



Toward an improved Mean Dynamic Topography CNES-CLS-2026

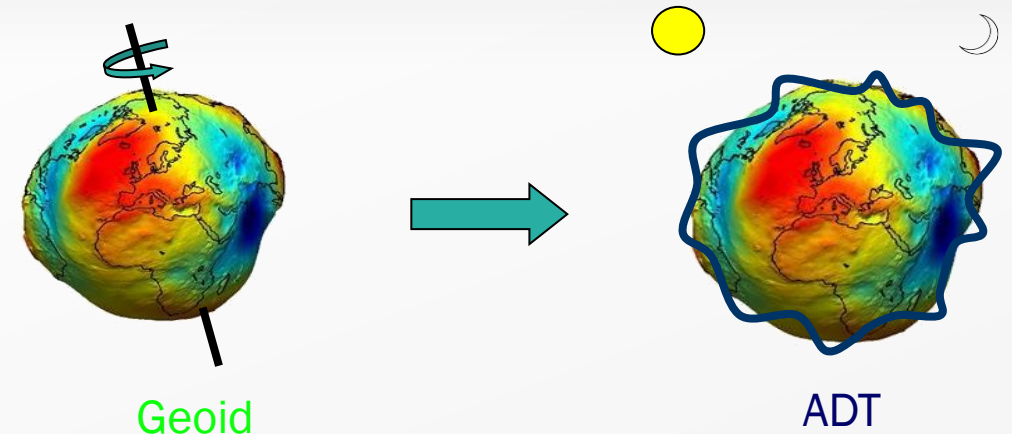
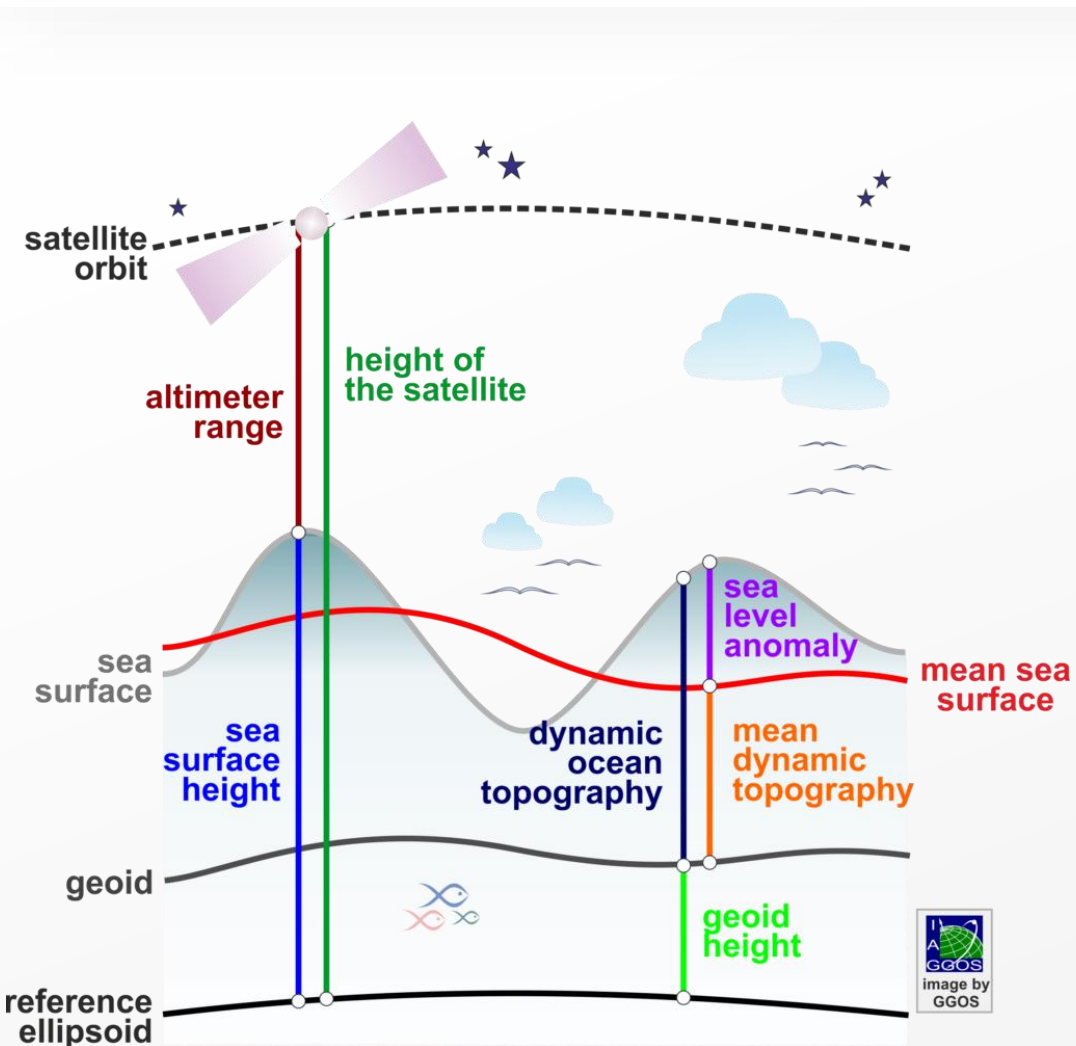
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(1) Collecte Localisation Satellite (CLS)

(2) Centre National d'Etudes Spatiales (CNES)



Heights and their surface of reference



Ocean at rest, submitted only to the Earth's gravity field

Dynamic of the ocean
→ Absolute Dynamic Topography (ADT)

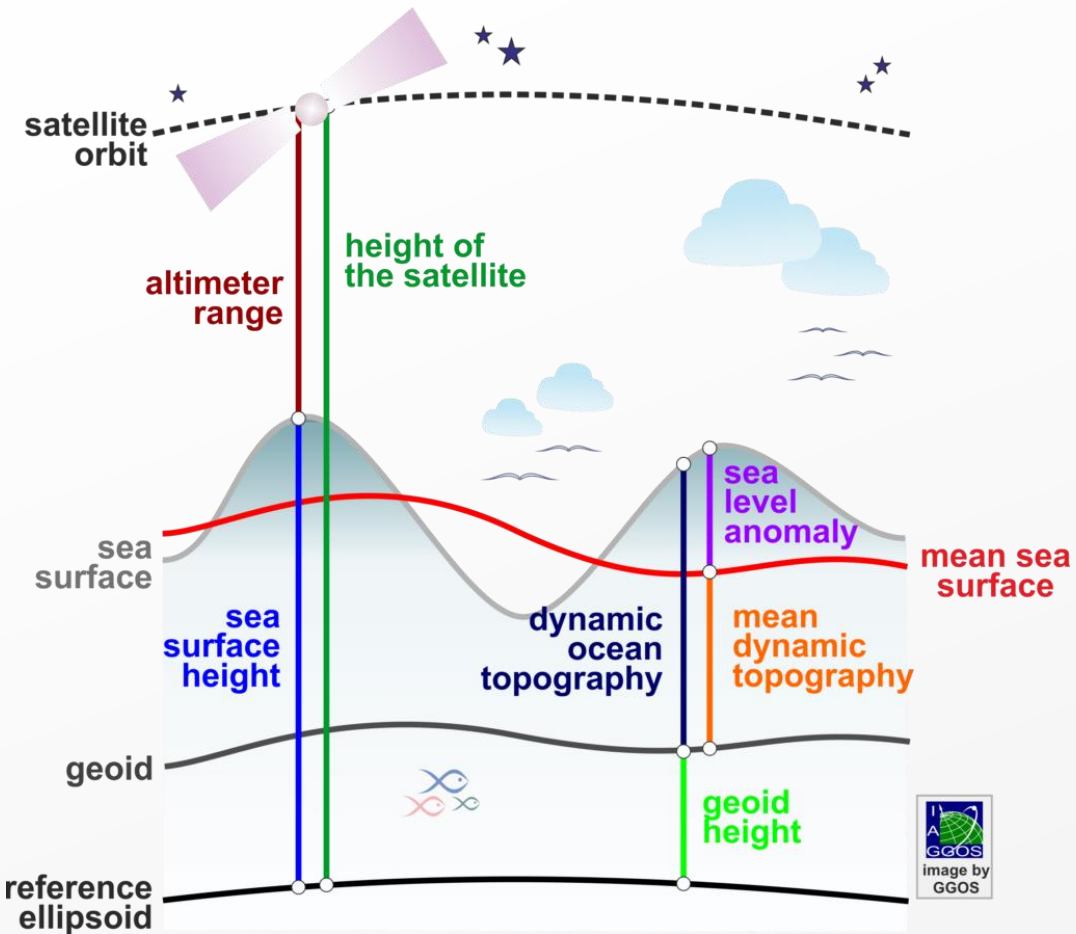
$$\text{ADT} = \text{SLA} + \text{MDT}$$

Altimetric product

Need to be estimated !

→ To compute the ADT, we need to estimate the MDT.

MDT estimation method



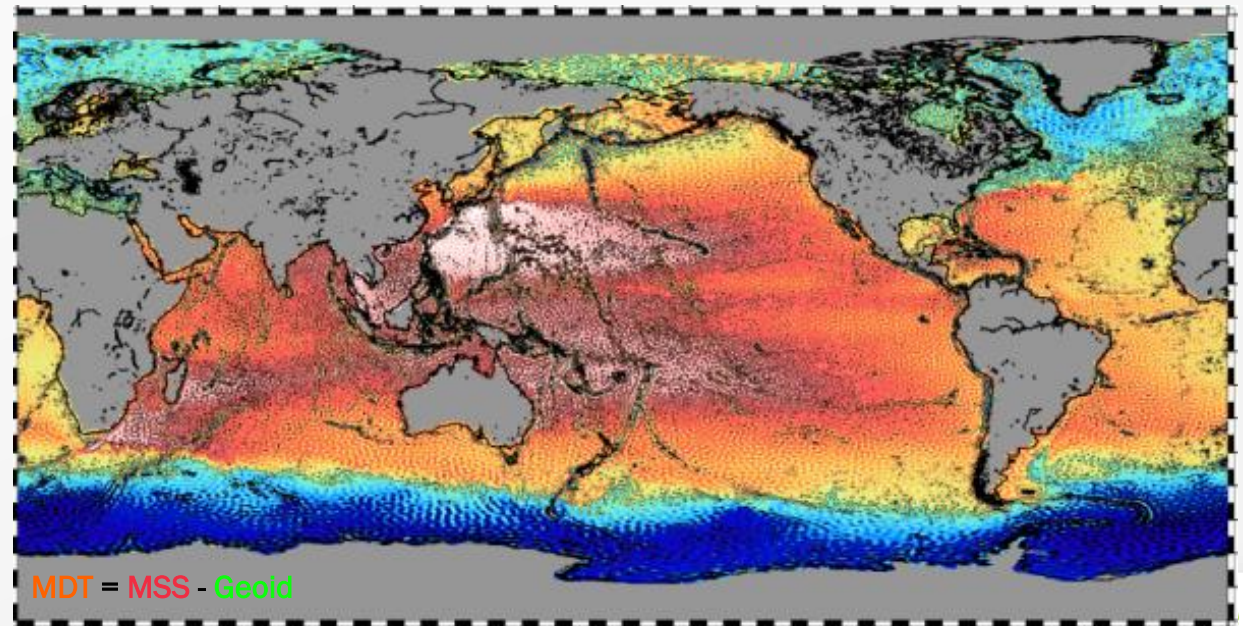
→ The MDT can be estimated with the MSS and the Geoid.

$$\text{MDT} = \text{MSS} - \text{Geoid}$$

→ The last CNES-CLS MSS product: MSS CNES-CLS-2025.

