Inter-Commission Committee on Theory (ICCT)

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President: Mattia Crespi (Italy)
Vice President: Amir Khodabandeh (Australia)
Past President: Pavel Novák (Czech Republic)

ICCT website - www.icct.iag-aig.org

1 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, Projects 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 consequently,
(ii) 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 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.

1.1 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 the objectives, the ICCT interacts and collaborates with other IAG entities (Commissions, Services, GGOS, other ICCs, Projects).

1.2 Program of Activities

The ICCT's program of activities include:

- participation as (co-)conveners of geodesy sessions at major conferences, such as IAG Assemblies, EGU General Assemblies and AGU Meetings,
- organization of Hotine-Marussi Symposia,
- initiation of summer schools on theoretical geodesy,
- and maintaining a website (http://icct.iag-aig.org) for dissemination of ICCT related information.

1.3 Structure

The structure of Inter-Commission Committees (ICCs) is specified in the IAG by-laws. The ICCT Steering Committee consists of the President, Vice President, Past President, representatives from each of the IAG Commissions, Services, GGOS, other ICCs (ICCC, ICCM), Projects (QuGe), Early Career Scientists (ECSs) and two Members-at-Large. ICCT activities are undertaken by Joint Study Groups (JSGs), affiliated to two or more IAG entities.

1.4 Steering Committee

The Steering Committee will usually meet once per year.

- President: Mattia Crespi (Italy)
- Vice President: Amir Khodabandeh (Australia)
- Past President: Pavel Novák (Czech Republic)

Representatives of IAG entities

- Commission 1: Paul Rebischung (France)
- Commission 2: Robert Tenzer (China-Hong Kong)
- Commission 3: Janusz Bogusz (Poland)
- Commission 4: Katarzyna Stępniak (Poland)
- Services - IGFS: Riccardo Barzaghi (Italy)
- Services - IERS: Geoffrey Blewitt (USA)
- GGOS: Michael Schmidt (Germany)

- ICCC: Marius Schlaack (Germany)
- ICCM: Shun-ichi Watanabe (Japan)
- QuGe: Jakob Flury (Germany)

Members-at-Large

- Laura Fernandez (Argentina)
- Yap Loudi (Cameroon)

Representative of Early Career Scientists

- Michela Ravanelli (Italy)

1.5 Overview of Joint Study Groups

Hereafter, the ICCT Joint Study Groups (JSGs) for the 2023-2027 period are listed, together their Chairs (and Vice-Chairs, for some of them) and their affiliations with other IAG entities.

JSG T.38 Exploring the similarities and dissimilarities among different geoid/quasi-geoid modelling techniques in view of cm-precise and cm-accurate geoid/quasigeoid
Chair: Ropesh Goyal (India)
Vice-Chair: Sten Claessens (Australia)
Affiliations: Commission 2, IGFS

JSG T.39 Gravitational field modelling and analysis for oblate and prolate planetary bodies
Chair: Michal Šprlák (Czech Republic)
Affiliations: Commission 2, ICGEM

JSG T.40 Modelling the gravity field of irregularly shaped celestial bodies
Chair: Zhi Yin (China)
Affiliations: Commissions 1,2, IGFS

JSG T.41 Geodetic quality/integrity modelling, monitoring and design
Chair: Safoora Zaminpardaz (Australia)
Affiliations: Commissions 1,2,3,4

JSG T.42 Theoretical developments and applications of combined methods for a better understanding of the Earth's lithospheric formation, structure, and dynamics
Chair: Robert Tenzer (China-Hong Kong)
Affiliations: Commissions 2,3

JSG T.43 Statistical methods in regional gravity field modelling
Chair: Mehdi Eshagh (Czech Republic)
Affiliations: Commissions 1,2, IGFS

JSG T.44 Atmospheric coupling studies
Chair: Andres Calabia Aibar (Spain)
Vice-Chair: Binod Adhikari (Nepal)
Affiliations: Commission 4, GGOS (GSWR)

JSG T.45 Dynamic gravity modelling of given distributions
Chair: Dimitrios Tsoulis (Greece)
Affiliations: Commissions 2,3

JSG T.46 Deformation, rotation and gravity field modeling for Earth and space
Chair: Yoshiyuki Tanaka (Japan)
Affiliations: Commissions 2,3

JSG T.47 Height datum: Definition, New Concepts, and Standardization
Chair: Xiaopeng Li (USA)
Vice-Chair: Marcelo Santos (Canada)
Affiliations: Commission 2, IGFS

JSG T.48 Theoretical Foundations of Machine and Deep Learning in Geodesy
Chair: Lotfi Massarweh (The Netherlands)
Vice-chair: Mostafa Kiani Shahvandi (Switzerland)
Affiliations: Commissions 2,3,4, GGOS (AI4G)

JSG T.49 High-resolution probing of the troposphere and ionosphere
Chair: Michela Ravanelli (Italy)
Affiliations: Commission 4, GGOS (Geohazards Monitoring, GSWR)

