GHRSST
GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

On the use of Sea Surface Temperature (SST) for improving the altimeter derived surface currents: a sensitivity study to SST products

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esa
ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile
CLS

Context

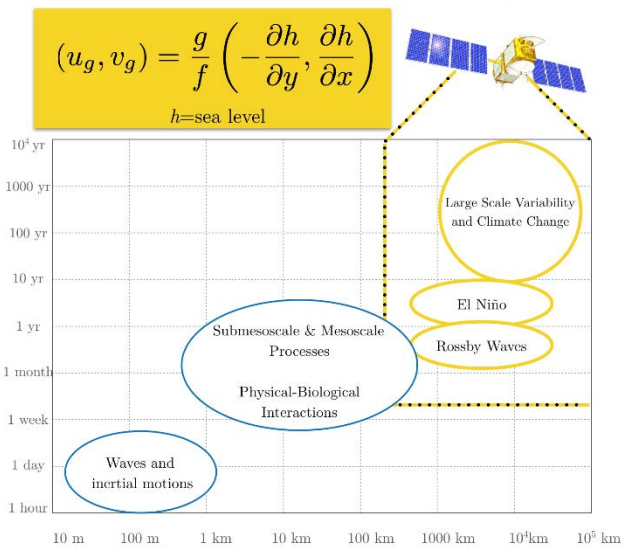
Satellite Altimetry: synoptic monitoring of the sea-surface currents at operational level

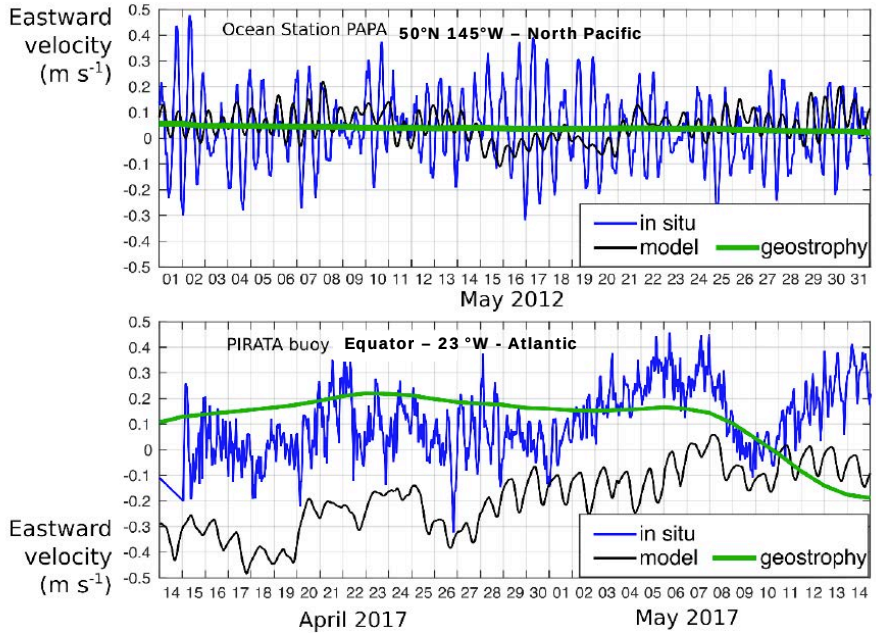
Only the geostrophic component ($\mathbf{u_g}$,$\mathbf{v_g}$) of the sea-surface motion is obtained:
incomplete description of the sea surface circulation

A FACT…

$$(u_g, v_g) = \frac{g}{f}\left(-\frac{\partial h}{\partial y}, \frac{\partial h}{\partial x}\right)$$

h=sea level





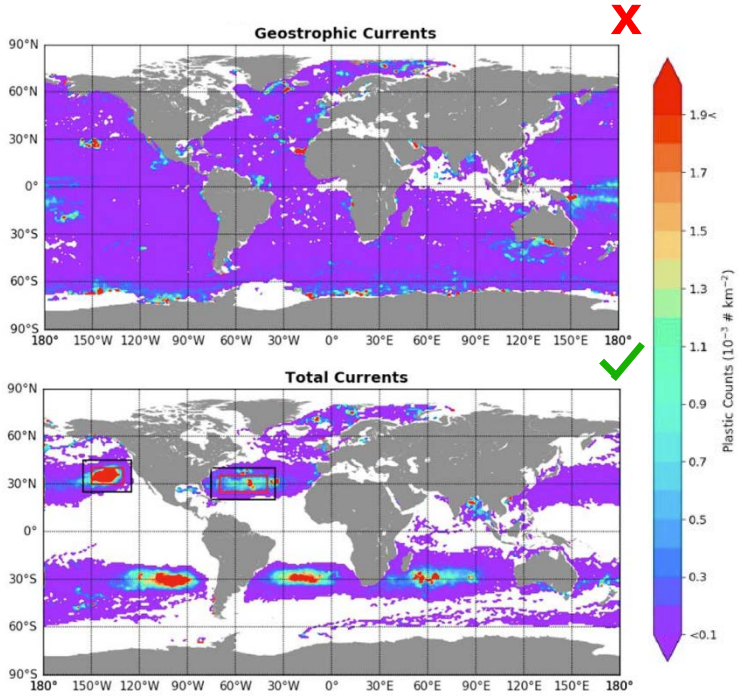
The **total surface currents** are not in **geostrophic** balance

(from ESA EE9 UCM, Cambrige, July 2019)

