On Generation of Solitary Waves by Moving Disturbances

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This study is an exploration of the recently identified phenomenon of periodic generation of solitary waves on a layer of shallow water by moving disturbances, such as a surface pressure or a submerged body moving with a transcritical velocity U with respect to the water layer which initially was at rest. This phenomenon was first identified numerically by Wu & Wu (1982) who employed the generalized Boussinesq model proposed by Wu (1980), (1981), for the case of two-dimensional surface pressure distribution on a layer of water, otherwise of uniform depth, h. Further numerical results have been obtained for the case of two-dimensional arched bump moving along the floor of a water layer by Lee (1985), who also carried out a corresponding series of experiments with intent to cast needed light on the basic mechanism underlying the phenomenon.

Over the transcritical range of $0.2 < F_h < 1.2$ ($F_h = U/\sqrt{gh}$, g being the gravitational acceleration), the numerical results show that a series of solitons are generated, one after another, to surge ahead of the moving disturbance in procession, causing the water immediately behind the disturbance to deplete over an ever-prolonging stretch of suppressed water surface, which is in turn followed by a train of cnoidal-like waves whose front extends downstream with the local group velocity of the waves. Comparison between theory and experiment has established specifically the range of validity of the theoretical models of the Boussinesq and Korteweg-de Vries classes.

Evidently, this phenomenon is the result of a balanced interplay of the nonlinear and dispersive effects. However, the characteristic quantities such as the amplitude and period of generation of the solitons, which are expected to be some rather involved functionals of the motion, still remain undetermined as such.

The study is pressing on for the answer to the question concerning the basic mechanism by detailed examination of how the excess mass, momentum and energy are distributed in space and time as well as by means of local expansions of the solution.

Discussion

Wehausen: Wu's analysis is important. One can measure and compute solitons, but understanding the generation mechanism is difficult and this work is an important step in that direction. Concerning the Andaman sea picture, could the bottom contours and topography effectively provide "tank walls" for soliton generation?

Wu: The bottom topographical variations may serve this purpose, but I am not sure. Another possible source is a tidal surge from a transverse array of estuary-like openings. This issue should be kept open.

Wehausen: It is hard to test this experimentally, but in a very wide basin perhaps something could be done.

Akylas: The model fails at subcritical and supercritical Froude numbers, where a more complete theory is required.

Wu: The model is capable of making satisfactory predictions (albeit still somewhat crude) over a transcritical range, but may not be able to predict when to look for breaking waves.

Tuck: You did not tell us how to find the depression height h_1.

Wu: That calculation is self-contained. Consideration of the surface elevation with the complete set of equations leads to the parameter h_1.

Mei: Have you performed experiments at very high supercritical Froude numbers?

Wu: The non-linear theory is valid up to F_n=1.4 and even greater, but in the two-dimensional case solitons cease to exist for $F_n \gtrsim 1.2$ and experimental results show solitons breaking for $F_n \approx 1.2$. Solitons have been measured at Fn as low as 0.4, being then very weak, but discernible. When the F_n is sufficiently high ($F_n > 1.2$ in the 2D case), no solitons are radiated.