Journal of Sustainability Science and Management
Volume 6 *Number* 2, December 2011: 206-214
ISSN: 1823-8556

SEASONAL VARIATION OF WATER CHARACTERISTICS DURING INTER-MONSOON ALONG THE EAST COAST OF JOHOR

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Abstract: Inter-seasonal influence of monsoon on the South China Sea oceanographic condition is apparent. Nonetheless, little information exists on temporal variation in the southeast coast of Peninsular Malaysia especially near Johor. Two cruises have been conducted in two different monsoon seasons, both in October 2004 and March 2005. Accordingly, in this study, we examine the water-characteristics profile of the two periods. The results show that the differences in the hydrographical structures are apparent. In March, lower temperature is recorded with higher salinity than October. The TS diagram also suggests that the water of both periods do not share any similarity. This indicates that the water mass of both seasons might originate from different places. Comparisons with earlier studies suggest that influence of current circulation pattern during monsoon period toward the water profile is believed to be main reason. Additionally, some local effects such as sea surface heat flux and wind stress are also among the factors. This oceanographic seasonal differences described in this study are not only important for the area, but will also provide valuable information for the coastal region of southern South China Sea where the understanding of the temporal variation is lacking.

KEYWORDS: Monsoon, South China Sea, Water Characteristic

Introduction

The southern South China Sea (SSCS) is a semi-enclosed tropical continental shelf sea which is bordered by Peninsular Malaysia in the west and Borneo in the east. It is basically a shallow continental shelf basin with average depth of 60 m. The region in general is primarily subjected to the monsoon season (Chu *et al*. 1999). The northeast monsoon dominates the SSCS region during November to March which results in strong northeasterly monsoon wind, while the southwest monsoon provides the region with southwesterly wind between April to August.

Predominant monsoon wind system in the vicinity has strong influence on the current system. Earlier research has proved that the seasonal SCS circulation is mostly affected by monsoon winds (Dale 1956, Fang *et al.* 2002, Shaw and Chao 1994, Wyrtki 1961). In the SSCS, the current move southward along Peninsular Malaysia during northeast monsoon and move in the opposite direction during southwest monsoon. Nonetheless, no specific study has been made in the southern region. Inadequate observational data within the region has lead to lack of understanding of the region circulation and water characteristics.

Strong current along Peninsular Malaysia during the two monsoon seasons is a clear indication of coastal current presence in the area. Wyrtki (1961), in his early work, has shown strong current movement within the SSCS flows close to the Peninsular Malaysia land mass in both seasons. Later findings from modelling studies provided clearer view of the flow pattern and position. This information so far provided little information on the influence of current system towards the water-mass distribution and its characteristics between monsoon seasons. Some cruise data and earlier studies provided some information of water characteristics and its changes between seasons (Yanagi *et al*. 2001,

Received: 11 November 2010 / Accepted: 2 May 2011

Wyrtki 1961). In addition, study on sea-surface temperature and influence of current movement from global ocean model along nearshore Peninsular Malaysia shows that the water distribution is influenced strongly by current flowing southward during northeast monsoon (Akhir 2008). Both field data and modelling study so far offer good information but are non-conclusive.

Hydrographic condition study in a specific area of Terengganu coast show that water characteristics is influenced by monsoon. It is reported that during northeast monsoon, temperature and salinity recorded are lower (Saadon and Carmerlengo 1994). The study suggested that this was due to heavy rainfall and lower solar radiation due to overcast skies. Nearshore area is also influenced by the influx from main rivers along Peninsular Malaysia where freshwater volume increases during the northeast monsoon. Nonetheless, during southwest monsoon, understanding is still lacking. Hypothetically, water originating from Karimata Straits is warm. Northward current will bring warmer water from the south with a relatively lesser strength to the northern region along Peninsular Malaysia. Lower input from the main rivers during this time will reduce the influence on salinity which is expected to be higher. Nevertheless, the factors and analysis provided by this study mainly relates to local impact. None of it relate to the influence of northern water during northeast monsoon. However, this is understandable because the study site was close to the coastal area.

