Watershed-scale Modeling of Hydrologic and Water Quality Effects of Climate Change: The Monocacy River Basin Example

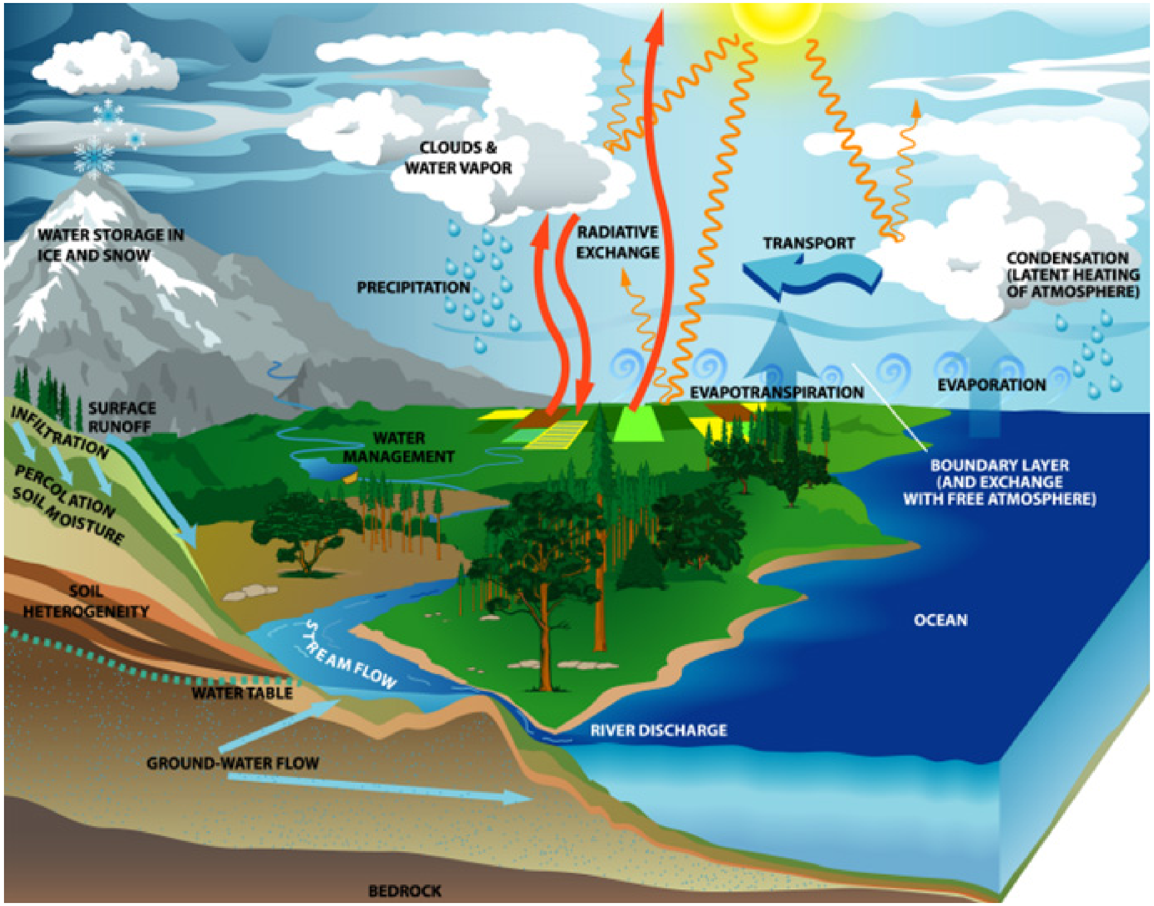
Thomas Johnson

US EPA, National Center for Environmental Assessment

John Kittle Jr., John Imhoff, Mark Gray

Aqua Terra Consultants

Climate and Water Resources



Climate and Water Resources Management

- Managing the risk associated with seasonal to inter-annual climate variability central to water management
  - Past is typically assumed a guide to the future
- Long term climatic trends may lead to unprecedented conditions and events that challenge this assumption

A Blueprint for Assessing Impacts

- Establish decision context
- Develop conceptual model
- Locate and collect available data on climate change
- Determine if available data adequate to meet goals
- Determine what tools and techniques are available and most suitable
- Assess sensitivity of endpoints to plausible changes
- Loop to previous steps

