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Lagrangian transport by breaking deep-water surface waves

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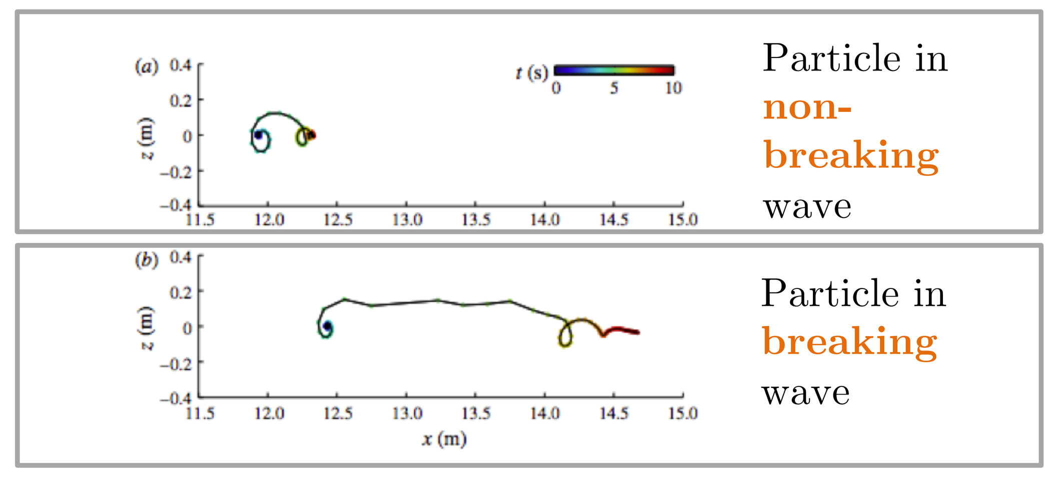
1. Introduction

We report on a theoretical, numerical, laboratory and field study of the Lagrangian transport by deep-water breaking waves.

Breaking waves contribute significantly to the wave induced mass transport.

Important for enhanced models of upper ocean dynamics.

DNS of Particle trajectories in non-breaking and breaking waves



Particles in breaking waves can travel **up to order of magnitude further**.

Background

Effects of waves on upper ocean processes usually enters through **Stokes drift** (i.e. through the vortex force).

Crucial component of models of Langmuir circulations and upper ocean turbulence.

Lagrangian drift can significantly affect these upper ocean processes, especially at submesoscales, and should be considered in further developments of coupled ocean–atmosphere models.

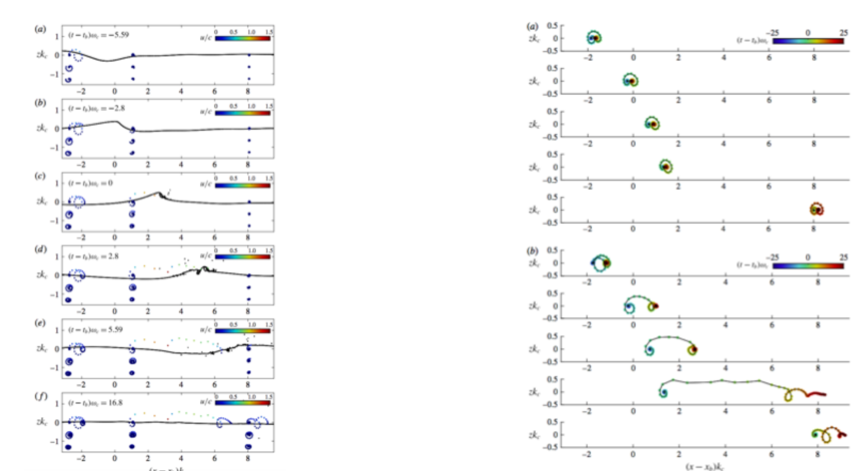
2. Lagrangian transport by breaking surface waves

Characterize drift due to non-breaking and breaking deep-water wave packets.

Use direct numerical simulations (Gerris flow solver) of breaking deep-water surface gravity waves.

Theoretical predictions for non-breaking packets and scaling argument of drift due to breaking examined.

