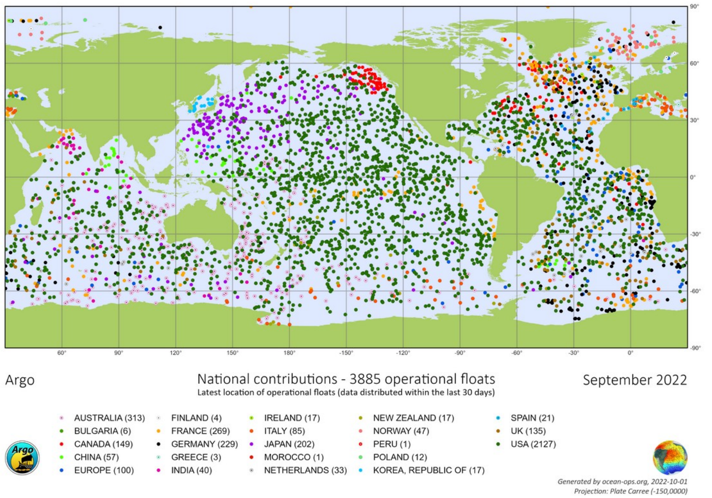
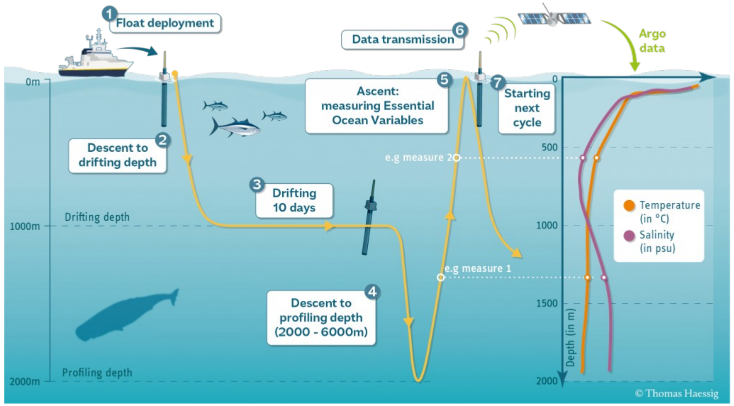
Mapping global in situ data set : understanding uncertainties on global ocean state estimates

Nicolas Kolodziejczyk (UBO/LOPS/SNO Argo France)
collab :William Llovel (CNRS/LOPS), Annaig Prijent (Ifremer/LOPS), Thierry Penduff (CNRS/IGE),Jean-Marc Molines (CNRS/IGE)

REFMAR, 17 October 2022, Océnopolis, Brest

The international OneArgo Program

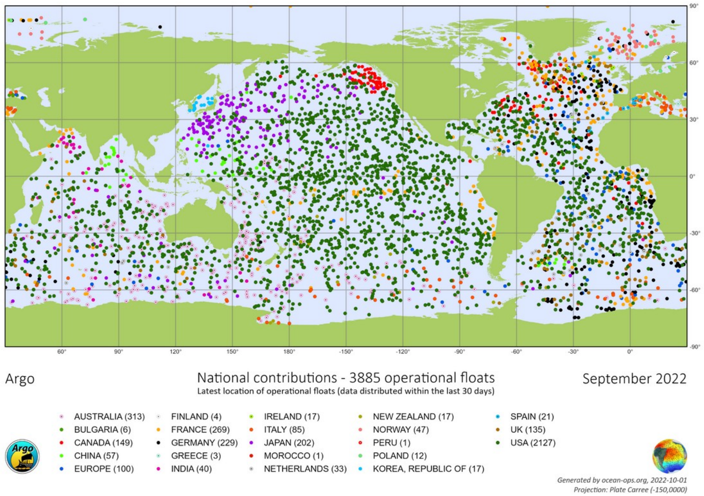




- **International coordinated effort**
- **>3900** autonomous floats :T/S over 2000 m depth, 3°x3°x10 days
- Since 2019, OneArgo : **Deep Argo** (>2000 m depth) and **BGC Argo** (6 new BGC parameters) missions
- Provide data for:
  - → Operational oceanography
  - → Climate and oceanography sciences

