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Evaluation Of Methods To Determine The Spectral Variations Of Aerosol Optical Thickness

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Introduction

The aerosol optical thickness, AOT varies with wavelength, which is defined using Angstrom exponent, α as given below. [Angstrom, 1929]. However this is a well know approximation that has been used to show the spectral variation of AOT, $\tau_a(\lambda)$, which is limited to a wavelength range.

$$\tau_a(\lambda) = \beta\lambda^{-\alpha} \quad 1$$

where α is the Angstrom exponent and β is the extinction coefficient corresponding to a 1- μ m wavelength and depends on the concentration of aerosol in the atmosphere. It is assumed that neither α nor β depends on the wavelength. The Angstrom is an indicator of the aerosol particle size, with smaller values of α indicating large particles and larger values indicating relatively smaller aerosol particles. The Angstrom exponent is related to Junge type the particle size distribution, given as

$$\frac{dN}{d \ln r} = cr^{-v} \quad \text{where } v = \alpha - 2. \quad 2$$

Here we have analyzed the AOT measured using a hand held sunphotometer at the coastal station on the west coast of India, Dona-Paula, Goa for the year 2000- 2006. Seasonal and diurnal variations are observed of AOT and Angstrom exponent. [Suresh, 2005].

Method

Here we use three methods that determine the spectral variations of AOT. These methods are Volz method, Linear fitting and Polynomial fitting. The first two methods determine the Angstrom exponent, while the last method use a second order polynomial fit to the spectral variation of τ_a .

Volz Method

We can then use the relation to determine the value of α using any two wavelengths, λ_1 and λ_2 . [Cachorro, 1987]. This is the most preferred method.

$$\alpha = -\frac{d \ln(\tau_a)}{d \ln(\lambda)} = -\frac{\ln\left(\frac{\tau_{a1}}{\tau_{a2}}\right)}{\ln\left(\frac{\lambda_1}{\lambda_2}\right)} \quad 3$$

Linear Fit

The spectral variation of $\tau_a(\lambda)$ is defined by the α , which is the negative of the first derivative of the $\ln(\tau_a)$ with $\ln(\lambda)$. We can also obtain the same by finding the negative of the slope of logarithmic spectral variation of τ_a i.e $\ln(\tau_a)$ versus $\ln(\lambda)$.

$$\ln \tau_a(\lambda) = -\alpha \ln \lambda + \ln \beta \quad 4$$

Here we use $\tau_a(\lambda)$ at multiple wavelengths and a robust fitting method to determine α .

Polynomial Fit

Most of the times the Aerosol size distributions do not follow the Junge type distribution as given in equation 2. [King, 1976]. The departure from this model often result

in the curvature in the log spectral variation of the $\tau_a(\lambda)$. Thus the spectral variation is better modeled using a second order polynomial fit as given below [Eck, 1999].

$$\ln \tau_a(\lambda) = a_0 + a_1(\ln \lambda) + a_2(\ln \lambda)^2 \quad 5$$

Second Derivative,

Though spectral variation of AOT can be modeled by linear or polynomial fitting, we can quantify the curvature using the derivative of the α with respect to $\ln \lambda$ or the second derivative of $\ln(\tau_a)$ versus $\ln \lambda$. The negative of the second derivative is given as

$$-\alpha''(\lambda) = -\frac{d\alpha}{d \ln(\lambda)} \quad 6$$

The α'' is a measure of the rate of change of slope (α') with respect to the wavelength.

Results

A distinct seasonal variation of the Angstrom exponent, α is observed. (See Table. I).

Table I

Season	α	SD	α'	SD
Summer	0.97	0.32	0.22	0.07
Post Monsoon	0.87	0.32	0.22	0.09
Winter	1.39	0.26	0.14	0.06

