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A Deep Study on Real-Time Atmospheric Aerosols and Variability Over Indian Subcontinent Environment

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***Abstract*---**Study of atmospheric aerosols is very complex owing to their short life time and, chemical constituents. Aerosol loading is highly regional and there life time is very short. An attempt has been made in this paper to study the variability of atmospheric aerosols over Indian subcontinent using a statistical parameter Coefficient of Variation (COV). The magnitude of variability over this region is studied. The factors influencing the variability are studied to find the reasons for difference in magnitude over different regions. Rainfall naturally influences the variability aerosols due to scavenging, but if it is the only factor influencing the variability, the study is absurd. It is found that the influence of rainfall on COV is not pronounced as it is not a seasonal phenomenon. Influence of other parameters viz. Topography, wind vector, thermal power plants and population on variability of aerosols is clearly found. These results help in classifying aerosol zones on the basis of variability of aerosol optical depth. The study also helps in finding the cause of aerosol loading over a region. Measures can be taken to decrease the loading if it is due to local sources.
***Keywords*---**COV, AOD, GPCP, MODIS.

Introduction

Atmospheric aerosols are one of the significant component that influences the climate system; Their impact is most uncertainty the magnitude of uncertainty is still not estimated their effect on the global climate system is one of the major uncertainties of present climate predictions [1, 13, 21]. Their chemical composition

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and concentration levels are very harmful [8]. Aerosols affect the environment and all life in many ways. They can be harmful and toxic, to the life [10, 29]. They enter the respiratory system cause adverse effects to human health (26, 24, 4). Hence it is necessary to achieve an advanced understanding of the processes that generate, redistribute, and remove aerosols in the atmosphere. The life time of atmospheric aerosols (tropospheric) is very small ranging from hours to a week. Properties of Atmospheric aerosols change rapidly with space and time. Hence study of their temporal variability is very important and necessary to assess their impact on climate change. Researchers have studied the variability of aerosol properties at particular place with respect to a particular location [7, 18,17, 16].The variability of atmospheric aerosols contains information on the processes that determine its concentration. The influence of atmospheric aerosols is depends on their sources, and sinks life time in the atmospheres of. [3, 19] have used a statistical parameter, coefficient of variation for studying the spatial variability of atmospheric aerosols. They have classified the study area into two regions viz. low COV region and high COV region but reasons for the variability of Aerosol optical depth were not explained. An attempt is made in this paper to explore the reasons for variability of aerosol optical depth over different regions in the study area. If rain fall is the cause of the variability then the variability is completely due to washout and there is no reason for studying the variability. It is assumed that the variability is not a season specific characteristic and it is dependent on different parameters including the magnitude of AOD over a region. Hence influence of various parameters on variability of atmospheric aerosols viz. Rainfall, wind, topography, population density (cause of anthropogenic emissions), emissions due to thermal power plants etc are analyzed in this study.

Data and Methodology

The region in between co-ordinates (5° N, 65° E) and (40° N, 100° E) is selected for the present study. Satellite data is the only source for getting simultaneous measurements over a large area. Hence aerosol optical depth retrieved from MODIS onboard Terra is used. MODIS AOD is preferred over other data as it is available for a longer period and it is available at least twice for a period of three days for any region on the globe. We used daily level-2 Collection 005 AODdata for a period of 20 years i.e. from January 2001 to December 2020. The MODIS Level 2 aerosol product is 10 km and up to 40 km at edges of the scan. The study region is divided into 7225 grid boxes each of size 0.4° x 0.4° (nearly 40km) for convenience. Details of the MODIS aerosol products and can be found in (15, 30, 31.Level2 MODISdata is available at http://ladsweb.nascom.nasa.gov. Rainfall pattern is studied using GPCP daily precipitation data. The GPCP one-degree daily Precipitation data provides daily, global 1°x1° gridded fields of precipitation. The GPCP precipitationdata providesrainfall on seasonal and inter annual time scales [14].The data is available from the GPCP website http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html.

