__Original Research Article__

COMPARATIVE ANALYSIS OF AEROSOL OPTICAL PROPERTIES OVER HIGH ALTITUDE REGION OF WESTERN GHATS IN SOUTHERN INDIA

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ABSTRACT

OBSERVATIONS OF AEROSOLS AND BLACK CARBON (BC) WERE CARRIED OUT AT OOTY, HIGH ALTITUDE REGION IN WESTERN GHATS USING MULTI WAVELENGTH SOLAR RADIOMETER (MWR) AND AETHALOMETER. FOR THE YEARS 2018 AND 2021, THE OPTICAL CHARACTERISTICS OF AEROSOLS AND CLOUDS (OPAC) MODEL WAS USED TO ESTIMATE MONTHLY, SEASONAL, AND SPECTRAL VARIATIONS OF AEROSOL OPTICAL PROPERTIES SUCH AS AEROSOL OPTICAL DEPTH (AOD), SINGLE SCATTERING ALBEDO (SSA), AND ASYMMETRY PARAMETER (ASY). THE DOMINANCE OF FINE ANTHROPOGENIC AEROSOLS WAS SHOWN BY HIGHER AOD DURING THE PRE-MONSOON PERIOD. THE MAXIMUM AND MINIMUM SEASONAL VARIATION OF AOD OCCURRED DURING PRE-MONSOON (1.1 ± 0.02) AND WINTER (0.21 ± 0.001) RESPECTIVELY. THE SIGNIFICANT SPECTRAL VARIATION OF AOD OCCURRED DURING MARCH TO MAY AS IT DECREASES WITH THE INCREASE IN WAVELENGTH .THE SSA INCREASES AS THE WAVELENGTH INCREASES, RANGED BETWEEN 0.83 ± 0.02 AND 0.77 ± 0.01.THE VARIABILITY OF SSA IS SIGNIFICANT DURING JANUARY AND FEBRUARY WHICH IS A CHARACTERISTIC OF COARSE TYPE AEROSOLS. ASYMMETRY PARAMETER WITH THE MONTHLY MEAN OF 0.75 ± 0.01 INDICATED THE FORWARD SCATTERING OF AEROSOLS AND THERE IS NO SIGNIFICANT DIFFERENCE IN THEM OVER THE YEARS.

Keywords: Aerosols, Aerosol Optical Depth, Asymmetry Parameter, Single Scattering Albedo, Variations

1. INTRODUCTION

Atmospheric aerosols are solid or liquid particulate matter suspended in air that are micrometer to submicron in size. These particles have a significant impact on the earth's radiation budget, indirectly by functioning as cloud condensation nuclei thus modifying cloud microphysical properties and directly by scattering and absorbing energy from the sun.

Aerosols are produced in the atmosphere by a variety of natural and human-caused activities and distributed horizontally and vertically in the atmosphere by the current air circulation [1]. The increased aerosol load in the atmosphere due to the rapid population growth and urbanization has significant impact on the local, regional and global climate. Aerosols' potential to influence radiation budget, air quality and human health is determined by their size and chemical properties [2]. The chemical composition of aerosols is defined by their sources, whereas their particle sizes are influenced by the process of manufacturing and the meteorological factors they experience during their lifetime. In general, anthropogenic aerosols are submicron in size (fine mode) and aerosols from the natural sources are of coarse mode.

The effect of aerosols on the atmosphere and climate can be better understood with the knowledge on their optical properties Due to their short lifetime in the atmosphere and a variety of sources, aerosol optical characteristics exhibit greater temporal and geographical variability [3]. Aerosol optical characteristics must be measured continuously in order to model their impact to climate change. Several researches have used satellite data and ground based monitoring instruments to investigate spatial and temporal coverage of aerosol optical properties. The optical properties of aerosols can be processed and studied with the help of OPAC (Optical Properties of Aerosols and Clouds) model. The OPAC database contains information on diverse aerosol components, such as their particles size and refractive indices, for the ultraviolet to far infrared spectral range. The researcher can combine these components to make new mixtures, i.e., distinct types of aerosols with varied phase functions, optical characteristics, and microphysical properties [4].

