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RESEARCH ARTICLE

ESTIMATING MISSING METEOROLOGICAL DATA BY EMPIRICAL FUNCTIONSIN SOME LOCALITIES OF CHAD

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ABSTRACT

This study on the yearly means of some meteorological parameters in some localities of Chad solves the problem of lack of meteorological data which is very crucial in developing countries. The main idea is to treat by the least square method the existing chronological series to establish regression functions for further use in the problems of interpolation and extrapolation. Our decision is based on the comparison of the degree of fitnessε of these functions and their corresponding standard deviation s. When$|\varepsilon| < s$ we conclude that the function is useable for interpolation and extrapolation in order to find missing meteorological data. For the interpolation we have obtained good results. What concerns the extrapolation, it should be done with care particularly for the relative humidity of the air because of its high variability and also when the interval of time in sufficiently long.

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INTRODUCTION

The problem of regular meteorological data is very crucial in developing countries (Dubief, 2001). The reasons are multiple: poverty, social insecurity, analphabetism, between others. Another difficulty is the poor territorial coverage with meteorological stations. They do complicate the operations of interpolation and extrapolation of data. Many of these problems are encountered in Chad, (Caramel, 2018), where it is rare to have chronological series of meteorological data without missing information. To understand the climate change in order to manage the present and prevent the future, we must master the past and this is only possible if all needed information is available to enable scientists to carry accurate scientific multidisciplinary investigations (PNUD, 2010). Our goal in this paper is to estimate missing meteorological data by interpolation and to extend the existing chronological series by extrapolation using empirical functions established by numerical treatment of the available information.
The work is divided into four sections and the references presented in an alphabetic order. The first is the introduction to the problem. The second exposes the material and methodology. The third presents the results and their analysis. The conclusion and recommendations are in the fourth section.

MATERIAL AND METHODOS

Material

The material comes from the National Service of Meteorology of Chad in N'djaména. It is not primary data, but already treated one and presented in tabular forms of either monthly or yearly means. In this work we are interested with the yearly means of the in solation; minimal, normal and maximal temperature of the air; minimal and maximal relative humidity of the air in the localities of Moundou, N'djaména, Pala and Sarh, all situated in the southern part of the country. These meteorological stations are based at the airport. They are well equipped with well trained personnel. Thus, the quality of data is acceptable.

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A first data screening has permitted us to eliminate none coherent one. The periods of coverage generally go from 1971 to 2004, but many of them start around 1980.

Methodology

First, experimental points M(t,X) are plotted in a coordinate axes with the time t on the abscissa and X – on the ordinates. X is the yearly mean of the considered parameter. Then, the configuration of the clouds of points is analyzed to find out the form of the relationship X(t). At last, the least square method is applied to find the analytic expression of X(t). To facilitate computations, put 1988 for t = 0. Then 1987 corresponds to t = -1, 1986, to t = -2, and so on, 1971, to t = -17. 1989 corresponds to t = 1, 1990, to t = 2, and so on, 2004, to t = 16. The interpolation and extrapolation are realized using X(t). For t included in the period of investigation, it is the interpolation. For t situated outside this period and earlier 1971, it is the backward extrapolation and for t after 2004–the forward extrapolation. For each year, the value of standard deviation, s, and the absolute value of the degree of fitness of each formula, i.e. the difference between experimental data, X_{exp}, and its corresponding theoretical value X_{th}, $|\varepsilon| = |X_{exp} - X_{th}|$, are calculated. Comparing s and $|\varepsilon|$permits us to decide on the validity of the formula X(t) and its implementation in operational works. If$|\varepsilon|$ <s, the model is acceptable and its implementation possible. Inversely.

Results and analysis

In the text, X will be replaced by its corresponding parameter: I, T, and f for the insolation, temperature and relative humidity of the air, respectively.

Insolation, I(t) in hours.

The established linear regression functions are.

For Moundou: I(t) = 0.00094t + 7.8. (3.1)

For N'djaména: I(t) = 0.01526t + 8.6. (3.2)

For Pala: I(t) = - 0.0328t + 7.8. (3.3)

For Sarh: I(t) = 0.00558t + 7.3. (3.4)

The results of simulations are presented in Table 3.1.

Table 3.1. Results of simulations of the yearly means of I(t) in some localities of Chad

