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Generation of Kelvin-Helmholtz Billows and Internal Solitons at Geophysical Fronts

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Kelvin-Helmholtz billows and internal solitons are two distinct types of fine-scale (10-100 m) flow structure, generally studied separately, that contribute significantly to turbulence in lakes, oceans and atmospheres. Kelvin-Helmholtz billows are self-organized swirls that initially develop when the destabilizing effect of vertical current shear overcomes the stabilizing effect of density stratification. Being in turn gravitationally unstable, the billows then break into turbulence. Internal solitons are hump-shaped nonlinear gravity waves that propagate along density interfaces. These waves may also break into turbulence when encountering destabilizing conditions, sometime in a manner comparable to surface wave breaking on beaches. Although patchy and episodic, these two nonlinear and nonhydrostatic processes are widespread and energetic enough to participate in global-scale air and water masses modifications. Yet, these fine-scale processes are unresolved, and even unparameterized in many cases, in global circulation models and in the vast majority of regional-scale models, making predictions questionable. One reason for this shortcoming is due to the limited understanding of their generation mechanisms. While the basic mechanism for generating Kelvin-Helmholtz billows is understood, the shear origin is often not. As for internal solitons, there is only a handful number of known generation mechanisms, but these alone cannot explain the richness of the observed wave field. Based on field observations and idealized numerical simulations we report here a new mechanism by which a forced intrusion at a convergent front in the Saguenay Fjord (Canada) can simultaneously generate Kelvin-Helmholtz billows and trains of internal solitons that are energetically comparable to those generated by internal tide steepening in the South China Sea. Given the widespread occurrences and importance of geophysical fronts, this result suggests that fronts may be important for generating turbulence and internal waves in geophysical fluids.