Development of the Statistical ARIMA Model: An Application for Predicting the Upcoming of MJO Index

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Abstract. This study is mainly concerned in development one of the most important equatorial atmospheric phenomena that we call as the Madden Julian Oscillation (MJO) which having strong impacts to the extreme rainfall anomalies over the Indonesian Maritime Continent (IMC). In this study, we focused to the big floods over Jakarta and surrounded area that suspecting caused by the impacts of MJO. We concentrated to develop the MJO index using the statistical model that we call as Box-Jenikis (ARIMA) ini 1996, 2002, and 2007, respectively. They are the RMM (Real Multivariate MJO) index as represented by RMM1 and RMM2, respectively. There are some steps to develop that model, starting from identification of data, estimated, determined model, before finally we applied that model for investigation some big floods that occurred at Jakarta in 1996, 2002, and 2007 respectively. We found the best of estimated model for the RMM1 and RMM2 prediction is ARIMA (2,1,2). Detailed steps how that model can be extracted and applying to predict the rainfall anomalies over Jakarta for 3 to 6 months later is discussed at this paper.

1. Introduction

Currently, the Atmospheric Science and Technology Centre of National Institute of Aeronautics and Space (LAPAN) in Bandung is developing both models, dynamical and statistical weather and/or climate model. The dynamical weather and/or climate model is designed based on the Global Circulation Models (GCM), and Limited Area Model (LAM), respectively. While, for the statistical, we still develop the Box-Jenkins (ARIMA) model [1, 5]. As a pre-dominant peak/mode oscillation of the Intra Seasonal Variability (ISV) at the equatorial region (including the Indonesia Maritime Continent, IMC), the characteristics, mechanism, propagation, and
The prediction of Madden-Julian Oscillation (MJO) is very important. MJO is the major fluctuation in tropical weather on weekly to monthly timescales. The MJO can be characterized as an eastward moving 'pulse' of cloud and rainfall near the equator that typically recurs every 30 to 60 days [3, 4]. There are many ways to predict the MJO index. One of them is that we call as the Real-time Multivariate MJO (RMM) Index. The MJO phase diagram illustrates the progression of the MJO through different phases, which generally coincide with locations along the equator around the globe. RMM1 and RMM2 are mathematical methods that combine cloud amount and winds at upper and lower levels of the atmosphere to provide a measure of the strength and location of the MJO (http://www.bom.gov.au/climate/mjo/). Based on the above reason, it is necessary to develop an RMM1 and RMM2 using the ARIMA model for predicting the extreme rainfall over Jakarta in 1996, 2002, and 2007.

2. Materials and Methods

The daily of the Real-time Multivariate MJO series 1 and 2 that we call as the RMM1 and RMM2 for period of 1 March 1979 to 1 March 2009 (30 years observation) is taken from http://www.bom.gov.au/climate/mjo/graphics/rmm.74toRealtime.txt. The pentad anomaly of Outgoing Longwave Radiation (OLR) data for the same period observation at position of 100°E, 120°E, and 140°E, respectively is taken from http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/proj_norm_order.ascii. We mainly apply the Box-Jenkins (ARIMA) technique to get the best estimated model of RMM1 and RMM2 index prediction. For the reference, we mainly refer to the paper written by [6].

3. Main Result

The results of this study is divided into several steps. They are: identification of data, estimated, predicted, and application of that model for the real problem. Firstly, we are analysing the identification of data as shown below.

3.1. Identification of data

![Identification of RMM1 and RMM2](image_url)

*Figure 1. An identification of RMM1 and RMM2.*
Fig. 1 above is showing an identification of RMM1 and RMM2 data. We can see if they look same each other. To get more information the RMM1 and RMM2 data can be shown in Table 1. While, for data plotting, data, Autocorrelation Function (ACF), and Partial Autocorrelation Function (PACF) as the first differential can be seen at Fig. 2, respectively.

![Fig. 1: Identification of RMM1 and RMM2 data.](image1)

**Figure 2.** As same as Fig. 1, but for 3 and 6 months later.

As same as Fig. 1, but for Plot data, Autocorrelation Function (ACF), and Partial Autocorrelation Function (PACF) as the first differencing.

