EXTREME TEMPERATURE ANALYSIS IN THE ANDROY REGION OF MADAGASCAR

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ABSTRACT

In this study, we analyze the occurrence of certain extreme climatic phenomena in the Androy region of Madagascar and their period of return from 1979 to 2015. The theory of extreme values, more particularly the Gumbel Distribution is the main statistical tool used in this work; this allowed us to know the extreme values and their time of return in the 4 districts of Androy region. The multiple linear regression method and the Mann Kendall test showed that the minimum and maximum temperatures tend to increase during the 36 years (1979-2015) in the three districts other than Tsihombe district, in which finds a downward trend.

Keyword: *occurrence, extreme phenomena, Gumbel Distribution*

1. INTRODUCTION

Climate change is currently one of the environmental issues facing humanity. Globally, climate change is manifested by the rise in temperature at the surface of the earth and oceans, leading to spatiotemporal rainfall disruption, sea-level rise and the prolongation of dry or wet ecological months. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), releases of greenhouse gases (GHGs) from human activities are responsible for climate change. GHG emissions and their constant increase are responsible for rising temperatures causing warming. This increase is expected to continue in the coming decades, reaching levels of about + 1.4 ° C to + 5.8 ° C worldwide by 2100 (IPCC, 2007). [1]

Madagascar is facing a serious and prolonged drought in the south of the country since 2012, raising the level of food insecurity to an alarming level. The crisis is resulting in a total loss of crops in a region where most farmers live on rainfed agriculture and livestock. Around 900,000 people are in need of emergency food assistance and many are forced into desperate ways to survive. Southern Madagascar is the poorest region of the country, with 90% of the population living on less than $ 2 a day (USAID / TANANARIVE PRESS RELEASE, MADAGASCAR, 2016). [2]

Especially the region of Androy located in the southern part of Madagascar is known for its harsh and hostile weather conditions if we only mention the drought that prevails in the region or the cyclical "KERE[(1)]" suffered by the population. This region is classified among the arid region of Madagascar.

The present work aims to analyze the occurrence of certain extreme climatic phenomena in the Androy region of Madagascar and their period of return from 1979 to 2015.

2. METHODOLOGY

2.1 Used datas

This study uses daily average temperature data observed at 2m from the ERA-Interim experiment of the ECMWF (European Center for Medium range Weather Forecasts), covering the period from 1979 to 2015.

2.2 Study zone

Our study area is the Androy region of Madagascar which is composed of 4 districts: Ambovombe, Beloha, Bekily and Tsihombe and limited by the following geographical coordinates (Figure 1):

