

THE APPLICATIONS OF ANGSTROM EXPONENT AND MEASURES OF SHAPES IN THE CLASSIFICATIONS OF AEROSOLS SIZE DISTRIBUTIONS

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ABSTRACT

In this work, Angstrom exponent (α) and curvature (α_2), skewness and kurtosis are used to give a clear particles size distribution. This is because some researchers reported the existence of negative curvatures for fine mode aerosols and near zero or positive curvatures are characteristic of size distributions with a dominant coarse-mode or bimodal distribution with coarse-mode aerosols having a significant relative magnitude. The aerosol types used in this work are Sahara and Urban aerosols that are extracted from Optical Properties of Aerosols and Clouds (OPAC4.0). From the results, it is discovered that α and skewness can be used to determine the main dominance particles size distribution in terms of number. The kurtosis can be used to determine the dominant particles in terms of volume. The α_2 signifies whether the particle distribution is either monomodal or bimodal. It shows that when α_2 is negative, it signifies monomodal distribution while when α_2 is positive it signifies bimodal type of size distribution.

Keywords: Angstrom exponent, curvatures, skewness, kurtosis, size distribution.

INTRODUCTION

Aerosol particles result from different sources and processes. At any place in the atmosphere there exists a mixture of particles of different origin. To describe the wide range of possible compositions, the aerosol particles are modeled as components (Deepak and Gerber, 1983), each of them meant to be representative for a certain origin, that is, an internal mixture of all chemical substances that have a similar origin. These components may be externally mixed to form aerosol types. External mixture means that there is no physical or chemical interaction between particles of different components.

In atmospheric physics, Angstrom exponents (α and β) are used as measures to determine the aerosols size distributions. The Angstrom exponent (α) depends on the size

distribution of aerosols and is a measure of the ratio of the concentration of coarse to accumulation mode aerosols, with higher values representing increased abundance of accumulation mode aerosols. Higher and positive values of α indicate dominance of fine/accumulation mode aerosols in the aerosol size spectrum, whereas lower and negative values of α indicate the dominance of coarse mode aerosol particles (Moorthy *et al.*, 2001; Singh *et al.*, 2005).

It is typically noted in introductory statistics courses that distributions can be characterized in terms of central tendency, variability, and shape. In atmospheric physics, performing a particle size analysis is the best way to answer the question: What size are those particles? Once the analysis is complete the user has a variety of approaches for reporting the results.

The need to study these concepts arises from the fact that the measures of central tendency and dispersion alone fail to describe a distribution completely. It is possible to have frequency distributions which differ widely in their nature and composition and yet may have the same central tendency and dispersion. Thus, there is the need to supplement the measures of central tendency and dispersion. Some of the supplements to be discussed are the numerical methods of the measures of shapes (skewness and kurtosis).

The aim of this work is to determine the applications of skewness and kurtosis with Angstrom wavelength exponent α and curvature α^2 (the coefficient of the second order polynomial) in the analysis of the atmospheric aerosols particles size distributions. The atmospheric aerosols used are desert and urban aerosols. These aerosols are extracted from Optical Properties of Aerosols and Clouds (OPAC) 4.0, at the relative humidity (RHs) of 0, 50, 70, 80, 90, 95, 98, and 99% at wavelengths of 0.40 to 0.8 μm .

2 THEORY

Measures of central tendency provide information about a representative value of the data set. Arithmetic mean, simply called

the mean, the median, and the mode are the most common measures of central tendency. For symmetric distributions, such as the one shown in Figure 1, all central values are equivalent: mean = median = mode. For non-symmetric distributions the mean, the median and the mode will have three different values as shown in Figure 1.

A histogram can give a general idea of the shape of a distribution, but two numerical measures of shape give a more precise evaluation: skewness tells about the amount and direction of skew (departure from horizontal symmetry), and kurtosis tells you how tall and sharp the central peak is, relative to a standard bell curve (vertical measures).

A distribution is said to be skewed if the observations above and below the mean are not symmetrically distributed. A zero value of skewness implies a symmetric distribution. The distribution is positively skewed when the mean is greater than the median and negatively skewed when the mean is less than the median.

A textbook discussing the concepts would typically begin by showing the relative positions of the mean, median, and mode in smooth population probability density functions, as illustrated in Figure 1.

Figure 2 shows how histograms can be used to give the general idea of the different types of size distributions.

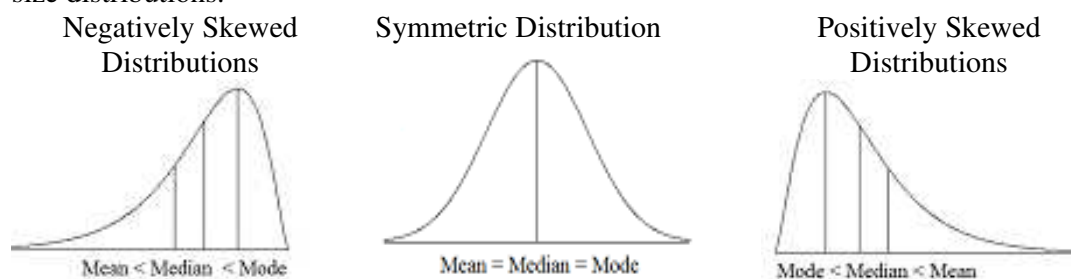


Figure 1: Sketches showing general position of mean, median and mode in a population.

