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

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N. Picot [3], G. Dibarboure [3]
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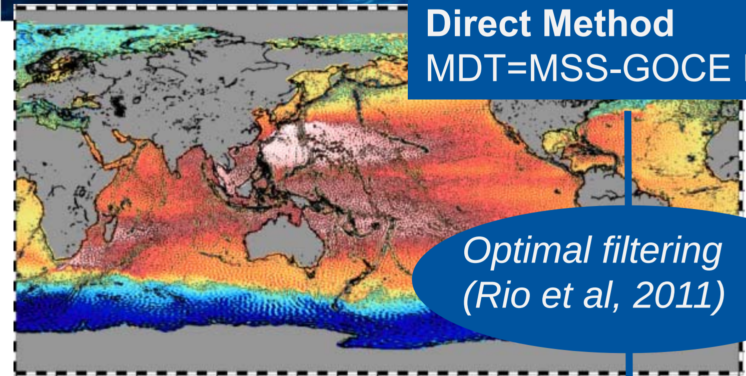
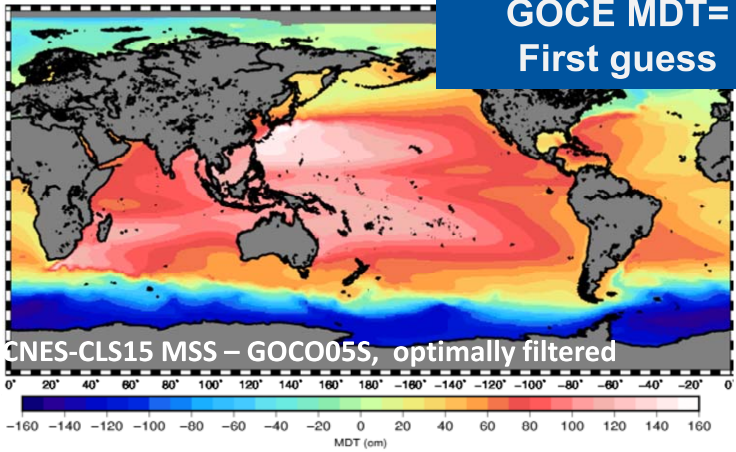
METHOD



Direct Method
MDT=MSS-GOCE R5

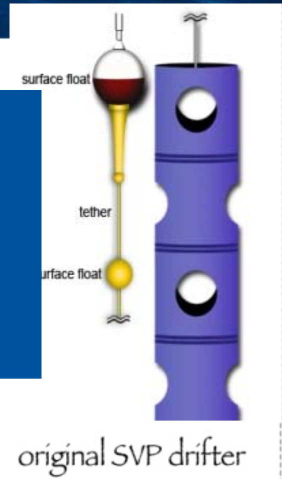
Optimal filtering (Rio et al, 2011)

GOCE MDT= First guess



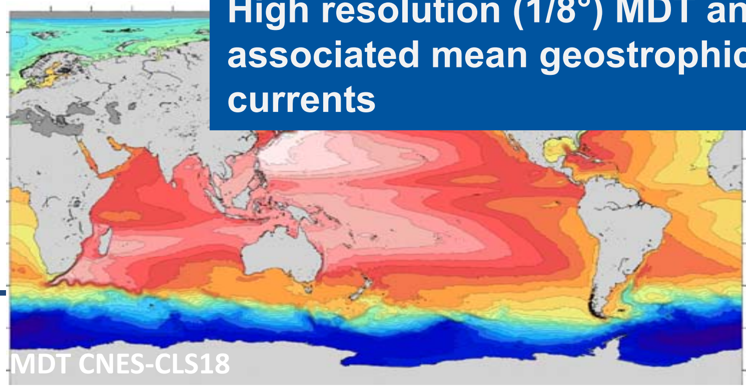
- Scales larger than 125 km
- Can be less accurate along the coast

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



Multivariate Objective Analysis

High resolution (1/8°) MDT and associated mean geostrophic currents

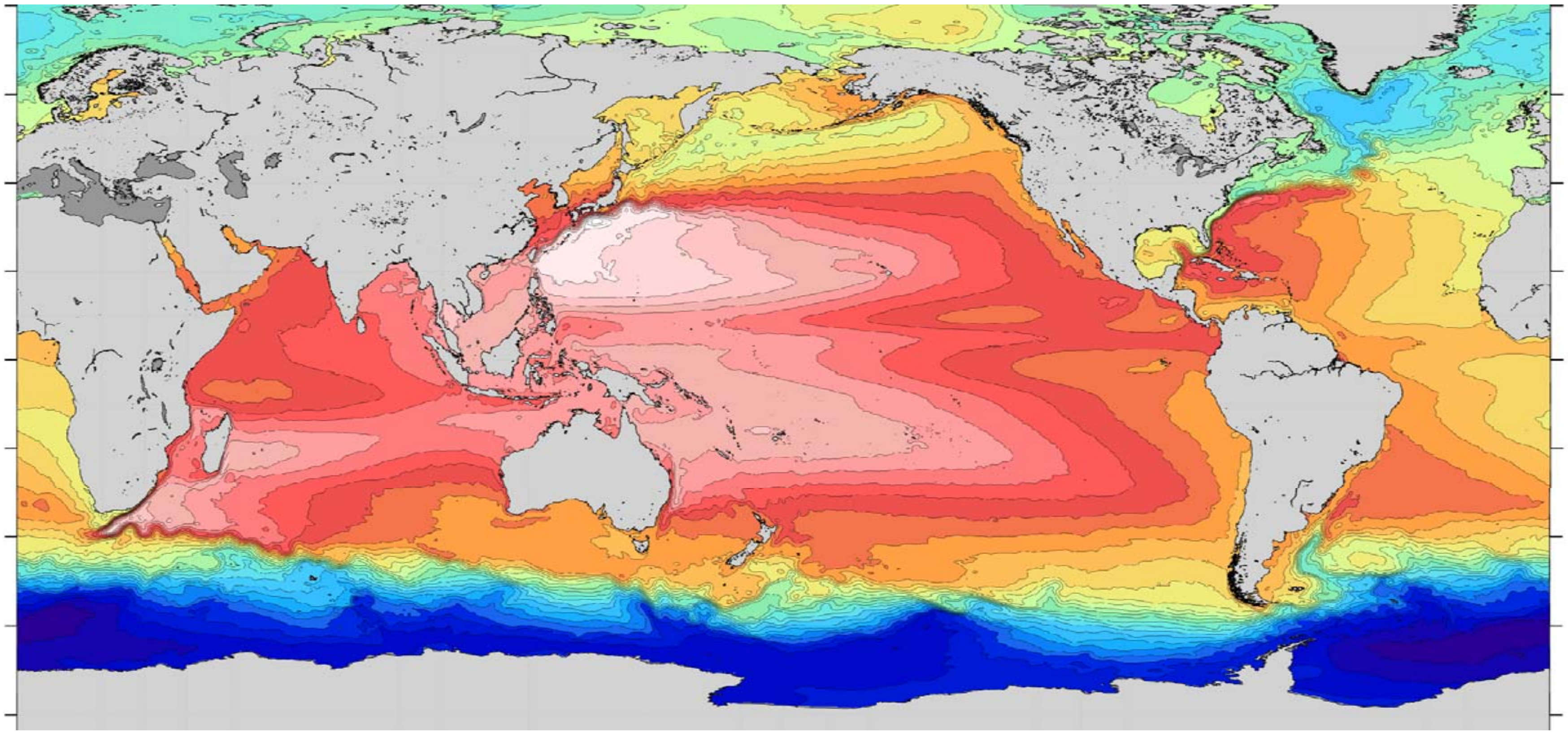


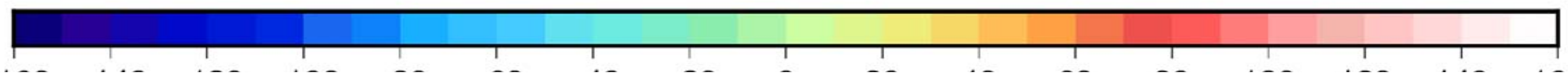
Rio and Hernandez,2004
Rio et al, 2005, 2011, 2014

What is new ?