• Latitude: between 24 ° 13 'and 25 ° 24' South

• Longitude: between 45 ° 20 'and 46 ° 26' East

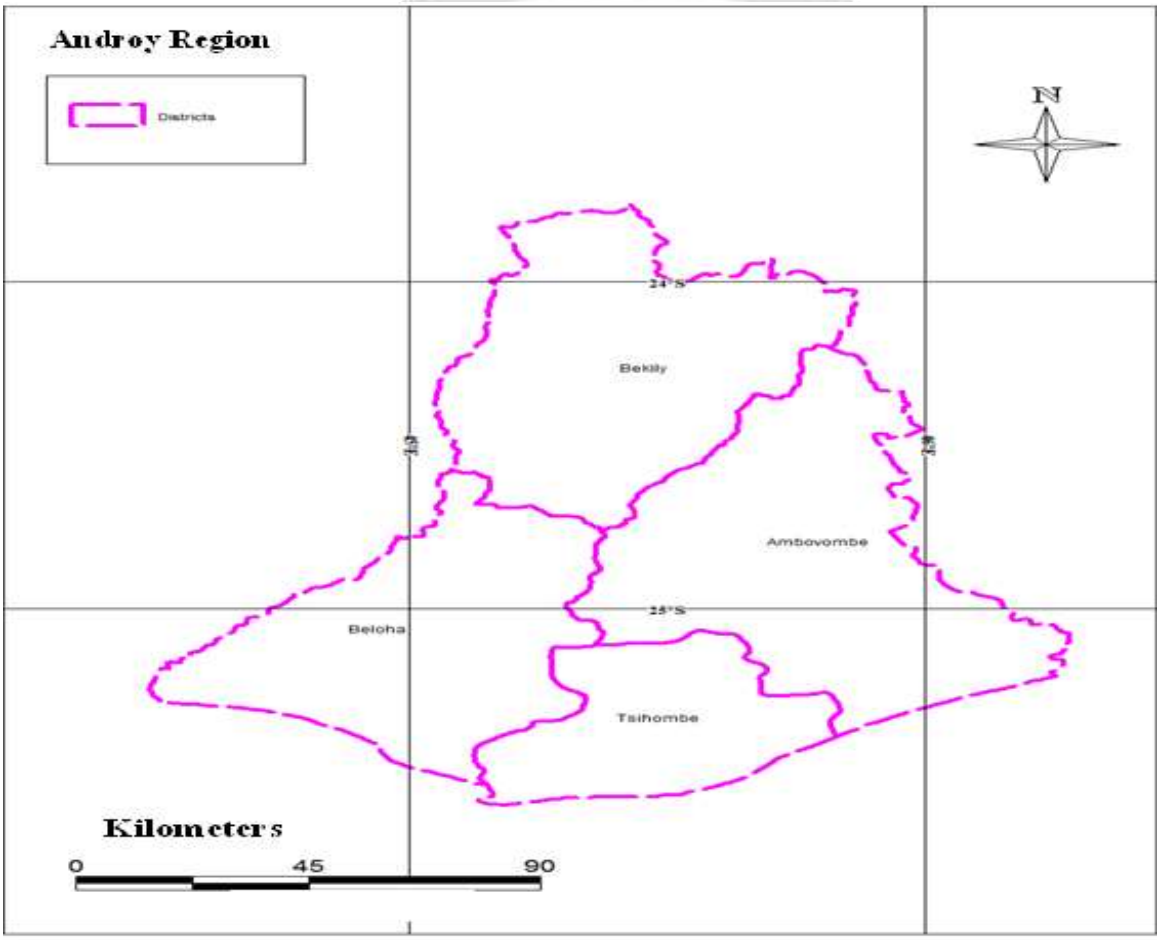

Fig -1: Location Map of Androy Region of Madagascar

2.3 Tools

The data was processed by the MATLAB R2015b software. Three extreme indices or indicators were calculated in this study (Table 1)

Table -1: Description of the 3 indices used in the analysis of extreme climate events

Index	Name of the index	Definition
TX90	Warm day	90th percentile value of maximums of annual maximum temperatures
TN90	Warm night	90th percentile value of maximums of annual minimum temperatures
TN10	Cold night	10th percentile value of minimums of annual minimum temperatures

2.4 Methods

- The Gumbel distribution [3] [4] [5] [6]

The Gumbel distribution which is a Generalized Extreme Value (GEV) distribution, allowed to adjust and to deal with the stochastic behavior of the upper or lower tail of the initial distribution of the studied climatic parameters, and define their return period (T). We therefore want to calculate the return period of the minimum and maximum temperatures to better characterize the hazard.

The Gumbel distribution is given by the following expressions:

- Distribution function:

$$F(Q) = \exp\left[-\exp(-\frac{Q-\alpha}{\beta})\right] \quad (1)$$

- Probability density function:

$$p(Q) = \frac{\exp(-z)z}{\beta} \quad (2) \quad \text{where } z = \exp(-\frac{Q-\alpha}{\beta}) \quad \text{with } \alpha = m_Q - 0.45\sigma_Q \text{ and } \beta = \frac{\sigma_Q}{1.28}$$

where m_Q is the mean of the flows and σ_Q is the standard deviation.

The temperatures considered are the annual temperatures, we take the daily maximum temperature.

m_Q and σ_Q are conventionally given by:

$$m_Q = \frac{1}{N}\sum_{i=1}^{N} Q_i \quad (3) \qquad \text{and} \qquad \sigma_Q = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(Q_i - m_Q)^2} \quad (4)$$ (where N is the number of temperature values)

- Simple linear regression [7] [8] [9]

The regression method was used to determine trends over the entire length of the time series used. The trends are highlighted by an affine type regression line: y= ax +b (5)

This equation is obtained by calculating the slope "a" which is a directing coefficient. The existence of a linear trend (upward or downward) and its significance is determined by the nonparametric test of Mann (1945) - Kendall (1970).

