STUDY ON VARIABILITY MECHANISM OF 1997/1998 ENSO IN PACIFIC OCEAN AND EASTERN PART OF INDONESIAN ARCHIPELAGO

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Abstract

El Nino-Southem Oscillation (ENSO) is one of the most important climate anomalies humans are concerned about. It brought many changes in physical of the ocean. This phenomenon causes changes in sea surface temperature (SST). During El-Nino condition, the SST is much warmer in eastern side of Pacific Ocean than normal condition, and during La-Nina event the SST in eastern Pacific Ocean is cooler than normal condition. From July 1997, the warm water has spread from the western Pacific Ocean towards the east and the winds in the western Pacific were blowing strongly towards the east, pushing the warm water eastward on December 1997 and January 1998. Strong La-Nina condition on November and December 1998, the Eastern Pacific was cooler than usual, and the cool water extended farther westward than usual. In October 1997, during El-Nino event 1997, the SST in eastern part of Indonesia Archipelago was cooler. The varies of SST in Pacific Ocean during El-Nino 1997 was influenced the Indonesian Through Flow (ITF). During El-Nino event 1997, surface current flown strongly from Pacific Ocean to the Indian Ocean. On the other hand, since March 1998 the surface current inversed from Indonesian Sea to the Pacific Ocean.

Keywords: ENSO, SST, ITF

I. Introduction

El Nino-Southem Oscillation (ENSO) is one of the most important climate anomalies humans are concerned about. Research on ENSO has • become a significant part in certain fields of science such as climatology, oceanography, and ecology. ENSO does not only cause disastrous climate to the areas in the vicinity of equatorial Pacific, such as Indonesia, Peru and Ecuador, but also causes climate anomalies to a number of regions far away (Trenberth, 1996). It is even blamed tor its role in global warming, as indicated by GCM modeling (Delworth and Knutson, 2000). Unfortunately, the understanding of ENSO is still far from sufficient. The cause of ENSO phenomena is still not clear, making it difficult to predict ENSO events before over one year. Some claimed that the prediction of the 1998 ENSO was a big success, but in fact this prediction was made just from the early signs of typical ENSO events, and nobody predicted that this event was such a big one (Kerr, 1999). Similarly, why ENSO events disappear is also unclear. The best known fact is that they come and go with cyclicity of 2-7 years. Ironically, the reasons for this cyclicity remain largely unknown. Moreover, the mechanisms behind ENSO events are not clear yet, what we already know is that ENSO events may not be climatic anomalies, but a reflection of an inherently unstable tropical ocean and atmospheric system (Trenberth, 1996).

The lack of understanding of ENSO events also undermines the possible

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important role of the equatorial oceans in global climate changes. From the canonical view of the important global climate changes (e.g. glaciations), ENSO events were initiated from higher latitudes, especially North Atlantic (Broeker and Denton, 1989). The credibility of this view is acquired chiefly from the plausible mechanisms of higher latitude initiation and a whole set of scenarios that follow.

There is considerable and growing interest in the progress that has been made since the earliest decades of this century with regard to research and understanding of ENSO. Research in this area began at the turn of the twentieth century with Sir Gilbert Walker's research on the Southern Oscillation, a seesaw of pressure systems across the equatorial Pacific Ocean, centered on Darwin (Australia) and Tahiti. He also identified, through a variety of statistical measures, linkages over relatively large distances, called teleconnections, between seemingly unrelated climate anomalies.

. The Indonesian Archipelago is unique in that it represents the only low latitude interocean connection on the planet. The seas of the Indonesian Archipelago are an artery carrying tropical thermocline water from the Pacific to the Indian Ocean. Known as the 'Indonesian •Throughflow' (ITF), this transport is driven by the Pacific/Indian interocean pressure gradient. The large scale climate variability and its changes in Sea Surface Temperature (SST), Sea Level Pressure (SLP), current and salinity in the Indonesian region are important and overlooked components in the ENSO instability mechanism.

II. Research Method

The study area is the Pacific Ocean and eastern part of Indonesian archipelago (HOoE - 8O0W and lOoN - lOoS). This research began by collecting long term data, such as satellite image and in-situ data in 1993, 1997, and 1998. LI AVHRR satellite images from NOAA were used to get SST data. The SSH, surface current and SST data along the equator zone were provided by Colorado Centre for Astrodynamic Research (CCAR). Data from the TAO/Triton buoy were used to retrieve the SST and current in-situ data. The SOI values used in this study were available from existing research data. ENSO condition and Normal conditions were compared in order to know the variability of ENSO mechanism in the Equatorial region and the Indonesian archipelago.

