STUDY AND FORECAST OF RAINY SEASONS AT MIARINARIVO (19°S, 47°E)

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Abrstract :

The purpose of this project is to model in order to short term forecast the rainy seasons. One grid point (19°S, 47°E) located in the region of Miarinarivo-Itasy was taken as an example for the application. The data are the daily precipitations within the last 38 years (from 1979 to 2017). The rainy seasons were determined through the Anomalous Accumulation Method (AA). Two models were compared: the additive and the multiplicative seasonal model of the Holt-Winter's exponential smoothing (HW). The Mean Absolute Percentage Error (MAPE) was used to check the quality of the model. The findings show that the additive seasonal model of Holt-Winter (α=0.1; β=0.3; ϒ=0.3) is a good forecasting model with a value of MAPE equal to 12.1%. Rainy season 2018-2019: November, 10th 2018 – March, 21st 2019.

Key-words: Miarinarivo, onset, end, rainy seasons, Holt-Winter, MAPE, AA

1. Introduction:

Madagascar is located in the south-West of the Indian ocean and possesses two seasons: wet season and dry season. Previously, onset and ends dates forecast of rainy seasons over different zones were determined [1], [2], [3]. In this project, the study is going to be at one grid point within Itasy. It is one of 22 regions of the island where 20.1% of the soil is arable [4**]**. Actually, the rainy seasons of this region start in November [5]**.** The determination of the specific onset and end dates of its rainy seasons can help avoid early sowing dates and improve the crop yields. However, the effect of the climate change makes the determination of the rainy seasons calendar difficult. 12 [6]. Moreover, this event is felt through the distribution of rainfall, its quantity, and through the early or late onset of rainy seasons in the island [7].

This is the reason why this project aims to model in order to forecast rainy season by minimizing the errors. A climatological study, from 1979 to 2017 was done. place of study is within Miarinarivo at a grid point (latitude 19°S and longitude 47°E).

2. Methods:

2.1 Zone of study

As can be seen on figure 1, the study was done at a grid point (19°S, 47°E) within Miarinarivo-Itasy.

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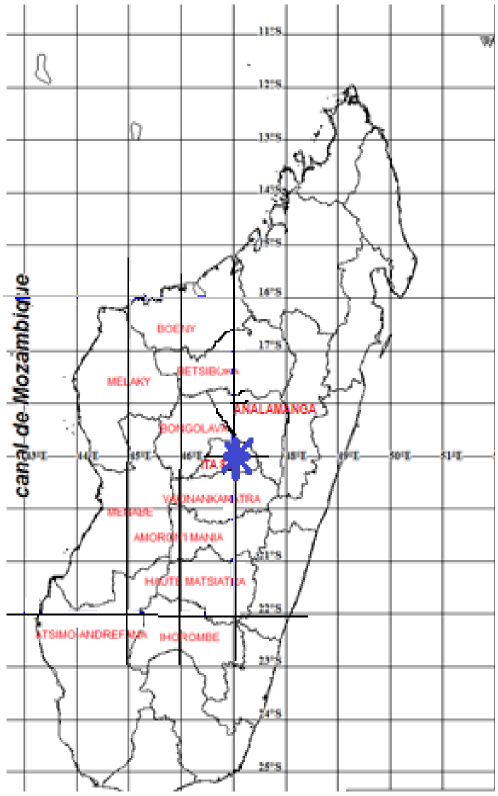

Figure 1: Representation of the place of study (19°S, 47°E)

On this map, the grid point is represented by a blue star.

2.2 Materials

The data are daily precipitations, from 1979 to 2017, which were uploaded from the ECMWF (Europe Center for Medium Range Weather) site through ERA-Int experiences.

The software MATLAB was used throughout the research for programming. Excel and XLstat, were used for compilation and for checking the results respectively.

