Sains Malaysiana 43(3)(2014): 389–398

Simulation of Southwest Monsoon Current Circulation and Temperature in the East Coast of Peninsular Malaysia

(Simulasi Peredaran Arus dan Suhu Monsun Barat Daya di Perairan Pantai Timur Semenanjung Malaysia)

FARSHID DARYABOR*, FREDOLIN TANGANG & LIEW JUNENG

ABSTRACT

This study investigates the southwest monsoon circulation and temperature along the east coast of Peninsular Malaysia by using the Regional Ocean Modeling System at 9 km resolution. The simulated circulation shows strong northward flowing western boundary currents along the east coast of Peninsular Malaysia with maximum speed of approximately of 0.6-0.7 ms^{-1}. The western boundary current, that extends to a depth of about 35 m, continues flowing northward up to approximately 7^{o}N where it changes direction eastward. The circulation along the east coast of Peninsular Malaysia is also characterized by two anti-cyclonic eddies. Furthermore, an elongated of cooler sea surface temperature that stretches along the coast was also simulated. The existence of this cool SST pattern is associated with coastal upwelling process due to localized lifting of isotherms near the coast as a response to the southerly-southwesterly wind stress along the coast during the southwest monsoon.

Keywords: Coastal upwelling; current circulation; east coast of Peninsular Malaysia; Regional Ocean Modeling System; western boundary current

ABSTRAK

Kajian ini mengkaji peredaran arus dan suhu di pesisir laut pantai timur Semenanjung Malaysia dengan menggunakan Sistem Model Laut Serantau pada resolusi 9 km. Peredaran arus yang disimulasi menunjukkan arus sempadan barat yang kuat mengalir ke utara sepanjang pesisir pantai Semenanjung Malaysia dengan kelajuan maksimum 0.6 - 0.7 ms^{-1}. Arus sempadan barat yang mencapai kedalaman sehingga 35 m, mengalir ke utara sehigga ke latitud 7^{o}U sebelum ia bertukar arah ke timur. Peredaran sepanjang pesisir pantai Semenanjung Malaysia juga dicirikan oleh dua pusar anti-siklon. Selain itu terdapat kawasan memanjang bersuhu permukaan laut yang rendah sepanjang pesisir laut pantai. Kewujudan kawasan bersuhu rendah ini adalah berkaitan dengan proses pengaliratasan akibat pengangkatan isoterma berhampiran pesisir pantai sebagai respon kepada tegasan angin barat daya semasa musim monsun barat daya.

Kata kunci: Arus sempadan barat; pengaliratasan pesisir pantai; perederan arus; pesisir pantai timur Semenanjung Malaysia; Sistem Model Laut Serantau

INTRODUCTION

Peninsular Malaysia is located in the southern region of the South China Sea (SSCS) with the Sunda Shelf acting as a submerged connection to Indochina Peninsular, Sumatra, Java and Borneo Island (Figure 1). The Sunda Shelf is mostly shallow with maximum depth of approximately 100 m. Circulation patterns from the intermediate to the upper layers in the SSCS are primarily forced by the Asian-Australian monsoon wind (Cai et al. 2007; Wyrtki 1961). However, considering its close proximity with the Indian and Pacific Oceans, the SSCS is also influenced by other monsoon systems in the region. The SSCS is affected by four monsoon subsystems: The subtropical East Asian monsoon; The tropical Indian monsoon; The western North Pacific monsoon and The Australian monsoon (Wang et al. 2009). The southwest monsoon usually commences in late May or early June and continues to late August. Generally, the wind in the SSCS during this period is light and variable with some observed periodic changes in wind flow patterns. The dominant wind flow for the southwest monsoon is generally southwesterly with speed of approximately below 7 m/s (Wyrtki 1961).

The complex bathymetry, coastlines and existence of large islands, such as Natuna Island are also important in determining the local circulation patterns (Akhir 2012; Akhir & Chuen 2011; Cai et al. 2007; Tangang et al. 2011). The major features of current circulation in the SSCS during the southwest monsoon include the strong western boundary currents along the east coast Peninsular Malaysia and several eddy systems. These features are parts of the monsoonal circulation in the South China Sea, which is anti-cyclonic during summer monsoon (Chu et al. 1999). The small-scale eddies are probably generated by baroclinic instability and the temperature differences between surface and middle layers (Qiu & Chen 2005; Qu 2001). Moreover, strong wind stress, which causes vertical stratification due to velocity shears, could also be another factor in the generation of eddies (Gill et al. 1974).

Current circulation in the region has been described in earlier works, which were largely based on ship drifts and limited observations (Dale 1956; Wytrki 1961). Works based on numerical models in the region started in the 1980s and continue to recent years (Chu et al. 1999; Gan et al. 2006; Liu & Yang 2001; Li et al. 1992; Morimoto et al. 2000; Pohlmann 1987; Qu 2000; Shaw & Chao 1994; Yaocun & Qian 1999). Recently, Tangang et al. (2011) using a wave-tide-circulation coupled model showed that the currents pattern from the intermediate to the upper layers is affected by the local monsoon system. Furthermore, Tangang et al. (2011) described the existence of strong western boundary current and subsurface anti-cyclonic eddy in east coast of Peninsular Malaysia during the southwest monsoon period.

The distribution of sea surface temperature (SST) in this region has also been investigated by numerous studies, both using observation and modeling (Akhir 2012; Cai et al. 2007; Chu et al. 1999; Tangang et al. 2011; Wyrtki 1961, Yanagi et al. 2001). Generally, the SSTs in the basin are relatively warmer during summer because of increased solar radiation and the advection of warm waters from the southern region, especially from the Java Sea. During summer the SST ranges between 28.5 and 30.5°C compared to 25 and 29°C during winter (Tangang et al. 2011). Despite numerous studies in the SSCS, there is still lack of focused investigation in the east coast of Peninsular Malaysia. This study investigates in detailed the major features of current circulation and temperature distribution along the east coast of Peninsular Malaysia using the Regional Ocean Modeling System (ROMS).

