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AEROSOL CHARACTERISTIC VARIATIONS IN DIFFERENT ENVIRONMENTS OVER INDIAN REGION

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1. Introduction

Atmospheric aerosol characteristics basically vary with environment besides their complex height-time variations at any location. Over urban, rural and coastal stations, aerosols behave entirely in different way as compared to the high-altitude stations. For example, measurements over high-altitude locations yield background levels of aerosol concentration. Added, these stations generally lie in the boundary layer during daytime and in the free troposphere during the nighttime, thus provide unique opportunity to investigate the transport/mixing of aerosols and gases from / between the boundary layer to / and the free troposphere. There is lack of knowledge about the distribution of aerosols and gases in the free troposphere in the tropical zone — one of the less studied region of the planet. Moreover, under seasonally varying wind patterns, high-altitude stations, being in the free troposphere during night, become very important for regional study of pollutants, particularly during early morning / night transition period. In order to address some of these issues, extensive observations of aerosol optical, microphysical and radiative parameters have been carried out at two urban stations with different topography, Sinhgad, a high-altitude rural background station, situated on a hill-top with flat terrain, Trivandrum, representing coastal environment during transition from winter to summer of 2006-07. This particular period was chosen for studying also the interesting phenomenon of haze in and around some of the sites. A suite of instruments consisting of multi-channel CIMEL sun-sky radiometer; MICROTOPS II sun-photometer, ozonometer; a short-wave pyranometer has been deployed in the study. Simultaneous measurements using these facilities have been made on some selected experimental days during December 2006-May 2007. The details of the complete observational program, experimental facilities deployed and more interesting results obtained are presented.

2. Description of Experimental Sites

a. *Trivandrum (8.53^{o}N, 76.86^{o}E. 0.0 m AMSL)*

Trivandrum also known as Thiruvananthapuram, is the capital of the Indian state of Kerala. It is located on the west coast of India near the extreme south of the mainland. The experiments were conducted in the campus of TERLS (Thumba Equatorial Rocket Launching Station) located at Thumba village. The city has a tropical climate and therefore does not experience distinct seasons. The mean maximum temperature 34 °C and the mean minimum temperature is 21 °C. The humidity is high and rises to about 90% during the monsoon season. Thiruvananthapuram is the first city along the path of the south-west monsoons and gets its first showers in early June. The city gets heavy rainfall of around 1700 mm per year. The city also gets rain from the receding north-east monsoons which hit the city by October. The dry season sets in by December. December, January and February are the coldest months while March, April and May are the hottest. The winter temperature comes down to about 20°C and summer temperatures can sometimes go as high as 35°C.

b. *Sinhgad (18.36°N, 73.75°E, 1450 m AMSL)*

Sinhgad is a fort located near the city of Pune, India, situated on a hill rising about 1400 metres above the surrounding countryside. Sinhagad is 25 Km. from Pune. Heating during the daylight hours warms the air along the mountain slopes. This warm air rises, generating a valley breeze. After sunset, cooling of the air near the mountain can result in cool air drainage into the valley, producing the mountain breeze.

c. *Pune (18.53°N, 73.80°E, 559 m AMSL)*

Pune is a city located in the western Indian state of Maharashtra. It is situated at the eastern edge of the Western ghats on the Deccan plateau.

d. *Ahmedabad (23.02°N, 72.52°E, 55 m AMSL)*

It is located on the banks of the River Sabarmati. The experiments were conducted in the campus of Space Applications Centre (SAC). The city is located in a sandy and dry area. Aside from the monsoon season, the climate is dry. The weather is hot through the months of March to June — the average summer maximum is 36°C (97°F), and the average minimum is 23°C (73°F). From November to February, the average maximum temperature is 30°C, the average minimum is 15°C, and the climate is extremely dry. Cold northerly winds are responsible for a mild chill in January. The southwest monsoon brings a humid climate from mid-June to mid-September. The average rainfall is 93.2 cm, but infrequent heavy torrential rains cause the river to flood. In recent years, Ahmedabad has suffered from increasing air, water and soil pollution from neighboring industrial areas and textile mills.

