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Evolution of 2015/2016 El Niño and Its Impact on Indonesia

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Abstract. A coupled ocean-atmosphere mode, namely the El Niño event, took place in the tropical Pacific during 2015 – 2016. The event developed in spring (April – May 2015), peaked in late fall to early winter (November – December 2015) and terminated in spring (April – May 2016). The intensity of the event, indicated by the Niño3.4 index, is classified as a strong event. Compare to the previous events, the 2015/2016 El Niño event is one of the strongest event during the last two decades. This study examined the evolution of the event and highlighted some of the important aspects of its influence on the Indonesian climate.

INTRODUCTION

Coupled ocean-atmosphere mode in the tropical Pacific Ocean, namely the El Niño/Southern Oscillation (ENSO), is the dominant interannual climate-phenomenon affecting global weather conditions worldwide. The swing between the warm El Niño and cold La Niña event has a great influences on the surrounding continent because of heat flux across atmosphere-ocean-continent boundaries [1]. In the eastern tropical Pacific Ocean, the El Niño could greatly impact Peruvian and Californian fishery activities. Meanwhile, in the western tropical Pacific, the event reduces precipitation leading to severe drought condition. The situation is opposite during the La Niña condition [2]

Previous study has classified that last 1997/98 El Niño event was regarded as the strongest El Niño event in the 20th century [3][2]. This strong El Niño event was followed by a prolonged La Niña event that developed in mid-1998 and lasted until early 2001. In 2015, an El Niño with strength similar to the 1997/98 event took place in the tropical Indian Ocean. The sea surface temperature (SST) pattern clearly shows a warming (cooling) trend in the eastern (western) tropical Pacific affecting the distribution of precipitation over the surrounding continents.

This study is designed to evaluate the evolution of 2015/16 El Niño event and examine its possible impact on the Indonesian climate. The rest of the paper is organized as follows. In the next section, the data and analysis methods are described. The oceanic-atmospheric evolution of the event as well as its impact on the precipitation over the maritime continent are investigated in Section 3. The last section is reserved for a summary and discussion.

DATA AND METHOD

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 with horizontal resolution of $1° \times 1°$ for a period of January 1990 to July 2016 were used in the present study. Monthly horizontal and vertical wind data are obtained from the National Center for Atmospheric Environmental Prediction–National Center for

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Atmospheric Research (NCEP–NCAR) Reanalysis are used in this study [4]. The data are from January 1990 to July 2016 with a horizontal resolution of 2.5° in both longitude and latitude were used in this study. Monthly precipitation data from the Tropical Rainfall Measurement Mission (TRMM) with a horizontal resolution of 0.25° × 0.25°and covers a period of January 1999 – February 2016 were used in this study. In addition, near-surface velocity data from the Ocean Surface Current Analysis-Real time (OSCAR) project representing oceanic flow at 15 m depth are used [5]. The data were available from 21 October 1992 to 1 July 2016 with horizontal resolution of 1° × 1° and temporal resolution of 5 days.

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 [6]. Note that the anomaly fields are calculated as a deviation from the monthly climatology of all fields for a period of January 1990 – December 2015, except for the precipitation which was calculated over a period of January 199 to December 2015.

RESULTS

Evolution of the 2015/16 El Niño Event

We begin the discussion by illustrating the evolution of Niño3.4 index as a prologue to describing the detailed evolution of the 2015/16 El Niño event. Figure 1 presents the time series of Niño3.4 index from January 2014 to July 2016. The Niño3.4 index started to develop in boreal spring (early April 2015). The intensity of the event was continuously strengthened as indicated by simultanuos increase of the Niño3.4 index. The 2015/16 El Niño reached its peak in boreal winter (November 2015). After reaching its peak, the intensity of the event was gradually decreasing from December. Rapid decrease of the Niño3.4 index was first observed in late-winter/early spring (February 2016). The Niño3.4 index changed sign by the end of spring (May 2016) as the El Niño event was completely terminated.