Argo France

https://www.argo-france.fr/

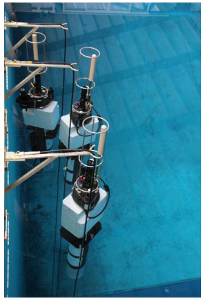


- IR*/ERIC EuroArgo
- 10 % global contribution, 30 % European contribution
- Operate a Global Data Center

Argo France activities :

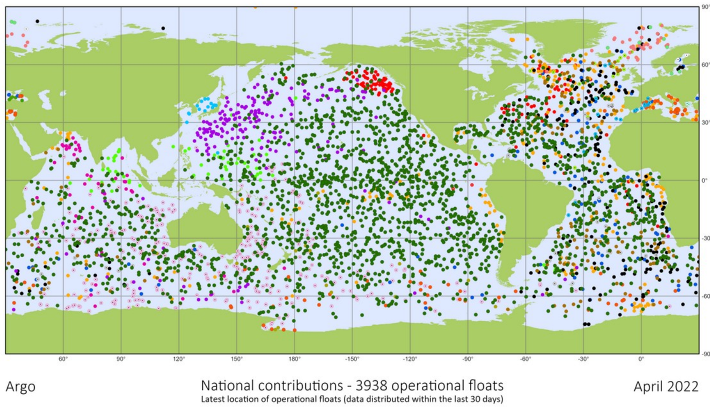
- Technology developement (floats, sensor, ...)
- At sea operation (procurement, deployement, ...)
- Data management (DAC, GDAC, DMQC, ...)
- Scientific steering, activities, SNO Argo France (publication, community animation, …)

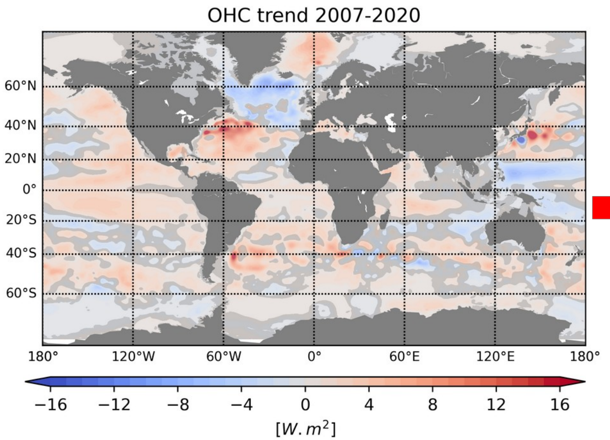
→ **High level data products**

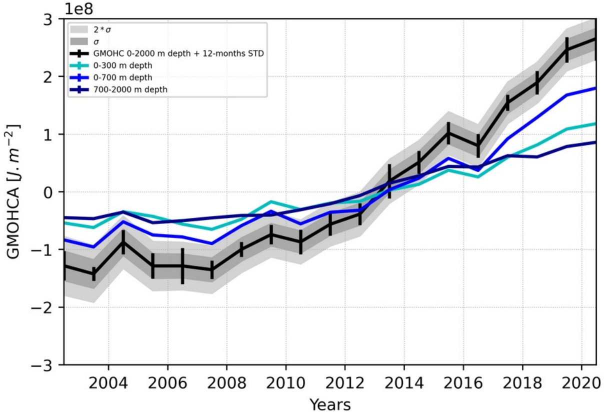


Mapping in situ data for monitoring climate indices

- Ocean plays a key role in climate system (e.g. ~93% of global heat excess since 70’s)
- In situ Global Ocean Observing System dedicated to collect sustain timeseries over the water column
- Since 2000’s, Argo allows to monitor global to regional ocean variability including Heat, Freshwater, i.e. Steric sea level budget
- Pending uncertainties on global and regional budget (e.g. to close EEI, SL budget)

