RELATIONSHIP BETWEEN TEMPERATURE AND PRECIPITATION IN SOUTHERN OF MADAGASCAR USING VECTOR ERROR CORRECTION MODEL

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ABSTRACT

The aim of this paper is to study the relationship between temperature and precipitation in southern of Madagascar using Vector Error Correction Model. We start from annual precipitation and temperature data representation of two zones in Southern of Madagascar. We use Vector Error Correction Model to make modeling. In the first time, we choose the lag which corresponds to the minimum of Aikaike Information Criterion. Then, we test the cointegration rank using Johansen approach. In the next step, we estimate the coefficients of the model. Then, we test the validity of the model. If the model is not valid, we choose another lag. After validating the model, we use Granger causality test to test the causality between temperature and precipitation. In the end, we interpret the impulse response function to characterize the impact of variation of temperature.

Keyword: - *Granger causality, Impulse response function, Precipitation, Temperature, Vector Error Correction Model.*

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1. INTRODUCTION

Climate change is a global problem. It impacts both rich and developing countries. The Intergovernmental Panel on Climate Change (IPCC) was created to make follow-up and advise politicians to solve the problem of climate change [1]. Global warming and its impacts are the primary interests of the IPCC's activity. Madagascar is also subject to the problem of climate change. Southern of Madagascar has an aride climate. The temperature is high and the precipitation is low.

The problem is as follow: what is the impact of temperature variation on precipitation?

To solve this problem, we use the theories of Vector Error Correction Model (VECM) [2]. VECM models were officially introduced by Danish Statistician and Econometer Johansen in 1988. The author is a renowned researcher in the field of time series analysis and world famous for cointegration theory. The history of Vector Error Correction Model (VECM) begins with the error correction models invented by American economist Engle and British economist Granger in 1987. At the time, Engle and Granger designed the cointegration test and error correction models to model the links that bind petrochemicals in the production process and their dependence on the price of oil. The algorithm proposed by Engle and Granger in 1987 is a single-equation modeling and is applied to price prediction. a year later, in 1988, Johansen generalized the work of Engle and Granger in the field of multivariate analysis. This generalization led to the birth of vector error correction or VECM models. Le même auteur du modèle VECM a continué les recherches sur les modèles VECM avec l'économètre Juselius (sa femme) et arrivent à estimer les modèles VECM par maximum de vraissemblance en 1990 [3].

The objective of our work is to quantify the relationship between temperature and precipitation in Southern of Madagascar.

2. METHODS

2.1 Experimentation data

We use annual precipitation and temperature data from ECMWF (European Center for Medium-Range Weather Forecast) [4]. Data are from 1979 to 2017.

Figure 1 below slow as the area on which the precipitation data was taken. The area is "zone 1" in yellow.

