Analysis of El Niño Event in 2015 and the Impact to the Increase of Hotspots in Sumatera and Kalimantan Region of Indonesia

Ardila Yananto[1], Saraswati Dewi[1]
[1] (Engineer): Weather Modification Technology Center, Agency for Assessment and Application of Technology, BPPT, Tangerang Selatan, Indonesia
e-mail: Ardi.geo@gmail.com

Abstract— Global climate in 2015 was greatly affected by the occurrence of El Niño Southern Oscillation. The appearance of El Niño has been widely predicted since 2015 by various research institutions in the world that work in the field of Meteorology and Climatology. In early September 2015, experts from World Meteorological Organization (WMO) stated that the El Niño occurred in 2015 will be one of the strongest El Niño in history. Based on a calculation, the value of Sea Surface Temperature (SST) in the waters of the East-Central Pacific Ocean tends to be warmer more than 2 degrees Celsius from the average value. El Niño that impact most areas of Indonesia will always be associated in drought due to reduced rainfall intensity. Drought, in further, has resulted in increasing hotspots significantly compared to previous years, especially in the Sumatera and Kalimantan region of Indonesia, creating smog disaster in 2015. The main objective of this research was to analyze the occurrence of El Niño in 2015 and its influence on increase of hotspot in Sumatera and Kalimantan both in temporal and spatial scale. This research use the integration of Meteorological-Climatological and Geographic Information Systems Science based, Nino -3.4, Sea Surface Temperature (SST) and Wind Gradient for El Niño events analysis, also MODIS Satellite high accuracy data for Hotspot distribution analysis. It can be seen that there was a most powerful El Niño phenomenon compared the history that the peak event in November 2015 with value 2.95 of Nino -3.4. Gradient Wind from June to December 2015 has shown the movement of water vapor Pacific Ocean tendency towards the East, resulting decrease of rainfall intensity in the Pacific Ocean in the Central and Western region including Indonesia. Based on the analysis both spatial and temporal, it's shown that South Sumatera and Central Kalimantan are regions with highest increase in total hotspot, the total hotspot increased by 363% for South Sumatera and by 231% for Central Kalimantan.

Keywords— El Niño, Sea Surface Temperature, Wind Gradient, Rainfall, Hotspot

INTRODUCTION

El Niño is one phenomenon occurs in Tropical Pacific Ocean. El Niño is a global phenomenon as a result of sea-air interaction, marked by increased Sea Surface Temperature (SST) at the eastern Pacific along equator. At the normal years, northern and north eastern Australia SSTs are ≥28°C while Pacific Ocean near South America SSTs are ± 20°C [1].

Indonesia Archipelago is located between Indian and Pacific Ocean. As the result, its rainfall is strongly affected by the change of SST around it. When there is an increase in SST at central and eastern Pacific around equator, known as El Niño, it's associated with decreasing rainfall in Indonesia. Otherwise, when there is a decrease in SST at central and eastern Pacific, known as La Niña, it's associated with increasing rainfall in Indonesia [2]

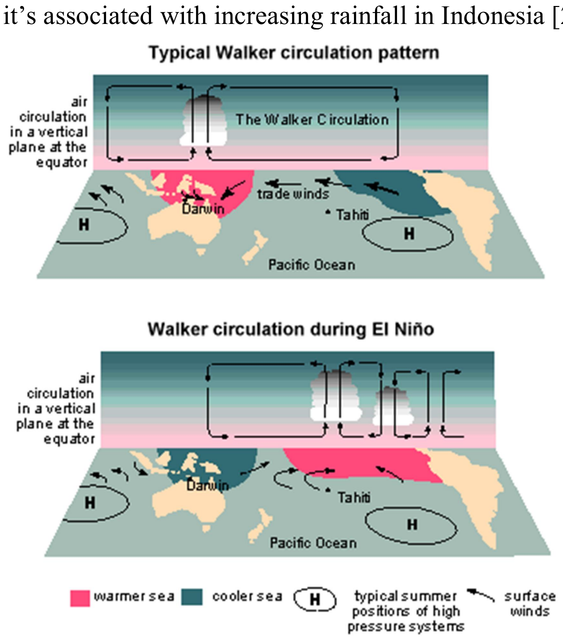


Figure 1. Walker circulation pattern at normal condition (top) and El Niño condition (bottom)

El Niño phenomenon has an impact on most of Indonesia regions and always be associated with the drought due to the decrease of rainfall. In February 2015, at Sumatera region particularly in Riau and Kalimantan region, many hotspots began to appear as the result of land and forest fires. The objective of this paper is to analyze the factors influencing El Niño event in 2015 and to understand the effect of El Niño event on increasing number of hotspot at Sumatera and Kalimantan region both spatially and temporally.

