Monitoring the regional Ocean Heat Content change over the Atlantic Ocean with the space geodetic approach

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The estimation of the regional Ocean Heat Content (OHC) is essential for climate analysis and future climate predictions. The 4DAtlantic-OHC Project (2021-2023) aimed at developing and testing space geodetic methods to estimate the regional **ocean heat content (OHC)** change over the Atlantic Ocean from satellite altimetry and gravimetry. The strategy developed in the frame of the ESA MOHeaCAN Project was extended at regional scale both for the data generation and the uncertainty estimate.

The space geodetic approach

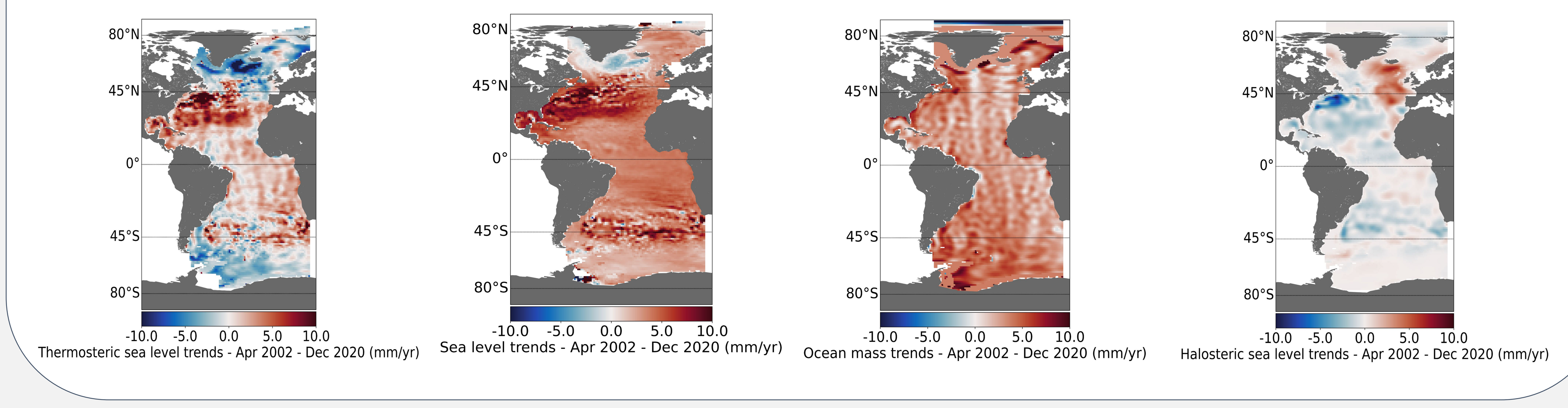
OHC change time series may be inferred by different methods (Meyssignac et al., 2019). An indirect approach is the space geodetic approach which relies on the **sea level budget** equation. The ESA-funded project MOHeaCAN acted as a proof-of-concept, describing the application of the space geodetic approach on a global scale (Marti et al., 2022). The space geodetic approach aims at measuring the thermosteric sea level change due to seawater density change induced by temperature based on differences between the **total sea level** change derived from satellite altimetry measurements and the **barystatic sea level** change from satellite gravity measurements. **Halosteric sea level** variations due to saline contraction are estimated from in situ data and removed from the total sea level variations (Figure 1).

Figure 1: Deriving thermal expansion of the ocean

From the sea level budget equation, **thermosteric sea level change** is calculated:

$$\Delta SL_{thermosteric} = \Delta SL_{total} - \Delta SL_{mass} - \Delta SL_{halosteric}$$

- ΔSL_{total}: Space altimetry from Copernicus Climate Change Service
- ΔSL_{mass}: Space gravimetry ensemble from GRACE(-FO), update of Blazquez et al. 2018
- $\Delta SL_{halosteric}$: In situ based, from Argo, combination of ISAS20 (0-2000m) and EN4.2.2.l09 (below 2000m)



The OHC change is computed at regional scales (Figure 3) by dividing the thermosteric sea level change with the **Integrated Expansion Efficiency of Heat** (IEEH) coefficient: it expresses the change in ocean density due to heat uptake (Figure 2) and it is estimated from in situ temperature and salinity measurements.
OHC change uncertainties are estimated by uncertainty propagation from input data until OHC change.