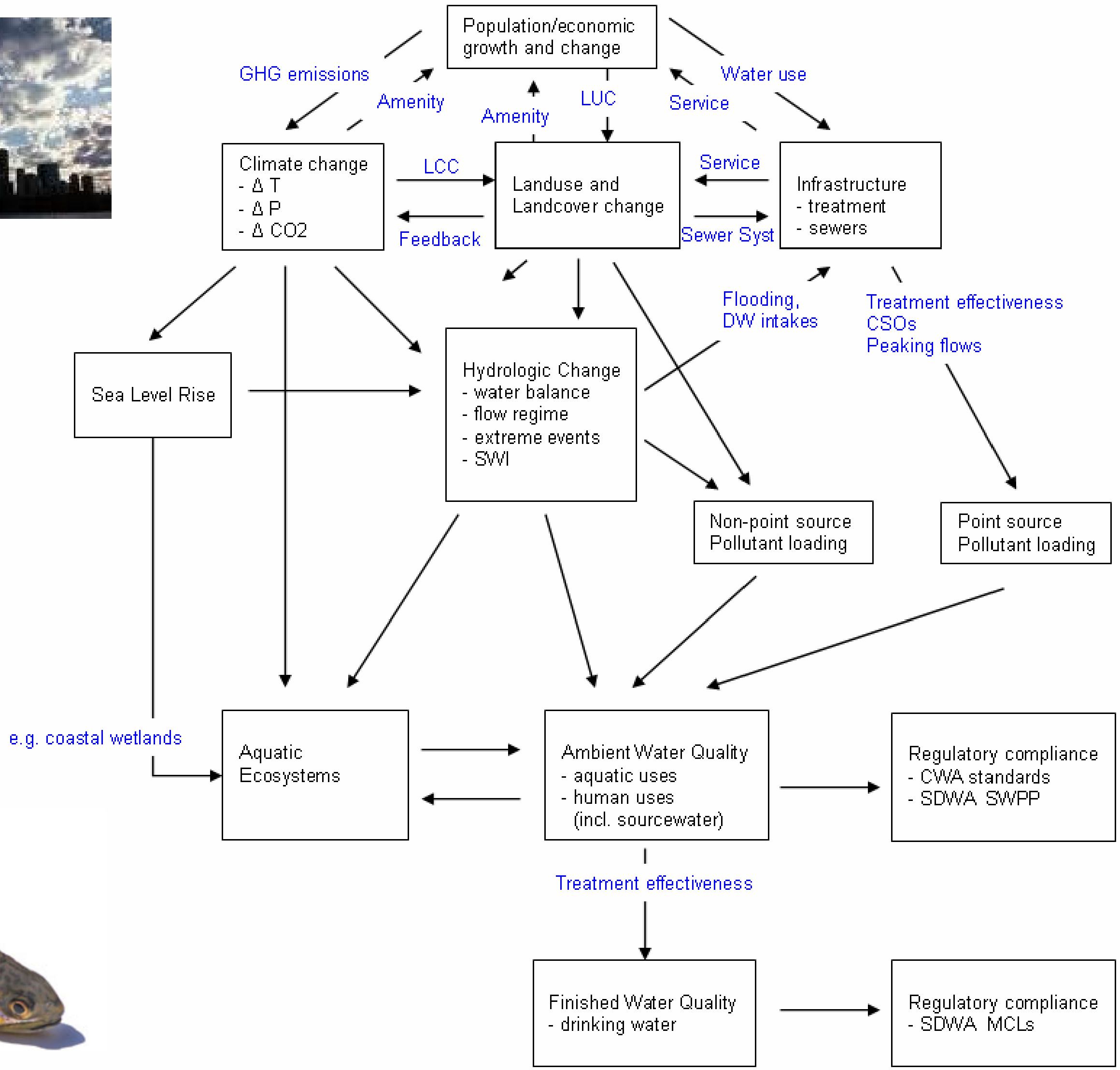
Decision Context

- The Monocacy River, a tributary to the Chesapeake Bay
- Focus on flow and WQ endpoints important to the Chesapeake Bay Program, ICPRB
  - flow / water budget
  - sediment
  - nutrients
- Goals:
  - the sensitivity of endpoints to plausible changes in climate (at 2030 and 2100)
  - how climate change will interact with other stressors (e.g. land use)
  - how management strategies will perform under changing conditions

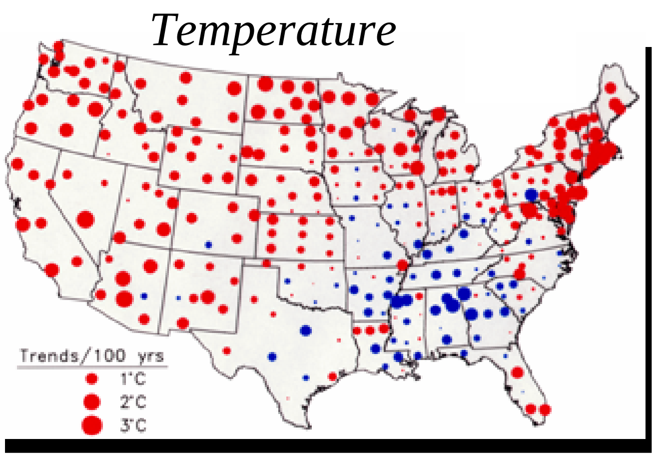
Monocacy River Watershed

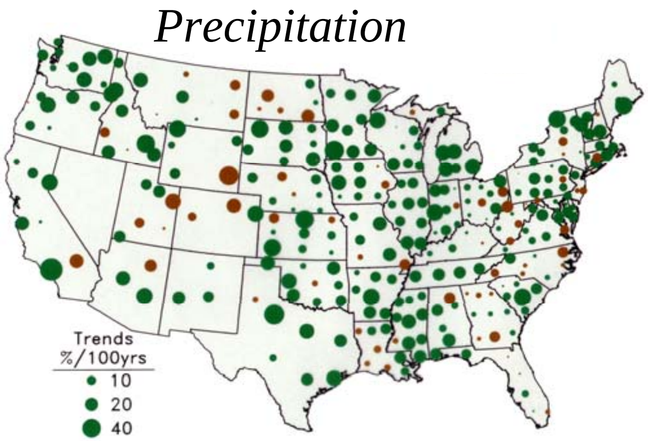
- Drainage area ~ 800 sq. mi
- Landuse
  - 75% agriculture
  - 25% urban
  - 25% forest
- USGS streamgage just below Frederick

Conceptual Model Linking Stressors and Endpoints

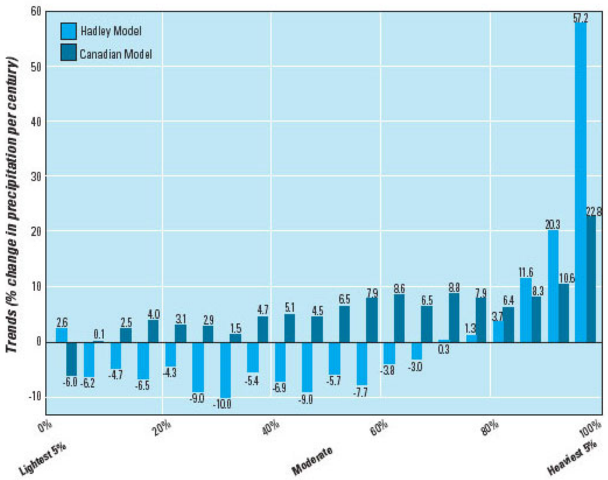


Available Data: Observed Trends (1901-1998)





Available Data: Projected Precip Intensity Trends (2100)



Source: NCDC/NESDIS/NOAA

Available Data: PSU/EPA CARA Project

- GCM projections from 7 IPCC TAR models
- Two IPCC storylines (A2/B2)

* CCCM - Canadian Centre for Climate Modeling and Analysis

* CSIRO - Australia's Commonwealth Scientific and Industrial Research Organization

* ECHM - German High Performance Computing Centre for Climate- and Earth System Research

