Inter-Commission Committee on Theory (ICCT)

http://icct.kma.zcu.cz

President: **N. Sneeuw** (Germany)
Vice President: **P. Novák** (Czech Republic)

Terms of Reference

The Inter-Commission Committee on Theory (ICCT) was formally approved and established after the IUGG XXI Assembly in Sapporo, 2003, to succeed the former IAG Section IV on General Theory and Methodology and, more importantly, to interact actively and directly with other IAG entities. In accordance with the IAG by-laws, the first two 4-year periods were reviewed in 2011. IAG approved the continuation of ICCT at the IUGG XXIII Assembly in Melbourne, 2011.

Recognizing that observing systems in all branches of geodesy have advanced to such an extent that geodetic measurements (i) are now of unprecedented accuracy and quality, can readily cover a region of any scale up to tens of thousands of kilometres, yield non-conventional data types, and can be provided continuously; and (ii) consequently, demand advanced mathematical modelling in order to obtain the maximum benefit of such technological advance, the ICCT (1) strongly encourages frontier mathematical and physical research, directly motivated by geodetic need and practice, as a contribution to science and engineering in general and the theoretical foundations of geodesy in particular; (2) provides the channel of communication amongst the different IAG entities of commissions/services/projects on the ground of theory and methodology, and directly cooperates with and supports these entities in the topical work; (3) helps the IAG in articulating mathematical and physical challenges of geodesy as a subject of science and in attracting young talents to geodesy. The ICCT should strive to attract and serve as home to mathematically motivated/oriented geodesists and to applied mathematicians; and (4) encourages closer research ties with and gets directly involved in relevant areas of the Earth sciences, bearing in mind that geodesy has always been playing an important role in understanding the physics of the Earth.

Objectives

The overall objectives of the ICCT are
to act as international focus of theoretical geodesy,
to encourage and initiate activities to advance geodetic theory in all branches of geodesy,
to monitor developments in geodetic methodology.

To achieve these objectives, the ICCT interacts and collaborates with the IAG Commissions, GGOS and other IAG related entities (services, projects).

Structure

Joint Study Groups

JSG 0.1: Application of time series analysis in geodesy
(joint with GGOS and all Commissions)
Chair: W. Kosek (Poland)

JSG 0.2: Gravity field modelling in support of height system realization
(joint with Commissions 1, 2 and GGOS)
Chair: P. Novák (Czech Republic)

JSG 0.3: Comparison of current methodologies in regional gravity field modelling
(joint with Commissions 2, 3)
Chairs: M. Schmidt, Ch. Gerlach (Germany)

JSG 0.4: Coordinate systems in numerical weather models
(joint with all Commissions)
Chair: Th. Hobiger (Japan)

JSG 0.5: Multi-sensor combination for the separation of integral geodetic signals
(joint with Commissions 2, 3 and GGOS)
Chair: F. Seitz (Germany)

JSG 0.6: Applicability of current GRACE solution strategies to the next generation of inter-satellite range observations
(joint with Commission 2)
Chairs: M. Weigelt (Germany), A. Jäggi (Switzerland)

JSG 0.7: Computational methods for high-resolution gravity field modelling and nonlinear diffusion filtering
(joint with Commissions 2, 3 and GGOS)
Chairs: R. Čunderlík, K. Mikula (Slovakia)

JSG 0.8: Earth system interaction from space geodesy
(joint with all Commissions)
Chair: S. Jin (China)

JSG 0.9: Future developments of ITRF models and their geophysical interpretation
(joint with Commission 1 and IERS)
Chair: A. Dermanis (Greece)

Program of Activities

The ICCT's program of activities include

participation as (co-)conveners of geodesy sessions at major conferences (IAG, EGU, AGU, …),
organization of a Hotine-Marussi symposium,
initiation of a summer school on theoretical geodesy,
maintaining a website for dissemination of ICCT related information.

Steering Committee

• President	N. Sneeuw	Germany
• Vice-President	P. Novák	Czech Rep.
• Representatives:		
• Commission 1	T. van Dam	Luxembourg
• Commission 2	U. Marti	Switzerland
• Commission 3	R. Gross	USA
• Commission 4	D. Brzezinska	USA
• GGOS	H. Kutterer	Germany

JSG 0.1: Application of Time-Series Analysis in Geodesy

Chair: W. Kosek (Poland)
Affiliation: GGOS, all commissions

Introduction

Observations provided by modern space geodetic techniques (geometric and gravimetric) deliver a global picture of dynamics of the Earth. Such observations are usually represented as time series which describe (1) changes of surface geometry of the Earth due to horizontal and vertical deformations of the land, ocean and cryosphere, (2) fluctuations in the orientation of the Earth divided into precession, nutation, polar motion and spin rate, and (3) variations of the Earth's gravitational field and the centre of mass of the Earth. The vision and goal of GGOS is to understand the dynamic Earth's system by quantifying our planet's changes in space and time and integrate all observations and elements of the Earth's system into one unique physical and mathematical model. To meet the GGOS requirements, all temporal variations of the Earth's dynamics – which represent the total and hence integral effect of mass exchange between all elements of Earth's system including atmosphere, ocean and hydrology – should be properly described by time series methods.

