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Britchi A, Bukarest/Romania (11.-24.6.)
Ghitau D, Prof., Bucharest/Rumania (16.7.-26.8.)
Issawy E, Prof. Dr., Cairo/Egypt (14.-26.6.)
Tenzer R, Prof., Wuhan/China (10.-19.7.)
Varga P, Prof. Dr., Budapest/Hungary (2.10.-29.11.)
Wang L, Luxembourg/Luxembourg (1.-31.10.)
You RJ, Prof. Dr., Tainan/Taiwan (5.8.-12.9.)

Research

Monitoring the water cycle using remote sensing approaches

In recent decades, remote sensing techniques have successfully been deployed to monitor the temporal variation of earth related phenomena. To understand the impact of climate change and human activities on earth water resources, monitoring the variation of water storage over long periods is a primary issue. On the other hand, this variation is a fundamental key to estimate the hydroelectric power generation variation and fresh water recreation.

Among the spaceborne sensors, satellite altimetry can provide surface water height with repeat periods of 10 and 35 days. Optical and SAR (Synthetic Aperture Radar) satellite imagery provide the opportunity to monitor the spatial change in coastline, which can serve as a way to determine the water extent repeatedly in an appropriate time interval.

The inland delta of the Niger river is one of the most fragile ecosystems of Sub-Saharan Africa. Patterns of land cover and land use vary extremely due to the pre-flood and post-flood hydrographical conditions of the Niger river and its tributaries. Spaceborne sensors provide a number of novel ways to monitor the hydrological cycle and its interannual and interseasonal changes.

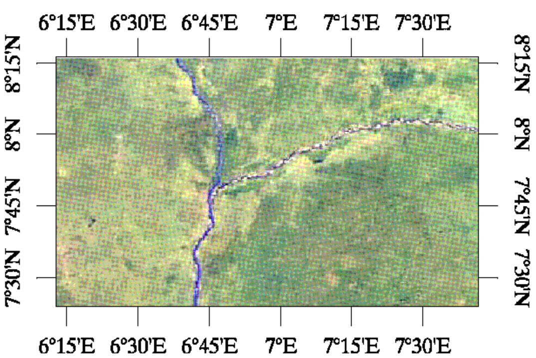


Figure 1: Part of Niger river

Daily snapshots of MODIS (Moderate Resolution Imaging Spectroradiometer) images in Terra and Aqua mode are appropriate for water cycle monitoring because of the availability in different bands and their time interval. While the difference between water and soil in infrared bands is remarkable, the water body is easily identified by applying k-means clustering in infrared bands. Here, MODIS level 3, 16-day vegetation indices (MOD13Q1) data sets with 250 m spatial resolution are used to determine the variation of width in two selected sections of Niger river.

To monitor the water area, all cloud free MODIS images are collected. Each of them are separately classified in two classes (water and land) applying k-means clustering. Finally, the water area is computed in each snapshot.

To evaluate the relationship between the variation of water level and water area, the variation of river width at an in situ gauge is compared with daily runoff during six years. Figure 3 demonstrates that there is a good agreement between water level and water area variations.

Water area together with water level are two fundamental parameters of the hydrological water cycle. Spaceborne geodetic sensors provide valuable information for monitoring the hydrological behaviour of lakes and rivers. Accurate estimation of these parameters gives us a promising sign to obtain the runoff without in situ data.

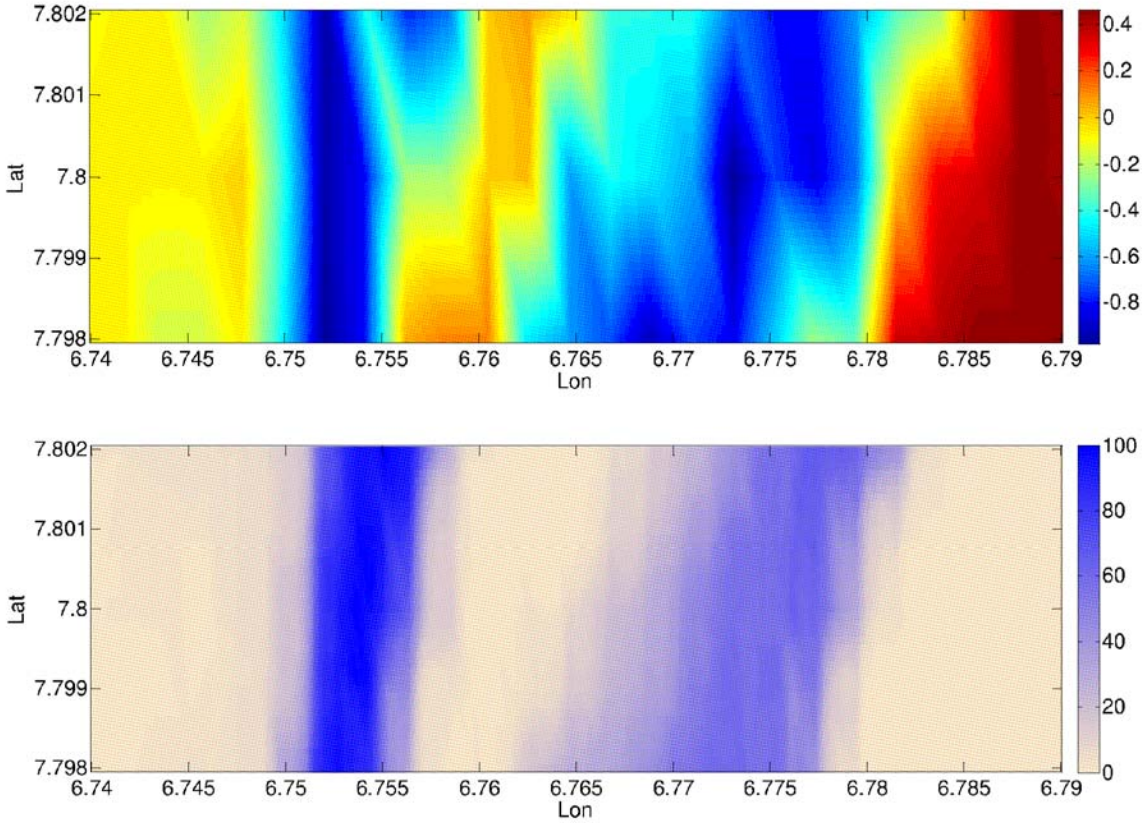


Figure 2: A NDVI image of the river near the in situ gage (top). Percentage of water coverage over 12 years (bottom)

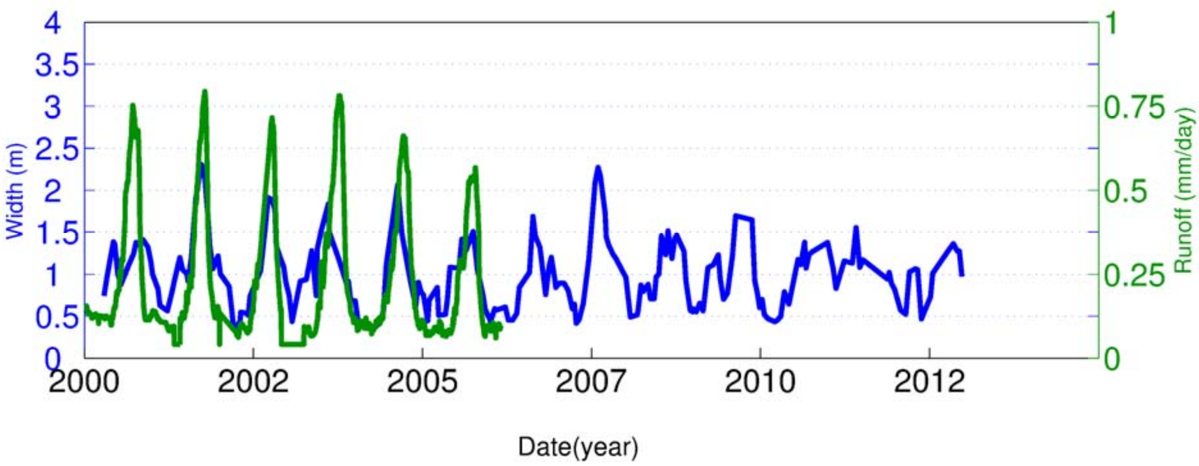


Figure 3: Relationship between daily runoff and river width near the in-situ gauge

Monitoring the water cycle using spaceborne geodetic sensors

Spaceborne sensors provide a number of novel ways to monitor the hydrological cycle and its inter-annual changes. The use of GRACE gravity data allows to determine continental water storage changes and to close the water budget on short time scales. Satellite altimetry can be used as a tool for monitoring inland water surface elevations. Optical satellite imagery provides the opportunity to monitor the spatial change in coastline, which can serve as a way to determine the water extent repeatedly in an appropriate time interval (Figure 4).

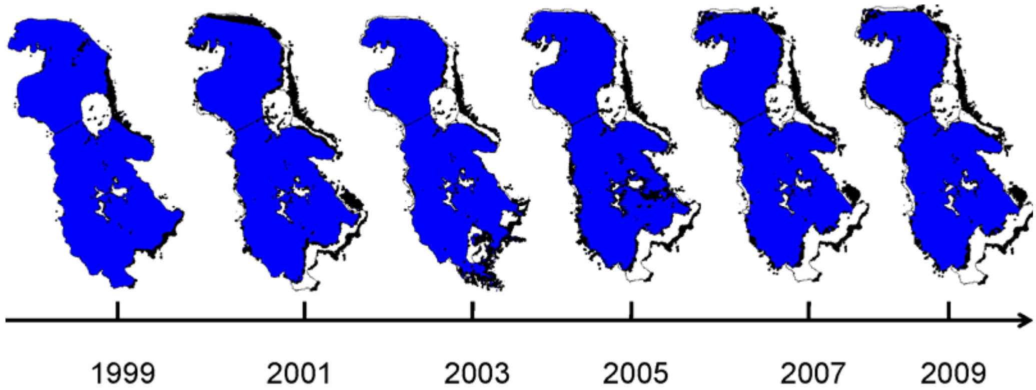


Figure 4: Surface water extent of Lake Urmia, Iran, obtained from MODIS imagery from 1999 to 2009

Assimilation of data sets from different sensors enables a better understanding of the hydrological cycle. The assimilation, for instance, allows us to monitor the desiccation of Lake Urmia in Iran. The Urmia Lake, a hypersaline lake in northwestern Iran is under the threat of drying up. The high importance of the lake's watershed for agricultural purposes demands a comprehensive monitoring of the watershed's behaviour.

