Effect of air pollution on agricultural outcome over Faya

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Abstract. It has been reported that aerosol deposition on the leaf is absorbed as nutrient. The proximity of Faya to the Sahara desert has contributed immensely to the net aerosol loading over the area. The aerosol optical depth (AOD) was obtained from satellite measurement (Multi-angle Imaging Spectro-Radiometer). After treating the AOD satellite dataset of fifteen years (2000-2013), aerosol loading over Faya was derived. The dataset is important to understand the yearly aerosol loading influence over the area. In this way, the excess aerosol deposition on the leaf may be detrimental to the health of the plant and hinder its productivity.

1. Introduction

One of the known techniques for looking at the dimension of contamination over a zone is the aerosol optical depth (AOD). The AOD is directly proportional to the air pollution over a geographical area. The sources of air pollution is mainly anthropogenic. However, there are influences of natural pollution sources such as Sahara desert dust influx. Optical properties of airborne particles have extreme impact over the nearby radiative driving and radiation equalization of the earth. The collaboration among vaporized and sun powered radiation can be portrayed by AOD. Hence, AOD can be used to portray the airborne sunlight based radiation are the termination and dispersing coefficients that describe the aerosol transport and accumulation over a geographical area. Airborne optical properties are significantly depicted by the Multi-angle Imaging Spectro-Radiometer (at 500 nm wavelength). The AOD can be characterized as the negative normal logarithm of the portion of sun oriented radiation that isn't dispersed or assimilated on a way by airborne particles. Angstrom exponent depicts the reliance of the AOD on wavelength. There are a few procedures embraced as of late to measure optical properties. For instance, aerosol radiative properties have been utilized to ascertain its optical properties (Calvello et al., 2010)

The water-solvent piece of airborne particles begins from gas to molecule change and comprises of different sorts of sulfates, nitrates, natural and water-dissolvable substances. The residue speaks to the incombustible dark carbon. Mineral airborne or desert dust comprises of a blend of quartz and earth minerals. Antarctic vaporized or sulfate airborne comprises of a lot of sulfate, that is, 75% H2SO4. It is viewed as just for figuring the vaporized optical profundity. In recent time, we begun to estimate the aerosols loading of over fifty towns and cities across West Africa using basically the optical properties. It was observed that the West Africa climate system was very unique and no single model could capture the aerosols loading of more than three towns or cities in West Africa. The West African regional scale dispersion model (WASDM) was then borne because of the necessity to know the current state of pollution over West African cities. WASDM has been validated using the AOD dataset of over sixty locations in West Africa (Emetere et al. 2015, 2016).
In this paper, the primary goal is to measurably and computationally decide the aerosol loading over Faya to see the future dangers that must be promptly evaded. The information gives a decent foundation for further examination on aerosol loading; the information gives specialist essential understanding towards designing sun-photometer over Faya-Chad; the information evaluates the degree of air contamination; the information gives modeler important knowledge on vaporized stacking and maintenance challenges over Faya-Chad. It was reported that aerosol deposition on the leaf is absorbed as nutrient (Burkhardt, 2010). However, our hypothesis is that if much aerosols are deposited on the leaf, it may affect the plant and indirectly affect the productivity of the plant.

2. Experimental Design, Materials and Methods
Faya-Largeau is the largest city in northern Chad and was the capital of the region of Bourkou-Ennedi-Tibesti. The latitude and longitude of Faya are 17°55’32.52”N and 19°6’15.41”E 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 West African regional scale dispersion model (WASDM) is generally governed by three equations i.e.

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

1

\(V, P, C(x,y,z), K, S\) 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. In order to understand the dynamics of the atmospheric convection of the dispersion, equation (1) is resolved in accordance to the lorentz atmospheric convection model.

