COMPARISON OF INTERCONTINENTAL AEROSOLS: DESERT AND MONSOON-INFLUENCED REGIONS

AIM:

This work is to compare the optical and physical properties of aerosols at 440μm,675μm,870μm and 1020μm spectral bands between Desert and Monsoon-influenced regions. In this work Zinder and Beijing were chosen to represent desert and Monsoon influenced regions respectively.

Place and Duration of Study:

Four years data of Aerosol Optical Depth (AOD) were extracted from level 2.0 quality assured almucantar version products of AERONET data, at both Beijing-CAM (116.317^0E &39.933^0N) and Zinder Airport (8.984^0E & 13.775^0N) between 2012 and 2015.

Methodology:

In this work, physical and optical properties of aerosols were determined using Angstrom equations. Angstrom exponent, Curvature, Turbidity coefficient and Spectral variation of the aerosols in each of Zinder Airport and Beijing-CAMP were determined and the results were then compared. Both the physical and optical properties of the aerosols were determined from the calculated values of Angstrom exponent, Curvature, Turbidity coefficient and spectral variation.

Results:

The results obtained showed that there was dominant coarse-mode aerosols particles size in Zinder city, whereas domination of fine-mode aerosol particles in Beijing was found. The results also showed that the overall Aerosol Optical Depth (AOD) in Zinder is higher than that of Beijing but the atmosphere of Beijing was hazier than that of Zinder.

Conclusion:

The prevalence of coarse-mode particles size in Zinder was due to desert dust particles in the region, whereas the prevalence of fine-mode particle in Beijing was due to anthropogenic aerosol particle in the region which may be resulted from heavy industrialization in China. The higher Aerosol loading in Zinder is responsible for absorbing light coming from the sun which, in turn, makes the atmosphere clear, whereas the lesser aerosol loading in Beijing is responsible for scattering light coming from the sun, thereby obstructing the atmospheric visibility in the region.

Keywords: Angstrom exponent, Turbidity coefficient, Aerosol Optical Depth, Curvature, AERONET

1.0 Introduction

Apart from green-house gases, aerosol is another important agent of radiative forcing that affects the planet Earth [1-3]. Aerosol affects our environment [1-3], influences cloud formation [4], and causes overall increase or decrease in atmospheric temperature [5]. Aerosol also affects human health by penetrating deep down into respiratory and cardiovascular system [6, 7]. These effects of aerosol make it necessary to monitor it via both ground-based observation and satellite [4, 8, and 9]. However, it is difficult to monitor aerosol properties via satellite because satellites always rely on backscattering signals which are more often than not contaminated signals [10]. This is the reason why ground-based measurements are more commonly used to get accurate aerosol data since the ground-based instruments are mounted to take measurements directly facing the sun.

There are numerous number of ground-based Sun-photometer networks across the globe that are used for aerosol monitoring. These include SKY-Radiometer network (SKYNET) and Aerosol Robotic Network (AERONET). AERONET is a very popular and reliable source of aerosol data; it provides measurements in over 400 data stations worldwide for accurate retrieval of aerosol optical depth (AOD), single scattering albedo (SSA), aerosol particle size distribution (PSD) by taking into account direct solar measurement and scattering measurement[14,15]; and it became a yardstick for satellite AOD retrieval[16,17]. Two of the AERONET data stations are Beijing-CAM in China and Zinder Airport in Niger republic.

Beijing is the capital city of China; it is located in North-China, the East-Asian region, situated at longitude 116.317^{0}E and latitude 39.9330N with a population of more than 19 million [18]. Beijing belongs to the warm temperate zone, half moist continental monsoon climate, featuring four distinct seasons: Arid multi-windy spring, hot and multi-rain summer, sunny and fresh autumn and the cold and dry winter and has experienced rapid economic development over the past decades. Beijing shows distinct seasonal transition. Atmospheric pollution is a concerned problem in Beijing due to human activities and frequent dust storm events in the city. Zinder, on the other hands, is one of the most popular cities in Niger republic. It is located at Longitude 8.984^0 E and Latitude 13.775^0 N in the West-African sub-region. It is typically characterized as a Sahara desert area with vertually no rainfall. The arid nature of zinder makes it possible for dust to prevail and likely to cause haze in the atmosphere. Figures 1a and 1b respectively depict Beijing and Zinder cities.

