Estimation of snow albedo reduction by light absorbing impurities using a Monte Carlo radiative transfer model

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Radiative forcing and climate change greatly depend on earth's surface albedo and its temporal and spatial variation. The surface albedo depends on the surface characteristics and ranges from 5-10% for calm ocean waters to 80% for some snow-covered areas. Clean and fresh snow surfaces have the highest albedo and are most sensitive to contamination with light absorbing impurities that can greatly reduce surface albedo and change overall radiative forcing estimates. Accurate estimation of snow albedo, as well as understanding of climate feedbacks from changes in snow-covered areas, is important for radiative forcing, snow energy balance, and predicting seasonal snowmelt and runoff rates. In particular, light absorbing particles from wildfires, if deposited onto snow surfaces, can greatly alter snow albedo and have been identified as a major contributor to regional climate forcing if seasonal snow cover is involved. However, uncertainty associated with quantification of albedo reduction by these light absorbing particles is high. Light absorbing particles can be mineral dust, black carbon (BC), brown carbon (BrC), or complex mixtures of them. So far, scientific work has focused on dust and BC and very little is known about the role of BrC.

We have applied a simple "Monte Carlo ray/photon tracing approach" to calculate the albedo of pure snow using fundamental optical constants [1]. Parametrization of single scattering parameters (i.e., single scattering albedo $\tilde{\omega}$ and asymmetry parameter g of pure snow was based on fractal, droxtal, and hallow column geometries along with spheres [2]. The single scattering parameters of impurities (from Siberian peat fire) were extracted from observation-based size distribution information and retrieved refractive index values from datasets obtained during laboratory combustion of biomass samples. Prior to any kind of multiple scattering calculation, Refractive indices of both snow and impurity were internally (using volume mixing rule of effective medium approximation) and externally mixed (where snow and smoke aerosols particles treated separately. In our Monte Carlo Approach, we have considered multiple scattering to be the "collection" of single scattering events. Using this approach, we vary the effective snow grain size and impurity concentrations to explore the snow albedo over a wide wavelength range (200–2000 nm). Results will be compared with those of the SNICAR two-stream model (http://snow.engin.umich.edu/snicarcode) for snow radiative transfer to better understand the differences in snow albedo computation between plane-parallel methods and statistical Monte Carlo methods.

References

[1] Warren, S. G., and Brandt, R. E., 2008: Optical constants of ice from the ultraviolet to the microwave: a revised compilation. *J. Geophys. Res.* **113**, D14220.

[2] Räisänen, P., Kokhanovsky, A., Guyot, G., Jourdan, O., and Nousiainen, T., 2015: Parameterization of single-scattering properties of snow. *Cryosphere* **9**, 1277–1301.

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