The SOI is an index used to quantify the strength of an ENSO event. It is calculated from the difference between the sea level pressure (SLP) at Tahiti and Darwin. If the SOI is low, less wind blows from Tahiti to Darwin, means weaker trade winds. Variability of SOI can be shown in Figure 1.

In this research, the sea surface temperature analyzed from the AVHRR sensors aboard the NOAA satellite. The LI NOAA data (HRPT standard) was obtained

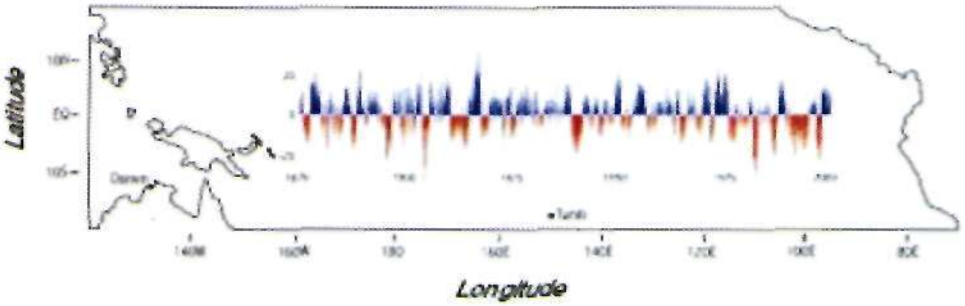


Figure 1. The monthly Southern Oscillation Index (Reid, 2006)

from LAPAN. Sea surface temperature was calculated using McMillin and Crosby formula:

$$SST(DN) = Tb4 + 2.702\ (Tb4 - Tb5) - 0.582 - 273$$

Where:

SST(DN) = sea surface temperature in digital number

Tb = *brightness temperature*

III. Variability mechanism **of ENSO 1997/1998 in Pacific Ocean**

The "normal" conditions are for warmer SSTs to the west of the equatorial Pacific basin and cooler SSTs to the east. El Nino events are characterized by warmer than usual surface water along the equator in the eastern Pacific Ocean and weaker than usual trade winds in the equatorial Pacific. The long term mean and monthly distributions of SST in Equatorial Region during El Nino conditions are shown in Figure 2.

These figures are showing the extremely different of SST between long term mean and El Nino conditions in December 1997 and January 1998. During El Nino conditions, warmer SSTs spread further east, produc ing the warmer, ocean surface temperatures in Pacific Ocean. The SOI value was negative, that means weaker trade winds, may cause a lower rainfall over the western Pacific and excessive rain on parts of Peru and Ecuador. Rainfall follows the warm water eastward. The eastward displacement of the atmospheric heat source overlaying the warmest water results in large changes in the global atmospheric circulation, which in turn force changes in weather in regions far removed from the tropical Pacific.

Along the equator, the trade winds blow warm surface water westward in the direction of Asia, where it piles up. In the east, near South America, the water is replaced with cold water from below. This causes a temperature difference between the west (Australia and Asia) and the east (the Americas) of the Pacific. Air rises more over warm water than over cold water. Where air rises and cools as it enters higher altitudes, the water vapor in the air condenses and it rains, that is why it rains much more over the warm western Pacific near Asia than over the cold eastern Pacific near Peru and Ecuador. Also, the rising air in the west draws in more air, and this is partly responsible for the strength of the trade winds.

La Nina conditions are associated with cooler SSTs extending further west and warmer temperatures contracting to the west. The long term mean and monthly distributions of SST in Equatorial Region during La Nina conditions are shown in Figure 3. These figures are showing the extremely different of SST between normal and La Nina conditions in November and December 1998. During La Nina conditions, warmer SSTs spread further west, producing the cooler ocean surface temperatures in Pacific Ocean. The SOI value was positive, that means stronger trade winds. It may cause an increase in precipitation, particularly over Indonesia, and abnormally high sea surface heights over the western Pacific. Generally, drier conditions are experienced over Peru and Ecuador.

The explanations for El Nino conditions were supported by in-shu data. The SSTs in Equatorial Region from TAO/Triton buoy are shown in Figure 4. According to these figures, the SST spread eastward and causes warmer water in equatorial Pacific Ocean and may causes rainfall in centre part of Pacific Ocean.

According to *in-situ* data (Triton/TAO data), the SSTs during La Nina conditions are shown in Figure 5. These data were supported the result by satellite images. The cooler water spread westward and may cause higher rainfall over Indonesia.