The water storage change data from GRACE, surface water level over different parts of the lake from satellite altimetry, surface water extent estimation from optical imagery and in situ in situ observation of precipitation are assimilated to monitor the Urmia lake hydrological cycle (Figure 5).

A linear dynamic system consisting of a stochastic process model and observation equations is developed to assimilate the data from different sources. The dynamic system is solved by a Kalman filter to achieve an unbiased estimation with minimum variance. The assimilation results highlight an extra desiccation after 2009 in contrast to the increase of GRACE mass storage and precipitation.

CryoSat-2 for hydrological purposes: data processing, visualization and analysis

The publicly available global river discharge database is limited in spatial and temporal coverage.

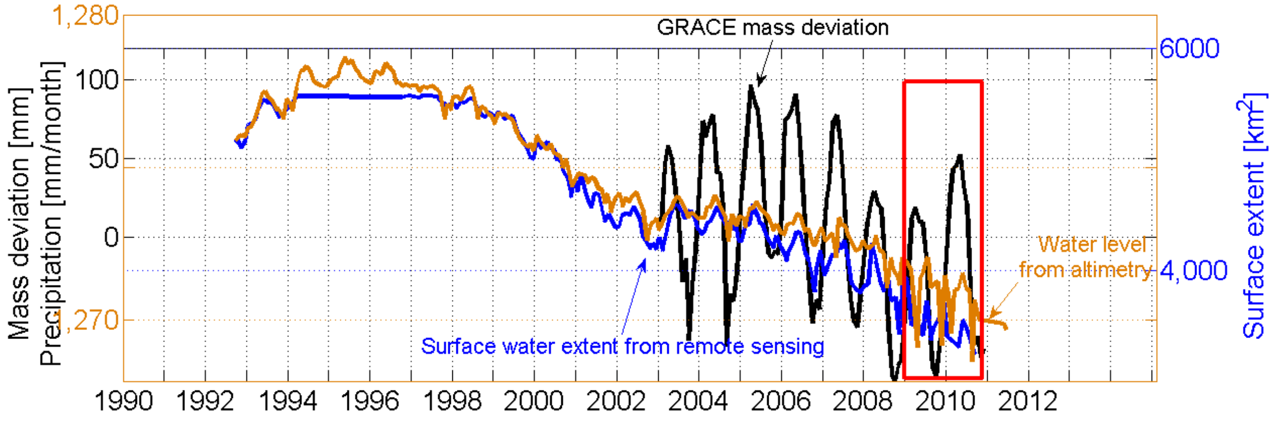


Figure 5: All in one: Time series of mass deviation from GRACE, precipitation from GPCC, precipitation of Nazchoolay station, surface water extent from remote sensing approach and water level from satellite altimetry

Although regional exceptions exist, the population of the database has declined over the past several years. As discharge is one of the most important parameters for modeling hydrological interactions, alternative measuring techniques must be sought. Our ultimate goal is to develop an algorithm to derive river discharge estimation without the need of current or past in situ data. For that purpose, only water level data is not sufficient and other types of hydrological data like slope, channel width, etc. are needed. Therefore the capability of the CryoSat-2 satellite for hydrological studies of rivers, more precisely of their water level, extent and slope is investigated. CryoSat-2 is a remote sensing satellite of ESA, which is originally designed for the monitoring of sea and land ice surfaces. It provides global radar altimetry data that can also be used for other areas of application.

A GUI based on MATLAB, called CryoTrack, has been developed, which allows the end user to comprehend the tracks of the CryoSat-2 satellite on a global grid and to access their measurements for selected area and period (Figure 6). With the help of this software, CryoSat-2 data was used to determine water height, extent and slope of rivers, by combining the information of several radar altimetry quantities. Analyzing several intersections between the satellite tracks and the Niger River as a case study revealed that slope and river water height can be estimated from CryoSat-2 data with

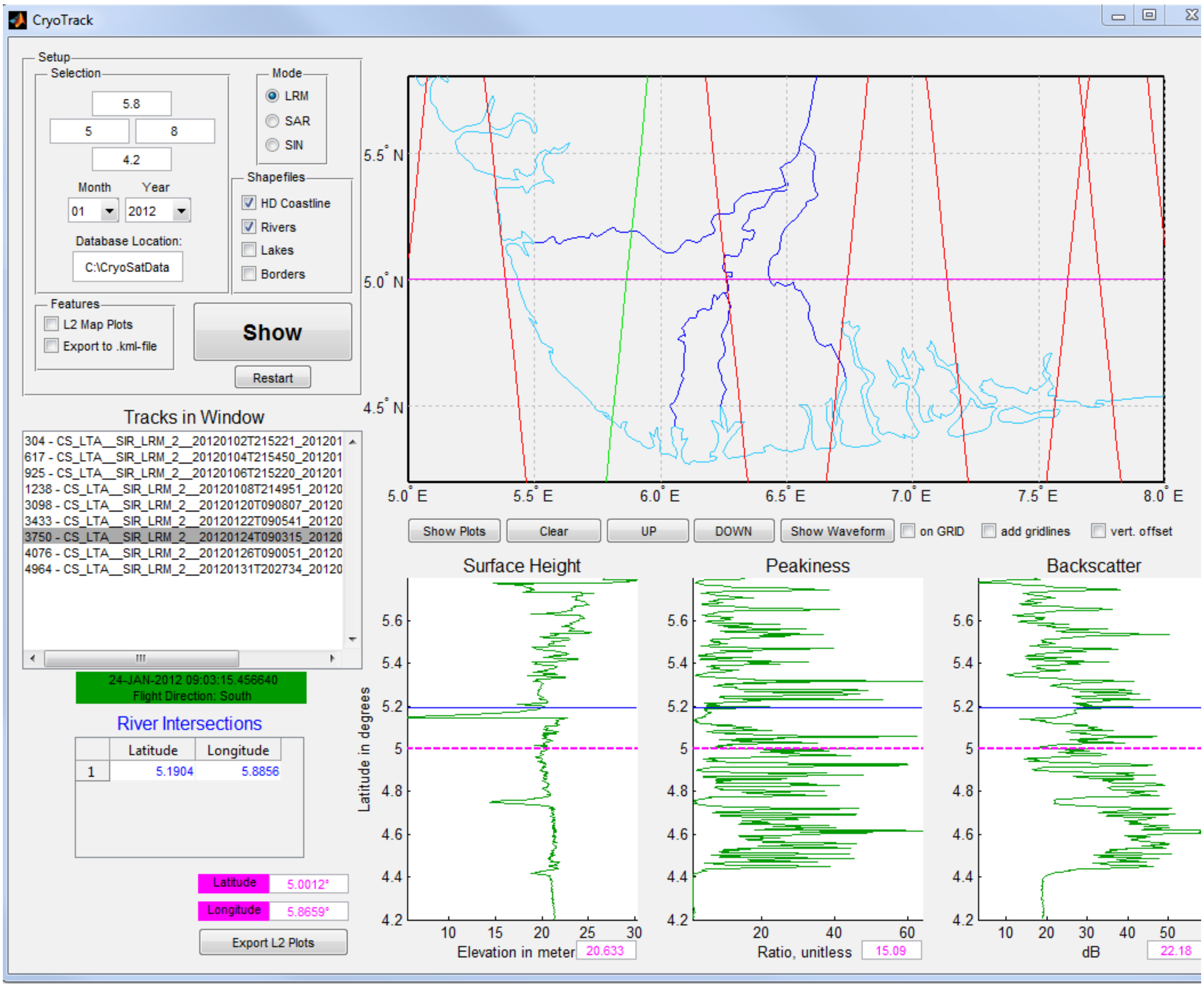


Figure 6: CryoTrack graphical user interface based on MATLAB

acceptable accuracies. Our analysis shows that the transitions between water and land surfaces can be identified for wide rivers, for which their distance allows estimation the river width.

With the help of this software, CryoSat-2 data was used to determine water extent and slope of rivers, by combining the information of several radar altimetry quantities. Analyzing several intersections between the satellite tracks and the Niger River as a case study revealed that slope and river water height can be estimated from CryoSat-2 data with acceptable accuracies. Our analysis shows that the transitions between water and land surfaces can be identified for wide rivers, for which their distance allows estimation the river width.

Least squares prediction of discharge

In response to the limitations of the existing in situ discharge database, we estimate river discharge of ungauged basins by least squares prediction. In this method, discharge is predicted by mapping the discharge characteristics of gauged basins into ungauged ones through statistical correlations of past data (Figure 7).

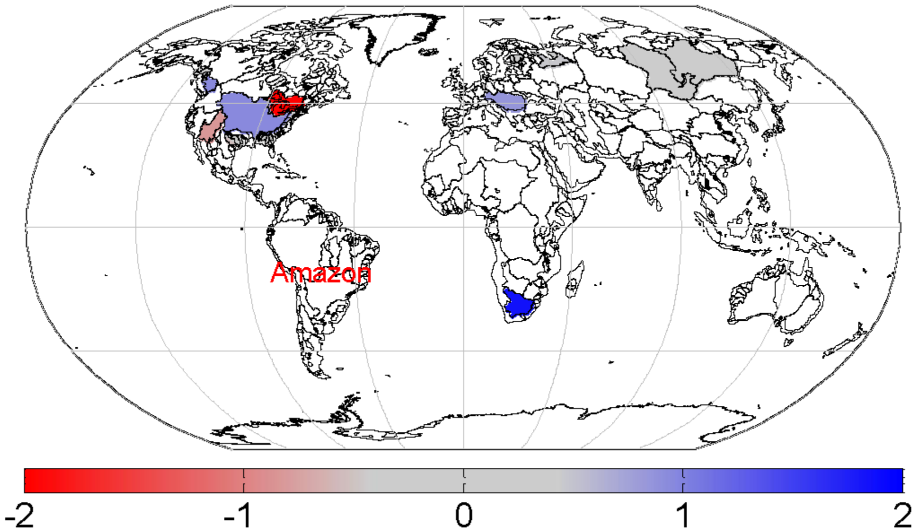


Figure 7: Contribution of 24 catchments to map the discharge characteristics into Amazon. The discharge characteristics generated through available past data between 1980-1990. For validation purposes, Amazon is considered to be ungauged here.

We follow two scenarios to form the covariance matrices out of available past in situ river discharge: (1) at the signal level, and (2) at the residual level after subtracting monthly mean values. Our validation shows that both scenarios are able to capture discharge values with relative errors less than 15% for 80% of the 25 catchments under study. We obtain Nash-Sutcliffe coefficients of over 0.4 for about 90% and of over 0.75 for about 50% of the catchments under study. We are thus able to avoid the complexity of hydrological modeling and the challenges (e.g. uncertainty) of spaceborne approaches for discharge estimation over ungauged basins.

