How strong was the 2015/2016 El Niño event?

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How strong was the 2015/2016 El Niño event?

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Abstract. On the interannual timescale, the Indonesian climate is strongly influenced by a coupled ocean-atmosphere modes in the tropical Pacific Ocean. During a warm phase (El Niño event), negative sea surface temperature anomalies (SSTA) in the western tropical Pacific lead to suppress convection activities causing reduce precipitation over the maritime continent. The situation is reverse during the cold season(La Niña event). In this study, the evolution of 2015/2016 El Niño event is evaluated based on the collected data by the Tropical Atmosphere Ocean/ Triangle Trans-Ocean Buoy Network (TAO/TRITON) buoys. The results show that the evolution of the event has started in boreal spring (April – May 2015). It came to thepeak in boreal fall/winter (October – December 2015). The event lasted until boreal spring before it terminated in April/May 2016. In addition, the intensity of the event is classified as a strong event, and it is one of the strongest El Niño events during the last three decades.

1. Introduction

On interannual time-scale, the Indonesian climate is strongly influenced by a coupled ocean-atmosphere mode in the tropical Indo-Pacific region. From the equatorial Pacific, a swing of warm and cold phase, refers to the El Niño and La Niña phase, significantly modulates the rainfall intensity and distribution over the Indonesian region [12,3,4]. The significant reduce of rainfall intensity was observed during the occurrence of the El Niño event, while excess rainfall was observed over most of the Indonesian region during the La Niña event [5].

Theintensity of theEl Niño and La Niña eventscan bemeasured using oceanicindex as well as atmospheric index. The oceanic index describes the sea surface temperature anomaly (SSTA) in the equatorial Pacific Ocean [5]. Positive SSTA exceeding one standard deviation and lasting for at least five consecutive months that indicates an El Niño event. The situation is reversed for the La Niña event [4,6]. Meanwhile, the atmospheric index is expressing the sea level pressure gradient between the eastern and western tropical Pacific[5]. This index is well known as the Southern Oscillation Index (SOI) that is calculated as a gradient in the sea level between Tahiti and Darwin, Australia. During El Niño (La Niña) event, the sea level pressure in the western (eastern) tropical Pacific is higher than that observed in the eastern (western) counter part.

During 2015/2016, the Niño3.4 index indicated a positive value and most part of the Indonesian regions have experienced deficit rainfall. Note that the Niño3.4 index is a sea surface temperature(SST) anomaly index representing the El Niño conditions. It is calculated as an average SST anomaly in the equatorial Pacific Ocean bounded by a box of 170°W - 120°W, 5°S - 5°N. This study is designed to describehow strong was the 2015/2016 El Niño eventcompared to previous El Niño events.

2. Data and Methods

2.1. Data

This study relies on the observed oceanic and atmospheric parameters based on the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON) buoys project [7,8].The TAO/TRITON buoys provide various oceanic and atmospheric dataset. However, in this study only oceanic temperature atmospheric winds are used. The TAO/TRITON buoys recorded the oceanic temperature with various vertical resolutions from 1 m in the upper 10 m to 250 m in the deeper layers [8]. The TAO buoys recorded the oceanic temperature from 1 m depthdown to depth of 750 m, while the TRITON buoys recorded the temperature from 1.5 m down to depth of 750 m, The TAO buoys measured the winds at height of 4 m above sea level, while the TRITON buoys recorded the winds at height of 3.5 m above sea level. In addition, this study also used the Niño3.4 index obtained from the Observing System Monitoring Center, National Oceanic and Atmospheric Administration (NOAA).

2.2. Method

The monthly value of the Niño3.4 index was used to show the time evolution of 2015/2016 El Niño event. The Niño3.4 is defined as an averaged SSTA in the region bounded by 5°N to 5°S, from 170°W to 120°W [8]. Note that the anomaly fields are calculated as a deviation from the monthly climatology of all fields for a period of January 2000 – December 2015.

