Improved 2D Surface Currents from the synergetic use of altimetry and Sea Surface Temperature data

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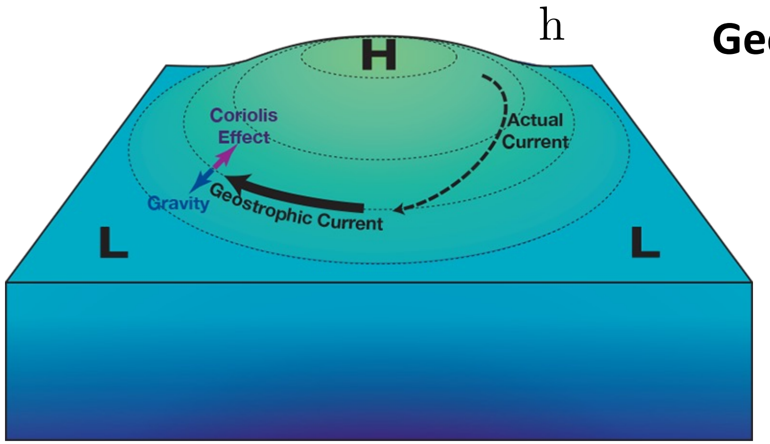
Context

Altimeter-derived currents: **Theoretical Limits**

Geostrophic Approximation: the ocean currents are inferred from the ocean surface topography, thus neglecting geostrophically unbalanced motions



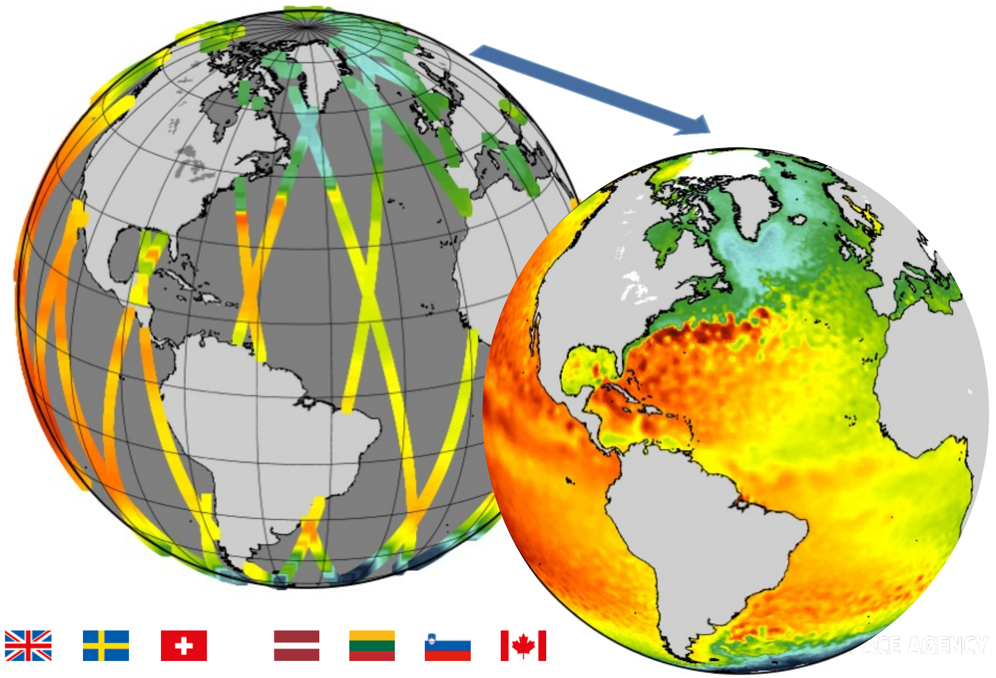
Geostrophic Balance

$$u_{GEO} = -\frac{g}{f}\frac{\partial h}{\partial y}$$

$$v_{GEO} = \frac{g}{f}\frac{\partial h}{\partial x}$$

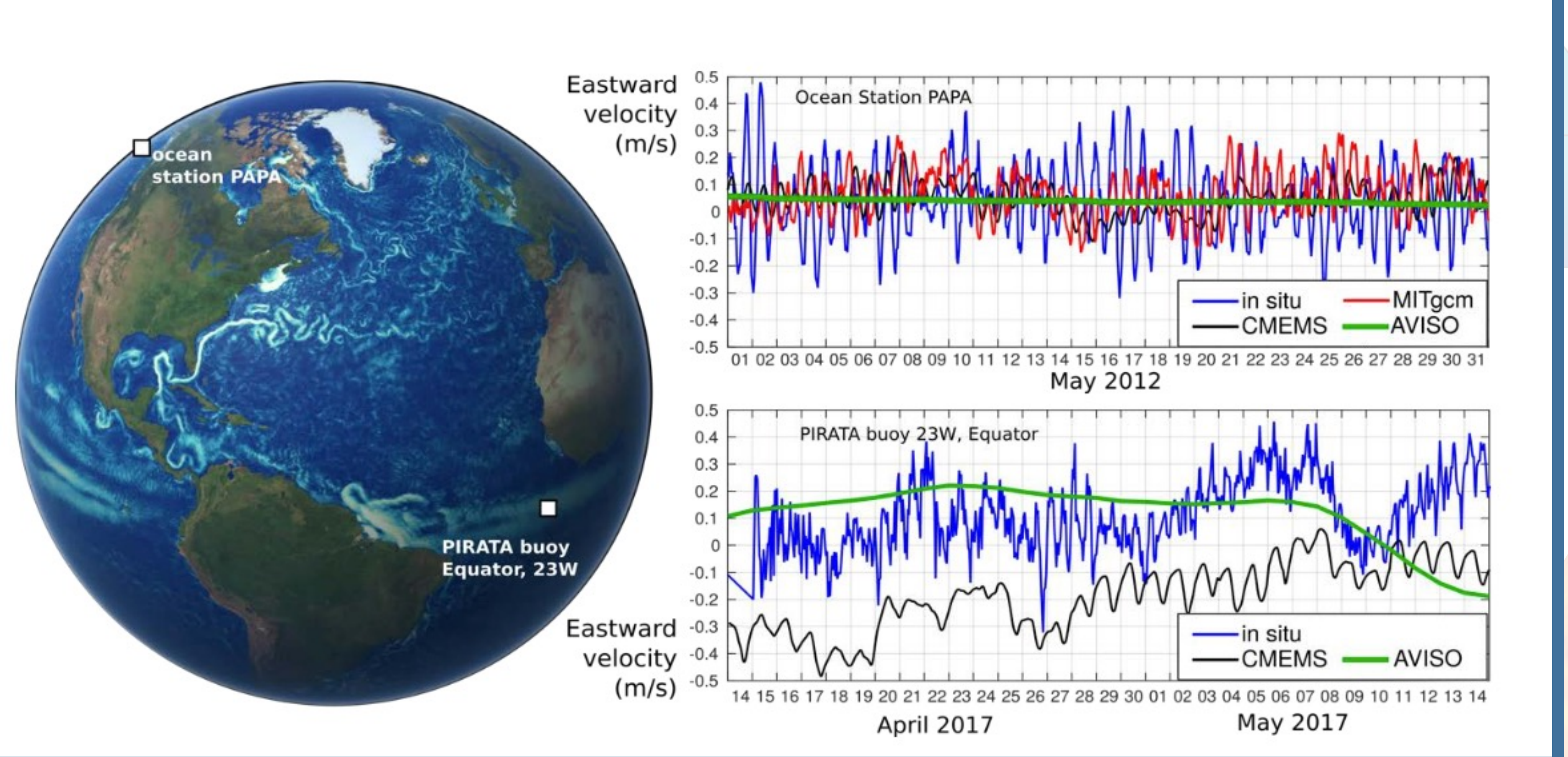
Altimeter-derived currents: **Intrinsic Limits**

Nadir-looking Radar Altimeters **observations are optimally interpolated to get 2D maps of the ocean surface topography and derived quantities (Ugeo, Vgeo…)**



