Air pollution Estimation Over Bouake

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Abstract. Air pollution over Bouake-Cote d’Ivoire was considered. Fifteen years primary (aerosol optical depth) dataset was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR). Its aerosol loading dataset were generated from the primary dataset. The dataset depicts the air quality over the area. The statistical analysis of the dataset was also presented. The close ranges of values of the variance, average deviation and standard deviation are close indication that the correlation of each year would be naturally be >0.75. The averages of the AOD over the years i.e. is within the range of 0.4±0.05. It was observed that air pollution over Ponta is seasonal and comes from same source. Hence the pollution over is sustained due to a same pollution routine over the years. If the sources of anthropogenic emission in the region were not curbed, there would be massive health discomforts in the nearest future.

Keywords: air pollution, aerosol, Brikama, aerosol loadings

1. Introduction
Air contamination introduce toxins into the air that are harmful to human wellbeing and the planet overall. Government in developed nations have laws that curbs indiscriminate release of pollution into the atmosphere. Unfortunately, the under developed world have no or weak laws that controls indiscriminate anthropogenic pollutions. For example, in the US, there is a Clean Air Act that is regulated and enforced by the U.S. Ecological Protection Agency (EPA). The importance of clean air acts or laws are to curb the release of pollutions that have grave effect on health and climate system. For example, air contaminants such as carbon dioxide and methane raises the world's temperature and expans warmth. Climate change is reality and are caused by accumulated allergenic air poisons including mold (on account of moist conditions brought about by extraordinary climate and expanded flooding) and dust (because of a more extended dust season and more dust generation).
In this research, the values of air pollution parameters were documented so that the government of the region can start planning for a clean air future for its inhabitants. Hence, the dataset that is documented in this research is meant to: give a good background for further study on aerosol loading; provide meteorological centers insight towards configuring sun-photometer over Bouake-Cote d’Ivoire; to quantify the extent of air pollution; provide modeller necessary insight on aerosol loading and retention challenges over Bouake-Cote d’Ivoire.
The campaign (by the main author) on air pollution documentation over most cities in West Africa has been very successful. Most importantly is the introduction of the term ‘aerosol loading’ to describe accumulated air pollutions in the atmosphere for a long time. The life time of these pollutants can be as high as 100 years. This means that aerosol loading may last longer than 300 years before its technicallly eradicated. Since air pollution cannot be completely eradicated, it is important to advocate for a safe atmosphere. Aerosol loading calculation using West African regional scale dispersion model (WASDM) has showed great success in relating more with air quality [1-2]. Hence, the importance of...
this dataset can be seen in Ref [2-6]. Dataset on aerosol loading shows the accumulative particulates transport within its lifetime.

2. Experimental Design, Materials and Methods

Bouaké is the second-largest city in Côte d’Ivoire. It is the seat of three levels of subdivision—Vallée du Bandama District, Gbêkê Region, and Bouaké Department. Bouake is located on longitude and latitude of 5.0391° W and 7.6905° N respectively (Figure 1). The dataset was obtained from MISR (https://l0dup05.larc.nasa.gov/L3Web/download). The data was processed using excel. The conversion from AOD to aerosol loading was done using WASDM. The google map is shown in Figure 2.

![Figure 1: Geographical map of Bouake](image1)

![Figure 2: Google map of Bouake](image2)
WASDM was used aerosol loading over a region [6-7]:
\[
\psi(\lambda) = a_1^2 \cos \left( \frac{n_1\pi(\lambda)}{2} x \right) \cos \left( \frac{n_1\pi(\lambda)}{2} y \right) + \cdots + a_n^2 \cos \left( \frac{n_n\pi(\lambda)}{2} x \right) \cos \left( \frac{n_n\pi(\lambda)}{2} y \right)
\] (1)

\(a\) is atmospheric constant gotten from the fifteen years aerosol optical depth (AOD) dataset from MISR, \(n\) is the tuning constant, \(\tau(\lambda)\) is the AOD of the area and \(\psi(\lambda)\) is the aerosol loading. The validation of the summarized dataset was done using mathematical models and statistical software. The analysis of equations (1) was done using the C++ codes.

