Bigeye Tuna Cath Relative to Sea Surface Height Anomaly during El Nino and Indian Ocean Dipole Event in Eastern Indian Ocean

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Abstract

The study is aimed at understanding the variability of sea surface height anomaly (SSHA) of Eastern tropical Indian Ocean (EIO) and assessing its impact on bigeye tuna catchability. A nine-year (1993-2001) time series of SSHA data set are used in this investigation. A six-year daily tuna fish catch data (1997-1999, and 2004-2006) and a eight-years (1993-2000) monthly average of tuna hook rate is derived from a tuna fishing company "Perikanan Samodra Besar" (PSB) Corp. Ltd. logbooks of 15-20 fishing vessels operated in EIO. Daily and an eight-year of monthly mean SSHA derived from data base of Colorado Center of Astrodynamics Research and NASA-POET-JPL respectively. The Spectrum analysis of SSHA and HR anomaly shows there are two dominant signals are representation of the annual and inter-annual variability. Significant interannual variability of SSHA is influenced El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole mode (IOD). During ENSO and IOD event, SSHA negative in IOD corresponding to shallow thermocline depth and enhanching upwelling strength. The Monte Carlo analysis shows that the relationship between of the highest hook rate and negative SSHA is significant especially in latitude of 13°S, where tuna fishing ground concentrated. The depth of thermocline become shallower and enhanching upwelling might have contributed to increase the bigeye tuna catchibility by providing suitable ambient temperature and feeding ground.

1. Introduction

The Eastern Indian Ocean region (4°S-16°S and 105°E-120°E) has long been considered as an important area for pelagic fisheries in general and tuna fisheries in particular. The productive pelagic fisheries in this area are sustained through enhanced biological production due to seasonal coastal upwelling during southeast monsoon season occur from June to September (Wirtky, 1962; Purba, 1995; Susanto et al., 2001; Gaol et al., 2003). In 1973, PSB Corp. Ltd starting operated 3 units longliner 100 GT in EIO, but after 1974 total longliner increase to become 17 units. The dominant catch are yellowfin (*Thunnus albacares*) about 61% and bigeye (*Thunnus obesus*) about 30 % respectively. Since 1992, PSB Corp. Ltd. has been changed the type of longline to become depth long line, with hooks set at depth between 100 and 300 meter, made the dominant catch changed to become 73 % bigeye and 6 % bigeye tuna.

Many scientists have been conducted research to investigate the variability of EIO. They concluded that EIO is high variability, which influenced by the monsoon system (Wirtky, 1962; Birol and Morrow, 2001; Susanto et al., 2001), Indonesian through flow (ITF) (Bray et al., 1996; Fieux et al., 1996), climatic phenomena such as El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole Mode (IODM) (Meyers, 1996; Saji et al., 1999; Webster et al., 1999; Shinoda et al., 2004). The variability of oceanographic conditions such as temperature, salinity and dissolve oxygen will be playing an important role on distribution and availability of fish (Sharp & Dizon., 1978; Sund et al., 1981). Hanamoto, 1985 found that the optimum fishing layer of bigeye tuna are closed to temperature between 10° and 15° C, where the isodepth in EIO are varieties from 200 m to 400 m.

Since 1982/83 the extra ENSO occurred, the scientist's interes to its impact on marine ecosystem rapid growth especially in Pacific Ocean. They conclude that climate variability was impact on community composition, species ubundance and distribution, recruitment level, and tropics structure (Arntz & Razona, 1990; Lehodey et al., 1997; Kimura et al., 1997; Sunchez et al., 2000; Sugimoto et al., 2001; Gaol et al., 2002). Recenly, Menard et al., (2007) base on the statistic data of Japanese longline fishery found strong association between tuna and climatic series for the 4- and 5-yr periodic modes i.e. the periodic band of El Nino signal propagation in Indian Ocean. High total catch anomalies associated with low sea level height. During El Nino and DM event occur negative sea surface height anomalies (SSHA)

