Studies on Satellite and ground based measurements of SUV, UVA, and AOD over Hyderabad

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ABSTRACT

Atmospheric carbonaceous aerosols and their radiative effects are important components of the climate system by their effects on the atmosphere. Large urban areas often are the sources of extreme heavy pollution affecting climate around them and the population's health within them. Urban pollution sources are continuous which contribute to the overall regional background aerosol concentrations. Hyderabad is one of the fastest growing urban cities with increase in vehicular traffic and industry activity. The seasonal variation of aerosol characterization over a typical semiarid urban environment namely Hyderabad was studied using both satellite data and ground based instrumentation. Aerosol optical depth (AOD) was measured from MICROTOPS-II Sunphotometer and Ozonometer at wavelengths 380, 440, 500, 675, 870 and 1020nm during the period of 2001 to 2006 over Hyderabad. Meteorological parameters like air temperature, relative humidity wind speed and wind direction were measured from Meteorological station. SUV and UVA concentrations were measured using UV-meter during 2001-2006.

Day-to-day variation of AOD, SUV, and UVA during the period of 2001 to 2006 over Hyderabad was studied. Correlation between ground measured , SUV & TOMS UV, AOD & SUV, AOD from 2004 to 2006 were analysed. The change in the values of SUV & UVA before and after rainfall is also discussed.

Introduction

Solar ultra violet radiation reaching the earth's surface has been largely discussed owing to its biological and photochemical activity. The UV radiation is often sub-divided into three bands UV-C (100 – 280 nm) UV-B radiation (280-315 nm) and UV-A radiation

(315-400 nm). UV radiation can be measured as irradiance – the power incident upon a surface unit area – in units of w/m^2 or as a radiant exposure or dose energy incident upon a unit surface area in a period of time (J/m2).

Great emphasis has been placed on the surface reaching particularly ultra–violet–B (UV-B) radiation. The shorter wavelengths that comprise UV–B are most dangerous portion of UV radiation at surface. Exposure to UV–B radiation has adverse effects on human and other organisms. For man, the detrimental effects of over exposure to UV–B include sunburn (erythema), skin cancer, DNA damage, suppression of immune system and cataracts. Some species of plants and animals also are damaged due to increase in UV–B exposure. The most important factors influencing the UV–B radiation reaching earth's surface are atmospheric ozone, sun elevation (SZA), atmospheric altitude, clouds, haze and ground reflection.

The UV–B region comprises only 1.25% of the total extra terrestrial irradiance and 0.5% of surface irradiance, which is small energetically, but its significant biological activity magnified its importance in the biosphere. Ozone acts as a regulator of UV–B due to strong absorption characteristics over the ultraviolet region. The majority of ozone absorption occurs in stratospheric ozone layer. Emissions from biomass burning and anthropogenic activities increase the concentration of aerosol particles in the atmosphere and surface ozone. The intensity of UV radiation received at ground is largely determined by the atmospheric aerosols. Examination of the record of solar ultraviolet measurements showed substantial reduction of UV–B radiation on days with high level of air pollution, which are associated with high concentration of particulate matter. Tropospheric aerosol is the most important UV–B attenuating factor up to 40%. The diffusion of UV – B irradiance increases with the increasing solar zenith angle and turbidity. Absorption and scattering characteristics are influenced by the variability of tropospheric pollutants and these characteristics are associated with the chemical composition of the aerosols.

The importance of influence of aerosols on surface UV radiation was introduced by Liu etal., (1991). Several investigations show that UV–B transmission through the atmosphere as well as the surface UV irradiance are negatively correlated with aerosol optical depth (Wenny et al., 1998). Based on long term sequences of aerosol optical depth (AOD), Krzyscin and Puchalski (1998) found that a 10% increase in AOD manifests itself in about a 1.5% decrease in daily erythemal UV dose and extreme values of AOD were associated with changes in erythemal UV doses of 20-30% Krotkov etal., (1998) found that over certain parts of the earth with a high loading of absorbing particles the aerosols could reduce the UV flux at the surface by more than 50% . Kylling et al., (1998) estimated that changes in aerosol loading could give larger variations in the surface UV radiation than changes in the ozone column.

Reuder and Schwander (1999) concluded that potential day-to-day variability in atmospheric aerosols could produce changes in the spectral integrated UV radiation quantities up to 20-45%. Their calculations demonstrated that UV–B radiation changes due to typical variability could be equivalent to ozone amount variations in the range of 40-80 Du.

The global scale daily erythemal UV radiation data at the earth's surface are available from the Total Ozone Mapping Spectrometer (TOMS) employed by the NASA, Goddard Space Flight Centre. Ground based measurements show that sun measured UV irradiances in the Southern Hemisphere exceed those at comparable latitudes in Northern Hemisphere by up to 40% where as the corresponding satellite based estimation show only 10-15% differences (Madronich etal., 1998). The ground based UV radiation measurements at more sites reduce these discrepancies, obviously caused by the atmospheric pollution and aerosols. As the short-term variation in aerosols is the source of uncertainties for deriving surface UV radiation from satellite data, the simultaneous measurement of aerosol and UV radiation are of great importance. Changes in atmospheric aerosol loading strongly affect radiative properties of aerosol & spectral characteristics of UV radiation reaching the earth' s surface. The characteristics of UV–B radiation are of great importance also in terms of biological impact of solar UV radiation. Biological response to UV exposure is strongly dependent on wavelength. Spectral sensitivity functions (action spectra) show that many biological responses are far greater at shorter wavelengths in the UV–B region than in the UV-A region (Madronich etal., 1998, Moan and Dahlback., 1991).

Methodology

Aerosol Optical depth (AOD) was measured at NRSC, Balanagar, Hyderabad,A.P,India at wavelengths 380, 440, 500, 675, 870 and 1020nm using MICROTOPS-II sunphotometer having measurement accuracy of ±2%. The detector consists of a silicon photodiode mounted behind a set of continuous variable interference filters. The field of view of the instrument is 1.8°.The AOD,$\tau_A(\lambda)$, was retrieved from the measuring data by accounting for Rayleigh scattering,$\tau_R(\lambda)$,and the contribution of gas absorbers is as follows:

$$\tau_A(\lambda) = \tau(\lambda) - \tau_R(\lambda) - \tau_{O3}(\lambda) - \tau_{H2O}(\lambda)$$

where $\tau_{O3}(\lambda)$ is the ozone optical depth and $\tau_{H2O}(\lambda)$ is the water vapour optical depth. The Rayleigh scattering has been calculated by the formula $\tau_R(\lambda) = (P/P_o)$ x0.008735 x $\lambda^{-4.08}$. In this formula P is the actual air pressure in hPa and P_o = 1013.25 hPa. During 2004 – 2006, a total of above 800 independent measurements of aerosol optical depth and UV_{ery} measurements have been carried out. Total columnar ozone has been measured using MICROTOPS – II ozonometer. UV radiometer from Solar Light Co has been used to measure SUV in 280 – 315 nm. The cosine response of the instrument is ± 5% with a resolution of 0.01 minimum erythemal dose per hour (MED/hr). The MED/hr is a measure of sunburning effect of solar radiation.