Residence time of atmospheric aerosols depend on the topography of a region. Aerosol particles present in the low altitude regions have longer residence time as they cannot be transported easily by wind and aerosols transported by winds from surrounding regions also get accumulated. Hence an attemptwas made to study the variability of atmospheric aerosols w.r.t. the topography of the region.

The data is available from NOAA Global Land One-km Base Elevation Project (GLOBE) website https://www.ngdc.noaa.gov/mgg/topo/globe.html. Aerosol loading in the atmosphere is proportional to the population density at a place. The population density of India has gone up to 382 persons per square kilometer in 2011 from 32 persons per square kilometer in 2001.(https://censusindia.gov.in/).The study is limited to 2011 as reliable information on census is not available after 2011. A statistical parameter called Coefficient of variation is used to study the variability of Aerosol optical depth over Indian subcontinent. COV is defined as the ratio of standard deviation to the mean of the data. COV is preferred over standard deviation as it represents the variability of the parameter with respect to its magnitude.

Results and Discussions

Atmospheric aerosols have a very short lifetime and their residence time is influenced by meteorological parameters. Influence of some of the parameters on the variability of aerosol optical depth is studied in the present work. Mean AOD for the whole study period is shown in the fig1. It can be observed that the north western andnorth eastern parts of India are highly loaded with aerosols when compared with the southern part of India. The AOD over east coast is also high when compared to that of west coast and this may be due to the transport of aerosols from land to Bay of Bengal(22). The Indo-Gangetic plain is highly loaded with aerosols irrespective of the season. The south western peninsula has a very low AOD when compared to other regions.Central Maharashtra and western Madhya Pradesh show high AOD.This region has a very high rainfall rate when compared to other regions and quick washout may be the reason for less AOD. It is found from fig 2 that most of the high altitude regions exhibit high variability of AOD and regions located at lower altitude show less variability. Topography of the study region has been plotted infig 3 and compared with fig 2. Similarity is clearly found between the two plots. Most of high altitude regions exhibit high COV except for some regions in Maharashtra. Low altitude regions including Indo-Gangetic plain show low COV indicating less variability of AOD. It can be found from fig 1 that Indo-Gangetic plain has high AOD throughout the study period and this fact supports the above result. Hence it can be inferred that topography also influences the lifetime of the Aerosols in the atmosphere.

Rainfall data cannot be correlated with AOD as both the data are not simultaneously available. MODIS does not provide AOD for regions which are covered with clouds or regions experiencing rainfall. The importance of comparing the rainfall with COV is that if rainfall influences the COV, it can be taken as granted that the variability is purely due to the wash down of aerosols which is a natural phenomena and influence of other parameters can be neglected. GPCP rainfall data for the whole study is separated for different seasons and plotted to find the effect of rainfall on variability. The magnitude of the rainfall is in the study region in monsoon (June, July, August and September) and in post monsoon (October and November). The rainfall is comparatively less in the remaining period. It can be clearly found from fig 3 that rainfall pattern is not matching with the COV of AOD. AOD is seen to be varying throughout the study period irrespective of the season and hence it can be consideredthat the variability of AOD is not only due to the washout. COV of AOD has been plotted for different seasons with vector wind plotted over it to study the seasonal variability of AOD and influence of magnitude and direction of wind on it. Fig4 shows that COV of AOD is almost similar during each season indicating that COV is not a season specific characteristic for AOD. COV is found to be high over the region ofArabian Seain the monsoon season in the direction of monsoon circulation owing to the transport of dust from the west. The COV is low over the Indo-Gangetic plain irrespective of the season which strengthens the fact that there are constant sources of aerosol particles over this region.The figure also shows that the COV is following the wind direction indicating that wind transport is one of the main factors influencing the magnitude of variability of Aerosols.