Figure 2: IEEH mean value

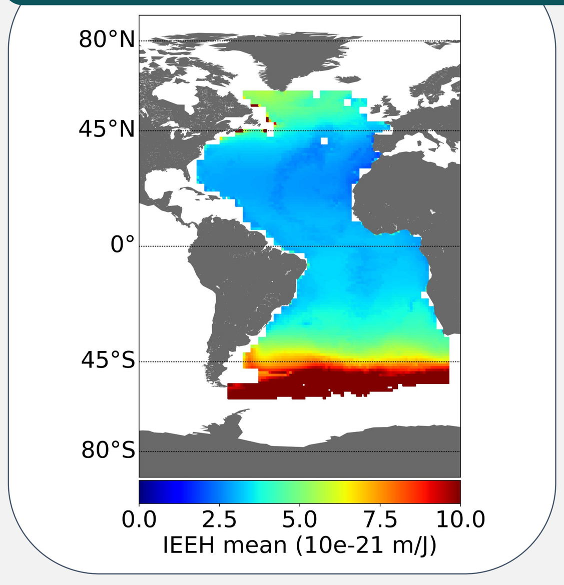
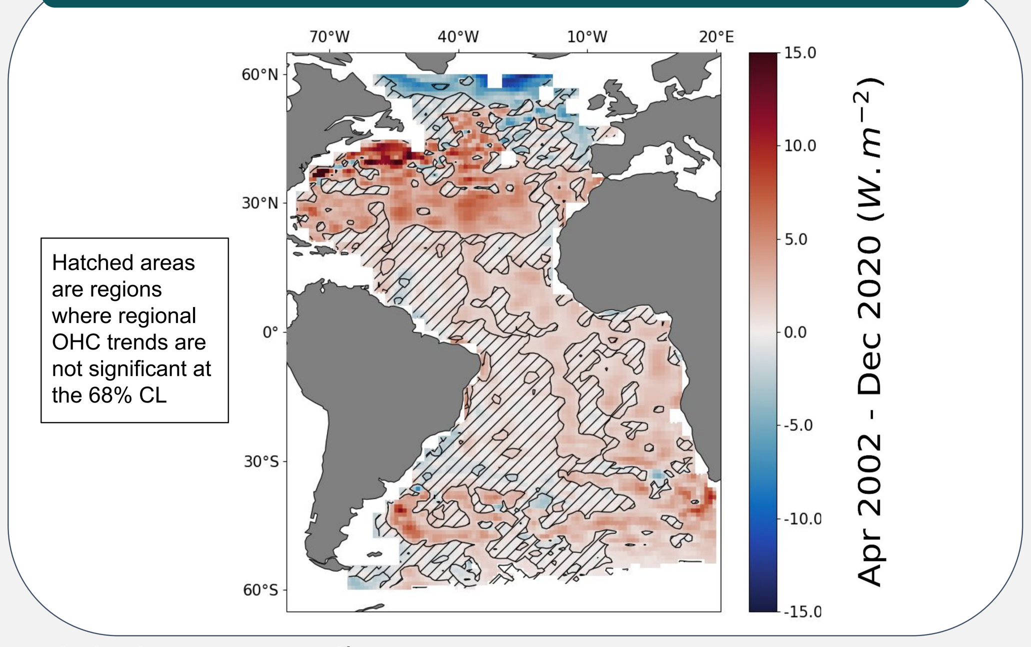


Figure 3: Ocean Heat Content trends



- ➔ trend over the Atlantic basin of 0.17 W/m² (21% of the global OHC trend).
- ➔ warming pattern has been evidenced in the southern and western parts of the North Atlantic,
- ➔ northeastern part exhibits cooling trends.
- ➔ OHC trends uncertainties essentially due to manometric uncertainties (GRACE(-FO) data) ranging from 70% in the eastern part of the basin to over 99% in the western part.

Validation of the product

Validation activities were carried out over the Subtropical North Atlantic (SPNA) region (Figure 4a-b) and in the Subpolar North Atlantic (SNA) region (Figure 5a-b) against Argo dataset. Furthermore, the use of data from RAPID (Figure 4 c-d) and A25-OVIDE (Figure 5c) mooring sections highlights a good consistency in OHC trends with the space geodetic product.

