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Identification and analysis of transient waves in shallow water using the KdV-based nonlinear Fourier transform (KdV-NLFT)

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The interaction of nonlinear waves in shallow water causes nonlinear wave-wave interactions that might significantly modify the observed free surface. For the elementary understanding of the underlying processes in wave propagation and the wave interactions it is essential to separate the underlying wave components and their nonlinear interactions. Since 2008 a KdV-based nonlinear Fourier transform (KdV-NLFT) is implemented and successfully applied at Leichtweiß-Institute (LWI) that solves the Korteweg-deVries equation by application of a cnoidal basis for the spectral decomposition of the original data. Therefore, the KdV-NLFT is adaptive within the cnoidal wave limit and the free surface is decomposed into cnoidal waves that span the whole range of possible wave forms in shallow water from linear over slightly and strongly nonlinear waves up to solitons. The number and type of the components depend on the original data. For linear data the KdV-NLFT provides the same results as the conventional Fourier transform. Furthermore, the nonlinear wave-wave interactions are explicitly separated from the underlying basic cnoidal wave components and can be displayed and analysed separately.
The KdV-NLFT is successfully applied to different shallow water problems such as the fission of solitons over submerged reefs, the harmonic generation, the problem of bound and free harmonics and the transformation of long linear waves into asymmetric waves and finally their disintegration into a train of solitons (as shown by Zabusky and Kruskal, 1965). The analysis results show that for some applications the conventional concepts that have been developed based on the results of the linear conventional Fourier transform are not sufficient to explain the ongoing nonlinear processes. In contrast, by application of the KdV-NLFT the observed processes in soliton fission, harmonic generation, bound and free harmonics and the transformation of long waves in shallow water can easily be explained by simple dispersion effects of the underlying cnoidal waves. Furthermore, by introduction of the concept of transient nonlinear waves the stability of wave forms in shallow water can be determined and the propagation and dispersion of instable transient waves in shallow water can be predicted.