Oceanic Mass Variability Observed by Bottom Pressure Sensors and GRACE Satellites

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1. Introduction

Gravity field products of the Gravity Recovery and Climate Experiment (GRACE) satellite mission are assessed to estimate the capability of space-borne gravity measurements to detect the temporal variability of the oceanic mass distribution and its currents.

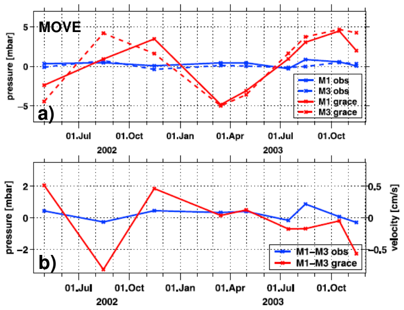
Here, GRACE data is validated against in-situ measurements of ocean bottom pressure (OBP) at three different sites:

- *RAPID* (RAPID Climate Change) array at 26°N in the tropical North Atlantic
- *MOVE* (Meridional Overturning Variability Experiment) array at 16°N in the tropical North Atlantic
- *ACC* array at 44°S - 50°S in the Antarctic Circumpolar Current

3. MOVE and RAPID

The *MOVE* and *RAPID* mooring arrays (Fig. 1) in the tropical North Atlantic monitor the Meridional Overturning Circulation (MOC) by means of integrating geostrophic measurements.

A number of PIES and pressure gauges provides timeseries of ocean bottom pressure (OBP) allowing ground-truth validation of GRACE OBP.



- Monthly OBP variability of 0.01 dbar observed in MOVE and RAPID moorings (Figs. 2a and 3a)
- GRACE data show a seasonal cycle of 0.04 dbar (Figs. 2a and 3a)
- OBP differences also greatly overestimated by GRACE (Figs. 2b and 3b)
- Reasons for low performance of GRACE to observe oceanic variability still unclear

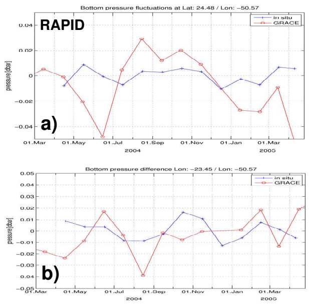


Fig. 2 a) MOVE OBP timeseries (blue) and GRACE OBP RL01 product (red). b) OBP differences and corresponding geostrophic current velocity anomalies.

Fig. 3 a) RAPID in-situ OBP (blue) and GRACE OBP RL03 product (red) at mooring site MAR2. b) OBP differences MAR2-EB1.

Locations M3, M1, MAR2 and EB1 indicated on Fig. 1.

2. Data

GRACE satellite data:

Here, de-tided and de-aliased monthly averaged GRACE GSM+GAC RL03 products provided by GFZ Potsdam [see *Flechtner*, 2006] are used as GRACE OBP estimate. A spatial Gaussian filter of 1000 km (MOVE, RAPID) or 500 km (ACC) has been applied for smoothing of smaller scale variability in the GRACE gravity field solutions. Spatial distribution of short-term variability is shown in Fig. 1.

In-situ data:

MOVE and *ACC* arrays: Pressure sensors / Inverted Echo Sounder (PIES, manufactured by University of Rhode Island). *RAPID* array*:* SeaBird Seagauges SBE26. All instruments are deployed at the sea floor and use the same type of pressure sensor. For comparison with GRACE, de-trended timeseries of monthly averages are used.

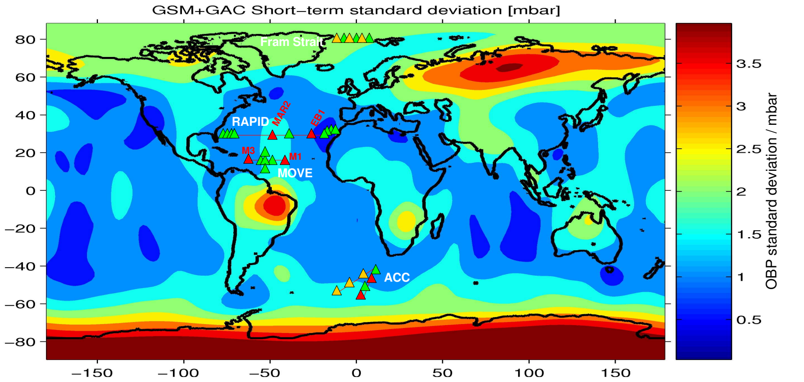


Fig. 1: Standard deviation in mbar of OBP inferred from GFZ monthly gravity field solutions. Note, that the largest variability of gravity is observed over land (hydrological cycle). The smallest amplitudes are found over the ocean in low latitudes. OBP ground truth sites: ▲ OBP sensor timeseries shown here; ▲ Other OBP sensors currently deployed; ▲ planned OBP sensors/ PIES deployments.

4. Antarctic Circumpolar Current (ACC)

In mid and high latitudes, OBP variability is larger than in the tropics due to the more barotropic structure of ocean currents, and a larger Coriolis parameter. In the ACC, GRACE may hence serve better to detect oceanic mass flux variability.

Here, data from two PIES deployed from 2002 to 2005 are shown, covering the northern part of the ACC (Fig. 4).

