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Research Article

AEROSOL CHARACTERISTICS OVER EAST COAST OF INDIA DURING WINTER TIME

Siriki Srinivasa Rao*

Physics Mrs.A.V.N.College, Visakhapatnam Andhra Pradesh, India

A R T I C L E I N F O

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Measurement of aerosol properties during a typical winter season at three select locations, namely Visakhapatnam, Kharagpur and Kolkata on the East coast of India to better understand and quantify the spatial heterogeneity in the distribution of aerosols over the region and to study their impact on the regional radiative forcing. An attempt is also made to assess the transport pathways from one part of this region to another. Higher AODs at all wavelengths in the afternoon hours over Visakhapatnam (VSP) resembled those observed at Kolkata (KOL) in morning time. The Angstrom size index α was observed to be high ~ 1.7 at VSP, ~ 1.4 at Kharagpur (KGP) and ~ 1.1 at KOL during the clear sky conditions indicating the variability in the dominance of fine mode particles from location to location. The surface level aerosol mode mass concentrations (in g/m^3) at KOL and VSP are more or less similar excepting a larger nucleation mode concentration at KOL. In the context of widespread aerosol haze in this region during wintertime, the observed results have implications on hydrological cycle resulting in global consequences.

INTRODUCTION

Atmospheric aerosols are the largest sources of uncertainty in the current estimates of radiative forcing in terms of source strength, lifetime and transport. A variety of sources, both natural and anthropogenic, and short lifetimes of aerosols result in spatial and temporal heterogeneous aerosol field, making aerosol characterization and modelling a real challenge [*Smirnov et al., 2002*]. Indian subcontinent and surrounding regions are rich sources for many kinds of aerosols of natural and anthropogenic origin such as mineral dust, soot, nitrates, sulphates and organic aerosols. This region has been the focus of investigations due to its potential impact on regional and global climate. *Rasch et al.* [2001] reported that three points of entry are found for the anthropogenic aerosol to the INDOEX region; a strong near-surface southward flow near Mumbai, a deeper plume flowing south and east off Kolkata coast and a westward flow originating from south East Asia and entering Bay of Bengal. The analysis suggests that India is the dominant source of aerosol in the Arabian Sea and Bay of Bengal near the surface, but Asia, Africa and rest of the world also contribute at higher levels.

In recent years, several regional experimental studies focussed to India and adjoining regions of Asia to characterize the aerosols and to assess their radiative impacts at a regional scale [*Satheesh et al.,* 1999; *Lelieveld et al.,* 2001; *Huebert et al.,* 2003; *Vinoj et al.,* 2004; *Girolamo et al.,* 2004; *Moorthy et al.,* 2005; *Tripathi et al.,* 2005; *Niranjan et al.,* 2005; *Ganguly et al.,* 2006]. However, majority of these studies were conducted either over oceans or were largely weighted by a fair-weather season. Recent observations have revealed pockets of high aerosol loading / optical depth in the north Indian regions around the Ganga basin, particularly during the winter season [*Girolamo et al.,* 2005; *Tripathi et al.,* 2005; *Jethva et al.,* 2005] when the prevailing meteorological conditions are favourable for confinement of aerosols.

It has been reported that the Asian continental outflow of air mass into the open ocean starts in November and continues up to April and therefore, the regional distribution of aerosols over the Indian Ocean during this period is substantially modified by the characteristics of the continental aerosol composition. Realizing the need for characterizing the aerosol optical and physical properties over the Indian sub-continent, the current emphasis is on determining the regional variations in wintertime aerosol characteristics at select locations on the East coast of India to better understand and quantify the spatial heterogeneity in the distribution of aerosols over the region, to study their impact on the regional climate and also to study their transport pathways from one part of this region to another.

