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Newsletter EGSIEM

European Gravity Service for Improved Emergency Management

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COVER PAGE OF THE NEW YORK TIMES MAGAZINE (SEP. 12, 2017) WHICH SHOWS HOW IMPORTANT THE PIONEERING GRACE MISSION IS FOR MONITORING CLIMATE CHANGE (CREDIT: [JON GERTNER]).

GRACE Mission: New Release of AOD1B Product

Gravity-based indicators of regional flood and drought conditions as provided by the EGSIEM service are derived from global gravity fields obtained from sensor data from the Gravity Recovery And Climate Experiment (GRACE) satellite mission. Since non-tidal mass re-distributions associated with transient atmospheric weather systems and wind-driven sea-level changes take place at time-scales of several hours only, its gravitational signals cannot be deduced reliably from GRACE science products alone. Instead, such signals need to be taken into account already during the precise orbit determination of the satellites by means of an *a priori* model with particularly high temporal resolution to avoid temporal aliasing. Further, gravity fields from the GRACE mission provide a horizontal resolution of a few hundred km, but are inherently insensitive in discriminating between masses at, above or beyond the Earth's surface. To aid the vertical signal separation and to isolate atmospheric mass variability from terrestrial water storage variations, continental ice-mass changes, or tectonic processes, an *a priori* model of high-resolution global non-tidal atmospheric mass variability is typically subtracted during the gravity field estimation process.

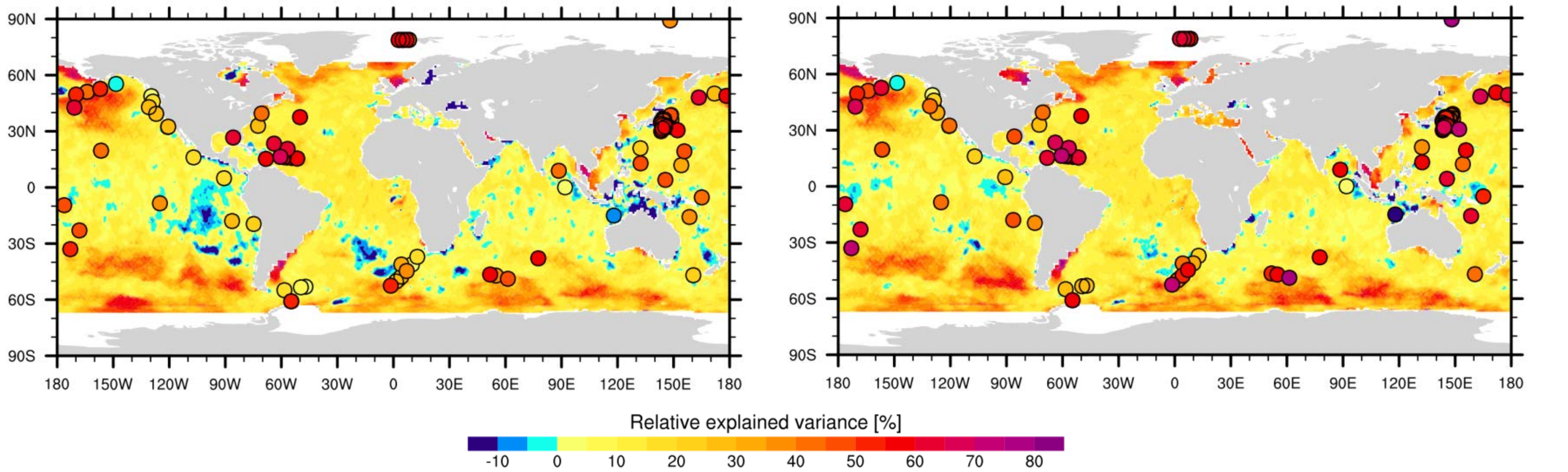

FIG. 1: RELATIVE VARIANCES OF SEA-LEVEL VARIABILITY FROM JASON-2 (GRID) & IN SITU OBP (CIRCLES) FROM AOD1B RL05 (LEFT) AND RL06 (RIGHT).

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GRACE New Release AODL1B RL06 Products (cont'd)

To achieve this the background model needs to be stable over the duration of the mission in order to avoid introducing spurious effects into the gravity field time-series that are subsequently prone to be interpreted erroneously in an entirely different geophysical context. Both purposes are served by the GRACE Atmosphere and Ocean De-Aliasing Level-1B (AOD1B) product, which has been processed since the launch of the mission by the German Research Center for Geosciences (GFZ) in Potsdam. Release 06 is based on numerical weather prediction data from the European Centre for Medium Range Weather Forecasts (ECMWF), and a simulation from the global ocean circulation model MPIOM consistently forced with ECMWF atmospheric data. AOD1B is given in Stokes coefficients, expanded up to d/o 180 and has a temporal sampling of 3 hours.

