Physical Characteristics of Watermass in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

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ABSTRACT

Our study provides new information on the physical characteristics of watermass in the South China Sea. We analyzed the temperature, salinity and density profiles to determine the effect of the NE monsoon on the variability of the physical properties of watermass, in the Gulf of Thailand and the east coast of Peninsular Malaysia. CTD data were obtained from both the M.V. SEAFDEC cruises conducted before (September 1995) and after (April 1996) the northeast (NE) monsoon season.

We concluded that the NE monsoon caused the variability of the physical properties of watermasses, in the study area, slightly. We observed the movement of the thermocline, halocline and pycnocline layers from deeper depth to shallower depth, before and after the NE monsoon season, respectively. This movement indicates the possible occurrence of downwelling and upwelling processes in the region.

Key words: Thermocline, halocline, pycnocline, downwelling and upwelling processes.

Introduction

The climate of the east of Peninsular Malaysia is controlled by the seasonal monsoon winds. These winds are generated by the difference in atmospheric pressure between the northern (Asian continent) and the southern (Australia) hemispheres [Nasir and Camerlengo (1997), Nasir and Marghany (1996)]. During the northern winter (summer), the northeast (southwest) wind prevails from November to March (May to September) over the South China Sea.

Between these two seasonal monsoon winds, two transitional periods are clearly distinguishable. They last for about four to seven weeks in April and October [Morgan and Valencia (1983)].

The first and second cruises - on board M.V. SEAFDEC - of the SEAFDEC collaborative research program in the South China Sea, between Malaysia and Thailand, were conducted from 5 to 28 September 1995 (before northeast monsoon season) and from 24 April to 17 May 1996 (after the NE monsoon season). The cruises started in the northern coast of the Gulf of Thailand and ended in the sourhern coast of Johore, Peninsular Malaysia. The objective of the cruises was to do a comprehensive survey of the South China Sea in all fields of oceanography.

Since these two cruises were conducted before and after the NE monsoon season, a study on the seasonal variations of the physical characteristics of watermass in the Gulf of Thailand and the east coast of Peninsular Malaysia was conducted. For this purpose, the temperature, the salinity and the density profiles, from both M.V. SEAFDEC cruises, were analyzed and compared.

Our results show that there are slight variations in temperature, salinity and density profiles before and after the NE monsoon season. Furthermore, salinity and density (temperature) values are slightly higher (lower) before than those after the NE monsoon season. These results agree with earlier findings [Nasir and Camerlengo (1997) and Nasir *et al.* (1997)].

Materials and Methods

Temperature and salinity data were collected, using CTD, in the Gulf of Thailand and the east coast of Peninsular Malaysia, before and after the NE monsoon season. The data were gathered from 81 sampling stations (Fig. 1), during the M.V. SEAFDEC first cruise (5 to 28 September 1995) and second cruise (24 April to 17 May 1996). For this investigation, only data from selected sampling stations, were analyzed.

Density data was derived from salinity and temperature data using sigma-t computation tables [Knauss (1987)]. The temperature, the salinity and the density profiles, before and after the NE monsoon season, were plotted, compared and analyzed.

Results

Profiles of temperature, salinity and density are shown in the Appendix, respectively, for both before (thin lines) and after (thick lines) the NE monsoon season. Each figure is divided into two groups; A and B. Group A and B represent data collected from the Gulf of Thailand and the east coast of Peninsular Malaysia, respectively. The sampling station numbers are shown in the bottom right corner of each graphs.

