Technical Challenges and Opportunities in Determining the Potential Effects of Climate Change on Water Quality in New England

Steven Winnett
US EPA New England

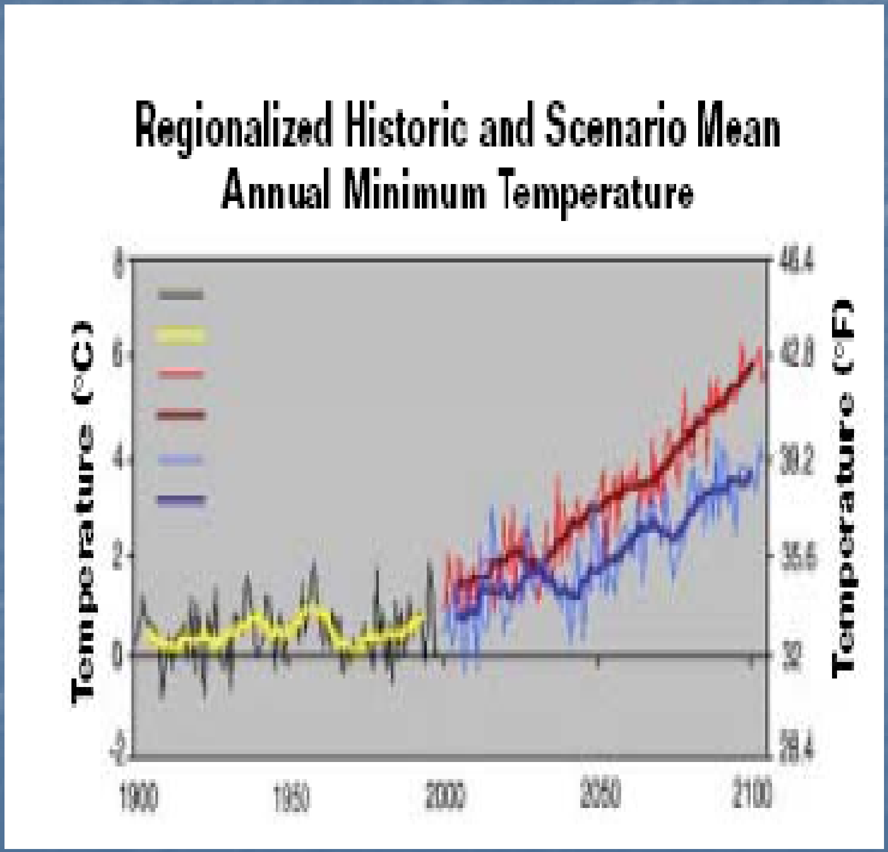
May 17, 2010

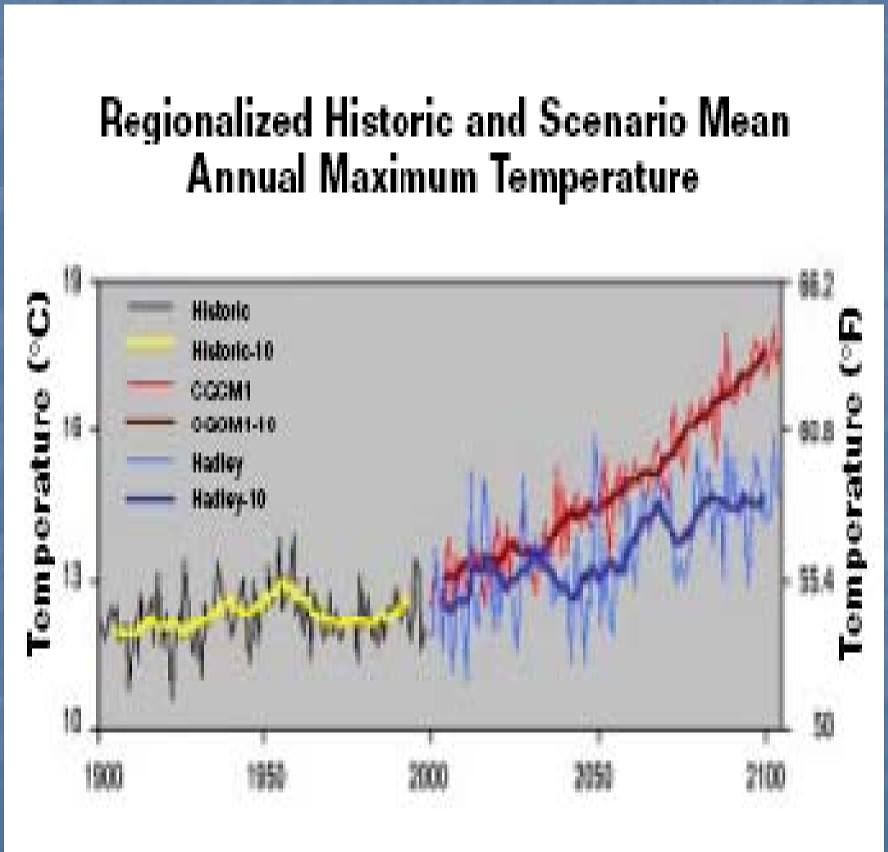
- Why Do We Care About Climate Change and Water Quality?
- What are the Challenges in Assessing the Effects of Climate Change?
- What Have We Observed So Far?
- What are the Opportunities for Better Assessments in the Future?

Climate Change and Water Quality

- Alter timing and amount of rain/snowfall, and streamflow
- Reduce the snowpack and spring runoff
- Extended low flow periods in summer
- More short term droughts
- More higher intensity storms
- Increased frequency of extreme heat days

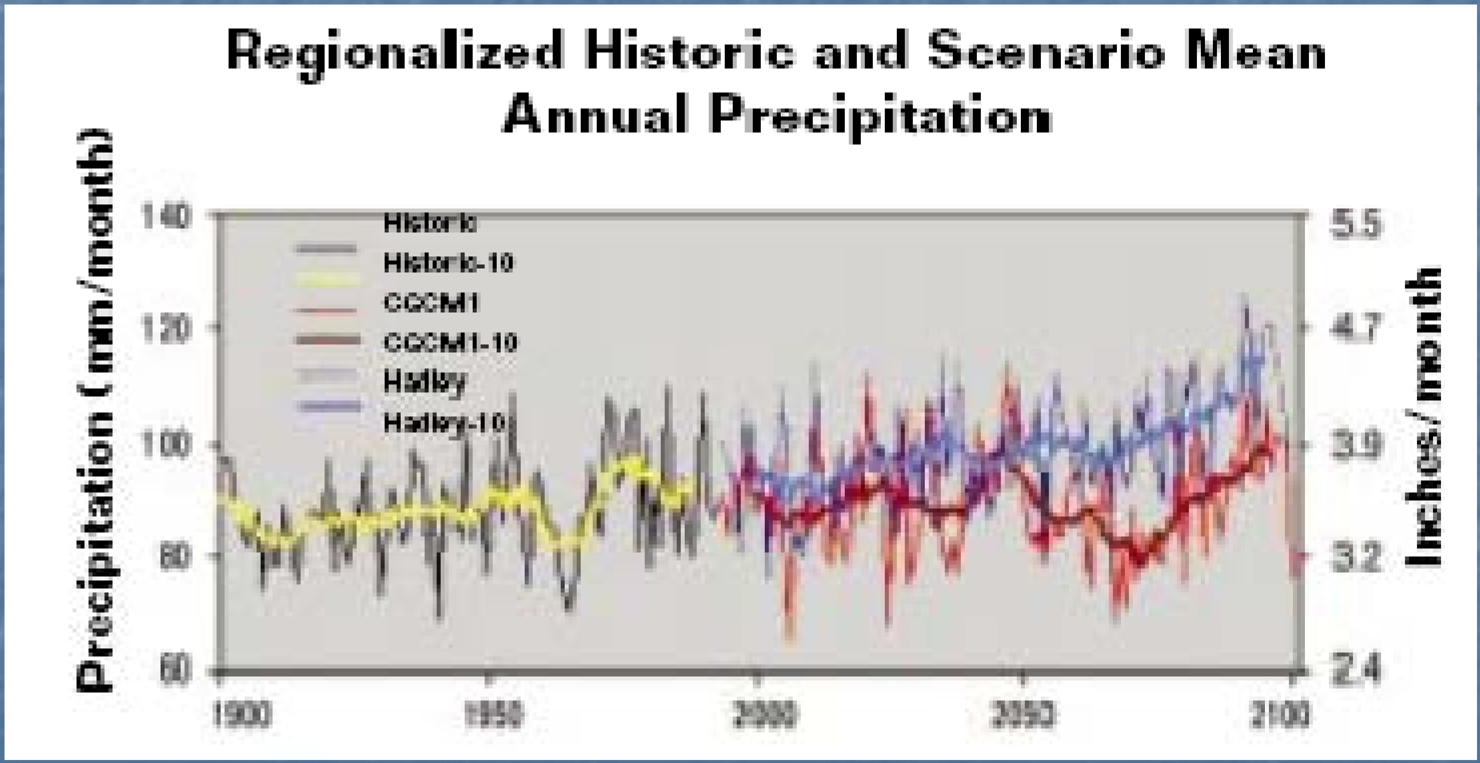
Projected changes in temperature in New England





Source: USGCRP New England Regional Assessment

Projected changes in precipitation in New England



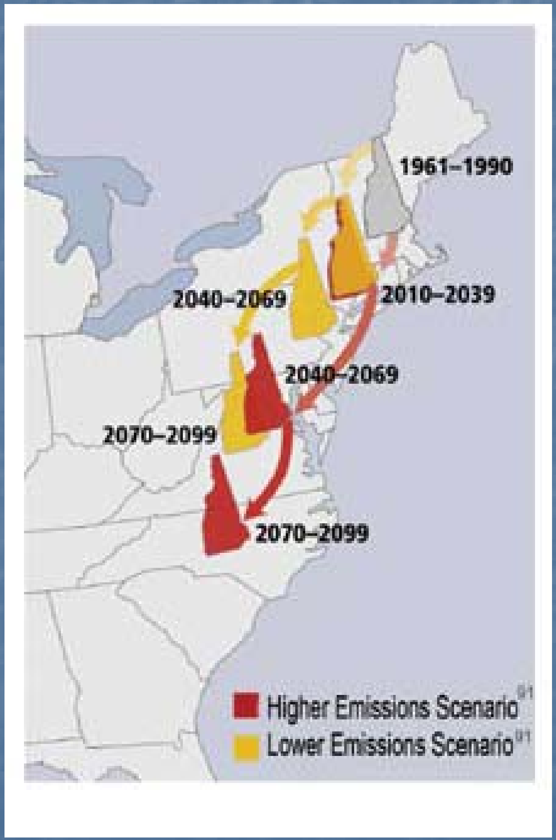
Source: USGCRP New England Regional Assessment

