On the control of spatial and temporal oceanic scales by existing and future observing systems: an OSSE approach

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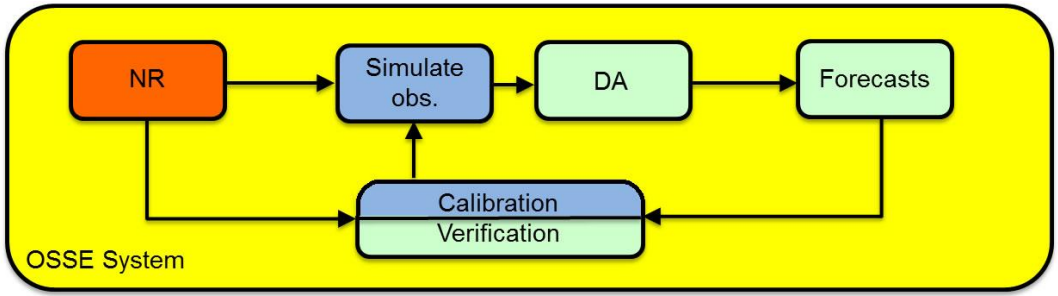
Observation impact assessment

Observation impact studies are performed at MOi and OceanPredict centers to:

- ✓ verify that observation information is « optimally » used in the analysis step and improve the assimilation components,
- ✓ quantify the impact of the observation network in ocean analyses and forecasts,
- ✓ demonstrate the value of an observation network for ocean analyses and forecasts,
- ✓ test future observing system design from an integrated system perspective involving satellite and in-situ observations and numerical models.

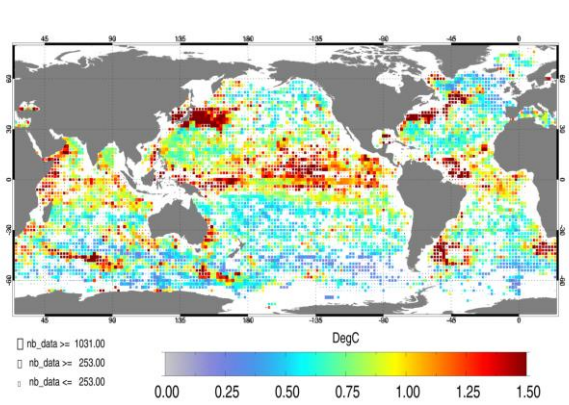
OSEs (Observing System Evaluations) => assessing the impact of existing data sets on a (by withholding observations). Other approaches (e.g. DFS) are also used.

OSSEs (Observing System Simulation Experiments) => help designing new observing systems and to perform preparatory data assimilation work.

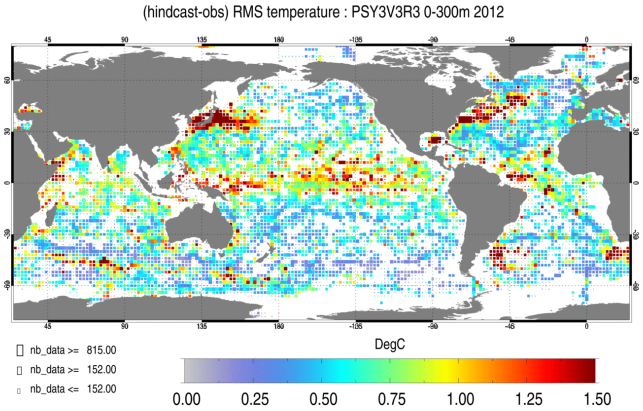


Impact of the present ARGO network on the global ¼° analysis

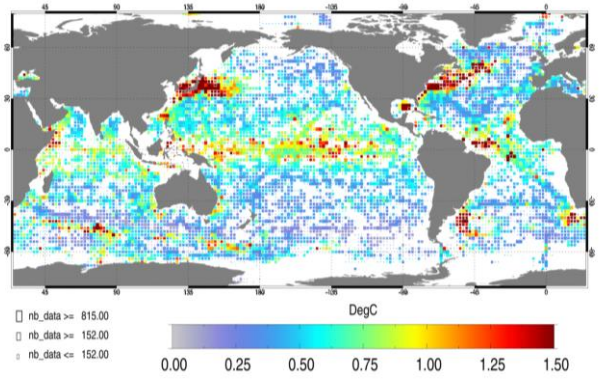
Global RMS 0-300m misfit between the *in-situ* temperature observations and OSEs analysis



Run-No Argo



Run-Argo/2



Run- All Argo

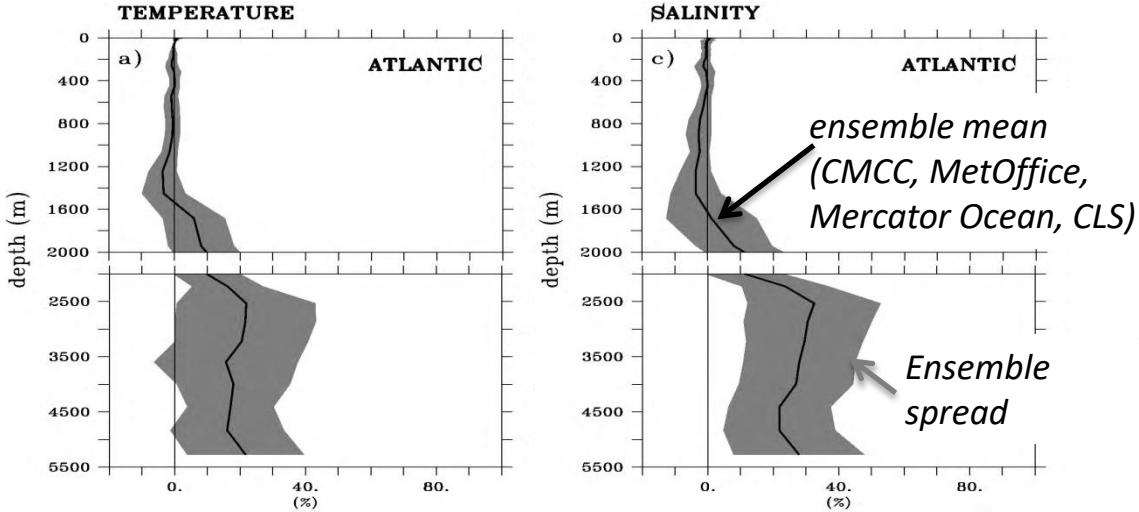
Regions of higher impact:

- at depth, **water masses from outflow or deep convection are better represented**,
- in the surface layers, the largest impact is found in the **tropical band and energetic ocean regions (WBC,…)**,
- keeping only half of the ARGO floats degrades significantly the analysis.

Turpin et al., 2016

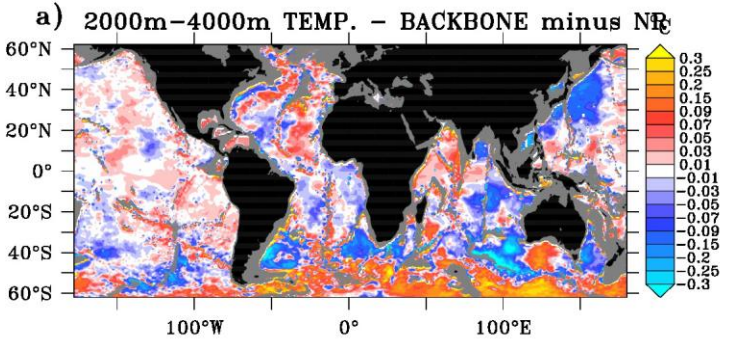
Multi System Deep Argo OSSEs (CMCC, MetOffice, Mercator Ocean, CLS)

- Impact of deep-Argo on T and S in the 2000-4000m layer is very strong, the Southern Ocean remains under sampled.
- Compared with Argo4000, Argo6000 significantly reduces biases in the 4000-6000m layer.

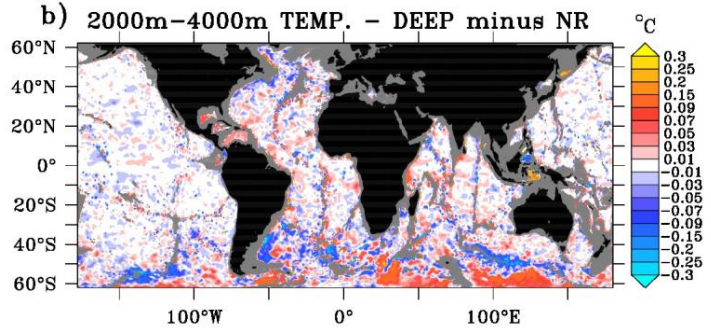


Temperature and salinity profiles of error reduction in % of the DEEP exp. as compared with the BACKBONE experiment, relative to the Nature Run fields.

Backbone (MOi)



Backbone + Deep Argo (MOi)



Ocean deep temperature error (2000-4000 m)

AtlantOS

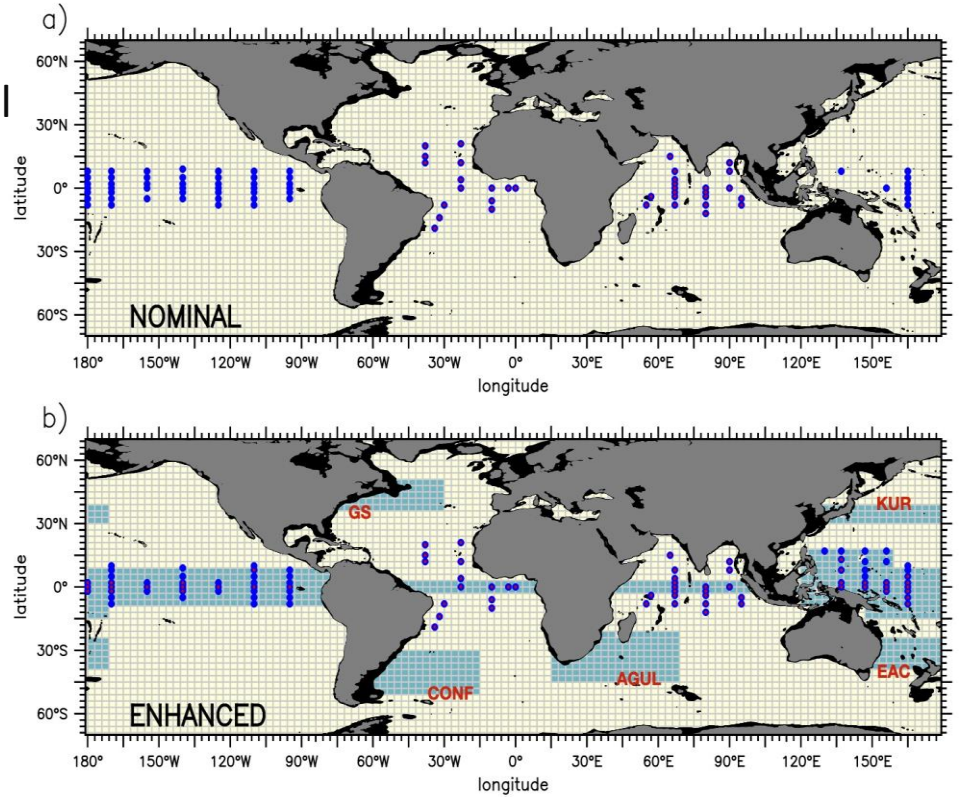
Gasparin et al.: J. Climate, 2019; Frontier in Marine Sci., 2019