JSG T.50 High-precision GNSS theory and algorithms
Chair: Dimitrios Psychas (The Netherlands)
Affiliations: Commissions 1,4

2 Joint Study Groups

JSG T.38: Exploring the similarities and dissimilarities among different geoid/quasigeoid modelling techniques in view of cm-precise and cm-accurate geoid/quasigeoid

Chair: Ropesh Goyal (India)
Vice-Chair: Sten Claessens (Australia)
Affiliations: Commission 2, IGFS

Terms of Reference

It is over 170 years since George Gabriel Stokes published his seminal formula for geoid determination using gravity anomalies. The formula was derived in spherical approximation and is valid under some well-known assumptions. Since then, geoid modelling has revolved more or less around handling these assumptions. As a result, there are now various geoid and quasigeoid computation methods of both types, i.e., methods with and without requiring the Stokes integration. However, despite this long-elapsed time, the determination of a cm-precise and/or cm-accurate geoid and quasigeoid remains an ongoing quest, although it has been achieved in a few studies.

With the computation of cm-precise and/or cm-accurate geoid, a supposition can be formed that solutions from different geoid modelling methods should converge within a given threshold, with an ideal threshold value being one-cm. The rationale is that, for a region, all the methods can be used to calculate the geoid using the same data and underlying theory. Still, methods differ primarily due to different handling of the data, and assumptions and approximations. Different methods provide different solutions due to many aspects including but not limited to: 1. different modifications of Stokes's kernel, 2. different prediction/interpolation/extrapolation methods for non-Stokes integrating geoid modelling methods, 3. use of geodetic versus geocentric coordinates, 4. different Global Geopotential Models, 5. different gridding and merging techniques, 6. different parameter sweeps (integration radius and kernel modification degree), and 7. different handling of topography, atmosphere, spherical approximation, and downward continuation.

Given these possible sources for differences in geoid models, it becomes inevitable to first create a rigorous definition of a "cm-precise" and "cm-accurate" geoid followed by a comparative study of intermediate steps of different geoid modelling methods, in addition to comparing only the final results from different methods separately. Comparative study of intermediate steps is essential given the fact that if using the same datasets in different methods, it is expected to have geoid differences less than one cm when the methods are designed to take into account all effects greater than one cm.

Further, in view of cm-precise and/or cm-accurate geoid, it is important to compare multiple methods and parameter sweeps in different areas. This is because it would form an ideal strategy for a consistently precise/accurate geoid model. The difference between the precise geoid and consistently precise geoid is that the precision, in the latter, should be preserved when a geoid model is validated region-wise in addition to the validation with the complete ground truth. Otherwise, cm-precise geoid may have limited meaning.

Objectives

- Develop a statistical definition of cm-precise and cm-accurate geoid/quasi-geoid.
- Study and quantify the differences in handling the topography, atmosphere, ellipsoidal correction, and downward continuation in different geoid/quasigeoid modelling methods.
- Study, quantify and reduce the assumptions and approximations in different geoid modelling methods to attain congruency within some threshold.
- Study the requirement for merging various components/steps of different geoid modelling methods.
- Develop external validation techniques to determine region- or nationwide consistency in precision and accuracy of developed geoid/quasigeoid models.

Program of Activities

- Presenting research findings at major international geodetic conferences, meetings, and workshops.
- Preparation of joint publications with JSG members.
- Organizing a session at the Hotine-Marussi Symposium 2026.
- Organizing splinter meetings at major international conferences and a series of online workshop.
- Supporting and cooperating with IAG commissions, services, and other study and working groups on gravity modelling and height systems.

Members

Ropesh Goyal (India); Chair
Sten Claessens (Australia); Vice-Chair
Ismael Foroughi (Canada)
Jonas Ågren (Sweden)
Xiaopeng Li (USA)
Bihter Erol (Turkey)
Jack McCubbine (Australia)
Pavel Novák (Czech Republic)
Koji Matsuo (Japan)
Riccardo Barzaghi (Italy)
Michal Šprlák (Czech Republic)
Jianliang Huang (Canada)
Yan-Ming Wang (USA)
Cheinway Hwang (China-Taipei)
Neda Darbeheshti (Australia)

Associate Members

Jack McCubbine (Australia)

JSG T.39: Gravitational field modelling and analysis for oblate and prolate planetary bodies

Chair: Michal Šprlák (Czech Republic)
Affiliations: Commission 2, ICGEM

Terms of Reference

Gravitation belongs to the four known fundamental physical interactions and represents a crucial quantity reflecting the state of attracting masses. Its knowledge stands at the core of important applications, e.g., 1) establishing planetary reference systems for positioning and predicting orbits of artificial satellites in geodesy; 2) studying inner structures, (sub-)surface processes, and thermal evolutions of planetary bodies in geophysics and planetary sciences; 3) detecting mass transport for understanding climate change and mechanisms of natural hazards in environmental sciences; or 4) navigating terrestrial or space vehicles in transport, military and space exploration. In general, gravitation is indispensable for advancing science, industry, and research; and for addressing a broad range of societal issues, such as sustainable energy, environmental aspects, or infrastructure development.

