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Identifying spatial and temporal oceanic scales constrained by existing and future observations

F. Gasparin[1,*], **E. Rémy[1]**, R. Balakrishnan[1,**], J.M. Lellouche[1], S. Cravatte[2], G. Ruggiero[1]

1 Mercator Ocean International, Toulouse, France,
2 Université de Toulouse, LEGOS (IRD/UPS/CNES/CNRS), Nouméa, New Caledonia

** Now at Université de Toulouse, LEGOS (IRD/UPS/CNES/ CNRS), France*
*** Now at, Indian National Center for Ocean Information Services (INCOIS), INDIA*

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Relevance of ocean observations for operational systems ?

Recurring evaluation needed due to :

the continuous development of oceanic models and data assimilation techniques

the increased diversity of assimilated in situ platforms

But, more and more difficult

to establish how information from observations is used

to determine the utility/relevance of a change of the global ocean observing system on ocean analyses.

Main results from two different approaches recently published (almost)

1. Observing System Simulation Experiments to disentangle in situ and satellite information (H2020 Eurosea project, 2019-2023)

*Gasparin, Lellouche, , Cravatte, Ruggiero, Rohith, Le Traon, & Remy (2023). On the control of **spatial and temporal oceanic scales** by existing and future observing systems: An observing system simulation experiment approach. Frontiers in Marine Science, 10, 1021650.*

2. Comparison of the GLORYS12 reanalysis and its twin-free version to investigate oceanic processes at intraseasonal scales

*Rohith, Gasparin, Ruggiero, Remy, Cravatte. On the **intraseasonal oceanic processes** constrained by data assimilation: a case study of the Tropical Pacific (In revision, Monthly Weather Review)*

Disentangling in situ and satellite information

1. Observing System Simulation Experiments to disentangle in situ and satellite information (H2020 Eurosea project, 2019-2023)

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Disentangling in situ and satellite information

Design Experiments

OSSE system:

- Nature Run : Free version of GLORYS12 (1/12°)
- Assimilation system : ¼° global Mercator Ocean system
- Synthetic obs. : In situ (Argo, moorings), SST, SSH

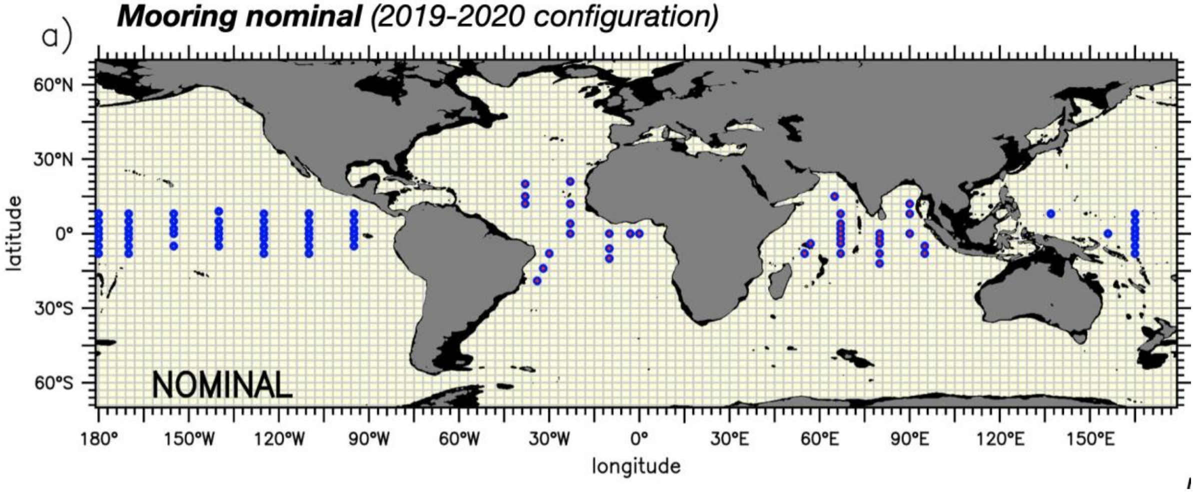
Experiments :

- 2-yr OSSE experiments (2016-2017)
- 3 OSSE to assess <u>existing</u> observing system components
- 3 OSSE to assess <u>extensions</u> (Argo & Tropical moorings; Oceanobs 19) – *NOT SHOWN TODAY*

Calibration of realistic experiments :

- Synthetic observation error – (Gasparin et al., 2019)
- Similar distance between
  NOMINAL & FREE and GLORYS12 & FREEGLORYS12
  NOMINAL & Obs. and GLORYS12 & Obs.