3. Results

The time evolution of the 2015/2016 El Niño is represented by the time series of the Niño3.4 index shown in Figure 1. It is shown that the evolution of 2015/2016 El Niño was started in boreal spring 2015 (April-May) when the index exceeding one standard deviation. The index gradually increased from boreal summer to boreal fall, and it reached the peak in October/November. The termination of the 2015/2016 El Niño was started as the index gradually decreasing in December 2015. The event was completely terminated in boreal spring 2016 (April/May) when the index fall below one standard deviation. Note that the 2015/2016 El Niño was lasting for about one year from boreal spring 2015 to boreal spring 2016.

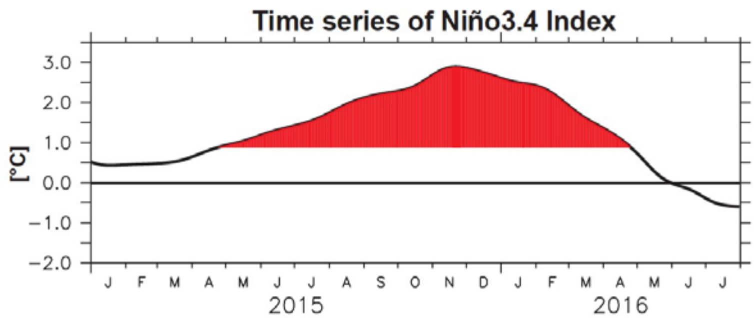

Figure 1. Time series of Niño3.4 index from January 2015 to July 2016 and wasdefined as anaveraged sea surface temperature anomaly between 5°N– 5°S, 170°–120°W.

Spatial evolution ofthe 2015/2016 El Niño event can be seen in Figure 2. At the initial evolution of the event, the easterly surface winds in the eastern tropical Pacific were weakened, while the westerly winds in the western part were strengthened (Figure 2a). As a result, the SST in the eastern tropical Pacific anomalously warm, while in the western the SST anomalously cold. By October 2015, the easterly winds in the eastern tropical Pacific were terminated and anomalous westerly winds were observed along the equatorial Pacific (Figure 2d). The maximum warm SSTA in the eastern Pacific was observed in November 2015 (Figures 2e) as the El Niño came to its peak phase (see Figure 1). The anomalous westerly winds gradually weakened in the following months, and the easterly winds replaced the westerly anomalies in the eastern Pacific since January 2016 (Figure 2g). As the result, the SSTA in the eastern (western) Pacific got cooling (warming). By February 2016, strong easterly winds were observed in the eastern Pacific, while in the western Pacific the anomalous westerly winds were terminated and maximum warm SSTA remained in the central Pacific (Figure 2h).

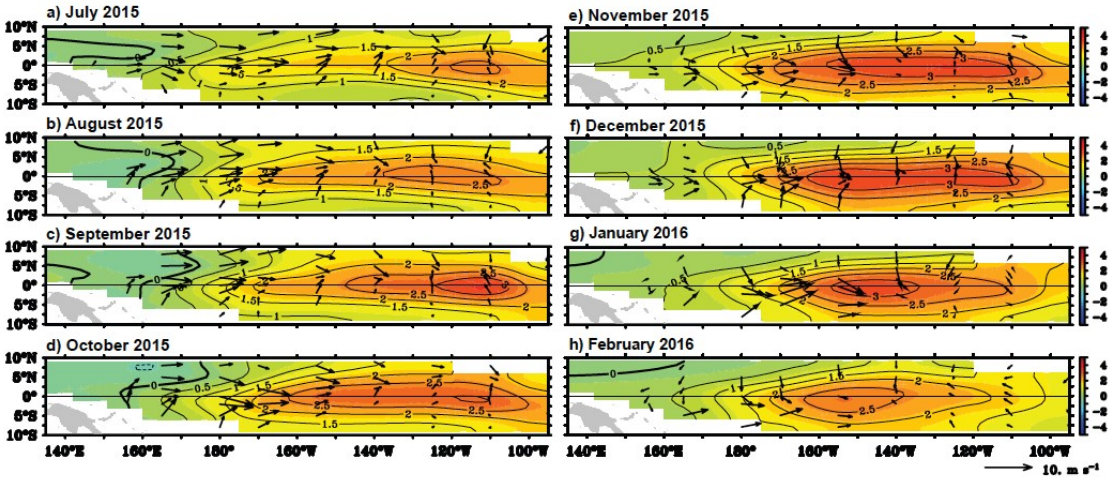

Figure 2. Ocean-atmosphere evolution associated with the 2015/2016El Niño is represented by SSTA (*shaded* in °C) and surface wind anomalies (*vectors* in Nm/s) from July 2015 through February 2016.

