

Integration of snow management practices into a detailed snow pack model

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The management of snow on ski slopes is a key socio-economic and environmental issue in mountain regions. Indeed the winter sports industry has become a very competitive global market although this economy remains particularly sensitive to weather and snow conditions. The understanding and implementation of snow management in detailed snowpack models is a major step towards a more realistic assessment of the evolution of snow conditions in ski resorts concerning past, present and future climate conditions.

Here we describe in a detailed manner the integration of snow management processes (grooming, snow-making) into the snowpack model Crocus (Spandre et al., *Cold Reg. Sci. Technol.*, in press). The effect of the tiller is explicitly taken into account and its effects on snow properties (density, snow microstructure) are simulated in addition to the compaction induced by the weight of the grooming machine. The production of snow in Crocus is carried out with respect to specific rules and current meteorological conditions. Model configurations and results are described in detail through sensitivity tests of the model of all parameters related to snow management processes. In-situ observations were carried out in four resorts in the French Alps during the 2014-2015 winter season considering for each resort natural, groomed only and groomed plus snowmaking conditions. The model provides realistic simulations of the snowpack properties with respect to these observations. The main uncertainty pertains to the efficiency of the snowmaking process. The observed ratio between the mass of machine-made snow on ski slopes and the water mass used for production was found to be lower than was expected from the literature, in every resort. The model now referred to as "Crocus-Resort" has been proven to provide realistic simulations of snow conditions on ski slopes and may be used for further investigations.

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