# GSTM 2016 - Abstractlist by session

**A.1** **Poster**

T. Bandikova, N. Harvey, C. Sakumura, C. Mccullough

**Presenter** Tamara Bandikova

**SCA1B RL03 - data processing and improved features**

The spacecraft's orientation in the inertial frame is a core piece of information needed for the recovery of the Earth's gravity field from GRACE observations. The current SCA1B RL02 contains several errors (incorrect SCA quaternion combination, invalid stellar aberration correction) which need to be corrected. In order to facilitate the upcoming RL06 of the gravity field models, a new version of SCA1B data product is being generated and will be released even before the final Level-1 data reprocessing that is planned after the mission termination. SCA1B RL03 represents the spacecraft's attitude reconstructed from SCA attitude quaternions and ACC angular accelerations using a square root information filter. The sensor fusion requires a detailed noise modeling for both SCA and ACC measurements. This includes among others: solving for SCA orientation, SCA Field-of-View errors, ACC bias random walk, ACC 1-per-rev, 2-per-rev errors and intrusion of the linear accelerations into angular accelerations. The comparison of SCA1B RL02 and RL03 reveals reduced high frequency noise in RL03 above 3·10^-2 Hz, which is due to the SCA/ACC sensor fusion, and also reduced noise between 5·10^-3 Hz and 3·10^-2 Hz due to correct weighting of the SCA strong and weak axes measurement. Further, thanks to the combination with the ACC angular acceleration, significant improvement is achieved for the periods when data from only one star camera is available. The new attitude solution results in reduced noise in the GRACE gravity field models, see Sakumura et al., 2016.

**A.1** **Poster**

S. Behzadpour, T. Mayer-Gürr, J. Flury, S. Goswami

**Presenter** Saniya Behzadpour

**A wavelet-based non-stationary noise modelling in GRACE gravity field determination**

The accurate modelling of the stochastic behaviour of the GRACE mission observations is an important task in the time variable gravity field determination. After fitting a model in the least-squares sense, Residual analysis procedure is necessary to determine whether all the necessary model assumptions are valid before performing inference. Using Short Time Fourier Transform (STFT) to determine the time varying spectrum of frequencies in the residuals, it has been show that stationarity assumption may not be realistic to cope with the complex range rate data noise. A general non-stationary noise model to incorporate the time-varying stochastic properties of range rate noise (such as sudden changes in the range rate data) is needed for a more accurate data analysis. The Discrete Wavelet Transform (DWT) is of particular interest for analysis of non-stationary and transient time series. Wavelet provides an appropriate basis for separating noise from the signal of interest, as after decomposition, the small coefficients are more likely due to noise and large coefficient due to important signal features. The motivation is to dampen the effect of small coefficients by means of robust covariance matrix in parameter estimation procedure. Implementation of gravity parameter estimation in wavelet domain, estimation of noise covariance by using thresholding techniques, and comparison of the results with ITSG-2016 solution in time-frequency and spatial domains are discussed.

**A.1 Talk**

J.-M. Lemoine, R. Biancale, S. Bourgogne, P. Gégout, S. Bruinsma

**Presenter** Stéphane Bourgogne

**CNES/GRGS RL03-v2 solutions**

In this talk we will present the latest release of CNES/GRGS GRACE+SLR solutions: release RL03-v2, which provides both monthly and 10-day solutions. We will illustrate the interest of our inversion technique (two-step truncated SVD) with respect to the traditional least squares minimization technique, as well our most recent results. Websites: grgs.obs-mip.fr/grace, thegraceplotter.com.

**A.1 Poster**

B. Devaraju, M. Weigelt, J. Müller

**Presenter** Balaji Devaraju

**Ocean-tide aliasing errors in the analysis of low-low satellite-to-satellite tracking data**

The aliasing of tidal and non-tidal geophysical signals with frequencies of less than one month into the monthly time-variable GRACE gravity field solutions is an often observed but only partially understood phenomenon. While aliasing affects all the spherical harmonic coefficients, their impact on the higher harmonic degrees and orders can be reduced via parameter pre-elimination of low-degree sub-monthly (two-day) solutions -- often denoted as the Wiese approach. In this study, we specifically look at how the ocean-tide aliasing errors affect into the sub-monthly and monthly solutions using simulated data. Only the static gravity field and an ocean-tide model are used for simulating a GRACE-like mission scenario. This allows us to specify upper bounds for the ocean-tide aliasing errors, which we provide for the major diurnal and semi-diurnal ocean-tides. In addition to this, we investigate the possibility to use nuisance parameters to absorb the ocean-tide aliasing errors.

**A.1 Talk**

S. Goswami, J. Flury

**Presenter** Sujata Goswami

**Identification and separation of GRACE sensor errors in range-rate residuals**

In order to reach the accuracy of the GRACE baseline, predicted earlier from the design simulations, efforts are ongoing since a decade. GRACE error budget is highly dominated by noise from sensors, dealiasing models and modeling errors. GRACE range-rate residuals contain these errors. Thus, their analysis provides an insight to understand the individual contribution to the error budget. Hence, we analyze the range-rate residuals with focus on contribution of sensor errors due to mispointing and bad ranging performance in GRACE solutions. For the analysis of pointing errors, we consider two different reprocessed attitude datasets with differences in pointing performance. Then range-rate residuals are computed from these two datasets respectively and analysed. We further compare the system noise of four K- and Ka- band frequencies of the two spacecrafts, with range-rate residuals. Strong signatures of mispointing errors can be seen in the range-rate residuals. Also, correlation between range frequency noise and range-rate residuals are seen.

**A.1 Poster**

B. Haines, W. Bertiger, S. Desai, N. Harvey, D. Kuang, M. Miller, D.-N. Yuan

**Presenter** Bruce Haines

**Large Scale Geopotential and Terrestrial Reference Frame from GPS and the GRACE Mission**

We describe a unified approach to recover time-variable gravity (TVG) and realize the terrestrial reference frame (TRF) using data from the GRACE missions and a global network of terrestrial GPS stations. Laying the groundwork for this approach are recent results demonstrating that GRACE can be powerfully exploited as an orbiting fiducial laboratory to improve the accuracy of the TRF realized from GPS alone. The rapidly moving baselines formed between ground stations and GRACE dramatically improve the spatio-temporal coverage of the global geodetic network, while also subverting systematic errors linked to the repeating geometries of the GPS orbital planes. We review results from our TRF realizations, and describe the expansion of the underlying solution strategy to include TVG. Under development as part of our new GRACE investigation, this strategy is based on the concurrent processing of the GRACE accelerometer, inter-GRACE range, and GPS tracking data from ground stations and the GRACE satellites. We think the simultaneous reduction of all these data sets offers the best promise for improving the GRACE TVG, especially at the longest wavelengths. Early efforts have been focused on two elements of the strategy: 1) analysis of the accelerometer data, which has revealed an important cross-axis aliasing; and 2) ongoing development, and verification of the software, based on modernized GIPSY, which is needed to address the special parameterization challenges of the estimation problem. We describe the current status of these studies, and outline our plans for the coming year.

**A.1** **Talk**

A. Horvath, M. Murböck, R. Pail

**Presenter** Alexander Horvath

**GRACE time variable decorrelation filters based on monthly covariance information**

Aiming for an as accurate as possible estimation of geophysical signals, based on global GRACE gravity field solutions, calls for best possible post processing strategies. This work investigates the feasibility and performance of time VAriable DEcoRrelation (VADER) filters derived from month-to-month covariance information on decadal GRACE time series. The VADER filter is based on publicly available data only and does not need an own Level-2 processing chain. Closed loop (CL) simulations, incorporating stochastic and deterministic error budgets, serve as basis for the design of the filter setup used for real data processing. The CL experiments demonstrate the impact of using temporally varying error and signal covariance data used for the design of decorrelation filters. The results indicate an average improvement of recovered signal of 15% for an eleven year time period using time-variable instead of static decorrelation. Single months benefit from over 50% increase in recovered signal. The outcome of the simulations is fed into the design and setup of real data filtering. As real data the ITSG-Grace2016 time variable gravity field time series with its associated full monthly covariance matrices is used. To assess the validity of the approach, linear mass trend estimates for the Antarctic Ice Sheet and its sub-regions are computed using VADER filters and compared to independent estimates from both, GRACE and other mass balance techniques.The mass change results obtained show very good agreement with other estimates and are robust against variations of the filter strength.

**A.1** **Talk**

B. Klinger, T. Mayer-Gürr

**Presenter** Beate Klinger

**The role of accelerometer data calibration within the ITSG-Grace2016 release: impact on C20 coefficients**

We present a two-step approach used for accelerometer data calibration within the ITSG-Grace2016 release and analyze its impact on the recovered gravity field solutions, especially on the C20 coefficients. Within the ITSG-Grace2016 release, the accelerometer biases are estimated daily using uniform cubic basis splines (UCBS), the scale factors are also estimated daily using a fully-populated scale factor matrix. Therefore, not only the sale factors in along-track, cross-track and radial direction are estimated, but also the non-orthogonality of the accelerometer axes and the misalignment between the Accelerometer Frame (AF) and the Science Reference Frame (SRF) are taken into account. This approach aims at improving the gravity field recovery, hence it does not guarantee a physically correct model. The setup of the calibration parameters is likely to also absorb mismodeled or non-accelerometer induced spurious signals that otherwise map into the gravity field coefficients. For the ITSG-Grace2016 release, the improved calibration parametrization not only contributed to a noise reduction, but also significantly improved the estimates of the C20 coefficients. We show that the offset between SLR and GRACE derived C20 time series can be reduced remarkably by the use of a fully-populated scale factor matrix, demonstrating the merit of this new approach. Based on our results, we suggest the presence of a clear temperature-dependent behavior (biases and scale factors) and the presence of off-diagonal elements within the accelerometer scale factor matrix.

