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Nonlinear wave resonance from bottom vibrations in uniform open-channel flow

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It is known from linear theory that resonant surface waves with zero group velocity radiated from bottom vibrations may occur in uniform open-channel flow (Tyvand and Torheim 2012). Their amplitude is infinite according to linear theory for strictly oscillatory motion. This resonance phenomenon is studied numerically in the time domain, with fully nonlinear free-surface conditions.
In this theoretical study of 2D nonlinear water waves, we consider an open channel with uniform basic flow U and an undisturbed water depth h. The gravitational acceleration is g. The waves are generated by a concentrated bottom source which is turned on at time t=0. This 2D oscillating source has constant flux amplitude q0 and constant angular frequency ω.
The resonant waves exist only for Froude numbers F = U/sqrt(gh) < 1. They have a critical angular frequency ωc with an associated wave number kc. The group velocity of the linearized critical wave is zero, with phase velocity in the upstream direction. At resonance there are in addition two regular waves, both having phase and group velocities in the downstream direction. In our numerical study of nonlinear resonance, we first consider the critical frequency ω = ωc(F) for each choice of Froude number F. We try to identify the two regular waves in the total numerical solution. The wave amplitude above the source location grows linearly with time until it reaches a saturation amplitude. We study the energy evolution at resonance and how the resonant amplitude decays spatially around the source location. We investigate the dependency of nonlinear resonance on the Froude number F and the source strength q0. In linear theory, resonance occurs at only one angular frequency ωc(F). Nonlinearity alters resonance to take place over a broader interval of angular frequencies around ω = ωc.

P.A. Tyvand and T. Torheim (2012) Eur. J. Mech. B/Fluids 36, 39-47.