Studies of Atmospheric Aerosol's Parameters during Pre-Diwali to Post–Diwali festival period over Indian Semi Arid Station i.e., Udaipur

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Abstract

The paper describes day to day changes observed in atmospheric aerosol's parameters namely AI_{300}, AOD_{550}, α, TWC, β and MC from their background reference day value over Udaipur during Pre to Post-Diwali period from 2002 to 2007. Before Diwali to Diwali, daily variations in such aerosol's parameters values show the substantial increase order of 30- 60% from their respective background. Afterward Diwali, such change in AI_{300} shows the decreasing behavior, in sharp contrast to this, daily variations in AOD_{550}, β and MC exhibit either lower value or attain the same peak value depending upon the corresponding level of TWC and rainfall activity of that particular year. These variations are not instantly but with certain delay in the same period. A considerable amount of implication in aerosols loading is observed in terms of reduction in SHWRF from 20-30% during the enhancement period of aerosol's parameters. However, DSWRF does not show any appreciable change. The main possible causes of increase in aerosol's loadings within above period are discussed in views of inter mixed effect of local emission activity and long range transport of aerosols from heavy polluted IGP site and in reduction of PBL height and wind speed.

Keywords: aerosol $index_{300}$, aerosol optical $depth_{550}$, total water vapour content, planetary boundary layer

1. Introducation

Atmospheric aerosols are microscopic solid and liquid particles of several chemical species suspended in the Earth's atmosphere (Albrecht, 1989; Charlson et al., 1992). Although, their sizes are so small but their direct consequences alter the net incoming solar–terrestrial radiation to exert positive and negative atmospheric aerosol's radiative forcing effect at the Earth's surface and atmosphere through scattering and absorption processes. At the same time, other indirect aerosols affect are on cloud condensation properties and earth-hydrological cycle system, etc., hence on the precipitation too (Haywood & Shine, 1995; Hansen et al., 1997; Haywood & Boucher, 2000; Satheesh & Ramanathan, 2000; Satheesh & Moorthy, 2005; Tripathi et al., 2007).

Among the most commonly used atmospheric aerosol's parameters for atmospheric aerosol's characteristics, the Aerosols Optical Depth (AOD) is one of the important key parameter, which represents the extinction of solar radiation due to aerosols. It is indicator of the extent of particulate matter present in the air at a particular place. Another set of usual aerosol's parameters are Ångström parameters (α and β) that give an idea about the relative abundance of fine-to-coarse sized particles and turbidity or loading of aerosols in the atmosphere (Ångström, 1964).

As the aerosols are produced due to a wide range of global natural activities such as forest fire, dust storms & oceanic waves and also due to a large number of regional and local anthropogenic activities such as burning of fossil-fuel, industrial waste, automobiles, home furnaces, etc. Besides above man-made activities, specific intensive fire ignition and crack work activities belong to same category such as anthropogenic aerosols activities also take place during a certain celebration period like Diwali in India, Lass Fallas in Spain, Lantern festival in Beijing, New year celebration all around the worldwide and other major similar ceremonies (Mandal et al., 1997; Eck et al., 1998; Novakov et al., 2000; Badrinath et al., 2004; Drewnick et al., 2006; Vecchi et al., 2007; Wang et al., 2007).

As the major Indian festivals like Diwali, Garbha and Dashera are mainly celebrated across the Indian Subcontinent in the span of a few weeks of October or November of each year. During this period, the large number of anthropogenic activities like bursting of firecrackers and sparkles, burning of bio-gases and residues of waste agricultural crop materials etc., taking place over Indian urban and rural sites e.g., Indo- Gangetic Plain (IGP) (Badarinath et al., 2009; Sharma et al., 2010). During same months, the IGP region is associated with higher incidences of bio-mass burning and residues of waste agricultural crop's fire activities, which are observed maximum in Punjab and Haryana states followed by Uttar Pradesh, Madhya Pradesh and Maharashtra (Badarinath et al., 2006, 2009). At recent reported work, the effects of firework activities on short term perturbation in air pollutant levels and its chemical compositions were carried out by several researchers during past years of Indian festival Diwali, New-Year and other celebrations over India and other parts of the globe (Attri et al., 2001; Ravindra et al., 2003; Barman et al., 2008; Thakur et al., 2010). Their main findings suggested that in such occasions, exceptionally high emission levels of several air pollutants (i.e., different trace toxic metals present in various sizes of Suspended Particulate Matters), air toxic gases and chemical matters were observed above the prescribed limit of their National Ambient Air Quality Standard levels. These extensive findings have established the fact that the injections of these materials are responsible for accumulation of air pollutants and aerosols in the Earth's atmosphere for short duration. Hence, these have become unusual extra sources of acute short term air pollution episodes (Khaiwal et al; 2003; Kulshrestha et al., 2004; Ganguly, 2009; Singh et al., 2010).

Few Indian researchers also carried out the studies to concern the perturbation in aerosols loading characteristics during such specific events. Variations in some of the atmospheric aerosol's parameters during Diwali over major Indian cities were reported by several group members at Trivandrum, Bangalore, Hyderabad, Ahmedabad, Delhi and Kanpur. They showed the increase in Aerosols Optical Thickness ($AOT_{300, 550, 1020}$) at different wavelengths 300, 550, 1020nm over Kanpur and the Arabian Sea (Singh et al., 2003; Badarinath et al., 2009), Black Carbon (BC) mass density over Trivandrum (Babu & Moorthy, 2001), Bangalore (Nair et al., 2010), Ahmedabad (Ramachandran & Rajesh, 2007), Delhi (Singh et al., 2010) during Diwali. However, such studies have given preliminary evidence about an increase of AOT, concentration of aerosol's sizes greater than the micro size level, BC and decrease in Single Scattering Albedo (SSA) around Diwali only over urban sites. These efforts have created a lot of motivation to perform the detailed investigation on the variations in the large number of atmospheric aerosol's parameters, their effects on solar radiation parameters and linked to the meteorological parameters around the several weeks of Diwali.

In view of the above perspectives, the variations in several atmospheric aerosol's parameters and its interrelation to solar-radiation and meteorological parameters during these episodic Diwali events are undertaken as the main objectives of the present course of work over Udaipur (Geo. Lat. 24.6° N, Geo. Long. 73.7° E, 580m AMSL) using the data set from 2002 to 2007 (Figure 1). An attempt has also been made to correlate these extra perturbations in aerosol's parameters with other plausible meteorological parameters like Wind Speed (WS, m/sec) and Planetary Boundary Layer Hight (PBL, meter) from Pre-Diwali to Post-Diwali, including Diwali days.

Figure 1. Geographical map of observation site Udaipur (India)

The data set for present investigation is a Satellite-borne measurements of daily values of the atmospheric

Aerosols UV Index at 300nm (AI_{300}) retrieved from space borned instruments like Total Ozone Mapping Spectrometer (TOMS) (References there in) and Aura Ozone Montitoring Instrument (OMI) (References there in). The daily data set of Aerosols Optical Depth at 550nm (AOD_{550}), Mass Concentration (MC, μg/cm^2), Total Water Vapour Content (TWC, cm), Ångström Coefficient (α, 470/600nm) are measured by MODIS-Terra Satellite (References there in). The data sets of PBL, Wind-Speed, Sensible Heat Radiation Flux Density (SHRFD, W/m^2), Downward Short Waves Radiation Fluxes Density (DSWRFD, W/m^2) are taken from the NCEP/NCAR and re-analysis by using a NOAA website for a period from 2005 to 2009 (References there in).

