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Dense bubble plumes, wave breaking, and air-water gas exchange

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Bubble plume characteristics, size distribution, and wave breaking characteristics were measured for mechanical wind-steepened wave breaking in a large, fresh water wind channel and a wind speed of 13 m/s. Bubble plumes exhibited a wide range of size distributions, physical extent, and dynamics, which were used to develop a classification scheme. The coupled evolution of wave-breaking, wave properties, and bubble-plume characteristics were investigated. A significant differentiation amongst plumes was the ability of some plumes to optically obscure (termed dense) the image background. Dense plumes (as opposed to diffuse plumes) were found to contain a large radius peak in the bubble population size distribution, F, and thus are enhanced in large bubbles. Population defined as the total number of bubbles in the plume. Diffuse plumes are well-described by a weakly size decreasing F(r), for r$<$1000 μm, and a more strongly size decreasing F(r) for r$>$1000 μm, where r is radius (Leifer and De Leeuw, 2006).

The bubble-plume formation rate, P, for each class, wave-breaking rate, and wave characteristics were measured with respect to fetch. The wave-breaking rate and intensity were strongly fetch dependent. In general, the trends in P and wave breaking are similar, reaching a maximum at the fetch of maximum wave breaking. The ratio of P for dense to diffuse plumes is even more sensitive to the occurrence of the most intense wave breaking, where dense plume formation is the greatest.

Using P and the bubble-size population distributions for each plume class, the global bubble-plume, injection size-distribution, Y(r), was calculated and decreased as r^(-1.2), for r$<$1700 μm and as r^(-3.9) for larger r. The volume injection rate for the study area was 640 cm3 s-1 divided approximately equally between bubbles smaller

and larger than r˜1700-μm (Leifer et al., 2006)

The significance of dense versus diffuse plumes with respect to gas exchange of significant atmospheric gases was tested with a numerical bubble model and demonstrated that the large bubbles in dense plumes plays a very significant roll in the overall bubble-mediated air-water gas exchange, including the dependency of gas exchange on solubility and Schmidt number.

Leifer, I., and G. De Leeuw. 2006. Bubbles generated from wind-steepened breaking waves: Part 1. Bubble-plume bubbles. J. Geophys. Res., In Press.

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