3. Instrumentation

The equipment deployed at the sites include a Cimel sun-sky radiometer which operates at four principle wavelengths of 440, 675, 870 and 1020 nm, Microtops II (sunphotometer and ozonometer), a short-wave pyranometer that measures down-welling radiative flux in the spectral band covering from 0.28μ to 3.0μ and a hand-held thermo-hygrometer. In addition, an aethalometer and GRIMM aerosol size spectrometer have also been operated at Sinhgad site. A brief description of the above equipment and method of data analysis have been published elsewhere (Devara et al., 2005; Safai et al., 2007).

4. Discussion of Results

(i) *Aerosol spectral characteristics and size fraction*

Figure 1 shows the wavelength dependence of aerosol optical depth retrieved from the sun-sky radiometer at all the four experimental sites considered in the study. The data archived at Pune during different intermediate epochs of the study period is also shown plotted in the figure for comparison. One common feature that is common at all sites is that AOD decreases with increase in wavelength. Higher AODs contributed by more accumulation-mode aerosol particles were observed over Pune during April and lower AODs were noticed over Sinhgad during February. The AODs contributed by coarse-mode particles appear to be almost similar at Pune and Ahmedabad. In the month of February, when the AOD measurements were available at three sites, AODs over Trivandrum are found to lie in between those at Pune and Sinhgad. Considering the AODs at smaller 440 nm and at 1020 nm wavelengths represent contributions by accumulation and coarse-mode particles, respectively, their ratios are shown plotted in Figure 2.

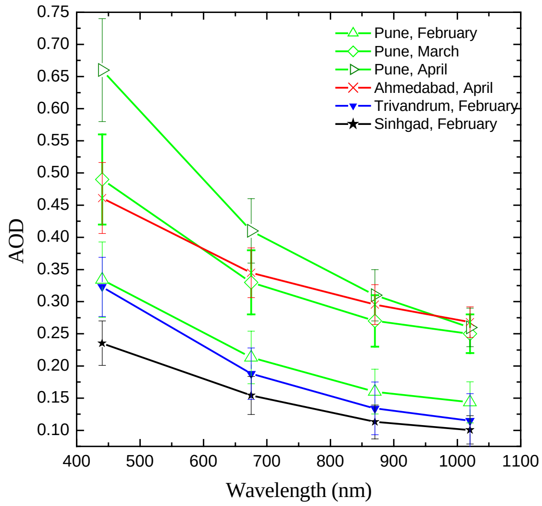

Figure 1: Association between AOD and wave- length of observation at different sites during AOD different epochs of study period. Vertical bars Numbers with Indicate error in the measurements

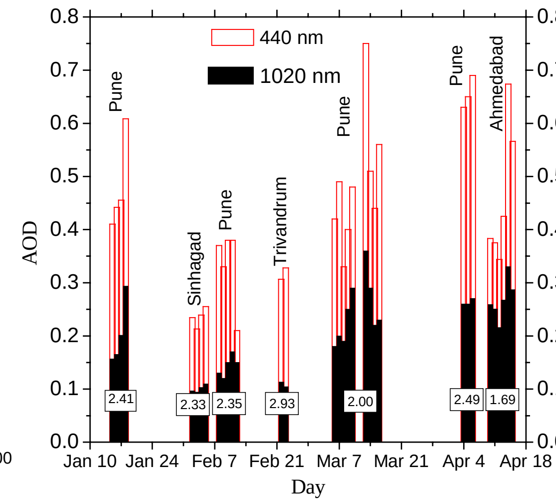

Figure 2: Relative contributions of accum-ulation- and coarse-mode particles to different epochs of study period.at different observation sites boarder are AOD_{440}/AOD_{1020}.