DATA AND METHODS

NUMERICAL MODEL

The ROMS was setup in a two-domain configuration. The coarse model domain, which is located from 20°S to 30°N and 90°E to 140°E, encompasses the Indian and Pacific Oceans with horizontal grid resolution of 0.5° × 0.5° (~ 50 km), and 30 vertical S-levels. The second domain (2°S to 15°N and 97°E to 117°E) comes with 0.08° × 0.08° horizontal spacing (~ 9 km) and also 30 vertical S-levels (Figure 1). However, the focus of this study is to investigate the major features of current circulation and temperature distribution along the east coast of Peninsular Malaysia region bounded by the dashed lines in Figure 1.

The ROMS model was run for six years using climatological monthly mean salinity and temperature of the World Ocean Atlas 2005 (WOA2005) (Locarnini et al. 2006) as open-boundary conditions. The analysis was based on the model result of the second domain from year 3 to 6 of the simulation period. The velocities and elevations at the boundaries of the parent domain were based on the geostrophic and hydrostatic equations (Marchesiello et al. 2001). The bathymetry used in both domains was based

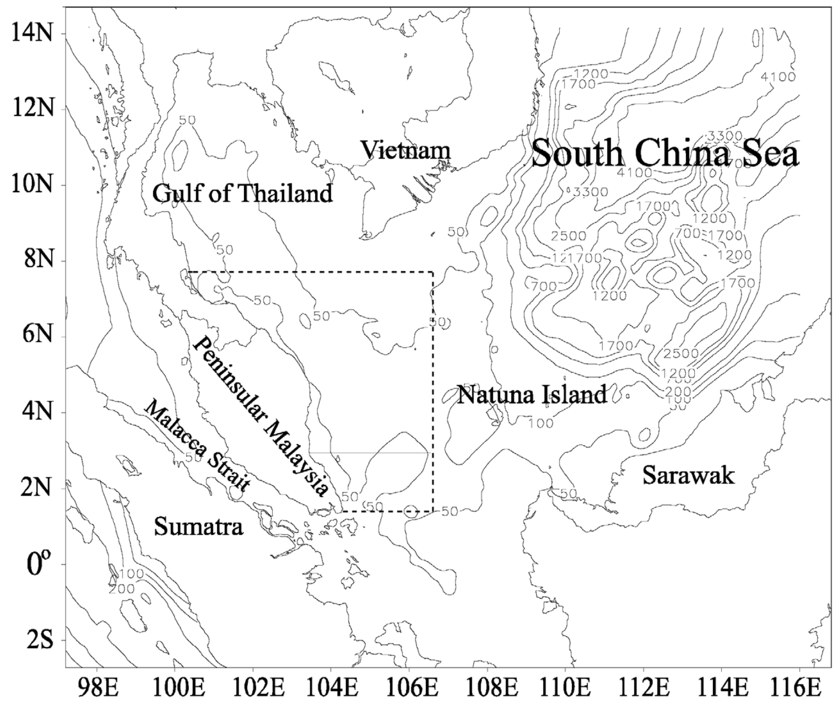

FIGURE 1. Topography in the finest resolution model domain of the two-domain nested model (unit is in m). The area bounded by the dashed lines indicates the region of interest. The solid line indicates the location cross-section of velocity and temperature profiles

on the ETOPO2 at 3.7 km horizontal resolution (Smith & Sandwell 1997). Furthermore, the topography was also smoothed with a slope parameter of less than 0.25 to avoid pressure gradient error (Penven et al. 2008). The surface forcings of the model (wind stress, net heat & surface freshwater fluxes) were obtained from the Comprehensive Ocean–Atmosphere Data Set (COADS) (Da Silva et al. 1994). Figure 2 shows the wind stress computed from COADS for June-July-August (JJA) period. Along the east coast of Peninsular Malaysia, the wind stress is parallel to the coast. The model was initialized at 15 January with temperature and salinity fields assume values from the WOA2005. The parent and child domains used time steps of 18 and 3 min, respectively.

DATASET FOR MODEL VALIDATION

The modeled currents and SST distribution patterns were compared with the Simple Ocean Data Assimilation (SODA) Version 2.2.6 (Carton & Giese 2008). The SODA is an oceanic reanalysis data set for the global ocean with 0.5° horizontal resolution spanning from 1865 to 2008. In the absence of direct observational data, SODA can be used to validate model. Fang et al. (2012) indicated that SODA is a reasonable product for model validation in the South China Sea (SCS). In addition, Reynolds' SST version 2, based on daily optimum interpolation of 0.25° horizontal resolution that spans from 2000 to 2005 (Reynolds et al. 2007), was also used to validate the model.

RESULTS AND DISCUSSION

CURRENT CIRCULATION PATTERN

Figures 3 and 4 show the ROMS simulated current circulation pattern during the southwest monsoon for the upper (0 to 15 m depth) and middle (15 to 35 m depth) layers, respectively. Generally, the circulation patterns resemble those of SODA and earlier studies (Cai et al. 2007; Chu et al. 1999; Morimoto et al. 2000; Tangang et al. 2011). The major features of the simulated circulation, especially at the upper and middle layers, include the strong western boundary current along the east coast of Peninsular Malaysia and two anti-cyclonic eddy systems, marked as E1 and E2 in Figure 3. However, these two eddy systems are much weaker compared with the western boundary current. Nevertheless, detailed examination of the pattern of the simulated current and those of SODA shows some differences. The simulated western boundary appears to be slightly stronger than those of SODA. Moreover, the simulated western boundary currents along the east coast of Peninsular Malaysia are narrower compared with those in Tangang et al. (2011). Figure 3 also shows that the northward flowing current changes into eastward flowing current when it approaches the northern tip of Vietnam at about 7°N. It is also rather interesting to note that the western boundary current continues to flow north after it leaves east coast of

