Air pollution Estimation Over Ponta

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Abstract. The principal challenge of air pollution reportage in most communities of West Africa is the unavailability of working data. In this paper, satellite measurements were used to derive salient parameter (aerosol loading) to describe air quality over Ponta-Cape Verde was considered. Fifteen years primary (aerosol optical depth) dataset was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR). The dataset is important to quantify the extent of air pollution in the research area. The statistical analysis of the dataset was also presented. 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.

Keywords: air pollution, aerosol, Brikama, aerosol loadings

1. Introduction

At the moment, not much is known about ground measurement dataset over some areas in Cape Verde [1]. The main source of dataset is satellite measurement only [2-5]. In this paper, we show the aerosol loading measurements that was derived from the aerosol optical depth dataset through the West African regional scale dispersion model (WASDM) [6, 7]. The objective of this paper is to further the sensitization of West African communities to its current air pollution state.

The danger of air pollution is enormous. About 33% of human die from stroke, lung malignant growth cardiovascular, respiratory sickness and coronary illness. This is having a proportional impact to that of smoking tobacco and other societal dangers. Air pollution is firmly connected to environmental change. Environmental change caused by is non-renewable energy source ignition (fossil fuel burning) which contributes largely to anthropogenic emission. The United Nation UN Intergovernmental Panel on Climate Change cautioned that coal-burning as a means of generating power must finish by 2050. This decision would largely confine worldwide temperature alteration to 1.5C [8].

The mode of air pollution in most developing region can be summarized via Figure 1. From literature, biomass and fossil fuel burning is most prominent. Other sources of pollution are also significant. The accumulation of all these sources of pollution in the atmosphere over time is referred to as aerosol loading. The aerosol loading is a vital parameter that show how long the emitted aerosols interfere with the atmosphere.
In this research, we documented the dataset of aerosol optical depth (AOD) and aerosol loading. Hence, this research: gives a good background for further study on aerosol loading; provides meteorological centres insight towards configuring sun-photometer over Ponta-Cape Verde; helps to quantify the extent of air pollution; provides modeller necessary insight on aerosol loading and retention challenges over Ponta-Cape Verde.

2. Experimental Design, Materials and Methods
Ponta do Sol is the northernmost town on the island of Santo Antão and Cape Verde. Ponta is located on longitude and latitude of -25° 00' 0.00" W and 17° 06' 60.00" N (Figure 2). 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.

WASDM was used aerosol loading over a region [6-7]:

![Diagram showing sources of air pollution](image1.png)

**Figure 1:** Sources of air pollution

![Geographical map of Ponta](image2.png)

**Figure 2:** Geographical map of Ponta
\[
\psi(\lambda) = a_1^2 \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} y\right) + \cdots + a_n^2 \cos\left(\frac{n_n \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_n \pi \tau(\lambda)}{2} y\right)
\]

(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:

\[
I_n(x) = (i)^{-n} J_n(ix)
\]

(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:

\[
F(x; n) = \frac{\gamma\left(\frac{n+x}{2}\right)}{\Gamma\left(\frac{n}{2}\right)}
\]

(3)

\( \gamma \) 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:

\[
f(x; d_1, d_2) = \frac{\left(\frac{d_1 x + d_2}{d_1 + d_2}\right)^{d_1 + d_2}}{x B\left(\frac{d_1 + d_2}{2}\right)}
\]

(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 [8]. It was observed the months of highest AOD varied significantly between May to August 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 [6]. 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 Ponta is very high at the moment. It further supports the ascertainment 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 June of every year. Since high rain rate is one of the factors that reduce aerosol loading, it is inferred that the research area has high rain rate in June 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. It means the pattern of aerosol dispersion in the research area is unique as there are no data spikes over the years. This result is further affirmed by the averages of the AOD over the years i.e. within the range of 0.3±0.05. The year 2012 had the highest AOD average over the years. The standard error is a good indication that the satellite measurement has a very low bias. Hence, the dataset presented is reliable for modelling and optimization process.

Table 1: Summarized Aerosol Optical Depth Dataset over Ponta

| Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Jan   | 0.630| 0.163| 0.244| 0.174| 0.152| 0.233| 0.194| 0.449| 0.454| 0.151| 0.237| 0.128| 0.238| 0.1 |
| Feb   | 0.516| 0.386| 0.508| 0.188| 0.120| 0.138| 0.335| 0.184| 0.148| 0.090| 0.198| 0.238| 0.2 |
| Mar   | 0.374| 0.237| 0.184| 0.286| 0.336| 0.118| 0.363| 0.193| 0.358| 0.192| 0.144| 0.132| 0.390| 0.1 |
| Apr   | 0.619| 0.356| 0.281| 0.267| 0.303| 0.266| 0.248| 0.285| 0.471| 0.185| 0.183| 0.212| 0.372| 0.1 |
| May   | 0.636| 0.212| 0.405| 0.501| 0.282| 0.477| 0.229| 0.293| 0.337| 0.457| 0.640| 0.294| 0.740| 0.3 |
| Jun   | 0.354| 0.731| 0.586| 0.669| 0.563| 0.448| 0.695| 0.428| 0.611| 0.415| 0.653| 0.463| 0.360| 0.5 |
| Jul   | 0.559| 0.444| 0.685| 0.699| 0.425| 0.555| 0.695| 0.534| 0.604| 0.565| 0.414| 0.508| 0.799| 0.4 |
| Aug   | 0.289| 0.533| 0.356| 0.438| 0.431| 0.455| 0.603| 0.535| 0.630| 0.495| 0.608| 0.570| 0.601| 0.5 |
| Sep   | 0.413| 0.359| 0.409| 0.430| 0.531| 0.533| 0.413| 0.443| 0.510| 0.639| 0.503| 0.405| 0.271| 0.3 |
| Oct   | 0.164| 0.288| 0.141| 0.327| 0.388| 0.340| 0.273| 0.346| 0.133| 0.263| 0.175| 0.489| 0.261| 0.2 |
| Nov   | 0.192| 0.205| 0.163| 0.216| 0.117| 0.153| 0.292| 0.241| 0.225| 0.467| 0.212| 0.214| 0.1 |
| Dec   | 0.243| 0.201| 0.222| 0.301| 0.108| 0.383| 0.384| 0.184| 0.096| 0.121| 0.227| 0.173 |
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 Ponta

