The New CNES-CLS18 Mean Dynamic Topography

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A **new Mean Dynamic Topography** has been computed for the global ocean using a similar method as described in Rio and Hernandez (2003), Rio et al. (2005), Rio et al. (2009), Rio et al (2014).

Compared to the previous CNES-CLS13 field, the main improvements are:

✓ The use of the latest GOCO05S geoid model (Mayer-Gürr T., et al., 2015) based on **$10^{1/2}$ years of GRACE** data and the entire reprocessed **GOCE data (Nov 2009-Oct 2013).**

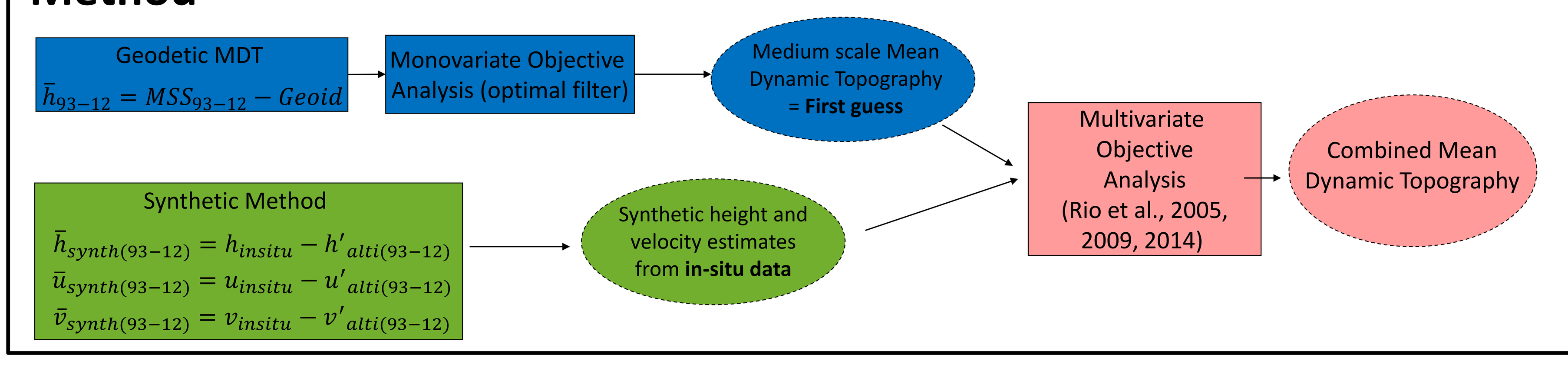
✓ The use of an **updated dataset of dynamic heights and drifting buoy velocities including Argo float surface velocities (1993-2016)**

✓ The use of an **improved processing to compute the first guess.**

✓ The use of an **improved Ekman model** to extract the geostrophic component of the buoy velocities.

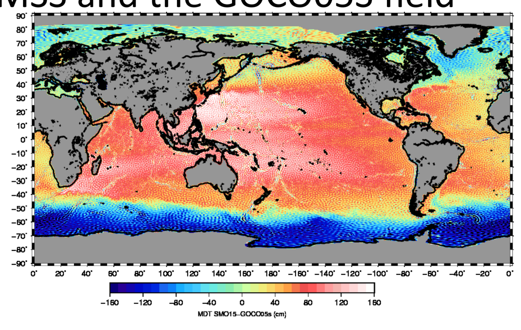
✓ Estimation was done on a **1/8° resolution grid** (instead of 1/4° for CNES-CLS13).

