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Analysing the Dangerous Trends of Air Pollution Over Bo-Sierra Leone Using Fourteen Years of Aerosol Optical Depth Data

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ABSTRACT

The atmospheric air quality of a given location gives an indication of the health risks or exposures of the inhabitants of such a place. One major parameter for determining the amount of aerosols in an atmospheric region is the aerosol optical depth (AOD). It is a vital tool for predicting the air quality over a geographic enclave. In this paper, the pollution state of Bo-Sierra Leone was considered. Fifteen years primary (aerosol optical depth) dataset was obtained from a Multi-angle Imaging Spectro-Radiometer (MISR). The secondary datasets that were generated from the primary data were aerosol loading, particle sizes, Angstrom parameter and the statistics of the primary dataset. The results obtained from the investigation are relevant for tackling the excesses that result from errors emanating from the instruments mounted on the ground for data generation. The years October 2001 and 2004 show similar Angstrom value (0.25) in the month of March 2008 but was highest (0.31) in the month of May 2009 followed by the value estimated (0.29) for October 2012; however, it was either lower or somewhat insignificant for other years. Aerosol loading was found to be constant and highest (0.9442) for the months of January-February, and May-November (2000). Years with higher aerosol loading were indicative of higher potentials for pollution relative to years of lower aerosol distribution/concentration.

INTRODUCTION

In recent times, there have been tremendous improvements and progress on studies centered on aerosols. One of such known methods of examining the air pollution over an area is by taking measurements of its aerosol optical depth (AOD). Severe consequences on optical properties of aerosols have been known to have substantial effects on the local radiative forcing and radiation balance of the earth (Emetere et al. 2015, Emetere et al. 2016). According to Lau et al. (2009), in the Boreal summer, the high volume atmospheric feedback was said to have been set off by water absorbing aerosols, precipitation and cloudiness in the West African/Eastern Atlantic, but were lower in the Caribbean and West Atlantic regions owing to the shortwave and longwave radiations that cool and warm the earth's surface as they exchange heat with the surroundings. The interaction between aerosol and solar radiation can be described by its optical properties. The optical parameters used to describe the aerosol-solar radiations are the extinction and scattering coefficients, the aerosol depth and the single-scattering phase (Kokhanovsky et al. 2006). The Sahara Desert is one of the main contributors of the annual total dust around the globe which is estimated at 2-4 billion tons annually (Goudie & Middleton 2001, Ginoux et al. 2001). The effect of dust particulates on precipitation from Western Africa has been examined based on the mechanisms responsible for the occurrence as well as their sensitivity to the absorptive properties of aerosols in the region (Solmon et al. 2008). In Europe, Asia and America, implementation of real-time resolution monitoring instruments and Trace Gases Research Infrastructure (ACTRIS) as well as Interagency Monitoring of Protected Visual Environments (IMPROVE) programmes have been adopted as means of characterizing fine particles whereas, in Africa, it has been observed that there are relatively few documentations of particle-related pollution (Prenni et al. 2016, Schurman et al. 2015). Field campaigns such as Pollution des Capitales Africanes (POLCA) identified anthropogenic sources of aerosols as well as bush burning as having a high influence on demographic growth, traffic regulations, traditional cultivations (Liousse et al. 2010), and their impact on health (Val et al. 2013). The ubiquitous nature and dominant presence of oxygenated species in organic aerosols from anthropogenic sources and their influence in the Northern Hemisphere of the mid-latitudes have been reported (Zhang et al. 2007). In Ghana, the release of halogenated substances comprising of bromine and chlorine and mixed forms of halogenated dioxin-related compounds from combustion in soils has been studied (Tue et al. 2016). According to Tue et al. (2016), AOD remains a very useful parameter in aerosol investigation studies, hence, in this study, multi-angle imaging of aerosols in Bo was carried out since no study has been discussed in relation to the sources and effects of aerosols in that area.