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



*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

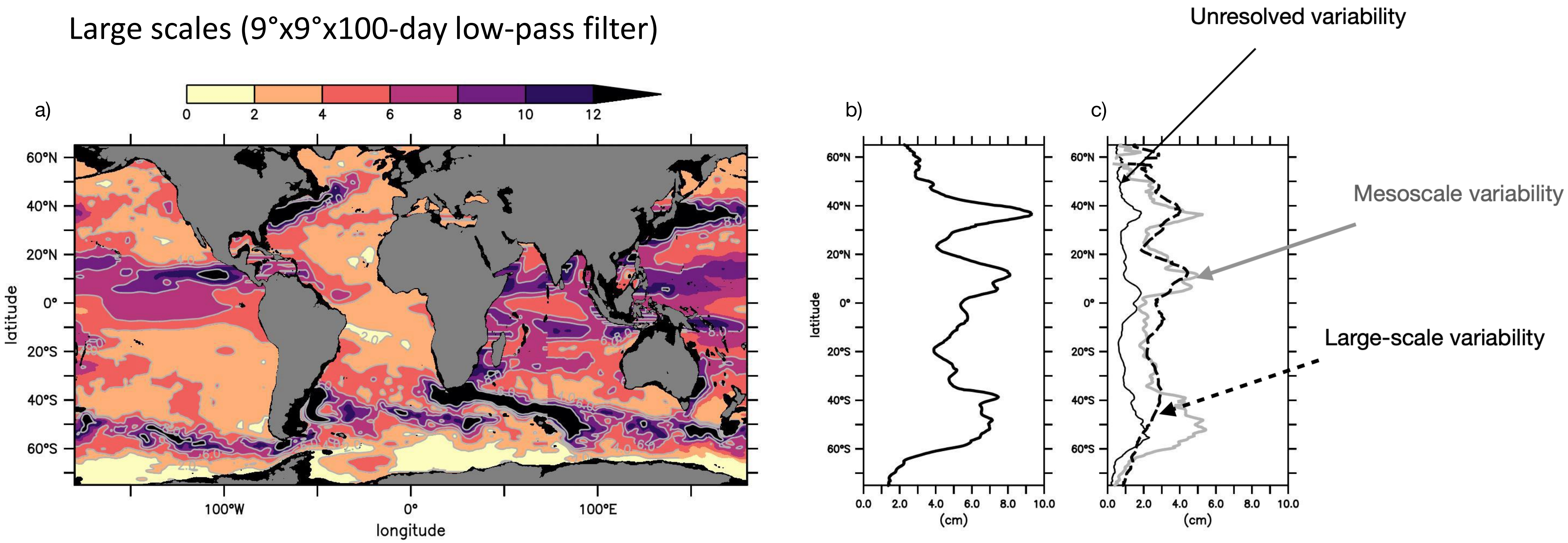
Disentangling in situ and satellite information

Variability amplitude for **various scales**

Unresolved scales (1°x1°x20-day high-pass filter),

Intermediate-Mesoscale (between 1°x1°x20-day and 9°x9°x100-day)

