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RECENT DYNAMIC OCEAN TOPOGRAPHY MODELS AND THEIR COMPARISON

Summary

Regarding the rapidly growing satellite altimetry database and corresponding products worldwide, an investigation of different mean dynamic ocean topography (MDT) models was assessed to be important for further use in geodetic applications. The efficiency and quality of different MDT models are discussed in view of adopted geoids as reference surfaces. The models used are: 1) The ECCO model based on hydrology and altimetry data, 2) The combined MDT Rio-05 constructed in CSL AVISO (2005) from data for the period 1993-1999, 3) The combined MDT CNES-CLS09 model at the grid points 15'x15' based on altimetry and hydrology data for the period 1993-2007 (CSL AVISO, 2009), 4) The DNSC08MDT solution of mean dynamic topography (Danish National Space Center) obtained from the geometrical differences between the DNSC08 mean sea surface and the EGM2008 geoid model.

The concluding results of the investigation are: 1) statistics of all mean dyamic topography models leads to the approximately same standard deviations about 70 cm and range from -2 m to 2 m; 2) all differences among various MDT models give much smaller standard deviations about 6 – 15 cm; 3) all such differences among various MDT give larger mean deviation, which can be explained by different geoid models or reference surfaces adopted for each solution; 4) better agreement provides MDT CNES-CLS09 and DNSC08MDT models. As a result, we prefer MDT CNES-CLS09 and DNSC08MDT solutions since their noise level corresponds to an estimated accuracy of modern satellite altimetry data.

INTRODUCTION

Mean Sea Surfaces Heights (SSH) is the essentially satellite altimetry product which corresponds to the geoid heights and the mean dynamic topography (MDT) averaged over an appropriate period and referred to the geoid surface. Sea Level Anomalies (SLA) are free of the geoid height. Recent SSH, MDT, and SLA developments for oceanography and geodesy are given usually at suitable points of regular grid in the form of digital models. The goal of this paper is to compare different mean dynamic topography MDT models for their selection and further use for the marine geoid solutions. In particular, the following MDT models constructed during last years were considered: 1) The combined MDT CNES-CLS09 model in the grid 15’x15’ based on altimetry and hydrology data for the period 1993-2007 (CSL AVISO, 2009), 2) The combined solution DNSC08MDT of mean dynamic topography derived in the Danish National Space Center developed from the geometrical differences between the DNSC08 mean sea surface and the EGM2008 geoid model, 3) The combined MDT Rio-05 of the global ocean constructed in CSL AVISO (2005) from data for the period 1993-1999, 4) The combined ECCO model based on hydrology and altimetry data which was applied for the construction of the EIGEN gravity field models. All these models provide a common reference to different satellite datasets such as TOPEX/POSEIDON, ERS-1, ERS-2 GFO, Jason-1, Jason-2, and ENVISAT. It should be pointed out that all these models include mean dynamic topography (as difference between the mean sea surface and the geoid surface), eastward and northward components of geostrophic currents.

THE INITIAL MDT MODELS

Combined Mean Dynamic Topography Rio-05.

The CLS (Space Oceanography Division) Combined Mean Dynamic Topography (CMDT) named Rio-05 was computed at the regular grid points 30’x30’ over the 1993-1999 period using hydrographic data, surface drifter velocities and altimetry. According to Rio and Hernandez (2004) and Rio et al (2005) this model refers to the EIGEN-GRACE03S geoid.