This study intends to find correlation between aerosol particle size distribution, PSD; aerosol optical depth, AOD; and atmospheric visibilty in the two cities, using four years of level 2.0 AERONET data in Beijing-CAM and Zinder airport between 2012 to 2015.

Figure 1a: Map of Zinder

Figure 1b: Map of Beijing

2.0 Material and Method

Four years (2012-2015) of level 2.0, *'the quality assured'* AOD data each of Zinder and Beijing were extracted from AERONET database using standard retrieval procedure of AERONET products. These raw data archive files were unpacked using WinRAR 4.11 wizard and viewed through the Microsoft excel windows. The AOD data used were measured at four spectral bands, namely: 440nm, 675nm, 870nm and 1020nm.

Annual median averages of the AODs alongside their corresponding wavelengths were computed and arranged in tabular forms. Statistical comparison between annual AOD in Zinder and that of Beijing was carried out.

The annual mean AODs of both Zinder and Beijing were plotted against their corresponding wavelengths and the graphs were fitted on the second order polynomial curve in natural

logarithmic coordinates using least square fitting procedure to determine the Angstrom coefficients in both Zinder and Beijing. The Angstrom coefficients determined were *Curvature* (α_2) and *Turbidity* (β).

Angstrom equation is given as:

$$\tau = \lambda^{-\alpha} \quad \ldots\ldots (1)$$

The linear equation that links the natural-logarithmic AOD and the corresponding natural-logarithmic wavelength is:

$$\ln\tau = -\alpha\ln\lambda + \beta \quad \ldots\ldots (2)$$

The second order polynomial equation relating the AOD and the wavelength in natural logarithmic form is:

$$\ln\tau = \alpha_2\ln\lambda^2 + \alpha_1\ln\lambda^1 + \beta \quad \ldots\ldots (3)$$

Where: τ is the AOD; α_2 is the curvature; β is the turbidity coefficient; α is the Angstrom exponent.

Angstrom equation was also employed to determine the annual Angstrom exponents in each city. The expression for Angstrom equation is given as:

$$\alpha = -\frac{d\ln\tau}{d\ln\lambda} \quad \ldots\ldots (4)$$

Spectral variation of AOD (α') was also determined using the expression of the second derivative of Angstrom exponent (α)

$$\alpha' = \frac{d\alpha}{d\ln\lambda} = -2\alpha_2 \quad \ldots\ldots (5)$$

The values of α_2, β, R^2 and α' were presented in a tabular form. Where: R^2 is the least square value of the residual.

3.0 Results and Discussions

Values of annual median AODs in both Zinder and Beijing at four different spectral channels, from the year 2012 to the year 2015 were presented in table 1 below. The AODs in each case decreased with corresponding increase in wavelength. This decreasing trend of AOD with wavelength was presented in figures 2a-2b. Figure 2a compares AODs between Zinder and Beijing in 2012 at the four considered wavelengths. In each case, AOD in Zinder was higher than AOD in Beijing. At 440µm, the difference between Zinder and Beijing AODs was 0.028 which is a reasonably small value. At 1020µm, however, the difference in AODs in Zinder and Beijing was relatively high of value 0.126. This implies that 1020µm channel showed highest difference in AOD whereas 440µm channel showed lowest difference in AOD in the two cities in the year 2012.

In 2013, Zinder also showed higher AOD values in all considered spectral channels except at 440µm. At 440µm, the AOD value in Beijing was 0.425, whereas that of Zinder was 0.412. This implies that the AOD in Beijing at 440µm channel is higher by 0.013. At 1020µm and 675µm respectively, Zinder showed highest and lowest values of AOD more than Beijing with respective values of 0.307 and 0.357.

The case of year 2014 is similar to that of 2013. Value of AOD in Beijing at 440µm was 0.273 which was higher than that of Zinder of 0.227 at the same spectral channel. The difference was 0.046 which was more significant than that of 2013. However, AOD of Zinder was higher than that of Beijing in the remaining three spectral channels in 2014. The difference was highest at 1020µm with value 0.022 and lowest at 870µm with value 0.011.

In 2015, AOD in Zinder, was higher than that of Beijing throughout the spectral channels. The differences were 0.149, 0.232, 0.243 and0.241 at 440µm, 670µm, 870µm and 1020µm respectively.

Table 1: Annual Median AODs at Four Spectral Channels in Zinder and Beijing, 2012-2015.

