Study of the behavior of climatic variables causing drought in the southwest part of Madagascar

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ABSTRACT

The objective of this study is to determine the origins of drought in the southwest part of Madagascar.
In this study the ombrothermal diagram is used to determine the seasons and the standardized precipitation index method to know the different types of drought. The analysis of the intercorrelations shows that humidity and temperatures are correlated with precipitation in the dry zone but the correlation in the humid zone goes with the winds. The superpositions of variables such as 200 hPa winds and 850 hPa humidity show that this wind transports humidity from the southwest part to the eastern part of Madagascar. This phenomenon made it possible to conclude that the transport of humidity by winds is one of the sources causing drought in the southwest part of Madagascar. The study showed that in general the southwest part of Madagascar is affected by a drought close to normal.

Keyword: *precipitation, humidity, wind, SPI, ombrothermal diagram*

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1. INTRODUCTION

For several years, global warming has affected countries around the world as a result of climate change. Every year, countries aware of this scourge try to come together for three reasons, on the one hand it is to know the origin or the reason of this problem, and on the other hand, to know what impact it has. The third most important point of the meeting is to clearly determine the solution that could be effective in eradicating this scourge. Regarding Madagascar, we see this problem more precisely in the South-West part of Madagascar. This prompted us to study this problem further, to minimize its impact. This is the reason why we chose the title of this work: “Study of the behavior of climatic variables causing drought in the South-West part of Madagascar”. Therefore, we will subdivide our work into two large distinct parts which are directly linked. The first part consists of determining the methodologies and the second part aims to demonstrate the results obtained.

2. METHODOLOGY

2.1 Weather data

The data used are daily reanalysis data of the ERA-Interim experiment of the ECMWF (European Center for Medium range Weather Forecasts) on a synoptic scale with a grid of 0.5°x0.5° for precipitation, humidity and winds over the period 1979-2017. The study area is delimited by latitudes 19°S and 25°S and longitudes 37°E and 43°E.

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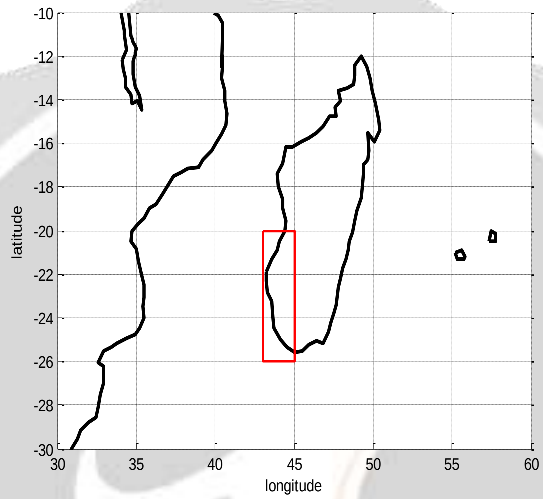


Figure 1: representation of the study area

2.2 Statistical methods

2.2.1 SPI index calculation method

The Standardized Precipitation Index (SPI) is based on statistical calculations of precipitation over a long period of time. The SPI was developed in 1993 by Mc KEE, N.J. DOESKEN & J. KLEIST of Colorado State University, for the determination of rainfall deficits. It is a very important, powerful and simple index to calculate. Precipitation data is actually the only parameter required. In addition, the SPI index is just as effective for analyzing wet periods or cycles as it is for dry periods or cycles. This index is calculated by the following formula:

$$SPI=\frac{1}{N_i}\sum_{j=1}^{N_i}\frac{P_j^i-\bar{P}_i}{\delta_i}$$

P_j^i : the rain of year at station j

P_j : the interannual average rainfall of station j

δ_i : the standard deviation of the series of seasonal accumulations at station j

N_i : the number of stations in year i.

2.2.2 Correlation coefficient

The correlation coefficient between two variables X and Y is a measure which varies between -1 and 1.