→ Satellite gravity missions (GOCE, GRACE, ...) measure the geoid.

→ But satellite-derived geoids do not resolve scales below ~125 km.



MDT estimation method

Direct Method
 $\text{MDT} = \text{MSS} - \text{Geoid}$

Optimal filtering

First guess

Multivariate
Objective Analysis

High resolution ($1/8^\circ$)
MDT and associated mean
geostrophic currents

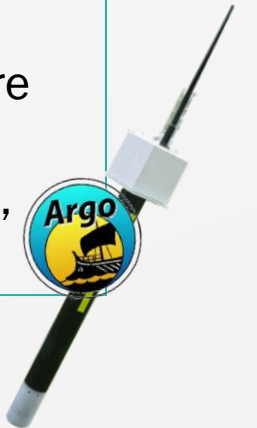
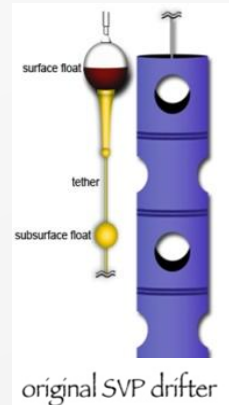
The noisy small scales are optimally filtered

Rio et al, 2011

The short scales of the MDT (and corresponding geostrophic currents) are estimated by combining altimetric anomalies and in-situ data (Argo floats, drifting buoys)

Rio and Hernandez, 2004

Rio et al, 2005, 2011, 2014



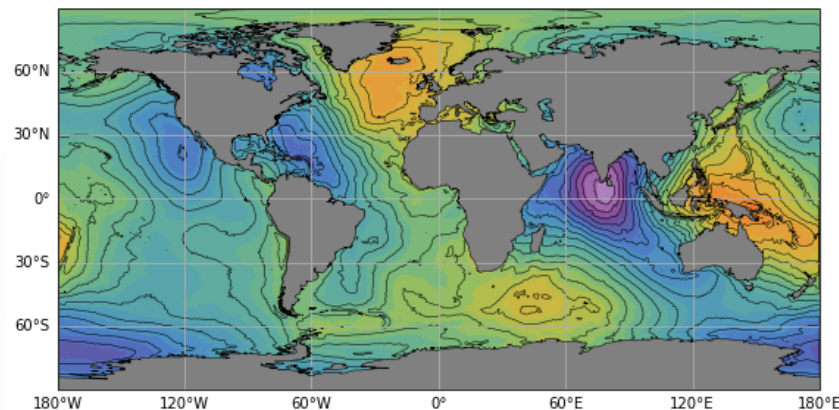
Toward a new MDT CNES-CLS-2026

- › Update of the first guess with last MSS and Geoid products
- › New pre-processing of the in-situ data to improve spatial resolution
- › Optimization of the Multivariate Objective Analysis parameterization to reduce artefacts
- › Validation of the MDT

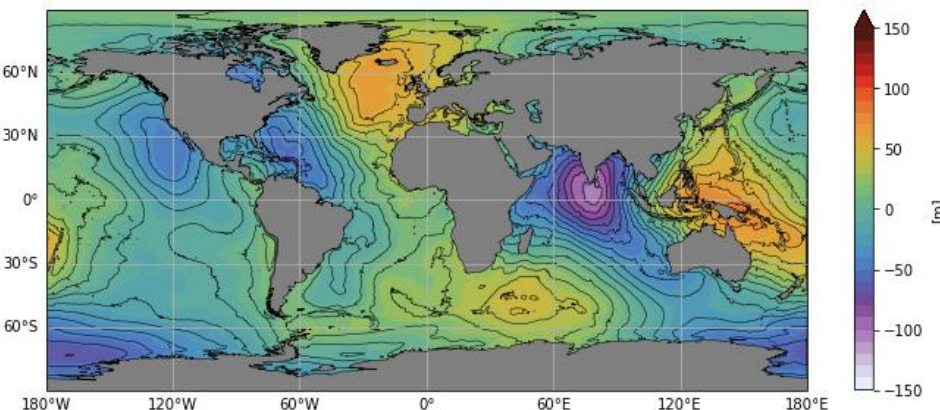
Toward a new MDT CNES-CLS-2026: First Guess