Context

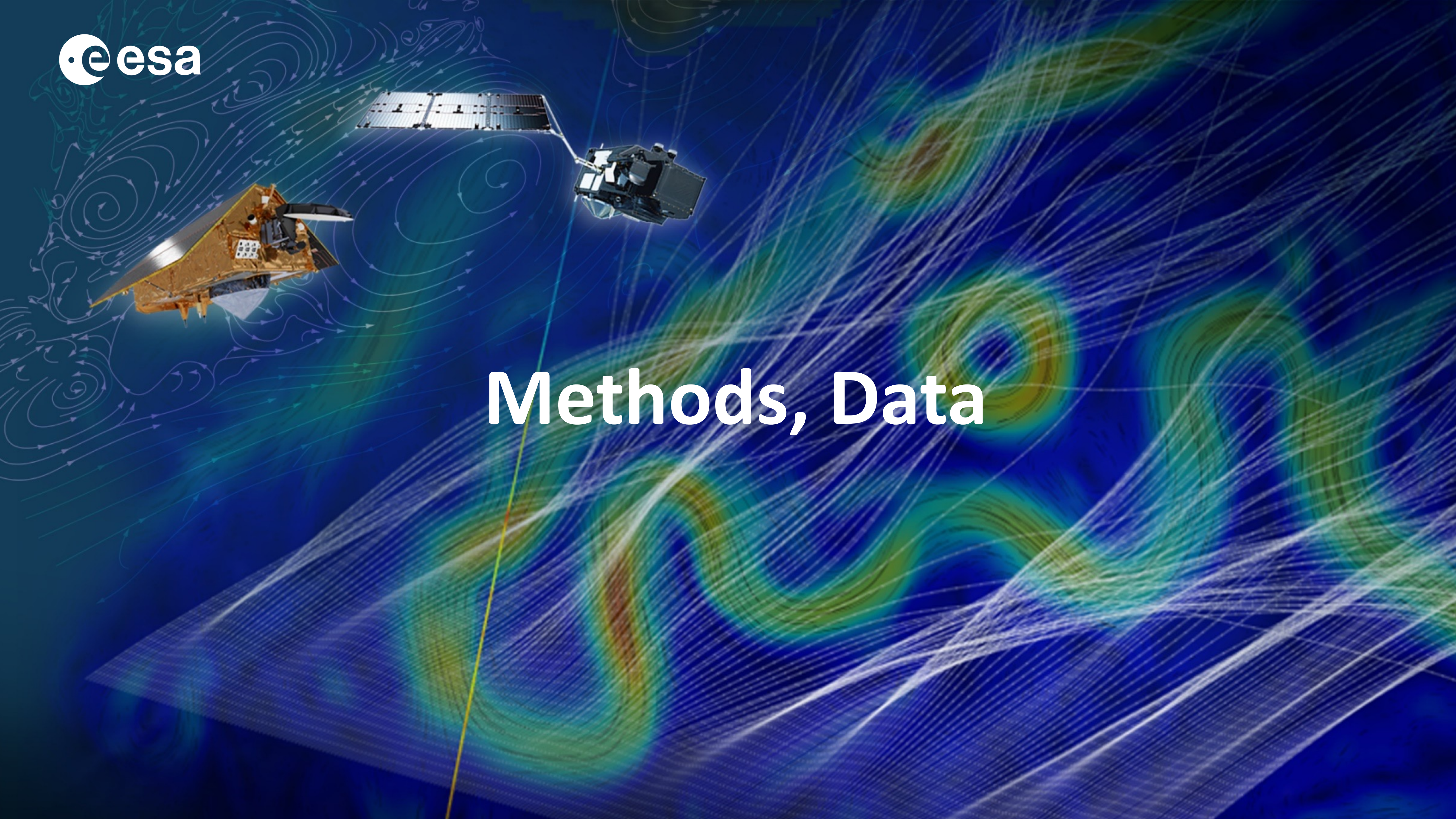
An example of the Altimeter system limitations



- In situ
- Model
- Altimeter

From ESA(2019). *Report for Mission Selection: SKIM*, European Space Agency, Noordwijk, The Netherlands, ESA-EOPSM-SKIM-RP-3550, 264pp.

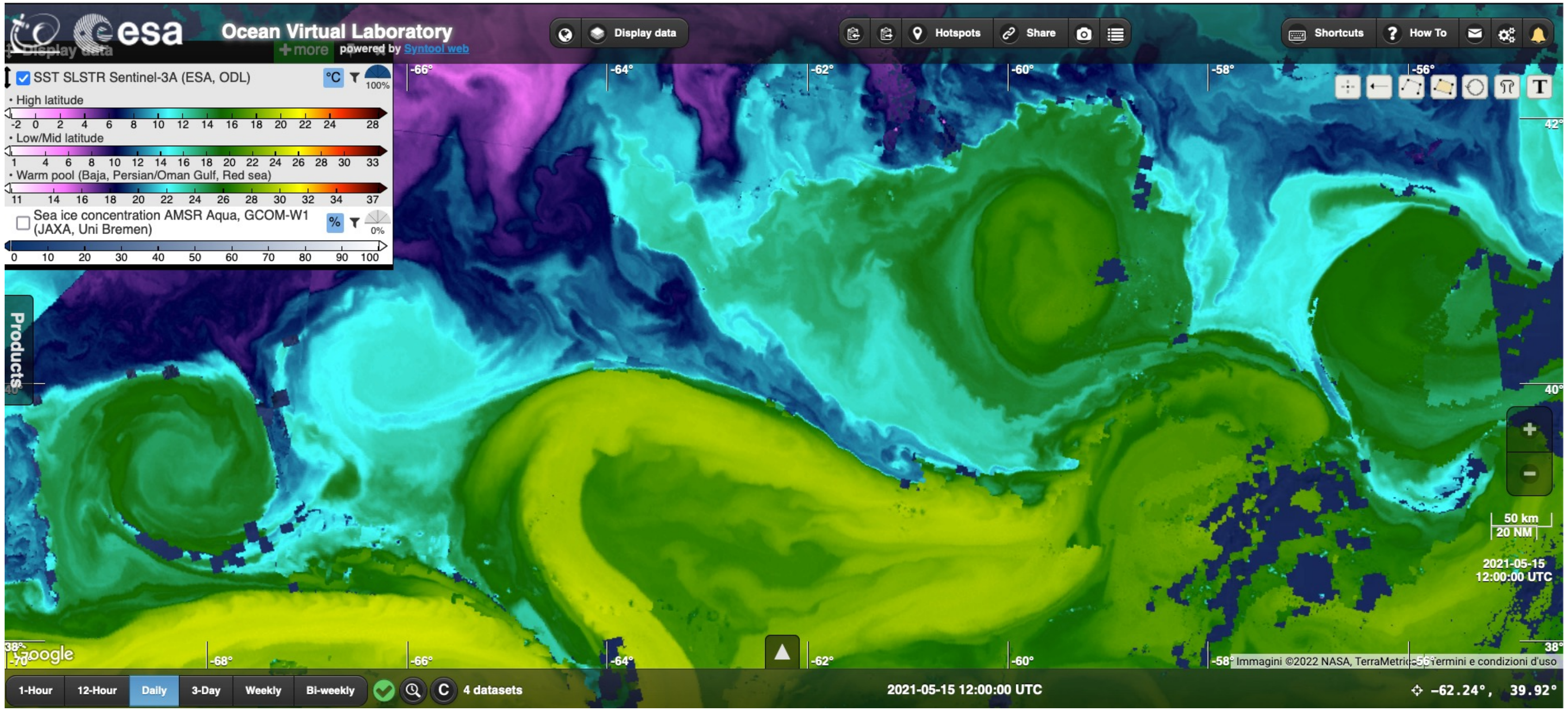
Methods, Data



Methods & Data

The Piterbarg 2009 Method : overview and implementation

Merged Altimeter + SST Currents: we extract dynamical information from HR satellite-derived tracer observations



WOC (2010-2019)

- **Copernicus DUACS-18 Altimeter** Geostrophic Velocities (1/4°, daily)
- **Copernicus OSTIA SST** (remapped to 1/10°,daily)

Activities carried out within: ESA-Globcurrent ESA-CIRCOL ESA-WOC

Methods & Data

The Piterbarg 2009 Method : overview and implementation

Require the velocity field (u,v) to obey to the SST evolution equation

$$\frac{\partial \mathrm{SST}}{\partial \mathrm{t}} + u\frac{\partial \mathrm{SST}}{\partial \mathrm{x}} + v\frac{\partial \mathrm{SST}}{\partial \mathrm{y}} = F$$

F= source and sink terms

We use a **background velocity** information **(u_{bck}, v_{bck})** so that the **satellite tracer information is used to obtain an optimized merged velocity: Optimal Currents (u_{opt}, v_{opt})**

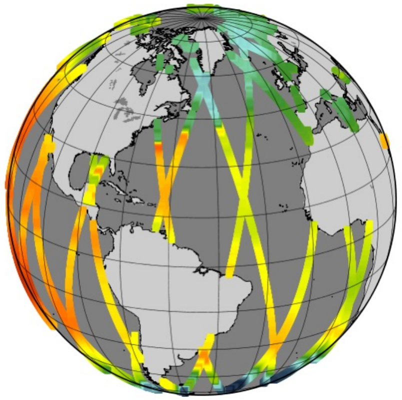
SET OF EQUATIONS FOR PERFECTLY KNOWN FORCING

$$\mathrm{u_{opt}} = \mathrm{u_{bck}} - \frac{\mathrm{A(Au_{bck} + Bv_{bck} + E)}}{\mathrm{A^2 + B^2}} = \mathrm{u_{bck}} + \mathrm{u_{corr}}$$

$$\mathrm{v_{opt}} = \mathrm{v_{bck}} - \frac{\mathrm{B(Au_{bck} + Bv_{bck} + E)}}{\mathrm{A^2 + B^2}} = \mathrm{v_{bck}} + \mathrm{v_{corr}}$$

$$\mathrm{A} = \frac{\partial \mathrm{SST}}{\partial \mathrm{x}} \quad \mathrm{B} = \frac{\partial \mathrm{SST}}{\partial \mathrm{y}} \quad \mathrm{E} = \frac{\partial \mathrm{SST}}{\partial \mathrm{t}} - \mathrm{F}$$

u_{bck} , v_{bck} (Altimeter)



