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Evolution and impact of the 2016 negative Indian Ocean Dipole

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Abstract. Strong negative Indian Ocean Dipole (IOD) event took place in the tropical Indian Ocean during 2016. Based on the Dipole Mode Index (DMI), the event has shown two peaks: in July and September. It is shown that the second peak was stronger than the first peak. Evolution of the event has started in May, reached its first peak in July, weaken in August, but rebounded and came to its second peak in September. The event was terminated in November. Robust sea surface temperature (SST) dipole patterns were observed during both peaks. In July, the SST anomaly in the eastern (western) pole of the IOD reached +1°C (-1.5°C). Meanwhile, during the second peak of the event, the SST anomaly in the eastern (western) pole of the IOD rose (fall) to nearly +2.5°C (-1°C). As a consequence, strong convective activities were observed over the maritime continent causing heavy rainfall during the peak of the event. On the other hand, there was a significant reduce of the rainfall over the eastern Africa during the peak of the event.

1. Introduction

The Indian Ocean Dipole (IOD) is one of dominant coupled ocean-atmosphere mode originated in the tropical Indian Ocean [1,2,3]. A positive IOD has a unique characteristic in which the sea surface temperature (SST) anomaly formed a dipole pattern with negative (positive) SST anomaly covers the southeastern (western and central) tropical Indian Ocean. Associated with these SST patterns, the atmospheric winds anomalously westward, driving anomalous surface westward currents and creating poleward Ekman transport. The divergence of these Ekman transports cause equatorial upwelling and shoal (deepen) the thermocline in the eastern (western) equatorial Indian Ocean leading to cool (warm) SST there. Cool (warm) SST in the eastern (western and central) equatorial Indian Ocean suppressed (enhanced) atmospheric convections. As a consequence, the eastern (western) tropical Indian Ocean and its surrounding continent experience deficit (surplus) rainfall [4,5]. The situation is reverse during the negative IOD event.

The occurrence of the IOD event has a biennial tendency, in which a positive IOD event will be followed by a negative IOD event in the following year [1]. Moreover, the intensity of the event is measured using a Dipole Mode Index (DMI) indicating a gradient in SST anomaly between the western tropical Indian Ocean (10°S - 10°N, 50°E - 70°E) and its eastern counterpart (10°S - 0°S, 90°E - 110°E) [1]. A positive (negative) DMI is referred to a positive (negative) IOD event. During positive IOD event, the SST in the southeastern tropical Indian Ocean experiences cooling associated with anomalously strong southeasterly winds along the southern coast of Java and Sumatra and easterly wind anomalies along the eastern equatorial Indian Ocean. As a consequence, the convective activities shifted westward to the central or even further westward leading to enhanced (decreased) precipitation over the East Africa and India (Indonesia and Australia) [6].

During boreal summer/fall 2016, the DMI indicated a negative value (negative IOD event). In addition, most part of the Indonesian regions have experienced surplus precipitation. This study is designed to describe the evolution of negative IOD event in 2016 and evaluate its possible impact on the Indonesia.

2. Data and Methods

The DMI is defined as a gradient of the SST anomaly between the western tropical Indian Ocean (10°S - 10°N, 50°E - 70°E) and its eastern counterpart (10°S - 0°S, 90°E - 110°E) [1]. In this study, the SST data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation Sea Surface Temperature (OISST) Version 2. The data are available from September 1981 until present with a uniform horizontal resolution of 0.25°.

The atmospheric wind data were from the ERA-Interim of the European Centre for Medium-Range Weather Forecasts (ECMWF). This is a low-level wind on the 850 mb pressure level. This level is located above the friction layer where the clouds and precipitation occur. Therefore, this is quite valuable for analyzing all types of synoptic weather patterns. The ECMWF winds have horizontal resolution of 0.5°× 0.5°. The data are available for period of January 1979 until present. Meanwhile, the precipitation data were obtained from the Tropical Rainfall Measuring Mission (TRMM) with horizontal resolution of 0.25° × 0.25° and are available from January 1998 until present. Note that, the anomalies of all variables are defined as the deviation from the monthly climatology over a period of 2001-2015.

