Monitoring the Ocean Heat Content and the Earth Energy imbalance from space altimetry and space gravimetry: the MOHeaCAN project

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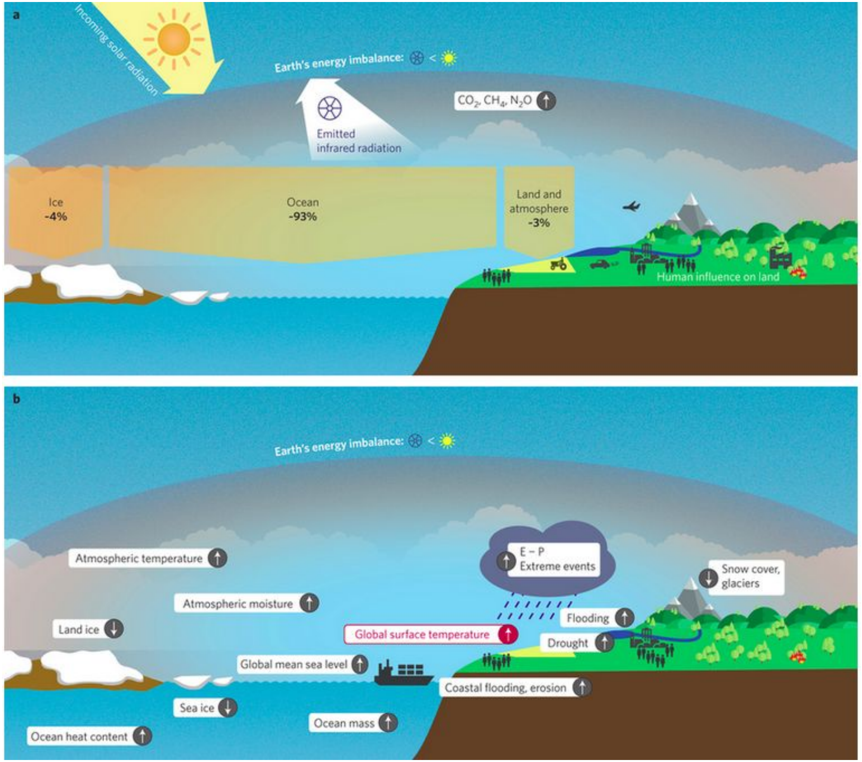
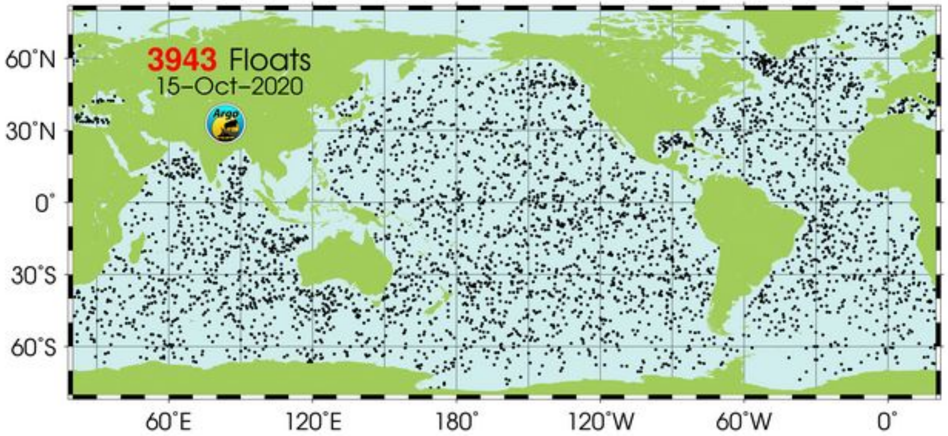
- ➔ Earth energy imbalance (EEI) indicator provides a quantitative estimate of climate change. Recent studies suggest that the EEI response to anthropogenic greenhouse gases and aerosols emissions is 0.5-1 W.m^{-2} (<< 340 W.m^{-2} incoming solar radiation).
- ➔ An accuracy of 0.3 W.m^{-2} (ideally 0.1 W.m^{-2}) is necessary to assess the long-term mean EEI due to anthropogenic forcing at decadal time scales.
- ➔ The ocean heat content (OHC) is a very good proxy to estimate EEI as ocean is the major heat reservoir (93% EEI)

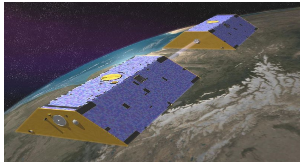


➔ OHC can be derived from different approaches:

