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Simulating multi-scale oceanic processes around Taiwan on unstructured grids

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ABSTRACT

We validate a 3D unstructured-grid (UG) model for simulating multi-scale processes as occurred in Northwestern Pacific around Taiwan using recently developed new techniques (Zhang et al., Ocean Modeling, 102, 64–81, 2016) that require *no* bathymetry smoothing even for this region with prevalent steep bottom slopes and many islands. The focus is on short-term forecast for several months instead of long-term variability. Compared with satellite products, the errors for the simulated Sea-surface Height (SSH) and Sea-surface Temperature (SST) are similar to a reference data-assimilated global model. In the nearshore region, comparison with 34 tide gauges located around Taiwan indicates an average RMSE of 13 cm for the tidal elevation. The average RMSE for SST at 6 coastal buoys is 1.2 °C. The mean transport and eddy kinetic energy compare reasonably with previously published values and the reference model used to provide boundary and initial conditions. The model suggests ~2-day interruption of Kuroshio east of Taiwan during a typhoon period. The effect of tidal mixing is shown to be significant nearshore. The multi-scale model is easily extendable to target regions of interest due to its UG framework and a flexible vertical gridding system, which is shown to be superior to terrain-following co-ordinates.

1. Introduction

The Northwestern Pacific (NWP), including major marginal seas (Bohai, Yellow Sea, East China Sea (ECS), South China Sea (SCS), Sea of Japan (SoJ)), is home to over a quarter of the world's population, and plays an important part in world's climate system (Kobashi et al., 2008; Lin et al., 2009). Therefore it's important to improve our understanding and prediction of this system before we can effectively manage the natural resource and mitigate hazards.

Previous studies of NWP reveal a rather complex system. Major boundary current systems in NWP are the Mindanao Current and Kuroshio, which are the southern and northern branches of the westward-flowing North Equatorial Current respectively, separated at 12–13°N at the coast of Philippines. The Kuroshio carries warm and salty water northward to Taiwan and Japan, and the northward-flowing waters of the Kuroshio western boundary current leave the Japanese coast to flow eastward into the North Pacific as a free meandering jet ('Kuroshio Extension'). There are also an abundance of recirculation eddies of size 200–500 km on each side of Kuroshio (Oey et al., 2013).

Multiple current systems exist in the marginal seas of NWP, driven by seasonal monsoon, topography and interacting with Kuroshio. Major current systems include China Coastal Current (CCC), Taiwan Warm Current (TWC), Yellow Sea Warm Current (YSWC), and Tsushima Current (TSC). Ichikawa and Beardsley (2002) and Teague et al. (2003) studied the origin of the Tsushima Current in winter and summer. Cho et al. (2009) studied the connectivity among the major straits in NWP, and found strong seasonality in the Taiwan Strait (TWS), the Korea Strait, and the Soya Strait but relatively low seasonality in the Tsugaru Strait. A climatological description of circulation in and around the East China Sea, including Yangtze plume dispersal pathways, is given by Lee and Chao (2003). The transport across Luzon Strait is discussed in Tian et al. (2006), Liang et al. (2008) among others. The mean transports across critical straits/transects were estimated by Johns et al. (2001), Teague et al. (2003,2005), and Jan et al. (2006).

The focus region in this study is Taiwan, located between SCS and ECS. The SCS located to the south of this region is linked to the Pacific

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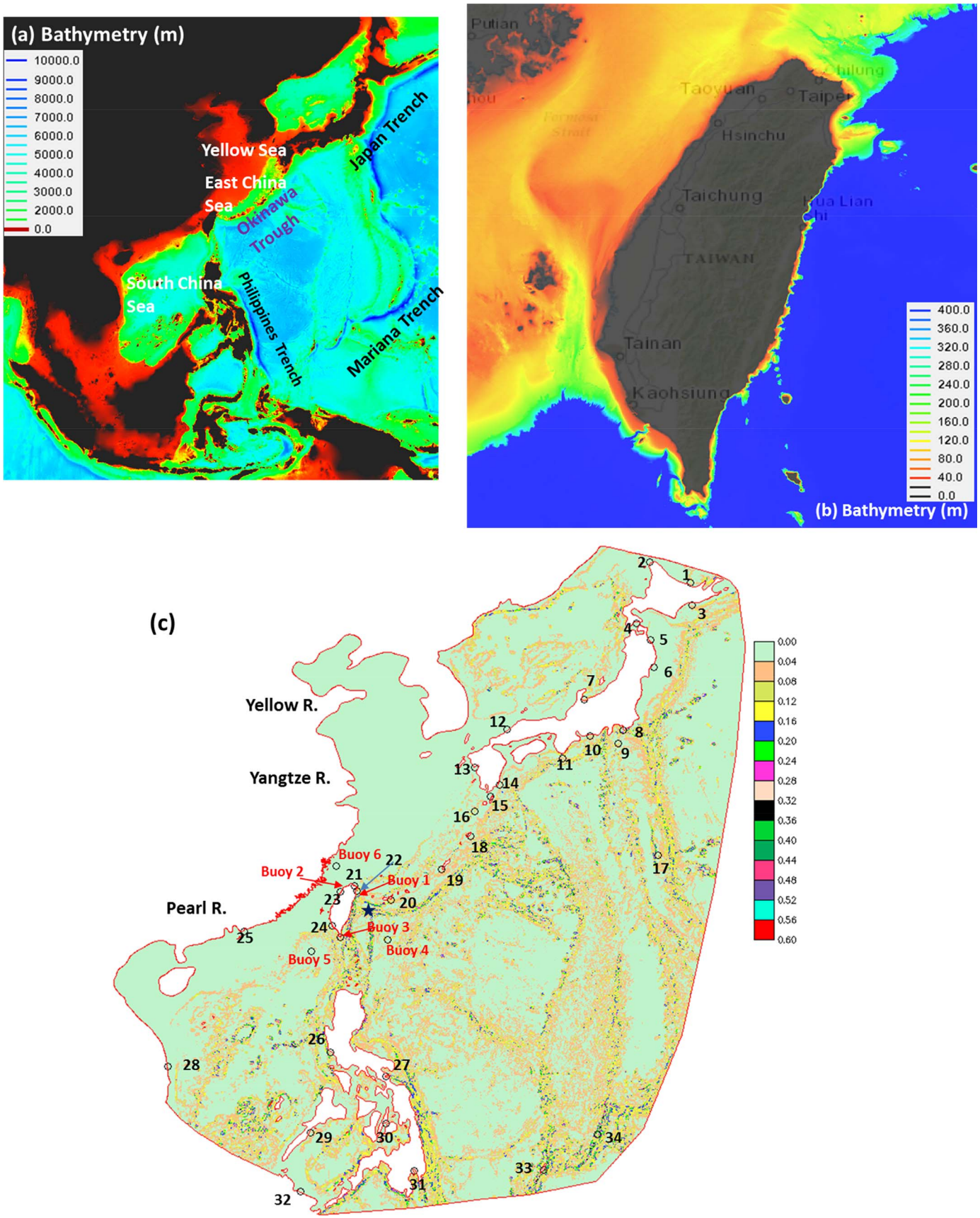

Fig. 1. (a) Bathymetry in NWP; (b) zoom-in around Taiwan; (c) bottom slope $|\nabla h|$ as seen by the DEM (also shown are locations of GLOSS tide gauges and 6 CWB buoys).