2. Data Analysis

To perform the present investigation, daily positive AI_{300} values over Udaipur have been downloaded from their website for the specified sixty-day period, which cover Garbha, Navratri, Pre-Diwali, Diwali and after fifteen days of Diwali for each year from 2002 to 2007. The positive value of AI_{300} is a useful parameter for tracking regional transport of the UV absorbing nature of aerosols like dust, smoke and ash over all Earth's surface (Badarinath et al., 2006). The each day values for the corresponding period of AOD_{550}, α, MC and TWC parameters over an observational site are retrieved from the website. The values of aerosols loading parameter or turbidity coefficient (β) are computed from measured values of α, λ and AOD_{550} using the well-known Ångström power law relation (Ångström, 1964) given by

$$AOD_{550}=\beta\lambda^{-\alpha} \qquad (1)$$

Where, the measured parameters are AOD_{550}, λ (wavelength, which is at 550 nm), α (Ångström coefficient, indicating the size distribution) and β (turbidity coefficient, which is measured of aerosols loading properties).

The daily noon hours PBL height, Wind Speed, SHRFD and DSWRFD data set are extracted for the similar months from 2005 to 2009 from their website (References there in).

As atmospheric aerosols exhibit large day to day, month to month variations and exert a direct effect on the incident solar radiation intensity reaching on the Earth's surface (Moorthy et al., 1999, 2007). In order to remove all the day to day and seasonal variation in aerosol's parameters or extract the overall changes in aerosol's parameters during such specific anthropogenic episodes of aerosols loading activities, following method has been adopted to remove the normal background trend (normal trend) from the available daytime data series (Babu and Moorthy, 2001; Singh et al., 2003).

The corresponding daily values of such parameters of the prescribed period from 2001 to 2008 are used for atmospheric aerosol's parameters (References there in). However, for meteorological and solar radiation parameters, these available data on noon hours are employed for the period from 2005 to 2009 (References there in).

From such daily values of each particular Julian day of each different year, the average day values and its standard deviation of the above parameters are calculated separately from their respective values of Julian day (October and November's days) for the different years. These average particular Julian day values of each parameter are treated as Back Ground Reference Day Values (BGRDV) of the respective parameters of particular monthly calendar dates of the daily value for the entire study period.

The individual daily values of all the parameters in the above each monthly calendar date of each year is then converted into daily Percentage Deviation (PD) relative to BGRDV plus its 1.5 of standard deviation values as follows.

The daily value of PD (the each calendar date of a particular month for the specific year) of AOT's parameters is (Jinping, 2009)

$$PD=(AOT_{obs} - BGRDV)\times 100/BGRDV \qquad (2)$$

where, AOT_{obs} is the observed values of the various parameters of AOT.

In order to examine the statistical significance of observed changes in aerosol's parameters, the Correlation Coefficients (R) with its percentage level of confidence (%CL), between the AOD_{550} with different aerosol's parameters like α (470/600 nm), MC, β and TWC is estimated from their daily data set values during Pre-Diwali to Post-Diwali period and are shown in Table -2.

The observed results of day to day variation in PD of the above-mentioned parameters for each specific year are plotted in Figures 2, 3 and 5. In these figures, the Diwali day is illustrated by marking vertical lines on the day axis at zero day, whereas Pre-Diwali days are marked by its negative number of days.

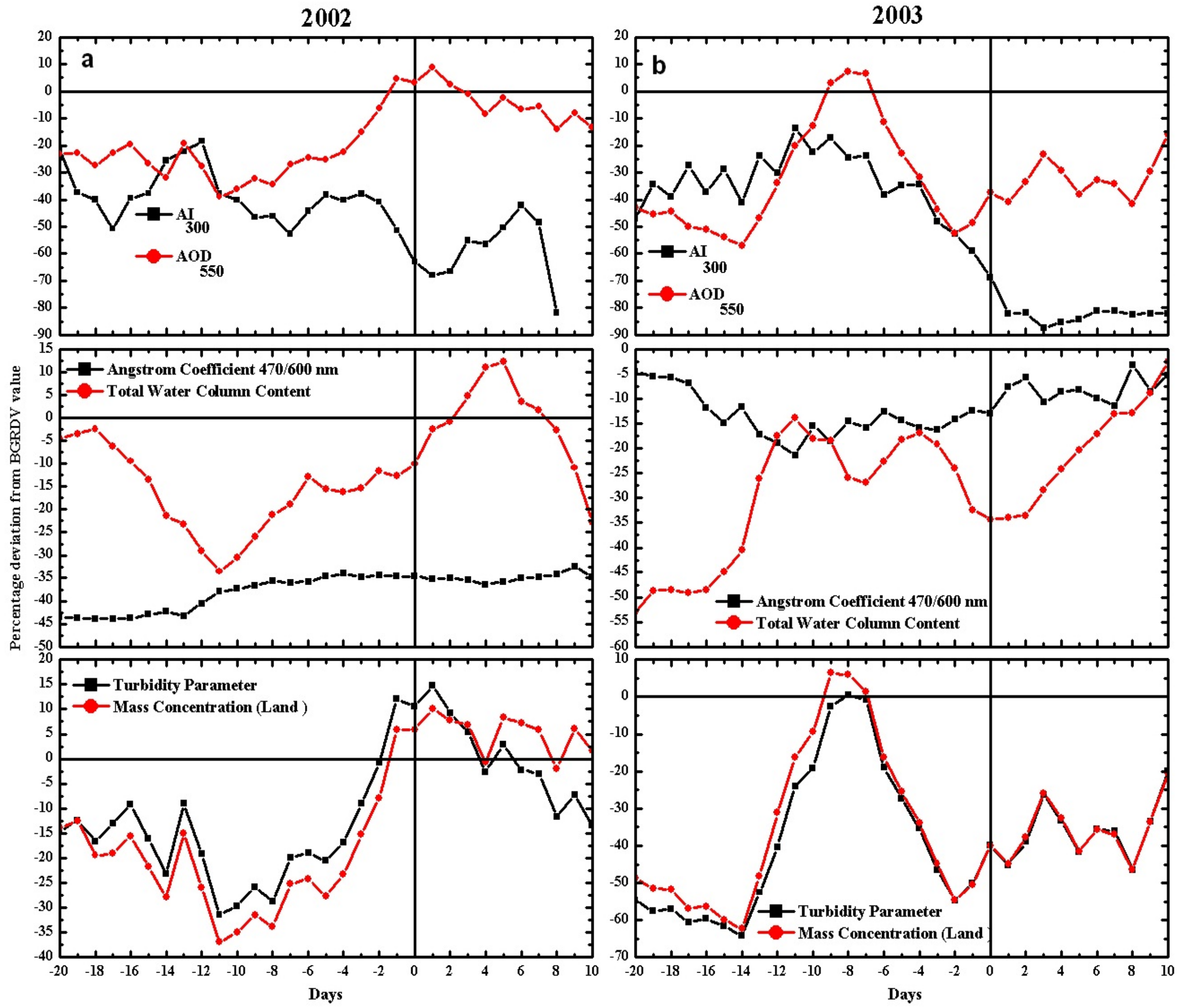


Figure 2(a, b). Day to day variability in PD value of AI_{300}, AOD_{550}, Ångström Coefficient (α, 470/600nm), Turbidity Parameter (β), Mass Concentration (Land), Total Water Vapour Content from Pre-Diwali to Post-Diwali over Udaipur in the years 2002 and 2003