λ(µm)	AOD (2012)		AOD (2013)		AOD (2014)		AOD (2015)	
λ(µm)	Zinder	Beijing	Zinder	Beijing	Zinder	Beijing	Zinder	Beijing
0.440	0.386	0.358	0.412	0.425	0.227	0.273	0.442	0.293
0.675	0.301	0.208	0.357	0.247	0.171	0.160	0.406	0.174
0.870	0.260	0.152	0.324	0.196	0.140	0.123	0.380	0.137
1.020	0.243	0.117	0.307	0.173	0.124	0.102	0.360	0.119

Table 2: Angstrom Parameters in Zinder and Beijing, 2012-2015.

Year	α_2		β		R^2		α		α'	
Year	Zinder	Beijing	Zinder	Beijing	Zinder	Beijing	Zinder	Beinjing	Zinder	Beijing
2012	0.329	0.570	0.640	0.792	0.999	0.996	0.580	1.256	-0.658	-1.140
2013	0.154	0.844	0.561	0.988	1.000	0.995	0.354	1.135	-0.308	-1.688
2014	0.172	0.506	0.382	0.632	1.000	0.0.995	0.710	1.170	-0.344	-1.012
2015	-	0.540	0.502	0.663	0.998	0.996	0.222	1.115	-	-1.080