When r = -1, it means we have a perfect negative relationship, and when r = 1, it means we have a perfect positive relationship. When r = 0, there is no relationship at all. The covariance between two variables X and Y is a generalization of the notion of variance and is a mathematically simple way of describing the relationship between two variables which is not very informative for humans.

$$\text{Cov}(X, Y) = \frac{1}{N}\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})$$

Since we multiply a quantity that depends on X by a quantity that depends on Y and then calculate the average, we can think of the covariance formula as an "average cross product" between X and Y.

3. RESULTS

The work carried out in this part consists of comparing the behavior of the variables of the wet zone to those of the dry zone.

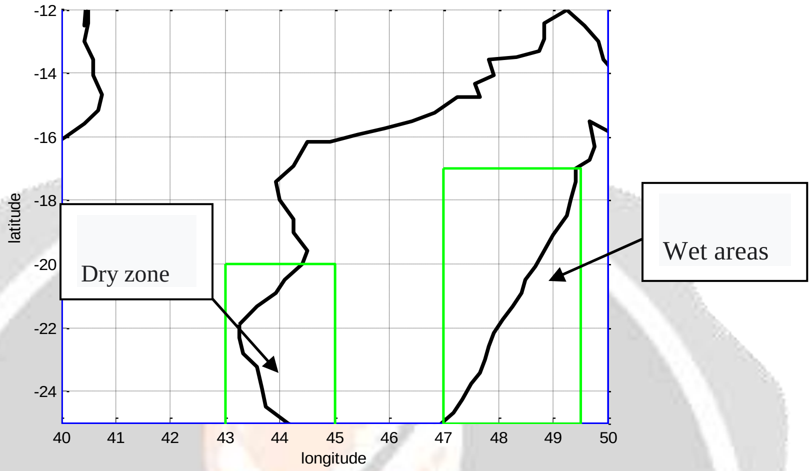
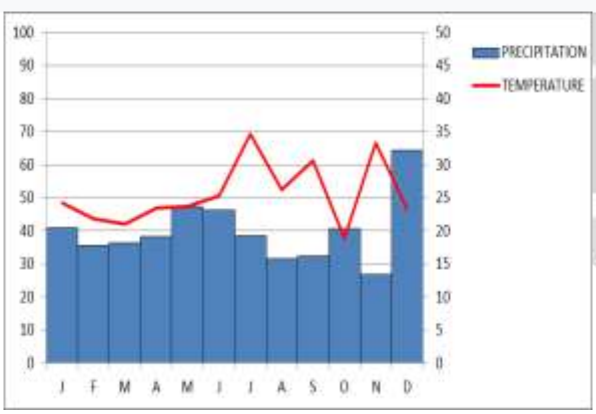


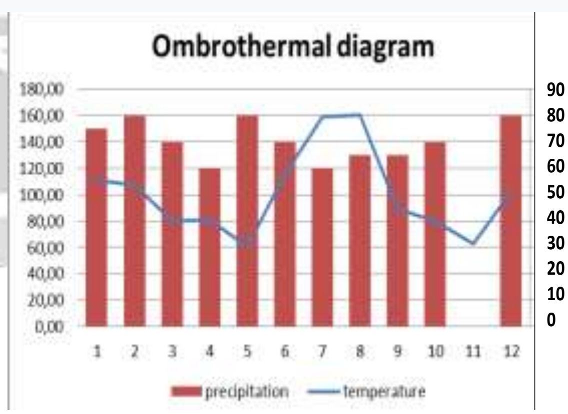
Figure 2: Representations of the dry zone in the southwest part of Madagascar and the wet zone in the East

3.1 Analysis of the different types of drought in the southwest part of Madagascar

Figure 3 is the ombrothermal diagram. It allows us to distinguish between dry and wet seasons. It represents the cumulative monthly precipitation, in millimeters in the form of blue bars. The average monthly temperatures in Celsui are superimposed (curve in red). The scale is P=2T, that is to say that 2mm of precipitation corresponds graphically to 1°C of temperature. By observing, we see in Figure 3 (a) that the South-West part of Madagascar is almost in total drought while Figure 3 (b) represents a wet period throughout the year except in the months of July and August in the eastern part.



