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PHYSICS

SEASONAL VARIATION OF ATMOSPHERIC AEROSOLS OVER PROMINENT HOTSPOT REGIONS IN SOUTH INDIA BY EMPLOYING MODIS DATA

K.M. Praseed[1], Nishanth T[2], Sheela M. Joseph[2] and M.K. Satheesh Kumar[2*]

[1]*Department of Physics, Sir Syed College, Taliparamba, Kerala, India*
[2]*Department of Atmospheric Science, Kannur University Kerala, India*

Abstract

Mounting the amount of aerosols in the atmosphere is a subject of deep concern all over the globe. This elevated level of aerosol concentrations has proven direct impact on the radiative forcing (Gadhavi and Jayaraman A, 2004) and subsequent climate change. Thus it becomes imperative to study the inter-annual and seasonal variations of aerosols with the aid of remote sensing method by employing MODIS data. This paper pertains to the study of seasonal variations of Aerosol Optical Depths over three different locations which are lying along the same latitude in South India. The five year (2005-2009) observation is presented and it reveals that aerosol abundance has strong dependence on the geography, environment and local climate at a specific region. The variation of aerosol abundance is found to be higher at the coastal region than the region surrounded by land mass.

Keywords: Aerosols, AOD, Angstrom Exponent, MODIS

Introduction

Aerosols are generally classified as suspended particulates in the atmosphere that play an important role in the Earth's radiation budget owing to their scattering and absorbing capabilities and indirectly acting as cloud condensation nuclei (Charlson et al., 1992) . Sand dust, mineral dust, hygroscopic marine aerosols etc. are considered to be the common aerosols and their elevated concentrations has been a serious concern in the context of enhanced anthropogenic and industrial activities. Aerosols have been exhibiting a strong influence on the radiative forcing of climate and their concentrations and optical properties are one of the largest uncertainties reported in the current assessment of climate change (Satheesh et al, 1997). Though aerosols in the free troposphere have a residence time of the order of one week, elevated aerosol concentration has an adverse effect on human life and air quality. At the surface, their concentrations are more near the source and it decreases with distance from the source. The promising impact of atmospheric aerosols with regard to Indian monsoon variability has got considerable scientific interest recently. Ground observations have limitations primarily due to their being focused to point measurements and which is significantly influenced by the local effects. Thus the use of remote sensing in the form of space-born technique is quite imperative to retrieve near concurrent observations of aerosol properties of a region concerned. Moreover, satellite measurements would yield the vertical profile which provides prominent tools to carry out modeling studies. This work mainly addressed to the seasonal variation of aerosol concentrations by using MODIS monthly mean Aerosol Optical Depth (AOD) data at three distinct regions in South India which are lying along the same latitude of 12 N. The prominence of these regions is that they are situated on either side of the Western Ghats along the same latitude by which a comparison of aerosol loading could be investigated. This would further pave a way to investigate the significant influence of mountain terrain on the advection of aerosol during its transport. In addition to this, the present study investigates the aerosol loading during the seasons including pre-monsoon and post monsoon periods which are different at these locations.

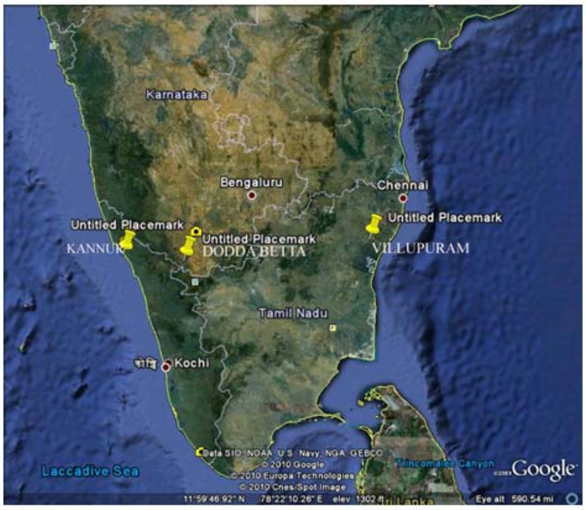
Observation sites

The sites are shown in fig.1 taken from Google map. The regions of interest are: Kannur (12 N, 75.3 E) situated along the coastal belt of the Arabian Sea in the north of Kerala State, a region of weak industrial activities. The south-west monsoon is quite active during the period from June to September which produces heavy rain. Dodda Betta (11.55 N, 76.46 E) is a hill station in Tamil Nadu state and this is the second highest peak in the western ghats at a height of 2236 m above mean sea level. Hence a free troposphere is existing here which is free from hectic convective activities. The weather is quite cold and

* Corresponding Author, *Email*: satheeshmk@gmail.com, Tel: +91 09446541575

very often it becomes cloudy early in the morning and late in the evening. Villupuram (11.5 N, 79.5 E), is a region in Tamil Nadu which is lying 35 kms interior to Bay of Bengal coast. Being land locked region, the climate is mostly humid and hot and hence dry weather is experienced during winter time. Rain fall is maximum during November-December when north-east monsoon becomes intense over this region.

