Inter-Commission Committee on Theory (ICCT)

President: **Pavel Novák** (Czech Republic)
Vice President: **Mattia Crespi** (Italy)

http://icct.kma.zcu.cz

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, namely commissions, services and the Global Geodetic Observing System (GGOS). 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. At the IUGG XXIV Assembly in Prague, 2015, ICCT became a permanent entity within the IAG structure.

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, 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 theoretical foundations of geodesy in particular; (2) provides the channel of communication amongst different IAG entities of commissions, services and projects on the ground of theory and methodology, and directly cooperates with and supports these entities in the topical work; (3) helps IAG in articulating mathematical and physical challenges of geodesy as a subject of science and in attracting young talents to geodesy. ICCT strives to attract and serve as home to all mathematically motivated and oriented geodesists as well as to applied mathematicians; and (4) encourages closer research ties with and gets directly involved in relevant areas of 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, ICCT interacts and collaborates with the IAG Commissions, GGOS and other IAG related entities (services, projects).

Program of Activities

The ICCT's program of activities includes

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

Structure

The general structure of Inter-Commission Committees is specified in the IAG By-laws (§17). The Steering Committee includes the president, the vice-president, the past president, one representative appointed by each Commission, and two representatives of the IAG services. The ICCT activities are structured in study groups. Due to the inter-commission character of the ICCT, these study groups are always joint study groups, affiliated to one or more of the Commissions, GGOS and/or IAG services.

Joint Study Groups

JSG 0.10: High-rate GNSS
Chair: M. Crespi (Italy)
(Affiliation: Commission 4 and GGOS)

JSG 0.11: Multiresolution aspects of potential field theory
Chair: D. Tsoulis (Greece)
(Affiliation: Commissions 2, 3 and GGOS)

JSG 0.12: Advanced computational methods for recovery of high-resolution gravity field models
Chair: R. Čunderlík (Slovak Republic)
(Affiliation: Commission 2 and GGOS)

JSG 0.13: Integral equations of potential theory for continuation and transformation of classical and new gravitational observables
Chair: M. Šprlák (Czech Republic)
(Affiliation: Commission 2 and GGOS)

JSG 0.14: Fusion of multi-technique satellite geodetic data
Chair: K. Sośnica (Poland)
(Affiliation: Commission 4 and GGOS)

JSG 0.15 Regional geoid/quasi-geoid modelling – Theoretical framework for the sub-centimetre accuracy
Chair: J. Huang (Canada)
(Affiliation: Commission 2 and GGOS)

JSG 0.16 Earth's inner structure from combined geodetic and geophysical sources
Chair: R. Tenzer (China)
(Affiliation: Commissions 2 and 3)

JSG 0.17 Multi-GNSS theory and algorithms
Chair: A. Khodabandeh (Australia)
(Affiliation: Commission 4 and GGOS)

JSG 0.18 High resolution harmonic analysis and synthesis of potential fields
Chair: S. Claessens (Australia)
(Affiliation: Commission 2 and GGOS)

JSG 0.19 Time series analysis in geodesy
Chair: W. Kosek (Poland)
(Affiliation: Commission 3 and GGOS)

JSG 0.20 Space weather and ionosphere
Chair: K. Börger (Germany)
(Affiliation: Commission 4 and GGOS)

JSG 0.21 Geophysical modelling of time variations in deformation and gravity
Chair: Y. Tanaka (Japan)
(Affiliation: Commissions 2 and 3)

JSG 0.22 Definition of next generation terrestrial reference frames
Chair: K. Kotsakis (Greece)
(Affiliation: Commissions 1 and GGOS)

Steering Committee

ICCT President:	Pavel Novák (Czech Republic)
ICCT Vice-President:	Mattia Crespi (Italy)
ICCT Past-President:	Nico Sneeuw (Germany)
Representative Comm. 1:	Geoffrey Blewitt (USA)
Representative Comm. 2:	Roland Pail (Germany)
Representative Comm. 3:	Manabu Hashimoto (Japan)
Representative Comm. 4:	Marcelo Santos (Canada)
Representative of GGOS:	Hansjörg Kutterer (Germany)
Representative of IGFS:	Riccardo Barzaghi (Italy)
Representative of IERS:	Jürgen Müller (Germany)

Joint Study Groups of the ICCT

JSG 0.10: High-rate GNSS

(Affiliation: Commission 1, 3, 4, and GGOS)

Chair: M. Crespi (Italy)

Introduction

Global Navigation Satellite Systems (GNSS) have become for a long time an indispensable tool to get accurate and reliable information about positioning and timing; in addition, GNSS are able to provide information related to physical properties of media passed through by GNSS signals. Therefore, GNSS play a central role both in geodesy and geomatics and in several branches of geophysics, representing a cornerstone for the observation and monitoring of our planet.

So, it is not surprising that, from the very beginning of the GNSS era, the goal was pursued to widen the range in space (from local to global) and time (from short to long term) of the observed phenomena, in order to cover the largest possible field of applications, both in science and in engineering; two complementary, but primary as well, goals were, obviously, to get this information with the highest accuracy and in the shortest time.

The advances in technology and the deployment of new constellations, after GPS (in the next years the European Galileo, the Chinese BeiDou and the Japanese QZSS will be completed) remarkably contributed to transform this *three-goals dream* in reality, but significant challenges still remain when very fast phenomena have to be observed, mainly if real-time results are looked for.

Actually, for almost 15 years, starting from the noble birth in seismology, and the very first experiences in structural monitoring, high-rate GNSS have demonstrated its usefulness and power in providing precise positioning information in fast time-varying environments. At the beginning, high-rate observations were mostly limited at 1 Hz, but the technology development provided GNSS equipment (in some cases even at low-cost) capable to collect measurements at much higher rates, up to 100 Hz, therefore opening new possibilities, and at the same time new challenges and problems.

So, it is necessary to think about how to optimally process this potential huge heap of data, in order to supply information of high value for a large (and likely increasing) variety of applications, some of them listed hereafter without the claim to be exhaustive: better understanding of the geophysical/geodynamical processes mechanics; monitoring of ground shaking and displacement during earthquakes, also for contribution to tsunami early warning; tracking the fast variations of the ionosphere; real-time controlling landslides and the safety of structures; providing detailed trajectories and kinematic parameters (not only position, but also velocity and acceleration) of high dynamic platforms such as airborne sensors, high-speed terrestrial vehicles and even athlete and sport vehicles monitoring.

Further, due to the contemporary technological development of other sensors (hereafter referred as ancillary sensors) related to positioning and kinematics capable of collecting data at high rates (among which MEMS accelerometers and gyros play a central role, also for their low cost), the feasibility of a unique device for high-rate observations embedding GNSS receiver and MEMS sensors became reality. Again this opens new opportunities and problems, first of all related to sensors integration.