EXPERIMENTAL DESIGN, MATERIALS AND METHODS

The primary data were obtained using a Multi-angle Imaging Spectro-Radiometer (MISR). The tunning and atmospheric constants for fourteen years were obtained using the West African regional Scale Dispersion Model (WASDM) from the AOD dataset. The tunning and atmospheric constants are factors that determine the accuracy of ground instruments such as sun photometer (Emetere et al. 2016). The secondary dataset aerosol loading was generated using the extended WASDM as presented in Tables 1-3.

Bo geographical map is shown in Fig. 1, and its geographical coordinates are 07°57’53” N, 011°44’18” W. It is said to be the third biggest city in the Southern province.

The West African regional scale dispersion model (WASDM) for calculating aerosol loading over a region is given by:

$$\psi(\lambda) = a_1{}^2 \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} y\right) + \cdots$$

$$\ldots a_n{}^2 \cos\left(\frac{n_n \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_n \pi \tau(\lambda)}{2} y\right) \quad \ldots(1)$$

Where, a is atmospheric constant obtained from the fifteen years aerosol optical depth (AOD) dataset from MISR, n is the tunning constant, $\tau(\lambda)$ is the AOD of the area and $\psi(\lambda)$ is the aerosol loading.

The digital voltage and Angstrom parameters of the study area can be obtained from equations (2) and (3) respectively.

$$I(555) = \frac{I_o(555)}{R^2} \exp(m * \tau(555)) \quad \ldots(2)$$

Where, I is the solar radiance over the SPM detector at wavelength λ = 555 nm, I_o is the measure of solar radiation behind the atmosphere, R is the mean Earth-Sun distance in astronomical units, τ is the total optical depth, the average of each month is referred to as the total AOD, and m is the optical air mass.

$$\alpha = -\frac{d \ln(\tau)}{d \ln(\lambda)} \quad \ldots(3)$$

Where, α is the Angstrom parameter, τ is the aerosol optical depth, and λ is the wavelength. The radius of the particles for atmospheric aerosol and back-envelope was calculated using proposals by Kokhanovsky et al. (2006). The analysis of equations (1) was done using the C++ codes.

RESULTS AND DISCUSSION

The primary data were obtained from Multi-angle Imaging Spectro-Radiometer (MISR). The aerosol loading was derived from data presented in Fig. 2 using the West African regional scale dispersion model (WASDM), and tabulated in Tables 1-3. The angstrom parameter is presented in Tables 4-6. The radius of particles (back of envelope calculation) is presented in Tables 7-9, and radius of particles (at-

Fig. 1: Geographical map of Bo.

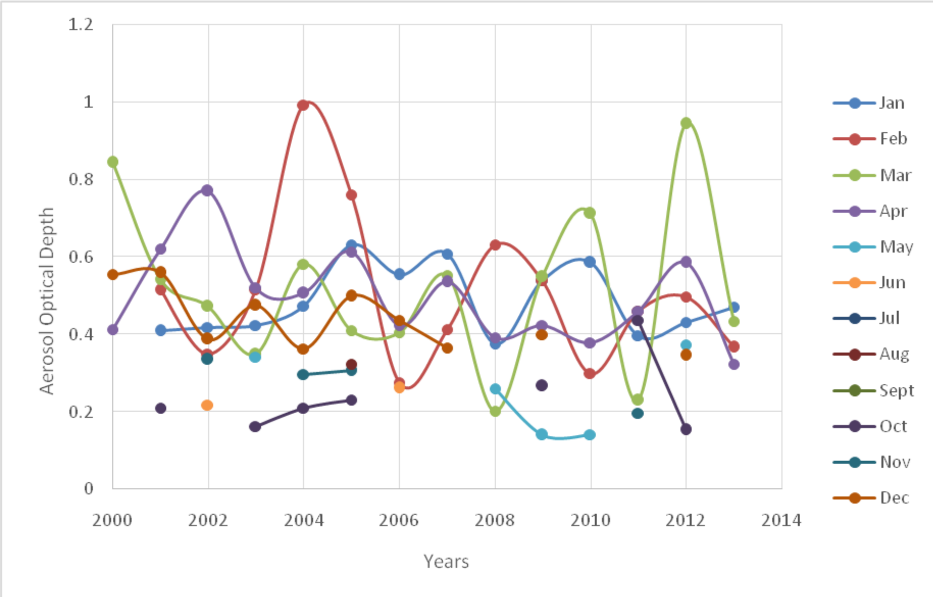

Fig. 2: Aerosol Optical Depth Dataset over Bo from 2000 to 2013.

mospheric aerosols) is presented in Tables 10-12. The statistics of the data presented in Fig. 2 are given in Tables 13-15.

