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Modelling the impact of future climate change on operating conditions of ski resorts in the French Alps

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Grooming and artificial snowmaking have become pivotal components of ski resorts operations. They are employed to mitigate the impacts of the high inter-annual variability, as well as observed and projected decreases of natural snow amounts in mountains. Because snowmaking intrinsically depends on meteorological conditions (wet bulb temperature and wind-speed), it makes it an adaptation measure which is itself climate sensitive. Furthermore, the physical behaviour of managed snow is different than that of natural now, mostly because of its higher density, so that the sensitivity of snow on ski slopes to meteorological conditions must be assessed specifically. Climate projections of natural snow conditions, which regularly make the headlines of newspapers because of their direct and dramatic relationship to atmospheric warming in Alpine areas, may not directly translate into information appropriate to address the impact of climate change on ski resorts operations.

Here we introduce novel results from a model chain which makes it possible to compute, at the ski resort level, snow conditions accounting for grooming and/or snowmaking using the Crocus-Resort snowpack model and a spatially explicit framework for representing ski resorts. The model chain was developed and applied to the 129 ski resorts of the French Alps, primarily driven by SAFRAN reanalysis data from 1960 to 2016 (Spandre, 2016). This contribution will introduce novel results based on this innovative model chain, driven by ensembles of climate projections spanning the entire 21st century. Climate data stem from the EURO-CORDEX database, and were statistically adjusted using the ADAMONT method (Verfaillie et al., 2017 GMD) using the SAFRAN reanalysis as an observation dataset. Multiple GCM/RCM combinations were considered for the following three emission scenarios RCP 2.6, RCP 4.5 and RCP 8.6, thereby providing resort-level and Alpine-wide assessments of natural and managed snow conditions spanning the 21st century in a continuous manner.

Results are analyzed in the context of assessing whether snowmaking, at expected fractional coverage values of 40% French Alps ski resorts surface area at the turn of the 2020s, can provide adequate mitigation to declining natural snowfall and rising temperatures. Taking the entire French Alps ski industry as a whole, it is found that the number and intensity of “poor snow” years does not significantly increase when snowmaking is employed, under all climate scenarios until 2050, in comparison to the situation of the past decades. This indicates that despite temperature increases, there are enough “cold windows” available in early winter to produce snow in sufficient amounts to sustain the current reliability level of snow conditions. However, this requires two- to threefold increase of the water demand required to produce snow during a the winter season. Additional equipment, energy and manpower functioning costs are also expected to increase in the same proportions, with significant economic implications. This study corroborates the “shift of concern”, already identified by previous studies and assessments, from the climatic feasibility of snowmaking as an adaptation measure, into a water resources and socio-economic equation, in which climate change may play a secondary role.