All in all, it is clear that high-rate GNSS (and ancillary sensors) observations represent a great resource for future investigations in Earth sciences and for applications in engineering, while stimulating an attention from the methodological point of view in order to exploit their full potential and extract the best information. This is the reason why it is worth to focus on high-rate (and, if possible, real-time) GNSS within ICCT.

Objectives

- To realize the inventories of:
  - available and applied methodologies for high-rate GNSS, in order to highlight their pros and cons and the open problems;
  - present and foreseen applications of high-rate GNSS for science and engineering, with a special concern to the estimated quantities (geodetic, kinematic, physical), in order to focus on related problems (still open and possibly new) and draw future challenges;
  - technology (hw, both for GNSS and ancillary sensors, and sw, possibly FOSS), pointing out what is ready and what is coming, with a special concern for the supplied observations and for their functional and stochastic modelling with the by-product of establishing a standardized terminology.
- To address known (mostly cross-linked) problems related to high-rate GNSS as (not an exhaustive list): revision and refinement of functional and stochastic models; evaluation and impact of observations time-correlation; impact of multipath and constellation change; outliers detection and removal; issues about GNSS constellations interoperability; ancillary sensors evaluation, cross-calibration and integration.
- To address new problems and future challenges arising from the inventories.

- To investigate the inter-action with present real-time global (IGS-RTS, EUREF-IP, etc.) and regional/local positioning services: how can these services support high-rate GNSS observations and, on reverse, how can they benefit of high-rate GNSS observations.

Program of activities

- To launch a questionnaire for the above mentioned inventory of methodologies, applications and technologies.
- To open a web page with information concerning high-rate GNSS and its wide applications in science and engineering, with special emphasis on exchange of ideas, provision and updating bibliographic list of references of research results and relevant publications from different disciplines.
- To launch proposal for two (one science and one engineering oriented) state-of-the-art review papers in high-rate GNSS co-authored by the JSG members.
- To organize a session at the forthcoming Hotine-Marussi symposium.
- To promote sessions and presentation of the research results at international symposia both related to Earth science (IAG/IUGG, EGU, AGU) and engineering (meetings in structural and geotechnical engineering).

Members

Mattia Crespi (Italy), Chair
Juan Carlos Baez (Chile)
Elisa Benedetti (United Kingdom)
Geo Boffi (Switzerland)
Gabriele Colosimo (Switzerland)
Athanasios Dermanis (Greece)
Roberto Devoti (Italy)
Jeff Freymueller (USA)
Joao Francisco Galera Monico (Brazil)
Jianghui Geng (Germany)
Kosuke Heki (Japan)
Melvin Hoyer (Venezuela)
Nanthi Nadarajah (Australia)
Yusaku Ohta (Japan)
Ruey-Juin Rau (China-Taipei)
Eugenio Realini (Italy)
Chris Rizos (Australia)
Nico Sneeuw (Germany)
Peiliang Xu (Japan)

JSG 0.11: Multiresolutional aspects of potential field theory
(Affiliation: Commission 2, 3, and GGOS)

Chair: D. Tsoulis (Greece)

Introduction

The mathematical description and numerical computation of the gravity signal of finite distributions play a central role in gravity field modelling and interpretation. Thereby, the study of the field induced by ideal geometrical bodies, such as the cylinder, the rectangular prism or the generally shaped polyhedron, is of special importance both as fundamental case studies but also in the frame of terrain correction computations over finite geographical regions. Analytical and numerical tools have been developed for the potential function and its derivatives up to the second order for the most familiar ideal bodies, which are widely used in gravity related studies. Also, an abundance of implementations has been proposed for computing these quantities over grids of computational points, elaborating data from digital terrain or crustal databases.

Scope of the Study Group is to investigate the possibilities of applying wavelet and multiscale analysis methods to compute the gravitational effect of known density distributions. Starting from the cases of ideal bodies and moving towards applications involving DTM data, or hidden structures in the Earth's interior, it will be attempted to derive explicit approaches for the individual existing analytical, numerical or combined (hybrid) methodologies. In this process, the mathematical consequences of expressing in the wavelet representation standard tools of potential theory, such as the Gauss or Green theorem, involved for example in the analytical derivations of the polyhedral gravity signal, will be addressed. Finally, a linkage to the coefficients obtained from the numerical approaches but also to the potential coefficients of currently available Earth gravity models will also be envisaged.

Objectives

- Bibliographical survey and identification of multiresolutional techniques for expressing the gravity field signal of finite distributions.
- Case studies for different geometrical finite shapes.
- Comparison and assessment against existing analytical, numerical and hybrid solutions.
- Computations over finite regions in the frame of classical terrain correction computations.
- Band limited validation against Earth gravity models.

Program of activities

- Active participation at major geodetic meetings.
- Organize a session at the forthcoming Hotine-Marussi Symposium.
- Compile a bibliography with key publications both on theory and applied case studies.
- Collaborate with other working groups and affiliated IAG Commissions.

Members

Dimitrios Tsoulis (Greece), Chair
Katrin Bentel (USA)
Maria Grazia D'Urso (Italy)
Christian Gerlach (Germany)
Wolfgang Keller (Germany)
Christopher Kotsakis (Greece)
Michael Kuhn (Australia)
Volker Michel (Germany)
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Corresponding members

Christopher Jekeli (USA)
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JSG 0.12: Advanced computational methods for recovery of high-resolution gravity field models
(Affiliation: Commission 2 and GGOS)

Chair: R. Čunderlík (Slovak Republic)

Introduction

Efficient numerical methods and HPC (high performance computing) facilities provide new opportunities in many applications in geodesy. The goal of the JSG is to apply numerical methods and/or HPC techniques mostly for gravity field modelling and nonlinear filtering of various geodetic data. The discretization numerical methods like the finite element method (FEM), finite volume method (FVM) and boundary element method (BEM) or the meshless methods like the method of fundamental solutions (MFS) or singular boundary method (SOR) can efficiently be used to solve the geodetic boundary value problems and nonlinear diffusion filtering, or to process e.g. the GOCE observations. Their parallel implementations and large-scale parallel computations on clusters with distributed memory using the MPI (Message Passing Interface) standards allow to solve such problems in spatial domains while obtaining high-resolution numerical solutions.

The JSG is also open for researchers dealing with classical approaches of gravity field modelling (e.g. the spherical or ellipsoidal harmonics) that are using high performance computing to speed up their processing of enormous amount of input data. This includes large-scale parallel computations on massively parallel architectures as well as heterogeneous parallel computations using graphics processing units (GPUs).

