Warm Pool Fluctuations Due to The Effect of ENSO in West Pacific and Indonesia Seas (Study Case El-Nino 2015)

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Abstract. Warm pool in Pacific Ocean is a good subject to study ocean dynamics and atmospheric conditions in the Pacific Ocean. Warm pool is defined as a water mass with temperatures above 29°C located in the Pacific Ocean. Warm pool is very influenced by the dynamics of both ocean and atmosphere conditions, which is primarily an El-Nino Southern Oscillation (ENSO) phenomenon. The last ENSO phenomenon occurred in 2015, the very strong El-Nino, which is a fairly severe event comparable to El-Nino 1998. Thus, this research was conducted with the aim of identifying the characteristics of warm pool in the western Pacific ocean and Indonesian waters along with their changes due to the El-Nino phenomenon in 2015. To be able to understand the warm pool characteristic of warm pool, this research use 3 dimensional hydrodynamic model from Regional Ocean Model System (ROMS). Then, the model results are verified using 2 buoy data of TAO / TRITON and obtained each RMSE 0.368 and 0.654 and correlation 0.843 and 0.81. From this research, we can conclude that there is a shrinkage extents of warm pool surface profile when the El-Nino event occurs in 2015 compared to normal condition. When normal conditions, warm pool is located from the equator up to 10°LU and disappears when the peak El-Nino occurs the warm pool only on the equatorial area. In addition, from vertical profiles warm pool can reach until 50m depth when the normal condition then disapperars when El-Nino peak occurs.

1. Introduction

Warm pool in Pacific Ocean has been a subject of research for many years because it’s a good subject to examine the dynamics of ocean and atmospheric interaction in the Pacific Ocean [see reviews by Picaut et al. (1996), Ilahude et al. (1999), and Santoso et al. (2011)]. Warm pool is defined as a warm water mass that located in the Pacific Ocean with temperatures above 29°C [1]. The warm pool will be strongly influenced by meteorology-oceanography condition in the Pacific Ocean itself. However, the center of warm pool will be located permanently between 10°N and 10°S and around 170°E [2].

Warmpool in the Pacific Ocean is often associated with El-Nino Southern Oscillation (ENSO) phenomenon as in ENSO 1986-1988 or in 1992-1998 [3]. ENSO itself has two distinct condition known as El-Nino and La-Nina. The warm pool will oscillate West-East direction in Pacific Ocean due to ENSO phenomenon. Water mass of warm pool will be transferred by Indonesia Throughflow to Indonesian water and influenced it that proved by interannual temperature anomaly with cycle periods around 4-7 years in Indonesia Seas [4]. This periods are closely correlated with ENSO phenomenon in...
Pacific Seas. Last ENSO occurred at 2015 that classified as “very high El-Nino” like ENSO at 1998. So this research was held to identify the fluctuation of warm pool due to El-Nino 2015 in West Pacific and Indonesian Seas.

2. Research methods
This method of this research is 3 dimensional (3D) numerical modelling using Regional Ocean Modeling System (ROMS), ROMS-Rutgers versions. Arakawa C grid system and sigma coordinat are applied in this model [5]. This hydrodynamics model include the equation of momentum, continuity, and also temperature and salinity transport [6]. The domain model in this research is around West Pacific and Indonesian Seas, exactly at 20° Northern Latitude (NL) - 15° Southern Latitude (SL), 90° - 150° East Longitude (EL) (Fig. 1).

![Figure 1. Domain area of modelling](image)

The data used into the model include bathymetry and atmospheric forcing datas. The bathymetry data used Shuttle Radar Topography Mission (SRTM) with resolution 15 seconds (15’’). Furthermore, this model also used atmospheric forcing such as momentum flux from wind, heat flux, atmospheric pressure, and specified humidity. The detail of this atmospheric forcing are presented in Table 1.

| Component            | Units | Resolution | Source  |
|----------------------|-------|------------|---------|
| Heat Flux            | Watt  | 2.5° x 2.5°| NCEP    |
| Wind Forcing         | m/s   | 0.5° x 0.5°| NOGAPS  |
| Air Temperature      | °K    | 1.875° x 1.875° | NCEP    |
| Specified Humidity   | Kg/kg | 2.5° x 2.5° | NCEP    |
| Atmospheric Pressure | Pascal| 2.5° x 2.5° | ECMWF   |

3. Results and Discussion
ROMS model was verified by comparing model results with measurement data obtained from Tropical Atmospheric Ocean (TAO/TRITON) buoys in the Pacific Ocean. The buoy locations are described in Fig. 2, precisely at 137°EL 5°NL and 137°EL 8°NL, respectively. The verified data are sea surface temperature (SST) from January 1st on 2014 to March 31st on 2016 between ROMS model data and buoy data. The selection of these buoys is based on the location and the data availability.
Figure 2. Tropical Atmospheric Ocean (TAO/TRITON) buoys location

The SST values between ROMS model results and TAO / TRITON buoy data in both locations is relatively same (Fig. 3). This statement proven by the RMSE values are 0.368°C in buoy 1 and 0.654°C in buoy 2. Furthermore, the correlation between the ROMS model results and TAO / TRITON buoy data also shows good results around 0.843 on buoy 1 and 0.81 on buoy 2. From those values we can conclude that the model is good enough to use in this research.

