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Study of Aerosol Optical and Physical Properties (Including AOD, Angstrom Exponent & UV Aerosol Index) by using GIS and Remote Sensing Over Pune City

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ABSTRACT

Aerosols are one of the basic elements that plays a major role in daily life. Aerosol refers to the dispersion of solid or fluid particles of microscopic size in gaseous media with diameters between about 0.002 µm to about 100 µm, such as dust, smoke, or mist. The aerosols generally have a complex nature with respect to space, time, microphysical, chemical, and optical properties. These aerosols influence climate and as well as human health in many ways. These aerosol particles result in several health issues from allergy to cardiovascular and respiratory problems. Here we have focused over an city of Pune (25.3176°N, 82.9739°E), Maharashtra, India which is a major IT hub and fastest growing smart city in India. In the present work, Aerosol data (AOD, Angstrom Exponent and UV aerosol Index) analyzed from NASA based satellite Giovanni and data derived from MODIS (aqua and Terra) and OMI (Ozone Monitoring Station) for calculation of annual, monthly and seasonal data of Aerosol on Pune city. The analysis is done on long term basis for the 2014 to 2023.These parameters showed large variability on daily, monthly, and seasonal time scales during the study period. To understand the impact of aerosols on Pune city, a regression and Linear analysis was done with aerosol parameters. This paper generally deals with the variation of aerosols properties and their change in annual, monthlyand seasonal variation of parameter over year. It further deals about the trend analysis and growth of aerosols over Pune city. This paper helps us understand the different aerosol properties and their interactions. It also helps in understanding direct and semi direct effects that comes under aerosol- radiation interactions. This paper will help a beginner who is working on the basic aerosol concepts and definitions to have a clear-cut view of aerosols in simple terms.

Keywords, Aerosol Optical Depth; Angstrom Exponent; UV Index; Urban Area; OMI; Pune

INTRODUCTION

Aerosols are small liquid or solid particles suspended in the atmosphere. They can be emitted directly (such as dust, sea salt, black carbon (BC) and volcanic aerosols) or formed indirectly through chemical reactions (including sulfate, nitrate, ammonium, and secondary organic aerosols). Aerosol particles not only affect health of living organisms, but it also affects the earth's budget by trapping solar radiation due to effect of scattering and absorption. The rapid growth in emerging economies over the last decades has led to dangerous levels of air pollution throughout Asia (Grandey and Cheng 2016; Cohen et al. 2017; Lelieveld e tal. 2018). As a result, air pollution levels in many South Asian cities are above the World Health Organization guideline values (WHO 2018). Depending on the structural and compositional characteristics, aerosols can scatter and/or absorb shortwave radiation, as quantified through the single-scattering albedo. Purely scattering aerosols include sulfates, nitrates, ammonium and sea-salt particles, whereas absorbing aerosols are primarily BC, with dust and organic carbon partly absorbing in the ultraviolet (UV) spectrum. The present paper is study on Pune city which is the second-largest city in the state of Maharashtra after Mumbai and is an important city in terms of its economic and industrial growth. On the globe, Pune discovers its area at 18.5204° N, 73.8567°. The city's total area is 15.642 km2, and the municipal corporation area covers 518 km2. Pune lies on the western marginof the Deccan plateau, at an altitude of 560 m (1,840 ft) above sea level.

Aerosol optical depth is the degree which shows the extinction of solar radiation due to effect of absorption and scattering.

AOD is a dimensionless number which shows column integrated aerosol presence. The angstrom exponent presents the fineness of aerosol particles in the atmosphere. More the value angstrom exponent finer will be particles present in the atmosphere UV index shows the presence of absorptive or non-absorptive type of aerosol. Positive or more values of UV index show absorptive nature and negative or less values show non absorptive nature of aerosol.

METHODOLOGY

Daily data of aerosol parameters (like aerosol optical depth, angstrom exponent and UV aerosol index) are taken in the form of 1°×1° grid (i.e. 18.516-19.516°N, 73.856°-74.856°E) by NASA based Giovanni site which gives data from OMI (Ozone measuring instrument) and MODIS satellite over Pune city.