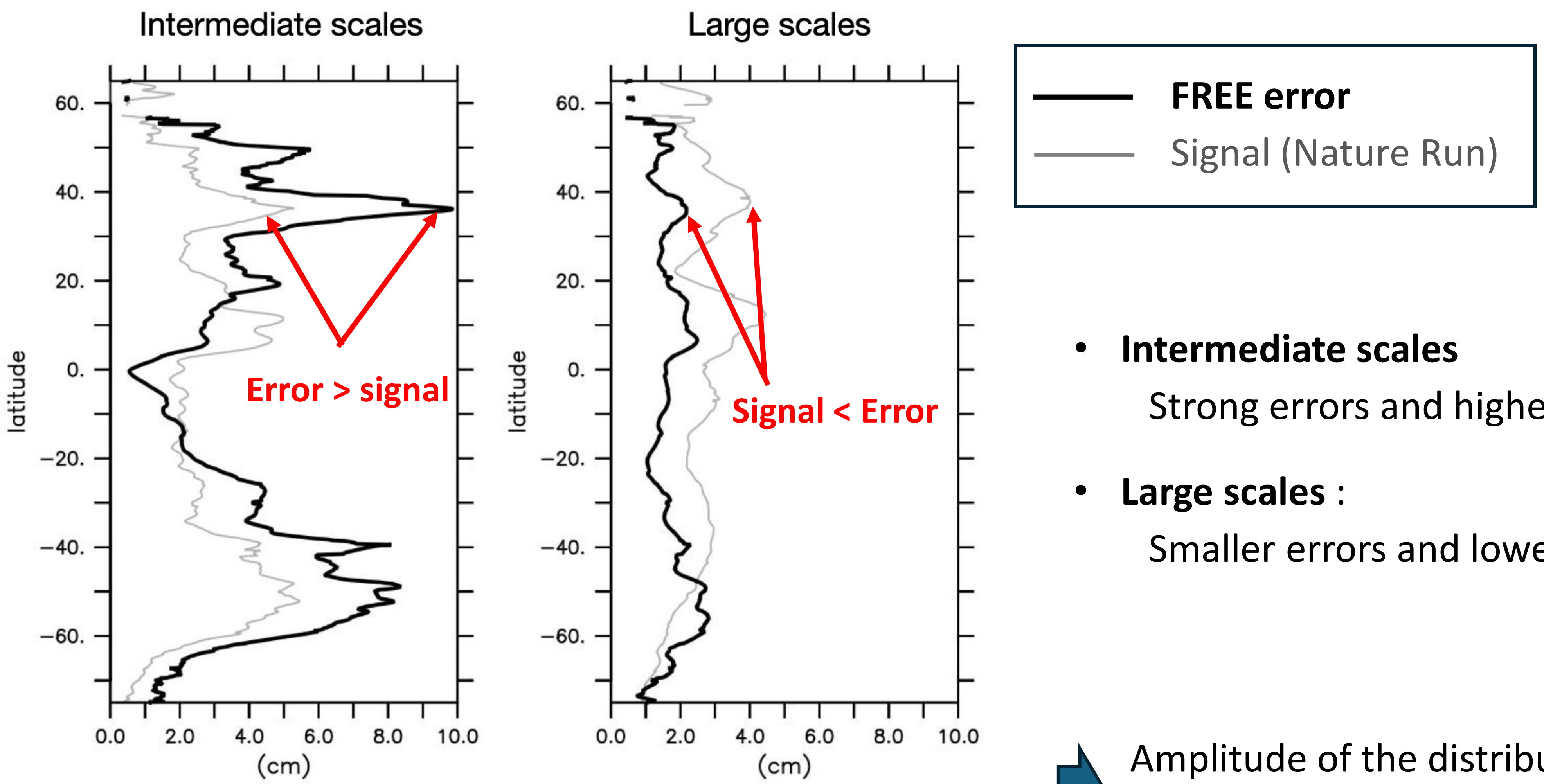
Large scales (9°x9°x100-day low-pass filter)



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

Disentangling in situ and satellite information

Residual error from the **non-assimilated** simulation (FREE)



