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Estimating aerosol optical depth (AOD) seasonal variability in Pakistan by using MISR

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Abstract

Estimation of aerosol optical depth is an important phenomenon to determine the environment pollution, determine climate change and to mitigate air borne diseases in all regions of Pakistan. For an estimation of aerosols optical depth, related data is downloaded from the National Aeronautics and Space Administration (NASA)-World View of two different months of the same year i.e. 1st January 2017 for winter in Pakistan and 1st May 2017 for summer in Pakistan. After the images acquisition, further application of Geographic Information System (GIS) has been applied to generate the maps and results is analyzed for the said months. It has been observed by analysis that during the winter season the value of Aerosol optical depth (AOD) is increased up to 2.29 in Pakistan which means that aerosols are dense in number and during summer the value of Aerosol optical depth (AOD) is approximately 0.44 which is less than winter value because air masses travel only short distances in summer and cause the less concentration of aerosols. So, it is necessary to take effective steps to control and overcome the winter concentration of aerosols which becomes the main cause of urban haze, smog, pollution along with hazardous effects to human health like respiratory diseases and eye infections.

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Introduction

Aerosol Optical Depth (AOD) is the measurment of aerosols (e.g., urban haze, smoke particles, desert dust, sea salt) spread within a column of air from the instrument (Earth's surface) to the top of the atmosphere. It effects our climate for instance more aerosols usually cause rainfall and show the pre-monsoon season. Contrary, in winter high concentration of aerosols cause urban haze, low temprature which effect badly to human health. Aerosols are one of important element of climate system because they absorb and scatter solar and terrestrial radiation. After Absorb and scattering aerosols creates high surface along with atmospheric radioactive forcing effects. Aerosol climatology includes the measurement of light extinction by aerosol scattering and absorption, by procedures such as aerosol optical depth (AOD), angstrom exponent (α), single-scattering albedo (ω), and size distribution (Acharya and Sreekesh, 2013).

Anthropogenic aerosols are also closely linked to the climate system, their net effect by reflecting sunlight is to cool the climate system. In the atmosphere, it also absorbs sunlight, further cooling the surface but warming the atmosphere in the process. As condensation nuclei, aerosols also impact hydrological cycle changing the properties of clouds (Kaufman *et al.*, 2002). Control policies regarding greenhouse gasses emission and sulfur dioxide are formulated to evaluate the aerosol impact on past, current and future (Charlson *et al.,* 1992).

Aerosols are creating some serious climatical and environmental issues. In Bangladesh, Moderate resolution Imaging Spectroradiometer (MODIS) Level 3 remote sensing data is used to make Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model, during the period of 2002-2011.

It is also used to generate a backward course to identify the origins of air masses, with the aim of understanding the spatio-temporal variability in aerosol concentration. Result show that during pre-monsoon season, maximum AOD values comes while in post-monsoon season AOD trend becomes minimum which is only decrease during monsoon season while show increasing trend in all other season (Mamun *et al.,* 2014).

Variation in clouds properties occur mainly due to aerosol variations and clouds has a direct link with our climate. More aerosol as nuclei in clouds means more rainfall occurred. That's why interaction between aerosols and clouds is become the subject of considerable scientific research, due to the importance of clouds in controlling climate. Seasonal study of Aerosol Optical Depth (AOD) by using Moderate Resolution Imaging Spectro Radiometer (MODIS) on board NASA's Terra satellite data and Multi-angle Imaging Spectro Radiometer (MISR) data which shows that maximum value is found in monsoon season (Alam *et al.,* 2013).

Materials and methods

Study area

Pakistan is in the North-Western part of great Indo-Pak sub-continent. It is a beautiful country which stretches from Himalaya Mountains in the north and end at Arabian sea in the south. It has plains in Punjab and Sindh and great coastal boundaries in the south of Sindh and Baluchistan. Its geographical coordinates are 30.3753° N and 69.3451° E. Pakistan is surrounded by countries of Iran, Afghanistan, China and India with a coast on the Arabian Sea.

The total area of Pakistan is 803,936 Km^2. It is a land of varied landscapes ranging from perpetually snowcapped peaks of Himalayan Range like the Karakoram, K-2 elevation 28,265 ft. (8,615 m) to lush green canal irrigated plain areas. Pakistan is in the tropical monsoon zone; therefore, extremely hot and dry in April, hot and very humid in September, cool to dry in November and very cold in December. Due to the presence of monsoonal activity in Pakistan, the overall climate of Pakistan remains arid and semi-arid (ICID, PAKISTAN). The study area map of Pakistan is shown in Fig. 1.

