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Propagation of Upwelling on Western-Coast Sumatra During Madden-Julian Oscillation Event

Yosafat Donni Haryanto[1,3*], Novi Fitrianti[2], AgusHartoko[3], Sutrisno Anggoro[3], Muhammad Zainuri[3]

[1] State College of Meteorology Climatology and Geophysics, Jl. Perhubungan 1 No.5 Pondok Aren, Tengerang Selatan, 15221

[2] Indonesia Agency For Meteorology Climatology and Geophisycs, Jl.Angkasa I No.2 Kemayoran Jakarta Pusat, DKI Jakarta, 10720

[3] Coastal Resource Management, Faculty of Fisheries and Marine Sciences, Diponegoro University, Jl. Prof. H.Soedharto, SH, Tembalang, Semarang, 50275

* Corresponding author's e-mail: yosafatdonni@gmail.com

ABSTRACT

Madden-Julian oscillation (MJO) is an atmospheric oscillation due to atmospheric phenomenon that occurs due to the uniformity of solar energy received at the surface of the earth, MJO is a natural occurrence in the sea-atmosphere system. When the MJO is active, in general there will be a disturbance in the upper air which is then followed by an anomaly at sea surface pressure causing the changes in the wind on the surface. The changes in the surface wind affect the sea surface currents which then cause the occurrence of coastal upwelling downwelling. The upwelling process itself is a process whereby a sea mass is pushed upward along the continent, when the beach is to the left of the wind direction, the ecological transport leads to the mass of water away from the coast. As a result, there is a mass vacuum (divergence) in the coastal area. This mass void will be filled by the mass of water from the inner layer that moves to the surface. Indonesian territory itself is passed by MJO in phases 3, 4 and 5, while for Sumatra region is passed by MJO phase 3 and 4. This research aims to identify the propagation of coastal upwelling during MJO on the west coast of Sumatera, therefore the data of geopotential height, surface pressure sea (MSLP), zonal and meridional components and sea surface temperature are used to analyze how the MJO effect on the coastal upwelling occurs in the research area. The analysis was conducted in June, July and August by comparing the atmospheric conditions at the time of strong MJO in phases 3 and 4 with normal viewing of anomaly geopotential height and MSLP and then seeing the anomaly surface wind changes from zonal wind (u) and meridional wind (v) and changes in SST in Sumatra region. The result shows that there is a change of GH and MSLP when MJO passes the west coast of Sumatra and then follows the change in the value of u and v and SST to identify the upwelling, while the anomaly change negative SST does not occur when MJO is active but has time lag (lag). In this analysis it was found that SST anomaly occurs when the anomaly changes in both the upper and surface water occurring after 5 days in phases 3, 4 and 5.

Keywords: MJO, upwelling, coastal upwelling, coastal downwelling, mean sea level pressure, potential velocity, zonal wind, meridional wind, sea surface temperature.

INTRODUCTION

Upwelling is the movement of water masses over the surface of the sea that carry many nutrients and have a high primary fertility rate. Marine waters where upwelling occurs constitute a potential fishing ground because it is rich in nutrients (Ihsan, 2013). Upwelling is usually in the water depth range of 200–300 m (Bowden & Ferguson, 1980), while Cole and Mcglade (1998) suggest that upwelling can also occur in shallow waters with a depth of 20–40 m. Bowden (1983) states that the seasonal variations of upwelling occur with respect to the wind strength.

According to Barnes (1988), this upwelling process can occur in three forms: the first upwelling that occurs at a time of deep current encounters an obstacle such as a mid-ocean ridge, where the current is deflected upwards and the water flows to the surface and upwelling caused by currents that drift away from the coast due to continuous winds over land for some time. This current brings the coastal surface water mass to the open seas that results in empty spaces in the coastal area which are then filled with the water mass below it. According to Sahala and Stewart (1985), the upwelling process is a process whereby the sea mass is pushed upwards from a depth of about 100 to 200 meters that occurs along the coast across many continents. Because in general the current movement always forms an angle both from and towards the sea as the effect of the Coriolis force and Ekman divergence, thus causing the flow of sea water away from the coastline.

