Hydrologic and Water Temperature Response to Climate Variation in New England

Robert Lent, USGS Maine WSC

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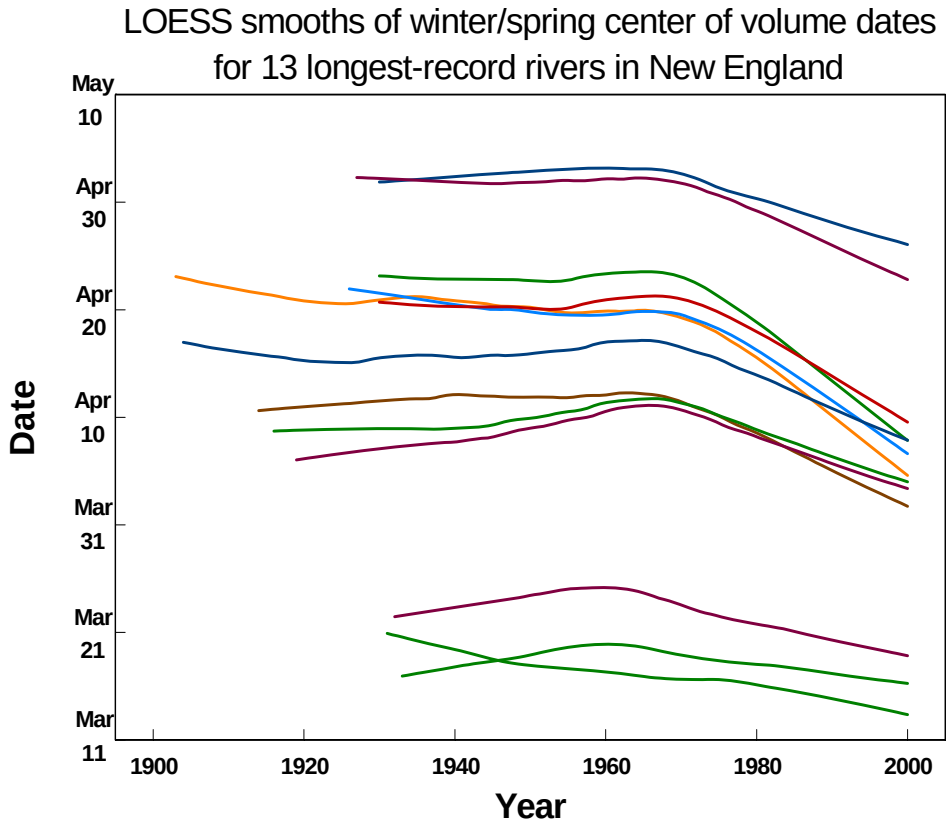
New England Hydrology is Sensitive to Climate Change

- Spring runoff dominates the annual hydrograph
- Occurring significantly earlier in northern New England in recent years
- Timing related to air temperatures



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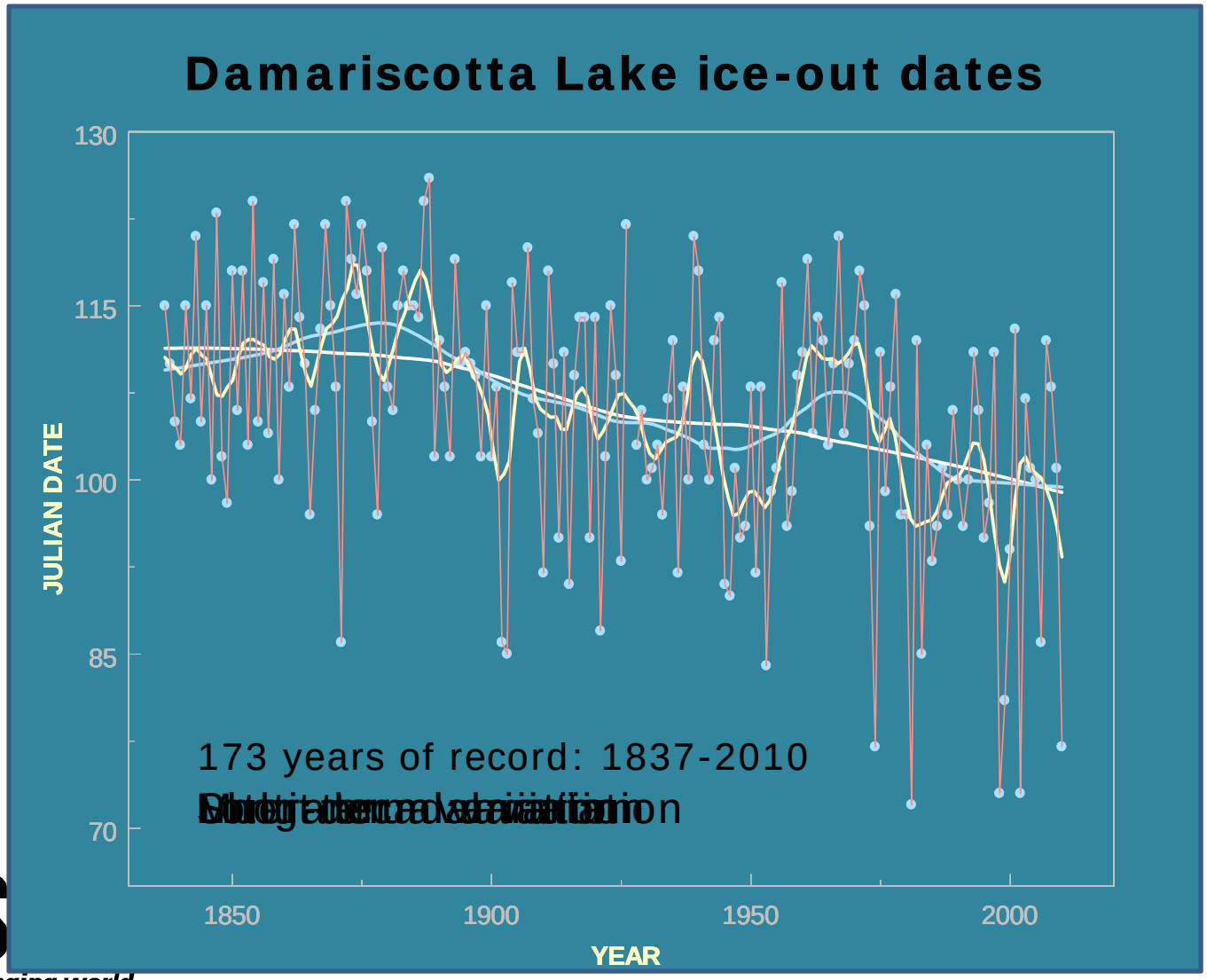
Hodgkins and others, 2003

Variations in Timing



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Timing of Hydrologic Response to Climate Change

Modeled maximum annual snowpack water-equivalent changes in the Royal River basin in southern, Maine

Temperature change

Precip Change	0° C	+2° C	+4° C	+6° C
0 %	0 %	-50 %	-75 %	-86 %
+15 %	+20 %	-38 %	-71 %	-83 %
+30 %	+42 %	-25 %	-67 %	-80 %

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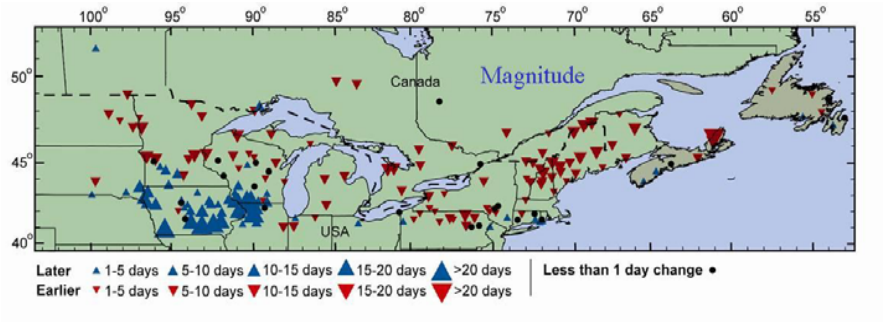
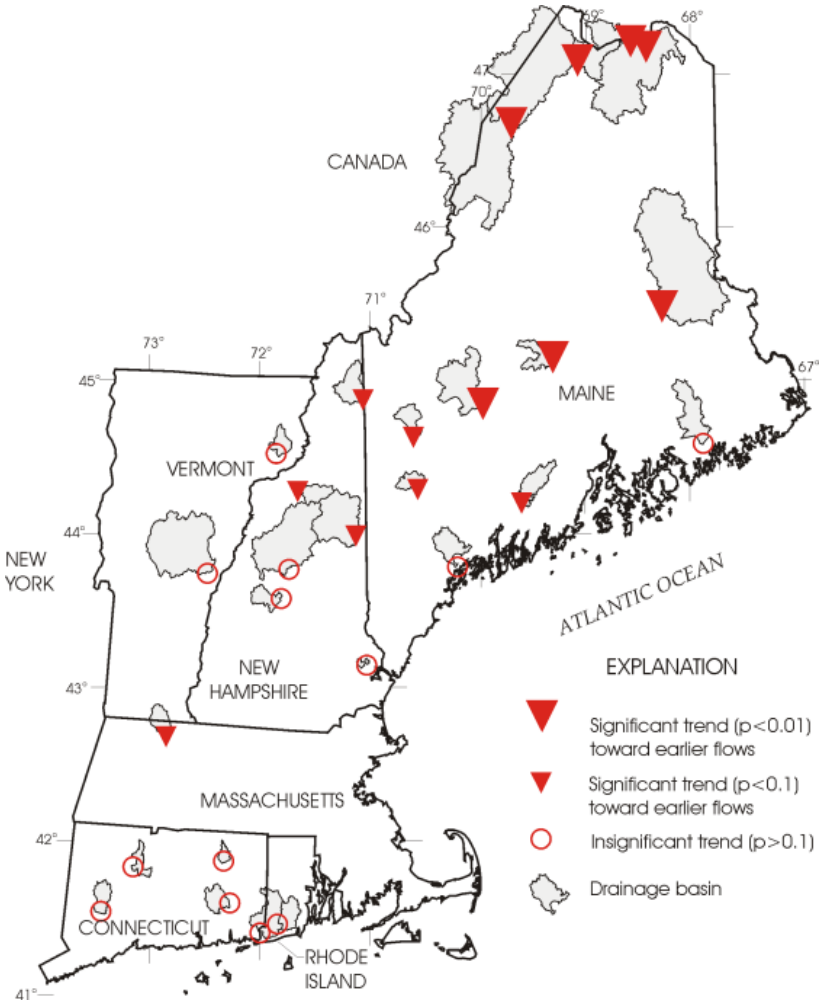
Regional Variation

