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Rainfall Prediction Due to the Madden Julian Oscillation Factor at the Equator

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ABSTRACT
In this research, the process of spectral analysis (Fast Fourier Transform) was carried out as a step to find out the phenomena that affect rainfall in the equatorial region which are represented by the cities of Kototabang, Pontianak, Gorontalo and Biak. This is followed by predicting rainfall due to the MJO phenomenon, which is obtained after performing a Bandpass Filter with a cut off of 30 and 90 days on rainfall time series data and the Inverse Fast Fourier Transform (IFFT), using the ARIMA method. The results showed that the study area under study generally had an equatorial rainfall pattern type. This rainfall is dominantly influenced by annual (monsoon) and semi-annual (ITCZ) phenomena. There is an intra-seasonal phenomenon (MJO) although it does not have a big impact on rainfall. ARIMA provides fairly good rainfall prediction results for a short period of time. Monthly rainfall predictions show values below 90 mm, with the lowest predicted rainfall occurring in January in Gorontalo (42.57 mm), and the highest in February in Biak (86.83 mm).

Keywords*: ARIMA, equator, Madden Julian Oscillation, rainfall prediction*

1. PRELIMINARY

Indonesia is a country located at the coordinates 6º LU – 11º LS and 95º E – 141º E, where astronomically this country is traversed by the equator. Geographically, Indonesia is flanked by two continents (Asia and Australia) and two oceans (Pacific and Indian). These various conditions cause Indonesia to have varied rainfall in each region. Madden Julian Oscillation (MJO) is a phenomenon in the form of intra-seasonal atmospheric oscillations that move from the west (Indian Ocean) to the east of the earth. This is marked by the process of convective propagation from the area above the Indian Ocean to the eastern region, namely the Pacific Ocean where the movement crosses the eastern region.

Indonesia. MJO is a phenomenon related to intra-seasonal variability, which has a considerable influence on the climate system and weather, especially in the tropics (Zhang, 2013). According to Seto (2004), the MJO phenomenon is related to the formation of hot pools in the eastern Indian Ocean and western Pacific Ocean, where there is an eastward movement along with westerly winds followed by convection of thick cumulus clouds which can trigger high-intensity rain. According to Lau (1985), MJO is an event associated with the formation of convective clouds around the equator and has an intraseasonal pattern. MJO is often considered as a major contribution to the occurrence of flooding in Indonesia, especially at the equatorial region. Therefore, it is important to know the prediction of rainfall in the study area which is caused only by the MJO phenomenon.

2. LITERATURE REVIEW

Due to its geographic and astronomical conditions, Indonesia is directly affected by several types of climate variations. Some that can be mentioned are:

2.1 Intra-Seasonal Variation

2.1.1 Madden Jullian Oscillation (MJO)

According to Suhardi, et al. (2018), MJO is marked by the eastward propagation of atmospheric waves caused by the interaction between the atmosphere and the ocean. This phenomenon is quite influential on inter-seasonal variability in the tropics. According to Geerts and Wheeler (1998), MJO generally influences rainfall patterns in Indonesia and its surrounding areas crossed by the equator. The MJO period is 30-90 days (Madden & Jullian, 1994).

2.2. Semi Annual Variation

2.2.1. Inter Tropical Convergence Zone (ITCZ)

The ITCZ is an area of low pressure around the equator where the trade winds from BBU and trade winds from the BBS meet, where the area traversed by this phenomenon will usually experience increased rainfall due to the potential for the formation of convective clouds. (Lapan, 2015). The ITCZ has an oscillation period of 6 months (Aldrian, 2003).

2.3.Annual Variation

2.3.1. Monsoon

According to Putra (2014), in general, the Indonesian region is affected by two monsoons, namely the Asian monsoon and the Australian monsoon. The characteristic of the Asian monsoon is that it produces hot and wet conditions in summer and dry and cold conditions in winter. Meanwhile, according to Loo (2014), during the Australian monsoon, the wind will bring dry and cold air masses towards Asia. The oscillation period of the monsoon is 12 months (Hermawan, 2015).

