Stationarity is Dead

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CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

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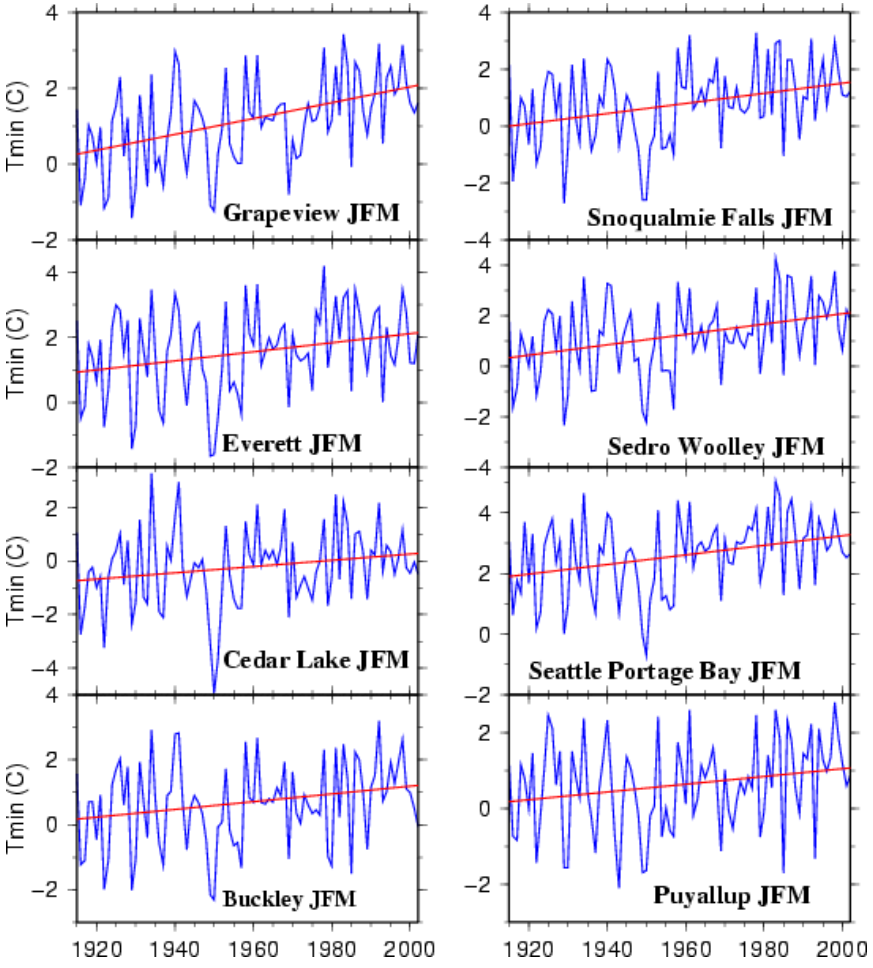
Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering.