**A.1 Poster**

J. M. Lemoine, S. Bourgogne, S. Bruinsma, R. Biancale

**Presenter** Jean-Michel Lemoine

**On the limitations and dangers of GRACE unconstrained solutions**

The GRACE PI groups (JPL, CSR and GFZ) as well as many international groups (UBERN, TUGRAZ, TONGJI,...) produce unconstrained GRACE solutions which need to be filtered using dedicated filters (e.g. Swenson & Wahr, Gaussian or DDK-type filters) in order to be used. On the other hand some groups have adopted a different approach where a regularization process is applied during the solution computation, either in the form of a stabilization constraint (GRGS RL02) or using Truncated Singular Value Decomposition (GRGS RL03-v2) or by changing the set of recovered coefficients (Ramillien & Seoane or GSFC's or JPL's mascons). Both approaches (a posteriori filtering or a priori stabilization) reduce greatly the noise of the GRACE solutions but result in a smoothing of the recovered signal leading to a damping of the solutions at the shortest wavelengths, compared to the true signal.
It has been shown by some authors that in some limited parts of the world (Greenland and Antarctica), thanks to a denser and more favorable geometry of the GRACE measurements near the poles, the unconstrained solutions can be used without filtering, at least for the retrieval of long term features such as the mean trend.
While this may seem enticing because the signal recovered is stronger and better localized than in the case of filtered solutions, it can also make erroneous signatures appear, principally because of the truncation of the spherical harmonics , and therefore carries the danger of a mis-interpretation of the geophysical signals. It is this problem which we address in the current poster.

**A.1 Talk**

B. D. Loomis, S. B. Luthcke

**Presenter** Bryant Loomis

**Assessment and calibration of regional mass change solutions from inter-satellite range-acceleration residuals**

We present a new method to assess and calibrate regional mass change solutions directly from GRACE inter-satellite range-acceleration residuals. This procedure requires the time series of inter-satellite measurement residuals for the duration of the mission relative to two different forward models. To demonstrate this method we use: (1) NASA GSFC global mascons; and (2) Steric-corrected sea level anomalies from satellite altimetry in the Mediterranean, Black, Red, and Caspian Seas, and the GSFC mascons everywhere else. The different mass signals produce different localized inter-satellite residuals, where smaller magnitudes indicate better agreement to the GRACE L1B observations. We also show that if the global models are of sufficient accuracy; the difference in the local residuals is linearly related to the difference in the mass. This linear relationship defines a simple differential correction that can be applied to directly calibrate the regional time series of mass change without the need to form and invert normal equations. The results of this procedure are presented for the large inland and marginal seas and compared to the steric-corrected altimetry mass signals.

**A.1 Talk**

S. B. Luthcke, B. D. Loomis, T. Sabaka, D. D. Rowlands

**Presenter** Scott B. Luthcke

**NASA GSFC Version 2 Global Mascon Solution**

NASA Goddard Space Flight Center has recently completed the production and validation of the second generation global mascon solution. This solution is comprised of 1 arc-degree global mass concentration parameters at monthly time intervals spanning January, 2003 through March, 2016. The mascon solution is estimated directly from the reduction of the GRACE inter-satellite K-band range rate observations taking into account the full noise covariance along with the accelerometer, and precise orbit data. Solution regularization is applied directly in the estimation through a signal covariance derived from geolocatable anisotropic constraints and applying a latitudinal dependent weighting. In addition to the ocean, atmosphere and tide forward models, the mascon solution applies high-resolution forward models of hydrology, steric corrected sea-level anomalies from altimetry for both ocean and inland seas, glacial isostatic adjustment, and co-seismic earthquake signals. The mascon solution is iterated to convergence, relaxing the weight of the regularization on each iteration as the power in the residual mascon signal is significantly reduced. The resultant mascon solution minimizes signal damping, leakage and correlated errors while maximizing spatial resolution. The solution is distributed in convenient HDF5 and ASCII formats with separate data products for terrestrial water storage and cryosphere, ocean bottom pressure, and ocean mass applications. We present the details of the Version 2 global mascon solution and distributed data products, as well as solution perfo

**A.1 Talk**

T. Mayer-Guerr, B. Klinger, A. Kvas, N. Zehentner, M. Ellmer, S. Behzadpour

**Presenter** Mayer-Guerr

**Insights into the ITSG-Grace2016 processing**

The ITSG-Grace2016 gravity field solutions are the latest release computed at TU Graz. The release consists of monthly unconstrained and daily Kalman filtered solutions. Compared to the former ITSG-Grace2014 release, multiple improvements within the processing chain have been implemented: updated background models, instrument data screening and calibration, improved numerical orbit integration, and covariance function estimation. This contribution shows the improvements in terms of internal and external validation.

**A.1 Talk**

M. Murböck, A. Horvath, R. Pail

**Presenter** Michael Murböck

**Correlation analysis of GRACE gravity field models**

The GRACE mission successfully detects the temporal gravity changes in system Earth on a global scale with homogeneously distributed quality for more than 14.5 years. In order to be able to derive realistic level 3 products it is important to have a realistic variance covariance matrix (VCM). The VCM mainly depends on the observed gravity functional and the stochastics of the instrument noise as well as on orbital altitude and geometry. Therefore GRACE and GRACE Follow-On gravity field VCMs change with time. In this study we analyse the correlation matrix for different mission assumptions in the spectral and spatial domain. Different orbit geometries are compared (different altitudes for circular exact repeat orbits and real GRACE orbits) and the connection to spherical harmonic (SH) resonance orders is shown. When sorting the correlation matrix by the SH order m prominent off diagonal correlations can be seen. Correlations increase between coefficients k_i and k_j with constant m_i ± m_j. Furthermore we recommend when using gravity field models to estimate also empirical VCMs from the estimated signal reduced coefficients to be compared with the formal VCMs provided by the processing centres. We present the assessment of such empirical covariances for different long term GRACE solutions. One important indication of good stochastic modelling is a good agreement between formal and empirical covariances which is studied for the different solutions.

**A.1 Poster**

C. Sakumura, N. Harvey, T. Bandikova, C. McCullough

**Presenter** Carly Sakumura

**GRACE Level 1 Release-03: Parameterization, alignment, and gravity field results**

The Release-03 reprocessing campaign for GRACE Level-1 data was initiated to correct errors in the current GRACE products identified in Bandikova (2014), Harvey (2016) and improve the spacecraft attitude reconstruction and through an optimal combination of star camera and accelerometer data. The current attitude determination process is complicated by regular blinding of one or both cameras from the sun and moon, correlated error in the star camera field of view, and determination of instrument alignment. The RL03 SCA1B products use a Kalman filter algorithm to combine the star camera and accelerometer data into a higher fidelity attitude solution with fewer gaps, eliminates jumps when only data from a single camera is available, and reduces high frequency noise. In this study we discuss (1) the characterization and error sources of the on-board accelerometers, (2) determination of the absolute alignment and its use in the attitude Kalman filter, and (3) the sensitivity and impact of the new SCA1B products on Level-2 gravity field products.

**A.1 Talk**

B. D. Vishwakarma, B. Devaraju, N. Sneeuw

**Presenter** Bramha Dutt Vishwakarma

**Minimizing the signal damage due to filtering of GRACE observed mass changes**

Filtering is essential to extract meaningful information from GRACE gravity field products. Filtering or convolution, being a linear operator, affects both the signal and the noise. While the noise is suppressed to a minimum, the signal is changed in an unknown way, which increases the uncertainty in the GRACE results. Several efforts have been made to understand and minimize the effects of filtering on the signal, and many of them use hydro-geophysical models to compute various correction terms such as bias, leakage or scale factors for improving the filtered products. Since GRACE should ideally improve the hydrological models, we do not want hydrological models to improve GRACE. Furthermore, if we use models to improve GRACE, then the uncertainty in those models propagate into the GRACE error budget. A prevalent notion is that filtering affects only the amplitude of the signal, but we show that also the phase of the time series is affected. For certain catchments, the phase change can introduce a shift of nearly a month in the time series. Apart from better understanding of the process, we also develop a data driven method to minimize the impact of filtering. We relate the true signal and the filtered signal mathematically without requiring any model. We first validate our method in a closed-loop environment, and then for 32 catchments, we compare it with other known methods to outline its efficacy. The method performs best for catchments above filter resolution, and is on par with other methods for smaller catchments.

**A.2 Talk**

A. Bezděk, J. Sebera, J. Encarnação, J. Klokočník

**Presenter** Ales Bezděk

**Time-variable gravity from GPS tracking of Grace and Swarm**

Since 2002 GRACE provides monthly gravity fields from K-band ranging (KBR) between two GRACE satellites. These KBR gravity monthlies have enabled the global observation of time-varying Earth mass signal at a regional scale (about 400 km resolution). Apart from KBR, monthly gravity solutions can be computed from onboard GPS data. The newly reprocessed GPS monthlies from 14 years of GRACE data are shown to yield correct time-variable gravity signal (seasonality, trends, interannual variations) at a spatial resolution of 1300 km (harmonic degree 15). We show that GPS fields from new Swarm mission are of similar quality as GRACE GPS monthlies. Thus, Swarm GPS monthlies represent new and independent source of information on time-variable gravity, and, although with lower resolution and accuracy, they can be used for its monitoring, particularly if GRACE KBR/GPS data become unavailable before GRACE Follow-On is launched (2017 August).

**A.2 Talk**

B. Christophe, B. Foulon, F. Liorzou, V. Lebat, D. Boulanger, P.-A. Huynh

**Presenter** Bruno Christophe

**Expected performance of GRACE-FO accelerometers and status of MicroSTAR development for future gravity missions**

In the beginning of 2016, ONERA has delivered the 2 accelerometer flight models at Airbus DS for integration inside the twin GFO satellites as well as the spare model. These models have been extensively tested and characterised in order to predict the performance in orbit and give the best parameters to translate the science telemetry into acceleration. The paper will present the results of these analyses. In parallel, ONERA works on new accelerometer concept, MicroSTAR, for future gravity mission. A brief status of the development will be also presented.

