ODYSEA mission project: study of Near Inertial Oscillation signal in drifter databases and evaluation of multi-temporal mapping of the total current (including NIOs) through OSSE.

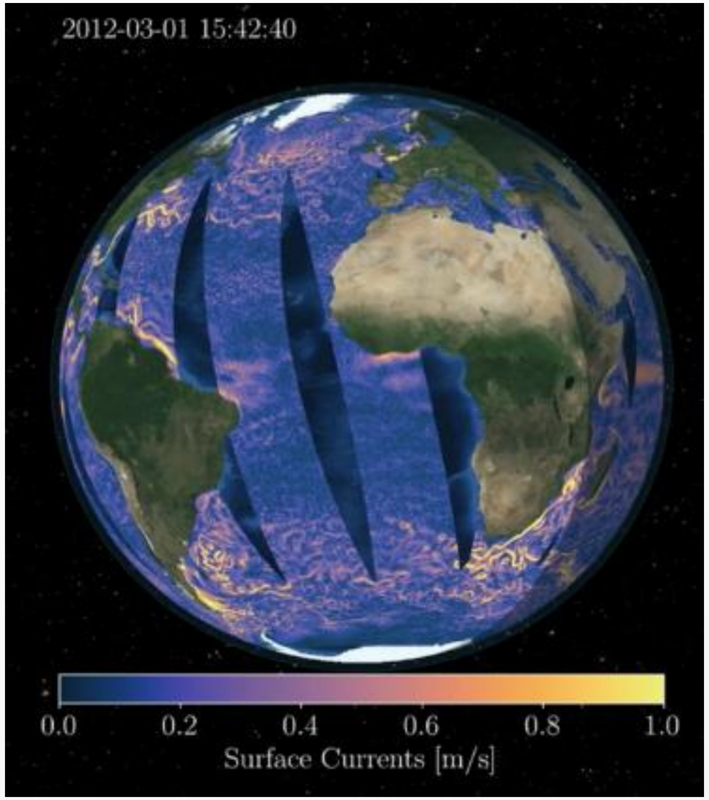
A-TSCV Workshop - June 13, 2023

S. Jousset, H. Etienne, C. Ubelmann and G. Dibarboure

- Total surface current : a wide variety of dynamical components, a few are observed and/or predict today

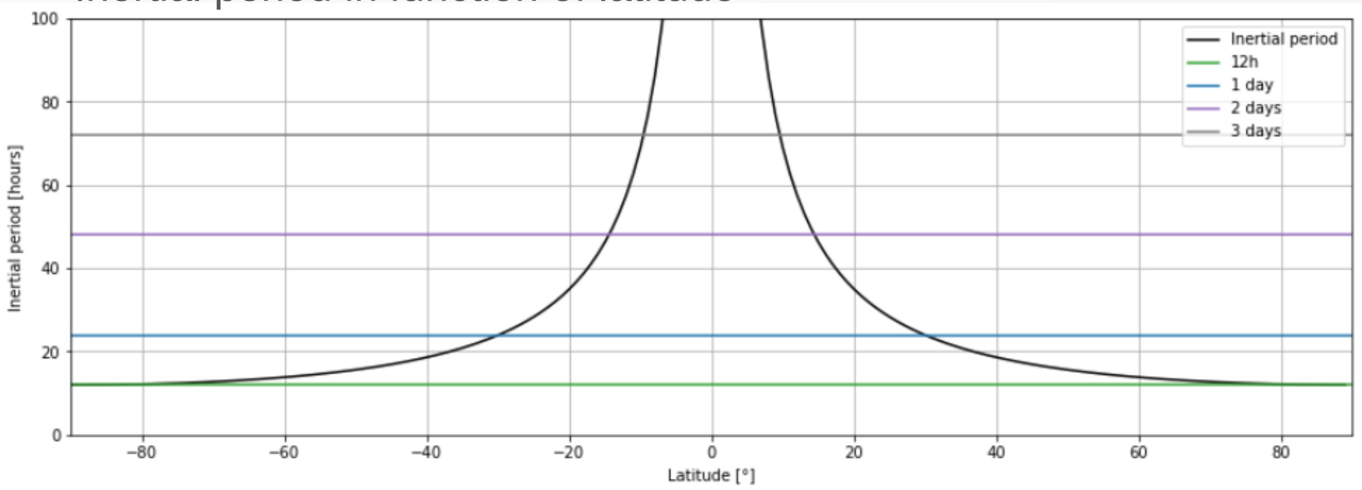
- Odysea mission : assuming we can observe the sum of the dynamical components, what about the separation and the mapping of the challenging components (as Near Inertial Oscillations NIO) ?

Sampling of surface ocean currents by the ODYSEA simulator.



- **Odysea revisit time ~12 hours** in mid-latitudes (Torres et al, preprint 2023)
- **At 10 km**

Inertial period in function of latitude



➢ **Inertia oscillations are too high-frequency to be perfectly observed by odysea, and this can aliase current observation.**

From Torres, H. et al (preprint 2023)
https://doi.org/10.20944/preprints202305.1423.v1

CLS

Outline

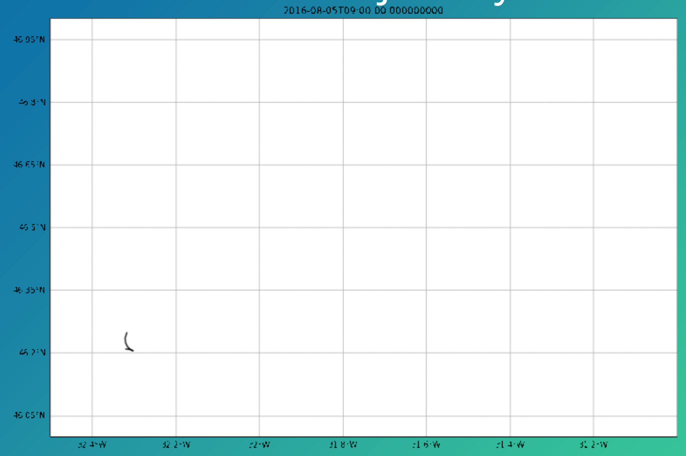
1. Study of NIO signal in drifter databases

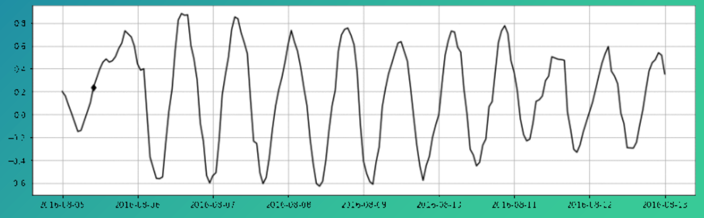
- Over what distance does the NIO signal remain the same? Or strongly correlated ?

2. Evaluation of multi-temporal mapping of the total current (including NIOs) through OSSE

- Is the MIOST method capable of reconstructing the NIO (Near Inertial Oscillation) signal with odysea observations in an OSSE (Observing System Simulation Experiment)?