Context

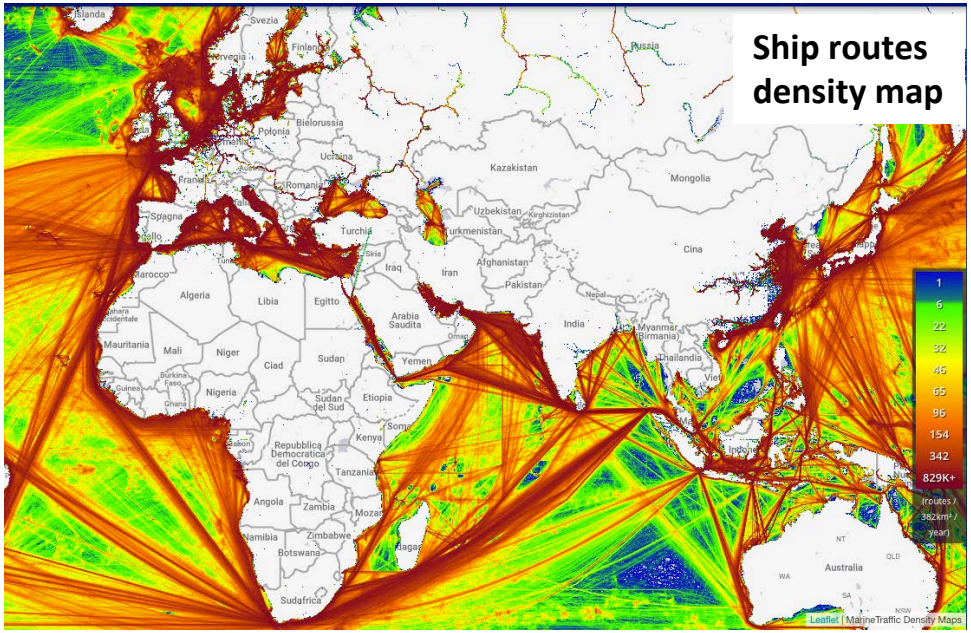
Satellite Altimetry: synoptic monitoring of the sea-surface currents at operational level

Only the geostrophic component of the sea-surface motion is obtained: incomplete description of the Sea surface circulation



12 yrs run: the geostrophic currents are unable to **describe the observed floating pollutants distributions** in the global ocean: **we need the total currents** (Onink et al. 2019)

SOME APPLICATIONS…



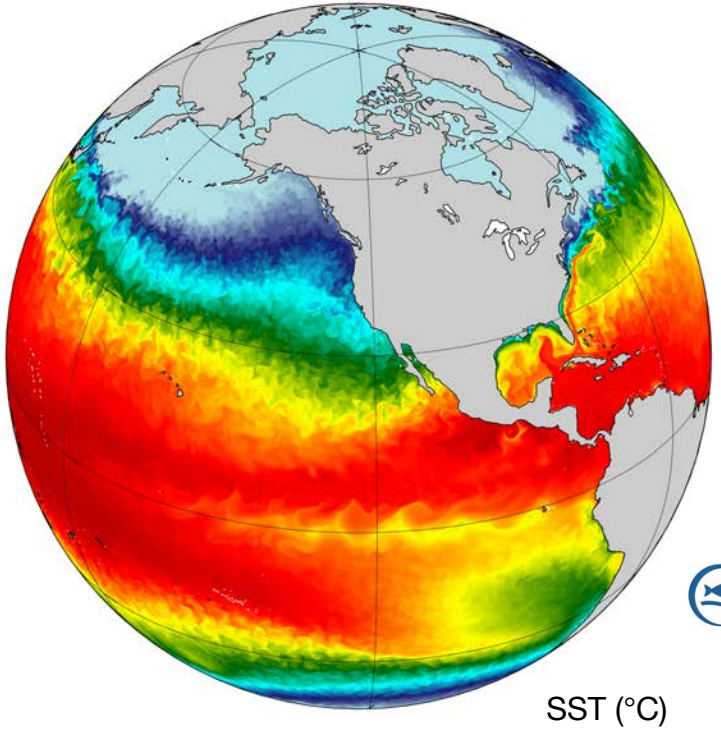
The **total surface currents are essential for safe navigation Search&Rescue activities**

Context

Satellite Altimetry: synoptic monitoring of the sea-surface currents at operational level

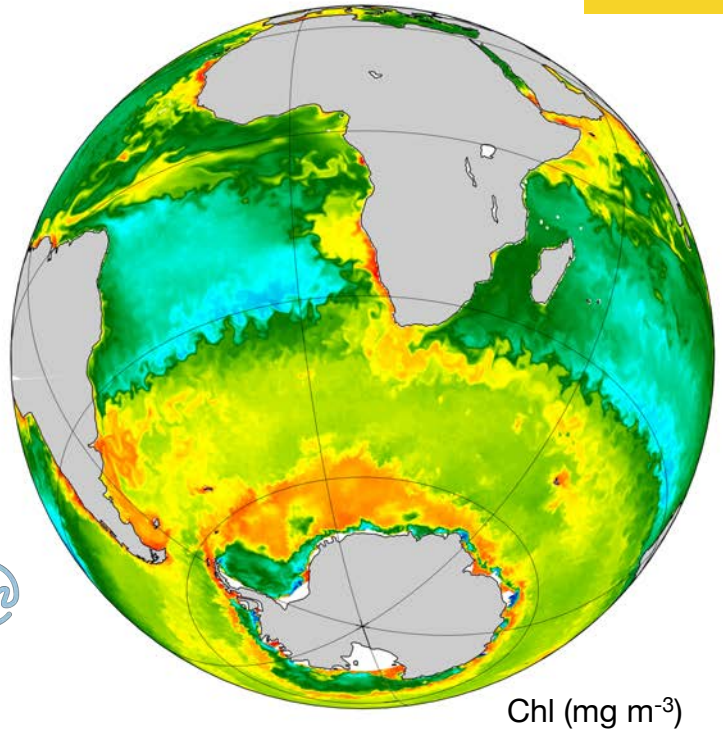
Dynamical information can be inferred from independent observations (High-resolution tracers)

A SOLUTION ?



