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Evaluation of a 1-D snowpack model SMAP applied in the Greenland ice sheet

Masashi Niwano (1), Teruo Aoki (1), Sumito Matoba (2), Satoru Yamaguchi (3), Tomonori Tanikawa (4), Hideaki Motoyama (5), and Katsuyuki Kuchiki (1)

(1) Meteorological Research Institute, Physical Meteorology Research Department, Tsukuba, Japan (mniwano@mri-jma.go.jp), (2) Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan, (3) Snow and Ice Research Center, National Research Institute for Earth Science and Disaster Prevention, Nagaoka, Japan, (4) Earth Observation Research Center, Japan Aerospace Exploration Agency, Tsukuba, Japan, (5) National Institute of Polar Research, Tachikawa, Japan

Snow and ice on the Greenland ice sheet (GrIS) are melting rapidly in recent years. In order to understand the mechanism and to perform reliable future projection on the mass balance of GrIS, we employ the 1-D physical snowpack model named Snow Metamorphism and Albedo Process (SMAP), which was originally developed and validated against seasonal snowpack, and adapt it for the simulation of polar snowpack. In the present study we tested SMAP using the data obtained during the 2012 intensive field observations (30 June to 13 July, 2012) conducted in the site SIGMA-A, which locates on northwest part of GrIS (78˚03'N, 67˚38'W, 1,490 m a.s.l.). During the latter half of the expedition period we encountered the record melt event where surface snow and ice over 97% of GrIS melted abruptly. In the model test the initial physical states of snowpack were given from those obtained by snow-pit observations carried out on 30 June. From the initial state we calculated temporal evolution of physical parameters of snowpack by forcing measured meteorological data, mass concentrations of snow impurities, and snow temperature at the depth of bottom ice formation in the latest annual layer (initial depth was 88 cm). The model performance was evaluated in terms of snow surface temperature, shortwave albedo, relative snow depth (to the ice formation in the latest annual layer), profiles of snow temperature, and snow density. Regarding snow surface temperature and shortwave albedo SMAP overestimated both, nevertheless biases were small (+0.143 ˚C and +0.014, respectively), suggesting that the snow-atmosphere energy exchange (snow surface energy balance) is modeled adequately. To calculate accurate relative snow depth it is necessary to simulate mass balance precisely. The acquired small bias (-0.026 m) shows that SMAP estimates mass balance successfully. Finally, as for profiles of snow temperature and snow density we found that SMAP tended to underestimate the former, while overestimate the latter. However, obtained small biases (less than 1 ˚C and ranged between 30 and 90 kg m^{-3}, respectively) indicate that SMAP calculates internal physical properties of snowpack in an appropriate manner if relevant upper and lower boundary conditions are imposed.