Estimation of sea level variations of the Java Sea during the ENSO period using the HYCOM

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The sea level of the Java Sea is reproduced using HYbrid Coordinate Ocean Model (HYCOM) setting up in the horizontal grid from 100°E to 125°E and from 10°S to 8°N. The model is initialized by ocean temperature and salinity profiles from Levitus 1998 and forced by the atmospheric field derived from NCEP reanalysis. In this research HYCOM is applied to explain the El Niño Southern Oscillation (ENSO) impacts on the sea level of the Java Sea. The monthly tide gauge sea level data are produced based on hourly sea level data from 1993 to 1997. Altimeter sea level data are based on weekly merged products between TOPEX/Poseidon and ERS absolute dynamic topography (ADT). The simulated sea level both HYCOM and ADT agree well with the tide gauge sea level. The sea level of the Java Sea is high during the La Niña period and low during the El Niño period.

KEY WORDS: Sea level, Java Sea, HYCOM, ENSO

1. INTRODUCTION

Jakarta, Semarang and Surabaya, which are located along the northern coast of the Java Island (Fig. 1) are easily affected by the sea level change of the Java Sea (Arthurton, 1998). This condition worsened by the land subsidence along the North Jakarta, and Semarang since 1980s (Hirose, et al., 2001). Subsidence level in Jakarta measured using SAR (Synthetic Aparture Radar) was around 10 cm from 1993 to 1995 and 6 cm from 1995 to 1998.

A large scale weakening of the trade winds and warming of the surface layers in the eastern and central equatorial Pacific Ocean characterizes El Niño. El Niño events occur irregularly at intervals of 2 to 7 years, although the average is about once every 3 to 4 years (McPhaden, 1993). And during the strong 1997 to 1998 El Niño years particularly on the southeast monsoon, Indonesia had severe drought (Kumar, et al, 1999). On the other hand, the La Niña phases create the heavy rainfall and flooding, particularly in the northwest monsoon during the strong La Niña 1998/1999 period. Moreover, Sofian and Kozai (2003) reported the sea level is 200mm higher than 5 years average (from 1993 to 1997) during the La Niña period which caused the flooding area are widespread in the northern coast of the Java Island.

Based on the previous research, an attempt was may to reproduce the weekly mean sea surface height of the Java Sea using HYCOM (Bleck, 2002) and evaluate the sea level using altimeter-derived absolute dynamic topography (ADT) data (merging between TOPEX/Poseidon and ERS) (Aviso, 2004).

2. MODEL CONFIGURATION

In this section we will describe the HYCOM configuration and the altimeter data used for validation of HYCOM outputs.

The model is applied to evaluate the interaction among wind, SST, and sea level, particularly during the ENSO years. The study area is the Indonesian Sea including the Southern South China Sea, the Java Sea, the Sulawesi Sea, the Karimata Strait, and the Makassar Strait as shown in the Fig. 1. The horizontal grid is spanning from 100°E to 125°E and from 10°S to 8°N (called JSM, Java Sea Model), and the grid resolutions are Mercator 0.1° longitude and latitude. The model is configured with 22 layers, and the bottom topography is based on ETOPO2 data. The model uses KPP (K-Profile Parameterization) vertical mixing. The explanation of KPP and HYCOM equations and numerical algorithms can be found in Large et al., (1994) and Bleck (2002) respectively. The World Ocean Atlas (WOA) 1998 monthly climatology that contains salinity and temperature profiles is used for the initial conditions. The model is forced by the weekly NCEP reanalysis data which includes wind stress, wind speed, surface air temperature, surface specific humidity, net shortwave and longwave radiations, and precipitation. The model's SST is forced with NOAA optimal interpolation (OI) SST to obtain more realistic SST distributions during the El Niño and La Niña. The JSM is nested to the model which is configured with 22 layers, and setting up from 30°E to 60°W and from 35°S to 35°N with 0.5°longitude and latitude grid mesh resolutions (called IPM, Indo-Pacific Ocean Model). IPM bottom topography is based on ETOPO5 data. IPM uses