Applications of the aforementioned numerical methods for gravity field modelling involve a detailed discretization of the real Earth's surface considering its topography. It naturally leads to the oblique derivative problem that needs to be treated. In case of FEM or FVM, unstructured meshes above the topography will be constructed. The meshless methods like MFS or SBM, that are based on the point-masses modelling, can be applied for processing of gravity gradients observed by the GOCE satellite mission. To reach precise and high-resolution solutions, an elimination of far zone contributions is practically inevitable. This can be performed using the fast multipole method or iterative procedures. In both cases such an elimination process improves conditioning of the system matrix and numerical stability of the problem.

Another aim of the JSG is to investigate and develop nonlinear filtering methods that allow adaptive smoothing, which effectively reduces the noise while preserves main structures in data. 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 where the diffusivity coefficients depend on a combination of the edge detector and a mean curvature of the filtered function. This will avoid undesirable smoothing of local extremes.

Objectives

The main objectives of the study group are as follows:

- To develop algorithms for detailed discretization of the real Earth's surface including the possibility of adaptive refinement procedures.
- To create unstructured meshes above the topography for the FVM or FEM approach.
- To develop the FVM, BEM or FEM numerical models for solving the geodetic BVPs that will treat the oblique derivative problem.
- To develop numerical models based on MFS or SBM for processing the GOCE observations.
- To develop parallel implementations of algorithms using the standard MPI procedures.
- To perform large-scale parallel computations on clusters with distributed memory.
- To investigate and develop methods for nonlinear diffusion filtering of data on the Earth's surface where the diffusivity coefficients depend on a combination of the edge detector and a mean curvature of the filtered function.
- To derive the semi-implicit numerical schemes for the nonlinear diffusion equation on closed surfaces using the surface FVM.
- To apply the developed nonlinear filtering methods to real geodetic data.

Program of activities

- Active participation at major geodetic workshops and conferences.
- Organization of group working meetings at main international symposia.
- Organization of conference sessions.

Members

Róbert Čunderlík (Slovak Republic), Chair
Karol Mikula (Slovak Republic), Vice-chair
Jan Martin Brockmann (Germany)
Walyeldeen Godah (Poland)
Petr Holota (Czech Republic)
Michal Kollár (Slovak Republic)
Marek Macák (Slovak Republic)
Zuzana Minarechová (Slovak Republic)
Otakar Nesvadba (Czech Republic)
Wolf-Dieter Schuh (Germany)

JSG 0.13: Integral equations of potential theory for continuation and transformation of classical and new gravitational observables

(Affiliation: Commission 2 and GGOS)

Chair: M. Šprlák (Czech Republic**)**

Introduction

The description of the Earth's gravitational field and its temporal variations belongs to fundamental pillars of modern geodesy. The accurate knowledge of the global gravitational field is important in many applications including precise positioning, metrology, geophysics, geodynamics, oceanography, hydrology, cryospheric and other geosciences. Various observation techniques for collecting gravitational data have been invented based on terrestrial, marine, airborne and more recently, satellite sensors. On the other hand, different parametrization methods of the gravitational field were established in geodesy, however, often with unobservable parameters. For this reason, the geodetic science has traditionally been formulating various gravitational parameter transformations, including those based on solving boundary/initial value problems of potential theory through Fredholm's integral equations.

Traditionally, Stokes's, Vening-Meinesz's and Hotine's integrals have been of interest in geodesy as they accommodated geodetic applications. In recent history, new geodetic integral transformations were formulated. This effort was mainly initiated by new gravitational observables that became available to geodesists with the advent of precise GNSS (Global Navigation Satellite System) positioning, satellite altimetry and aerial gravimetry/gradiometry. The family of integral transformations has enormously been extended with satellite-to-satellite tracking and satellite gradiometric data available from recent gravity-dedicated satellite missions.

Besides numerous efforts in developing integral equations to cover new observables in geodesy, many aspects of integral equations remain challenging. This joint study group aims for systematic treatment of integral transformation in geodesy, as many formulations have been performed by making use of various approaches. Many solutions are based on spherical approximation that cannot be justified for globally distributed satellite data and with respect to requirements of various data users requiring gravitational data to be distributed the reference ellipsoid or at constant geodetic altitude. On the other hand, the integral equations in spherical approximation possess symmetric properties that allow for studying their spatial and spectral properties; they also motivate for adopting a generalized notation. New numerically efficient, stable and accurate methods for upward/downward continuation, comparison, validation, transformation, combination and/or for interpretation of gravitational data are also of high interest with increasing availability of large amounts of new data.

Objectives

- To consider different types of gravitational data, i.e., terrestrial, aerial and satellite, available today and to formulate their mathematical relation to the gravitational potential.
- To study mathematical properties of differential operators in spherical and Jacobi ellipsoidal coordinates, which relate various functionals of the gravitational potential.
- To complete the family of integral equations relating various types of current and foreseen gravitational data and to derive corresponding spherical and ellipsoidal Green's functions.
- To study accurate and numerically stable methods for upward/downward continuation of gravitational field parameters.
- To investigate optimal combination techniques of heterogeneous gravitational field observables for gravitational field modelling at all scales.
- To investigate conditionality as well as spatial and spectral properties of linear operators based on discretized integral equations.
- To classify integral transformations and to propose suitable generalized notation for a variety of classical and new integral equations in geodesy.

Program of activities

- Presenting research results at major international geodetic and geophysical conferences, meetings and workshops.
- Organizing a session at the forthcoming Hotine-Marussi Symposium 2017.
- Cooperating with related IAG Commissions and GGOS.
- Monitoring activities of JGS members as well as other scientists related to the scope of JGS activities.
- Providing bibliographic list of relevant publications from different disciplines in the area of JSG interest.

Members

Michal Šprlák (Czech Republic), Chair
Alireza Ardalan (Iran)
Mehdi Eshagh (Sweden)
Will Featherstone (Australia)
Ismael Foroughi (Canada)
Peter Holota (Czech Republic)
Juraj Janák (Slovak Republic)
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Pavel Novák (Czech Republic)
Martin Pitoňák (Czech Republic)
Robert Tenzer (China)
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JSG 0.14: Fusion of multi-technique satellite geodetic data

(Affiliation: Commission 1, 3, 4, and GGOS)

Chair: K. Sośnica (Poland)

Introduction

Observations provided by space geodetic techniques deliver a global picture of the changing system Earth, in particular temporal changes of the Earth's gravity field, irregularities in the Earth's rotation and variations of station positions due to various geodynamical phenomena. Different techniques are characterized by different accuracy and different sensitivity to geodetic parameters, e.g., GNSS provides most accurate pole coordinates, but cannot provide the absolute information on UT1-UTC; thus, it must be integrated with VLBI or LLR data. GRACE observations provide state-of-the-art and most accurate information on temporal changes of the gravity field, but the temporal changes of the Earth's oblateness or the geocentre motion can be better determined using SLR data. Therefore, a fusion of various space geodetic observations is an indispensable prerequisite for a reliable description of the varying system Earth.