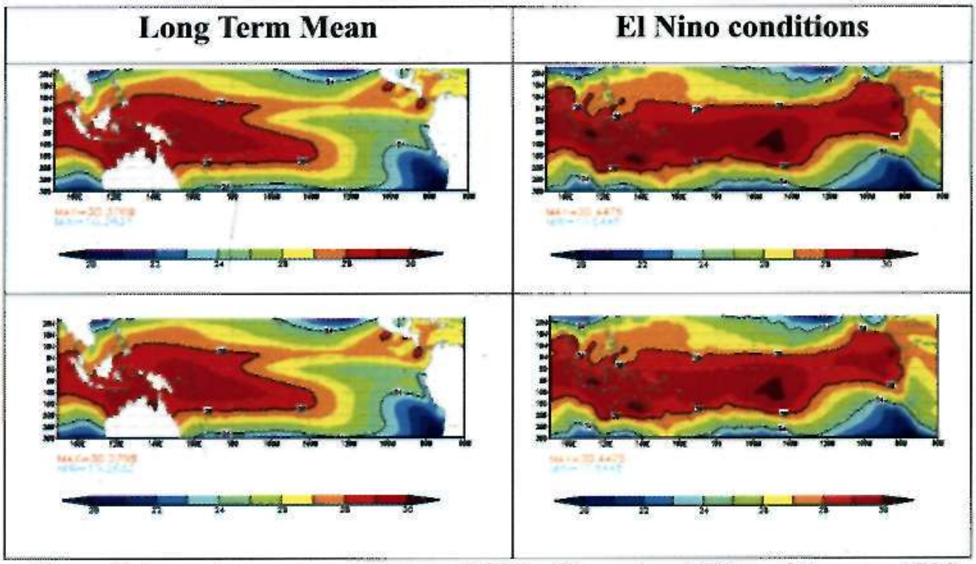


Figure 2. Long term mean and mean SST in December 1997 and January 1998

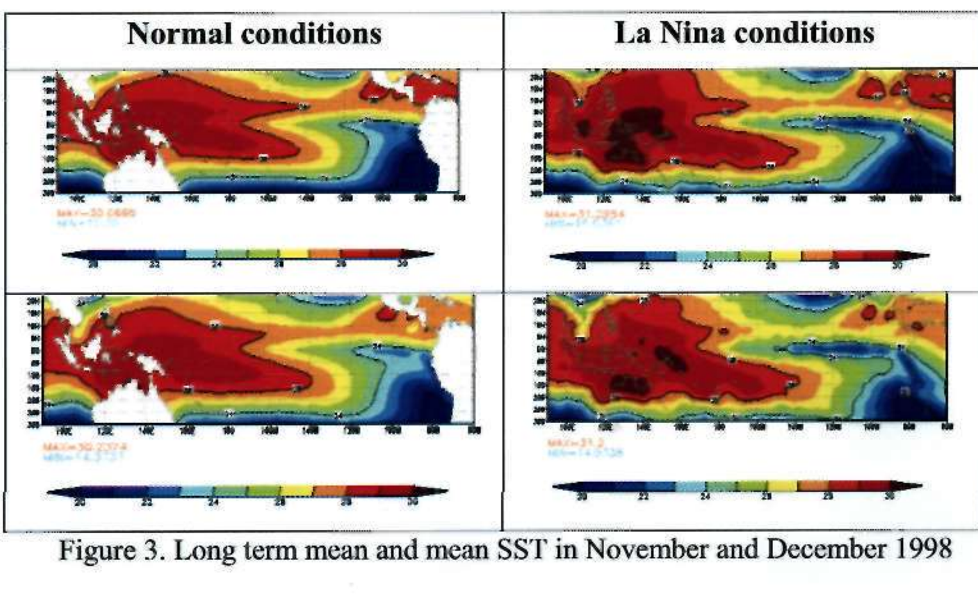


Figure 3. Long term mean and mean SST in November and December 1998

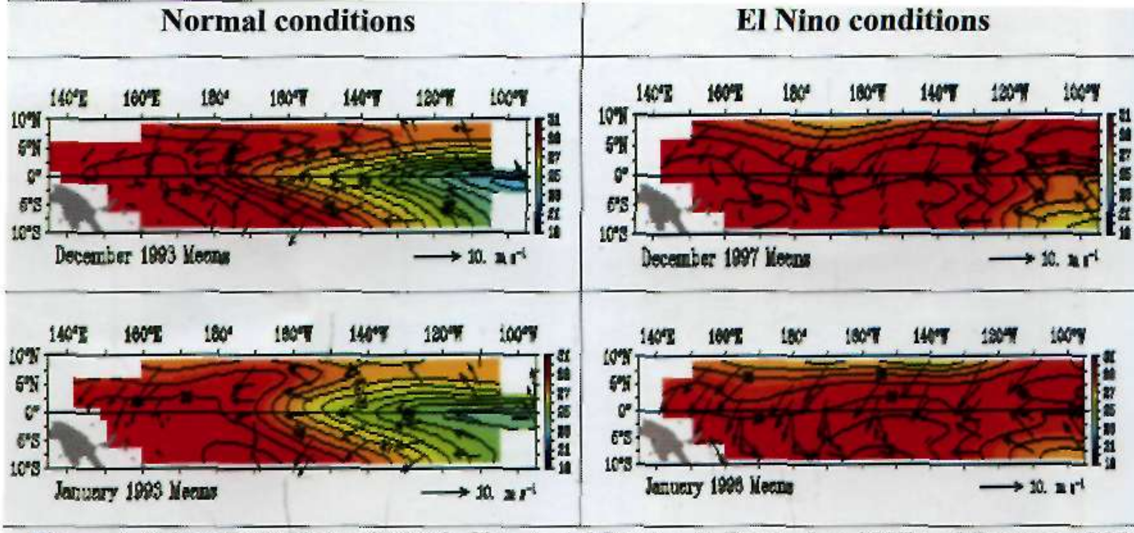