Since in this analysis Satellite based data are used which is obtained by NASA based satellite. The source of this data is OMI (Ozone monitoring instrument) and MODIS (moderate resolution imagingspectroradiometer).

The mean observed data obtained from Ozone measuring instrument over an urban area Pune is analyzed in the form of monthly mean data and its standard deviation. All collected area averaged data is shown with the help of graphical representation which further shows the variation of aerosol parameters.

In the study period of analysis (From 2014 to 2023) three parameters that is AOD, angstrom exponent and UV index are analyzed yearly and monthly-:

Yearly Variation:

Year	AOD (Mean ± std dev)	Angstrom exponent(Mean ± std dev)	UV Index (Mean ± std dev)
2014	0.50191±0.077249	1.2839±0.287103	0.8593±0.10802
2015	0.53191±0.156279	1.3263±0.251087	0.8932±0.13240
2016	0.46375±0.105447	1.1204±0.371491	1.0416±0.19500
2017	0.47940±0.079415	1.2223±0.306885	1.1899±0.2378
2018	0.63929±0.223865	1.4023±0.18269	1.1584±0.2885
2019	0.48675±0.117888	1.266±0.26423	0.9428±0.1216
2020	0.48425±0.099524	1.3667±0.48498	0.8363±0.1702
2021	0.57558±0.197281	1.217±0.64653	0.8497±0.1865
2022	0.55495±0.106882	1.3531±0.3213	0.7370±0.6735
2023	0.58418±0.136428	1.5389±0.11018	0.8063±0.0844

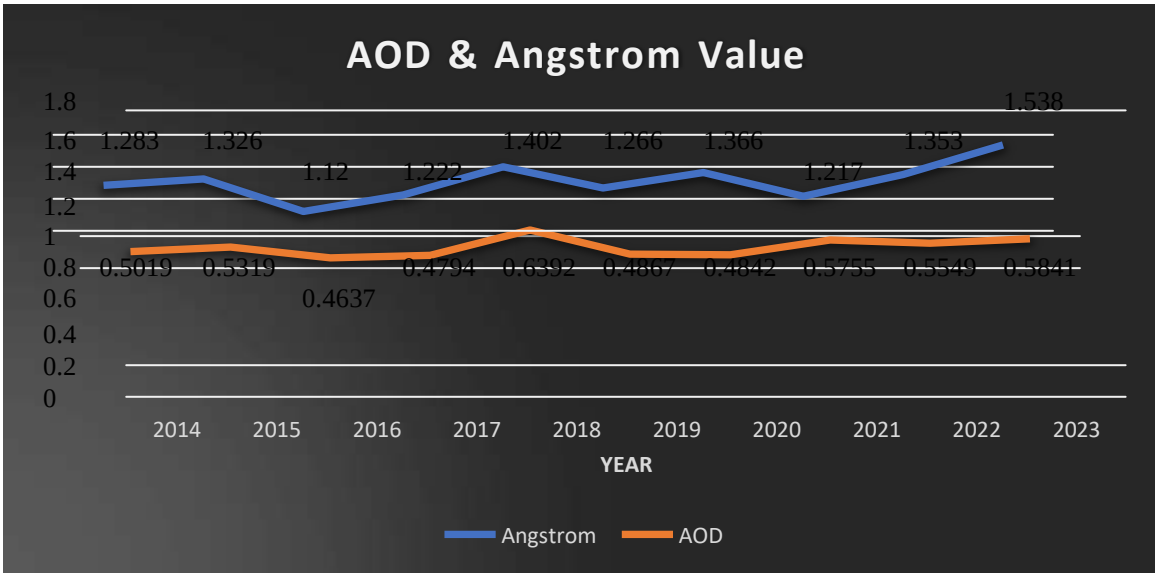
Monthly Variations:

Months	AOD (Mean ± std dev)	Angstrom exponent(Mean ± std dev)	UV Index (Mean ± std dev)
January	0.5922 ±0.07831	1.4504 ±0.10347	0.8593±.10802
February	0.4797±0.09217	1.3681±0.18835	0.8932±0.13240
March	0.5064±0.11006	1.3174±0.25571	1.0416±.19500
April	0.4983±0.09119	1.189±0.29088	1.1899±0.2378
May	0.5283±0.11358	1.0775±0.22810	1.1584±.2885
June	0.55215±0.13269	0.7654±0.48315	0.9428±0.1216
July	0.34510±0.3818	0(Data not available)	0.8363±.1702
August	0.5±0.38897	0(Data not available)	0.8497±.1865
September	0.4218±0.16903	1.3545±0.49006	0.7370±.06735
October	0.5322±0.12846	1.5392±0.06995	0.8063±0.0844
November	0.5278±0.12007	1.5237±0.09104	0.9513±0.1849
December	0.4835±0.15497	1.5071±0.08027	0.8362±0.0712

RESULTS AND DISCUSSION

Annual variation of AOD and angstrom exponent:

The pattern of variation of AOD is similar from 2014 to 2015 and 2021 to2023 while decreasing patternfrom 2015 to 2017 and 2018 to 2020. Angstrom exponent shows a continuous change in pattern from 2014 to 2023.Angstrom Exponent increase continuously from 2021 to 2023. This graph shows the clear dependency of AOD on angstrom exponent. Approximately similar variation of AOD in the year of 2014,2015 and 2021 to 2023 shows due to slight change in anthropogenic aerosol.



Annual variation of UV Aerosol Index

Positive values of Aerosol Index generally represent absorbing aerosols (dust and smoke) while small or negative values

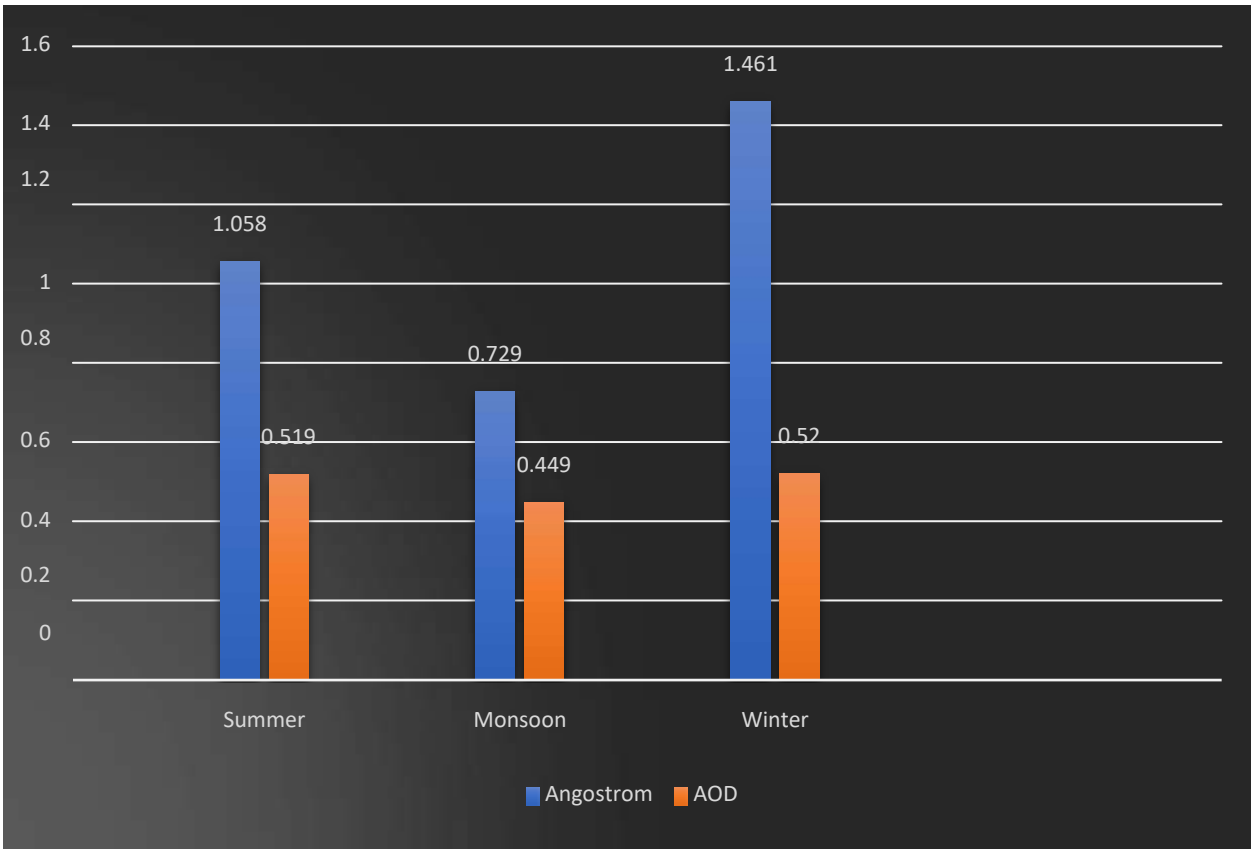
represent non-absorbing aerosols and clouds. Almost a rising pattern of UV aerosol index can be noticed in time span of 2014 to 2018 which is an indication of enhanced proportion of absorbing type aerosol over the year during mentioned year.

