

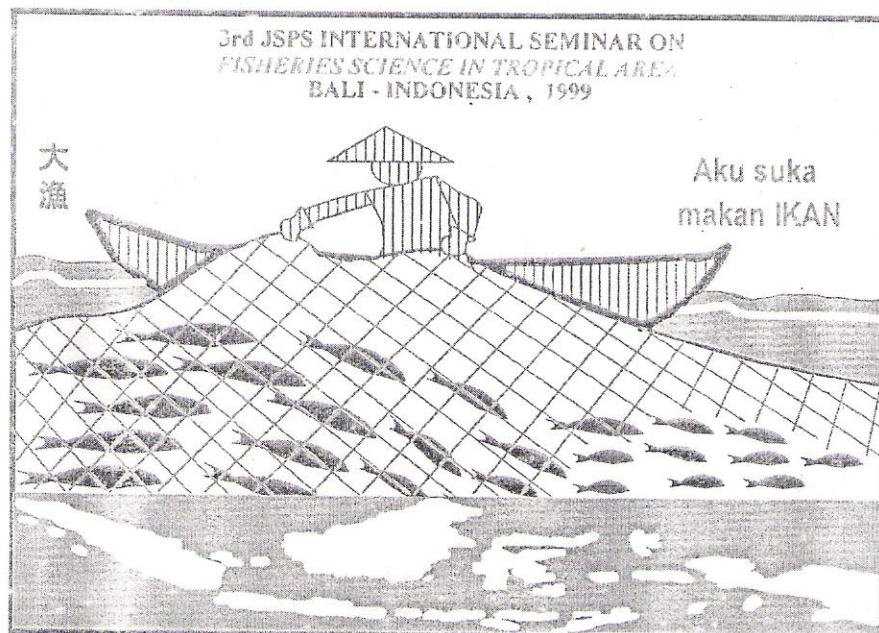
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EL NIÑO SOUTHERN OSCILLATION (ENSO) IMPACT ON SEA SURFACE TEMPERATURE (SST) DERIVED FROM SATELLITE IMAGERY : A PRELIMINARY STUDY

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El Niño Southern Oscillation (ENSO) impact on sea surface temperature (SST) derived from satellite imagery in the Gulf of Mexico and in the Java Sea has been investigated. The ENSO years is defined as the years that fall during El Niño events and the standard deviation of the Southern Oscillation Index ≤ -1.5 . Therefore, the ENSO years in this paper are 1987, 1991, 1994, 1997 and 1998. Other years are treated as non-ENSO years. SST monthly mean for the years of 1987-1993 is estimated from AVHRR Pathfinder, SST monthly mean for the years of 1993-1998 is estimated from AVHRR USF receiver and SST monthly years of 1994-1997 is estimated from AVHRR LAPAN (Indonesia).

Monthly mean SST values during ENSO years along the Gulf of Mexico are higher than that of the non-ENSO years for the Spring (Apr, May, Jun) and Summer (Jul, Aug, Sep) with the average different of 0.427°C , and in the Java Sea on the contrary. Meanwhile, for the Fall and Winter seasons, the monthly mean SST values during the ENSO years along the Gulf of Mexico are slightly lower than that of non-ENSO years. SST along the Gulf of Mexico are uniformly distributed during the Summer season and varies during Winter, Spring, and Fall seasons.

Introduction

The Southern Oscillation is an inter-annual see-saw in tropical sea level pressure between the eastern and western hemisphere, with center action located over Indonesia and the tropical South Pacific Ocean (Glantz¹, Philander²; Quin *et al.*,³). The Southern Oscillation index is the sea level pressure different between Darwin (12.4°S , 130.9°E) in northern Australia and Tahiti (17.5°S , 149.67°W) in the South Pacific Ocean with a high negative value indicate a warm event and a high positive value indicate a cold event (also referred to La Niña). However, it is important to note that there is not a one-to-one correspondence between the occurrence of Southern Oscillation events and El Niño events, Glantz,¹.