Various time series methods have been applied to analyze such geodetic and related geophysical time series in order to better understand the relation between all elements of the Earth's system. The interactions between different components of the Earth's system are very complex, thus the nature of the considered signals in the geodetic time series is mostly wideband, irregular and non-stationary. Therefore, the application of time frequency analysis methods based on wavelet coefficients – e.g. time-frequency cross-spectra, coherence and semblance – is necessary to reliably detect the features of the temporal or spatial variability of signals included in various geodetic data, and other associated geophysical data.

Geodetic time series may include, for instance, temporal variations of site positions, tropospheric delay, ionospheric total electron content, masses in specific water storage compartments or estimated orbit parameters as well as surface data including gravity field, sea level and ionosphere maps. The main problems to be scrutinized concern the estimation of deterministic (including trend and periodic variations) and stochastic (non-periodic variations and random fluctuations) components of the time series along with the application of the appropriate digital filters for extracting specific components with a chosen frequency bandwidth. The application of semblance filtering enables to compute the common signals, understood in frame of the time-frequency approach, which are embedded in various geodetic/geophysical time series.

Numerous methods of time series analysis may be employed for processing raw data from various geodetic measurements in order to promote the quality level of signal enhancement. The issue of improvement of the edge effects in time series analysis may also be considered. Indeed, they may either affect the reliability of long-range tendency (trends) estimated from data or the real-time processing and prediction.

The development of combination strategies for time- and space-dependent data processing, including multi-mission sensor data, is also very important. Numerous observation techniques, providing data with different spatial and temporal resolutions and scales, can be combined to compute the most reliable geodetic products. It is now known that incorporating space variables in the process of geodetic time series modelling and prediction can lead to a significant improvement of the prediction performance. Usually multi-sensor data comprises a large number of individual effects, e.g. oceanic, atmospheric and hydrological contributions. In Earth system analysis one key point at present and in the future will be the development of separation techniques. In this context principal component analysis and related techniques can be applied.

Objectives

- To study geodetic time series and their geophysical causes in different frequency bands using time series analysis methods, mainly for better understanding of their causes and prediction improvement.
- The evaluation of appropriate covariance matrices corresponding to the time series by applying the law of error propagation, including weighting schemes, regularization, etc.
- Determining statistical significance levels of the results obtained by different time series analysis methods and algorithms applied to geodetic time series.
- The comparison of different time series analysis methods and their recommendation, with a particular emphasis put on solving problems concerning specific geodetic data.
- Developing and implementing the algorithms – aiming to seek and utilize spatio-temporal correlations – for geodetic time series modelling and prediction.
- Better understanding of how large-scale environmental processes, such as for instance oceanic and atmospheric oscillations and climate change, impact modelling strategies employed for numerous geodetic data.
- Developing combination strategies for time- and space-dependent data obtained from different geodetic observations.
- Developing separation techniques for integral measurements in individual contributions.

Program of activities

Updating the webpage, so that the information on time series analysis and its application in geodesy (including relevant multidisciplinary publications and the unification of terminology applied in time series analysis) will be available.
Participating in working meetings at the international symposia and presenting scientific results at the appropriate sessions.
Collaboration with other working groups dealing with geodetic time-series e.g. Cost ES0701 Improved constraints on models of GIA or the Climate Change Working Group.

Members

- W. Kosek (Poland), chair
- R. Abarca del Rio (Chile)
- O. Akyilmaz (Turkey)
- J. Böhm (Austria)
- L. Fernandez (Argentina)
- R. Gross (USA)
- M. Kalarus (Poland)
- M. O. Karslioglu (Turkey)
- H. Neuner (Germany)
- T. Niedzielski (Poland)
- S. Petrov (Russia)
- W. Popinski (Poland)
- M. Schmidt (Germany)
- M. van Camp (Belgium)
- O. de Viron (France)
- J. Vondrák (Czech Republic)
- D. Zheng (China)
- Y. Zhou (China)