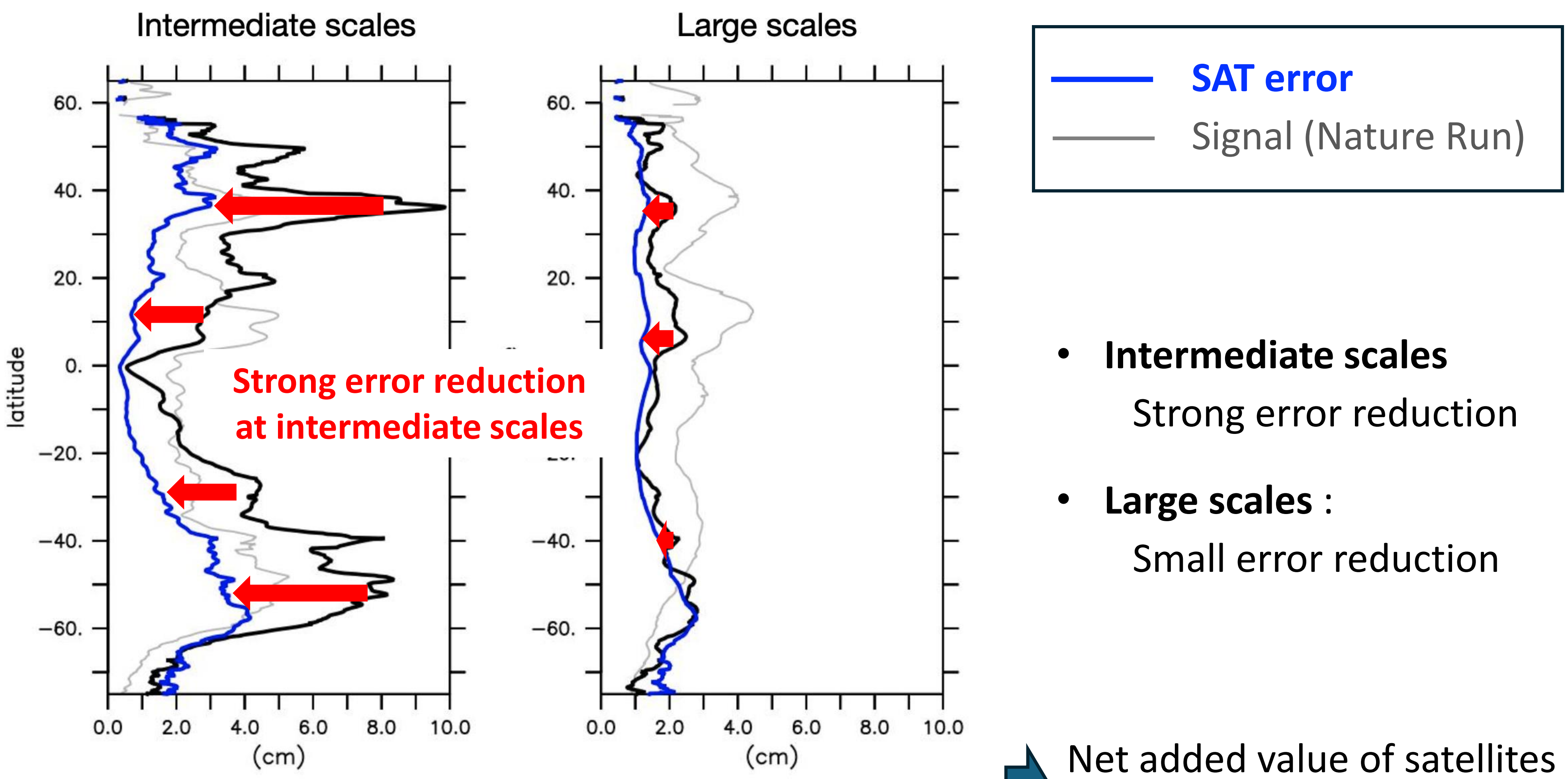
Zonally averaged steric height (SH, cm) RMS difference between the Nature Run and experiment (FREE)

- **Intermediate scales**
  Strong errors and higher than the signal
- **Large scales** :
  Smaller errors and lower than the signal

➔ Amplitude of the distributed differently across scales compared to the signal amplitude

Disentangling in situ and satellite information

Residual error from the OSSE with **satellites** assimilation only (SAT)



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

- **Intermediate scales**
  Strong error reduction
- **Large scales** :
  Small error reduction