2.3 Methods

The first step is the determination of the onset dates and the end dates of rainy seasons through the application of the Anomalous Accumulation method [8], [9], [10] on the daily precipitation. This method is described as:

$$A(\mathrm{day}) = \sum_{n=1}^{\mathrm{day}} (R(n) - \overline{R}) \qquad (1)$$

with $R(n)$: Daily precipitation and $\overline{R}$: statistical mean

Then these onset dates and end dates of rainy seasons from 1979 to 2017 were gathered to compose a new datum.

Once the new datum is formed, the second step corresponds to the determination of the forecasting model trough the analysis of the new datum curve shape [11]. The Holt-Winter's exponential smoothing was in use as a short time [12] forecasting model. Two models are discussed: the additive seasonal model and the multiplicative seasonal model. Each model possesses three parameters 0< **α**<1, 0<**β**<1, and 0<**γ**<1 corresponding respectively to level, trend and seasonality [13]. Then, the three smoothing parameters is determined by comparing the values of the Mean Absolute Percentage Errors (MAPE) [14] corresponding to different triplets **(α, β, γ).** Once the parameters are determined, they are applied to both models: the additive and the multiplicative models.

The Holt Winter's Additive model:

$$\text{Level } b_t = \alpha(y_t - S_{t-s}) - (1-\alpha)(b_{t-1} + a_{t-1}) \qquad (2)$$

$$\text{Trend } a_t = \beta(b_t - b_{t-1}) + (1-\beta)\, a_{t-1} \qquad (3)$$

$$\text{Seasonal } S_t = \Upsilon(y_t - b_t) + (1-\Upsilon)S_{t-s} \qquad (4)$$

$$\text{forecast } F_{t+h} = b_t + ha_t + S_{t+h-s} \qquad (5)$$

The Holt Winter's Multiplicative model:

$$\text{Level } b_t = \alpha\frac{y_t}{S_{t-s}} + (1-\alpha)(b_{t-1} + a_{t-1}) \qquad (6)$$

$$\text{Trend } a_t = \beta(b_t - b_{t-1}) + (1-\beta)\, a_{t-1} \qquad (7)$$

$$\text{Seasonal } S_t = \Upsilon\frac{y_t}{b_t} + (1-\Upsilon)S_{t-s} \qquad (8)$$

$$\text{forecast } F_{t+h} = (b_t + ha_t)S_{t+h-s} \qquad (9)$$

h is the horizon and y_t is the actual observation.

The best model is the one which possesses a minimum value of MAPE. The evaluation of the model quality was done through the standard accuracy measure MAPE [14]. It is described by this equation:

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{y_t - F_t}{y_t}\right| \qquad (10)$$

Actually, there is classification of the model quality corresponding to the value of MAPE (Table 1).

Table 1: Quality of the model corresponding to the value of MAPE [15]

Value of the MAPE(%)	Quality of the model
MAPE < 10	Excellent
10 < MAPE< 20	Good
20 < MAPE< 30	Mean
MAPE > 30	Bad

After the determination of the best model, the fird and last step is the application of this model over the grid point. This consists in the validation of the model and the forecasting of the onset and end dates of the next rainy season.

To give an idea of the methodology, here is a diagramm (figure 2).