However, the space geodetic observations are typically not free of artifacts related to deficiencies in various models used in the data reduction process. GNSS satellite orbits are very sensitive to deficiencies in solar radiation pressure modeling affecting, e.g., the accuracy of GNSS-derived Earth rotation parameters and geocentre coordinates. Deficiencies in modelling of antenna phase center offsets, albedo and the antenna thrust limit the reliability of GNSS- and DORIS-derived scale of the terrestrial reference frame, despite a good global coverage of GNSS receivers and DORIS beacons. VLBI solutions are affected by an inhomogeneous quality delivered by different stations and antenna deformations. SLR technique is affected by the Blue-Sky effect which is related to the weather dependency of laser observations and the station-dependent satellite signature effect due to multiple reflections from many retroreflectors. Moreover, un-modeled horizontal gradients of the troposphere delay in SLR analyzes also limit the quality of SLR solutions. Finally, GRACE data are very sensitive to aliasing with diurnal and semidiurnal tides, whereas GOCE and Swarm orbits show a worse quality around the geomagnetic equator due to deficiencies in ionosphere delay modeling.

Separation of real geophysical signals and artifacts in geodetic observations yield a very challenging objective. A fusion of different observational techniques of space geodesy may enhance our knowledge on systematic effects, improve the consistency between different observational techniques, and may help us to mitigate artifacts in the geodetic time series.

The mitigation of artifacts using parameters derived by a fusion of different techniques of space geodesy should comprise three steps: 1) identification of an artifact through an analysis of geodetic parameters derived from multiple techniques, 2) delivering a way to model an artifact; 3) applying the developed model to standard solutions by the analysis centers.

Improving the consistency level through mitigating artifacts in space geodetic observations will bring us closer to fulfilling the objectives of the Global Geodetic Observing System (GGOS), i.e., the 1-mm accuracy of positions and 0.1-mm/year accuracy of the velocity determination. Without a deep knowledge of systematic effects in satellite geodetic data and without a proper modelling thereof, the accomplishment of the GGOS goals will never be possible.

Objectives

- Developing of data fusion methods based on geodetic data from different sources.
- Accuracy assessment and simulations of geodetic observations in order to fulfil GGOS' goals.
- Study time series of geodetic parameters (geometry, gravity and rotation) and other derivative parameters (e.g., troposphere and ionosphere delays) determined using different techniques of space geodesy.
- Investigating biases and systematic effects in single techniques.
- Combination of satellite geodetic observations at the observation level and software synchronization.
- Investigating various methods of technique co-locations: through local ties, global ties, co-location in space.
- Identifying artifacts in time series of geodetic parameters using e.g., spatial, temporal, and spectral analyzes.
- Elaborating methods aimed at mitigating systematic effects and artifacts.
- Determination of the statistical significance levels of the results obtained by techniques using different methods and algorithms.
- Comparison of different methods in order to point out their advantages and disadvantages.
- Recommendations for analysis working groups and conventions.

Program of activities

- Preparing a web page with information concerning integration and consistency of satellite geodetic techniques and their integration with special emphasis on exchange of ideas, providing and updating bibliographic list of references of research results and relevant publications from different disciplines.
- Working meetings at the international symposia and presentation of research results at the appropriate sessions.

Members

Krzysztof Sośnica (Poland), Chair
Mathis Blossfeld (Germany)
Sara Bruni (Italy)
Claudia Flohrer (Germany)
Andrea Maier (Switzerland)
Toshimichi Otsubo (Japan)
Daniela Thaller (Germany)
Karina Wilgan (Poland)
Agnieszka Wnek (Poland)

JSG 0.15: Regional geoid/quasi-geoid modelling – Theoretical framework for the sub-centimetre accuracy

(Affiliation: Commission 2 and GGOS)

Chair: J. Huang (Canada)

Introduction

A theoretical framework for the regional geoid/quasi-geoid modelling is a conceptual structure to solve a geodetic boundary value problem regionally. It is a physically sound integration of a set of coherent definitions, physical models and constants, geodetic reference systems and mathematical equations. Current frameworks are designed to solve one of the two geodetic boundary value problems (BVPs): Stokes's and Molodensky's. These frameworks were originally established and subsequently refined for many decades to get the best accuracy of the geoid/quasi-geoid model. The regional geoid/quasi-geoid model can now be determined with an accuracy of a few centimeters in a number of regions in the world, and has been adopted to define new vertical datums replacing the spirit-leveling networks in New Zealand and Canada. More and more countries are modernizing their existing height systems with the geoid-based datum. Yet the geoid model still needs further improvement to match the accuracy of the GNSS-based heightening. This requires the theory and its numerical realization, to be of sub-centimeter accuracy, and the availability of adequate data.

Regional geoid/quasi-geoid modelling often involves the combination of satellite, aerial, terrestrial (shipborne and land) gravity data through the remove-compute-restore Stokes method and the least-squares collocation. Satellite gravity data from recent gravity missions (GRACE and GOCE) enable to model the geoid components with an accuracy of 1-2 cm at the spatial resolution of 100 km. Aerial gravity data are covering more regions with a variety of accuracies and spatial resolutions such as the US GRAV-D project. They often overlap with terrestrial gravity data which are still unique in determining the high-degree geoid components. It can be foreseen that gravity data coverage will extend everywhere over lands, in particular, aerial data, in the near future. Furthermore, the digital elevation models required for the gravity reduction have achieved global coverage with redundancy. A pressing question to answer is if these data are sufficiently accurate for the sub-centimeter geoid/quasi-geoid determination. This joint study group focuses on refining and establishing if necessary the theoretical frameworks of the sub-centimeter geoid/quasi-geoid.

Objectives

The theoretical frameworks of the sub-centimeter geoid/quasi-geoid consist of, but are not limited to, the following components to study:

- Physical constant GM.
- W_0 convention and changes.
- Geo-center convention and motion with respect to the International Terrestrial Reference Frame (ITRF).
- Geodetic Reference Systems.
- Proper formulation of the geodetic BVPs.
- Nonlinear solution of the formulated geodetic BVPs.
- Data type, distribution and quality requirements.
- Data interpolation and extrapolation methods.
- Gravity reduction including downward or upward continuation from observation points down or up to the geoid, in particular over mountainous regions, polar glaciers and ice caps.
- Anomalous topographic mass density effect on the geoid model.
- Spectral combination of different types of gravity data.
- Transformation between geoid and quasi-geoid models.
- The time-variable geoid/quasi-geoid change modelling;
- Estimation of the geoid/quasi-geoid model inaccuracies.
- Independent validation of geoid/quasi-geoid models.
- Applications of new tools such as the radial basis functions.

