Effect of global climate (ENSO) on regional climate (rainfall and air temperature) in the Morotai Island region

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Abstract. ENSO (El Nino Southern Oscillation) is a global climate anomaly that plays an important role in annual climate and usually causes a shift in climate parameters. ENSO has many impacts on the climate and the sea in Indonesia, especially in eastern Indonesia. Besides rainfall, ENSO can also affect extreme weather, longer dry and rainy seasons and drought in various regions in Indonesia including Morotai Island. Empirically the value of SOI and Nino 3.4 is an indicator of the ENSO phenomenon. This study aims to analyze the effect of ENSO on climate parameters (rainfall and air temperature) that occur on Morotai Island. The results showed that in 3 decades on 1987-2017 there were 18 times of ENSO (SOI indicator) and 13 times of ENSO (Nino 3.4 indicator), with the category of weak-moderate to strong. The regional climate of Morotai Island is included in the monsoonal pattern in region A and the local pattern in region C. Morotai Island rainfall is categorized as normal which is seen from the average annual rainfall of 119 mm month^{-1}. The highest rainfall in June was 159.2 mm and the lowest in September-October was 93.79 mm. The results of the regression-correlation analysis showed no significance and a weak correlation between ENSO and the two climate parameters (rainfall and air temperature) on the SOI indicator. This can be seen in the SOI p-value ranging from 0.017 to 0.026 < 0.05 and r values ranging from 0.231 to 0.30. Whereas the p value of the Nino 3.4 indicator shows that there is a significant correlation between Nino 3.4 with rainfall and air temperature, with a p value of 0.019 < 0.05 and an r value of Nino 3.4 of 0.401 and 0.540.
Key Words: El Nino, La Nina, SOI, Nino 3.4, climate, Morotai.

Indtroduction. ENSO (El Nino Southern Oscillation), known as the El Nino and La Nina phenomena, is the global interaction of the sea with the atmosphere resulting in anomalous sea surface temperature (SST) in the equatorial Pacific Ocean (Fox 2000; Aldrian 2008; As-syakur 2010). El Nino is marked by an increase in SST above normal (warm) in the waters of the central and eastern Pacific Ocean, usually followed by a decrease in rainfall and an increase in air temperature in Indonesia. Whereas La Nina is characterized by SST in the waters of the eastern and middle Pacific Ocean experiencing a decrease in temperature and turning to cold. This is usually stimulating an increase in rainfall in Indonesia above normal (Mulyana 2002a; Qian et al 2010; Yananto & Sibarani 2016).

The ENSO phenomenon has many impacts on the climate and the sea in Indonesia, especially in eastern Indonesia (Aldrian & Susanto 2003). Both the El Nino and La Nina climate anomalies play an important role in the annual climate and usually cause a shift in climate parameters, especially changes in the amount of rainfall (Hidayat & Ando 2014). Furthermore, the shape and amount of rainfall are affected climate factors such as wind, temperature, humidity and atmospheric pressure (BMKG 2018). Besides being able to influence high rainfall, ENSO events also affect extreme weather, longer period of dry and rainy seasons and drought in various regions in Indonesia (Irawan 2006).

El Nino and La Nina events are shown by the Southern Oscillation Index (SOI) and SST in the Pacific Ocean (Nabilah et al 2017). Anomaly value of the SST of the reference area is known as the area of Nino 3.4. (Dupe et al 2002; Kirono & Partridge 2002). While the SOI value is based on differences in air pressure above sea level between Tahiti and Darwin which is not like normal conditions. This index is calculated based on two data in the southern region of the Equator, namely in Haiti which is located at 17.6S 149.6W, and Darwin which is located at 12.4S, 130.9E (WMO 1999; Fox 2000; Nicholls & Beard 2000; Yananto & Sibarani 2016). In general, if a negative SOI value on an El Nino event reaches -10 or less there will be a decrease in rainfall below normal, meanwhile if in the La Nina event a positive SOI value reaches +10 or more there will be an increase in rainfall above normal (Fox 2000; Bambang 2006; Tongkukut 2011). SOI values in Southeast Asia and Australia are strongly correlated with rainfall. Therefore changes in SOI values are a good indicator of changes in rainfall in the region (Podbury et al 1998; Nicholls & Beard 2000). If El Nino occurs or a negative SOI value occurs, the rainfall in the region may fall below normal, conversely if La Nina is indicated by a positive SOI value, it can cause an increase in rainfall (WMO 1999). However, a negative SOI value is not always followed by a drastic decrease in rainfall if the negative SOI value is not too extreme.

Morotai Island waters in eastern Indonesia have unique characteristics regionally and locally. Geographically, Morotai Island is located between the western Pacific Ocean, the Halmahera Sea and the Sulawesi Sea and has mountainous and hilly areas with steep slopes. With its position close to ENSO activities and local climate factors, the formation of clouds and rain on Morotai Island is affected by these conditions and is vulnerable to both regional and global climate. There were no researches related to the ENSO phenomenon performed on Morotai Island. These phenomena are related to strange rainfall and air temperatures on Morotai Island. Therefore, it is important to analyze them in order to minimize and anticipate losses that can be caused by the global climate phenomenon (ENSO).

This study aims to analyze the influence of global climate (ENSO) toward regional climate (rainfall and temperature) on Morotai Island. Furthermore, this research will provide information about the role of ENSO on variations in regional climate anomalies of rainfall and air temperature on Morotai Island.

Material and Method

Research location. This research was performed for 6 months, from July to December 2017 at Morotai Island, North Maluku Province, Indonesia (Figure 1).