Global distribution of the UV intensity was evaluated with archived data of the Earth Probe (EP)/Total Ozone Mapping Spectrometer (TOMS). TOMS instrument is the second-generation backscatter ultraviolet ozone sounder. TOMS measures the total column density of ozone under all daytime observing and geophysical conditions by observing both incoming solar energy and backscattered UV radiation at six wavelengths. Backscattered radiation is solar radiation that has penetrated to the Earth's lower atmosphere and is then scattered by air molecules and clouds back through the stratosphere to the satellite sensors. Along that path, a fraction of the UV is absorbed by ozone. By comparing the amount of backscattered radiation to observations of incoming solar energy at identical wavelengths, one can calculate the Earth's albedo. Changes in albedo at the selected wavelengths can be used to derive the amount of ozone above the surface. TOMS makes 35 measurements every 8 seconds, each covering 50–200km wide on the ground, strung along a line perpendicular to the motion of the satellite. Due to the nature of the platform's orbits, the high northern latitudes were not completely covered during the Antarctic ozone hole season. Almost 200,000 daily measurements covered every single spot on the Earth except areas near poles, where the Sun remains close to or below the horizon during the entire 24 hr period. Effects of topography on the amount of radiation reaching the surface can be significant. Higher altitude regions will receive more direct beam radiation than lower altitude regions since the number of scattering events decrease with the density of the atmosphere, resulting in less radiation being scattered back to space. Rand's global elevation and depth dataset obtained from the National Center for Atmospheric Research (NCAR) Data Support Section was used to scale surface-level UV dose calculations at each grid cell. A nominal scaling factor of 6% increase per kilometer change in altitude was employed to estimate exposure levels for areas above sea level.

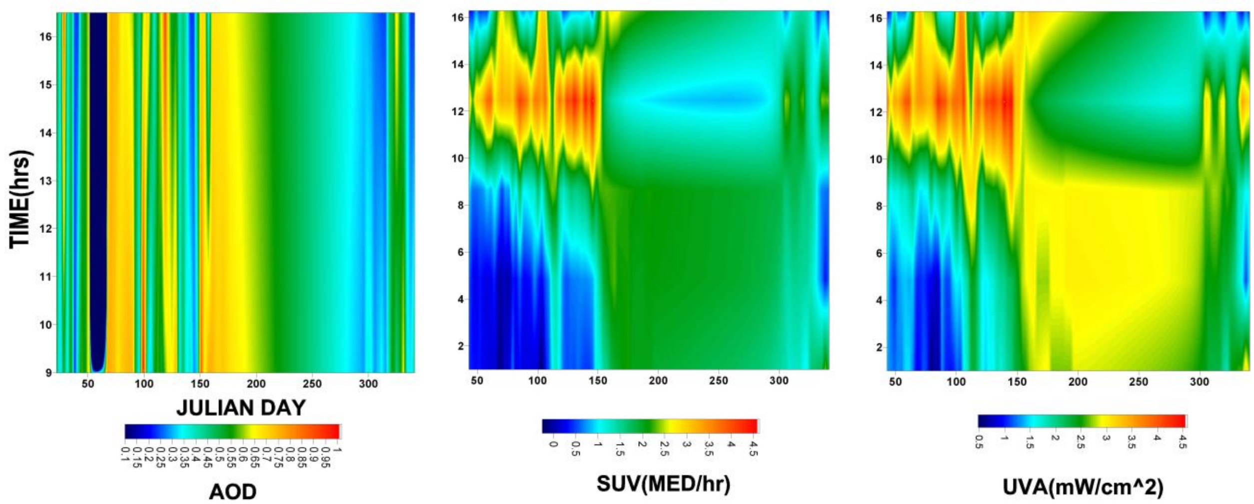
Results and Discussion.

1. Diurnal and seasonal variation of AOD, SUV, UVA:

Aerosol optical depth (AOD) at 500nm was measured using sunphotometer on each experimental day. The diurnal and seasonal variations of AOD, SUV, and UVA on all the days during the period 2001 to 2005, and from January to May during 2006 were shown in Fig.1a, 1b, 1c. Since data points are limited during monsoon season there is a gap in the graph while depicting spatially in Fig.1. The winter season of December-February shows slightly increased AOD values compared to monsoon season of June-October in all the years. This indicates slow addition of aerosols into the atmosphere after wet removal processes during monsoon season. Maximum AOD during summer season(March-May) is due to experiences of high aerosol loading with abundance of coarse-mode particles of soil-dust origin due to the occurrence of dust storm, strong convection and wind blown dust. The minimum AOD values observed during monsoon season suggests decrease in tropospheric aerosol loading due to wet removal processes like washout and cloud scavenging. The observed minimum AODs during post monsoon could be due to weak production and strong wet removal processes that remove most of the aerosols from the atmosphere. High AOD during winter period has been attributed to lower wind speed and relative humidity, which offers the best condition for gas to particle conversion processes. Seasonal patterns of AOD during 2001-2006 remained same and are in agreement with other studies over Indian region (Devara P C S, Pandithurai et al., 1996) and (Niranjan etal.,1995).

Daily SUV and UVA variation during 2001-2006 at the study site is shown in Fig.1. The seasonal variation of SUV and UVA at noon time shows relatively low values during December and January (around (SUV= 1MED/hr and UVA =2MED/hr) except for the year 2003. The values are high compared to other years (SUV=2.6MED/hr, UVA=3.8MED/hr). The values reached maximum during summer period March to May (>3MED/hr).. Comparison of day to day variation of AOD, SUV and UVA in Fig..1.suggests that different levels of aerosol loading in the boundary layer results in significant modulation of solar UV radiation reaching the ground, especially during the days of high aerosol loading. The aerosol loading is observed to be high during 2002, and low SUV observed during 2002 also supports the impact of aerosols on the reduction of ground reaching SUV, especially during summer season. The observations in the present study are in confirmity with other studies reported in literature (Kylling et al., 1998) and (Krzyscin J W et al., 1998). The SUV varies markedly through the year and is more intense during summer season. Seasonal and diurnal cycles of solar radiation are responsible for observed variations in the SUV intensities.

2001


TIME(hrs)
JULIAN DAY
AOD
SUV(MED/hr)
UVA(mW/cm^2)

