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Estimate of the global and regional Ocean Heat Content changes from space gravimetry and altimetry observations to assess the Earth Energy Imbalance variations and trend

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The Earth energy imbalance (EEI) at the top of the atmosphere (TOA) is the cause of the energy accumulation in the climate system. Measuring the EEI is challenging because it is a globally integrated variable whose variations are small (0.5-1 W.m−2) compared to the amount of energy entering and leaving the climate system (~ 340 W.m-2). 91% of the excess of energy stored by the planet in response to the EEI is accumulated in the ocean in the form of heat making the ocean heat content (OHC) change an accurate proxy of EEI.

In this work, we adopt the space geodetic approach which relies on the sea level budget equation to estimate the OHC changes. The thermosteric sea level change is derived at regional scale from a combination of space altimetry and space gravimetry observations, and divided by the integrated expansion efficiency of heat to estimate the OHC changes. The global OHC (GOHC) change is then estimated by a spatial integration of the regional OHC changes. The uncertainty in GOHC is estimated by propagation of the uncertainty of input data using the input data error variance-covariance matrix to account for the instrumental and post-processing errors and for the time correlation in errors.

Regional estimates of the OHC changes are validated over the Atlantic Ocean directly against data from in-situ Argo profiles and indirectly by an energy budget approach. In the energy budget approach, surface heat flux derived from ERA5 and CERES TOA radiation budget are combined with regional OHC changes to estimate the north Atlantic meridional heat transport which is then validated against in-situ RAPID and OSNAP estimates. Both validations show good agreement in terms of signal amplitudes and variability with time correlations above 0.6.

Over the period 1993-2022, the GOHC shows a significant positive trend of 0.75 W m-2 [0.61, 1.04]

at the 90% confidence level, indicating a positive mean ocean heat uptake or EEI. Comparisons with GOHC estimates based on in-situ ocean temperature measurements over the full ocean depth show good agreement over 2005-2019 (Marti et al. 2023, in review). Over 2000-2020, the ocean heat uptake presents a positive trend of 0.33 W/m²/decade, significant at the 90% confidence level and in agreement with CERES estimate. This EEI trend reflects an acceleration in ocean warming.

The two space geodetic products based on space altimetry and space gravimetry are freely available on the AVISO website. One estimating the GOHC and EEI (https://doi.org/10.24400/527896/a01-2020.003), the other estimating regional OHC over the Atlantic Ocean (https://doi.org/10.24400/527896/a01-2022.012).