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Characterization of the sub-mesoscale energy cascade in the Alboran Sea thermocline from spectral analysis of multichannel seismic data

Valenti Sallares (1), Jhon F. Moncada (1), Berta Biescas (2), and Dirk Klaeschen (3)

(1) Institute of Marine Sciences - CMIMA - CSIC, Barcelona, Spain (vsallares@cmima.csic.es), (2) Istituto di Scienze Marine - CNR, Bologna, Italy, (3) Geomar, Helmholtz center for ocean Resaearch Kiel, Germany

Large-scale ocean dynamics is linked to small-scale mixing by means of turbulence, which enables the exchange of kinetic energy across the scales. At equilibrium, the energy flux that is injected at the production range must be balanced by mixing at the dissipation range. While the physics of the different ranges is now well established, an observational gap exists at the 10^3-10^1 m scale that prevents to characterize the transition from the anisotropic internal wave motions to isotropic turbulence. This lack of empirical evidence limits our understanding of the mechanisms governing the downward energy cascade, hampering the predictive capability of ocean circulation models. Here we show that this observational gap can be covered using high-resolution multichannel seismic (HR-MCS) data. Spectral analysis of acoustic reflectors imaged in the Alboran Sea (Western Mediterranean) thermocline evidences that this transition is caused by shear instabilities. In particular, we show that the averaged horizontal wavenumber (k_x) spectra of the reflector's vertical displacements display three subranges that reproduce theoretical spectral slopes of internal waves [λ_x>100 m, with $\lambda_{x=}k_x^{-1}$], Kelvin-Helmholtz (KH)-type shear instabilities[100 m> λ_x>33 m], and turbulence[λ_x<33 m]. The presence of the transitional subrange in the averaged spectrum indicates that the whole chain of events is occurring continuously and simultaneously in the surveyed area. The availability of a system providing observational data at the appropriate scales opens new perspectives to incorporate small-scale mixing in predictive ocean modelling research.