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Sensitivity of snow models to the accuracy of the meteorological forcing in a mountain environment

Silvia Terzago (1), Paolo Pogliotti (2), Edoardo Cremonese (2), Umberto Morra di Cella (2), Simone Gabellani (3), Gaia Piazzi (3), Daniele Dolia (3), Claudio Cassardo (4), Valentina Andreoli (4), Jost von Hardenberg (1), Elisa Palazzi (1), and Antonello Provenzale (5)

(1) Institute of Atmospheric Sciences and Climate, National Research Council of Italy, Torino, Italy (s.terzago@isac.cnr.it), (2) Regional Agency for Environmental Protection of Valle d'Aosta, Aosta, Italy, (3) CIMA Research Foundation, International Centre on Environmental Monitoring, Savona, Italy, (4) Department of Physics, University of Torino, Italy, (5) Institute of Geosciences and Earth Resources, National Research Council of Italy, Pisa, Italy

A wide range of snow models with different degrees of complexity is currently available, and typically the higher is the model sophistication, the heavier are input data requirements and computational costs. The choice of an appropriate degree of complexity depends on the specific purpose. Multi-layer, physically-based snow models are typically used to reconstruct the vertical structure of the snowpack with a high level of detail and high accuracy, for example useful for avalanche risk forecasting, while simpler physical or empirical snow models are employed as one component of a modelling chain, or when a coarse estimate of snow cover characteristics is sufficient.

Among the major challenges for cryospheric modelling research are i) the quantification of the snow model complexity which is needed to achieve accurate estimates of snow mass in different modelling frameworks and ii) the assessment of how the accuracy of the meteorological variables used to force snow models affects the quality of snow simulations. The latter aspect is particularly crucial in high mountain environments, where the variability of meteorological parameters is high both in space and time.

In the present work five snow models of different complexity – the multi-layer models SNOWPACK and GeoTOP, the intermediate complexity models UTOPIA and SMASH, and the relatively simpler model S3M – are compared to assess their ability in reproducing the temporal evolution of snow water equivalent, snow density and snow depth, at the experimental site of Torgnon, 2160 m a.s.l. in the Western Italian Alps. High-quality meteorological forcing and detailed characterization of snowpack properties are available for this measurement site. First, we evaluate the models forced by the accurate Torgnon station measurements at 30 minute temporal resolution, to measure the model skills in case of "optimal" forcing. Second, we force the models with input data with gradually lowered frequency and/or accuracy, which are obtained by spatial interpolation of neighboring station measurements and from three global reanalyses (ERA-Interim, ERA5 and GLDAS) by extracting the meteorological time series at the gridpoint closest to the Torgnon station.

This study provides information on how sensitive the snow models are to the accuracy of forcing data, exploring the feasibility of driving these models with coarser spatial and temporal resolution datasets, including interpolation of surface station measurements and reanalyses, typically the only data available in remote mountain areas. Guidelines on the trade-offs between model complexity and model performances are also provided, with the perspective of employing the best performing models to simulate past and future snowpack conditions at fine spatial scales.