Atmospheric water-soluble constituents in fine and coarse mode aerosols from high-altitude site in western India: Long-range transport and seasonal variability

Ashwini Kumar, M.M. Sarin

Physical Research Laboratory, Ahmedabad 380 009, India

A R T I C L E   I N F O

Article history:
Received 1 June 2009
Accepted 25 December 2009

Keywords:
Aerosol chemistry
Mineral dust
Acid uptake

A B S T R A C T

We present a comprehensive one-year data set on water-soluble ionic species (Na+, NH4+, K+, Mg2+, Ca2+, Cl−, NO3−, SO42−, and HCO3−) in PM2.5 (fine) and PM10–2.5 (coarse) aerosols from a high-altitude site (Mt. Abu, 24.6° N, 72.7° E, 1680 m asl) in high-dust region of western India. The water-soluble ionic composition (WSIC) varied from 1.0 to 19.5 μg m⁻³ in the fine mode and constitutes 50, 39 and 31% of the aerosol mass during winter, summer and monsoon respectively, with dominant contribution from SO42−, NH4+ and HCO3−. Furthermore, a two-fold increase in the abundances of nss-SO42− and NH4+ and their co-variability during wintertime, relative to high-dust conditions in summer, suggest dominance of anthropogenic sources and long-range transport of combustion products (biomass burning and fossil-fuel emissions) from northern India. In the coarse mode, WSIC ranged from 0.1 to 24.8 μg m⁻³ and its contribution to aerosol mass was consistently low (annual average ~ 21%) with predominance of Ca2+ and HCO3−, indicating contribution from carbonate rich mineral dust. The nss-SO42− /NO3− mass ratio exhibits extreme variability during winter, with values ranging from 2.7 to 101 in PM2.5 and 0.001 to 2.7 in coarse (PM10–2.5) mode. The relatively high abundance of nitrate in the coarse mode, during all seasons, indicates its association with mineral dust. The temporal variability is further evident from significantly lower aerosol mass and WSIC during the SW-monsoon (July–Sept) due to efficient washout. The chemical data set also documents near quantitative neutralization of acidic species (NO3−, SO42−, and HCO3−) by NH4 in PM2.5 and mineral dust in PM10–2.5, thus, representing a dominant atmospheric chemical transformation process occurring in the high-dust semi-arid region.

1. Introduction

It is well recognized that ubiquitous presence of aerosols in the atmosphere, derived from natural sources (mineral dust, sea-salts and volcanic emissions), had a pronounced impact on the global climate system in the past. With the present-day growing anthropogenic activities (contributing to sulphate, nitrate and carbonaceous species), the global mean aerosol burden of the atmosphere has been substantially altered (both in terms of physical and chemical properties of aerosols). As a result, the recent studies on direct effects of aerosols have gained significant importance in amplifying/damping climate change on a regional to global scale. In addition, an increase in number density of sub-micron size particles and their ability to act as cloud condensation nuclei (CCN) have become the basis for studying the indirect effects of aerosols (Ramanathan et al., 2001a,b). Recent studies have shown that the atmospheric radiative forcing due to anthropogenic aerosols is capable of offsetting the forcing caused by the greenhouse gases (Intergovernmental Panel on Climate Change (IPCC, 2001)). However, a large degree of uncertainty in the earlier evaluation (IPCC, 2001) has been somewhat better constrained in recent years through the availability of emerging data on chemical and physical properties of aerosols (IPCC, 2007). From a different perspective, increase in the abundances of mineral and anthropogenic aerosols has potential to affect the atmospheric chemistry as well as marine ecosystem in remote oceanic regions (Duce et al., 1991; Jickells, 1999; Arimoto, 2001; Jickells et al., 2005).

The south Asian region is currently undergoing rapid industrialization, thus, making this region a hot spot for anthropogenic emissions (Arimoto et al., 1996; Streets et al., 2003). Moreover, mineral aerosols produced from land-use changes and disturbed soils are the important constituents of the atmosphere, especially those originating from the arid and semi-arid region of Asia (Dentener et al., 1996; Song and Carmichael, 2001; Rastogi and...