GSTM 2014 - Abstractlist 30.09.

08:30 **A.1**

T. Mayer-Guerr, N. Zehentner, B. Klinger, A. Kvas

Presenter T. Mayer-Guerr

ITSG-Grace2014: a new GRACE gravity field release computed in Graz

The ITSG-Grace2014 relase is the successor of the ITG-Grace2010 release and consists of several parts - A high resolution unconstrained static model (up to degree 200) provided with trend and annual signal - Monthly unconstraint solutions with different resolutions (up to degree 60, 90, 120) - Daily snapshots derived by using a Kalman smoother. The static field and the monthly solutions are provided with full variance covariance matrices. Compared to the former release multiple improvements in the processing chain are implemented: - Updated background models - GPS observations: better ionospheric modelling - Combination of star camera and angular accelerations - Combined estimation of KBR antenna center together with gravity field estimation - Estimation of error covariance functions with variance component estimation method - Combined estimation of monthly solutions together with daily gravity field variations The ITSG-Grace2014 release is presented, some effects of the changes in the processing are discussed.

08:45 **A.1**

Ulrich Meyer, Adrian Jäggi

Presenter Ulrich Meyer

AIUB-RL02 monthly gravity field solutions from GRACE kinematic orbits and range rate observations

The Astronomical Institute of the University of Bern (AIUB) presents its second release of monthly gravity field solutions from GRACE data covering the time span from March 2003 to March 2014. AIUB-RL02 is based on RL02 of the GRACE L1B data, on the dealiasing products AOD1B-RL05, and the ocean tide model EOT11A. A major improvement could be achieved by taking secondary waves (admittances) of the ocean tide model into account. Last but not least a major improvement was achieved by the additional estimation of daily accelerometer scale factors (not co-estimated in AIUB-RL02). Not only an artificial variability with a period of 160d in C20 could be removed, but the overall noise of the monthly gravity fields (evaluated by their standard deviations over the oceans) during times of pronounced solar flux was drastically reduced. The effects of all individual model improvements and changes in the parametrization are illustrated separately.

09:00 A.1

Jean-Michel Lemoine, Sean Bruinsma, Pascal Gégout, Richard Biancale, Stéphane Bourgogne

Presenter Jean-Michel Lemoine

Release 3 of the GRACE gravity solutions from CNES/GRGS

The GRACE mission, already more than 12 years in operation, has provided a large-scale vision of the temporal gravity variations occurring on the Earth's surface. Using the reprocessed Level-1B "v2" data, the CNES/GRGS team has done a full reiteration of the GRACE and LAGEOS data processing based on upgraded data, models and inversion procedures. This new release (RL03) is now available on the GRGS web site. It features, in addition to using the new L1B-v2 data: - an improved a priori gravity model, closely following the actual gravity variations already observed by GRACE, - the use of FES2012 ocean tide model, - the use of the atmospheric dealiasing fields ECMWF ERA-interim (every 3 hours), - the use of the oceanic dealiasing fields TUGO (every 3 hours), - some changes in the K-Band ranging and accelerometer parameterization, - an inversion procedure using truncated Eigen values allowing (as it was already the case for RL02) a direct interpretation of the gravity solutions without the need for additional filtering, - an extension of the maximal degree of the time-variable parameters from 50 to 80. The CNES/GRGS RL03 solutions will be compared with the RL05 solutions from CSR, GFZ and JPL, focusing particularly on the areas of the Earth where the spatial resolution of the solutions is important and challenging as in the vicinity of the three major earthquakes of Sumatra, Maule and Tōhoku. The small artefacts which have been identified in RL03 solutions, and were presented at the IGFS meeting, have since been studied. The outcome of these studies will be presented here.

09:15 A.1

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

Presenter B. Loomis

Progress towards the next generation of GSFC global mascons

The latest developments of the NASA GSFC global mascon time-variable gravity product are discussed. Monthly sets of mascons are directly estimated from the inter-satellite K-band range-rate observations and take into account the full noise covariance. The primary benefit of the mascon approach is the ability to apply anisotropic constraints via a regularization matrix in the non-linear least squares update to the state. This approach reduces signal leakage and eliminates the need for post-processing steps when forming time-series of regional mass change. The current constraint strategy and other candidate strategies in development are discussed. This recent global mascon solution applies state-of-the-art models, IERS 2010 conventions, and a newly-optimized arc parameterization. Global and regional mass change signals from the GSFC mascon solution are analyzed and compared to available models and the GSFC and GRACE project spherical harmonic solutions.

09:30 A.1

Beate Klinger, Torsten Mayer-Gürr

Presenter Beate Klinger

Combination of GRACE star camera and angular acceleration data: impact on monthly gravity field models

The GRACE satellite mission provides K-band ranging (KBR) measurements between the two twin satellites GRACE-A and GRACE-B for the purpose of gravity field recovery. Although the accuracy of gravity field solutions has increased during the last years, there still remains an offset between the present error level and the GRACE baseline accuracy. Unmodeled errors in the Level-1B data products related to the alignment are one of the potential contributors to the error budget, since the precise inter-satellite pointing is one of the essential requirements for the KBR ranging. Up to now, the attitude determination and the alignment between the two satellites were carried out solely by the two star cameras on board each spacecraft. However, the accelerometer provides additional information in terms of angular accelerations. Therefore, we combine both angular accelerometer and star camera data (ACC1B, SCA1B) in a least squares approach to improve the satellites' attitude determination. As a result, the high-frequent noise of the attitude data is decreased significantly. In order to benefit from the improvements on the sensor data level, other error sources and disturbances within the GRACE observations have to be identified. Based on these results, we show that improved modeling and processing methodologies (e.g. outlier detection) contribute to the overall accuracy of the recovered monthly gravity field solutions. The purpose of the presented work is to investigate the assets and drawbacks of this type of sensor fusion and its impact on the recovered gravity field solutions.

