Project: **499**

Project title: **GFZ - Erdsystem-Modellierung**

Principal investigator: **Maik Thomas**

Report period: **2019-01-01 to 2019-12-31**

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 one major part in determining gravity and rotational variability. Therefore, the processing of global geodetic measurements - including the satellite gravimetry missions GRACE (2002 - 2017) and GRACE-FO (launched May 22nd, 2018); 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 three peer-reviewed projects

> **NAODEMO** ("Next-Generation Non-Tidal Atmospheric and Oceanic De-Aliasing Models", DFG-Geschäftszeichen: DO1311/4-1)
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> **ESAEOP** ("Independent Generation of Earth Orientation Parameters", funded by the European Space Agency ESA, Contract No. 4000120430/17/D/SR)
>
> **TIDUS** ("Improved Tidal Dynamics and Uncertainty Estimation for Satellite Gravimetry", DFG-Geschäftszeichen: TH864/15-1)

we performed new simulations of the time-evolution of the global ocean bottom pressure field. The projects made use of the same numerical experiments with the current ocean component of the MPI Earth System Model, MPIOM (Jungclaus et al., 2013) and are in particular concerned with short-term mass variability. Thus, the projects 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 2019 on the following activities:

Earth rotation predictions:

The rotational speed of the Earth and the position of the rotational pole vary slowly in time caused by angular momentum changes due to mass re-distributions in atmosphere, oceans, and the terrestrial hydrosphere. Short-term forecasts from ECMWF and DWD were used to force both MPIOM and a land surface scheme and discharge model (LSDM) to predict the Earth's rotation. Numerous hindcast experiments over 2 years (2016 and 2017) have been performed to identify the best prediction settings for forecast horizons between 1 and 90 days. Results were published in several papers (Dill et al., 2018b; Dobslaw and Dill, 2018; Dill and Dobslaw, 2019; Ron et al., 2019), and are currently being prepared for routine use at the European Space Agency as part of the ongoing ESAEOP project.

Elastic Surface Loading Deformations:

Elastic surface loading deformations as calculated based on high-resolution surface mass distributions from MPIOM and various land surface models have been applied in a number of studies. Those include methodological developments to account for high-resolution river geometry information (Dill et al., 2018a); the assessment of deformation effects of an actively managed artificial water reservoir (Neelmeijer et al., 2018), and the discussion of surface loading effects on globally distributed networks of geodetic station observations (Männel et al., 2019). Data underlying those studies is also distributed via the Global Geophysical Fluid Centre of the International Earth Rotation and Reference Systems Service (IERS).

Simulated ocean bottom pressure for GRACE:

Simulated ocean bottom pressure from MPIOM is routinely provided as a background model for the processing of satellite sensor data from the gravimetry missions GRACE and GRACE Follow-On (Dobslaw et al., 2017) as processed with the help of DKRZ resources in the past. The continuously updated data stream allows us to contribute to various studies related to GRACE including the release of the most recent Level-2 reprocessing (Dahle et al., 2019); a first combination of gravity fields from various processing groups in the EGSIEM consortium (Jäggi et al., 2019); the assessment of long-term trends in land water storage (Jensen et al., 2019); and a review of the accomplishments of the whole GRACE mission published in Nature Climate Change (Tapley et al., 2019).

Simulated bottom pressure in combination with a data-base of in-situ observations of that quantity also allowed the validation of both GRACE gravity fields (Chen et al., 2018) and numerical ocean model simulations (Poropat et al., 2018), as well as the assessment of future gravity mission constellation concepts (Poropat et al., 2019). It also enabled a number of further GRACE application studies that specifically focus on the solid Earth response to surface loads of varying size and geometry (Wang et al, 2018; 2019a; 2019b). This GRACE-related work is being continued in the frame of the NAODEMO and TIDUS projects as a German contribution to the joint U.S.-German Science Data System of the GRACE-FO mission.

References

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, 263-269. doi:10.1093/gji/ggx302.

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.

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

Chen, Q., **Poropat, L.,** Zhang, L., **Dobslaw, H.,** Weigelt, M., van Dam, T. (2018): Validation of the EGSIEM GRACE Gravity Fields Using GNSS Coordinate Timeseries and In-Situ Ocean Bottom Pressure Records. - Remote Sensing, 10, 12, 1976.

Dahle, C., Murböck, M., Flechtner, F., **Dobslaw, H.,** Michalak, G., Neumayer, K., Abrykosov, O., Reinhold, A., König, R., **Sulzbach, R.,** Förste, C. (2019): The GFZ GRACE RL06 Monthly Gravity Field Time Series: Processing Details and Quality Assessment. - Remote Sensing, 11, 18, 2116.

Dill, R., Dobslaw, H. (2019): Seasonal Variations in Global Mean Sea-Level and Consequences on the Excitation of Length-of-Day Changes. - Geophysical Journal International, 218, 2, pp. 801-816.