2002

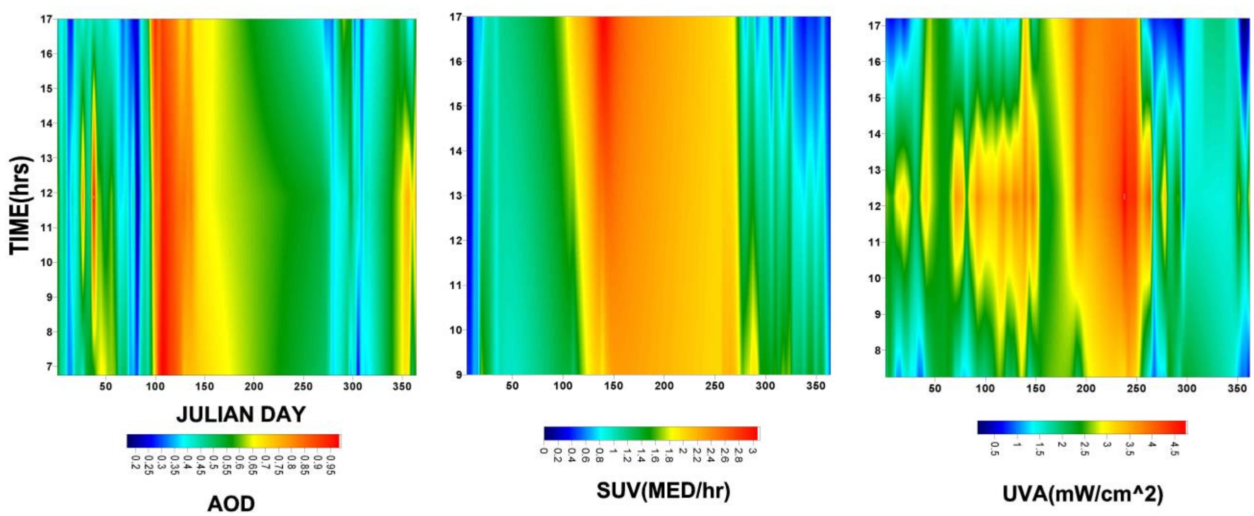
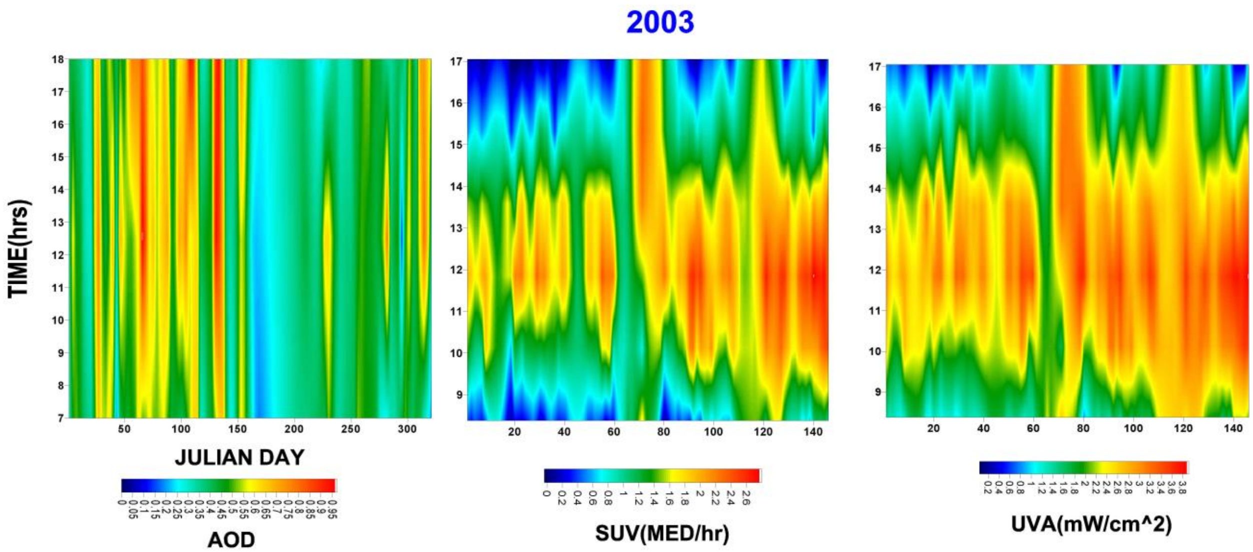

TIME(hrs)
JULIAN DAY
AOD
SUV(MED/hr)
UVA(mW/cm^2)

Fig.1a. Day to day variation of AOD, SUV, UVA during 2001 & 2002



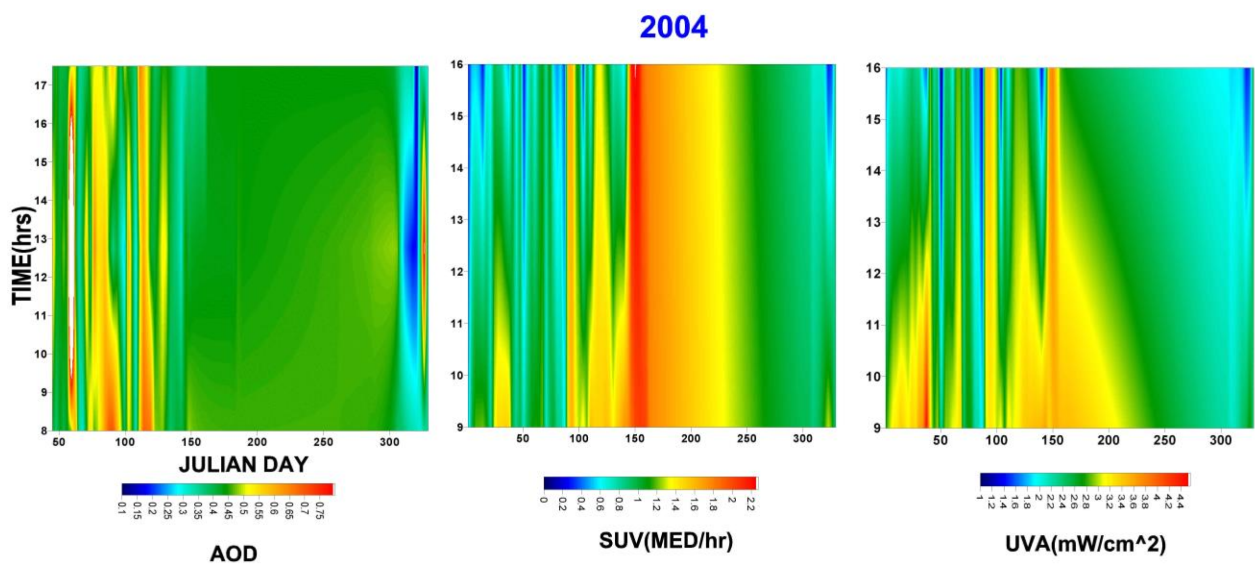
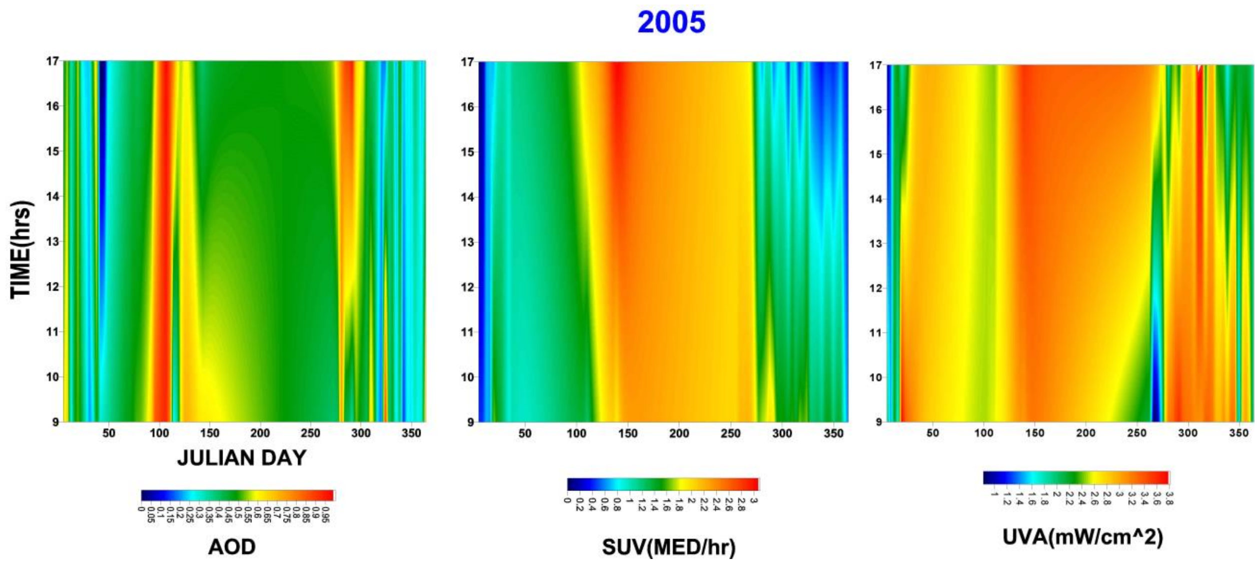


