P1.19 TOPEX/POSEIDON ALTIMETRY REVEALS THE VIETNAM SUMMER RECIRCULATION

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1. INTRODUCTION

Indications of seasonal recirculation near Vietnam in TOPEX/Poseidon (T/P) altimetry observations motivated this high-resolution modeling study of the southern South China Sea (SCS). Monsoon wind forcing dominates the circulation dynamics of the SCS, perpetually alternating the SCS between states that reverse the western boundary current. TOPEX/Poseidon altimetry data provides, for the first time, relatively high temporal resolution observations with near-simultaneous spatial coverage of the deep basin. The new data permit clearer identification of significant seasonal features.

During the southwest monsoon (spring-summer), the southern SCS develops an anticyclonic gyre with a northward western boundary current. This northward flow turns offshore along the coast of Vietnam as an easterly jet. With the easterly jet, a pair of recirculation cells form and remain, with the anticyclonic recirculation cell dominating the dynamics of the region until destroyed by the shift to the northeast monsoon (autumn-winter). This study demonstrates that the evolution of the anticyclonic recirculation cell near 12N 111E, hereafter the Vietnam Summer Recirculation (VSR), is governed by gyre-scale dynamics strongly influenced by topography, and that its seasonal destruction is caused by the migrating monsoon winds.

2. DATA

TOPEX / Poseidon (T/P) altimetry (WOCE, 1998a) is used to identify seasonal circulation features and to validate modeling results. Wind stress data derived from European Remote Sensing (ERS) satellite scatterometers are used to force the models. The ERS wind stress data (WOCE, 1998b), August 1991 through October 1999, completely overlaps the T/P altimetry span, allowing circulation modeling for which there are observations of both the forcing and the net response. The spatial and temporal resolutions of the data sets are similar. A biharmonic spline interpolated data to the ETOPO5 bathymetric data (NOAA_NGDC, 1988) grid selected for the model domain.

3. MODEL

The South China Sea is a semi-enclosed basin characterized by a well-defined deep basin. The 100-m contour defines the modeling domain, with vertical walls closing deep-water straits. Closing the Luzon Strait does not notably affect the southern SCS (Yang, et al., 2000). Both 1.5-layer reduced-gravity and 2.0-layer closed-basin versions of the primitive-equation, beta-plane Navy Layered Ocean Model (NLOM) (Wallcraft, 1991) were employed with 1/12th-degree zonal and meridional resolution. Two parallel wind forcing series, were examined: 1) steady ERS mean-summer wind forcing spin-up for highlighting processes; and 2) realistic sequential ERS winds for evaluating contributions to the annual cycle.

4. RESULTS

The general results are presented first and then factors contributing to the formation of the Vietnam Summer Recirculation (VSR) are examined, followed by an analysis of the VSR's destruction.

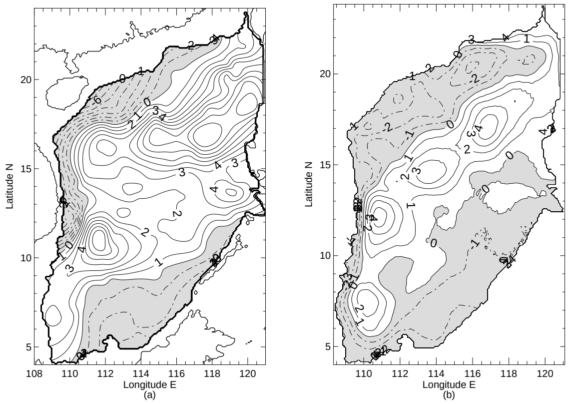

Fig. 1. Mean summer sea surface height anomalies (Contour interval = 1 cm; gray (dot-dash) < 0): (a) TOPEX/Poseidon, (b) model.

4.1 General Description

As defined by barotropic flow, the zonal and meridional extents of the VSR are about 110 E to 112 E and about 11 N to 13 N respectively. Persistent broader VSR upper-layer anticyclonic recirculation begins in March and continues through summer, achieving a mean summer magnitude of 4 Sv and vanishing in October and November. Mean VSR lower-layer anticyclonic flow is evident in the VSR region in all months except October and November, exceeding 2 Sv for the mean spring flow. VSR mean anticyclonic barotropic flow reaches its maximum in summer (over 5 Sv), vanishing in autumn and returning in winter.

