Inter-Commission on Theory (ICCT)

http://icct.kma.zcu.cz

President: Nico Sneeuw (Germany)
Vice President: Pavel Novák (Czech Republic)

Structure

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Overview

All joint study groups show a good level of activities, be it in organizing workshops, in comparing software through a common data set or in participating in international research teams. As such, it is recommended that all JSG's complete their 4-year period. Internal group communication runs through various channels JSG06 even issues a periodical bulletin (JSG06 Newsletter).

An ICCT Splinter Meeting was held during the EGU 2012 (Vienna). Most of the Study Group chairs were able to participate. They reported on the on-going and future activities of their respective groups. Moreover, the initial plans for the Hotine-Marussi meeting were discussed.

VIII Hotine-Marussi Symposium

The main highlight of ICCT is the organization of the VIII Hotine-Marussi Symposium in Rome. Since the inception of ICCT, the already existing series of Hotine-Marussi Symposia falls under the responsibility of ICCT. Earlier ICCT-organized Symposia were the numbers VI (2006, Wuhan) and VII (2009, Rome).

June 17–21, 2013, the VIII Hotine-Marussi Symposium took place in Rome. The venue was the same as 2009, namely at the Faculty of Engineering of the Sapienza University of Rome. Also the local organization was in the hands of Prof. Mattia Crespi again. From a total attendance of about 100 participants about 70 oral presentations and 15 posters were contributed to the following sessions:

1. Geodetic Data Analysis (W. Kosek, R. Gross, C. Kreemer)
2. Theoretical aspects of reference frames (A. Dermanis, T. Van Dam)
3. Digital Terrain Modeling, Synthetic Aperture Radar and new sensors: theory and methods (M. Crespi, E. Pottier)
4. Geopotential modeling, boundary value problems and height systems (P. Novák, M. Schmidt, C. Gerlach)
5. Atmospheric modeling in geodesy (T. Hobiger, M. Schindelegger)
6. Gravity field mapping methodology from GRACE and future gravity missions (M. Weigelt, A. Jäggi)
7. Inverse modeling, estimation theory (P. Xu)
8. Computational geodesy (R. Čunderlík, K. Mikula)
9. Special Session at Accademia Nazionale dei Lincei (F. Sansò, R. Barzaghi, N. Sneeuw)

The session topics follow roughly the study group structure of ICCT. Conveners (in brackets) were recruited (mostly) from the study group chairs and members.

True to the InterCommission nature of ICCT, the sessions dealt with the full width of topics in theoretical geodesy. During the special session at the Accademia Nazionale dei Lincei Fernando Sansò was honoured for his long-term involvement in the organization of the series of Hotine-Marussi Symposium, after taking over the baton from Antonio Marussi in 1985. It was decided to rename the VIII Hotine-Marussi Symposium by adding "*in honour of Fernando Sansò*" to its title.

Other meetings

The individual study groups organized several workshops, a summer school and conference sessions:

- EGU session G1.1 "Recent Developments in Geodetic Theory" over the past several years.
- EGU session G1.2 "Mathematical methods in the analysis and interpretation of potential field data and other geodetic time series" (EGU 2011, 2012, 2013).
- International Workshop on "Regional Gravity and Geomagnetic Field Modelling" Munich, Germany, 2012.
- Session G5.1 "Observing and understanding Earth rotation variability and its geophysical excitation" at EGU 2012; Science Meeting of IAU Commission 19 "Rotation of the Earth" at IAU 2012; Session G3.3 "Observing and understanding Earth rotation variability and its geophysical excitation" at EGU 2013.
- International Symposium on "Space Geodesy and Earth System" (SGES2012), Shanghai, 2012; International Summer School on "Space Geodesy and Earth System", Shanghai, 2012.

Joint Study Group 0.1: Application of Time Series Analysis in Geodesy

Chair: Westlaw Kosek (Poland)

In October 2010 the US Naval Observatory (USNO 2013) together with the Space Research Centre (SRC 2013) in Warsaw initiated the IERS Earth Orientation Parameters Combination of Prediction Pilot Project (EOPCPPP). The goal of this project is to determine the feasibility of combining Earth Orientation Parameters (EOP) predictions on an operational basis. The pole coordinate data predictions from different prediction contributors and ensemble predictions computed by the USNO were studied to determine the statistical properties of polar motion forecasts (Kosek et al. 2012). Short term prediction errors of pole coordinates data are caused by wideband short period oscillations in joint atmospheric-ocean excitation functions and their increase can be also caused by the change of phase of the annual oscillation in this function (Kosek 2012). The combination of the least-squares and multivariate autoregressive prediction using the axial component of the atmospheric angular momentum excitation function method was applied to predict UT1–UTC data which improved their prediction accuracy in relation to the combination of the least-squares and the autoregressive prediction of the univariate time series (Niedzielski and Kosek 2012).

Higher order semblance function reveals that addition of hydrology angular momentum to the sum of atmospheric and oceanic excitation functions of polar motion improves the phase agreement between the geodetic and fluid excitation functions in the annual frequency band. The common oscillations in the geodetic and fluid excitation functions of polar motion can be detected using wavelet based semblance filtering (Kosek et al., 2011).

At the University of Wroclaw in Poland the real time system and service for sea level prediction called PROGNOCEAN has been built (Niedzielski and Mizinski 2013). The aim of this system is computation of altimeter-derived sea level anomalies data prediction for 1 day, 1 week and 2 weeks in the future, together with the maps of the mean prediction errors. The predictions are computed in real time, so the users are available to evaluate the performance of the system and service. The forecasting strategies are based on a few time series methods: (1) extrapolation of the polynomial-harmonic model, (2) extrapolation of the polynomial-harmonic model with autoregressive prediction, (3) extrapolation of the polynomial-harmonic model with self-exciting threshold autoregressive model, (4) extrapolation of the polynomial-harmonic model with auto covariance prediction, (5) extrapolation of the polynomial-harmonic model with vector autoregressive prediction, (6) extrapolation of the polynomial-harmonic model with generalized space-time autoregressive model (Prognocean 2013).

A software package TSoft for the analysis of Time Series and Earth Tides has been created by Paul Vauterin in the Royal Observatory of Belgium. It allows the user to process the data in a fully interactive and graphical way and has a number of important advantages, particularly in the field of error correction of (strongly perturbed) data, and the detection and processing of special events (e.g. free oscillations after Earthquakes (ROB 2013).

The influence of the hydrological noise on repeated gravity measurements has been investigated on the basis of the time series of 18 superconducting gravimeters (SGs) and on predictions inferred from the Land Dynamics (LaD) world Gascoyne land water energy balances model. It is shown that the PSDs of the hydrological effects flattens at low frequency and is characterized by a generalized Gauss Markov structure (Van Camp et al. 2010).

