“Noise” generation in climatologically driven ocean models with different grid resolutions

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We are testing the **hypothesis** that nonlinear-systems like ocean dynamics are generating variability by themselves without any external forcing. We examine the output of a three-layer nested numerical simulation which was performed with an almost global model with 1° grid resolution, an embedded West Pacific model (WestPac) with 0.2° grid resolution, and an embedded Southern China Sea (SCS) model with 0.04° grid resolution. The variability, which can be conceptualized as “noise”, is mostly created in the model component of higher grid resolution.

The model used is Hybrid Coordinate Ocean Model (HYCOM) that is exposed to periodic climatological atmospheric forcing, with a fixed annual cycle but without weather disturbances. The atmospheric forcing comes from the Comprehensive Ocean-Atmosphere Data set (COADS). The simulation regions are shown in Figure 1 (see Tang et al., 2018). We analyzed daily averages for every layer model over a 21-year period.

We measure the amount of variability by the variance of daily values (centered on the long-term monthly means) at each grid point. The variable considered is the daily barotropic stream function (BS). The maps in Figure 2 show the spatial distributions of the logarithm of BS variances in the SCS in two seasons (summer and winter monsoon) simulated by three models (global, West-Pacific and South China Sea). Table 1 lists the daily BS variances averaged across the SCS.

The variances in the WestPac are somewhat increased compared to the global run; for the SCS-simulation we find substantially larger variances. We propose that the models ability to generate eddies in the South China Sea is the main cause for the increase in variability.

Our experiments support the concept that dynamical models of the ocean generate internal, unprovoked variability. This “noise” generation is stronger in models with higher resolution. Indeed such behavior is to be expected from the "stochastic climate model" (Hasselmann, 1976). This noise represents for certain issues a nuisance (hiding real effects of forcing) but is also constitutive for the dynamical properties of the system (von Storch et al., 2001). “Noise” has significant implications for issues like “detection and attribution of climate change” and for numerical experimentation with ocean models.

Hasselmann, K., 1976: Stochastic climate models. Part I. Theory. *Tellus* 28, 473-485.

von Storch, H., J.-S. von Storch, and P. Müller, 2001: Noise in the Climate System - Ubiquitous, Constitutive and Concealing. In B. Engquist and W. Schmid (eds.) *Mathematics Unlimited - 2001 and Beyond*. Part II. Springer Verlag, 1179-1194.

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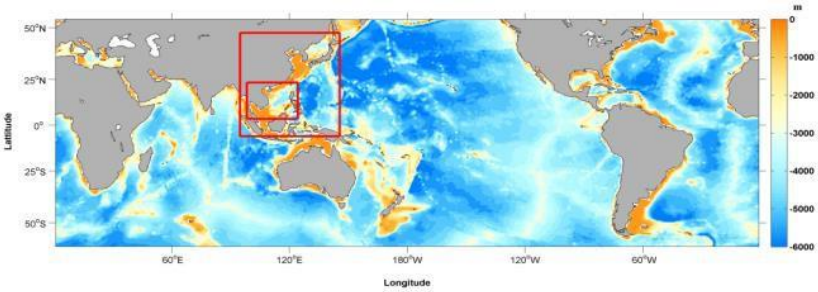

Fig. 1 The regions of the three-nested numerical simulation.

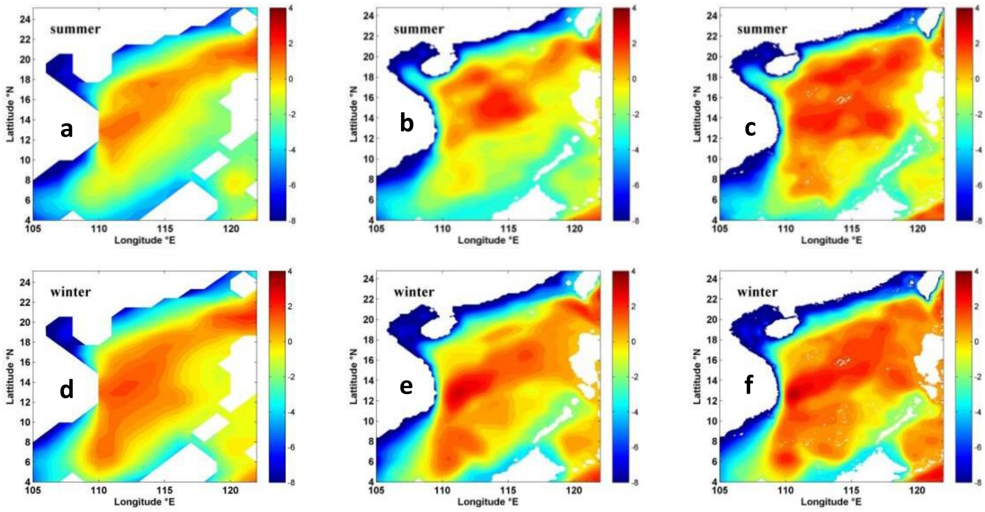

Fig.2 The spatial distributions of logarithm of BS variances in the SCS simulated by the global model (a, d), WestPac model (b, e) and the SCS model (c, f).

Table 1 The spatial averages of the daily BS variances in the SCS simulated by three models

	Global model (SV^2)	**WestPac Model (SV^2)**	**SCS Model (Sv^2)**
Spring	**0.8396**	**1.2777**	**1.7187**
Summer	**0.5801**	**0.8328**	**1.6161**
Fall	**2.2413**	**2.5619**	**3.2377**
Winter	**1.0744**	**1.4574**	**1.9925**
Year	**3.2975**	**5.3550**	**6.1782**