Madden-Julian Oscillation (MJO) Signal over Kototabang, West Sumatera Based on the Mini Automatic Weather Station (MAWS) Data Analysis Using the Wavelet Technique

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Abstract. This study is mainly concerned an application of Mini Automatic Weather Station (MAWS) at Kototabang, West Sumatera nearby the location of an Equatorial Atmosphere Radar (EAR) side. We are interest to use this data to investigate the propagation of the Madden-Julian Oscillation (MJO). We examined of daily MAWS data for 3 years observations started from January 2001 to Mei 2004. By applying wavelet analysis, we found the MJO at Kototabang have 32 days oscillations as shown in Fig.1 below. In this study, we concentrate just for local mechanism only. We will show in this paper that at the phase of the MJO with a dipole structure to the convection anomalies, there is enhanced tropical convection over the eastern Indian Ocean and reduced convection over the western Pacific. Over the equatorial western Indian Ocean, the equatorial Rossby wave response to the west of the enhanced convection includes a region of anomalous surface divergence associated with the anomalous surface westerlies and pressure ridge. This tends to suppress ascent in the boundary layer and shuts off the deep convection, eventually leading to a convective anomaly of the opposite sign. Over the Indonesian sector, the equatorial Kelvin wave response to the east of the enhanced convection includes a region of anomalous surface convergence into the anomalous equatorial surface easterlies and pressure trough, which will tend to favour convection in this region. The Indonesian sector is also influenced by an equatorial Rossby wave response (of opposite sign) to the west of the reduced convection over the western Pacific, which also has a region of anomalous surface convergence associated with its anomalous equatorial surface easterlies and pressure trough. Hence, convective anomalies of either sign tend to erode themselves from the west and initiate a convective anomaly of opposite sign via their equatorial Rossby wave response, and expand to the east via their equatorial Kelvin wave response.

Keywords: MAWS, MJO, rainfall and Kototabang

1. Introduction
In the tropics weather is not as predictable as in mid-latitudes. That is because in mid-latitudes the weather variables (clouds, precipitation, wind, temperature, and pressure) are largely governed by the upper-tropospheric Rossby waves, which interact with surface weather in a process called baroclinic instability. In the tropics there is no such dominant instability or wave motion, and therefore the weather is less predictable for the 1-10 day period. Until recently it was believed that tropical weather variations on time scales less than a year were essentially random.

In 1971 Roland Madden and Paul Julian1) stumbled upon a 40-50 day oscillation when analysing zonal wind anomalies in the tropical Pacific. They used ten years of pressure records at Canton (at 2.8° S in the Pacific) and upper level winds at Singapore. The oscillation of surface and
upper-level winds was remarkably clear in Singapore. Until the early 1980's little attention was paid to this oscillation, which became known as the Madden and Julian Oscillation (MJO), and some scientists questioned its global significance. Since the 1982-83 El Niño event, low-frequency variations in the tropics, both on intra-annual (less than a year) and inter-annual (more than a year) timescales, have received much more attention, and the number of MJO-related publications grew rapidly.

The MJO, also referred to as the 30-60 day or 40-50 day oscillation, turns out to be the main intra-annual fluctuation that explains weather variations in the tropics. The MJO affects the entire tropical troposphere but is most evident in the Indian and western Pacific Oceans. The MJO involves variations in wind, sea surface temperature (SST), cloudiness, and rainfall. Because most tropical rainfall is convective, and convective cloud tops are very cold (emitting little longwave radiation), the MJO is most obvious in the variation of outgoing longwave radiation (OLR), as measured by an infrared sensor on a satellite.

Figure 1 below from Elleman (1997)2) shows how the OLR anomalies in the eastern hemisphere propagate to the east at around 5 m/s. The OLR signal in the western hemisphere is weaker, and the recurrence interval for the eastward propagating OLR anomalies in the eastern hemisphere is about 30 to 60 days. How exactly the anomaly propagates from the dateline to Africa (i.e. through the western hemisphere) is not well understood. It appears that near the dateline a weak Kelvin wave propagates eastward and poleward at a speed exceeding 10 m/s.