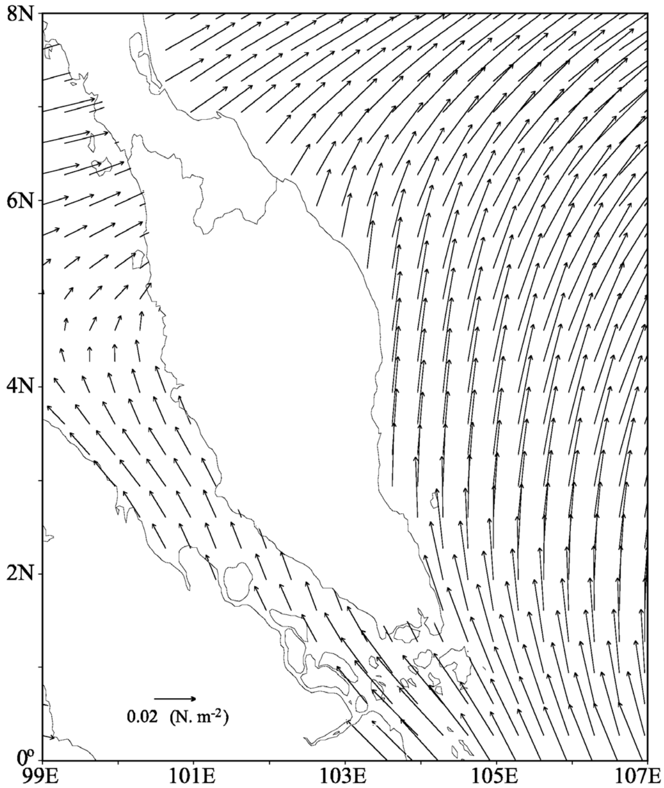

FIGURE 2. Southwest monsoon wind stress (Nm^{-2}) over the area of interest calculated based on COADS dataset

Peninsular Malaysia rather than flowing along the coast to the Gulf of Thailand. These currents later bifurcates into two branches with one branch flows northeastward to feed to the strong current along coast of Vietnam while the other component flows eastward to feed into the anti-cyclonic eddy centered at 8°N, 111°E. These simulated major patterns of the circulation are consistent with those of SODA (Figure 3(b)). However, the two eddies are not visible at the upper layer of SODA, probably because of low resolution of SODA product. Similarly, the eddy systems were also not simulated at the surface layer in Tangang et al. (2011). However, at the middle layer, the signatures of these eddy systems are visible in SODA albeit much weaker in magnitude (Figure 4). However, Tangang et al. (2011) simulated only one anti-cyclonic eddy at sub-surface, which its generation was attributed to both wind stress curl and bathymetry in the area. At the middle layer, the western boundary currents along the east coast of Peninsular Malaysia in SODA are weaker than those of ROMS. Indeed, as shown the vertical cross-section at 3°N (Figure 5), the simulated western boundary currents are stronger than those of SODA, probably because of its low resolution. The maximum speed of the ROMS simulated currents is between 0.6 and 0.7 ms^{-1} compared with 0.2 ms^{-1} for SODA. However, the location of the simulated current is correctly positioned at about 104.6°E. In Tangang et al. (2011), the western boundary currents appear broader. The differences between the features simulated in this study and those of Tangang et al. (2011) could be due to the different bathymetry and boundary conditions used.

SEA SURFACE TEMPERATURE DISTRIBUTION

The simulated SST during the southwest monsoon (i.e. June to August) is consistent with the Reynold's SST (Figure 6) as well as with other previous studies (Cai

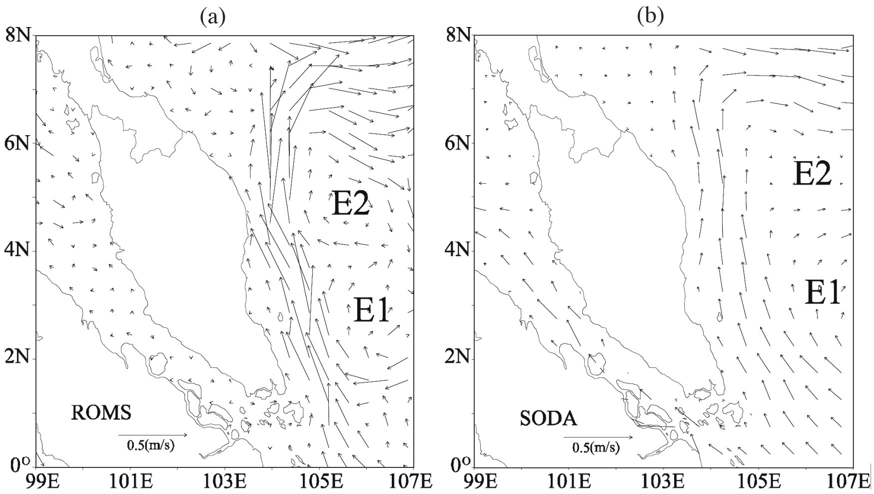

FIGURE 3. Southwest monsoon current circulation patterns of the upper layer current (ms^{-1}), (a) ROMS and (b) from SODA. The labels E1 and E2 indicate the anti-cyclonic eddy systems