Impacts of Increased Temperatures on Aquatic Ecosystems

- <u>Effects of warmer water temperatures</u>
  - Reduced dissolved oxygen concentrations
  - Decreased volume of water for dilution of chemical inputs
    - Increased concentration of nutrients and pollutants
  - Changes in the rate of chemical reactions in the water column, sediment-water interface, and water-atmosphere interface
  - Thresholds for certain species may be reached
    - Cold-water fish lose important habitat
  - Increased algal blooms
  - Decreased snow pack, changes in spring runoff, and reduced groundwater recharge

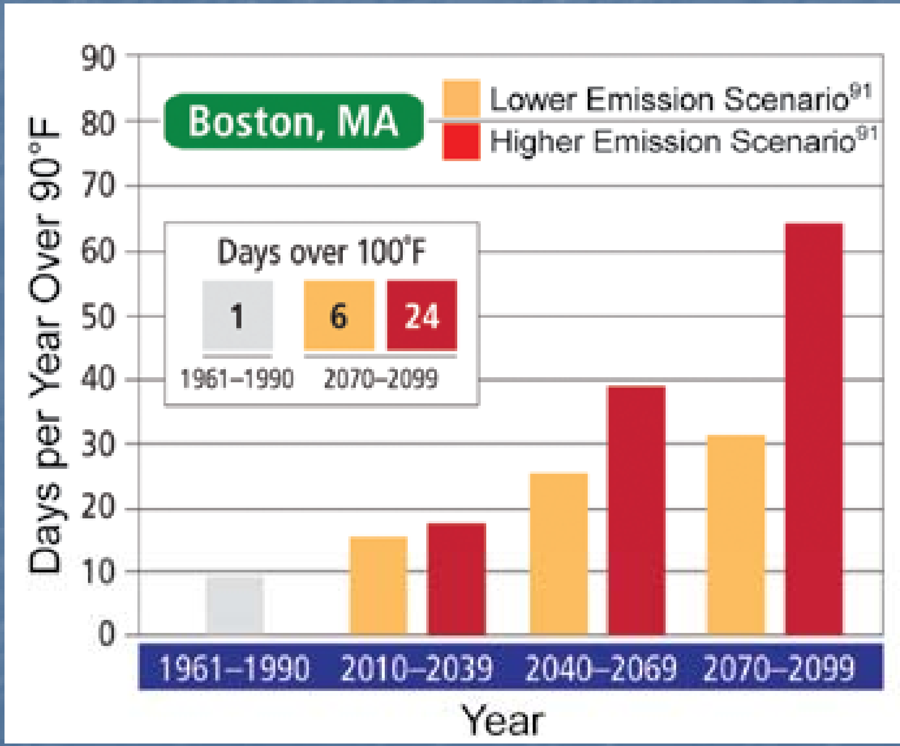
Projections of temperature changes in New England

Climate on the Move: Changing Summers in New Hampshire



Hayhoe *et al.* Fig. from Frumhoff *et al.*

Projected Days per Year over 90°F in Boston



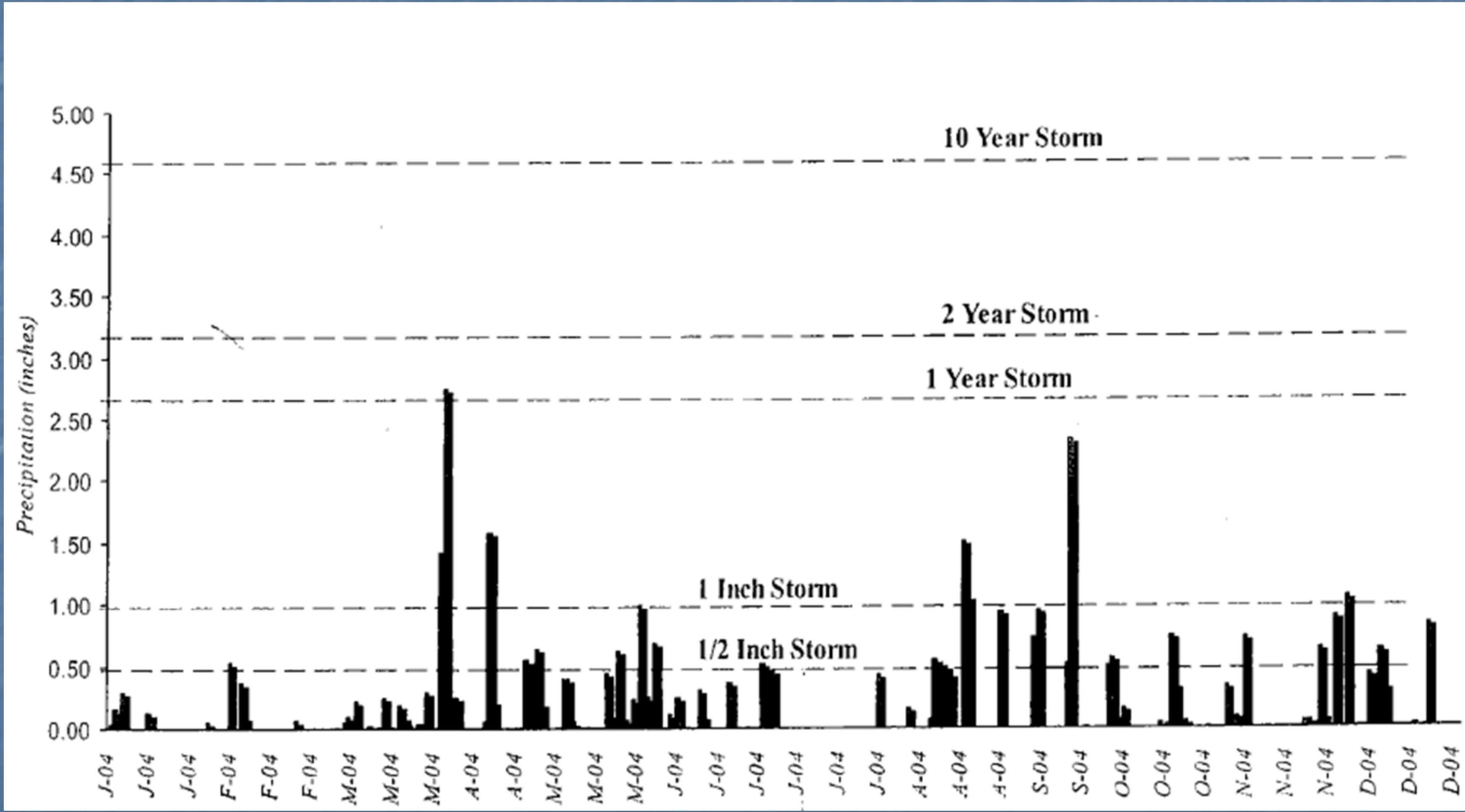
Hayhoe *et al.*

U.S. Global Change Research Program: **Global Climate Change Impacts in the United States**

Impacts on Aquatic Ecosystems of Higher Intensity Precipitation Events and Resulting Higher Flows

- Increased delivery of sediments, sediment-enriched pollutants *(e.g*., phosphorous, pesticides) and soluble pollutants (*e.g.,* nitrates) to rivers and streams
- Increased damage to aquatic systems through stream scour, displaced biota, and disrupted habitat
- Increased storm intensity makes it more difficult to capture runoff from the bigger storms
  - Likelihood is for fewer low intensity storms and more high intensity storms
- Simultaneously, increased drought and low flows in summer will stress aquatic systems

Importance of Understanding Typical Rainfall Patterns for Mgmt Efforts

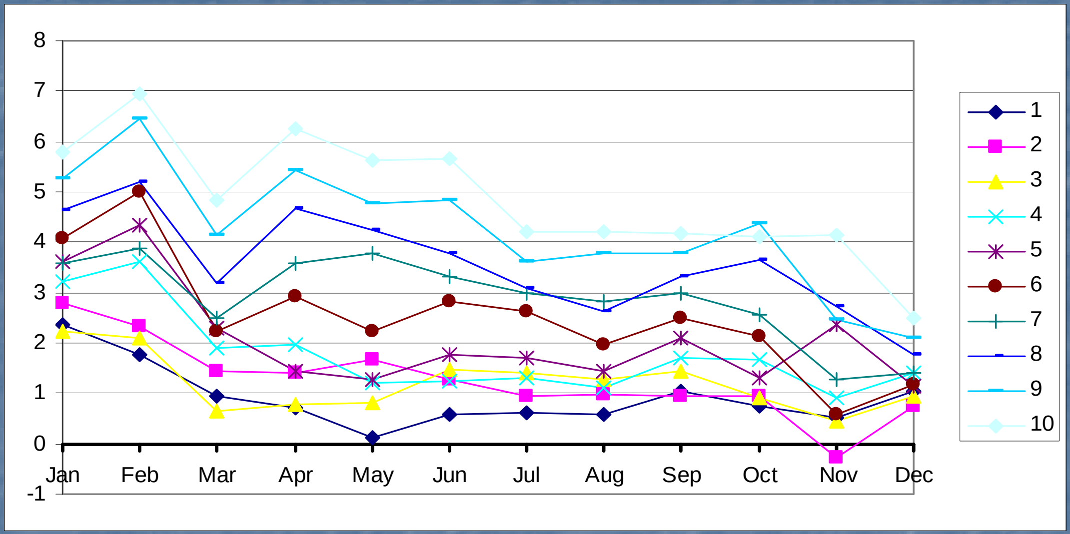


New England rainfall is approximately 43 inches/year spread over 100 storms; note the large number of small storms contribute substantial flow volume.