Being one of the world's most densely inhabited regions, anthropogenic pollution is a well-known problem in South Asia. Aerosol loading in the Indian region had been observed to be growing over the last decade [5]. Several researches conducted in India have highlighted the geographical and temporal diversity of aerosol optical characteristics over longer periods of time. Srivastava *et al.* (2017) examined the optical characteristics of aerosols over South Asia, finding seasonal variability and significant changes in annual mean AOD over through the research area. [6] Madhavan *et al.*(2021) studied the seasonal variability of aerosol optical properties from 2008 to 2013 which showed the significant spectral and seasonal dependence of SSA and AOD [7]. The seasonal heterogeneity of aerosols studied by Singh *et al.* (2020) concluded AOD varies greatly during premonsoon and lowest observed during monsoon [8]. In order to gain the knowledge on aerosol optical properties, continuous measurement of AOD and BC concentrations were carried out at Ooty. And the outcome were discussed in this paper for the years 2018 and 2021 which is crucial to understand how aerosols and BC have changed throughout time and how they affect regional climate.

2. MATERIAL AND METHODS

2.1 Description of the Observational site

For monitoring of aerosols and BC concentration, observations were carried out in high altitude Aerosol Radiative Forcing over India (ARFI) observatory located at Ooty, Nilgiris which forms a part of Western Ghats. Ooty has a population of 83,430 people who are living in a 13-square-kilometer area, according to the 2011 census. The hill sides of Nilgiris and its environment are covered in dense woods, coffee, tea plantations, and trees like as conifers, eucalyptus, and pine etc. The source of pollution in Ooty is tea industries, wood burning for domestic purpose and vehicular traffic which is significant during winter and summer [9] [10]. For the years 2018 and 2021, the study period was separated into two seasons: winter (January and February) and premonsoon (March to May) at ARFI Observatory, Ooty.

2.2 Instrumentation and Data analysis

2.2.1 Aethalometer and Multi Wavelength Solar Radiometer

To study about the aerosol optical properties, primary input data of BC and AOD analysis for the years 2018 and 2021 done utilizing seven channel Aethalometer (AE-31 Magee Scientific, USA) and Multi Wavelength Solar Radiometer (MWR).

2.2.1.1 Aethalometer

AE-31 was used to obtain BC measurements. The attenuation of a beam of light passing through a sample in the filter paper is equal to the total BC deposition [11]. BC was measured at 880 nm because at this wavelength other aerosols does not show the significant absorption [12].In the present study , attenuation of light beam is measured for every 5 minutes with the flow rate of 4 L min -1.

2.2.1.2 Multi-wavelength Solar Radiometer (MWR)

MWR was used to conduct spectral AOD measurements at the study site, which was designed and developed by the Space Physics Laboratory at Trivandrum. This instrument is used to measure the surface encountering direct solar radiation at specified wavelengths in real time. MWR is capable of measuring radiation in the range of 380 -1025 nm during clear sky conditions [13] [14].

2.2.2 Optical Properties of Aerosols and Clouds (OPAC) model

Hess *et al.*(1998) designed OPAC software which provides information on the microphysical characteristics of aerosols and clouds. Soot, sea salt, sulphate, minerals, and water soluble and insoluble aerosols are all components of various aerosol combinations. Optical properties of various aerosol mixtures can be estimated with this model. The aerosol vertical height, relative humidity, and wavelength range are all included in this model. This model includes eleven aerosol components, six distinct forms of water clouds, and three different types of ice clouds. Absorption, scattering coefficients, Asymmetry Parameter (ASY), Aerosol Optical Depth (AOD), Single Scattering Albedo (SSA), can all be computed using the OPAC model [4].

In this study, the continental average model is chosen for the estimation of optical characteristics since it is suited for the high altitude regions. Continental average type includes BC number density (8300 per cm3), water soluble aerosols (7000 per cm3) and insoluble aerosols (0.4 per cm3).In this model, mass concentration of number density of BC is 0.5 μg/m3. But the number density of soot particles is adjusted to obtain the best fit between the OPAC derived AOD and measured AOD.BC number density calculated from BC mass concentration, wavelength of 500 nm, relative humidity of 50% is applied for the estimation of aerosol optical properties.

3. RESULTS AND DISCUSSION

3.1 Seasonal and Monthly variations of Aerosol Optical Properties

3.1.1 Aerosol Optical Depth (AOD)

AOD provides information about the attenuation of sun beam by dust and aerosol particles. The total aerosol content in the vertical column of the atmosphere is determined using AOD. AOD exhibited significant monthly variations over the study site [Fig 1].The monthly mean AOD varied between 0.22 ± 0.001 to 2.3 ± 0.02 and 0.21 ± 0.004 to 0.96 ± 0.03 during 2018 and 2021 respectively. Higher AOD occurred during premonsoon (1.1 ± 0.02 in 2018 and 1.8 ± 0.002 in 2021) due to the occurrence of fine aerosol particles. Lower AOD of 0.2 ± 0.001 found during January (2021) and February (2018).However, marginal increase of AOD seen during premonsoon of 2021 compared to 2018.AOD estimated over the study site are comparable to that of AOD observed at Hanle (4500m amsl) where the maximum AOD found during spring and minimum AOD during winter [15] and at Darjeeling (2000m amsl) where the dominance of AOD occurred during premonsoon [16]. OPAC calculated AOD and MWR AOD shows the good correlation with each other during the study period.

