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How storms modify baroclinic energy fluxes in a seasonally stratified shelf sea: inertial-tidal interaction

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The oceans' rich internal wave field is an essential link in the energy cascade from large to small scale motions and is a major source of energy available for vertical mixing. In shallow shelf seas, vertical mixing across the thermocline maintains elevated summer time production, helping continental shelves to make a disproportionally large contribution to total ocean primary production relative to their surface area. Temperate shelf seas are therefore a significant CO_2 sink and a critical link in the ocean-earth-atmosphere system. The two most energetic parts of the global internal wave spectrum are near-inertial waves with frequencies $\omega \approx$f, and the lunar semi-diurnal frequency, M_2.

Using data from a mooring array, we demonstrate how wind generated near-inertial oscillations can modify baroclinic internal wave energy fluxes in the Celtic Sea, a seasonally stratified shelf. Linear fluxes of baroclinic energy are dominated by the semi-diurnal tide that outside of the complex generation zone drives a modest 28-48 W m^{-1} directly on-shelf. Given the complex 3-dimensional nature of the generation and propagation however spatial variability is high and net flux vectors may differ by 90° or more within an internal tidal wavelength. Horizontal energy fluxes driven independently by near-inertial motions are an order of magnitude weaker, but non-linear interaction between the vertical shear of inertial-oscillations and the vertical velocity associated with the M_2 internal tide is a significant source of energy at the sum of their frequencies (M_2+f). The phase relationship between M_2 and f determines whether this non-linear interaction constructively enhances or destructively dampens the linear tidal component of the flux, a phasing that introduces a 2-2.3 day counter-clockwise beating to the energy transport. Relative to the M_2 contribution, this beating and increase in flux magnitude explains an additional 10% of the variability of the full flux time series. Over individual tidal periods, inertial-tidal interaction resulted in a 50% increase in flux magnitude. Over the whole 2 week deployment, a 25-43% increase in positive on-shelf energy flux was observed. Our data set clearly identifies a switch between tidal and inertially dominated shear and energy flux regimes. These findings are highly relevant in the much needed development of mixing parameterizations for shelf sea models where non-linear interactions and the processes driving temporal and spatial variability of shear, instability and consequently turbulence are of importance. Failure to represent the inertial-tidal interactions described here will lead to underestimation of the magnitude and episodic nature of turbulent dissipation and thermocline mixing.