Impact of ocean observations on climate signals in ECMWF global ocean reanalysis system

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Context

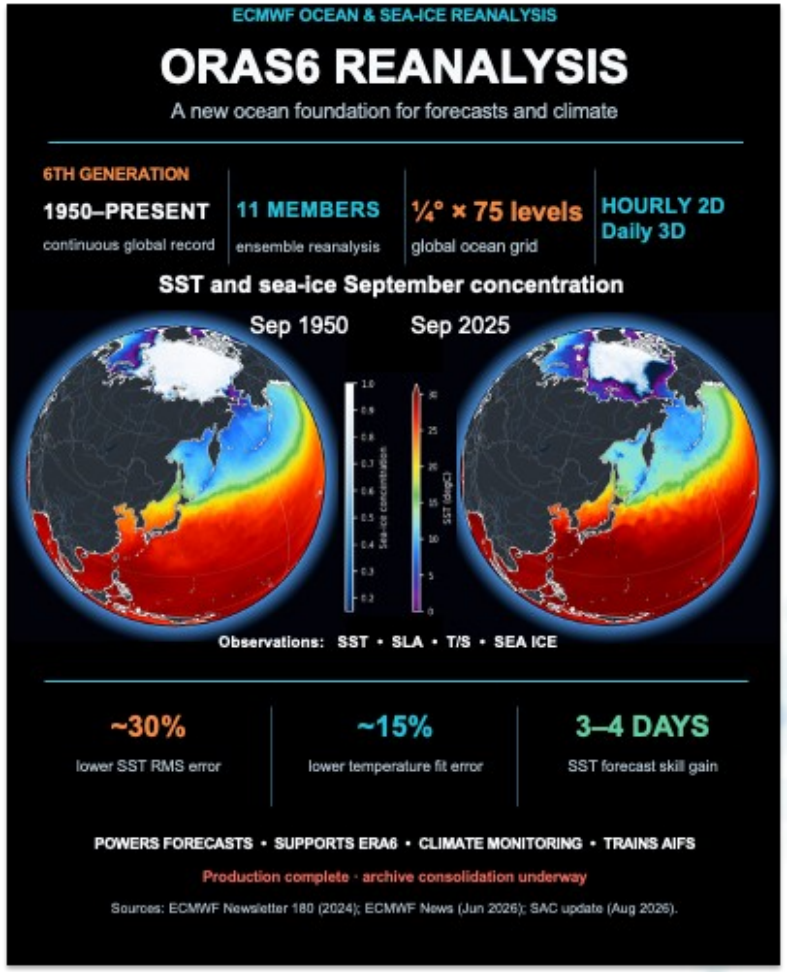
Ocean reanalysis systems combine ocean observations with a dynamical ocean model through data assimilation to produce a “time-consistent” record of ocean states

Ocean reanalysis are widely used as ICs for FC activities but also for climate studies: OHC, EEI, MHW etc…

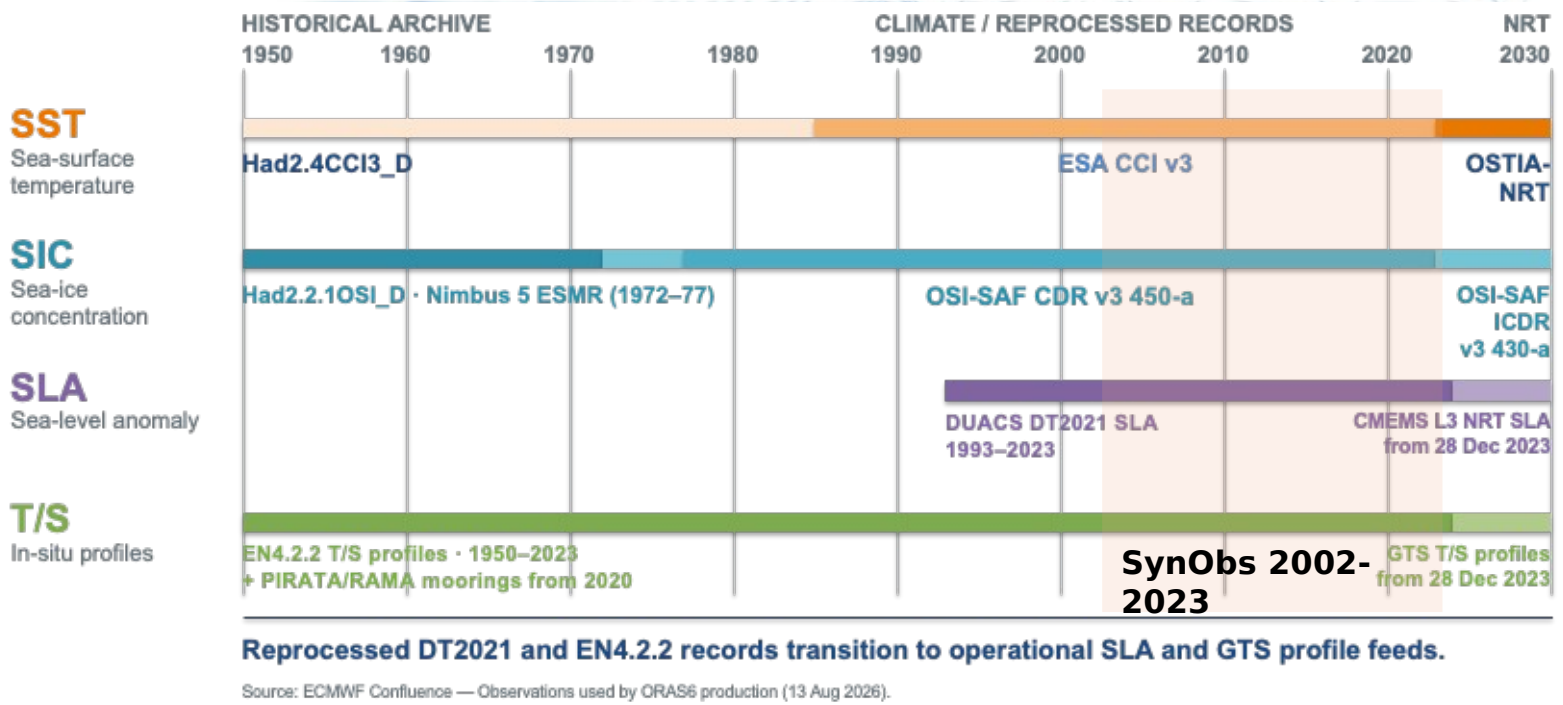
Reliance on an evolving ocean observing system means that the consistency of the reanalysis record is challenged by:

- Observation spatial and temporal coverage
- Quality of observation (sensor drift, spurious signals)
- Continuity of various observations types (satellites, in situ)
- Complementarity between different observing types in a DA context
- …

ECMWF Ocean and sea-ice reanalysis: ORAS6



ORAS6 DA relies on four complementary observation systems



ORAS6 and SynObs OSEs

SynObs is an UN-Decade activity that aims at demonstrating the value of the ocean observing system for both weather and climate prediction and climate monitoring and provide guidance for the design of future observing systems (Fuji et al, 2024)

SynObs OSEs are based on a **prototype version of ORAS6**:

- Period 2002-2023
- **80% of Argo** data (20% for validation)

OSE	SST	Argo	Mooring	Other in-situ types	Altimetry	Sea ice
CNTL	Included	80%	Included	Included	Included	Included
NoInsitu	Included	—	—	—	Included	Included
NoArgo	Included	—	Included	Included	Included	Included
HalfArgo	Included	50%	Included	Included	Included	Included
NoMoor	Included	80%	—	Included	Included	Included
NoSST	—	80%	Included	Included	Included	Included
NoAlti	Included	80%	Included	Included	—	Included
NoIce	Included	80%	Included	Included	Included	—
Free	—	—	—	—	—	—

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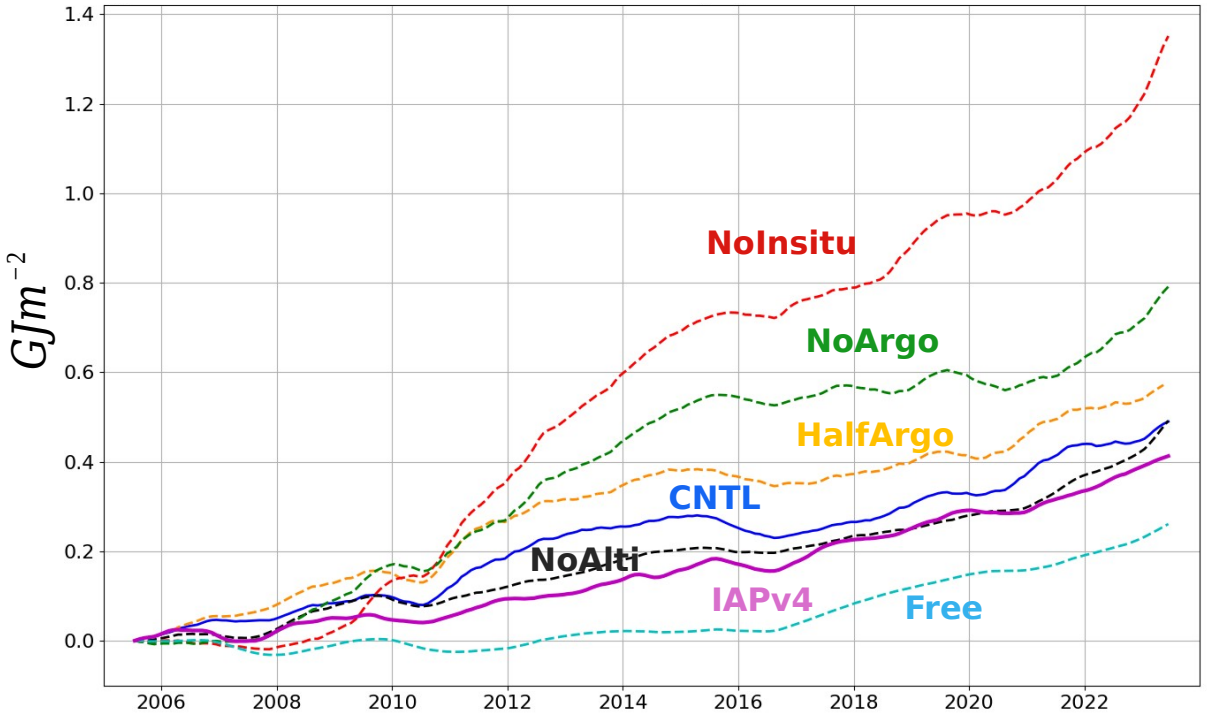
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NoIce	Included	80%	Included	Included	Included	—
Free	—	—	—	—	—	—