SST (°C)

5 10 15 20 25 30



Chl (mg m^{-3})

0.01 0.1 1 5

New methodologies have to be explored. We rely on patterns of a high-resolution surface oceanic tracers (SST in our study)

Methods and Data

Methods and Data

Past Achievements: Synergies between SSH and SST data - The Piterbarg 2009 (PIT09) Method

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

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

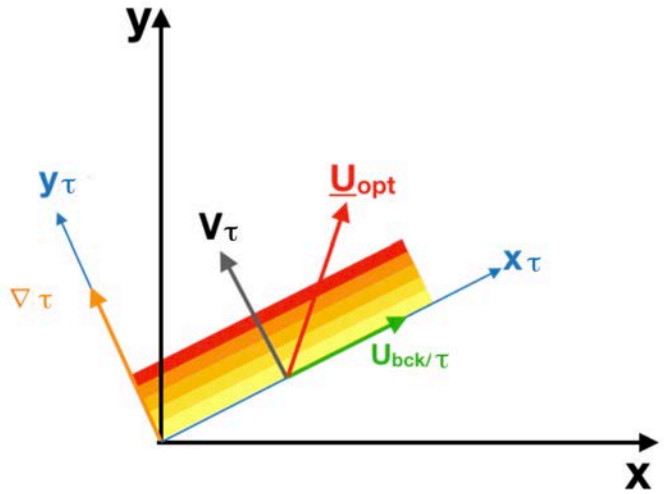
F= source and sink terms

Piterbarg et al. 2009, Mercatini et al. 2010: Use a **background velocity** information (geostrophy) **(u_{geo}, v_{geo})** so that the **satellite tracer information is used to obtain an optimized merged velocity: OPtimal Currents - OPC (u_{opc}, v_{opc})**

$$u_{opc} = u_{geo} - \frac{A(Au_{geo} + Bv_{geo} + E)}{A^2 + B^2} = u_{geo} + u_{CORR}$$

$$v_{opc} = v_{geo} - \frac{B(Au_{geo} + Bv_{geo} + E)}{A^2 + B^2} = v_{geo} + v_{CORR}$$

$$\mathbf{A} = \partial_x \tau \quad \mathbf{B} = \partial_y \tau \quad \mathbf{E} = \partial_t \tau - F$$



τ = SST in our study

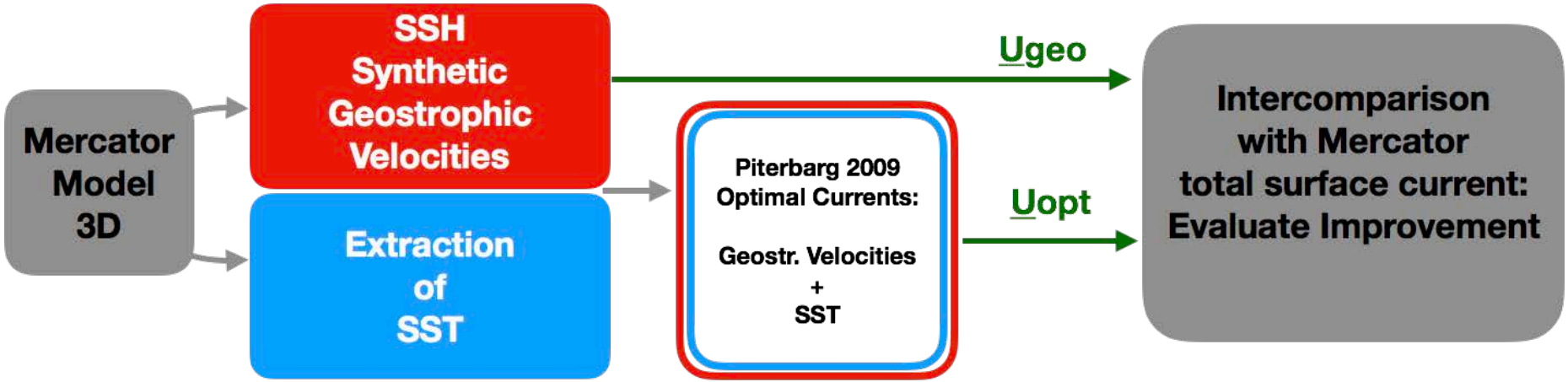
Methods and Data

Past Achievements: Synergies between SSH and SST data - The Piterbarg 2009 (PIT09) Method