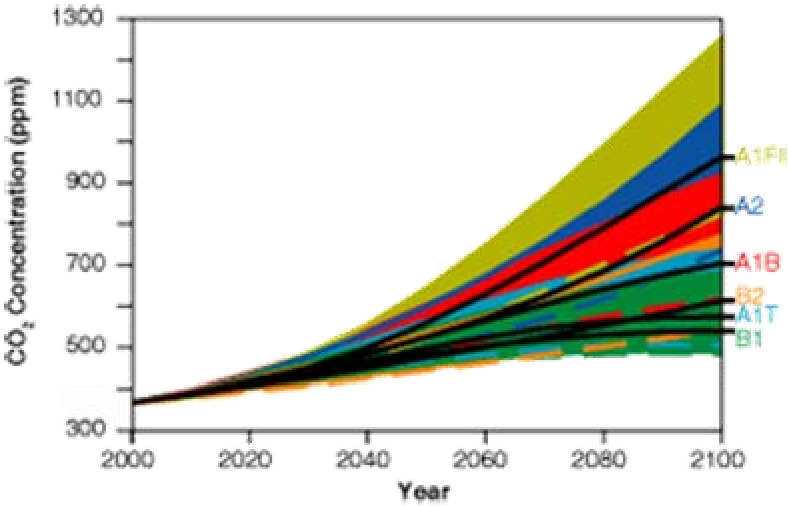
* GFDL - Geophysical Fluid Dynamics Laboratory

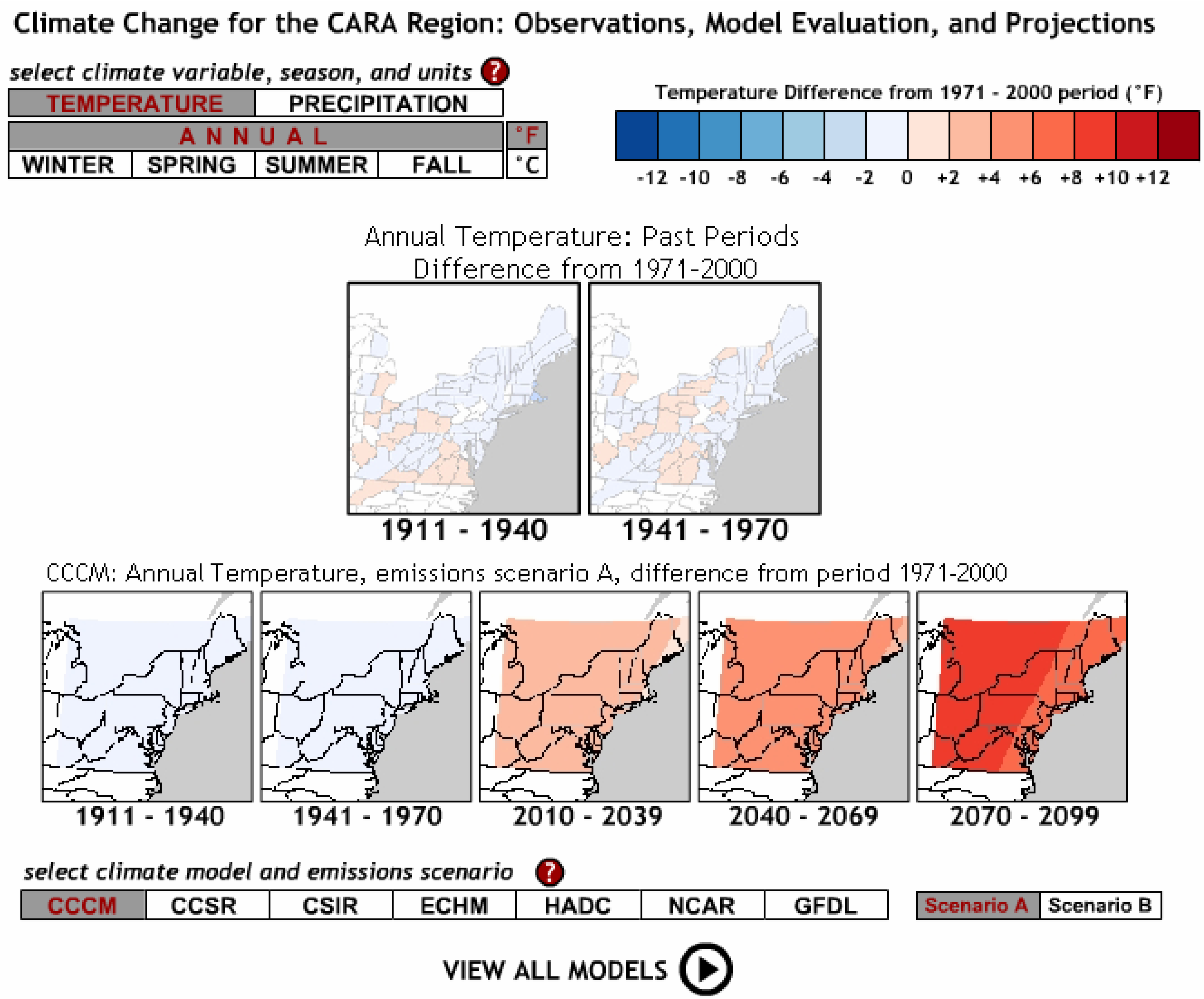
* HDCM - Hadley Centre for Climate Prediction and Research

