Impact of using an improved Mean Dynamic Topography on the Mercator-Ocean analysis and forecasts.

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OUTLINE

- Some words about observation-based Mean Dynamic Topography (MDT) calculation
- Why does Mercator Ocean require a MDT?
- A recent OSE study aiming at quantifying the impact of improved Observation-based MDT on the model analysis and forecasts

Mean Dynamic Topogra

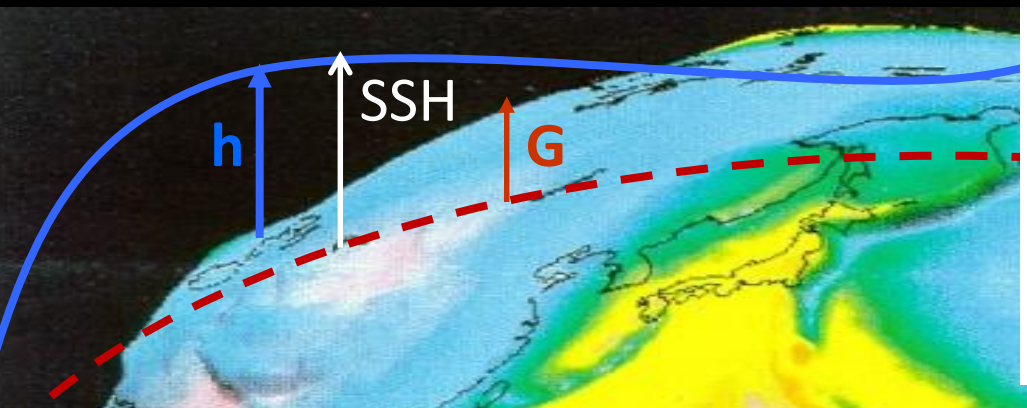
Some very simple equations

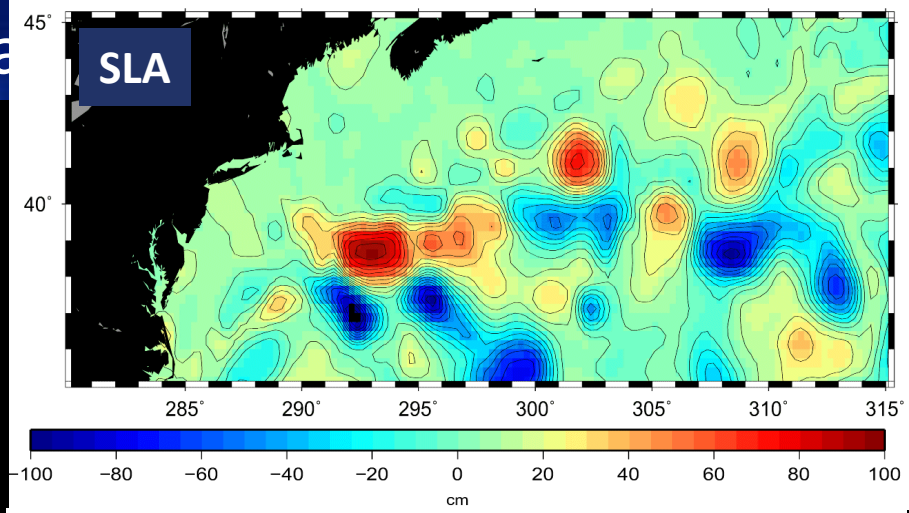
SSH=h+G ⟷ h=SSH-G

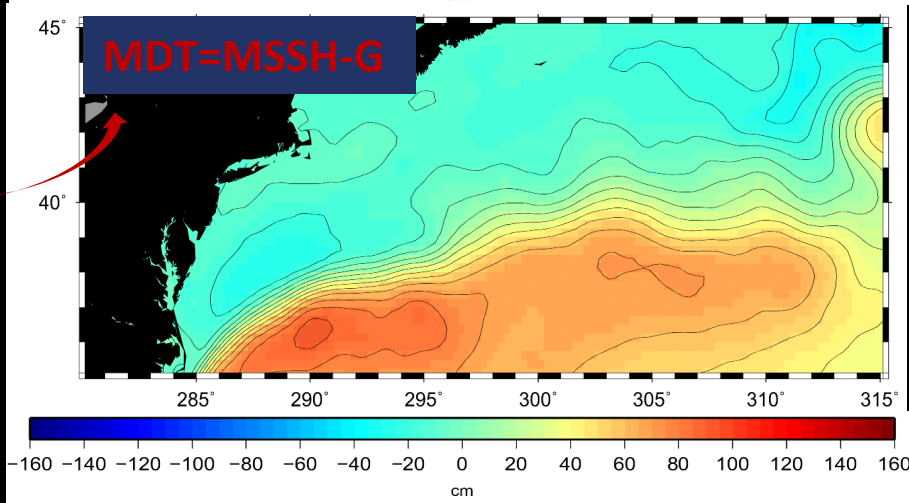
MSSH=MDT+G ⟷ MDT=MSSH-G

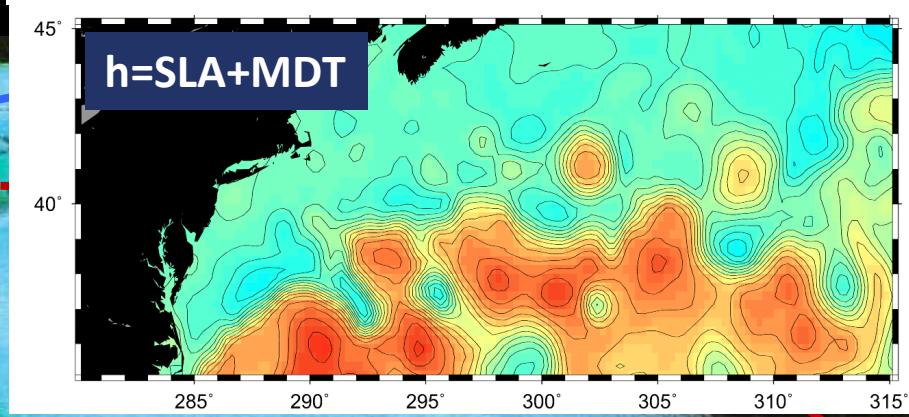
SSH-MSSH=h-MDT=SLA

h=SLA+MDT









Calculation of external, observation-based MDT

Rio et al, 2004, 2011, 2014a (global ocean)

Rio et al, 2007, 2014b (Mediterranean Sea)

Direct Method

MDT=MSS-Geoid

filtering

Medium scale (~100km)
« geodetic »MDT
=First guess

Synthetic Method

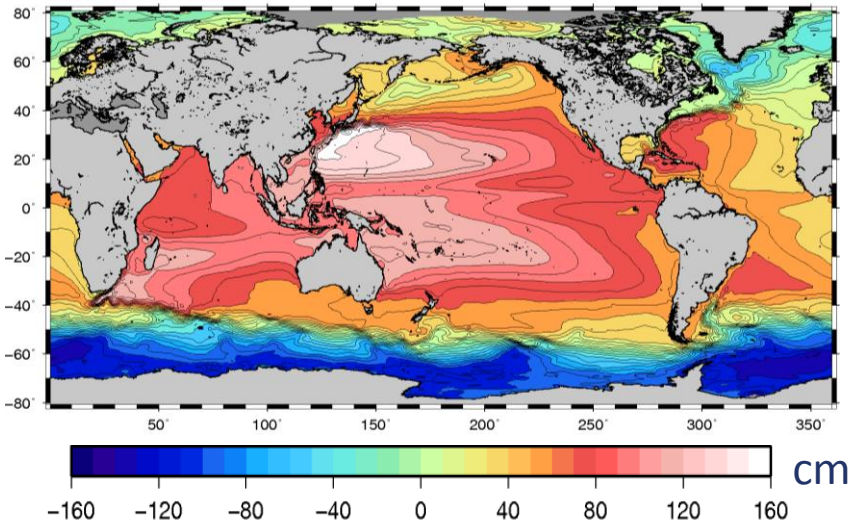
The short scales of the MDT (and corresponding geostrophic currents) are estimated by combining altimetric anomalies and in-situ data

