

The effect of ENSO to the variability of sea surface height in western Pacific Ocean and eastern Indian Ocean and its connectivity to the Indonesia Throughflow (ITF)

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Abstract. The differences of altimetry in the Pacific Ocean and the Indian Ocean causes the Indonesia Throughflow or commonly called ITF. The altimetry will have variation when the ENSO (El Nino Southern Oscillation) occur. The altimetry data from AVISO is used to find out how much the influence of ENSO to variations of that indicator in particular the altimetry difference between the western Pacific Ocean to the eastern Indian Ocean. When El Nino occurred, the altimetry in the western Pacific Ocean will be lower than the altimetry of eastern Indian Ocean while the opposite condition occurs when the La Nina happened that the differences of altimetry in western Pacific Ocean higher than the altimetry in eastern Indian Ocean. These differences will affect the transport of ITF.

1. Introduction

ENSO (El Nino Southern oscillation) is phenomenon that influence climate variability takes place in Indonesia, the equatorial Pacific and the world [1]. ENSO phenomenon consists of two events as El Nino and La Nina. El Nino occurs when an increase in sea surface temperatures in the eastern and central Pacific Ocean associated with decreased rainfall in Indonesia while when La Niña occurs indicates the opposite condition [2, 3]. The phenomenon of El Niño and La Niña can be learned from a number of indicators such as sea surface temperature anomalies, the southern oscillation index, sea surface height, and Indonesia Throughflow or commonly called the ITF [1].

El Nino and La Nina is a phenomenon in the equatorial Pacific Ocean characterized by a five consecutive 3-month running mean of sea surface temperature (SST) anomalies in the Niño 3.4 region that is above (below) the threshold of +0.5°C (-0.5°C). This standard of measure is known as the Oceanic Niño Index (<https://www.ncdc.noaa.gov/teleconnections/ens0/indicators/sst.php>).



Indonesia Throughflow (ITF) is a system of ocean circulation in Indonesian waters where there is a current path that brings water masses from the Pacific Ocean to the Indian Ocean [4]. These currents occur due to differences in sea surface height between the Pacific Ocean and the Indian Ocean [5]. The ITF is mainly caused by differences in sea level between the Pacific Ocean and the Indian Ocean, namely the inner surface of the tropical western Pacific Ocean is higher than in the eastern Indian Ocean, resulting in a pressure gradient resulting current to flow from the Pacific to the Indian Ocean [4]. Indicators to assess the ITF is important to observe the sea surface heights in the Pacific and Indian Ocean as well as the variability of sea surface temperature in Indonesian waters [1].

ITF is an important part of the Global Conveyor Belt which connects the Pacific and Indian Oceans in the tropical zone [5]. Has many research projects on the ITF since a few hundred years ago [6]. Most publications on the ITF has investigated the variability of volume and heat flux at different time scales of decades to inter-annual and seasonal ranges as well as the phenomenon of Indian Ocean Dipole (IOD) [7] and the El Niño Southern Oscillation (ENSO) [8, 9].

Several studies have been conducted to identify the characteristics of some waters in Indonesia which is traversed by the ITF at the time of occurrence of El Niño and La Niña. The phenomenon of El Niño and La Niña effect on the ITF transport through the Strait of Lifamatola which is one of the eastern part of the ITF which has a threshold at a depth of approximately 1940 m to represent the occurrence of El Niño and La Niña [10]. The other studies in the Timor Sea about the weather phenomenon El Niño and La Niña impact on transport ITF shown variation of parameters such as sea temperature, salinity and ITF transport [4]. Sea surface height in the Pacific Ocean and the Indian Ocean is an important indicator in assessing the ITF [1]. This study will examine how different sea surface heights in the western Pacific and eastern Indian Ocean during El Niño and La Niña.

Research on the effects of El Niño and La Niña on parameters ITF has been conducted by several researchers. However, in this study focuses on sea surface height value differences between the western Pacific Ocean to the Indian Ocean at the time of the eastern part of El Niño and La Niña.

