Accuracy of the SMAP model-simulated snow density, temperature, and grain shapes at Sapporo, Japan

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A multi-layered physical snowpack model has a special feature that it can calculate temporal evolution of detailed snow internal stratigraphy. This characteristic is a considerable advantage of such a model, because it is impossible for a typical land surface model to simulate realistic layer structure of the snowpack. In the present study, we evaluated a 1-D multilayered physical snowpack model SMAP (Snow Metamorphism and Albedo Process) in terms of snow density, temperature and grain shapes using in-situ data obtained at Sapporo (43°05’N, 141°21’E, 15 m a.s.l.), Japan from the 2005 to 2015 winters (November to April). The model was driven by quality controlled 30-min averaged data for air temperature, relative humidity, wind speed, surface pressure, snow depth, liquid precipitation, downward and upward shortwave radiant flux, downward longwave radiant flux, and ground surface soil heat flux measured with an AWS installed at Sapporo.

Before investigating accuracy of the model-simulated snow internal physical properties, the SMAP model was evaluated in terms of column-integrated snow water equivalent (SWE) and snow surface temperature in order to check the mass and surface energy balances are calculated adequately. At Sapporo, SWE data was obtained by snow pit measurements, while snow surface temperature was observed with the AWS. Comparison of observed and simulated column-integrated SWE revealed that the model tended to underestimate SWE (mean error; ME was −19 mm); however, root mean square error (RMSE) was 34 mm, and these scores are better than those for simulations driven by not snow depth but precipitation (ME was less than −25 mm and RMSE was more than 40 mm). It suggests that the correction technique for precipitation measurements considering catch efficiency of a rain gauge is still insufficient. As for snow surface temperature simulated by the SMAP model, systematic overestimation nor underestimation was not found (ME = 0.4 ºC), and obtained RMSE was also in a sufficiently low (1.6 ºC). Overall, these results assure that the mass and surface energy balances of the snowpack at Sapporo were modeled and calculated reasonable enough by the SMAP model.

In the model validation in terms of snow internal physical properties, accuracy of the model-simulated snow density and temperature were investigated first using the in-situ measured data from snow pit works. Validation results indicated that the model tended to underestimate snow density (ME = −51 kg m^{-3}) and overestimate snow temperature (ME = 0.4 ºC); however, RMSE for both properties were sufficiently small (88 kg m^{-3} and 1.6 ºC, respectively). In order to permit higher precision of the model, it would be necessary to develop physically based schemes for new snow density and effective thermal conductivity of the snowpack. Next, snow grain shapes simulated by the SMAP model was evaluated using the manually measured data obtained from snow pit works. During accumulation period (November to February), precipitation particles, decomposing and fragmented precipitation particles, rounded grains, and melt forms were mainly observed at Sapporo. Generally, they were stratified from the surface to the bottom of the snowpack. On the other hand, during ablation period (March and April), melt forms were principally observed in the snowpack every winter period. Basically, these above mentioned features could be reproduced by the model; however, faceted crystals and depth hoar, which are generally developed through the temperature gradient metamorphisms, were not simulated by the model at all. It suggests that improving physical processes under the temperature gradient metamorphism, and reconsidering the method to diagnose snow grain shape from snow physical properties such as geometric grain size and water content are

quite necessary.

Keywords: the SMAP model, snow metamorphism, snow internal physical properties

