Identifying constrained scales by ocean observations in global ocean analyses

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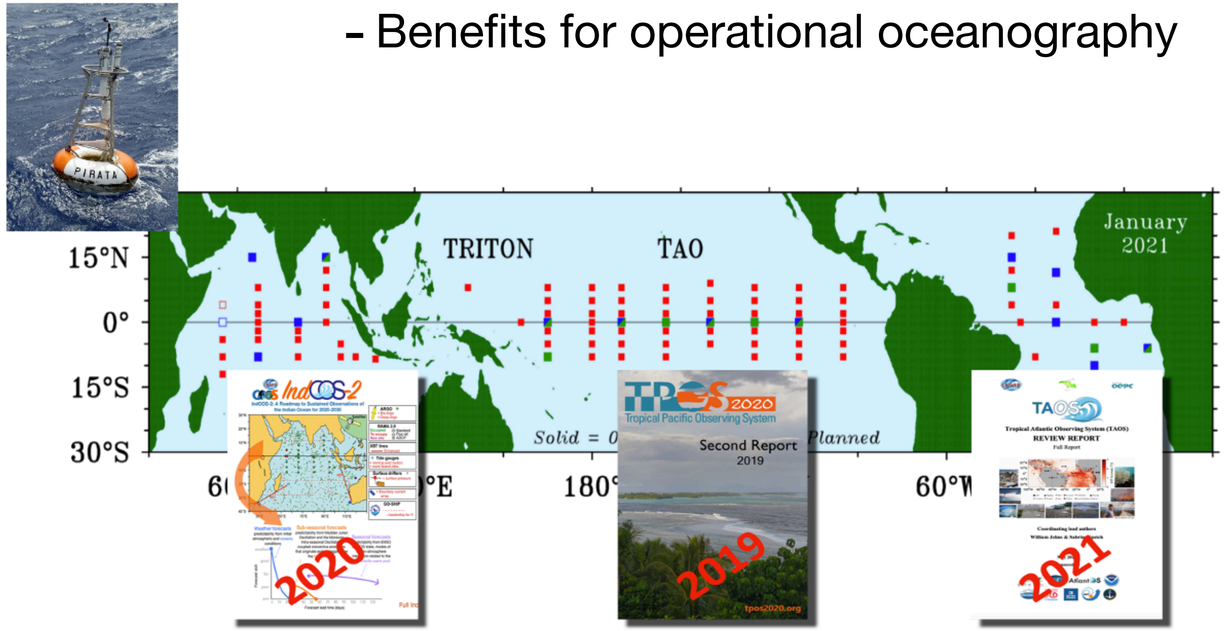
OUTLINE

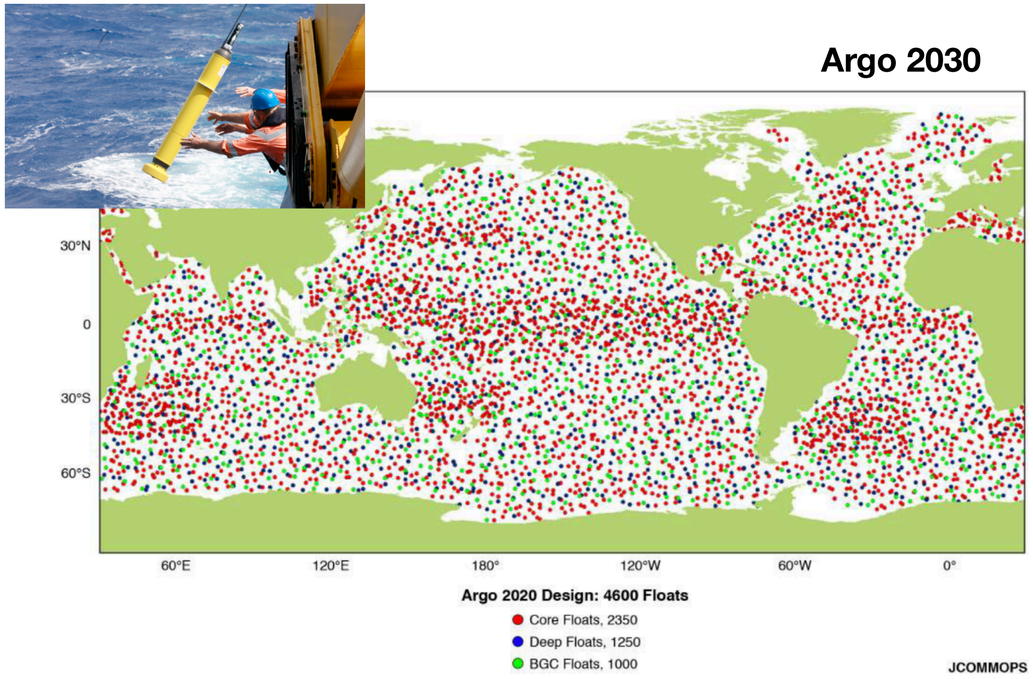
1. Introduction
2. The OSSE framework
3. Spatial and temporal scales constrained by observations
4. Potential outcomes of in situ observing system enhancements
5. Discussion and conclusion

Gasparin, Lellouche, Cravatte, Ruggiero, Remy: Diverse impacts of existing and future observing systems on oceanic analyses: a multiscale approach, to be submitted

International recommandations for in situ observing systems

- Three historical data sets (>20 years)
- Benefits for operational oceanography





Objective : Impact of future in situ observations on global ocean analysis (reduction of the residual error ?)

Outcome : Guidelines for the physical in situ observing system

Main components of numerical experiments

I. Nature Run (free version of GLORYS12)

→ *Representation of the « true » ocean*
→ *Generation of synthetic simulated observations*
→ *Reference for numerical experiments*

- Unconstrained simulation
- 1/12°
- ERA-Interim forcing
- 1991-2017 simulation

II. Experimental analysis system

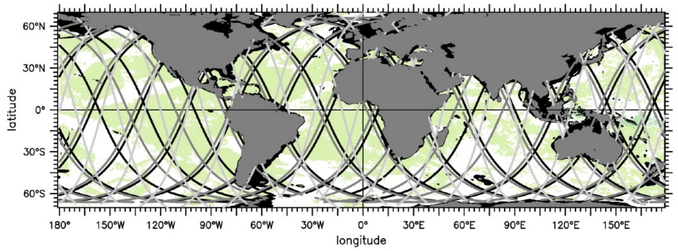
→ *Use for data assimilation of different designs*
→ *Comparison of outputs with Nature Run*

- Data assimilation of synthetic observations
- 1/4°
- IFS forcing (operational)
- 2015-2017 simulations

