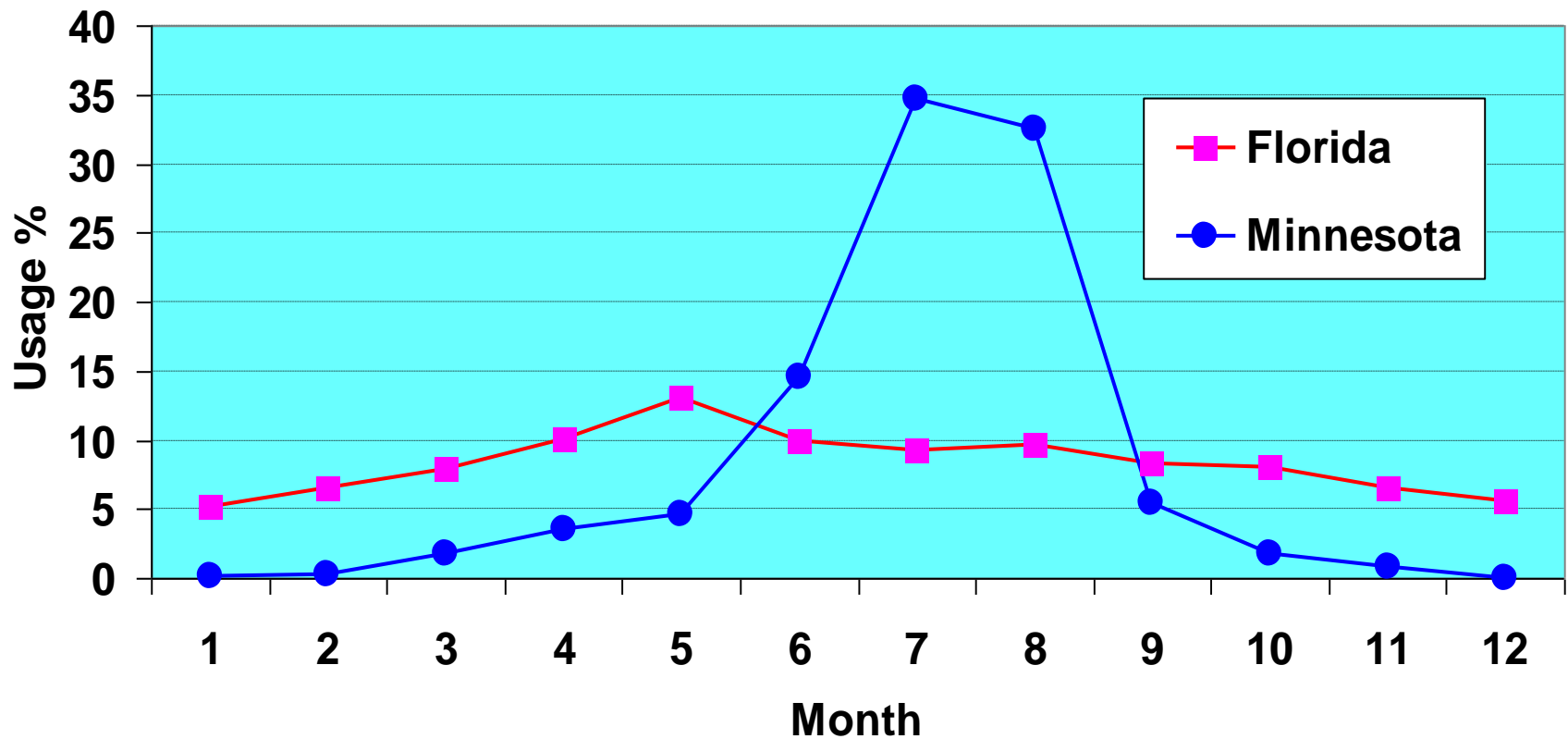
Data Source: NPA Data Services, Inc. , 1999

Population Growth (1967-2050)



