Temperature and Salinity Profiling Analysis off Sarawak Waters, Malaysia

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ABSTRACT Prime Scientific Sailing Expedition (EPSP 2009), was carried out in the South China Sea (SCS) along Sarawak waters for nine days from 20 to 29 June 2009. The main objective was to enhance physical oceanography data to support the management of marine ecosystem and other marine resources off Sarawak waters. The main purpose of this present study is to construct vertical temperature and salinity structures off Sarawak waters and to define the water properties based on differ water depths. The temperature and salinity data were obtained using Conductivity-Temperature-Depth (CTD) from sea surface down to 523 m water depth. The measurement was done along the transect line that consists of 60 sampling stations involved with furthest distance offshore at ~471 km. Vertical profiles of temperature, salinity and temperature-salinity (T-S) diagrams of each station were plotted and analyzed based on location and water depth. Offshore sampling stations at water depth greater than 50 m are known as deep waters while near shore sampling station at water depth less than 50m is known as shallow waters. The constructed vertical profiles showed that as water depth increases, salinity increases whereas temperature decreases. Comparison of minimum and maximum temperature range of shallow and deep waters is 15°C and 1°C respectively. However, there is only 0.71°C difference of salinity between minimum salinity of shallow waters and deep waters. The seawater variable of Sarawak waters are impacted by the distance from mainland and its geographical location as well as the rivers influx into the SCS. Constant climate change due to seasonal monsoon and high rainfall as it is located in the tropical region contribute to the spatial temperature and salinity in this area. High rivers runoff into the SCS can reduce the salinity of the water at coastal area. Salinity increases as sampling location further offshore. High rainfall may decreases water temperature and salinity at water surface.

KEYWORDS: South China Sea; Sarawak Waters; vertical structures; temperature-salinity diagram

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INTRODUCTION

Malaysian waters are known to be one of the most diverse marine ecosystem and high diversity of marine resources (Mazlan *et al.*, 2005). Lack of physical oceanographic information has inspired the Prime Scientific Sailing Expedition in 2009 (PMSP'09) to be conducted at offshore area of Malaysian waters. Among the very few oceanographic cruises that has been done before on Malaysian waters were the South East Asian Fisheries Development Centre (SEAFDEC) cruise done in 1999 (Saadon *et al.*, 1999) at the east coast of peninsular Malaysia and the oceanographic cruises conducted by Institute of Oceanography (INOS), Universiti Malaysia Terengganu (UMT) in 2003 and 2004 respectively (Roseli & Akhir, 2014). PMSP '09 was organized by the National Oceanography Directorate, Ministry of Science and Technology and Innovation (MOSTI) to support the conservation of marine ecosystem and marine resources within Malaysia waters.

Common seawater variable measured in any marine expedition including this particular study are water temperature and salinity (Tomczak & Godfrey, 1994). High temperature variation in the upper layer of the sea in the study area are due to external environmental factors such as energy transfer process, external and internal forces that render water movement without heat transfer to or from the atmosphere (Reddy, 2001). The temperature change layers may occur at certain depth of the water column known as thermocline (Thurman & Trujillo, 2003). Salinity is defined as

concentration of dissolved salt as a basic property (Reddy, 2001). Variations of salinity in the water column of the study area are influenced by several factors namely precipitation, evaporation, river runoff and seawater mixing at various layers of the ocean (Thurman & Trujillo, 2003). Lower salinity values are usually found in the coastal areas where large rivers flow into the sea. Rapid vertical change of salinity at certain parts of the water column is known as halocline.

Information of water variables off Sarawak waters is very limited and scarce. Despite numerous studies were made on SCS waters, but there are very little focusing on the features off Sarawak waters. The most recent study on water mass in within this area was during the cruise (Saadon *et al.*, 1998) while temperature and salinity profiles off Sarawak coast was done during the Matahari Expedition (Saadon *et al.*, 1988). Thus the objective of this study is to identify the vertical temperature and salinity variation off Sarawak waters. It also determines the formation of thermocline and halocline location properties in the water column.