Update of Geoid and MSS products

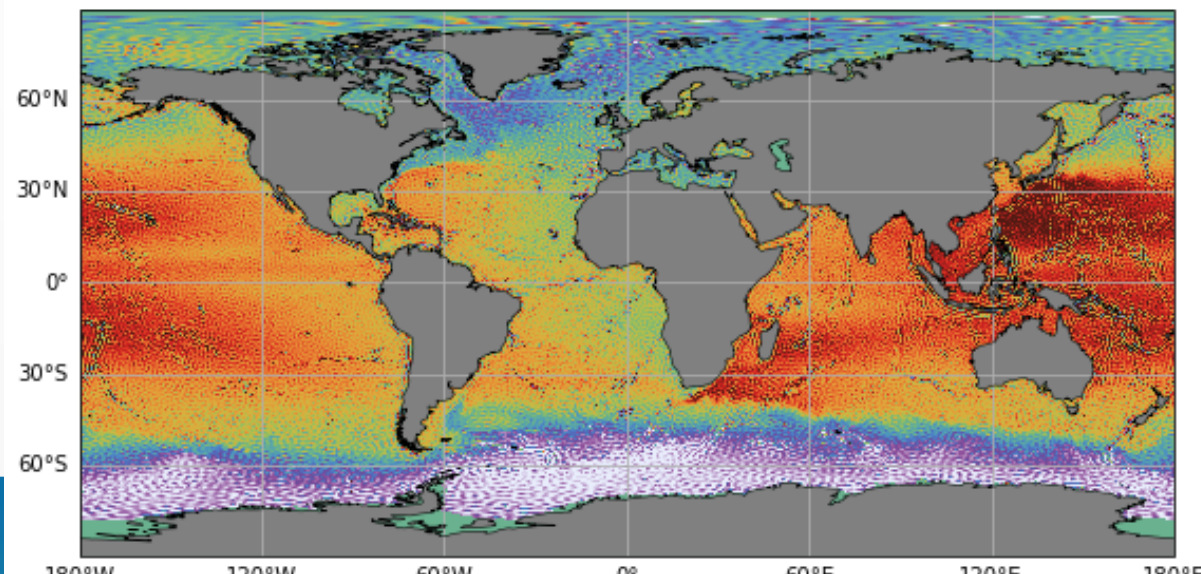
(a) Geoid GOCO2025s



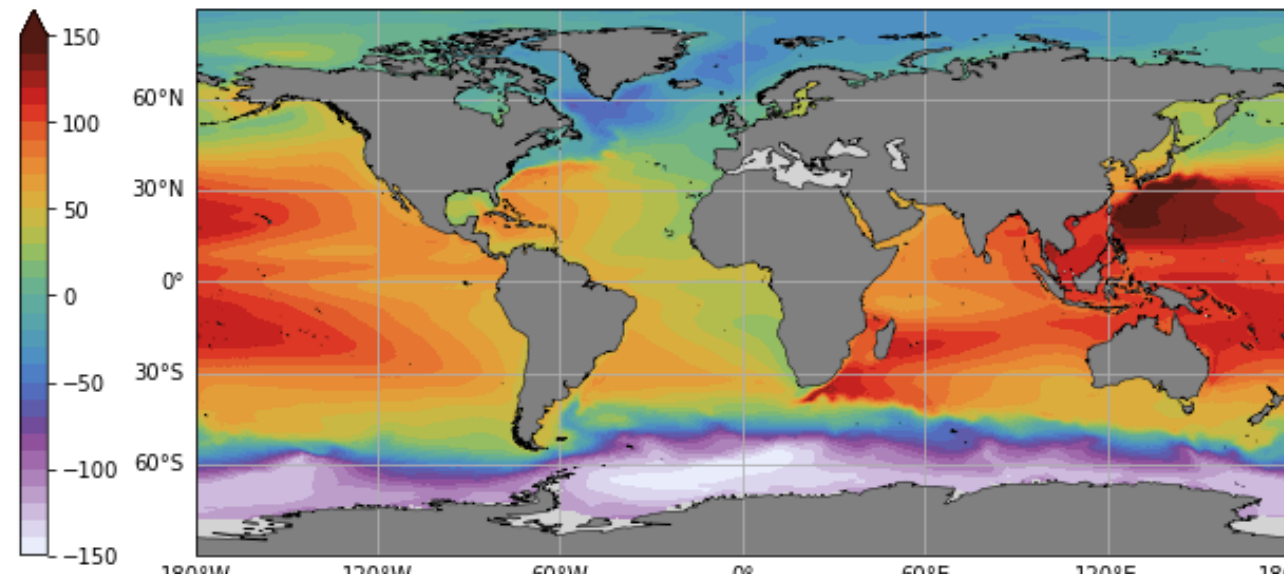
(b) MSS CNES-CLS-2025



MDT=MSS-Geoid



First Guess 2026

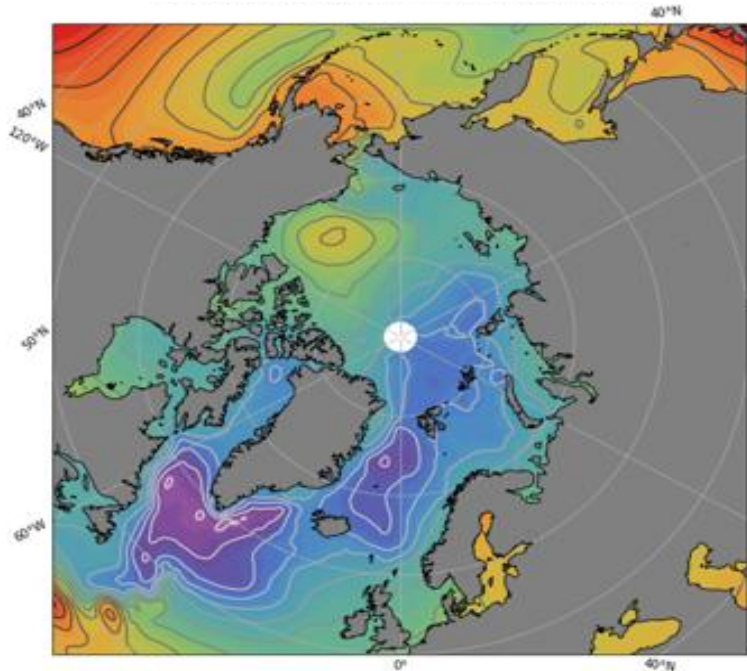


Toward a new MDT CNES-CLS-2026: First Guess

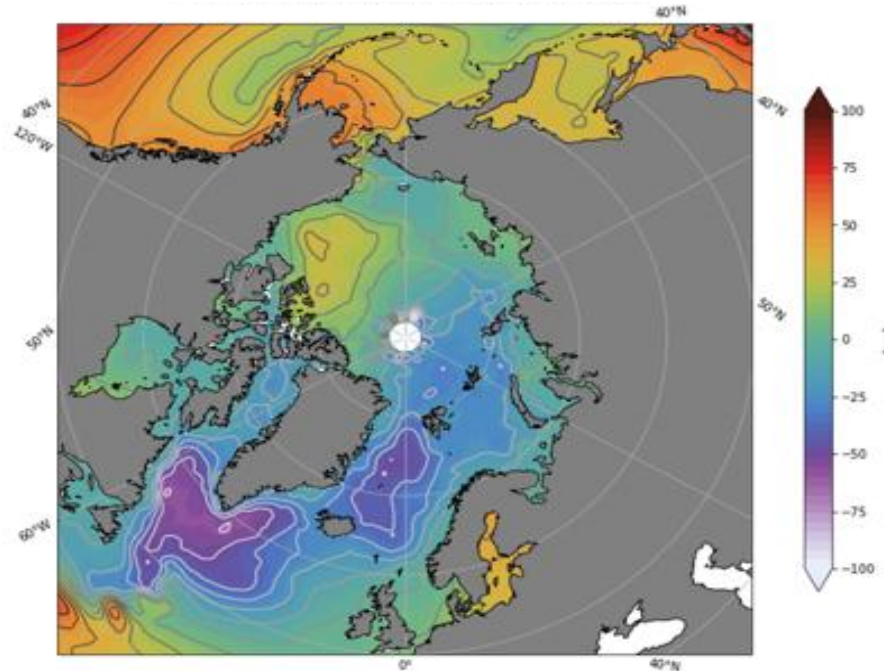
The new first guess 2026 improves some structures.

Ex : The Arctic

(a) CNES-CLS26v1



(b) CNES-CLS22

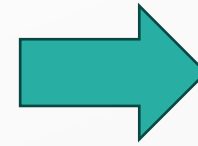


- › Improvement of some structures in the Arctic, for instance the Beaufort Gyre.

Toward a new MDT CNES-CLS-2026: new processing of in situ data

Update of the databases for height (Argo) and speed (SVP drifters)

- T/S profiles : data [2021-2024] added
- Drifters : data [mi-2021-2025] added
- Use of **DUACS DT2024** products
- Last version of Ekman current and wind-slippage for the drifters processing



