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Effects of multiple wavenumbers on gravity and gravity-capillary wave-current fields

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Water waves in the oceans and seas play an important role in hydrodynamic processes, global circulation and climate. Water wave measurements and models often assume decoupled wave-current motion. Whereas, real world water waves are often coupled with current. In the presence of current, water wave dispersion is known to have a multi-valued form. The dispersion relation has multiple wavenumber solutions for a given absolute frequency. For surface gravity waves, it has been demonstrated that dual wavenumber solutions produce new nonlinear interactions Kouskoulas and Toledo (2017). These nonlinear interactions introduce significant quantitative and qualitative effects in wave-current fields. Effects include a shorter wavelength component moving with a lower wave celerity, nonlinear spatial focusing, and spatial undulations in the mean water level. The second solution is also shown to produce a mechanism which may easily result in localized violations of wave breaking criteria.

A new analytical perturbation solution is presented which accounts for multiple wavenumber solutions and surface tension effects. The solution demonstrates the significance of nonlinear interactions between triple wavenumber solutions in the gravity-capillary and pure capillary wave regimes. The length scales of these effects are significant to remote sensing and radar measurements. The importance of nonlinear interactions between multiple wavenumbers to hydrodynamic processes include wavebreaking and wind-wave interactions and on remote sensing using radars. Notably, the theoretical results seem to suggest a correspondence with real world observations of whitecapping Gemmrich et al. (2008). Lastly, new resonance conditions involving multiple wavenumber solutions and their bound waves are demonstrated.

Gemmrich J.R., Banner M.L. and Garrett C.. Spectrally resolved energy dissipa- tion rate and momentum flux of breaking waves. Journal of Physical Oceanography, 38(6):1296– 1312, 2008.

Kouskoulas D.M. and Toledo Y. Effects of dual wavenumber dispersion solutions on a nonlinear monochromatic wave-current field. Coastal Eng., 130:26–33, 2017.