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Stratified Coastal Trapped Waves and Mean Flows

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LONG-TERM GOALS

Our long term goals are to identify the roles that rectified subinertial waves and mesoscale motions play in the mean-flow transport of fluid properties in the coastal ocean and to apply these ideas to cross-margin transport of physical, chemical, and biological properties. In addition, we are interested in the interaction and relative effect of wave-driven transport versus frictionally driven boundary layer transport.

OBJECTIVES

Coastal waves and wave-generated mean flows are studied in a stratified, rotating model ocean. Waves trapped to the coast are generated by time-dependent flow over a sloping and irregular bottom. In this study, we will study the rectified flow resulting from oscillatory forcing over a sloping bottom, both with and without additional ridges, and with and without stratification. Short-term goals of this study include quantifying the evolution of the vertical structure of the along-slope mean flow driven by non-linear interactions of the coastal trapped wave and damped by friction. The effects of stratification on the cross-slope overturning circulation will be examined to evaluate the strength of wave-driven mean flow versus frictionally driven flow.

APPROACH

The approach for this research is to use laboratory experiments and two types of numerical models. The laboratory experiments are fully non-linear by their very nature, while the numerical models provide a useful venue for studying specific processes and offer much better diagnostics. The approach that we will take here is to do a series of laboratory experiments each with additional physical complications. In the laboratory experiments, we will do experiments both with a bowl-shaped tank, and with a bowl shaped tanked with four radial ridges to generate wave-driven motions and study the rectified motion resulting from oscillating the rotation rate of the tank and the interaction of friction, wave-drag, and stratification. Numerical experiments will be done in parallel to simulate the stratified problem to be able to diagnose the causes of any rectified circulation observed.

In addition to the isopycnal numerical model that will be used to simulate the laboratory experiment, work continues on developing a formulation of the overturning circulation in a stratified fluid where nearly geostrophic flow interacts with strongly varying topography. This analysis of possible mean-flow formulations may help in better parameterizing the effects of ocean eddies in large-scale general circulation models when the influence of topography cannot be ignored.

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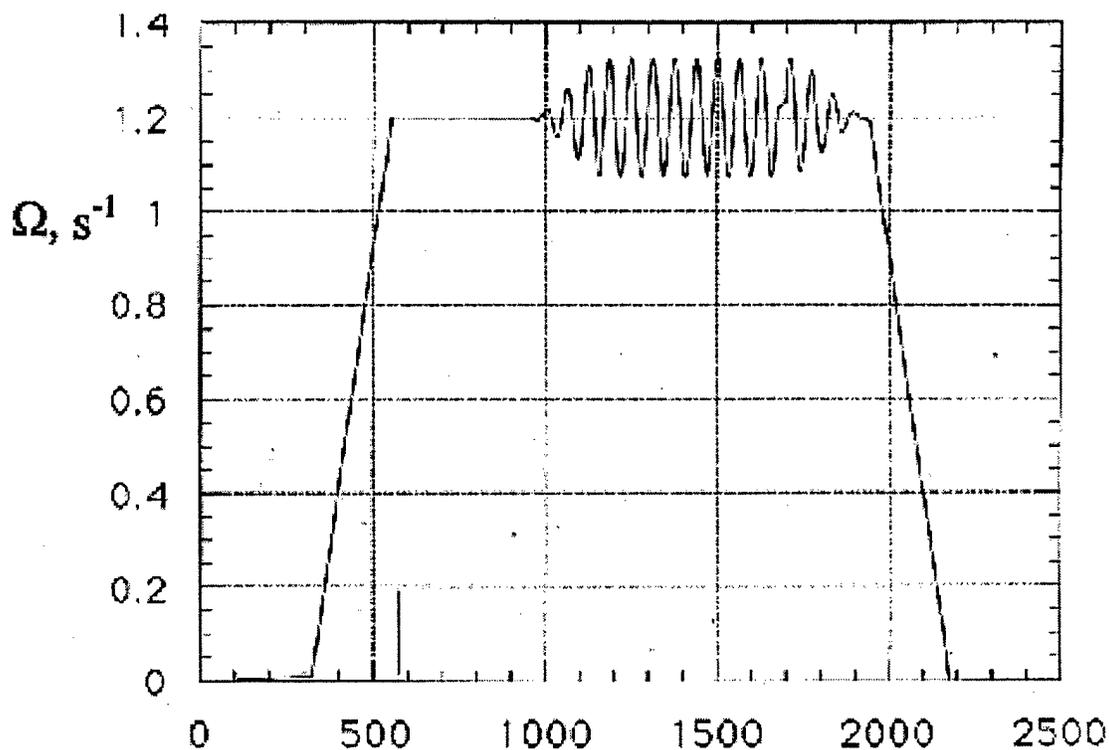


Figure 1. Time evolution of rotation rate for rotating table. Notice that oscillation frequency, amplitude and time-scale over which the cycle is turned on can be controlled.

