A Boussinesq-type method for fully nonlinear waves interacting with a rapidly varying bathymetry

New equations are derived for fully nonlinear and highly dispersive water waves interacting with a rapidly varying bathymetry. The derivation is an extension of a recent high order Boussinesq type formulation valid on a mildly sloping bottom. It is based on a series expansion from a rapidly spatially varying expansion level and the resulting general velocity formulation is given as a triple-summation of terms involving high derivatives of this expansion level. For practical implementation, it is necessary to simplify and truncate this general formulation and we do this by assuming that the expansion level (but not the bathymetry) is slowly varying in space. On this basis, the general expressions are simplified to include first and second derivatives of the expansion level and up to fifth-derivatives of the velocity variables. With this new approach, the accuracy of the dispersion relation can locally deteriorate, and we provide a guideline for using this technique within acceptable accuracy bounds. Numerical results are given for the linear reflection from a plane shelf, a Gaussian shaped trench, and a symmetric trench with sloped transitions. Furthermore, we simulate the linear class I and class II Bragg scattering from an undular sea bottom. The computations are verified against measurements, theoretical solutions and numerical models from the literature. Finally, we make a detailed investigation of nonlinear class III Bragg scattering and results are given for the sub-harmonic and super-harmonic interactions with the sea bed. We provide a new explanation and a prediction of the resulting downshift/upshift of the peak reflection/transmission as a function of wave steepness. (C) 2005 Elsevier B.V. All rights reserved.