**A.2 Talk**

C. Dahle, A. Jäggi, D. Arnold, U. Meyer

**Presenter** Christoph Dahle

**Gravity field recovery from hl-SST: latest results from Swarm and other satellites**

In view of a potential gap between the GRACE and GRACE-FO missions, ESA's Swarm mission allows to estimate the long-wavelength part of the Earth's gravity field and its variations in time by means of high-low satellite-to-satellite tracking (hl-SST). At the Astronomical Institute of the University of Bern (AIUB), kinematic Swarm orbits are routinely processed and gravity field solutions are derived thereof. Currently, the Swarm time-series covers 33 months (December 2013 - August 2016). The quality of the Swarm orbits and gravity field solutions is assessed. Systematic errors along the Earth's geomagnetic equator and their relationship to the GPS receiver settings onboard Swarm, which have been updated several times so far during the mission, are discussed. Comparisons to as well as combinations with other hl-SST solutions (GRACE, Sentinel) are shown in order to show what one can expect to obtain as possible best gravity field time series in the absence of GRACE/GRACE-FO inter-satellite ranging data.

**A.2 Talk**

N. Darbeheshti, M. Naeimi, V. Müller, H. Wegener, F. Wöske, T. Kato, M. Hewitson, G. Heinzel, J. Flury

**Presenter** Neda Darbeheshti

**Mock Data Challenges for the GRACE Follow-On Community**

The GRACE Follow-On satellites equipped with a laser ranging instrument (LRI) will improve the spatial and temporal resolution of Earth's gravity field measurements. Analyzing the complex data set from this mission is a significant challenge. The LRI data streams require completely new processing algorithms, besides GRACE Follow-On has more overlapping observations: attitude information from three star camera heads, accelerometer data, and ranging information from KBR, LRI and GNSS makes the optimal fusion of these observations more important. The SFB geo-Q releases GRACE Follow-On mock data challenges, which consist of simulated GRACE level 1B data format for interested researchers and institutes to develop and test their analysis tools. The challenges are also useful for inter-comparison of the analysis techniques between experienced research centers. The data challenges range from simple gravity field recovery to more advanced forms involving the LRI noise models. We introduce the challenges and our strategy to simulate data. Moreover, we compare the simulated orbit with the integrated orbit from our newly developed High Performance Satellite Dynamics Simulator for GRACE-like orbit and attitude simulation.

**A.2 Talk**

F. Flechtner, F. Webb, M. Watkins, S. Bettadpur, F. Landerer, L. Grunwaldt, C. Dahle

**Presenter** Frank Flechtner

**Status of the GRACE Follow-On Mission**

The GRACE Follow-On Mission has now advanced to the Assembly and Test Phase with the delivery of essentially all satellite subsystems and science instruments. Although the launcher had to be exchanged, as of the time of this abstract submission, the project continues to plan for a launch late 2017. The project team is conducting tests of satellite and instrument operation and performance and putting together updated simulations of expected performance on-orbit, including intersatellite ranging (both microwave and laser), accelerometer, thermal variability and deformation, and other errors. In addition, all required ground analysis software of the Science Data System is in development and testing at JPL, UTCSR, and GFZ, in preparation for fully integrated end-to-end (international) testing from Level-1 through Level-3 data in the coming year. In this presentation, we will provide the detailed status of project integration and test, the latest simulations of science performance, and schedule for remaining project milestones.

## A.2 Poster

V. Müller, G. Heinzel

**Presenter** Vitali Müller

**Sensitivity of Space Laser Interferometry in GRACE Follow-On & NGGM**

The GRACE Follow-On (GRACE-FO) mission with its laser ranging interferometer (LRI) will provide the first demonstration of precise inter-satellite ranging by means of laser light. Future gravimetric missions will likely utilize this technology as primary instrument for low-low satellite-to-satellite tracking. This poster illustrates the main error contributors for the laser interferometric ranging signal with focus on relativistic effects. Moreover, the particularities of the e.motion² (2014) payload concept are shown and extended to improve the sensitivity of NGGM further.

## A.2 Talk

V. Müller for the GRACE Follow-On LRI Team

**Presenter** Vitali Müller

**Laser Interferometry for GRACE Follow-On & NGGM**

The GRACE Follow-On (GRACE-FO) mission with its laser ranging interferometer (LRI) will provide the first demonstration of precise inter-satellite ranging by means of laser light. Future gravimetric missions will likely utilize this technology as primary instrument for low-low satellite-to-satellite tracking. The significantly shorter wavelength of optical radiation allows to resolve smaller distance changes compared to microwaves. However, this requires a sensible design such as the LRI to reduce the otherwise dominating error sources, e.g. induced by S/C attitude jitter or laser frequency fluctuations. In this talk the working principle of the LRI is presented with an overview of remaining major error contributors. Moreover, some verification results of the design and flight hardware are shown. The learned lessons are considered in studies for future GRACE-like missions, e.g. in the e.motion² concept. Some of the potential improvements for future missions are addressed as well.

**A.2 Talk**

M. Murböck, T. Gruber, R. Pail, I. Daras

**Presenter** Michael Murböck

**Earth System Mass Transport Mission 2 - e.motion2**

Recently a group of European scientists with technological and industrial partners a new gravity field mission was proposed as Earth Explorer 9 to European Space Agency. The main goal of the proposed mission is the long term observation of the time variable gravity field with significantly increased spatial and temporal resolution compared to the GRACE or GRACE Follow-On (FO) missions. Thus our knowledge about the global water cycle (continental hydrology, ocean, ice, and atmosphere) as well as about processes of the solid Earth can be improved. Starting from the existing concepts of single pair GRACE and GRACE-FO missions, new and improved observation techniques are needed. This concerns in particular the observation of inter-satellite distances and non-gravitational accelerations, and most important the implementation of an optimized constellation of satellite pairs. In particular the team proposed a double pair mission concept (Bender type) with a near-polar and an inclined pair. Both pairs are equipped with a laser interferometer for distance change observations at the 10 nm level, with an accelerometer of the 1E-11 m/s² class for the observation of non-gravitational forces and with a drag compensation system to fly at low orbit heights. All together this enables a duplication of spatial resolution of mass variability observations, a significant reduction of the correlated errors like spatial striping and in particular the observation of short term mass variations with reasonable spatial resolution avoiding de-aliasing with external model information to a large extent.

**B.1 Talk**

S.-C. Han

**Presenter** Shin-Chan Han

**Daily inversion of regional mass variation from GPS displacement and GRACE gravity: A case study in Australia**

This study discusses a method to invert GPS displacement data to determine daily variations of regional mass redistribution. Just like monthly GRACE gravity field data are interpreted as a result of surface mass loading (through its gravitational effect), daily GPS displacement data are assumed to be caused by daily surface mass changes (through displacement effect). The method is based on inverting a regional set of continuous GPS stations by using the localized harmonic basis functions (spherical 'Slepian' functions). Because these basis functions are merely a linear combination of spherical harmonic basis functions, it is straightforward to apply the spherical Earth load Love numbers (consistent with GRACE processing) to obtain the surface mass distribution from GPS deformation data. The combination of GRACE and GPS data is also straightforward through the linear relationship between two basis functions. I discuss the overall technique and demonstrate the recovery of daily mass variations in Australia from the continuous GPS data during the last decade and compare with the daily-averaged AOD models as well as monthly GRACE solutions.

**B.1** **Talk**

E. R. Ivins, S. Adhikari, E. Larour, T. S. James

**Presenter** Erik R. Ivins

**Assessment of Antarctic GIA Models as they affect GRACE and Altimetry: A Treatment within IMBIE-2**

Reconstruction of the Last Glacial Maximum (LGM) and global sea-level during the past 100,000 years is one of the grand challenges in Earth sciences. What is required of contemporary models is consideration of all processes that are capable for both building and collapsing continental bound ice mass. Glacial isostatic adjustment is the process by which the solid Earth and ocean respond to cryosphere and ocean mass changes associated with LGM. Construction of any 'near-perfect' forward ice model would require understanding (or constraining) surface mass balance processes, ice stream flux, calving dynamics and grounding line migration over a 100 thousand year time scale. Should such a grand numerical problem be capable of computation, it would usher in a new era of better models that could provide realistic forecasts of future sea-level rise from ice sheet demise/growth in a warming world. Currently we are far away from achieving such a goal (Bindschadler et al., 2013; Pattyn et al., 2016) and, consequently, all hind-casting ice models used for Antarctic evolution require clever use of glacio-geological information and ice core data. Here I discuss the recent data-based GIA assessments and correction for GRACE-based ice mass balance determination, that contrast to forward model treatments. Discrepant results are about 60 ± 18 Gt/yr and are likely rooted in the model-dependencies of all types, but are especially influenced by the inclusion or exclusion of specific GNSS vertical motion data collected during the past two decades.

**B.1** **Talk**

I. Sasgen, S. A. Khan

**Presenter** Ingo Sasgen

**A revised GIA-prediction for Greenland based on GNET GPS data**

The Glacial Isostatic Adjustment (GIA) is an important component of the gravimetric mass balance in Greenland inferred from GRACE. Here, we use time series of surface deformation measured with the Greenland Global Positioning System Network (GNET) to determine and evaluate GIA-induced uplift rates. We compare the GPS-measured GIA signature with GIA predictions and find that forward-models considerably underestimate uplift in the northwest and southeast sectors of the ice sheet. In particular, unpredicted large and localized GIA uplift rates of +12 mm/yr are found in southeast Greenland; these are explained by centennial ice retreat of the Kangerdlugssuaq Glacier in the presence of a low-viscous upper mantle, which is a consequence of Greenland passing over the Iceland Hotspot about 40 Ma BP. We reconstruct the evolution of the Greenland ice sheet since LGM based on the newly available GNET GPS data. We show that an additional mass loss since the Last Glacial Maximum (LGM) of 1.5 m sea level equivalent is required in the northwest and southeast of the ice sheet, which are the marine-based sectors dominating modern mass loss. We conclude from the GPS-constrained model that corrections of GIA in Greenland have been underestimated by 10 to 20 Gt/yr in ice-mass balance estimates from GRACE.