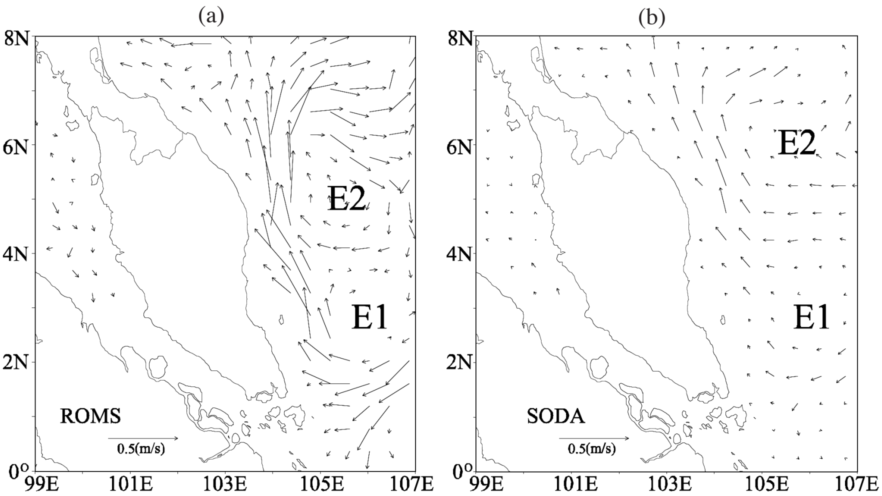

FIGURE 4. As in Figure 3 except for the middle layer

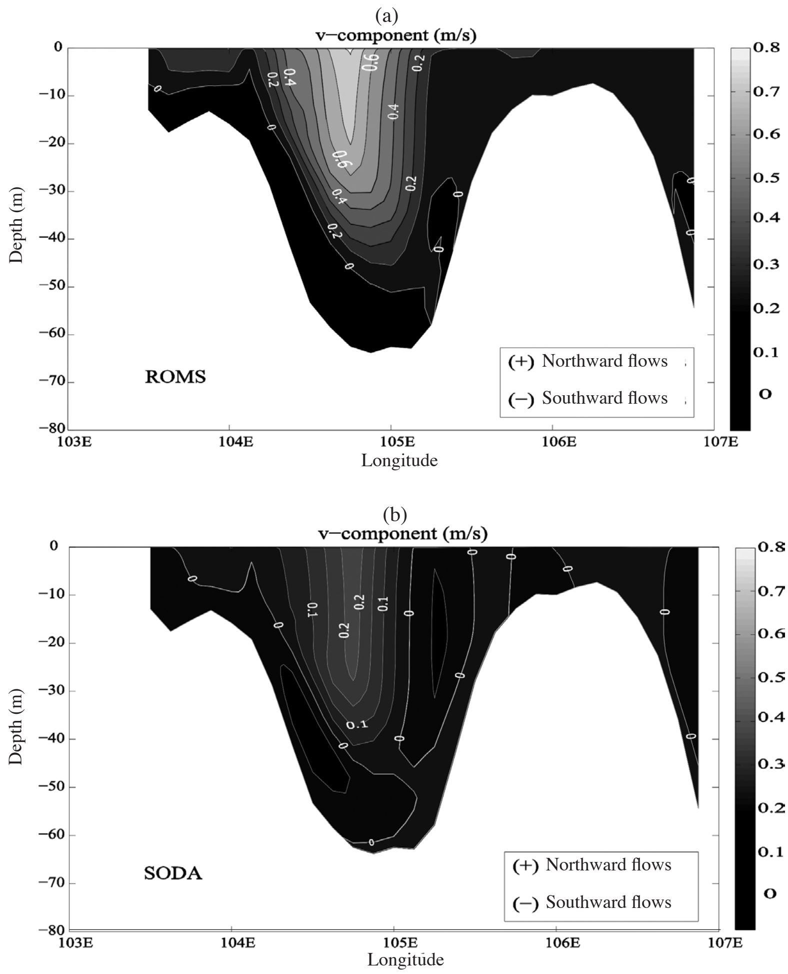

FIGURE 5. The zonal velocity cross section at 3ºN. Positive (negative) indicates northward (southward) flows in (a) ROMS and b) SODA. Unit is in ms^{-1}

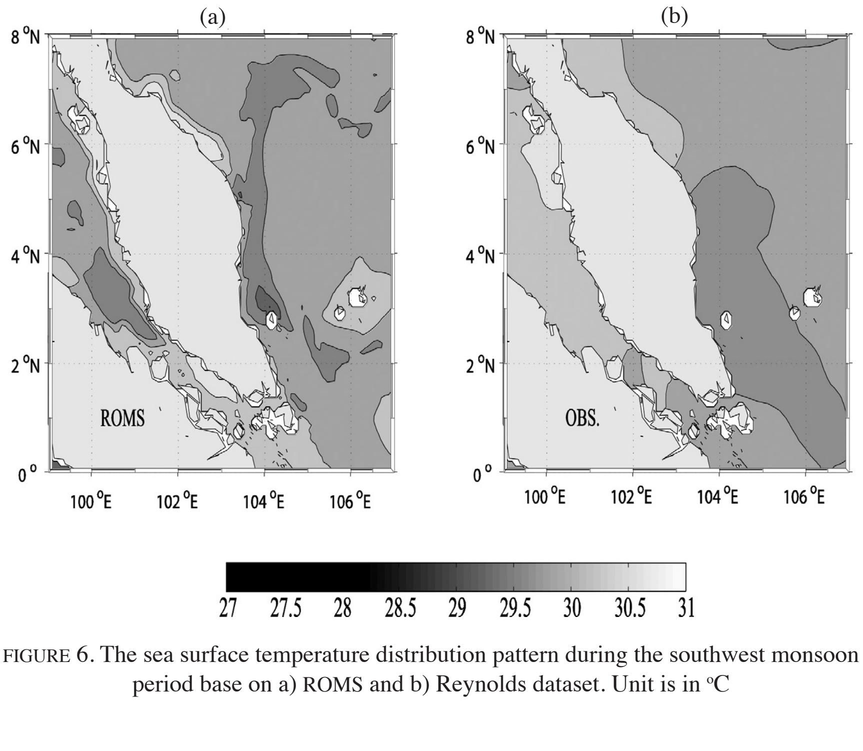

FIGURE 6. The sea surface temperature distribution pattern during the southwest monsoon period base on a) ROMS and b) Reynolds dataset. Unit is in ºC

et al. 2005, 2007; Hu et al. 2000; Morimoto et al. 2000; Tangang et al. 2011). During the southwest monsoon period, warmer SST > 28.5°C dominates the southern region of the SCS due to advection of warm water from Java Sea as well as high insolation (Cai et al. 2007; Chu et al. 1997, 1998; Shen & Lau 1995; Tomita & Yasunari 1996; Yanagi et al. 2001). Interestingly, along the east of Peninsular Malaysia an elongated cooler SST can be found both in the simulated and observed SST (Figure 6). This is also consistent with the simulated summer SST of Tangang et al. (2011) that indicated similar feature of elongated cooler SST along east coast of Peninsular Malaysia.

