

Inter-decadal Cyclic Patterns in Historical Hydrologic Data

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Summary

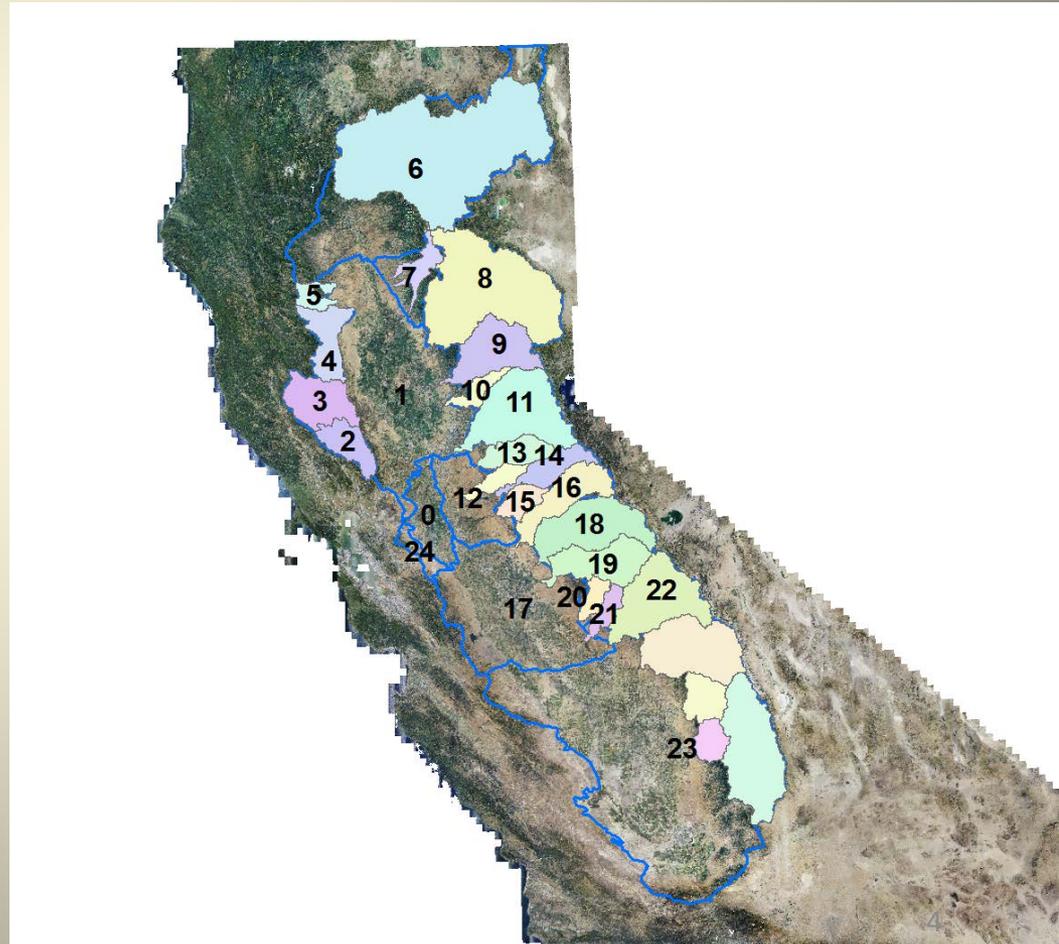
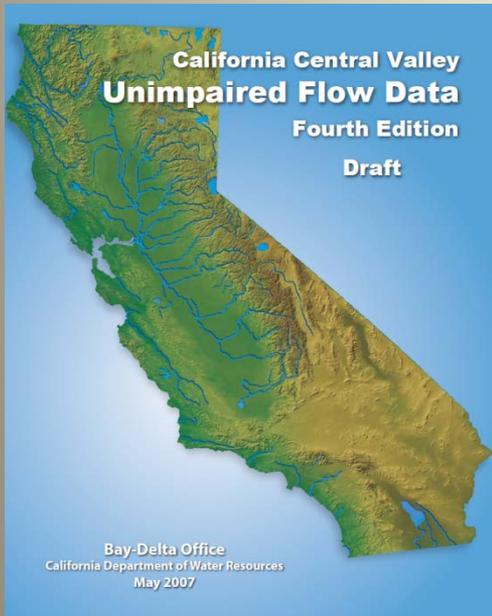
- A common 13.9-year cyclic pattern was detected in observed monthly precipitation and unimpaired streamflow data in 24+ major upper watersheds in California.
- The climate indices showing 13.9-years cycles are ENSO and Arctic Oscillation. Further study is needed to make the connection with the 13.9-year hydrologic cycle.
- Limitation and caution: data records analyzed are limited to approximately recent 100 years. Test of statistical significance is necessary.
- Gridded precipitation data in California from a few GCM models tested do not show similar inter-decadal cyclic pattern.