Drifter trajectory





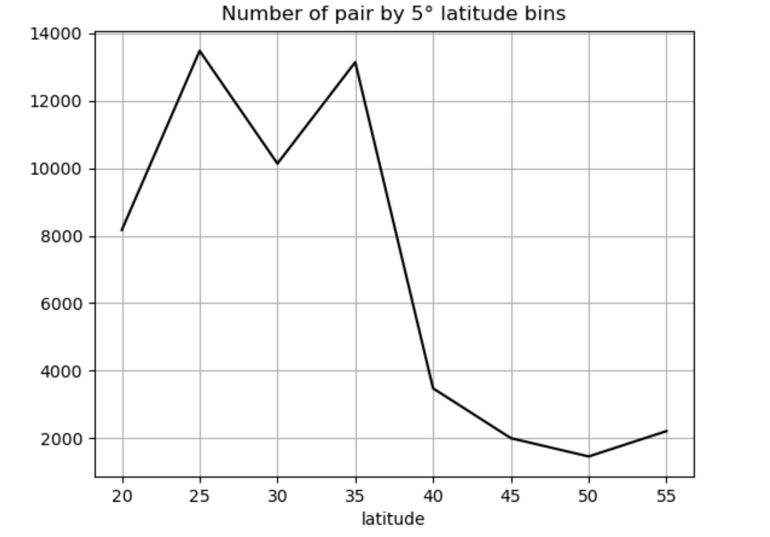
U component

1 - Study of NIO signals in drifter databases

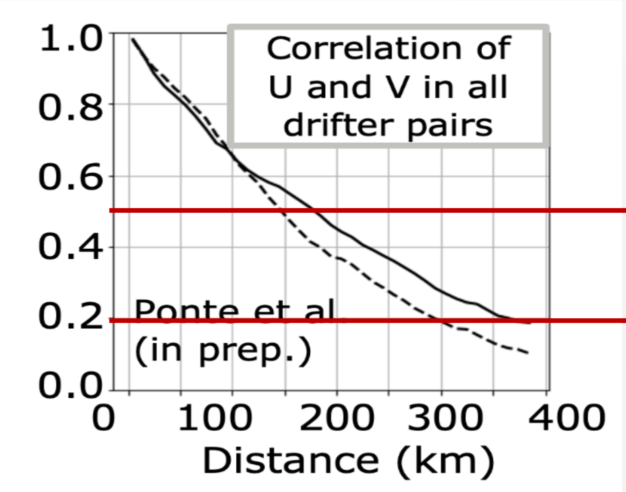
- Over what distance does the NIO signal remain the same? Or strongly correlated ?

Method

- Use of drogued drifters (AOML base) in the North Atlantic (20°N - 60°N) from 2010-2021
- Get pair of drifters with overlapping time series (longer than 72h):
  - Regional selection
  - Compute distance between pair of drifters(< 1500km)
  - Selection by 5° latitude (homogeneous inertial frequency.)
- Extract near inertial signal:
  - Band pass filtering around inertia frequency.
- Define diagnostics:
  - Compute U/V correlation
  - Compare signal spectrum (NIO, low frequencies...)
- Try to compare to Ponte et al results



Number of drifter pairs in 5° latitude band



$D_{0.5}$ = [150 ; 180] km

$D_{0.2}$ = [300 ; 380] km

Filtering and metrics:

- Use of a Lanczos filter:

  - filtering wave lenght > 1.5* inertia

  - filtering wave lenght < 0.3 * inertia

Drifters are filtered in 5° latitude band (cut of the trajectories).

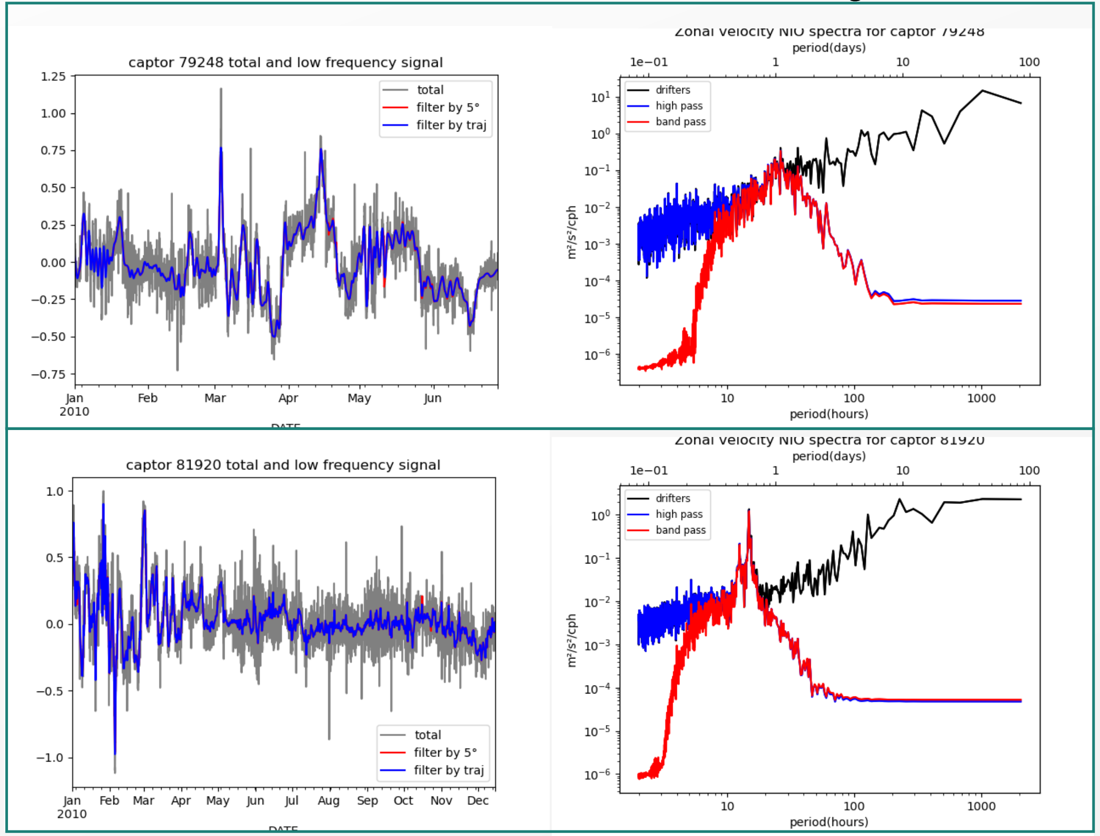
- Compute U/V correlation between drifters (of each pair) as a function of distance:

  For (x,y) pairs in 5km bins:

$$COR(x,y) = \frac{COV(x,y)}{VAR(x)^{1/2}VAR(y)^{1/2}}$$

Stotal signal and low fequencies

Spectrum of total, low frequency and pass band filtered signal.



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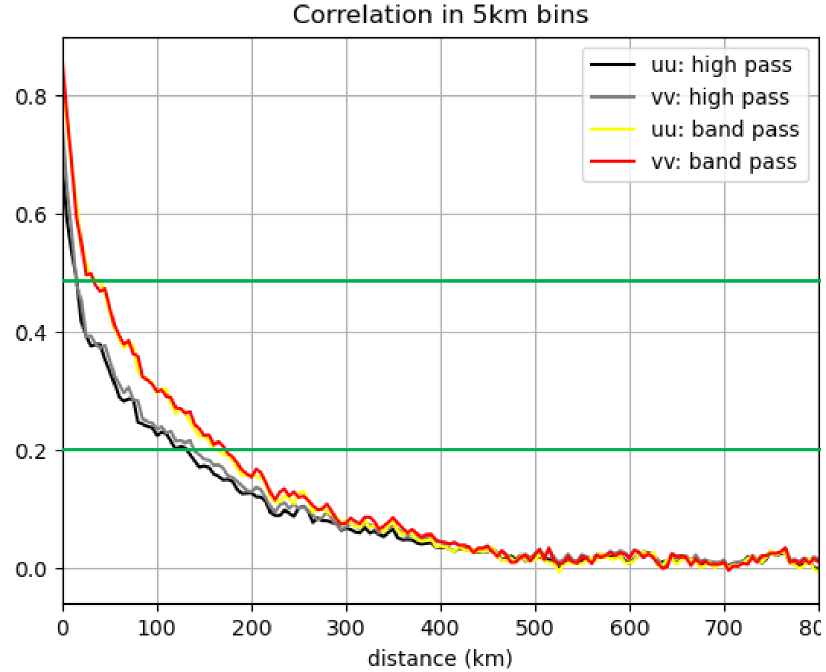
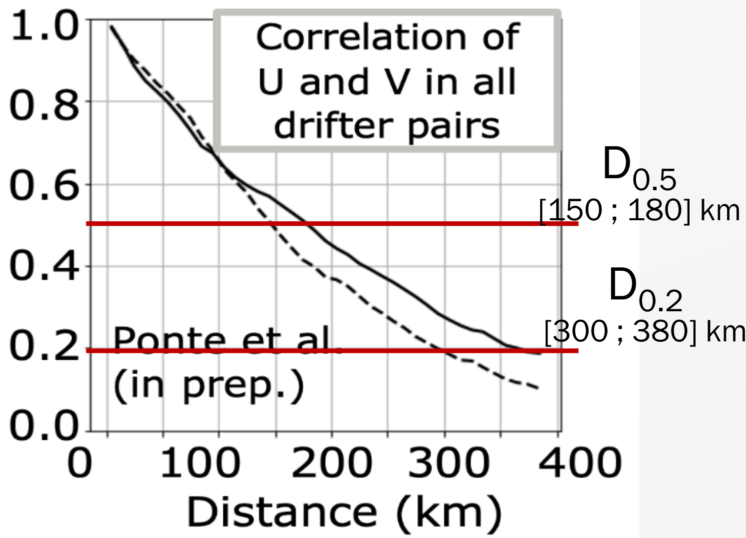
Correlation results for NIO