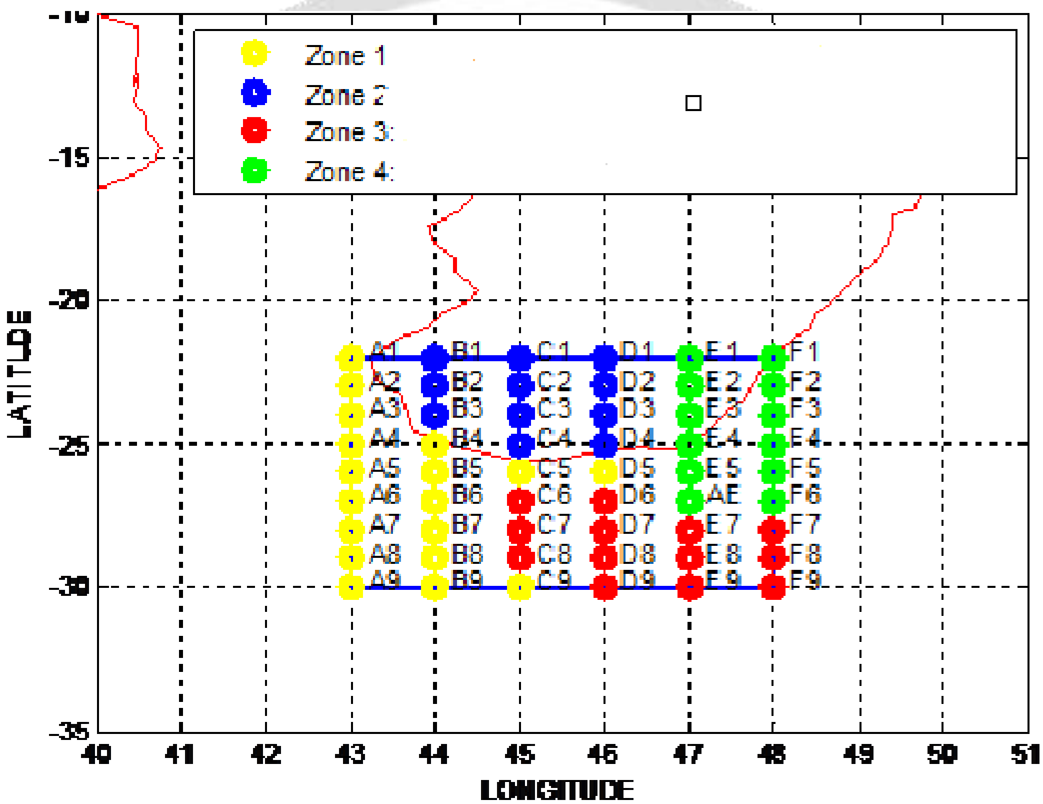

Fig -1 Area of study for precipitation data (zone 1)

Figure 2 below slow as the area on which the temperature data was taken. The area is "zone 1" in yellow.

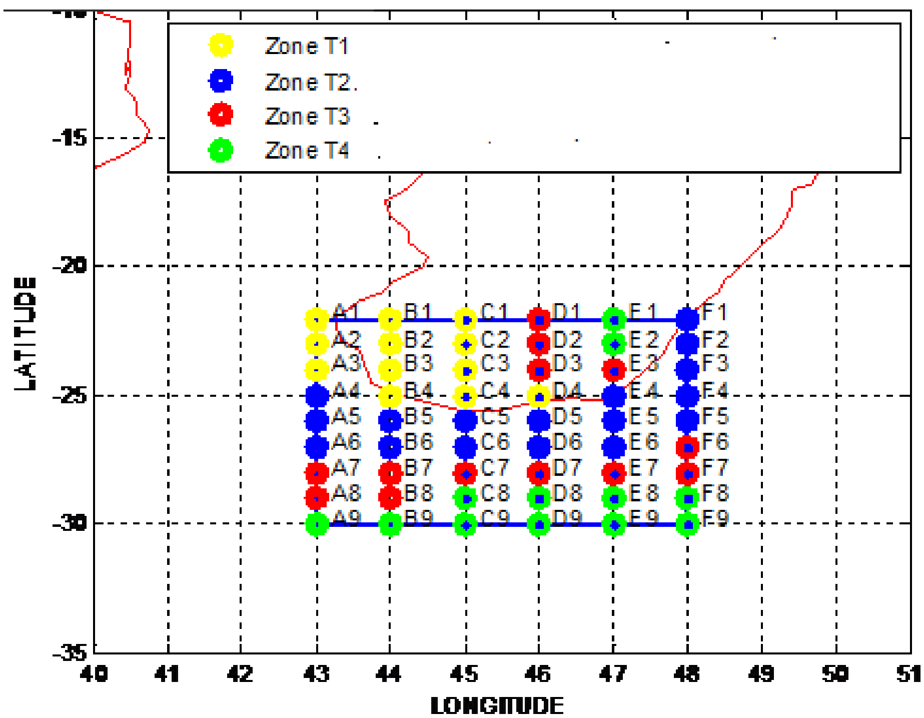

Fig -2 Area of study for temperature data (zone T_4)

We can also see all datasets in Table -1 bellow.

Table -1: Datasets for precipitation and temperature

Year	Precipitation for zone $_1$ (mm)	Temperature for zone T_4 (°C)
1979	437.7	21.3
1980	508.9	21.4
1981	675.4	21.3
1982	747.9	21.2
1983	481.4	21.7
1984	770.3	21.4
1985	617.9	21.7
1986	528.5	21.4
1987	546.6	21.7

1988	442.5	21.8
1989	698.5	21.4
1990	614.5	21.4
1991	569.4	21.6
1992	433.3	21.8
1993	576.4	21.4
1994	577.7	21.1
1995	675.5	21.3
1996	693.6	21.7
1997	705.9	21.7
1998	555.8	21.6
1999	687	21.8
2000	546.4	22.0
2001	596.7	22.1
2002	445.2	21.4
2003	687.4	21.6
2004	507.1	22.1
2005	474.3	21.8
2006	484.4	22.1
2007	603.5	22.1
2008	552.3	21.5
2009	548.1	21.4
2010	401.8	21.7
2011	760.7	21.7

2012	589.1	22.0
2013	489.6	21.3
2014	541.6	21.7
2015	592.6	22.0
2016	464.9	21.7
2017	508.1	21.8