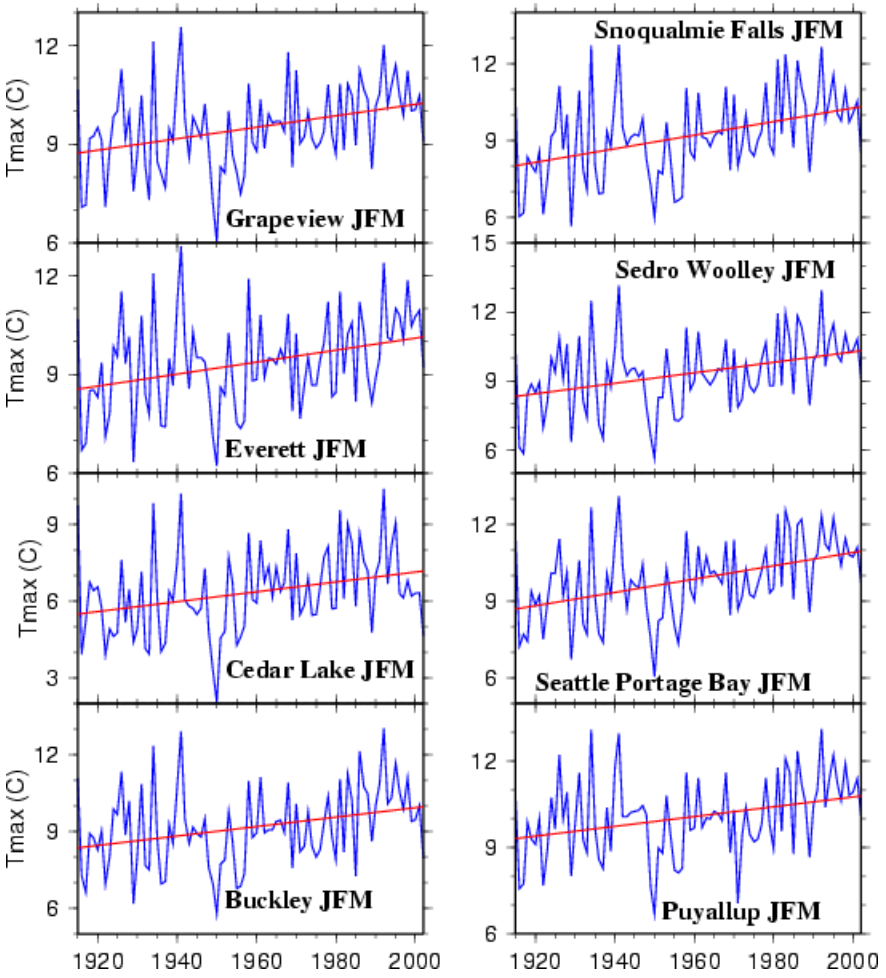
In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning.

Trends in winter-average daily temperature minima and maxima, selected Puget Sound basin stations

Winter daily minima 1916-2003



Winter daily maxima 1916-2003



DECLINING SNOWPACK

Climate Changes in the Mountain West

ARTICLES

DECLINING MOUNTAIN SNOWPACK IN WESTERN NORTH AMERICA*

BY PHILIP W. MOTE, ALAN F. HAMLET, MARTYN P. CLARK, AND DENNIS P. LETTENMAIER

The West's snow resources are already declining as the climate warms.