UPWELLING ALONG EAST COAST OF PENINSULAR MALAYSIA

The existence of an elongated cooler SST along the east coast of Peninsular Malaysia cannot be explained by the advection of warm water from the south, particularly Java Sea. Hence, this cooler SST could be due to the coastal upwelling process that may occur along the east coast of Peninsular Malaysia in response to the strong southwest monsoon wind over this region during this period (Figure 2). A strong upwelling also occurs along Vietnam coast during this season due the strong southwest monsoon wind along the coast (Hu et al. 2011; Tangang et al. 2011; Xie et al. 2003). The upwelled cooler water is also advected further north by the strong western boundary current along the east coast of Peninsular Malaysia (Figure 6). Figure 7 shows the vertical velocity cross-section at 3°N, as indicated by the solid line in Figure 1. Positive vertical velocity can be seen at some depths indicating the occurrence of an upwelling. At about 104°E and depth of about 20 m, the positive vertical velocity corresponds well with the position of the elongated cooler SST along east coast of Peninsular Malaysia (Figure 7). Further evidence of the occurrence of upwelling in the region is the uplifting of the isotherms towards the coast due to upward flow of cooler water from below in the area (Figure 8). The shoaling of these isotherms is in response to the off-shore Ekman transport due to the southerly – southwesterly wind stress along the coast (Xie et al. 2003; Yanagi et al. 2001). As indicated in this figure, both the ROMS simulated and SODA temperature cross-sections are consistent to each other.

ROLE OF THE SOUTHWEST MONSOON WIND

In this section we investigate the role of the southwest monsoon wind in generating the major oceanographic features along the east coast of Peninsular Malaysia including the strong western boundary current, anti-cyclonic eddy systems and the upwelling occurrence along the coast. This was achieved by re-running the model without wind stress forcing. Figure 9 indicates the circulation patterns both at the upper and middle layers, which show the disappearance of the strong western boundary current along the east coast of Peninsular Malaysia. Also, only one of the eddy systems remains visible albeit much weaker compared with those with wind stress forcing. Hence, the existence of these circulation features is basically a response to the strong southwest monsoonal wind over this region. However, the eddy generation could also be due to the wind stress

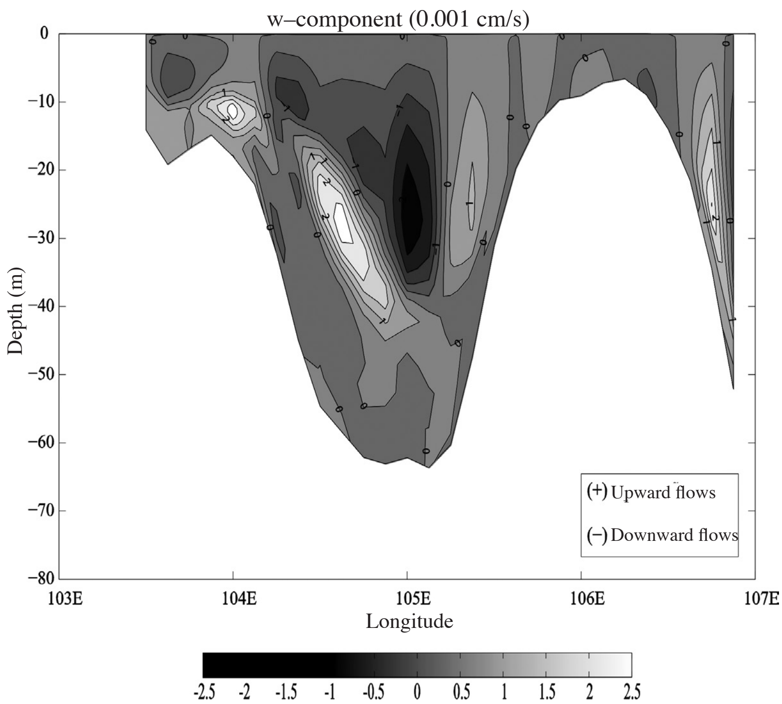

FIGURE 7. The ROMS simulated vertical velocity cross-section at 3°N. Positive (negative) indicates upward (downward) flow. Unit is in 0.001 cms^{-1}