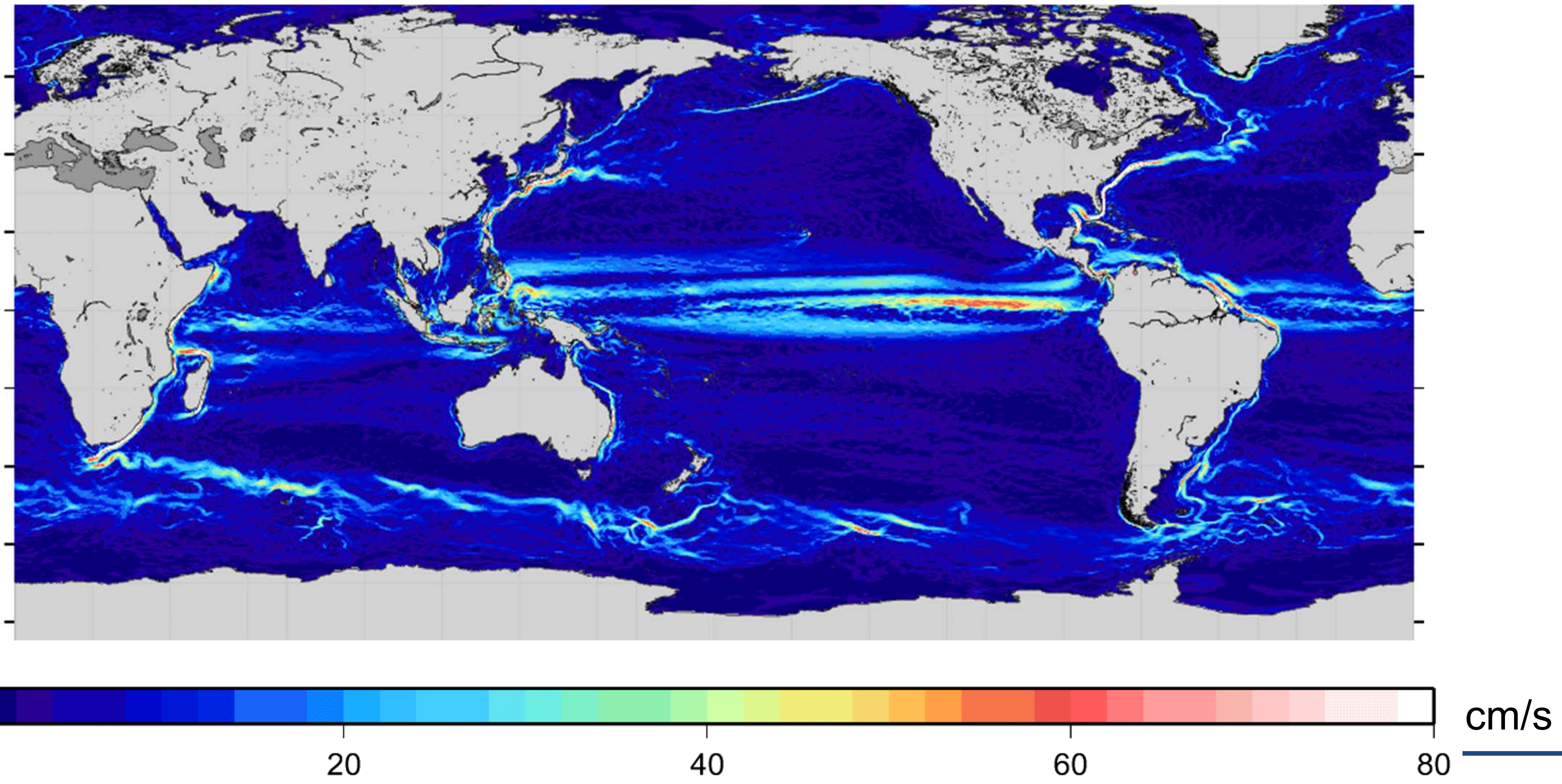
	MDT CNES-CLS13	MDT CNES-CLS18
MSS	CNES-CLS11 (Schaeffer et al, 2012)	**CNES-CLS15** (Pujol et al, 2018)
Geoid	EGM-DIR-R4 (Bruinsma et al, 2012) 2 years of reprocessed GOCE data +7 years of GRACE data	**GOCO05S** (Mayer-Gürr,et al. 2015) Complete GOCE mission (Nov 2009-October 2013) + 10.5 years of GRACE data
First Guess filtering	Optimal filter (Rio et al, 2011)	Optimal filter (Rio et al, 2011) **with updated parameters**
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** **Start to implement improvement**
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)**
Altimeter data	Delayed-Time DUACS-2010 (Dibarboure et al, 2011)	Delayed-Time **CMEMS-DUACS 2018** (Taburet et al, under review)
Resolution	Global ¼°	Global **1/8°**

CNES-CLS18
Mean Dynamic Topography

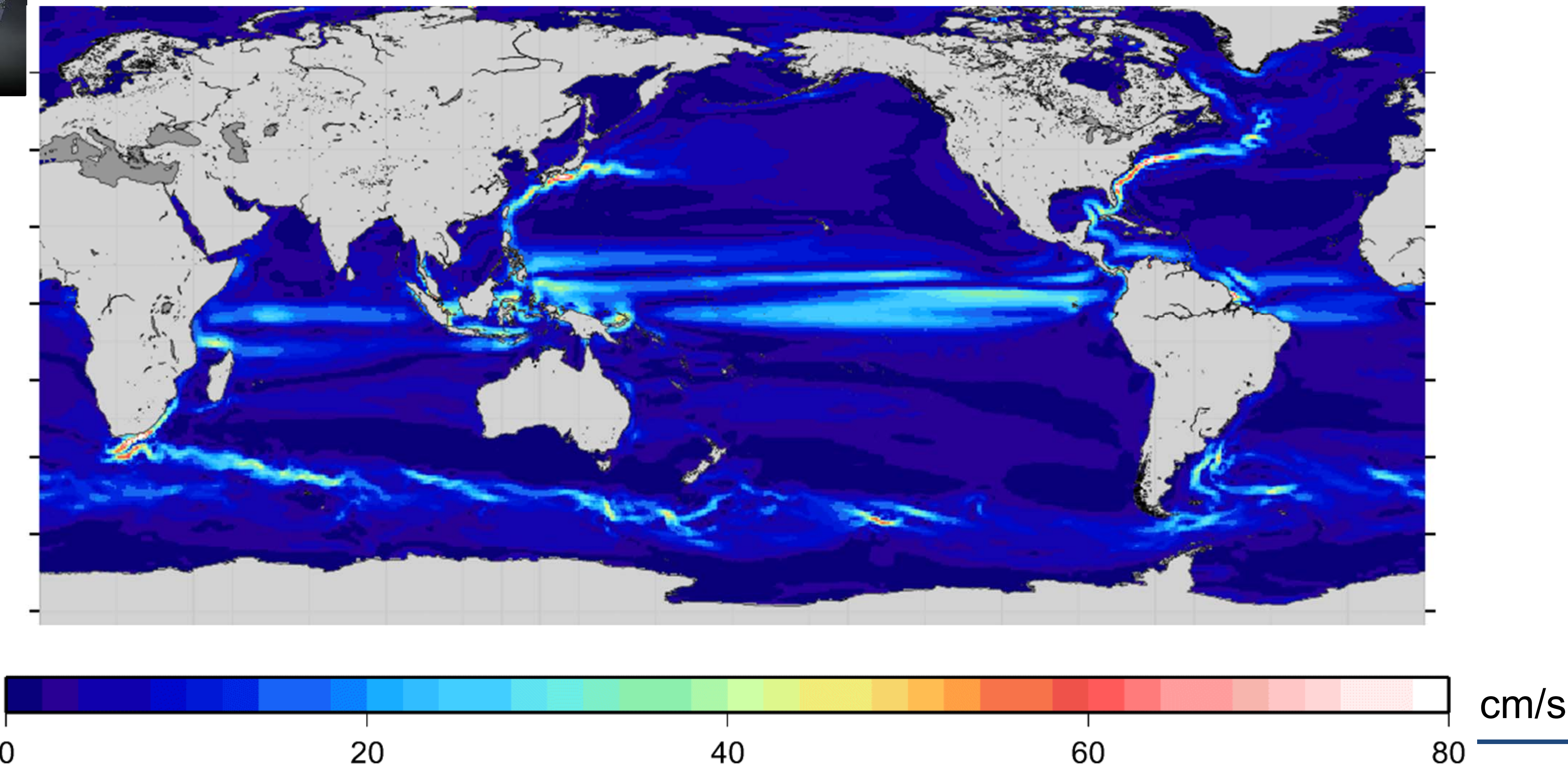




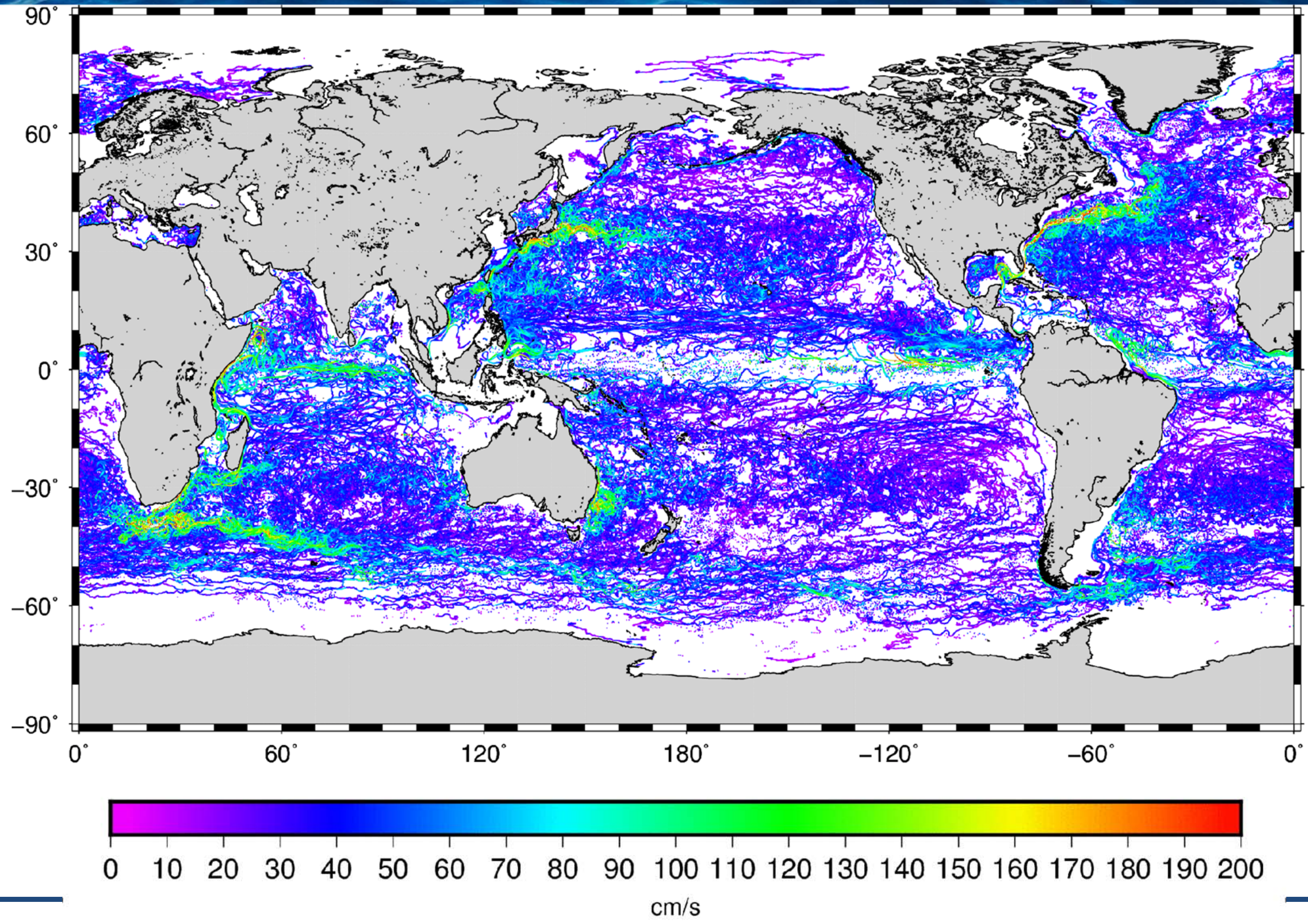
Mean geostrophic velocities
CNES-CLS18 MDT



