MJO (Madden-Julian Oscillation) Analysis of the Chlorophyll-a Distribution in Western Waters Bengkulu

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Abstract. The global phenomenon Madden-Julian Oscillation (MJO) is one of the dominant oscillation in the equatorial region of the Indian Ocean that oscillates between 30-60 days and experience the process of convection movement from west to east. MJO has a correlation of high intensity rainfall of the area in its path. During its journey eastward, the MJO is influenced by the position of the sun. When the sun in the equatorial MJO moves straight east. Meanwhile, when the position of the sun in the south of the equator, MJO shifted slightly to the south of the equator, known as the propagation of the south-east (south-eastern propagation). When the position of the sun is in the north of the equator, MJO shifted slightly to the north of the equator, known as the propagation of the north-east (north-east of propagation). Waters west of Bengkulu has a huge potential in the fisheries sector, which is situated overlooking the Indian Ocean. The phenomenon MJO influence on rainfall, sea surface temperature, and the concentration of chlorophyll-a. This study aims to look at the temporal distribution of sea surface temperature and chlorophyll-a and decide how MJO relationship with SST and precipitation conditions and increasing the amount of chlorophyll during the phase of the MJO in Bengkulu waters. The dataset used is data of chlorophyll-a which download in oceanscolor.gsfc.nasa.gov, sea surface temperature data is used is a model of Kaplan Extended V2, RMM1 index data and RMM2 on www.bom.gov.au and rainfall data of Bengkulu region. The method used is descriptive statistical methods, Conditional Probability and logistics regression. From the above explanation can be said that there is a relationship between the incidence of MJO by the number of chlorophyll-a. Odds the addition of chlorophyll-a have a linear relationship with the duration of the incident MJO in Bengkulu, odds increase the amount of chlorophyll-a in Bengkulu region reaches a threshold value of 0.5, it means that the length occurrence MJO able to identify increasing the number of chlorophyll-a in Bengkulu.

1. Introduction

Bengkulu has a huge potential in the fisheries sub-sector, especially marine fisheries. The layout of the area, mostly overlooking the Indian Ocean to reach 525 km long coastline, causing Bengkulu province has a territorial sea area of 53,000 km². In the field of marine and fisheries Bengkulu province has a potential of 145 334 tonnes.
Chlorophyll-a is an important component that boosted phytoplankton and aquatic plants, both of which are a natural food source for fish. Chlorophyll-a is a pigment active in plant cells have a role pentingterhadap the process of photosynthesis [1].

Conditions in Indonesia which is located between two continents (Asia and Australia) and two oceans (Indian and Pacific) also led to Indonesia affected by various climatic phenomena, both locally, regionally, and globally. One influential global phenomenon is the phenomenon of the Madden-Julian Oscillation (MJO). MJO first discovered by the Madden-Julian in 1971. MJO is one of the dominant oscillation in the equatorial region. This phenomenon oscillates between 30-60 days and experience the movement process of convection from west to east [2] [3]. Stated that the active phase of the MJO has a correlation of the intensity of the high rainfall of the area in its path [4]. During its journey eastward, the MJO is influenced by the position of the sun. When the sun is on the equator the MJO moves straight to the east. Meanwhile, when the position of the sun in the south of the equator, then a trip MJO slightly shifted towards the south of the equator known as the propagation of the south-east (south-eastern propagation). When the position of the sun is in the north of the equator, then a trip MJO slightly shifted to the north of the equator, known as the propagation of the north-east (north-eastern propagation).

In conducting the fisheries, the fishing area information is crucial for the efficiency and effectiveness of the arrest can be improved. Information can be obtained through the collection area of oceanographic parameters. Oceanographic parameters is one of the factors which influenced the variability in the catches, such as chlorophyll-a and sea surface temperature. Phytoplankton are located in the layer of light (photic) containing chlorophyll-a is useful for photosynthesis. Chlorophyll-a is capable of absorbing blue light and green, so the presence of phytoplankton can be detected by the ability of chlorophyll-a. Plankton, both phytoplankton and zooplankton have an important role in the marine ecosystem because plankton into food for many species of other marine animals. This oceanographic parameters can be recorded and diintrepretasi through remote sensing.