(a)



(b)

Figure 3: representation of ombrothermal diagram in the dry zone (a) and wet zone (b)

Figure 3 representation of ombrothermal diagram in the dry zone (a) and wet zone (b). To properly carry out our

studies, we must analyze the variation of the standardized precipitation index as a function of time. Positive values of the SPI index represent a wet season, negative values indicate a wet season.
The data used here is annual data. Figure 4 shows us that the near-normal drought season that dominated the southwest region of Madagascar is 38% during the period of our study and the moderate drought is only 21%.
In 2013, this area was affected by extreme humidity, with the Standardized Precipitation Index value reaching 2.151. In general, this area is characterized by a close to normal season.

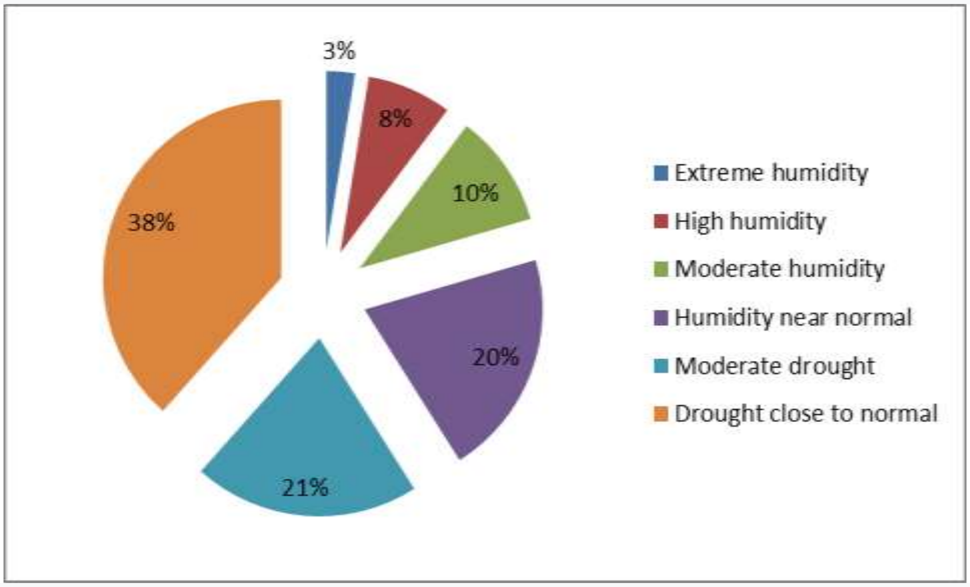


Figure 4: Extent of drought in the southwest region of Madagascar from 1979 to 2017

3.2 Study of the behavior of climatic variables in the South-West zone and the East zone of Madagascar
Table 1 represents the intercorrelation between precipitation and other climatic variables over the period 1979-2017 in the South-West and East part of Madagascar. We see that the specific humidity has zero phase shifts with precipitation and presents a weak correlation. This shows that these parameters evolve in the same way and in the same direction in the South-West zone and the East zone of Madagascar. Regarding the maximum temperature and the minimum temperature, they are 24 months behind in the dry zone and 12 months ahead for the humid zones, they have the same phase shifts, i.e. negative. These two variables have no influence on precipitation.
However, the correlation coefficients are less than 0.5, signifying the absence of linear dependence between precipitation and wind (200hPa and 950hPa) in the southwest part of Madagascar. According to this first analysis, we can affirm that precipitation and humidity are in phases, this allows us to say that these variables are in favorable conditions.
In the eastern part, the delay is 7 months for the winds (200hPa and 950hPa) and the correlation coefficients between two parts are different, in one of these zones it is weak but the other it is very strong.
Indeed, the 200hPa wind presents a long-term memory effect.