The science of determining gravitational fields at macroscales is called physical geodesy. This intriguing subject has been an inherent component of the International Association of Geodesy (IAG) and is officially considered one of main pillars of the modern geodetic research. The current status of physical geodesy may even be understated as countless scientists take numerous key products, i.e., static and time-variable gravitational fields, for granted and access them freely from IAG international services, e.g., the International Centre for Global Earth Models (ICGEM), International Gravimetric Bureau, International Gravity Field Service and International Service for the Geoid, as well as from ESA's Planetary Science Archive or NASA's Planetary Data System Geoscience Node.

The international services and their products originate from an intricate modelling. This non-trivial process essentially combines these three key components:

- Experimental data are geometric, gravitational, and auxiliary measurements collected by various sensors. For the Earth, these data originate from an ultimate infrastructure of the IAG called the Global Geodetic Observing System.
- Methodology is the underlying mathematical apparatus. Physical geodesy employs potential theory by studying and advancing boundary-value problems (BVPs), integral transformations and equations, and forward modelling of potential fields. Alternatively, statistical methods, e.g., the least-squares collocation, have been developed.
- Computational tools are elements of discrete mathematics and computer science, e.g., numerical methods and algorithms, software, and hardware.

The standard conceptual framework for the gravitational field determination by potential theory often relies on spherical approximation. Nevertheless, as proved by the expeditions of the French Academy of Sciences to South America and Lapland already in the 18th century, Earth's shape is much closer to a rotational ellipsoid flattened at the poles (flattening $\approx 1/298$). Contemporary investigations of solar system planetary bodies have revealed that many resemble prolate or oblate ellipsoids with many of them flattened more significantly than the Earth. Four such spheroidal bodies have recently been of an immense research interest: 1) Mars (flattening $\approx 1/170$) being intensely explored by satellite and lander missions as it represents a potential target for future colonisation, 2) the asteroid Bennu (flattening $\approx 1/8.5$) explored by the sample-return satellite mission OSIRIS-REx, 3) the dwarf planet Ceres (flattening $\approx 1/13.4$), and 4) the asteroid Vesta (flattening $\approx 1/5.7$), both explored by the satellite mission Dawn. In addition, several comets and asteroids with spheroidal (ellipsoidal) shapes have been subject to an intense small body research. Thus, there is an urgent need for formulating a modern conceptual framework for the gravitational field determination.

Objectives

- To complete the class of spheroidal integral transformations relating various types of gravitational data.
- To derive the mathematical theory for the spheroidal forward modelling in the spatial and in the spectral domain.
- To propose a rigorous method for estimating surface mass variations for flattened planetary bodies.
- To develop efficient and accurate software tools for the spheroidal gravitational field modelling.

Program of Activities

- To cooperate with related IAG entities (Commission 2, ICGEM).

- To present research findings at geodetic and geophysical conferences.
- To monitor research activities of JSG members and of other scientists, whose research interests are related to the scopes of JSG.
- To organise a session at Hotine-Marussi Symposium 2026.

Members

Michal Šprlák (Czech Republic); Chair
Blažej Bucha (Slovakia)
Sten Claessens (Australia)
Mehdi Eshagh (Sweden)
Khosro Ghobadi-Far (USA)
Elmas Sinem Ince van der Wal (Germany)
Martina Idžanović (Norway)
Pavel Novák (Czech Republic)
Vegard Ophaug (Norway)
Georgios Panou (Greece)
Martin Pitoňák (Czech Republic)
Mahdiyeh Razeghi (Australia)
Natthachet Tangdamrongsub (Thailand)

JSG T.40: Modelling the gravity field of irregularly shaped celestial bodies

Chair: Zhi Yin (China)
Affiliations: Commissions 1,2, IGFS

Terms of Reference

Deep space exploration missions such as the past (e.g., ROSETTA and Hayabusa), present (e.g. OSIRIS-REx) and planned missions (e.g., HERA, Psyche, MMX, and Chang'e-2) will significantly change the way how we understand and utilize the solar system. In deep space exploration activities, the modelling of the targeted extraterrestrial bodies' gravity fields is an important work. However, unlike the sphere-like Earth, small solar system bodies like asteroids and comets are usually irregularly shaped in geometry, making the so-called complex-boundary value problems (CBVPs) of them more challenging than the geodetic boundary value problem (GBVP) of the Earth. For instance, the divergence problem of the spherical harmonic expansion in the CBVP is more complicated than that in the GBVP. To some extent, the small solar system bodies' CBVPs can be treated as extreme cases of the Earth's GBVP, and theories and methods for solving the CBVP can be applied to the GBVP in a downwardly compatible way.

