Dead Waters: Large amplitude interfacial waves generated by a boat in a stratified fluid

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October 9, 2008

Abstract

We present fluid dynamics videos of the motion of a boat on a two-layer or three-layer fluid. Under certain specific conditions, this setup generates large amplitude interfacial waves, while no surface waves are visible. The boat is slowed down leading to a peristaltic effect and sometimes even stopped: this is the so-called dead water phenomenon.

The phenomenon of dead water was first encountered by F. Nansen on the Barentsz Sea, and later carefully studied by Ekman [1]. It has been recently studied in the two layer situation by Leo Maas [2].

We performed experiments [3] by studying a toy boat moving in a long and thin plexiglass tank $300\,\mathrm{x}\,41\,\mathrm{x}\,10.4\,\mathrm{cm}^3$, filled with several layers of water with different densities. The boat is pulled by a thin rope (invisible in the video) at constant horizontal force. Its motion is recorded with a video camera approximately 4 m to the side of the tank. We present first a setup with two different layers. The 5 cm upper fresh water layer, colored in red, has a density $\rho_1 = 1.000(7)$ g.cm^{-3}, while the 12 cm transparent bottom salted one corresponds to $\rho_2 = 1.022(5)$ g.cm^{-3}.

At the beginning of the Video 1 or Video 2, the boat reaches a constant velocity almost immediately, while one distinguishes, at the rear of the boat, no surface wave but a striking interfacial wave. The wave, generated by the motion of the boat, increases its amplitude and therefore its speed. Consequently, the wave catches up to the boat and slows it down. Sometimes it is even stopped. The wave breaks because it hits the boat. The boat being released from its trap, it starts its motion again, and the process repeats.

The second part of the video shows that the phenomenon persists in the three-layer situation. The interfacial wave generated in the upper interface is transferred to the bottom one (see Fig. 1). One can see the boat might be stopped again. The spatio-temporal plot which emphasizes the different waves emitted in front or at the back of the boat, shows that a nice quantitative analysis can thus be performed. Several patterns of the waves have been identified: i) in-phase and ii) out-of-phase interfacial waves, iii) soliton-like excitation emitted in front of the boat when it stops.

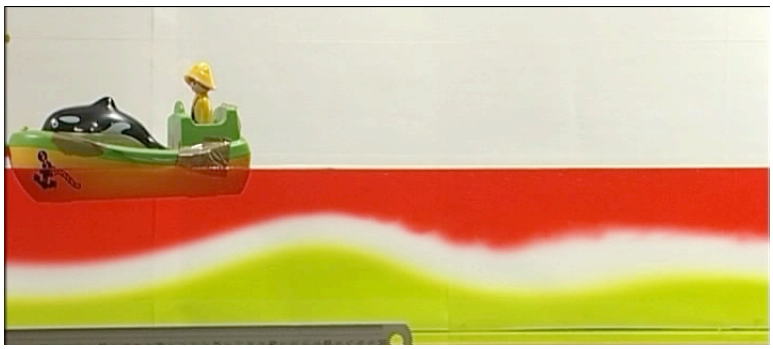

Figure 1: (Color) Large amplitude interfacial waves generated by a boat moving on a three-layer stratified fluid. Note the total absence of surface waves.

Acknowledgments

We warmly thank Leo Maas for suggestions and Playmobil© for the quality of the boat. This work has been partially supported by 2005-ANR project TOPOGI-3D.

References

[1] V.W. Ekman. *On dead water*. Norw. N. Polar Exped. 1893-1896: Sci Results, XV, Christiana, (1904).

[2] L. Maas, NIOZ, Netherland Institute of Sea Research, unpublished (2005).

[3] R. Vasseur, M. Mercier, T. Dauxois, "Interfacial Waves in stratified fluids", to be published (2008).