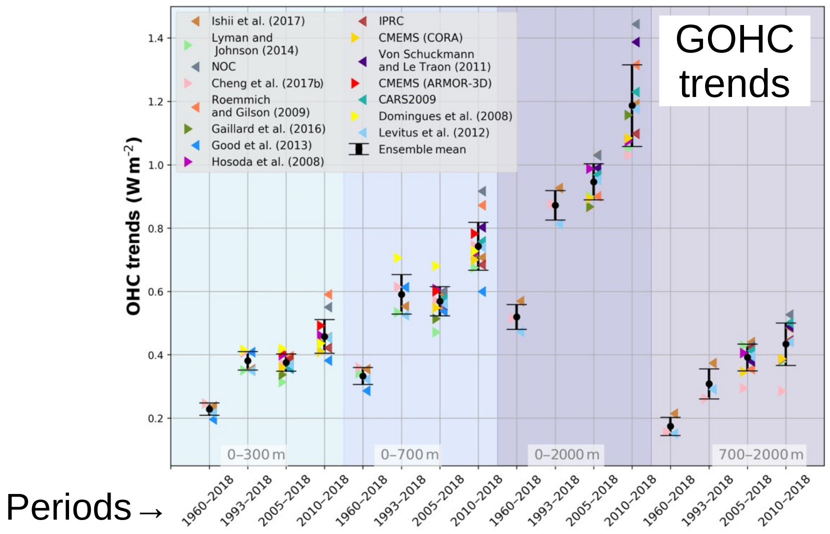




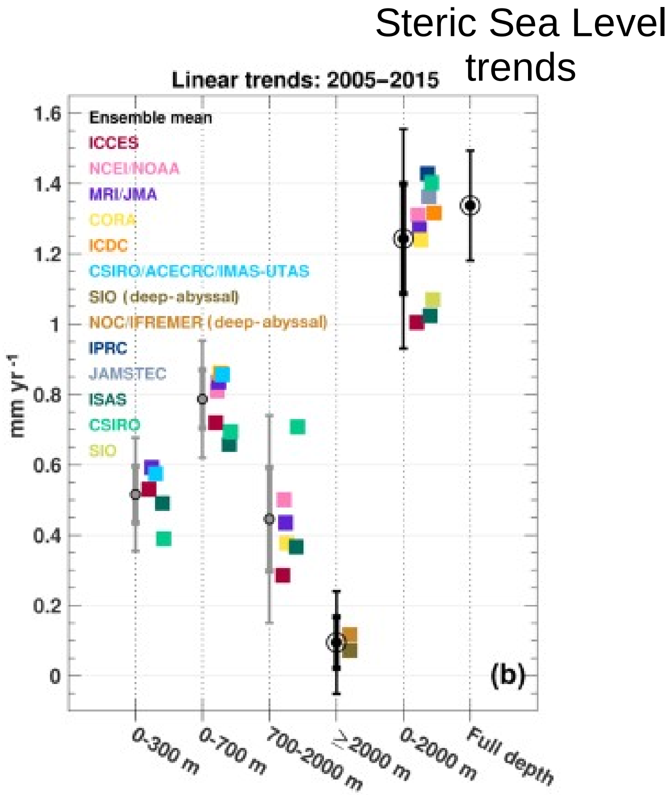


adapted rom Kolodziejczyk et al. 2019
https://www.umr-lops.fr/SNO-Argo/Products/ISAS-in-situ-T-S-gridded-fields/Climate-indices

G-OHC/SL trends source of uncertainties ?



(von Schuckmann et al., 2020)



(WCRP Sea Level Change, 2018)

1) Sampling
2) Data quality
3) OI ’a priori’ statistics sensitivity
4) Impact ‘Intrinsic’ (eddies) variability of the ocean

Method : ISAS tool and configuration

- **Optimal Interpolation** (*Bretherton,1976*)
  → Global T/S field (0-2000 m)
  → 2002-2020
  → Résolution : 0.5° Mercator, 187 z-levels (→ 5500 m depth)

- **In situ data**
  → Argo (ISAS20 Argo only), Marine Mammals (MEMO), TAO-TRITON-PIRATA-RAMA Mooring, ITP, CTD

