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Variations of Southern South China Sea Characteristics near Pahang

(Perubahan Ciri Laut China Selatan Bahagian Selatan Berdekatan Pahang)

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ABSTRACT

Oceanographic cruises in Pahang water in October 2003 and April 2004, monsoon transition months, produce data on water characteristics. The temperature in both months showed higher values in nearshore compared to the offshore stations. The nearshore salinity in both months is lower than offshore stations. Comparatively, there were smaller differences in temperature and salinity in October than in April, with very little variation between nearshore and offshore stations. T-S diagram showed significant differences between October and April water characteristics. According to the water characteristic observations, the temperature and salinity in October was lower than in April, while dissolved oxygen was higher than in April. The lower temperature and salinity taken during the sampling time in October suggested that during this time, the study area already received the influences of strong winds due to upcoming monsoon. The warmer and saltier water obtained in April showed that during this time, the study area was influenced by southwest monsoon. Winds related to rainfall were observed to have impact to the dynamics of water characteristics during both months.

Keywords: Current circulation; monsoon transition month; salinity; South China Sea; temperature

ABSTRAK

Pelayaran oseanografi di kawasan perairan Pahang pada bulan Oktober 2003 dan April 2004, bulan peralihan monsun, menghasilkan data mengenai ciri air. Suhu air pada kedua-dua bulan menunjukkan nilai yang lebih tinggi di kawasan pesisir pantai berbanding dengan stesen luar pesisir. Kemasinan di kawasan pesisir pantai pula adalah lebih rendah daripada stesen luar pesisir bagi kedua-dua bulan. Secara perbandingan, terdapat perbezaan kecil dalam suhu dan kemasinan pada bulan Oktober berbanding bulan April, dengan perubahan yang sangat sedikit di antara stesen berhampiran pantai dan luar pesisir. Gambarajah TS menunjukkan perbezaan yang signifikan antara ciri air pada bulan Oktober dan April. Menurut pemerhatian ciri air, suhu dan kemasinan pada bulan Oktober adalah lebih rendah berbanding pada bulan April, manakala oksigen terlarut adalah lebih tinggi berbanding pada bulan April. Suhu air laut dan kemasinan yang lebih rendah yang diambil pada bulan Oktober memperlihatkan bahawa pada masa ini, kawasan kajian telah menerima pengaruh angin kuat berikutan monsun yang bakal tiba. Suhu laut yang semakin panas dan masin yang diperoleh pada bulan April menunjukkan bahawa pada masa ini, kawasan kajian telah dipengaruhi oleh monsun barat daya. Angin yang turut berkaitan dengan hujan diperhatikan memberi kesan kepada ciri dinamik air pada kedua-dua bulan.

Kata kunci: Bulan peralihan monsun; kemasinan; Laut Cina Selatan; peredaran arus; suhu

INTRODUCTION

Information and knowledge regarding the physical characteristics of seawater at the east coast peninsular Malaysia, especially ~50 km towards the offshore, is very important as it affects local activities. Pahang water is situated in the southern region of the South China Sea (SCS) off the central east coast of peninsular Malaysia. The coastal area of the northern Pahang water was fed by the Pahang River, the largest river in peninsular Malaysia which flows into the SCS (Figure 1). Earlier studies (Hu et al. 2000; Wyrtki 1961) suggested that water properties in the SCS were mainly influenced by monsoons: the northeast monsoon (October to March) and the southwest monsoon (June to August). Between those seasons, April and October appear to be transition months (Morgan & Valencia 1983; Wyrtki 1961). The monsoon transition periods present special challenges, however, and a deep understanding of the Pahang water is lacking. The last comprehensive study of the Pahang water was done by Mohsin et al. (1986) documented in Ekspedisi Matahari book report. There is only recently, the composite study of datasets collected by INOS between 2002 and 2010 in the SCS and a study on selected regions in Johor were done by Akhir et al. (2011) and Akhir and Yong (2011) respectively. Both studies suggested that during the inter-monsoon period, the coming month, for instance April, will have northeast monsoon characteristics while October will still retain southwest monsoon characteristics. However, those are still unclear and need more on data collection and explanation.

