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Emerging hydroclimatic regimes in a changing climate: Understanding the nature of decadal variability and secular trends for resource management and decision-making

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ICTP Conference On Decadal Predictability / August 2010

Emerging hydroclimatic regimes in a changing climate

Understanding the nature of decadal variability and secular trends for resource management and decision making

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Joint work with:

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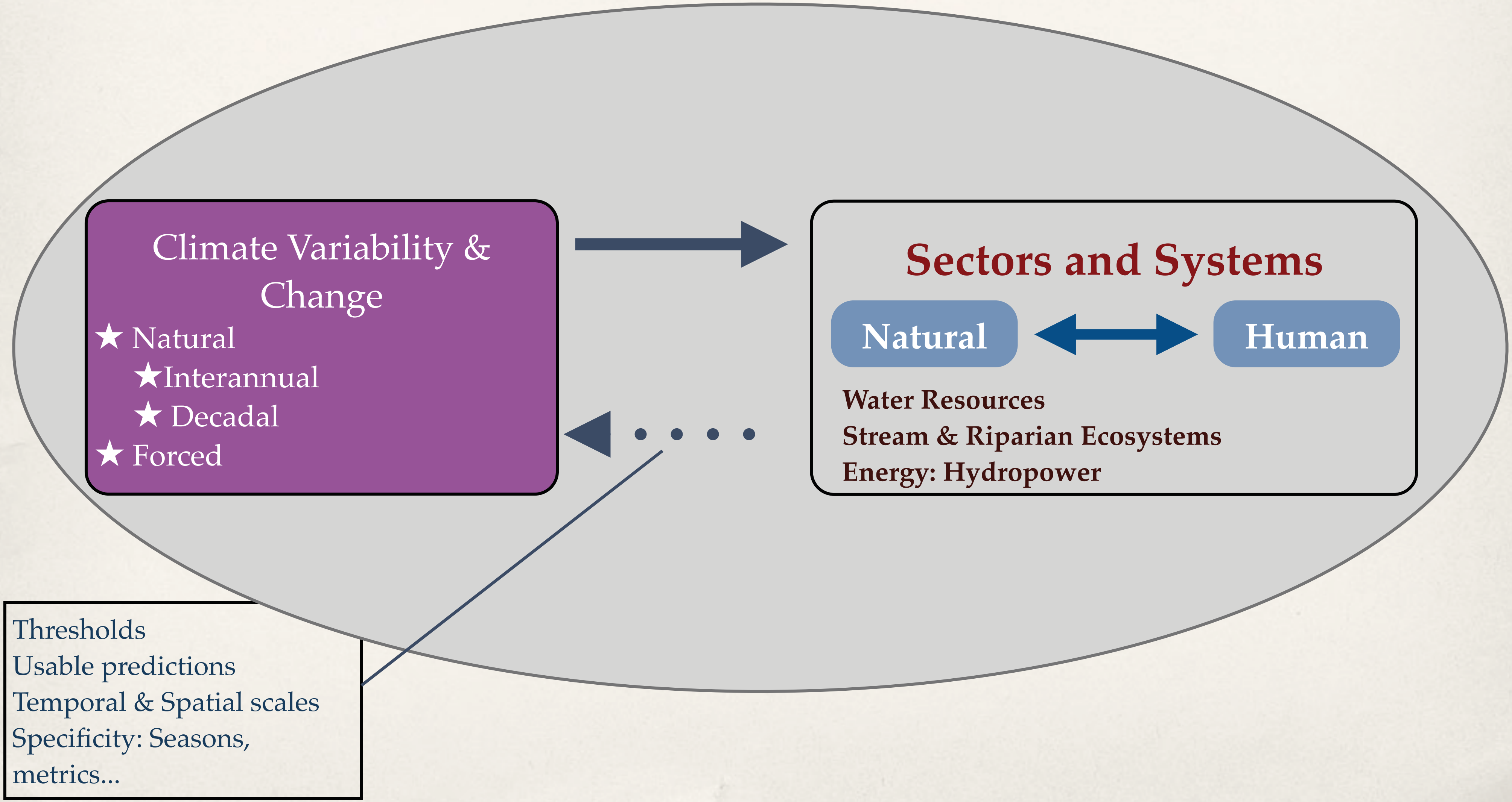
Jon K. Eischeid, *NOAA Earth System Research Laboratory, Boulder*

Decadal Predictability: Broader Context

		Considerations of use?	
		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

(adapted from *Pasteur's Quadrant: Basic Science and Technological Innovation*, Stokes 1997).


Climate Variability & Change
★ Natural
★Interannual
★ Decadal
★ Forced
Sectors and Systems
Natural
Human
Water Resources
Stream & Riparian Ecosystems
Energy: Hydropower
Thresholds
Usable predictions
Temporal & Spatial scales
Specificity: Seasons, metrics...

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L16401, doi:10.1029/2008GL034715, 2008

What a difference a century makes: Understanding the changing hydrologic regime and storage requirements in the Upper Colorado River basin

Shaleen Jain[1] and Jon K. Eischeid[2]

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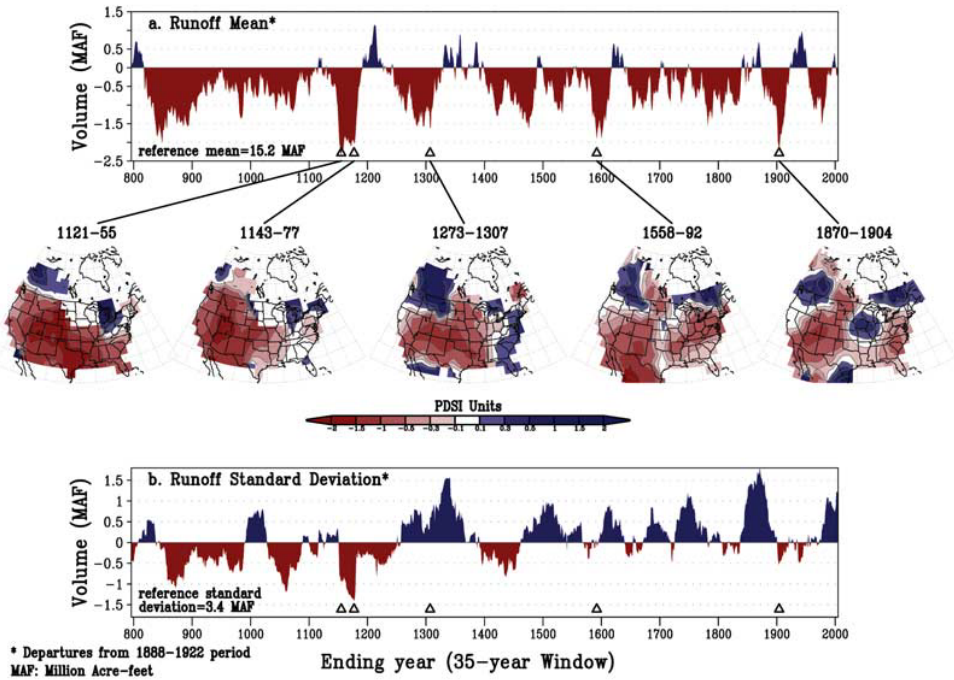

Figure 1. Long-term variations in the annual runoff for the UCRB (762–2005). (a) Variations in the mean runoff are assessed using 35-year moving averages. The results are shown as departures from a reference mean of 15.2 Million Acre-feet (MAF) from the 1888–1922 period. (b) Interannual variability of UCRB runoff is characterized based on the standard deviation. As in Figure 1a, the long-term variability is shown as a departure from a reference standard deviation of 3.4 MAF (1888–1922 period). Spatial extent and severity of aridity for five select dry periods (triangles are shown at the last year of the respective 35-year windows) is shown on the five maps of average PDSI over the focal periods.