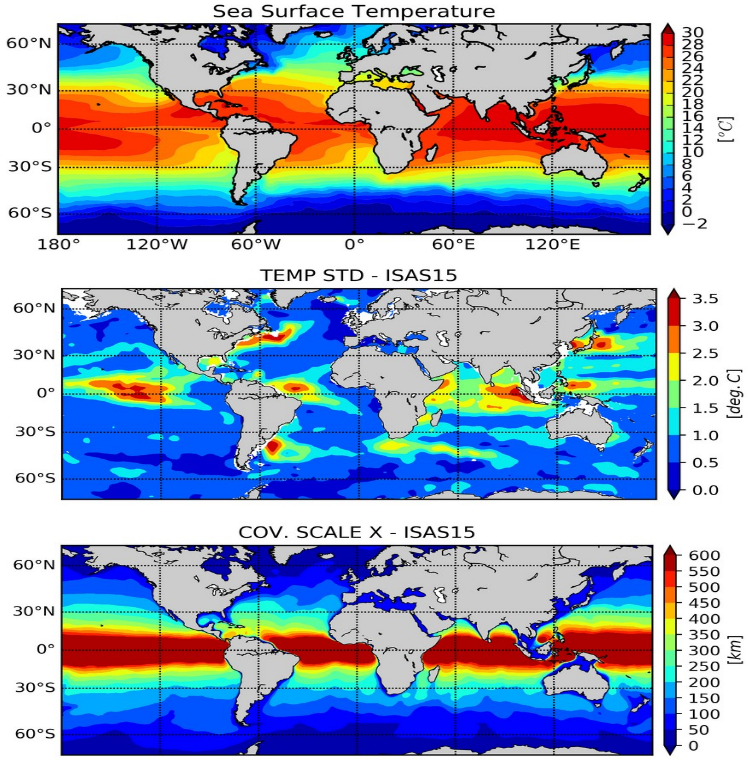
- **A priori statistics and covariance scale and weight**

$$C(dx, dy, dt) = \sum_{i=1}^{2} \sigma_{Li}^2 \exp\left(\frac{dx^2}{2L_{xi}^2} + \frac{dy^2}{2L_{yi}^2} + \frac{dt^2}{2L_{ti}^2}\right), \qquad (4)$$

T=45 days, L_1 = 300 km, L_2 = 4*Rossby radius
Equatorial cov X scale < 600km
f/h along bathymetry

$$\sigma^2 = \sigma_{L1}^2 + \sigma_{L2}^2 + \sigma_{UR}^2 + \sigma_{ME}^2, \qquad (6)$$

w_1 = 1; w_2 = 2 ; w_{ur} = 8 ; ME negligible



Monthly Clim. T

STD. T

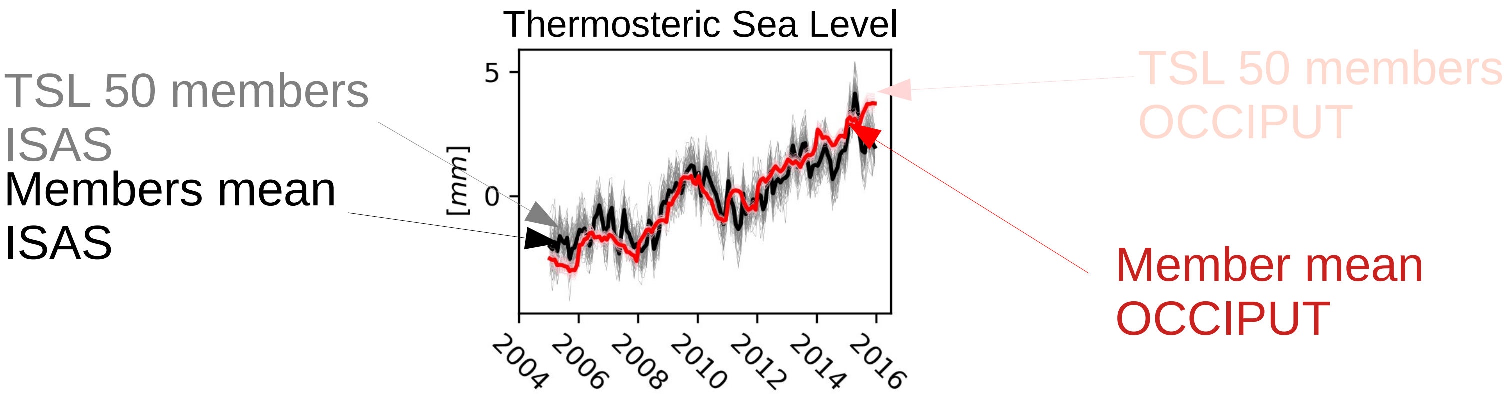
Zonal Cov. Scale

(Gaillard et al., 2016)

Method : Synthetic and ensemble approach

- How to get a « Truth » to assess error with method?
- Using global NEMO ORCA 0.25 + synthetic EN4 profiles data set (OCCIPUT, Penduff et al, 2014; Bessières et al.2017)
- Producing 50 member with same forcing and small perturbation in 1959 (only chaos will change among the members)
- Interpolation of 50 using ISAS tools over the Argo period (2005-2015, ISAS15 config.)