Table 1: summary of the results of monthly inter-correlations between precipitation and other variables

	Daily phase shift of the inter-correlation		Inter-correlation coefficient		Coefficient of linear correlation	
	dry	humid	dry	humid	dry	humid
Maximum temperature	-24	12	**0.5182**	**0.57**	-0.053	-0 .805
Minimum temperature	-24	12	**0.5156**	**0.5848**	-0.595	-0 .8076
Hq 700hPa	0	0	**0.6598**	**0.8129**	-0.4828	-0 .7112

Hq 850hPa	0	0	**0.6503**	**0.7875**	-0.4828	-0 .7266
Hq 950hPa	0	0	**0.6168**	**0.8011**	-0.516	-0 .7631
Vent 200hPa	5	-7	0.4015	**0.578**	-0.4881	-0 .7076
Vent 950hPa	-7	-7	0.2374	**0 .5682**	-0.2989	-0 .4265

Table 2 represents the monthly quantities of the climatological mean of the variables in the dry zone. In the months of (JFMJA) the dry zone is temperate but in the month of October, low temperatures are observed. The Specific Humidity of the air at 700 hPa, 850 hPa and 950 hPa has a peak in February, April and March and a minimum value in November, October and December.

In table 3, in the eastern zone of Madagascar, in August the temperature was higher but in May, October and November the temperature dropped. The specific humidities (700 hPa and 850 hPa) are higher in May but for the months of December and October, they remain minimal.

Table 2: representation of monthly averages in the South-West zone of Madagascar

	J	F	M	A	M	J	J	A	S	O	N	D
TEMPERATURE	25,6	25,6	25,6	25,5	25,5	25,5	25,6	25,6	25,5	25,4	25,5	25,6
H700 (10^{-3})	3.90	4.05	4.04	3.90	3.80	3.84	3.75	3.64	3.46	3.27	3.25	3.54
H850 (10^{-3})	7.87	8.13	8.33	8.39	8.03	8.03	7.85	7.79	7.81	7.76	7.79	7.85
H950 (10^{-3})	11.61	11.88	12.23	12.09	11.97	22.88	12.16	11.8	11.66	11.66	11.5	11.46

Table 3: results of monthly averages of climatic variables in eastern zone

	J	F	M	A	M	J	J	A	S	O	N	D
TEMPERATURE	25,9	25,9	25,9	25,9	25,8	25,9	26,0	26,1	25,9	25,8	25,8	25,9
H700 (10^{-3})	4.99	5.19	5.45	5.66	5.67	5.55	5.19	5.06	5.06	4.99	4.93	4.83
H850 (10^{-3})	10.52	10.53	10.46	10.53	10.69	10.65	10.46	10.30	10.23	10.15	10.29	10.19
H950 (10^{-3})	12.77	12.93	12.98	12.92	12.72	12.70	12.82	12.90	12.87	12.85	12.67	12.66
V200hPa	17,6	16,5	19,2	16,8	17,0	17,3	17,8	17,7	17,9	17,0	18,0	19,3
V950hPa	3,2	3,1	3,2	3,7	3,6	3,3	2,9	3,5	3,2	3,2	3,5	3,5

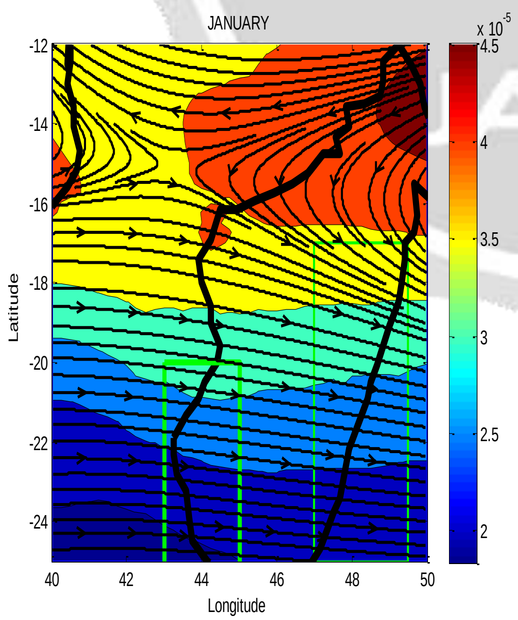
Figure 4 represents the directions of winds 200hPa and specific humidity 850hPa over the period 1979 to 2017 in the South-West zone and the East zone of Madagascar. We observe that:

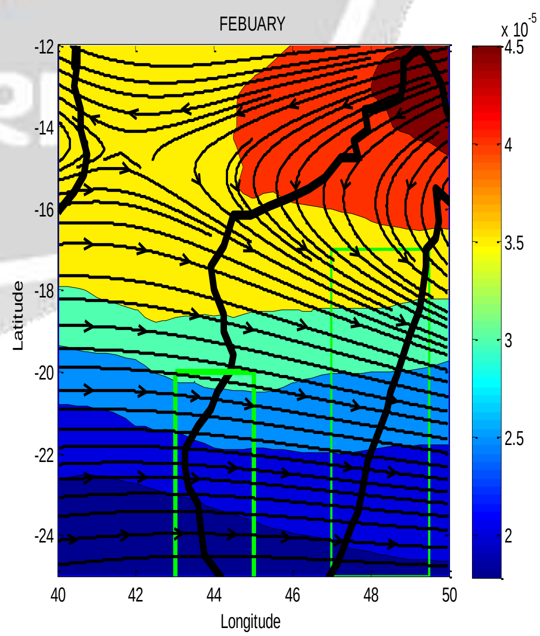
- In January, the 200 hPa winds coming from the North-East deviate from West to South-East. Its speed decreases from the low pressure zone towards the South-East. With humidity 850 hPa, we see that the humidity in the northern part of the big island remains more intense than in the southern part. We also note that the South East zone is always wetter than the South West zone and that the wind crosses the large island from North West to South East.
- During the month of February, 200 hPa winds circulate from the South-West, rising towards the West and heading towards the East and South-East on 18S and 25S but [18S 20S and 46E 50E], this wind blows from the North- Is circling towards the East with maximum and minimum speed. By observing the humidity at 850 hPa, we see that the northern part of Madagascar is more humid than the southern part.
- In March, on [16S to 25S], 200 hPa winds circulate from South-West West to South-East.

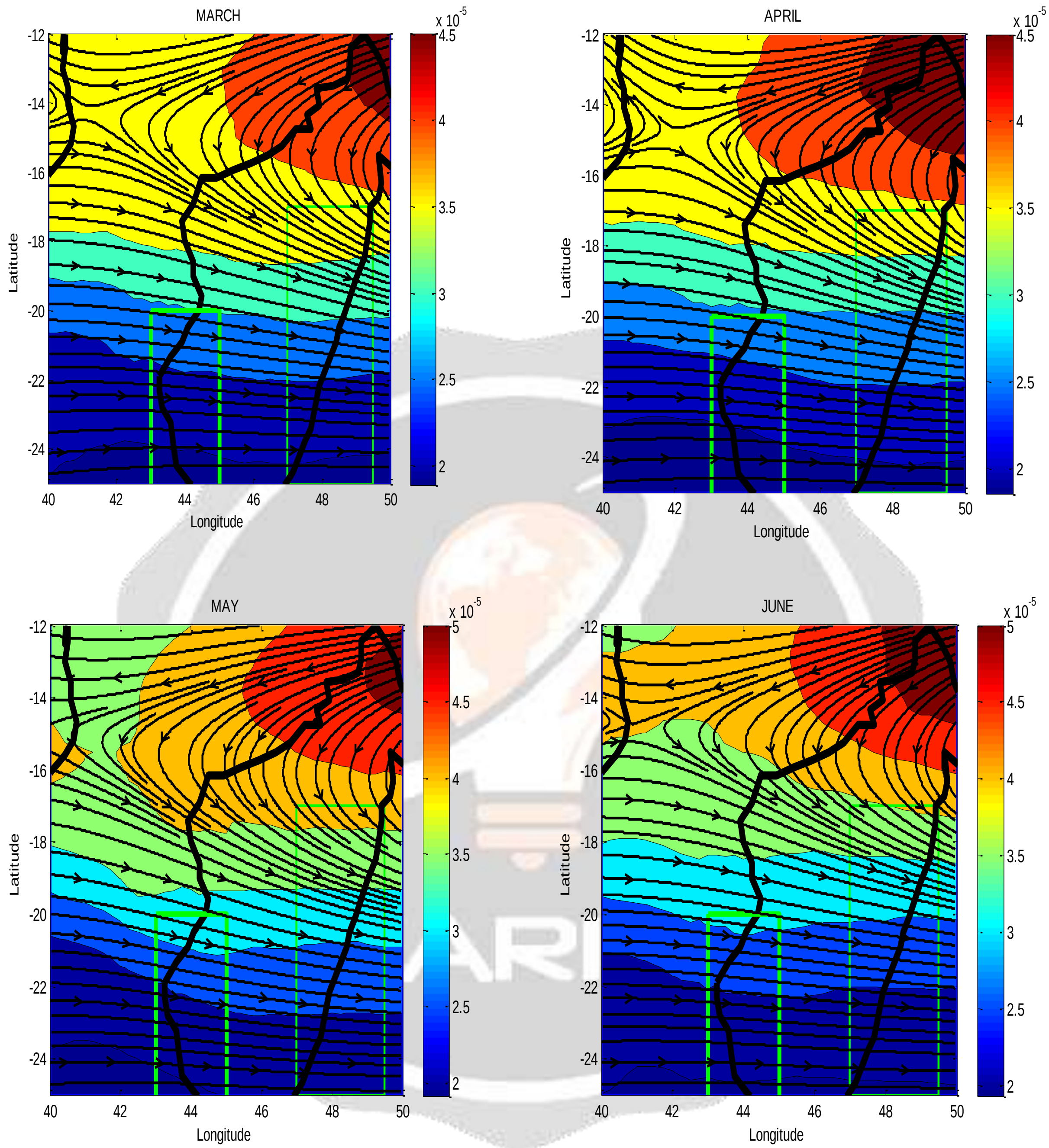
Humidity 850 hPa, going from North-West to North-East, the quantities of humidity continue to increase. But we see that the southern part is less humid than the northern part [20S 25S].