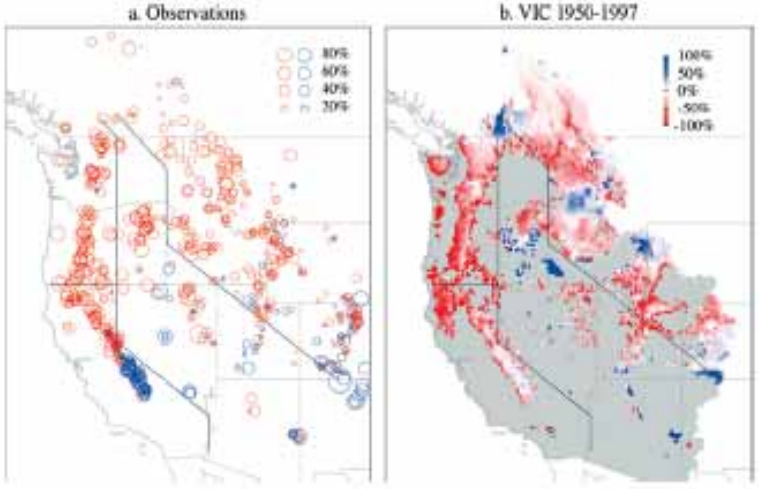
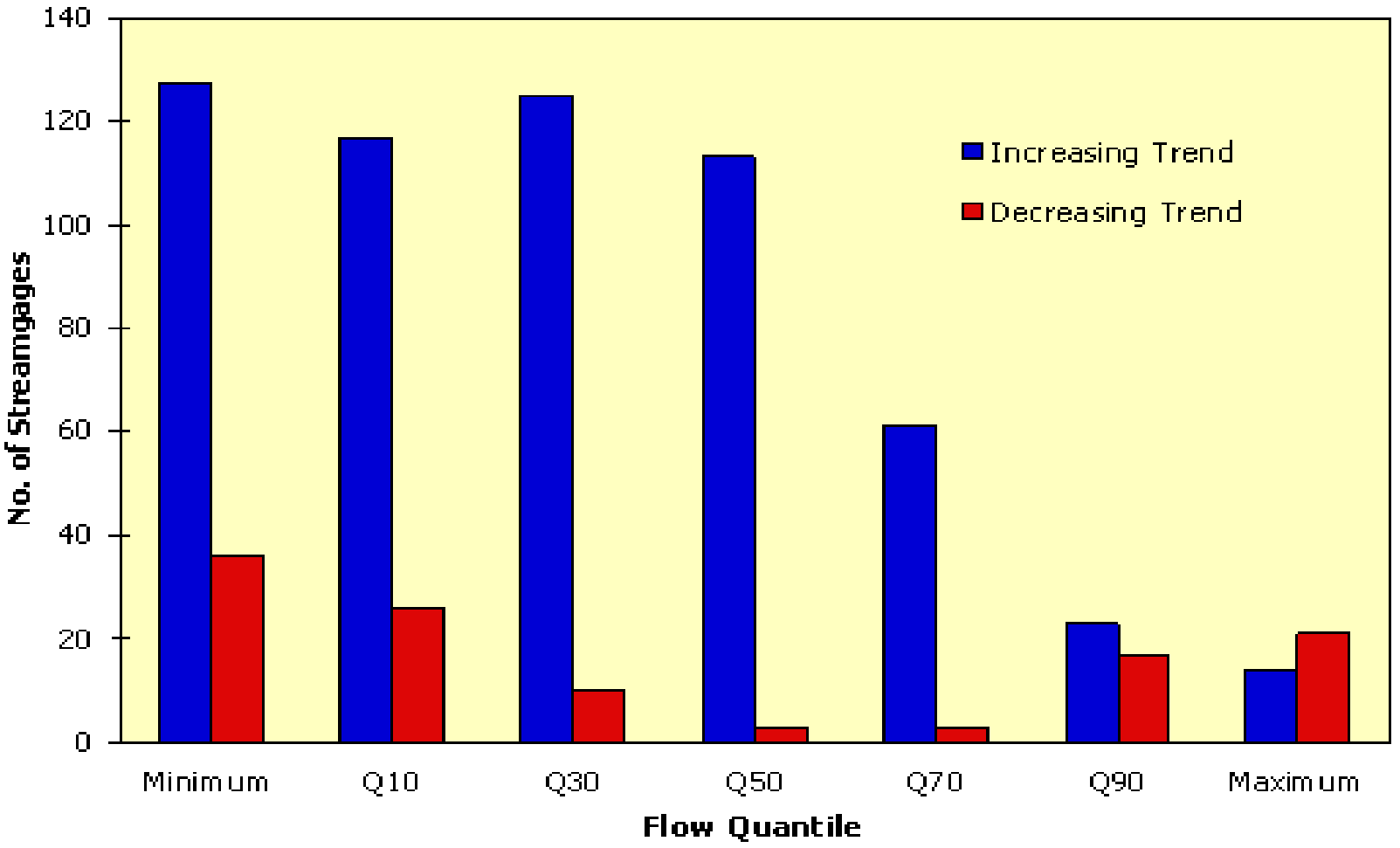