The new method of data processing was used for the absolute gravimeters (AGs) observations during intercomparison campaigns since 1980. A new criterion, based on the minimization of the L1 norm of the offsets, for fixing the constant of the ill-conditioned problem, was found to be statistically more precise than the one classically used (de Viron et al. 2011). Based on synthetic data representative of signals observed by superconducting gravimeters (SG) at various station locations, it was found that the addition of SG information mitigates the error in the estimation of gravity rates of change caused by the presence of long period, inter-annual, and annual signals in the AGs data. These results were discussed as a function of the sampling rate of the absolute gravity measurements, the duration of the observations, and the uncertainties of the AGs (Van Camp et al. 2013).

It was shown that 25 different climate indices associated with a great variety of climatic fields and geographic regions share a very substantial fraction of their variability. This common fraction can be captured and described by using no more than four leading modes of variability correlated with the sea surface temperature field. The preferred periodicities apparent in these modes reflect mainly the quasi-biennial and quasi-quadrennial periodicities of El Nino Southern Oscillation (de Viron et al. 2013).

Meetings

Since 2011 at each European Geosciences Union General Assembly the sessions G1.2 "Mathematical methods in the analysis and interpretation of potential field data and other geodetic time series" were organized, by two members of the JSG 0.1 study group (EGU 2011, 2012, 2013).

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ROB 2013, http://www.seismologie.be/TSOFT/tsoft.html

SRC 2013, http://www.cbk.waw.pl/eopcppp/cfp.html

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Joint Study Group 0.2: Gravity Field Modelling in Support of Height System Realization

Chair: Pavel Novák (Czech Republic)

Introduction and objectives

This report covers activities and scientific outputs of the Joint Study Group 0.2 (JSG0.2) for the period 2011–13. In its terms of reference, the group outlined several research topics (of a theoretical nature) that were closely related to gravity field modelling and its role for establishment of a world height system (WHS). It was emphasized that namely geometric properties of the Earth's gravity field were very significant in this respect as one particular equipotential surface of the Earth's gravity field served as a vertical datum in geodesy.
Theoretical issues include this (non-exhaustive) list:

- Combining heterogeneous gravity field observables by using spatial inversion, spherical radial functions, collocation and wavelets, etc. and by taking into account their sampling in time and space, spectral and stochastic properties.
- Studying stable, accurate and numerically efficient methods for continuation of gravity field parameters including satellite observables of type GRACE and GOCE.
- Advancing methods for gravity potential estimation based on its measured directional derivatives (gravity, gravity gradients) by exploiting advantages of simultaneous continuation and inversion of observations.
- Investigating gravity data specifications (stochastic properties, spatial and temporal sampling and spectral content) required by specific geodetic applications.
- Studying available Earth's gravitational models (EGM) in terms of their available resolution and accuracy for the purpose of WHS realization.
- Defining relations between an adopted conventional EGM and parameters of a geocentric reference ellipsoid of revolution approximating a time invariant equipotential surface of the adopted EGM aligned to reduced observables of mean sea level.

This study group (SG) is affiliated to IAG Commissions 1 (*Reference Frames*) and 2 (*Gravity Field*); co-operation with GGOS Theme 1 *Unified Global Height System* has been foreseen.

Report on published/presented results of the study group

Main scientific outcomes of the study group include journal publications, oral and poster presentations at international conferences and meetings, and eventually progress reports and final reports delivered to scientific authorities. The following overview provides just samples of these products.

Selected publications

Čunderlík R, Mikula K, Špir R (2012) An oblique derivative in the direct BEM formulation of the fixed gravimetric BVP. In: *7th Hotine-Marussi Symposium on Mathematical Geodesy*. International Association of Geodesy Symposia 137, DOI: 10.1007/978-3-642-22078-4_34.

Čunderlík R, Fašková Z, Mikula K (2012) Fixed gravimetric BVP for the vertical datum problem. In: *Geodesy for Planet Earth.* International Association of Geodesy Symposia 136, DOI: 10.1007/978-3-642-20338-1_40.

Featherstone WE (2013) Deterministic, stochastic, hybrid and band-limited modifications of Hotine's integral. *Journal of Geodesy* 87(5): 487-500, DOI: 10.1007/s00190-013-0612-9.

Filmer MS, Hirt C, Featherstone WE (2013) Error sources and data limitations for the prediction of surface gravity: a case study using benchmarks. *Studia Geophysica et Geodaetica* 57(1): 47-66, DOI: 10.1007/s11200-012-1114-6.

Featherstone WE, Filmer MS (2012) The north-south tilt in the Australian Height Datum is explained by the ocean's mean dynamic topography. *Journal of Geophysical Research –Oceans* 117: C08035, DOI: 10.1029/2012JC007974.

Hirt C, Kuhn M, Featherstone WE (2012) Topographic/isostatic evaluation of new-generation GOCE gravity field models. *Journal of Geophysical Research – Solid Earth* 117: B05407, DOI: 10.1029/2011JB008878.

Heck B (2011) A Brovar-type solution of the fixed geodetic boundary-value problem. *Studia Geophysica et Geodaetica* 55(3): 441-454, DOI: 10.1007/s11200-011-0025-2.

Gruber C, Novák P, Sebera J (2011) FFT-based high-performance spherical harmonic transformation. *Studia Geophysica et Geodaetica* 55(3): 489-500.

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Tenzer R, Hamayan, Novák P, Gladkikh V, Vajda P (2012) Global crust-mantle density contrast estimated from EGM2008, DTM2008, CRUST2.0 and ICE-5G. *Pure and Applied Geophysics* 169(9): 1663-1678.
Tenzer R, Novák P, Gladkikh V (2012) The bathymetric stripping corrections to gravity field quantities for a depth-dependent model of seawater density. *Marine Geodesy* 35: 1-23.

Selected oral and poster presentations

Abd-Elmotaal H, Kuehtreiber N (2012) Comparison between astro-gravimetric and astro-geodetic geoids for Austria. EGU2012-223.

Amjadiparvar B, Rangelova E, Sideris MG, Hayden TS (2013) The role of local gravity information in the unification of the North American vertical datums. EGU2013-6480.

Čunderlík R, Mikula K (2012) Realization of WHS based on the static gravity field observed by GOCE. International Symposium on Gravity, Geoid and Height Systems (GGHS2012). Venice, October 2012 (S5-179).

Elhabiby MM, Sideris MG, Keller W (2011) A combined multi-resolution multi-dimensional wavelet approach for the inversion of geodetic integrals. EGU2011-13775.

Fašková Z, Macák M, Čunderlík R, Mikula K (2012) Finite volume numerical scheme for high-resolution gravity field modelling and its parallel implementation. EGU2012-8827.

Gruber C, Novák P, Barthelmes F (2011) Derivation of topographic potential from global DEM models. EGU2011-10170.

Gruber C, Moon YJ, Flechtner F, Novák P, Daras I (2011) Submonthly GRACE solutions from localising integral equations and Kalman filtering. 25th General Assembly of IUGG, Melbourne, July 2011.

Heck B, Müßle M, Seitz K, Grombein T (2013) On the effect of planar approximation in the geodetic boundary value problem. EGU2013-8963.

Huang J, Véronneau M (2013) Contribution of the GRACE and GOCE models to a geopotential-based geodetic vertical datum in Canada. EGU2013-10164.