Instrumentation and Data

Comprehensive measurements of the aerosol physical properties at Kharagpur (KGP; 22.31^{0}N, 87.31^{0}E), Kolkata (KOL; 22.57^{0}N, 88.37^{0}E) and Visakhapatnam (VSP; 17.7^{0}N,

Corresponding author:* **Siriki Srinivasa Rao
Physics Mrs.A.V.N. College, Visakhapatnam Andhra Pradesh, India

83.3^{0}E) were carried out. Kharagpur is located just at the mouth of the pollution outflow vent from the north Indian region into Bay of Bengal., the average wind pattern over Indian sub-continent indicate that the surface level wind flow is predominantly from the northern polluted continent toward the ocean region (i.e., into Bay of Bengal) and down south, the flow pattern also shows winds from the Bay of Bengal to south Arabian sea across the peninsula. The clear sky days over Kharagpur are characterized by 10 km visibility, ~ 45% relative humidity (RH) and ~ 30^0 C ambient temperatures.

The measurements include the (1) aerosol spectral optical depth at 5 wavelengths centered about 0.38, 0.44, 0.5, 0.675, 0.87 µm using a MICROTOPS II Sun photometer (Solar Light Co., United States), with a Global Positioning System (GPS) receiver attached with the photometer to provide information on the location, altitude and pressure, (2) near-surface aerosol mass concentrations using a 10 channel Quartz Crystal Microbalance (QCM) Impactor (California Measurements Inc., United States), whose 50% aerodynamic diameters are 25, 12.5, 6.4, 3.2, 1.6, 0.8, 0.4, 0.2, 0.1, and 0.05 µm, respectively, with an air inlet at a flow rate of 0.24 L min^{-1} and sampled for a duration of 120 s (at KGP and KOL) and 300 s (at VSP),

RESULTS AND DISCUSSION

Spectral aerosol optical depths and Angstrom exponents

The aerosol optical depth (AOD or τ_λ), which is the integral of the atmospheric extinction coefficient from the surface to the top of the atmosphere, is an important parameter for visibility degradation (due to atmospheric pollution), solar radiation extinction, climate effects, and tropospheric corrections in remote sensing [*Dubovik et al.,* 2002].

Knowledge on the spectral dependence of AOD is important for adequately modeling the effects of aerosols in the radiation budget of the Earth-atmosphere system or for accurately retrieving the aerosol optical parameters from satellite remote sensors [*Eck et al.,* 1999]. Figure 3.1 (a), (b) and (c) represent the diurnal variation of aerosol optical depths over VSP (on 16 Feb 2005), KGP (on 3 Dec 2004) and KOL (on 28 Dec 2004) at 0.38 µm, 0.5 µm, and 0.87µm respectively on typical clear sky days of observation. It can be seen that the temporal variation of $\tau_{0.38}$, $\tau_{0.5}$ and $\tau_{0.85}$ over Kolkata are higher and unstable all throughout the day with peak value at noon and thereafter steeply decreased by evening. While over Kharagpur and Visakhapatnam, the diurnal variation remained stable showing contrasting features after 1400 IST with sharp increase in AODs over Visakhapatnam. By evening, the AOD values at Visakhapatnam resembled the AOD values observed over Kolkata in the morning time. *Singh et al.* [2004] studied the diurnal variability of AOD over Kanpur, northern India and found it to increase at noon and decrease in the afternoon during all seasons. They attributed this phenomenon to the diurnal cycle of local pollutants arising from anthropogenic activities. *Devara et al.* [1996] reported the ratio between afternoon and forenoon AOD show greater than 1.0 in pre-monsoon and less than 1.0 in winter season over Pune in western India. Generally, aerosol forcing estimates are made using either instantaneous or daytime mean aerosol optical properties for simulating fluxes with and without aerosols.