Table 1. Observed Rain Fall in mm over Udaipur during year from 2002-2007

Year	Rain fall in mm (Monsoon months)	Rain fall in mm (October month)	Rain fall in mm (November months)
2002	249.06	0.39	1.3
2003	452.99	0.26	0
2004	426.12	79.1	0
2005	526.48	0	0
2006	558.97	0	0
2007	539.82	0	0

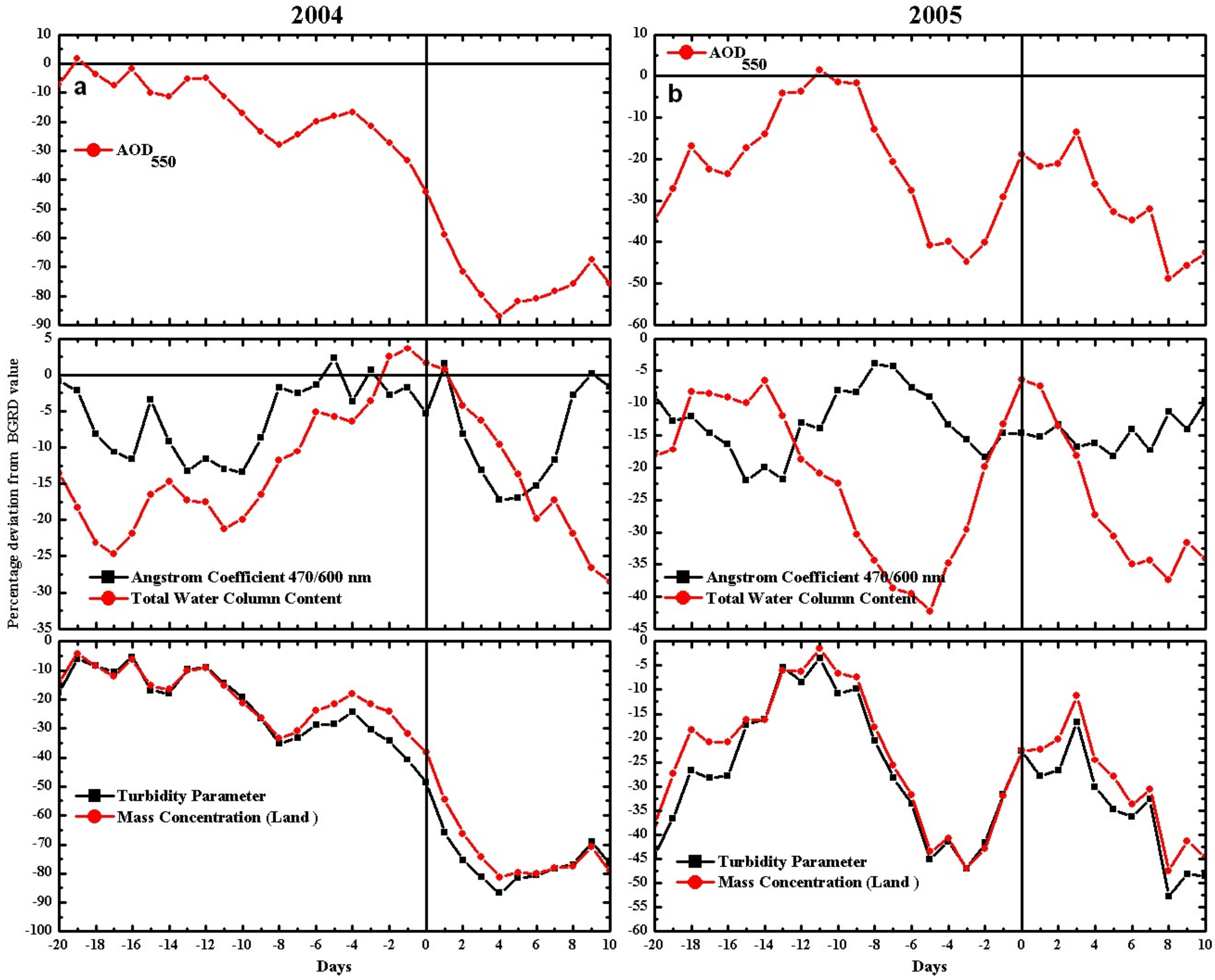
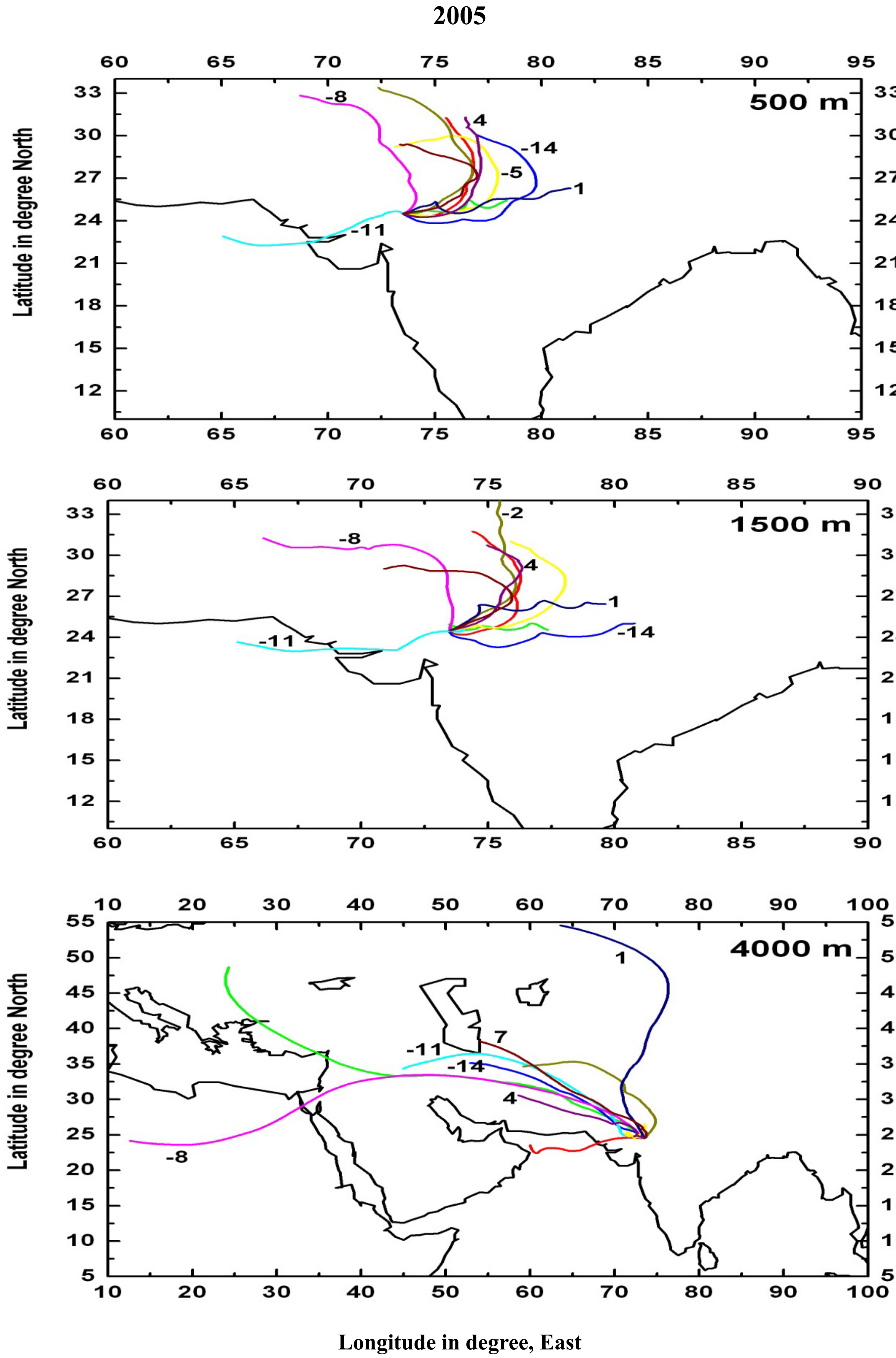


