Bio-Physical Interactions: Stratified Turbulence and Thin Biological Layers

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Subsurface thin biological layers (made up of phytoplankton, zooplankton, bacteria, etc), on the order of < 5m in the vertical and > 10km in the horizontal, have been observed within coastal regions and the ocean (see bottom left panel in Figure 1) [1, 2]. These thin layers can contain a large portion of the biomass in the water column, persist for long periods of time, and have a significant effect on the local ecosystem.

Several mechanisms have been proposed for the formation of these thin layers, from primarily biological or physical controls to more complex bio-physical interactions [3]. Because these layers have been seen near regions of high dissipation and stratification (see top left panel in Figure 1 [2]), we wish to examine the role that interactions between stratified shear mixing events, which can lead to the growth or destruction of layers in the density field, and the growth rate of the biology have in the formation or destruction of these thin biological layers.

The project will consist of performing and analyzing two dimensional simulations of a simple biologically reactive tracer subject to stratified shear mixing events with different mixing time scales, from the relatively fast and vigorous overturns of a Kelvin-Helmholtz billow to the slower and more steady Holmboe waves (see right panel groups in Figure **??**). Linear stability analysis will be used to determine appropriate stratified mixing events to explore and the biologically reactive tracer will be modeled as a simple "P" (or phytoplankton) system that is passively advected by the physical flow field and has a source/sink term according to

$$\frac{\mathrm{D}P}{\mathrm{D}t} = \mu(z)P(S-P) - \lambda P \tag{1}$$

where P is the concentration of the biologically reactive tracer, $\mu(z)$ is the depth dependent growth rate of P due to sunlight exposure, S is a constant carrying capacity, and λ is the death rate of the biologically reactive tracer. The overall goal is to examine which conditions lead to the entrainment and persistence of the "P" tracer below the stratified layer by varying the growth rate parameter of the "P" tracer and the mixing event time scale.

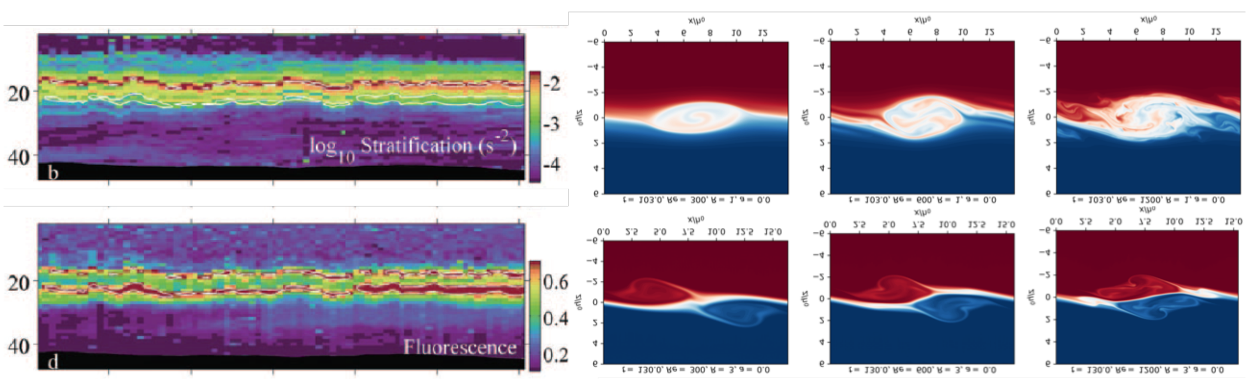

Figure 1: Left two panels adapted from from Shroyer et al 2014 [2] Figure 6: Example time series showing (b) stratification (N^2) and (d) fluorescence. Right grouping of panels show snapshots of stratified shear mixing events at different Reynolds numbers. (Top row) Kelvin-Helmholtz mixing events. (Bottom row) Holmboe mixing events.

References

[1] K. J. Benoit-Bird, E. L. Shroyer, and M. A. McManus. A critical scale in plankton aggregations across coastal ecosystems. *Geophysical Research Letters*, 40:3968–3974, 2013.

[2] E. L. Shroyer, K. J. Benoit-Bird, J. D. Nash, and J. N. Moum. Stratification and mixing regimes in biological thin layers over the mid-atlantic bight. *Limnology and Oceanography*, 59(4):1349–1363, 2014.

[3] P. J. S. Franks. Thin layers of phytoplankton: a model of formation by near-inertial wave shear. *Deep-Sea Research I*, 42(1):75–91, 1994.