Several factors that could affect salinity and temperature at the study area include precipitation, evaporation, cloud cover, upwelling and sinking(Marghany et al. 1996). The distribution of temperature and salinity varies from the southwest to the northeast monsoon period due to the seasonal effects. Temperature and salinity was found to be lower during the northeast monsoon than during the southwest monsoon (Camerlengo & Saadon 1996; Chua 1984; Zainal 1993).The water tends to have vertical mixing during the northeast monsoon period than during the southwest monsoon. Weak vertical mixing in the vertical layer from March through May was mainly due to large sea surface heating and weak sea surface wind. Water exchange between the Gulf of Thailand and the SCS that expands from March to May due to the coupled effect of intensified estuarine circulation and the Ekman transport by the southwest monsoon can also be said to develop this feature (Yanagi et al. 2001).

The aim of this study was thus to describe the variations of water characteristics near Pahang in two different sampling times, October and April. As mentioned before, October and April are two inter-monsoon periods where previous studies already noted the influences of previous or upcoming monsoon during the respective months. Therefore, this study will try to illustrate the differences in water properties between both transition months at the different site, Pahang coastal water.

MATERIALS AND METHODS

The study site was located in Pahang water (2.9°N to 3.9°N and 103.4°W to 103.9°W), south-western South China Sea (SCS) and was enclosed by 40 m isobaths. It encompassed an area of 6 transects with 24 stations (4 stations in each transect) spanning the cross section of the Pahang water (Figure 1). The distance between stations was ~10 km and the farthest sampling stations were located ~50 km offshore.

Datasets used in this study were selected from two oceanographic cruises conducted by the Institute of Oceanography (INOS), Universiti Malaysia Terengganu (UMT). The first cruise was from 10^{th} to 15^{th} October 2003 and the second was from 5 to 10^{th}April 2004. Data collected in both April and October indicated inter-monsoon seasons or monsoon transition months in accordance with (Wyrtki 1961), (Morgan & Valencia 1983) and (Chua 1984). Temperature, salinity and dissolved oxygen parameters used in this study were collected by using Hydrolab Datasonde 4a. Hydrolab data was taken in vertical profile for each station. It was lowered down from the ship until it reached the deepest water column and the data was logged into the attachable software on boat. Daily wind data and rainfall data included in this study were obtained from Malaysian Meteorological Department (MMD) similar to the sampling months. The wind sensor was installed at 10 m height from the ground and located at the Kuantan station (Pahang).

For analysis, temperature and salinity data were defined by alongshore, nearshore and offshore in April and October. Line 1 (nearshore stations) and Line 4 (outermost stations) in April and October were selected to plot the alongshore contours. Station A represents the northern part of sampling area, station F represents the southern part and Station C is situated at the Pahang River mouth. The temperature, salinity and dissolved oxygen data at near shore stations (Line 1 and 2) and offshore stations (Line 3 and 4) during both months were selected to plot the vertical profiles (Figure 1). These steps were used to illustrate the differences in nearshore and offshore water characteristics. Near shore stations are mostly influenced by freshwater output or local wind that affects the hydrographic condition at the area while Akhir and Yong (2011) mentioned that offshore stations are easier to analyse since they have deeper profiles than nearshore stations thus better interpretation of vertical stratification is obtained.