Years	t	Moundou				N'djaména				Pala				Sarh			
		I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s
1971	-17									8.4	8.4	0.0	1.5				
1972	-16									8.4	8.3	0.1	1.2				
1973	-15									8.2	8.3	0.1	1.4				
1974	-14									8.2	8.3	0.1	1.4				
1975	-13	8.0	7.8	0.2	2.0					8.2	8.2	0.0	1.6				
1976	-12		7.8								8.2						
1977	-11		7.8								8.2						
1978	-10		7.8								8.1						
1979	-9		7.8								8.1						
1980	-8		7.8								8.1						
1981	-7		7.8								8.0						
1982	-6		7.8								8.0						
1983	-5	7.8	7.8	0.0	2.1						8.0			7.0	7.3	0.3	1.1
1984	-4	8.1	7.8	0.3	0.8						7.9			7.4	7.3	0.1	0.9
1985	-3	7.4	7.8	0.4	0.8	8.2	8.6	0.4	1.6		7.9			7.0	7.3	0.3	1.2
1986	-2	7.9	7.8	0.1	1.3	8.8	8.6	0.2	1.1		7.9			7.4	7.3	0.1	1.1
1987	-1	7.9	7.8	0.1	1.1	9.1	8.6	0.5	1.0		7.8			7.6	7.3	0.3	1.0
1988	0	7.7	7.8	0.1	1.5	8.4	8.6	0.2	1.5	7.9	7.8	0.1	1.6	7.3	7.3	0.0	1.3
1989	1	8.4	7.8	0.6	1.4	8.9	8.6	0.3	1.2		7.8			7.5	7.3	0.2	1.3
1990	2	8.6	7.8	0.8	0.7	9.0	8.6	0.4	1.2	8.2	7.7	0.5	1.0	7.8	7.3	0.5	1.0
1991	3	7.7	7.8	0.1	1.4	8.6	8.6	0.0	1.2	7.6	7.7	0.1	1.1	6.8	7.3	0.5	1.3
1992	4	6.8	7.8	1.0	1.7	7.8	8.7	0.9	1.7	7.1	7.7	0.6	1.8		7.3		
1993	5	7.4	7.8	0.4	0.8	8.9	8.7	0.2	0.9	8.4	7.6	0.8	0.9	7.7	7.3	0.4	0.9
1994	6	7.4	7.8	0.4	1.8	8.8	8.7	0.1	1.3	7.6	7.6	0.0	1.5	7.5	7.3	0.2	1.2
1995	7	7.6	7.8	0.2	1.2	9.0	8.7	0.3	1.2	8.2	7.6	0.6	1.6	7.1	7.3	0.2	1.3
1996	8	7.9	7.8	0.1	1.3	9.0	8.7	0.3	1.2	6.9	7.5	0.6	1.7	7.3	7.3	0.0	0.9
1997	9	7.5	7.8	0.3	1.4	8.3	8.7	0.4	0.9	7.2	7.5	0.3	1.4	7.2	7.4	0.2	1.1
1998	10	7.7	7.8	0.1	1.5	8.5	8.8	0.3	1.5					7.5	7.4	0.1	1.5
1999	11	8.0	7.8	0.2	1.7	8.9	8.8	0.1	1.6					6.9	7.4	0.5	1.6
2000	12	7.8	7.8	0.0	1.7	9.3	8.8	0.5	1.1					7.4	7.4	0.0	1.5
2001	13		7.8			9.0	8.8	0.2	1.5					7.6	7.4	0.2	1.4
2002	14		7.8			8.9	8.8	0.1	1.1					7.4	7.4	0.0	1.1
2003	15		7.8			8.7	8.8	0.1	1.3					7.8	7.4	0.4	1.1
2004	16	7.5	7.8	0.3	1.4	8.8	8.8	0.0	1.1					7.1	7.4	0.3	1.2

The slopes of these linear regression functions are very small, indicating the slow time variation of the insolation. Their rank varies from 10^{-4} to 10^{-2}. For all the localities I_{th} is almost constant. For Moundou:I_{th} = 7.8 hours/year, for N'djaména: 8.6 ≤ I_{th}≤ 8.8 hours/year, for Pala: 7.5 ≤ I_{th}≤8.4 hours/year and for Sarh: 7.3 ≤ I_{th}≤7.4 hours/year.The intervals of variation of $I_{exp}$are. For Moundou: 7.4≤ I_{exp}≤ 9.3 hours/year, for N'djaména: 8.2≤I_{exp}≤ 9.1 hours/year, for Pala: 7.1≤I_{exp}≤8.2 hours/year and for Sarh: 6.8≤ I_{exp}≤7.8hours/year. For all the stations $|\varepsilon| < s$.

The first is one order less the second. Moreover, 0≤ $|\varepsilon|$ <1 except in 2001 when $|\varepsilon|$ =1.5 hours/year. Thus, the fitness of the established linear regression functions is good and their implementation in the operational works acceptable. In atable, if for a year and locality is only the theoretical data, it is an interpolated one. With formulas (3.1)-(3.4) we realize backward and forward extrapolations. The results are presented in Table 3.2 for the localities where the data is available. It shows that extrapolated and its corresponding experimental data are closer to one another. Moreover, the degree of fitness is one order less their corresponding standard deviation. Hence, our models are acceptable and implementable in such operational works.

Table 3.2. Results of simulations of the backward and forward extrapolations of theyearly means of I(t) in some localities of Chad

Years	t	N'djaména				Pala			
		I_{exp}	I_{th}	$\|\varepsilon\|$	s	I_{exp}	I_{th}	$\|\varepsilon\|$	s
1960	-28					8.0	8.7	0.7	1.4
1961	-27					8.5	8.7	0.2	1.9
1962	-26					8.2	8.7	0.5	1.5
1963	-25					8.2	8.6	0.4	1.8
1964	-24					7.9	8.6	0.7	1.9
1965	-23					8.7	8.6	0.1	1.8
1966	-22						8.5		
1967	-21						8.5		
1968	-20						8.5		
1969	-19					8.3	8.4	0.1	1.5
1970	-18					7.9	8.4	0.5	2.1
2005	17	8.4	8.9	0.5	1.2				
2006	18	8.6	8.9	0.3	1.4				
2007	19	8.8	8.9	0.1	1.6				
2008	20	8.7	8.9	0.2	1.5				
2009	21	8.4	8.9	0.5	1.2				
2010	22	8.4	8.9	0.5	1.6				
2011	23	8.8	9.0	0.2	1.3				
2012	24	8.2	9.0	0.8	1.7				
2013	25	8.7	9.0	0.3	1.3				
2014	26	8.7	9.0	0.3	1.3				

The time tendency of the insolation is to a very slow increment in all the localities except in Pala where a negative slope of its linear regression function means the decrement.

Minimal temperature of the air, T_{min} in °C.

The established linear regression functions for T_{min} are.

