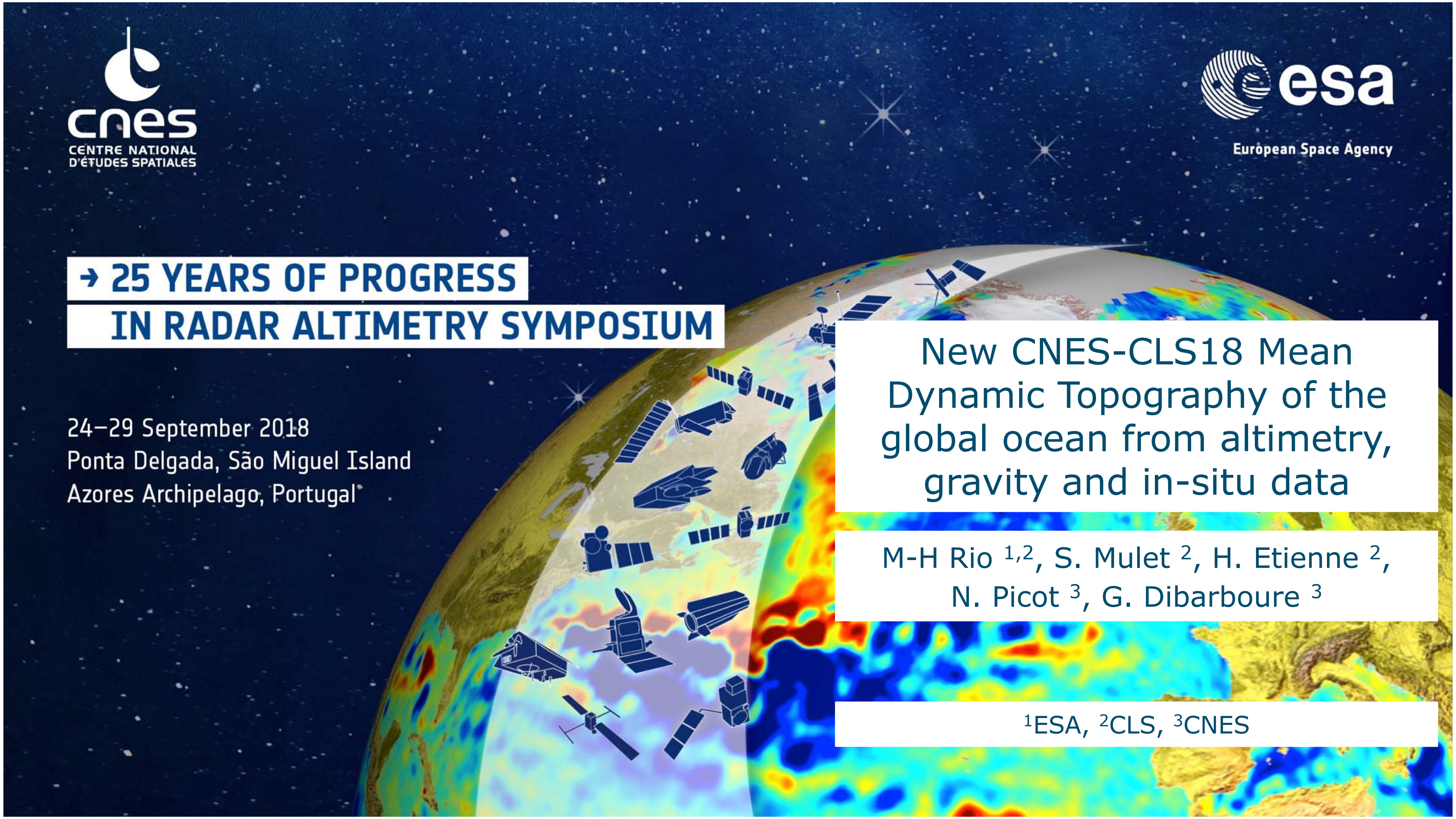


New CNES-CLS18 Mean Dynamic Topography of the global ocean from altimetry, gravity and in-situ data

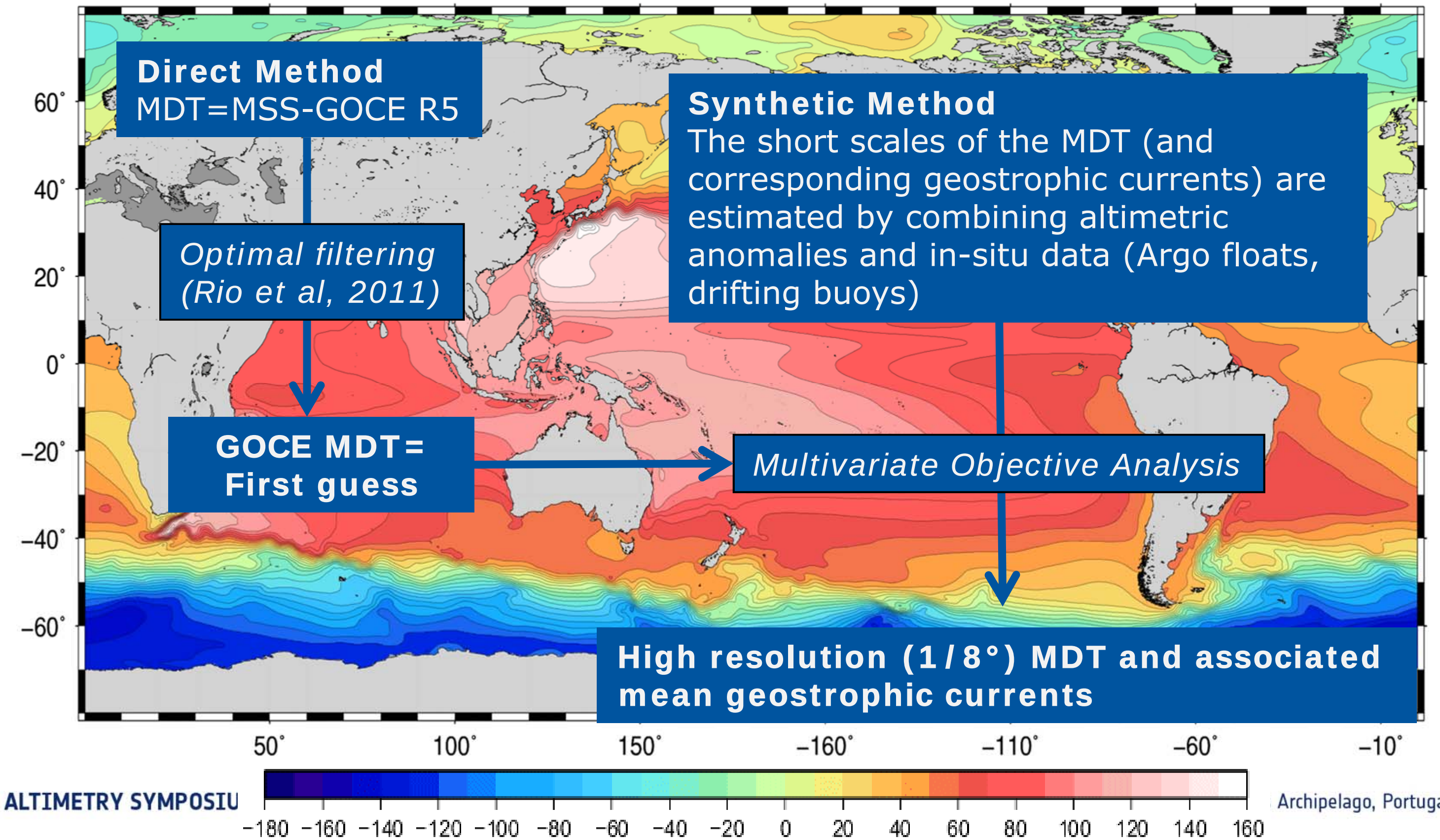
M-H Rio [1,2], S. Mulet [2], H. Etienne [2], N. Picot [3], G. Dibarboure [3]

[1]ESA, [2]CLS, [3]CNES

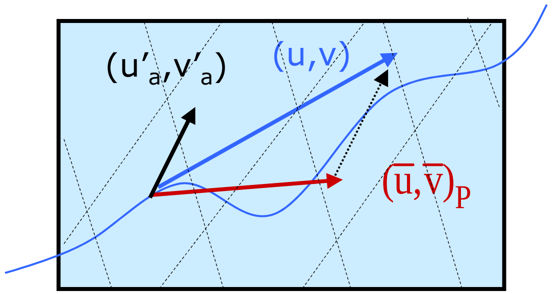
METHOD

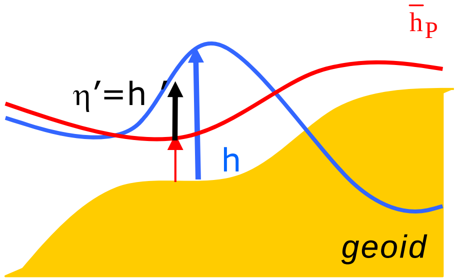
CNES-CLS15 MSS – GOCO05S, optimally filtered

Rio and Hernandez, 2004; Rio et al, 2005, 2011, 2014



Computation of mean heights and mean geostrophic velocities





At each position r and time t for which an oceanographic in-situ measurement is available: dynamic height h (r,t) or surface velocity u(r,t),v(r,t)

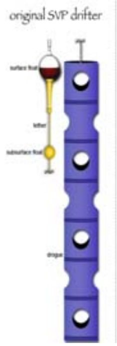
- the in-situ data is processed to match the physical content of the altimetric measurement.