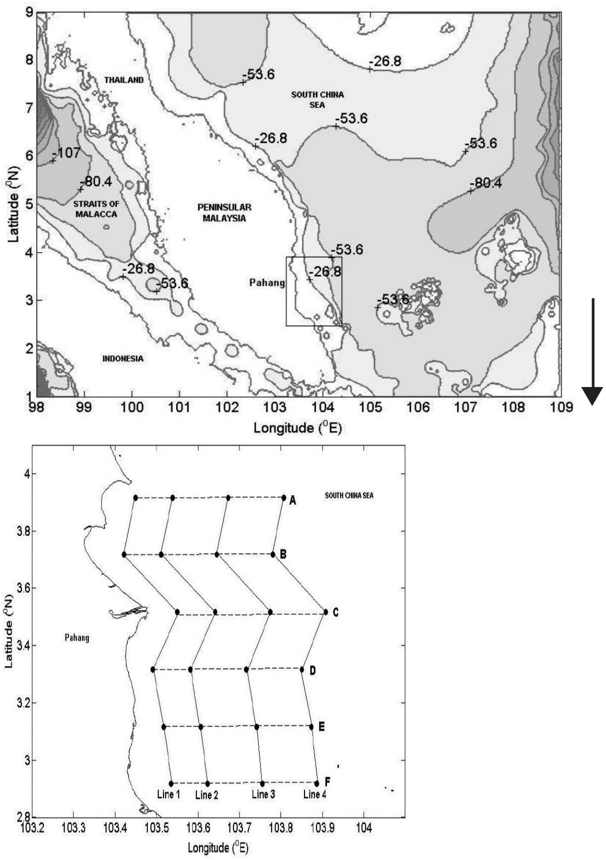

FIGURE 1. Map of study site along Pahang water

RESULTS

TEMPERATURE AND SALINITY

In both months for Line 1 (nearshore stations), the temperature at the centre shows greater values compared to the northern and southern part of the area (Figure 2(a) and 2(c)). For line 4 (outermost stations), the temperatures were higher at the northern part and decrease southward (Figure

2(b) and 2(d)). October temperatures nearshore ranged from 28.95-29.6°C and were cooler (28.79-29.37°C) at the offshore stations. In April, the nearshore temperature is filled with higher temperature (29.7-31.22°C) and tends to decrease towards offshore (28.47 – 30.5°C). Figure 4a and 4d showed a similar trend of temperature between nearshore and offshore stations in both months. Warmer temperatures were recorded at nearshore stations than at offshore station. Alongshore contours of temperature (Figure 2) show that water masses at the centre of the study area are distributed by distinct water. This occurred mainly at Stations C to E. The highest temperatures were found at the nearshore surfaces of Stations C to E (Figure 2(a) and 2(c)) and decreased as the depth increased. This differed markedly at offshore stations, where a lower temperature at the centre of the study area remained constant until reaching a 10 m depth in October and 15 m depth in April. If to compare the temperature distributions in between these two months, Figure 4(a) (October) and 4(d) (April) showed that April data has greater different between maximum and minimum temperatures with ~0.7°C. Its differ with temperature observed in October where the different between the maximum and the minimum temperature values was ~0.3°C. Thermocline where the rapid changes of temperature occurred with depth showed that it was more obvious in April than in October (Figure 4(a) & Figure 4(d)). The temperatures in October prominently well-mixed throughout the water column.

Previous studies showed that salinity values in seawater are always inversely proportional to temperature. If to compare by month, in October, the salinity was lower than in April (Akhir et al. 2011). Salinity at nearshore stations recorded in both months was lower than in offshore stations (Figures 3, 4(b) and 4(d)). Interestingly, in October, lower salinity (32.4-32.8 ppt) was observed at nearshore surface to 5 m depth of Stations B to E (Figure 3(a)). This feature was continuous until the offshore Station B to E (Figure 3(b)). This feature was not observed in cross-section plot of salinity in April (Figure 3(c) & 3(d)). In April, the stratification was more obvious from northern to southern Pahang water. The salinity increases towards the centre part and decreases at the southern part of the boundary (Figure 3(d)).

The vertical profiles of salinity showed a constant reading in October (Figure 4(b)) while April showed a significant variation of salinity between nearshore and offshore stations (Figure 4(e)). In October, the value at nearshore stations was 32.03-33.58 ppt and was 32.14-33.86 ppt at the offshore stations. In April, nearshore and offshore values obtained ranged from 32.08 - 34.44 ppt and 33.87-35.06ppt respectively.

