Does differing internal wave forcing drive variable behaviour in pycnocline mixing?

Matthew R. Palmer[1]
With contributions from Jeff A. Polton[1], Mark E. Inall[2], Tom P. Rippeth[3], Mattias Green[3], Jonathan Sharples[1,4] & John H. Simpson[3].
1. National Oceanography Centre, Liverpool, UK
2.Scottish Association for Marine Science, Oban, UK
3. School of Ocean Sciences, Bangor University, Wales
4. School of Environmental Sciences, University of Liverpool, Liverpool, UK
Dr. Matthew R. Palmer, National Oceanography Centre, 6 Brownlow St., Liverpool, UK. matthew.palmer@noc.ac.uk

Abstract:

In terms of its importance to the global carbon cycle, shelf seas seriously *punch above their weight*. Despite occupying a mere 7% of the ocean surface, seasonal or permanent stratification combined with high levels of nutrients result in shelf seas accounting for 15-30% of total oceanic primary production. In consequence they have been identified as hosting significant air-sea CO_2 fluxes and seasonally stratified shelf seas in particular have been identified as providing an important sink for atmospheric CO_2.

The first order paradigm for the water column structure in seasonally stratified temperate shelf seas may be considered as a balance between the stratifying influence of surface heating and the input of mechanical energy to mix the water column at the upper and lower boundaries, due to wind stress and the tidal shear respectively. Regional scale shelf sea models have some success in reproducing this paradigm, with vertical exchange calculated by second moment turbulence closure schemes that are essentially controlled by the estimated local stability of the flow. ‘Calibration’ of a background mixing level is however typically required in such schemes in order for a given model to correctly predict the diapycnal flux through this critical interface. The requirement for local tuning of pycnocline mixing reduces the success of models on shelf-wide scales since differing forcing mechanisms and mixing processes require specific methods and levels of tuning. The key limitation on the skill of these models in predicting the spatial and temporal variability in ecosystem dynamics and carbon exchange is consequently the capability to accurately represent the true nature of pycnocline turbulence and mixing. The further development of regional shelf sea models for accurate prediction of coastal and shelf sea biogeochemical cycles are therefore dependent on improving predictions of pycnocline exchange. Confidence in future predictions of the global carbon cycle is subsequently dependent on an improved ocean turbulence model that can be validated against observations.

Recent decades have seen significant advances in our understanding of ocean turbulence facilitated by developments in observational technology. In particular, the advent of microstructure profilers has vastly improved understanding of ocean turbulence from across all parts of our oceans, providing a method for estimation of fluxes of heat, salt and nutrients, suspension and disaggregation of sediments and permitted explicit closure of energy budgets. An extensive dataset now exists that permits the thorough investigation of pycnocline turbulence in terms of stability criteria such that proposed turbulence closure schemes and mixing parameterizations can be tested and improved upon.

Here we expand on the work of Palmer et al (2013) which examines data from three contrasting locations in the northwest European shelf seas and reveals contrasting behaviour of pycnocline turbulence when examined in *stability space*, that is relative to stabilizing stratification and destabilizing shear. Turbulence data are compared to the characteristics of proposed turbulence models to provide insight into the mixing mechanisms at each site and test the capability of such models in predicting shelf sea pycnocline turbulence.

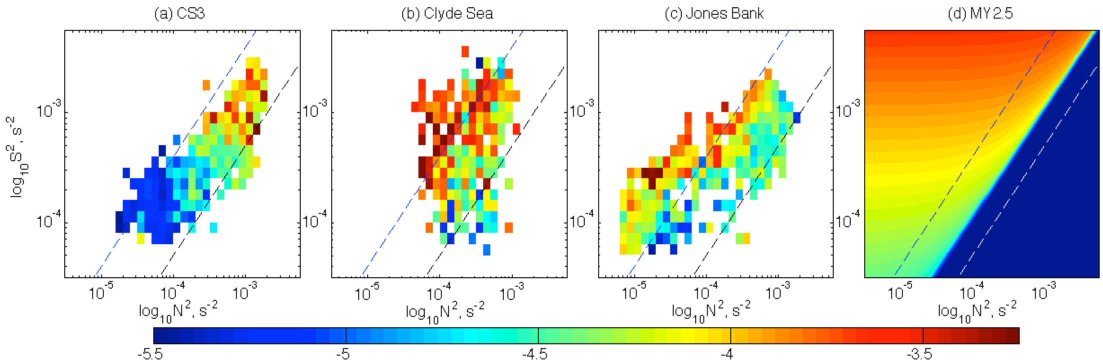

Figure: Turbulent dissipation ε arranged in N^2, S^2 space for three different sites (a) Celtic Sea (b) Clyde Sea (c) Jones Bank, and (d) predicted using a turbulence closure scheme (Mellor & Yamada, 1982). The blue and black dashed lines are Ri=1/4 and 2 respectively. Palmer et al, (2013).

We identify that much of the observed behavior of pycnocline turbulence and subsequently vertical mixing and diapycnal exchange, is replicable with the right choice of model and appropriate 'tuning' of free parameters. This suggests that if local observations are required to make the correct choice of turbulence model and appropriate tuning parameters then the predicative capability of regional scale ocean models is severely restricted. The small subset used in this study of what is an ever-growing global dataset of turbulence and hydrographic measurements may hold the key to more general solutions. The capability exists to provide extensive testing and validation of the numerous turbulence models proposed for use on shelf seas but the community must look beyond the basic constraints of stability space that so many models depend. The high levels of variability between applications of these models indicate an underlying misrepresentation of the physics they are designed to simulate.

This study identifies clear differences in ε distribution under differing forcing conditions and promotes the question of whether the mechanistic transition to turbulence and mixing from laminar, sheared flow is the same in all circumstances. These results suggest otherwise. However, our interpretation of such data is also limited since few datasets manage to capture coincident measurements at the appropriate mixing length scale. This presentation will also introduce new technology that will aim to provide coincident, long-term, high-resolution measurements of pycnocline turbulence and stability.