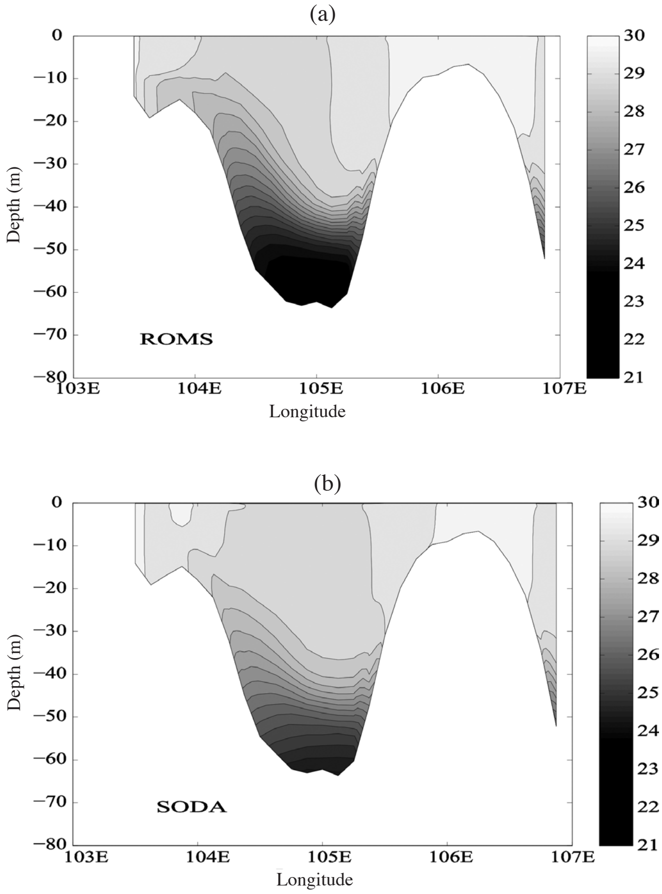

FIGURE 8. The isotherm cross-section at 3°N a) ROMS and b) SODA. Unit is in °C

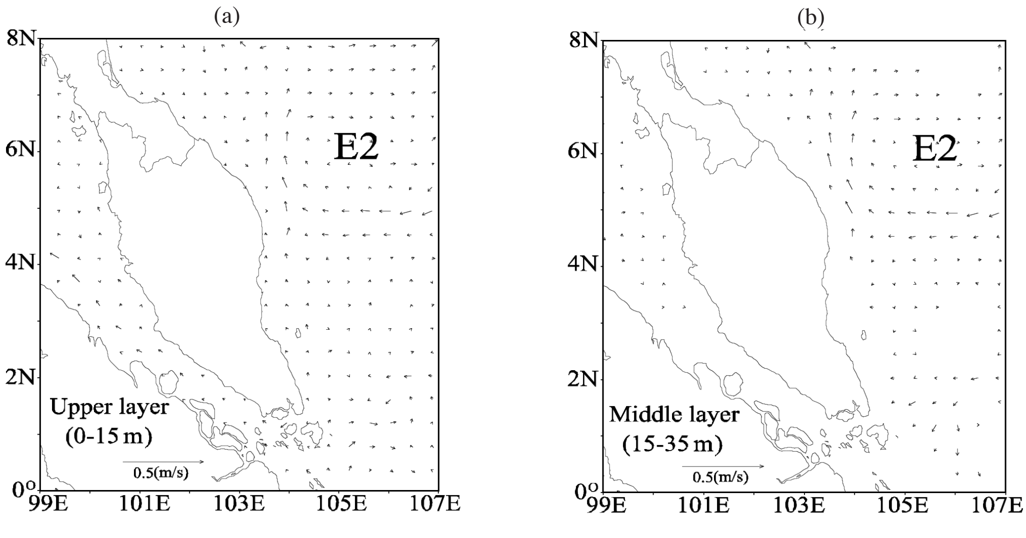

FIGURE 9. The simulated current circulation patterns for the no wind stress run a) upper layer and b) middle layer

curl and bathymetry complexity in the region (Tangang et al. 2011).

Figure 10 shows the SST distribution for the no wind stress run, which indicates the disappearance of the elongated cooler SST along the east coast of Peninsular Malaysia. In fact, an elongated slightly warmer SST prevails in the same areas. The disappearance of the elongated cooler SST indicates the absent of the coastal upwelling process. This is due to the absence of the long-shore wind stress that is required to generate off-shore Ekman flow for the upwelling process to occur (Xie et al. 2003; Yanagi et al. 2001). The lack of off-shore

Ekman flow would result in no upward flow for cooler water to reach the surface. The cross-section of the vertical velocity for the run without wind stress shows the absence of positive vertical velocity at 104°E, i.e. the location of upwelled flow in the run with stress (Figure 11). Furthermore, due to the absence of these upward flows, the isotherms for the cross-section at 3°N are flattened (Figure 12). Hence this result reiterates the roles of southwest monsoon in the upwelling process along the east coast of Peninsular Malaysia.

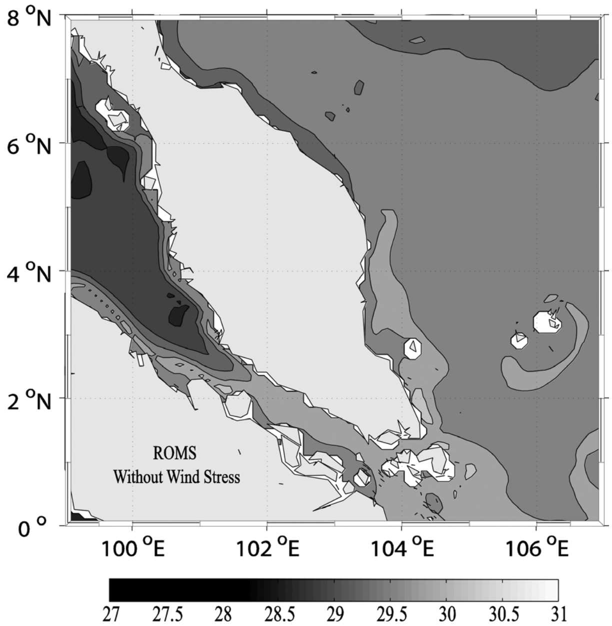

FIGURE 10. The simulated sea surface temperature for the no wind stress run. Unit is in °C