Figure 3. The comparison values of SST from model results with buoy TAO/TRITON data in 2 different location

To assess the effect of ENSO phenomenon on the warm pool, we compare the warm pool conditions between normal and El-Nino stage/conditions with Nino Index (Fig 4). This Nino Index obtained from SST anomalies in Nino 3.4 region at Pacific Ocean. In January 2014, SST anomalies are -0.25°C then increase in July 2014 to 0.5°C. This values indicate the Pacific Ocean were in the normal stage, neither El-Nino nor La-Nina occurred. In the few months before January 2015, the SST anomaly increase to 1°C and classified as moderate El-Nino. Then, the trend is increase continuously and become strong El-Nino in July 2015 and peaked on January 2016 where there was a very strong El-Nino with an SST anomaly of 2.5°C.
Figure 4. Nino 3.4 Index (Adapted from http://www.bom.gov.au/climate/enso/indices.shtml?bookmark=nino3.4)

From Nino 3.4 index (Fig. 4), we know that El-Nino occurred in 2014-2016. Then, we compare the characteristics of warm pool when normal ENSO (July 1st 2014), strong El-Nino (July 1st 2015), and very strong El-Nino (January 1st 2016). In normal ENSO conditions, sea surface temperature in the western Pacific Ocean is very high, exceed to 30°C (Fig. 5). This high SST areas are covering high latitudes regions (around 20°NL) due to the sun's position at northern hemisphere. However, not all regions with high SST can be defined as warm pools. Wrytki (1989) argues that warm pools are not involve high latitude regions and only in the equatorial area, around 10°NL to 10°SL. So, the high SST in high latitudes are strongly influenced by the position of the sun and cannot be defined as a warm pool.

Figure 5. Sea Surface Temperature at July 1st 2014
From Fig. 5, it can be seen that there is a very wide area of warm pool (black line around West Pacific Seas). This condition also followed by the thickness of warm pool column which can be seen through the vertical profile of temperature at 2.5°LU on July 1st 2014 (Fig. 6). The water column of warm pool had a uniform depth around 25-40m (black line in Fig. 6). The sun position at Northern hemisphere also supports the formation of this warm pool profile, either surface or vertical profiles.

**Figure 6.** Vertical profil of temperature at 2.5°LU on July 1st 2014

Then, we compare the result above with the moderate El-Nino on July 2015. In July 2015, SST anomaly in Nino 3.4 area reached 1.8°C (Fig 4) which indicates the warm pool are moved eastward (Nino 3.4 region). This statement proven by the sea surface temperature profile on July 2015 (Fig 7). The significant change is clearly seen in the warm pool area around 130°-150°EL and 10°NL-1°SL. Warm pool area, water mass with temperature equal to or more than 29°C is reduced significantly when compared to July 2014. This condition occurs due to warm pool movement to the East and only leaves a small portion in West Pacific Seas. At that time, the trade winds that resist the warm pool remain in the western Pacific Ocean will weaken. The weakening of the trade winds will result in the eastward shifting of the warm pool towards Peru.
The other evidence will be seen if we review the vertical profile of the temperature in July 2015 (Fig. 8). This profile area taken at 2.5°NL and 120°-150°EL. It can be seen that the mass of water warmpool, water mass temperature equal to or more than 29°C is very slight around the surface layer (black line). In certain longitude, the mass of water warm pool cannot be seen, as in the area 130° - 135°EL (Fig. 8). So, we can conclude that the warm pool location has shifted to the East Pacific and leaves only a small mass of the warm pool water.

The extreme condition, on very strong El-Nino will show the contrast reduce of warm water in the Western Pacific due when we compare between January 1st 2014 with January 1st 2016. As previously explained, on January 1st 2014 the Pacific Ocean is in normal condition and on the other hand there are very strong El-Nino on January 1st 2016 indicate by Nino 3.4 index (Fig. 4). On normal ENSO
condition, the warm pool is located at almost all regions around equatorial (130°-150°EL and 8°NL-1°SL) with depths reaching 50 meters. However, when there was a very strong El-Nino on January 1st, 2016, the warm pool in the Pacific Ocean area was reduced considerably. Warm pool or mass of water with a temperature more than or equal to 29°C is only located around the equator (Fig. 9).

![Sea Surface Temperature](image)

**Figure 9.** Sea Surface Temperature on January 1st 2016

Then if we look vertically at 2.5°NL, it is also seen that there is no water warm pool at 130°-150°BT area (Fig. 10). This also reinforces that warm pool conditions in the western Pacific Ocean will be affected by the ENSO phenomenon, especially El-Nino. From the comparison of warm pool conditions between July 1, 2014 and July 1, 2015 and January 1, 2014 can be seen ENSO phenomenon, especially El-Nino will affect the conditions and characteristics of the warm pool in the Western Pacific Seas.

![Vertical Profile of Temperature](image)

**Figure 10.** Vertical profile of temperature at 2.5°LU on January 1st 2016
4. Conclusions

1. The results of verification show the good result with a correlation of 0.843 on buoy 1 and 0.81 on buoy 2 and RMSE (Root Mean Square Error) values of 0.358 on buoy 1 and 0.654 on buoy 2 that indicate the model result is reliable to be used in this research.

2. There is warm pool area reduction when strong El-Nino on July 1st 2015 and very strong El-Nino on January 1st 2016.

3. The thickness of the warm pool will decrease from normal conditions on July 1st 2014 which reached 40m to be only at surface layer on strong El-Nino (July 1st 2015) and disappear completely on very strong El-Nino (January 1st 2016)

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