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Aerosol mass size distribution and black carbon over a high altitude location in Western Trans-Himalayas: Impact of a dust episode

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ABSTRACT

The information on the aerosol properties from remote locations provides insights into the background and natural conditions against which anthropogenic impacts could be compared. Measurements of the near surface aerosol mass size distribution from the high altitude remote site help us to understand the natural processes, such as, the association between Aeolian and fluvial processes that have a direct bearing on the mass concentrations, especially in the larger size ranges. In the present study, the total mass concentration and mass-size distribution of the near surface aerosols, measured using a 10-channel Quartz Crystal Microbalance (QCM) Impactor from a high altitude location-Hanle (32.78°N, 78.95°E, 4520 m asl) in the western Trans-Himalayas, have been used to characterize the composite aerosols. Also the impact of a highly localized, short-duration dust storm episode on the mass size distribution has been examined. In general, though the total mass concentration (M_t) remained very low ($\sim$0.75 ± 0.61 μg m^{-3}), interestingly, coarse mode (super-micron) aerosols contributed almost 72 ± 6% to the total aerosol mass loading near the surface. The mass-size distribution showed 3 modes, a fine particle mode ($\sim$0.2 μm), an accumulation mode at $\sim$0.5 μm, and a coarse mode at $\sim$3 μm. During a localized short duration dust storm episode, M_t reached as high as $\sim$13.5 μg m^{-3} with coarse mode aerosols contributing to nearly 90% of it. The mass size distribution changed significantly, with a broad coarse mode so that the accumulation mode became inconspicuous. Concurrent measurements of aerosol black carbon (BC) using twin wavelength measurements of the aethalometer showed an increase in the wavelength index of absorption, from the normal values of $\sim$1 to 1.5 signifying the enhanced absorption at the short wavelength (380 nm) by the dust.

1. Introduction

The regional and global environmental and climate impacts of dust and black carbon (BC) aerosols are widely acknowledged by the scientific community (Haywood et al., 2001; Jacobson, 2001; Kaufman et al., 2001; Deepshikha et al., 2005; Lau et al., 2006; IPCC, 2007; Moorthy et al., 2007; Ramanathan and Carmichael, 2008; Seinfeld, 2008; Lawrence and Lelieveld, 2010; Shao et al., 2011). The effects include the perturbation to regional radiative balance (Tanré et al., 2003; Moorthy et al., 2009), modification of ocean bio-geochemistry (Falkowski et al., 1998; Fung et al., 2000), depression of Infra Red radiance from the earth's surface as received by satellites (Legrand et al., 2001), influence induced on regional circulation (Lau et al., 2006; Rosenfeld et al., 2008), effect on visibility and health hazards (Morman and Plumlee, 2013; Harrison et al., 2010). Shao et al. (2011) provided a detailed review of dust cycle including its sources, sinks, transport patterns and the climatological influence of dust. Dust aerosols can affect the major weather processes and short-term climate at the local scale by absorbing and scattering shortwave solar radiation (Carlson and Benjamin, 1980; Prospero et al., 2002; Shao et al., 2011). If they are coated with absorbing aerosols like black carbon and during strong convective conditions, they can influence synoptic scale circulation systems also (Alpert et al., 1998; McFarquhar and Wang, 2006). Size distribution and mass concentration are among the most significant physical properties relevant to the environmental impact assessment of the poly-disperse aerosol system. These properties, like many other aerosol properties, are highly dependent on the source-sink characteristics, meteorological conditions, synoptic as well as mesoscale circulation processes and show high spatio-temporal variability. In this regard, the information on the mass size distribution from extremely remote locations assumes significance as they provide details about the background, natural conditions-far less impacted by anthropogenic

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activities. High altitude near-pristine locations offer some of the best locations to investigate this. While the aerosol mass loading over urban and semi-urban regions are reasonably well documented, such measurements from high altitude remote regions are sparse. This is true over the Indian Himalayan region. The reasons are several; and include the difficulties in making the measurements from such remote locations (instrumental and logistics) and an apparent absence of immediate relevance to a largely populated environment. However these offer ideal conditions for dust rising, with highly subdued human activities, the uneven and arid topography with large expanse of arid soil, devoid of vegetation and scanty rainfall and dry atmospheric conditions; all presenting a high-altitude desert like environments. The strong prevailing winds are conducive to lift the loose soil during summer season, when the soil is exposed due to the melting off of the snow cover. The topographical unevenness, which combined with arid and dry nature of Himalayas, is conducive for local scale dust mobilization (Prospero et al., 2002), more so in summer season because of the increased degree of disturbance of soil surface due to considerably high temperatures, wind speeds and low moisture content. In this paper we present the characteristics of near-surface aerosols over Hanle and examine and discuss the impact of a short dust storm in modifying these.