III. Synthetic data sets

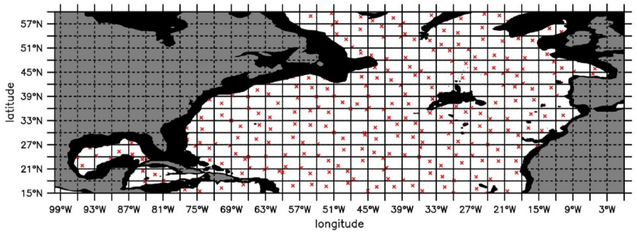
→ *Representation of different observing system designs*
→ *Extraction from the Nature Run*
→ *Assimilation in the experimental system*

Satellite observation designs

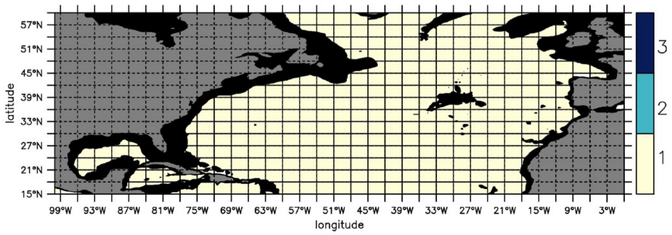


SSH observations (3 nadir altimeters)
SST observations from L3 product (green)

In situ observation designs

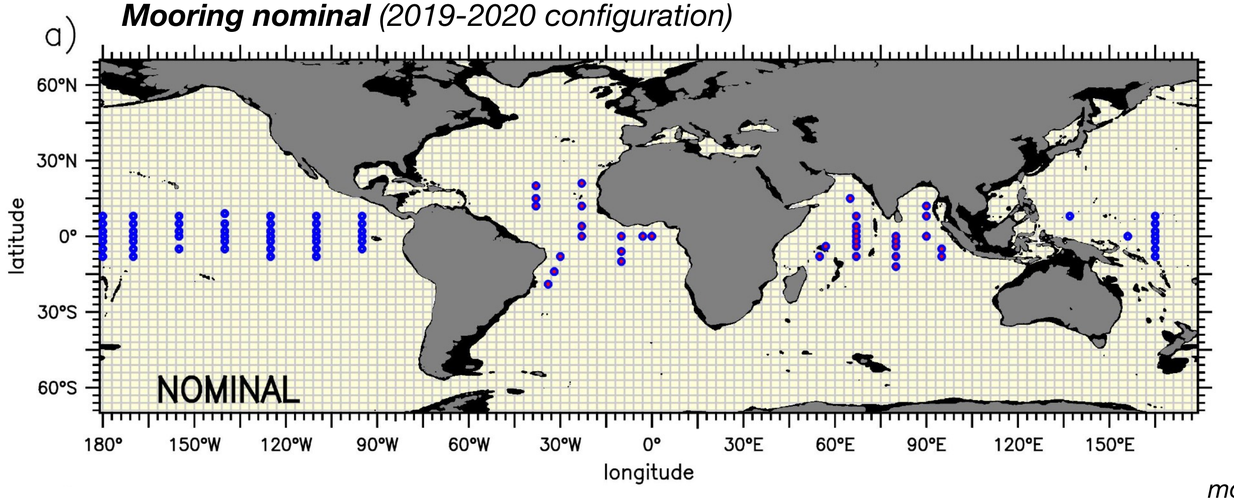


Number of Argo profiles per 3°x3°x10-day

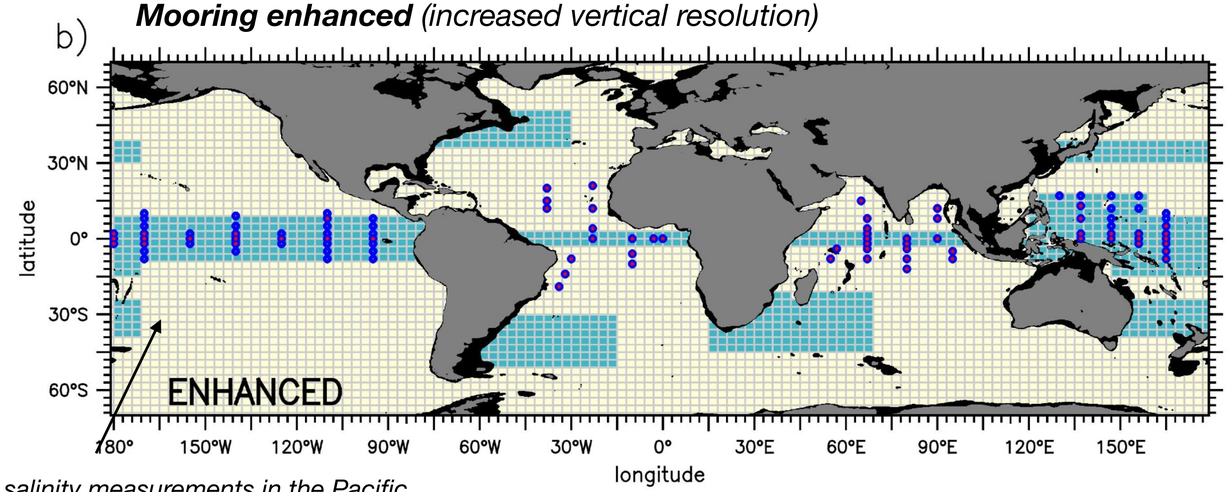


In situ observing system designs (Temperature/Salinity)

Argo nominal *(1 float per 3°x3°x10days; yellow)*
Mooring nominal *(2019-2020 configuration)*



Argo enhanced *(2 floats per 3°x3°x10days ; green)*
Mooring enhanced *(increased vertical resolution)*



more salinity measurements in the Pacific,
and process-focus design in the Pacific

