Impacts of El Nino and IOD on the Indonesian Climate

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1. INTRODUCTION

The Indonesian Maritime Continent (IMC) surrounding warm pool is known as the area having most active convection in the world. Indonesia is as large as the USA, consists of more than 17,000 islands, is located between the Pacific and Indian oceans and between the Asian and Australian continents. The influence of large-scale climate phenomena varies across the region due to island topography and/or ocean–atmosphere fluxes, which are imposed by sea-surface temperature (SST) variability.

The IMC is known for its characteristic abundant rainfall throughout the year, and plays the essential role as a center of atmospheric heat source of the earth climate system. Convective activity over Indonesia is a powerful atmospheric wave source and heat engine affecting the upper atmosphere and global atmospheric circulation. It is one of the three equatorial heat sources that are interpreted as the driving force for the global circulation. However, the dynamical coupling processes of equatorial atmosphere to marginal seas around Indonesia are not clear due to the scarcity of observational data in that region. Atmosphere-ocean interactions near the IMC also contribute to the inter-annual global climate variations such as the El Niño-Southern Oscillation (ENSO) and the Indian Ocean dipole (IOD) mode. Moreover, sea-land contrasts enforce local diurnal variations in wind, clouds and rainfall, which are quite dominant in the IMC and might contribute to intra-seasonal oscillations and interannual variations.

Spatial variation of rainfall over Indonesia is divided into three patterns (Figure 1). The division of analyzed areas are monsoon pattern (5° – 11° S, 101° – 117° E), equatorial pattern (5° N – 3° S, 91° – 99° E) + (5° N – 3° S, 109° – 117° E), and local pattern (1° – 7° S, 121° – 133° E).

Figure 1. Rainfall patterns in Indonesia. Yellow is for monsoon pattern, green is for equatorial pattern and red is for local pattern (sources: Meteorology Agency (BMG), Indonesia).
The distribution of seasonal rainfall time series appears like “v” or “u” for the monsoon pattern. It is observed that minimum rainfall occurs in June or July and the maximum occurs in December or January (Bannu, et. al, 2003). This pattern covers most parts of Indonesia; Lampung, Jakarta, Ujung Pandang and Kupang. Equatorial rainfall pattern is characterized by double rainfall peaks in annual cycle. Local rainfall pattern has unique characteristic and usually converse to monsoon rainfall.

ENS0 is a coupled ocean-atmosphere phenomenon of the tropical Pacific. In the normal condition, the tropical western Pacific is warmer than the eastern Pacific. As a result equatorial winds are westward helping the convection in the western Pacific and subsidence over eastern Pacific. The circulation cell in the vertical is called as the Walker circulation, which completes the ascending motion in the west and descending motion in the east with an eastward motion in the upper troposphere (Fig. 2, upper panel). A small change in the normal SST pattern in the western Pacific causes a change in the seasonal easterly surface winds along the equator. The change in the wind usually seen as westerly anomalies strengthens the growth of SST anomaly and the SST-wind coupled anomalies propagate eastward to develop El Nino condition. During the mature phase of El Nino, the anomalous Walker circulation appears reverse of the normal condition; the convection in the west is suppressed and the convection in the eastern Pacific is strengthened (Fig. 2, lower panel). Since the convection is suppressed in the western Pacific, El Nino causes drier conditions over Indonesia.
The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere climate mode in the tropical Indian Ocean. During a positive IOD event (Fig. 3), SST is anomalously warm in western Indian Ocean while it is colder than normal in the east (Saji et al. 1999; Yamagata et al. 2004). The changes in SST during IOD events are found to be associated with changes in the surface wind field of the central equatorial Indian Ocean. In fact, the winds reverse from the usual westerly to easterly direction during positive IOD events. Furthermore, the atmospheric convection that is normally situated over the eastern Indian Ocean warm pool shifts to the west. This configuration results in heavy rain in eastern Africa and leaves the Indonesian region with little rain (e.g. Behera et al. 2005, 2007), resulting in droughts and forest fires. Fossil corals from off Sumatra recorded IOD events for several times in the Holocene. Associated with these changes in wind and SST, and similar to ENSO, the state of the IOD affects convection over Indonesia and thus regional precipitation.

**Figure 3.** Schematic of positive (left) and negative (right) IOD phenomena obtained from JAMSTEC’s IOD website; http://www.jamstec.go.jp/frsgc/research/d1/iod/. SST anomalies are shaded (red color is for warm anomalies and blue is for cold). White patches indicate increased convective activities and arrows indicate anomalous wind directions during IOD events.