Impacts on Storage requirements

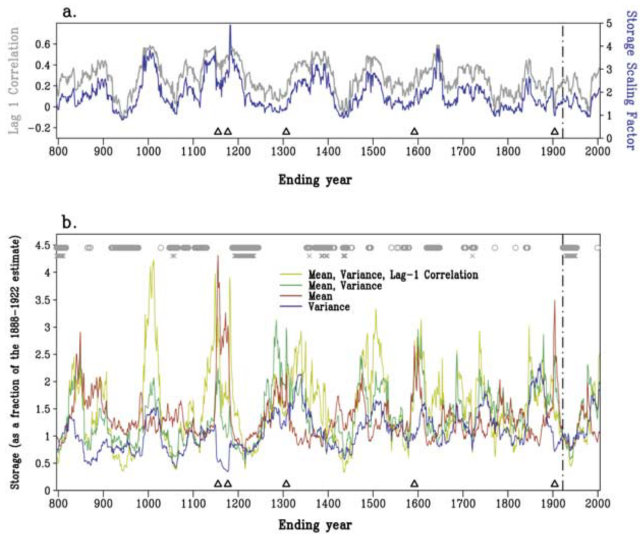

Figure 2. (a) Long-term variations in the serial correlation (ρ) of annual runoff for the UCRB (762–2005). Persistence in the runoff is based on lag-1 correlation estimates (grey) for 35-year moving windows. The impact of persistence of required storage expressed as $(1 + \rho)/(1 - \rho)$–this Storage Scaling factor (blue) is a ratio of required storage for any 35-year window to the estimate for the shown the 1888–1922 period. A vertical dashed line highlights the serial correlation estimate for the 35-year period ending in 1922. (b) Variations in the storage requirements estimated from the Gould-Dincer procedure—35-year moving window runoff segments are used to estimate the storage requirement for a hypothetical reservoir serving a water demand of 80% of the mean annual inflow computed for the 1888–1922 period, with 95% reliability. Storage for a particular 35-year period is expressed as a fraction of the baseline storage based on the 1888–1922 period. Consequently, the ratio attains a unit value at 1922 (shown as a dashed vertical line). For each period, the relative impact of the temporal variations in the mean, standard deviation, and serial correlation is examined by selectively including the variables for storage computations, while the remainder of variables is held constant at the 1888–1922 value. The periods that are not consistent with the carryover storage and first passage time assumptions are marked (by grey circles and crosses respectively).

Motivation

- Regional Case Studies, as a way to diagnose and understand:
  - Changing hydroclimatic baselines
  - Systemic thresholds
  - Near-term* amplification of Regional Risk:
    Natural Variability + Anthropogenic Change

*for example, up to 30-year time horizons

Streamflow/River Discharge

- Western United States
  - Changes in seasonality and implications for management and decision-making
- Northeastern United States
  - Wintertime climate sensitivity
  - Role of ENSO and other climatic drivers

- **Data: US Geological Survey Steamgauging Network**
  - **60-year daily records (selected based on minimal regulation)**

Considerations

- Snowmelt-dominated watersheds integrate precipitation and temperature variability.

- Magnitude and Timing sensitively linked to numerous natural and human systems functions.

- *"The natural flow regime (movement of water and sediments) organizes and defines running water ecosystems, and can be considered a "master variable" that limits the distribution and abundance of riverine species and regulates the ecological integrity of flowing water systems (Poff et al. 1997). In most instances, however, the importance of natural streamflow variability in maintaining healthy aquatic ecosystems is still greatly ignored in a management context"* (Braga, 1999).

- Adaptation strategies intimately linked to changing seasonality and its variability.

  - Episodic warming in mid-winter may cause loss of snowpack-abrupt shift in the seasonal cycle...dominant spring flow --> wintertime dominance.

Changes in Seasonality

Climatic Change
DOI 10.1007/s10584-010-9933-3

LETTER

High-resolution streamflow trend analysis applicable to annual decision calendars: a western United States case study

A letter

Jong-Suk Kim · Shaleen Jain

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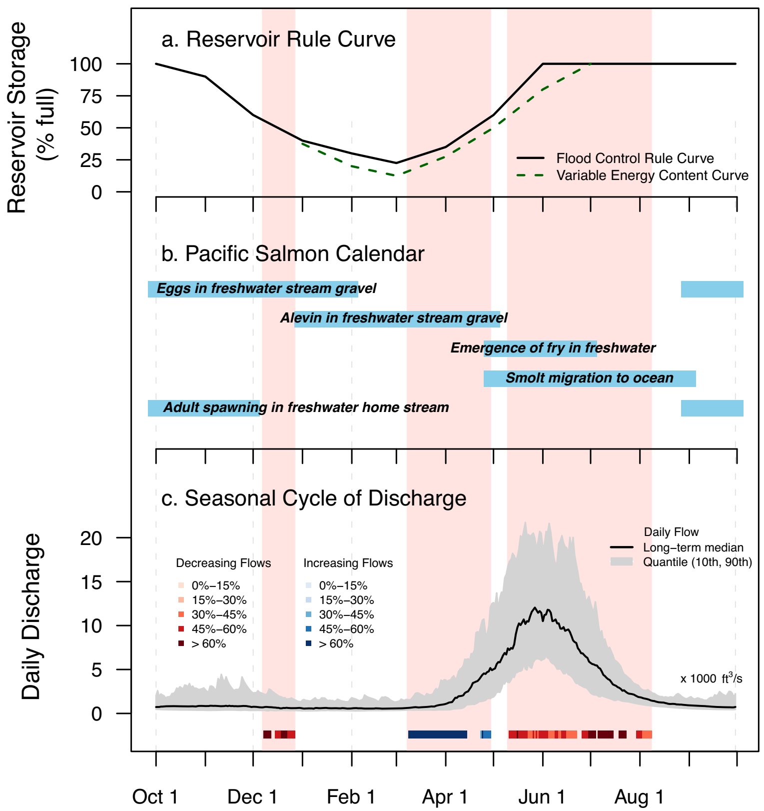
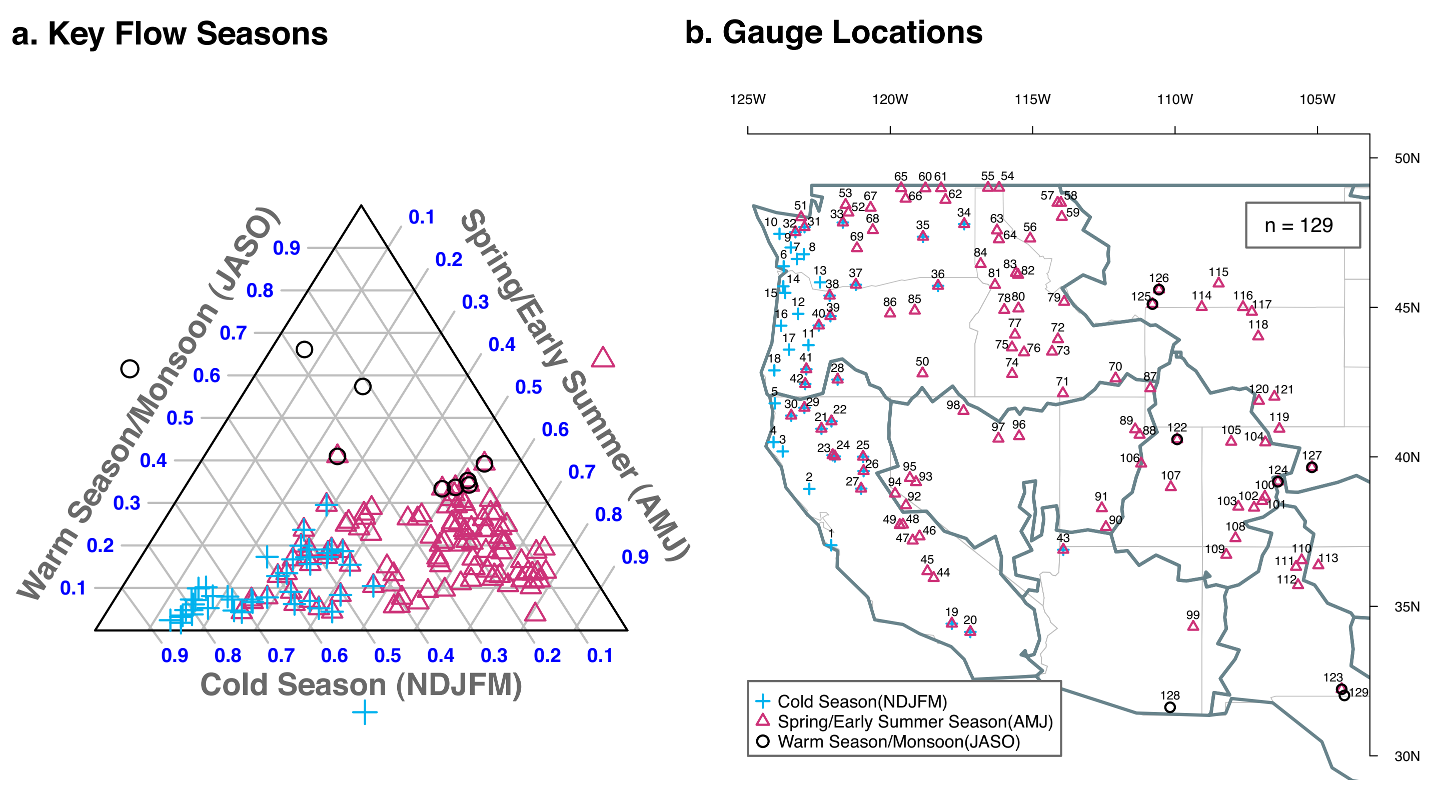
Abstract Changes in the seasonality of streamflow in the western United States have important implications for water resources management and the wellbeing of coupled human-natural systems. An assessment of changes in the timing and magnitude of streamflow resolved at fine time scales (days to weeks and seasons) is highly relevant to adaptive management strategies that are responsive to changing hydrologic baselines. In this paper, we present a regional analysis of the changes in streamflow seasonality through a broad classification of streams and quantification of increases and decreases in flow, based on a quantile regression methodology. This analysis affords a useful research product to examine the diversity of trends across seasons for individual streams. The trend analysis methodology can identify windows of change, thus revealing vulnerabilities within decision calendars and species lifecycles, an important consideration for adaptation and mitigation efforts.