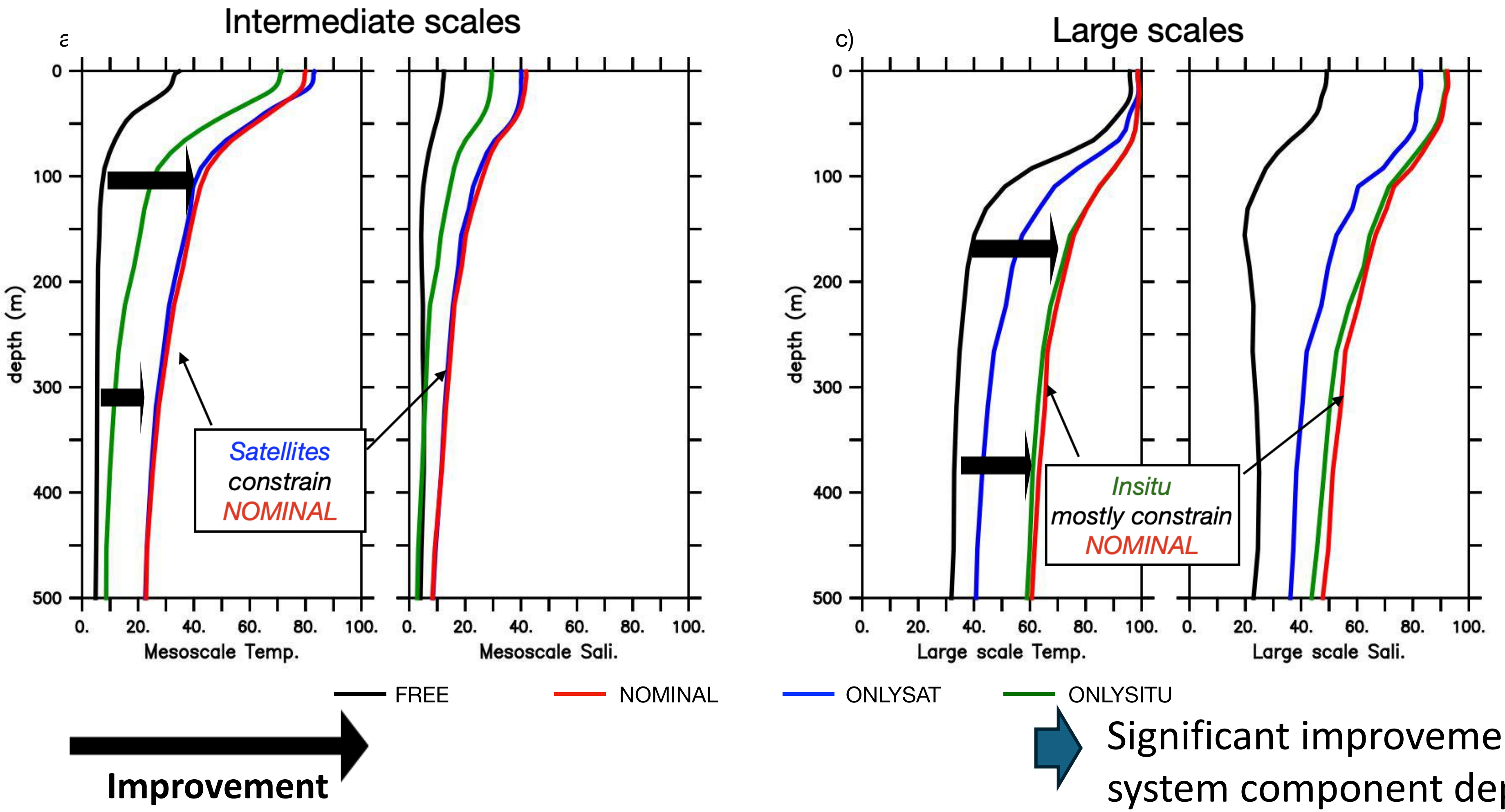
Net added value of satellites at intermediate scales

Added value of in situ for large-scales (not shown)

Disentangling in situ and satellite information

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

Globally averaged % of represented variance of the Nature Run for subsurface T/S



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

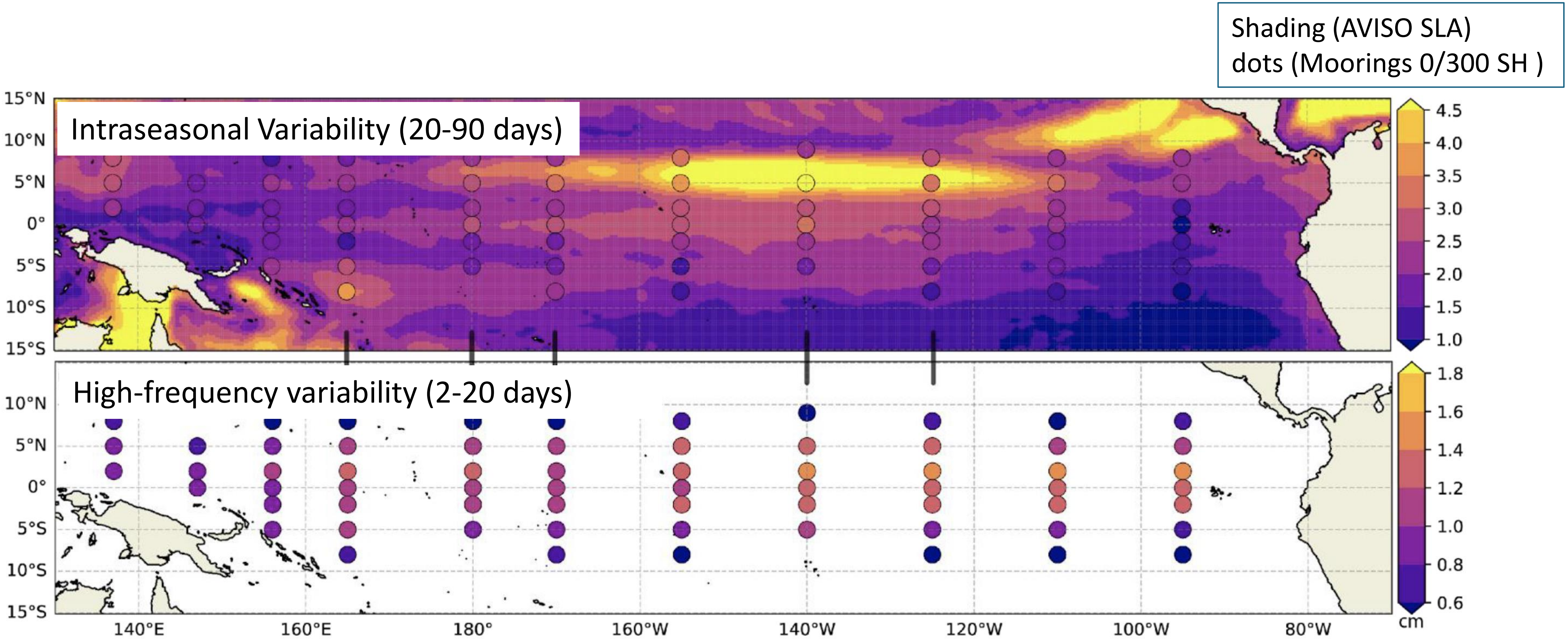
Significant improvement are seen for each observing system component depending on scales

