Theoretical Aid for Measuring Instruments in Niamey-Niger

Moses E. Emetere, Marvel L. Akinyemi, Omololu Akinojo

***Abstract*—The frequent failures of ground measuring devices e.g. radiosonde, weather stations in developing regions is worrisome. At the moment, AERONET or AMMA database shows a large volume of data loss. With only about 47% data set available to scientist, it is evident that accurate nowcast or forecast cannot be guaranteed. We propose that the challenge is not measuring device design error but systemic. A dispersion model was adopted from previous work to incorporate salient mathematical representations like Unified number. Fourteen years data set from Multi-angle Imaging SpectroRadiometer (MISR) was tested using the dispersion model. It revealed that the average atmospheric constant for Niamey-Niger is a_1 = 0.77975, a_2 = 0.693021 and the tuning constants is n_1 = 0.140187 and n_2 = 0.759236. Also, the yearly atmospheric constants affirmed the lower atmosphere of Niamey is very dynamic. Hence, it is recommended that radiosonde and weather station manufacturers should constantly review the atmospheric constant over a geographical location to enable about eighty percent data retrieval.**

***Index Terms*—Atmospheric constant, dispersion model, unified number, aerosols, Niamey**

I. Introduction

THE atmosphere is made up of a non-uniform spread of minute gas molecules or suspended particles in form of liquid gas or solid [4,6]. The spread of the particulates depends on the aerosol ejection sources present in the atmosphere or on the earth [5,7]. The spread of aerosol over a region scatters or absorbs light from the sun. Other atmospheric constituents that scatters or absorbs light includes; methane, ozone, nitrogen oxides, carbon(IV) oxide and water vapour.

Bock et al. [2] documented the biases of the radiosonde except for MODEM M2K2 sondes whose humidity biases are not known. Vaisala RS80-A sondes had large dry biases and Vaisala RS92 had weakly moist biases. The unknown biases of the MODEM M2K2 sondes and the lost of TEMP messages from reliable ground and satellite observations is a further affirmation of the need to document the atmospheric constants over geographical location such as Niamey (Nuret et al., [9]. To obtain the atmospheric or calibration constant over a geographical location, a long-term satellite or ground observations of aerosol and clouds are essential. Before now, calibration constant was obtained from standard laboratory lamps with low successes, that is, leading to the lost of TEMP messages.

The West Africa climate system is unique, hence a long-term satellite or ground observations of aerosol is needed to design and develop a mathematical model that would incorporate the independent atmospheric motion vectors [1] and inability of moisture convergence over the Sahel region [8].

In our previous research (Emetere et al., 2015b), we have designed a mathematical model that operates on a parametric retrieval mode. In this paper, we developed on the model to obtain the atmospheric constant over Niamey.

The use of automatic weather stations in developing regions like Niamey without reconfiguring the constants encrypted in the compact flash card engenders errors in weather forecast or data assimilation. A poor weather forecast translates to a fall in agricultural, forest and grazing production [3]. Hence, the need to generate reliable constants within Niamey is novel. In section two, the designed model reported earlier [7] was developed to reflect the Unified number derivations and kinetic aerosol layer transport. The methodology adopted to obtain the atmospheric constant over Niamey was discussed in section three. In section four, the acquired results were illustrated.

II. METHODOLOGY

Emetere and Akinyemi [4] propounded the 3D plume model. The model was initially used to investigate the pollution from cement factory. The model showed excellent correspondence with the pollutant dispersion and depositions around the factory. The governing equation was given as

$$\frac{\partial C}{\partial t} + V_x\frac{\partial C}{\partial x} - V_z\frac{\partial C}{\partial z} - V_y\frac{\partial C}{\partial y} = \frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{z2}\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_{y2}\frac{\partial C}{\partial y}\right) - P + S \quad (1)$$

Here, V is the wind velocity (m/s), P is the air upthrust, x is the wind coordinate measured in wind direction from the source, y is the cross-wind coordinate direction, z is the vertical coordinate measured from the ground, C(x,y,z) is the mean concentration of diffusing pollutants of diffusing substance at a point (x,y,z) [kg/m^3], Ky, Kz is the eddy

Manuscript received February 13, 2016; revised April 13, 2016.This work was supported in part by Covenant University.