NATL area

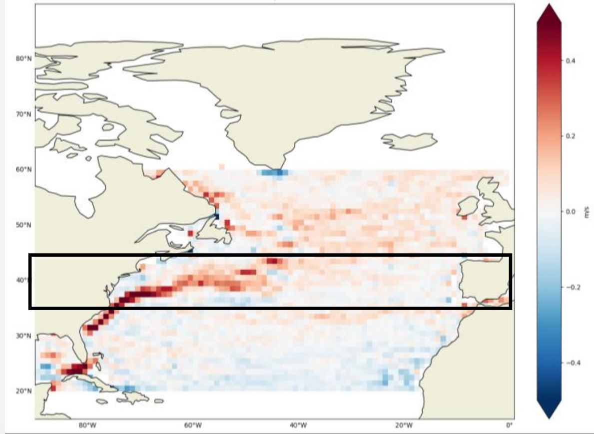


By 5° lat bins



- Over the NATL area, the 0.5 correlation threshold is reached at 30km and the 0.2 correlation threshold for 170km. These values are shorter than those of Ponte et al: the correlation curve decreases more rapidly with respect to distance.

- By latidude (5° bins), we find a deacrease of the correlation length scale between 35 and 45°N. This is an area of high variability.



Rotary spectrum comparison

- A first estimation is made splitting pair of drifters into 5 days long segments, with 50% overlap.

Gap shorter than 5h are filled (linear interpolation), and segments shorter than 5 days are discarded.

- For each (a,b) pair, the spectrum R(a), R(b) and R(b-a) are computed and averaged over all the segments.

→ R(a,b) = R(b-a)/[R(a)+R(b)] can be used to evaluate similarities (differences) between a and b.

  - R(a,b) ~ 0 when a,b are similare signals.
  - R(a,b) ~ 0.5 threshold where we consider signals are different.

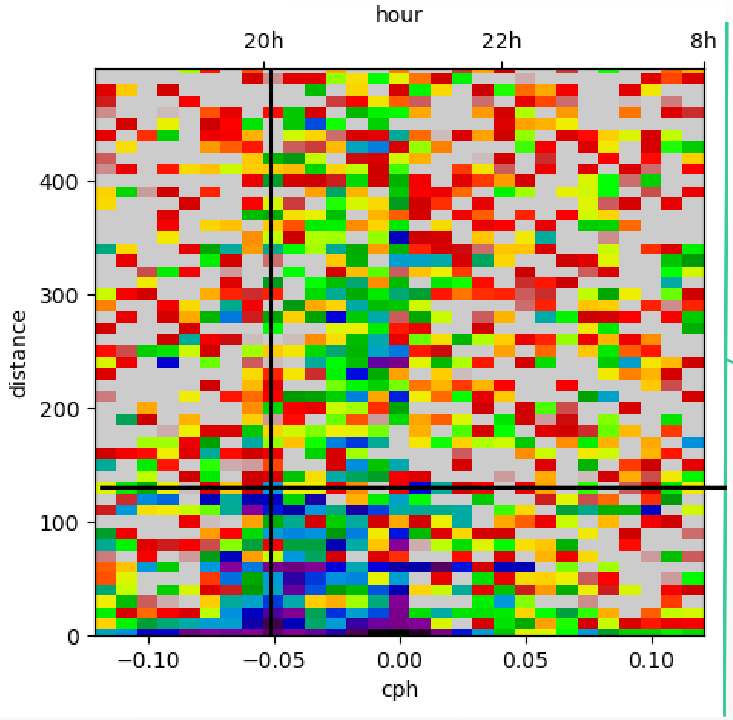
- In the following, total signal (unfiltered) is used to commute the rotary spectrum.

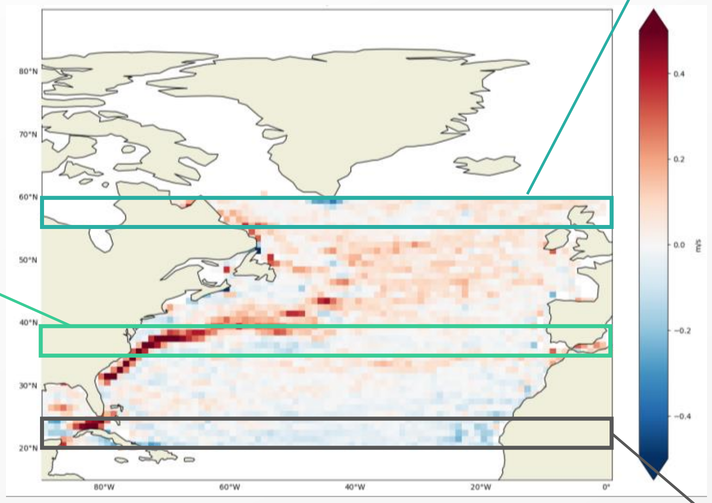
Rotary spectrum comparison per box of 5° of latiude

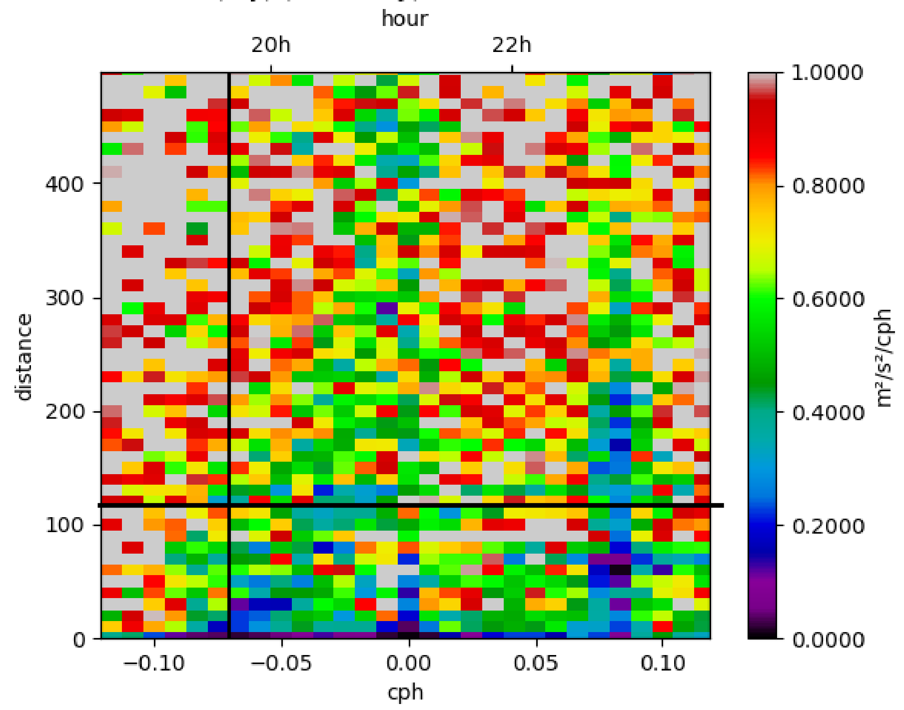
Results for the 0.5 threshod are between 100 and 200km

