International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Aerosol Optical Depth over Indian Sector

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***Abstract*— The concept of aerosol Optical Depth (AOD) is used to quantify the strength of aerosols from both natural and anthropogenic sources in causing climate change. The work is motivated from the rising concern for global climate change and the existing uncertainty in the current understanding due to the incomplete knowledge of aerosol optical. The goal of present work is to study the Aerosol optical over different environments in the Indian sector. The variation of AOD was studied for the season of winter, summer, monsoon, and post monsoon for the year of 2007 to 2013. The variation showed that the summer is been highly affected by AOD concentration all over the region followed by winter, monsoon and the least affection is for post monsoon.**

Keywords*— Aerosols, Lidar, CALIPSO, Seasonal Variation, Aerosol Optical Depth.

INTRODUCTION

Atmosphere is the thin layers of gases surrounding the earth. The major types of gases which comprise the atmosphere are nitrogen and oxygen which has concentration of 78% and 21%. Atmosphere is also comprised of water vapour of 4% and many trace gases like argon, carbon dioxide, neon, helium, methane, and many other gases which are not visible to us. Clouds are also parts of atmosphere. They cannot be called as gas as they are the condensed vapours in form of liquid droplet. Aerosols and many other pollutants like sulphur, nitrogen oxide are also the part of atmosphere which plays an important role in damaging the earth's atmosphere. The concentration of carbon dioxide, methane, nitrogen oxide and chlorofluorocarbons which are responsible for greenhouse effect are significantly lower than the nitrogen and oxygen. In order to describe earth's atmosphere we need to know about the parameters like pressure, temperature and air density.

Temperature:

Temperature depends on the motion molecules higher the motion of the molecule higher will be the temperature .The temperature varies as we go to high altitude from the ground level. It can be measured in three scales. In Fahrenheit (F) scale freezing point is 32°F and boiling point is 212°F. In Celsius (C) scale freezing point is 0°C and boiling point is 100°C the standard conversion formula to Fahrenheit from Celsius is $T(F) = (9/5)\ T(C) + 32$ .In Kelvin (K) scale freezing point is 273.15 K and boiling point is 373.15 K the standard conversion formula to Kelvin from Celsius is $T(K) = T(C) + 273.15$.

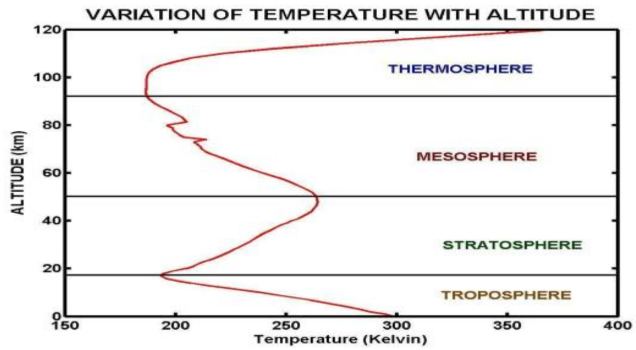
Pressure:

Atmospheric pressure can be defined the weight of air per unit area of the column of atmosphere above a given height. The pressure can be measured in Millibars (mb). As the number of molecule decreases with increase in altitude the pressure also decreases with increase in height.

Density:

Air density depends on pressure and temperature. As the pressure decreases with increase in height likewise air density also decreases as increase in height.

Density=pressure / (universal gas constant* temperature).



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Introduction to LIDAR

LIDAR stands for Light detection and ranging .Principle of Lidar is similar to the principle of Radar (Radio detection and ranging) and Sonar (sound navigation and ranging) the difference is that in Lidar the light pulse is emitted into the atmosphere. Light from the beam is scattered in all the directions from the molecules and particulates in the atmosphere. A portion of the light is scattered back i.e. it is back scattered towards the lidar system. This light is collected by a receiver telescope and is focused upon a photo detector, it measures the back scattered light as a function of distance from the lidar. The atmospheric parameters measurable with lidar include temperature, wind velocity, atomic and molecular species concentration, aerosol and cloud properties.