2. Data

Our study focused in EIO geographically 10°S-16°S and 105°E-120°. We used a nine-year (1993-2001) time series of SSHA data set are used in this investigation. A six-year daily tuna fish catch data (1997-1999, and 2004-2006) and a eight-years (1993-2000) monthly average of tuna hook rate is derived from a tuna fishing company "Perikanan Samodra Besar" (PSB) Corp. Ltd. logbooks of 15-20 fishing vessels operated in EIO. Daily and an eight-year of monthly mean SSHA derived from data base of Colorado Center of Astrodynamics Research and NASA-POET-JPL respectively. Bigeye tuna catch index (hereafter referred to as for HR) calculated from bigeye tuna catch divided 100 hooks of long line. We computed a catch rate (HR) which aggregated 1° x 1° grid area (Fig 1).

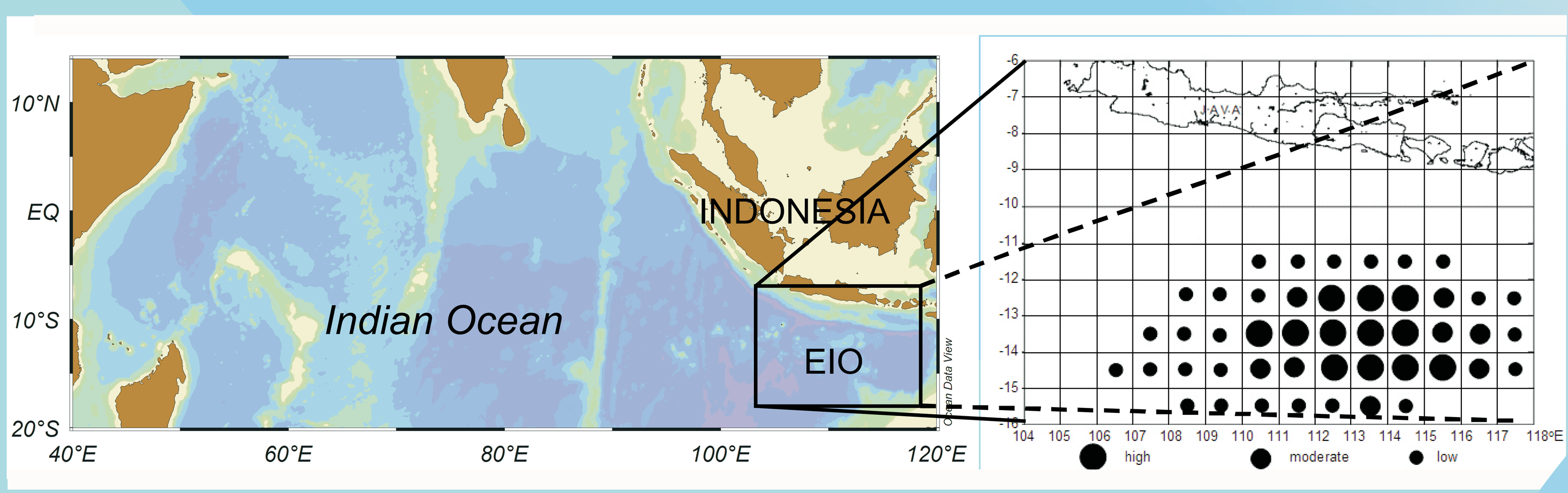

Fig 1. Area of study and spatial distribution of yearly average bigeye tuna HR (the biggest, medium, and small circles shows the area with high, moderate, and low frequency of HR > 0.8 respectively).

3. Result

Spectral analysis of monthly mean HR of Bigeye tuna and SSH anomaly during 1993-2000 shows two dominant signals are represented of annual and inter-annual variability (Fig 2). Annual variability of sea level in EIO is influenced by monsoon system, lower sea level during seasonal upwelling correspond to southeastern (SE) monsoon (Bray *et al.*, 1996; Susanto *et al.*, 2001). Such SSHA extremes (negative) correspond well with the duration of intense phase of IOD and ENSO (1996; Saji *et al.*, 1999; Webster *et al.*, 1999; Murtugudde *et al.*, 2000; Susanto *et al.*, 2001).