AODs for the months of January to December are presented in Fig. 2 from the year 2000-2013. In 2000, 2001, 2002, 2003 and 2004, it was highest in the months of March, December, April, April and February respectively. No AODs were recorded for the months of July-September for the five years. No AODs were recorded from October-November in 2000, November, 2001 and November, 2003. The highest AODs were recorded in February (2005), January (2006), January (2007), February (2008) and March, 2009 with no AODs recorded in the months of May-July and September, May and July-November, May-November, May-December and, May-September and November for all the five years respectively. For the years 2010-2013, the highest AOD was recorded in the month of March for the year 2010, while it was February, March and January for 2011, 2012 and 2013 respectively. No AOD was recorded in the months of June-December for the year 2010, May-September and December (2011), June-September and November (2012) as well as May-December in 2013. Years with higher AODs are indicative of the coverage area or spread relative to those of lower AODs in the Bo region.

Aerosol loading was found to be constant and highest (0.9442) for the months of January-February, and May-November (2000), May-September and November (2001), May and July-October (2002), June-September and November (2003) and, May-September (2004) (Table 4); May-July and September (2005), May and July-November (2006), May-November (2007), June-December (2008) and June-November (2009) (Table 2); June-December (2010), May-September and December (2011), June-September and November (2012) and, May-December 2013 (Table 3) whereas, it is lower for other months for all the five years. Years with higher aerosol loading are indicative of higher potentials for pollution relative to years of lower aerosol distribution/concentration.

Considering Tables 4-6, October, 2001 and 2004 show similar Angstrom value (0.25) in the month of March 2008 but was highest (0.31) in the month of May, 2009 followed by the value estimated (0.29) for October 2012; however, it was either lower or somewhat insignificant for other years.

A close look at Tables 7-9 shows that, the radius of the particulate back envelope is highest (0.599) in the month of February. Next to it is 0.57 for March, 2000. For April, 2001-2003, it was highest (i.e. 0.56) in April 2002 and February, 2005, it was 0.54 in March, and 0.53 in April 2001 whereas, it was either lower or unavailable for other months between 2000 and 2013.

The highest radius of particulate-atmospheric aerosols is also indicative of the particle size in the atmospheric region of Bo. The highest particle size (i.e. approximately, 8.28 E-07 microns) was recorded for the month of February in the year 2004, next to this value (i.e. approximately, 7.87 E-07 microns) was that calculated for the month of February, 2002 but it was either lower or not recorded for other years and

Table1: Aerosol loading over Bo from 2000-2004.

Month	2000	2001	2002	2003	2004
Jan	0.9442	0.87487591	0.87189803	0.86997934	0.85199253
Feb	0.9442	0.83630446	0.89347393	0.83618364	0.58418807
Mar	0.673138969	0.82561622	0.85269267	0.89361652	0.80789456
Apr	0.87368279	0.78986156	0.71427167	0.83387674	0.83930597
May	0.9442	0.9442	0.9442	0.89573264	0.9442
Jun	0.9442	0.9442	0.92436781	0.9442	0.9442
Jul	0.9442	0.9442	0.9442	0.9442	0.9442
Aug	0.9442	0.9442	0.9442	0.9442	0.9442
Sep	0.9442	0.9442	0.9442	0.9442	0.9442
Oct	0.9442	0.92561834	0.9442	0.93297562	0.92561834
Nov	0.9442	0.9442	0.89739471	0.9442	0.90727805
Dec	0.819468122	0.8174614	0.88187858	0.85169174	0.88940475

Table 2: Aerosol loading over Bo from 2005-2009.

