2019_19: Measuring the space and time evolution of the geometric, kinematic and dynamic properties of oceanic breaking waves

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The overarching goal of this project is to provide a better understanding and description of oceanic breaking waves for oceanographic, atmospheric science and engineering purposes.

Breaking waves at the ocean surface represent the most extreme flow occurring at the ocean-atmosphere interface: they generate high levels of upper ocean turbulence, entrain air into the water column which drives bubble-mediated air-sea exchange of gas and aerosol particles, disperse pollutants and nutrients, alter maximum wave height and crest height statistics and can generate large slamming forces on structures in the marine environment. Consequently breaking waves modulate the energy of the upper-ocean and surface wave field, drive ocean-atmosphere interfacial exchanges that influence weather and climate dynamics and impact engineering design.

Due to their intermittent occurrence at the ocean surface, associated high fluid velocities and high air fractions, detailed in-situ measurements of breaking waves in the ocean are extremely rare. Consequently, relatively little is known about the likelihood, scale and severity of individual oceanic breaking waves. Moreover, the complex hydrodynamics associated with breaking waves make accurate numerical simulations highly challenging and computationally expensive.

To address these challenges, this project seeks to develop a digital image-based remote sensing approach to describe the characteristics of oceanic breaking waves by measuring the space-time evolving whitecap foam signal generated by individual breaking waves. The student will have access to a multi-year dataset of stereovision sea surface images gathered from the Acqua Alta oceanographic research Tower (AAT) in the Adriatic Sea by co-supervisor Benetazzo. These images provide a detailed measurement of the time-evolving 3-D sea surface elevation field across a large area of ocean surface, from which directional wave spectra can be calculated. Further image datasets will be obtained by the student through the installation of additional camera equipment on the AAT during the course of the project. Through the development of bespoke digital image processing algorithms, the student will analyse...
the geometric, kinematic and dynamic properties of individual breaking waves and develop new statistical descriptions of their associated energy dissipation. These results will be complemented with data from a state-of-the-art numerical spectral wave model provided by co-supervisor Bidlot at the European Centre of Medium Range Forecasting (ECMWF). The student has the opportunity of working closely with the ECMWF during the project. The ECMWF modelling component represents the pathway by which the results from the field study can be applied in a global context, therefore representing a key component of the work.

The student will have the opportunity to apply the results generated from the field analysis of breaking waves to estimate breaking-wave-driven bubble-mediated air-sea fluxes of carbon dioxide concentration and aerosol production fluxes on a global scale using the ECMWF wave model. The breaking wave data collected will enable the student to develop breaking wave descriptions that can inform offshore engineering design standards. As such, this project offers the student a unique opportunity to work with supervisors with a range of expertise and make important breakthrough contributions to the description of breaking waves relevant to several diverse disciplines.