METHODS

The area study of this paper is Indonesia country especially Sumatera and Kalimantan region, where land and forest fires commonly occurs every year. The data used in this study are monthly mean rainfall data (2009-2015) from Tropical Rainfall Measuring Mission (TRMM) Jaxa obtained from hokusai.eorc.jaxa.jp. This data has 0.1° x 0.1° spatial resolution and 60 minutes temporal resolution. El Niño anomaly index used in this study are NINO3.4 SST Index, Southern Oscillation Index (SOI) and Indian Ocean Dipole (IOD) from Bureau of Meteorology Australia. Spatial data of Sea Surface Temperature (SST) for tropical Pacific Ocean was taken from Jet Propulsion Laboratory (JPL) NASA with 1 km spatial resolution, zonal wind data was taken from NCEP Reanalysis data and hotspot data was taken from National Institute of Aeronautics and Space (LAPAN) satellite Indonesia.

El Niño event in 2015 was analyzed using NINO3.4 SST Index, SOI, IOD, spatial pattern of SST, and zonal wind analysis at Pacific Ocean during January until December 2015. Furthermore, relationship between NINO3.4 index and actual rainfall intensity in 2015 was also analyzed especially for Sumatera and Kalimantan region. Otherwise, hotspot analysis will be analyzed using comparison between the distribution of hotspots in 2015, both spatial and temporal, and the distribution of hotspot at Sumatera and Kalimantan in previous 10 years period.

RESULTS AND DISCUSSION

a. Sea Surface Temperature and Nino 3.4 SST Index

Sea Surface Temperature (SST) is the water temperature close to ocean surface. Low SST yields to reduction of water vapor in the atmosphere, otherwise high SST yields to large number of water vapor in the atmosphere. The SST pattern in Indonesia is commonly following the annual movement of the sun. Indian ocean SST has a wide range of variability, 26°C in August and up to 31.5°C in February until March. Other areas in Indonesia commonly have relatively small SST changes ranged 29°C to 31.5°C and the timing for maximum and minimum SST will be different in each area.

In the El Niño event, NINO3.4 SST index is used as one of the indicator of the occurrence of ENSO (El Niño/ La Niña).

Table 1. El Niño and La Niña Prediction from NINO 3.4 SST Index

NINO 3.4 SST Index	Phenomenon
> + 1.5 ^oC	Strong El Niño
+1.0 ^oC to +1.5 ^oC	Moderate El Niño
+0.5 ^oC to +1.0 ^oC	Weak El Niño
- 0.5 ^oC to +0.5 ^oC	Neutral
-1.0 ^oC to -0.5 ^oC	Weak La Niña
-1.5 ^oC to -1.0 ^oC	Moderate La Niña
< -1.5 ^oC	Strong La Niña

Source: BMKG Indonesia

Graphical data of NINO3.4 SST index from January 2010 to April 2016 from Bureau of Meteorology Australia is represented in Figure 2. Based on the graphic, it can be seen that strong El Niño occurred in 2015 started from July and has weakened in April 2016. The strong El Niño has NINO3.4 SST index ranged from 1.6 to 2.95, where the strongest index was reached in November 2015.

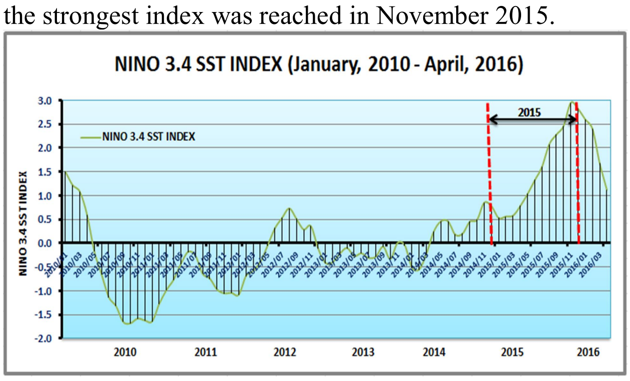
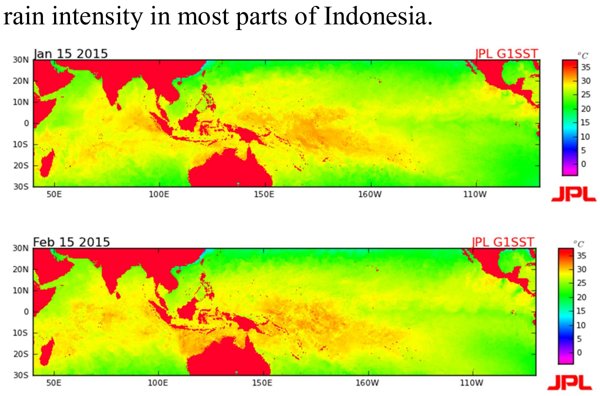


