SEASONAL AND INTER-ANNUAL VARIATION OF SEA SURFACE CURRENT IN THE GULF OF THAILAND

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ABSTRACT

In this study, the seasonal and inter-annual variation of sea surface current in the Gulf of Thailand were revealed through the use of WOD temperature and salinity data and monthly sea surface dynamic heights (SSDH) from TOPEX/Poseidon and ERS-2 altimetry data during 1995-2001. The mean dynamic height and mean geostrohic current were derived from the climatological data while SSDH data gave monthly dynamic heights and their geopstrophic currents. The mean geostrophic current showed strong southward and westward flow of South China Sea water along the gulf entrance. Counterclockwise eddy in the inner gulf and the western side of the gulf entrance associated with upwelling in the area. Seasonal geostrophic currents show basin-wide counterclockwise circulation during the southwest monsoon season and clockwise circulation during the northeast monsoon season. Upwelling was enhanced during the southwest monsoon season. The circulation patterns varied seasonally and inter-annually probably due to the variation in wind regime. And finally we found that congregation, spawning, and migration routes of short-bodied mackerel conform well with coastal upwelling and surface circulation in the gulf.

INTRODUCTION

The Gulf of Thailand is a shallow semi-enclosed bay on the continental shelf of southeast Asia. The NW-SE-aligned gulf has roughly a rectangular shape with the width of 400 km and the length of 720 km. The water is deeper in the central gulf with the deepest depth of about 80 m.

The gulf circulation is a very important physical parameter that controls the exchange of water mass, dispersion of organic and inorganic substances in the water body. Unfortunately, after many studies, the circulation in the Gulf of Thailand is still poorly known.

Earlier circulation studies were based on tidal records and tidal numerical models. Recently, with the use of altimetry data, basin-wide temporal surface circulation can be studied. In this study, seasonal circulation and intra-annual variation of sea surface current in the Gulf of Thailand were revealed through the use of archived climatic and altimetry data.

METHOD OF STUDY

Water surface geostrophic current is derived from dynamic topography of the sea surface. According to instrument and computation setup, the instantaneous dynamic topography consists of mean dynamic topography and Sea Surface Dynamic Height (SSDH). For this study, the mean dynamic topography is derived from water temperature and salinity data from World Ocean Data (WOD) set. The temperature and salinity data were interpolated and the mean dynamic heights were computed from interpolated data from the surface down to the bottom or to the 90-m depth. Mean geostrophic current were then computed directly from mean dynamic height and later added to the geostrophic current computed from the SSDH.
Monthly SSDH were computed from both TOPEX/Poseidon and ERS-2 altimetry data using method described by Morimoto *et. al.* (2000). Once the monthly SSDHs were obtained, the monthly geostrophic currents were computed and combined to the mean geostrophic current to get the monthly geostrophic current for the Gulf of Thailand. Seasonal geostrophic currents were also computed according 4 distinctive season periods and the mean seasonal geostrophic currents for 1995-2001 were finally computed.

RESULTS AND DISCUSSION

Fig. 1 displayed annual-averaged salinity, temperature at the surface. Traces of seawater from South China Sea which has high salinity and low temperature were found at the inner gulf and western west coast. The salinity and temperature distributions indicated the existing of CCW circulations and upwelling in those two areas. There was strong southwestward flow along the gulf entrance with the maximum current speed around 0.3 m/s while the magnitude of mean geostrophic current in the gulf was weak at the speed lesser than 0.1 m/s