Novák P, Sebera J, Val'ko M (2012) On the downward continuation of gravitational gradients. International Symposium on Gravity, Geoid and Height Systems (GGHS2012). Venice, October 2012 (S2-201).

Roman D, Véronneau M, Avalos D, Li X, Holmes S, Huang J (2012) Integration of gravity data into a seamless transnational height model for North America. International Symposium on Gravity, Geoid and Height Systems (GGHS2012). Venice, October 2012 (S5-075).

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Sebera J, Novák P, Vaľko M, Šprlák M, Bezděk A, Bouman J, Fuchs M (2013) Downward continuation of gridded and reprocessed GOCE gravitational gradients. EGU2013-8265.

Šprlák M, Novák P, Valko M, Sebera J (2013) Spherical integral formulas for upward/downward continuation of gravitational gradients onto gravitational gradients. 8th Hotine-Marussi Symposium, Rome, June 2013.

Wang YM, Li X, Holmes S, Roman D, Smith D (2013) Investigation of the use of deflections of vertical measured by DIADEM camera in the GSVS11 survey. EGU2013-12779.

Study group web page

The webpage of the group is http://icct.kma.zcu.cz/index.php/IC_SG2.

Report on activities of the study group

During the 2011–13 period, there were no specific sessions organized during regular geodetic conferences but one at the Hotine-Marussi Symposium 2013 in Rome. At this event, organized by ICCT, the session on geopotential modelling, boundary-value problems and height systems co-convened by chairmen of the JSG0.2 and JSG0.3 has been organized with total 11 oral and 2 poster presentations. Other contributions of the group's members can be found on programs of geodetic and geophysical conferences and meetings (such as EGU, AGU, GGHS2012) organized during the period starting after the IUGG General Assembly in Melbourne 2011. This report lists only some of the presented contributions. Activities within the scope of the JSG partially overlapped with project activities of its members including two projects of the ESA'S Support to Science Element (STSE) program (GOCE data in support of WHS and for geophysical exploration). These international projects represent a platform for scientific co-operation of scientists including regular meetings and visits.

Outlook and plans

To discuss activities of the JSG for the remaining two-year period (2013-15), there will be at hand two upcoming opportunities: VIII. Hotine-Marussi Symposium in Rome, June 2013, and the Scientific Assembly of the IAG in Potsdam, September 2013. Generally, the focus remains on the research areas specified above as the establishment of WHS remains one of the major scientific projects of IAG for the period until its next General Assembly in Prague in 2015.

Joint Study Group 0.3: Comparison of Current Methodologies in Regional Gravity Field Modelling

Chairs: Michael Schmidt, Christian Gerlach (Germany)

Introduction

The main objectives of JSG0.3 are:

- to collect information of available methodologies and strategies for regional modelling,
- to analyze the collected information in order to find specific properties of the different approaches and to find, why certain strategies have been chosen,
- to create a benchmark data set for comparative numerical studies,
- to carry out numerical comparisons between different solution strategies for estimating the model parameters and to validate the results with other approaches (spherical harmonic models, least-squares collocation, etc.),
- to quantify and interpret the differences of the comparisons with a focus on detection, explanation and treatment of inconsistencies and possible instabilities of the different approaches,
- to create guidelines for generating regional gravity solutions,
- to outline standards and conventions for future regional gravity products.

Since the focus is on the methodological foundations it is straightforward to compare different methodologies in regional gravity field modelling based on synthetic data.

A first initiative to motivate active contribution to this study was a workshop on regional potential field modelling (see next section). On the workshop it was agreed to prepare a set of simulated gravity field data which should be used for computing regional gravity field models by different groups employing different methodologies. This should facilitate a numerical comparison of the different approaches.

Workshop

On February 23–24, 2012, an international "Workshop on Regional Gravity and Geomagnetic Field Modelling" was held at the Bavarian Academy of Sciences and Humanities (BAdW) in Munich, Germany. The workshop was jointly organized by the German Geodetic Research Institute (DGFI, Michael Schmidt), the Commission for Geodesy and Glaciology of BAdW (KEG, Christian Gerlach) and the Institute for Geodesy and Geoinformatics of the University of Bonn (IGG, Jürgen Kusche).

The active participants were asked to present their modelling approach with regard to their

- field of application (gravity field, geomagnetic field, static or time-variable, etc.),
- the type of input data used (terrestrial, airborne, satellite data or a combination of those),
- the type of modelling approach used including choice of base functions and point grids, properties of the mathematical and stochastic models and details on the mathematical solution and regularization techniques which are employed.
- In addition, open question and specific problem areas were presented.

After a general introduction by Michael Schmidt on general aspects of regional modelling and the scope of the workshop several modelling approaches were presented by several groups. Table 1 gives an overview of the modelling approaches presented during the two workshop days. Altogether there were 31 participants from 11 different countries. The participation was not limited to the original members of JSG 0.3 which reflects the study groups open policy that interested research groups can join at any time.

Simulation Data

On the workshop it was agreed within the final discussion to generate a simulation data set to be used by all different groups in order to facilitate numerical comparison between the different methodologies. The data set was jointly prepared by DGFI and IGG Bonn; it is available from the web site of JGS 0.3 at http://jsg03.dgfi.badw.de. The data set is publicly available and all groups interested in testing their approach are invited to use the data set and share the results. First results of individual groups were presented during the VIII Hotine-Marussi Symposium in Rome, June 17-21, 2013. Comprehensive comparisons and evaluations of the individual results are planned for the beginning of 2014 and will be presented at the EGU General Assembly 2014 in Vienna at the end of April, so far results from the actively contributing groups are made available to JGS 0.3 by the end of 2013.

The data sets comprise terrestrial data on regular geographic coordinate grids, airborne data on synthetic flight tracks and satellite data along real orbits of GRACE and GOCE. They are provided for two test areas, namely in Europe and South America, both having an extension of 20° × 30°. The data is provided error-free along with time series of white noise errors. At a later stage the inclusion of coloured noise models is planned.

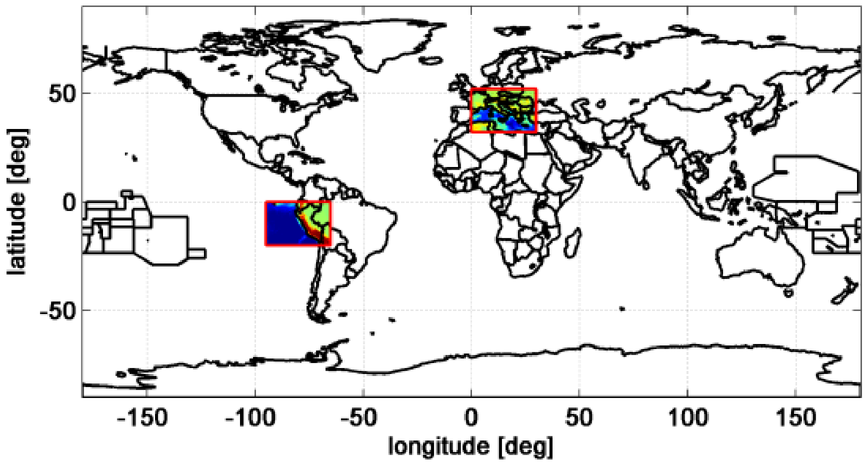

Figure 1: Global map with red boxes marking the test regions.