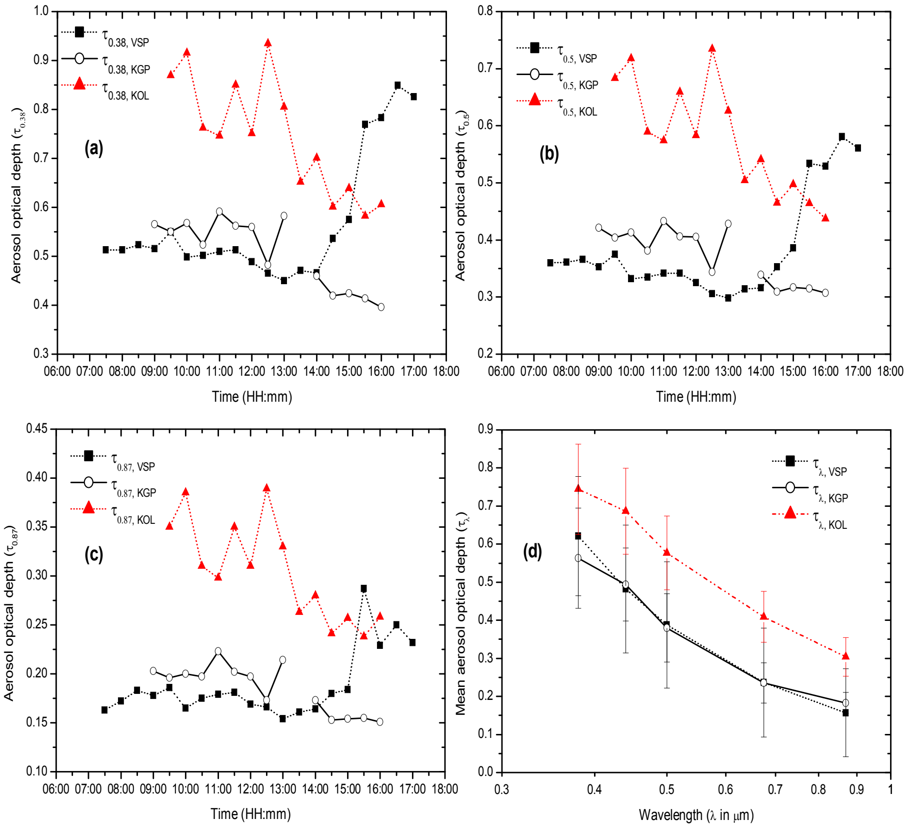

Figure 1 Temporal variation of aerosol optical depths over Visakhapatnam (VSP), Kharagpur (KGP) and Kolkata (KOL) at (a) 0.38 µm, (b) 0.5 µm, and (c) 0.87µm on typical clear sky days of observation. (d) Spectral variation of mean aerosol optical depth over VSP, KGP and KOL.

Mean seasonal diurnal variability over different geographical regions is valuable information to take into account while using instantaneous aerosol optical depth data to assess the aerosol radiative forcing.

Figure 1 (d) show the mean aerosol optical depth spectra for the available clear sky days respectively at Kharagpur and Kolkata during December 2004 (ISRO-GBP Land Campaign II) and at Visakhapatnam during February 2005The Angstrom size index (α) was observed to be high ~ 1.7 at VSP, ~ 1.4 at KGP and ~ 1.1 at KOL during the clear sky conditions in winter time, indicating the variability in the dominance of fine mode particles from location to location.

The mean spectral variation of AOD over Visakhapatnam and Kharagpur during the period of observation remained almost coincidental with a slight variation in the shorter and longer wavelengths, while over Kolkata the spectral AOD was high indicating increased columnar abundance in all size regimes. *Nair et al.* [2007] reported that both the long range transport of aerosols from the west and/or the movement of the cool meteorological front from the west to east would be responsible for the day to day changes in the aerosol concentrations over Kharagpur.

Role of transport

With a view to examine the role of long-range transport of aerosols in causing changes in the optical depth, composition, and physical characteristics of aerosols, the 7-day back trajectories for all the days on which the AOD data were available using the HYbrid Single Particle Legrangian Integrated Trajectory (HYSPLIT) model of the National Oceanic and Atmospheric Administration (NOAA) [*Draxler and Rolph*, 2003]. The 7-day period was considered in view of the typical residence time of ≥ 1 week for aerosols in the lower troposphere during the dry period. These trajectories usually back trace the course of an aerosols parcel, which reaches the particular altitude over the observation site, in space (latitude, longitude and altitude) and time (days), backward up to seven days.

