Atmospheric aerosol depositions on snow surface and their effect on climate

Teruo Aoki[1]; Taichu Tanaka[2]; Akihiro Uchiyama[3]; Masahiro Hosaka[4]; Etsuko Tanaka[1]; Katsuyuki Kuchiki[1]; Hiroki Motoyoshi[5]; Yuji Kodama[6]

[1] MRI; [2] Meteorological Research Institute; [3] JMA, MRI; [4] Climate Research Institute, MRI; [5] Polar Science, SOKENDAI; [6] ILTS, HU

Climate change due to greenhouse gases is predicted to be significant in the cryosphere and thus the studies on mechanism of radiation budget on snow/ice surface are important for accurate climate simulation in the cryosphere. Since the snow albedo is one of the most important parameter to control the radiation budget on snow/ice surfaces, an understanding of physical process of snow albedo and the modeling (and/or the parameterization) are necessary. Hansen and Nazarenko (2004) showed that snow albedo reduction due to the deposition of black carbon (BC) aerosols on snow/ice surface is caused to a 0.17^{o}C rise of globally averaged temperature over the past 100 years using their climate model. However, they did not calculate the effect of BC deposition explicitly, but gave the snow albedo reduction as a boundary condition. In the present study, relationship between snow albedo and snow impurities (water-insoluble solid particles contained with light absorption) is investigated from the data set of long-period radiation budget observation with frequent snow pit work in Sapporo. Based on this result, the physically based snow albedo model, in which the albedo changes depending on snow parameters, was developed and incorporated into a climate model to investigate the climate impact of the atmospheric aerosol depositions on snow surface.

It was found from the data of snow albedos and snow impurities observed in Sapporo during the winters since 2003 that the mass concentration of snow impurities was kept at values less than 10 ppmw in the accumulation season (December to February) and exceeded 100 ppmw in the melting season (March to April). The corresponded snow albedos remained generally stable in the accumulation season and decreased in the melting season. The measured relationships between snow albedos and mass concentration of snow impurities during two winters in Sapporo were compared with theoretically predicted relationships calculated using a radiative transfer model for the atmosphere-snow system in which different types (in light absorption) of impurity models based on MD and BC were assumed. The result suggests that the snow in Sapporo was contaminated not only with MD but also with more absorptive BC. These results indicate that both the effects of MD and BC have to be incorporated into the physically based snow albedo model.

Snow albedo essentially depends on snow impurities, snow grain size, geometric illumination condition, and the atmospheric condition. We then developed a physically based snow albedo model, which predicts the visible and near infrared albedos as functions of BC and MD concentrations for snow impurities, snow grain size, and solar zenith angle for direct and diffuse components of solar radiation. The model was incorporated into the land surface process (LSM) in Model of Aerosol Species IN the Global Atmosphere (MASINGAR). The result of climate simulations with MASINGAR for the snow contaminated case and snow impurity free case showed that radiation budget difference at the top of the atmosphere between both the cases is +0.7 W/m^2 (positive value means the heating due to snow impurities) for all sky conditions and +1.12 W/m^2 for clear sky. These values are comparable to the direct or indirect effect of radiative forcing due to the atmospheric aerosols. The future possible increases of BC and MD emissions would enhance the snow albedo reduction and thus snow melting in the Arctic.

References

Hansen, J. and L. Nazarenko. 2004: Soot climate forcing via snow and ice albedos. Proc. Natl. Acad. Sci. USA, 101, 423-428, doi: 10.1073/pnas.2237157100.