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Temperature-driven 'meteorological memory' and hydrological response of an Alpine river basin

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Alpine river basins have a very particular hydrological signal, associated with the importance of snow and/or ice melt for a range of elements of hydrological response, and notably : (1) the impacts of winter storage of precipitation in the snow pack ; and (2) longer term release of water from storage in glaciers. The presence of a potential 'stock' of water in such basins implies that in addition to being responsive to meteorological variability, they will also have a meteorological 'memory', associated with the effects of the recent past upon the size of the stock. This memory will be highly sensitive to both rainfall history and temperature history, as the latter will control the percentage of winter rainfall that is solid, as well as when and the rate at which water is released from the snow store. In turn, this memory effect has critical implications for river flow: (1) snow (and ice) melt can sustain low flows through the summer and autumn period; and (2), during the transition from winter to summer, there is a growing probability of convective rainfall events, often orographically-enhanced, whose runoff impacts may be significantly enhanced if there is a significant snow store. It follows that even in the absence of no systematic changes in precipitation, Alpine river basins may be extremely sensitive to changes in temperature, through its effect upon the meteorological memory of the basin. To understand these effects, we have recently reconstructed hourly river flows from the 1940s to present for a nivo-glacial Alpine basin (c. 5% glaciated) using the WaSIM-ETH model, which includes a full snow and glacier representation. The basin is interesting because since the 1940s, it has had no change land use and relatively stable land cover: it is thus an ideal basin for understanding the interactions between climate variability and hydrological response. The time period is useful because it includes a period from the 1970s to the early 1980s, which was associated with generally cooler winters with greater winter snow fall; as well as the period of relatively rapid climate amelioration since the 1980s. Our results show that the hydrological response of this system is dominated by a temperature-driven meterological memory and, specifically, the dynamics of snow storage. The maximum modeled hourly flows are found in years associated with a greater degree of snowpack preservation into the early summer when the probability of convective rainfall events is also greater. Such years are also associated with higher minimum river flows. Although the memory effect is strongest at the intra-annual scale, it was also possible to identify an inter-annual memory effect, in which information is transferred between years, and associated with particularly cool summers where snow-line retreat is significantly reduced. What follows from these observations is that hydrology of these basins can be much more strongly driven by temperature effects than rainfall effects, and exemplifies why they are likely to be so sensitive to future climate change.