There have been only a few studies involving the observational data of the SSCS circulation, especially around Malaysian waters. The most extensive study of SCS only covers the central deep basins. The large –scale circulation of the SCS basins has been known extensively, but the circulation and water characteristics on the southern SCS continental shelf has been left behind. The understanding of the southern region of the SCS so far only relies on the understanding of the few studies mentioned earlier. This study will try to illustrate clear seasonal characteristics of hydrographic profiles at the southwest of the SCS off Johor during two inter-monsoon seasons.

This particular site is important because it is the point where coastal currents enter SCS from Karimata Straits and also the last point where southward currents during northeast monsoon exit SCS. Therefore, information on the seasonal variability of predominant oceanographic condition along the coast will provide understanding for instance of the influence of the northern region towards southern region hydrographic profile. This seasonal influence of current towards the hydrographic profile of the area will provide further understanding of changes in water characteristics between the seasons.

The objectives of this study are to describe the seasonal difference in hydrographic characteristics of nearshore waters and to determine the factors that influence its changes between inter-periods of the monsoon seasons. The study was undertaken during two inter-monsoon periods where notably weak signal of northeast and southwest monsoon were present. Please note that this inter-monsoon period will also sometimes be referred as transitional-monsoon period throughout the text, but hold the same meaning.

Materials and methods

The study site is located in the southeast coast of Peninsular Malaysia (3°N – 1.5°N, 104°W-105°W), within the waters of Johor. The study site can be regarded as the most southern part of SCS. Further south is Karamata Straits, connecting SCS with Malacca Straits and Makasar Straits (Figure 1).

Data were obtained along the coast of southeast Peninsular Malaysia. The cruises were initiated by the Institute of Oceanography (INOS), Universiti Malaysia Terengganu (UMT). Two trips were conducted, the first trip was during October 2004 (4days) and the following was during March 2005 (4days). Time selection for both trips was intended to replicate the inter-monsoon seasons which was estimated to occur during April and October. Earlier research was unclear about the characteristics of these months. Hypothetically, during inter-monsoon, the coming month, for instance April, will have northeast-monsoon characteristics while October will still retain southwest-monsoon characteristics.

The cruises undertook 6 transects, with 5 stations along each transect. Stations were positioned ~10km apart along the transects with the outer stations positioned almost 50km from the coastline. In each transect, temperature, salinity and dissolved oxygen were taken using Hydrolab Datasonde 4a. Additionally, current data were obtained using current meter. For both measurements, intensity of data collections was higher from the surface up to 10m depth. From 10m depth to the bottom, data collections were less intense.

For analysis, this research will only use data from 2 offshore stations of each transect (Figure 1).This alongshore line will be named Line 1 and Line 2. These data selections are made to make sure suitable stations are chosen and to remove the frontal zones from the analysis. The frontal zone which usually lies at 20-30km from shore is known for its short-period variation. Homogenous shelf water located offshore; away from the frontal zones usually has less impact on short-term variation in the water characteristics, usually caused by freshwater output or local wind condition (Blanton, 1981). Moreover, offshore stations are easier to put into analysis context since they have deeper profiles than nearshore stations with depth usually below 20m (usually well mixed).