* NCAR - National Center for Atmospheric Research

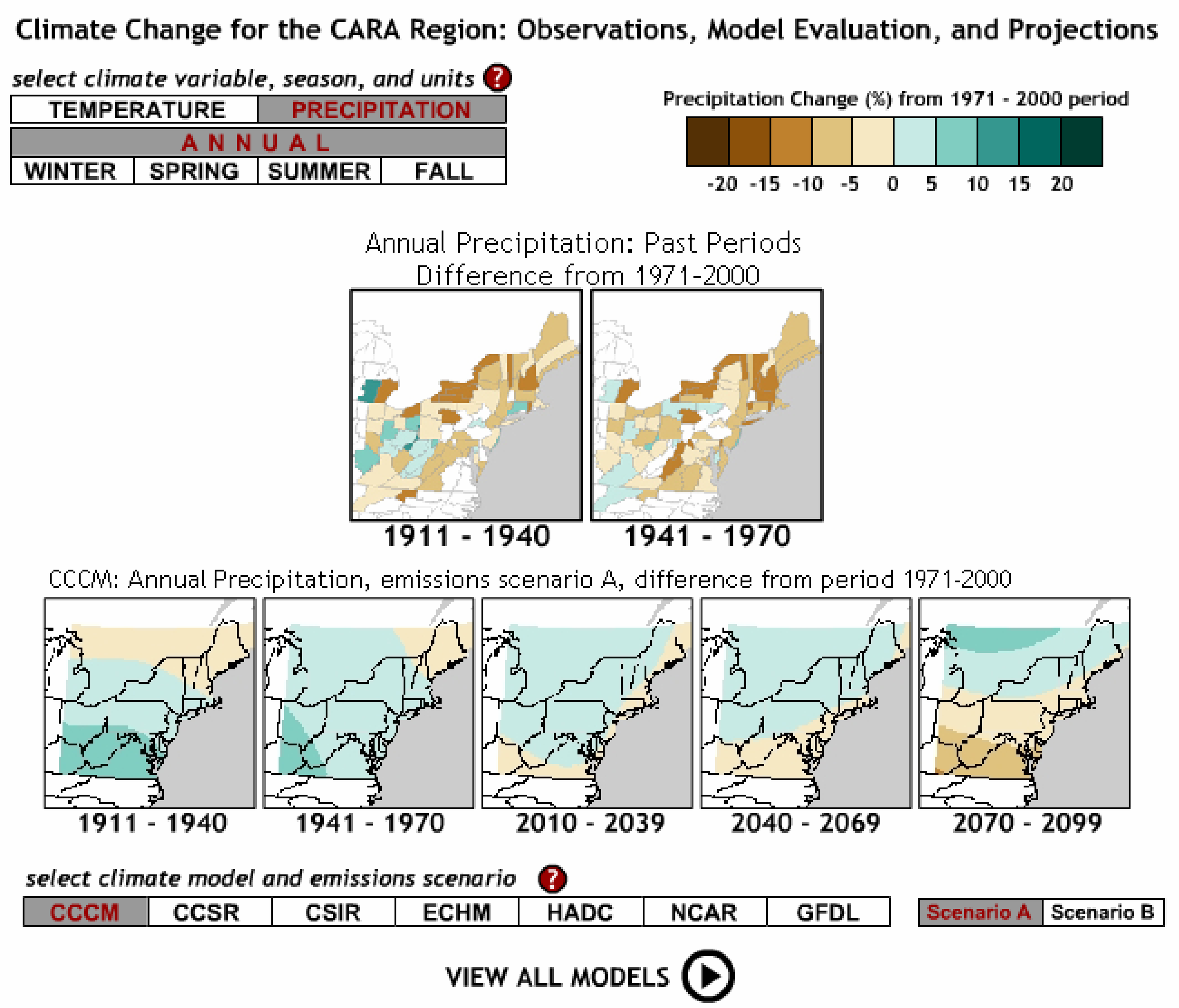
* CCSR - Univ. of Tokyo, Center for Climate System Research/ National Institute for Environmental Studies

Projected **global greenhouse gas concentrations** using IPCC "SRES" global scenarios





http://www.cei.psu.edu/cara/GCM/climate_change.html



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Data Adequate to Meet Goals

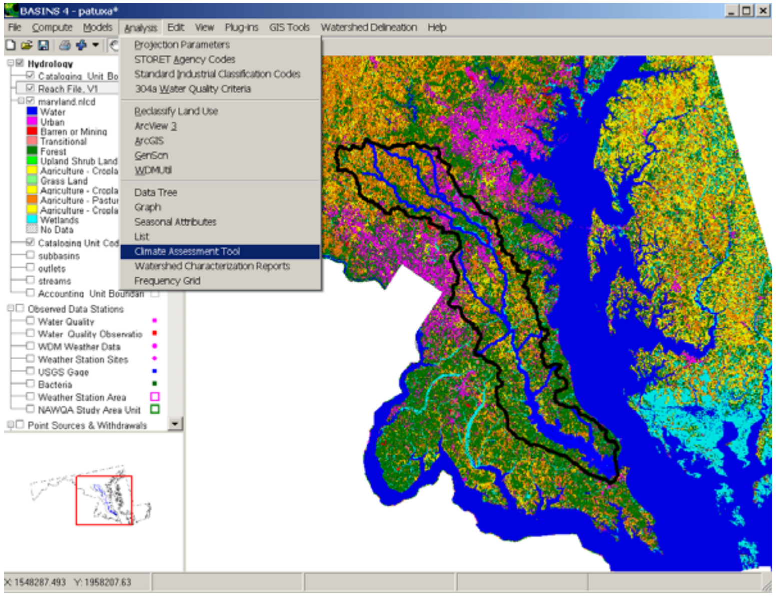
- Decided to use CARA data, and that this was adequate for sensitivity screening, identifying ranges of plausible impacts

Available Tools and Techniques

- Used BASINS-CAT tool to implement scenarios
  - Provides easy way to create weather data representative of a wide range of potential future changes in temperature and precipitation
  - CAT scenarios then be used to assess impacts on hydrology and water quality using BASINS HSPF
  - Provides capability to automate model runs to quickly build datasets on the sensitivity of different hydrologic or water quality endpoints

BASINS Climate Assessment Tool

- Released with EPA's BASINS 4 modeling system (for WinHSPF)
- Open source, MapWindow based platform

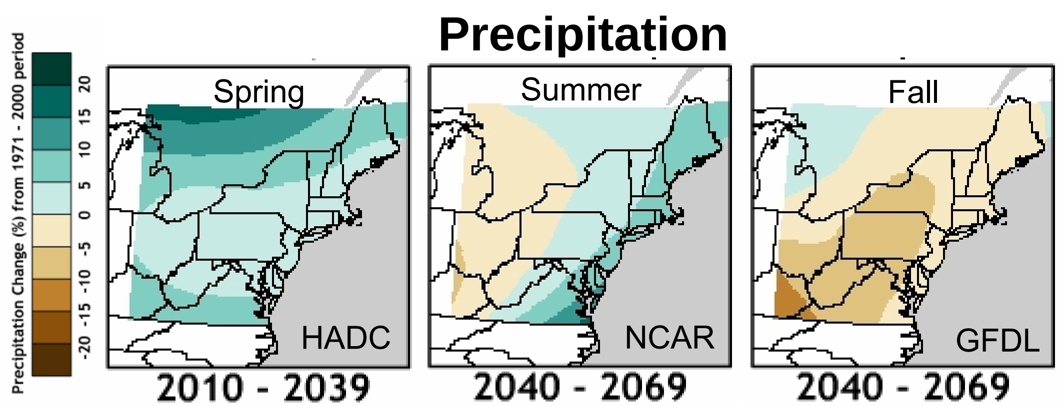


Consider Complex Climate Scenarios

Can modify historical data:

- Apply arithmetic operators to any time interval
- Apply arithmetic operators to selected events
- Add or remove events

…or generate new time series using the stochastic weather generator CLIGEN



Sensitivity Assessment

• Managers can assess their exposure to climate-related risks by understanding the sensitivity of key management goals to a range of plausible climatic conditions and events

"What change in climate would need to occur to cause a harmful system impact?"