For validation of the computations from the data sets an additional data also on regular geographic surface grids is provided. In order to allow validation of gravity field approximation at independent locations, the validation grids are shifted with respect to the observation data grids.

Table 1: Overview of modelling approaches presented at the "Workshop on Regional Gravity and Geomagnetic Field Modelling"

Functional model (base function)	Field of Application	Research Group
Spherical splines	Static and time-variable gravity field from satellite data	IGG, Bonn (Eicker, Schall, Kusche)
Spherical radial basis functions	Time-variable gravity field from satellite data	University of Life Sciences Ås, Norway (Bentel, Gerlach)
Spherical radial basis functions	Multi resolution representation of static and time-variable gravity field and combination of all data types	DGFI, Munich (Lieb, Schmidt)
Poisson multipole wavelets	Regional static gravity field refinement by combination of satellite and terrestrial data	IGN / IPGP Paris (Panet)
Spherical radial basis functions	Regional static and time-variable gravity field from satellite data	University Hannover (Naemi)
Spherical radial basis functions	Regional gravity field modelling from satellite data	University Stuttgart (Antoni)
Slepian functions	Spatiospectral localization on the sphere	Princeton University (Harig, Simons)
Global directional wavelets	Sensitivity of satellite formations and geomagnetic data analysis	Danish National Space Institute (Einarsson)
Regional empirical orthonormal functions	Geomagnetic field modeling	GFZ Potsdam (Schachtschneider)
Poisson multipole wavelets	Time variable gravity field from satellite data	University Potsdam (Fuhrmann)
Harmonic splines	Regional geomagnetic field	GFZ Potsdam (Lesur)
Least-squares collocation	Regional static gravity field from combination of all various data sources	Technical University Munich (Pail)
Greens function	Regional time-variable gravity field from satellite data	GFZ Potsdam (Fagioligni, Gruber)
Isoparametric boundary elements	Regional gravity field from satellite data	University Stuttgart (Weigelt)
Point mass modelling	Regional gravity field and geoid models from all available data	BKG Frankfurt (Schäfer)

Joint Study Group 0.4: Coordinate Systems in Numerical Weather Models

Chair: Thomas Hobiger (Japan)

Numerical weather models (NWM's) contain valuable information relevant for removing the environmental signal from geodetic data. Currently no clear documentation exists regarding how to deal with the height systems when carrying out the calculations in a geodetic reference frame. A "conventional" transformation model (available also as source code) would enable geodesists to handle such data easily and allow them to use data from different meteorological datasets. In addition, geodetic products such as GNSS-derived zenith total delays are being assimilated into NWMs. Thus, the transformations that convert the meteorological data into a geodetic reference frame should also support the use of geodetic data in meteorological models. This study group has been set up to 1) deal with the differences between geodetic and meteorological reference systems and 2) provide consistent models for transforming between the two systems.

Vertical transformation

In order to decide on a consistent transformation to/from numerical weather models the study group has started to investigate vertical transformation first, before making a decision on how to deal with horizontal coordinates.

Ellipsoidal heights ↔ geopotential heights

Ellipsoidal heights (h) can be obtained from orthometric heights (H) when the geoid undulation (N) is known.

$$h = H + N \quad (1)$$

Furthermore, orthometric heights relate to geopotential heights (Z) by

$$H = Z\, g_n / g_0 \quad (2)$$

where g_n denotes the conventional gravity constant used throughout the numerical weather model. g_0 is the mean gravity, defined as

$$g_0 = 1/\zeta \int g \, dz \quad (3)$$

where (vertical) integration has to be performed from the geoid surface to height ζ.

Error sources

Although the transformation between numerical weather model heights and geodetic (ellipsoidal) heights can be described in a mathematically unique sense (equations 1-3) the choice of geophysical models, the selection of constants or the definition of the origin can lead to uncertainties of the transformation which can reach several meters. Thus, in the next sections the following effects on ellipsoidal heights are being studied:

- Impact of the gravity model and the way how the mean gravity (g_0) is calculated
- Impact of the vertical direction w.r.t. the ellipsoid instead of the vertical w.r.t. a sphere (as used for numerical weather models)
- Uncertainty of the geoid (undulation)
- Using a different value for the conventional gravity constant.

In order to choose the mean gravity for the height transformation the study group has investigated how and to what extent the choice of the gravity model changes the obtained ellipsoidal height. In doing so, geopotential heights from a numerical weather model (g_n = 9.80665 m/s^2) had to be transformed to ellipsoidal heights (assuming a constant geoid undulation of N = 20 m). Calculations were performed on global 1x1 grids and it was assumed that geodetic latitude/longitude is identical to the one used in the numerical weather models. In total 8 contributions (from GFZ/Germany, GRGS/France, NICT/Japan, UNB/Canada(5 solutions) and VUT/Austria) were submitted. Fitting a linear function over all results, allows to derive a simple estimate for the uncertainty due to the choice of the mean gravity (see figure 0.4).

When the normal to the sphere is used instead of the normal to the ellipsoid, transformed heights are expected to be changed slightly as well. Similar to the study about the mean gravity model, GRGS evaluated data at various heights and grid points and computed the difference between two transformations, one using the normal to the ellipsoid and one using the normal w.r.t. a mean sphere.

Geoid undulations N need to be obtained from regional or global geoid models and applied to all grid points of the numerical weather model before obtaining ellipsoidal heights from orthometric heights (Equation 1). Thus, any error/uncertainty of these models directly propagates into the obtained ellipsoidal heights. Although regional geoid solutions can provide mm-accuracy such models don't cover the whole area of the numerical weather model. Thus, an error of 1 cm is taken as a (conservative) value for the uncertainty of geoid undulations on a global scale.

In case the gravity constant is inaccurate and not properly considered for the transformation, an additional error source for obtaining ellipsoidal heights results. However, most of the NWMs rely upon a value of g_n = 9.80665 m/s^2 or explicitly document the usage of another value. Thus, the impact from this error source can be assumed to be zero.