3.1.2Single Scattering Albedo (SSA)

The ratio of scatted radiation to the total amount of scattered and absorbed radiation gives SSA. The presence of absorbing and scattering aerosols is indicated by the presence of higher and lower SSA [17]. The highest SSA was 0.83 ± 0.02 in January 2021.The monthly variations of SSA between 2018 and 2021 was given in Fig.1.By comparing the monthly average of 2018, SSA values were higher in 2021.It indicates the increase of scattering type of aerosols in atmosphere over the years. Given the higher BC concentration during the pre-monsoon season, the existence of increased moisture content in the atmosphere can explain a higher SSA value, reflecting scattering aerosols overall dominance. Aerosols can acquire moisture according on their elemental composition and the moisture content in the environment, altering their phase and evolution [18]. The radius of hygroscopic aerosols increases with the increase in relative humidity. Aerosols increase in size, which favours a greater SSA [19]. Hence, a higher RH (83.3%) recorded at the observation site during May is responsible for increasing the scattering properties of aerosols. SSA at the study site are found to be less than that observed at Manora Peak (1950m amsl) which shows the range of 0.87 to 0.94 [20] and comparable to Hanle where the dominance of scattering aerosols occurred during winter [21].

3.1.3 Asymmetry Parameter (ASY)

ASY provides information about the scattering type of aerosols. The maximum ASY occurred during winter of both the years showed the dominance of large size particles over the study site [Fig.1].The average phase function of aerosols at study site (0.75 ± 0.01) is higher than the ASY observed at Hanle (0.67) and Merak (0.65) regions [21].