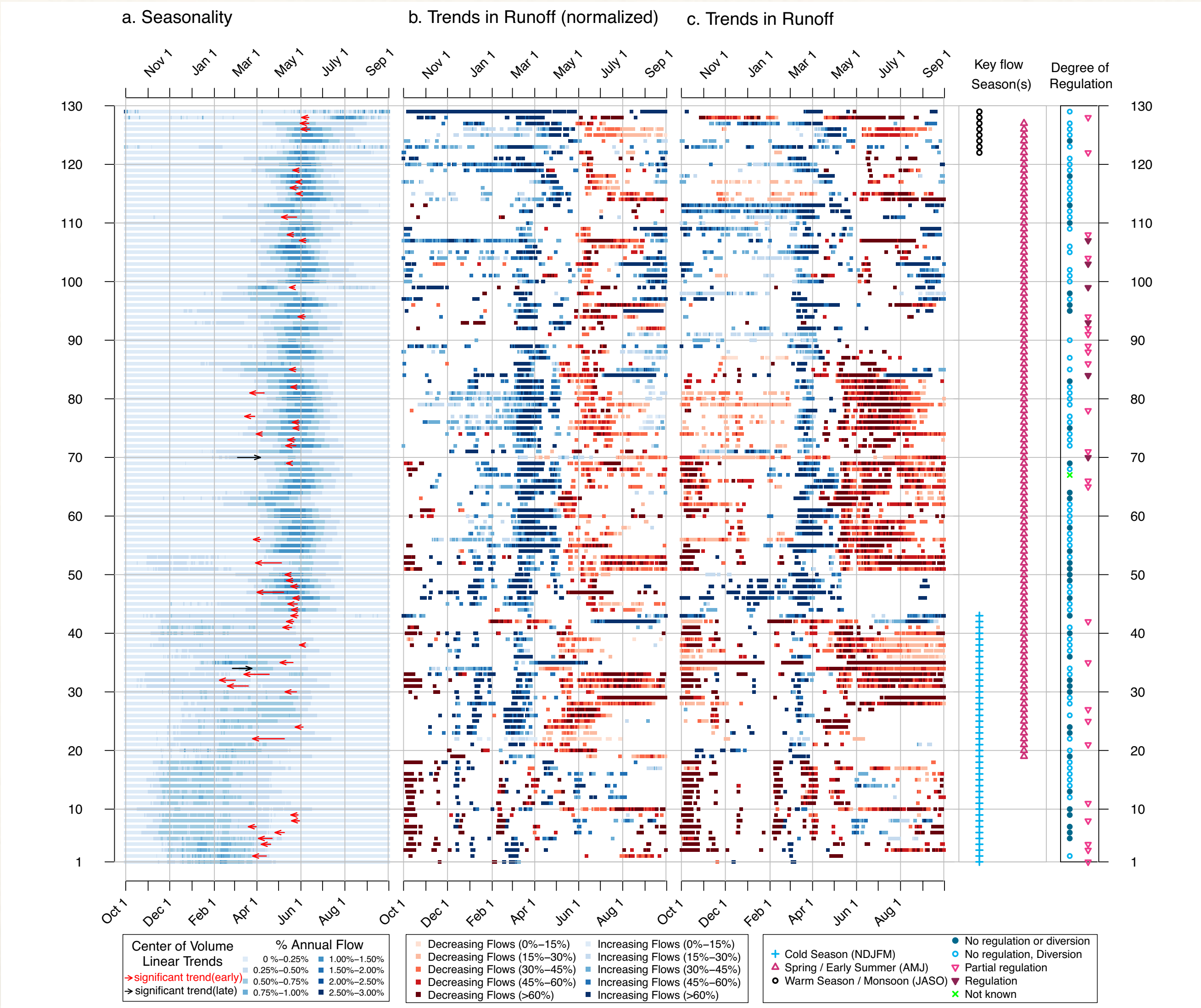
Annual (Decision) Calendars



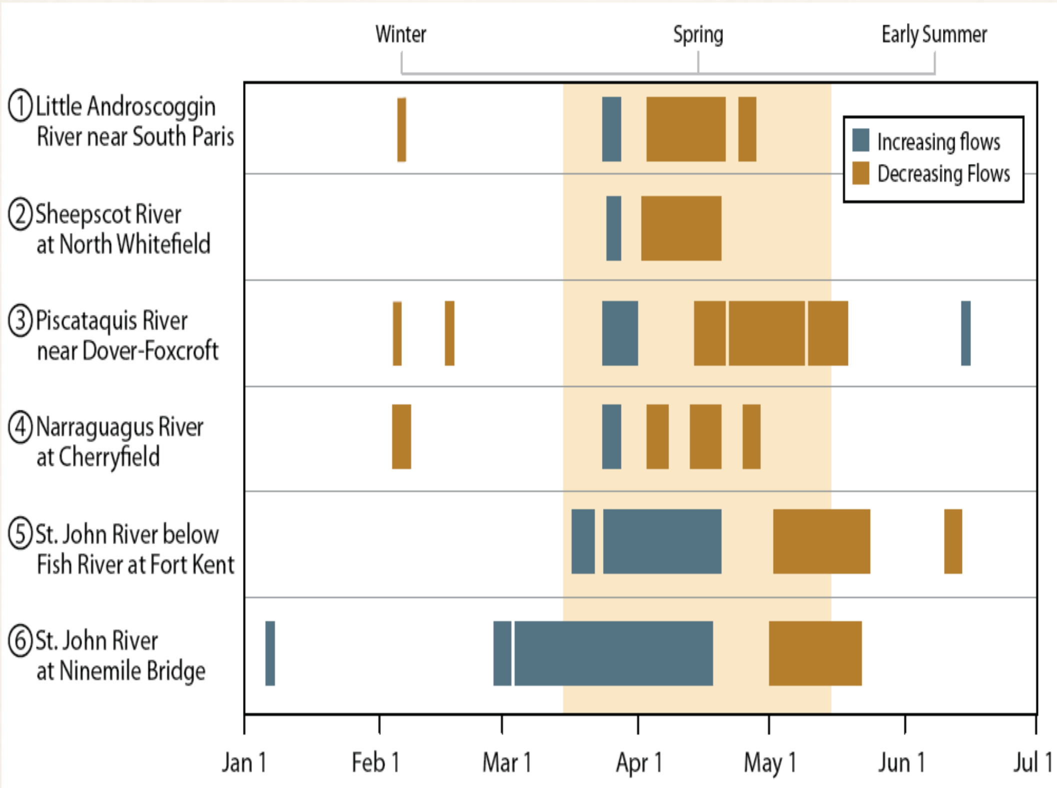


- Data: US Geological Survey Steamgauging Network (1948-2007)
  - 60-year daily records (selected based on minimal regulation)

Changes in Seasonality



Changing Seasonality of River Discharge

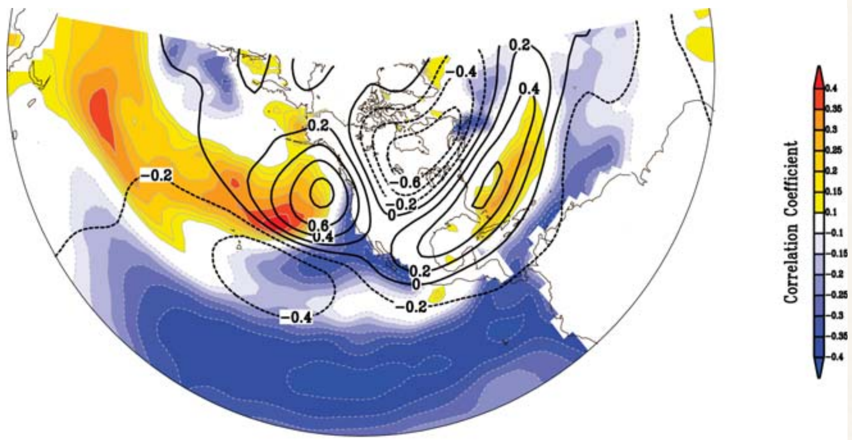


Stream gauges across Maine show statistically significant increases (blue) and decreases (brown) in river flows in