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4.2 Formation by Gyre-scale Dynamics

With the monsoon wind shift, a barotropic Rossby wave is immediately generated in the SCS, crossing the basin in several days. The initial circulation is barotropic Sverdrup flow. The basin completes its adjustment to the new monsoon regime when the baroclinic Rossby wave, generated at the eastern boundary subsequent to a wind shift, arrives at the western boundary. Based on the VSR latitude (12N) and a 200-m mean mixed-layer depth, this adjustment takes about 135 days. After the first baroclinic Rossby wave passes, the circulation evolves from barotropic to strongly baroclinic as the lower layer flow, now cut off from the wind forcing, begins to dissipate (Liu, et al., 1999). As expected from Cessi et al. (1987), the transport of the recirculation gyre (6 Sv) is three times larger than the theoretical Sverdrup transport (2 Sv). Western boundary Sverdrup return flow advects low-latitude potential vorticity (*q*) poleward, clearly driving the VSR from April through August.

4.3 Component Influences

Sensitivity cases highlight baroclinic / barotropic and topographic component contributions to the VSR. Wind-driven baroclinic flow defines the general circulation / recirculation pattern, with barotropic flow promoting stability and notably contributing to the location of recirculation. Simply including barotropic flow promotes anticyclonic recirculation centered on the VSR due to barotropic-baroclinic interaction. Adding topography produces additional competing barotropic / baroclinic recirculation effects. The baroclinic influences of topographically-constrained flow, destabilization of the offshore jet and drag, tend to offset barotropic tendencies resulting from the generation of mean bottom flow by eddy-topography interactions. An isolated topographic peak near the center of the VSR region focuses topographically-induced barotropic-baroclinic interactions, shifting recirculation northward and anchoring its position. A net anticyclonic barotropic-baroclinic interaction of about one Sv results, aided by closed potential vorticity contours that support anticyclonic flow around the VSR peak. Topography also appears to dampen fluctuations in the recirculation, providing indications of a free mode that are further supported by lower-level flow vectors.

4.4 Destruction by Migrating Winds

The SCS meets the three prerequisites for migrating winds to destroy recirculation (Liu, 1996). Different from an ocean basin, the narrow SCS allows both barotropic and baroclinic Rossby waves to have a time scale mismatch with advective development of the inertial recirculation. Consequently, the baroclinic mode amplifies rather than dampens recirculation destruction. Migration of the SCS wind forcing is best described as a pivoting zero-wind-curl line, with the pivot point anchored on the western boundary near 10N. The zero-wind-curl line migrates rapidly southward in July, with the migration range easily exceeding that needed to destroy recirculation (Liu, 1996). When the anticyclonic wind curl in the southern SCS suddenly disappears with the monsoon shift in late September, the strengthening equatorward western boundary current in the northern SCS is released to rapidly flow equatorward, reversing the western boundary current of the southern gyre. The rapidly advected cyclonic potential vorticity anomalies chaotically mix with the remnants of the recirculation, removing the injected anticyclonic potential vorticity anomaly, thereby, completely destroying the VSR recirculation by mid-October.

5. CONCLUSIONS

The VSR, a seasonal anticyclonic feature of the southern SCS, is driven by gyre-scale dynamics, principally Rossby wave adjustment and Sverdrup flow subject to strong topographic influence. Topography modifies and anchors the position of the VSR, providing closed potential vorticity contours conducive of an enhancing lower-layer anticyclonic free mode. Lower-level flow vectors and the dampening of flow fluctuations by topography provide evidence of a free mode. The barotropic Rossby wave generated by the semi-annual monsoon shift energizes the lower-level free mode with regular pulses. The migration of the monsoon wind forcing and chaotic mixing of *q* anomalies completely destroy the VSR each year.

6. REFERENCES

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