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SOLAR HEATING IN SNOWPACK AND RADIATIVE FORCING BY SNOW IMPURITIES EVALUATING BY A PHYSICALLY BASED SNOW ALBEDO MODEL

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For evaluating the radiative effects by the snow impurities and snow grain growth in the Arctic, a physically based snow albedo model (PBSAM, Aoki et al., 2011), which can be used in snowpack model, was developed. Since 2003, for developments of the snow albedo model such as the PBSAM and snowpack model, radiation budget and snow pit observation have been conducted at Sapporo (43°N, 141°E, 15 m a.s.l.), Hokkaido, Japan (e.g., Aoki et al. 2011, Kuchiki et al., 2009; Niwano et al., 2012). Using these data the visible and near-infrared (NIR) and shortwave (visible + NIR) broadband albedos, and solar heating profile in snowpack were calculated by PBSAM during five winters from 2006 to 2011. The input parameters to PBSAM for defining the modeled snow layer structure are snow grain size, mass concentrations of black carbon (BC) and mineral dust in the snowpack, snow water equivalent in each snow layer, which were measured twice a week. The broadband albedos calculated with PBSAM agreed well with the in-situ measurements, in which root mean square error was 0.056 for the shortwave albedo. The modeled snowpack consist of five snow layers of 0-2, 2-5, 5-10, 10-20 and 20-bottom. The solar heating (absorptivity) profile in these snow layers was calculated with PBSAM. When snow grain size was small in accumulation season (generally January and February), a large part of solar radiation absorbed by snowpack was absorbed by the topmost layer (0-2 cm). When snow grain size was large in melting season (generally March and April), the absorptivity in the second (2-5 cm) and the third (5-10 cm) layers increased. The lager snow grain size is, the lager light penetration depth is. Hence, the solar radiation penetrates and heats the deeper snow layers with an increase of snow grain size.

To estimate the quantitative effect of snow impurities on radiation budget the radiative forcing by snow impurities are calculated using PBSAM. The radiative forcing is defined as the difference in net solar radiation between impurity free case and impurity contained case for BC, dust and total impurities (BC + dust). The total radiative forcing is almost contributed from BC in accumulation season and from both BC and dust in melting season. However, BC forcing was generally larger than dust over the entire period. The values of radiative forcing were large in melting season (March and April) because of large solar radiation rather than high snow impurity concentrations in that season. Thus, the absolute value of radiative forcing is related to the snowpack duration. The radiative forcing averaged over five winters from 2006 to 2011 was 6.6 W m^{-2}, in which the contribution from BC was 73%. The albedo reduction averaged over the five winters was 0.055, in which the contribution from BC was 77%.

References
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