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The value of storage water: a climatological signature for global change impact studies

Baptiste Francois (1), Benoit Hingray (1), Frédéric Hendrikx (2), and Jean-Dominique Creutin (1)

(1) CNRS, LTHE, Grenoble, France (baptiste.francois@ujf-grenoble.fr), (2) EDF R&D (Electricité de France, Reserarch and Development), LNHE, Chatou, FRANCE

To produce hydroelectricity in a very flexible way, a large number of water accumulation reservoirs have been constructed in mountainous regions worldwide. In high elevation catchments, the snowpack space time evolution makes the hydrological regimes of rivers highly seasonal with low/high flows in the snow-accumulation/melt seasons respectively. In downstream regions, the electricity demand is also highly seasonal with maxima usually observed during the winter low flow period and minima during or after snowmelt floods. Accumulation reservoirs allow electricity production to fit the timing of electricity demand.

Besides hydroelectricity production, the management of the reservoirs may include other constraints related for example to irrigation water demand, low flow maintenance, floods management. Dynamic programming provides a theoretical basis to define the optimal management trajectory of such complex systems with given hazards on flows. We use one of its by-products to estimate the value of storage water (VSW): it represents the marginal benefit that could be obtained later for each additional cubic meter stored in the reservoir. The VSW depends on the current reservoir filling rate and varies in time, with seasonal but also inter-annual variations. The more difficult it will be to satisfy future demand with natural upstream water inflows only, the higher the VSW will be, the higher the interest of building additional water provision.

We use the VSW to characterize the adaptations of the optimal management strategy that would be required in a modified climate. The seasonal cycle of the VSW is simulated for a schematic water resource system (i.e alpine catchment + accumulation reservoir) for the present climate and a suite of future climate scenarios. A sensitivity analysis to the intensity of mean regional temperature change (increase) and/or precipitation change (decrease) is carried out. The influence of the nature of water demand on the VSW is analysed (energy production and/or low flows maintenance).

For all considered future climates, the inter-annual mean VSW is expected to increase. Temperature changes will modify its seasonality as a result of earlier snowmelt spring floods. These modifications result in changes of the optimal management trajectory. The increase in the mean inter-annual VSW implies higher and more frequent restrictions during the year especially to be able to face electricity demand peaks. Its change in seasonality implies that sooner water storage is required to satisfy winter water demand efficiently. Changes in mean VSW and in seasonality depend on priority levels prescribed between water uses. Changes in VSW are not a linear function of precipitation, temperature changes. The same apply when water uses are combined.

Keywords: Dynamic programming, Climate change, Value of storage water, Water shortage, Reservoir, Hydroelectricity