After we make the Mean Absolute Deviation (MAD) of the ARIMA model for data RMM1 and RMM2 for period of 1 March 1979 – 1 March 2009, then after we make Sum of Squares Error for RMM1 and RMM2, respectively for period of 1 March 1979 – 1 March 2009, we make an estimated model as showing below.
3.2. Estimated model
By the Box-Jenkins (ARIMA) technique analysis, we got the best model for the MJO prediction is ARIMA (2,1,2), where for RMM1:

\[ \hat{Z}_t = 1.68 Z_{t-1} - 0.722 Z_{t-2} - 0.02 a_{t-1} - 0.05 a_{t-2} \]

and for for RMM2 :

\[ \hat{Z}_t = 1.714 Z_{t-1} - 0.764 Z_{t-2} - 0.109 a_{t-1} - 0.05 a_{t-2} \]

3.3. Predicted model for 3 and 6 months later

![Figure 3. Comparison between original and model of data for 3 months prediction.](image3.png)

![Figure 4. As same as Fig. 3, but for 6 months later.](image4.png)

From Figure 3 and 4, we can clearly how that model can be used well for 3 and 6 months predictions.
3.4. Application of model

Figure 5 is showing the rainfall variability over Jakarta for period of January 1995 to December 2008. The variability looks clearly like sinusoidal function. It indicates that Jakarta looks mostly affected by the Monsoon system.

But, please note here, the intensity of that rainfall is increasing gradually with time. We suspect it cause by the other phenomena that we call as MJO as already been studied by [6] and [7].

We are trying now to apply that model to explain the rainfall anomalies prediction over Jakarta using the Real Time Multivariate MJO (RMM1 dan RMM2). We concentrate to analyze during rainy season (December, January, and February) in 1996, 2002, and 2007, respectively as showing at Figs 6 and 7, respectively.

Figure 6. Comparison between RMM1 and RMM2 observed and model for period of 1996 (a), 2002 (b), and 2007 (c), respectively.
Figure 7. The Hovmoller diagram as more detail explanations of Fig. 6 for period of 1996, 2002 and 2007, respectively

From figure 7, we can see that there are no any differences for the RMM1 and RMM2 prediction both for 3 and 6 months. The higher rainfall intensity over Jakarta (more than 600 mm/month) not always caused by the MJO active condition, although in that time MJO phase is located at phase 4 and 5 (around the Indonesia Maritime Continent, IMC).

We can see, although MJO active phase is located around Africa (very far away from Jakarta), but Jakarta was covered by big floods. It indicates that we need to consider the other phenomena can make significant contribution to increase the rainfall intensity. One of them is that we call as Cold Surge [2].

4. Conclusion
We found the best model for the RMM1 and RMM2 prediction is ARIMA (2,1,2). It means that the RMM1 and RMM2 are influenced by the phenomenon at second order on autoregressive, have the first differencing and also has the second order of moving average. MJO active with active phase not always followed by the extreme rainfall. In 1996 and 2002, we found that MJO with active is responsible for big floods over Jakarta and surrounded area. But, in 2007, big floods at Jakarta was occurred when the MJO with weak phase. It indicates that we need to consider the other phenomena such as Cold Surge.

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References
[1] Chatfield C 1984 *The Analysis of Time Series : An Introduction* London: Chapman and Hall
[2] Lestari D, Cold Surge dan MJO 2009 Pemicu Banjir Bandang Antara News 14 Februari 2009
[3] Madden R A, Julian P 1972 Description of global Svale circulation cells in tropics with a 40-50 day period. *J Atmos Sci* 29 pp 1109–1123.
[4] Madden R A, Julian P 1994 Observations of the 40-50 day tropical oscillation *Month Weather Rev* 122 pp 814–837
[5] Makridakis S G, Wheelwright S C, Hyndman R J *Forecasting: Methods and Application* 3rd Edition New York: Wiley
[6] Matthew C, Wheeler and Harry H, Hendon, 2004: An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction *Monthly Weather Review* 132 pp 1917–1932
[7] Seto T H 2002 Pengamatan Osilasi Madden Julian dengan radar atmosfer equator (EAR) di Bukittinggi Sumatera Barat *Sains & Teknologi Modifikasi Cuaca* 3 pp 121–124
[8] Wheeler M C, Hendon H H 2004 An all-season real-time multivariate MJO index: development of an index for monitoring and prediction *Month Weather Rev* 132 pp 1917–1932
[9] http://www.bom.gov.au/climate/mjo/, downloaded at November 8, 2016
[10] http://www.bom.gov.au/climate/mjo/graphics/rmm.74toRealtime.txt, downloaded at November 8, 2016
[11] http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/proj_norm_order.ascii, downloaded at November 8, 2016