DNS of focusing wave packets

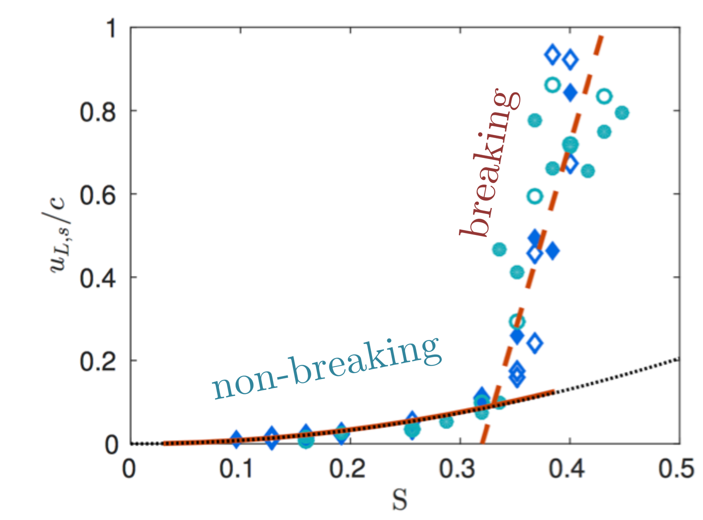


Scaling argument based on Pizzo (2017) implies the Lagrangian drift, u_L, goes like

$$u_L/c = \beta S,$$

S: slope of packet, β a scaling constant, c phase speed.

Results



Added drift at the surface is up to an order of magnitude larger than the drift obtained for non-breaking packets.

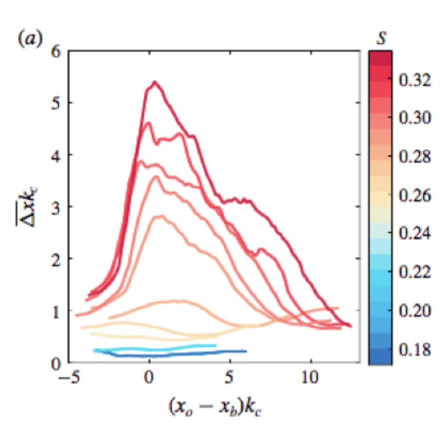
3. Laboratory studies of Lagrangian transport by breaking surface waves

Laboratory experiments conducted in the Hydraulics Laboratory at SIO to corroborate DNS results from Section 2.

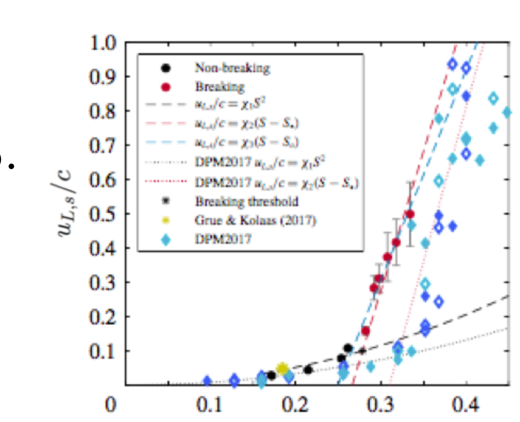
Quasi-neutrally buoyant particles tracked before/after breaking event to estimate total drift induced by breaking at the surface.

Spatial profile of drift induced by breaking found.

Results



Spatial (averaged) transport as a function of initial particle location.