→ **See William Llovel's presentation for further explanations (next session)**



(Llovel, Kolodziejczyk et al.,2022)

1) Analysis (mostly sampling) error and propagation

- Analysis equation :

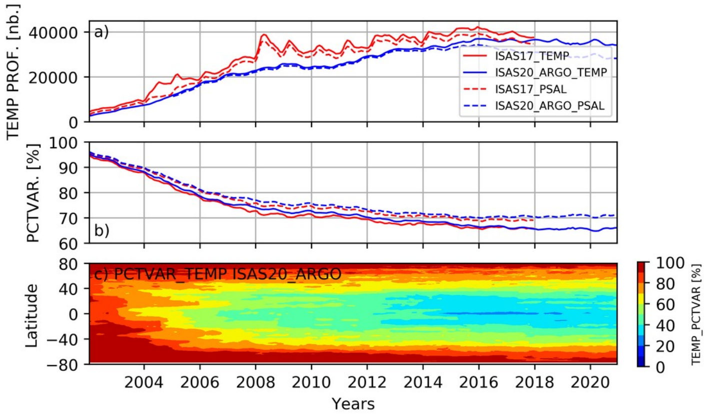
$$\mathbf{d} = \mathbf{y}^{\mathrm{o}} - \mathbf{y}^{\mathrm{f}}, \quad (1)$$

$$\mathbf{x}^{\mathrm{a}} = \mathbf{x}^{\mathrm{f}} + \mathbf{K}^{\mathrm{OI}}\mathbf{d}, \quad (2)$$

$$\mathbf{P}^{\mathrm{a}} = \mathbf{P} - \mathbf{K}^{\mathrm{OI}}\mathbf{C}_{\mathrm{ao}}^{\mathrm{T}}, \quad (3)$$

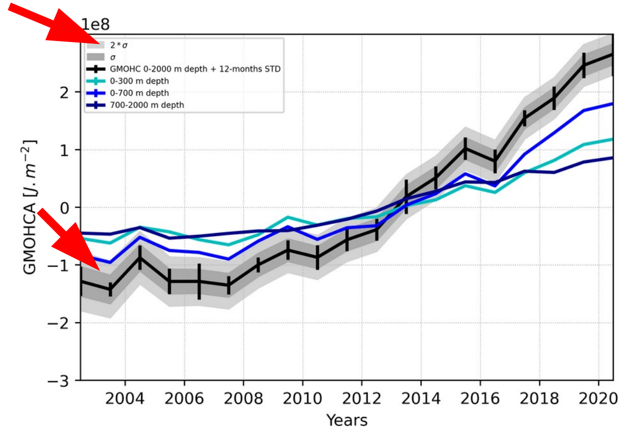
$$\mathbf{K}^{\mathrm{OI}} = \mathbf{C}_{ao}(\mathbf{C}_{oo} + \mathbf{R})^{-1}. \quad (4)$$

(Gaillard et al., 2016)



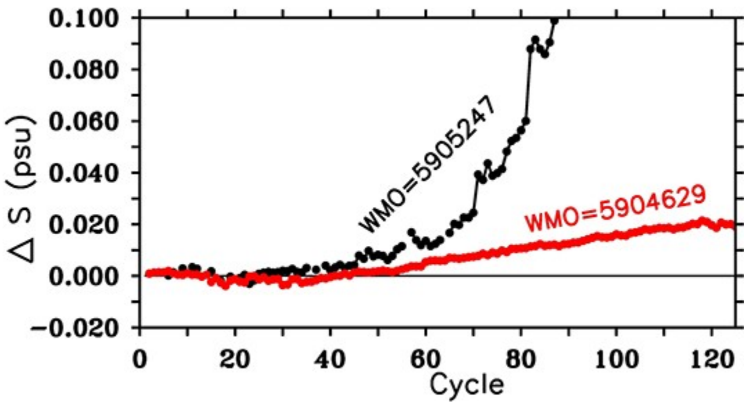
- Error propagation in heat budget taking account of vertical and horizontal correlation :