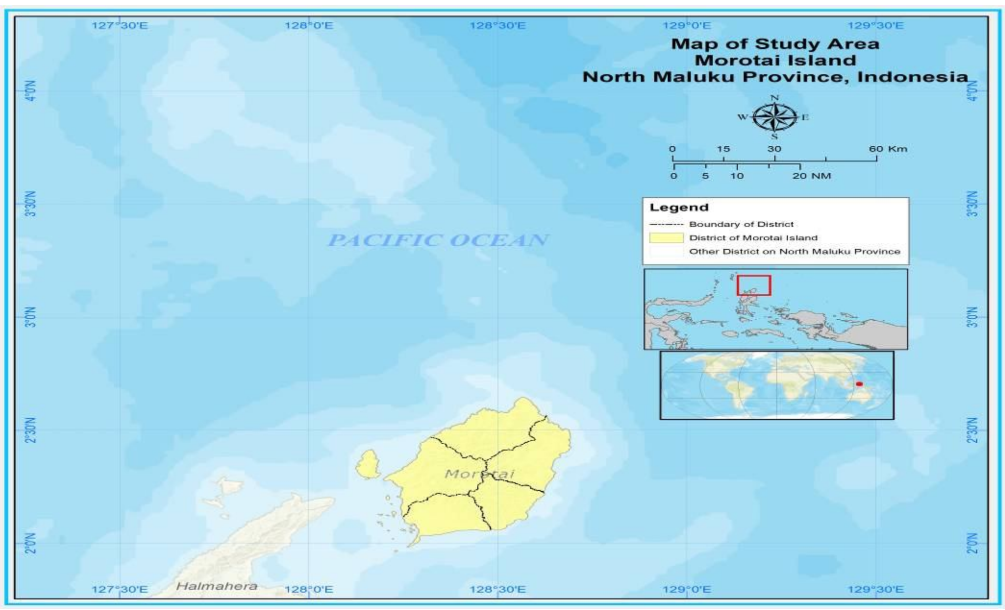


Figure 1. Research location (Source: Earth map, Indonesian Geospatial Agency).

Data source. This research was performed by using data sources in the form of SOI values obtained from the BOM (Bureau of Meteorology) website: http://www.bom.gov.au/climate/enso/indices and Nino values 3.4 SST index obtained from the NOAA (National Oceanic and Atmospheric Administration) website: http://www.cpc.ncep.noaa.gov/ in the Tropical Pacific Ocean region for 3 decades from 1987-2017. Regional climate data sources consisting of rainfall for the period 1987-2017 and temperatures for the period 2006-2017 were obtained from the Morotai Island Naval Base and BMKG Galela Halmahera Utara North Maluku Province which is a Morotai Island climate observation station.

The ENSO event is known by describing SOI and Nino 3.4 values in the equatorial Pacific Ocean. The SOI value is defined as the sea level presure (SLP) anomaly in the East Pacific, Tahiti at the position of 17.6^{o}S - 149.6^{o}W from the Western Pacific in Darwin, Australia at 12.4^{o}S - 130.9^{o}E. The Nino 3.4 SST anomaly is defined as the SST anomaly in the East and Central Pacific covering part of the Niño 3 region and part of the Niño 4 region, which is located at 120^{o}E - 170^{o}W and 50^{o}S - 50^{o}N.

The intensity of ENSO events (El Nino and La Nina) was detected by the magnitude or classification of the SOI and Nino 3.4 values of the SST index in Table 1 (Nabilah et al 2017). El Nino occurs when the value lasts for at least 3 months and La Nina occurs if the value lasts for 5 to 7 months (Tresnawati & Nuraini 2010; Susanto 2014; WMO 2016; BMKG 2018).

Table 1

El Nino and La Nina classification based on SOI and Nino 3.4

SOI	*Phenomenon*	*NINO 3.4*	*Phenomenon*
< -10	Strong El Nino	> + 1.5^{o}C	Strong El Nino
-10 s.d -5	Weak-moderate El Nino	+1.0^{o}C s.d +1.5^{o}C	Moderate El Nino
-5 s.d +5	Neutral	+0.5^{o}C s.d +1.0^{o}C	Weak El Nino
+5 s.d +10	Weak-moderate La Nina	- 0.5^{o}C s.d +0.5^{o}C	Neutral
> +10	Strong La Nina	-1.0^{o}C s.d -0.5^{o}C	Weak La Nina
		-1.5^{o}C s.d -1.0^{o}C	Moderate La Nina
		< -1.5^{o}C	Strong La Nina

Source: Meteorology, Climatology and Geophysics of Indonesia.

Data analysis. The phenomenon of ENSO events and regional climate elements (rainfall and air temperature) are shown in the form of tables and graphs. Rainfall patterns on Morotai Island were analyzed using the formula below:

$$Xmean = \frac{1}{n}\sum_{i=1}^{n} Xi$$

where: Xmean = monthly average rainfall (mm) in a given time period;
Xi = amount of rainfall in a particular month (mm);
n = amount of monthly rainfall (mm).

Meanwhile, determining the climate type on Morotai Island was performed using the provisions of Aldrian & Susanto (2003) who classify climate types in the Indonesian region consisting of 3 regions and 3 main patterns of annual rainfall. Region A (monsoonal pattern), Region B (equatorial pattern) and Region C (local pattern). Furthermore, to prove the correlation and significance between ENSO and Morotai Island climate variables, a regression-correlation analysis (Walpole 1994) was performed with the formula below:

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{\{n\sum X^2 - (\sum X^2)\}}\sqrt{\{n\sum Y^2 - (\sum Y)^2\}}}$$

where: r = correlation coefficient between X and Y;
X = monthly SOI value or Nino 3.4 monthly Index Value;
Y = monthly rainfall or monthly air temperature;
n = amount of data.

The r value ranged from -1 to 1. Positive sign means the correlation between variables is directly proportional and negative sign means the correlation between variables is inversely proportional. The significance of ENSO's correlation to the climate of Morotai Island is determined by looking at p-value < 0.05 or 0.1 = significant and p-value > 0.05 or 0.1 = insignificant. The criteria for rainfall intensity are known by using a classification from the BMKG (2018), with low (0-100 mm month^{-1}), normal (100-300 mm month^{-1}) and heavy (300-500 mm month^{-1}).