09:45 A.1

Peter L. Bender, Frank G. Lemoine, Scott B. Luthcke

Presenter Peter L. Bender

Progress Toward Development of a Four Revolution Empirical Correction Proceedure for GRACE Type Missions

At the GST meeting in 2013, an alternate procedure for correcting for acceleration noise and other sources of low frequency noise in the data from GRACE type missions was described. It is called Ocean Calibration, and relies mainly on using the inter-satellite range results over low latitude ocean areas to determine an empirical range correction function for 4 rev arcs, where all 4 revs cross the Pacific. A model for geoid height variation uncertainties in equatorial ocean areas was constructed based on the amplitude of variations in the ECCO-JPL ocean model. Also, a model for low frequency acceleration noise based on the nominal level for GRACE was used. For these models, simulations were carried out with fitting at 23 times of crossing of preferred sites. After trying a number of fitting functions, one with 16 parameters was chosen. With this fitting function, the contribution of geoid noise to the resulting geoid error was less than 3 mm, and the range noise contribution was a factor 7 less. These levels compare with 20 mm for the monthly geoid height variation due to hydrology (Gruber et al, 2011). However, the total low freq. noise in the GRACE level 1B range data is much higher than the nominal level (Ditmar et al, 2012), and the actual uncertainty in geoid models on a given day may be considerably less than the monthly hydrology variation level. Thus, until we understand more about the GRACE error sources, it is not clear if the Ocean Calibration approach would reduce the GRACE geopotential height variation errors and striping in the results substantially.

10:00 **A.1**

A. Horvath, M. Murböck, R. Pail, M. Horwath

Presenter Alexander Horvath

Mass signals from GRACE gravity fields with dedicated filtering using full covariance information

Proper reduction of correlated errors is a crucial step towards resolving mass signals from GRACE monthly gravity fields. We set up an approach leading towards anisotropic decorrelation, based on information taken from full covariance matrices of all gravity field data included in our estimation process. We use full normal equations from real GRACE data (AIUB, CSR). They serve as an apriori stochastic model in our least-squares adjustment process. Extensive analysis of the full variance-covariance matrices in terms of temporal variability and correlation structures are presented. Earlier analysis (Murböck et al. 2013) showed that anisotropic decorrelation which implies destriping can be achieved by down weighting specific bands of spherical harmonic orders. The impact of our approach on such specific order bands and the ability of temporal aliasing reduction is investigated in detail. The effect of our strategy on the estimated mass signals is compared to the impact of other post-processing tools such as Gaussian or Swenson & Wahr type filter. Synthetic datasets created with a closed-loop mission simulator serve as additional basis for validation purposes. Furthermore we analyze annual variability and mass trend signals. Murböck, M.; Pail, R.; Daras, I.; Gruber, T.: Optimal orbits for temporal gravity recovery regarding temporal aliasing; Journal of Geodesy, Springer Berlin Heidelberg, ISSN 0949-7714, ISSN (Online) 1432-1394, DOI: 10.1007/s00190-013-0671-y, 2013.

10:15 **A.1**

Jiangjun Ran, Pavel Ditmar, Roland Klees

Presenter Jiangjun Ran

Improved post-processing of GRACE monthly gravity fields to estimate regional mass variations of the Greenland Ice Sheet

Post-processing of monthly GRACE gravity field models with the aim to enhance the spatial resolution of mass anomalies over the Greenland Ice Sheet have been presented by various authors. Typically, they use the Stokes coefficients of monthly gravity models as input and add additional constraints to improve the spatial resolution and accuracy of estimated mass anomalies. Here we improve current post-processing techniques among others by including full noise variance-covariance information of the monthly Stokes coefficients, a more sophisticated regularization, and a careful choice of various parameters to be selected during the post-processing. Moreover, we analyze the error budget of high-resolution GrIS mass balance estimates and identify the processing strategy that minimizes the total error in the estimates obtained, using synthetic data. Furthermore, compared with Forsberg & Reeh (2007) and Baur & Sneeuw (2011), our processing scheme is extended further. In particular, the stochastic model of data noise is incorporated. We processed the synthetic data using various settings of processing parameters. This allows us to draw valuable conclusions regarding the optimal combination of data processing parameters. In particular, we find that the usage of stochastic model of data noise and the first-order Tikhonov regularization scheme lead to a noticeable improvement of the obtained results. Furthermore, according to the investigation of the error budget, we are able to understand better the dependence of solution quality on the choice of data processing parameters.

11:00 **A.1**

Christian Gruber, Andreas Groh, Christoph Dahle, Elisa Fagiolini

Presenter Christian Gruber

Evaluation of global and regional GRACE solutions

Since 2002 the Gravity Recovery And Climate Experiment (GRACE) mission has been measuring temporal variations of Earth's gravity field with unprecedented accuracy. This data set provides valuable information on the distribution and variation of mass in the Earth's subsystems such as atmosphere, hydrosphere, ocean and cryosphere. Reprocessed GRACE time-series of monthly gravity field spherical harmonic solutions generated at GFZ (RL05a) show significantly less noise and spurious artifacts. In addition, a regional method based on radial base functions and kalman filtering is capable to compute models in regional and global representation. This new method localizes the gravity observation to the closest regions and omits spatial correlations with farther regions. The present study makes use of both solutions in order to quantify recent ice-mass changes and their contribution to global sea-level rise. We further compare ice-induced crustal deformations due to the dynamic (un-)loading of the crustal layer with GPS uplift measurements along Greenland's coastline. Mass/Volume changes derived from ICESat laser altimetry measurements both in Greenland and Antarctica are used to validate the GRACE results. Hydrogical catchment basins are used to validate total water storage variations against water storage modeling from WGHM.

