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Adaptations of a physical-based hydrological model for alpine catchments. Application to the upper Durance catchment.

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The impact of global change on water resources is expected to be especially pronounced in mountainous areas. Future hydrological scenarios required for impact studies are classically simulated with hydrological models from future meteorological scenarios based on GCMs outputs. Future hydrological regimes of French rivers were estimated following this methodology by Boé et al. (2009) with the physical-based hydrological model SAFRAN-ISBA-MODCOU (SIM), developed by Météo-France. Scenarios obtained for the Alps seem however not very reliable due to the poor performance achieved by the model for the present climate over this region. This work presents possible improvements of SIM for a more relevant simulation of alpine catchments hydrological behavior. Results obtained for the upper Durance catchment (3580 km2) are given for illustration.

This catchment is located in Southern French Alps. Its outlet is the Serre-Ponçon lake, a large dam operated for hydropower production, with a key role for water supply in southeastern France. With altitudes ranging from 700 to 4100 meters, the catchment presents highly seasonal flows: minimum and maximum discharges are observed in winter and spring respectively due to snow accumulation and melt, low flows are sustained by glacier melt in late summer (39 km2 are covered by glaciers), major floods can be observed in fall due to large liquid precipitation amounts.

Two main limitations of SIM were identified for this catchment. First the 8km-side grid discretization gives a bad representation of the spatial variability of hydrological processes induced by elevation and orientation. Then, low flows are not well represented because the model doesn't include deep storage in aquifers nor ice melt from glaciers. We modified SIM accordingly. For the first point, we applied a discretization based on topography : we divided the catchment in 9 sub-catchments and further 300 meters elevation bands. The vertical variability of meteorological inputs and vegetation cover could be thus better accounted for. Then, each elevation band is divided in 7 exposure classes, in order to represent the influence on snow cover of the solar radiation spatial variability . This discretisation results in 539 Hydrological Units where hydrological processes are assumed to be homogeneous. For the second point, we first included the possibility for glacier melt in previous discretization. We next added a conceptual non-linear underground reservoir in order to simulate water retention by aquifers.

These adaptations lead to a clear improvement of simulations for all the hydrometric stations. Daily simulated discharges fit well with measurements (Nash score = 0.8). The model has a good ability to simulate interannual variability and it is robust under a long simulation period (1959-2006). This encourages us to use it in a modified climate context. We studied the effect of each model improvement with a set of sensitivity tests. Accounting for elevation bands allows simulating more persistent snow cover at high altitudes, contributing later to river flows. Adding underground storage leads to delay the snowmelt runoff transfer in river. The exposure influence is not so sensitive for discharges simulation, but it gives a more accurate description of the spatial variability of snow cover. Although glaciered areas are very small compared to total basin area, a better simulation of summer low flows is obtained including a glacier melt module.

Despite previous improvements, winter low flows are still slightly underestimated. As suggested by a simple sensitivity analysis, this could be partly due to the fact that the model doesn't correctly simulate basal snowmelt by ground heat flow.