Combined mean dynamic topography

Types of dataset: auxiliary products
Contents: mean of the 1993-1999 period sea surface above geoid, corrected from geophysical effects. The MDT_CNES-CLS09 is an estimate of the ocean MDT for the 1993-1999 period. The MDT for a different time period P can be easily deduced using altimetric Sea Level Anomalies referenced to the 1993-1999 period with : $MDT_P=MDT_{93\text{-}99}+\langle SLA_{93\text{-}99}\rangle_P$. The Ssalto/Duacs multimisson (M)ADT products from the Duacs 2014 (V15.0) are computed with a new MDT referenced over a twenty-year period [1993-2012] which doesn't correspond to this MDT CNES-CLS09.
Use: ocean circulation, operational oceanography
Description: based on 4.5 years of GRACE data, and 15 years of altimetry and *in-situ* data (hydrologic and drifters data). (More information).
Geographic coverage: global
Format: ASCII, NetCDF
Distribution media: Authenticated FTP
Condition of access: All auxiliary product users need an account, see Access to auxiliary products. To get an acces to the last version of MDT product, please fill in, select the given product and valid the following form:

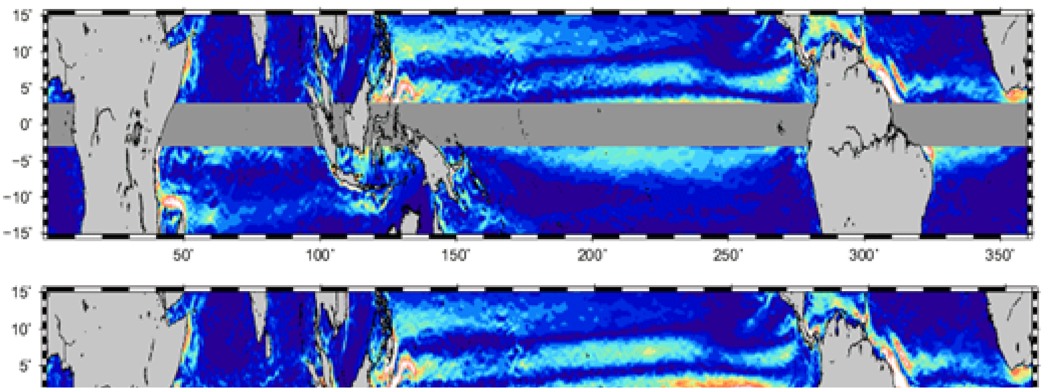
to get access Aviso products

File weight: 64 MB (Ascii) et 56 MB (NetCDF)
How to cite Aviso data?

Releases of MDT

March 2010: CNES-CLS09_v1.1

The strongest changes with the CNES-CLS09_v1.0 concern the mean velocity estimate in the equatorial band: due to the failure of the geostrophic approximation near the equator, no velocity estimates were given in the CNES-CLS09_v1.0 release for the [-3°,3°] latitudinal band. A specific work has been done to estimate the mean velocities at the equator.



The height differences between the two releases is small with a global mean difference of -0.02 cm and a rms difference of 0.05 cm.

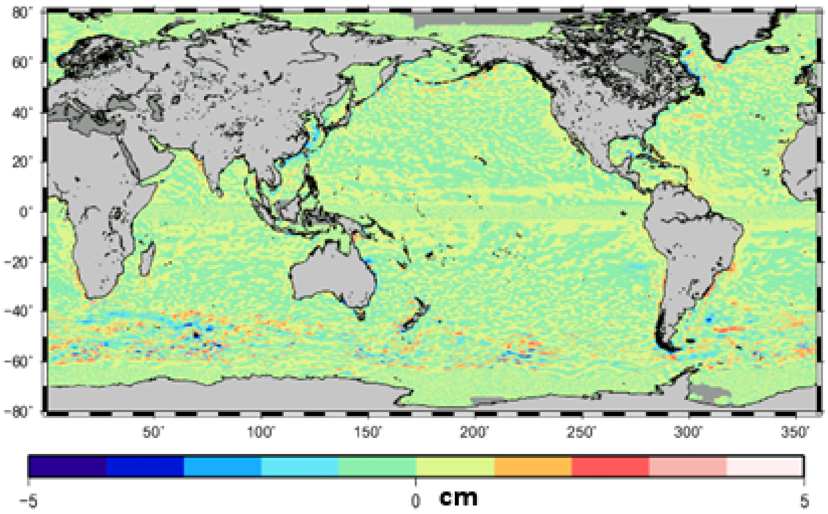


Figure 2: Map of height differences (in cm) between the CNES-CLS09_v1.0 MDT and the CNES-CLS09_v1.1 MDT

October 2009: CNES-CLS09_v1.0.