E

Methods & Data

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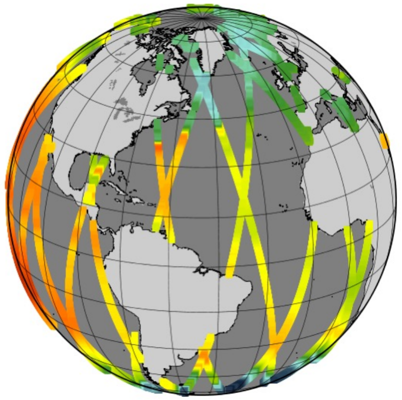
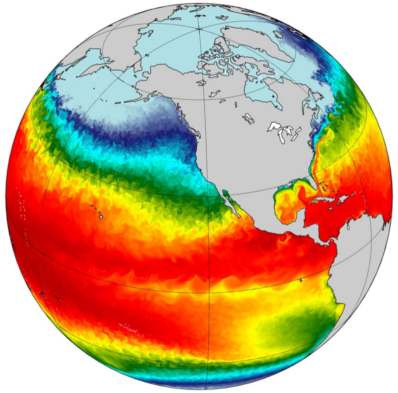


u_{corr} , v_{corr} (SST)



E

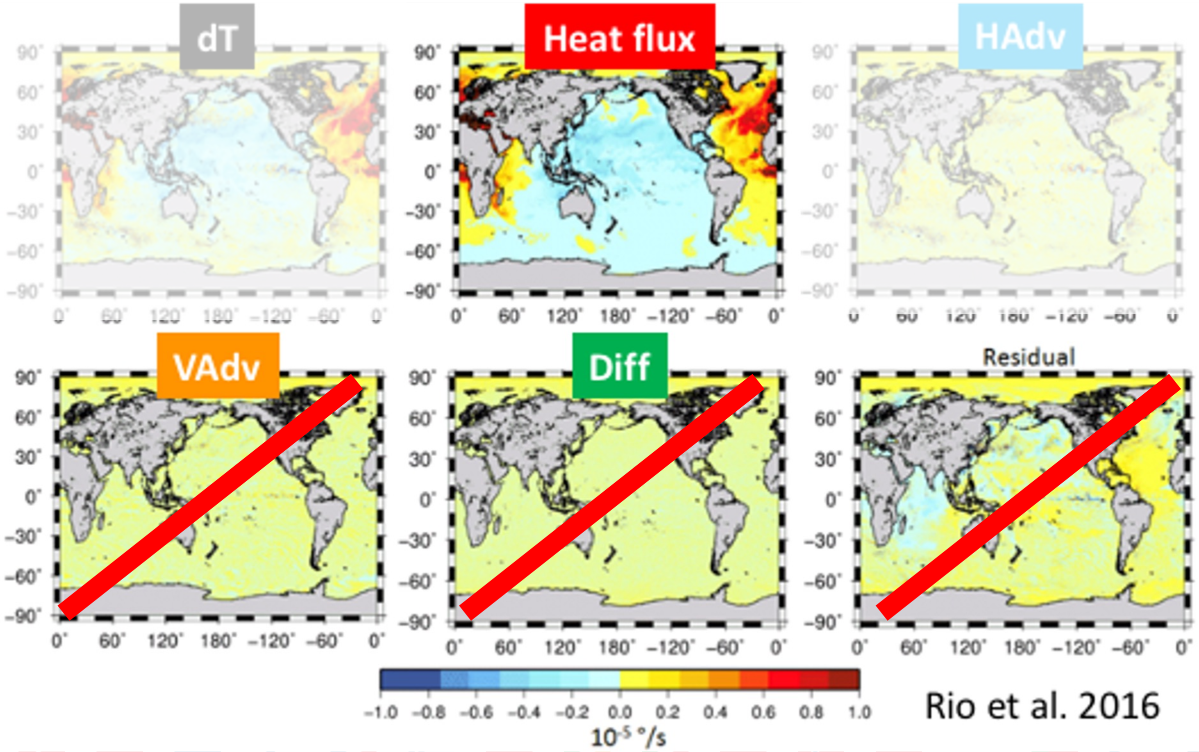
Methods & Data

The Piterbarg 2009 Method : overview and implementation

Forcing Term: we account for the heat balance equation in the oceanic mixed layer

FORCING

$$\underbrace{\frac{1}{H}\int_{z=0}^{H}\frac{\partial T(z)}{\partial t}dz}_{\text{dT}} + \underbrace{\frac{1}{H}\int_{z=0}^{H}u(z)\frac{\partial T(z)}{\partial x}+v(z)\frac{\partial T(z)}{\partial y}dz}_{\text{HAdv}} + \boxed{\underbrace{\frac{1}{H}\int_{z=0}^{H}w(z)\frac{\partial T(z)}{\partial z}dz}_{\text{VAdv}} = \underbrace{\frac{\kappa_x}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial x^2}dz + \frac{\kappa_y}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial y^2}dz + \frac{\kappa_z}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial z^2}dz}_{\text{Diff}} + \underbrace{\frac{Q(H)}{\rho c_p H}}_{\text{Heat flux}} - \underbrace{\frac{w_e}{H}(T_m - T_b)}_{\text{Entrain.}}}$$



Rio et al. 2016

Forcing Term approximated via surface information

$$F \simeq Qt$$

$$\boxed{Q_t = \partial_t SST_{>500km}}$$

Rio and Santoleri 2018

Methods & Data

The Piterbarg 2009 Method : overview and implementation

SET OF EQUATIONS FOR AN APPROXIMATED FORCING

$$u_{opt} = u_{bck} + u_0 \sin\phi + v_0 \cos\phi = u_{bck} + \text{correction}$$
$$v_{opt} = v_{bck} - u_0 \cos\phi + v_0 \sin\phi = v_{bck} + \text{correction}$$