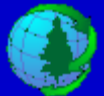
# Seasonal Water Use

Water Use by the Irrigation Sector

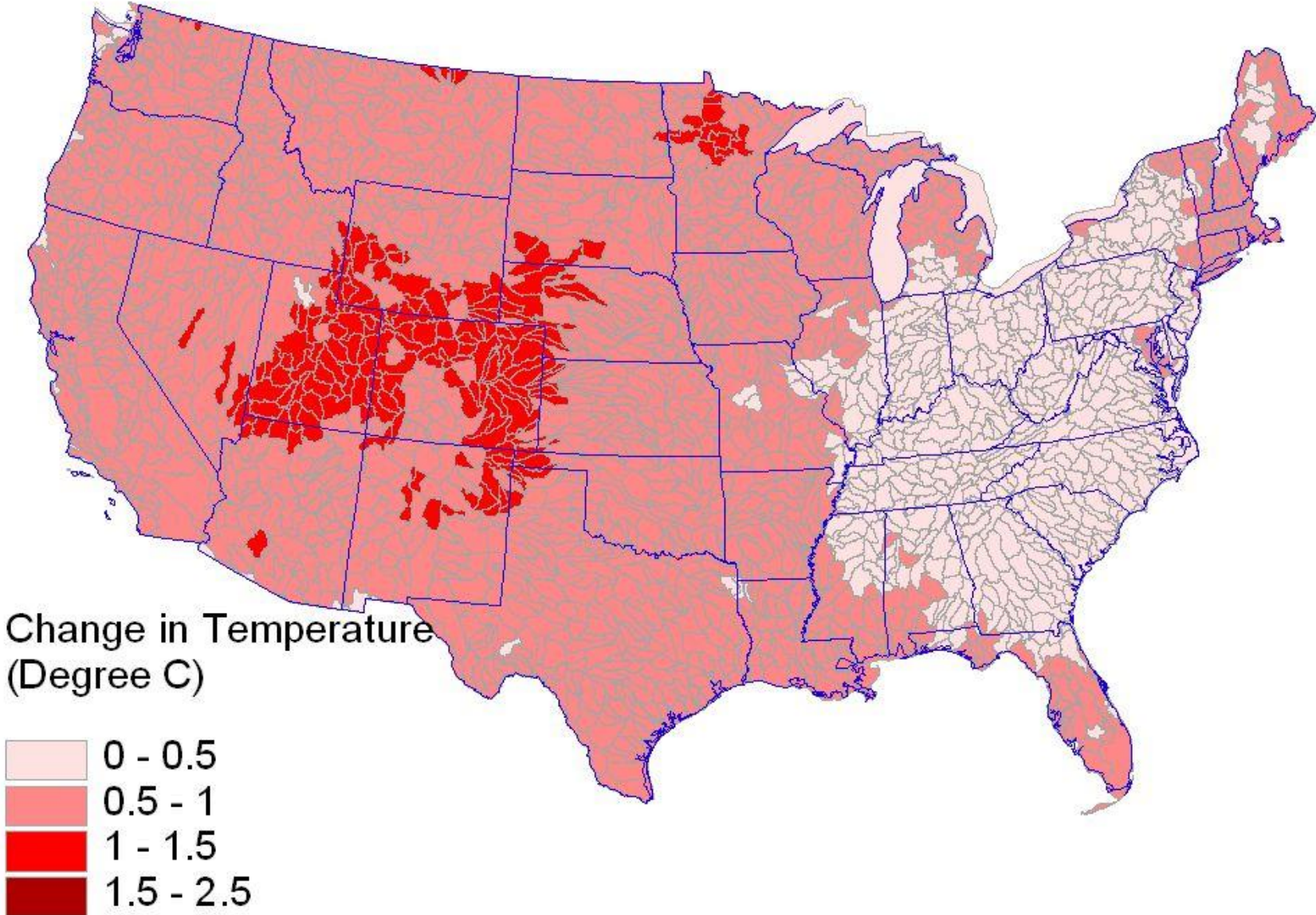


# Climate Change Models

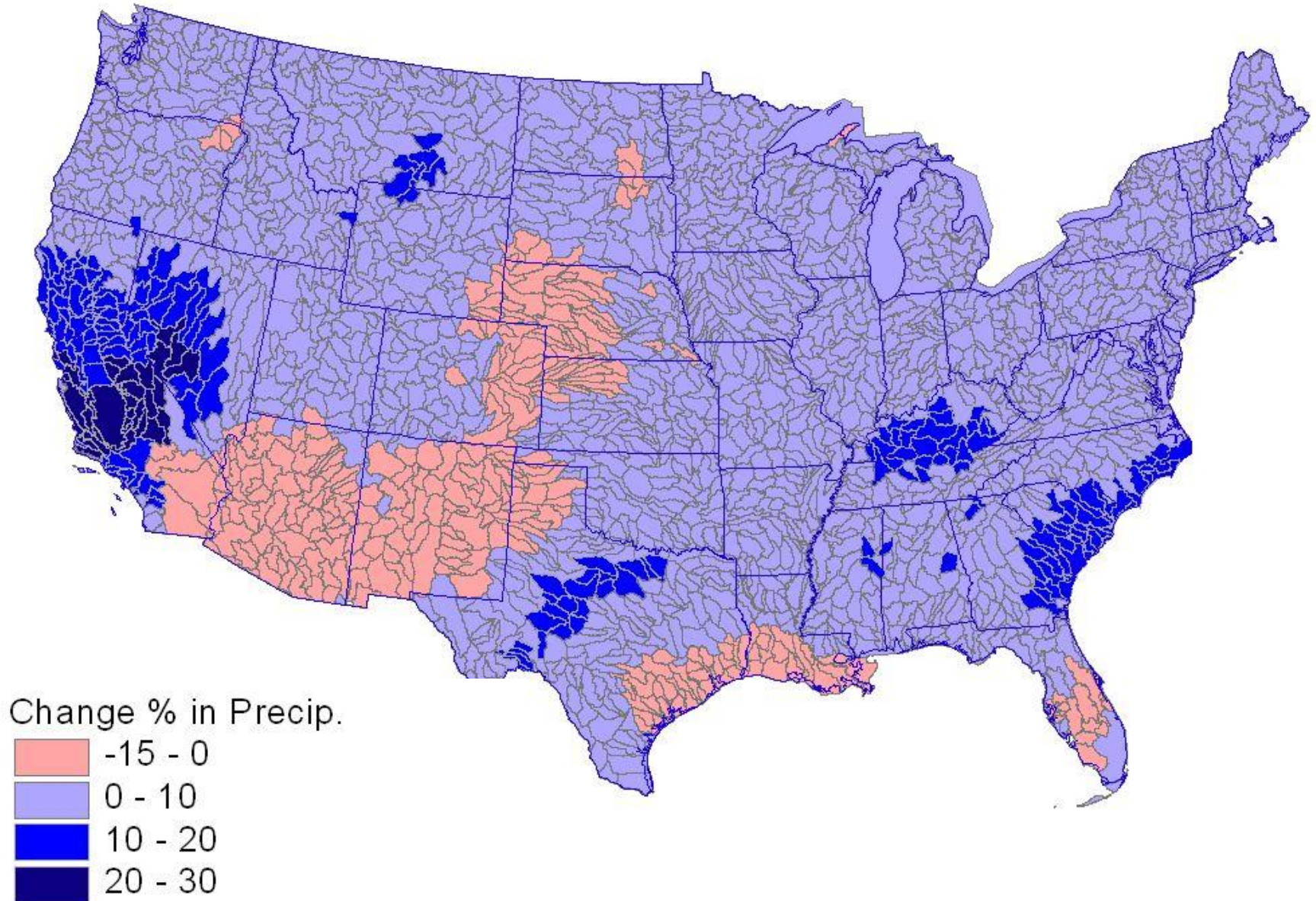
- U.K. Hadley Center (Had2CMSul)
  - (Warm, Wet Scenario)
- Canadian Climate Centre (CGC1)
  - (Hot, Dry Scenario)