Results

During the month of March, temperature recorded was between 28-29°C on the surface, and this is the same for both line 1 and 2 (Figure 2a and 2b). However as it gets deeper, the temperature decreases slightly with the depth and was much more consistent with 0.5°C range between stations in the deeper part. At some stations, the thermocline layer can clearly be seen at a depth of 20m. In October

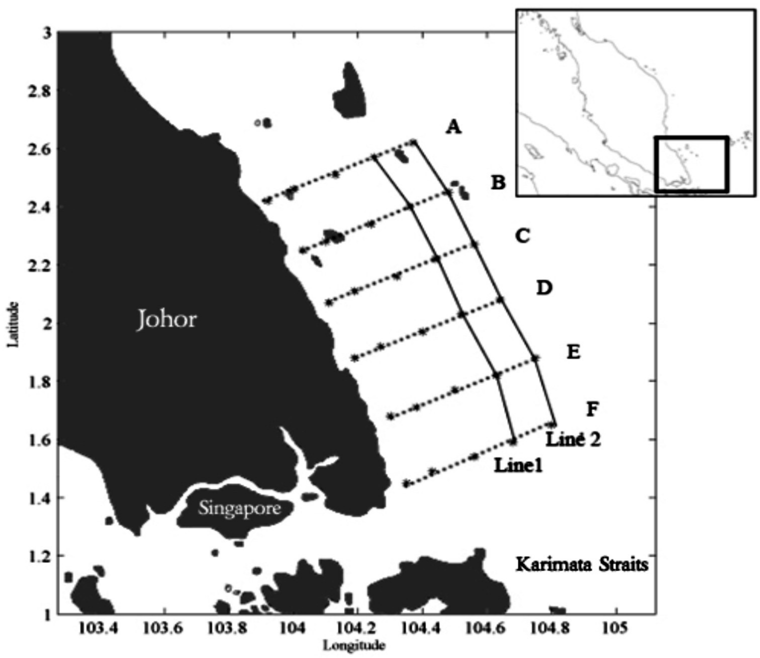

Figure 1. Map of study site including transects name.

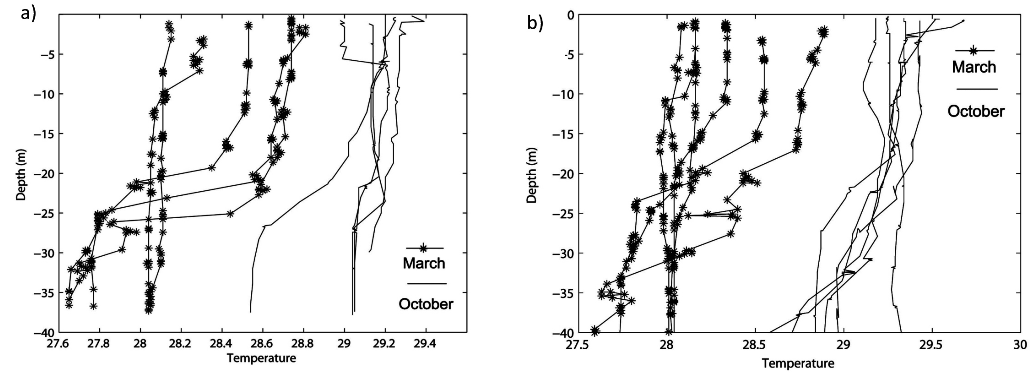

Figure 2. Temperature profiles of October 2004 and March 2005 for a) Line 1 and b) Line 2.

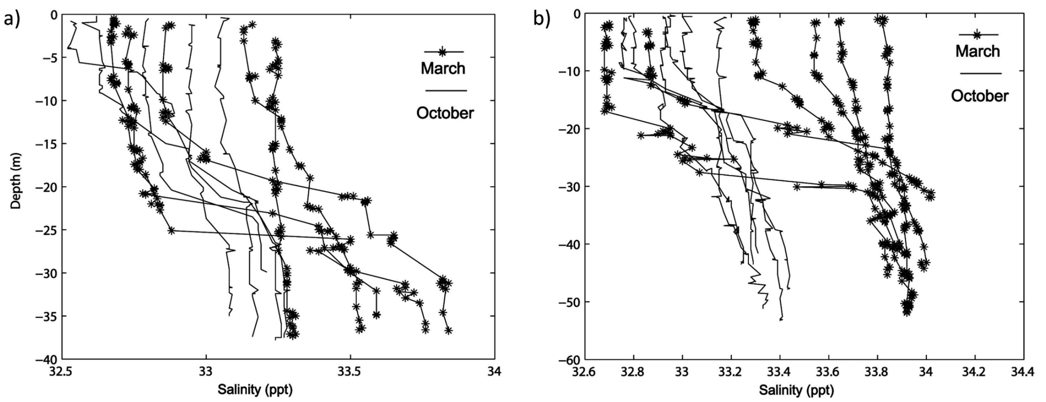

Figure 3. Salinity profiles of October 2004 and March 2005 for a) Line 1 and b) Line 2.