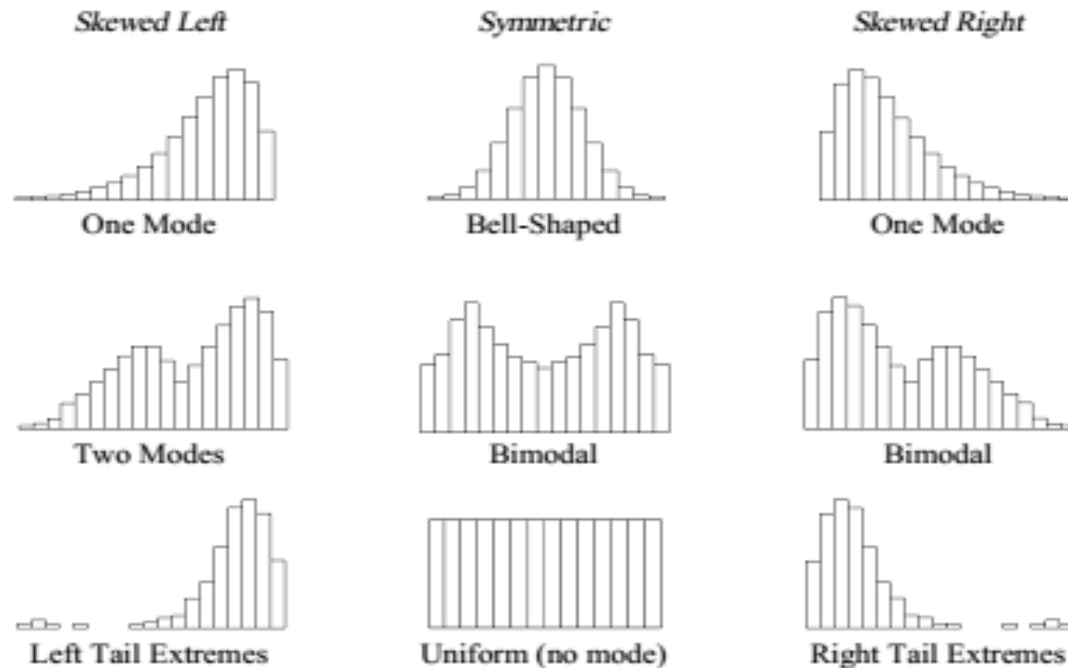


Figure 2: Illustrative prototype histograms

From Figures 1, it is observable that for negatively skewed (Skewed left), there are long tails and distortions that are caused by extremely small values which pull the mean downward so that it is less than the median. At the center, there are Symmetric Distributions in which the mean, the median and the mode are equal. By the right-hand side of the figures there are long tails to the right caused by extremely large values which pull the mean upward so that it is greater than the median.

From Figure 2, it can be seen that if the one mode (monomode) and the two modes (bimodal) are approximated using second order polynomial, it can be seen that the coefficients of the x^2 in the monomode will be negative, while the coefficients of x^2 in the bimodal will be positive.

The types of kurtosis are shown in Figure 3. Kurtosis is a measure of how peaked or flat a distribution is or is the degree of peakedness of a distribution, that is, whether it is of peaked or flat relative to a normal distribution (its departure from the vertical with respect to the normal distribution). The reference standard is a normal distribution, which has a kurtosis of 3. Often, excess kurtosis is presented instead of kurtosis, where excess kurtosis is simply “kurtosis – 3”. For example, the “kurtosis” reported by Excel and SPSS is actually the excess kurtosis.

Data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak.

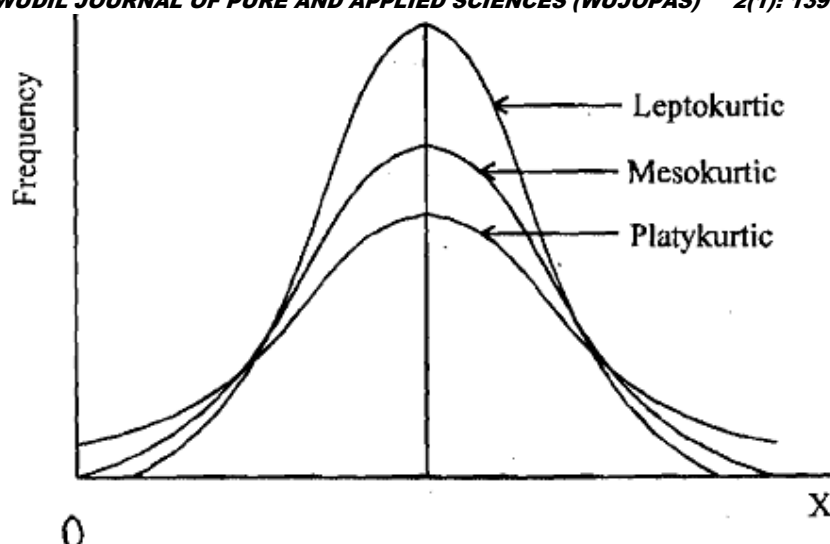


Figure 3: Meso, Lepto, and Platykurtic Distributions (Ronald L. Wasserstein and Nicole A. Lazar, 2016).

