Introduced flow variability and its propagation downstream of hydropower stations in Sweden

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Hydropower provides a low-carbon solution to a large portion of Sweden's energy demand, which is increasingly important in order to combat climate change. However, associated flow regulations introduce variability of the flow on the daily, weekly and seasonal time scales, driven by the varying energy demand. Additional variability is introduced when compensating for the shifting wind energy production. The Water framework directive requires all EU member states to evaluate the ecological impact from anthropogenic activities, such as hydropower. Ecological impacts must also be assessed when all hydropower permissions in Sweden are renewed over the coming 20 years. Because different species are sensitive to different longevity of high- and low-flow periods, it is important to understand the introduced variability of flow in terms of its dominant periods, and how quickly these perturbations are attenuated downstream of regulations.

In this work, time-series of flow from hydrological simulations with HYPE are analyzed with the Fourier transform to examine the amplitudes of perturbations of different periods, and their decay downstream of hydropower stations. HYPE is a catchment-based model that simulates rainfall-runoff as well as water quality processes. The Swedish model application has been developed over the past decade and covers all of Sweden. Seasonal regulations are modeled with calibrated input parameters, whereas short-term regulations are introduced with station updates from observations that are available at or close to the majority of hydropower regulations. Very high accuracy has been proven between the updated sub-catchments. This, together with a verified model for natural flow, gives us a unique opportunity to study the impact of hydropower on dominant periods and their decay over the entire country, as well as the mechanisms that govern this decay.

In many sub-catchments, especially in large regulated rivers in northern Sweden, Fourier analysis of daily time series results in dominance of the 7-day period. The exponential decay rate of this and other modes is presented for all Sweden and analyzed in terms of land use and other parameters. Short periods decay faster than long ones. Periods of one month or longer are amplified in the downstream direction in most of Sweden.

Apart from aid in ecological assessments, our analysis can be used to introduce short-term regulations in hydrological simulators, for either deterministic forecasts (the 7-day mode typically has a minimum value on Sundays) or for stochastic seasonal forecasts where it will impact
indicators such as the number of days below or above a threshold.