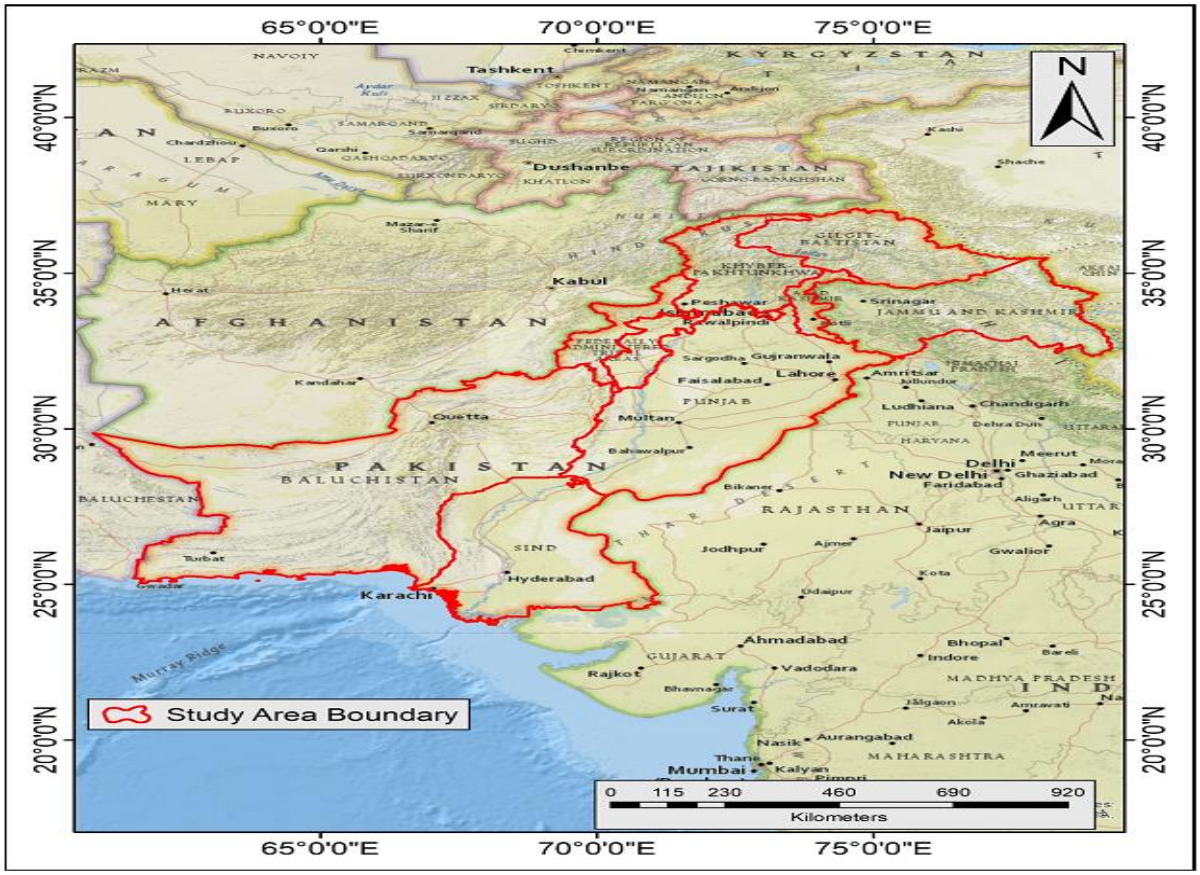

Fig. 1. Map showing study area Pakistan.

Data Acquisition

Data is acquired from National Aeronautics and Space Administration (NASA)-World View. Data is collected for two different months of the same year i.e. 2017. An estimation of aerosols in winter data 1st January 2017 is selected whereas for summer data image of 1st May 2017 is downloaded. After the attainment of images, further application of Geographic Information System (GIS) has been applied to generate maps and results are analyzed for the months of January and May 2017.

Aerosol Optical Depth (AOD)

According to NASA, "Aerosol Optical Thickness" is the degree to which aerosols prevent the transmission of light by absorption or scattering of light. The aerosol optical depth or optical thickness (τ) is defined as the non-segregated extinction coefficient over a vertical column of unit cross-section, it is also known as the normal optical thickness (Ledley, 2016).

Aerosol Optical Depth (AOD) is the measurment of aerosols (e.g., urban haze, smoke particles, desert dust, sea salt) distributed within a column of air from the instrument (Earth's surface) to the top of the atmosphere. The voltage (V) measured by a sun photometer is proportional to the spectral irradiance (I) reaching the instrument at the surface. The estimated top of the atmosphere spectral irradiance (Io) in terms of voltage (Vo) is obtained by sun photometer measurements at Mauna Loa Observatory in Hawaii. The total optical depth (τTOT) can be obtained using the following equation according to Beer-Lambert-Bouguer law:

$$V(\lambda) = Vo(\lambda)\, d2 \exp[-\tau(\lambda)TOT * m], \quad (1a)$$

where V is the digital voltage measured at wavelength λ, Vo is the extraterrestrial voltage, d is the ratio of the average to the actual Earth-Sun distance, τTOT is the total optical depth, and m is the optical air mass (Holben 1998).

