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Particle trapping via wave-topography interactions

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Abstract

Ocean surface waves cause floating particles to undergo a slow drift in the direction of propagation of the waves. This forward drift, commonly known as the Stokes drift, plays a crucial role in the transport of various tracer parcels, from sediments to pollutants, in the marine environment. We show that this drift is significantly affected when an incident surface wave travels over a small amplitude, corrugated sea-floor. The mechanism at work is Bragg resonance; reflected waves are generated via nonlinear resonant interactions between an incident wave and a rippled bottom. First, we theoretically explain the fundamental effect of two counter-propagating Stokes' waves on Stokes drift and then perform numerical simulation of Bragg resonance using High-order Spectral method. A monochromatic incident wave on interaction with a rippled patch of bottom topography yields a complex interference between the incident and reflected waves. When the velocity induced by the reflected waves exceeds that of the incident, particle trajectories reverse, leading to a backward drift. We observe that all parcels placed on the free surface above the patch are trapped, implying that the small amplitude rippled patch acts as a non-surface-invasive particle trap. We perform further investigations to study the effect of a constant mean current, various widths and (finite) amplitudes of the rippled patch, and also consider various patch geometries. These ideas explored in this work may be useful for designing artificial, corrugated sea-floor patches for mitigating microplastics and other forms of ocean pollution. We also expect that naturally occurring sea-floor corrugations, especially in littoral zones, may significantly affect tracer transport in oceans.