3 METHODOLOGY

The aerosols modeltypes extracted from OPAC 4.0, at the relative humidity of 0, 50, 70, 80, 90, 95, 98, and 99% at wavelengths

of 0.4 to 0.8 μ m are Desert and Urbanaerosols. The software mixes the components externally to form the aerosol types.

Table 1 Compositions of aerosol types at 0% RH (Hess et. al., 1998).

Aerosols Models	Aerosols Components	Number Concent. (cm ⁻³)	Number Mix Ratio	Volume Mix Ratio	R _{mod} (dry), (μ m):
Desert	Waso	2000	0.8695	0.01842	0.0212
	Minn	269.5	0.1172	0.03474	0.0700
	Mian	30.5	0.01326	0.7442	0.3900
	Micn	0.142	0.00006174	0.2026	1.9000
Urban	Inso	1.5	0.000009494	0.3832	0.4710
	Waso	28000	0.1772	0.4493	0.0212
	Soot	130000	0.8228	0.1675	0.0118

The *insorepresents* the *water-insoluble* part of aerosol particles and consists mostly of soil particles with a certain amount of organic material. The *wasorepresents* the *water-soluble* part of aerosol particles that originates from gas to particle conversion and consists of various kinds of sulfates, nitrates, and other, also organic, water-soluble substances. Thus, it contains more than only the sulfate aerosol that is often used to describe anthropogenic aerosol. The *soot* component is used to represent absorbing black carbon. Carbon is not soluble in water and, therefore, the particles are assumed not to grow with increasing

relative humidity. *Mineral* aerosol or desert dust is produced in arid regions. It consists of a mixture of quartz and clay minerals and is modeled with three modes to allow and consider increasing relative amount of large particles for increasing turbidity. mineral (nuclei mode, nonspherical) *minn*, mineral (accumulation mode, nonspherical) *mian*, mineral (coarse mode, nonspherical) *micn* are mineral aerosols or desert dusts that are produced in arid regions.

With rising humidity, the aerosol particles are more and more soaked with water from the surrounding humid air and swell.

The increase in particle size reduces the visibility. Quantitatively, the variation of the size distribution of the aerosol particles with relative humidity has to be taken into account (Kasten, 1968). An objective measure of visibility is the standard visual range or meteorological range (Koschmieder, 1926)

$$V(\lambda) = \frac{3.912}{\sigma_{ext}(\lambda)}$$

(1)

which is meteorological range refers to the visual range of a black object seen against the horizon sky by a standard observer having a contrast threshold 0.02 (Middleton, 1962). The visual extinction coefficient $\sigma_{ext}(\lambda)$ is a measure of the light scattering and absorbing properties of the atmosphere along the line of sight.

Variation of the extinction coefficient with wavelength is presented in the form of an inverse power law function (Angstrom, 1929); that is the spectral dependence of extinction by particles may be approximated as an inverse power law relationship:

$$\sigma_{ext}(\lambda) = \beta \lambda^{-\alpha}$$

(2)

where α and β are known as Angstrom parameters. The index α is the wavelength exponent or Angstrom coefficient; β is the turbidity coefficient representing the amount of aerosols present in the atmosphere in the vertical direction or the total aerosol loading in the atmosphere (Shaw *et. al.*, 1973; Satheesh and Moorthy, 1997).

One of the most important variables for the aerosol size distribution is the effective radius, which can be calculated using the Junge size distribution $n(r)$ (Junge, 1963):

$$n(r) = \frac{dN(r)}{dr} = C(z)r^{-(v+1)}$$

(3)

where N is the number density, r is the radius and $C(z)$ is a factor proportional to the aerosol concentration, which is dependent on the altitude z (Biggare *et. al.*, 1990). Through the relationship $v=\alpha+2$ (Iqbal, 1983; Bruegge *et. al.*, 1992), the exponent v can be obtained

from the value of α , which can be estimated from equation (2).