Figure 2. NINO 3.4 SST Index (January, 2010 - April, 2016)

El Niño event can also be analyzed using spatial data of Indonesia SST, Pacific Ocean, and Indian Ocean from April to December 2015 represented in Figure 3. It can be seen from Figure 3 that there has been a temperature anomaly since early 2015. Mid Pacific Ocean has greater value of SST than western Pacific including Indonesia. It is shown in Figure 3 that from January to June 2015 most of Indonesia area and eastern Indian Ocean has relatively high SST in the limited area. Therefore there was a possibility of cloud development resulting in rain at some parts in Indonesia. However, the Indonesia and Eastern Indian Ocean was relatively smaller than Mid Pacific Ocean SST in July to October 2015 so that most of Indonesia regions has very small amount of rainfall even no rain at all. This condition become the main factor of long period drought in the Indonesia regions and drastically increased hotspots in 2015 especially in July to October 2015. Meanwhile in November and December 2015, although the SST anomaly in Mid Pacific Ocean reached its peak, the SST in mostly Indonesia areas began to increase, triggering cloud development and increasing rain intensity in most parts of Indonesia.



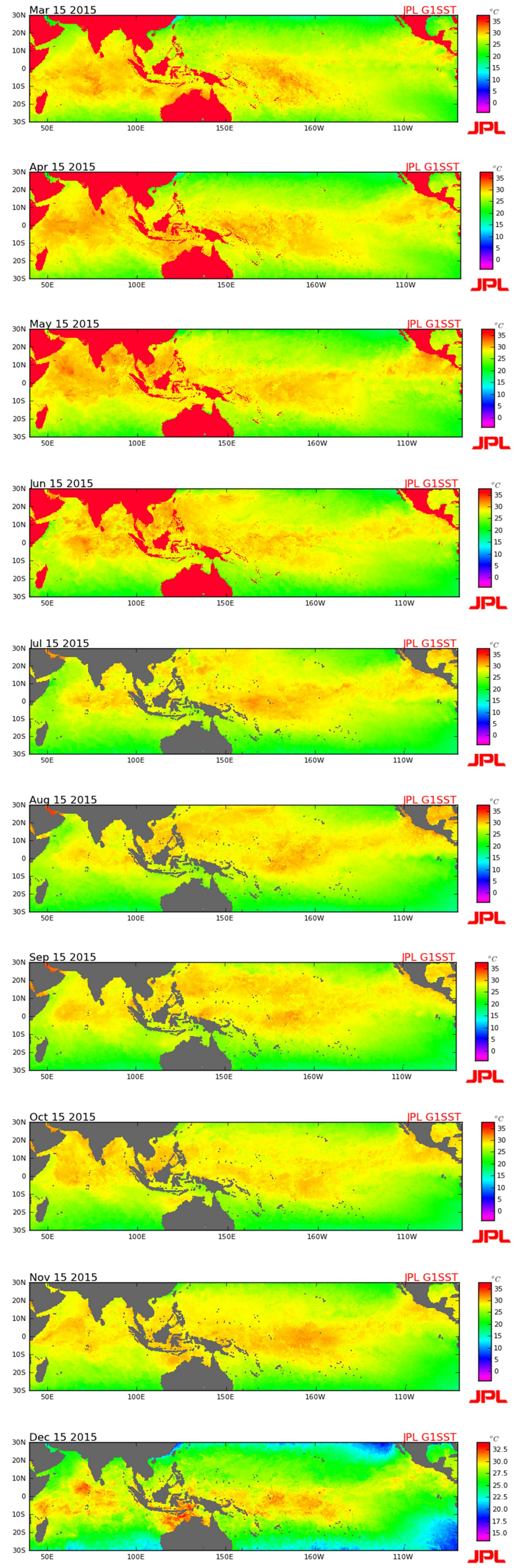


Figure 3. SST spatial pattern in Indonesia, Pacific Ocean, and Indian Ocean from January to December 2015

b. **Southern Oscillation Index (SOI)**

Southern Oscillation Index (SOI) is one of indexes to see the change of Sea Level Pressure (SLP) anomaly between Tahiti and Darwin. Positive SOI indicate the La Niña event, where Darwin SLP is smaller than normal while SLP Tahiti is higher than normal. Easterly wind becomes strong, creating a warm pool near Darwin. Otherwise, negative SOI indicate El Niño event where Darwin SLP is higher than normal while Tahiti SLP is smaller than normal. The easterly wind would be weakened and the warm pool will be shifted to IDT. The following Table is classification of Southern Oscillation Index (SOI) regarding to El-Nino and La-Nina event.