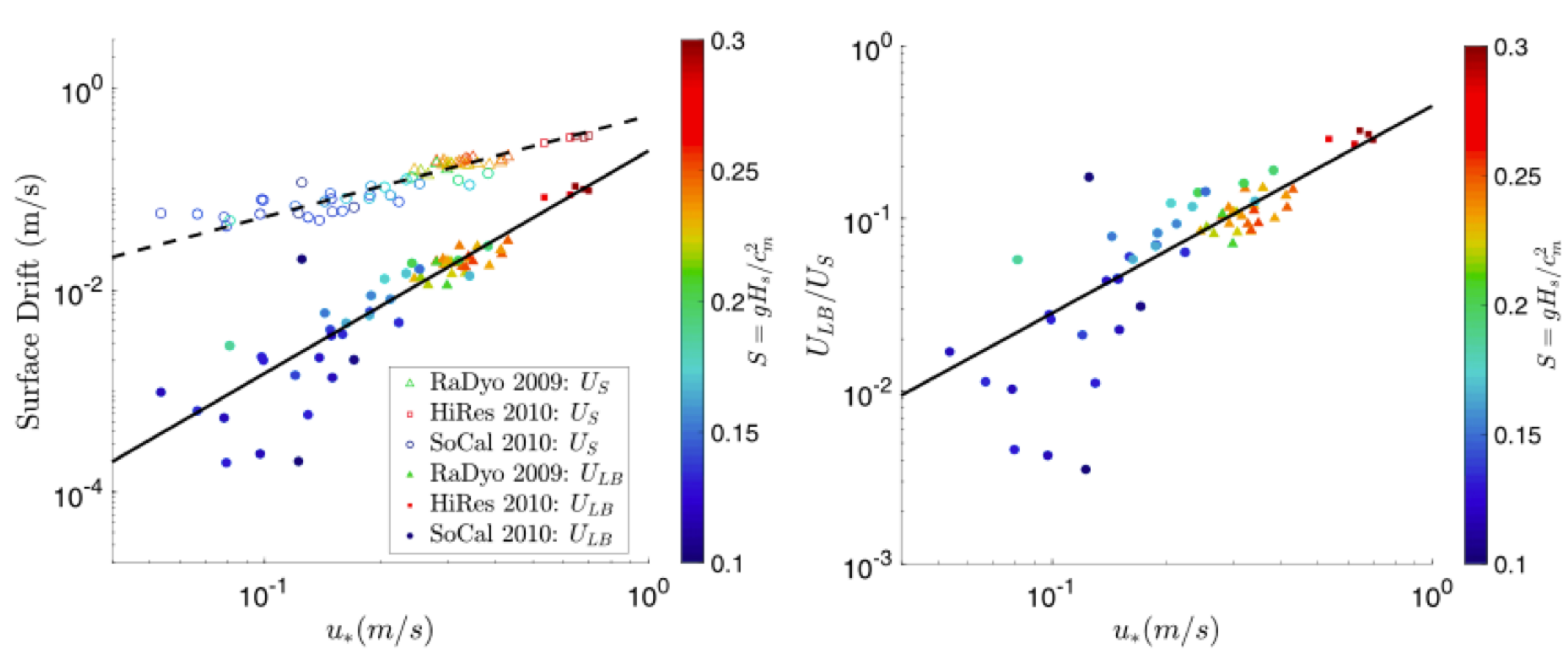
Total transport versus S. Agreement found with DNS.

4. Lagrangian Transport by Nonbreaking and Breaking Deep-Water Waves at the Ocean Surface

Use model of one breaking wave, plus observed breaking statistics, to estimate total drift induced by breaking at sea.

Scaling arguments for form of nonbreaking and breaking induced drift found, as a function of environmental variables.

Stokes drift versus drift induced by wave breaking



Find drift induced by breaking may be 30% of that of the Stokes drift, for environmental variables measured here (with wind speeds up to 16 m/s)

5. Conclusions

Theoretical, numerical, laboratory and field studies show that breaking can contribute significantly to wave-induced mass transport.

Wave induced mass transport important for many upper ocean processes.

Currently examining bandwidth effects on the transport induced by breaking.

References:

1: Pizzo, N.E. 2017 Surfing surface gravity waves. *Journal of Fluid Mechanics.* **823**, 316-328.

2: Deike, L., Pizzo, N.E., & Melville, W.K. 2017 Lagrangian transport by breaking waves. *Journal of Fluid Mechanics.* **829**, 364-391.

3: Lenain, Luc, Pizzo, N.E., and W. Kendall Melville "Laboratory studies of Lagrangian transport by breaking surface waves" *Journal of Fluid Mechanics* 876 (2019): R1-12.

4: Pizzo, N.E., W. Kendall Melville, and Luc Deike. "Lagrangian Transport by Nonbreaking and Breaking Deep-Water Waves at the Ocean Surface." *Journal of Physical Oceanography* 49.4 (2019): 983-992.