Mean geostrophic velocities
MSS-GOCO05S



Comparison to independent drifter velocities: YEAR 2017



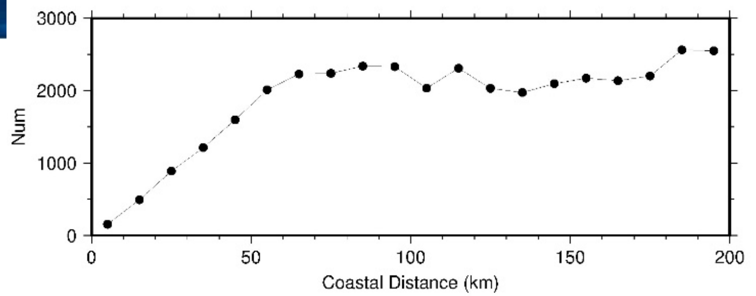
RMS (% of drifter variance) as a fonction of coastal distance

MDT13 First Guess (MSS CLS11-GOCE DIR4)

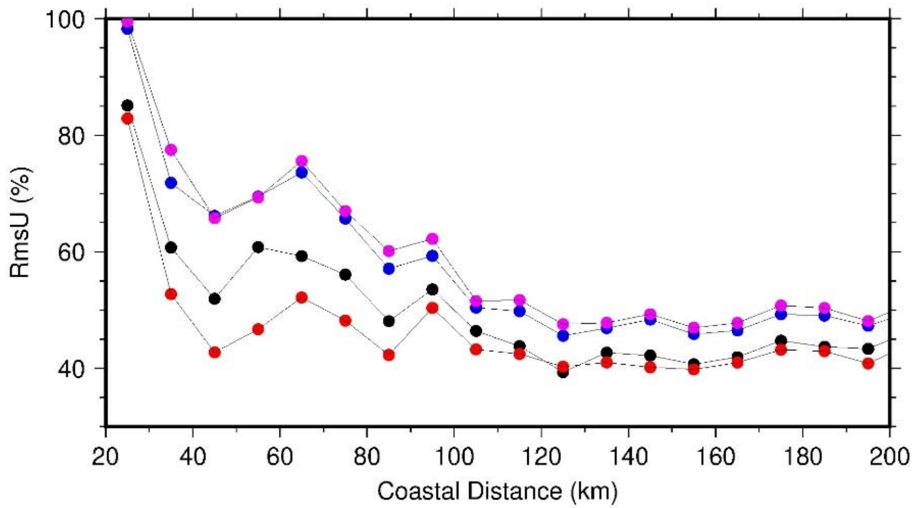
MDT18 First Guess (MSS CLS15-GOCO05S)