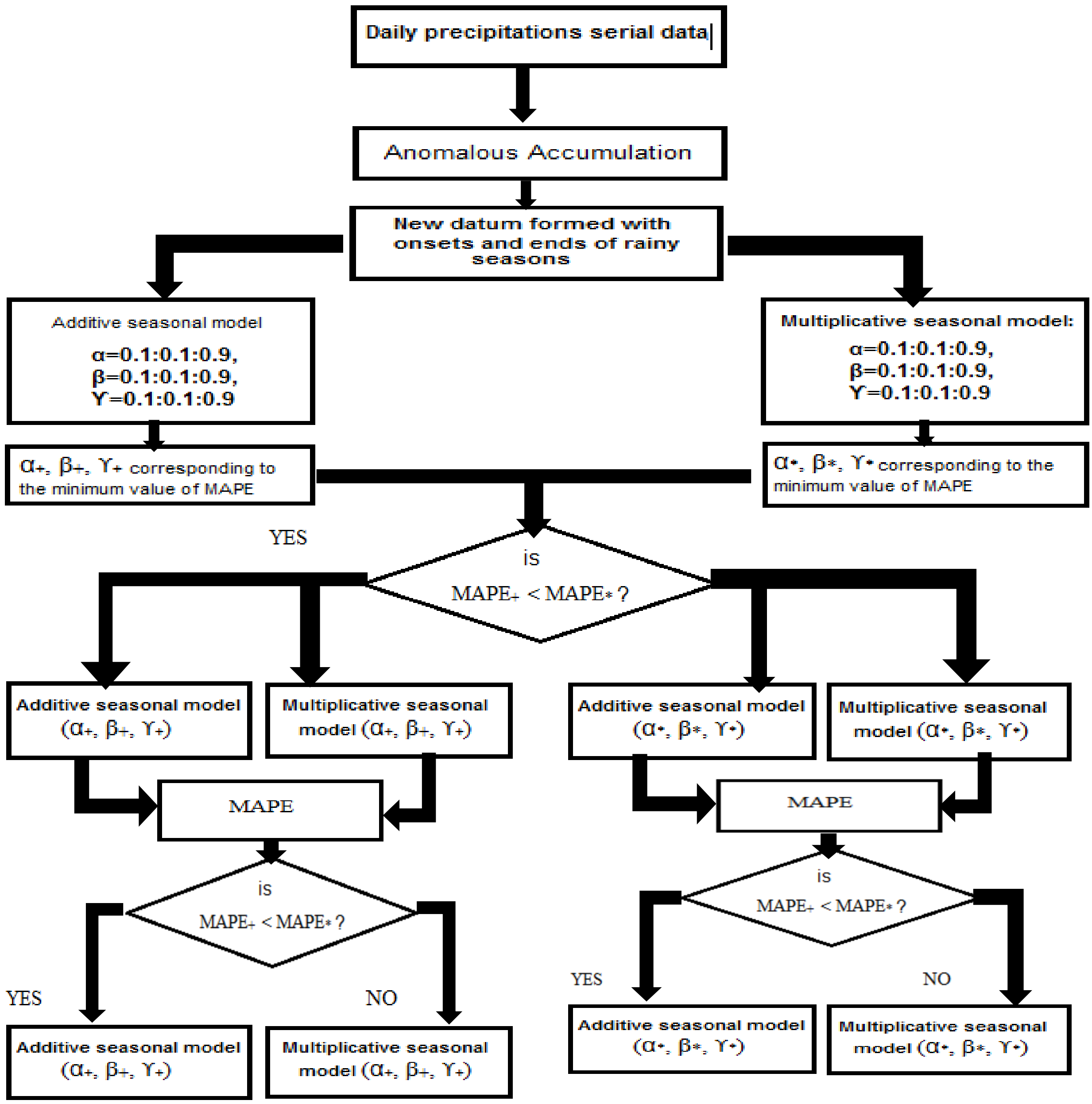

Figure 2: diagramm of the mothodology

$_+$: corresponding to the Additive seasosnal model

$_*$: corresponding to the Multiplicative seasonal model

3. Results:

3.1 The evolution of the rainy seasons

After applying the AA method on the daily precipitation, the onset dates and the end dates of the rainy seasons, from 1979 to 2017, were determined in order to create a new datum (figure 3). The minima represent the end dates of rainy seasons. The maxima correspond to the onset dates.