Program of activities

- The joint study group achieves its objectives through organizing splinter meetings in coincidence with major IAG conferences and workshops if possible.
- Circulating and sharing progress reports, papers and presentations.
- Presenting and publishing papers in the IAG symposia and scientific journals.

Members

Jianliang Huang (Canada), Chair
Yan Ming Wang (USA), Vice-chair
Riccardo Barzaghi (Italy)
Heiner Denker (Germany)
Will Featherstone (Australia)
René Forsberg (Denmark)
Christian Gerlach (Germany)
Christian Hirt (Germany)
Urs Marti (Switzerland)
Petr Vaníček (Canada)

JSG 0.16: Earth's inner structure from combined geodetic and geophysical sources

(Affiliation: Commissions 2 and 3)

Chair: R. Tenzer (China)

Introduction

The satellite gravimetry missions, CHAllenging Mini-satellite Payload (CHAMP), the GRavity field and Climate Experiment (GRACE) and the Gravity field and steady-state Ocean Circulation Explorer (GOCE), significantly improved our knowledge on the external gravitational field of the Earth at the long-to-medium wavelengths (approximately up to the spherical harmonic degree of 250). Such improved information in terms of the accuracy and resolution has been utilized in studies of the Earth's interior for a better understanding of the Earth's inner structure and processes occurring within the lithosphere and sub-lithospheric mantle. Whereas the long-wavelength spectrum of the Earth's gravitational field comprises mainly the signature of deep mantle density heterogeneities attributed to mantle convection, the medium wavelengths reflect the density structure of more shallow sources within the lithosphere. This allows studying and interpreting in more detail the gravitational features which are related to the global tectonism (including the oceanic subduction, orogenic formations, earthquakes, global lithospheric plate configuration, etc.), sub-lithospheric stresses, isostatic mechanisms, glacial isostatic adjustment and other related geodynamic phenomena. Moreover, the Global Gravitational Models (GGMs) have been extensively used in studies of the lithospheric density structure and density interfaces such as for the gravimetric recovery of the Moho depth, lithospheric thickness, and structure of sedimentary basins.

Since the gravity observations could not be used alone to interpret the Earth's inner density structure due to a non-uniqueness of inverse solutions (i.e., infinitely many 3-D density structures could be attributed to the gravity field), additional information is required to constrain the gravimetric methods for interpreting the Earth's interior. These constraining data comprise primarily results of seismic surveys as well as additional geophysical, geothermal and geochemical parameters of the Earth. Moreover, numerous recent gravimetric studies of the Earth's interior focus on the global and regional Moho recovery. The classical isostatic models (according to Airy and Pratt theories) are typically not able to model realistically the actual Moho geometry due to the fact that the isostatic mass balance depends on loading and effective elastic thickness, rigidity, rheology of the lithosphere and viscosity of the asthenosphere. Moreover, geodynamic processes such as the glacial isostatic adjustment, present-day glacial melting, plate motion and mantle convection contribute to the time-dependent isostatic balance. To overcome these issues, processing strategies of combining gravity and seismic data (and possibly also additional constraining information) have to be applied to determine the actual Moho geometry.

The gravimetric methods applied in studies of the Earth's inner density structure comprise - in principle - two categories. The methods for the gravimetric forward modelling are applied to model (and remove) the gravitational signature of known density structures in order to enhance the gravitational contribution of unknown (and sought) density structures and interfaces. The gravimetric inverse methods are then used to interpret these unknown density structures from the refined gravity data. It is obvious that the combination of gravity and seismic data (and other constraining information) is essential especially in solving the gravimetric inverse problems.

This gives us the platform and opportunities towards improving the theoretical and numerical methods applied in studies of Earth's interior from multiple data sources, primarily focusing but not restricting only to combining gravimetric and seismic data. It is expected that the gravity data could improve our knowledge of the Earth's interior over significant proportion of the world where seismic data are sparse or completely absent (such large parts of oceanic areas, Antarctica, Greenland and Africa). The gravity data could also provide additional information on the lithospheric structure and mechanisms, such as global tectonic configuration, geometry of subducted slabs, crustal thickening of orogenic formations and other phenomena.

Objectives

- Development of the theoretical and numerical algorithms for combined processing of gravity, seismic and other types of geophysical data for a recovery of the Earth's density structures and interfaces.
- Development of fast numerical algorithms for combined data inversions.
- Development of stochastic models for combined inversion including optimal weighting, regularization and spectral filtering.
- Better understanding of uncertainties of interpreted results based on the error analysis of input data and applied numerical models. Geophysical and geodynamic clarification of results and their uncertainties.
- Recommendations for optimal data combinations, better understanding of possibilities and limiting factors associated with individual data types used for geophysical and geodynamic interpretations.

Program of activities

- Launching of a web page with emphasis on exchange of ideas and recent progress, providing and updating bibliographic list of references of research results and relevant publications from different disciplines.
- Work progress meetings at the international symposia and presentation of research results at the appropriate sessions.
- Possible collaboration between various geoscience study groups dealing with the modeling of the Earth's interior and related scientific topics.

Members

Robert Tenzer (China), Chair
Mohammad Bagherbandi (Sweden)
Carla Braitenberg (Italy)
Mehdi Eshagh (Sweden)
Mirko Reguzzoni (Italy)
Lars Sjöberg (Sweden)
Xiaodong Song (USA)

JSG 0.17: Multi-GNSS theory and algorithms

(Affiliation: Commissions 1, 4, and GGOS)

Chair: A. Khodabandeh (Australia)

Introduction

In recent years, we are witnessing rapid development in the satellite-based navigation and positioning systems. Next to the upgrade of the GPS dual-frequency signals to the triple-frequency signals, the GLONASS satellites have been revitalized and become fully operational. The new global and regional satellite constellations are also joining the family of the navigation systems. These additions are the two global systems of Galileo and BeiDou satellites as well as the two regional systems of QZSS and IRNSS satellites. This namely means that many more satellites will be visible to the GNSS users, transmitting data on many more frequencies than the current GPS dual-frequency setup, thereby expecting considerable improvement in the performance of the positioning and non-positioning GNSS applications.

Such a proliferation of multi-system, multi-frequency data demands rigorous theoretical frameworks, models and algorithms that enable the near-future multiple GNSSs to serve as a high-accuracy and high-integrity tool for the Earth-, atmospheric- and space-sciences. For instance, recent studies have revealed the existence of non-zero inter-system and inter-system-type biases that, if ignored, result in a catastrophic failure of integer ambiguity resolution, thus deteriorating the corresponding ambiguity resolved solutions. The availability of the new multi-system, multi-frequency data does therefore appeal proper mathematical models in order to enable one to correctly integrate such data, thus correctly linking the data to the estimable parameters of interest.