Method

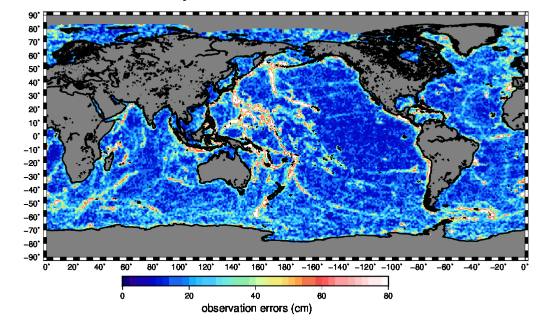


Computation of the geodetic MDT first guess through optimal filtering

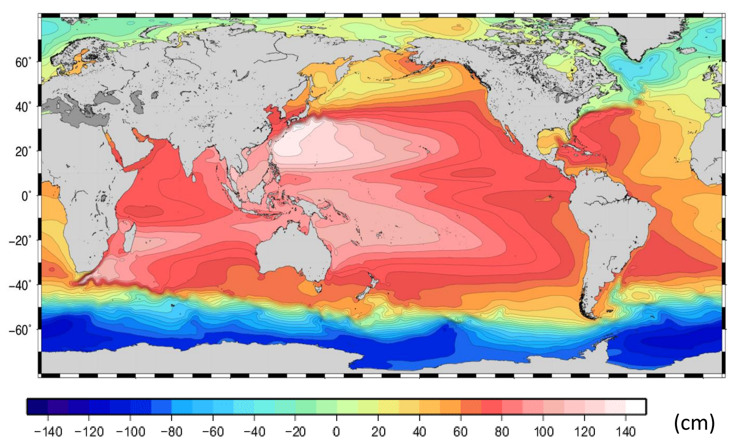
Difference between the CNES-CLS15 MSS and the GOCO05S field



Observation error = Standard deviation of the differences between the (CNES-CLS15 MSS – GOCO05S) and the MDT CNES-CLS13



FIRST GUESS: Medium scale MDT estimated from GRACE/GOCE and MSS CNES-CLS15



Estimate of synthetic MDT and associated synthetic mean current from in-situ data

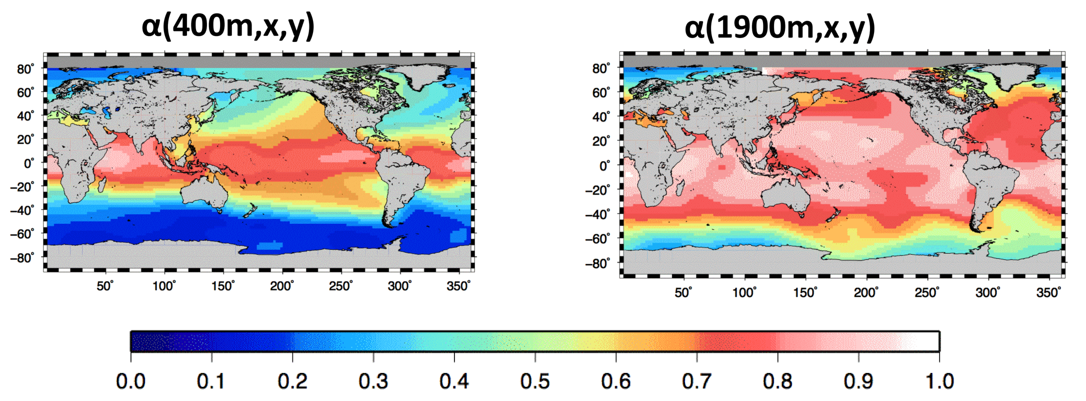
❑ Updated dataset of synthetic mean heights

➢ Computation of **instantaneous dynamic height** relative to the depth Pref ($hdyn_{/Pref}(t,x,y)$) from T/S profiles (CORA ; 1993-2016)

➢ The baroclinic component of the sea level variability is computed for the different reference depths (Guinehut et al., 2006) and removed to compute **mean dynamic height**

$$\bar{h}dyn_{/Pref}(x,y) = hdyn_{/Pref}(t,x,y) - \alpha(p_{ref},x,y) * SLA(t,x,y)$$

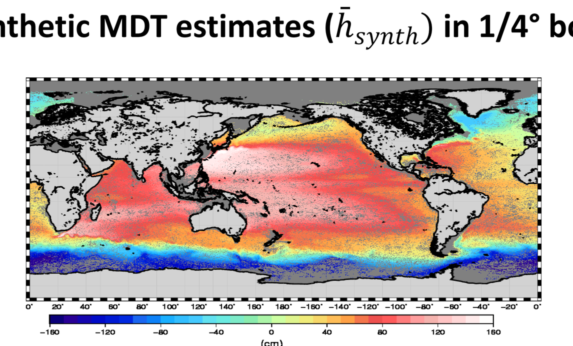
α(400m,x,y) **α(1900m,x,y)**

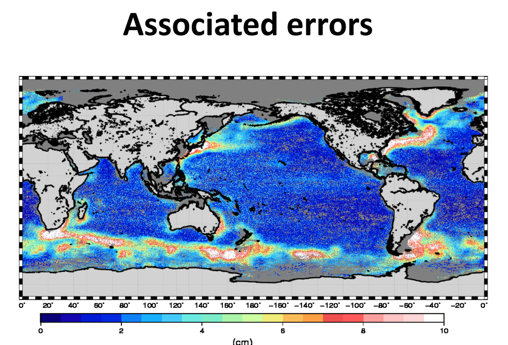


➢ The missing quantity (barotropic + baroclinic deeper than Pref) is estimated from the first guess – climatology/Pref and added.