3. Results

We first evaluate the evolution of 2016 negative IOD event using the time series of DMI shown in Figure 1. It is shown that the evolution of 2016 negative IOD was started in boreal spring (April/May) as the DMI gradually decreased. By the end of May, the DMI has exceeded its standard deviation and it continued to decrease. The DMI slightly increased from mid-July until mid-August and might be related to the intraseasonal westerly winds during summer monsoon [7]. After a short weakening of the event, the DMI again gradually decreased and reach a minimum value in September. By the end of September, the DMI rapidly increased and the IOD was terminated in November.

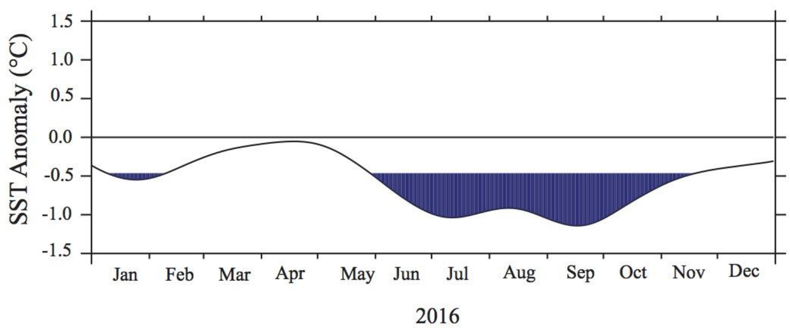

Figure 1. Time series of the Dipole Mode Index (DMI) for a period of January – December 2016. Note that the DMI was defined as a gradient of the SST anomaly (ºC) between the western tropical Indian Ocean (10°S - 10°N, 50°E - 70°E) and its eastern counterpart (10°S - 0°S, 90°E - 110°E).

In order to have a spatial description of the evolution of 2016 negative IOD event, monthly SST and winds anomalies are presented in Figure 2. The tropical Indian Ocean usually experiences basin-wide warming following an El Niño event as shown by positive SST anomalies during May 2016 just after the 2015/16 El Niño was terminated (Figure 2a) [8]. Strong westerly wind anomalies were observed, which were associated with the monsoon break [9]. The oceanic response to these westerly wind anomalies is downwelling Kelvin waves propagating eastward across the equatorial Indian Ocean and strong eastward surface currents so-called the Wyrtki jets (*not shown*) [10].