Figure 2 shows the 7-day back trajectories (at 1030 IST) obtained at 500 m, 1500 m and 2500 m asl on (a) 16 Feb 2005 (at VSP), (b) 3 Dec 2004 (at KGP) and (c) 28 Dec 2004 (at KOL). To the Visakhapatnam, the air masses were originating from the African region and Arabian Sea traversing through peninsula at constant altitude nearer to the surface level and ascended to 500 m and 1500 m, while the air parcel at 2500 m has descended from higher altitudes from the Bangladesh coast. In the case of the air masses reaching Kharagpur and Kolkata on the respective indicated days, the source regions were from northern India, Arabia and African region. Almost all the air masses were descended from high altitudes of source regions indicating the transformation of fine particles to accumulation or coarse mode particles.

It was also observed that there is no significant change in the pathways of the air masses at different altitudes reaching the source locations in the afternoon hours. Thus, it can be inferred that the increase in AODs at 0.38 µm, 0.5 µm and 0.87 µm over Visakhapatnam in the afternoon showing an increasing trend while contradicting with those of Kharagpur and Kolkata, are not due to any role of long range air mass transport. Higher AODs at all wavelengths in the afternoon hours over Visakhapatnam may be due to the possible role of higher surface wind speeds in the resulting entrainment or convection of drier air mass into the region of land-sea breeze mixing or building up of strong convective activity by afternoon resulting in an increase in moisture content in the lower atmosphere.

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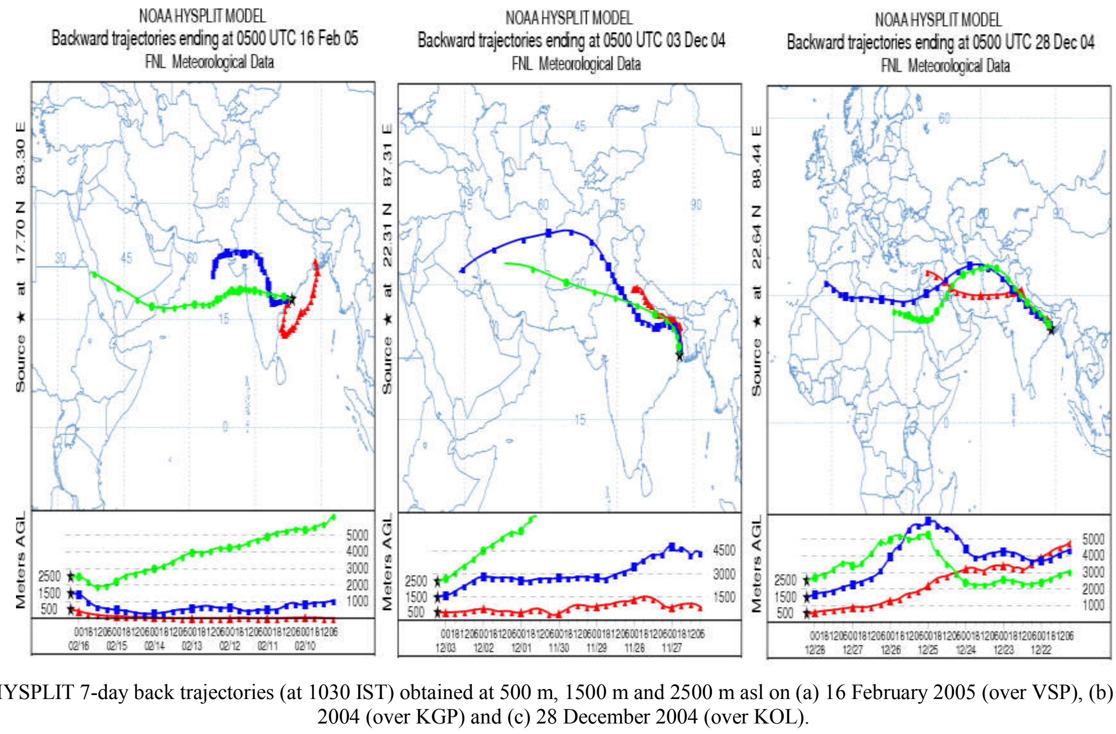

Figure 2 HYSPLIT 7-day back trajectories (at 1030 IST) obtained at 500 m, 1500 m and 2500 m asl on (a) 16 February 2005 (over VSP), (b) 3 December 2004 (over KGP) and (c) 28 December 2004 (over KOL).

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