Bigeye tuna HR is higher during SE monsoon is corresponded to seasonal upwelling. During ENSO and IOD event (1992, 97, and 98), HR tend to increase except in 1994. Relationship between monthly mean HR anomaly and SOI shows negative correlation with SOI negative, HR is increased. Menard *et al.*, (2007) has reported strong association's tuna and climate series for the 4- and 5-years mode, i.e. the periodic band of the El Nino propagation in Indian Ocean. Since shallow thermocline and feeding ground for tuna during El Nino and IOD-induced upwelling can increase the catch rate of bigeye using long line gear.

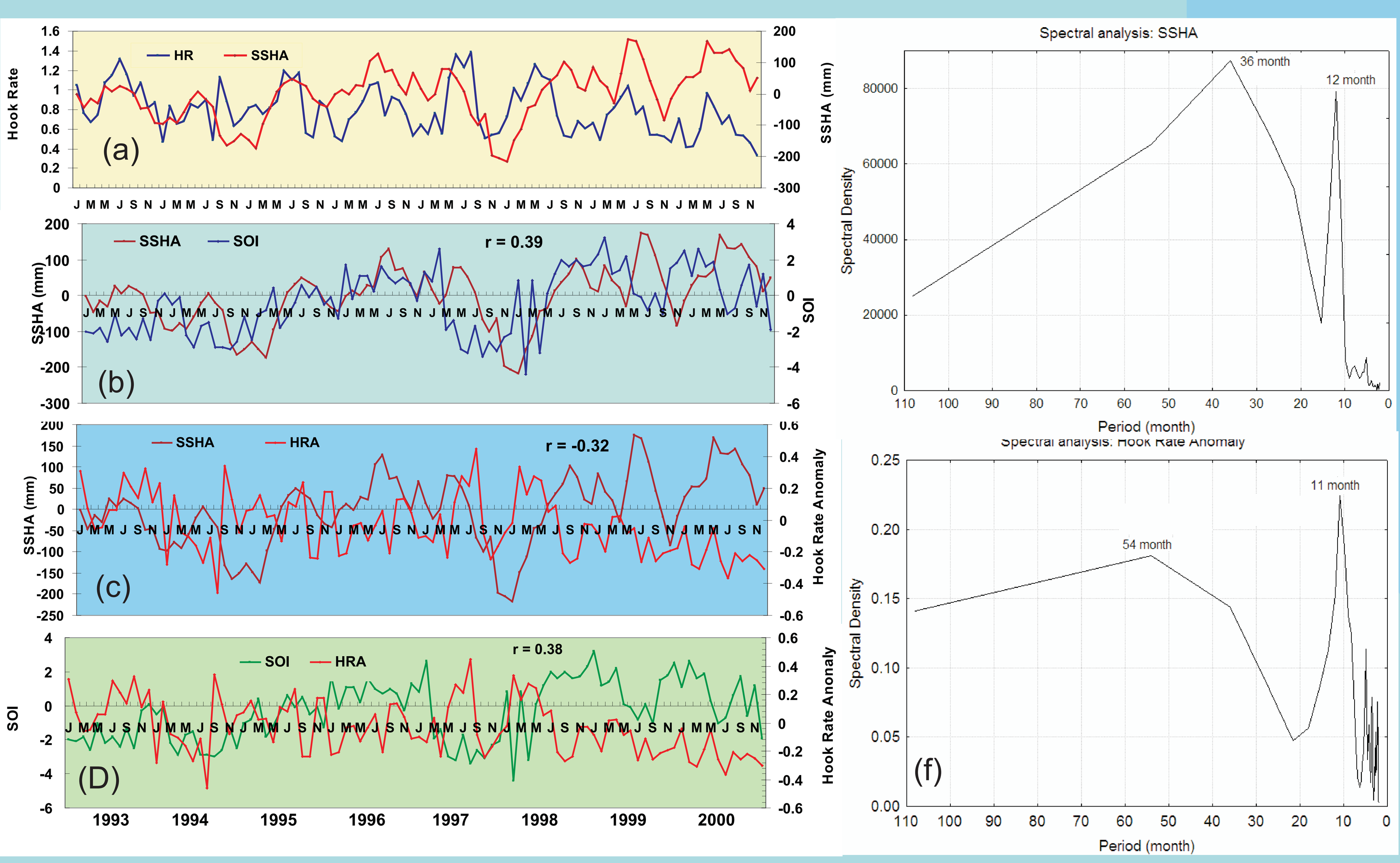

Fig 2. (a) The time plot of monthly mean of SSHA and HR for 1993-2000, (b) SSHA and SOI, (c) SSHA and HR anomaly, (d) SOI and HR anomaly, (e) spectral analysis of SSHA, and (f) spectral analysis of HR anomaly.

4. Discussion

Bigeye tuna is a highly migratory fish. The predominant bigeye tuna daytime distribution was between 220 and 240 m, whereas the predominant nighttime depth was 70 and 90 m (Hollan *et al.