Towards a theory for the surface layer of the ocean

Lead Supervisor: Miguel A. C. Teixeira, Department of Meteorology, University of Reading
Email: m.a.teixeira@reading.ac.uk

Co-supervisors: Alan Grant, Department of Meteorology, University of Reading, Email: a.l.m.grant@reading.ac.uk; Jean Bidlot, European Centre for Medium Range Weather Forecasts (ECMWF), Email: jean.bidlot@ecmwf.int

Due to their huge heat capacity, the oceans are an essential controlling factor in long-term climate variability and climate change. The oceanic boundary layer, corresponding to the upper tens to hundreds of meters of ocean, plays a key role in air-sea interaction, mediating the turbulent fluxes of momentum, heat, pollutants, and dissolved gases such as CO₂ (which controls the atmospheric greenhouse effect).

Several studies have highlighted deficiencies in the representation of the oceanic boundary layer in global models, causing an insufficiently deep thermocline (which bounds below the layer where properties such as temperature and salinity are well-mixed). This causes a positive temperature bias at the ocean surface, and errors in the atmospheric response to this forcing. Since nowadays many operational weather-forecasting centres are implementing fully-coupled atmosphere-ocean systems, understanding better the essence of these feedbacks is paramount.

Langmuir circulations, which consist of elongated vortices roughly aligned with the wind and perpendicular to the crests of surface waves (see figure), have been shown to play a key role in the ocean mixed layer via their strong vertical velocity perturbations, very effective for mixing properties vertically and deepening the thermocline.

The surface layer, which corresponds to the upper metres or tens of metres of the ocean in direct contact with the air-water interface, ultimately controls the fluxes across that interface and provides upper boundary-conditions for the mixed layer, but is often not resolved adequately by numerical models.

Observations have shown that the scaling behaviour of the oceanic surface layer is fundamentally different from that of its atmospheric counterpart. It is consensual that this is due to the effect of surface waves, but whether it results primarily from wave breaking, or from the interaction between non-breaking waves and turbulence, is under debate.
In this project we intend to clarify the contribution of non-breaking waves to the observed differences between the oceanic surface layer and its atmospheric counterpart, and to formulate a systematic description of its scaling properties regarding, for example, heat and momentum fluxes, as achieved for the atmosphere by Monin-Obukhov theory. This will allow the formulation of more robust boundary conditions at the air-water interface in coupled atmosphere-ocean models, and the improvement of air-sea interaction models.

The student will perform high-resolution Large-Eddy Simulations of the oceanic boundary layer using the LEM model, in conjunction with idealized calculations for physical insight. The project will also make use of recent oceanic turbulence measurements available from the OSMOSIS project. More specifically, the student will:

- Use the field data and LEM simulations to develop and test a theory for describing the variation of mean and turbulent quantities in the oceanic surface layer.
- Check to what extent the effect of non-breaking waves (via Langmuir circulations) can explain the behaviour of mean and turbulent quantities.
- Interact (at ECMWF) with researchers working on coupled ocean-waves-atmosphere systems to ascertain the consistency of ocean surface heat and momentum fluxes.
- Depending on results from previous tasks, develop and potentially perform preliminary testing of an improved parametrization of the impact of non-breaking waves for the upper ocean.

**Training opportunities:**
This project will provide skills in numerical and mathematical modelling and data analysis. It will offer opportunities to attend postgraduate modules and summer schools on fluid dynamics (e.g. the Summer School on Fluid Dynamics of Sustainability and the Environment), as well as visits to, scientific collaboration with, and opportunities to attend training courses, workshops and seminars at ECMWF.

**Student profile:**
This project is suitable for students with a good degree in physics, mathematics or a closely related environmental or physical science, and an interest in fluid dynamics and physical oceanography, particularly boundary layer processes.

[http://www.reading.ac.uk/nercdtp](http://www.reading.ac.uk/nercdtp)