MDT13

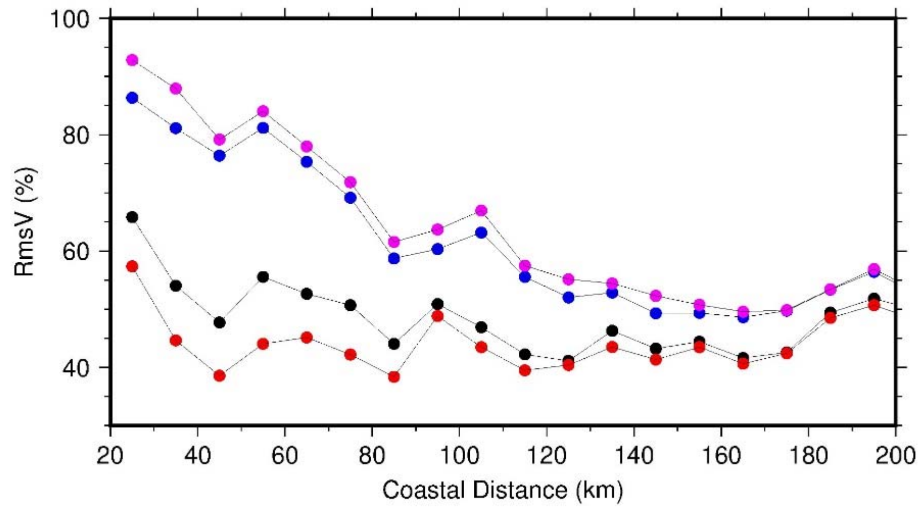
MDT18



Zonal component

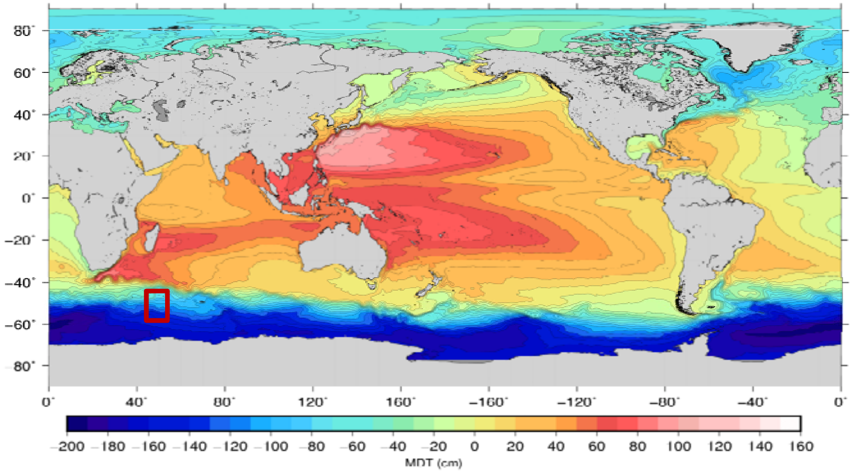


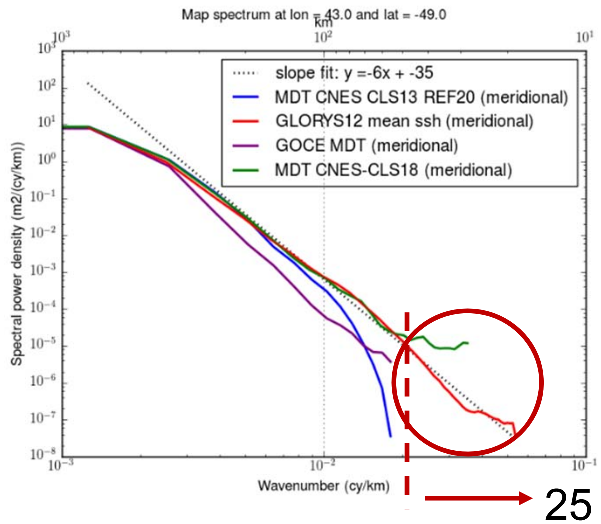
Meridional component



MDT resolution

Average of GLORYS12 ADT over 1993-2012

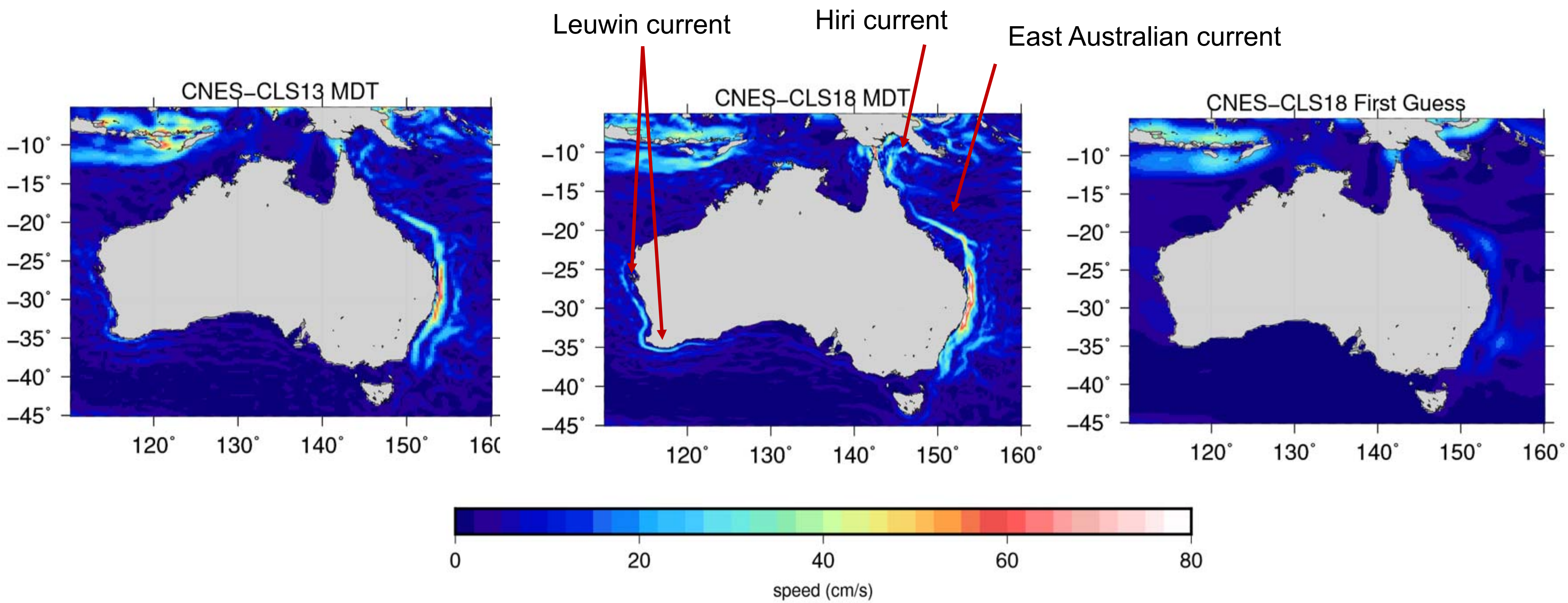




→Higher resolution
→May be residual noise

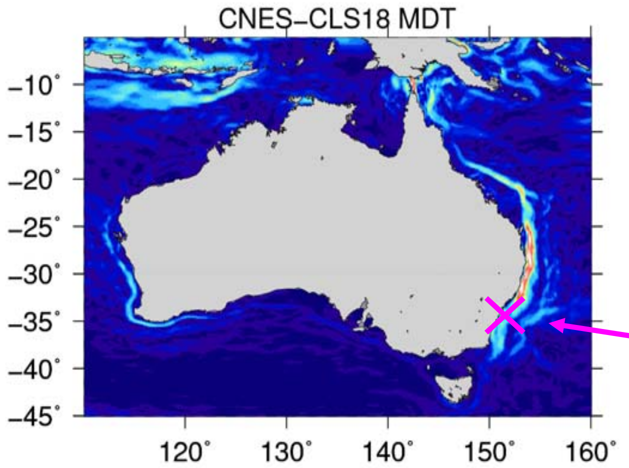
- Regional circulation
- Feedbacks from beta users

Mean Circulation around Australia



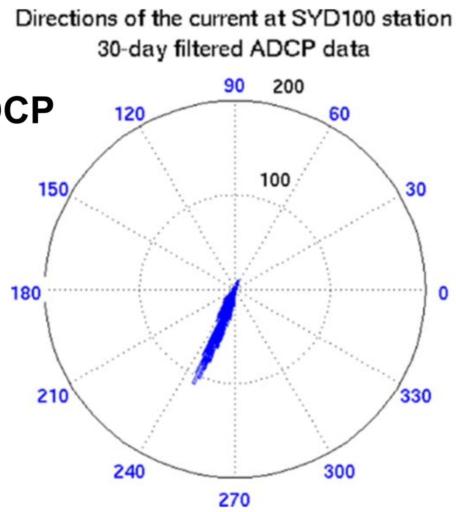
Mean Circulation around Australia

Courtesy of Mathilde Cancet (beta user)
(Cancet et al., 2019)

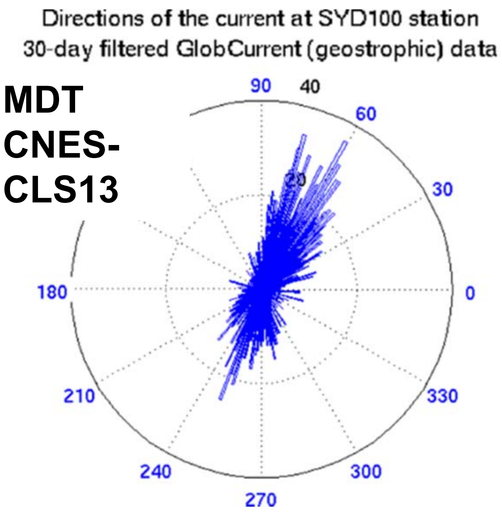


Comparison with ADCP

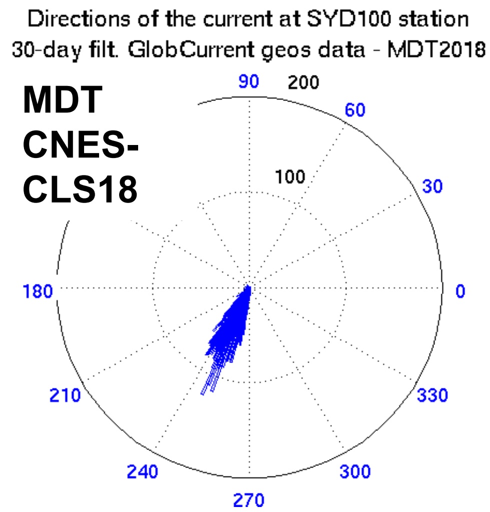
ADCP



MDT CNES-CLS13



MDT CNES-CLS18



Circulation in the Gulf of Maine

Courtesy of Hui Feng, Douglas Vandemark, John Wilkin

remote sensing MDPI

Article

Examining the Accuracy of GlobCurrent Upper Ocean Velocity Data Products on the Northwestern Atlantic Shelf

Hui Feng [1,*], Douglas Vandemark [1], Julia Levin [2] and John Wilkin [2]

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2 Department of Marine and Coastal Sciences, The State University of New Jersey, New Brunswick, NJ 08901, USA; julia@marine.rutgers.edu (J.L.); jwilkin@rutgers.edu (J.W.)

* Correspondence: hui.feng@unh.edu; Tel.: +1-603-862-3960

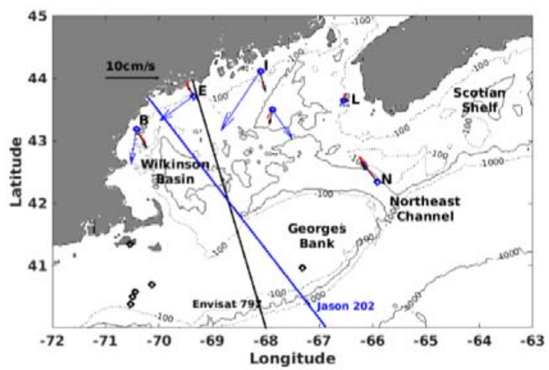

Figure 2. Mean upper ocean current vectors for both in situ ADCP current measurements and GlobCurrent products on the Northwest Atlantic shelf in the GoM. In situ data are depth-averaged mean current vectors U_{DA15m} in blue while GlobCurrent vector currents U_G (Geostrophic only) are in red and U_{GE15m} (Geostrophic and 15 m Ekman) are in black. Two satellite altimeter tracks (Envisat track E797, Jason track J202) are also shown.

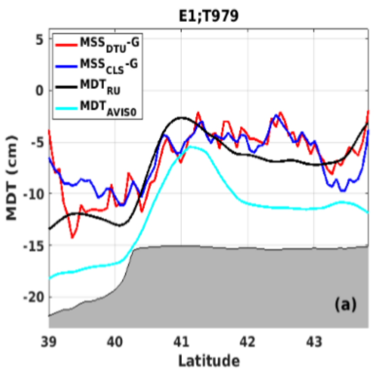

Figure 3. Derived mean dynamic topography (MDT) along (**a**) Envisat track E797 and (**b**) Jason track J202 from the western GoM across Georges Bank into the Atlantic slope region (Figure 2). Differing MDT estimates (see text) come from Mean Sea Surface (MSS) minus Geoid (G), either using MSS_{DTU} [6] or MSS_{CLS} [3] as well as from MDT_{AVISO} [4] and MDT_{RU} [48]. Grey areas depict the schematic bathymetry along these tracks. Note that the vertical offset between MDT_{RU} and MDT_{AVISO} is a matter of vertical datum but does not impact ocean dynamics.

remote sensing

MDPI

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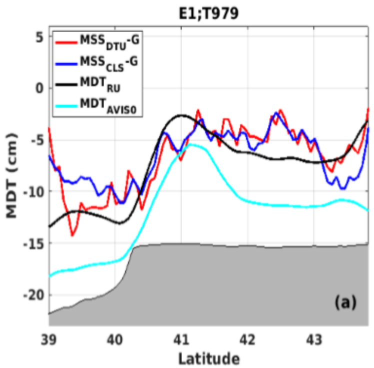