- Maine
  - Timing
  - Mountains to the Coast
- New England
  - Significance
  - North to south
- Regional gradients
  - Direction



Hodgkins and Dudley, 2006



Hodgkins and others, 2003

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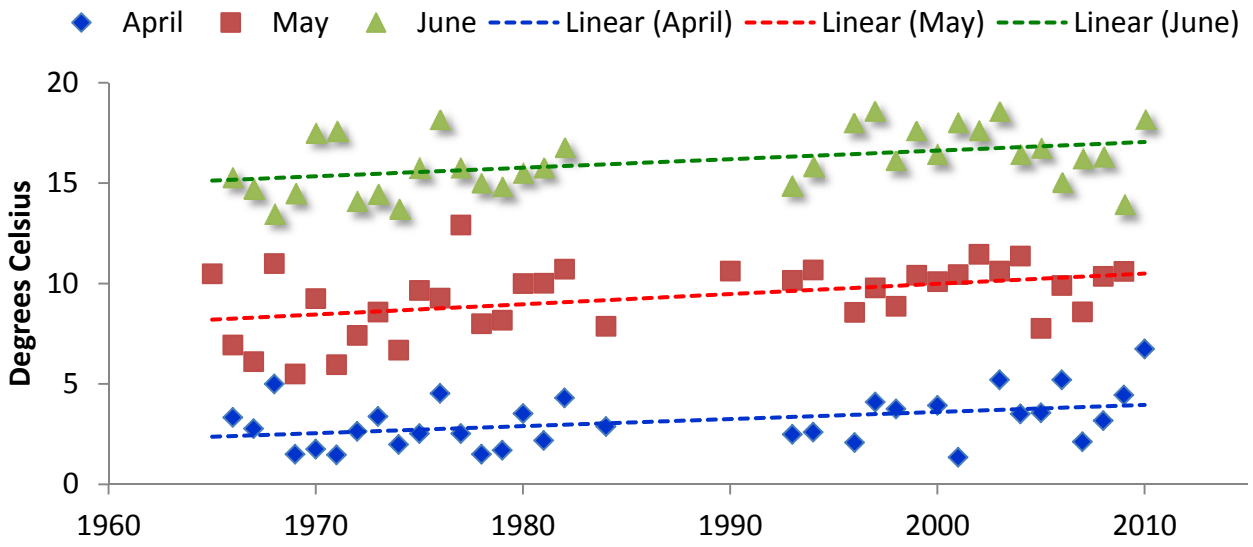
Water Temperature, Wild River, Gilead, Maine

(Benchmark)

Trends in water temperature, Wild River, Gilead, Maine



Updated from Huntington, et al. 2003

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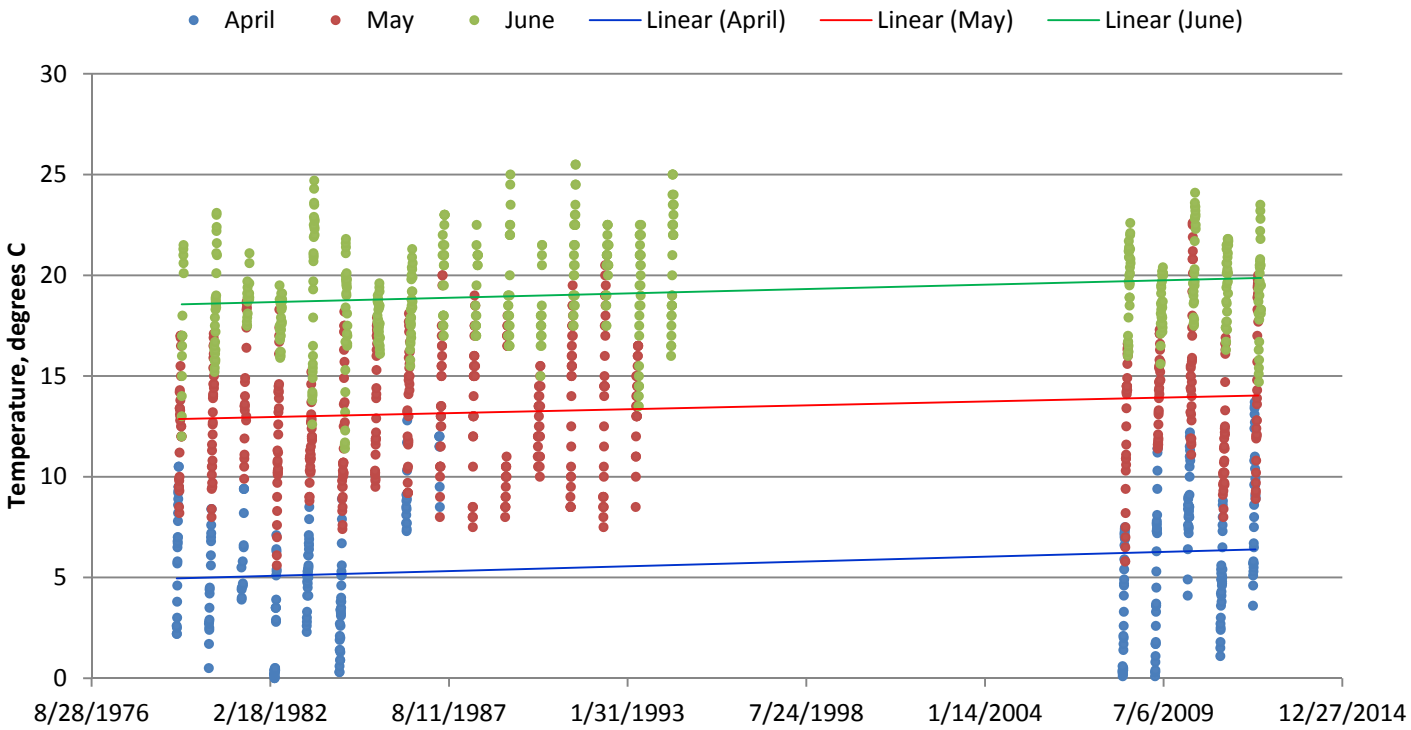
Water Temperature, Penobscot River, Eddington, Maine (NASQAN)



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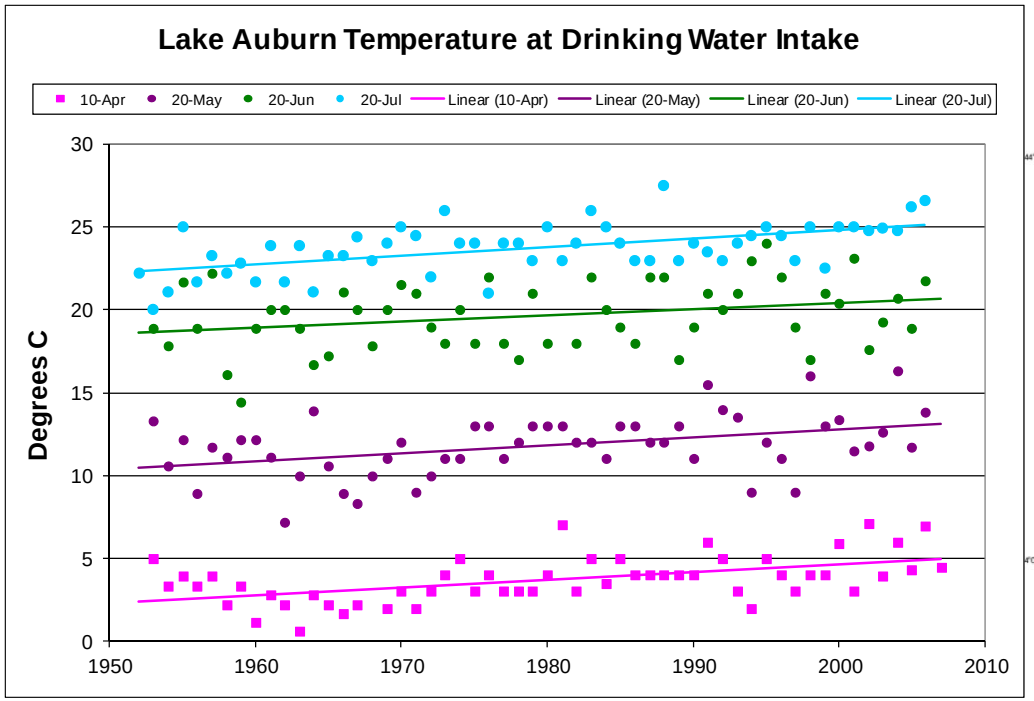
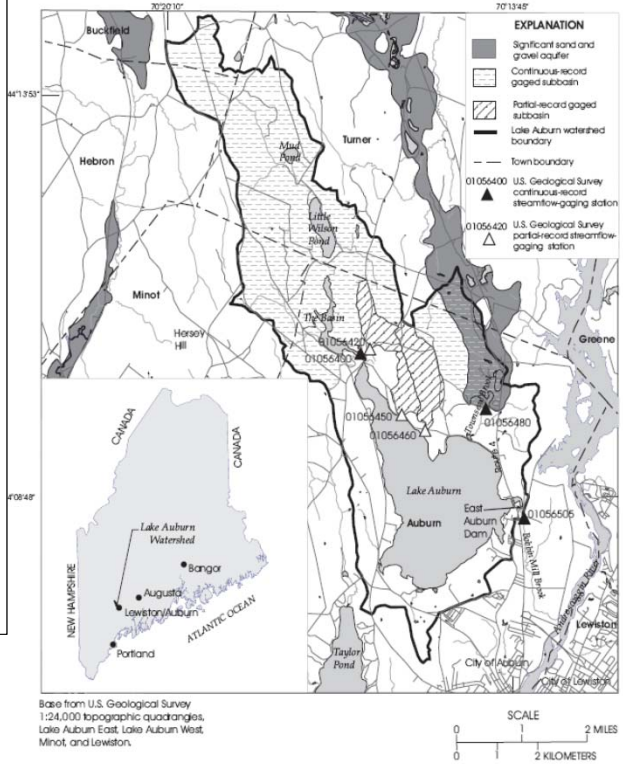
Water Temperature, Lake Auburn, Maine