2.4. Interannual Variations

2.4.1. El Nino

El Nino is a phenomenon that falls into the category of inter-annual cycles. This phenomenon is characterized by weakening trade winds and increasing sea surface temperatures in the central to eastern Pacific Ocean region (Salinger, 2005).

2.4.2. La Nina

This marine phenomenon has a broad impact on seasonal conditions in Indonesia where its influence is felt more in the eastern part of Indonesia than in the western part, as well as El Nino. Many studies on ENSO have been carried out by researchers showing the distribution of their influence on seasons in certain areas. Rain as a source of water in Indonesia is used for agriculture, energy and others.

2.4.3. IOD

In the "mature" phase of the IOD, the eastern Indian Ocean will experience a decrease in temperature, while in the western part it will experience an increase in temperature. The Indian Ocean Dipole (IOD) is an anomaly of the ocean-atmospheric system (Saji, et al., 1999).

3. DATA AND METHODS

3.1. Data

The data used in this study are daily rainfall data in 4 cities in the study area, namely Kototabang (0° 12'07" South Latitude – 100° 19 '05" East Longitude), Pontianak ((0°02'24" N – 0°05'37" S, 109°23'01"– 109°16'25" E), Gorontalo (00° 28' 17" –00° 35' 56" N and 122° 59' 44" – 123° 05' 59" BT), as well as Biak (0°21'-1°31' LS, 134°47'–136°48' E) obtained from the Website NASAPOWER(https://power.larc.nasa.gov/data-access-viewer/). The daily rainfall data used is for 30 years (1992- 2021).

3.2.Method

3.2.1. Spectral Analysis

The spectral analysis used in this research is the Fast Fourier Transformation (FFT) method. The purpose of doing this method is to find out the periodicity of the repetition of phenomena that might occur in region study if seen from the resulting periodogram.

3.2.2. Bandpass Filter

Bandpass filters will work by rejecting or attenuating frequency signals that are outside a predetermined range. In the bandpass filter, frequencies with high and low values will be eliminated and will only leave the appropriate frequency in the selected range. In this case, the selected frequency range is according to the MJO period, which is 30-90 days.

3.2.3. Inverse Fast Fourier Transformation (IFFT)

IFFT is an abbreviation for Inverse Fast Fourier Transformation. In IFFT, there will be a process of returning the signal from the frequency domain to the time domain after the FFT is carried out. From this process, the rainfall time series is obtained which is only influenced by the MJO phenomenon.

3.2.4. ARIMA

The stages contained in ARIMA are:

. Identify the stationarity of the data
This stage will identify whether the data used is stationary or not. If the data is considered not stationary with respect to the average, then the differencing (d) process will be carried out first.

b. Provisional Model Estimation
ARIMA provisional model estimation is seen based on the resulting ACF and PACF patterns.

Table 1 Determination model temporary according to Wei (1990)

ACF pattern	**PACF pattern**	**Model**
die down	*cut off*	AR (p)
cut off	*die down*	MA (q)
die down	*die down*	ARMA(p,q)
cut off	*cut off*	AR(p) or MA(q)

c. Significance Test
With the following conditions: Rejection area Ho if:

$$|t_{hitung}|>t_{a/2};f=n-n_p$$

where,
np = number of parameters

or use the value $p-value<\alpha$ (α=0,05) to reject Ho.

d. Residual Assumption Test Rejection area Ho if:

$$Q>X^2(a/df:K-k)$$

where (K means at lag K and k is the number of parameters) or value $p-value<\alpha$ (α=0,05).

e. Best Model Selection

Selection of the best model is determined based on the resulting Mean Absolute Percentage Error (MAPE) value.

Table 2 MAPE categories according to Lewis (1982)

Range MAPE	Meaning of Value
< 10%	Forecasting model capabilities very good
10-20%	Forecasting model capabilities good
20-50%	The model's forecasting ability is feasible
> 50%	Forecasting model capabilities bad

f. Predictive Equations

- Autoregressive (AR)

$$Yt = \alpha+\theta1Yt-1+\theta2Yt-2+\cdots+\theta pYt-p+et$$

where t = time series data
α = constant
θp = p-th autoregression parameter
e_t = error at time t