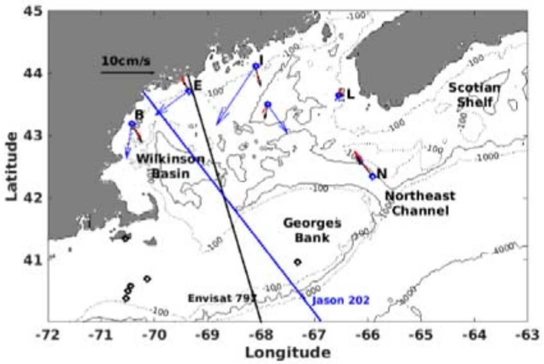

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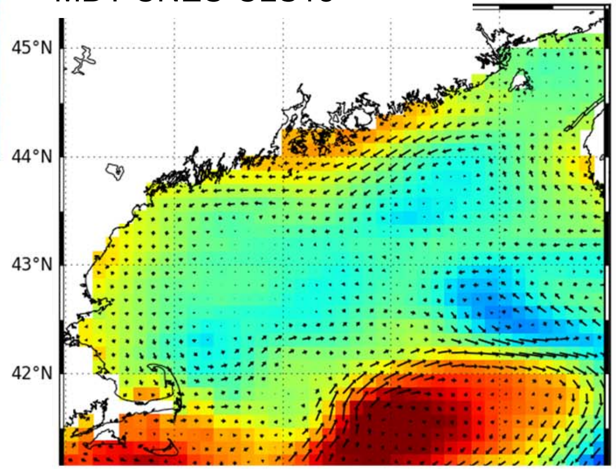
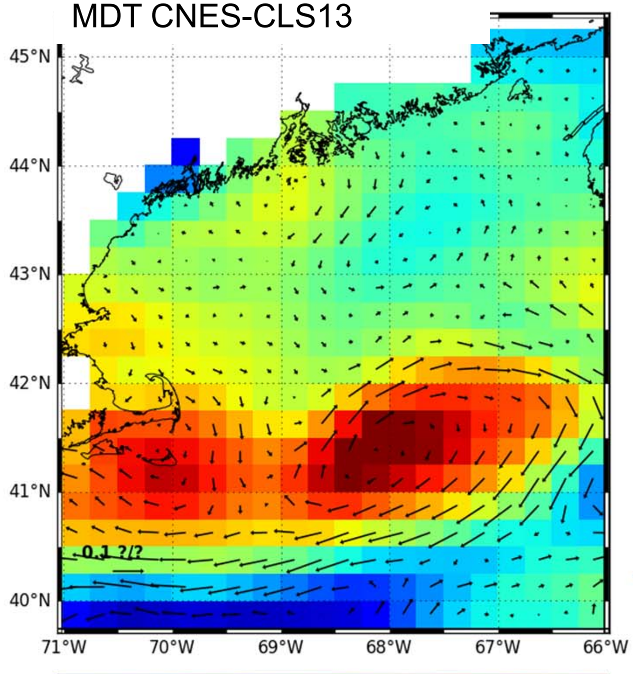
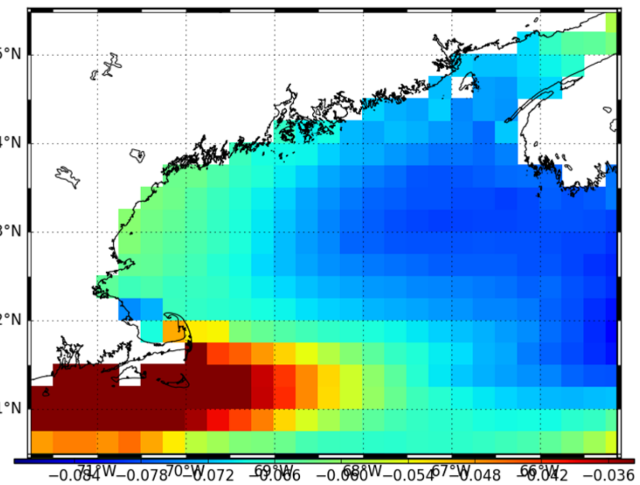
MDT CNES-CLS18



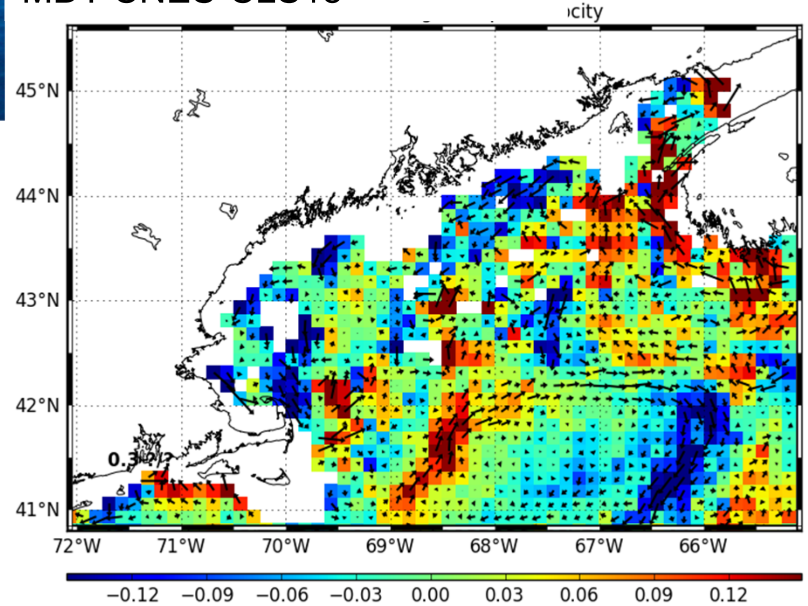
MDT CNES-CLS13



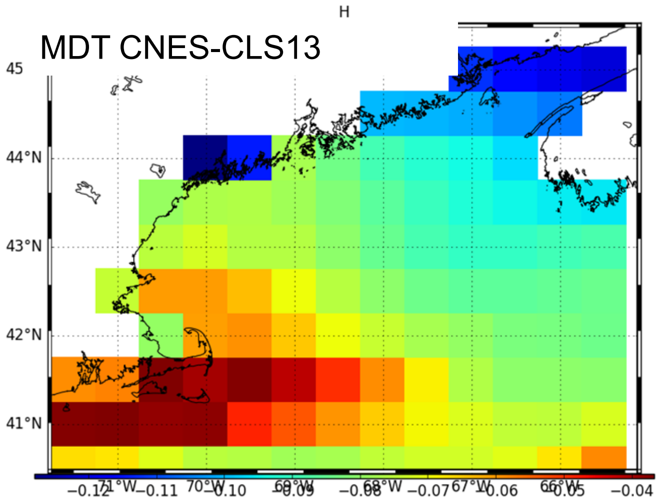
First Guess
MDT CNES-CLS18



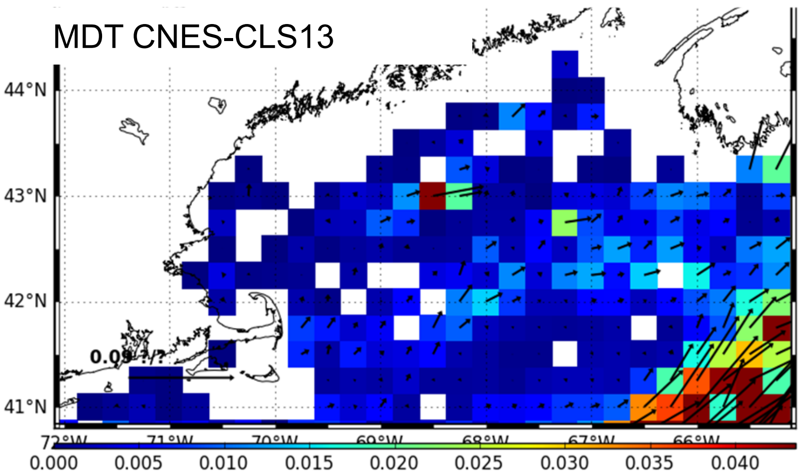
Super observation from Drifters
MDT CNES-CLS18