- the altimetric height/velocity anomaly is interpolated to the position/date of the in-situ data.

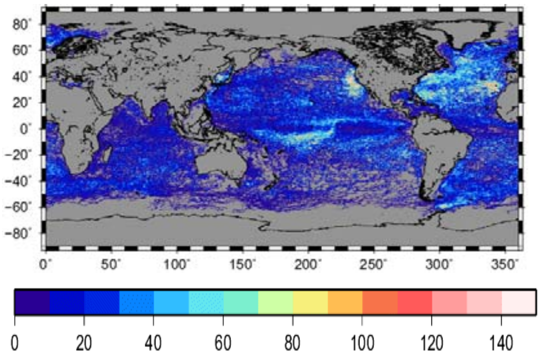
- the altimetric anomaly is subtracted from the in-situ height/velocity

$$\overline{h}_P = h_{insitu} - h'_P \qquad \overline{u}_P = u_{insitu} - u'_P \qquad \overline{v}_P = v_{insitu} - v'_P$$

Oceanographic in-situ measurements 1993-2016

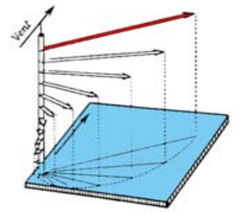


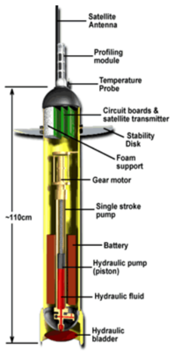
Number of SVP-type velocities (15m depth)



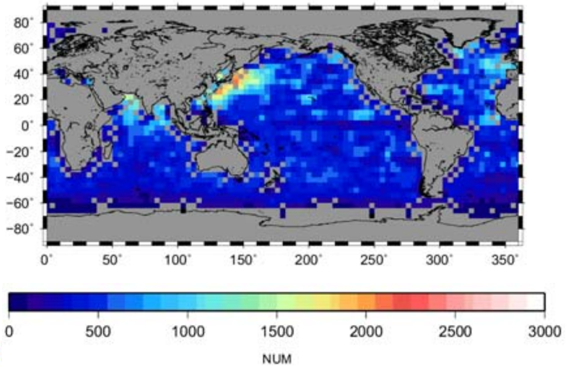
$$U_{buoy} = \boxed{U_{geost}} + U_{ekman} + U_{tides} + U_{inertial} + U_{stokes} + U_{ageost\_hf}$$

- ➢Modelization of Ekman/Stokes currents
- ➢Low pass filtering





Number of Argo floats (T/S profiles and surface velocities)



Dynamic Height relative to a reference depth Pref -> baroclinic component of the geostrophic current

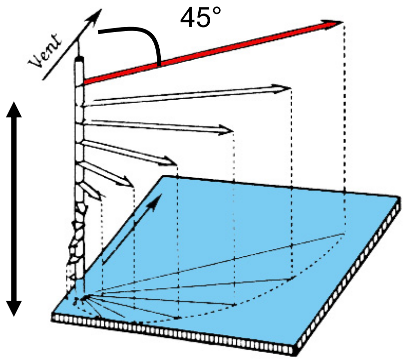
- ➢Processing is needed to add the missing barotropic and deep baroclinic component

Modeling Wind driven Currents (Ekman+Stokes)

$$u_e = \pm \frac{\pi\sqrt{2}}{\rho(f+w)D_e} e^{\frac{\pi}{D_e}z} * \tau_e * \cos\left(\frac{\pi}{4} + \frac{\pi}{D_e}z\right)$$

$$v_e = \frac{\pi\sqrt{2}}{\rho(f+w)D_e} e^{\frac{\pi}{D_e}z} * \tau_e * \sin\left(\frac{\pi}{4} + \frac{\pi}{D_e}z\right)$$

β θ



Model

Rio and Hernandez, 2003

$$\vec{u}_e = \beta \vec{\tau} e^{i\theta}$$

$\vec{u}_{buoy} - \vec{u}_{alti}$

low pass filtered 30 hours

Wind stress from ERA INTERIM

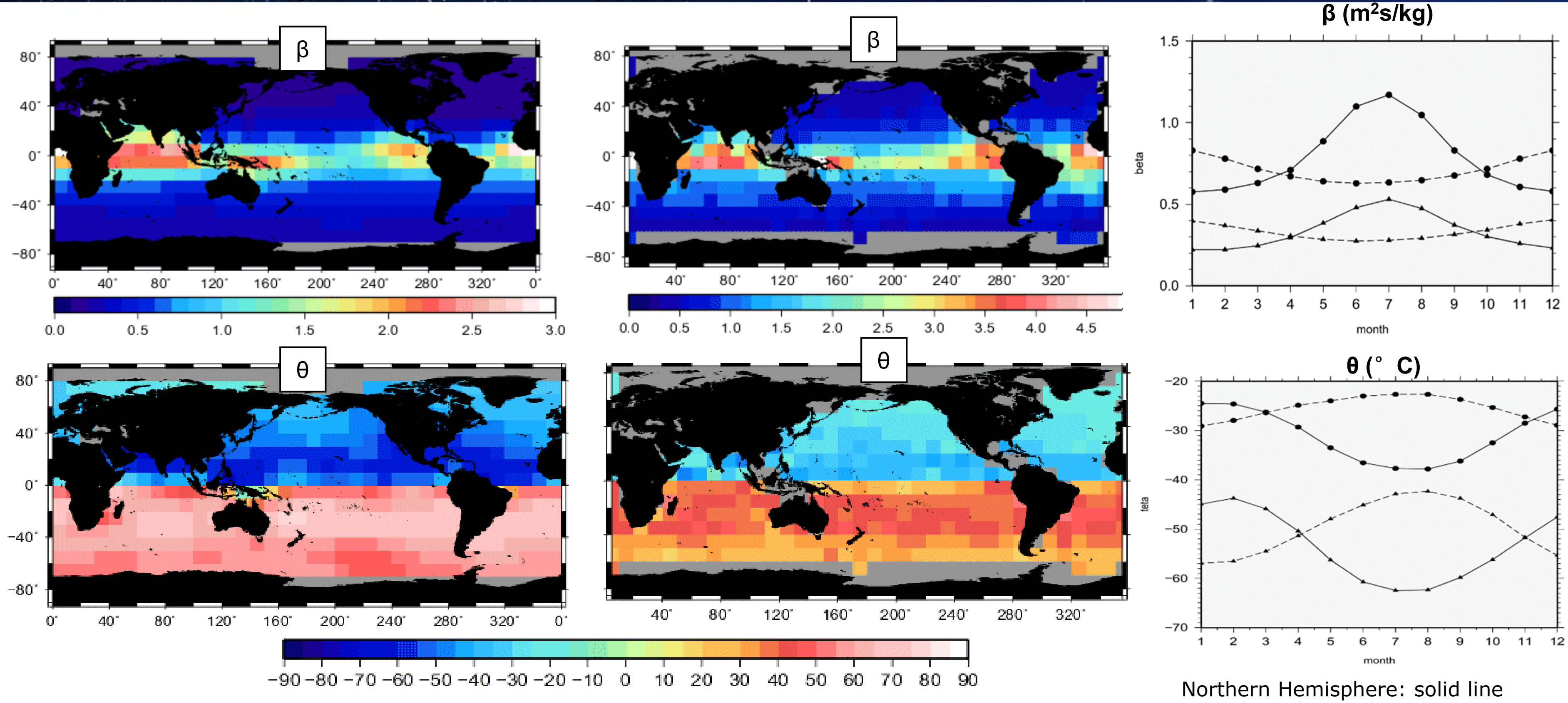
CNES-CLS13 MDT:

β and θ are estimated through least square fit by month and 4° by 4° boxes

Dataset for 15m depth model: SVP Drifting buoys flagged as DROGUED by the SD-DAC

Dataset for surface model: Yomaha surface velocities

Modeling Wind-driven Currents CNES-CLS13



Northern Hemisphere: solid line
Southern Hemisphere: dashed line
Surface: circles - 15m depth: triangles

Rio et al, 2014

Modeling Wind-driven Currents
NEW MODEL

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esa European Space Agency

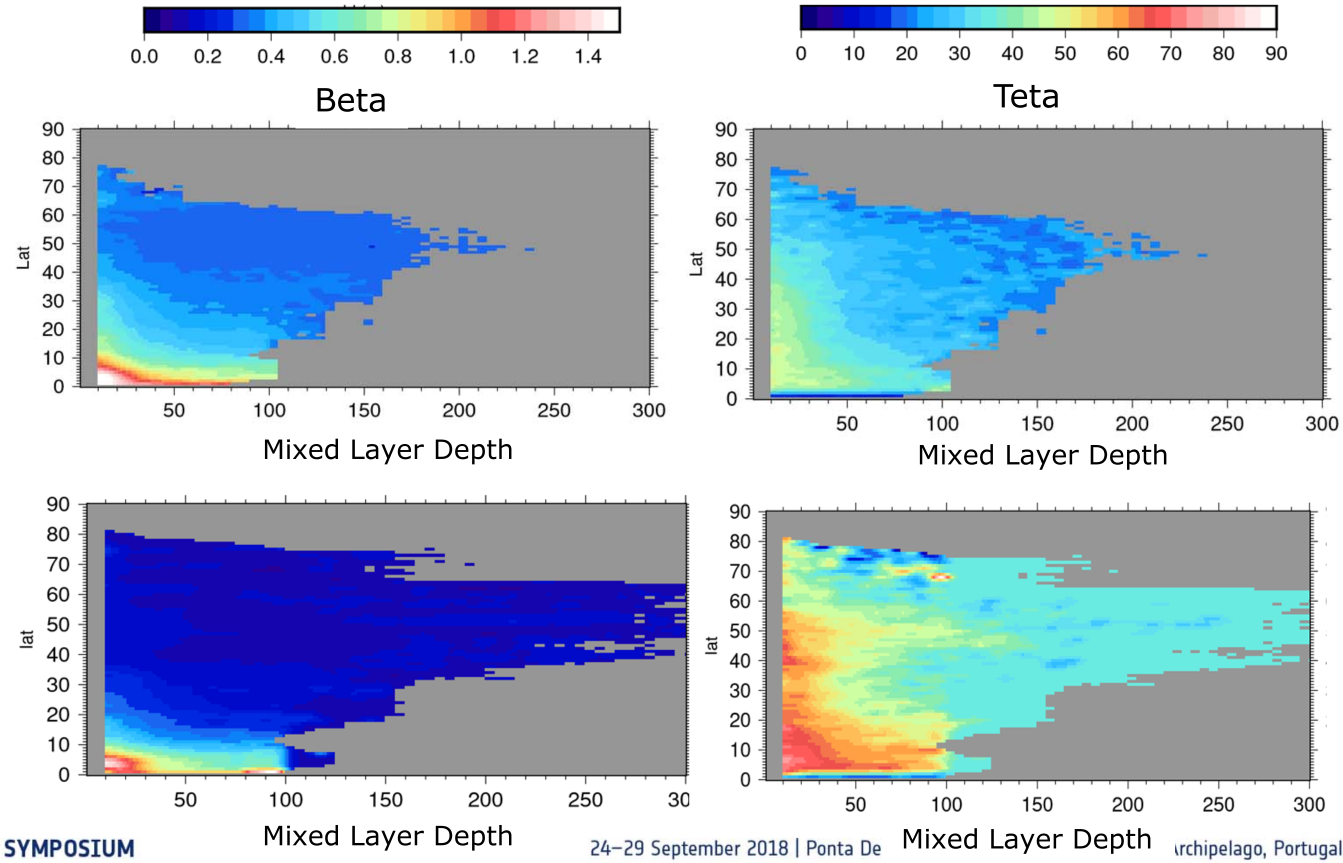
SURFACE

$$\vec{u}_w(z=0)=\beta_0 e^{i\theta_0}\vec{\tau}^{0.6}$$

15m depth

$$\vec{u}_w(z=15)=\beta_{15} e^{i\theta_{15}}\vec{\tau}^{0.7}$$

MLD from the weekly ARMOR3D T/S fields (Guinehut et al, 2012)



Modeling Wind-driven Currents NEW MODEL

% of variance explained by the models using independent dataset

<table>
<tr><th>Surface</th><th colspan="2">All LAT (206239 data)</th><th colspan="2">|LAT|>5 (991460)</th><th colspan="2">|LAT|<5 (86551)</th></tr>
<tr><td>Model</td><td>%U</td><td>%V</td><td>%U</td><td>%V</td><td>%U</td><td>%V</td></tr>
<tr><td>OLD</td><td>29.04</td><td>16.62</td><td>31.53</td><td>18.12</td><td>21.08</td><td>9.33</td></tr>
<tr><td>NEW</td><td>32.64</td><td>18.61</td><td>34.12</td><td>20.11</td><td>27.90</td><td>11.33</td></tr>
</table>

<table>
<tr><th>15 m</th><th colspan="2">All LAT (1451989 data)</th><th colspan="2">|LAT|>5 (1346484)</th><th colspan="2">|LAT|<5 (105259)</th></tr>
<tr><td>Model</td><td>%U</td><td>%V</td><td>%U</td><td>%V</td><td>%U</td><td>%V</td></tr>
<tr><td>OLD</td><td>13.0</td><td>10.2</td><td>13.82</td><td>10.86</td><td>10.8</td><td>7.45</td></tr>
<tr><td>NEW</td><td>15.67</td><td>11.35</td><td>15.33</td><td>11.67</td><td>16.37</td><td>9.93</td></tr>
</table>

CNES-CLS18
Mean Dynamic Topography

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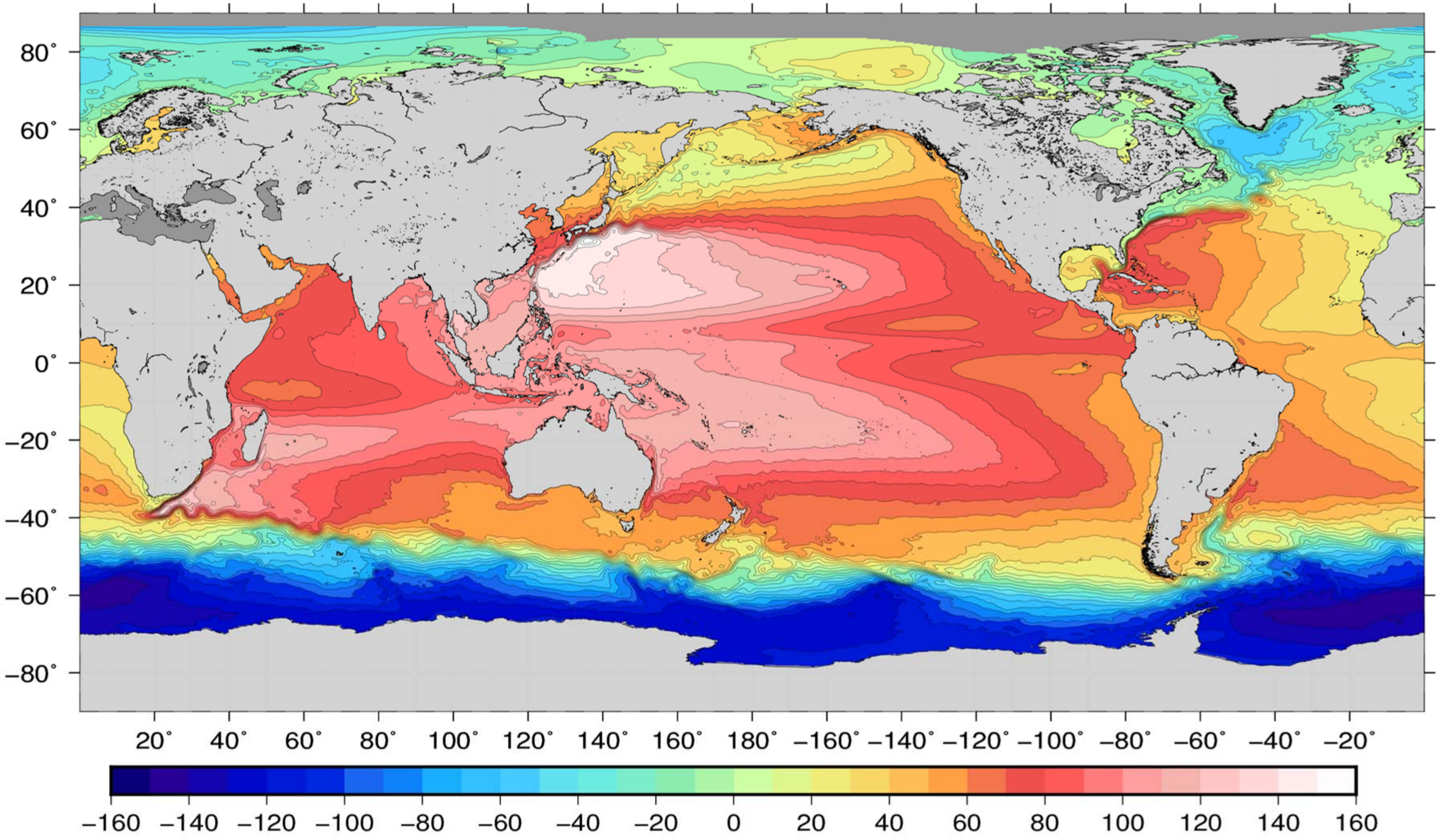
European Space Agency