Fig.1. Locations of the study area



Method

AOD is a measure of optical extinction of solar radiation reaching on the surface of the earth. Hence this physical quantity determines the abundance of aerosols present in a column of atmosphere at any location. Aerosols offer scattering centers for the solar radiation and the AOD provides the optical properties of thee scattering centers and hence it depends on the scattering and absorption efficiency. The meteorological parameters like wind speed & direction, relative humidity, rainfall and surface temperature significantly affect AOD over a region. Since the scattering efficiency depends on the particle size, the AOD can reveal the signature of size of particulate matter through Angstrom exponent (alpha) (Angstrom A, 1961) which is a measure of the relative dominance of fine submicron size particle over the coarse mode aerosols present. Ground based retrieval of AOD could be achieved with the aid of sun photometers and their limitations are, this can only provide with the AOD over a specific location in which local effects in the atmosphere could not be ignored. Thus remote sensing is more capable of comparing the variations of AOD at different regions simultaneously. One promising satellite sensor that measures AOD is MODIS which is quite prominent and the data are processed after removing the effect of cloud cover.

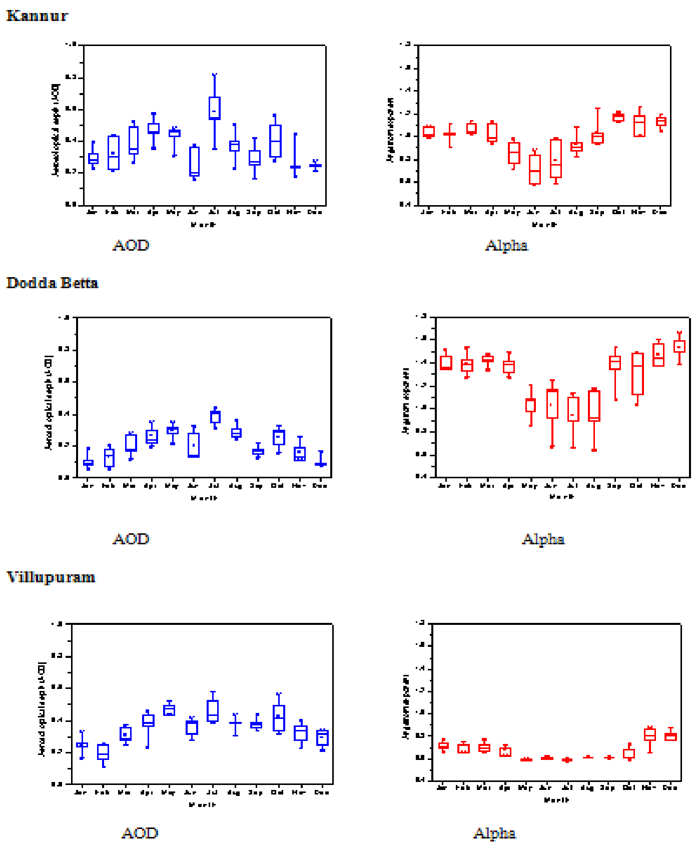
MODIS is a remote sensor onboard two Earth orbiting systems, Terra and Aqua satellites which provide an opportunity to study aerosols from space with good accuracy (Remer et al., 2003). In the present study, level 3 MODIS C005 atmospheric monthly global product AODs at 550nm at $1^{o} \times 1^{o}$ grid derived from both Terra and Aqua satellites are utilized. Both satellites operate at an altitude of 705 km with Terra space craft crossing the equator at about 10.30 IST and Aqua crossing the equator at about 13.30 IST. Subsequently, the mean values of the AOD and alpha retrieved from both satellite sensors operating in the wavelength region (470-600 nm) are used in this calculation. The data for five consecutive years (2005-2009) were analyzed with various statistical techniques.

