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RESEARCH ARTICLE

INVESTIGATING A FITTING FUNCTION FOR THE DISTRIBUTION OF AEROSOLS BY DIAMETER BETWEEN 0.1 –3.0MM IN N'DJAMÉNA – CHAD

***Njipouakouyou Samuel**

Department of Physics, Faculty of Pure and Applied Sciences, University of N'djaména–Chad

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ABSTRACT

On the base of the data set from the measurements during round-trip flights executed in the period from 2014 to 2015over N'djaménaand after its numerical treatment by the least square method, we have established that the distribution of aerosols by diameter can be best fitted by a negative power function for atmospheric layers below height 4000 m above the earth surface; the particles which are very active in atmospheric processes such as cloud and precipitations formation are smaller ones with diameter less or equal to 0.5 µm; there is high relationship between the diameter and the concentration of particles at a given level, particularly during the rainy season and layers < 4000m during the dry season.

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INTRODUCTION

Aerosols have been studied by many authors, (Zhou *et al.*, 1981; Chen *et al.*, 1996; Shi *et al.*, 1996; Sun *et al.*, 1996; Wang *et al.*, 1994). They have highlighted the importance of these particles in cloud and precipitations processes. They also indicated their great differences in temporal and spatial distributions. The specific purpose of our investigation is to establish a fitting relationship between diameter and concentration of the particles on the base of measurements made during round-trip flights over N'djaména. The established formulas will permit to estimate the concentration of aerosols by a given diameter and to determine the spectra of particles which arepredominantand whose interactions are decisive in atmospheric processes at the considered level. This paper is divided into four sections and the references. The first and present one introduces the problematic of the subject. The second provides information on data set and methodology. The results of investigation are presented and analyzed in the third section. The conclusion is given in the fourth section and the references in the alphabetic order closes the work.

DATA AND METHODOLOGY

Data: This data set comes from the measurements made during round-trip over N'djaména in 2014 – 2015 in the program OPEN, meaning in full: "Opération Ensémencement des Nuages", in French. Recall that N'djaména is the capital of the country. It is not industrialized at all, but it has a lot of vehicles and big buildings. It is under the influence of the desert of Sahara. The measurements were made from an aircraft which spirally ascended the sky of the city till about 6000 m above the earth surface. It was equipped with many instruments, between others the one which interest us: a PMI – PCASP – 100X probe to measure the concentration and diameter of aerosols in the range 0.1 – 3.0 µm. Two representative flights were considered, one at the beginning of the rainy season on 18.06.2014 and another in the dry season on 11.11.2015. The round-trips were made at the following levels: 900m, 970m, 1950m, 2500m, 2900m, 4000m, and 4800 m.At each level the aircraft did at least five round-trips. Hence, the data set analyzed was quite extensive.

Corresponding author: **Njipouakouyou Samuel**
Department of Physics, Faculty of Pure and Applied Sciences, University of N'djaména–Chad

MATERIALS AND METHODOLOGY

At eachlevel indicated aboveand for each diameter, an average concentration of particles was determined.Thus, we obtained a set of experimental points M(D, n) where D is the diameter and n – the concentration of particles. Then we plotted these points in a coordinate axes with D on the ox axis and n – on the oy axis. We obtained a cloud of points whose configuration was analyzed for finding the form of the relationship n(D) between D and n, and then the analytic expression of that function.

RESULTS AND ANALYSIS

The analysis of the configurations of clouds of points brought us to the conclusion that the searched relationship between D and n has a negative power form. Thus, its analytic expression is of the form:

$n(D) = bD^{-a}$, a> *0*, b> *0*. …………………..(3.1)

a and b are coefficients to be determined using the least square method. To easy this job, (3.1) should be linearized with the logarithmic functionin both members. So, (3.1) becomes:

$lg(n) = alg(D) + lg(b)$, ……………………(3.2)

where "lg" is the logarithm in base 10. Letting y = lg(n), x = lg(D) and B = lg(b), (3.2) gives:

$y = ax + B$. …………………….(3.3)

Height 2500 m.

$y = -1.4359x + 0.2126$; R = 0.9746; $n(D) = 1.6315D^{-1.4359}$.
Height 4800 m.

$y = -0.8334x + 0.2514$; R = 0.8893; $n(D) = 1.7840D^{-0.8334}$.
Flight of 11.11.2015.
Height 970 m.

$y = -1.5825x + 0.0303$; R = 0.9622; $n(D) = 1.0722D^{-1.5825}$.
Height 1950 m.

$y = -1.5884x - 0.0048$; R = 0.9713; $n(D) = 1.0111D^{-1.5884}$.
Height 2900 m.

$y = -1.5908x - 0.6941$; R = 0.9608; $n(D) = 0.2022D^{-1.5908}$.
Height 4000 m.

$y = -2.1950x – 1.0941$; R = 0.8881; $n(D) = 0.0805D^{-2.1950}$.
Height 4800 m.