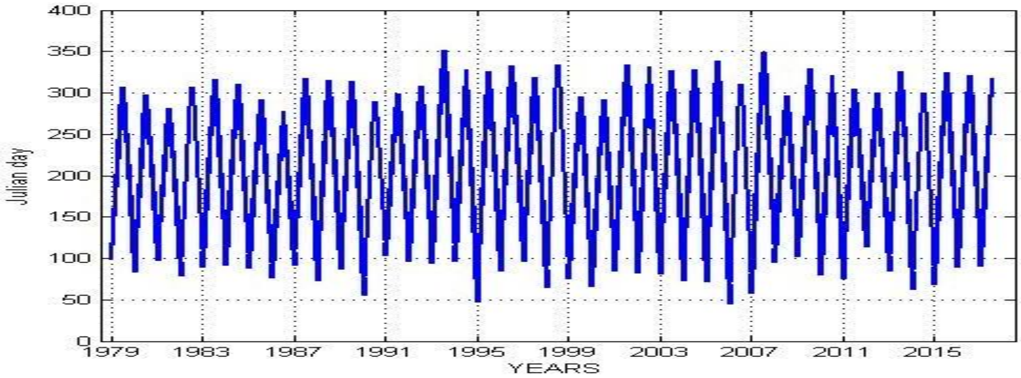

Figure 3: Representation of the new datum formed with onsets and ends of rainy seasons from 1979 to 2017 at (19°S, 47°E)

To have a specific look of the onsets and end dates of rainy seasons over this place, the fluctuation of both dates which limit rainy seasons will be represented separately (figure 4 and figure 5).

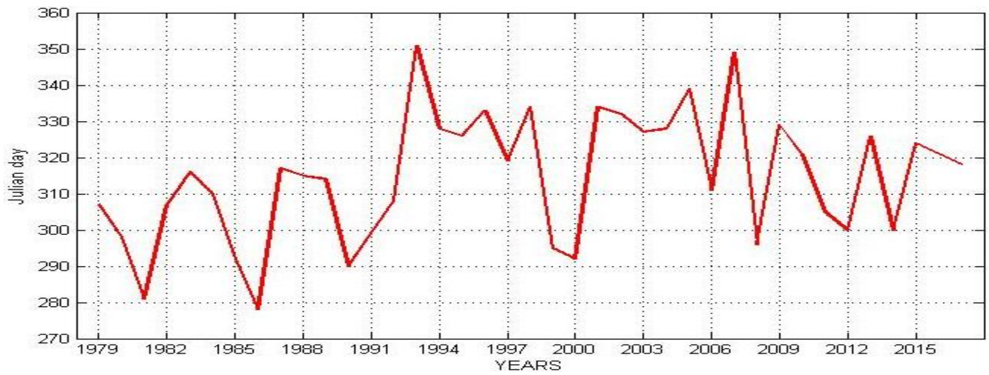

Figure 4: Start dates of rainy seasons from 1979 to 2017 at (19°S, 47°E)

The start dates of the rainy seasons at 19°S, 47°E fluctuate between the 278th (05th of October) and the 351th (17th of December) day of the year from 1979 to 2017. In average, statistically, the rainy seasons at this place start on the 11th of November. The minimum and the maximum were observed respectively in 1986 and in 1993.

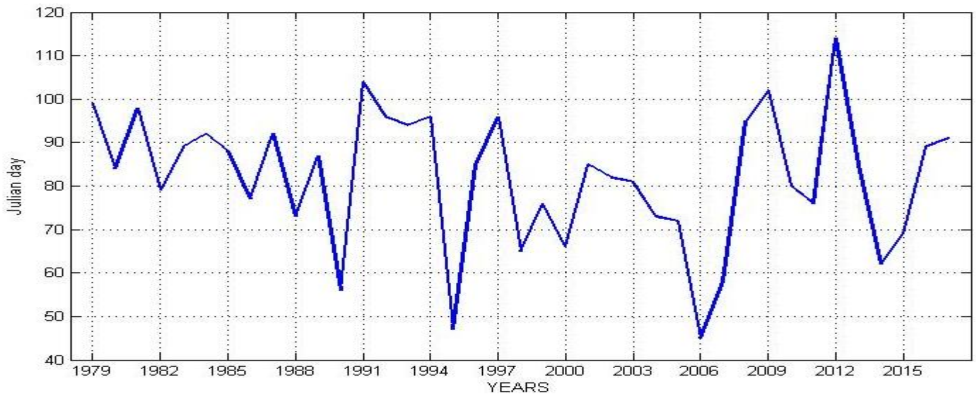

Figure 5: End dates of rainy seasons from 1979 to 2017 at (19°S, 47°E)

The end dates of the rainy seasons at the grid point (19°S, 47°E) vary between the 45th (14th of February) and the 114th (24th of April) day of a year. In average, statistically, the rainy seasons at this place end on the 19th of March. The minimum and the maximum were observed respectively in 2006 and in 2012.

