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Modeling a complex system of multipurpose reservoirs under prospective scenarios (hydrology, water uses, water management): the case of the Durance River basin (South Eastern France, 12 800 km2)

Céline Monteil (1), Frédéric Hendrickx (1), René Samie (1), and Eric Sauquet (2)
(1) EDF - R&D, LNHE, Chatou, France (celine-c.monteil@edf.fr), (2) Irstea, Villeurbanne, France (eric.sauquet@irstea.fr)

The Durance River and its main tributary, the Verdon River, are two major rivers located in the Southern part of France. Three large dams (Serre-Ponçon, Castillon and Sainte-Croix) were built on their streams during the second half of the 20th century for multiple purposes. Stored water is used for hydropower, recreational, industry, drinking water and irrigation. Flows are partly diverted to feed areas outside the basin. On average 30 plants located in the Durance and Verdon valleys currently produce a total of 600 million kWh per year, equal to the annual residential consumption of a city with over 2.5 million inhabitants. The Southern part of France has been recently affected by severe droughts (2003, 2007 and 2011) and the rules for water allocation and reservoir management are now questioned particularly in the light of global change.

The objective of the research project named "R^2D^2-2050" was to assess water availability and risks of water shortage in the mid-21st century by taking into account changes in both climate and water management. Therefore, a multi-model multi-scenario approach was considered to simulate regional climate, water resources and water demands under present-day (over the 1980-2009 baseline period) and under future conditions (over the 2036-2065 period). In addition, a model of water management was developed to simulate reservoir operating rules of the three dams. This model was calibrated to simulate water released from reservoir under constraints imposed by current day water allocation rules (e.g. downstream water requirements for irrigation, minimum water levels in the reservoirs during summer time for recreational purposes). Four territorial socio-economic scenarios were also elaborated with the help of stake holders to project water needs in the 2050s for the areas supplied with water from the Durance River basin.

Results suggest an increase of the average air temperature with consequences on snow accumulation, snowmelt processes but also evapotranspiration process. However changes in total precipitation are highly uncertain. The six tested rainfall-runoff models project reduced flows, especially in the spring and summer seasons. Depending on the socio-economic scenarios and the area, the downstream total water needs could decrease or remain stable. Considering the present day constraints, these changes would lead to a decrease in energy production (mainly due to reduced annual inflows) and to less flexibility for hydropower management during winter peak energy demand. Results of the R^2D^2 2050 project suggest also that the downscaling methods still fail to reproduce some crucial aspects of the climate at regional scale. Unexpected biases are propagated along the chain of models. The key issue to simulate accurately reservoir operations under present and future climate conditions is the filling curves that depict the balance between water supply and demand. Probabilistic filling curves were calibrated here to meet the constraint on water level in summer objective nine years over ten. A large proportion of regional climates generated over the baseline period lead to unrealistic curves, pointing out higher levels of requirement in models output to assess global change impacts on water management systems like on the Durance River basin.