The sizes of particles in aerosols generally cover several orders of magnitudes. As a result, the normal distribution fit of measured particles sizes often has a very large standard deviation. Another drawback in normal distribution is that it allows negative radii. That is why aerosol distributions are much better represented by a normal distribution of the logarithmic of the particle radii. In terms of individuals aerosols size distributions, lognormal distributions (such as., Deepak and Gerber, (1983)) are applied for each component i :

$$\frac{dN_i(r)}{dr} = \frac{N_i(r)}{\sqrt{2\pi} \log \sigma_i \ln 10} \exp \left[\frac{1}{2} \left(\frac{\log r - \log r_{modN_i(r)}}{\log \sigma_i} \right)^2 \right]$$

(4)

where r_{modN_i} is the mode radius, σ_i measures the width of the distribution, and N_i is the total particle number density of the component i 's particles per cubic centimeter. Substituting equation (2) into (1), the following equation is obtained also as a direct power law function

$$V(\lambda) = \frac{3.912}{\beta} \lambda^{\alpha}$$

(5)

Equation (5) can also be written as

$$\ln \left(\frac{V_{\lambda}}{3.912} \right) = -\ln(\beta) + \alpha \ln(\lambda)$$

(6)

Measurements indicate that the Angstrom exponent varies with wavelength, and a more precise empirical relationship between aerosol extinction and wavelength is obtained with a 2nd-order polynomial (King and Byrne, 1976; Eck *et. al.*, 1999; Eck. *et. al.*, 2001a, b; Kaufman, 1993; O'Neill *et al.*, 2001, 2003; Galadanci and Tijjani, 2014; Tijjani *et. al.*, 2013; Tijjani *et. al.*, 2014). This implies that it can also be applicable to visibility:

$$\ln \left(\frac{V_{\lambda}}{3.912} \right) = -\ln(\beta) + \alpha_1 \ln(\lambda) + \alpha_2 (\ln(\lambda))^2$$

(7)

Here the coefficient α_2 accounts for a “curvature” often observed in sunphotometry measurements. The spectral curvature of the Angstrom exponent contains useful information about the aerosol size distribution (King and Byrne, 1976; Kaufman, 1993; Eck *et al.*, 1999,2003; 2001b; Schauster *et al.*, 2006; O’Neill *et al.*, 2001; Kaskaoutis *et al.*, 2007a, b). Some authors have noted that the curvature is also an additional indicator of the aerosol particle size, with negative curvature indicating aerosol size distributions dominated by the fine mode or monomodal distribution and positive curvature indicating size distributions with a significant coarse mode contribution or

bimodal size distribution (Kaufman, 1993; Eck *et al.*, 1999; Eck. *et al.*, 2001b). Eck *et al.*, (1999,2003); Schauster *et al.*, (2006) O’Neill *et al.*, 2001; Kaskaoutis *et al.*, 2007a, b reported the existence of negative curvatures for fine mode and aerosols and near zero or positive curvatures are characteristic of size distributions with a dominant coarse-mode or bimodal distribution with coarse-mode aerosols having a significant relative magnitude.

4 RESULTS AND DISCUSSIONS

Here the results, analysis and observations of the data extracted from OPAC 4.0, is presented.

Desert

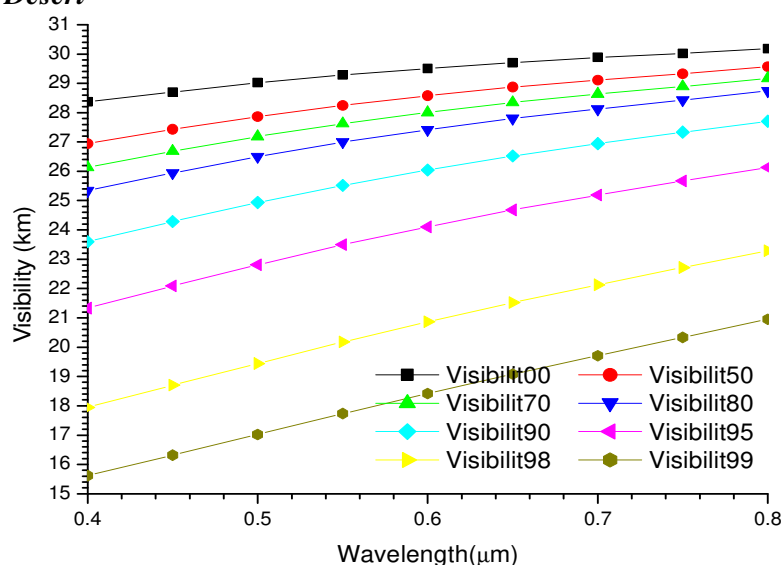


Figure 4: The plots of Visibilities with wavelengths for Desert aerosols at different RHs.

From the plots of Figure 4, it can be seen that the visibility increases with the increase in wavelength but decreases with the increase in RH.