$$\bar{h}_{synth}(x,y) = \bar{h}dyn_{/Pref}(x,y) + \left[MDT\ first\ guess - \bar{h}dyn^{CLIM}_{/Pref}(x,y)\right]$$

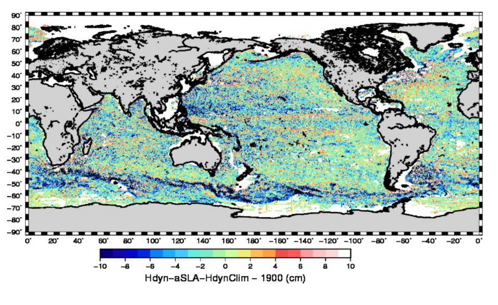
Synthetic MDT estimates ($\bar{h}_{synth}$) in 1/4° boxes **Associated errors**





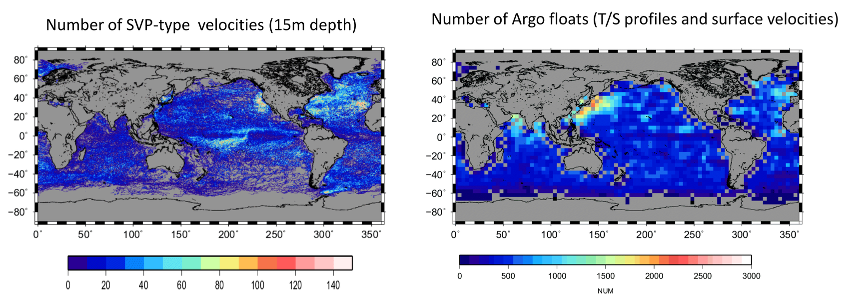
➢ The valuable signal added in the multivariate objective analyses is the smaller scales of the mean dynamic height:

$$\bar{h}dyn_{synth_{/Pref}}(x,y) - \bar{h}dyn^{CLIM}_{/Pref}(x,y)$$



❑ Updated dataset of synthetic mean velocities

➢ 15m-drogued and undrogued SVP drifting buoy velocities from 1993 to 2016
➢ Argo float surface velocities(YOMAHA database from 1997 to December 2012)
➢ Undrogued SVP buoys corrected from Wind Slippage
➢ Ekman currents at surface and 15m depth have been modelled and subtracted
➢ Further Max($\frac{2\pi}{f}$, 30h) low pass filtering has been applied to remove inertial and tidal currents
➢ Altimetric velocity anomalies have been interpolated along the buoy trajectory and removedto estimate mean currents

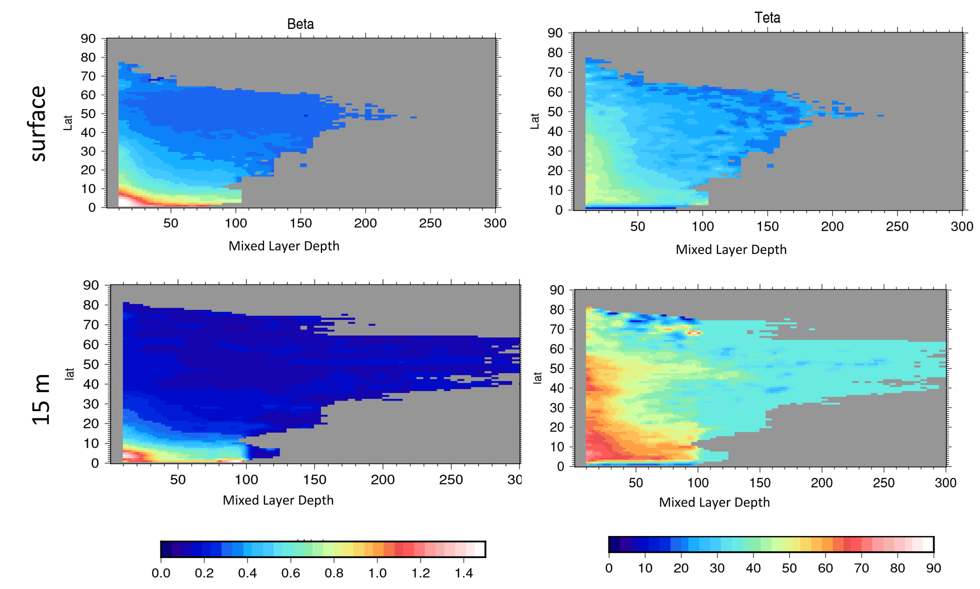


New wind-driven model (Ekman and Stockes)