Dill, R., Klemann, V., **Dobslaw, H.** (2018a): Relocation of River Storage From Global Hydrological Models to Georeferenced River Channels for Improved Load-Induced Surface Displacements. - Journal of Geophysical Research, 123, 8, pp. 7151-7164.

Dill, R., Dobslaw, H., Thomas, M. (2018b): Improved 90-day Earth orientation predictions from angular momentum forecasts of atmosphere, ocean, and terrestrial hydrosphere. - Journal of Geodesy. doi:10.1007/s00190-018-1158-7.

Dobslaw, H., Dill, R. (2018): Predicting Earth orientation changes from global forecasts of atmosphere-hydrosphere dynamics. - Advances in Space Research, 61, 4, pp. 1047-1057. doi:10.1016/j.asr.2017.11.044.

Jäggi, A., Weigelt, M., Flechtner, F., Güntner, A., Mayer-Gürr, T., Martinis, S., Bruinsma, S., Flury, J., Bourgogne, S., Steffen, H., Meyer, U., Jean, Y., Sušnik, A., Grahsl, A., Arnold, D., Cann-Guthauser, K., Dach, R., Li, Z., Chen, Q., van Dam, T., Gruber, C., **Poropat, L.,** Gouweleeuw, B., Kvas, A., Klinger, B., Lemoine, J., Biancale, R., Zwenzner, H., Bandikova, T., Shabanloui, A. (2019): European

Gravity Service for Improved Emergency Management (EGSIEM) - from concept to implementation. - Geophysical Journal International, 218, 3, pp. 1572-1590.

Jensen, L., Eicker, A., **Dobslaw, H.,** Stacke, T., Humphrey, V. (2019): Long-Term Wetting and Drying Trends in Land Water Storage Derived From GRACE and CMIP5 Models. - Journal of Geophysical Research (Atmospheres), 10.1029/2018JD029989.

Männel, B., **Dobslaw, H., Dill, R.,** Glaser, S., Balidakis, K., **Thomas, M.,** Schuh, H. (2019): Correcting surface loading at the observation level: impact on global GNSS and VLBI station networks. - Journal of Geodesy, 10.1007/s00190-019-01298-y.

Neelmeijer, J., Schöne, T., **Dill, R.,** Klemann, V., Motagh, M. (2018): Ground Deformations around the Toktogul Reservoir, Kyrgyzstan, from Envisat ASAR and Sentinel-1 Data—A Case Study about the Impact of Atmospheric Corrections on InSAR Time Series. - Remote Sensing, 10, 3, 462.

Poropat, L., Dobslaw, H., Zhang, L., Macrander, A., Boebel, O., **Thomas, M**. (2018): Time Variations in Ocean Bottom Pressure from a Few Hours to Many Years: in situ Data, Numerical Models, and GRACE Satellite Gravimetry. - Journal of Geophysical Research. doi:10.1029/2018JC014108.

Poropat, L., Kvas, A., Mayer-Gürr, T., **Dobslaw, H.** (2019): Mitigating Temporal Aliasing Effects of High-Frequency Geophysical Fluid Dynamics in Satellite Gravimetry. - Geophysical Journal International, 10.1093/gji/ggz439.

Ron, C., Vondrák, J., **Dill, R.,** Chapanov, Y. (2019): Combination of geo-magnetic jerks with updated ESMGFZ effective angular momentum functions for the modelling of polar motion excitation. - Acta Geodynamica et Geomaterialia, 16, 4, pp. 359-363.

Tapley, B. D., Watkins, M. M., Flechtner, F., Reigber, C., Bettadpur, S., Rodell, M., Sasgen, I., Famiglietti, J. S., Landerer, F. W., Chambers, D. P., Reager, J. T., Gardner, A. S., Save, H., Ivins, E. R., Swenson, S. C., Boening, C., Dahle, C., Wiese, D. N., **Dobslaw, H.,** Tamisiea, M. E., Velicogna, I. (2019): Contributions of GRACE to understanding climate change. - Nature Climate Change, 9, pp. 358-369.

Wang, L., Chen, C., **Thomas, M.,** Kaban, M. K., Güntner, A., Du, J. (2018): Increased water storage of Lake Qinghai during 2004 to 2012 from GRACE data, hydrological models, radar altimetry, and in-situ measurements. - Geophysical Journal International. doi:10.1093/gji/ggx443.

Wang, L., Khan, S. A., Bevis, M., Broeke, M. R., Kaban, M. K., **Thomas, M.,** Chen, C. (2019a): Downscaling GRACE Predictions of the Crustal Response to the Present-Day Mass Changes in Greenland. - Journal of Geophysical Research, 124, 5, pp. 5134-5152.

Wang, L., Kaban, M. K., **Thomas, M.,** Chen, C., Ma, X. (2019b): The Challenge of Spatial Resolutions for GRACE-Based Estimates Volume Changes of Larger Man-Made Lake: The Case of China’s Three Gorges Reservoir in the Yangtze River. - Remote Sensing, 11, 1, 99.