T-S DIAGRAM

The seasonal variation of water masses between April and October is well presented in the T-S diagram (Figure 5). The characteristics of temperature and salinity for both months can be distinguished clearly by this diagram. In April, the water masses experienced warmer temperatures and higher salinity compared to October. The distribution of temperature and salinity values were between 28.8-29.8°C and 32-34 ppt, respectively, in October, while in April they were 28.5-31.3°C and 32-35 ppt respectively. In April, the temperature and salinity differences were small with ~2°C temperature and ~2 ppt salinity. In October, the temperature values were almost constant with slight differences of ~1°C and the salinity values varied with differences of ~2 ppt.

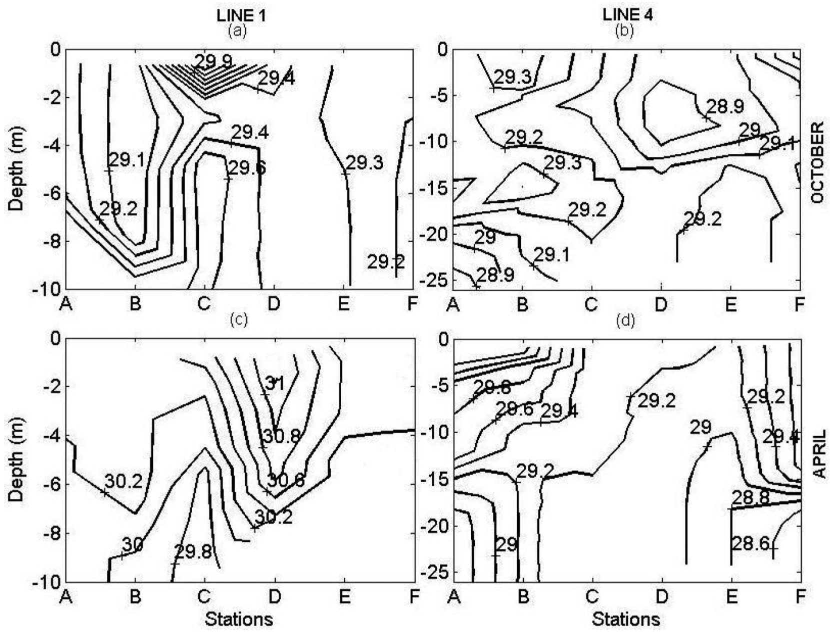

FIGURE 2. Along shore cross-section of temperature (°C) on (a) October 2003 at Line 1, (b) October 2003 at Line 4, (c) April 2004 at Line 1 and (d) April 2004 at Line 4

DISSOLVED OXYGEN

For analysis purposes, dissolved oxygen obtained from the hydrolab was taken into account for this study. Dissolved oxygen at nearshore and offshore stations for both months recorded a consistent reading with only slight differences (Figure 4(c) nd 4(f)). During October, the nearshore area contained a lower amount of dissolved oxygen(5.42-6.30 mg/L) which increased at the offshore stations(5.64-6.50 mg/L). The inverse was found in April when nearshore dissolved oxygen (5.59-6.33 mg/L) was slightly higher than offshore (5.24-6.05 mg/L). Compared monthly, dissolved oxygen obtained in October was greater (5.4-6.5 mg/L) than in April (5.3-6.3 mg/L), with only approximately 0.2 mg/L.

