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The response of the Mississippi River to climate fluctuations and reservoir construction as indicated by wavelet analysis of water and sediment fluxes, 1950-1975

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Most climate variables are measured at small spatial and temporal scales (e.g. temperature and precipitation at weather stations) making it inherently difficult to evaluate climate change at large scales. Great rivers like the Mississippi River in North America, however, integrate the hydrologic response to climate (precipitation, streamflow, suspended-sediment load) at near-continental scale. We identified the principal modes of variability in hydrologic time-series data for the Mississippi River for 1950-1975 and compared them to climate fluctuations and anthropogenic changes in the watershed. Because hydrologic processes can be non-stationary, we used continuous wavelet analysis to investigate the temporal and frequency changes in the time series, the first application of this technique to the Mississippi that we are aware of. Wavelet analysis of streamflow and suspended-sediment concentration showed common spectral structures dominated by intra-annual and annual fluctuations (i.e. 23.6% of total variance for streamflow and 8.9% for suspended sediment), however, significant inter-annual and multi-year fluctuations also were detected (7.1% for streamflow and 10.7% for suspended sediment). These results indicate strong climatic influences that, in addition to annual fluctuations, could be related to well-known patterns, for example, ENSO which has a strong influence on North American hydroclimatology.

For streamflow and suspended-sediment loads, signal non-stationarity results in clear temporal changes in wavelet spectra around 1960-65 and 1970. The analysis also indicates a loss of energy in the suspended-sediment load signal (decrease in loading) which can be attributed to anthropogenic changes, principally the construction of large reservoirs on the Missouri River in the 1950s. By parameterizing a sinusoidal model based on the observed spectral composition, we were able to remove the effect of this energy loss and estimate what suspended-sediment loads would be without the anthropogenic changes. From 1950 to 1975 the estimated decrease in sediment loading at the mouth of the Mississippi at the Gulf of Mexico was 2.25×10^8 $Mg.y^{-1}$.