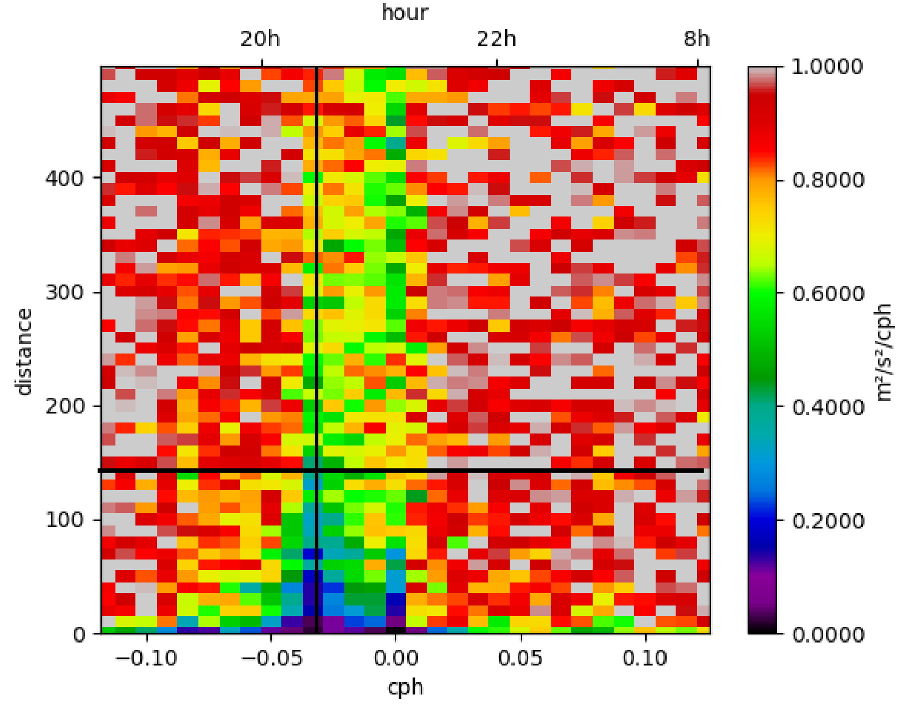
→ More similar to Ponte et al results (150 km to 180km)

→ Longer than the standard correlation results (~ 30km) found previously.









Perspectives:

This work is ongoing. We will continue this study by caracterizing the NIO length scale at global scale:

- Check if rotary spectrum method is still different from the standard correlation estimation.

→ Try to refine the band pass filtering to better extract the NIO signal.

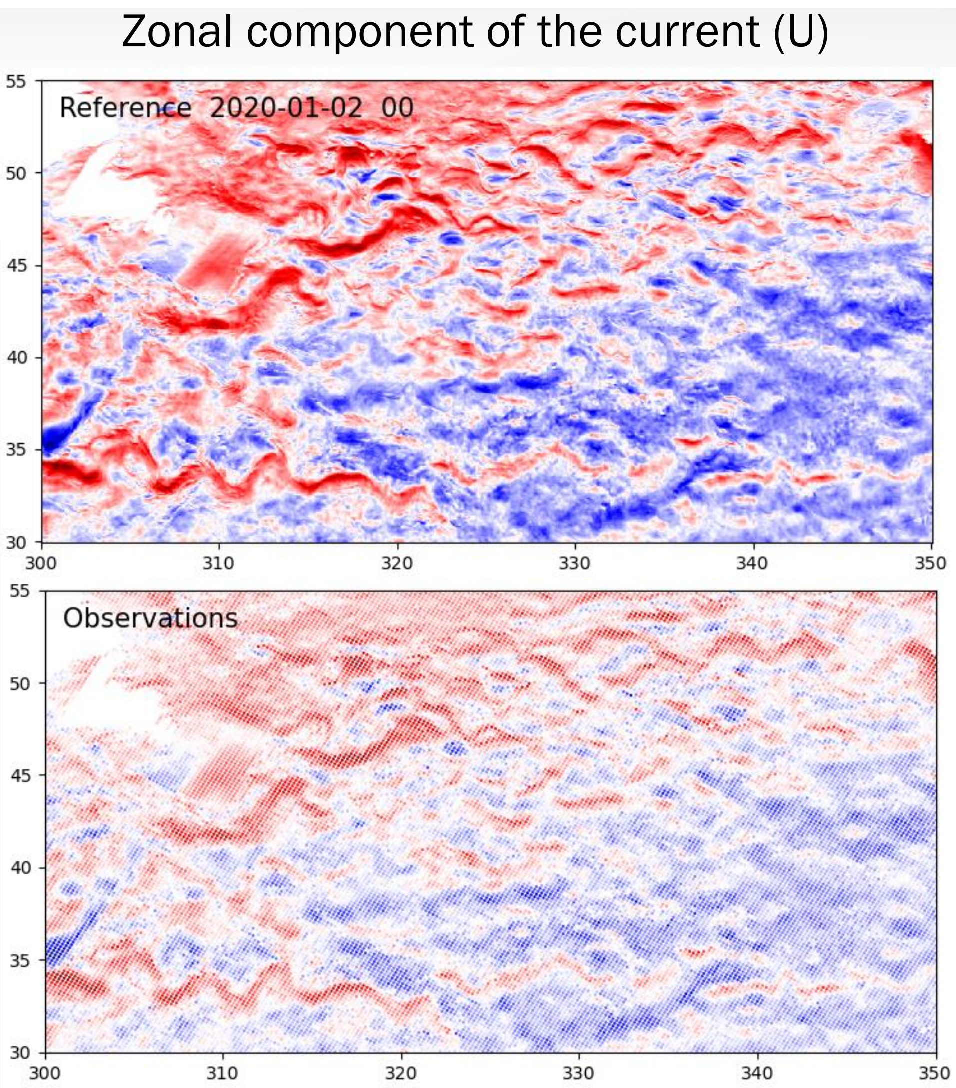
- Check any latitudinal dependancy of the NIO correlation length scales.

2 - Evaluation of multi-temporal mapping of the total current (including NIOs) through OSSE

- Is the MIOST method capable of reconstructing the NIO (Near Inertial Oscillation) signal with odysea observations in an OSSE (Observing System Simulation Experiment)?

Setting up OSSE experiments

- The model used as a reference is the MITgcm LLC coupled run (the degraded version we use is hourly, at 1/20°).
  - Model capable of representing inertial oscillations
- The study area is the North Atlantic.
- Simplified configuration of currents observed by ODYSEA:
  - as current pseudo-observations, we take a **snapshot of subsampled tide-filtered u,v currents** (approximately one point out of 5-6 in space), every 24 hours.
  - as SSH pseudo-observations, we take a **snapshot of subsampled tide-filtered SSH** (1 point out of 6), every 24 hours.
- Using MIOST for reconstruction



Multiscale Inversion for Ocean Surface Topography (MIOST) tool

Objective Analysis: $\mathbf{x_a} = \mathbf{BH^T(HBH^T + R)^{-1}y}$

Estimate ($\mathbf{x_a}$); (grid,obs) signal cov. ($\mathbf{BH^T}$); (obs,obs) signal cov. ($\mathbf{HBH^T}$); (obs,obs) error cov ($\mathbf{R}$); SLA obs ($\mathbf{y}$)

Ubelmann et al. (2021)

- Sherman – Morrison – Woodbury transformation: $\mathbf{x^a} = \left(\mathbf{H^TR^{-1}H + B^{-1}}\right)^{-1}\mathbf{H^TR^{-1}y}$

→ **Inversion in the state space** rather than in observation space (much bigger !)