# Air Temperature Change (HadCM2Sul) over Next 20 Years



# Precipitation Change (HadCM2Sul) over Next 20 Years



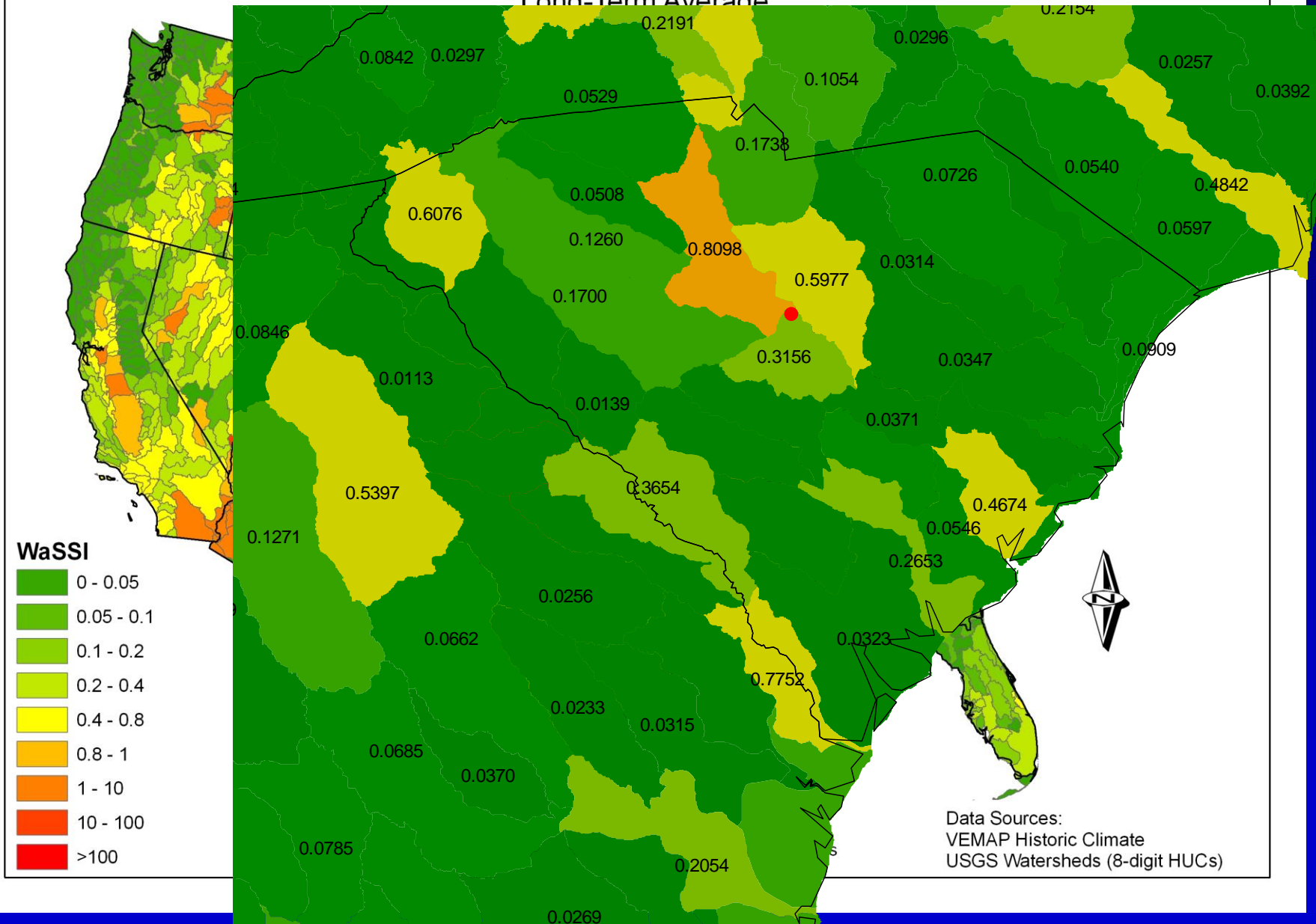


# Hypothetical Scenarios

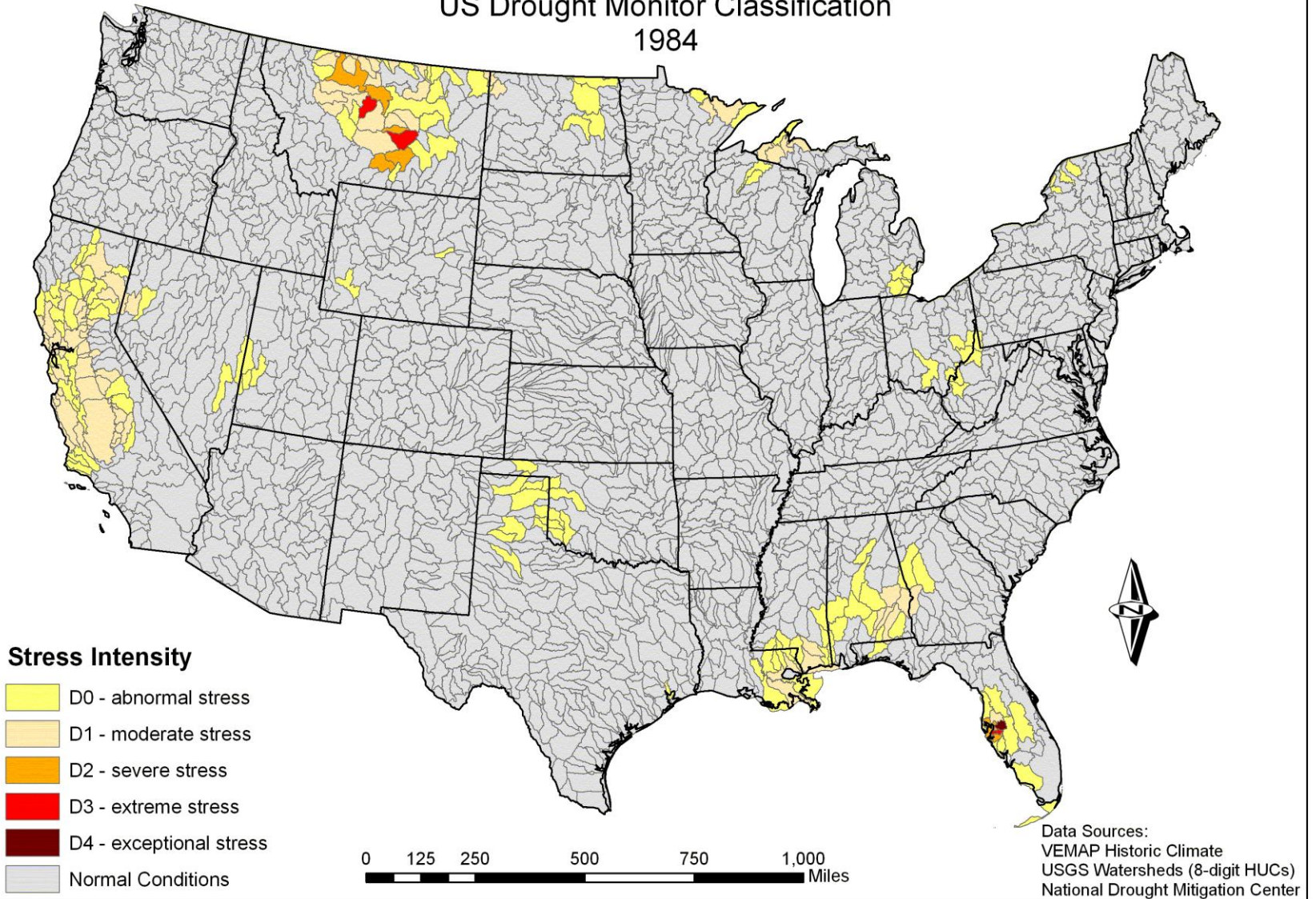
- Scenario 1 = Baseline
  - 1992 landcover, historic climate and water use
- Scenario 2 = climate change (HadCM2Sul, CGC1)
- Scenario 3 = Deforestation by 20% (Urbanization)
- Scenario 4 = Reduce irrigated land by 20%
- Scenario 5 = No groundwater supply
- Scenario 6 = 1.5 x Population