Multivariate Objective Analysis

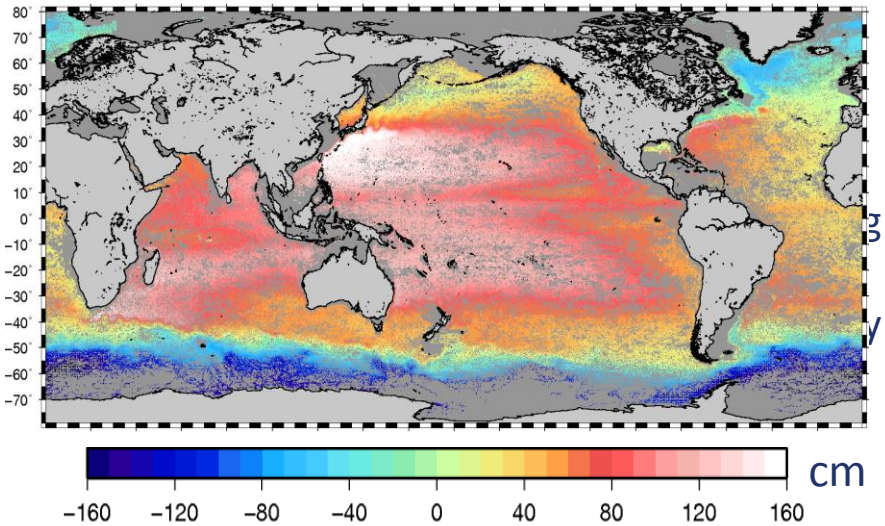
High resolution MDT

The CNES-CLS13 MDT (Rio et al, 2014)

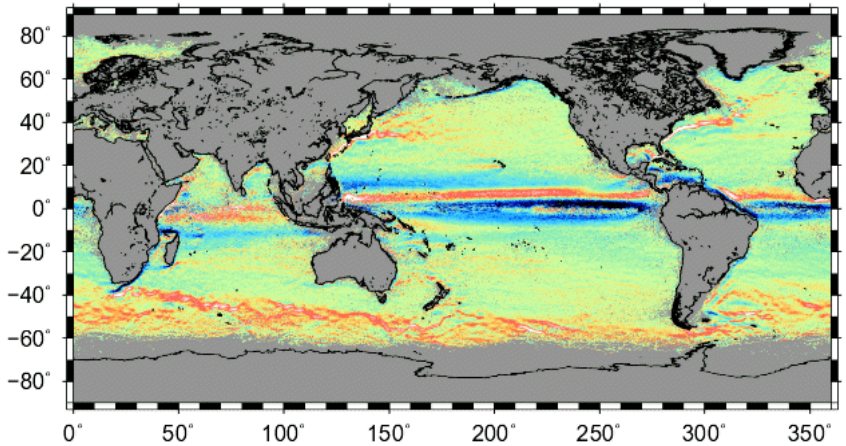
First Guess = MSS - Geoid
OPTIMALLY FILTERED



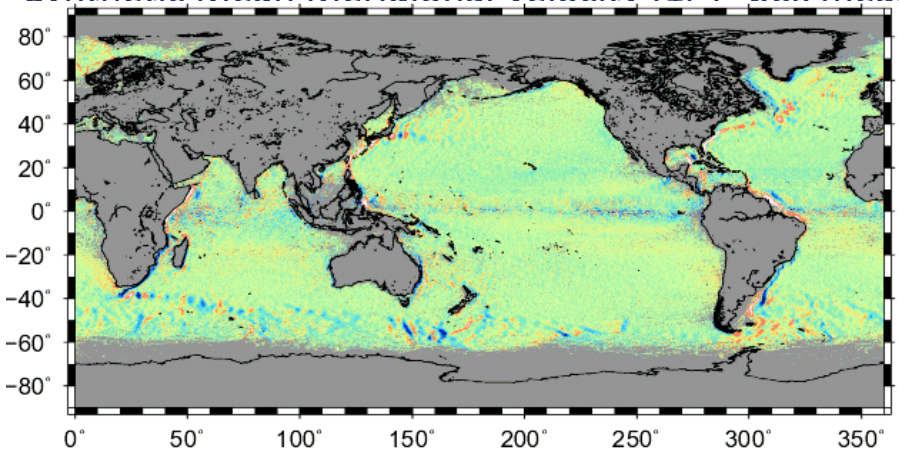
Synthetic Mean Heights (1/4° box means)

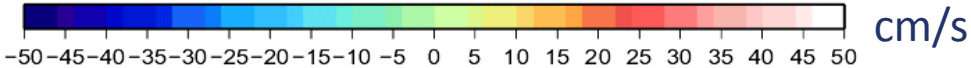


Synthetic Mean Zonal Velocity (1/4° box means)

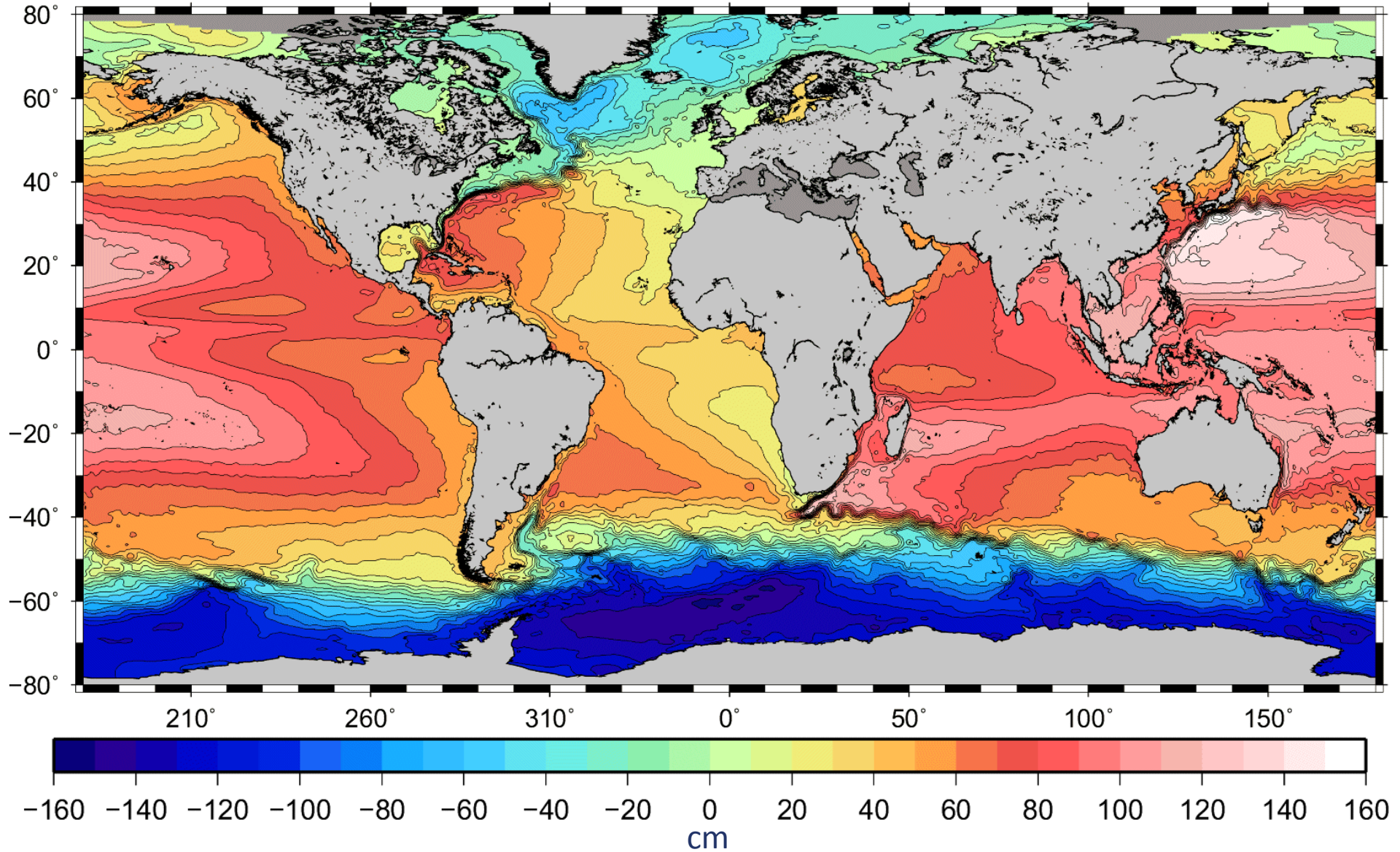


Synthetic Mean Meridional Velocity (1/4° box means)

