



Variability of precipitation and discharge in the Seine river basin (France) over the past 60 years and relation to the North Atlantic Oscillation

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In this study we investigated the variability of Seine river discharge (France) according to precipitation on the Seine river basin using daily time series over the 1946-2006 period. The study focuses on the determination of the dominant modes which control the variability of these hydrometeorological processes, and on the investigation of their relation to the North Atlantic Oscillation. In a second time, changes in short-term (i.e., high-frequency) events such as storms and sudden floods are analyzed, along with the temporal evolution of extremes using annual min/median/max time series to investigate what type of potential underlying climate fluctuations may constrain their variability. The methodological approach used for time series analyses consisted of continuous wavelet analysis for daily time series combined to wavelet scale-averaging for studying high-frequency characteristics, and Stavitsky-Golay filtering of annual extreme time series.

The first results revealed that precipitation and discharge clearly display similar spectral peaks highly localized in time. In general, continuous wavelet transforms of precipitation and discharge display a clear discontinuity around 1970. In more details, distinct time periods show up, each characterized by the pre-eminence of precise modes of variability: 1946 to 1968 (pre-eminence of a 1.8-4.7-yr and a 5.2-11.7-yr fluctuation), 1968 to 1985 (\approx 17.4-yr fluctuation), 1985 to 2006 (\approx 17.4-yr fluctuation with a pluriannual 5.2-7.7-yr). The annual oscillation is always strongly represented in discharge, although it is affected by changes in power throughout the period of study:

less powerful at the beginning of the series, much more powerful from 1990 to the end of the series. The daily NAO wavelet transform is characterized by a varying 2.1-3.7-yr fluctuation which loses power around 1970 to the benefit of lower time-scale fluctuations (8.3-10.3-yr and below). The NAO spectrum then reveals, as observed for hydrometeorological variables, an obvious break around 1970. However, the most powerful 5.2-7.7-yr feature detected in precipitation and discharge starting around 1985 was not observed in NAO, although the 8.3-10.3-yr band occurs at the same period. In the same way as we suggested in a previous work on the possible links between NAO and precipitation in northwestern France, the 5.2-7.7-yr in hydrometeorological data could coincide with a statistically significant shift of the NAO 2.8-3.7-yr inter-annual towards slightly highest frequencies (2.1-2.8-yr band) which appeared to be modulated by a ≈ 6 -7-yr fluctuation. The origin of the 5.2-7.7-yr pluriannual fluctuation does not seem to be directly linked to the NAO, although this oscillation may impact both NAO and hydrometeorological signals.

Short-term events were analyzed by averaging wavelet power over time scales inferior to the synoptic maximum. For both precipitation and discharge, the scale-averaged wavelet spectrum presents a discontinuity around 1970 after which variance seems to increase significantly. In addition, the temporal distribution of high-frequency variance is modulated by a ≈ 6 -7-yr oscillation for both precipitation and discharge. This oscillation may be related to the previously detected 5.2-7.7-yr pluriannual fluctuation and seems to be the main long-term feature controlling the short-term precipitation and discharge variability in the Seine river basin over the 60-yr period of study. The evolution of maximum, median and minimum discharge was finally studied using standardized annual maximum, median and minimum discharge time series. Among the main results, we could notice a pre-eminence of positive (i.e. above average) discharge anomalies after 1970, especially for maximum discharges. The application of a Stavitsky-Golay filter to those generated annual time series revealed the same modes of variability detected using wavelet analysis of daily time series, with a pre-eminence of a ≈ 6 -7-yr fluctuation as well.