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A statistical adjustment approach for climate projections of snow conditions in mountain regions using energy balance land surface models

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Projections of future climate change have been increasingly called for lately, as the reality of climate change has been gradually accepted and societies and governments have started to plan upcoming mitigation and adaptation policies. In mountain regions such as the Alps or the Pyrenees, where winter tourism and hydropower production are large contributors to the regional revenue, particular attention is brought to current and future snow availability. The question of the vulnerability of mountain ecosystems as well as the occurrence of climate-related hazards such as avalanches and debris-flows is also under consideration.

In order to generate projections of snow conditions, however, downscaling global climate models (GCMs) by using regional climate models (RCMs) is not sufficient to capture the fine-scale processes and thresholds at play. In particular, the altitudinal resolution matters, since the phase of precipitation is mainly controlled by the temperature which is altitude-dependent. Simulations from GCMs and RCMs moreover suffer from biases compared to local observations, due to their rather coarse spatial and altitudinal resolution, and often provide outputs at too coarse time resolution to drive impact models. RCM simulations must therefore be adjusted using empirical-statistical downscaling and error correction methods, before they can be used to drive specific models such as energy balance land surface models.

In this study, time series of hourly temperature, precipitation, wind speed, humidity, and short- and long-wave radiation were generated over the Pyrenees and the French Alps for the period 1950-2100, by using a new approach (named ADAMONT for ADjustment of RCM outputs to MOuNTain regions) based on quantile mapping applied to daily data, followed by time disaggregation accounting for weather patterns selection. We first introduce a thorough evaluation of the method using using model runs from the ALADIN RCM driven by a global reanalysis over the French Alps.

We then illustrate the potential of this method by processing outputs from EURO-CORDEX simulations spanning 6 different RCMs forced by 6 different GCMs under 3 representative concentration pathways scenarios (RCP 2.6, 4.5 and 8.5) over Europe, downscaled at the massif scale and for 300 m elevation bands and statistically adjusted against the extensive SAFRAN reanalysis (1958-2015). These corrected fields were then used to force the SURFEX/ISBA-Crocus land surface model over the Pyrenees and the French Alps. We show the wealth of information, which can be obtained through the systematic application of such a method to a large ensemble of climate projections, in order to capture upcoming trends with an explicit representation of their uncertainty.