2. Measurements

2.1. Location

The experimental location, Hanle (32.78°N, 78.96°E; 4520 m amsl), situated in western Indian Himalayas to the Southwest of the Tibetan Plateau, represents a free tropospheric environment far removed from any significant human activities (Moorthy et al., 2011; Babu et al., 2011). The measurement site, atop Mt Saraswati, is above ~300 m above the surrounding valley region (Fig. 1). The area around the observatory is mostly rocky and sandy with very little vegetation (like shrubs), which disappears by the end of summer and reappears only by next spring. This mountain peak is surrounded by several similar or taller peaks; many of them are snow covered or snow-capped, all maintaining a natural environment of sparse vegetation and arid regions akin to a tall mountain desert. In general, the site is significantly dry throughout the year with an annual precipitation of <10 cm (Verma et al., 2009).

2.2. Data

Near real time mass size distribution and total mass concentration of composite aerosols have been estimated using a 10-channel Quartz Crystal Microbalance (QCM) Impactor (Model: PC-2HX, California measurements) and mass concentrations of BC using a dual channel Aethalometer (Model AE31 of Magee Scientific) supplemented with an external pump to maintain a steady and sufficient sample flow at the ambient pressure of ~590 h Pa. The QCM aspires the ambient air and separates the particles into different size bins depending upon their aerodynamic diameter (D_a) (Pillai and Moorthy, 2001; Pillai et al., 2002). The sampling time is kept at 5 min and flow rate is monitored using a flow meter and fine-tuned to a pre-set value of 2 standard liters per minute (slpm). This is essential in order to maintain the 50% lower cutoff diameters, which vary as an inverse square root function of the volume flow rate as the desired cutoff is related to the total volumetric flow through the stage (May et al., 1976). This particular configuration enables segregation of particles into ten size bins between 10 μm and 0.1 μm with 50% lower cutoff diameters at 10 μm, 7, 4, 2.5, 1.2, 0.70, 0.45, 0.3, 0.2 and 0.1 μm respectively for the stages 1–10, respectively.

From the mass concentration M_{ci} (i = 1,10) in the individual stages, the total mass concentration is estimated as

$$M_T = \sum_{i=1}^{10} m_{ci} \quad (1)$$

Both parameters (M_T and m_{ci}) are used independently to infer on the aerosol characteristics. The size-segregated mass concentration information is used to separate M_T into Accumulation (M_{acc}) and Coarse mode (M_{coar}) aerosol mass concentrations: such that,

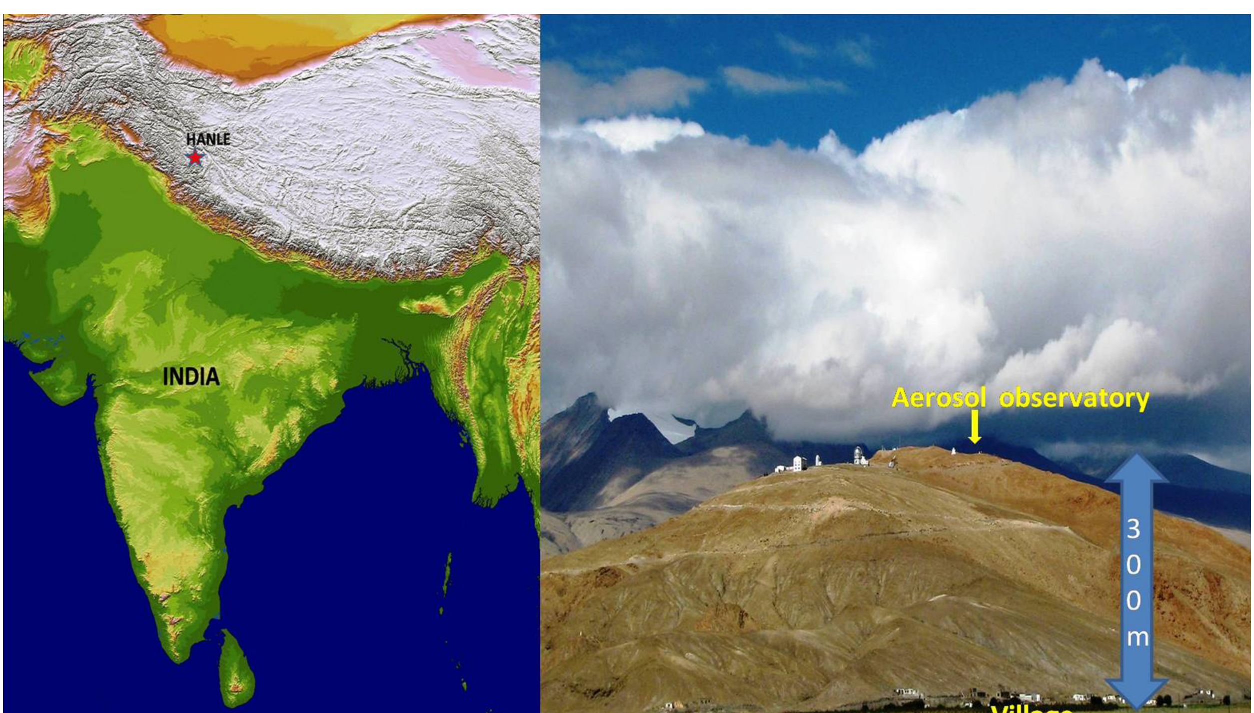

Fig. 1. (a) Geographic Location of Hanle marked by the red star (b) Aerosol observatory located on the mountain top. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)