- the direct measurement of in situ temperature based on temperature/Salinity profiles (e.g. ARGO floats),
- the measurement of the net ocean surface heat fluxes from space (CERES),
- the estimate from ocean reanalyses that assimilate observations from both satellite and in situ instruments,
- **the measurement of the thermal expansion of the ocean from space based on differences between the total sea-level content derived from altimetry measurements and the mass content derived from Gravimetry data (noted “Altimetry-Gravimetry”).**



ARGO network - https://argo.ucsd.edu

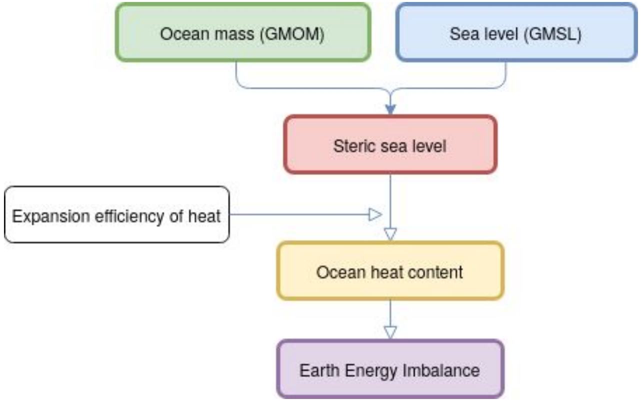


➔ **Objectives of the MOHeaCAN project:**

- to develop new algorithms to reach the target of 0.3 $W.m^{-2}$ for the EEI uncertainty estimation
- to estimate more realistic uncertainties for OHC
- to develop a software prototype to perform sensitivity studies through ensemble approach
- to validate OHC against other means of measurements (ARGO for example)

Product generation

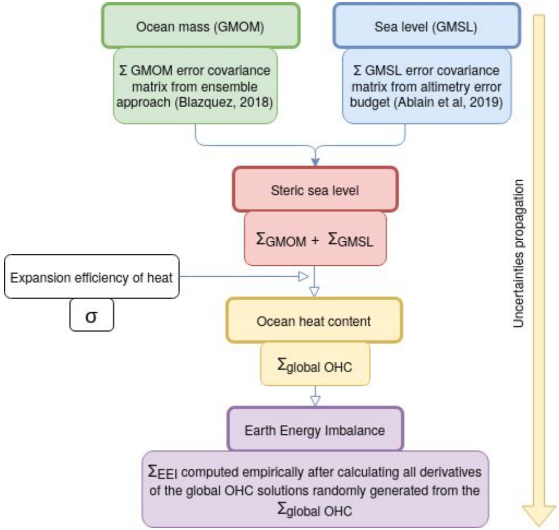
➔ **The processing chain is being developed to compute the OHC/EEI indicators:**



Altimetry-Gravimetry approach provides an independent estimate of the steric sea level representative of the full ocean column.

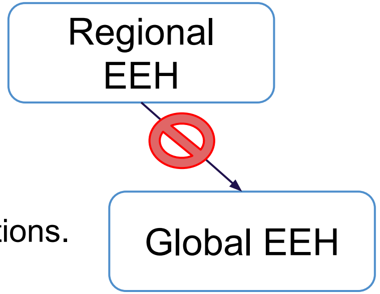
➔ **The uncertainties propagation has been specified at <u>global scale</u>:**

- using matrix covariance error



Error covariance matrix (∑) provides a full description of errors allowing the calculation of 1) trend uncertainties and 2) error envelop, etc.

Expansion Efficiency of Heat

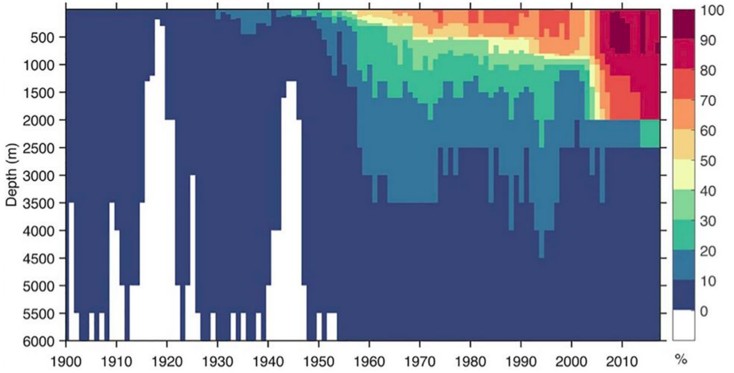


➔ **As a extensive variable, global EEH cannot be derived from regional EEH**

➔ **1) First step: estimation of the expansion efficiency of heat (EEH) at <u>regional</u> scales**