Figure 3(a, b). Day to day variability in PD value of AI_{300}, AOD_{550}. Ångström Coefficient (α, 470/600nm), Turbidity Parameter (β), Mass Concentration (Land), Total Water Column Content from Pre-Diwali to Post-Diwali over Udaipur in the year 2004 and 2005

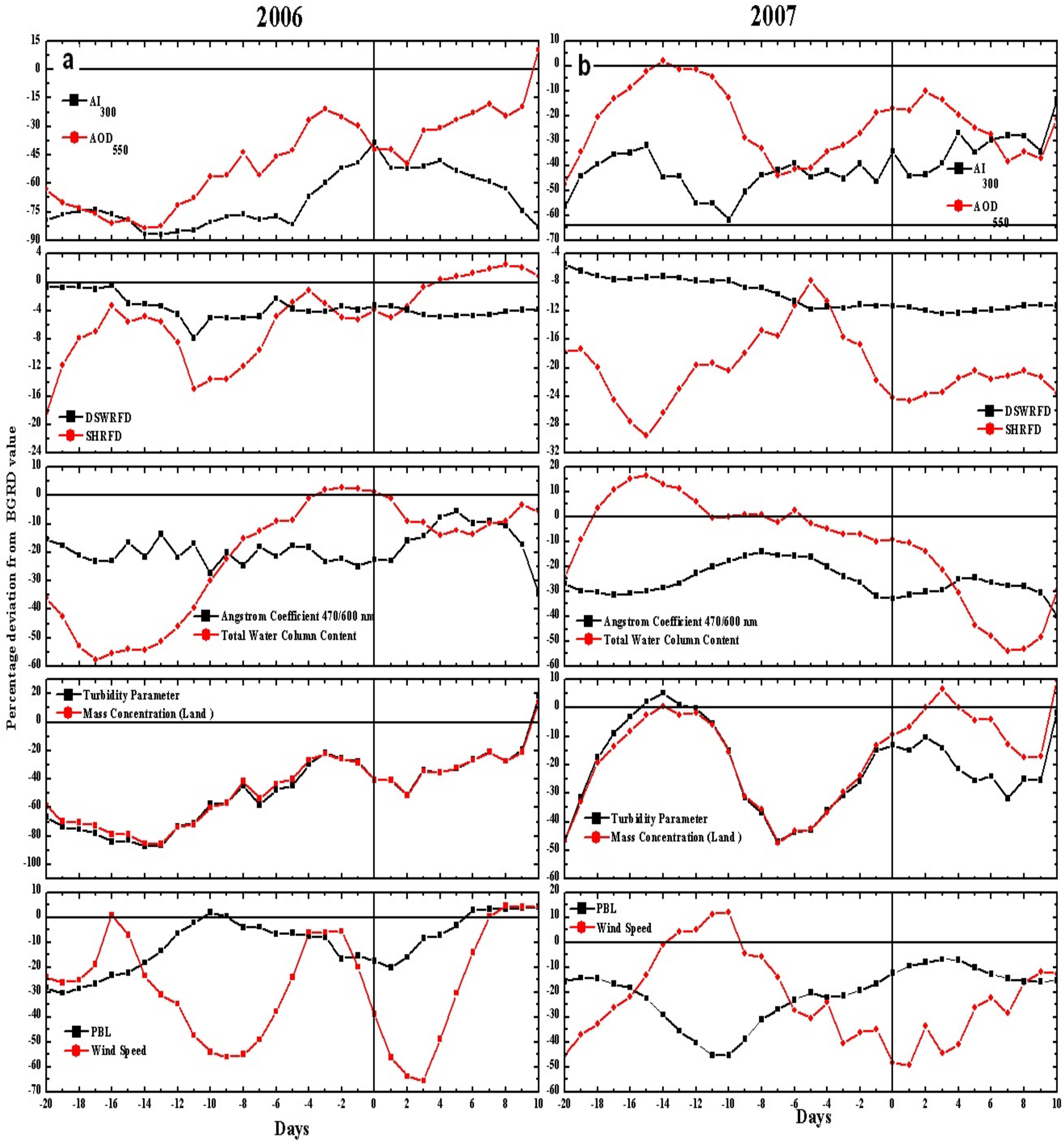
Table 2. Correlation coefficients (R with percentage level of confidence (%CL) between AOD_{550} with different aerosol's parameters like α (470/600nm), MC, β and TWC

Year	Ångström Coefficient α (470/ 600 nm)		Mass Concentration (MC)		Turbidity Parameter (β)		Total Water Vapour Column Content (TWC)	
	R	%CL	R	%CL	R	%CL	R	%CL
2002	-0.54**	>99	0.99**	>99	0.99**	>99	0.28	ns
2003	-0.35*	>90	0.98**	>99	0.89**	>99	0.24	ns
2004	-0.08	Ns	0.99**	>99	0.98**	>99	-0.09	ns
2005	-0.28	Ns	0.99**	>99	0.99**	>99	0.24	ns
2006	-0.54**	>99	0.94**	>99	0.94**	>99	0.23	ns
2007	-0.40*	>95	0.99**	>99	0.99**	>99	0.28	ns

ns = not significant (p>.05), *=significant (p>.01), **=significant (p>.001)