One aim of this JSG is to investigate, develop and verify new theories and methods on solving the irregularly shaped celestial bodies' CBVPs. It mainly focuses on the potential flow theory regarding a gravitational vector field as an equivalent potential-flow velocity field. In this way, the gravitational vector field is mapped onto a potential-flow velocity field, and the CBVP is able to be made amenable to off-the-shelf computational fluid dynamics (CFD) techniques. The other aim of this JSG is to investigate fast-computing integration techniques for modelling irregularly shaped celestial bodies' gravity fields in either spatial or frequency domain. It is an extension of the fast integration algorithms for the Earth's gravity field, allowing efficient assessments on the asteroids' or comets' gravity field solutions derived from the potential flow theory.

This JSG is open to the investigation on the highly nonlinear structure of an irregularly shaped celestial body's gravity field, in terms of equipotential surfaces, plumb lines or gravity tensors. It is also open to the research of irregularly shaped celestial bodies' surface environment simulations based on their gravity field models, such as the deep-space data processing, the gravity field visualization, the height system definition, the geophysical analysis, etc.

Objectives

- Develop and study new CBVP-solving theories and methods for modelling irregularly shaped celestial bodies' gravity fields.
- Investigate the innovative gravity field modelling approaches based on the potential flow theory and the numerical computation techniques.
- Develop fast-computing algorithms as well as parallel computation techniques for integrating an irregularly shaped celestial body's gravity field, in either space or frequency domain.
- Compare systematically the gravity fields calculated by CFD techniques and harmonic series expansions inside Brillouin surfaces.
- Investigate the highly nonlinear structure of an irregularly shaped celestial body's gravity field, via equipotential surfaces, plumb lines or high-order gravity tensors, by using the above new gravity field modelling theories and methods.
- Investigate the interior structure like the density distribution of an irregularly shaped celestial body by analyzing its exterior gravity field model.
- Develop a web-based or stand-alone software for visualizing and analyzing an irregularly shaped celestial body's gravity field, based on the Geographic Information System (GIS) technology.

Program of Activities

- Presenting findings at international geodetic conferences, meetings and workshops.
- Organizing working meetings at international symposia.
- Organizing sessions at international meetings and workshops (EGU, AGU, IAG, Hotine-Marussi Symposium, etc.) as needed.
- Releasing a webpage or a stand-alone software for cataloguing, visualizing and analyzing the irregularly shaped celestial body's gravity field.

Members

Zhi Yin (China); Chair
Michal Šprlák (Czech Republic)
Biao Lu (Denmark)

Zuzana Minarechová (Slovakia)
Marek Macák (Slovakia)
Xiaole Deng (Germany)
Junsheng Liu (China)
Georgia Gavriilidou (Greece)
Yabo Duan (China)
Leyuan Wu (United Kingdom)
Blažej Bucha (Slovakia)
Qinglu Mu (China)
Dimitrios Tsoulis (Greece)
Kefei Zhang (China)
Nico Sneeuw (Germany)

JSG T.41: Geodetic quality/integrity modelling, monitoring and design

Chair: Safoora Zaminpardaz (Australia)
Affiliations: Commissions 1,2,3,4

Terms of Reference

Geodetic observations are essential for a variety of applications including positioning, surveying and mapping, deformation monitoring, establishing reference frames, modelling the Earth's gravitational field, and atmospheric studies. Although, often, there exist well-established mathematical models (null hypothesis) used to estimate application-dependent parameters based on these observations, geodetic data is subject to a series of vulnerabilities, which, if passed unnoticed, make the mathematical model misspecified, thus deteriorating the reliability of the estimation results. Therefore, it is crucial to implement quality control and integrity monitoring mechanisms to ensure that the results produced by the estimation process meet the requirements of the application at hand. This can be achieved through combining parameter estimation with a statistical testing procedure aimed at finding the most likely model misspecification (multiple alternative hypotheses).

In combining estimation with testing, the outcome of testing determines how the parameters of interest get estimated. Therefore, the estimator that is outputted by combined estimation-testing schemes will inherit the characteristics of both the estimation and testing process. However, the customary procedure followed in practice often does not consider the impact of testing on estimation, thus providing faulty quality descriptions. This highlights the need to conduct comprehensive research on the individual elements and their interplay that influence geodetic quality control and integrity monitoring, with the aim of facilitating the development of tailored quality control procedures that are optimal for specific applications.

Objectives

- Characterize the link between statistical testing and parameter estimation in geodetic data processing.

- Develop rigorous quality indicators for the output of combined estimation-testing schemes including confidence region, confidence level and integrity risk.
- Investigate challenges, posed by testing multiple alternative hypotheses of different dimensions.
- Design optimal estimation-testing schemes the output of which meets application-dependent requirements.
- Develop computationally-efficient algorithms for evaluating the quality of the output of combined estimation-testing schemes.
- Disseminate the developed algorithms and numerical results through journals and conference proceedings.

Program of Activities

- Presenting research findings at international geodetic conferences, meetings and workshops.
- Interacting with other IAG entities.
- Monitoring research activities of JSG members and other scientists whose research interests are related to scopes of this JSG.
- Organizing working meetings at international symposia.
- Organizing a session at the Hotine-Marussi Symposium 2026.