The attempt to predict the fishing area (fishing ground) can be done through physical oceanographic conditions. Almost all the fish populations that live in marine waters have a range of temperature and chlorophyll-a is optimum for life [5]. By knowing the oceanographic parameters, especially the temperature and chlorophyll-a optimum of a species of fish in a body of water, then we can surmise the existence of a group of fish and can be used for the purpose of arrest (exploitation). This study aims to look at the temporal distribution of sea surface temperature and chlorophyll-a and decide how MJO relationship with SST and precipitation conditions and increasing the amount of chlorophyll during the phase of the MJO in Bengkulu waters. The expected benefits of this research is to provide information to the relevant parties regarding the potential fishing areas in marine waters Bengkulu.

2. Material And Method
The dataset used is data of chlorophyll-a which download in oceancolor.gsfc.nasa.gov, sea surface temperature data is used is a model of Kaplan Extended V2, RMM1 index data and RMM2 on www.bom.gov.au and rainfall data of Bengkulu region. The method used is descriptive statistical methods, Conditional Probability and logistic regression. Logistic regression is a mathematical model approaches that can be used to describe the relationship of several variables X with a dichotomous dependent variable / polimomus [6]. Binary logistic regression is a method of data analysis used to find the relationship between the response variable (y) that is binary or dichotomous with the predictor variable (x) which is polikotomus [7]. Logistic regression itself is perfect for making a probabilistic forecast, because it will never predict the probability is less than zero or greater than one [8]. Logistics equation is:

$$P = \frac{\exp(b_0 + b_1x)}{1 + \exp(b_0 + b_1x)}$$

(1)

Information: $P$ = Logistic Regression probability
\[ x = \text{Predictor} \]
\[ b_{0,1} = \text{Regression Coefficient} \]

Logistics curve depicted in the form S sigmoid with a z value ranging from \(-\infty\) to \(+\infty\) and the value \(z\) moves from 0 to 1. When the value of \(z\) approaches \(-\infty\) then the value \(f(z)\) moves closer to a value of 0, and if the value of \(z\) approaching \(+\infty\) then the value \(f(z)\) moves closer to the value of 1. The conditional probability (Conditional Probability) is the probability of an event A with the proviso events and happening / will happen first. Notation Probabilias conditional: \(Pr (A | B)\) probability of A on condition B occurs first. Mathematical formula for conditional Probabilities are:

\[
Pr (A | B) = \frac{Pr(A \cap B)}{Pr(B)}
\]

The data processing stages as follows :
1. Identification of MJO activity by collecting data using the data RMM1 MJO events and RMM2 in DJFM 2007-2012 by making spatial OLR.
2. Analysis of the current condition of SST when MJO and normal events.
3. Defining relationships SST conditions with rainfall during the MJO by way of conditional probability analysis with cumulative odds of 90%.
4. Determine the threshold values its long MJO events with the addition of chlorophyll-a at the time of the MJO with the terms, conditions, SST and precipitation predetermined cumulative odds by 90%.

3. Result And Discussion

3.1. MJO Identification
MJO position identification passing through Indonesia can be accomplished by creating composite spatial OLR of MJO phase 3, phase 4 and phase 5. The composite analysis is done by looking at the data RMM1 and RMM2 in each phase and then identify the periods of events that pass through Indonesia based on the phase 3, phase 4 and phase 5 on DJFM year period from 2007 to 2012 found that there were 223 days of activity. Figure A shows the MJO activity of phase 1 to phase 8.

