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Fully nonlinear water waves of high amplitude, propagating in finite depth

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The nonlinear, coupled-mode equations, developed by the authors (Athanassoulis & Belibassakis 2002, 2007), modelling the evolution of nonlinear water waves over a general bottom topography, are applied to the investigation of fully nonlinear waves of high-amplitude propagating in constant water depth. The vertical structure of the wave field is represented by means of a local-mode series expansion of the wave potential. This series contains the usual propagating and evanescent modes, plus an additional term, the free-surface mode, enabling to consistently treat the boundary conditions at the free surface. The role and significance of the additional free-surface mode, particularly concerning the fast rate of convergence of the modal series, is proved analytically and illustrated numerically.

In the present work, the coupled-mode system is applied to the numerical investigation of propagating waves in constant depth, from intermediate depth to shallow-water conditions. A variational reformulation of the complete, potential, non-linear water-wave equations is solved iteratively, with appropriate step-by-step adjustment of the propagation speed. The results are compared vs. Stokes and cnoidal wave theories (Fenton 1990), as well as vs. fully nonlinear Fourier schemes (e.g., Rienecker & Fenton 1981). A method is also developed for the determination of the nonlinear dispersion characteristics of steady travelling waves, and comparisons are presented with the corresponding approximate results obtained by various wave theories. Finally, the extension of the present method for modelling 3D fully non-linear waves is discussed.

References

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