JSG 0.2: Gravity Field Modelling in Support of World Height System Realization

Chair: P. Novák (Czech Republic)
Affiliation: Comm. 2, 1 and GGOS

Introduction

Description of the Earth's gravity field still remains a major research topic in geodesy. The main goal is to provide reliable global models covering all spatially-temporal frequencies of its scalar parameterization through the gravity potential. Detailed and accurate gravity field models are required for proper positioning and orientation of geodetic sensors (data geo-referencing). Geometric properties of the gravity field are then studied including those of its equipotential surfaces and their respective surface normals, since they play a fundamental role in definition and realization of geodetic reference systems. Gravity field models will be applied for definition and realization of a vertical reference system (currently under construction) that will support studies of the Earth system.

This study group is an entity of the Inter-Commission Committee on Theory. It is affiliated to Commissions 1 (Reference Frames) and 2 (Gravity Field); its close cooperation with GGOS Theme 1 "Unified Global Height System" is anticipated. It aims at bringing together scientists concerned namely with theoretical aspects in the areas of interest specified below.

Objectives

- Considering different types and large amounts of gravity-related data available today, large variety of gravity field models and the ongoing IAG project of realizing a world height system (WHS), this study group shall focuses on theoretical aspects related to the following (non-exhaustive to WHS) list of problems:
- To study available gravity field models in terms of their available resolution, accuracy and stability for the purpose of WHS realization.
- To define a role of a conventional model of the Earth's gravity field (EGM) to be used for WHS realization including its scale parameters.
- To study 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.
- To study theoretical aspects of various methods proposed for WHS definition and realization including investigations on tidal system effects.
- To investigate combination of heterogeneous gravity field observables by using spatial inversion, spherical radial functions, collocation, wavelets, etc. and by taking into account their sampling geometry, spectral and stochastic properties.
- To investigate methods of gravity field modelling based on combination of global gravitational models, ground and airborne gravity, GNSS/levelling height differences, altimetry data, deflections of the vertical, etc.
- To study stable, accurate and efficient methods for continuation of gravity field parameters including space-borne observables of type GRACE and GOCE.
- To advance theory and methods for solving various initial and boundary value problems (I/BVP) in geodesy.
- To study methods for gravity potential estimation based on its measured directional derivatives (gravity, gravity gradients) by exploiting advantages of simultaneous continuation and inversion of observations.
- To investigate requirements for gravity data (stochastic properties, spatially-temporal sampling, spectral content etc.) in terms of their specific geodetic applications.

Program of activities

Active participation at major geodetic conferences and meetings.
Organizing a session at the Hotine-Marussi Symposium 2013.
Co-operation with affiliated IAG Commissions and GGOS.
Electronic exchange of ideas and thoughts through a SG web page.
Monitoring activities of SG members and external individuals related to SG.
Compiling bibliography in the area of SG interest.

Members

- Pavel Novák (Czech Republic), chair
- Hussein Abd-Elmotaal (Egypt)
- Robert Čunderlík (Slovakia)
- Heiner Denker (Germany)
- Will Featherstone (Australia)
- René Forsberg (Denmark)
- Bernhard Heck (Germany)
- Jianliang Huang (Canada)
- Christopher Jekeli (USA)
- Dan Roman (USA)
- Fernando Sansò (Italy)
- Michael G Sideris (Canada)
- Lars Sjöberg (Sweden)
- Robert Tenzer (New Zealand)
- Yan-Ming Wang (USA)

JSG 0.3: Comparison of Current Methodologies in Regional Gravity Field Modelling

Chairs: M. Schmidt, Ch. Gerlach (Germany)
Affiliation: Comm. 2, 3

Introduction

Traditionally the gravitational potential of the Earth and other celestial bodies is modelled as a series expansion in terms of spherical harmonics. Although this representation is technically possible for ultra-high expansions, it is well-known that spherical harmonic approaches cannot represent data of heterogeneous density and quality in a proper way. In order to overcome these and other deficiencies regional modelling comes into question.

In the last years many groups have developed sophisticated approaches for regional modelling, e.g. the expansion of the gravity field or functionals of the field in terms of spherical (radial) base functions. Analogously to spherical harmonic approaches, also in regional modelling the unknown model parameters, i.e. the coefficients of the series expansion, can be either determined by means of numerical integration or as the solution of a parameter estimation process. Numerical integration techniques are widely used in the mathematical community and provide efficient and stable solutions. However, numerical integration techniques suffer from important disadvantages. Among others these methods (1) require the input data to be given on a spherical integration grid, (2) cannot provide estimated error variances and covariances of the model parameters and (3) have difficulties to handle the combination of data from different measurement techniques. Due to these disadvantages, parameter estimation is the preferred strategy in the geodetic community. Although solutions in regional modelling based on parameter estimation are generated by several groups since many years, a large number of unsolved problems and open questions still remain. They mostly arise from the condition of the normal equation system and are therefore directly connected to the parametrization of the gravity field, the type and distribution of observation data, the choice and location of base functions, possible regularisation schemes, etc.

