TEMPORAL CHARACTERISTICS OF AEROSOL PHYSICAL PROPERTIES AT VISAKHAPATNAM ON THE EAST COAST OF INDIA

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ABSTRACT

An extensive, multi institutional, multi instrumental and multi-platform field experiment ‘Integrated Campaign Aerosols, gases and Radiation Budget (ICARB)’ was carried out. The objective this Campaign ever conducted in the Indian region was to characterize the physico-chemical properties and radiative effects of the aerosols and trace gases over the Indian landmass and the adjoining oceanic regions of the Arabian Sea, Northern Indian Ocean, and Bay of Bengal. The temporal variations of aerosol optical depth, near surface aerosol mass size distributions and BC mass concentrations show significantly higher aerosol optical depth and near surface mass concentrations during the first and last weeks of April 2007. The mean BC mass fraction in the fine mode aerosol was around of 11 %. A comparison of the temporal variation of the Aerosol properties at Visakhapatnam with the MODIS derived aerosol optical depth along the cruise locations indicate a significant coincidence suggesting that the aerosol transport from the eastern coastal regions of the peninsular India plays an important role on the observed spatial variation in the aerosol optical depths over the near coastal oceanic regions of Bay of Bengal.

DATA AND METHODOLOGY

Visakhapatnam (17.7°N, 83.3°E) is a coastal industrial location on the east coast of India. During the ICARB period, the Aerosol spectral Optical Depths (AOD) were measured using a Microtops II sun Photometer operating at 380, 440, 500, 675 and 870 nm. Size segregated near surface aerosol mass concentrations were measured using a Quartz Crystal Microbalance (California Measurements Inc., USA) in 10 size channels with 50% aerodynamic cut-off diameters at 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 liters per minute and sampled for...
duration of 300 seconds for each measurement. A seven channel Magee Scientific Aethalometer was used to measure the near surface BC mass concentration. Niranjan et al., 2006, 2007 and Sreekanth et al., 2007.

RESULTS AND DISCUSSION

Aerosol Optical Depth

Aerosol optical depth is one single parameter that can characterize the atmospheric transparency. In figure 1 are shown the temporal variation of the Aerosol optical depth at 500 nm measured using a Microtops II sun Photometer at Visakhapatnam. The vertical line indicates the period when the ship was sailing in Bay of Bengal. The AOD shows a distinct day to day variability during the campaign period at Visakhapatnam. Significantly large Optical depths above the mean values (black line shown at 0.55 AO D) were observed during the first and last weeks of April 2006 with AOD at 500 nm crossing 0.7. An examination of the MODIS data for this station for the said period indicates a one to one correspondence between the ground based measurements (Microtops) and the MODIS data, with the Microtops optical depths.

To see the relative change in the aerosol mass size distribution, we have sorted the size segregated data in to nucleation (aerodynamic mean radius <0.1 µm), accumulation (aerodynamic mean radius between 0.1 µm to 1.0 µm) and coarse modes (aerodynamic mean radius >1.0 µm) and their day to day variability are shown in figure 3. The accumulation mode aerosol shows higher mass concentration and comparable day to day variability similar to total mass concentration during the first week of April 2006 while during the last week of April no significant increase in the surface accumulation mode mass is observed. On the contrary the nucleation mode aerosol shows some increase in the last week of April 2006. This indicates decoupling of column integrated features as seen in AOD from the near surface features as seen from the QCM mass distributions. To bring out the decoupling features more clearly, we have plotted the variation of the Angstrom aerosol size index alpha as a function of surface nucleation and accumulation mode aerosol mass concentration measured by QCM in figures 4 and 5 respectively. Assuming that the aerosol size distribution is uniform in the column integrated properties, an increase in alpha should be associated with a proportionate increase in the surface fine mode mass.

Near Surface aerosol mass concentration and BC mass Concentrations

In figure 2 are shown the near surface aerosol total mass concentrations measured by the QCM system. It may be seen that the near surface mass concentration also shows large day to day variability with relatively high values during the first half of April 2006. There was a slight increasing tendency during the last week of April.

Figure 1 Temporal variation of Microtops AOD (0.5 µm). Horizontal line indicates mean values. The vertical line indicates the BOB leg.