Result and Discussions

Southern Osicillation Index (SOI). Based on SOI values, over a period of 30 years (1997-2017) there have been 18 ENSO (El Nino and La Nina) with weak-moderate to strong classifications. The duration of ENSO events ranged from 5 to 13 months with an average SOI value ranging from -7.98 to -16.03 (El Nino) and +8.04 to +20.44 (La Nina). There were 6 strong El Nino and 4 weak-moderate El Nino occurred for the past 30 years. Whereas there were 5 strong La Nina and 3 weak-moderate La Nina occurred in the past 30 years. The peak of El Nino occurred in 1997/1998 reaching -16.03 with a duration of 13 months and La Nina occurred in 2010/2011 reaching +20.44 with a duration of 10 months.

SOI values with 3 consecutive months below the value of -5 indicates the occurrence of EL Nino and positive values above +5 indicates the occurrence of La Nina (Tresnawati & Nuraini 2010; Susanto 2014). Therefore, based on SOI values, 18 global SST anomalies have occurred in Darwin and Tahiti in the 1987-2017 period. Negative SOI is usually followed by an increase in temperature in the Pacific equator, a decrease in trade wind power and a reduction in rainfall intensity in the western Pacific region (Indonesia and Australia). A negative SOI indicates that the SST in Darwin was greater than normal, while the SST in Tahiti was lower than normal so that the eastern movement will be weaken and will support hot pools gathering in the Tahiti area or the Central Pacific Ocean (Yananto & Sibarani 2016). According to Podbury et al (1998) cited by Irawan (2006), SOI values in Australia and Southeast Asia are very closely correlated, where a decrease in SOI values results in a reduction in rainfall, on the contrary, the raising SOI value results in an increase of rainfall. A negative SOI number means that there is an air mass movement from Australia to the Pacific region and also air mass movement, which contains of water vapor in the Southeast Asian region that moves eastward, so that the region becomes short of water vapor. That results in a lack of rainfall. Years of ENSO events based on period and average SOI values are presented in Table 2.

Table 2

ENSO occurrence (El Nino and La Nina) based on the duration of time and the average value of SOI during the 1987-2017 period

Year	*Month*	*Duration (month)*	*Average SOI*	*Description*
1987	Jan-Sept	9	-13.47	Strong El Nino
1988-1989	July-July	12	+14.52	Strong La Nina
1991-1992	Sept-April	8	-14.36	Strong El Nino
1992-1993	Oct-Oct	13	-9.48	Weak-moderate El Nino
1994	July-Dec	7	-13.87	Strong El Nino
1997-1998	Mar-Apr	13	-16.03	Strong El Nino
1998-1999	June-April	11	+11.87	Strong La Nina
2000-2001	Aug-Mar	8	+9.81	Weak-moderate La Nina
2002	July-Dec	6	-8.67	Weak-moderate El Nino
2006	July-Oct	4	-10.09	Strong El Nino
2007-2008	Oct-Apr	7	+10.55	Strong La Nina
2008-2009	Aug-Feb	7	+12.10	Strong La Nina
2009-2010	Oct-Mar	6	-9.64	Weak-moderate El Nino
2010-2011	July-Apr	10	+20.44	Strong La Nina
2011	July-Jan	7	+10.68	Weak-moderate La Nina
2014-2015	Aug-Jan	6	-7.98	Weak-moderate El Nino
2015-2016	July-Feb	8	-13.81	Strong El Nino
2017	July-Nov	5	+8.04	Weak-moderate La Nina

Source: Analyzed data.

Nino 3.4. Based on the Nino 3.4 value in the same period (1987-2017), there have been 13 ENSO (El Nino and La Nina) with weak, moderate to strong classification. The duration of ENSO events ranged from 5 to 24 months with an average Nino 3.4 ranged from +0.66 to +1.84^{o}C (El Nino) and from -0.68 to -1.57^{o}C (La Nina). There were 2 strong El Nino, 4 moderate El Nino and 2 weak El Nino occurred for the past 30 years. Whereas 1 strong, 3 moderate and 1 weak La Nina occurred for the past 30 years.

Positive Nino 3.4 values for 3 to 7 consecutive months above +0.5^{o}C are indicating the occurrence of El Nino, whilst negative Nino 3.4 value below -0.5^{o}C indicates the occurrence of La Nina (Tresnawati & Nuraini 2010; Susanto 2014), therefore based on Nino 3.4 value, it can be seen that there have been 13 SST anomalies globally in the central and eastern Pacific Ocean in the period of 1987-2017. According to Ashok & Yamagata (2009), SST anomalies in Nino 3.4 occur due to the weakening of the eastern wind movement whilst the western winds from the Pacific Ocean are increasing in speed. The strong western winds cause the mass of water vapor to travel to the Pacific Ocean so that the Indonesian region experiences drought (El Nino) and vice versa when the eastern winds increase in speed, the wind velocity of the western wind is weakened. The strong moving winds cause water masses to go to Indonesia, resulting in increased rainfall in Indonesia (La Nina). The year of the ENSO event based on the time and average value of Nino 3.4 is presented in Table 3.

Table 3

Year of ENSO occurrence based on duration and average NINO 3.4 value from 1987 to 2017

Year	*Period*	*Duration (month)*	*Average Nino 3.4*	*Description*
1987-1988	Jan 87-Jan 88	13	1.18^{o}C	Moderate El Nino
1988/1989	May 88-Apr 89	12	-1.57^{o}C	Strong La Nina
1991/1992	Oct 91-June 92	9	1.29^{o}C	Moderate El Nino
1994-1995	Oct 94-Feb 95	5	1.04^{o}C	Moderate El Nino
1995-1996	Sept 95-Oct 96	6	-0.68^{o}C	Weak La Nina
1997-1998	July 97-May 98	11	1.84^{o}C	Strong El Nino
1998-2000	Oct 98-July 00	24	-1.12^{o}C	Moderate La Nina
2002-2003	June 02-Feb 03	9	0.93^{o}C	Weak El Nino
2004-2005	Aug 04-Jan 05	6	0.66^{o}C	Weak El Nino
2007-2008	Aug 07-May 08	10	-1.23^{o}C	Moderate La Nina
2009/2010	Des 09-April 10	5	1.21^{o}C	Moderate El Nino
2010/2011	June 10-May 11	12	-1.21^{o}C	Moderate La Nina
2015/2016	Apr 15-Apr 16	13	1.79^{o}C	Strong El Nino

Source: Analyzed data.