In the variability representation of UV index lesser value is found in the year of 2014 because of less pollution 2020,2021 because of covid -19and major lockdown observed in Pune city which shut many industrial and construction activities and anindication of cloud presence in that time zone.

Seasonal variation of AOD and angstrom exponent:
The climate of Pune has changed during the past 3 decades, especially since the rapid expansion of the population and construction work. Pune experiences three seasons: summer, monsoon, and winter.

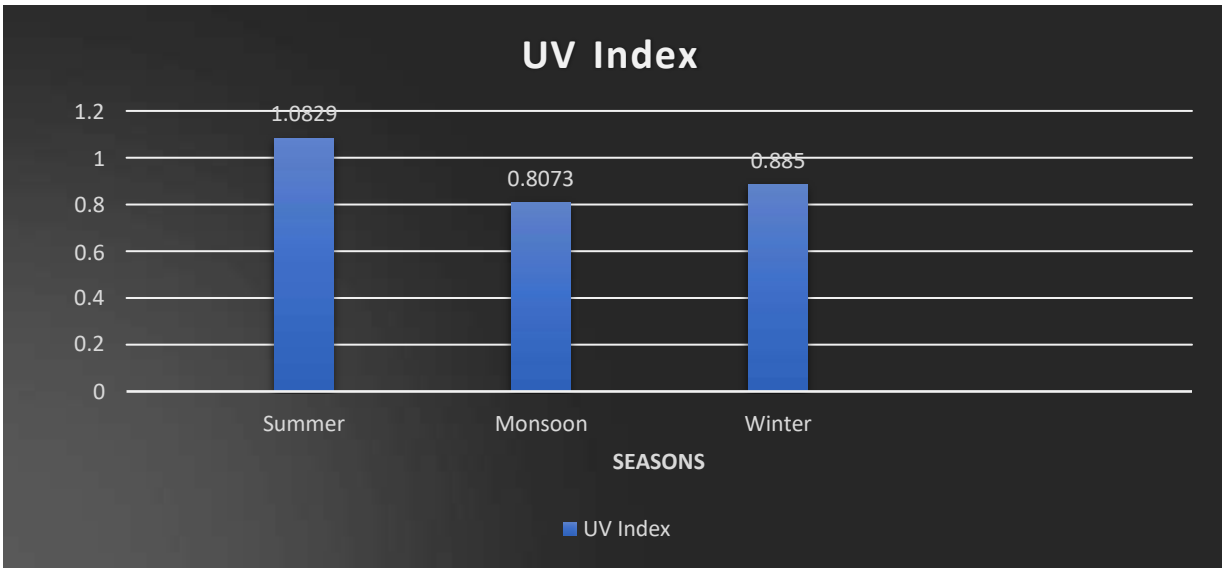
Typical summer months are from March to June often extending till 15 June, with maximum temperatures sometimes reaching 42 °C (108 °F). Seasonal variation of AOD and angstrom exponent shows similar trend in all seasons. There is a increasing pattern in Winter and summer season and it is showing decreasing pattern in Monsoon season. Both parameters are showing maximum mean value inwinter season due to hazy conditions.