# Historic Annual WaSSI Long-Term Average



**Historic Water Supply Stress Simulation**  
WaSSI Model  
US Drought Monitor Classification  
1984

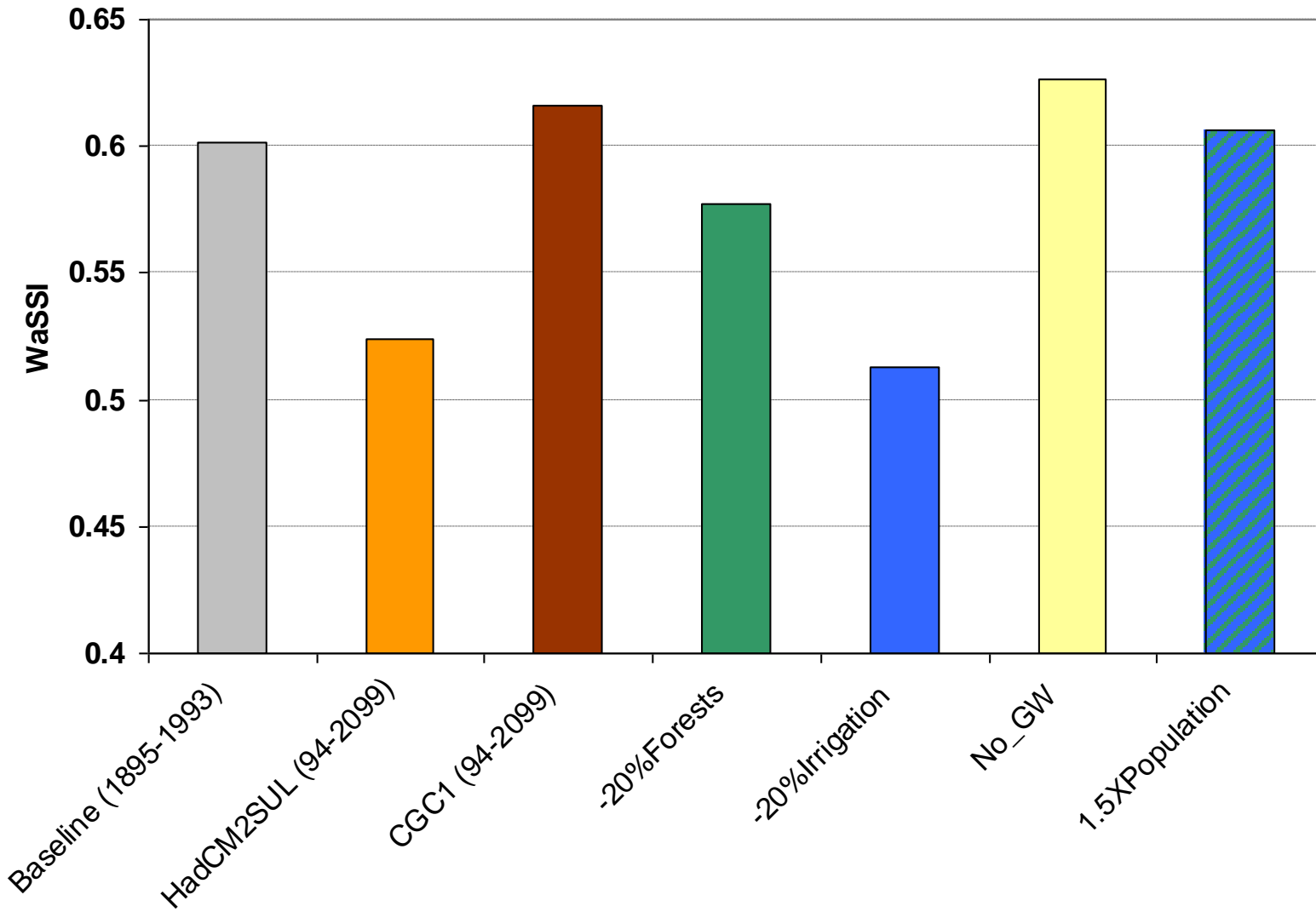


# Combined Effects of