Process the data to extract MDT and geostrophic currents from in situ database

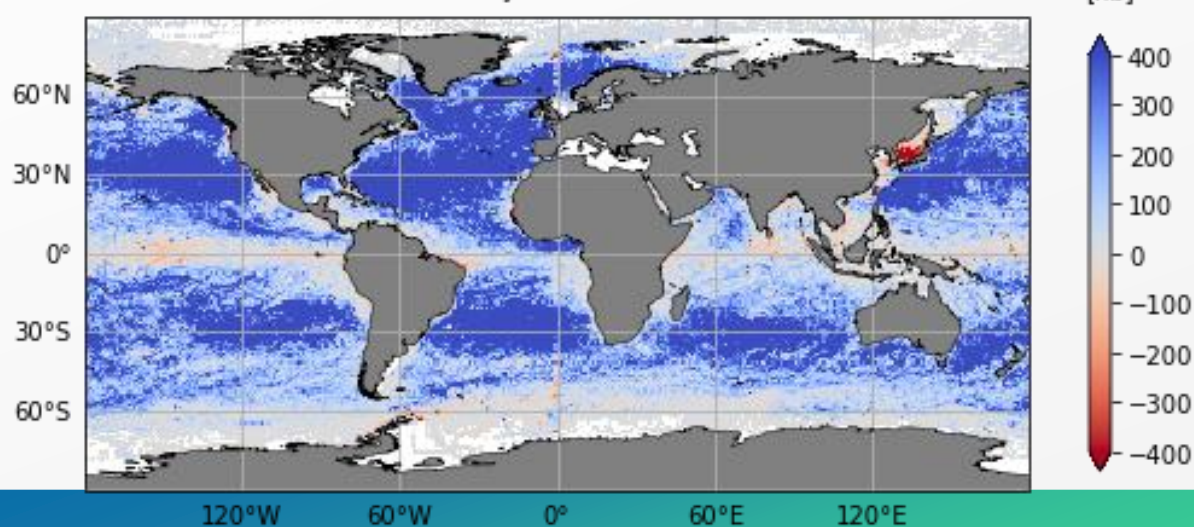
DRIFTERS

Remove ocean variability and ageostrophy

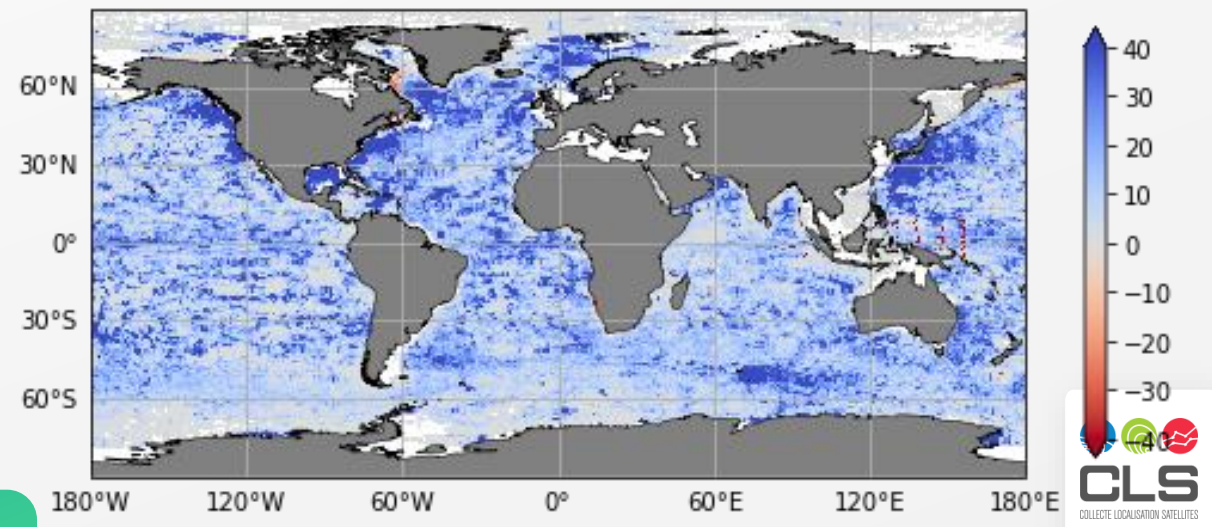
HEIGHT

Calculate dynamic height from T/S profiles and remove ocean variability

Drifters number 2026 - number 2022 by 1° boxes



T/S profiles number 2026 - number 2022 by 1° boxes

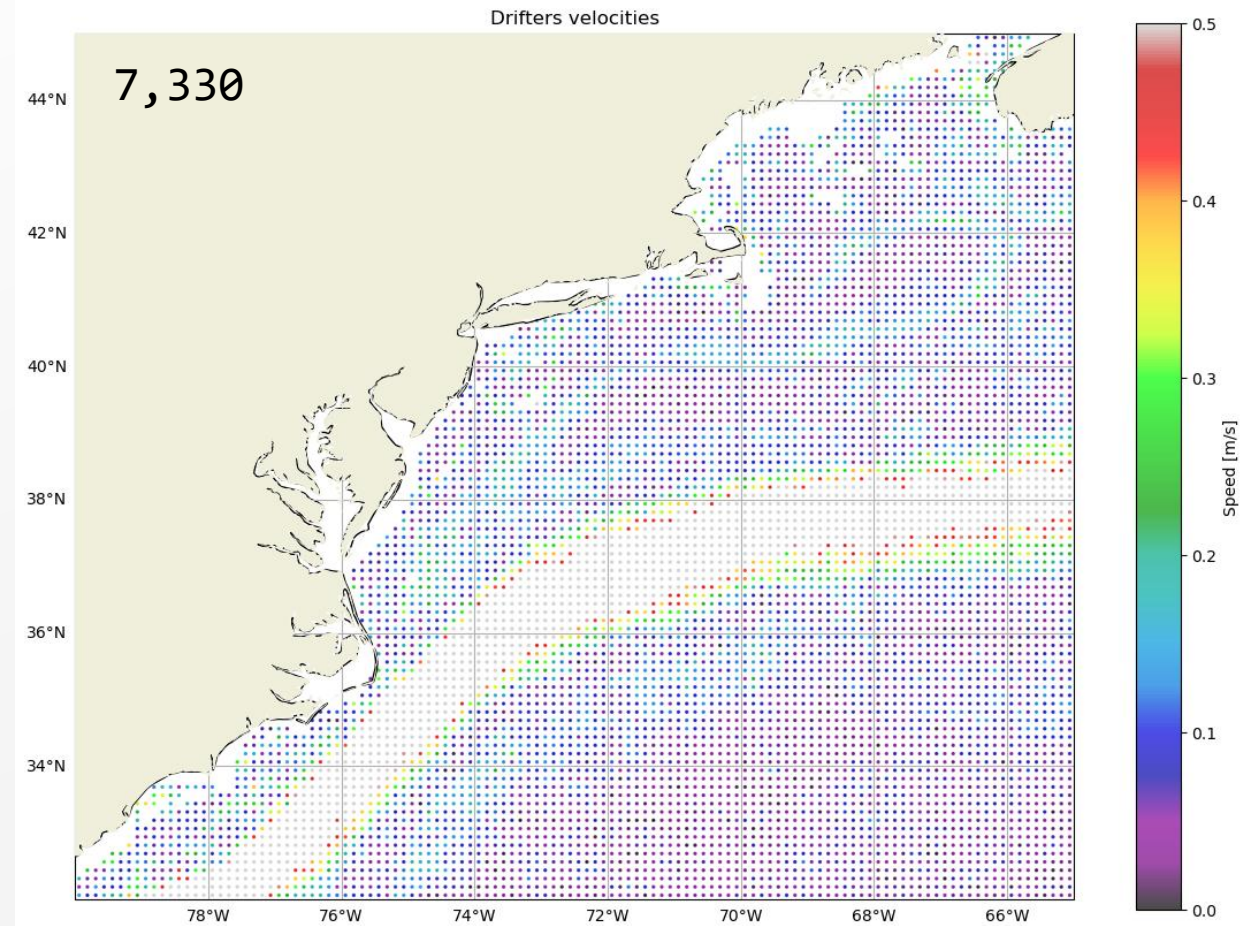
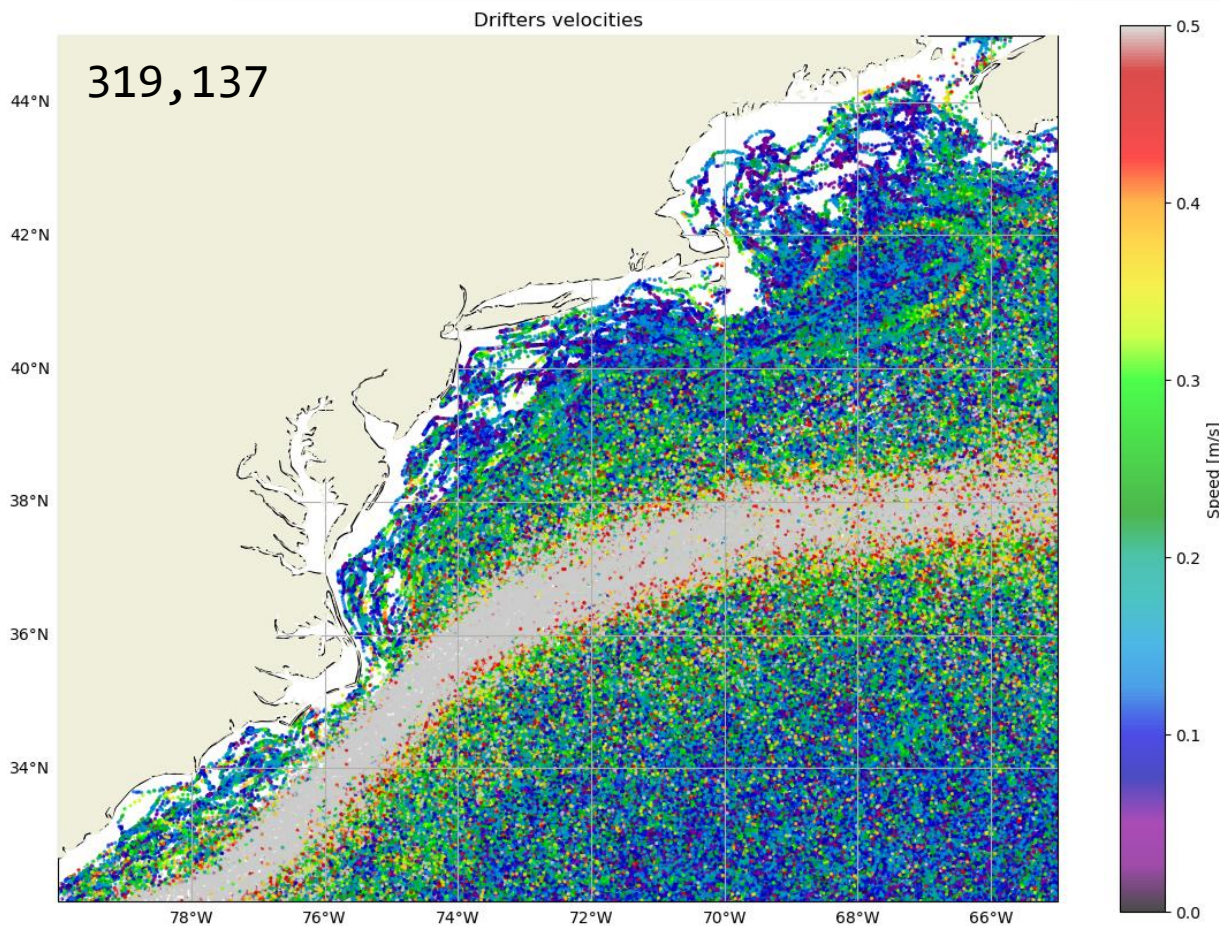


Toward a new MDT CNES-CLS-2026: new processing of in situ data

DRIFTERS

For MDT CNES-CLS-2022 : the drifters in situ data were averaged in $1/8^\circ$ boxes before added to the objective analysis.

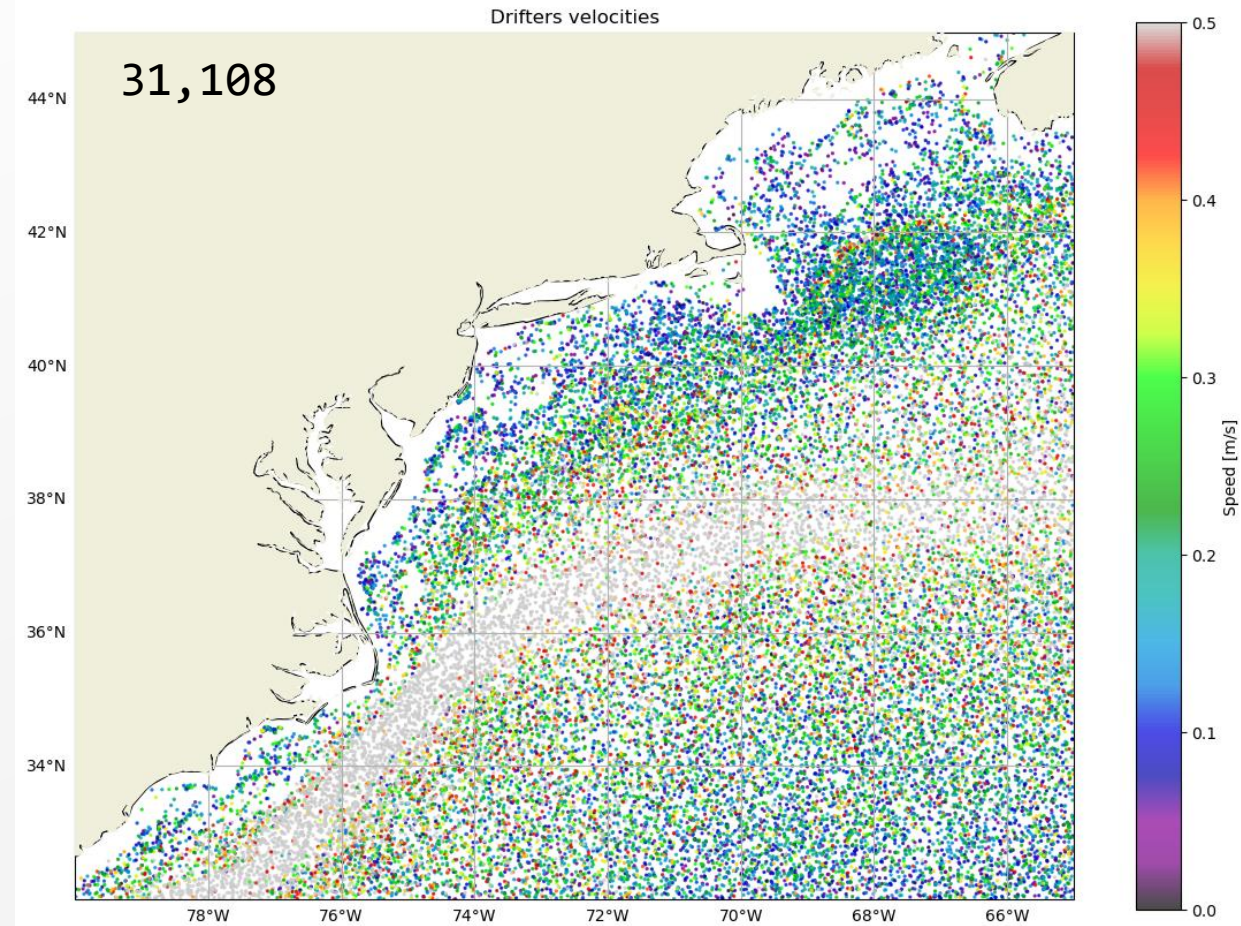
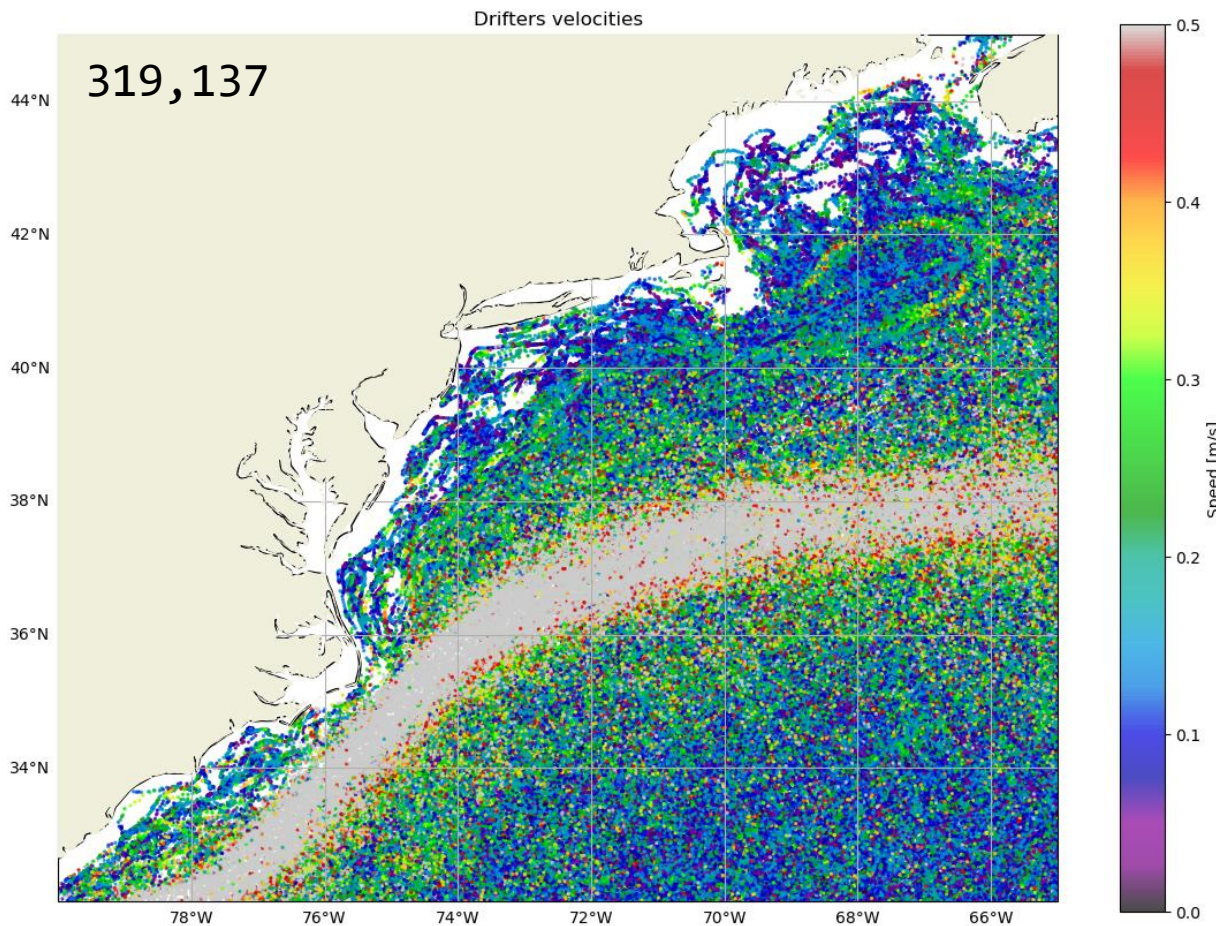
Example : Gulf Stream area.