Table 2. El Niño and La Niña Prediction from *Southern Oscillation Index* (SOI)

Southern Oscillation Index	Phenomenon
< -10	Strong El Niño
-10 s.d -5	Weak-Moderate El Niño
-5 s.d +5	Netral
+5 s.d +10	Weak-Moderate La Niña
> +10	Strong La Niña

Source: BMKG Indonesia

The Southern Oscillation Index (SOI) data from January to April 2015, obtained from bureau of Meteorology (BoM) Australia, is represented on Figure 4. Based on the graphic, it's shown relatively negative SOI during 2015 to early 2016. The SOI stayed constant in <-10 from May to October 2015 where the lowest occurred in October with SOI -20.2. So it can be inferred that there was a strong El Niño event in May to October 2015.

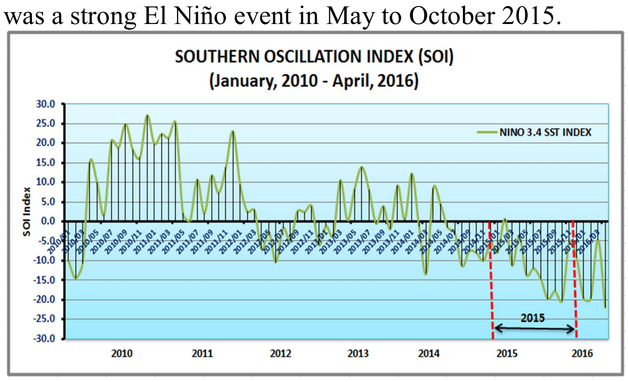
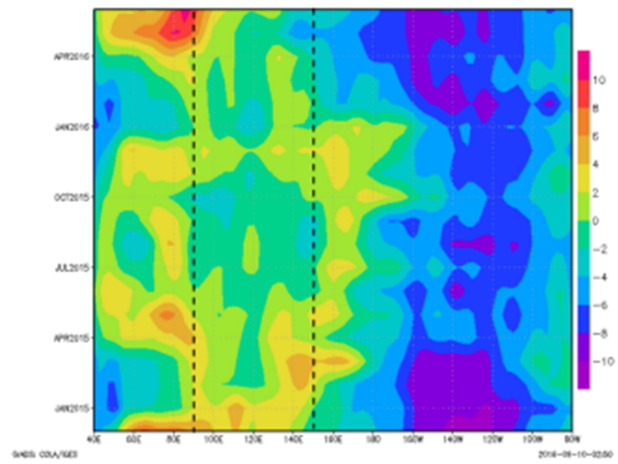


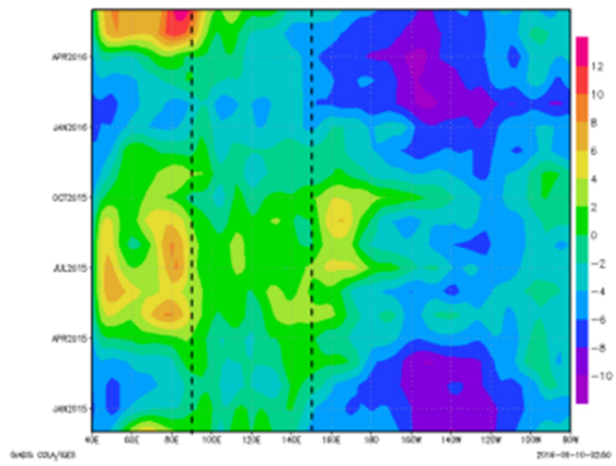
Figure 4. Southern Oscillation Index (SOI) (January, 2010 - April, 2016)

c. Zonal Wind Analysis

One of the parameters that indicate the occurrence of ENSO is the weakened Walker circulation. Walker circulation is the air circulation from East to West takes place throughout the year. When El Niño occurs, the center of low pressure moves into the Pacific Ocean Eastern part around Peru, this led to the strengthening of westerly wind. The strengthening of the westerly wind during ENSO events can be seen from zonal wind analysis. In this study the data used is the zonal wind data obtained from http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html with 2.5° x 2.5° spatial resolution and monthly temporal resolution. Zonal wind changes in ENSO drawn Hovmöller diagram shown in Figure 5. The zonal wind which moves in the positive x-axis has positive value and is called the westerly wind while zonal wind which moves in the negative x-axis has negative value and is called easterly wind. Figure 5a is a Hovmöller diagram for latitude 0 °. It can be seen that the westerly wind in Indonesia area (the area between the dotted lines) rose from late 2015 until mid-2015 and a meeting area westerly wind and easterlies wind shifted to the east in the Pacific Ocean. It can be seen in Figure 5b that the westerly wind rose in the period from March 2015 until October 2015 and the meeting area winds occur in the Eastern Pacific Ocean. Westerly wind began to weaken at the end of 2015. The low pressure area is shifted to the west Pacific Ocean.