Figure 4. Triton/TAO data of SST in Equatorial Region in December 1997 and January 1998

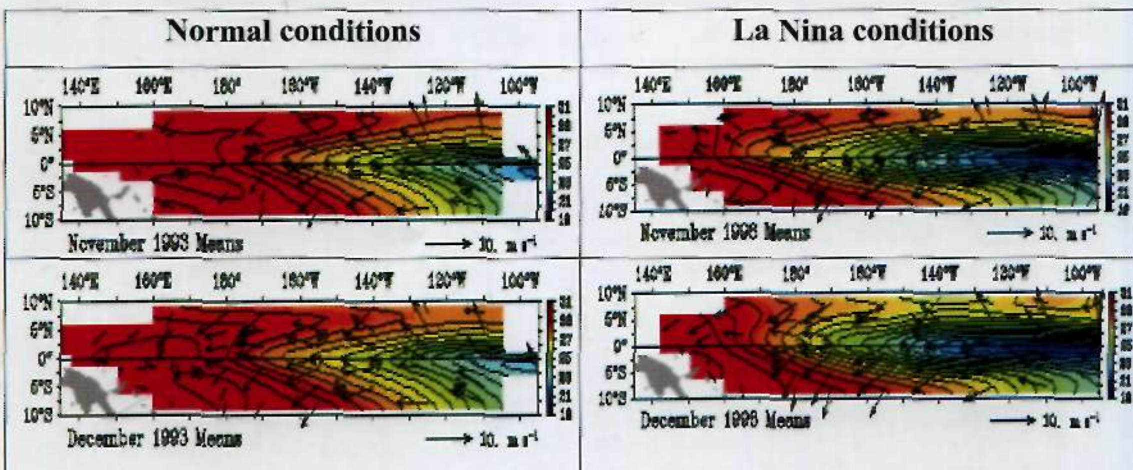


Figure 5. TAO/Triton data of SST in Equatorial Region in November and December 1998

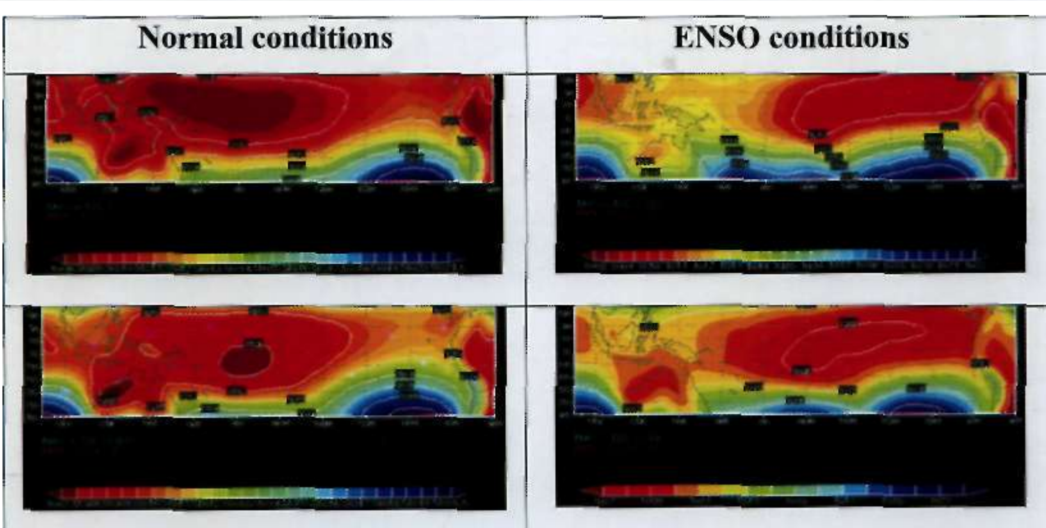


Figure 6. Long term mean and mean SLP in November and December 1997 (Levitus)