Toward a new MDT CNES-CLS-2026: new processing of in situ data

DRIFTERS

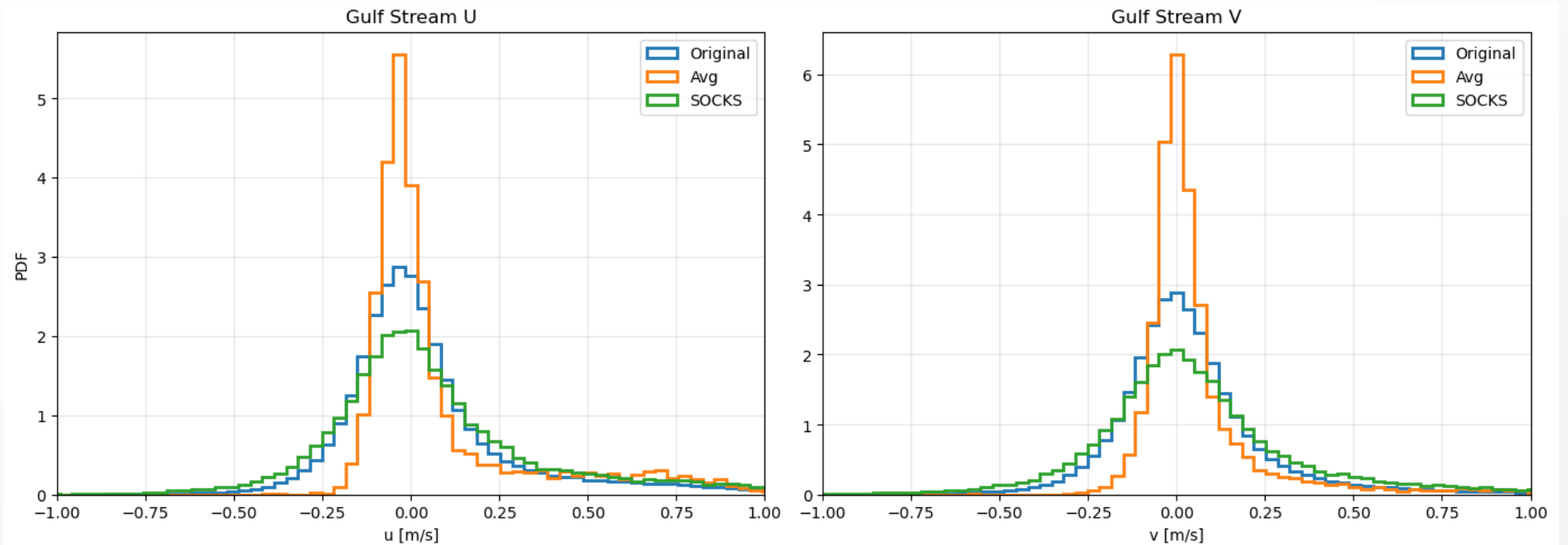
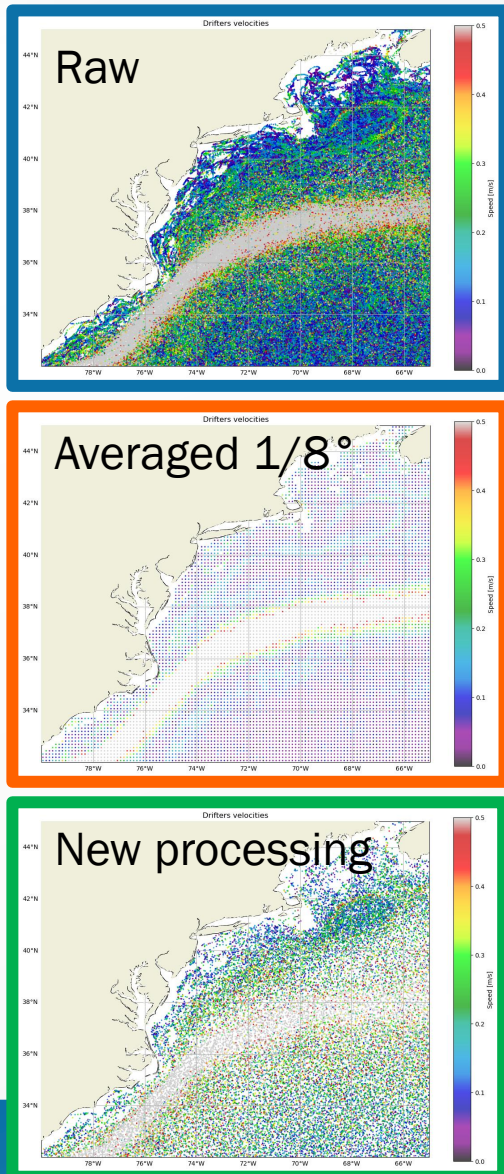
For MDT CNES-CLS-2026 : the drifters observations are clustered in super-observations based on their **proximity** and **similarity**.



Toward a new MDT CNES-CLS-2026: new processing of in situ data

DRIFTERS

Comparison of the speed distributions depending on the processing :



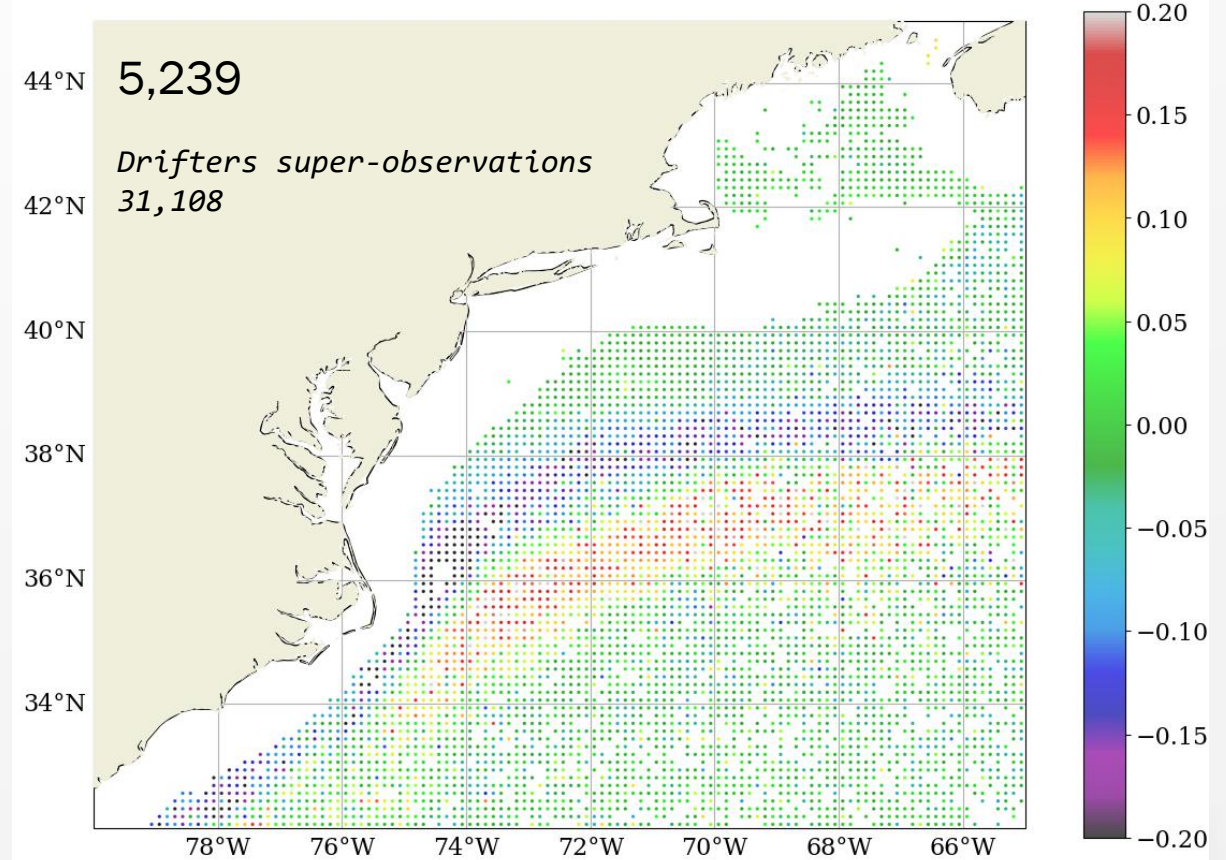
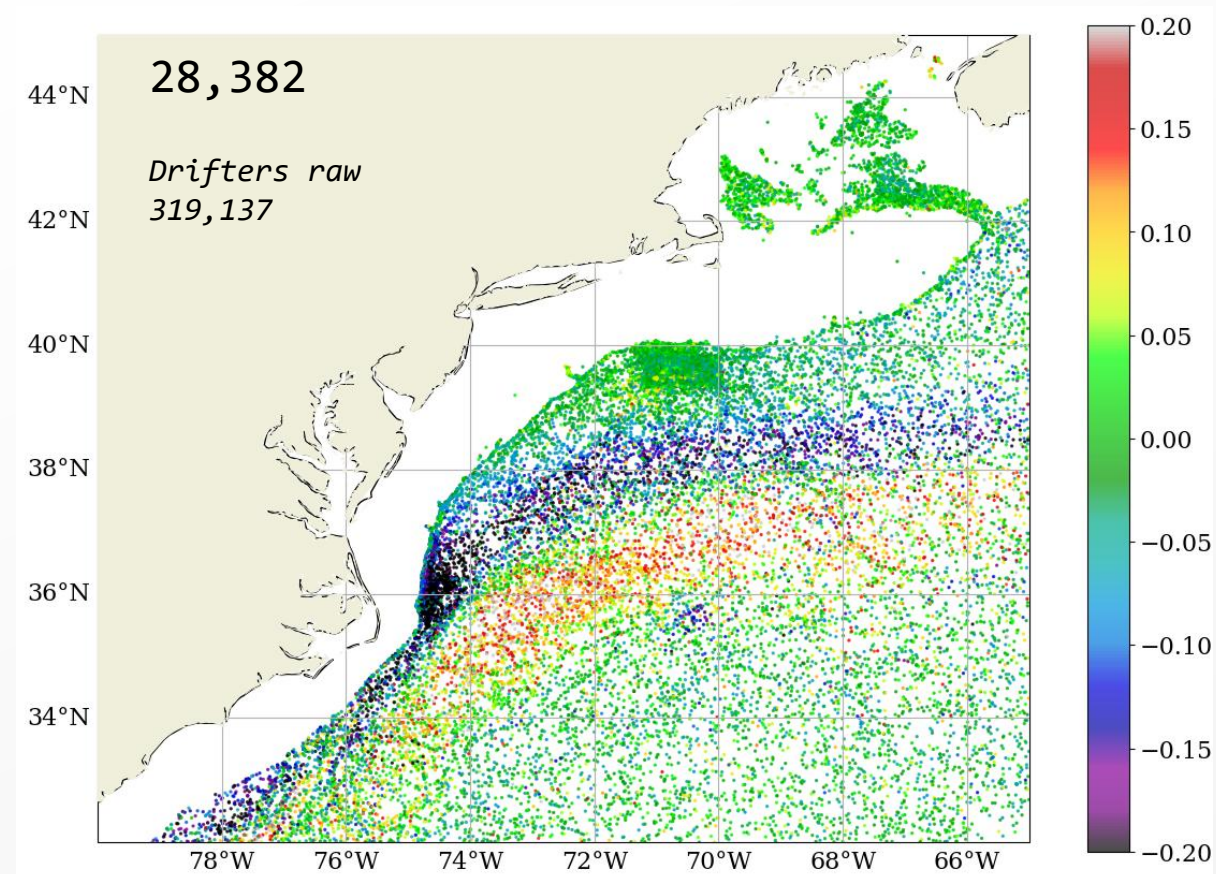
The new processing better preserves the U and V distributions observed in the original dataset compared to the averaging method.