ENSO intensity. Fluctuations in SOI and Nino 3.4 in 1987-2017 showed that El Nino did not occur one at a time but was often followed by La Nina. In the first decade of 1987-1996, the intensity of ENSO occurred in an interval of 4 to 7 years. El Nino is more common than La Nina in both on SOI indicators (4 times El Nino and 1 time La Nina) and Nino 3.4 indicators (3 times El Nino and 2 times La Nina). In the second decade of 1997-2006, the intensity of ENSO occurred in an interval of 2-4 years. El Nino occurred 6 times (3 times SOI indicator and 3 times Nino 3.4 indicator) and La Nina occurred 4 times (2 times SOI indicator and 1 time Nino 3.4 indicator). Then in the last decade of 2007-2017 the intensity of ENSO occurred at relatively shorter intervals of 1 to 3 years. In this decade La Nina is more common than El Nino on the SOI indicator (5 times La Nina and 3 times El Nino) and relatively similar to the Nino 3.4 indicator (2 times El Nino and 2 times La Nina). This shows that the frequency of the intensity of ENSO events is increasing in every decade.

The ENSO phenomenon plays a very important and globally influential on annual climate variations. For Indonesia, the influence of ENSO is felt in several regions. This is indicated by the amount of rainfall and sea surface temperature that is higher or lower than the normal limit in ENSO years compared to pre and post ENSO. According to Fox (2000) quoted by Irawan (2006), ENSO is a global climate anomaly, where El Nino symptoms are usually characterized by rising sea surface temperatures while La Nina is characterized by periodically decreasing sea surface temperatures in the Pacific region at intervals and increasing air pressure differences between Darwin and Tahiti. The results from Table 2, 3 and Figure 2, also reinforced by notes from Climate Prediction Center showed that there have been at least 22 times the El Nino phenomenon since 1950, three events took place with strong intensity in 1982/1983, 1987/1988 and 1997/1998 (Supari 2014). According to Bambang (2006), in one hundred twenty-five years from 1875 to 2000, El Nino has occurred at least about 35 times with moderate to strong intensity, and there has been a tendency to increase the frequency of El Nino in the last 20 years, namely in 1977/1978, 1982/1983, 1986 / 1987, 1991/92, 1993 and 1997/1998.

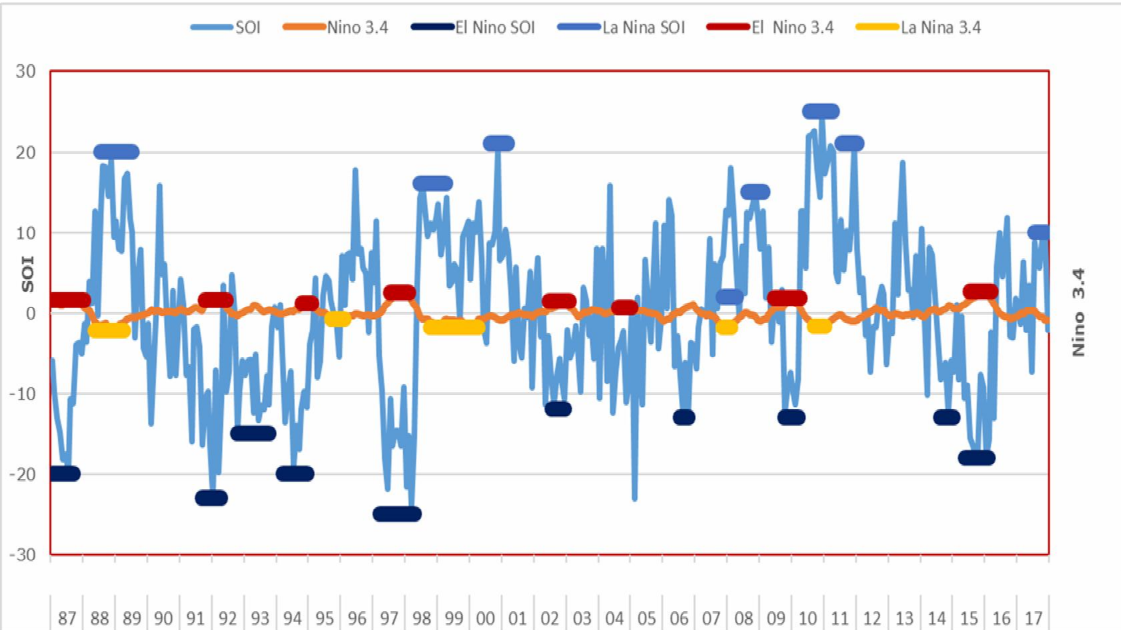


Figure 2. Fluctuations in SOI and Nino 3.4 values in the 1987-2017 period to see the events of the El Nino and La Nina phenomena.