MDT CNES-CLS13

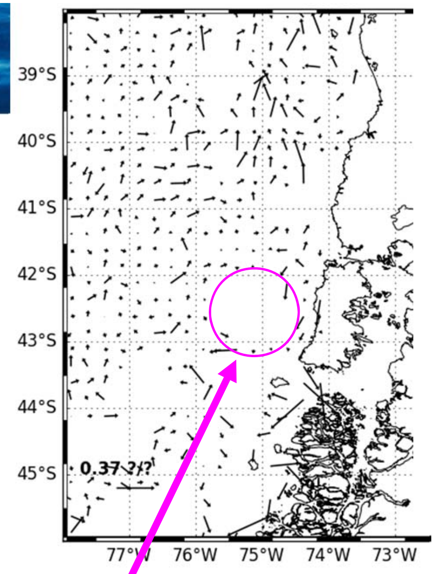


MDT CNES-CLS13

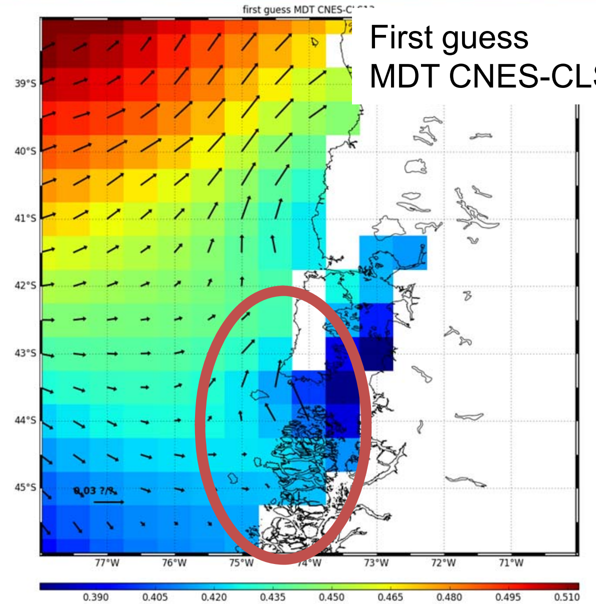


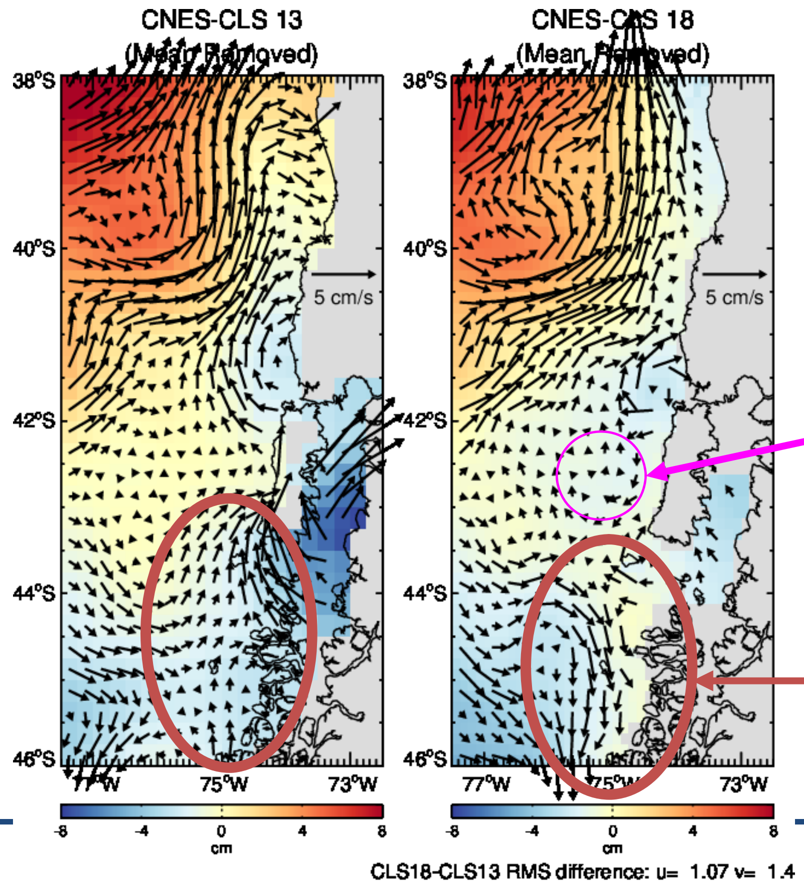
South Chile
Courtesy of Ted Strub

Super observation from Drifters
MDT CNES-CLS18



First guess
MDT CNES-CLS13

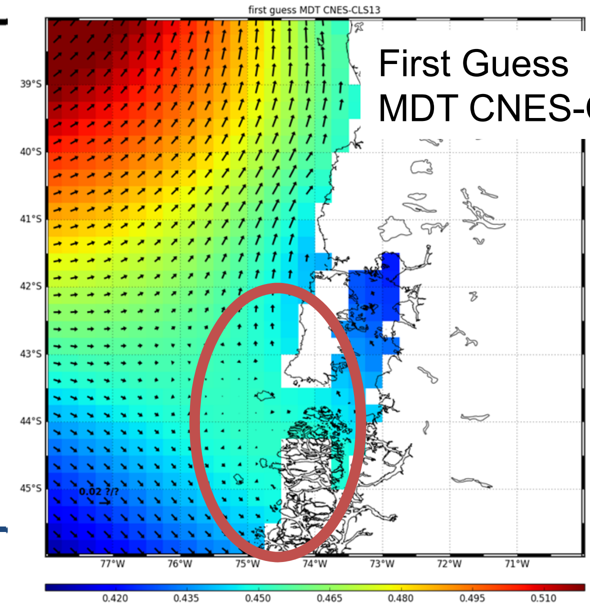




Is the eddy realistics ?
→May be due to one drifters observations
→ Associated error needs to be improved

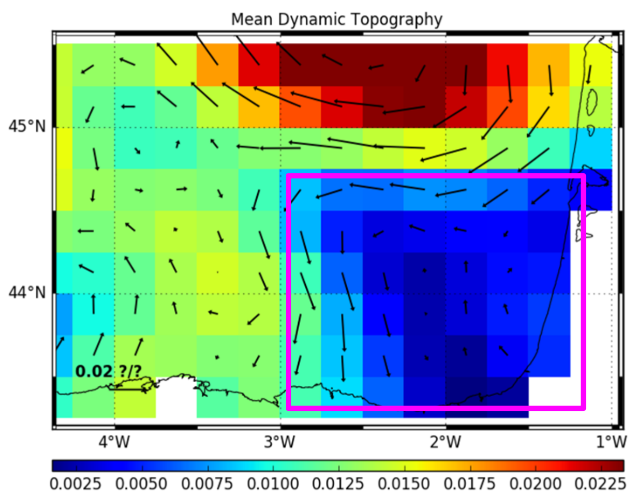
Much better thanks to the first guess !

First Guess
MDT CNES-CLS18

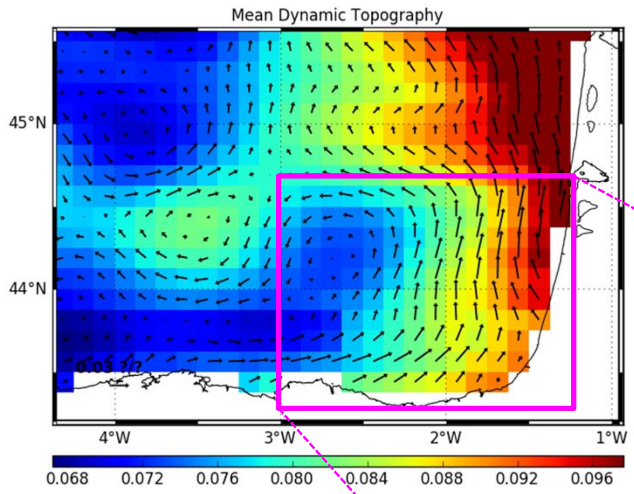


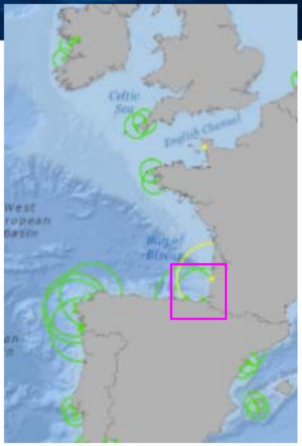
Circulation in the Bay Of Biscaye

MDT CNES-CLS13

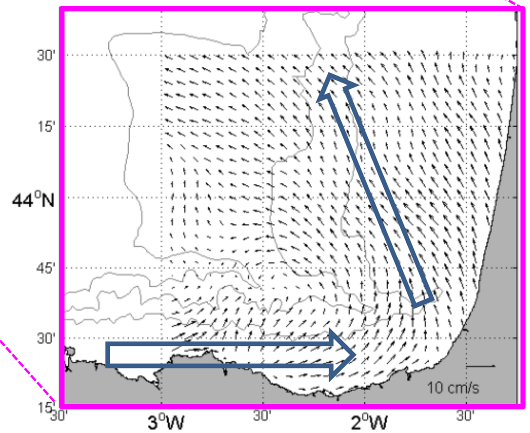


MDT CNES-CLS18





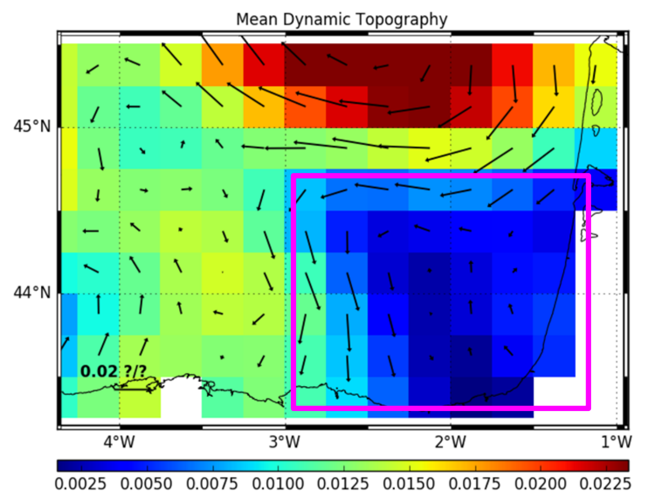
HF radar
Geostrophic mean current
2009-2018