Members

Safoora Zaminpardaz (Australia); Chair
Jinling Wang (Australia)
Vinicius Francisco Rofatto (Brazil)
Krzysztof Nowel (Poland)
Cemal Özer Yiğit (Turkey)
Zhetao Zhang (China)
Ling Yang (China)
Carlos Fortuny Lombraña (Netherlands)
Christian Lisdat (Germany - QuGe representative)

JSG T.42: Theoretical developments and applications of combined methods for a better understanding of the Earth's lithospheric formation, structure, and dynamics

Chair: Robert Tenzer (China-Hong Kong)
Affiliations: Commissions 2,3

Terms of Reference

The Earth's lithosphere is a rigid, outer layer of the Earth, consisting of the oceanic and continental parts. The origin, formation, and geological history of the oceanic and continental lithosphere differ significantly. Whereas a relatively homogenous structure of the oceanic lithosphere is mainly controlled by its thermal state and mantle flow dynamics, the formation of a much more complex structure of the continental lithosphere involved early stages of the Earth's cooling, the supercontinent cycle associated with the global tectonics, and many other geological processes. The study of the lithospheric structure and dynamics is essential for several scientific, societal, and economic aspects including the mitigation of natural hazard, the exploration of natural resources and geothermal energy, and the understanding of its influence on the Earth's climate and environmental changes.

Seismic, gravity, magnetic, and heat flow data have mainly been used to investigate the Earth's lithospheric structure. Seismic tomography (especially surface waves) and seismic reflection and refraction experiments provide images of the Earth's inner structure, importantly of density interfaces (such as the sediment basements, crust-mantle boundary (commonly called Moho), and lithosphere-asthenosphere boundary). Seismic velocities could also be inverted for density and temperature, and seismic attenuation and seismic anisotropy are correlated with temperature and strain, respectively. Global heat flow measurements help constrain the lithospheric geothermal gradient and the Earth's energy budget. Magneto-telluric studies image the Earth's electrical conductivity. Gravity field manifests the Earth's density structure and this information is used in studies of isostasy, lithospheric stresses, basement morphology, seafloor relief, or lithospheric elastic thickness.

Over the last few decades, the amount of these geophysical and geodetic data increased exponentially. Gravity dedicated satellite missions, for example, provide the information about the Earth's gravitational field and its changes globally with a relatively high accuracy and resolution. The satellite altimetry measurements provide information about the sea level topography and have been used to determine marine gravity data that are further used to predict the seafloor relief. The Global Navigation Satellite Systems (GNSS) together with the Interferometric Synthetic Aperture Radar (InSAR) techniques have been essential in monitoring tectonic motions, ground deformations, and changes in glacier cover. The Very Long Baseline Interferometry (VLBI) and other space geodetic techniques have been providing extremely accurate information on the tectonic motions and the parameters of the Earth's rotation and orientation, defined by the Earth's orientation parameters (EOPs), namely the polar motion, precision-nutation, universal time (UT1), and the length of day.

The substantial achievement in improved quality and increased amount of geophysical and geodetic data allows us to better understand the Earth's lithospheric structure and dynamics as well as its relationship with other geoscientific studies (such as the relationship between the tectonic configuration and the oceanic-atmospheric circulation). Until now several theoretical models and methodologies have been developed and practically applied in modelling and prediction of various geophysical, geological, geochemical, and environmental phenomena that are related to the lithospheric structure and processes. The substantial improvement of geophysical and geodetic data obviously offers a unique opportunity to develop and apply new methods that allow us to better understand already known as well as identify new phenomena and relationships in geosciences.

In the context of the current and future development, the focus of this study group is to develop and apply methods for a better understanding of the Earth's lithospheric formation, structure, and dynamics based on joint processing of various geodetic and geophysical data and constraining information. We expect that our research activities will substantially contribute to the current knowledge of the lithospheric structure and processes, including but not limited to the compensation stage of the crust/lithosphere, the lithospheric strength, mechanisms behind the oceanic subduction, the relation between the mantle convection pattern and the global tectonic configuration (and its spatiotemporal variations), and influence of the lithospheric structure on EOPs. Among specific topics of a high interest a novel research question is the influence of the global tectonic configuration (involving not only the continental and oceanic configuration but essentially also the lithospheric thickness) and the lithosphere-asthenosphere interaction on the EOPs. In this context we will also conduct geodynamic studies to investigate the difference in polar motion between an observation-based terrestrial reference frame and Tisserand's mean axes of the body (i.e., a mean mantle reference frame). The members of this study group will address some of these aspects within the following overall objectives.