2. Data and methodology

Sea surface height data used in this study come from <http://www.aviso.sea-surface-height.fr/en/data/products.html> [11]. The data obtained are daily sea surface height data with a resolution of $0.25^\circ \times 0.25^\circ$ to the length of the data is taken from the January 1993 to December 2015. The selected study area is the region of the western Pacific Ocean and the Indian Ocean to the east. The locations are at $125^\circ - 145^\circ \text{ E}$ and $10^\circ - 0^\circ \text{ N}$ to the Pacific Ocean to the west and $110^\circ - 130^\circ \text{ E}$ and $10^\circ - 20^\circ \text{ S}$ for the eastern part of the Indian Ocean region (figure 1) [12]. The location determination is based on the theory of the ITF stating that the ITF attributed to differences in sea surface height between the Pacific Ocean and the Indian Ocean [5].

To read the sea surface height data have been obtained from AVISO use ODV 4.7.8 software (Ocean Data View 4.7.8). The data is then converted into a text format that is then processed using Microsoft Excel. Processing data using Microsoft Excel is made to change the daily sea surface height data into monthly sea surface height data by way of averaging the daily data. Having obtained monthly sea surface height data, calculated the difference between sea level in the western Pacific Ocean on the sea level in the eastern part of the Indian Ocean. The calculation of the height difference is accomplished by reducing the value of sea surface height in the western Pacific Ocean with a value of sea surface height in the eastern Indian Ocean. The reason for this way is based on the theory that the ITF is caused by the difference in sea level between the Pacific Ocean and the Indian Ocean where the inner surface of the tropical Pacific Ocean West is higher than in the Indian Ocean in the east [4].

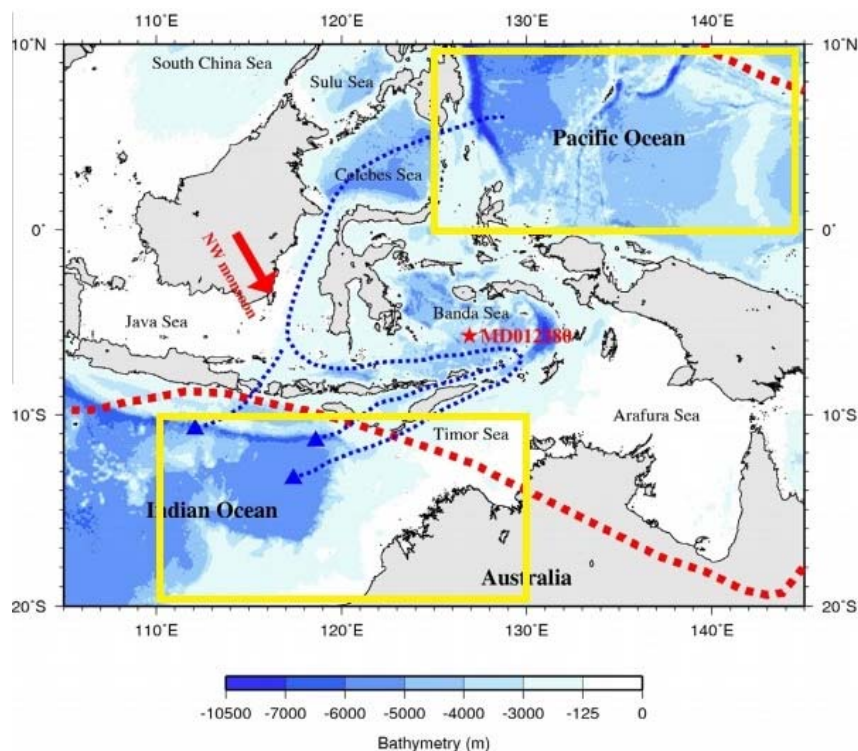


Figure 1. Research location (Source: Huang *et al.*, 2011)

To determine the condition of El Nino and La Nina, we used the sea surface temperature anomalies in the Nino 3.4 region. The anomaly data obtained from <http://www.cpc.ncep.noaa.gov>. If the value of Nino 3.4 SST anomalies greater than 0.5, then the condition is indicative of the occurrence of the El Nino phenomenon whereas if Nino 3.4 SST anomaly values smaller than -0.5 then indicate the occurrence of the phenomenon of La Nina. Furthermore, the period of time which indicates the occurrence of ENSO phenomenon will be compared against sea surface height conditions in both areas where he did research. Thus, it can be seen sea surface height variation among the sites to ENSO events.