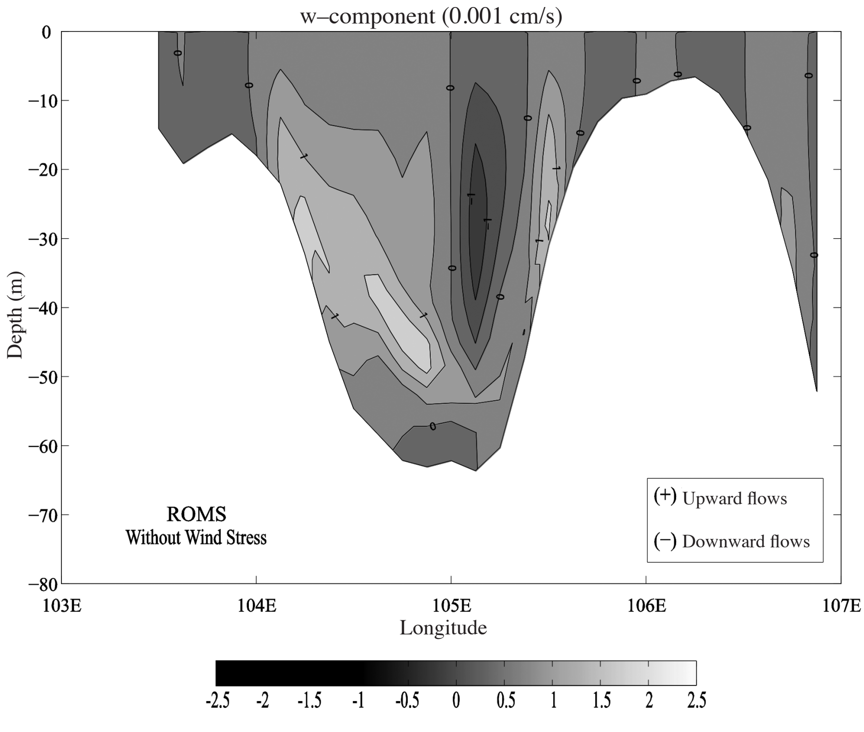

FIGURE 11. The vertical velocity cross-section at 3°N for the no wind stress run. Unit is in 0.001 cms^{-1}

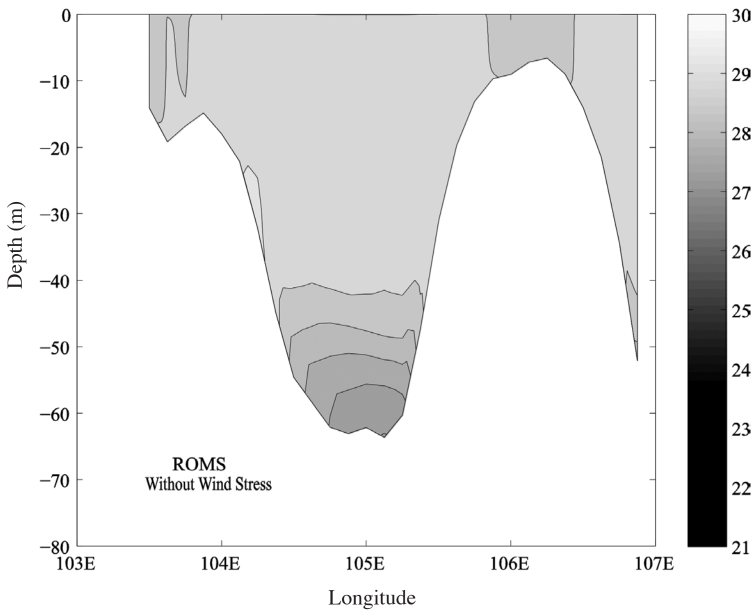

FIGURE 12. The temperature cross-section at 3°N for the no wind stress run. Unit is in °C

CONCLUSION

The ROMS was used to simulate major features of current circulation and sea surface temperature distribution along the east coast of Peninsular Malaysia during the southwest monsoon period. Model results were validated against SODA reanalysis and Reynolds SST datasets. The circulation along the east of Peninsular Malaysia is characterized by a strong western boundary current and two anti-cyclonic eddy systems. The western boundary current flows northward along the east coast of Peninsular Malaysia towards the southern tip of Vietnam where it changes direction at about 7°N to flow eastward. In addition to these features, the east coast of Peninsular Malaysia is also characterized by the elongated cooler SST as a result of coastal upwelling process in this area. The existence of these features owes to the strong southwest monsoon wind over this region during this period. The strong southerly – southwesterly wind stress along the coast generates the off-shore Ekman transport which in turn causes the localized lifting of isotherms near the coast resulting in net upward flows that bringing cold water from bottom to surface.

ACKNOWLEDGMENTS

This research is funded by the grants of MOHE LRGS/TD/2011/UKM/PG/01, MOSTI Science fund 04-01-02-SF0747 and Universiti Kebangsaan Malaysia DIP-2012-020 and DPP-2013-080.

REFERENCES

Akhir, M.F. & Chuen, Y.J. 2011. Seasonal variation of water characteristics during inter-monsoon along the east coast of Johor. *Journal of Sustainability Science and Management* 6(2): 206-214.

Akhir, M.F. 2012. Surface circulation and temperature distribution of southern South China Sea from global ocean model (OCCAM). *Sains Malaysiana* 41(6): 701-714.

Chu, P.C., Lu, S. & Chen, Y. 1997. Temporal and spatial variabilities of the South China Sea surface temperature anomaly. *Journal of Geophysical Research* 102: 20937-20955.

Chu, P.C., Edmons, N.L. & Fan, C.W. 1999. Dynamical mechanisms for the South China Sea seasonal circulation and thermohaline variability. *Journal of Physical Oceanography* 29: 2971-2989.

Cai, S., Su, J., Long, X., Wang, S. & Huang, Q. 2005. Numerical study on summer circulation and its establishment of the upper South China Sea. *Acta Oceanologica Sinica* 24(1): 31-38.

Cai, S.Q., Long, X. & Wang, S. 2007. A model study of the summer Southeast Vietnam offshore current in the southern South China Sea. *Continental Shelf Research* 27: 2357-2372.

