What did drive extreme drought event in Indonesia during boreal summer/fall 2014?

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Abstract. There are at least five climate-drivers influencing temporal variability of the Indonesian precipitation system, namely the diurnal cycle, the Madden-Julian Oscillation (MJO), the monsoon system, the Indian Ocean Dipole (IOD), and the El Niño–Southern Oscillation (ENSO). In particular, the IOD and the ENSO events will cause interannual variations in the Indonesian precipitation. During the positive IOD or the El Niño events, Indonesia experiences a severe drought event. On the other hand, during the negative IOD or the La Niña event, Indonesian will have excess precipitation. During 2014, most part of the Indonesian regions experience deficit precipitation leading to a severe drought event. This study is designed to evaluate the dynamics underlying the extreme climate event in 2014. Several climate indices, including the sea surface temperature (SST), outgoing long-wave radiation, and surface winds were evaluated to explain why Indonesia experience severe drought in 2014. The analysis indicates that the tropical Indo-Pacific climate modes (e.g. IOD and ENSO events) were in neutral conditions. It is, then, suggested that negative sea surface temperature anomalies in the Indonesian region, in particular in the eastern part suppressed convective activities leading to deficit precipitation over the maritime continent.

1. Introduction

Indonesia, so-called as the maritime continent, is located in between two oceans (Pacific and Indian Oceans) and two continents (Asian and Australian continents). As a consequence, the Indonesian climate variability is influenced significantly by the air-sea interaction in the Indo-Pacific region. On hourly and day-to-day variations, the Indonesia region is under influence of diurnal cycle. The Madden-Julian Oscillation (MJO) causes intraseasonal variability over the Indonesia region during boreal winter [1, 2]. During the active phase of the MJO event, tropical convection is developed leading to positive precipitation anomaly. On the other hand, the passive phase of the MJO event is associated with suppressed convection activity that causes negative precipitation anomaly.

On seasonal time-scale, the monsoonal wind forces seasonal variability of the Indonesian climate [3]. During the southeast monsoon from May to September, the Indonesian region will experience a dry season, while the northwest monsoon in November – February is associated with a wet season in Indonesia.
The Indonesian region is also under influence of the El Niño-Southern Oscillation (ENSO) from the Pacific Ocean as well as the Indian Ocean Dipole (IOD) from the Indian Ocean [4]. During the positive IOD and/or the El Niño events, most part of the Indonesia is experiencing a severe drought event. On the other hand, during the negative IOD and/or the La Niña events, the Indonesian region will have an excess precipitation.

A common way to highlight the IOD and ENSO events is by examining the pattern of sea surface temperature anomaly (SSTA) in the IOD and ENSO region. The IOD event is characterized by the Dipole Mode Index (DMI) indicating the SSTA different 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) [5]. On the other hand, the ENSO event can be evaluated by several indices in the Niño region. However, previous study has suggested that Niño3.4 is most suitable for evaluating the ENSO impact on the Indonesian precipitation [6].

During boreal summer/fall 2014, most part of the Indonesian regions has experienced deficit precipitation leading to a severe drought event. This study is designed to evaluate the dynamics underlying the extreme climate event in 2014, focusing on the anomalously very dry condition during boreal summer/fall 2014. In order to evaluate possible driver of the event, both the IOD and ENSO events are examined. In addition, the local SSTA variability within the Indonesian region is also examined.

2. Data and Methods

2.1. Data
Monthly precipitation data from the Global Precipitation Climatology Centre (GPCC) with a horizontal resolution of 0.5° x 0.5° and covers a period of January 1990 – December 2014 are used in this study [7]. Monthly wind and outgoing longwave radiation (OLR) data are obtained from the National Center for Atmospheric Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) Reanalysis are used in this study [8]. The data are available from January 1990 to December 2014 with a horizontal resolution of 2.5° in both longitude and latitude. Monthly extended reconstructed sea surface temperature (ERSST) Version 3 from National Oceanographic and Atmospheric Administration (NOAA) has also been used in this study. The data for a period of January 1990 to December 2014 were used in the present study.

2.2. Method
Monthly values of Dipole Mode Index (DMI) and Niño3.4 Index were used to represent climate variability in the Indo-Pacific region. The DMI is defined as the difference in SST anomaly between western tropical Indian Ocean region (50°E–70°E, 10°S–10°N) and its eastern region (90°E–110°E, 10°S–Equator) [5]. Meanwhile, the Niño3.4 Index is defined as an averaged SST anomaly in the region bounded by 5°N to 5°S, from 170°W to 120°W [9]. Note that the anomaly fields were calculated as a deviation from the monthly climatology of all fields for a period of January 1990 – December 2014.