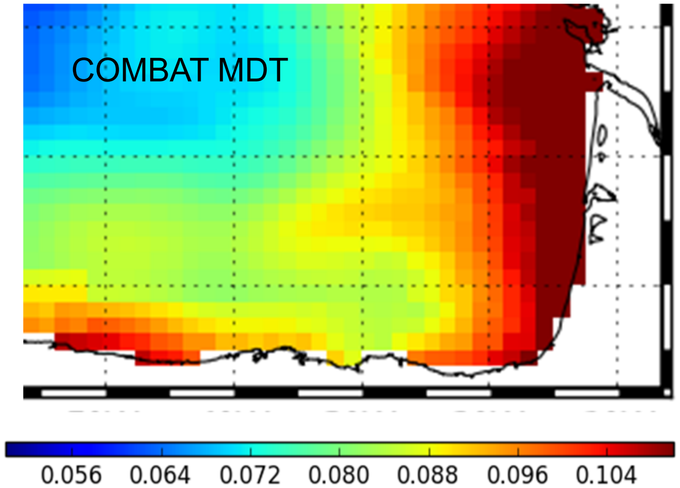


IPC: Iberian Poleward Current

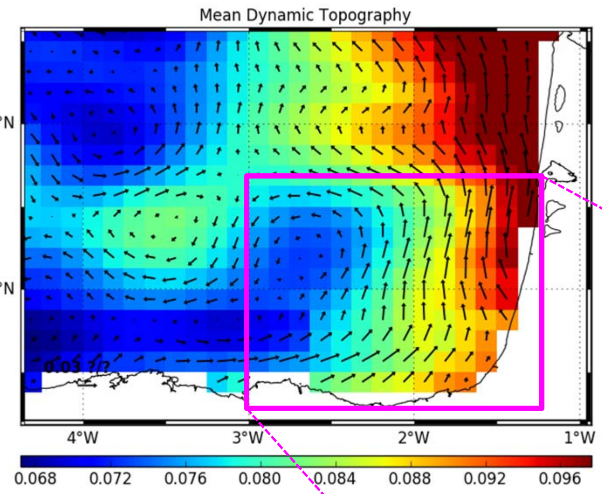
Circulation in the Bay Of Biscaye

MDT CNES-CLS13





MDT CNES-CLS18



HF radar
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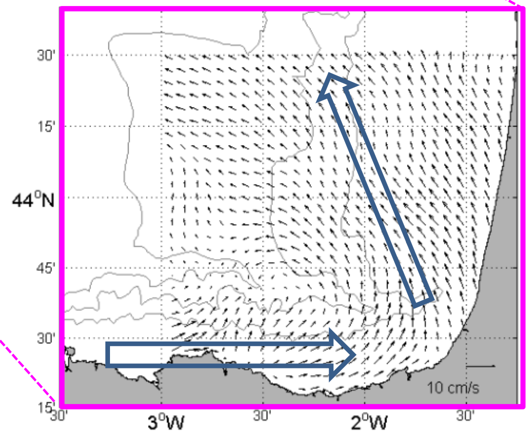
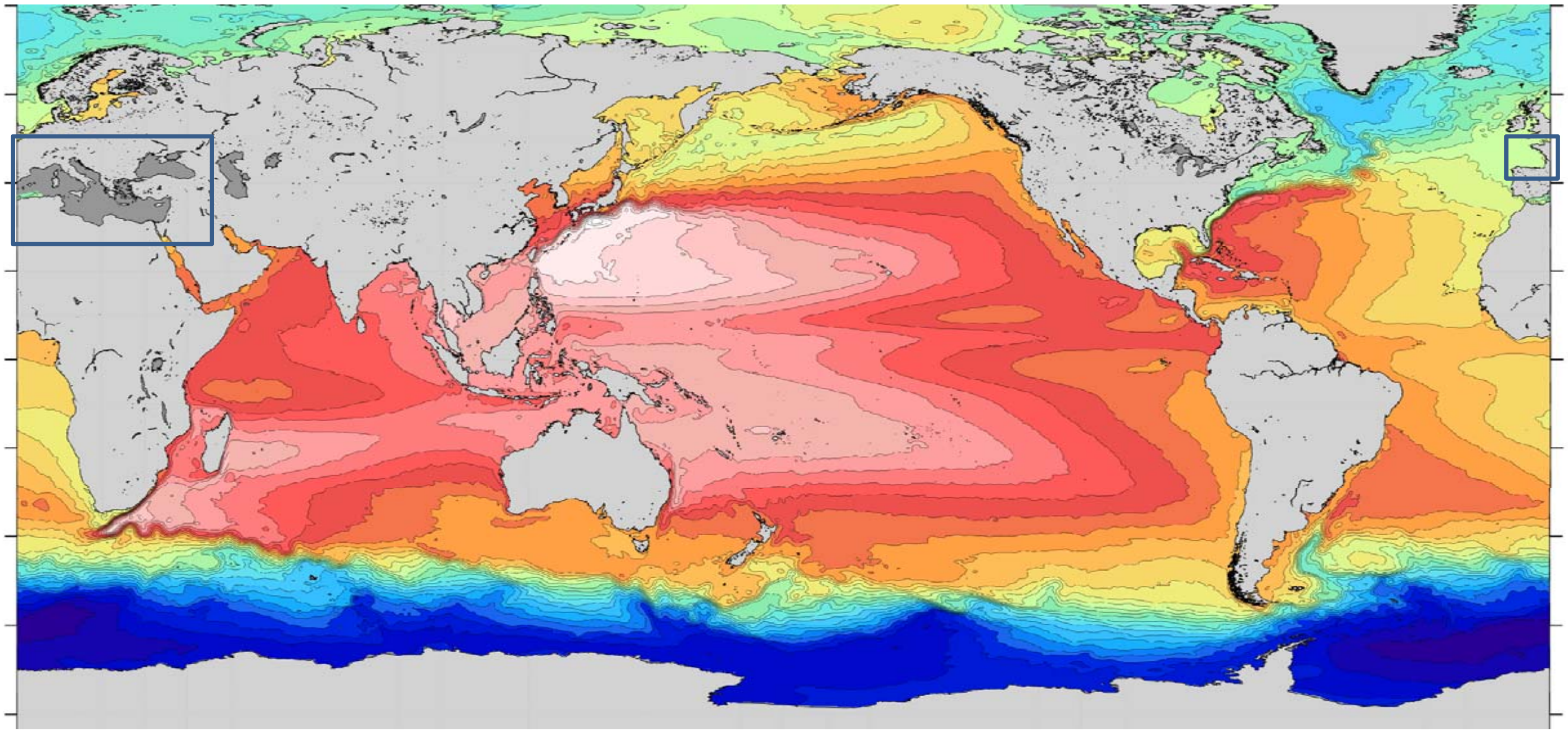


IPC: Iberian Poleward Current

Future work: regional MDTs CMEMNS



Very useful to compute regional MDTs

→ we learn a lot about limitations of global MDT

→ help to improve the GLOBAL

CONCLUSIONS

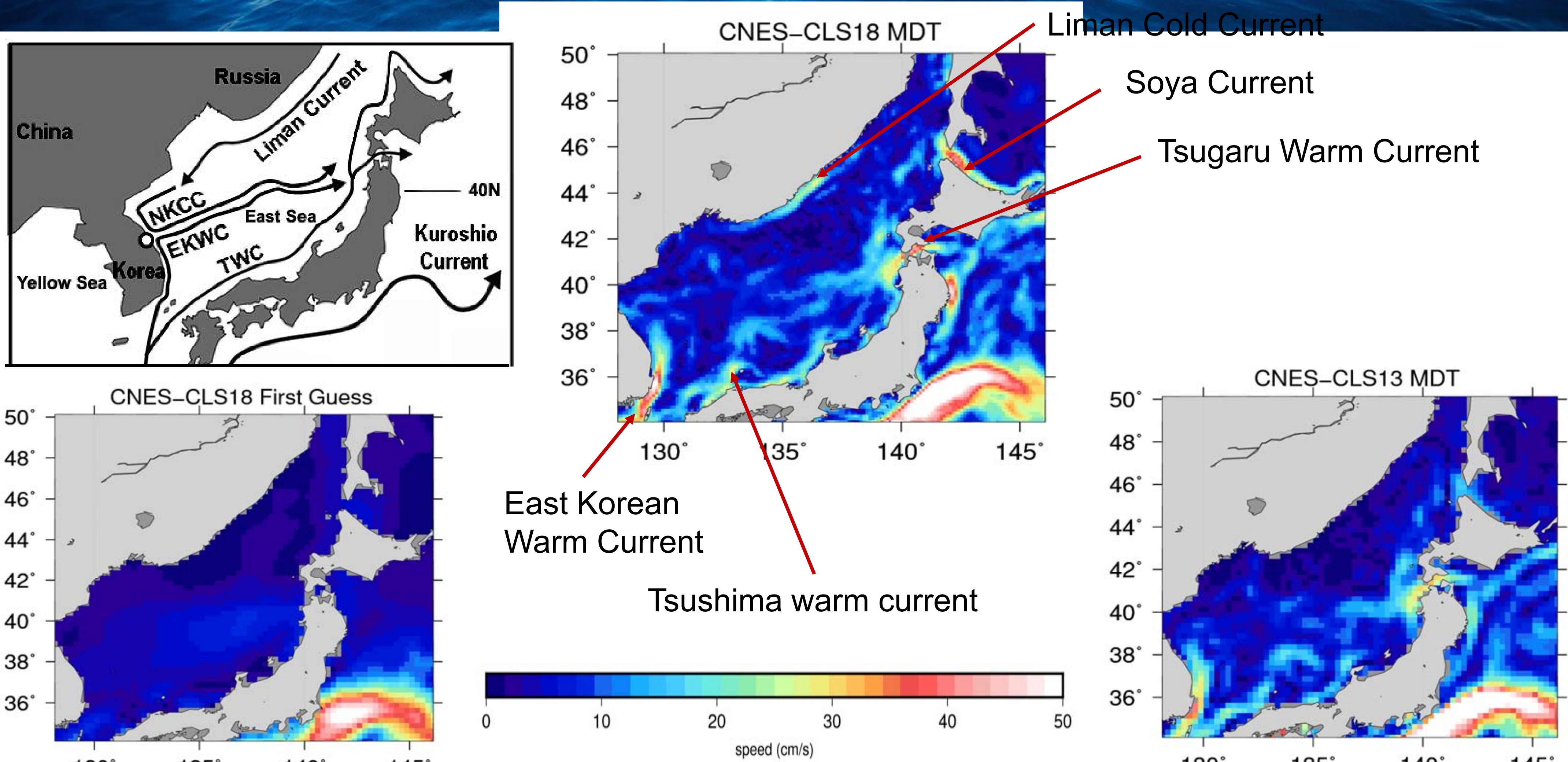
- Compared to the CNES-CLS13 solution, the New CNES-CLS18 MDT shows **improved performance everywhere**
- Most significant in **coastal** areas and in **strong western boundary currents**
- Validation/feedbacks done also by **beta users:** **Thanks a lot to all of them to theirs valuable feedbacks !!**

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

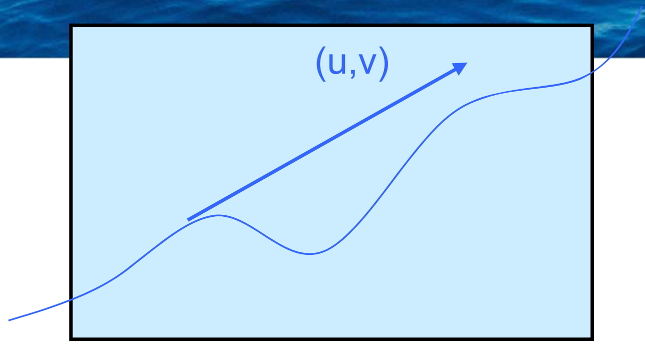
⇒ New in-situ observations are needed (HF radar), inclusion of other spaceborne measurements (SAR doppler, SST)

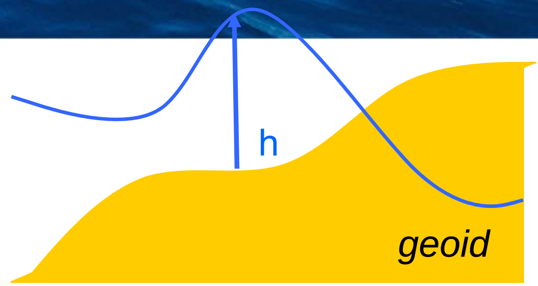
- Start to work on the next CNES-CLS MDT (2021 ?)
- If you are interested to be beta tester, let me know (smulet@groupcls.com)
- Do not hesitate to already give feedback about MDT CNES-CLS18 when available, feedbacks are always very helpful.
- Please inform us when you publish using CNES-CLS MDT