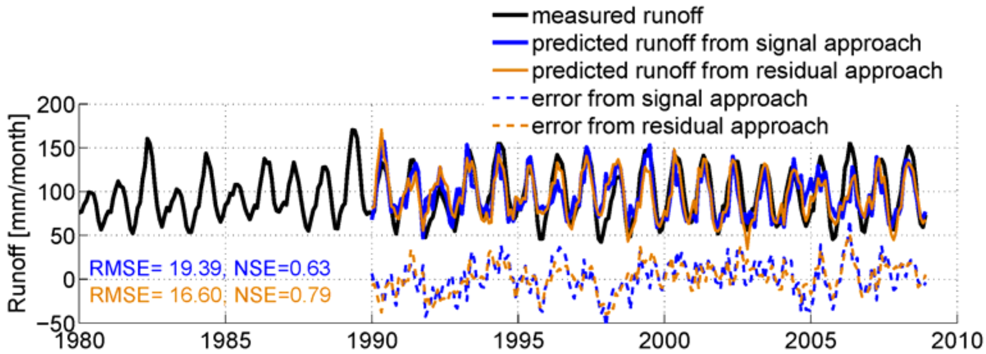


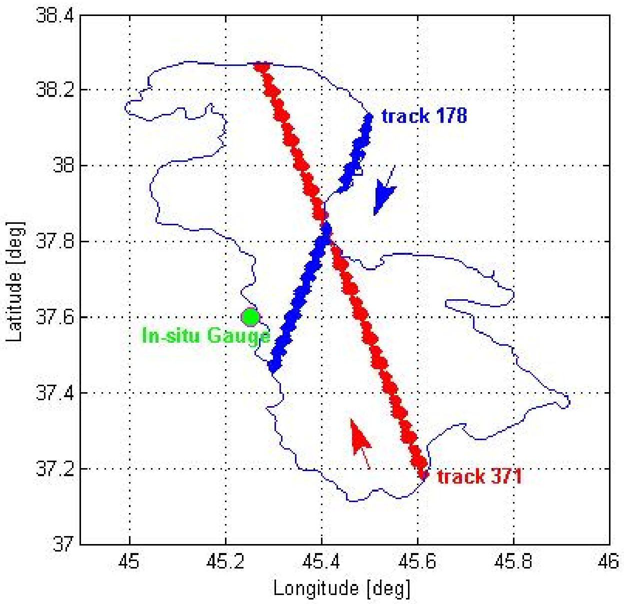
Figure 8: Prediction of discharge for the Amazon catchment with covariance matrices from a training period between 1980 and 1990.

Assessment the ability of pulse-limited altimetry in monitoring the water level of inland water body by full and sub-waveform retracking

Pulse-limited satellite altimetry was originally designed for oceanographic observations but they are able to monitor inland water bodies as well. So far, studying water level variations of inland water bodies, e.g. lakes, has been a challenge for this type of altimetry in terms of data quality. The returned altimetry waveforms can be seriously contaminated by topography and environmental error sources. Retracking is an efficacious method against this contamination to improve the accuracy of the range measurement and, consequently, to determine the water level. In addition, the choice of an optimal retracking algorithm appropriate for the specific regional water bodies is very important in this respect.

In this study we processed 18 Hz Envisat RA2 altimetry data, i.e. Sensor Geophysical Data records (SGDR), with different retrackers and 1 Hz Geophysical Data Records (GDRs) of this mission by on-board retrackers. First, for a given waveform the whole waveform, called full-waveform, was processed to estimate retracked water level variation using OCOG, Threshold and β-parameter retrackers. In the next step we assumed that the reflecting surface inside the radar foot print is a complex surface with different responses. Therefore a given waveform is considered as a combination of a number of small waveforms, called sub-waveforms. Each sub-waveform was processed by all of the mentioned retrackers to determine water level variations. Finally the result of different retracked heights were compared with on-board retrackers, and with available in-situ gauge data.

The largest salt lake in the middle east, Urmia lake, has been selected as a testing area in this study. This lake is drying up due to climate change and human activities, e.g. irrigation and dam construction. Our retracking analysis shows that sub-waveform retracking outperforms full-waveform retracking. The minimum RMS, i.e. 18 cm, was obtained by retracking sub-waveform with threshold 50% algorithm.



A general comparison of Figures 11 and 12 discloses the advantages of waveform retracking. By waveform retracking we can keep all of the measurements, even close to the shoreline, and have a qualified water level time series. We validated the water level obtained from satellite altimetry internally and externally. The internal validation shows that there is no bias and systematic error between ascending and descending track observations. The internal validation relates to the residual and precision of water level. It indicates that threshold retracking algorithm with different threshold values decreases the residual of the water level. The water level residual from ice-1 retacker is 27 cm while the residual from threshold 20% is 15 cm if we retrack the full-waveforms. But if we retrack the sub-waveforms with threshold 10% retracker the water level residual is 10 cm which is a significant improvement. The residual would be 13 cm if threshold 50% is used retrack the first detected sub-waveforms.

For the external validation we use available in-situ gauge data. To avoid elevation datum shift between in-situ gauge and satellite data the mean water level was removed from both time series. For full-waveform retracking there is improvement only by threshold retracker. The maximum improvement is 4 cm which is achieved by threshold 50%. For the β-5 parameter retracker the accuracy before retracking is much better than that after retracking. It shows that for the full-waveforms β-5 parameter is not a proper retracker in the case of Urmia lake. However, for the sub-waveforms β-5 parameter retracker shows good performance. It obtained an accuracy of 22 cm when we use the first sub-waveforms detected in the full-waveforms.

Generally we have improvement by all retrackers when the first sub-waveforms are retracked. The minimum RMS, i.e. 18 cm, has been estimated by threshold 50% retracker. That means we have 8

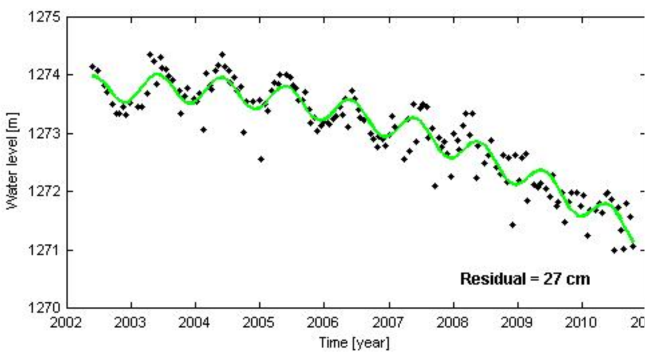


Figure 11: Water level of Urmia lake from standard on-board retracker, ice-1. It outperforms other on-board retrackers.

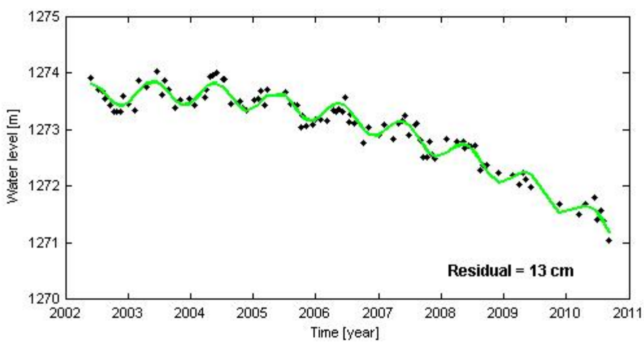


Figure 12: Water level of Urmia lake after waveform retracking using the first detected sub-waveform retracked by threshold 50% retracker.

cm improvement with respect to on-board retracker ice-1. Therefore, the first sub-waveform retracked by threshold 50% is the most robust estimator to monitor the water level variations of Urmia lake.

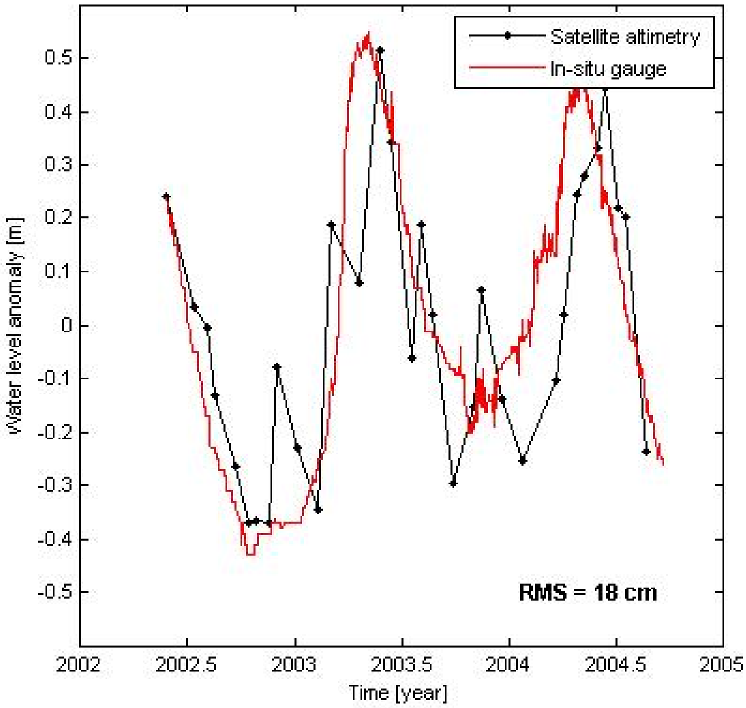


Figure 13: Validation of satellite derived water level against in-situ gauge water level time series

Comparison of GOCE-GPS hl-SST static gravity fields derived by different kinematic orbit analysis approaches

Several techniques have been proposed to exploit GPS-hl-SST (high-low satellite-to-satellite tracking) derived kinematic orbit information for the determination of long-wavelength gravity field features. These methods include the (i) energy balance approach, (ii) celestial mechanics approach, (iii) short-arc approach, (iv) point-wise acceleration approach, and (v) averaged acceleration approach. Although there is a general consensus that - except for energy balance - these methods theoretically provide equivalent results, real data gravity field solutions from kinematic orbit analysis have never been evaluated against each other within a consistent data processing environment. This research strives to close this gap. Within a joint project with the Space Research Institute of the Austrian Academy of Sciences GOCE gravity field estimates based on the aforementioned approaches have been compared. The individual solutions have been computed at the Institute of Navigation and Satellite Geodesy (energy balance approach, EBA) and the Institute of Theoretical Geodesy and Satellite Geodesy (short-arc approach, SAA) of Graz University of Technology, the Astronomical Institute of the University of Bern (celestial mechanics approach, CMA), the Department of Remote Sensing and Geoscience of the Delft University of Technology (averaged acceleration approach, AAA), and the Institute of Geodesy of the University of Stuttgart (point wise acceleration approach, PAA). Consistency concerns the input data sets, period of investigation, spherical harmonic resolution, a priori gravity field information and background models. The performance measures include formal errors, differences with respect to a state-of-the-art GRACE gravity field, (cumulative) geoid height differences, and SLR residuals from precise orbit determination of geodetic satellites (here: LAGEOS-1, Starlette). From the investigations (e.g. degree-RMS in Figure 14) it is concluded that real data analysis results are in agreement with the theoretical considerations concerning the (relative) performance of the different approaches: (i) the energy balance approach performs worse by approximately a factor of $\sqrt{3}$ and (ii) the other approaches perform similar. It was found that it is important (i) to consider the provided orbit covariances in the stochastic model, (ii) to account for the residual air-drag by common-mode accelerations as observed by the gradiometer (accelerometer) in the very low orbit height of GOCE and (iii) to exploit the full 1s-sampled GOCE kinematic orbit set.

