Monitoring the heat content change over the Atlantic Ocean with the space geodetic approach: the 4DATLANTIC-OHC Project

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Global Ocean Heat Content is a good proxy of the Earth Energy Imbalance (Meyssignac et al. 2019, von Schuckmann et al, 2020)

New method based on Space geodetic datasets to estimate the Global OHC (Marti et al., 2022)

Extend the method at regional scale to develop a gridded Atlantic OHC product to provide a realistic monitoring of the Atlantic ocean heat uptake

Estimate rigorously the associated uncertainty

Science investigation:

the role played by the Atlantic ocean in the climate system ?

the role and the impact of spatial pattern of ocean warming on the strength of climate feedbacks and climate sensitivity

- **Marti et al. 2022**: Monitoring the ocean heat content change and the Earth energy imbalance from **space altimetry** and **space gravimetry**

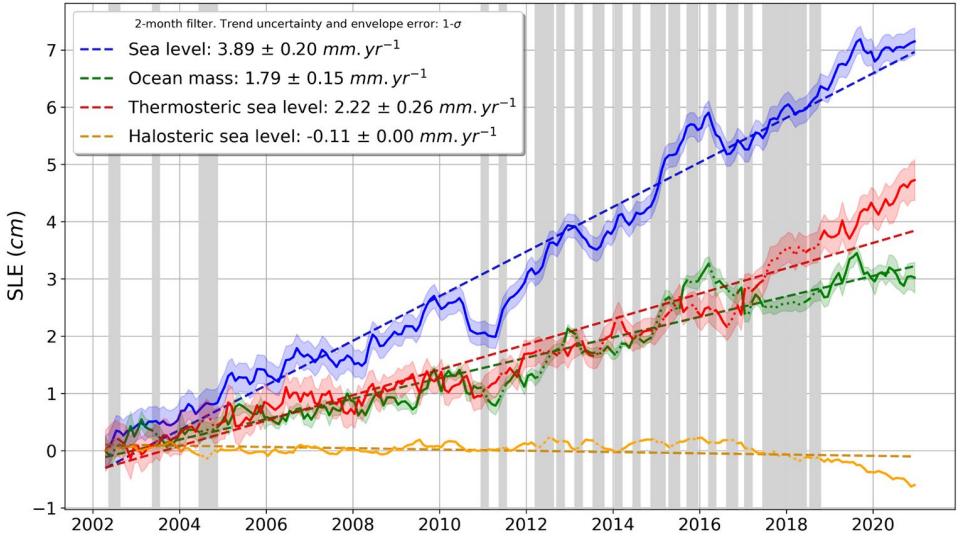
- The regional OHC (→ 1°x1°, monthly)

$$\Delta OHC = \frac{\Delta SL_{thermosteric}}{IEEH}$$

(IEEH = Integrated Expansion Efficiency of Heat)

- The Sea Level budget equation:

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



Global Mean Thermosteric Sea Level (red) obtained by removal of Ocean Mass (green) and Halosteric (orange) from the Sea Level (blue)

Sea level dataset from altimetry → ΔSL_{total}

- spatial resolution: 0.25° x 0.25°
- temporal resolution: daily
- temporal availability: altimetry era, January 1993 - August 2021
- units: m
- version: C3S

Gravimetry dataset from GRACE & GRACE follow on missions → ΔSL_{mass}

Ensemble of 288 OM solutions from Spherical Harmonic products and its ensemble mean update from (Blazquez et al., 2018)

- units: m equivalent water height (EWH)
- spatial resolution: 1° x 1°
- temporal resolution: monthly
- temporal availability: April 2002 - September 2021
- version: v1.5.1