the temperature was higher, between 29-29.5°C. The temperature during this month had smaller variation between stations than March. Between both months, temperature-profile difference is quite distinctive with differences between most stations exceeding 1°C. This seasonal variance in temperature is considered high in the equator region.

Salinity profile recorded during both months of October and March in Line 1(Figure 3a) ranged between 32.5-33.4ppt. Interestingly, the salinity for both months share the same properties at the first 20m depth. Nonetheless, below 20m the salinity profile for the month of March showed increasing of salinity up to nearly 1ppt from the surface in certain stations. The difference of salinity between the 2 months can be distinguished at the deeper layer. In line 2, the salinity property was slightly different. Although there was low salinity in the surface of 2 stations in March, the entire salinity for March in general was higher than October. Profile does not vary much with depth, however the bottom of mixed layer for the two months was around 20m depth where below that, the salinity started to show rapid increase. Difference between line1 and 2 is also important to note, where the surface layer has lower salinity than line 2 (~0.5ppt). Since line 1 is closer to the coast, this might be caused by the frontal zone area which is more likely to be influenced by nearshore water and dynamics.

From temperature and salinity profiles, the surface values for both months show well-mixed characteristics. This can clearly be seen from the contour plot of both temperature and salinity (Figure 4a, 4b, 5a and 5b). In October, well-mixed layer reached only the first 15m depth. Nonetheless, in March the stratification layer

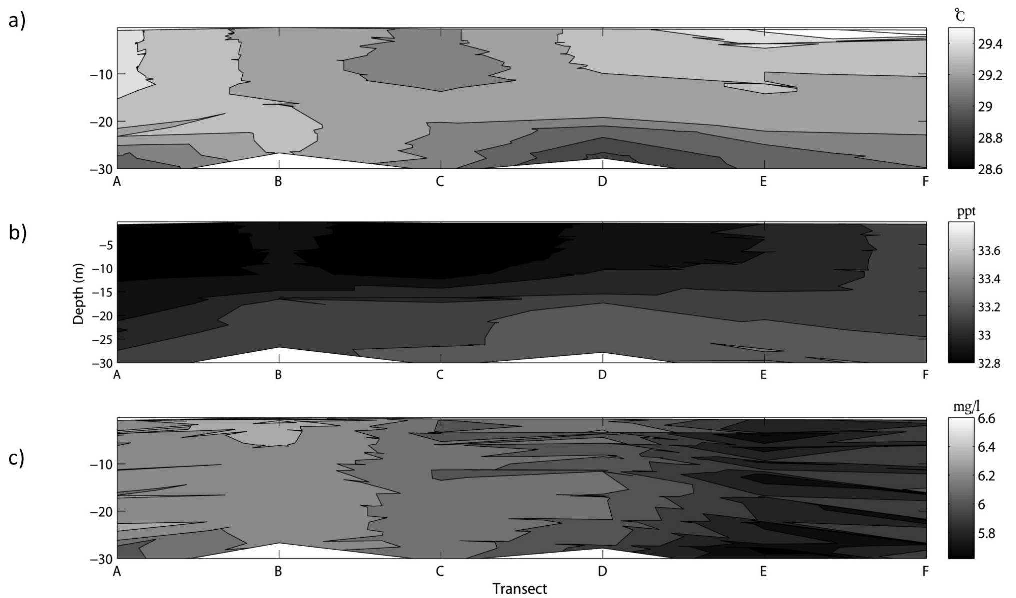

Figure 4. Contour plots for October 2004 from Line 2; a) Temperature b) salinity and c) Dissolve Oxygen.