Figures 4(a - c). Air Mass Backward Trajectories using NOAA Hysplit Model for 500, 1500 and 4000 m AGL observed over Udaipur during Pre-Diawli to Post-Diwali days of year 2005



Figures 5(a, b). Day to day variability in PD value of AI_{300}, AOD_{500}. Ångström Coefficient (α, 470/600nm), Turbidity Parameter (β), Mass Concentration (Land), Total Water Vapour Content along with SHRFD, DSWRFD, PBL & Wind Speed from Pre-Diwali to Post-Diwali over Udaipur in the years 2006 and 2007

2.1 Description of Observational Site

Udaipur (Geo. Lat. 24.6° N, Geo. Long. 73.7° E) is situated in the Southern part of Rajasthan, which is in the Western part of India. Its geographical position coordinates reveal that the city passes near by the tropic of cancer and therefore receive the high amount of the incident solar radiation (Ramachandram and Rajesh, 2007). The district population is around two million, which spread in about thirteen thousand square kilometers. Thirty-seven percent of the total geographical area is covered by the forest region (References there in). The altitude of the city is about 580m above the mean sea level. Hence, the city is situated well below the atmospheric boundary layer. The city is surrounded near by the Aravali Hills, large number of mines, smelters, several types of industrial activities and several natural lakes on three sides and the remaining Eastern side is open, which creates suitable geo-location well and valley of extra trapping of the atmospheric aerosols from highly populated cities located remote in North and North - Eastern India at the experimental site with the favorable wind velocity pattern in October and November.

During this period, the weather remains dry, cold, calm i.e., having low wind speed with rare rainfall activity at the observational site. The details about rainfall in the above periods are shown in Table -1. Yearly rainfall was below the normal level, which is 550mm over the observational site in 2002, 2004 and 2005. However, the rainfall is seen either normal or above it in years 2003, 2006 and 2007. Therefore, in the present paper, the results have been discussed separately for the years having low rainfall (2002, 2004 and 2005), normal rainfall (2003 & 2007) and comparatively higher rainfall (2006).

3. Results and Discussions

From the analysis of the Figures 2, 3 and 5, the following salient features have been emerging during different time spans of low and high rainfall years:

3.1 Low Monsoon Year (2002)

Among the various low monsoon years of 2002, 2004 and 2005, heavy drought was observed in 2002 in which observed yearly rainfall was half of the normal value (250mm) (as shown in Table -1), the most important striking feature, emerges from Figure 2(a), is that variations in PD of AI_{300} show the increasing trend (change of 25%) during the preceding days of Diwali. After that the values show the decreasing behavior until the completion of Diwali along with another minor peak that occurs after Diwali days.

The variation in PD of AOD_{550} shows the continuously increasing behavior, i.e., maximum change of 40% from the early before Diwali to the main festival days. Early after the celebration, the amplitude of PD of AOD_{550} remains almost the constant with maximum change during the festival as compared to the days before Diwali.

From the close look to nature in variation of AI_{300} and AOD_{550} along with TWC, the value of both AI_{300} and AOD_{550} parameters increase with the increase in TWC during the preceding Diwali days with certain delay. However, after this, the AOD_{550} continuously increases similar to increase in TWC and attains the peak value in Diwali and onwards. Neverthless, in the same period, the AI_{300} along with TWC varies in different nature during the Diwali period. It attributes the presence of the different nature of aerosols, i.e., AI_{300} and AOD_{550} from Pre-Diwali days to other remaining days.

It is also emerging from the figures that the overall substantial increase in β and MC values from -35% to +10% are seen from one week before Diwali to till Diwali days, subsequently, behavior of reduction is shown in aerosol's parameters. The net change from day to day β and MC values are showing the one to one mapping relation with corresponding changes in day to day AOD_{550} but in the case of TWC value, it has a certain delay in the same group of days, i.e., from Pre-Diwali to Diwali.

Thus, the maximum enhancement about 50% to 60% is seen in AOD_{550}, β and MC values, specifically around Diwali festival as compared to Pre-Diwali days. However, the values of α slightly decrease with an increase of AOD_{550}, β and MC, which further support the total reduction in AI_{300} by 45% from Pre-Diwali to after Diwali. These findings can further confirm based on statistical analysis of their respective positive correlation coefficient values with its significance confidence level above 90%, between AOD_{550} with β as well as AOD_{550} with MC, which are above the value of 0.99. The negative significant correlation coefficient value between AOD_{550} with α is found 0.54, but there is insignificant correlation value versus AOD_{550} and TWC.

In view of the above findings and statistical analysis, clearly the enhancement in the population density of both bigger and smaller size aerosols occurs in Pre-Diwali week. However, decrease in smaller aerosols and the increase in higher size of aerosol’s parameters reveal from Diwali to Post-Diwali days.

3.2 Moderate Monsson Year (2003)

During the normal rain year i.e., 2003, the significant enhancement in change of PD $AI_{300,}$ $AOD_{550,}$ MC, β and TWC is also observed with varying magnitude during Pre-Diwali days (Figure 2b). The maximum enhancement change in the PD value is found to be the highest order of 70% for MC and β, the lower value of 60% for AOD_{550} and then the lowest value of 30 to 40% in case of AI_{300} as well as and TWC around one week earlier in Diwali festival. The reduction of α along with an increase in AI_{300}, AOD_{550}, MC and β gives further more support of an increase in the occurrence of both bigger and smaller size aerosol's particles in Pre-Diwali due to the high value of the TWC in 2003 as similar to observe in 2002. After attaining such peak value, variation in AI_{300} shows the continuous decreasing trend till the after Diwali, but PD of AOD_{550}, MC and β value again exhibits minor peak after Diwali. However, the present findings also reveal the most pronounced changes in a bigger size of aerosols as compared to smaller size aerosols during high value of TWC from Pre-Diwali to Diwali days of 2003 as similar to observe in 2002. These findings are also seen statistically significant, which is clearly evident to their high positive correlation values of above 0.99 (order of confidence level above 99%) between PD of AOD_{550} with MC and β. The low negative significant correlation value is found versus AOD_{550} and α & insignificant correlation value between AOD_{550} and TWC.

3.3 Moderate Monsson Year (2004)

The behaviors of the PD value of AOD_{550}, α, β, TWC and MC during 2004 are represented in Figure 3(a). It is evident from the plots that during 2004, the values of PD of all studied parameters namely AOD_{550}, β and MC reveals continuously decreasing behavior from 0 to -90% from two weeks before Diwali to one week after Diwali, which is a slightly different observed trend than the other years. However, the values of α along with a TWC first decrease from third and second week before Diwali and later attain their peak values around the festival day. Here, it may be added that the abnormal 80mm rainfall was recorded over the observing site in October, 2004 i.e., Pre-Diwali to Diwali period. In view of statistical significance and correlation values, the best positive correlation coefficient values among AOD_{550}, β and MC also supports and validates the above discussed results.