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ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

diffusivities in the direction of the y- and z- axes [m^2/s], S is the source/sink term [kg/m^3-s]. The logarithmic distribution of the wind speed and exponential function form of turbulent diffusivity was incorporated into the refined equation (1). However, the turbulent diffusivity with its corresponding wind speed cannot be related by mere assumption and subsequent use of the Kriging interpolation method.

The raw MISR dataset was processed using Spread Sheet Application (Excel). The monthly mean was calculated for each year. We tested the accuracy of the data by applying the aerosol dispersion model that was propounded by Emetere et al. (2015a). An extension of the dispersion model used is given as

$$\psi(\lambda) = a_1{}^2\cos\left(\frac{n_1\pi\tau(\lambda)}{k_y} + \alpha\right)\cos\left(\frac{n_1\pi\tau(\lambda)}{k_z} + \alpha\right) + a_2{}^2\cos\left(\frac{n_2\pi\tau(\lambda)}{k_y} + \beta\right)\cos\left(\frac{n_2\pi\tau(\lambda)}{k_z} + \beta\right) \quad (2)$$

Here, α and β are the phase differences, k is the diffusivity, τ is the AOD, ψ is the concentration of contaminant, λ is the wavelength, 'a' and 'n' are atmospheric and tuning constants respectively.

The MISR operates at various directions i.e. nine different angles (70.5°, 60°, 45.6°, 26.1°, 0°, 26.1°, 45.6°, 60°, 20.5°) and gathers data in four different spectral bands (blue, green, red, and near-infrared) of the solar spectrum.

The blue band is at wavelength 443nm, the green band is at wavelength 555nm, the red band wavelength 670nm and the infrared band is at wavelength 865nm. MISR acquire images at two different levels of spatial resolution i.e. local and global mode. It gathers data at the local mode at 275 meter pixel size and 1.1Km at the global mode. Typically, the blue band is to analyze coastal and aerosol studies. The green band is to analyze Bathymetric mapping and estimating peak vegetation. The red band analysis the variable vegetation slopes and the infrared band analysis the biomass content and shorelines.

III. METHODOLOGY

The aerosol optical depth (AOD) for Niamey, Niger republic is shown in Figure 1a-j. The table of compliance to the lines of action is illustrated in Table 1. The lines of action are months with the highest frequency within the fourteen years observation. March, August and October has the peaks of the year while July has the major low. Table 1 illustrates the reliability of the long term aerosols dataset to be used for calibration purposes. Hence, the probability of obtaining reliable results from the satellite observation of Niamey, Niger is 0.518. For this analysis, we picked the wavelength with the highest AOD i.e. 440 nm.

Table 1: reliability of the long-term aerosol dataset.

Year	L1	L2	L3	L4
2000		✓	✓	✓
2001				✓
2002	✓	✓	✓	✓
2003	✓	✓	✓	✓
2004	✓	✓	✓	
2005	✓			
2006	✓	✓	✓	
2007	✓	✓	✓	
2008				
2009		✓		
2010	✓			
2011	✓			
2012		✓		
2013	✓	✓	✓	

The yellow boxes in Table 1, shows that 2000, 2002, 2003, 2004, 2006, 2007, and 2013 have high probability of determining its atmospheric constant. AOD pattern for 2005, 2008, 2010 and 2011 showed a stable non-conformity. Only 2009 and 2012 showed a distinct non-conformity. Hence, the estimation of the atmospheric constants over Niamey using equation (2) has the possibility of 87.5% success.

