

Interpolation for Aerosol Optical Depth at Four Wavelengths over Ilorin from Observed Aeronet Data

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ABSTRACT

The Aerosol Optical Depth (AOD), which is the integral part of the atmospheric extinction coefficient from the surface to the top of the atmosphere, is an important parameter for observation of visibility degradation due to atmospheric pollution, solar radiation extinction and other climate effects. The wavelength dependence of Aerosol Optical Depth (AOD) varies between different aerosol types because of their different physical and chemical characteristic. This paper presents new data points using interpolation for Aerosol Optical Depth (AOD) at four spectral wavelengths (440-870nm. The data used consist of measurements collected at Ilorin AERONET site (8°32'N, 4°34'E) for AOD and Angstrom exponent at the four wavelengths ($\alpha_{440-870}$). Angstrom empirical formula was used to compute new data points by interpolation. A Regression analysis was then used to estimate the relationship between the interpolated AOD and the observed AOD at the different wavelengths of 440nm, 500nm, 670nm and 870nm. The coefficients of determination were found to be 0.978, 0.980, 0.999 and 0.997 respectively, indicating that the interpolated data agrees well with the measured data.

Key words: Interpolation, Aerosol, AERONET, Aerosol Optical Depth (AOD)

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1. Introduction

Atmospheric aerosols are solid fine particles or liquid droplets suspended in air or another gas. Atmospheric aerosols originate from the condensation of gases and from the action of the wind on the earth's surface [1]: [2]. Aerosols in the atmosphere have several important and environmental effects; they scatter and absorb visible radiation, thereby limiting visibility and affect the earth climate both directly (by scattering and absorbing radiation) and indirectly (by serving as nuclei for cloud formation) as reported by [3]. Certain atmospheric aerosols absorb solar radiation, specifically carbonaceous particles and mineral dust [4], this absorption affects the atmosphere by reducing the radiation budgets reaching the surface and increasing the temperature at the top. Scattering of solar radiation by aerosols increases the Earth Albedo because a fraction of the scattered light is reflected back to space. There are two types of aerosols; the Natural aerosols (Fog, Forest exudates, Geyser steam e.t.c) and anthropogenic aerosols (Haze, Dust, Particulate air pollutants, Smoke e.t.c).

Aerosols have the ability to influence earth radiation budget as well as their effects on health, air quality and clouds [5]. Particles which are produced as a result of human activities (Anthropogenic) are in general smaller in size, and naturally produced particles are



generally bigger in size. Characterization of aerosol properties is important because of the rapid growth of both population and economic activities, which cause the anthropogenic aerosol emission rates to increase as a result of the increase in fossil-fuel combustion and biomass burning [6]. These pollutants directly affect the climate and at the same time increase the haze, fog, and cloudy conditions which decrease visibility, particularly under high atmospheric turbidity [7]; [4].

Atmospheric aerosols generally have a bimodal distribution, the smaller particles are referred to as the fine mode or accumulation mode aerosols, these particles have radii between 0.1 to 0.25 microns but the larger particles comprise of coarse mode with a radii ranging between 1.0 to 2.5 microns [8]. The behavior of dust aerosols are affected by their mineralogical composition [9].

2. Methodology

Interpolation method was used in this study to construct new data points within the range of a discrete set of known data points; the known data set was obtained from Ilorin AERONET site from 2005-2009 within the spectral range 440-870nm. The two Angstrom empirical relations used to compute the interpolated AODs are as follows:

$$\tau_2 = e^{-(\ln \lambda_2 - \ln \lambda_1)} + \tau_1 \dots \dots \dots (1)$$

$$\beta = \tau_\lambda \lambda^\alpha \dots \dots \dots (2)$$

where α is the Angstrom Exponent

τ_2 is AOD at wavelength 2

τ_1 is AOD at wavelength 1

λ is wavelength

β is the Atmospheric turbidity

The data of Angstrom exponent ($\alpha_{440-870nm}$) [10] and the Aerosol optical depth (τ_λ) were obtained at different spectral bands (440, 500, 670, and 870nm) from Ilorin AERONET (AEROSOL ROBOTIC NETWORK) site for period of five years (2005- 2009), AERONET is a network of ground-based aerosol monitoring station that provides long term, continuous and readily accessible public domain database of aerosol optical properties for aerosol research and characterization as reported by [11].

