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Influences of IOD and ENSO to Indonesian rainfall variability: role of atmosphere-ocean interaction in the Indo-Pacific sector

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Abstract

The relative influences of Indian Ocean dipole (IOD) and El Niño–Southern Oscillation (ENSO) on Indonesian rainfall are investigated for seasonal time scales. For the period 1960–2011, observation and reanalysis products during September to November (SON) are used to assess the impacts of ENSO and IOD in Indonesian region. Composite of SSTs and Indonesian rainfall anomalies shows detailed features in the different phases of ENSO and IOD. A distinct impact on rainfall anomalies is found during the years when an El Niño and a positive IOD event or a La Nina and a negative IOD event co-occur indicating the interplay of ENSO and IOD in generating rainfall anomalies in Indonesian region. The atmospheric circulation and sea surface temperatures associated with these responses are discussed. Using composite analysis of anomalies of rainfall, sea surface temperature (SSTs), and circulation at any atmospheric levels, it is shown that positive anomalies of rainfall over Indonesia start to be decreased when SSTs surrounding Indonesia are cool and The Walker Circulation is weakened, resulting in anomalous surface easterlies across Indonesia. The composite analysis of rainfall anomalies and the SSTs showed that rainfall variability in Indonesia is clearly influenced by IOD and ENSO phenomena. This study highlights the atmosphere–ocean interaction in Indo-Pacific sector which plays an important role on Indonesian rainfall variability.

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Keywords: Indonesian rainfall; ENSO; IOD; atmosphere–ocean interaction

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1. Introduction

IOD (Indian Ocean Dipole) is a pattern of internal variability with anomalously low sea surface temperatures of Sumatra and high sea surface temperatures in the western Indian Ocean, with accompanying wind and precipitation anomalies [1]. ENSO (El Niño-Southern Oscillation) is a naturally occurring phenomenon involving fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere. The vertical wind motions which resulted by IOD and ENSO could be generally seen in Walker Circulation. Walker Circulation comprises east-west atmospheric circulation cells along the equatorial belt responsing the differences in ocean temperature. Fluctuations of the Walker Circulation can lead to extreme weather conditions in different parts of the world [2].

IOD in the Indian Ocean and ENSO in the Pacific Ocean are the result of interactions between the oceans and atmosphere on each respective area. Both of the phenomena can be generally identified by sea surface temperature (SSTs) anomaly, and their impact can be seen directly on rainfall that occurs around the world. Ashok et al. [3] have pointed out that the effect of single and combination of ENSO and IOD during the Indian Summer Monsoon was clearly identified. In addition, they found that the IOD significantly influences the precipitation and reduces the impact of ENSO concurrently. Moreover, the research conducted by Meyers [4] found that the probability of below average of Australian precipitation at June to November period had different condition when the phenomena of IOD, ENSO, and the both combinations were occurred. The impact of decreasing rainfall is significant when El Niño and positive IOD were concurrently occurred. Meanwhile, the rainfall is significantly increased when La Nina and negative IOD were concurrently occurred.

Rainfall variability caused by IOD, ENSO, and the both combinations is unique in several regions. Indonesia is strongly influenced by the IOD and ENSO on rainfall in dry season (June-November) and weakly influenced in wet season (December-May) [5]. Based on that, it needs a study to estimate the impacts of ENSO and IOD on Indonesian rainfall and to observe the ocean-atmosphere's conditions over Indonesia to explain the Indonesian rainfall variability on IOD, ENSO, and the both combinations.

2. Methods

The region of this study is the equatorial region of the Indian Ocean to the Pacific Ocean (20ºN-20ºS and 30ºE-60ºW). Monthly data of observational and reanalysis products from NOAA for 1960 to 2011 period are used. They are Extended Reconstructed Sea Surface Temperature V3B (ERSST) data [6], zonal-meridional-vertical wind data (u; v; ω) from reanalysis NCEP / NCAR products [7], and rainfall data from the Climatic Research Unit (CRU) [8]. These data are used to observe the ocean-atmosphere and rainfall conditions. Procedures of analysis data are carried out in two stages. They are identification of IOD and ENSO (Niño 3.4) years and the composite analysis of data when the phenomenon of IOD, ENSO, and a combination of both are occurred.

The identification of IOD and ENSO years are done by analyzing the changes of sea surface temperatures (SSTs) in their respective territories. This aspect gives a representation in upwelling which represents oceanic process that links the slow physics of thermocline dynamics to SSTs [4].The strength of upwelling in western and eastern Indian Ocean is essential to control IOD cycle and also in the central and eastern Pacific is essential to control the process in the ENSO cycle. The areas for IOD phenomena are western in 50°E to 70°E and 10°S to 10°N and eastern in 90°E to 110°E and 10°S to 0°S [1], and one of the areas for ENSO which has higher response is Nino 3.4 in 50ºN to 50ºS and 120ºW to 170ºW) [9]. Sea surface temperature (SSTs) anomaly is obtained by calculating the climatology of 30-year based periods data (January 1961 - December 1990). Smoothing average on the ENSO phenomenon is done by five months running mean, while the IOD is done by three months running mean. Smoothing average is used to define the trend of the data, and the difference in months of running mean is caused by the longer occurrence of ENSO than IOD. The results are plotted and identified, where SSTs anomaly of Niño 3.4 and IOD is higher (lower) than 0.5ºC (-0.5ºC) for six months respectively resulting El Niño and positive IOD (La Nina and negative IOD).

Composite analysis is used for investigating ocean-atmosphere physics over Indo-Pacific when the phenomena of IOD, ENSO, and combinations of both are occurred. Data for composite analysis are from IOD and ENSO years resulted from the first stage. Data during September to November (SON), dry season, are used because they have the