We earlier clarified in section three that equation (2) would be fitted into the Matlab curve fitting tool to resolve the constants for each MISR dataset. The constants obtained via the curve fitting tool are referred to as the atmospheric constants which are expressed in years as shown in Figure 1a-j. In the year 2000 (Figure 1a), the proposed model fairly described the MISR data (represented by line dot and thick lines respectively). The proposed model determined the AOD for five months i.e. March, May, August, September and October. The proposed model determined the AOD value for nine months in 2001 (Figure 1b); five months in 2002 and 2006 (Figures 1c and 1g); six months in 2003 to 2005 (Figure 1d-f); eight months in 2007 (Figure 1h); seven months in 2008 and 2010 (Figures 1 e and & f); six months in 2009 and 2011 (Figure 1g and 1h); five months in 2012 (Figure1i); seven months in 2013 (Figure 1j).

In the average, the atmospheric constant for Niamey-Niger for fourteen years is a_1 = 0.77975, a_2 = 0.693021, n_1 = 0.140187 and n_2 = 0.759236. n_1 and n_2 refers to the tuning constants while a_1 and a_2 refers to the atmospheric constant required for the accurate calibration of measuring devices in Niamey-Niger. The constants are configured into the compact flash card which may be written in python.

IV. CONCLUSION

The reliability of the fourteen years MISR dataset was tested via the aid of 'action lines' which describes months of highest frequency within the dataset. The reliability test affirmed the possibility of 87.5% success when the long-term aerosols dataset is used. We used the instrumentality of equation (2) to obtain the atmospheric constants via the Matlab curve fitting tool. The curve fitting tool showed that the proposed model could predict a minimum of five months and maximum of eight months within any year in Niamey. These results further buttress on the authenticity of the atmospheric constants over the troposphere of Niamey. The highest atmospheric and tuning constants were obtained in 2000 and 2013 respectively. It further revealed that the average atmospheric constant for Niamey-Niger is a_1 = 0.77975, a_2 = 0.693021, n_1 = 0.140187 and n_2 = 0.759236. Hence, the objective of the paper, that is, to document the atmospheric constant over Niamey was successfully achieved. This simply means that radiosonde and other measuring instrument could achieve over eighty percent data acquisition on a daily basis if the atmospheric constants calibrated accordingly.

ACKNOWLEDGMENT

The authors appreciate NASA for generously allowing us use their data sets. The authors recognize the partial sponsorship of their host institution. The authors appreciate the contribution of the reviewers.

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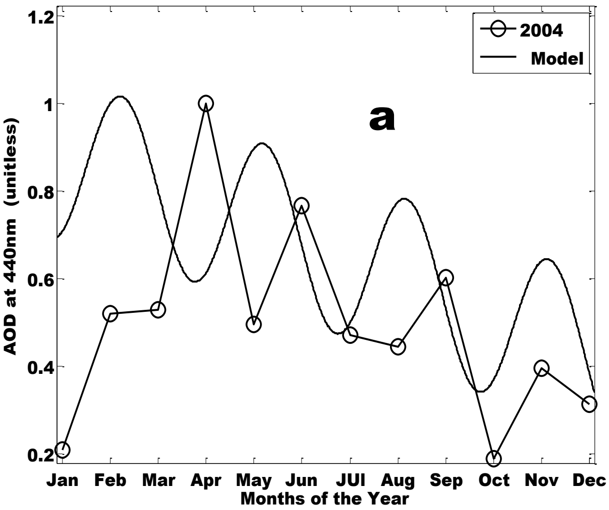