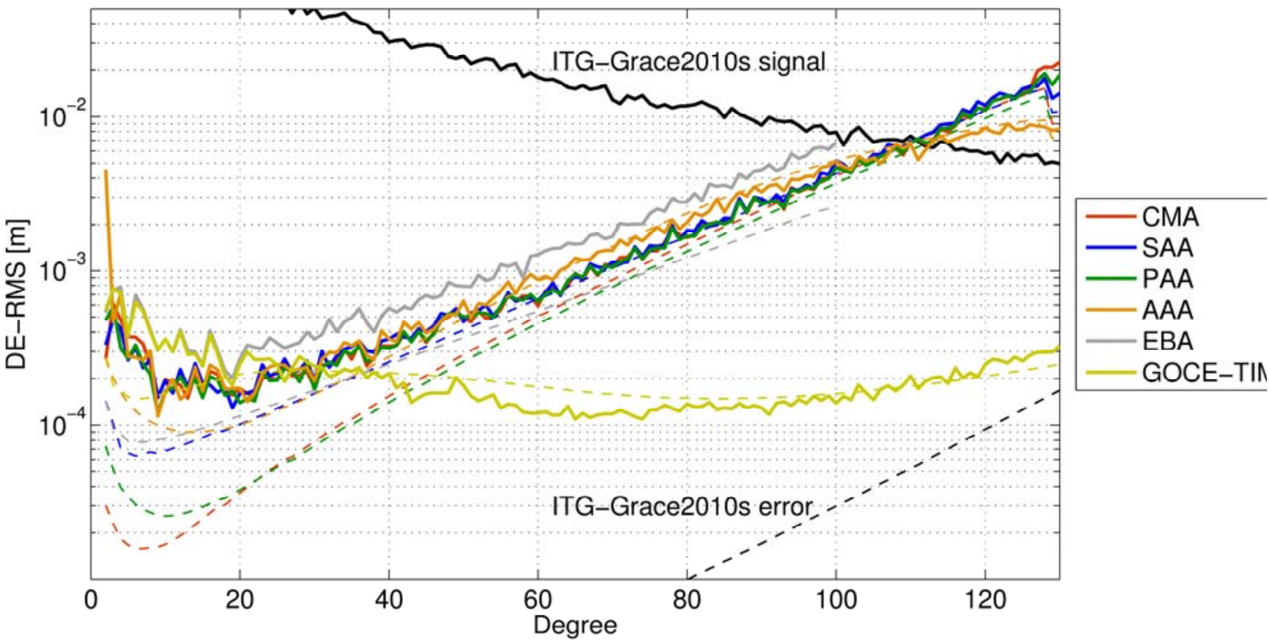


Figure 14: Results for the GOCE-R1 period. Black solid graph: ITG-Grace2010s signal; solid color graphs: DE-RMS of recovered spherical harmonic coefficients w.r.t. ITG-Grace2010s; dashed graphs: formal errors; near-zonal coefficients affected by the polar gap are omitted.

Comparison of mass trend and annual amplitude estimates from different time variable GOCE-GPS hl-SST gravity field recoveries

Recently it has been demonstrated from real data analysis of CHAMP that the detection of annual gravity signals and gravity trends from hl-SST (high-low satellite-to-satellite tracking) is possible for long-wavelength features, although the accuracy of a low-low SST mission like GRACE cannot be reached. This demonstrates the capability of hl-SST based time variable gravity recovery from ESA's magnetic field mission Swarm for bridging a possible gap between GRACE and GRACE-FO. As a continuation of the comparison of static GOCE-SST solutions, a comparison campaign for time variable GOCE-SST gravity field solutions from different research groups was established. The aim was the evaluation of the different orbit processing algorithms, different gravity recovery procedures and dedicated post-processing strategies which have been adopted, as a second aim the results from CHAMP should be confirmed and third it was of interest if a higher spatial resolution can be reached due to the much lower GOCE orbit. The investigated time-variable solutions comprise (i) monthly gravity fields produced by the Institute of Geodesy of the University of Stuttgart (GIS) using the GOCE standard kinematic orbit product, the acceleration approach and polar gap regularization (REG), (ii) 20-day solution from the Department of Astronomics and Space Mission (DEOS) of the Delft University of Technology using a simple standard dynamic approach but accounting for daily variations by means of the Wiese approach and using the GOCE orbit subcycle (20 days) as recovery period and (iii) monthly GOCE and GRACE (and the combined result) hl-SST solutions generated by the Theoretical Geodesy and Satellite Geodesy (ITSG) of Graz University of Technology using a sophistic orbit determination method with improved ionosphere modeling and the short arc approach.

The different solutions have been evaluated by the Space Research Institute of the Austrian Academy of Sciences by means of trend and annual amplitude estimates for important basins, as displayed in Figure 15. The results show that (i) a sophisticated orbit determination approach with advanced ionosphere modeling together with careful stochastic modeling within the gravity recovery approach is of great benefit, (ii) the quality of CHAMP is not completely met, probably because problems involved with the inclined sun synchronous orbit and (iii) the combination of measurements from several satellites, here GRACE and GOCE, leads to big improvements (which demonstrates the potential of Swarm for gap-bridging).

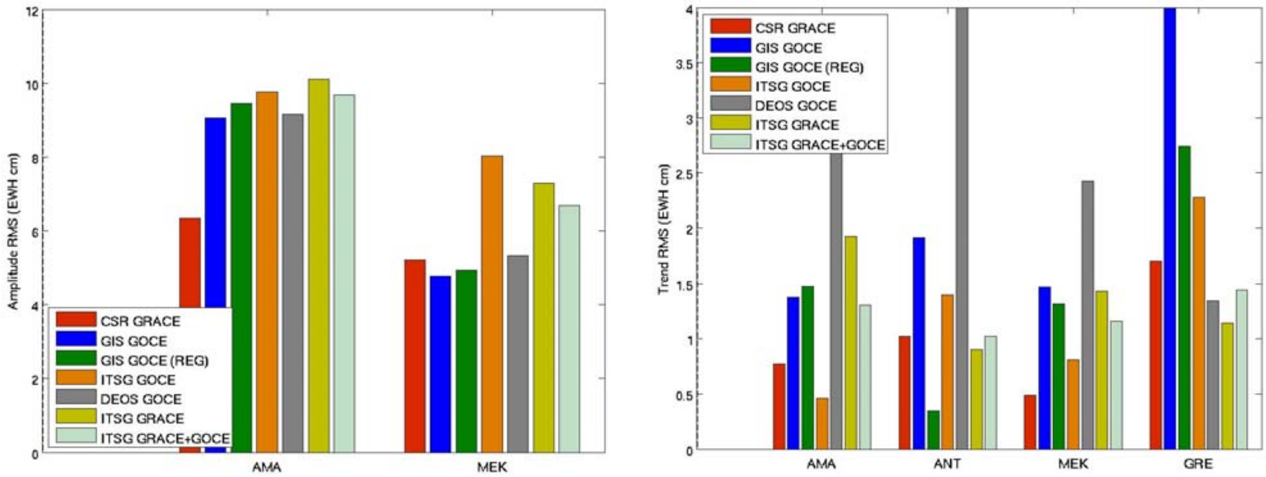


Figure 15: Estimates of annual amplitudes (left) and mass trends (right) for important basins from various time variable GOCE-GPS hl-SST gravity field recoveries (Gaussian smoothing of R = 1500 km applied) in comparison to CSR GRACE ll-SST solution; basins: Greenland (GRE), Amazonas (AMA), Mekong (MEK), Antarctica (ANT)

Investigations on the capability of Swarm as a gap-filling mission for estimating time-variable gravity fields and mass variations

Recently, the implementation of the GRACE Follow-On mission has been approved. However, this successor of GRACE is planned to become operational in 2017 at the earliest. In order to fill a potential gap of 3-4 years between GRACE and GRACE-FO, the capability of the magnetic field mission Swarm, which was launched in November 2013, as a gap filler for time-variable gravity field determination has to be investigated. Since the three Swarm satellites, two of which fly on a pendulum formation, are equipped with high-quality GPS receivers and accelerometers, orbit analysis from high-low Satellite-to-Satellite Tracking (hl-SST) can be applied for geopotential recovery. As data analysis from CHAMP and GRACE has shown, the detection of annual gravity signals and gravity trends from hl-SST is possible for long-wavelength features corresponding to a Gaussian radius of 1000 km, although the accuracy of a low-low SST mission like GRACE cannot be reached. However, since Swarm is a three-satellite constellation and might provide GPS data of higher quality compared to previous missions, improved gravity field recovery can be expected.

One of the most important scientific results of GRACE is the estimation of mass trends such as the ice mass loss on Greenland or water accumulation in the Amazon Basin. The potential of Swarm for the continuation of such mass trend time series is investigated. By means of reduced-scale simulations using the acceleration approach and taking into account time-variable background models of atmosphere, ocean, hydrology, ice, solid Earth and ocean tides as well as measurement noise a first simulation cycle based on monthly solutions (up to degree 60) was investigated.

In order to improve the data quality and extract the time variable signals, a Kalman-based filter approach is employed. The prediction model is derived directly from the time series of each coefficient separately and consists of the mean, a trend and a sine/cosine function with the main frequency at 1 cycles per year. The Kalman-filtered time series show a clear improvement in both the temporal and spectral domain without smoothing the signals of interest significantly, although the effect on detected basin mass trends was quite negligible in the simulations.