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

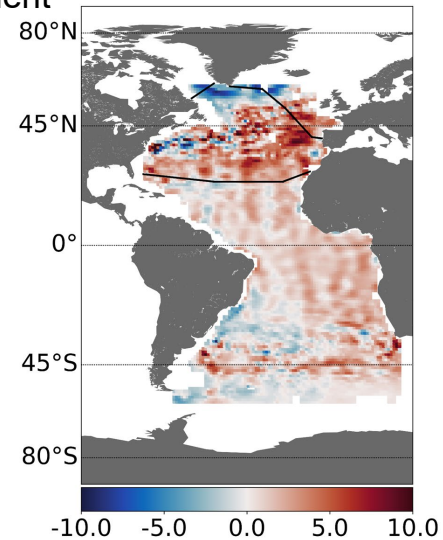
ISAS temperature and salinity gridded fields (Ifremer): ISAS20_ARGO release interpolated on 187 standard depth levels between 0-5500 m depth and 0.5°x0.5° global horizontal grid. ISAS20 use the version 8 of ISAS and updated statistics to produce the monthly analysis (Monthly Climatology and annual STD computed from WOA18A5B7). ISAS20 gridded fields analyze the Argo and Deep-Argo temperature and salinity data alone between 2002-2020 https://www.seanoe.org/data/00412/52367/

EN4 temperature and salinity gridded fields (MetOffice): Version is 4.2.2.l09 (Levitus member) EN4 files are available from https://www.metoffice.gov.uk/hadobs/en4/download-en4-2-2.html m from 1900 to the present day

For the study: Combination of ISAS20 product (0-2000m) and EN4 (2000-6000m).

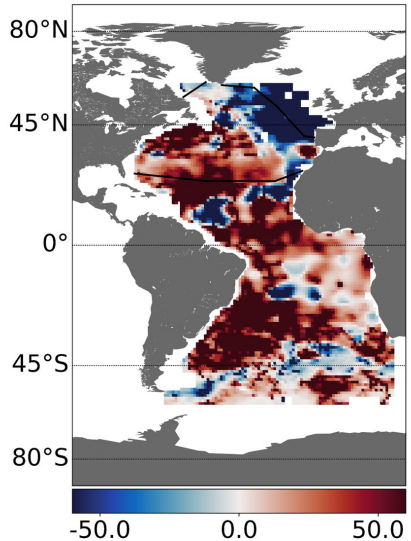
$$\Delta SL_{total} = \Delta SL_{thermosteric} + \Delta SL_{halosteric} + \Delta SL_{mass}$$

OHC trends **without** removal of halosteric component



Ocean Heat Content trends - Apr 2002 - Dec 2020 ($W.m^{-2}$)

OHC trends **difference** (%)



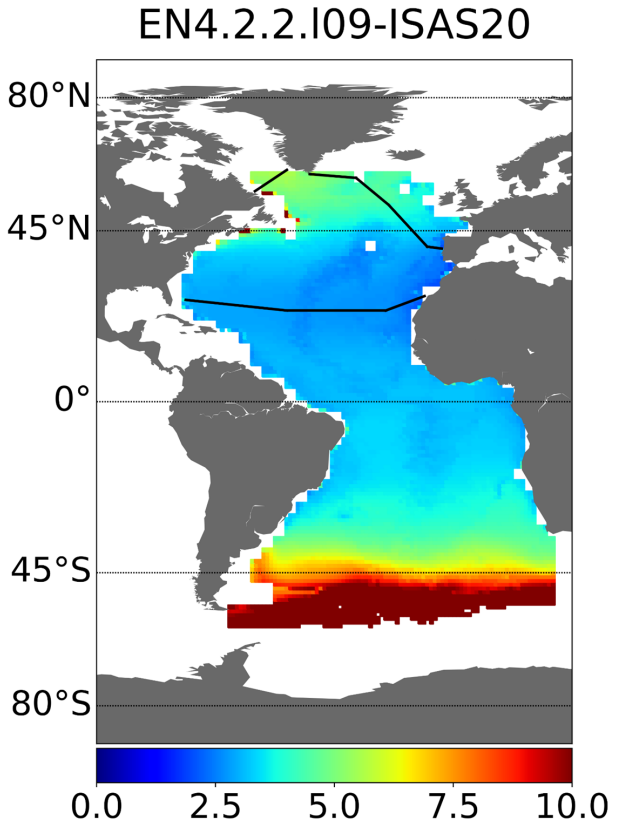
Ocean Heat Content relative trends - Apr 2002 - Dec 2020 (%)