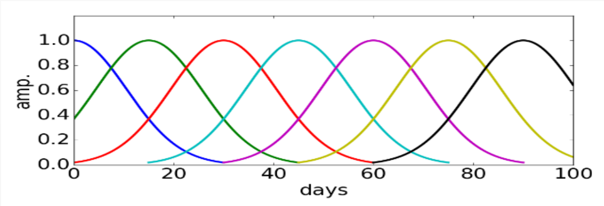
- Decomposition of the signal in different components:

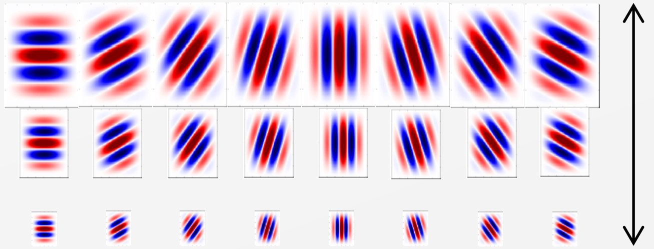
  $\mathrm{x} = \mathrm{x_{geo}} + \mathrm{x_{ek}} + \mathrm{x_{NIO}} \ldots$

- Projection of each component on a wavelet basis

$$\mathbf{x_{geo}} = \mathbf{\Gamma_{geo}\eta_{geo}}$$

Temporal decorrelation scale:
~10 days (depend on the area as in DUACS)

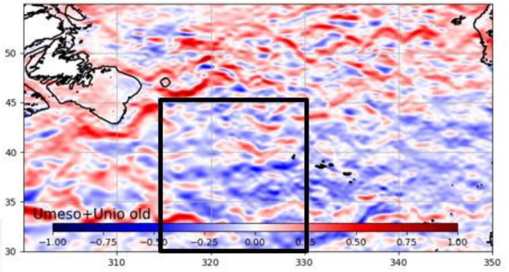




Spatial extension :
80 to 800 km

Ubelmann, C., Dibarboure, G., Gaultier, L., Ponte, A., Ardhuin, F., Ballarotta, M., & Faugere, Y. (2021). Reconstructing ocean surface current combining altimetry and future spaceborne Doppler data. *Journal of Geophysical Research: Oceans*, *126*, e2020JC016560. https://doi.org/10.1029/2020JC016560

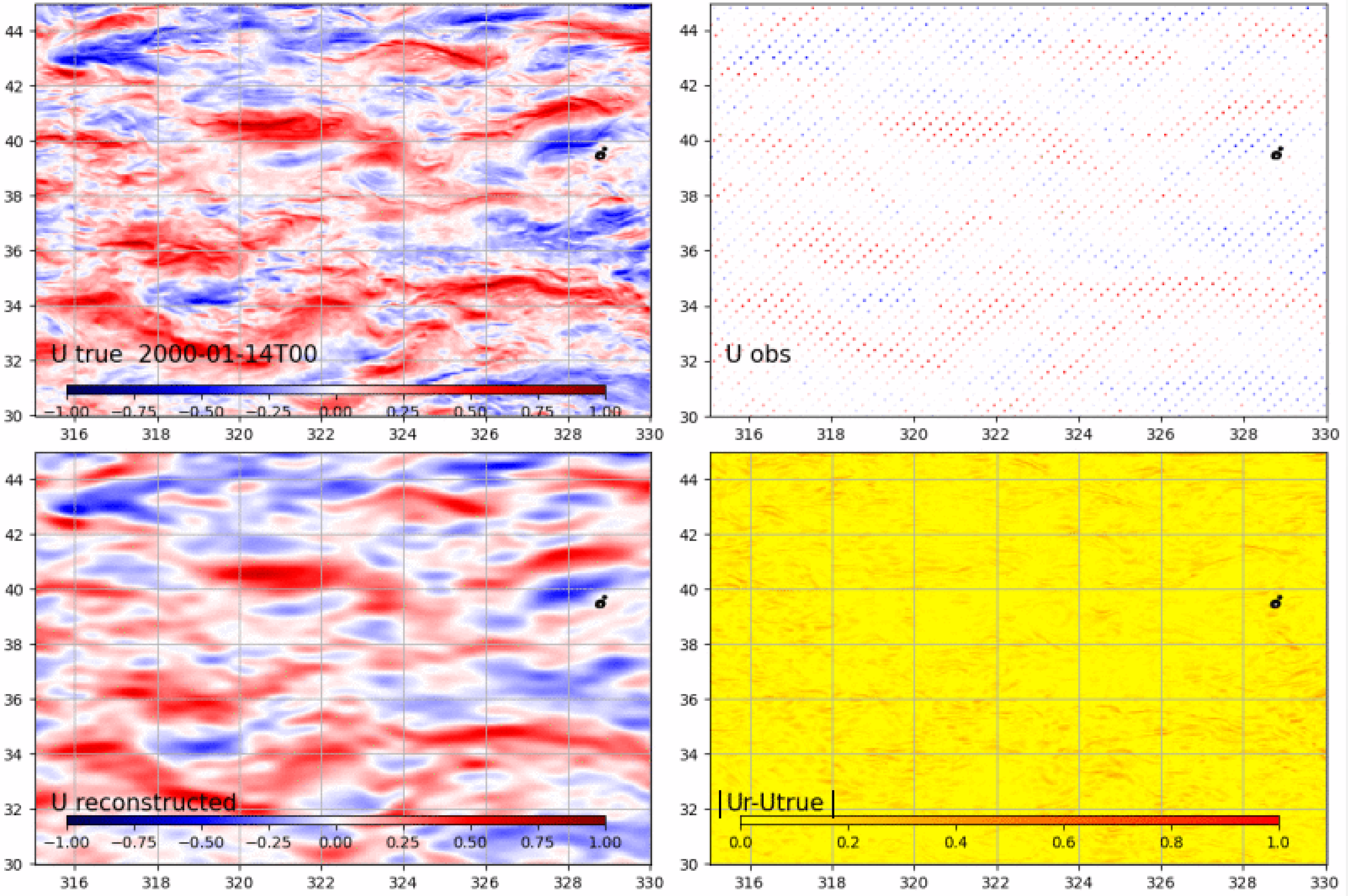
Results on 15°x15° area, from January 4 to February 18, 2000

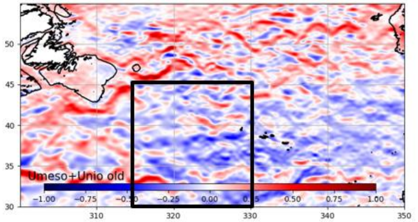


OSSE experiment:

- Geostrophic modes
- Ageostrophic modes
  - **NIO** (fast mode)
    - wavelet characteristic length: 100km
    - wavelet decorrelation time: ~5h
  - **Rotational and divergent ageostrophic modes** (slower ageostrophic modes)
    - wavelet characteristic length: 400km
    - wavelet decorrelation time: 5d
- Observations: U,V snapshots degraded every 24h + SSH every 24h
- 40-days test over a reduced area (315-330°E; 30-45°N)

Zonal component of the current (U) - (4 days plotted)