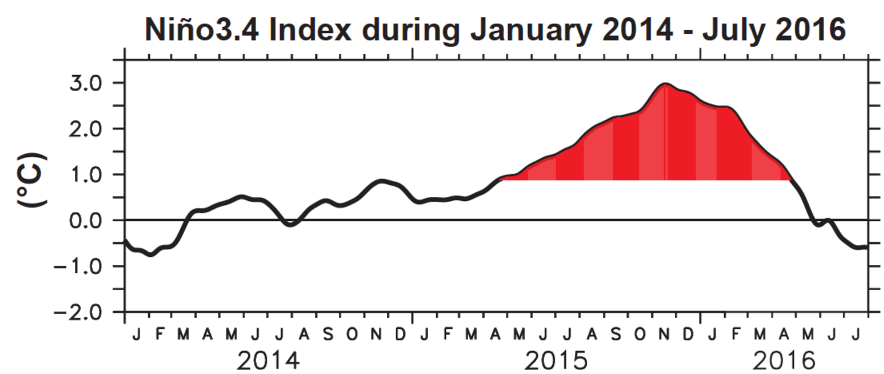

FIGURE 1. Time series of the Niño3.4 index from January 2014 to July 2016, which is is defined as an averaged SST anomaly in the region bounded by 5°N to 5°S, from 170°W to 120°W.

The evolution of the 2015/16 El Niño event is described in Figure 2. The initial development of the 2015/16 El Niño could be identified by the warming of SST near the date line in boreal spring 2015 (Figure 2c), coincident with an increase in westerly wind burst activity in the western Pacific (Figure 2a). Episodic westerly wind forcing was strengthened from boreal summer and steady westerly wind forcing was observed between 140°E - 120°W until late-winter (Figure 2a). These westerly wind forcing excited eastward zonal current anomalies associated with downwelling equatorial Kelvin waves that were observed in boreal summer to late boreal fall (Figure 2b). Episodic westerly wind forcing in the western Pacific continued to excite downwelling equatorial Kelvin waves that acumulate warm water in the eastern Pacific. These winds also excited westward propagating upwelling Rossby waves that elevated the thermocline west of the date line (Figures 2a-b). In particular, strong westerly winds in June – July 2015, September – October 2015 and December 2015 – January 2016 with extensive zonal fetch led to basin scale warming of over 1°C. Note that these strong wind anomalies forced downwelling equatorial Kelvin wave that left above normal SST anomalies at all longitudes east of the date line in early summer to late winter (Fig. 2c). At the same time, intensified surface winds in the western Pacific produced cooling of the warm pool west of the date line. These SST changes lead to a weakening of the largescale zonal SST gradient and to an eastward extension in deep atmospheric convection along the equator towards the date line.

