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A Langmuir turbulence parameterization with a constrained potential energy conversion rate for application to climate simulations

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Accurate modeling of the ocean surface boundary layer (OSBL) is critical for many coupled ocean-atmosphere problems spanning from tropical cyclones to climate. One approach to parameterize vertical mixing in this regime follows the Kraus-Turner-Niiler paradigm, which emphasizes a constrained budget for the integrated potential energy conversion rate in the OSBL. The Kraus-Turner-Niiler method was originally implemented using bulk (well-mixed) boundary layer models, but is generalized within the energetic Planetary Boundary Layer parameterization (ePBL) to allow finite vertical mixing inside the OSBL. In this study we utilize a suite of Large Eddy Simulations to constrain the total integrated potential energy conversion rate by vertical mixing for ePBL to parameterize boundary layer processes including convective turbulence, wind-driven shear turbulence, and Langmuir turbulence. A feature of the ePBL parameterization is that it is insensitive to ocean model design factors such as vertical resolution and model time-step, which is a critical feature for application to climate simulation. We utilize the new parameterization to investigate the impact of surface waves via Langmuir turbulence on coupled global ocean climate simulation. Our results are generally consistent with previous studies, showing that Langmuir turbulence increases vertical mixing for wind-driven (Summer) mixed layers, but it has a muted relative impact on mixing in convective (Winter) mixed layers. This acts to reduce mixing biases common to ocean climate simulation. We note similarities and differences in this theory and previous studies to identify remaining uncertainties and challenges for future OSBL parameterization development.