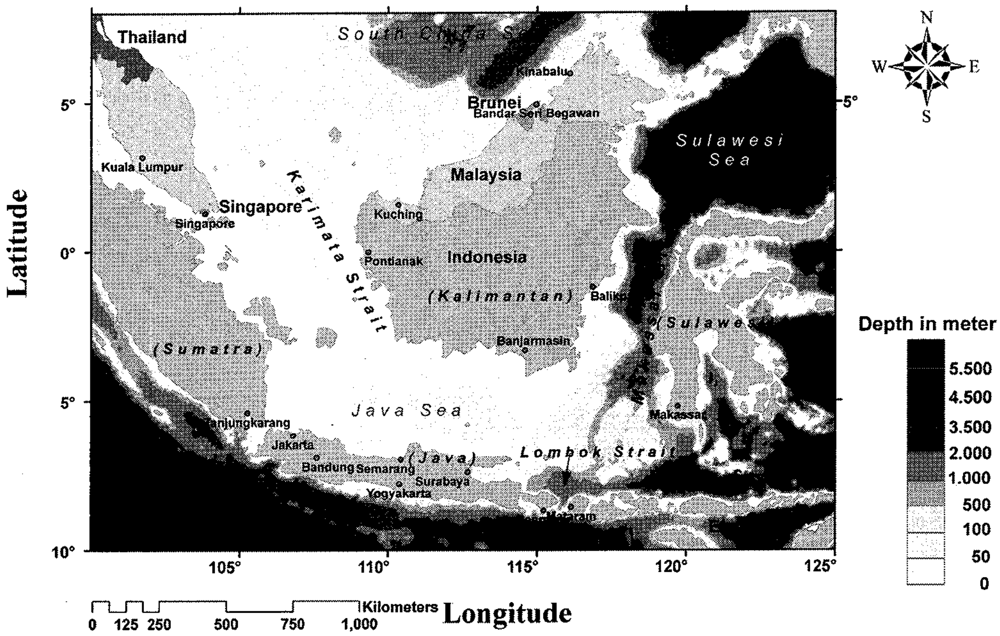


Fig. 1. Bathymetric map of the Indonesian Sea, including the Makassar, Karimata Straits, and the Java Sea.

the same parameter of forcing fields, initial conditions and mixing layer model as used in the ISM.

The sensible and latent heat fluxes are calculated during model runs using the model SST and the bulk formulae. The relaxation time scale increases from 0.1 to 3 days with distance away from the boundaries. The precipitation and evaporation are also included in this model.

3. RESULTS AND DISCUSSION

Fig. 2 shows the Southern Oscillation Index (SOI) from 1993 to 1997. Based on the magnitude of SOI, the El Niño 1993, 1994 and 1997 can be categorized as weak, moderate and strong years respectively. On the other hand, the ENSO phase during 1996 can be classified as the normal to weak La Niña period.

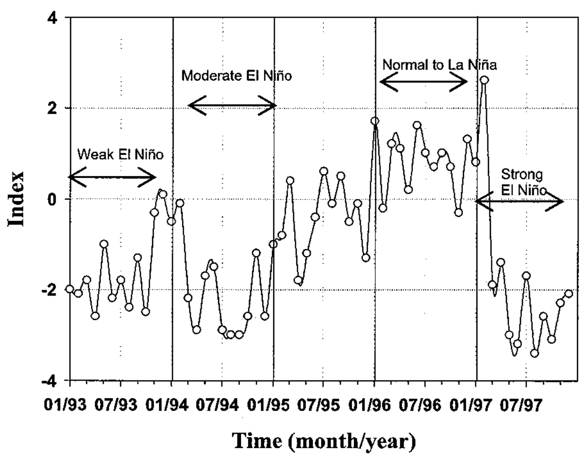
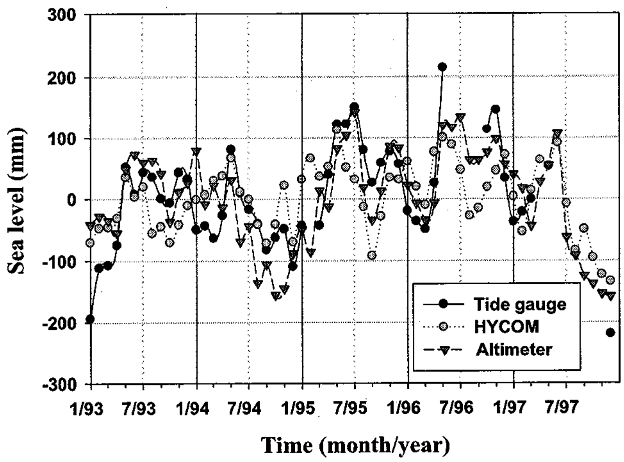