Rainfall intensity. Morotai Island has a longer dry season each year than the rainy season. Monthly rainfall during 1987-2017 fluctuated from low to heavy category while the average annual rainfalls were fluctuated from low to normal category. Monthly rainfall above the normal category occurred in June 2001, 2006, 2015 and 2017 which were amounted to 314.5-665.4 mm, then in December 2003 and 2017 by 311.4-350 mm, in April 2008 and 2013 by 350-364 mm and in January and February 2009 by 332.8-472.6 mm. While the lowest rainfall below normal occurred in November 1991 (7.3 mm), December 1999 (9.8 mm), October 2002 and 2006 (1.2 mm and 3.2 mm respectively) and in September 2009 and 2015 (2 mm and 8 mm respectively). The intensity of average annual rainfall below normal occurred in 1987-1990 (60.3-81.89 mm), in 1994-2000 (36.98-89.61 mm), in 2002 (91.83 mm), in 2005 (93.46 mm) and 2011 (84.06 mm). This decrease in annual rainfall below normal indicates that summer was relatively high on Morotai Island in those years. The intensity of average annual rainfall which is relatively high but still categorized as normal occurred in 1991-1993 (112.08-1 41.93 mm), 2001 (156.4 mm), in 2003-2004 (118.46-161.35 mm), in 2006-2010 (140.88-202.58 mm) and in 2012-2017 (155.58-236.52 mm). The intensity of average annual rainfall on Morotai Island is presented in Figure 3a.

In Figure 3b, the peak of monthly rainfall occurred in June with an average rainfall of 159.2 mm month^{-1} and the lowest rainfall occurred in October with an average monthly rainfall of 89.5 mm month^{-1}. The rainy season occurred in November to January (NDJ) and May-June (MJ). While the dry season occurred in February to April (FMA) and July to October (JASO). Based on the results of the analysis of average monthly and annual rainfall, Morotai Island is included in the category of normal rainfall (BMKG Indonesia).

There is a correlation between the decrease in rainfall on Morotai Island with ENSO (SOI and Nino 3.4 indicators) in the Pacific Ocean equator (Tables 2, 3 and Figure 3). In 1987/1988 strong El Nino occurred in Pacific Ocean equator from January to September with an average SOI value of -13.47 and moderate El Nino occurred in the East and Central Pacific Ocean with an average Nino 3.4 value of 1.18^{o}C for 13 months (January-January), then the Morotai Island rainfall in the same month decreased below normal by 66.75-96.30 mm. Likewise in 1994/1995 strong El Nino occurred with an average SOI value of -13.87 for 7 months (July-September) and moderate El Nino occurred with an average Nino 3.4 value of 1.04^{o}C for 5 months (October-February), the Morotai Island rainfall in the same month also decreased below normal by 65.2-96.25 mm. Next, in 1997/1998, strong El Nino occurred with an average SOI value of -16.3 for 13 months (March-April) and strong El Nino occurred with an average Nino 3.4 value of 1.84^{o}C for 11 months (July-May), the rainfall in Morotai Island decreased below normal from January 1997 to December 1998 of 17.4 to 94.9 mm. Then in 2002 and 2004/2005, weak El Nino occurred in the equatorial Pacific Ocean with an average SOI value of -8.67 for 6 months (July-December), and weak-moderate El Nino occurred in the Central and Eastern Pacific Ocean with average Nino 3.4 value of 0.66-0.93^{o}C for 6-9 months (July-May, August-January), the Morotai Island rainfall was decreased below normal by 38.4 - 95.6 mm.

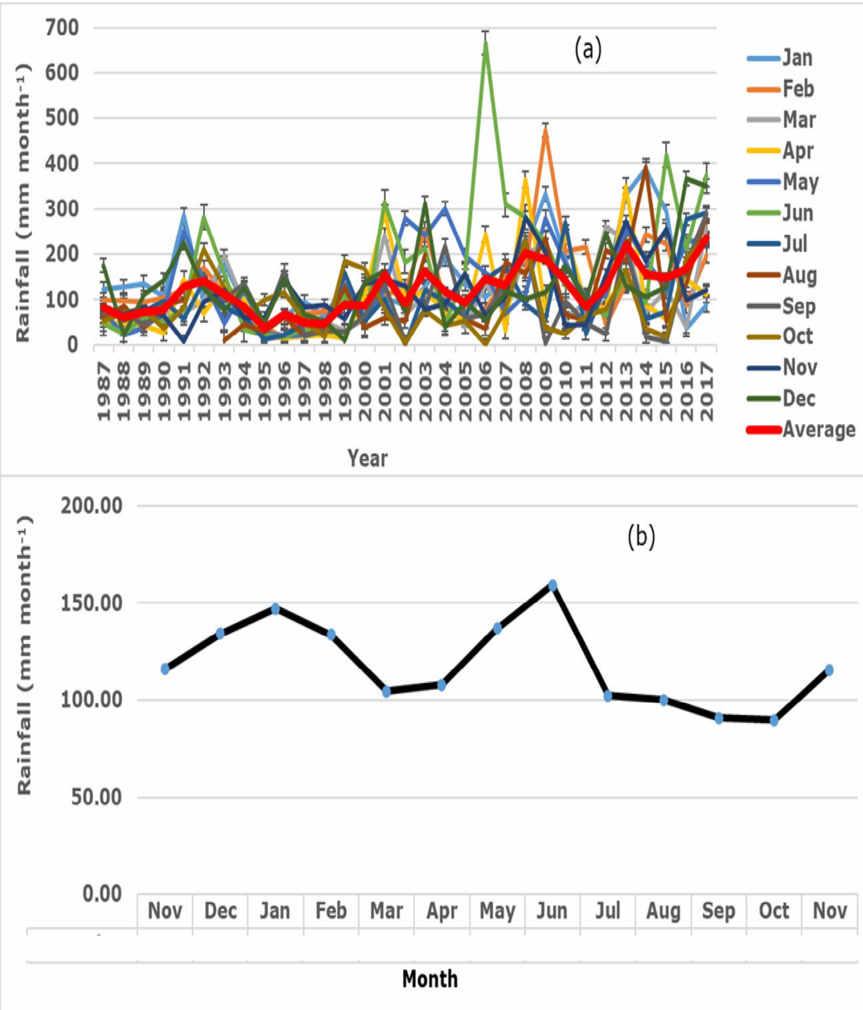


Figure 3. The intensity and rainfall pattern of Morotai Island for the period 1987-2017 based on annual averages (a) and monthly averages (b).

