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In this work, we first present a semi-analytical method for the evolution of linear fully-dispersive transient waves generated by an initial surface displacement and propagating over a constant depth. The procedure starts from Fourier and Hankel transforms and involves a combination of the method of stationary phase, the method of uniform asymptotic approximations and various Airy integral formulations. Secondly, we develop efficient convolution techniques expressed as single and double summations over the source area. These formulations are flexible, extremely fast and highly accurate even for the dispersive tail of the transient waves. To verify the accuracy of the embedded dispersion properties, we consider test cases with sharp-edged disturbances in 1D and 2D. Furthermore, we consider the case of a relatively blunt Gaussian disturbance in 2D. In all cases the agreement between the convolution results and simulations with a high-order Boussinesq model is outstanding. Finally, we make an attempt to extend the convolution methods to geophysical tsunami problems taking into account e.g. uneven bottom effects. Unfortunately, refraction/diffraction effects cannot easily be incorporated, so instead we focus on the incorporation of linear shoaling and its effect on travel time and temporal evolution of the surface elevation. The procedure is tested on data from the 2011 Japan tsunami. Convolution results are likewise compared to model simulations based on the nonlinear shallow water equations and both are compared with field observations from 10 deep water DART buoys. The near-field results are generally satisfactory, while the far-field results leave much to be desired.

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