The Madden-Julian oscillation (MJO) is an equatorial pattern of rainfall anomaly that is on a planetary scale. MJO is characterized as enhanced and suppressed by tropical precipitation, observed primarily over the Indian Ocean and Pacific Ocean. MJO affects the entire troposphere of the tropics even more clearly in the Indian Ocean and in the Pacific Ocean. The MJO phenomenon is closely related to the changes in important parameters of the ocean and atmosphere, including wind velocity and direction, sea surface temperature (SPL), surface variability of chlorophyll-a, and surface current patterns. This study aims to analyze the effect of MJO on the propagation of coastal upwelling on the west coast of Sumatra.

DATA AND METHOD

This research uses outgoing longwave radiation, potential velocity, sea level pressure, sea surface temperature, zonal wind and meridional wind. The data used was downloaded from www.esrl.noaa.gov/psd/ with resolution 2.50×2.50. The phenomenon of MJO itself does not have the effect of bringing heavy rain when the Sun's position is not to the south of the equator as it is in the period of December-January-February. Therefore, the data used in December, January and February (DJF) of 2007–2012, is daily and then selected where it is statistically based on index RMM1 and RMM2, determined as an active MJO incident. Data processing is done by identifying the spread of active MJO in Indonesia in DJF especially on the west coast of Sumatra by using spatial data of OLR, after identifying the phase of MJO event in the analysis area, then MJO propagation is determined on the basis of SST temperature change and Termoklin depth. Afterwards, it is possible to identify when the active MJO phase is by analyzing the changes occurring in the atmosphere and the impact on the surface wind that causes coastal upwelling in the area of analysis. In this study, the time event is divided into 4 ranges, i.e. 5, 10, 15 and 20 days, which are based on active MJO events.

RESULTS AND DISCUSSION

Identifying the MJO

One way of identifying MJO positions passing through Indonesia can be done by spatially making OLR composites from phase 3, phase 4 and phase 5 MJO. The composite analysis is done by looking at RMM1 and RMM2 data at each phase and then identifying the periods of events passing through Indonesia based on phase 3, phase 4 and phase 5 of DJFM period 2007–2012, i.e. 223 activity days. Figure A shows the MJO activity from phase 1 to phase 8.

In Figure 3, showing OLR composite in phase 3, phase 4 and phase 5, it can be seen that when the MJO is in phase 3, the lowest OLR value <180 in Sumatra region then moves during phase 4 covering Java, Kalimantan and extending to the South of Sulawesi. The region of Sumatra is almost entirelz covered by low-value OLR <180. For phase 5, the lowest OLR values have shifted towards the eastern part of Indonesia, whereas in Sumatra the area is still covered by low OLR values ranging from 180–190. Therefore, the propagation of MJOs for this study is analyzed on the west coast of Sumatra using the time incidence when MJO is active in phase 3, phase 4 and phase 5.

Upper Air Disturbance

Figure 4 shows the geopotential height at 850 mb layer in the analysis area around the west coast of Sumatra. On the first day of active MJO, the geopotential height tends to be low and then increases until day 9, although the increase is not too significant. Afterwards, from the 10th day,

