How accurate are the recent geoid models based on GOCE and GRACE data for oceanographic applications?

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ABSTRACT

In the framework of the ESA HPF (High Processing Facility), a number of gravity models have been computed from the GOCE data since the beginning of the mission in 2009. In addition to the classical method (the so-called direct approach) that combines orbit and gravity modelling using the orbit perturbation theory, two alternative methods have been developped dedicated to the GOCE mission, i.e. the time-wise and the space-wise approaches. Also, after preliminary models were delivered in June 2010 based on 71 days of GOCE data, and then in March 2011 based on more than 6 months of GOCE data, new models have been made available recently, based on more than twelve months of data. In addition to the HPF products, geoid models have been computed recently that combine both GRACE and GOCE data (EIGEN6S, GOCO02S).

In this work, the accuracy of the different models for oceanographic application has been assessed. Both the impact of the different methodolgies used to compute the gravity field as well as the contribution of the four months of supplementary data have been checked.

For that purpose, the different GOCE geoids were used to determine the ocean MDT (Mean Dynamic Topography) which was subsequently compared with other MDT estimates derived using other geoid models, ocean circulation model outputs, or in-situ oceanographic data. The MDT comparisons were carried out by analysing MDT residuals as well as their associated geostrophic surface currents at different maximum harmonic degrees or intervals. Finally, both global and regional assessments have been performed.

METHOD

Computation of the ocean Mean Dynamic Topography (MDT)

MDT=Mean Sea Surface – Geoid height

✓MSS=MSS_CNES_CLS10

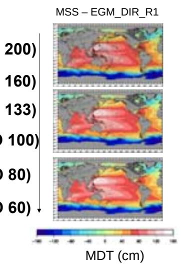
✓

Geoid Model	SH	Data
ITG-Grace2010s	180	GRACE (7y)
EGM_DIR-R1*	240	GOCE (2m)
EGM_TIM-R1	224	GOCE (2m)
EGM_SPW-R1	210	GOCE (2m)
EGM_DIR-R2	240	GOCE (6m)
EGM_TIM-R2	250	GOCE (6m)
EGM_SPW-R2	240	GOCE (6m)
GOCO02S	250	GRACE (7y) + GOCE (8m)

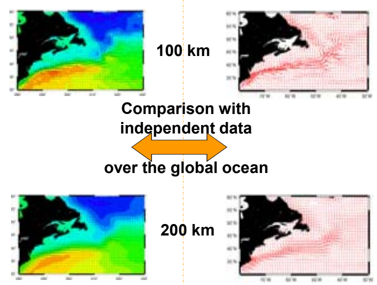
constrained toward a combined GRACE solution (including surface data)

Filtering of the MDT with a gaussian filter

100 km (DO 200)
125 km (DO 160)
150 km (DO 133)
200 km (DO 100)
250 km (DO 80)
350 km (DO 60)

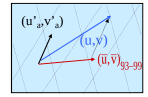


Computation of the geostrophic currents



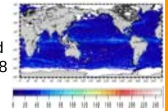
Computation of **synthetic estimate of mean geostrophic velocities** from in-situ oceanographic measurements and altimetry

$(u,v)_{93-99} = (u,v) - (u'_a, v'_a)$



oAltimetric Sea Level Anomalies from Aviso

oSurface current velocities measured by SVP type drifting buoys and distributed by AOML over the 1993-2008 period.



oDrifter velocities are processed to extract only the geostrophic component:
→ Ekman currents are modeled (Rio et al, 2011) and subtracted
→A 3 days low pass filter is applied along the drifter trajectories
oDrifter velocities are filtered with a gaussian filter onto a regular grid

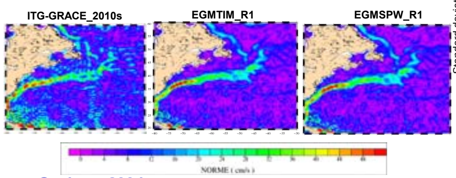
Improvement of GOCE over GRACE

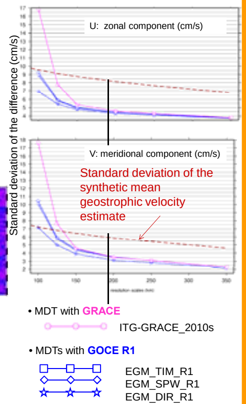
We compute standard deviation of the difference between synthetic mean geostrophic velocity estimate and geostrophic velocities estimated from geoid models. The statistics are made over the global ocean.

▪ **Scales < 200 km**

Standard deviation is much smaller with MDT computed with GOCE geoid model than with GRACE geoid model.
→ 2 months of GOCE data improve a lot compared with 7 years of GRACE data

Intensity of the velocities in the Gulf Stream area - 100 km





▪ **Scales > 200 km**

GOCE and GRACE have similar performances for the computation of MDT.

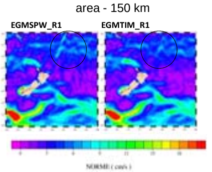
Impact of the different approaches (DIR, TIM and SPW)

▪ **First releases (R1)**

• Standard deviation is much smaller with EGM_DIR_R1 than with other approaches. It is because EGM_DIR_R1 is constrained toward Eigen51C (geoid model that combines GRACE and surface data)

• EGM_SPW_R1 and EGM_TIM_R1 give similar results but the space-wise approach is a bit noiser than the time-wise approach.