Month	2005	2006	2007	2008	2009
Jan	0.78459989	0.81978937	0.79566699	0.88537229	0.82624465
Feb	0.71887331	0.91218078	0.87390444	0.78467894	0.82652349
Mar	0.87451234	0.87615786	0.82075099	0.92699862	0.82216978
Apr	0.7931237	0.87043286	0.82770541	0.88050991	0.87040456
May	0.9442	0.9442	0.9442	0.91581677	0.9359111
Jun	0.9442	0.91560025	0.9442	0.9442	0.9442
Jul	0.9442	0.9442	0.9442	0.9442	0.9442
Aug	0.90063623	0.9442	0.9442	0.9442	0.9442
Sep	0.9442	0.9442	0.9442	0.9442	0.9442
Oct	0.9217474	0.9442	0.9442	0.9442	0.91428443
Nov	0.90503837	0.9442	0.9442	0.9442	0.9442
Dec	0.84246665	0.86540358	0.88873703	0.9442	0.87816234

Table 3: Aerosol loading over Bo from 2010-2013.

Month	2010	2011	2012	2013
Jan	0.80588675	0.87891356	0.86749108	0.85331578
Feb	0.9067858	0.85707546	0.84305455	0.88828977
Mar	0.74501573	0.92203575	0.61344323	0.86671125
Apr	0.88457439	0.85689222	0.80618497	0.90045904
May	0.93579262	0.9442	0.88610436	0.9442
Jun	0.9442	0.9442	0.9442	0.9442
Jul	0.9442	0.9442	0.9442	0.9442
Aug	0.9442	0.9442	0.9442	0.9442
Sep	0.9442	0.9442	0.9442	0.9442
Oct	0.9442	0.86549106	0.93430591	0.9442
Nov	0.9442	0.92799951	0.9442	0.9442
Dec	0.9442	0.9442	0.89432664	0.9442

months between the year 2000 and 2013 (Tables 10-12).

In this section, results from statistical analysis are presented. The mean AOD, confidence interval, variance, standard deviation, coefficient of variation, skew, kurtosis and Kolmogorov Smirnov statistics were estimated. Within the 95% confidence interval of the analysis, the estimated values lie in the region of 0.11-0.54 from 2000-2004; 0.11-0.2 from 2005 and 2009 and approximately, 0.11-0.28 from 2010-2013 while the highest AOD (1.26) was recorded for the year 2000 in the 99% confidence interval for all the years i.e. from 2000-2013. The highest mean AOD was recorded in the year 2000 which validates the concentration of aerosols in Bo for that year. The estimated variances were in the range of 0.02-0.06 from 2000-2004, 0.01-0.035 between 2005 and 2009 and, 0.06 (for the year 2012) - 0.0043 (for the year 2013) which are characteristics of the accura-

Table 4: Angstrom parameter over Bo for 2000-2004.

Month	2000	2001	2002	2003	2004
Jan	-	0.14133045	0.1379144	0.13578512	0.11807721
Feb	-	0.10516903	0.16659102	0.10507678	0.00111167
Mar	0.02690278	0.09736726	0.11870139	0.16681791	0.08579634
Apr	0.139944951	0.07539589	0.04136194	0.10333418	0.10749291
May	-	-	-	0.17026084	-
Jun	-	-	0.24178915	-	-
Jul	-	-	-	-	-
Aug	-	-	-	-	-
Sep	-	-	-	-	-
Oct	-	0.24697826	-	0.28707299	0.24697826
Nov	-	-	0.17307015	-	0.19212364
Dec	0.09317774	0.09185264	0.14996268	0.11781045	0.16036676

Table 5: Angstrom parameter over Bo for 2005-2009.

