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Severe Drought Event in Indonesia Following 2015/16 El Niño/positive Indian Dipole Events

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Abstract. During boreal fall and winter 2015/16, Indonesia experienced catastrophic drought event causing many environmental problems. This study explored dynamical evolution of drought event in Indonesia associated with those two climate modes. Based on the Niño3.4 index, the evolution of the El Niño has started in April 2015, reached its peak in January 2016 and terminated in April 2016. Meanwhile, the Dipole Mode Index (DMI) revealed that the evolution of positive Indian Ocean Dipole has started in August, reached its peak in September and terminated in November 2015. It is shown that during those two events, Indonesia experienced severe drought in which the precipitation was extremely decreased. During the peak drought condition co-occurring with the dry season, the anomalous of precipitation reached −450 mm/month in September 2015. The peak of the drought was associated with the El Niño and positive Indian Ocean Dipole sea surface temperature anomaly (SSTA) patterns, in which negative SSTA covered the eastern tropical Indian Ocean and the western Pacific Ocean including Indonesia seas. Meanwhile, positive SSTA observed in the western tropical Indian Ocean and Eastern Pacific Ocean.

1. Introduction

In 2015/16, Indonesia experienced catastrophic drought. It was expected that was influenced by coupled ocean-atmosphere phenomenon in the tropical Pacific Ocean and the tropical Indian Ocean. Previous studies have found that during dry season precipitation in Indonesia region has high correlation with the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) events [1–3]. The ENSO is one major mode of climate variability that takes place in the tropical Pacific Ocean [4]. Meanwhile, the IOD is a coupled ocean-atmosphere phenomenon in the tropical Indian Ocean that has strong impact on the Indian Ocean rim countries [5,6]. A positive IOD is characterized by low sea surface temperature (SST) anomaly in the southeastern tropical Indian Ocean (off west Sumatra and south Java) and high SST anomaly in the western/central tropical Indian Ocean, associated with southeasterly (easterly) wind anomalies along the coast of Sumatra and Java (equator). As a consequence of change in the ocean-atmosphere circulation is an excess precipitation over the east Africa, India, and southeast Asia, and deficit precipitation over the Indonesian region and Australia [7–9]. The purpose of this study is to analyze the dynamical evolution of drought event in the Indonesian region during 2015 associated with those two climate modes.

2. Data and Method

This study used three datasets, namely precipitation, SST, and low-level wind (850 mb). The precipitation data were obtained from the Tropical Rainfall Measuring Mission (TRMM) with horizontal resolution of 0.25° × 0.25° (https://mirador.gsfc.nasa.gov/). The data are available from January 1998 until present. The SST data were from the National Oceanic and Atmospheric Administration (NOAA)'s Optimum Interpolation Sea Surface Temperature (OISST) Version 2 (https://www.esrl.noaa.gov/psd/). The data are available from September 1981 until present, having horizontal resolution of 0.25° × 0.25°. Meanwhile, the low-level wind data were from the ERA-Interim of the European Centre for Medium-Range Weather Forecasts (ECMWF) with a constant horizontal resolution of 0.5° for period of January 1979 until present (http://apps.ecmwf.int/datasets/data/).

Monthly value of the Nino3.4 index and the Dipole Mode Index (DMI) were used to represent the evolution of two types of climate mode in the Indo-Pacific region. The Nino3.4 index is defined as an average SST anomaly in the equatorial Pacific Ocean bounded by 5°N to 5°S and 170°W to 120°W [4]. Meanwhile, the DMI which is defined as a difference in SST anomaly between western the tropical Indian Ocean region (10°S to 10°N and 50°E to 70°E) and its eastern region (0°S to 10°S and 90°E to 110°E) [5]. Note that, the anomalies of all variables are defined as the deviation from the monthly climatology over a period of 2001-2015.

3. Result and Discussion

3.1. Evolution of ENSO and IOD events 2015/16

We first calculated the SST anomaly based on Niño3.4 index and DMI region to identify the evolution of ENSO and IOD events. It is shown that during 2015 to 2016 the positive IOD event was co-occurred with the El Niño event. The evolution of El Niño event started from April 2015. It became stronger and reached the peak in January 2016 with a maximum Niño3.4 index reaching >2.5 °C. The event decayed in April 2016 (Figure 1a). The DMI revealed that the evolution of positive IOD has started in June/July, reached its peak in September and terminated in November 2015 (Figure 1b).