3.2 Modeling and forecasting of the rainy seasons

After compiling 729 times the code program and after comparing the value of the MAPE corresponding to the different triplet (α, β, ϒ), the best parameters corresponding to the minima values of MAPE for both models are shown on table 2.

Table 2: The best smoothing parameters for both methods corresponding to the new datum at (19°S, 47°E)

Type of the model	MAPE(%)	Alpha	Beta	Gamma
Additive seasonal model	12.72	0.1	0.2	0.4
Multiplicative seasonal model	**12.68**	**0.1**	**0.3**	**0.3**

The comparison of the MAPE values corresponding to both models shows that the MAPE of the Multiplicative seasonal model is less than the Additive one. So, the best smoothing parameters are (α=0.1, β=0.3, ϒ=0.3).

The application of these smoothing parameters (α=0.1, β=0.3, ϒ=0.3) to the two models leads to the comparison of the values of MAPE corresponding to both models (figure 6).

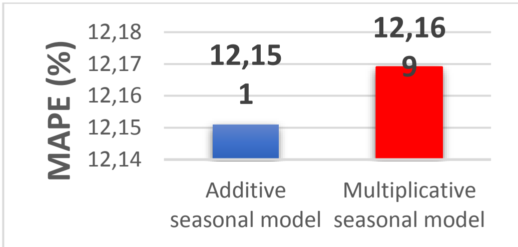

Figure 6: Comparison of the two models through their values of MAPE with (α=0.1, β=0.3, ϒ=0.3) at 19°S, 47°E

As shown on this figure, the MAPE of the Multiplicative seasonal model is upper than the MAPE of the Additive seasonal model with a value equal to 12.15%. Then, the Additive seasonal model of the Holt-Winter's exponential smoothing with α=0.1, β=0.3, and ϒ=0.3 is going to be kept for the application. As the model is determined, let us validate it through the comparison of the theoretical values and the values of the new datum. The year 2017 was kept for the validation of the model (table 3).

Table 3: Validation of the Additive seasonal model (α=0.1, β=0.3, ϒ=0.3) at (19°S, 47°E) in 2017

Data	Additive seasonal model	95% lower band	95% upper band
April, 01st	March, 21st	February, 12th	April, 27th
November, 14th	November, 10th	October, 04th	December, 18th

The value of the MAPE corresponding to the validation of the model is 6.6%. So, the validation of the model is excellent. There is 10 days and 4 days between the datum and the model for end date and onset date respectively.

The forecast of the onset and end dates of the next rainy season, I mean for rainy season 2018-2019 is shown on table 4.

Table 4: Forecast of rainy season 2018-2019 at (19°S, 47°E)

Year	Forecast dates	95% lower band	95% upper band
Onset 2018/2019)	November, 10th	February, 08th	May, 01st
End (2018/2019)	March, 21st	September, 30th	December, 22nd

In this table, the year of the forecast is written in bold. In fact, the rainy seasons of Madagascar start within the 3 last months of the year and end within the 3rd and the 4th month of the next year. So, the next rainy season is supposed to start on the 10th of November 2018 and end on the 21st of March 2019. An error of $\pm$ 42 days and a value of error being $\pm$ 45.5 days are observed for the onset date and the end date respectively.

The new datum, the model, and the application of the model are represented on the figure 7 for a sight.