Mean geostrophic velocities
CNES-CLS18 MDT

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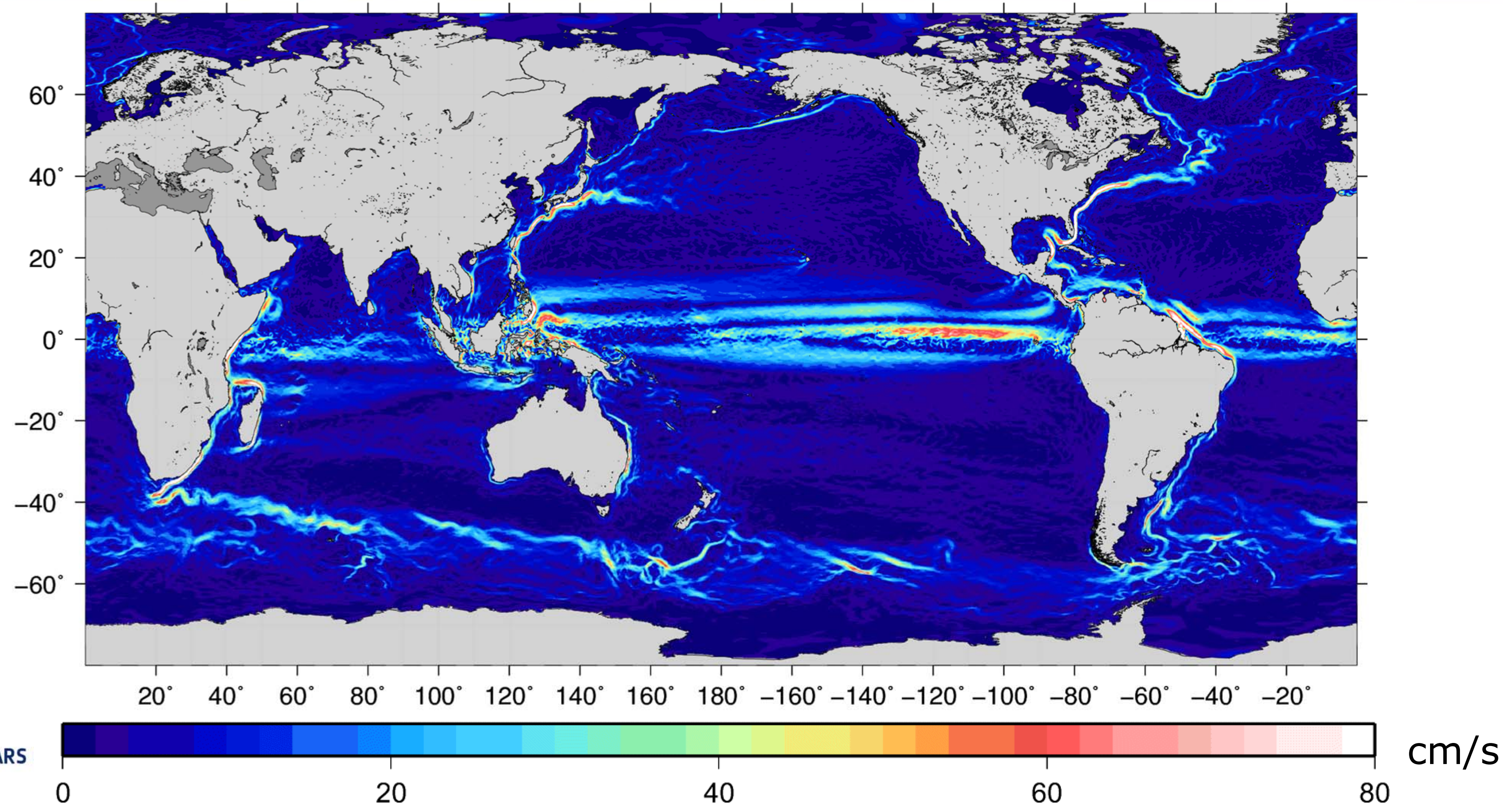
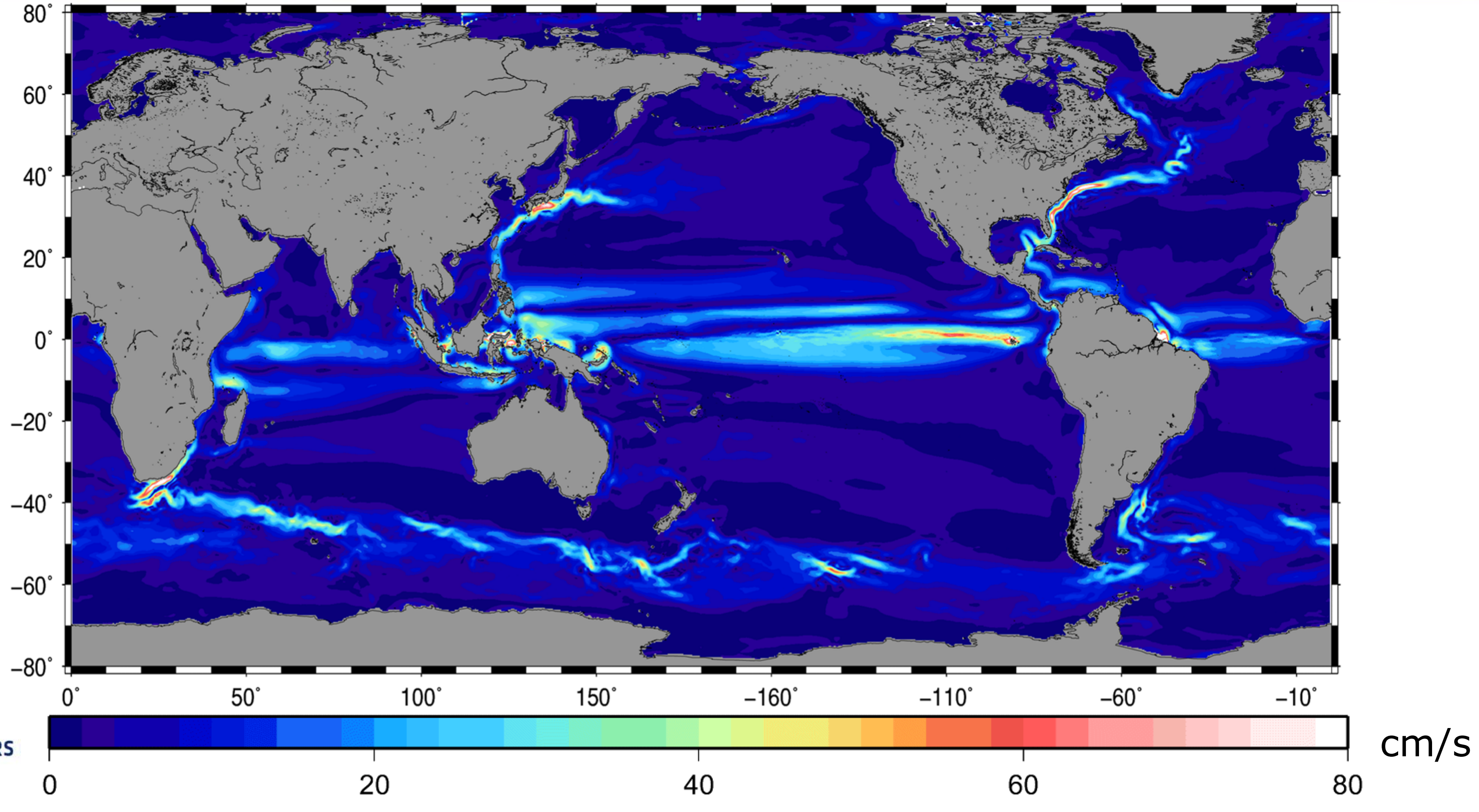
esa European Space Agency