Several gaps, at times spanning many days often occur in the AOD data series, thus, making the use of monthly or annual averages reliable than the daily averages for evaluating long term trends with the data, in this analysis the usage of monthly and annual data of the Angstrom exponent and AOD was used. The AOD data in this study was computed in three data quality levels (1.0, 1.5, and 2.0), level 2.0 was used which is cloud screen and quality assured. Interpolation method was used to construct new data points of AOD within the range of discrete set of known AOD data points which were measured by the solar extinction AERONET Algorithm, the known data points at different wavelength (440, 500, 670, and 870nm) from 2005-2009 and the interpolated data points were computed in this study using the following relationship;

$$\alpha = - \left(\frac{\ln \tau_2 - \ln \tau_1}{\ln \lambda_2 - \ln \lambda_1} \right) \dots \dots \dots (3)$$

where α is the Angstrom Exponent

τ_2 Is AOD at wavelength 2

τ_1 Is AOD at wavelength 1

λ is wavelength

Now by cross multiplying equation (3),

$$\alpha(\ln\lambda_2 - \ln\lambda_1) = -(\ln\tau_2 - \ln\tau_1) \dots \dots \dots (4)$$

Rearranging equation (4)

$$\alpha(\ln\lambda_2 - \ln\lambda_1) = (\ln\tau_1 - \ln\tau_2) \dots \dots \dots (5)$$

$$\ln\tau_2 = -\alpha(\ln\lambda_2 - \ln\lambda_1) + \ln\tau_1 \dots \dots \dots (6)$$

Taking natural log of side of equation (6)

$$\tau_2 = e^{-(\ln\lambda_2 - \ln\lambda_1) + \tau_1} \dots \dots \dots (7)$$

Equation (7) was used in this study to calculate the new data points (interpolated AODs) at different spectral bands (440, 500, 670 and 870nm) from 2005-2009. The interpolated AOD(τ_2) data was calculated, for each year from 2005-2009 the procedure was repeated at different wavelengths (λ_1 and λ_2) from 440-870nm and the new constructed data set (interpolated AOD (τ_2)) was tabulated.

3. Results and Discussion

3.1 Average AODs for Observed and Interpolated AERONET Data Sets

Figure 1 shows the trend between different spectral channels (440, 500, 670, & 870nm) for averages of AOD for 2005-2009; the average AOD for four spectral wavelengths was plotted for five years against month from January-December.

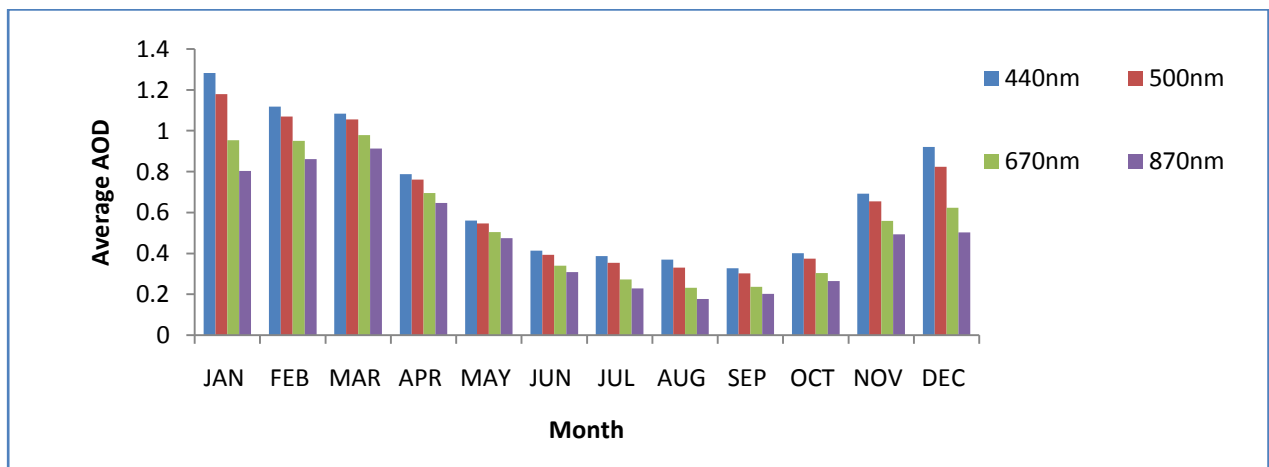


Figure1: Observed Average AOD against Month

The average AOD is highest in January with a value of 1.2826 at 440nm within five years period of study, AOD has a value of 1.1796 at 500nm still in January then followed by 1.1188 in February at 440nm and this shows that aerosol particles in the Atmosphere are more influential at shorter wavelength than at longer wavelength. It has been shown that the lower the wavelength the higher the AOD [12]: [13]. The lowest Average AOD in this trend is in August with a value of 0.1774 at 870nm this is the time when rainfall is at its peak, there is washing away of aerosol which result in lower AOD. The Average interpolated AOD was also plotted as shown in Figure 2