Background and Approach

- Between 2009-2013, BDO has worked on rainfall-runoff modeling for major rim upper watersheds in the Central Valley: Feather River using PRMS and 25 other watersheds using SWAT hydrologic models.
- Analysis of historical data was an important part of model development and calibration.
- Wavelet spectral analysis was applied to observed precipitation and streamflow time series data to detect dominant cyclic patterns.

Upper Watersheds with SWAT Models

When tested for the 13.9 year cyclic Pattern, all the unimpaired flow Subbasins, UF1 – UF21, and Kings, Kaweah, Tule and Kern Rivers in UF23 show a common cyclic pattern. (UF1-UF24 as defined in 2007 DWR report)



What is Wavelet Analysis

- Wavelet analysis (also called wavelet theory or just wavelets) is a mathematical approach to extract information on the amplitude of dominant periodic signals within a time series, and how this amplitude varies with time.
- Wavelet analysis is a better alternative approach for non-stationary time series data than Fourier analysis.

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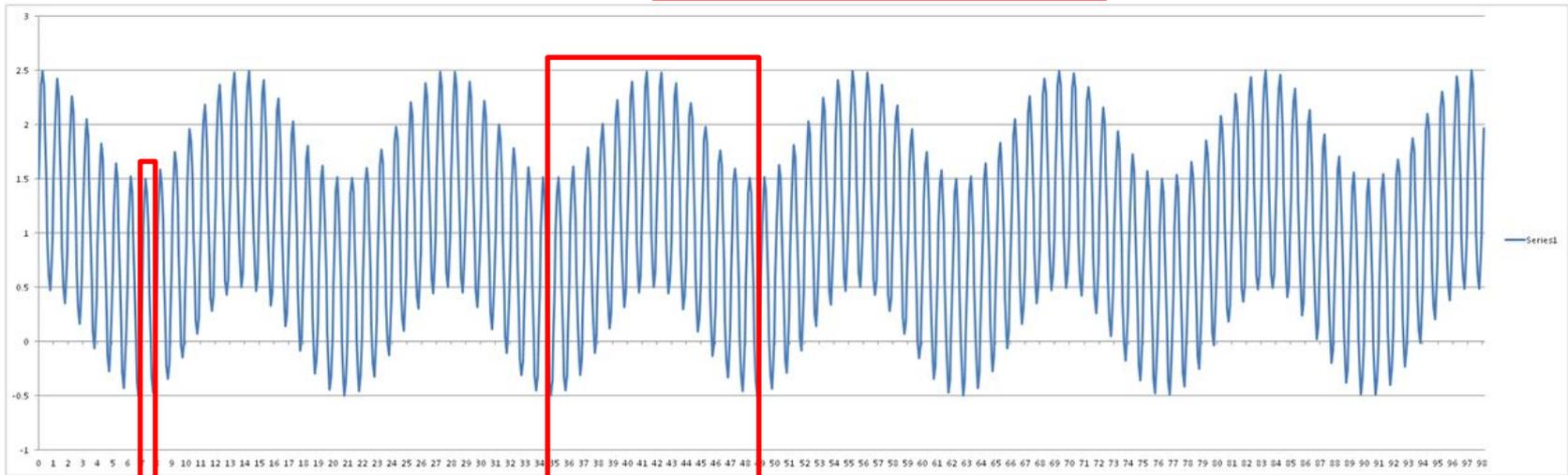
Hydrological response to climate warming: The Upper Feather River Watershed

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Simple Wavelet Example: A perfect periodic time series with cycles at 1.0 and 13.9.