→ 25 YEARS

tugal

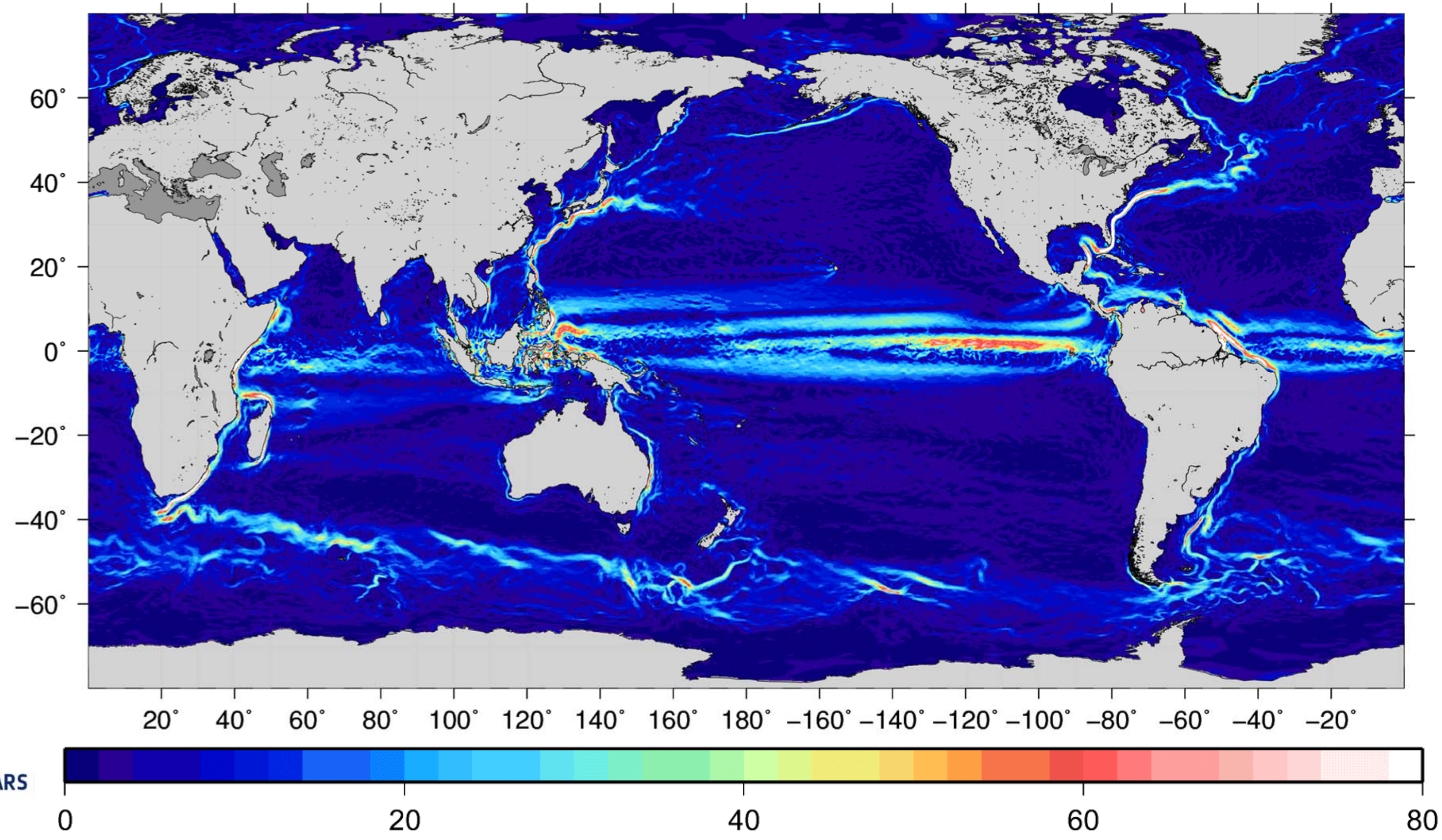
Mean geostrophic velocities
MSS-GOCO05S: Resolution 100 km