Challenges in Assessing Climate Change Impacts

- Old precipitation patterns are invalid – can't apply old data to project changes **Stationarity is dead**.
- Need climate models to reflect new patterns of precipitation intensity, duration, frequency
- Projecting precipitation has been a General Circulation Model (GCM) weakness; models much better, or more consistent, at projecting temperature changes

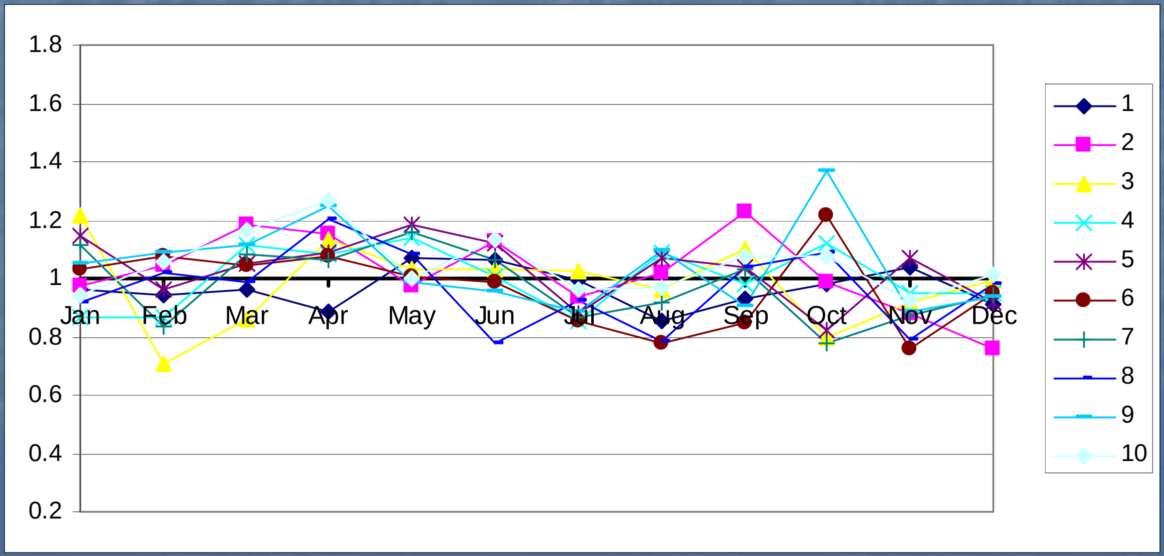
GCM Precipitation & Temperature



Comparison of 1990s GCM **temperature** projections, Central NH, deg. C difference from current

CCCM1 w/sulfates

Comparison of 1990s GCM **precipitation** projections, Central NH, ratio of difference from current



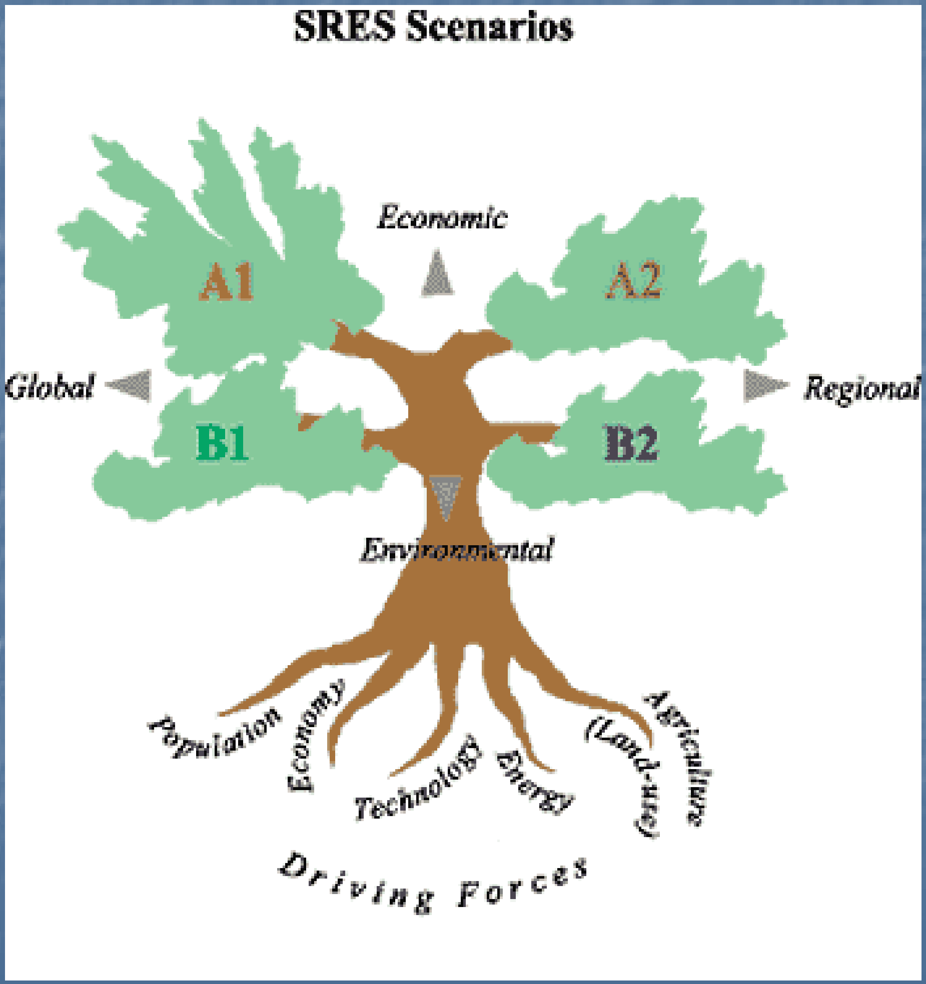
CCCM1 w/sulfates

Challenges II

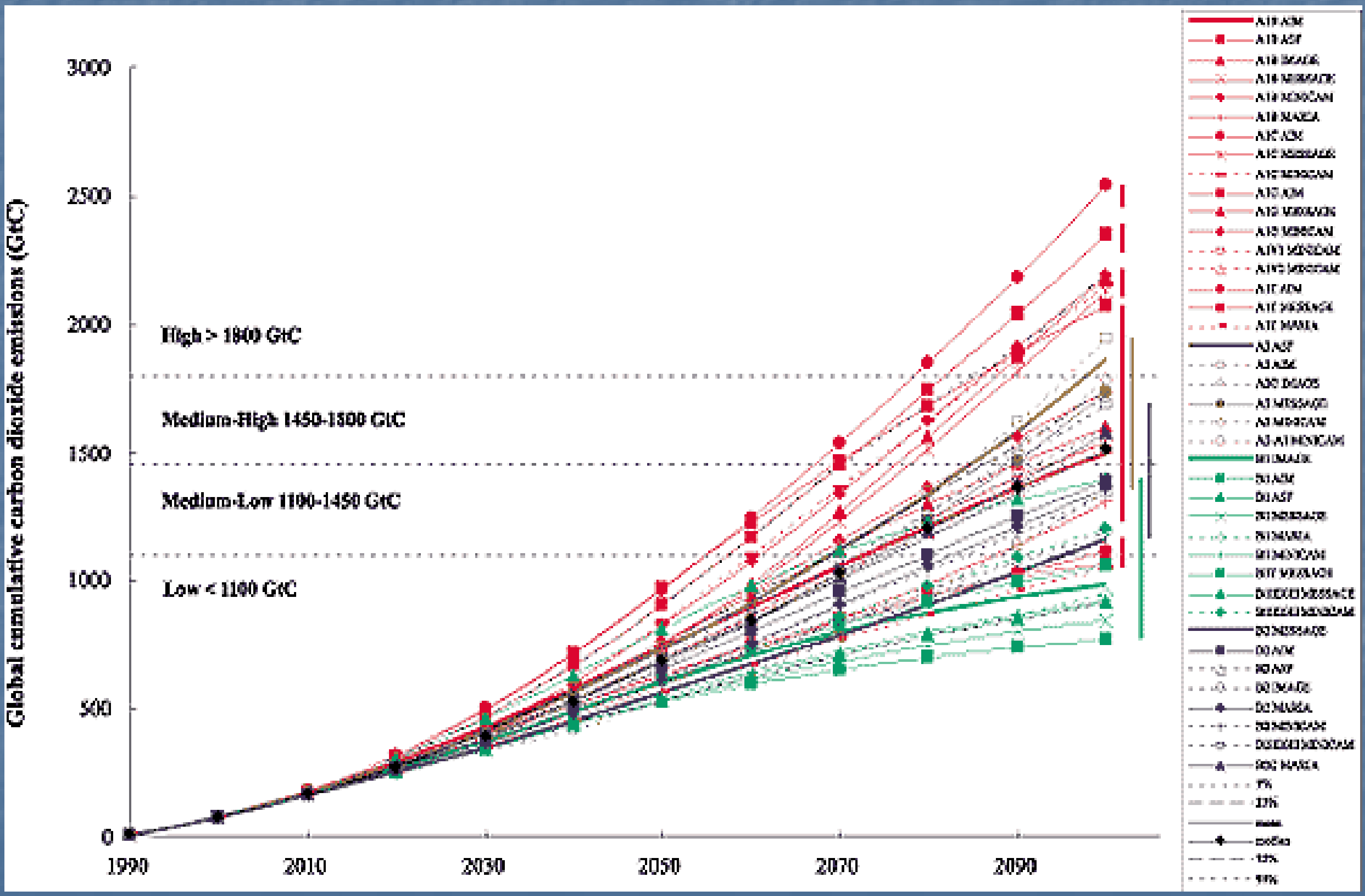
- Which GCM models and emissions scenarios to use?
- If not GCMs, considering precip profiles: hi, med, low departure from historic patterns
- Selection of subbasins: size, topography, degree of flow regulation, presence of wetlands; path to water
- Just climate change, add land use, demographic data, some combination?
- Simple analysis (flow duration curves, P8 model) and/or complex models: HSPF or SWAT?
- Can we get higher resolution climatic results that are more meaningful to local users?