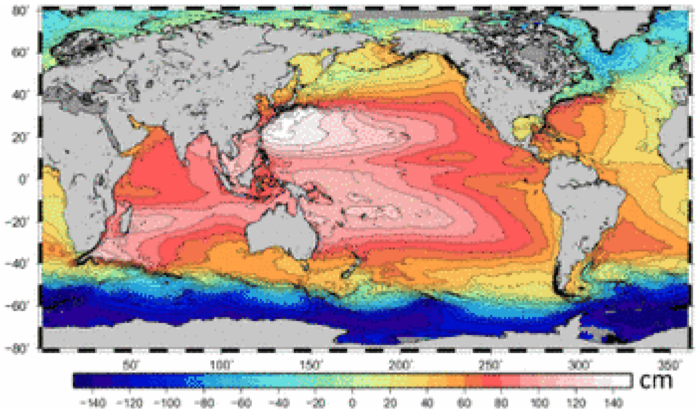
Compared to the previous RIO05 field, the main improvements are:

- The use of the recent EIGEN-GRGS.RL02.MEAN-FIELD based on 4,5 years of GRACE data
- The use of an updated dataset of drifting buoy velocities(1993-2008)and dynamic heights(1993-2007)
- The use of an improved Ekman model to extract the geostrophic component of the buoy velocities
- The use of an improved processing method of the dynamic heights allowing to make use of T/S profiles to different reference depths.
- Estimation was done on a 1/4° resolution grid(instead of 1/2° for RIO05).

2005: Rio05 MDT

The Combined Mean Dynamic Topography (CMDT)

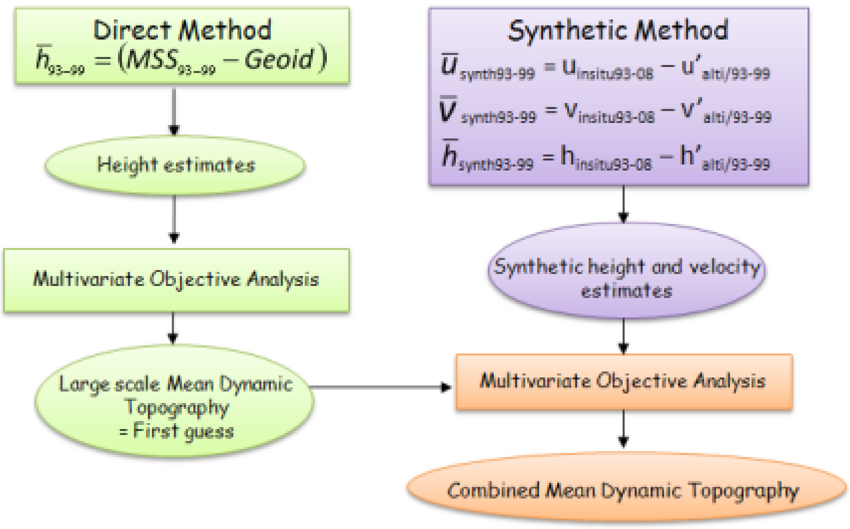
The issue of estimating a global Mean Dynamic Topography (MDT) is to reference the altimeter Sea Level Anomalies (SLA), computed relative to a 7 year (1993-1999) mean profile, in order to obtain absolute measurements of the ocean dynamic topography.
Required MDT has to be consistent with altimeter physical content and shall therefore correspond to the mean over 1993-1999 of the geostrophic, barotropic and baroclinic ocean circulation.