Numerical experiments to ***evaluate the nominal design***

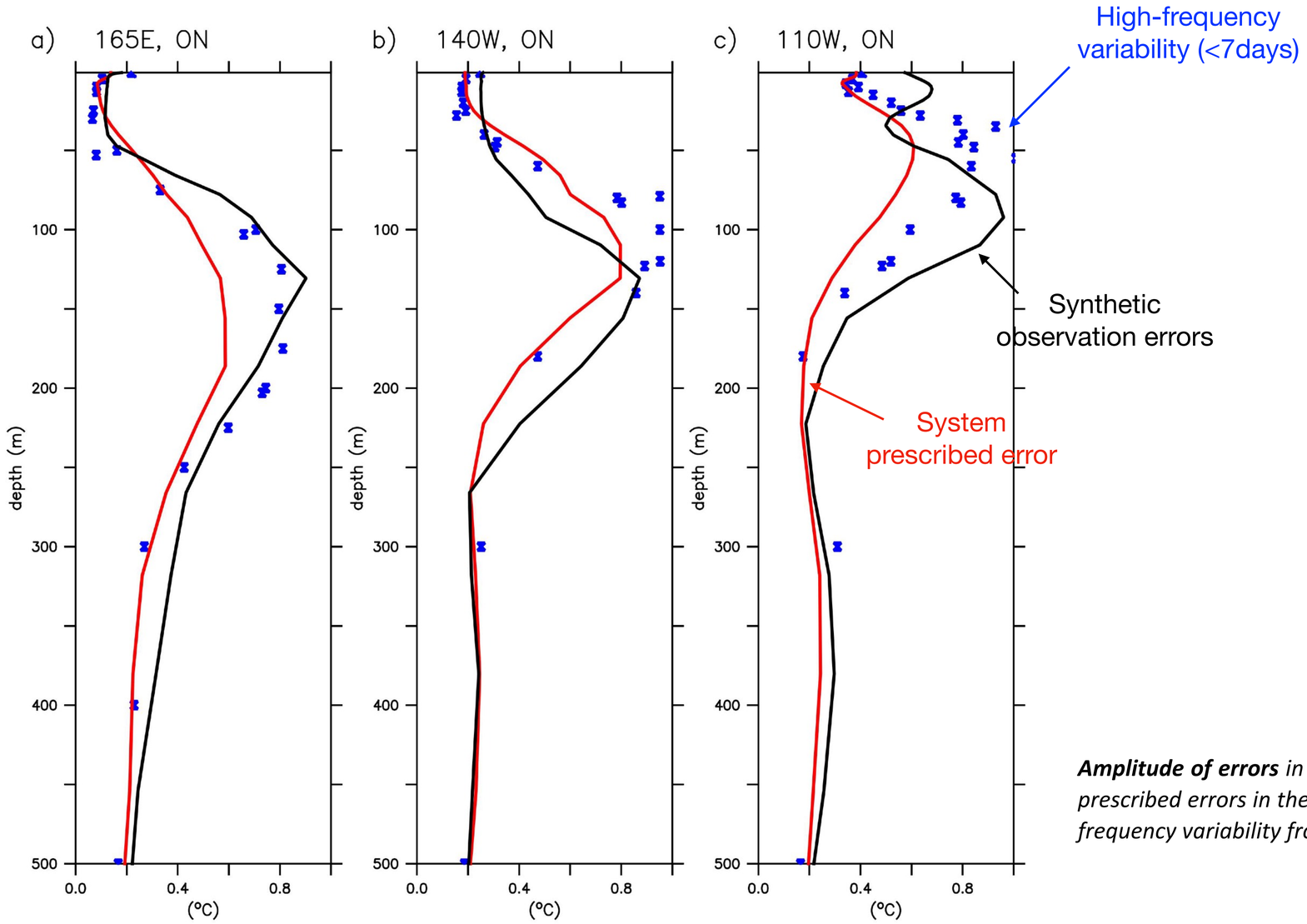
FREE	No data assimilation
ONLYSITU	Only Argo and Moorings
ONLYSAT	Only SST and altimetry
NOMINAL	Argo, Mooring, SST, altimetry

Numerical experiments to ***evaluate potential in situ enhancements***

ENHANCED_AR	Nominal + Argo extension (WBC, Equator)
ENHANCED_MO	Nominal + Mooring extensions
ENHANCED_AR_MO	Nominal + Argo and Mooring extension

Calibration of the system

Appropriate additional error on synthetic observation

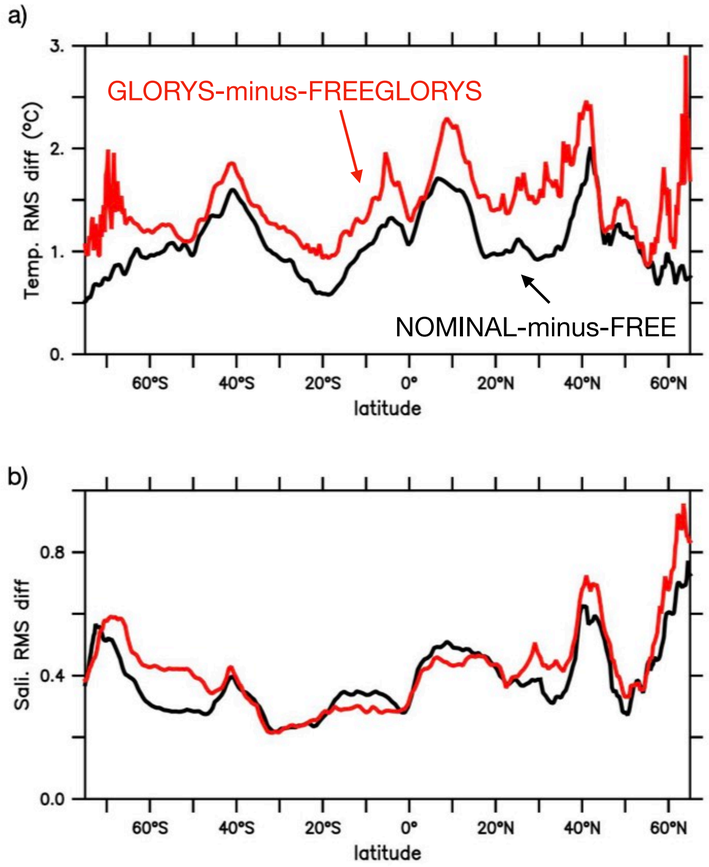


Amplitude of errors *in synthetic temperature (black lines), plus prescribed errors in the operational system (red lines) and high-frequency variability from moorings (<7 days; blue crosses)*