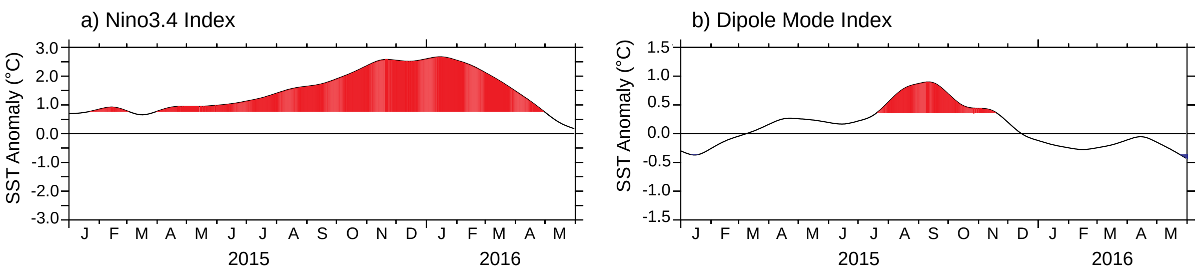

Figure 1. Time series of (a) Niño3.4 Index and (b) DMI during January 2015 to May 2016. Positive anomaly (shading) shows El Niño and positive IOD events.

3.2. Spatial Patterns of Precipitation during El Niño/Positive IOD 2015/16

Precipitation over the Indonesian region is generally decreased during 2015/16 (Figure 2). This condition associated with the El Niño and positive IOD events are concurrently occurred [10,11]. The significant negative precipitation anomalies first appeared over Sumatra, Kalimantan, and Papua Islands in July 2015. This drought condition continued and reached its peak in September-October

2015. During the peak of positive IOD event, almost all of area in the Indonesia experienced severe drought. The precipitation in the Indonesian region is decreased up to −450 mm/month (Figure 2e).