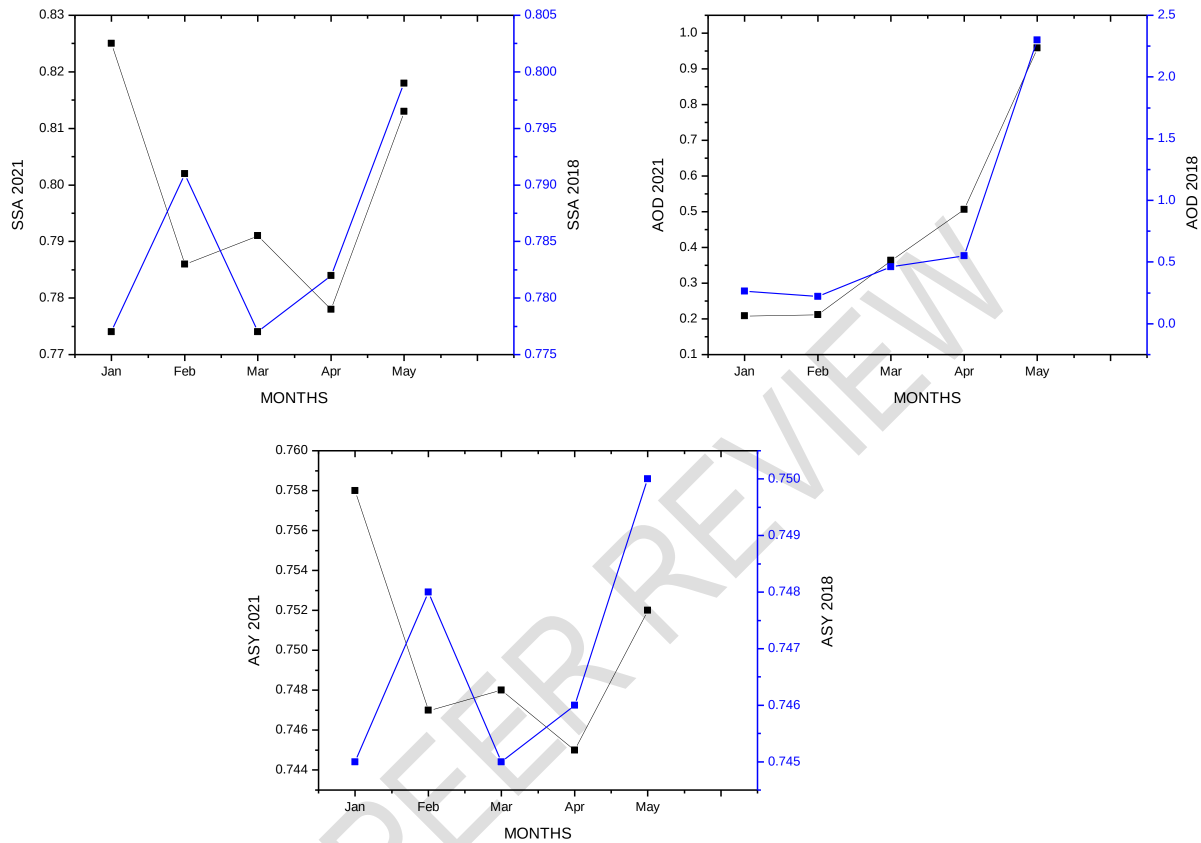

Fig.1. Monthly variations in AOD, SSA and, ASY at 500 nm over the study site.

3.2 Spectral variation of Aerosol optical properties

During the study period, the spectral variability of AOD, SSA, and ASY at nine distinct wavelengths (350, 400, 450, 500, 650, 750, 800, 900, 1250 nm) estimated (2018 and 2021) was represented in the Fig.2. AOD's spectral variability provides information on the particles size of aerosols in a given location [22] [23]. AOD does not have the significant spectral variability during January and February (winter).It indicates the presence of coarse aerosol particles over the study site. But AOD had higher wavelength dependence during March to May (premonsoon) as it decreases with the increase in wavelength, indicating the presence of fine aerosol particles. SSA increases with the increase in wavelength and it was found to be higher in winter compared to pre monsoon [Fig 2]. It was due to the presence of fine aerosol particles during the premonsoon over the study site which is evident from Fig.3 which shows SSA decreases with the increase in BC over the study site [24] ASY, unlike SSA, decreases as wavelength increases, which is most visible in the 350-800 nm region .It indicates the presence of fine aerosol particles but a small increase at the higher wavelength showed the occurrence of coarse particles.