Calibration of the system

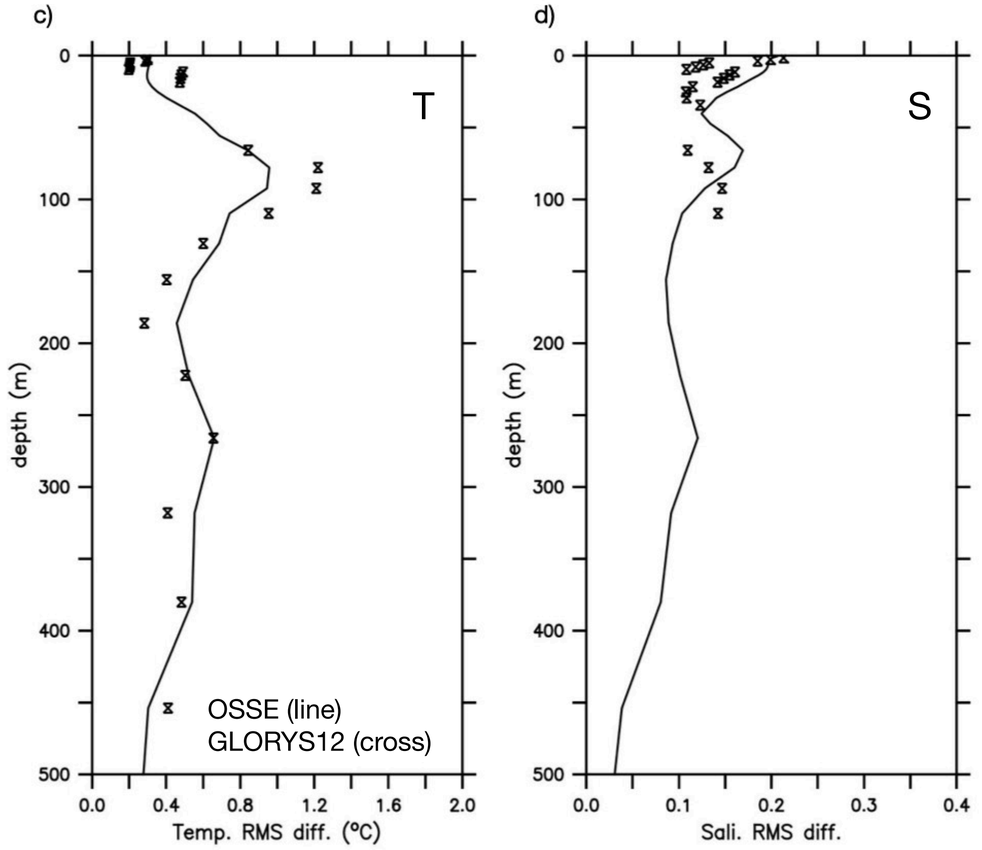
Consistent impact of assimilation with GLORYS12 reanalysis

Zonally-averaged RMS difference



***100-m temperature and 10-m salinity RMS diff.**, zonally averaged, between the free and assimilated simulations for the OSSE system (black) and the GLORYS system (red)*

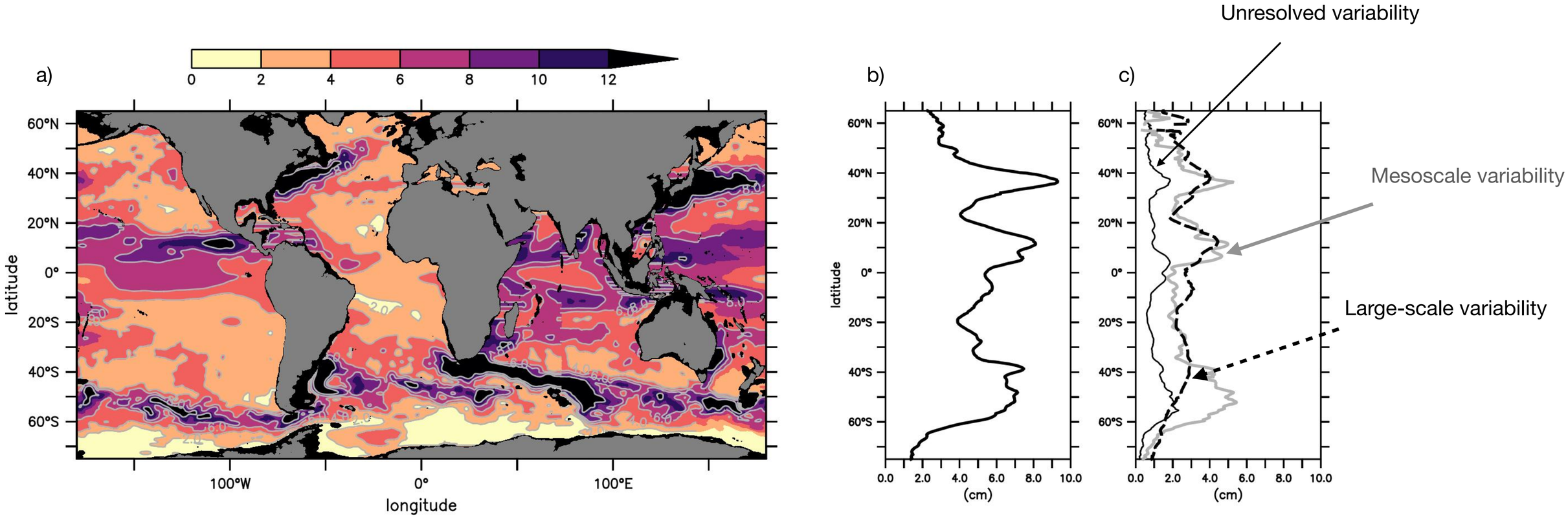
Distance between the assimilation run and observations



***Temperature and salinity RMS residuals** at 23°W, 0° (Atlantic) from the OSSE system and the GLORYS12 reanalysis*

Spatial and temporal scales constrained by observations

Amplitude of the signal at various scales



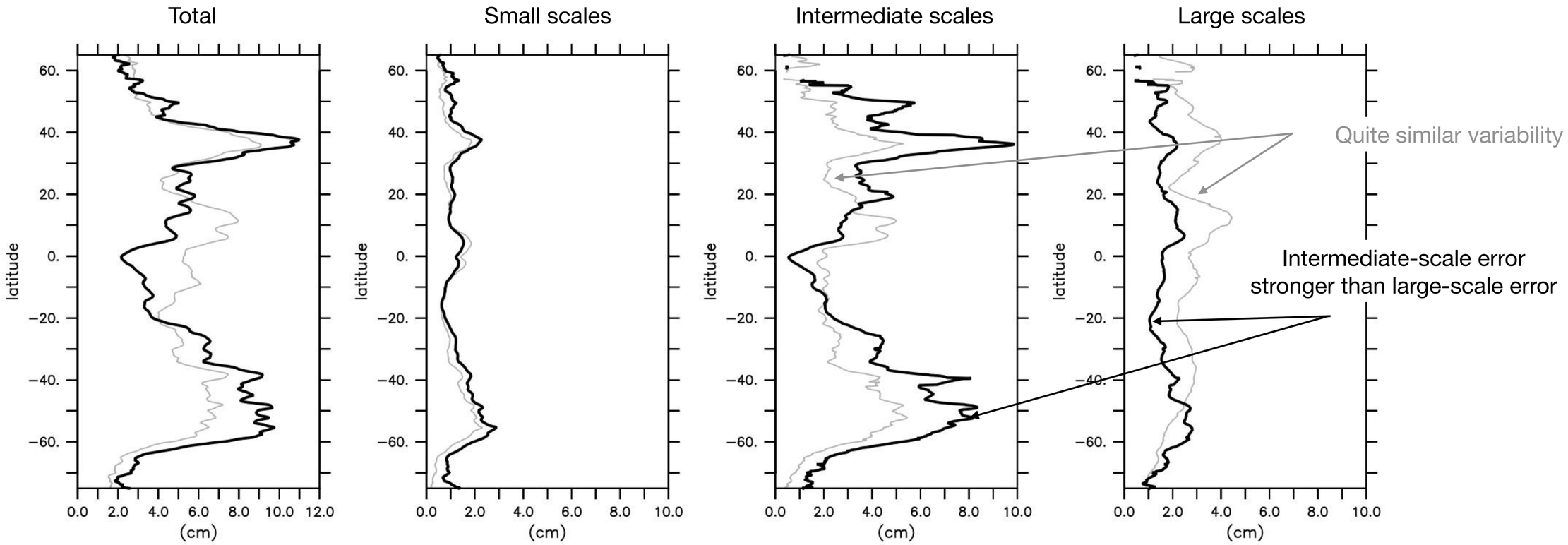
Standard deviation of the daily steric height (SH, cm) from the FREE experiment ((a) spatial map, (b) zonal-average).