(Supplied)





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Hydrologic Variables

Annual

- Streamflow
  - Magnitude of annual flow
  - Magnitude of annual peak flow
  - Frequency of peaks above base
- Rain/Snow/Ice
  - Annual Temperature
  - Annual precipitation

Winter/Spring

- Streamflow
  - Timing of winter-spring runoff
- Groundwater
  - Timing of seasonal peaks
  - Amount of seasonal recharge
- Rain/Snow/Ice
  - River ice thickness
  - Ice-affected flow
  - Lake ice out
  - Late-winter snowpack
  - Snow/rain Ratio
  - Seasonal Temp
  - Seasonal precip

Summer/Fall

- Streamflow
  - Magnitude of summer baseflow
- Groundwater
  - Timing of seasonal maximum and minimum
  - Amount of seasonal recharge
- Rain/Snow/Ice
  - Seasonal Temperature
  - Seasonal precipitation

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Hydrologic Variables

Timing

Temperature

- Streamflow
  - Timing of winter-spring runoff
  - Frequency of peaks above base
- Groundwater
  - Timing of seasonal maximum and minimum
- Rain/Snow/Ice
  - Days of ice-affected flow
  - Date of spring lake ice-out

Amount

Precipitation

- Streamflow
  - Magnitude of annual flow
  - Magnitude of annual peak flow
  - Magnitude of summer baseflow
  - Magnitude of summer stormflow
  - Magnitude of runoff/unit area
- Groundwater
  - Amount of seasonal recharge
- Rain/Snow/Ice
  - River ice thickness
  - Late-winter snowpack
  - Snow/rain ratio

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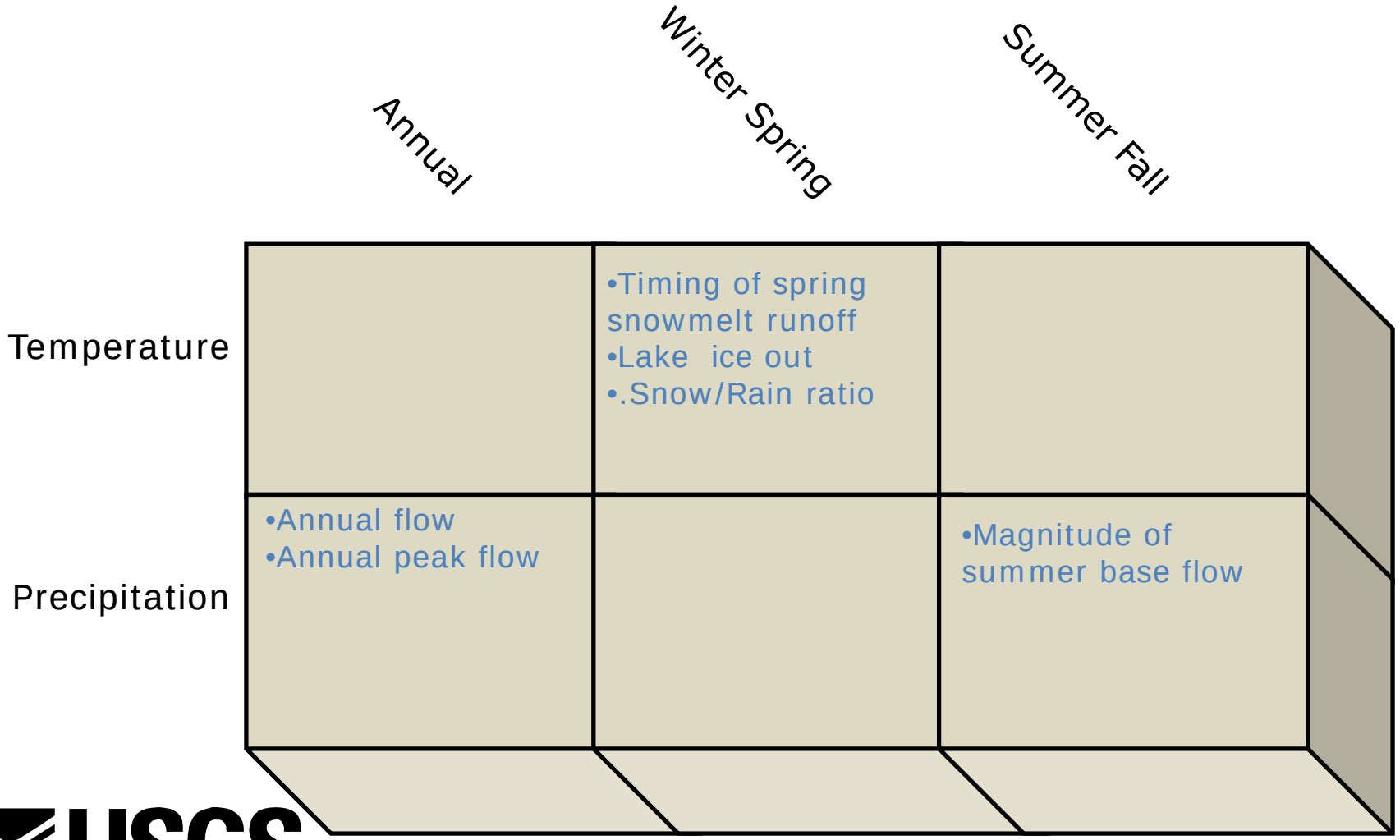
New England Variables



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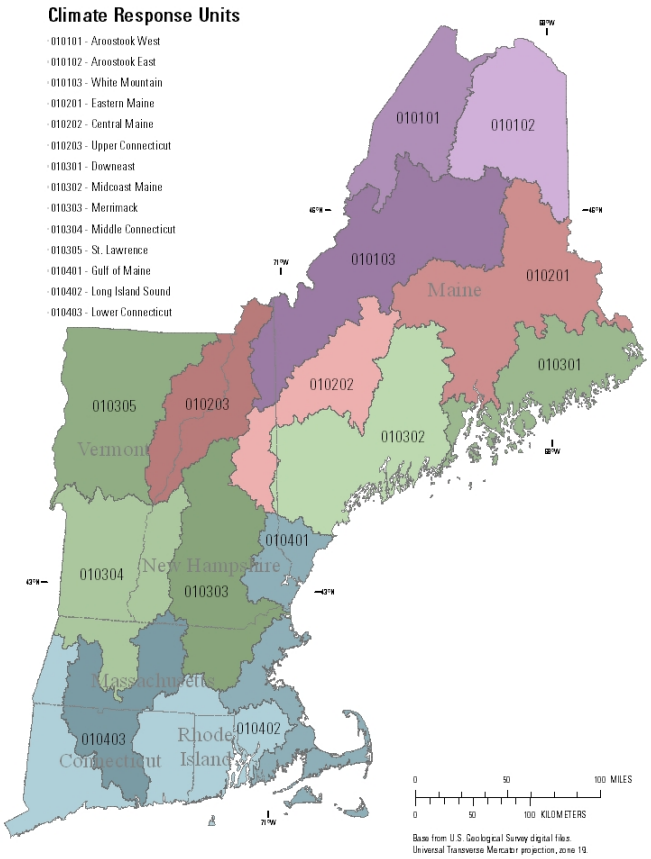
Proposed New England Climate Response Network

- Spatial variability of hydrologic variables
- Regional boundaries
  - Major watersheds
  - USEPA Ecoregions
- Important resources
  - Critical habitat
  - Native American lands
  - Federal lands
  - Drinking-water supplies