Combined Mean Dynamic Topography CNES-CLS09

The MDT CNES-CLS09 model (Rio et al., 2009) was computed at the regular grid points 15’x15’ using a similar method as for the Rio-05 MDT solution. First, a large scale MDT is obtained from the CLS01 altimetric mean SSH and the recent geoid model EIGEN-GRGS.RL02.MEAN-FIELD based on 4.5 years of GRACE data. This model EIGEN-GRGS.RL02.MEAN-FIELD includes the time independent harmonic coefficients up to degree/order 160 and time dependent constituent in the form of time dependent changes of harmonic coefficients up to degree/order 50 including secular, annual and semiannual variations. Then, altimetric sea level anomalies are subtracted from *in-situ* measurements of the ocean state (dynamic heights and geostrophic surface velocities)

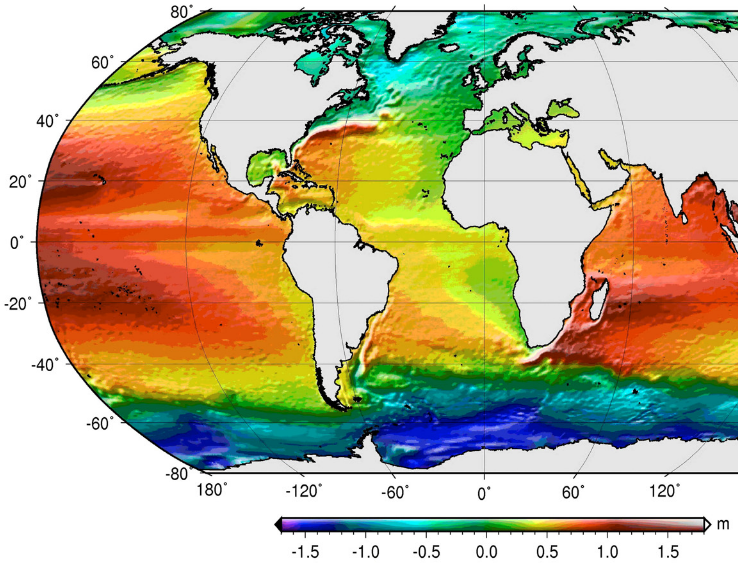

Figure 1. Mean dynamical ocean topography according to the MDT model CNES-CLS09

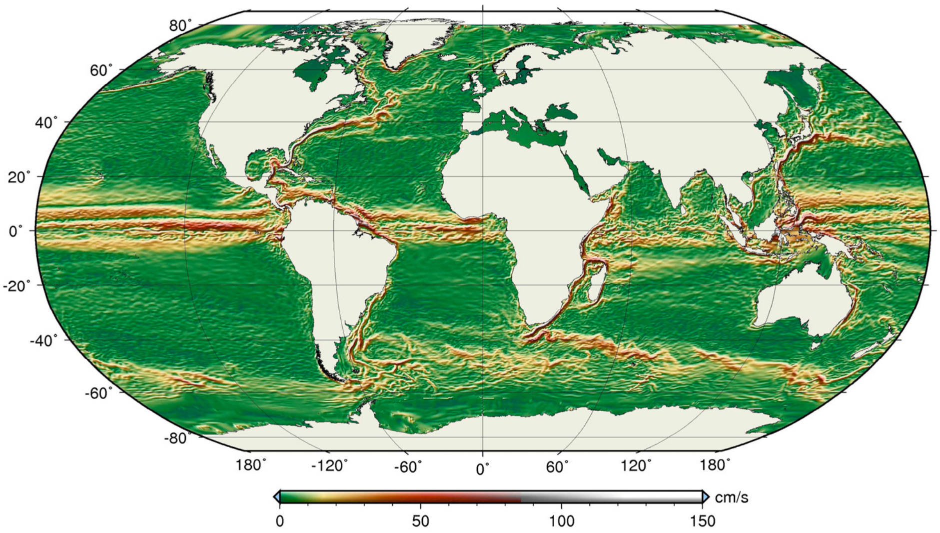

Figure 2. Length of the velocity vector [cm/s] of geostrophic currents CNES-CLS09

to compute synthetic estimates of the MDT and the corresponding geostrophic mean currents. Compared to the previous Rio-05 MDT, the main improvements are (Rio et al., 2009): the use of the recent EIGEN-GRGS.RL02.MEAN-FIELD based on 4.5 years of GRACE data and the application of an updated dataset of drifting buoy velocities (1993-2008) and dynamic heights (1993-2007), including the ARGO data. Fig.1 illustrates the MDT CNES-CLS09 model. In addition fig. 2 demonstrates length of the velocity vector of geostrophic currents CNES-CLS09 model.