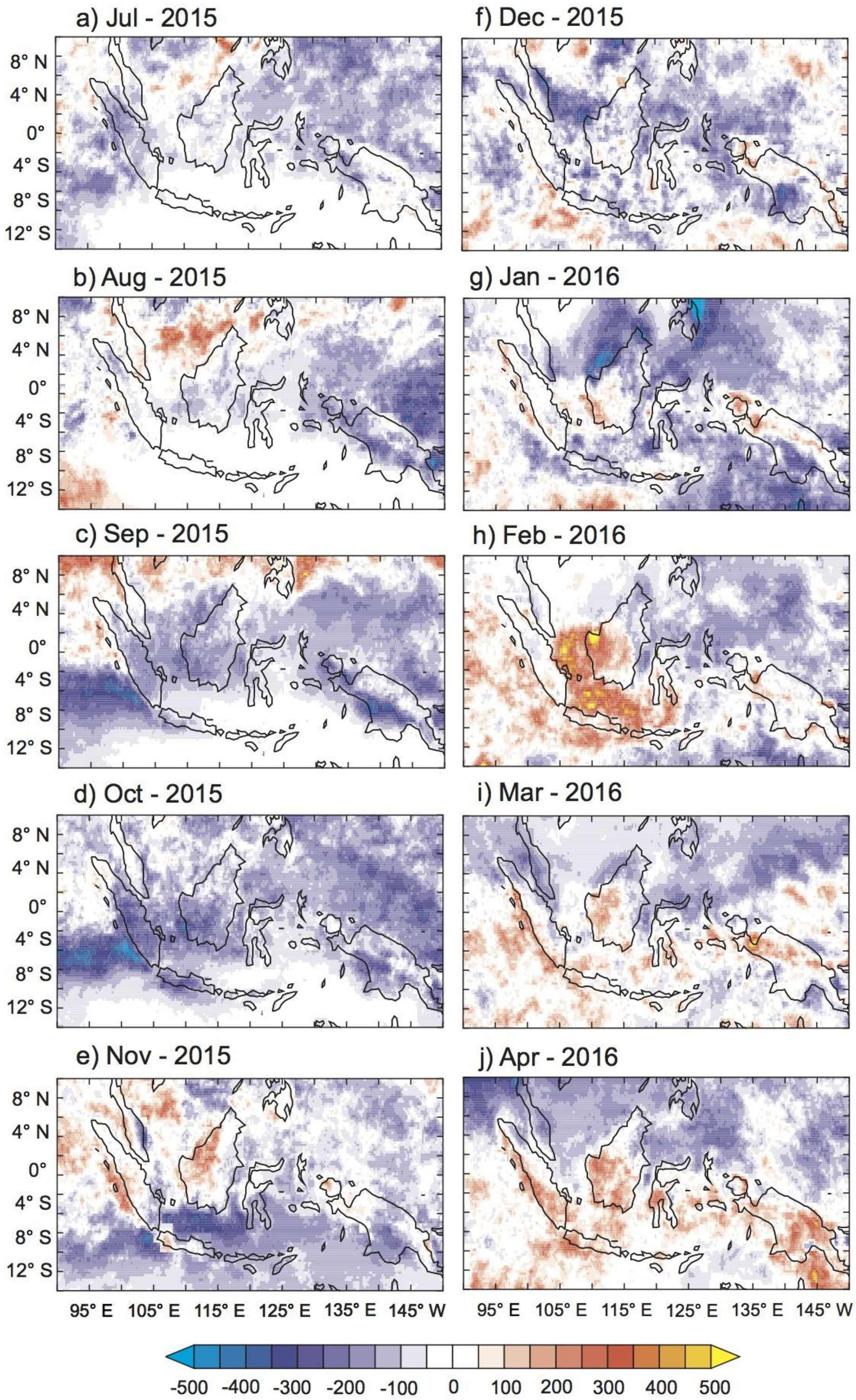

Figure 2. Spatial patterns of anomalous precipitation (mm/month) over the Indonesian region. Figures 2a to 2j indicate anomalies during July 2015 to April 2016.

In November 2015, while the positive IOD has decayed, the positive precipitation anomalies were observed in northern part of Sumatra, northeastern part of Kalimantan, west Java, and northern Papua Islands. However, the drought condition in southeastern Papua Island was persisting until the peak of El Niño event in January 2016. It is interesting to note that the intensity of negative precipitation anomalies in this area was higher during the peak of positive IOD and approach the peak of El Niño events (September and December 2015).

3.3. Ocean-Atmosphere Interaction in the Indo-Pacific Region

In order to explain the severe drought condition in Indonesian region during 2015/16, we evaluated the ocean-atmosphere interaction in the Indo-Pacific region. Figure 3 shows the spatial patterns of SST and horizontal wind anomalies in the Indo-Pacific region. The negative precipitation anomalies over the Indonesian region associated with negative SST anomalies in the Indonesian seas, eastern tropical Indian Ocean and western tropical Pacific Ocean.