• For the month of April, the 200 hPa winds coming from the South-West deviate from West to South-East. Its speed decreases from the low pressure zone towards the South-East. On the other hand, for humidity 700 hPa and 850 hPa, we see that the humidity rates decrease very slowly from North-West to North-East.But on [22S 25S], the quantities of this humidity are very small; by visualizing the wind directions, we can say that the eastern parts were able to benefit from the humidity of the North.

- In May and June, 200 hPa winds blow from North-East to West, circling from the North-East. Its speed decreases from the low pressure zone towards the South-East. By analyzing the 850 hPa humidity, we see that the grid points [47 E 50 E] have the most intense humidities. Going south, this humidity only decreases little by little. We notice the wind direction going from North-West to South-East.
- In July, the 200 hPa winds coming from the North-East undergo a deviation from West to South-East on [12S 18S and 45 E 50E], but in the other parts, the winds flow from South-West towards South East. Its speed decreases from the low pressure zone towards the South-East. With humidity 850 hPa, we see that the humidity in the northern part of the big island remains more intense than the southern part. We also note that the northern part is always wetter than the southern part and that the wind crosses from the North-West-West to the South-East.
- In August, 200 hPa winds blow from the South-West rising from the West to the South-East with its maximum and minimum speed. When we analyze the humidity at 850 hPa, we see that the humidity levels decrease going down towards the southern part and we see that the south-western parts are completely dry. The directions of the wind will bring humidity to the eastern part thanks to the intercorrelation between rainfall and 200 hPa winds.
- In September, 200 hPa winds blow from the South-West descending towards the South-East on [18S 25S], while on the grid points [14S 18S and 45 E 50E and 40E 43E], these winds have deviation from North-West to South-East and from North-East to West. By observing the humidity at 850 hPa, we see that the humidity levels continue to decrease going down towards the southern part.
- In October and November, 200 hPa winds come from North-West to East and deviate towards South-West on [18S 19S and 43E 44E]. These winds blow from South-West to South-East, with a downward direction. At 200 hPa humidity, we see that the northern parts are more humid than the south. This allows us to say that as we move towards the South, humidity levels only decrease. Looking at the directions of these winds; we can say that the eastern part is always wetter than the others.
- In December, 200 hPa winds circulate from South-West West to East and deviate towards North East. When we analyze the 850 hPa humidity, we see that its quantity is higher in the western part [13S 18S] and diffused towards the North, towards the East and towards the South. Apparently remains a dry area. zone to that of the South-East zone; the latter is more humid than the first. Indeed, due to the inter-correlation between precipitation and humidity which is late by 7 months, and that of the 200 hPa speed is also 7 months; the eastern part always gains more humidity than the other zones and, in the dry zone, the humidity simply passes through.