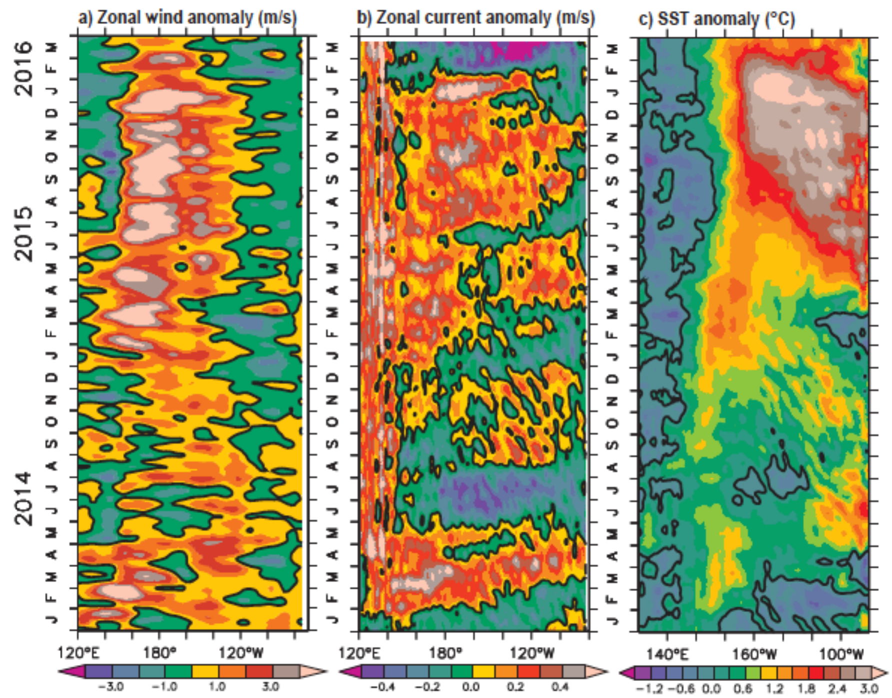

FIGURE 2. Time-longitude diagrams of (a) zonal wind anomalies, (b) near-surface zonal current anomalies, and (c) sea surface temperature anomalies averaged between 5°S and 5°N along the equatorial Pacific Ocean for a period of January 2014 – March 2016.

In order to have a better spatio-temporal description of the SST anomalies and wind circulations during the 2015/16 El Niño, seasonal average of SST and winds are presented in Figure 3. It is shown that as SST warmed in the central Pacific, anomalous deep convection and cloudiness associated with the ascending branch of the Walker Circulation shifted eastward and became anchored near the date line. The largest SST anomalies during the current event were concentrated in the eastern equatorial Pacific, with relatively weak and short-lived warming in the central Pacific. The pattern of anomalies resembled that observed during the 1997-98 El event. Typically, largest SST anomalies are concentrated further east along the equator and the coastal warmings are more pronounced. What accounts for the differences in SST anomaly patterns between El Niños is at present not well understood.

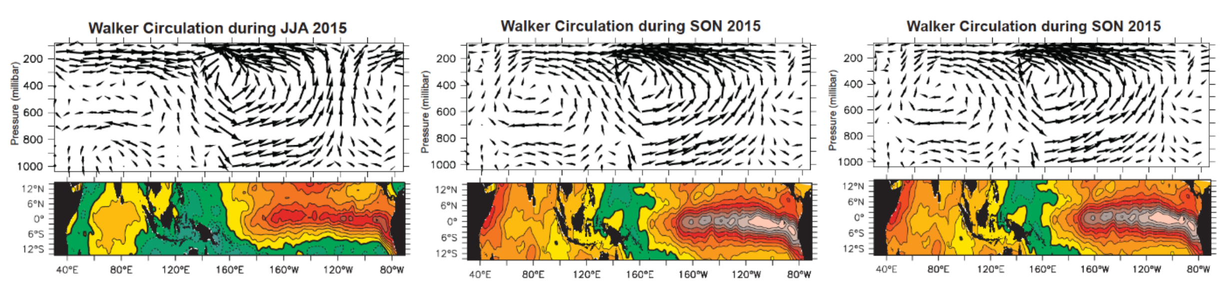

FIGURE 3. Zonal and vertical velocity anomalies along the equator averaged over the region of 5°S - 5°N (*upper panel*) and seasonal SST anomalies (*lower panel*) during JJA season (*left panel*), SON season (*central panel*) and DJF season (*right panel*).

Impact of the 2015/16 El Niño Event on the Indonesian Climate

In order to evaluate the impact of 2015/16 El Niño event on the Indonesian climate, spatial map of precipitation anomaly is shown in Figure 4. It is shown that negative anomalies were observed over the maritime continent since boreal spring 2015 coincident with the initial development of the El Niño event. Interestingly, the northen part of Sumatra experience weak influence of the El Niño event, which is indicated by positive precipitation anomaly during JJA and SON season (Figures 4b-c). We noted that Indonesia experienced the most dry season during SON season (Figure 4c). High precipitation was observed in the central Pacific colocated with the ascending Walker Circulation over the warm SST. In DJF season, the eastern Indonesian region still has negative precipitation, while the western region already receive precipitation (Figure 4d). This is associated with a basin-wide warming in the tropical Indian Ocean the El Niño event.