The AE>1 values are indicating about the dominance of fine particles during winter season. During winter and summer season the aerosols were originated from biomass/biofuel burning and due to vehicular pollution over the city



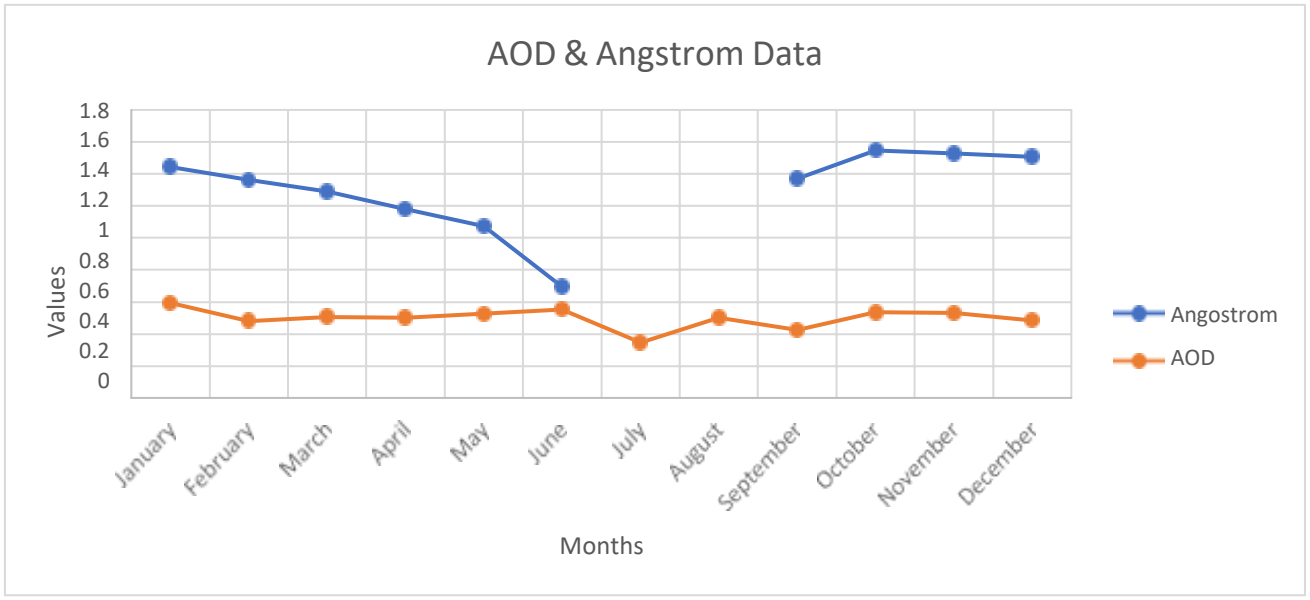
Seasonal variation of UV Aerosol Index:
Measure of UV aerosol index was found highest in the span of Summer among all the seasons because of presence of absorbing kind of atmospheric aerosols in environment of study area. Low value of this parameter was found in monsoon season because of the reason that there are lot of cloud formation in the span of monsoon period which gives low measure of UV aerosol index. Since all the absorbing kindof aerosols are responsible for the alteration of radiation balance of earth.

Since in all the seasons, all mean measures of this index are showing its positive values, so they are having absorbing aerosolsin every seasons.