![Figure 1: Geographical map of Faya](https://l0dup05.larc.nasa.gov/L3Web/download)
Let $\frac{\partial t}{\partial z} \approx \frac{1}{z}$, $\frac{\partial t}{\partial y} \approx \frac{1}{y}$, $\frac{\partial t}{\partial x} \approx \frac{1}{x}$ and $\frac{\partial C}{\partial t} \approx C_t$

\[
\begin{align*}
\frac{\partial C}{\partial z} &= \frac{\partial t}{\partial z} \times \frac{\partial C}{\partial t} \\
\frac{\partial C}{\partial x} &= \frac{\partial t}{\partial x} \times \frac{\partial C}{\partial t} \\
\frac{\partial C}{\partial y} &= \frac{\partial t}{\partial y} \times \frac{\partial C}{\partial t}
\end{align*}
\] (2)

Hence

\[
\frac{\partial C}{\partial z} = \frac{C_t}{z}, \quad \frac{\partial C}{\partial y} = \frac{C_t}{y}, \quad \frac{\partial C}{\partial x} = \frac{C_t}{x}
\]

Let $\frac{\partial}{\partial y} \left( K_y \frac{\partial C}{\partial y} \right) = 0, \frac{\partial}{\partial z} \left( K_z \frac{\partial C}{\partial z} \right) = 0, \frac{\partial}{\partial x} \left( K_x \frac{\partial C}{\partial x} \right) = 0$

Hence, equation (1) becomes

\[
\frac{\partial C}{\partial y} = \frac{C_t}{V_y} + \frac{V_x C_t}{V_y V_x} + \frac{P}{V_y} - \frac{S}{V_y}
\] (3)

since

\[
\frac{\partial t}{\partial y} = \frac{1}{V_y} + \frac{V_x}{V_y} - \frac{V_z}{V_y} + \frac{P}{C_t V_y} - \frac{S}{C_t V_y}
\]

\[
\frac{\partial y}{\partial t} = \frac{V_y}{V_z} \frac{V_x}{V_z} - \frac{C_t V_y}{S}
\] (4)

Let $\alpha = \frac{V_y}{V_z}, \beta = \frac{V_x}{V_z}, \rho = \frac{V_x}{V_z}$

The inverse of equation (4) becomes

\[
\frac{\partial y}{\partial t} = \alpha x - \beta z + \frac{C_t V_y}{p} - \frac{C_t V_y}{S}
\] (5)

Using the same principle,

\[
\frac{\partial z}{\partial t} = \rho x - \frac{y}{\rho} + \frac{C_t V_y}{p} - \frac{C_t V_y}{S}
\] (6)

\[
\frac{\partial x}{\partial t} = \frac{z}{\rho} + \frac{y}{\alpha} - \frac{C_t V_y}{p} + \frac{C_t V_y}{S}
\] (7)

Hence, equations (5-7) describes the the lorentz form. The analysis of equations (5-7) was done using the C++ codes.

3. Results and Discussion

The aerosol optical depth (AOD) is presented in Figure 1. The high peaks can be seen on the averages shown in Table 1. The WASDM was used to derive the aerosol loading over the study area as shown in Table 2. It can be seen that the aerosol loading is high. Hence, the likely aerosol deposition will be high. This means that the stomata of the leaf (Figure 2) may have excess aerosol on its surface. The statistics supports the likeliness of the stomata being affected by aerosols.
Table 1: Summarized Aerosol Optical Depth Dataset over Faya

| Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Jan   | 0.26 | 0.31 | 0.27 | 0.31 | 0.33 | 0.38 | 0.27 | 0.48 | 0.31 | 0.32 | 0.23 | 0.26 |      |      |
| Feb   | 0.45 | 0.29 | 0.38 | 0.40 | 0.46 | 0.54 | 0.39 | 0.30 | 0.37 | 0.33 | 0.41 |      |      | 0.45 |
| Mar   | 0.36 | 0.40 | 0.41 | 0.70 | 0.51 | 0.50 | 0.57 | 0.47 | 0.30 | 0.41 | 0.56 | 0.54 | 0.36 | 0.40 |
| Apr   | 0.64 | 0.73 | 0.82 | 0.62 | 0.55 | 0.67 | 0.40 | 0.72 | 0.55 | 0.55 | 0.73 | 0.67 | 0.64 | 0.73 |
| May   | 0.61 | 0.60 | 0.57 | 0.45 | 0.63 | 0.56 | 0.57 | 0.65 | 0.57 | 0.45 | 0.49 | 0.59 | 0.60 | 0.52 |
| Jun   | 0.51 | 0.42 | 0.44 | 0.56 | 0.47 | 0.67 | 0.59 | 0.45 | 0.49 | 0.59 | 0.60 | 0.52 | 0.51 | 0.42 |
| Jul   | 0.69 | 0.57 | 0.56 | 0.51 | 0.68 | 0.71 | 0.71 | 0.79 | 0.66 | 0.54 | 0.61 | 0.61 | 0.69 | 0.57 |
| Aug   | 0.75 | 0.74 | 0.72 | 0.68 | 0.39 | 0.74 | 0.60 | 0.69 | 0.53 | 0.68 | 0.71 | 1.06 | 0.75 | 0.74 |
| Sep   | 0.60 | 0.41 | 0.54 | 0.49 | 0.49 | 0.51 | 0.45 | 0.40 | 0.54 | 0.51 | 0.49 | 0.39 | 0.60 | 0.41 |
| Oct   | 0.34 | 0.41 | 0.47 | 0.32 | 0.41 | 0.36 | 0.36 | 0.33 | 0.30 | 0.37 | 0.44 | 0.41 | 0.34 | 0.41 |
| Nov   | 0.30 | 0.27 | 0.28 | 0.30 | 0.30 | 0.24 | 0.35 | 0.29 | 0.33 | 0.34 | 0.36 | 0.26 | 0.30 | 0.27 |
| Dec   | 0.27 | 0.27 | 0.26 | 0.23 | 0.27 | 0.31 | 0.26 | 0.25 | 0.35 | 0.28 | 0.27 | 0.27 | 0.27 | 0.27 |

Table 2: Aerosol loading over Faya

| Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Jan   | 0.94 | 0.92 | 0.91 | 0.91 | 0.90 | 0.90 | 0.89 | 0.91 | 0.85 | 0.90 | 0.90 | 0.92 | 0.94 | 0.92 |
| Feb   | 0.94 | 0.86 | 0.91 | 0.88 | 0.88 | 0.86 | 0.83 | 0.88 | 0.91 | 0.89 | 0.90 | 0.88 | 0.94 | 0.86 |
| Mar   | 0.89 | 0.88 | 0.88 | 0.75 | 0.84 | 0.84 | 0.81 | 0.85 | 0.91 | 0.87 | 0.82 | 0.83 | 0.89 | 0.88 |
| Apr   | 0.78 | 0.74 | 0.68 | 0.79 | 0.82 | 0.77 | 0.88 | 0.74 | 0.82 | 0.82 | 0.74 | 0.77 | 0.78 | 0.74 |
| May   | 0.79 | 0.80 | 0.81 | 0.86 | 0.79 | 0.82 | 0.81 | 0.78 | 0.81 | 0.86 | 0.77 | 0.84 | 0.79 | 0.80 |
| Jun   | 0.84 | 0.87 | 0.86 | 0.82 | 0.85 | 0.76 | 0.81 | 0.86 | 0.85 | 0.81 | 0.80 | 0.83 | 0.84 | 0.87 |
Table 3: statistics of aerosols content over Faya