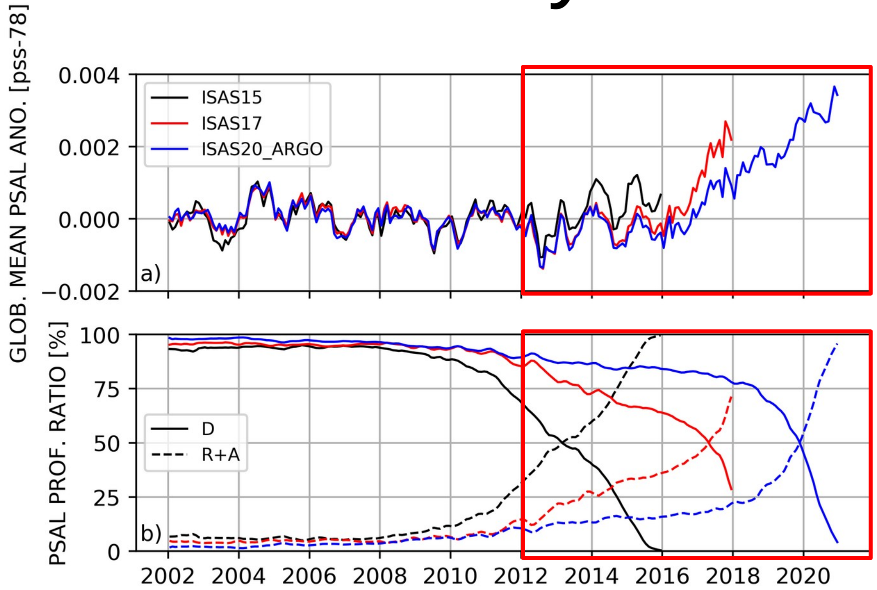
$$\sigma_f^2 = \sum_i^n a_i^2 \sigma_i^2 + \sum_i^n \sum_{j(j \neq i)}^n a_i a_j \rho_{ij} \sigma_i \sigma_j$$



ρ is the vertical/horizontal correlation

2) Error due to data quality : example of salinity drift on SBE conductivity cells





- Conductivity measurements drift (Bio-fooling , clogging, ...)
- Ad hoc post calibration are used (OWC method)
- Abnormal, fast and more often drifts are observed since 2015
- Error larger than 0.01 PSS-78 for RT (~25% fleet, *Wong et al., 2020*)
- This salinity drift have been treated in DMQC, but data in RT in analysis could impact global budget (→ see *Barnoud et al., 2021*)

Doi : 2016/02
Doi : 2019/01
Doi : 2021/01

3) Sensitivity to a priori statistics

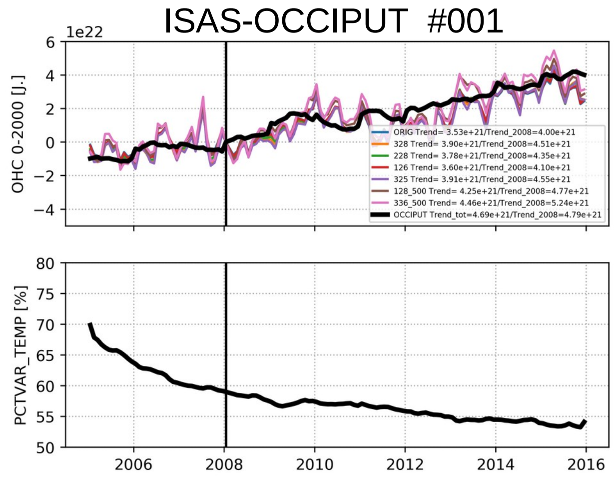
- **Using synthetic data changing covariance weights and scales**