Objectives

- Improvement of (regional and continental-scale) lithospheric density models based on combining geodetic and geophysical data and additional geological constraining information, focusing on regions with insufficient seismic data coverage.
- Development of a preliminary global density model of the mantle below the lithosphere-asthenosphere boundary based on the combined analysis of seismic and gravity data, focusing on the seismic data conversion to mass densities within the gravimetric inversion scheme constrained by geothermal, geochemical, geodynamic, and other information.
- Contributing to a better understanding of the interaction between the mantle dynamics and tectonic motions.
- Improvement of the supercontinent cycle models.
- Study of the influence of the lithospheric structure and dynamics on EOPs.
- Study of the sea surface changes and its relation with the global climate change

Program of Activities

- Presenting research findings at major international geodetic or geophysical conferences, meetings, and workshops.
- Interacting with related IAG Commissions.
- Monitoring research activities of JSG members and of other scientists, whose research interests are relevant to the scopes of JSG.
- Providing a bibliographic list of publications from different branches of science relevant to JSG scopes.
- Organizing a session at the Hotine-Marussi Symposium 2026.

Members

Robert Tenzer (China-Hong Kong); Chair
Mohammad Bagherbandi (Sweden)
Mirko Reguzzoni (Italy)

Aleksej Baranov (Russia)
Franck Ghomsi (Cameroon)
Wenjin Chen (China)
Mehdi Eshagh (Sweden, Czech Republic)
Jianli Chen (China-Hong Kong)
Luan Thanh Pham (Vietnam)
Rebekka Steffen (Sweden)
Jose Manuel Ferrandiz Leal (Spain)
Bernhard Steinberger (Germany)

JSG T.43: Statistical methods in regional gravity field modelling

Chair: Mehdi Eshagh (Czech Republic)
Affiliations: Commissions 1,2, IGFS

Terms of Reference

These days, owing to significant advancements in sensor technology, vast amounts of precise data are being collected. Physical Geodesy is undergoing a modernisation process, largely due to the integration of highly precise data sensors, such as those based on quantum technology. Statistical methods have become an integral tool in contemporary Physical Geodesy dedicated to the measurement and comprehension of the Earth's shape, gravity field, and dynamic processes that shape our planet's surface. Given the intricate and variable nature of geodetic data, acquired from diverse sources like satellite missions, ground-based observations, and remote sensing, the need for advanced statistical techniques has become apparent. These techniques enable the accurate analysis and interpretation of this wealth of information. In this context, statistical methods serve not only to describe and model geodetic data but also to quantify uncertainties of geodetic solutions and to evaluate their reliability.

The primary objective of Physical Geodesy is to model the geoid and gravity field of the Earth, for which numerous methods have been developed. However, less attention has been given to providing a comprehensive quality description of the products of Physical Geodesy from a statistical perspective. In many instances, these products are validated using independent data to gain insights into their quality. While attempts have been made to estimate uncertainties in global gravity models, which typically result from least-squares estimation processes, less emphasis has been placed on assessing the internal quality of results, especially when dealing with local gravity field or geoid modelling. Statistical tests play a crucial role in justifying and distinguishing gravitational signals from the noise generated by various measurement tools, including terrestrial, marine, airborne, or satellite sensors. Therefore, more in-depth investigations into downward continuation, regularisation methods, least-squares collocation, variance-covariance component estimation, time-series analysis, and robust statistics, are necessary to handle data collected by modern sensors and extract valuable insights regarding Earth's gravity field modelling.

These studies extend beyond gravity field modelling and encompass applications in other disciplines such as Oceanography, Hydrology, Geophysics, as well as space and planetary science. The scope of this study group also involves the development of statistical methods for quality assessment in other relevant disciplines.

Objectives

- Investigate the propagation of errors arising from all gravimetric measurements to enhance the accuracy of Physical Geodesy products.
- Investigate the accuracy of determining the (high-frequency) gravity field and international vertical reference frame, considering the stochastic characteristics of regional gravity data (including surface, shipborne, altimetry-based, airborne, etc.).
- Assess the level of precision required in measured data to achieve a specified quality in the resulting Physical Geodesy products.
- Do research and develop various inversion and regularisation methods endowed with stochastic properties, thereby advancing the precision of geodetic solutions, specifically for integral equations in downward continuation.
- Develop variance-covariance component estimation techniques to provide comprehensive quality descriptions and facilitate the optimal integration of gravimetric data and products such as geoid models and heights.
- Extend the horizons of least-squares collocation techniques, exploring further developments and applications to refine geodetic computations.
- Enhance and refine spectral combination methods with a focus on error estimation, ensuring robust and reliable geodetic results.
- Statistically analyse of time-variable global and local gravity field products and their applications.

Program of Activities

- Presenting findings at international geodetic or geophysical conferences, meetings, and workshops.
- Interacting with other IAG entities.
- Monitoring research activities of JSG members and other scientists whose research interests are related to scopes of this JSG.
- Organising a session at the Hotine-Marussi Symposium 2026.