Small scales (1°x1°x20-day high-pass filter),
Large scales (9°x9°x100-day low-pass filter)
Intermediate scales (between 1°x1°x20-day and 9°x9°x100-day)

Spatial and temporal scales constrained by observations

Residual error from the **non-assimilated simulation**

Signal variability
FREE error



Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (FREE)

Small scales (1°x1°x20-day high-pass filter),
Large scales (9°x9°x100-day low-pass filter)
Intermediate scales (between 1°x1°x20-day and 9°x9°x100-day)

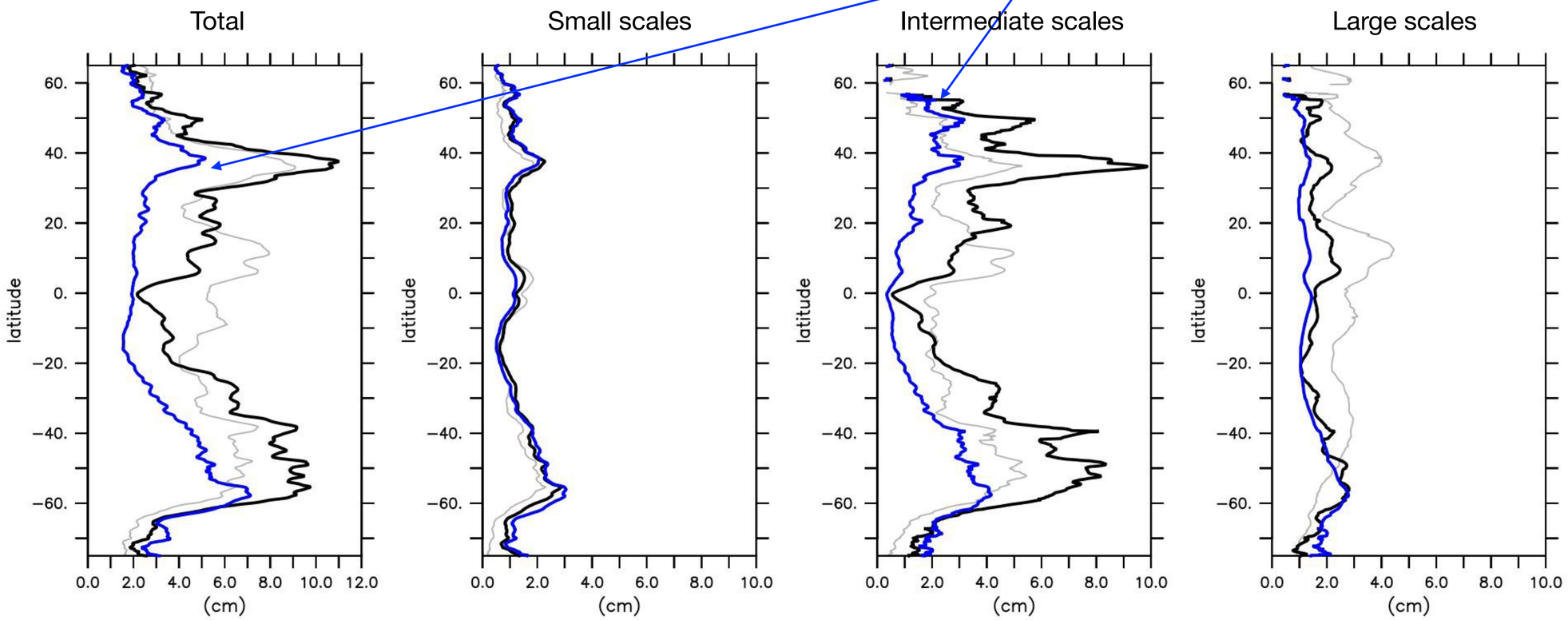
Amplitude of the residual error differently distributed over scales than the signal amplitude

Spatial and temporal scales constrained by observations

Error from the **simulation with satellites assimilation only**

Strong reduction at intermediate scales (mesoscale)

Signal variability
FREE error
ONLYSAT error



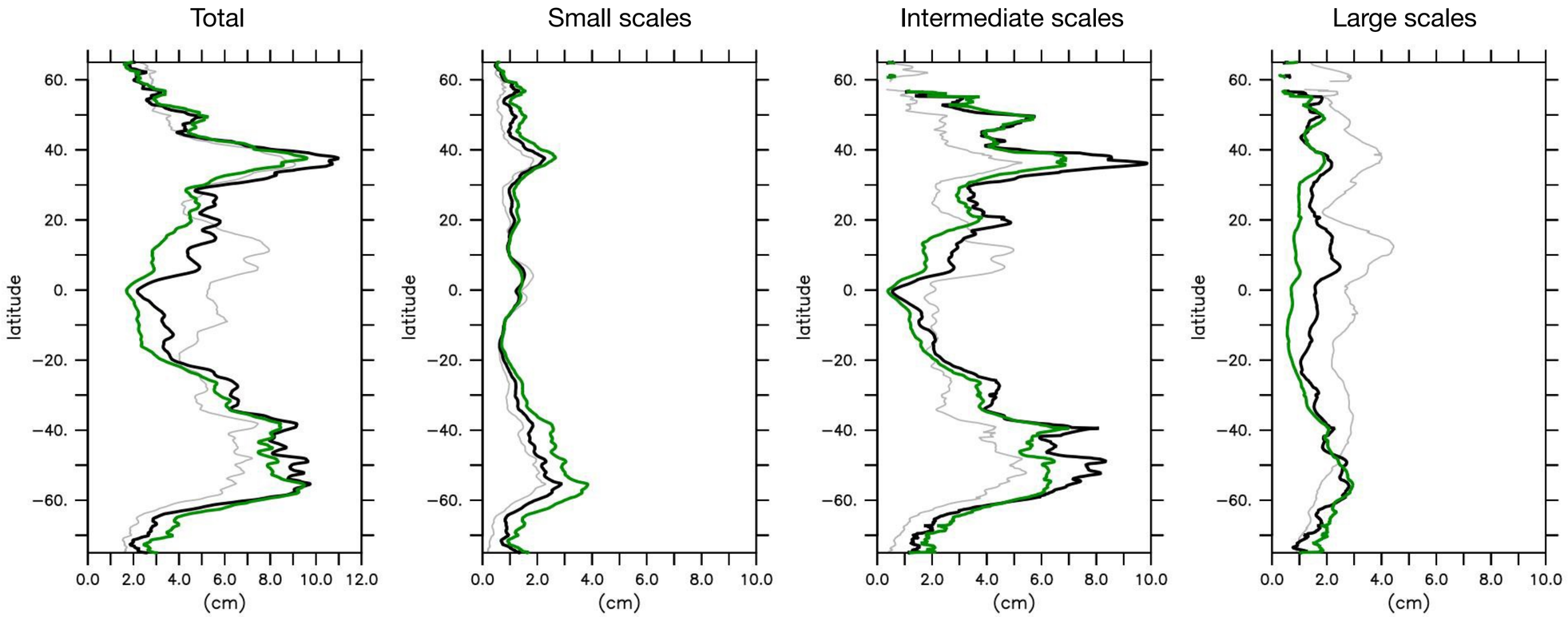
Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (ONLYSAT)