late Winter and Spring, respectively. The Shaded block represents the regulatory season used by the Maine Department of Environmental Protection to prescribe season-specific Aquatic Base Flow levels. A Mann-Kendall statistical test on daily streamflow data confirmed trends during the 1952-2007 period.

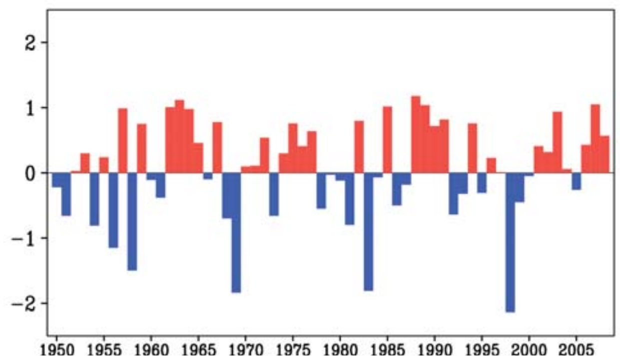
Maine Climate Report, 2009

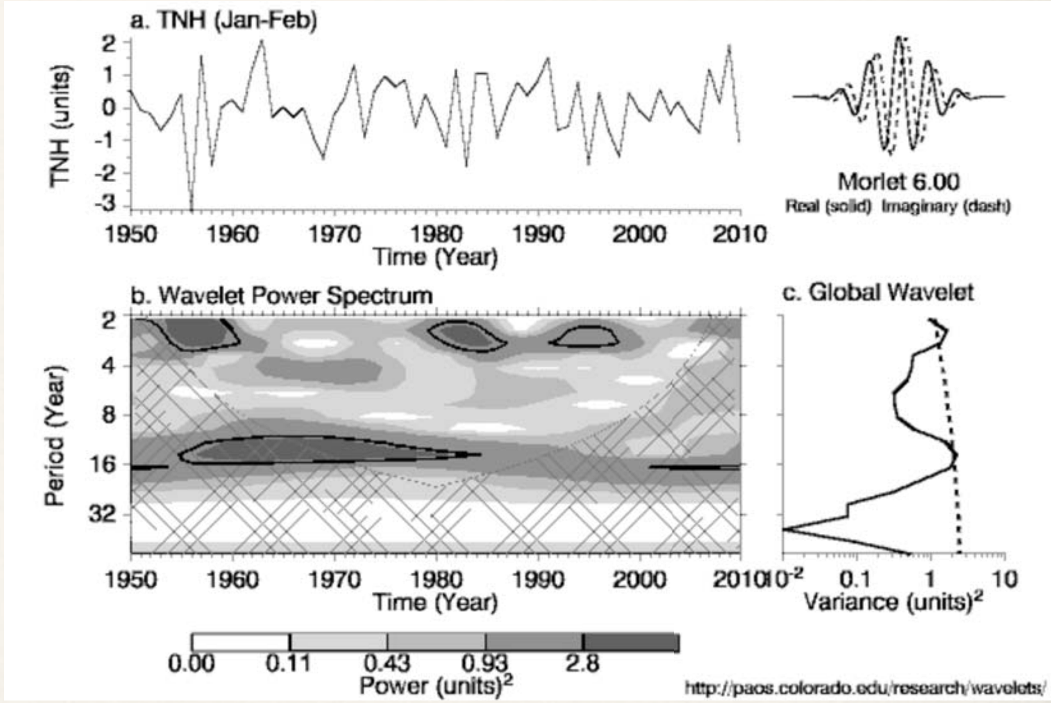
Midwinter-sensitivity in snow-dominated river systems