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

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

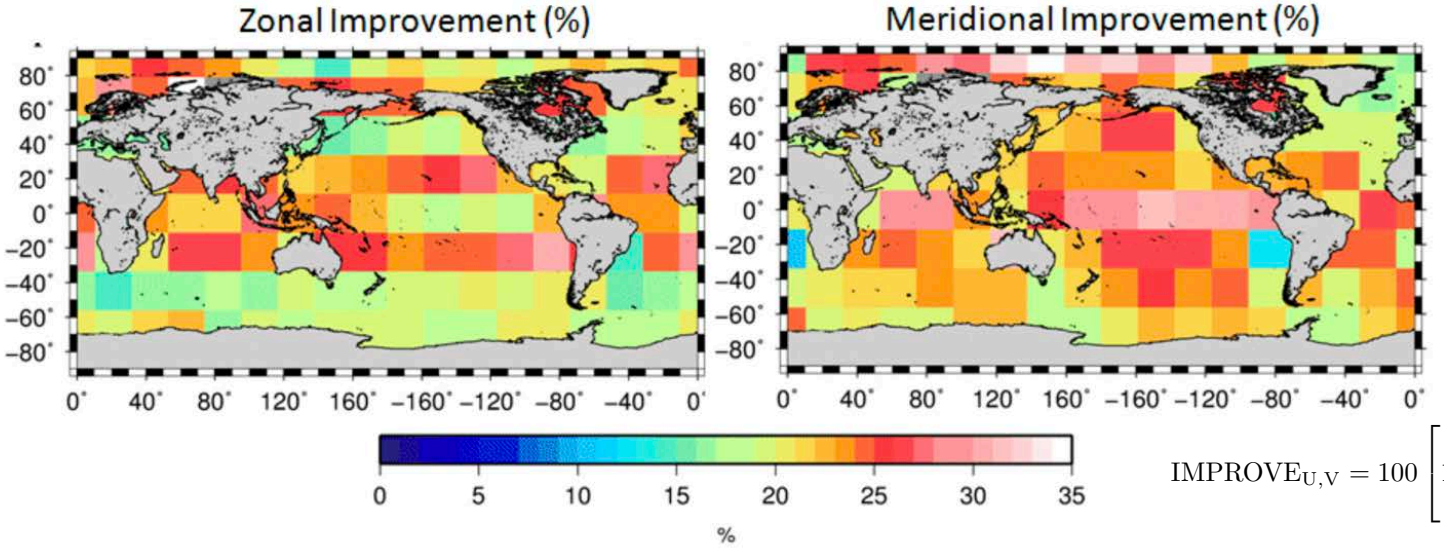
Rio et al 2016 (RS16): Implementing the PIT09 method in an **Observing System Simulation Experiment (OSSE)**



Methods and Data

Past Achievements: Synergies between SSH and SST data - The Piterbarg 2009 (PIT09) Method

Results from **Observing System Experiment (OSSE):** the Altimeter-derived currents were improved up to 35%



$$\mathrm{IMPROVE}_{\mathrm{U,V}} = 100\left[1 - \left(\frac{\mathrm{RMSE}^{\mathrm{OPC}}_{\mathrm{U,V}}}{\mathrm{RMSE}^{\mathrm{GEO}}_{\mathrm{U,V}}}\right)^2\right]$$

- **Rio et al 2016 (RS16)**: successful application to global scale SST and altimeter-derived currents in a numerical experiment ;
- Guideline for application to satellite-derived dataset: Forcing term ~ satellite derived $\partial_t \mathrm{SST}$;
- Successful implementation demonstrated by **Rio and Santoleri 2018** (**RS18**) but the zonal flow in the southern ocean is degraded with respect to the altimeter-estimates!

Methods and Data

Application of PIT09 and RS18 methods to satellite Derived Data (2014-2016)

- DUACS-18 Geostrophic Velocities: 2 Satellites (2SAT) configuration
  Prod: CLS dx=1/4° dt=daily
- DUACS-18 Geostrophic Velocities: 4 SAT configuration
  Prod: CLS dx=1/4° dt=daily

Geostrophic currents

- REMSS L4 Sea-surface temperature (merged MW+IR product)
  Prod: REMSS dx=1/10° dt=daily

- OSTIA L4 Sea-surface temperature
  Prod: Met Office dx=1/20° dt=daily

+

- Multi-Scale UHR (MUR) L4 Sea-surface temperature
  Prod: Nasa JPL dx=1/100° dt=daily