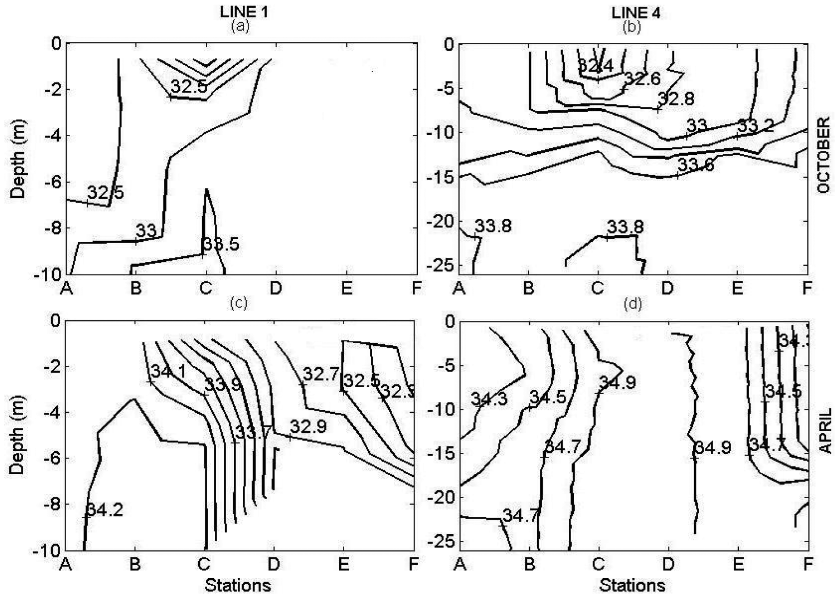

FIGURE 3. Along shore cross-section of salinity (ppt) on (a) October 2003 at Line 1, (b) October 2003 at Line 4, (c) April 2004 at Line 1 and (d) April 2004 at Line 4