The aerosol loading was calculated from the WASDM. Further analysis were carried-out using the modified Bessel equation, F distribution and Chi-Square distribution. The modified Bessel functions, \(I_n(x)\), (also known as the hyperbolic Bessel Functions) is mathematically represented as:
\[
I_n(x) = (i)^{-n} I_n(ix)
\] (2)

\(x\) is the value at which to evaluate the function, \(n\) is order of the Bessel function. In this work, \(n=3\) so as to mimic the aerosol loading trend. The chi-squared distribution is commonly used to study variation within a given parameter. It is mathematically written as
\[
F(x; n) = \frac{\gamma\left(\frac{n}{2}\right)}{\Gamma\left(\frac{n}{2}\right)} (3)
\]

\(y\) is the lower incomplete gamma function.

F probability distribution is used to determine whether two data sets have different degrees of diversity. It is mathematically written as:
\[
f(x; d_1, d_2) = \frac{\Gamma\left(\frac{d_1}{2}\right)\Gamma\left(\frac{d_2}{2}\right)}{\Gamma\left(\frac{d_1+d_2}{2}\right)} \left(\frac{d_1+d_2}{2}\right)^{-\frac{d_1+d_2}{2}} (4)
\]

3. Results and Discussion
The summarized primary data was obtained from Multi-angle Imaging Spectro-Radiometer (MISR) is shown in Table 1 for 550 nm wavelength [7]. It was observed the months of highest AOD varied significantly between January to March over the years (see blue boxes in Table 1). This result signifies that the air pollution over Ponta is seasonal and comes from same source. Hence the pollution over is sustained due to a same pollution routine over the years. The missing dataset was due to biases as discussed above [2]. Table 1 shows that the satellite biases over Bouake is high. The aerosol loading over the area was obtained using the West African regional scale dispersion model (WASDM) from the primary dataset as presented in Figure 3. The aerosol loading of Bouake is very high at the moment. It further supports the assertions made with the interpretation of AOD in Table 1. If the sources of anthropogenic emission in the region is not curbed, there would be massive health discomforts in the nearest future. The modified Bessel function shows that the aerosol loading significantly reduce around February of every year. Since high rain rate is one of the factors that reduce aerosol loading. Due to huge AOD data loss, it cannot be inferred that the research area has high rain rate in February every year. The Chi distribution shows that the variation of aerosol loading changes every year. Also, it reveals that the effect of aerosol loading is the same all through the year. The F probability distribution shows that there is a significant occurrence in December. Hence, the aerosol loading may not be high in December, however, the significance is highest in December. The
statistical analysis of the summarized primary dataset is shown in Tables 2. The close ranges of values of the variance, average deviation and standard deviation are close indication that the correlation of each year would be naturally be >0.75. The averages of the AOD over the years i.e. is within the range of 0.4±0.05.

Table 1: Summarized Aerosol Optical Depth Dataset over Bouake

| Month | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Jan   | 0.838 | 0.454 | 0.465 | 0.497 | 0.476 | 0.825 | 0.461 | 0.645 | 0.359 | 0.627 | 0.492 | 0.583 | 0.385 | 0.41 |
| Feb   | 0.285 | 0.658 | 0.396 | 0.616 | 0.714 | 0.502 | 0.316 | 0.417 | 0.729 | 0.481 | 0.254 | 0.416 | 0.658 | 0.41 |
| Mar   | 0.366 | 0.865 | 0.481 | 0.763 | 0.521 | 0.847 | 0.558 | 0.518 | 0.451 | 0.599 | 0.31 |
| Apr   | 0.290 | 0.446 | 0.453 | 0.330 | 0.366 | 0.381 | 0.352 | 0.285 | 0.11 |
| May   | 0.269 | 0.436 | 0.139 | 0.337 | 0.338 | 0.257 | 0.371 | 0.379 |
| Jun   | 0.270 |       |       |       |       |       |       |       |       |       |       |       |       |
| Jul   |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Aug   |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Sep   | 0.433 | 0.262 |       |       |       |       |       |       |       |       |       |       |       |
| Oct   | 0.433 | 0.262 | 0.070 |       |       |       |       |       |       |       |       |       |       |
| Nov   | 0.258 | 0.502 | 0.413 | 0.073 | 0.323 | 0.329 | 0.533 | 0.251 | 0.375 |
| Dec   | 0.322 | 0.355 | 0.368 | 0.549 | 0.431 | 0.416 | 0.422 | 0.419 | 0.396 |
Figure 3: Analysis of aerosol loading (a) aerosol loading (b) Modified Bessel analysis (c) Chi-square distribution (d) F probability distribution