a. Correlation between TNH and 250 hPa geopotential height and SSTs

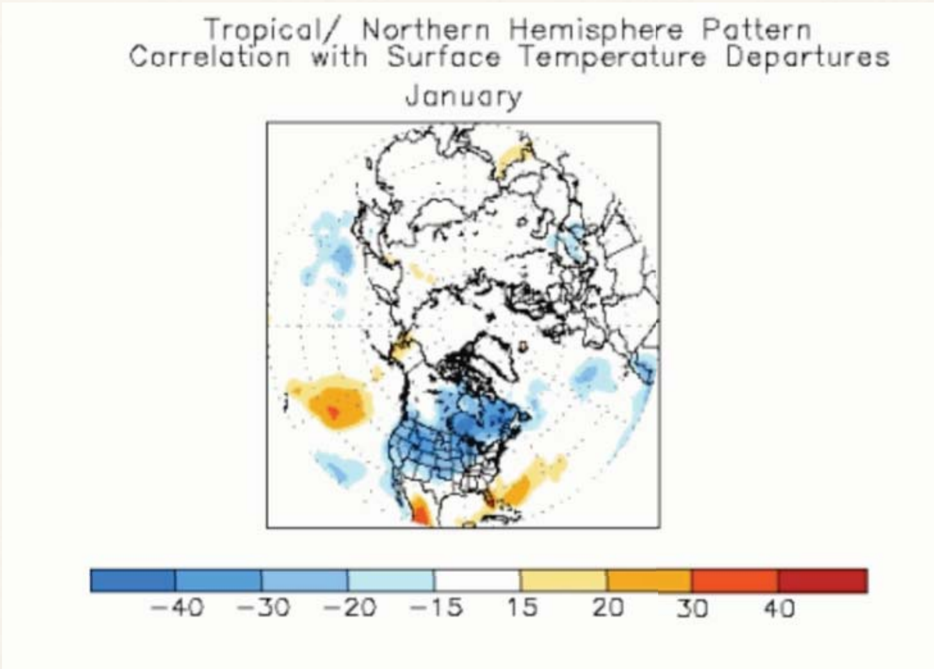


b. Wintertime Tropical Northern Hemisphere Pattern

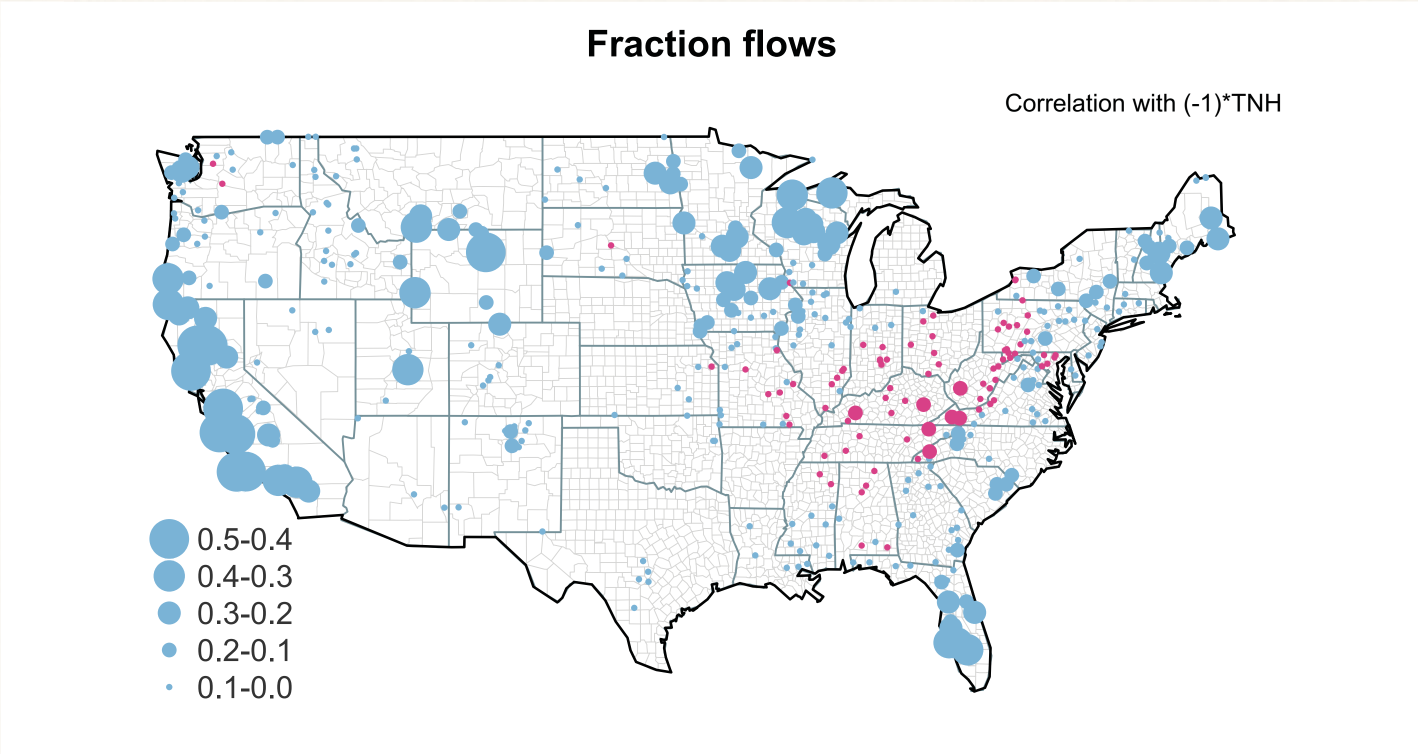




TNH-related Temperature variability

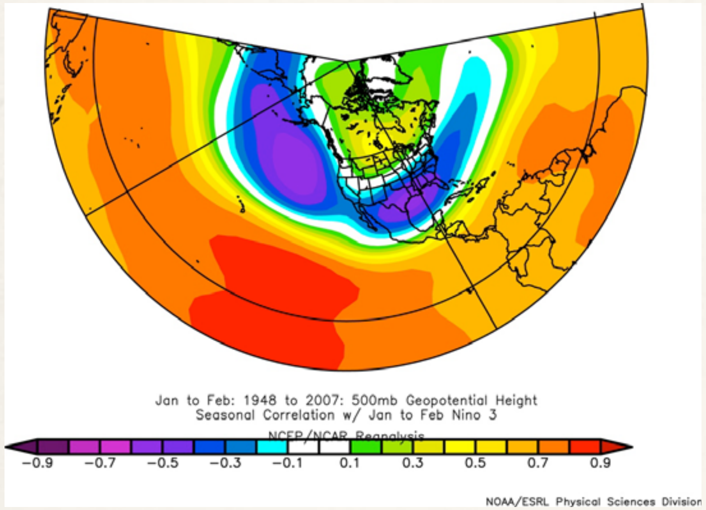


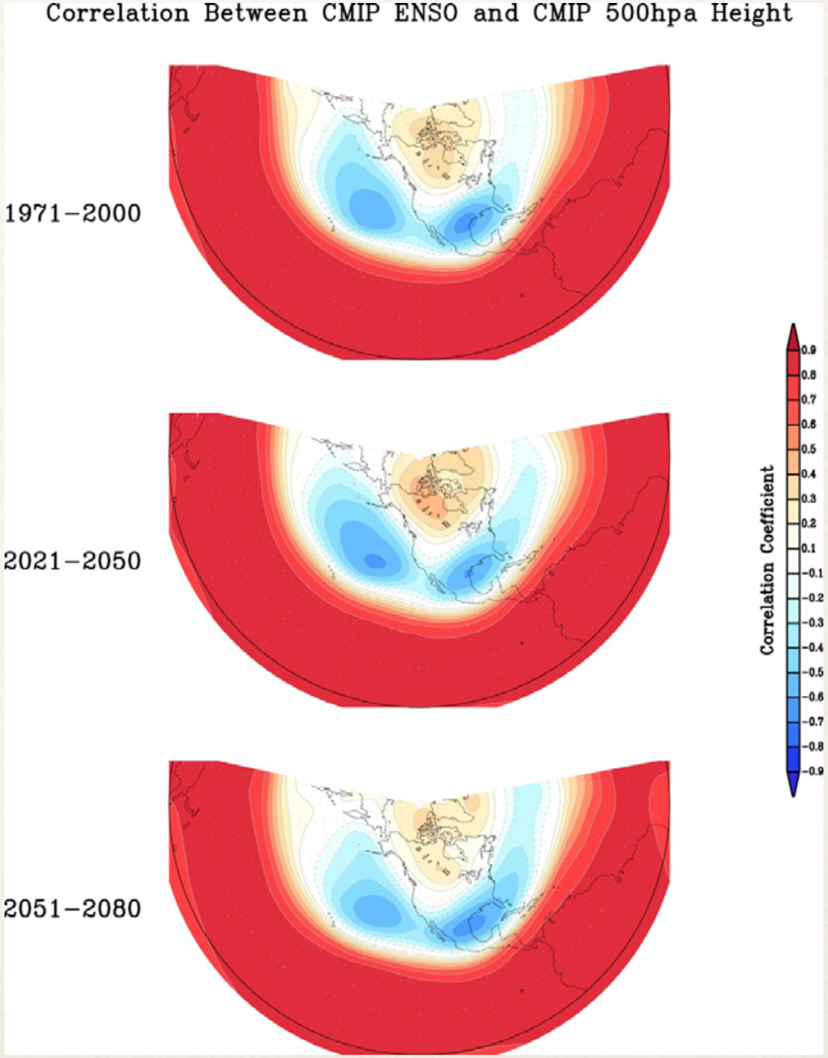
