Circulations and Thermohaline Structures of the East Asian Regional Seas (EAMS) Simualted by a Nested Basin/Coastal Model

Peter C. Chu
Naval Postgraduate School, Monterey, California 93943, USA

Shihua Lu and Yuchun Chen
Institute of Plateau Atmospheric Physics, Academia Sinica, Lanzhou, China

1 Introduction

The Japan/East Sea (JES), Yellow Sea (YS), East China Sea (ECS), and South China Sea (SCS) are major east Asian marginal seas (EAMS). The complex topography includes the broad shallows of the Sunda Shelf in the south/southwest of SCS; the continental shelf of the Asian landmass in the north, extending from the Gulf of Tonkin to the YS; a deep, elliptical shaped SCS and JES basins, and numerous reef islands and underwater plateaus scattered throughout. The shelf that extends from the Gulf of Tonkin to the YS is consistently near 70 m deep, and averages 150 km in width.

One of the difficult problems in marginal sea modeling is the uncertainty of the open boundary condition (OBC). Three approaches, local-type, inverse-type, and nested basin/coastal modeling are available for determining OBC. The third approach is to use nested basin/coastal model: integration of the basin model provides the OBC for the coastal model. In this study, we will use the nested Princeton Ocean Model (POM) developed by *Blumberg and Mellor* [1987] to simulate the east Asian regional sea circulation and thermohaline structure.

2 Model Description

Here, we use a rectilinear grid with horizontal spacing of 1° by 1° for the North Pacific basin model, and of 0.25° by 0.25° for the regional model (Fig. 1). Both models have 23 vertical sigma coordinate levels and use realistic bathymetry data from the Naval Oceanographic Office DBDB5 database (5 minute by 5 minute resolution). The basin model domain is 80°E - 90°W, 30°S - 65°N, and the regional model domain is 98° - 143°E, 0° - 50°N. The barotropic (baroclinic) mode time steps are 50 s and 25 s (1800 s and 900 s) for basin and coastal models, respectively. The horizontal diffusivities are modeled using the *Smagorinsky* [1963] form with the coefficient chosen to be 0.2 for this application. The bottom stress is assumed to follow a quadratic law and the drag coefficient is specified as 0.0025 [*Blumberg and Mellor*, 1987].

3 Atmospheric Forcing

The wind forcing for ocean models is depicted by

$$\rho_0 K_M (\partial u/\partial z, \partial v/\partial z)_{z=0} = (\tau_{0x}, \tau_{0y}) \qquad (1)$$

where (u, v) and (τ_{0x}, τ_{0y}) are the two components of the water velocity and wind stress vectors, respectively. Surface thermohaline forcing is depicted by

$$K_H \frac{\partial \theta}{\partial z} = \frac{Q_H}{\rho c_p}, \quad K_S \frac{\partial S}{\partial z} = S(E - P) \qquad (2)$$

where c_p is the specific heat, and Q_H is net surface heat flux (downward positive), E the evaporation rate, and P the precipitation rate, respectively. The surface wind and thermohaline forcing at each time step are interpolated from monthly mean climatological Q_H and $E - P$ from the COADS, which was taken as the value at the middle of the month.

4 Lateral Boundary Conditions

Solid lateral boundaries, i.e., the modeled ocean bordered by land, were defined using a free slip condition for velocity and a zero gradient condition for temperature and salinity. No advective or diffusive heat, salt or velocity fluxes occur through these boundaries. Since we are interested in the regional model results, the OBCs for the basin model are set as rigid boundaries. OBCs for the coastal model are determined from the basin model output at each time step.

5 MODEL INITIALIZATION

The model year consists of 360 days (30 days per month), day 361 corresponds to 1 January. We integrated the nested POM model for seven years from zero velocity and January temperature and salinity climatological fields [*Levitus and Boyer*, 1994; *Levitus et al.*, 1994] with COADS monthly mean surface wind stress and salt and heat fluxes. We use the last four years' output for analysis.

