Interaction between madden-julian oscillation and monsoon related to big floods over south sulawesi in january 2019

E Hermawan¹, T Harjana¹, A Ridho², T Maulana²

¹Center of Atmospheric Science and Technology, National Institute of Aeronautics and Space Republic of Indonesia (LAPAN)
²Physics Department, Faculty of Science and Mathematics, Diponegoro University

Corresponding author: eddy.hermawan1962@gmail.com

Abstract. Study of interaction between MJO and Monsoon and their impact on the extreme rainfall over the Maritime Continent (MC) until now not yet fully understood due to the limitation of data observation. However, there many techniques to derive the extreme rainfall from the satellite data, especially for GSMap (Global Satellite Mapping of Precipitation) that already designed with good spatial-temporal resolution. In this study, we have investigated the interaction between MJO and Asian Monsoon when they are interactive simultaneously. By taking the Makasar city as a sample of big floods over South Sulawesi dated January 22, 2019, we found a good agreement between MJO, Monsoon, and their impact on the extreme rainfall in that time. We applied four techniques, namely; temporal, spatial, Hovmoller, and PSD (Power Spectral Density), respectively. Then, we found the MJO in phases 4 and 5 were responsible for the occurring of big rainfall over South Sulawesi. For this reason, we suspect the development of the MJO index model, especially for phases 4 and 5 when passing over South Sulawesi is very important for the next investigation.

1. Introduction
An extreme rainfall event occurred over South Sulawesi which resulted in big floods. Daily rainfall of 84.4 mm was observed at Paotere Maritime Meteorology Observatory on 22 January 2019. Until 25 January 2019, the flood had not subsided, making it the worst in a decade.

Rainfall pattern on South Sulawesi is typically monsoonal, unimodal with the peak of rainfall that occurs in December-January-February and dryness peak in June-July-August [1]. Convective activity, diurnal cycle, on South Sulawesi.

The Madden-Julian Oscillation (MJO) is an intraseasonal oscillation with a period of 30 to 90 days in the tropical atmosphere. It is characterized by circulating cells that move east along the equatorial plane of the Indian Ocean to the western Pacific Ocean. This movement resulting in variations of rainfall on the region through, especially in the Maritime Continent.

Wu et al. (2013) examined the effects of an active phase of the MJO on an extreme rainfall event that occurred in Jakarta of January 2013. The study showed that strong to moderate westerly winds in the lower troposphere caused by an active phase of the MJO, in conjunction with the trans-equatorial monsoonal flow [2].

South Sulawesi is located in the tropics region on the foot of Sulawesi Island. It is surrounded by the sea on the west, south, to the east, and the mountainous region on the north. The MJO has a strong impact on precipitation on the island and the surroundings. Even so, but due to in-situ observation data.
that are often incomplete, the effect of how MJO has an effect on extreme rainfall on the island is not clearly understood, especially in the middle region in the Maritime Continent.

GSMaP is The Global Satellite Mapping of Precipitation (GSMaP) which distributed by the Earth Observation Research Center, Japan Aerospace Exploration Agency. Verification of high-resolution satellite-based rainfall estimates around Indonesia using a gauge-calibrated ground radar dataset [3]. Therefore satellite technology can obtain rainfall data for a region with limited equipment and can study the rainfall characteristics in that area. Based on the previous study using GSMaP data concluded that the product provides promising potentiality for the application of monitoring rainfall conditions preceding flood events in Indonesia [4]. Hence, the goal of this study is to identify the meteorological factors that influence the extreme rainfall events of 22 January 2019 in South Sulawesi, which focus on the effects of MJO on the active phase.

2. Data and method
We use rainfall data products near real-time gauge v.7 from GSMaP with 0.25º spatial resolution and hourly temporal resolution over South Sulawesi in December-January-February 2018-2019. Surface daily observation data obtained from Paotere Maritime Meteorological Station 5°6'37.5"S and 119°25'11.5"E in January 2019. Daily outgoing longwave radiation (OLR) uninterpolated data with spatial resolution 2.5º from NOAA/OAR/ESRL. Zonal and meridional wind level 850 Mb data extracted from Era-Interim 5 available on ECMWF Database. For comparison, we use daily accumulated precipitation data from GPM 3IMERGM v06 with 0.1º spatial resolution extracted from Giovanni GSFC NASA. We apply the Power Spectral Density (PSD) technique when we investigate the characteristic of OLR anomaly data on the rainfall rate in this selected region (South Sulawesi).

3. Results and discussions
We start our research by showing the Real Multivariate MJO (RMM) Diagram for RMM1 and RMM2 for the period of 7 January to 6 April 2019 below.

![RMM Diagram](image)

**Figure 1.** The RMM1 and RMM2 Diagram for the period of 7 January to 6 April 2019

Looking at this figure, we can see that on January 19, means two days before big floods over South of Sulawesi has corresponded with the MJO index position at phase 4. We select this phase since phase 4
is related well with the position of Makasar city that located at around 120E. To get more information about the RMM index position, we are showing here Table 1.

