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Aerosol extinction properties over coastal West Bengal Gangetic plain under inter-seasonal and sea breeze influenced transport processes

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ABSTRACT

We analysed the atmospheric aerosol extinction properties under an influence of inter-seasonal and sea breeze (SB) transport processes over coastal West Bengal (WB) Gangetic plain (WBGP). The predominant frequency of airmass back trajectory path was through the Arabian Sea (AS) during southwest monsoon (SWmon) and that through the Indo-Gangetic plain (IGP) during transition to winter (Twin) season and the Bay of Bengal during transition to summer (Tsumm) season. Aerosol surface concentration (Sconc) and aerosol extinction exhibited heterogeneity in the seasonal variability over coastal WBGP with their highest seasonal mean being during winter and summer seasons respectively. Seasonal mean extinction was respectively 17% and 30% higher during winter and summer seasons than that during SWmon. While angstrom exponent (AE) was less than one during SWmon, Tsumm, and summer seasons, it was near to one during Twin and winter monsoon (Wmon), and was more than one during winter season. Relative contribution (%) of upper (at altitude above 1 km) aerosol layer (UAL) to aerosol extinction during summer was four times of that during winter. Seasonally distinct vertical distribution of aerosol extinction associated with meteorological and SB influenced transport and that due to influence of high rise open burning emissions was inferred. Possible aerosol subtypes extracted during days in Tsumm were inferred to be mostly constituted of dust and polluted dust during daytime, in addition to polluted continental and smoke in UAL during nighttime. In contrast to that at nearby urban location (Kolkata, KOL), intensity of updraft of airmass evaluated during evening/SB activity hour (1730 local time, (LT)) at study site (Kharagpur, KGP) was as high as 3.5 times the intensity during near to noon hour (1130 LT); this intensity was the highest along coast of westBengal-Orissa. Enhanced Sconc and relative contribution of UAL to aerosol extinction (58% compared to 36% only at nearby urban location) was inferred associated with SB activity.

1. Introduction

Atmospheric aerosols are one of the important atmospheric parameters that influence the Earth's energy balance (Remer et al., 2005; Ramanathan et al., 2001; Haywood and Ramaswamy, 1998). This influence is directly through scattering and absorption of solar radiation and indirectly through changing the cloud properties and its lifetime (Myhre, 2009; Kaufman et al., 2002; Satheesh and Ramanathan, 2000). Aerosol particles arise from various anthropogenic sources, such as emissions from combustion of fossil fuel (coal and oil) for energy and transportation, industrial and agricultural activities, biomass burning, and deforestation (Seinfeld and Pandis, 1998). These particles are also of natural origin comprising of constituents such as the wind-blown dust and sea salt. The relative distribution of anthropogenic and natural components influence aerosol optical properties and subsequently their ability to interact with solar radiation. Anthropogenic aerosol particles have been identified as an important atmospheric pollutant and climate forcing agent that vary greatly in their ability to affect air quality and impose climate change (Forster et al., 2007; Calvo et al., 2013; Reid et al., 2013). Unlike greenhouse gases, aerosols are short-lived with a residence time of about a week in the atmosphere, and hence they are more concentrated in the source regions and exhibit a strong spatial and temporal variation. In addition, this variation at the receptor site is also affected by seasonal change in the transport of aerosols with air mass originating in source regions having distinct emission flux or chemical composition; this transport thus causes change in the aerosol physical, chemical, and optical characteristics (Quinn et al., 2002; Franke et al., 2003). Recent studies have suggested link between variation in aerosol load, their chemical and optical properties and source of origin of air mass trajectory such as that from continental or oceanic regions (Moorthy et al., 2005, 2008; Ganguly et al., 2005; Kedia and Ramachandran, 2008; Guazzotti et al., 2003).

Besides strength of emission from anthropogenic or natural sources or seasonal change in transport of aerosols, atmospheric loading of aerosol pollutants is also largely affected by existing meteorological conditions (Reid et al., 2013).Over India, aerosols induced reduced visibility and formation of fog due to the low atmospheric dispersive ability of

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aerosol pollutants associated with prevailing meteorological conditions are frequent during winter, especially over the region of IGP (Nair et al., 2007; Ganguly et al., 2006). Besides, it is also required to consider especially over coastal locations, the possible role of sea breeze (SB) activity on distribution of pollutants (Ge et al., 2014; Wang et al., 2013; Melas et al., 1998; Mastrantonio et al., 1994). The temperature gradient between land and water surface in coastal area leads to the development of mesoscale meteorological phenomena of land/sea breeze activity (Wang et al., 2013; Boyouk et al., 2011; Miller et al., 2003; Moorthy et al., 1993, 2003; Babu and Moorthy, 2001; Simpson, 1994). Inter-seasonal and sea breeze influenced transport processes would cause heterogeneity in aerosol properties which can lead to aerosols induced climate forcing and climate impact differently on the coastal regions than that obtained globally and thereby inducing uncertainty in estimates of climate forcing parameters (Myhre et al., 2013; Ge et al., 2014).