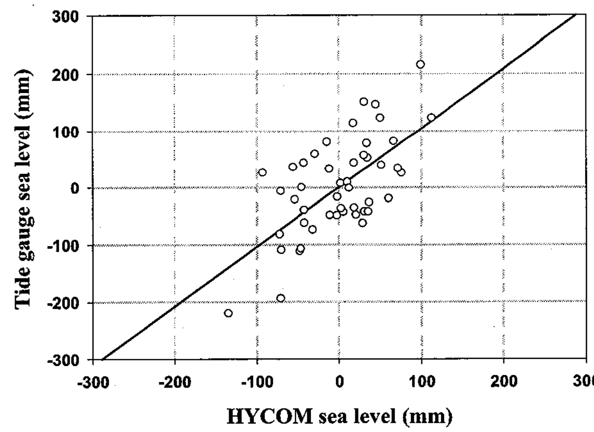
Fig. 2. Southern Oscillation Index from 1993 to 1997 (from CDC, NOAA)

During a normal year, the easterly trade winds push and pile the water in the Equatorial Pacific into the western part of the Pacific basin. The sea level is high in the western Pacific and low in the eastern Pacific. El Niño is signed by the rising of air pressure over the Indian Ocean, Indonesia, and Australia, and the falling of air pressure over the Tahiti. The trade winds weaken. This allows the warm water in the western pacific to move to the eastern pacific. Eastward warm water movement decreases the sea level in the western Pacific, and raise the sea level in the eastern Pacific. On the other hand, during the La Niña, easterly trade winds strengthen. The warm water and equatorial convective rainfall are confined to the extreme western part of the Pacific Ocean. The sea level in the western Pacific is higher than normal.

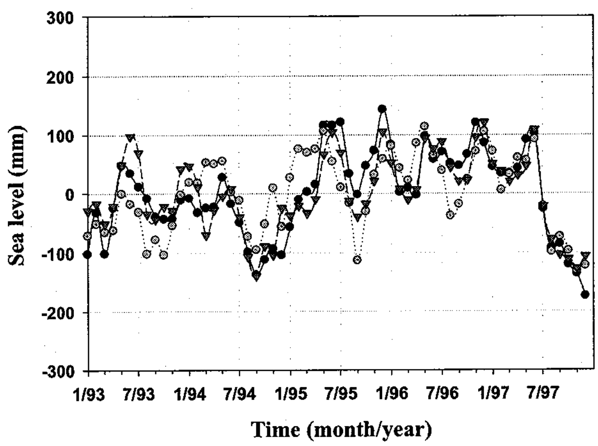
Fig. 3 shows the variation of monthly sea level anomaly (SLA) (relative to 5 years mean from 1993 to 1997) along the northern coast of the Java Island based on HYCOM SSH, tide gauges, and altimeter ADT. The SLA characteristic follows the monsoonal season. In general SLA represents the negative maximum in September or October during the southeast monsoon, and increase to the positive maximum in December or January during the northwest monsoon. Deviation between the annual negative and positive maximum SLA is around 150 mm every years except in the moderate (1994/1995) and strong El Niño (1997/1998) years respectively. In the weak ENSO year the deviation between the annual negative and positive maximum SLA is not clearly different from the one during the normal year (1996). As the impact of the eastward warm pool water movement, the negative maximum SLA is occurred in January 1995 (moderate El Niño) and in