| Statistics              | 2000   | 2001   | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   |
|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Number of values        | 10.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 12.000 | 11.000 |        |
| Minimum                 | 0.164  | 0.163  | 0.141  | 0.163  | 0.152  | 0.108  | 0.138  | 0.193  | 0.133  | 0.096  | 0.090  | 0.128  | 0.173  |        |
| Maximum                 | 0.636  | 0.731  | 0.685  | 0.699  | 0.563  | 0.555  | 0.695  | 0.535  | 0.630  | 0.639  | 0.653  | 0.570  | 0.799  |        |
| Mean                    | 0.455  | 0.345  | 0.338  | 0.390  | 0.343  | 0.314  | 0.366  | 0.376  | 0.393  | 0.319  | 0.353  | 0.320  | 0.388  |        |
| First quartile          | 0.354  | 0.224  | 0.203  | 0.245  | 0.249  | 0.119  | 0.212  | 0.292  | 0.213  | 0.168  | 0.159  | 0.205  | 0.238  |        |
| Third quartile          | 0.619  | 0.415  | 0.407  | 0.505  | 0.428  | 0.466  | 0.508  | 0.446  | 0.557  | 0.476  | 0.555  | 0.476  | 0.495  |        |
| Standard error          | 0.051  | 0.047  | 0.048  | 0.052  | 0.037  | 0.051  | 0.058  | 0.030  | 0.052  | 0.053  | 0.063  | 0.046  | 0.061  |        |
| 95% confidence interval | 0.116  | 0.104  | 0.105  | 0.115  | 0.082  | 0.111  | 0.128  | 0.067  | 0.114  | 0.117  | 0.138  | 0.100  | 0.134  |        |
| 99% confidence interval | 0.166  | 0.147  | 0.149  | 0.162  | 0.116  | 0.157  | 0.180  | 0.094  | 0.161  | 0.166  | 0.194  | 0.142  | 0.189  |        |
| Variance                | 0.026  | 0.027  | 0.028  | 0.033  | 0.017  | 0.031  | 0.040  | 0.011  | 0.032  | 0.034  | 0.047  | 0.025  | 0.045  |        |
| Average deviation       | 0.137  | 0.123  | 0.129  | 0.151  | 0.104  | 0.154  | 0.160  | 0.086  | 0.154  | 0.162  | 0.194  | 0.139  | 0.163  |        |
| Standard deviation      | 0.162  | 0.164  | 0.166  | 0.181  | 0.130  | 0.175  | 0.201  | 0.105  | 0.179  | 0.185  | 0.217  | 0.158  | 0.211  |        |
| Coefficient of variation| 0.355  | 0.475  | 0.491  | 0.464  | 0.378  | 0.557  | 0.549  | 0.279  | 0.457  | 0.578  | 0.614  | 0.494  | 0.544  |        |
| Skew                    | -0.464 | 1.249  | 0.963  | 0.448  | 0.279  | 0.040  | 0.721  | 0.053  | -0.082 | 0.521  | 0.220  | 0.332  | 1.123  |        |
| Kurtosis                | -0.841 | 1.576  | 0.352  | -0.686 | -0.714 | -1.797 | -0.841 | -0.646 | -1.514 | -1.279 | -1.794 | -1.582 | -0.039 |        |
| Kolmogorov-Smirnov stat | 0.146  | 0.152  | 0.168  | 0.138  | 0.120  | 0.200  | 0.179  | 0.120  | 0.134  | 0.203  | 0.203  | 0.222  | 0.246  |        |
| Critical K-S stat, alpha= 0.10 | 0.369 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 |        |
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|        | Critical K-S stat, alpha=.05 | Critical K-S stat, alpha=.01 |
|--------|------------------------------|------------------------------|
|        | 0.409                        | 0.489                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.375                        | 0.449                        |
|        | 0.391                        | 0.468                        |

4. Conclusion

Generally, it observed that the aerosol loading in Ponta 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. Also, the modified Bessel function shows that the aerosol loading significantly reduce around June of every year, hence, infers that that the research area has high rain rate in June every year. 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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