In a second step, mass trends are estimated by fitting a regression line together with annual/semi-annual signals to (residual) mass-variation time-series. Figure 16 displays the mass trends for smoothing radii of R = 1000 km. Although the spatial map of mass trends looks quite noisy compared to the input signals the major trend signals, e.g. Greenland are clearly visible. The trend estimates for such dominant basins with stable spatial patterns can be determined quite accurate (deviations within 10-30%) while for basins with smaller trend signals the spatial patterns appear unstable and the errors are much larger. The results show the possible capability of Swarm for long-wavelength time-variable gravity recovery and mass trend estimation for basins with large signals (this holds also for the estimation of annual amplitudes) and motivates further investigations.

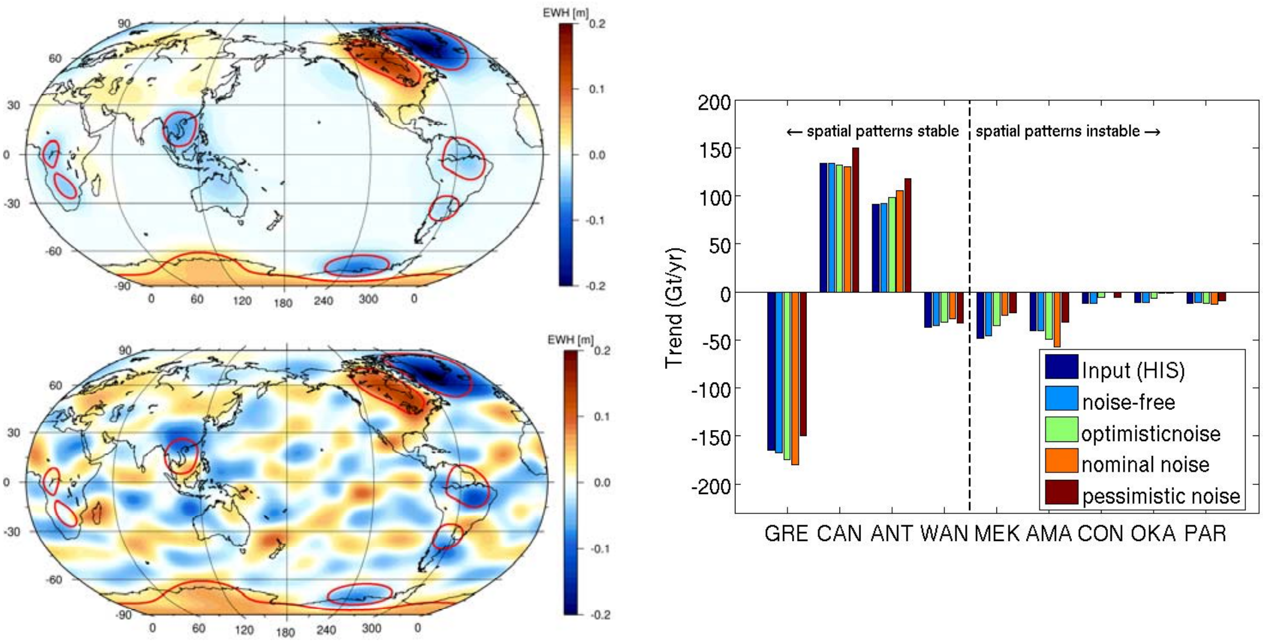


Figure 16: Mass trend estimates from simulated 5 years SWARM time series using Gaussian smoothing of R = 1000 km; top left: spatial map of trends from input models; bottom left: spatial map of estimated trends from simulated SWARM mission with pessimistic noise assumptions; right: estimated trends for major basins (different noise assumptions); basins: Greenland (GRE), Canada (CAN), Antarctica (ANT), West Antarctica (WAN), Mekong (MEK), Amazonas (AMA), Congo (CON), Okavango (OKA), Parana (PAR)

Influence of ground-track pattern distribution of double inline satellite pair missions on quality of the gravity solutions

The quality of recovery of time-variable gravity field is improved by employing two pairs of inline satellites. Iran Pour et al. (2013) showed that gravity solutions from two pairs of satellites significantly improve quality compared to the twice larger time-interval of the single pair scenarios with the same altitude. As an example, it has been shown that the 3-day gravity solutions of SH maximum degree 90 by two pair missions have quality improvement by approximately 5 times compared to the 6-day solutions of the single pair scenarios with the same altitude. That is indeed because of using an inclined satellite mission together with the near-polar mission where we simply add East-West measurement component to the North-South component of the near-polar satellite mission. It is also important to remember that 3-day gravity solutions also benefit from higher time resolutions compared to 6-day solutions. However, among the dual scenarios, it can be seen that the scenarios with slow ground-track gap evolution have the lowest quality. That is for example the scenario 2.5 of Table 1 (compared to the other scenarios of the table) where the repeat modes of the satellite pairs are drifting (β/α = 95/6) and slow skipping (β/α = 338/25) orbits. That means the gap evolution of the ground-track affects the solutions' quality. The influence of the missions' altitudes on the quality of gravity solution, on the other hand, can be clearly seen for 3-day solutions of the first four scenarios of Table 1.

scenario	β/α [rev./day]	inclination [deg]	altitude [km]	error rms [mm]		
				3 d	6 d	32 d
1	503/32 503/32	89.5 72	333.8 305.0	0.8	0.4	0.2
2	125/8 503/32	89.5 72	360.7 305.0	0.9	0.4	0.2
3	503/32 125/8	89.5 72	333.8 332.1	1.1	0.4	0.2
4	125/8 125/8	89.5 72	360.7 332.1	1.2	0.4	0.2
5	95/6 338/25	89.5 72	301.3 362.9	1.3	0.7	0.3

Table 1: Global geoid height error rms for 3-day, 6-day and 32-day recoveries of different dual inline formation mission scenarios (L_{max} = 90)

The impact of ascending node angle difference of two pair mission scenarios ($\Delta\Omega$) has been investigated for the scenario 2.5 (Table 2). No significant influence of the different $\Delta\Omega$ has been seen for the long time-intervals solutions. However, for short-time gravity recovery of the sub-Nyquist solution (3-day recovery for SH maximum degree 90), one can see the effect of the ascending node angle difference, where $\Delta\Omega$ = 180° gives the smallest error. This means that for the short-time solutions, the ground-track pattern distribution gets more important.

$\Delta\Omega$ [deg]	error [mm]		
	3 d	6 d	32 d
0	1.7	0.7	0.3
90	1.7	0.6	0.3
180	1.3	0.7	0.3

Table 2: Recovery errors of 3, 6 and 32-days of scenarios 5; Different $\Delta\Omega$ [deg]

Comparison of surface loading-induced deformations from GPS and GRACE

Mass transport and mass redistribution within the Earth system induce surface mass loading variation. Thus, it consequently leads to the surface deformation of the solid Earth.

The surface deformations can either be derived from GRACE through time-variable gravity field or be observed by IGS stations in 3D GPS coordinates. The surface deformations derived from GRACE are spatially smoothed with about 350 km spatial resolution. However, the deformations of

IGS stations observed by GPS are discrete point measurements on the globe. Therefore, the consistency between the deformations from GRACE and GPS needs to be validated.

To investigate the level of agreement between GPS and GRACE, a number of IGS stations in three regions are selected (Tibetan plateau, Danube basin and Great Lakes area) with period of 8 years (2003-2011). The loading induced deformations occur primarily in vertical direction. As a result, the deformations in vertical direction from GRACE have quite consistent periodical patterns with ones from GPS as shown in Figure 17.

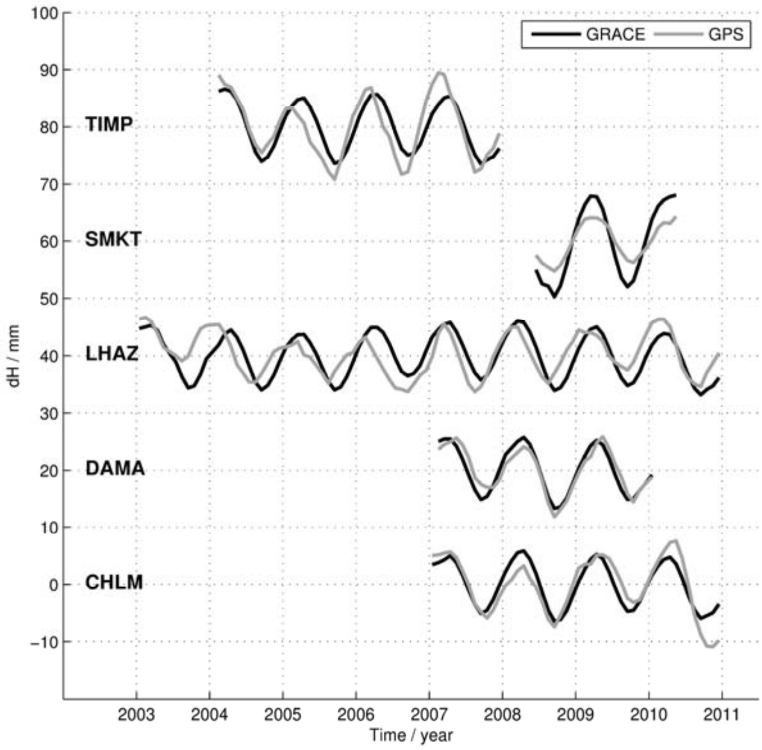


Figure 17: Comparisons of height displacements time series from GRACE and GPS of five IGS stations on Tibetan plateau

Many factors cause the disagreement between GPS and GRACE. The choice of optimal filter for GRACE solutions is among one of them. Isotropic Gaussian filter, anisotropic Gaussian filter, destriping filter and stochastic filter are compared to search for the best option. After investigation of the GPS sites located in Europe, we find that the destriping filter can significantly improve the consistencies. The optimum radius for the isotropic Gaussian filter combined with the destriping filter is around 350 km. For anisotropic Gaussian smoothing, there is no distinct difference with or without destriping filter. The optimum radius for the anisotropic Gaussian filter is around 300 km.

Compared with the deterministic filters, the stochastic filter does not show improvements over all the GPS sites located in Europe. However, the stochastic filter does provide higher spatial resolutions and performs better at GPS sites where significant mass variation happens, see Figure 18. This motivates us to do further comparison over other regions, e.g. Amazon and Greenland.

