Using altimetry and oceanographic in situ measurements for geoid's model assessment.

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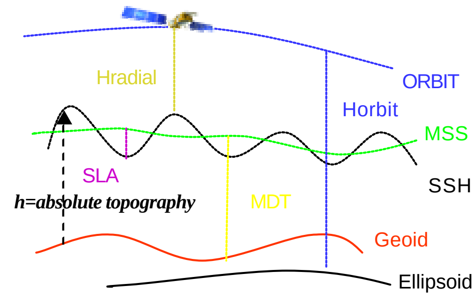
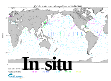
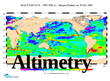
During the last three years, thanks to the exploitation of GRACE data, our knowledge of the geoid at long and medium wavelengths has been drastically and continuously improved. The accuracy of the latest geoid models, based on GRACE data, now reaches the centimetric level at a 400 km wavelength whereas in the past, these wavelengths were described with a precision not better than some decimetres by global geoid models such as EGM96. **The aim of this poster is to adopt an oceanographic point of view to assess previous and new geoid models at all resolution** (wavelengths). Indeed, a major outcome of the increased geoid accuracy is that **altimetric and geoid heights now have consistent error levels at wavelengths greater than 400 km and can therefore be combined for oceanographic purposes.** In particular, we can subtract an available geoid model from an altimetric Mean Sea Surface (MSS), both filtered at a same wavelength, to obtain a "direct" estimate of the ocean Mean Dynamic Topography (MDT) and the corresponding mean geostrophic circulation. These estimates are then compared to independent, "synthetic" estimates of the MDT, obtained through the combination of oceanographic in-situ data (drifting buoy velocities, hydrological profiles) and altimetric Sea Level Anomalies (SLA). In quantifying the impact of using a particular geoid model to compute the ocean MDT we directly assess the accuracy of the geoid model. The method is used to inter-compare different geoid models available based on GRACE data (the satellite-only solutions and the combined solutions obtained by different centers as GFZ, CNES, CSR). Comparison is also done with the historic EGM96 solution.



Method





Optimal Interpolation

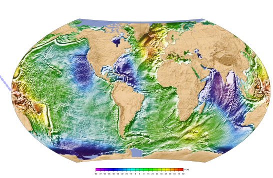
Synthetic Mean Dynamic Heights & Velocities

Filtering (Gaussian)*

* *A gaussian resolution of ?/2 means that* ***65% of the spatial scales shorter than ?/2*** *are filtered (and* ***94% of spatial scales shorter than ?/4****).*

INTERCOMPARISONS

One way to assess the accuracy of a geoid model is to compare "synthetic" elements of the MDT (heights and velocities) to the "gravimetric" MDT calculated from the difference between MSS and geoid. These analysis are performed at different wavelengths. Due to the higher precision of the filtered MSS (lower than 1 cm) the accuracy of the oceanic circulation is directly depending on the geoid model and its accuracy.

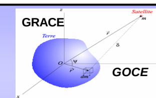


MSS_CLS01

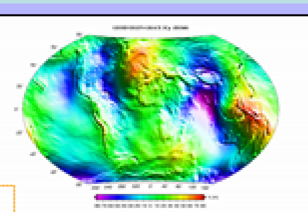
MDT(gravimetric) = MSS - Geoid

Filtering (Gaussian)* & Direct Difference

Development in Spherical Harmonics (SH)



$$T(\mathbf{r}_{mer}, j, l) = GM \sum_{n=2}^{\infty} \frac{a_e^n}{r^{n+1}} \sum_{m=0}^{n} P_{n,m}(\sin j)\,(C_{n,m}\cos m l + S_{n,m}\sin m l)$$



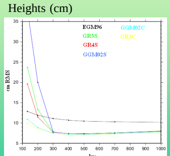
The Geoid Model

Results

Oceanographic assessment

• **Comparisons with synthetic data:**

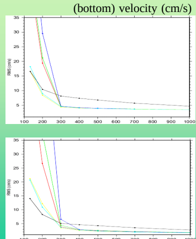
Heights (cm)



• *Abscissa (Gaussian) = resolution (wavelength/2)*

• *GR = are the EIGEN_GRACE models*

Zonal (top) and meridional (bottom) velocity (cm/s)



These figures show the RMS differences obtained, at various wavelengths ? between the synthetic MDT (height and velocity) and the "gravimetric" MDT. Different contributions participate to the RMS value:

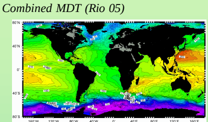
$$RMS_{\lambda}^{2} = \varepsilon_{synth_{\lambda}}^{2} + \varepsilon_{N_{\lambda}}^{2} + \varepsilon_{MSS_{\lambda}}^{2}$$

At spatial scales lower than 300 km, results clearly highlight a **better accuracy of EIGEN_GL4S compared to EIGEN_G3S** and a **better accuracy of the combined solutions compared to the satellite-only** solutions.