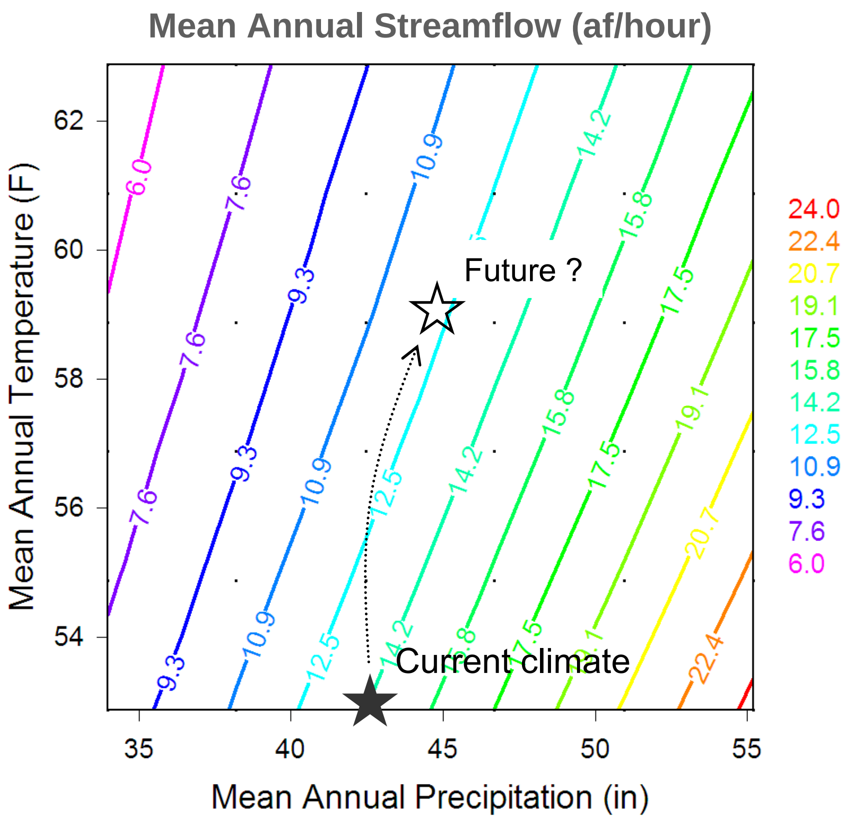
Examples:

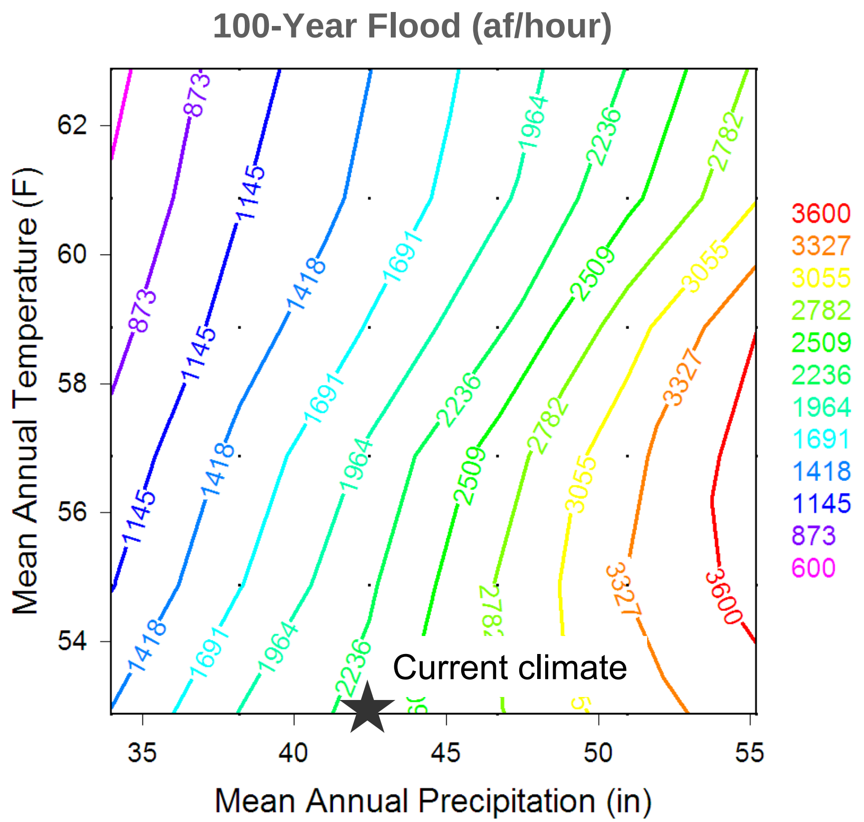
What Δ air temp? ⟶ Δ water temp ⟶ harmful to fish

Monocacy Assessment: Map Sensitivity to Full Range of Plausible Changes in Temperature and Precipitation

- Average historical annual temperature = 52.8 ^{o}F
  - Assess increases of 0, 2, 4, 6, 8, 10 ^{o}F
- Average historical annual precipitation = 42.5 in
  - Assess changes of -20, -10, 0, +10, +20, +30 percent
- Consider:
  - Mean annual streamflow
  - 100-year flood event
  - Mean annual sediment loading
  - Mean annual phosphorus loading
  - Mean annual nitrogen loading

Map Sensitivity to Full Range of Plausible Changes in Temperature and Precipitation