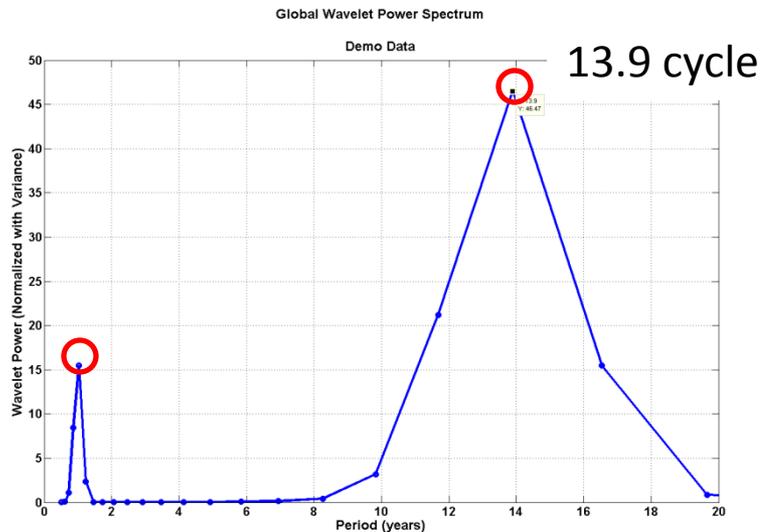
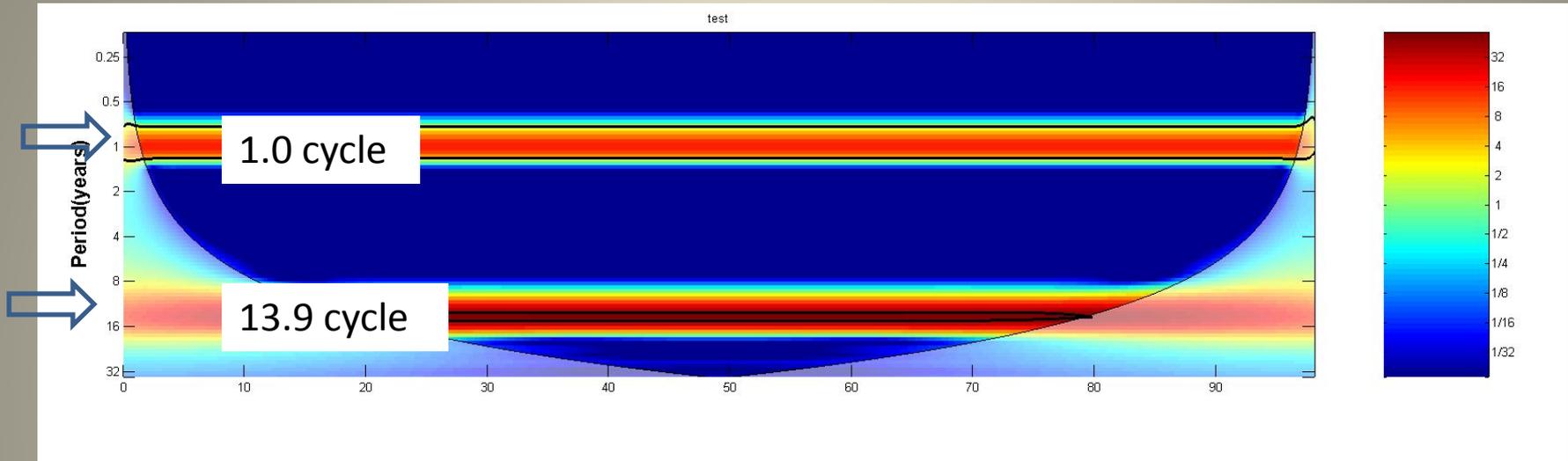
$$Q = \sin(2 * \pi * t) + 0.5 * \cos\left(2 * \pi * \frac{t}{13.9}\right) + 1.0$$



1.0 cycle

13.9 cycle

Wavelet Spectrum for the Example



The wavelet spectral analysis detected the cycles at 1.0 and 13.9.

MULTI-YEAR DROUGHTS OF LARGE-SCALE EXTENT SINCE 1900

Feather River Unimpaired Streamflow above Lake Oroville (CDEC station: FTO)