It is clear from Fig. 2 that coarse particles' contribution to AOD is found to be more at Pune and Ahmedabad during pre-monsoon months due to frequent rise of dust driven by convective activity. Higher fractions at Pune during winter months may be attributed to near-ground temperature inversions leading to formation of haze. It is clear from the figure that the concentration of accumulation-mode particles is almost twice that of the coarse-mode particles, with the highest fraction over Trivandrum during the study period, which could be due to land-breeze and sea-breeze interactions. The next highest fraction observed over Pune is ascribed to the intense convective activity associated dust-storm activity.

(ii) Aerosol size distribution and water vapor

Figure 3 portrays the variation of Angstrom exponent (indicator of aerosol size) and turbidity coefficient (indicator of aerosol loading) over different sites during the study period. It is clear from the figure that alpha values are higher over Trivandrum, indicating abundance of larger particles while they are smaller over Ahmedabad, indicating more of smaller particles. The alpha values over Pune indicate relatively higher values indicating abundance of accumulation particles throughout the study period. The higher beta values, indicating more aerosol loading, are found over Pune and Ahmedabad. The columnar precipitable water content observed over the four sites is plotted in Figure 4. The water content is maximum

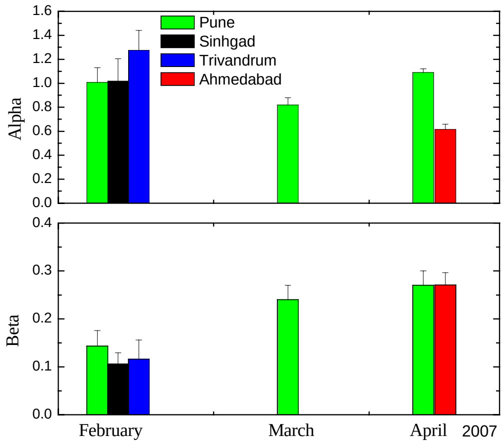

Figure 3: Alpha and beta values observed over estimated water different sites during February-April 2007

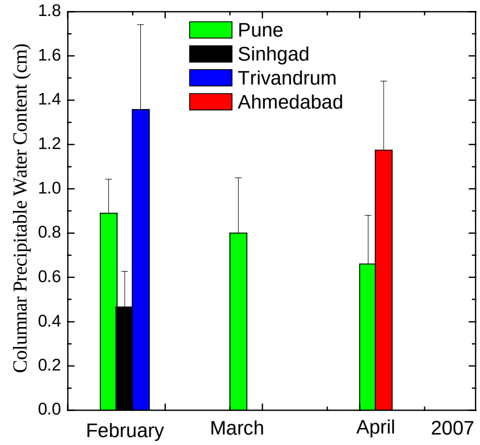

Figure 4: Solar radiometer- vapor content variations over four sites

at Trivandrum, which may have helped in the growth of hygroscopic particles present over this station. This is consistent with the observation of abundance of coarse-mode particles over this station. This feature is noticed in a different way over Ahmedabad, where the water vapor content is also found to be sufficiently high. But, it is interesting to note that the concentration of coarse-mode particles over this station is not high. This implies that aerosols over Ahmedabad are more of hydrophobic or non-hygroscopic. This could be the reason for low levels of coarse-mode particles albeit the water vapor content is high at this site during the period of study.

5. Conclusions

The results of the study indicate, as expected, low values of aerosol optical depth (AOD) over Sinhgad to very high values over Ahmedabad and Pune, and intermediate values over Trivandrum. The results also show an association between radiometer-derived AOD and size distribution and surface-level black carbon concentration and meteorological parameters. The aerosol size distribution derived from direct as well as remote sensing methods have been examined in conjunction with HYSPLIT model back trajectories to understand the source regions and associated long-range transport of aerosols and pre-cursor gases, particularly during the periods of haze.

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