Mixing by internal waves: the role of Parametric Subharmonic Instability

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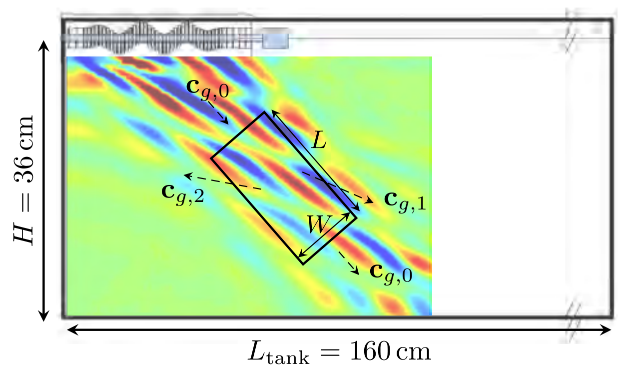
An essential ingredient of the thermohaline circulation is the mechanism by which the denser water that is produced in the high latitude regions (colder and saltier), once it has flowed down the continental slopes towards the abyssal ocean, can come back to the surface to close the loop. This process involves an energy input to provide the gain of potential energy necessary to lift this denser water. It is believed that turbulent mixing, generated by winds and tides, is the mechanism that performs this task [1]. One possible way is via the breaking of internal gravity waves [2], ubiquitous in the ocean, allowing a transfer of energy from large scales to small scales, where this energy is partly dissipated in heat and partly converted in potential energy through diapycnal mixing.

Several processes can lead to the breaking of internal waves and they usually involve non linear interactions between waves. We study experimentally, in rotating and non-rotating frame, the parametric subharmonic instability (PSI), which is the resonant mechanism by which a primary wave is unstable to infinitesimal perturbations, transferring energy through the quadratic nonlinearity of the Navier-Stokes equation to two secondary waves, satisfying temporal and spatial resonant conditions [3]. This instability provides an efficient mechanism to transfer energy from large to smaller scales.

Using a time-frequency analysis, we observe the time evolution of the secondary waves, thus measuring the growth rate of the instability. In addition, a Hilbert transform method allows the measurement of the different wave vectors. We compare these measurements with theoretical predictions and numerical simulations, and study the dependence of the instability with primary wave frequency and amplitude, revealing an effect of the confinement due to the finite size of the beam, on the selection of the unstable mode [4]. This effect is interpreted using a simple model based on the following idea: in a narrow beam, the secondary waves, having a group velocity which is not collinear with that of the primary wave, will exit the primary beam (see figure 1.a), thus ceasing to interact with the primary wave and therefore restraining the instability.

We also show that global rotation of the fluid (figure 1.b) can counteract this confinement effect, through a reduction of the group velocity of the secondary waves, thus less prone to exit the confining region.

Possible applications of these observations to oceanic situations will be discussed.



a

b

Fig. 1: (a) Sketch of the set-up. The wave generator is lying horizontally at the top of the wave tank. The vertical density gradient field of a typical wave beam generated at the top of the domain and undergoing PSI is presented as background of the figure. The dashed arrows indicate the group velocity of the three wave beams. The tilted rectangle of length L and width W corresponds to the control area used in the model. (b) Photo of the experimental set-up on the rotating table.

References

[1] Munk W.H. & Wunsch C. *Deep See Research* **45**:1977-2010, 1998.
[2] Staquet C. & Sommeria J. *Annu. Rev. Fluid Mech.* **34**:559-593, 2002.
[3] Bourget B. et al *J. Fluid Mech.* **723**:1-20, 2013.
[4] Bourget B. et al *J. Fluid Mech.* **759**:739-750, 2014.

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