SEASONAL PATTERNS OF WATER MASSES IN THE SOUTH CHINA SEA USING OCEAN DATA VIEW SOFTWARE

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1. Introduction

Water mass is a body of ocean water with a distinctive narrow range of temperature and salinity and a particular density resulting from these two parameters. Salinity and temperature determine seawater density and buoyancy, driving the extent of ocean stratification, mixing, and water mass formation. Water stratification occurs when water of high and low salinity (halocline), as well as cold and warm water (thermocline), different densities, forms layers that act as barriers to water mixing. Water masses variation are formed as the result of climatic effects in specific regions such as monsoon season. During monsoon seasons, the movement of ocean currents can be predicted from the intrusion of different water masses. Thus, the pattern of water movement can be investigated by studying the water masses.

The South China Sea (SCS) is the largest marginal sea in the southeastern Asian waters, covering approximately $3.5x10^{12}m^2$ global surface areas. It stretches from the equator to 23°N and from 99°E to 121°E with a maximum depth reaching 5000m. Linking the Pacific and Indian Ocean, the SCS has been an important sea lane for over thousand years. The region's ecosystem, fishery, and environmental condition are influenced by a monsoonal system, with the winds and ocean currents reversing direction twice a year. The Northeast Monsoon reaches its maximum strength and covers the entire SCS in December. In contrast, the Southwest Monsoon expands over the whole basin in July and August (Morton and Blackmore, 2001; Wang et al., 2009)

As the ocean provides the slow and more predictable component of the climate system, understanding and monitoring the SCS water masses is necessary. Ocean Data View (ODV) software is used as a tool to process the secondary data of the SCS from World Ocean Database 2005. The seasonal pattern of the SCS water masses over the monsoon season can be observed from high-quality graphical display of oceanographic profile data produced by ODV.

2. Problem Statement

Recent studies have recommended that the South China Sea throughflow (SCSTF) act as a heat and freshwater conveyor, playing a key role in controlling the climate of the South China Sea. The SCSTF involves the inflow from Luzon Strait and Taiwan Strait at the north and the outflow to Karimata Strait at the south. Due to the intrusion and the movement of water masses around the South China Sea, an understanding of the physical-chemical variations over the monsoon seasons is essential. Ocean Data View software can be used to provide visualization of the water mass patterns for this purpose.

3. Research Objective

This study will focus on investigation of the physical properties of seawater which are salinity, water temperature, and dissolved oxygen. The specific objectives of this study are:

1. To map the physical-chemical variations over the monsoon seasons.
2. To study the intrusion and movement of water masses in the South China Sea.

4. Literature Review

The major circulation in the South China Sea (SCS) is driven by the monsoon winds (Wyrtki,1961), which are the Northeast Monsoon and Southwest Monsoon. Based on early hydrographic data, sea level records, and ship drifts, Wyrtki (1961) first noted that water enters the SCS in winter (Northeast Monsoon) and flows back to the Pacific in summer (Southwest Monsoon).

This is true, however, only for the surface layer, where ocean circulation is predominantly forced by monsoonal winds. Within the depth range of the thermocline, later observations revealed that there is a Kuroshio branch toward the SCS both in winter and summer (e.g., Qiu et al., 1984; Guo, 1985), and the intrusion of the North Pacific Tropical Water seems to occur during most, if not all, seasons of the year (e.g., Shaw, 1989, 1991; Qu et al., 2000), presumably as a result of westward pressure gradient along the continental slope south of China (e.g., Qu, 2000; Hsueh and Zhong, 2004).

Climatically, the SCS is part of the Indo-Pacific warm pool and experiences strong interannual variations associated with the El Nino and Southern Oscillation (ENSO). There, sea surface temperature gets warmer during the mature phase of El Nino, resulting in a weaker monsoon and less marine productivity, and the situation tends to be reversed during the mature phase of La Nina. (e.g., Chao et al., 1996; Qu et al., 2009; Swapna et al., 2009; Rong et al., 2007).