Fig.1b. Day to day variation of AOD, SUV, UVA during 2003 & 2004



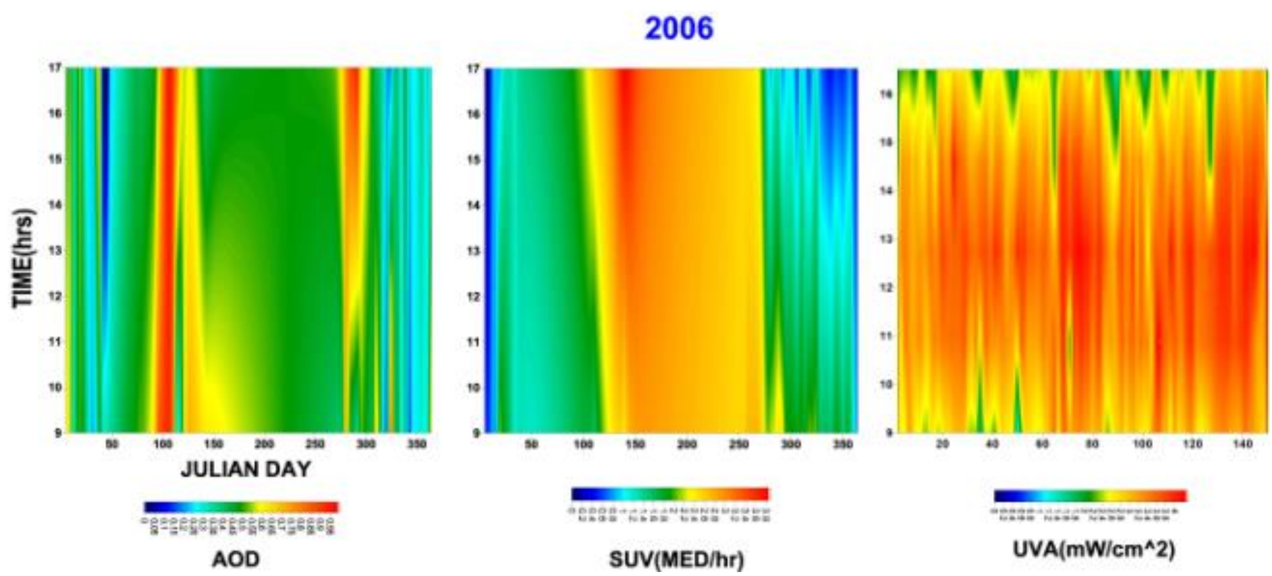


Fig.1c. Day to day variation of AOD, SUV, UVA during 2005 & 2006

2.Variation of UV-B radiation on high pollution and low pollution days

In the present study an attempt has been made to study the impact of variations in aerosol loading on SUV intensities. Fig.2 shows the representative example of diurnal variation of AOD during relatively high pollution day (10 Apr. 2006) and low pollution day (09 Apr. 2006) days. The relative humidity on both the days is around 55%. During high pollution days, AOD at 500nm ranges from 0.63 to 0.88, whereas during low pollution days it ranges from 0.49 to 0.81. Fig.3 shows corresponding diurnal variation of SUV during high and low pollution days. During low pollution days SUV ranges from 0.82 to 3.33 MED/hr, whereas during high pollution days SUV ranges from 0.62 to 2.78 MED/hr. The diurnal SUV variation throughout the course of the day shows Gaussian type of variation. However it is interesting to note that diurnal course of SUV curve is bell shaped during low aerosol loading day where as distortion in the shape of the curve has been observed during high aerosol loading. SUV is moderately stronger during afternoon hours. UV radiation is much more attenuated at high solar zenith angles in the early morning and late afternoon because of increased absorption by stratospheric ozone during its increased path length through the atmosphere. Radiation at the UV wavelengths is scattered much more than visible wavelengths. This results in a drastic decrease in UV radiation reaching the surface. The slant path is minimum around the summer time, which leads to the largest UV exposure. Day to day variation of AOD and SUV during2004, 2005, and 2006suggested that SUV has significantly reduced during the days having high aerosol loading [Fig.4(a-c)]. This observation is similar to other studies cited in the literature (Krzyscin and Puchalski., 1998; Kylling et al., 1998). UV radiation has historically been more intense during the summer because of its low columnar ozone and the closest earth-sun separation occurrence during the summer.

Fig.5a,5b,5c shows statistical fit through the average data points of AOD and SUV during 2004, 2005, 2006 suggesting negative gradient, and similar observations have been reported in earlier studies (Wenny B.N et al., 1998). The slopes of the figures 5a, 5b, and 5c suggest that every 0.1 increase in AOD causes 0.0847MED/hr (2004), 0.07566MED/hr(2005), 0.04489MED/hr(2006) reduction in ground reaching SUV. This is the average direct radiative forcing efficiency at surface by aerosols in the SUV over tropical urban environments of Hyderabad. Figures 5d & 5e show the relation between SUV and AOD during forenoon and afternoon hours. It is observed that the slope of the data points is high during afternoon hours compared to morning hours suggesting drastic decrease in SUV during afternoon with increasing AOD.

