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Subsurface Droplet Size Distribution generated as breaking waves
entrain an oil slick

CHENG LI, JESSE MILLER, JOSEPH KATZ, Johns Hopkins University — Breaking waves are a primary mechanism for entraining and dispersing oil spills. Knowledge of the resulting droplet size distribution is crucial for predicting the transport and fate of this oil. In this on-going experimental study, a controlled oil slick of varying viscosity ($\mu_d$), density ($\rho_d$), interfacial tension ($\sigma$), and thickness $\delta$ =0.5mm are entrained by waves of varying energy ($E_w$). The changes to droplet size over time, from seconds to hours, are measured at several locations using multi-resolution holography, which covers sizes ranging from $\mu$m to mm. Using dispersants to reduce $\sigma$, the Webber number, $We= E_w \delta /\sigma$, and Ohnesorge number, $Oh= \mu_d / (\rho_d \delta \sigma)^{0.5}$, are varied from 6 to 813 and from 0.09 to 0.95, respectively. Droplets smaller than the turbulence scale (2-30 $\mu$m – diameter), are generated by “micro-threading”. Their size distribution becomes steeper and their total number increase substantially with decreasing interfacial tension. For slopes smaller than -3, measured for $\sigma$ around $10^{-1}$ mN/m, the volumetric size distribution decreases with diameter, i.e. most of the oil breaks into micron-scale droplets. For high interfacial tension oil, the concentration of small droplets increases with wave energy, but this effect diminishes as $\sigma$ decreases. Droplets larger than 100 $\mu$m are generated by turbulent shear. Hence, their number is impacted by $\mu_d$ and $E_w$. Increasing $We$ from 6 to 15 ($Oh$ from 0.09 to 2.95) increases the initial number of droplets by up to 5 times, but the distribution slopes remain largely similar.

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