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Virtual energy storage-gain due to spatiotemporal coordination of hydropower over Europe

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The viability of a renewable electricity system depends on long-term climate variations, uneven spatiotemporal distribution of renewable energy, and technical constraints. A major problem is to achieve a sustainable balance of water usage and consumption, as well as adequate energy and water distribution and storage capacities. In particular, hydropower offers a large capacity for energy storage and production flexibility, but only stands for a minor part of the total energy potential. In this study we explored the spatial and temporal variance of hydropower availability for a 35-year period based on historical hydro-meteorological data from large parts of Europe. A spectral analysis of these historical time-series shows that spatiotemporal coordination of the hydropower system covered in the Global Reservoir and Dam Database (GRanD) can potentially contribute with a “virtual” energy storage capacity that is up to four times the actual energy storage capacity contained in the existing hydropower reservoirs. Such virtual energy storage capacity implies reduced water storage demand, hence, indirectly contributes to reduced constraints of the food-water-energy nexus also in a wider system perspective. We found that the most significant benefits from a spatiotemporal management arise at distances of 1,200 – 3,000 km, i.e. on the continental scale, which can have implications for a future renewable energy system at large. The analysis also covers what we denote “energy-domain-specific drought”, which implies a shortage of energy storage capacity to avoid a deficit of energy for a given time period, and which may be reduced by the spatiotemporal coordination of power production.