Evaluating properties of Solitary Internal Waves and mixing on the North-West shelf through in situ observations, satellite images and high-resolution modelling

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Introduction:

Shelf seas are incredibly important in the global carbon cycle as they make a disproportionately high contribution to oceanic primary production and support the majority of marine fish species. In order to understand and accurately predict the functioning of such seas, it is essential to better understand the mechanisms that help transport life sustaining nutrients into the upper ocean, where photosynthesis can take place. In seasonally stratifying shelf seas, such as those surrounding the UK and northern Europe, the development of stratification, which is required to support sustained growth in the upper ocean, acts to inhibit the transfer of nutrient rich deep water, thus restricting the vertical flux of heat, nutrients and gases. Somewhat paradoxically, the developing thermocline also provides a mechanism for enhanced internal mixing by supporting the generation and propagation of internal waves, which are known to provide turbulent mixing through enhanced shear and wave-breaking.

Existing models of vertical turbulent mixing are predominantly developed for the deep ocean and largely fail to accurately predict thermocline mixing on the shelf breaks. One reason for this is that solitary internal waves (SIW) are completely missing from even the state-of-the-art regional scale models (1.5-1.8km). Such waves are seen to contribute significantly to thermocline mixing, although the sporadic nature of such mixing is beyond the current scope of turbulence closure schemes. SIWs are regularly observed from satellite images and from in situ observations made with moorings, ships and autonomous gliders .

Technology is only now suitably placed to provide a comprehensive understanding of these complex SIWs, through the combined analysis of satellite imagery, in situ observations of temperature, salinity and turbulent characteristics, combined with the latest, high-resolution Atlantic Marginal Model (AMM60), which permits the linear internal tides.

Project Summary:

The overall objective of this project is to quantify the properties of SIWs in the North-West shelf and their effect on the mixing in pycnoline:

(1) using satellite SAR images of SIW surface signatures and in situ observations, such as: propagation direction of wave packets, wavelength of solitary waves and inter-packet separations, group speed of SIW packets, energy fluxes (Jackson, 2009, Moum et al. 2007, Kozlov et al, 2017).

(2) To evaluate, what fraction of SIW energy flux is transferred to turbulence and mixing across the shelf and to identify the locations of SIW energy flux convergence, using satellite information, and the relationship with bottom topography anomalies.

(3) Using a combination of outputs from new generation NWES models (Graham et al, 2017, Guihou et al, 2017) to identify the relationships between modelled long internal waves and SIW statistics.

The work will use observational data sets collected during the FASTNET and recent Shelf Sea Biogeochemistry programmes, e.g. a 17 month long ADCP time series from the Celtic Sea will be used to evaluate the dissipation rate of turbulent kinetic energy and shear production, full water column temperature, salinity and velocity. A series of month long cruises and glider deployments throughout 2014-2015 will provide vertical and horizontal high resolution data sets of temperature, salinity and dissipation rate along cross-shelf transects (from the deep ocean to the shallow shelf). This information will be used to help detect SIW and long internal waves and to determine stratification properties, and will be compared with SIW packets detected from SAR images. This will allow relationships to be established between the vertical and horizontal structure of internal waves, energy fluxes and amplitudes to be evaluated, and conditions of generation examined.

The student will be trained in the processing and analysis of observational data sets, model setup, scientific writing and presentation. They will participate in the doctoral training programme of the University of Liverpool, attend both national and international conferences to present their work and will be encouraged to apply for international training schools.

Image 1 - ISW fronts in 2009 in the Celtic Sea, detected from SAR images, totally 433 wave packets during June-September 2009

Image 2 - ISW fronts in the Celtic Sea, detected from SAR images during June 2009.

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