Increased rainfall, which occurred in 2000/2001, 2007/2008, 2008/2009, 2010/2011 and 2017 in Morotai Island shows a connection with La Nina in the equatorial Pacific Ocean (Table 2, 3 and Figure 3). In 2000/2001, weak La Nina occurred with an average SOI value of +9.81 for 8 months (August-March), so Morotai Island rainfall at the same month experienced fluctuations from low to normal (37.9-242.3 mm). Then in 2007-2008, strong La Nina occurred with an average SOI value of +10.55 for 7 months (October-April) and an average Nino 3.4 value of 1.23^{o}C (moderate La Nina) for 10 months (August-May), the Morotai Island rainfall at the same month increased from a low category of 77.3 mm in October to a heavy category of 364.5 mm in April. In 2008-2009, strong La Nina occurred with an average SOI value of +12.10 for 7 months (August-February), so Morotai Island rainfall in the same month increased from normal category by 157.1 mm in August to heavy category by 472.6 mm in February. Furthermore, in 2010-2011, strong La Nina occurred with an average SOI value of +20.44 for 10 months (July-April) and an average Nino 3.4 value of 1.21^{o}C (moderate La Nina) for 12 months (June-May), however the Morotai Island rainfall in the same month fluctuated from low to normal (43.5-268 mm). Then in 2017, La Nina occurred in the Pacific Ocean equator with an average SOI value of +8.04 for 5 months (July-November), then the Morotai Island rainfall at the same month increased from the normal category by 290 mm in October and became heavy category by 350 mm in December. According to Hidayat & Ando (2014), ENSO has a role in the annual climate and will cause changes in rainfall in some area. El Nino is usually followed by a decrease in rainfall and La Nina is followed by an increase in rainfall in Indonesia (Aldrian 2008; Fox 2010; As-syakur 2010; Yananto & Sibarani 2016).

Rainfall pattern*.* Morotai Island has a relatively different monthly and annual rainfall pattern compared to other regions in Indonesia (Aldrian & Susanto 2003). This difference shows the unique characteristics of Morotai Island. According to Aldrian & Susanto (2003) climate types in the Indonesian region consist of 3 regions and 3 main patterns of annual rainfall. Region A (monsoon), region B (equatorial) and region C (local) have 3 main patterns namely monsoonal patterns, equatorial patterns and local patterns. Monsoonal pattern is characterized by a type of rainfall that is unimodal (one peak of the rainy season) where in June, July and August (JJA) occurs the dry season, while for December, January and February (DJF) is the rainy season. Equatorial pattern is characterized by the type of rainfall in the form of bimodal (two rain peaks) which usually occurs around March and October (MO) or during the equinox. The local pattern is characterized by the unimodal rain pattern (one rain peak) in June-July (JJ), but with the opposite shape with monsoon rain type.

Morotai Island has anomalies from all three regions and annual rainfall patterns because it has a climate type with 2 annual rainfall patterns, namely monsoonal patterns in region A and local patterns in region C. Rain peak occurs in May-June with an average rainfall of 136, 89-159.2 mm month^{-1} following the local pattern in region C while the rain peak in December, January, February (DJF) with an average rainfall of 133.47-146.94 mm month^{-1} following the monsoonal pattern in region C. The dry peak occurs in September-October reaches 89.52-93.79 mm month^{-1} following the local pattern. This shows that the climate in Morotai Island Regency, besides being influenced by Monsoon (Asia-Australia) and the Indonesian Crossflow (ARLINDO), is also influenced by the topography and physiography of Morotai Island itself. According to Nabilah et al (2017), that variations in rainfall are influenced by local factors, land breezes and sea breezes, convection activities, the direction of air flow on the surface, variations in the distribution of land and sea flow and global atmospheric pattern. Furthermore according to Tjasyono (1999), complex topographic influences such as valley breezes, mountain breezes, land breezes, sea breezes and physiographic conditions such as latitude, altitude, wind patterns (trade and monsoon winds), land and water landscape distribution, and mountains play an important role and influential for the formation and diversity of weather and climate in Indonesian territory. Therefore, the unique pattern of rainfall in the Morotai Island district is thought to be influenced by the characteristics of these factors.

The results of regression and correlation analysis showed that there is no significant correlation between ENSO and rainfall (SOI indicator) on Morotai Island which can be seen from $r = 0.231$ and p-value $= 0.076 < 0.1$. However, correlation between

ENSO (nino indicator 3.4) and rainfall showed a significant and relatively strong relationship which can be seen from the value of r = -0.401 and p-value = 0.019 < 0.05, (Table 4).

Table 4
Correlation and significance of ENSO on rainfall and temperature using SOI and NINO 3.4 indicators in 2013-2017

Climate variable	*ENSO*			
	SOI		*Nino 3.4*	
	r	*p-value*	*r*	*p-value*
Rainfall (mm)	0.231	0.076*	-0.401	0.019**
Air temperature (^oC)	-0.308	0.017**	0.540	0.000**

* significant < 0.1; ** significant < 0.05.

The scatter plot results showed the significance of a positive pattern correlation between SOI and rainfall (Figure 4a). The higher the SOI in the Pacific Ocean equator, the higher the rainfall on Morotai Island. But it is inversely proportional between rainfall and Nino 3.4 (Figure 4b). The significance of the negative pattern relationship between rainfall and Nino 3.4 showed that the higher the Nino 3.4 index in the East and Central Pacific Ocean, the lower the rainfall on Morotai Island.