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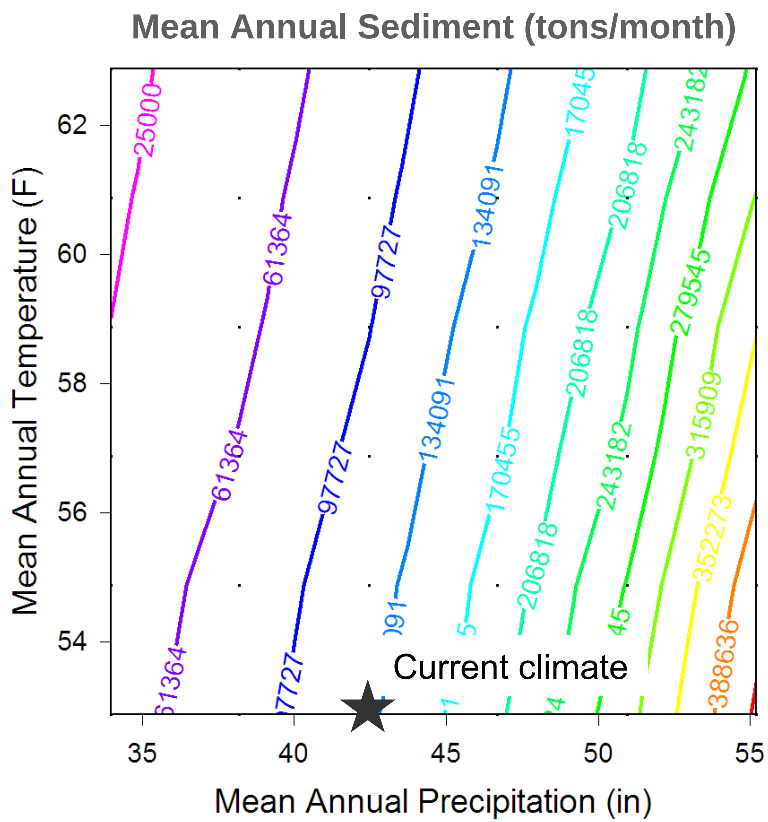