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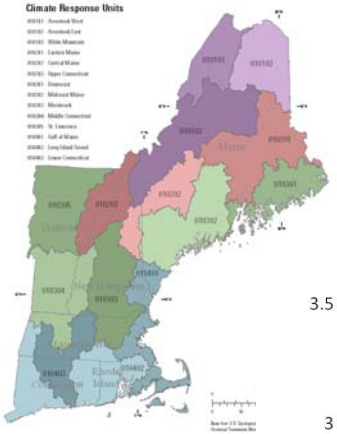
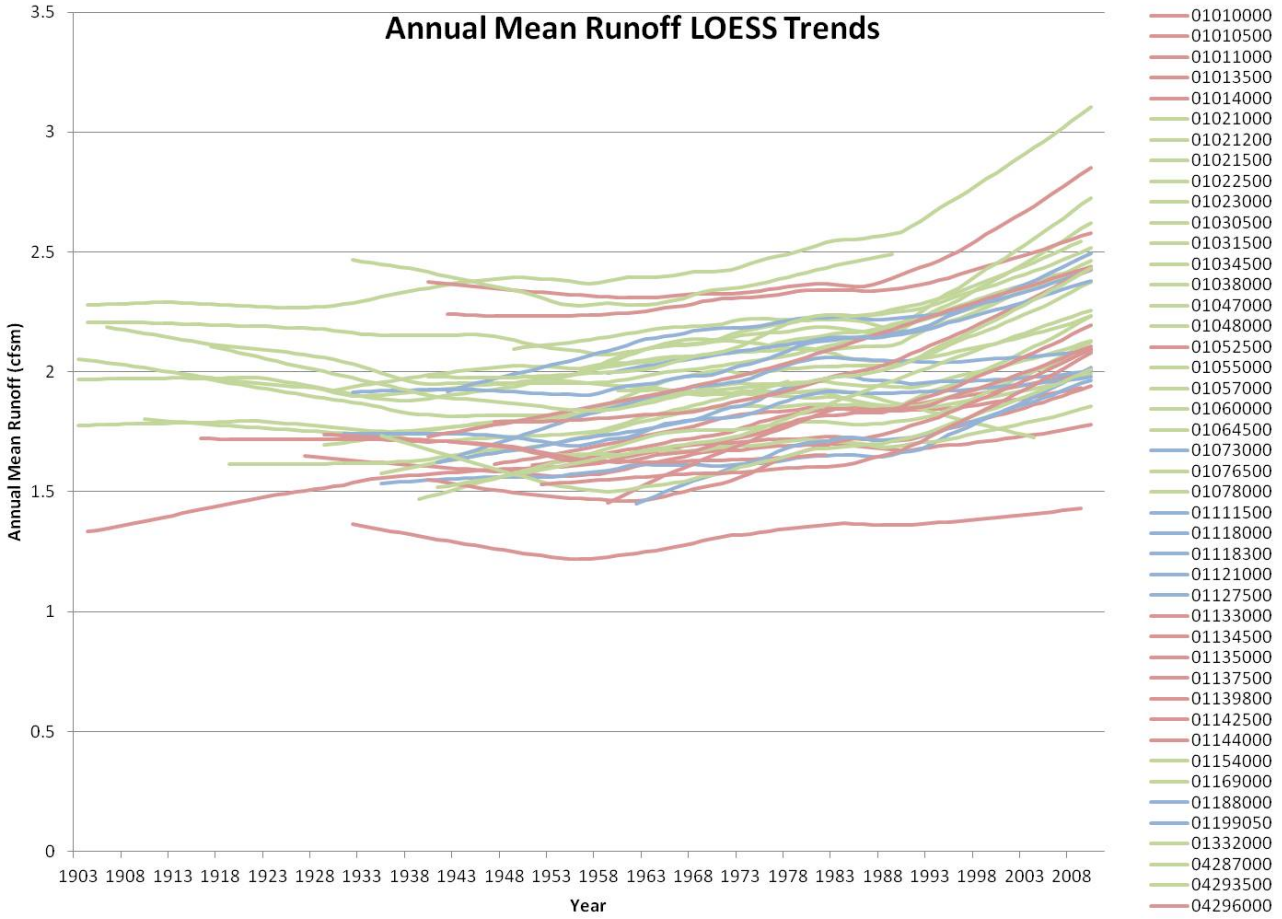


Annual Mean Runoff



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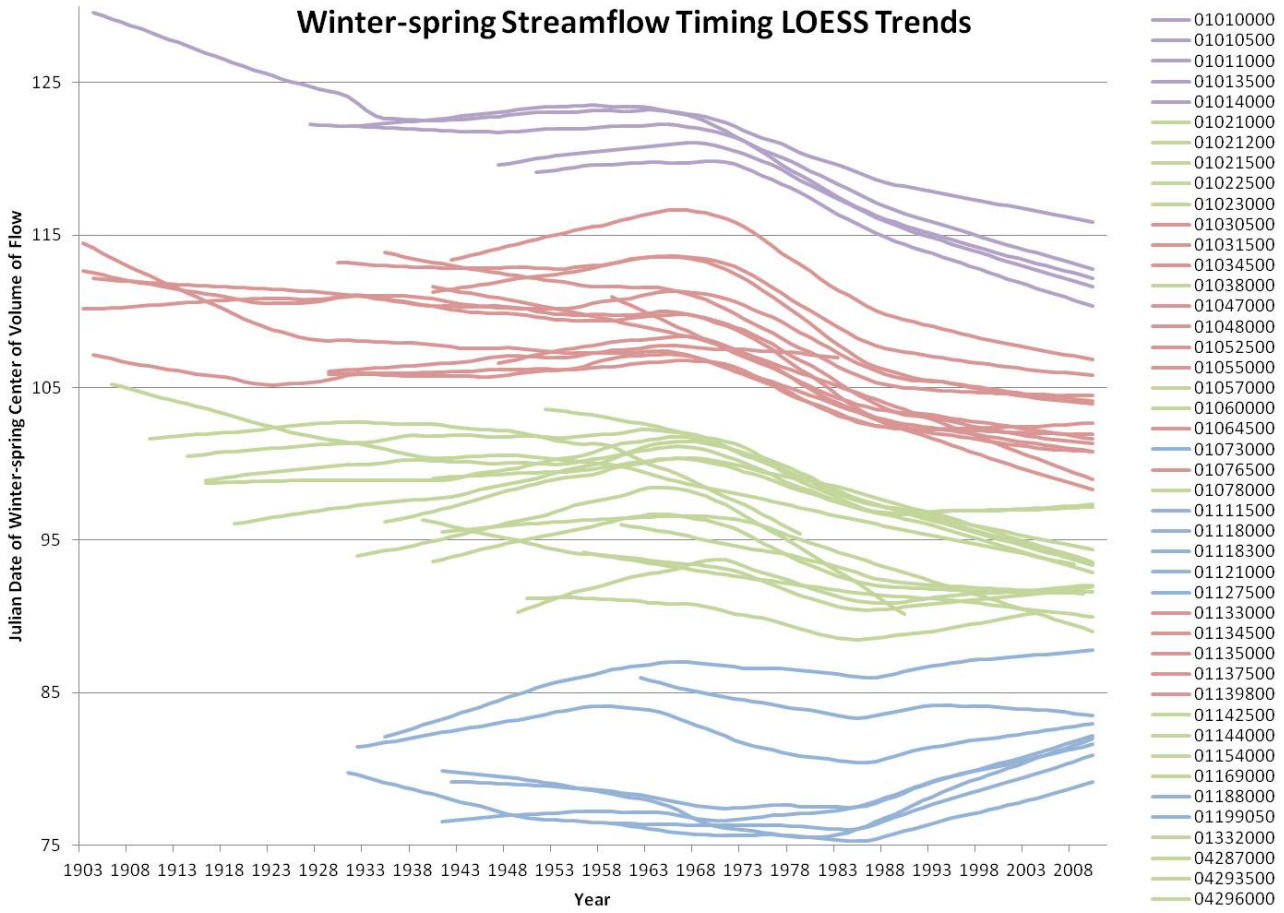
Winter-Spring Streamflow



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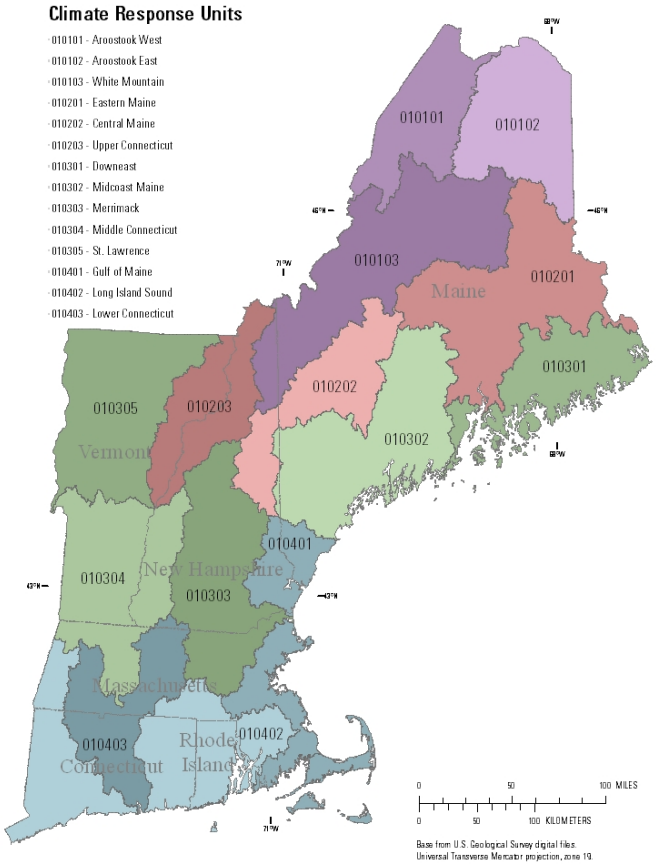
Proposed New England CRU

