Local generation of internal solitary waves in a pycnocline: numerical simulations

Introduction

Non-Linear Internal waves (NLW) have been detected in the Bay of Biscay far from the coast, at a distance too large to be explained by generation at the shelf break (cf. [1], [2], [3]). A mechanism for their presence far from the coast has been proposed ([2]): the local interaction of an internal wave beam (IW, here the internal tide) with the seasonal thermocline, inducing an interfacial displacement that degenerates into a train of solitons, or NLW. Such a local generation is rare however, implying very restrictive conditions for it to occur.

Simplifying hypotheses:

- Linearized problem (valid in the early stage of the generation)
- Forcing wave is plane (instead of beam-like), horizontal wavelength is $\lambda_h$.
- 3-layer system: 1/ Mixed layer with $N=0$; 2/ Pycnocline with $N=N_p$; 3/ Deep-water layer with $N=N_f$, $N_p$ is determined by conserving $N(2)dz = g\ln(p_0/p_0)$. A simple condition can be found to generate a mode-3 IW in the pycnocline:

$$v_0 = \frac{\Delta \rho}{\rho} \frac{\rho_0^2/\rho}{\rho_0^2/\rho - 1}$$

Here, this gives $v_0 = 1.78 m/s$ and $v_0 = 8.9 mm/s$ (cf. prev. section).

Fixing the forcing $v_0$, the vertical displacement will be fixed too, with a phase of $\phi$, $\Delta N = 2.3 \%, \lambda = 1.5 m$.

Condition on $\lambda$, to get a mode-3 (left) or a mode-3 (right) IW. The phase difference between red & blue lines is 180° and their associated displacements are indicated.

Numerical Set-Up

The set-up reproduces the geometry of the Coriolis turntable in Grenoble, where experiments on this subject have been performed in Sep. 2008. The MITgcm code is used in a 2D configuration. The total height of the numerical domain is $H = 80 m$ with a length $L$ of a few meters. The incompressible Boussinesq equations are solved by a finite volume method (including a second order finite difference scheme) and are advanced in time with a 3rd order Adams-Bashforth scheme. The background stratification is an idealized continuous temperature profile representing the stratification in the Bay of Biscay in summer. Forcing occurs through a temporally oscillating velocity field, close to a Thomas & Stevenson profile, which is imposed at the left boundary of the domain (see figure below). The parameters that will be varied next will be $\Delta N$, $\lambda$, $\lambda_h$ and the resolution.

References


First conclusions and perspectives

Summary:

- Successful simulation of the interaction between an IW and pycnocline waves and successful reproduction of the generation of NLW.
- Method to get NLW of mode-3 based on the matching of the phase speeds of the IW and the phase speed of the mode-3 internal gravity wave that has the frequency of the NLW.
- Simple argument to understand what vertical structure is selected.

Perspectives:

- Better understanding of the generation: what model would best describe the NLW (KdV, eKdV, BO...?) + influence of the amplitude => description of the transition to non-linear dynamics and determination of the number of emerging solitons (inverse scattering method).
- Application to the oceanic case: -> 400x4 km² with rotation.
- Quantification of the energetic transfers.

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