11:15 **A.1**

Y. Sun, P. Ditmar, R. Riccardo

Presenter Y. Sun

Determination of changes in the Earth's dynamic oblateness from GRACE, an ocean bottom pressure model and a glacial isostatic adjustment model

A new methodology proposed to estimate changes in the Earth's dynamic oblateness on a monthly basis. The algorithm is simple and uses only publicly available data/models, namely monthly GRACE gravity field solutions, an ocean bottom pressure (OBP) model and a glacial isostatic adjustment (GIA) model. The result influenced by the choice of input models as well as by processing details such as what filter is applied to the GRACE solutions. We test differrent combinations of input models and processing parameters and compare the resulting time-series with an independent solution based on satellite laser ranging (SLR) data. The best time-series achieved in this study compares remarkably well with that of the SLR in terms of RMS differences, amplitudes and phases. Trend estimates, derived from the obtained time-series, denpend also on the GIA model used. The proposed method thus can provide high-quality degree-2 zonal coefficient replacement for the originally corrupted one in a monthly GRACE gravity model. It can also be used as a validation of various GIA models, in combination with independent observation of dynamic oblateness (e.g., from SLR).

11:30 A.1

Na Wei, Tonie van Dam, Matthias Weigelt, Thierry Meyrath

Presenter Na Wei

Seasonal Variations of Low-degree Spherical Harmonic Derived from GPS Data and Loading Models

We derived the seasonal variations of spherical harmonics by combing GPS displacement series from ITRF2008 residuals and modelled ocean bottom pressure (OBP) from ECCO (Estimating the Circulation & Climate of the Ocean). Monthly surface mass density coefficients are estimated up to degree 20. In this contribution, we try to separate the no-mass signals from ITRF-GPS residuals by introducing translation parameters to the joint inversion. A variance component estimation (VCE) is also adopted to optimize the stochastic model for OBP input data, and the uncertainty of ECCO data is thus estimated to be 1.4 cm. We focus on the seasonal variations of degree-1 and degree-2 terms derived from the combination. These estimations are then compared with coefficients predicted from atmospheric, oceanic, and hydrological models. They are also compared with independent coefficients from accurately measured satellite laser ranging (SLR) and Gravity Recovery and Climate Experiment (GRACE) data. Results show that the uncertainties of geocenter motion from GPS/ECCO are better than 0.5 mm in the X and Y component and 1.0 mm in the Z component. GPS/ECCO geocenter motion agree well with SLR, and the correlation coefficients are 0.74, 0.64 and 0.62, respectively. GPS/ECCO $\Delta C20$ (0.90) and $\Delta S21$ (0.88) are highly correlated with SLR. GPS/ECCO $\Delta C20$ and $\Delta S21$ have slightly larger sub-seasonal uncertainty than SLR. Obvious S2 tide aliasing errors still exists in GRACE(RL05) $\Delta C20$ series.

11:45 A.1

A. Jäggi, M. Weigelt, F. Flechtner, A. Güntner , T. Mayer-Gürr, S. Martinis, S. Bruinsma, J. Flury, S. Bourgogne

Presenter A. Jäggi

European Gravity Service for Improved Emergency Management - a new Horizon2020 project to serve the international community and improve the accessibility to gravity field products

A proposal for a European Gravity Service for Improved Emergency Management (EGSIEM) has been submitted in response to the Earth Observation Call EO-1-2014 of the Horizon 2020 Framework Programme. EGSIEM shall demonstrate that observations of the redistribution of water and ice mass derived from the current GRACE mission, the future GRACE-FO mission, and additional data provide critical and complementary information to more traditional Earth Observation products and open the door for innovative approaches to flood and drought monitoring and forecasting. The EGSIEM project is currently in its final negotiating phase with the European Commission and is expected to start in early 2015. We present the three key objectives that EGSIEM shall address: 1) to establish a scientific combination service to deliver the best gravity products for applications in Earth and environmental science research based on the unified knowledge of the European GRACE community, 2) to establish a near real-time and regional service to reduce the latency and increase the temporal resolution of the mass redistribution products, and 3) to establish a hydrological and early warning service to develop gravity-based indicators for extreme hydrological events and to demonstrate their value for flood and drought forecasting and monitoring services. All of these services shall be tailored to the various needs of the respective communities. Significant efforts shall be devoted to transform the service products into user-friendly and easy-to-interpret data sets and the development of visualization tools.

Poster **A.1**

C. Siemes, M. Fehringer, R. Floberghagen, B. Frommknecht, R. Haagmans

Presenter Christian Siemes

Evolution of GOCE gravity gradient performance during mission lifetime

This presentation provides an overview of the performance evolution of gravity gradients provided by the Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission during mission lifetime. GOCE was launched on 17 March 2009 when the solar cycle was close to a minimum. Since then, the solar cycle advanced towards an expected maximum in early 2013, while accordingly the drag environment became harsher. In addition, beginning in August 2012, GOCE's orbit has been lowered several times from an altitude of 256 km to eventually 224 km, which led the satellite into an even harsher drag environment. Since the gravity gradiometer requires a "quiet" environment for providing ultimate performance, the GOCE satellite is equipped with a drag-free control system that compensates drag in flight direction. Drag perpendicular to the flight direction, however, is not compensated. Therefore, we oppose the evolution of gravity gradient performance to the evolution of drag measured by the accelerometers, in particular for the across-track direction where drag attacks the largest cross-section of the satellite. Through combining frequency and spatial domain analyses, we show that the performance evolution in regions around the geomagnetic poles is different from the one outside these regions. Furthermore, special attention is paid to gravity gradients acquired before, after and also during orbit lowering maneuvers. In addition to the analysis of gravity gradients, we show a time series of GOCE gravity field solutions, each based on SGG and SST data of two months.

Poster **A.1**

Tamara Bandikova, Ulrich Meyer, Beate Klinger, Paul Tregoning, Jakob Flury, Torsten Mayer-Gürr

Presenter Tamara Bandikova

Improved star camera attitude data and their effect on the gravity field

Efforts are ongoing to decrease the noise of the GRACE gravity field models and hence to arrive closer to the GRACE baseline. The most significant error sources belong the untreated errors in the observation data and the imperfections in the background models. The recent study (Bandikova&Flury,2014) revealed that the current release of the star camera attitude data (SCA1B RL02) contain noise systematically higher than expected by about a factor 3-4. This is due to an incorrect implementation of the algorithms for quaternion combination in the JPL processing routines. Generating improved SCA data requires that valid data from both star camera heads are available which is not always the case because the Sun and Moon at times blind one camera. In the gravity field modeling, the attitude data are needed for the KBR antenna offset correction and to orient the non-gravitational linear accelerations sensed by the accelerometer. Hence any improvement in the SCA data is expected to be reflected in the gravity field models. In order to quantify the effect on the gravity field, we processed one month of observation data using two different approaches: the celestial mechanics approach (AIUB) and the variational equations approach (ITSG). We show that the noise in the KBR observations and the linear accelerations has effectively decreased. However, the effect on the gravity field on a global scale is hardly evident. We conclude that, at the current level of accuracy, the errors seen in the temporal gravity fields are dominated by errors coming from sources other than the attitude data.