- From monthly 3D in situ temperature and salinity fields based on 11 various ARGO solutions.
- Representative of the 0–2000 m ocean column over the 2005-2016 period
- Use of the thermodynamic equation of sea water TESO-10 to compute the ratio SSL/OHC in each cell at each timestep

Meyssignac, B., Padilla Polo, S. and Blazquez, A.: Estimate of the Expansion Efficiency of Heat (EEH) coefficient at global and regional scales, In prep., 24th August, 2020.

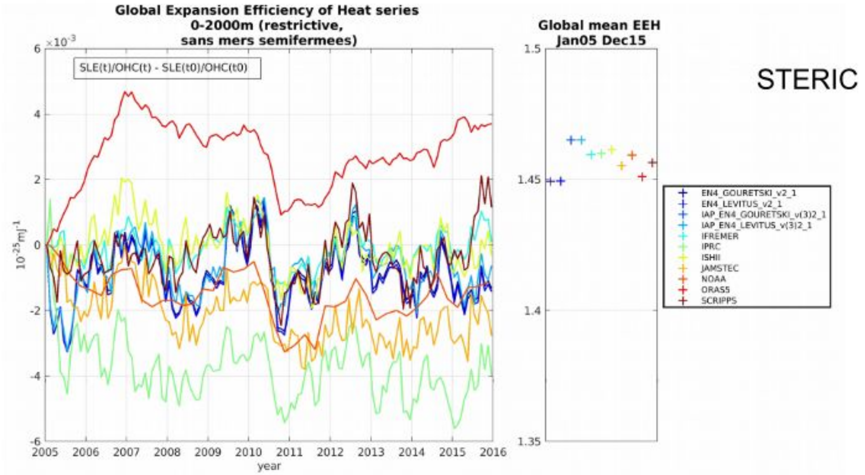


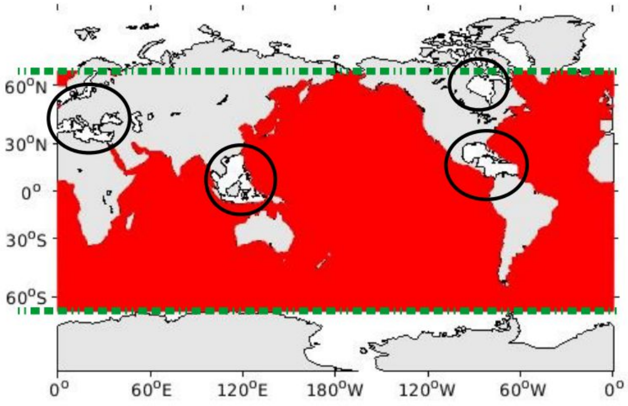
Argo data coverage (in %) for 3° × 3° boxes over the global ocean area, Meyssignac et al, 2019

Expansion Efficiency of Heat

➔ **2) Second step: estimation of the expansion efficiency of heat (EEH) at <u>global</u> scale**

- The previous methodology is applied at global scale





Results representative of 0–2000 m - restrictive mask (no high latitude, no enclosed-seas) over 2005-2016