Members

Mehdi Eshagh (Czech Republic); Chair
Michal Šprlák (Czech Republic)
Juraj Janák (Slovakia)
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Riccardo Barzaghi (Italy)

Robert Tenzer (China-Hong Kong)
Dimitrios Tsoulis (Greece)
Ismael Foroughi (Canada)
Majid Abrehdary (Sweden)
Petr Vaníček (Canada)
Ling Yang (China)
Ryan A. Hardy (USA)

JSG T.44: Atmospheric coupling studies

Chair: Andres Calabia Aibar (Spain)
Vice-Chair: Binod Adhikari (Nepal)
Affiliations: Commission 4, GGOS (GSWR)

Terms of Reference

We are a dedicated team of academics, researchers, and scientists committed to enhancing our understanding of the interactions between solar wind and Earth, including the coupling processes within the magnetosphere, thermosphere, and ionosphere. Our work involves conducting comprehensive simulations of solar wind to understand its characteristics and variability, and studying the effects of solar wind on Earth's upper atmosphere. We are also focused on developing predictive models to forecast these effects, which can help mitigate potential detrimental effects on orbiting, aerial, and ground-based technologies.

In addition to our research, we believe in the power of collaboration and knowledge sharing. We plan to create a platform for sharing data and model products that are freely available for the scientific community. We also strive to enhance international cooperation by sharing knowledge and research tools, co-supervising theses, and helping to improve manuscripts. We are excited about the journey ahead and look forward to making significant contributions to the scientific community.

Objectives

The primary objective of the JSG is to enhance our understanding of the interactions between solar wind and Earth, including the coupling processes within the magnetosphere, thermosphere, and ionosphere. This will be achieved through the study of solar wind simulations and the effects of solar wind on Earth's upper atmosphere.

The scope of the JSG includes but is not limited to:

- Atmosphere Coupling: Investigating the effects of solar wind on Earth's upper atmosphere. This includes studying the coupling processes within the magnetosphere, thermosphere, and ionosphere.
- Solar Wind Simulations: Conducting comprehensive simulations of solar wind to understand its characteristics and variability. This includes studying the effects of solar wind on the magnetosphere, thermosphere, and ionosphere
- Predictive Modelling: Developing predictive models to forecast the effects of solar wind on Earth's upper atmosphere. This will help in mitigating the potential detrimental effects on orbiting, aerial, and ground-based technologies.

- Data Sharing: Creating a platform for sharing data and model products that are freely available for the scientific community. This will foster collaboration and accelerate research in this field.
- International Cooperation: Enhancing international cooperation by sharing knowledge and research tools, co-supervising theses, and helping to improve manuscripts.

Program of Activities

- Presenting findings at international geodetic or geophysical conferences, meetings, and workshops.
- Interacting with other IAG entities.
- Monitoring research activities of JSG members and other scientists whose research interests are related to scopes of this JSG.
- Organising a session at the Hotine-Marussi Symposium 2026.

Members

Andres Calabia Aibar (Spain); Chair
Binod Adhikari (Nepal); Vice-Chair
Yury Yasyukevich (Russia)
Anoruo Chukwuma (Nigeria)
Munawar Shah (Pakistan)
Astrid Maute (USA)
Gang Lu (USA)
Naomi Maruyama (USA)
Christine Amory-Mazaudier (France)
Ayomide Olabode (Germany)
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Virginia Klausner de Oliveira (Brazil)
Yan Xiang (China)
Ashok Silwal (Nepal)
Mohamed Ahmed Ahmed Freeshah (Egypt)

JSG T.45: Dynamic gravity modelling of given distributions

Chair: Dimitrios Tsoulis (Greece)
Affiliations: Commissions 2,3

Terms of Reference

Forward gravity field modelling is a core topic in geodetic theory. The geometrical definition of the shape and the numerical evaluation of the corresponding gravity signal of a known mass distribution is an indispensable tool for gravity modelling and interpretation studies at different scales. Involving different theoretical and computational strategies of potential field theory and including the comparison of the computed signal with the observed gravity field, the specific research topic determines a characteristic interface between geodesy and geophysics.

The computation of precise terrain effects, gravity anomalies and geoid, the downward continuation of satellite data, or solving for an extended family of integral equations of potential theory are only some of the most common applications. Directly correlated with the real density distributions in the Earth's interior, the evaluation of the gravitational potential of a given distribution and its spatial derivatives up to higher orders is the shared objective.

The availability of an abundance of terrestrial and satellite data of global coverage and increasing spatial resolution provides a challenging background for revisiting known theoretical aspects and especially investigating the computational limits and possibilities of forward gravity modelling induced by known mass distributions. Satellite observations provide global grids of gravity related quantities at satellite altitude, global crustal databases offer detailed layered information of the shape and consistency of the Earth's crust, while satellite methods produce Digital Elevation Models that represent the continental part of the topographic surface with unprecedented resolution.

At the same time, in the era of dedicated satellite gravity missions, one of the most prominent research objectives for the scientific exploitation of current and future satellite data is capturing real mass changes in the Earth's interior. These mass balance studies, related, for example, to the water cycle or seismic activity, are linked to the gravity signal of specific distributions.

