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Effects of high-frequency motions on mixed-layer deepening

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The U.S. Naval Research Laboratory conducted a three-week field experiment to investigate coherent structures in the mixed layer (ML), and their effects on mixing and ML depth during wintertime under variable wind and surface-wave conditions. Atmospheric flux, ocean current, and hydrographic observations were collected in February 2017 on the outer shelf (depths from 80 to 100 m) in the Gulf of Mexico. Wintertime weather was dominated by passages of atmospheric cold fronts followed by dry and low-wind periods. Winds varied from 2 to 17 m/s and significant surface-wave heights (Hs) were between 0.3 and 3.2 m, while ocean currents were eastward with three-week mean speeds of about 24 cm/s near the surface and 4 cm/s near the bottom. The ML depth ranged from about 2 to 77 m. Winds were greater than 10 m/s and Hs was larger than 1.5 m when atmospheric cold fronts passed over the study area. At the onset of high-wind/large surface-wave events, current-shear increased, Richardson number (Ri) dropped below the critical value of 0.25 near the surface, and the ML began to deepen indicating initial development of shear- and wave-driven mixing. As wind/wave forcing continued larger values of shear and low Ri occurred as the ML deepened further. The high-shear region extended below the ML depth. Moreover, velocity observations indicated development of coherent structures that extended from the sea surface to the bottom of the ML with along-wind, cross-wind, and vertical velocities as high as 10, 10, and 5 cm/s, respectively. These structures seemed to have characteristics of Langmuir circulations and persisted until winds and surface waves subsided.