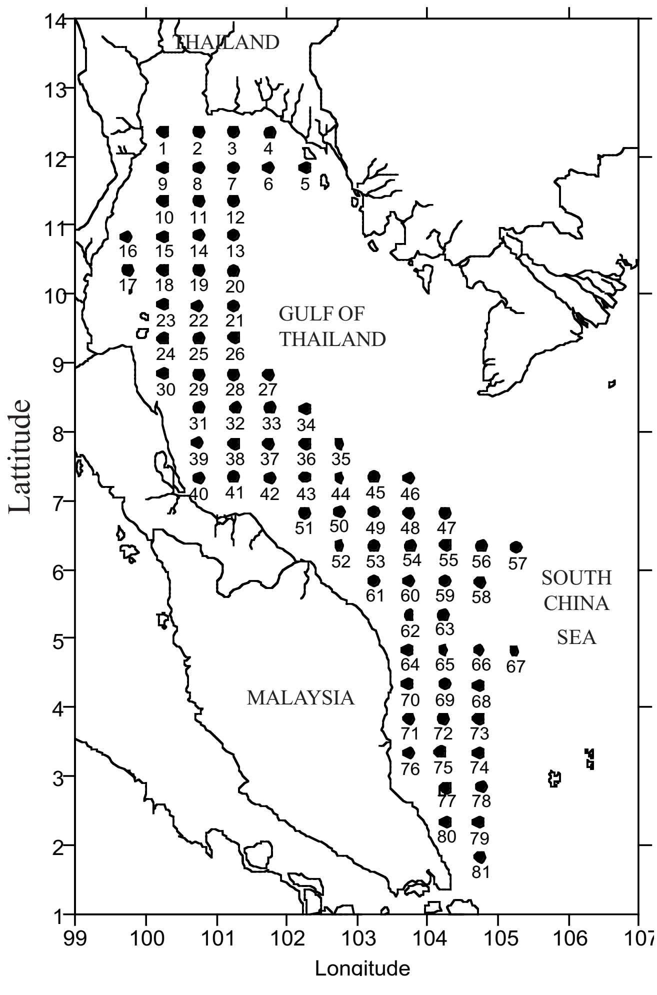

Fig. 1. Location of 81 sampling station during both of the M.V. SEAFDEC cruises.

Temberature profiles

Surface water temperatures, at all stations, are slightly higher (about 1^{o}C) after as compared to before the NE monsoon season, except for stations in the southern tips of Peninsular Malaysia. The difference between surface water temperatures, after and before the NE monsoon season, decreases from the north to the south of the study area.

However, bottom water temperatures, in the Gulf of Thailand and northern region of the east coast of Peninsular Malaysia, are slightly lower after (about 0.5^{o}C)as compared to before the NE monsoon season. In other parts of the east coast of Peninsular Malaysia, bottom water temperatures are mostly higher after than before the NE monsoon season.

In the Gulf of Thailand, the thermocline layers are more distinct after the NE monsoon season. Some stations (Stations 32, 34 and 39) have two thermocline layers. Before the NE monssoon season, many stations, in the Gulf of Thailand, have no thermocline layer which indicates a very well-mixed situation.

In the east coast of Peninsular Malaysia, thermocline layers are present both before and after the NE monsoon season. However, before the NE monsoon season, thermocline layers are mainly found at deeper depth as compared to after the NE monsoon season.

Salinity profiles

In the Gulf of Thailand, surface salinity are higher (about 1 psu) before as compare to after the NE monsoon. Stations in the northern half of the Gulf have high salinity, in the water column, before the NE monsoon. Halocline layers are present at some stations both before and after the NE monsoon. Halocline layers, before (after) the NE monsoon season, are generally found in deeper (shallower) depth.

In the east coast of Peninsular Malaysia, halocline layers are present both before and after the NE monsoon season. These layers are observed at deeper depth before the NE monsoon season.

Density profiles

Surface water densities are generally higher before as compared to after the NE monsoon season, except for areas in the southern part of the east coast of Peninsular Malaysia. Pcynocline layers are present in most sampling stations, both before and after the NE monsoon season. These layers are found at deeper depth before as compare to after the NE monsoon season.

In the northern region of the Gulf of Thailand (stations 6-20), water densities in the water column are higher before as compared to after the NE monsoon season. However, in the sourhern part of the east coast of Peninsular Malaysia (stations 77-81), water densities in the water column are lower before as compared to after the NE monsoon season.

Discussions

Air mass descends over the cold Asian continent during winter enhancing the formation of a high atmospheric pressure system. At the same time, air mass rises over the warm Australian continent. A low atmospheric pressure system is formed. These differences in atmospheric pressure system in unison with Coriolis effect, generate a NE wind in the Gulf of Thailand and along the east coast of Peninsular Malaysia (from November to March). This period is generally known as the NE monsoon season.

In the northern summer, in the Asian continent, the reciprocal is true. A high and low atmospheric pressure system over Australia and the Asian continents, respectively, are enhanced. As a consequence of this a SW wind prevails over the Gulf of Thailand and Peninsular Malaysia (from

May to September). This period is known as the SW monsoon season.

Two transitional periods between the two monsoon seasons are distinguishable. These periods happen in April and October. They tend to last for about four to seven weeks [Nasir and Marghany (1996)].

