Regional Climate Change: The Role of Light-Absorbing Aerosols and Snow-Albedo Feedback

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We illustrate evidence of mountain snowmelt produced by climate change and global warming, followed by a discussion of the role of anthropogenic light-absorbing black carbon (or soot) in direct radiative forcings and regional warming. Two specific mountain areas, including the Sierra Nevada Mountains in the western United States and the Tibetan Plateau, were studied. For the latter, we review the existing observations and analyses and the importance of anthropogenic black carbon in the reduction of snow cover. For the former, the presence in the Sierras of black carbon and dust particles resulting from the trans-Pacific transport of these aerosols from East Asia is illustrated by satellite data and a chemical transport model.

Black carbon particles, which have highly complex and often inhomogeneous morphologies, are a type of aerosol that profoundly affect vertical heating profiles by directly absorbing sunlight in the atmosphere. The radiative transfer schemes that have been used in modern climate models have not taken into consideration the effects their open/closed cell structures and the external/internal mixing states in snow grains have on the evaluation of snow albedo reduction. We introduce a new theoretical development for the construction of fractal soot aggregates by mean of stochastic procedures using homogeneous and core-shell spheres with smooth or rough surfaces as building blocks. The complex aggregate shape and composition can then be accounted for in light absorption and scattering calculations by using the hit-and-miss Monte Carlo geometric photon tracing and surface-wave approach. We demonstrate that small soot particles on the order of 1 μm, internally mixed with snow grains, could effectively reduce snow albedo by as much as 5-10%.

Indeed, the deposition of black carbon would substantially reduce mountain-snow albedo, which would lead to surface warming and snowmelt, critical to surface temperature amplification and feedback. Finally, we discuss the importance of solar insolation distribution in three-dimensional and intense topography in conjunction with aerosols-snow-albedo feedback.