12:00 A.2

Mike Watkins, Frank Flechtner, Phil Morton, Frank Webb, Franz-Heinrich Massmann, Ludwig Grunwaldt

Presenter Mike Watkins

Status of the GRACE Follow-On Mission

GRACE Follow-On, a joint US/German satellite mission to extend the critical global mass flux data records from the GRACE mission, continues to mature and advance on both sides of the Atlantic. In early January 2012, GRACE-FO was advanced by NASA to Phase A following the successful Mission Concept Review in late October, 2011. The transition into Phase B happened in September 2012 following a successful System Requirements and Mission Definition Review in July 2012. In January 2014 the Preliminary Design Review (PDR) was conducted, followed by the transition into phase C in March 2014. The current launch date is August 2017. The presentation will focus on the project status after the successful Project PDR and the Science Data System (SDS), Mission Operations System (MOS) and Launch Vehicle System (LVS) PDRs as well as science payload Critical Design Reviews (CDR) of the microwave instrument (MWI), accelerometer and laser ranging interferometer (LRI) demonstrator.

12:15 A.2

Bernard Foulon, Bruno Christophe, Vincent Lebat, Damien Boulanger, Francoise Liorzou

Presenter Bruno Christophe

Development status of the GRACE Follow-On accelerometer and first results of the Engineering Model testing

The design of the electrostatic space accelerometers developed by Onera for the GRACE Follow-On mission is very similar to the one of the SuperStar accelerometers operating in orbit on board the twin GRACE satellites since more than twelve years. However, they take advantage of the return of experience of the GRACE and GOCE missions, in order to improve their thermal behaviour, in particular the stability of the front end electronics functions. The presentation will provide the status of the GFO accelerometer at the time of its Critical Design Review with in particular the results of the Engineering Model testing on the Onera's laboratory pendulum bench and during catapult free falls at ZARM drop tower facility.

12:30 A.2

Christina Bogan for the LRI team

Presenter Christina Bogan

The Laser Ranging interferometer for GRACE Follow On - current status

Apart form the microwave ranging the Grace Follow On mission will use in parallel a laser interferometer to sense the inter satellite distant changes. This laser ranging interferometer (LRI) will on the one hand demonstrate, for the first time, the operation of an inter satellite laser interferometer. On the other the LRI will improve the measurement sensitivity to dissolve the spatial variations and temporal evolution of the Earth?s gravitational field. In this talk we will present the current status of the LRI which is a joint US/German project. The instrument consists of several subsystems that are a laser, an optical bench subsystem, a triple mirror assembly, a laser ranging processor, cavity assembly, baffles and harness. During the last year the LRI, including all subsystems, has successfully passed the critical design review. Thus, the engineering models have demonstrated the required performance and flight hardware is currently being build.

12:45 A.2

Srinivas Bettadpur, Christopher McCullough, John Ries, Minkang Cheng

Presenter Srinivas Bettadpur

Use of GNSS and SLR tracking of LEO satellites for bridging between GRACE and GRACE-FO

Simple experimentation shows that direct discrimination of the broad, continental scale feature requires gravity field determination to at least degree 7 or more. We show that both GRACE-GPS and SLR data are essential for independent estimation of the field to this degree/order. We look at the quality of these estimates at different time-scales, discuss the best parametrization strategies, and the validation of the results. The applications to filling potential gaps between GRACE and GRACE-FO missions are also discussed.

13:00 A.2

M. Weigelt, T. van Dam, O. Baur, M. J. Tourian, H. Steffen, K. Sosnica, A. Jäggi, N. Zehentner, T. Mayer-Gürr, N. Sneeuw

Presenter Matthias Weigelt

How well can the combination hlSST and SLR replace GRACE? A discussion from the point of view of applications

GRACE is undoubtedly one of the most important sources to observe mass transport on global scales. However, GRACE has outlived its predicted life time and the satellite system is showing signs of fatigue. As the value of any geophysical or environmental record is proportional to the length of the time series, the geo-scientific communities are seriously concerned about maintaining the gravity field time-series. In recent times efforts are undertaken to bridge a possible and likely gap between GRACE and GRACE-Follow On. One promising candidate is high-low satellite-to-satellite tracking (hlSST) of low-Earth orbiting satellites by GNSS in combination with SLR. SLR is known to provide highest quality time-variable gravity for the very low degrees (2-5). HlSST provides a higher spatial resolution but at a lower precision in the very low degrees. Thus it seems natural to combine these two techniques and the benefit has already been demonstrated in the past. However, how well can such a combination "replace" GRACE? Having both techniques available at this moment we are able to scrutinize the combined hlSST-SLR product versus GRACE from the application point of view. We will look at various aspects such as GNSS loading observations, mass trends for various regions, compare to hydrological and hydro-meteorological observations and attempt as the ultimate challenge the recovery of the GIA signal in Fennoscandia and North-America. We provide insight into the current quality of this type of time-variable gravity solution and identify limitations and challenges for future work.