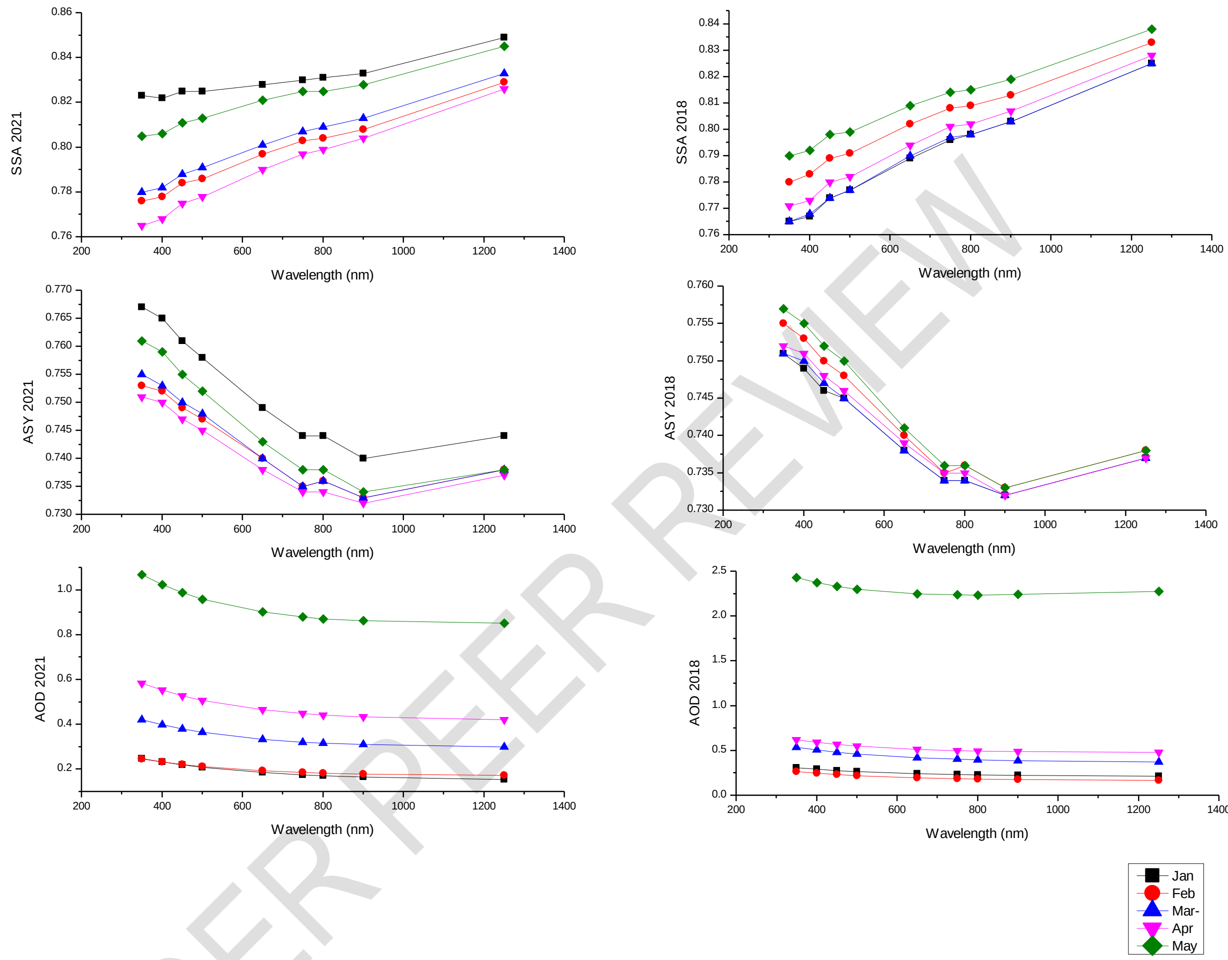

Fig. 2. Spectral variation of AOD, SSA, AP during the observational period 2018 and 2021 over the high altitude region,Ooty.

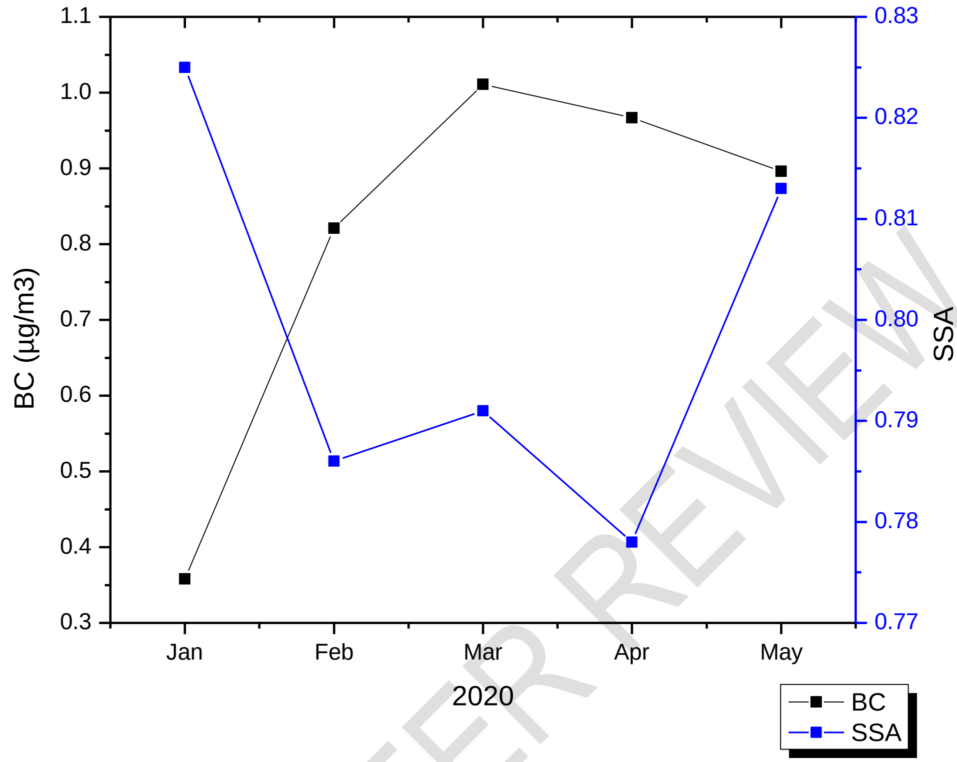

Fig.3. Comparison between BC concentration and SSA at observational site, Ooty

4. CONCLUSION

This study revealed the variation of aerosol optical characteristics over time. Even if they are minor, these changes have a significant impact on the climate system of this region. Further studies on aerosol radiative forcing can be undertaken in future for better understanding of the significance of aerosols in climate change over this high altitude region.

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