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Solar radiative effects of black carbon suspended in surface snow and in the atmosphere

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Black carbon (BC) aerosol represents one of the most important anthropogenic emission products in the Arctic and has an important impact on the radiative budget due to its strong light absorption and scattering behavior. The radiative forcing of BC does not depend only on the total atmospheric load, but it is also influenced by its vertical distribution from the upper atmosphere down to the snow. BC particles in a high altitude absorb and scatter a significant part of the incoming solar radiation causing dimming at the surface, which finally leads to local cooling of the near-surface air temperature. Locally produced and long-traveled BC particles are deposited on snow and ice surfaces by dry and wet removal from the atmosphere. The resulting reduction of the spectral surface albedo leads to a positive radiative forcing and a warming of the near-surface air. To quantify the two opposite surface radiative effects of atmospheric BC and BC in snow, a sensitivity study based on measured BC concentrations was performed.

An atmospheric radiative transfer model, the library for radiative transfer (libRadtran), was iteratively coupled with the Two-streAm Radiative TransfEr in Snow (TARTES) snow model. Two measured atmospheric BC mass concentration vertical profiles are considered. BC data from the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) campaign represent a rather polluted spring season, whereas the Arctic CLoud Observations Using airborne measurements during polar Day (ACLOUD) campaign the more pristine summer season. On the basis of the radiative transfer simulations using the measured BC profiles vertical profiles of the solar radiative forcing by BC in the atmosphere and in snow are presented. The diurnal cycle of BC radiative forcing is analyzed to estimate the impact of the solar zenith angle (SZA) and the daily mean radiative forcing. The simulations show that for 30 ng g^{-1} BC deposited in fresh snow and a maximum noon SZA of 60° the warming effect of BC suspended in snow dominates the radiative forcing at the surface leading to a positive surface radiative forcing of 2.2 W m^{-2}. The daily mean value is about 1.7 W m^{-2}. The surface cooling by atmospheric BC is significantly lower in the range of -0.25 W m^{-2}. However, in the atmosphere, a warming of BC containing layers of 0.4 K per day was calculated for the polluted ARCTAS BC profile. For the clean conditions of ACLOUD BC only warms by 0.05 K per day.

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