Climate Change Storylines

Emphasis on human wealth or sustainability; Globalization or regionalization

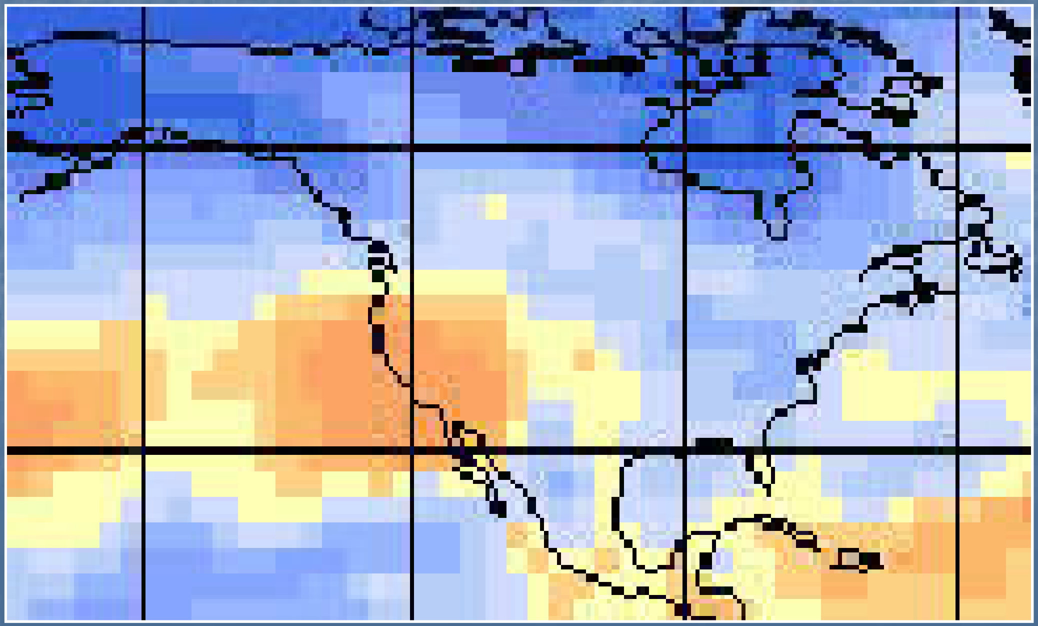


IPCC Emissions Scenarios



Challenges, III

- Scale: GCM grid cells are 22K sq. miles
- Any grid in NE/NY may contain variations of 1000s of feet of topography, several times, across that expanse
- Need downscaled GCM scenarios to account for local climate effects



1 grid cell = 22,500 square miles (150 miles on a side)

US composed of ~160 cells

Downscaling

Obtain local-scale climate changes from regional-scale models

Dynamical: a higher resolution, limited-area numerical meteorological model (e.g. regional climate model)

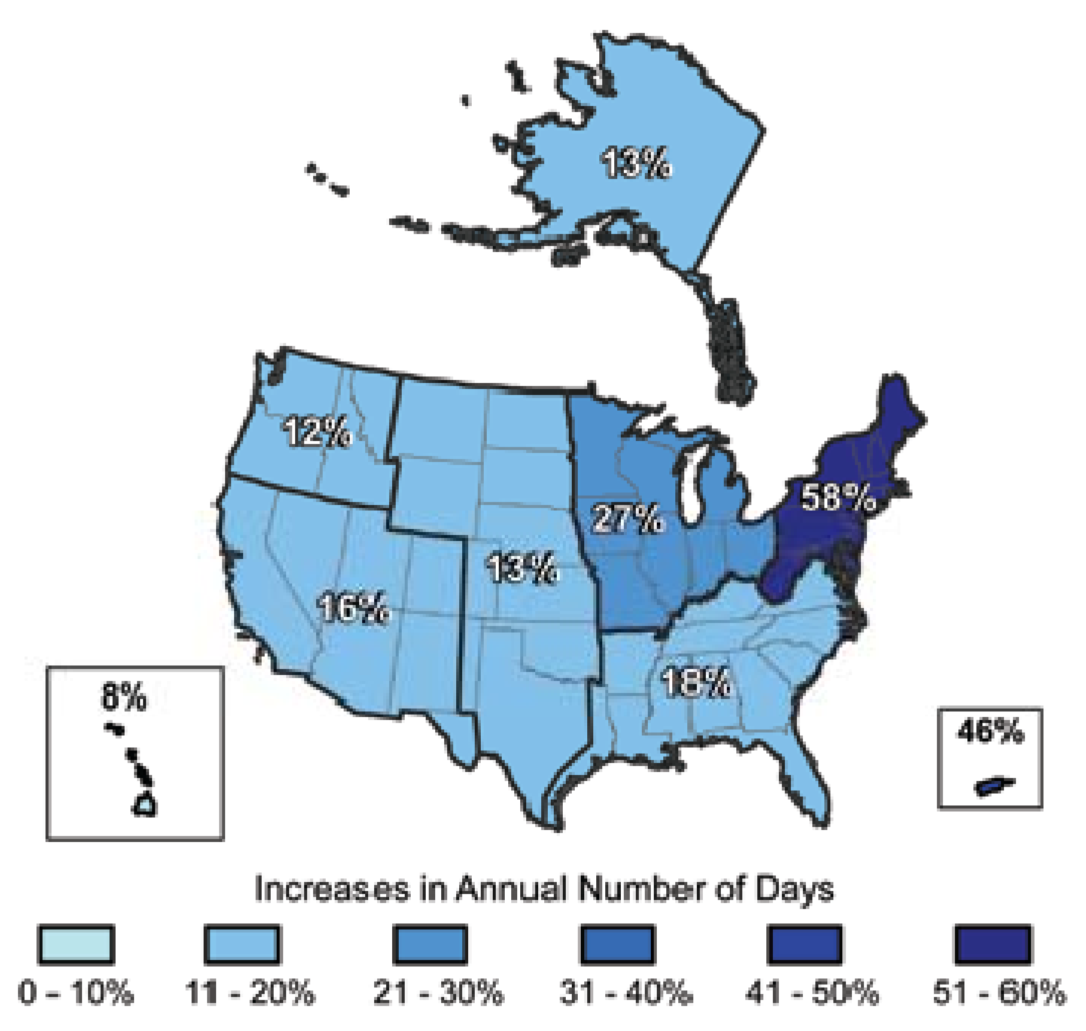
- Requires a large amount of computational and data storage resources.
- Takes a long time to complete the simulations.

Statistical: empirical relationships between large- and small-scale observations are developed, then applied to global climate model output to provide regional detail. Computationally inexpensive and many representations can be generated quickly.

Challenges IV: Modeling a "Water"

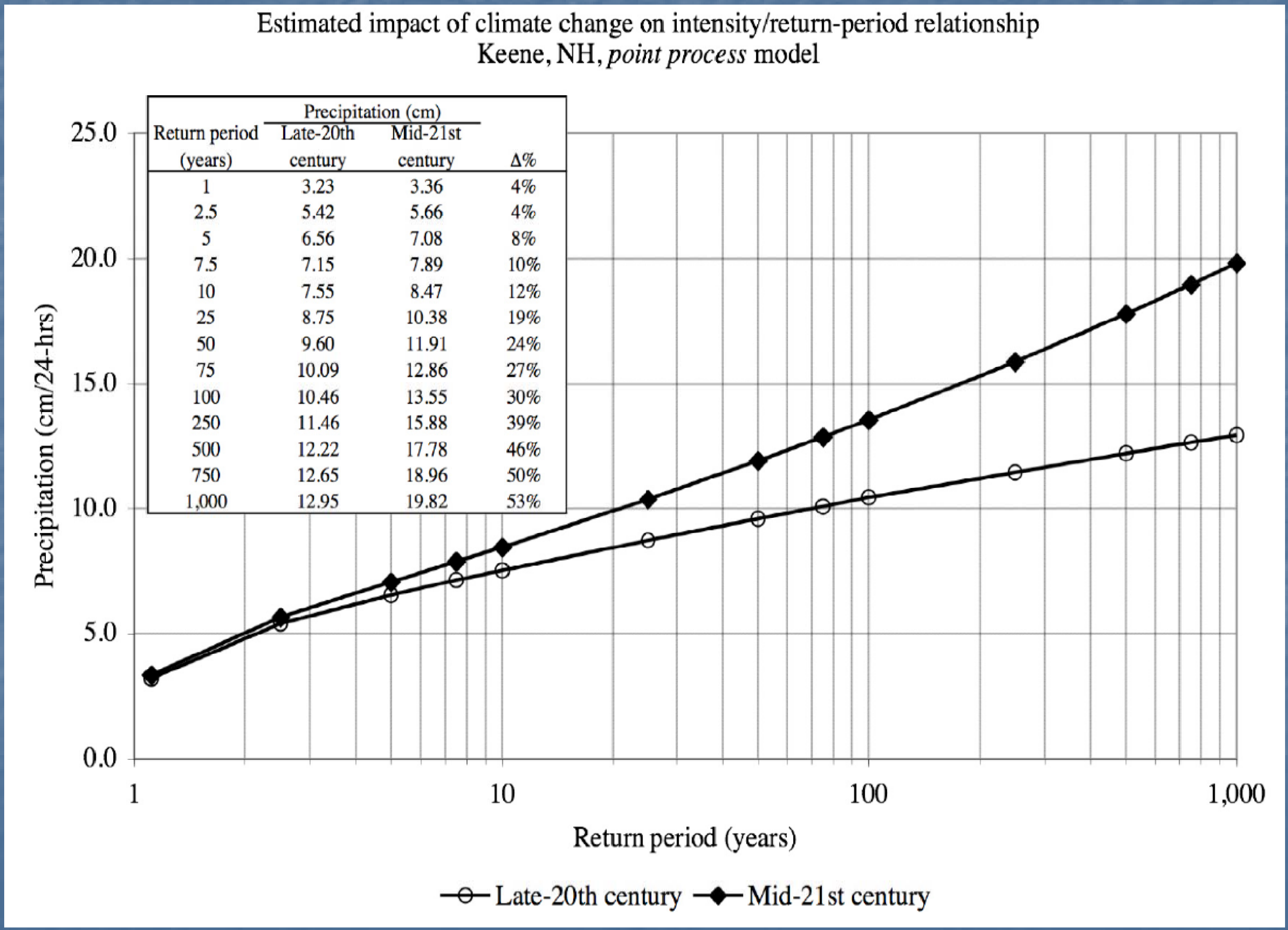
- Models driven by tributary, outlet, and WWTF flows
- May/may not account for vertical mixing, layers, or stratification
- Chemical interactions in the water column
- Exchange rates across water segments may be wind or current dependant
- May factor in water levels and evaporation
- Contributions from ground water
- Atmospheric deposition of materials
- Climate data: precipitation and temperature
- BMP performance for control measures