6 MODEL RESULTS

Velocity, temperature, and salinity at major straits (e.g., Tsushima, Taiwan, Luzon, and Karimata, etc.) are obtained from the nested POM model. The volume transports (Sv, 1 Sv = 10^6 m^3/s) were computed for all the straits. Here, we present the simulated volume transports at the Taiwan Strait (Fig. 2a) and the Tsushima/Korea Strait (Fig. 2b). The volume transport through the Taiwan Strait is almost northward except in August-September. The maximum northward transport is around 4 Sv in late June. The volume transport through the Tsushima/Korea Strait has two peaks: 3.5 Sv in mid-June and 3 Sv in late November. The large transport in early winter agrees quite well with *Egawa et al.'s* [1993] ADCP observations.

The most obvious feature of EAMS model circulation is the western boundary current, and its meandering and eddies (Fig. 3). Model simulated two major western boundary current systems: the SCS western boundary current and the Kuroshio. The SCS western boundary current starts from the southern boundary (Gaspar/Karimata Strait), and the Kuroshio begins where the North Equatorial Current approaches Philippines and continues northward east of Taiwan. The two currents merge into one current at the north tip of Taiwan. This strong current crosses the ridge that connects and Taiwan with the Okinawa Islands and Kyushu and continues along the continental rise east of the East China Sea. The thermal structure and its temporal variabilities were also well simulated (Fig. 4).

7 ACKNOWLEDGMENTS

The authors wish to thank George Mellor and Tal Ezer of the Princeton University for most kindly proving us with a copy of the POM code. This work was funded by the Office of Naval Research NOMP Program, the Naval Oceanographic Office, and the Naval Postgraduate School.

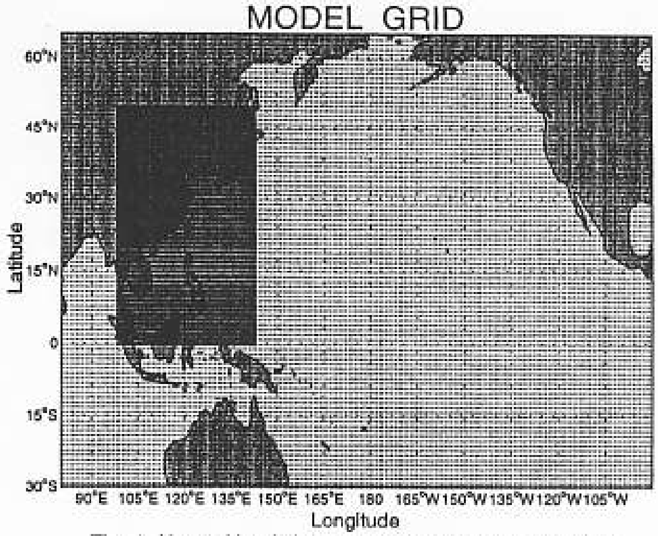

Fig. 1. Nested basin/coastal EAMS circulation model.

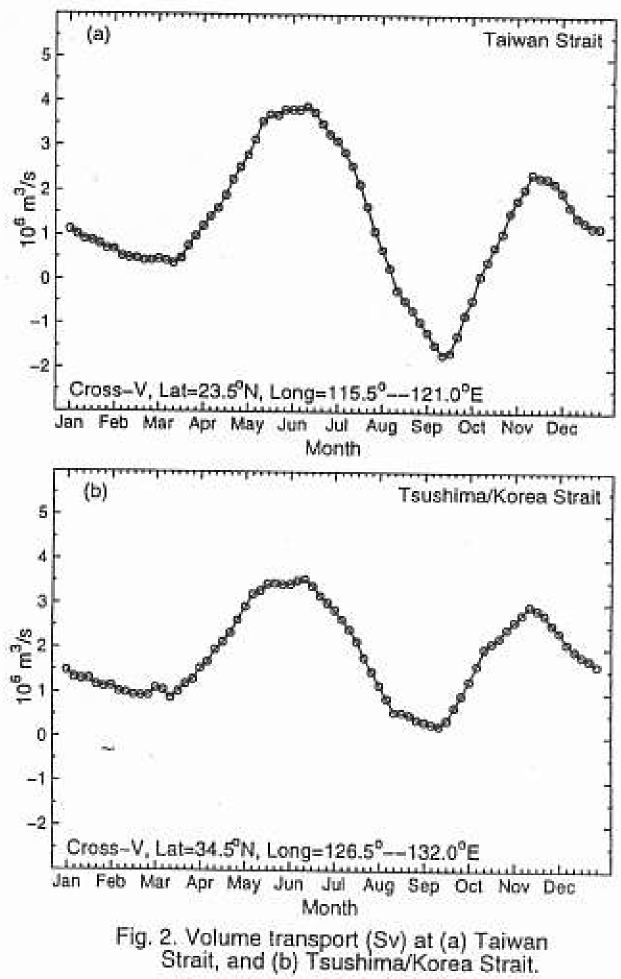

Fig. 2. Volume transport (Sv) at (a) Taiwan Strait, and (b) Tsushima/Korea Strait.