For Moundou: $T_{min}(t) = -0.0106t + 20.6.$ (3.5)

For N'djaména: $T_{min}(t) = -0.00248t + 21.6.$ (3.6)

For Pala: $T_{min}(t) = -0.0364t + 21.5.$ (3.7)

For Sarh: $T_{min}(t) = 0.0648t + 21.0.$ (3.8)

The results of simulations with (3.5) – (3.8) are presented in Table 3.3.

The slopes of these linear regression functions are negative, except in Sarh. They are of order 10^{-3} – 10^{-2}. Their small and negative values indicate that T_{min} slowly decreases from year to year and varies inthe intervals: 20.4≤$T_{min,th}$≤20.7°C and19.7≤$T_{min,exp}$≤21.0°C (for Moundou),$T_{min,th}$=21.6°C, a constant, and 20.1≤$T_{min,exp}$≤22.3°C (for N'djaména), 20.9≤$T_{min,th}$≤21.5°C and 19.6≤$T_{min,exp}$≤21.9°C (for Pala), 21.1≤$T_{min,th}$≤22.0°C and20.2≤$T_{min,exp}$≤22.2 °C (for Sarh).

The degree of fitness of these functions is one order less the standard deviation. Both corresponding experimental and theoretical values of T_{min} are closer between themselves. Hence, the established regression functions are usable for interpolation.

The results of simulations of the forward extrapolation by formulas (3.5)-(3.8) are presented in Table 3.4.

Comparison of Tables 3.4 and 3.3 shows a slight increase of the degree of fitness in the former table indicating a small increment of the difference between experimental and theoretical data. All over the degree of fitness of the regression functions are less than their corresponding standard deviation. Thus, these models are implementable in operational works.

Normal temperature of the air, T_{norm}in °C .

The established linear regression functions for T_{nom} are.

For Moundou: $T_{norm}(t) = 0.0672t + 26.9.$ (3.9)

For N'djaména: $T_{norm}(t) = - 0.0636t + 29.0.$ (3.10)

For Pala: $T_{norm}(t) = 0.1315t + 26.6.$ (3.11)

For Sarh: $T_{norm}(t) = 0.02233t + 27.9.$ (3.12)

Table 3.3. Results of simulations of the yearly means of T_{min} in some localities of Chad

	t	Moundou				N'djaména				Pala				Sarh			
		T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s
1982	-6					21.0	21.6	0.6	4.0								
1983	-5	21.0	20.7	0.3	3.3	21.3	21.6	0.3	4.4								
1984	-4	20.5	20.6	0.1	3.1	22.8	21.6	1.2	5.0								
1985	-3	20.7	20.6	0.1	2.5	22.2	21.6	0.6	3.6								
1986	-2	20.8	20.6	0.2	3.5	21.8	21.6	0.2	4.1								
1987	-1	20.6	20.6	0.0	3.6	21.5	21.6	0.1	3.8	21.4	21.5	0.1	2.5				
1988	0	20.5	20.6	0.1	2.9	21.3	21.6	0.3	4.0	21.9	21.5	0.4	2.8				
1989	1	19.7	20.6	0.9	3.3	20.1	21.6	1.5	4.6		21.5			20.2	21.1	0.9	3.3
1990	2	21.0	20.6	0.4	2.3	22.2	21.6	0.6	3.5	21.5	21.4	0.1	2.3	21.6	21.1	0.5	2.1
1991	3	20.8	20.6	0.2	2.8	21.7	21.6	0.1	3.8	21.5	21.4	0.1	2.9	21.5	21.2	0.3	2.6
1992	4	20.3	20.6	0.3	3.3	21.1	21.6	0.5	4.3	20.6	21.4	0.2	3.4	21.2	21.3	0.1	4.2
1993	5	20.8	20.5	0.3	2.9	21.3	21.6	0.3	4.1	21.1	21.3	0.2	2.8	21.2	21.3	0.1	2.9
1994	6	20.3	20.5	0.2	3.4	21.5	21.6	0.1	4.5	21.1	21.3	0.2	3.0	21.3	21.4	0.1	3.1
1995	7	20.0	20.5	0.5	3.5	21.3	21.6	0.3	4.7	21.1	21.2	0.1	3.1	21.7	21.5	0.2	2.7
1996	8	20.7	20.5	0.2	4.4	21.6	21.6	0.0	4.0	21.2	21.2	0.0	3.3		21.5		
1997	9	20.3	20.5	0.2	2.9	21.8	21.6	0.2	4.0	21.2	21.2	0.0	2.4		21.6		
1998	10	21.0	20.5	0.5	3.1	22.3	21.6	0.7	4.1	21.8	21.1	0.7	3.0	22.0	21.6	0.4	3.2
1999	11	20.5	20.5	0.0	2.9	21.2	21.6	0.4	4.4	21.8	21.1	0.7	3.0	21.9	21.7	0.2	2.7
2000	12	20.5	20.5	0.0	3.4		21.6			21.8	21.1	0.7	3.2	21.3	21.8	0.5	2.9
2001	13	20.2	20.5	0.3	3.0	21.0	21.6	0.6	4.5	19.6	21.0	1.4	2.7	21.6	21.8	0.2	3.4
2002	14	20.4	20.5	0.1	3.3	21.4	21.6	0.2	4.6	20.3	21.0	0.7	4.6	22.0	21.9	0.1	3.5
2003	15	20.1	20.4	0.3	3.6	21.8	21.6	0.2	4.0	21.5	21.0	0.5	4.3	22.2	22.0	0.2	3.1
2004	16	20.4	20.4	0.0	3.3	21.8	21.6	0.2	3.9		20.9			21.7	22.0	0.3	2.7