. Coal based thermal power plants affect the air quality of the surrounding regions due to black carbon emissions along with many other pollutants. The magnitude of atmospheric aerosols in the atmosphere is influenced by the emissions from thermal power stations(25). Influence of thermal power plants over a region is studiedby plotting the location of thermal power plants on the COV (fig 5). Except for a few, the regions having thermal plants exhibit high AOD owing to the emissions from burning the coal which indicate that power plants have a considerable contribution to the total AOD. Existence of more thermal power plants in the Indo-Gangetic plain may be one of the reasons for constant high AOD throughout the year. Except for a few thermal power plants all the others lie in the low COV regions indicating that AOD is constant in those regions due to constant emissions from them. Anthropogenic emission has increased a lot with the start of industrial revolution(3,13,28,27,11,6). Hence population density is one of the factors influencing the magnitude of aerosol loading over a region. Population density maps for the years 2001 and 2011, obtained from Census India website (2022) are used in the study (fig 6). The census. There is no reliable source for population data after 2011 hence the study is limited only up to 2011.The population density has increased in almost all the states but it is found that the increase is more in the northern states especially in Delhi, Uttar Pradesh, Bihar and West Bengal and the signatures of high AOD over these regions can be clearly found in fig 1 and fig 2a indicating that population density in region has influence on the variability of Atmospheric Aerosols. Regions like Madhya Pradesh, Meghalaya, and Mizoram having comparatively less population density show less AOD as well as less COV.

Conclusions

Variability of AOD is studied using COV. This study gives information on the factors influencing the magnitude and life time of atmospheric aerosols. It is found that the variability of aerosols is not season specific and the rainfall pattern is also not comparable with the COV pattern hence the impact of intensity of rainfall on it is very small. It is found that topography map (fig 2b) is in resemblance with that of COV indicating that topography of a region affects the variability and hence magnitude and life time of atmospheric aerosols. High altitude regions (except for a small region in Maharashtra) are found to have high COV and the variability may be due to transport by wind. Low altitude regions including Indo-Gangetic plain has low COV. Fig 4 shows that COV of AOD is similar through all seasons indicating that variability of AOD is not a season specific characteristic and it depends mainly on the location of the region and different types of emissions in that region. It is also found from fig 4 that wind definitely influences the aerosol variability. The variability of AOD over the thermal power stations is very less (low COV) indicating that emissions from thermal power plants in the region dominates AOD from any other source or through transport. By comparing fig 2(a) andfig 6 it is found that that regions with high population density show low COV indicating that the magnitude of AOD is constant throughout the year and most of the aerosols are due to anthropogenic emissions. Hence we can conclude that variability of AOD is influenced by topography, vector wind, emissions from thermal power plant and population density of a region. The study of variability enables us to classify the study region into two type's namely high COV region and low COV region. As the AOD over high COV region is variable more number of observations are needed to study the aerosol climatology over the region and a minimum number of observations are enough over a low COV region as the magnitude of AOD over the region is almost constant throughout the year irrespective of different seasons. As atmospheric aerosols are highly regional, more number of ground based observatories is needed to study the whole Indian subcontinent. These results will be useful for setting up aerosol observatories.

