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Parameterizations in High Resolution Isopycnal Wind-Driven Ocean Models

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Progress Report

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1. Introduction

For our CHAMMP project, we proposed to implement and test new numerical schemes, parameterizations of boundary layer flow and development and implement mixed layer physics in an existing isopycnal models. The objectives for the proposed research were:

- implement the Arakawa and Hsu, (1990) scheme in an existing isopycnal model of the Indian Ocean;
- Recode the new model for a highly parallel architecture;
- determine effects of various parameterizations of islands;
- determine the correct lateral boundary condition for boundary layer currents, as for instance the Gulf Stream and other western boundary currents.; and
- incorporate a oceanic mixed layer on top of the isopycnal deep layers.

This is, therefore, primarily a model development project, with emphasis on determining the influence and parameterization of narrow flows along continents and through chains of small islands on the large scale oceanic circulation, which is resolved by climate models.

The new model is based on the multi-layer FSU Indian Ocean model, developed by Jensen, (1991). Our research strategy is to:

- recode a one-layer version of the Indian Ocean Model for a highly parallel computer
- add thermodynamics to a rectangular domain version of the new model
- implement the irregular domain from the Indian Ocean Model into the box model
- change the numerical scheme for the continuity equation to the scheme proposed by Arakawa and Hsu, (1990).
- perform parameterization experiments with various coast line and island geometries

The recoding will be done to ensure a high degree of parallelism without sacrificing portability.

Test runs with artificial wind stress and heat flux will used to determine model stability, performance and optimization for the new model configuration. Tests will include western boundary currents, coastal upwelling and equatorial dynamics. The development of parallel code will be done in cooperation with other CHAMMP participants, mainly the ocean modelling group at LANL. The mixed layer model is proposed to be of a bulk type with prognostic equations for temperature and salinity, similar, but more general, to that used by McCreary and Kundu, 1989.

2. Accomplishments since August 1, 1992

One of the PI's (Tommy Jensen) participated in a course 'Programming the Connection Machine System' held September 14-18 at LANL, by Thinking Machine Corporation. We have now a single layer version of the Indian Ocean model, recoded for the CM-200 machine at LANL.

The code makes very efficient use of CSHIFT operators to compute finite differences . The CPU time used on a 512 floating point processor CM-200 is slightly less than on a single processor Cray YMP. Recent tests on the CM-5 with vector units showed a slower performance than on the CM-5 for the same number of processors. However, the preliminary state of the system software on the CM-5 during these tests have most likely influenced the timing.

A 1/3° by 1/3° resolution model of the Indian Ocean was run on the CM-200. Forced by annual and semi-annual zonal winds in a 6° wide band around the equator, a total of 16 three-year runs were made. The runs were used to study a potential Kelvin-Rossby mode resonance in the Indian Ocean. Fig. 1 shows the resonant case forced by semi-annual forcing. Given the right combination of stratification, basin width and periodicity of wind stress, equatorial Kelvin and Rossby waves combine to a standing mode with large amplitudes. As shown in Fig. 1 the influence of the equatorial waves and associated jets on pole ward latitudes are significant. A manuscript presenting these results will be submitted to Journal of Geophysical Research in 1993.