14:15 A.2

K. Sośnica, A. Jäggi, M. Weigelt, T. van Dam, N. Zehentner, T. Mayer-Gürr

Presenter Krzysztof Sośnica

Time varying gravity from SLR and combined SLR and high-low satellite-to-satellite tracking data

The SLR observations to spherical geodetic satellites, e.g., LAGEOS-1/2, Starlette, Stella, AJISAI and LARES, provide remarkable information about the temporal variations of the very long wavelength part of the Earth's gravity field. As opposed to the low Earth orbiting satellites tracked by GPS high-low satellite-to-satellite tracking (GPS hl-SST), the spherical geodetic SLR satellites are not continuously tracked and the number of SLR observations is limited by the sparse and inhomogeneous network of SLR stations. Despite these limitations, the combination of the SLR data with the GPS hl-SST data reveals that the strong SLR observations substantially contribute to the recovery of time variable signals and do not only improve the gravity field coefficients of degree 2 but also those of higher-degrees. We present the methodology, results, and limitations of SLR-only gravity field estimates as obtained from rigorous multi-satellite SLR solutions. We then combine the normal equations from the multi-satellite SLR solutions with normal equations based on GPS hl-SST tracking from CHAMP, GRACE, GOCE, and other low Earth orbiting satellites to generate monthly solutions. Dedicated post-processing such as spatial and temporal filtering further enhances the solutions and allow recovering the time-variable gravity field with remarkable precision and spatial resolution. The methodology thus resembles an important step towards bridging a possible gap between GRACE and GRACE-FO.

14:30 A.2

Norbert Zehentner, Torsten Mayer-Gürr, Matthias Weigelt, Adrian Jäggi

Presenter Norbert Zehentner

Non-dedicated satellite missions for time variable gravity field estimation

For most investigations based on time variable gravity field information it is of crucial importance to have a time series which is almost continuous and as long as possible. The series of GRACE gravity field solutions will be continued by GRACE-FO. Nevertheless there is a possible gap between the two time series. In recent years high-low satellite-to-satellite tracking has been proposed as a possible gap filler for several times. However, most investigations concentrated on data from gravity field missions, like CHAMP, GRACE or GOCE, and assumed similar performance for other missions in the future. We used data from a wide range of satellite missions and investigated the possibility to retrieve time variable gravity field signal from kinematic orbits. Our investigation not only includes dedicated missions, like CHAMP, GRACE and GOCE, because the more interesting question is which other satellite mission is capable of providing comparable results based on the principle of SST-hl. Therefore, we used observation data from the satellite missions TerraSAR-X, TanDEM-X, MetOpA, MetOpB, Swarm, COSMIC, and SAC-C. We will present individual results as well as different combinations and discuss advantages and disadvantages of certain missions. The results will show which mission can be used to observe variations in the Earth's gravity field.

14:45 A.2

Christian Siemes, Olivier Carraz, Luca Massotti, Roger Haagmans, Pierluigi Silvestrin

Presenter Christian Siemes

ESA's Activities related to Next Generation Gravity Mission Concepts

The presentation addresses the activities and preparatory studies of future ESA mission concepts devoted to improve our understanding of the Earth’s mass transport phenomena causing temporal variations in the gravity field. ESA’s initiatives started in 2003 with a study on observation techniques for solid Earth missions, continued thereafter with several system studies and technology developments. Preferred mission concepts under Earth Explorer programmatic boundary conditions were identified in the “Assessment of a Next Generation Gravity Mission to Monitor the Variations of the Earth’s Gravity Field” (NGGM) and studied with prioritized science requirements and detailed system designs. These activities received precious inputs from the in-flight lesson learnt from the American-German GRACE mission and ESA’s GOCE mission. Since then, several complementary science and technology studies were initiated and are currently running. The latest results concerning the satellite architectures and constellations will be presented as well as remaining open issues for future concepts. Recently, a new gravity gradiometer instrument concept based on cold atom interferometry has been developed (see http://arxiv.org/pdf/1406.0765v1.pdf). It provides measurements of the diagonal components of the gravity gradient tensor, the spacecraft angular rates and non-gravitational forces acting on the spacecraft. We present a first assessment of the instrument’s performance including first simulations of mean and time-variable gravity field retrieval.

15:00 A.2

R. Pail, R. Bingham, C. Braitenberg, A. Eicker, R. Floberghagen, R. Haagmans, M. Horwath, T.J. Johnson, L. Longuevergne, I. Panet, C. Rolstad-Denby, B. Wouters

Presenter Roland Pail

Consolidated science requirements for a next generation gravity field mission

Before the background of a cooperation by ESA with other space agencies to jointly realize a future gravity field mission (beyond GRACE-FO) most probably in the form of a double- our multi-pair formation, in an internationally coordinated initiative among the main user communities of gravity field products the science requirements for such a mission have been reviewed and defined. This activity was realized as a joint initiative of the IAG, the GGOS Working Group on Satellite Missions, and the IUGG. After about one year of preparation, in a user workshop that was held in September 2014 consensus among the user communities of hydrology, ocean, cryosphere, solid Earth and atmosphere on consolidated science requirements could be achieved. Based on limited number of mission scenarios which took also technical feasibility into account, a consolidated view on the science requirements among the international user communities was derived, research fields that could not be tackled by current gravity missions have been identified, and the added value (qualitatively and quantitatively) of these scenarios with respect to science return has been evaluated. The resulting document shall form the basis for further programmatic and technological developments. In this contribution, the main outcomes of the user workshop will be presented. An overview of the specific requirements of the individual user groups, the consensus on consolidated requirements as well as the new research fields that have been identified during this process will be discussed.

15:15 A.2

M. Murböck, Th. Gruber and NGGM-D team

Presenter T. Gruber

Next generation satellite gravimetry mission study (NGGM-D)

The main goal of this project is to develop an advanced mission concept for long term monitoring of mass variations in the system Earth in order to improve our knowledge about the global and regional water cycle as well as about processes of the solid Earth. In times of global change this is needed to make more realistic predictions of system Earth parameters. Starting from the existing concepts of the GRACE and GRACE Follow-On missions, sensitivity and spatial resolution shall be increased, such that also smaller scale time variable signals can be resolved, which cannot be detected with the current techniques. For such a mission new and significantly improved observation techniques are needed. This concerns in particular the measurement of inter-satellite distances, the observation of non-gravitational accelerations and the configuration of the satellite orbits or of a constellation of satellites. These new components and their complex interactions form the basis for a new space based observation concept for mass variations in system Earth. The German Aerospace Center (DLR) funded a preparatory study in order to develop a mission concept for a next generation gravity field mission. The study was coordinated by Technische Universität München and incorporated all major players in the field of satellite gravimetry in Germany. By joining scientific, technological and industrial expertise the resulting mission concept can form the baseline for a potential and realistic mission proposal. The paper presents the results obtained from this study and the proposed mission concept.