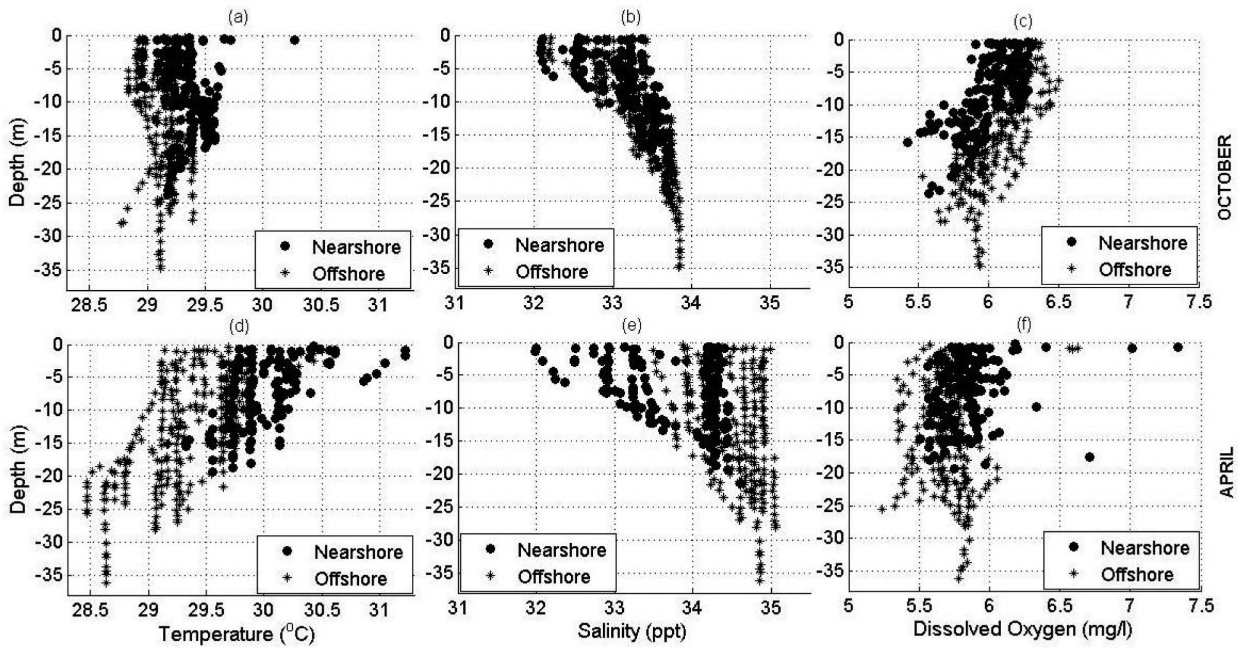

FIGURE 4. Profiles of (a) and (d) temperature (°C), (b) and (e) salinity (ppt) and; (c) and (f) dissolved oxygen (mg/l) on October 2003 and April 2004, respectively. Dotted symbols indicate nearshore stations (Line 1 and 2) and diamond symbols indicate offshore stations (Line 3 and 4) (Figure 2)

DISCUSSION

The SCS is mainly influenced by both the northeast monsoon and the southwest monsoon. Significant seasonal variations in water masses and currents at the SCS were proven according to several previous studies (Akhir et al. 2011; Akhir & Yong 2011; Camerlengo & Saadon 1996; Hu et al. 2000; Marghany et al. 1996; Saadon & Maged 1996; Wyrtki 1961; Yanagi et al. 2001). In between these two monsoons, there are two transition months that notably influenced the water characteristics at the site.

The results presented in Figures 2, 3 and 4 show the vertical structure of water properties and spatial spreading at the stations during both months. In October, the temperature and salinity at nearshore and offshore stations experienced almost constant reading with slight differences between minimum and maximum values. During the northeast monsoon (October to March), the east coast of Peninsular Malaysia is dominated by overcast skies and high precipitation, lowering the sea temperature and salinity. Homogenous temperatures between all the stations in October (except at the centre of the study area) maybe due to overcast skies that reduce the sun's penetration to the sea water, which then reduces the sea's surface heating. Similar characteristics were also observed in vertical profiles of temperature, salinity and dissolved oxygen and water column from nearshore to offshore and from northern to southern part of Pahang coastal water where it is well-mixed. It was expected that the water masses characteristics in October were already gets influenced by the upcoming stronger sea surface wind (Figure 7(a)). Winds are normally stronger during the northeast monsoon than during the southwest monsoon (Wyrtki 1961). Strong winds create turbulence in the sea water (Spigel & Imberger 1980) and brings strong waves and rough sea condition to the site which allows mixing to be greater in October. This strong wind causes the upper water to mix and also causes the mixed layer to increase to deeper layers.

Interestingly, in October, lower salinity from nearshore to offshore (0-5m depth), Stations B to E, show that there is some influence from the river nearby (Figure 3(a) & 3(d)) according to the geographical location of these stations that situated at the mouth of Pahang river. According to MMD, high total rainfall was recorded during this month (Figure 7(c)) which causes the river discharge to be increased. This higher freshwater discharge from the river that only been observed at that particular site can be said to be influenced by the strong winds that bring the high precipitation to the area which then caused the area nearby to have minima salinity values confine in 5 m depth.

In October, there were higher dissolved oxygen values compared to April. According to Kennish (1994), the solubility of dissolved gases is a function of salinity, temperature and partial pressure. As salinity and the temperature increase, gaseous solubility decreases. Since oxygen is more soluble in cooler water (Saadon et al. 1988), October's lower sea temperatures allow the oxygen to dissolve more than it does in April, when warmer atmospheric conditions and high sea surface heating reduces oxygen solubility. However, for both months, the dissolved oxygen along Pahang coastal water (0-50 km) showed that this area was distributed by the healthy range of oxygen contains which are above 3mg/L.

In April, the nearshore stations experienced higher temperatures and lower salinity. The southwest monsoon (June to August), characterized by warm atmospheric conditions and reduced precipitation (Figure 8(c)) caused the sea water to heat more resulting in high temperature values. The heating increased evaporation while reduced precipitation resulting in decreased river discharge.