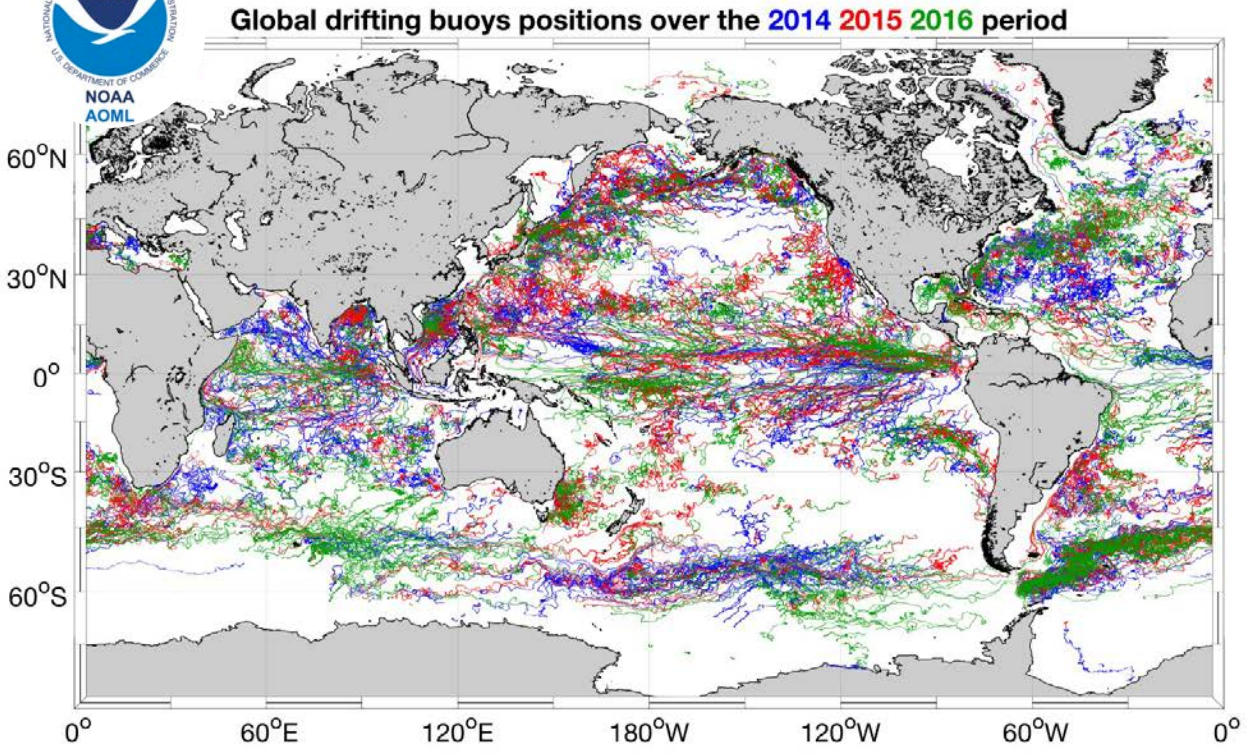
Sea-surface Temperature

Comparative Study

Methods and Data

Application of PIT09 and RS18 methods to satellite Derived Data (2014-2016)

In-situ measured currents from the NOAA-AOML Surface Drifters Data Assembly Center



Obs. distribution

2014	2015	2016
38%	31%	31%

Used for Validation of the Optimal Currents

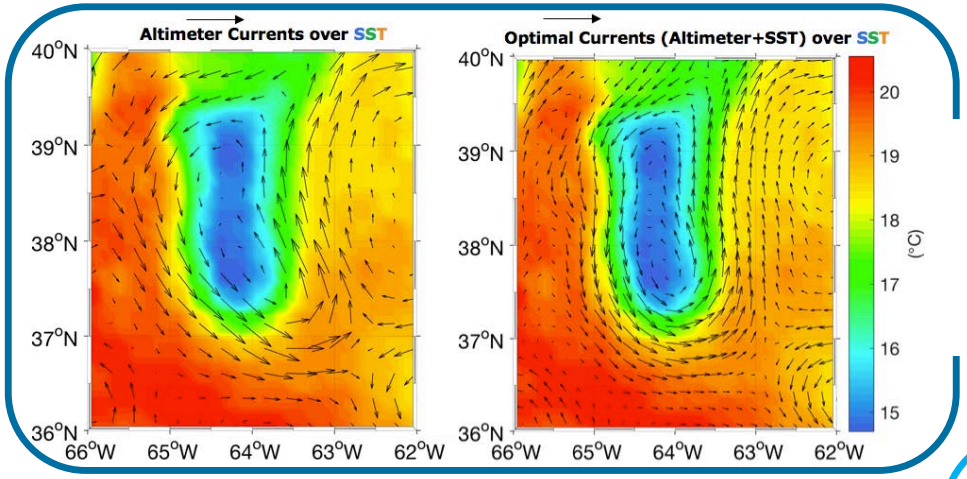
Metrics: RMSD, % of improvement ($IMPROVE_{(U,V)}$)

$$\mathrm{IMPROVE}_{\mathrm{U,V}} = 100\left[1 - \left(\frac{\mathrm{RMSE}^{\mathrm{OPC}}_{\mathrm{U,V}}}{\mathrm{RMSE}^{\mathrm{GEO}}_{\mathrm{U,V}}}\right)^2\right]$$

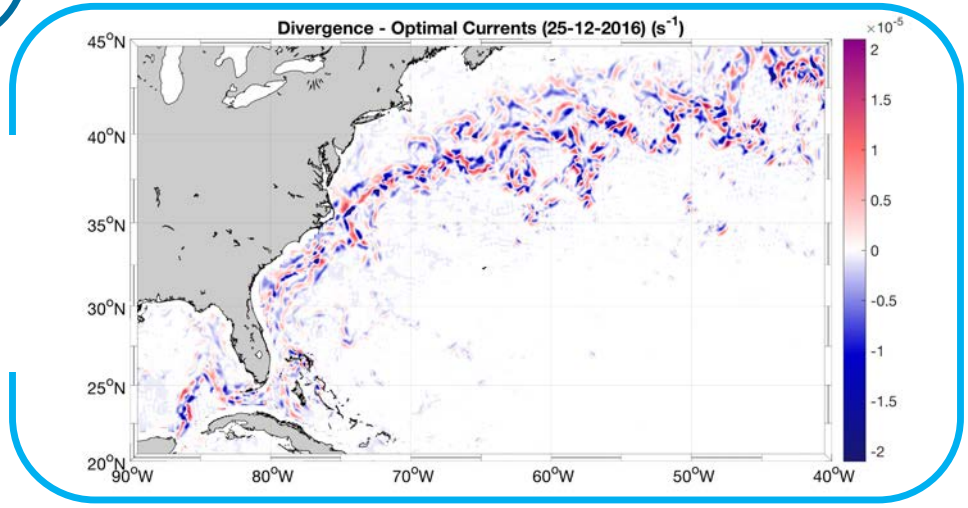
Results

Results

Qualitative Comparisons in the Gulf Stream Area (DUACS + REMSS SST)