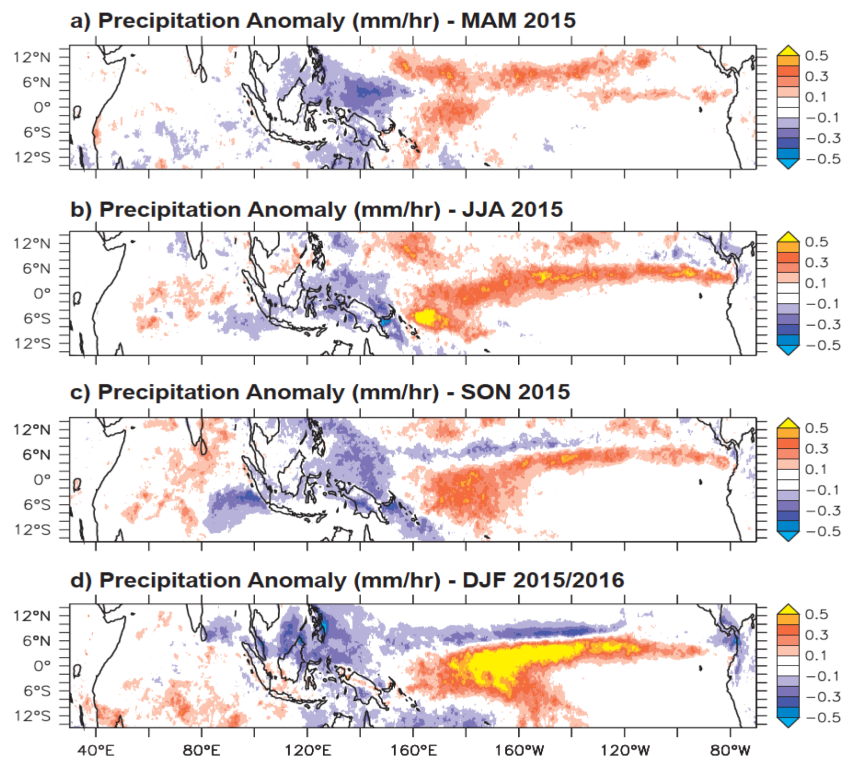

FIGURE 4. Distribution of precipitation anomaly (mm/hr) recorded by the satelite TRMM for a period of (a) MAM, (b) JJA, (c) SON and (d) DJF.

SUMMARY

Our analysis underscore the role played by both episodic atmospheric forcing (largely associated with the Maden-Julian Oscillation) and large-scale low frequency ocean-atmosphere dynamics in the genesis of 2015/16 El Niño events. It is shown that the onset of the 2015/16 El Niño was linked to westerly wind events, particularly the strong westerly wind forcing observed between 140°E - 120°W from boreal summer until late-winter. These strong westerly wind forcing excited eastward proagating dwonwelling equatorial Kelvin waves. These dwonwelling waves deepened (shoaling) thermocline in the east (west) leading to warm (cold) SST anomalies in the eastern (western) tropical Pacific. The change in SST pattern has shifted the convective anomalies. The ascending (descending) Walker circulation were observed over warm (cold) SST region leading to enhanced (suppressed) convective activities. In addition, this study has shown that the 2015/16 El Niño event cause extreme drought over almost entire Indonesian region. The peak drought event occurred in boreal fall (SON season) coincident with the peak of the 2015/16 El Niño event.

