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On the physical mechanism of front-back asymmetry of nonlinear gravity-capillary waves

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In nature wind waves of all scales are asymmetric both with respect to the horizontal and vertical axes. The front-back (or fore-aft asymmetry), i.e. the asymmetry with respect to the vertical axis, manifests itself in steeper front slopes. Although it can be important for remote sensing of sea surface and wave field interaction with wind, especially for the waves of gravity-capillary range, at present the understanding of physical mechanisms causing the gravity-capillary waves asymmetry and its dependence on parameters is very poor; there has been no study dedicated to this problem. Here we address this gap.

The decimetre-range water waves in many respects essentially differ from the waves of other ranges: wind forcing is stronger, steep waves develop a characteristic pattern of capillary ripples on their forward slopes. These 'parasitic capillaries', generated by a narrow pressure distribution associated with an underlying longer wave' crest, remain quasi-stationary with regard to the longer wave. The train of capillaries is localised on the front slope and decays towards the trough.

We investigate the nature of the asymmetry of such waves by extensive numerical simulations of the Euler equations employing the method of conformal mapping for two-dimensional potential flow and taking into account wave generation by wind and dissipation due to molecular viscosity. We examine the role of various factors contributing to the wave profile asymmetry: wind pumping, viscous stresses, the Reynolds stresses caused by ripples and found the latter to be by far the most important. It is the lop-sided ripple distribution which leads to noticeable fore-aft asymmetry of the mean wave profile. We also found how the asymmetry depends on wavelength, steepness, wind and viscosity, which enables us to parametrize these dependencies for applications in microwave remote sensing and wave generation.