- Two intensive stations in each Climate Response Unit
- Data Collection
  - Continuous water temperature
  - Continuous air temperature
- Modeling
  - Calibrated watershed model
  - PRMS
- Opportunity for additional data collection



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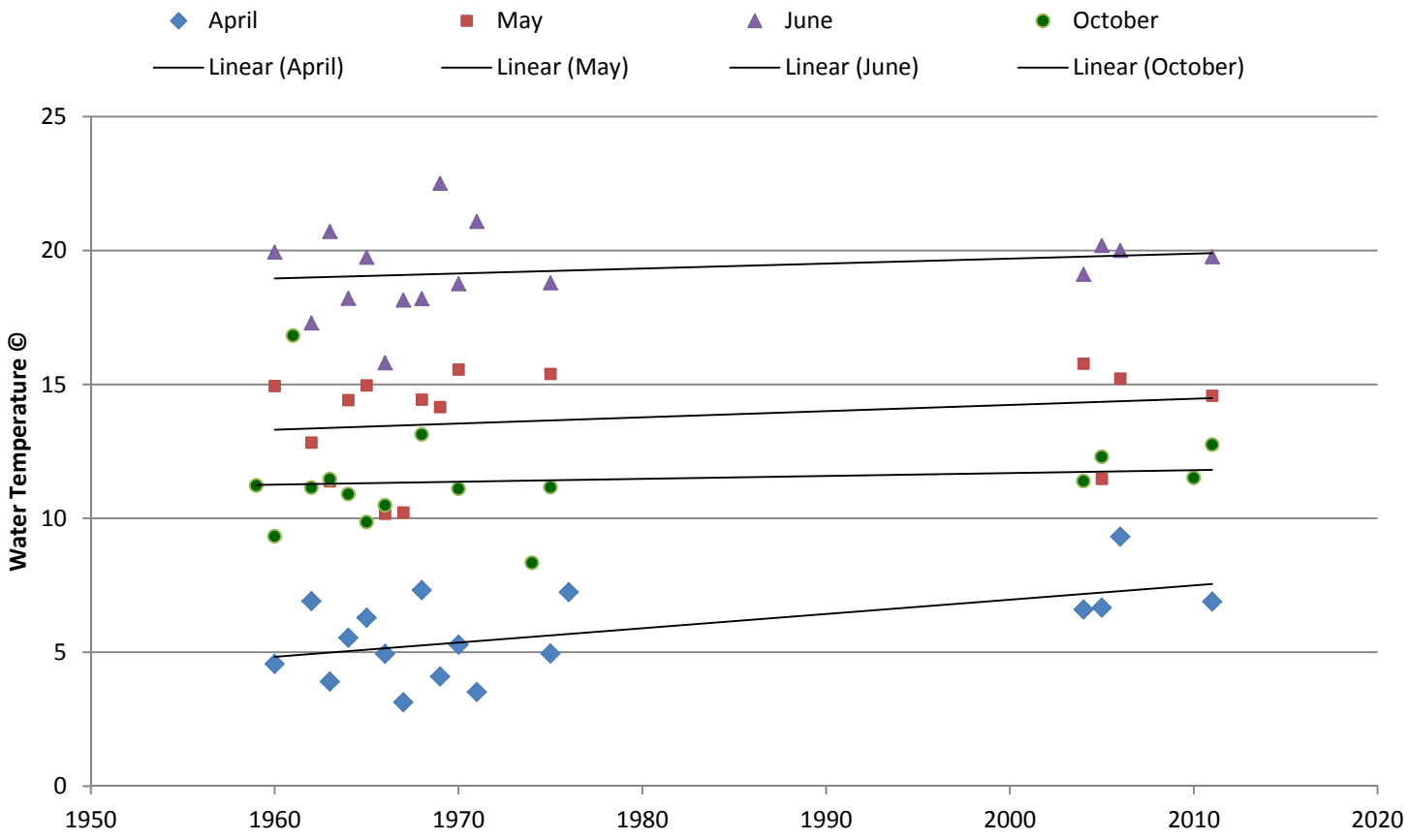
Mean Monthly Water Temperature Sheepscot River at Whitefield USGS Station ID 10138000



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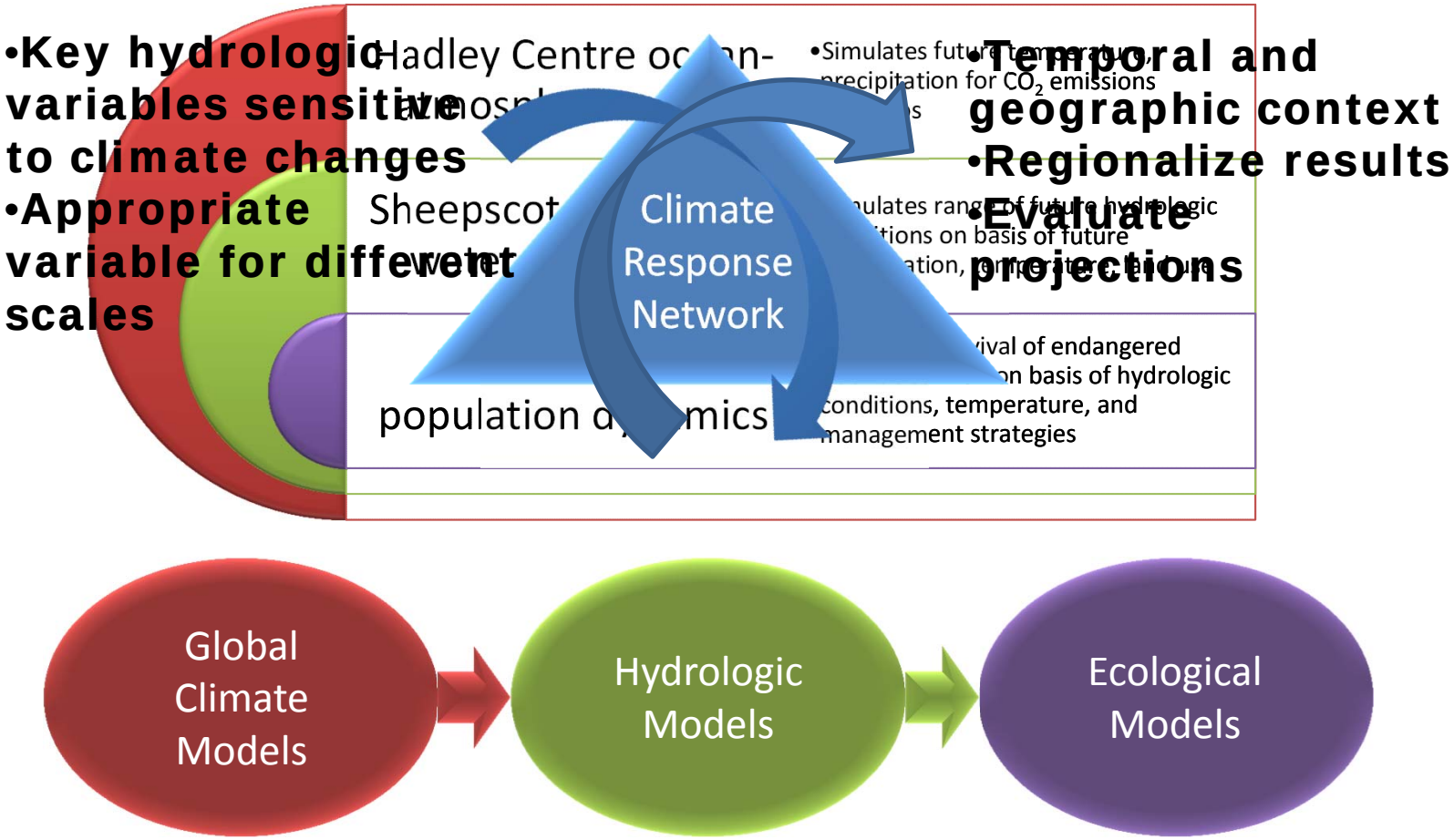
Provisional, unpublished data from USGS records, compiled by T. G. Huntington.