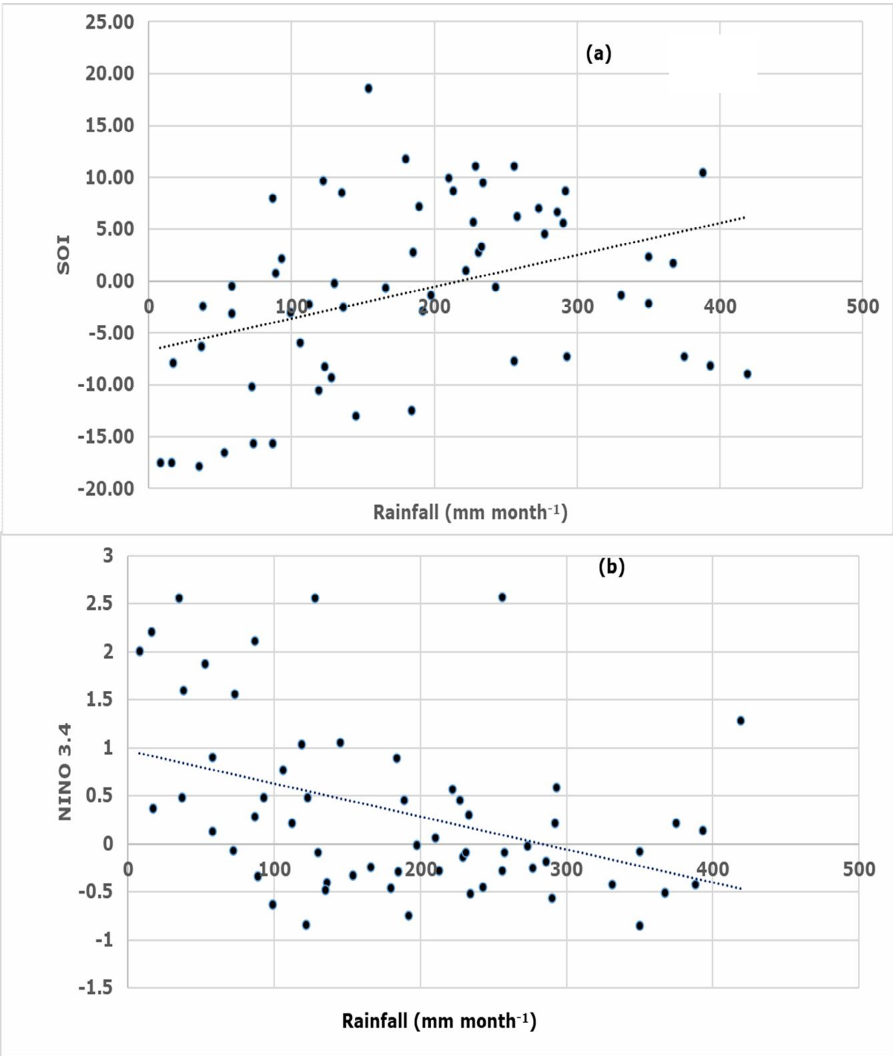
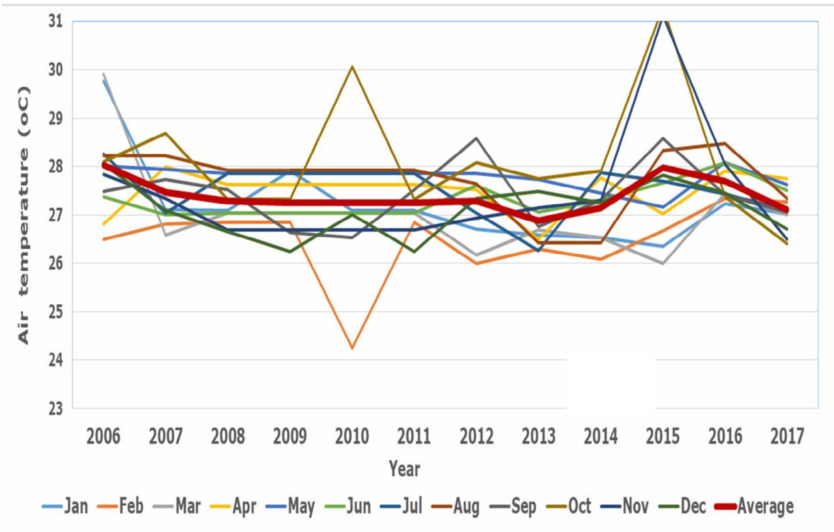


Figure 4. Correlation between ENSO and Rainfall Based on SOI value (a) and Nino 3.4 value (b).

Air temperature. Air temperatures in Morotai Island were fluctuated every month during the period of 2006-2017. The highest average annual air temperatures occurred in 2006, 2012 and 2015. While the lowest average annual temperatures occurred in 2013 and 2017 (Figure 5a).

The role of ENSO toward the changes in the annual temperature of Morotai Island, in the period 2006-2017, is related to the year of ENSO events in the equatorial Pacific Ocean (Tables 2 and 3). The result showed that there is a correlation between the increase in air temperature on Morotai Island with strong El Nino event in the Pacific Ocean equator in 2006 and 2015 and the decrease in air temperature with strong La Nina event in 2010. According to Mulyana (2002a, b) and Yananto & Sibarani (2016), an increase in air temperature in Indonesia will be followed by a decrease in rainfall due to El Nino occurrence in the central and eastern Pacific Ocean whereas a decrease in temperature turns to cold usually stimulates an increase in rainfall in Indonesia due to La Nina occurrence in the eastern and central Pacific Ocean.

Air temperature in Morotai Island fluctuated every month between 24.25 to 31.28^{o}C during the period of 2006-2017. The highest average air temperature occurred in October by 31.2^{o}C and the lowest occurred in February by 24.25^{o}C. Increases in Morotai Island temperature occurred in March to May (MAM), June to August (JJA) and September-October (SO). While a decrease in average temperatures occurred in February, June, September and December (Figure 5b).