Potential impact of Argo planned extension on global analysis

OSSEs were performed with synthetic T/S profiles from Argo floats (shading) and tropical moorings (dots) for 2 designs:

- Nominal: 1 Argo float per 3°x3°x10-day,
- Enhanced: 2 Argo floats per 3°x3°x10-day in WBC and in the Tropics.

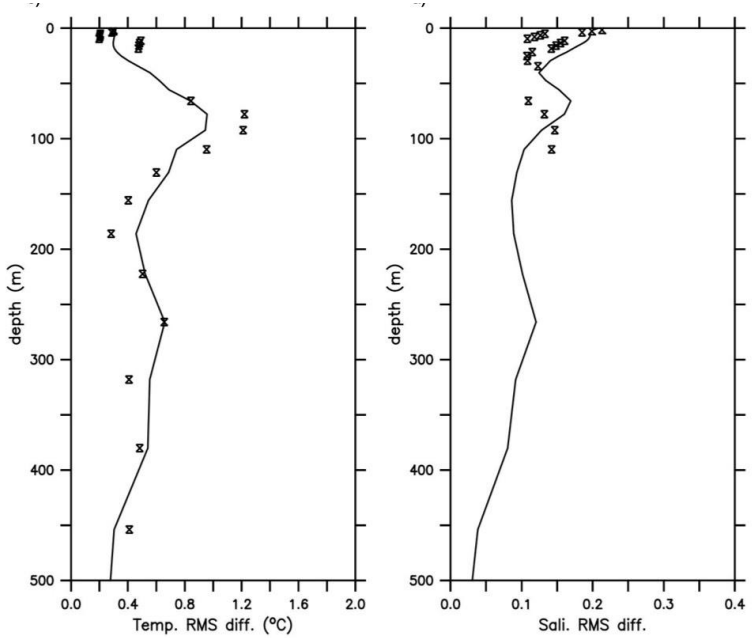
- What will be the impact of the Argo extensions?
- What is the complementarity between different observing systems in constraining the analysis between Altimetry, Tropical moorings and Argo data?



Gasparin et al.: On the control of spatial and temporal oceanic scales by existing and future observing systems: an OSSE approach, submitted to Frontiers.

Design and calibration of the OSSEs

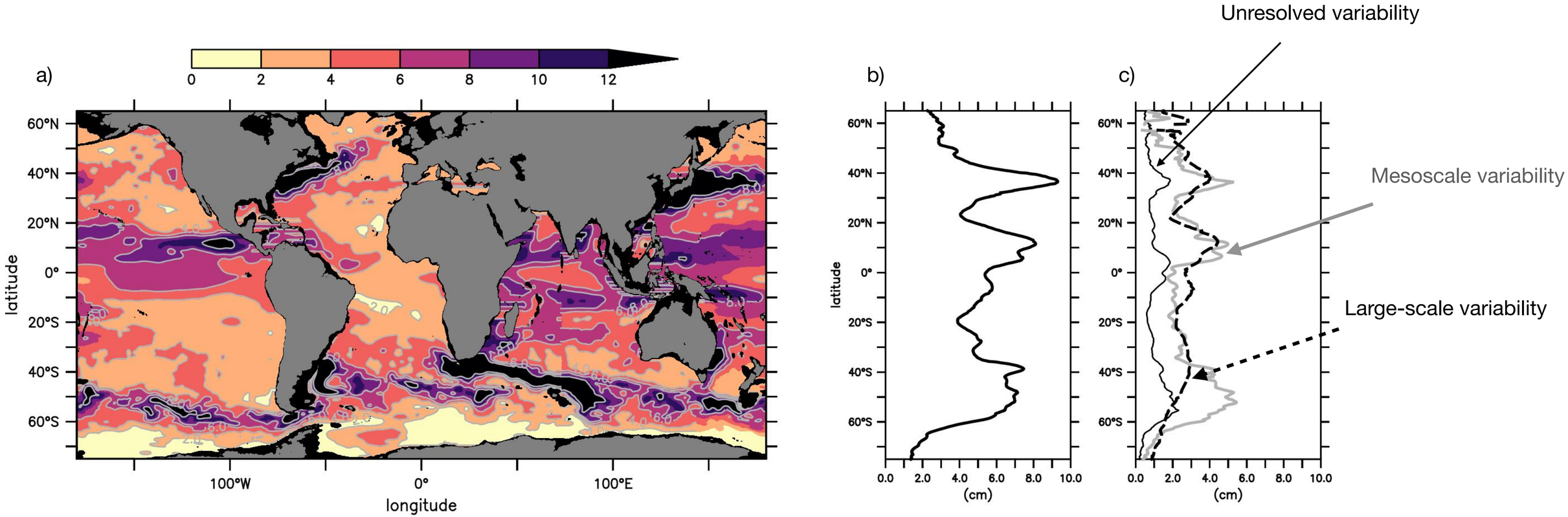
Experiment name	Assimilated observations
FREE	No data assimilation
ONLYSITU	Only Argo and Moorings
ONLYSAT	Only SST and altimetry
NOMINAL	Argo, Mooring, SST, altimetry
ENHANCED_AR	Nominal + Argo extension (WBC, Equator)
ENHANCED_MO	Nominal + Mooring extensions
ENHANCED_AR_MO	Nominal + Argo and Mooring extension



