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Atmospheric configurations of aerosols loading and retention over Bolgatanga-Ghana

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Abstract. Bolgatanga is located on latitude of 10.78 °N and longitude 0.85 °W. This research is aimed to estimate the aerosols loading and retention over Bolgatanga-Ghana through a conceptual model that is made up of analytical, statistical and Matlab curve-fitting tool. The model's accuracy was established over the aerosol optical depth for a thirteen-year satellite data set from the Multi-angle imaging spectro-reflectometer (MISR). The maximum aerosol retention was 31.73%. Its atmospheric constants, tuning constants and the phase difference over Bolgatanga was found to 0.67, 0.24 and $\pm\pi/4$ respectively. The phase difference expresses the different kinds of network topologies and beam forming methods for measuring devices that may be used in Bolgatanga. Therefore a good estimation of the aerosols loading and retention over Bolgatanga, we may be in the best position to controlling its effect on health, farming, rainfall pattern, cloud formation and regional climate.

1. Introduction

Studies on the significance of aerosols on climate change have received considerable attention in recent years. Several remote sensing techniques have been deployed in the past with the zest to gain insight or better understanding of the effects of aerosols on climate change. Such remote sensors read-off large volumes of data which suffices for the spatial and temporal coverage of the areas or vicinities under study. For scientific applications, it is pertinent that such data are qualitative. For example, data obtained from ground remote sensing have been previously used for understanding aerosol effects on atmospheric heat budget as reported in Cloud Screening of Sky Radio Meter Data Manual [1-4], validating satellite measurements [5] and model simulations [6].

Mathematical modeling of the removal of liquid aerosols from gases flowing through channels without any form of packing and channels filled with fine random packing was carried out by Anatoly et al [7]. Some conservation/governing equations for aerosols were established. For the separation efficiency of aerosols in the packed bed layer, a convective mass transfer equation was adopted. Some assumptions were made and a 3D equation describing steady state mass transfer of aerosols was obtained. A particle deposition velocity was established in relation to the particle relaxation time. The finite difference technique was employed in the numerical solution. Also, the work of Chan et al [8] presents an equilibrium kinetic model of secondary organic aerosols (SOA). They employed the model as a way of examining the effects of SOA formation of the gas phase oxidation of the products initially generated to more or less volatile species. From the findings, it is evident that, while different controlling/interacting mechanisms can lead to differing SOA growth behavior, it becomes generally impossible to deduce the actual mechanism for SOA formation with absolute dependence of the SOA growth data.



In this paper we examine a conceptual model to estimate the aerosols loading and retention over Bolgatanga. It would greatly assist in projecting its negative effects on health, agriculture and communication in the future.

2. Source of Data and location

Bolgatanga is the fourth most crowded city in northern Ghana and it is situated on longitude 0.85°W and latitude 10.78°N in the Sahelian geographic locale south of the Sahara, henceforth, we expect a high effect of the north east winds from close by Sahara desert. Likewise, it is additionally affected by the neighborhood steppe atmosphere. Its metropolitan enclave is around 499 km². Bolgatanga has normal temperature and precipitation of 26.1 °C and 752 mm individually. The distance of Bolgatanga to the Sahara is around 2826 km. Before now, no aerosols ground data was accessible; consequently, the satellite is generally accepted. Fourteen years satellite observation was gotten from the Multi-angled Imaging SpectroRadiometry (MISR). The details of the MISR are given by Emeterere [9].

3. Methodology

A statistical approach [9] was adopted. The raw MISR dataset was processed using Excel. The mean for every month was figured all as the year progressed. We tried the precision of the information by applying the airborne scattering model that was propounded by Emeterere et al.[10]. An expansion of the scattering model utilized is given as

$$\psi(\lambda) = a_1^2 \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} + \alpha\right) \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} + \beta\right) + \dots \dots a_n^2 \cos\left(\frac{n_n \pi \tau(\lambda)}{2} + \alpha\right) \cos\left(\frac{n_n \pi \tau(\lambda)}{2} + \beta\right) \quad (1)$$

Here α and β are the stage contrasts or the phase difference, k is the diffusivity, τ is the AOD, ψ is the convergence of contaminant, λ is recognized as the wavelength, 'a' is the environmental or atmospheric constant and 'n' is the tuning constants.

