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On the Upper Ocean Thermal Structure in a Western North Pacific Ocean Model: Model Evaluation and Sensitivity Study

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ABSTRACT

Seasonal variations in the upper water column of the western North Pacific are simulated with the Regional Ocean Model System (ROMS). The model is driven by surface fluxes of heat, momentum and freshwater without prescribing sea surface temperature or salinity. A series of numerical experiments are conducted to explore the sensitivity of the upper ocean thermal structure to the parameterized solar penetration scheme and two common practices to control model climate through a flux correction term and a nudging term. The absorption of solar radiation by the water column beneath the sea surface destabilizes the upper layers to cause a stronger mixing and deeper mixed layer in the warm season (from April to September). Therefore, removing solar penetration from the model results in an exceptionally stable surface layer, and tends to produce an overly shallow mixed layer in the warm season. The experiment with a prescribed net surface heat flux shows that the model is unable to maintain a heat balance in the upper water column, producing a cooling trend. Experiments with a flux correction term are able to keep the simulated sea surface temperature (*SST*) from a long term drift by adjusting the amount of the net surface heat flux. However, unrealistic net surface heat flux is produced in the experiment, when the model assumes no solar penetration. The implementation of a weak temperature nudging (1/50 days) toward a long term mean climatology prevents the model from simulating a cold bias during long term integration. The experiment with solar penetration and a weak nudging produces reasonable interannual variability during the period of 1995 - 2006 without flux corrections. The nudging terms steer advective heat fluxes towards the climatological mean state so as to avoid long-term drift in upper water column heat content. A detailed understanding of the function of nudging terms in controlling the hydrodynamics of the water column remains to be investigated.

Key words: ROMS, Upper ocean thermal structure, Western North Pacific, Solar penetration, Interannual variation, Model sensitivity

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1. INTRODUCTION

The ocean is a dominant component determining the Earth's heat balance. Based simply on the physical properties of water and air, namely the specific heat and density, Rossby (1959) suggested that ocean heat content dominates and contributes substantially to the climate variability. Since then, ocean models have been developed to simulate natural and anthropogenic climate changes. Many models have succeeded in simulating an El Niño evolution since the Tropical Ocean - Global Atmosphere (TOGA) era (e.g., Guilyardi et al. 2009 and references therein). In recent decades, ocean models are increasingly dependent upon research for studying the earth response to increasing greenhouse warming. The radiative imbalance of the Earth's climate system can be diagnosed by the change in the heat content of the ocean (e.g., Pielke 2003). Observational studies have shown that the heat content of the upper ocean has been increasing over the last 48 years in the world's oceans (Levitus et al. 2000; Levitus et al. 2005). Observed ocean heat content changes have been reproduced by both a forced ocean model (Barnett et al. 2001) and coupled global climate model (Hansen et al. 2005). Both models are driven by anthropogenic factors, such as concentrations of greenhouse gases and the

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