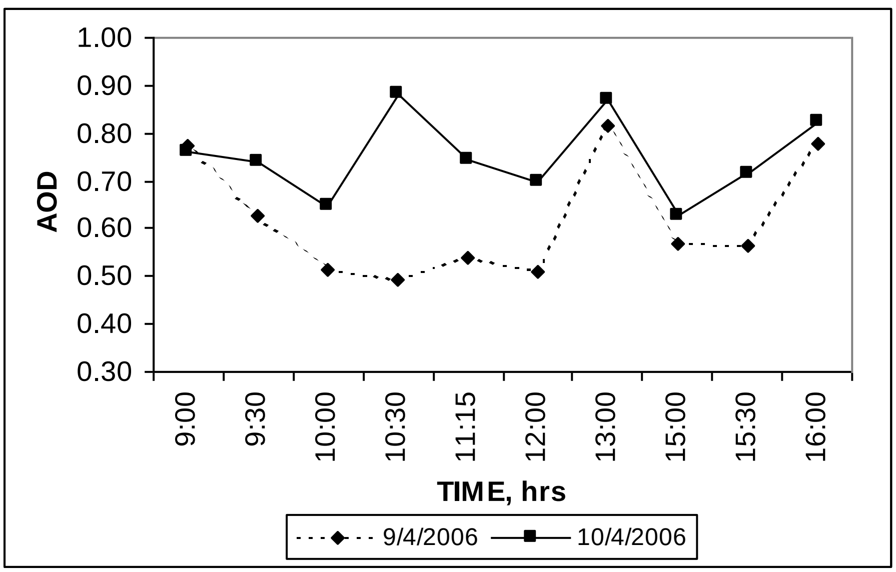


Fig.2.Variation of AOD on 09 April, 2006 and 10 April, 2006

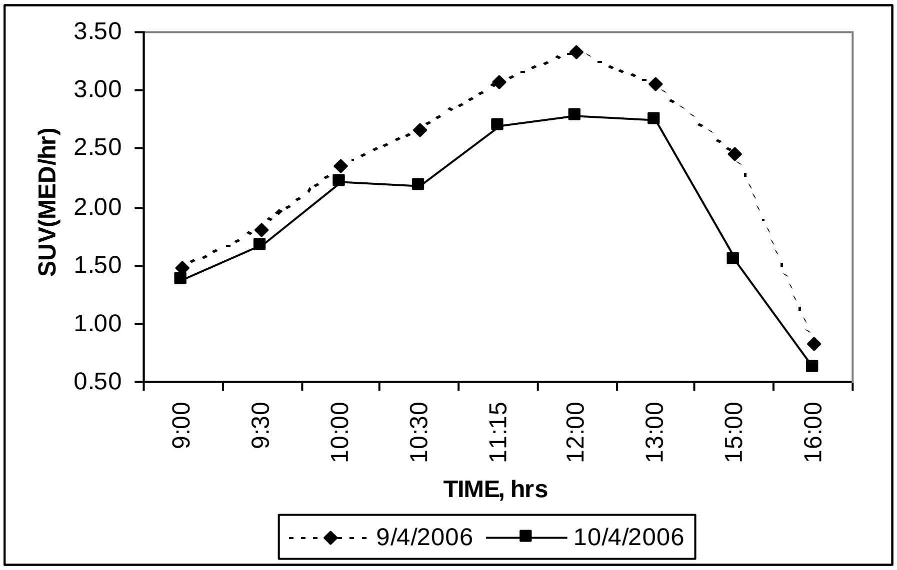
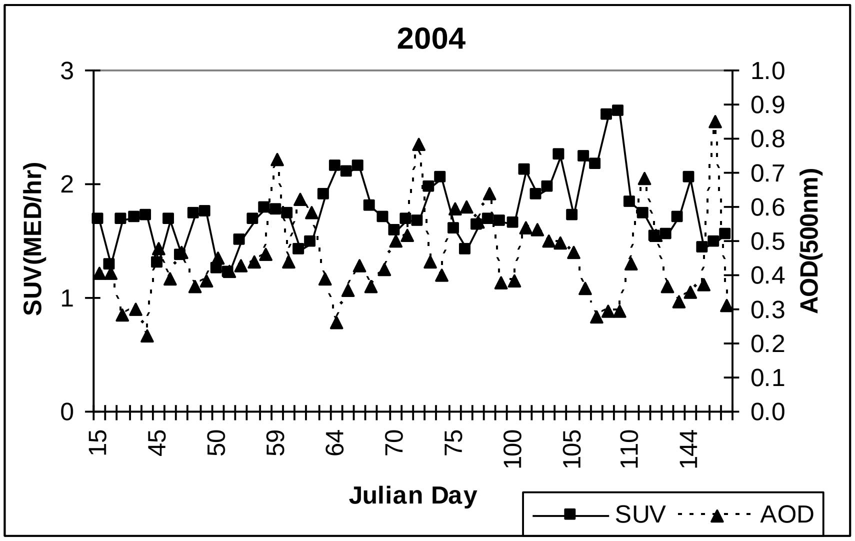
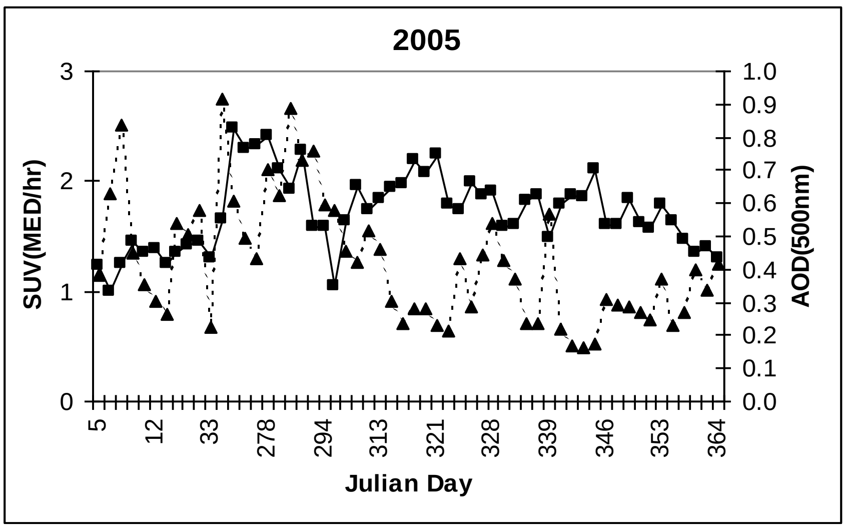


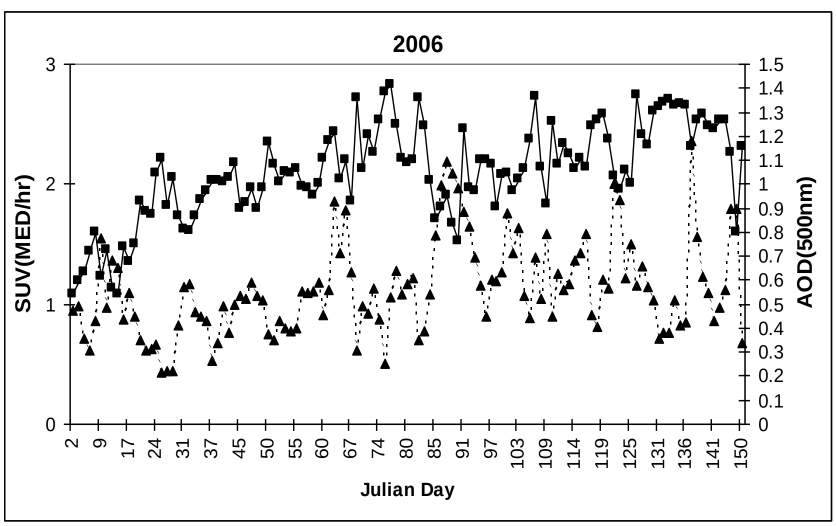
Fig.3.Variation of SUV on 09 April, 2006 and 10 April, 2006



(a)



(b)



(c)

Fig .4(a-c). Day to day variations of SUV & AOD(500nm) during 2004, 2005 & 2006

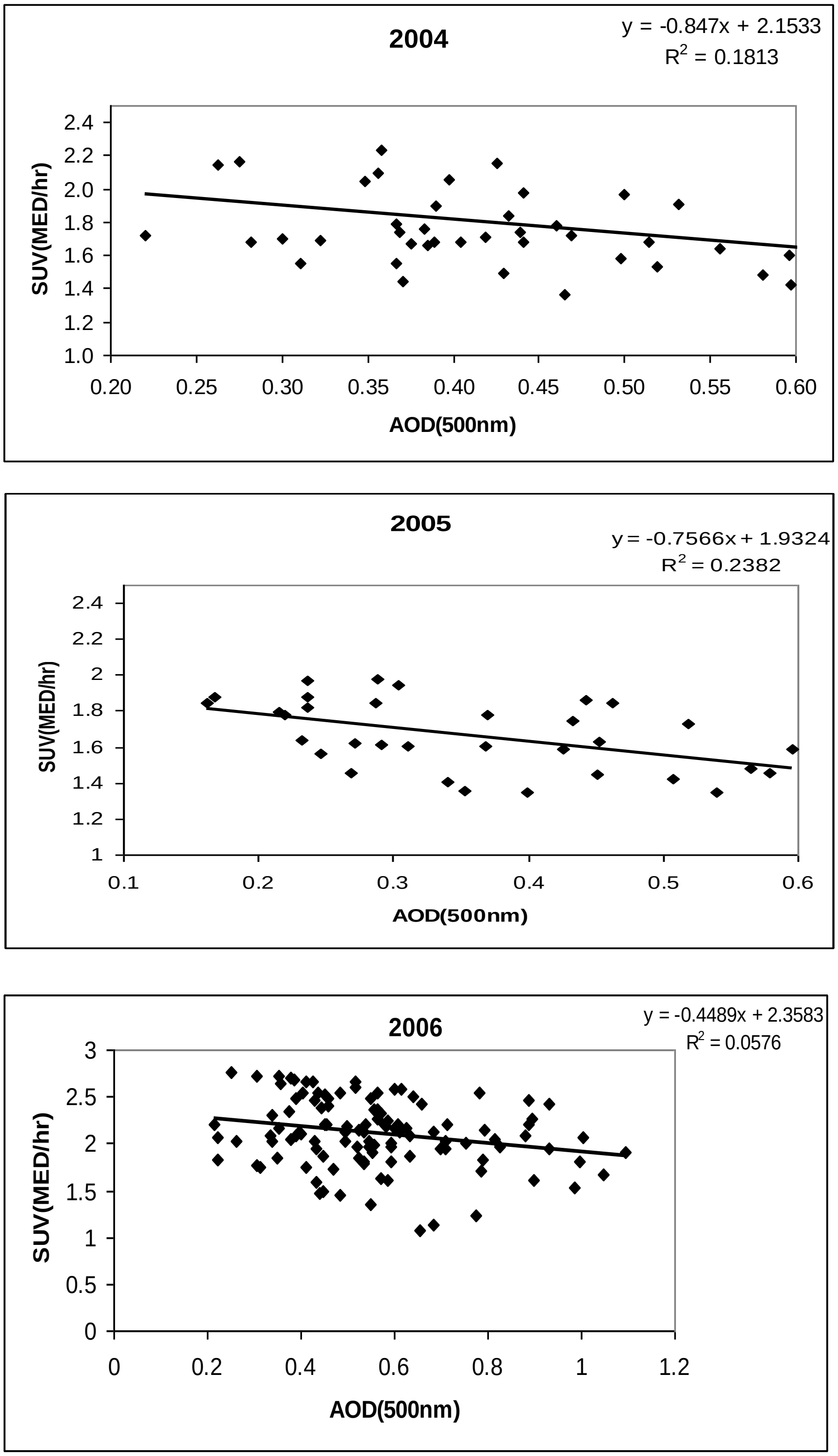
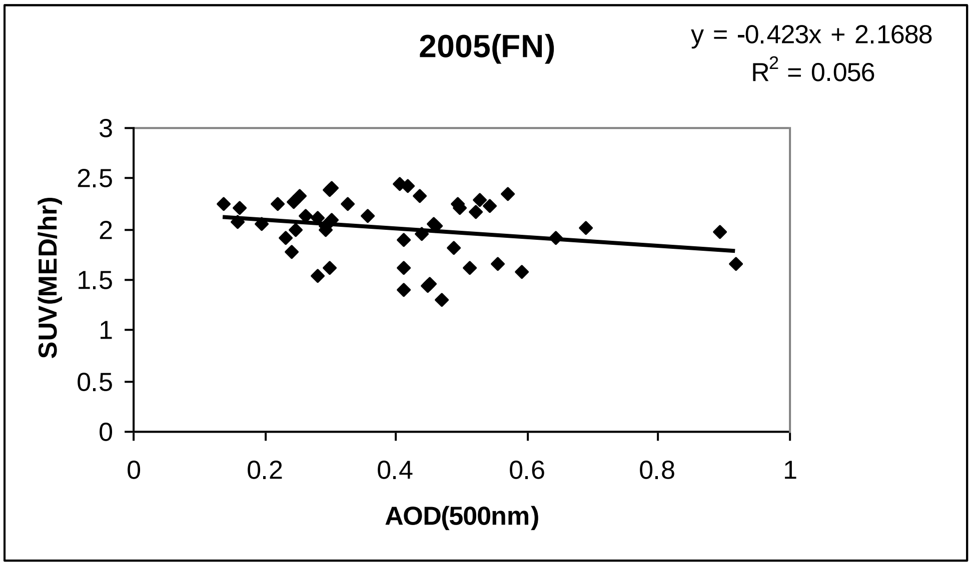


Fig .5(a-c) Scatter plots of SUV & AOD (500nm) during 2004, 2005 & 2006



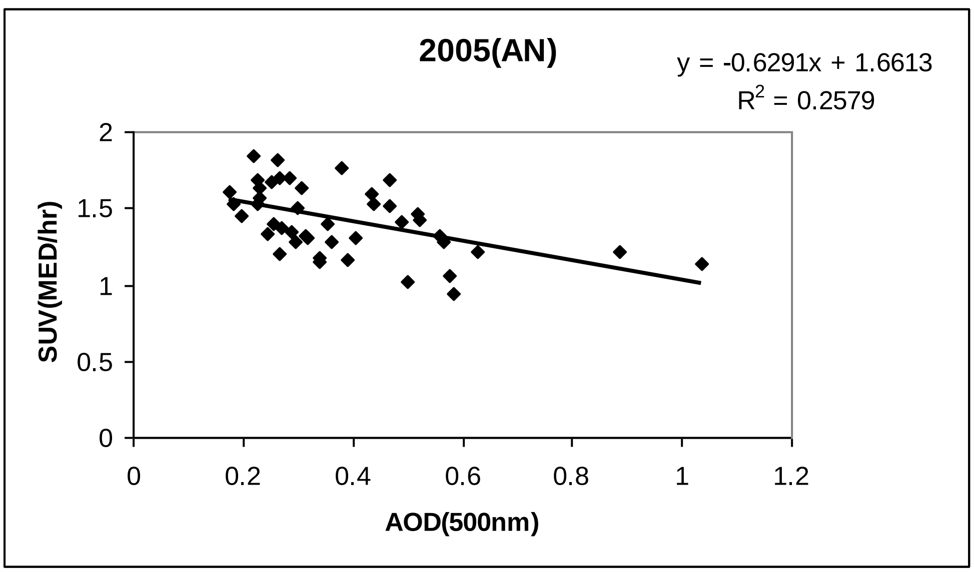
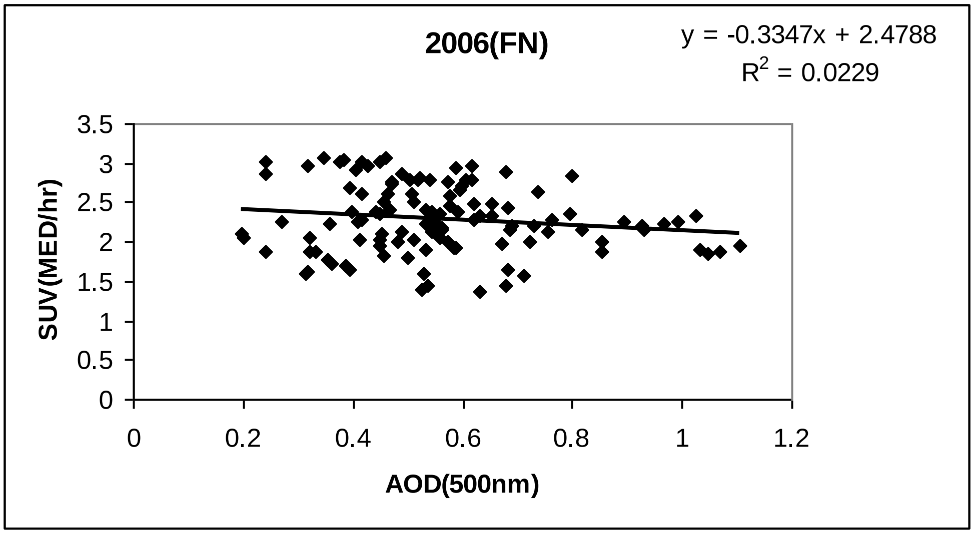


Fig.5d. Scatter plots of SUV & AOD (500nm) during 2005(FN&AN)



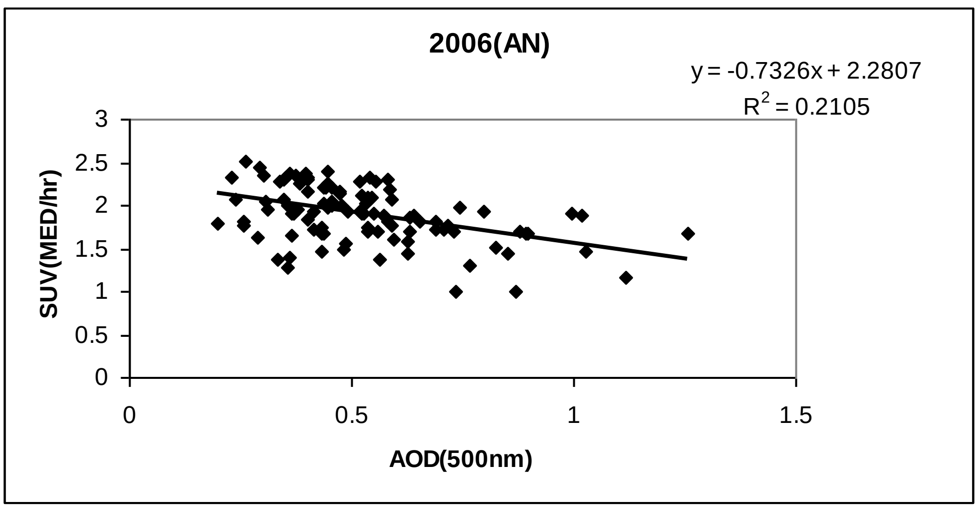
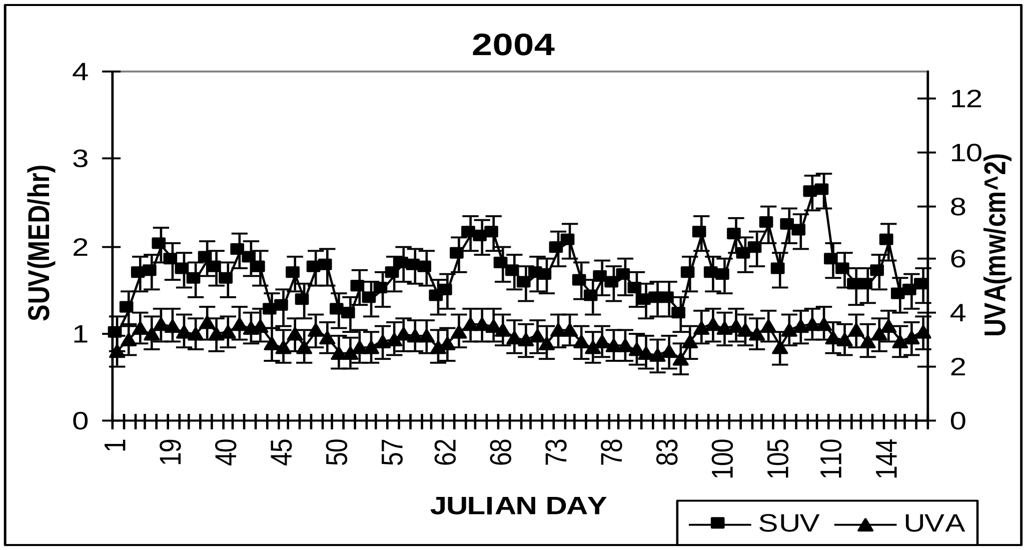
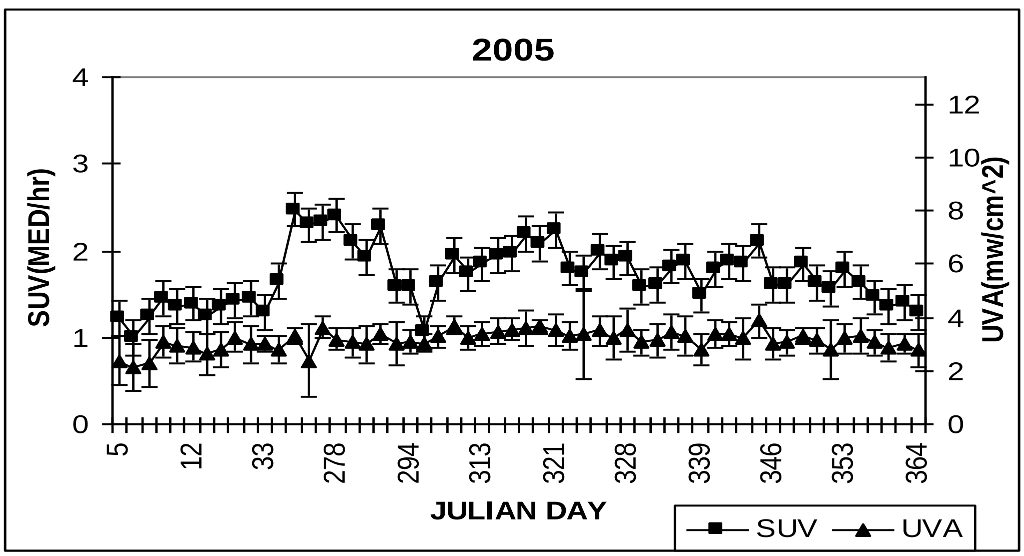


Fig.5e. Scatter plots of SUV & AOD (500nm) during 2006(FN&AN)

Day to day variations of SUV and UVA during the years 2004, 2005 and 2006 is shown in Fig.6a, 6b, 6c. The values of SUV radiation are higher compared to UV-A throughout the year. Both SUV and UVA gradually increased from January having a primary peak in summer and a secondary peak around October , the values slowly receding towards December. SUV and UVA showed similar variation with respect to the Julian day.



