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Seasonal variations of aerosol over Dona Paula, a coastal site on the west coast of India

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Abstract

We report here the observations of the aerosol studies carried-out for three years (2000–2002) at Dona-Paula, Goa (15.456°N, 73.801°E), a coastal site on the west coast of India. Aerosol optical depths were measured using a five channel sunphotometer with wavelengths at 440, 500, 675, 870 and 936 nm. The site enjoys a tropical climate and is under the influence of the strong southwest or summer monsoon and weak northeast or winter monsoon. Being a coastal station land-sea breeze play an important role in the variations of the aerosol loading over the site and their transport to the Arabian Sea. The mean aerosol optical thicknesses (AOT) at 500 and 870 nm are 0.46 (±0.15) and 0.23 (±0.097), respectively, while the Angstrom exponent is 1.31 (±0.347). The aerosol properties over the site showed a distinct seasonal variations, with high values of AOT observed during summer, with mean values of 0.48 (±0.15) and 0.26 (±0.09) at 500 and 870 nm, respectively, while during the winter relatively low values were observed, with mean value of 0.41 (±0.14) and 0.19 (±0.09) at 500 and 870 nm, respectively. The values of Angstrom exponents observed at the site suggest that the aerosol comprise mostly of the small size particles, with relatively larger particles being observed during summer than winter. An anti-correlation is observed between the inter-annual variations in the aerosol loading and the rainfall over Goa. Aerosol properties show diurnal variations, with comparatively lower values of AOT being observed in the evening. These diurnal variations are within a limit of 10% of the average values observed for the day. Seasonal patterns in the diurnal variations of aerosol optical depths have been observed. Considering the effect of the meteorological parameters over the aerosol, it is observed that the AOT is positively correlated with water vapor column, however the wind is found to aid in the reduction of aerosol load over Goa. It can be inferred from the weak negative correlation between AOT and Angstrom exponent that the contribution of large size particles in increasing the aerosol load was marginal. The aerosol optical depth derived from SeaWiFS at 865 nm was found to agree well with the measured values at 870 nm. However, the Angstrom exponent values from SeaWiFS at 510 nm were found to be underestimated.

Keywords: Goa; India; Asia; Aerosol; Coastal aerosol; Atmospheric turbidity; Diurnal variation

1. Introduction

Studies of the aerosols have gained equal importance of recent due to its equal importance on the regional and global impact on the climate and environment, as compared to the greenhouse gases. The multidisciplinary

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studies with multi-platform observations of the effect of aerosols over the Asian subcontinent and Indian Ocean under Indian Ocean Experiment (INDOEX) program provided a better understanding of the aerosols over this region and some costal stations. One of the salient observations has been of the haze due to atmospheric pollution over Asia, which is mostly attributed to biomass burning and fossil fuel combustion, and it has been of concern due to their impacts on the environment and climate (Ramanathan et al., 2002; Ramanathan and Ramana, 2003; UNEP, 2002). Haze due to air pollution is not a local phenomenon observed only in the Asian region as it is observed in other industrialized and urban inhabited regions such as North America, Europe and China (Kaufman et al., 2002). However this Asian haze is a cause of concern as industrialization, economics and population are growing at a rapid pace in these countries and it could have an impact on the agriculture, economics, environment and climate.

Regulatory bodies in India have been monitoring pollution levels at major cities and they have noticed high concentrations of particles, which are of concern due to their ill effects on the health of the public (Mitra and Sharma, 2002). Anthropogenic sources such as biomass burning and fossil fuel combustion are reported to contribute above 75% of the aerosol observed over the Indian sub continent which is further confirmed due to their high black carbon content and absorbing nature (Gabriel et al., 2002). In India contributions to the $PM_{2.5}$ (particles of size less than 2.5 μm) from fossil fuel combustion (~68%) are mainly from industries utilizing coal combustion, while emissions from biomass combustion are spread all over India (~32%) (Reddy and Venkataraman, 2000). With the growth of the use of four and two wheelers in India, air pollutions from them are increasing at an equal pace.

Understanding the coastal aerosol variations will allow for a better atmospheric correction algorithm for ocean color satellite sensor such as IRS-P4 OCM and thus provide required geophysical parameters to a greater accuracy from the satellite data (Elgar et al., 2001).

2. Measurements

2.1. Site description

All the measurements given here were carried-out at National Institute of Oceanography, Dona-Paula, Goa, India, (15.456°N, 73.801°E). To the north it has coastal regions with similar meteorological conditions as Goa, which also includes some of the most industrialized cities such as Mumbai (Bombay) and Pune and much further north we have the dry land of Gujarat and the deserts of Rajasthan. It has Arabian Sea to its west and far across there are the dry, dusty and arid lands of Arabia. On the eastern side there is a stretch of mountains running parallel to the west coast known as Western Ghats. The measurement site, Dona-Paula is at a height of about 25 m above mean sea level and less than 500 m away from the Arabian Sea. Being situated at the west coast of India, it has a typical coastal and tropical climate. It is influenced by the reversal of monsoon winds and to a greater extent by the summer or the Southwest monsoon (June–August) than by the weaker winter monsoon or the Northeast monsoon (November–January). Sea and land breeze also play an important role.

2.2. Data collection using sunphotometer

The aerosol optical thickness (AOT) were obtained using a handheld sunphotometer, MicroTops-II (Solar Light Co., USA) at five wavelengths which are close to the recommended wavelengths by the World Meteorological Organization, 440, 500, 675 (2 nm FWHM), 870 and 936 nm (10 nm FWHM) (http://www.solar.com). It also provides additional parameters such as water vapor column WVC (cm), atmospheric pressure and the solar irradiances at above mentioned five wavelengths. All the measurements using the sunphotometer and processing the data were carried-out in accordance with the standard protocol (Frouin et al., 2003).

2.3. Calibration

The long-term stability of the instrument was found to be good and the degradation of the filter or the drifts in the calibration values were found to be marginal. The sunphotometer was calibrated at factory and on land. On land calibrations were carried out with measurements at a high mountain (Gurushikhar, Mt. Abu, Rajasthan, about 1720 m above mean sea level) using the standard Langley-Bouger technique as per the protocol given for the validation of ocean color satellite (Pietras et al., 2003). Factory calibrations were carried-out in the year 2000. The calibration constants obtained from the data collected at Mt. Abu on 22 April, 2002, did not show any large variations from the values obtained from the calibrations at factory.

2.4. Meteorological variations of the site

The site of measurement, Dona-Paula has a typical tropical climate and coastal weather and being a coastal region it is under the influence of the sea and land breeze. The monthly mean values of the wind speed (vector average) and relative humidity obtained from an automated weather station are given in Fig. 1. The average wind speed at the site is 2.2 m s^{-1} and with the exception of winds during south-west or summer monsoon when the highest winds are observed. The