Table 2: Results of the regression analysis of equation (6) for Desert aerosols

RH (%)	R ²	Sig.	α	Sig.	β	Sig.
0	0.9963	8.87E-10	0.0892	8.87E-10	0.0324	1.59E-22
50	0.9965	7.43E-10	0.1332	7.43E-10	0.0328	2.25E-21
70	0.9970	4.22E-10	0.1580	4.22E-10	0.0330	4.27E-21
80	0.9974	2.59E-10	0.1811	2.59E-10	0.0333	6.95E-21
90	0.9988	1.80E-11	0.2323	1.80E-11	0.0342	2.89E-21
95	0.9995	5.75E-13	0.2941	5.75E-13	0.0358	5.29E-22
98	0.9998	2.44E-14	0.3785	2.44E-14	0.0395	1.62E-22
99	0.9991	7.63E-12	0.4269	7.63E-12	0.0436	1.46E-19

Based on the contents of Table 2 and by observing the values of R^2 and the significances of all the coefficients, it can be said that the data fitted the equation model very well (equation 6). The increase of α with RH signifies the decrease of very large

coarse mode particles. But since it is less than 1 it shows that coarse mode particles are still the most dominant. The β (turbidity coefficient) increases with the increase in RH, and this also contributes to the decrease in visibility with RH.

Table 3: Results of the regression analysis of equation (7) for Desert aerosols

RH (%)	R^2	Sig.	α_1	Sig.	α_2	Sig.	β	Sig.
0	0.9998	5.96E-12	0.0590	8.17E-07	-0.0270	3.78E-05	0.0326	6.03E-21
50	0.9998	3.71E-12	0.0891	4.78E-07	-0.0391	2.74E-05	0.0331	4.26E-20
70	0.9999	1.15E-12	0.1096	1.21E-07	-0.0429	1.38E-05	0.0334	3.73E-20
80	0.9999	1.42E-12	0.1296	1.23E-07	-0.0457	2.58E-05	0.0337	1.06E-19
90	0.9999	2.48E-13	0.1874	1.06E-08	-0.0399	4.45E-05	0.0345	8.58E-20
95	0.9999	5.61E-13	0.2618	1.32E-08	-0.0286	0.00203	0.0360	8.60E-19
98	0.9999	5.20E-13	0.4004	4.35E-09	0.0195	0.03222	0.0393	4.23E-18
99	0.9999	3.08E-13	0.4992	1.42E-09	0.0641	1.16E-04	0.0428	6.09E-18

From table 3, by observing the values of R^2 and the significances of all the coefficients, it can be said that the data fitted the equation model very well. The increase of α_1 with RH is similar to that of α in table 3. The negative signs of α_2 at RHs 0 to 95% showed that these are monomode distributions of coarse mode particles. From 0 to 80% RHs, the values of α_2 increase in magnitude, this shows increase in the curvature, and it shows increase in the dominance of coarse particles despite their decrease because of the increase in RH as shown by the increase in the values of α_1 . The decrease in the magnitude of α_2 at RHs 90 and 95% showed

a little increase in the significance of fine mode particles. At 98 and 99% RH α_2 becomes positive; this is where the bimodal distribution appears. But since α and α_1 are less than 1, this signifies bimodal distribution with the dominance of coarse mode particles with the traceable amount of fine mode particles. The increase in the values of α_2 between RHs 98 and 99% signifies increase in the traces on fine mode particles despite the dominance of coarse mode particles. But β (turbidity coefficient) increases with the increase in RH, and this also contributes to the decrease in visibility with RH.

Table 4: The skewness and kurtosis of Desert aerosols

	Vis00	Vis50	Vis70	Vis80	Vis90	Vis95	Vis98	Vis99
Mean	29.408	28.437	27.854	27.255	25.876	23.945	20.753	18.354
Median	29.502	28.576	28.003	27.414	26.045	24.104	20.864	18.418
Skewness	-0.476	-0.458	-0.437	-0.417	-0.350	-0.284	-0.165	-0.088
Kurtosis	-0.878	-0.889	-0.922	-0.939	-1.042	-1.106	-1.187	-1.210

As indicated by Table 4 and by observing the decrease in the values of mean, median and mode, it can be said that there is a decrease in the number of particles as the relative humidity increased. By observing the skewness, it can be seen that they are all

negative (negatively skewed), this is an indication of the dominance of coarse mode particles compared to fine mode particles. The decrease in magnitude with RH shows that larger particles are decreasing more in number than the fine particles.

From the kurtosis, it can be said that it is negative (platykurtic), and this shows that the distribution is below the normal distribution and also that coarse particles are more dominants. The increase in the magnitude with the increase in RH reflects the increase in volume of the coarse particles compared with fine mode particles.

Comparing α and the skewness they both show the dominance of coarse mode particles. This is because α is less than 1.0

and the skewness is negative. From the sign of α_2 (negative), it shows that the aerosols have monomodal distribution at 0 to 95% RH and bimodal at 98 and 99%. The signs of the kurtosis (platykurtic) show the dominance of coarse mode particle distribution, and the increase in the magnitude of the kurtosis signifies the increase in the dominance of coarse mode particles with respect to RH.