(a)



(b)

Fig 6(a, b) . Day to day variations of SUV & UVA during 2004 & 2005

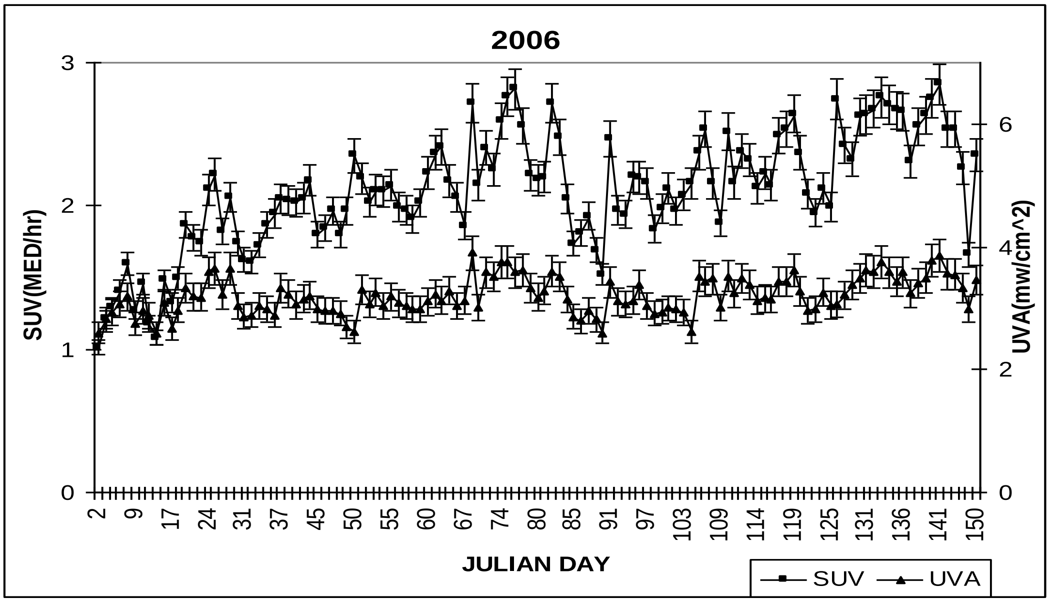
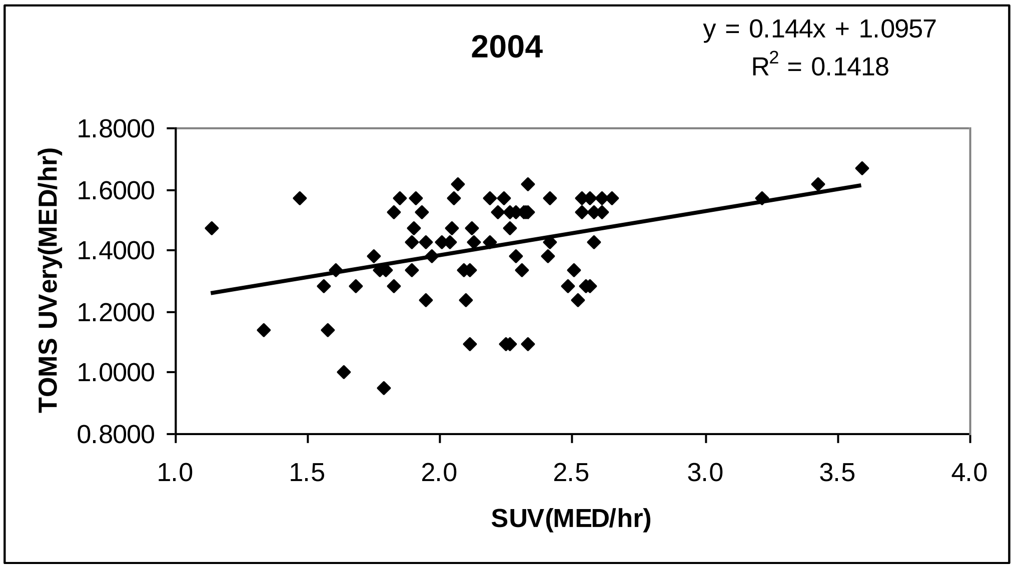


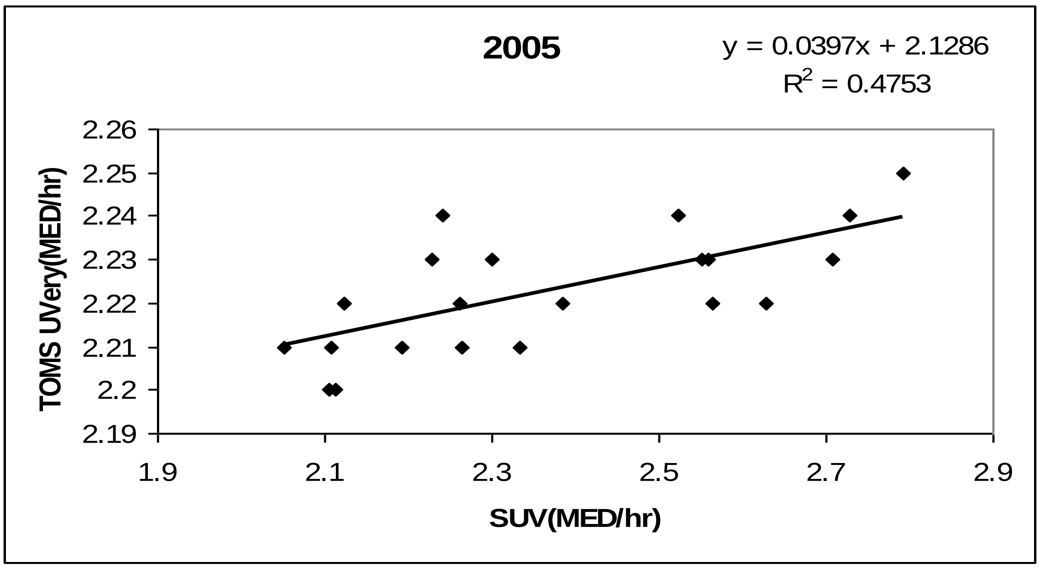
Fig. 6.c. Day to day variation of SUV & UVA during 2006

3.Relationship between satellite and ground based measurements of SUV and TOMS UV_{ery}

For finding out the relationship between aerosol and the surface erythemal UV radiation. the measured surface erythemal UV irradiances for the years 2004 and 2005 were compared with TOMS UV erythemal radiation and scatter plots are shown in Figures 7a, 7b. Ground measured SUV showed a positive correlation with TOMS UV_{ery} during the period with the corresponding slopes of 0.144 and 0.0397with values of r^2 0.1418 and 0.4753 respectively.



(a)



(b)

Fig 7.(a, b) Scatter plots of SUV & TOMS UVery during 2004 & 2005

Summary and Conclusions of the chapter

Results of the study suggest that tropospheric aerosol loading has significant impact on variations in the ground reaching UV_{ery} radiation in tropical urban environment at 500nm.The results of study suggest that SUV decreases at the rate of nearly 0.1 MED/hr per unit increase in aerosol optical depth. In addition to this, Synchronous observations on AOD and ground reaching SUV radiation during normal day and the day after rainfall event suggested ~45% attenuation of ground reaching UV-B radiation during normal high aerosol loading days.

The seasonal variation of SUV and UVA at noon time show relatively low values during December and January, around (SUV= 1MED/hr and UVA =2mW/cm^2) except for the year 2003. The values are high in 2003 compared to other years (SUV=2.6MED/hr, UVA=3.8 mW/cm^2). The values reached maximum during March and May (>3MED/hr). Comparison of day to day variation of AOD, SUV and UVA suggested that different levels of aerosol loading in the boundary layer results in significant modulation of solar UV radiation reaching the ground. The aerosol loading is observed to be high during 2002, where as low SUV observed during 2002 also supports the impact of aerosols on the reduction of ground reaching SUV, especially during summer season.

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