➢ Uw(z=0m) and Uw(z=15m) are estimated by subtracting the altimeter geostrophic velocities from the Argo float surface velocities and the 15m depth SVP velocities respectively (+30h low pass filtered)
➢ β and θ are estimated through least square fit as a function of Mixed Layer Depth (MLD) and latitude. The MLD is derived from the weekly ARMOR3D T/S fields (Guinehut et al, 2012)

$$\vec{u}_w(z=0) = \beta_0 e^{i\theta_0} \vec{\tau}^{0.6} \qquad \vec{u}_w(z=15) = \beta_{15} e^{i\theta_{15}} \vec{\tau}^{0.7}$$

τ is the 3 hourly ERA-INTERIM wind stress, Uw is the wind-driven component (Ekman and Stokes)

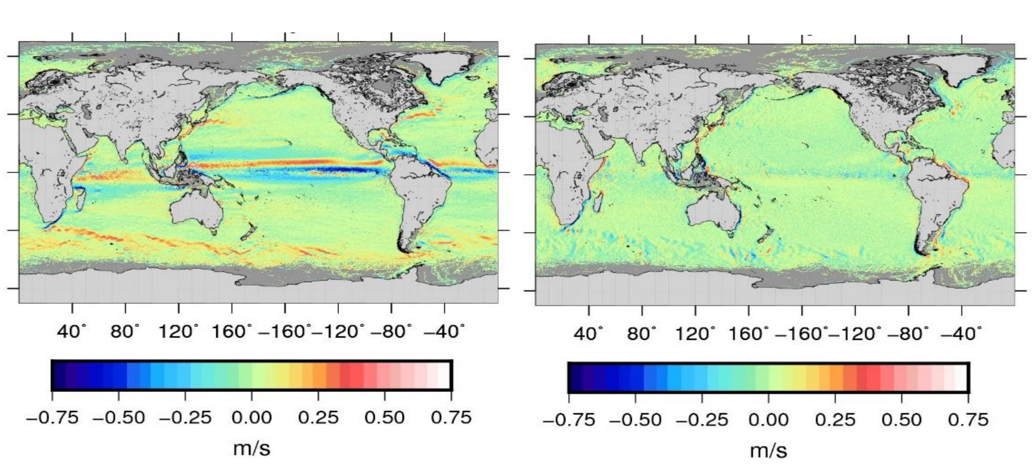


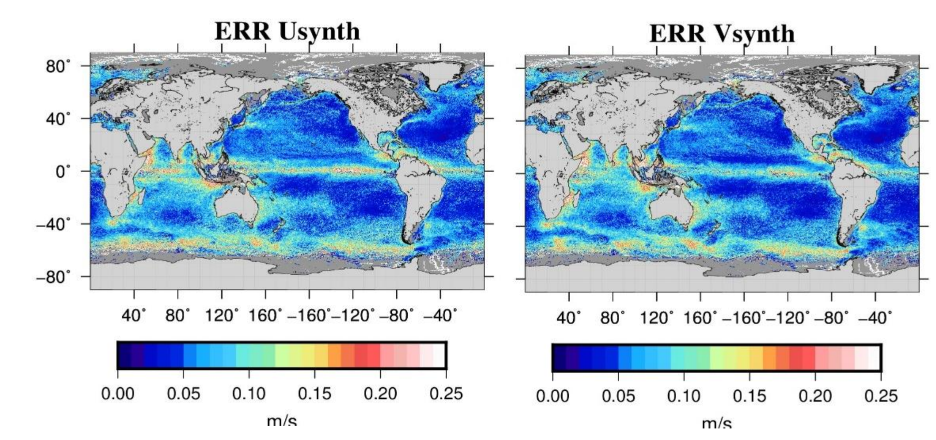
% of variance explained by the wind-driven models using independent dataset

	All LAT (206239 data)		|LAT|>5 (991460)		|LAT|<5 (86551)	
Model	%U	%V	%U	%V	%U	%V
OLD	29.04	16.62	31.53	18.12	21.08	9.33
NEW	32.64	18.61	34.12	20.11	27.90	11.33

