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Performance assessment for an operational ocean model of the Taiwan Strait

Xinyou Lin[a,c], Xiao-Hai Yan[b,c], Yuwu Jiang[a,*], Zhenchang Zhang[d]

[a] State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, Fujian, P. R. China
[b] College of Earth, Ocean and Environment, University of Delaware, Newark, Delaware 19716, USA
[c] Joint Institute for Coastal Research and Management (UD/XMU Joint-CRM), Xiamen University, Xiamen 361005, Fujian, P. R. China
[d] College of Computer and Information Science, Fujian Agriculture and Forestry University, Fuzhou, 350002, P. R. China

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ABSTRACT

The Taiwan Strait Nowcast/Forecast System (TFOR), which is based on the Regional Ocean Modeling System, may be the first operational ocean model to include both tide and circulation processes in the Taiwan Strait. In this study, we assessed the performance of TFOR by investigating the differences between observational data and the results obtained by TFOR, thereby illustrating the ability of TFOR to reproduce significant physical processes. We also evaluated the utility and reliability of TFOR products for successful applications in maritime search and rescue. The mean bias, root mean-squared difference, correlation coefficient (CC), and Willmott skill for the differences in temperature between the cruise observations and the TFOR results were −0.01°C, 1.2°C, 0.87, and 0.92, respectively, and those for the corresponding salinity results were 0.06 PSU, 0.4 PSU, 0.74, and 0.83, respectively. The distributions of the TFOR M_2 harmonic constants indicated that TFOR simulates the tidal characteristics well in the Taiwan Strait. The CC between the Taiwan Strait volume transport based on the TFOR results and the along-strait wind stress was 0.77, thereby indicating that monsoon winds exert an important influence on the variability in volume transport through the Taiwan Strait. Statistical analyses of the TFOR results showed that the annual, spring, summer, autumn, and winter mean transport volumes were 1.16, 1.28, 2.52, 0.80, and 0.04 Sv, respectively. In conclusion, the TFOR is robust and it can simulate the temperature, salinity, and velocity in a reasonable and stable manner.

1. Introduction

The Taiwan Strait (TWS) is located between Taiwan Island and mainland China, where it connects the East China Sea (ECS) to the South China Sea (SCS), as shown in Fig. 1a. Its bottom topography is somewhat complex, but the average water depth is only approximately 60 m. Its major topographic features are presented in Fig. 1a, including the Kuan-Yin Depression (KYD), Changyun Ridge (CYR), Taiwan Bank (TWB), Wuchou Trough (WCT), and Penghu Channel (PHC). The TWS is under a subtropical monsoon regime, where it is dominated by stronger northeasterly winds in the winter and weaker southwesterly winds in the summer (Ke and Hu, 1991). The regional flows in the TWS have been studied for decades based on *in-situ* observations, remote sensing, and numerical modeling (Hu et al., 2010b). The monsoon system has been regarded as the primary force responsible for flow variations in the TWS (Wyrtki, 1961), while it strongly affects the Zhemin Coastal Current (ZCC, marked in Fig. 1a), which flows southwestward in the upper layer along the east coast of mainland China (Hong et al., 2011a). The SCS Warm Current near the TWB flows northeastward all year round together with the Kuroshio Branch Current (KBC, marked in Fig. 1), and it is considered another cause of flow variations in the TWS (Guan and Chen, 1964; Guan, 1978a, 1978b). Nitani (1972) described the surface coastal current flows in the TWS, including a southwestward flow in the winter but northeastward flow in the summer in the western TWS as well as a northeastward flow in both the summer and winter in the eastern TWS. Chuang (1985) reported a mean northward current with occasional flow reversals in the TWS. The flow reversals were confirmed by Liang et al. (2003) based on shipboard acoustic Doppler current profiler (sb-ADCP) observations. Barotropic numerical models have been used to study the roles of the CYR, wind stress, and KBC in the TWS (Jan et al., 1994a, 1994b; Cai and Wang, 1997). The modeling results obtained by Jan et al. (1994b) indicated that the flow pattern around the CYR is determined mainly by the bottom topography and the inertial effect. The latter is associated with the incoming flows. Cai and Wang (1997) indicated that the

* Corresponding author. Tel.: +86-592-2185510; fax: +86-592-2185570.
E-mail address: ywjiang@xmu.edu.cn (Y. Jiang).