Mean Dynamic Topography DNSC08MDT

The combined solution DNSC08MDT (Danish National Space Center) of mean dynamic topography was obtained from the geometrical differences between the DNSC08 mean sea surface and the EGM2008 geoid model (Anderson, Knudsen, 2008). It should be noted that the mean DNSC08 SSH is identical to the DNSC07 Sea Surface Heights solution. The combined solution DNSC08MDT was based on the geometrical difference between the DNSC08 mean sea surface and the EGM2008 geoid up to degree/order 2160 with modeling of the time dependent sea surface heights h, through time-independent constituent h_0 at reference epoch, a linear sea level change h_1 (over 12 years) and the annual cycle in sea level via the following expression

$$h = h_0 + h_1 t + h_2 \cos(\omega_{ann} t) + h_3 \sin(\omega_{ann} t) + \varepsilon\,, \tag{1}$$

where ω_{ann} is the frequency of the annual cycle, ε is the error component. All residual altimetry observations for each year is averaged to calculate the mean annual change. In contrast to all other solutions this model includes in the whole 12 years of various data using TOPEX/POSEIDON + Jason-1 as reference together with ICESAT data added in the Arctic Ocean.

Combined Mean Dynamic Topography ECCO

The MDT ECCO model was computed in 2002 (http://www.ecco-group.org/products.htm) at the regular grid points 30’x30’ in the framework of the ECCO project (Estimating the Circulation and Climate of the Ocean). This old version of ECCO model was taken into account because of its wide application to reduce altimetry observations to geoid heights in the frame of the EIGEN gravity field construction starting from the EIGEN-CG01C model up to degree/order 360.

RESULTS OF COMPARISON

Table 1 contains statistics of different mean dynamical topography models. It has to be pointed out that MDT DNSC08 solution was adopted here according to purely geodetic estimate developed from the DNSC08 Mean Sea surface using the geometrical difference $\text{MDT} = \text{MSS} - \text{Geoid}$, where EGM08 geoid was adopted according to (Pavlis et al., 2008) based on GRACE data, other space and gravity data of high resolution. Despite of different statistics in Table 1 we should note the standard deviation about 0.64 – 0.73 m as the most stable characteristic of various MDT solutions. Fig. 3, Fig. 4, and Fig. 5 reflect comparisons between MDT CNES-CLS09, MDT DNSC08, MDT ECCO, and MDT Rio-05 models respectively. All these figures illustrate basically various values of mean deviations caused by corresponding gravity fields and geoid models as reference surfaces.

Table 1. Statistics of different MDT models

Statistics	Rio-05	CNES-CLS09	ECCO	DNSC08
Minimum	-1.611	-1.695	-1.718	-2.183
Maximum	1.904	1.807	0.909	3.494
Mean	0.264	0.255	-0.137	-0.047
Standard deviation	0.713	0.726	0.638	0.714

Table 2. Statistics of differences between various MDT models

Statistics	CNES-CLS09–Rio-05	CNES-CLS09–ECCO	CNES-CLS09–DNSC08
Minimum	-2.270	-0.482	-1.709
Maximum	0.209	1.434	1.583
Mean	-1.185	0.445	0.289
Standard deviation	0.060	0.151	0.081