1918–1920

1923–1926

1928–1935

1947–1950

1959–1962

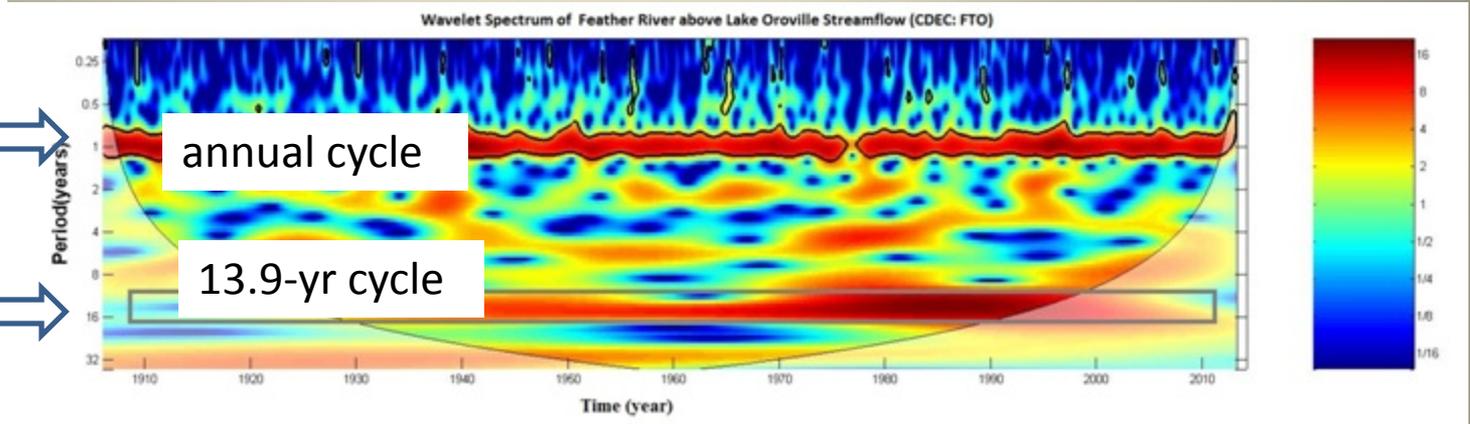
1976–1977

1987–1992

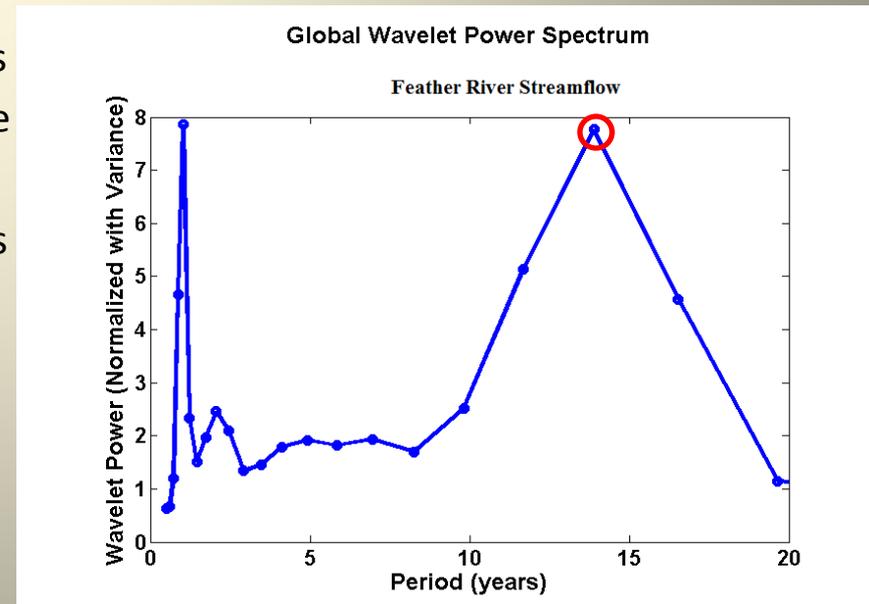
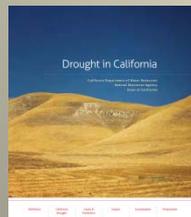
2000–2002

2007–2009

(Based on statewide runoff)



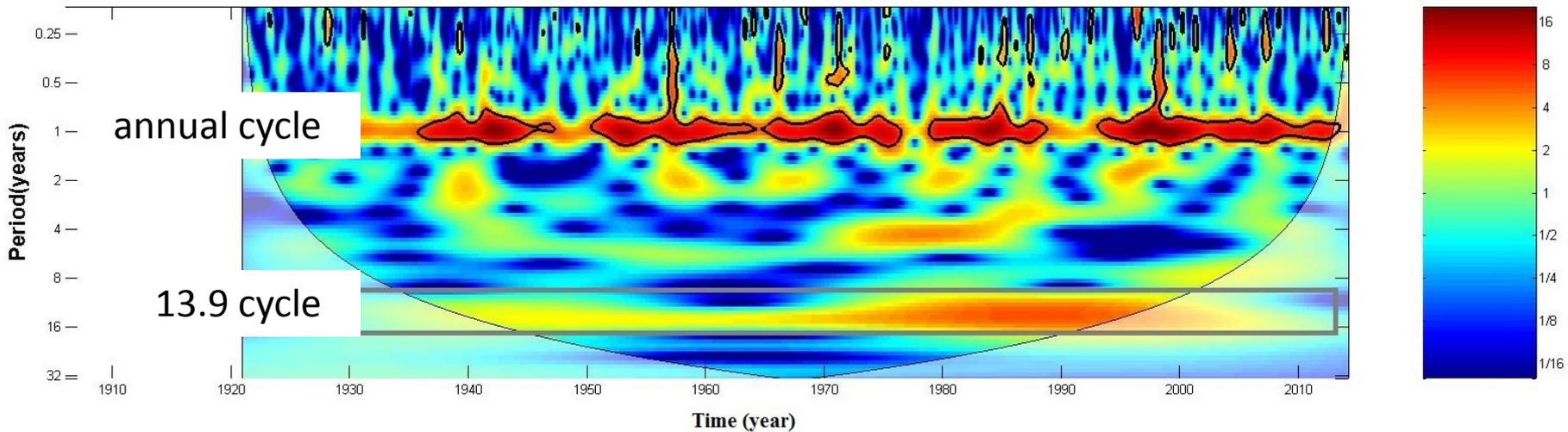
- Monthly streamflow data shows wavelet power peaks at annual cycle and 13.9 years.
- Implication: multi-year droughts



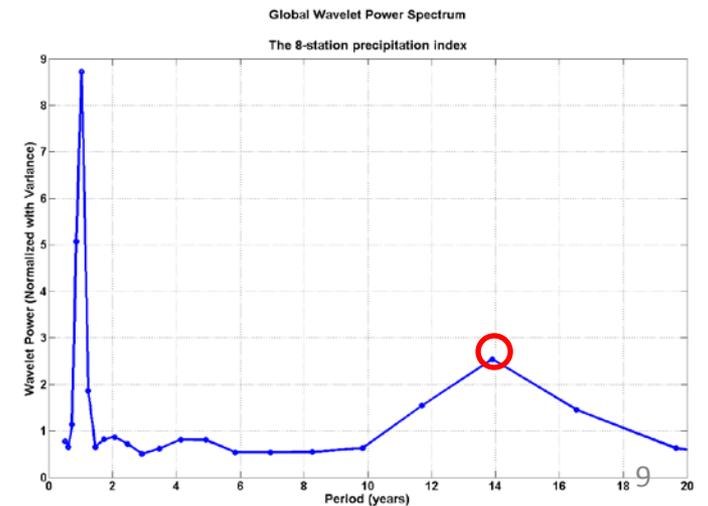
(Drought in California, 2012, DWR)