- Halosteric signal has a significant impact on OHC trends estimates (up to 60%)

Integrated Expansion Efficiency of Heat

$$\Delta OHC = \frac{\Delta SL_{thermosteric}}{IEEH}$$

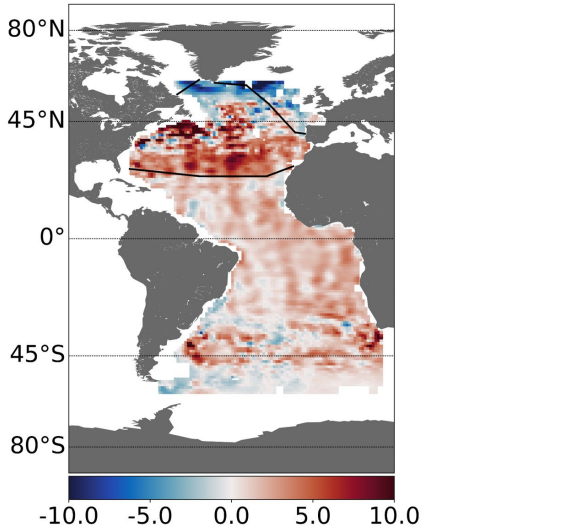
- IEEH is the division of local estimates of Thermosteric Sea Level over OHC
- In-situ OHC and thermosteric are filtered at 3 years to remove the HF variability
- IEEH is dependent on temperature, salinity, and pressure; increasing with temperature and pressure and decreasing with salinity
- Combination of EN4 (NOC) and ISAS (Ifremer) product to be representative of the full water column



Spatial distribution of IEEH mean over 2005-2015 (10e-21m/J)

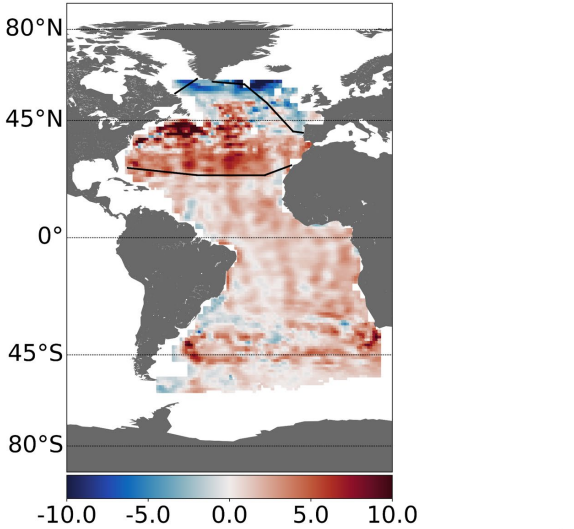
Deep ocean contribution : Use of Argo EN4.2.2.l09 dataset from 2000m to 6000m

OHC trends (0-2000m)