Associated with the propagation of convective anomalies, the MJO involves variations in the global circulation. The MJO affects the intensity and break periods of the Asian and Australian monsoons and interacts with El Niño. Wet spells in the Australian monsoon occur about 40 days apart. Fairly weak correlations with the midlatitude rainfall patterns and jet stream characteristics have also been found3). It has long been known that dry spells as well as wet spells occur in the north Australian monsoon season4). The wet spells usually last longer than the dry spells, which last from a few days to two weeks. Wet spells in northern Australia are associated with westerly winds at the surface, and easterly wind anomalies aloft. Many wet spells seem to originate as cold air outbreaks over Southeast Asia, where it is winter.

A synoptic analysis of the evolution leading up to a wet spell was performed for a large number of cases during 1980-19925). The surges are initially evident over one of three regions: the South China Sea, the northwest Pacific (near Japan) and Indochina. Five days later there is an increase of northerly
surface wind over Indonesia. The onset of a wet westerly monsoon wind over the Top End of Australia then occurs another 2-5 days later, usually leading to high rainfalls there.

With the center of suppressed convection, clear skies associated with a stronger-than-normal trade wind inversion allow more shortwave radiation to reach the ocean surface as shown in Figure 2, causing a slight SST increase as the wave travels eastward\(^6\). The Trade winds too are stronger than normal, explaining enhanced evaporation from the sea surface.

![Figure 2: Schematic of the MJO](Image)

Figure 2: Schematic of the MJO. The cross section represents the equatorial belt around the globe, or just the eastern hemisphere. E stands for evaporation, SW for net shortwave radiation absorbed by the ocean. The converging bold green arrows indicate the location of strongest moisture convergence. The hollow green arrows show the anomalous circulation associated with the MJO. The areas of enhanced convection are indicated by the yellow schematic thunderstorm. (adapted from Elleman 1997)

Easterly winds (and the evaporation rate) weaken near the western edge of the suppressed convection region, and this leads to low-level moisture convergence. This triggers deep convection, leading to the other half of the OLR oscillation, i.e. the region of enhanced convection. This region is comprised of one or more super cloud clusters (SCCs) that move eastward along with the MJ wave. Within the SCCs, westward-moving cloud clusters form at the eastern edge of the SCC and die at the western edge. These smaller clusters have a lifetime of one to two days. In turn, the individual mesoscale convective systems within these smaller clusters typically move eastward, usually by discrete propagation, and have a lifetime of 6-12 hours. The SCCs travel eastward at 5-10 m/s, not as a long-lived storm complex, but rather as a moving wave or oscillation, i.e. the MJO. The MJO has a wavenumber of 1-2, that is at any time there are one or two areas around the equator with enhanced convection, and one or two with suppressed convection.

Equatorially trapped waves (Kelvin and Rossby waves) that explain the evolution of an El Niño event are also the driving mechanism for the MJO. These waves occur in the entire troposphere from 30° N to 30° S, mainly in the eastern hemisphere. Surface air flows away from the suppressed convection in both zonal directions towards enhanced convection regions. In the upper troposphere, anomalous easterlies exit the west side of the enhanced convection (Figure 2). The strong westerlies from the east side of the enhanced convection flow into the region of suppressed convection as shown in Figure 3 below\(^7\).
When suppressed convection is strong from the Indian Ocean to the middle Pacific Ocean, anomalous cyclonic gyres at 200 mb trail the region of suppressed convection. Similarly, anticyclonic gyres at 200 mb trail the enhanced convection region once it becomes strong in the Indian and western Pacific Oceans. Gyres in the opposite sense are produced at surface, but they are much weaker than the ones at the tropopause. The zonal circulation and horizontal gyres are important processes by which the MJO shuffles mass around the tropics.

The explanation above is simplistic, in that it idealises the oscillation, as it isolates it from other variations. As mentioned before, the speed and size are variable, and the MJO mainly affects rainfall patterns in Indonesia and surrounding areas. Not all of the elements of the MJO -- convection, zonal wind, moisture convergence, and SST anomalies -- are always visible. It is only when the 30-60 day oscillations are extracted from a series of MJO events that the idealised picture of the MJO emerges. Consecutive oscillations have varying amplitudes, periods, and wavelengths.