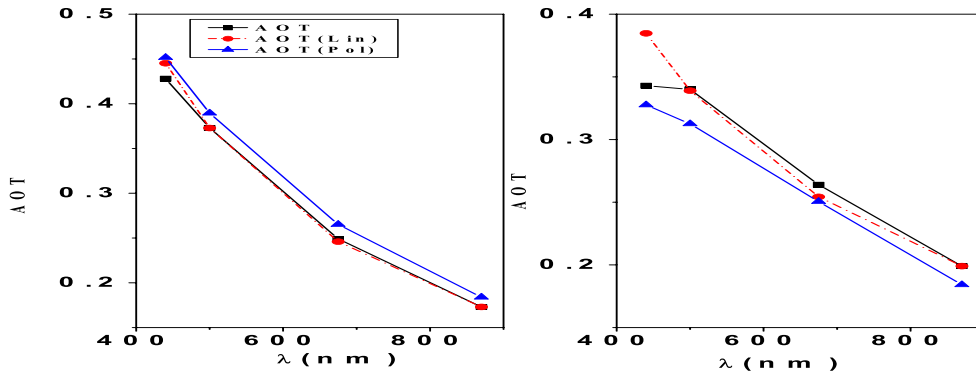


Fig.1 Comparisons of AOT derived from Angstrom exponent

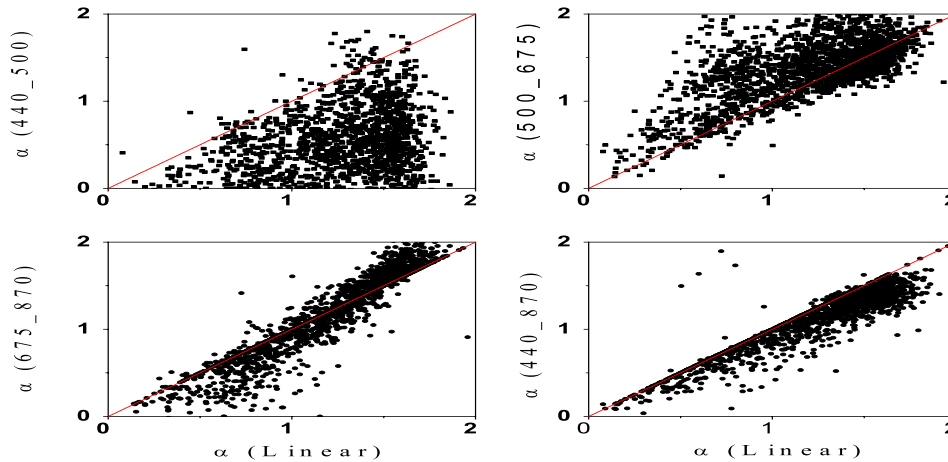


Fig.2 Comparison of α Volz method with Linear Fit

The mean for the period of observations 2000-2006 of α is 1.22 (SD = 0.38) and α' is 0.18

(SD=0.1). The results of the spectral variations computed using linear fit and polynomial fit are shown in Fig. 1. It can be seen that AOT reconstructed using the α derived from the linear fit is found to closely agree with the measured $\alpha_a(\lambda)$, while the polynomial fit mimics the spectral variation and the curvature seen in the $\alpha_a(\lambda)$ at lower wavelengths. (See Fig1). The Volz method is evaluated for the wavelength pairs, 440-500, 500-675, 675-870 and 440-870 nm. It is observed that the values of α obtained from the pair of wavelengths when compared with those obtained using linear fit are comparable for the wavelength pairs 675-870 and 440-870 ($R^2 \sim 0.9$). This indicates that α (λ , 870) is nearly independent of wavelength and thus 870 nm is a better reference band. [Wang, 2000]. The values of α using the 440-500 and 500-675 are found to be underestimated. (See Fig. 2).

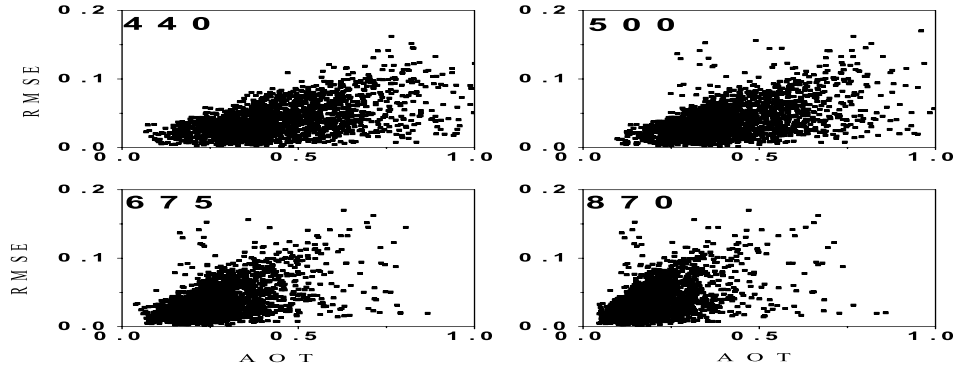


Fig 3. RMSE (Polynomial) versus AOT

Though it has been reported that the polynomial model provide values closer to the measured AOT [Eck, 1999], our observations indicate that spectral AOT values derived using the Angstrom exponent provide values with less error. The RMSE (Root mean square error) values is derived using the reconstructed $\alpha_a(\lambda)$ values from the model and the actual measured $\alpha_a(\lambda)$.

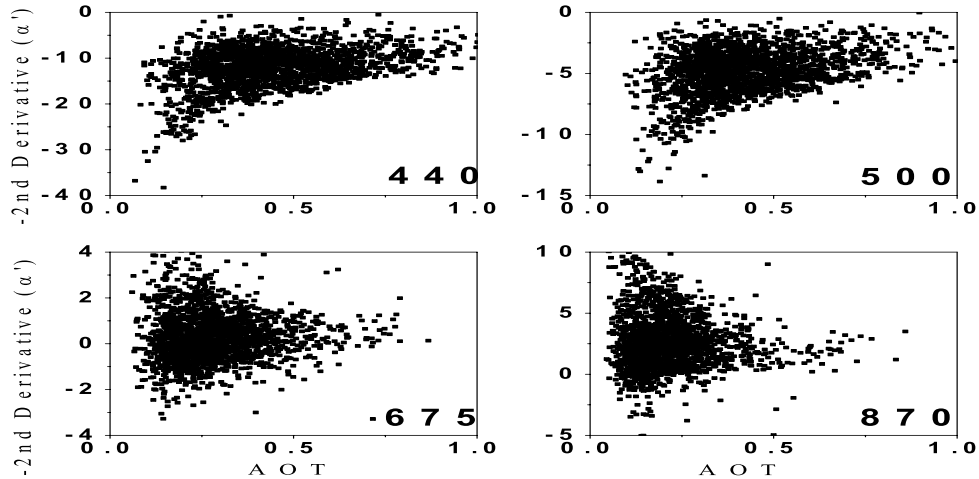


Fig.4 Variations of negative of second derivative, (α') for AOT (λ)

RMSE values using linear fit (mean RMSE = 0.31) are lower than those of polynomial fit (mean RMSE = 0.042). RMSE values using polynomial are found to increase with the values of AOT, and such a trend is not seen using the AOT values derived using the Angstrom exponent values from linear fit. (Fig. 3). For lower wavelengths 440 and 500 nm, the negative of the second derivative α' , is found to increase with $\alpha_a(\lambda)$.

Acknowledgement

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