Toward a new MDT CNES-CLS-2026: new processing of in situ data

T/S PROFILES

For MDT CNES-CLS-2022 : the height in situ data were averaged in $1/8^\circ$ boxes before added to the objective analysis.

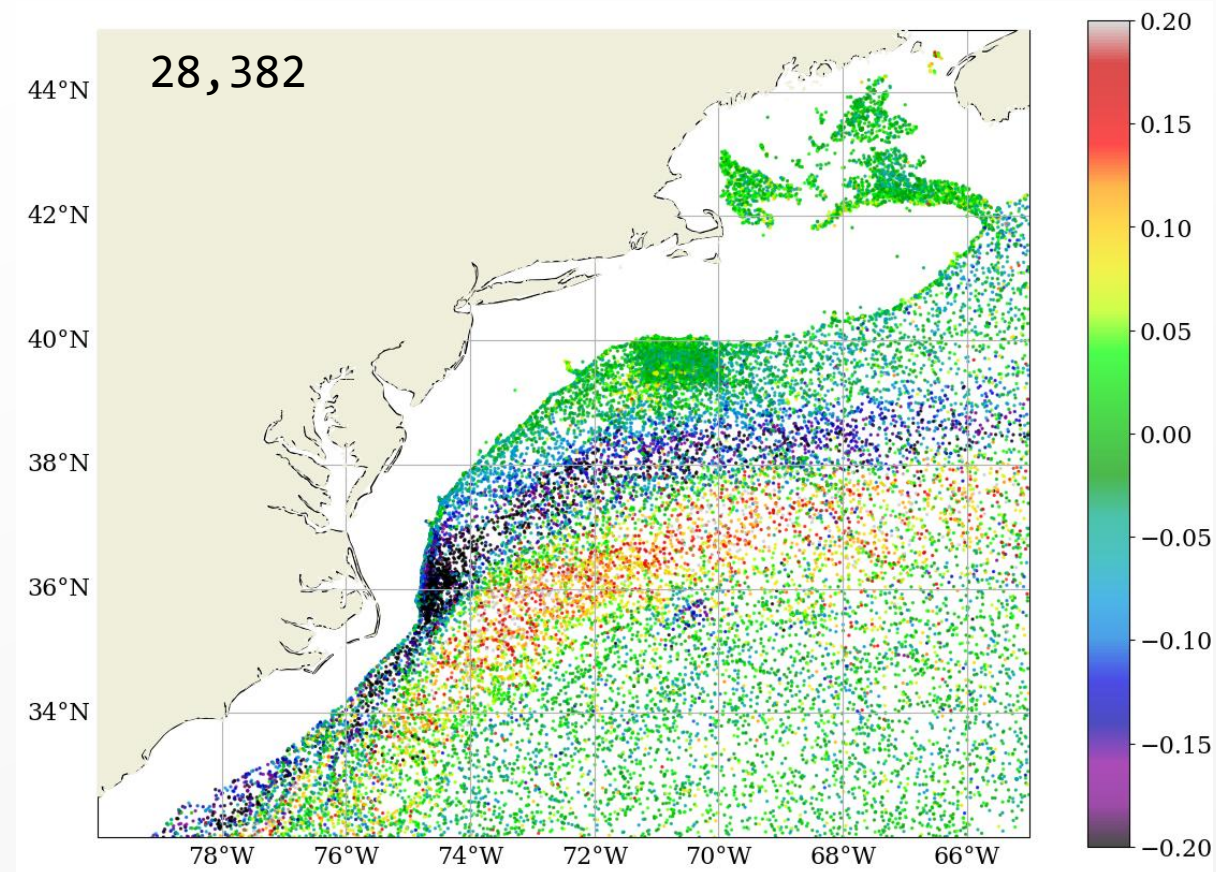
Example : Gulf Stream area.