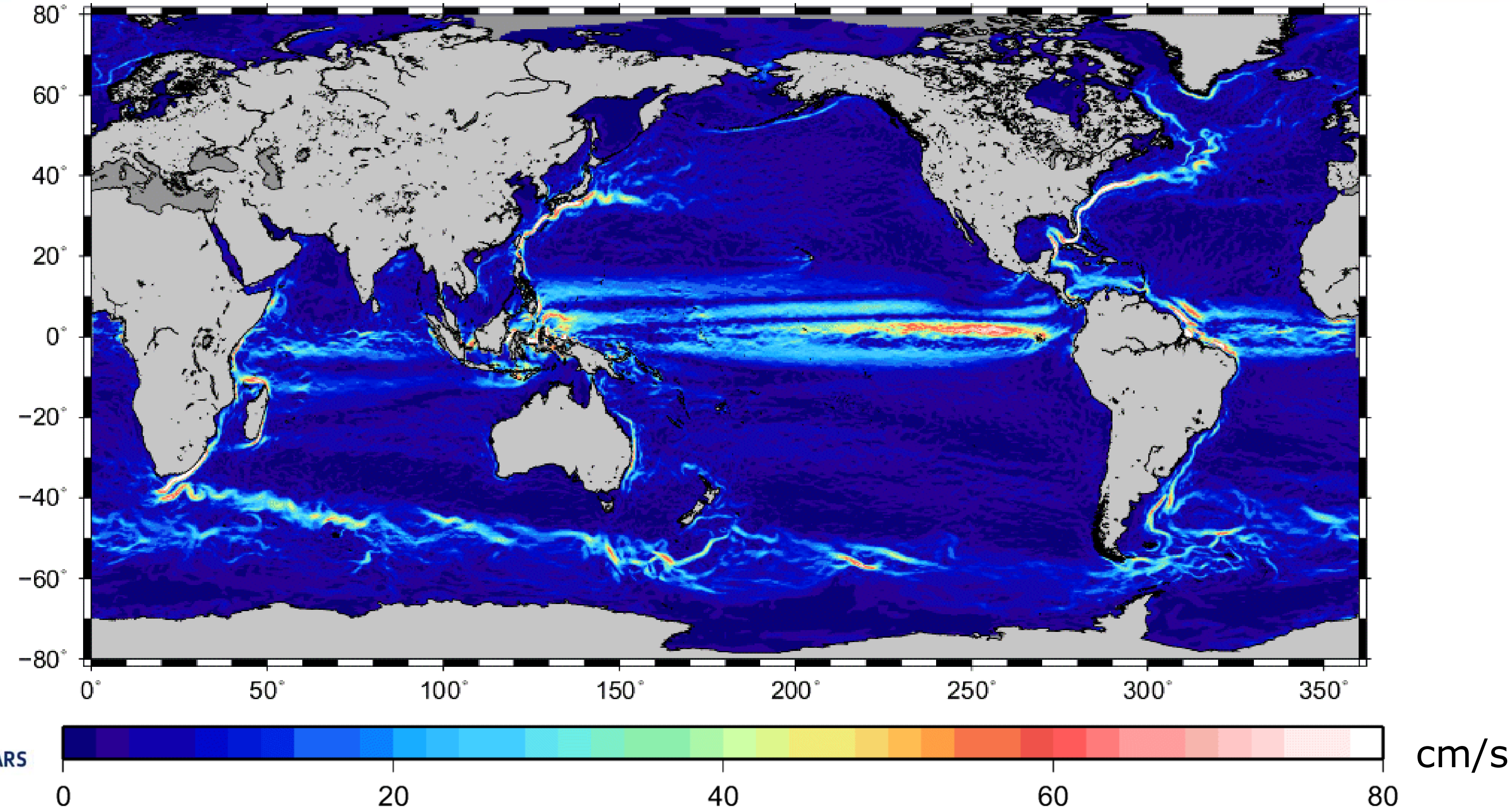
→ 25 YEARS

tugal

Mean geostrophic velocities
CNES-CLS18 MDT



Mean geostrophic velocities CNES-CLS13 MDT



Validation in the Agulhas Current: Comparison to SAR Doppler velocities

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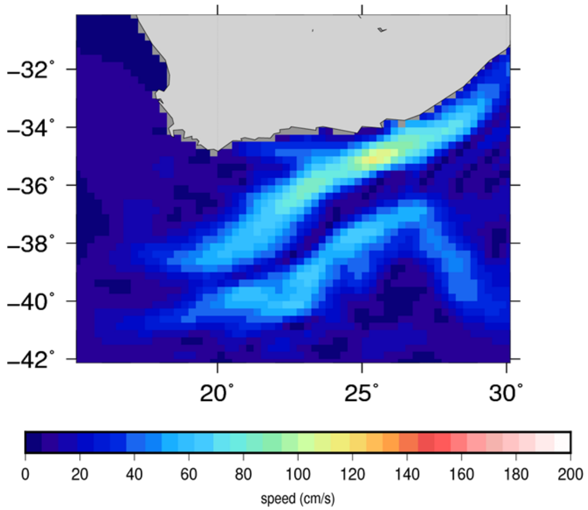
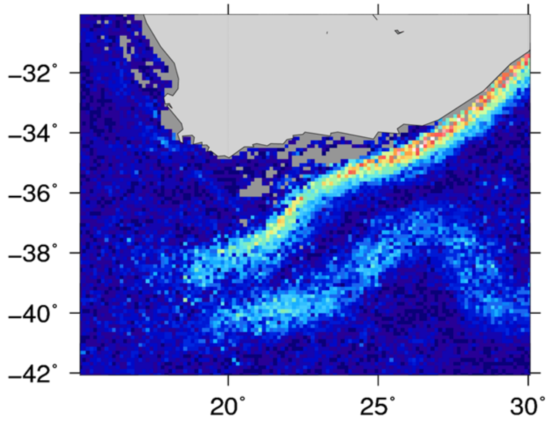
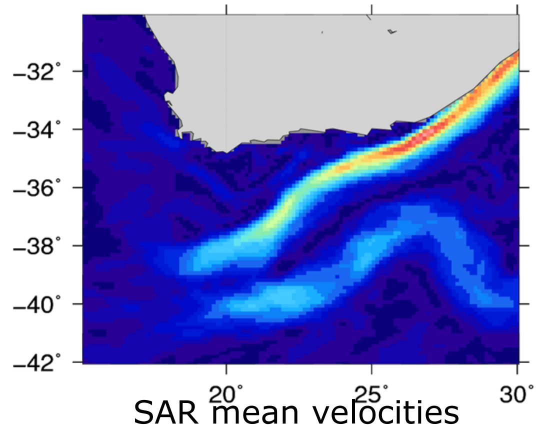
CNES–CLS18 First Guess



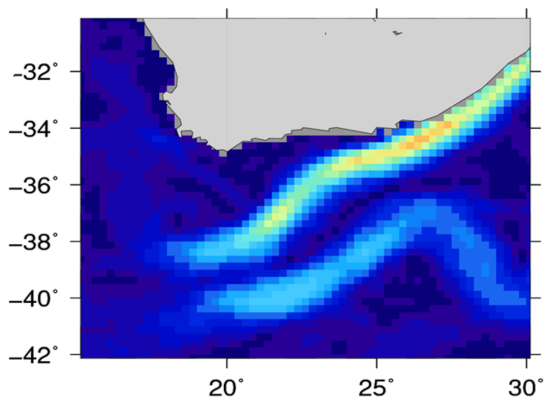
Drifter 1/8 ALL



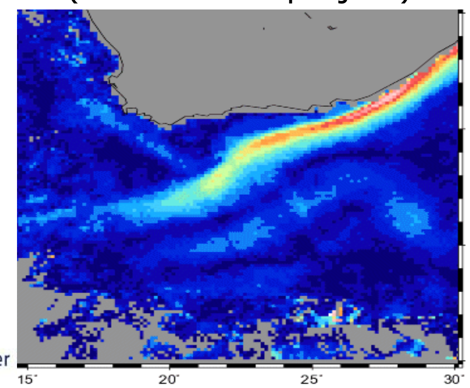
CNES–CLS18 MDT



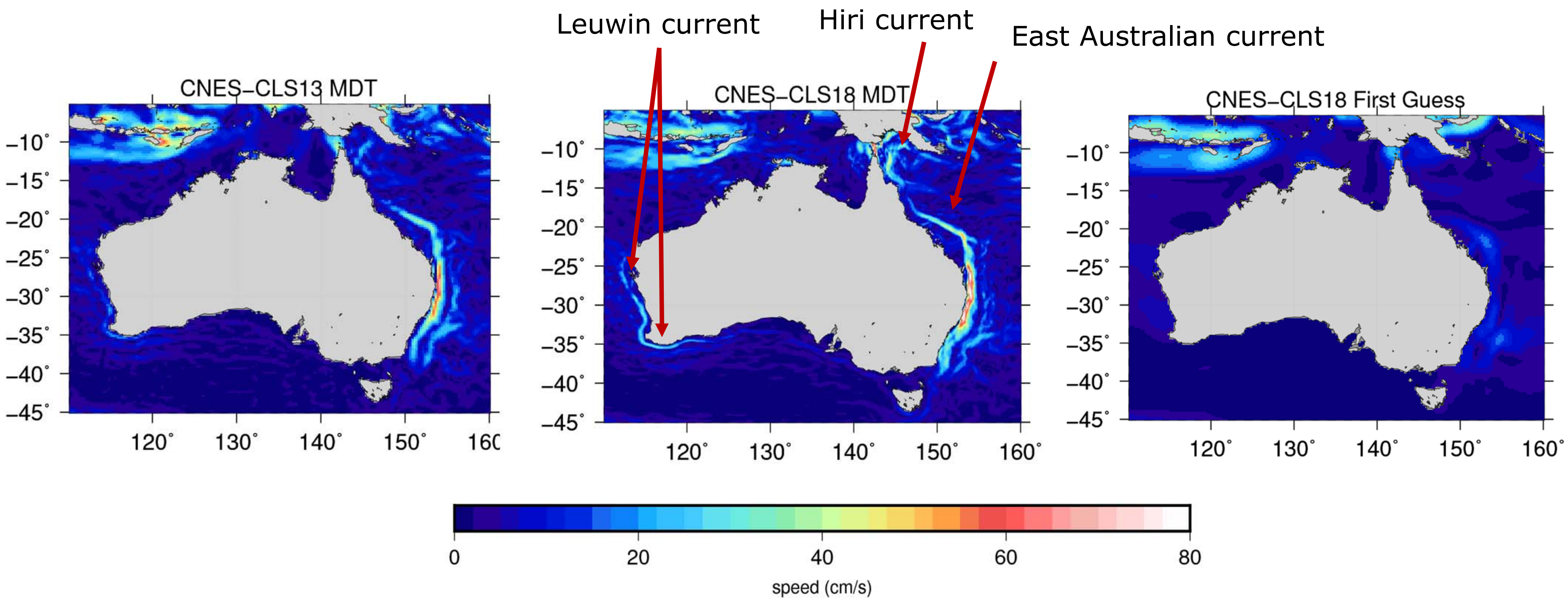
CNES–CLS13 MDT



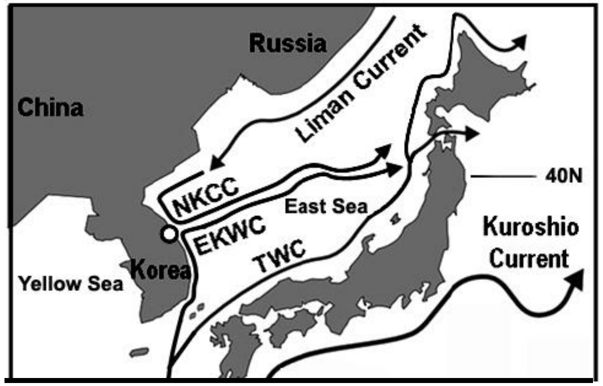
SAR mean velocities
(GlobCurrent project)