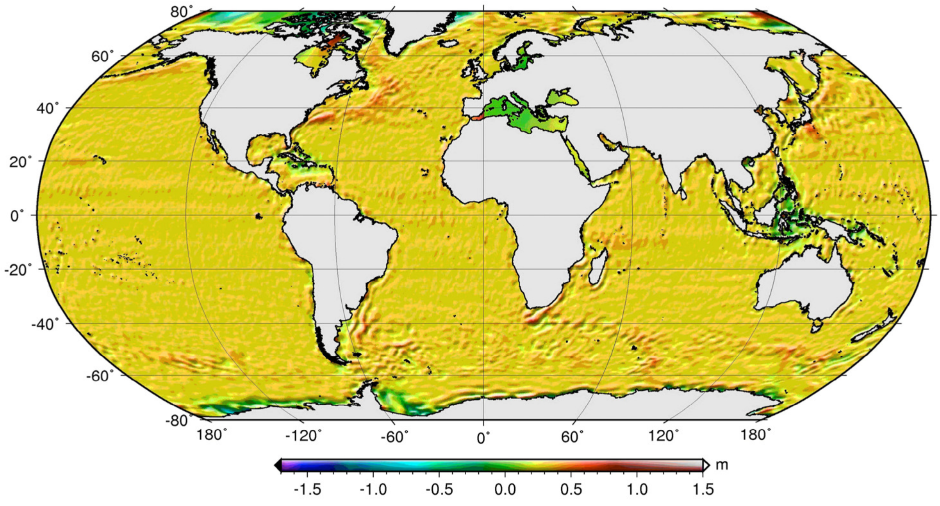

Figure 3. Difference [m] between CNES-CLS09 and DNSC08 MDT models

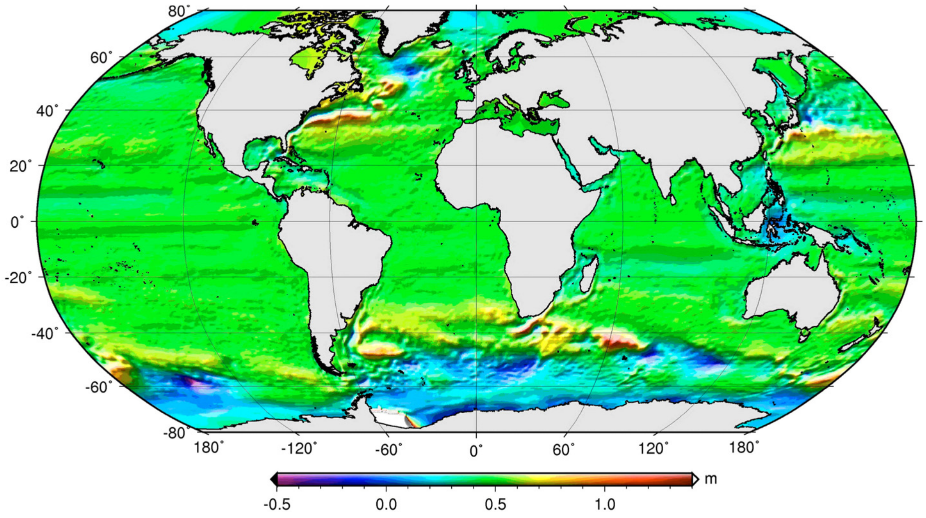

Figure 4. Difference [m] between CNES-CLS09 and ECCO MDT models

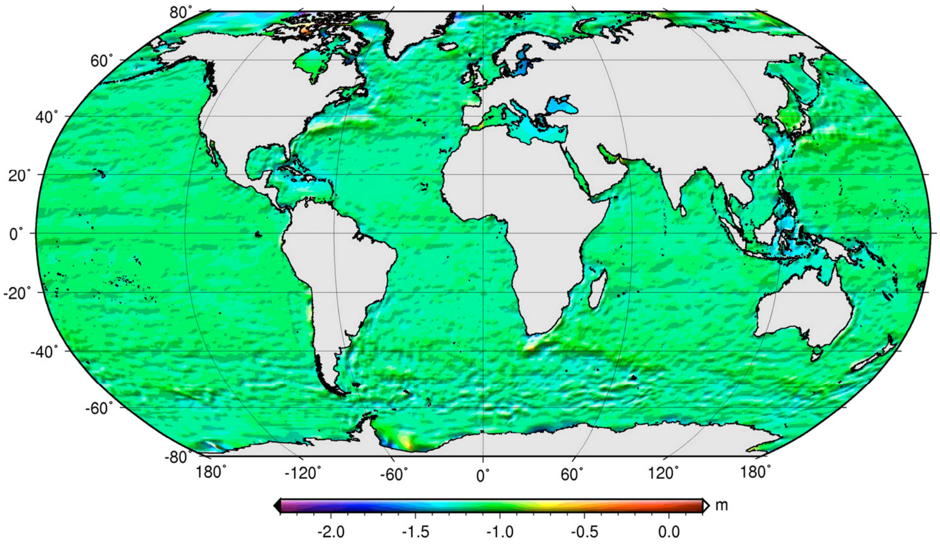

Figure 5. Difference [m] between CNES-CLS09 and Rio-05 MDT models

According to Table 2 and Fig. 5, a great mean deviation of 1.18 m corresponds to the difference between the two AVISO solutions MDT Rio-05 and MDT CNES-CLS09. As stated by Fig. 3 a smallest mean deviation 0.29 m represents the difference between mean dynamical topography models MDT

CNES-CLS09 and MDT DNSC08 despite of the application in the DNSC08 case the gravity field EGM08 with a most high resolution in contrast to other solutions. Standard deviations from Table 2 indicate a better agreement about 0.06 m of the two AVISO MDT solutions and a poor quality accordance about 0.15 m between AVISO CNES-CLS09 and ECCO (2002) MDT models.

CONCLUSIONS

Results of a comparison between different solutions of the mean dynamical topography were considered. In summary we can conclude.

– All MDT models as a rule are related to various geoid models that provides different mean deviations among them and can achieve values more than 1 m.

– The best agreement in terms of the standard deviation (st.dev = 6 cm) we get between the two AVISO solutions MDT CNES-CLS09 (2009) and MDT Rio-05 (2005).

– The best accordance in terms of the mean deviation (29 cm) we get between independent solutions MDT CNES-CLS09 (2009) and MDT DNSC08 (2008). It should be noted that these models are characterized by st.dev = 8 cm.