*, 1990). Temperature and thermocline depth seem to be the main environmental factors governing the vertical and horizontal distribution of bigeye tuna. Bigeye tuna were taken in waters ranging widely in temperature from 9 °C to 28 °C. However, the optimum of temperature for fishing ranges between 10°C and 15°C (Hanamoto, 1985). The depth of isotherm 10°C and 15°C ($IT_{10o\text{-}15o}$) in EIO are varieties from 150 to 400 m, whereas in fishing ground area from 200 to 400 m. The PT. PSB tuna long line gear is normally set so that the hooks reach depths of 100 to 280 m. There fore, finding the depth of IT($_{10^o\text{-}15^o}$) less than 280 m, the maximum depth of hook is very important for setting longline.

Fig 3 shows an example result of overlay between SSHA and HR of bigeye tuna in EIO. The HR > 1.0 concentrated in the front between SSH positive and negative. During El Nino and IOD event, upwelling extended both in time and space in EIO (Susanto *et al.*, 2000). Occurrence of cyclonic and anti-cyclonic eddies might also have contributed to increase of catchability by providing suitable ambient temperature and feeding grounds for bigeye. Catch rate of bigeye tend to increase around area with SSHA negative (Fig 5). The Monte Carlo analysis between SSHA and HR shows the significant correlation between SSHA negative and HR >.1.5 around area of -13°S where tuna fishing vessels concentrated.

