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Snow physical parameters retrieved from a ground-based spectral radiometer using different shape models of snow particles

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Snow grain size and mass concentration of light absorbing impurities in snow are important parameters controlling snow albedo. An increase in snow grain size reduces the near-infrared albedo and that in light absorbing impurities reduces the visible albedo. Since the latter effect is larger for large snow grains, light absorbing impurities enhance the absorption of solar radiation and speed up grain growth, causing further albedo reduction. Therefore, monitoring of these snow parameters is important for understanding the resulting change of snow albedo. We developed an algorithm for retrieval of snow physical parameters using a ground-based spectral radiometer system for albedo and flux (GSAF). A two-snow layer model was adopted to retrieve snow grain sizes in top and bottom snow layers and mass concentration of light absorbing impurities optically equivalent to soot in whole snow layer from the three spectral channels at the wavelength of 0.44, 0.86, 1.23 μm. Three models of snow particle shape were used in the algorithm: sphere, spheroid and aggregate. The optical properties for spheres were based on Mie theory, while those for spheroids and aggregates were calculated using the geometrical optics approximation. In the spheroid model, the aspect ratio a/c of the prolate spheroid increased with the particle size, that is, elongated for small particles and close to sphere for large particles. The aggregate model was represented as aggregates of Voronoi cells. The snow grain size of the nonspherical particles was defined as the sphere radius that has the same volume-to-surface area ratio.

To validate the retrieval algorithm and effect of snow particle shape, we performed continuous measurements with the GSAF at two snow fields in Hokkaido, Japan. The retrieved snow grain sizes maintained relatively small in the accumulation season and gradually increased in the melting season. The snow grain sizes in the top layer were generally smaller than those in the bottom layer, which was consistent with the in-situ measurement. The agreements between retrieved and in-situ measured snow grain sizes were well with the spheroid model when the snow grains were small and with the aggregates model when the snow grains were large. The result implies that the shape model of prolate spheroid and aggregate are suitable for small snow grains such as new snow and for large snow grains such as granular snow, respectively. On the other hand, the soot mass concentrations were retrieved higher at an urban site than at a rural site, which was the same as in-situ measurements. They increased in the melting season as well as snow grain size. The spheroid model estimated generally higher soot concentrations than the sphere and aggregate models. Compared with the in-situ measured mass concentrations of elemental carbon, the retrieved soot concentrations were overestimated as a whole. The main cause of the overestimation is the light absorbing effect of the other impurities such as mineral dust which are not assumed in the algorithm.