A simple technique to evaluate aerosols loading in the atmosphere of Lome-Togo

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Abstract. The reality of aerosol loading is synonymous to climate change. According to National Aeronautics and Space Administration (NASA) imagery, aerosol deposition over West is very high compared to other parts of the world. The danger of aerosol loading is grave when in excess and little effort is made by government in the West Africa region to embark on ground measurement of aerosol optical depth (AOD). In this paper, the satellite measurement (Multi-angle Imaging Spectro-Radiometer) was used to obtain the aerosol optical over the research area. The computational analysis was carried out using the MATLAB software. The percentage of increase of aerosols loading was high in 2001, 2005 and 2011 that was 5.7%, 24.5%, 8% and 11.1%. Cumulatively increase of aerosol loading within 15 years was 11.7%. It is therefore recommended that government in the region should be more committed to ground measurement of AOD to ascertain the state of air pollution in the lower troposphere.

1. Introduction

Atmospheric aerosol are pollutants that a minute to cause health challenges. They possess known life-time and can be present in the atmosphere for more than ten years[1]. Atmospheric aerosols can accumulate over the years in the atmosphere. These effect leads to huge health risk ranging from respiratory problems to cancer. The size of a typical aerosol particulate is 0.1μm < d < 2.5 μm. The alphabet’ d represent the diameter of the particulate. Other effect of high aerosol loading over a region includes high atmospheric corrossion, active cloud condensation nuclei (CCN) formation [2-3], unpredictable rain variation and fluctuating solar irradiance.

Atmospheric aerosol particles are realeased into the atmosphere via anthropogenic activities such as biomass burning, agricultural waste, fossil fuel burning, domestic pollution, industrial pollution and automobile emissions. Also, atmospheric aerosol pollution can be from natural agents such as Sahara dust, volcanic activity, whirl wind etc. All this activity has its effect on the global climate system. NASA Goddard Institute for Space Studies concentrated on the climate simulations for 1951–1998 [4]. The SI2000 climate model is an evidence that atmospheric aerosols affects surface temperature sensitivity (3/4 °C per W/m²),aerosols’ radiative forcing [5-7].

According to National Aeronautics and Space Administration (NASA) imagery, aerosol deposition over West is very high compared to other parts of the world [8].The most disturbing angle to this discovery is that the governments over the region have little efforts to fund scientific research on aerosol optical depth (AOD) measurement. At the moment, the AOD over the region can be understood using the satellite measurement. That is the basic reason the West African regional scale dispersion model (WASDM) was borne [8].It has shown huge successes as to determine the average speed of travelling aerosol particulates, average sizes of aerosol particulates, atmospheric constants for some cities and aerosol loading over 70 cities in West Africa.
In this paper, the interest is to determine the aerosol loading over Lome by percentage analysis, the atmospheric constant over the city. The atmospheric constant helps scientists to configure ground measuring device and achieve high measuring efficiencies.

2. Research Site

The research site is an agrarian site, though in recent times, the presence of industry is noticed around the city. The research site is located within latitude and longitude of 6.17° N and 1.35° E respectively. The influx of population into the city center has influenced the level of domestic pollution in the area. Also the influence of the Sahara dust during its dry season have significant influence on its aerosol loading. The research site is located close to the ocean as presented in Figure 1. There is the possibility of marine aerosols influx into the research site.