(a)



(b)

Figure 5. Zonal Wind Analysis from December 2014 to June 2016 in level 850 mb in latitude 0° (a) and latitude 2° (b).

d. Indian Ocean Dipole (IOD)

Indian Ocean Dipole (IOD) is an air-sea interaction that occurs in the Indian Ocean, where there is a difference between the sea surface temperature of the West Indian Ocean or the East African coast and the SST in the East Indian Ocean or West coast of Sumatera. IOD Index (Indian Ocean Dipole or index DM (Dipole Mode) is defined as the difference of se surface temperature anomaly between eastern Indian Ocean and the western Indian Ocean, where the index value of IOD > 0.4 is classified as IOD (+) and index value of IOD <- 0.4 is classified as IOD (-). IOD (+) means that sea surface temperatures in the eastern coast of Africa is higher than the sea surface temperature on the western coast of Sumatera, the opposite is the IOD (-). Thus the IOD (+) is the cold phase northwest coast of West Sumatera with weakened convection. On the contrary, IOD (-) is the hot phase of the West coast of Sumatera so that convection strengthened resulting in an increase of rainfall in the western region of Indonesia during the phase of IOD (-).

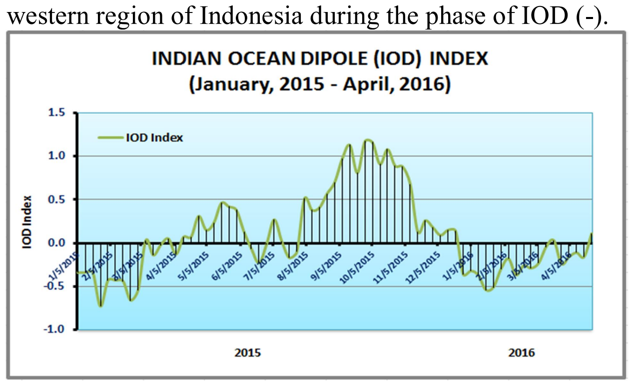
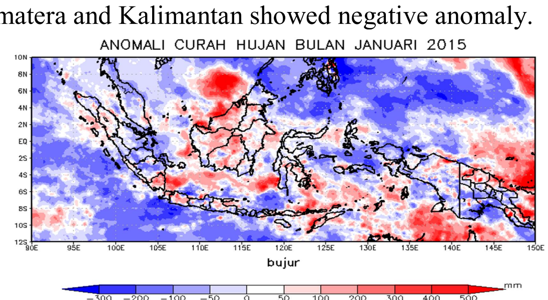


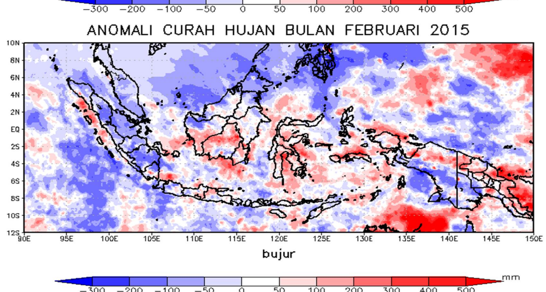
Figure 6. *Indian Ocean Dipole (IOD) Index (January, 2015 – April, 2016)*

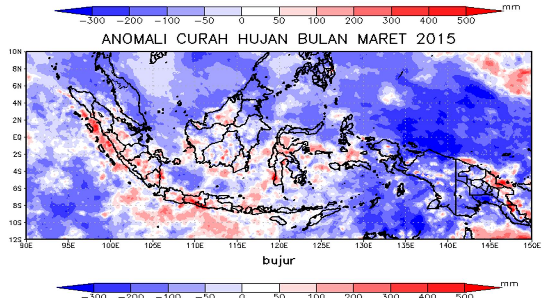
Figure 6 represented Indian Ocean Dipole (IOD) Index from January 2015 to April 2016. Based on the graphic, we know that In January to March 2015 the IOD Index is still relatively on the negative (-) value, means that although there has been an indication of El Niño occurrence since the beginning of 2015, but the formation of clouds in parts of Indonesia, especially in Indonesia's western region is still being influenced by the heat phases in the West Sumatera so that in Indonesia's western region is still got a lot of rainfall even though below the average intensity of rainfall historical data. But starting in June 2015 IOD Index has relative to the positive (+) value and reached its peak at the end of September 2015. IOD Index reached (+) 1.17 indicate sea surface temperatures on the East coast of Africa are higher than sea surface temperatures on the West coast of Sumatera, so the convection on the western coast of Sumatera will be weakened and it will further increase the effect of existing El Niño especially in July and October 2015. In the early 2016 IOD back in the position of the negative (-) and it will help in increasing rainfall in some parts of Indonesia even though there was in strong level El Niño from January to March 2016.