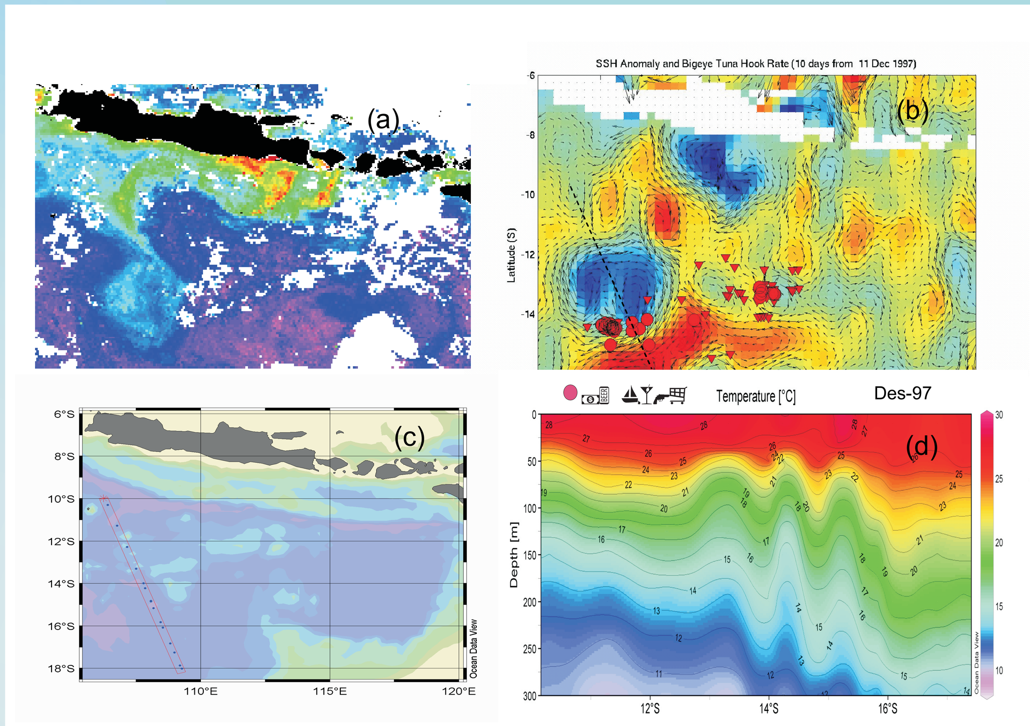

Fig 3. Oceanographic parameters anomaly in Eastern Indian Ocean in 1997 El Nino and IOD event. (a) chlorophyll-a distribution, (a) overlay of tuna catch (HR) on sea surface height anomaly, (c) XBT stations, (d) vertical section of temperature (December 1997).

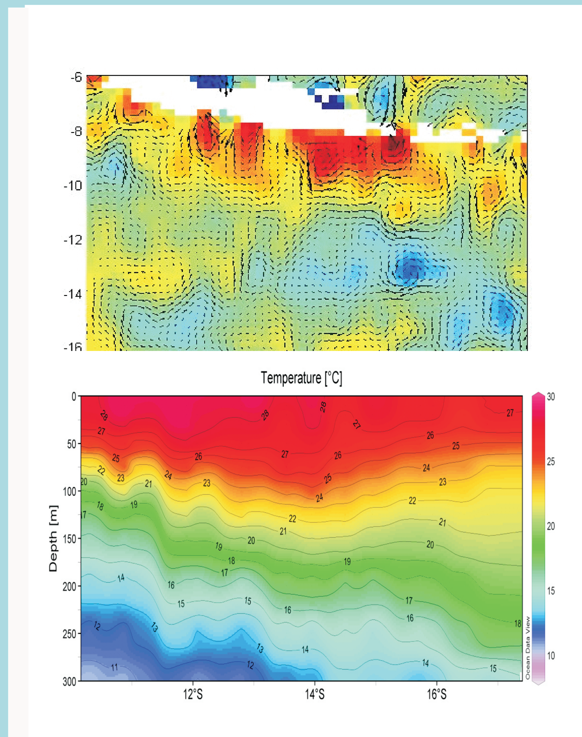

Fig 4. Oceanographic parameters anomaly in EIO during normal condition.

Sea level and thermocline depth are negatively correlated over the Indian Ocean, with low sea level corresponding to shallow thermocline depth and vice versa (Bray *et al.*, 1996; Susanto *et al*, 2001; Yu, 2003). In area where SSHA is lower, the optimum depth for fishing is shallower so that hooks can reach swimming layer of bigeye and catchability increased. Upwelling processes around tuna fishing ground improves and enhance the fertility of waters since nutrient increases. That area has higher productivity and food is responsibility for tuna abundance. Tuna are expected to be plentiful in upwelling area because the micronecton, unless the waters too cool or turbid (Sund *et al.*, 1981).