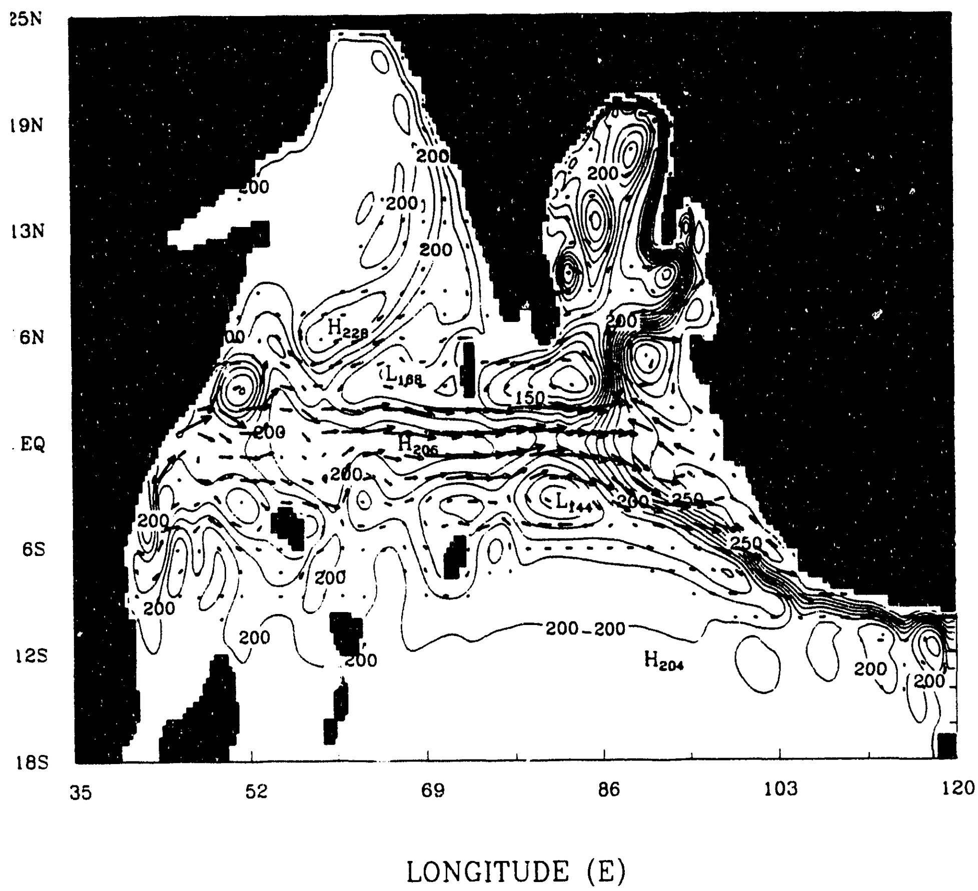

Figure 1: Thermocline depth variation and currents as a result of resonant equatorial wind forcing. The model code is a parallel version of the FSU Indian Ocean model (Jensen, 1991).

Programming the new version of the model is well under way. A prototype model which includes prognostic temperature and salinity for a single layer reduced gravity model in a rectangular basin has been developed. It includes at this time simple Kraus-Turner mixed layer physics. However, the model is also prepared to include vertical mixing using the method of Pacanowski and Philander(1986) for deeper layers. Various The advection schemes has been tested in the model. These include leap-frog, 1. order upstream differencing (donor cell), Lax-Wendroff and that of Takacs (1985). The latter is similar to the Arakawa and Hsu (1991) positive definite scheme, which will be used in later versions of the model. The color plate (Fig. 2) shows a sample test run from the rectangular model. A temperature anomaly in the upper layer of an initially quiet ocean generates equatorial currents and thermocline anomalies during the adjustment towards a steady state.

3. Plans for 1993

Our most important objective for 1993 is to include the irregular geometry for the new thermodynamic version of the model. The task is to combine the multi-layer Indian Ocean code and the prototype thermodynamic code in a modular form. This work has been started and will be completed in 1993. The Arakawa and Hsu scheme will be added next. The modular form of the code and use of c-compiler directives will ensure efficient code for both the Cray and the Connection Machine CM-5.

Secondly, we should be able to perform the first investigations of flow around groups of islands for the parameterization efforts with the new model.

