The Tsushima Warm Current and its Various Branches

Doron Nof
Department of Oceanography 4320
Florida State University
Tallahassee, FL 32306-4320
phone: (904) 644-2736 fax: (904) 644-2581 email: nof@ocean.fsu.edu

Award #: N00014-01-0291

LONG-TERM GOALS

The goal of this project is to (i) determine why the Tsushima Warm Current (TWC) splits into three separate branches; and (ii) understand how and why the Ulleung Warm Eddy (UWE) is formed.

OBJECTIVES

We have conducted analytical and numerical investigations of the Tsushima Warm Current to determine the connection between both bifurcation and eddy formation and western boundary currents separation in the Japan/East Sea. We have proposed a new hypothesis, whereby the initial splitting of the TWC is due to the Tsushima Island and its related topography, whereas the secondary splitting of the western part of the TWC is due to a double separation of the western boundary current system. We also propose to investigate the alternative possibility that the secondary bifurcation is topographically induced. In order to understand the formation of the UWE, we propose that this quasi-permanent eddy is formed in order to compensate for the momentum flux of the poleward flowing boundary current. Achievement of these goals will result in improved understanding of the Japan/East Sea.

The nature of my modeling work is that I simultaneously work on several projects; some of these projects are not necessarily closely related to each other. For this reason, some of the publications which are listed at the end of this report may appear to be somewhat disjointed.

WORK COMPLETED

A one-layer and a two-layer configuration of the Japan/East Sea have been run with idealized step-down bottom topography (the step is ten times the base depth of the basin) and idealized subtropical wind stress forcing. An inspection of the results of these simulations indicates that, as expected, the formation of the second branch of the TWC is due to bottom topography. A peculiar step-induced bifurcation of the upper layer is observed. It is attributed to variations in thickness transmitted from below to the upper layer (Fig. 1).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **The Tsushima Warm Current and its Various Branches**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Oceanography 4320,,Florida State University,,Tallahassee,,FL, 32306**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The goal of this project is to (i) determine why the Tsushima Warm Current (TWC) splits into three separate branches; and (ii) understand how and why the Ulleung Warm Eddy (UWE) is formed.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