If a > 0: the trend is on the rise
If a < 0: the trend is down.
If p-value < (Alpha =0, 05): the trend is significant at the 5% level
If p-value > (Alpha =0, 05): the trend is not significant at the 5% threshold

- Mann-Kendall test [10]

This test is non-parametric and allows to detect trends that are not necessarily linear. It is based on statistics:

$$MK = \sum_{k=1}^{N-1} \sum_{j=k+1}^{N} signe(y_j - y_k) \quad (6)$$ where signe *()* is the function defined by:

$$signe(x) = \begin{cases} +1 \ if \ x > 0 \\ 0 \ if \ x = 0 \\ -1 \ if \ x < 0 \end{cases}$$

In practice we use standard statistics

$$MK_{norm} = \begin{cases} (MK - 1) / \sigma_{MK} \ if \ MK > 0 \\ 0 \ if \ MK = 0 \\ (MK + 1) / \sigma_{MK} \ if \ MK < 0 \end{cases} \quad (3) \text{ where } \sigma_{MK} = \sqrt{\frac{N(N-1)(2N+5)}{18}}$$

3. RESULTS AND DISCUSSION

3.1 Evolution of minimum and maximum temperatures

3.1.1 Warm days

Fig -2 represents the occurrence of warm days in the districts of Beloha, Bekily, Ambovombe and Tsihombe. It is noted that the temperature tends to increase in the districts of Beloha (0.062 ° C), Bekily (0.071 ° C), Ambovombe (0.053 ° C) during the period from 1979 to 2015. And according to the test of Mann Kendall, the trends are significant. On the other hand, a downward trend was found in the district of Tsihombe. The variation is not significant, of the order of 0.002 ° C.