Validation with Satellite Altimetry and *in situ* Ocean Bottom Pressure

The efficacy of the new AOD1B version in representing high-frequency mass variability was thoroughly tested before release. At sub-monthly time-scales, sea-level variability, as measured by satellite altimetry, is largely consistent with pressure variations at the bottom of the sea. We therefore utilized 4 years of satellite altimetry data from Jason-2, together with a database of *in situ* ocean bottom pressure observations. Both datasets where processed in order to remove instrumental effects and geophysical signals not related to non-tidal mass variability. In a final step, both AOD1B RL06 and its predecessor (RL05) were applied to further reduce (or explain) the residual variance at periods between 1 and 30 days (Fig. 1). Results are largely consistent among the two observation types and show improvements in the Arctic, Hudson Bay, Baltic, Mediterranean, Red Sea, and Gulf of Carpentaria.

Impact on GRACE K-Band Residuals

We also tested the impact of exchanging AOD1B on the primary GRACE sensor data, the K-Band range-rate (KBRR) measurements between the two co-orbiting spacecraft. We evaluated KBRR pre-fit residuals over the year 2008 obtained after initial data screening and precise orbit determination, but prior to the gravity field adjustment. KBRR residuals are transformed into K-Band range acceleration residuals by differencing KBRR in time followed by a fifth-order Butterworth low-pass filter with a cut-off period of 60 sec. Acceleration residuals (Fig. 2) are reduced when replacing RL05 with RL06 in many of the regions already identified above, and additionally also along the Siberian Shelf, where artificial drifts present in RL05 are now corrected in RL06.

Summary

AOD1B RL06 provides non-tidal global mass variability in atmosphere and oceans every 3 hours expanded in Stokes Coefficients up to spherical harmonic degree 180. The series has been available since January 1976 and allows the consistent re-processing of all geodetic satellites relevant for gravity field research. AOD1B is routinely updated once per day at 10 h UTC with all eight time-steps of the previous day. Near real time applications and also low-resolution AOD1B products based on forecasted atmospheric variability are made available for up to 6 days into the future. All data and documentation are publicly accessible via www.gfz-potsdam.de/en/esmdata

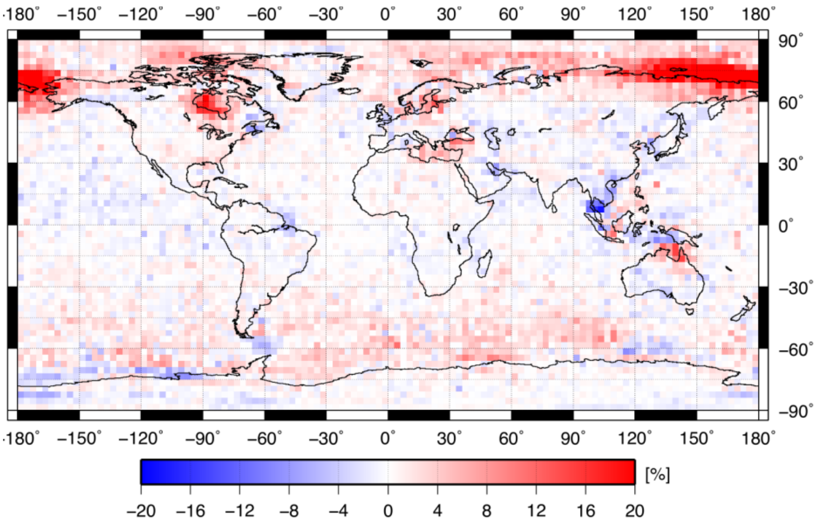

Fig. 2: Relative reduction in GRACE K-band range-rate acceleration residuals when replacing AOD1B RL05 with RL06.

For more information about GRACE AOD release 06 products, please refer to **Henryk Dobslaw** (dobslaw@gfz-potsdam.de) at the German Research Center for Geosciences (GFZ), Dep. 1: Geodesy, Telegrafenberg, Potsdam.

Reference:

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, Geophys. J. Int., 211, 263-269, 10.1093/gji/ggx302.