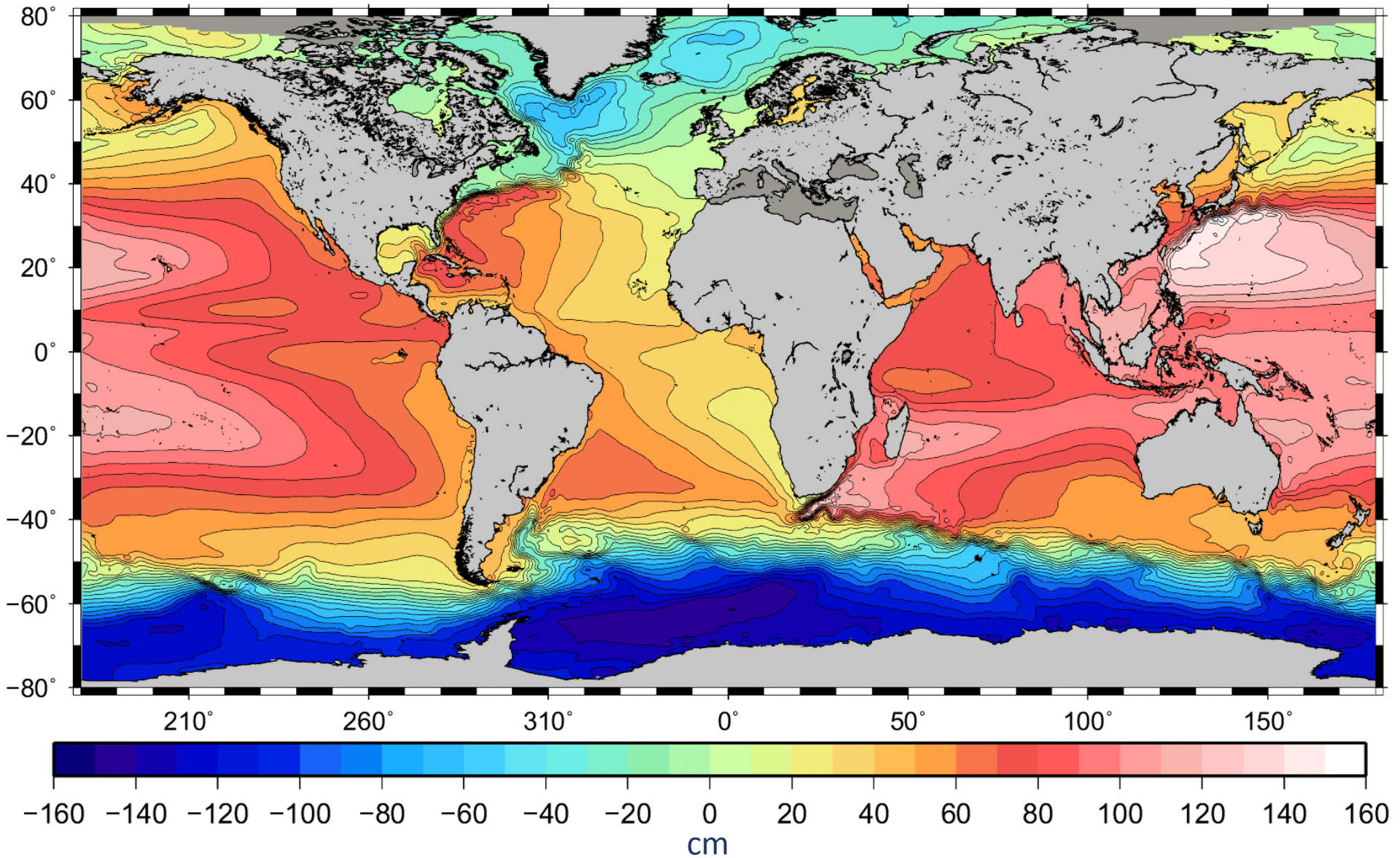




The CNES-CLS13 MDT



The GOCE only MDT (First Guess)



