Langmuir circulation due to shear flow over wavy topography

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Langmuir circulations (LC) in their traditional form are large rolling fluid flow pattern created by the interplay of surface waves and a near-surface shear current, typically both created by the wind. A celebrated theory by Craik and Leibovich (1976) describes two kinematic mechanisms which cause instabilities which grow into Langmuir rolls, both involving only the shear of the flow and the kinematic driving of flow undulations by a wavy surface, but containing no direct reference to the wind as a driving force. The same kinematic processes are present also in boundary layer flow over a wavy bottom topography in almost perfect analogy.

We present a theory of Langmuir-like circulations created by boundary layer flow over a topography in the form of a regular pattern of two monochromatic waves crossing at an oblique angle. Thus, the Craik-Leibovich instability sometimes referred to as CL1 is triggered and the close analogy with surface waves allows us to follow the general procedure of Craik (1970).

A flow of arbitrary shear profile is assumed over the bottom topography. In the opposite limits of transient inviscid flow and steady-state viscous flow simple equations for the stream function in cross-current plane can be derived and easily solved numerically. For the special case of a power-law velocity profile, explicit leading-order solutions are available. This allows us to quickly map out the circulation response to different parameters: wavelength, crossing angle and wave amplitude. The study is supplemented with direct numerical simulations which verify the manifestation of Langmuir-like circulations over wavy geometries with a no-slip boundary condition.

References