Processing of SLR Observations at CNES

Due to the high level of uncertainty of the GRACE-only solutions for the degree 2 of the gravity field, the addition of Satellite Laser Ranging (SLR) data from dedicated geodetic satellites is necessary. Similarly to all other GRACE solutions this is also the case for the EGSIEM solution, and the choice is either to substitute the degree-2 coefficients by a SLR-only solution, or to incorporate SLR normal equations to the GRACE normal equations for the solution of the degree 2. In order to give an insight on SLR data processing, here is a description of how the data from four SLR geodetic satellites (LAGEOS-1, LAGEOS-2, Starlette and Stella) are processed at CNES. The data are processed in 5-day arcs and then cumulated per month or per 10-day periods, depending on the temporal resolution required. In addition to the gravity coefficients, the empirical dynamical parameters that are solved are: 1 drag parameter every 6 hours plus 1 periodic once-per-rev parameter along-track and 1 solar pressure parameter per arc for Starlette and Stella. For LAGEOS-1 and LAGEOS-2, which are sensitive to minute accelerations, one constant along-track parameter is solved-for per arc as well as one solar pressure parameter per arc. In addition, the Yarkovsky-Schach effect is taken into account for those satellites through one set of constant empirical accelerations in the orbital plane per arc (one acceleration along the line of nodes and one, in the orbital plane, perpendicular to the line of nodes). This effect comes from the spin of these spherical satellites and the fact that, under heating by the sun, one of their hemispheres becomes warmer than the other, thus producing a small radiative acceleration along their spin axis.

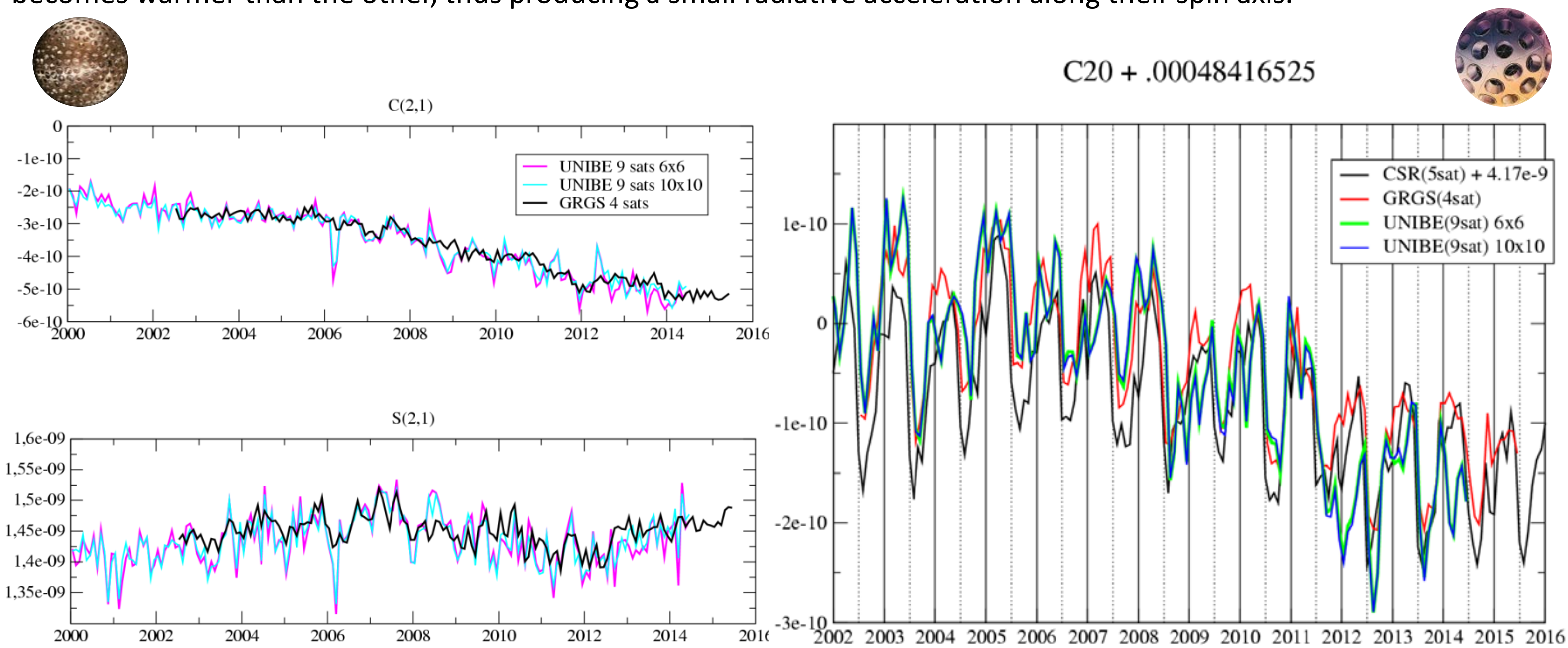

Fig. 3: Time Series of Earth's Gravity Field Spherical Harmonic Coefficients C_{21} and S_{21}; Analysed by the University of Bern and GRGS from Different SLR constellations (Left) - Time Series of the Earth's Oblateness (C_{20}) by CSR, GRGS and University of Bern from various SLR Constellations (Right).