Winter Streamflow Fraction



Flow Volume (Jan-Feb)
Flow Volume (Jan-July)

ENSO-related teleconnections in to the future

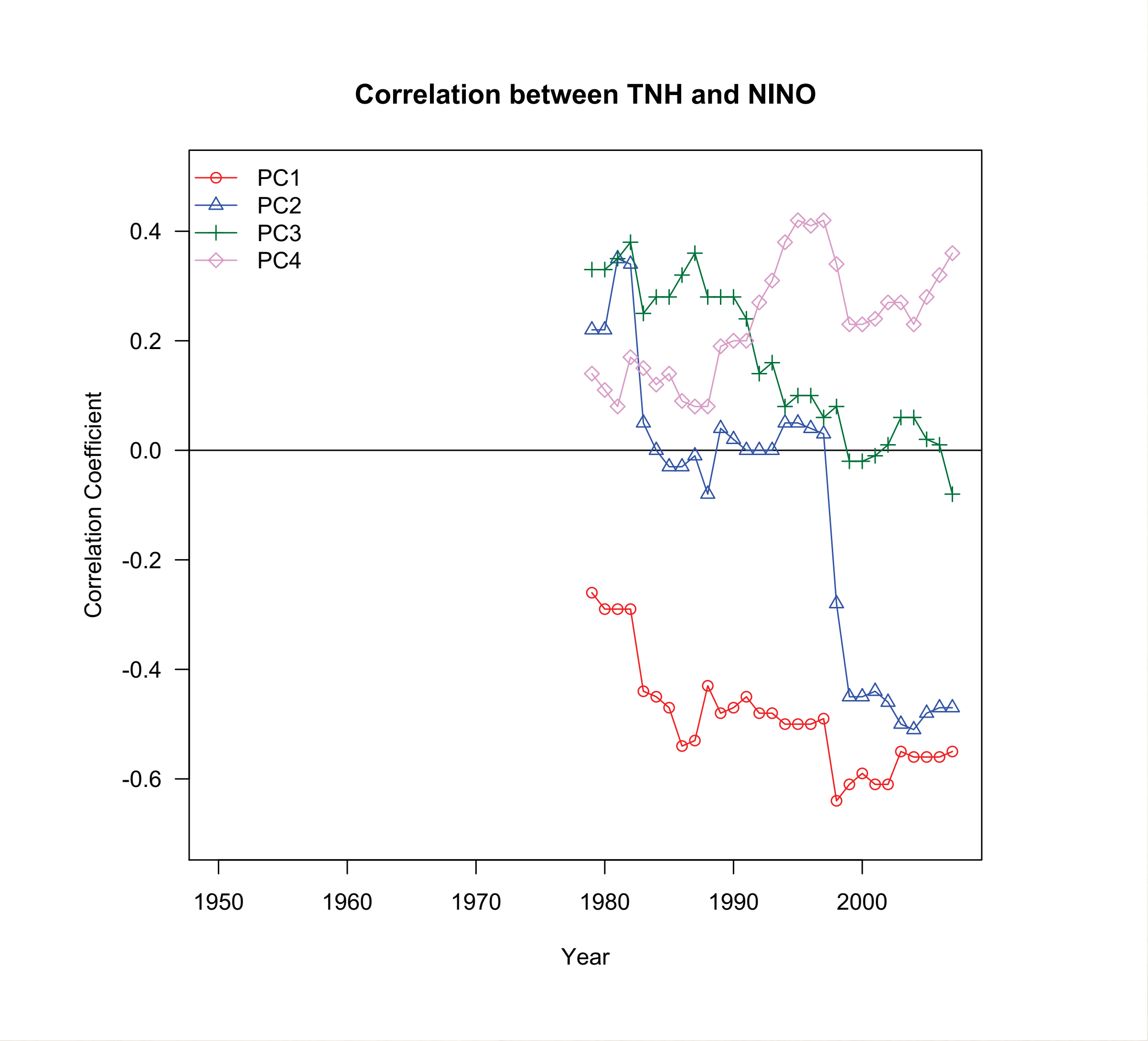




Detrended NINO3 and 500hPa heights

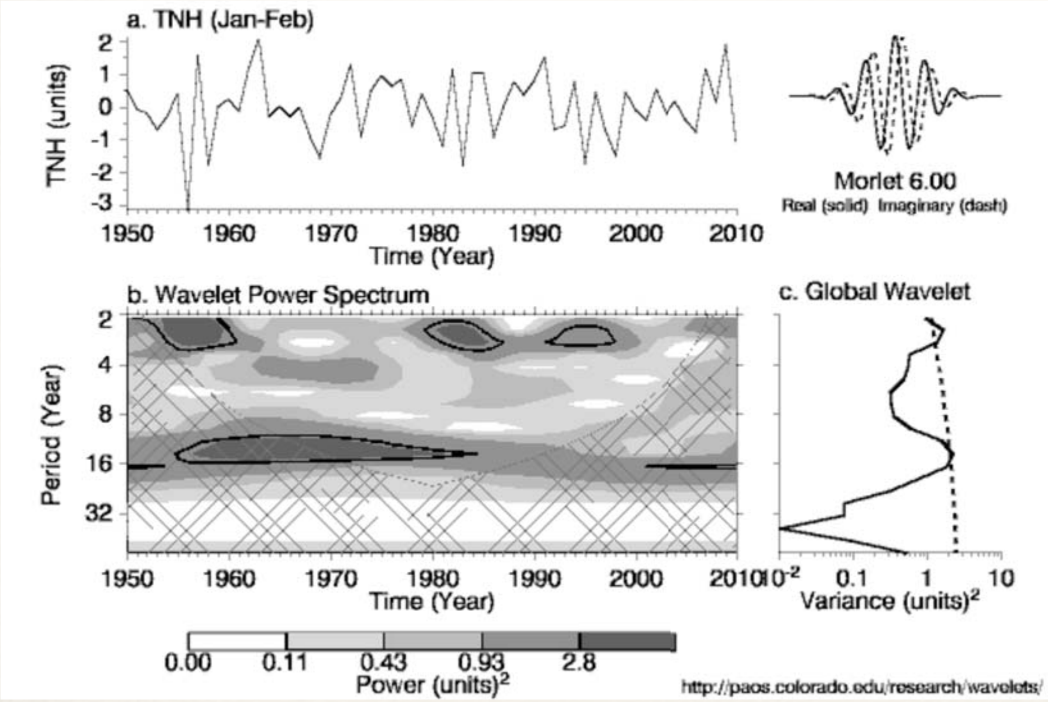
GFDL 2.0
GFDL 2.1
ECHAM5
MRI_CGCM2
NCAR_CCSM3