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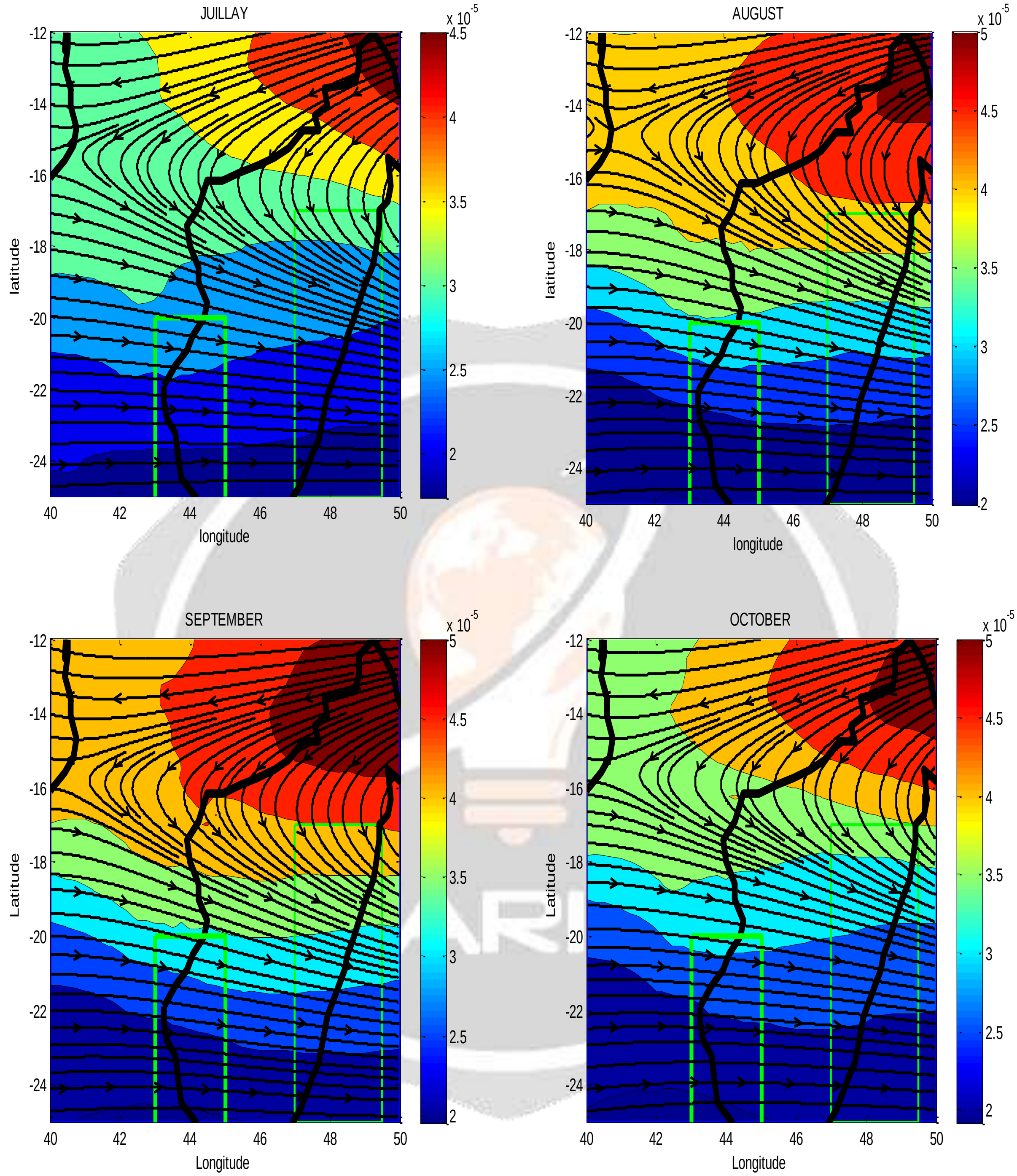
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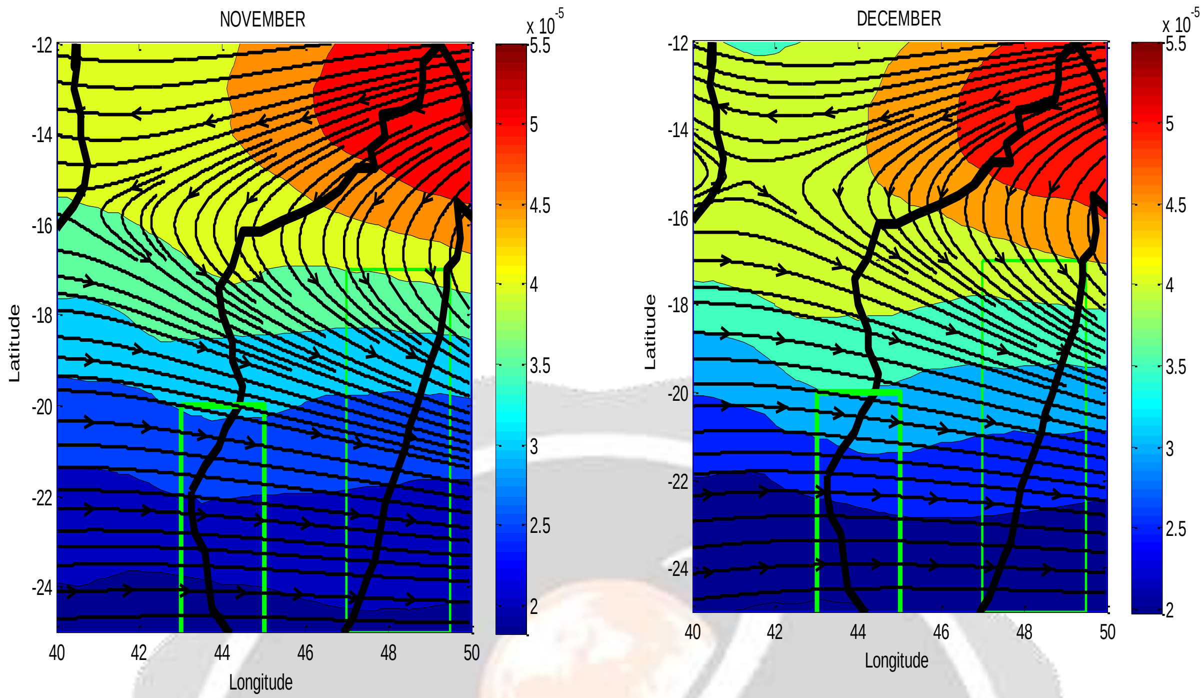

Figure 4: Representation of wind directions 200hPa and specific humidity 850hPa during the period 1979 – 2017 in two areas

4. CONCLUSIONS

An in-depth study on the existence of drought in the southwest part of Madagascar was carried out using appropriate methods highlighting the contribution of wind and temperature. This phenomenon was demonstrated using two methods:

- On the one hand, thanks to the method of calculating the SPI index, it was possible for us to confirm the presence of drought in our study area. The results showed that only two months of the year there is precipitation in this area.
- On the other hand, the correlation coefficient method applied to temperatures and wind was a reliable source for highlighting drought in our study area.

This method made it possible to determine the state of drought in the southwest part of Madagascar and to explain the cause.

6. REFERENCES

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