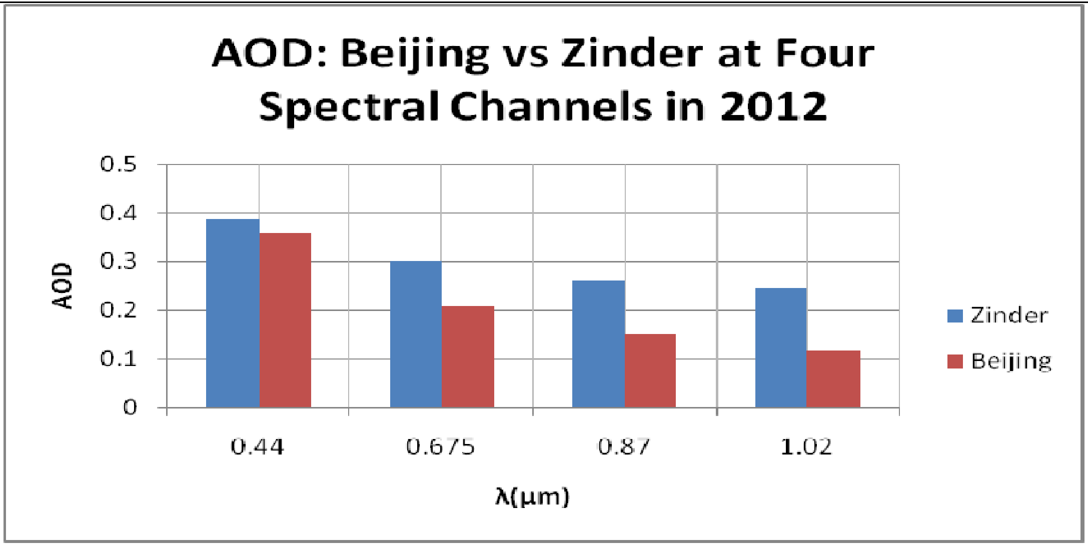

Figure 2a

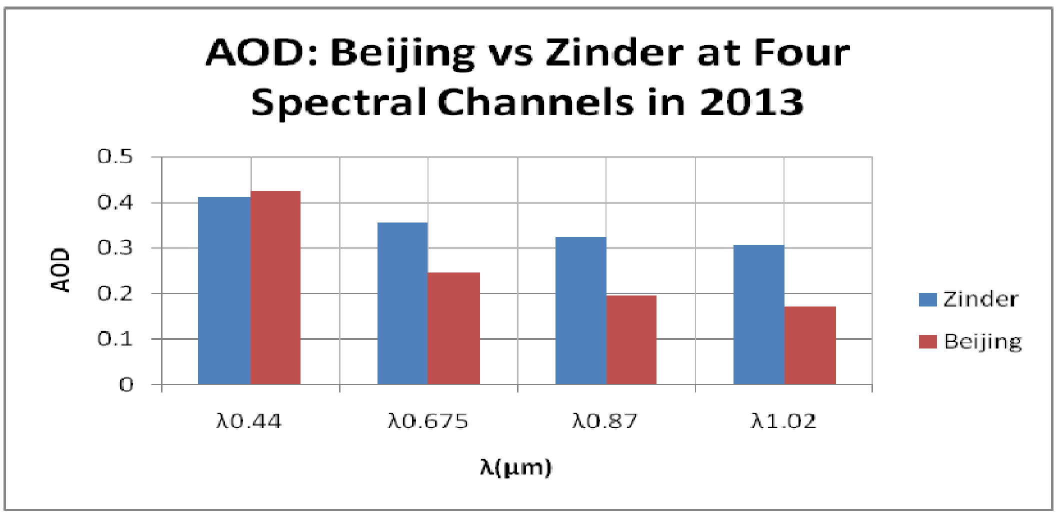

Figure 2b

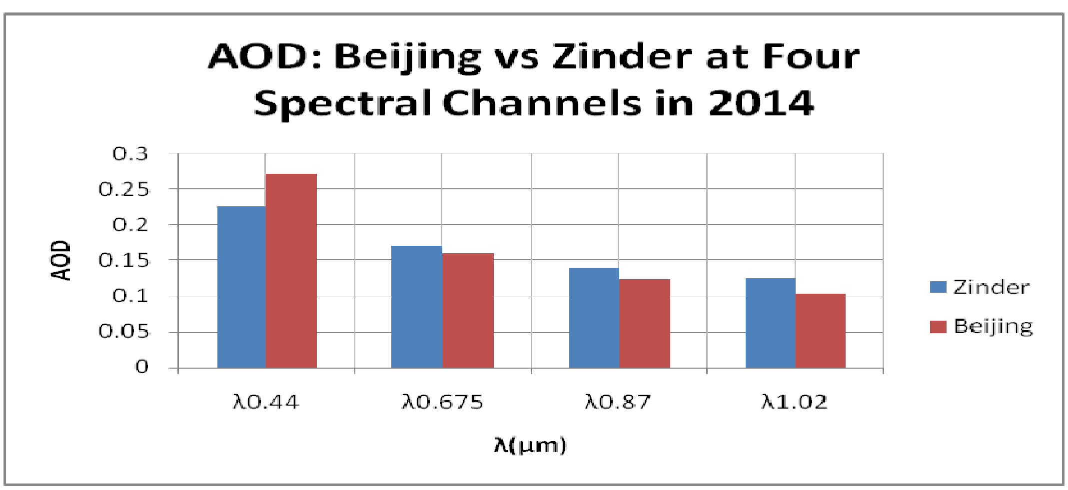

Figure 2c

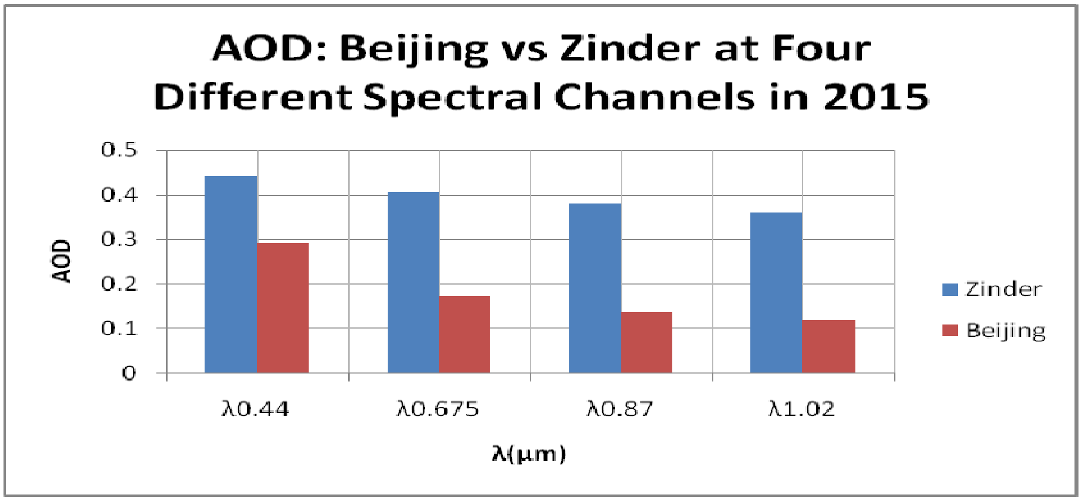

Figure 2d