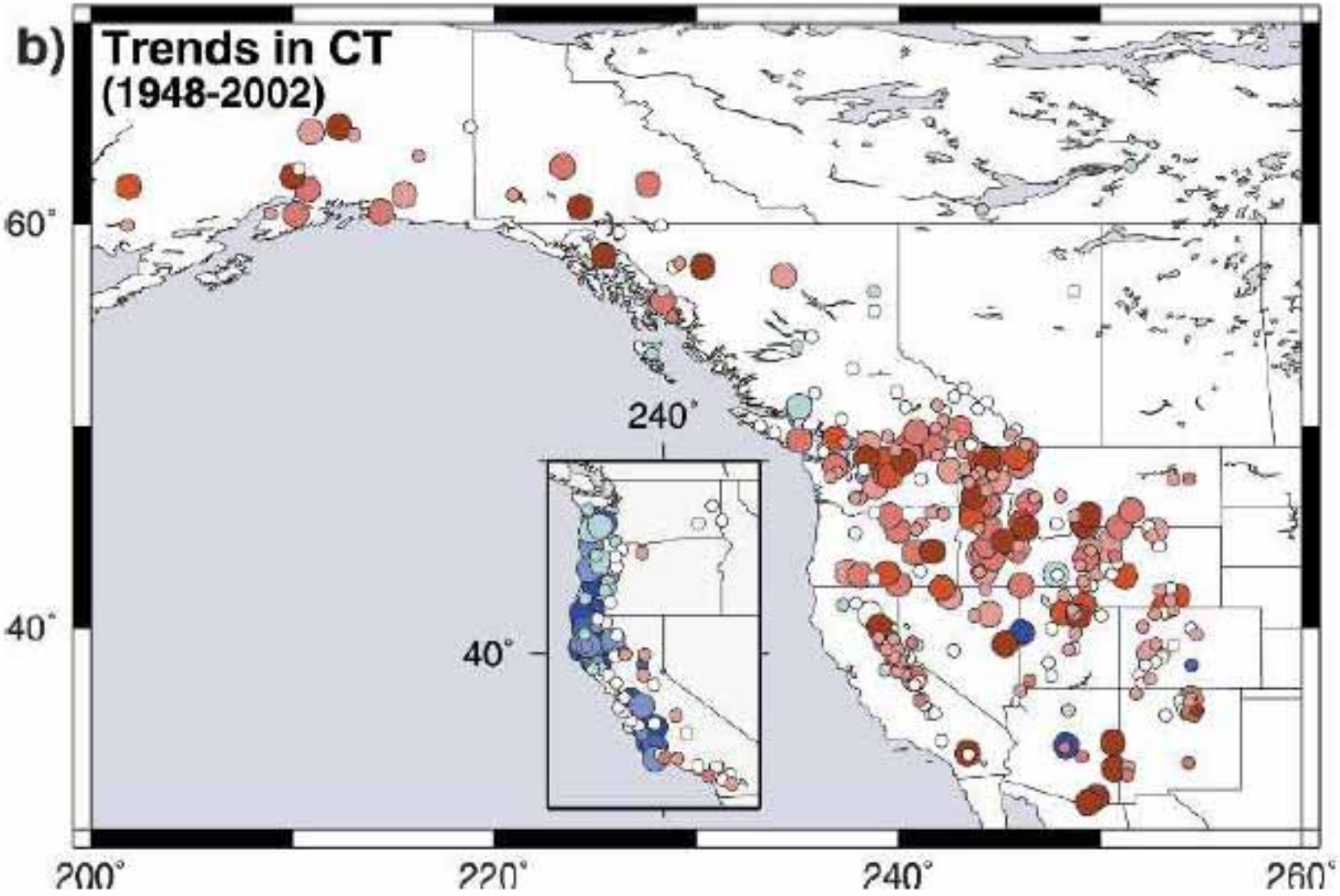