| Statistics          | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  |
|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Number of values    | 10.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 10.00 | 12.00 |
| Minimum             | 0.27  | 0.26  | 0.26  | 0.23  | 0.27  | 0.24  | 0.26  | 0.25  | 0.30  | 0.28  | 0.27  | 0.23  | 0.27  | 0.26  |
| Maximum             | 0.75  | 0.74  | 0.82  | 0.70  | 0.68  | 0.74  | 0.71  | 0.79  | 0.66  | 0.68  | 0.73  | 1.06  | 0.75  | 0.74  |
| Mean                | 0.51  | 0.46  | 0.47  | 0.46  | 0.45  | 0.51  | 0.48  | 0.47  | 0.45  | 0.45  | 0.51  | 0.49  | 0.51  | 0.46  |
| First quartile      | 0.34  | 0.34  | 0.30  | 0.31  | 0.35  | 0.35  | 0.37  | 0.31  | 0.32  | 0.35  | 0.34  | 0.33  | 0.34  | 0.34  |
| Third quartile      | 0.64  | 0.59  | 0.56  | 0.59  | 0.53  | 0.67  | 0.58  | 0.67  | 0.55  | 0.55  | 0.64  | 0.58  | 0.64  | 0.59  |
| Standard error      | 0.06  | 0.05  | 0.05  | 0.05  | 0.04  | 0.05  | 0.04  | 0.05  | 0.04  | 0.04  | 0.05  | 0.07  | 0.06  | 0.05  |
| 95% confidence interval | 0.13  | 0.11  | 0.11  | 0.10  | 0.08  | 0.11  | 0.08  | 0.12  | 0.08  | 0.08  | 0.10  | 0.14  | 0.13  | 0.11  |
| 99% confidence interval | 0.18  | 0.15  | 0.16  | 0.15  | 0.11  | 0.15  | 0.12  | 0.17  | 0.11  | 0.11  | 0.15  | 0.20  | 0.18  | 0.15  |
| Variance            | 0.03  | 0.03  | 0.03  | 0.03  | 0.02  | 0.03  | 0.02  | 0.04  | 0.02  | 0.02  | 0.03  | 0.05  | 0.03  | 0.03  |
| Average deviation   | 0.15  | 0.13  | 0.14  | 0.14  | 0.10  | 0.14  | 0.12  | 0.16  | 0.11  | 0.10  | 0.14  | 0.16  | 0.15  | 0.13  |
| Standard deviation  | 0.18  | 0.17  | 0.18  | 0.16  | 0.13  | 0.17  | 0.13  | 0.19  | 0.13  | 0.12  | 0.16  | 0.23  | 0.18  | 0.17  |
| Coefficient of variation | 0.35  | 0.36  | 0.38  | 0.35  | 0.28  | 0.34  | 0.28  | 0.40  | 0.28  | 0.28  | 0.32  | 0.47  | 0.35  | 0.36  |
| Skew                | -0.15 | 0.51  | 0.60  | 0.09  | 0.31  | -0.10 | -0.05 | 0.47  | 0.02  | 0.38  | -0.11 | 1.44  | -0.15 | 0.51  |
| Kurtosis            | -1.78 | -0.75 | -0.36 | -1.31 | -0.70 | -1.32 | -0.95 | -1.51 | -0.83 | -1.54 | 2.99  | -1.78 | -0.75 | -0.75 |
| Kolmogorov-Smirnov stat, alpha=.10 | 0.21 | 0.19  | 0.15  | 0.14  | 0.13  | 0.17  | 0.17  | 0.17  | 0.20  | 0.16  | 0.15  | 0.17  | 0.21  | 0.19  |

The penetration of the aerosols into the stomata of the leaf can be inferred from the Kolmogorov-Smirnov as inferred by (Burkhardt et al., 2012).
Figure 3: The stomata mechanism that aid aerosol absorption (Source: askabiologist.asu.edu)

4. Conclusion
From the aerosol loading and statistical evidence, it can be inferred that the excess deposition of atmospheric aerosol is not advantageous to well-being of plants especially in regions of high aerosol loading. Hence, technical experiments show that the detailed absorption of aerosol at the stomata is required to further confirm the hypothesis presented in this paper.

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