Figure 2 Temporal variation of near surface total mass concentration.
The solid line in both the plots indicates the regression line which supports this assumption. But in some cases shown as solid dots in these figures, an increase in alpha is not associated with a proportionate increase in surface fine mode aerosol mass (either in the nucleation or accumulation mode) indicating that the surface aerosol features differ from the column integrated aerosol physical properties. This indicates the need for vertical profiling of aerosol mass concentration as the difference observed in the near surface and column integrated feature could be due to the changes in the aerosol physical properties at altitudes above the mixing region.

Figure 3 Temporal variation of size segregated mass concentration in the nucleation, accumulation and coarse mode

Figure 4 Plot showing the variation of aerosol size index as a function of near surface nucleation mode aerosol mass concentration.
In figure 6 are shown the surface BC mass concentrations at 1000 hrs and 1500 hrs IST for all the days of observations during the campaign period. It may be seen that the surface BC mass concentrations were higher during the first and last weeks of April 2006 as seen in the surface aerosol mass concentrations and the aerosol optical depths. However, very large values of BC mass concentration were recorded during 19-24th March 2006. The percent BC mass fraction in the fine mode aerosol was 11 though on some days in fluctuated significantly from this mean value. A more detailed discussion on the BC mass fraction to the composite aerosol at Visakhapatnam, its relation to column AODs and the implications on BC radiative forcing are available in Sreekanth et al. (2007).

Figure 5 Plot showing the variation of aerosol size index as a function of near surface accumulation mode aerosol mass concentration.

Meteorological studies show that the high aerosol concentrations over the Arabian Sea and tropical Indian Ocean could be linked to transport from Indian sub-continent and also from sources in the Middle East and North Africa (Krishnamurti et al., 1998).

DISCUSSION

Systematic characterization of aerosols over the oceans is needed to understand the aerosol effect on climate and on transport of pollutants between continents (Smirnov et al., 2002). Villevalde et al. (1994) reported that the optical properties of maritime aerosols influencing the Pacific Ocean measurements are substantially different from those of the north Atlantic data indicating the regional differences in the aerosol properties of oceanic regions. It was reported that in coastal areas and inland seas the values of AOD are higher largely depending on the continental sources. In this context the measurements at adjoining coastal locations like Visakhapatnam during ICARB assume importance, particularly with reference to the cruise observations in the Bay of Bengal region. In order to see if the observed temporal variation in the aerosol physical properties are in anyway affecting the spatio-temporal variations in the aerosol optical depth along the cruise track, we have compared the MODIS aerosol optical depth at 550 nm along the cruise track in the Bay of Bengal region with the temporal variation in the aerosol optical depth at Visakhapatnam and are shown in figure 7. The aerosol optical depths along the cruise track were in general low compared to the AODs observed at Visakhapatnam.
But it is interesting to see the temporal variation at Visakhapatnam is getting reflected as a spatial variability with a good resemblance. Satheesh and Moorthy 1997 reported significant enhancement in AOD at shorter wavelengths in the near coastal regions compared to far coastal regions and that the Ångstrom exponent ‘α’ doubles in the near coastal regions compared to far coastal regions. Airmasses that come from different source regions into the Bay of Bengal region carrying aerosols of different species are responsible for the spatial and temporal variations in the observed AOD spectra (Ramachandran and Jayaraman 2003). Major sources of aerosols over the northern Bay of Bengal are the eastern coast of India (Ganguly et al., 2005 and Satheesh et al., 2006). Vinoj et al (2004) also reported that aerosol optical depths over BOB were high with α approximately equal to 1.1 indicating the presence of significant amount of sub-micron aerosol. It is known from the general wind pattern that the air mass pathways are from peninsular India on to the Northern BOB and it is quite possible that the mean wind flow from the peninsular India via the eastern coastal regions could significantly contribute to the aerosol loading over the regions covered by the ICARB track. The observed results from the eastern coastal region of Visakhapatnam in conjunction with the MODIS derived AODs over the cruise track are in conformity with this proposition. To get an idea on the scaling distance of continental influence on the aerosol properties over the oceanic regions, we have evaluated the gradient in AOD (along the diagonal path) at various cruise locations, assuming Visakhapatnam as the source point for the outflow from the continental region and the results are presented in figure 8. It may be seen that in the near coastal locations, the AOD gradient is low (approximately 0.03 per deg latitude), while in the farther coastal regions the gradient is high. This indicates that the near coastal regions are significantly affected by the aerosol sources from the nearby continental locations while the influence falls off rapidly as the distance from the coast increases.

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