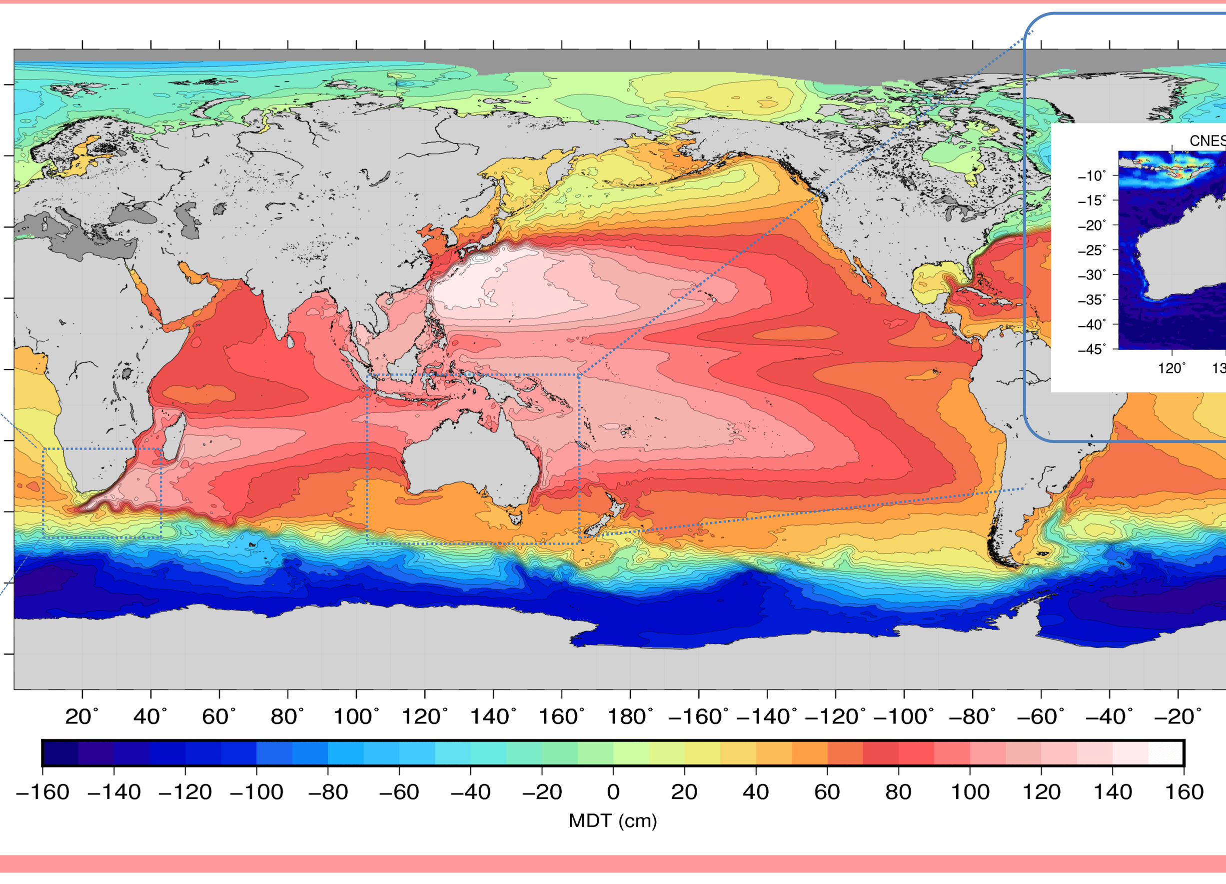
	All LAT (1451989 data)		|LAT|>5 (1346484)		|LAT|<5 (105259)	
Model	%U	%V	%U	%V	%U	%V
OLD	13.0	10.2	13.82	10.86	10.8	7.45
NEW	15.67	11.35	15.33	11.67	16.37	9.93

