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A new local theory of available potential energy for quantifying energy pathways in the oceans

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Lorenz's theory of available potential energy (APE) has recently received much attention in the context of ocean energetics, for it is increasingly realized to be a key tool for clarifying the relative importance of the surface buoyancy fluxes in powering the ocean circulation, a controversial issue over the past 15 years or so. So far, however, most recent approaches have been restricted to global APE budgets, often for idealized equations of state, which is arguably of limited interest to understand the precise nature of the energy pathways in the oceans. Here, we will present a local extension of the theory of available potential energy, which is developed for the primitive equations that form the basis of most current general ocean circulation models, and which is valid for an arbitrary nonlinear equation of state. Another advantage of the new theory is that it does not require the reference state underlying Lorenz's APE theory to be necessarily the state of minimum potential energy obtained in an adiabatic re-arrangement of the fluid parcels, and hence does not suffer from traditional difficulties pertaining to how to do the sorting of the fluid parcels. The main result of this work is the ability in some instances to link local conversion of APE into kinetic energy directly to the local production of APE by surface fluxes. The framework is also shown to be useful to provide an energy-based characterization of oceanic water masses.