Ocean Heat Content

Ocean Heat Content is an indicator of the absorption of heat by the ocean

Global ocean heat content 0-700m: accumulation from 2005



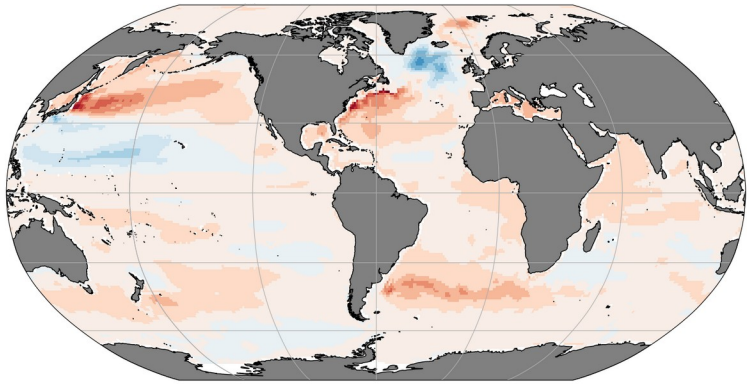
- OHC is drifting without subsurface constraint
- In situ obs (and Argo in particular) play a crucial role in anchoring the ocean subsurface
- Altimeter observations impacts OHC in 2011-2016 (mostly in the Tropics)
  - Lower in situ coverage to counterbalance weight given to SL obs

OSEs show the importance of a consistent ocean observing system for a balanced DA system but also the need for resilient DA systems that can adapt to rapid changes in the observing system