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

Spatial and temporal scales constrained by observations

Amplitude of the signal at various scales



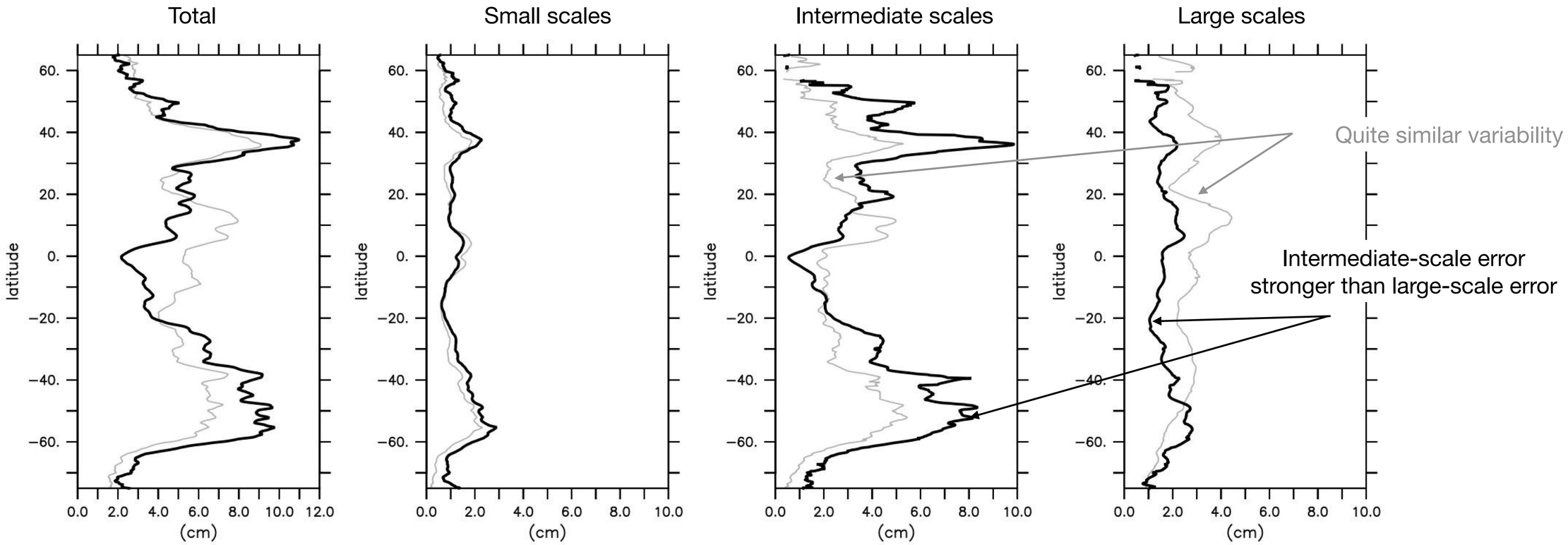
Standard deviation of the daily steric height (SH, cm) from the FREE experiment ((a) spatial map, (b) zonal-average).

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)

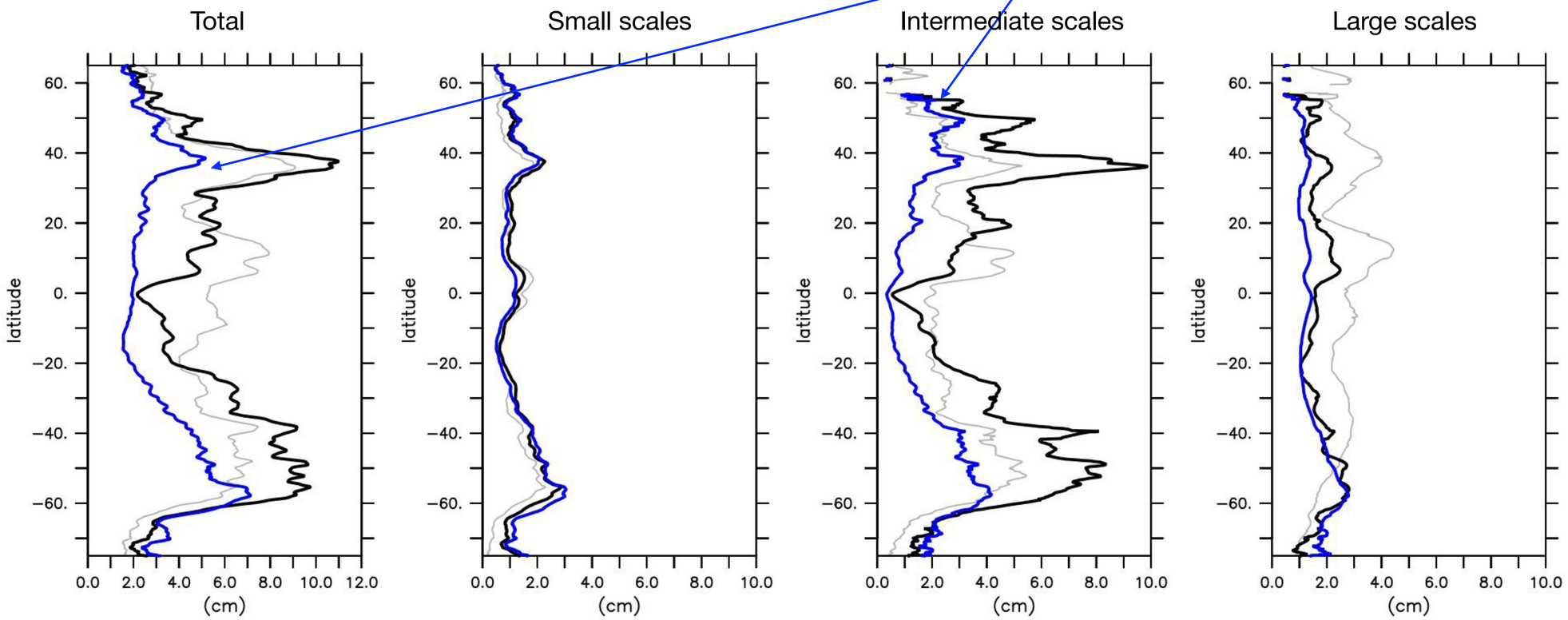
Amplitude of the residual error differently distributed over scales than the signal amplitude