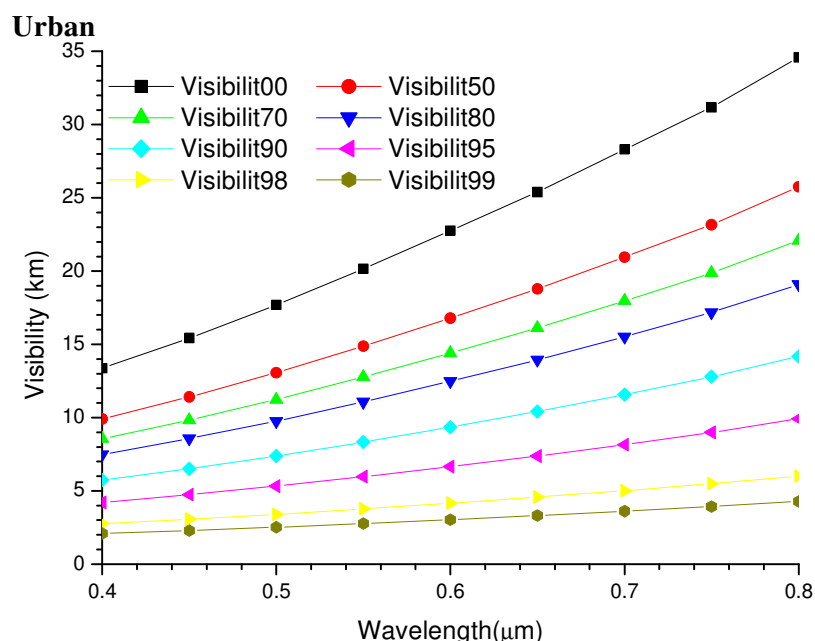


Figure 5: The plots of Visibilities with wavelengths for Urban aerosols

From the plots of figure 5, it can be seen that the visibility increases with the increase in wavelength but decreases with the increase in RH.

Table 5: Results of the regression analysis of equation (6) for Urbanaerosols

RH (%)	R ²	Sig.	α	Sig.	β	Sig.
0	0.9990	9.17E-12	1.373	9.17E-12	0.0216	1.52E-16
50	0.9984	4.33E-11	1.379	4.33E-11	0.0291	1.31E-15
70	0.9982	7.71E-11	1.369	7.71E-11	0.0341	3.05E-15
80	0.9978	1.39E-10	1.353	1.39E-10	0.0396	6.97E-15
90	0.9972	3.32E-10	1.309	3.32E-10	0.0540	2.68E-14
95	0.9964	8.43E-10	1.239	8.43E-10	0.0785	1.21E-13
98	0.9951	2.47E-09	1.123	2.47E-09	0.1332	9.09E-13
99	0.9939	5.07E-09	1.036	5.07E-09	0.1906	4.22E-12

By keen observations of table 5 and by observing the values of R² and the significances of all the coefficients, it can be said that the data fitted the equation model

very well. The increase of α with RH (0 and 50%) signifies the increase in the dominance of fine/accumulation modes over coarse modes particles.

As from 70 to 99% RH, it can be observed that it decreases with the increase in RH. This shows that as from 70% the carbon is acting as cloud condensation nuclei, which causes increase of coarse particles over

fine/accumulation particles. But β (turbidity coefficient) increases with the increase in RH, and this also contributes to the decrease in visibility with RH.

Table 6: Results of the regression analysis of equation (7) for Urbanaerosols

RH (%)	R ²	Sig.	α_1	Sig.	α_2	Sig.	β	Sig.
0	0.9999	1.62E-13	1.6137	7.24E-10	0.2136	5.18E-05	0.0204	9.98E-16
50	1.0000	5.16E-14	1.6856	1.83E-10	0.2721	4.31E-06	0.0271	5.13E-16
70	1.0000	3.96E-14	1.7011	1.27E-10	0.2943	2.01E-06	0.0315	4.88E-16
80	1.0000	3.37E-14	1.7104	9.79E-11	0.3170	1.03E-06	0.0364	5.01E-16
90	1.0000	2.32E-14	1.7010	5.70E-11	0.3480	3.36E-07	0.0492	5.01E-16
95	1.0000	1.12E-14	1.6649	2.26E-11	0.3775	7.29E-08	0.0710	3.80E-16
98	1.0000	7.50E-15	1.5729	1.19E-11	0.3993	1.95E-08	0.1196	5.30E-16
99	1.0000	7.41E-15	1.4975	9.77E-12	0.4090	1.04E-08	0.1708	9.78E-16

From Table 6, by observing the values of R² and the significances of all the coefficients, it can be said that the data fitted the equation model very well. The increase of α_1 with RH (0 to 80%) signifies the increase in the dominance of fine/accumulation modes over coarse modes particles. But its decrease from 80 to 99%, signifies increase in the concentrations of coarse mode particles as the carbon particles are acting as cloud condensation nuclei. From the sign of α_2 , it

can be seen that it is positive, and this shows that it is a bimodal type of particle distributions with the dominance of fine mode particles. The increase in the values of α_2 , with RH shows the increase in the concentrations of coarse as the fine particles are becoming bigger as they act as cloud condensation nuclei. But β (turbidity coefficient) increases with the increase in RH and this also contributes to the decrease in visibility with RH.

