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Measurements of the Structure of Shear Instabilities at high Re

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Introduction

Corcos and Sherman (1976) proposed that shear instabilities at high Reynolds number should rapidly develop secondary instabilities, leading to mixing in the braids of the primary instabilities. Braid-dominated mixing contrasts many laboratory and numerical simulations at low and moderate Re, which indicate most intense mixing in the cores. Observations by Geyer et al. (2010) of instabilities at high Re support the Corcos and Sherman hypothesis. Here we present similar observations of instabilities with secondary instabilities and turbulence within the braids and stable, weakly stratified conditions where the cores should be. This braid-dominated regime appears to be the result of instability initiated at relatively high Ri, on the order of 0.15-0.2, in which the secondary instabilities grow much more rapidly than the primary instability.

Methods

Multi-frequency echo sounders (Lavery et al., 2013) were mounted on a vessel to provide imagery as well as calibrated acoustic backscatter intensity. The backscatter intensity provides estimates of the scalar variance spectrum, from which the scalar variance dissipation rate and buoyancy flux are estimated. Turbulence-resolving, in situ measurements of velocity and water properties from a rigid mast provide high-resolution estimates of the density and velocity structure, turbulent kinetic energy dissipation rate, and scalar variance dissipation. Microstructure conductivity profiles provide estimates of overturn scales and the spatially varying density gradient.

Results and Discussion

An example of the observed structure of the instabilities is shown in Fig. 1. Turbulent microstructure within the braids causes intensified acoustic backscatter, and the intervening fluid shows the absence of salinity microstructure. The salinity gradient is only roughly resolved by the mast, but it shows intensified gradients within the braids (as expected) and stably stratified conditions where the cores of the shear instabilities should be. Vertical profiles confirm that the shear instabilities rarely exhibit overturns at the scales of the primary instabilities, although overturns at the scale of the braid thickness are common. Secondary instabilities are evident within the braids, with vertical scales consistent with the observed overturns. The initial Richardson number of the instabilities is difficult to estimate, due to the prevalence of finite-amplitude disturbances, but it appears to be in the range of 0.15-0.2. The slopes of the braids are low, consistent with theoretical expectation for high Ri instabilities. Most notable is the lack of core roll-up and the high turbulent intensity within the braids.

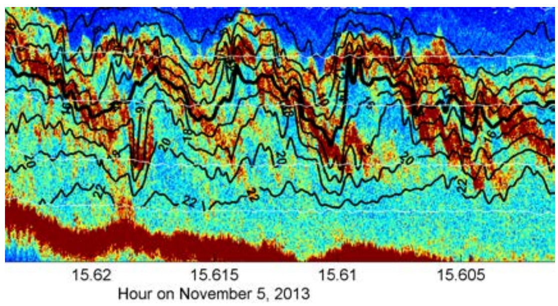

Fig. 1: Acoustic backscatter amplitude (color) and salinity contours (black). Vertical scale is 3.5 m, and horizontal scale is approximately 70 m. Surface velocity is 1.4 m/s (right-to-left) and bottom velocity is 0.2 m/s in the opposite direction. The seabed is evident at the bottom of the image.

References

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