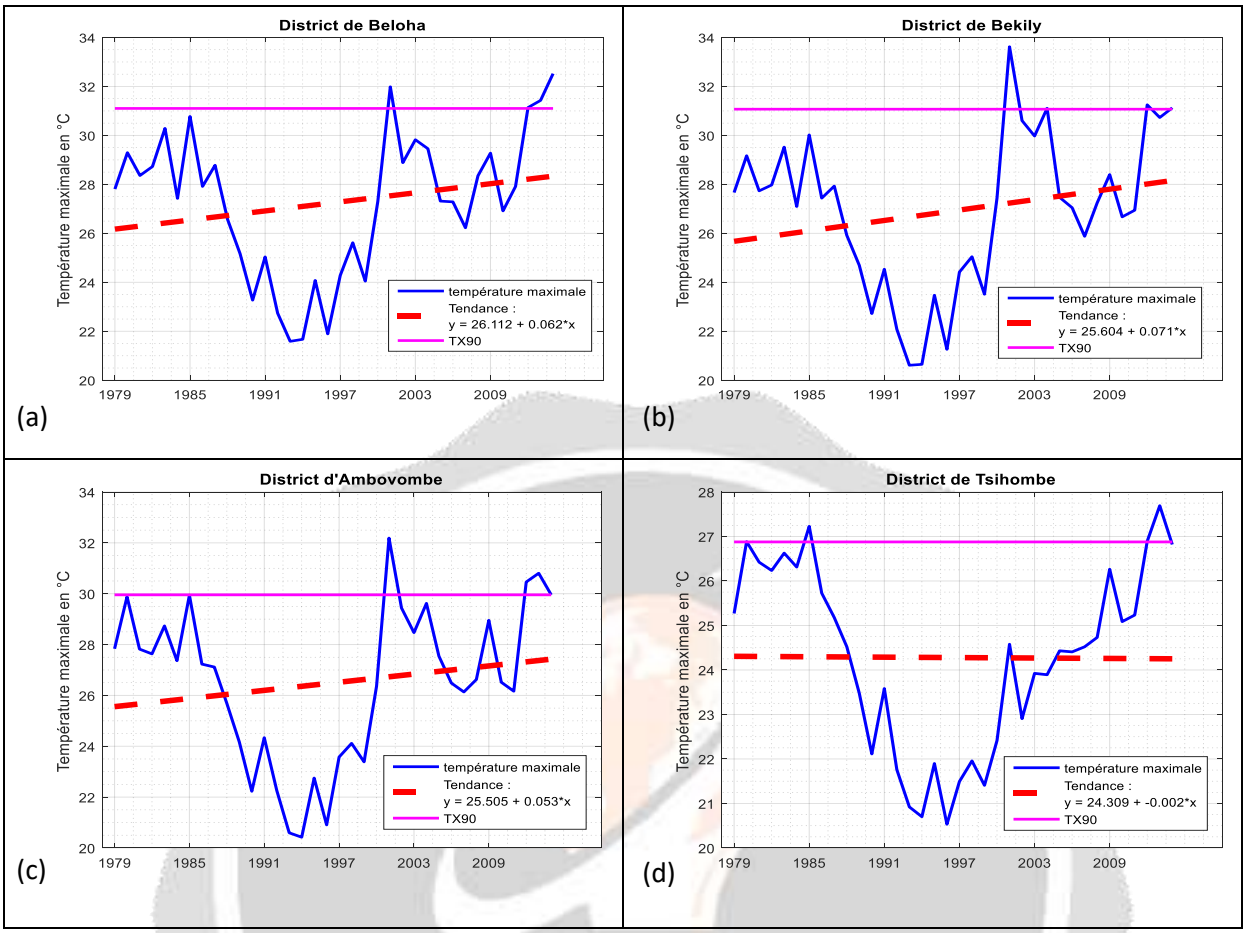

Fig -2: Occurrence of warm days in districts of Beloha (a), Bekily (b), Ambovombe (c), Tsihombe (d)

Concerning the 90 percentiles (TX90), we found in the 4 districts the following values (Table -2):

Table -2: TX90 values in the 4 districts

Districts	**TX90**
Beloha	31°C
Bekily	31°C
Ambovombe	30°C
Tsihombe	27°C

In Table -2, it can be seen that in district of Tsihombe, the 90th percentile is lower than in the other three districts. A maximum extreme temperature or warm day is defined if it is greater than or equal to TX90. From 1979 to 2010, the occurrence of warm days found in the 4 districts is shown in Table -3 below:

Table -3: Values of warm days and corresponding years in the 4 districts

Districts	Year	Temperature
Beloha	2002	31,99°C
	2014	31,43°C
	2015	32,52°C
Bekily	2002	33,62°C
	2005	31,11°C
	2013	31,25°C
Ambovombe	2002	32,19°C
	2013	30,46°C
	2014	30,81°C
Tsihombe	1986	27,23°C
	2014	27,69°C

In Table -3 we counted in the district of:

- Beloha : 3 warm days
- Bekily : 3 warm days
- Ambovombe 3 warm days
- Tsihombe : 2 warm days

3.1.2 Cold Nights and Warm Nights

Figure 2 shows that with the exception of the district Tsihombe where the minimum temperature has a downward trend of 0.006 ° C, this trend is significantly increasing in the other three districts.

A night is classified as warm when the minimum temperature is greater than or equal to TN90 and is considered cold if the minimum temperature is less than or equal to TN10.

