On the connection between whitecap foam signatures and breaking wave energy dissipation.

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Air entraining breaking waves, also known as whitecaps, are thought to be dominant mechanism dissipating surface wave energy in deep water. Due to the broadband scattering of light associated with the sub-surface bubble plume and the associated surface foam, whitecaps are readily identifiable features on the ocean surface. As such, detection of whitecaps present an unambiguous way to detect surface wave breaking in digital images of the sea surface. Consequently, sea surface imaging for whitecaps has long been used to generate statistics of average quantities such as total whitecap coverage of the sea surface, or more detailed phase-averaged descriptions of breaking crest lengths following the Phillips “lambda” distribution framework. Such measurements have provided a wealth of knowledge relating to various aspects of oceanic breaking covering breaking wave kinematics, dynamics and as well as providing useful data for scaling exchange processes such as marine aerosol production and gas exchange. However, there is a paucity of data related to the severity of, or total energy dissipated by, individual oceanic whitecaps, and the exact relationship between oceanic whitecap coverage, breaking wave energy dissipation and wind energy input rate remains unclear.
In this talk I will present results from a laboratory experiment aimed at calibrating the whitecap foam signature measured using digital cameras to infer the total energy dissipated by individual breaking wave whitecaps [Callaghan et al., 2016]. The experimental data show that the volume of the two-phase flow integrated in time during active wave breaking is almost linearly proportional to the total energy dissipated by breaking. The value of a turbulence strength parameter (Ω) is determined relating the breaking wave “volume-time-integral” to total energy dissipation. When data from 3 previous experimental campaigns are included, the value of □ is found to be relatively constant over almost 3 orders of magnitude in measured breaking wave energy dissipation. Using a whitecap decay time as a proxy for bubble plume penetration depth allows estimates of individual whitecap energy dissipation to be inferred from measurements of surface whitecap foam. The experimental results are used to formulate an energy-balance model for oceanic whitecap coverage, with model estimates compared to in-situ whitecap coverage measurements made in the North
Atlantic at wind speeds up to 23 m/s. Best agreement is found when bubble plume penetration depth increases with increasing forcing and energy dissipation due to other processes is also accounted for.

Reference:

Callaghan, A. H., G. B. Deane, and M. D. Stokes (2016), Laboratory air entraining breaking waves: Imaging visible foam signatures to estimate energy dissipation, Geophys. Res. Lett., 43, doi:10.1002/2016GL071226.