In order to examine the dynamics underlying of the evolution on 2015/2016El Niño event, we then examined time-longitude evolution of theanomalous zonal wind, dynamic height, SST, and the upper layer heat content (Figure 3).From early 2015, a series of strong intraseasonal westerly wind anomalies was observed in western equatorial Pacific (Figure 3a). The westerly wind anomalies were strengthened in boreal spring and expanded eastward. These intraseasonal westerly wind anomalies excited intraseasonaldownwelling Kelvin propagating eastward across the equatorial Pacific as shown by intraseasonal variations in the dynamic height (Figure 3b). The series of these wind-focedintraseasonal Kelvin waves warmed the eastern Pacific (Figure 3c) and accumulated the heat in the eastern Pacific (Figure 3d). In the western Pacific, the SST anomalously negative due to the upwelling of cold subsurface water, so that the heat content anomalously is negative. During the peak phase of the 2015/2016El Niño, the SSTA in the eastern Pacific could reach >3°C (Figure 3c).

At the end of 2015, strong westerly wind anomalies were observed in the western equatorial Pacific, while easterly wind anomalies already occupied the eastern Pacific (Figure 3a). These strong westerly wind anomalies forced downwelling Kelvin waves with amplitude smaller than that of the previous downwelling waves (Figure 3b). Starting from early 2016, the westerly wind anomalies in the western equatorial Pacific were weaken even reversed their direction, while the easterly wind anomalies in the eastern Pacific were strengthened (Figure 3a). The easterly wind anomalies in the eastern Pacific induced upwelling causing cool SSTA and reducing heat content in the eastern Pacific(Figures 3c-d). In June/July 2016, the western Pacific warm pool was returned as positive

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SSTA occupied the western Pacific, while the eastern Pacific cold tongue replaced the positive SSTA in the eastern Pacific (Figure 3c).

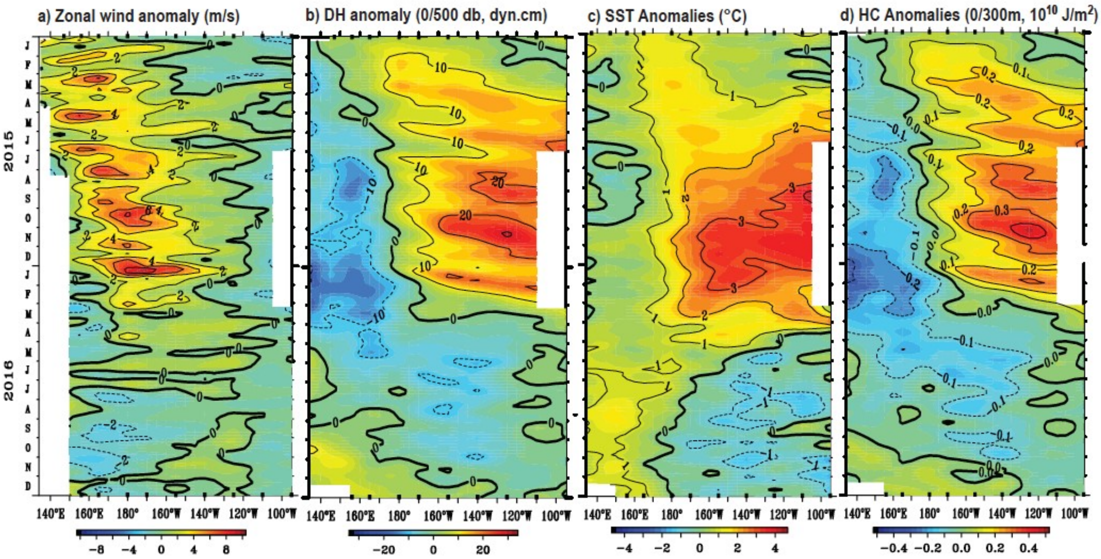

Figure 3. Time-longitude diagram of a) zonal wind anomaly (m/s), b) dynamic height anomaly (0/500 db, dyn.cm), c) sea surface temperature anomaly (°C), and d) heat content in the upper 300 m depth ($\times 10^{10}$ J/m^2) from January 2015 – December 2016.