List of Figure Captions

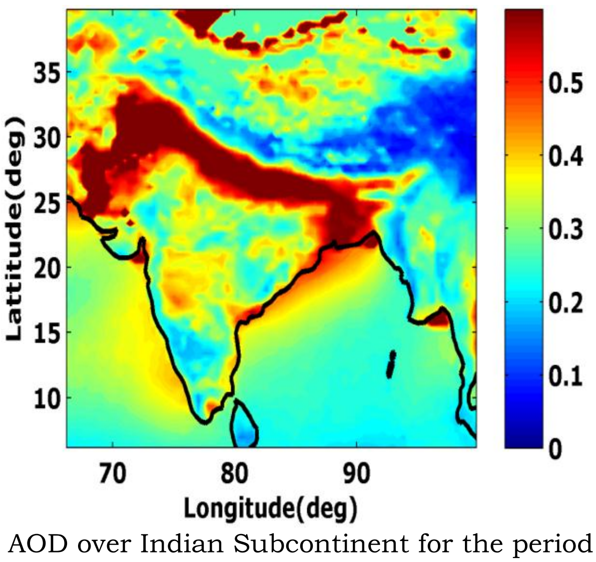

Fig 1. Mean AOD over Indian Subcontinent for the period 2001-2020

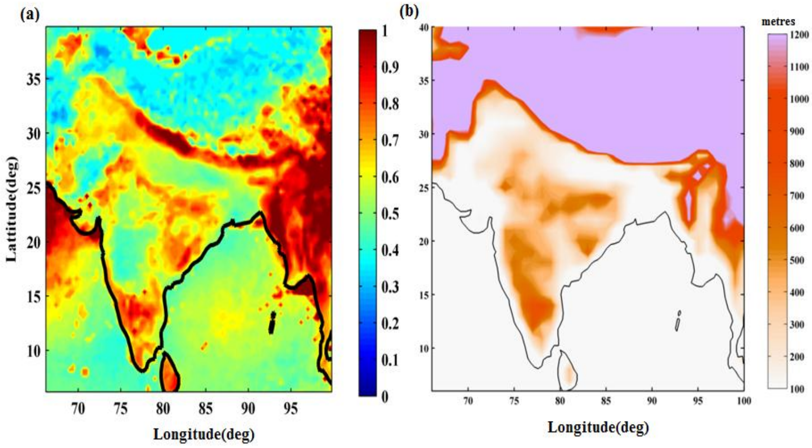

Fig 2. (a) COV of AOD over Indian Subcontinent for the period 2001-2020,
(b) Topography of the study region