Synthetic Velocity estimates in 1/8° boxes

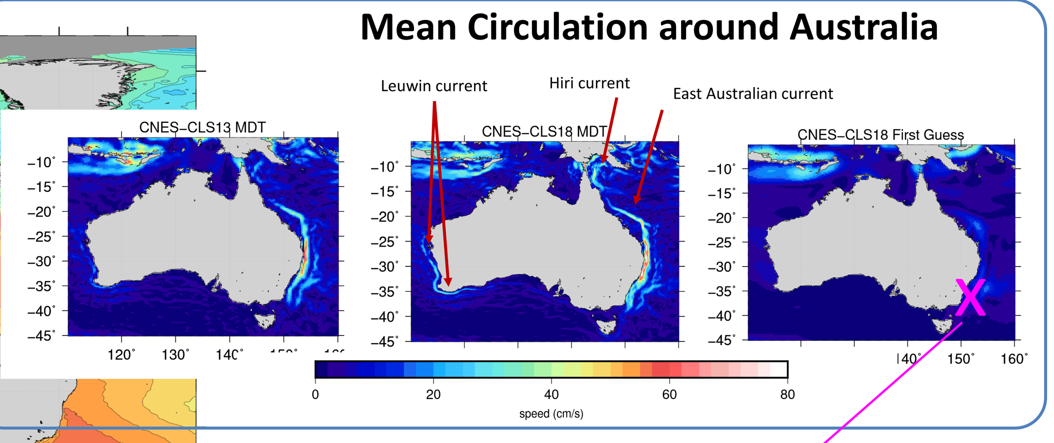




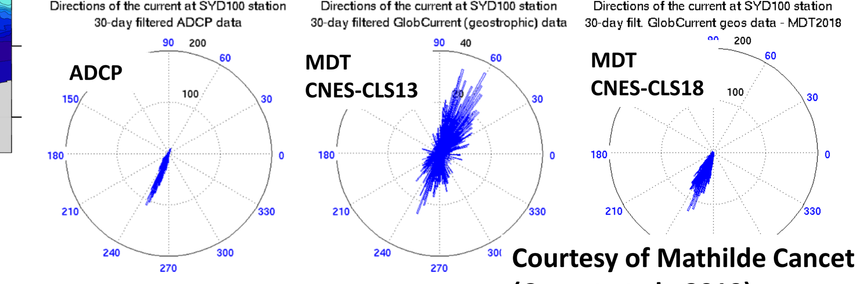
Combination of the first guess and in-situ data through multivariate objective analysis → MDT CNES-CLS18 (1/8°)



Mean Circulation around Australia

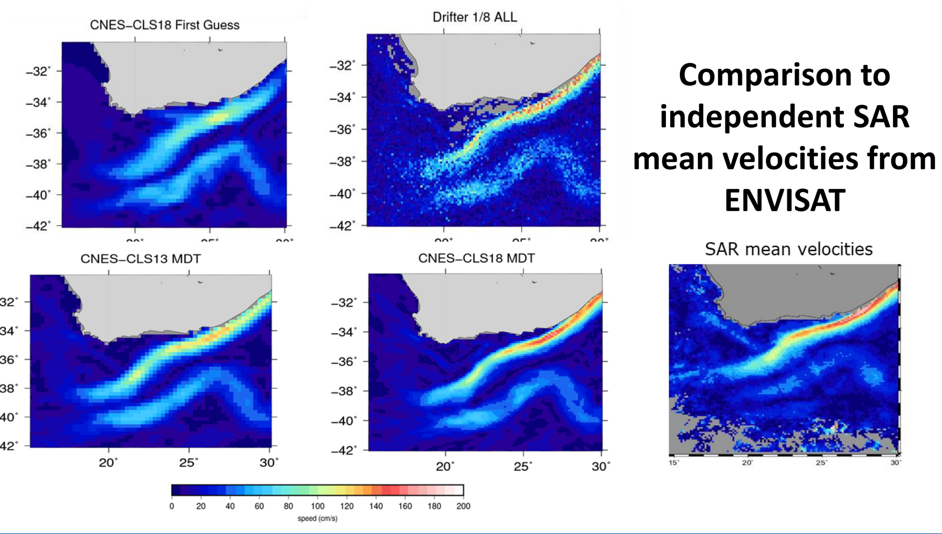


Comparison with ADCP



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

Mean Circulation in the Aghulas current



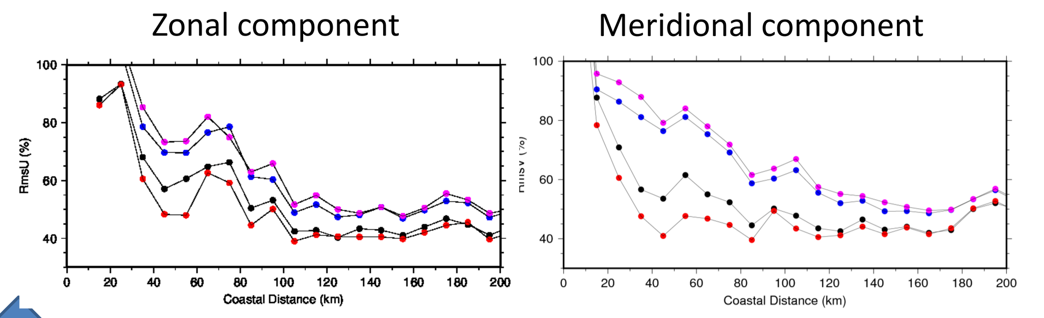
Comparison to independent SAR mean velocities from ENVISAT