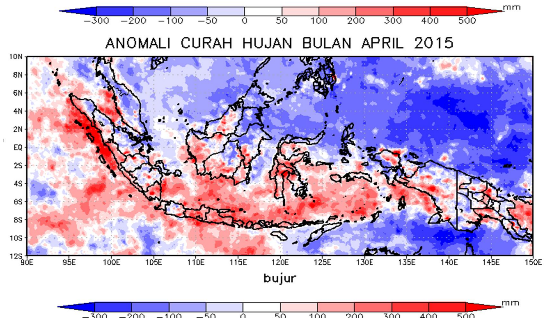
e. **Rainfall Anomaly**

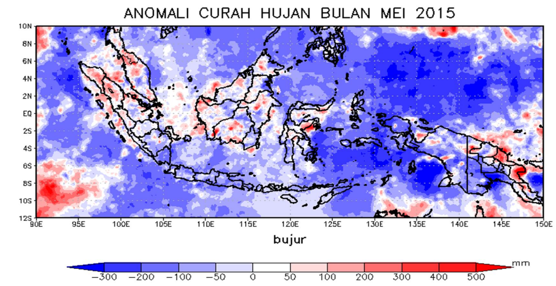
The shifting center of low pressure due to weakened easterly wind in the Walker circulation affects the intensity of rainfall, especially in some areas in Indonesia. The increasing number of hotspots in some areas at Sumatera and Kalimantan were caused by a reduction in the intensity of rainfall, causing drought. Rainfall data used in this study is the rainfall data from the Tropical Rainfall Measuring Mission satellite (TRMM) with 0.1 ° x 0.1 ° spatial resolution and one hour temporal resolution. Precipitation anomalies can be observed from the monthly average historical data and are presented in Figure 7. The negative anomalies indicate the monthly rainfall is smaller than the average rainfall. This can be seen on Rainfall Anomalies May to October 2015, the monthly rainfall in Sumatera and Kalimantan showed negative anomaly.