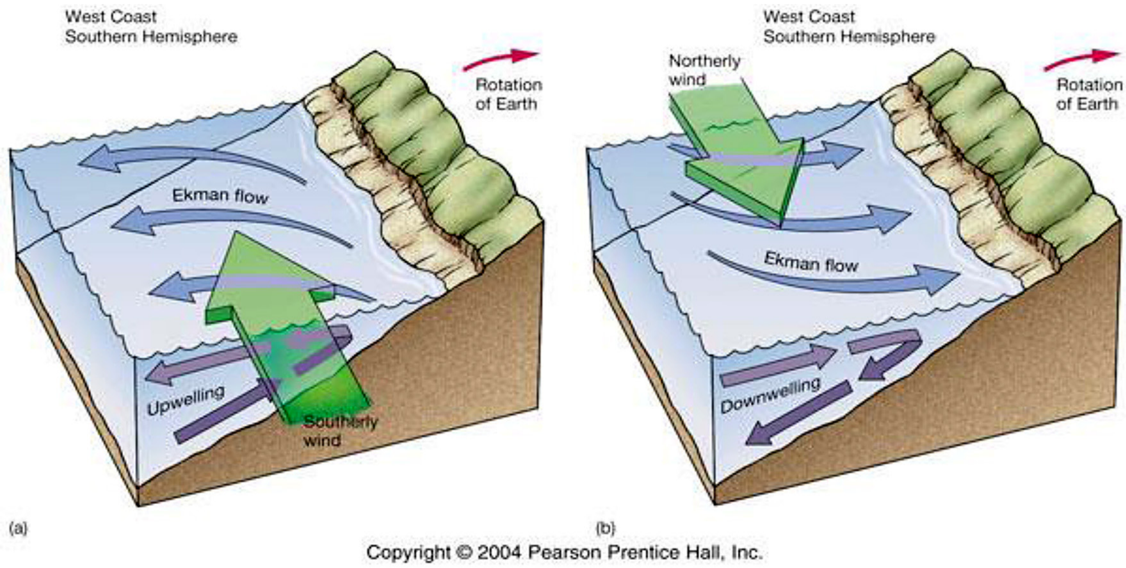

Figure 1. Coastal upwelling

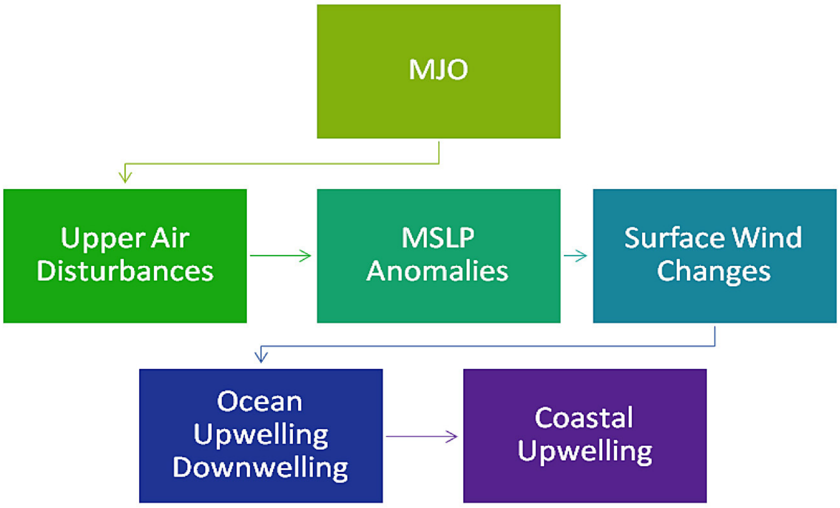

Figure 2. Mechanism by which the MJO could potentially influence the ocean currents and upwelling along the Northwest coast

there is a sharp decrease until the 13th day and afterwards it rises again. If the geopotentials of a pressure bag rise, it means that there is a high pressure area on the face, whereas if the geopotential is down, there is a low pressure region at the bottom. In the graph above, it can be seen that when MJO is active, geopotential in the analysis area shows a low enough value indicating that there is a low pressure region in the area. Moreover, the low geopotential value indicates that the air in that area tends to move upward. The decrease of the lowest geopotential value of the height occurs on the 13th day of the active MJO, causing the greater potential of convective cloud due to the amount of air transported at the upper layer.