Mean Circulation in the Japan Sea



Computation of mean heights and mean geostrophic velocities from In-Situ

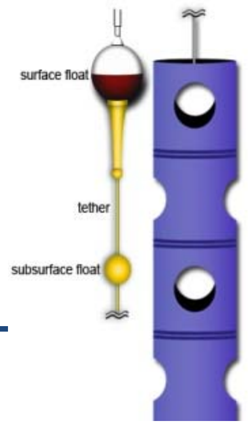




At each position r and time t for which an oceanographic in-situ measurement is available: dynamic height h (r,t) or surface velocity u(r,t),v(r,t)

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

- 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

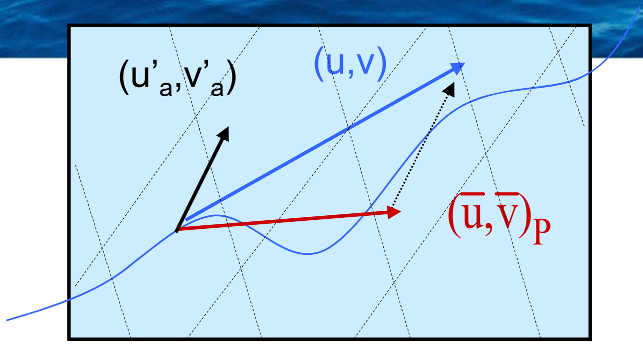


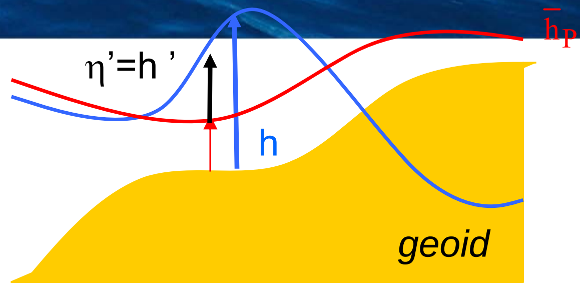
$$U_{buoy} = U_{geost} + U_{ekman} + U_{stokes} + U_{tides} + U_{inertial} + U_{ageost\_hf} (+U_{slip})$$

- Wind slippage correction for undrogued drifters
- Low pass filtering
- Modelization of Ekman/Stokes (wind driven) currents

NEW

Computation of mean heights and mean geostrophic velocities from In-Situ





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 to estimate a mean

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

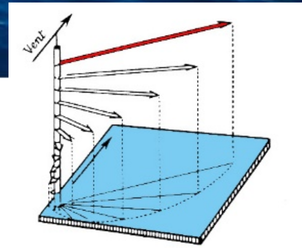
Modeling Wind-driven Currents (Ekman+Stokes) NEW MODEL

$$\vec{u}_w = \beta \, e^{i\theta} \, \vec{\tau}^{\alpha}$$

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

low pass filtered 30 hours

Wind stress from ERA INTERIM



MDT CNES-CLS13:

β and θ are estimated through least square fit by month and 4°x4° boxes

MDT CNES-CLS18:

β and θ = f(lat , MLD)

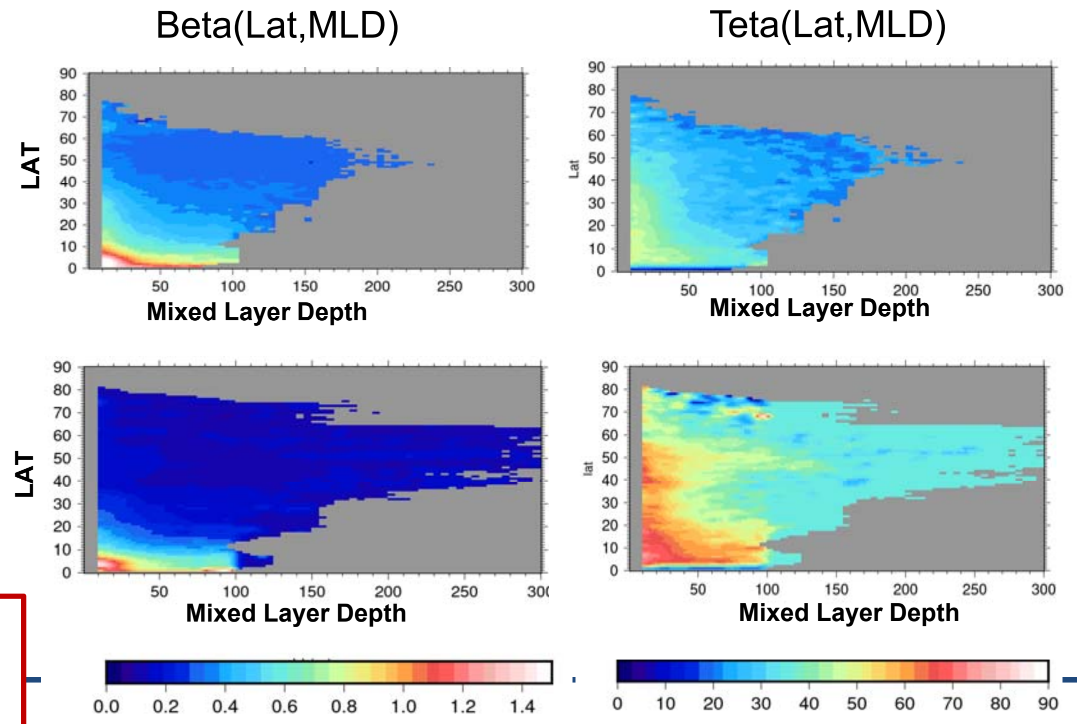
MLD
- Include temporal variability
- from the weekly CMEMS ARMOR3D T/S fields (*Guinehut et al, 2012*)

SURFACE

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

15m depth

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



Comparison with independant dataset
➔ % variance explained increases with the new model (~2%)

remote sensing

Article

Examining the Accuracy of GlobCurrent Upper Ocean Velocity Data Products on the Northwestern Atlantic Shelf

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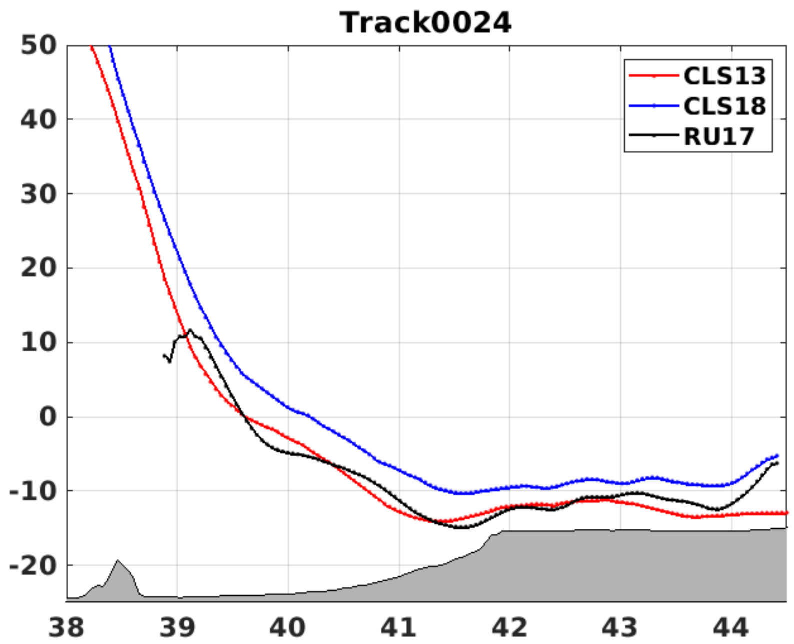

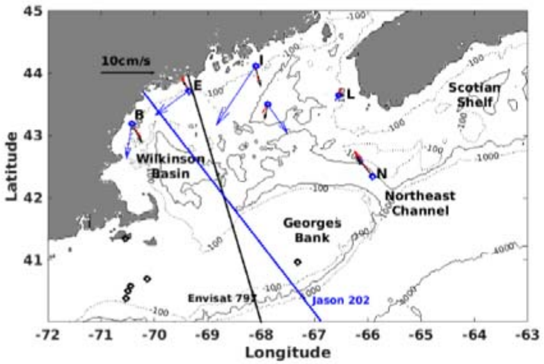

Figure 2. Mean upper ocean current vectors for both in situ ADCP current measurements and GlobCurrent products on the Northwest Atlantic shelf in the GoM. In situ data are depth-averaged mean current vectors U_{DA15m} in blue while GlobCurrent vector currents U_G (Geostrophic only) are in red and U_{GE15m} (Geostrophic and 15 m Ekman) are in black. Two satellite altimeter tracks (Envisat track E797, Jason track J202) are also shown.

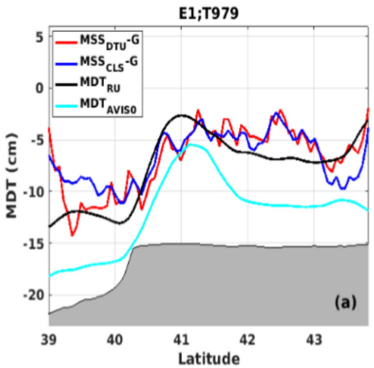

Figure 3. Derived mean dynamic topography (MDT) along (**a**) Envisat track E797 and (**b**) Jason track J202 from the western GoM across Georges Bank into the Atlantic slope region (Figure 2). Differing MDT estimates (see text) come from Mean Sea Surface (MSS) minus Geoid (G), either using MSS_{DTU} [6] or MSS_{CLS} [3] as well as from MDT_{AVISO} [4] and MDT_{RU} [48]. Grey areas depict the schematic bathymetry along these tracks. Note that the vertical offset between MDT_{RU} and MDT_{AVISO} is a matter of vertical datum but does not impact ocean dynamics.

% of variance explained by the models using independent dataset

Surface

	All LAT (206239 data)	
Model	%U	%V
OLD (MDT13)	29.04	16.62
NEW (MDT18)	32.64	18.61

15 m

	All LAT (1451989 data)	
Model	%U	%V
OLD (MDT13)	13.0	10.2
NEW (MDT18)	15.67	11.35

→ Comparison with independant dataset ➔ % Variance explained increases with the new model !