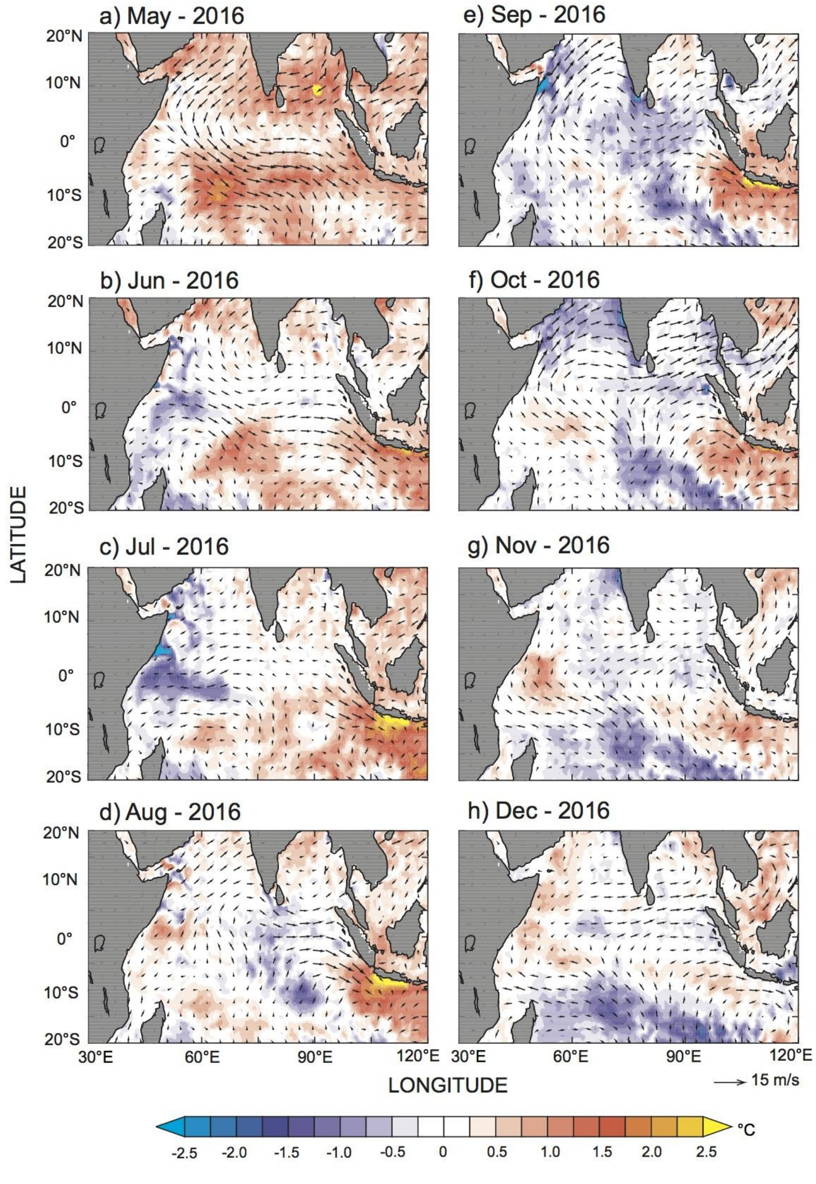

Figure 2. Monthly anomalies of sea surface temperature (*shaded,* °C) and low-level winds (*vector,* m/s) during May – December 2016.

In June, the winds over the equator remained eastward, while along the southern coast of Sumatra and Java strong northwesterly winds were observed (Figure 2b). These northwesterly winds induced downwelling along the coast that warmed the SST and deepened the thermocline. In July, the westerly winds along the equator were significantly weakened while along the coast remained strong (Figure 2c). By August, the westerly winds along the equator and northeasterly winds along the coast were strengthened (Figure 2d). The SST in the eastern tropical Indian Ocean off south Java rose to nearly

+2.5°C, while that in the central Indian Ocean fall to nearly –1°C. The negative IOD event came to its peak in September as the SST anomalies show a dipole pattern with positive (negative) anomalies occupied the eastern (central) tropical Indian Ocean (Figure 2e). The winds anomalies were weakened in the following months and the dipole pattern was completely diminished in December 2016 (Figures 2f-h).