Table 2: statistics of aerosols content over Bouake

| Statistics                  | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|-----------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Number of values            | 3.000| 5.000| 6.000| 6.000| 6.000| 7.000| 6.000| 7.000| 7.000| 5.000| 6.000| 7.000| 7.000| 8.000|
| Minimum                     | 0.285| 0.269| 0.262| 0.329| 0.070| 0.139| 0.316| 0.303| 0.257| 0.329| 0.136| 0.251| 0.087| 0.1  |
| Maximum                     | 0.838| 0.658| 0.865| 0.616| 0.763| 0.825| 0.847| 0.645| 0.729| 0.627| 0.533| 0.583| 0.658| 0.4  |
| Mean                        | 0.518| 0.407| 0.459| 0.458| 0.478| 0.436| 0.457| 0.448| 0.422| 0.445| 0.370| 0.407| 0.380| 0.3  |
| First quartile              | #N/A | 0.285| 0.322| 0.388| 0.270| 0.282| 0.337| 0.332| 0.326| 0.361| 0.254| 0.359| 0.272| 0.1  |
| Third quartile              | #N/A | 0.505| 0.465| 0.497| 0.714| 0.516| 0.461| 0.556| 0.496| 0.517| 0.492| 0.443| 0.497| 0.4  |
| Standard error              | 0.165| 0.071| 0.087| 0.040| 0.109| 0.083| 0.081| 0.051| 0.060| 0.052| 0.061| 0.038| 0.065| 0.0  |
| 95% confidence interval     | 0.711| 0.196| 0.223| 0.104| 0.280| 0.203| 0.208| 0.125| 0.147| 0.144| 0.157| 0.093| 0.153| 0.1  |
| 99% confidence interval     | 1.640| 0.325| 0.350| 0.163| 0.439| 0.308| 0.326| 0.189| 0.223| 0.239| 0.247| 0.142| 0.227| 0.2  |
| Variance                    | 0.082| 0.025| 0.045| 0.010| 0.071| 0.048| 0.039| 0.018| 0.025| 0.013| 0.023| 0.010| 0.034| 0.0  |
| Average deviation           | 0.213| 0.119| 0.137| 0.073| 0.206| 0.159| 0.131| 0.116| 0.118| 0.087| 0.116| 0.069| 0.129| 0.1  |
| Standard deviation          | 0.286| 0.158| 0.213| 0.099| 0.267| 0.220| 0.198| 0.135| 0.159| 0.116| 0.150| 0.101| 0.183| 0.1  |
| Coefficient of variation    | 0.552| 0.387| 0.463| 0.216| 0.558| 0.504| 0.433| 0.301| 0.377| 0.261| 0.406| 0.248| 0.482| 0.4  |
| Skew                        | 1.228| 1.219| 1.748| 0.478| 0.629| 0.601| 2.084| 0.356| 1.364| 1.088| 0.710| 0.340| 0.122| 0.1  |
| Kurtosis                    | #N/A | 1.085| 3.621| 0.519| 0.816| 0.965| 4.569| 1.837| 1.802| 0.952| 0.576| 1.595| 0.053| 2.0  |
| Kolmogorov-Smirnov stat     | 0.285| 0.203| 0.322| 0.181| 0.164| 0.207| 0.326| 0.222| 0.225| 0.197| 0.196| 0.190| 0.217| 0.1  |
| Critical K-S stat           | 0.636| 0.509| 0.468| 0.468| 0.468| 0.468| 0.468| 0.436| 0.436| 0.509| 0.468| 0.436| 0.410| 0.5  |
4. Conclusion
Generally, it observed that the aerosol loading in Bouake is very high at the moment. The research affirms that air pollution over Ponta is seasonal and comes from same source. Hence the pollution over is sustained due to a same pollution routine over the years. The missing dataset shows that the satellite biases over Bouake are high. The close ranges of values of the variance, average deviation and standard deviation are close indication that the correlation of each year would be naturally be >0.75. The averages of the AOD over the years i.e. is within the range of ±0.05. It is recommended that government in the region should embark on a sporadic campaign to curb excessive dispersion of aerosols into the atmosphere.

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| alpha = .10 | 0.708 | 0.563 | 0.519 | 0.519 | 0.483 | 0.519 | 0.483 | 0.483 | 0.519 | 0.483 | 0.454 | 0.5 |
| Critical K-S stat, alpha = .05 | 0.829 | 0.669 | 0.617 | 0.617 | 0.576 | 0.617 | 0.576 | 0.576 | 0.669 | 0.617 | 0.576 | 0.542 | 0.6 |
| Critical K-S stat, alpha = .01 | 0.708 | 0.563 | 0.519 | 0.519 | 0.483 | 0.519 | 0.483 | 0.483 | 0.519 | 0.483 | 0.454 | 0.5 |