3. Results
We first evaluate the convective activities during boreal summer/fall 2014 as an indicator for the precipitation. It is shown that the suppressed convective activities during boreal summer/fall 2014 were indicated by the positive OLR as shown in figure 1. Note that the negative OLR anomalies mean that the ocean gains heat leading to increase convective activity. On the other hand, the positive OLR anomalies indicate that the ocean loses heat from the surface heat flux, thus decrease convective activity. During boreal summer (JASO) 2014, it is clearly shown that over the western-central Indonesian region (e.g. Sumatra, Java, Kalimantan, Nusa Tenggara and Sulawesi) and eastern part of Papua, the OLR show positive anomalies. The positive anomalies leads to decrease convective activities.
As expected, the suppressed convective activity resulted in low precipitation (figure 2). The precipitation shows robust negative anomalies during boreal spring to boreal fall 2014. Deficit precipitation anomalies are seen over most of the Indonesian region, except over the northern part of Sumatra and over the eastern part of Papua. It is clearly seen that the precipitation patterns are associated with positive OLR anomalies as shown in figure 1.

Figure 1. Map of OLR anomalies averaged during boreal summer/fall (July – October) 2014 (W/m²).

Figure 2. As in figure 1 except for the precipitation anomalies (mm/day).
In order to examine the dynamics underlying the extreme drought event during boreal summer/fall 2014, we first analyze the possible evolution IOD event by evaluating the DMI (figure 3). It was shown that the DMI has negative value during July – September 2014. The negative DMI was first observed in early June 2014. After a short warming from mid-June to early July, the index rapidly decreased until mid-August 2014. The DMI rapidly increased from early September 2014, although it remained negative until late October. A positive value was first observed in early November 2014. Note that the negative DMI indicates negative IOD event indicating positive SSTA in the eastern tropical Indian Ocean [5]. It is well known that convective activities often observed over warm SST. Therefore, the negative DMI is associated with surplus precipitation over the eastern tropical Indian Ocean and the maritime continent [5]. Since the DMI has negative value during boreal summer indicative of the negative IOD event, we may suggest that the extreme drought event during boreal summer 2014 was not correlated with the IOD event.

The evolution of the ENSO event was evaluated from the time series of the Niño3.4 index (figure 4). It was shown that positive index was first observed in March 2014 and gradually increased until May 2014. The index was suddenly decreased in late June and reached a negative value in late July/early August 2014. The index again increased in September and remained positive until December 2014. Although the index had a positive value during boreal summer to winter (July – December) 2014, the maximum value of the index was still below one standard deviation. This indicated that the ENSO only has a weak signal/normal condition during boreal summer to winter 2014. Thus we may conclude that extreme drought event in boreal summer 2014 was not correlated with the ENSO signal.
We then turn into the local SST variation associated with the monsoonal winds (figure 5). It was shown that negative SST anomaly was observed in the Indonesian seas region in July – August 2014. Negative SST anomaly was also observed in the eastern tropical Indian Ocean off south Java and east Papua as well as in the South China Sea during July 2014 (figure 5a). In August, negative SST anomaly remained in the central and eastern Indonesian seas, off south Java and off east Papua, while warming SST was observed in the South China Sea (figure 5b). In September, the SST fields have shown positive anomalies over most of the Indonesian seas, except in the Maluku Sea and off west Sumatra (figure 5c). Positive anomalies covered most of the Indonesian region in October 2014 (figure 5d). These negative SST anomalies might suppress the convective activities over the Indonesian region and thus reduced the precipitation.

![Maps of SST anomaly](image)

**Figure 5.** Maps of the sea surface temperature anomaly during boreal summer/fall (JASO) 2014.

4. Conclusion
During 2014, most part of the Indonesian regions has experienced deficit precipitation leading to a severe drought event. This study was designed to evaluate the dynamics underlying the extreme drought event occurring in boreal summer/fall 2014. The results have shown that the IOD event had a weak signal during boreal summer/fall 2014. In addition, the El Niño event has indicated a weak evolution from July – October 2014, suggesting that the El Niño might not cause a severe drought event in 2014 over the Indonesian region.

Meanwhile, examination on the sea surface temperature (SST) within the Indonesian seas region indicates that the SST was significantly below the normal condition. Thus it might suggest that this low SST, associated with the southeast monsoon season, suppressed the convective activities over the Indonesian region indicated by positive OLR anomalies. This suppressed convective activities resulted in negative precipitation anomalies leading to a severe drought in Indonesia during boreal summer/fall 2014.

Acknowledgment
This study is supported by the Ministry of Research, Technology and Higher Education through a Competency Research Grant (HIKOM) 2016.
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