Climate, Population, and Landuse Change

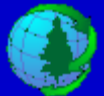
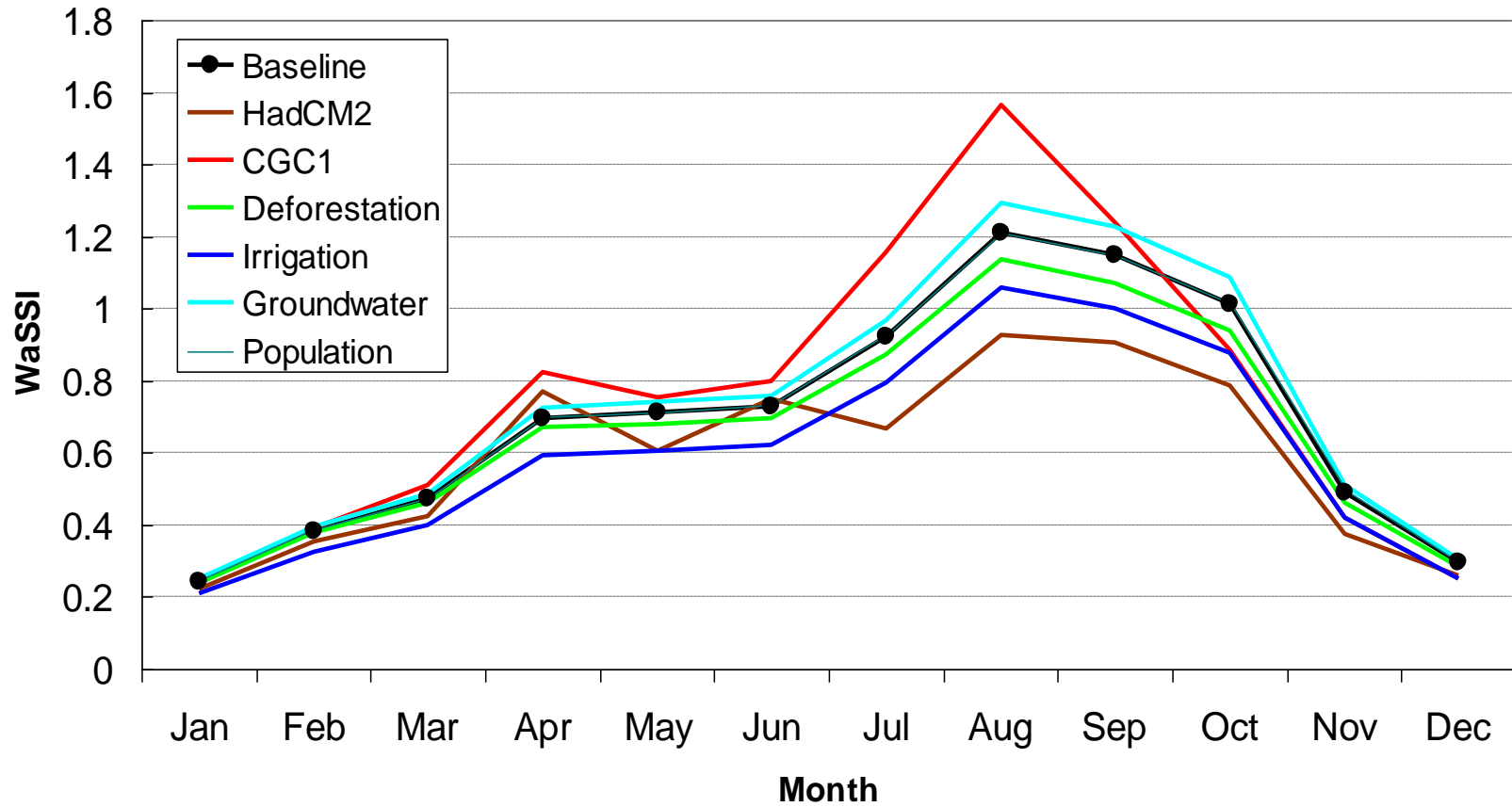
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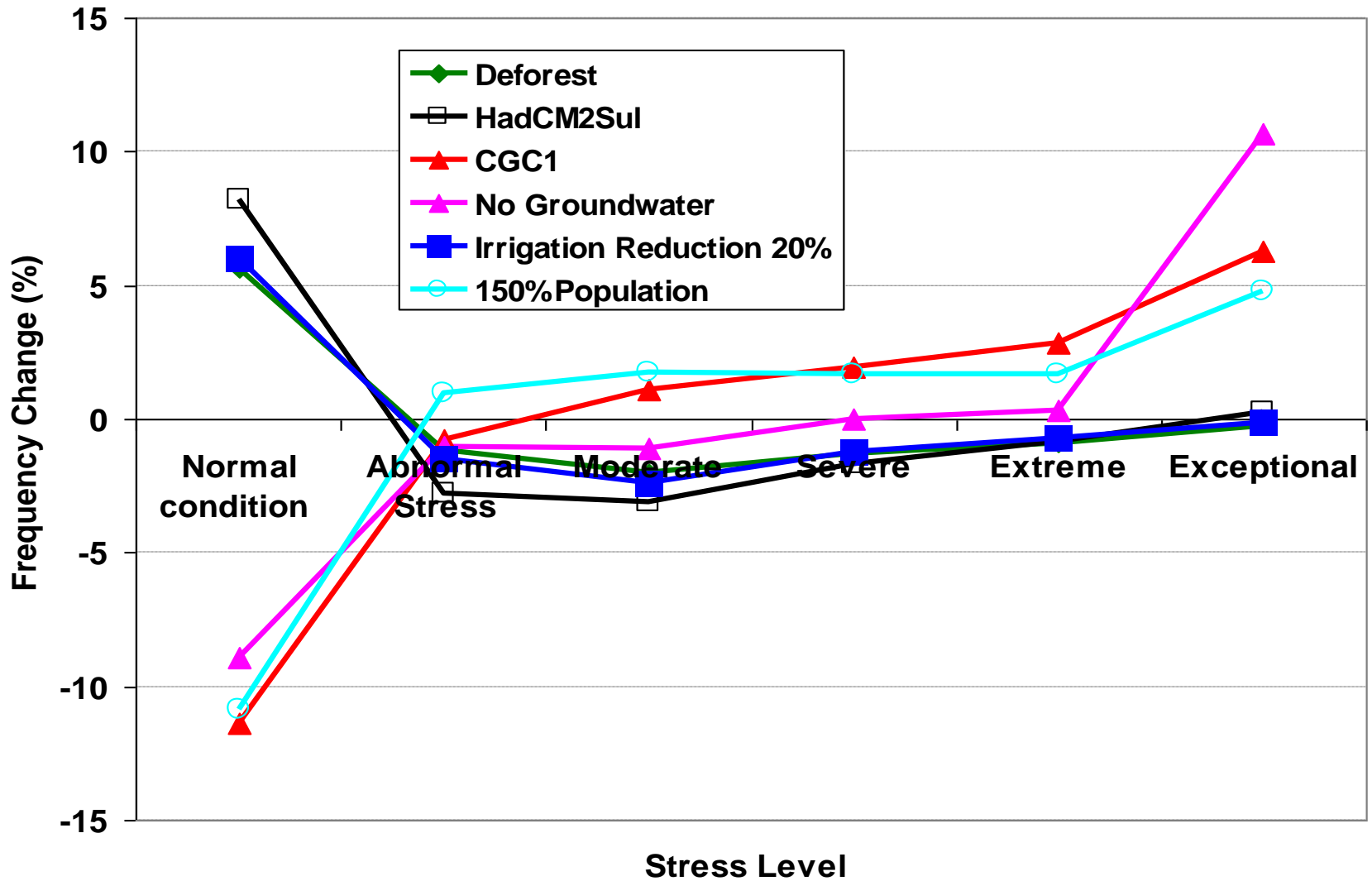
# National WaSSI