15:30 **A.2**

I. Daras, R. Pail, P. Visser, M. Weigelt, S. Iran-Pour, M. Murböck, S. Tonetti, T. Gruber, J. de Teixeira da Encarnação, S. Cesare, C. Siemes, J. van den IJssel, S. Cornara, T. van Dam, N. Sneeuw, R. Haagmans

Presenter Ilias Daras

Treatment of temporal aliasing on future gravity satellite missions - an insight into ESA-SC4MGV project

One of the biggest constrains for future gravity satellite missions on their way to achieve the expected accuracy that new generation sensors could provide, is the error induced by temporal aliasing, which remains one of the biggest contributors to the error budget. Within the scope of the ESA-SC4MGV project, we investigate the impact of temporal aliasing on future gravity satellite missions as well as methods for its minimization. This is succeeded on one hand by optimizing the choice for the orbital configuration, and on the other by optimizing the gravity field techniques accordingly. Our optimized orbit constellation consists of two in-line pairs of a Bender type configuration and is used as our "basis" scenario. Using the "basis" scenario, we investigate gravity field processing methods that lead in a reduction of the temporal aliasing errors. As a first step we apply the so-called "Wiese" approach, which suggests co-estimating low resolution gravity fields at short time intervals in order to directly compute the short-term signals that alias into the combined solution. We demonstrate the ability of the "Wiese" approach to minimize temporal aliasing errors for our "basis" scenario. As a step forward, we experiment with alternative parameterizations that combine low and medium gravity fields at different time intervals, in order to achieve the best results in terms of minimization of temporal aliasing errors. Our preliminary results show a further improvement compared to the standard "Wiese" approach.

15:45 **A.2**

M. Weigelt, S. Iran-Pour, M. Murböck, S. Tonetti, P. Visser, I. Daras, J. de Teixeira da Encarnação, S. Cesare, C. Siemes, J. van den IJssel, S. Cornara, T. Gruber, T. van Dam, R. Pail, N. Sneeuw, R.

Presenter Matthias Weigelt

A methodology to choose the orbit for a double pair scenario future gravity satellite mission ? experiences from the ESA SC4MGV project

For next generation gravity field missions (NGGM) a likely mission scenario is to fly two pairs of satellites in a Bender configuration, where one satellite is in a (near-)polar and another satellite is in an inclined orbit (normally around 70°). Naturally the question of an optimal orbit configuration arises especially in the view of optimizing the temporal and spatial resolution whilst minimizing aliasing of undesired signal content such as e.g. ocean tides, among others. The parameters search space for finding near-optimal scenarios is a function of orbital parameters of both pairs. Each parameter has its own impact on gravity recovery quality. Based on experience from previous studies, the search space can be reduced but the remaining parameters still need to be optimized. We employ within the ESA-SC4MGV project a genetic algorithm. The approach yields a set of candidate scenarios which are scrutinized afterwards. In this talk we focus on the importance of the latter, i.e. an in-depth analysis of the simulated results down to the level of applications e.g. in hydrology. We will present examples where the results of the gravity field recovery itself seem reasonable but derived water storage changes suffer from an artificial quarterly signals. Therefore, we emphasize the need to employ a full-scale end-to-end simulation which is ongoing in the current project phase.

Poster **A.2**

Ilias Daras, Roland Pail

Presenter Ilias Daras

Towards a full exploitation of next generation sensors on-board future LL-SST type gravity field missions

Next generation gravity field missions of low-low satellite-to-satellite tracking (LL-SST) type are expected to fly optimized formations and make use of the most accurate sensors. In the upcoming GRACE Follow-on mission, the traditional K-band ranging instrument will be supplemented with a laser interferometer of several nms accuracy. Consequently, the processing method for gravity field recovery has to meet the performance requirements of those new generation sensors to deliver the most precise gravity field possible. In this study we present an analysis of the potential performance of new sensors and their impact in gravity field solutions. We investigate the ability of current gravity field processing methods to fully exploit the new sensor accuracies. We demonstrate that processing with standard precision may be a limiting factor for taking full advantage of new generation sensors that future satellite missions will carry. Therefore an alternative version of our simulator is presented, which uses in hybrid mode double and quadruple precision at different processing steps, primarily aiming to minimize round-off system errors. Results using the enhanced precision show a big reduction of system errors that were present at the standard precision processing. As a next step, error sources with a priori known frequency behavior are assessed via stochastic modeling. Alternatively, empirical parameterization is also engaged in order to minimize the effect of the propagated noise into the solutions, and the results are compared with the stochastic modeling.

Poster **A.2**

Henryk Dobslaw, Inga Bergmann-Wolf, Robert Dill, Ehsan Forootan, Volker Klemann, Jürgen Kusche, Ingo Sasgen

Presenter Henryk Dobslaw

The Updated ESA Earth System Model for Gravity Mission Simulation Studies

The ability of any satellite gravity mission concept to monitor mass transport processes in the Earth system is typically tested well ahead of its implementation by means of numerous simulation studies. For such simulations, a suitable source model is required to (i) represent rapid mass motions in for example the atmosphere and oceans, in order to realistically include the effects of temporal aliasing due to non-tidal high-frequency mass variability into the retrieved gravity fields. Moreover, (ii) low-frequency variability needs to present at realistic amplitudes and frequencies at in particular small spatial scales, in order to assess to what extent a new mission concept might provide further insight into physical processes not observed by a satellite system before. The new source model presented in this study attempts to fulfill both requirements: Based on ECMWF's recent atmospheric reanalysis ERA Interim and corresponding simulations from numerical models of the other Earth system components, it offers spherical harmonic coefficients of the mass variability in atmosphere, oceans, the terrestrial hydrosphere including the ice-sheets and glaciers, as well as the solid Earth with high temporal (6 hours) and spatial (d/o 180) resolution for a period of 12 years.