In the present study, we evaluate to the best of our knowledge for the first time the atmospheric aerosol extinction properties under inter-seasonal and sea-breeze influenced transport processes over coastal West Bengal Gangetic plain (WBGP). The present study is carried out in a semi-urban atmosphere on WBGP, about 80 km inland from the Bay of Bengal (Fig. 1a) at Kharagpur (22.3 °N, 87.3 °E). The study site is located near the mouth of the Ganges Delta, about 120 km southwest of an urban location and a major city on Ganges Delta and WBGP, Kolkata (22.5 °N, 88.3 °E). The city of Kolkata, situated on the banks of Hooghly river about 200 km upstream from the sea, has a riverine port. The Ganges Delta and coastal locations have been identified vulnerable to impacts of climate change, including increased flooding from the sea and changed run-off of rivers arising from Himalayan glaciers and sediment load from the basins (Parry et al., 2007; Ericson et al., 2006). The specific objectives of the present study include (i) evaluating aerosol extinction properties under influence of inter-seasonal airmass emission characteristics, (ii) examining the prevalence of sea breeze activity and its impact on vertical distribution of airmass on east coast of India, (iii) investigating the influence of sea breeze activity on distribution of surface aerosol pollutants and aerosol extinction properties over coastal location in West Bengal Gangetic plain.

2. Methodology

2.1. Observational data of aerosol surface and columnar characteristics

Measurements to investigate aerosol surface and columnar characteristics over the coastal WBGP were carried out at Kharagpur (22.3 °N, 87.3 °E); location of the study site is shown in Fig. 1a. Path of seven day back trajectories prevalent at the study site during seasonal periods (description of seasons is discussed in Section 2.2) is also shown in Fig. 1a. The relative frequency of back trajectory path (discussed in Sections 2.3 and 3.1) at the surface and elevated atmospheric layers is also shown in Fig. 1b and c respectively. Aerosol measurements were done on the roof terrace (about 12 m above the ground level) of a building of Department of Civil Engineering at Indian Institute of Technology (IIT) Kharagpur. Measurements of aerosol surface mass concentration were carried out during the period from June 2008 to May 2010. A single-stage High Volume Sampler (HVS) (APM 450 Envirotech High-volume PM_{10} sampler, operated on a 24-hourly basis at a flow rate of 0.7–1.1 $m^3\ min^{-1}$) was used for collection of finer aerosol particles (PM_{10} — mass in particles smaller than 10 μm aerodynamic diameter) on Whatmann GF/A filter papers. Concentration of finer and coarser (mass in particles greater than 10 μm aerodynamic diameter) aerosol particles were combined to obtain concentration of total suspended particulate matter (TSP). Samples for aerosol surface mass

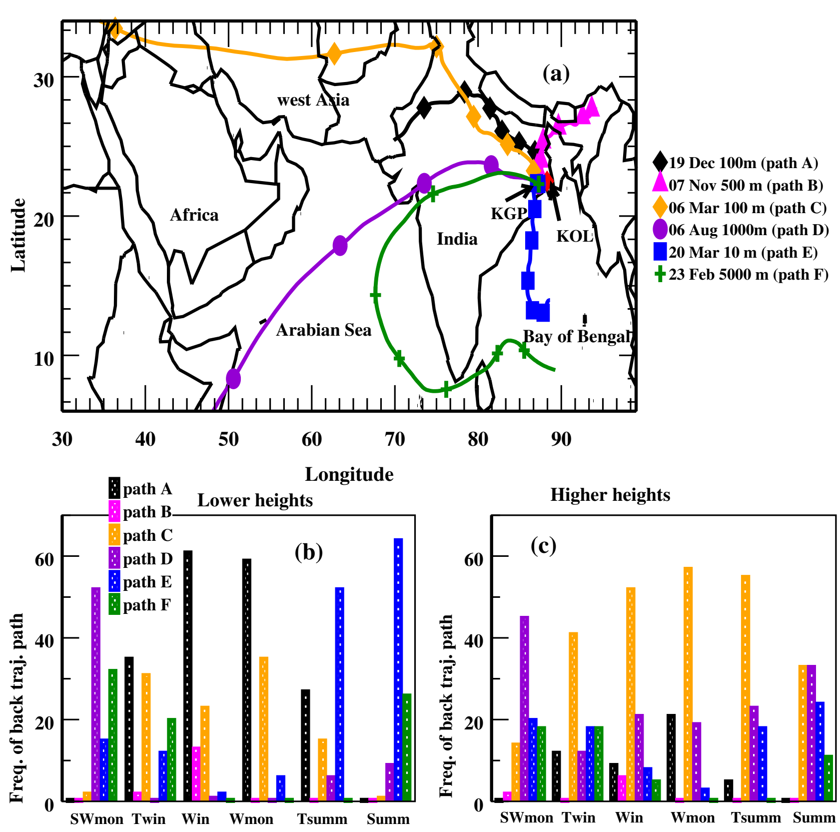

Fig. 1. (a) Location of study site Kharagpur (KGP) and a near-by urban location, Kolkata (KOL) over WBGP on the map of India. Lines show airmass back trajectory paths at Kharagpur; (b) relative frequency (%) of back trajectory paths (described in Section 2.3) at lower (10 m to 500 m) heights during different seasonal periods; (c) same as (b) but for higher heights (1000 m and 5000 m). The number of back trajectories studied during each season is also shown near the respective season on the *x* axis.