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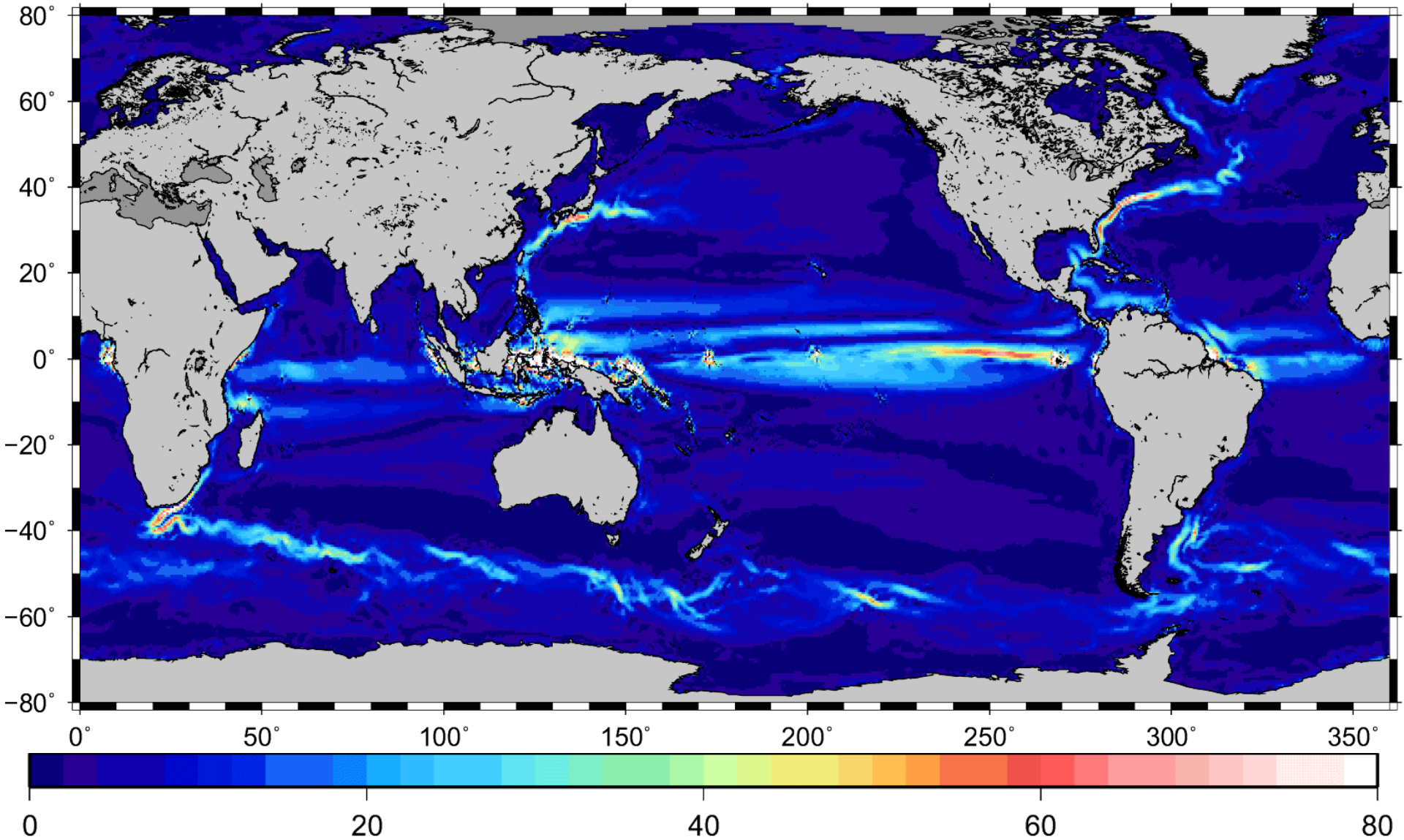
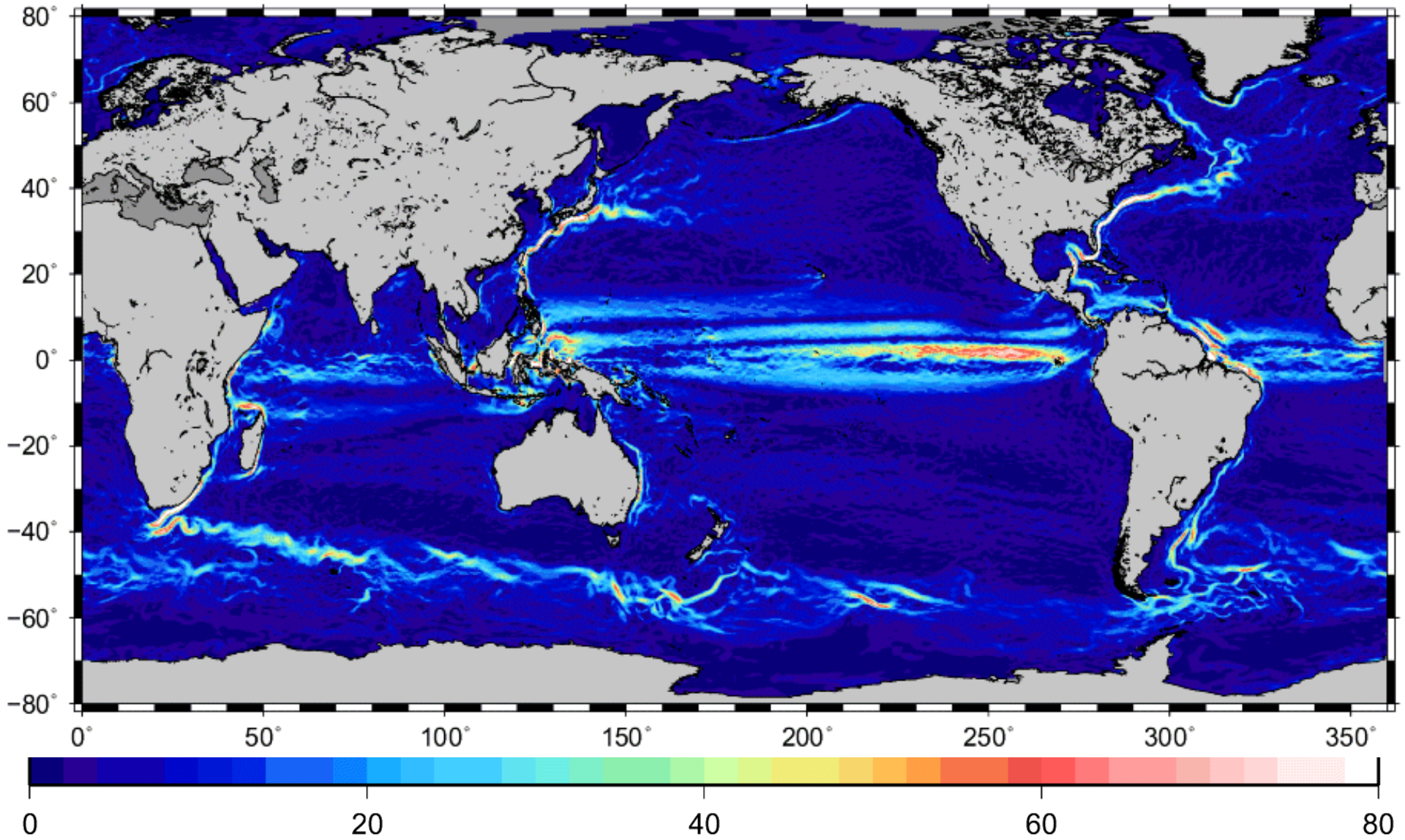


The CNES-CLS13 MDT



Why does Mercator-Ocean require a MDT?

Mercator Ocean is operating in near real time ocean analysis and forecasting systems.

The global ocean model solution is driven toward the in situ and satellite observations thanks to the data assimilation.

- The Ocean Numerical Model NEMO represents the Dynamical Topography of the ocean.
- The satellite altimeters provide the along the track Sea Level Anomalies.

→ to constrain the evolution of the dynamical topography of the ocean model with the observed along track Sea Level Anomaly, a Mean Dynamical ocean Topography is required:

DT Ocean = Mean DT + SLA

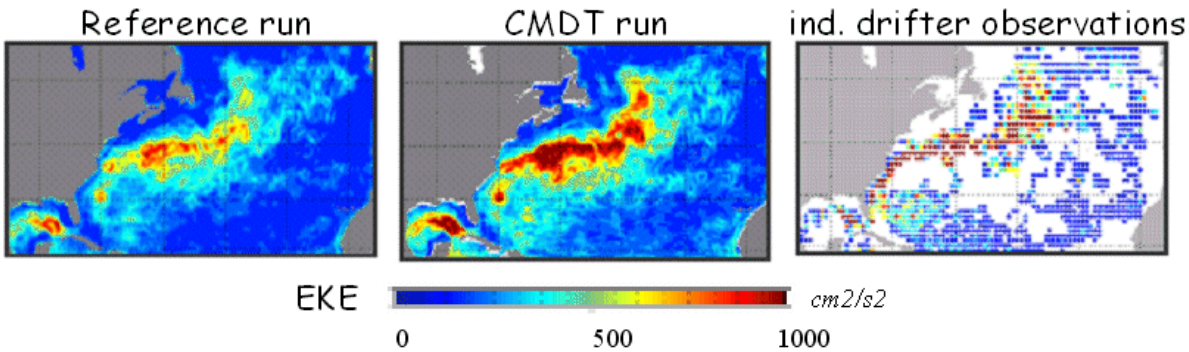
Why does Mercator-Ocean require a MDT?

Back to the past: a slide from the 2nd GODAE OSE-OSSE workshop, Toulouse, June 4-5, 2012

Example in the Mercator system

- A twin experiment was used covering 8 months (starting in September 2001) to compare the model outputs (analyses and forecasts) using the model MDT (OLD RUN) or the observed MDT (NEW RUN).
- **OLD RUN**: Model MDT from 1/3° PSY1v1 MERCATOR forced model run (i.e. no assimilation) covering Jan 1992 to Dec 1995
- **NEW RUN**: Observed MDT (Rio et al, 2004)

8 months EKE in the Gulf Stream



Haines et al, 2011: *An ocean modelling and assimilation guide to using GOCE geoid products*

Twin experiment configuration

A twin experimenthas been run at Mercator to investigate the impact of an improved MDT on the model analysis and forecasts.

- PSY3V4R1 configuration, ¼°
- 18 months twin experiment: from May, 14th 2014 to December, 30th 2015
- 7days assimilation cycle
- ECMWF atmospheric forcing
- Data assimilated:
  - daily SST maps (AVHRR-AMSR)
  - in-situ T/S profiles
  - altimeter Sea Level Anomalies (Jason 2, Cryosat 2,Hayiang 2 et Saral/Altika)

The only difference between the two run is the Mean Dynamic Topography assimilated:

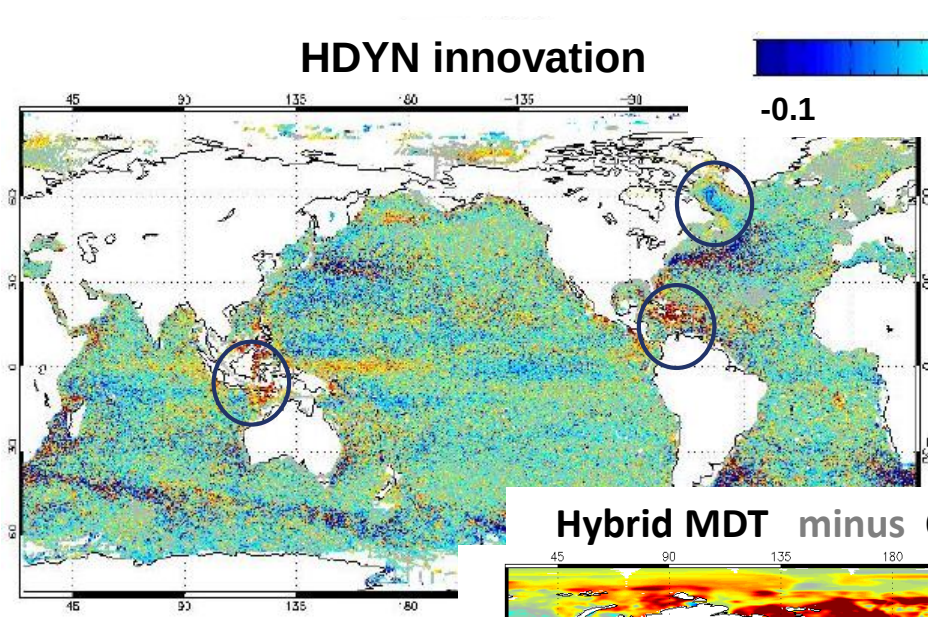
- OSE V2: the assimilated hybrid MDT is based on the CNES-CLS09 MDT from Rio et al (2011)
- OSE V3: the assimilated hybrid MDT is based on the CNES-CLS13 MDT from Rio et al (2014)

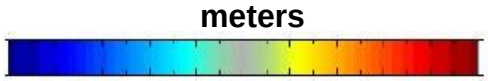
Main differences between the CNES-CLS09 and CNES-CLS13 MDT: the **use of the GOCE geoid model instead of GRACE**, the use of an **updated in-situ dataset**.

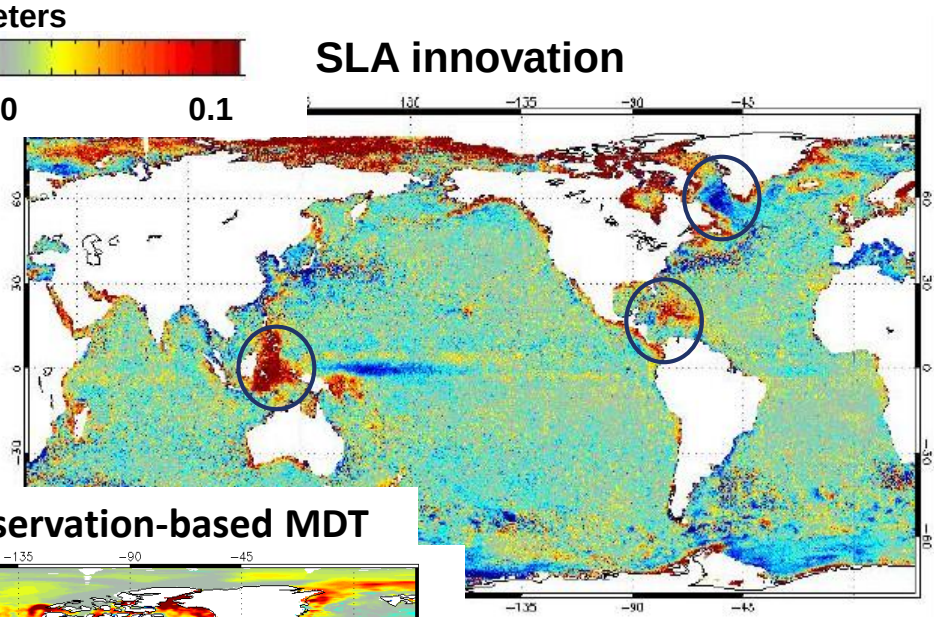
The Mercator-Ocean « hybrid » MDT

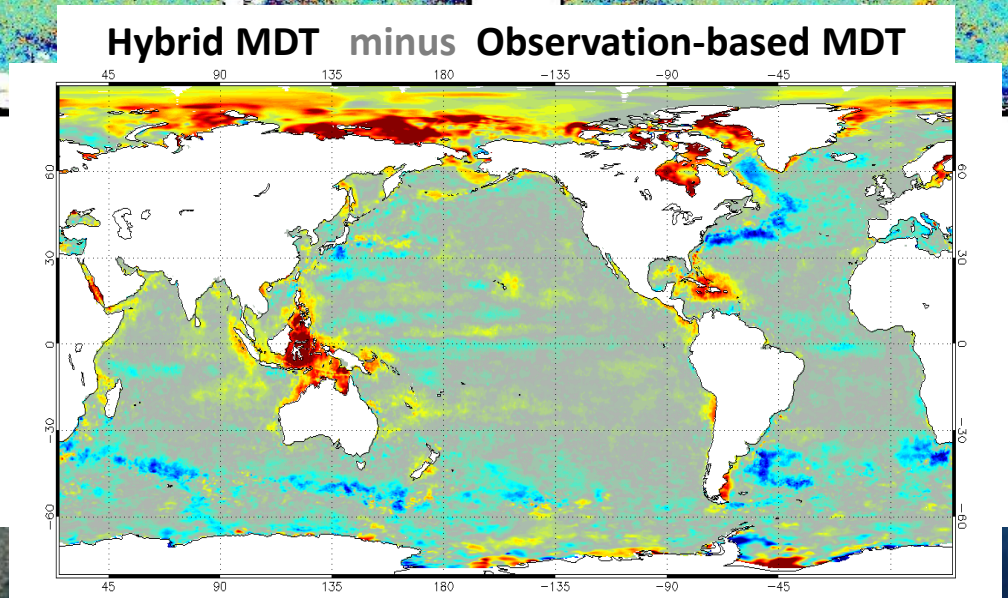
A correction of the external “observation based” MDT is done which takes into account:

- SLA innovations,
- HDYN innovations computed from vertical T/S innovations (below 2000m, climatology is used),
- Most recent satellite-only geoid model based on GRACE and GOCE data,





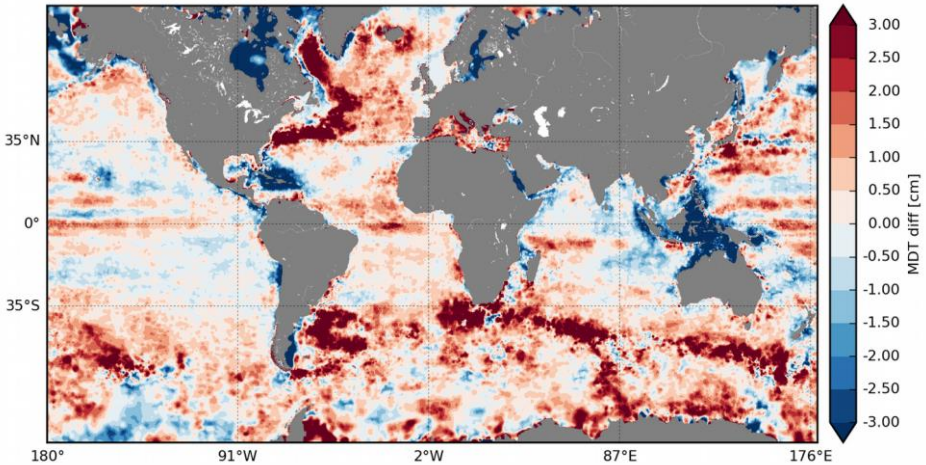




RESULTS

Hybrid MDT =HMDT

HMDT V2-HMDT V3

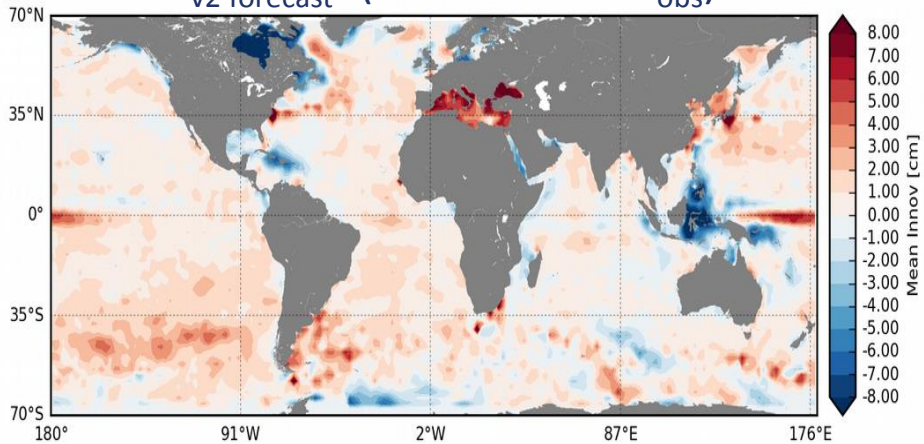


-> Better agreement between the model forecast and the "observed" DT when an improved MDT version is used.