WORK COMPLETED

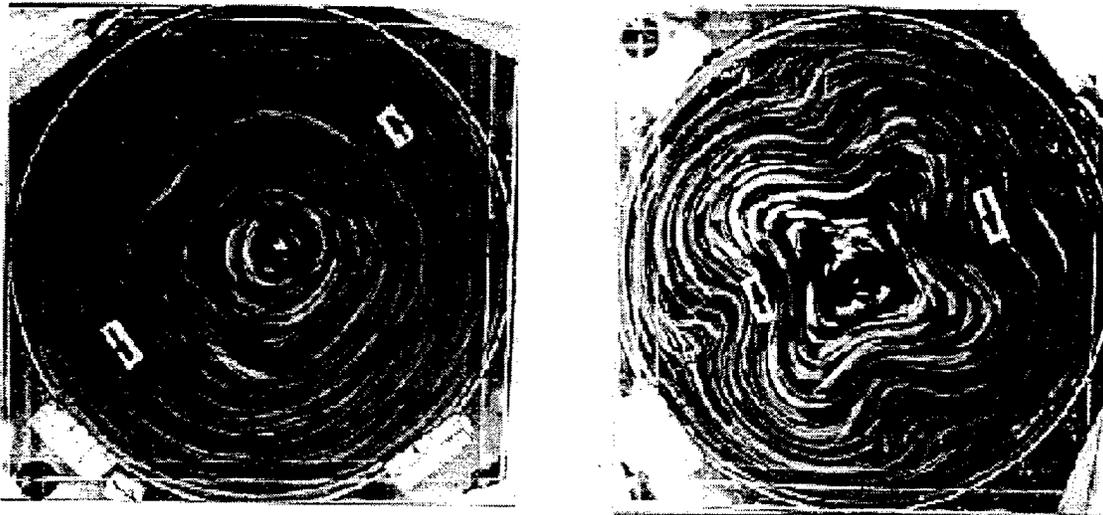
With the loss of Dr. Daniel Ohlsen to the project, we have moved the laboratory experiments to the University of Washington and have recruited Dr. Boris Boubnov, visiting from Moscow University to complete the laboratory experiments. Progress on the laboratory experiments is as follows:

1. Laboratory apparatus has been shipped to the University of Washington and the experiments have been set up at the University of Washington.
2. A rotating table in Dr. Peter Rhines's Geophysical Fluid Dynamics Laboratory has been configured to spin-up the experiment, and a driver has been written that allows the rotation rate to be oscillatory with specified amplitude and frequency. This allows a series of experiments to be completed with relative ease (Fig. 1). A series of homogeneous and stratified experiments have been performed.

RESULTS

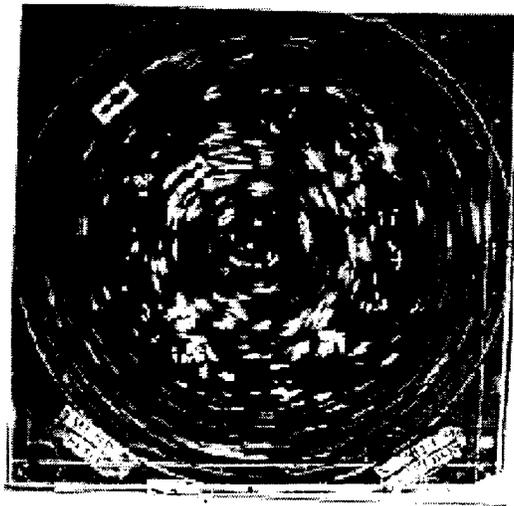
Initial laboratory experiments with oscillatory frequency show that there is a flow reversal near the center of the tank, both in the homogeneous and stratified configurations. In the

LBSR- large bowl with small ridges



$N=0$

$\Omega, \text{s}^{-1}, \omega = \Delta\Omega = 0.05 \text{ s}^{-1}$



$N=2.1 \text{ s}^{-1}$

$\Omega = 0.5 \text{ s}^{-1}, \omega = 0.1 \text{ s}^{-1}, \Delta\Omega = 0.02 \text{ s}^{-1}$

Figure 2. Streak photograph from laboratory configuration at the University of Washington. Notice the flow reversal at the center of the tank.

absence of ridges, we have also shown that frictional boundary layer effects can cause a rectified (although much smaller) circulation to result (Figure 2).

The contrast between the stratified and unstratified problems in a smooth bowl is particularly striking. In the mean, there is a cyclonic circulation around the edge of the bowl in a homogeneous fluid, but it is anticyclonic in the stratified fluid (not shown). The impact of this purely frictionally flow can be explained by the theory of MacCready and Rhines and others on the shut-down of the Ekman layer in a stratified fluid.

IMPACTS/APPLICATIONS

We expect to gain a new understanding of one possible forcing mechanism of cross-margin transport and extend our results to wind-forced wave motions on the continental shelf. The relative strength of frictional and wave-driven fluxes will be estimated in the controlled framework and laboratory and numerical models. From these results, the relative sizes of their influence on the continental shelf will be able to be estimated.

PUBLICATIONS

- Ohlsen, D., L. Thompson, and D. Darr, 1998. Coastal Trapped waves and Mean flow. *EOS Transactions*, 79(1) (Suppl.), OS142.
- Thompson, L. and F. Evans, Topographic Rossby-wave mean flow interaction, in preparation for *Journal of Physical Oceanography*.
- Thompson, L. and D. Ohlsen, Coastal Trapped waves and Mean flow, in preparation for *Journal of Physical Oceanography*.
- Thompson, L. Coastal trapped wave-mean flow interaction. In preparation for *Journal of Physical Oceanography*.