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Large radiative forcing efficiency of atmospheric aerosols over the Himalaya

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This study is based on measurements made at the Nepal Climate Observatory at Pyramid (NCO-P, 27.95 N, 86.82 E), located at 5079 m altitude in the Sagamartha National Park, Eastern Nepal Himalaya. We analised seasonal variations of solar downward irradiance (SW), columnar water vapour content (wv), aerosol optical depth at 500 nm (τ) and surface albedo (A) in the period between 2007 and 2010, in order to obtain the radiative perturbations produced by aerosols in the SW. SW measurements are carried out by a CMP21 pyranometer, while A is derived from a CNR1 radiometer. Values of wv and τ are retrieved from the measurements by the EVK2-CNR Cimel sunphotometer operating within the AERONET network.

τ was found to be lower than 0.1 in 98% of the cases. However, during the pre-monsoon season, especially in the months of April and May, cases with τ reaching 0.27 were recorded.

The aerosol surface shortwave radiative effect in cloud-free periods was estimated during the elevated aerosol optical depth cases using different methods. The "hybrid method" was applied using experimental measurements of solar downward irradiance and simulations made with the MODTRAN (MODerate resolution atmospheric TRANsmission) model. The dependency of SW on A and wv was determined from MODTRAN simulations, and was used to correct experimental measurements for albedo and water vapour changes. The radiative perturbation produced by aerosol was thus obtained as the difference between the measured irradiances and the modelled values for aerosol-free conditions and the same water vapour and albedo values, and at the same solar zenith angle. The aerosol radiative effect was also derived by comparing elevated and low aerosol optical depth cases, at similar values of solar zenith angle, albedo, and column water vapour. In addition the direct method, relating SW to changes in τ, was also used.

These three methods produce consistent results. Although the overall aerosol radiative perturbation is small, it becomes relatively large during elevated aerosol cases. The radiative forcing efficiency (radiative effect produced by a unit aerosol optical depth) is significantly larger than at other sites worldwide, reaching values above 360 W/m^2 at about 50° solar zenith angle. The maximum radiative effect is about -90$\pm$18 Wm^{-2} (for τ=0.25), corresponding to a reduction by more than 10% of the solar radiation at the surface.

During these elevated aerosol events high concentrations of pollutants were measured: PM10 and PM 2.5 showed concentrations higher than 50 ng m^{-3}, while the black carbon concentration reached 3000 ng m^{-3}. The backtrajectory analysis for the elevated aerosol cases shows that the polluted airmasses observed at NCO-P come from Indo-Gangetic plain and Punjab, regions characterized by the highest industrial and demographic concentration of the Indian subcontinent.