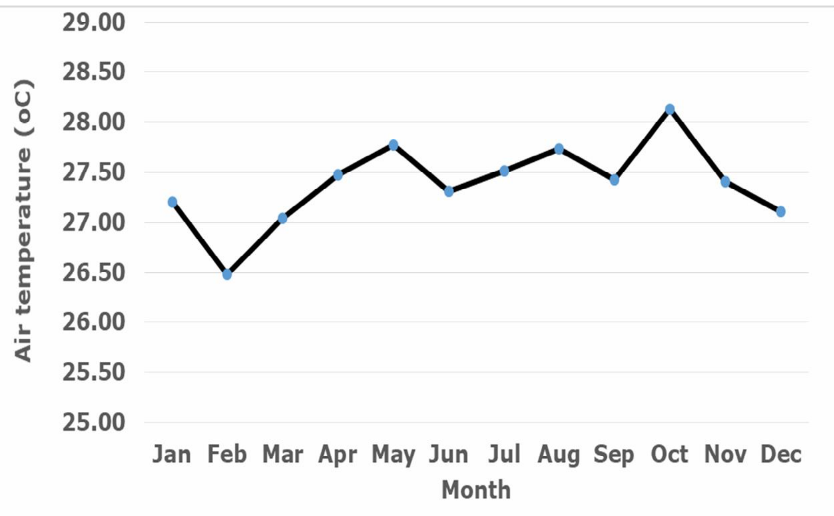
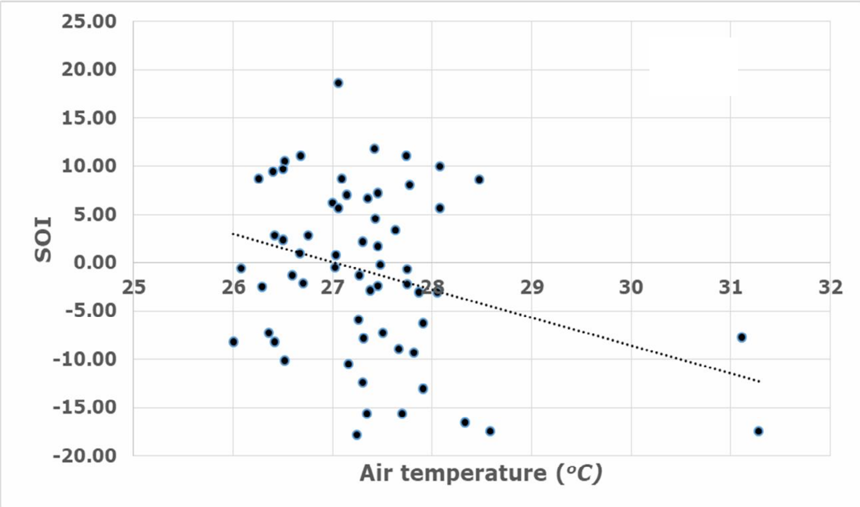


Figure 5. The temperature of Morotai Island in the period of 2006-2017 based on annual average (a) and monthly average temperature (b).

The results of regression and correlation analysis between SOI and temperature changes in Morotai Island showed a weak correlation which can be seen from the r-SOI value = 0.038 and p-value = 0.017 < 0.05 (Table 4). On the contrary, the correlation and significance between ENSO Nino 3.4 indicator and air temperature showed a relatively strong correlation which can be seen from r-value = 0.540 and p-value = 0.000 < 0.05 (Table 4).

The result of scatter plot in Figure 6a showed a significance of the negative patterned relationship between SOI and air temperature. This means that the higher the SOI in the equatorial Pacific Ocean the lower the air temperature on Morotai Island. But it is inversely proportional between Nino 3.4 and air temperature (Figure 6b). The significance of a positive patterned relationship between Nino 3.4 and air temperature indicates the higher Nino 3.4 in the east and central Pacific Ocean, the lower the air temperature on Morotai Island.



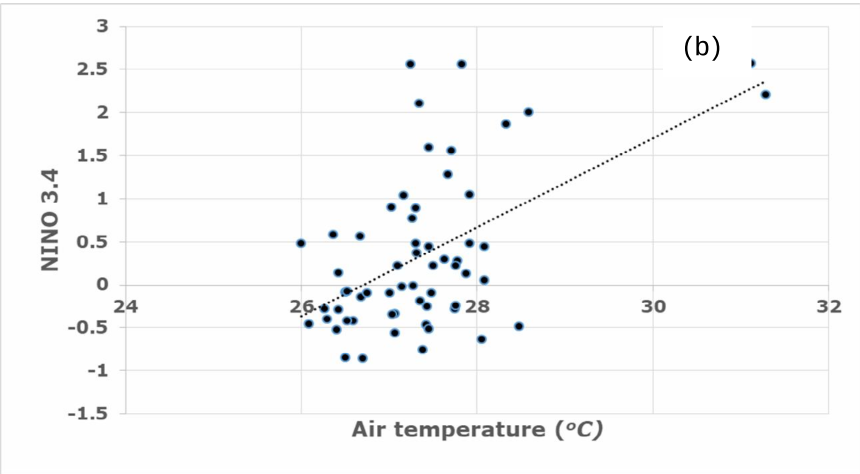


Figure 6. Correlation between ENSO and air temperature based on SOI (a) and Nino 3.4 values indicators (b).

Conclusions. There have been ENSO occurrences for 13 to 18 times in the Pacific Ocean equator by using SOI and NINO 3.4 indicators for three decades of the 1987-2017 period. Rainfall in Morotai Island is categorized as normal rainfall with a climate with 2 annual rainfall patterns, namely monsoonal patterns and local patterns in region A and region C. This difference in pattern is thought to be influenced by not only the West Monsoon and the Indonesian cross currents but also influenced by the topography and physiography conditions of the Morotai Island region. ENSO (El Nino and La Nina) on the SOI indicator does not affect the regional climate (rainfall and air temperature) on Morotai Island but does affect the Nino indicator 3.4 with a fairly strong correlation.

Acknowledgements. Special thanks to the the Ministry of Research and Technology and LPDP for funding this research.

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Received: 14 January 2020. Accepted: 28 March 2020. Published online: 12 May 2020.
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How to cite this article:
Muksin D., Simbolon D., Wiyono E. S., Sondita M. F. A., 2020 Effect of global climate (ENSO) on regional climate (rainfall and air temperature) in the Morotai Island region. AES Bioflux 12(2):97-109.