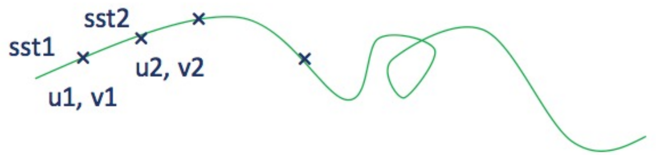
correction

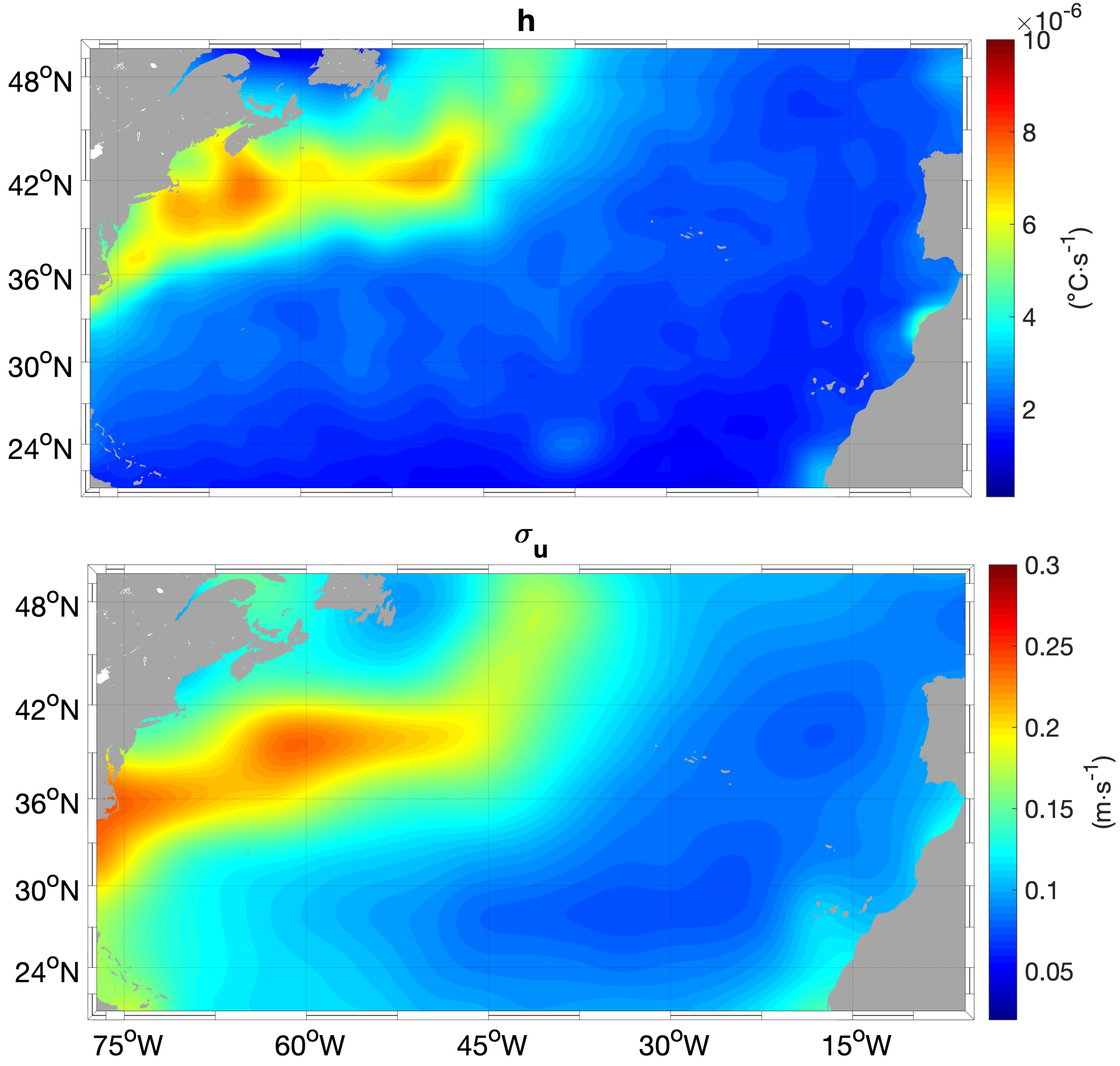
$$u_0 = f(\partial_x SST, \partial_y SST, \overline{u_{bck}}, \sigma_u, \sigma_v, h, \partial_t SST)$$
$$v_0 = u_0 \cdot f(\phi, \sigma_u, \sigma_v)$$
$$\phi = f(\partial_x SST, \partial_y SST)$$

$-h$ Uncertainty on the Forcing

$-(\sigma_u, \sigma_v)$ Uncertainly on the background velocities

Estimated via colocation with in-situ measurements (1993-2018)





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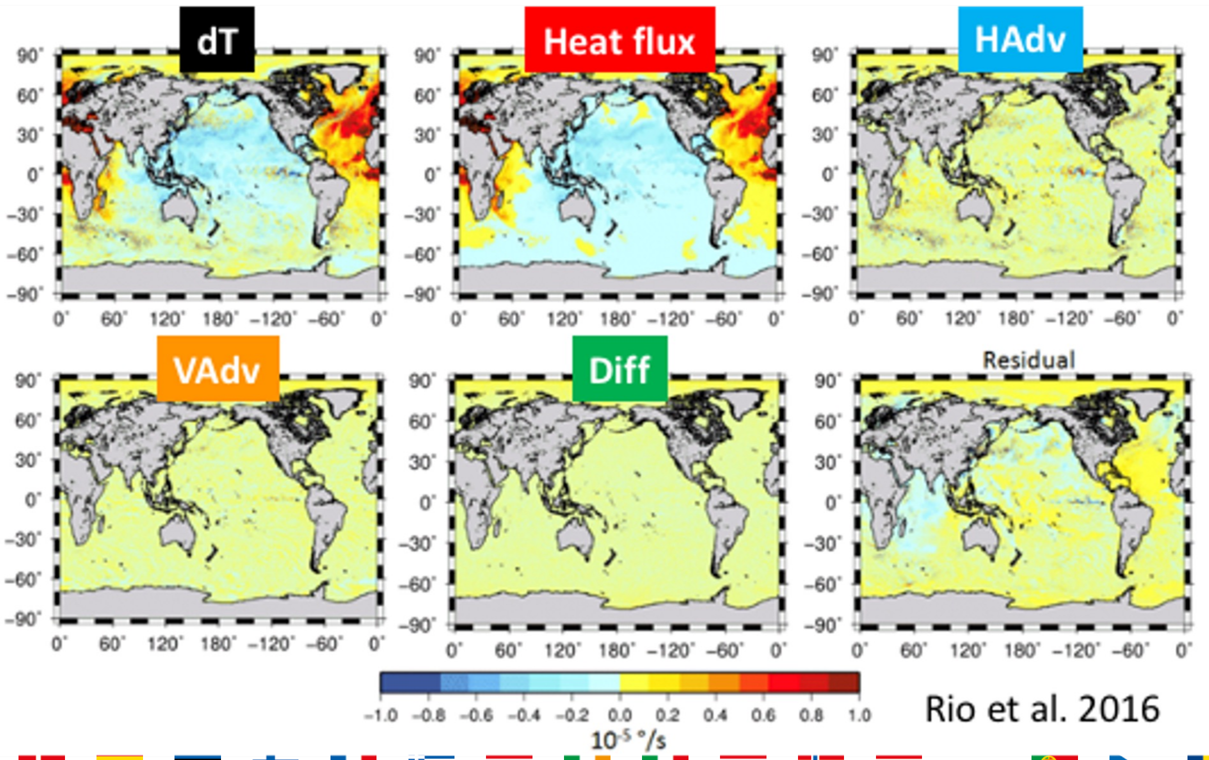