**B.1** **Poster**

J. Sauber, S.-C. Han, F. Pollitz, S. Luthcke, J. Freymueller

**Presenter** Jeanne Sauber

**GRACE, GRACE-FO and NGGM: Contributions and future prospects for advancing seismic cycle science**

Here we summarize current advances in our understanding of earthquake source processes and the rheological response of the Earth to great megathrust and strike-slip earthquakes. Looking to the future, we simulate what might be achieved with greater spatial and temporal resolution with GRACE-FO and NGGM.

**B.2** **Poster**

A. Groh, M. Horwath, A. Horvath, R. Forsberg, R. Meister, A. Shepherd

**Presenter** Groh, A.

**Antarctic ice mass balance products by the ESA Climate Change Initiative**

Within the framework of ESA's Climate Change Initiative (CCI) mass balance products for both the Antarctic Ice Sheet (AIS) and the Greenland Ice Sheet (GIS) have been developed by the AIS_cci and the GIS_cci project. These Gravimetric Mass Balance (GMB) products are derived from satellite gravimetry data acquired by GRACE (Gravity Recovery and Climate Experiment), which is the only sensor directly sensitive to changes in mass. Using monthly GRACE gravity field solutions covering the period from 2002 until present two different GMB products are derived: (a) time series of monthly mass changes for the entire ice sheet and for individual drainage basins, and (b) gridded mass changes covering the entire ice sheet. The gridded product depicts spatial patterns of mass changes at a formal resolution of about 50 km, although the effective resolution provided by GRACE is about 200-500km. We present the first release of the ESA CCI GMB products for the Antarctic Ice Sheet. They are derived from GRACE monthly gravity field solutions by a refinement of the regional integration approach which directly tailors sensitivity kernels by a formal optimization procedure to minimize the sum of propagated GRACE solution errors and leakage errors. This approach involves the incorporation of information on the structure of GRACE errors and the structure of those mass change signals that are most relevant for leakage errors. Based on our products we discuss the latest mass balance estimates. The GMB products are freely accessible through an AIS_cci data portal (data1.geo.tu-dresden.de).

**B.2** **Talk**

R. A. Hardy, R. S. Nerem, D. N. Wiese

**Presenter** Ryan A. Hardy

**Atmospheric Errors in GRACE Estimates of Ice Sheet Mass Loss**

Accurate estimation of changes in the mass of the Greenland and Antarctic ice sheets with GRACE requires forward modeling of atmospheric gravity signals to reduce aliasing and biases due to variations in surface pressure. This is accomplished by using the ECMWF Operational Analysis model. This model contains known drifts and discontinuities associated with its operational nature. The remoteness of Greenland and Antarctica introduce a challenge in accurately observing and modeling surface pressure. Replacement of ECMWF with alternative models on monthly timescales represents a first-order method of correcting its errors. We compare ECMWF with time series of in situ surface pressure measurements distributed over Antarctica and Greenland and surface pressure fields generated from reanalyses. We find certain reanalyses outperform ECMWF in terms of RMS agreement with observations. Over Antarctica, these new models reveal significant underestimates in the acceleration of its mass loss. Over Greenland, these errors introduce discrete errors in the mass loss time series. Pressure fields generated from combinations of in situ observations and the spatial statistics of the reanalyses validate these results. Finally, we attempt to retrieve surface pressure signals with GRACE using JPL mascon solutions, probing the utility of satellite gravity as a meteorological observable.

**B.2** **Talk**

M. Horwath, A. Groh

**Presenter** Martin Horwath

**The GRACE mass change estimators developed for ESA's CCI ice sheet mass balance products**

ESA's Climate Change Initiative (CCI) has published GRACE-based mass change time series and grids as operational, well-documented data products (data1.geo.tu-dresden.de, esa-www.icesheets-cci.org). We explain the methodology used for the Antarctic Ice Sheet products. Two approaches exist to infer mass changes from GRACE solutions: The regional integration approach integrates GRACE-based surface mass changes using specific integration kernels. The forward modeling (or mascon/inverse) approach prescribes a finite set of mass change patterns and adjusts their amplitudes to the GRACE gravity field changes. Forward modeling approaches ultimately estimate mass changes by linear functionals of the gravity field changes, or in other words, sensitivity kernels. Therefore, they are just special realizations of the regional integration approach. In our approach, we directly tailor sensitivity kernels, i.e., mass change estimators. We use a formal optimization to minimize the sum of propagated GRACE errors and leakage errors. For this aim we incorporate covariance information on the GRACE errors and on the mass change signals. We explain the realization that we currently apply for the Antarctic Ice Sheet CCI project and we discuss limitations and envisaged further developments. We show results for the Antarctic Ice Sheet in terms of time series of drainage basin mass changes and time series of gridded changes. We illustrate that the developments invested in these products have led to a very good compromise between dampening GRACE errors and maintaining spatial resolution.

**B.2** **Talk**

M. Bevis, S. A. Khan, P. Knudsen

**Presenter** Per Knudsen

**Observing the deglaciation of Greenland by GRACE and GNET GPS**

Between the start of 2003 and the middle 2013, the total mass of ice in Greenland declined at an accelerating rate, and this rate increases nearly constantly of about 24 Gt per year. Then, a dramatic reversal occurred, and almost no additional ice mass was lost in the subsequent two years. In 2015 the melting had resumed reducing the ice mass in Greenland. Here, we study the spatial and temporal variations of ice mass change using observations from (1) the Gravity Recovery and Climate Experiment (GRACE), (2) a network of Global Positioning System (GPS) receivers, and (3) combination of airborne and satellite altimetry data (e.g. cryostat-2, icesat, NASA's airborne topographic mapper (ATM) flights).

**B.2** **Talk**

I. Velicogna, E. Ciraci', T. Sutterley, Y. Mohajerani

**Presenter** Isabella Velicogna

**Ice Sheets, glaciers and ice caps mass balance from GRACE and other data**

We use observations of time-variable gravity from GRACE to determine the mass changes for the Antarctic and Greenland Ice Sheets, and the Glaciers and Ice Caps (GIC) for the time period 2002-2016. To estimate the contribution of the GIC, we use a least square mascon approach combined with new inventories to optimize the distribution of mascons and recover the GRACE signal more accurately. The contribution from the GIC is dominated by the mass loss of the Canadian Arctic Archipelago, followed by Alaska, Patagonia and the High Mountains of Asia. In Greenland, Antarctica, the Canadian Ice Caps and a few others, we compare our GRACE results with output products from surface mass balance models, e.g. MAR and RACMO. This comparison provides an evaluation of the SMB models where ice dynamics is not dominant, as well as help us constrain the partitioning of mass loss between surface processes and ice dynamics in other sectors. This work, combined with altimetry time series from ICESat/ATM/LVIS allows us to evaluate uncertainties of the mass balance results. This work was conducted at UC Irvine and at Caltech's Jet Propulsion Laboratory under a contract with NASA's Cryospheric Science Program.

**B.3 Poster**

T. Fecher, P. Knudsen, S. Bettadpur, T. Gruber, N. Maximenko, N. Pie, F. Siegismund, D. Stammer

**Presenter** Per Knudsen

**Optimal Geoid Modelling to determine the Mean Ocean Circulation - Project Overview and early Results**

The ESA project GOCE-OGMOC (Optimal Geoid Modelling based on GOCE and GRACE third-party mission data and merging with altimetric sea surface data to optimally determine Ocean Circulation) examines the influence of the satellite missions GRACE and in particular GOCE in ocean modelling applications. The project goal is an improved processing of satellite and ground data for the preparation and combination of gravity and altimetry data on the way to an optimal MDT solution. Explicitly, the two main objectives are (i) to enhance the GRACE error modelling and optimally combine GOCE and GRACE [and optionally terrestrial/altimetric data] and (ii) to integrate the optimal Earth gravity field model with MSS and drifter information to derive a state-of-the art MDT including an error assessment. The main work packages referring to (i) are the characterization of geoid model errors, the identification of GRACE error sources, the revision of GRACE error models, the optimisation of weighting schemes for the participating data sets and finally the estimation of an optimally combined gravity field model. In this context, also the leakage of terrestrial data into coastal regions shall be investigated, as leakage is not only a problem for the gravity field model itself, but is also mirrored in a derived MDT solution. Related to (ii) the tasks are the revision of MSS error covariances, the assessment of the mean circulation using drifter data sets and the computation of an optimal geodetic MDT as well as a so called state-of-the-art MDT.

**B.3 Talk**

F. Landerer, D. Wiese

**Presenter** Felix Landerer

**Updates to the global sea level budget: assessing trends and biases in ocean mass**

**B.3 Talk**

K. J. Quinn, R. M. Ponte

**Presenter** Katherine J. Quinn

**Using GRACE to improve estimates of ocean circulation**

The latest version of the global ocean state estimate from the “Estimating the Circulation and Climate of the Ocean” (ECCO) project has assimilated the JPL GRACE mascon estimates of ocean bottom pressure (OBP) and net ocean mass variability. We compare the OBP fields from various GRACE estimates to two versions of ECCO: release 1 (pre- GRACE assimilation) and release 3 (GRACE assimilated). These comparisons show where GRACE is having a positive impact on the ocean state estimate. Some of the most notable changes between ECCO releases are to the global net freshwater flux, and variability in the Arctic and Southern Ocean, precisely where the cost estimates indicated GRACE would have the largest impact. We also use in-situ bottom pressure recorder data to validate both GRACE and ECCO.