Added value of satellites for **mesoscale activity** at latitudes of Western Boundary Currents regions

Spatial and temporal scales constrained by observations

Error from the **simulation with in situ assimilation only**

Signal variability
FREE error
ONLYSITU

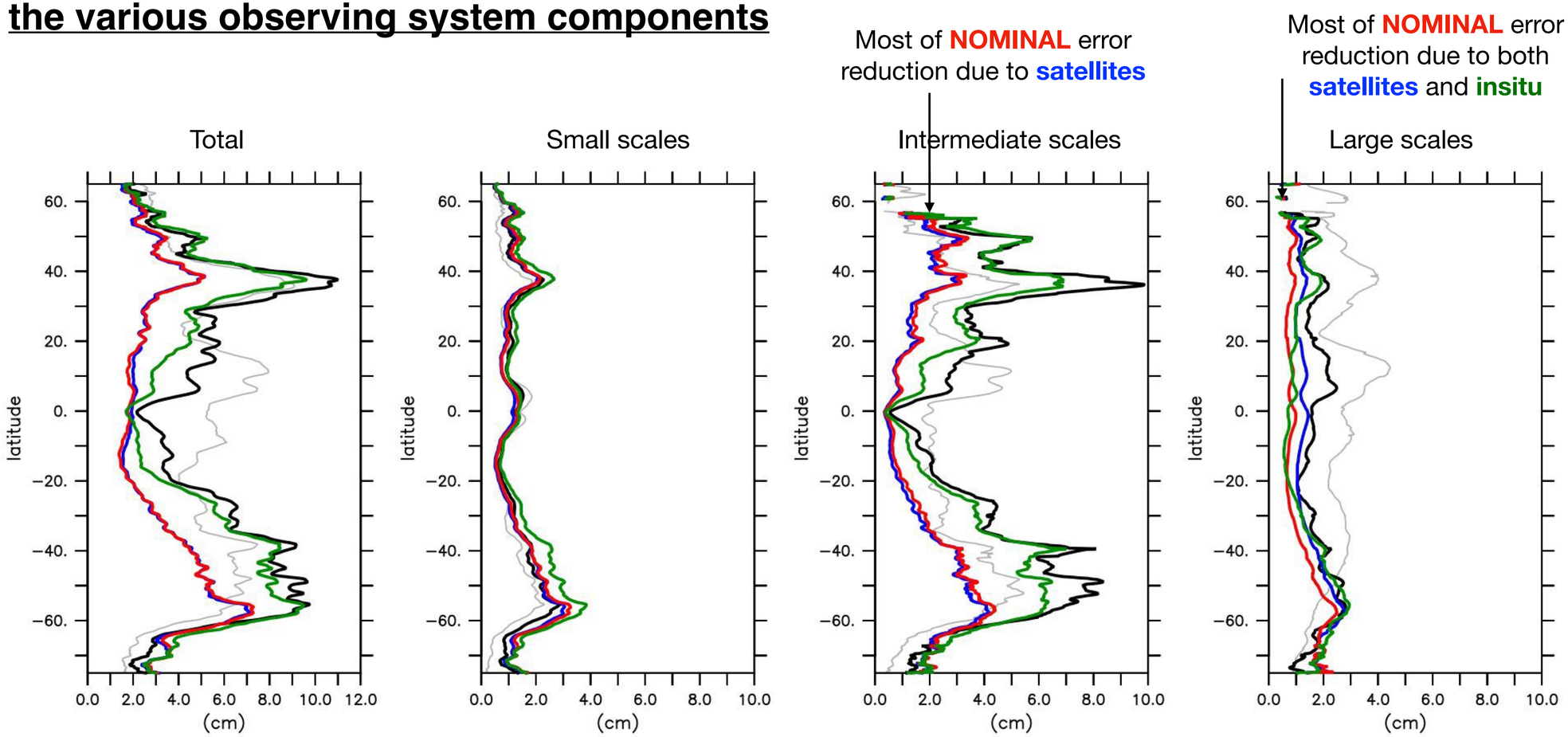


Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (ONLYSITU)

Added value of insitu for **large-scale variability**
preferentially in low-latitude regions

