Abstract View

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Mixed Layer Deepening Due to Langmuir Circulation

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ABSTRACT

The interaction between wind-driven Langmuir circulation and preexisting stratification is examined in order to elucidate its role in the deepening of the ocean surface mixed layer. For linear stratification, a numerical model suggests that Langmuir cells initially engulf water and create a homogeneous surface layer. The depth $\tilde{h}$ of this layer can be understood in terms of a Froude number Fr = $\tilde{w}_{dn}/(N\tilde{h})$, where $\tilde{w}_{dn}$ is the maximum downwelling velocity generated by Langmuir circulation in homogeneous water and N is the buoyancy frequency. Numerical results show that Fr is a constant $\approx$ 0.6. Using computed values of $\tilde{w}_{dn}$, this implies that the rapid mixed layer deepening stops at $\tilde{h} = cu_*/N$ in which u_* is the water friction velocity and the coefficient c is about 10 for fully developed seas. Alternatively, the deepening is arrested when the buoyancy jump Δb at the mixed layer base reaches about $50u^2_*/\tilde{h}$. The above formula, compared with the Price, Weller, and Pinkel value of 0.65 for the bulk Richardson number R_b associated with shear mixing, suggests that engulfment by Langmuir circulation dominates mixed layer deepening if the velocity difference $|\Delta\tilde{\mathbf{u}}|$ across the base of the mixed layer is less than about $0.01U_w$, where U_w is the wind speed. The buoyancy jump criterion is tested for two-layer stratification profiles and found to be a robust formula suitable for incorporation into one-dimensional mixed layer models.

The possibility of further mixed layer deepening through shear instability is studied by examining the distribution of the gradient Richardson number Ri_g, particularly in a transition region beneath the mixed layer. It has great variability across wind, reaching minimum values beneath downwelling jets, but can fall below 0.25, indicating the onset of shear instability. Thus, Langmuir cells may facilitate shear instability in a horizontally confined region beneath downwelling jets, although further study will require allowance for a different background shear.

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