Table 3.4. Results of simulations of the forward extrapolation of the yearly means of T_{min} in some localities of Chad

Years	t	Moundou				N'djaména				Pala				Sarh			
		T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s
2005	17	21.4	20.4	1.0	3.1	22.7	21.6	1.1	8					22.2	22.1	0.1	3.3
2006	18	20.7	20.4	0.3	3.2	22.2	21.6	0.6	3.7	22.4	20.8	1.6	1.7	22.0	22.2	0.2	2.9
2007	19	20.7	20.4	0.3	3.5	22.0	21.6	0.4	4.1	22.3	20.7	1.6	1.8	20.6	22.2	1.6	3.3
2008	20	20.8	20.4	0.4	3.3	21.8	21.6	0.2	3.8	21.9	20.6	1.3	2.6	20.4	22.3	1.9	2.5
2009	21	21.2	20.4	0.8	2.8	22.4	21.5	0.9	3.6					21.5	22.4	0.9	2.8
2010	22					22.8	21.5	1.3	4.0					21.8	22.4	0.6	2.9
2011	23					22.0	21.5	0.5	4.3					20.9	22.5	1.6	3.5
2012	24					22.2	21.5	0.7	4.1					22.2	22.6	0.4	1.5
2013	25					22.5	21.5	1.0	3.5								
2014	26					22.2	21.5	0.7	4.2								

The slopes of all the linear regression functions are of order 10^{-2}–10^{-1}higher the corresponding ones of T_{min}. Consequently the time tendency of T_{norm} is more important the one of T_{min}. Moreover their positive values indicate the yearly increment of T_{norm}except in N'djaména where the slope is negative. The results of simulations of T_{nom} by formulas (3.9) – (3.12) are presented in Table 3.5. It shows that the degree of fitness of the regression functions is one order less their corresponding standard deviation. The intervals of variation of $T_{nom}$are: $26.1 \leq T_{norm,exp} \leq 29.4$°C and $26.8 \leq T_{norm,th} \leq 28.0$°C in Moundou, $27.2 \leq T_{norm,exp} \leq 30.2$°C and $28.0 \leq T_{norm,th} \leq 29.4$°C in N'djaména,$26.1 \leq T_{norm,exp} \leq 29.6$°C and $26.5 \leq T_{norm,th} \leq 28.7$°C in Pala,$26.7 \leq T_{norm,exp} \leq 28.3$°C and $27.8 \leq T_{norm,th} \leq 28.3$°C in Sarh. It is easily remarkable that these intervals are not wide. This analysis permits us to conclude on the usability of these models in operational works. The results of extrapolation by formulas (3.9) – (3.12) are presented in Table 3.6. It shows that while remaining inferior to their corresponding standard deviation, the degree of fitness of these functions increases with the time increasing. Moreover, for some years both characteristics are of a same order, 10^1.

Both $T_{normexp}$ and $T_{norm,th}$ vary in small intervals. Also the degree of fitness and their corresponding standard deviation tend to have a same order particularly when the extrapolating period is sufficiently long, indicating that these models should be implemented with care.

Maximal temperature of the air, T_{max}in °C .

The established linear regression functions for T_{max} are.

For Moundou: $T_{max}(t) = 0.01988t + 34.4$. (3.13)

For N'djaména: $T_{max}(t) = 0.0187t + 35.8$. (3.14)

For Pala: $T_{max}(t) = 0.0275t + 33.8$. (3.15)

For Sarh: $T_{max}(t) = - 0.02754t + 35.2$. (3.16)

Table 3.5.Results of simulations of the yearly means of T_{norm} in some localities of Chad

Years	t	Moundou				N'djaména				Pala				Sarh			
		T_{exp}	T_{th}	$\|\varepsilon\|$	s	T_{exp}	T_{th}	$\|\varepsilon\|$	s	T_{exp}	T_{th}	$\|\varepsilon\|$	s	T_{exp}	T_{th}	$\|\varepsilon\|$	s
1982	-6					30.2	29.4	0.8	3.3								
1983	-5					29.3	29.3	0.0	4.6					27.1	27.8	0.7	2.1
1984	-4					29.1	29.3	0.2	3.6					27.8	27.8	0.0	2.1
1985	-3					28.7	29.2	0.5	3.1					27.4	27.8	0.4	2.2
1986	-2	27.5	26.8	0.7	2.9	28.7	29.1	0.4	3.7					27.7	27.9	0.2	2.6
1987	-1	27.4	26.8	0.6	2.6	28.8	29.1	0.3	3.1	27.1	26.5	0.6	2.8	28.1	27.9	0.2	2.2
1988	0	26.5	26.9	0.4	3.0	27.7	29.0	1.3	2.5	27.2	26.6	0.6	2.9	27.8	27.9	0.1	2.7
1989	1	26.1	27.0	0.9	2.4		28.9			26.1	26.7	0.6	3.0	26.7	27.9	1.2	2.3
1990	2	27.2	27.0	0.2	1.9	27.2	28.9	1.7	1.9	27.3	26.9	0.4	2.2	27.8	27.9	0.1	1.9
1991	3	26.9	27.1	0.2	2.4	28.3	28.8	0.5	3.1	26.9	27.0	0.1	2.6	27.7	28.0	0.3	2.2
1992	4	26.4	27.2	0.8	2.4	27.9	27.7	0.8	3.7	26.6	27.1	0.5	2.6	27.2	28.0	0.8	2.4
1993	5	27.1	27.2	0.1	2.1	28.3	28.7	0.4	3.5	27.1	27.3	0.2	2.5		28.0		
1994	6	26.9	27.3	0.4	2.5	28.1	28.6	0.5	3.7	27.0	27.4	0.4	2.7	27.8	28.0	0.2	2.5
1995	7	26.9	27.4	0.5	2.5	28.1	28.6	0.5	3.7	26.9	27.5	0.6	2.7	27.7	28.1	0.4	2.2
1996	8	27.0	27.4	0.4	2.6	28.5	28.5	0.0	3.1	27.8	27.7	0.1	3.0	27.5	28.1	0.6	2.1
1997	9	28.8	27.5	1.3	1.9	28.6	28.4	0.2	3.2	27.3	27.8	0.5	1.9	27.4	28.1	0.7	1.8
1998	10	29.4	27.6	1.8	2.9	28.8	28.4	0.4	3.5	28.3	27.9	0.4	2.9	28.2	28.1	0.1	2.7
1999	11	28.7	27.6	1.1	3.2	28.4	28.3	0.1	3.4	28.0	28.0	0.0	3.3	27.5	28.1	0.6	2.5
2000	12	28.6	27.7	0.9	3.3	27.9	28.2	0.3	3.5	28.5	28.2	0.3	2.8	27.6	28.2	0.6	2.2
2001	13	26.9	27.8	0.9	2.4	27.9	28.2	0.3	3.5	27.5	28.3	0.8	2.3	27.8	28.2	0.4	2.7
2002	14	26.6	27.8	1.2	2.4	28.3	28.1	0.2	4.1	29.6	28.4	1.2	3.1	28.1	28.2	0.1	3.0
2003	15	27.6	27.9	0.3	3.0	28.3	28.0	0.3	3.3		28.6				28.2		
2004	16		28.0			28.6	28.0	0.6	3.2		28.7				28.3		