Rio et al. 2016

$$F \simeq Qt$$

$$Q_t = \partial_t SST_{>500km}$$

Rio and Santoleri 2018

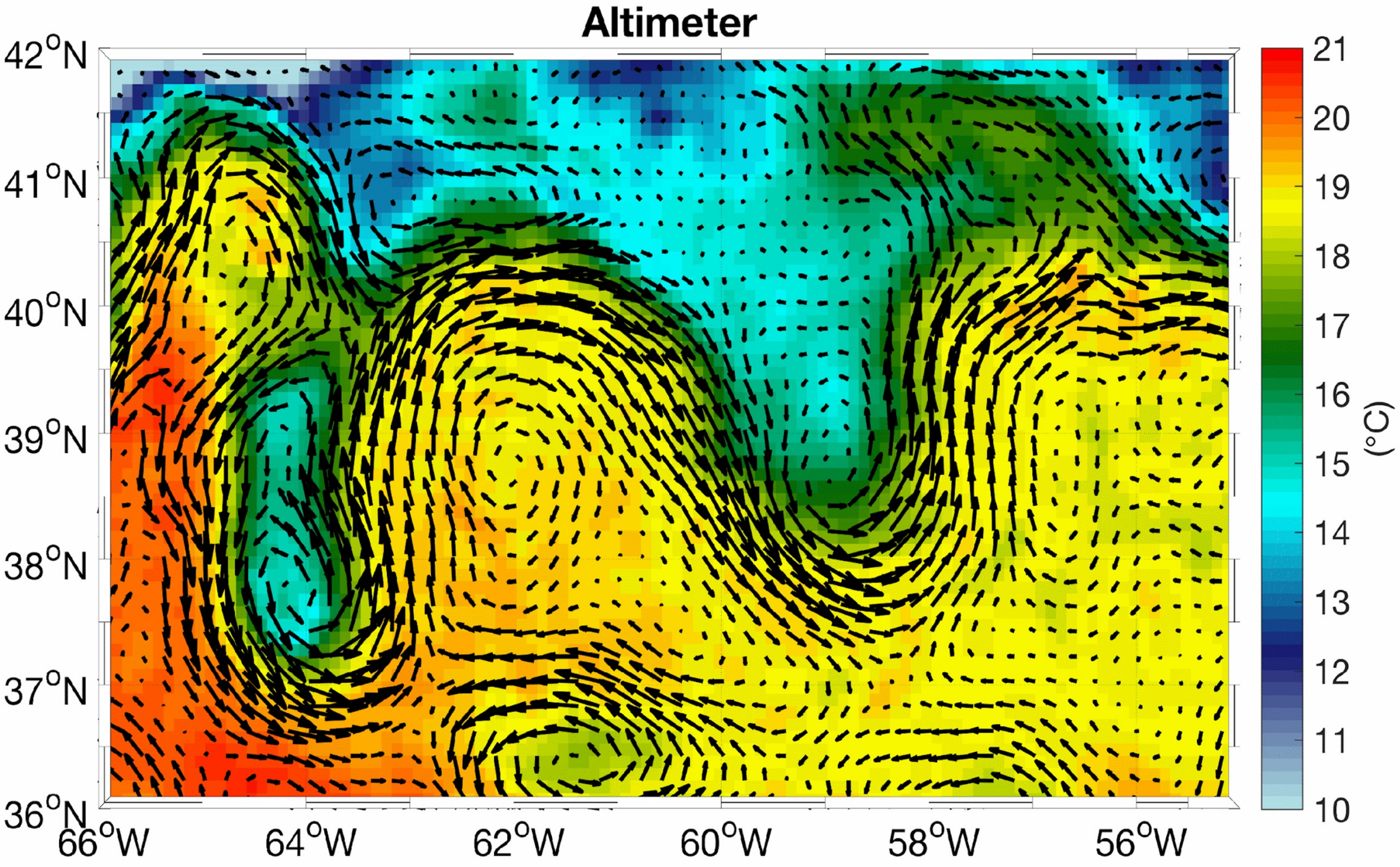
$$Q_t = \partial_t SST_{>1000km}$$

Fine-tuning for WOC Area

Results

WOC NATL 2D

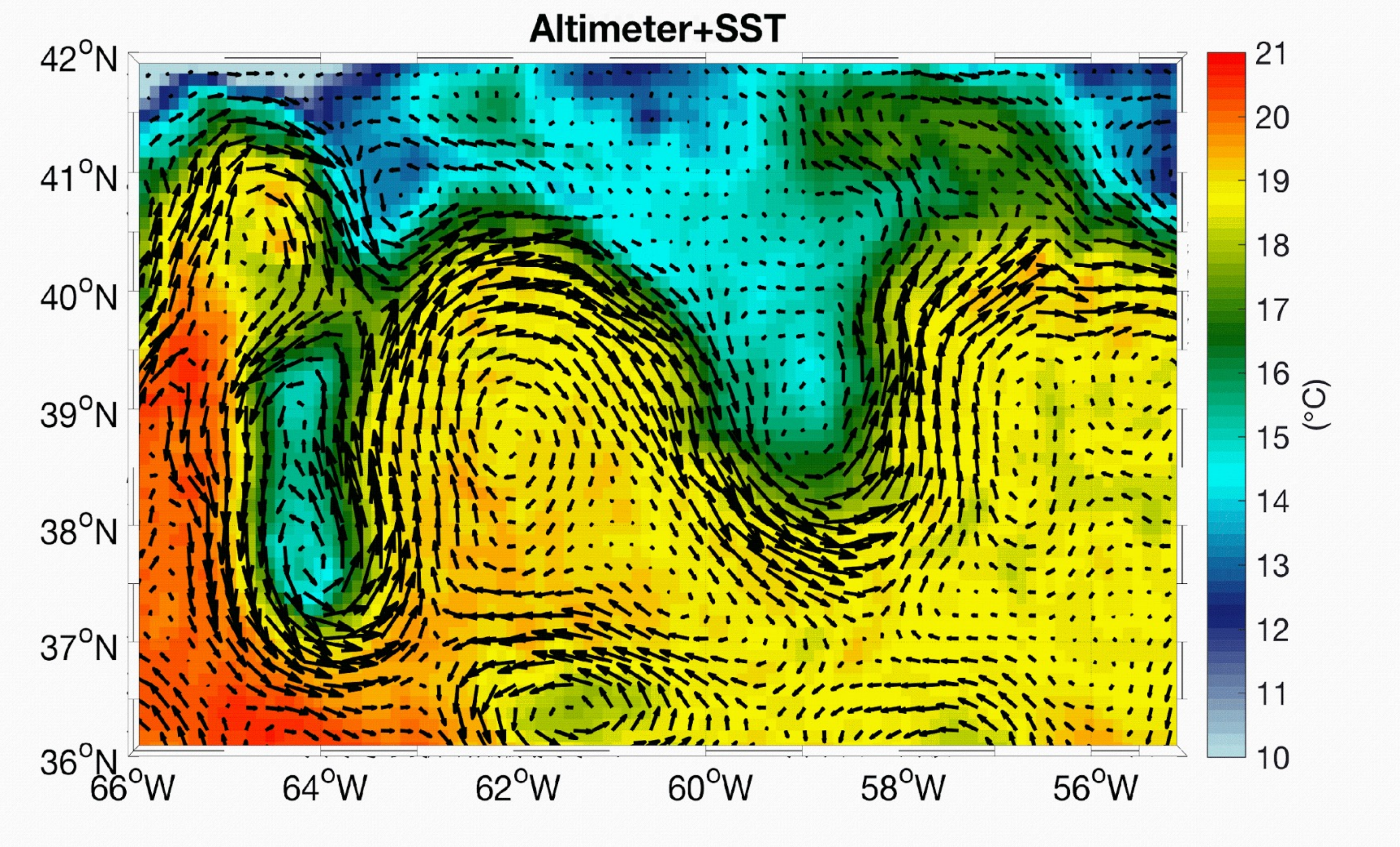
March 24th, 2015



HR SST gradients provide a constraint for the Altimeter geostrophic currents, yielding corrections mainly in **large SST gradient areas**

WOC NATL 2D

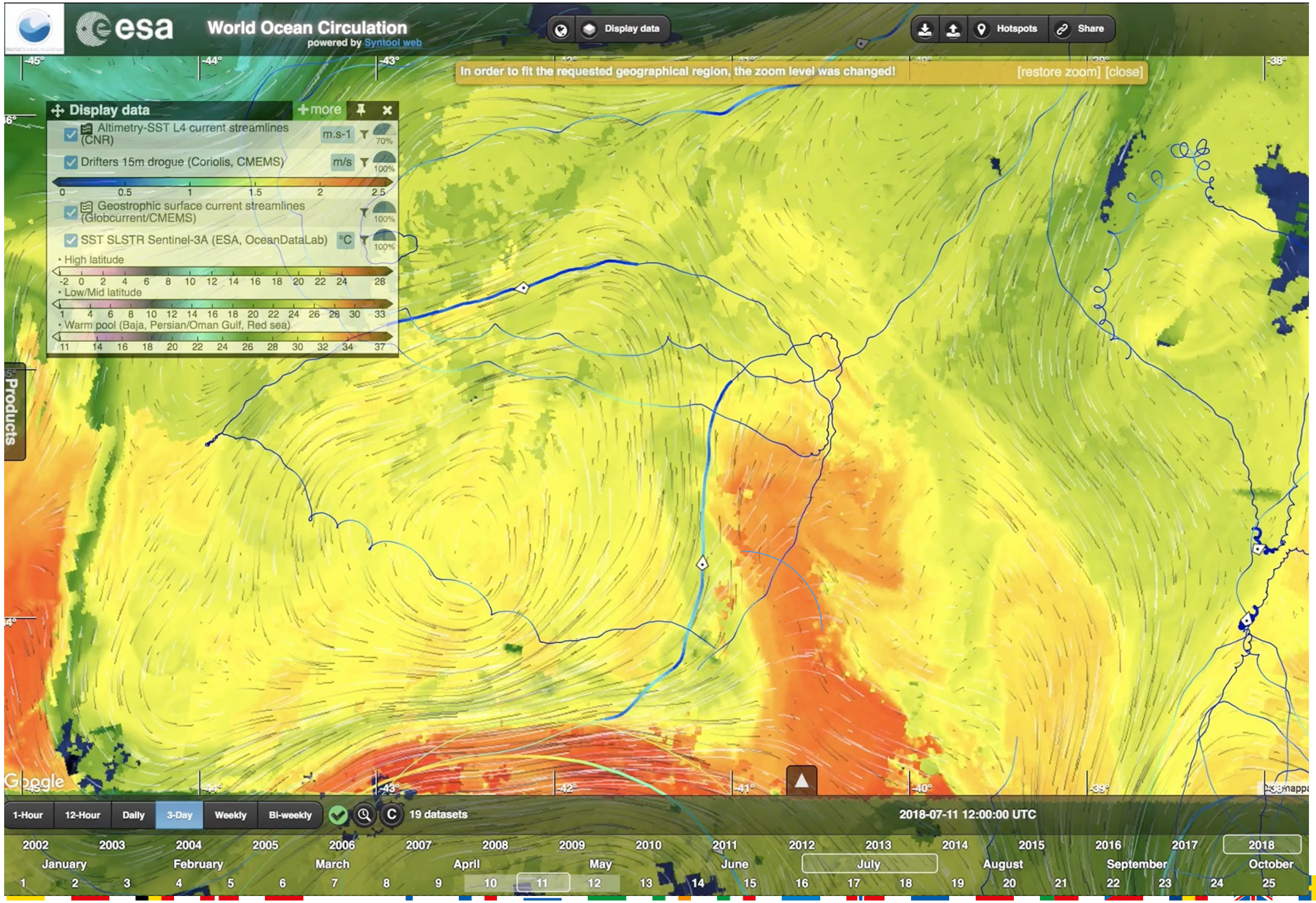
March 24th, 2015



HR SST gradients provide a constraint for the Altimeter geostrophic currents, yielding corrections mainly in **large SST gradient areas**