The scientific community uses the term El Niño Southern Oscillation (ENSO), combination of El Niño (ocean component of ENSO) and Southern Oscillation (atmospheric component of ENSO), to identify cases of warm eastern and central equatorial Pacific Sea Surface Temperature (SST) anomalies (Philander²; Trenberth⁴; Quin *et al.*³; Bigg⁵).

ENSO events occur irregularly at intervals of 2-7 years, at an average of about 3-4 years. They typically last 12-18 months and affect weather, climate, marine ecosystems, terrestrial ecosystems, and economies worldwide (Anonymous⁶; Polis⁷).

The ENSO event of 1997/1998 is recognized to be the strongest ENSO in recorded history. It is causing a very long drought in Southeast Asian Countries and in Australia with severe economic consequences. In the United States, ENSO has caused heavy rain and increasing number of typhoons and hurricanes in the eastern Pacific Ocean compared to non-ENSO years.

Studies about ENSO's impacts on SST in Pacific Ocean have been numerous. Meanwhile, very few studies

have been conducted in the Atlantic Ocean, and specifically in the Gulf of Mexico. Enfield and Mayer⁸, concluded that tropical Atlantic SST variability is correlated with ENSO. The region most affected by ENSO is the North Atlantic area of NE trades west of 40°W along 10°N - 20°N and extending into the Caribbean Sea. There, about 50-80% of the anomalous SST variability seems to be associated with the ENSO. Several studies of ENSO variability and/or internal variability in the Atlantic sector had been conducted such as Hastenrath⁹, Covey and Hastenrath¹⁰.

The Gulf of Mexico experiences 6-12 hurricanes during non-ENSO years. This number is reduced during ENSO years. Particularly in 1997 had practically zero hurricane incidence in the Gulf of Mexico. Precipitation in 1997 in Florida is much higher than during a normal year and there appears to be a much increased frequency of cold fronts sweeping through the region. These phenomena probably have a large impact on the SST of the Gulf of Mexico.

In Indonesian Sea-water, correlation between fish catch and ENSO (represented by SOI) consistent in the time and space domain (Pariwono¹¹).

Objective of this study is to investigate the impact on ENSO evidences on SST derived from satellite imagery in the Gulf of Mexico and the Java Sea and surrounding.

Methods

SST data are derived from satellite imagery from the AVHRR NASA Pathfinder for the period of 1987-1993, USF local area coverage AVHRR for the period of 1993-1998 in the Gulf of Mexico, and LAPAN (Indonesia) local area coverage for period of east monsoon seasons (June-October, 1994-1997) in the Java Sea.

Nine boxes are selected around the Gulf of Mexico for study areas representing center of the Loop Current,

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KEYWORDS: ENSO, Java Sea, Gulf of Mexico, satellite imagery, SST.

northeast of Gulf of Mexico (GOM), northwest of GOM, southwest of GOM, and central of GOM (Fig. 1.) and five boxes in the Java Sea (Fig. 2)

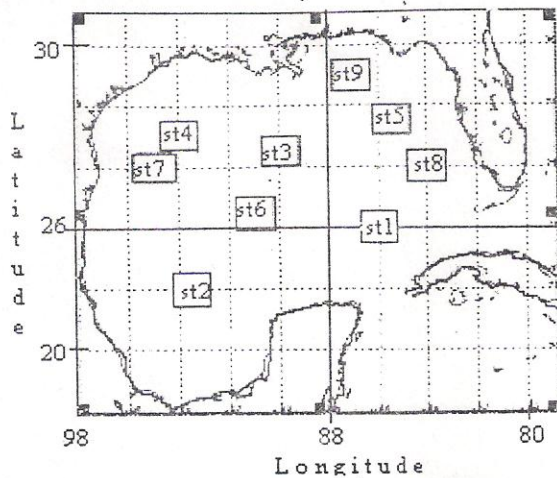


Fig. 1. Selected Sites of Study Areas in the Gulf of Mexico. Stations 1;2;3;4;5;6; 7;8; and 9 are centered at the coordinate of -86.0,24.0; -93.5,22.0; -90.0, 26.5; -94.0,27.0; -85.5,27.5; -91.0,24.5; -95.0,26.0; -84.0,26.0; and -87.0,29.0 respectively.