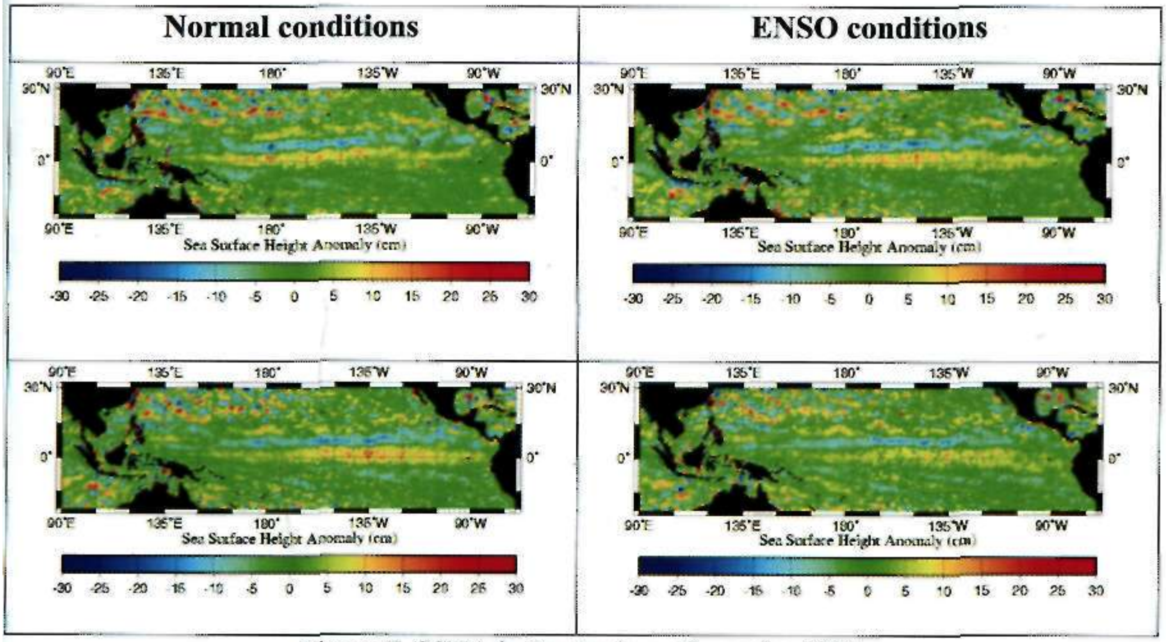


Figure 7. SSHA in September - December1997

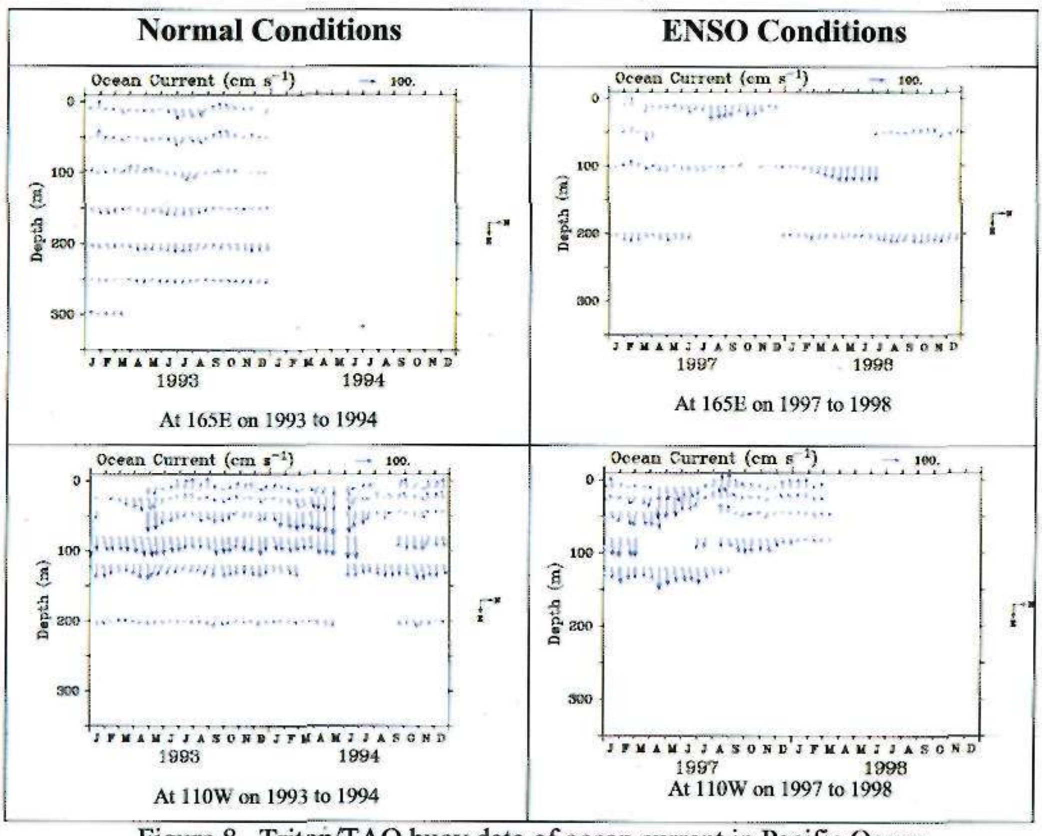