The heat and freshwater gain of the SCS are balanced by horizontal advection, with inflow of cold and salty water through the Luzon strait and outflow of warm and fresh water through the Mindoro and Karimata straits (Fang et al., 2009). This circulation has been termed as the South China Sea throughflow (SCSTF) and extensively studied in recent years. The SCSTF refers to the inflow through Luzon Strait and the outflow through the Karimata, Mindoro and Taiwan Straits (e.g., Qu et al., 2005, 2006a; Wang et al., 2006b; Yu et al., 2007).

5. Research Methodology

1. Secondary data collection

   Physical properties and bathymetry data for the South China Sea (Fig. 1) were obtained from the World Ocean Database 2005 (National Oceanographic and Atmospheric Agency (NOAA)) from year 1900 to 2008. The data specified from 30°N to 5°S of latitude and from 95°E to 120°E of longitude.

2. Data processing and analysis

   ODV software version 3.3.1-2007 (Schlitzer, 2007) was used to process the data and to create contour plot visualizations. The data downloaded then will be evaluate their quality by omitting stations whose coordinates placed on land and sampling at deep depth (greater than 300m depth). The final dataset comprised 123816 stations. Descriptive analysis will be used to validate the data. The station data in the Straits will divide into five sections A, B, C, D and E at different locations (Fig. 1).

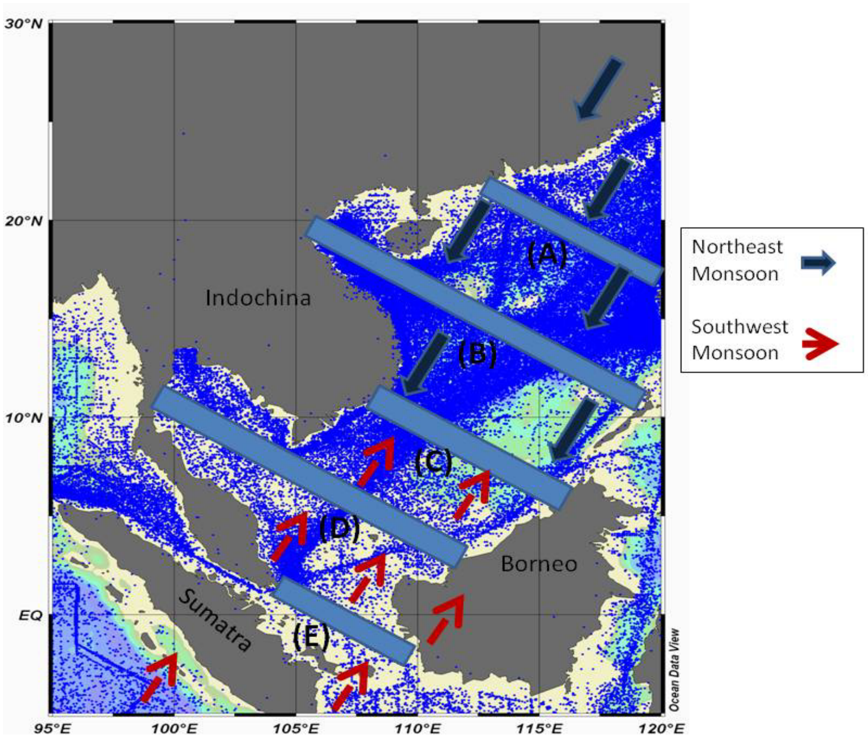

Fig. 1. Location of the South China Sea study area and location of stations from the World Ocean Data Base 2005. The five sections labeled A, B, C, D and E used for vertical section plots are also indicated.

3. Data presentation

Two formats will be used to present the results of visualization of the water temperature, salinity and dissolved oxygen. Data are separated into the four monsoon seasons (Table 1) and five sections at the different location of the South China Sea area. Surface contour plots and vertical contour plot will be presented.

TABLE 1. Monsoon periods used for sea data separation.

Season	Period (months)
Northeast Monsoon	November, December, January, February (NDJF)
Inter monsoon 1	March, April, May (MAM)
Southwest monsoon	June, July, August (JJA)
Inter monsoon 2	September, October (SO)

6. Expected Output

- The improved understanding of seasonal water masses variation in the South China Sea.

- The ocean circulation and movement of the South China Sea from physical-chemical variations over the monsoon seasons.
- Comparison with the previous studies in South China Sea.

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