Increases in the Number of Days with Very Heavy Precipitation (1958 to 2007)



U.S. Global Change Research Program: **Global Climate Change Impacts in the United States,** Updated from Grossman *et al.*

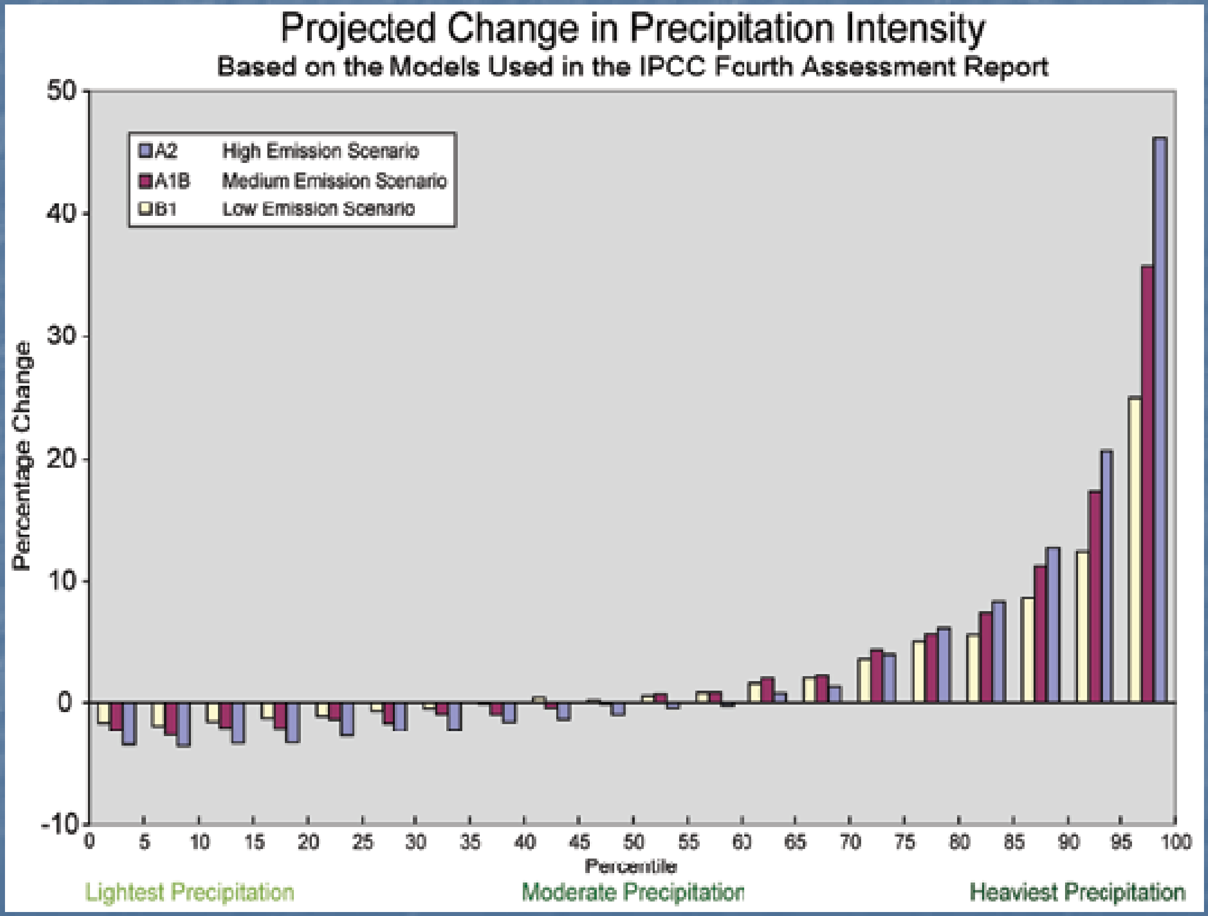
Frequency & Intensity



Return period (years)	Precipitation (cm) Late-20th century	Mid-21st century	Δ%
1	3.23	3.36	4%
2.5	5.42	5.66	4%
5	6.56	7.08	8%
7.5	7.15	7.89	10%
10	7.55	8.47	12%
25	8.75	10.38	19%
50	9.60	11.91	24%
75	10.09	12.86	27%
100	10.46	13.55	30%
250	11.46	15.88	39%
500	12.22	17.78	46%
750	12.65	18.96	50%
1,000	12.95	19.82	53%

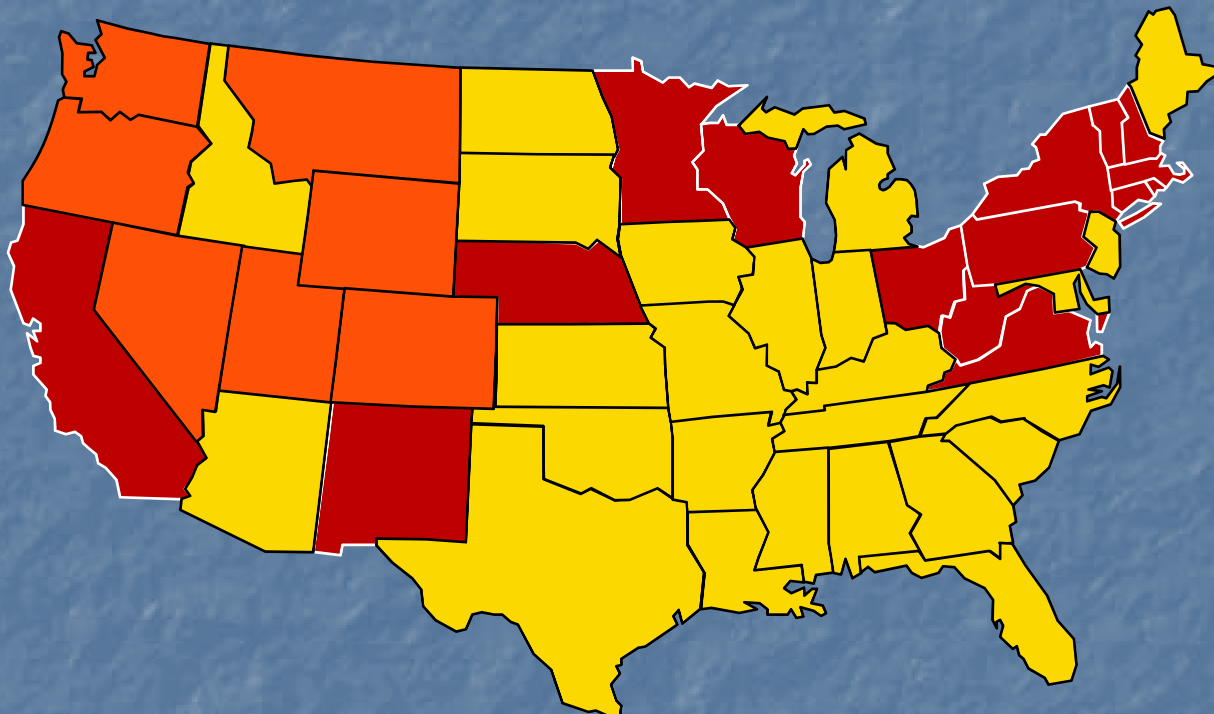
University of New Hampshire Stormwater Center, J. Houle.

Projected Changes in Precipitation Intensity



Source: Climate Change Science Program report: Weather and Climate Extremes in a Changing Climate (2008)