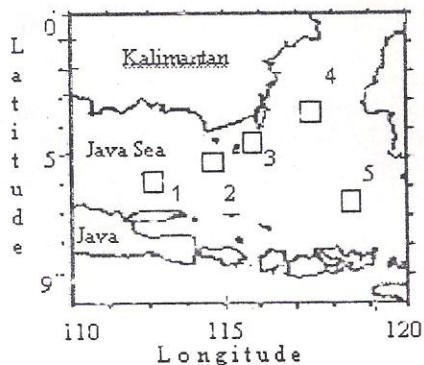


Fig. 2. Selected Sites of Study Areas in the Java Sea. Stations 1;2;3;4; and 5 are centered at the coordinate of (112.5, -6.0; 114.5,-5.5; 115.5,-4.5; 117.5,-3.0; 117.0,-7.0) respectively.

Monthly mean SST AVHRR Pathfinder is calculated from monthly mean SST day-time (ascending) and night-time (descending) using IDL routine. Sea surface temperature for AVHRR Pathfinder is estimated using the

formula of $SST = -3.0 + 0.15 * \text{grey values}$, SST for AVHRR USF local area coverage is estimated using the formula of $SST = -2.1 + 0.1992 * \text{grey value}$ and SST for AVHRR LAPAN local area coverage is estimated using formula of $SST = TW4 + 2.702 (TW4-TW5) - 0.528 - 273.0^{\circ}C$, where TW4 and TW5 are channel-4 and channel-5 of NOAA-AVHRR.

ENSO years herein are defined as years with standard deviation value of Southern Oscillation Index (SOI) ≤ -1.5 (Fig. 3). The determination for this value is based on the literature of ENSO years which fall into above SOI range. Therefore, in this study, ENSO years are the years of 1987,1991,1994,1997, and 1998 respectively.

Descriptive statistic is used to compare monthly mean SST during ENSO years versus non-ENSO years. T-test is used to test the statistical significant of monthly mean of ENSO years versus non-ENSO years.

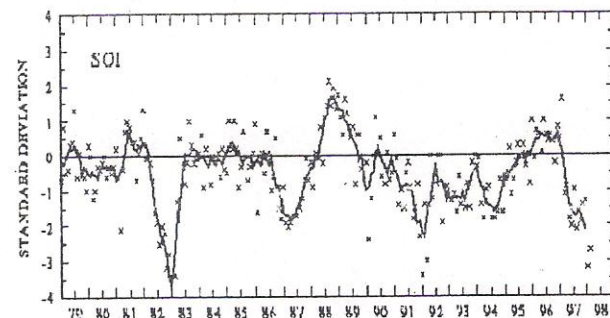


Fig. 3. Standard Deviation of Southern Oscillation Index for Determining ENSO Years.

Result

Monthly mean SST for each station of nine selected stations and the average of all nine selected stations during non-ENSO and ENSO years are presented at Table 1 and 2. The average of SST from all selected nine stations range from 22.331 $^{\circ}C$ (February) to 29.467 $^{\circ}C$ (August) for non-ENSO years (Table 1) and from 21.919 $^{\circ}C$ (February) to 29.791 $^{\circ}C$ (August) during the ENSO years (Table 2).

Station one located at the center of the Loop Current experience higher value of monthly mean SST than that of other stations for most months of all year long except for July, August, and September both during the non-ENSO and ENSO year (Fig. 4, 5).

Table 1. SST Mean Data during the Non-ENSO Years (88, 89, 90, 92, 93, 95, and 96) from Nine Stations of the GOM.