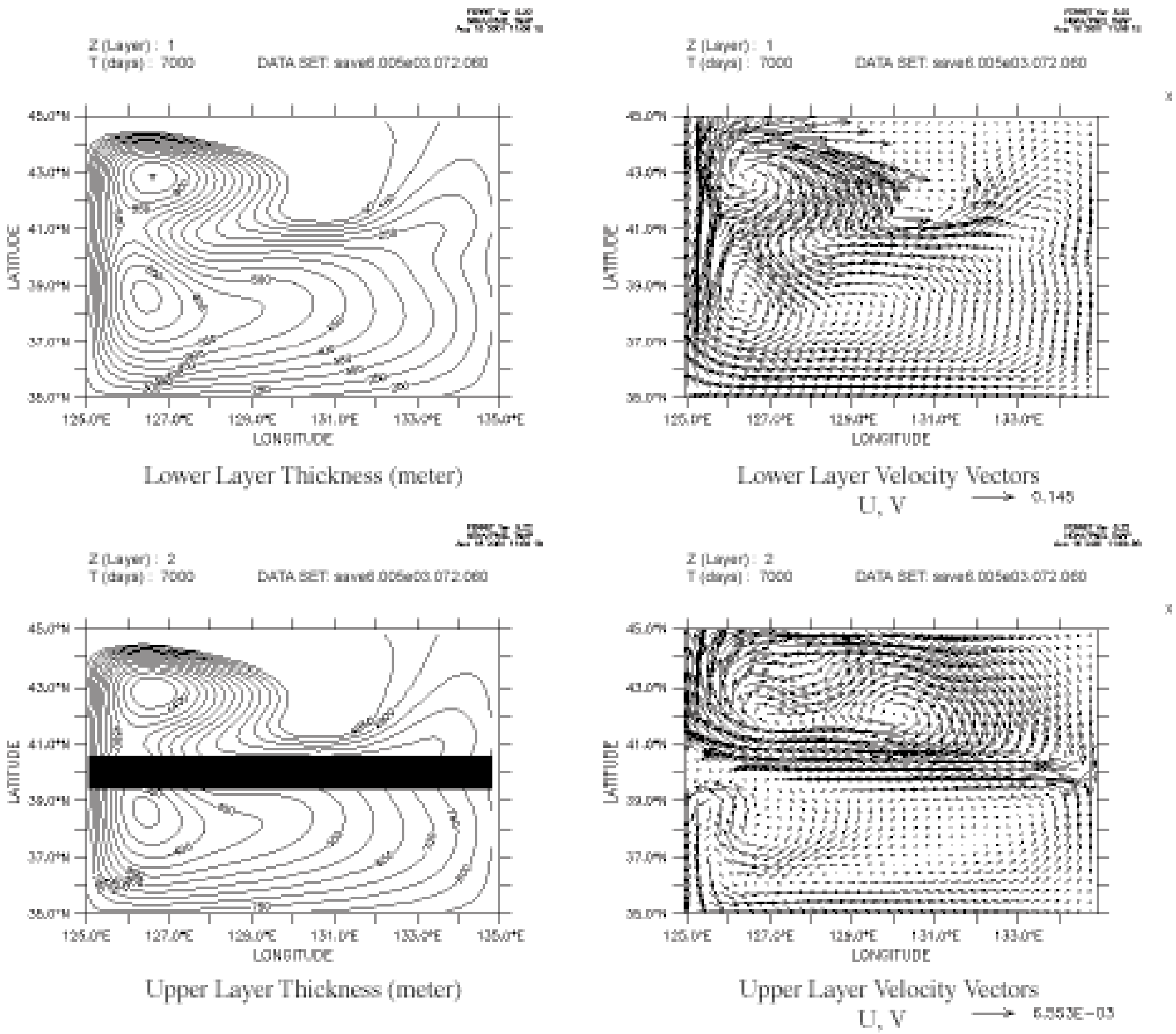

Fig. 1. The response of a simple two-layer marginal sea to a varying bottom topography. The bottom is flat everywhere; a zonal step is situated across the basin at approximately 40˚N.

RESULTS

Research has resulted in the preparation and publication of several papers, listed at the end of this report in the order that they were completed. Most have not been supported solely by ONR but also by NSF and NASA.

In what follows I describe a detailed summary of the results (arranged in the order that the manuscripts have been completed during the past year).

A quasi-island model addresses the exchange between the Pacific-Indian Ocean system and the Southern Ocean (paper #1). The calculations suggest that the Indian and Pacific Oceans have a meridional overturning cell with a transport of 18 Sv (± 5 Sv). The cell is driven by both winds and thermohaline processes but the calculation does not require solving the complete wind-thermohaline problem. The computational method takes Africa, Asia and Europe to be a "pseudo island;" i.e., the combined continent is entirely surrounded by water but has no net circulation around it. The continuation of sea level around the continent allows one to analytically compute the zonal upper layer transport which is first forced meridionally from the Southern Ocean to the Pacific and Indian Oceans and then forced down to lower levels.

In paper #2, we used a nonlinear one-and-a-half-layer model to examine the spreading of Indonesian Throughflow waters into the southern Indian Ocean. We constructed an analytical solution with the aid of the "slowly varying" approach and performed process-oriented numerical simulations. We found that, immediately after emptying into the ocean, the outflow splits into two branches. One branch forms a chain of high amplitude anticyclonic eddies which drift westward and penetrate into the interior of the Indian Ocean. The second branch carries the remainder of the mass flux via a coastal southward flowing current. Ultimately, this second branch separates from the coast and turns westward. We concluded that the eddies recently observed to the west of the Island of Timor are a result of the above eddies generation process which is not related to the classical eddies generation process associated with instabilities (i.e., the breakdown of a known steady solution). This perhaps explains why some of the Indonesian Throughflow water forms the source of the southward flowing coastal Leeuwin Current.

Paper #3 examines the formation of Reddies (i.e., isolated lenses containing Red Sea water). We propose that the "Reddy maker" is a combination of three processes, the natural reduction in the bottom slope which the outflow senses as it approaches the bottom of the ocean, the entrainment-induced increase in the outflow's thickness, and the entrainment-induced decrease in the outflow's density. This is supported by the idea that, in contrast to Meddies which are formed downstream of abrupt changes in the shape of the boundary against which they lean, Reddies have been observed upstream of such abrupt geographical changes.

RELATED PROJECTS

This project is closely related to work funded by the Binational Science Foundation, grant # 96–105, which focused on Reddies in the Red Sea rather than flows in the Japan/East Sea. Also, related research on the Leeuwin Current in the southern Indian Ocean has resulted in paper #2 listed below.

PUBLICATIONS

1. Nof, D., 2001: Is there a (suppressed) meridional overturning cell in the Pacific and Indian Oceans? *J. Phys. Oceanogr.*, revised and resubmitted.

2. Nof, D., T. Pichevin and J. Sprintall, 2001: Teddies and the origin of the Leeuwin Current. *J. Phys. Ocn.*, submitted.

3. Nof, D., N. Paldor and S. Van Gorder, 2001: The Reddy maker. *Deep-Sea Res.*, submitted.