Figure 2: Comparison of Annual AOD between Zinder and Beijing Cities

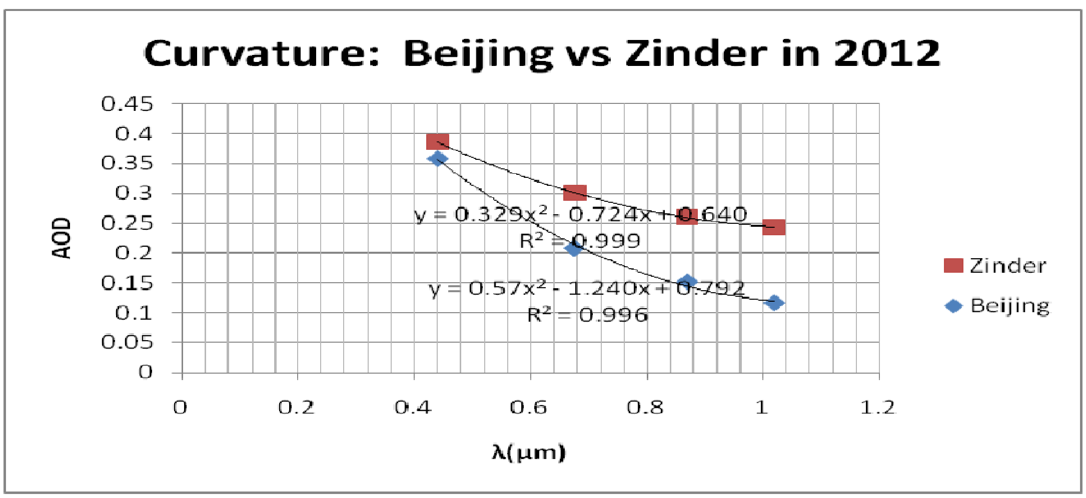

Figure 3a

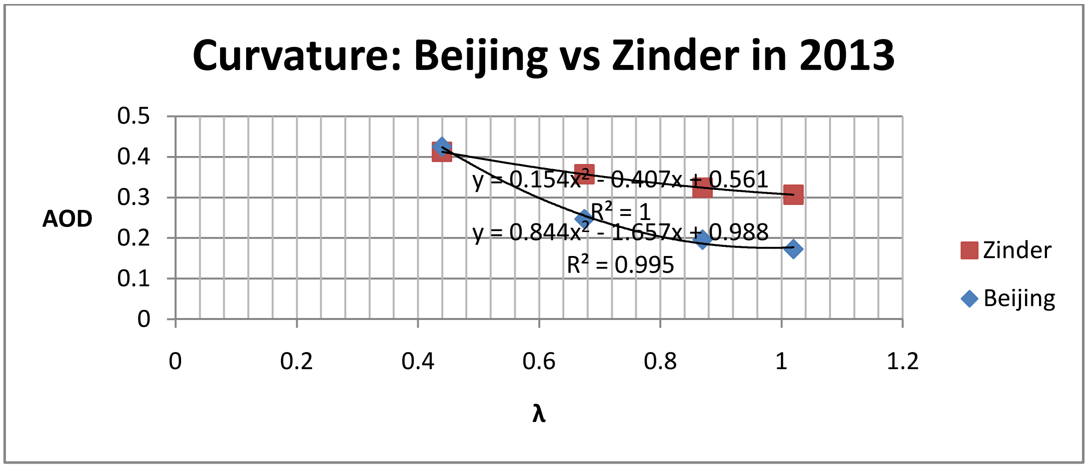

Figure 3b

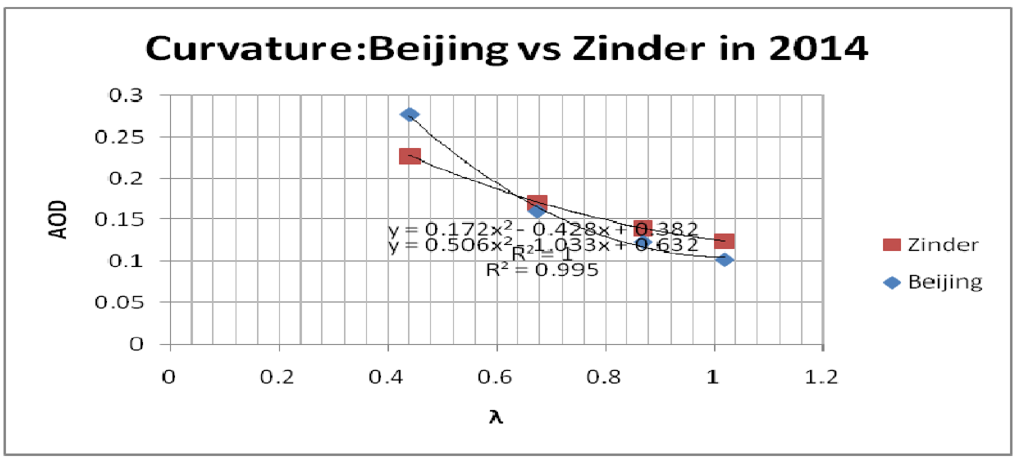

Figure 3c

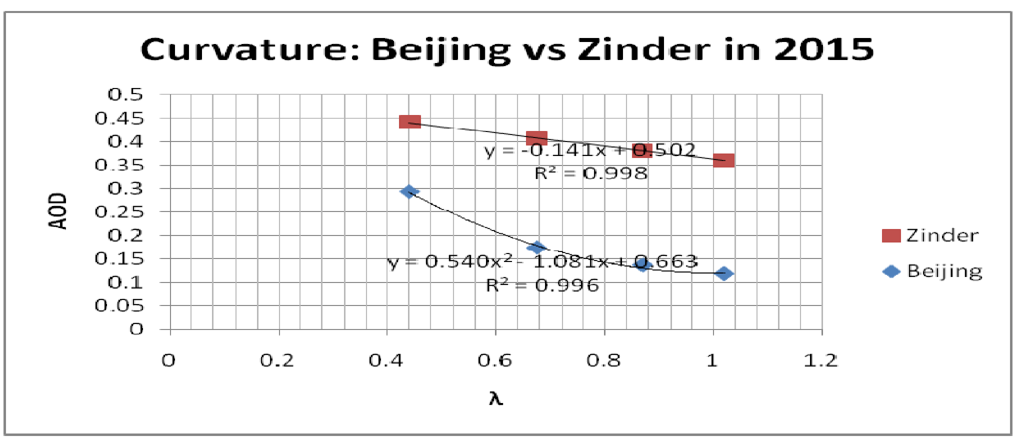