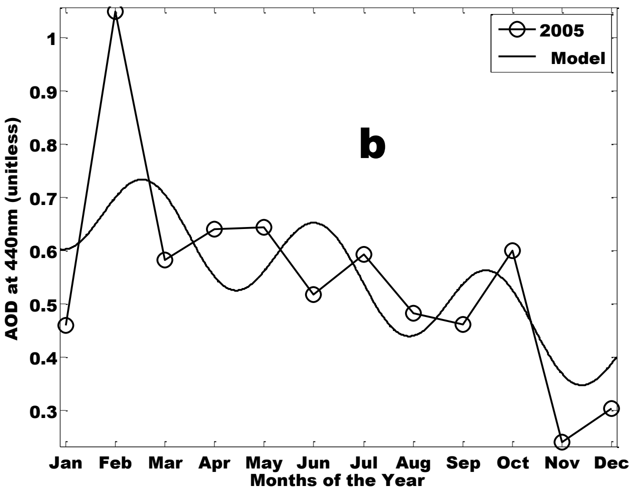

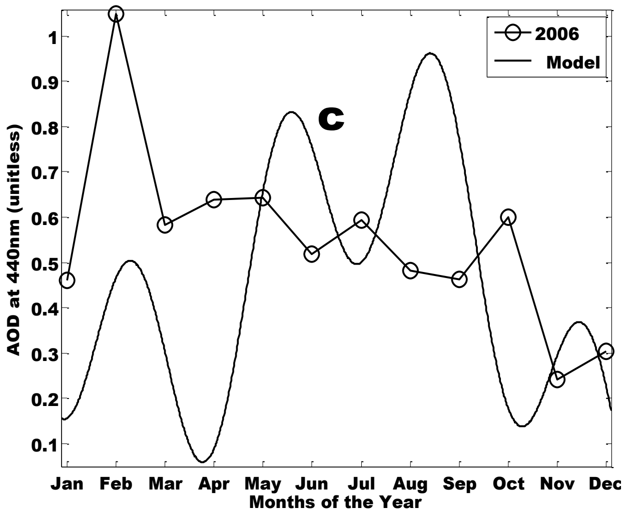

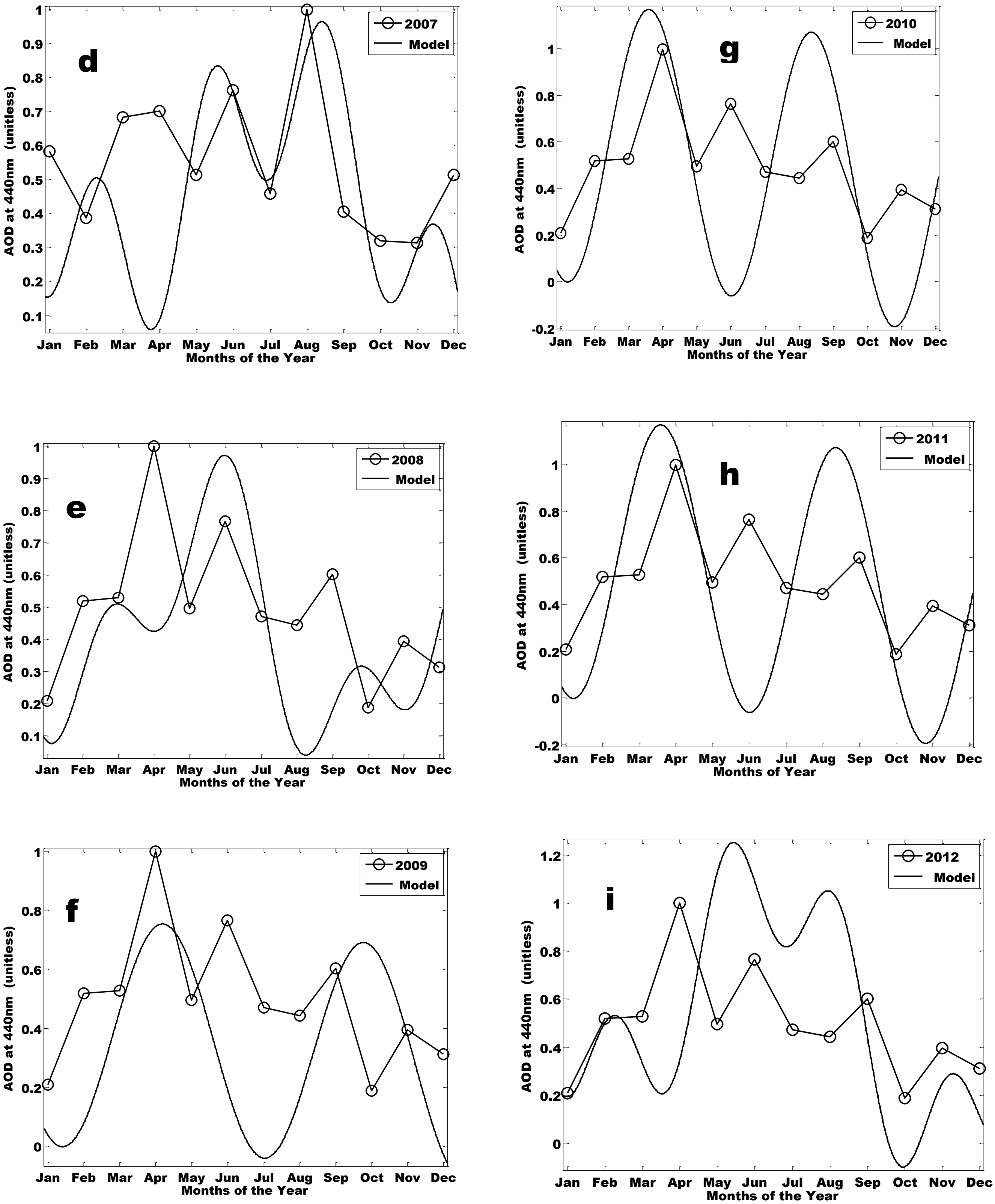

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

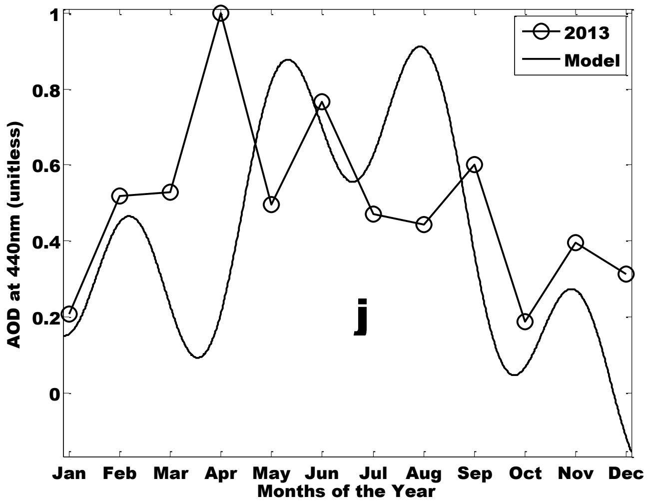

Fig. 1. Fourteen years AOD pattern at 440nm

Table 2: Atmospheric constants for Niamey with errors of ±0.01

Year	a_1	a_2	n_1	n_2
2000	0.8394±0.01	1.357±0.01	0.1129±0.01	0.8819±0.01
2001	0.8667±0.01	1.137±0.01	0.1074±0.01	0.9848±0.01
2002	0.7035±0.01	0.7578±0.01	0.2388±0.01	0.7797±0.01
2003	0.9213±0.01	0	0	0.4746±0.01
2004	0.6092±0.01	1.192±0.01	0.01576±0.01	0.8934±0.01
2005	0.4084±0.01	1.114±0.01	0.01346±0.01	0.7647±0.01
2006	0.7145±0.01	0.7876±0.01	0.2596±0.01	0.8587±0.01
2007	0.7145±0.01	0.7876±0.01	0.2596±0.01	0.8587±0.01
2008	0.6525±0.01	0.7952±0.01	0.3604±0.01	0.7569±0.01
2009	0.8764±0.01	0	0	0.4747±0.01
2010	1.092±0.01	0	0	0.5551±0.01
2011	1.092±0.01	0	0	0.5551±0.01
2012	0.7373±0.01	0.9673±0.01	0.3062±0.01	0.8871±0.01
2013	0.6888±0.01	0.8068±0.01	0.2885±0.01	0.9039±0.01

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)