FIG. 1. Linear trends in 1 Apr SWE relative to the starting value for the linear fit (i.e., the 1950 value for the best-fit line): (a) at 824 snow course locations in the western United States and Canada for the period 1950–97, with negative trends shown by red circles and positive by blue circles; (b) from the simulation by the VIC hydrologic model (domain shown in gray) for the period 1950–97. Lines on the maps divide the West into four regions for analysis shown in subsequent figures.

Number of statistically significant increasing and decreasing trends in U.S. streamflow (of 395 stations) by quantile (from Lins and Slack, 1999)





From Stewart et al, 2005

Finding a replacement

- **Option 1: Ensemble methods**
  - **Heritage in stochastic hydrology**
  - **Well adapted to risk estimation**
  - **Not well accepted (practitioners like to identify with specific critical periods; methods opaque, and results method-dependent**
  - **Legal issues?**
  - **Standard approach in weather and climate forecasting**
- **Option 2: Hybrid approach (adjust the historic time series)**

“Synthetic hydrology” c. 1970

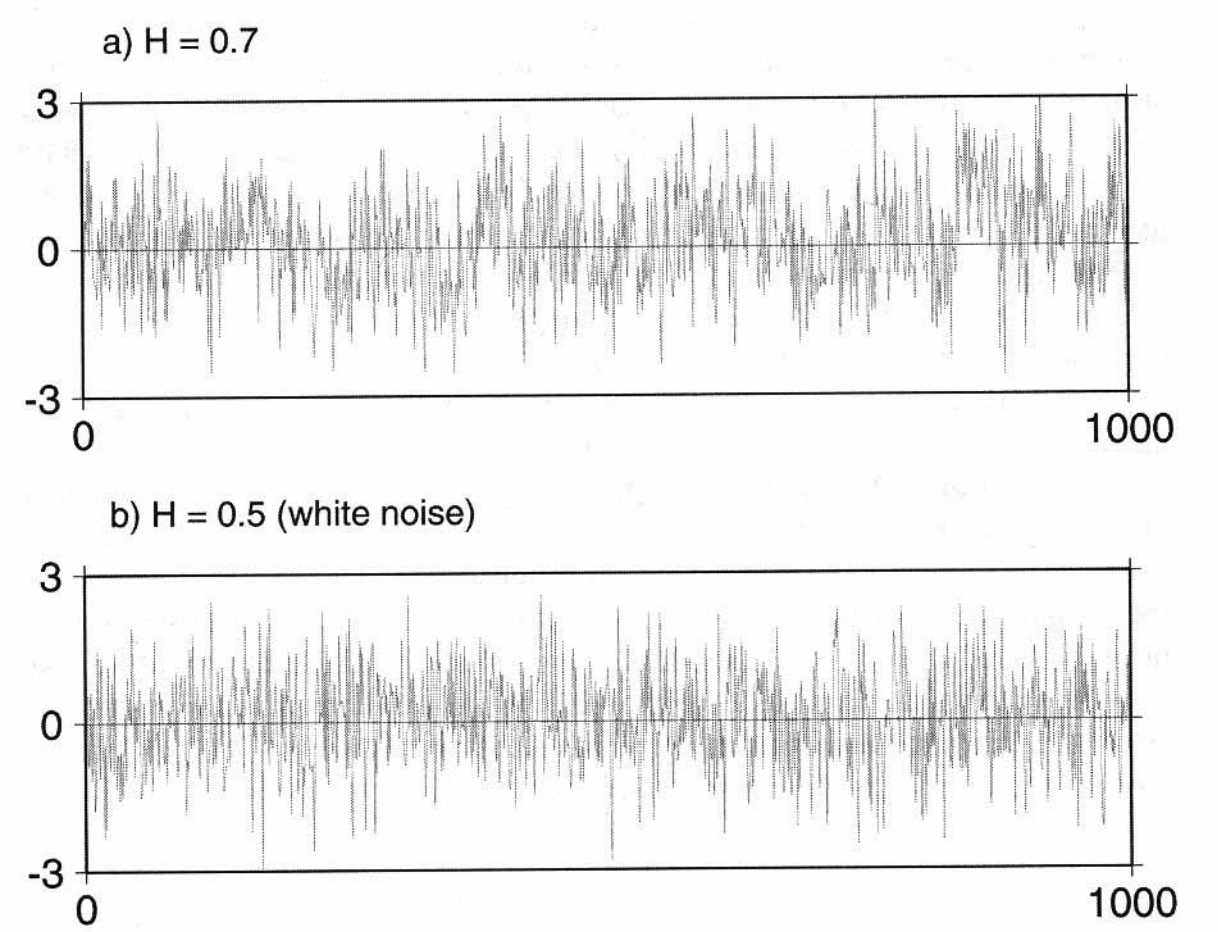
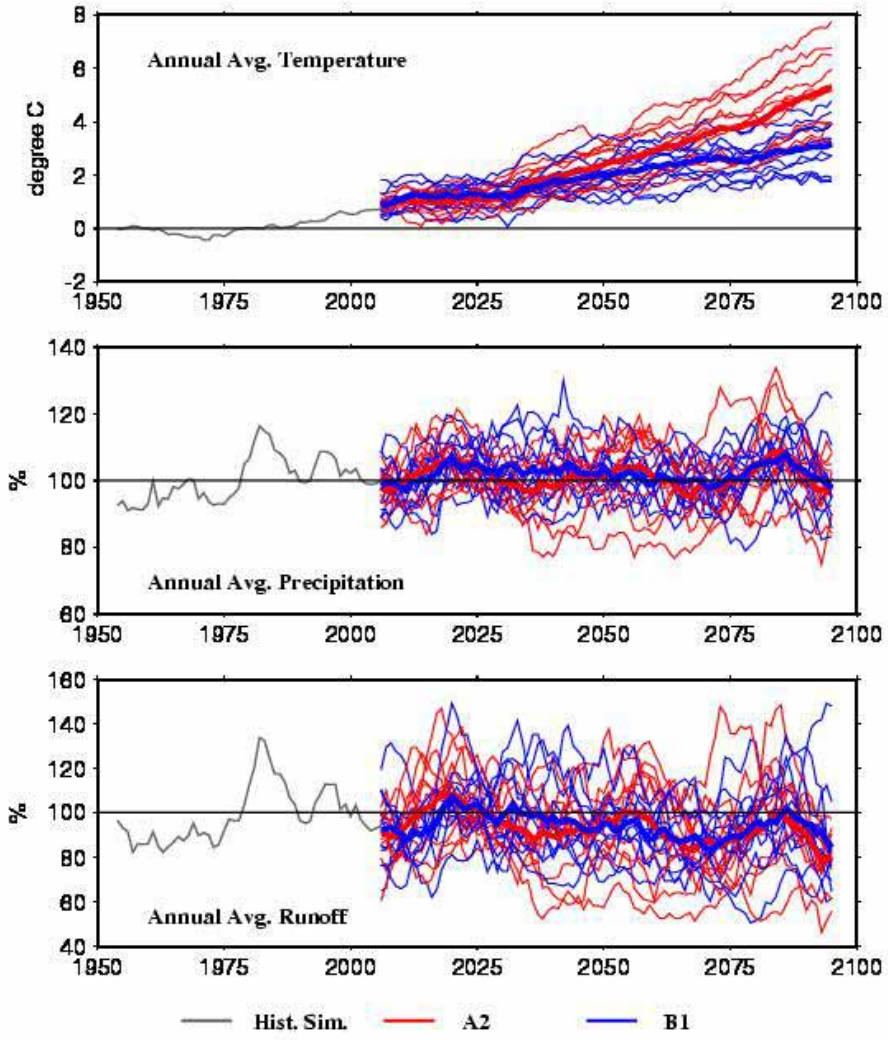
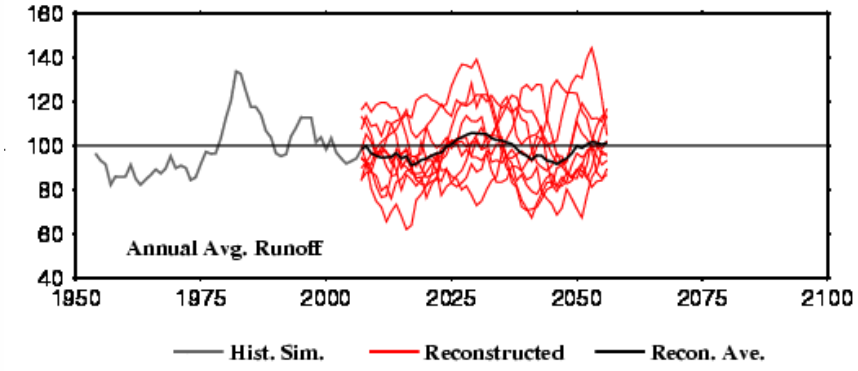


Figure adapted from Mandelbrot and Wallis (1969)