3. Result

The calculation results of average difference of altimetry in the western Pacific Ocean region and Indian Ocean east part shows the variation of the ENSO phenomenon. At the time of the sea surface temperature anomaly Nino 3.4 higher value of 0.5 indicating the occurrence of El Nino, sea surface height difference between the eastern Pacific Ocean and the Indian Ocean east section indicates a negative value. It shows that in the event of El Nino conditions in the Pacific Ocean sea surface height western part is lower than it would be in the eastern part of the Indian Ocean. The opposite occurs when sea surface temperature anomaly Nino 3.4 worth less than 0.5 indicating the occurrence of La Nina, sea surface height difference between the eastern Pacific Ocean and the Indian Ocean east section indicates a negative value. It shows that in the event of El Nino conditions in the Pacific Ocean sea surface height western part is lower than it would be in the eastern part of the Indian Ocean.

Table 1. The monthly difference of sea surface height to ENSO phenomena

Waktu	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agu	Sep	Okt	Nov	Des
1993	-0.06	0.00	-0.02	-0.10	-0.08	-0.06	-0.06	-0.03	-0.02	0.01	-0.01	-0.07
1994	-0.09	-0.05	0.00	-0.03	-0.05	-0.02	-0.01	0.04	0.01	0.05	0.03	-0.05
1995	-0.08	-0.08	-0.03	-0.03	-0.03	-0.01	0.03	0.06	0.06	0.05	0.05	0.01
1996	-0.03	-0.02	-0.02	0.02	-0.03	-0.04	-0.01	0.01	0.04	0.03	0.03	-0.03
1997	-0.10	-0.06	-0.09	-0.07	-0.10	-0.08	-0.07	-0.04	-0.05	-0.06	-0.07	-0.10
1998	-0.09	-0.07	-0.04	0.00	0.01	0.03	0.01	0.04	0.06	0.08	0.04	-0.01
1999	0.01	0.05	0.07	0.04	0.00	0.00	0.04	0.05	0.07	0.10	0.04	0.00
2000	0.00	0.03	0.04	0.00	-0.03	-0.01	0.02	0.03	0.05	0.03	0.01	-0.03
2001	-0.01	0.03	0.02	0.00	-0.02	-0.01	-0.02	0.01	0.04	0.05	0.01	-0.05
2002	-0.09	-0.03	-0.07	-0.06	-0.06	-0.04	-0.03	-0.04	-0.05	-0.07	-0.10	-0.14
2003	-0.12	-0.11	-0.03	-0.01	-0.01	-0.05	-0.02	0.00	0.02	0.06	-0.01	-0.04
2004	-0.04	0.00	-0.02	-0.06	-0.08	-0.06	-0.05	-0.01	0.04	0.03	0.02	-0.03
2005	-0.05	-0.05	-0.02	-0.03	-0.02	-0.01	0.01	0.01	0.04	0.03	0.01	-0.03
2006	-0.02	0.01	0.05	0.03	0.01	0.02	0.01	0.01	0.02	0.03	-0.01	-0.04
2007	-0.04	-0.05	-0.02	-0.04	-0.05	-0.01	0.03	0.05	0.08	0.11	0.09	0.06
2008	0.07	0.10	0.08	0.02	-0.03	0.00	0.05	0.09	0.08	0.05	0.03	0.05
2009	0.02	0.03	0.02	0.01	-0.03	-0.01	-0.01	0.01	0.03	-0.01	-0.05	-0.11
2010	-0.12	-0.11	-0.06	-0.01	0.01	0.04	0.04	0.04	0.06	0.02	0.03	0.00
2011	0.01	0.01	0.01	-0.04	-0.04	-0.04	-0.02	0.02	0.09	0.10	0.07	0.03
2012	0.02	0.00	0.03	-0.03	-0.02	0.02	0.04	0.08	0.07	0.06	0.00	0.00
2013	0.01	-0.01	0.02	0.05	0.02	0.00	0.00	0.02	0.05	0.04	-0.01	0.01
2014	-0.02	-0.03	-0.08	-0.09	-0.10	-0.07	-0.04	-0.02	0.00	0.01	-0.01	-0.05
2015	-0.08	-0.13	-0.12	-0.11	-0.13	-0.14	-0.11	-0.11	-0.07	-0.07	-0.09	-0.13
Rata-rata	-0.04	-0.02	-0.01	-0.02	-0.04	-0.02	-0.01	0.01	0.03	0.03	0.00	-0.03