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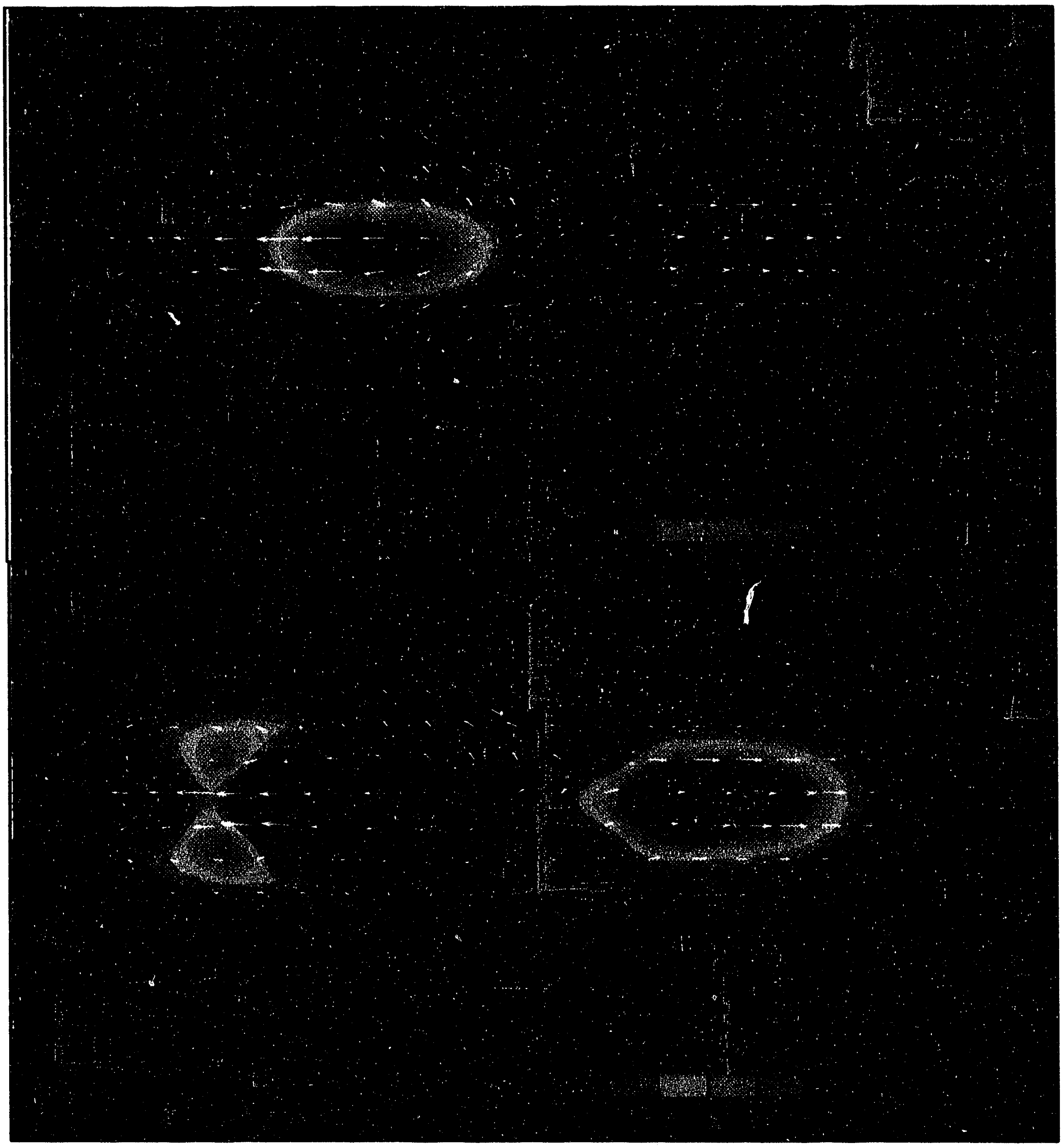

Fig. 2. Temperature (top) and thermocline depth anomaly (bottom) after 10 days. Initial temperature and surface elevation is pyramidal. Current velocities are shown in both plots. Equatorial waves are generated by the warm pertubation . Note that temperature advection is very slow compared to the wave response.

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