- All biases are reduced in OSE-V3
- However biases still visible in:
- Hudson bay
- Mediterranean Sea
- Indonesian throughflow

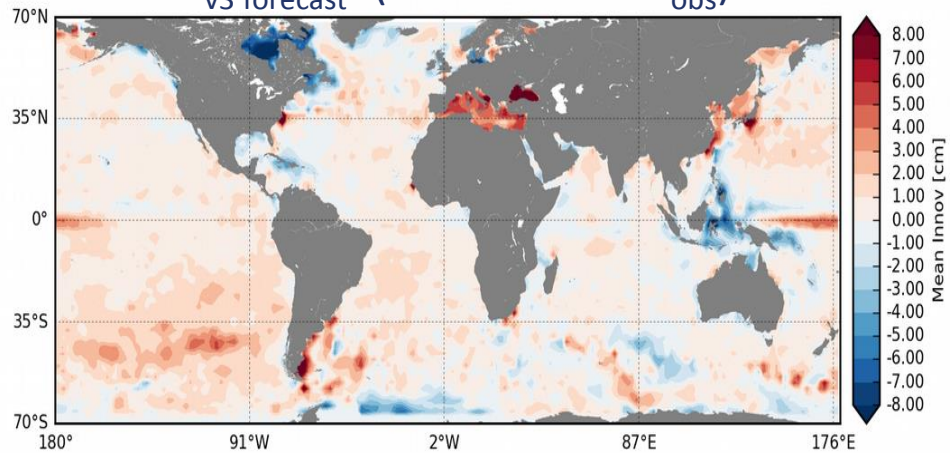
OSE V2 mean innovation (model-observation)

$DT_{v2\ forecast}$- (HMDTv2 + SLA_{obs}) in cm

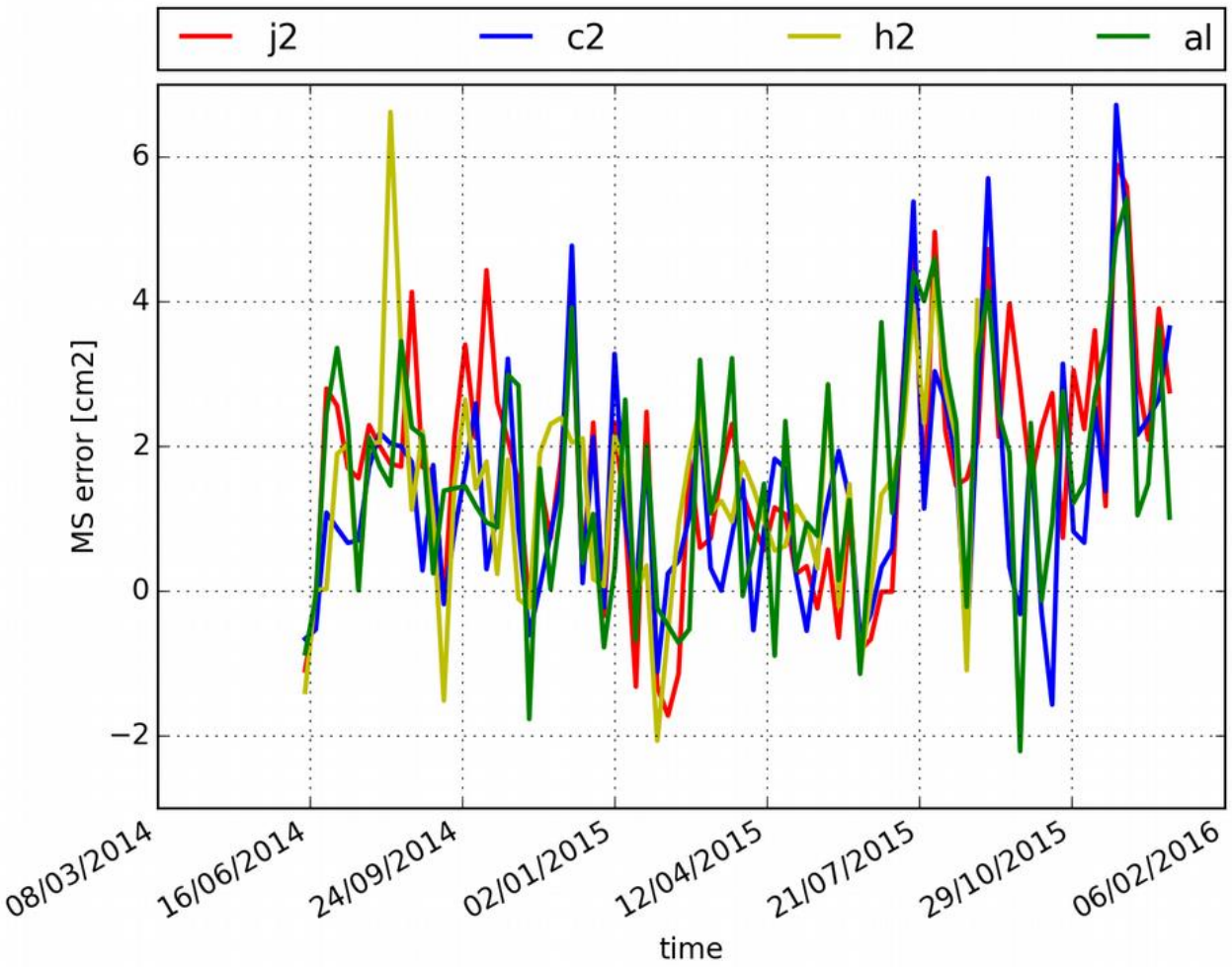


OSE V3 mean innovation (model-observation)

$DT_{v3\ forecast}$- (HMDTv3 + SLA_{obs}) in cm



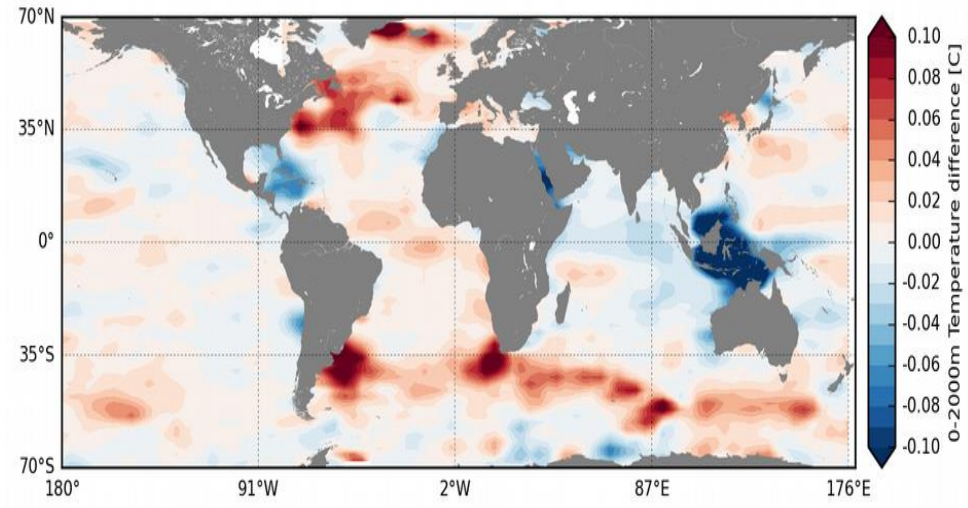
Mean innovation difference (OSEV2-OSEV3) along different altimeter tracks