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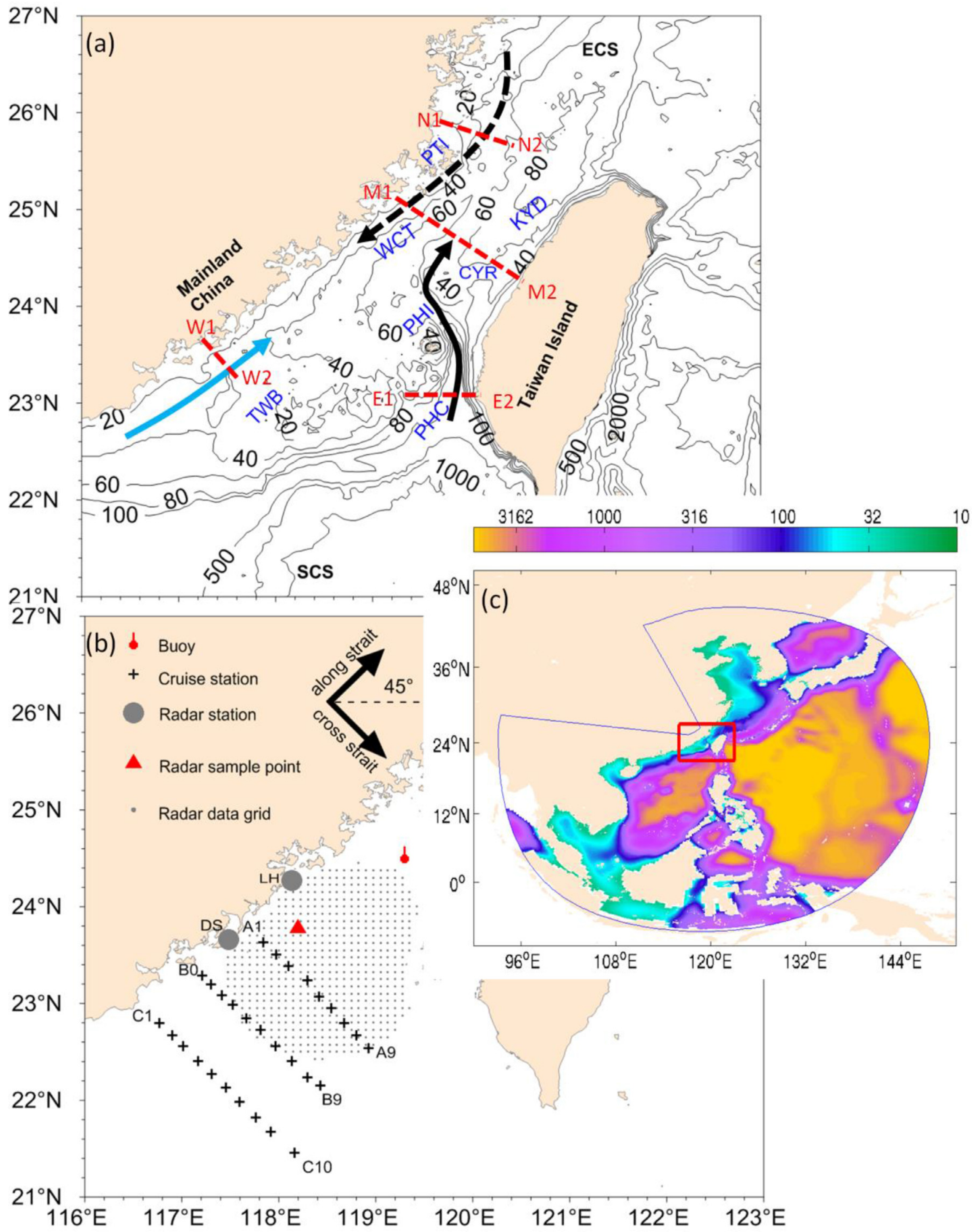

Fig. 1. Bottom topography (unit: m) of Taiwan Strait (a) and TFOR (c), and observations (b) in the Taiwan Strait. (a) SCS, ECS, KYD, WCT, CYR, TWB, PHI, PHC, and PTI denote South China Sea, East China Sea, Kuan-Yin Depression, Wuchou Trough, Changyun Ridge, Taiwan Bank, Penghu Island, Penghu Channel, and Pingtan Island, respectively. Zhemin Coastal Current (ZCC) is denoted by a dashed black arrow, Guangdong Coastal Current (GCC) by a solid blue arrow, and Kuroshio Branch Current (KBC) by a solid black arrow (combined with the extension of the SCS Warm Current). Dashed red lines indicate sections N1–N2, W1–W2, E1–E2, and M1–M2. (b) DS and LH denote two radar stations (gray solid circles) in Dongshan and Longhai with their coverage regions indicated by gray points. The red solid triangle denotes the radar sample point, where most radar velocities are available. The red mooring buoy is set at the center of the Taiwan Strait. Ship tracks are shown by the three black lines corresponding to stations A1–A9, B0–B9, and C1–C10 in June 2010. (c) The blue line delineates the TFOR domain and the red rectangle shows the location of panel (a).

wind, bottom topography, and Kuroshio current have great effects on the circulation in the TWS. The flow patterns in winter and summer were simulated by Jan et al. (1994b and 1998). The transport reversals during October and November 1999 were examined by Ko et al. (2003) using a real-time North Pacific Ocean model, and reexamined by Wu and Hsin (2005) with a 1/8° resolution hindcast model. Jan et al. (2004) showed that the reflection of the southward propagating tidal wave based on the deep trench in the southern strait is responsible for the complex wave propagation pattern. Wu et al. (2007) used modeling results to illustrate the transient, seasonal, and inter-annual variability of flows in the TWS. Zhu et al. (2008a) analyzed long-term measurements of