MSLP anomalies

Figure 5 shows the MSLP anomalies. At the time of 5 days of active MJO, the SLP anomaly in the area of Sumatra is still negative but in the northern part of Sumatra, it amounts to about -0.4 – -0.2 and with that value, SLP is moving almost entirely covering the region of Sumatra until day 10. Until the 15th day of active MJO, there is an increase in the value of SLP anomaly ranging from about -0.2 to 0.2, covering up to the entire region of Sumatra and spreading to the Indian Ocean, while at day 20, the value of SLP anomaly increases, with the values ranging from 0.2 to 0.4 and the contour of the pressure is get-

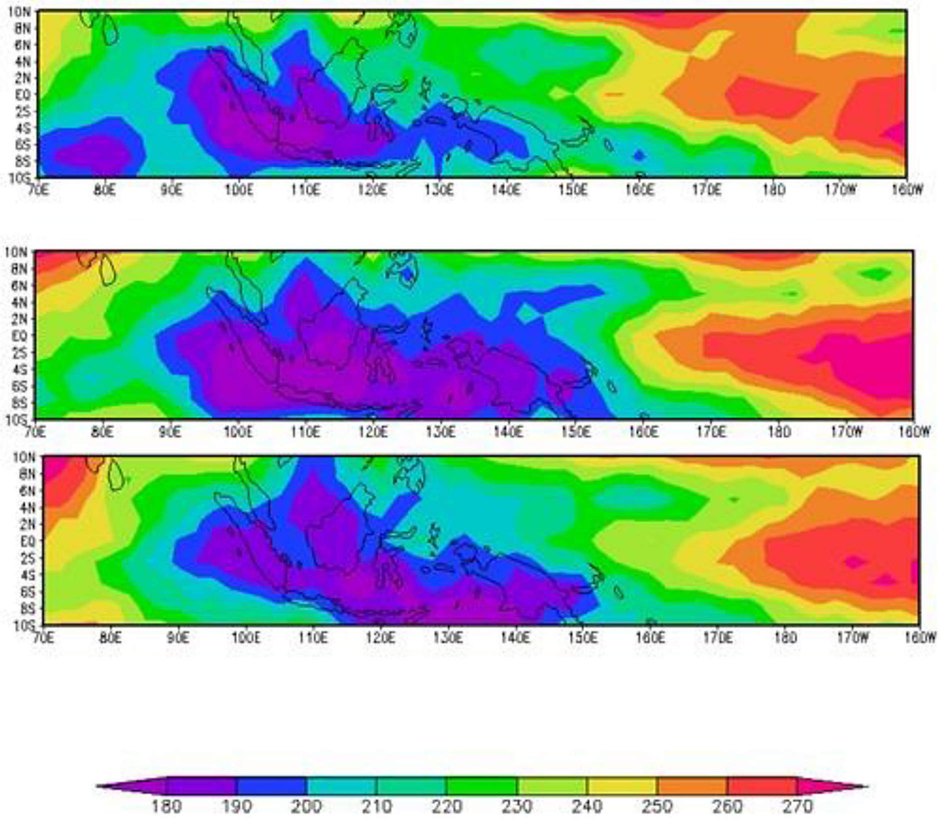

Figure 3. OLR Composite in phase 3, phase 4 and phase 5

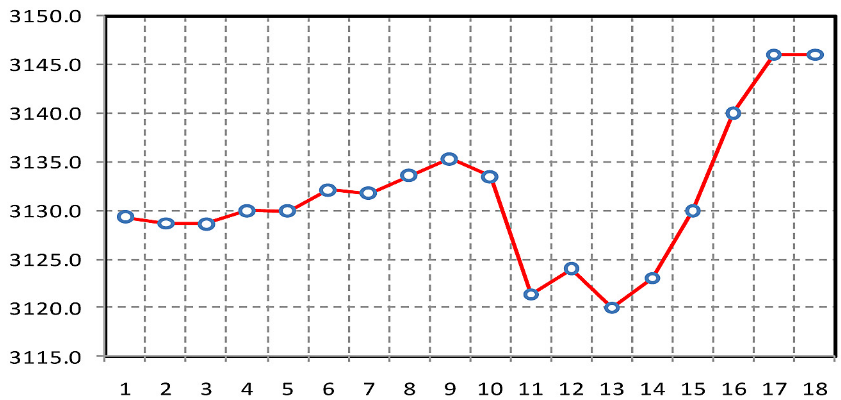

Figure 4. Geopotential height at 850 mb

ting higher towards the Indian Ocean. An increase in the value of SLP is indicated to strengthen the increase of western winds in areas with high values of pressure anomaly.