Therefore, no similar feature as observed at the stations near to Pahang River in October can be found in April

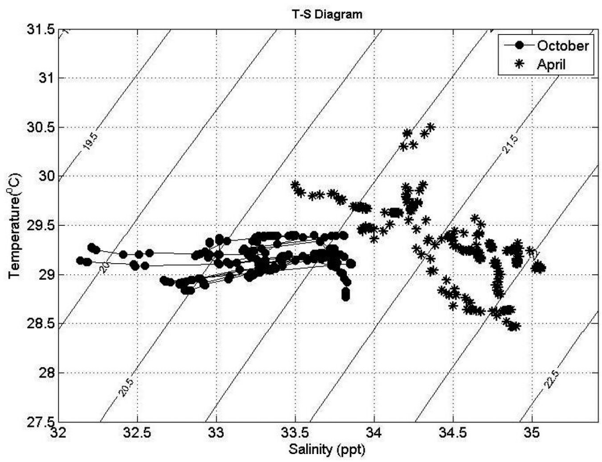

FIGURE 5. T-S (temperature-salinity) diagram across isopycnal line on October 2003 (solid lines with symbols) and on April 2004 (scatter symbols)

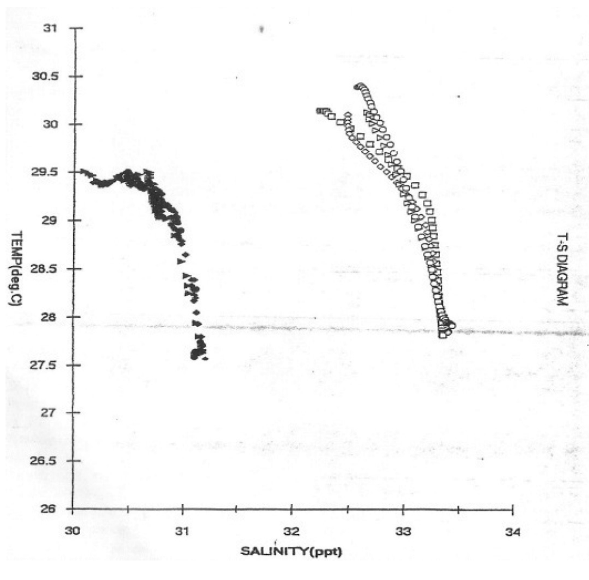

FIGURE 6. T-S diagram adapted from (Saadon & Camerlengo 1996)

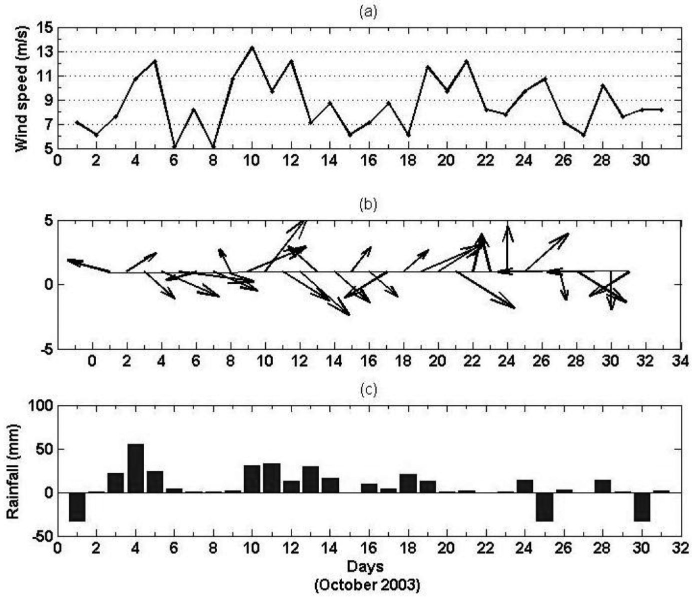

FIGURE 7. Daily wind data and rainfall obtained from Malaysian Meteorological Department (MMD) in October 2003. Data recorded at Kuantan Station (Pahang). a) Daily wind speed data, units in m/s. b) Daily wind direction (towards) and c) Rainfall data, units in mm. Maximum daily wind speed recorded in October 2003 can reach up to 12 - 13 m/s

