Experimental Study of nonlinear internal waves in infinite or semi-infinite ocean

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Experiments were performed on the large 14m diameter rotating platform, and showed that an important parameter for long nonlinear internal waves is the ratio of a characteristic length of the wave upon the internal Rossby radius of deformation. These experiments suggested new theoretical developments, in order to get an unified view of both linear and nonlinear waves in rotating fluid.

From the experiments, it appeared clearly that, in infinite rotating fluid, when the rotation is strong, i.e. when the Rossby radius of deformation is smaller than, or of the same order of magnitude as the characteristic wave-length, there is no solitary waves, but only dispersive waves, and the analysis shows that there is also the possibility of periodic waves, propagating faster than the critical phase-speed, and with a horizontal crest, i.e. Sverdrup waves. In infinite fluid, when the rotation is weak or very weak, i.e. when the Rossby radius of deformation is larger or much larger than the characteristic length, then there is either solitary waves solutions of the Ostrovskiy equation, or solitary waves solutions of the Korteveg-de Vries equation, respectively. Experimentally, it is easy to show that there exist solitary waves, with an horizontal crest, propagating with a celerity which is function of the amplitude, and a characteristic length inversely proportional to the square root of the amplitude, i.e. fulfilling the K.d.V. conditions. But with the wave generator that we used, we could not observe Ostrovskiy solitary waves.

In semi-infinite ocean, for all cases, we observed nonlinear Kelvin waves, propagating along the side-wall. But the shape of the wave greatly depends of the initial condition. When this condition is bi-dimensional, as in the infinite ocean, then the wave crest is curved backward, as in a channel, and that curvature is likely due to the superposition of a Kelvin solitary wave and Poincaré waves propagating at the same phase-speed. Actually, it can be shown that Poincaré waves are but superpositions of Sverdrup waves propagating in two symetrical directions. But when the initial condition is three-dimensional, and roughly correspond to a Kelvin wave, then what is observed downstream is a nonlinear Kelvin wave, with a crest perpendicular to the side, and propagating with a celerity faster than the critical phase-speed.

To our knowledge, it is the first time that such a complete set of experimental data and analytical developments is available, for long nonlinear waves in rotating fluid.

Now, if the generation mechanism is a cylindrical body moving along a vertical wall and all located in the lower layer, if the lower layer is thinner than the upper layer, then the body generates nonlinear Kelvin waves which propagate downstream in front of the body, as in a channel, and their crest is curved backward. The amplitude and number of waves observed at a given place downstream the body, is function of the distance between the body and the wall, as well as of the diameter of the body. If the lower layer is thicker than the upper layer, then there is no wave generation, but only an upwelling generation, and the front of this upwelling moves at the critical phase speed. This models the upwelling and waves generated by an island located near a coast. Some experiments were also realized with a cape, and gave similar results.