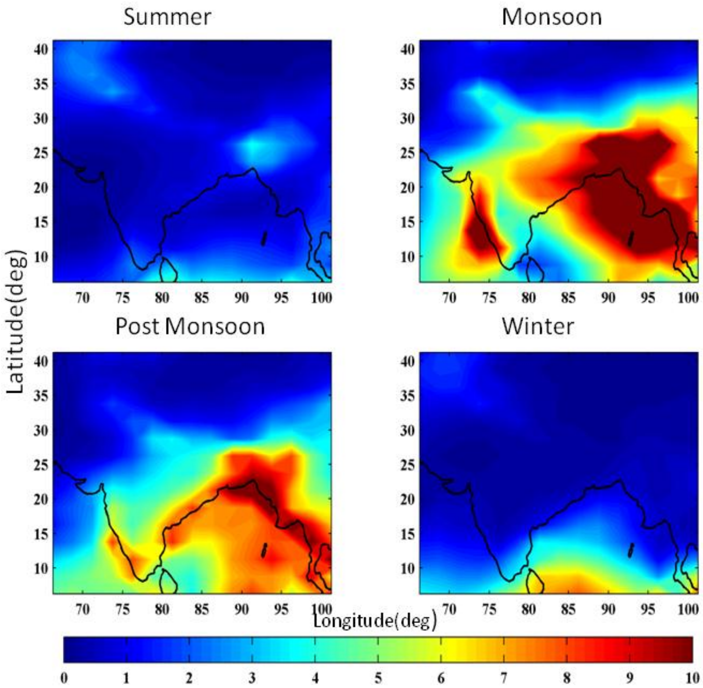

Fig 3. GPCP Rainfall for the period 2001 to 2020 for different seasons

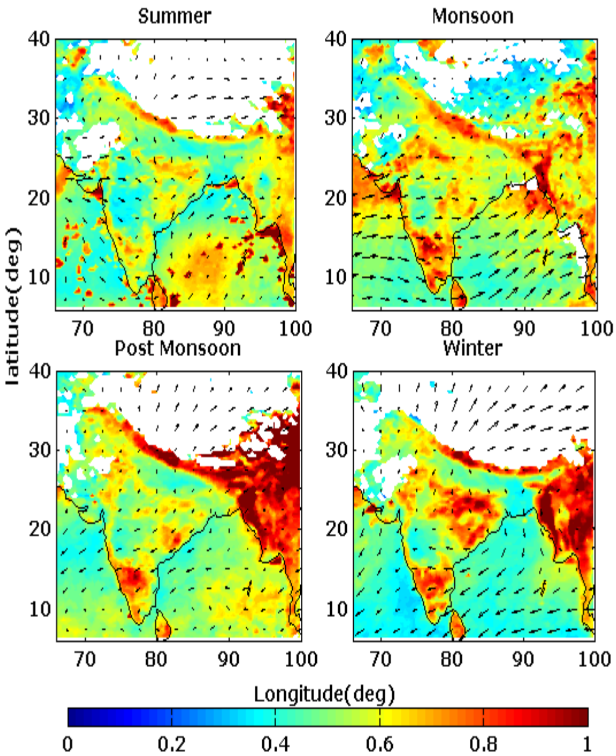

Fig 4. Seasonal variation of COV of AOD with Wind vector plotted over and above

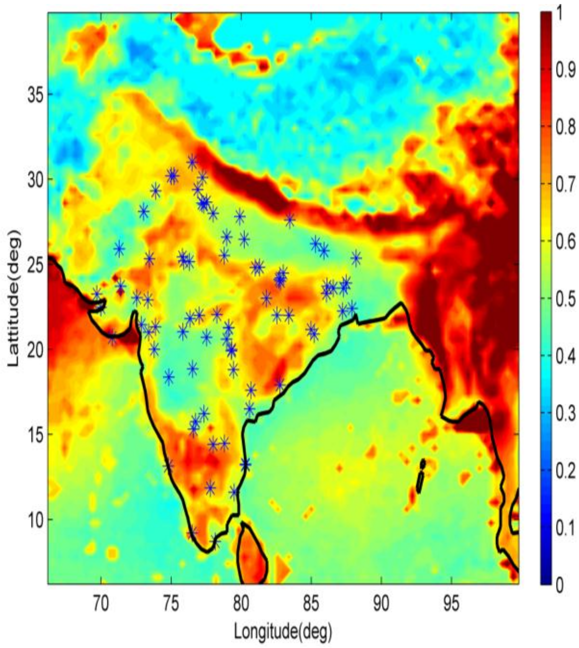

Fig 5. COV of AOD for the period 2001-2020.* indicate the existence of thermal power plants

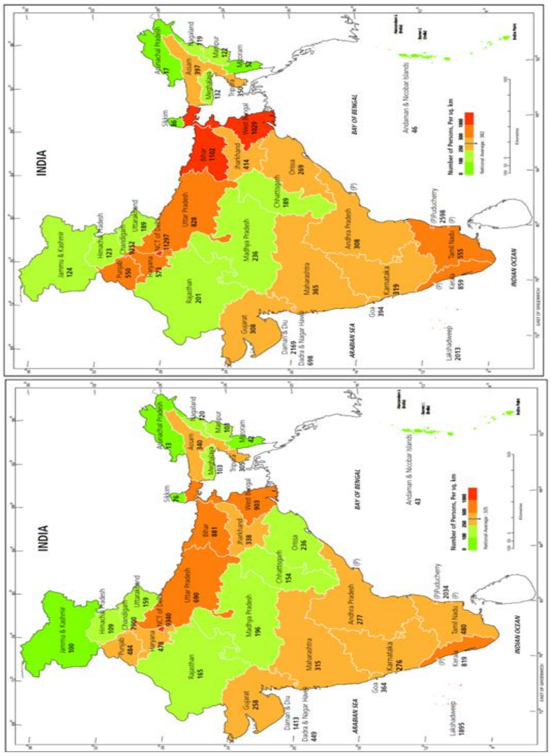

Fig 6. Population density maps for the years 2001 and 2011. (Census India website 2011, Data is not available after 2011)

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