Figure 8 . Triton/TAO buoy data of ocean current in Pacific Ocean

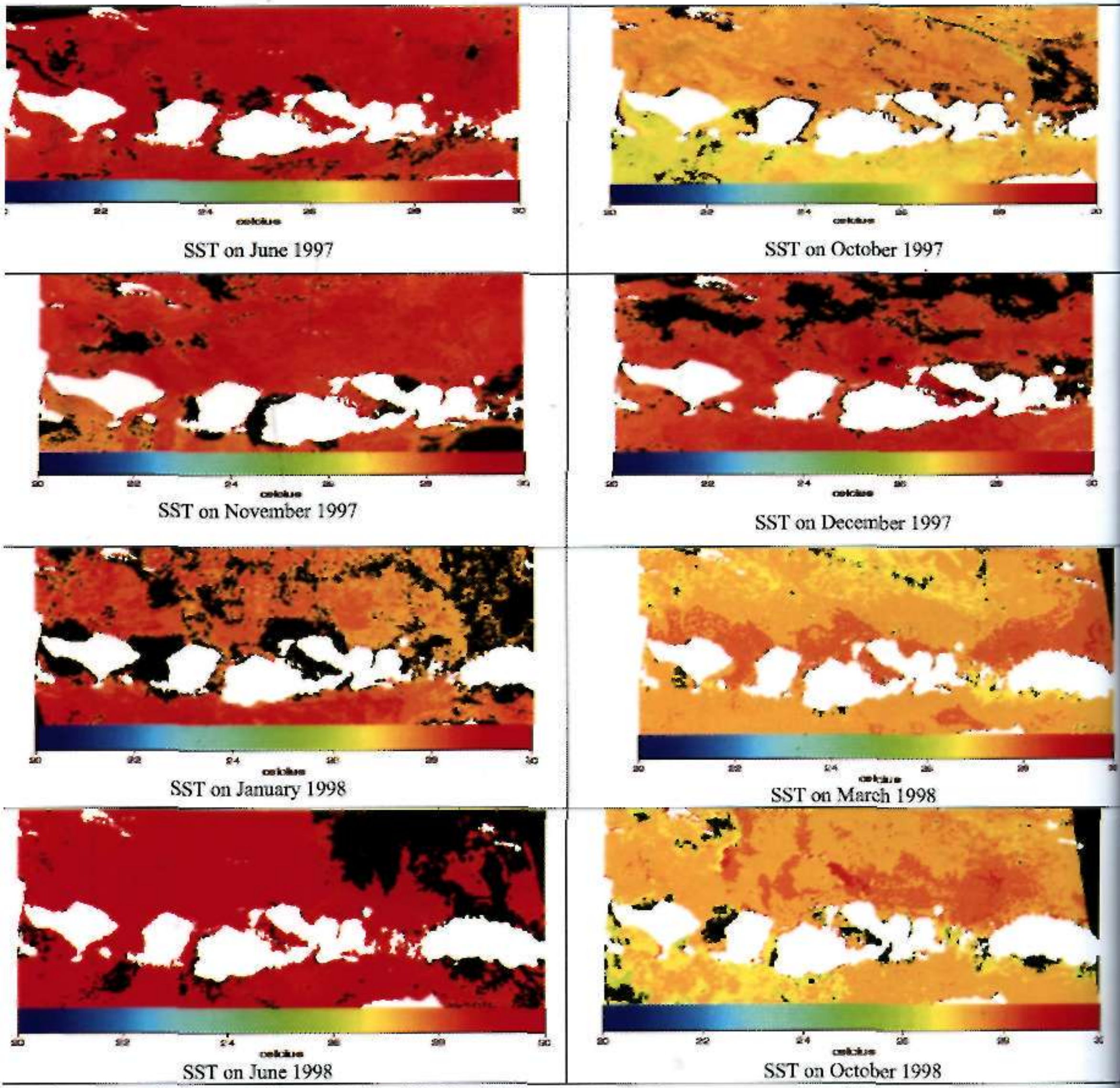
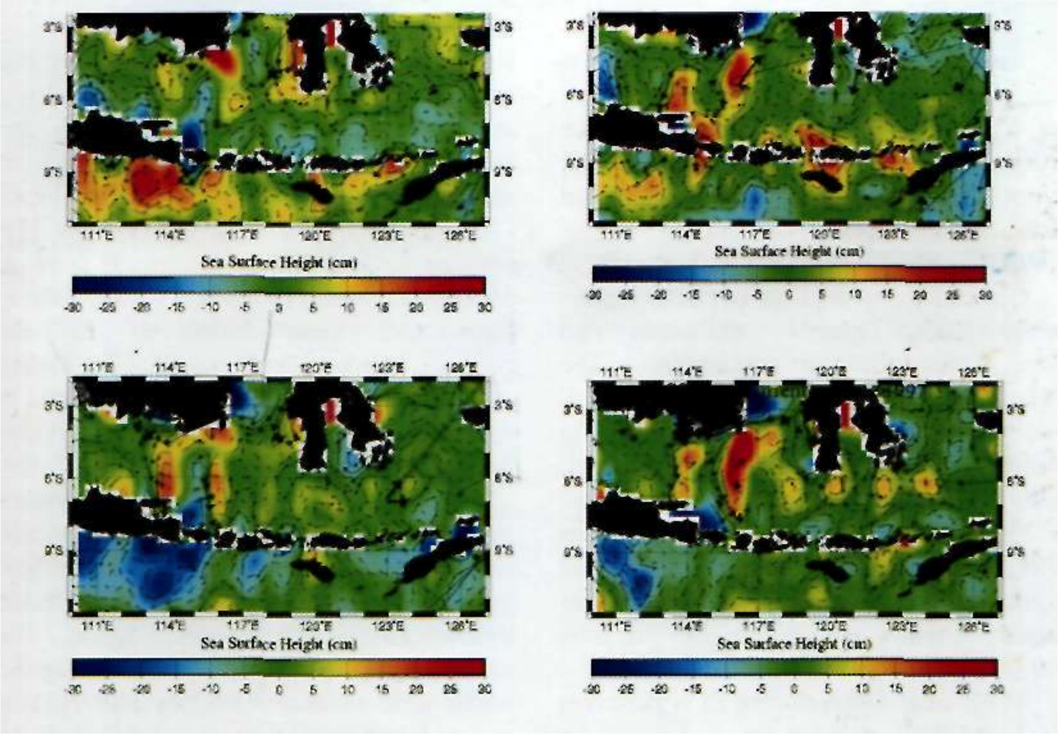