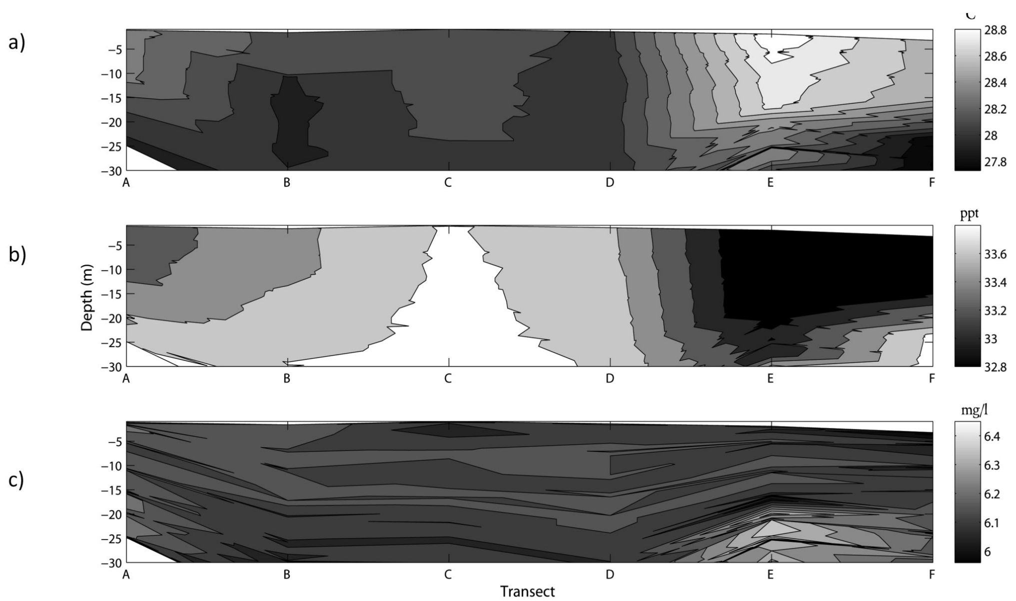

Figure 5. Contour plots for March 2005 from Line 2; a) Temperature b) salinity and c) Dissolved Oxygen.

reached up to 25m. It is important to note that the temperature variation of the surface layer in October is not high (~0.3°C) and this is also applies to its salinity values, so this layer can be considered as well-mixed. But this is not the case for March. The surface stratification reached up to 1°C between stations, and it showed an increment from north to south. Throughout the alongshore contour, temperature and salinity at transect C is somehow different from other stations for both months. Interestingly, during March it clearly showed that the whole water

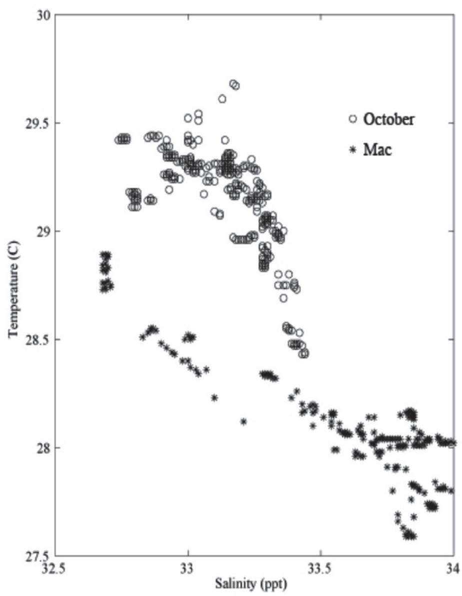

Figure 6. T/S diagram for alongshore station along Line 2.

