Lagrangian transport by breaking deep-water surface waves

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Abstract

The Lagrangian transport due to breaking deep water surface gravity waves is examined using theoretical, numerical, and observational studies. First, a theoretical criterion for particles to surf an underlying surface gravity wave is presented. It is found that particles traveling near the phase speed of an underlying wave, in a geometrically confined region on the forward face of the crest, increase in speed. Next, this theory is employed to study the Lagrangian transport due to non-breaking and breaking waves. Direct numerical simulations of focusing wave packets are presented, and it is found that breaking may enhance drift by up to an order of magnitude, compared to the classical Stokes drift prediction. A simple scaling argument implies that the drift due to breaking is proportional to a measure of the slope of the waves as compared to the unbroken Stokes drift which scales with the slope squared, where this measure of the slope is always less than 1. Finally, this model is combined with ocean field data of breaking wave statistics to estimate the Lagrangian drift due to breaking. This is compared with the classical prediction of Stokes drift, and it is found that breaking may provide a large contribution to the wave induced mass transport. Implications for a better description of upper ocean processes are discussed.