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Decadal Variability of Aerosols and Trace Gases over a Tropical Urban Station (Pune, India)

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Atmospheric aerosols are of great importance because of their impact on human health, visibility, continental and maritime ecosystems, or the Earthąęs climate, requiring dedicated monitoring of their concentrations and properties at both regional and global scales. However, because aerosols can settle out or transform, they tend to have shorter atmospheric lifetimes than greenhouse gases, which results in vertical, horizontal, and temporal gradients in aerosol particle concentrations. These spatial gradients are more responsible to regional rather than global aerosol forcing effects. The amassing of continuous aerosol measurements is one of the most powerful ways of monitoring regional aerosol properties, calibrating satellite remote sensing instruments and testing model results [Huebert et al., 2003; Holben et al., 1998]. As atmospheric aerosols show high degree of variability in space and time in their characteristics and as anthropogenic share of total aerosol loading is quite substantial, it is essential to monitor systematically the aerosol features over longer time scales. The ground-based instruments used are MICROTOPS-II and Argon-ion lidar MICROTOPS-II gives the columnar information of aerosol optical depth at 380, 440, 500, 675, 870 and 1020 nm, columnar ozone and column water vapor content while the lidar gives the aerosol concentration profile at 514.5 nm wavelength. Also various datasets from different satellite sensors, like TOMS, MODIS, MISR, SEA-Wifs. The AOD derived from different satellites; MODIS at 550 nm, TOMS at 380 nm and MISR at 550 nm and from ground-based sun-photometer at 380, 500 and 1020 nm are plotted in figure 1 from 1998 to 2006.

Figure 1: Monthly mean values of AOD plotted from 1998 to 2006 for MICROTOPS and different satellite sensors.

It may be noted here that the AOD variations recorded at the radiometer wavelength of 380 nm (representative of fine aerosol particles) and of 500 nm (representative of sub-micron aerosol particles) are only included in this figure. The representative sizes of aerosol particles at sensing wavelengths of 380 nm and 500 nm include fine and accumulation-mode (< 1 čgm radius). Coarse-mode (> 1 čgm radius) particles need sensing at longer wavelengths, which was achieved in the present paper with the remaining channels at wavelengths of 675, 870 and 1020 nm of the radiometer. The data gaps during the south-west monsoon (June-September) in the plot are due to unfavourable sky conditions, and many times due to rain during that period. A significant annual variation in all the above three parameters with maximum AOD in pre-monsoon months and relatively minimum in wither months is clear from the figure. The high convective activity and frequent occurrence of dust storms are responsible for the higher AODs during the pre-monsoon. Subsequently, the AOD values attain minimum due to cloud-scavenging and rain-washout processes during the monsoon and thereafter they slowly build-up during post-monsoon and winter months and becomes maximum again in pre-monsoon. Thus the annual cycle goes on over this experimental station. The difference between monthly averages from the two instruments is partly due to the different number of days forming each monthly mean, as the two instruments have different measurement schedules and due to the difference in wavelength considered. Nevertheless, the annual pattern of the AOD variability is similar for all datasets considered, with maximum values in the summer periods and minimum values in winter. There is a continuous increase of AOD seen for the period considered from 1998 to 2006. The increase may be attributed to more vehicular emissions and urbanization of the station. In addition to the boundary layer aerosols originating mainly from local sources, transport of aerosols at higher altitudes also contribute to the total AOD column, especially in the summer months. The path corresponding to different wavelengths resembles the different size of aerosol particles present in the column of atmosphere. A specific wavelength dependence of AOD i.e. decrease of AOD with increase in wavelength, which is consistent with the Mie scattering theory for aerosol particles, can be clearly seen from the figure. The major supporting factor for the increase of rainfall over Pune, not only depends solely on the aerosol concentration in troposphere but also on the availability of water vapor content. Water vapor is the most important greenhouse gas and its affects are different in different layers of atmosphere. The lower tropospheric water vapor is responsible for precipitation and strongly interacts with aerosols and stratus clouds. The upper tropospheric water vapor strongly interacts with cirrus clouds and may significantly increase warming, while lower stratospheric water vapor has large chemical and radiative impacts. The aerosol concentration is increasing that too absorbing aerosol concentration over Pune and to see the behavior of water vapor in accordance to AOD over this station we plotted the monthly total column water vapor content derived from MODIS and MICROTOPS-II as seen in figure 2 from 1998-2006. The water vapor also shows an annual cycle more in the summer monsoon months and less during winter. The MODIS columnar water vapor shows relatively high values as compared to MICROTOPS but the interesting feature is that the water vapor shows an increasing trend over this tropical station. Thus, it implies that though the aerosols over this urban station are increasing continuously, amount of water vapor available is also increasing and ensures more rainfall.

Figure 2: Variation in total column water vapor obtained from MICROTOPS-II and MODIS sensor for 1998 to 2006.

Figure 3: Inter-annual variation of total column ozone obtained from TOMS sensor from 1979 to 2006.

Ozone is the important parameter, which absorbs the UV radiation entering into the atmosphere, and avoids the radiation reaching the surface thus saving the living organisms from harmful effects of UV. The plot in figure 3 from 1979-2006 reflects the inter-annual variation. The ozone starts building up in pre-monsoon, continues its stability in the monsoon and then shows a decrease in post-monsoon and winter. The annual means show the decreasing trend of ozone over Pune which may allow the UV radiation to reach the surface. The seasonal means reflect the same feature. In the inter-annual variation it reflects more clearly. The decrease is around 12 DU. The reason could be due to increase in the aerosol and water vapor content. Though the aerosol and water vapor content show an increase at the tropospheric level, it scatters the radiation back, which affects the photochemical reactions taking place in stratosphere and thus inhibits the production of ozone instead of initiating it [Dentener et al., 1996].

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