Correction of
Cross SST gradient
Circulation components

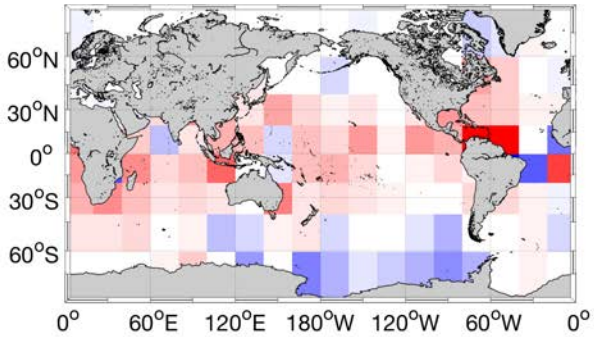


Divergence/convergence patterns become evident in large SST gradient areas

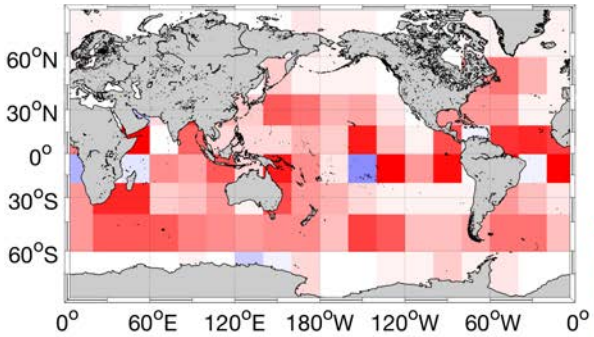
Results

2014-2016 - %Improvement (validation against in-situ measured currents) – REMSS in agreement with RS18

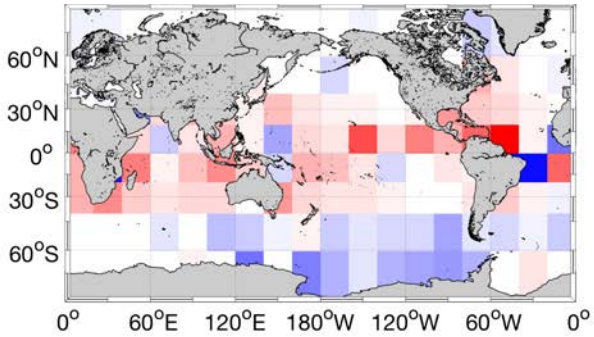
Zonal – 2sat



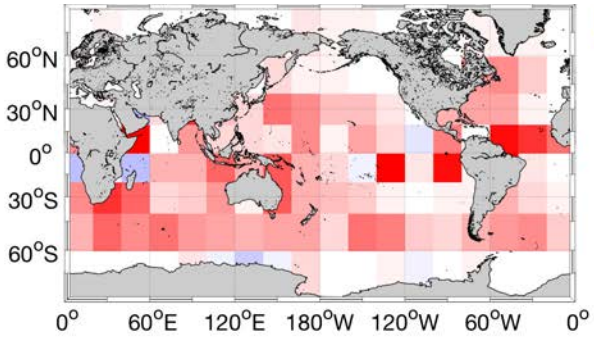
Meridional – 2sat

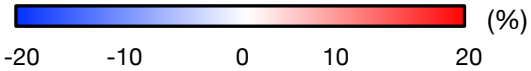


Zonal – 4sat



Meridional – 4sat





$$\mathrm{IMPROVE}_{\mathrm{U,V}} = 100\left[1 - \left(\frac{\mathrm{RMSE}^{\mathrm{OPC}}_{\mathrm{U,V}}}{\mathrm{RMSE}^{\mathrm{GEO}}_{\mathrm{U,V}}}\right)^2\right]$$

REMSS SST

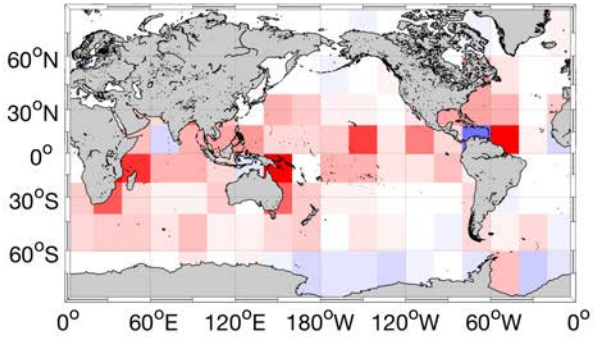
Local improvements up to 24 % at global scale (also confirmed by dedicated studies in the Mediterranean Sea):

- **Larger for 2SAT case and for meridional flow**
- **Degradation in the Southern Ocean…can this be solved?**