Figure 1 RMMI dan RMM2 DJFM Period 2007 – 2012
In Figure 2 above found that in the current phase of the MJO is 3, the lowest value of OLR occurs in the southern part of Sumatra, partial ocean Java to Kalimantan. Lowest OLR value is also present in some areas of analysis, Bengkulu waters.

At the time of phase 4 low OLR values move towards the east and covers an area of southern Sumatra, Java Sea and extends to South Sulawesi. While in the area of analysis is almost covered by the low OLR values.
At the time of the MJO is at phase 5, the position of the MJO are in Indonesian maritime continent. OLR and the lowest value moved eastwards and are in the northern region of Australia. OLR low value currently on the Indian Ocean region to the northeastern Australian waters. While in the area of research is still visible low OLR values, although the area coverage of the lowest OLR only cover part of research area. Based on the images A, B and C because the study area is located in Bengkulu waters, to identify the MJO influence on crops Clorofil a then analysis MJO impact on the phase 3, phase 4 and phase 5 which in this phase is the lowest passing through the area OLR value analysis.

3.2 SST Conditions AT The MJO Events

Analysis of the condition of SST (Sea Surface Temperature) at the time of the events MJO in the period DJFM during phase 3, fase4 and phase 5 is done by classifying the data daily at the time of the MJO is then viewed condition averages are then compared to average conditions DJFM SST during the periods when the MJO event does not occur. For SST conditions in the region can be explained by the analysis of B. chart below:

In the graph 1. above shows that when the MJO phenomenon occurred in waters Bengkulu SST conditions show improvement. In December, January and March showed an increase when compared to normal except in February where conditions at the time of occurrence of the phenomenon SST MJO
and its not happening this phenomenon showed no change. It is caused by a phenomenon at least MJO in February during the 2007-2012 period.

Linkage analysis of events and conditions SST MJO is done by finding the relationship between the index and the value of SST MJO in the event MJO by using correlation method. The MJO index is calculated using data RMM1 and RMM2 through the equation $\sqrt{RMM1^2 + RMM2^2}$ where, according to [9] [10] divided into 8 categories MJO phase of strong and weak. Classification MJO index in this study were divided into three, namely, weak (0-1.5), moderate (1.5-2.5), and strong (> 2.5). Of calculation using correlation method is found that the correlation between SST and the index MJO is equal to 0.1, the value is classified as the correlation value is quite small considering the rainfall in the region is not only influenced by the SST, but if there is an increase or decrease in SST significantly will cause a change in the amount of rainfall.

3.3 Probability of Rainfall on SST

Calculations conducted by using odds Conditional Probability, namely by looking at cumulative odds that exceeds 90%, the calculation is done by dividing the SST class 5 and 4 classes of rainfall, while class divisions are as follows:

| Class | SST   | Class | Rainfall |
|-------|-------|-------|----------|
| 1     | 0 - 25.7 | 1     | <20      |
| 2     | 25.7 - 26.7 | 2     | 20 - 50  |
| 3     | 26.7 - 27.7 | 3     | 50 - 100 |
| 4     | 27.7 - 28.8 | 4     | >100     |
| 5     | >28.8    |       |          |

By calculating the frequency of occurrence conditional above, where chances of rainfall on the condition that the SST condition has occurred then divided by its number of occurrences conditional lot, the importance of such probability in the following table:

| SST     | 0 - 25.7 | 25.7 - 26.7 | 26.7 - 27.7 | 27.7 - 28.8 | >28.8 |
|---------|----------|-------------|-------------|-------------|-------|
| <20     | 0        | 0           | 0           | 73%         | 72%   |
| 20 - 50 | 0        | 0           | 0           | 21%         | 18%   |
| 50 - 100| 0        | 0           | 0           | 6%          | 7%    |
| >100    | 0        | 0           | 0           | 0%          | 3%    |
| Total   | 0        | 0           | 0           | 100%        | 100%  |
From the above table is found that the highest odds for rainfall <20 mm / day obtained on condition of SST warm and toasty, in this study were taken cumulative odds by 90% so that, got that for result rainfall ranges from 20-50 mm / day is required SST in warm conditions in terms of SST conditions > 27.7oC, given on condition of SST > 28.8 °C was also exceeded 90% chance. Furthermore, the threshold values determined in phase 3 day duration, phase 4 and phase 5 to increase the amount of chlorophyll begins by calculating the likelihood of hot spots are generated through binary logistic regression method on any additional criteria chlorophyll, while the additional criteria ie +0.01, +0.02, +0.05 and +0.1. The chlorophyll additional criteria adapted to the conditions warm SST (> 27.7) and rainfall of 20-50 mm / day.