In 2006, the array is to be extended to 6 - 9 PIES, improving integrated geostrophic estimates of the ACC and ensuring a 2-dimensional coverage of large-scale coherent OBP signals observed by GRACE.

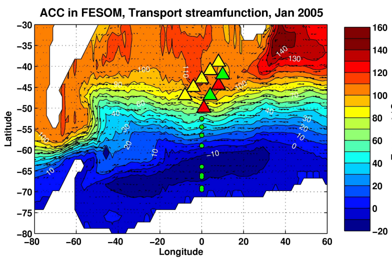
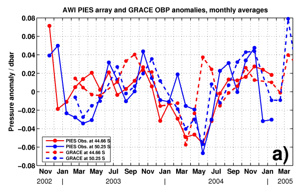


Fig. 4: ACC in FESOM ocean model [see *Böning*, 2006]. Transport streamfunction (colour shading) and *u*h* transport vectors (monthly mean Jan 2005). In the northern part of the ACC, ▲ PIES deployed 2002-2005 (see Fig. 5). ▲ further present deployments, ▲ planned array extension. ● hydrographic moorings in sea-ice covered regions.

- OBP variability 0.04 dbar on timescales of 3 months to 1 year (Fig. 5 a)
- GRACE variability amplitude similar to in-situ observations. Significant correlation of 0.45 at northern site, 0.68 at southern site (Fig. 5 a)
- GRACE shows some capability to determine OBP differences between both sites (correlation to in-situ observations 0.33, Fig. 5 b)
- Independend validation of numerical models: Both in-situ and GRACE OBP differences yield a barotropic transport RMS variability of 11 Sv (Fig. 5b). This is consistent with the FESOM model transport variability range. The model mean transport across the array is 40 +/- 4 Sv, total ACC transport 135 Sv (Fig. 4).



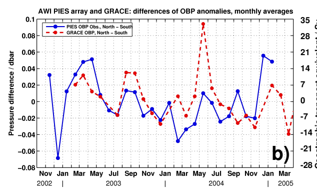


Fig. 5 a) Monthly averages of OBP in ACC array. Red: Northern site at 44°S 8°E, blue: Southern site at 50°S 1°E. Solid lines: In-situ observations, dashed lines: GRACE.
b) OBP differences between both sites. Solid blue line: In-situ, dashed red line: GRACE.

5. Conclusions

Results

Ocean bottom pressure (OBP) timeseries at 26°N (RAPID), 16°N (MOVE) and 44-50°S (ACC array) have been evaluated:

- In the tropical North Atlantic, the observed monthly OBP variability is about <= 0.01 dbar. In the Antarctic Circumpolar Current, OBP variability is larger (0.04 dbar).
- The performance of GRACE to capture oceanic mass variability varies greatly between different ground truth sites. In the tropical North Atlantic, GRACE shows unrealistically large signal amplitudes, whereas in the ACC region, GRACE has a much better skill to observe OBP variability.

Further research

- Validation of GRACE data at various OBP ground-truth sites
- Determine the reasons for the GRACE deficiencies in the tropical North Atlantic and better skills in the ACC region
- Investigation of ACC array PIES data, altimetry and GRACE with respect to mass transport and heat content variability of the ACC
- Validation/ Comparison with Ocean Models

6. Future Aims

- Extended measurements of OBP in the South Atlantic (ACC array) and North Atlantic (MOVE at 16°N, Fram Strait at 79°N) by AWI
- Cooperation with projects observing OBP at other locations (MOVE, RAPID and others)
- Establishing a global data base of OBP measurements
- Validation of GRACE gravimetry data using all available ground truth sites of OBP measurements to improve GRACE estimates of oceanic mass flux variability

Related contributions to EGU 2006:
Böning, C., Timmermann, R., Danilov, S., Schröter, J., Boebel, O. (2006): A global finite element ocean model: Circulation and bottom pressure anomalies in the South Atlantic, EGU General Assembly 2006, Abstract EGU06-EGU06-A-04139, Vienna, Austria, 02-07 April 2006. **Poster XY0717 on Thursday, 06 April 2006. Author in attendance: 13:30 - 15:00.**
Flechtner,F., Koenig, R., Meyer, Ul., Neumayer, K.H., Rothacher, M., Schmidt, R. (2006): Determination of the Earth's Gravity Field from CHAMP, GRACE and LAGEOS at GFZ Potsdam, EGU General Assembly 2006, Abstract EGU06-A-05902, Vienna, Austria, 02-07 April 2006. **Oral presentation on Monday, 02 April 2006 11:30, Lecture Room 6 (K).**

References:
Kanzow, T., F. Flechtner, A. Chave, R. Schmidt, P. Schwintzer, and U. Send (2005), Seasonal variation of ocean bottom pressure derived from Gravity Recovery and Climate Experiment (GRACE): Local validation and global patterns, J. Geophys. Res.,110, C09001, doi:10.1029/2004JC002772.

Weblinks:
GRACE: http://www.gfz-potsdam.de/grace/
MOVE: http://www.ifm.uni-kiel.de/allgemein/research/projects/clivar/send/clivar.html
RAPID: http://www.noc.soton.ac.uk/rapid/rapid.php
"Improved GRACE Level-1 and Level-2 Products and their Validation by Ocean Bottom Pressure": http://www.geotechnologien.de/forschung/forsch2.2l.html (German only).

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