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Supporting Information for

**Turbulent Mixing in a Far-Field Plume during the Transition to Upwelling Conditions: Microstructure Observations from an AUV**

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**Additional Supporting Information (Files uploaded separately)**

Datasets S1 to S8, which include binned ADCP data and vehicle data for each transect (2 files per transect)

**Introduction**

Text S1 describes the calculation of the turbulent dissipation rate. Text S2 derives an estimate of the buoyancy flux due to cross-shore and alongshore shear. Table S1 contains additional dissipation statistics that may be of interest to some readers.

**Text S1: Estimating the turbulent dissipation rate**

Shear spectra were estimated via fast Fourier transform (FFT) of measured shear signals and ensemble averaging six 512-point FFTs using a 50% overlapped cosine window. Traveling at 1.5 m s-1, this FFT length corresponds to a 1.5 m spatial scale that adequately resolves the inertial subrange even at low dissipation rates and ensures high degrees of freedom for the observed range of dissipation rates. The finite size of airfoil probes causes velocity fluctuations to be spatially averaged as eddy size approaches the width of the probe, which can be accounted for by adjusting filtered shear spectra based on the wavenumber response function [*Macoun & Lueck* 2004]. The half-power wavenumber response for the probes used in this study is 48 cpm.

Prior to integration, the adjusted shear spectra were despiked using a 0.5 Hz high-pass Butterworth filter and corrected for vehicle motion using the integrated Microrider accelerometers, following the spectral method outlined in *Goodman et al* [2006]. The removal of shear signals coherent with the accelerometers by this method has been reported to reduce shear variance by an average factor of two [*Goodman et al* 2006, *Fer et al* 2014]; we observed an average reduction by a factor of four overall, with reductions less than a factor of two evident at high dissipation rates (Table S1).

Using RSI ODAS v4.2 MATLAB code, dissipation rates were estimated from Nasmyth empirical spectra [*Oakey* 1982] by first integrating observed shear spectra, , for wavenumbers less than 10 cpm (within the inertial subrange). This initial estimate was then used to inform the selection of the dissipation calculation, either using an integration (variance) method or fitting the inertial subrange of the observed spectra to Nasmyth spectra. For dissipation rates less than 1 x 10-5 m2 s-3 (nearly all of the data), the variance method was used. The upper limit of integration was determined by the initial dissipation estimate and was restricted to wavenumbers between 10 cpm and 150 cpm. More information on the estimation of dissipation rates from Microrider measurements can be found in *Lueck* [2016].

Wave orbital velocities can bias microstructure shear measurements near the surface by reducing the ratio of along-stream velocity, *u,* to cross-stream velocity over the airfoil probes below the level at which reliable shear measurements can be obtained (*3v < u or 3w < u* [*Lueck* 2016]). Assuming a monochromatic wave field with significant wave height and peak period as shown in Fig. 1c, the maximum depth at which wave orbitals are one-third of the vehicle speed is ~1.5 m below the water surface. The dissipation estimates presented here, which were collected below z = -1.5 m, are therefore largely unaffected by wave orbitals and represent real physical structure within the plume.

**Text S2: Partitioning the turbulent buoyancy flux**

To estimate the contribution of cross-shore shear production to the total buoyancy flux, we start with the steady-state homogeneous turbulent kinetic energy (TKE) budget [*Gregg* 1987]:

 (S2.1)

where, *g* is gravity, ρ0 is the density of seawater, *-<u’w’>* and *-<v’w’>* are cross-shore and alongshore components of the Reynolds stress, and U and V are the cross-shore and alongshore mean velocity, respectively. The lhs of (S2.1) represents the shear production of turbulence (P), which is balanced by the sum of the turbulent buoyancy flux (B, first term on rhs) and the TKE dissipation rate (second term rhs). Expressed in terms of the turbulent diffusivity (*Kz*) and the eddy viscosity (*Km*), P and B become:

 (S2.2)  (S2.3)

where *S* is the vertical shear in the mean horizontal velocity. Equation (S2.1) can be used to infer P and B when ε is measured, such that [*Gregg* 1987]:

  (S2.4)  (S2.5)

where the mixing efficiency, Γ, is a function of the flux Richardson number [*Ivy & Imberger* 1991]:

 (S2.6)  (S2.7).

Estimating total shear production using equation (S2.5), the eddy viscosity can then be estimated via (S2.3) as:

  (S2.8)

Such that the cross-shore shear production and alongshore-shear production are defined as:

  (S2.9)  (S2.10).

Assuming that the mixing efficiency is a known function of *Rig* (Eqn. 3 in the manuscript) and that a Px = Bx + εx balance exists in the cross-shore direction, we can then combine (S2.4), (S2.5), (S2.8), and (S2.9) to estimate the contribution of cross-shore shear production to total mixing as:

  (S2.11).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *2.5%* | *50%* | *97.5%* | *mean* |
|  | 0.60 cpm | 0.69 cpm | 0.78 cpm | 0.69 cpm |
|  | 15.1 cpm | 35.5 cpm | 84.7 cpm | 39.0 cpm |
|  | 5.04 x 10-9 m2 s-3 | 6.26 x 10-8 m2 s-3 | 7.77 x 10-7 m2 s-3 | 1.43 x 10-7 m2 s-3 |
|  | 1.00 x 10-9 m2 s-3 | 1.83 x 10-8 m2 s-3 | 6.75 x 10-7 m2 s-3 | 9.93 x 10-8 m2 s-3 |
|  | 0.71 | 3.41 | 14.01 | 4.42 |

**Table S1**: Dissipation rate statistics: mean and 2.5, 50, and 97.5 percentile values estimated from lognormal distributions of the upper and lower integration limits (klower, kupper) and the dissipation estimate from raw shear spectra (εraw) and shear spectra filtered using accelerometer data (εclean).

**Captions to Datasets**

Dataset S1. Binned ADCP data from Transect 1.
Dataset S2. Vehicle data from Transect 1.
Dataset S3. Binned ADCP data from Transect 2.
Dataset S4. Vehicle data from Transect 2.
Dataset S5. Binned ADCP data from Transect 3.
Dataset S6. Vehicle data from Transect 3.
Dataset S7. Binned ADCP data from Transect 4.
Dataset S8. Vehicle data from Transect 4.