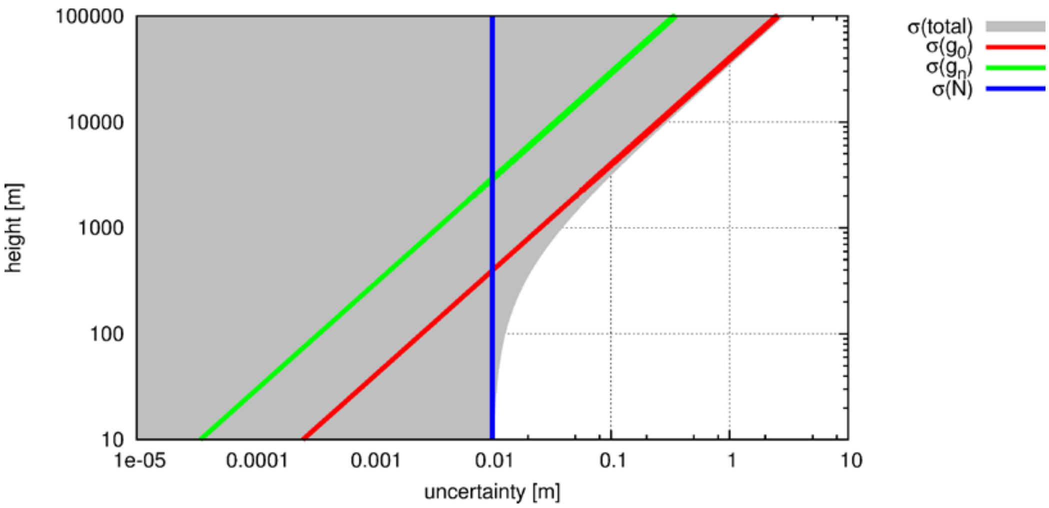

Figure 0.4: Uncertainties of □(g_0), □(g_n), □(N) and the total error budget of the height transformation.

As shown in figure 0.4, the uncertainty of the geoid model, resulting mostly from the geoid undulation (N) dominates the overall error budget in the lower height domains, i.e. <500 m. Above that height, the choice of the gravity model and the way in which the mean gravity acceleration is computed becomes more important, and this error source starts to reduce the accuracy of the transformation. Thus, for a consistent and conventional height transformation between geopotential heights from a numerical weather model and ellipsoidal heights it is important that

- geoid undulations are known with mm-accuracy on a global scale
- the gravity model provides both geoid undulations and gravity acceleration at a given location
- the proper direction of the normal w.r.t. the reference figure is properly considered for the highest accuracy.

Fortunately, most of the atmospheric parameters relevant for geodesy (mainly pressure) decrease exponentially with height, which reduces the impact of an imperfect height transformation when performing an integration/summation in vertical direction.

Next steps and horizontal transformation

The study group has agreed that a conventional vertical transformation should be made available for users online and should be provided in three programming languages (FORTRAN, C/C++ and Matlab). Depending on the accuracy requirement and computational efforts, three different versions of the transformation will be provided.

1. A "conventional algorithm" based on EGM96 which transforms between the two systems. The model is expected to provide both, mean gravity as well as geoid undulations, and should be available in Fortran, Matlab and C/C++.
2. A "reduced algorithm" similar to (1) which uses a sub-set of the spherical harmonic coefficients. Source codes should be available in Fortran, Matlab and C/C++ and aims at high performance for reduced accuracy applications.
3. A "simple algorithm" which is also available in Fortran, Matlab and C/C++. This algorithm will use an (semi-) analytical expression for the gravity calculations and requires the user to input geoid undulations manually.

Routines should be made available around summer after the output from different programming languages has been checked for consistency, especially for model (1),which deals with high degree/order spherical harmonics.

Based on various discussions it appears that horizontal coordinates in numerical weather models are equivalent to geodetic (WGS84 based) latitude/longitude pairs. Meteorologists deal with geodetic coordinates directly, i.e. they apply them on the sphere without any transformation. Although this method is straightforward for operational use, it might lead to some inconsistencies since the total volume of the atmosphere is changed. Thus, the study group will draft and circulate a document that lists questions concerning horizontal coordinates, which need to be addressed to weather agencies. A draft version will be provided during the summer months with the goal to have a complete list of important questions for weather agencies before September 2013.

Joint Study Group 0.5: Multi-Sensor Combination for the Separation of Integral Geodetic Signals

Chair: Florian Seitz (Germany)

Introduction and Objectives

This document presents a status report of the work undertaken in the framework of the ICCT Joint Study Group JSG0.5 since its creation in 2011. Activities of the study group are focussed on the analysis and interpretation of observations from modern space-borne methods of Earth observation. A large part of the parameters derived from space geodetic observation techniques are integral quantities of the Earth system. Among the most prominent ones are parameters related to Earth rotation and the gravity field, whose variations reflect the superposed effect of a multitude of dynamical processes and interactions in various subsystems of the Earth. The integral geodetic quantities provide fundamental and unique information on different balances in the Earth system, in particular on the balances of mass and angular momentum that are directly related to (variations of) the gravity field and Earth rotation.

In respective balance equations, the geodetic parameters reflect the integrative effect of all mass- and angular momentum-related processes in the Earth system. For studies of suchlike processes, Geodesy provides important input in the form of highly accurate parameter time series covering many decades. Variations of Earth rotation have even been determined for more than one and a half century using continuously improved astrometric and space geodetic observation techniques. Thus geodesy provides an excellent data base for the analysis of long term changes in the Earth system and contributes fundamentally to an improved understanding of large-scale processes.

However, in general the integral parameter time series cannot be separated into contributions of specific processes without further information. Their separation and therewith their geophysical interpretation requires complementary data from observation techniques that are unequally sensitive for individual effects and/or from numerical models. Activities of the study group are focussed on the development of strategies for the separation of the integral geodetic signals on the basis of modern space-based Earth observation systems. A multitude of simultaneously operating satellite systems with different objectives is available today. They offer a broad spectrum of information on global and regional-scale processes at different temporal resolutions. Ongoing research within the study group deals with the question in which way the combination of heterogeneous data sets allows for the quantification of individual contributors to the balances of mass and angular momentum. The activities are coordinated between the participating scientists and conducted in interdisciplinary collaboration. The study group is primarily affiliated with the IAG commissions 2 (Gravity field) and 3 (Earth rotation and geodynamics).

Report of Activities of the Study Group

Publications of SG Members

Singh, A., Seitz, F., Schwatke, C.: **Application of multi-sensor satellite data to observe water storage variations.** J. Selected Topics in Applied Earth Obs. and Remote Sens., 99, 1–7, 2013.

Abelen, S., Seitz, F.: Relating satellite gravimetry data to global soil moisture products via data harmonization and correlation analysis. Remote Sensing of Environ., 136, 89-98, 2013.

Schnitzer, S., Seitz, F., Eicker, A., Güntner, A., Wattenbach, W., Menzel, A.: Estimation of soil loss by water erosion in the Chinese Loess Plateau using Universal Soil Loss Equation and GRACE. Geophysical J. International, 193, Nr. 3, 1283-1290, 2013.

Seitz, F., Hedman, K., Meyer, F., Lee, H.: Multi-sensor space observation of heavy flood and drought conditions in the Amazon region. In: Rizos, C., Willis, P. (eds.) Earth on the Edge: Science for a Sustainable Planet, IAG Symposia, Vol. 139, 2013.

Singh, A., Seitz, F.: Water Storage Variations in the Aral Sea from Multi-sensor Satellite Data in comparison with Results from GRACE gravimetry. IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 3042-3045, 2012.

Schmeer, M., Schmidt, M., Bosch, W., Seitz, F.: Separation of mass signals within GRACE monthly gravity field models by means of empirical orthogonal functions. J Geodynamics, 59, 124-132, 2012.

Seitz, F., Kirschner, S., Neubersch, D.: Determination of the Earth's Pole Tide Love Number k2 from Observations of Polar Motion Using an Adaptive Kalman Filter Approach. J. Geophysical Research, Vol. 117, Nr. B09, EID B09403, 2012.