Table 7: The skewness and kurtosis of Urban aerosols

	Vis00	Vis50	Vis70	Vis80	Vis90	Vis95	Vis98	Vis99
Mean	23.207	17.190	14.760	12.790	9.583	6.815	4.249	3.095
Median	22.757	16.790	14.404	12.474	9.348	6.651	4.157	3.033
Mode	13.365	9.911	8.560	7.483	5.730	4.211	2.767	2.093
Skewness	0.211	0.240	0.248	0.256	0.261	0.264	0.259	0.256
Kurtosis	-1.134	-1.116	-1.111	-1.105	-1.102	-1.103	-1.108	-1.115

Based on Table 7 and by observing the decrease in the values of mean, median and mode, it can be said that there is a decrease in the number of particles as the relative humidity increases. By observing the skewness, it can be seen that it is positively skewed. This shows that there is a dominance of fine mode particles. Its increase with the increase in RH from 0 to 95% shows that finer particles are becoming more in number compared to coarse particles. But from 95 to 99% there is a

decrease, and this shows the position where the soot particles became cloud condensation nuclei. From the perspective of the kurtosis, it is negative (platykurtic). This shows that the particles are below normal distribution. The decrease in the magnitude of the kurtosis with the increase in RH (0 to 90%) shows that there is an increase in the concentration of fine particles by volume because of the sedimentation of coarse particles with the increase in RH.

But the increase from 95 to 99% shows that some of the larger have started sedimenting and the fine particles have started becoming bigger by acting as cloud condensation nuclei.

By comparing α and skewness they both show the dominance of fine mode particles. This is because, α is greater than 1.0 and the skewness is positive. The signs of α_2 (positive) show the presence of coarse mode particles with the dominance of fine modes. Therefore, this shows that the particle distribution is bimodal with the dominance of fine mode particles.

CONCLUSION

From the analysis of the data, it can be concluded that skewness can be used for verification to determine the most dominant types of aerosols after determining the Angstrom exponents. This is because, there some arguments on the range of values of the exponents to ascertain whether the distribution is fine mode or coarse mode. Now, α_2 can only be used to determine model distribution whether as monomodal or bimodal. This shows that there is the need to modify the importance of curvature as pointed out by some researchers (Kaufman,

1993; Eck et. al., 1999,2003; 2001b; Schauster et. al., 2006; O'Neill et al, 2001; Kaskaoutis et. al., 2007a,b) on its use as an additional indicator of the aerosol particle size. Such that negative curvature indicates aerosol size distributions dominated by the fine mode or monomodal distribution and positive curvature indicates size distributions with a significant coarse mode contribution or bimodal size distribution.

From the kurtosis perspective, it can be used to determine the degree of the variabilities between the average particle sizes and the most common (mode).

Finally, it can be concluded that, α and skewness can be used to determine the most dominance particle distributions of aerosols (positive signifies dominance of fine mode particle while negative signifies coarse mode particles) by number, kurtosis to be used in determining the most dominant by volume (positive signifies the distribution is dominant by volume of fine mode particles, while negative signifies the dominant of coarse mode particles by volume) and α_2 to be used to determine the types of mode distributions (monomodal or bimodal).

REFERENCES

- Ångström A. K., (1929). *On the atmospheric transmission of sun radiation and on dust in the air*. Geogr. Ann., 11, 156-166.
- Biggar, S. F., Gellman D. I., and Slater P. N., (1990): *Improved evaluation of optical depth components from Langley plot data*. Remote Sens. Environ., 32, 91-101.
- Bruegge, C. J., R. N. Halthore, B. Markham, M. Spanner, and R. W. Wrigley, (1992). *Aerosol optical depth retrievals over the Konza prairie*. J. Geophys. Res., 97, 18743-18758.
- Deepak, A., and Gerber H. E., Eds., (1983). *Report of the experts meeting on aerosols and their climatic effects*. WCP-55, 107 pp. [Available from World Meteorological Organization, Case Postale No. 5, CH-1211 Geneva, Switzerland.]
- Eck, T. F., Holben, B. N., Dubovic, O., Smirnov, A., Slutsker, I., Lobert, J. M., and Ramanathan, V. (2001a). *Column-integrated aerosol optical properties over the Maldives during the northeast monsoon for 1998–2000*, J. Geophys. Res., 106, 28 555–28 566.
- Eck, T. F., Holben, B. N., Reid, J. S., Dubovic, O., Smirnov, A., O'Neil, N. T., Slutsker, I., and Kinne, S. (1999). *Wavelength dependence of the optical depth of biomass burning, urban, and desert dust aerosols*, J. Geophys. Res., 104(D24), 31 333–31 349.
- Eck, T. F., Holben, B. N., Ward, D. E., Dubovic, O., Reid, J. S., Smirnov, A., Mukelabai, M. M., Hsu, N. C.,