Table 1: Date, RMM1, RMM2, Amplitude and Phase for Period of 19 to 22 January 2019
(source: http://www.bom.gov.au/climate/mjo/)

| Date       | RMM1 | RMM2 | Amplitude | Phase |
|------------|------|------|-----------|-------|
| 19-01-2019 | 1.19 | -0.56| 1.32      | 4     |
| 20-01-2019 | 1.45 | -0.46| 1.53      | 4     |
| 21-01-2019 | 1.63 | 0.09 | 1.63      | 5     |
| 22-01-2019 | 1.82 | 0.63 | 1.93      | 5     |

3.1. Temporal analysis

From Table 1, we can see that during phases 4 and 5, the amplitude of the MJO index is located more than one. It means that a strong MJO signal appeared at that time. But, we don’t know when exactly, the big floods were coming to South Sulawesi. For this reason, we are showing below the time series analysis of the Temperature Black Body (TBB) of HIMAWARI data satellite represented as the convective index, the precipitation that taken from GSMaP satellite as showing at Figures 2, 3, 4 and 5, respectively. While for observation can be seen in Figure 6. Please note here, it used only one single station to describe the rainfall intensity during that time, namely Paotere Makasar Station as belongs to BMKG.

Figure 2. The time-series of TBB parameter taken from HIMAWARI for a period of 21 to 22 January 2019 for every 30 minutes. The red cycle indicates that big rainfall was occurring at that time.

Figure 3. As the same as Fig. 2, but for the rainfall intensity and rainfall accumulation.
What we can see here is almost all figures (Fig. 2 to Fig. 6), the big rainfall over Makasar was occurred at about January 22, 2019, at around 0.00 UTC (+ 7 hours) if we use the Western Indonesia Local Time.

3.2. Spatial analysis
To get more comprehensive information, we are showing some spatial analysis using the GSMaP data as following as Figures 7, 8, 9, and 10, respectively.

Figure 4. As the same as Fig. 2, but for the rainfall intensity

Figure 5. As the same as Fig. 2, but for the rainfall intensity using 3IMERGHH v06

Figure 6. As the same as Fig. 2, but for the rainfall intensity taken from Paotere Makasar Sta.
Figure 7. The GSMaP data analysis for big rain over Indonesia, especially South Sulawesi dated on January 22, 2019, at around 00.00 UTC or 07.00 Local Time for the Western Part of Indonesia.

Figure 8. As the same as Fig. 7, but for detailed information.

Figure 9. As the same as Fig. 7, but taken from earth.null school net.
3.3. Hovmoller analysis
To get more information due to the big floods over South Sulawesi, we are showing in Figures 11 and 12 using the Hovmoller technique analysis.

Figure 11. Hourly precipitation map in mm/hour
3.4. Spectral technique analysis
To get more information due to the big floods over South Sulawesi, we are showing at these figures some of the spectral technique analyses (Fig. 13 and 14). Please note here, it found 73 pentad signal in Fig. 13, especially that indicates that South Sulawesi is mostly affected by the Monsoon system.

Figure 13. The spectral technique analysis for MJO index and precipitation using FFT

For all those analyses we can mention here that the big rainfall that causes the big floods over South Sulawesi occurred on January 22, 2019, at around 00.00 UTC or 07.00 LT for the Western Part of Indonesia region.
Figure 14. As the same as Fig. 13, but for Wavelet technique

4. Conclusion
The extreme rainfall generally occurs when the strong Asian Winter Monsoon was passing over South Sulawesi. But, please note here, not only Monsoon itself but sometimes the strong MJO event also passing over South Sulawesi. We called the simultaneous observation coming together at the same time and passing together over South Sulawesi. Because of them, we suspect the big rainfall over South Sulawesi caused by the simultaneously of Monsoon and MJO system. By applying four techniques, namely are Temporal, Spatial, Hovmoller, and Spectral analysis, respectively, we found the big rainfall that causes the big floods over South Sulawesi was occur on January 22, 2019, at about 00.00 UTC or 07.00 LT for the Western Part Indonesia region. We found also the MJO at phases 4 and 5 is responsible for the upcoming big rainfall over South Sulawesi. For this reason, we suspect the MJO index model, especially for phase 4 and 5 is very important next time investigation.

Acknowledgment
Thanks a lot is given to LAPAN in Bandung that has already supported this study. Thanks also are given to the Faculty of Science and Mathematic Diponegoro University Semarang for nice collaboration and cooperation.

References
[1] Aldrian E, Dwi Susanto R 2003 Int. J. Climatol, 23, 1435–1452
[2] Wu P, Arbaın A A, Mori S, J-I Hamada, M Hattori, Syamsudin F and M D Yamanaka 2013 SOLA, 9, 79–83
[3] Ushio T, Kubota T, Shige S, Okamoto K, Aonashi K, Inoue T, Takahashi N, Iguchi T, Kachi M, Oki R, Morimoto T and Kawasaki Z 2009 J. Meteor. Soc. Japan, 87A, 137-151
[4] Sugiartha N, Ogawara K, Tanaka Te, Mahendra M S 2017 Int. J. Environ. Geosci. Vol 1(1) 36-47