METHODOLOGY

PMSP '09 was conducted in the Malaysian Borneo waters which covering the South China Sea (SCS), Sulu Sea and Celebes Sea. However, this study was only focusing on SCS, part of Sarawak waters (Figure 1). Datasets comprises of water temperature and salinity was collected using SBE 19Plus Conductivity-temperature-depth (CTD) profiler from 20 to 29 June 2009 (nine days) during the Southwest (SW) monsoon season. Overall, 60 sampling stations were set up which were spread in areas from 2.8737°N to 4.4446°N and 109.9034°E to 113.3421°E. The CTD sampling interval was setup at 4Hz measurement were made down to 523 m water depth. The closet sampling station (St 6) to the mainland is about 17 km from nearest point. The furthest sampling station (St 32) distance offshore is approximately 471 km from nearest mainland point.

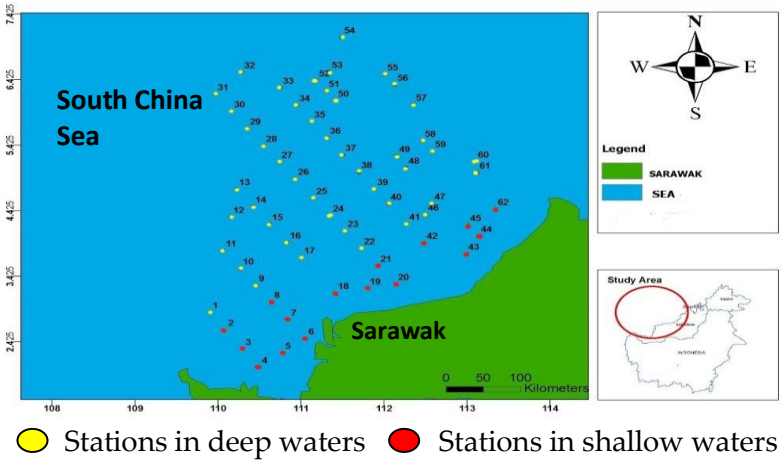

Figure 1. Location of 60 stations off EEZ Sarawak waters

The datasets consist of vary readings manipulated and constructed using Microsoft Excel. Temperature and salinity profiles were plotted for each station, and then the data were combined to produce the overall result. Vertical temperature and salinity data from 60 CTD stations were constructed and divided into two areas based on the location and water depth. Shallow water is sampling station located closer to coastal area with water depth less than 50 m and deep water is sampling station located at offshore area and has water depth greater than 50 m. Mean and standard deviation (std) of the measured data at different location were also calculated since every station has different number of readings. The number of data for each station is more or less than 100 readings.

RESULT AND DISCUSSION

The vertical distributions of temperature off Sarawak water are shown in Figure 3. The vertical distribution of temperature of shallow waters is ranging from 23°C to 32°C (30.26±0.55°C) while the temperature range of vertical distribution at deep waters is from 8°C to 31°C (23.83±5.88). Comparison of minimum and maximum temperature range of shallow water and deep waters is 15°C and 1°C respectively (Table 1).

Vertical distribution of salinity at shallow water is ranging from 30 psu to 33.5 psu with mean±Std of 32.52±0.4 psu (Figure 4). The vertical distribution of salinity increases in deep waters with ranging between 30.7 psu to 34.8 psu and mean±std of 33.69±0.64 psu (Table 1). However, there is only 0.7 difference of salinity between minimum salinity of shallow waters and deep waters.

Table 1. Water properties of shallow and deep waters

	Shallow waters	Deep waters
Location	Coastal	Offshore
Water depth (m)	<50	>50
Temperature (°C)	23-32	8-31
Temperature mean±Std (°C)	30.26±0.55	23.83±5.88
Salinity (psu)	30-33.5	30.7-34.8
Salinity mean±Std (psu)	32.52±0.4	33.69±0.64

There is high variation of temperature range between shallow and deep waters area detected (Figure 3). However, both areas showed water temperature decreased for increasing depth. Warm sea surface temperature ranging from 23°C to 32°C is located at shallow waters but significant decrease of temperature can be seen at water depth from 50 m to 200 m. Temperature gradually decreased in upper water column add persistently well stratified. The temperature decreased constantly until it reached the isothermal layers. Formation of thermocline at shallow water was located near the water surface. Significant thermocline layer is observed in deeper waters at water depth between 100 m to 200 m.