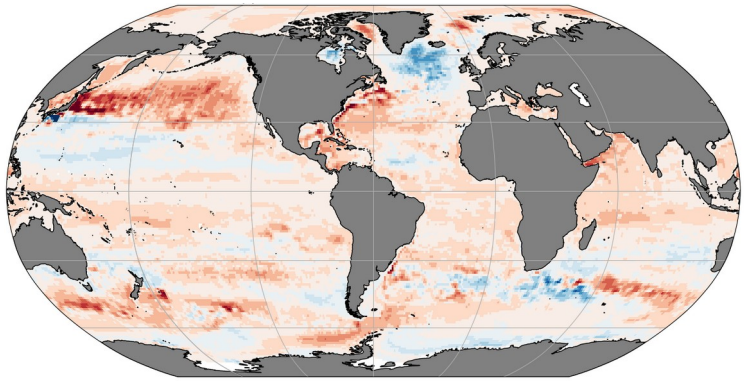
Ocean Heat Content long-term trend

Global ocean heat content 0-700m 2000-2023 trend in W/m2

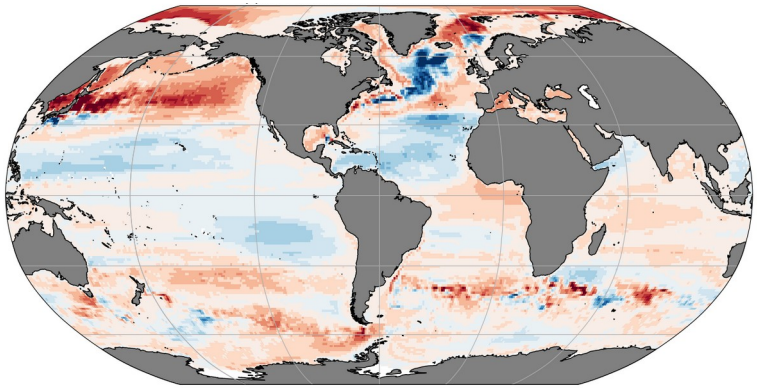
IAPv4



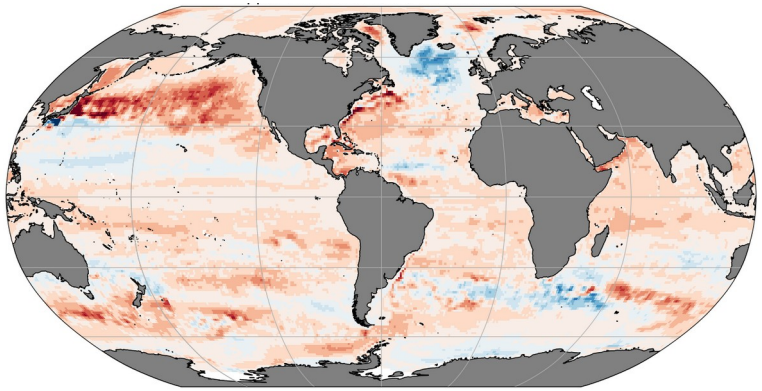
CNTL



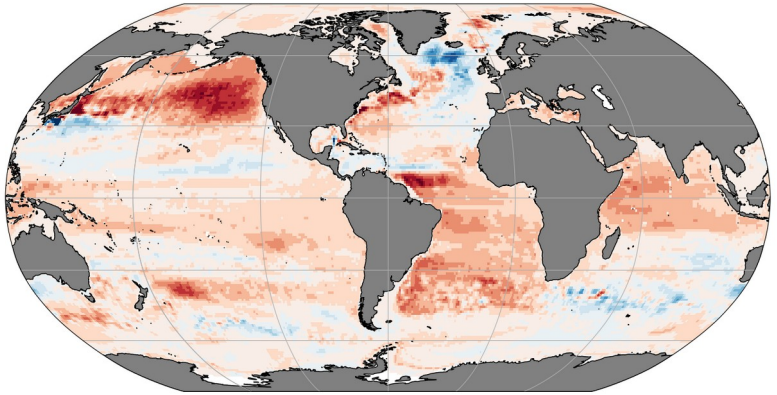
Free



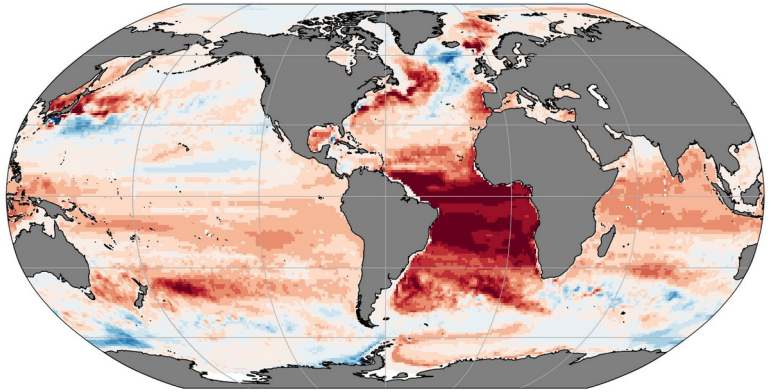
HalfArgo

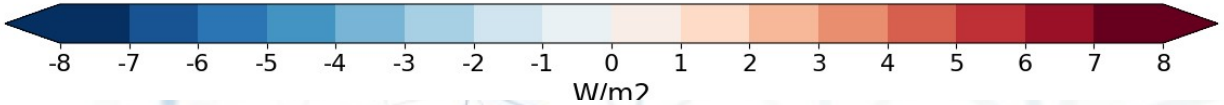


NoArgo



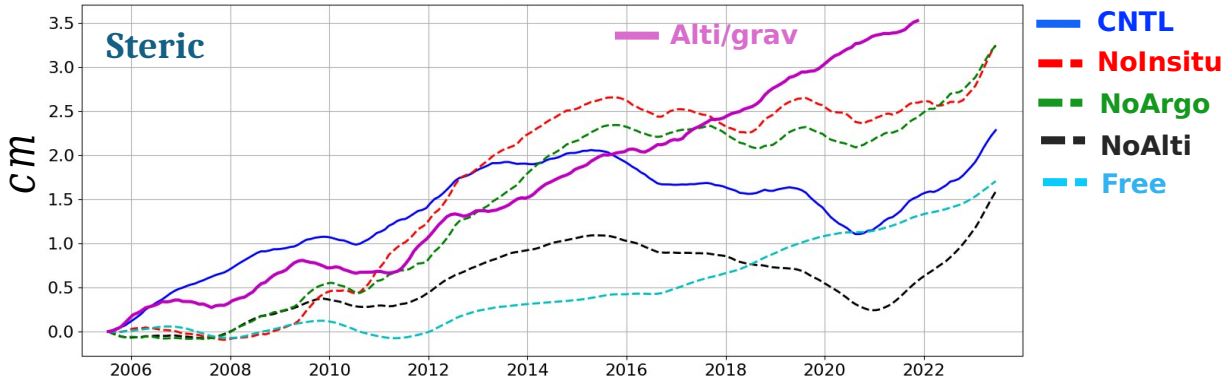
NoInsitu

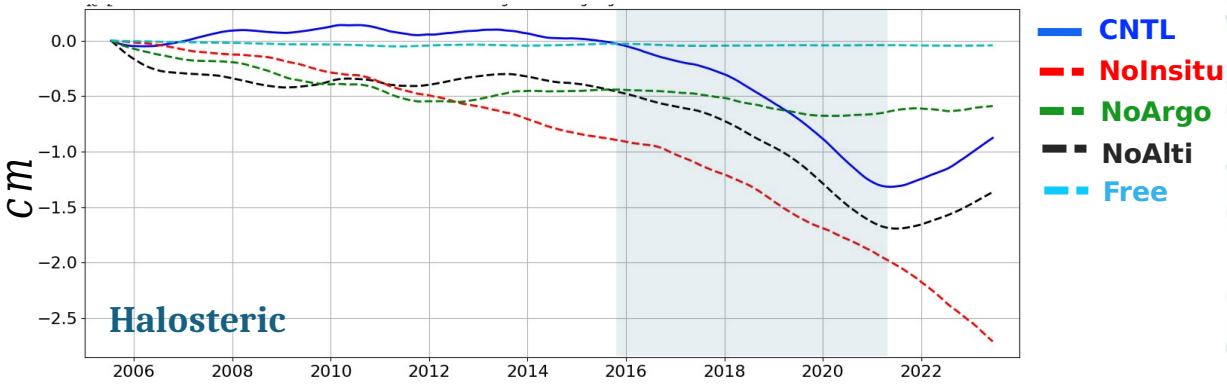


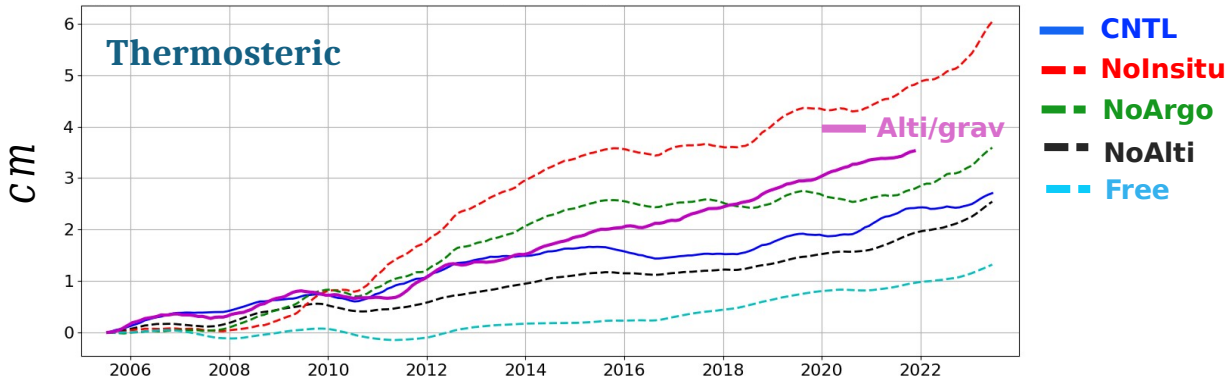


Ocean Steric Height

Steric height is the part of the sea level controlled by density changes, mostly driven by the thermal expansion/contraction of the water column