Figure 9. The variability of SST (derived from NOAA) in eastern part of Indonesian Archipelago during 1997/1998 ENSO



SSH and current on October 1997 SSH and current on December 1997

Figure 10. SSH and surface current during ENSO 1997

Normally, the SLP are higher in the east than west of Pacific Ocean. According to the Figure 6, there were some differences with normal conditions in 1997 to 1998. During El Nino events, the lower pressure spread eastward in Pacific Ocean, started in March 1997. This conditions extremely difference in October 1997 to April 1998.

The SLP has correlation with SST when we compare those two variables. The SST spread from higher SLP to the lower SLP

The variability of SSH can be determined from SSH Anomaly (SSHA) that is shown in Figure 7. Anomalies can identify unusual patterns with normal conditions. According to the figure, denote of SSHA in Equatorial Pacific Ocean during El-Nino events around 5-15 cm. It means that there were differences of SSH. SSH in Pacific Ocean got higher than normal conditions when the ocean became warmer.

The ocean currents during EL-Nino event are shown in Figure 8. At 165oE, the surface current generally is going eastward. Since July up to September 1997 the surface current became stronger compared with normal condition in 1993; surface was current flowing from western part of Pacific Ocean eastward, this phenomena was happened because central part of Pacific Ocean was warmer than in western part. But at HOo E, during July up to September 1997 the surface current was flowing from eastern Pacific Ocean to the west, that's agree with SST phenomena.