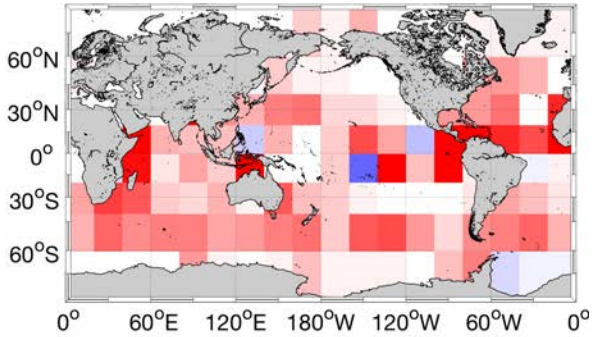
Results

2014-2016 - %Improvement (validation against in-situ measured currents) – OSTIA

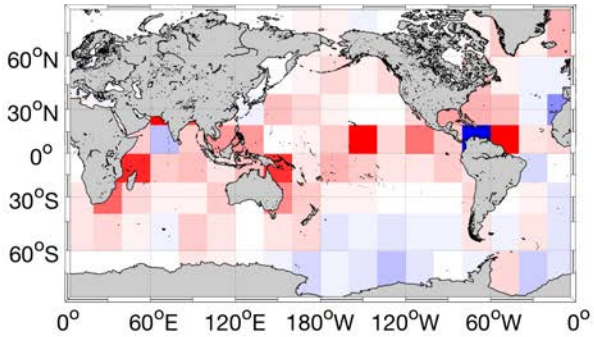
Zonal – 2sat



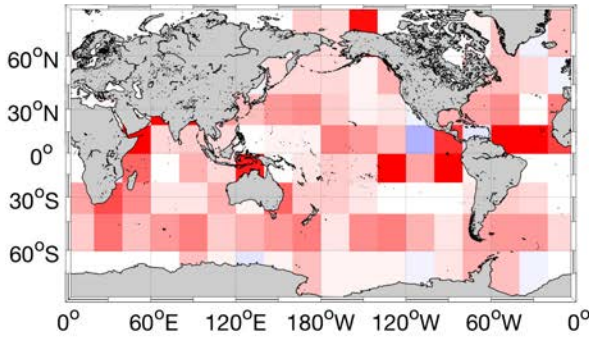
Meridional – 2sat

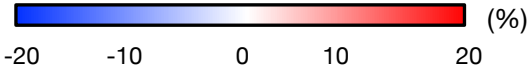


Zonal – 4sat



Meridional – 4sat





$$\mathrm{IMPROVE}_{\mathrm{U,V}} = 100\left[1 - \left(\frac{\mathrm{RMSE}^{\mathrm{OPC}}_{\mathrm{U,V}}}{\mathrm{RMSE}^{\mathrm{GEO}}_{\mathrm{U,V}}}\right)^2\right]$$

OSTIA SST

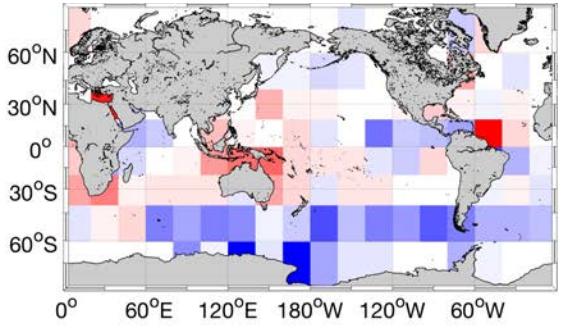
Overall: slightly reduced improvements compared to the REMSS case

- **Larger for 2SAT case and for meridional flow**
- **<u>Degradation in the Southern Ocean is reduced!</u>**

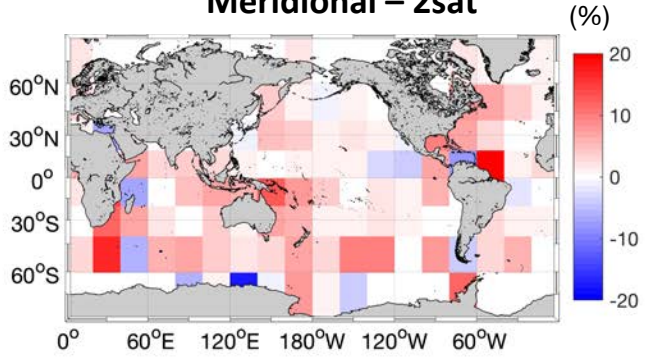
Results

2014-2016 - %Improvement (validation against in-situ measured currents) – MUR

Zonal – 2sat



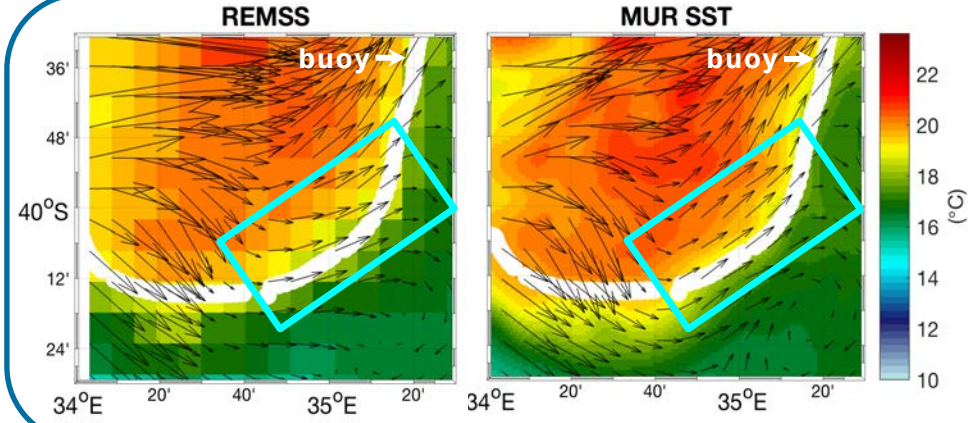
Meridional – 2sat



$$\mathrm{IMPROVE}_{U,V} = 100\left[1 - \left(\frac{\mathrm{RMSE}^{OPC}_{U,V}}{\mathrm{RMSE}^{GEO}_{U,V}}\right)^2\right]$$

MUR SST

issues in global scale optimal currents reconstruction but… Interesting benefits for local applications