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



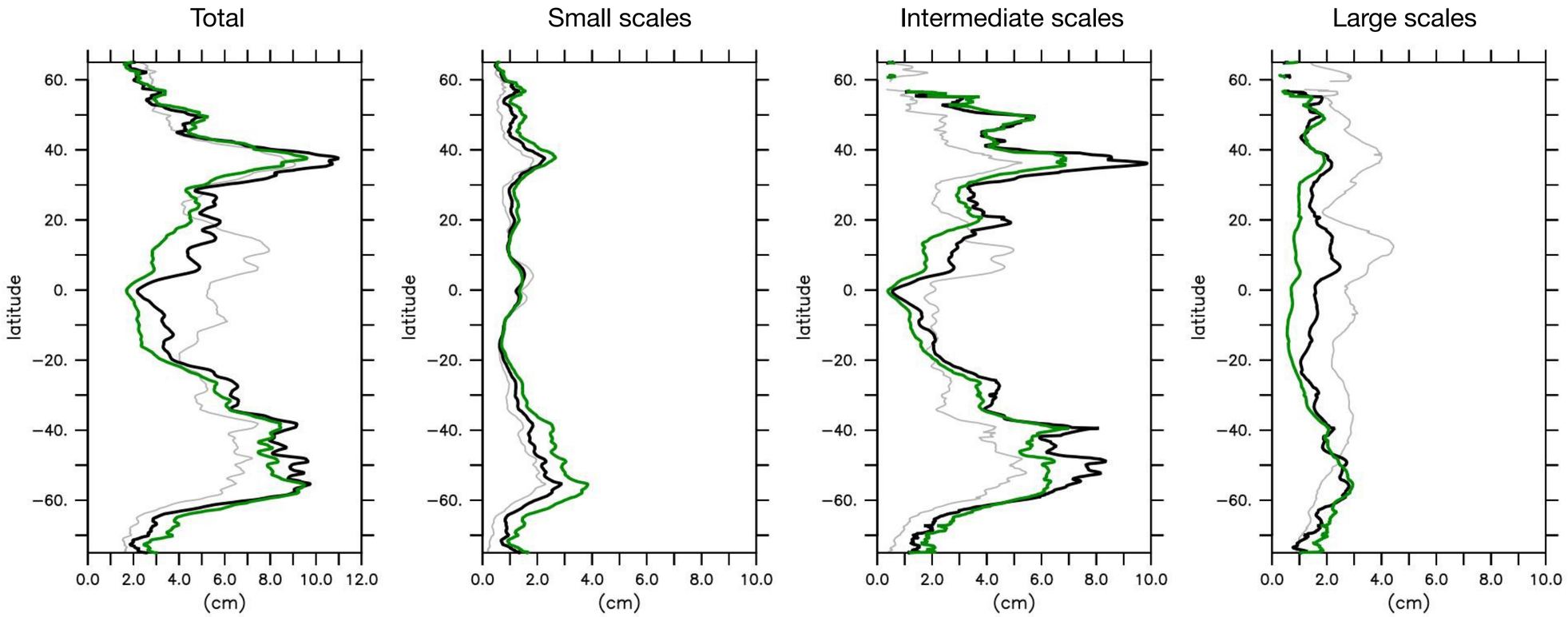
Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (ONLYSAT)