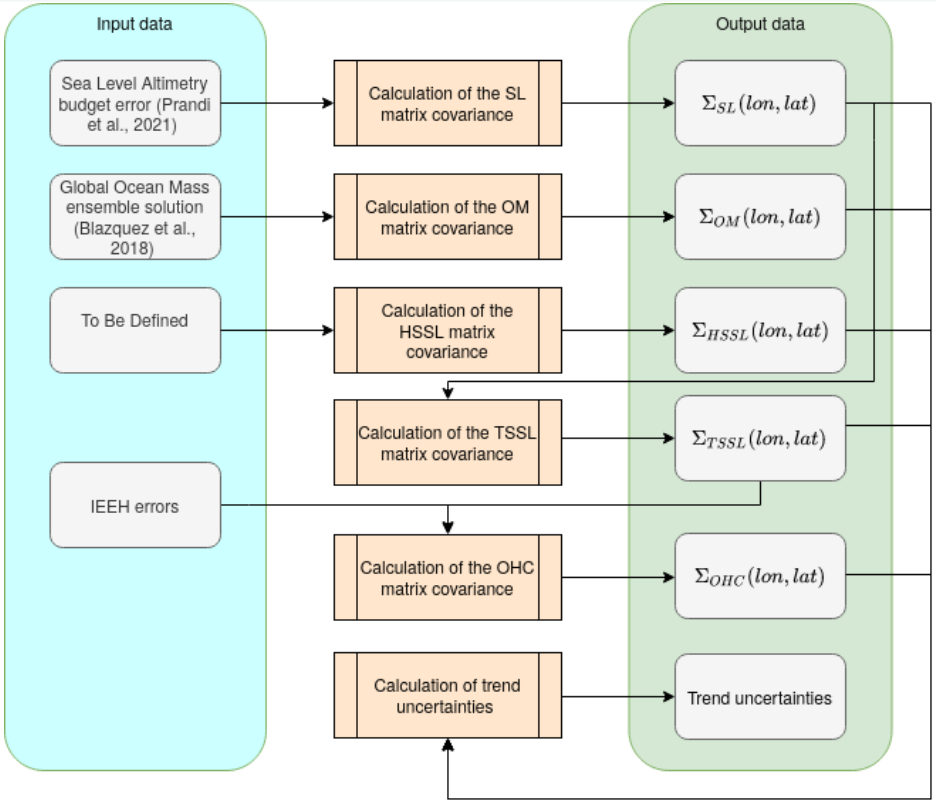
Ocean Heat Content trends - Apr 2002 - Dec 2020 ($W.m^{-2}$)

OHC trends (full depth)

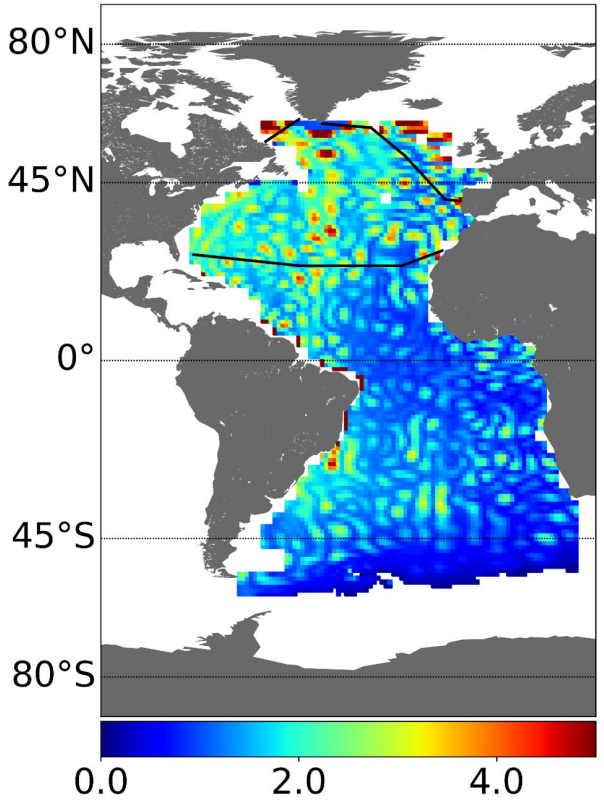


Ocean Heat Content trends - Apr 2002 - Dec 2020 ($W.m^{-2}$)

- Weak difference but represents a 5% decrease integrated over the Atlantic Ocean
- Really important to calculation the IEEH as accurately and rigorously possible
- The temporal variations of IEEH are quite negligible but we have taken them into account by using a time dependent IEEH (monthly)