Combined Mean Dynamic Topography MDT_CNES-CLS09

This work combines several steps:

- We first use a direct method to estimate at large scale a MDT using the CLS01 MSS and the EIGEN-GRGS.RL02.MEAN-FIELD (this model is based on 4.5 years of GRACE data).
- Then we use a synthetic method where sea level anomalies are subtracted from *in-situ* measurements of the ocean state (dynamic heights over the 1993-2007 period and geostrophic surface velocities over the 1993-2008 period) to compute synthetic estimates of the MDT and the corresponding geostrophic surface velocities.
- Then, using a multivariate objective analysis, the synthetic estimates of heights and velocities are computed and used to improve the first guess of the MDT at large scale. It's the calculation of the CMDT.
- Finally, a validation is done by comparing the MDT_CNES-CLS09 with others MDT: Rio05, Maximenko et *al.* 2009, Glorys1V1 and DNC08.

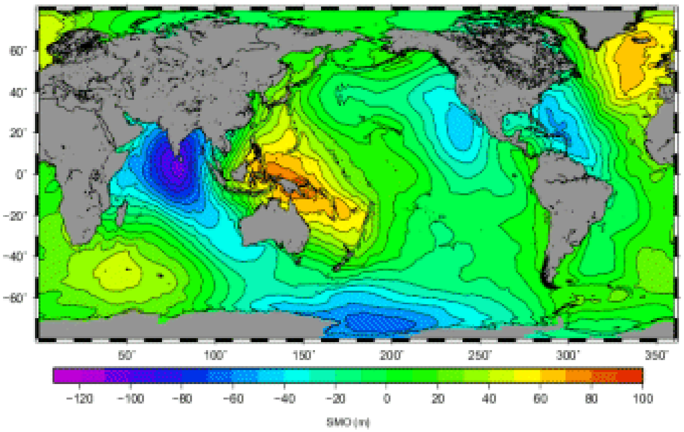


Calculation method for MDT_CNES-CLS09.

See also references & publications.

The direct method

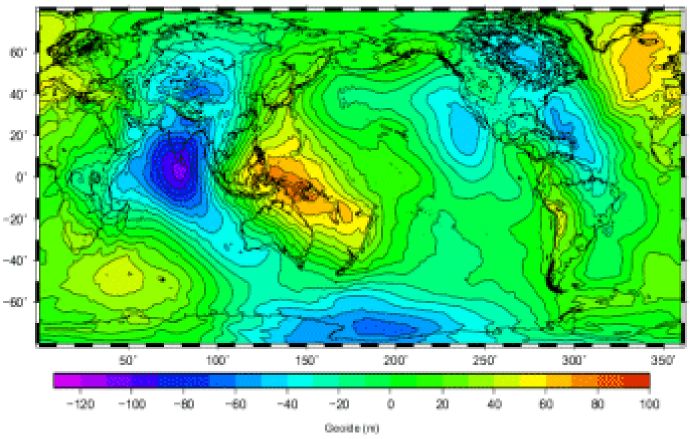
The altimeter provides the sea surface height relative to the reference ellipsoid. It is the sum of the geoid plus the dynamic topography, once removed other oceanic and atmospheric effects. By averaging altimetric heights over a given period, a Mean Sea Surface (MSS) can be estimated.



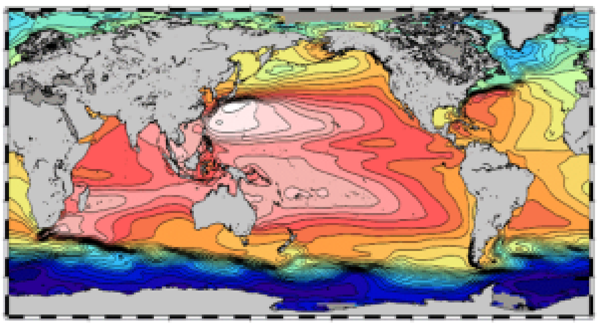
Mean Sea Surface CLS01.

The MSS is referenced to the Earth ellipsoid; we use CLS01 MSS , computed using altimeter data averaged over the 1993-1999 period.

MSS is the sum of the geoid plus the mean dynamic topography MDT. Thus, by subtracting the geoid we can obtain the Mean Dynamic topography MDT; this is the so called "direct method".



Unfortunately, geoid accuracy is poor, but can be used at large scale. The EIGEN-GRGS.RL02.MEAN-FIELD geoid is used here, where wavelenth shorter than 300 km are filtered out. The corresponding filtering is also applied to CLS01 MSS, in order to have consistent scales.