Month	Sta1	Sta2	Sta3	Sta4	Sta5	Sta6	Sta7	Sta8	Sta9	Average
1	25.74	24.04	22.56	21.79	22.56	23.39	22.34	22.63	20.58	22.85
2	25.55	23.37	22.09	21.09	21.76	22.83	21.61	22.45	20.23	22.33
3	25.54	23.32	22.55	21.14	22.15	22.51	21.83	22.70	20.75	22.50
4	26.09	24.87	23.54	22.46	23.41	23.75	23.16	23.73	21.94	23.66
5	27.03	26.44	25.37	24.94	25.55	25.60	25.28	25.56	24.67	25.60
6	28.17	28.02	27.85	27.73	27.63	27.75	27.75	27.69	27.48	27.79
7	29.03	28.67	29.15	29.23	29.15	29.02	29.04	29.13	29.23	29.07
8	29.39	29.28	29.52	29.54	29.40	29.62	29.56	29.52	29.35	29.47
9	29.57	29.25	29.35	29.09	29.22	29.48	29.12	29.40	29.02	29.28
10	27.95	27.38	27.04	26.89	26.75	27.49	27.10	27.25	26.01	27.10
11	26.74	26.31	25.30	24.90	25.10	26.14	25.17	25.79	24.05	25.50
12	25.84	24.75	23.20	22.72	23.20	24.23	23.12	23.76	21.94	23.64

Table 2. SST Mean Data during the ENSO Years (87,91,94,97,and 98) from Nine Stations of the Gulf of Mexico.

Month	Sta1	Sta2	Sta3	Sta4	Sta5	Sta6	Sta7	Sta8	Sta9	Average
1	25.73	23.93	22.61	21.87	22.93	23.37	22.27	23.21	20.82	22.97
2	25.31	22.93	21.45	20.70	22.00	22.41	20.65	22.10	19.73	21.92
3	25.58	23.67	22.32	21.19	22.74	22.90	21.45	23.21	20.46	22.61
4	26.53	25.47	23.44	22.80	23.64	24.24	23.14	24.42	21.94	23.96
5	27.71	27.14	26.09	25.65	26.37	26.32	25.88	26.75	25.52	26.38
6	28.48	28.66	28.22	28.79	27.84	28.43	28.85	28.03	27.57	28.32
7	29.48	28.86	29.70	29.78	29.65	29.60	29.52	29.78	29.74	29.57
8	29.77	29.52	29.81	29.90	29.76	29.96	29.74	30.04	29.62	29.79
9	29.45	29.49	29.32	29.37	29.13	29.54	29.54	29.37	28.92	29.35
10	27.62	27.57	26.98	26.79	26.47	27.23	27.01	27.04	25.87	26.95
11	26.99	26.40	25.70	24.72	24.68	25.91	24.70	25.33	23.51	25.33
12	26.33	24.85	24.05	23.43	22.99	24.53	23.75	23.95	21.79	23.96

Station nine located at the northeast of the Gulf of Mexico depict the lowest monthly SST mean during non-ENSO and ENSO years. The range of monthly mean SST among nine stations during non-ENSO years for Winter (Jan-Mar), Spring (Apr-Jun), Summer (Jul-Sep), and Fall (Oct-Dec) are 20.227-25.735°C, 21.943-28.167°C, 29.019-29.568°C, and 21.940-27.954°C respectively (Table 1). The range of monthly mean during ENSO years for Winter (Jan-Mar), Spring (Apr-Jun), Summer (Jul-Sep), and Fall (Oct-Dec) are 19.723-25.728°C, 21.939-28.849°C, 28.859-30.042°C, and 21.793-27.622°C respectively (Table 2). From the above data, it is clear that during the Summer seasons both during non-ENSO and ENSO years the sea surface temperature are relatively uniformly distributed along the Gulf of Mexico since the range of the temperature are very narrow compare to other seasons (Fig. 4,5)