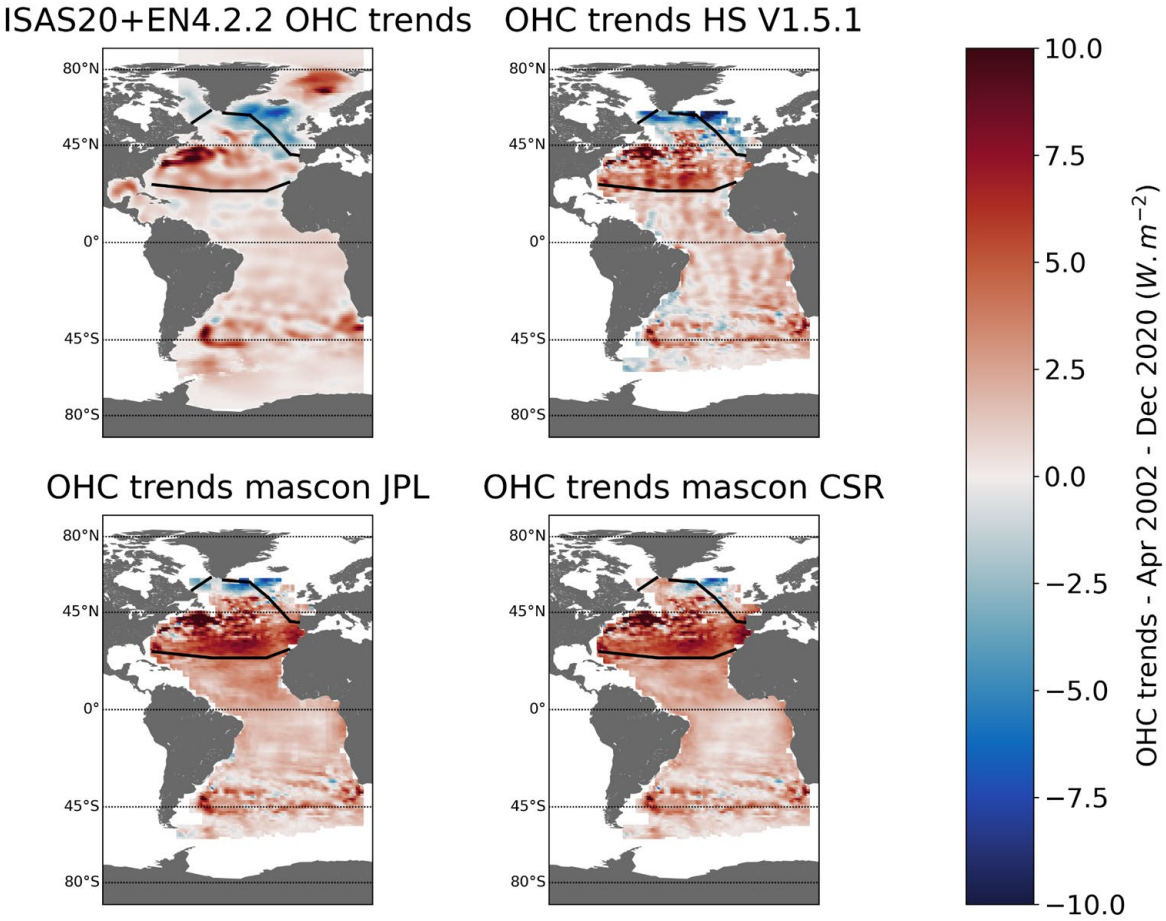


Uncertainty calculation and propagation chain

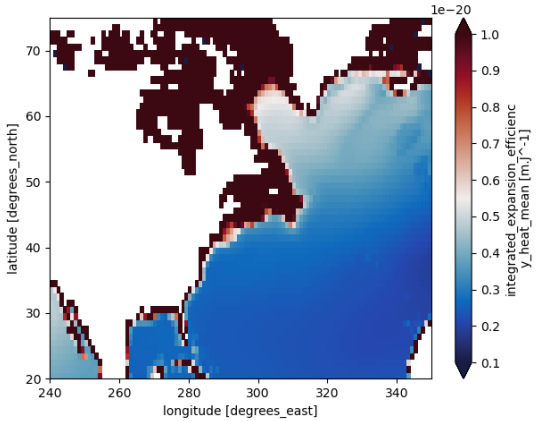


OHC trends uncertainties (W/m²) over Jul 2002 - Jul 2020 preliminary results

LPS – 27/05/2022


ISAS20+EN4.2.2 OHC trends
OHC trends HS V1.5.1
OHC trends mascon JPL
OHC trends mascon CSR
80°N
45°N
0°
45°S
80°S
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
OHC trends - Apr 2002 - Dec 2020 (W.m⁻²)