Month	2005	2006	2007	2008	2009
Jan	0.07257549	0.09339174	0.07861384	0.15463013	0.09780706
Feb	0.04311861	0.20353757	0.14020061	0.07261722	0.09800292
Mar	0.14090581	0.14284522	0.09403549	0.25312481	0.09499402
Apr	0.07718987	0.13628355	0.09883803	0.14820354	0.13625236
May	-	-	-	0.21317937	0.31114461
Jun	-	0.21257187	-	-	-
Jul	-	-	-	-	-
Aug	0.17884296	-	-	-	-
Sep	-	-	-	-	-
Oct	0.23189507	-	-	-	0.20897504
Nov	0.1873993	-	-	-	-
Dec	0.11000992	0.13091539	0.15938888	-	0.14527036

Table 6: Angstrom parameter over Bo for 2010-2013.

Month	2010	2011	2012	2013
Jan	0.08457639	0.14619776	0.133102	0.11926079
Feb	0.19106153	0.12271662	0.11048635	0.15874029
Mar	0.0537552	0.23292604	0.00895247	0.13227848
Apr	0.15354075	0.12254489	0.08475653	0.17851666
May	0.31001824	-	0.15564242	-
Jun	-	-	-	-
Jul	-	-	-	-
Aug	-	-	-	-
Sep	-	-	-	-
Oct	-	0.1310059	0.29709239	-
Nov	-	0.25789664	-	-
Dec	-	-	0.16795725	-

cies achieved in the estimated values. The average deviations were in the range of 0.11-0.17 from 2000-2004, 0.082-0.15 for 2005-2009 and 0.05-0.18 respectively. Standard deviations are in the range of 0.12-0.23 for year 2000-2013 whereas, the highest coefficient of variation was recorded for the year 2010. Based on the estimated skews between 2000 and 2013, the aerosol distribution for years 2001, 2003, 2007, 2009, 2011 and 2013 are all negatively skewed, whereas those of other years are positively skewed. The estimated Kurtosis was not available for the year 2000 and lies in the range of 0.99 (lowest in 2003) to 3.24 (highest in 2002) approximately, for the years 2000-2004, it was in the range of -2.08 (lowest in 2007) to 1.25 (highest in 2009) for the years 2005-2009 while it was in the range of -2.74 (lowest 2012) to 2.1 (highest in 2013) between 2010 and 2013. The highest estimated Kolmogorov Smirnov statistic (KSS)

Table 7: Radius of particulate-back of envelope calculation between 2000 and 2004.

Month	2000	2001	2002	2003	2004
Jan	-	0.46806728	0.47088507	0.47265002	0.48758664
Feb	-	0.4987713	0.4477474	0.49885215	0.59882922
Mar	0.572298937	0.50565538	0.4870522	0.44756894	0.51604063
Apr	0.469208098	0.52555723	0.55794296	0.50038185	0.49673894
May	-	-	-	0.44486967	-
Jun	-	-	0.3923311	-	-
Jul	-	-	-	-	-
Aug	-	-	-	-	-
Sep	-	-	-	-	-
Oct	-	0.38877037	-	0.36232529	0.38877037
Nov	-	-	0.44267922	-	0.42810497
Dec		0.51057859	0.46102175	0.48781522	0.45267085

Table 8: Radius of particulate-back of envelope calculation between 2005 and 2009.

Month	2005	2006	2007	2008	2009
Jan	0.52816806	0.50919975	0.52259414	0.45725651	0.5052648
Feb	0.55622354	0.41960515	0.46899738	0.52812933	0.50509096
Mar	0.46841663	0.4668232	0.50862414	0.38459444	0.50776826
Apr	0.52390326	0.47223628	0.50435038	0.46244889	0.47226217
May	-	-	-	0.41255664	0.34732071
Jun	-	0.41299723	-	-	-
Jul	-	-	-	-	-
Aug	0.4382119	-	-	-	-
Sep	-	-	-	-	-
Oct	0.39921097	-	-	-	0.41561548
Nov	0.43167332	-	-	-	-
Dec	0.49454702	0.47671142	0.45344927	-	0.46483831

Table 9: Radius of particulate-back of envelope calculation between 2010 and 2013.