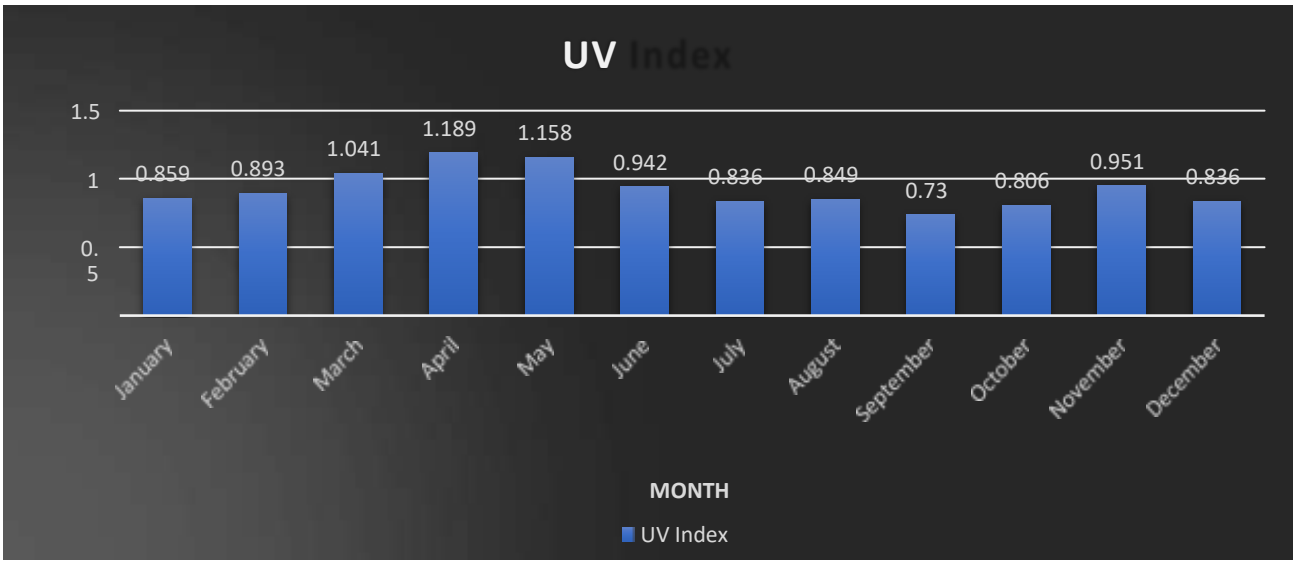
Monthly variation of AOD and angstrom exponent

Monthly variation of AOD and angstrom exponent similar pattern from January to April, April to June and August to December. AOD shows a diminishing pattern from June to August because of rainfall which cause decrease in temperature over these months in the study area which causes less convection of aerosols present near the earth. Angstrom exponent monthly mean data high in month of January, November and December and Daily mean data of July and August not available in MODIS and OMI which shows no pattern from June to August due to non-availability of data.



Monthly Variation of UV Aerosol Index:

Among all the monthly averaged measures, the high value of UV index is found in the month of March, April and May which come in the category of pre-monsoon period. Since there is availability of absorbing aerosols in this duration which gives great value of UV aerosol index. Minimum value of this parameter of aerosol was found in the span of July, August and September which comes under monsoon period



CONCLUSIONS

Aerosol optical properties (including AOD, angstrom exponent and UV aerosol index) in the city of Pune which is located at at 18.5204° N, 73.8567°including AOD, angstrom exponent and UV aerosol index are studied using data obtained by MODIS and OMI. The annual variation of AOD is between 0.50 and 0.53 for wavelength 550 nm. The maximum mean and standard deviation of AOD is 0.63929± 0.22386 in 2018 whereas angstrom exponent have its maximum value of 1.5389±0.11018 in 2023 and UV index have its maximum mean value of 1.051917± 0.235322 in 2018. In the analysis of monthly variation AOD exponent varies (0.34510±0.3818 to 0.5922 ±0.07831) have its maximum value of 0.5922 ±0.07831 in January. Angstrom exponent varies from 0.7654±0.48315to 1.5392±0.06995 having maximum value in October and minimum in June. In July and August Angstrom exponent data not available in both satellites. UV Index have its maximum value of 1.1584±.2885 in May and minimum value of 0.7370±.06735 in September. Seasonal variation shows that AOD have its maximum value in summer and winter is approximately same 0.520588± 0.0524 and 0.51975± 0.023894 due to same temperature. Angstrom exponent is having maximum value of 1.46125 ± 0.071365 in winter and in summer its value is1.05835±0.108006. An exponential dependence of α on AOD in winter and summerindicates that the dust aerosols are major contributors of atmospheric turbidity in Pune. In seasonal variation analysis, UV aerosol index have its maximum value of 1.08295± 0.112977 in summer season due to presence of absorbing aerosol and it has minimum value of 0.807325± 0.050272 in Monsoon season due presence of non-absorbing aerosol like clouds.

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