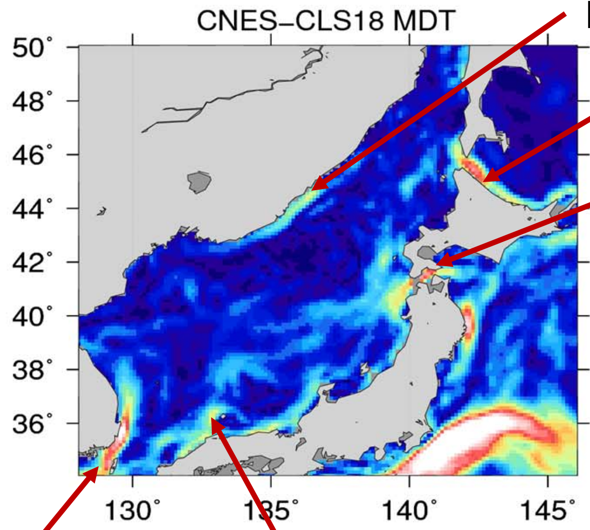


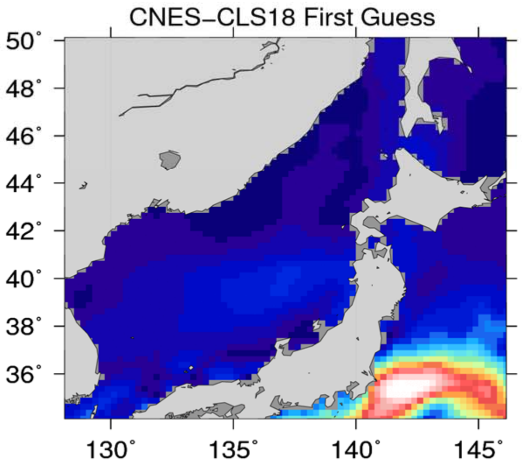
Mean Circulation around Australia

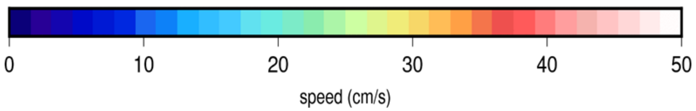


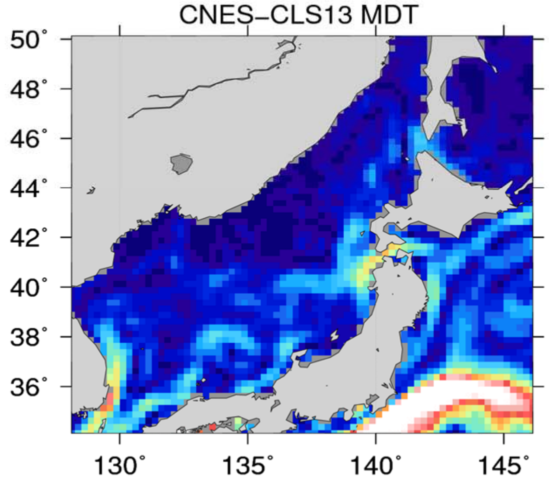
Mean Circulation in the Japan Sea



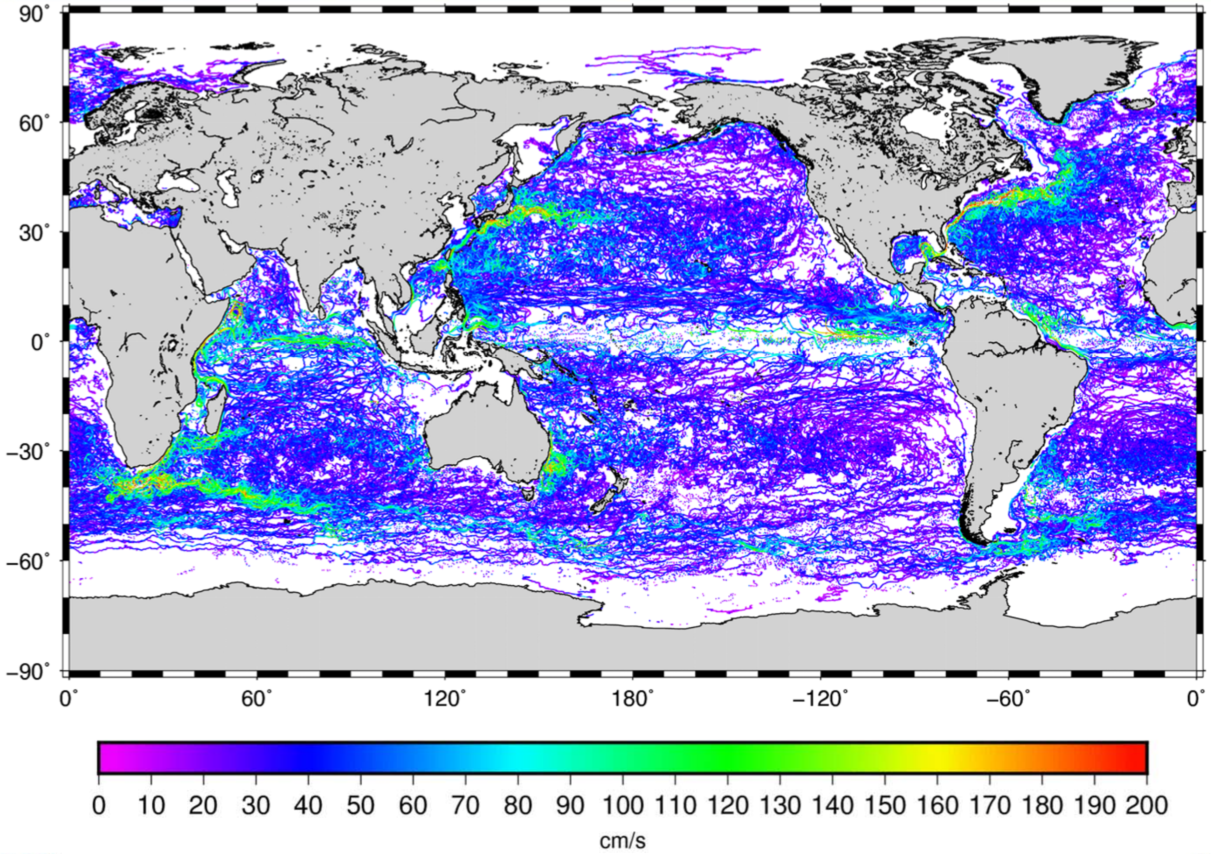






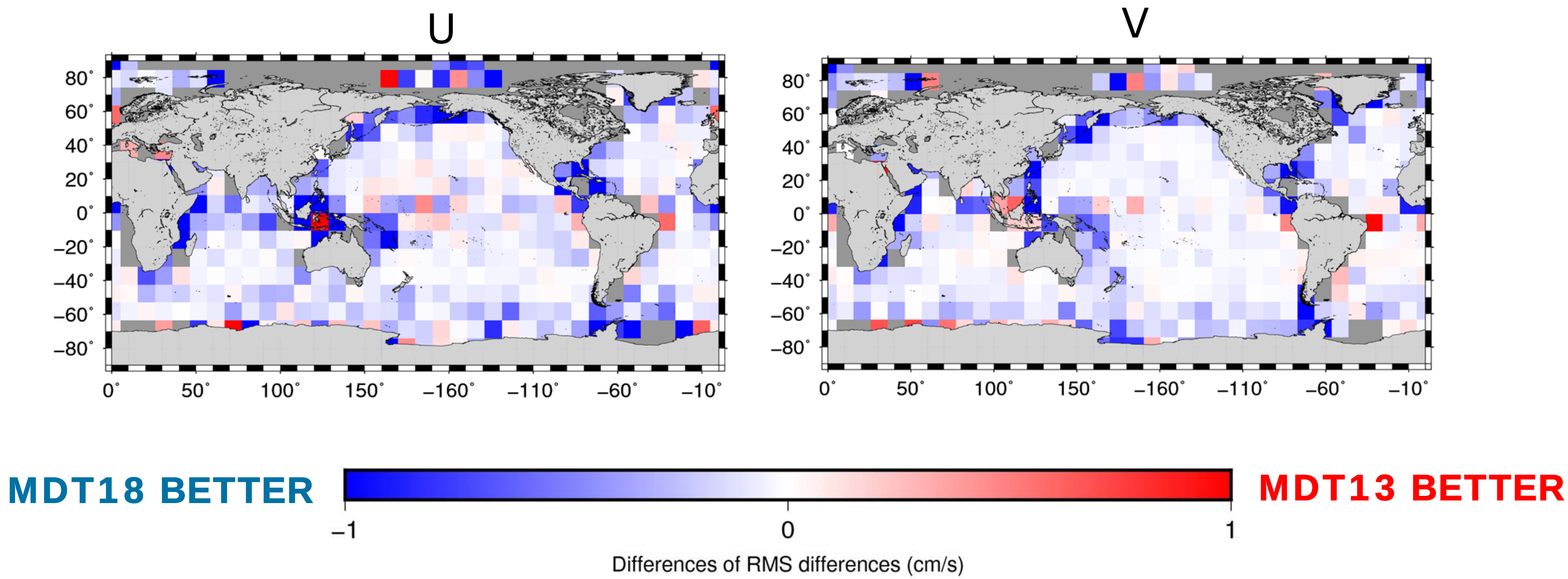


Comparison to independent drifter velocities: YEAR 2017



Comparison to independent drifter velocities: YEAR 2017

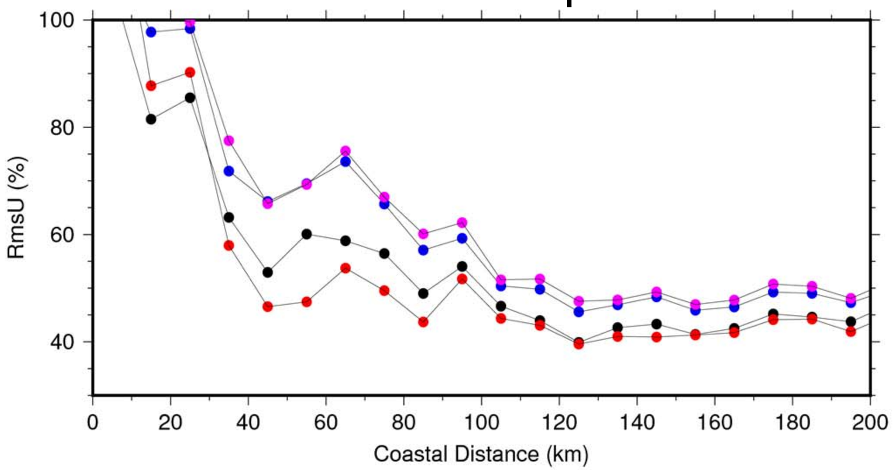
RMS(Drifter-CNES-CLS18)-RMS(Drifter-CNES-CLS13)



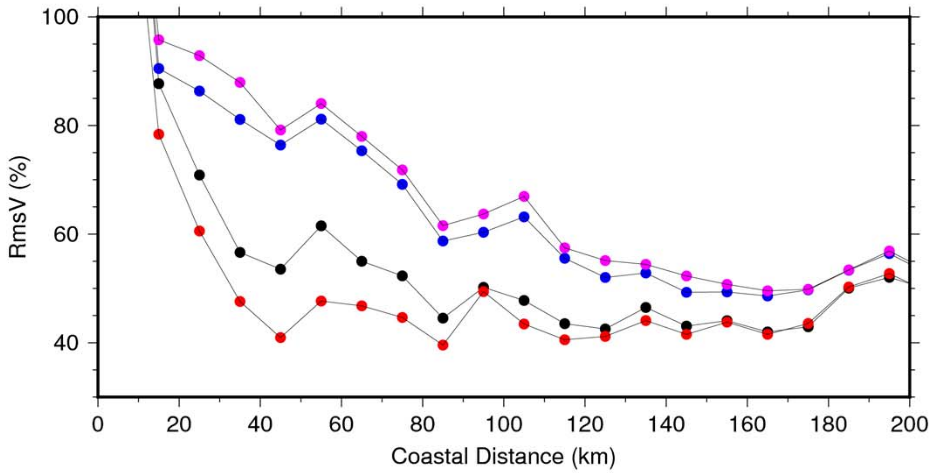
RMS (% of drifter variance) as a fonction of coastal distance

MDT13 First Guess (MSS CLS11-GOCE DIR4)
MDT18 First Guess (MSS CLS15-GOCO05S)
MDT13
MDT18

Zonal component

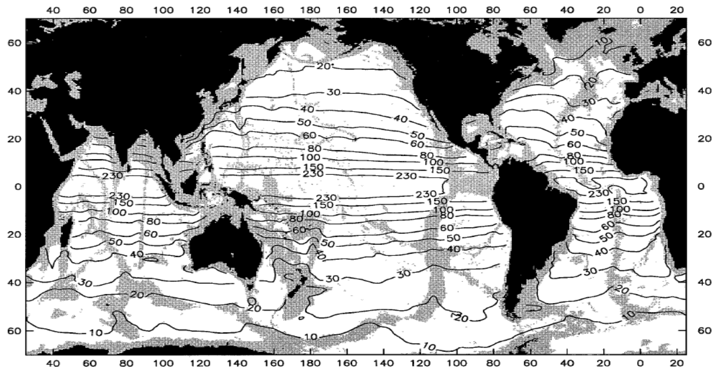


Meridional component



Expected MDT resolution ?

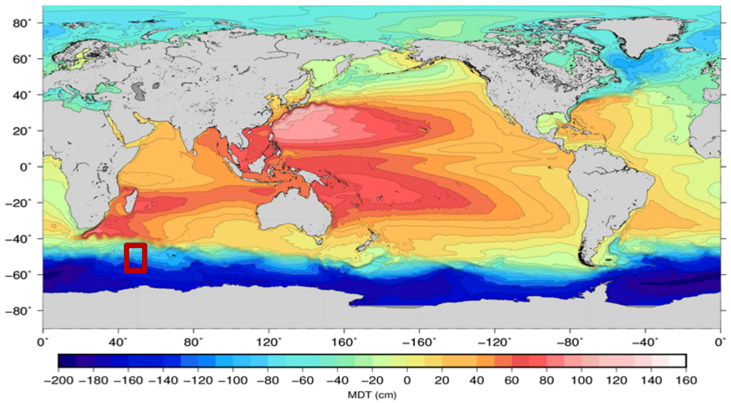
First Baroclinic Rossby Radius of Deformation:

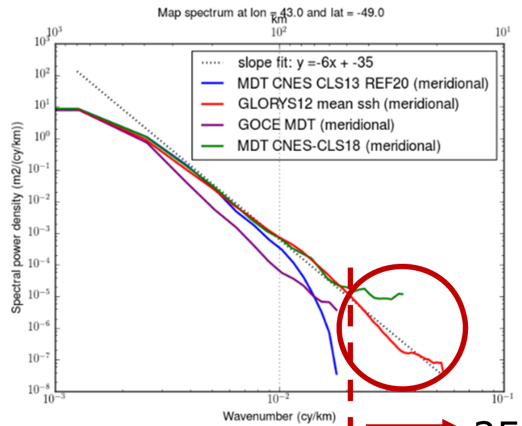


$$\lambda = \frac{1}{|f|m\pi}\int_{-H}^{0} N(z)dz$$

- High latitudes
- Shallow waters / Coastal areas
- Highly stratified areas

Average of GLORYS12 ADT over 1993-2012





25 km resolution

	MDT CNES-CLS13	MDT CNES-CLS18
MSS	CNES-CLS11 (Schaeffer et al, 2012)	CNES-CLS15 (pujol et al, 2018)
Geoid	EGM-DIR-R4 (Bruinsma et al, 2012) 2 years of reprocessed GOCE data +7 years of GRACE data	GOCO05S (Mayer-Gürr,et al. 2015) Complete GOCE mission (Nov 2009-October 2013) + 10.5 years of GRACE data
First Guess filtering	Optimal filter (Rio et al, 2011)	Optimal filter (Rio et al, 2011)