California's Northern Sierra 8-station Precipitation Index (CDEC station: 8SI)

Wavelet Spectrum of The 8-station Precipitation (The 8 station precip index includes: Mt Shasta City, Shasta Dam, Mineral, Quincy, Brush Creek, Sierraville, Blue Canyon, Pacific House, CDEC: 8SI)



- Monthly Precipitation data also show wavelet power peaks at annual cycle and 13.9 years.



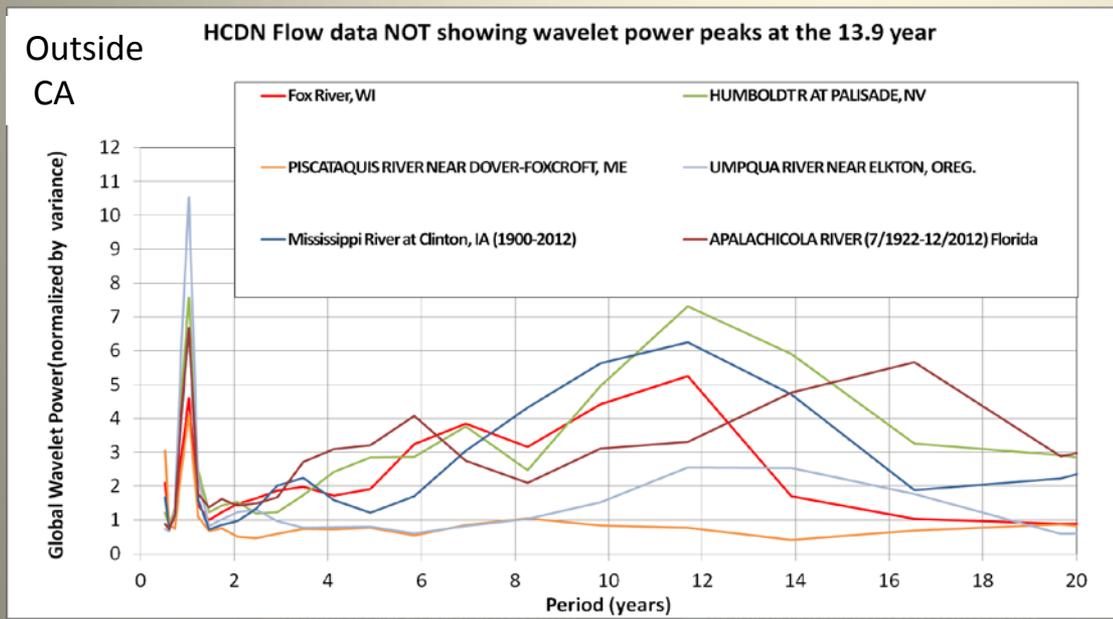
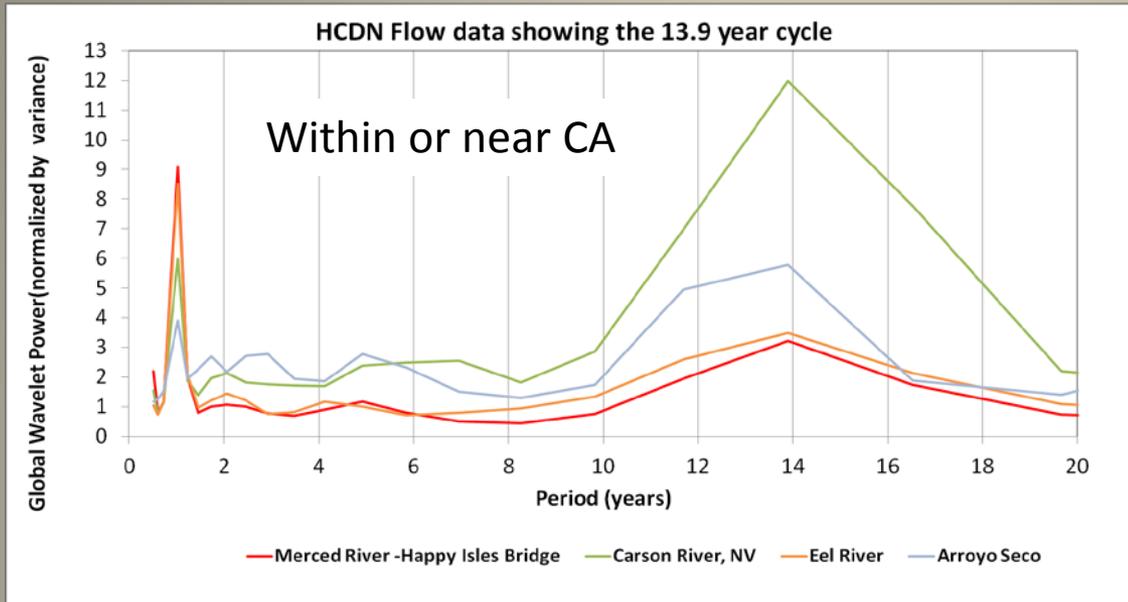
Measured Unimpaired USGS HCDN Streamflow Gage Locations Used in Further Testing