Table 3.6.Results of simulations of the extrapolation of the yearly means ofT_{norm}in some localities of Chad

Years	t	Moundou				N'djaména			
		T_{exp}	T_{th}	$\|\varepsilon\|$	s	T_{exp}	T_{th}	$\|\varepsilon\|$	s
2005	17	27.2	28.0	0.8	2.9	29.1	27.9	1.2	3.4
2006	18	27.2	28.1	0.9	2.7	28.7	27.9	0.8	3.0
2007	19	27.2	28.2	1.0	2.9	28.6	27.8	0.8	3.5
2008	20	27.6	28.2	0.6	2.4	28.1	27.7	0.4	3.4
2009	21	27.2	28.3	1.1	2.0	29.1	27.7	1.4	2.8
2010	22					29.2	27.6	1.6	3.5
2011	23					28.7	27.5	1.2	3.6
2012	24					28.5	27.5	1.0	3.4
2013	25					29.3	27.4	1.9	3.1
2014	26					29.0	27.3	1.7	3.6

The slopes of these linear regression functions are positive except in Sarh and are of order 10^{-2}. These positive small values indicate the slowly time variation of T_{max} which increases with the time increasing. The results of simulations are in Table 3.7. Itshows that the degree of fitness is one order less the corresponding standard deviation. The intervals of variation of $T_{max,exp}$ and $T_{max,th}$ are: $33.8 \leq T_{max,exp} \leq 36.2$°C and $34.3 \leq T_{max,th} \leq 34.7$°C in Moundou,$33.7 \leq T_{max,exp} \leq 36.9$°C and $35.7 \leq T_{max,th} \leq 36.1$°C in N'djaména,$33.1 \leq T_{max,exp} \leq 36.6$°C and $33.3 \leq T_{max,th} \leq 34.2$°C in Pala,$33.0 \leq T_{max,exp} \leq 35.7$°C and $34.8 \leq T_{max,th} \leq 35.3$°C in Sarh. The results of simulations of the extrapolation of T_{max} are in Table 3.8. Its analysis indicates some increase in the values of the degree of fitness in both localities indicating some slight discordance between experimental and corresponding theoretical points. In general$|\varepsilon|$remains one order less thans. Thus the extrapolation is feasible and should be done with care, particularly when the extrapolating period is sufficiently long.

Table 3.7.Results of simulations of the yearly means of T_{max} in some localities of Chad