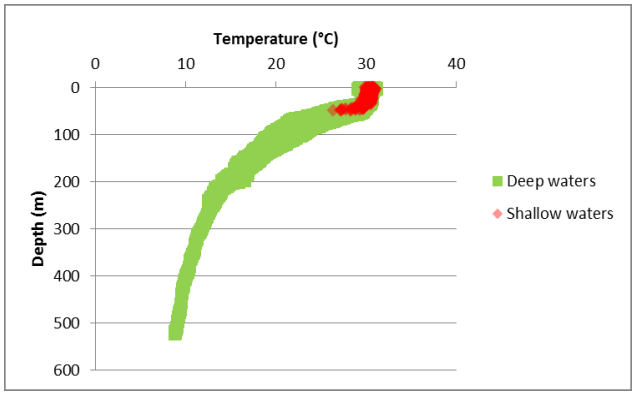

Figure 2. Temperature profile of CTD casts in Sarawak waters

There is high variation of salinity range between shallow and deep water (Figure 3). However, the variation of salinity is greater in the shallow waters compared to the deep waters. Generally, salinity increased for increasing water depth. In this study, salinity increased up to the isohaline layer. Drastic change of salinity profile with depth indicates the obvious halocline layer presence at water depth between 100 m to 200 m followed by constant salinity known as isohaline layer at water

depth of ~250 m downwards. Wide range of salinity can be seen at the subsurface especially at water depth down to 100 m.

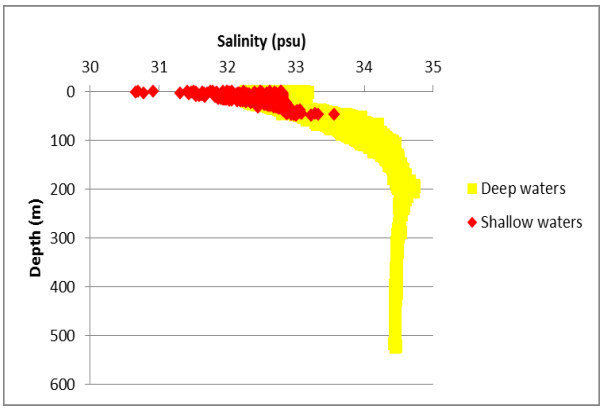

Figure 3. Salinity profile off Sarawak waters

The study area is located in tropical region where the sea surface temperature is consistently high throughout the year (Wyrtki, 1961). However, there will be also variation of water temperature during day and night. The high variation of mean±std temperature at shallow waters (30.26±0.55°C) compared to deep waters (23.83±5.88°C) (Table 1) is due to the fact that greater difference of water depth measurement that has been taken in those stations. Decrease of temperature as water depth increase down isothermal layers contributes to large variation of temperature in deep waters (Figure 2).

Most of the low salinity (< 33 psu) data belongs to station located at shallow waters (Figure 3) which is probably affected by the river influx from mainland of Sarawak such as Rajang River, the longest river in Malaysia and Baram River. Other factor that may have contributed to the low salinity of the waters is the high rainfall of tropical region. According to Lim & Leonard (2003), the annual rainfall of Malaysia is around 3000 mm to 5500 mm per year thus endowed the land with perpetual streams and long rivers. Comparison of study done in 1998 (Saadon *et al.*, 1998) and this finding indicates that only small variation in both deep and shallow waters stations. However, this study showed that there is a high variation of temperature as well as high variation of salinity observed between deep and shallow waters.

Each station that is labeled earlier in Figure 1 indicates its water depth and shows its distance from the mainland. According to Wyrtki (1961), distribution of the discharge from land and the presence of large bay with only small water exchange leads to the formation of region at very low salinity thus serves as sources for lowering the salinity in the area. For example, sampling between Station 3 to 7 has low salinity (32.52±0.4 psu) due to its location near to the large bay and its distance from the shore. There is also difference of minimum sea temperature between surface and deeper waters due to the distance factors from mainland and water depth. The formation of thermocline and halocline layers can be observed at water depth between 100 m to 200 m at deeper water but these layers are no clear for sampling stations located at shallow waters. The location of the thermocline and halocline layers at different seasonal monsoon season.

CONCLUSION

There is high variation of temperature as well as high variation of salinity between shallow and deep waters of Sarawak waters. The shallow waters are categorized as temperature and salinity

range from 23°C to 32°C, and 30.0 psu - 33.5 psu, respectively. The deep waters have temperature between 8°C and 31°C, and salinity between 30.7 psu to 34.8 psu. Location of thermocline and halocline are clear at water depth between 100 m and 200 m. It is suggested that repeating of measurement at the same location and monsoon season to compare this findings. Measurement should be done during Northeast or inter monsoon season. Further study will be conducted to define the water mass within these areas.

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