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Research Article

A Simple Technique to Evaluate Aerosols Loading in the Atmosphere of Binkolo-Sierra Leone

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Abstract. Research has shown that air pollution in most of cities and towns in West Africa becoming critical. This research is an ongoing work in West African cities to determine the level of pollution. A fifteen years dataset was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR). Computational and statistical analysis was adopted. The percentage of increased of aerosols loading in 2000, 2004, 2008 and 2012 was 12.2%, 9%, 11.9% and 9%. The cumulative increase of aerosol loading within 15 years was 1.8%. These results show that Binkolo is currently having excess deposition of anthropogenic particulates into the atmosphere.

Keywords. Air pollution; Aerosol; Binkolo; Sierra Leone; Sustainability

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1. Introduction

The West Africa region occupies a strategic location of the African continent. The region is located at the north of the equator and westward into the Atlantic Ocean. The region is unique because it encompasses major climatic zones. West Africa comprises of a dense rain forest along the coastal belt and extends to the sub-Sahelian savanna in the north. There are over 72 million hectares of forest in West Africa (Mari *et al*. [8]) which contributes to its ozone distribution. The life form activities within the region are somewhat unique via the aerosol loadings each year. The aerosols loading across this region are uncontrolled for now due to industrial pollution, agricultural pollution, Sahara dust and domestic activities. This region experiences the monsoon signatures, such as, distinct seasonal shift in the prevailing winds, alternation between winter dry conditions and summer rainy conditions (Janicot *et al*. [7]).

The West Africa region is made up of eighteen countries namely Nigeria, Ghana, Benin, Burkina Faso, Cameroun, Cape Verde, Cote d'Ivoire, Equatorial Guinea, Gambia, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone and Togo. According to the United State agency, the population of human in West Africa is over 300 million (Feedthenation [6]). The predominant occupation is agriculture; hence, agricultural pollution from biomass burning is expected to be relatively high. Undoubtedly aerosols loading over West Africa has influence on its climatic system. In our quest to estimate the aerosol loading in sixty four cities in West Africa, we developed the West African regional scale dispersion model (WASDM).

The WASDM have successfully described the relationship between aerosols and the West African climate system. The model was validated by the aerosols loading of over fifty towns and cities in West Africa (Emetere *et al.* [4, 5]).

The broad pollution spectrum across West Africa needs to be understood to assimilate the aerosol retention modalities particularly in Binkolo to avert indirect or direct effect of air pollution. In this paper, the West African regional scale dispersion model (WASDM) was used to analyze aerosol optical depth dataset over Binkolo to estimate the average aerosol loading over the region. The model was validated by statistical tool.

2. Research Site

Sierra Leone lies within the latitude of 6°N and 9°N, and longitude of 11° W and 13°W. Sierra Leone is surrounded by Guinea, Liberia and Atlantic Ocean in the northeast, southeast, and west respectively. Sierra Leone is bounded within an area of 71,740 km^2. Sierra Leone has four geographical regions: upland plateau, coastal Guinean mangroves, the wooded hill country, and the eastern mountains. It has two seasons; wet season around May to November, and dry season around December to May. Binkolo is located on longitude and latitude of −13.24° and 8.49° (Figure 1).

3. Methodology

The West African regional scale dispersion model (WASDM) is generally governed by three equations (Emetere *et al.* [4]) i.e.

$$\frac{\partial C}{\partial t} + V_x\frac{\partial C}{\partial x} - V_z\frac{\partial C}{\partial z} - V_y\frac{\partial C}{\partial y} = \frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{z_2}\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_{y_2}\frac{\partial C}{\partial y}\right) - P + S, \quad (1)$$

$$V_z\frac{\partial C}{\partial z} = \frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial x}\left(K_z\frac{\partial C}{\partial x}\right), \quad (2)$$

