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# Black Carbon and Dust in the snow of Chilean Central Andes: From albedo reductions to radiative forcing

**Maria Florencia Ruggeri**, Ximena Fadic, Gonzalo Barcaza, and Francisco Cereceda-Balic
Centre for Environmental Technologies (CETAM), Universidad Técnica Federico Santa María, Valparaíso, Chile
(maria.ruggeri@usm.cl)

The cryosphere, a vital component of the Earth's climate system, holds substantial importance in both the hydrological cycle and the energy balance. Current apprehension turns around alterations in the cryosphere linked to the reduction in Surface Snow Albedo (SSA).

The decrease in SSA is primarily attributed to the presence of light-absorbing particles (LAPs) and the growth of snow grain size (SGS). The quantitative assessment of these SSA reductions' climatic impact is reflected through their Radiative Forcing (RF), indicating the change they induce in the net radiative flux at the tropopause or the top of the atmosphere. LAPs, mainly composed of Black Carbon (BC) and Mineral Dust (MD), contribute to albedo reduction at visible wavelengths. BC originates from the incomplete combustion of fossil fuels and biomass, while MD primarily emanates from arid and semi-arid regions with low vegetation cover. Precise RF calculations resulting from SSA reductions gain significance, particularly in regions where snow cover governs freshwater availability. Chile exemplifies such a concern, possessing the largest portion of the Andean cryosphere, highly responsive to climate change. This has significant implications for water resources, impacting freshwater availability for Chile's residents and key economic activities.

To quantify the Radiative Forcing RF generated by LAPs in the Chilean Central Andes, snow samples were collected at Portillo, from 2017 to 2022. NUNATAK-1 is a portable, flexible, collaborative scientific platform belonging to the Centre for Environmental Technologies (CETAM-UTFSM), specially designed for research campaigns under extreme conditions, equipped with different automatic and real-time monitoring instruments to measure meteorology, net albedo, solar radiation, gases and aerosols, among others. The samples underwent analysis to determine BC and MD concentrations, following the methodologies outlined in Cereceda-Balic et al. (2022). Snow albedo was modeled using the SNow, ICe, and Aerosol Radiation (SNICAR). Evaluating the singular and combined effects of LAPs, snow albedo was simulated for four scenarios: clean snow (without LAPs), BC only, dust only, and BC + dust. RF represents the variance in absorption between LAP-influenced scenarios and clean snow. For RF calculation, measured solar irradiance specific to each sampling date at the designated site was used. BC concentrations ranged from 2.6 to 717.2 ng $g^{-1}$, while MD concentrations varied between 1.6 and 181.3 mg $kg^{-1}$, leading to SSA reductions of up to 21% relative to clean snow. Notably, it was observed that the absorption produced by BC and MD could be comparable, underscoring the significant role of MD in this

semiarid location. Moreover, even with relatively moderate or low LAP concentrations in the snow, substantial RF values are generated, emphasizing the heightened climatic influence of LAPs in the region.

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