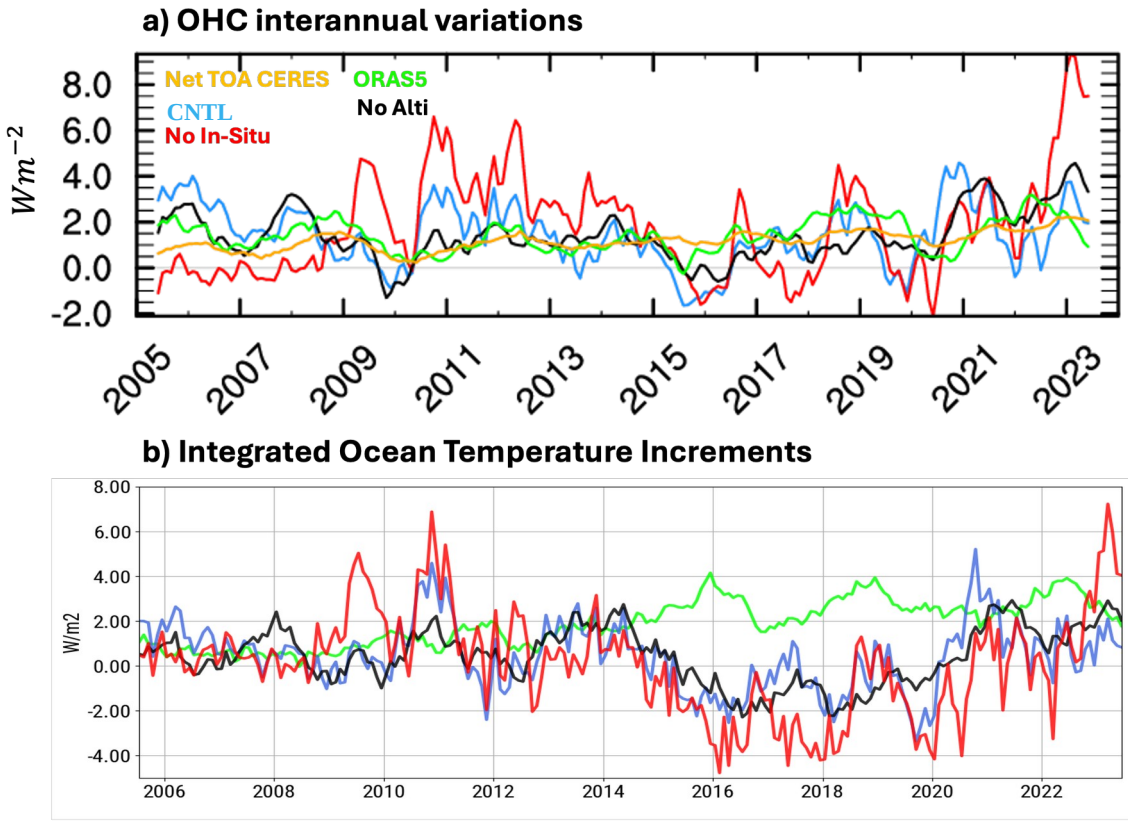




- Steric height impacted by drift in Argo salinity sensor from mid-2010s
  - ➢ compromising the reliability of global sea level budget from reanalysis and the steric consistency of the product
- OSEs useful to detect and assess the impact of sensor drift

Ocean heat content and EEI monitoring

Ocean heat content has been used for EEI monitoring (Hakuba et al, 2024; Mayer et al, 2026)