![Geographical map of Lome](image)

Figure 1: Geographical map of Lome

3. Methodology

The dispersion modalities over the region agrees with WASDM and it is mathematically represented by the listed governing equations i.e.

\[
\frac{\partial C}{\partial t} + V_x \frac{\partial C}{\partial x} + V_y \frac{\partial C}{\partial y} + V_z \frac{\partial C}{\partial z} = \frac{\partial}{\partial x} \left( K_x \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial C}{\partial z} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial C}{\partial y} \right) - P + S
\]  

(1)

\[
V_x \frac{\partial C}{\partial x} = \frac{\partial}{\partial x} \left( K_x \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial C}{\partial z} \right)
\]  

(2)

\[
V_y \frac{\partial C}{\partial y} = \frac{\partial}{\partial x} \left( K_x \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial C}{\partial z} \right)
\]  

(3)

\[V, P, C(x,y,z), K_x, K_y, K_z, S\] represents the wind velocity (m/s), air upthrust, mean concentration [kg/m^3], eddy diffusivities [m^2/s] and S is the source/sink term [kg/m^3s] respectively. The solution for the governing equation was solved using the MATLAB software. The atmospheric constant as well as the yearly aerosol loading was calculated. The yearly aerosol loading was statitically derived from the beta probability distribution and its is statistically written as (Weisstein, 2003):
\[ x = \frac{\tau_j - \tau_{low}}{\tau_{high} - \tau_{low}} \]  
(4)

Where \( \tau_j \), \( \tau_{low} \), and \( \tau_{high} \) are the inputted, lowest and highest AOD respectively. The AOD dataset was fifteen years satellite measurement, that is, Multi-angle Imaging Spectro-Radiometer (MISR). The dataset was first treated using the Microsoft excell program. The average monthly dataset was obtained before the onward processing via the MATLAB software.

4. Result and Discussion

It is observed that AOD over the research site was very scanty (June to September as presented in Figure 2). It was reported by scientists [8-9] that this challenges is caused by natural biases in satellite measurement. The biases originates from Lome has scanty AOD data especially from precipitable water content (in the atmosphere of the measured location), moisture content at point of measurement, cloud scavenging and low rain drop rate. It was reported that rain drop rate also reduce the aerosol loading in the atmosphere [8.9]. The missing data in the two rainy seasons (April to July;September to late November)in Lome show that the rain rate in the research is not potent enough to reducing atmospheric aerosol loading over its atmosphere. The WASDM was used to ascertain the dispersion method over Lome, it was observed that the AOD pattern agreed with WASDM (Figure 3 and Figure 4). It was also observed that the highest AOD was in the month February and the lowest AOD observed in the month of November. WASDM was used to generate the atmospheric constant (Table 1) in the region using the curve-fitting experimentation Figures 3 & 4. The atmospheric constants \( a, b, n, \alpha, \) and \( \beta \) are defined as atmospheric/decay/growth constant \( a \), phase difference \( \alpha \) and \( \beta \), tuning constant \( n \), and multiplier constant \( b \).

![Figure 2: Lome measurement of AOD for 2000 - 2013](image-url)
Figure 3: WASDM verification of AOD in Lome for 2001

Figure 4: WASDM verification of AOD in Lome between 2000-2013
Table 1: Measurement of atmospheric constant in Lome

| Location | $a_1$  | $a_2$  | $n_1$ | $n_2$   | $\alpha$ | B |
|----------|--------|--------|-------|---------|----------|---|
| Lome     | 0.621  | 0.7398 | 0.1997| 0.2936  | $\pi/6$  | $\pi/6$ |

From equation 4 above, it was observed that yearly percentage aerosol loading increases in 2001, 2005 and 2011 were 5.7%, 24.5%, 8% and 11.1% respectively. Cumulatively, it was observed that aerosol loading over Lome increased average by a factor 11.7% in the years under consideration (i.e. 15 years). These results has proven that the air pollution over the research area-Lome has increased beyond the standards highlighted in the UN report [9]. If this pollution is not curbed, there are the possibilities of increased health challenges as well as atmospheric pollution over the research site.

**Conclusion**

It was shown that the air pollution over Lome is currently high. The cumulative aerosol loading over Lome was observed to increase average by a factor 11.7%. This means that the life-form in the region are exposed to high risk of respiratory challenges. More so, there will be an increased rate of atmospheric corrosion. Hence, it is recommended that the government of Togo should endeavour to fund the ground measurement of AOD in the area.

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