2. Comparison of the GLORYS12 reanalysis and its twin-free version to investigate oceanic processes at intraseasonal scales

Rohith, Gasparin, Ruggiero, Remy, Cravatte. On the ***intraseasonal oceanic processes*** *constrained by data assimilation: a case study of the Tropical Pacific (In revision, Monthly Weather Review)*

Impact on oceanic processes at intraseasonal scales

Both **altimetry and moorings** capture oceanic subseasonal variability

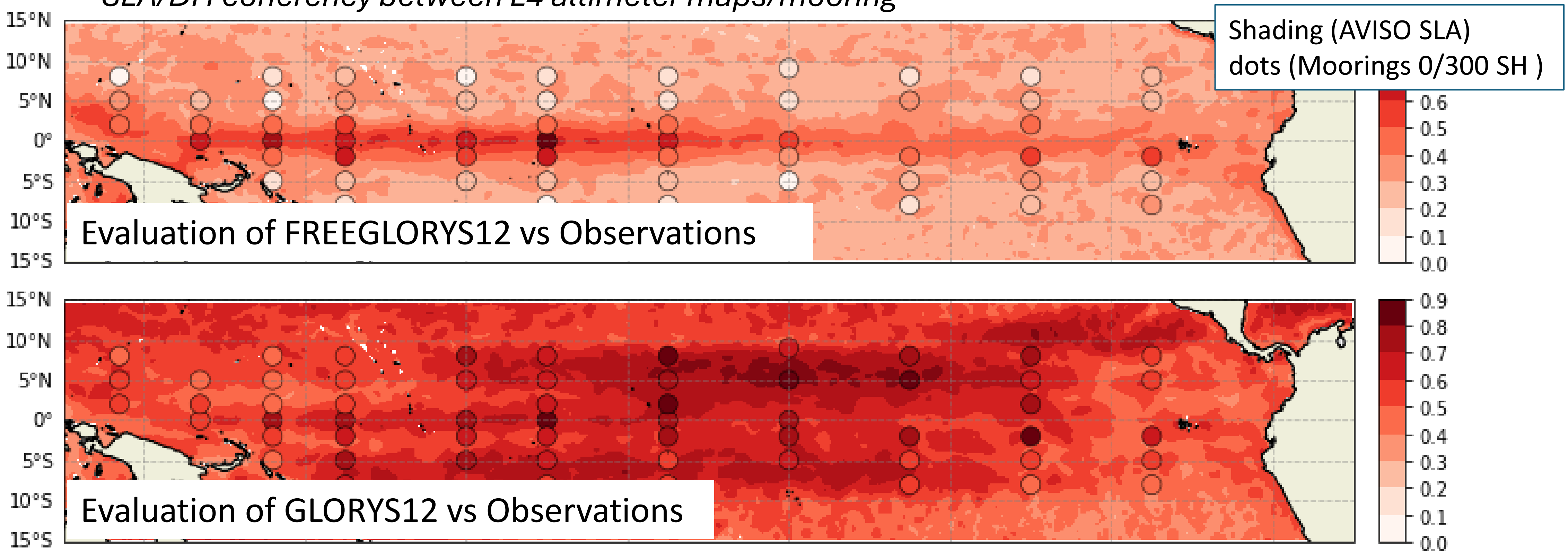


- **Altimetry :** global coverage + intraseasonal and longer timescales
- **Moorings :** point-wise locations + entire frequency spectrum

