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Mineral dust radiative effect on snow in European Alps

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Mineral Dust (MD) is known to increase the absorption of solar radiation when deposited on snow and ice. This process causes a decrease in the albedo and may enhance snow melting, resulting in a positive radiative forcing (RF) in climate system. The RF from MD on snow can assume high values ($\sim$100-200 W/m^2) after depositional events altering snow and ice radiative balance and hydrological cycle.

In this study, we analyzed a significant MD transport happened during spring in 2014 and in particular its impact on snow optical properties. The dust plume was entrained in the troposphere over the Saharan desert (North African Grand Erg Oriental) during the passage of a cold front, and then transported NE over the Mediterranean by cyclonic atmospheric conditions. MD reached the European Alps where it was deposited by snowfall. We conducted a field proximal sensing survey in 10 plots (2x2 meters) at the Artavaggio plains (Lecco, Italy) with a hyperspectral radiometer (ASD Field-spec pro) collecting reflected radiance of snow in a spectral range between 350 and 2500 nm. Surface snow samples were collected and analyzed in clean room with microparticle counter in order to determine the size distribution and the concentration of MD in each sample. In addition, total mass of insoluble material was also measured by filtering the melted snow. Observed spectra were compared to those simulated by parameterizing the Snow, Ice, and Aerosol Radiation (SNICAR) radiative transfer model with observed variables such as snow grain size, snow density and size distribution of MD. We defined a novel spectral index, the Snow Darkening Index (SDI) to combine red and green wavelengths showing nonlinear correlation with measured MD concentration. Instantaneous radiative forcing was then estimated as the spectral difference between upwelling irradiance of plot containing MD and pure snow plots. MD concentration was up to 107 ppm and total mass of insoluble material up to 325 ppm. Measured RF values reached 153 W/m^2 in the highest concentrated plot.

During the survey, an overflight of a four-rotors Unmanned Aerial Vehicle (UAV) equipped with an RGB digital camera sensor was organized. Data from UAV were analysed in order to produce a high resolution Digital Surface Model and an orthomosaic image of the area. Furthermore, RBG channels were combined to produce a detailed SDI map of the study area. Finally, a Landsat 8 Operational Land Imager (OLI) tile was atmospherically and topographically corrected and maps of SDI in central European Alps were calculated from red and green reflectances. MD in snow showed high spatial variability with higher concentration in South facing slopes. These results represent the first evidence that aeolian transported MD from desert region can strongly influence snow and ice radiative balance in European Alps.