Courtesy of Michael Mayer

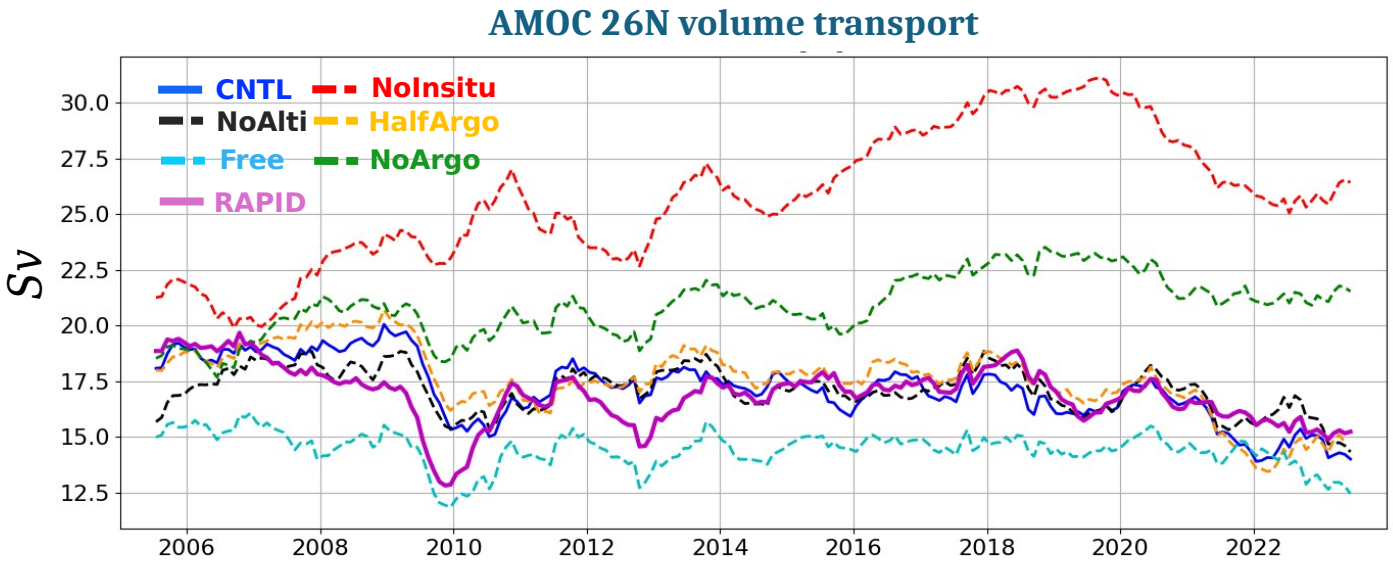
Correlation d/dt OHC wrt CERES TOC

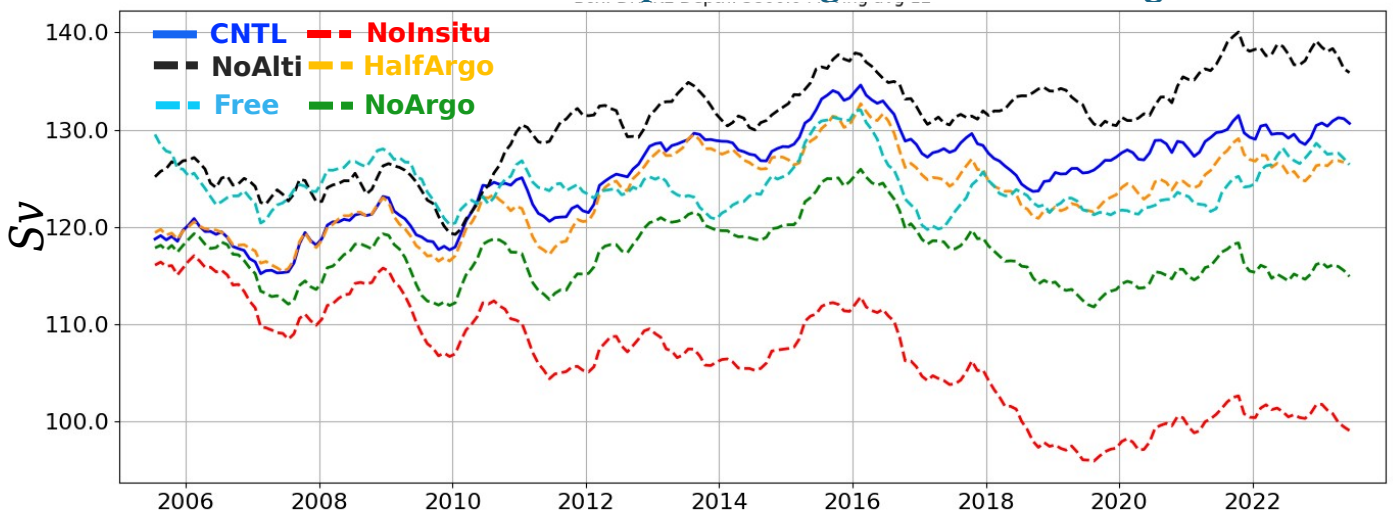
d/dt OHC vs CERES TOA	0-300m	0-700m	0-bottom
ORAS5	0.72	0.69	0.62
CNTL	0.38	0.23	0.08
NoAlti	0.73	0.65	0.48
NoInsitu	0.47	0.48	

Courtesy of Michael Mayer

- Interannual variations of OHC do not correlate well with CERES TOA
- Assimilation of altimeter data triggers high variability of temperature increments
- Need to revise the relative weight of altimeter wrt in situ observations for climate applications