Drifter Data	SD-DAC drifter, both drogued and undrogued: 1993-2012 Argo floats surface velocities: 1997-2013	SD-DAC drifter, both drogued and undrogued: 1993-2016 Argo floats surface velocities: 1997-2016
Ekman model	Parameters fitted over the period 1993-2012, by longitude, latitude and month (Rio et al, 2014) Two levels: 0m and 15m	Parameters fitted over the period 1993-2016 by latitude and Mixed Layer Depth (from ARMOR3D) Two levels: 0m and 15m
Wind Slippage correction	Rio et al, 2012	Update of Rio et al, 2012 in order not to discard the trajectories beginning/end
Drifter filtering	3 days	Max (24 hours, Inertial Period)
Hydrological data	CTD (Cora3.4), ARGO Pref variable 200/400/900/1200/1900 Period 1993-2012	CTD and ARGO Pref variable 200/400/900/1200/1900 from CORA4.2 (1993-2013), CORA5.0 (2014-2015) and CORA5.1 (2016) Period 1993-2016
Altimeter data	Delayed-Time DUACS-2010 (Dibarboure et al, 2011)	Delayed-Time DUACS-2018 (Taburet et al, in preparation)

CONCLUSIONS

- Compared to the CNES-CLS13 solution, the New CNES-CLS18 MDT shows **improved performance everywhere**

- Most signifcant in **coastal** areas and in **strong western boundary currents**

Planning: Further validation by « super-users » will now be performed before public release early 2019 on the AVISO website

Further improvements needed: **At short scales, At high latitudes, In coastal areas**

⇒ Continuous improvement of MSS, geoid, in-situ observation processing
⇒ New in-situ observations are needed (HF radar), inclusion of other spaceborne measurements (SAR doppler, SST)