U.S. Geological Survey Hydro-Climatic Data Network (HCDN):
Streamflow Data Set, 1874 – 2013

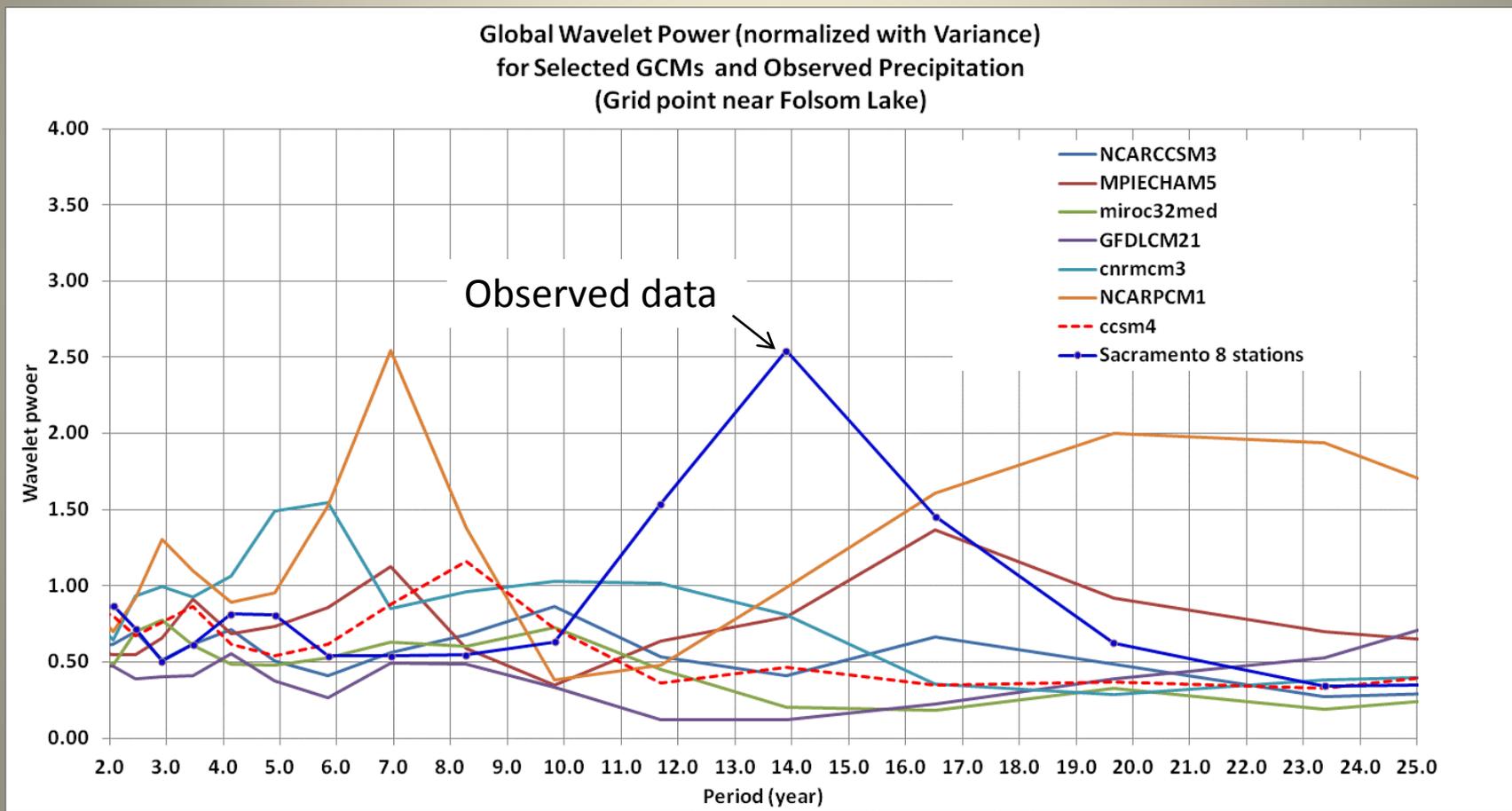
By J.R. Slack, Alan M. Lumb, and Jurate Maciunas Landwehr
USGS Water-Resources Investigations Report 93-4076