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

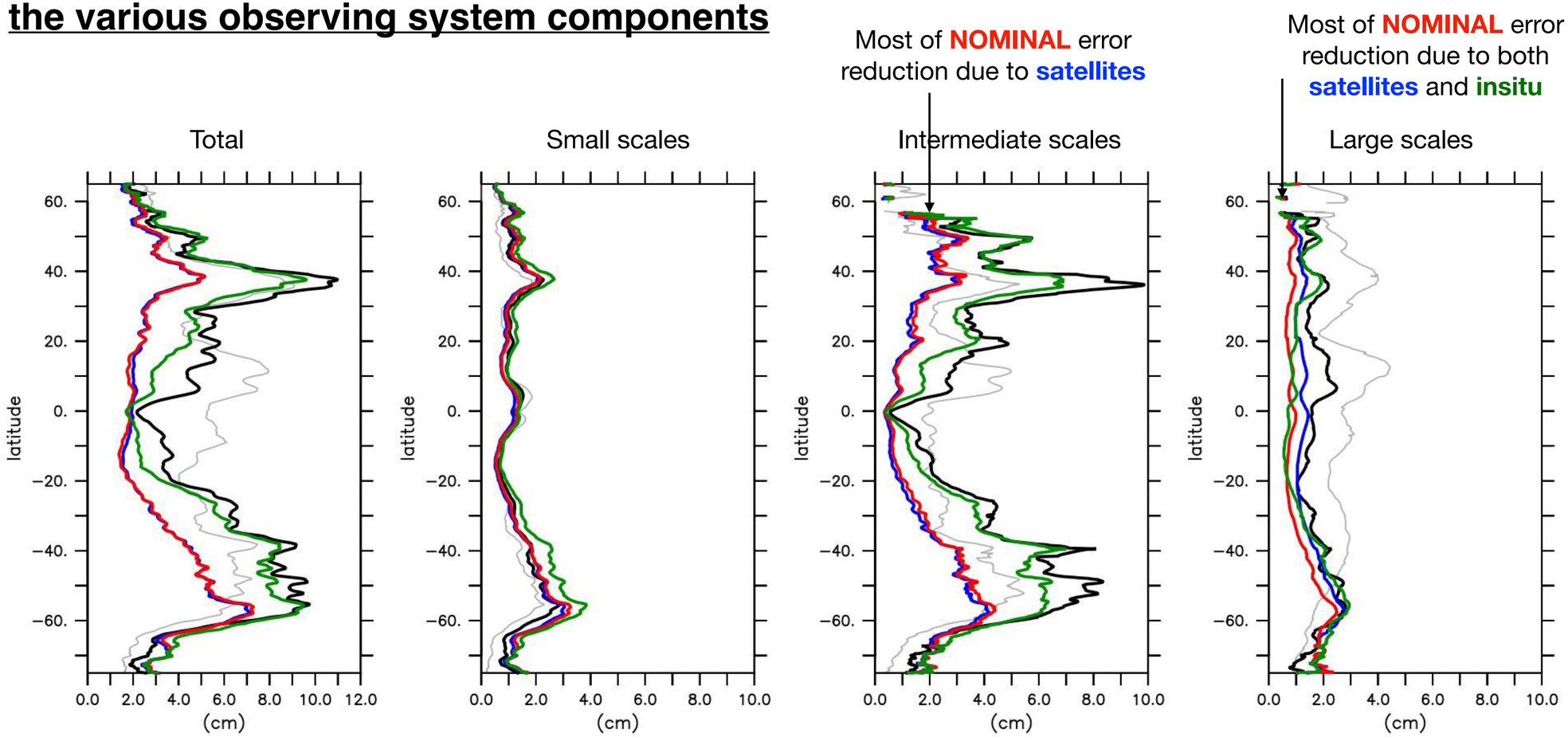


Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (ONLYSITU)

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

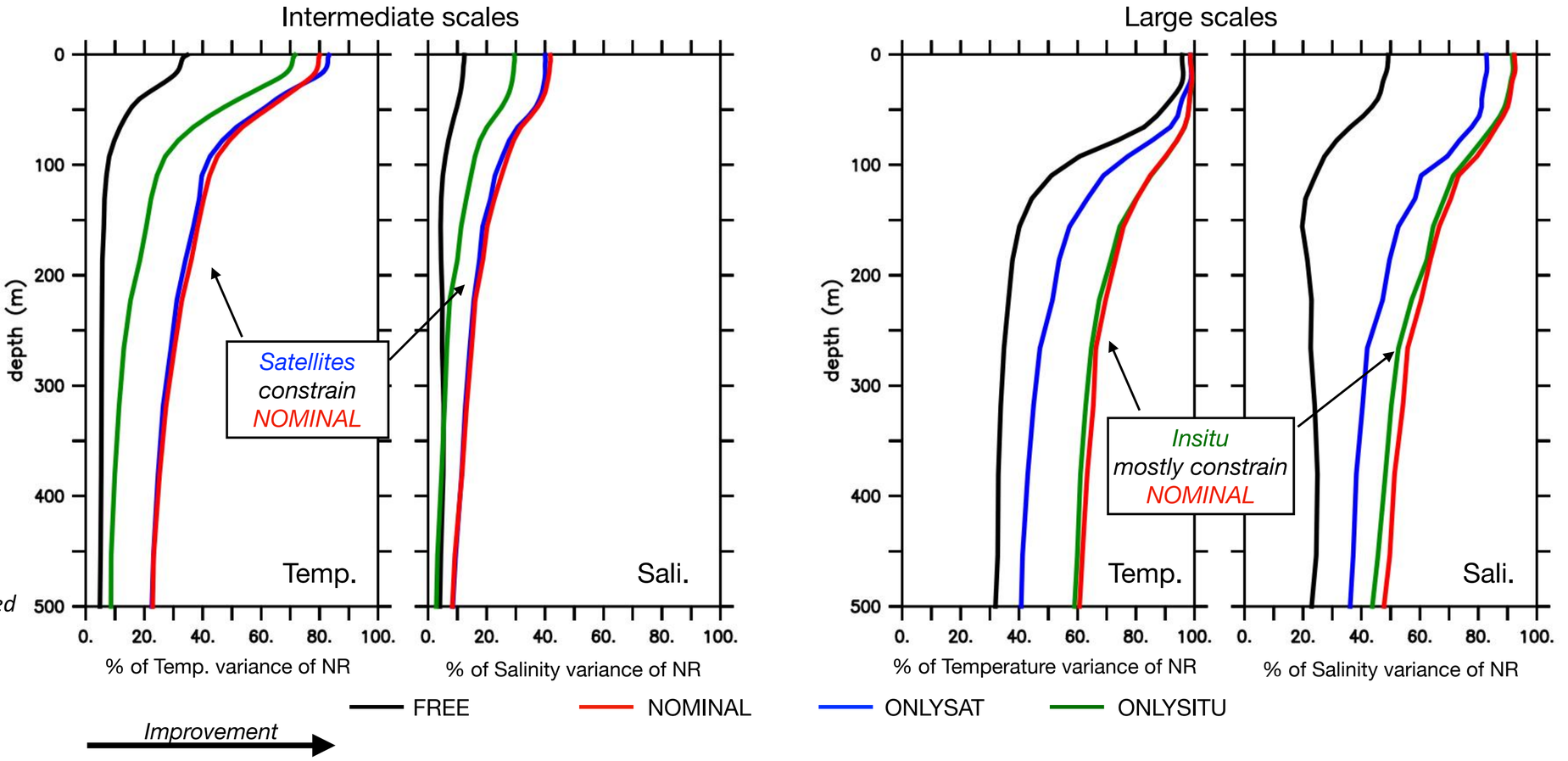
Strong **complementarity** of satellites and in situ