Surface wind change and upwelling

The presence of disturbances in the upper atmosphere causes a change in the surface wind and the occurrence of coastal upwelling, as seen in Figure 1. When the MJO is active there is an upper air disturbance where the geopotential altitude becomes lower, which causes a decrease in the pressure. This can be explained by Figure 5, where on day 1–5 MJO is active, there is a lower SLP anomaly in the northern part of Sumatra, as an increase in the anomaly of the SLP value causes an increase in the western wind which can be explained in Figure 6. There, the west-northwest wind occurs with the speed of >2 m/s and parallel to the beach. In Figure 6 presents the MJO active in the Sumatra region. The western breeze occur-

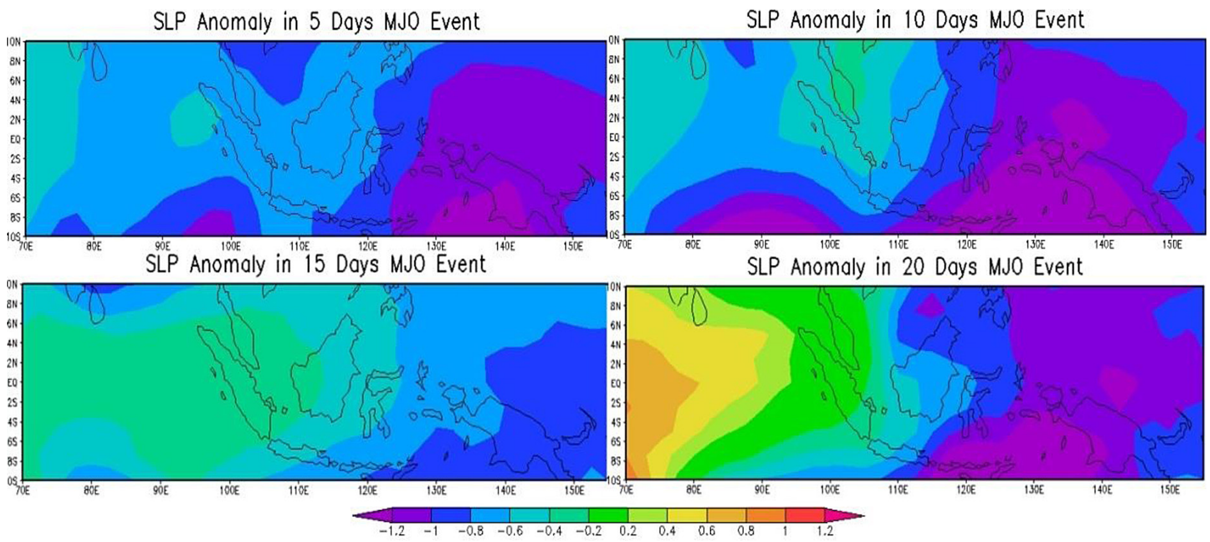

Figure 5. Sea level pressure anomaly

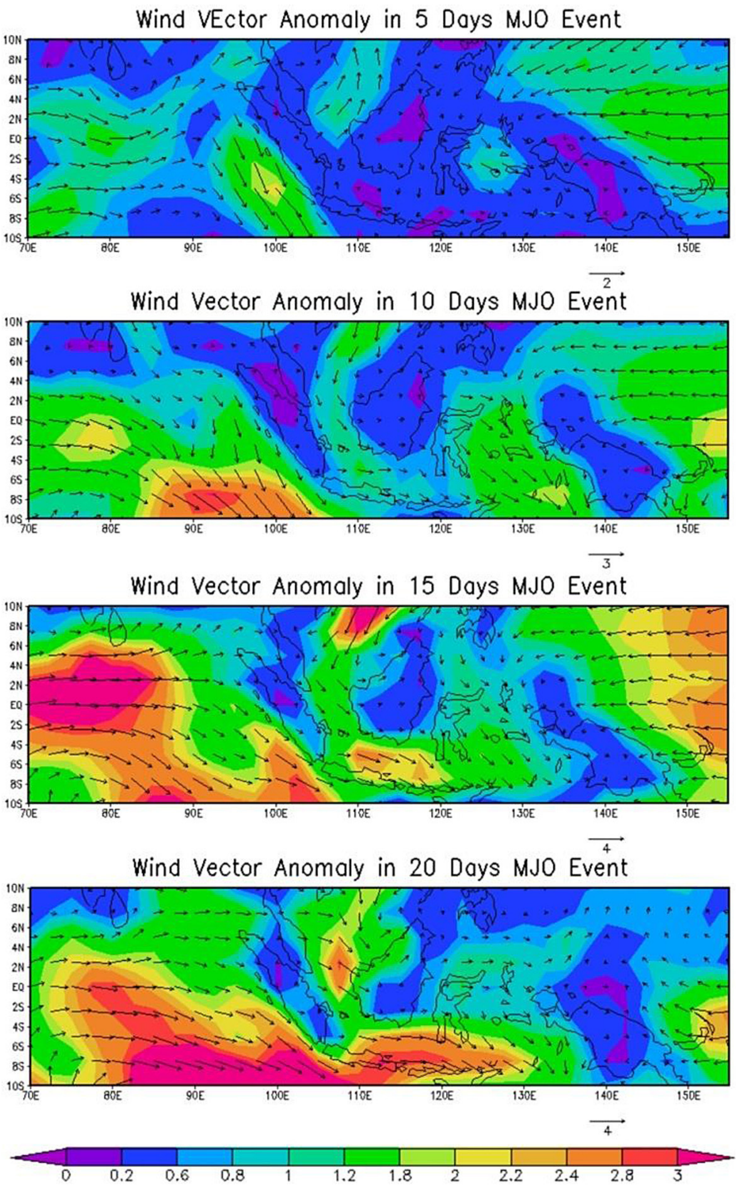

Figure 6. Strengthening of the direction of the wind

ring in the region can be explained because of the positive value of the SLP anomaly, the increase is 0.5–1 m / s every 5 days of MJO incident.

Figure 6 shows the strengthening of the direction of the wind from the west which is parallel to the coastal position. The reinforcement of the wind occurs after 5 days of active MJO and there is the addition of wind speed on the west coast coastal area of Sumatra up to 1 m/s after more than 5 days MJO incident, as the reinforcement caused Ekman's transport away from the coast moving the water mass away from the coast. As a result of this divergence in coastal areas, the vacuum will be filled by the mass of water from the inner layer moving to the surface causing upwelling.

Figure 7 presents the sea surface temperature anomaly, when the occurrence of western breeze on the west coast of Sumatera region on the day 1 – 5 day of MJO incident indirectly causes the occurrence of negative anomaly, indicating upwelling in the area of analysis but the negative anomaly has a lag after more than 5 days of active MJO. This is indicated by the decrease of SST anomaly value on the western part of Sumatra around the coast of Aceh and North Sumatra and then the spreading of the negative anomaly when the MJO is active until the 15th day. It then occurs almost in the most of the coastal area of the island of Sumatra. Then, on the 20th day, of upwelling occurs on the entire west coast of Sumatera and it spreads to the Indian Ocean. The lag time of sea level decrease occurred at the time of active MJO caused by the increase of western wind after 5 days of MJO incident.