Month	2010	2011	2012	2013
Jan	0.51714792	0.4640815	0.47488346	0.48657373
Feb	0.42890461	0.48362826	0.49413321	0.4539663
Mar	0.54592509	0.39848848	0.59063615	0.47557109
Apr	0.45813256	0.48377421	0.51698426	0.4384632
May	0.34800874	-	0.45644396	-
Jun	-	-	-	-
Jul	-	-	-	-
Aug	-	-	-	-
Sep	-	-	-	-
Oct	-	0.47663562	0.3560027	-
Nov	-	0.38138344	-	-
Dec	-	-	0.44667389	-

(0.27) was recorded in 2001 while the lowest value (0.18) in 2003, the lowest KSS, i.e. 0.164 was recorded in 2005 and the highest, i.e. 0.256 was recorded in 2007; the critical K statistic values determined at α = 0.1, 0.5 and 0.01 respectively, were 0.436, 0.483 and 0.576 at those conditions, respectively. Critical Kolmogorov statistic CK-S values for varying alpha values in the range of 0.01-0.1 were found to give values in the range of 0.636 (year 2000)-0.436 for years 2002-2004 but differed slightly in the year 2001 for alpha = 0.1; for alpha = 0.05, the CK-S value was highest (i.e. approximately, 0.71) in 2005 and lowest (0.483) for 2002-2004 whereas, when alpha = 0.01, the highest value (0.829) was seen for the year 2010. It dropped to 0.617 in 2011 and reduced to 0.567 in 2012 and remained constant throughout 2013. Years with very low standard errors show that the statistical results were very accurate. Hence, the instrument

Table 10: Radius of particulate-atmospheric aerosols between 2000 and 2004.

Month	2000	2001	2002	2003	2004
Jan	-	5.4392E-07	5.4872E-07	5.5174E-07	5.7809E-07
Feb	-	5.9873E-07	5.1062E-07	5.9888E-07	8.2795E-07
Mar	7.5811E-07	6.1185E-07	5.7712E-07	5.1033E-07	6.3227E-07
Apr	5.45857E-07	6.5169E-07	7.2332E-07	6.0177E-07	5.9492E-07
May	-	-	-	5.0607E-07	-
Jun	-	-	4.2938E-07	-	-
Jul	-	-	-	-	-
Aug	-	-	-	-	-
Sep	-	-	-	-	-
Oct	-	4.2456E-07	-	3.8999E-07	4.2456E-07
Nov	-	-	5.0264E-07	-	4.8036E-07
Dec	6.19107E-07	6.2143E-07	5.3213E-07	5.785E-07	5.1849E-07

Table 11: Radius of particulate-atmospheric aerosols between 2005 and 2013.

Month	2005	2006	2007	2008	2009
Jan	7.5795E-07	6.1873E-07	6.4557E-07	5.2593E-07	6.111E-07
Feb	7.8657E-07	4.6779E-07	5.455E-07	6.5706E-07	6.1076E-07
Mar	6.9698E-07	5.4182E-07	6.1761E-07	4.1896E-07	6.1594E-07
Apr	7.536E-07	5.5103E-07	6.0934E-07	5.3449E-07	5.5107E-07
May	-	-	-	4.576E-07	3.7123E-07
Jun	-	4.5823E-07	-	-	-
Jul	-	-	-	-	-
Aug	6.6615E-07	-	-	-	-
Sep	-	-	-	-	-
Oct	6.2633E-07	-	-	-	4.62E-07
Nov	6.5948E-07	-	-	-	-
Dec	7.2365E-07	5.5877E-07	5.1975E-07	-	5.3848E-07

Table 12: Radius of particulate-atmospheric aerosols from 2010-2013.