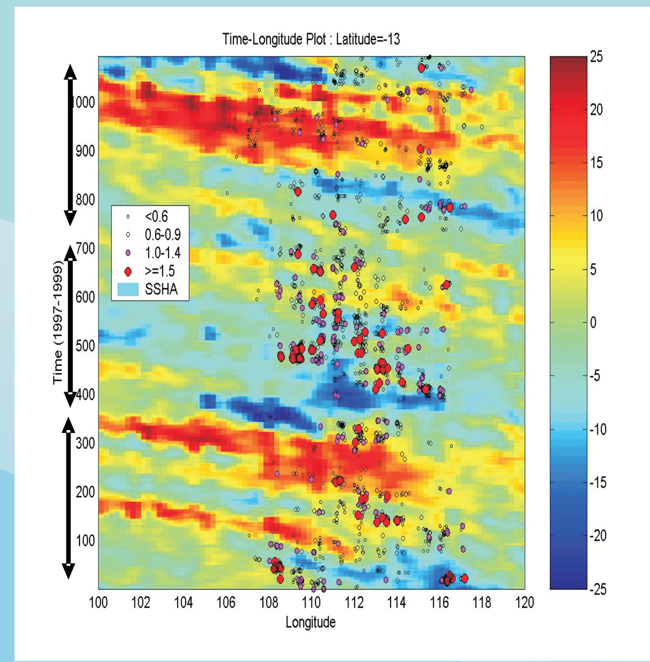

Fig. 5. Hovmuller plot of SSHA and daily tuna hook rate (1997-1999) around of -13°S

5. Conclusion

Variability of SSHA in EIO influenced both of SE monsoon and El Nino and IOD. During El Nino and IOD event, upwelling extended in time and space. Since shallow thermocline during El Nino and IOD-induced upwelling enhance the fertility of waters can increase the catch rate of bigeye using long line gear.

Acknowledgements. We thanks the Colorado Center for Astrodymanics Researh (CCAR) and my suvervisor (Dr. Robert Leben), University of Colorado at Boulder for the research facilities for processing altimeter data. This work was undertaken during the tenure of Partnerships Ocean Global Observation Observation (POGO) Fellowship to principal author.

References

Bray N.A., S. Hautala, J. Chong and J, Pariwono, 1996. Large-Scale Sea Level, Termocline, And Wind Variation In The Indonesian Throughflow Region. *J. Geophys. Res., 101*, 12.239-12.254.

Biorol, F and R. Morrow. (2001). Source of the baroclinic waves in the south Indian Ocean. *Journal of Geophysical Research,* 106, 9145-9160.

Hanamoto, E. 1986. Effect Of Oceanographic Environment On Big Eye Tuna Distribution. Bulletin of. Japanese Society of Fisheries Oceanography 51, 203-216.

Holland K. N., R. W. Brill, and R. K. C. Chang.1990. Movements of Thunnus Albacares and Thunnus Obesus Near Fish Agregating Devices. Fishery Bulletin, 88: 494-507.

Menard, F, Marsac, F, bellier, E, and B Cazelles. 2007. Climat oscillations and tuna catch rate in Indian Ocean: a wavelet approach to time series analysis. Fish Oceanography 16, 95-14.

Meyer, G. 1996. variation of Indonesian throuhflow and the El Nino southern oscillation, *Journal of Geophysical Research* 101, 12255-12263.

Saji, N.H., B.N. Goswani, P.N Vinayachandran, and T. Yamagata. 1999. A dipole in the tropical Indian Ocean, *Nature 401*, 360.363.

Shinoda, T., Hendon, H. H., & Alexander, M. A. (2004). Surface and subsurface dipole variability in Indian Ocean and its relation with ENSO. Deep-sea Research I, 51, 619-635.

Susanto, R.D., and A.L. Gordon. 2000. Upwelling along the coast of Java and Sumatara and its relation to ENSO. *J. of Geophys. Res. Lett.*, 28, 1599-1602.

Webster, P.J., A.M. Moore, J.P. Ioschningg, and R. R. Leben. 1999. Couple ocean-atmosphere dynamics in the Indian Ocean during 1997-98. *Nature, 401*, 217-255.