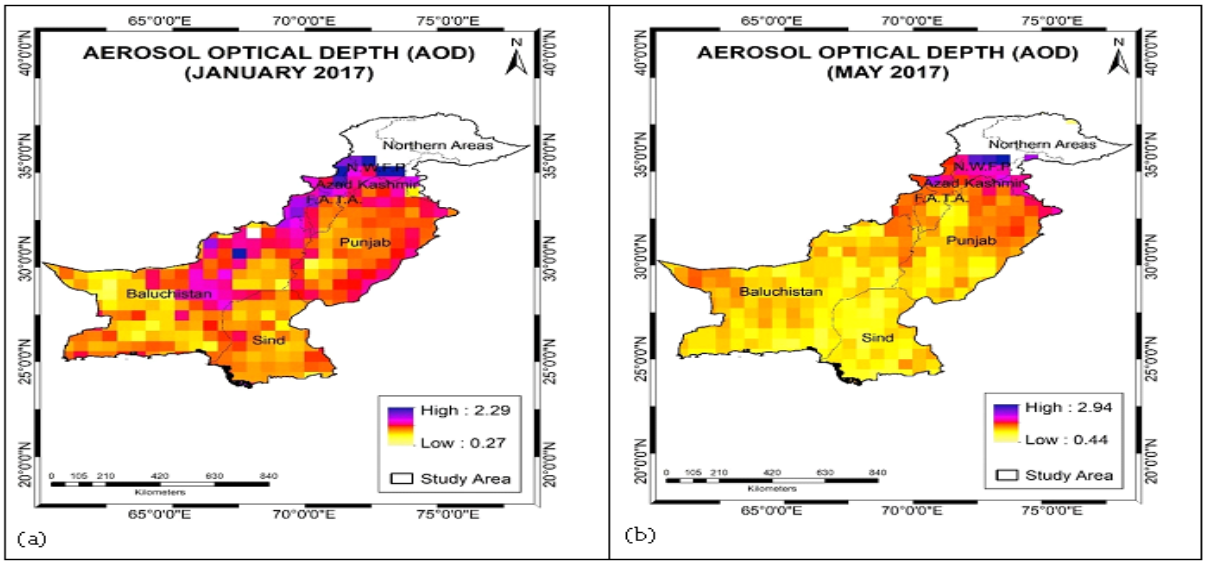

Fig. 2. Aerosol Optical Depth (AOD) analyzed by MISR for Pakistan (a) January 2017 (b) May 2017.

Other atmospheric constituents can scatter light and must be considered when calculating the AOD.

The optical depth due to water vapor, Rayleigh scattering, and other wavelength-dependent trace gases must be subtracted from the total optical depth to obtain the aerosol component:

$\tau(\lambda)Aerosol = \tau(\lambda)TOT - \tau(\lambda)water - \tau(\lambda)Rayleigh - \tau(\lambda)O3 - \tau(\lambda)NO2 - \tau(\lambda)CO2 - \tau(\lambda)CH4$ (1b)

On the basis of above equation data is collected from NASA and apply MISR analysis to measure the AOD in both summer and winter season to show its effect on season.

Results and discussion

Data used in this research is of MODIS-Terra satellite, which has spatial and spectral information around the earth. Daily coverage of MODIS- Aerosols Optical Depth (AOD) is useful for daily measurements by Multi-Angle Imaging Spectro Radiometer (MISR).

Aerosol maps are produced from the acquired data which is based on the facts of particles change and on the way of atmosphere reflects and absorbs visible and infrared light. An optical thickness that shows > 0.1is of crystal clear sky whereas value 1 shows haze conditions (NASA, 2018).

In Pakistan, the assessment of seasonal variability in AOD is evaluated with the help of MISR analysis which is performed on the collected data of NASA of both winter and summer 2017 with specific dates. The association of aerosols with air masses shows that in winter they have remained for a long time, therefore, aerosols have cooled the weather of Pakistan particularly in areas of north-west and south-west. The value of AOD in winter is raised to 2.29 which means that aerosols were dense in number as also shown in Fig. 2(a), the blue and red pixels shows high values of aerosols while the pixels of yellow and orange shows fewer aerosols in areas of Punjab, southern Sindh and Baluchistan. In contrast, during summer in May 2017 air masses are used to travel only short distances and the concentration of aerosols was less i.e. 0.44 as compared to winters.