Poster A.2

Matthias Ellmer, Torsten Mayer-Gürr

Presenter Matthias Ellmer

GRACE follow-on sensor noise with realistic background models

We performed multiple simulation studies of a GRACE-like satellite mission based on the current K-Band ranging instrument (KBR), while also using a laser-ranging instrument (LRI) as a drop-in replacement. We based our simulated data on real GRACE observations for April 2006. We used the variational equation approach to generate reduced dynamic orbits that were fitted to the actual GRACE kinematic orbits. Synthetic satellite ranging, star camera, accelerometer and kinematic orbit data was computed from these orbits. We synchronized all simulated instruments with the real measurements to account for data gaps. The next step was the introduction of effects that would reproduce the features of the real observations. For this, we used the two parameters of accelerometer noise and time-variable gravity. We degraded the AOD1B dealiasing product used in the generation of the fundamental orbit data with partial components of the updated ESA earth system model dataset in the recovery step. The resulting residual time-variable gravity signal lead to results that are similar to, and slightly better than, those of the real solution in both spectral and spatial domains. The LRI showed improved performance above degree and order 100. A further increase of accelerometer noise by a factor of 9 brought KBR degree variances in line with real data.

Poster A.2

Bernard Foulon, Bruno Christophe, Francoise Liorzou

Presenter Bernard Foulon

MICROSTAR, a "miniaturized" ultra sensitive accelerometer for future space missions

With its mature technology inherited from the electrostatic accelerometers of the GRACE and GOCE geodesy missions, the MicroSTAR accelerometer is a new electrostatic accelerometer with limited weight-volume-power budgets for small satellite missions. The Sensor Unit comprising its Front End Electronics is weighting 1.5 kg inside less than 1 litre and with a maximum power consumption of 1.5 W. If not directly provided by the satellite, an associated Interface and Control Unit, contained in ¾ litre weighting 1.2 kg and consuming 2 W, insures the data packaging and transfer toward the satellite bus and provides to the instrument regulated power lines. With its cubic proof-mass positioned at the CoG of the satellite, MicroSTAR can provide, along its 3 axes, the measurements of the non gravitational forces acting on the satellite with a resolution performance up to 1.5E-11 m/s2/sqrt(Hz) in the measurement bandwidth from 0.2 mHz to 100 mHz. The poster will present a description of the MicroSTAR instrument, its detailed performance budget, the status of the prototype model developed under Onera's internal funding and its possible interest for some future small satellite LEO missions (as GRACE 2 or GRASP) or for planetary missions inside the solar system.

Poster A.2

Bernard Foulon, Bruno Christophe, Vincent Lebat, Karim Douch, Isabelle Panet

Presenter Bernard Foulon

GREMLIT: a planar electrostatic gradiometer for airborne geodesy

Taking advantage of technologies, developed by ONERA for the GRACE and GOCE space missions, the GREMLIT airborne gravity gradiometer is more particularly developed to provide complementary measurements at the short wavelengths in particular in the areas where spatial distribution and quality of ground data remain quite uneven like for example land/sea transition. Built using a double deck of a compact planar assembly of 4 electrostatic accelerometers leading to a cubic configuration gradiometer, the GREMLIT instrument is mounted on a dedicated stabilized platform which is controlled by the common mode outputs of the instrument itself along the horizontal directions. In addition to the realization of a one axis prototype model, detailed numerical simulations have been conducted over some realistic coastal test areas. Taking into account the data sheet performance of the associated commercial angular and data rate sensors and assuming actual airplane acceleration measurements, they lead to exhibit accuracy below 1E along the Txx and Tyy horizontal components. The poster will present the description and the characteristics of the whole instrument including the specific controlled platform and also some synthetic results of the simulations.

Poster A.2

Vitali Müller for the LRI-D team

Presenter Vitali Müller

Inter-satellite ranging for GRACE Follow-On and NGGM

The GRACE Follow-On mission will use microwaves and laser light to determine variations in the satellite separation. The main microwave ranging instrument has been used successfully already in GRACE. The novel laser ranging instrument (LRI) shall demonstrate feasibility and functionality of inter-satellite laser interferometry with the benefit of an improved ranging sensitivity. The technology and instrument is attracting attention due to potential applications in future geodesy missions and in the gravitational wave mission LISA. Concepts, noise sources and challanges of satellite-satellite laser interferometry will be introduced. In particular the GRACE Follow-On LRI working principle will be explained.

16:30 B.2

Jianli Chen

Presenter Jianli Chen

Reducing Leakage Error in GRACE-Estimated Antarctic Mass Balance

Spatial leakage is a major limitation for quantitative interpretation of satellite gravity measurements from the Gravity Recovery and Climate Experiment (GRACE). It arises from the limited range of spherical harmonics (SH) available and additional filtering to suppress noise in high degree and order SH coefficients. Using synthetic data to simulate ice mass changes over Antarctica, we illustrate the quantitative effects of a limited range of SH coefficients (degree and order 60) and additional filtering, which in combination can attenuate signal amplitudes by up to 60%, and evaluate potential leakage effects on Antarctic mass rate estimates from ocean bottom pressure and terrestrial water storage (TWS) changes using model estimates and ice melting over Greenland, and Canadian Arctic Archipelago (CAA). We present details of a forward modeling algorithm used successfully in previous studies, and show that it is capable of removing these biases from GRACE estimates. Examples show how to implement the method by constraining locations of presumed mass changes, or leaving these locations unspecified within a continental region. Our analysis indicates that leakage effect from far-field TWS change and Greenland and CAA ice melting on Antarctica mass rate estimates appears minimal and negligible. However, leakage from long-term ocean bottom pressure change in the surrounding Antarctic Circumpolar Current regions may bias Antarctica mass rate estimates by up to 20 Gigatonne per year (Gt/yr).