The maximum range unto which the lidar can detect is 100km from the ground to the atmosphere. The time taken for the laser pulse to return back to the receiver telescope gives the range of the atmospheric volume being studied and the amplitude of the return is proportional to the volume density of the atmospheric particles or molecules.

Lidar is very useful instrument as since it is providing the knowledge of earth's atmosphere for many years, it is capable of detecting the amount of depletion of ozone, Lidar is an instrument which can be operated by two ways, one of them is it can be operated from ground and the other way is by fixing that instrument on the Space Shuttle which gives global observation of atmospheric parameters, known as space born lidar.

The first lidar principle was introduced in 1930 before the invention of laser; it was introduced to study the presence of air density in the upper atmosphere. The next attempt was made in 1938 to determine the clouds, and then in the year 1953.Modern lidar technology started after 1960's as in 1960 the invention of laser took place, different type of laser came into existence such as pulsed laser in 1062, ruby laser in 1963.With the invention of different type of laser it has been possible for lidar to determine the various parameters of atmosphere with high accuracy and with high speed.

Space born lidar was introduced with the aim of understanding the change in climatic condition, presence of pollutants in troposphere and stratosphere, the transport of pollutants. The first space born lidar introduced by NASA in the year 1994 known as LITE flew on STS-65Discovery mission. It provided the measurements of aerosols and clouds in the troposphere and stratosphere as well as the temperature profile using the 355nm wavelength of light.

In 1996 combined mission of France and Russia introduced the ALLISA space born lidar Nd:YAG laser light was used to study the vertical profile of clouds. In the year 2003 space born lidar known as GLAS: Geoscience Laser Altimeter System (on-board ICESat)was launched with the objective of having the topography measurement at 1064nm, the study of aerosols and other atmospheric parameters were measured using 532nm wavelength of light .CALIOP (Cloud Aerosol Lidar with orthogonal Polarization) flown aboard the satellite CALIPSO (Cloud-Aerosol Lidar infrared pathfinder Satellite Observations). Launched in April 2006, it provides global observation of aerosols and cloud. CALIPSO satellite flies as a part of constellation of satellites such as Aqua, Cloud sat, Parasol and Aura called the ''A-Train''.

CALIPSO has ability of providing the data for the long-range transport of pollutant. The main objectives of providing the data are:-

a) To improve observationally-based estimates of direct and indirect aerosol radiative forcing.

b) To improve characterization of surface radiative fluxes and atmospheric heating rates; and

c) To improve model parameterizations of cloud-climate feedbacks.

NASA has many future missions such as ICE Sat II, DESDsyn-I, ASCENDS, ACE, LIST, GRACE-II, 3-D Winds for the study of atmospheric parameters such as changes in climatic condition, deformation of natural hazards, vegetation structure for ecosystem health, aerosol and cloud profile, land surface topography for landslide hazards and water runoff, tracking large-scale water movements, topographic winds for weather forecasting and pollution transport.

Instrument Description and working:

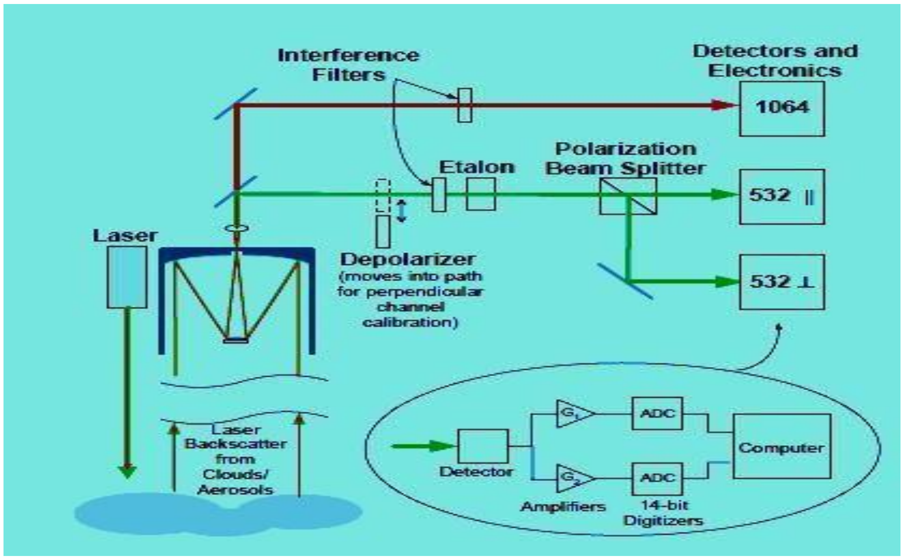
CALIPSO consists of two wavelengths polarization lidar, infrared imaging radiometer and wide field camera, IIR and WFC data will be used to retrieve cloud emission and effective particle size. These all provides data for vertical distribution of aerosols in the atmosphere and also their extinction coefficients, it has the ability of detecting the aerosols over bright surface and the aerosols which lies under the thin clouds with the help of transmitting and receiving system.Laser radiator, Beam splitter, Nd:YAG laser light having wavelength of 532nm and1064nm, telescope, Photomultiplier tubes, and avalanche photodiode. Photomultiplier tubes (PMTs) are the detectors used for detecting 532 nm wavelength of light as they provide with large linear dynamic range, very low dark noise, and high efficiency. An avalanche Photodiode (APD) detector is used for detecting 1064 nm wavelength of light., dark noise is an issue in this wavelength as it is much larger than in the case of PMTs. A polarization beam splitter is an instrument used for separating the 532 nm wavelength of light for parallel and perpendicular returns from the atmosphere. A narrow band etalon is used in combination with a dielectric interference filter in the 532 nm wavelength of light channel to reduce the solar background illumination, where as interference filter is only required as it is capable of providing sufficient solar rejection in 1064nm of channel.

Lidar Signal Processing

PMT and APD are the two detectors which detect the laser light after passing through the receiving telescope, PMT detects the light having the wavelength of 532nm and whereas the APD detect the light having the wavelength of 1064nm.

To get the profile signal a timer is fixed with laser as the laser is fired in the atmosphere the timer will be switched on. PMT detectors are not always on the switched on mode to get it on switched on mode the laser pulse should reach at the altitude of 115 km above the MSL (mean sea level) after that the produced signals from all three channels are stored. The APD detector has no restriction they are always on switched on mode.

PMT detector will switch off and it will stop processing of data as the time corresponds to the range of 18.5 km below the sea level. The data acquired between the range of 40 km and –2 km are used to create the profile data which are required. The portions of the profile above the range of 60 km and below –11are used to measure the DC (Dark current)



Data Analysis

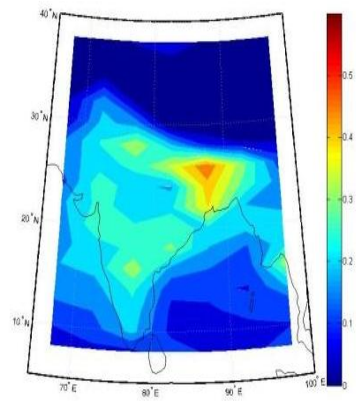
The aerosol data that is collected from the CALIPSO satellite were captured for the Indian region. This study of data provides the study of AOD ("Aerosol Optical Depth" is the degree to which aerosols prevent the transmission of light by absorption or scattering of light) for the particular region in India.

The data are studied for the period of the year January 2007 to December 2013; the comparative study was made for every month of all these years. The seasonal variation was also studied for all the years, the season were divided month wise as December, January & February are winter. March, April &May are summer. Jun, July, August as monsoon. September, October November as post monsoon.

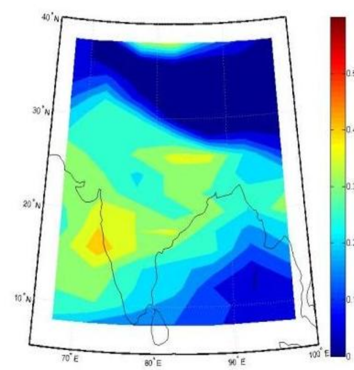
The study of AOD provides the amount of aerosol for per unit volume at a particular region, the data were collect from the NASAS website http:/mynasadata.larc.nasa.gov/.The data collected were studied with the help of the software like Mat lab and Origin.