The aim of the proposed SG is to find guidelines on suitable strategies for setting up the parameter estimation of regional gravity field modelling. This includes appropriate strategies for the combination of satellite, airborne and terrestrial data. The focus of the SG is on the methodological foundation of regional gravity field modelling based on series expansions in terms of localizing base functions. Therefore numerical studies will be concentrated on simulations based on synthetic data. It is not the aim of the SG to process and compare solutions from real data.

Objectives

The main objectives of this SG are:

- to collect information of available methodologies and strategies for regional modelling, including
  - the type of base functions (splines, wavelets, Slepian function, Mascons, etc.),
  - the point grids for placing the functions (standard grid, icosahedra, Reuter grid, etc. on a sphere, ellipsoid, etc.),
  - the choice and establishment of an appropriate adjustment model (combination strategy, variance component estimation, rank deficiency problems, e.g., due to downward continuation, etc.),
  - the consideration of model errors (truncation errors, edge effects, leakage, etc.),
  - the specific field of application,
- 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.
- Comparable work outside gravity field determination, e.g. in the mathematical communities and in geomagnetic field determination will be taken into account.
- To achieve the objectives, the SG interacts and collaborates with other ICCT SGs as well as IAG Commission 2. As a matter of fact the outcomes of the SG can be also used by other IAG commissions, especially in Commission 3.
- The SG's work will be distributed to IAG sister associations through respective members.

Program of Activities

The SG’s program of activities will include
organization of SG meetings and of one or more scientific workshops on regional modelling
participation in respective symposia (EGU, AGU, etc.),
publication of important findings in proper journals,
maintaining a website for general information as well as for internal exchange of data sets and results,
supporting ICCT activities

Members

- Michael Schmidt (Germany), chair
- Christian Gerlach (Germany); chair
- Katrin Bentel (Norway)
- Annette Eicker (Germany)
- Indridi Einarsson (Denmark)
- Junyi Guo (USA)
- Majid Naeimi (Germany)
- Isabelle Panet (France)
- Judith Schall (Germany)
- Uwe Schäfer (Germany)
- Frederick Simons (USA)
- C.K. Shum (USA)
- Matthias Weigelt (Germany)
- Gongyou Wu (China)

JSG 0.4: Coordinate Systems in Numerical Weather Models

Chair: T. Hobiger (Japan)
Affiliation: all Commissions

Introduction

Numerical weather models (NWMs) contain valuable information that is relevant for a variety of geodetic models. Currently no clear description exists regarding how to deal with the NWM coordinate systems when carrying out the calculations in a geodetic reference frame. The problem can be split into two questions: First, how to relate the horizontal NWM coordinates, which are in most cases geocentric coordinates, derived initially from either Cartesian or spectral representations, properly into an ellipsoidal/geodetic frame? Second, how to transform the NWM height system into elliptical heights as used within geodesy? Although some work has been already done to answer these questions, still no procedures, guidelines or standards have been defined in order to consistently transform the meteorological information into a geodetic reference frame.

The study group will categorize the NWM coordinate systems, create mathematical models for transformation and summarize these findings in a peer-reviewed paper that will act as guidelines for those who intend to utilize NWM information. In addition, it will be necessary to define such transformations in both ways, in order to enable the assimilation of geodetic measurements into meteorological models as well. Moreover, the study group will deal with the issue of surface data contained in NWM and how this information can be consistently used.

Objectives

- Understand the horizontal coordinate systems of the different NWMs, ranging from global to small-scale regional models
- Understand the vertical coordinate systems of the different NWMs, ranging from global to small-scale regional models
- Formulate a clear mathematical description on how to transform between NWMs and a geodetic frame (in both directions)
- Summarize these findings in a peer-reviewed paper that will act as a standard for future use of NWM-produced fields.

Program of activities

Launch a web-page for dissemination of information, presentation, communication, outreach purposes; provide a bibliography
Conduct working meetings in association with international conferences; present research results in appropriate sessions
Organize workshops dedicated mainly to problem identification and to motivation of relevant scientific research
Produce at least one peer-reviewed paper that presents a clear and consistent description of how to transform information from and to NWMs, and the relevance of different NWM structures, and, if possible, a second paper that deals with the uncertainty of the NWM related coordinate information will be considered.

Members

- Thomas Hobiger (Japan), chair
- Johannes Boehm (Austria)
- Tonie van Dam (Luxembourg)
- Pascal Gegout (France)
- Rüdiger Haas (Sweden)
- Ryuichi Ichikawa (Japan)
- Arthur Niell (USA)
- Felipe Nievinski (USA)
- David Salstein (USA)
- Marcelo Santos (Canada)
- Michael Schindelegger (Austria)
- Henrik Vedel (Denmark)
- Jens Wickert (Germany)
- Florian Zus (Germany)

JSG 0.5: Multi-Sensor Combination for the Separation of Integral Geodetic Signals

Chair: F. Seitz (Germany)
Affiliation: Comm. 2, 3 and GGOS

Introduction

A large part of the geodetic 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. Variations of those parameters 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 for different balances in the Earth system, in particular for 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 describe the integral effect of exchange processes of mass and angular momentum in the Earth system. In contrast to many other disciplines of geosciences, geodesy is characterized by a very long observation history. Partly, the previously mentioned parameters have been determined over many decades with continuously improved space 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. Within the study group it shall be investigated 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 research activities shall be coordinated between the participating scientists and shall be conducted in interdisciplinary collaboration. At all times the group is open for new contacts and members in order to embed the activities in a wide context. The study group is primarily affiliated with the IAG commissions 2 (Gravity field) and 3 (Earth rotation and geodynamics).

Objectives

The primary objective of the study group is the development of strategies for multi-sensor combinations with the aim of separating time series of integral geodetic parameters related to Earth rotation and gravity field. The separation of the parameter time series into contributions of individual underlying effects fosters the understanding of dynamical processes and interactions in the Earth system. This is of particular interest in the view of global change.

Individual contributions from various subsystems of the Earth shall be quantified and balanced. In particular our investigations focus on the separation of the Earth rotation parameters (polar motion and variations of length-of-day) into contributions of atmospheric and hydrospheric angular momentum variations, and on the separation of GRACE gravity field observations over continents into the contributions of individual hydrological storage compartments, such as groundwater, surface water, soil moisture and snow.

Investigations in the frame of the study group will exploit the synergies of various observation systems (satellite altimetry, optical and radar remote sensing, SMOS, and others) for the separation of the signals and combine their output with numerical models. Among the most important steps are compilation and assessment of background information for individual observation systems and sensors (mode of operation, sensitivity, accuracy, deficiencies) as well as theoretical studies which (new) information on the Earth system can be gained from a combination of different observation methods.

In particular the research comprises the following topics:

- potential und usability of contemporary space-borne and terrestrial sensors for an improved understanding of processes within atmosphere and hydrosphere.
- analysis of accuracy, temporal and spatial resolution and coverage of different data sets
- theoretical and numerical studies on the combination of heterogeneous observation types. This comprehends investigations on appropriate methods for parameter estimation including error propagation, the analysis of linear dependencies between parameters and the solution of rank deficiency problems.
- mathematical methods for the enhancement of the information content (e.g. filters)
- quantification of variations of mass and angular momentum in different subsystems from multi-sensor analysis
- analysis of the consistencies of balances between individual effects and integral geodetic parameters on different spatial scales

- formulation of recommendations for future research and (if possible) for future satellite missions on the basis of balance inconsistencies

Planned Activities

- Set-up of a SG webpage for dissemination of information (activities and a bibliographic list of references) and for presentation and communication of research results.
- Organization of conference sessions / workshops:
  - planned in 2013: Conference Session in the Hotine Marussi Symposium
  - planned in 2014: 2nd workshop on the Quality of Geodetic Observing and Monitoring Systems (QuGOMS' 14)
- Common publications of SG members
- Common fund raising activities (e.g. for PhD positions)

Principal Scientific Outcome / Results

By the end of the 4-year period 2011-2015 the following outcome shall be achieved:
Mature experience in geodetic multi-sensor data combination including data availability, formats, combination strategies and accuracy aspects
Numerical results for separated hydrological contributions to integral mass variations observed by GRACE for selected study areas.
Numerical results for separated atmospheric/hydrospheric contributions Earth rotation parameters on seasonal to inter-annual time scales
Initiation of at least one common funded project with positions for PhD students working in the topical field of the study group

Members

- Florian Seitz (Germany), chair
- Sarah Abelen (Germany)
- Rodrigo Abarca del Rio (Chile)
- Andreas Güntner (Germany)
- Karin Hedman (Germany)
- Franz Meyer (USA)
- Michael Schmidt (Germany)
- Manuela Seitz (Germany)
- Alka Singh (India)

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

Chairs: M. Weigelt (Germany)
A. Jäggi (Switzerland)
Affiliation: Comm. 2

Problem statement

The GRACE-mission (Tapley et al., 2004b) proved to be one of the most important satellite missions in recent times as it enabled the recovery of the static gravity field with unprecedented accuracy and, for the first time, the determination of temporal variations on a monthly (and shorter) basis. The key instrument is the K-band ranging system which continuously measures the changes of the distance between the two GRACE satellites with an accuracy of a few micrometer. Thanks to the success of this mission, proposals have been made for the development of a GRACE-follow-on mission and a next-generation GRACE satellite system, respectively. Apart from options for a multi-satellite mission, the major improvement will be the replacement of the microwave based K-band ranging system by laser interferometry (Bender et al., 2003). The expected improvement in the accuracy is in the range of a factor 10 to 1000.

Two types of solution strategies exist for the determination of gravity field quantities from kinematic observations (range, range-rate and range-acceleration). The first type is based on numerical integration. The most common ones are the classical integration of the variational equations (Reigber, 1989; Tapley et al., 2004a), the Celestial Mechanics Approach (Beutler et al., 2010) or the short-arc method (Mayer-Gürr, 2006). The second type of solution strategies tries to make use of in-situ (pseudo)-observations. The most typical ones are the energy balance approach (Jekeli, 1998; Han, 2003), the relative acceleration approach (Liu, 2008) or the line-of-sight gradiometry approach (Keller and Sharifi, 2005).

From a theoretical point of view all approaches are in one way or the other based on Newton's equation of motion and thus all of them should be applicable to the next generation of satellite missions as well. Practically, problems arise due to the necessity of approximations and linearizations, the accumulation of errors, the combination of highly-precise with less precise quantities, e.g. K-band with GPS, and the incorporation of auxiliary measurements, e.g. accelerometer data. These problems are often circumvented by introducing reference orbits, reducing the solution strategies to residual quantities, and by frequently solving for initial conditions and/or additional empirical or stochastic parameter. In the context of the next generation of low-low satellite-to-satellite tracking systems, the question is whether these methods are still sufficient to fully exploit the potential of the improved range observations.

Objectives

Observations are related to gravity field quantities by means of geometry, kinematics and dynamics. The gravity field is then represented by global or local base functions. The focus of this study group is primarily on the use of spherical harmonics as base function with different approaches to relate the observations to the gravity field. However, since local methods also proofed to yield high-quality solutions, this group will be affiliated with the proposed study group on the "Methodology of Regional Gravity Field Modelling" by M. Schmidt and Ch. Gerlach in order to investigate the interplay with regional modelling. The usage of other global base functions is also welcome.

The objectives of the study group are therefore to:

- investigate each solution strategy, identify approximations and linearizations and test them for their permissibility to the next generation of inter-satellite range observations,
- identify limitations or the necessity for additional and/or more accurate measurements,
- quantify the sensitivity to error sources, e.g. in tidal or non-gravitational force modelling,
- investigate the interaction with global and local modelling,
- extend the applicability to planetary satellite mission, e.g. GRAIL,
- establish a platform for the discussion and in-depth understanding of each approach and provide documentation.

It will not be the objective of this study group to identify the “best” approach as from a theoretical point of view all approaches are able to yield a solution as long as the necessary observations with sufficient accuracy have been made and approximations and linearization errors remain below the proposed accuracy of the new range observation. Further, solutions need validation which is done best with different and independent solution strategies in order to identify possible systematic effects.

Methodology and Output

The investigation will be based on an in-depth analysis of the theoretical foundations of each approach in combination with a simulation study with step-wise increasing realism. The preparation of the simulated data set and each approach will be assigned separate work packages with subtasks, which include the above mentioned objectives. Each member is supposed to assign himself to at least one work package and contribute by adding to the discussion of the principles of each approach, supplying simulated data sets, carry out numerical investigations or develop solutions to specific problems.

The primary output is the result of the collaborative investigation of the different approaches aiming at the identification of possible challenges and the development of solutions ensuring their applicability to the next generation of inter-satellite range observations. These findings are supposed to be well documented in journal paper, possibly in a special issue of Journal of Geodesy or similar by the end of 2014. A workshop is envisaged in the vicinity of the Hotine-Marussi symposium in 2013.