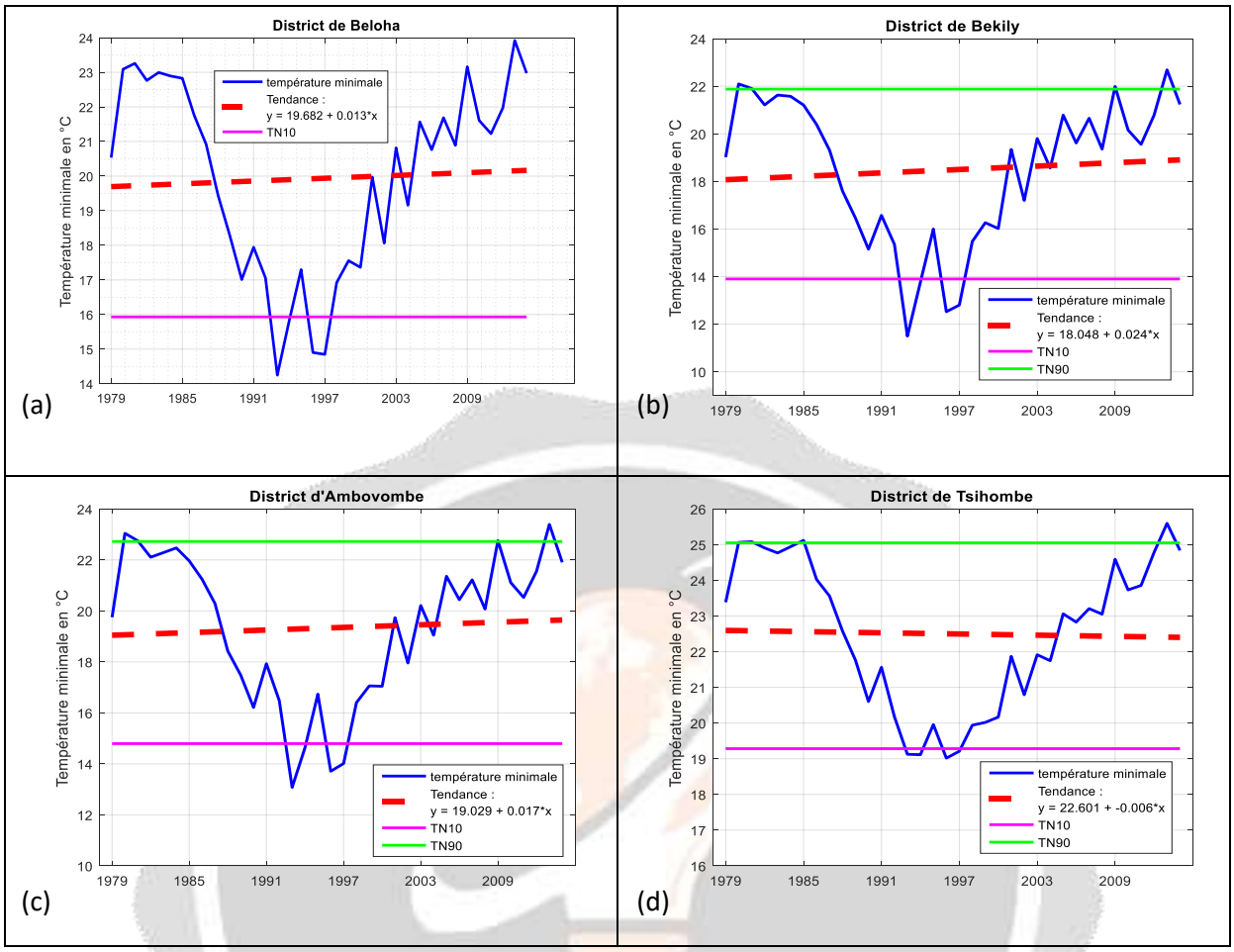

Fig –3: Occurrence of cold and warm nights in the Districts of Beloha (a), Bekily (b), Ambovombe (c), Tsihombe (d)

Below are the values of TN1O and TN90 found :

Table –4: TN90 and TN10 values in the 4 districts

Districts	TN10	TN90
Beloha	16°C	23°C
Bekily	14°C	22°C
Ambovombe	15°C	22°C
Tsihombe	19,5°C	25°C

As with the maximum temperature, there are also extreme values that exceeded the TN90 and TN10 values in the 4 districts from 1979 to 2015.

Warm nights

In Table –5, we have enumerated in the districts of:

- Beloha: 3 warm nights
- Bekily: 3 warm nights
- Ambovombe: 2 warm nights
- Tsihombe: 2 warm nights

Table –5: Warm nights and corresponding years values in the 4 districts

Districts	Year	Temperature
Beloha	1982	23,26°C
	2010	23,16°C
	2014	23,92°C
Bekily	1981	22,10°C
	2010	21,99°C
	2014	22,69°C
Ambovombe	1981	23,04°C
	2014	23,39°C
Tsihombe	1986	25,12°C
	2014	25,60°C

Cold nights

In Table –6, we have enumerated in the districts of:

- Beloha: 3 cold nights
- Bekily: 3 cold nights
- Ambovombe: 3 cold nights
- Tsihombe: 4 cold nights

Table –6: Values of cold nights and corresponding years in the 4 districts

Districts	Year	Temperature
Beloha	1994	14,25°C
	1997	14,90°C
	1998	14,85°C
Bekily	1994	11,50°C
	1997	12,52°C
	1998	12,80°C
Ambovombe	1994	13,08°C
	1997	13,71°C
	1998	14,01°C
Tsihombe	1994	19,13°C
	1995	19,11°C
	1997	19,02°C
	1998	19,21°C

3.2 Return Periods of Minimum and Maximum temperature in the 4 districts

Table –7 allows us to see the return periods of the extremes of minimum and maximum temperatures.

For the return period of 2 years, concerning:

The minimum temperature: every 2 years the extreme minimum temperatures in the 18 ° C, 19.5 ° C, 20 ° C, 23 ° C can be repeated in the districts of Bekily, Ambovombe, Beloha, Tsihombe.