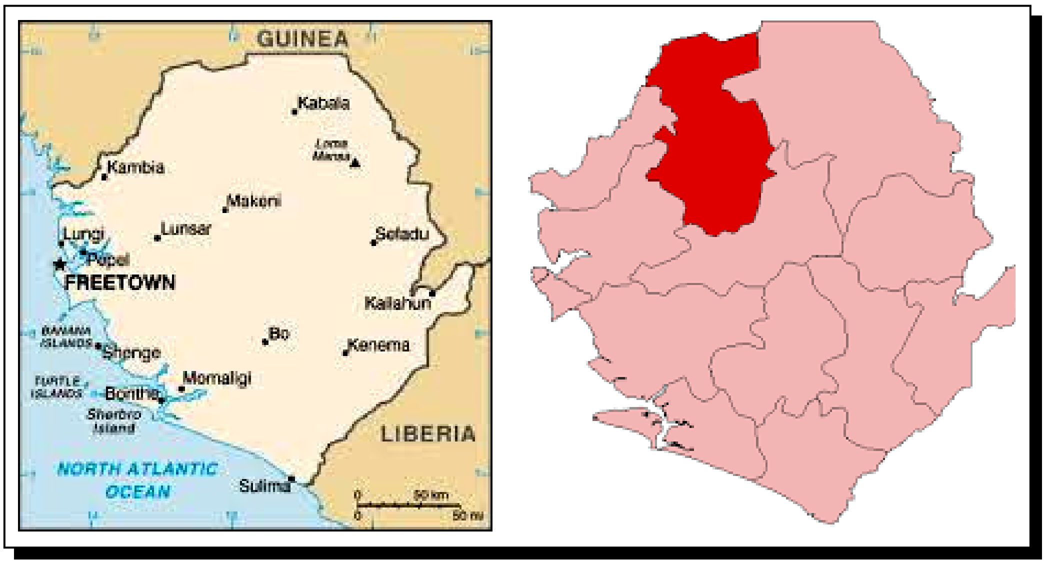

Figure 1. Geographical map of Binkolo

$$V_x \frac{\partial C}{\partial x} = \frac{\partial}{\partial y}\left(K_{y_2}\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{z_2}\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial x}\left(K_{z_2}\frac{\partial C}{\partial x}\right), \tag{3}$$

V is the wind velocity (m/s), P is the air upthrust, $C(x,y,z)$ is the mean concentration of diffusing pollutants of diffusing substance at a point (x,y,z) [kg/m^3], K_y, K_x is the eddy diffusivities in the direction of the y- and x- axes [m^2/s] and S is the source/sink term [kg/m^{3}s].

The solution of equation (2) shown in Emetere *et al.* [4] was used to determine salient atmospheric constant that is common to Binkolo.

The beta probability distribution (Weisstein [11]) was used tool was used to monitor the average increase of aerosols over the region. The beta probability distribution is given as

$$x = \frac{\tau_j - \tau_{\text{low}}}{\tau_{\text{high}} - \tau_{\text{low}}}. \tag{4}$$

τ_j is the inputted aerosols optical depth (AOD), τ_{low} is the lowest AOD in the year/month, τ_{high} is the highest AOD in the year/month. The dataset was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR). The data can be obtained on `http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MISR_Daily_L3`.

4. Result and Discussion

Binkolo has scanty AOD data especially from June to September (Figure 2). The scanty AOD data may be as a result of the moisture content (Adebiyi *et al.* [1]), cloud scavenging (Dani *et al.* [3]), precipitable water content (Vijayakumar and Devara [10]) and high rain drop rate (Boucher and Quaas [2]). The AOD pattern over Binkolo agreed with proposed model (Figure 3 and 4). The yearly aerosols loading are unstable due to uncontrolled anthropogenic activities.

Using the WASDM, the curve-fitting experimentation over Bonkodou was very perfect as shown in Figures 3 and 4. Most importantly, a set of atmospheric constants (a, b, n, α and β) were obtained as shown in Table 1. a is known as the atmospheric/decay/growth constant,

α and β is the phase difference, n is tuning constant, b is the multiplier constant. For easy representation, the three constants are referred to as meteorological constants. The statistical analysis of the AOD is shown in Table 2.