➔ **1) EEH map defined on a 3-degree resolution grid**

➔ **2) New estimate of the global EEH:** ε = 0.15 ± 0.03 m.YJ^{-1}

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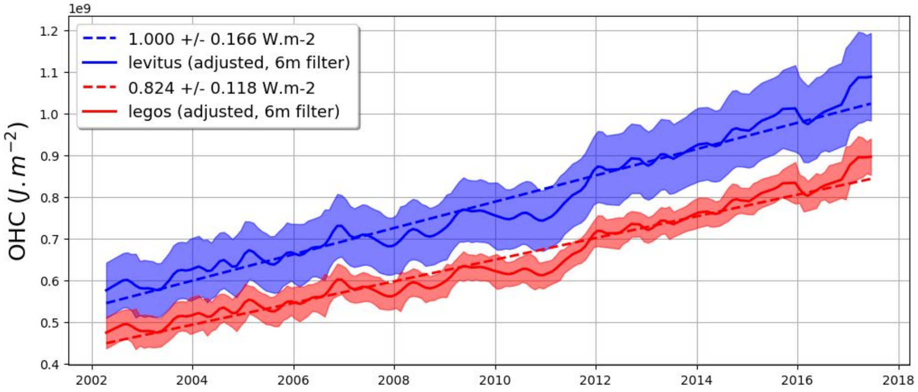
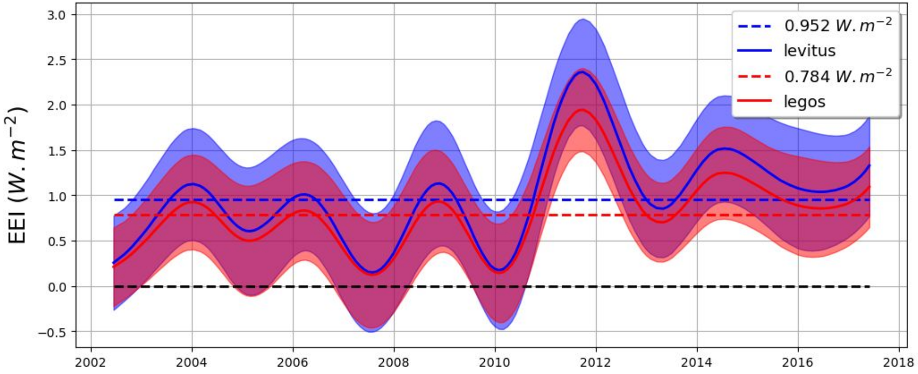
➔ **"Round Robin" intercomparisons** were performed to compare standards (altimetry/gravimetry data) and algorithms 1 vs 1 and to assess MOHeaCAN product versions.

Example: impact of the global expansion efficiency of heat on the OHC/EEI indicators

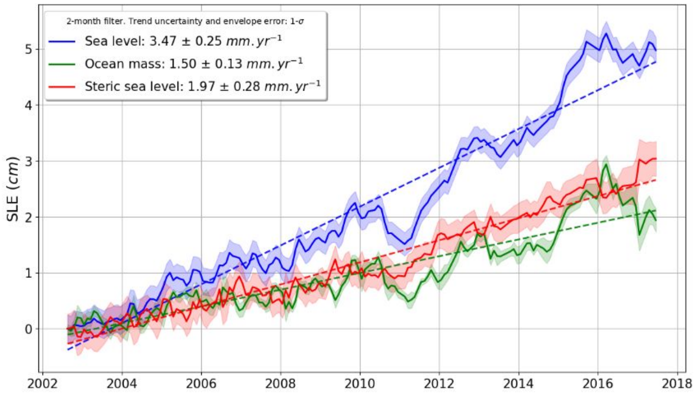
New coefficient estimation: 0.15 $m.YJ^{-1}$	Kuhlbrodt and Gregory (2012), as Levitus et al., 2012: 0.12 $m.YJ^{-1}$



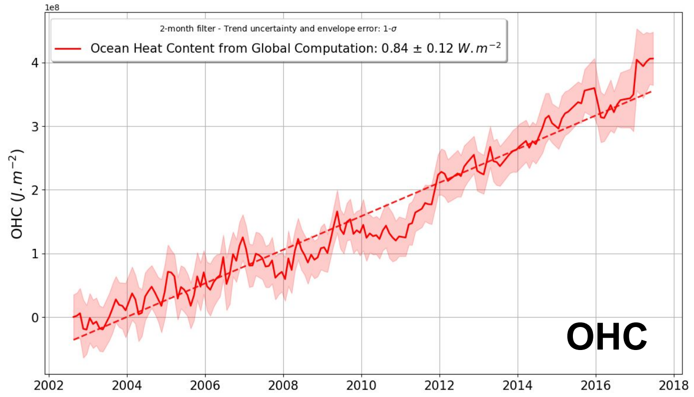


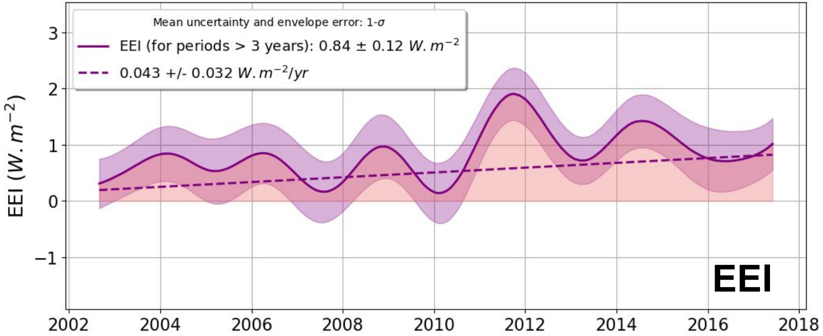
Results at global scale

Global Mean Steric Sea Level (red curve) inferred from Altimetry Sea level (blue curve) and Ocean Mass from gravimetry data (green curve)