WOC NATL 2D

July 11th, 2018



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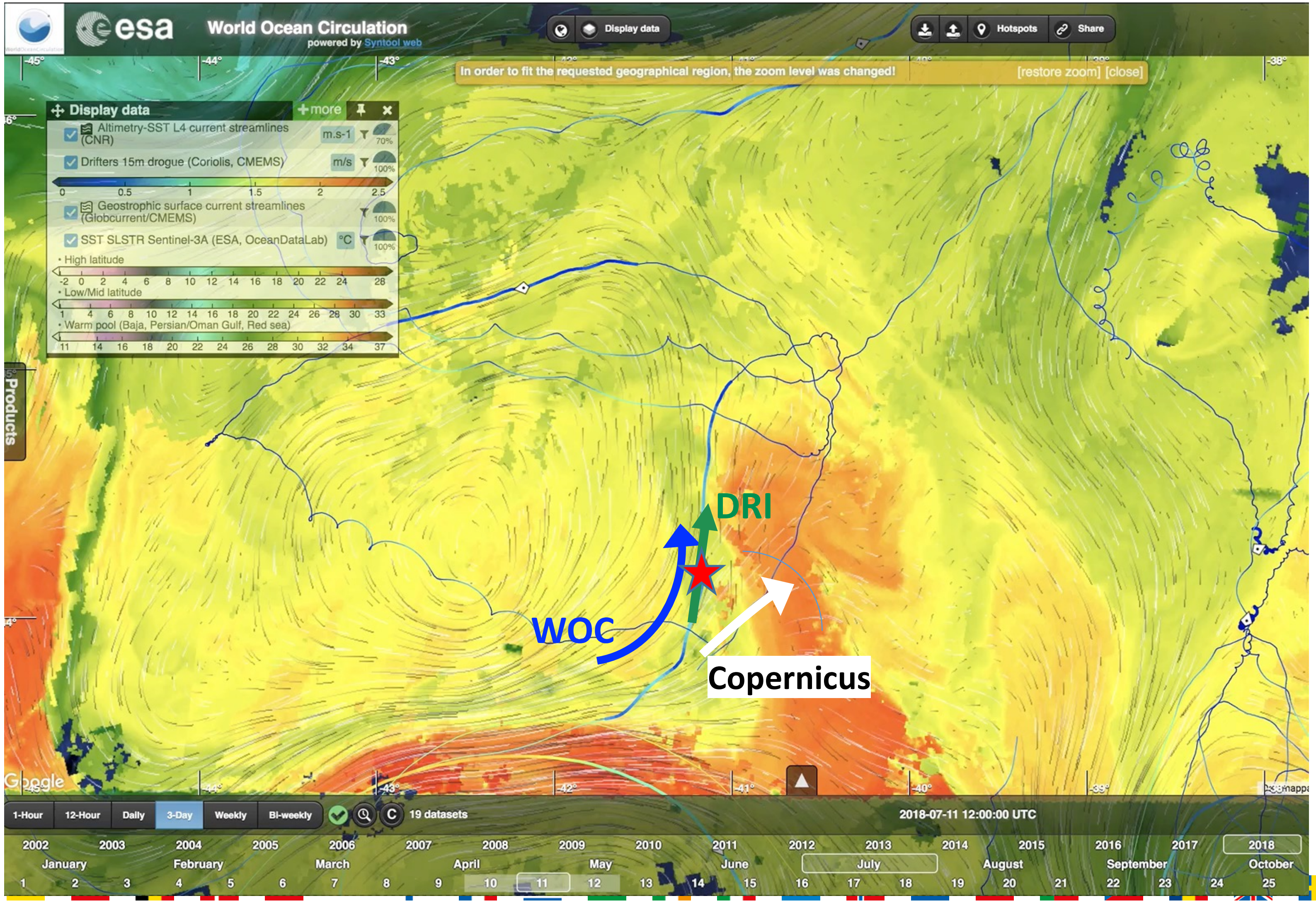
https://odl.bzh/ngvDR7bm

WOC NATL 2D

July 11th, 2018



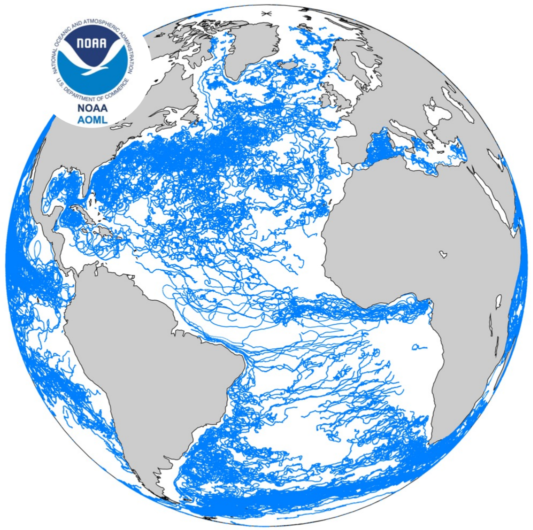
HR SST gradients provide a constraint for the Altimeter geostrophic currents, yielding corrections mainly in **large SST gradient areas**

https://odl.bzh/ngvDR7bm

WOC NATL 2D

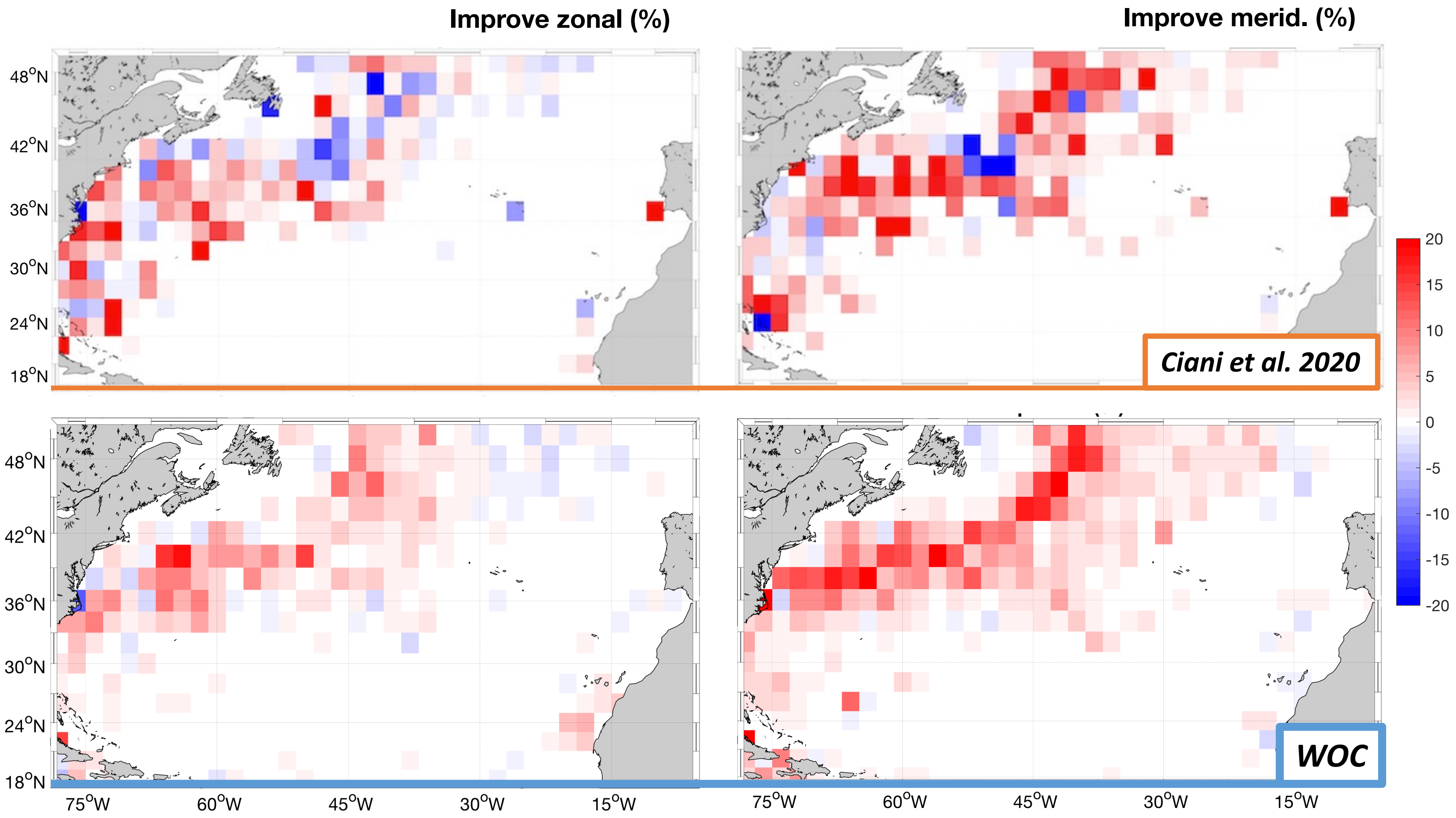
Comparison with previous OPTimized currents in the 2014-2016 period (Ciani et al. 2020)