The Seasonal Variation of Aerosol Optical Depth for the year of 2007

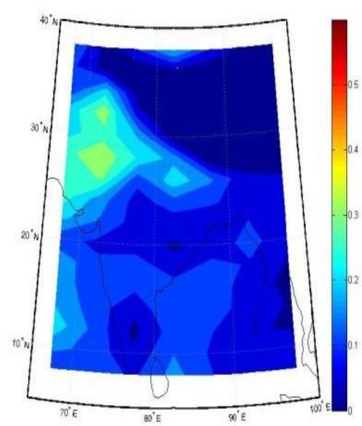
Aerosol Optical Depth for the season of winter 2007



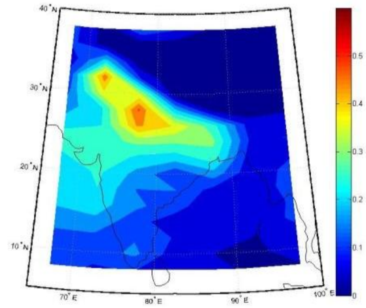
Aerosol Optical Depth for the season of summer 2007



Aerosol Optical Depth for the season of monsoon 2007



Aerosol Optical Depth for the season of post monsoon 2007

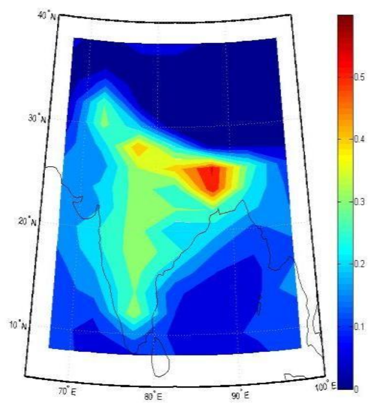


The distribution of AOD for the Indian region is studied and the seasonal variation for the year of 2007 shows the maximum and the minimum value AOD the particular season. The color in the plot depicts the value of AOD and the value of it is noted on the color bar.

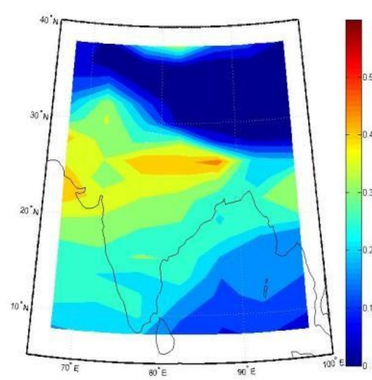
The eastern part of the Indian region shows the value of AOD about 0.4 for the winter season, the maximum distribution of AOD is found for the season of summer and mostly in the south part. The least distribution is found for the monsoon season

The Seasonal Variation of Aerosol Optical Depth for the year of 2008

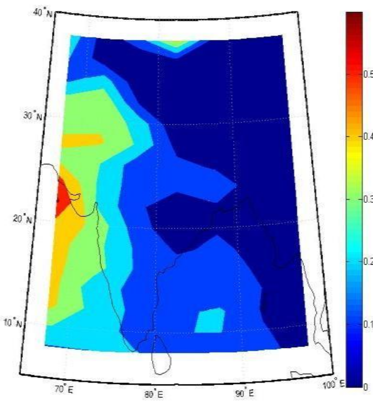
Aerosol Optical Depth for the season of winter 2008



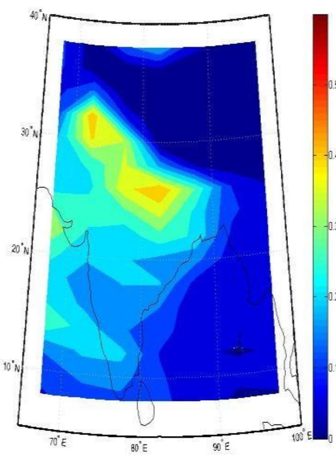
Aerosol Optical Depth for the season of summer 2008



Aerosol Optical Depth for the season of monsoon 2008



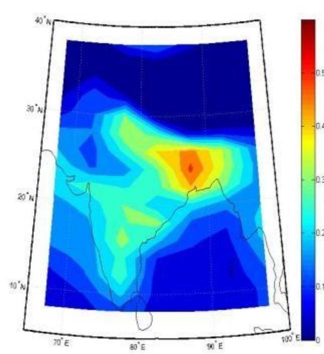
Aerosol Optical Depth for the season of post monsoon 2008