Validation:

❑ Comparison with independant drifter velocities

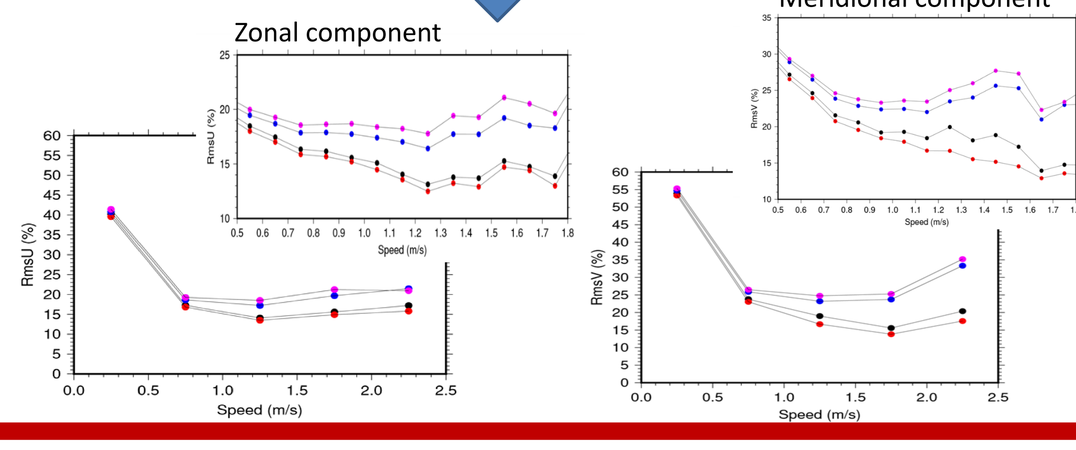
Both the old CNES-CLS13 and the new CNES-CLS18 geostrophic mean velocities have been added to the altimeter derived geostrophic velocity anomalies to get daily maps of absolute geostrophic velocities. These velocities have then been interpolated along the drifter trajectories and compared to the drifter velocities as a function of coastal distance and oceanic variance level

Zonal component Meridional component

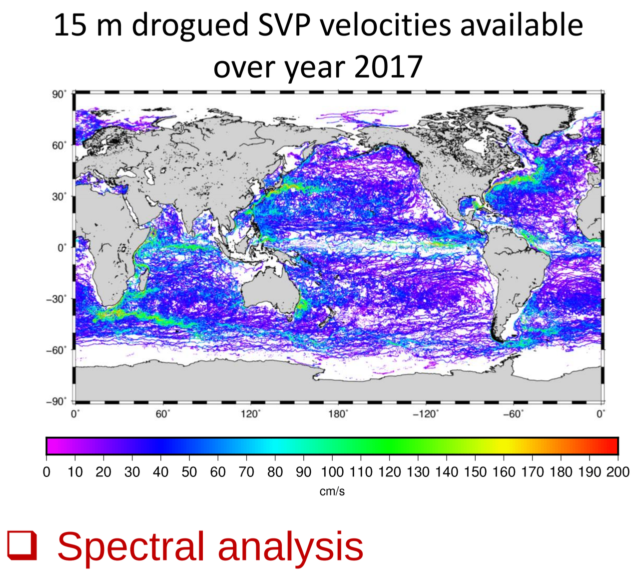


Significant improvement is obtained in coastal areas and in strong currents

Zonal component Meridional component

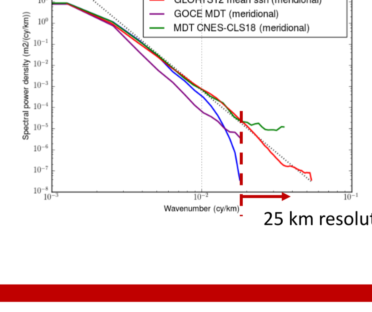


15 m drogued SVP velocities available over year 2017



❑ Spectral analysis

Increased energy is found at short scales in the new MDT CNES-CLS18 compared to either the first guess and the previous MDT CNES-CLS13. The energy level is in good agreement with MDT from GLORYS12 (average over 1993-2012 of the dynamic topographies from the 1/12° numerical model from Mercator Ocean) until 25 km of resolution