Years	t	Moundou				N'djaména				Pala				Sarh			
		I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s	I_{exp}	I_{th}	$\lvert\varepsilon\rvert$	s
1971	-17									33.2	33.3	0.1	3.6				
1972	-16									33.4	33.4	0.0	2.5				
1973	-15									34.5	33.4	1.1	3.0				
1974	-14									33.4	33.4	0.0	3.1				
1975	-13									33.4	33.4	0.0	3.6				
1976	-12									33.7	33.5	0.2	3.3				
1977	-11									33.7	33.5	0.2	3.4				
1978	-10										33.5						
1979	-9										33.6						
1980	-8										33.6						
1981	-7										33.6						
1982	-6										33.6						
1983	-5	34.8	34.3	0.5	3.3						33.7			35.7	35.3	0.4	3.4
1984	-4	34.6	34.3	0.3	2.5	36.2	35.7	0.5	3.2		33.7			35.7	35.3	0.4	2.4
1985	-3	34.2	34.3	0.1	3.0	35.9	35.7	0.2	3.1		33.7			34.7	35.3	0.6	3.0
1986	-2	34.6	34.4	0.2	3.4	36.1	35.8	0.3	4.0		33.7			35.3	35.3	0.0	3.3
1987	-1	35.1	34.4	0.7	3.0	36.4	35.8	0.6	2.7	33.5	33.8	0.3	2.8	35.5	35.2	0.3	2.9
1988	0	34.3	34.4	0.1	3.7	35.5	35.8	0.3	3.9	33.7	33.8	0.1	3.8	35.1	35.2	0.1	3.6
1989	1	33.7	34.4	0.7	2.9	34.7	35.8	1.1	3.7	33.0	33.8	0.8	3.2	34.5	35.2	0.7	2.7
1990	2	34.8	34.4	0.4	2.8	36.8	35.8	1.0	3.4	34.0	33.9	0.1	2.9	35.6	35.1	0.5	2.7
1991	3	34.2	34.5	0.3	3.1	35.6	35.9	0.3	3.2	33.1	33.9	0.8	2.9	35.0	35.1	0.1	2.6
1992	4	33.8	34.5	0.7	2.8	35.2	35.9	0.7	3.7	33.2	33.9	0.7	3.0	34.5	35.1	0.6	3.0
1993	5	34.5	34.5	0.0	2.7	35.9	35.9	0.0	3.6	34.1	33.9	0.2	3.1	34.7	35.1	0.4	2.8
1994	6	34.3	34.5	0.2	3.2	35.4	35.9	0.5	3.9	33.5	34.0	0.5	3.4	35.1	35.0	0.1	3.4
1995	7	34.0	34.5	0.5	2.8	35.6	35.9	0.3	3.5	33.6	34.0	0.4	3.1	34.9	35.0	0.1	3.1
1996	8	34.6	34.6	0.0	3.1	36.7	35.9	0.8	2.8	33.3	34.0	0.7	3.2	35.4	35.0	0.4	3.0
1997	9	34.1	34.6	0.5	2.2	34.9	36.0	1.1	4.4	33.5	34.0	0.5	2.5	35.1	35.0	0.1	2.5
1998	10	35.2	34.6	0.6	3.3	35.1	36.0	0.9	4.1		34.1				34.9		
1999	11	34.9	34.6	0.3	3.4	37.5	36.0	1.5	4.1	34.1	34.1	0.0	3.8	34.8	34.9	0.1	3.9
2000	12	34.5	34.6	0.1	3.5	33.7	36.0	2.3	3.7	34.4	34.1	0.3	3.3	35.1	34.9	0.2	3.3
2001	13	34.8	34.7	0.1	3.2	36.3	36.0	0.3	3.6	34.1	34.2	0.1	2.8	35.4	34.8	0.6	2.9
2002	14	34.1	34.7	0.6	2.7	36.7	36.1	0.6	4.0	34.3	34.2	0.1	3.4	33.0	34.8	1.8	2.6
2003	15	36.2	34.7	1.5	2.7	36.6	36.1	0.5	3.5	36.6	34.2	2.4	2.8	35.6	34.8	0.8	3.7
2004	16	34.5	34.7	0.2	2.9	36.9	36.1	0.8	3.1		34.2			35.0	34.8	0.2	3.1

In general, the slopes of the linear regression functions of T_{norm} and T_{max} are at least one order more the ones of T_{min}. Moreover most of them are positive and vary in the interval from $10^{-3}$to 10^{-1}. It is then obvious that the time tendency of both T_{norm} and T_{max} should cover the one of T_{min}. Consequently, we conclude that the resultant time variation of the yearly means of the temperature of the air in the considered localities is to a slowly increment with the time increasing.

Table 3.8.Results of simulations of the extrapolation of the yearly means T_{max}in some localities of Chad

Years	t	Moundou				N'djaména			
		T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s	T_{exp}	T_{th}	$\lvert\varepsilon\rvert$	s
2005	17	34.4	34.7	0.3	3.7	37.2	36.1	1.1	3.6
2006	18	34.5	34.8	0.3	3.6	36.9	36.1	0.8	3.2
2007	19	34.2	34.8	0.6	3.9	36.8	36.2	0.6	3.9
2008	20	35.2	34.8	0.4	2.4	36.0	36.2	0.2	4.1
2009	21	34.3	34.8	0.5	2.8	37.6	36.2	1.4	2.7
2010	22		34.8			37.3	36.2	1.1	3.8
2011	23		34.9			37.1	36.2	0.9	3.4
2012	24	34.2	34.9	0.7	1.8	36.2	36.2	0.0	3.8
2013	25	35.4	34.9	0.5	3.3	37.4	36.3	1.1	3.8
2014	26	35.7	34.9	0.8	2.9	36.4	36.3	0.1	3.6

Minimal relative humidity of the air, f_{min}in %.

The established linear regression functions for f_{min} are

For Moundou: $f_{min}(t) = - 0.65767t + 42.$ (3.17)

For N'djaména: $f_{min}(t) = 0.09034t + 35.$ (3.18)

For Pala: $f_{min}(t) = - 0.8572t + 42.$ (3.19)

For Sarh: $f_{min}(t) = 1.17921t + 33.$ (3.20)