CONCLUSION

The occurrence of coastal upwelling on the western coast of Sumatra is due to the atmospheric disturbances which can be seen in the geopotential height analysis which shows lower values than normal. Moreover, low sea level pressure causes an increase in the surface wind velocity parallel to coastal areas, the increase of the western wind caused the Ekman transport away from the coast resulting in coastal upwelling that spread to the Indian Ocean on the 20th day of active MJO. In addition, the upwelling process that occurs on the west coast of Sumatra does not appear when the MJO is active but has a time lag (lag) for 5 days and spreads from the northern coast of Sumatra, covering almost the entire west coast.

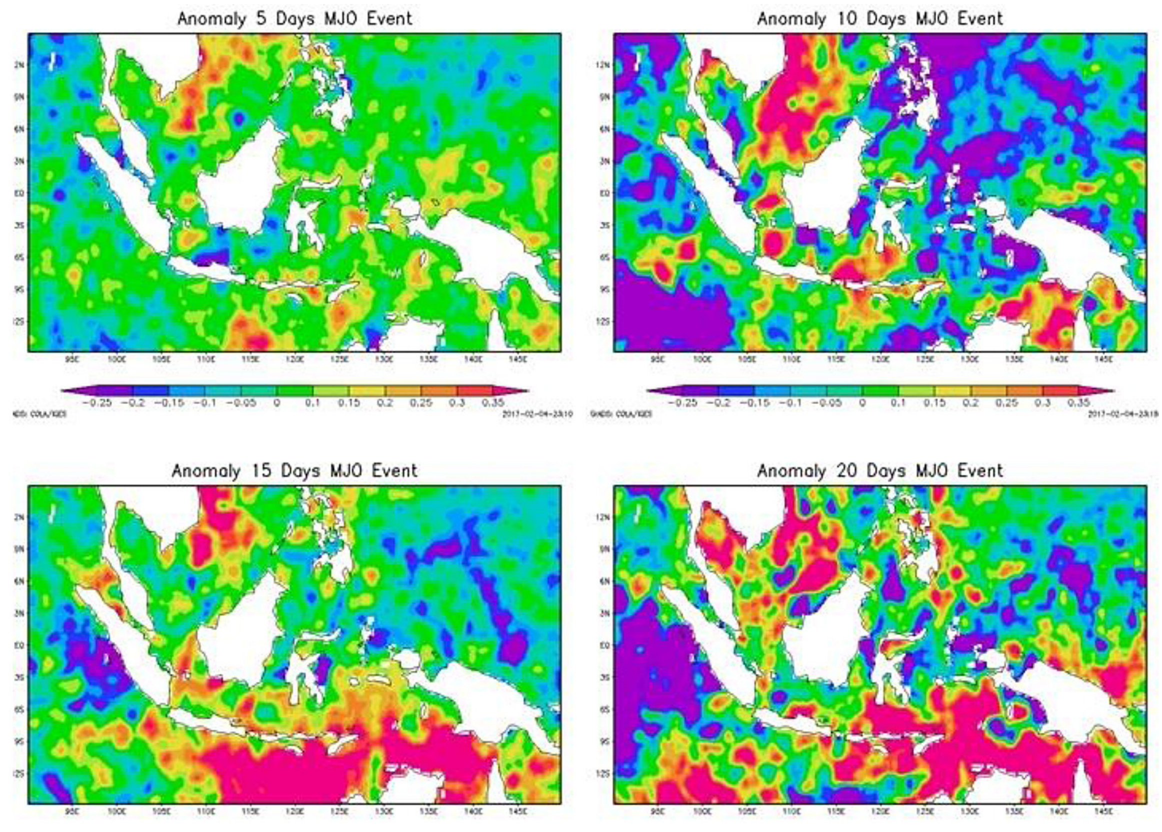

Figure 7. Sea surface temperature anomaly

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