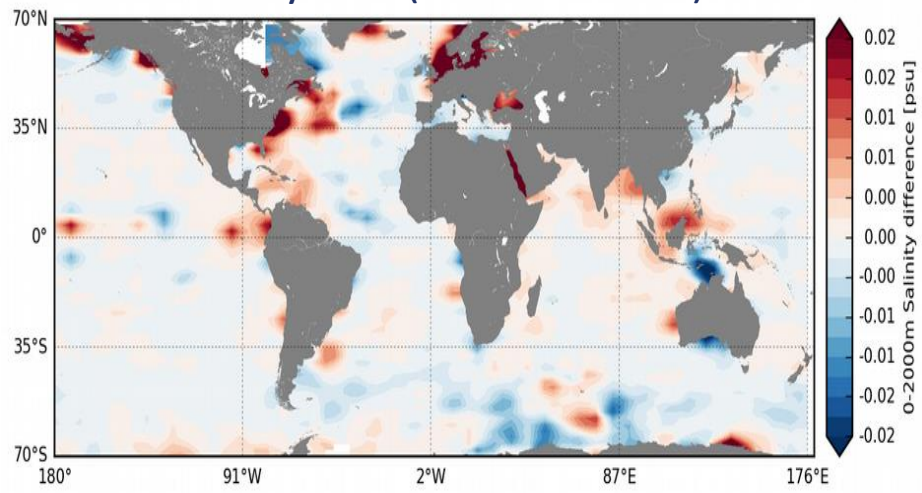
- **Gain around 2cm²**
- **Similar to the gain obtained adding a fourth altimeter to a three altimeter constellation**

Impact on model temperature and salinity

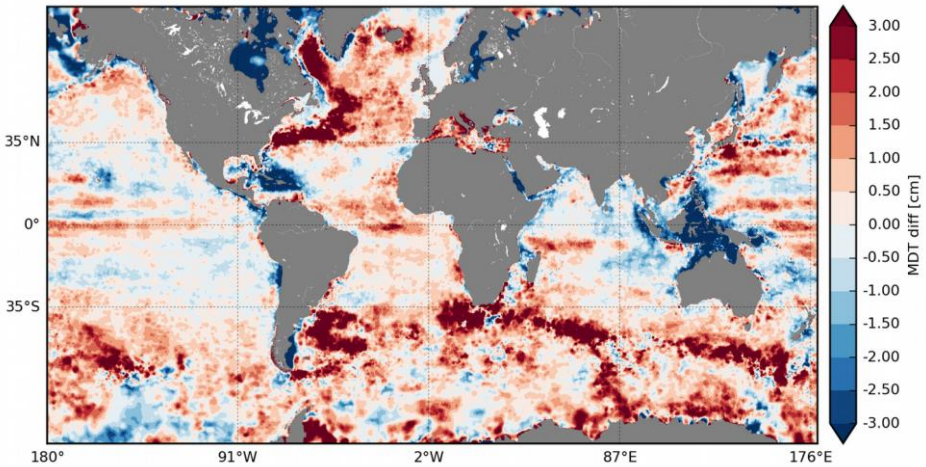
Differences between temperature bias (OSEV2-OSEV3)



Differences between absolute salinity bias (OSEV2-OSEV3)



HMDT V2-HMDT V3

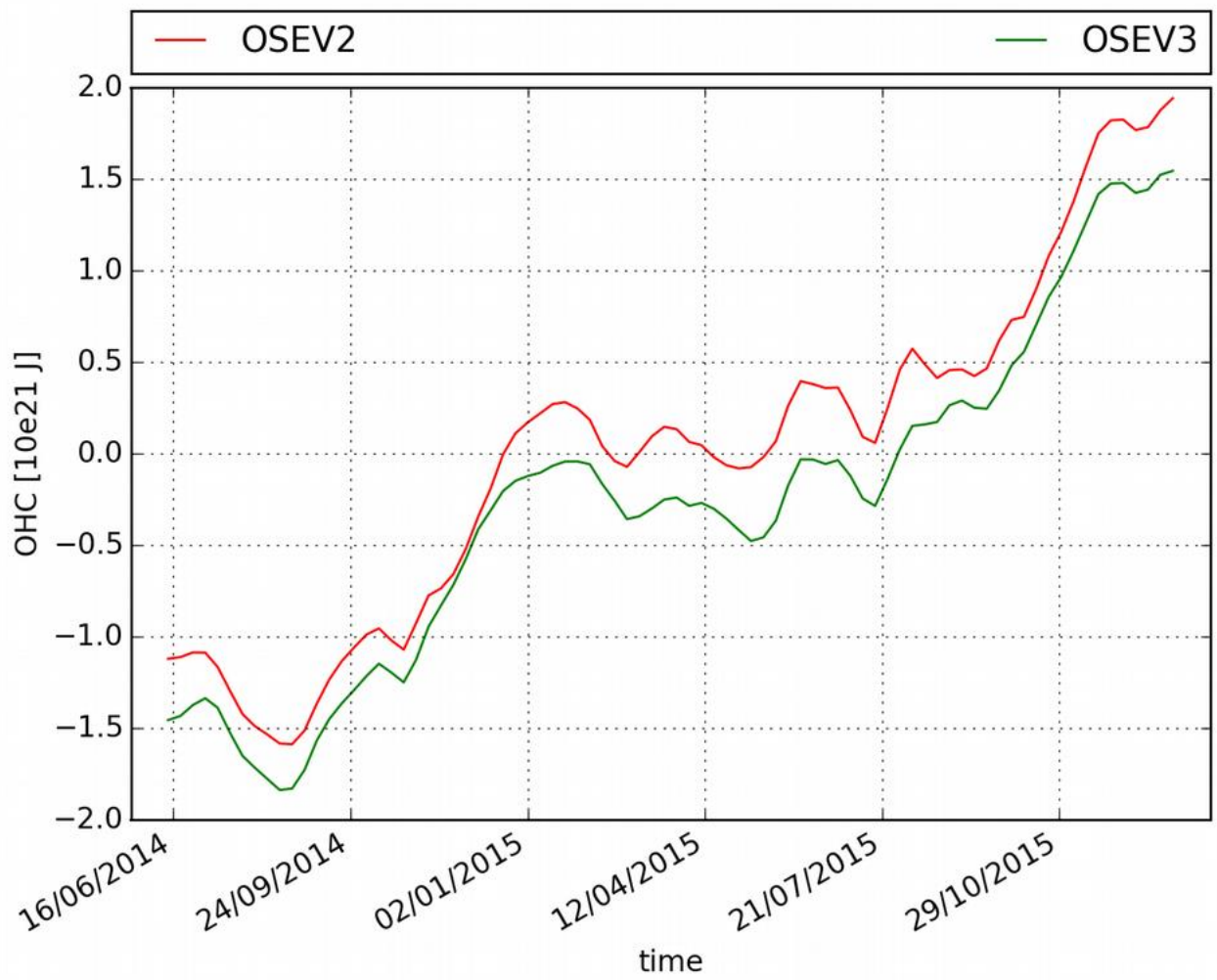


Where the MSSH was too high (for instance in the ACC) a steric effect compensation was performed by the model by increasing the temperature in the water column, resulting in a positive SST bias.

This effect is reduced with the OSEV3 MDT.

-> MDT changes have impact not only on the SSH estimation but also on the 3D temperature and salinity fields