Global Ocean Heat Content from MOHeaCAN





Evolution of EEI from MOHeaCAN for periods higher than 3 years:

- *Error envelop superimposed*
- *Positive mean value (0.84) is in line with scientific litterature (within error bars at the 90% CL)*
- *Uncertainty is 0.12 W.m^{-2} (1-σ): objective is to reduce this uncertainty level.*

Results at regional scales

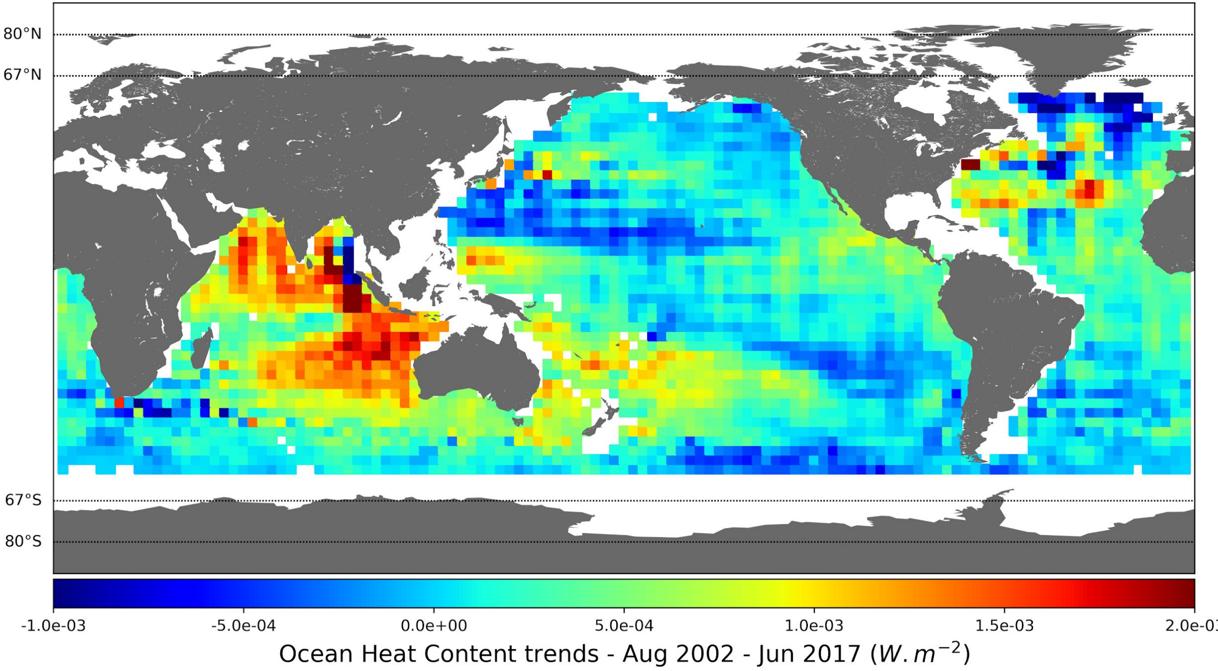
➔ **Focus on regional OHC trends:**

Gravimetry:
Updated GRACE and GRACE-FO ensemble from *Blazquez et al, 2018*

Altimetry:
C3S
https://climate.copernicus.eu/

Expansion Efficiency of Heat:
Meyssignac et al, in prep, 2020

➔ **Limitations**:
- ARGO spatial coverage - OHC is provided on 84% of the ocean surface
- Seisms in gravimetry data (eg. Sumatra 2004)...



Future work and perspective

➔ The project will be completed by the end of 2020 with:

- Scientific analyses with regards to other OHC/EEI products based on in situ data (e.g. ARGO), models or other spatial data (e.g. CERES)
- The submission of an article to a peer-reviewed journal

➔ MOHeaCAN OHC/EEI products will be available in December via ODATIS. Feedback from users are expected in the following months.

➔ Future work: improving the processing chain and input data in order to release a new version of OHC/EEI products, eg:

- to extend temporal time series (e.g GRACE time series (mid-2016) with GRACE-FO mission)
- to improve uncertainties characterisation

Thanks for reading!
Any questions?
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