Singh, A., Seitz, F., Schwatke, C.: Inter-annual water storage changes in the Aral Sea from multi-mission satellite altimetry, optical remote sensing, and GRACE satellite gravimetry. Remote Sensing of Environ., 123, 187-195, 2012.

Seitz, F., Thomas, M.: Simulation, prediction and analysis of Earth rotation parameters with a dynamic Earth system model. in: Schuh, H., et al. (eds.) Proc. "Journées 2011 Systèmes de Référence Spatio-temporels", 109-112, TU Wien, 2012.

Abelen, S., Seitz, F., Schmidt, M., Güntner, A.: Analysis of regional variations in soil moisture by means of remote sensing, satellite gravimetry and hydrological modelling. In: Hafeez, M., et al. (eds.) GRACE, Remote Sensing and Ground-based Methods in Multi-Scale Hydrology, IAHS Red Book Series, Nr. 343, 9-15, 2011.

Conference Contributions of SG Members

Seitz, F., Hedman, K., Spiridonova, S.: Intersection of SAR imagery with medium resolution DEM for the estimation of regional water storage changes. German Geodetic Week, Hannover, 10.10.2012.

Seitz, F., Kirschner, S.: Application of Earth rotation parameters in Earth system science. IAU XXVIII GA, Beijing, 30.08.2012.

Seitz, F.: Understanding Earth Rotation: Physical Foundations and Interpretation. International Summer School on Space Geodesy and Earth System, Shanghai, 23.08.2012.

Singh, A., Seitz, F.: Water storage variations in the Aral Sea from multi-sensor satellite data in comparison with results from GRACE gravimetry. IGARSS, Munich, 25.07.2012.

Singh, A., Seitz, F., Schwatke, C.: Observations of Water Storage Variations in the Aral Sea from Multi-sensor Satellite data. 2nd IAHR Europe Congress, Munich, 28.06.2012.

Abelen, S., Seitz, F., Güntner, A.: Global comparison of soil moisture variations as derived from remote sensing, satellite gravimetry, and hydrological modeling. EGU, Vienna, 25.04.2012.

Seitz, F., Kirschner, S.: Simulation, prediction and analysis of polar motion with a dynamic Earth system model. EGU, Vienna, 23.04.2012.

Seitz, F., Abelen, S., Singh, A., Schnitzer, S.: Compartmental water storage changes from multi-sensor data and their signatures in GRACE observations. SPP 1257 Workshop on GRACE-Hydrology, Bonn, 13.02.2012.

Singh, A., Seitz, F., Schwatke, C.: Inter-annual water storage changes in the Aral Sea from multi-mission satellite altimetry, remote sensing and GRACE satellite gravimetry. German Geodetic Week 2011, Nuremberg, 28.09.2011.

Rinner, C., Seitz, F., Abelen, S.: Comparison of soil moisture products of the sensors AMSR-E and MIRAS. German Geodetic Week 2011, Nuremberg, 28.09.2011.

Seitz, F.: Simulation, prediction and analysis of Earth rotation parameters with a dynamic Earth system model. Journées "Systèmes de référence spatio-temporels", Vienna, 20.09.2011.

Abelen, S., Seitz, F., Güntner, A., Schmidt, M.: Analysis of regional variations in soil moisture by means of remote sensing, satellite gravimetry and hydrological modeling. IUGG XXV GA, Melbourne, 05.07.2011.

Seitz, F., Schmidt, M., Shum, C.K., Hedman, K., Lee, H., Meyer, F.: Multi-sensor space and in-situ monitoring of extreme hydrological conditions in the Amazon region. IUGG XXV GA, Melbourne, 03.07.2011.

Abelen, S., Seitz, F., Güntner, A., Schmidt, M.: Signals of soil moisture variations in remote sensing and gravity field observations. IUGG XXV GA, Melbourne, 02.07.2011.

Study group web page

The webpage of the group is http://icct.kma.zcu.cz/index.php/IC_SG5

Conference Sessions

EGU General Assembly, Vienna, 23 April 2012:

Session G5.1: Observing and understanding Earth rotation variability and its geophysical excitation (Convenor: F. Seitz): 6 oral presentations, 18 posters.

IAU General Assembly, Beijing, 29-39 August 2012:

Science Meeting of IAU Commission 19 – Rotation of the Earth (Convenor: F. Seitz)**:** 10 oral presentations.

German Geodetic Week, Hannover, 11 October 2012:

Session 5: GGOS – Global Geodetic Observing System (Co-Convenor: F. Seitz): 5 oral presentations.

EGU General Assembly, Vienna, 4 April 2013:

Session G3.3: Observing and understanding Earth rotation variability and its geophysical excitation (Convenor: F. Seitz): 6 oral presentations, 14 posters.

German Geodetic Week, Essen, 8-10 October 2013:

Session 5: GGOS – Global Geodetic Observing System (Co-Convenor: F. Seitz)

Joint third party funded projects

The activities of the JSG also include the proposal of joint third-party funded projects in the thematic field of the JSG in order to raise funds for the employment of PhD students. In the context of the study group a common project with three positions for PhD students is ongoing in the frame of the International Graduate School of Science and Engineering (IGSSE) of the Technische Universität München (TUM). The project CLIVAR-Hydro (*Signals of Climate Variability in Continental Hydrology from Multi-Sensor Space and In-situ Observations and Hydro-logical Modeling*) has been initiated in 2010. A follow-up proposal for two additional PhD positions has been developed in collaboration between members of JSG0.5 and has been submitted in 2013.

Scientists perform mutual research visits at the institutions involved, where they work together for several months in the frame of the common project. The exchange of personnel between the institutions is financed through project funds. From March until November 2013 a PhD student of the Universidad de Conceptión has been working at DGFI and the TUM. From November until December 2013 a PhD student from the TUM will join the group in Chile. This mobility significantly contributes to fostering the collaboration within JSG0.5.

Joint Study Group 0.6: Applicability of Current GRACE Solution Strategies to the Next Generation of Inter-Satellite Range Observations

Chairs: Matthias Weigelt (Germany), Adrian Jäggi (Switzerland)

The main objective of this study group is the preparation and testing of existing solution strategies for their applicability to the upcoming GRACE-Follow On and future satellite missions. These missions will be equipped with improved instruments such as the laser interferometer (LRI). Existing solution strategies however make often use of linearization and/or depend on augmentation with other observed quantities, e.g. GPS. With the improved accuracy provided by the new instruments it needs to be tested if the existing solution strategies are still suitable. For example, despite the improvements in the inter-satellite observation, an improvement in the GPS-observations with the same order of magnitude may not be expected. Recognizing the need for these investigations, the proposal listed several objectives, among them identification of approximations and linearizations, the identification of limitations and the need for more accurate observations and the impact of errors in the tidal and non-tidal gravitational forces. In order to achieve these targets, first dedicated simulated observations and error information needed to be created.