**B.3 Poster**

C. G. Piecuch, K. J. Quinn, R. M. Ponte

**Presenter** Katherine Quinn

**Validating GRACE time-variable data over the coastal ocean using tide gauges**

Validation of GRACE data over the ocean typically relies upon comparisons to observations from bottom pressure (BP) recorders. However, in situ BP records are sparse and prone to drift, restricting comparisons with GRACE data to short periods at a few sites. An alternative means for validating GRACE BP solutions is to compare with tide gauge sea level (SL) data, which are more plentiful than in situ BP records and not subject to temporal drift. Here we describe the first comparison between GRACE BP and tide gauge SL over the global coastal ocean. Significant correlations between SL and BP are observed along broad, shallow continental coasts, consistent with basic expectations from ocean dynamics. The correspondence between SL and BP is considerably stronger when using more recent GRACE mascons solutions than earlier solutions based on spherical harmonics. An ocean model (ECCO2) corroborates patterns observed in the data, showing strong coupling between SL and BP along continental coasts. The model suggests that improved correspondence between tide gauge and mascons fields compared to spherical harmonics is consistent with better representation of shorter spatial scales. Results establish the superior quality of recent GRACE data releases; more generally, they demonstrate that tide gauge records are useful for validating GRACE data and show that satellite gravimetry can be used for interpreting coastal SL data.

**B.3** **Poster**

C. G. Piecuch, K. J. Quinn

**Presenter** Katherine Quinn

**El Niño, La Niña, and the global sea level budget**

Previous studies show that nonseasonal variations in global-mean sea level (GMSL) are significantly correlated with El Niño-Southern Oscillation (ENSO). However, it has remained unclear to what extent these ENSO-related GMSL fluctuations correspond to steric (i.e., density) or barystatic (mass) effects. Here we diagnose the GMSL budget for ENSO events observationally using data from profiling floats, satellite gravimetry, and radar altimetry during 2005-2015. Steric and barystatic effects make comparable contributions to the GMSL budget during ENSO, in contrast to previous interpretations based largely on hydrological models, which emphasize the barystatic component. The steric contributions reflect changes in global ocean heat content, centered on the Pacific.
Distributions of ocean heat storage in the Pacific arise from a mix of diabatic and adiabatic effects. Results have implications for understanding the surface warming slowdown and demonstrate the usefulness of the Global Ocean Observing System for constraining Earth's hydrological cycle and radiation imbalance.

**B.3** **Talk**

R. D. Ray, B. D. Loomis, S. B. Luthcke

**Presenter** R D Ray

**Ocean tide solutions and residuals from GRACE range-rate data**

A series of global tidal solutions have been computed from GRACE range-rate data for a number of major constituents. Preliminary solutions show that the GRACE time series is sufficiently long that there is little "cross-talk" between constituents, so we are now computing the constituents individually in separate inversions, generally via spherical harmonics to degree/order 60, sometimes higher. Non-tidal mass variability is separately modeled and removed from the GRACE residuals prior to attempting tidal solutions; for this we use standard models augmented by prior GRACE global mascon solutions, which include cryospheric mass variability. Even though our prior mascon solutions included estimates of various GRACE state and accelerometer parameters, it appears essential that such arc parameters be re-estimated during tidal inversion. Global solutions for M2, O1, and K1 are physically reasonable at long wavelengths. In contrast, S2 is problematic, displaying too much correlation with non-tidal 161-day variability. We have also analyzed GRACE residuals for tidal variability, following up on work that was published by Stammer et al (Rev. Geophysics, 2014) in which 6 global tide models were tested with GRACE data. Those tests are here supplemented by tests of the new FES2014 model, plus our own GRACE-adjusted model. These long-wavelength GRACE tidal solutions can be used for processing GRACE data, but they cannot be used in other applications until they are properly assimilated into a high-resolution numerical ocean tide model. Work along those lines is in progress.

**B.3 Talk**

C. Lück, J. Kusche, R. Rietbroek, S. Schön, Le Ren, J. Schröter, A. Androsov, S. Danilov

**Presenter** Christina Lück

**Time variable gravity field retrieval from kinematic orbits from the CHAMP and SWARM missions**

Variations of ocean mass changes, linked to ocean bottom pressure changes are still not sufficiently understood on long times scales. The observation of these oceanic mass signals on global scale has only been become possible on a global scale since the advent of the GRACE mission. Within the project "Consistent Ocean mass Time Series from LEO Potential Field Missions" (CONTIM), we investigate how time series of ocean mass variations can be extended beyond and before the GRACE mission lifespan, by making use of geodetic measurements of low earth orbiters (LEO). Furthermore, the methods developed here may also be used as gap-filler observations for the GRACE time series. Another topic of investigation is whether one can exploit the baseline information of the SWARM constellation to improve the gravity field retrieval. It is planned that SWARM data can also be used in specialized inversion schemes where ocean mass changes are parametrized by dedicated patterns (e.g. Rietbroek et al. 2016). In this contribution, we use kinematic orbits from the SWARM and CHAMP missions to estimate gravity fields of low spherical harmonic degree and order. We show how these fields compare to the more accurate GRACE solutions, and how the choice of truncation and pre-processing steps affect the solutions.

**B.3 Poster**

B. Uebbing, R. Rietbroek, J. Kusche

**Presenter** Roelof Rietbroek

**Sea level budget in the Bay of Bengal (2002–2014) from GRACE and altimetry**

The Bay of Bengal is bordered by low-lying and densely populated coastal areas which are vulnerable to storm surges and sea level rise. Accounting for future sea level rise requires understanding the present-day sea level budget. Here, we combine data from the Gravity Recovery and Climate Experiment (GRACE) satellite with altimetry from the JASON 1 and 2 mission. We explain the total altimetric sea level rise (6.1 mm/a over 2002–2014) by mass and steric components. We find that current mass trends in the Bay of Bengal are slightly above global mean, while steric trends are much larger: 2.2–3.1 mm/a if we disregard a residual required to close the budget, and 4.3–4.6 mm/a, if, as an upper bound, we attribute this residual entirely to steric expansion.
Our method uses altimetry and GRACE data in a least squares inversion, where mass anomalies are parameterized through gravitationally self-consistent fingerprints, and steric expansion through EOFs. We validate our estimates by comparing to Argo and modeling for the Indian Ocean, and by comparing total water storage change (TWSC) for the Ganges and Brahmaputra basins to the conventional GRACE approach. We find good agreement for TWSC, and reasonable agreement for steric heights, depending on the ocean region and Argo product. We ascribe differences to weaknesses of the Argo data, but we also find the inversion to be to some extent sensitive with respect to the EOFs. Finally, combining our estimates with CMIP5-simulations, we estimate that Bay of Bengal absolute sea level may rise for additional 37 cm under the RCP4.5 scenario and 40 cm under RCP8.5 until 2050, with respect to

**B.4 Talk**

A. Behrangi, A. Gardner, J. Reager, J. Fisher

**Presenter** Ali Behrangi

**Using GRACE to constrain precipitation amount over cold regions**

Here we show that GRACE can advance quantification and analysis of precipitation in high latitudes and high altitudes, where the uncertainties in the current precipitation products are highest. With the lack of high quality precipitation estimates in cold regions and the growing need for more spatiotemporally comprehensive precipitation estimates, GRACE (and in near future GRACE-FO) can provide unique and independent information that has been underutilized for the improvement of precipitation analysis. This is especially timely with significant advancements in the refinement of the GRACE gravity solution. More specifically we demonstrate this by performing case studies over Eurasia and two Endorheic basins in the Tibetan plateau. GRACE estimates suggest that the global precipitation climatology project (GPCP) is likely overestimating precipitation over Eurasia, consistent with CloudSat observations. In Tibetan plateau basins, GRACE suggests that most of the current precipitation products (except near real-time TRMM 3B42) likely underestimate monthly precipitation, especially during cold season when snow and mixed-phased precipitation occur more frequently. We discuss that, lacking high quality ground station observations, GRACE can provide a viable alternative for constraining monthly or seasonal precipitation rates estimated from other remotely-sensed precipitation products that often tend to show significant biases in cold regions.

**B.4 Poster**

G. Pavlic, J. Crowley, J. Huang, S. Wang, A. Rivera, J. Henton, A. Lambert, C. Klatt

**Presenter** John Crowley

**Seasonal groundwater storage variation in Canada from 14 years of GRACE observations**

Assessing water storage variations on a national scale is beneficial for managing water resources, for sustainable development of society and economy, to identify regional drought and flood risks, and to protect the environment in Canada. Seasonal variation in total water storage (TWS) and groundwater storage (GWS) are functions of rainfall, runoff rates and evapotranspiration. In this study, we aim to quantify seasonal TWS and GWS variations in three Canadian river basins (Mackenzie, Saskatchewan and Assiniboine) as well as nationally using monthly gravity models (release 5) derived from the Gravity Recovery and Climate Experiment (GRACE) for the period of 2012-2016. GWS is calculated by removing the surface water component (soil moisture, snow, ice, large lake and river variations) from the TWS using two Land Surface Models (LSMs): the Global Land Data Assimilation System produced by NASA (GLDAS-1, see Rodell et al., 2004 for details) and the Ecological Assimilation of Land and Climate Observations (EALCO) produced by Natural Resources Canada (Wang, 2008). TWS and GWS variations are presented using four average seasonal maps and reveal large annual variations on the order of hundreds of mm of equivalent water depth. Variations in the three river basins are shown as 14-year time series of the average anomalies over the respective basins and indicate gradual increases in water storage. Uncertainty introduced by the glacial isostatic adjustment (GIA) correction is also assessed using a variety of modern GIA models and is found to be significant over much of Eastern Canada.

**B.4** **Talk**

W. Feng, L. Longuevergne, J. Kusche, D. Long, M. Zhong, S. Liang, H. Xu

**Presenter** Wei Feng

**Closing the groundwater storage budget in the North China Plain using GRACE, GPS and InSAR**

Water storage and pressure variations in the subsurface generate measurable gravity changes and surface displacements. This study presents the joint interpretation of GRACE and GPS/InSAR observations to better constrain shallow and deep groundwater storage (GWS) variations associated with unsustainable pumping and impact of climate variability in the North China Plain (NCP). On seasonal timescales, GRACE-derived GWS variations are well explained by the combined effect of groundwater abstraction due to anthropogenic irrigation activities and groundwater recharge from natural precipitation. The GRACE-derived GWS depletion rate is -8.4+/-1.0 km³/yr (i.e., -1.7+/-0.2 cm/yr in equivalent water height) during 2002-2014, which is significantly larger than the estimates from phreatic monitoring well observations (-1.2+/-0.1 km³/yr) and statistics from government bulletins (-1.9 km³/yr). The difference among them indicates the significant GWS depletion in the confined deep aquifers of NCP, generating large subsidence rates, which has been largely underestimated up to now. The GWS depletion rate in deep aquifers estimated from GPS/InSAR observations is -6.4 km³/yr during 2002-2014, which well explains the difference between the GRACE estimate and results from phreatic well observations and bulletins. Both GRACE and surface deformation offer a pertinent monitoring for complex aquifer systems, where water is redistributed between surface, shallow and deep aquifer systems.