Table 3.1. Experimental (n_{exp}) and theoretical (n_{th}) values of the concentration of aerosols at different heights and periods in N'djaména – Chad

D µm	H=970m 18.06.2014 n_{exp}	H=970m 18.06.2014 n_{th}	H=970m 11.11.2015 n_{exp}	H=970m 11.11.2015 n_{th}	H=4800m 18.06.2014 n_{exp}	H=4800m 18.06.2014 n_{th}	H=4800m 11.11.2015 n_{th}	H=4800m 11.11.2015 n_{th}
0.1	111.86	105.83	37.31	41.00	14.40	12.16	5483.79	1003.69
0.11	54.32	86.88	23.26	35.26	7.52	11.23	4897.70	728.22
0.12	51.31	72.56	19.35	30.73	7.93	10.44	1510.14	543.33
0.13	49.98	61.49	20.09	27.07	7.61	9.77	799.53	415.00
0.14	52.75	52.74	30.71	24.07	9.24	9.18	1435.28	323.37
0.15	49.50	45.73	21.91	21.58	8.41	8.67	208.56	256.35
0.16	28.10	40.01	13.27	19.49	4.86	8.22	629.36	206.30
0.17	27.39	35.29	13.31	17.71	5.18	7.81	691.68	168.21
0.18	25.52	31.35	13.84	16.17	5.14	7.45	646.94	138.77
0.20	46.27	25.21	24.68	13.69	9.61	6.82	942.00	97.34
0.22	37.42	20.70	21.52	11.77	8.58	6.30	432.74	70.62
0.24	30.23	17.29	18.15	10.26	7.56	5.86	121.74	52.69
0.26	22.36	14.65	14.12	9.04	6.14	5.48	17.03	40.25
0.28	16.08	12.56	9.71	8.04	4.92	5.15	1.35	31.36
0.30	13.58	10.89	9.95	7.21	5.41	4.87	0.61	24.86
0.4	12.87	6.01	7.02	4.57	8.36	3.83	0.39	9.44
0.5	2.19	3.78	2.16	3.21	4.46	3.18	0.15	4.45
0.6	0.79	2.60	1.09	2.41	2.54	2.73	0.08	2.41
0.8	1.50	1.43	2.00	1.53	5.01	2.15	0.08	0.92
1.0	0.90	0.90	1.07	1.07	2.98	1.78	0.02	0.43
1.2	0.57	0.62	0.88	0.80	1.75	1.53	0.01	0.23
1.4	0.43	0.45	0.57	0.63	1.33	1.35	0.00	0.14
1.6	0.18	0.34	0.31	0.51	0.83	1.21	0.01	0.09
1.8	0.30	0.27	0.43	0.42	1.04	1.09	0.00	0.06
2.0	0.24	0.21	0.30	0.36	0.85	1.00	0.00	0.04
2.2	0.24	0.18	0.36	0.31	0.93	0.92	0.01	0.03
2.4	0.18	0.15	0.27	0.27	0.83	0.86	0.00	0.02
2.6	0.17	0.12	0.21	0.24	0.64	0.80	0.00	0.02
2.8	0.09	0.11	0.16	0.21	0.49	0.76	0.00	0.01
3.0	0.08	0.09	0.31	0.19	0.57	0.71	0.01	0.01

The numerical treatment of the set of data for each flight and height gives us the equation of regression, formula (3.3), the coefficients of correlation, R, and the searched negative power function which are as follows:

Flight of 18.06.2014.

Height 900 m.

$y = -1.6302x + 0.1384$; R = 0.9738; $n(D) = 1.3753D^{-1.6302}$.
Height 970 m.

$y = -2.0696x - 0.0451$; R = 0.9713; $n(D) = 0.9014D^{-2.0696}$.

$y = -3.3662x – 0.3646$; R = 0.6936; $n(D) = 0.4319D^{-3.3662}$.

The examen of these models indicates that they fit with the reality. In fact, the concentration of particles should decrease with the increase of their diameter. This justifies the negative exponents in the power functions. From the earth surface till around altitude 3000 m, particles of diameters ≤ 0.5µm are more than those whose diameters are > 0.5 µm. Moreover, the concentration of the first ones is higher by the beginning of the rainy season, i.e. in June, than in the dry season, i.e. in November. In general, in the lower layers of the atmosphere the concentration of smaller aerosols, D≤ 0.5 µm, is at least 10 times higher the concentration of bigger ones, D > 0.5 µm,whose concentration is of order 10^{-2} – 10^{-1}. For the atmospheric layers upper altitude 4800 m, the concentration of aerosols of diameters ≤ 0.24 µm increased considerable to order 10^3 while for particles with diameters between 0.26 – 0.3 µm this order fell to 10^1 and for particles with diameters ≥ 0.6 µmit was of order 10^{-2}. These conclusions are illustrated in Table 3.1 built for levels 970 and 4000 m where n_{exp} and n_{th} indicate respectively the experimental and theoretical (calculated from the above formulas) values of the concentration of aerosols for the corresponding diameter. Thus, it is clear that aerosols with diameters ≤ 0.5 µm play an important role in the cloud and precipitations processes in N'djaména. Comparison of experimental and theoretical values of the concentration brought us to the following conclusions. In the lower layers of the troposphere till the vicinity ofaltitude 4000 m, the corresponding values of n_{exp} and $n_{th}$are in general closer to one another for all the spectra. Upper 4000 m, there are considerable differences between themselves, particularly during the dry season. Hence, lower this height, the negative power function is better for fitting the concentration of aerosols with their diameters. This is not correct for the upper atmospheric layers. The high values of the coefficients of correlation indicate a high relationship between the diameter D and the concentration n.

Conclusion

This study shows that aerosols with diameters ≤ 0.5µm are preponderant in the atmosphere in N'djaména. They consequently play a determinant role in cloud and precipitations processes in this locality. Moreover the concentration of particles decreases with the increase of their diameter. Particles with diameter ≤ 0.5µm are at least 10 times more than those with diameter ＞ 0.5µm. For best fitting the spectrum of aerosols with diameter between 0.1–3.0µm, the negative power function $n(D) = bD^{-a}$, a and b positive constants, is better for atmospheric layers less than 4000m height.

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