Provide Systematic Information to Resource Managers



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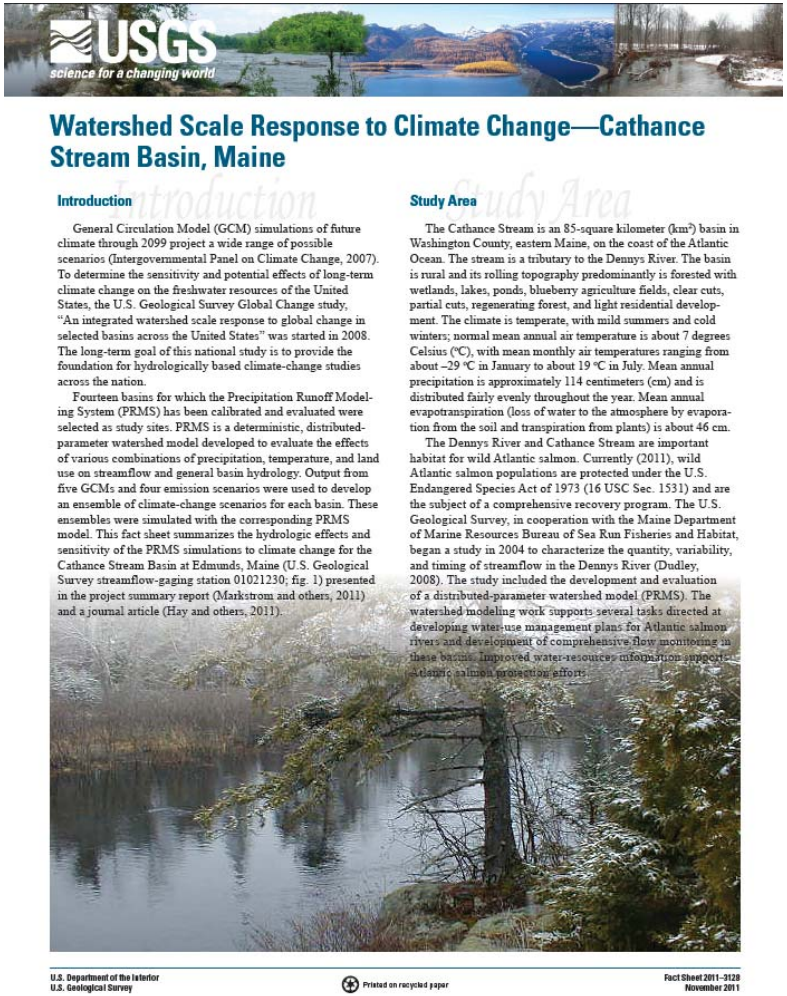
Watershed Scale Response to Climate Change

- Watershed responses for 14 basins across the United States
- Carbon-emission scenarios from the World Climate Research Programme
- Statistically downscaled scenarios to representing future climatic conditions



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Watershed Scale Response to Climate Change—Cathance Stream Basin, Maine

Introduction

General Circulation Model (GCM) simulations of future climate through 2099 project a wide range of possible scenarios (Intergovernmental Panel on Climate Change, 2007). To determine the sensitivity and potential effects of long-term climate change on the freshwater resources of the United States, the U.S. Geological Survey Global Change study, "An integrated watershed scale response to global change in selected basins across the United States" was started in 2008. The long-term goal of this national study is to provide the foundation for hydrologically based climate-change studies across the nation.

Fourteen basins for which the Precipitation Runoff Modeling System (PRMS) has been calibrated and evaluated were selected as study sites. PRMS is a deterministic, distributed-parameter watershed model developed to evaluate the effects of various combinations of precipitation, temperature, and land use on streamflow and general basin hydrology. Output from five GCMs and four emission scenarios were used to develop an ensemble of climate-change scenarios for each basin. These ensembles were simulated with the corresponding PRMS model. This fact sheet summarizes the hydrologic effects and sensitivity of the PRMS simulations to climate change for the Cathance Stream Basin at Edmunds, Maine (U.S. Geological Survey streamflow-gaging station 01021230; fig. 1) presented in the project summary report (Markstrom and others, 2011) and a journal article (Hay and others, 2011).

Study Area

The Cathance Stream is an 85-square kilometer (km²) basin in Washington County, eastern Maine, on the coast of the Atlantic Ocean. The stream is a tributary to the Dennys River. The basin is rural and its rolling topography predominantly is forested with wetlands, lakes, ponds, blueberry agriculture fields, clear cuts, partial cuts, regenerating forest, and light residential development. The climate is temperate, with mild summers and cold winters; normal mean annual air temperature is about 7 degrees Celsius (°C), with mean monthly air temperatures ranging from about –29 °C in January to about 19 °C in July. Mean annual precipitation is approximately 114 centimeters (cm) and is distributed fairly evenly throughout the year. Mean annual evapotranspiration (loss of water to the atmosphere by evaporation from the soil and transpiration from plants) is about 46 cm.

The Dennys River and Cathance Stream are important habitat for wild Atlantic salmon. Currently (2011), wild Atlantic salmon populations are protected under the U.S. Endangered Species Act of 1973 (16 USC Sec. 1531) and are the subject of a comprehensive recovery program. The U.S. Geological Survey, in cooperation with the Maine Department of Marine Resources Bureau of Sea Run Fisheries and Habitat, began a study in 2004 to characterize the quantity, variability, and timing of streamflow in the Dennys River (Dudley, 2008). The study included the development and evaluation of a distributed-parameter watershed model (PRMS). The watershed modeling work supports several tasks directed at developing water-use management plans for Atlantic salmon rivers and development of comprehensive flow monitoring in these basins. Improved water-resources information supports salmon protection efforts.

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U.S. Geological Survey

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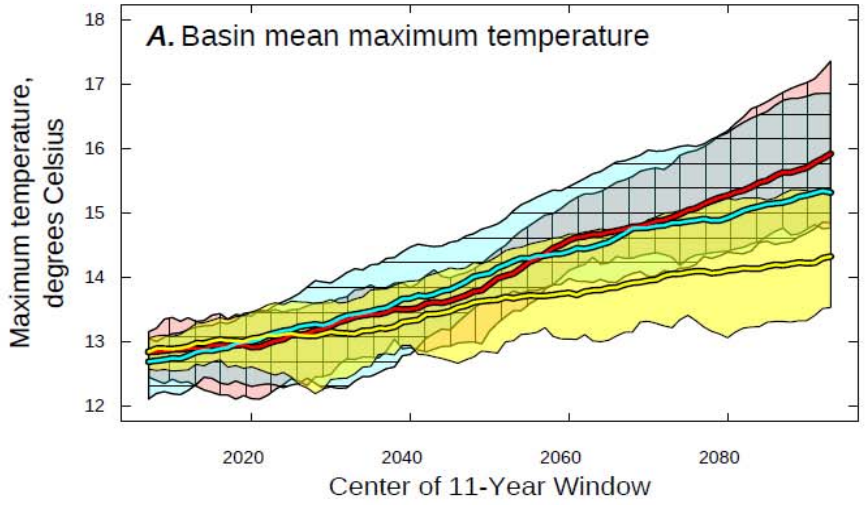
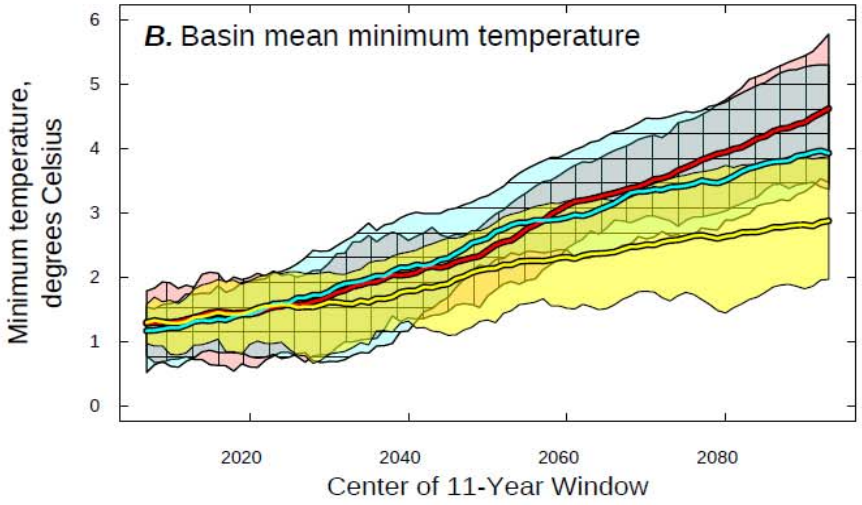
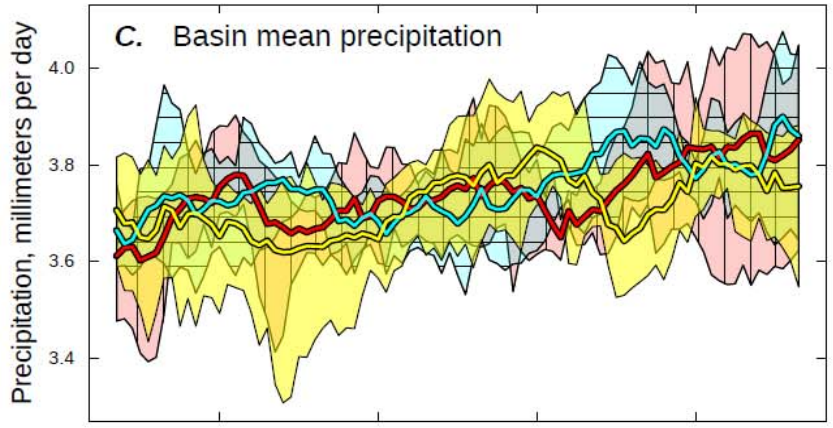
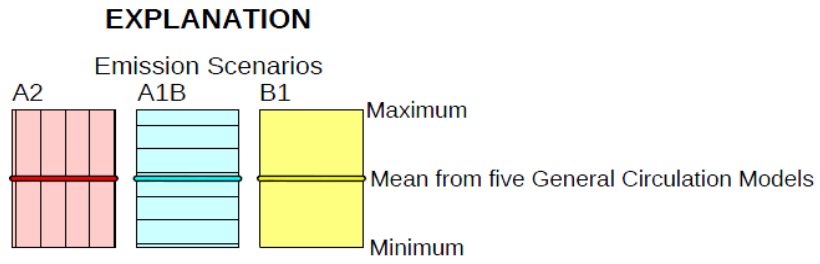
Watershed Scale Response to Climate Change

GCM model inputs from emissions scenarios: low (B1), medium (A1B), and high (A2)









