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The Spacing of Langmuir Circulation in Strong Wavy Shear

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The inviscid instability of $O(\varepsilon)$ two-dimensional free surface gravity waves propagating along an $O(1)$ parallel shear flow is considered. The modes of instability involve spanwise-periodic longitudinal vortices resembling oceanic Langmuir circulation. Here, not only are wave-induced mean effects important but also wave modulation, caused by developing mean streamwise-velocity anomalies. The former is described by a generalized Lagrangian-mean formulation and the latter by a modified Rayleigh equation. Since both effects are essential, the instability is called “generalized Craik-Leibovich (CLg).Of specific interest is whether spanwise distortion of the wave field acts to enhance or inhibit instability to longitudinal vortices. Also of interest is whether the instability gives rise to a preferred spacing for the vortices and whether that spacing concurs well or poorly with experiment. The layer depth is varied from much less than the e-folding depth of the $O(\varepsilon)$ wave motion, to infinity. Relative to an identical shear flow with rigid though wavy top boundary, it is found that wave modulation acts to increase the maximum growth rate of the instability. Finally, the preferred spacings calculated herein concur well with those observed in laboratory experiments, with the implication that the instability acting in the experiments very likely is CLg.

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