**B.4** **Talk**

B. Forman, J. Wang, M. Girotto, R. H. Reichle, G. De Lannoy, M. Rodell

**Presenter** Bart Forman

**Towards Year-round Estimation of Terrestrial Water Storage via Multi-sensor Assimilation GRACE/GRACE-FO, AMSR-E/AMSR-2, SMOS and SMAP**

The goal of this project is to simultaneously merge multi-frequency, multi-polarization microwave observations with gravimetric retrievals collected by satellite-based instrumentation in order to improve model estimates of snow water equivalent (SWE), soil moisture (SM), groundwater, and terrestrial water storage (TWS) across regional and continental scales. General science questions include: 1. What is the complementary gain via inclusion of low-frequency and/or high-frequency microwave brightness temperature (Tb) assimilation in conjunction with GRACE TWS assimilation? How do such synergistic effects manifest themselves in space and time relative to GRACE assimilation alone? 2. Can a multi-variate assimilation framework effectively downscale GRACE TWS retrievals in space and time thereby adding spatial and temporal resolution to the GRACE retrievals that currently does not exist? If so, what is the quantifiable gain to the GRACE observations? 3. How, if at all, has TWS variability changed over the years? And what are the relationships between SWE, soil moisture, and groundwater variability? Experiments will systematically highlight measurable model improvements associated with “step-wise” assimilation using low frequency (L-band; 1.4 GHz) to higher frequencies (X-band to Ka-band; 10 GHz to 36 GHz) along with GRACE, and as a result, systematically quantify the role that ancillary observational products can be used to enhance and effectively downscale GRACE retrievals in space and time.

**B.4 Talk**

B. T. Gouweleeuw, A. Kvas, C. Gruber, M. Schumacher, T. Mayer-Gürr, F. Flechtner, J. Kusche, A. Güntner

**Presenter** Ben Gouweleeuw

**Towards near-real time daily GRACE solutions for global flood and drought monitoring**

Water storage anomalies from the Gravity Recovery and Climate Experiment (GRACE) satellite mission have been shown to be a unique descriptor of large-scale hydrological extreme events. However, possibly due to its coarse temporal and spatial resolution and the latency of standard products of about 2 months, the comprehensive information from GRACE on total water storage variations has rarely been evaluated for near-real time flood and drought monitoring or forecasting so far. The Horizon 2020 funded EGSIEM (European Gravity Service for Improved Emergency Management) project is scheduled to launch a near-real time test run of GRACE gravity field data, which will provide daily solutions with a latency of 5 days. This fast availability allows the monitoring of total water storage variations related to hydrological extreme events as they occur, as opposed to a 'confirmation after occurrence', which is the current situation. A first hydrological evaluation of daily GRACE gravity field solutions for floods in the Ganges-Brahmaputra Delta in 2004 and 2007 confirms their potential for gravity-based large-scale flood monitoring. This particularly applies to short-lived, high-volume floods, as they occur in Bangladesh with a 4-5 year return period. The subsequent assimilation of daily GRACE data into a (global) hydrological model - carried out jointly within the framework of the Belmont Forum funded BanD-AID project - decomposes total water storage into its individual components (e.g., surface water) and opens up the possibility of flood early warning and forecasting.

**B.4 Poster**

V. Grigoriev, N. Frolova, L. Zotov, A. Gelfan, Y. Motovilov, I. Krylenko

**Presenter** Vadim

**Water balance of river basins of the European Russia**

The interrelation between elements of a water balance of river basins of the European Russia has been analyzed. It was revealed that the role of terrestrial water storage change (TWSC) is comparable to the contribution of variability of the river's runoff. So, the ratio of TWSC standard deviation and river flow standard deviation in the south exceeds 1.5-2 and in the north drops to 0.5 (September was chosen as the beginning of year in order to exclude influence of seasonal snow cover). Thus the significant role in dynamics of TWS is played by the first snowless month (April for the southern rivers, May for northern). So in the basins of the Don and Kuban statistically significant relationship between TWS in April and October is traced, for the period of April-August it is also significant for the Ural and Oka basins. In the basins of Don, Ural, Kama and Oka in summer months the negative correlation of terrestrial water storages with potential evaporation (r = - 0.7-0.9) is revealed. This is caused by the nonlinear response of potential evaporation value to reduction of the range of air temperature. Reduction of the range of air temperature near the ground surface at augmentation of moisture storages takes place due to the change of thermal properties of soil, in particular of heat capacity and thermal conductivity. For longer period (1956 - 2014) the relationship of annual precipitation and potential evaporation has been considered. So, for 411 river basins the average correlation coefficient has appeared to be -0.42.

**B.4 Talk**

J. Kusche, A. Eicker, E. Forootan, A. Springer, L. Longuevergne

**Presenter** Juergen Kusche

**How many years GRACE/GRACE-FO are required to detect whether droughts and floods occur more frequently?**

Using data from the Gravity Recovery and Climate Experiment (GRACE) mission, we derive statistically robust 'hotspot' regions of high probability of peak anomalous - i.e. with respect to seasonal, trend and climatology - water storage (of up to 0.7 m one-in-five-year return level) and flux (up to 0.14 m/mon). Analysis of, and comparison with, up to 32 years of ERA-Interim reanalysis fields reveals generally good agree ment of these hotspot regions to GRACE results, and that most exceptions are located in the Tropics. However, a simulation experiment reveals that differences in frequency between ERA-INTERIM and observed by GRACE are statistically significant, and further error analysis suggests that by around the year 2020 it will be possible to detect temporal changes in the frequency of extreme total fluxes (i.e. combined effects of mainly precipitation and floods) for at least 10-20% of the continental area, assuming that we have an uninterrupted continuation of GRACE by its follow-up GRACE-FO. Kusche, J., A. Eicker, E. Forootan, A. Springer, and L. Longuevergne (2016), Mapping probabilities of extreme continental water storage changes from space gravimetry, Geophys. Res. Lett., 43, 8026-8034, doi:10.1002/2016GL069538.

**B.4 Talk**

A. Kvas, B. Klinger, S. Behzadpour, M. Ellmer, N. Zehentner, T. Mayer-Gürr

**Presenter** Andreas Kvas

**ITSG-Grace2016 - Daily Gravity Field Solutions from GRACE**

The Gravity Field And Climate Experiment (GRACE) has granted invaluable insight into the redistribution of surface mass by providing monthly snapshots of the Earth's gravity field. Highly dynamic events such as floods, which can build up and drain on time scales from hours to weeks, are however difficult to capture with the comparatively coarse sampling rate of one month. ITSG-Grace2016 is the latest time series of GRACE solutions computed at Graz University of Technology (TU Graz), providing daily, global, Kalman smoothed gravity field snapshots. The release covers the complete GRACE observation time span starting from April 2002 and is continuously updated. The processing strategy applied is also the basis of the EGSIEM (European Gravity Service for Improved Emergency Management) Near Real-Time Service aiming to provide daily gravity field solutions with a maximum delay of five days. The service will be jointly run by GFZ (German Research Centre for Geosciences) and TU Graz, with each analysis center providing an independent solution. We show the added value of the daily solutions by comparison with in-situ data and output from different global hydrological models. High frequent variations in river discharge are well reflected in the GRACE derived total water storage anomalies for mid- to large scale flood events. These comparisons suggest that daily GRACE products contain high-frequency gravity field information and represent a suitable data source for the monitoring of hydrological extreme events.

**B.4 Poster**

V. Kröger, A. Shabanloui, J. Müller

**Presenter** Jürgen Müller

**Mass variations in the Chinese permafrost region determined from GRACE data and complementary hydrological models**

The Chinese permafrost region - in terms of areal extent - has the third rank in the world after Russia and Canada. In addition, China contains the largest alpine permafrost area on Earth. Permafrost variations including the hydrological budget, carbon dioxide ($CO_2$) and methane ($N_2$) emission belong to the most challenging contributions to global climate change and the eco-system of the Earth. And, mountain permafrost regions are very sensitive to global climate change. Therefore, monitoring of the change pattern in this partly frozen mountain area is a key factor for understanding the underlying kinematic-dynamic processes. Taking such information into account is very helpful to predict possible consequences for the Earth climate. Temporal mass variations in this region are related to various hydrological processes including thawing of permafrost layers. Therefore, the accurate and precise estimation of mass variations based on GRACE monthly Earth's gravity solutions plays a central role to understand and predict the ongoing processes in the Chinese mountains. In order to separate the various signal contributions, various hydrological components in terms of precipitation, runoff and evapotranspiration have to be considered using different models and specific data. In this study, mass variations in the Chinese permafrost region based on GRACE results and different hydrological models/data are jointly investigated.

**B.4 Talk**

J. T. Reager, C. David, A. Trefler, H. Macedo, E. Beighley, J. Famiglietti

**Presenter** JT Reager

**Progress in understanding hydrologic flooding using GRACE**

GRACE data have been shown to capture the extreme hydrologic conditions associated with floods - as the land surface becomes saturated, the capacity of soils to hold more water decreases - this is an important hydrologic mechanism in many inland flood events. Recent research and progress on this topic will be presented, including results and analysis from three projects: (1) evaluation of a model-data fusion approach for high-resolution GRACE downscaling; (2) a coupled analysis of land water storage and high-resolution river storage to estimate the runoff generation process and the contributions of baseflow to streamflow; and (3) a global assessment of the historic flood occurrence data base, to determine the frequency of flood intensity based on storage. These results demonstrate the extent to which knowledge of storage conditions can help in flood prediction, and explores the range of conditions, scales and intensities for which storage-driven flood processes are relevant.