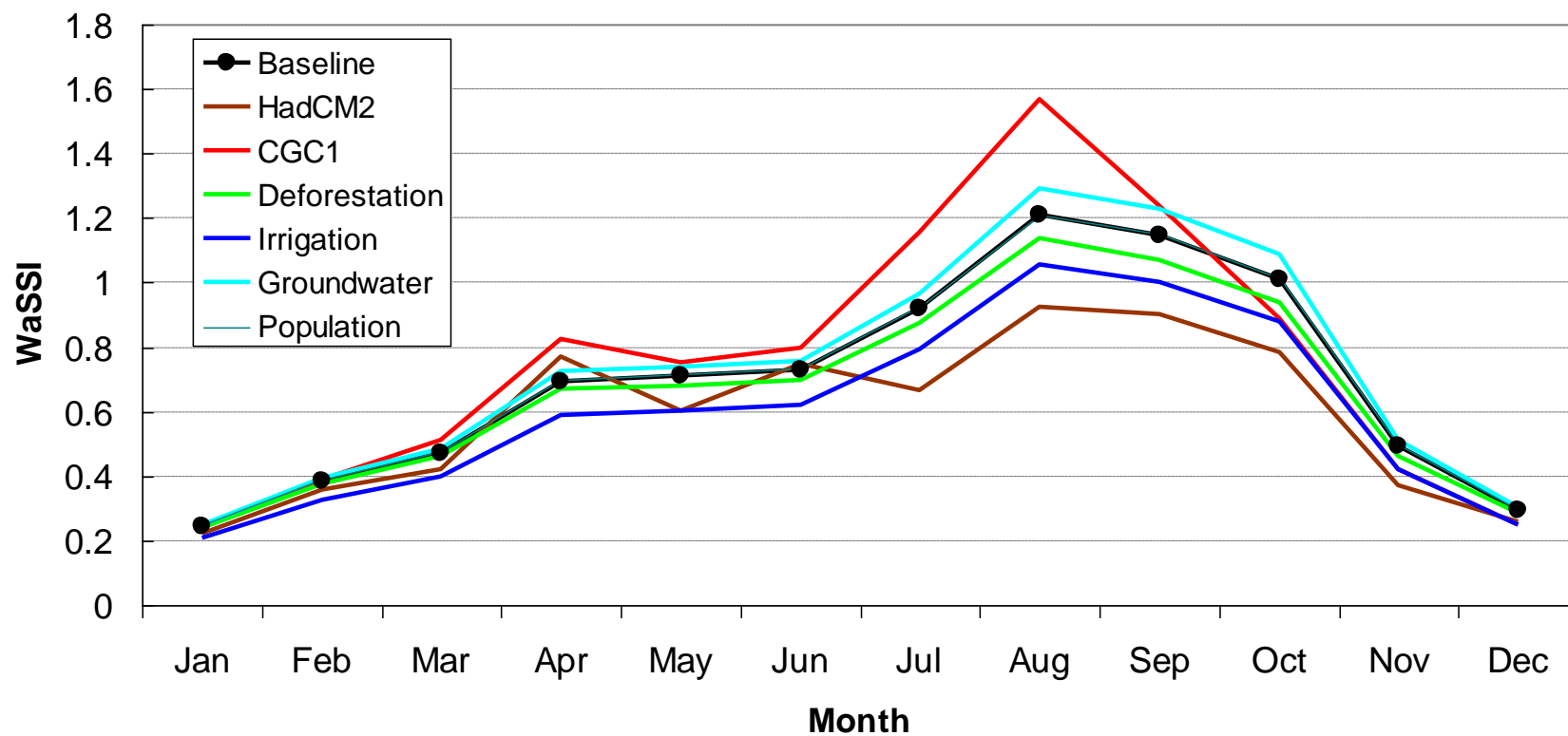
## Averaged Monthly WaSSI (1895-1993)