Spatial and temporal scales constrained by observations

Impacts of **the various observing system components**



Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiments

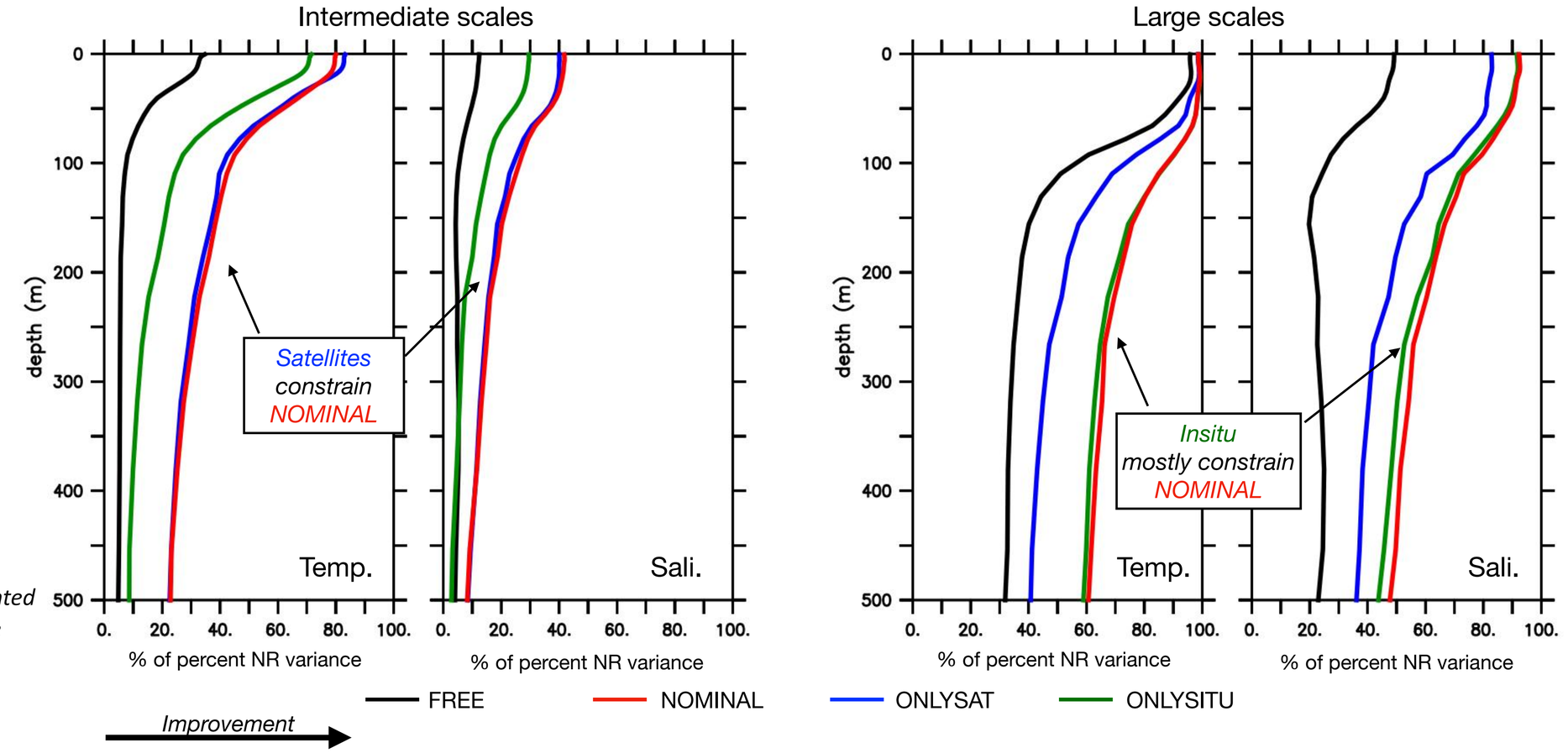
Signal variability
FREE error
NOMINAL error

ONLYSAT error
ONLYSITU error

Strong **complementarity** of satellites and in situ

Spatial and temporal scales constrained by observations

Impacts of the various observing system components **in depth**



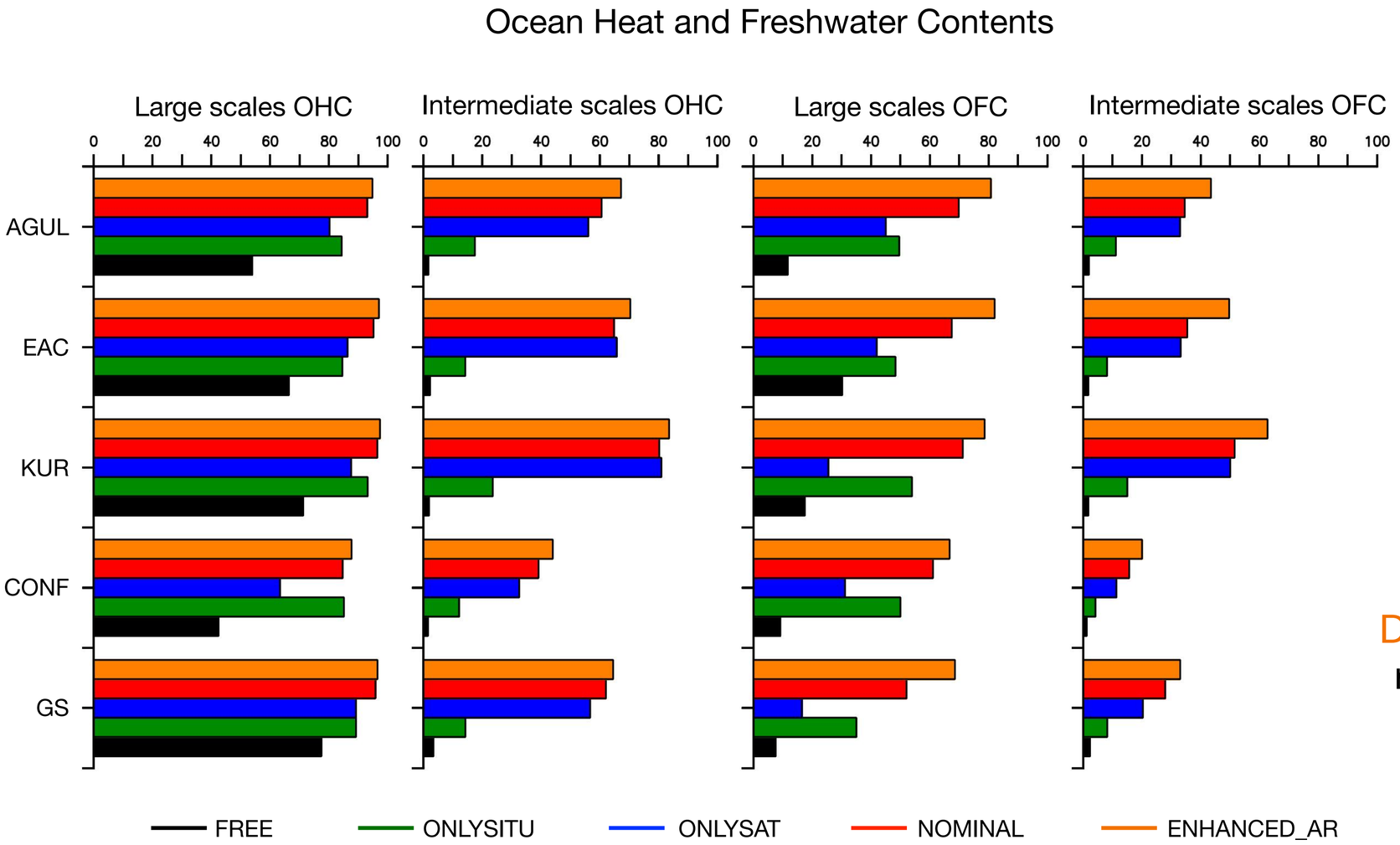
Globally averaged percentage of represented variance of the Nature Run for subsurface temperature and salinity

