A Characterization of Arctic Aerosols and Their Forcing of the Surface Radiation Budget

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Aerosols, transported from distant source regions, influence the Arctic radiation balance. When deposited on snow and ice, carbonaceous particles reduce the surface albedo, which accelerates melting, leading to a temperature-albedo feedback that amplifies Arctic warming. Black Carbon (BC), in particular, has been implicated as a major warming agent at high latitudes. BC and co-emitted aerosols in the atmosphere, however, attenuate sunlight and radiatively cool the surface. Warming by soot deposition and cooling by atmospheric aerosols are referred to as “darkening" and “dimming” effects, respectively. Empirical quantification of the net radiative forcing by aerosols is needed to improve climate impact assessments. In this study, climatologies of spectral Aerosol Optical Depth (AOD) (2001-2011) and equivalent BC (1989-2011) from three climate observatories are used to characterize Arctic aerosols. Since the 1980s, concentrations of BC in the Arctic have decreased markedly, while AOD has increased slightly during the past decade. Variations are attributed to changing emission inventories and source strengths of natural aerosols, including biomass smoke and volcanic aerosol, further influenced by deposition rates and airflow patterns. A parameterization is developed to estimate the radiative forcing efficiency of wildfire smoke to compare with simulated forcing by BC deposited on snow. On a seasonal basis, dimming > darkening, resulting in a significant net radiative cooling at the surface. The results highlight the need to verify global circulation model simulations used currently to assess the climate impacts of BC and co-emitted aerosols at high latitudes.

Figure 1. The Arctic climate is influenced by the transport of aerosols from lower latitudes. Here, a thick layer of haze enshrouds Svalbard.

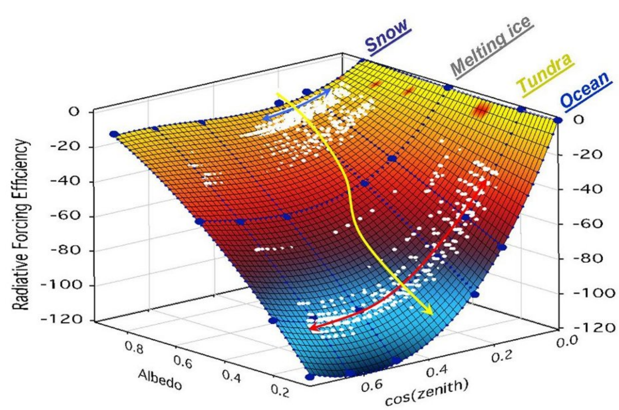

Figure 2. Radiative Forcing Efficiency varies greatly with solar angle and surface albedo during the annual cycle; example for smoke.