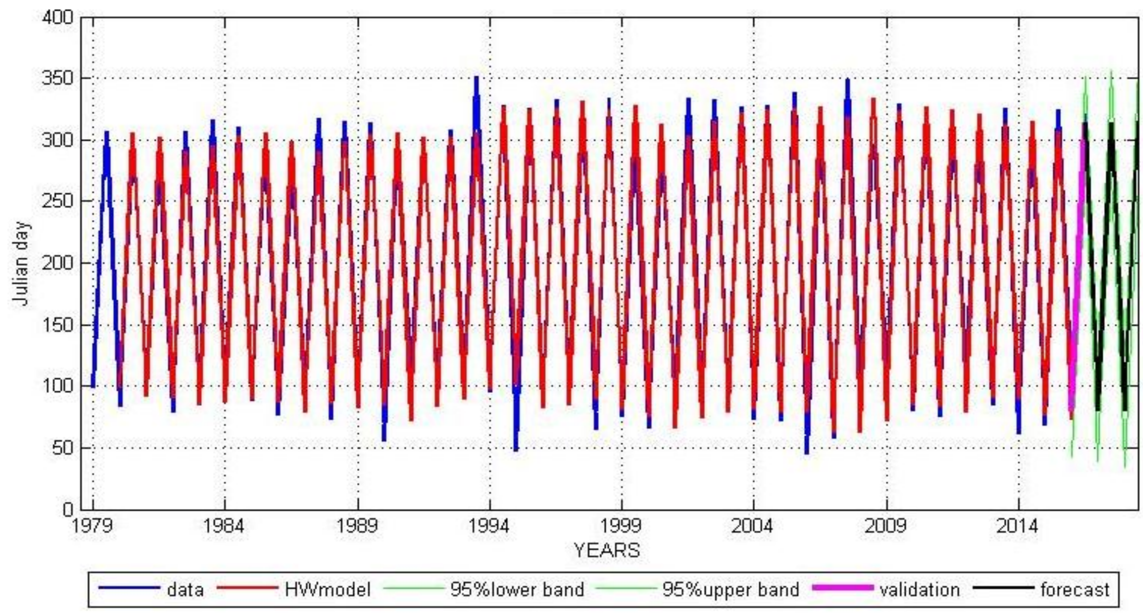

Figure 7: The modeling of rainy seasons at (19°S, 47°E) from 1979 to 2017

Large time lags are observed between the datum curve(blue) and the model curve(red) on 1993, 1995, 2001, and 2006. For example, in 1993, the onset date of the model(red) lags behind the datum(blue) one. Despite these errors, the datum curve(blue) overlaps with the model curve(red). The validation(magenta) and the forecast(black) curves are limited by a 95% confident band(green).

4. Discussion and conclusion:

The new datum is a periodic curve (figure 3) with a period equal to two. In fact, there is one wet season and one dry season over all regions of Madagascar each year [16]. The onset of the wet seasons is within the 3 last months of the year, especially in November [5] over the central part of Madagascar. As can be seen on figure 4, the start dates of rainy seasons at (19°S,47°E) is in November, dates within the period of the onset of wet season. The end of the wet seasons is between March and April [3]. The end dates of rainy seasons at (19°S, 47°E) (figure 4) are within this period. Actually, there is no link

between the onset dates and the end dates of rainy seasons at the grid point (19°S, 47°E) from 1979 to 2017. Among 729 values of MAPE, 12.68 was the minimum one which corresponds to α=0.1, β=0.3, and ϒ=0.3 (table 2). The values of smoothing parameters are less than 0.4. With a value of MAPE being 12.15% (figure 6), the Additive seasonal model is classified as a good [15] model with an excellent [15] validation (table 3) with a value of MAPE equal to 6.6%. The application of the model shows that the rainy season 2018-2019 is supposed to start on the 10th of November 2018 and end on the 21st of March 2019 with an error being $\pm$ 43.5 days (table 4). It is the time lags between some onset and end dates of actual data and the model (figure 7) which makes this error large enough. This error is large enough if we want to forecast rainy seasons with specific onset and end dates. So, a future project is dedicated to minimize this error. May be, the analysis of other validation error measures such as the Mean Absolute Deviation(MAD), Mean Square Error(MSE), … and the reduction of the parameters step into less than 0.1 can make the model more specific. Another outlook is the determination of two independent forecasting models: for the onset dates and for the end dates.