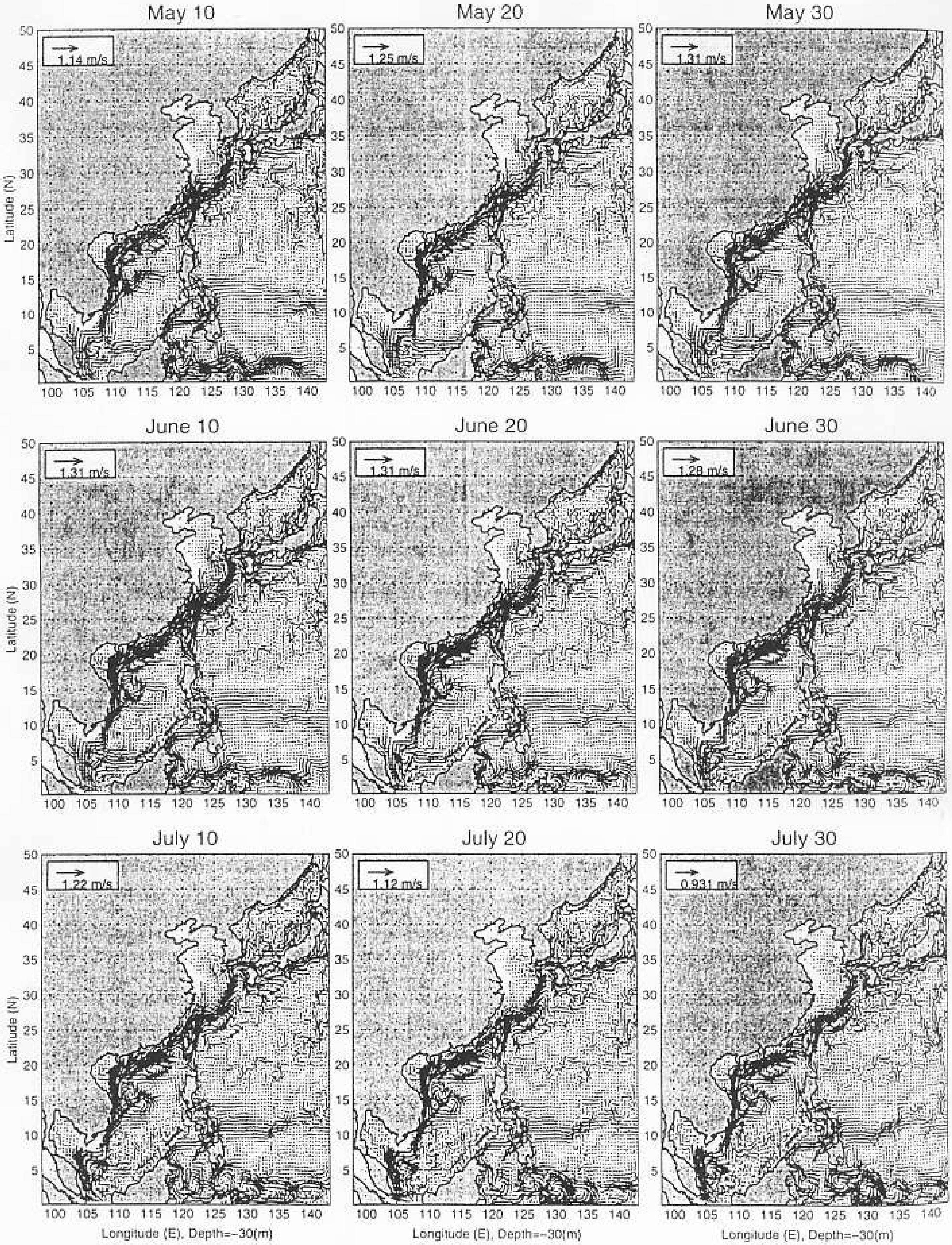

Fig. 3. Temporally varying model circulation at 30 m depth.