Members

- Matthias Weigelt (Germany), chair
- Adrian Jäggi (Switzerland), chair
- Markus Antoni (Germany)
- Oliver Baur (Austria)
- Richard Biancale (France)
- Sean Bruinsma (France)
- Christoph Dahle (Germany)
- Christian Gerlach (Germany)
- Thomas Gruber (Germany)
- Shin-Chan Han (USA)
- Hassan Hashemi Farahani (The Netherlands)
- Wolfgang Keller (Germany)
- Jean-Michel Lemoine (France)
- Anno Löcher (Germany)
- Torsten Mayer-Gürr (Austria)
- Philip Moore (UK)
- Himanshu Save (USA)
- Mohammad Sharifi (Iran)
- Natthachet Tangdamrongsub (Taiwan)
- Pieter Visser (The Netherlands)

Corresponding members

- Christian Gruber (Germany)
- Majid Naeimi (Germany)
- Jean-Claude Raimondo (Germany)
- Michael Schmidt (Germany)

JSG 0.7: Computational Methods for High-Resolution Gravity Field Modelling and Nonlinear Diffusion Filtering

Chairs: R. Čunderlík, K. Mikula (Slovakia)
Affiliation: Comm. 2, 3 and GGOS

Introduction

Efficient numerical methods and HPC (High Performance Computing) facilities provide new opportunities in many applications in geodesy. The goal of the IC SG is to apply numerical methods like the finite element method (FEM), finite volume method (FVM), boundary element method (BEM) and others mostly for gravity field modelling and non-linear filtering of data on the Earth's surface. An advantage is that such numerical methods use finite elements as basic functions with local supports. Therefore a refinement of the discretization is very straightforward allowing adaptive refinement procedures as well.

In case of gravity field modelling, a parallelization of algorithms using the standard MPI (Message Passing Interface) procedures and computations on clusters with distributed memory allows to achieve global or local gravity field models of very high-resolution, where a level of the discretization practically depends on capacity of available HPC facilities. The aforementioned numerical methods allow a detailed discretization of the real Earth's surface considering its topography. To get precise numerical solution to the geodetic boundary-value problems (BVPs) on such complicated surface it is also necessary handle problems like the oblique derivative.

Data filtering occurs in many applications of geosciences. A quality of filtering is essential for correct interpretations of obtained results. In geodesy we usually use methods based on the Gaussian filtering that corresponds to a linear diffusion. Such filtering has a uniform smoothing effect, which also blurs "edges" representing important structures in the filtered data. In contrary, a nonlinear diffusion allows adaptive smoothing that can preserve main structures in data, while a noise is effectively reduced. In image processing there are known at least two basic nonlinear diffusion models; (i) the regularized Perona-Malik model, where the diffusion coefficient depends on an edge detector, and (ii) the geodesic mean curvature flow model based on a geometrical diffusion of level-sets of the image intensity.

The aim of the SG is to investigate and develop nonlinear filtering methods that would be useful for a variety of geodetic data, e.g., from satellite missions, satellite altimetry and others. A choice of an appropriate numerical technique is open to members of the SG. An example of the proposed approach is based on a numerical solution of partial differential equations using a surface finite volume method. It leads to a semi-implicit numerical scheme of the nonlinear diffusion equation on a closed surface.

Objectives

- to develop numerical models for solving the geodetic BVPs using numerical methods like FEM, FVM, BEM and others,
- to investigate the problem of oblique derivative,
- to implement parallelization of numerical algorithms using the standard MPI procedures,
- to perform large-scale parallel computations on clusters with distributed memory,
- to investigate methods for nonlinear filtering of data on closed surfaces using the regularized Perona-Malik model or mean curvature flow model,
- to derive fully-implicit and semi-implicit numerical schemes for the linear and nonlinear diffusion equation on closed surfaces using the surface FVM,
- to develop algorithms for the nonlinear filtering of data on the Earth's surface,
- to summarize the developed methods and achieved numerical results in journal papers.

Program of activities

active participation in major geodetic conferences,
working meetings at international symposia,
organization of a conference session.

Membership

- Róbert Čunderlík (Slovakia), chair
- Karol Mikula (Slovakia), chair
- Ahmed Abdalla, New Zealand
- Michal Beneš (Czech Republic)
- Zuzana Fašková (Slovakia)
- Marek Macák (Slovakia)
- Otakar Nesvadba (Czech Republic)
- Róbert Špir (Slovakia)
- Róbert Tenzer (New Zealand)

JSG 0.8: Earth System Interaction from Space Geodesy

Chair: S. Jin (China)
Affiliation: Comm. 2, 3 and 4

Introduction

The gravity field and geodetic mass loading reflect mass redistribution and transport in the Earth's fluid envelope, and in particular interactions between atmosphere, hydrosphere, cryosphere, land surface and the solid Earth due to climate change and tectonics activities, e.g., dynamic and kinematic processes and co-/post-seismic deformation. However, the traditional ground techniques are very difficult to obtain high temporal-spatial resolution information and processes, particularly in Tibet.

With the launch of the Gravity Recovery and Climate Experiment (GRACE) mission since 2002, it was very successful to monitor the Earth's time-variable gravity field by determining very accurately the relative position of a pair of Low Earth Orbit (LEO) satellites. Therefore, the new generation of the gravity field derived from terrestrial and space gravimetry, provides a unique opportunity to investigate gravity-solid earth coupling, physics and dynamics of the Earth's interior, and mass flux interaction within the Earth system, together with GPS/InSAR.

Objectives

- To quantify mass transport within the Earth's fluid envelope and their interaction in the Earth system.
- To monitor tectonic motions using gravimetry/GPS, including India-Tibet collision, post-glacial uplift and the deformation associated with active tectonic events, such as earthquakes and volcanoes.
- To develop inversion algorithm and theories in a Spherical Earth on gravity field related deformation and gravity-solid Earth coupling, e.g. crust thickness, isostatic Moho undulations, mass loadings and geodynamics.
- To develop methods to extract a geodynamic signals related to Solid-Earth mantle and/or core and to understand the physical properties of the Earth interior and its dynamics from the joint use of gravity data and other geophysical measurements.
- To analyze and model geodynamic processes from isostatic modelling of gravity and topography data as well as density structure of the Earth's deep interior.
- To address mantle viscosity from analyzing post-seismic deformations of large earthquakes and post-glacial rebound (PGR) and to explain the physical relationships between deformation, seismicity, mantle dynamics, lithospheric rheology, isostatic response, etc.
- To achieve these objectives, the IC SG interacts and collaborates with the ICCT and all IAG Commissions.

Program of Activities

- Organization of SG workshop and of conference sessions,
- Participation in related scientific conference and symposia,
- Supporting contributions to the ICCT activities.

Membership

- Shuanggen Jin (China)
- David J. Crossley (USA)
- Carla Braitenberg (Italy)
- Isabelle Panet (France)
- Jacques Hinderer (France)
- Séverine Rosat (France)
- Tonie M. van Dam (Luxembourg)
- Urs Marti (Switzerland)
- Patrick Wu (Canada)
- Isabella Velicogna (USA)
- Nico Sneeuw (Germany)

JSG 0.9: Future Developments of ITRF Models and their Geophysical Interpretation

Chair: A. Dermanis (Greece)
Affiliation: Comm. 1 and IERS

Terms of Reference

The realization of a reference system by means of a reference frame, in the form of coordinate time series or coordinate functions for a global set of control stations is a complicated procedure. It involves input data from various space techniques each one based on its own advanced modelling and observation analysis techniques, as well as, criteria for the optimal selection of the time evolution of the reference frame among all data compatible possibilities.

The relevant "observed" coordinate time series demonstrate significant signals of periodic, non-periodic variations and discontinuities, which pose the challenge of departing from the current ITRF model of linear time evolution, realized by reference epoch coordinates and constant velocities.

The remaining residual signal in coordinate variations is dominated by an almost periodic term with varying amplitude and phase, especially in the height component. The inclusion of additional terms in the ITRF model is an intricate problem that deserves further research and careful planning.

It is also important to understand the nature of these coordinate variations in order to adopt models that are meaningful from the geophysical point of view and not a simple fit to the observed data.

Since geophysical processes causing coordinate variations also cause variations in the gravity field, it is worthwhile to investigate the possibility of incorporating result results from space gravity missions in ITRF modelling.

The working group is primarily aiming in identification of new ITRF models, investigation of their performance and motivation of relevant scientific research.

Objectives

- Geophysical interpretation of non-linear coordinate variations and development of relevant models
- Extension of ITRF beyond the current linear (constant velocity) model, treatment of periodic and discontinuous station coordinate time series and establishment of proper procedures for estimation of extended ITRF parameters and quality assessment of the obtained results.

Program of Activities

- Launching of a web-page for dissemination of information, presentation, communication, outreach purposes, and providing a bibliography.
- Working meetings at international symposia and presentation of research results in appropriate sessions.
- Organization of workshops dedicated mainly to problem identification and motivation of relevant scientific research.
- Organization of a second IAG School on Reference Frames.

Membership

- A. Dermanis (Greece), chair
- Z. Altamimi (France)
- X. Collilieux (France)
- H. Drewes (Germany)
- F. Sansò (Italy)
- T. van Dam (Luxembourg)