Further Testing Results



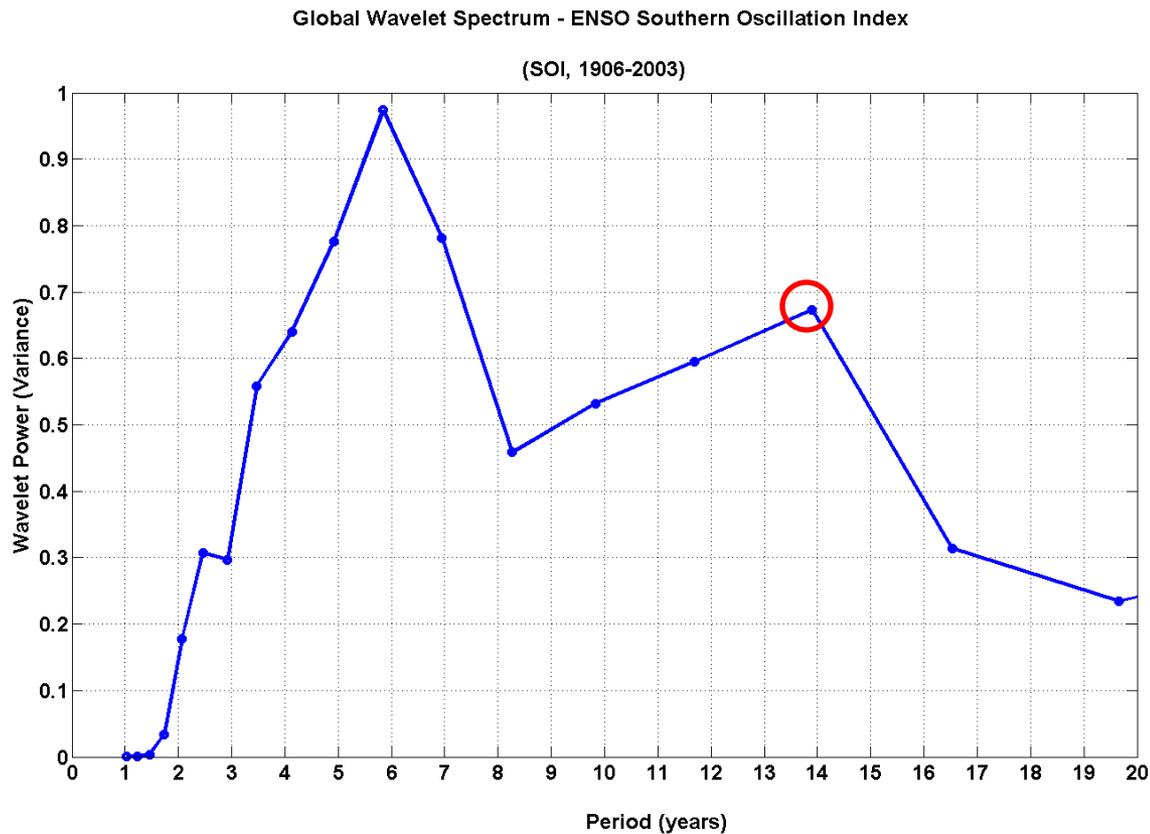
- Decadal cycle for other rivers outside of California: shifted to 11.7 years (Wisconsin, Nevada, Mississippi River (IA) and Oregon; or 16.5 years (Florida) or disappeared (Maine) with about 100 years of flow data.

Test on Selected GCM Precipitation Data (gridded, no downscaling)