The intensity of the 205/2016 El Niñowas compared with that of the previous El Niñoevents during the last three decades from 1980 to 2016. Note that the Niño3.4index was used to represent each El Niño event. There were 6 strong El Niño events observed during 1980 – 2016, namely the 1981/1982, 1991/1992, 1997/1998, 2002/2003, 2009/2010 and 2015/2016 El Niño event (Figure 4). It is clearly shown that 3 out of 6 events were categorized as a strong El Niño event in which the Niño3.4 index exceeding 2.5°C. Those 3 events are the 1981/1982, 1997/1998 and 2015/2016 El Niño events. In particular, the 2015/2016 El Niño has a comparable magnitude with the El Niño on 1997/1998. However, the initial development of the 2015/2016 El Niñowas slightly slower than that the 1997/1998 El Niño.

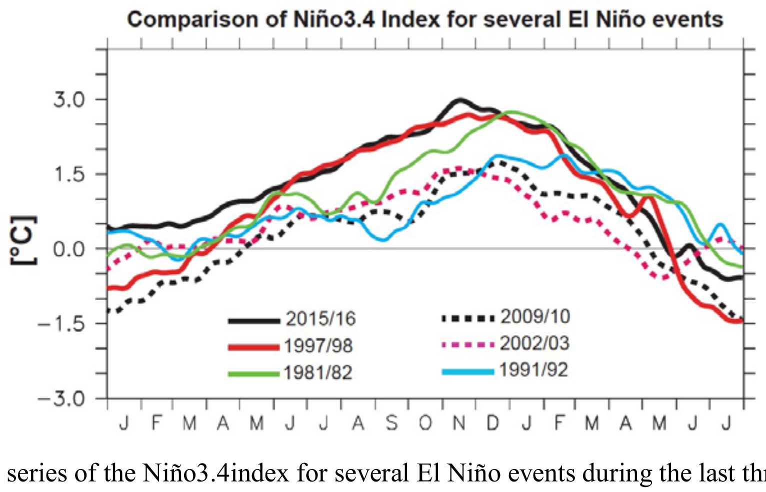

Figure 4. Time series of the Niño3.4index for several El Niño events during the last three decades.

4. Conclusion

During boreal spring 2015 until boreal spring 2016, El Niñoevent took place in the tropical Pacific. This extreme climate event has caused catastrophic climate event around the globe. In particular, most part of the Indonesian regions has experienced deficit precipitation leading to a severe drought event. This study was designed to evaluate the dynamics of the evolution of the 2015/2016 El Niño event and compared with previous El Niño events.

The results show that the development of 2015/2016 El Niño was induced by a series of strong intraseasonal westerly winds observed in the western Pacific from the early spring to late autumn 2015. These intraseasonal westerly winds forced intraseasonaldownwelling Kelvin waves that accumulating oceanic heat content in the eastern equatorial Pacific. These intraseasonaldownwelling Kelvin waves together with a weakening of easterly winds in the eastern equatorial Pacific warmed SST there, leading to a further weakening of easterly winds. As the El Niño came to its peak phase, the positive (negative) SSTA occupied the eastern (western) equatorial Pacific. The termination of 2015/2016 El Niño was associated with the weakening of westerly winds in the western equatorial Pacific and the strengthening of easterly winds in the eastern equatorial Pacific in early 2016. The easterly winds in the eastern Pacific induced upwelling of cool subsurface water leading to a negative SSTA and reducing heat content in the eastern equatorial Pacific. By spring 2016, positive SSTA occupied the western Pacific, while the eastern Pacific cold tongue replaced the positive SSTA there.

The 2015/2016 El Niño was one of the strongest El Niño events in the last three decades. It has comparable amplitude with the 1997/1998 El Niño, and it was lasting a relatively longer, from boreal spring 2015 until boreal spring 2016.

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