16:45 B.2

Jennifer Bonin, Don Chambers, Himanshu Save

Presenter Jennifer Bonin

What GRACE resolution is required to numerically separate Greenland's glacial mass balance from its surface mass balance?

Mass change occurring over Greenland can be divided into two parts. Large-scale patterns in surface melting, runoff, and sublimation, as balanced by precipitation, result in changes in the surface mass balance (SMB), while changes in rates of ice discharge of marine-terminating outlet glaciers determine the glacial mass balance (GMB). While in most cases, these two types of mass change are modeled and measured separately, GRACE intrinsically lacks the direct ability to separate one cause from the other. We demonstrate one theoretical way to separate SMB from GMB with GRACE, using a least squares inversion technique. However, we find that the limited 60x60 spherical harmonic representation of GRACE RL05 does not provide sufficient resolution to adequately accomplish the task. We then determine the GRACE spatial resolution needed to actually separate the SMB from GMS signals, within acceptable error limits.

17:00 **B.2**

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

Presenter S.B. Luthcke

Current estimates of land ice mass evolution from the NASA GSFC mascon solution

Current land ice mass changes are determined from the latest NASA GSFC global mascon solution. The mascons describe the time variable gravity signal at monthly intervals and are directly estimated from the GRACE K-band range-rate observations, taking into account the full data noise covariance, and applying a mascon regularization matrix which acts to reduce signal leakage while maximizing signal recovery. The solution signals and errors are analyzed and discussed. An optimized Ensemble Empirical Mode Decomposition (EEMD) algorithm is applied to each land ice region to accurately determine the timing of the non-stationary seasonal signal without relying on a priori information. This approach enables the construction of meaningful annual net balance maps which highlight the spatial and temporal variability of land ice mass evolution throughout the GRACE mission.

17:15 **B.2**

M. J. Talpe, R. S. Nerem, F. G. Lemoine, F. Landerer

Presenter R. S. Nerem

Two Decades of Mass Change in Greenland and Antarctica

We use complimentary SLR/DORIS solutions to extend the record of time-variable gravity prior to GRACE by a full decade. The reconstructed fields are generated by combining the EOF spatial modes from GRACE with the temporal modes from an SLR/DORIS solution computed at NASA/GSFC. The most recent solution contains a weekly solution for 33 coefficients (up to degree and order 5, without the [5,0] terms but with [6,1] terms) and a full error covariance. The errors in the reconstruction were considered from two sources: (1) the fact that the GRACE EOF modes do not span the entire solution time frame, and (2) the errors in the SLR/DORIS solutions. We will focus on the mass change over 1992 – present for Greenland and Antarctica, because the signals are largest in these regions. We will also show the mass change of two regions away from the poles that have experienced notable interannual variability as a way to evaluate the spatial resolution of the reconstructed fields. In these reconstructed mass change curves, we also show the contribution of each mode as well as the contribution of different degrees from the SLR/DORIS solutions.

17:30 B.2

Isabella Velicogna

Presenter Isabella velicogna

Regional pattern of ice mass balance with GRACE in Greenland, Antarctica and the Canadian Arctic Archipelago

We apply a mascon approach to the data of the NASA/DLR GRACE mission to determine the regional acceleration in mass loss of Greenland, Antarctica and the Canadian Arctic Archipelago for 2003-2013. In Greenland, the southeast and northwest generate 70% of the loss (280±58 Gt/yr) mostly from ice dynamics, the southwest accounts for 54% of the total acceleration in loss (25.4±1.2 Gt/yr2) from an increase in runoff, followed by the northwest (34%). We find no significant acceleration in the northeast. In Antarctica, the Amundsen Sea Embayment (ASE) sector and the Peninsula account for 64% and 17%, respectively, of the total loss (180±10 Gt/yr) mainly from ice dynamics. The ASE contributes most of the acceleration in loss (11±4 Gt/yr2). This result is consistent with independent observations from altimetry (Operation IceBridge, Envisat and ICESat-1) and the mass budget method (surface mass balance versus ice discharge along the periphery). Queen Maud Land, East Antarctica is the only sector with a significant mass gain due to a local increase in snowfall (63±5 Gt/yr). In the Canadian Arctic Archipelago (CAA), we find a mass loss of 73 Gt/yr in 2003-2013, which corresponds to a mass loss per unit area disproportionally large compared to that in Greenland. We also show updated time series for the remaining glaciers and ice caps. This work was performed at UCI and JPL under a contract with NASA and CSR.

17:45 B.2

Yvonne Firing, Carmen Boening, David Wiese, Michael Watkins, Nicole Schlegel, Eric Larour

Presenter Carmen Boening

Antarctic Ice Mass Balance from GRACE

The Antarctic ice mass balance and rates of change of ice mass over the past decade are analyzed based on observations from the Gravity Recovery and Climate Experiment (GRACE) satellites, in the form of JPL RL05M mascon solutions. Surface mass balance (SMB) fluxes from ERA-Interim successfully account for the seasonal GRACE-measured mass variability. Trends in the residual (GRACE mass - SMB accumulation) mass time series in different Antarctic drainage basins are consistent with time-mean ice discharge rates based on radar-derived ice velocities and thicknesses. GRACE also resolves accelerations in regional ice mass change rates, including increasing rates of mass gain in East Antarctica and accelerating ice mass loss in West Antarctica. Most of the increasing mass loss rate in West Antarctica is explained by decreasing SMB (principally precipitation) over this time period, part of the characteristic decadal variability in regional SMB. The residual acceleration of 2+/-1 Gt/yr, which is concentrated in the Amundsen Sea Embayment (ASE) basins, represents the contribution from increasing ice discharge rates. An Ice Sheet System Model (ISSM) run with constant ocean forcing and stationary grounding lines both underpredicts the largest trends in the ASE and produces negligible acceleration or interannual variability in discharge, highlighting the potential importance of ocean forcing for setting ice discharge rates at interannual to decadal time scales.