Toward a new MDT CNES-CLS-2026: new processing of in situ data

T/S PROFILES

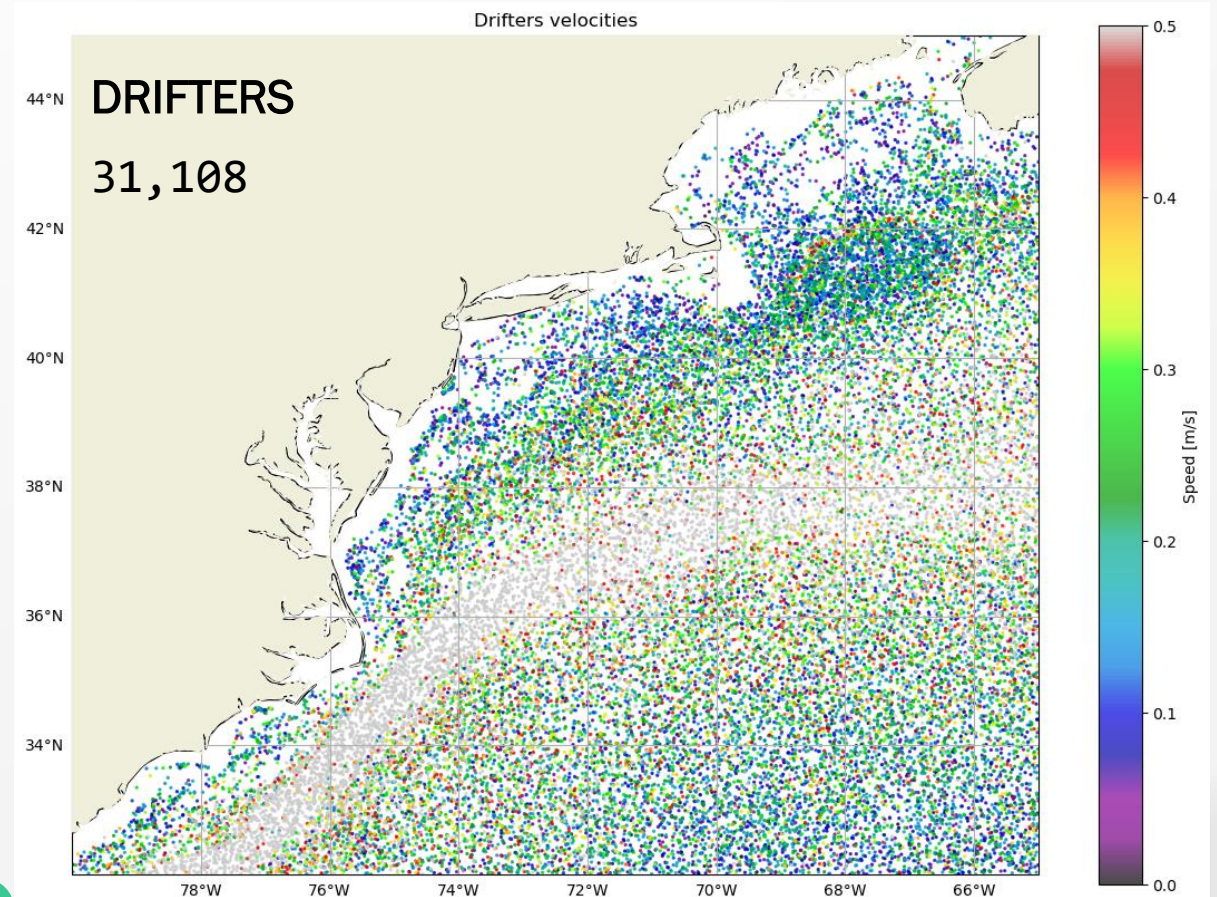
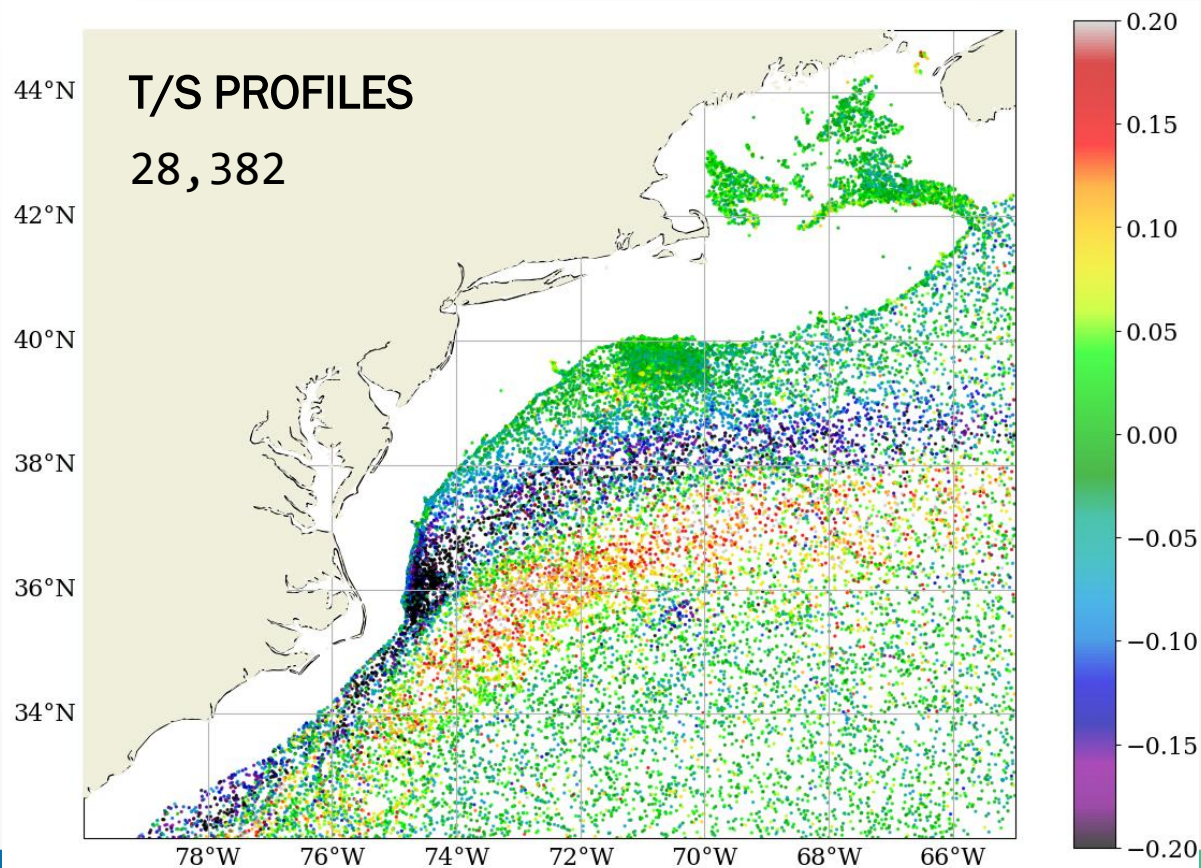
For MDT CNES-CLS-2026 : the height in situ data are kept without any processing.



Toward a new MDT CNES-CLS-2026: new processing of in situ data

The new processing allows :

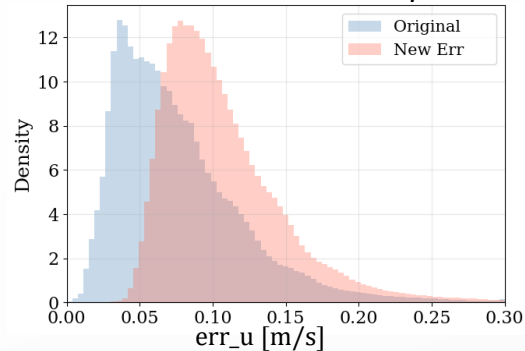
- › The integration of heterogeneous observations,
- › Better preservation of the original speed and dynamic height distributions,
- › A more balanced sampling of both fields.



Toward a new MDT CNES-CLS-2026: new error model of in situ data

A new error budget was developed for in situ data. Details for the drifters :

Distribution of the zonal speed errors



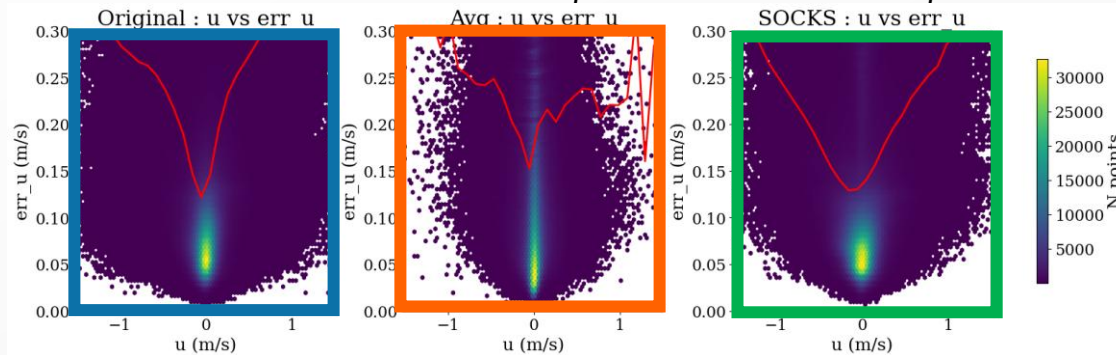
ERRORS OF THE RAW OBSERVATIONS

- › An ageostrophic error term was added for the drifters
- › The error budget was increased to better account for observational uncertainties