Impact on oceanic processes at intraseasonal scales

Evaluating coherency (and phase-not shown) at intraseasonal scales (20-90 days)

SLA/DH coherency between L4 altimeter maps/mooring

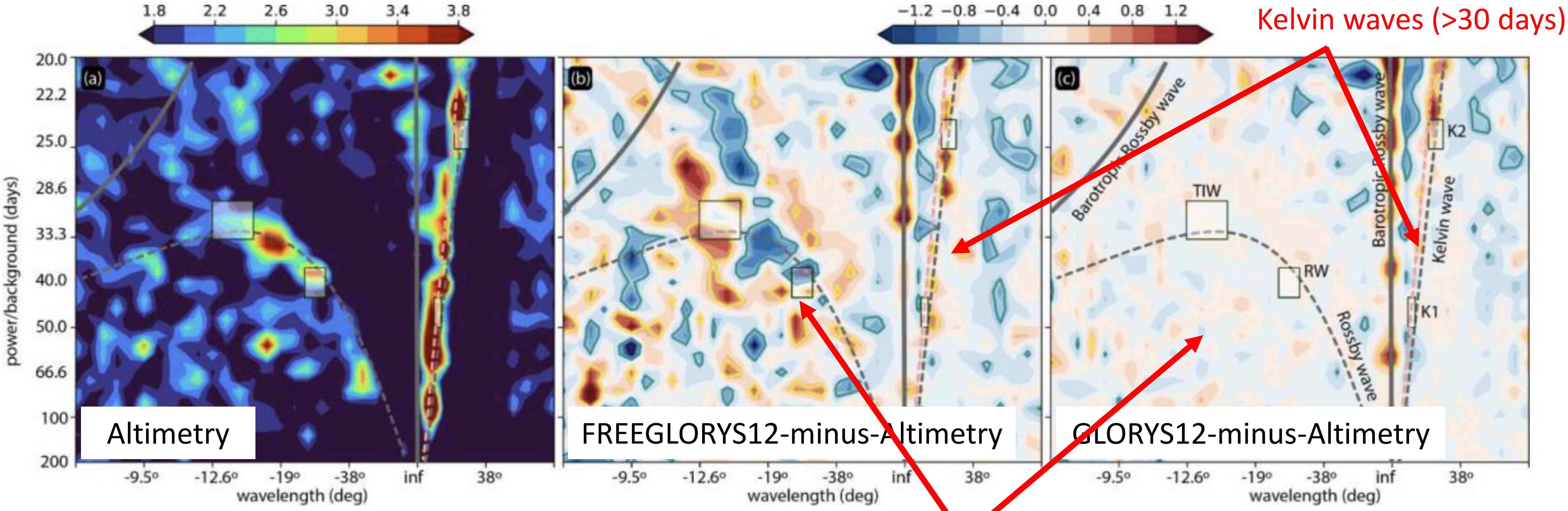


- Both FREEGLORYS12 and GLORYS12 resolve intraseasonal variability along the equator
- Significant improvement off the equator in the Tropical Instability Wave (TIW) area.
- Slight improvement in high-frequency oceanic processes in GLORYS12 (not shown)

Impact on oceanic processes at intraseasonal scales

Sea-level energy distribution in wavenumber and frequency space

Space-time spectrum of SLA averaged over 6.75°S - 6.75°N



Small discrepancies for Kelvin waves (>30 days)