Simulation of observations:

The first step to allow for addressing the above mentioned important targets is the creation of simulated data sets which are applicable to theoretical questions but offer also a great deal of realism at the same time. Both are often contradicting aims as the increase of realism may obscure the impact of e.g. linearization errors. Therefore, the group opted for two data sets: one based on orbit integration with only a static gravity field and one with high degree of realism including various time variable signals.

For the first one, members of the group suggested to make use of the heritage of earlier investigations. The decision was made to use the SC7 data set which has been developed by a team led by the University of Bonn in 2003. This data set is based on an orbit integration of the gravity field EGM96 to degree and order 300 and provides noise-free data for 30 days with a 5 second sampling. The data set includes position and velocity for both satellites. Inter-satellite quantities need to be derived separately by the user.

The second data set was prepared by colleagues at the German Research Centre for Geoscience in Potsdam and is based on orbit integration of the static gravity field EIGEN-GL04C up to degree and order 90 but includes also astronomic and ocean tides, geophysical effects inducing a time variable gravity signal or non-gravitational forces. Details are listed in table 1.

Table 1: Models included in the preparation of the simulated data set with a high degree of realism

Source	Implementation
Static gravity field	EIGEN-GL04C up to 90x90
Planetary Ephemerides	JPL DE405 - only Sun and Moon
Ocean tides	EOT08a up to 50x50; only 8 waves: Q1, O1, P1, K1, N2, M2, S2, K2
Time variable gravity field	AOHIS ESA model up to 90x90
Non-gravitational accelerations	atmospheric drag, solar radiation pressure, Earth albedo and infra-red radiation (also provided separately)

The data set is again prepared for 30 days and with a five second sampling. Satellite-specific as well as inter-satellite quantities are provided including attitude information for both satellites. Currently, the data set is limited to one month only in order to minimize the amount of storage needed for the data but additional data sets may be prepared in the future in order to allow for investigations related to the time variable gravity field.

Simulation of noise

The second important step is the preparation of realistic noise time series for the various simulated sensors, e.g. the inter-satellite K-Band and LRI observations. These noise time series are therefore only prepared for the second data set at the moment. Currently, two types of noise data sets are under development. The first one has been prepared in the framework of the “BMBF-Geotechnologien” program "Zukunftskonzepte für Schwerefeldmissionen” and is kindly made available to members of this study group. This data set is currently reformatted to allow for easy usage.

The second data set is prepared based on noise PSDs provided by Frank Flechtner from the German Research Centre for Geoscience. The PSDs are converted to noise time series by estimating filter coefficients and filtering white noise sequences. The resulting time series resemble noise time series with the same properties as the provided PSDs.

Both data sets will be released shortly to the group members.

Derivation of a variant of the differential gravimetry approach

Additionally to the high effort to prepare the simulated data sets, first theoretical investigations also took place. The focus has been primarily on the differential gravimetry approach being one that needs augmentation with GPS-observations. The poorer accuracy of this type of observations prevents normally the full exploitation of the K-Band information. The standard approach circumvents this by reducing the observations to residual quantities using a priori information and estimating for corrections to the a priori gravity field. This approach demands a high computational effort and appears to be of limited use in the application to the more precise LRI observations. Therefore, alternatives have been investigated and one possibility was to replace the GPS-observations by observations of the rotation rate made by the star cameras. For this, the differential gravimetry approach needed to be reformulated in terms of rotational quantities. This has been successfully achieved and the new formulation allows for considerable insight into the nature of the satellite observation system. For example, an analytical explanation for the poor East-West observability of GRACE is at hand now. Also investigations are ongoing if the provided accuracy of the star cameras is sufficient. Both results will be presented at the VIII Hotine-Marussi symposium in Rome.

Organisational and other achievements

Besides the technical progress also other activities have been successfully accomplished. The members of the group assigned themselves to various workgroups allowing for a structured approach to the various objectives of the study group. The exchange of information and knowledge has been fostered, e.g. a literature list with the most important and relevant publications for the investigated approaches has been compiled and made available to the members of the group. Group members are updated about the developments within the group by means of the internal newsletter “JSG0.6 Circular”.

Future plans

The release of the aforementioned noise time series will be a major milestone for the activities of the group. The next steps will include a benchmark comparison which will allow identifying strength and weaknesses of the various approaches in a dedicated but common environment. One major point of concern for example is the numerical accuracy of the integration in the various approaches based on variational equations. The accumulation of errors may prevent the full exploitation of the LRI-observation.

Another important point for which activities has been triggered is the impact of the accelerometer data. This type of data often needs the co-estimation of instrument specific parameters which correlate with the gravity field and orbit parameters. The impact is still unclear but will be investigated in the upcoming activities.

At the same time, attention is paid to the impact of background models, e.g. the ocean tide models. Deficient ocean tide models yield aliasing of high frequency signal to the gravity field. The phenomenon has been observed but the underlying mechanism is still not well understood mostly due to the complex interaction of the sampling along the orbit with the spatial and temporal coverage of the Earth.

Last but not least, the interlink to the study group JSG0.3 will be fostered. Having a full set of (global) simulated data set available will allow the members of this study group to test their modelling tools with realistic GRACE-type of observations.

Joint Study Group 0.7: Computational Methodsfor High-Resolution Gravity Field Modelling and Nonlinear Diffusion Filtering

Chairs: Róbert Čunderlik, Karol Mikula (Slovakia)

Recent activities of the JSG-0.7 have been mainly focused on development of new approaches for high-resolution gravity field modelling and nonlinear diffusion filtering using efficient numerical methods, namely the boundary element method (BEM), finite volume method (FVM) and method of fundamental solution (MFS). Some of the achieved results were presented in the GGHS-2012 symposium in Venice (October 2012) and EU-2013 in Wien (April 2013). Recent results will be presented in the VIII Hotine-Marussi Symposium in Roma (June 2013) where our JSG is organizing the session "Computational geodesy". Some of the results have been already published in the journal papers or proceedings from conferences, or are preparing for submitting. Below is a more detail description of our activities.

High-resolution gravity field modelling

Boundary element method

In case of the developed parallel approach by BEM, which considers real topography of the Earth's surface, the problem of oblique derivative has been investigated. There have been proposed and tested algorithms where the oblique derivative is decomposed to normal and tangential components. The numerical experiments have been applied for high-resolution global gravity field modelling as well as for precise local modelling using discrete terrestrial gravimetric measurements, e.g. in Slovakia and New Zealand.

Finite volume method

There have been proposed and developed new approach by FVM for global and local modelling. The parallel implementation using the MPI procedures and large-scale parallel computations on clusters with distributed memory has resulted in the global FVM solutions with the horizontal resolution corresponding to the spherical harmonics (SH) up to degree 2160 (EGM-2008). This approach has been successfully applied for local modelling as well. Nowadays the problem of oblique derivative is incorporating in the proposed numerical schemes.