## Overall Effects of Multiple Scenarios on WaSSI Distribution

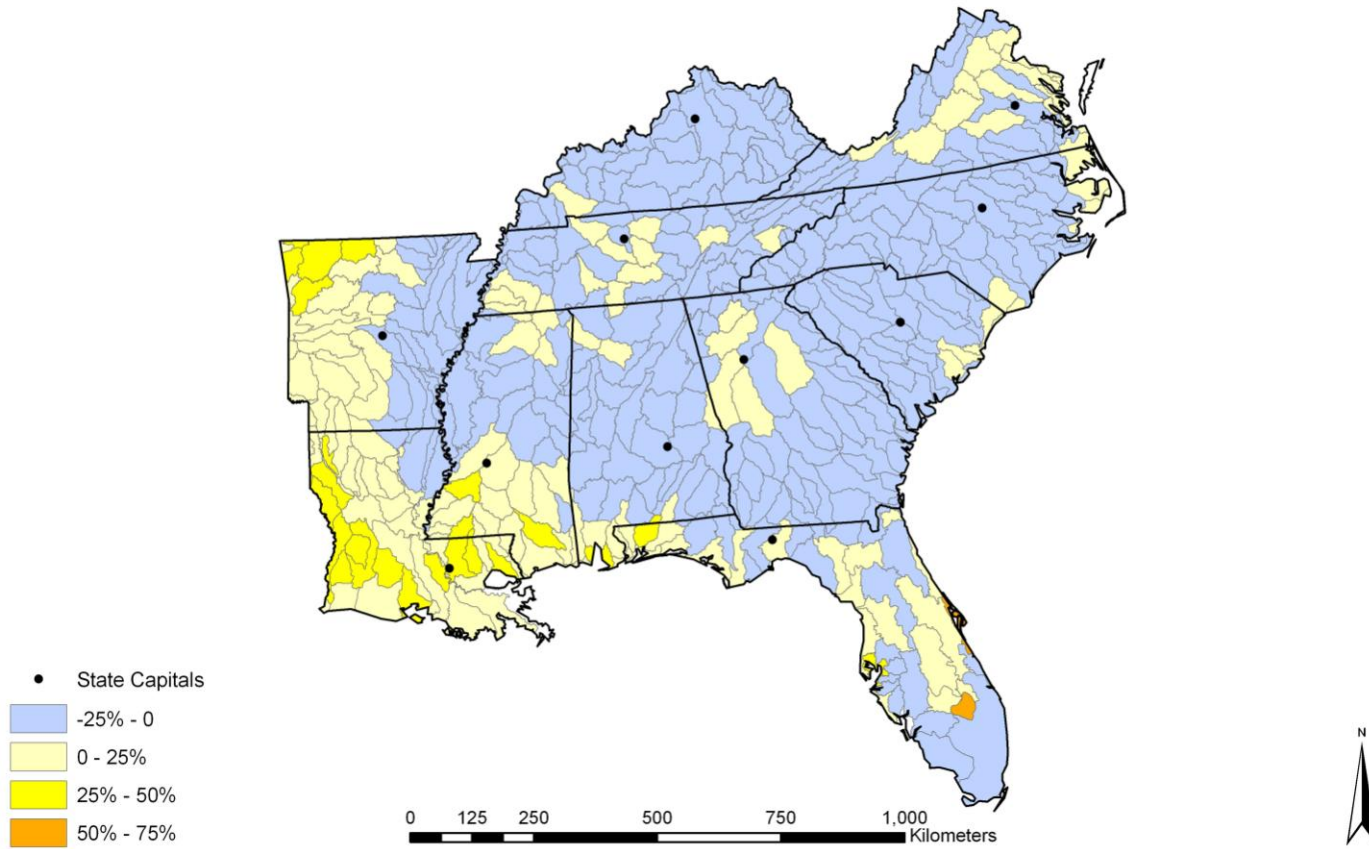


## Averaged Monthly WaSSI (1895-1993)

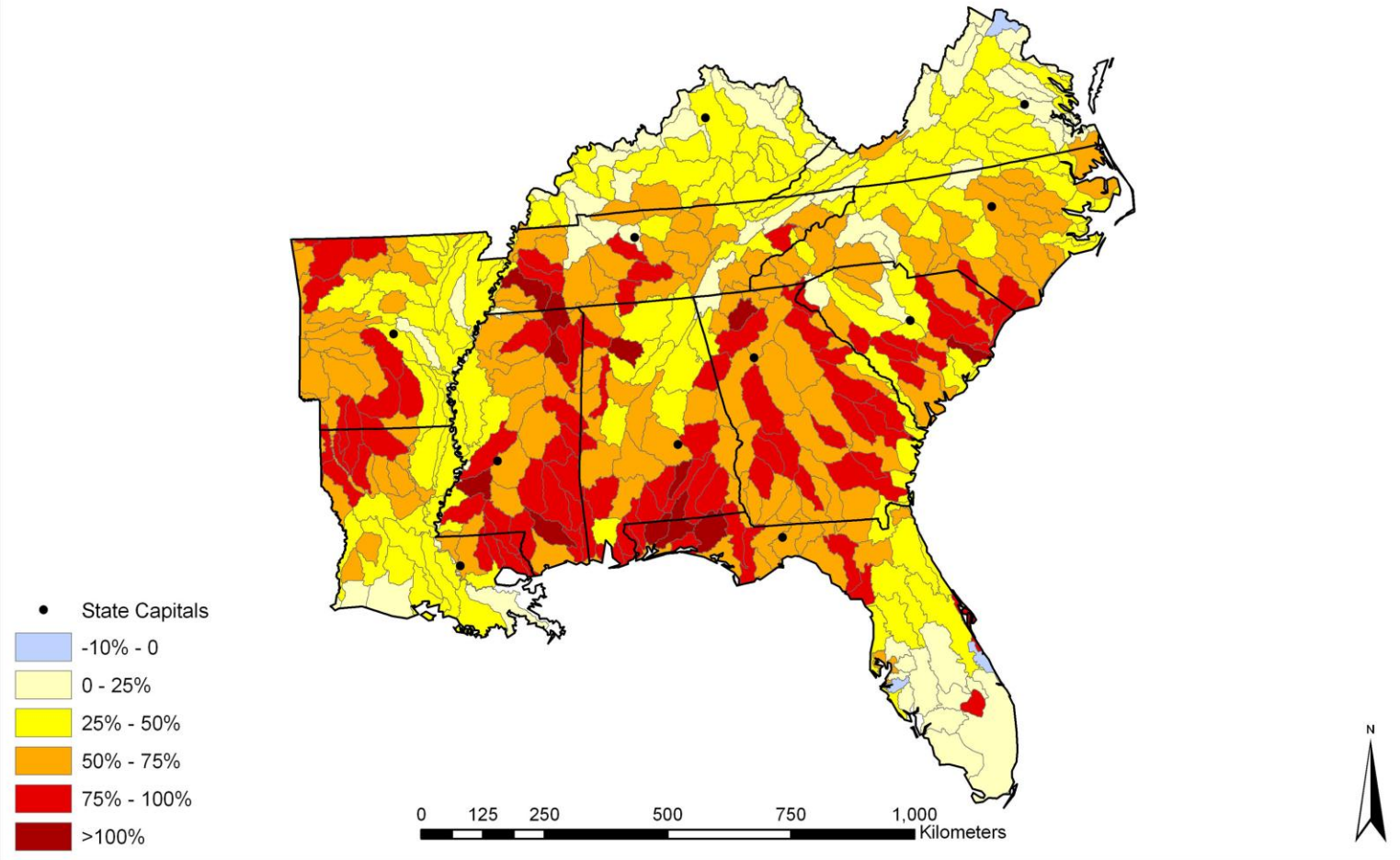




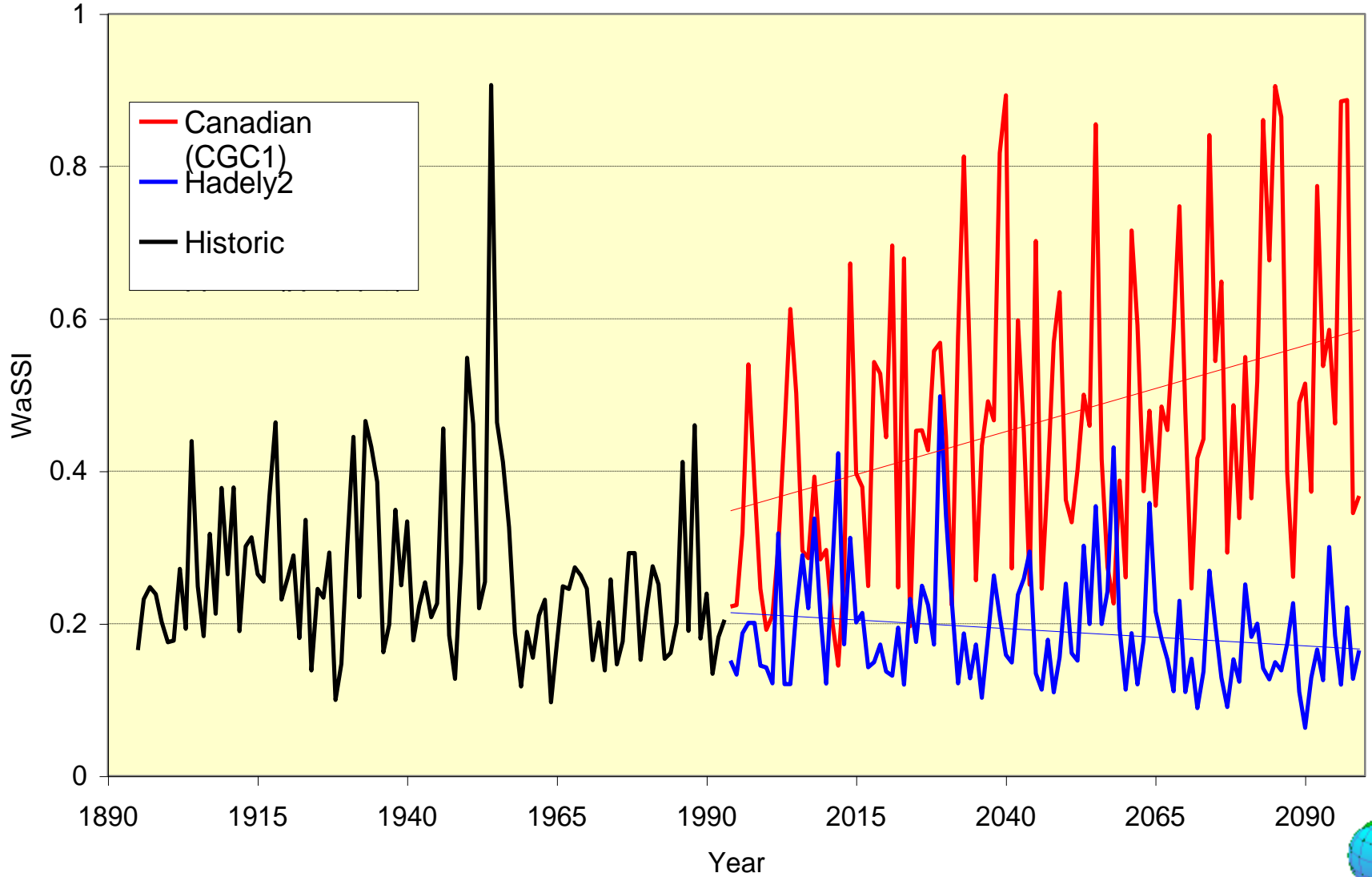
Percent Change In Water Supply Stress Index  
Had2CMSul Climate Change + Population + Landuse/Landcover Change  
2020