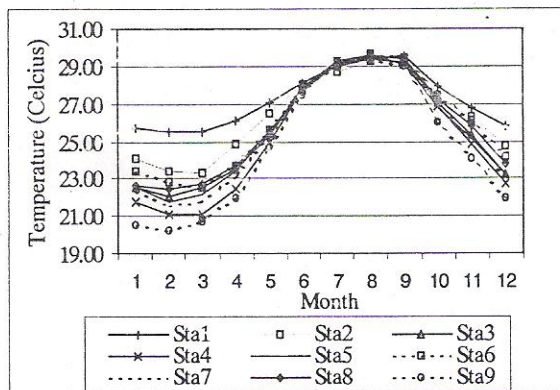


Fig. 4. SST Average Non-ENSO Years (87-98). Derived from Satellite Imagery from Nine Stations.

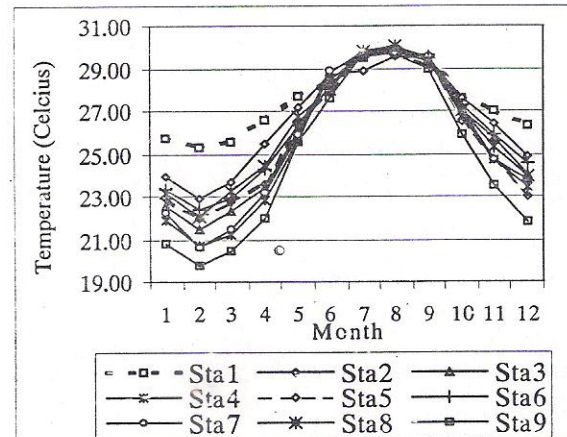


Fig. 5. SST Average ENSO Years (87-98). Derived from Satellite Imagery from Nine Stations.

In the Java Sea, monthly SST for each station of five selected stations and average of all five selected nine stations during non-ENSO and ENSO for period of east monsoon seasons, (June, August, September and October (1994-1997) years are presented at Table 3.

Table 3. SST (°C) Mean Data during ENSO and Non ENSO Years (1994-1997) in the Java Sea.

Period	St1	St2	St3	St4	St5
ENSO	27.76	27.72	28.05	28.45	28.05
Non-ENSO	29.10	28.55	28.62	28.78	28.95

In general, SST average value in the Java Sea and its surrounding for the non-ENSO years are higher than that of the ENSO year for the east monsoon seasons (Fig. 6).

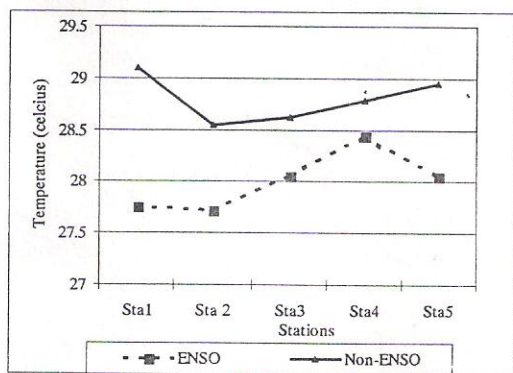


Fig. 6. SST Average Non-ENSO versus ENSO Years (1994-1997) for east monsoon seasons in the Java Sea.

The range of monthly mean SST during ENSO years in the Java Sea of five selected stations are 27.72-28.45°C and for Non-ENSO years range from 28.55-29.10°C. This result is coherent with the study conducted by Pariwono¹¹⁾ that found SST range in the Java Sea from 26.30-28.80°C.

Discussion

In general, monthly mean SST value in the GOM for the ENSO years are higher than that of the non-ENSO years for the Spring and Summer seasons. The different between monthly mean SST from all nine stations during the ENSO years and non-ENSO years range from 0.969°C to 0.778°C with the average of 0.427°C for the Spring and Summer seasons. On the other hand, monthly mean SST values in the Gulf of Mexico for the ENSO years are slightly lower than that of non-ENSO years for the Fall and Winter seasons (Fig. 7). The monthly mean SST plots for each station during non-ENSO and ENSO years are presented in Appendix 1.