The North of Pakistan is snow-covered area due to the presence of the Himalayas which indicate no aerosols presence i.e. shown in Fig. 2(b) the empty or white region. While on the other hand, moderately concentrated area with blue and pink pixels that indicates high aerosols whereas yellow and orange pixel illustrate the presence of low aerosols in Southern Punjab, Baluchistan and Sindh (figure 2b). MISR views each scene around the earth by nine different angles and shows smaller detailed spatial

and spectral ranges (Donkelar *et al.,* 2010). MISR captures radiometric and geometric earth images in four spectral bands at every nine angles that's why this is used to analyze the AOD effects on seasonal variability and it also reveals that monsoon rainfall tends to reduce aerosol concentrations by washing aerosols out of the atmosphere; this effect is mainly restricted to the eastern and south-eastern parts of Pakistan. For the justification of analysis performed by using MISR- satellite, histogram was generated to compare the concentration of aerosols in Pakistan for both seasons. Histograms as shown in fig. 3(a) January 2017 or fig. 3(b) May 2017 clearly discriminates the difference of aerosol presence in these two months.

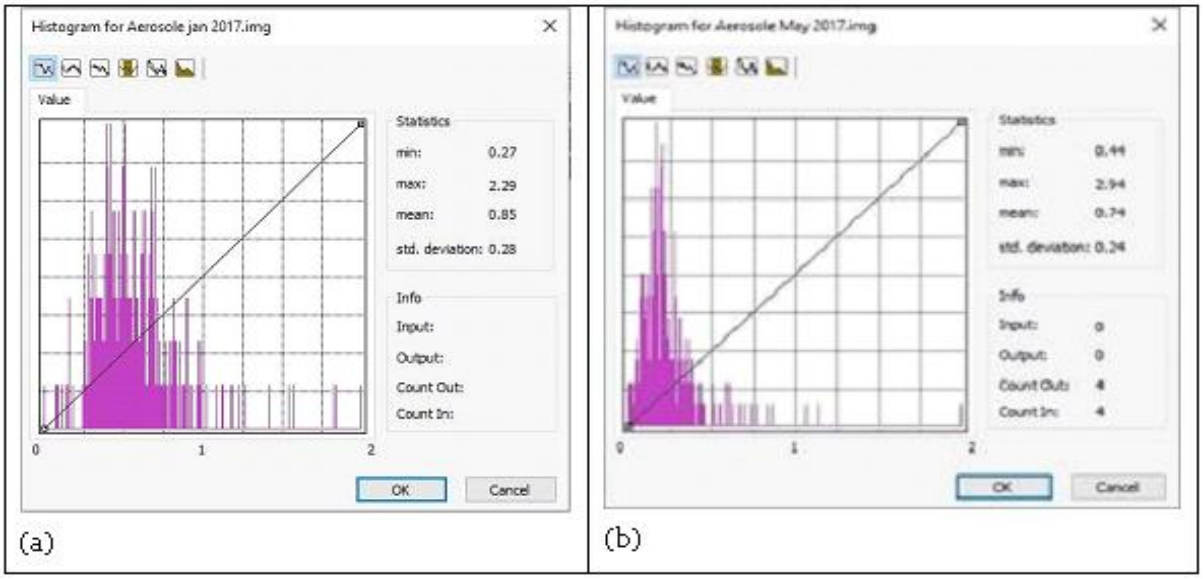

Fig. 3. Aerosol Optical Depth (AOD) Histogram analyzed by MISR for Pakistan (a) January 2017 (b) May 2017.

Conclusion

Aerosol optical depth (AOD) tells us how much direct sunlight is prevented from reaching the ground by the presence of dust particles or elements of smoke and fog (smog).

The presence of these pollutants could block sunbeams by absorbing or by scattering it. It is a dimensionless figure that is associated to the amount of aerosol in the vertical column of atmosphere over the observation location. The value for clean atmosphere is 0.01 while 0.4 is for very hazy condition of atmosphere. An average aerosol optical depth for the U.S. is 0.1 to 0.15.

Consequently, this short and comprehensive study provides a short seasonal shift of aerosols in Pakistan. There is an association of aerosols with air masses and seasons.

In Pakistan, the concentration of aerosols is high in winter due to stagnate air mass while in summer concentration of aerosols is low because air mass slowly moves.

The relationship of aerosols with environment also elaborates that our climate is not clear and pollution free. Industrialization and urban expansion with other anthropogenic activities like burning of fossils fuel in vehicles, have been increased from last three decades.

The increasing use of air-conditioners in concrete buildings are accelerating the situation to be worst. Using satellite images aerosols can be mapped easily to know about areas with high concentration of aerosols which show that reduction and control of aerosols also need for a better environment, human health and for environmental friendly earth.

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