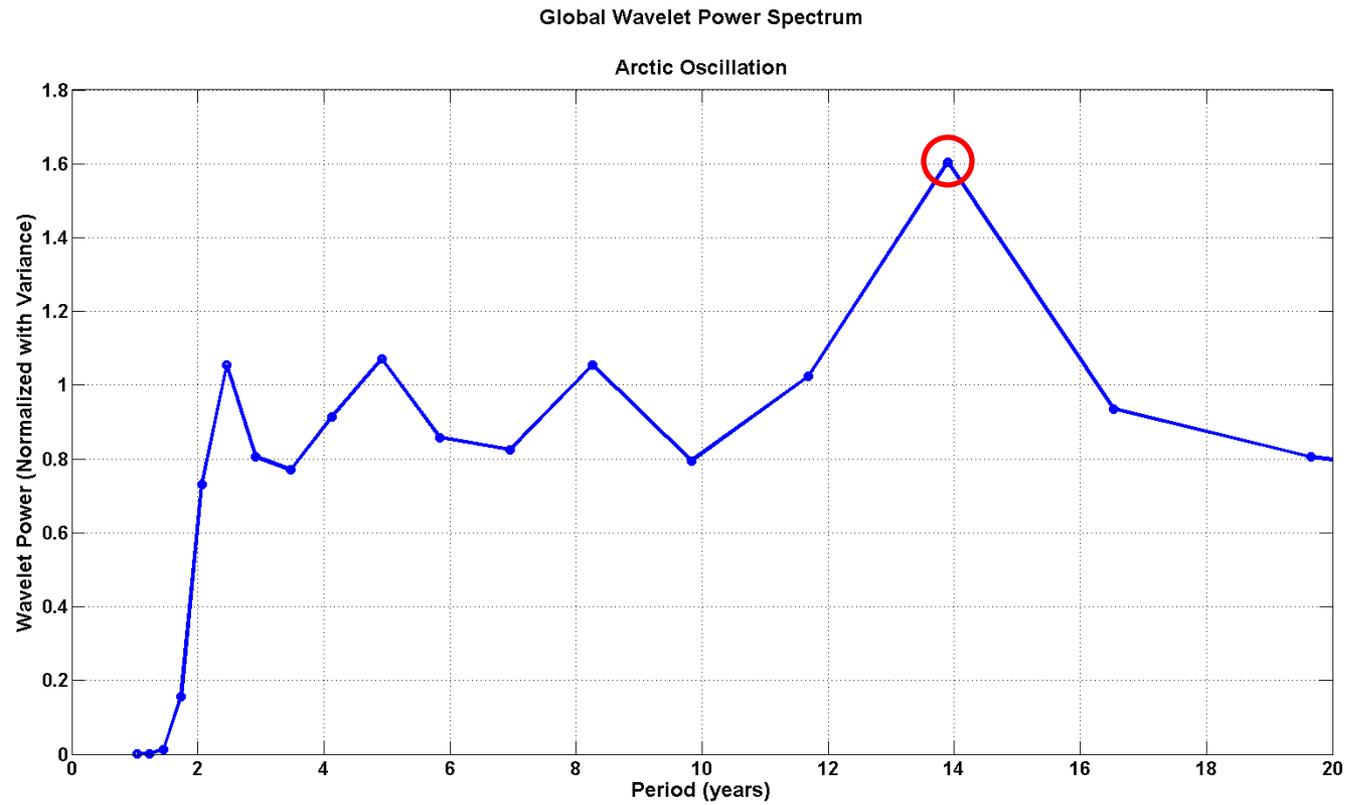


Possible Explanation of the Observation: Connection to Climate Indices?

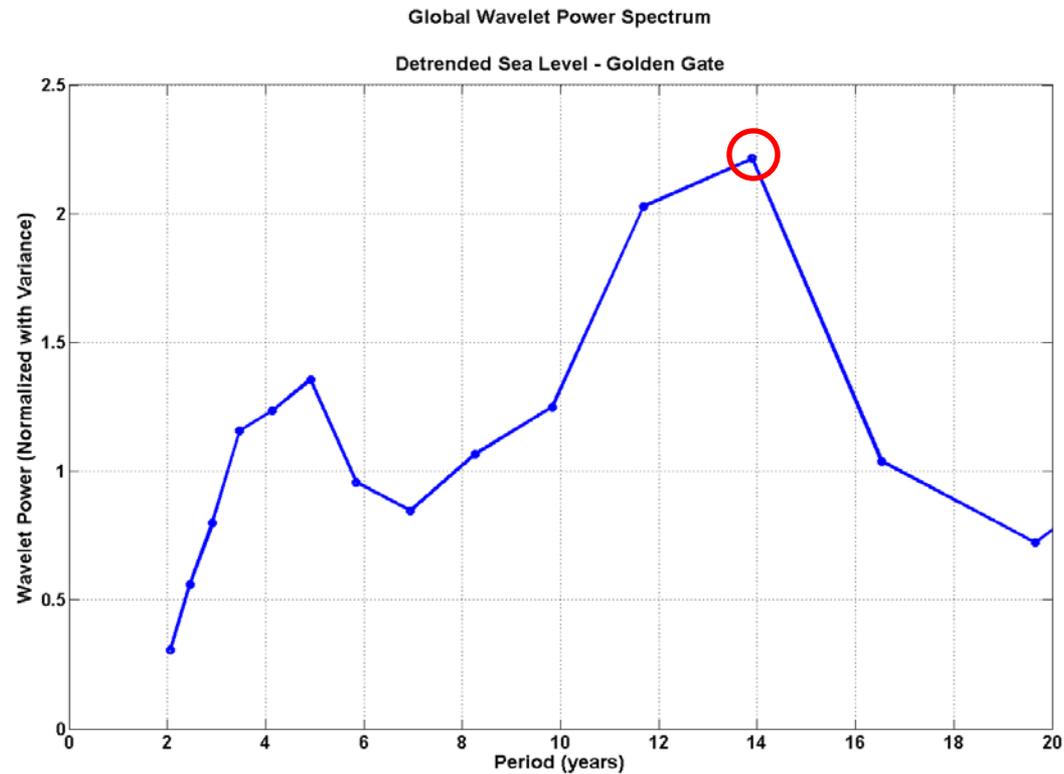
(1) ENSO (El Niño-Southern Oscillation)



(2) Arctic Oscillation



(3) Sea Level Data – Golden Gate



Cycles in CA Hydrologic Data