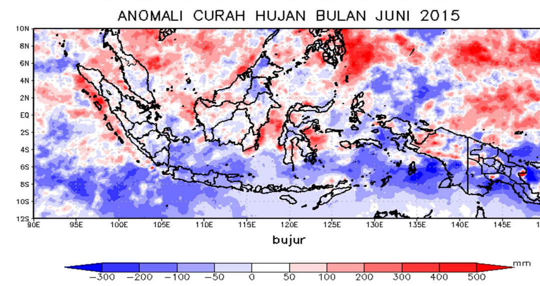


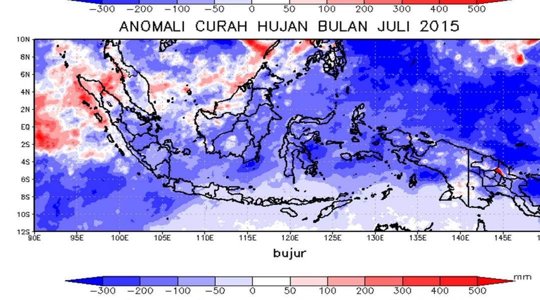


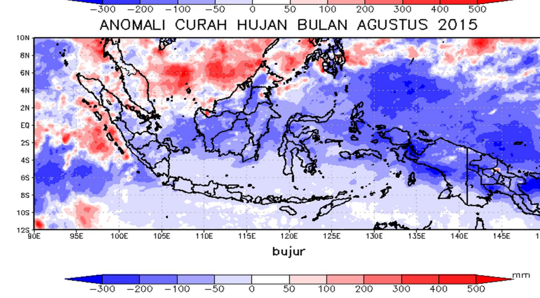


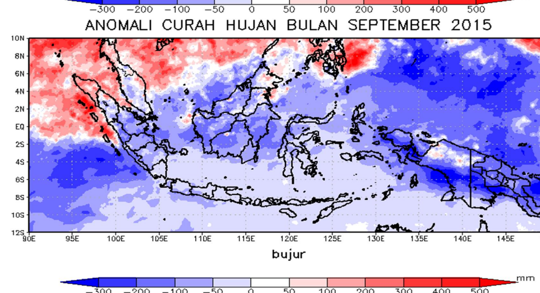


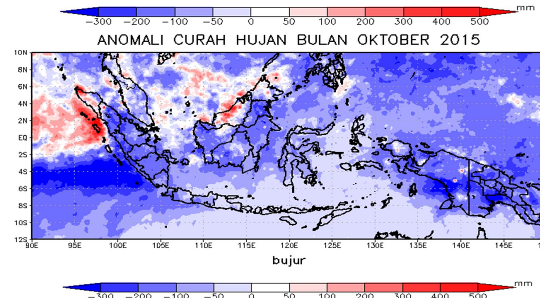


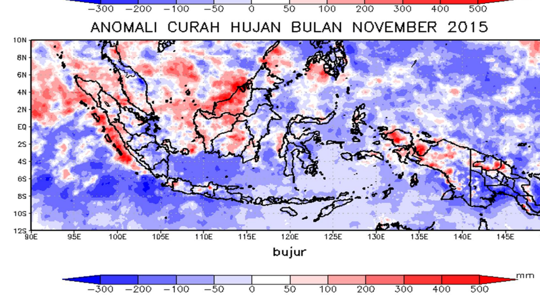












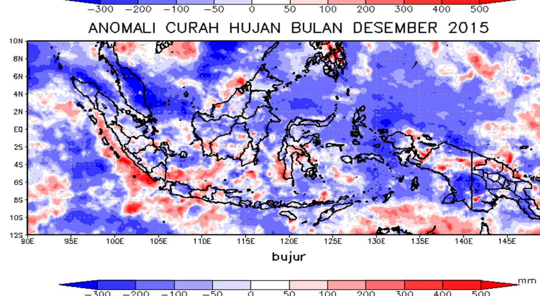


Figure 7. Indonesia rainfall anomaly from January to December 2015

The occurrence of negative anomalies of rainfall in Sumatera and Kalimantan due to ENSO caused drought and the increasing number of hotspots.

f. Hotspot Analysis

Based on the number of hotspots in the past ten years from 2006 to 2015, represented in Figure 8, it can be seen that the strong El Niño event in 2015 has a great influence on the increased number of hotspots in Sumatera and Kalimantan, Indonesia. Besides, MODIS satellite imagery showed the number of hotspots in Sumatera and Kalimantan with a confidence level above 70% in 2015 was the highest in the past 10 years, with the number of hotspots more than 50,000 hotspots.

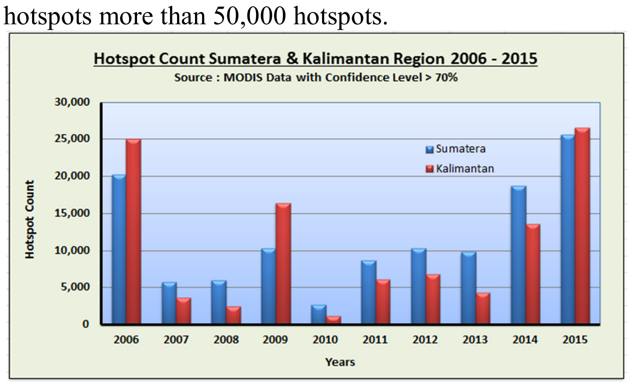


Figure 8. Total hotspot in Kalimantan and Sumatera (2006-2015)

Increasing number of hotspots in Sumatera and Kalimantan in 2015 for each month is also highly correlated with monthly rainfall anomalies in Sumatera and Kalimantan. The analysis of precipitation anomalies in the previous discussion showed that there was negative rainfall anomalies at extreme levels in most parts of Indonesia began in July to October 2015. Based on Figure 9 which represents the monthly chart the number of hotspots in Sumatera and Kalimantan in 2015, it can be seen that the increasing number of hotspots in the two regions began to increase rapidly since July and continued to increase until October 2015. Meanwhile, in November 2015 the number of hotspots decreased dramatically with the increase in the amount of rainfall in most parts of Indonesia compared to the previous months due to increasing sea surface temperatures in some Indonesia sea areas and the West coast Sumatera.

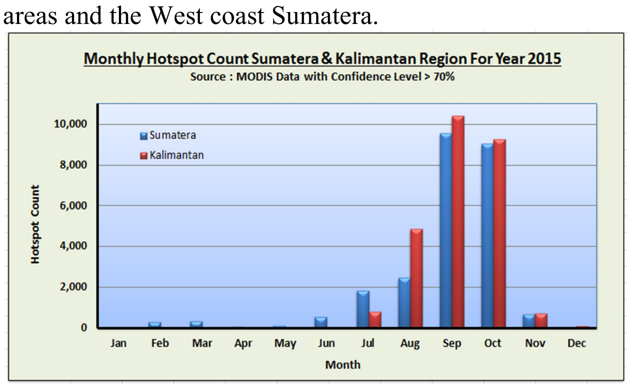


Figure 9. Monthly hotspot count in Sumatera and Kalimantan 2015.

