Arctic climate sensitivity to black carbon: Location and timing matter

M. G. FLANNER[1]

[1]Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, MI 48109, USA (correspondance: flanner@umich.edu)

Light absorbing aerosols like black carbon (BC) can warm climate through solar energy absorption, opposing the global net cooling effect of anthropogenic aerosols. The Arctic summer is uniquely vulnerable to radiative perturbations from BC because this environment is highly reflective and, during the solstice, exposed to more insolation than anywhere on Earth. Despite this vulnerability, the response of Arctic surface climate to BC cannot be easily inferred from top-of-atmosphere radiative forcing.

Here, results from idealized equilibrium climate simulations [1] are presented to characterize the response of the Arctic climate system to BC located: 1) at different altitudes in the Arctic atmosphere, 2) in Arctic surface snow and sea-ice, and 3) in the extra-Arctic atmosphere and snow. BC residing in the Arctic boundary layer and snow causes very strong warming normalized to radiative forcing or mass, resulting from powerful surface albedo feedback and removal of low clouds. Although BC at higher altitudes has a larger radiative efficiency due to its exposure to stronger insolation, it causes much weaker surface warming or even cooling. This phenomenon results from: 1) stable atmospheric conditions that prevail during the spring and early summer in the Arctic, which prevent efficient mixing between heated air aloft and the surface, 2) reduced surface insolation from BC absorption, which causes immediate surface cooling and further stabilizes the atmosphere, 3) enhanced cloud formation beneath the BC via the "semi-direct effect", and 4) reduced dynamical energy transport into the Arctic caused by a reduced latitudinal temperature gradient. BC forcing exerted at mid-latitudes, however, has the effect of increasing poleward energy transport and is thus relatively effective at warming the Arctic.

These results indicate that the pathway of atmospheric transport to the Arctic and likelihood of BC deposition within the Arctic can both strongly govern the climate impact of any particular emission source. These results also suggest that models must simulate reasonable vertical profiles of BC and local deposition processes in order to accurately capture high-latitude climate response to BC.

[1] Flanner, M. G. (2013), Arctic climate sensitivity to local black carbon, *J. Geophys. Res. Atmos.*, **118**, 1840-1851, doi:10.1002/jgrd.50176.