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Sensitivity of surface temperature calculations to different subsurface schemes used in a spatially distributed operational snow model

Matthias Dusch (1), Marc Olefs (2), Roland Koch (2), and Friedrich Obleitner (1)

(1) Institute of Atmospheric and Cryospheric Sciences (ACINN), University of Innsbruck, Innsbruck, Austria, (2) Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Climate Research, Vienna, Austria (marc.olefs@zamg.ac.at)

Snow surface temperature (SST) characterizes surface exchange processes and is a key variable in atmospheric, glaciological and hydrological models. It determines emitted longwave radiation as well as sensible, latent and conductive heat fluxes.

The SST in numerical models is usually calculated by solving the energy balance in an iterative scheme tracking changes in internal energy of the snow cover, as well as turbulent and radiative fluxes. This is computational expensive, especially when models are used for area-wide simulations. Testing alternative methods being sufficiently fast and accurate in predicting SST is particularly crucial for models in an operational (nowcasting) setup, as is considered here.

For this study we compare three different methods:
(1) a simple conductive heat flux scheme with 2 vertical snow layers,
(2) a computationally more expensive conductive heat flux scheme with 100 vertical snow layers, which iteratively solves a vertical temperature profile of the snowpack,
(3) a recently published approach by Pomeroy et al. (2016). The latter propose a radiative-psychrometric model (RPM), which calculates SST based on sensible and latent heat fluxes, as well as longwave and near-infrared radiation. The approach is strongly based on the frequently observed decoupling of the SST from subsurface snow temperatures and does not require the time consuming calculation of vertical snow temperature profiles.

The methods are applied to a point version of the distributed snow cover model SNOWGRID (Olefs et al., 2013), which calculates the spatial variations of snow height and water equivalent in very high spatial and temporal resolution across Austria. To validate the results, we run the model for multiple locations based on input from automatic weather stations. Comparison of modeled SST to values derived from observations is considered as a measure of the skill of the model to correctly treat surface exchange processes. Comparison of simulated and observed snow height serves to demonstrate the skill to reproduce the mass balance evolution.

Regarding SST calculation the skills of method (1) and (2) are comparable, while using method (3) decreases the RMSE by around 25%. Method (2) provides better results regarding snow height compared to method (1). But the computation time can increase up to 10 times due to calculating vertical temperature profiles. The RPM model (3) is about 30% faster than the simple scheme (1), while it still provides snow height results comparable to (2).