Significant improvement are seen for each observing system component depending on scales

Potential outcomes of in situ observing system enhancements

Doubling Argo in western boundary currents

Percentage of the Nature Run represented variance, area-averaged in western boundary current regions, for 0-700 m Ocean Heat (OHC) and Freshwater Contents (OFC)

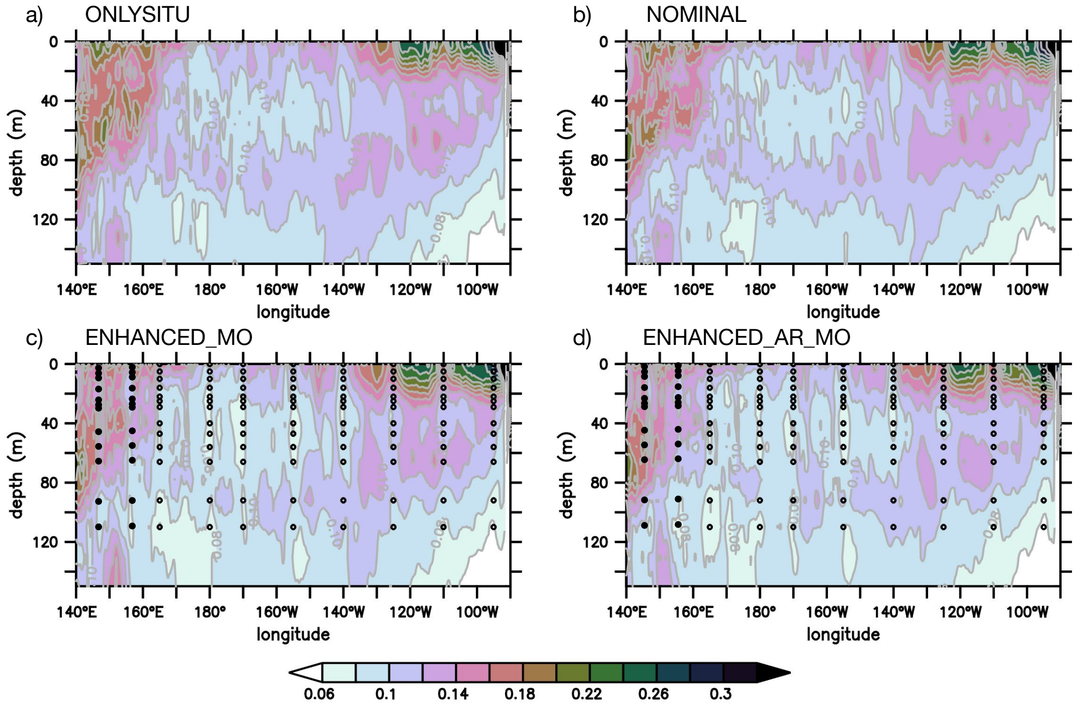


Doubling Argo increases the % of NR represented variance at both scales (up to 15% for salinity)

Potential outcomes of in situ observing system enhancements

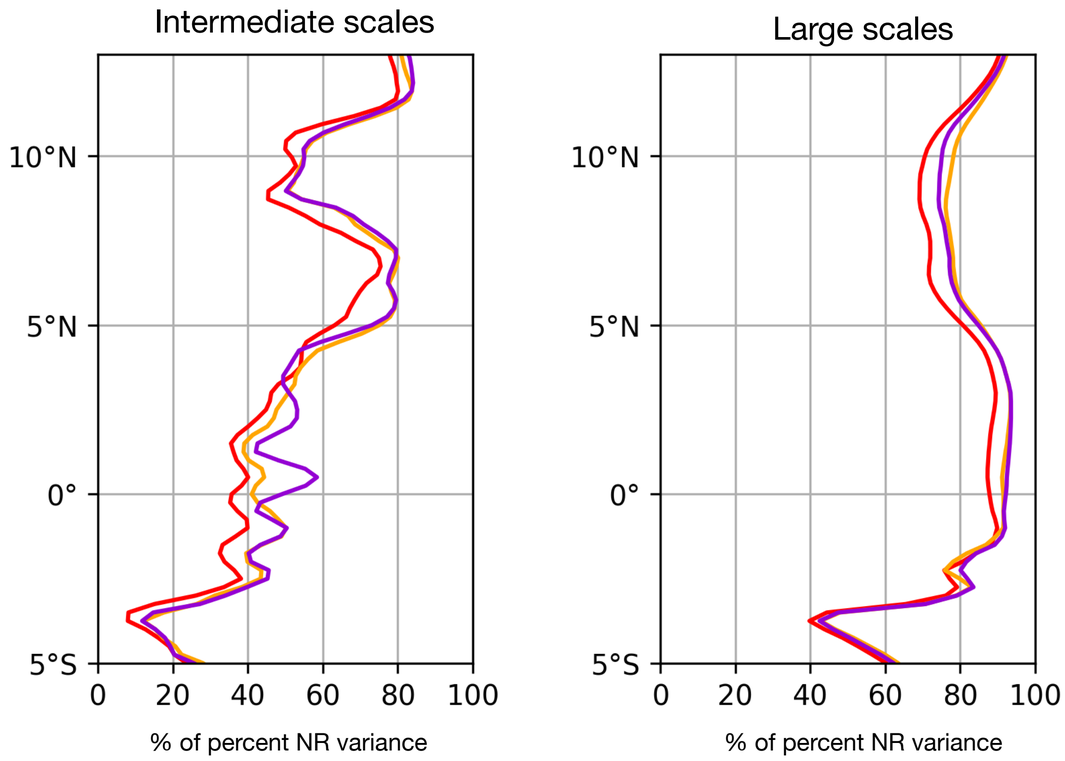
Argo doubling and mooring enhancements in tropics

RMS difference of equatorial salinity from the Nature Run



Black dots indicate the location of salinity observations assimilated from tropical moorings.

Mixed layer depth representation (western Pacific)



Potential improvements of in situ enhancements are seen, but …

further investigations are needed at regional scales and to adapt data assimilation technics

Conclusion

1. Numerical experiments have been performed to assess the current in situ observing system and potential extensions, based on **a well-calibrated experimental framework**

2. Impact assessment of in situ observations includes **both satellites and in situ ocean observing system**

3. **There is a scale dependency** of the contribution of ocean observations

4. Observing system components acts on **different space and time scales**

    1. Altimetry is the main contributor of intermediate variability (mesoscale)

    2. In situ provides the best information about the large-scale signal (altimetry also contributes)

5. Argo extension strongly benefits to the representation of **WBC ocean and freshwater contents**

6. **In situ enhancements (both Argo and moorings)** increase the percentage of represented variance up to 20 %, but work still needed to make the best use of ocean observations