Bubble Plume Bubbles from Wind-Steepened Wave Breaking

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Breaking-wave bubbles are important to many geophysical processes; however, most bubble measurements are of the steady-state background population rather than the formation population, i.e., bubbles in the bubble plumes. Measurements of bubbles inside bubble plumes from wind-stress breaking waves were made during the LUMINY experiment using a non-invasive, video bubble measurement system. The bubble-plume bubble-population is much greater than in the background population, and the distribution is much shallower. Thus, compared to the background population, bubble plumes are enriched in large bubbles.

Bubble plumes showed significant variability in dynamics, bubble distributions, and physical extents. To preserve this diversity, a classification scheme was developed and time-resolved, bubble size-distributions were calculated for each plume class. Comparison of the bubble distributions suggested the most important distinction was between bubble plumes termed «dense» and «diffuse». These distinctions were based on the optical ability to obscure the background and related to the relative importance of large \( r > 1000 \) µm bubbles, where \( r \) is radius. At injection, diffuse plumes were weakly size dependant to \( r \approx 1000 \) µm, decreasing steeply for larger bubbles. Dense plumes were multimodal with a steeply decreasing small bubble population and a second peak at \( r \approx 1700 \) to 2000 µm, decreasing steeply for larger bubbles. Dense plumes were significantly enhanced in large bubbles compared with diffuse plumes. Surprisingly, void fractions of diffuse plumes were greater at maximum penetration than void fractions of dense plumes. Finally, the injection and rise phases were approximately equal in time.