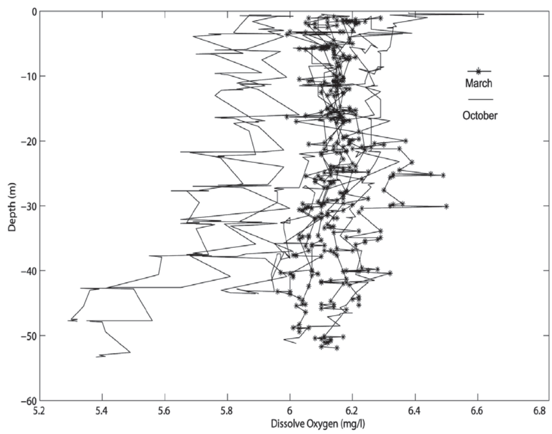

Figure 7. Dissolve Oxygen profile at line 2.

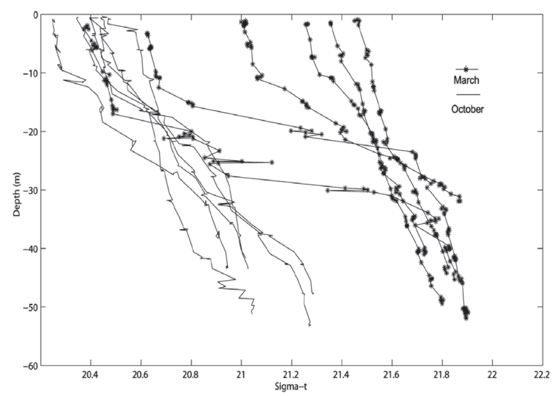

Figure 8. Sigma-t profile at line 2.

column was mixed while in October high temperature and low salinity at the transect was noted in comparison to adjacent transects.

Water mass characteristics from the month of October and March is shown in the T/S diagram (Figure 6). The characteristics of water mass between the two months are clearly distinguishable. October water was much higher in temperature while covering the salinity values between 32.7 to 33.5 ppt. Meanwhile, March water was cooler with higher values of salinity especially at subsurface, which is more than 33.5ppt.

Dissolved oxygen is also compared between the two months. This is to make clear the differences of water characteristics between the two. High DO was observed during the month of March, which lies between 6 and 6.4 mg/l (Figure 7). It does not differ much from the profile of other parameters where surface share same values but start to disintegrate as it gets lower than 20m depth. Nevertheless, contour figures show that the changes in DO between transect can be seen in October (Figure 4c). The DO decreases from north to south, but during March the DO change between transects were insignificant. However, the south part seemed to have lower DO than the north (Figure 5c).

During March, the sigma-t was high compared to October. On average, the difference is about 1 (Figure 8). And the difference was almost the same throughout the depth. The property of sigma-t from the contour plot representing alongshore distribution shows similar changes as temperature and salinity. Surface density in October is almost well-mixed. Nonetheless, the northern part is much lower than the southern part of the study site (Figure 9a). Stratification of March water profile shows that southern part was filled with lower density water (Figure 9b).