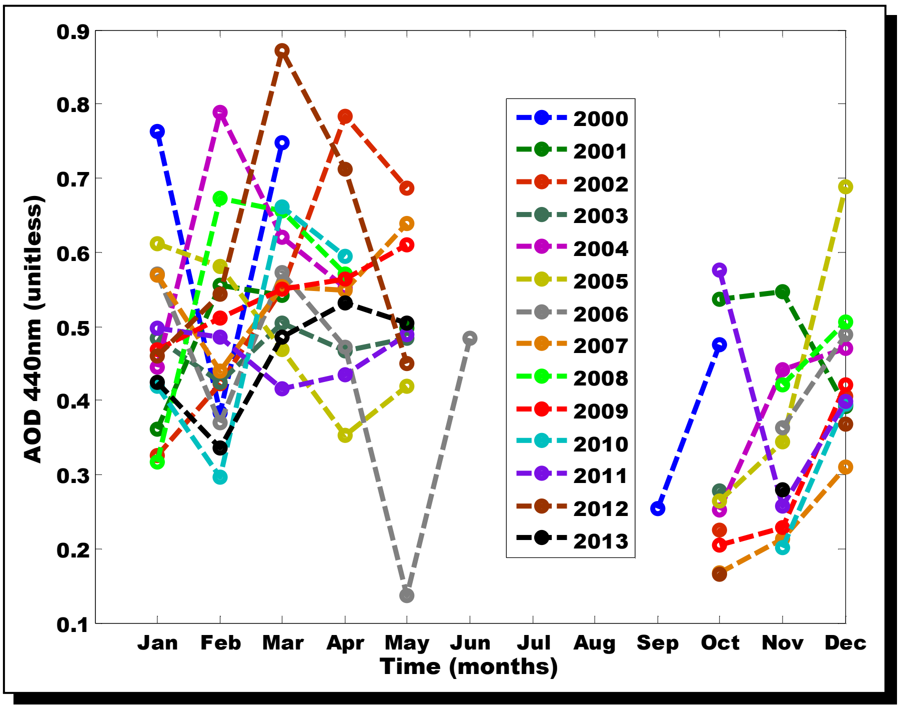

Figure 2. AOD pattern for Binkolo during 2000-2003

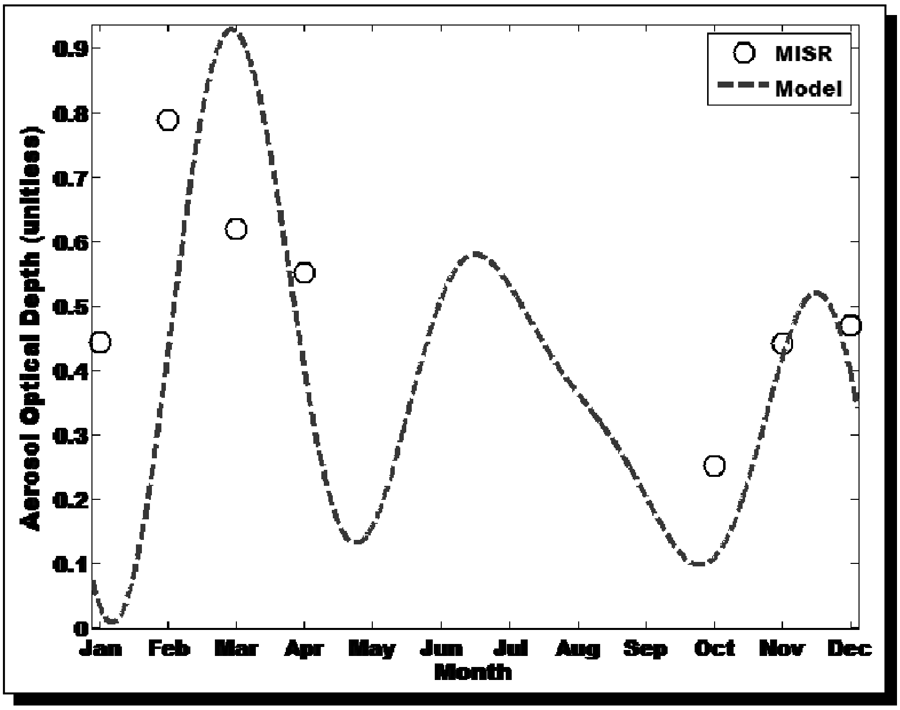

Figure 3. AOD for new model and MISR (Binkolo during 2001)