Figure 3d

Figure 3: Comparison of Curvature and Turbidity Coefficient between Zinder and Beijing Cities

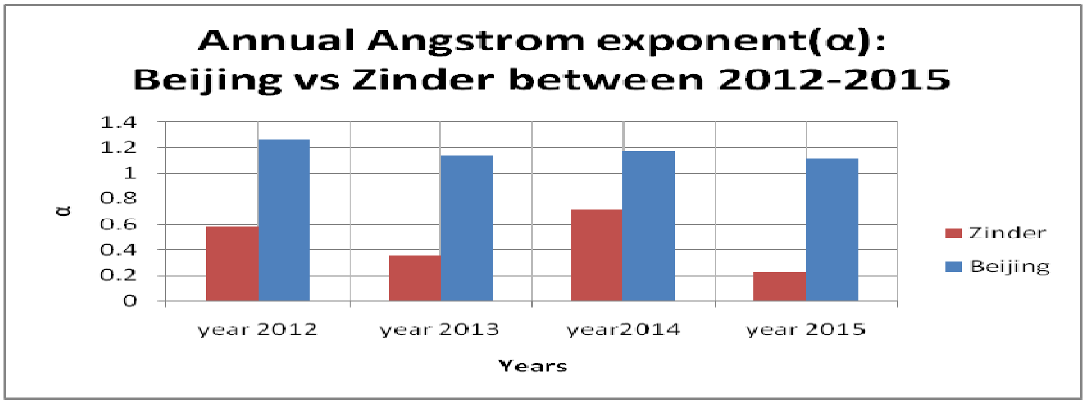

Figure 4: Comparison of Angstrom Exponent between Zinder and Beijing Cities.