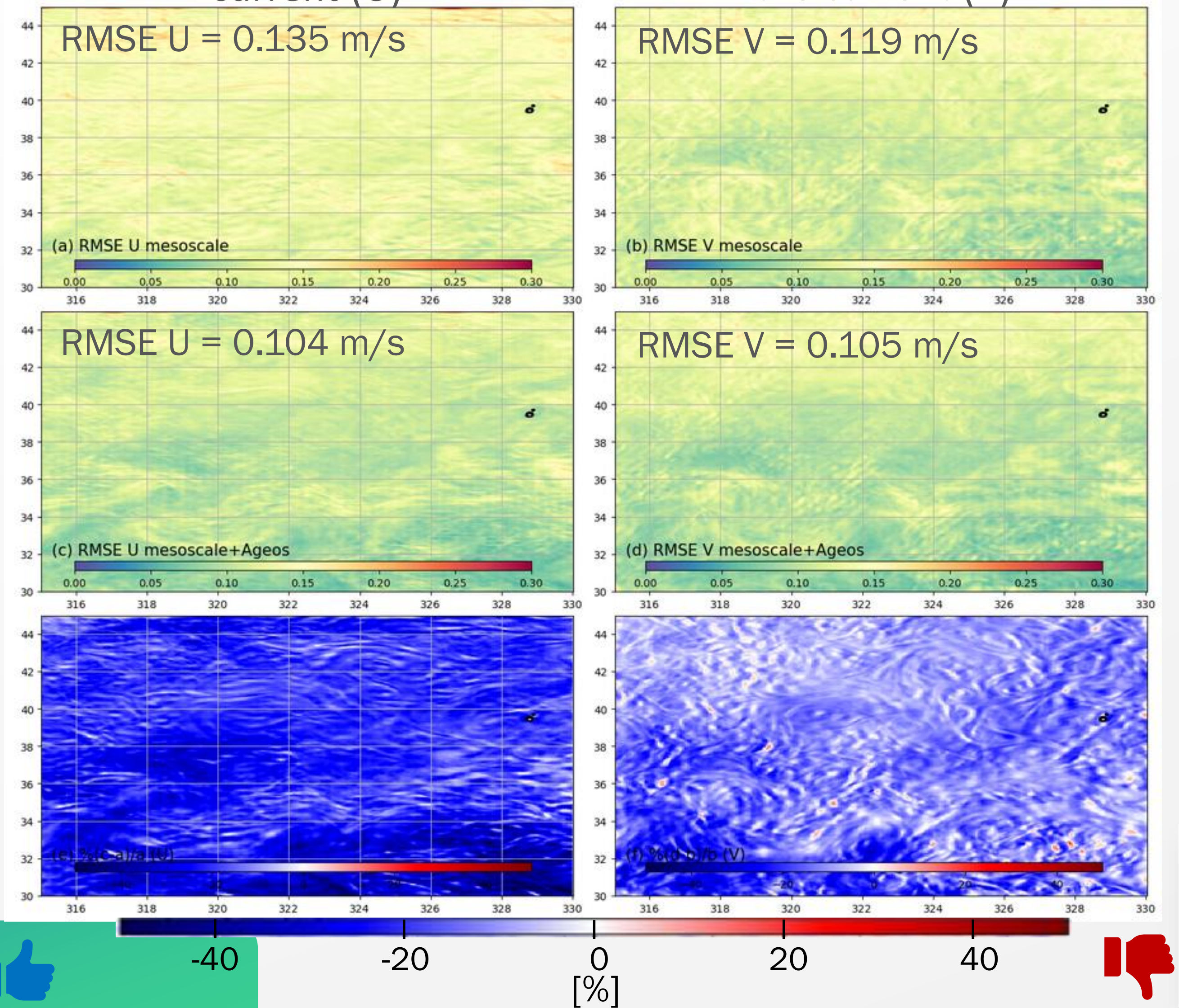




Root Mean Squared Difference with the truth (simulation)

Zonal component of the current (U)

Meridional component of the current (V)



RMS of differences between U(geostrophic modes) and Utrue

RMS of differences between U(geostrophic + slower ageostrophic modes) and Utrue

$$\frac{RMS(U_{geo+ageo}-U_{true})-RMS(U_{geo}-U_{true})}{RMS(U_{geo}-U_{true})}$$

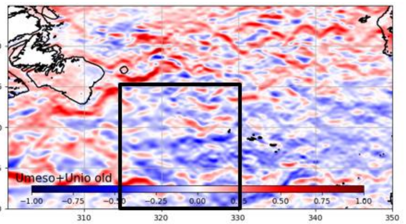
-22%

-12%

improvement

degradation

Root Mean Squared Difference with the truth (simulation)



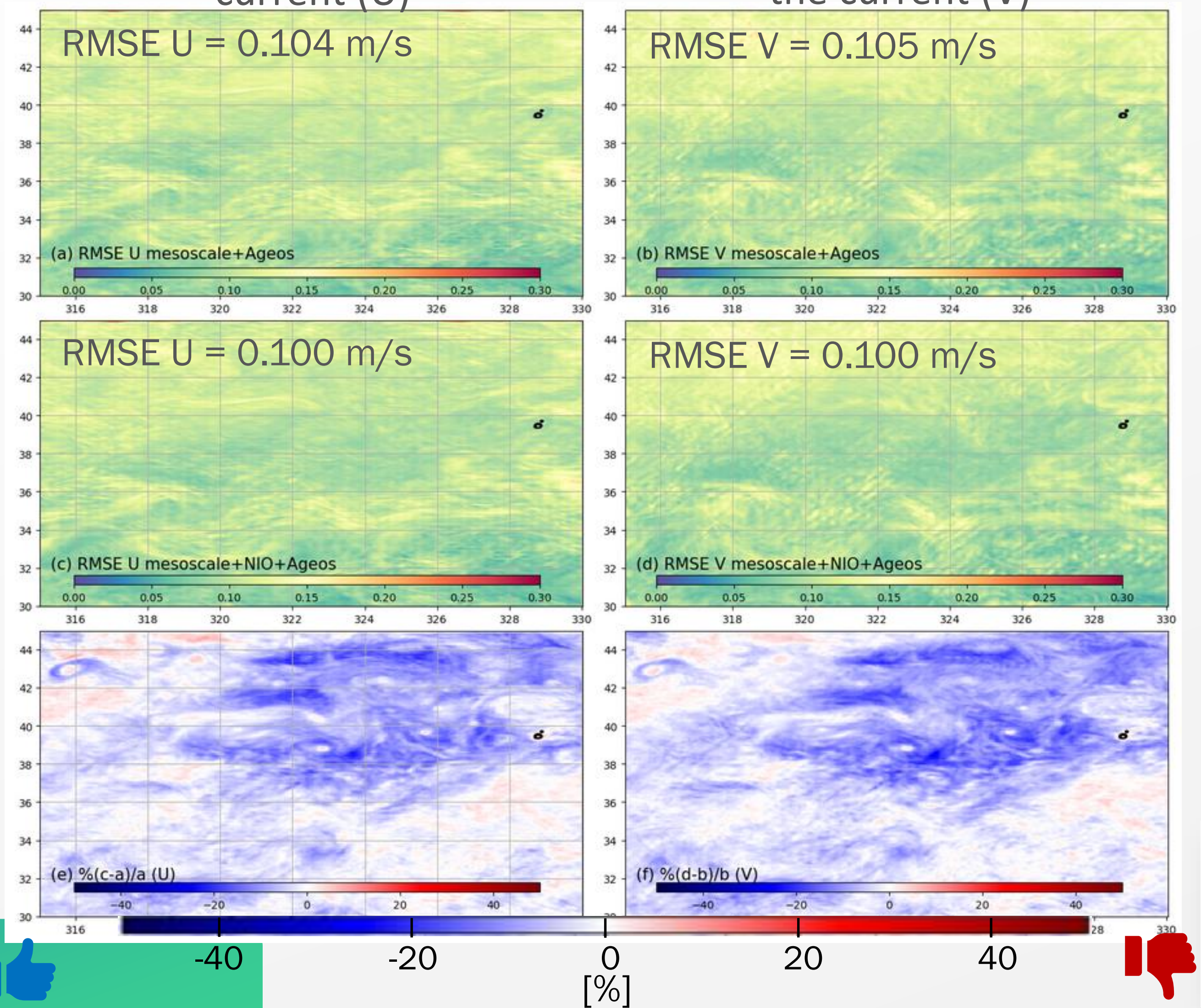
Zonal component of the current (U)

