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Intercomparison of three snow metamorphism schemes

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The snow cover plays an important role in the Earth's climate system. For example, snow albedo feedback results in the enhanced warming especially in the Arctic. Therefore, a sophisticated snow process model with high accuracy is needed in general circulation models (GCM) for climate simulations. Recently, some physically based snow albedo models have been developed. These models explicitly consider the physical nature of the snow albedo that the visible albedo strongly depends on snow impurities such as black carbon or dust, while the near-infrared albedo strongly depends on snow grain size. To utilize these physically based snow albedo models in GCM, optically equivalent snow grain radius (r_{opt}), which is a radius of sphere with the same specific surface area (SSA) as that of a non-spherical real snow grain, is required to be calculated in GCM, because r_{opt} is an input parameter for these physically based snow albedo models. We developed a snow metamorphism module for GCM to calculate temporal changes in r_{opt}. It was developed using a one-dimensional snowpack model; Snow Metamorphism and Albedo Process (SMAP) model (Niwano et al., 2011, manuscript in preparation), and validated against measured data in Sapporo, Japan. In the module, the geometric shape of a snow grain was assumed to consist of two connecting spherical ice particles, which have the same radius r_g and are connected by a neck. The temporal changes in r_g were governed by the following four snow metamorphism processes: (1) equitemperature metamorphism, (2) temperature gradient metamorphism, (3) wet snow metamorphism, and (4) snow metamorphism under alternating temperature gradient. We finally obtained r_{opt} by calculating SSA from r_g and neck size of the snow grain. On the other hand, recently, two parameterizations to calculate snow SSA directly have been developed, though they cannot calculate the changes in snow SSA under wet snow condition. The first one is that by Domine et al. (2007), which employs a diagnostic equation as functions of snow grain shape and snow density (hereafter, we refer to it as 'D07'). The second one is that by Taillandier et al. (2007), which employs a prognostic equation as functions of the initial snow SSA, snow age, and snow temperature (hereafter, we refer to it as 'T07'). These two parameterizations were validated in Alaska, and reasonable agreements against observed snow SSA were demonstrated by Jacobi et al. (2010). However, the effects of D07 and T07 on the accuracy of calculated snow albedo are unclear. Therefore, we incorporated these two schemes into SMAP model, and evaluated their performances together with the original scheme of SMAP model using meteorological and snow impurities data measured in Sapporo. Since D07 and T07 do not take wet snow metamorphism into account, the evaluation was conducted during January and February, 2008. We confirmed that root mean square errors of calculated snow albedos were 0.0491, 0.0467, and 0.0449, and the mean errors were -0.0031, 0.0227, and -0.0041 for SMAP original scheme, D07, and T07, respectively. These results indicate that the performances of these three snow metamorphism schemes are comparable for dry snow.

Keywords: snow albedo, snow metamorphism, snow model, specific surface area of snow