Loss of Habitat for Brown Trout from a Doubling of CO_2 - 2050



Not included in analysis *

1-49% Loss

50-100% Loss

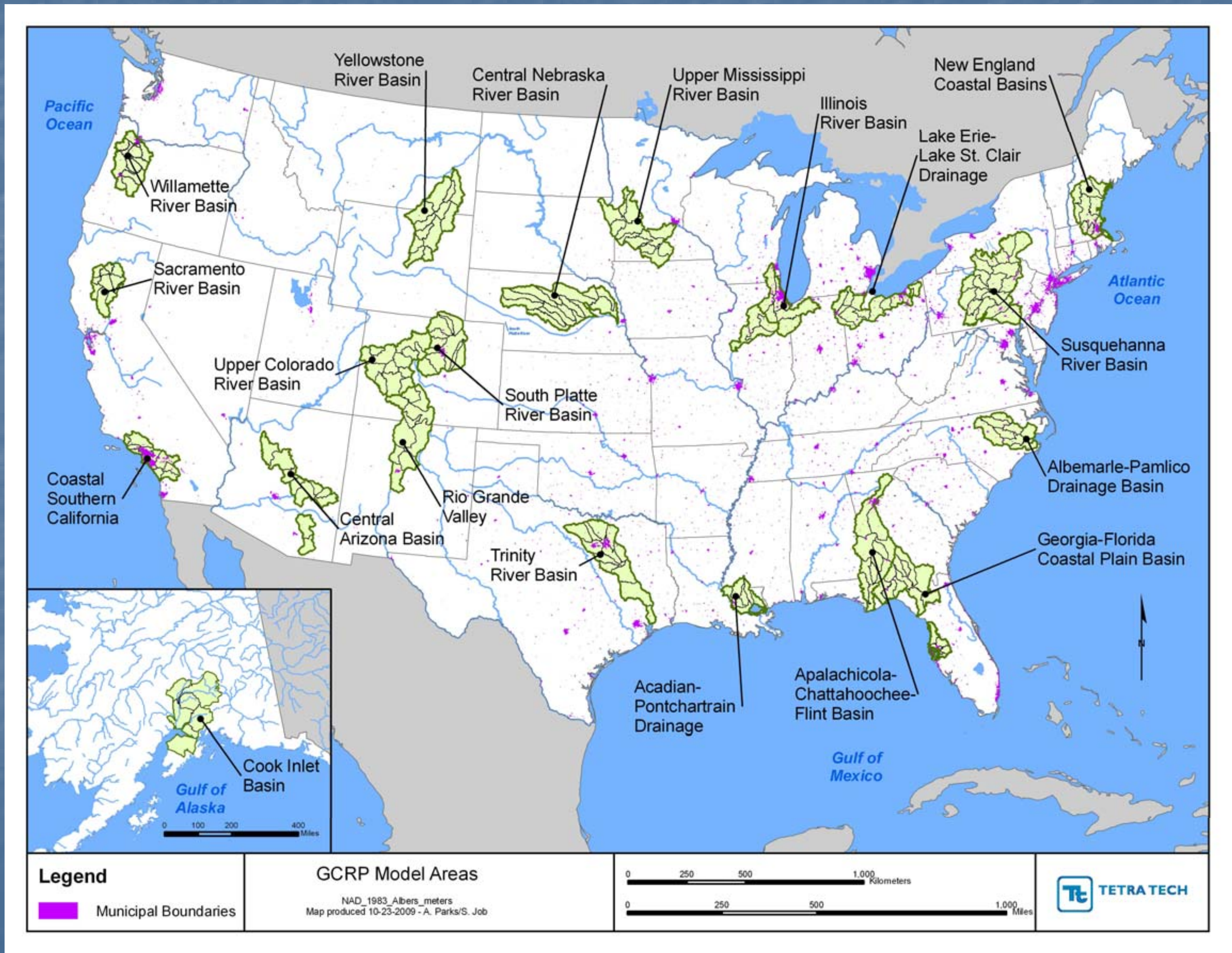
Source: EPA, 1995

GFDL Climate Change Scenario

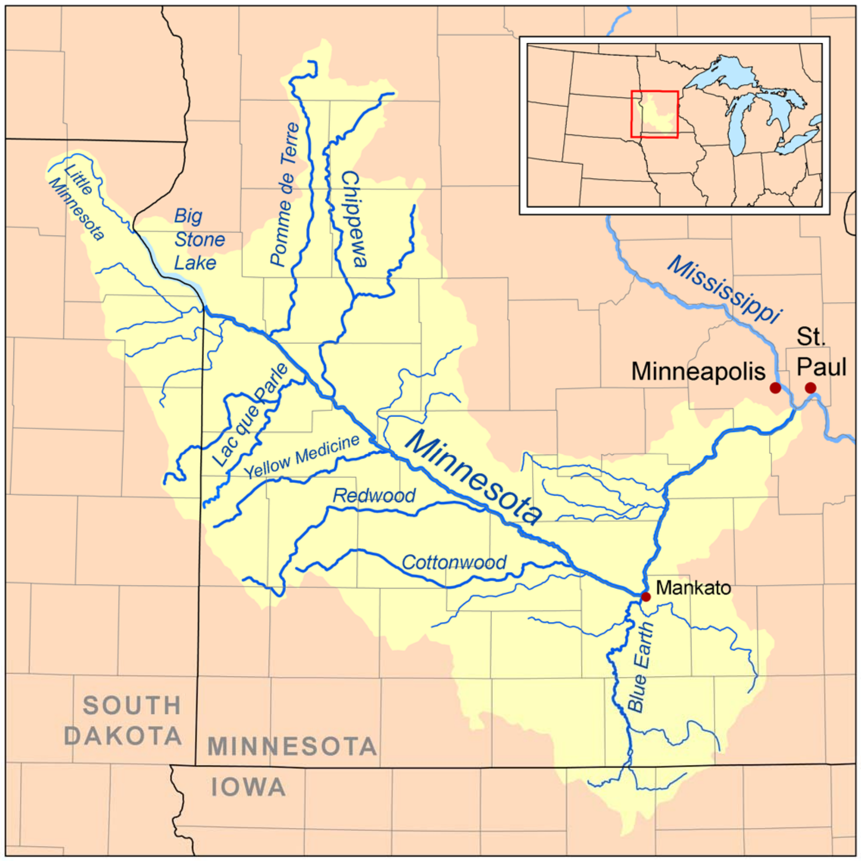
Hydrologic Change Scenarios: EPA ORD ***20 Watersheds Modeling Study***

- Watershed modeling in 20 U.S. watershed regions (~10 HUC 8 watersheds each)
- Focus on nutrients, sediment, streamflow
- Averaged daily data for 30-year historical and 30-year future periods (2040 – 2070)
- 2 water quality models, HSPF and SWAT
- 6 climate change scenarios based on <u>REGIONAL</u> downscaled models
  - Based on 4 GCMs
  - Also 4 <u>Statistically</u> downscaled models' scenarios
- 2 Land-Use change scenarios

EPA ORD 20 Watersheds Study



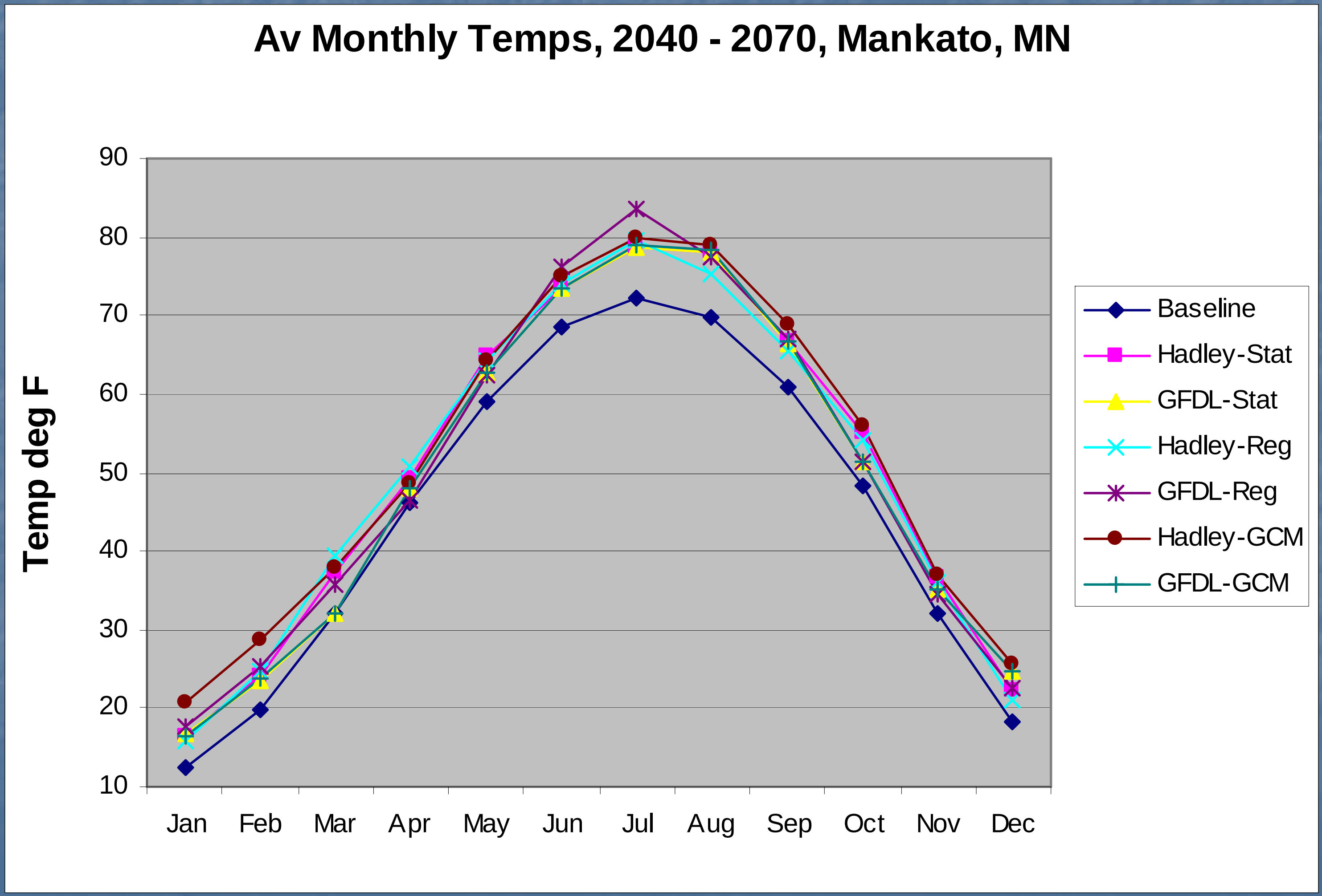
Minnesota River case results



Location:
Minnesota River near Mankato, MN
- 16,200 sq. miles
- 76% crop, 1% forest, 1% impervious

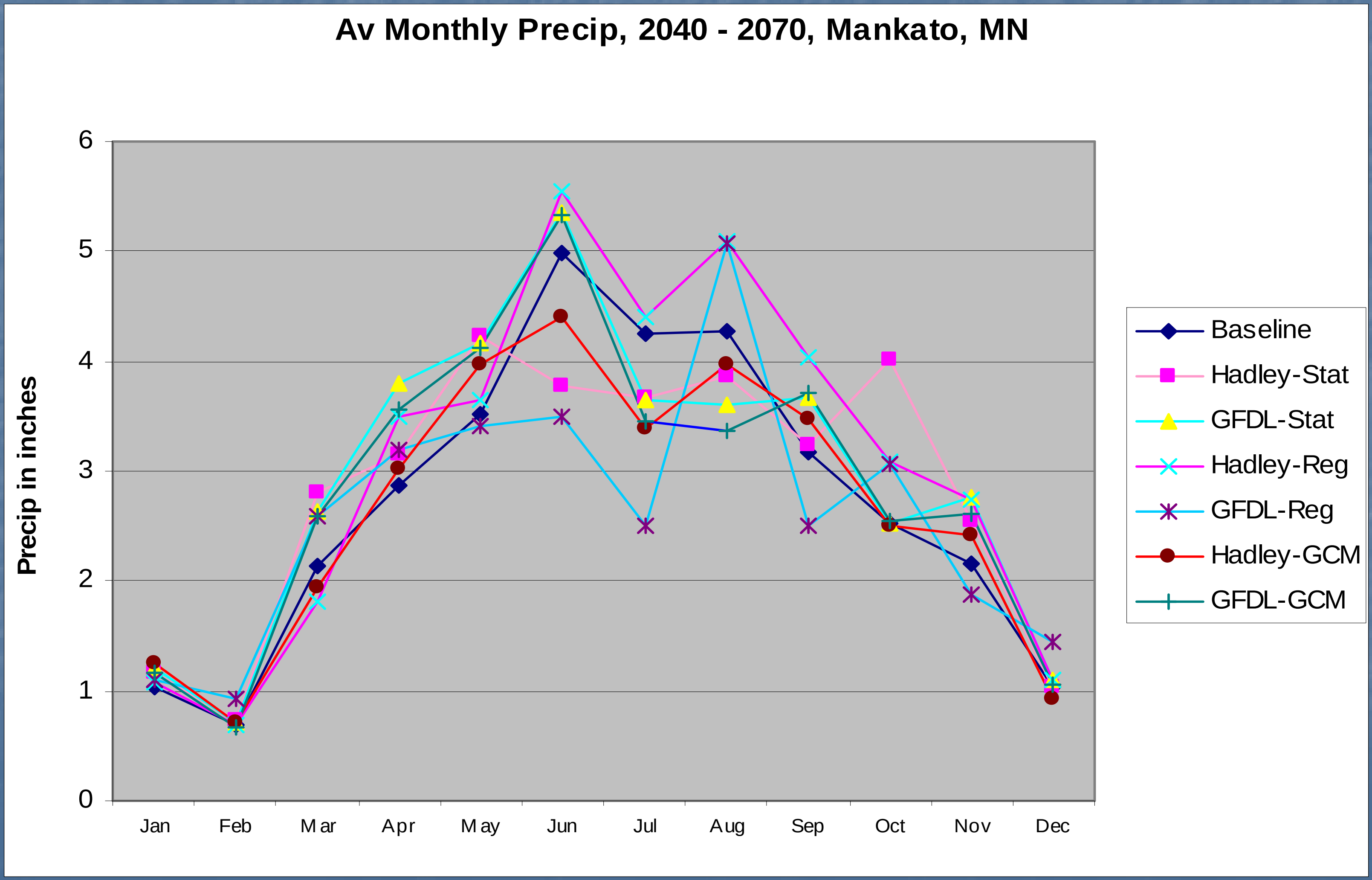
Temperature Change Between 1973-2002 and 2040-2070, Minnesota River