3.4 Moderate Monsson Year (2005)

The variations of PD magnitudes of AOD_{550}, β, MC, TWC and α in the year 2005 are plotted with function of days (Figure 3b). From the figures, it is seen that PD magnitudes of AOD_{550}, β and MC systematically increases by +30% to 40% within third to second week of Pre-Diwali. However, from Diwali to Post-Diwali days, the values of such parameters are seen to be reduced abruptly up to 40% in a few days before Diwali and then again, show the increasing trend after Diwali. Also, the variation in PD of α remains unchanged with observed changes in AOD_{550}, β and MC. Here, the variation in TWC seems to be again positive correlated to the variation of AOD_{550}, β and MC in the entire Pre Diwali to Diwali period as well as Diwali to Post-Diwali period with certain delay time. These results can also be further supported by the best positive significant value of the order above 0.98 with its significance confidence level above 99% versus AOD_{550}, β and MC only.

Referring to the above results from 2002 to 2005, it is quite obvious that the corresponding increase in aerosols loading parameters like AOD_{550}, β, MC and AI_{300} are observed in range of 50% and 30% respectively before the enhancement of the TWC condition during Pre-Diwali period, i.e., October months. While, during Diwali to Post-Diwali period only in higher size of aerosols particles show more increasing characteristics as compared to lower aerosol's size parameter. Thus, overall variation in PD of AOD_{550}, β and MC is almost similar in nature with observed corresponding change in accordance to the nature of TWC variation with certain delay but not instant. The magnitudes of α are found to be significantly well correlated to the corresponding proportionate increase or decrease in observed TWC and lead the nature of transformation in size of aerosol's particles in the Pre-Diwali days. During Diwali to Post-Diwali period, there is no significant change in the values of α.

Earlier, Singh et al. (2003) also reported the aerosol's behavior from only three-day prior and three days after the Diwali day's observations during 2001 and 2002 at Kanpur. They found the increases of AOD about 16% at wavelength 340nm, 18% at 550nm and low value of 13% at 1020nm. Similarly, from ten days before and after Diwali period, Badarinath et al. (2009) observed the increase of 30% in AOD_{550} values and slight changes in AI_{300} during the Diwali period as compared to Post-Diwali period over the Arabian Sea during the year 2007. On the basis of similar work reported by Kharol & Badarinath (2006) and Sharma et al. (2010) over IGP region in the same month like in October month, they observed the similar increasing trend in AOT_{550} value from 0.5 to 2.3 and 0.3 to 1.6 from the Multi Wavelength Radiometer and MODIS data respectively over Patiala, Hyderabad and linked to the incidence of biomass and agricultural crop residue burning activity period i.e., October and November. In such period, people start the local activities of the burning of biomass and waste agricultural materials about ten to fifteen days before to main Diwali day.

By comparing present findings with the results obtained by other Indian researchers in different years, it is quite imperative that an increase in AOD_{550} (about 40% to 60%) is more affected as compared to AI_{300} value in the present investigation, which are quite consistent with the earlier observations about aerosol's characteristics over Kanpur and the Arabian Sea. However, they interpreted their investigations based on the combined effects of local and long range transported aerosols in the form of crop residue burning and Diwali firework. Based on previous studies and the present work, some of the most plausible causes of perturbation in aerosol's loadings from Pre-Diwali to after Diwali seem to be the local and regional advection of aerosols from the polluted region to study region.

In order to understand the delay effect and the fluctuation in change in PD of aerosol's parameters based on long range aerosols transport phenomena during Pre to Post-Diwali days, the backward air mass wind trajectories of three-day periods are plotted at different observing heights, i.e., 500m, 1500m (below boundary-layer height) and 4000m (free tropospheric height) above the mean surface level in Figures 4(a-c). Although, the air mass trajectories essentially back trace the course of an aerosol's parcel, which reaches the particular altitude over the ending point of the site in space and time (latitude, longitude, altitude and days). The air mass trajectory of the three-day period is used in the present course of work in view of the typical residence time about one week for aerosols in the lower troposphere (Moorthy et al., 2003). From the figures, it is evident that during Pre-Diwali to Post-Diwali period, air mass trajectories of 500 and 1500m are showing the advection of aerosols confined mainly from Northern to North-Eastern region i.e., IGP region to the study area, however, the air mass trajectory of 4000m is illustrating the path of advection aerosols from North-Western part of India and its adjoining countries to observing region.

Thus, during Pre-Diwali, higher value of all atmospheric aerosol's parameters over the observing site can be observed due to the transportation of the aerosols from the Western, Northern and North-Eastern part of India, i.e., IGP region, where maximum incidences of burning of biomass and residues of agricultural crop materials take place in such months along with the increase in value of TWC. However, during Diwali to after Diwali days, the main possible source of higher values of AOD_{550}, MC and β aerosol's parameters and lower value of AI_{300} could be attributed due to the fact of the local site emission activity and transportation of aerosols from IGP region from where fires ignition work activities take place before a few days of Diwali and Diwali days.

3.5 High Monsson Year (2006-2007)

In order to ascertain more detailed studies, the influence of these episodic events on the day to day variation in aerosols loading parameters and their inter association with local meteorological parameters and their subsequent effects on solar radiation parameters, the behavior of PD of AI_{300}, AOD_{550}, α, β, MC, TWC along with SHFD, SWDFD, PBL and wind speed are shown against the function of the respective days of the years 2006 in Figure 5(a). It is observed from the figure that during 2006, in which highest rainfall is recorded as compared to other years, the change in concentrations of AOD_{550}, β and MC has gradually increased on the order of 35% to 50% in Pre to Post-Diwali duration as similarly observed for other years with a few days before Diwali, but the variation in AI_{300} is seen in a lower range, i.e., 30% for the same period, but after Diwali, the PD of AI_{300} showed the decreasing behavior, which is also analogous to that observed in other years.

As similar to previous observations, the behavior of change in AI_{300}, AOD_{550}, α, β, MC and TWC repeats the same pattern in 2007 as compared with other years (Figure 5b). Only the maximum change in the parameters was noticed around eight to ten days before Diwali in 2007, however, in a high rainfall year, i.e., 2006, these timings are seen to be different, i.e., earlier around Diwali days.

It is more appropriate to notice at this junction that influence in amplitude of change in SHWRFD is seen more predominant by the amount of 20% to 30% as compared to the observed change in the amplitude range about only 7% in DWSWRF within such a specified period of 2006 and 2007. It may be explained on the basis of well established fact that a vertically incident solar intensity beam is attenuated by the factor exp (-AOD). Therefore, based on calculation, at least 20 to 30% reduction in solar radiation intensity of SHWRF and less in DWSWRF may be linked to proportioning increase in AOD_{550} by about 30 to 50% and in AI_{300}, the enhancement is about 20 to 30% for such atmospheric polluting episodes. Further, it is also seen that the amplitude of reduction in SHWRF as well as in DWSWRF level, duration coincides with the increase in aerosol loading nature duration, which are seen more pronounced in the low rainfall year (2007) as compared to high rainfall year (2006).