Objectives

The main objectives of this joint study group are:

- to identify and investigate challenges that are posed by processing and integrating the data of the next generation navigation and positioning satellite systems,
- to develop new functional and stochastic models linking the multi-GNSS observations to the positioning and non-positioning parameters,
- to derive optimal methods that are capable of handling the data-processing of large-scale networks of mixed-receiver types tracking multi-GNSS satellites,
- to conduct an in-depth analysis of the systematic satellite- and receiver-dependent biases that are present either within one or between multiple satellite systems,

- to develop rigorous quality-control and integrity tools for evaluating the reliability of the multi-GNSS data and guarding the underlying models against any mis-modelled effects,
- to access the compatibility of the real-time multi-GNSS input parameters for positioning and non-positioning products,
- to articulate the theoretical developments and findings through the journals and conference proceedings.

Program of activities

While the investigation will strongly be based on the theoretical aspects of the multi-GNSS observation modelling and challenges, they will be also accompanied by numerical studies of both the simulated and real-world data. Given the expertise of each member, the underlying studies will be conducted on both individual and collaborative bases. The outputs of the group study is to provide the geodetic and GNSS communities with well-documented models and algorithmic methods through the journals and conference proceedings.

Members

Amir Khodabandeh (Australia), Chair
Ali Reza Amiri-Simkooei (Iran)
Simon Banville (Canada)
Gabriele Giorgi (Germany)
Nobuaki Kubo (Japan)
Bofeng Li (China)
Thalia Nikolaidou (Canada)
Robert Odolinski (Australia)
Peter J.G. Teunissen (Australia)
Pawel Wielgosz (Poland)

JSG 0.18: High resolution harmonic analysis and synthesis of potential fields
(Affiliation: Commission 2 and GGOS)

Chair: S. Claessens (Australia)

Introduction

The gravitational fields of the Earth and other celestial bodies in the Solar System are customarily represented by a series of spherical harmonic coefficients. The models made up of these harmonic coefficients are used widely in a large range of applications within geodesy. In addition, spherical harmonics are now used in many other areas of science such as geomagnetism, particle physics, planetary geophysics, biochemistry and computer graphics, but one of the first applications of spherical harmonics was related to the gravitational potential, and geodesists are still at the forefront of research into spherical harmonics. This holds true especially when it comes to the extension of spherical harmonic series to ever higher degree and order (d/o).

The maximum d/o of spherical harmonic series of the Earth's gravitational potential has risen steadily over the past decades. The highest d/o models currently listed by the International Centre for Global Earth Models (ICGEM) have a maximum d/o of 2190. In recent years, spherical harmonic models of the topography and topographic potential to d/o 10,800 have been computed, and with ever-increasing computational prowess, expansions to even higher d/o are feasible. For comparison, the current highest-resolution global gravity model has a resolution of 7.2” in the space domain, which is roughly equivalent to d/o 90,000 in the frequency domain, while the highest-resolution global Digital Elevation Model has a resolution of 5 m, equivalent to d/o ~4,000,000.

The increasing maximum d/o of harmonic models has posed and continues to pose both theoretical and practical challenges for the geodetic community. For example, the computation of associated Legendre functions of the first kind, which are required for spherical harmonic analysis and synthesis, is traditionally subject to numerical instabilities and underflow/overflow problems. Much progress has been made on this issue by selection of suitable recurrence relations, summation strategies, and use of extended range arithmetic, but further improvements to efficiency may still be achieved.

There are further separate challenges in ultra-high d/o harmonic analysis (the forward harmonic transform) and synthesis (the inverse harmonic transform). Many methods for the forward harmonic transform exist, typically separated into least-squares and quadrature methods, and further comparison between the two at high d/o, including studying the influence of aliasing, is of interest. The inverse harmonic transform, including synthesis of a large variety of quantities, has received much interest in recent years. In moving towards higher d/o series, highly efficient algorithms for synthesis on irregular surfaces and/or in scattered point locations, are of utmost importance.

Another question that has occupied geodesists for many decades is whether there is a substantial benefit to the use of oblate ellipsoidal (or spheroidal) harmonics instead of spherical harmonics. The limitations of the spherical harmonic series for use on or near the Earth's surface are becoming more and more apparent as the maximum d/o of the harmonic series increase. There are still open questions about the divergence effect and the amplification of the omission error in spherical and spheroidal harmonic series inside the Brillouin surface.

The Hotine-Jekeli transformation between spherical and spheroidal harmonic coefficients has proven very useful, in particular for spherical harmonic analysis of data on a reference ellipsoid. It has recently been improved upon and extended, while alternatives using surface spherical harmonics have also been proposed, but the performance of the transformations at very high d/o may be improved further. A direct use of spheroidal harmonic series requires (ratios of) associated Legendre functions of the second kind, and their stable and efficient computation is also of ongoing interest.

Objectives

The objectives of this joint study group are to:

- Create and compare stable and efficient methods for computation of ultra-high degree and order associated Legendre functions of the first and second kind (or ratios thereof), plus its derivatives and integrals.
- Study the divergence effect of ultra-high degree spherical and spheroidal harmonic series inside the Brillouin sphere/spheroid.
- Verify the numerical performance of transformations between spherical and spheroidal harmonic coefficients to ultra-high degree and order.
- Compare least-squares and quadrature approaches to very high-degree and order spherical and spheroidal harmonic analysis.
- Study efficient methods for ultra-high degree and order harmonic analysis (forward harmonic transform) for a variety of data types and boundary surfaces.
- Study efficient methods for ultra-high degree and order harmonic synthesis (inverse harmonic transform) of point values and area means of all potential quantities of interest on regular and irregular surfaces.

Program of activities

- Providing a platform for increased cooperation between group members, facilitating and encouraging exchange of ideas and research results.
- Creating and updating a bibliographic list of relevant publications from both the geodetic community as well as other disciplines for the perusal of group members.
- Organizing working meetings at international symposia and presenting research results in the appropriate sessions.

Members

Sten Claessens (Australia), Chair
Hussein Abd-Elmotaal (Egypt)
Oleh Abrykosov (Germany)
Blažej Bucha (Slovak Republic)
Toshio Fukushima (Japan)
Thomas Grombein (Germany)
Christian Gruber (Germany)
Eliška Hamáčková (Czech Republic)
Christian Hirt (Germany)
Christopher Jekeli (USA)
Otakar Nesvadba (Czech Republic)
Moritz Rexer (Germany)
Josef Sebera (Czech Republic)
Kurt Seitz (Germany)

JSG 0.19: Time series analysis in geodesy

(Affiliation: Commission 3 and GGOS)

Chair: W. Kosek (Poland)

Introduction

Observations of the space geodesy techniques and on the Earth's surface deliver a global picture of the Earth dynamics represented in the form of time series which describe 1) changes of the Earth surface geometry, 2) the fluctuations in the Earth orientation, and 3) the variations of the Earth’s gravitational field. The Earth's surface geometry, rotation and gravity field are the three components of the Global Geodetic Observing System (GGOS) which integrates them into one unique physical and mathematical model. However, temporal variations of these three components represent the total, integral effect of all global mass exchange between all elements of the Earth’s system including the Earth's interior and fluid layers: atmosphere, ocean and land hydrology.