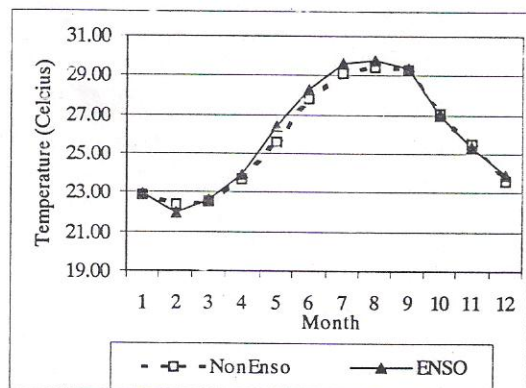


Fig. 7. SST Average Non-ENSO versus ENSO Years (87-89) Derived from Satellite Imagery, Gulf of Mexico

The minimum and maximum value of monthly mean SST of nine selected stations in the Gulf of Mexico occur in February and August respectively for non-ENSO and ENSO years. This result is coherent with the study conducted by Muller-Karger¹²⁾ that found SST maxima in Gulf of Mexico occur in July to September and minima occur in February to March.

The range of SST monthly mean among nine stations from the largest to the lowest value occur during Winter,

Fall, Spring, and Summer seasons respectively. For instance, in February, the range among nine stations of monthly mean SST during non-ENSO years (between station number nine and station number one) is 5.319°C, whereas for ENSO years the range between the two stations is 5.577°C. Meanwhile for the Summer season (July), the range among nine stations of monthly mean SST during non-ENSO years (i.e. station number two and station number nine) is 0.561°C, whereas for ENSO years (i.e. station number two and station number eight) is 0.925°C. These results indicate that during the Winter, Fall, and Spring seasons the SST could be affected by instability of atmosphere and ocean. Whereas during the Summer time, ocean and atmosphere are more stable.

A high variability of monthly mean SST occur along stations that located near the shore (e.g., stations 9, 7, 4, and 8). These results indicate that SST in these regions could be influenced by cold front from the continent specifically from the northern continent.

The lower monthly mean SST for Fall and Winter seasons during ENSO years could be connected to the cold front from northern continent and due to increasing of precipitation in the Gulf of Mexico area. As precipitation increase for October, November, December, January, February, and March during ENSO years, then this condition will increase the atmospheric relative humidity and then will decrease atmospheric temperature which will finally decrease sea surface temperature.

The lower monthly mean SST during ENSO year in Java Sea could be connected to the cold front shifted to the north in South Pacific, east of Australia. That cold front affecting the Java Sea by passing Arafuru Sea, then flowing to the west with current during east monsoon season.

Conclusion

Defining ENSO years as the years that fall in standard deviation of Southern Oscillation Index ≤ -1.5 , the SST mean monthly mean along Gulf of Mexico range from 22.331°C (February) to 29.467°C (August) for non-ENSO years and 21.919°C (February) to 29.791°C (August) during the ENSO years.

Monthly mean SST value in the GOM for the ENSO years are higher than that of the non-ENSO years for the Spring and Summer seasons with the average different of 0.427°C. Meanwhile, for the Fall and Winter seasons, the monthly mean SST values in the GOM for the ENSO years are slightly lower than that of non-ENSO years.

Distribution of monthly mean SST along Gulf of Mexico varies during Winter, Spring and Fall seasons. Whereas, the distribution during Summer season is uniform along the Gulf of Mexico.

Monthly mean SST value in the Java Sea for the ENSO years are lower than that of the Non-ENSO year for the east monsoon season.

To understand the effect of lower SST in the Arafuru Sea during ENSO year and its impact for marine living resources, needed further study using the same sources of data.

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