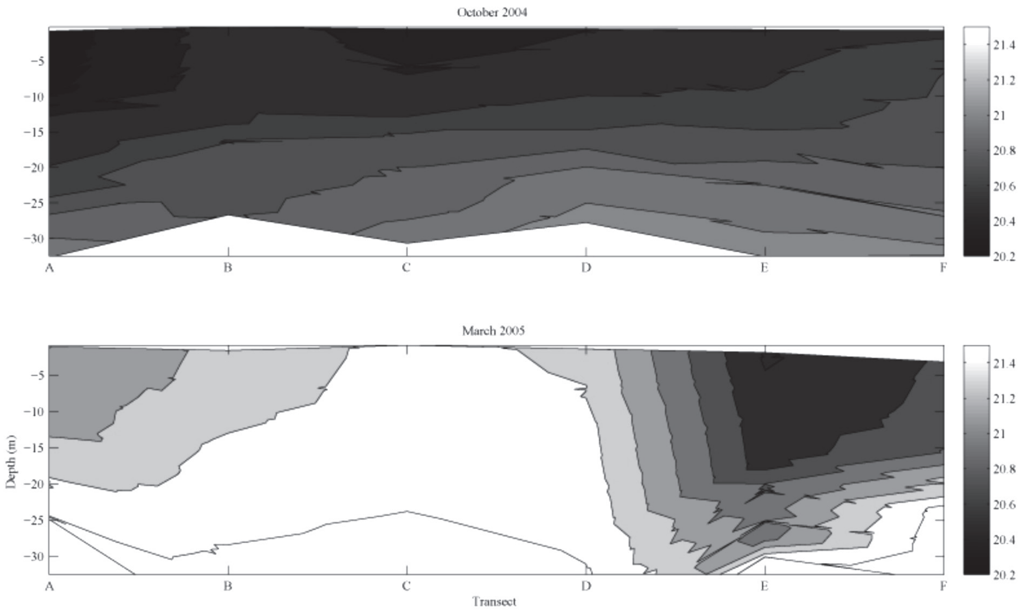

Figure 9. Contour of sigma-t.

Discussion

Although the two cruises provide a very limited representation of the dynamics of the water properties distribution, observation at both periods of sampling time showed clear pattern seasonality of the physical variables for the water column. Earlier study on the area by Wyrtki (1961) and Yanagi *et al.* (2001), which concentrated most of the work in the wider area of SCS and Gulf of Thailand respectively, provides some useful information for this study. The Johor area is unique given that it is the at the tail part of the SCS current, a southward current that flows from the north during northeast monsoon and the area is also the entrance for the SCS southwest-monsoon northward flow.

The water-property characteristics described conform with earlier hypothesis that the water at the area of east coast of Johor which is the southernmost part of SCS, is subject to seasonal changes. During the northeast-monsoon transition period (October) the overall temperature is higher while salinity is lower compared to the southwest-monsoon transition period (March). This characteristic is expected because the influence of both monsoon waters brings different water profiles from both north (northeast monsoon) and south (southwest monsoon). In general, the water profiles show a signal of thermocline layer consistently between 15-25m depth for both seasons.

The northeast monsoon is the strongest between the two monsoons. During this time, SCS water at the eastern coast from Vietnam to Malaysia is influenced by strong current flowing from the northern part. The current which starts near Taiwan brings low-temperature and high-salinity winter water to the south. Shaw and Chao (1994) provided some data from cross-sectional area off Vietnam coast where they recorded low temperature (22°C) and high salinity (34ppt). The same water is believed to feed the southern SCS continental shelf. Since this is the case, there is no doubt that low-temperature and high-salinity water is flooded into Penisular Malaysia and into the Johor coast. This water distribution is not new to the region. Earlier, Wyrtki (1961) and Yanagi *et. al*. (2000) studies within the SCS and the Gulf of Thailand reported that cold-water mass with high salinity is present at the area during northeast monsoon. This water is also high in density. Interestingly, the study also recorded

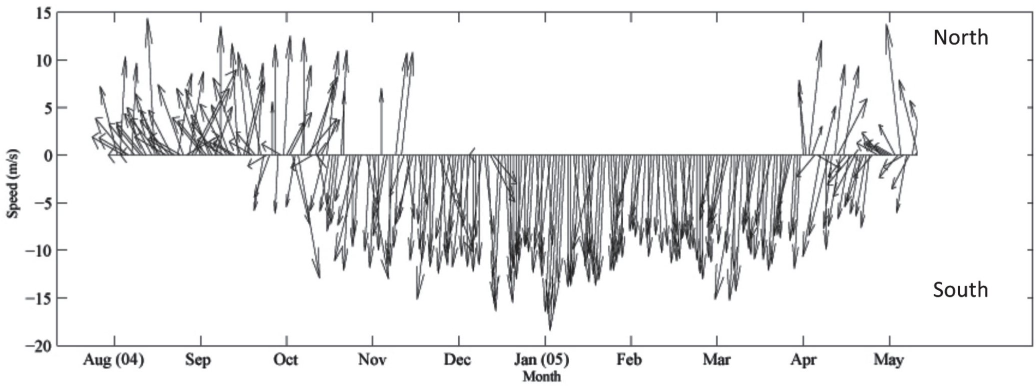

Figure 10. Wind speeds at east coast of Johor from August 2004 to May 2005.