The maximum temperature: a temperature in the 28 ° C is identified for the districts of Beloha and Bekily; and for the districts of Ambovombe and Tsihombe the temperatures in the 27 ° C and 25 ° C are found respectively;

For the return period of 5 years, concerning:

The minimum temperature: every 5 years the extreme minimum temperatures in the 21 ° C, 22 ° C, 23 ° C, 25 ° C can be repeated in the districts of Bekily, Ambovombe, Beloha, and Tsihombe.

The maximum temperature: a temperature in the 31 ° C is identified for the districts of Beloha and Ambovombe, and the temperatures in the 32 ° C and 27 ° C are found respectively in the districts of Bekily and Tsihombe.

For the return period of 10 years, concerning:

The minimum temperature: every 10 years the extreme minimum temperatures in the 23 ° C, 24 ° C, 25 ° C, 26 ° C can be repeated in the districts of Bekily, Ambovombe, Beloha, and Tsihombe.

The maximum temperature: a temperature in the 33 ° C is identified for the districts of Beloha and Ambovombe, and the temperatures in the 34 ° C and 28 ° C are found respectively in the districts of Bekily and Tsihombe.

For the return period of 20 years, concerning:

The minimum temperature: every 20 years the extreme minimum temperatures in the 24,3 ° C, 25 ° C, 25,1 ° C, 26,4 ° C in the districts of Bekily, Ambovombe, Beloha, and Tsihombe can be repeated.

The maximum temperature: a temperature in the 34 ° C is identified for the districts of Beloha and Ambovombe, and temperatures in the 35 ° C and 28.5 ° C respectively for the districts of Bekily and Tsihombe.

For the return period of 25 years we have regarding:

The minimum temperature: every 25 years the minimum extreme temperatures in the 24.5 ° C, 25.2 ° C, 25.5 ° C, 26.7 ° C in the districts of Bekily, Beloha, Ambovombe and Tsihombe can be repeated.

The maximum temperature: a temperature in the 36 ° C is identified for the districts of Beloha, Ambovombe and Bekily, and in the 29 ° C for the district of Tsihombe.

Table –7: Minimum and maximum extreme temperature return times in the 4 districts

Return period (year)	2	5	10	20	25
Minimum temperature (°C) (District of Beloha)	20	23	25	25.1	25.2
Minimum temperature (°C) (District of Bekily)	18	21	23	24.3	24.5
Minimum temperature (°C) (District of Ambovombe)	19.5	22	24	25	25.5
Minimum temperature (°C) (District of Tsihombe)	23	25	26	26.4	26.7
Maximum temperature (°C) (District of Beloha)	28	31	33	34	36
Maximum temperature (°C) (District of Bekily)	28	32	34	35	36
Maximum temperature (°C) (District of Ambovombe)	27	31	33	34	36
Maximum temperature (°C) (District of Tsihombe)	25	27	28	28 ,5	29

4. CONCLUSIONS

The analysis of the minimum and maximum temperature data allowed us to know extreme values and their period of return in the 4 districts of the region Androy. Minimum and maximum temperatures tend to increase from 1979 to 2015 in the three districts other than Tsihombe district, where there is a downward trend.

In general, extreme values of maximum temperatures have been found in the four districts, namely:

• District of Beloha: temperature in the 31.99 ° C for the year 2002; 31.43 ° C for 2014 and 32.52 ° C for 2015

• District of Bekily: temperature in the 33.62 ° C for the year 2002; 31.11 ° C for 2005 and 31.25 ° C for 2013

• District of Ambovombe: temperature in the 32.19 ° C for the year 2002; 30.46 ° C for 2013 and 30.81 ° C for 2014

• District of Tsihombe : temperature in the 27.23 ° C for the year 1986 and 27.69 ° C for 2014

It has also been detected that extreme maximum temperatures are repeated every 2 years, 5 years, 10 years, 20 years and 25 years. The temperature in the 36°C is repeated every 25 years in the districts of Beloha, Bekily and

Ambovombe. The temperature in the 34°C is repeated every 20 years in the districts of Beloha and Ambovombe while the temperature in the 35 ° C for the district of Bekily.

It has been noted that the temperature is not very extreme in Tsihombe district as compared to the other three districts. In addition, it is the only district of this region which is located near the sea, remains to know if this is the cause.

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