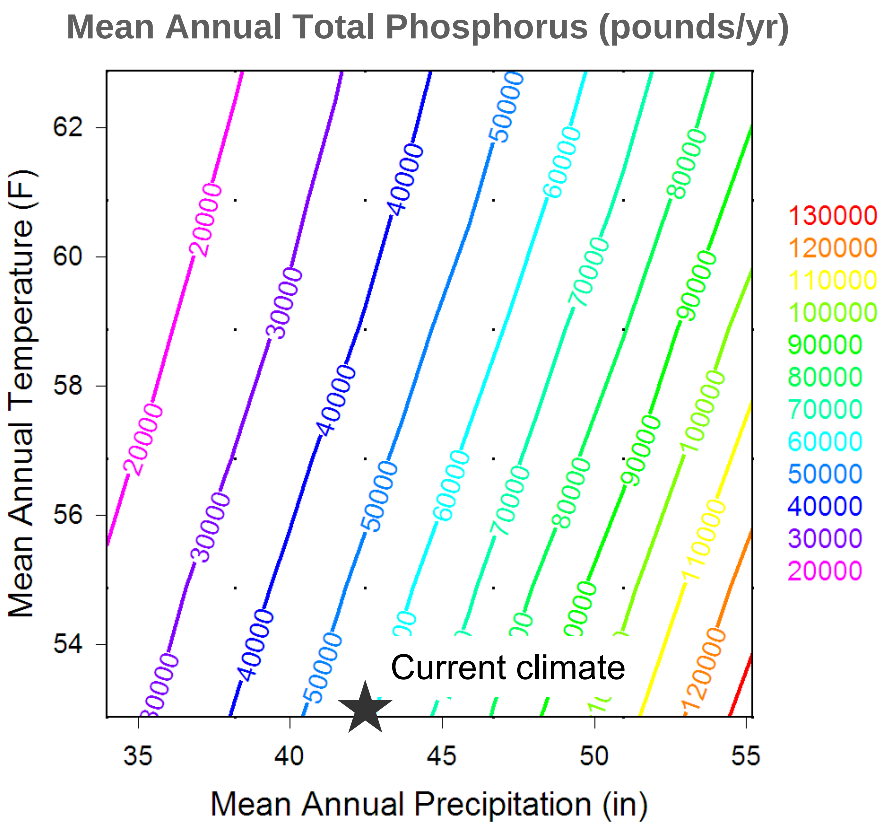

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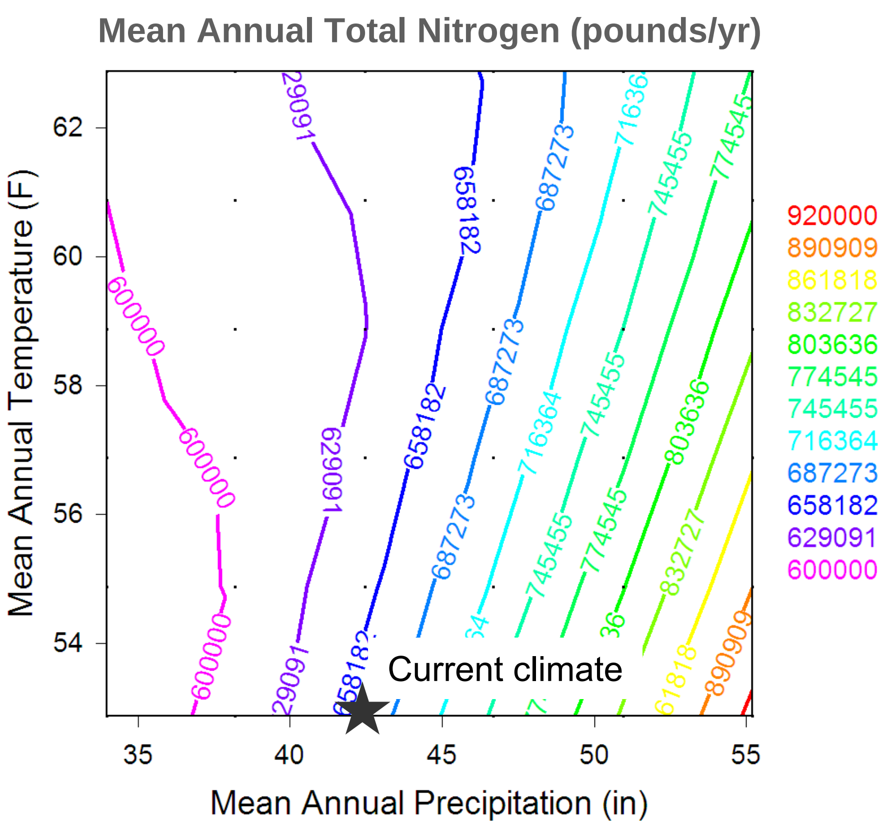
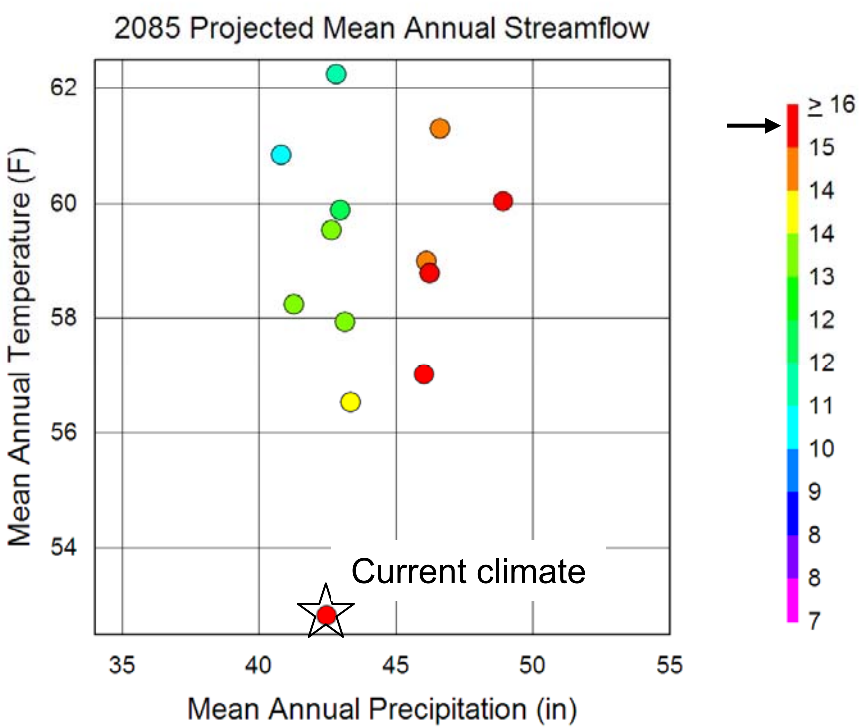
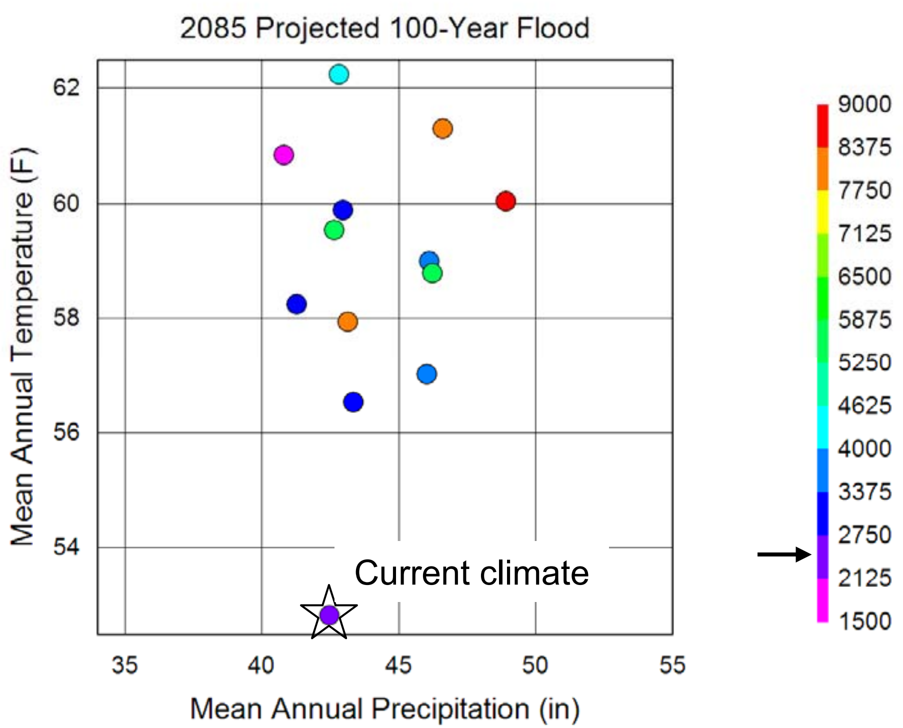


Monocacy Assessment: Map Sensitivity to Range of Model Projections

- Base on year 2085 (average of period 2070-2099)
- Projections from 7 IPCC TAR models
- Assuming 2 IPCC SRES storylines (A2/B2)
- Precipitation changes implemented in 3 ways:
  - Modify all events using uniform multiplyer
  - Modify only large events; greater than 70^{th} percentile
  - Modify only largest events; greater than 90^{th} percentile

Map Sensitivity to Range of Model Projections





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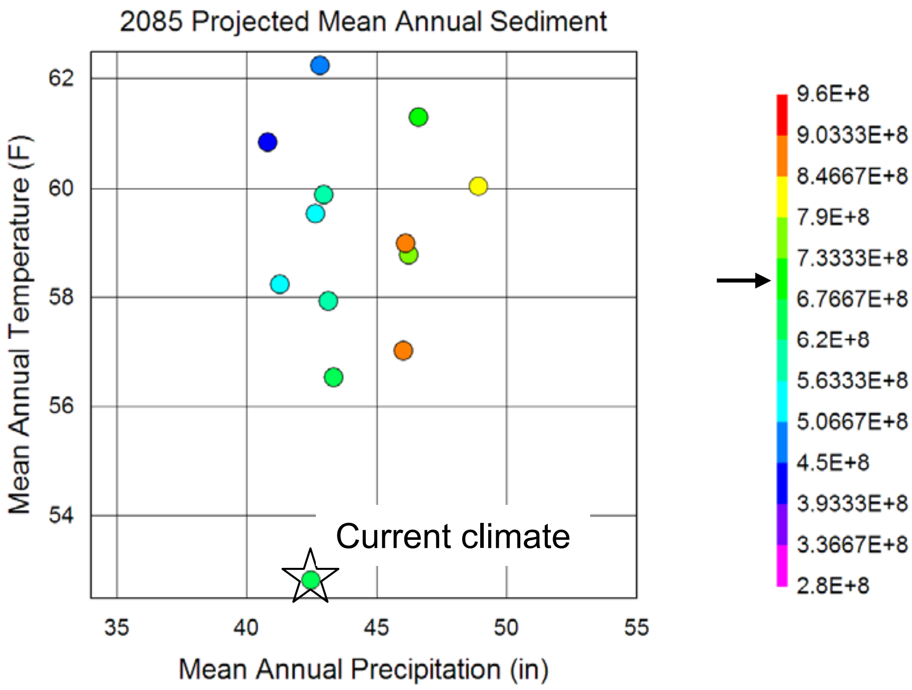