Note: Red (El Nino) and Blue (La Nina)

Presented in a comparison chart between Nino 3.4 SST anomaly for differences sea surface height, can be seen the opposite pattern between these two parameters. When Nino 3.4 SST anomaly is positive then the difference between sea surface height is negative, whereas when the anomaly Nino 3.4 is negative then the difference between sea surface height be a positive value

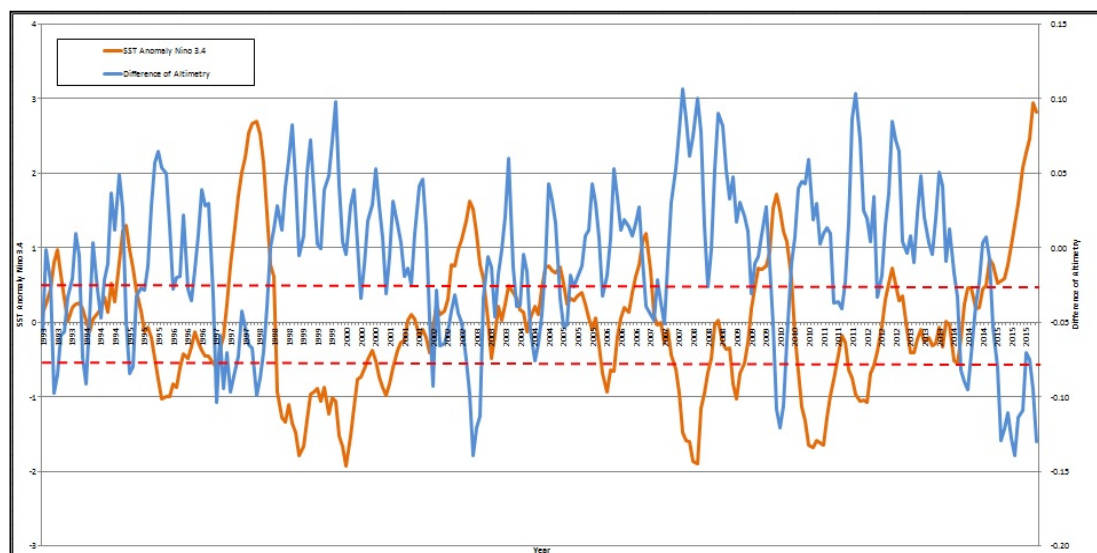


Figure 2. The comparison table between SST anomaly Nino 3.4 and difference of sea surface height (western Pacific Ocean and eastern Indian Ocean)

If it compared to the average value of the difference between sea surface height during the years 1993 - 2015 against the average difference sea surface height during El Nino and La Nina clearly indicates that at the time of El Nino in the western Pacific Ocean will be lower than the Indian Ocean to the east and conditions the opposite occurs during La Nina.