Ensembles of Colorado River (Lees Ferry) temperature, precipitation, and discharge for IPCC A2 and B1 scenarios (left), and 50-year segments of tree ring reconstructions of Colorado Discharge (from Woodhouse et al, 2006)

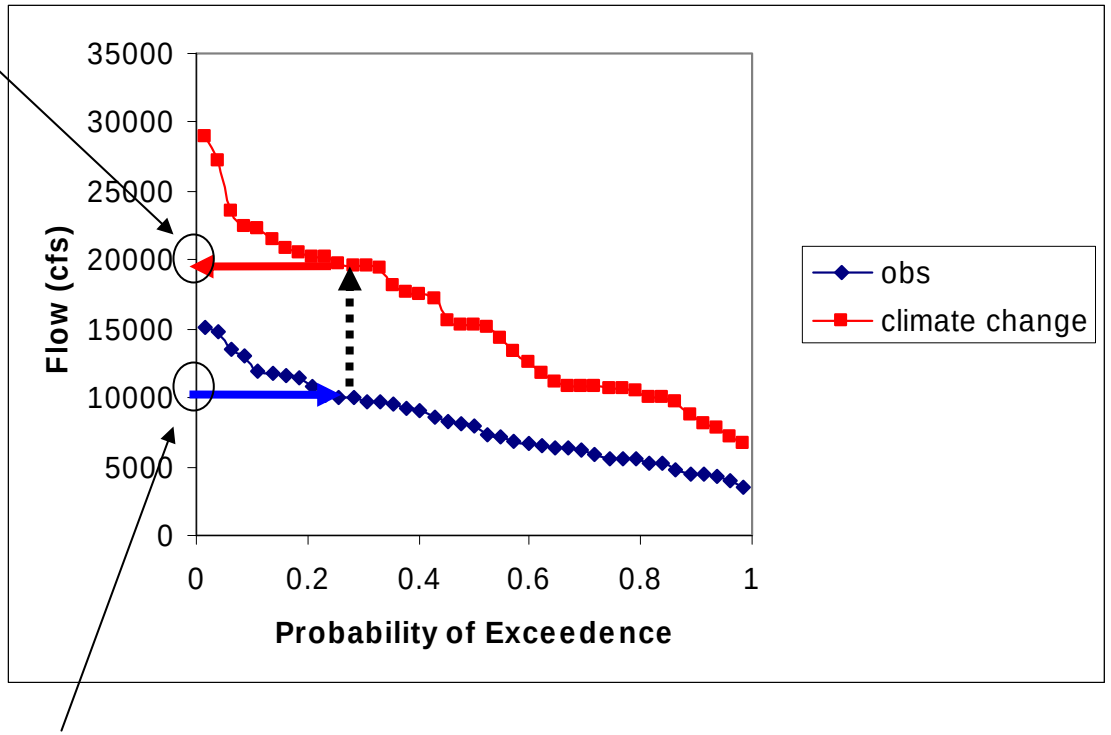


Hybrid Climate Change Perturbations

New time series value = 19000

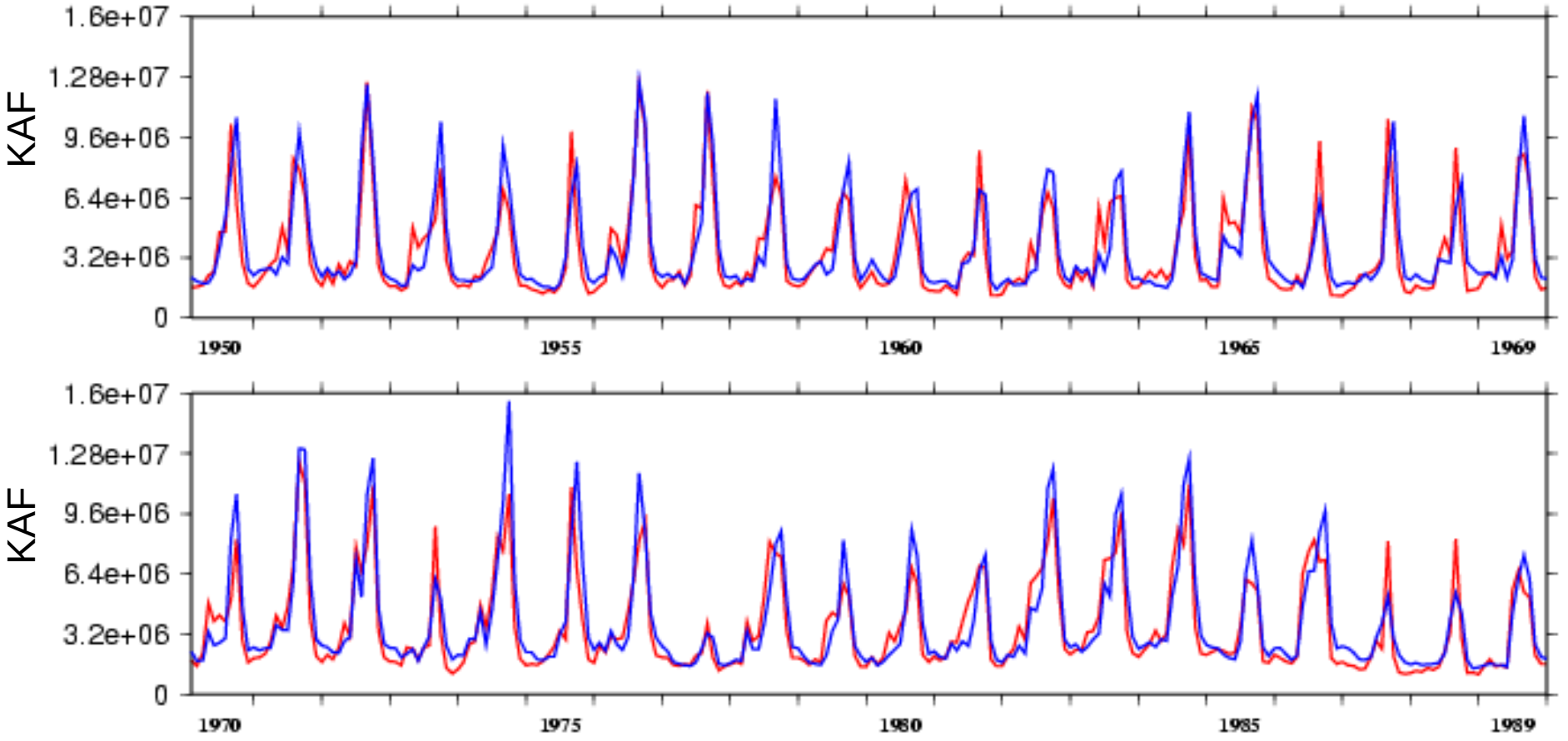
Objective:

Combine the time series behavior of an observed precipitation, temperature, or streamflow record with changes in probability distributions associated with climate change.



Value from observed time series = 10000

Observed and Climate Change Adjusted Naturalized Streamflow Time Series for the Snake River at Ice Harbor



Blue = Observed time series
Red = Climate change time series

Other implications of nonstationarity

- Hydrologic network design (station discontinuance algorithms won’t work)
- Need for stability in the evolution of climate scenarios (while recognizing that they will almost certainly change over time)

Another complication: Water resources research has died in the U.S.

- No federal agency has a competitive research program dedicated to water resources research (e.g., equivalent to the old OWRT)
- As a result, very few Ph.D. students (and hence young faculty) have entered the area
- And in turn, the research that would identify alternatives to classic stationarity assumptions is not being done

See Lettenmaier, “Have we dropped the ball on water resources”, ASCE *JWRPM* editorial, to appear Nov., 2008

Conclusions

- Ample evidence that stationarity assumption is no longer defensible for water planning (especially in the western U.S.)
- What to replace it with remains an open question
- A key element though will have to be weaning practitioners from critical period analysis, to risk based approaches (not a new idea!!)
- Support for the basic research needed to develop alternative methods (a new Harvard Water Program?) is lacking