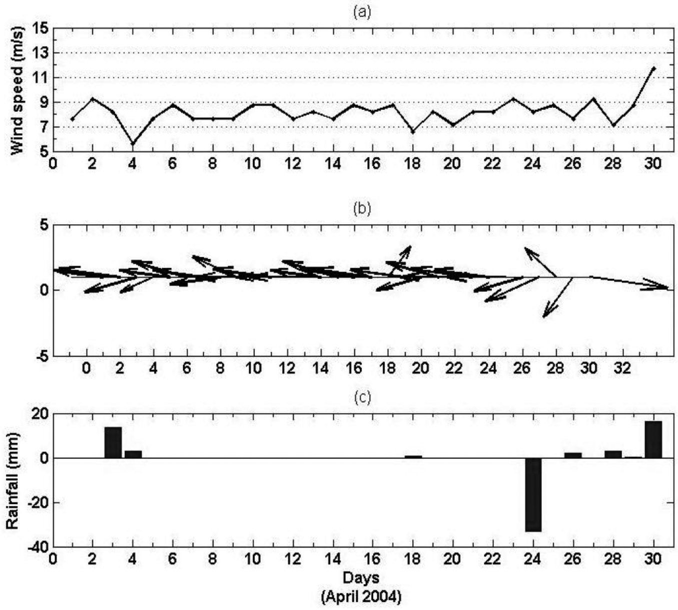

FIGURE 8. Daily wind data and rainfall obtained from Malaysian Meteorological Department (MMD) in April 2004. Data recorded at Kuantan Station (Pahang). a) Daily wind speed data, units in m/s. b) daily wind direction (towards) and c) rainfall data, units in mm. Maximum daily wind speed recorded in April 2004 can reach up to 12 m/s and throughout the month, the maximum wind speed is mostly 9 m/s

sampling. This also explained why salinity was greater during the southwest monsoon compared to the northeast monsoon. This was in accordance with results from Saadon and Camerlengo (1996) and Marghany et al. (1996).

Stratification, with a slight thermocline and halocline, was observed in April at the offshore stations (Line 4) at 15 m and 20 m depths (Figure 3(d) and 3(e)). In a previous study near this study area, stratification was most developed in March–May due to large sea surface heating and weak sea surface wind (Yanagi et al. 2001). Weaker wind was observed from the MMD data recorded in April 2004 (Figure 8(a)) causes the turbulence to be less effective. Less turbulence in water column caused the water parcel does not return to its initial location when it oscillates in the ocean. These water parcels were then remain at the suitable density. At this time, the stratification was said to be more stable.

Monthly variations between October and April water mass can be observed clearly through entropy (T-S) diagram (Figure 5). In October, temperature and salinity are lower than in April. The T-S diagram produced by Saadon and Camerlengo (1996) resembles closely the data presented in the above T-S diagram (Figure 6).

CONCLUSION

It was observed that winds play an important role in the dynamics of the water characteristics at the site. Well-mixed water spread, low temperature and salinity showed the influences of strong winds recorded in October. This strong wind allowed the precipitation to increase and caused the surface water of the area near to Pahang River to have salinity minimum towards the offshore. Even though the river feature is a great influence on the area, monsoonal effects on the water characteristics are still the most significant influence.

Warmer temperatures and high salinity with stratified layers suggested the influences of upcoming southwest monsoon in April. Thermocline and halocline (outermost stations) was more prominent in this month compared to in October. As mentioned by previous author, stratification can be developed in the condition of great sea surface heating and weaker wind. This similar condition that was observed in this present study can be said to stabilize the stratification during this month.

This study so far had provides additional information about the water characteristics at the Pahang water during monsoon transitional months. Further study can increase understanding of the tidal effects on the coastal area combined with the river influence on the water characteristics especially salinity. Apart from field data observation, comprehensive coastal modeling can provide better information of coastal circulation at the region.

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