With regard to particle size characterization in each city, although aerosol particles size can be determined using volume concentration in 22 radius bins, the angstrom exponent values were used instead as an index for the characterization. Conventionally, values of α range are between zero to two (0-2); fine-modes of aerosol particles take values of >0.6, whereas coarse-modes take lesser values of <0.6. [11, 19 and 20]. From table 2, all α-values in Beijing were >0.6. This signifies the prevalence of fine mode particles in Beijing. In Beijing, fine mode fraction was larger than 50%, even more than 70% for summer [21]. Average α-values in Beijing recorded in the year 2016 were from around 1.0 (1.1) in 2005 to around 1.1 (1.2) in 2014 [21]. This α-value of 1.1 (1.2) in 2014 agrees very well with our value of 1.170 recorded in 2014. For Zinder, on the other hand, α-values were <0.6. This implies dominance of coarse mode particles in the region. However, α-value recorded in 2014 was 0.710 which indicates dominance of fine mode particles according to [22]. This might be due to error of instrumentation, meteorological factor or inadequacy of the Angstrom formula used in the calculation. However, it was reported that any value of α in order of zero can be considered as coarse-mode [22]. So based on this report, this α-value of 0.710 is considered as an indicator of coarse mode mixed with reasonable amount of fine-mode particles. Thus domination of coarse mode particles in Zinder was due to the fact that Zinder is a Sahara region which is typically characterized with dust aerosol. Comparison of Angstrom exponent between Zinder and Beijing was given in figure 4. Moreover, studies show that curvature of coarse mode aerosol particles and that of bimodal aerosol particles in which coarse mode is dominant always appear positive; it changes rapidly with aerosol properties and it affects the value of α'. From table 2, all α_2-values were positive, which indicates prevalence of coarse mode particles in both Beijing and Zinder. However, curvature of $\ln\tau$ versus $\ln\lambda$ was found to be negative for biomas burning aerosols in Bolivia and Zambia, and for urban industrial aerosol in USA [22]. Based on this report, it is possible that fine-mode particles that were claimed to be of more than 50% in Beijing are not up to that amount. That is why the curvature did not appear to be concave as typically found with fine-mode

particles. Besides in Beijing, dust storm is very common and it is possible that the dust events have dominated the influence of fine particles from anthropogenic sources. Throughout the considered four years, Beijing showed higher values of α_2 than Zinder which can be seen from table 2. The curvature is also obvious on the curves in figures 3a-3d. Nevertheless, in 2015, linear fit was found to be the best fit for AOD data in Zinder. This is because, the curvature in that case was found to be very small which was considered insignificant and this necessitated the use of linear fit, instead of the polynomial fit. In this case it was concluded that the small value of the curvature was due to bimodal aerosol size distribution dominated by coarse mode particles [22]

Moreover, the curvature is more significant under high turbidity condition. This implies low curvature, high AOD and high α'-values. Change in curvature in spectral AOD can be due to the existence of more than one type of aerosol present in the atmosphere [22]. From figure 3, curvature changes more rapidly in Beijing than in Zinder; this implies that in Beijing, aerosol types are more than one. This is expected in a mega city like Beijing with population of more than 19 million. Fine-mode aerosol particles are expected from human activities in the city; coarse–mode aerosols particles are expected from dust storm which is very frequent in Beijing.

Values of $\beta<0.1$ signify relatively clear atmosphere, whereas values of $\beta>0.2$ signify relatively hazy atmosphere [23]. Based on this convention, since values of β from table 2 were all greater than 0.2, then it was concluded that the overall atmospheric status in both Zinder and Beijing was hazy from 2012 to 2015. From table 2, Beijing showed maximum haze status in 2012 with β-value 0.72 and minimum haze status in 2014 with β-value 0.416. On the other hands, Zinder showed maximum haze status of β-value 0.640 in 2012 and minimum haze status of β-value 0.300 in 2014.

4.0 Conclusion

Based on observation and retrieval of aerosol data in two AERONET sites in Zinder and Beijing, from 2012 to 2015, aerosol optical depth (AOD), Angstrom exponent (α), Turbidity coefficient as well as curvature of each city were analyzed and compared to get the variability and similarity of physical and optical properties of aerosol in the two cities. The results found show that there is domination of coarse-mode particles in Zinder due to desert dust prevalence in all the four years of the study. The results, on the other hand, show that there is a mixture of fine-mode and coarse-mode particles in Beijing. The results also revealed that both Zinder and Beijing atmospheres where typically characterized with haze due to dust (as in the case of Zinder) and due to dust storm and excessive anthropogenic aerosol release in the atmosphere (as in the case of Beijing). In case of Zinder, the desert dust absorbs more light than it scatters, thereby causing less haze. In case of Beijing, the anthropogenic aerosols, which are dominant, scatter more light than it absorbs, thereby causing more haze in the region.

5.0 References

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