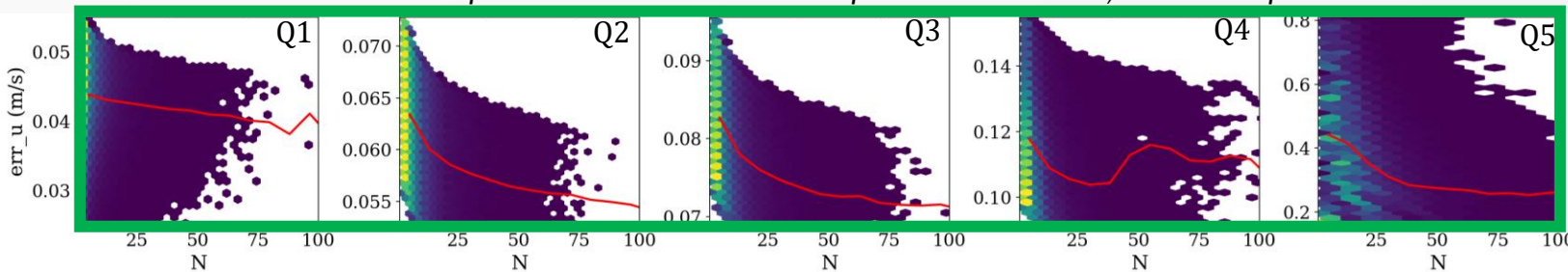
ERRORS OF THE SUPER-OBSERVATIONS

- › Errors of the super-obs closer to the raw errors

Distribution of the zonal speed errors vs. zonal speed



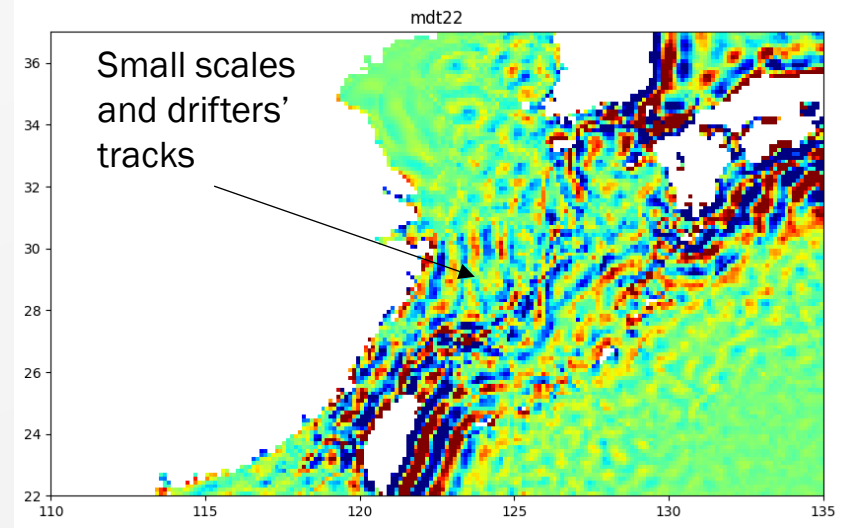
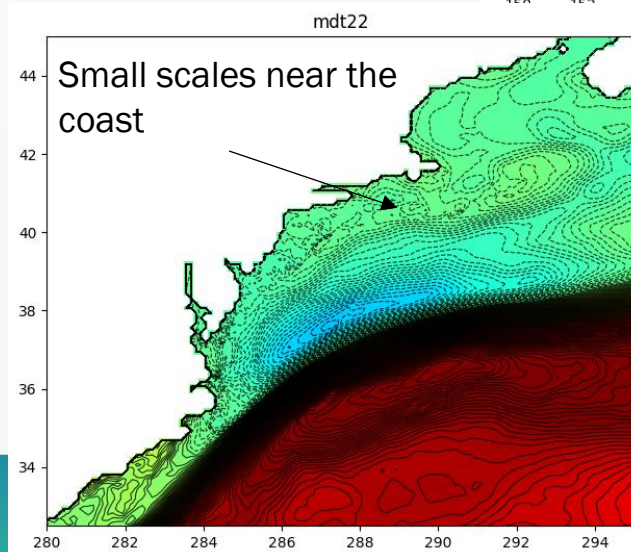
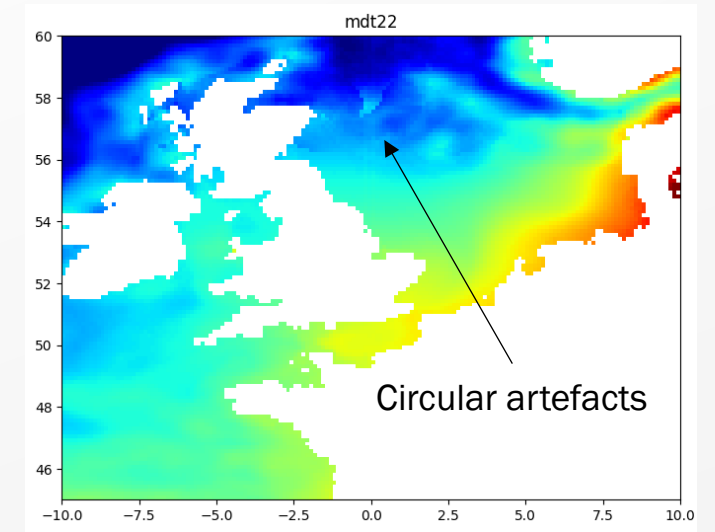
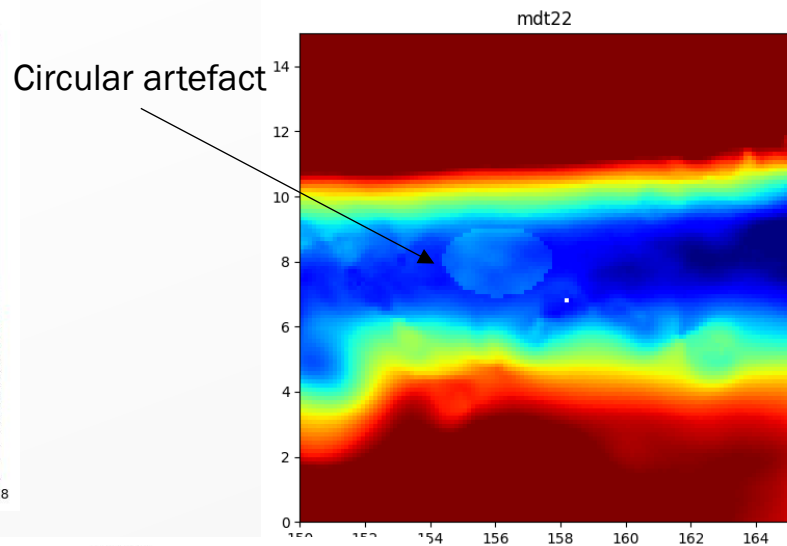
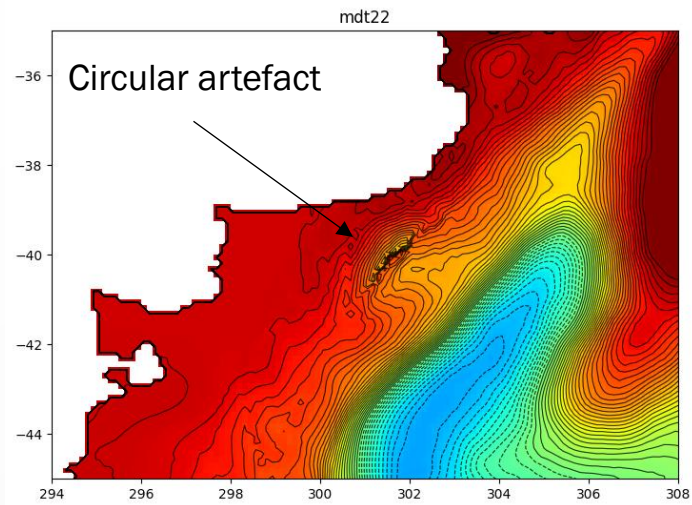
Distribution of the zonal speed errors vs. Size of super-observations, for error quintiles



- › For a given error budget, larger clusters (higher N) are associated with lower analysis errors.
- › The objective analysis places greater confidence in super-observations derived from a larger number of observations.

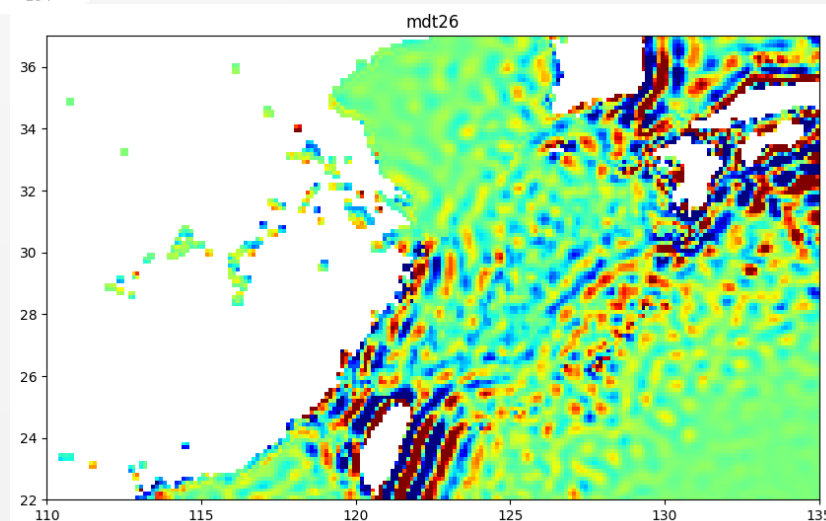
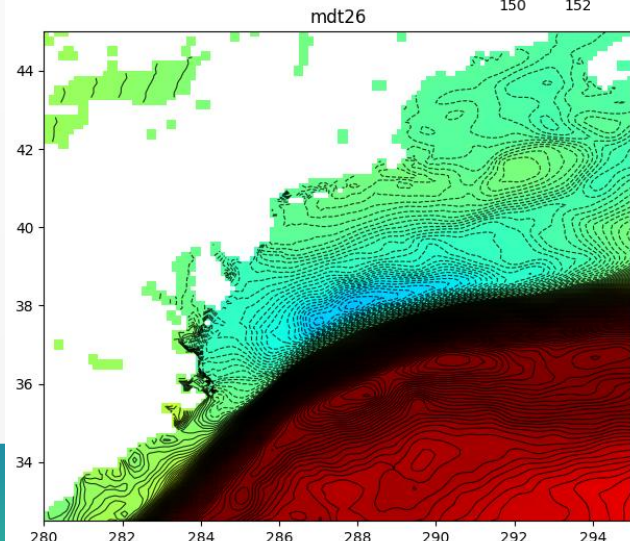
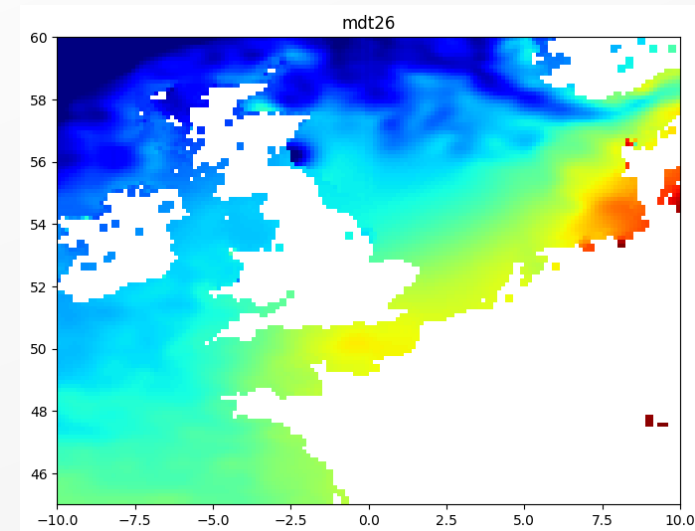
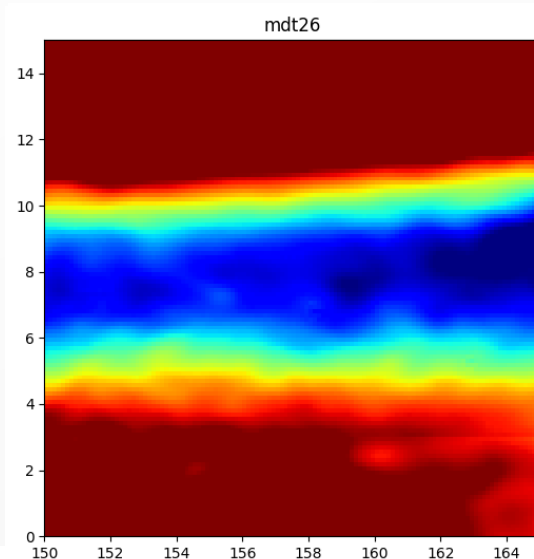
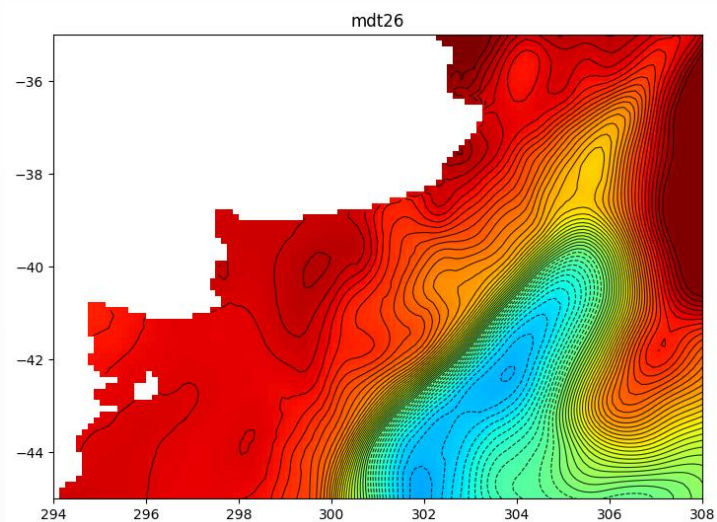
Toward a new MDT CNES-CLS-2026: validation

- Last available version: MDT CNES-CLS-2022.
- Some artefacts (probably due to the Multivariate Objective Analysis parametrization).



Toward a new MDT CNES-CLS-2026: validation

Corrected artefacts in MDT2026-beta versions



Toward a new MDT CNES-CLS-2026: validation

Good results obtained locally with independent data validation.

The global parametrization of the multivariate objective analysis is still under development.

Global validation using independent data is ongoing :

- Do global pointwise RMSE validations favor MDT solutions with too small-scale features or noise?
- How can all spatial scales of the MDT be properly validated?
- How can specific structures be independently assessed?

Take-home messages

A new MDT CNES-CLS-2026 product is currently under work :

- › Update Geoid and MSS products
- › Updated drifters and T/S profiles databases
- › New processing of in situ data
- › Revised error budget
- › The current local MDTs reduce artefacts observed in the 2022 version
- › A global beta version will be available by the end of the summer



We are looking for volunteers to beta-test the latest version
in specific regions

jgamot@groupcls.com

Thank you !