Spatial and temporal scales constrained by observations

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

$$\% \text{ of variance} = 1 - \frac{\text{Var(Exp-NatureRun)}}{\text{Var(NatureRun)}}$$

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

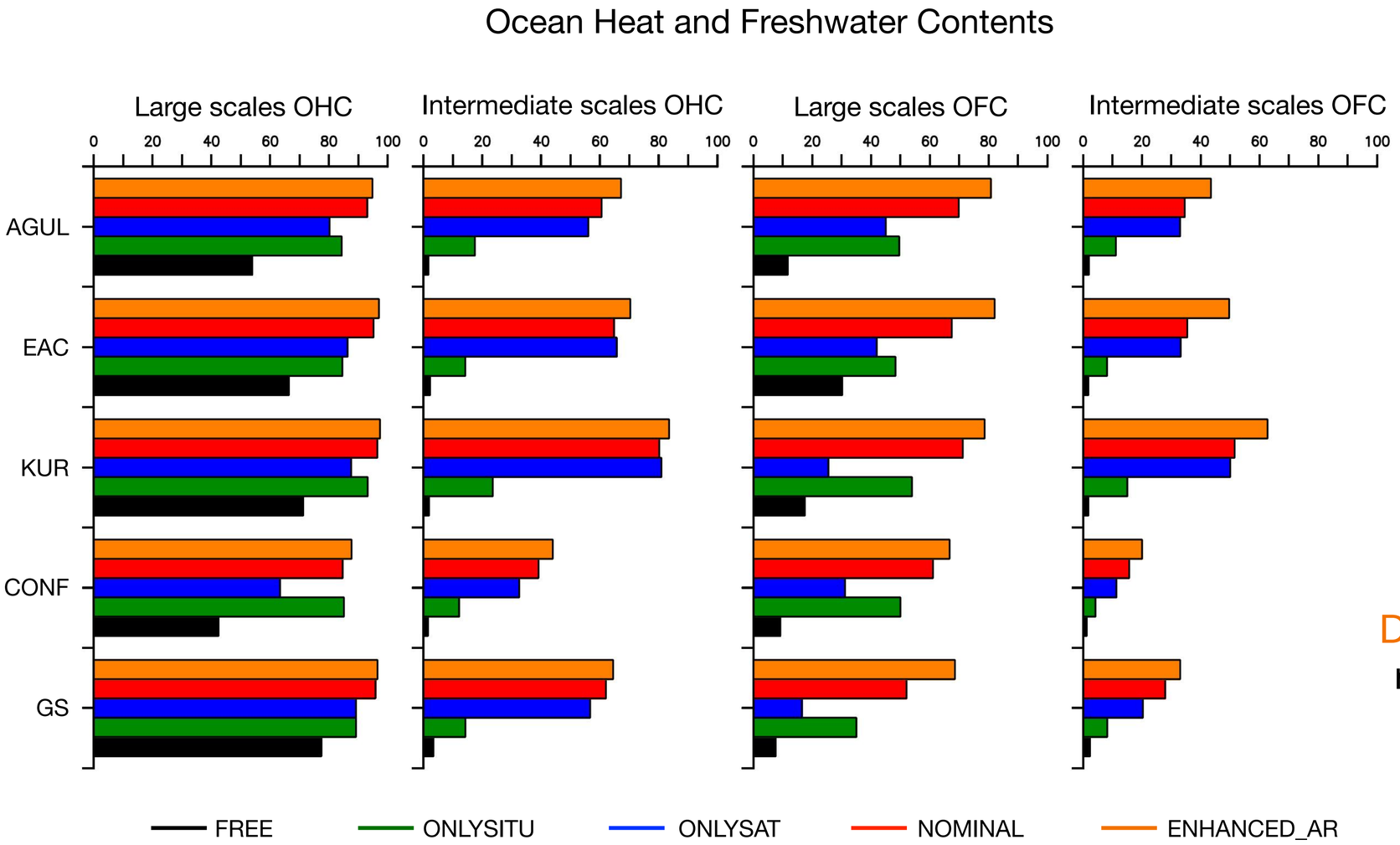


Significant improvement are seen for each observing system component depending on scales

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)