Impact on global Ocean Heat Content calculation



-> MDT accuracy is fundamental for climatic ocean studies

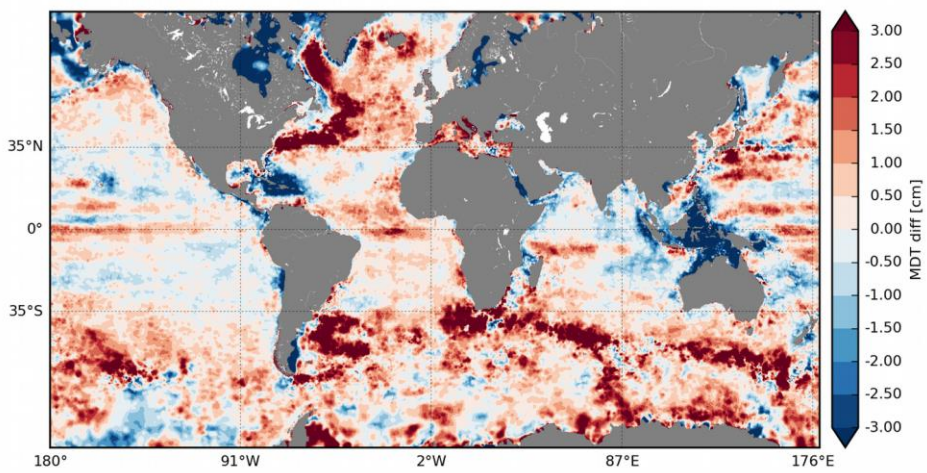
Impact on forecast skills

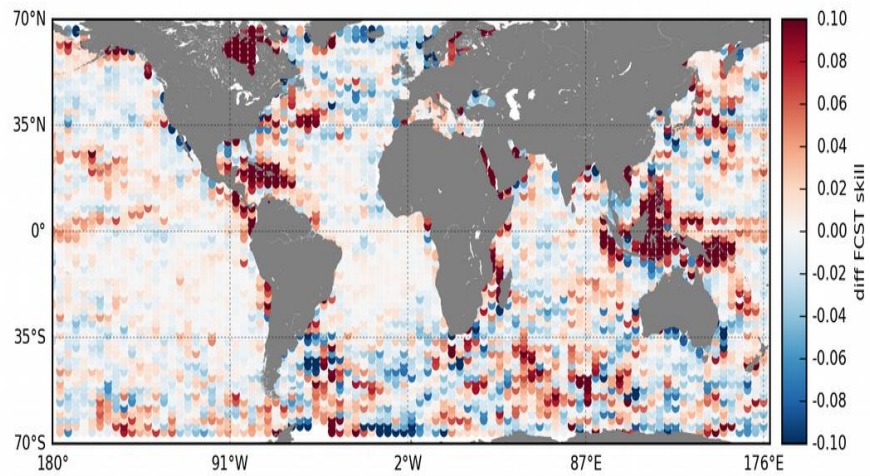
$$\text{FCSTskill}_{N}(x,y) = 1 - \frac{H[\text{FCSTerror}_N]}{H[\text{Persistence}]}$$

FCSTerrorN = (model-observatios)² for forecast cycle N

H= average in 2° by 4° boxes

HMDT V2-HMDT V3



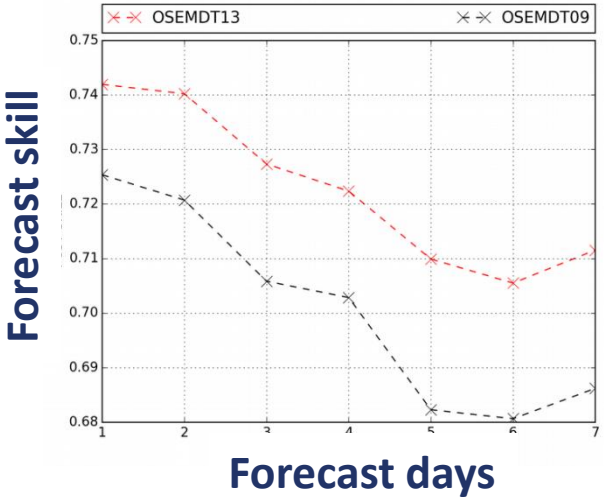


The use of an improved MDT leads to a better forecasting skill of the system

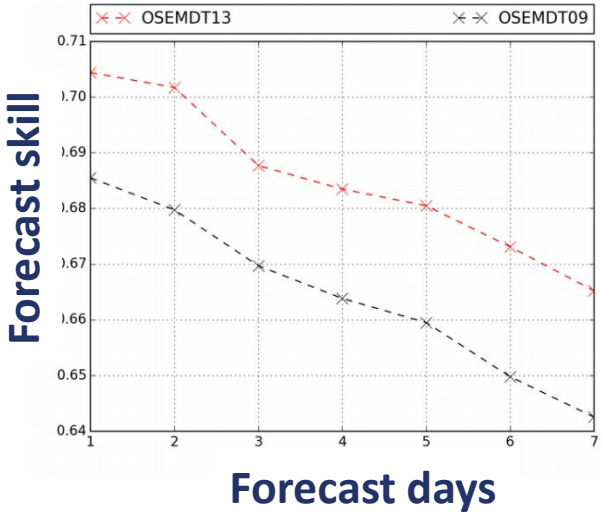
Impact on forecast skills

OSEV2 vs OSEV3

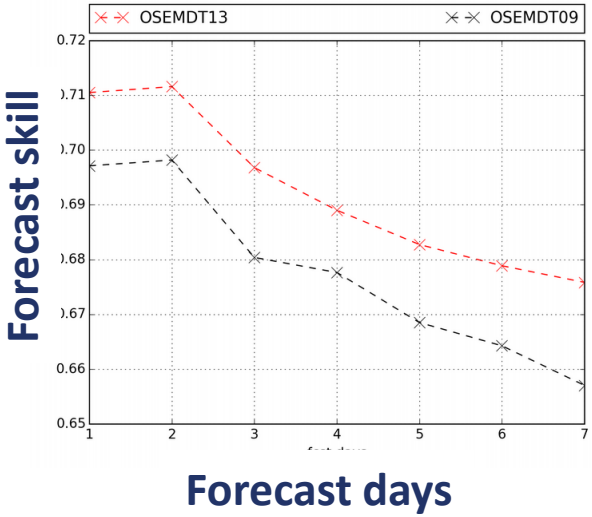
Gulfstream



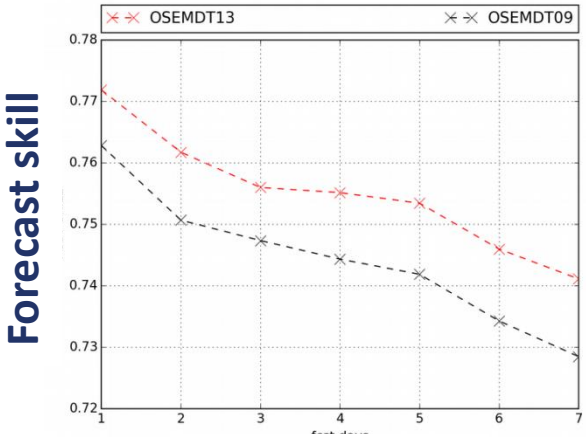
Kuroshio



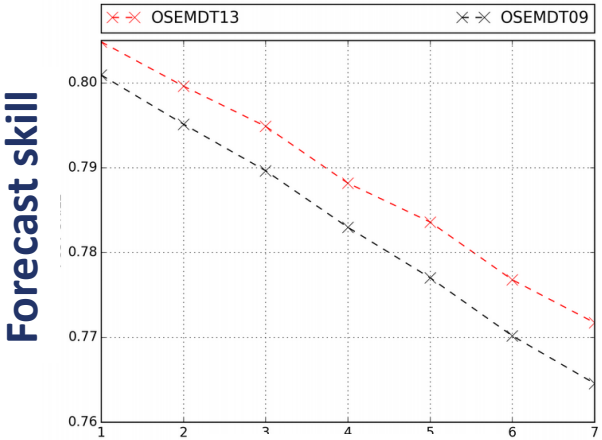
Agulhas



North Atlantic



Global



- Forecast skill improved by 1 day in global, up to 3 days in the Gulfstream

CONCLUSION

The Mean Dynamic Topography is **a KEY reference surface** for assimilating altimeter SLA into the Mercator-Ocean operational forecasting system.

Improving the MDT accuracy leads to:

- Improvement, **not only of the surface variable**, as the dynamic height, **but also of the model 3D thermohaline structure.**
- **Direct impact on the integrated ocean heat content, ocean heat and volume transport**
- Improvement of the model **forecast skill,** which is one of the prime objectives of operational forecasting systems.

CONCLUSION

The CNES-CLS13 observation-based MDT is already ready for use in assimilation systems _> you can download it from the Aviso website www.aviso.altimetry.fr

We are currently working on an improved version (CNES project) that will be made available mid 2018

✓Improved GOCE geoid model

✓Improved altimeter Mean Sea Surface

✓Updated dataset of in-situ T/S profiles (Argo floats) and drifting buoy velocities ([1993-2012] -> [1993-2016] = 4 additional years

✓Improved methodology

If you are interested, contact me : mrio@cls.fr