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A revised sea level budget equation to accurately represent physical processes driving sea level rise

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The sea level budget (SLB) equates changes in sea surface height (SSH) to the sum of various geophysical processes that contribute to sea level change. Currently, it is a common practice to explain a change in SSH as a sum of ocean mass and steric change, assuming that solid-Earth motion is corrected for and completely explained by secular visco-elastic relaxation of mantle, due to the process of glacial isostatic adjustment. Yet, since the Solid Earth also responds elastically to changes in present day mass load near the surface of the Earth, we can expect the ocean bottom to respond to ongoing ocean mass changes. This elastic ocean bottom deformation (OBD) has been ignored until very recently because the contribution of ocean mass to sea level rise was thought to be smaller than the steric contribution and the resulting OBD was within observation system uncertainties. However, ocean mass change has increased rapidly in the last 2 decades. Therefore, OBD is no longer negligible and recent studies have shown that its magnitude is similar to that of the deep steric sea level contribution: a global mean of about 0.1 mm/yr but regional changes at some places can be more than 10 times the global mean. Although now an important part of the SLB, especially for regional sea level, OBD is considered by only a few budget studies and they treat it as a spatially uniform correction. This is due to lack of a mathematical framework that defines the contribution of OBD to the SLB. Here, we use a mass-volume framework to derive, for the first time, a SLB equation that partitions SSH change into its component parts accurately and it includes OBD as a physical response of the Earth system. This updated SLB equation is important for various disciplines of Earth Sciences that use the SLB equation: as a constraint to assess the quality of observational time-series; as a means to quantify the importance of each component of sea level change; and, to adequately include all processes in global and regional sea level projections. We recommend using the updated SLB equation for sea level budget studies. We also revisit the contemporary SLB with the updated SLB equation using satellite altimetry data, GRACE data, and ARGO data.