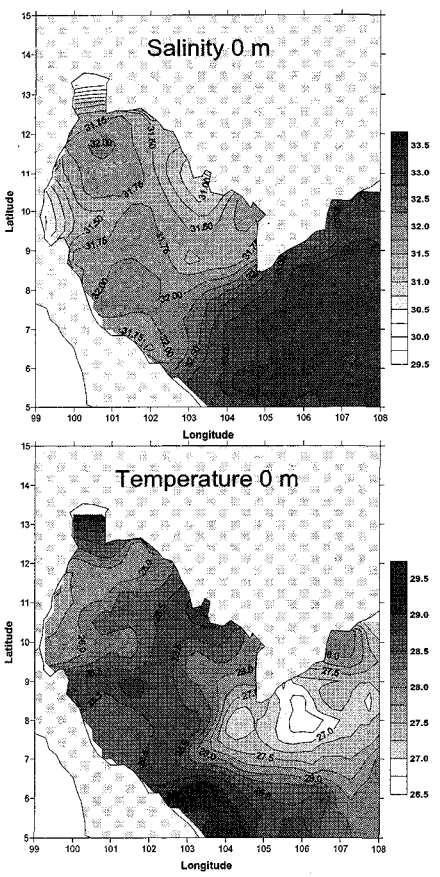

Figure 1. Salinity, temperature at the surface.

Fig. 2 showed examples of monthly variability of sea surface dynamic height (SSDH) from combined TOPEX/Poseidon and ERS-2 altimetry data for the Gulf of Thailand in January and September 1999 respectively. In general, the gulf experienced high SSDH during the northeast monsoon season. Circulation in the gulf was dominated by CW eddies and CCW meandering (not shown). On the other hand, low SSDH occurred during the southwest monsoon season and the circulation in the gulf was dominated by CCW eddies and meandering.

The current magnitude in the gulf was greater than 0.3 m/s, about 2-3 times that of mean geostrophic current.

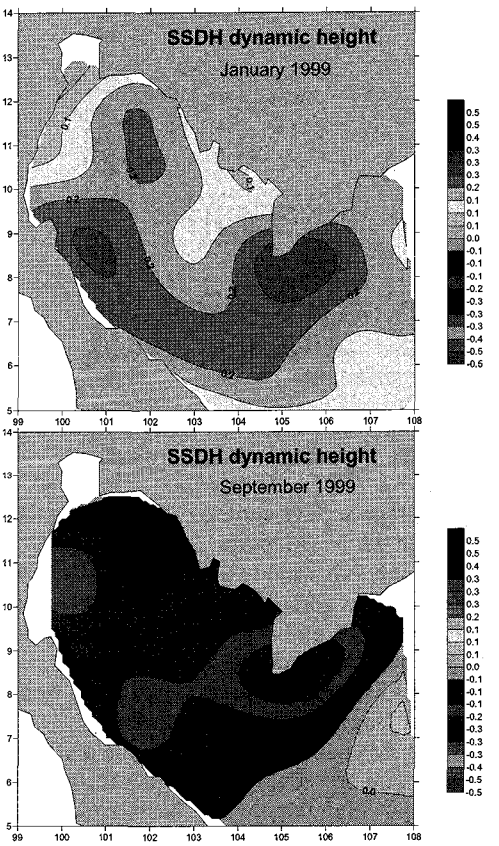

Figure 2 Example of monthly sea surface dynamic height (SSDH, m) in January 1999 (NE monsoon) and in September 1999 (SW monsoon).

Figs. 3-6 displayed seasonal averaged total geostrophic current in the Gulf of Thailand during 1995-2001. During the northeast monsoon season (Nov – Feb, Fig. 3), the strong northeast wind brought about the strong westward and southward flow at the gulf entrance. When the water encountered the gulf's west coast, it turned right and created the basin-wide CW circulation near the coast. Morimoto (2000) also founded basin-wide CW circulation in the gulf during the NE monsoon season. At 10° latitude, river discharge from the gulf west coast created an eastward flow that bisected the circulation in the gulf into half. The inner gulf was dominated by eastward flow and a weak CW eddy. A pair of CW and CCW eddies were located in the western side of the southern loop. Long-shore current (about 0.1 m/s) was stronger than that in the central gulf. The circulation pattern in the gulf obtained from this study was far more complex than those suggested by earlier studies.