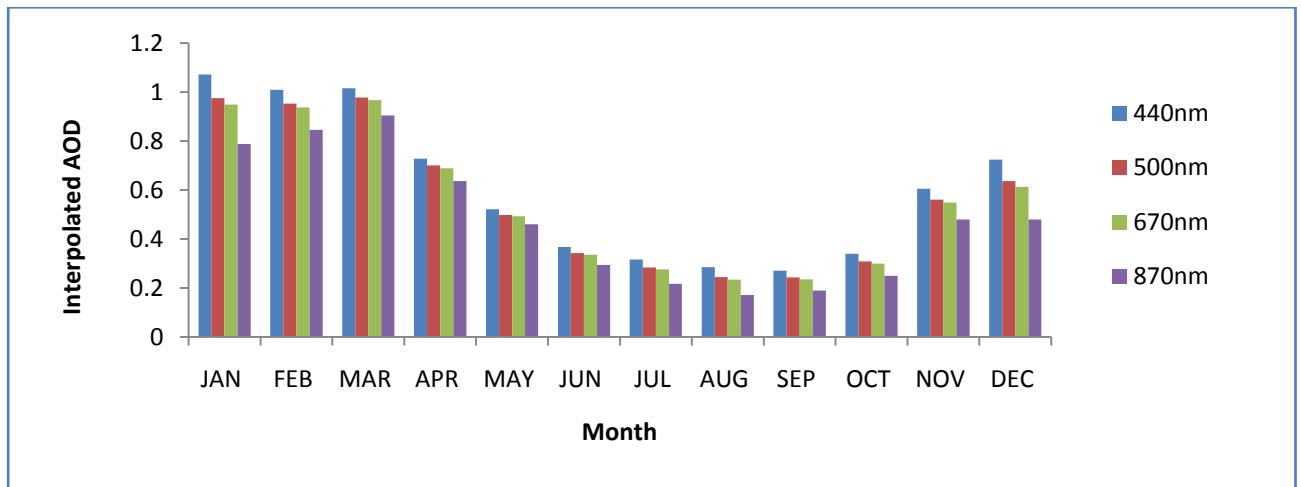


Figure 2: Average Interpolated AOD versus Month from 2005-2009

A plot of the measured and interpolated AOD was done at the four wavelengths to observe the trend as shown in figure 3. From the figure, it can be seen that for all the wavelengths, the interpolated values are slightly below the measured values. The only exception, where there is a close agreement of the two is at 675nm. In the months of June, July, August, September and October, the agreement of the two values is at the two wavelengths of 500 nm and 675 nm

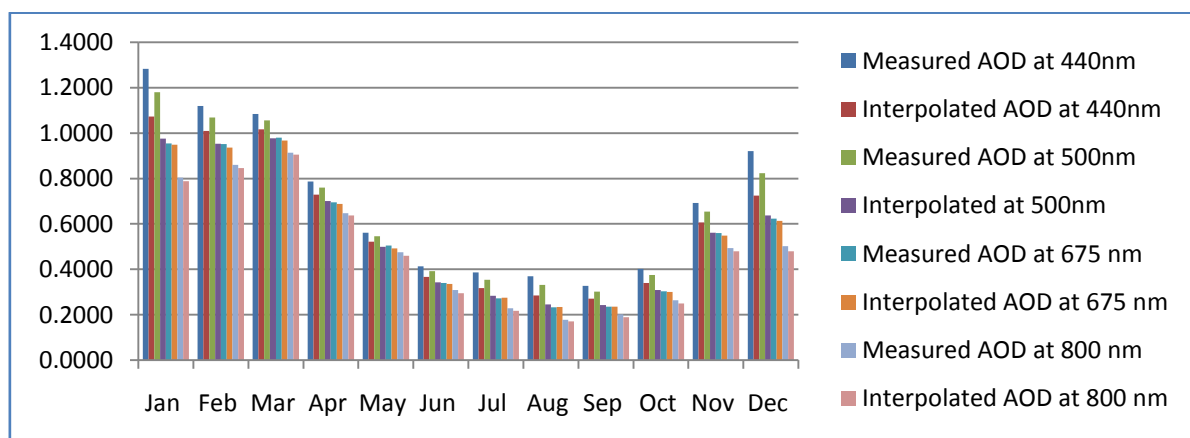


Figure 3. Average of the AOD from 2005-2009 of measured and interpolated values for the four wavelengths

3.2 Regression Analysis between Interpolated and Observed AODs

The regression analysis was done in this research to estimate the statistical relationship between the interpolated and observed AODs, the following graphs 4a, 4b, 4c and 4d shows the statistical relationship between the two AODs in which the average AODs for interpolated data set against ground-based measured data set at the four wavelengths: 440, 500, 670 and 870nm from 2005-2009 were plotted.