Method of fundamental solutions

There has been developed new approach by MFS for global gravity field modelling. This approach has been proposed to process the direct GOCE measurements. So far, the developed algorithm is designed to derive the disturbing potential or its derivatives from the observed Tzz components. The numerical experiments have studied how a depth of the fictitious boundary, where the source points are located, influences accuracy of the achieved results. Ideas of the singular boundary method have been applied in case that source points are located directly on the Earth's surface. A parallel implementation of algorithms, iterative elimination of far zones' interactions and large-scale computations have resulted in the GOCE-based global gravity field models. Then they have been used to evaluate the geopotential on the mean sea surface models. It yields the W_0 estimates that are fully independent from ones obtained by SH-based methods.

Nonlinear diffusion filtering

There have been proposed and developed new approaches for linear and nonlinear diffusion filtering on a closed surface like a sphere, ellipsoid or the triangulated approximation of the real Earth's surface. The surface FVM have been used to derive an implicit numerical scheme for the linear diffusion and semi-implicit numerical schemes for the nonlinear diffusion equations on such closed surfaces. Two nonlinear models have been considered. In case of the Perona-Malik model, which is suitable for reducing an additive noise, the developed method has been applied for filtering various data, e.g., the satellite-only mean dynamic topography or the direct GOCE measurements. This model as well as numerical experiments has been recently published in Journal of Geodesy (2013, Vol. 87). Another nonlinear filtering model based on the geodesic mean curvature flow, which is suitable for reducing noise of the type "salt & pepper", has been already proposed and now is in process of development. The first testing numerical experiments have been successfully accomplished.

Joint Study Group 0.8: Earth System Interaction from Space Geodesy

Chair: Shuanggen Jin (China)

Activities

- **18-21 August 2012**, Shuanggen Jin organized International Symposium on Space Geodesy and Earth System (SGES2012) as Chair of Symposium, Shanghai, China.

  The International Symposium on Space Geodesy and Earth System (SGES2012) was held in Shanghai, China, August 18-21, 2012, which was hosted by the Shanghai Astronomical Observatory, Chinese Academy of Sciences. Prof. Shuanggen Jin was the chair of the symposium. About 180 participants from over 15 countries or districts attended the SGES2012. Topics include data retrieval of space geodetic techniques, reference frame, atmospheric-ionospheric sounding and disturbance, gravity field, crustal deformation and earthquake geodesy, GIA, Earth rotation, hydrological cycle, ocean circulation, sea level change, and ice sheet mass balance as well as their coupling in the Earth system. This SGES symposium was sponsored by the International Association of Geodesy (IAG) and Global Geodetic Observing System (GGOS).

  The SGES2012 provided a forum for assessing current technological capabilities and presenting recent results of space geodetic observations and understanding the physical processes and coupling in the Earth system, and future impacts on climate. More information can be found at http://www.shao.ac.cn/meetings
- 2**1-25 August 2012**, Shuanggen Jin organized International Summer School on Space Geodesy and Earth System.

  Over 100 participants attended the International Summer School on Space Geodesy and Earth System, including 4th undergraduates, graduates, post-docs and young scientists. Lectures are Zuheir Altamimi (IGN, France), Richard Gross (JPL, NASA, USA) , Manabu Hashimoto (Kyoto Univ., Japan) , Shuanggen Jin (SHAO, CAS, China), Roland Klees (Delft Uni. Tech., Netherlands), Harald Schuh (Vienna Uni. Tech., Austria), Florian Seitz (Tech. Uni. Munich, Germany) , Shimon Wdowinski (University of Miami, USA), Jens Wickert (GFZ, Potsdam, Germany) and Jeffrey T. Freymueller (Uni. of Alaska, USA). This Summer School introduced the space geodetic techniques and capabilities of measuring the Earth's shape, gravity field and rotation, e.g., GNSS, VLBI, Altimetry, InSAR, Gravimetry, which provided the opportunity to discuss and exchange experiences and ideas for researchers to understand the physical processes and coupling in the Earth system, and future impacts on climate.
- **10-18 November 2011**, Shuanggen Jin was invited to visit and give several talks at Taiwan National Chiao Tung University, National Cheng Kung University, National Central University and Institute of Earth Sciences, Academia Sinica, Taiwan
- **25-31 March 2012**, Shuanggen Jin was invited to give a talk at Universiti Teknologi Malaysia (UTM), Johor, Malaysia and Chaired one Session with one talk at Progress In Electromagnetics Research Symposium (PIERS), Kuala Lumpur, Malaysia.

Publications

Jin, S.G., and G. Feng (2013), Global groundwater cycles and extreme events responses observed by satellite gravimetry, in U. Marti et al. (Eds.), IAG Symposia Book Series: Gravity, Geoid and Height Systems (GGHS2012), Venice, Italy, 9-12 October 2012, Springer Verlag, Heidelberg, Germany

Jin, S.G., T. van Dam, and S. Wdowinski (Eds.) (2013), Earth System Observing and Modelling from Space Geodesy, Special Issue in Journal of Geodynamics, Elsevier, ISSN: 0264-3707

Jin, S.G. (2013), Satellite Gravimetry: Mass Transport and Redistribution in the Earth System, in S.G. Jin (Ed.), Geodetic Sciences: Observations, Modeling and Applications, InTech-Publisher, Rijeka, Croatia, ISBN: 980-953-307-595-7

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Jin, S.G., and G. Feng (2013), Large-scale variations of global groundwater from satellite gravimetry and hydrological models, 2002-2012, Global Planet. Change, 106, 20-30, doi: 10.1016/j.gloplacha.2013.02.008.

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Feng, G., S.G. Jin, and T. Zhang (2013), Coastal sea level changes in the Europe from GPS, Tide Gauge, Satellite Altimetry and GRACE, 1993-2011, Adv. Space Res., 51(6), 1019-1028, doi: 10.1016/j.asr.2012.09.011.

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Zhang, L., S.G. Jin, and T. Zhang (2012), Seasonal variations of Earth's surface loading deformation estimated from GPS and satellite gravimetry, J. Geod. Geodyn., 32(2), 32-38.

Sanchez-Reales, J., M. Vigo, S.G. Jin, and B. Chao (2012), Global surface geostrophic currents of ocean derived from satellite altimetry and GOCE geoid, Mar. Geod., 35(S1), 175-189, doi: 10.1080/01490419.2012.718696.

Jin, S.G., and X. Zhang (2012), Variations and geophysical excitation of Earth's dynamic oblateness estimated from GPS, OBP, and GRACE, Chin. Sci. Bull., 57(36), 3484-3492, doi: 10.1360/972011-1934.

Jin, S.G., Lijun Zhang, and B. Tapley (2011), The understanding of length-of-day variations from satellite gravity and laser ranging measurements, Geophys. J. Int., 184(2), 651-660, doi: 10.1111/j.1365-246X.2010.04869.x.

Verhagen S., D. Gregner-Brzezinska, G. Retscher, M. Santos, X. Ding, Y. Gao, and S.G. Jin (2012), Geodetic sensor systems and sensor networks-Positioning and Applications, in N. Sneeuw et al. (Eds.) IAG Symposia Book Series: VII Hotine-Marussi Symposium on Theoretical Geodesy, Rome, Italy, 6-10 July 2009, Springer Verlag, Heidelberg, Germany, ISBN: 978-3-642-22077-7, 137, pp.47-51, doi: 10.1007/978-3-642-220784_7.