2. RESULTS

ENSO and IOD are two dominant modes of climate variations in the tropical Pacific and Indian Oceans. Both modes are shown to influence the climate conditions of several parts of the world. Being placed in between those to basins, the Indonesian climate is expected to be influenced by both phenomena. In this project we try to investigate those influences arising from different phases of El Nino and IOD. During a positive IOD year, the eastern Indian Ocean is colder than normal while the western Indian Ocean is warmer than normal. Since the IOD index is defined as a difference between the western box and the eastern box, the index is positive during a positive IOD year. It is negative during negative IOD year.

For determining the El Nino/La Nina and positive/negative IOD years, we have downloaded Nino3 index and Indian Ocean dipole mode index from the NOAA and JAMSTEC websites. Both of ENSO (Nino 3.4) and dipole mode indices were overlaid to one graph shown in Figure 4. From the figure, we find that El Nino and a positive IOD event occurred from May 1997 to April

![Figure 4 Dipole mode index showing three anomalous events of ENSO and IOD (1997-1998, 2006-2007, 2007-2008)](image)

2.1 Seasonal precipitation of Indonesia during El Nino and Positive IOD (June 1997-February 1998)

Figure 5 showed that during strong El Nino and positive IOD co-occurrence, all of Indonesian region became extremely dry with anomaly of precipitation reaching values of -300 mm/day during June-August 1997. The anomalies reach values of order -500 mm/day in September-November 1997, when both IOD and El Nino were on their peak phases. The negative anomalies were between -200 and -600 mm/day during December 1997-February 1998. Due to this influence of IOD and ENSO the dry season of Indonesia became longer than normal dry season which usually lasts for three months during boreal summer (June-July-August). During El Nino year the Walker circulation in Pacific becomes weaker, which suppresses the atmospheric convection over the Maritime Continent. The convection is further suppressed by a positive IOD event. The eastern part of Indonesia suffers from droughts related to positive IOD whereas the western part of Indonesia (Kalimantan region) suffers from El Nino condition.
Figure 5. Anomaly of precipitation for a) June-August 1997, b) September-November 1997 and c) December 1997-February 1998

2.2 Precipitation of Indonesia during 2006 El Nino and positive IOD (June 2006-February 2007)

During 2006, an El Nino evolved together with a positive IOD. However, the El Nino of 2006 was not as strong as that of the 1997 (Behera 2009 – personal communication). We find that the positive IOD of 2006 developed late in that year. Therefore, the convection in the Maritime Continent was not as much suppressed during June-August of 2006 (Figure 6) compared to June-August of 1997.
Nevertheless, we find that almost all part of eastern Indonesia (Java, Sumatra, and Kalimantan) have negative anomaly of about -100 mm/day because of evolving positive IOD. From the analysis of surface winds, SST and sea surface height anomalies, we find that the downwelling Kelvin waves were weaker in 2006 summer because of weak westerly anomalies. The weaker anomalies are probably related to late evolution of a positive IOD event. During September-November of 2006, all of Indonesia became dry because of the mature phases of positive IOD then El Nino. However, during December 2006 - February 2007, negative IOD started to develop because of early demise of 2006 positive IOD. So, northeastern parts of northwestern Indonesia became wet.

2.3 Precipitation of Indonesia during La Nina and Positive IOD (June 2007-February 2008)

Figure 7 shows the precipitation of Indonesia region from June 2007 to February 2008. We know that there is unique case during 2007 when La Nina and positive IOD occurred together. Results (Figure 4) show that from June 2007 to February 2008, precipitation all over Indonesia became positive (except western region namely Java and Sumatra). It can be understood because western Indonesia is influenced by the Indian Ocean and eastern part is influenced by Pacific
Ocean owing to their close vicinities. We also notice that the suppressed convections/negative rainfall anomalies are confined to south of the equator during this event.

![Figure 7 Anomaly of precipitation June 2007-February 2008](image)

3. Conclusion

ENSO and IOD introduce varied impacts on the rainfall of Indonesia. This is demonstrated using three different cases, namely 1997, 2006, and 2007. In 1997 case, when a strong El Nino accompanied by a strong positive IOD, most parts of Indonesia have negative anomalies of precipitations during JJA (June-July-August), SON (September-October-November) and DJF (December-January-February). The precipitation anomalies were between -300 and -500 millimeter/day. In the case of 2006 when a weak El Nino accompanied by a weak positive IOD, precipitation anomalies of Indonesian regions have varied between -100 and -400 millimeter. The unique case occurred during 2007, when a weak positive IOD opposed the positive influence of a La Nina event. During June-July-August 2007, most of Indonesian regions have positive anomalies of precipitation which range from 100 to 300 millimeter/day, except in Sumatra Island where precipitation anomaly was -200 millimeter/day. The same condition occurred during September-October-November and December-January-February when only some parts of Sumatra, Java, Kalimantan, Sulawesi have negative anomalies of precipitation.
REFERENCES

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