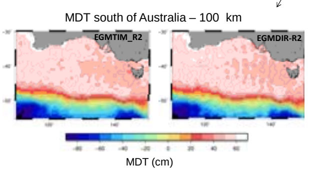
Intensity of the velocities in New Zealand area - 150 km

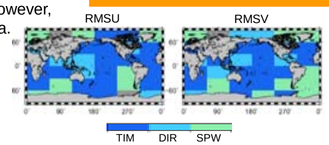


▪ **Second releases (R2)**

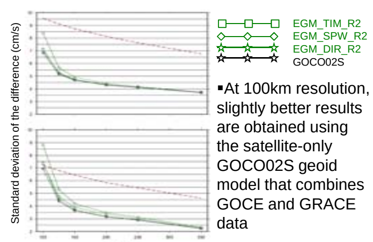
EGM_DIR_R2 and EGM_TIM_R2 gives globally similar results. Differences are seen depending on the areas. In the Kuroshio area MDT computed with EGM_DIR_R2 is less noisy than the one computed with EGM_TIM_R2. However, it is the contrary south of Australia.

MDT south of Australia – 100 km





▪RMS differences between the synthetic velocities and the velocities from the different MDTs **at 100km resolution** have been computed by 60° by 60° boxes.
The colors give for each box the geoid model for which the smallest RMS difference is obtained

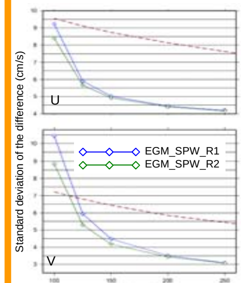


▪At 100km resolution, slightly better results are obtained using the satellite-only GOCO02S geoid model that combines GOCE and GRACE data

Impact of more GOCE data — Release 1 versus Release 2

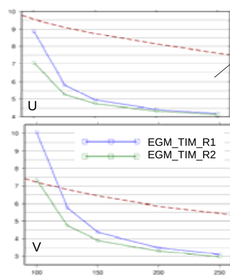
▪ **EGM_SPW= GOCE only**

• EGM_SPW_R2 gives standard deviations of the difference smaller than EGM_SPW_R1 (by around 1.5 cm/s at 100 km)
• EGM_SPW_R2 is less noisy than EGM_SPW_R1
→ 4 more months of GOCE data improve a lot the GOCE only geoid model.

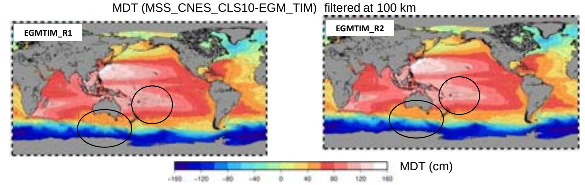


▪ **EGM_TIM = GOCE only**

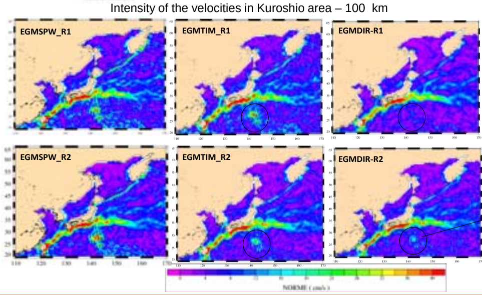
• EGM_TIM_R2 gives standard deviations of the difference smaller than EGM_TIM_R1 (by more than 2cm/s at 100 km)
• EGM_TIM_R2 is much less noisy than EGM_TIM_R1
→ 4 more months of GOCE data improve a lot the GOCE only geoid model.



MDT (MSS_CNES_CLS10-EGM_TIM) filtered at 100 km



Intensity of the velocities in Kuroshio area – 100 km

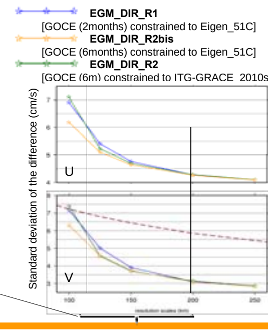


▪ **EGM_DIR = GOCE data constrained toward an apriori model**

EGM_DIR_R1 and R2 are both constrained toward an apriori geoid model but not the same. EGM_DIR_R1 is constrained toward Eigen_51C that combines surface data and GRACE data. EGM_DIR_R2 is constrained toward ITG_Grace2010s.

• To quantify the impact of more GOCE data, we compare EGM_DIR_R1 and EGM_DIR_R2bis (exactly the same model but with more GOCE data). The improvement is less significant than with EGM_TIM (at 100 km less than 1cm)

• At 100km EGM_DIR_R1 gives better results than EGM_DIR_R2 thanks to the surface data. But between 120 and 200 km, EGM_DIR_R2 is slightly better
→ GOCE improves mostly scales between 120 and 200 km compared with model that combines surface and GRACE data



CONCLUSIONS

The computation of Mean Dynamic Topographies from different geoid models and the comparisons with independent data from in-situ oceanographic measurements and altimetry permit to carry out an independent validation of the preliminary GOCE Level-2 products at different resolution scales.

▪ The use of only 2 months of GOCE data improves a lot the MDT scales shorter than 200km (DO 100) compared with geoid using 7 years of GRACE data.

▪ The addition of 4 months of GOCE data for the second release has brought significant improvement at scales shorter than 200km

▪ Further improvement is therefore expected with the third release by HPF of GOCE geoid models, due in the coming weeks.