IV. Variability mechanism of ENSO 1997/1998 in Eastern Part of Indonesian Archipelago

The eastern part of Indonesian archipelago is important place correspond to Indonesian trough flow (ITF), where the current flowing from ihe Pacific Ocean through the eastern Indonesian sea (trough the Makassar Strait and flowing to the Lombok Strait and the Banda Sea to the Timor). The variability of SST in Eastern Part of Indonesian Archipelago during 1997/1998 ENSO are shown in Figure 9.

Generally, the SST in northern Lesser Sunda (Bali, Lombok, Sumbawa and Flores) was higher than southern part. The SST in June 1997, around 28oC to 29oC was warmer than October 1997 (26oC to 27oC), but from November 1997 to March 1998 the SST was almost the same (28oC to 29oC). In October 1997 and October 1998, the SST was cooler than other months. From November 1997 the water became warmer and got higher in June 1998, reached 30oC.

In October 1997, during El-Nino event 1997, the SST was cooler. It causes the surface pressure get higher around Indonesian ocean. This phenomenon probably was much influenced by the change of season in Indonesia, from summer season to the winter season. But during El-Nino 1997, the warm water was occurred in the centre part of Pacific Ocean, hence, the sea water from Indonesian sea will be flown to the Pacific Ocean.

During El-Nino 1997/i 998 the sea surface temperature in central Pacific region was warmer than usual. It meant that the current inverse to the central pacific from Indonesian seas.

The distributions of surface current flowing to the Indonesian Trough Flow (ITF) path during ENSO 1997 are shown in Figure 10. In January 1997, the surface current was flowing southward through Makassar and Lombok Straits but in June 1997, the surface current became weak, these was influenced by Indian Ocean Kelvin Waves (IOKWs) which produced strong northward current into Lombok Strait. ITF flows through Makassar Strait causes eddy in Java Sea. Both Kelvin and Rosby waves are slow and weak waves, but together with the positive feedback from atmospheric system, they could become the pacemaker of ENSO events and result in the apparent cyclicity (Peng, 2000). From October 1997 to February 1998 the ITF became stronger flows southward through Makassar and Lombok Strait, these phenomena most influenced by the pressure gradient between Pacific Ocean and Indian Ocean. Few eddies haprJened in southern sea of Indonesia and around Java Sea.

The ITF is governed by strong pressure gradient from the Pacific to the Indian Oceans. The annual and semi annual variations in transport are related dynamically to the monsoon winds. The annual signals have a maximum during the south west monsoon in July and August and minimum in January and February. This is because winds arc blowing westward during the south west monsoon in the southern tropical Indian Ocean and causes a lowering of sea level on the eastern side (and increase on the western side). Reversely during the north east monsoon, winds reverses in the tropical Indian Ocean, leading to an increase of sea level on its eastern side, thus minimizing the annual variations.

Changes in the ITF current have an influence on the weather for the entire region. As warm water flows from the Pacific to the Indian Oceans, the resulting rise in temperature causes increased rainfall along coastal area, due to evaporation. When this precipitation runs off into coastal waters, there is an increase in freshwater in South China and Java Seas. The additional freshwater then travels into the path of the ITF, resulting in a cooler current and less heat transferred to the Indian Ocean. This in turn leads to reduced rainfall in coastal areas, and reduced freshwater levels in the path of the ITF, resetting the system to its original state. This system of negative feedback establishes a stable cycle of alternating temperatures in the ITF, and corresponding rhythms in surrounding rainfall levels (Gordon ctal., 2004).

Concluding Remark

The extremely different of SST between normal and El Nino conditions arc during December 1997 and January 1998. The wanner SSTs spread further east, producing the warmer ocean surface temperatures in Pacific Ocean. The extremely different of SST between normal and La Nina conditions are during November and December 1998. During La Nina conditions, wanner SSTs spread further west, producing the cooler ocean surface temperatures in Pacific Ocean. These satellite images data were supported by in-situ data from TAO/Triton buoy.

In October 1997, during El-Nino event 1997, the SST in eastern part of Indonesian Archipelago was cooler. It causes the surface pressure get higher around Indonesian ocean. The warm water was occurred in centre part of Pacific Ocean, hence the sea water from Indonesian sea will be flown to the Pacific Ocean. The Surface current flowing to the ITF path was shown clearly, during June to December 1997 the current flow strongly to the Makassar Strait and Lombok Strait from Pacific Ocean to the Indian Ocean. This condition most responsible to the difference of SST between Pacific Ocean and Indian Ocean.

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