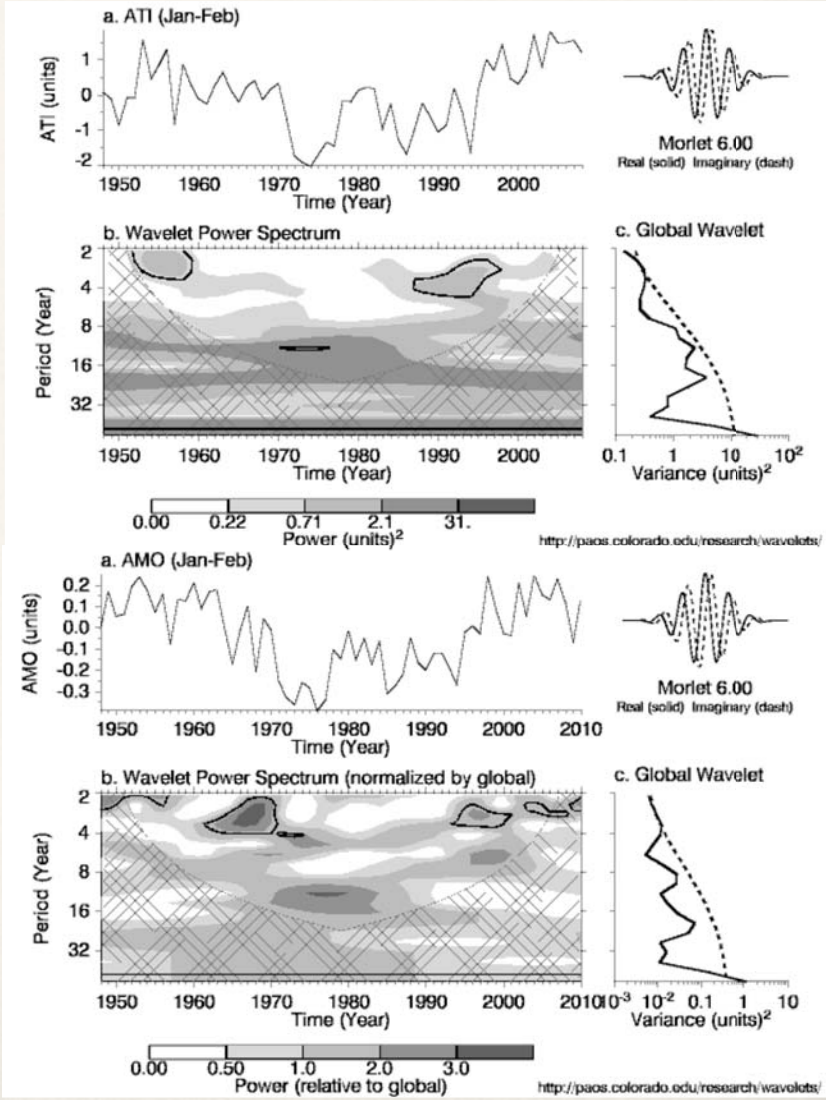
Changes in Correlation

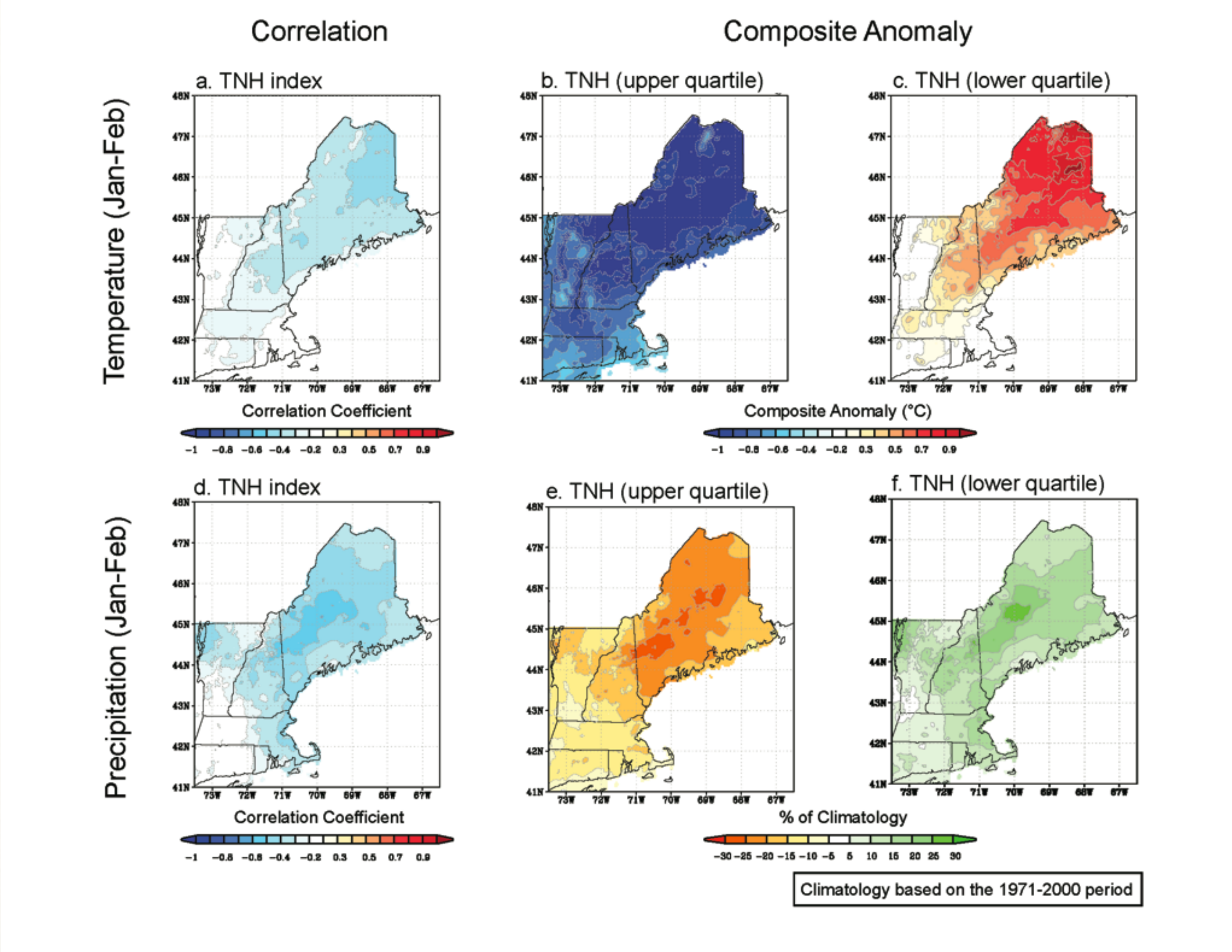


30-year moving window

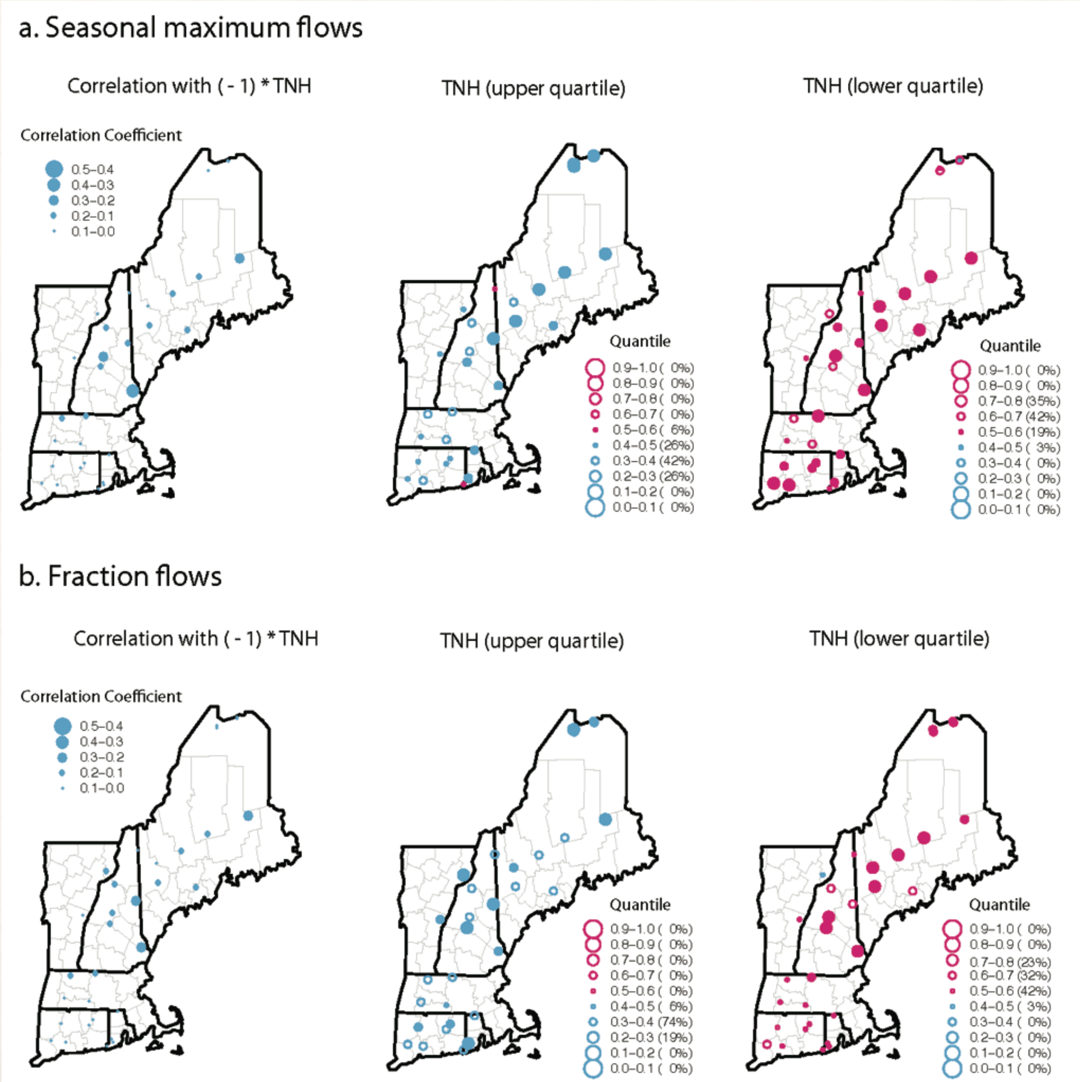
AMO and Atlantic Tripole Index



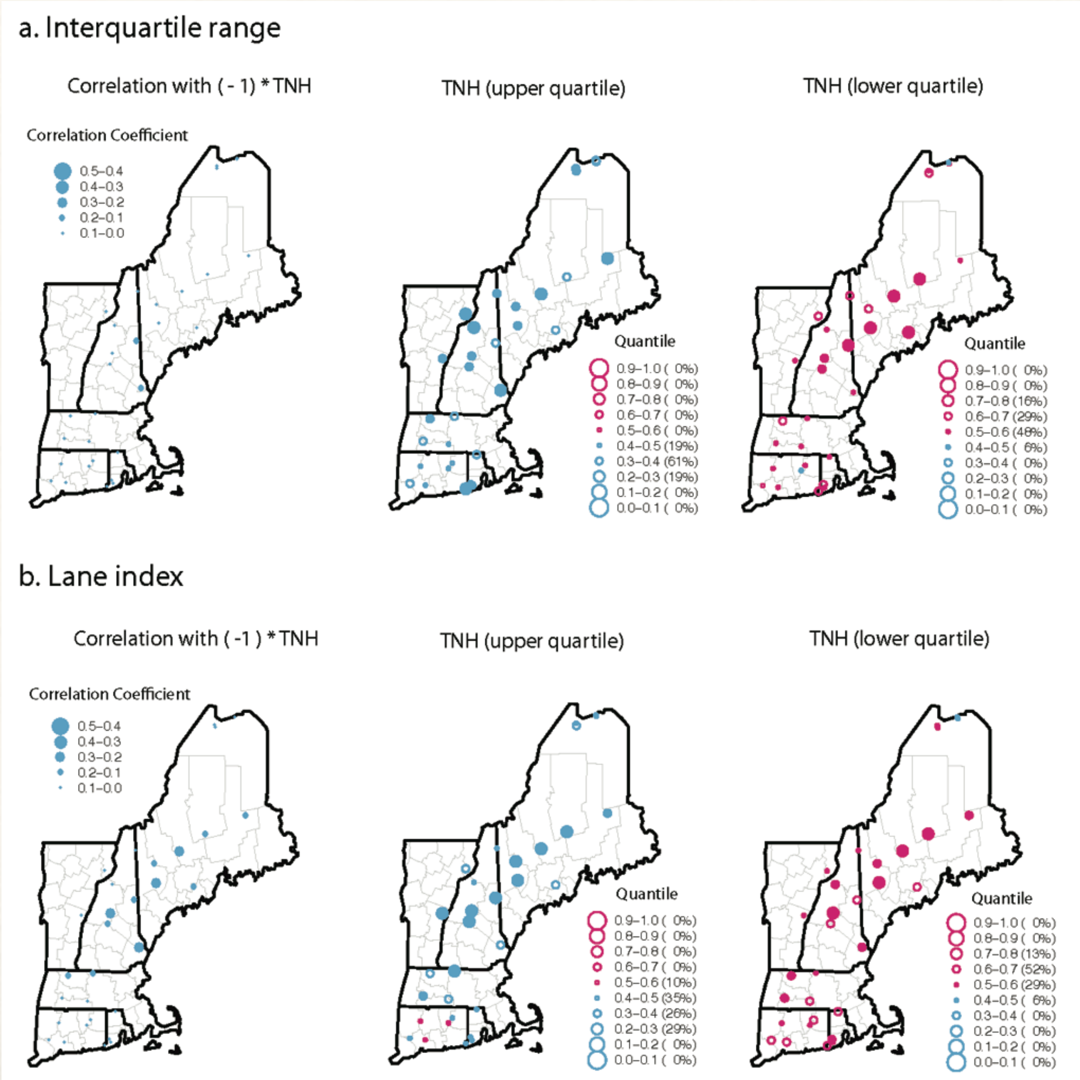



Correlation
Composite Anomaly
a. TNH index
b. TNH (upper quartile)
c. TNH (lower quartile)
Temperature (Jan-Feb)
Correlation Coefficient
Composite Anomaly (°C)
d. TNH index
e. TNH (upper quartile)
f. TNH (lower quartile)
Precipitation (Jan-Feb)
Correlation Coefficient
% of Climatology
Climatology based on the 1971-2000 period

Sensitivity of River Discharge to ENSO-related variability



Sensitivity of River Discharge to ENSO-related variability



Conclusions

- Regional diagnostic studies provide an important perspective regarding decadal and longer-time scale variability *(must co-evolve with mechanistic and modeling work)*
- Annual decision calendars intimately linked to human and natural systems.
- Understanding the seasonal-specific role of decadal variability of great utility in vulnerability and adaptation work
- Decadal and longer-time modulation of seasonal-to-interannual variability may have significantly impact the near-term risk for emerging hydroclimatic regimes in the North American region.