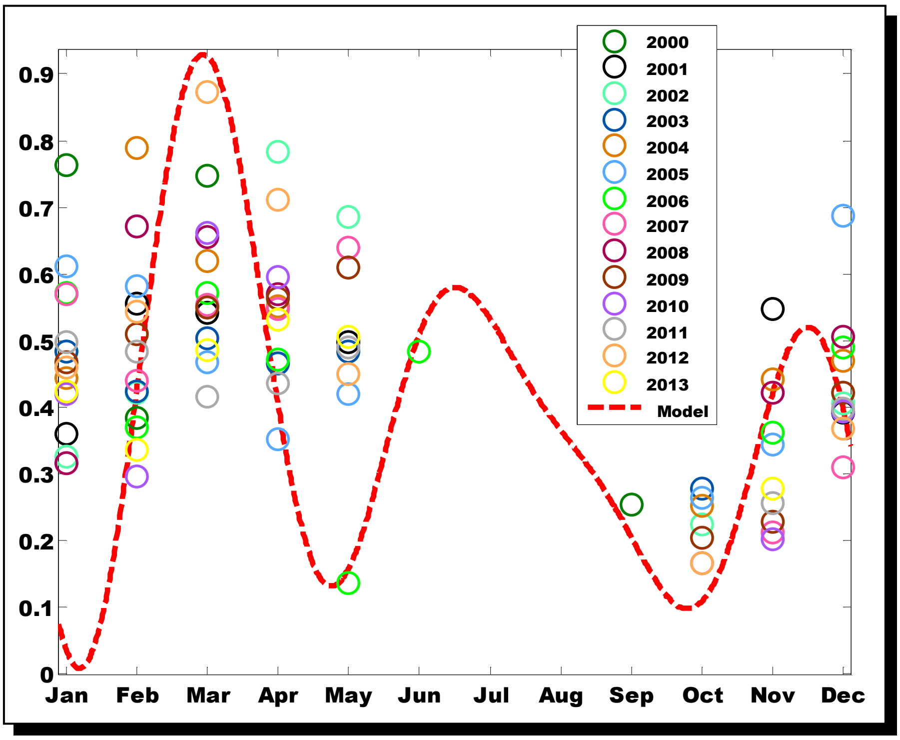

Figure 4. AOD for new model and MISR (Binkolo during 2000-2013)

Table 1. Atmospheric constants over Binkolo

Location	a_1	a_2	n_1	n_2	α	β
Binkolo	0.6378	0.7898	0.2192	0.272	$\frac{\pi}{6}$	$\frac{\pi}{6}$

Table 2. Statistical analysis of aerosols optical depth

Year	2001	2002	2003	2004	2005	2006	2007
Number of values	5	7	7	7	7	8	8
Minimum	0.25	0.36	0.23	0.28	0.25	0.26	0.137
Maximum	0.76	0.56	0.78	0.5	0.79	0.69	0.572
99% confidence interval	0.46	0.11	0.28	0.11	0.23	0.18	0.176
Standard deviation	0.22	0.08	0.2	0.08	0.17	0.15	0.143
Coefficient of variation	0.43	0.16	0.41	0.18	0.33	0.32	0.33
Year	2008	2009	2010	2011	2012	2013	2014
Number of values	8	6	8	6	8	7	6
Minimum	0.17	0.32	0.2	0.2	0.26	0.17	0.279
Maximum	0.64	0.67	0.61	0.66	0.58	0.87	0.531
99% confidence interval	0.22	0.23	0.19	0.29	0.12	0.32	0.166
Standard deviation	0.18	0.14	0.15	0.17	0.09	0.23	0.101
Coefficient of variation	0.42	0.26	0.34	0.41	0.21	0.45	0.236

The percentage increase of aerosols loading in 2000, 2004, 2008 and 2012 was 12.2%, 9%, 11.9% and 9%. The cumulative increase of aerosol loading within 15 years was 1.8%. These results show that Binkolo is currently having excess deposition of air pollution into the atmosphere. UN report showed that an estimated 6.5 million deaths (11.6 per cent of all global deaths) were associated with indoor and outdoor air pollution (UN [9]).

5. Conclusion

Data loss was as a result of the moisture content, cloud scavenging, precipitable water content and high rain drop rate. It was shown that the increase of aerosol loading over Binkolo can rise to 12%. Hence, this research affirms that Binkolo is among the cities reported by United Nations to be severely polluted. Further work should focus on the determination of the source of pollution within the city.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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