Averaged meridional spectra in the Antarctic Circumpolar Current

Conclusion

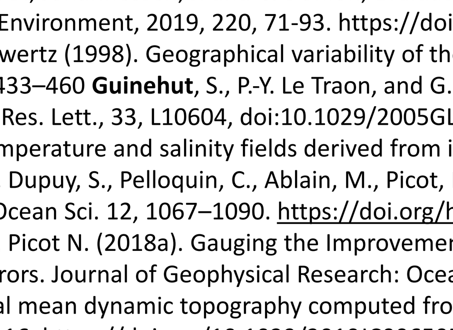
A new global 1/8° CNES-CLS18 Mean Dynamic Topography (MDT) and associated mean geostrophic currents has been estimated for reference period 1993-2012 (the same reference period than the CMEMS/AVISO Sea Level Anomalies (SLA)).

It is shown to resolve shorter spatial scales than previous CNES-CLS13 MDT. Significant improvement are obtained in strong and energetic currents and in (near) coastal areas.

In the context of the upcoming high resolution altimetry SWOT mission, further improvements are still needed mainly in coastal areas, at high latitudes and in strongly stratified areas where the expected spatial scales of the geostrophically balanced motion are smaller in accordence with the First Baroclinic Rossby Radius of Deformation (Chelton et al., 1998)

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

High latitudes — Shallow waters, Coastal areas — Highly stratified areas



First Baroclinic Rossby Radius of Deformation:

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References: Cancet, M., Griffin, D., Cahill, M., Chapron, B., Johannessen, J. and C. Donlon, Evaluation of GlobCurrent surface ocean current products: a case study in Australia, Remote Sensing of Environment, 2019, 220, 71-93. https://doi.org/10.1016/j.rse.2018.10.029. **Chelton** D. B., R. A. deSzoeke, M. G. Schlax, K. El Naggar et N. Siwertz (1998). Geographical variability of the first baroclinic rossby radius of deformation. Journal of Physical Oceanography, 28(3):433–460 **Guinehut**, S., P.-Y. Le Traon, and G. Larnicol (2006), What can we learn from global altimetry/hydrography comparisons?, Geophys. Res. Lett., 33, L10604, doi:10.1029/2005GL025551. **Guinehut S**., A.-L. Dhomps, G. Larnicol et P.-Y. Le Traon (2012). High resolution 3-D temperature and salinity fields derived from in situ and satellite observations. Ocean Sci., 8(5):845–857. **Pujol,** M.-I., Faugère, Y., Taburet, G., Dupuy, S., Pelloquin, C., Ablain, M., Picot, N., 2016. DUACS DT2014: the new multi-mission altimeter data set reprocessed over 20 years. Ocean Sci. 12, 1067–1090. https://doi.org/https://doi.org/10.5194/os-12-1067-2016 **Pujol** I, Schaeffer P, Faugere Y, Raynal M, Dibarboure G, Picot N. (2018a). Gauging the Improvement of Recent Mean Sea Surface Models: A New Approach for Identifying and Quantifying Their Errors. Journal of Geophysical Research: Oceans. 20 10.1029/2017JC013503. **Rio**, M.H., Guinehut, S., Larnicol, G., 2011. New CNES-CLS09 global mean dynamic topography computed from the combination of GRACE data, altimetry, and in situ measurements. J. Geophys. Res. 116. https://doi.org/10.1029/2010JC006505 **Rio,** M.-H., Hernandez, F., 2004. A mean dynamic topography computed over the world ocean from altimetry, in situ measurements, and a geoid model. J. Geophys. Res. 109, C12032. https://doi.org/10.1029/2003JC002226 **Rio,** M.-H., Mulet, S., Picot, N., 2014. Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents. Geophys. Res. Lett. 41, 2014GL061773. https://doi.org/10.1002/2014GL061773 **Taburet,** G., Sanchez-Roman, A., Ballarotta, M., Pujol, M.-I., Legeais, J.-F., Fournier, F., Faugere, Y., and Dibarboure, G.: DUACS DT-2018: 25 years of reprocessed sea level altimeter products, Ocean Sci. Discuss., https://doi.org/10.5194/os-2018-150, in review, 2019.