Oceanic Dynamic Topography at large scale achieved by optimal filtering of mean sea surface minus the geoid, and used as a first guess for further steps of the processing.

The two surfaces (Mean Sea Surface - Geoid) are subtracted, and provide after optimal filtering, a first guess of the mean dynamic topography at a large scale. The resolution of this first guess is limited to the resolution for which the errors on geoid are about one centimeter.

The Synthetic Method

The synthetic method consists in removing for each observation of the total ocean signal, the ocean variability measured by altimetry.

The temperature and salinity profiles are used to compute the synthetic heights. All measurements of Argo floats from 2002 to 2008 and all temperature and salinity profiles from CTD relative to the 1993-2007 period are taken into account.

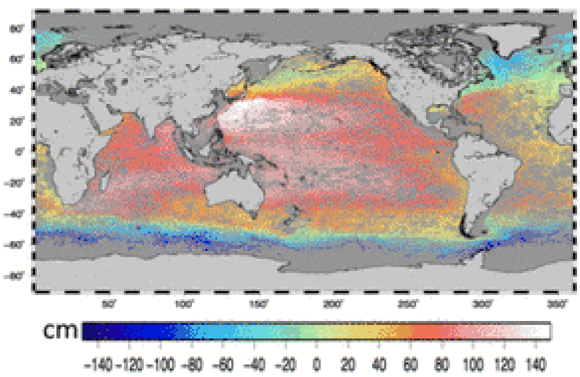
Geostrophic velocities from drifting buoys are extracted to compute the synthetic velocities. Between 1993 and 2008, 2 800 000 measurements of *in-situ* geostrophic velocities across the globe, are taken into account.

Computation of the synthetic observations of heights

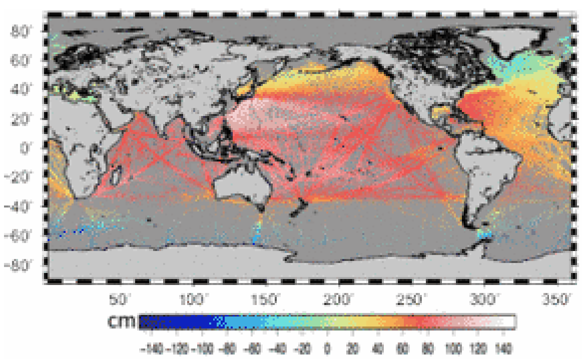
All the profiles are used to compute by integration along the water column a set of synthetic estimates of the mean dynamic topography according to the equation:

$\langle h \rangle_{1993-1999} = h_{insitu} - h'_{alti}$

However, by integrating these temperature and salinity measurements along the water column, the sea surface height obtained is representative of the steric content until the baseline profile. To return to a synthetic estimate of the ocean dynamic topography (barotropic and baroclinic components from the surface to the bottom), we had to add an estimate of the mean dynamic topography to this baseline profile. The missing component is approximated by subtracting to a large-scale estimate of the mean dynamic topography, a large-scale estimate of the mean steric component referenced to the depth of the baseline profile.



Synthetic observations of the MDT_CNES-CLS09 (in cm) averaged on a grid box size of 0.25°x0.25°.



Synthetic observations of the MDT Rio05 (in cm) averaged on a grid box size of 0.5°x0.5°.

By comparing this new set of synthetic estimates of heights with the combined mean dynamic topography Rio05, which was computed on a grid box size of 0.5°x0.5°, we observe that the sampling is significantly improved, particularly in the Southern Hemisphere, made possible to the Argo program.