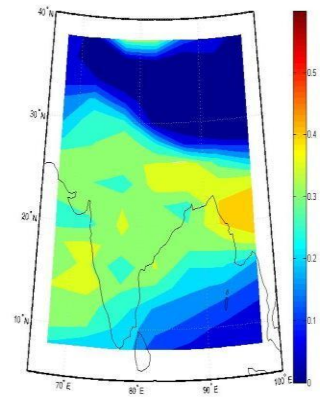
The year of 2008 shows the AOD distribution over Indian region and the maximum of distribution is found for the summer season. The distribution is less in the monsoon season. The color represents the value of AOD for the particular region and the distribution of value is shown on the color bar.

The Seasonal Variation of Aerosol Optical Depth for the year of 2009

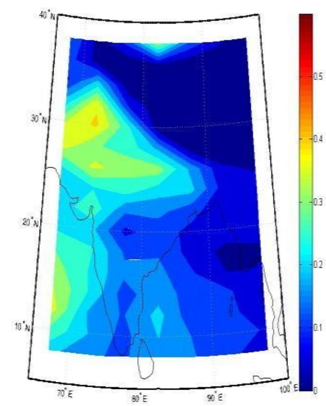
Aerosol Optical Depth for the season of winter 2009



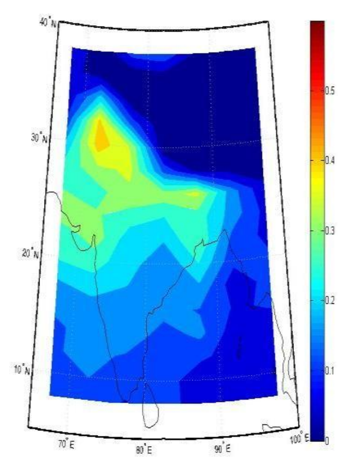
Aerosol Optical Depth for the season of summer 2009



Aerosol Optical Depth for the season of monsoon 2009



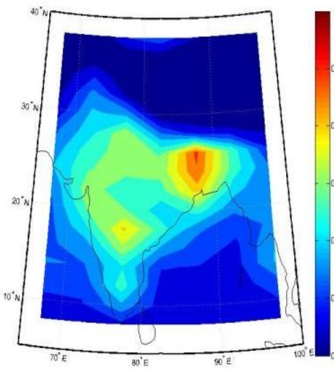
Aerosol Optical Depth for the season of post monsoon 2009



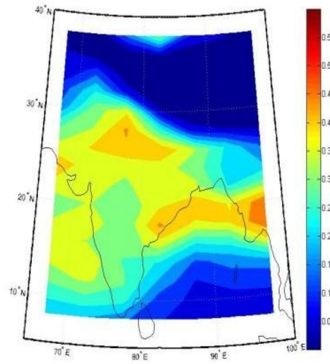
The year of 2009 also shows the AOD distribution over Indian region and the maximum of distribution is found for the summer season. The distribution is less in the monsoon season. The color represents the value of AOD for the particular region and the distribution of value is shown on the color bar. The value of distribution and the value of AOD for the year lie between the values of 0 to 0.6.

The Seasonal Variation of Aerosol Optical Depth for the year of 2010

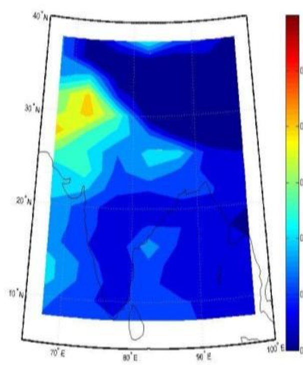
Aerosol Optical Depth for the season of winter 2010



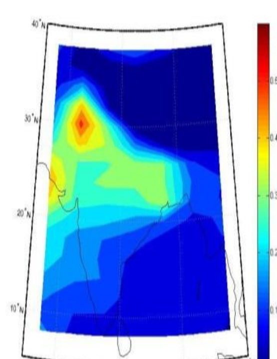
Aerosol Optical Depth for the season of summer 2010



