EARTH OBSERVATION

Monitoring the Ocean Heat Content change and the Earth Energy Imbalance from Space Altimetry and Gravimetry missions

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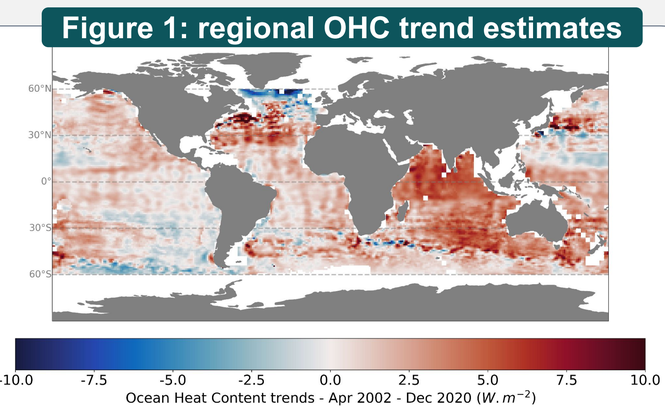
The **Earth energy imbalance (EEI)** at the top of the atmosphere is responsible for the accumulation of heat in the climate system. The EEI monitoring is therefore necessary to better understand the Earth's warming climate. Measuring the EEI is challenging as it is a globally integrated variable whose variations are small (0.5-1 W/m²) compared to the amount of energy entering and leaving the climate system (~ 340 W/m²). Since the **ocean absorbs about 90 %** of the excess energy stored by the Earth system, estimating the **ocean heat content (OHC)** change provides an accurate proxy of the EEI.

From the regional OHC change estimates…

- The regional OHC estimates can be derived from several approaches (Meyssignac et al. 2019):
  - in situ temperature/salinity profiles,
  - space observations of the ocean surface net fluxes,
  - ocean model reanalyses

- In the following, regional OHC change are estimated from the **space geodetic approach** (Marti et al., 2022):
  - It relies on the **sea level budget equation** : $$\Delta OHC = \frac{\Delta SL - \Delta OM - \Delta HSSL}{IEEH}$$
  - Sea level altimetric products from C3S and ocean mass solutions from (Blazquez et al. 2018) are used
  - More detailed description is given in the poster **SC12022_005** *(4DATLANTIC-OHC Project)*

Figure 1: regional OHC trend estimates



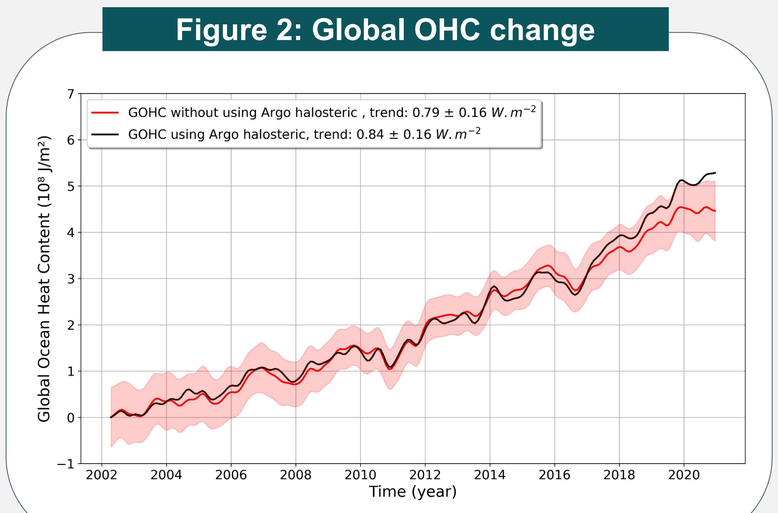
..To the global OHC change and EEI…

Global OHC change estimates results from the sum of regional OHC change estimates (Figure 2):

- Referenced to Top-of-atmosphere surface (5.13×10^{14} m²).

- Argo-based halosteric sea level variations **are not corrected** due to anomalies on the conductivity sensors from 2016 onwards (Wong et al., 2020).