Based on the figure 5 it can be concluded that the best verification tilapia contained in 0.5 probability model with verification value is always above 40%. Furthermore, a threshold value of 0.5 was used as
odds of determining the limits increase in the number of chlorophyll which is then linked to the duration of the third phase of MJO events.

In Figure 6 describes the relationship between the odds increase in the number of chlorophyll-a with a long phase of MJO, to increase the amount of chlorophyll 0.01 on a threshold value of 0.5 occurred while longer phase are in the range of 4-7 days. This may imply that the addition amount of chlorophyll of 0.01 in Bengkulu region occurs when the incident MJO phase 3, phase 4 and phase 5 is bertutut succession occurred over four days by assuming that for 4 consecutive days average conditions SST in these waters warm and occurs rainfall 20-50 mm / day.

In Figure 7 describes the relationship between the odds increase in the number of chlorophyll-a with a long phase of MJO, to increase the amount of chlorophyll 0.02 on a threshold value of 0.5 occurred while longer phase is in the range 7-10 days. This may imply that the increase in the number of chlorophyll amounted to 0.02 in Bengkulu region occurs when the incident MJO phase 3, phase 4 and
phase 5 is bertutut succession occurred over 7 days by assuming that for 7 consecutive days average conditions SST in these waters warm and occurs rainfall 20-50 mm / day.

Figure 8. Probability od Addition 0,5 chlorophyll-a In Phase 3,4 and 5.

In Figure 8 describes the relationship between the odds increase in the number of chlorophyll-a with a long phase of MJO, to increase the amount of chlorophyll 0:05 on a threshold value of 0.5 occurred while longer phase is in the range 12-13 days. This may imply that the addition amount of chlorophyll of 0.05 in Bengkulu region occurs when the incident MJO phase 3, phase 4 and phase 5 is bertutut succession occurs over 12 days by assuming that for 12 consecutive days average conditions SST in these waters warm and occurs rainfall 20-50 mm / day.

Figure 9. Probability od Addition 0,1 chlorophyll-a In Phase 3,4 and 5.

In Figure 9 describes the relationship between the odds increase in the number of chlorophyll-a with a long phase of MJO, to increase the amount of chlorophyll 0.1 on a threshold value of 0.5 occurred while longer phase is in the range 16-18 days. This may imply that the increase in the number of chlorophyll by 0.1 in Bengkulu region occurs when the incident MJO phase 3, phase 4 and phase 5 is...
bertutut succession occurs over 16 days by assuming that for 7 consecutive days average conditions SST in these waters warm and occurs rainfall 20-50 mm / day. Opportunity increase in the number of chlorophyll highest reaching 70% at the time of long MJO events over 19 days.

4. Conclusion
From the above explanation can be said that there is a relationship between the incidence of MJO by the number of chlorophyll. Later in figure 4 to figure 7 has described odds the addition of chlorophyll-a have a linear relationship with the duration of the incident MJO in Bengkulu, odds increase the amount of chlorophyll in Bengkulu region reaches a threshold value of 0.5, it means that the length occurrence MJO able to identify increasing the number of chlorophyll in Bengkulu. Furthermore, the amount of chlorophyll-a at the time of the incident MJO can be used to detect areas that have the best fishing ground.

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