Different time series analysis methods have been applied to analyze all these geodetic time series for better understanding of the relations between all elements of the Earth’s system as well as their geophysical causes. The interactions between different components of the Earth’s system are very complex so the nature of considered signals in the geodetic time series is mostly wideband, irregular and non-stationary. Thus, it is recommended to apply wavelet based spectra-temporal analysis methods to analyze these geodetic time series as well as to explain their relations to geophysical processes in different frequency bands using time-frequency semblance and coherence methods. These spectra-temporal analysis methods and time-frequency semblance and coherence may be further developed to display reliably the features of the temporal or spatial variability of signals existing in various geodetic data, as well as in other source data sources.

Geodetic time series include for example horizontal and vertical deformations of site positions determined from observations of space geodetic techniques. These site positions change due to e.g. plate tectonics, postglacial rebound, atmospheric, hydrology and ocean loading and earthquakes. However they are used to build the global international terrestrial reference frame (ITRF) which must be stable reference for all other geodetic observations including e.g., satellite orbit parameters and Earth's orientation parameters which consist of precession, nutation, polar motion and UT1-UTC that are necessary for transformation between the terrestrial and celestial reference frames. Geodetic time series include also temporal variations of Earth's gravity field where 1 arc-deg spherical harmonics correspond to the Earth’s centre of mass variations (long term mean of them determines the ITRF origin) and degree 2 spherical harmonics correspond to Earth rotation changes. Time series analysis methods can be also applied to analyze data on the Earth's surface including maps of the gravity field, sea level, ice covers, ionospheric total electron content and tropospheric delay as well as temporal variations of such surface data. The main problems to deal with include the estimation of deterministic (including trend and periodic variations) and stochastic (non-periodic variations and random changes) components of the geodetic time series as well as the application of digital filters for extracting specific components with a chosen frequency bandwidth.

The multiple methods of time series analysis may be encouraged to be applied to the preprocessing of raw data from various geodetic measurements in order to promote the quality level of enhancement of signals existing in these data. The topic on the improvement of the edge effects in time series analysis may also be considered, since they may affect the reliability of long-range tendency (trends) estimated from data series as well as the real-time data processing and prediction.

For coping with small geodetic samples one can apply simulation-based methods and if the data are sparse, Monte-Carlo simulation or bootstrap technique may be useful. Understanding the nature of geodetic time series is very important from the point of view of appropriate spectral analysis as well as application of filtering and prediction methods.

Objectives

- Study of the nature of geodetic time series to choose optimum time series analysis methods for filtering, spectral analysis, time frequency analysis and prediction.
- Study of Earth's geometry, rotation and gravity field variations and their geophysical causes in different frequency bands.
- Evaluation of appropriate covariance matrices for the time series by applying the law of error propagation to the original measurements, including weighting schemes, regularization, etc.
- Determination of the statistical significance levels of the results obtained by different time series analysis methods and algorithms applied to geodetic time series.
- Development and comparison of different time series analysis methods in order to point out their advantages and disadvantages.

- Recommendations of different time series analysis methods for solving problems concerning specific geodetic time series.

Program of activities

- Launching of a website about time series analysis in geodesy providing list of papers from different disciplines as well as unification of terminology applied in time series analysis;
- Working meetings at the international symposia and presentation of research results at the appropriate sessions.

Members

Wieslaw Kosek (Poland), Chair
Orhan Akyilmaz (Turkey)
Johannes Boehm (Austria)
Xavier Collilieux (France)
Laura Fernandez (Argentina)
Richard Gross (USA)
Mahmut O. Karslioglu (Turkey)
Hans Neuner (Germany)
Tomasz Niedzielski (Poland)
Sergei Petrov (Russia)
Waldemar Popinski (Poland)
Michael Schmidt (Germany)
Michel Van Camp (Belgium)
Olivier de Viron (France)
Jan Vondrák (Czech Republic)
Dawei Zheng (China)
Yonghong Zhou (China)

JSG 0.20: Space weather and ionosphere
(Affiliation: Commissions 1, 4 and GGOS)

Chair: Klaus Börger (Germany)
Vice-chair: Mahmut Onur Karsioglu (Turkey)

Introduction

It is well known that space geodetic methods are under influence of ionospheric refraction, and therefore from the very beginning of these techniques geodesy deals with the ionosphere. In this context sophisticated methods and models have been developed in order to determine, to represent and to predict the ionosphere. Apart from this the ionosphere fits into another issue called „space weather“, which describes interactions between the constituents of space and Earth. To be more precise space weather means the conditions in space with a significant impact on space-based and ground-based technology as well as on Earth and its inhabitants. Solar radiation, that is electromagnetic emission as well as particle emission, is the main cause or “driver” of space weather.

Originally, geodesy, or to be more precise, space geodetic methods have considered the ionosphere as a disturbing factor that affects the signal propagation and that has to be corrected. This (geodetic) perspective has been changed over time and the ionosphere has become a target value so that geodetic observations are used to determine the ionosphere. Different groups have developed models of high quality, e.g., 3D-models which describe the ionosphere as a function of longitude, latitude and time or even 4D-models accounting for the height as well. However, since the ionosphere is a manifestation of space weather, geodesy should contribute to space weather research, and in this respect completely new scientific questions arise, in particular with respect to the so called “geo-effect”, which is the impact of space weather in general.

There are two principal goals of the proposed joint study group. Firstly, to connect the “geodetic” ionosphere research with solar-terrestrial physics, in order to consider the complete cause-effect-chain. Second, the above mentioned “geo-effect” has to be investigated in detail, which is an important aspect, because modern society depends to a great extent on technology, i.e., technology that can be disturbed, that can be harmed or that even can be destroyed by extreme space weather events.

Objectives

- Improvements and enlargements of ionosphere models (including scintillations).
- Geodetic contributions to investigate the impact of space weather/the ionosphere (extreme events) on satellite motion.
- Geodetic contributions to investigate the impact of space weather/the ionosphere (extreme events) on communication.
- Iinvestigations of the impact of space weather/the ionosphere (extreme events) on remote sensing products.
- Investigations of the impact of space weather/the ionosphere (extreme events) on terrestrial technical infrastructure (metallic networks, power grids).
- "Geodetic observations" of currents (ring current, electrojets).

Program of activities

- Maintaining of a website for general information as well as for internal exchange of data sets and results.
- Organization of a workshop w.r.t. space weather and geo-effects.
- Publishing important findings.