The rate of maintenance can be resolved from the coefficient of difference for every year. This was finished by considering the past and current years which are indicated separately as G_p and G_r respectively. Thus we propound that the aerosol retention between two years as:

$$A = \left| \frac{G_r - G_p}{G_r} \right|^2 \times 100\% \quad (2)$$

The aerosols retention can be figured from Tables 2-3 to acquire Tables 4-5. Any factual instrument could be utilized to get the aerosols retention. In this paper, the Matlab and Excel bundles were utilized to acquire the outcomes that are reported in the ensuing segment

4. Results and Implications

The Bolgatanga monthly AOD trend agreed perfectly with the proposed model (see Figures 1 to 2). The AOD pattern over Bolgatanga is a gamma distribution with the average maximum in March. From Figure 2, it can be inferred that the type of aerosols in the area are majorly dust particulates from the northeast wind. The AOD retrieval technique by MISR is perfect over Bolgatanga. A trivial explanation is that the area falls within the satellite orbit. Beyond the trivial reason, Bolgatanga has a more stable weather compared to other parts of the country.

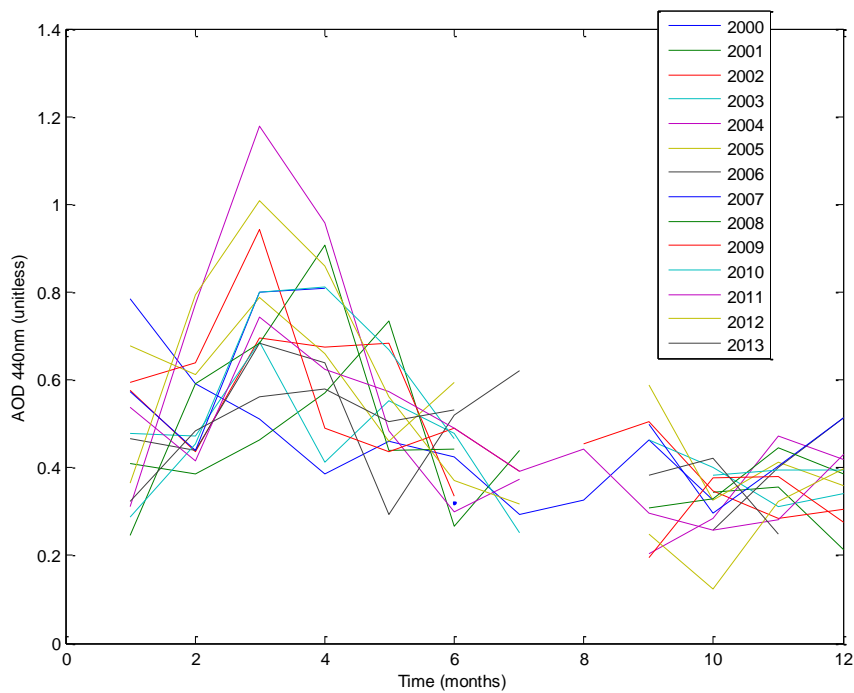


Figure 1. AOD pattern for Bolgatanga (2000 – 2013)