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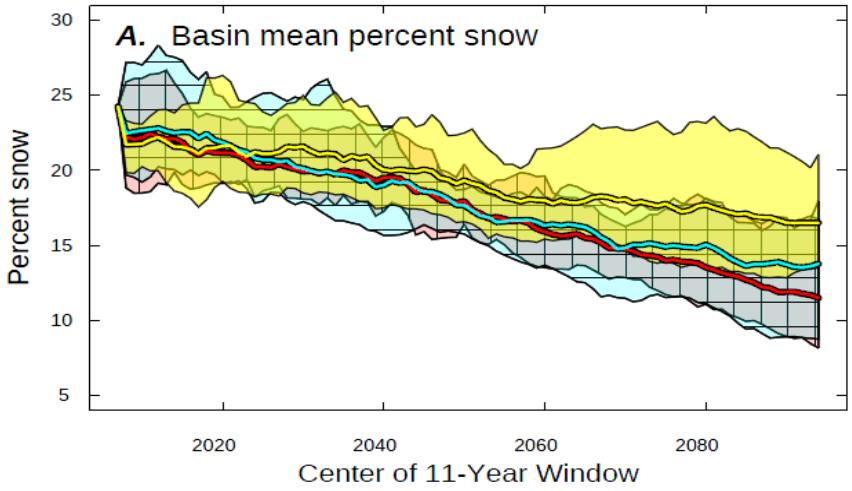
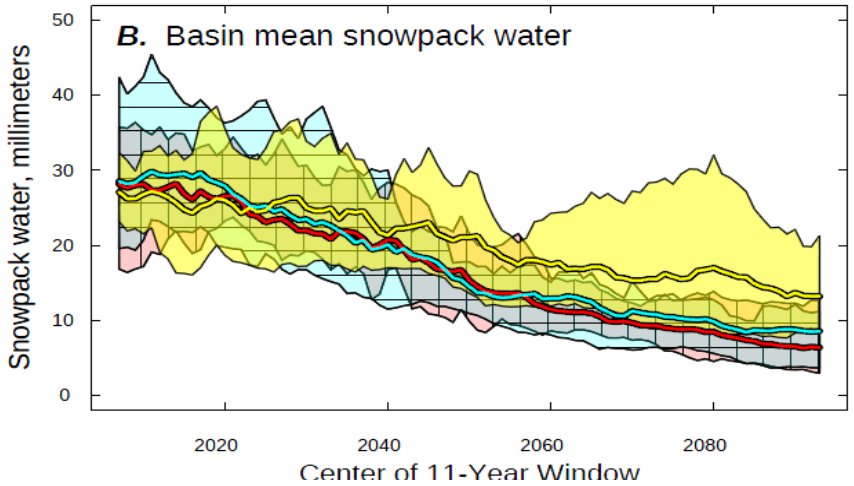
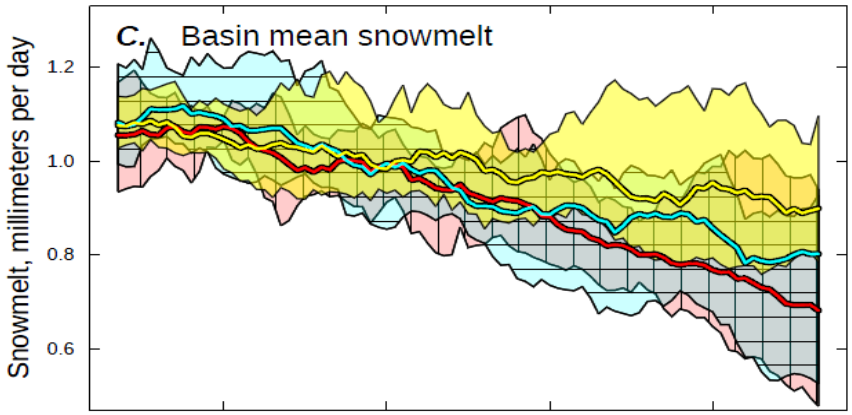
Baseline 11-year window is 1989

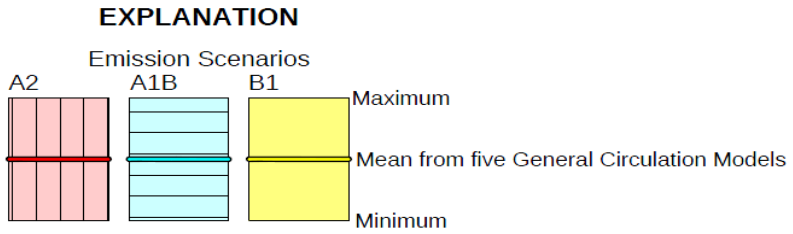
Watershed Scale Response to Climate Change

Projected changes in snowmelt-driven hydrology









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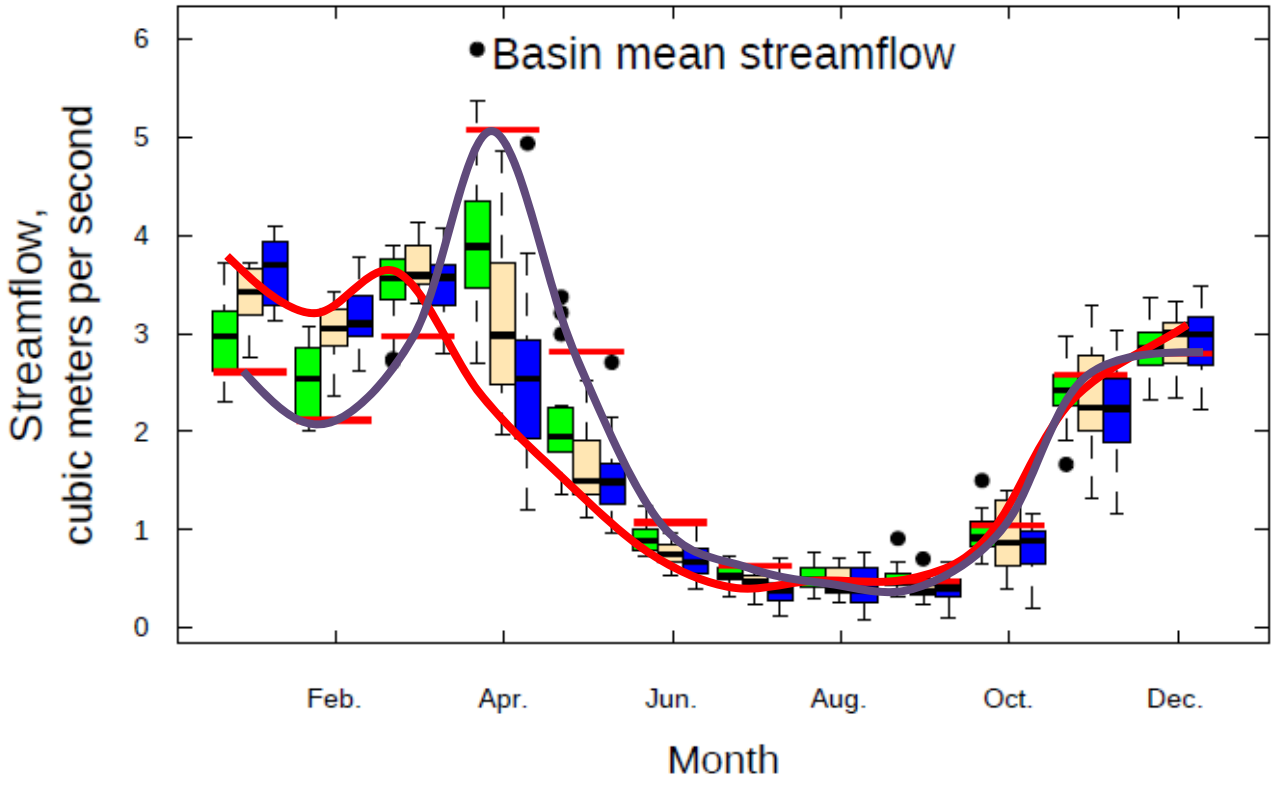
Watershed Scale Response to Climate Change

Projected shifts in snowmelt contribution to streamflow, all scenarios



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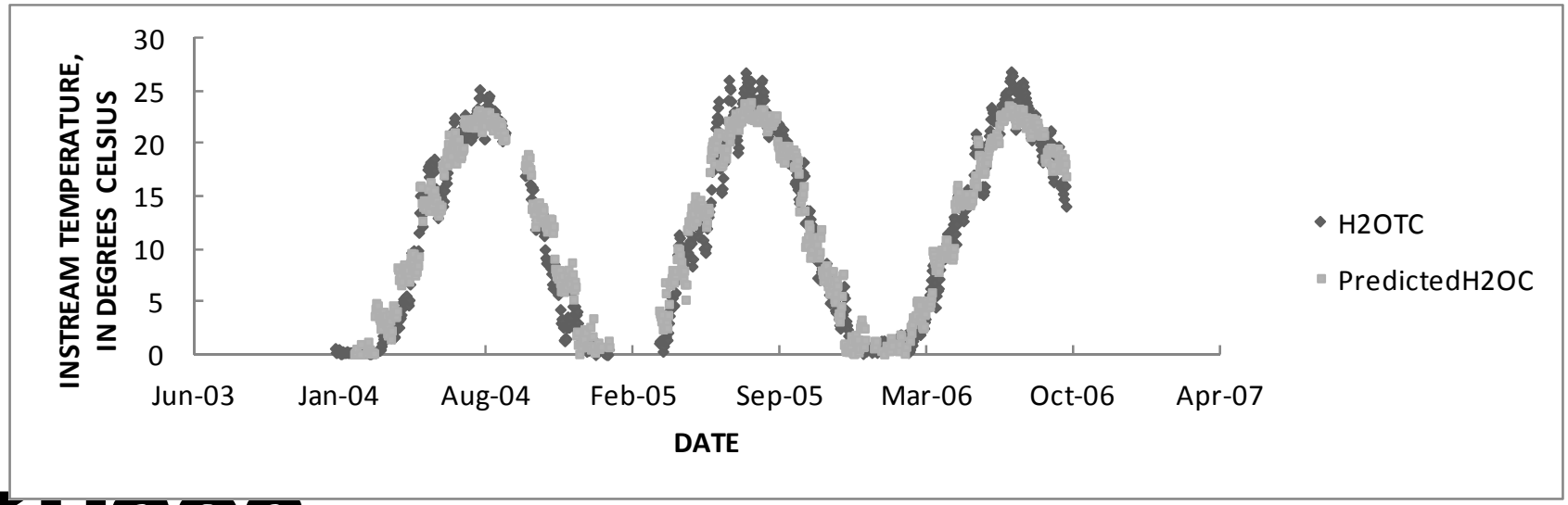
Estimating river water temperature using air temperature: Sheepscot River