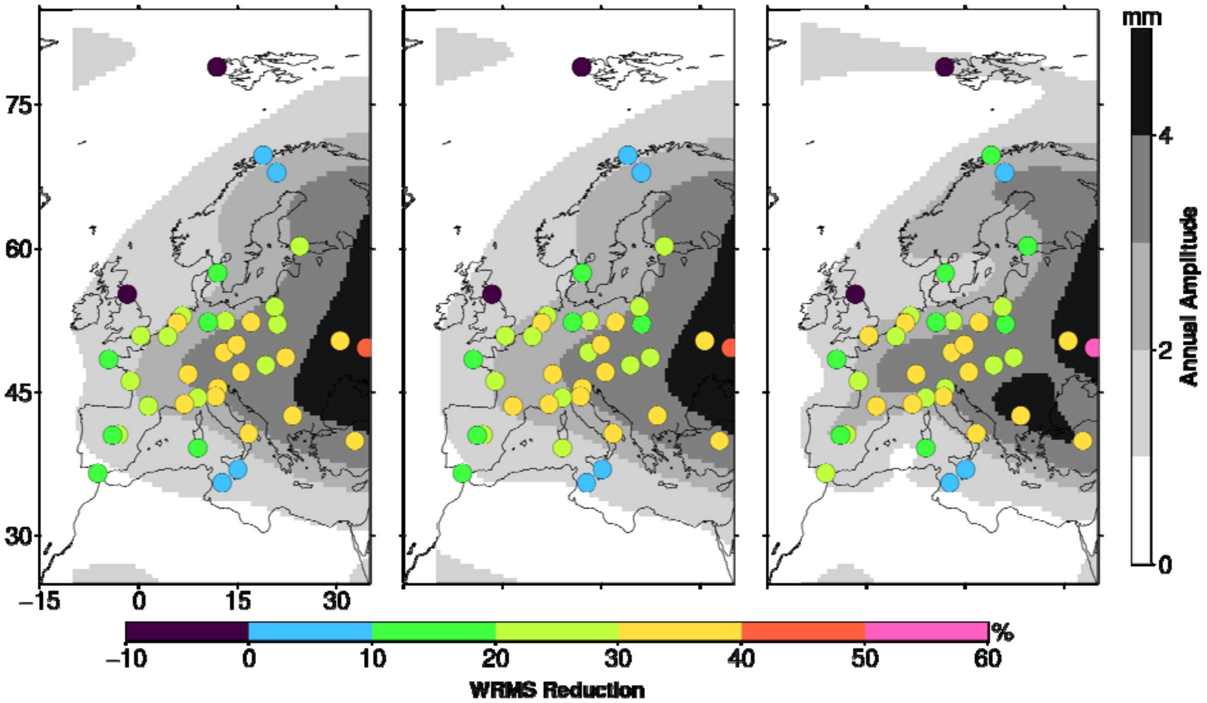


Figure 18: Background of each subplot illustrates grid amplitudes of annual height deformations from GRACE data filtered by the isotropic Gaussian filter of a radius at 350 km combining with the destriping filter IGD (left), the anisotropic Gaussian filter with a radius of 300 km (middle) and the stochastic filter (right), respectively. Circles indicate the weighted root mean squares (WRMS) reduction in the GPS signals after removing GRACE from GPS.

Modelling of the Earth's gravity field by boundary elements

The recovery of the Earth's gravity field is usually performed by spherical harmonics. This set of base functions is the natural choice for spherical bodies and has several advantages, but the resolution is limited by the sub area with the worst data distribution. In case of inhomogeneous data distribution (polar gaps and convergence of tracks in satellite observations), areas with different behavior of the field (e.g. ocean vs. land) or additional terrestrial data, the recovery of the gravity field is separated in two parts. The global behavior is determined via spherical harmonics and the effect of this smoothed field is removed from the signal. The residual signal is analyzed by localizing base functions like wavelets, radial basis functions or boundary elements, to recover the remaining structures.

In the concept of boundary elements, the residual field is assumed to be the result of a single layer on a reference figure, either the sphere or ellipsoid, or even the topography of the Earth. The residual potential of a single layer at position $\bar{x}$ is given by

$$T(\overline{\boldsymbol{x}}) = G \iint_S \frac{\sigma(\overline{\boldsymbol{y}})}{|\overline{\boldsymbol{x}} - \overline{\boldsymbol{y}}|} d\overline{\boldsymbol{y}},$$

where σ denotes the density and $\bar{y}$ the location in the layer (G: gravitational constant, S surface).

The single layer is subdivided into I simpler geometries s_i. Triangles are the most common patches, as they enable a flexible representation of any surface (Figure 19). Each triangle is defined by nodes located at the corners ($k = 1,2,3$), where the density values $\sigma_{i,k}$ are estimated in the adjustment. Then the single layer potential is approximated by

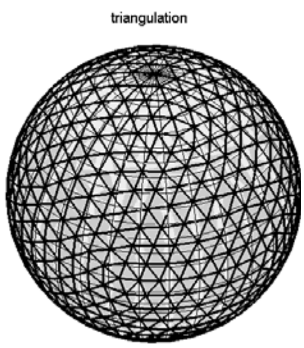


Figure 19: Triangulation of a sphere

$$T(\overline{\boldsymbol{x}}) = G\sum_{i=1}^{I}\iint_{s_i}\frac{\sigma(\overline{\boldsymbol{y}})}{|\overline{\boldsymbol{x}}-\overline{\boldsymbol{y}}|}d\overline{\boldsymbol{y}},$$

where the density $\sigma(\overline{\boldsymbol{y}})$ is a linear interpolation of the density values $\sigma_{i,k}$ in the nodes into the interior of the element s_i.

In a first study, only the signal of the boundary elements themselves is considered. The simulation consists of 120 boundary elements in two distinct areas of the globe. The boundary elements form a network of almost 200 triangles with a mean lateral length of 480 km. The potential along the orbit is computed via a simplified energy balance approach (cf. Figure 20). Using the same triangles in the analysis, the residuals in the orbit are more than 12 orders of magnitudes smaller than the simulated signal (cf. Figure 21), whereas the approximation on ground still achieve 10 orders of magnitudes.

The gravity field recovery from (simulated) potential values looks promising, but for real data the more accurate satellite observations – in particular relative range and rate-rates – has to be developed and implemented for the boundary element method. In addition, the adequate combination of spherical harmonics and the boundary elements and the combination of observation types require further investigations.

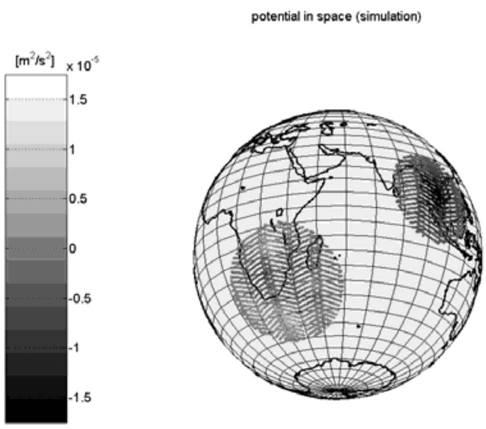


Figure 20: Potential in the orbit generated by 120 triangular boundary elements.

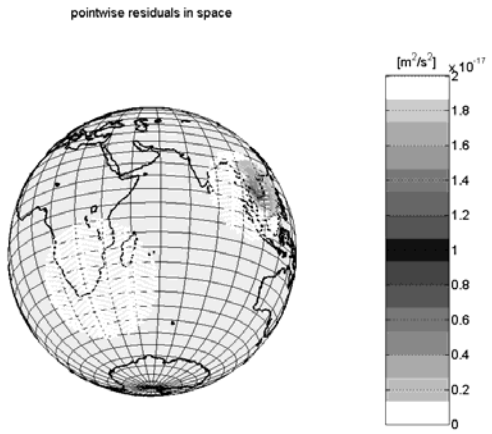


Figure 21: Point wise residuals in the orbit

Theses

Doctoral Theses
(http://www.uni-stuttgart.de/gi/research/dissertations.en.html)

IRAN POUR S: Sampling the Earth's Time-Variable Gravity Field from Satellite Orbit - Design of Future Gravity Satellite Missions
TOURIAN MJ: Application of spaceborne geodetic sensors for hydrology

Diploma/Master Theses
(http://www.uni-stuttgart.de/gi/education/dipl/diploma_theses.en.html)

CAO W: Change detection using SAR data
CHEN J: Precise positioning with low-cost GNSS receivers
REINHOLD A: Basislinienbestimmung mit GPS-Daten an Bord TerraSAR-X und TanDEM-X im Hinblick auf die Modellierung der Bahnmanöver (Baseline determination with GPS data on board TerraSAR-X and TanDEM-X with respect to maneuver modeling)
ZHANG Y: Coherency Analysis between SGs at BFO and Strasbourg

Bachelor Theses
(http://www.uni-stuttgart.de/gi/education/dipl/study_reports.en.html)

MAYER V: CryoSat-2 for hydrological purposes: Data processing, visualization and analysis
THOR R: Least-squares prediction of runoff

Awards

TOURIAN MJ: Winner of Outstanding Student Paper Award in AGU fall meeting 2013

Publications
(http://www.uni-stuttgart.de/gi/research/index.en.html)

Refereed Journal Publications

ANTONI M AND W KELLER: Closed solution of the Hill differential equation for short arcs and a local mass anomaly in the central body. Celestial Mechanics and Dynamical Astronomy 115, pp 107-121, DOI: 10.1007/s10569-012-9454-7
CHEN Q, T VAN DAM, N SNEEUW, X COLLILIEUX, M WEIGELT AND P REBISCHUNG: Singular spectrum analysis for modeling seasonal signals from GPS time series. Journal of Geodynamics 72, pp 25-35, DOI: 10.1016/j.jog.2013.05.005
IRAN POUR S, T REUBELT AND N SNEEUW: Quality assessment of sub-Nyquist recovery from future gravity satellite missions. Journal of Advances in Space Research 52, pp 916-929, DOI:10.1016/j.asr.2013.05.026
KRAWINKEL T, D HÜCKER, C SCHIKSCHNEIT, K BEERMANN, J FLURY, S VEY, M ANTONI AND U FELDMANN-WESTENDORFF: Sub-cm-Konsistenz von nivellierten Normalhöhen, GNSS-Positionen und Quasigeoid im Testgebiet Harz. Zeitschrift für Geodäsie, Geoinformation und Landmanagement 138, pp 201-209
NAJIBI N, A ABEDINI AND H NAJIBI: Analysis of Sea Ice Leads in Baffin Island Sea Using Spaced Based Infrared Remote Sensing Data and Mathematical Hydrological Models. International Journal of Geosciences Research 1, pp 1-11