The NE monsoon season brings heavy rain at the east coast of Peninsular Malaysia. Maximum precipitation, with values ranging from 600 to 800 mm of rainfall, is recorded in November and December [Camerlengo *et al.* (1996a), Camerlengo *et al.* (1997)]. Minimum precipitation is observed during the SW monsoon, especially in July and August [Camerlengo *et al.* (1996b)].

The NE monsoon season (especially in November and December) causes a major decrease of both evaporation and insolation values along the east coast of Peninsular Malaysia [Camerlengo *et al.* (1996c)]. Overcast skies prevent solar radiation into the lower atmosphere. However, highest insolation value is registered in Febreuary and March at the east coast of Peninsular Malaysia.

The NE monsoon wind is stronger than the SW monsoon wind [Taira *et al.* (1996)]. This is due to the fact that the NE monsoon wind is in the same direction as the prevailing NE trade wind of the northern hemisphere. During the NE and SW monsoon seasons, average wind speed of 9 m/s and 6 m/s, respectively, have been recorded [Wang *et al.* (1994)].

Wave heights along the east coast of Peninsular Malaysia are hihger during the NE monsoon season as compared to the SW monsoon season. Wave heights of over 3.5 m during November to January, have been recorded [Malaysian Meteorological Service (1991)]. Larger wave heights, during the NE monsoon season, are due to the stronger wind speed and larger wind fetch as compared to the wind during the SW monsoon season.

Overcast skies, during the NE monsoon season, block the incoming solar radiation. This reduces the sea surface temperature (SST). However, the SST increases, as the sky clears up, after the NE monsoon season is over.

Heavy rainfalls, during the NE monsoon season, increase freshwater runoff in the Gulf of Thailand and along the east coast of Peninsular Malaysia [Nasir *et al*. (1997)], thus, reducing surface water salinity and density values at all sampling station. In the northern part of the Gulf of Thailand, freshwater runoff even makes the water column less saline and less dense. In most deep offshore stations - again due to freshwater runoff - higher salinity and density values in the bottom water have been recorded, after the NE monsoon season.

The halocline and the pycnocline layers are present, at most stations, both before and after the NE monsoon season. However, these layers are at deeper depth before as compared to after the NE monsoon season. This is due to the fact that wave heights are higher, just before the NE monsoon season. This enhances mixing throughout the vertical column.

The movement of the thermocline, halocline and pcynocline layers from deeper depth to shallower depth, before and after the NE monsoon season, respectively, could possibly be due to upwelling and downwelling processes. Usually, during downwelling, these layers move to a deeper depth. However, they will move to a shallower depth during upwelling [Kennish (1994)].

The southern tip of the east coast of Peninsular Malaysia (Stations 77-81), shows a different variation of physical properties as to the northern part of the study area. We don't know what causes this variation. Perhaps a further investigation is needed in this particular part of the study area.

Conclusions

The vertical profiles of temperature, salinity and density in the Gulf of Thailand and along the east coast of Peninsular Malaysia, before and after the NE monsoon season, were analyzed. Our results generally agree with early observations [Nasir and Camerlengo (1997)].

Our results show that the variability of the physical properties, in the Gulf of Thailand and along the east coast of Peninsular Malaysia, is due to the monsoon season. Profiles of temperature, salinity and density show slight different in these physical values, before and after the NE monsoon season, are recorded. In some stations (especially in the northern Gulf of Thailand), temperature, salinity and density values are the same throughout the water column, indicating a well-mixed condition, before the onset of the NE monsoon.

Thermocline, halocline and pycnocline layers are present, both before and after the NE monsoon season. However, these layers are at deeper depth before the onset of the NE monsoon and move to a shallower depth after the NE monsoon. This movement of physical layers, from deeper to shallower depth, can be linked to the downwelling and upwelling processes in the region.

In southern part of the east coast of Peninsular Malaysia (particularly the southern tip), the variability of the physical properties of the watermass is difference as compared to the rest of the study area. We do not have enough data to explain this difference.

We feel that more physical oceanographic cruises, to study the variability of the physical properties during both SW and NE monsoon seasons, are needed. The physical oceanographic data in the South China Sea (especially in the east coast of Peninsular Malaysia), are too scarce to make a good comparison of the variability of physical properties during both monsoon seasons.

Acknowledgment

The authors would like to extend their thanks to Universiti Putra Malaysia Terengganu for cooperating in this research.

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