The slopes of these functions are negative in Moundou and Pala and positive in N'djaména and Sarh. Their orders are in the interval $10^{-2} – 10^{1}$. In the localities where the slopes are positive (negative), f_{min} should increase (decrease) with the time increasing. The results of simulations by formulas (3.17) – (3.20) are in Table 3.9.It shows that $f_{min,exp}$, $f_{min,th}$ and sare of a same order, 10^{1},expressinga high time variability of this parameter. For a few years, the degree of fitness of the linear regression functions and those characteristics are of the same order, but in general the former is one order less the seconds. The intervals of variation of $f_{min,exp}$ and $f_{min,th}$ are: $25 \leq f_{min,exp} \leq 62\%$ and $28 \leq f_{min,th} \leq 53\%$ in Moundou, $18 \leq T_{min,exp} \leq 48\%$ and $28 \leq f_{min,th} \leq 52\%$ in N'djaména, $32 \leq f_{min,exp} \leq 54\%$ and $31 \leq f_{min,th} \leq 53\%$ in Pala, $31 \leq f_{min,exp} \leq 39\%$ and $35 \leq f_{min,th} \leq 36\%$ in Sarh. The results of simulations of the extrapolation of f_{min} are in Table 3.10. It shows that $f_{min,exp}$, $f_{min,th}$ and s are still of the same order. The degree of fitness still remains high, but less its corresponding standard deviation. Tables 3.9 and 3.10 show that while remaining less than $f_{min,exp}$ and $f_{min,th}$, the standard deviation is sometimes closer them indicating how wide if the interval of variability of the relative humidity of the air. This situation tells us that these models should be used with care as their estimations should be sufficiently different from the experimental value no matter the correctness of the interval of validity of both values.

Table 3.9.Results of simulations of the yearly means of f_{min} in some localities of Chad

Years	t	Moundou				N'djaména				Pala				Sarh			
		f_{exp}	f_{th}	$\|\varepsilon\|$	s	f_{exp}	f_{th}	$\|\varepsilon\|$	s	f_{exp}	f_{th}	$\|\varepsilon\|$	s	f_{exp}	f_{th}	$\|\varepsilon\|$	s
1971	-17									53	53	0	23				
1972	-16									54	53	1	22				
1973	-15									50	52	2	23				
1974	-14									53	51	2	24				
1975	-13	61	53	8	20					54	51	3	24				
1976	-12	62	52	10	18					54	50	4	23				
1977	-11	59	51	8	21					52	49	3	25				
1978	-10	62	51	11	22					54	49	5	24				
1979	-9		50								48						
1980	-8		49								47						
1981	-7		48								47						
1982	-6		47								46						
1983	-5	38	46	8	18						45			39	35	4	19
1984	-4	35	45	10	17	18	28	10	10		45			31	35	4	17
1985	-3	32	45	10	20	20	29	9	16		44			34	35	1	18
1986	-2	34	44	10	20	21	31	10	19		43			34	35	1	19
1987	-1	33	43	10	21	33	32	1	20		43			34	35	1	20
1988	0	34	42	8	21	44	33	11	25	33	42	9	24	35	35	0	20
1989	1	51	41	10	32	42	34	8	24		41			31	35	4	20
1990	2	30	40	10	18	28	35	7	17	35	41	6	21	35	35	0	17
1991	3	34	39	5	50	44	37	7	25	36	40	4	25	37	35	2	18
1992	4	31	39	8	21	43	38	5	24	34	39	5	22	38	35	3	20
1993	5	32	38	6	17	45	39	6	21	33	39	6	22	37	35	2	18
1994	6	31	37	6	20	43	40	3	26	33	38	5	23	38	36	2	21
1995	7	43	36	7	25	46	41	5	22	32	37	5	22	36	36	0	19
1996	8	52	35	17	22	42	42	0	22	35	37	2	23	38	36	2	20
1997	9		34			43	44	1	23	40	36	4	22	39	36	3	21
1998	10		33			46	45	1	25	35	35	0	23	36	36	0	21
1999	11		33			47	46	1	25	36	35	1	23	38	36	2	20
2000	12	33	32	1	22	46	47	1	22	36	34	2	21	33	36	3	19
2001	13	34	31	3	21	45	48	3	21	54	33	21	35	39	36	3	22
2002	14	37	30	7	20	47	50	3	24	34	33	1	21	34	36	1	18
2003	15	25	29	4	19	47	51	4	21		32			35	36	1	2035
2004	16	35	28	7	21	48	52	4	26		31			35	36	1	21

Table 3.10.Results of simulations of the extrapolation of the yearly means of f_{min} in some localities of Chad

Years	t	Moundou				Pala				Sarh			
		f_{exp}	f_{th}	$\|\varepsilon\|$	s	f_{exp}	f_{th}	$\|\varepsilon\|$	s	f_{exp}	f_{th}	$\|\varepsilon\|$	s
1961	-27					49	60	11	25				
1962	-26					53	59	6	23				
1963	-25					52	58	6	24				
1964	-24					53	58	5	22				
1965	-23					53	57	4	22				
1966	-22					55	56	1	19				
1967	-21					54	56	2	24				
1968	-20					56	55	1	25				
1969	-19					54	54	0	26				
1970	-18					52	54	2	25				
2005	17	40	27	13	21					35	37	2	20
2006	18	37	27	10	23					36	37	1	21
2007	19	34	26	8	25					36	37	1	20
2008	20	26	25	1	15					35	37	2	18
2009	21	38	24	14	20					33	37	4	19
2010	22									35	37	2	20
2011	23									30	37	7	20
2012	24									44	37	7	20