- **Product improvement: spatial coverage near coasts**
  - using the ECCOv4 reanalysis to complete In-situ observations



- First version of Atlantic OHC products will be delivered in Septembre 2022
  - temporal availability: April 2002 - September 2021
  - spatial resolution: 1° x 1°
  - temporal resolution: monthly

- **Available on the AVISO website**

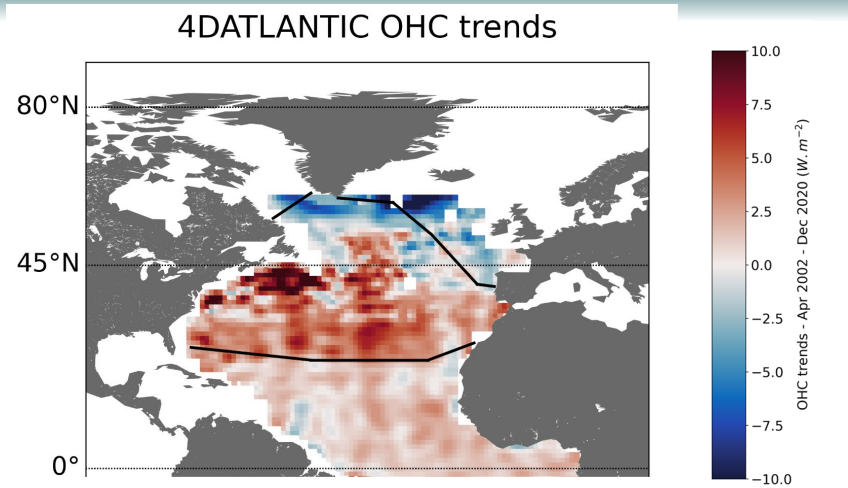
https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/ocean-heat-content-and-earth-energy-imbalance.html

referenced with a DOI

- **Products validation**
  - RAPID-MOCHA section (NOC)
  - OVIDE-AR7W section (LOPS)

- **Science case**

Estimating the Meridional Heat Transport (MHT) in the North Atlantic with a regional heat budget (LEGOS)



- **Early adopters assessment**

Use Case 1: Improvement of the operational decadal predictions

Test EO based OHC products for initialisation of decadal system

Use Case 2: Contribution to the Copernicus Marine Service ocean

Analyse consistency of EO based OHC products with existing CMEMS products used for the Ocean State Report

Use Case 3: Evaluation for use as part of climate indicators dashboard

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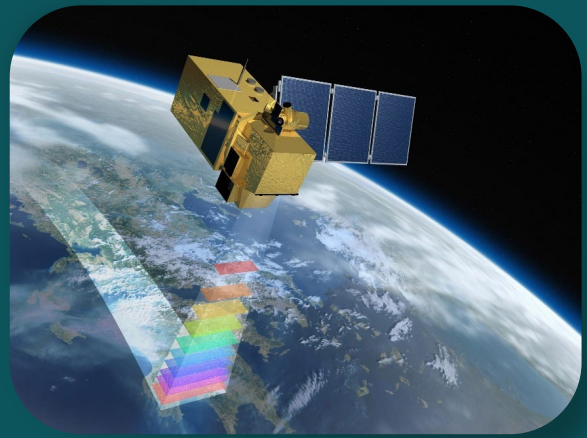
Thank you for your attention.



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Main scientific objective:

- to better understand the role played by the Atlantic Ocean in the climate system especially the Atlantic Meridional Overturning Circulation (AMOC)

Objective-1: Develop an EO-based OHC product over Atlantic Ocean

- Method based on space geodetic measurements (Altimetry & Gravimetry)
- To properly provide the product uncertainty

Objective-2: Validation and scientific activities

- Provide Science Case Study focused on the Meridional Heat Transport (MHT) in the North Atlantic with a regional heat budget
- To perform independent comparison with in situ data for the quality assessment

Objective-3: Transfer our results to implement solutions for society through Use Cases

- Climate monitoring and predicting community
- Operational community (Copernicus)