5. References:

[1] N. H. Razanatompoharimanga, ‘*repartition quotidienne des precipitations dans la partie centrale de Madagascar*’ – diplome DEA - 2012 - Université d’Antananarivo - biblio.univ-antananarivo.mg/pdfs/razanatompoharimangaNiryH_PC_M2_12.pdf.

[2] N. H. Razanatompoharimanga, A.A. Ratiarison, N. A. Rakotovao," *Rainy season over the central part of Madagascar* " http://www.slac.stanford.edu/econf/C161013/hepmad16_talks/razanatompo.pdf

[3] Niry H. Razanatompoharimanga, A.A. Ratiarison, J. M. Rabeharisoa, M.Djafar: « *The distribution of rainfall in the central part of Madagascar* ». www.slac.standford.edu.econf/C130904/papers/Razanatompoharimanga.pdf

[4] *Vice-Primature Chargée de l'Economie et de l'Industrie de Madagascar,* **RÉGION : ITASY,** https://annumada.bdelmada.com/region/itasy.html ce 06/03/18

[5] N. H. Razanatompoharimanga,*‘Prévision des périodes de pluies (débuts et fins) dans la partie Centre-Ouest de Madagascar’* thèse de Doctorat-Physique du Globe de l’Energie et de l’Environement, Université d’Antananarivo-Madagascar, 15/01/2016, biblio.univ-antananarivo.mg/pdfs/razanatompoharimangaNiryH_PH_DNR_16.pdf

[6] Christensen J H, Hewitson B, Busuioc A, Chen A, Gao X, Held I, et al;, "Regional Climate Projections," Cambridge University Press In : Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller, 2007

[7] S. RANDRIAMANGA, "Les périodes sèches estivales de Madagascar vues par METEOSAT.," in *Climat, couverture végétale et érosion des sols à Madagascar*. Lyon 3: Université Jean Moulin, 2006, vol. 2, pp. 50-60, Apport de la télédétection et des SIG, document de synthèse des travaux, HDR, Université Jean Moulin, Lyon3

[8] Brant liebmann, Dave Allured, Suzana J. Camargo, Anji Seth, "Onset of the rainy season ovr tropical Brazil in observations and a general circulation model simulation," http:// ams.confex.com/ams/pdfpaper/ 34786pdf *consulté le 20/04/14*

[9] J. Marengo, B. Liebmann, R. Fu S. camargo & A Seth, "Dynamics and predictability of rainy season onset and Demise for South America in Observation and GCMSimulations: ECHAM4.5"

[10] D. ARVOR et al., "Apport des données TRMM 3B42 à l'étude des précipitations au MATO GROSO," vol. 5, pp. 49-69, 2008
[11] S. Prajakta & Kalekar, "Time series forecasting using Holt-Winters Exponential Smoothing," December 2004
[12] Goldfarb, C. Pardoux et B., *Prévision à court temr: méthode de lissage exponentiel, version 1.3*. Université Paris-Dauphine, Janvier 2013 ressources.aunege.fr/nuxeon/site/esuprevision/6649e19c-1113-4060-a809-0deb 3959ffd5/res/publication_papier_prevision_130104.pdf consulté le 26/07/2014
[13] Prajakta S. Kalekar(04329008),*Time series Forecasting using Holt-Winters Exponential Smoothing*, Kanwal Rekhi School of Information Technology Under the guidance of Prof. Bernard December 6, 2004 https://labs.omniti.com/people/jesus/papers/holtwinters.pdf
[14] R. Thafer, *A proposed Technique for the Problem of Selective the best Forecqsting Model in Time Series. A case Study*. Iraqi Journal of Statistical Science, 2008, vol. 14
[15] A. Ramudhin, "Prévision de la Demande," https://cours.etsmtl.ca/gpa784/Cours/Cours4.ppt consulté le 26/07/2014
[16] Climate in Madagascar, 1994, Country Studies, Area Handbook of the Dept. of US Army, www.wildmadagascar.org