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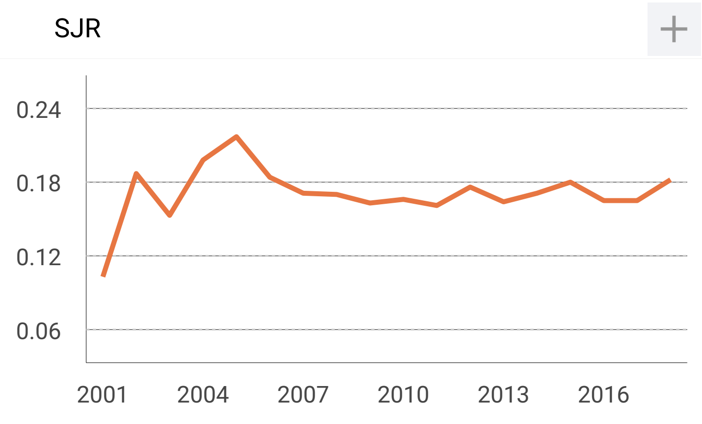

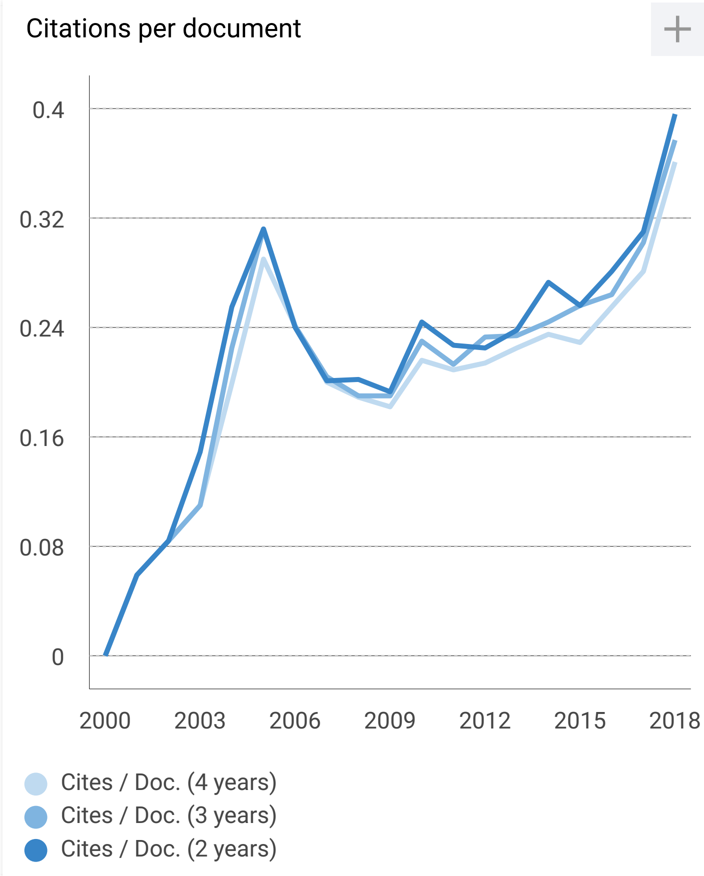

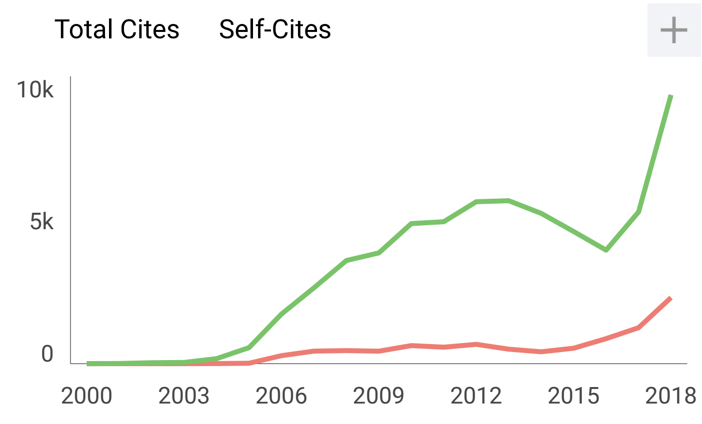