2.2 Methods

The methodology adopted is as follow:
Step 1: Choose the lag order according to the Aikake Information Criterion
Step 2: Test the cointegration rank using Johansen's approach
Step 3: Estimate the VECM model's coefficients
Step 4: Validate the model
Step 5: Test causation between the two series using Granger causality test
Step 6: Plot the impulse response function

a) Step 1 : Lag order selection

The selected lag order is that which corresponds to the minimum of Aikake Information Criterion (AIC).

b) Step 2 : Test the cointegration rank using Johansen's approach

We use Johansen's test to detect the cointegration rank of the two series [5]. If the rank of cointegration is zero, it means that the two series are not cointegrated. If the rank of cointegration is one or two, it means that both series are cointegrated.

c) Step 3 : Estimate the VECM model's coefficients

After choosing the lag order which is the only parameter of the VECM model, we estimate the coefficients. The equation of the bivariate VECM model is:

$$\Delta Y_t = \beta_0 + \pi Y_{t-1} + U_t$$

Avec $\Delta Y_t = \begin{pmatrix} \Delta y_{1t} \\ \Delta y_{2t} \end{pmatrix}$, $\beta_0 = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix}$, $\pi = \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix}$, $Y_{t-1} = \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix}$, $U_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$.

Where y_{1t} and y_{2t} are the two time series. The others ara coefficients to be estimated.

d) Step 4 : Validate the model

A valid model is a model whose associated residuals are white noise. We use adjusted portmanteau test to test residuals [6]. If the model is not valid, we choose another lag order.

e) Step 5 : Test the causation between the two time series using Granger causality

We use Granger causality test for VECM [7] model to test if the temperature of zone T_4 cause the precipitation in zone 1 or vice versa.

f) Step 6 : Plot the Impulse Response Function

The last step is to plot the Impulse Response Function (IRF) of the model. With this function, we can appreciate the impact of the variation of the temperature on the precipitation.

3. RESULTS

3.1 Result of lag order selection

The selected lag is with which we obtain the minimum of AIC. Table -2 show us AIC value according to the lag order. So the selected lag is 2.

Table -2: AIC value according to the lag order

Lag order	AIC
0	6.586
1	6.722
2	***6.555***
3	6.606
4	6.654
5	6.874

3.2 Result of cointegration rank according to Johansen's approach

Johansen's statistical test revealed that the cointegration rank is 2. So, temperature in zone T4 and precipitation in zone 1 are cointegrated. They have long-run relationship. Table -3 allow us more details about this test.

Table -3: Johansen cointegration test using trace test statistic with 5% significance level

R_0	R_1	Statistic test	Critical value
0	0	37.37	18.37
1	1	15.02	3.8

3.3 Result of the estimation of the model's coefficients

Figure 3 is a screenshot of the result of the estimation of the coefficients of the model.

Det. terms outside the coint. relation & lagged endog. parameters for equation Température de la Zone T4

	coef	std err	z	P>|z|	[0.025	0.975]
L1.Température de la Zone T4	-0.0509	0.186	-0.274	0.784	-0.415	0.313
L1.Précipitation de la Zone 1	-0.0008	0.001	-1.352	0.176	-0.002	0.000
L2.Température de la Zone T4	-0.3083	0.151	-2.045	0.041	-0.604	-0.013
L2.Précipitation de la Zone 1	-0.0012	0.000	-2.990	0.003	-0.002	-0.000

Det. terms outside the coint. relation & lagged endog. parameters for equation Précipitation de la Zone 1

	coef	std err	z	P>|z|	[0.025	0.975]
L1.Température de la Zone T4	177.0144	71.527	2.475	0.013	36.824	317.205
L1.Précipitation de la Zone 1	0.3046	0.227	1.344	0.179	-0.140	0.749
L2.Température de la Zone T4	127.4233	58.082	2.194	0.028	13.584	241.262
L2.Précipitation de la Zone 1	0.1833	0.149	1.233	0.218	-0.108	0.475

Loading coefficients (alpha) for equation Température de la Zone T4

	coef	std err	z	P>|z|	[0.025	0.975]
ec1	-0.5306	0.221	-2.406	0.016	-0.963	-0.098
ec2	0.0011	0.001	1.434	0.152	-0.000	0.003

Loading coefficients (alpha) for equation Précipitation de la Zone 1

	coef	std err	z	P>|z|	[0.025	0.975]
ec1	-283.8446	84.979	-3.340	0.001	-450.401	-117.289
ec2	-1.6072	0.303	-5.299	0.000	-2.202	-1.013

Fig -3 Results of the estimation of the coefficients of the model

3.4 Model validation result

According to the adjusted portmanteau test, residuals are white noise. So our model is valid. Table -4 shows us more details about this test.