Aerosol Optical Depth for the season of monsoon 2010



Aerosol Optical Depth for the season of post monsoon 2010

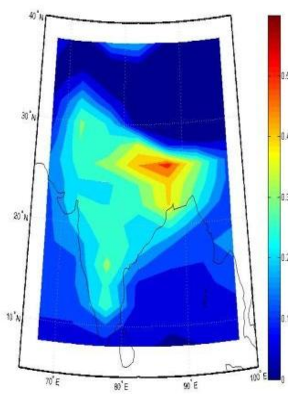


The distribution of AOD for the Indian region is studied and the seasonal variation for the year of 2008 shows the maximum and the minimum value of AOD for the particular season. The color in the plot depicts the value of AOD and the value of it is noted on the color bar

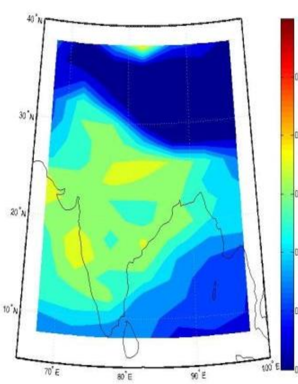
The northern part of the Indian region shows the distribution of AOD about 0.4 for all the season i.e. summer, winter, monsoon and post monsoon. The maximum distribution of AOD is found for the season of summer and mostly in the south part. The least distribution is found for the monsoon season.

The Seasonal Variation of Aerosol Optical Depth for the year of 2011

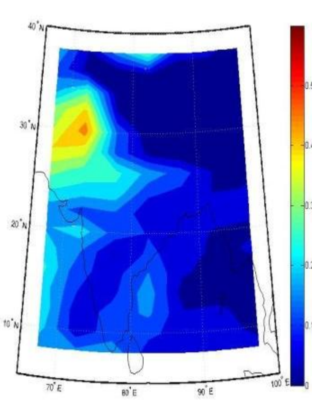
Aerosol Optical Depth for the season of winter 2011.



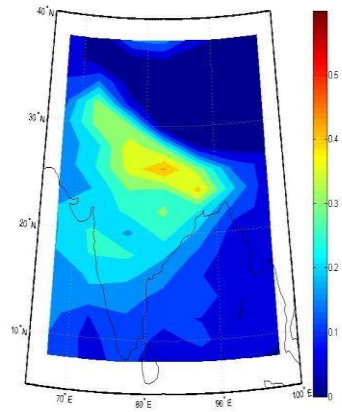
Aerosol Optical Depth for the season of summer 2011



Aerosol Optical Depth for the season of monsoon 2011



Aerosol Optical Depth for the season of post monsoon 2011



The distribution of AOD for the Indian region is studied and the seasonal variation for the year of 20011 shows the maximum and the minimum value AOD the particular season. The color in the plot depicts the value of AOD and the value of it is noted on the color bar.

The North part of the Indian region shows the a high value of AOD about 0.5 for the winter season, the maximum distribution of AOD is found for the season of summer and mostly in the south part. The least distribution is found for the monsoon season. The season of post monsoon is also not much affected with the AOD the distribution of is found to be less in the season.

CONCLUSIONS

In this report we have introduced the Space born lidar data CALIPSO of NASA which provides global data of clouds and aerosols. The study done in the report is done for the year of

2007 to 2011 by using the CALIPSO data. The study provided the information of Aerosol optical Depth for the Indian region the analyses provided the clear picture presenting the AOD at a particular region for a particular month.

The data provided were studied by using the software like Mat lab and Origin. The data over some region provides the value as zero because there may be some loss of data for the region because of instrumental error or the satellite might have not followed the path for that particular region.

An increase in AODs over locations where manmade aerosols are dominant, such as New Delhi, suggests an increase in the amount of aerosols from fossil fuel and biomass burning activities during the last decade. While increasing trend in AODs over the northeast region indicates an increase in the amount of aerosols produced from biomass burning and forest fire.

During winter relative humidity is low and manmade aerosols dominate, while during summer natural aerosols

The seasonal variation of AODs over different locations in India will prove useful in the assessments of regional and global climate impact due to aerosols.

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