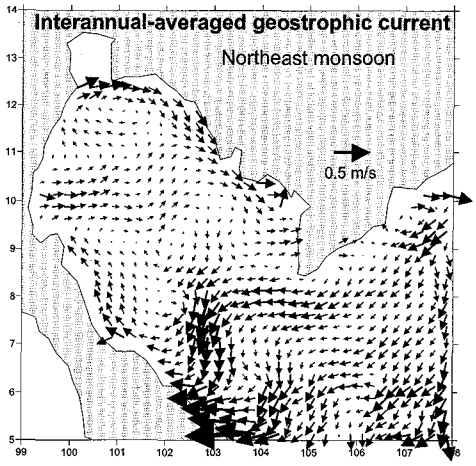

Figure 3. Inter-annual averaged geostrophic current during the northeast monsoon season.

Fig. 4 showed average surface current pattern during the first inter-monsoon period (Mar-Apr). The prevailing wind changed from N-NE wind to S-SE wind. The area experienced hot summer period due to the S to SE winds. The westward flow at the gulf entrance was dominance with the addition of a CCW eddy at the tip of Cape Camau. There was westward and northward flows from southern east coast, suggesting possible coastal upwelling. Water along northern portion of the gulf west coast flowed eastward and southward, suggesting another possible coastal upwelling region. The basin-wide circulation in the gulf disappeared probably because the gulf's geometry aligned with the SE wind. Current in the central gulf was rather weak with a small weak CW eddy in the center.

Fig. 5 displayed the average surface current during the southwest monsoon (May-Sep). The gulf experienced rainy season with strong west to southwest wind from the Indian Ocean. The circulation pattern was almost opposite to that during the northeast monsoon season. The wind caused strong northward flow from the west coast outside the gulf. Part of the current turned eastward at the mouth of the gulf, bringing water out of the bay. The continued northward flow at the central of the gulf southern boundary probably initiated the basin-wide CCW circulation as suggested by many authors (Wyrthki 1961, Morimoto 2000). However, the circulation pattern was more complex than previously thought. There were 2 CCW eddies inside the basin-wide CCW circulation. The inner CCW eddy enhanced upwelling in the northern part of the inner gulf while the lower CCW eddy extended along the lower half of the gulf west coast. Small size CW eddy was found coupling with lower CCW eddy. This CW eddy was also found through out the year. The circulation pattern suggested divergence of surface current in the southeastern side of the gulf which was not inside the basin-wide circulation ring. The upwelled water from the divergence flow supported the southeastward and the northwestward flow.

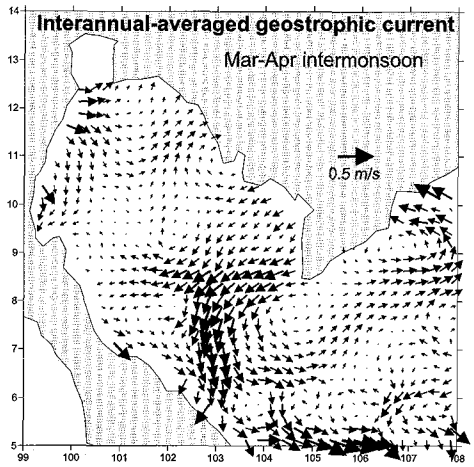

Figure 4. Inter-annual averaged geostrophic current during the first inter-monsoon period.

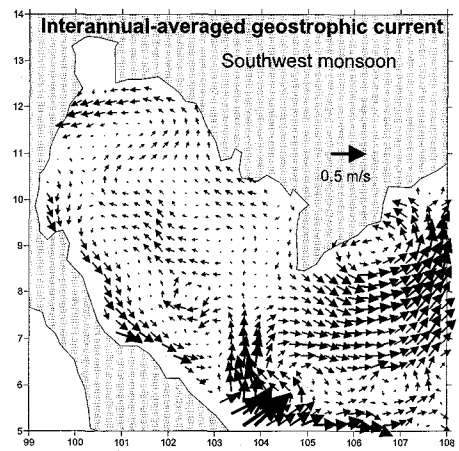

Figure 5. Inter-annual averaged geostrophic current during the southwest monsoon season.