The comparison of different mean dynamical topography models referred to various geoids agrees on a level of 6 – 15 cm. These values correspond to the estimation of relative geoid accuracies below 10 cm in marine areas. It is evident that additional study for introduction and application of Helmert transformation parameters is necessary to reduce any mean dynamical topography model from given to some conventional geoid surface. If such conventional geoid is adopted as EGM08 model up to degree/order 2160 we will be able to apply the DNSC08 solution as a basis referred to the EGM08.

REFERENCES

Andersen O.B. and Knudsen P. 2008. *The DNSC08MDT Mean Dynamic Topography*, (DTU-SPACE).

Pavlis N.K., Holmes S.A., Kenyon S.C., Factor J.K. 2008. *An Earth Gravitational Model to Degree 2160:EGM2008.* Geophysical Research Abstracts, Vol. 10, EGU2008–A–01891, 2008, EGU General Assembly 2008.

Rio M.-H. and Hernandez F. 2004. *A mean dynamical topography computed over the world ocean from altimetry, in-situ measurements and a geoid model.* Journal of Geophysical Research, Vol. 109 (C12).

Rio M.-H., P. Schaeffer, et al. 2005. *The estimation of the ocean Mean Dynamic Topography through the combination of altimetric data, in-situ measurements and GRACE geoid: From global to regional studies.* Proceedings of the GOCINA international workshop, Luxembourg

Rio M-H, Schaeffer P., Moreaux G., Lemoine J-M, Bronner E. 2009. *A new Mean Dynamic Topography computed over the global ocean from GRACE data, altimetry and in-situ measurements.* Poster communication at OceanObs09 symposium, 21-25 September 2009, Venice.

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