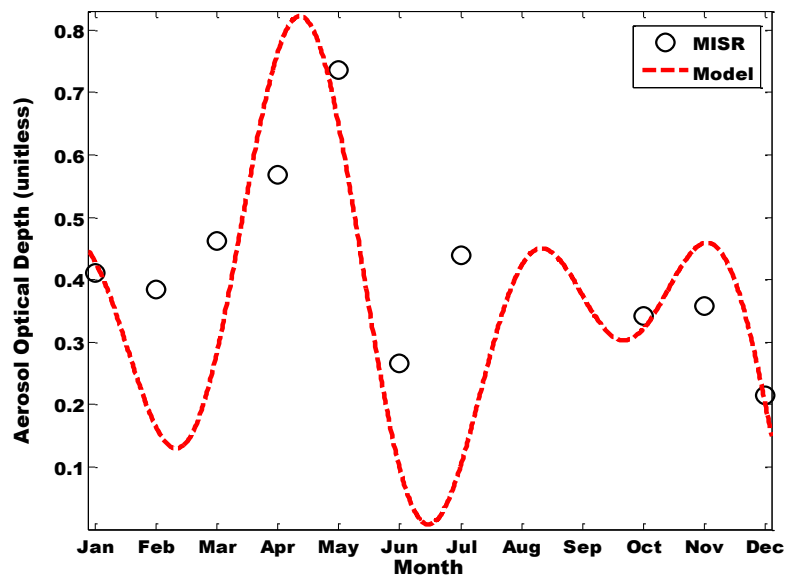


Figure 2. AOD for new model and MISR for the year 2002

Figures 2 give the model predictions and the data generated from satellite. In Figure 2, the aerosol optical depths as obtained from the satellite (MISR) image agrees with the AOD predictions of the model for the year 2000 for all other months except that slight deviations can be seen in the months of July, August, October and November. In Figure 4, the AOD estimated for the year 2002 from by the model seems to agree with those of the MISR for all other months except for the clear deviation in March and slight deviations in the months of May, June, October, November and December. From

Figure 1 to 2, the environmental constants, stage contrasts and tuning constants can be acquired from the Matlab and equation (2) as appeared in Table 1 underneath

Table 1. Atmospheric constants over Bolgatanga

Location	a_1	a_2	n_1	n_2	α	β
Bolgatanga	0.667	0.6403	0.242	0.1515	$\pm \frac{\pi}{4}$	$\pm \frac{\pi}{4}$

Note that this paper do not query the unwavering quality of the ITU model but suggests that aerosol retention should be incorporated into the ITU model as shown in equation (3).

$$N = \frac{77.6P}{T} + 3.73 \times 10^5 \frac{e}{T^2} = N_{dry} + N_{wet} \quad (N - units) \quad (3)$$

where e represent the water vapor pressure, P is the atmospheric or barometric pressure (hPa) and T is the total temperature (K). The numerical connection between relative humidity and water vapor pressure is communicated in the accompanying equation:

$$e = \frac{RH}{100} a \exp \left[\frac{bT}{T+c} \right] \quad (4)$$

Here, temperature T in the above equation is given in °C and the coefficients a, b and c is given as: a = 6.1121, b = 17.502 and c = 240.97. Leck and Svensson [11] gave the assurance that the coefficients a, b and c are impacted by the optical state over a topographical area. This paper hence proposes the ITU model requires the addition of the environmental constants to understand the signal budgeting over Bolgatanga. By this idea, we factually analyzed the AOD loading over Bolgatanga as appeared in Tables 2 and 3.

In 2005, the highest 99% confidence interval, standard deviation variance, AOD mean, 95% confidence interval and coefficient of variation were obtained. The highest skew and kurtosis can be found in 2010. The highest Kolmogorov-Smirnov stat can be found in 2004. The most noteworthy AOD mean, 95% certainty interim, 99% certainty interim, fluctuation, standard deviation and coefficient of variety were acquired in 2005. The most astounding skew and kurtosis can be found in 2010. The most noteworthy Kolmogorov-Smirnov detail can be found in 2004. This outcomes demonstrates that the lower air of Bolgatanga may not be as dynamic as those of urban communities in in West Africa [12]. Henceforth we analyzed the aerosol retention in Tables 5 and 6.