Month	2010	2011	2012	2013
Jan	6.345E-07	5.3722E-07	5.556E-07	5.7626E-07
Feb	4.8156E-07	5.7097E-07	5.9007E-07	5.2058E-07
Mar	6.9569E-07	4.3782E-07	8.0557E-07	5.5679E-07
Apr	5.2737E-07	5.7123E-07	6.3417E-07	4.9609E-07
May	3.7208E-07	-	5.2461E-07	-
Jun	-	-	-	-
Jul	-	-	-	-
Aug	-	-	-	-
Sep	-	-	-	-
Oct	-	5.5864E-07	3.8202E-07	-
Nov	-	4.147E-07	-	-
Dec	-	-	5.0892E-07	-

is very reliable for taking aerosol property measurements in Bo. The validity of the AOD statistical analyses is dependent on the atmospheric condition/activities responsible for the distribution of aerosols in the region. Furthermore, the aerosol distribution was skewed to further buttress on the accuracy of the statistical analyses. The years with the least standard deviation and coefficient of variation were indicative of high levels of accuracy in the measurements whereas, the years with the highest standard deviations and coefficients of variation were indicative of how inefficiently, the instrument could malfunction or give errors in the estimated values. The recorded average deviations show the influential role of the particulate concentration/loading for the years 2000-2013. More noteworthy is the non-uniformity in the coefficient of variation estimated for the years thus, showing irregularity in the atmospheric distribution of aerosols

Table 13: AOD statistics over Bo from 2000-2004.

Statistics	2000	2001	2002	2003	2004
Number of values	3	6	7	7	7
Number of missing values	9	6	5	5	5
Minimum	0.413	0.21	0.217	0.163	0.21
Maximum	0.843666667	0.621	0.77	0.5205	0.993
Mean	0.603888889	0.475844444	0.421333333	0.39811	0.48939
First quartile	-	0.4094	0.3385	0.34288	0.3135
Third quartile	-	0.559666667	0.458833333	0.50485	0.56288
Standard error	0.126703114	0.060238146	0.065419808	0.047853	0.096818
95% confidence interval	0.545203498	0.154872273	0.160082271	0.1171	0.23691
99% confidence interval	1.257528403	0.242880203	0.24251123	0.17739	0.3589
Variance	0.048161037	0.021771805	0.029958259	0.01603	0.065616
Average deviation	0.159851852	0.110762963	0.114190476	0.097669	0.17524
Standard deviation	0.21945623	0.14755272	0.173084544	0.12661	0.25616
Coefficient of variation	0.3634	0.31009	0.4108	0.31802	0.52342
Skew	0.953	-1.411	1.482	-1.082	1.354
Kurtosis	-	1.912	3.238	0.989	2.417
Kolmogorov-Smirnov stat	0.255	0.27	0.241	0.183	0.217
Critical K-S stat, alpha=.10	0.636	0.468	0.436	0.436	0.436
Critical K-S stat, alpha=.05	0.708	0.519	0.483	0.483	0.483
Critical K-S stat, alpha=.01	0.829	0.617	0.576	0.576	0.576

Table 14: AOD statistics over Bo from 2005-2009.

Statistics	2005	2006	2007	2008	2009
Number of values	8	6	5	5	7
Number of missing values	4	6	7	7	5
Minimum	0.231	0.261	0.36525	0.202	0.14
Maximum	0.7615	0.55425	0.6085	0.632	0.548666667
Mean	0.472145833	0.392833333	0.494716667	0.37248	0.407869048
First quartile	0.3145	0.276333333	0.4005625	0.2455	0.300083333
Third quartile	0.623083333	0.43725	0.566125	0.452	0.538833333
Standard error	0.065734408	0.044732885	0.045519193	0.07398	0.058945585
95% confidence interval	0.155461874	0.115008248	0.12636128	0.20537	0.144239846
99% confidence interval	0.230004692	0.180362993	0.209570365	0.34061	0.218511283
Variance	0.034568099	0.012006186	0.010359985	0.027366	0.024322074
Average deviation	0.154520833	0.082777778	0.08474	0.11318	0.119221088
Standard deviation	0.185924981	0.109572743	0.10178401	0.16543	0.155955358
Coefficient of variation	0.39379	0.27893	0.20574	0.44412	0.38237
Skew	0.268	0.103	-0.395	1.022	-0.907
Kurtosis	-1.249	-0.569	-2.082	1.249	-0.256
Kolmogorov-Smirnov stat	0.164	0.212	0.256	0.253	0.227
Critical K-S stat, alpha=.10	0.41	0.468	0.509	0.509	0.436
Critical K-S stat, alpha=.05	0.454	0.519	0.563	0.563	0.483
Critical K-S stat, alpha=.01	0.542	0.617	0.669	0.669	0.576