**B.4 Talk**

M. Rodell

**Presenter** Matthew Rodell

**Global Trends in Terrestrial Water Storage from 14 Years of GRACE**

This presentation describes the sources of the largest apparent trends in terrestrial water storage observed around the world by GRACE during the past 14 years. These sources can be categorized as natural interannual variability, direct human impacts (e.g., groundwater extraction), or climate change. Some regions are affected by multiple factors. The GRACE based terrestrial water storage trends are compared with precipitation data, irrigation data, and hydroclimatic predictions, as well as other published information, in order to build the case for each postulated source. We also forecast whether each trend is likely to continue.

**B.4 Talk**

M. Sultan, K. Fathy, M. Ahmed, H. Save, S. Bettadpur, K. Chouinard

**Presenter** Mohamed Sultan

**What more can GRACE Solutions tells us about Aquifers and their Interactions with Artificial Lakes**

The Nubian Aquifer System (NAS) covers large territories in Sudan, Libya, Chad, and Egypt. An integrated (GRACE, remote sensing, geochemistry, geochronology, geophysics, field) investigation was conducted to assess temporal and spatial variations in TWS over the NAS, identify controlling factors, assess impact of Lake Nasser surface water variations and structures on TWS. Spatial correlations of GRACE monthly (period: 2002 to 2015) solutions (CSR RL05; CSR 1° x 1° mascon solutions) with other relevant datasets the Western Desert (area: 700,000 km2) of Egypt and laser altimetry data (Jason-1; OSTM) over Lake Nasser (area: 3,000 km2) revealed the following: (1) reversals in relative surface water levels in Lake Nasser: in year 2002 to 2005 a decrease (from +4 to -5 m) was observed, followed by an increase (+5 m) by year 2007, then a decrease (- 4.2 m) by year 2010, and finally an increase (+4.3 m) by year 2015, (2) a positive correspondence between lake Nasser relative water levels and the observed TWS over the Lake (2002-2005: decrease in TWS [rate: –10.12 mm/yr]; 2005-2007 increase [rate: +3.05 mm/yr]; 2007-2010 decrease [rate: -13.51 mm/yr]; and 2010-2015 increase [rate: +4.55 mm/yr]), (3) a positive correspondence between the Lake water levels on one hand and the TWS for surrounding areas (up to 400 km from lake), (4) variations in precipitation cannot account for observed TWS variations, and (5) E-W and NE-SW-trending faults and basement uplifts intersect the flow at high angles, impede the S to N groundwater flow and impound groundwater in the up-gradient.

**B.4** **Talk**

S. Weyand, L. Sahib, C. Gruber

**Presenter** Susanne Weyand

**Groundwater budgeting over deserted area by GRACE, case study in Saudi Arabia**

Since 1980 the freshwater consumption in Saudi Arabia has led to significant groundwater level depression. The annual water consumption for Agriculture, Public water supply and industry e.g. in 2009 amounts to 19 km³, where the water source in desert areas mainly depends on fossil groundwater. Total water storage (TWS) estimates groundwater storage changes because surface water and soil moisture anomalies are negligible, due to high evapotranspiration. GRACE models - as a proven tool for TWS - were compared with monitored pumping field measurements but can not show the full groundwater extraction ratio. This study takes into account the geological activities, leakage of internal/external signal, omission error in order to reduce the misclosure.

**B.4** **Poster**

D. Argus, F. Landerer, D. Wiese, Y. Fu, T. Farr, B. Thomas, J. Famiglietti, J. T. Reager, M. Watkins

**Presenter** David Wiese

**Sustained water loss in the Sierra Nevada, California, during drought from 2011 to 2015 inferred from GPS**

We use GPS observations of solid Earth's elastic response to mass loading to infer changes in water mass at Earth's surface as a function of location across the western U.S. from 2006 to 2016. Data from GPS sites on top of aquifers and near volcanoes are first eliminated, elastic deformation due to known changes in reservoir water and estimated changes in Central Valley groundwater are next corrected for, and vertical land displacements are then inverted for change in equivalent water thickness. A straightforward elastic model shows that unloading of 24 km³ of Central Valley groundwater from 2012 to 2015 produces 4 mm of elastic uplift of the western Sierra Nevada, about 1/4 of the 16 mm of uplift observed during the time period. Geologic constraints limit tectonic uplift during the past several million years to be less than 0.2 mm/yr, amounting to less than 1 mm of uplift from 2012 to 2015. The rise and fall of the Sierra Nevada is therefore due to change in water in the province: From the GPS vertical data we deduce that the Sierra Nevada lost 18 km³ of water from Oct 2006 to Sep 2009, gained 31 km³ of water from Oct 2009 to Sep 2010, and lost 47 km³ of water from Oct 2011 to Sep 2015. Snow accumulation is insignificant in California in Sep and Oct. Nonseasonal changes in soil moisture are just a few km³. Therefore changes in groundwater in alluvium adjacent to rivers and in fractures in crystalline basement are inferred to be large and play an important role in modulating changes in Central Valley groundwater.

**B.4** **Talk**

L. Zhang, H. Dobslaw, C. Dahle, K.-H. Neumayer, F. Flechtner, M. Thomas

**Presenter** Liangjing Zhang

**Investigating different filter and rescaling methods on simulated GRACE-like TWS variations for hydrological applications**

By operating for more than one decade now, the GRACE satellite provides valuable information on the total water storage (TWS) for hydro-meteorological applications. The increasing interest in use of the GRACE-based TWS requires an in-depth assessment of the reliability of the outputs and also its uncertainties. However, since GRACE offers an unique way to provide high spatial and temporal scale TWS, there is no global ground truth data available to fully validate the results. In this contribution, we re-assess a number of commonly used post-processing methods using a simulated GRACE-type gravity field time-series based on realistic orbits and instrument error assumptions as well as background error assumptions out of the updated ESA Earth System Model. Three different versions of non-isotropic DDK filter haven been applied. Rescaling factors estimated from four different hydrological models and the ensemble median are applied to the post-processed simulated GRACE-type TWS estimates to correct the bias and leakage. TWS uncertainties that include (i) measurement, (ii) leakage, and (iii) re-scaling errors are provided as well. Since TWS anomalies out of the post-processed simulation results can be readily compared to the time-variable Earth System Model initially used as "truth" during the forward simulation step, we are able to thoroughly check the plausibility of our error estimation assessment and will subsequently recommend a processing strategy that shall also be applied for planned GRACE and GRACE-FO Level-3 products for terrestrial applications provided by GFZ.

**B.5** **Poster**

A. Blazquez, B. Meyssignac, J.-M. Lemoine, E. Berthier

**Presenter** Alejandro Blazquez

**Uncertainty in GRACE estimates of the mass redistributions at the Earth surface and impact on the sea level budget**

We propose to revisit the estimate of the components of the global water budget from GRACE (in terms of trends over 2004-2014) and to evaluate the associated uncertainty using an ensemble of global GRACE solutions from 5 processing centers: CSR, GFZ, GRGS, JPL and TUG. For each GRACE solution we test a range of post-processing, filtering and modelling parameters, including the effects of the glacial isostatic adjustment correction, to get a spread of estimates of the global water budget components. This spread should better reflects the underlying uncertainty in ice sheet mass loss, continental water storage changes and the ocean mass changes estimates from GRACE. The implications on the closure of the global water budget and the sea level budget are further analysed. Previous studies have used a similar ensemble approach based on different GRACE solutions and different post processing to assess the uncertainty in GRACE estimates of the water budget components. But they all focused on a single component such as the ocean mass changes (Quinn and Ponte 2010), the ice sheet ice loss (I. Velicogna and Wahr 2013; Shepherd et al. 2012) or the glacier ice loss (Gardner et al. 2013). Here we analyse all the components together in a consistent way. This novel approach enables to explore whether the uncertainty in the different components of the global water budget are correlated or not when assessed with GRACE measurements. This issue is essential when assessing the closure of the global water budget and the sea level budget.

**B.5** **Talk**

J. Dickey, E. Bidenbach, O. de Viron, F. Landerer

**Presenter** Jean Dickey

**Interannual Signature detected in the Earth's Geocenter**

Global mass redistribution alters Earth rotation, produces temporal variations of the gravitational field, and shifts the position of geocenter, which is defined as the center of figure (CF) of the Earth relative to the center of mass (CM) of the Earth including mass load. Variation of the geocenter reflects the global mass balance and the interactions between the solid Earth and the mobile masses on the Earth. Among all the Earth reference system parameters, the geocenter motion is the lesser known and analyzed quantity. It can be determined by several techniques; presently Satellite Laser Ranging (SLR) gives the best results. Two geocenter series derived from SLR are utilized: 1) the analysis of Luceri et al., 2016, and 2) Pavlis et al., 2016. The agreement between the two geocenter series is very good; here, we use the Luceri et al., 2016 solution. Motion of the geocenter mirrors the global degree one mass distribution in the climate system and inside the solid Earth. The seasonal cycle dominates the time series, which we remove by subtracting a composite seasonal cycle. This allows us to study interannual and longer variabilities. We then investigate the climate signature in the geocenter motion, with a particular focus on the interannual timescale.

**B.5** **Talk**

E. R. Ivins, S. Adhikari

**Presenter** Erik R. Ivins

**On the Role of GRACE-derived Interannual Hydrosphere/Cryosphere Mass Budgets on Modeling Earth Rotation**

Although the angular variations of the Earth's pole position away from its mean are a well explained at annual and 434-day periods, the sources for interannual and interdecadal variability are uncertain. Variations at annual periods are caused by changes in the mass and angular momentum forced by all Earth surface changes that have near seasonality. The 434-day period is explained as a resonance between the cumulative driving forces having periods near the Chandler wobble free eigenmode of the Earth and is well understood theoretically. The Earth also has a longer-term drift that is explained primarily as a response to the ice age changes in the moments of inertial of the Earth. However, there has been a long-standing search for the origins of pole variations that have a period near 10 years. Fifteen years of GRACE time-varying gravity fields provide robust estimates of the water transport related changes to the Earth's inertia tensor. Using GRACE Release 05 coefficients and the standard recipe (Bettadpur, 2012) for full field retrieval, we show that ice mass losses from Greenland and Antarctica, and when combined with changes in continental hydrology, explain almost all the main features of interannual time scale polar wander. The discovery has broad interdisciplinary implications, including mass closure in the transport equation and gravitational coupling to the world's oceans. We show that decadal scale pole variations are directly linked to global changes continental water.