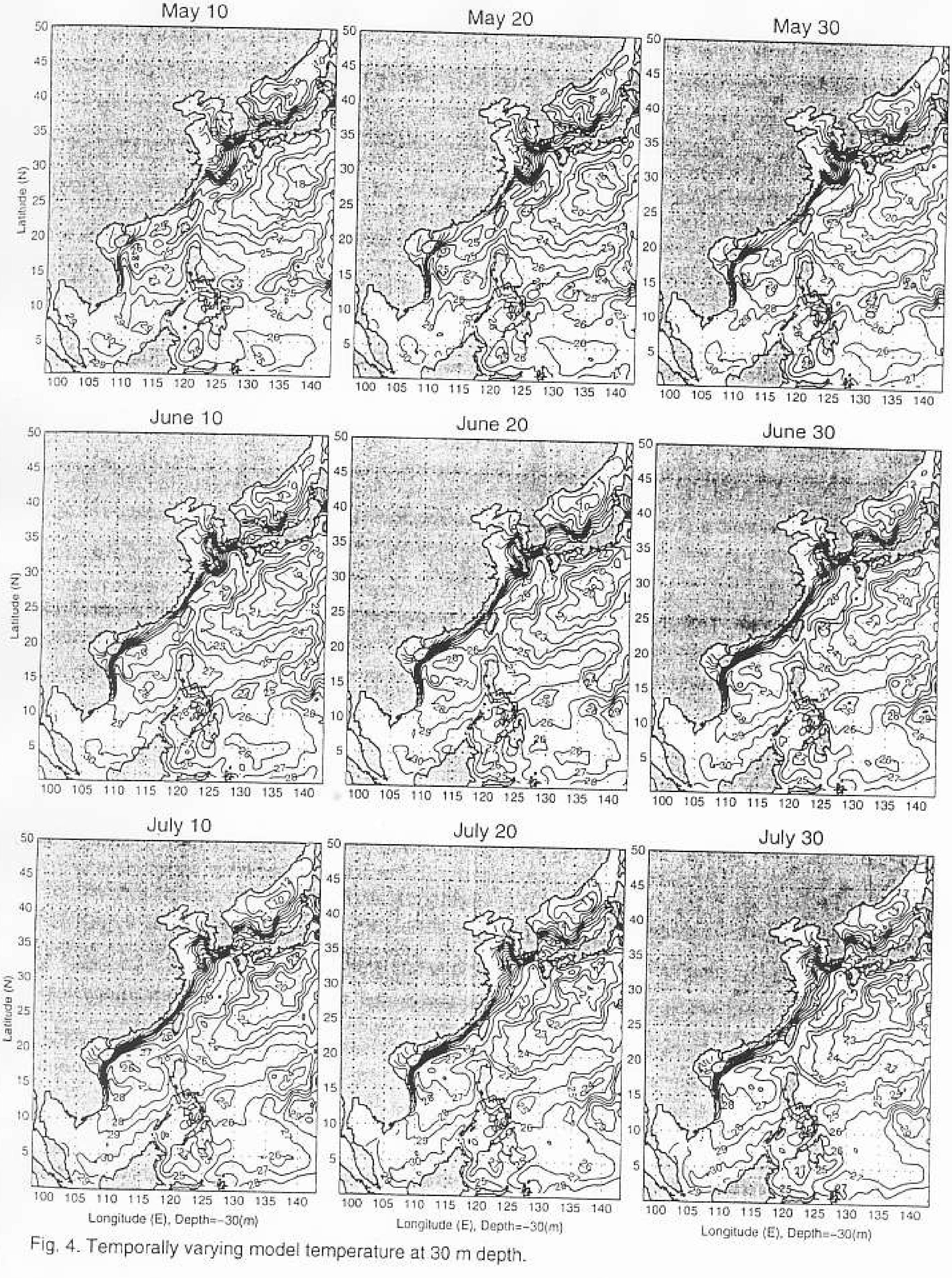

Fig. 4. Temporally varying model temperature at 30 m depth.