Project: **499**

Project title: **Numerical Simulation of High-Frequency Ocean Bottom Pressure Variability**

Project lead: **Maik Thomas**

Report period: **2017-01-01 to 2017-12-31**

A central focus of the scientific discipline Geodesy is the precise measurement of the Earth's external gravity field and its time-variable rotation. Beside the large-scale dynamics of atmosphere and terrestrial hydrosphere the spatially and temporally highly variable ocean bottom pressure plays a major part in determining gravity and rotational variability. Therefore, the processing of global geodetic measurements (including the satellite gravimetry mission GRACE and its potential successor GRACE-FO, Very Long Baseline Interferometry based on a network of globally distributed radio telescopes, and station positions of a permanent network of stations receiving Global Navigational Satellite System (GNSS) signals) requires prior information from numerical ocean models in order to separate signals caused by ocean bottom pressure variability from other geophysical relevant signal sources.

For two peer-reviewed projects

- **ASPIRE** ("Atmosphere-Induced Short Period Variations of Earth Rotation", founded by Deutsche Forschungsgemeinschaft und Fonds zur Förderung der Wissenschaft (Austria)
- **GRACE-FO** ("Realisierung der Deutschen Projektanteile der GRACE-Follow On Satellitenmission", funded by the German Ministry for Education and Research

we performed new simulations of the time-evolution of the global ocean bottom pressure field. Both projects made use of the same numerical experiments with the current ocean component of the MPI Earth System Model, MPIOM (Jungclaus et al., 2013). The projects **ASPIRE** and **GRACE-FO** are in particular concerned with short-term mass variability, and thus required simulations that are additionally forced with atmospheric surface pressure (usually turned off in standard MPIOM experiments), the incorporation of oceanic self-attraction and loading parametrizations (initially coded, but not yet fully tested and tuned in MPIOM), and the consideration of 3-hourly sampled atmospheric forcing (standard MPIOM re-analysis experiments use 6 hourly forcing only) in order to fully resolve atmospheric pressure tides and their corresponding oceanic response.

In particular, the project focussed in 2017 on the following activities:

Sensitivity Analysis for Wind Forcing:

To test and tune the self-attraction and loading parametrizations, in particular the vertical momentum transfer parametrization in response to time-variable surface winds, several short model experiments over the period 2007 -- 2011 under 3-hourly forcing from the ECMWF HRES operational model were performed. The results were evaluated both against globally distributed in situ ocean bottom pressure observations, and (for a sub-set of experiments) also against global sea-level anomalies from the Jason satellite altimetry missions, as well as against range-rate residuals of the GRACE satellite gravimetry mission.

Multi-Decade Reference Simulation Covering the Era of Geodetic Satellites:

Satellites equipped with laser retro-reflectors have been launched already in the year 1976, and it is custom in the geodetic community to re-process the whole time-series of available observational data with updated correction models. Thus, model-based correction models as aimed for in the **GRACE-FO** and **ASPIRE** projects need to cover more than 4 decades with high spatial and temporal resolution. Based on the model configuration specified within WP1, long-term simulations over that period based on 3-hourly ECMWF reanalysis forcing data sets were performed. The additional 3-hourly forcing information was obtained from the short-term forecasts available from both ERA-40 and ERA-Interim, respectively.

Preparation of a new oceanic De-Aliasing Product:

The new 40 years-long reference simulation was used as the basis for the latest release 06 of the Atmosphere and Ocean De-Aliasing Product AOD1B (Dobslaw et al., 2017). The series is currently applied in the reprocessing of the full GRACE mission record (2002 -- 2017) and additionally also under consideration for an planned re-processing of all LAGEOS observations that started in the year 1976.

Preparation of a new Oceanic Effective Angular Momentum Function Series:

The new 40 years-long reference simulation is currently also used to calculate a new high-resolution series of ocean effective angular momentum functions required to interprete the observed variations in the Earth's pole coordinates and the changes in the Earth rotational velocity. Comparisons with geodetic observations are expected to provide information about the potential predictability of Earth orientation changes based on geophysical model data (Dobslaw and Dill, submitted).

References

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Dobslaw, H., Flechtner, F., Bergmann-Wolf, I., Dahle, C., Dill, R., Esselborn, S., Thomas, M. (2013). Simulating high-frequency atmosphere-ocean mass variability for dealiasing of satellite gravity observations: AOD1B RL05. *J. Geophys. Res.*, *118*(7), 3704–3711. doi:10.1002/jgrc.20271.

Jungclaus, J. H., Fischer, N., Haak, H., Lohmann, K., Marotzke, J., Matei, D. von Storch, J. S. (2013). Characteristics of the ocean simulations in the Max Planck Institute Ocean Model (MPIOM), the ocean component of the MPI-Earth system model. *Journal of Advances in Modeling Earth Systems*, *5*(2), 422–446. doi:10.1002/jame.20023.

Thomas, M., Sündermann, J., & Maier-Reimer, E. (2001). Consideration of ocean tides in an OGCM and impacts on subseasonal to decadal polar motion excitation. *Geophysical Research Letters*, *28*(12), 2457–2460. doi:10.1029/2000GL012234.

ISI Publications based on project #499 results from the last two years

Dobslaw, H., Bergmann-Wolf, I., Dill, R., Poropat, L., Thomas, M., Dahle, C., Esselborn, S., König, R., Flechtner, F. (2017): A new high-resolution model of non-tidal atmosphere and ocean mass variability for de-aliasing of satellite gravity observations: AOD1B RL06. - Geophysical Journal International, 211, 1, pp. 263-269. http://doi.org/10.1093/gji/ggx302.

Wang, L., Chen, C., Thomas, M., Kaban, M. K., Güntner, A., Du, J. (2017 online): Increased water storage of Lake Qinghai during 2004 to 2012 from GRACE data, hydrological models, radar altimetry, and in-situ measurements. - Geophysical Journal International. http://doi.org/10.1093/gji/ggx443.

Schmidt, T., Schoon, L., Dobslaw, H., Matthes, K., Thomas, M. (2016): UTLS temperature validation of MPI-ESM decadal hindcast experiments with GPS radio occultations. - Meteorologische Zeitschrift, 25, 6, p. 673-683. http://doi.org/10.1127/metz/2015/0601.

Zhang, L., Dobslaw, H., Stacke, T., Güntner, A., Dill, R., Thomas, M. (2017): Validation of terrestrial water storage variations as simulated by different global numerical models with GRACE satellite observations. - Hydrology and Earth System Sciences, 21, 2, pp. 821-837. http://doi.org/10.5194/hess-21-821-2017.

Zhang, L., Dobslaw, H., Thomas, M. (2016): Globally gridded terrestrial water storage variations from GRACE satellite gravimetry for hydrometeorological applications. - Geophysical Journal International, 206, 1, pp. 368-378. http://doi.org/10.1093/gji/ggw153.

Zhang, L., Dobslaw, H., Dahle, C., Sasgen, I., Thomas, M. (2016): Validation of MPI-ESM Decadal Hindcast Experiments with Terrestrial Water Storage Variations as Observed by the GRACE Satellite Mission. - Meteorologische Zeitschrift, 25, 6, pp. 685-694. http://doi.org/10.1127/metz/2015/0596.