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Entropy production and buoyancy power input in the oceans

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A controversial topic in oceanography for the past hundred years has been whether surface buoyancy fluxes can contribute significantly to the mechanical power input of energy in the oceans. On one side, a popular interpretation of Sandstrom's "theorem" holds that the buoyancy power input B must be negligible in the oceans, because buoyancy fluxes are approximately applied at the same pressure level. On the other side, observational estimates of B based on the available potential energy production rate G(APE) suggest that B is comparable with the mechanical power input due to the wind and tides. To a large extent, the controversy stems from the lack of agreement on how to define and quantify the power input due buoyancy forcing in stratified fluids. This is in contrast with the problem of estimating the power input due to the wind and tides, which is comparatively well understood. The purpose of this work will be to review the fundamental issues associated with the definition and estimation of B starting from first principles. The main result is that there appear to be several possible physically-meaningful approaches to defining and quantifying B in ways that only involve the surface buoyancy forcing. One of them is in terms of the APE production rate G(APE), as has been proposed before. An alternative measure involves the entropy production rate by surface buoyancy fluxes. The two measures appear very different, however. The physical origin for such differences will be discussed and clarified.