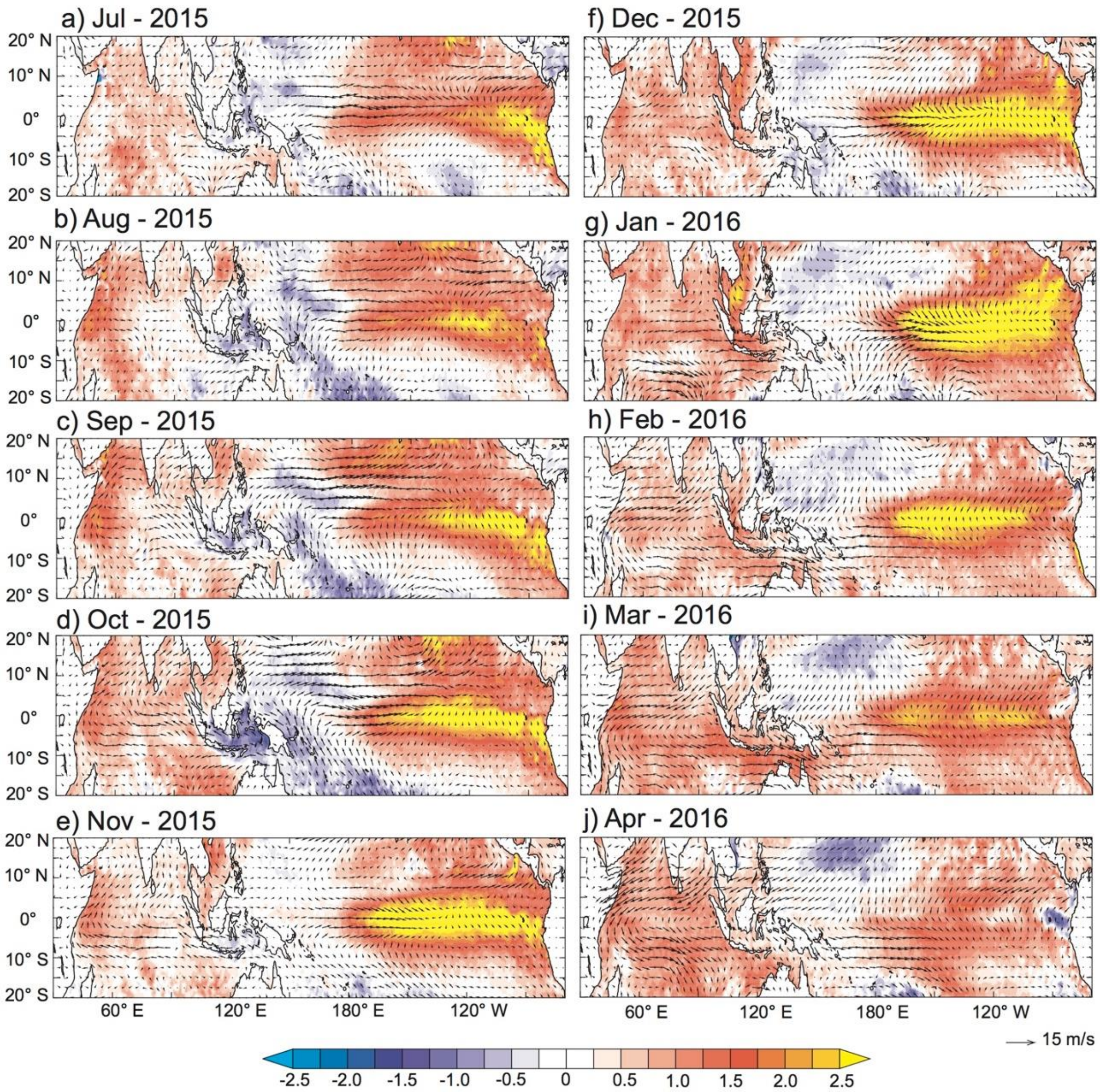

Figure 3. Spatial patterns of the low-level wind anomalies (m/s; *vector*) superimposed on the SST anomalies (°C; *shading*) over the Indo-Pacific region. Figures 3a to 3j indicate anomalies during July 2015 to April 2016.

During the El Niño and positive IOD events, the Indonesian seas experienced cooling phase. The most striking feature was observed during the maturing phase of the positive IOD. Meanwhile, the warmer SST anomalies was observed in the western tropical Indian Ocean and in the eastern to central tropical Pacific Ocean. The cooling effect of SST anomalies in Indonesian Seas and the warming effect of SST anomalies in the western tropical Indian Ocean and the eastern to central tropical Pacific Ocean have caused divergence wind originated from the Indonesia area. Therefore, the strong westerly wind anomalies were observed in the western tropical Pacific Ocean and strong southeasterly wind anomalies were observed in the eastern tropical Indian Ocean. This divergence circulation causes a descending atmospheric motion over the Indonesian region leading to a suppressed convection. As the positive IOD event terminated, the western Indonesian seas started to warm (Figure 3d).

4. Conclusion

The severe drought condition in the Indonesian region during 2015/16 is caused by the El Niño and positive IOD events that simultaneously occurred. The precipitation anomalies in the Indonesian region decreased drastically in dry season and continued until wet season. This condition is associated with SST and horizontal wind anomalies in the tropical Pacific Ocean and the tropical Indian Ocean. During the dry season, the SST in the Indonesian seas and its surrounding water was anomalously negative. Meanwhile, positive SST anomalies have covered the western (eastern) tropical Indian (Pacific) Ocean. This caused a divergence winds over the Indonesian region, leading to a descending atmospheric motion and a suppressed convection.

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