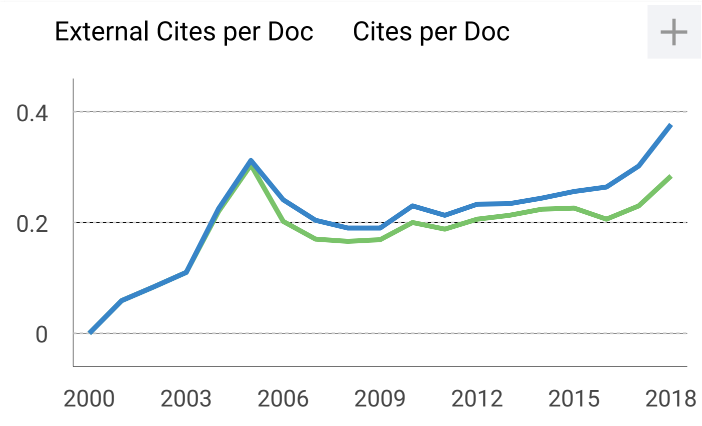

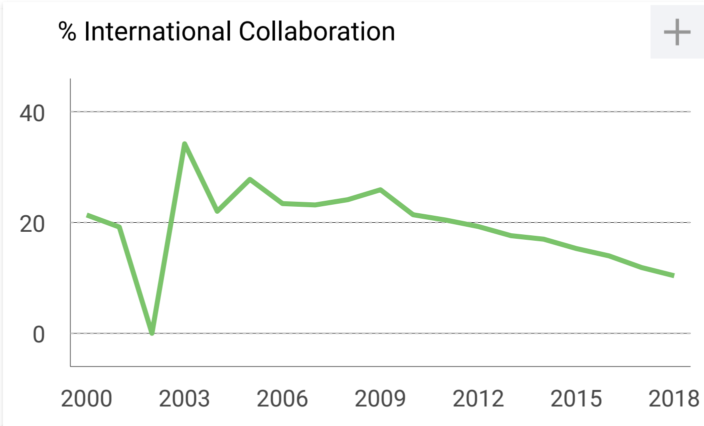

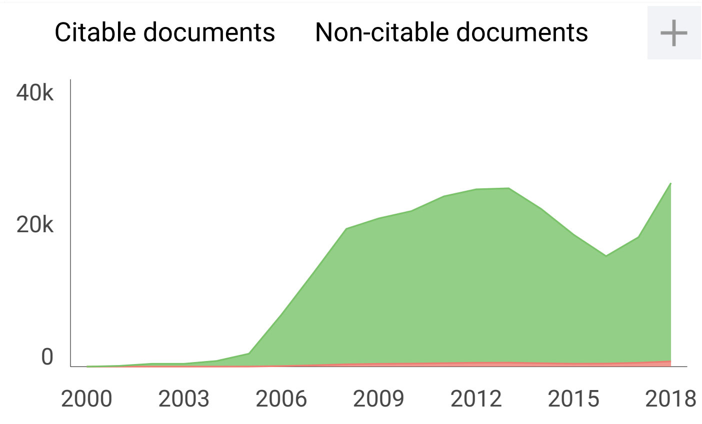

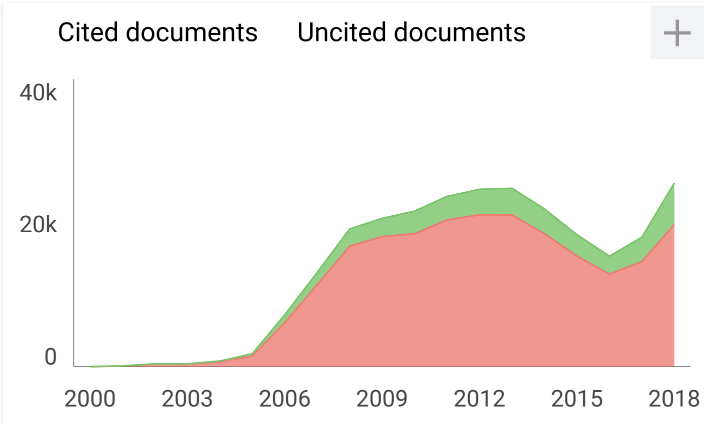

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