Results and Discussion

Monthly mean AOD and alpha are depicted in the form of Box-Whisker plots which are shown in fig 2. The box edge represents 25^{th} and 75^{th} percentile and whisker ends represents maxima and minima. The average values of AOD and alpha at the three locations are tabulated and shown in Table.1. It is found that AOD over Kannur has a tendency to increase from winter season to summer season. Subsequently, the Angstrom exponent α is low during monsoon period and it becomes high during winter months.

The observed seasonal variation in AOD is a result of the complexity in the production, transport and removal of aerosols. Thus, the atmospheric dynamics play a vital role in the distribution and removal of aerosols in any specific location. The seasonal variations of meteorological parameters severely affect the aerosol loading. During winter months, atmospheric boundary layer is shallow which ensures a minimum mixing volume for the pollutants and particles, during summer month boundary layer height is higher and therefore pollutants have additional volume for scattering and absorption of solar radiation passing through it. Relative humidity is found to be high during monsoon months owing to the intense rain. The marine aerosols which are mostly hygroscopic can intake the water and can grow in size(Murthy K K et al,1997). Also during monsoon months stronger winds from the Arabian Sea can transport sea salt particles in humid environment by which they grow in their size. This is attributed to the low value of alpha at Kannur due to the dominance of coarse mode particles.

Fig. 2. Whisker plot of AOD and Angstrom exponent at three locations for a period of five years from 2005



In Dodda Betta also AOD is low in winter months (Dec-Feb) and high in summer months.. Alpha is found to be high throughout the year except in spring time. This high value of alpha indicates that particles with smaller dimensions are more abundant over this hill station which has a free troposphere. The low value of AOD over this location may be due to the influence of Western Ghats which forbids the transport of aerosols from the west coast region of India where the south-west monsoon is active. The lower values of alpha observed in spring time may be due to the hectic anthropogenic activities in connection with the tourism festivals and the presence of biogenic aerosols.

At Villupuram region, AOD is minimum during winter (Nov-Feb) season and maximum in summer (April-July). Alpha values are low throughout the year except in rainy months (Nov-Jan). The higher AOD values observed during summer are due to the increase in convective activities that enhance wind speed and surface temperature. The low value of AOD in winter is caused by the low surface temperature which results in the weak production of soil derived mineral dust from the surface. The slight reduction in alpha during rainy season is a result of the fine mode particles which are non-hygroscopic in nature.

Table.1 Seasonal variations of AOD and Angstrom Exponent at the three locations during 2005-2009

Location	Season	AOD	Alpha	LCV
Kannur	Winter	0.25±0 .03	1.14 ±0 .03	0.466
	Summer	0.43 ±0 .04	1.04 ±0.02	
	Monsoon	0.38 ±0 .13	0.82 ±0 .09	
Dodda Betta	Winter	0.11± 0.01	1.44±0.07	0.375
	Summer	0.27±0.07	1.39±0.02	
	Monsoon	0.21±0.06	0.99±0.05	
Villupuram	Winter	0.26± 0 .06	0.75±0.05	
	Summer	0.42± 0.05	0.71±0.10	0.2852
	Monsoon	0.37±0.07	0.61±0.03	

In order to explore the variability of aerosol concentration over a region, the Local Coefficient of Variation (LCV) method has been adopted. A high value of LCV over a given region indicates that aerosol concentration variability is more compared to other location and vice versa .In our observation, LCV is found to be minimum (0.2852 medium (0.375) at Kannur and maximum (0.466) at the Dodda Betta region. This further envisages that the movement of aerosols is much higher over Dodda Betta region thanks to the cold environment and sporadic clouds. Villupuram being a plain landmass, the air currents are found to be a minimum due to the lack of land and sea breeze. Kannur being a costal belt which experiences land and sea breeze, the transport of land based aerosols and marine aerosols is much higher over this location.

Conclusion

The seasonal variations of AOD and alpha have been explored with the aid of MODIS data over three distinct locations in southern region of India. It is found that there is a significant difference in the aerosol abundance and their size distributions at these three regions lying along more or less the same latitude. From the analysis, it has been revealed that seasons and climate affect the aerosol loading tremendously. Likewise, the Western Ghats plays a vital role in the transportation of fine mode aerosols and the land and sea breeze offer an additional pace to the transfer of aerosols and their mixing. To substantiate this, ground based observations highly essential in these regions to analyze the effects of local climate on the aerosol distribution and its properties in detail.

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