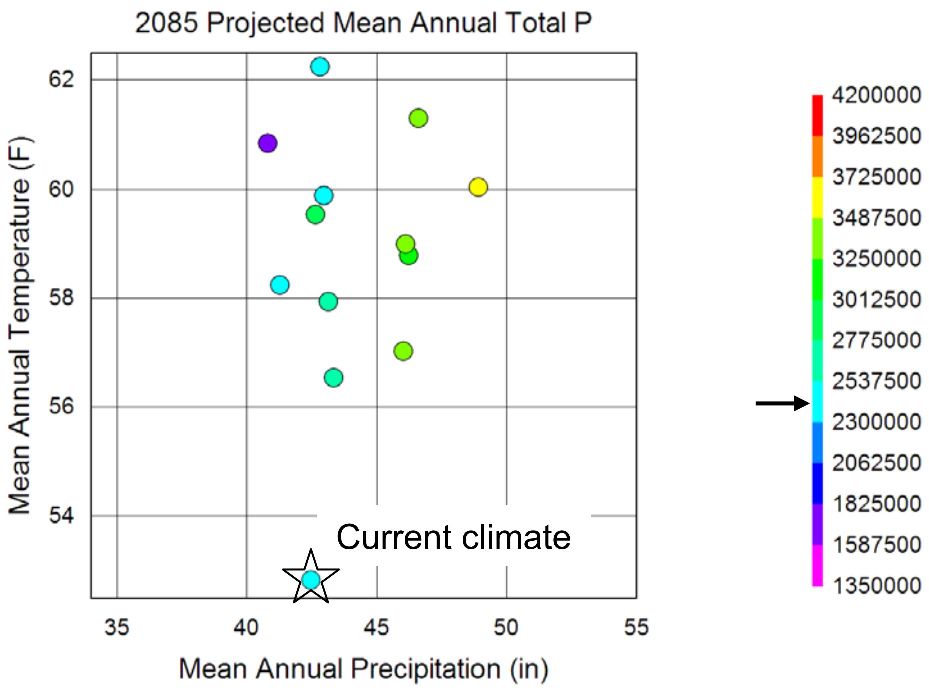

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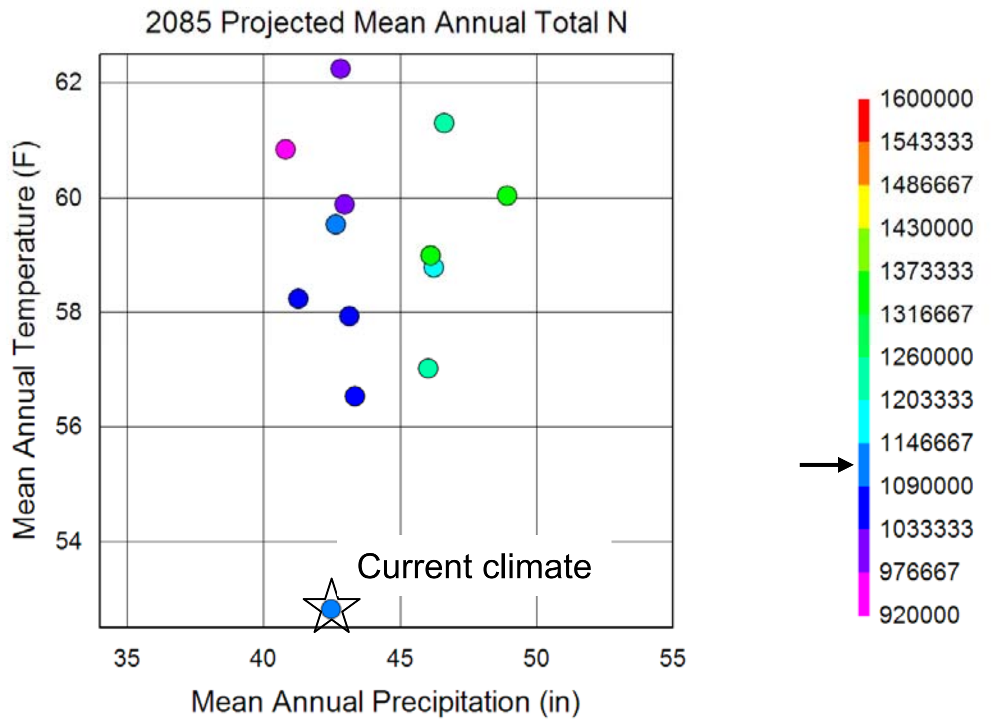
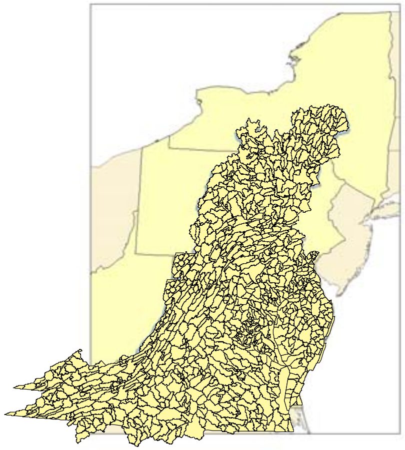


Loop to Previous Steps

- Monocacy – future work will consider effects of BMPs, concurrent effects of landcover change
- Chesapeake Bay program will use this to data to design a similar assessment for the entire Chesapeake Bay using the Phase V Bay Model
  - Identify high, middle, and low impact scenarios from the Monocacy case study (based on N loading)



Take-Home Messages

- ✓ Watershed hydrology and pollutant loading are highly climate sensitive
- ✓ Tools are available to assess sensitivity and improve understanding of potential impacts
- ✓ The response of aquatic ecosystems to these and other climatic, hydrologic, and water quality changes has implications for Biocriteria Program goals

End