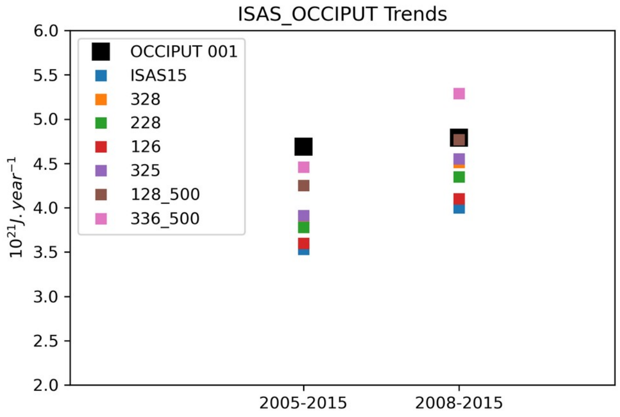
$$C(dx, dy, dt) = \sum_{i=1}^{2} \sigma_{Li}^2 \exp\left(\frac{dx^2}{2L_{xi}^2} + \frac{dy^2}{2L_{yi}^2} + \frac{dt^2}{2L_{ti}^2}\right), \qquad (4)$$

T=45 days, **L_1 = 300 km**, L_2 = 4*Rossby radius
Equatorial cov X scale < 600km
f/h along bathymetry

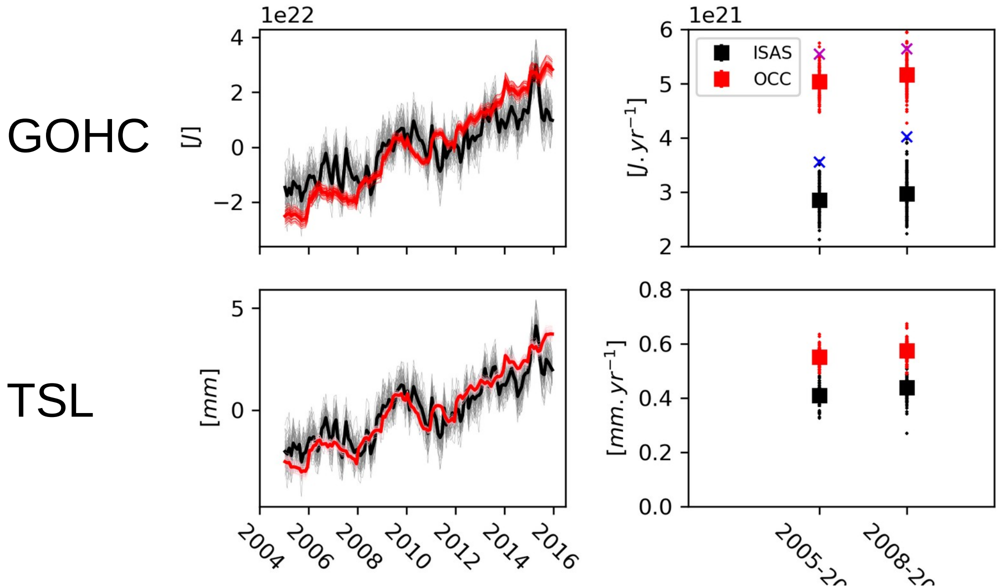
$$\sigma^2 = \sigma_{L1}^2 + \sigma_{L2}^2 + \sigma_{\mathrm{UR}}^2 + \sigma_{\mathrm{ME}}^2, \qquad (6)$$

w_1 = 1; w_2 = 2 ; w_{ur} = 8 ; ME negligible





4) Impact of ‘intrinsic’ variability on GOHC and GTSL



- OHC/TSL trends differ due intrinsic variability
- ISAS/OCCIPUT trends differ due to OI tuning
- ISAS TSL is closer to OCCIPUT TSL trend due also to OI tuning

  → **See William Llovel’s presentation for further analysis (next session)**

Conclusion and perspectives

- Compute global budget from in situ measurements necessitate analysis tools with a priori hypothesis and caveats
- Source of error are identified : method, data quality, a priori statistics, intrinsic variability ...
- Synthetic approach helps to better constrain analysis parameters and consistency among TSL/OHC global budget

https://www.argo-france.fr/
ISAS fields : https://www.seanoe.org/data/00412/52367/

Extra-slides