Najibi N, A Abedini and RA Sheibani: Harmonic Decomposition Tidal Analysis and Prediction Based on Astronomical Arguments and Nodal Corrections in Persian Gulf, Iran. Research Journal of Environmental and Earth Sciences 5, pp 381-392

Sahami Shirazi A, J Clawson, Y Hassanpour, MJ Tourian, A Schmidt, EH Chi, M Borazio and K Van Laerhoven: Already Up? Using Mobile Phones to Track and Share Sleep Behavior. International Journal of Human-Computer Studies 71, pp 878-888, DOI: 10.1016/j.ijhcs.2013.03.001

Tourian MJ, N Sneeuw and A Bárdossy: A quantile function approach to discharge estimation from satellite altimetry (ENVISAT). Water Resources Research 49, pp 1-13, DOI: 10.1002/wrcr.20348

Vishwakarama BD, K Jain, N Sneeuw and B Devaraju: Mumbai 2005, Bihar 2008 Flood Reflected in Mass Changes Seen by GRACE Satellites. Journal of the Indian Society of Remote Sensing 41, pp 687-695, DOI: 10.1007/s12524-012-0256-x

Weigelt M, N Sneeuw, EJO Schrama and PNAM Visser: An improved sampling rule for mapping geopotential functions of a planet from a near polar orbit. Journal of Geodesy 87, pp 127-142, DOI: 10.1007/s00190-012-0585-0

Weigelt M, T van Dam, A Jäggi, L Prange, W Keller and N Sneeuw: Time-variable gravity signal in Greenland revealed by high-low satellite-to-satellite tracking. Journal of Geophysical Research: Solid Earth 118, pp 3848-3859, DOI: 10.1002/jgrb.50283

Other Refereed Contributions

Roth M, N Sneeuw and W Keller: Euler Deconvolution of GOCE Gravity Gradiometry Data. In: Nagel W, D Kröner and M Resch (Eds.): High Performance Computing in Science and Engineering '12, Springer-Verlag Berlin Heidelberg, pp 503-515, DOI: 10.1007/978-3-642-33374-3_36

Non-refereed Contributions

Sneeuw N, B Devaraju and MJ Tourian: Die Vermessung der Welt aus dem All. Themenheft Forschung 9, Universität Stuttgart, 56-63

Poster presentations

Antoni M, M Weigelt, W Keller and T van Dam: Boundary elements for modelling gravitational signals observed by inter-satellite ranging. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

Baur O, H Bock, P Ditmar, H Hashemi Farahani, A Jäggi, T Mayer-Gürr, T Reubelt and N Zehentner: Comparison of GOCE-GPS gravity fields derived by different approaches. EGU General Assembly, Vienna, Austria (7.-12.4.)

Baur O and T Reubelt: Mass Change Detection from Swarm Time-Variable Gravity. Dragon III Symposium, Palermo, Italy (3.-7.6.)

Chen Q, J Zhang, B Devaraju and N Sneeuw: Seasonal loading deformation from GPS and GRACE observations on the Tibetan Plateau. Dragon III Symposium, Palermo, Italy (3.-7.6.)

Chen Q, J Zhang, L Wang, T Van Dam, M Weigelt, B Devaraju and N Sneeuw: Comparison of seasonal hydrological loading information from GPS and GRACE observations. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

Elmi O, MJ Tourian and N Sneeuw: Monitoring of the hydrological cycle using remote sensing approaches. ESA Advanced Training Course in Land Remote Sensing, Athens, Greece

Gruber Th, R Pail, M Murböck, N Sneeuw, T Reubelt, S Iran Pour, J Müller, J Flury, P Brieden, M Naemi, K Danzmann, G Heinzel, B Sheard, V Müller, J Kusche, A Löcher, D

FEILI, F FLECHTNER, JC RAIMONDO, B DOLL, X WANG AND M LANGEMANN: Next Generation Satellite Gravimetry Mission Study (NGGM-D). AGU Fall Meeting, San Francisco, USA (9.-13.12.)

IRAN POUR S, T REUBELT, M ELLMER AND N SNEEUW: Influence of Ground-Track Pattern Distribution of Double Inline Satellite Pair on Quality of the Gravity Solutions. ESA Living Planet Symposium, Edinburgh, UK (9.-13.9.)

MURBÖCK M, R PAIL, T REUBELT, N SNEEUW, T GRUBER AND I DARAS: On Reducing Temporal Aliasing with Multi-Satellite Formations. ESA Living Planet Symposium, Edinburgh, UK (9.-13.9.)

REUBELT T, O BAUR, M WEIGELT AND N SNEEUW: On the capability of SWARM for estimating time-variable gravity fields and mass variations. EGU General Assembly, Vienna, Austria (7.-12.4.)

ROOHI S and N SNEEUW: Analysis of sampling behavior of candidate SWOT satellite orbits. ESA Living Planet Symposium, Edinburgh, UK (9.-13.9.)

SHARIFI MA, N SNEEUW and K GHOBADI: Analysis of GOCE data based on the Rosborough method. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

TOURIAN MJ, O ELMI AND N SNEEUW: A multi-sensor approach to monitor the desiccation of Lake Urmia in Iran. EGU General Assembly, Vienna, Austria (7.-12.4.)

VARGA P, FW KRUMM, EW GRAFAREND, N SNEEUW, F HORVATH AND AA SCHREIDER: Axial rotation and paleogeodynamics during Phaneorozoic. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

WEIGELT M, T VAN DAM, A JÄGGI, L PRANGE, N SNEEUW AND W KELLER: Long-term mass changes over Greenland derived from high-low satellite-to-satellite tracking. EGU General Assembly, Vienna, Austria (7.-12.4.)

WU G, O ELMI, MJ TOURIAN AND N SNEEUW: Combined Measurements of Lake Level and Surface Extent Change. ESA Living Planet Symposium, Edinburgh, UK (9.-13.9.)

WU G, O ELMI, MJ TOURIAN AND N SNEEUW: Combined Measurement of Lake Levels and Surface Extent Change in the Yangtze River Basin. Dragon III Symposium, Palermo, Italy (3.-7.6.)

YE Z, N SNEEUW and L LIU: Computation of topographic and isostatic effect on GOCE in the frequency domain. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

ZHANG Y, R WIDMER-SCHNIDRIG and N SNEEUW**:** Can SGs be used to validate GRACE Gravity Field Models ? – Coherency Analysis between SGs at BFO and Strasbourg. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

Conference presentations

BAUR O, T REUBELT AND M WEIGELT: Bridging the gap between GRACE and GRACE follow-on: the potential of SWARM and SLR to detect time-variable gravity. ESA Living Planet Symposium, Edinburgh, UK (9.-13.9.)

CHEN Q, M WEIGELT, N SNEEUW AND T VAN DAM**:** On time-variable seasonal signals: comparison of SSA and Kalman filtering based approaches. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

DAVOODIANIDALIKI M, A ABEDINI AND M SHANKAYI: Adaptive Edge Detection using Adjusted Ant Colony Optimization. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-1/W3, 2013. SMPR 2013, Tehran, Iran (5.-8.10.)

DEVARAJU B and N SNEEUW: On the spatial resolution of filters on the sphere. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

ELMI O, MJ TOURIAN AND N SNEEUW: A comparison between remote sensing approaches to water extent monitoring. EGU General Assembly, Vienna, Austria (7.-12.4.)

ELSAKA B, JC RAIMONDO, P BRIEDEN, T REUBELT, J KUSCHE, F FLECHTNER, N SNEEUW AND J MÜLLER: Full-scale numerical simulation scenarios using three-month observations of possible future satellite-gravimetric missions. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

GRAFAREND E: Das duale Paar Moritz-Molodenskij: Geodätische Höhen und Höhensysteme. 80 Jahre Helmut Moritz, Leibniz-Sozietät der Wissenschaften, Berlin (15.11.)

GRAFAREND E: Space Gradiometry on the International Reference Ellipsoid. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

GRAFAREND E: The Geometry of Kepler orbit/ perturbed Kepler orbit in Maupertuis Manifolds by minimizing the scalar of the Riemann Curvature Tensor, aspects of the Kustaanheimo-Stiefel elements in Satellite Geodesy. EGU General Assembly, Vienna, Austria (7.-12.4.)

GRIBOVSZKI K, G BOKELMANN, G SZEIDOVITZ, P VARGA, I PASKALEVA, L BRIMICH AND K KOVÁCS: Comprehensive investigation of intact, vulnerable stalagmites standing in Hungarian, Bulgarian, Slovakian and Austrian caves in order to estimate of an upper limit on prehistoric peak ground horizontal acceleration. Vienna Congress on Recent Advances in Earthquake Engineering and Structural Dynamics and 13. D-A-CH Tagung

GRIBOVSZKI K, L BRIMICH, P VARGA, K KOVÁCS, CC SHEN, S KELE, Á TÖRÖK AND A NOVÁK: Estimation of an upper limit on prehistoric horizontal peak ground acceleration using the parameters of intact stalagmites and the mechanical properties of broken stalagmites in Domica cave, Slovakia. Geophysical Research Abstracts 15, EGU2013-11541, 2013, EGU General Assembly, Vienna, Austria (7.-12.4.)

IRAN POUR S, T REUBELT AND N SNEEUW: Searching for the optimal dual pair gravity satellite missions. Geodätische Woche Essen (8.-10.10.)

KRUMM FW, G MENES AND P VARGA: Tidal friction and despinning of axial rotation of the Earth. Session VI: Tides and earth reology. Earth Tide Symposium, Warsaw, Poland (15.-19.4.)

LORENZ C, H KUNSTMANN, B DEVARAJU AND N SNEEUW: Assimilation of GRACE and hydrometeorological information for improving large-scale total water storage changes. EGU General Assembly, Vienna, Austria (7.-12.4.)

MEYER U, A JÄGGI, H BOCK, G BEUTLER, C DAHLE and N SNEEUW: Orbit and gravity field: common versus sequential analysis. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

REUBELT T, O BAUR, M WEIGELT, T MAYER-GÜRR, N SNEEUW, T VAN DAM AND MJ TOURIAN: On the capability of non-dedicated GPS-tracked satellite constellations for estimating mass variations: case study Swarm. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

RIEGGER J AND MJ TOURIAN: Characterization of Runoff- Storage Relationships by Satellite-Gravimetry and Remote Sensing. EGU General Assembly, Vienna, Austria (7.-12.4.)

ROOHI S and N SNEEUW: Lake level variations from satellite radar altimetry with retracking of multi-leading edge. Geodätische Woche Essen (8.-10.10.)

ROOHI S and N SNEEUW: Monitoring drying up of Urmia lake with satellite altimetry. EGU General Assembly, Vienna, Austria (7.-12.4.)