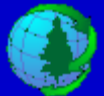
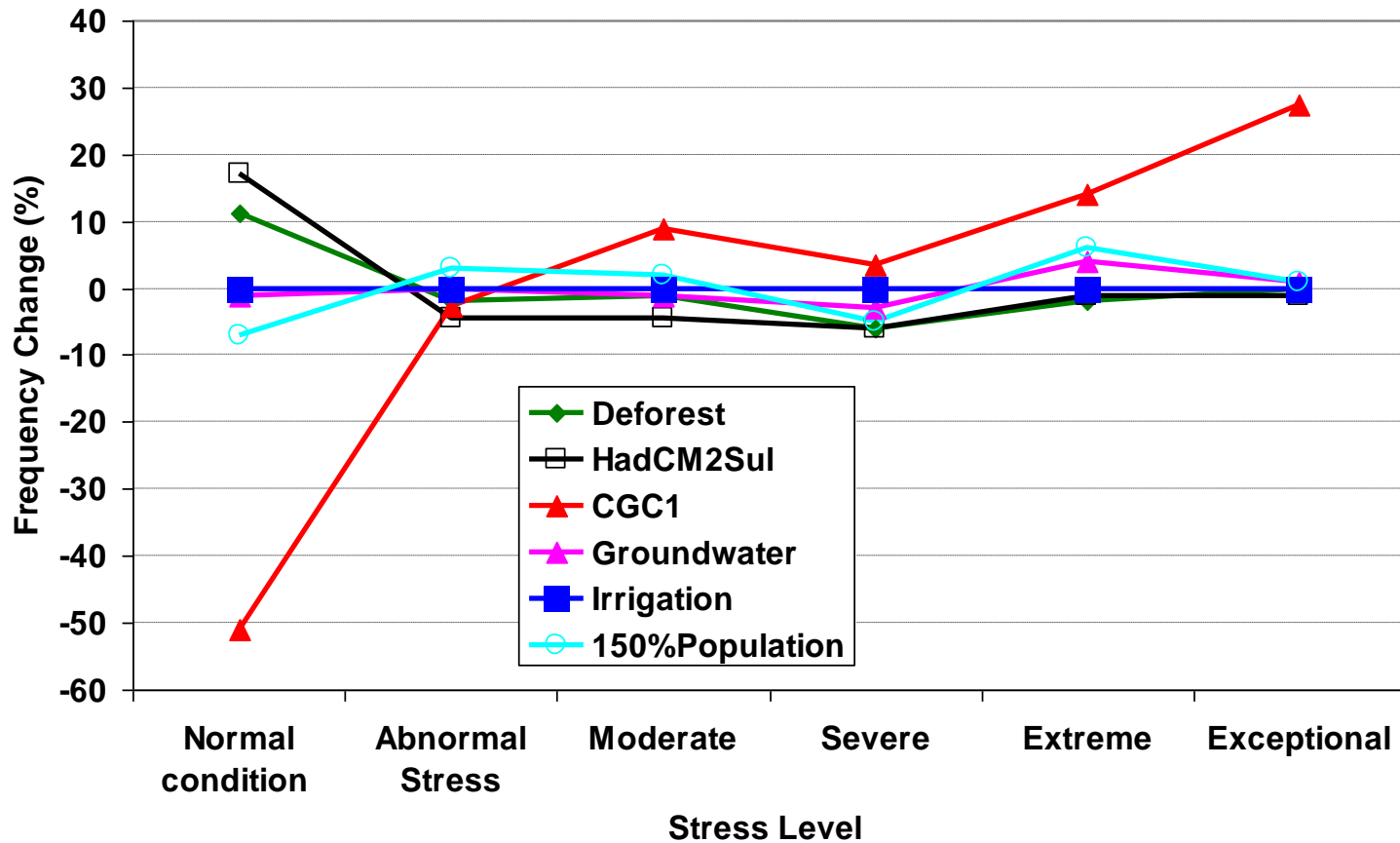
# Percent Change In Water Supply Stress Index CGC1 Climate Change + Population + Landuse/Landcover Change 2020



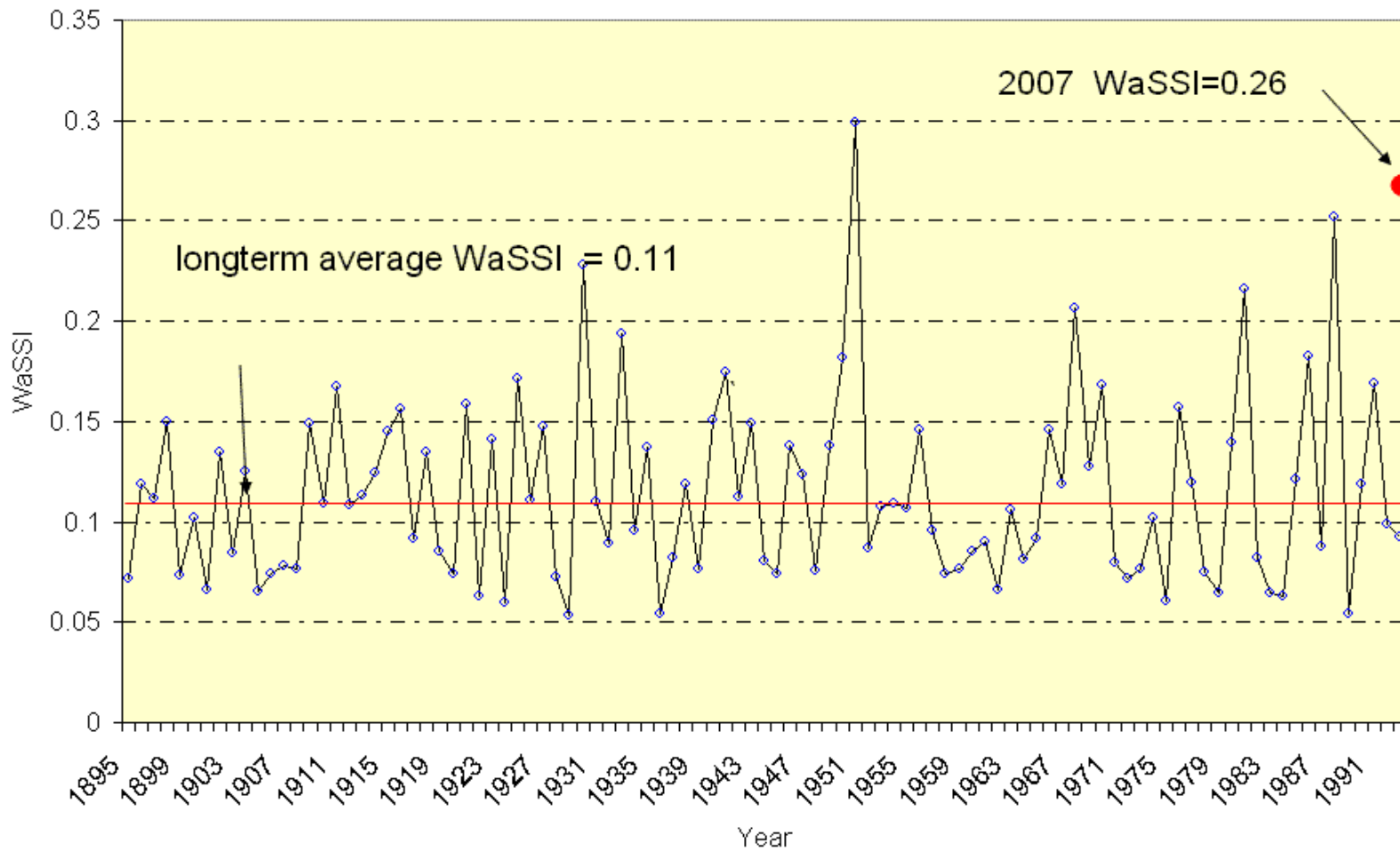
# Water Supply Stress Index (WaSSI) (Columbia, SC HUC 3050110)



### Effects of Multiple Scenarios on WaSSI Distribution (Columbia, HUC3050110)



Historical WaSSI (1895-1993)  
around Raleigh, NC (Watershed HUC# = 3020201)



# Take Home Messages

- ✓ Climate change will likely stress regional water resources both in quantity and quality; but large uncertainty remains on the location and magnitude; Improved climate change and hydrologic model predictions needed;
- ✓ Water supply in Western U.S. will be mostly affected by climate change;
- ✓ Water supply in Eastern U.S. is sensitive to precipitation; Serious water supply problems during dry years, such as 2007.
- ✓ Regardless of climate change, population growth will cause water stress problems in metropolitan areas.



# Take Home Messages

- ✓ Climate change is real, and it will bring change to the historical water supply-demand relations.
- ✓ Water supply and demand should be addressed together.
- ✓ Now the question is what are we going to do about it. We do not know the exact impacts, but we must understand the risk, and water managers need to start developing mitigation and adaptation strategies;



**Thank You for Your  
Attention!**

SGCP