Table 3.11.Results of simulation of the yearly means of f_{max} in some localities of Chad

	t	Moundou				N'djaména				Pala				Sarh			
		f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s	f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s	f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s	f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s
1983	-5	87	80	7	18	64	56	8	23					81	77	4	21
1984	-4	87	80	7	14	53	56	3	21					76	78	2	23
1985	-3	77	80	3	23	53	57	4	27					77	78	1	24
1986	-2	78	79	1	20	57	57	0	26					77	78	1	21
1987	-1	75	79	4	21	53	58	5	26					76	78	2	23
1988	0	78	79	1	21	61	58	3	27	63	64	1	29	78	78	0	22
1989	1	75	79	4	25	57	58	1	26	59	64	5	28	75	78	3	21
1990	2	77	79	2	23	55	59	4	26	66	64	2	28	77	78	1	22
1991	3	79	78	1	22	61	59	2	28	69	64	5	31	80	78	2	19
1992	4	75	78	3	25	59	60	1	26	65	64	1	29	80	78	2	21
1993	5	76	78	2	22	58	60	2	25	65	64	1	31	81	79	2	20
1994	6	78	78	0	23	60	61	1	27	64	64	0	30	78	79	1	22
1995	7	78	77	1	21	63	61	2	24	62	64	2	12	81	79	2	21
1996	8		77			60	61	1	25	61	64	3	29	84	79	5	17
1997	9		77			61	62	1	27	68	64	4	27	81	79	2	21
1998	10		77			62	62	0	27	63	64	1	28	79	79	0	21
1999	11		77			66	63	3	24	66	64	2	29	82	79	3	17
2000	12	76	76	0	23	64	63	1	23	67	64	3	25	79	79	0	19
2001	13	79	76	3	20	65	64	1	22	66	65	1	30	83	80	3	18
2002	14	80	76	4	20	63	64	1	22	60	65	5	27	78	80	2	17
2003	15	71	76	5	23	64	64	0	24		65			76	80	4	21
2004	16	79	75	4	20	62	65	3	24		65			78	80	2	21

Table 3.12.Results of simulations of the forward extrapolations of the yearly means of the T_{max} in some localities of Chad

Years	t	Moundou				N'djaména				Sarh			
		f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s	f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s	f_{exp}	f_{th}	$\lvert\varepsilon\rvert$	s
2005	18	85	75	10	15	61	65	4	25	79	80	1	20
2006	19	77	75	2	20	62	66	4	25	78	80	2	20
2007	20	72	75	3	25	62	66	4	25	80	80	0	18
2008	21	65	75	10	23	63	66	3	23	79	80	1	19
2009	22	82	74	8	17	57	67	10	27	79	81	2	16
2010	23					61	67	6	26	78	81	3	19
2011	24					58	68	10	26	74	81	7	18
2012	25					61	68	7	27	80	81	1	20
2013	26					62	69	7	22	85	81	4	17
2014	27					58	69	11	23				

Maximal relative humidity of the air, f_{max} in %

The established linear regression functions for f_{max} are.

For Moundou: $f_{max}(t) = -0.2189t + 89.$ (3.21)

For N'djaména: $f_{max}(t) = 0.4241t + 58.$ (3.22)

For Pala: $f_{max}(t) = 0.03929t +64.$ (3.23)

For Sarh: $f_{max}(t) = 0.1191t +78.$ (3.24)

The slopes of these functions are small and positive except in Moundou. Their orders are in the interval $10^{-2} – 10^{-1}$.It indicates that the time tendency of this parameter is to a slight increment with the time increasing, except in Moundou where it decreases. Analyzing the slopes in formulas (3.17) – (3.20) and (3.21) – (3.24) tells that the resulting time tendency of the relative humidity of the air in the considered localities is to a slow increment with the time increasing. The results of simulations by formulas (3.21) ((3.24) are presented in Table 3.11. It shows that the order of $f_{max,exp}$, $f_{max,th}$ and their corresponding standard deviation is almost the same and equal to 10^1.

Sometimes their values are closer ones to others confirming that the relative humidity of the air has a high time variability. The intervals of variation of $f_{max,exp}$ and $f_{max,th}$ are: $71 \leq f_{max,exp} \leq 87\%$ and $75 \leq f_{max,th} \leq 80\%$ in Moundou,$53 \leq T_{max,exp} \leq 66\%$ and $56 \leq f_{max,th} \leq 65\%$ in N'djaména,$59 \leq f_{max,exp} \leq 69\%$ and $64 \leq f_{max,th} \leq 65\%$ in Pala,$75 \leq f_{max,exp} \leq 83\%$ and $77 \leq f_{max,th} \leq 80\%$ in Sarh. The results of simulations of the extrapolation of f_{max} by formulas (3.21) – (3.24) are presented in Table 3.12. It shows $f_{max,exp}$, $f_{max,th}$ and their corresponding standard deviation are still of the same order while the degree of fitness is one order less than its corresponding standard deviation. This study indicates that in general these models are carefully usable for estimation missing meteorological data of the relative humidity of the air in chronological series.

Conclusion and Recommendation

In this paper we have established time linear regression functions for some atmospheric parameters in some localities of Chad. These formulas have given the opportunity to realize interpolation and extrapolation, i.e. estimating missing meteorological data inside considered periods, interpolation, and outside these periods, extrapolation. Moreover, they have permitted us to diagnose the time tendencies of these parameters. In general, good results are obtained for the first operation, meaning that this procedure is realizable in practical works when interpolating. For the second operation, acceptable results are reached, particularly when the extrapolation periods are not long. In both cases, better results should be reached if the used data was representative, accurate and for sufficiently long periods. This paper indicates that the yearly means of these atmospheric parameters very slowly change with time increasing. Thus, our procedure is recommendable to operators, but to be used with care particularly for hygroscopic characteristics of the air and sufficiently long periods.

REFERENCES

Jean Dubief, 2001. Données météorologiques du nord de l’Afrique à l’équateur. Ed. Karthala, ISBN 2-84586-187-7. 86p.

Laurence Caramel, 2018. Sur le Lac Tchad, un réseau d’observations scientifiques en ruine. Le Monde du 25-02-2018 à 18h56.

Programme des Nations Unies pour le Développement (PNUD), 2010. Une vision nouvelle pour les services météorologiques et climatiques en Afrique, N.Y., N.Y. 10017, 304 East, 45thstr, 9th Floor, 137p.

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