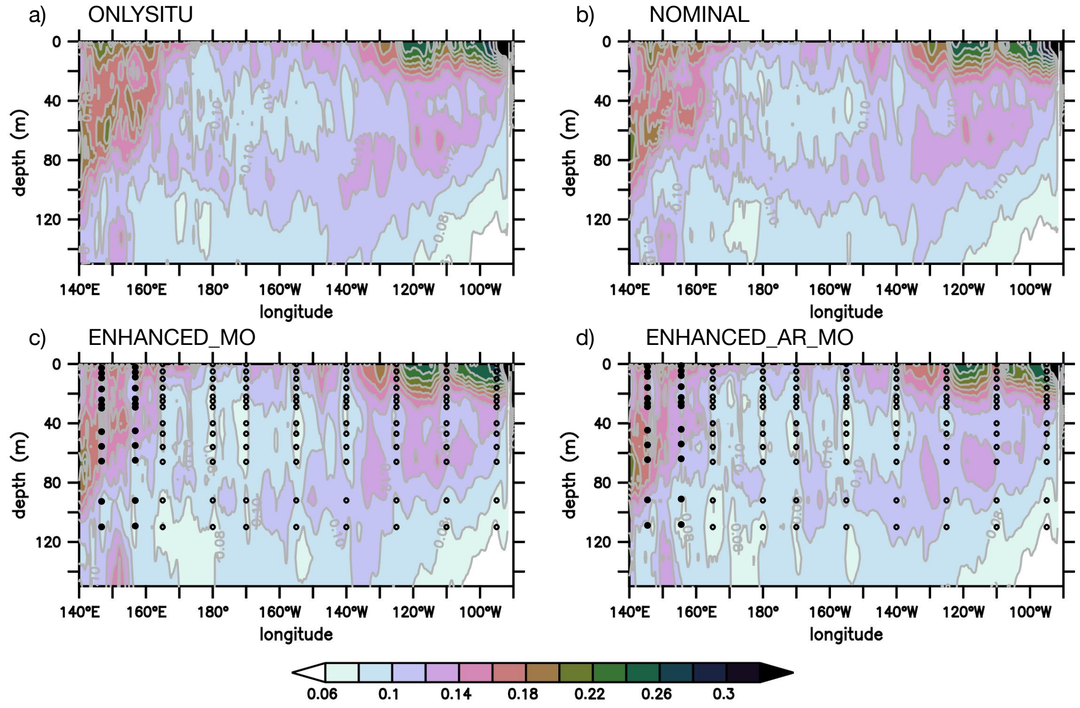


Doubling Argo increases the % of NR represented variance at both scales (up to 15% for salinity)

Potential outcomes of in situ observing system enhancements

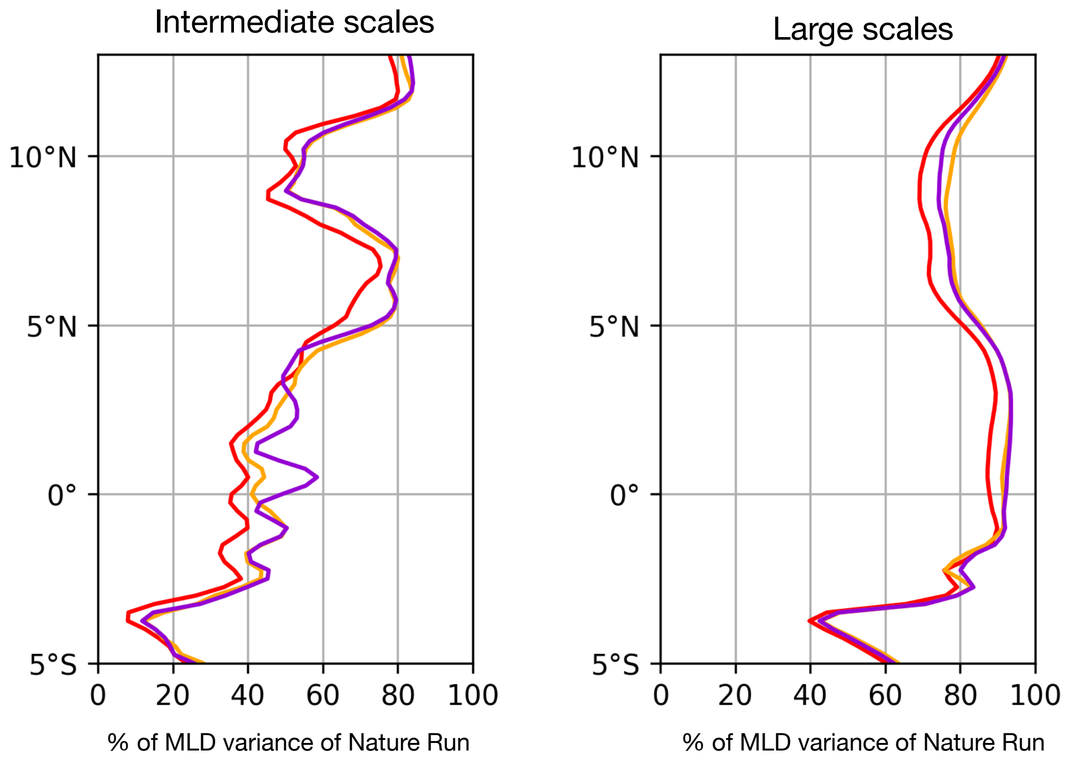
Argo doubling and mooring enhancements in tropics

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 (MLD, 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