Ocean volume transports: AMOC and ACC

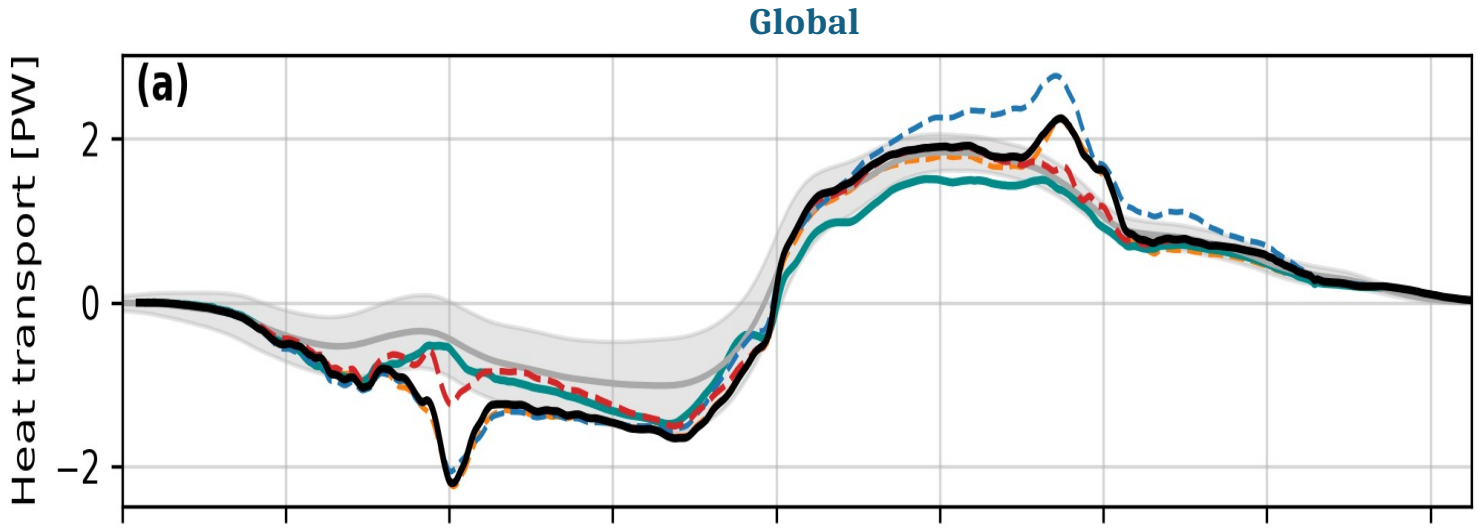


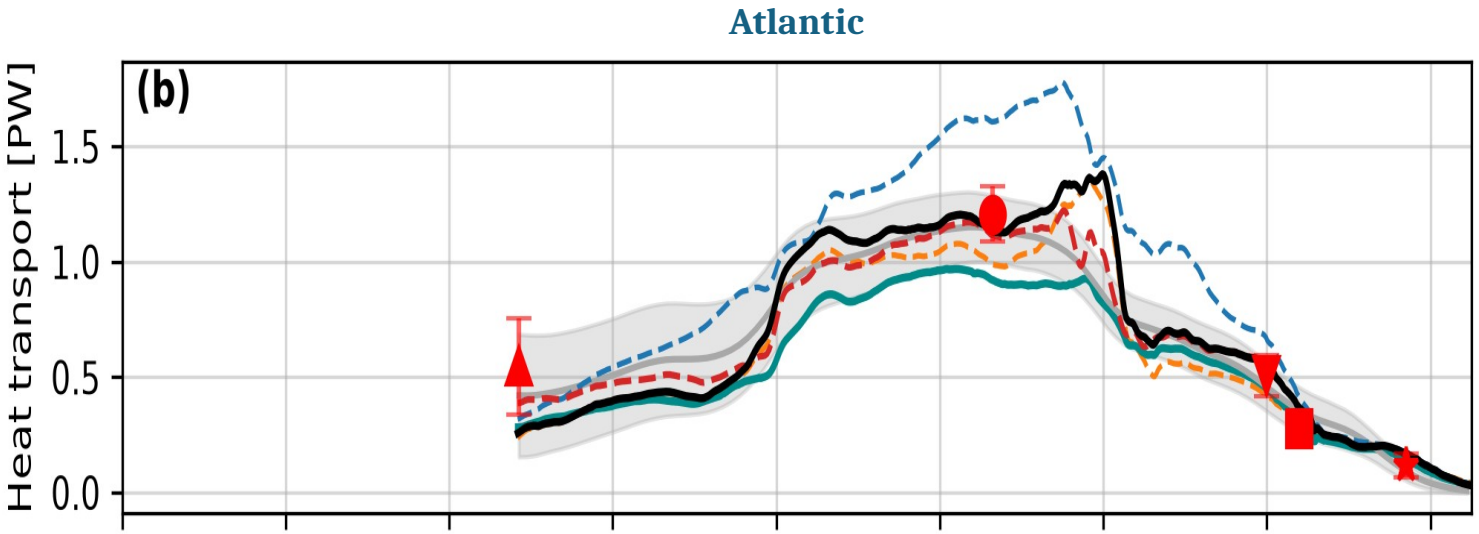


- AMOC overestimated and drifting without subsurface constraint: unbalanced observing system
- High sensitivity of the ACC: in situ profiles help maintaining intensity

➢ In situ profiles are essential to anchor the ocean interior and maintain transports in major current systems

Ocean Meridional Heat Transport





CNTL
NoAlti
NoInsitu
NoSST
ORAS5
Inferred
SAMBA
RAPID
OSNAP
GSR+Davis
Fram+BSO

- Fair representation of MHT intensity in the N Hem
- Altimeter observation impact the MHT in WBC and ACC