The MJO exhibits the mixed Kelvin-Rossby wave structure over the eastern hemisphere, but over the western hemisphere, it only shows a Kelvin wave structure. It moves through the eastern hemisphere at around 5 m/s and through the western hemisphere at a higher speed (at least 10 m/s). The oscillation is stronger in the northern hemisphere winter. It is also in this season that the negative OLR anomalies are most likely to propagate along the equator from the Indian Ocean to the central Pacific Ocean. In the northern hemisphere summer, many of the anomalies veer away from the tropics before they make it to the central Pacific. Notwithstanding its complexity and dependence on convection, the essence of the MJO (its periodicity, structure and zonal asymmetry) can be simulated in a GCM.

2. Method
Based on the basic concept of MJO above, we used the daily of MAWS (Mini Automatic Weather Station) data installed by Shimane University, Japan and located near by the EAR (Equatorial Atmosphere Radar) at position on 0.2°S ; 100.32°E and 865 m from MSL (mean sea level) in period of
Januari 2001 to May 2004. We used the wavelet transforms analysis taken from Matlab software to obtain the global wavelet spectrum. Wavelet transforms are a mathematical means for performing signal analysis when signal frequency varies over time. For certain classes of signals and images, wavelet analysis provides more precise information about signal data than other signal analysis techniques.

3. Results and Discussions
The result of wavelet analysis can be shown in Figure 4 below. We need to compare this result with another study which have been done by Renggono et. al (2001)^11.

![Wavelet Analysis Results](image)

**Figure 4:** The daily MAWS Rainfall Observation at Kototabang

The upper panel of Figure 4 shows the time series of daily MAWS data, while the middle and upper panel show the wavelet power spectrum and average variance of MAWS data analysis, respectively. If we look carefully the middle panel of this figure, we can see that the most predominant peak of MAWS data is not MJO oscillation, it is close to 256 days oscillation. We suspect it is related well to the Monsoon phenomena which has oscillation in between 6 month to 1 year oscillation. We call this phenomena as Annual Oscillation (AO).

Although, it not as peak dominant oscillation, but we found another peak oscillation near by 32 days oscillation. We strongly suspect that it is close to the MJO phenomena, since some researchers before determined this phenomena is located in between 30 to 60 days oscillations. This is an important result, since MJO has already suspected have a strong correlation with Dipole Mode (DM) oscillation which occurred over the Tropical Indian Ocean and Western Pacific including Indonesia and have 3 to 6 months oscillation period. We tried to explain this phenomena by showing this Figure 5 below.
Figure 5: The differences between stratiform and convective cloud over Kototabang observed with the Boundary Layer Radar (BLR) (after Renggono, et. al, 2001)

The left and right panel of Figure 5 shows the comparison between stratiform and convective cloud over Kototabang using the BLR data, respectively. We can see the differences between stratiform and convective cloud clearly. Stratiform cloud has two peak dominant oscillations, in March and November, although it has another peak in July, but still it is not clear. While, convective cloud has more rapid oscillation, close to every 2-3 months oscillation, in April, July, September/October and December. We suspect it mostly effected by the Dipole Mode phenomena.

4. Summary
We have already presented here an application of MAWS (Mini Automatic Weather Station) data in determining a fine structure of MJO (Madden-Julian Oscillation) near by EAR (Equatorial Atmosphere Radar) site at Kototabang, West Sumatera, Indonesia. By using wavelet analysis taken from Matlab software, we successfully found the MJO oscillation at Kototabang area that is 32 days oscillation. Theoretically, the MJO oscillation is between 30-60 days oscillation and most dominant appeared near by the Western part of Sumatera Island.

5. Future Works
We need to continue this study to improve the significant correlation between MJO and Dipole Mode oscillation, since both phenomena are suspected appeared near the cost of Sumatera Island. We need to know also the propagation wave of both oscillation, especially from stratosphere to troposphere still near by EAR site. For this reason, we strongly recommend to use the EAR data, since this instrument can detect these oscillations from 2 km to 22 km above mean sea leave (MSL) and spatial designed to observed an atmospheric parameter with good time and spatial high resolution.

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