Based on the analysis of the hotspot density in Sumatera and Kalimantan over past five years from 2011 to 2015, represented in Figure 10, it can be seen that the distribution of hotspots in 2011 to 2012 in Sumatera were concentrated in Riau Province and South Sumatera and the distribution of hotspots in Kalimantan region were concentrated in the southern part between the Central Kalimantan and South Kalimantan. While in the year 2013 to 2014 the location of hotspots was concentrated in Riau for Sumatera and Central Kalimantan for Kalimantan region. The number of hotspots in 2015 strong El Niño event in Sumatera were more concentrated in the South Sumatera while the number of hotspots in Borneo region were also concentrated in Central Kalimantan.

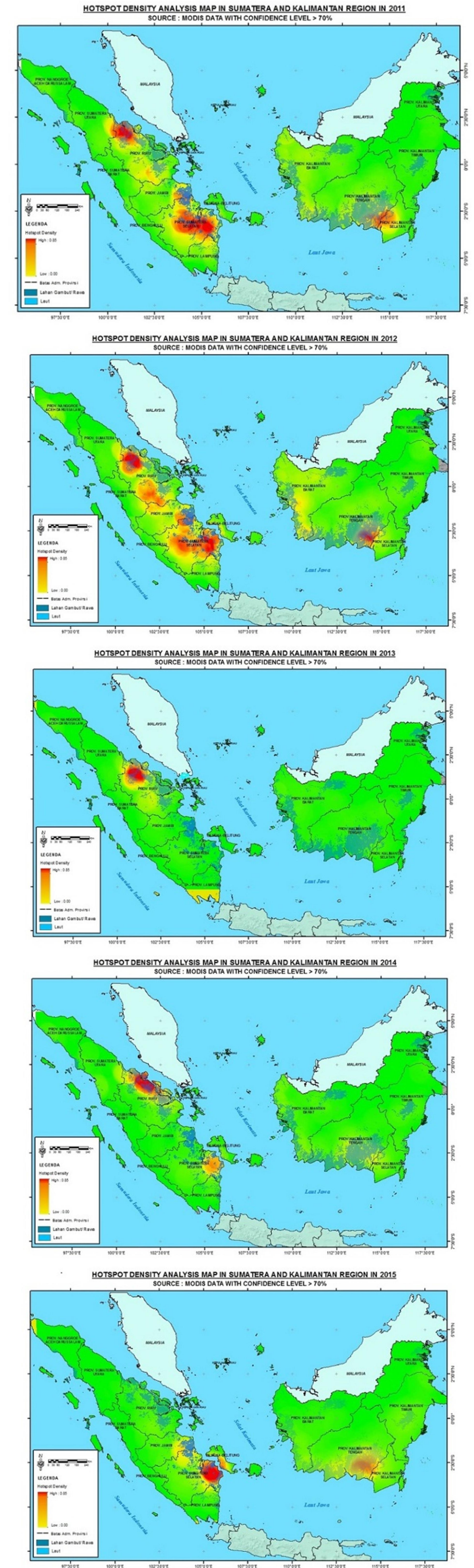


***Figure 10.** Hotspot density analysis in Sumatera and Kalimantan (2011 – 2015)*

CONCLUSION

Based on data processing and data analysis, there are some points that can be inferred:

1. Based on the NINO 3.4 SST index and the Southern Oscillation Index (SOI), it is known that there was a strong El Niño event occurred in 2015.
2. The analysis of the zonal wind also showed that in 2015 there was a weakening Walker circulation so that the low pressure center moved from western part of the Pacific Ocean to the Eastern Pacific Ocean indicating the El Niño phenomenon in 2015.
3. Shifting center of low pressure due to weak easterly wind in the Walker circulation has influenced the decrease in the intensity of rainfall in most parts of Indonesia, especially from July to October 2015.
4. Indian Ocean Dipole (IOD) Index data showed that starting in June 2015 the IOD index is in a positive position (+) and reached its peak at the end of September 2015 in which the IOD index reached (+) 1.17 which indicated sea surface temperatures on the East coast Africa was higher than sea surface temperatures in the western coast of Sumatera, resulting weak convection on the western coast of Sumatera and increasing impact of the El Niño phenomenon in Indonesia.
5. Based on the analysis of the number of hotspots, it can be seen that the number of hotspots in Kalimantan and Sumatera in 2015 was the highest during the past ten years. There was sharp increase of hotspots from July to October 2015 and were concentrated in South Sumatera and Central Kalimantan.

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