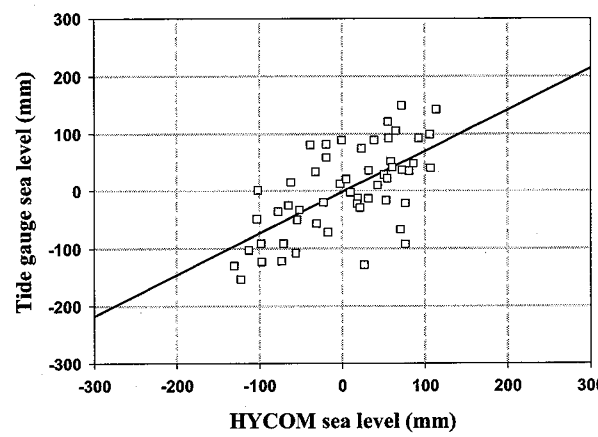
a. Sea level anomalies at Jakarta



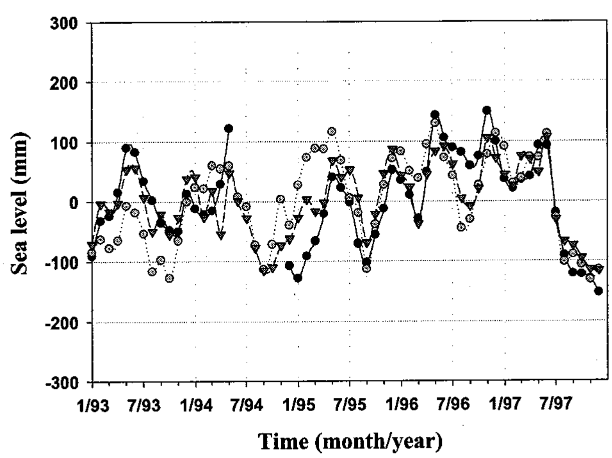
a. Correlation between tide gauge and HYCOM at Jakarta



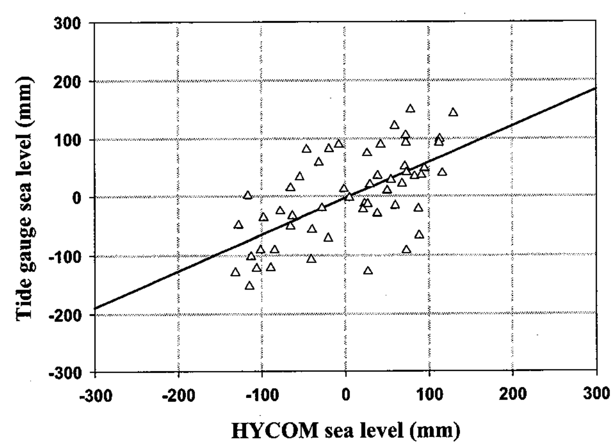
b. Sea level anomalies at Jepara



b. Correlation between tide gauge and HYCOM at Jepara



c. Sea level anomalies at Surabaya



c. Correlation between tide gauge and HYCOM at Surabaya

Fig. 3. Tide gauge, HYCOM and altimeter sea level anomalies relatives to 5 years mean from January 1993 to December 1997 at Jakarta, Jepara and Surabaya.

Fig. 4. Correlation between HYCOM and tide gauge sea levels at Jakarta, Jepara and Surabaya.

December 1997 (strong El Niño) respectively. The positive maximum SLA are around 150mm for the duration of the weak La Niña 1996 year. In general, the SLA higher than 5 years mean during the weak La Niña 1996.

Fig. 4 shows the correlation between tide gauge and HYCOM sea level (correlation figure between tide gauge and ADT not shown). The correlation between tide gauge sea level and ADT is 0.73, 0.88, and 0.83 at Jakarta, Jepara, and Surabaya respectively. The RMS errors are ranging from 4cm to 6cm, during the entire period. The correlation between tide gauge sea level and HYCOM SSH is 0.64, 0.73, and 0.62 at Jakarta, Jepara, and Surabaya respectively. The RMS errors are varying from 5cm to 7cm.

4. CONCLUSIONS

1. The simulated sea level both HYCOM and ADT agree well with the tide gauge sea level.
2. The sea level of the Java Sea is high during the La Niña period and low during the El Niño period.

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