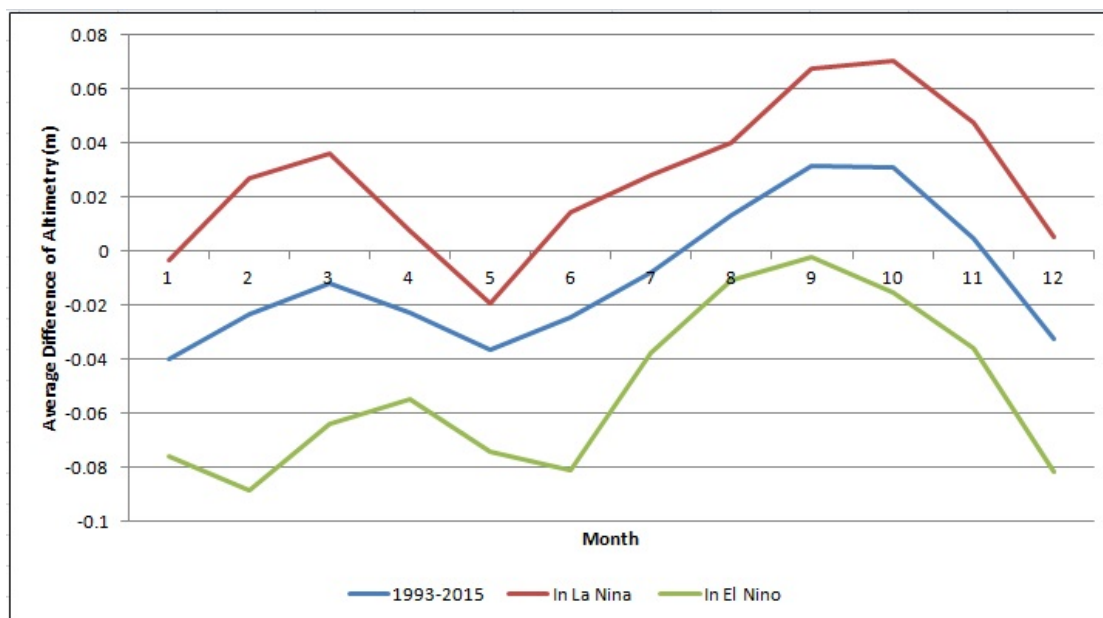


Figure 3. The comparison table between average difference of sea surface height in 1993-2015, El Nino, and La Nina

4. Discussion

From the calculation results obtained, shows that the sea level or sea surface height in the western Pacific Ocean and the Indian Ocean east section varies with ENSO events. In previous references mentioned by Hasanuddin (1998) [4] that the western Pacific ocean are higher than the Indian Ocean there are differences in the eastern part of the data processing is performed in this study. Sea surface height altitude in the western Pacific Ocean can also be lower than the height of sea surface height in the eastern Indian Ocean.

The characteristic of ITF itself throughout the current year is always moving from the Pacific Ocean to the Indian Ocean [4] if it is associated with the calculated variation sea surface height in both locations, will be related to the speed of flow and transport ITF itself. In a study conducted Safitri the ITF in 2012 in the Timor Sea, showed that when La Nina transport ITF will be higher than during El Nino. Similar to Safitri's research in 2012, previous studies during a La Nina debit ITF transport will be larger. If it is associated with the difference between sea surface height results during ENSO then there is a match against former research.

In the event of La Nina sea surface height in the western Pacific Ocean will be higher than the sea surface height in the eastern Indian Ocean. Sea surface height higher in the north will cause a larger gradient for supporting normal conditions ITF itself that moves from the Pacific Ocean to the Indian Ocean to transport ITF becoming stronger. Whereas in the event of El Nino sea surface height in the western Pacific Ocean become leih low compared with sea surface height in the eastern part of the Indian Ocean thus undermining the normal conditions of the ITF itself that causes the transport ITF becoming weaker.

5. Conclusion

ENSO effect on sea surface height variation in the western Pacific Ocean and the Indian Ocean east section which relate to the ITF transport. The size of the ITF transport associated with sea surface height conditions at both sites were impacted strengthen or weaken the normal conditions ITF. So, it makes a pressure gradient variations that cause variations in transport ITF.

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