- Moving Averages (MA)

$$Yt=\alpha+et-\theta 1et-1+\theta 2et-2-\cdots-\theta qet-k$$

where Yt = time series data
α = constant
θ = moving average parameters
$et-k$ = error at t-k

- ARMA

$$Yt=\alpha+\theta_1 Y_{t-1}+\theta_2 Y_{t-2}+\cdots+\theta_p Y_{t-p}+e_t-\phi 1et-1-\phi 2et-2-\cdots-\phi qet-q$$

where: Yt = time series data
α = constant
θ,φ = model parameters
$et-q$= error when t-q

4. RESULTS AND DISCUSSION

4.1. Phenomena Affecting Rainfall in the Equator Region

Daily rainfall data from each study area will first through the stages of spectral analysis using Fast Fourier Transformation (FFT).

The following is a table of the FFT results for each study area:

Table 3 Rainfall FFT Results for Study Area

Kotatabang			Pontianak			Gorontalo			Biak		
Magnitude	Period (month)	Period (day)	Magnitude	Period (month)	Period (day)	Magnitude	Period (month)	Period (day)	Magnitude	Period (month)	Period (day)
10,740	12.17	365.26	11,735	12.17	365.26	6,765	12.1	365.26	5,463	52.18	1565.42
10.208	6.08	182.63	9,695	6.08	182.63	6,458	6.08	182.63	4,709	73.05	2191
5,566	30.43	913.16	5,976	13.52	405.85	4,504	52.1	1565.42	4,597	12.17	365.26
5.187	18.26	547.90	5,632	18.26	547.90	3,851	121.7	3652.6	4,581	6.08	182.63
5.129	6.05	121.75	5.157	1.69	50.73	3,744	36.5	1095.80	4,411	36.52	1095.8
4,690	20.29	608.77	5.132	1.89	56.77	3,395	73.05	2191.6	4,077	30.43	913.16
4,554	1.32	39.84	4,606	365.2	10,958	3,188	28.09	842.9	3.141	121.7	3652.6
4,430	1.20	36.28	4,420	0.80	24,297	2,951	365.2	10958	2,849	2,788	83.64
4,341	1.41	42.30	4.136	0.53	16.02	2,741	30.4	913.16	2,774	22.82	684.87
4,210	45.65	1369.75	4,022	0.62	18.86	2,714	24.35	730.53	2,689	33.2	996.18

Based on the table above, the Municipalities of Kototabang and Pontianak provide FFT results in the form of the 12th month (monsoon) having the biggest signal affecting rainfall followed by ITCZ (6 months) and IOD. For the period of intra-seasonal oscillation (or MJO, marked in red) is ranked below.
In the study area of Gorontalo City, the 12th month (monsoon) has the first rank for the period with magnitude the highest, the 6th month (ITCZ) as the second rank, and the 18th month (IOD) as the third rank. Periods of intra-seasonal oscillations are ranked below this, where they are highlighted in red.

In the study area of Biak City, the 52nd month (ENSO) has the first rank, followed by monsoon and ITCZ. For the period of intra-seasonal oscillation, it appears to be ranked 8th.

4.2. Prediction of Rainfall

After going through the ARIMA stages, the monthly rainfall predictions for each study area are obtained as follows:

Table 4 . Prediction of Monthly Rainfall in the Study Area

Study Area	**Rainfall Prediction (mm)**	
	January 2022	February 2022
Biak	85.30	86,83
Gorontalo	42.57	45,59
Kotatabang	66,57	85,32
Pontianak	70,71	69,36

Based on the rainfall prediction table, it can be seen that the average rainfall produced is below 90 mm. The highest rainfall value is found in February in Biak City, which is 86.83 mm. Meanwhile, the lowest rainfall is in Gorontalo City in January, which is 42.57 mm.
Overall, the phenomenon of Annual Oscillation and Semi Annual Oscillation tends to have the most dominant impact on rainfall in the equatorial region. Meanwhile, the phenomenon of intra-seasonal oscillations (MJO) seems to provide a signal in the study area, but tends not to be too dominant.

The ARIMA method produces predictions of monthly rainfall in each study area with a value below 90 mm, with the lowest predicted rainfall occurring in January in Gorontalo (42.57 mm), and the highest in February in Biak (86.83 mm).

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