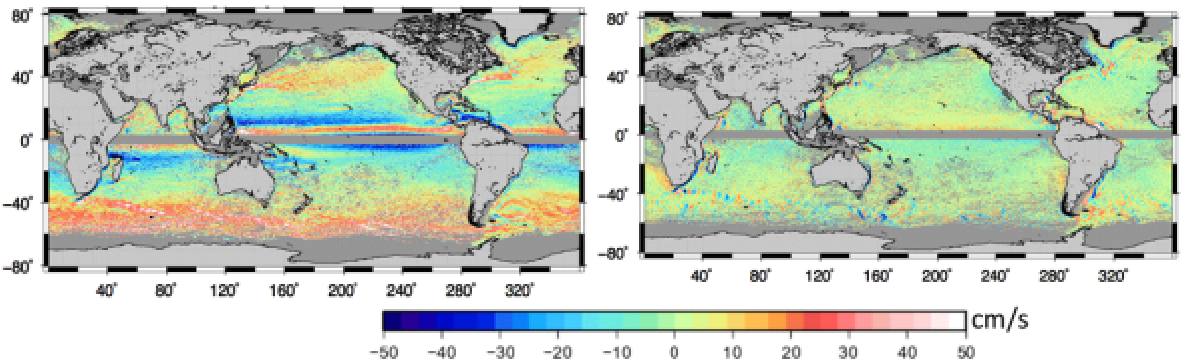
Computation of the synthetic observations of velocities

In a similar way, geostrophic velocities deduced from surface drifters can be used together with geostrophic velocities (anomalies) computed with altimeter slopes. The synthetic observations of velocities are computed by subtracting, along the drifting buoys paths, the altimetric velocity anomaly to the geostrophic velocity extracted from the buoy velocity according to the equation:

$$\langle \mathbf{U} \rangle_{1993\text{-}1999} = \mathbf{U}_{insitu} - \mathbf{U}'_{alti} \quad \text{and} \quad \langle \mathbf{V} \rangle_{1993\text{-}1999} = \mathbf{V}_{insitu} - \mathbf{V}'_{alti}$$

In addition to the geostrophic component, the velocity extracted from the drifting buoy path includes the tide currents, the Ekman currents, the inertial currents and others high-frequency ageostrophic currents. To extracte the only geostrophic component from the drifting buoys velocities, we had to precisely model each of these ageostrophic components and subtract them to the buoy velocity.

Le retrait des courants de marées et barotropes haute fréquence ne sont, à l'heure actuelle, pas encore suffisamment précis pour corriger les vitesses de bouées dérivantes. The removal of tidal and high-frequency barotropic currents are, currently, not yet precise enough to correct the drifting buoys velocities. Only the component of the Ekman currents, computed along the path, is removing from the drifting buoys velocities. Then a low pass filtering is applied to remove the signals with a period less than 3 days. Finally, the synthetic observations of mean geostrophic velocities are obtained after averaging in a grid box size of 0.25 ° by 0.25.

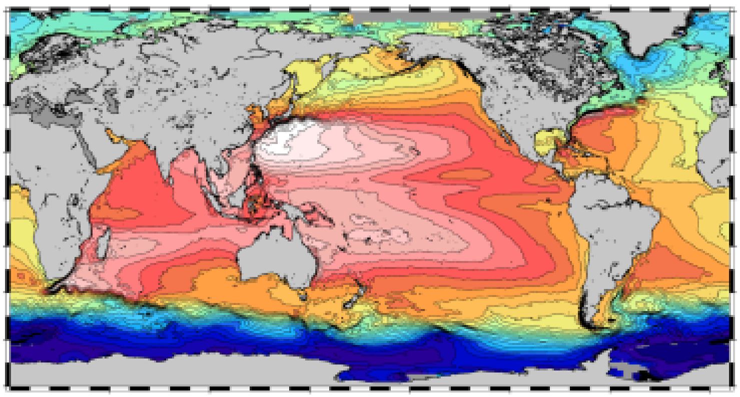


Synthetic estimates of the mean geostrophic velocities (in cm/s) computed on a grid box size of 0.25°x0.25° for the zonal (left) and meridian (right) components.

Those estimates of height and velocity are finally combined in a multivariate objective analysis in order to improve locally the first guess computed with the direct method.

Calculation of the Combined Mean Dynamic Topography

Those estimates of height and velocity are finally combined in a multivariate objective analysis in order to improve locally the first guess computed with the direct method.



Combined Mean Dynamic Topography (in cm)
MDT_CNES-CLS09. Credits Cnes/CLS.

Comparison of Global Mean Dynamic Topographies

The Combined Mean Dynamic Topography MDT_CNES-CLS09 is compared to 4 other MDT: Rio05, Maximenko et *al.*, 2009, Glorys1V1 and DNSC08.