almost the same reading from what Shaw and Chao (1994) did in Vietnam coast. The finding strongly suggests that the water characteristics along the Johor coast shown during the northeast monsoon is influenced by the southward current originating probably from the northern SCS. Because of density difference, some studies also suggest that high-density water from the north flow south because of density gradient. This is an interesting fact, because previously it was regarded that the circulation was mainly forced by the monsoon wind system.

The southwest monsoon usually starts in the month of July with a southwest favourable wind starting during this time of the year and it starts to generate water which flows from the Karimata Straits toward the SCS. The water during this month is usually less saline and higher in temperature. Given the fact that the water originates from the equator region, higher-temperature water is likely. During the transitional period, the water still maintains its characteristics of southwest monsoon. High-temperature mixed-layer water during this study is not only subject to the fact that the current from the south brings warmer water to the region, but it is also known for two other factors which is possibly contributes to this. Yanagi *et. al*. (2000) suggested that high surface heating and weak wind during this period caused the water to be higher in temperature, especially on the surface. It is believed that the Johor weaker wind stress provided less mixing on the surface. Along the Johor coast, the wind speed and direction recording agree with the suggestion (Figure 10). Starting from May, the wind starts to incline northward. However, the strength of the wind speed was weaker and its direction was not as concentrated as what can be seen happening during the months of November to April. High sea-surface heat flux combined with this factor provided very little mixing on the surface. This is probably one of the reasons why thermocline layer is slightly lower (~15m) during this month, compared to March which is ~20m depth.

There is also one interesting feature during both October and March. At transect C, it is found that water properties at the area always differ from its surrounding. Low temperature was recorded for both months at this transect. Further analysis was made and high precipitation during the cruise tracking past transect C is believed to be the factor. Data from Meteorological Department showed high precipitation for two days with a maximum 68mm recorded. These data recorded as the cruise passed the area is believed to be significant for the water temperature to be cooler than its surroundings. Moreover, in the same latitude of transect C, there is a river mouth of Sungai Sedili Besar (~2°N) which can produce significant freshwater influx during rainy days. Nevertheless, the station is 50km from the coast and any impact from the river is unfeasible. This argument fits nicely with the October dataset because the salinity profile at transect C is lower. Nevertheless, there is something peculiar about the March data. Although it recorded low temperature at transect C the salinity is higher than it surroundings. Precipitation is recorded during that period of the cruise, however it is lower compared to October. So far there is no answer of why the salinity at that particular station is higher than the rest. This also could suggest that lower temperature on the surface is probably caused by other factors.

Conclusion

The water characteristics along the Johor coast in general, follow the common pattern of monsoonal system of the SCS. Although the data from the cruise is relative to transitional period of the monsoon, its influence is still present during that time. Apart from the monsoonal system that influences the water characteristic, local heating and precipitation also contribute to the regional water-mass distribution. River influence and its extent towards the offshore is not known in this study, so the influence of it towards the water profile will be worthy of future study. Further study should also combine this information with the knowledge of current circulation of the local system. This will lead to a better understanding of the dynamics of water-mass distribution.

Acknowledgement

The authors wish to thank the Institute of Oceanography (INOS), UMT for the data they provided and to all persons involved during the October 2004 and March 2005 scientific research cruise. Special dedication to the late Prof. Dr. Law Ah Theem who was the project leader of this data collected back then.

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