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Informing efficient reservoir filling strategies by seasonal drought forecasts

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With more than 3500 hydropower dams currently being planned or built around the world, the need for optimal dam planning is more compelling than ever. Current literature efforts are directed towards strategic sizing and siting of dams to maximize economic return and minimize environmental impacts in regime conditions. However, also the initial transient phase of reservoir filling may have substantial environmental and economic implications and, especially in large projects, it can be responsible for critical sectoral conflicts associated to dam development. In this phase, precaution towards downstream impacts requires transiting high percentages of inflow, resulting in multi-years, even decadal, filling transients. Conversely, upstream interests (e.g., hydropower production) favor fast impoundment of water, albeit generating critical periods of minimal streamflow downstream. In this process, hydroclimatic variability plays a key role: if the filling occurs during a dry spell, augmented impacts must be endured by upstream and downstream sectors.

The state of global climate teleconnections represents a valuable source of predictability of local hydrometeorological anomalies, which can provide a dual support to dam planning. First, in scheduling a favorable time to start the filling operations based on local effects of long-term climatic oscillations, and second, in designing effective filling strategies adaptive to medium-term hydroclimatic variability. In this work, we consider the case study of the Omo-Turkana basin (Ethiopia-Kenya) to demonstrate the use of seasonal drought forecasts based on multiple climate teleconnections for modulating reservoir filling operations according to the predicted drought conditions, e.g. by transiting higher fractions of the inflow when a drought is forecasted. This case study is in this respect exemplary, because the impacts due to the construction and filling of Gibe III dam and to the current construction of Koysha dam, raised the strong opposition of local communities and international organizations. We run a retrospective analysis of Gibe III filling and compare the impacts of the historical filling strategy to designed alternative strategies, demonstrating the potential to significantly decrease downstream impacts, for instance by successfully maintaining the level of downstream Lake Turkana up to one meter higher than historically observed. Our approach also shows that 2015 was an unfavorable year to begin the filling operations of Gibe III, and significant damage could be avoided by delaying or anticipating the operations by 2-3 years. Finally, we predict that the planned time to start filling the Koysha dam, 2021, occurs at the beginning of a multi-year drought and we issue recommendations on more favorable timings.