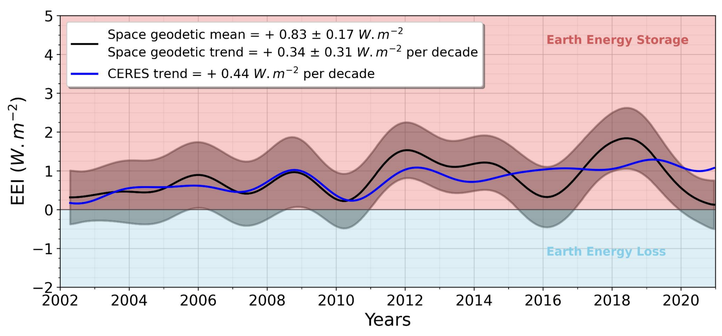
Figure 2: Global OHC change



EEI is obtained computing the time derivative of the global OHC time series (Figure 3) after:

- removing out the **internal ocean variability in OHC change** with a low pass filter at 3 years,
- dividing by the energy absorption factor into the global ocean : **90% of the EEI**, von Schuckmann et al., 2020).

Figure 3: EEI



The positive mean value of EEI (**+0.83 ± 0.16 W m^{-2}**) indicates that the **earth system is storing energy** with a very good confidence level, and the positive trend of the EEI evolution (**+0.03 W m^{-2} yr^{-1}**) shows that this is probably happening more and more rapidly.

..And their uncertainties

Uncertainties calculation is a main task in order to verify the EEI stability requirements:

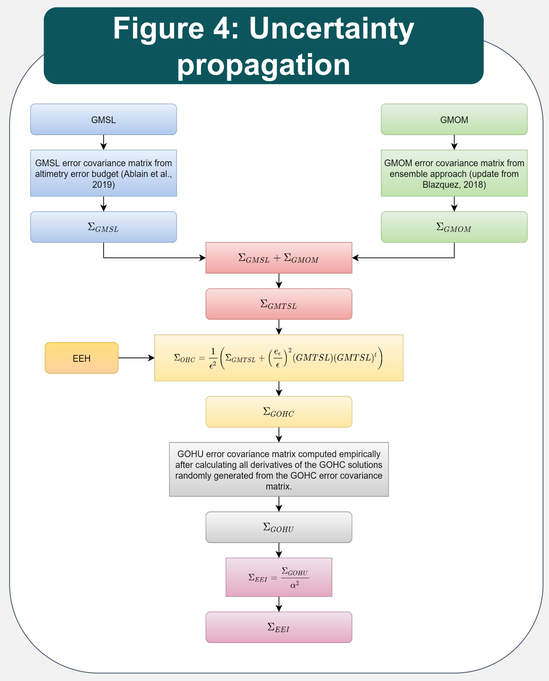
- < 0.3 W m^{-2} for the mean
- < 0.1 W m^{-2} at interannual scales

Global OHC & EEI uncertainties are estimated:

- propagating the variance-covariance matrices (Σ) of sea level (Ablain, 2019) and ocean mass computed from an ensemble approach (Blazquez, 2018),
- until the the global OHC and EEI (Figure 4).

Uncertainty on the trends or accelerations are calculated **at any time and for any period length** applying an adapted mathematical formalism using Σ .

Figure 4: Uncertainty propagation



Comparisons and assessment

- Comparisons with temperature and salinity profiles from 6 Argo-based datasets highlight higer global OHC trends with the space geodetic approach (+0.2 W m-2, Table 1), but in **agreement within the 90% confidence level interval**
- Comparisons with Clouds and the Earth's Radiant Energy System (CERES) allow us to to assess the space geodetic EEI variations (Figure 3, blue curve):
  - **good correlation** are observed before 2016
  - 0.4 W m^{-2} EEI **discrepancies after 2016** are under investigations

Data type	Depth range	Global OHC trends (W m^{-2}) (uncertainties at 10-90 %CL)		
		2005-2016	2002-2016	2002-2020
Satellite data from altimetry (C3S) and gravimetry (GRACE/GRACE-FO) missions	0-bottom	**+0.78 ± 0.19**	**+0.71 ± 0.18**	**+0.79 ± 0.16**
Temperature and salinity profiles from 6 Argo based datasets	0-2000m (with deep ocean contribution of +0.07 W m^{-2})	**+0.57 ± 0.10**	**+0.55 ± 0.10**	**+0.60 ± 0.10**

Table 1: global OHC trends comparison

Dissemination & perspectives

The global OHC and EEI product based on space geodetic approach is publicly available on the **ODATIS/AVISO** portal:

https://doi.org/10.24400/527896/a01-2020.003

Future work:

- Improve the temporal resolution of the EEI spatial geodetic indicator to monthly scale to monitor climate change more accurately and to be able to measure the effect of mitigation measures such as greenhouse gas (GHG) emission reductions.

References

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- ESA MOHeaCAN project: https://eo4society.esa.int/projects/moheacan/

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