- O' Neil, N. T., and Slutsker, I. (2001b). *Characterization of the optical properties of biomass burning aerosols in Zambia during the 1997 ZIBBEE field campaign*, J. Geophys. Res., 106(D4), 3425–3448.
- Eck, T. F., Holben, B. N., Ward, D. E., et al. (2003) Variability of biomass burning aerosol optical 30 characteristics in southern Africa during SAFARI 2000 dry season campaign and a comparison of single scattering albedo estimates from radiometric measurements, J. Geophys. Res., 108(D13), 8477, doi:10.1029/2002JD002321.
- Galadanci, G. S. M. and Tijjani, B. I. (2014). *Effect of Relative Humidity on Arctic Aerosols*, Advances in Physics Theories and Applications ISSN 2224-719X (Paper) ISSN 2225-0638 (Online) Vol.36, 2014 www.iiste.org
- Hess M., Koepke P., and Schult I. (1998). *Optical Properties of Aerosols and Clouds: The Software Package OPAC*, Bulletin of the American Meteorological Society, Vol. 79, No. 5, 831-844.
- Iqbal M., (1983). *An introduction to solar radiation*. Academic Press.
- Junge, C. E., (1963). *Air Chemistry and Radiochemistry*. Academic Press.
- Kaskaoutis D. G., Kambezidis H. D., Hatzianastassiou N., Kosmopoulos P. G., and Badarinath K. V. S. (2007a) Aerosol climatology: dependence of the Angstrom exponent on wavelength over four AERONET sites.
- Kaskaoutis, D. G., Kambezidis, H. D., Hatzianastassiou, N., Kosmopoulos, P. G., and Badarinath, K. V. S. (2007b): Aerosol climatology: On the discrimination of aerosol types over four AERONET sites, Atmos. Chem. Phys. Discuss.
- Kasten, F. (1968). *Der Einfluss der Aerosol-Großenverteilung und ihrer Veränderung mit der relativen Feuchte auf die Sichtweite*. Beitrage zur Physik der Atmosphäre 41, 33-61.
- Kaufman, Y. J. (1993), Aerosol optical thickness and atmospheric path radiance, J. Geophys. Res., 98, 2677-2992.
- King, M. D. and Byrne, D. M. (1976). *A method for inferring total ozone content from spectral variation of total optical depth obtained with a solar radiometer*, J. Atmos. Sci., 33, 2242–2251.
- Koschmieder, M. (1926). *Theorie der horizontalen Sichtweite*. Beitrage zur Physik der Atmosphäre 12, 33-66 and 171-181.
- Middleton, W. E. K. (1962). *Variation Through the Atmosphere*. Toronto, University of Toronto Press, pp. 104-106.
- Moorthy K. K., Saha A., Prasad B. S. N., Niranjana K., Jhurry D. and Pillai P. S. (2001) *Aerosol optical over peninsular India and adjoining oceans during the INDOEX campaigns: Spatial, temporal and spectral characteristics*; J. Geophys. Res. 106, 539–28,554.
- O'Neill, N. T., Dubovic, O., and Eck, T. F. (2001). *Modified Angstrom exponent for the characterization of submicrometer aerosols*, Appl. Opt., 40(15), 2368–2375.
- O'Neill, N. T., Eck, T. F., Smirnov, A., Holben, B. N., and Thulasiraman, S. (2003). *Spectral discrimination of coarse and fine mode optical depth*, J. Geophys. Res., 108(D17), 4559, doi:10.1029/2002JD002975.
- Ronald L. W., and Nicole A. L., (2016), American Statistical Association Releases Statement on Statistical Significance and P-Values. Provides Principles to Improve the Conduct and Interpretation of Quantitative Science, *The American Statistician*, 60 (2), 129-133.

- Satheesh S. K. and Moorthy K. K. (1997). *Aerosol characteristics over coastal regions of the Arabian Sea*; Tellus 49B, 417–428.
- Schauster, G. L., Dubovik, O., and Holben, B. N.(2006):Angstrom exponent and bimodal aerosol size distributions, J. Geophys. Res., 111, D07207, doi:10.1029/2005JD006328.
- Shaw G. E., Regan J. A. and Herman B. M. (1973). *Investigations of atmospheric extinctions using direct solar radiation measurements made with a multiple wavelength radiometer*; J. Appl. Meteor.12374–380.
- Singh S., Nath S., Kohli R. and Singh R. (2005). *Aerosols over Delhi during pre-monsoon months: Characteristics and effects on surface radiation forcing*; Geophys. Res. Lett. 32L13808 doi:10.1029/2005GL023062.
- Tijjani B. I., Sha'aibu F. and Aliyu A. (2013). *The Effect Of Hygroscopic Growth On Marine Aerosols*, Fire Journal of Natural and Applied sciences.1(2),70-88.
- Tijjani B. I., Sha'aibu F. and Aliyu A. (March 2014). *The Effect of Relative Humidity on Maritime Polluted Aerosols*, International Journal of Pure and Applied Physics Vol.2, No.1, pp.9-36.