グリーンランド氷床表面の積雪融解に対する積雪粒径プロファイルの影響

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The effects of snow grain size profile on the Greenland ice sheet snow surface melt

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In July 2012, extreme surface melt events occurred on the Greenland Ice Sheet (GrIS). Generally, surface melt is physically controlled by the surface energy balance, where net shortwave radiant flux is the main energy source for melt during summer. Although (optically equivalent) snow grain size profile affects near-infrared albedo and in turn net shortwave radiant flux, its qualitative impacts on the surface melt events is unclear. In the present study we investigated effects of snow grain size profile on the surface melt event observed at the site SIGMA-A (78°03’N, 67°38’W, 1,490 m a.s.l.), which locates on northwest part of GrIS, during 30 June to 10 July 2012 through numerical studies with a physically based 1-D snowpack model SMAP. Observed snow physical state at SIGMA-A during 30 June to 13 July is indicated in Figure 1 in terms of snow grain shape profile. As shown in this figure, top melt form layers (depicted with red color) were expanded day by day as a result of surface melt during the period.

First of all, we simulated temporal evolution of physical states of near-surface snowpack at SIGMA-A during 30 June to 10 July 2012 by forcing *in-situ* meteorological data obtained at SIGMA-A. The depth of simulated snow layer, which was characterized by a thick bottom ice formation, was 88 cm on 30 June. The initial states of snowpack were given from the snow pit observation counducted on 30 June 2012, 16:45 UTC. It was found that the simulated shortwave albedo (ctrl in Figure 2) agreed well with measurements (R^2 = 0.820, root mean square error = 0.019, and mean error = 0.008).

Next, we performed two sensitivity tests with SMAP, where initial snow grain size profile was modulated in order to assess its impacts on the surface energy balance. In these tests we replaced the original snow grain size profile for the top 21 cm melt form layers depicted in Figure 1 (average snow grain size was 0.6 mm) with smaller (test1) and larger profiles (test2). In test1 top 21 cm snow grain size was equally set to be 0.02 mm, which is almost the minimum value for new snow. On the other hand, in test2, 1.0 mm, which is the typical maximum value for melt form observed in seasonal snowpack in Japan, was arranged in the top 21 cm layers. Figure 2 illustrates simulated shortwave albedos for test1 and test2 cases comparing against ctrl case. Obviously, simulated shortwave albedo for test1 is higher than that for ctrl continuously, while that for test2 was kept smaller than that for ctrl. Comparing simulated results for test1 and test2 we could know how surface energy balance could be varied with snow grain size profile. Obtained average differences in simulated shortwave albedo and net shortwave radiant flux between test1 and test2 were 0.06 and 21.8 W/m^2, respectively. It implies that snow grain size profile played an important role in controlling surface melt rate, which is an consequence of the surface energy balance, at SIGMA-A during 30 June to 10 July 2012.

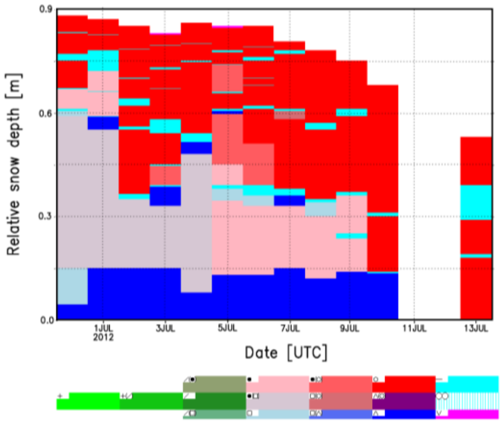

Figure 1. Temporal evolution of observed snow grain shape profile for the near-surface snow layer at SIGMA-A during 30 June to 13 July 2012. Vertical axis (relative snow depth) denotes height above the bottom thick ice formation, which was 88 cm depth on 30 June.

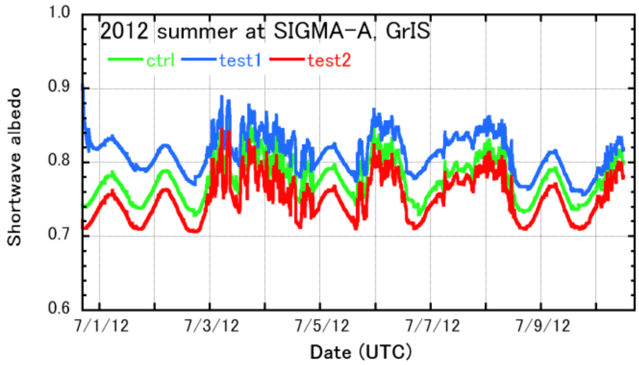

Figure 2. Simulations of Shortwave albedo at SIGMA-A during 30 June to 10 July 2012 with observed initial snow grain size profile (ctrl), reduced initial snow grain size profile (test1), and increased initial snow grain size profile (test2).