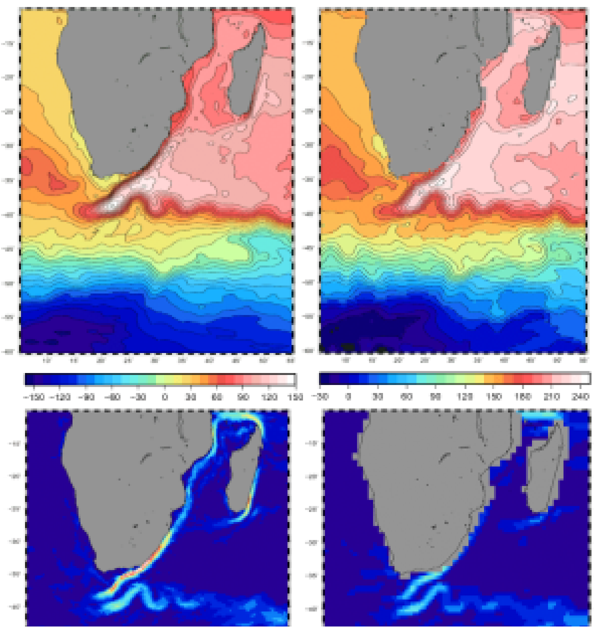
To precisely quantify the differences between the models, the five MDT have been compared with independant data (which were not used for the computation of the synthetic estimation of velocities) from surface drifters in the following areas: Agulhas current, Kuroshio, Gulf Stream , Drake passage, and the Circumpolar Current around Antarctica.

Altimeter anomalies of geostrophic velocities are added to each MDT, in order to produce the full ocean currents, and compared to concurrent drifter velocities after subtraction of Ekman currents which are filtered on a 3-day period.
Differences are presented (root mean square) here for each area. These differences are due to smoothing differences between altimetry and lagrangian data, noise in each data set, and MDT errors. Because we use exactly the same set of data, the lowest differences correspond to the more precise MDT (see tables below).

- DIFF RMS-U and DIFF RMS-V correspond to the differences RMS for the zonal and the meridian components respectively, computed from the differents MDT models and the velocities extracted from the drifting buoys.
- Au and Av respectively correspond to the zonal and meridian regression slopes between the velocities computed from the differents MDT models and the velocities extracted from the drifting buoys.

See another statistical comparisons such as the standard deviation, the correlation coefficient, etc, on the poster presented at Oceanobs, 2009 (A New Mean Dynamic Topography Computed Over the Global Ocean from GRACE Data, Altimetry and In-situ Measurements, pdf).

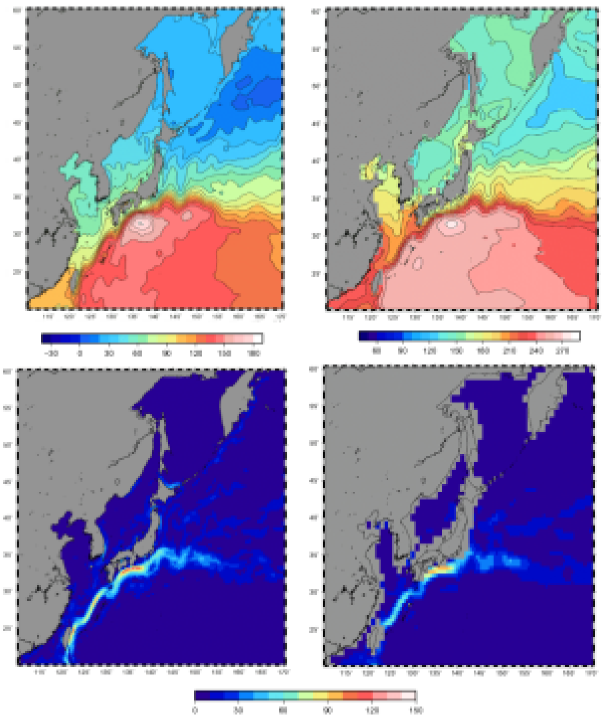
AGHULAS current



	CNES-CLS09	RIO-05	MAX-08	GLO-RYS	DNSC-08	First Guess
DIFF RMS-U	13.0 (12.9)	13.4	13.2	13.4	13.9	14.1
DIFF RMS-V	12.6 (12.4)	13.1	12.8	12.8	14.2	14.1
Au	0.67 (0.68)	0.63	0.64	0.65	0.65	0.60
Av	0.65 (0.66)	0.63	0.64	0.65	0.62	0.58