Figure 6 showed average surface current pattern during the second inter-monsoon period (October). The wind was calm and the wind direction can vary from SW to NE winds depending on the strength of the monsoon during each year. The northward and eastward flow at the mouth of the gulf already changed into the westward and southward flow. The basin-wide CCW circulation in the gulf disappeared. The CW eddy was still existed on the western side near the mouth of the gulf. The circulation in the gulf was full of meandering and eddies. Water mass from the inner gulf flowed southward and

diverted into southwestward flow and eastward flow when it met a CCW eddy in the central gulf. The southwestward current flowed along the gulf west coast and turned around the CCW eddy in the central gulf and converged with the eastward current again. The CCW eddy which associated with upwelling might be the residual from the SW monsoon season (Wyrthki, 1961). Another upwelling area was along the southwestern coast where there existed a CCW eddy. There appeared to be a CW meandering with a CW eddy in the center at the southeastern side of the gulf. It was the place where surface water would sink. Surprisingly, mean upwelling and downwelling area during this season conformed with those from the field survey by NAGA Expedition during October 19-31, 1959.

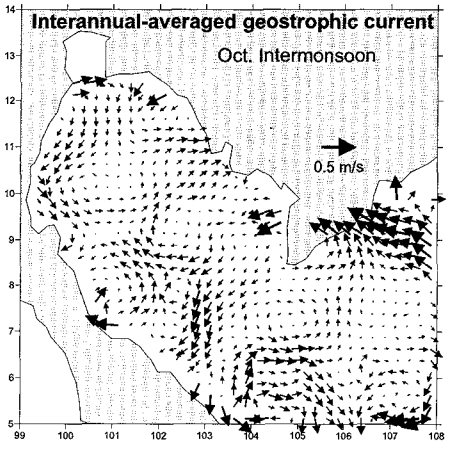

Figure 6. Inter-annual averaged geostrophic current during the second inter-monsoon period.

There were some inter-annual variabilities among the seasonal geostrophic current. For example, the basin-wide CCW circulation existed in every southwest monsoon during 1995-2001. But the CCW eddy in the inner gulf changed the shape and location each year. The variabilities might be caused by the inter-annual variabilities in wind regime.n order to link the circulation variability to the wind field forcing.

One application of the gulf circulation is to help understanding the migration and spawning behaviors of the short-bodied mackerel (*Rastrelliger neclectus*) in the gulf of Thailand. The short-bodies mackerel is a pelagic fish that lives in school. Because of the coastal upwelling, the fish congregated in the gulf western coast from Prachuab Kirikhan to Surat Thani every year from Feburay to May for spawning and rearing. After that, the fish migrated with the current to the offshore area and can be found in the inner Gulf during July. During August and September the grown-up fish can be found in the upper Gulf of Thailand.

CONCLUSION

We computed total geostrophic circulation through the use of WOD climatological and TOPEX/Poseidon & ERS-2 altimetry data. The annual-averaged surface salinity and temperature suggested upwelling which associated with CCW eddies in the inner gulf and the western coast of the gulf. The SSDH data showed water set-up and set-down in the gulf in accordance with the prevailing NE and SW monsoon winds. The combined geostrophic currents showed basin-wide circulation with eddies and meanderings within it. Basin-wide CCW circulation existed during the SW monsoon season while the basin-wide CW circulation existed during the NE monsoon season. Inter-annual variabilities among the seasonal geostrophic current existed and it might be due to variation in wind regime. And finally we tried to link the gulf circulation with the life cycle of short-bodied mackerel in the gulf and found that the congregation and spawning coincided with upwelling along the western coast. Also the migration routes conformed with circulation pattern in the gulf.

References

Morimoto, A, K. Yoshimoto, and T. Yanagi. 2000. Characteristics of sea surface circulation and eddy field in the South China Sea revealed by satellite altimetry data. Journal of Oceanography, Vol. 56 pp. 331-344.

Wyrtki, K. 1961. NAGA Report, Volume 2, Scientific Results of Marine Investigations of the South China Sea and the Gulf of Thailand 1959-1961. The University of California, Scripps Institute of Oceanography, La jolla, California, U.S.A.

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