Table 2. Statistical AOD analysis 2000-2006

Statistical Tool	2000	2001	2002	2003	2004	2005	2006
Standard Error	0.047	0.047	0.047	0.036	0.094	0.048	0.045
95% confidence interval	0.105	0.107	0.105	0.08	0.209	0.108	0.101
99% confidence interval	0.151	0.154	0.15	0.114	0.298	0.155	0.146
Variance	0.022	0.022	0.025	0.014	0.097	0.023	0.02
Standard deviation	0.147	0.149	0.157	0.119	0.312	0.15	0.142
Coefficient of variation	0.323	0.357	0.326	0.271	0.595	0.275	0.293
Skew	1.258	0.945	0.236	0.468	1.234	-0.12	-0.231
Kurtosis	1.799	1.326	-1.588	0.818	0.526	-1.05	-0.845
Kolmogorov-Smirnov stat	0.185	0.184	0.168	0.196	0.279	0.203	0.132

Considering the data in Table 2, the estimated variances show that the highest deviation of the estimated monthly means from the 13-year mean was obtained for the year 2005 which reveals that it is farthest from the 13-year mean with that of 2001 showing the least deviation. From the estimated standard deviations, it is clear that the amount/degree of aerosol dispersion of the monthly means from the 13-year mean is lowest for the year 2001 with the highest seen in the year 2005; those of other years lie between these values.

Table 3. Statistical AOD analysis 2007-2013

Statistical Tool	2007	2008	2009	2010	2011	2012	2013
Standard Error	0.062	0.063	0.061	0.064	0.042	0.085	0.038
95% confidence interval	0.142	0.142	0.135	0.148	0.093	0.189	0.087
99% confidence interval	0.207	0.205	0.192	0.216	0.131	0.269	0.126
Variance	0.034	0.04	0.04	0.037	0.021	0.079	0.013
Standard deviation	0.185	0.199	0.201	0.193	0.146	0.281	0.113
Coefficient of variation	0.358	0.417	0.424	0.372	0.319	0.576	0.251
Skew	0.689	1.204	1.164	0.723	0.437	0.794	-0.646
Kurtosis	-0.56	1.282	2.211	-1.08	-0.23	-0.54	-0.624
Kolmogorov-Smirnov stat	0.172	0.266	0.193	0.271	0.125	0.262	0.176

In Tables 4 and 5, two years that have the highest atmospheric aerosols retention were 2004 and 2013. Hence, skew and kurtosis may be used as perfect indicators to determine atmospheric aerosols retention. The relevance of the atmospheric aerosols retention over a region has incredible impact on aeronautics plans [13], human wellbeing [14], measuring instruments, earth's energy budget and meteorology [15].

Table 4. Atmospheric aerosols retention over Bolgatanga 2001-2006

	2001	2002	2003	2004	2005	2006
Aerosol deposition	1.13	0.76	2.89	29.72	29.02	0.44

Table 5. Atmospheric aerosols retention over Bolgatanga 2007-2013

	2007	2008	2009	2010	2011	2012	2013
Aerosol deposition	4.89	2.75	0.03	1.51	2.01	64.27	31.73

5. Conclusion

The new model seems to be somewhat reliable based on the accurate predictions as compared with satellite data. Hence, the estimation of the aerosols loading and retention over Bolgatanga-Ghana through a conceptual model that is made up of analytical, statistical and Matlab curve-fitting tool was a huge success. However, slight modifications ought to be made in order to improve on the model's accuracy. The aerosol distribution for all other years was found to be platykurtic except for the year 2010 which shows a leptokurtic distribution. However, all other years had normal aerosol distribution. Also, all the years considered, show a random distribution of the aerosols. The maximum aerosol retention was 31.73%. Its atmospheric constants, tuning constants and the phase difference over

Bolgatanga was found to 0.67, 0.24 and $\pm\pi/4$ respectively. The phase difference expresses the different kinds of network topologies and beam forming methods for measuring devices that may be used in Bolgatanga.

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