*** Preliminary Data ***



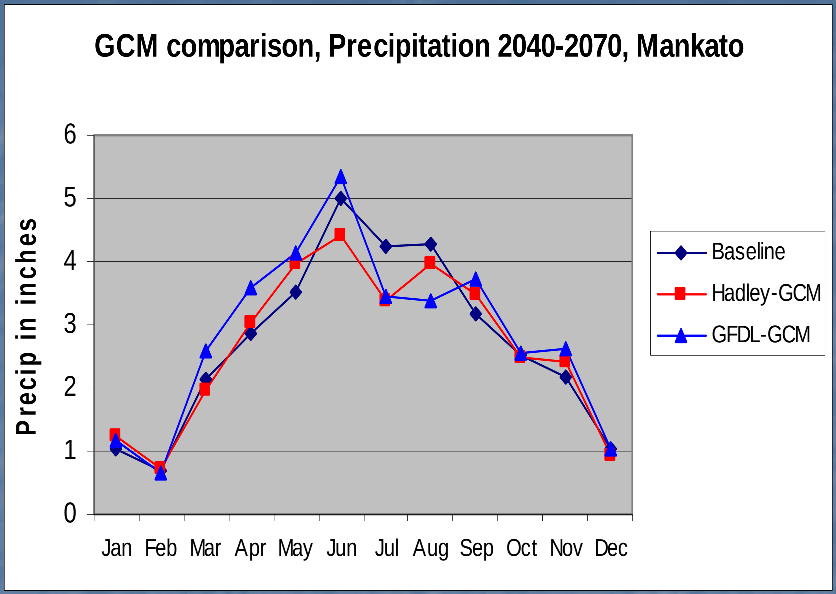
Precipitation Change Between 1973-2002 and 2040-2070, Minnesota River