Validation by means of drifting buoys – derived currents



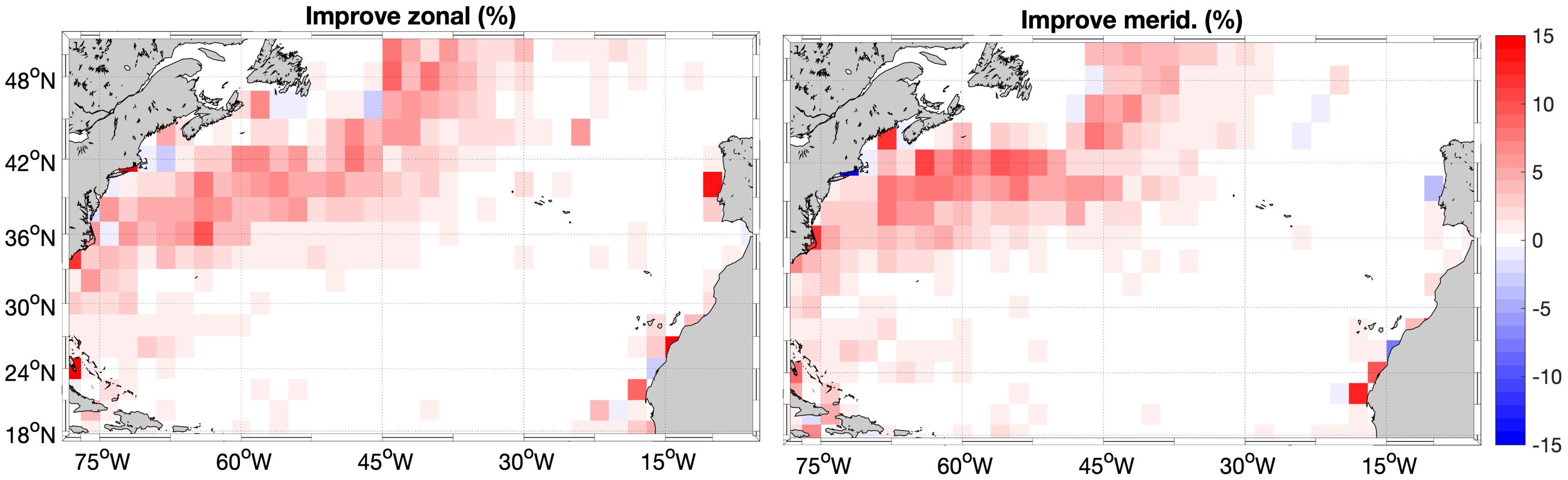
IMPROVEment computed in 2°x2° boxes

$$\mathrm{IMPROVE}_{(U,V)} = 100 \cdot \left[1 - \left(\frac{RMS^{OPT}_{(U,V)}}{RMS^{BCK}_{(U,V)}}\right)^2\right]$$



Improvements in WOC due to the new release of the OSTIA L4 SSTs and fine tuning on the forcing term

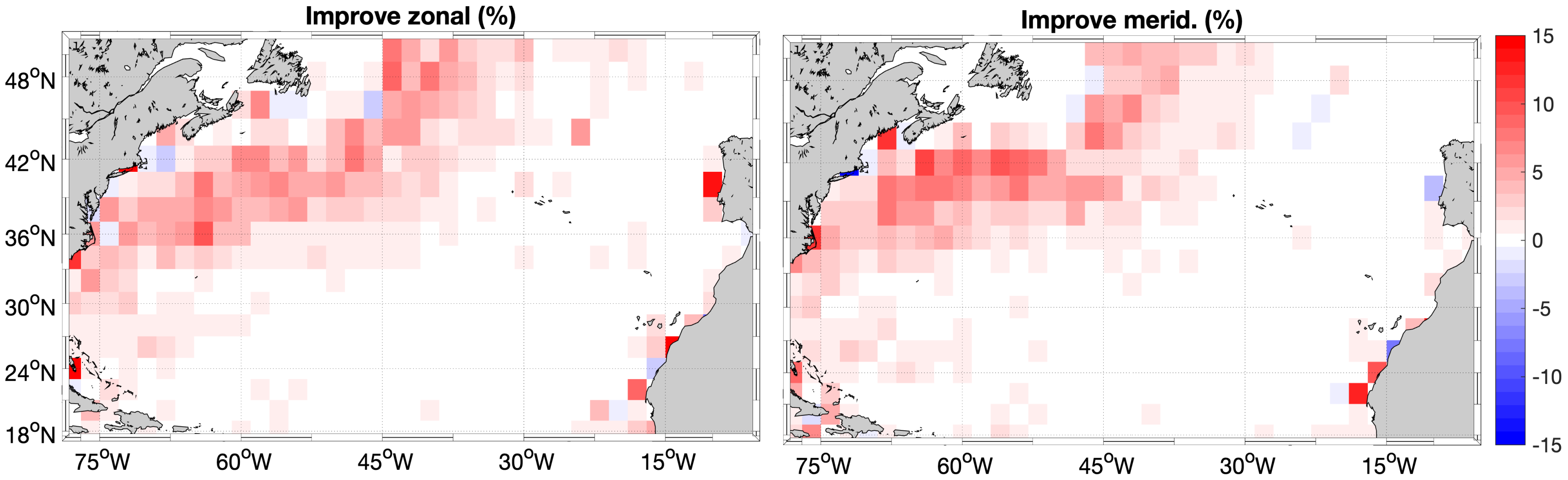
WOC NATL 2D



Percentage of improvement,
evaluated via comparison with
in-situ measured currents in 2010-2019

10 yrs validation confirms the behaviour
Found for the 2014-2016 case:

WOC NATL 2D



Percentage of improvement,
evaluated via comparison with
in-situ measured currents in 2010-2019

10 yrs validation confirms the behaviour
Found for the 2014-2016 case:

IMPROVEMENTS COVER ~70% of the basin
INTENSIFIED OVER LARGE SST GRADIENT AREAS

Concluding Remarks

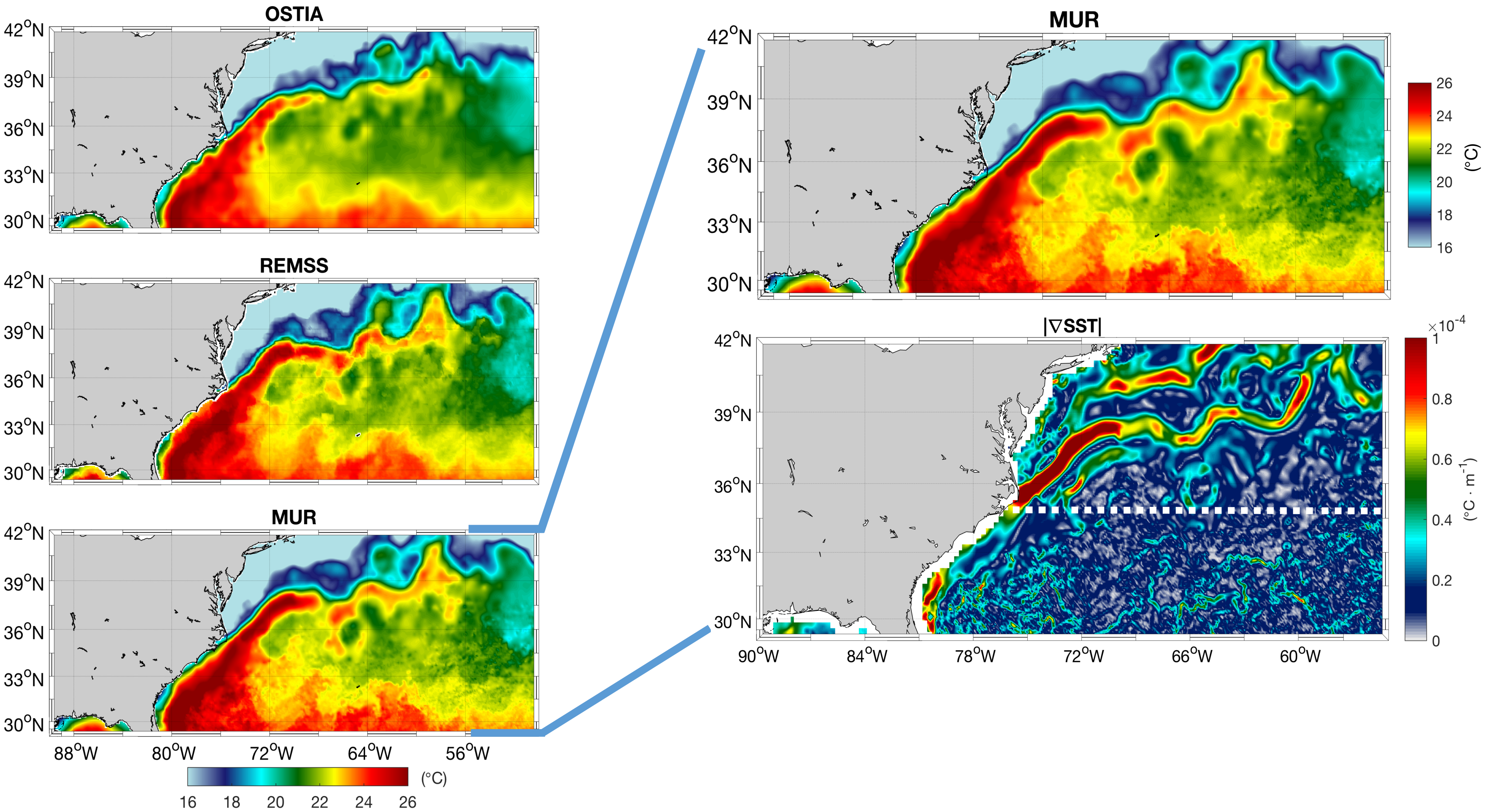
Concluding Remarks

WOC NATL2D product

- **2010-2019 – North Atlantic Region, available via the WOC Catalogue**
- **Correction of altimeter-derived geostrophic currents via dynamical information contained in higher resolution satellite-derived tracers--> spatial gradients, temporal derivatives**
- **Corrections are enhanced in large SST gradient areas (along the Gulf Stream Axis in our application)**
- 10 year long validation suggests an improvement by 15% of the Altimeter-derived currents (best performances for the meridional component of the surface currents)

Concluding Remarks & Perspectives

SST gradients are crucial for our synergetic reconstruction



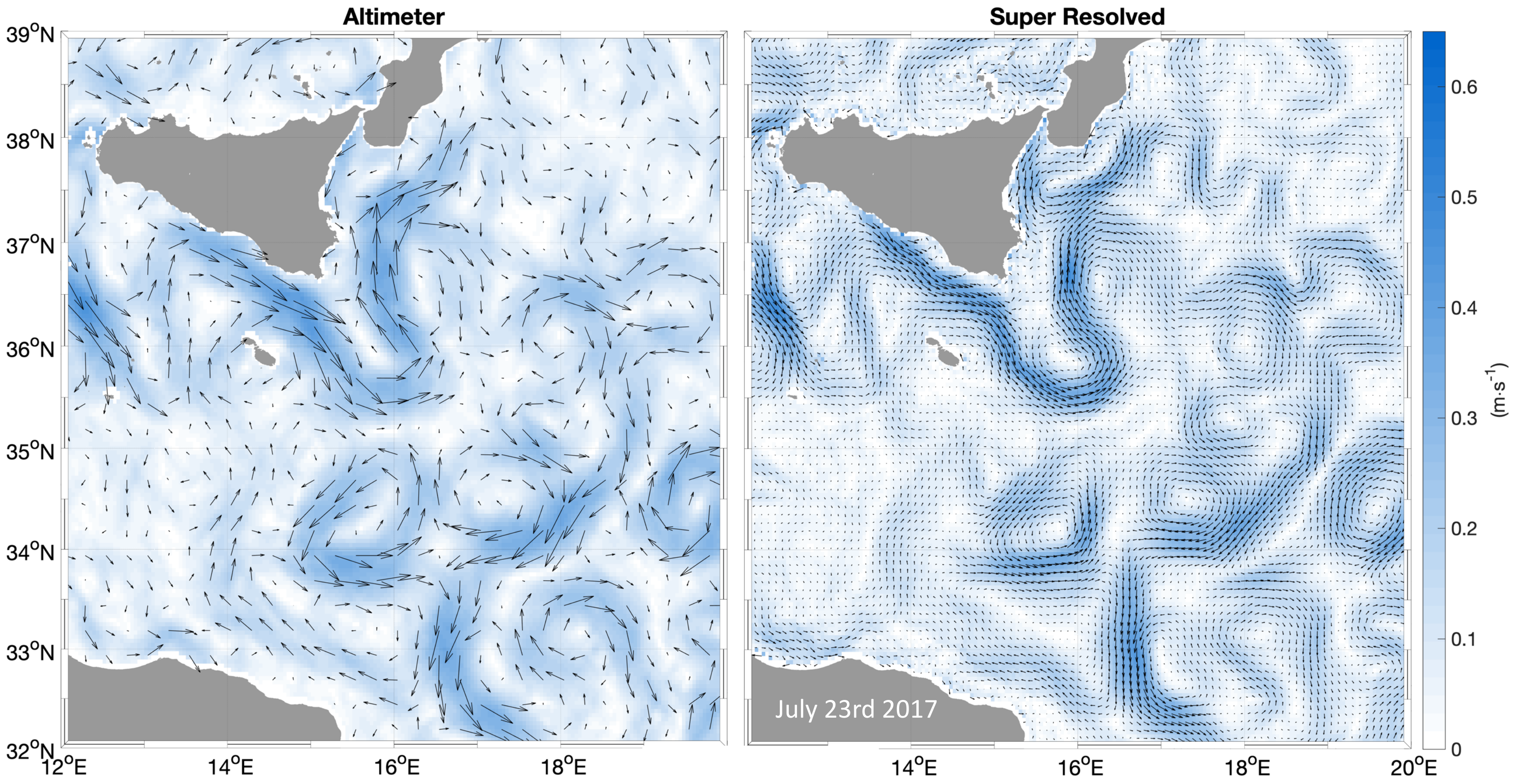
- **Build dynamically consistent and homogeneous L4 SST analyses** in order to improve the representation of SST gradients
- Issue reported and discussed within the GHRSST community
- BENEFITS EXPECTED FROM The ESA-CIMR satellite mission (Pearson et al. 2019)

Concluding Remarks & Perspectives

Test New Algorithms for the exploitation for Altimetry and SST synergy
(we are presently working on a Convolutional Neural Network Approach based on the ESA-CIRCOL inputs)

AIM:
Joint Prediction of surface currents and SST via CNN, learning an end to end mapping between LR and HR data (based on model data, applicable to future SWOT observations.)

Example of application to the Copernicus Satellite-derived Geostrophic currents →



Thank you!

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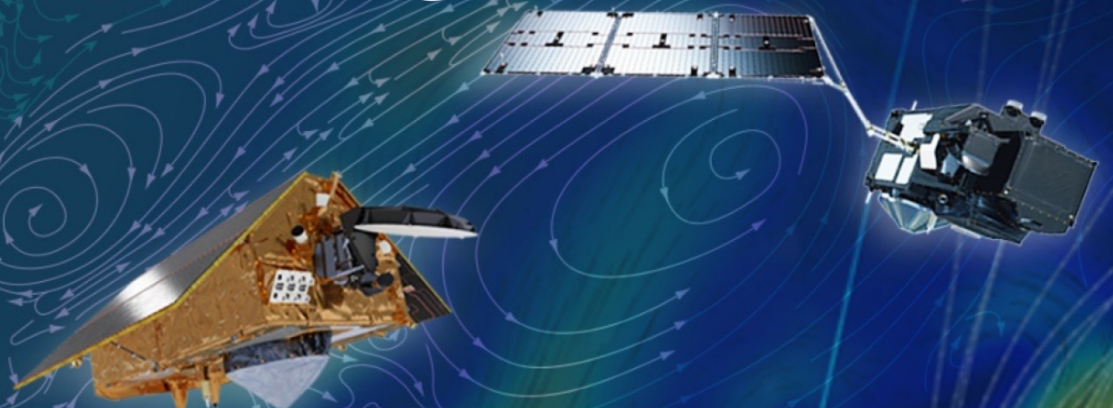

Thank you!

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remote sensing

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Deadline for manuscript submissions:
30 April 2023

Message from the Guest Editors

This Special Issue aims to publish studies covering different uses of remote sensing by describing and understanding the dynamical causes and mechanisms of ocean variability on different spatial (from local to global) and temporal (hourly to multi-decadal) scales. We welcome studies relying on single- to multi-variable approaches, combining in situ and remotely sensed data, capitalizing on recent advances in data-driven algorithms, and aiming at identifying the critical processes that need to be deepened and included in climate models. Papers with an interdisciplinary character that combine physical oceanography with other fields, ranging from atmosphere to biogeochemistry, from fisheries to ecology, from hazards to forecasting, are highly encouraged. Articles may address, but are not limited to, the following topics: