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Available Potential Energy: A Clarification

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ABSTRACT

In order to clarify some inconsistencies in the literature, on ocean energetics, the evaluation of the available potential energy (APE) is reconsidered. Attention is focused on the baroclinic APE under conditions in which the hydrostatic approximation prevails. Following Margules and Lorenz (ML), we define this as the difference between the total enthalpy of a given sample state of the fluid and that of an isentropically leveled state having the same mass. It is partly gravitational potential energy and partly elastic internal energy. For emphasis, we denote this as the ML APE. It differs from the gravitational part (APE_g) by an amount that depends on whether the elastic internal energy is released (as in the atmosphere) or stored (as in the ocean) during an isentropic leveling process. In the ocean the ML APE is found to be somewhat less than the APE_g, in contrast to the atmosphere where the ML APE greatly exceeds the APE_g. This difference is ascribed to the temperature dependency of compressibility, which has opposite sign as well as different magnitude for sea water as compared to air.

A series expansion of the ML APE which explicitly accounts for mass conservation is given for a general binary fluid. The leading term in this expansion is positive definite for a stably stratified reference state and is equivalent to an approximation of APE frequently employed in ocean modeling studies. It is shown that this is a reasonable approximation (±10%) even for large perturbations, as in Gulf Stream rings.

A similar series expansion of the APE_g shows that for seawater the difference from the ML APE should not exceed ∼20%. On the other hand, estimates based on the unexpanded form of the APE_g are vulnerable to serious error unless special care is taken to assure that the reference state is consistent with mass conservation. Some examples of erroneous estimates for Gulf Stream rings, in which the APE is too large by a factor of 3 or more, are identified. The correct estimates of the APE are comparable to the kinetic energy for the case of mesoscale eddies in the sea.

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