Westward propagating signal

Eastward propagating signal

Large positive anomalies in FREEGLORYS12 in TIW region

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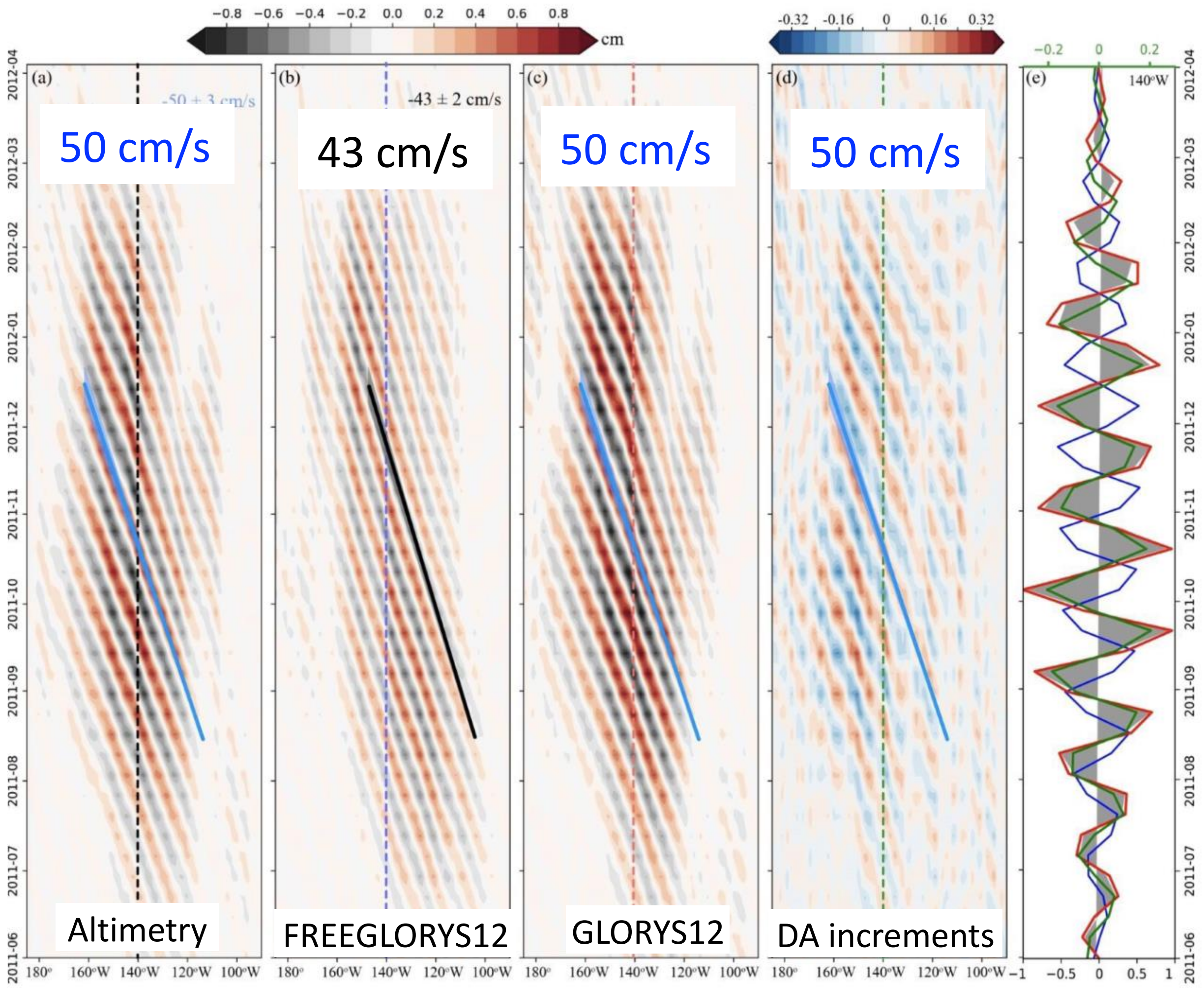
Impact on oceanic processes at intraseasonal scales

Propagation speed of Tropical Instability Waves

Time-longitude plots of SLA along 5°N latitude for the TIW box



- TIWs propagate at 50 cm/s in observed & GLORYS12
- Slower propagation in FREEGLORYS12 at 43 cm/s.

How does DA improve TIW propagation speed ?

1. Modifying background stratification ?

2. Directly forcing faster anomaly movement ?

Westward propagation of DA increments at 50 cm/s

More realistic mean oceanic stratification

Relative contribution of direct/indirect is still an open question

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Conclusion

- The **relevance of ocean observations for operational systems** can be evaluated using various methodologies.

- The contribution of ocean observations shows **scale-dependent characteristics**, with a significant impact observed at intraseasonal scales.

- The net effect on intraseasonal scales arises from **both direct (local increments) and indirect (background conditions)** influences (still open question).

- Given the potential fragility of ocean observing systems in the coming decade, it is essential to **sustain these activities** in order to anticipate any changes in the ocean observing system.