Atlantic salmon modeling

•National Climate Change and Wildlife Science Center (NCCWSC) Project

•Investigation of changes in summer low streamflows and stream temperatures and the potential effects of those changes on endangered Atlantic salmon populations



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Estimating lake-surface water temperature from air temperature: Spednic Lake

- Project with International Joint Commission, St. Croix River Board
- Quantify effects, if any, of historical lake-level management and meteorological conditions (from 1970 to 2008) on smallmouth bass year-class failure

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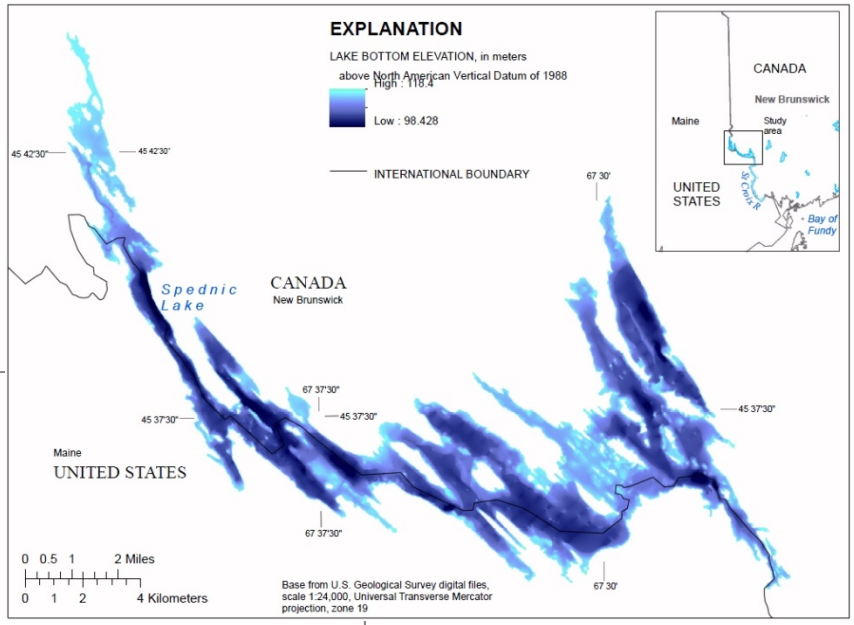
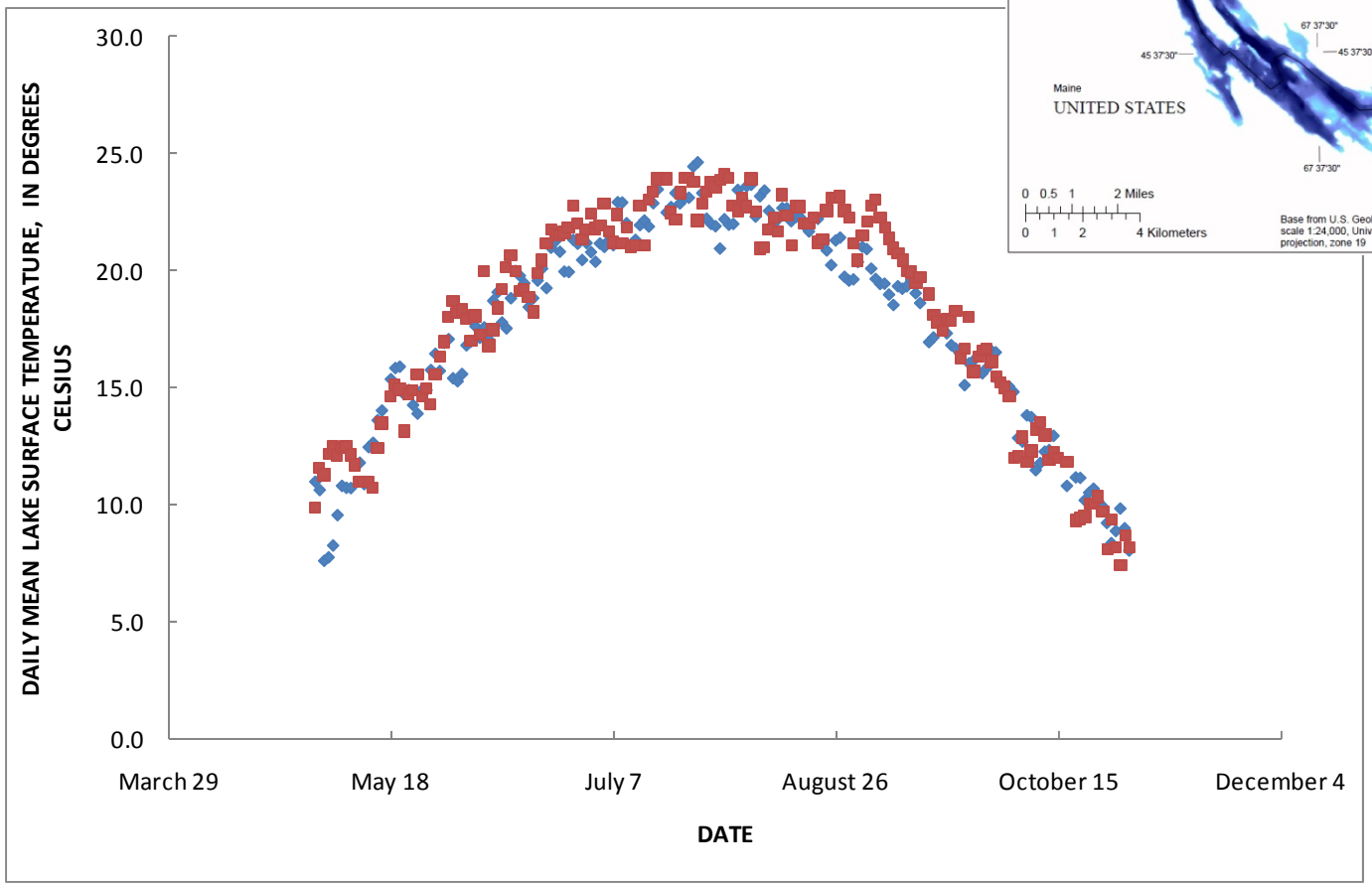
Estimating lake-surface water temperature from air temperature: Spednic Lake





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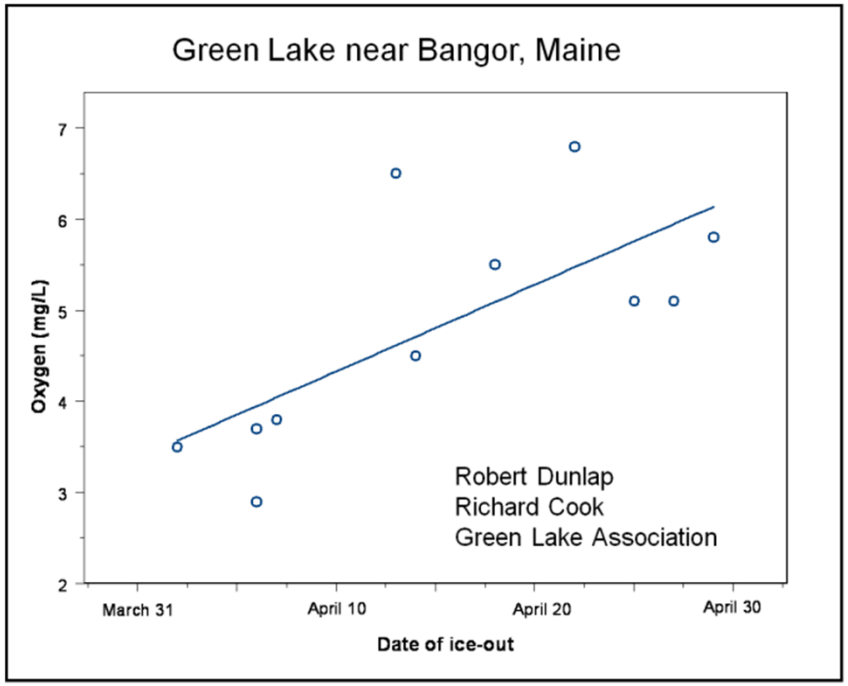
Effects of Climate Change and Eutrophication on Hypolimnetic Oxygen Demand in Lakes



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Thank You

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- For publications:
  - http://me.water.usgs.gov/publications/climate.html

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