**B.5** **Talk**

A. Schlicht

**Presenter** Anja Schlicht

**Disturbances on accelerometers and the behaviour of a metal shield in a delute plasma**

Electromagnetic waves in a plasma have a unique propagation behavior as the free electrons and ions react on the electric field of the wave. In the dispersion relation distinct resonances and cut-off frequencies occur depending on the magnetic field strength and plasma density. We focus in our discussion on very low frequencies which propagate in the whistler mode. We will discuss why these frequencies disturb the accelerometer and why metals may not shield these frequencies. We review the observed disturbances on GRACE and GOCE and show how they can be related to very low frequencies in a plasma.

**B.5** **Talk**

L. V. Zotov, N. S. Sidorenkov, N. A. Chujkova

**Presenter** Leonid Zotov

**Climate change signals and LOD**

We collect arguments, which could help to explain the observed similarities in climate change signals and Earth rotation, in particular, the length of day (LOD) variations. The degree-2 coefficients of the Earth gravity field from GRACE and SLR, Earth flattening changes in response to polar glaciers melting and sea level variations are analyzed as possible keys to these phenomena. The long-term trends are of major interest in our study. We suggest using the Earth rotation parameters to improve the estimates of mass changes in Antarctic and Greenland.

**B.6** **Talk**

C. Gruber, C. Dahle, K.-H. Neumayer, F. Flechtner

**Presenter** Christian Gruber

**GFZ GRACE solutions offering alternative gridded data products and near real time processing**

Standard GFZ GRACE gravity fields are provided as sets of monthly spherical harmonics and are processed with a latency of about 60 days due to the consolidation and acquisition of required geophysical background models (e.g. AOD1B), ancillary data (e.g. Earth orientation parameters) and instrument data. Generally, the GRACE user community is requesting shorter latencies and also much shorter data accumulation phases (e.g. daily resolution). In order to fulfill these needs, the so called RBF (Radial Basis Function) method has been developed at GFZ. This approach offers the direct estimation of mass changes on a grid, similar to mascons, using a batch-wise, constraint and stabilized GRACE data processing to provide either monthly or daily Kalman filtered solutions. The main features of the RBF approach and its potentially resulting data products will be presented and the latest results are compared with other available GRACE time-series. In the framework of the EU Horizon2020 project EGSIEM, an automated near real time (NRT) processing of daily RBF solutions shall be established for NRT flood monitoring starting in April 2017. In order to achieve this, we have replaced the final Earth orientation parameters with predicted values, our GFZ GPS precise orbits and clocks with rapid science products from AIUB (Bern) and the standard GRACE L1B data with corresponding quick-look products provided by JPL. We will present the impact of these changes on the GRACE orbits and subsequent gravity field estimates for constraint daily results and unconstraint monthly inversion results.

**B.6** **Poster**

S. D. Desai, B. J. Haines, D. Kuang

**Presenter** shailen.desai@jpl.nasa.gov

**Sensitivity Study of Low-Earth Orbiter Precise Orbit Determination to Time Variable Gravity**

As a first step of our GRACE science team investigation we perform sensitivity studies of the impact of time-variable gravity (TVG) fields on GPS-based precise orbit determination (POD) of low-Earth orbiters. Of particular interest to our investigation is the difference between GPS-based dynamic and reduced-dynamic POD solutions, as those differences provide an opportunity to recover long-wavelength TVG. In this presentation, we focus on the two recently (early 2016) launched satellites, Jason-3 and Sentinel-3A. Both have geodetic quality GPS payloads and particularly stringent requirements on POD accuracy. We consider two particular types of contributions to TVG. The first includes empirical models of secular and seasonal representations of TVG that are based upon GRACE observations, and the second is the TVG contribution from the atmosphere and oceans using the respective de-aliasing products. These two recent launches are particularly useful as they span time periods that are completely independent of the GRACE-based observations used to derive the empirical TVG models. The primary metrics we use to evaluate the impact of these TVG models include differences between dynamic and reduced-dynamic GPS-based POD solutions and post-fit data residuals. However, we also consider the impact on empirical acceleration parameters that are included as part of the overall orbit determination strategy. We also use satellite laser ranging observations of the satellites as an independent source for evaluating the impact of TVG on the accuracy of the POD solutions.

**B.6** **Talk**

B. Doorn, M. Jasinski, J. T. Reager, M. Srinivasan

**Presenter** Michael Jasinski

**The GRACE Missions Applications Plan: Innovative Use of Science Data for Policy, Business, and Management Decision Support**

The NASA Applied Sciences Program supports applied research and targeted projects focused on innovative and practical uses of Earth remote sensing observations and modeling resources for societal benefit. The approach is to engage interested private and public stakeholders including international partners, who desire to improve their decision-making tools and techniques through incorporation of science data products. Participation from mission inception allows stakeholders to be ready to use the data at launch. Principal application focus areas include water resources, natural disasters, ecological forecasting, and health and air quality. The recently developed GRACE Applications Plan (AP) provides a framework for implementing the above vision for the suite of gravity missions including GRACE launched in 2002, GRACE Follow On (GRACE-FO) scheduled to launch in 2018, and future GRACE-like missions. The main elements of implementation are to: i) increase awareness of GRACE mission and data products through applications workshops, tutorials, and town halls, ii) identify and engage a diverse applications community of potential GRACE data users, iii) facilitate understanding and use of GRACE data products through communication and partnering with GRACE project scientists, iv) share knowledge and experience through formulation of a GRACE Applications Team that includes a Working Group, established GRACE researchers, and an expanding GRACE applications community, and v) engage strategic government and private partners who recognize and support the added value GRACE data bring.

**B.6** **Talk**

M. A. Karegar, T. H. Dixon, E. Forootan, J. Kusche

**Presenter** Makan A. Karegar

**A new hybrid GRACE-Model estimation of hydrological influences on the GPS derived vertical deformation**

For decades, continuously operating GNSS networks have been providing essentially global positioning observations and offering opportunities to study the Earth's crustal deformation. The long-term and periodic deformation derived from analyzing these networks likely reflect different physical processes such as tectonic activity, hydrological induced mass redistribution, anthropogenic oil or water extractions, and etc. This requires an application of signal separation techniques to extract the signals of interest. For example, in the tectonic or geo-mechanical applications, the hydrological-induced deformations are considered as a source that could hamper estimation of deformations if they have not been accounted for. In this study, we explore the effects of hydrological signals on GPS-derived vertical deformation in the central North America. A new hybrid technique is developed to combine the total water storage (TWS) estimations from GRACE products and hydrological models in the spectral and spatial domains, and correct their effects on GNSS derived deformations. The numerical results indicate that our proposed method offers a flexible opportunity to combine long wavelength TWS from GRACE and short wavelength changes from hydrological models, and therefore it improves the reduction of the hydrological-origin deformation in GPS time series.

**B.6 Talk**

U. Meyer, Y. Jean, A. Jäggi, A. Susnik, D. Arnold, C. Dahle, T. Mayer-Gürr, J.-M. Lemoine

**Presenter** Ulrich Meyer

**EGSIEM combinations of GRACE monthly gravity fields**

The scientific combination service of the Horizon 2020 project European Gravity Service for Improved Emergency Management (EGSIEM) aims at delivering the best gravity products, in terms of quality, robustness and reliability, for applications in Earth and environmental science research. This goal is achieved by combination of the results of the associated processing centers (ACs), each of which performs independent analysis methods but employs consistent processing standards. During the first 18 months of the project the standards and the concept of combination were defined and common reference frame products (GPS orbits and clock corrections) were reprocessed. Now follows a test phase of operational combination and external validation of the individual and combined monthly fields. Two versions of combined monthly gravity fields are produced for the years 2006 and 2007. First a combination on solution level is performed as the weighted average of the carefully screened individual solutions. The weights are derived iteratively by pairwise comparison to the mean of all contributions applying variance component estimation (VCE). The second combination type is based on normalized normal equations (NEQs) of the individual ACs' solutions. Due to different noise models applied by the individual ACs it turned out inapplicable to base this combination on variance factors. Instead empirical weights are derived that lead to equal contribution. Consequently the weights derived by the VCE on solution level are applied.

**B.6 Poster**

M. Srinivasan, J. T. Reager, M. Jasinski

**Presenter** Margaret Srinivasan

**The GRACE Missions Applications Approach: a framework for collaboration**

The NASA Applied Sciences Program is supporting, the GRACE and GRACE FO projects in the development of a mission Applications approach designed to highlight existing and potential applied uses and user communities of mission data products. The GRACE missions will join other NASA and international partner missions in formulating working groups that include mission science team members. The GRACE Applications Working Group (GAWG) will be the driving force behind implementation of the GRACE Applications Plan. The plan is designed to be a framework for defining and engaging public and private sector communities who may use or be using GRACE data products. The role of the applied science community is to demonstrate the high value of the science, data products, models and applications from the missions, and to identify societal benefits that can stem from these. The activities of the GAWG will focus on developing and implementing a systematic approach to engage the science and operational communities of the GRACE missions, identify relevant applications, and work with the Applications leads to develop tutorials, focus sessions, and workshops to implement the GRACE Applications Plan. The hydrology applications of the GRACE mission include measurements of storage changes in land surface and groundwater, fluxes at the land-ocean-atmosphere boundary, and measurement of changes in ice sheets and glaciers. GRACE observations and time series of data are invaluable for improved monitoring and prediction of Earth system processes including climate indicators.