The measurement parameters that are solved are one SLR range bias per station and per arc. Using the ITRF2014 for the station coordinates and EIGEN-GRGS.RL03-v2.MEAN-FIELD for the *a priori* gravity field, the mean SLR residuals are 8.4 mm for LAGEOS-1, 8.0 mm for LAGEOS-2, 10.5 mm for Starlette and 10.4 mm for Stella. The time series of gravity coefficients for spherical harmonics degree 1 and degree 2, from SLR-only solutions, can be compared with those of other groups. For example in Fig. 3, C(2,1) and S(2,1) from CNES/GRGS (based on 4 SLR satellites) are compared to those obtained at the University of Bern with 9 SLR satellites, and the C(2,0) coefficient is also compared to the time series provided, through Technical Note 07, by CSR (based on 5 SLR satellites) for substitution in the RL05 GRACE solutions (Cheng, M.K., B. D. Tapley, and J. C. Ries, "Deceleration in the Earth's oblateness", Jour. Geophys. Res., V118, 1-8, doi:10.1002/jgrb.50058, 2013). In the case of the CNES/GRGS GRACE solutions, we do not substitute the SLR time series of the C(2,0) coefficient, but we add the SLR normal equations to the GRACE ones, before solving for the parameters, thus obtaining a combined solution for the very low degrees of the gravity field.

The CNES/GRGS SLR-only solutions for degrees 1 and 2 are available for download at:

http://gravitegrace.get.obs-mip.fr/grgs.obs-mip.fr/data/RL03-v3/archives/CNES-GRGS.SLR-only.v2.monthly.coeff.tar.gz

For more information, please contact Jean-Michel Lemoine(Jean-michel.lemoine@cnes.fr).

EGSIEM Autumn School

FIG. 4: EGSIEM AUTUMN SCHOOL GROUP PHOTO

The EGSIEM Autumn School for Satellite Gravimetry Applications took place at the German Research Center for Geosciences (GFZ) in Potsdam, Germany from Sep. 11 – 15. Around 45 attendees (plus 12 lecturers) from 16 different countries enjoyed a very interesting week in the beautiful city of Potsdam. In various lectures and practical exercises they learned how to handle the GRACE and future GRACE-FO datasets and how to incorporate them into geophysical applications. The Autumn School started with an ice breaker event on Monday. It was a great opportunity to get to know each other a little better at the GFZ cafeteria, thanks to the local organizing team at GFZ and to the support of the German ministry for training and research. After the welcomes an introduction to GRACE and GNSS was given by Prof. Adrian Jäggi and Dr. Ulrich Meyer. On Tuesday, Prof. Torsten Mayer-Gürr began by explaining the secrets behind gravity field modeling in terms of spherical harmonic basis functions, before offering all participants some hands-on experience in deriving gravity maps from GRACE datasets. The rest of the day was then dedicated to hydrological applications with a lecture plus practical on hydrological modeling given by Prof. Andreas Güntner and an evening talk on hydrological data assimilation by Prof. Annette Eicker. On Wednesday, the applications moved towards the cryosphere and the effects of the last ice age. Prof. Martin Horwath started with a lecture on ice sheet signals and followed with a practical part. Students had the chance to compute their own GRACE-derived time series in polar regions, and to study the melting of ice sheets and glaciers. In the afternoon, Dr. Holger Steffen provided a comprehensive overview on the process of Glacial Isostatic Adjustment (GIA) and how it can be observed by satellites, before Prof. Tonie van Dam concluded the day with her evening lecture on GNSS loading. On Thursday morning, Dr. Hendrik Zwenzner gave an introduction to remote sensing and after lunch Prof. Frank Flechtner's talk on the status of the GRACE-FO mission offered a fascinating insight into the preparation steps and tests that are necessary before the two satellites will be launched next Spring. During the afternoon, a boat cruise on the surrounding lakes presented one of the highlights of the week, where all enjoyed the scenery and the historic sights around Potsdam. On Friday, Matthias Weigelt first presented some key results of the EGSIEM project, before a practical by Stéphane Bourgogne, introduced the EGSIEM plotter as a handy tool for evaluating GRACE L3 products, concluded the Autumn School.

FIG. 5: STUDENTS COMBINE TO SOLVE EXERCISES

FIG. 6: BOAT CRUISE ON THE SURROUNDING LAKES

Many thanks to Prof. Annette Eicker for providing the pictures.

Bundesministerium für Bildung und Forschung

GFZ Helmholtz Centre Potsdam

MEET EGSIEM

AGU Fall Meeting
New Orleans, USA
Dec. 11 – 15, 2017

EGU 2018
Vienna, Germany
Apr. 8 - 13, 2018

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