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Radiative forcing by dust deposition in mountain snow cover

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Regional, intracontinental, and intercontinental dust transport frequently deposit in mountain snow cover. Winter and spring storms entrain radiatively absorbing dust from desert regions and redistribute optically thick layers to the snow cover in the San Juan Mountains of Colorado as wet and dry deposition. Dust loading in the atmosphere temporarily decreases the surface irradiance through scattering and absorption. However, dust loading at the snow surface, which persists well beyond the atmospheric presence of the dust event, positively forces tropospheric temperatures through direct and indirect effects. Absorption by dust in the snow increases near-surface snowpack temperatures, decreasing the column cold content of the snowpack and increasing the energy available for melt. Enhanced absorption represents the direct effect of dust deposition on the regional radiative budget. Indirect effects occur as associated increases in snow grain size (further lowering albedo) and the more rapid snowpack ablation that reveals a darker substrate. We observed several significant dust deposition events during the mountain snowcover season in the years 2002/2003, 2003/2004, and 2004/2005. The average date of the first dust event of the season over this period was March 18, the average date of all dust events was April 5, and the average date of the last dust deposition on snow was April 28. Dust events came as late as May 11, 2004. Our monitoring of surface radiative fluxes commenced in winter 2005 at an alpine meteorological tower and a subalpine meteorological tower in the San Juan Mountains. In the winter/spring of 2005, dust presence represented a radiative forcing enhancement of 35-70% relative to dust-free conditions. Chemical and mineralogical analysis of dust samples from snowcover and ensemble backtrajectory analyses indicate dust provenance in the southwestern US, with strong absorption in the wavelength range 0.3-0.6 micrometers. In this work we present analyses of detailed in situ mea-

surements of broadband and spectral shortwave radiation, field measurements of the hyperspectral shortwave radiation, and coupling of the above measurements with remotely sensed multispectral and hyperspectral imagery to estimate the impact of dust deposits on regional radiative forcing. Given the regional extent of dust deposition, direct and indirect effects of dust in snow may provide a positive forcing of tropospheric temperatures that would significantly outweigh the negative forcing of dust loading in the atmosphere at the regional scale.