Imperial College London

Natural Environment Research Council

2024_15_Civil_AC: How Important are Oceanic Bubbles in mitigating the Climate Emergency?

Supervisors: Dr Adrian Callaghan (mailto:a.callaghan@imperial.ac.uk); Dr. Tom Bell (Plymouth Marine Laboratory); Dr. Mingxi Yang (Plymouth Marine Laboratory)

Department: Department of Civil and Environmental Engineering

The Climate Emergency is being largely driven by increases in the concentration of CO2 (carbon dioxide) in the atmosphere due to fossil fuel combustion. Approximately 25% of the atmospheric CO2 emitted by human activities is taken up by the global oceans. While the direct interfacial transfer of CO2 across the water surface is quite well-understood, there remains large uncertainties in how important bubbles formed by breaking waves are in gas transfer, especially in extreme conditions.

This project will focus on laboratory, field and statistical modelling efforts to better constrain the estimates of air to sea transfer of CO2 by oceanic breaking waves. The laboratory component comprises experiments to measure the mass transfer of CO2 from individual bubbles in a water tank to develop a quantitative physical model of bubble-mediated air-to-water CO2 transfer. The field component of the experimental effort will involve the collection and analysis of sea surface images to directly measure breaking wave statistics during the Atlantic Meridional Transect 6-week oceanographic cruise between the UK and Chile. The modelling effort will focus on developing better statistical descriptions of the distributions of the horizontal scale of breaking waves and the vertical scale of bubble plume penetration depth. These statistical distributions will be constrained following an energy-balance approach that places an upper limit on the wave energy that can be dissipated by a population of breaking waves in a given sea state.

The combined laboratory, field and modelling datasets will be leveraged to (i) develop an improved understanding of bubble-mediated CO2 gas exchange in a broad range of wind and wave conditions and (ii) to yield new sea-state based estimates of the flux of CO2 across the air-sea interface. The project offers a unique opportunity to work across scientific disciplines, perform detailed laboratory experiments, participate in an oceanographic cruise, and develop state-of-the-art models of bubble-mediated gas exchange of CO2 applicable over the global oceans.

If you have a strong curiosity about climate science, ocean waves and fluid mechanics, which is supported by a first class honours degree in Physics, Mathematics, Oceanography or another numerate background, then please send an email to Dr. Callaghan (a.callaghan@imperial.ac.uk) for further information on the project. The successful candidate can expect to gain extensive experience in digital image acquisition and processing, laboratory methods, air-sea interaction science and data analysis.