At spatial scales greater than 300 km the performances of the "new" GRACE models are very similar and much improved in comparison to the previous EGM96 solution.

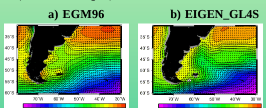
Optimal resolution for oceanographic application is today 300-400 km (SH50-70), in good consistency with the results from the geoid models comparisons

Combined MDT (Rio 05)

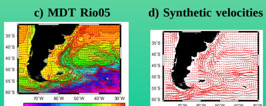


The CMDT Rio05 (Rio et al, 2005) is a reference field calculated by combining, through an optimal analysis, the gravimetric MDT (medium wavelengths) and the synthetic MDT estimates (short wavelengths).

a) EGM96 **b) EIGEN_GL4S**

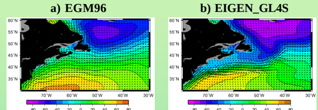


c) MDT Rio05 **d) Synthetic velocities**

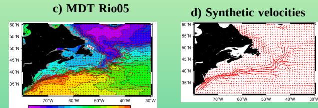


• **MDT comparisons at 400 km resolution**

a) EGM96 **b) EIGEN_GL4S**



c) MDT Rio05 **d) Synthetic velocities**

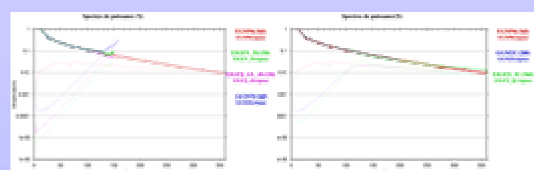


The [a,b] maps show the oceanic circulation calculated from the difference between the MSS_CLS01 and the geoid models EGM96 and EIGEN_GL4S. Each field [a, b, d] is filtered at a resolution of 400 km (wavelength of 800 km, SH50). Compared with the MDT Rio05 [c] and the synthetic velocity field [d], it is clear that the MDT based on EIGEN_GL4S model (2 years of GRACE data) provides a much more realistic field than the MDT based on EGM96.

Comparison to the RIO05 field allows to highlight the shortest scales (< 300-400 km) of the MDT not resolved yet by the most accurate GRACE geoid models.

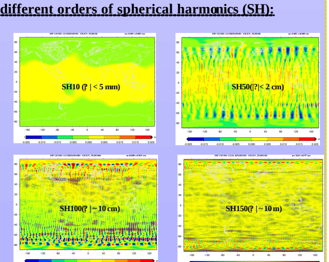
Geoid models comparisons

• **Comparisons between models (power spectrum):** The "satellite-only" solutions (GGM02S, EIGEN_G3S, EIGEN_GL4S) are consistent with EGM96 up to SH100 (wavelength of 400 km). The combined models (GGM02C, EIGEN_G3C) diverge from EGM96 after SH200. This shows that the shortest wavelengths for these solutions are well constrained by the "ground gravimetric" data.



• **Comparisons between grids at different orders of spherical harmonics (SH):**

These maps show the "direct" differences between two Earth Gravity models (GGM02S & EIGEN_G3S) calculated from 1 year of GRACE data. The discrepancy level depends on the SH development order. For orders lower than SH100, the differences are smaller than 10 cm and these models can be used for oceanic applications (i.e. MDT). After SH100, the differences between models quickly go to several meters, a value higher than the ocean sea level amplitude (+/- 2m).



GRACE Models: (2005) GGM02S - EIGEN_G3S

Conclusions:

An independent method to validate new geoid models has been developped based on the comparison of « gravimetric » MDT to « oceanographic » MDT. Results show the huge improvement of the new GRACE models in comparison to the previous EGM96 model and the strong contribution of gravimetric in-situ data to constrain the scales shorter than 300 km in the combined solutions.

The optimal resolution for using the new GRACE geoid models for oceanographic application is 300-400 km (SH50-70). At that resolution gravimetric MDTs match the oceanographic MDTs at better than 5 cm rms and the corresponding mean geostrophic circulation at better than 3-4 cm/s rms.

References: 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.