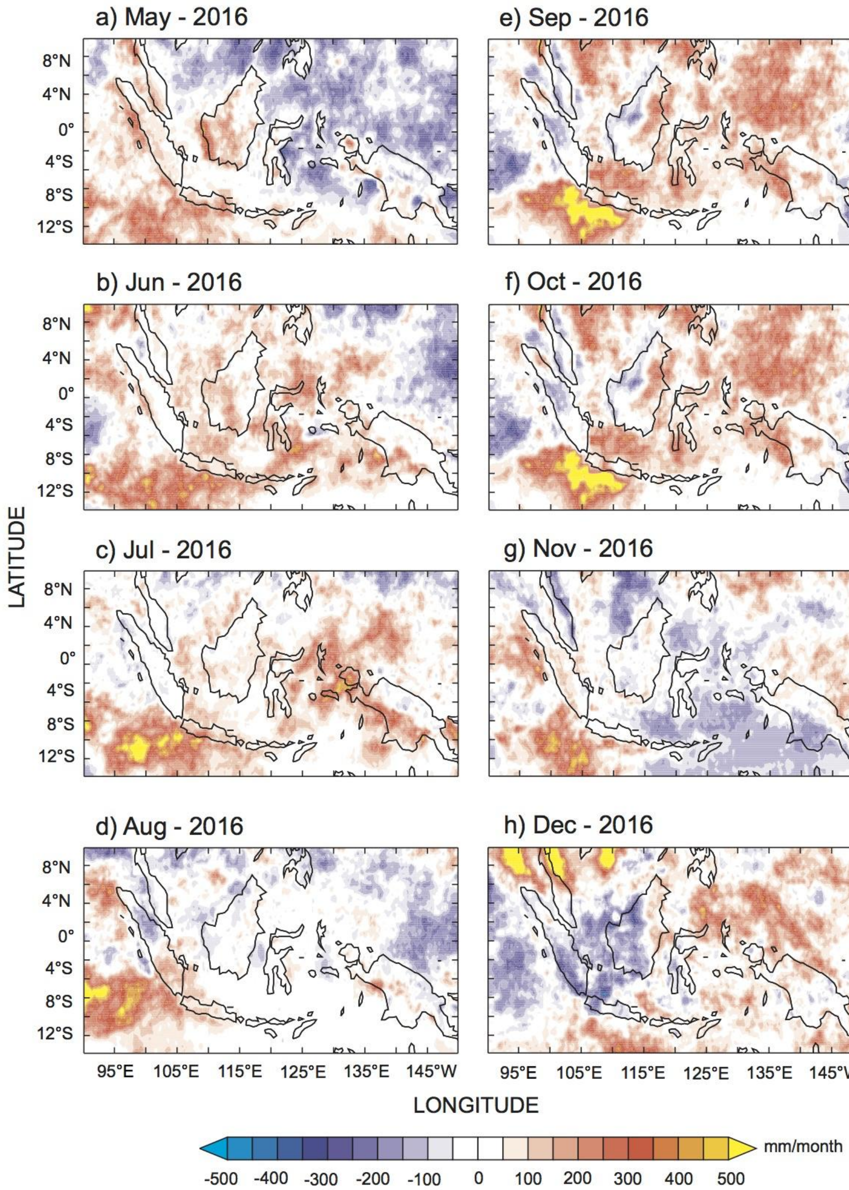

Figure 3. Same as in Figure 2 except for monthly precipitation during May – December 2016 (mm/month).

The 2016 negative IOD event significantly impact the precipitation over the maritime continent. As discussed in previous studies [1-3], the evolution of IOD event is correlated with the convective activities. Warm SST anomalies were associated with enhanced convective activities leading to increased precipitation. During 2016, most part of the Indonesian regions experienced surplus precipitation (Figure 3). Interestingly, it is also shown that anomalously high precipitations were observed over high SST anomalies indicating a strong coupled air-sea interaction in that area (Figures

3d-f). It should be noted that in early spring 2016, the eastern Indonesian regions were still under the influence of 2015/15 El Niño event (figure 3a) [11]. In addition, the local SST could also influence the convective activities over the Indonesian region that could enhanced/decreased the precipitation [12].

4. Conclusion

During 2016, strong negative IOD event took place in the tropical Indian Ocean. The event has shown two peaks: in July and September, in which the second peak was stronger than the first peak. Evolution of the event has started in May, reached its first peak in July, weaken in August, but rebounded and came to its second peak in September. The event was terminated in November, though the SST dipole pattern was completely diminished in December. During the peak of the event in September, the SST anomaly in the eastern (western) pole of the IOD rose (fall) to nearly +2.5°C (-1°C). As a consequence, strong convective activities were observed over the maritime continent causing heavy rainfall during the peak of the event. Note that the eastern Indonesian regions were still under influenced of Pacific mode in early 2016. Moreover, the local SST could also influence the convective activities over the maritime continent.

Acknowledgment

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References

[1] Saji N H and Yamagata T 2003*Clim. Res.* **25** 151
[2] Webster P J, Moore A M, Loschnigg J P and Leben R R 1999 *Nature* **401** 356
[3] Murtugudde, R, McCreary J P and Busalacchi A J 2000 *J. Geophys. Res*. **105** 3295
[4] Iskandar I, Mardiansyah W and Setiabudidaya D 2014 *Makara J. Sci.* **18** 106
[5] Endo S and Tozuka T 2015 *Clim. Dyn.* **46** 3371
[6] Yamagata T, Behera S K, Luo J, Masson S, Jury M R and Rao S A 2004 Coupled oceanatmosphere variability in the tropical Indian Ocean *Earth's Climate: The ocean-atmosphere interaction* eds C. Wang, S.P. Xie and J.A. Carton (Washington D C: American Geophysical Union) p 189
[7] Senan R, Sengupta D and Goswami B N 2003 *Geophys. Res. Lett*. **30** 1750,
[8] Yu L and Rienecker M M 2000 *J. Geophy. Res*. **105** 16923
[9] Wyrtki K 1961 *NAGA Report: Physical oceanography of the Southeast Asian waters* (California The University of California)
[10] Wyrtki K 1973 *Science* **181** 262
[11] Iskandar I, Utari P A, Lestari D O, Sari Q W, Setiabudidaya D, Khakim M Y N, Yustian I and Dahlan Z 2017 *Proc. Int. Symposium on earth hazard and disaster mitigation 2016: The 6th annual symposium on earthquake and related geohazard research for disaster risk reduction* (Bandung) vol 1857 (New York: AIP Publishing) 080001
[12] Iskandar I, Mardiansyah W, Setiabudidaya D, Poerwono P, Yusyian I and Dahlan Z 2017 *J. Phys.: Conf. Ser.* **187** 012073