

A Novel Approach to Understanding the Effects of Turbulence on Frontogenesis

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Fronts are an important submesoscale feature in the ocean mixed layer, as they provide a direct link in the forward energy cascade from the mesoscales down to the dissipative scales. Dynamics associated with frontal sharpening, also known as frontogenesis, dictate how energy is transferred to the smaller scales through the overturning circulation and frontal instabilities. However, classic theory of fronts predicts that the cross-frontal scale becomes infinitely thin within a finite time, an unphysical outcome that does not comply with observations and model simulations. The presence of turbulence may be responsible for keeping the fronts at the scale observed, yet a complete understanding of how and why this happens is a long-standing problem. A perturbation analysis is used to include the essential effects of parameterized turbulence in the form of eddy viscosity and diffusivity, as a first order correction to existing strain-induced inviscid, adiabatic frontogenesis theory. A modified solution is obtained by using potential vorticity (PV) and surface conditions to quantify the contribution of turbulent fluxes. It is found that horizontal viscosity and vertical diffusivity tend to be frontolytic and oppose frontal sharpening, whereas vertical viscosity and horizontal diffusivity tend to be frontogenetic and strengthen the front. Surface conditions alone, specifically near the front maximum, are sufficient to obtain the first order correction to the along-front velocity, whereas surface conditions and PV fluxes are both necessary to describe the overturning circulation. Diagnosis of resolved arrested fronts in Large Eddy Simulations allows quantitative evaluation of the theory, generalized to a broad assessment of frontal width under different conditions and instabilities.