  ➔ need better DA balance between SL and subsurface observations

Courtesy of Susanna Winkelbauer

Conclusion

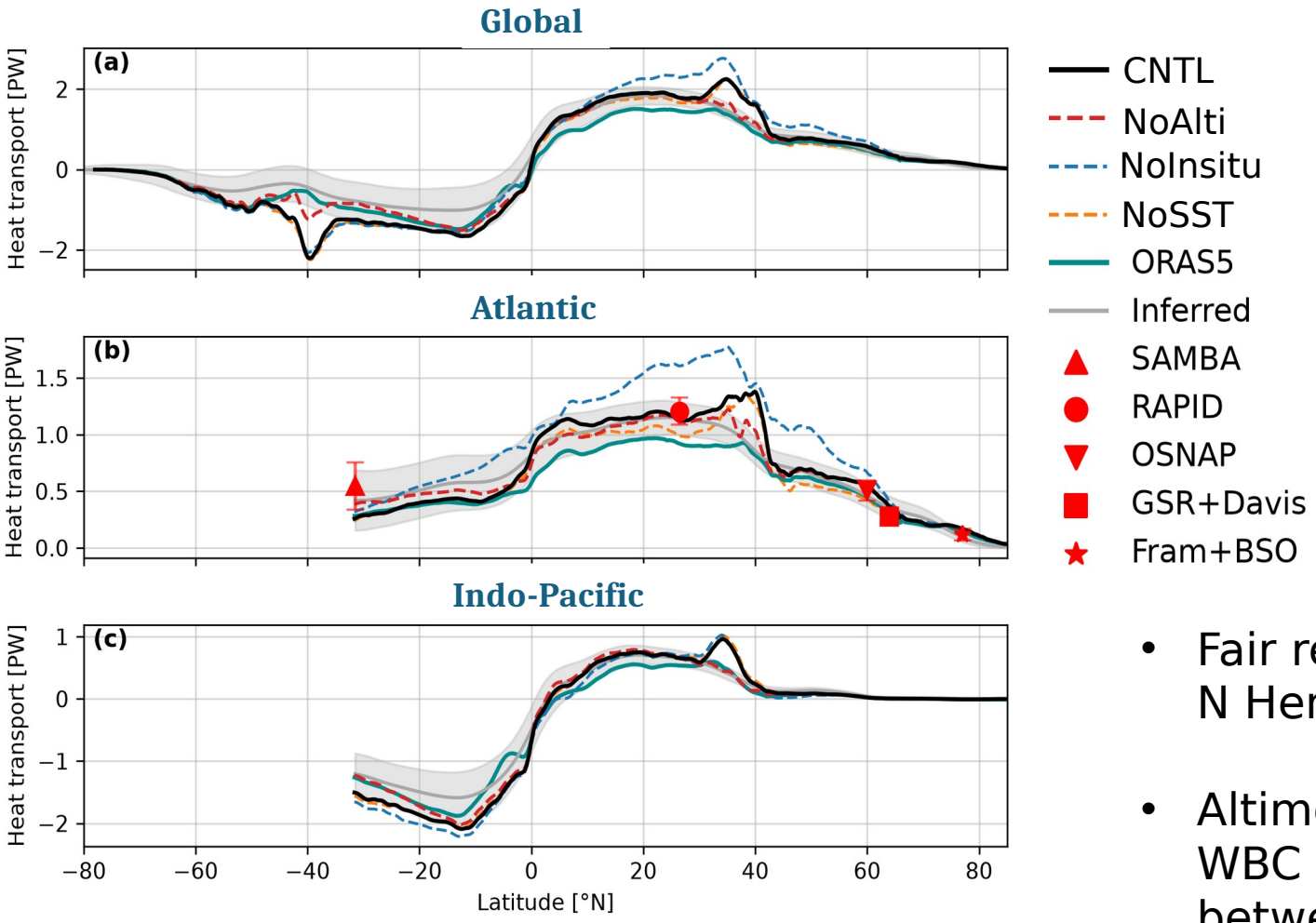
- OSEs conducted in the ORAS6 system to assess the impact of observations on climate signals
- In situ surface observations are crucial to anchor the ocean state and dynamics
- OSEs showed the need for a complete and consistent ocean observing system to represent accurate climate signals
- Need to build DA systems that are resilient to observing system changes and optimally use the information from observations

Thank you for your attention!

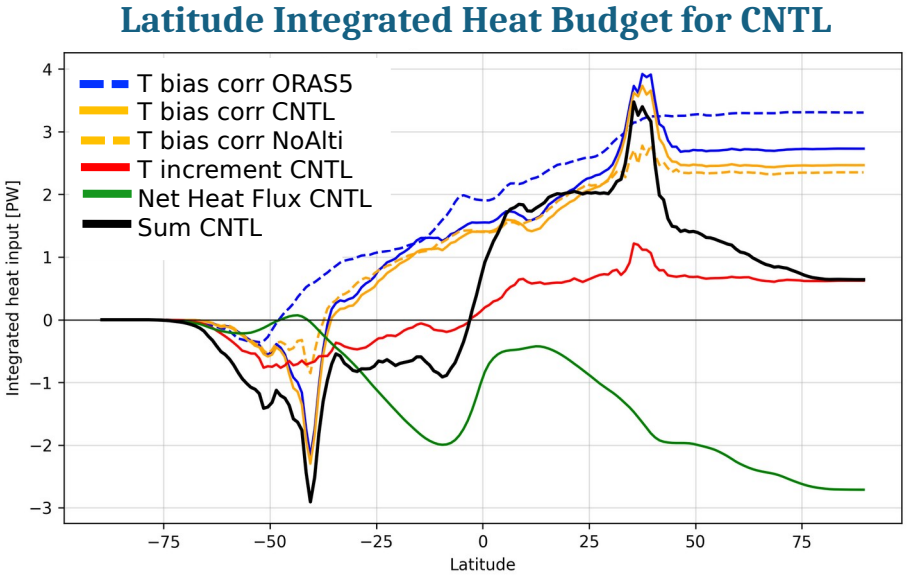


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Ocean Meridional Heat Transport



Courtesy of Susanna Winkelbauer



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- Fair representation of MHT intensity in the N Hem
- Altimeter observation impact the MHT in WBC and ACC ➔ need better DA balance between SL and subsurface observations
- In situ profiles needed to constrain the MHT