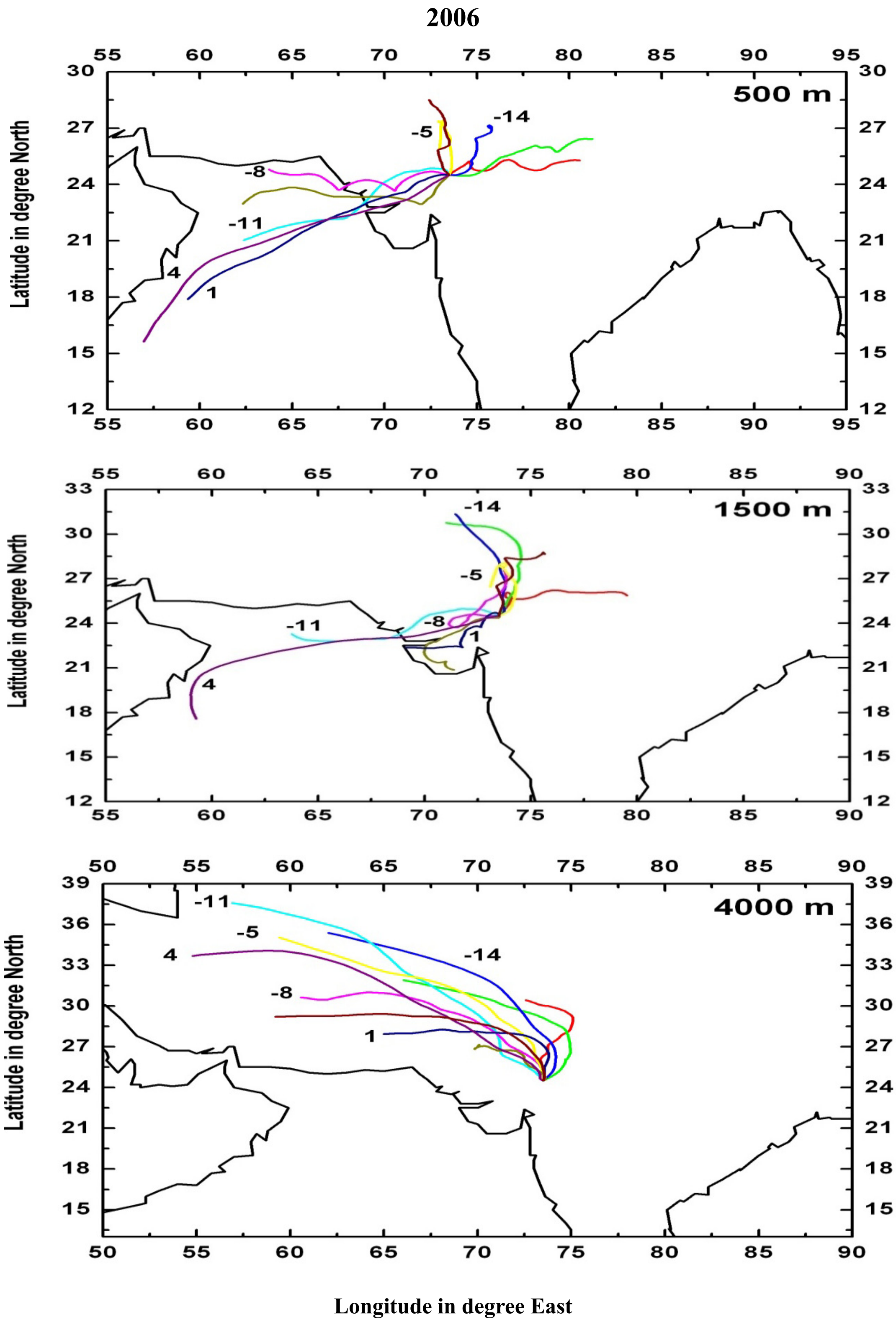
As the aerosol properties are dependent on the meteorological activities, therefore, the similar variation of the aerosol parameters along with wind speed and PBL are also shown in the same figures. It is evident from the figures that the PD values of the PBL and wind speed decrease in the range of 25 to 40% and 5 to 10% (small range) respectively, in the same group of days of the increasing the several aerosol's parameters and reduction of incident solar radiation parameters. Thus, the combine action of compression of PBL and small decrease in wind speed produces the favorable environmental conditions to enhance aerosol's loadings nature and exhibits the direct aerosol's effect in terms of reduction in the incidence thermal solar radiation, i.e., SHWRF and ventilation coefficient or high pollution level during the period from Pre to Post-Diwali days, including Diwali.

In order to demonstrate the role of transportation on anthropogenic aerosols loadings in such particular period, the air mass backward winds trajectories at different height, ranges for observational site are plotted in Figures 6-7(a-c) for each October and November months separately for the years 2006 and 2007. It is obvious from the figure that there is different nature of the path as well as a source region of air mass wind trajectories of 500 and 1500m in the years 2006 and 2007. However, there are close similarities in the overall nature of air mass backward wind trajectories of the 4000m source region in all studied years, which is mainly confined in the North-West and West region, i.e., West Asian countries in the year from 2005 to 2007. However, there is the different nature of trajectories as well as their source region for advection of aerosols of the source region at 500, 1500m in the study period, in 2006, the starting point of air mass backward wind trajectories of 500 and 1500m covers the wider region, i.e., from area of heavy surface polluted and agricultural activity's sites like Northern and North-Eastern part as Indo-Gangetic Region to South-West direction from the observational site, whereas in 2007, air mass trajectories of 500 and 1500m cover the shorter region in Northern and North-Eastern sides similar to be observed in 2005, which seems to be the another cause of large change in all aerosol's parameters and solar radiation parameters in year 2005 and 2007 as compared to the observed lower aerosols loading during 2006. It is therefore, readily inferred that the PD value of above discussed aerosol’s parameters gradually increased as the trajectories travel more and more to the shorter region of North and North East.

Thus, besides an increase in the TWC, favorable lowering of PBL and wind speed value condition in before Diwali, another major possible suggested cause of higher aerosol’s parameter's value, namely, AI_{300}, AOD_{550}, α, β and MC during preceding Diwali days might be due to advection of aerosols from heavy populated and air polluted side like as IGP region. These regions have witnessed of incidence of maximum burning of bio-masses and residues of waste agricultural crop material's activity in such a specified period and region (Badarinath et al., 2009; Sharma et al., 2010). This strongly suggests that advection of aerosols loading activities for the IGP region at 500m and 1500m might be playing an important role in modulating the aerosol loading and causing the day to day changes in aerosol's parameters over Udaipur in such specified period as evident from the different air mass backward trajectories depicted in Figures 6 and 7.