Table -4: Adjusted portmanteau-test for residual autocorrelation

Adjusted Portmanteau-test for residual autocorrelation: H_0: residual autocorrelation up to lag 5 is zero. Conclusion**: Fail to reject H_0 at 5% significance level**.		
Test statistic	Critical value	p-value
1	3.8	

3.5 Result of causality test

The statistics tests show us that temperature of the zone T_4 Granger cause precipitation of the zone 1 and vice versa. Table -5 and Table -6 allows us more details of the result of statistics tests.

Table -5: Adjusted portmanteau-test for residual autocorrelation

Granger causality F-test. H_0: Temperature of the Zone T_4 does not Granger-cause Precipitation of the Zone 1. Conclusion: **Reject H_0 at 5% significance level**		
Test statistic	Critical value	p-value
3.3	2.8	0.03

Table -6: Adjusted portmanteau-test for residual autocorrelation

Granger causality F-test. H_0: Precipitation of the Zone 1 does not Granger-cause Temperature of the Zone T_4. Conclusion: **Reject H_0 at 5% significance level**		
Test statistic	Critical value	p-value
3.3	2.8	0.026

3.6 Impulse Response Function

We can see in Figure -4 shows us the Impulse Response Function. This is the impact of the variation of one unit of temperature of the zone T_4 on the precipitation of zone 1. As an interpretation of the figure, the increase of 1 ° C in temperature over the T_4 zone causes a decrease in precipitation of about 110mm over the next year then a drop of 60mm during the next year then a 105mm drop for the following year.

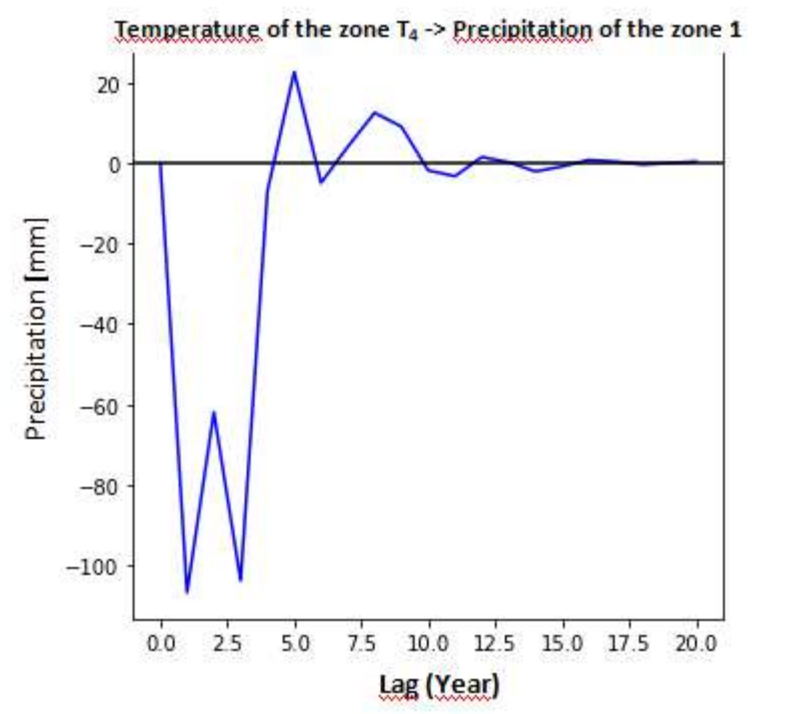

Fig -4 Impulse Response Function (IRF)

4. DISCUSSIONS

VECM model is a statistical approach often used in macroeconomics. We use apply this theory in Climatologie. In our work, the selection of the lag order of the model is based on the Aikake Information Criterion (AIC). Other researchers use other criterion such as Bayesian Information Criterion (BIC) [8], Hannan and Quinn [9], etc.

5. CONCLUSION

In this paper, we studied the relationship between temperature and precipitation in Southern of Madagascar. We use Vector Error Model. The result shows us that temperature (of the zone T_4) cause precipitation (of the zone 1) and vice versa. This causation is a long-run relationship. Thanks to the Impulse Response Function, we can see the impact of the increase of 1 ° C in temperature of the zone T_4 on the precipitation of zone 1. We retain that this shock causes a decrease in precipitation of about 110mm over the next year then a drop of 60mm during the next year then a 105mm drop for the following year.

6. REFERENCES

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