EGU21-5916
https://doi.org/10.5194/egusphere-egu21-5916
EGU General Assembly 2021

Contrasting signatures of the sources and types of aerosols in the western and eastern Himalayas: Radiative implications

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The rapid changes in the pattern of atmospheric warming over the Himalayas, along with severe degradation of Himalayan glaciers in recent years suggest the inevitability of accurate source characterization and quantification of the impact of aerosols on the Himalayan atmosphere and snow. In this regard, extensive study of the chemical compositions of aerosols at two distinct regions, Himansh (32.4°N, 77.6°E, ~ 4080 m a.s.l) and Lachung (27.4°N, 88.4°E, ~ 2700 m a.s.l), elucidates distinct signatures of the sources and types of aerosols prevailing over the western and eastern parts of Himalayas. The mass-mixing ratios of water-soluble (Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cl-, SO_4^{2-}, NO_3^-, MSA^-, $C_2O_4^{2-}$), carbonaceous (EC, OC, WSOC) and selected elemental (Al, Fe, Cu, Cr, Ti) species depicted significant abundance of mineral dust aerosols (~ 67%), along with a significant contribution of carbonaceous aerosols (~ 9%) during summer to autumn (August-October) over the western Himalayan site. On the other hand, the eastern Himalayan site is found to be dominant of OC (~ 53% in winter) followed by SO_4^{2-} (as high as 37% in spring) and EC (8-12%) during August to February. However, OC/EC and WSOC/OC ratios showed significantly higher values over both the sites (~ 12.5, and 0.56 at Himansh; ~ 5.7 and ~ 0.74 at Lachung) indicating the secondary formation of organic aerosols via chemical aging over both the sites. The enrichment factors estimated from the concentrations of trace elements over the western Himalayan site revealed the influence of anthropogenic source contribution from the regional hot-spots of Indo-Gangetic Plains, in addition to that of west Asia and the Middle East countries. On the other hand, the source apportionment of aerosols (based on positive matrix factorization - PMF model) over the eastern Himalayas demonstrated the biomass-burning aerosols (25.94%), secondary formation of aerosols via chemical aging (15.94%), vehicular and industrial emissions (20.54%), primary emission sources associated with mineral dust sources (22.28%) and aged secondary aerosols (15.31%) as the major sources of aerosols. Due to abundant anthropogenic source impacts at the eastern Himalayan site, the atmospheric forcing is most elevated in winter (13.4 ± 4.4 Wm^{-2}), which is more than two times the average values seen at the western Himalayan region during the study period. The heavily polluted eastern part of the IGP is a potential anthropogenic source region contributing to the aerosol loading at the eastern Himalayas. These observations have far-reaching implications in view of the role of aerosols on regional radiative balance and their impact on snow/glacier coverage.