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Clouds, regional surface albedo and the downwelling solar irradiance: spectral dependence

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Multiple reflections between the surface and the cloud base can greatly influence the downwelling solar irradiance observed at the surface. Moreover, this influence depends not only on the local albedo value but on the distribution of surface albedo several or even several tens of kilometers away from the observation site. Thus, horizontal variations in surface albedo can complicate the interpretation of irradiance measurements, e.g. at typical near-costal Arctic observation sites. In our previous study (Pirazzini and Räisänen, J. Geophys. Res., 113, D20108, doi:10.1029/2008JD009815; hereafter PR08), this issue was addressed using a backward Monte Carlo radiative transfer model. An innovative feature of this model is that it keeps track of where the photons contributing to the observed downward irradiance have experienced surface reflections. The probability density function p(r) of these reflections, where r is the distance from the observation site, was then utilized to develop a parametrization for the effective surface albedo of a horizontally heterogeneous surface.

The study by PR08 considered only broadband results integrated over the solar spectrum. Here we extend this work by considering spectral variations in snow albedo and in the distance distribution p(r) of surface reflections. Consistent with PR08, it is found that cloud base height is the most important parameter influencing p(r): the higher the cloud base, the larger the region which influences the downwelling irradiance at the observation site. However, there are also significant spectral variations. In general, the relative impact of far-away surface reflections decreases with increasing wavelength, being largest in the UVA region and smallest in the near-IR region, particularly at wavelengths larger than 1.5 μm. The main factor leading to this behaviour is the strong spectral variation of snow albedo, albedo values being much higher in the UV and visible region (over 0.9 for pure small-grained snow) than at wavelengths larger than 1.5 μm (below 0.3). Rayleigh scattering by air molecules also influences the p(r) substantially at short wavelengths: in particular, when the cloud base is low and the cloud relatively thin optically, Rayleigh scattering above the cloud can enhance the role of far-away surface reflections. In comparison, spectral variations in cloud reflectance play a relatively minor role. Finally, the implications of these findings for the spectral effective albedo of a horizontally heterogeneous surface are discussed.