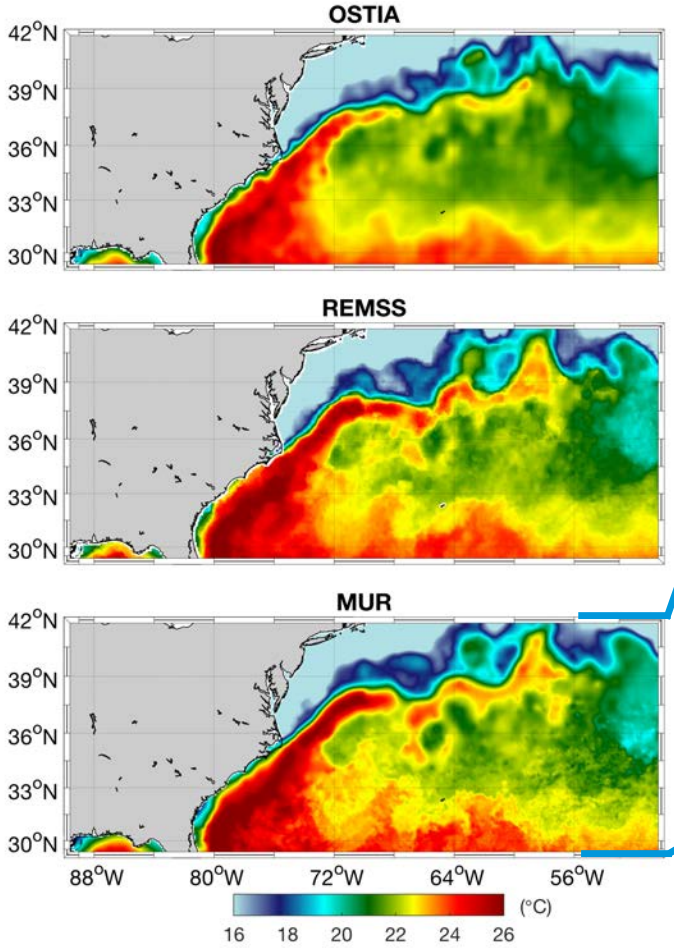


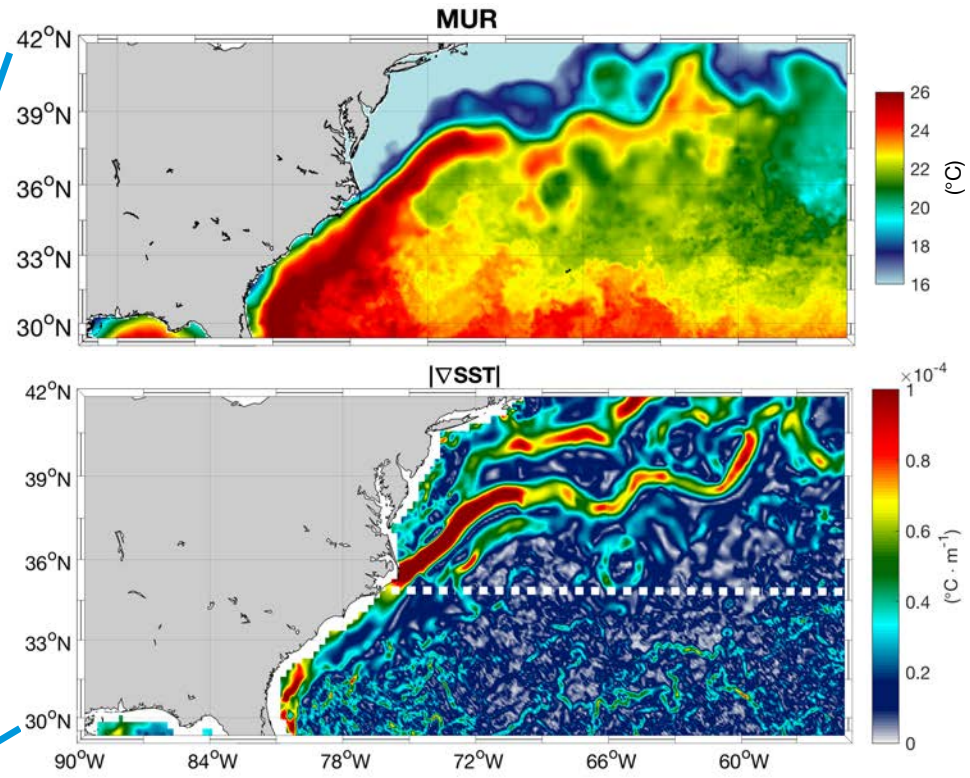
REMSS vs MUR SST
(higher effective resolution SSTs in our study)

Optimal currents compared with a Lagrangian buoy trajectory, March 24th 2015. <u>In this local application, MUR yields the best performances</u>

Results

A close check at the SST data (2016-01-01) – Gulf Stream





MUR: Inhomogeneities in the effective spatial resolution

Conclusions and Perspectives

Conclusions

- GENERAL: Optimal reconstruction exhibits **better performances** in retrieving the **meridional** component of the motion, in the **equatorial band** and in correspondence of the **major currents.** The synergistic surface currents are **also exhibit non-zero divergences;**

- Optimal reconstruction based on the DUACS-18 background currents: **better overall performances using the REMSS SST** in stronger SST gradient areas;

- **OSTIA**, very good global performances and **complementarities with the REMSS SST** for the optimal currents in the Southern Ocean
  MUR SST: issue for the surface currents reconstruction at global scale but suitable for local fine-scale applications;

- SST data quality at high latitudes is crucial! Expected improvements with the all-weather capabilities of the **Copernicus Imaging Microwave Radiometer (CIMR) mission (2026+ timeframe)**

- **Spatial Spectral Homogeneity in the SST data is crucial for the currents reconstruction**;

- Application with high Operational Potential

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Thank you and stay safe!

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