MIXING FROM THE BLACK SEA TO THE AEGEAN VIA THE BOSPHORUS

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Abstract
The waters surrounding western Turkey contain a rich variety of mixing regimes owing to differing combinations of currents, stratification and bathymetry. Examples from disparate situations observed between 1994 and 2004 will be compared while identifying and quantifying the major mixing processes encountered.
Keywords : Bosphorus, Black Sea, Aegean Sea, Water Transport.

Meeting Umit Unluata at the 1991 IUGG nutured an interest aroused by a recent paper [1] about the exchange through the Bosphorus into a broader curiosity about the fascinating oceanographic environments feeding into the strait. Working from R/V Bilim in 1994 with Emin, Latif and Sukru, we examined hydraulics and turbulence of the Bosphorus in detail, discovering that the exchange flow is far from the idealized case described by analytical models [2]. In particular, the complex bathymetry and shape result in the narrowest part of the channel, known as the Contraction, not having the smallest cross-section and upper and lower parts of the exchange flow crossing the southern sill on opposite sides of the channel [3]. Owing to the intense turbulence, the regime appears to be at least partly controlled by friction rather than being the simple exchange of ideal fluids assumed in many hydraulic models.

During late summer we found very weak background mixing on the shelf north of the strait [4,5], very different than on shelves adjacent to the open ocean where tidal currents produce turbulence levels decades larger than the nearly molecular diffusivities we observed. No so, however, during late winter of 2003, when, working from R/V Knorr we found a strong rim current flowing over sharp cliffs apparently produced by massive slumps that removed portions of the continental slope. Where the slope is smooth, e.g., just west of the Bosphorus, mixing was much weaker, but above the levels found in late summer.

In the middle of the Black Sea's western gyre turbulent dissipation rates in the oxycline were moderately strong during a cold air outbreak that cooled the overlying surface water to 6.1°C [6]. Owing to the very strong stratification produced by the halocline, these dissipation rates correspond to diapycnal diffusivities of only (1-4) x 10^{-6} m^2/s, too low to resupply the suboxic layer by vertical mixing. In spite of the winds accompanying the cold air outbreak, turbulence in the weakly stratified water below the halocline was so weak that we are reformulating the way we compute dissipation rates to distinguish very weak turbulence from noise.

As we found while working on R/V Oceanus during late autumn of 2004, the Aegean has a two-layer density structure similar to the Black Sea, with equally weak mixing away from land. To our great surprise, internal tides, though weak, are significant and produce mixing signatures near some bathymetry. Low-frequency flows along the continental slopes seem to be the other process generating strong mixing close to the bottom.

References

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