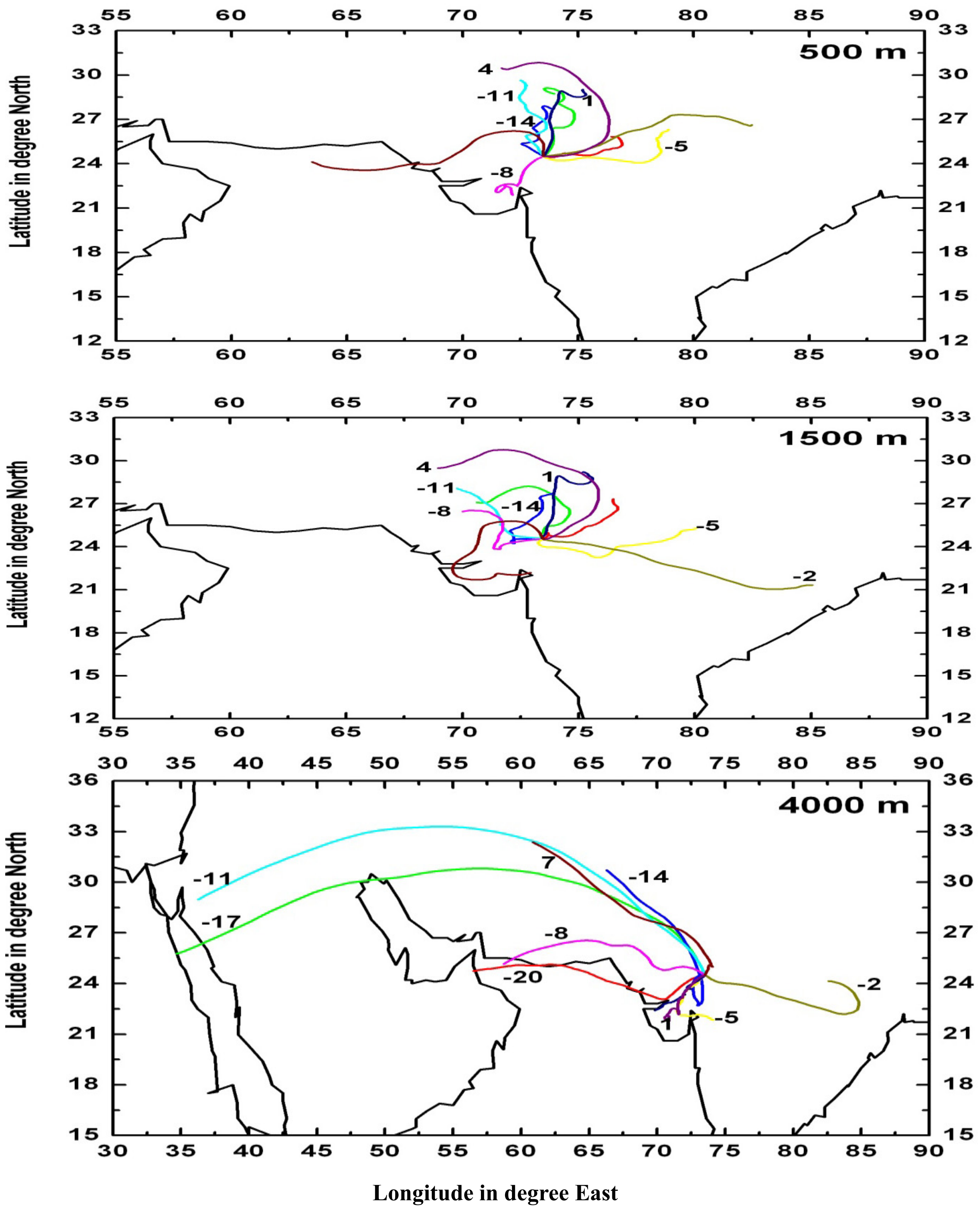
But, Diwali to Post-Diwali days, reduction in AI_{300} and higher AOD_{550}, α, β and MC values could be due to the maximum occurrence of intensive activities of fire-ignition in Diwali days around observing site as well as the IGP region as compared to the West Asian countries.

In the present study variation of all aerosols loading parameter values do not show smooth and instant variations. But effects on atmospheric aerosol’s parameters are observed after some days of occurring, these events on the surface. Therefore, the present work refers that the persistence of increasing and decreasing of the aerosols loading, prior to after Diwali days, is likely to be attributed due to combined local and regional effects i.e., presence of soot and organic carbon compound injected into the atmosphere due to burning of various types of residue agricultural materials, crackers, fireworks over distant region and local surrounding areas and also due to the favorable situation arises from transportation of aerosols carried by the wind from heavily populated urban and also agricultural zone in such a period as depicted from the wind trajectory diagram of different years 2005 to 2007 in Figures 4, 6 and 7.



Figures 6(a - c). Air Mass Backward Trajectories using NOAA Hysplit Model for 500, 1500 and 4000m AGL observed over Udaipur during Pre-Diawli to Post-Diwali days of year 2006

2007



Figures 7(a - c). Air Mass Backward Trajectories using NOAA Hysplit Model for 500, 1500 and 4000m AGL observed over Udaipur during Pre-Diawli to Post-Diwali days of year 2007

4. Conclusions

The effects on aerosol's parameters are investigated through interaction among local meteorological, boundary layer dynamic parameters, solar radiation, TWC, advection of aerosols from a different position of the source region of air mass backward wind trajectories from Pre-Diwali to Post-Diwali period in Udaipur.

From their analysis, the following main facts are summarized below:

1) During Pre-Diwali period, significant changes in peak value of 20% to 50% in several aerosols loading

parameters like AOD_{550}, MC, β and AI_{300} are observed from Pre-Diwali to Diwali days depending on the extent of nature of variation in TWC and position of the source region of air mass backward wind trajectories in that particular year.

2) After Diwali, the value of AI_{300} is found to be continually decreasing, whereas the value of AOD_{550}, MC and β are either remain unchanged or increase with the increase in TWC or transportation of the aerosols from far region i.e., IGP sites to the observing site and over local region, where the extensive firework activities take place on the occasion.

3) The overall changes observed in PD of AOD_{550} with β and MC is almost in the same phase. Its variations also showed the corresponding changes in accordance to the variation in TWC.

4) The increase in aerosols loading parameters i.e., AOD_{550}, MC and β (from 30% to 50%) during the study period has shown its implication on the dimming effect in incident incoming solar radiation in terms of decrease in SHWRF and DWSWRF value from 20 to 30% and 10 to 20% respectively.

5) The enhancement in aerosols loading characteristics are observed during the decrease in PBL and wind speed, thus lowering the magnitude of ventilation coefficient value.

6) The present study supports and confirms the earlier findings that increase in the concentration of all aerosol's parameters before Diwali could be more due to the aerosols transportation phenomena such as from IGP region and lower for long range transport of aerosols phenomena from Western to the Northern part of India during Pre-Diwali period along with an increase in TWC in such specified days over Udaipur. But, after Diwali, the main possible suggested reason about observed higher values of AOD_{550}, β, MC and lower value of AI_{300} seems to be due to the transportation of aerosols from IGP region from where fires ignition work activities take place a few days before Diwali.

In order to summarize all the most plausible source of identification of the overall reduction or enhancement of the above same parameters could be due to the formation and enhancement of the bigger size of aerosol condensation properties of aerosols in the presence of water level, adverse meteorological conditions and also advection of transport aerosols of crop residue burning and firework activities that specially take place before and up to Diwali in the IGP region and local region too.

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The daily positive AI_{300} values over Udaipur are available at http://aura.gsfc.nasa.gov/

The each day values for the corresponding period of AOD_{550}, α, MC and TWC parameters are available at http:// gdata1.sci.gsfc. nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS DAILY_L3

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