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Effects of snow grain non-sphericity on climate simulations: Sensitivity tests with the NorESM model

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Snow grains are non-spherical and generally irregular in shape. Still, in radiative transfer calculations, they are often treated as spheres. This also applies to the computation of snow albedo in the Snow, Ice, and Aerosol Radiation (SNICAR) model and in the Los Alamos sea ice model, version 4 (CICE4), both of which are employed in the Community Earth System Model and in the Norwegian Earth System Model (NorESM). In this work, we evaluate the effect of snow grain shape on climate simulated by NorESM in a slab ocean configuration of the model. An experiment with spherical snow grains (SPH) is compared with another (NONSPH) in which the snow shortwave single-scattering properties are based on a combination of non-spherical snow grain shapes optimized using measurements of angular scattering by blowing snow.

The key difference between these treatments is that the asymmetry parameter is smaller in the non-spherical case (≈ 0.78 in the visible region) than in the spherical case (≈ 0.89). Therefore, for a given snow grain size, the use of non-spherical snow grains yields a higher snow broadband albedo, typically by ≈0.03. Consequently, considering the spherical case as the baseline, the use of non-spherical snow grains results in a negative radiative forcing (RF), with a global-mean top-of-the-model value of $\approx -0.22\,\mathrm{W\,m^{-2}}$. Although this global-mean RF is modest, it has a rather substantial impact on the climate simulated by NoRESM. In particular, the global annual-mean 2-m air temperature in NONSPH is $1.17\,\mathrm{K}$ lower than in SPH, with substantially larger differences at high latitudes. The climatic response is amplified by strong snow and sea ice feedbacks. It is further found that the difference between NONSPH and SPH could be largely "tuned away" by adjusting the snow grain size in the NONSPH experiment by $\approx 70\%$.

The impact of snow grain shape on the radiative effect (RE) of absorbing aerosols in snow (black carbon and mineral dust) is also discussed. For an optically thick snowpack with a given snow grain effective size, the absorbing aerosol RE is smaller for non-spherical than for spherical snow grains. The reason for this is that due to the lower asymmetry parameter of the non-spherical snow grains, solar radiation does not penetrate as deep in snow as in the case of spherical snow grains. However, in a climate model simulation, the RE is sensitive to patterns of aerosol deposition and simulated snow cover. In fact, the global land-area mean absorbing aerosol RE is larger in the NONSPH than SPH experiment (0.193 vs. $0.168\,\mathrm{W\,m^{-2}}$), owing to later snowmelt in spring.