Figure 4: Validation over the SPNA region

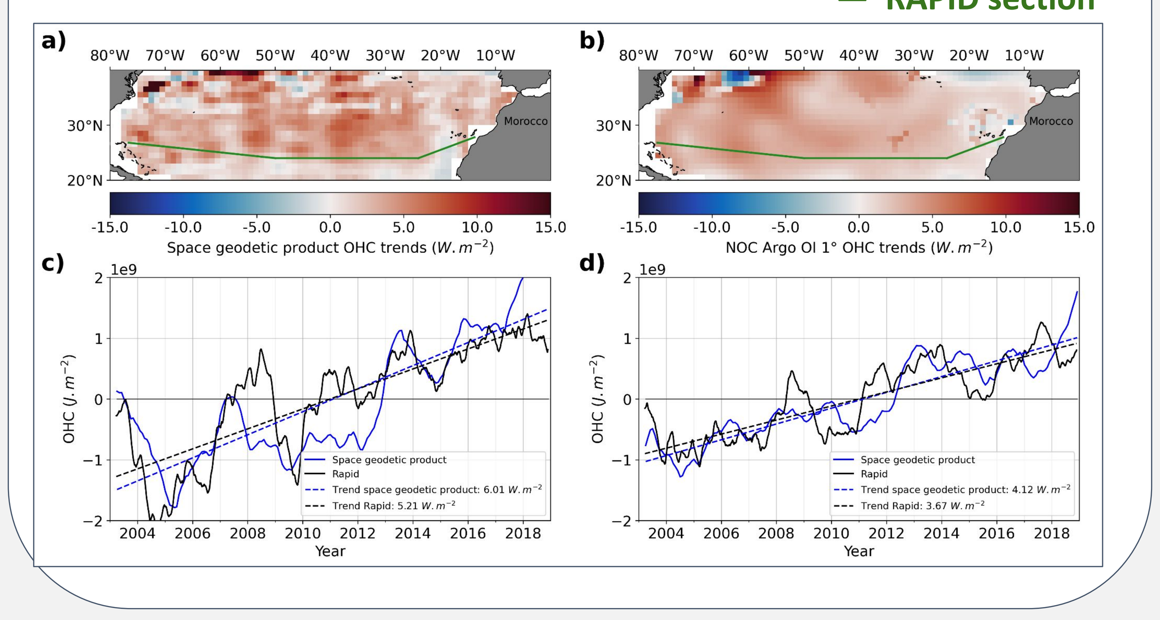
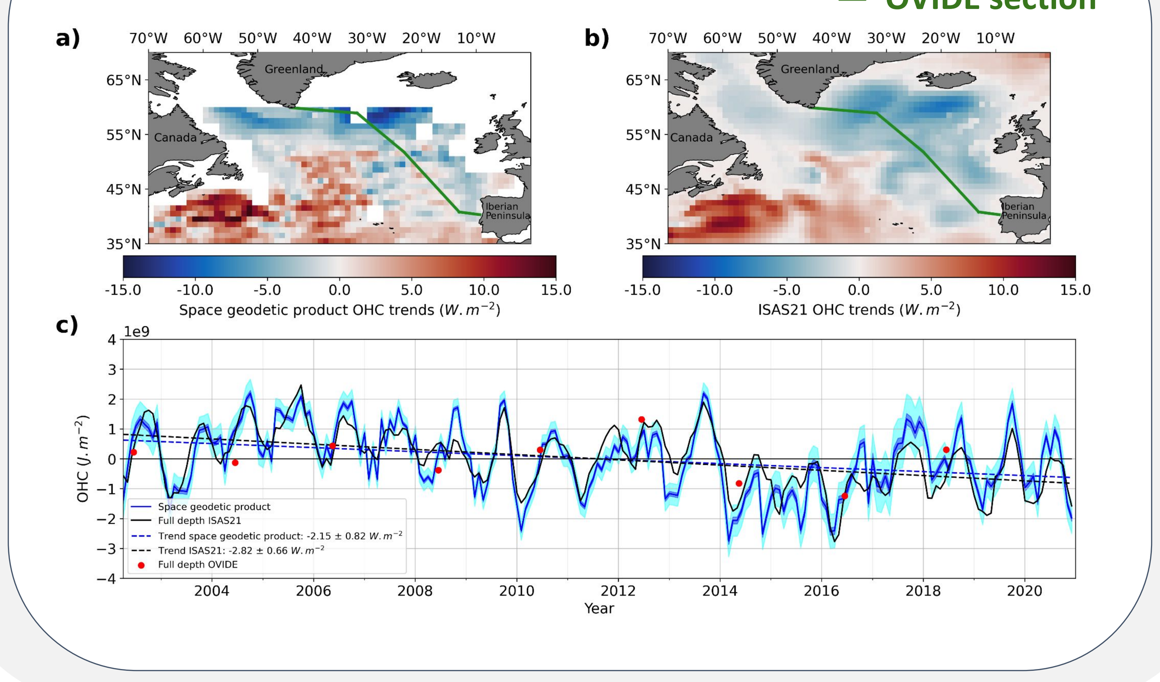


Figure 5: Validation over the SNA region



Science use case

- Estimate the Meridional Heat Transport (MHT) in the North Atlantic with a regional ocean heat budget approach
- Validate it against in-situ data (RAPID & OSNAP)
- Analyse the variability of the MHT and its cause in the North Atlantic

Dissemination & perspectives

- ➔ The product is available to the scientific community on the **ODATIS/AVISO** portal: https://doi.org/10.24400/527896/A01-2022.012
- ➔ **Estimation of the OHC change and its uncertainties on a regional scale using the geodetic approach is described in detail in Rousseau et al. 2023**
- ➔ **Perspectives**
  - ◆ To extend the progress made to other ocean basins
  - ◆ To improve our knowledge on the global energy budget
  - ◆ To transfer the results to a sustainable Essential Climate Variable (ECV)

Use case studies

Several use case studies have been realised such as:

- The improvement of the operational decadal predictions (BSC),
- The contribution to the Copernicus Marine Service ocean reporting activities (MOi),
- The evaluation for use as part of MetOffice climate indicators dashboard (MetOffice)

References

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

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