SHARIFI MA, N SNEEUW, MR SEIF AND S FARZANEH: A semi-analytical formulation of the Earth's flattening on the satellite formation flying observables using the Lagrange coefficients. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

SNEEUW N: Rosborough representation in satellite gravimetry. Hotine-Marussi Symposium, Rome, Italy (17.-21.6.)

SNEEUW N, R THOR AND MJ TOURIAN: River discharge from ungauged catchments by least-squares prediction. Geodätische Woche Essen (8.-10.10.)

THOR R, MJ TOURIAN AND N SNEEUW: Least squares prediction of discharge over ungauged basins. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

TOURIAN MJ, C LORENZ, B DEVARAJU, J RIEGGER, H KUNSTMANN AND N SNEEUW: Estimating runoff using hydro-geodetic approaches; assessment and comparison. AGU Fall Meeting, San Francisco, USA (9.-13.12.)

TOURIAN MJ, R THOR, J RIEGGER AND N SNEEUW: Runoff estimation using satellite altimetry, GRACE and least squares prediction. Geodätische Woche Essen (8.-10.10.)

VAN DAM T, MJ TOURIAN, M WEIGELT, N SNEEUW, A JÄGGI AND L PRANGE: Hydrological mass changes inferred from high-low satellite-to-satellite tracking data. EGU General Assembly, Vienna, Austria (7.-12.4.)

VARGA P, FW KRUMM, EW GRAFAREND, N SNEEUW, F HORVATH AND AA SCHREIDER: Axial rotation and paleogeodynamics during Phaneorozoic. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.), Theme 4, p 434

WANG L, T VAN DAM, M WEIGELT, Q CHEN, MJ TOURIAN AND N SNEEUW: An inversion approach for determining water storage change from 3-D GPS coordinates time series in Europe. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

WEIGELT M, T VAN DAM, T BANDIKOVA, J FLURY AND N SNEEUW: A variant of the differential gravimetry approach for low-low satellite-to-satellite tracking based on angular velocities. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

WU G, O ELMI, MJ TOURIAN AND N SNEEUW: Combined Measurements of Lake Levels and Surface Extent Change. Geodätische Woche Essen (8.-10.10.)

XU X, T REUBELT, O BAUR, X ZOU AND H WEI: A GOCE only gravity model from space-wise observables along the orbit based on the least-square method. IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)

Books and Miscellaneous

FLECHTNER F, N SNEEUW AND W-D SCHUH (EDS.): Observation of the System Earth from Space – CHAMP, GRACE, GOCE and Future Missions. Geotechnologien Science Report No. 20, Springer Heidelberg New York

ROTH M: GOCEXML2ASCII – an XML to ASCII converter for GOCE level 2 EGG_NOM and SST_PSO data

Guest Lectures and Lectures on special occasions

KLUMPP K-H (Kretz + Klumpp Ingenieurgesellschaft mbH Pfinztal): Bahnprojekt Stuttgart 21 / Wendlingen-Ulm: Eine besondere Herausforderung an die Ingenieurvermessung (8.2.)

MOTAGH, M (Dept. of Geodesy and Remote Sensing, GFZ Potsdam): Emerging applications of InSAR Geodesy for geodynamics and engineering studies (11.7.)

TENZER, R (School of Geodesy and Geomatics, Wuhan University, China): Gravimetric forward and inverse modeling of crust structure in a frequency domain (16.7.)

TENZER, R (School of Geodesy and Geomatics, Wuhan University, China): Analysis of sea variations offshore New Zealand (16.7.)

Lectures at other universities

GRAFAREND E

System Dynamics of Polar Motion and Length-of-Day Variation, National Geodetic Research Institute, Masala, Helsinki (23.8.)

Satellite Gradiometry on the International Reference Ellipsoid, Université Paris 8, Diderot, Laboratoire LAREG, Paris, France (12.4.)

Research Stays

GRAFAREND E: Finnish Geodetic Institute, Masala/Helsinki, Finland (13.8.-3.9.)

Lecture Notes
(http://www.uni-stuttgart.de/gi/education/MSC/lecturenotes.en.html

http://www.uni-stuttgart.de/gi/education/BSC/lecturenotes.en.html
http://www.uni-stuttgart.de/gi/geoengine/lecturenotes.html)

GRAFAREND E AND F KRUMM
Kartenprojektionen (Map Projections), 238 pages
KELLER W
Dynamic Satellite Geodesy, 90 pages
Foundations of Satellite Geodesy, 51 pages
Observation Techniques in Satellite Geodesy, 50 pages
KRUMM F AND SNEEUW N
Adjustment Theory, 155 pages
KRUMM F
Adjustment Theory, 104 pages
Map Projections and Geodetic Coordinate Systems, 177 pages
Mathematical Geodesy, 165 pages
Reference Systems, 174 pages
SNEEUW N
Dynamic Satellite Geodesy (draft), 90 pages
Introduction to Geodesy and Geodynamics, Part Geodesy, 31 pages
History of Geodesy, 38 pages
Physical Geodesy, 137 pages
SNEEUW N AND WEIGELT M
Analytic Orbit Computation of Artificial Satellites, a historical introduction, 36 pages
WOLF D
Continuum Mechanics in Geophysics and Geodesy: Fundamental Principles, 100 pages

Participation in Conferences, Meetings and Workshops

ANTONI M
IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)
GRAFAREND E
European Geosciences Union (EGU), General Assembly 2013, Vienna, Austria (7.-12.4.)
VIII. Hotine-Marussi Symposium 2013, Rom, Italy (17.-21.6.)
80 Jahre Helmut Moritz, Leibniz Societät der Wissenschaften, Berlin (15.11.)
REUBELT T
EGU General Assembly, Vienna, Austria (7.-12.4.)
IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)
ROOHI S
European Geosciences Union (EGU), General Assembly 2013, Vienna, Austria (7.-12.4.)
Geodetic Week, Essen, Germany (8.-10.10.)
SCHLESINGER R
Erfahrungsaustausch der Anwender des Relativgravimeters Scintrex CG-5, Landesamt für Vermessung und Geoinformation Rheinland-Pfalz, Koblenz (19.-20.2.)
SNEEUW N
European Geosciences Union (EGU), General Assembly 2013, Vienna, Austria (7.-12.4.)
Dragon 3 - 2013 Palermo Symposium / ESA Cooperation Programme, Palermo, Italy (3.-7.6.)
VIII. Hotine-Marussi Symposium 2013, Rom, Italy (17.-21.6.)
IAG Scientific Assembly, Potsdam, Germany (1.-6.9.)
Geodetic Week, Essen, Germany (8.-10.10.)
TOURIAN M
CryoSat Third User Workshop, Dresden, Germany (12.-14.3.)

European Geosciences Union (EGU), General Assembly 2013, Vienna, Austria (7.-12.4.)
Geodetic Week, Essen, Germany (8.-10.10.)

University Service

GRAFAREND E
Member Faculty of Aerospace Engineering and Geodesy
Member Faculty of Civil- and Environmental Engineering
Member Faculty of Mathematics and Physics
KELLER W
Associated Dean (Academic)
ROTH M
Member of the PR-committee Geodesy and Geoinformatics
SNEEUW N
Search Committee Satellitentechnik
Stand-by Member Senate Committee for Structural Development and Research, Stuttgart

Professional Service (National)

GRAFAREND E
Emeritus Member German Geodetic Commission (DGK)
SNEEUW N
Full Member Deutsche Geodätische Kommission (DGK)
Chair DGK section "Erdmessung"
Member Scientific Board of DGK
Member Scientific Advisory Committee of DGFI
Chair AK7 (Working Group 7), "Experimentelle, Angewandte und Theoretische Geodäsie", within DVW (Gesellschaft für Geodäsie, GeoInformation und LandManagement)
Search Committee Geodätische Erdsystemforschung, TU Dresden

Professional Service (International)

GRAFAREND E
Elected Member of the Finnish Academy of Sciences and Letters, Finland
Elected Member of the Hungarian Academy of Sciences, Hungary
Member Royal Astronomical Society, Great Britain
Corresponding Member Österreichische Geodätische Kommission (ÖGK)
Member Flat Earth Society
Elected Member Leibniz-Sozietät, Berlin
Fellow International Association of Geodesy (IAG)
SNEEUW N
Member Editorial Board of Studia Geophysica et Geodaetica
Member Editorial Board of Journal of Geodesy and Geoinformation
President IAG InterCommission Committee on Theory (ICCT)
Member of IAG GGOS Working Group Satellite Missions
Fellow International Association of Geodesy (IAG)

Courses - Lecture/Lab/Seminar

Advanced Mathematics	Keller, Antoni, Roth	3/2/0
Aktuelle Geodätische Satellitenmissionen	Sneeuw, Antoni	2/2/0
Amtliche Geoinformation	Heß	2/0/0
Amtliches Vermessungswesen und Liegenschaftskataster	Steudle	2/0/0
Ausgewählte Kapitel der Parameterschätzung	Krumm	2/2/0

Ausgleichungsrechnung I	Krumm, Roth	1/1/0
Dynamische Erdmodelle	Engels	1/1/0
Dynamische Satellitengeodäsie	Keller, Sneeuw, Tourian	1/0.5/0
Einführung Geodäsie und Geoinformatik	Sneeuw	0.5/0.5/0
Fernerkundung in der Hydrologie und Wasserwirtschaft	Tourian	0.5/0.5/0
Grundstücksbewertung	Bolenz	1/0/0
Integrated Field Work Geodesy and Geoinformatics	Keller, Sneeuw et al.	10 days
Koordinaten- und Zeitsysteme in der Geodäsie, Luft- und Raumfahrt	Sneeuw	2/0/0
Landesvermessung	Krumm, Roth	2/2/0
Map Projections and Geodetic Coordinate Systems	Krumm, Roth	4/2/0
Physical Geodesy	Sneeuw, Reubelt	2/1/0
Physikalische Geodäsie (B.Sc.)	Sneeuw, Reubelt	2/2/0
Physikalische Geodäsie (M.Sc.)	Engels, Reubelt	2/2/0
Referenzsysteme	Krumm	2/2/0
Satellite Geodesy	Keller	2/1/0
Satellite Geodesy Observation Techniques	Antoni	1/1/0
Satellitengeodäsie (B.Sc.)	Sneeuw, Reubelt	1/1/0
Satellitengeodäsie (M.Sc.)	Keller, Sneeuw, Tourian	2/0.5/0
Schwerefeldmodellierung	Keller	2/2/0
Statistical Inference	Krumm, Roth	2/1/0
Wertermittlung	Bolenz	2/0/0