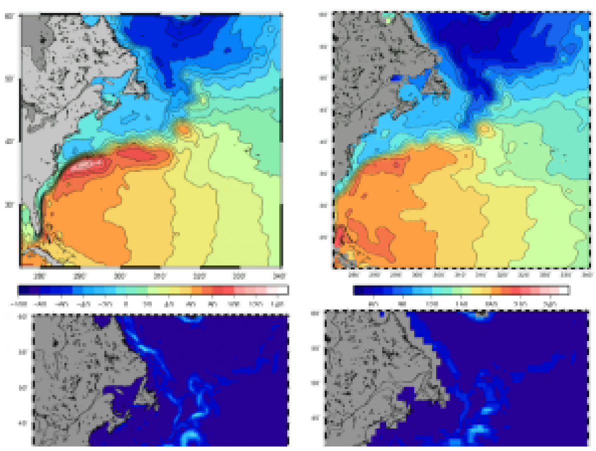
KUROSHIO area

	CNES-CLS09	RIO-05	MAX-08	GLO-RYS	DNSC-08	First Guess
DIFF RMS-U	14.6 (14.3)	15.3	15.1	14.9	15.4	16.5
DIFF RMS-V	15.0 (14.9)	16.0	15.7	15.6	16.2	17.5
Au	0.69 (0.71)	0.64	0.63	0.66	0.66	0.57
Av	0.64 (0.66)	0.59	0.58	0.63	0.61	0.51



Top: Mean Dynamic Topography in the Kuroshio area. Bottom: Mean geostrophic current velocity module. (left: MDT_CNES-CLS09, right: MDT Rio05). Credits Cnes/CLS.

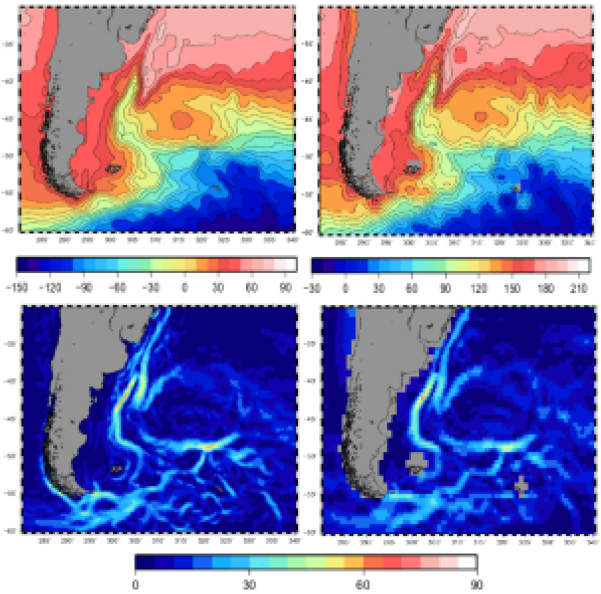
GULF STREAM area



	CNES-CLS09	RIO-05	MAX-08	GLO-RYS	DNSC-08	First Guess
DIFF RMS-U	12.3 (12.0)	12.3	12.5	12.3	12.6	13.4
DIFF RMS-V	11.6 (11.6)	11.7	11.8	11.8	12.0	13.0
Au	0.62 (0.60)	0.57	0.55	0.58	0.59	0.54
Av	0.58 (0.59)	0.57	0.56	0.57	0.58	0.54

DRAKE FALKLAND area

	CNES-CLS09	RIO-05	MAX-08	GLO-RYS	DNSC-08	First Guess
DIFF RMS-U	12.5 (12.4)	13.1	13.0	13.0	13.6	13.9
DIFF RMS-V	12.4 (12.3)	12.8	12.8	12.7	13.7	13.9
Au	0.61 (0.62)	0.58	0.56	0.60	0.55	0.52
Av	0.61 (0.61)	0.61	0.57	0.62	0.55	0.52



Top: Mean Dynamic Topography in the Drake/Fakland area. Bottom: Mean geostrophic current velocity module. (left: MDT_CNES-CLS09, right: MDT Rio05). Credits Cnes/CLS.