within the Bo region. The years with the highest skews confirmed the tendency for a significant effect of aerosols, i.e. high tendency for pollution of the surrounding environment of Bo.

The standard error of mean is a statement of probability that bothers on how the mean AOD weight deviates from the average AOD for the years; based on the estimated errors, the accuracy is in the range of 88-98%. Comparing the estimated variances, the estimated AODs for the years show that the calculated variances are far off the actual mean of the samples by a minimum of 1%. The estimated average deviations are a measure of how the AODs deviate from the average AOD in the area. From the estimated standard deviations, one could see the way the measured AODs spread from the mean/median AODs for all the years. The coefficient of variation (i.e. standard deviation/mean), is a meas-

Table 15: AOD statistics over Bo from 2010-2013.

Statistics	2010	2011	2012	2013
Number of values	5	6	7	4
Number of missing values	7	6	5	8
Minimum	0.141	0.196	0.153	0.323666667
Maximum	0.712	0.461	0.945	0.470666667
Mean	0.4234	0.3635	0.476011905	0.398645833
First quartile	0.2595	0.2295	0.353	0.345208333
Third quartile	0.6175	0.4605	0.563375	0.452083333
Standard error	0.1017	0.048803	0.093351944	0.032965933
95% confidence interval	0.2824	0.12547	0.228432207	0.104897599
99% confidence interval	0.4683	0.19677	0.346055657	0.192554016
Variance	0.05173	0.01429	0.061002098	0.004347011
Average deviation	0.1805	0.1005	0.171370748	0.0534375
Standard deviation	0.2274	0.11954	0.246986028	0.065931866
Coefficient of variation	0.53719	0.32887	0.51887	0.16539
Skew	0.135	-0.848	1.044	-0.089
Kurtosis	-1.349	-1.729	2.1	-2.736
Kolmogorov-Smirnov stat	0.177	0.277	0.186	0.202
Critical K-S stat, alpha=.10	0.509	0.468	0.436	0.565
Critical K-S stat, alpha=.05	0.563	0.519	0.483	0.624
Critical K-S stat, alpha=.01	0.669	0.617	0.576	0.734

ure of the risks involved in trying to get the desired results based on the instrument/equipment used, which provides evidence of inaccuracies since the risks are somewhat significant. Skewness is a measure of imbalance or asymmetry of a set of recorded AODs from the mean AODs for the different years, however, it is the degree of distortion to the left or right of a distribution as well as by how much it differs from a normal distribution. The estimated skews show that the AODs for some years were skewed to the left, hence the AODs recorded do not define a normal distribution, but an asymmetric type with the AODs more negatively skewed. Again, since the estimated Kurtosis for the years were mostly negative, it then implies that the AOD distribution is characterized by thick tails compared to a normal distribution, hence, it is non-platykurtic. The estimated Kolmogorov values are a means of knowing if the estimated AODs belong to the same category of data, i.e. not measured off the distribution, however, all the recorded values show that they are in order and can actually represent the AOD distribution of the region described.

CONCLUSIONS

The aerosol optical depth of aerosols in the atmospheric region of Bo was obtained. The estimated parameters show clearly that the aerosol distribution of the region from 2000-2013 had a significant influence on the average climatic condition of the region within the period. It was also observed that the AOD of some months were not available, which may have been due to their low levels of significance in such months of the year. The statistical analyses of the aerosol distribution show that the calculated Kurtosis were mostly negative thus exhibiting thick tails; hence, a non-platykurtic distribution.

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