Effects of the Submesoscale Anticyclonic Eddies Induced by Kuroshio in East China Sea

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ABSTRACT

For maintaining biological diversity in the coral coasts around Ryukyu Islands, Japan, a role played by the adjacent Kuroshio warm current is anticipated to be necessary for larval and nutrient transport. In order to understand dynamics and mixing between Kuroshio and the islands, we develop a detailed ocean downscaling model around Ryukyu Islands in a doubly nested configuration using ROMS at horizontal resolutions down to 1km, forced by the assimilative JCOPE2 and JMA-GSM/MSM. The model successfully reproduces anticyclonic eddies that are significantly retained on the western side of the islands to promote lateral mixing in the area.

KEY WORDS: ROMS; downscaling; submesoscale; eddy mixing; Kuroshio; Ryukyu Island; East China Sea

INTRODUCTION

Okinawa is home to ecologically significant coral reefs situated at the northernmost end of the border between the Pacific and the Indian Oceans. These corals lie within a biodiversity hotspot that supports the highest diversity of endemic species, plants and animals in the world. For preserving biodiversity and marine ecosystem in the coral coasts around Ryukyu Islands, a role played by the adjacent Kuroshio warm current is considered to be substantial for larval and nutrient transport. Guo et al. (2003) showed that the path and vertical structure of the Kuroshio in the East China Sea, including the Ryukyu Islands, become more realistic as the model’s horizontal resolution increases on the basis of a triply nested ocean modeling using POM. Another numerical study using a high-resolution ocean model in this area indicates that the southwestward counter-Kuroshio Current and mesoscale eddies, at O (100) km, have non-trivial influence on volume and heat transport between Kuroshio and the Islands (Nadaoka et al., 2006). Recently, to enhance the clarity of the dynamical processes in the upper oceans, studies on effects of submesoscale dynamics, at O (10) km or less, on the mean structure, eddies, frontal processes, stratification, etc. have been conducted quite actively (e.g., Uchiyama et al., 2012). However, effects of the submesoscale phenomenon on the oceanic structure have not been fully investigated yet around the Ryukyu Island. Another important point here is that the Kuroshio in the area is considered to be largely affected by the shallow island topography on its east side that may result in unique turbulence. Therefore, we focus in the present study on two effects of 1) submesoscale eddies and their stirring, and 2) shallow island topography, in order to better understand dynamics and mixing between the Kuroshio and the islands. We thus conduct numerical experiments based on a detailed doubly nested ocean downscaling model using ROMS (Regional Ocean Modeling System; Shchepetkin and McWilliams, 2005) at horizontal resolution down to 1km around the Ryukyu Islands, forced by realistic assimilative meteorological and oceanic products to approach these scientific questions.

NUMERICAL MODEL

Figure 1 shows the oceanic downscaling model in doubly nested configuration embedded in the JCOPE2 (Japan Coastal Ocean Predictability Experiments; Miyazawa et al., 2009) domain. We rely on an one-way offline nesting approach to successively reduce the horizontal grid size from about 10 km (JCOPE2) \(\rightarrow\) 3 km (ROMS-L1) \(\rightarrow\) 1 km (ROMS-L2). The outer domain is ROMS-L1 with a horizontal resolution of 3km and 32 vertical layers, designed to encompass a fairly wide area to consider possible impacts of the Kuroshio flowing in from the Taiwan Strait and the Luzon Strait, and climatological freshwater discharge of the Yangtze River. The inner ROMS-L2