Meridional component of the current (V)

RMS of differences between U(geostrophic + slower ageostrophic modes) and Utrue

RMS of differences between U(geostrophic + slower ageostrophic + NIO modes) and Utrue

$$\frac{RMS(U_{geo+ageo+NIO}-U_{true})-RMS(U_{geo+ageo}-U_{true})}{RMS(U_{geo}+ageo-U_{true})}$$



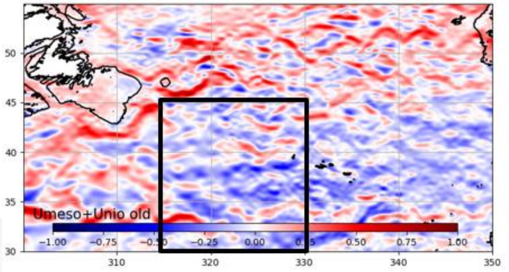
-4%

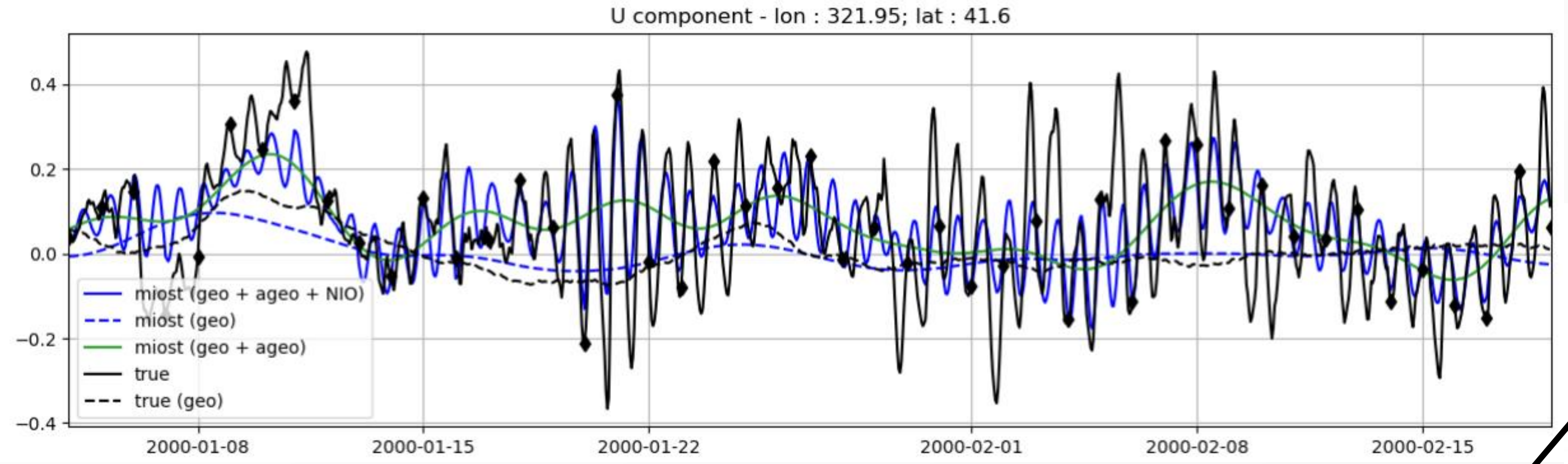
-5%

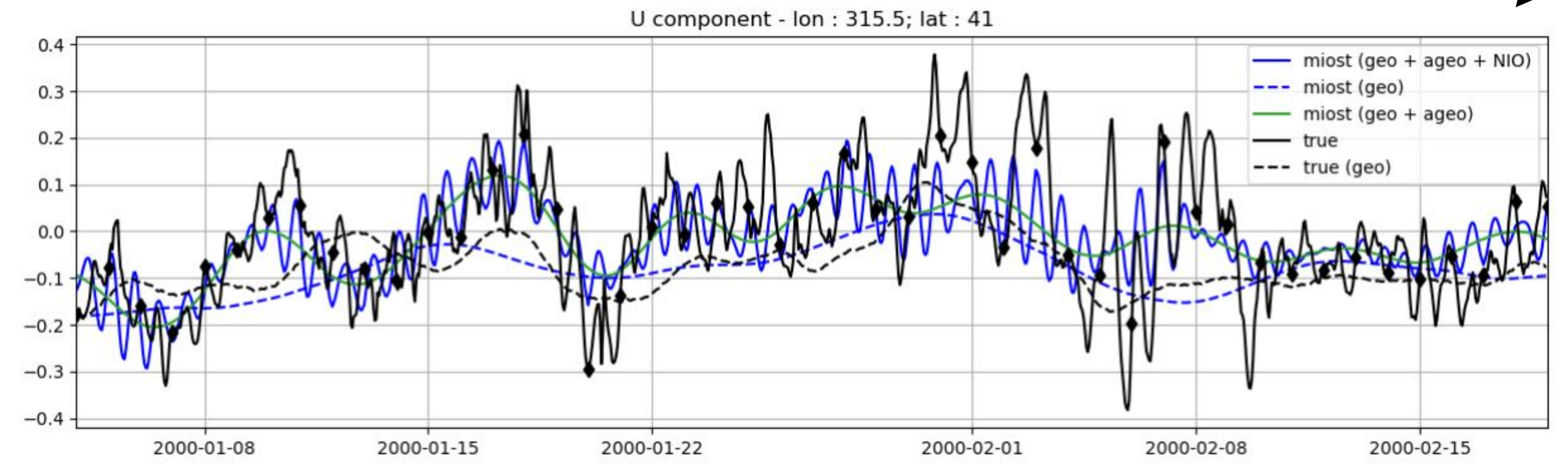
improvement

degradation

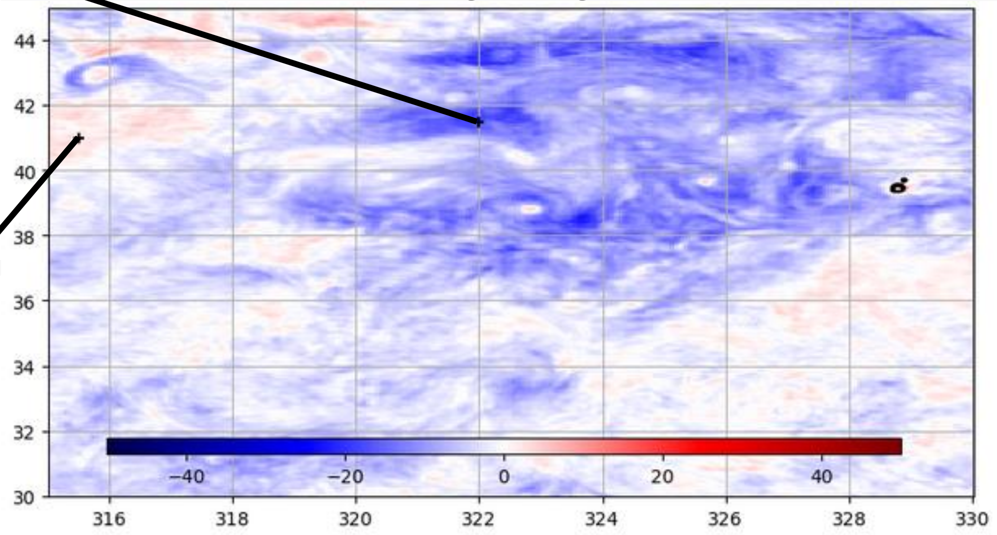
Time series of the U current component







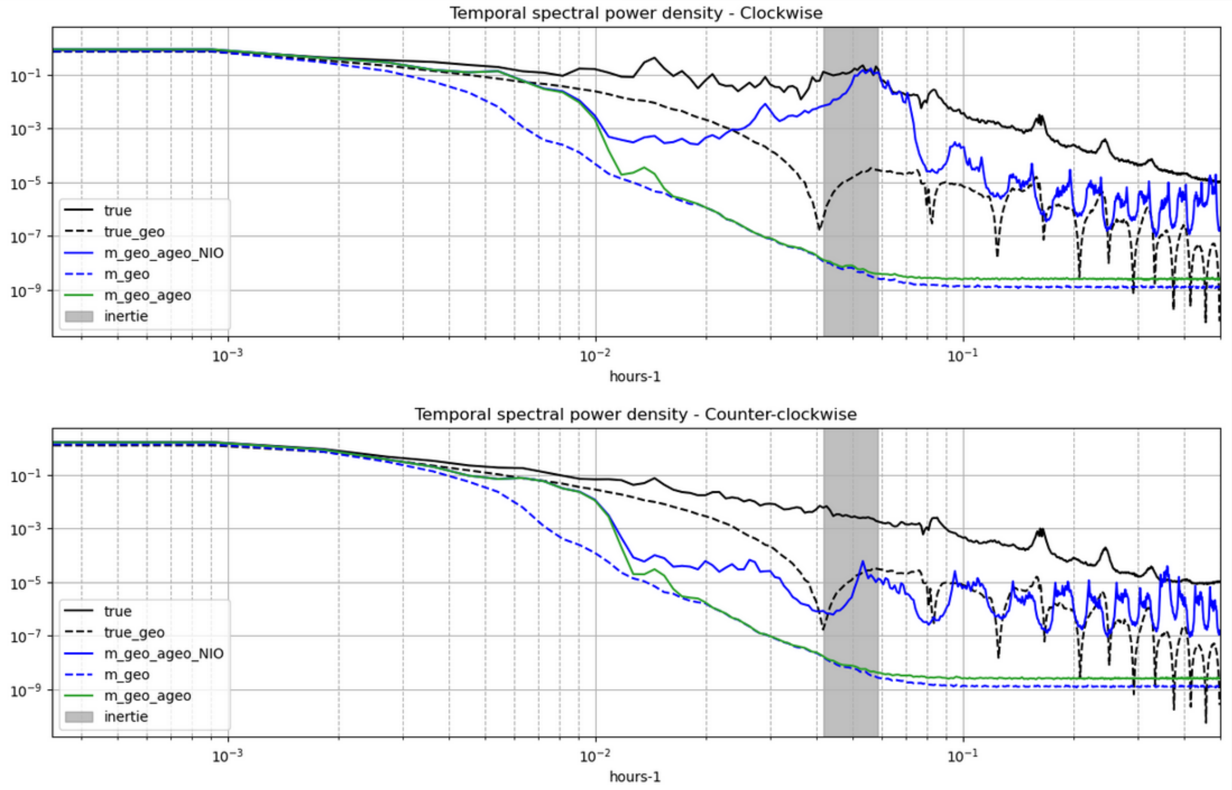
$$\frac{RMSE_{geo+ageos+NIO} + RMSE_{geo+ageos}}{RMSE_{geo+ageos}}$$

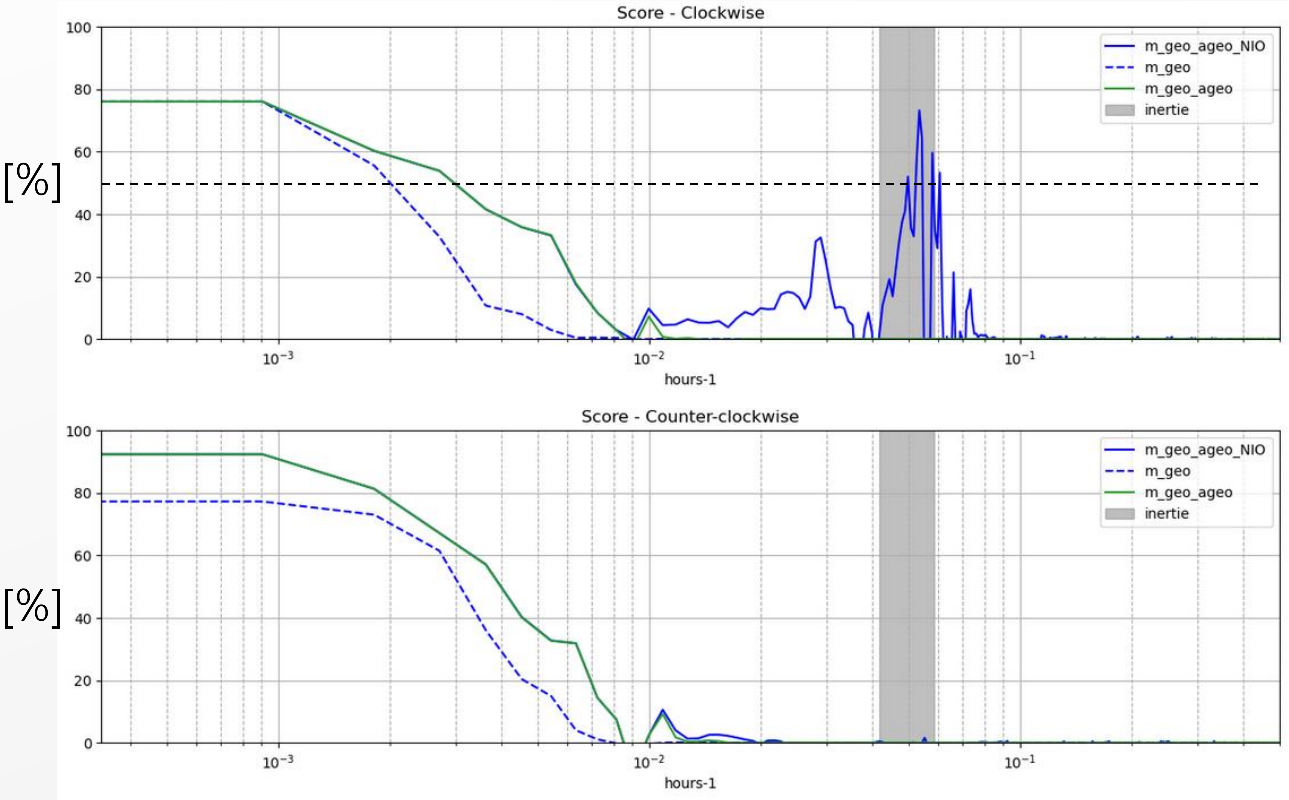


- Top time series (favorable): well-phased oscillations but lack in amplitude
- Bottom time series: oscillations not always well phased

Rotary spectra and score

$$\text{Score (\%)} = 1 - \frac{Spec(exp - true)}{Spec(true)}$$





- Noise in the inertial band
- Inertial band: ~50% of the represented signal
- Beginning of inertial band, less energy. Why?

Conclusions/Future work

- Miost reconstructs around 50% of the inertial signal (spectral diagnostics) with observations over the entire zone, every 24 hours.
- The NIO mode reduces the RMS of the differences with the true run by 4-5% on the U and V components of the current.

➢ To obtain this result, we have reduced the characteristic size of the NIO mode wavelets (300 km for the SKIM study and 100 km here). Is this because the NIOs are less spatially organized in this simulation?

- Now it's time to test Miost with these parameters, using realistic pseudo-observations (from Lucile G.) in terms of geometry and revisit time, to evaluate the reconstruction.

Thank you