Carton, J.A. & Giese, B.S. 2008. A reanalysis of ocean climate using simple ocean data assimilation (SODA). *Monthly Weather Review* 136: 2999-3017.

Dale, W.L. 1956. Wind and drift current in the South China Sea. *The Malayan Journal of Tropical Geography* 8: 1-31.

Da Silva, A.M., Young, C.C. & Levitus, S. 1994. Atlas of Surface Marine Data. Vol. 1. Algorithms and Procedures, NOAA Atlas NESDIS 6, U.S. Department of Commerce, NOAA, NESDIS, USA.

Fang, G.H., Gang, W., Yue, F. & Wendong, F. 2012. A review on the South China Sea western boundary current. *Acta Oceanologica Sinica* 31(5): 1-10.

Gill, A.E., Green, J.S.A. & Simmons, A.J. 1974. Energy partition in the large-scale ocean circulation and the production of mid-ocean eddies. *Deep Sea Research* 21: 499-528.

Gan, J., Li, H., Curchitser, E.N. & Haidvogel, D.B. 2006. Modeling South China Sea circulation: Response to seasonal forcing regimes. *Journal of Geophysical Research: Oceans*. 111: C6.

Hu, J.Y., Kawamura, H., Hong, H. & Qi, Y.Q. 2000. A review on the currents in the South China Sea: Seasonal circulation, South China Sea warm current and Kuroshio intrusion. *Journal of Oceanography* 56: 607-624.

Hu, J.Y., Gan, J., Sun, Z., Zhu, J. & Dai, M. 2011. Observed three-dimensional structure of a cold eddy in the Southwestern South China Sea. *Journal of Geophysical Research: Oceans*. 116: C5.

Li, R.F., Zeng, Q.C., Ji, Z.Z. & Guan, D. 1992. Numerical simulation for a northeastward flowing current from area off the eastern Hainan Island to Tsugaru/Soya Strait. *La mer* 30: 229-238.

Liu, Z. & Yang, H. 2001. Regional dynamics of seasonal variability in the South China Sea. *Journal of Physical Oceanography* 31: 272-284.

Locarnini, R.A., Mishonov, A.V., Antonov, J.I., Boyer, T.P. & Garcia, H.E. 2006. World Ocean Atlas 2005, Volume 1: Temperature. S. Levitus, Ed. NOAA Atlas NESDIS 61. Washington, D.C.: U.S. Government Printing Office.

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

Marchesiello, P., McWilliams, J.C. & Shchepetkin, A. 2001. Open boundary condition for long-term integration of regional oceanic models. *Ocean Modeling* 3: 1-21.

Pohlmann, T. 1987. A three-dimensional circulation model of the South China Sea. In *Three-Dimensional Models of Marine and Estuarine Dynamics,* edited by Nihoul, J. & Jamart, B. USA: Elsevier Science.

Penven, P., Marchesiello, P., Debreu, L. & Lefevre, J. 2008. Software tools for pre-and post-processing of oceanic regional simulations. *Journal of Environmental Modelling and Software* 23: 660-662.

Qu, T. 2000. Upper-layer circulation in the South China Sea. *Journal of Physical Oceanography* 30: 1450-1460.

Qu, T. 2001. Role of ocean dynamics in determining the mean seasonal cycle of the South China Sea surface temperature. *Journal of Geophysical Research* 106(C4): 6943-6955.

Qiu, B. & Chen, S. 2005. Eddy-induced heat transport in the subtropical North Pacific from Argo, TMI, and Altimetry measurements. *Journal of Physical Oceanography* 35: 458-473.

Reynolds, R.W., Smith, T.M., Liu, C., Chelton, D.B., Casey, K.S. & Schlax, M.G. 2007. Daily high-resolution blended analyses for sea surface temperature. *Journal of Climate* 20: 5473-5496.

Shaw, P.T. & Chao, S.Y. 1994. Surface circulation in the South China Sea. *Deep-Sea Research I* 40(11/12): 1663-1683.

Shen, S. & Lau, K.M. 1995. Biennial oscillation associated with the East Asian summer monsoon and tropical sea surface temperature. *Journal of Meteorological Society of Japan* 73: 105-124.

Smith, W.H.F. & Sandwell, D.T. 1997. Global seafloor topography from satellite altimetry and ship depth soundings. *Science* 277: 1957-1962.

Tomita, T. & Yasunari, T. 1996. Role of the northeast winter monsoon on the biennial oscillation of the ENSO/monsoon system. *Journal of Meteorological Society of Japan* 74: 399-413.

Tangang, T.F., Xia, C., Qiao, F., Juneng, L. & Shan, F. 2011. Seasonal circulations in the Malay Peninsula Eastern continental shelf from a wave–tide–circulation coupled model. *Ocean Dynamics* 61(9): 1317-1328.

Wyrtki, K. 1961. Scientific results of marine investigations of the South China Sea and the Gulf of Thailand 1959–1961. Naga Report 2.

Wang, B., Huang, F., Wu, Z., Yang, J., Fu, X. & Kikuchi, K. 2009. Multi-scale climate variability of the South China Sea monsoon: A review. *Dynamics of Atmospheres and Oceans* 47: 15-37.

Xie, S.P., Xie, Q., Wang, D.X. & Liu, W.T. 2003. Summer upwelling in the South China Sea and its role in regional climate variations. *Journal of Geophysical Research* 108: C8.

Yaocun, Z. & Qian, Y. 1999. Numerical simulation of the regional ocean circulation in the coastal areas of China. *Advances in Atmospheric Sciences* 16(3): 443-450.

Yanagi, T., Sachoemar, I.S., Takao, T. & Fujiwara, S. 2001. Seasonal variation of stratification in the Gulf of Thailand. *Journal of Oceanography* 57: 461-470.

School of Environmental and Natural Resource Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia

*Corresponding author; email: farshiddaryabor@gmail.com

Received: 15 January 2013
Accepted: 3 August 2013