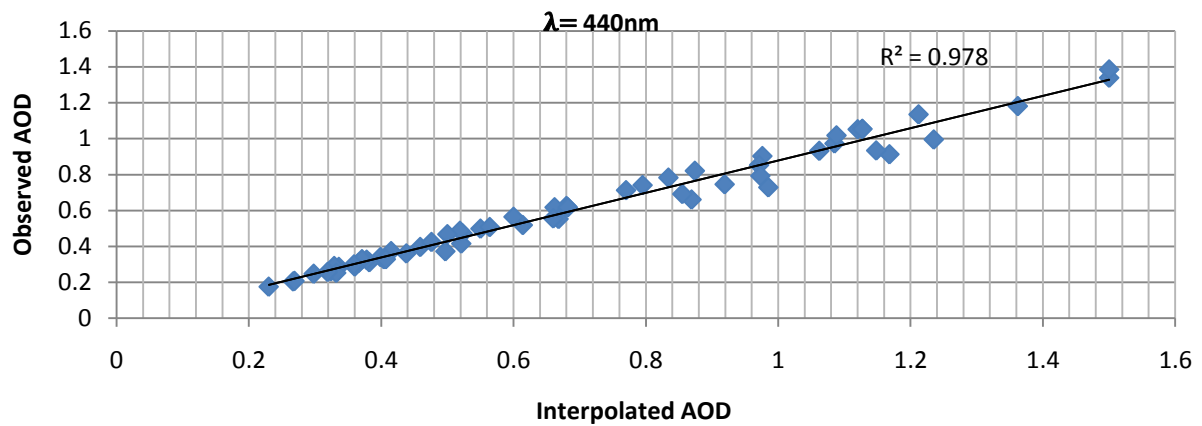


Figure 4a: Observed AOD versus Interpolated AOD

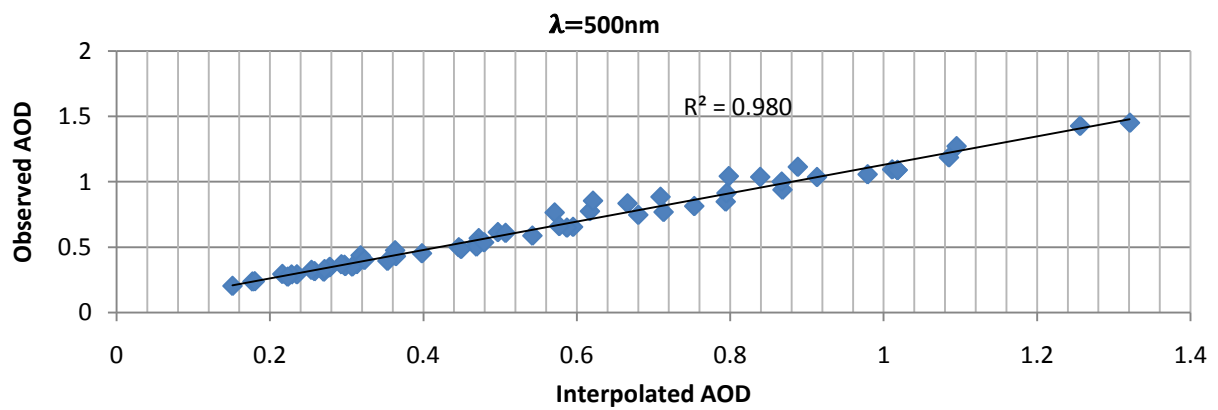


Figure 4b: Observed AOD versus Interpolated AOD

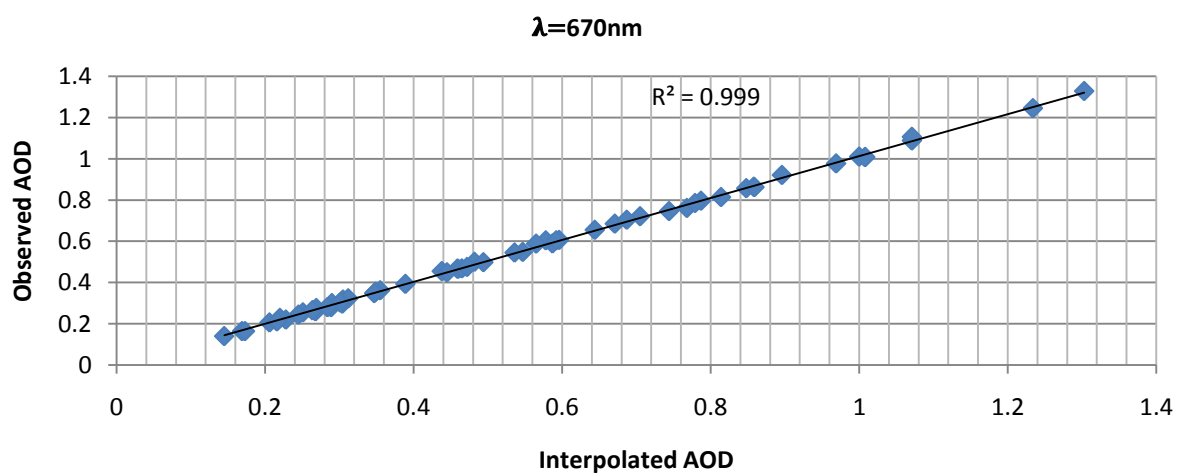


Figure 4c: Observed AOD versus Interpolated AOD

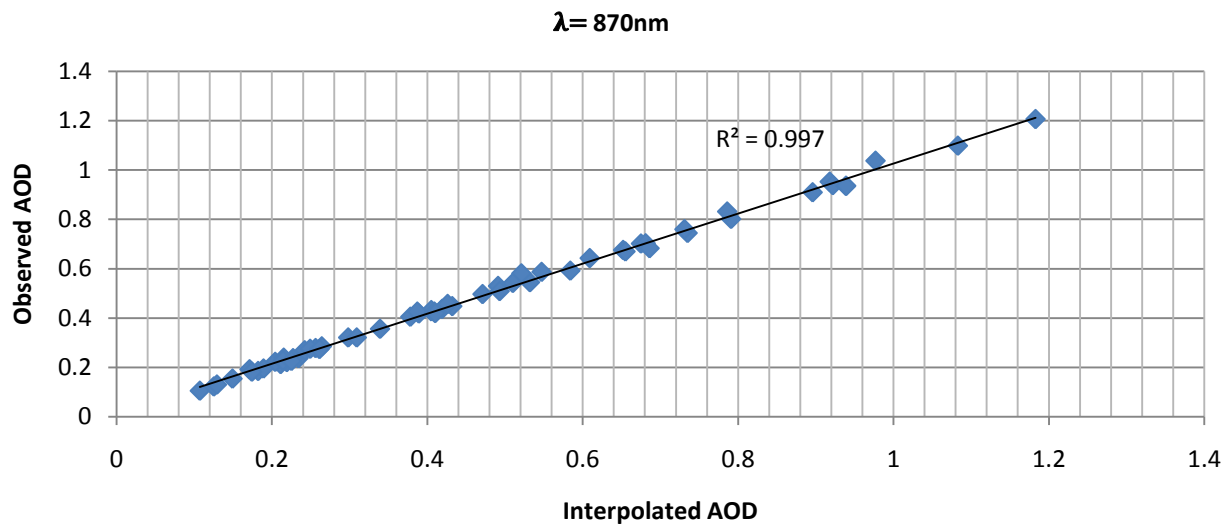


Figure 4d: Observed AOD versus Interpolated AOD

The regression in figure 4a, 4b, 4c and 4d shows that at wavelength 440nm the coefficient of determination is very close to 1 with a value of 0.978, at 500nm a value of 0.980 was obtained and at wavelength of 670nm and 870nm, the coefficient of determination produced values of 0.999 and 0.997 respectively. This indicates good relationship between the interpolated data set and the observed data set because all the data points in the four graphs plotted in this study are connected via the regression line in the manner that the distance from the line to the points plotted were the smallest. The regression analysis revealed that, the higher the values the more related the observed AOD and interpolated AOD are. Looking at the four values obtained in the study which revealed a good relationship at different wavelengths, this shows that, the interpolation method used in the study can be applied to construct new data points (interpolated data) wherever there are missing data in the ground-based AERONET measurements.

4. Conclusion

In conclusion, the data obtained from observation of AOD in Ilorin (8°32'N, 4°34'E) AERONET site from 2005-2009 at wavelengths of 440-870nm shows that, the method employed in the study of constructing new data points (interpolated) within the range of discrete known data sets (observed data) revealed a significant relationship between the two AODs. Although, the interpolated AOD is slightly lower than the measured value at the selected wavelengths for the average AOD of the years 2005-2009, however, there is a good agreement at 500 nm and 675 nm for the months of June to October.

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