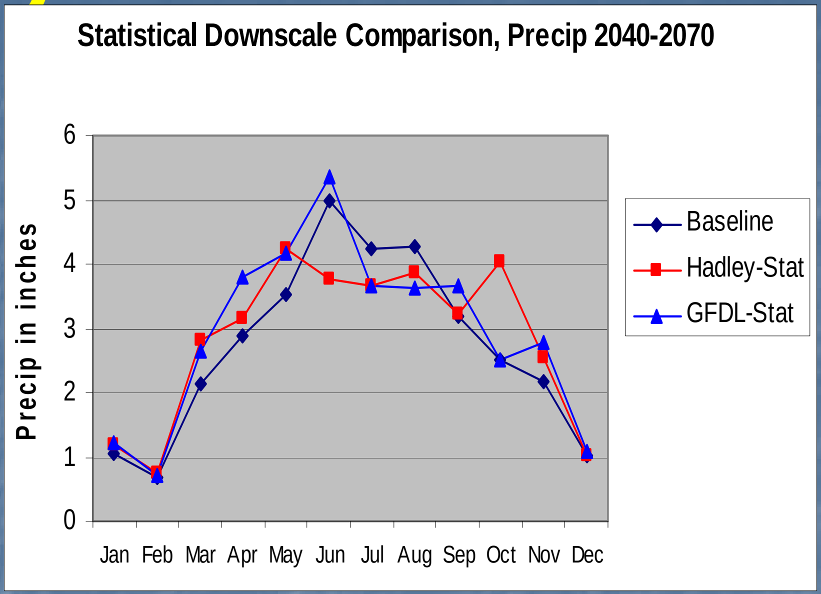
*** Preliminary Data ***

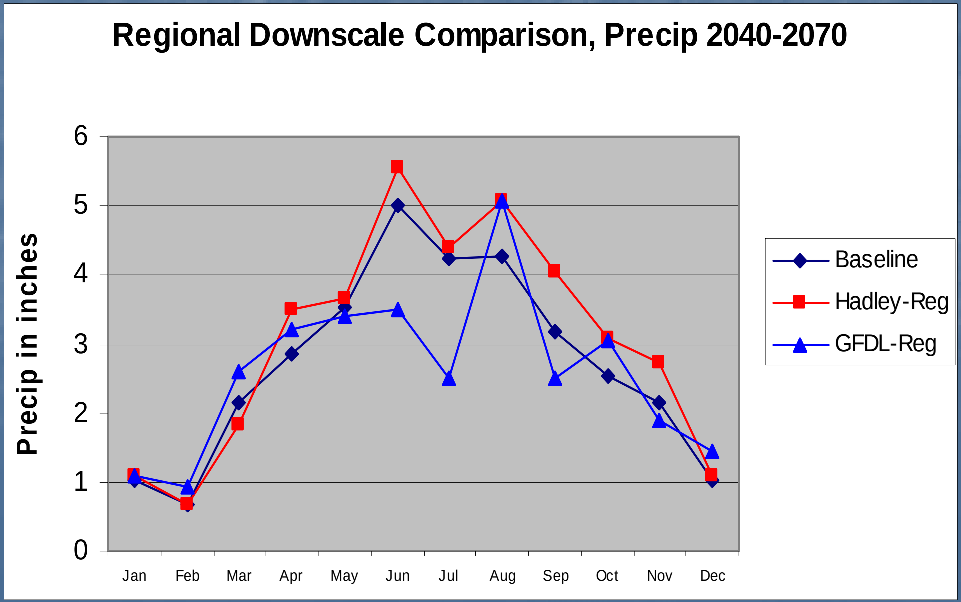


Precipitation Model Comparisons

*** Preliminary Data ***

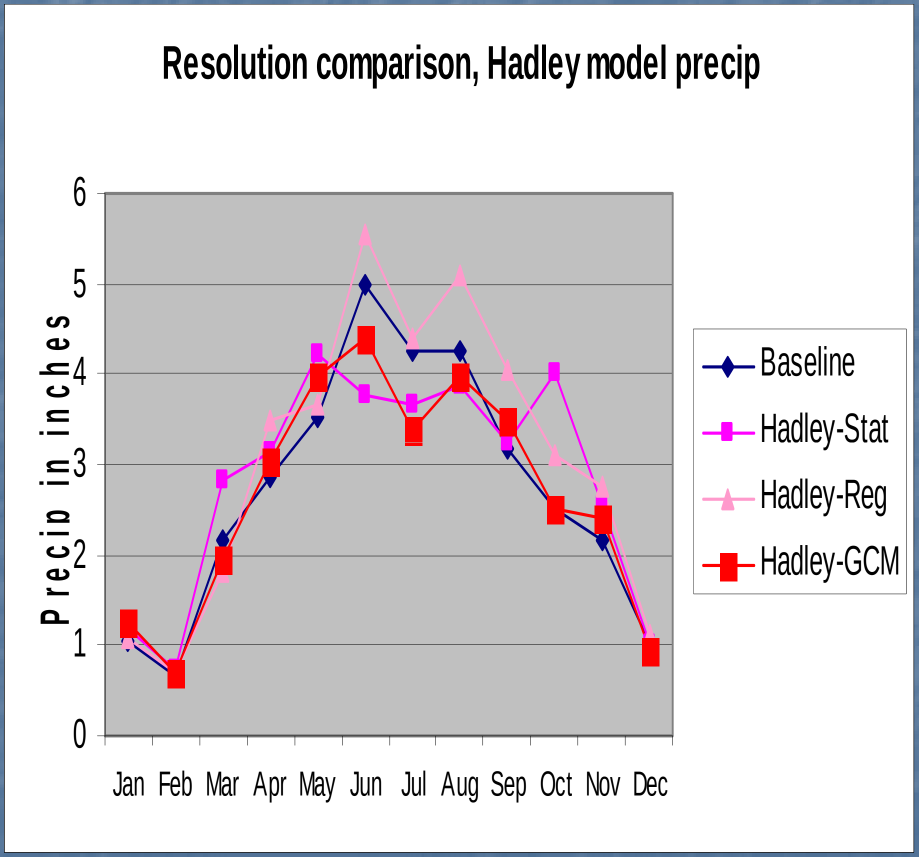


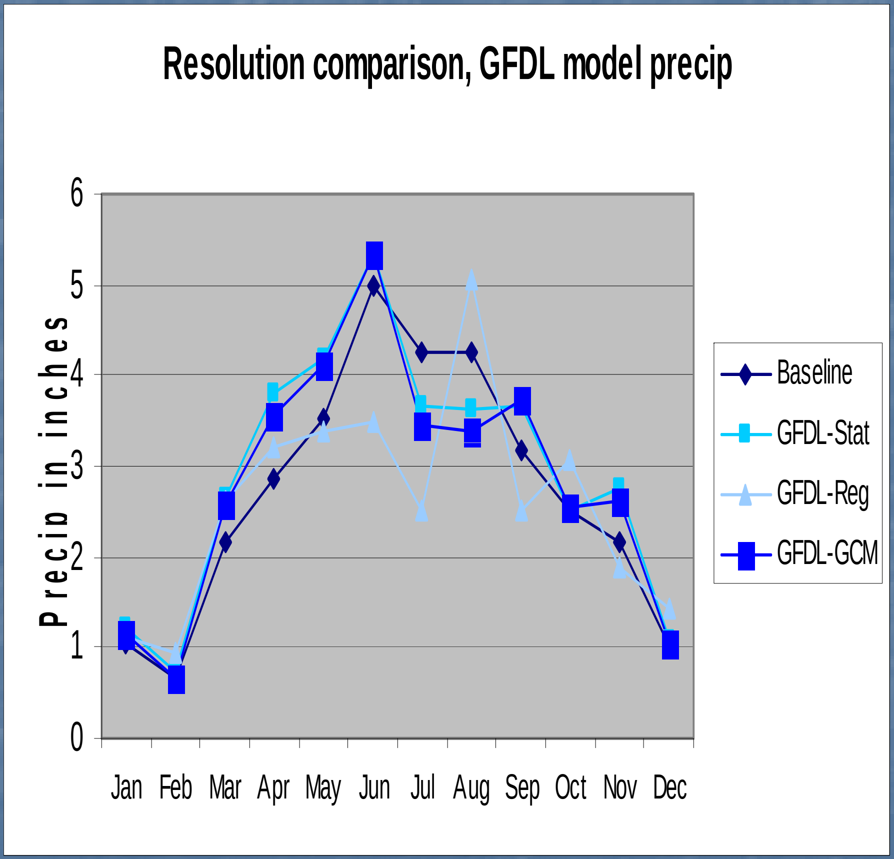




Precipitation Model Comparisons, Minnesota River

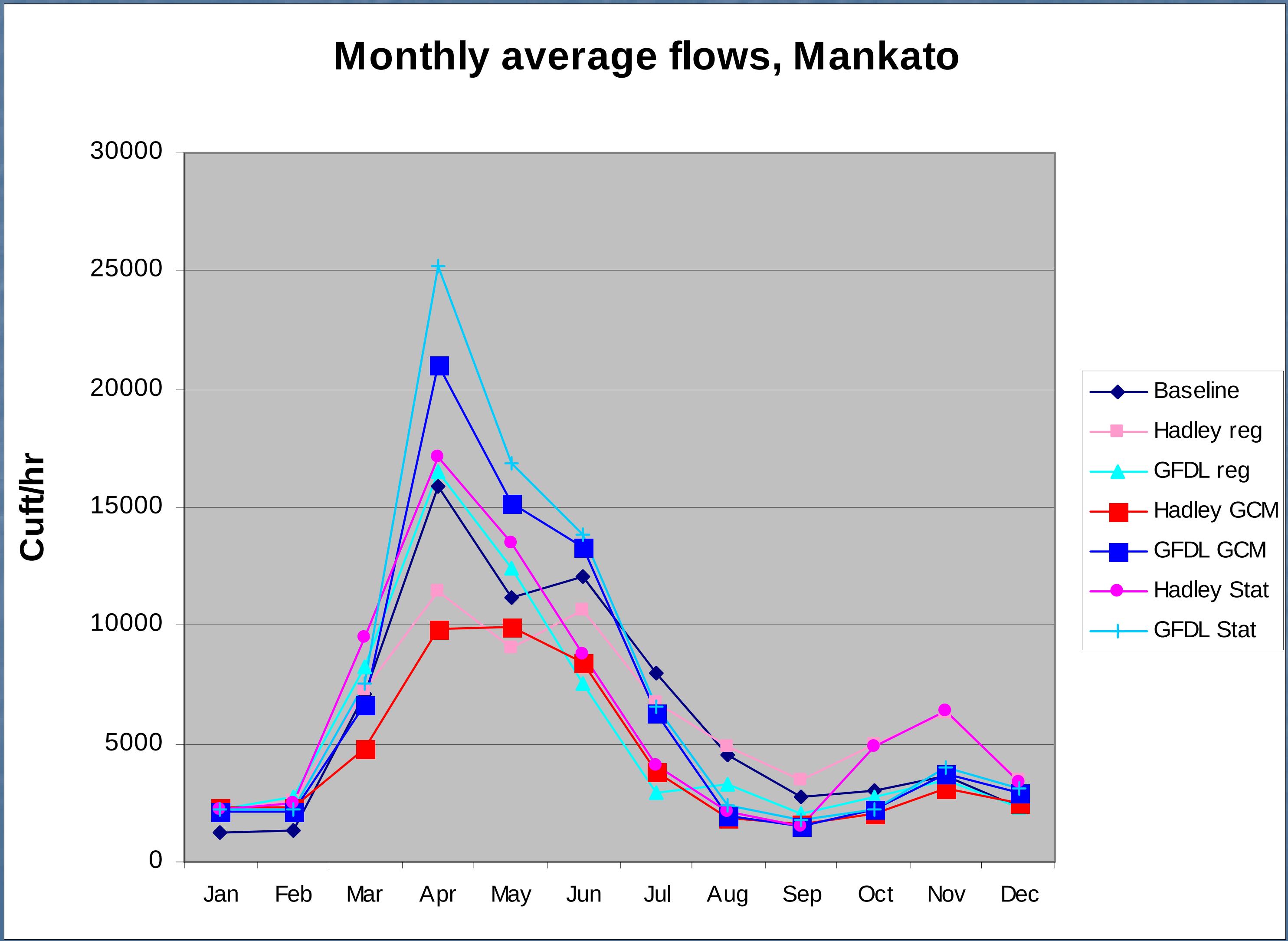
*** Preliminary Data ***





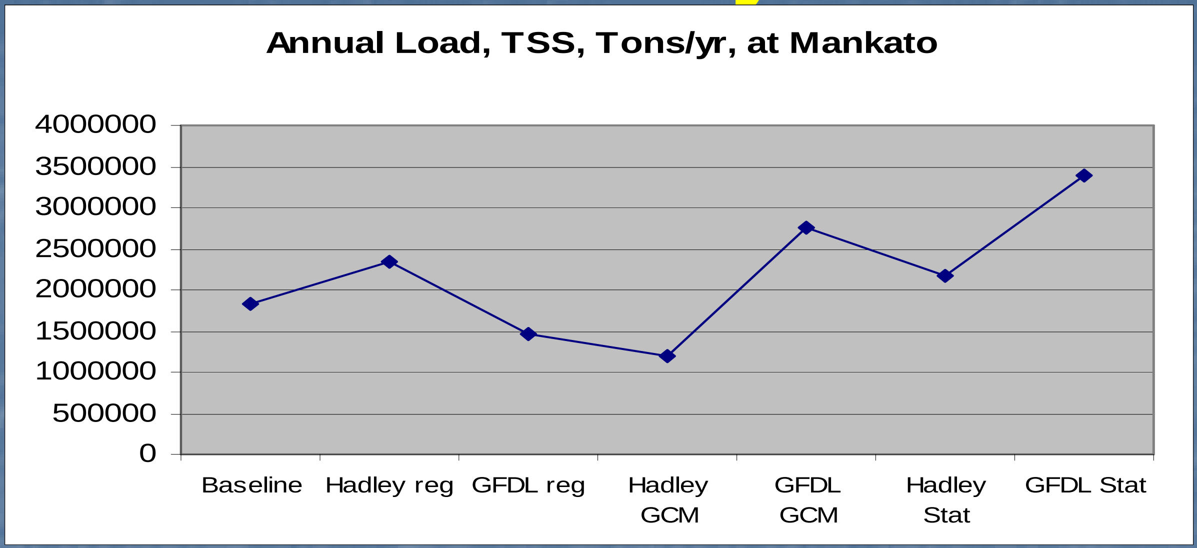
Flow Results, Minnesota River

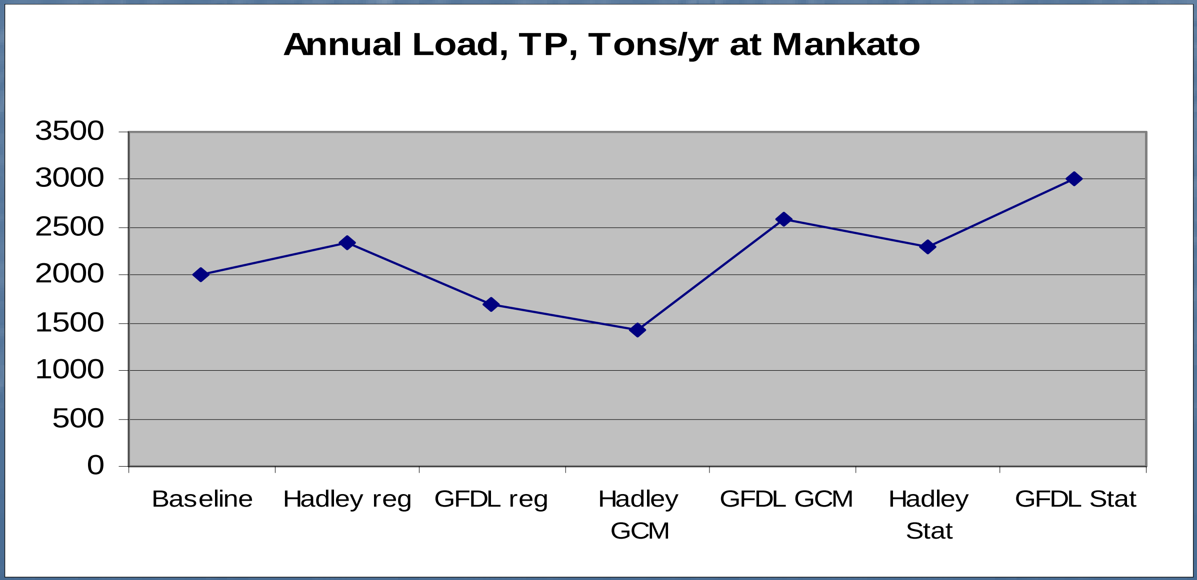
*** Preliminary Data ***



Loading results, Minnesota River Study

*** Preliminary Data ***





Next Year

Results for the New England Coastal Basin
And Lake Champlain

Thank you

Questions??