Members

Klaus Börger (Germany), Chair
Mahmut Onur Karsioglu (Turkey), Vice-chair
Ehsan Forootan (Germany)
Barbara Görres (Germany)
Johannes Hinrichs (Germany)
Jürgen Matzka (Germany)
Michael Schmidt (Germany)
George Zhizhao Liu (Hong Kong, China)

JSG 0.21: Geophysical modelling of time variations in deformation and gravity

(Affiliation: Commissions 2 and 3)

Chair: Y. Tanaka (Japan)

Introduction

In recent years, the observational accuracy of ground-, satellite- and space-geodetic techniques has significantly improved which enables us to monitor temporal variations in surface deformations and gravity over various space and time scales. These variations are related to a wide range of surface and internal Earth's processes, including the deformational response to glacial loading, solid Earth and ocean tides, atmospheric and non-tidal ocean loadings, hydrological phenomena, earthquake and volcano activity, tsunamis from seismic to GIA-process frequencies. The interpretation of such high-accuracy observational data, more advanced theories are required in order to describe the individual processes and to quantify the individual signals in the geodetic data. To facilitate this, interactions between geophysical modelling and data modelling is mandatory.

Objectives

- Development of 1-D, 2-D, and 3-D elastic/anelastic Earth models for simulating the individual processes causing variations in deformation and gravity.
- Development of phenomenological or dynamic theories to treat deformation and gravity variations which cannot be described by the above earth models (e.g., hydrology, cryosphere, poroelasticity) and consideration of such effects in the above earth models.
- Theoretical study to reveal the mechanisms of the individual processes.
- Comparative study of theoretical methods using the existing codes.
- Forward and inverse modelling of deformation and gravity variations using observational data.
- Development of observational data analysis methods to extract the individual geophysical signals.

Program of activities

- To launch an e-mail list to share information concerning research results and to interchange ideas for solving related problems.
- To open a web page to share publication lists and its update.

- To hold an international workshop focusing on the above research theme.
- To have sessions at international meetings (EGU, AGU, IAG, etc.) as needed.

Members

Yoshiyuki Tanaka (Japan), Chair
David Al-Attar (UK)
Johannes Bouman (Germany)
Taco Broerse (The Netherlands)
Gabriele Cambiotti (Italy)
Benjamin Fong Chao (China-Taipei)
Jose Fernandez (Spain)
Luce Fleitout (France)
Guangyu Fu (China)
Pablo Jose Gonzales (UK)
Shin-Chan Han (Australia)
Erik Ivins (USA)
Volker Klemann (Germany)
Zdeněk Martinec (Ireland)
Masao Nakada (Japan)
Jun'ichi Okuno (Japan)
Riccardo Riva (The Netherlands)
Giorgio Spada (Italy)
Peter Vajda (Slovak Republic)
Wouter van der Wal (The Netherlands)

JSG 0.22: Definition of next generation terrestrial reference frames

(Affiliation: Commission 1 and GGOS)
(JSG 0.22 was dissolved on 2017-07-30)

Chair: C. Kotsakis (Greece)

Introduction

The Terrestrial Reference Frame (TRF) is required for measuring the Earth's orientation in space, for positioning objects at the Earth's surface as well as satellites in orbit around the Earth, and for the analysis of geophysical processes and their spatiotemporal variations. TRFs are currently constructed by sets of tri-dimensional coordinates of ground stations, which implicitly realize the three orthogonal axes of the corresponding frame. To account for Earth's deformations, these coordinates have been commonly modelled as piece-wise linear functions of time which are estimated from space geodetic data under various processing strategies, resulting to the usual type of geodetic frame solutions in terms of station coordinates (at some reference epoch) and constant velocities. Most recently, post-seismic deformation has been added as well in geodetic frame solutions. The requirements of the Earth science community for the accuracy level of such secular TRFs for present-day applications are in the order of 1 mm and 0.1 mm/year, which is not generally achievable at present. Improvements in data analysis models, coordinate variation models, optimal estimation procedures and datum definition choices (e.g., NNR conditions) should still be investigated in order to enhance the present positioning accuracy under the "linear" TRF framework.

Moreover, the consideration of seasonal changes in the station positions due to the effect of geophysical loading signals and other complex tectonic motions has created an additional interest towards the development of "non-linear" TRFs aiming to provide highly accurate coordinates of the quasi-instantaneous positions in a global network. This approach overcomes the limitation of global secular frames which model the average positions over a long time span, yet it creates significant new challenges and open problems that need to be resolved to meet the aforementioned accuracy requirements.

The above considerations provide the motivation for this JSG whose work will be focused to studying and improving the current approaches for the definition and realization of global TRFs from space geodetic data, in support of Earth mapping and monitoring applications. The principal aim is to identify the major issues causing the current internal/external accuracy limitations in global

TRF solutions, and to investigate ways to overcome them either in the linear or the non-linear modeling framework.

Objectives

- To review and compare from the theoretical point of view the current approaches for the definition and realization of global TRFs, including data reduction strategies and frame estimation methodologies.
- To evaluate the distortion caused by hidden datum information within the unconstrained normal equations (NEQs) to combination solutions by the "minimum constraints" approach, and to develop efficient tools enforcing the appropriate rank deficiency in input NEQs when computing TRF solutions.
- To study the role of the 7/14-parameter Helmert transformation model in handling non-linear (non-secular) global frames, as well as to investigate the frame transformation problem in the presence of modeled seasonal variations in the respective coordinates.
- To study theoretical and numerical aspects of the stacking problem, both at the NEQ level and at the coordinate time-series level, with unknown non-linear seasonal terms when estimating a global frame from space geodetic data.
- To compare the aforementioned methodology with other alternative approaches in non-linear frame modeling, such as the computation of high-rate time series of global TRFs.
- To investigate the modeling choices for the datum definition in global TRFs with particular emphasis on the frame orientation and the different types of no-net-rotation (NNR) conditions.

Program of activities

- Active participation at major geodetic meetings, promotion of related sessions at international scientific symposia and publication of important findings related to the JSG objectives.
- Proposal for a state-of-art review paper in global frame theory, realization methodologies and open problems, co-authored by the JSG members.
- Organize a related session at the forthcoming Hotine-Marussi Symposium.
- Launching a web page with emphasis on exchange of research ideas, recent results, updated bibliographic list of references and relevant publications from other disciplines.

Members

Christopher Kotsakis (Greece), Chair
Zuheir Altamimi (France)
Michael Bevis (USA)
Mathis Bloßfeld (Germany)
David Coulot (France)
Athanasios Dermanis (Greece)
Richard Gross (USA)
Tom Herring (USA)
Michael Schindelegger (Austria)
Manuela Seitz (Germany)
Krzysztof Sośnica (Poland)