In this context, the complete theoretical framework that evaluates the gravity effect of a given distribution using analytical or numerical techniques emerges again at the forefront of research interest, examining both ideal bodies and real distributions. Thereby, of special interest is the ability to evaluate numerically the spherical harmonic coefficients for the gravitational potential of a finite source, thus providing a bandlimited spectral input for the observed gravity signal. Variations in the numerical values of these coefficients can also be obtained by algorithms that arise from a stochastic procedure, enabling an association with the corresponding observed mass changes. In this manner the task in question is reformulated to a dynamic gravity signal evaluation procedure, that can be tailored to real phenomena.

Objectives

- Examine new theoretical developments (numerical or analytical) in expressing the gravity signal of ideal geometric distributions
- Implement and validate different techniques for the evaluation of potential spherical harmonic coefficients for finite three dimensional sources
- Revisit and expand the stochastic approach for spherical harmonics evaluation of given sources
- Perform forward gravity modelling validation studies at different scales, using the available high resolution digital elevation models and focusing on optimization methods that reduce the high computational load and take the accuracy estimates of the input data into account
- Compute the gravity effect of structures in the Earth's interior and embed this effort in the frame of mass change and mass balance problems

Program of Activities

- Participation in forthcoming IAG conferences with splinter meetings and proposed sessions
- Preparation of joint publications with the JSG members
- Organising a session at the Hotine-Marussi Symposium 2026

Members

Dimitrios Tsoulis, (Greece); Chair
Judit Benedek, (Hungary)
Georgia Gavriilidou, (Greece)
Christian Gerlach, (Germany)
Ropesh Goyal, (India)
Michael Kuhn, (Australia)
Pavel Novák, (Czech Republic)
Paolo Panicucci, (Italy)
Gábor Papp, (Hungary)
Alberto Pastorutti, (Italy)
Daniele Sampietro, (Italy)
Matej Varga, (Switzerland)
Jérôme Verdun, (France)

JSG T.46: Deformation, rotation and gravity field modeling for Earth and space

Chair: Yoshiyuki Tanaka (Japan)
Affiliations: Commissions 2,3

Terms of Reference

Measurements of deformation, rotation and gravity field are the three pillars of modern geodesy and the Global Geodetic Observation System (GGOS). To interpret the measured temporal variations by the GGOS, various geophysical phenomena have been dynamically modelled. The spatiotemporal resolution of recent space geodetic observations has improved dramatically. This trend is expected to continue through an increase in the number of GNSS and InSAR satellites and ground stations including those operated by private companies as well as planned satellite gravity missions like the Mass-Change and Geosciences International Constellation (MAGIC). In addition, novel sensors have been developed to measure gravity gradients and potential changes. Based on such techniques, observation targets are expected to extend to those occurring on other celestial bodies.

The diverse data with high spatiotemporal resolutions motivate us to develop theories to describe the processes causing deformation, rotation and gravity field variations. The Joint Study Group consists of scientists working on dynamic modelling based on different approaches. The targets of the modelling include local, regional and global variations which occur near the surface down to the inner core of the Earth and other celestial bodies. Observations include contributions from a variety of geophysical phenomena. The developed models can also be used as a correction model to separate those contributions. To share different perspectives for modelling stimulates the activities of each member and can produce and/or evolve collaborative studies.

Objectives

- Forward modelling:
  - Target phenomena: co- and post-seismic deformation, other tectonic processes, surface loading and mass transports, hydrological effects, glacial isostatic adjustment, tides and rotation, etc.
  - Properties of the material structure to be modelled: elasticity, viscoelasticity, plasticity, poroelasticity, electromagnetic, thermal and chemical properties, heterogeneities and anisotropies, etc.
  - Modelling approaches: analytical, semianalytical and fully numerical methods and associated approximation methods, etc.
  - Comparison between different theories.
  - Opening developed software (if possible)
- Inverse modelling:
  - Integration of diverse data.
  - Effective processing of big data.
  - Applications of the developed theories to real observations for new scientific findings.

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 information, such as publication lists and its update.
- To propel collaborations with related working groups and projects (e.g., Hydrologic signature in geodetic observations, Chair: Carla Braitenberg (WG in Commission 3), Novel Sensors and Quantum Technology for Geodesy: QuGe).
- To have sessions at international meetings and workshops as needed.
- Software comparison (co- and post-seismic deformation)
- Organising a session at the Hotine-Marussi Symposium 2026

Members

Yoshiyuki Tanaka (Japan); Chair
Shin-Chan Han (Australia)
Hom Nath Gharti (Canada)
Guangyu Fu (China)
Isabelle Panet (France)
Volker Klemann (Germany)
Zdeněk Martinec (Ireland)
Alberto Pastorutti (Italy)
Carla Braitenberg (Italy)

Daniel Melini (Italy)
Elia Giliberti (Italy)
Giorgio Spada (Italy)
Junichi Okuno (Japan)
Taco Broerse (Netherlands)
Riccardo Riva (Netherlands)
Wouter van der Wal (Netherlands)
Peter Vajda (Slovak Republic)
José Fernández (Spain)
Kuanhung Chen (China-Taipei)
Jeanne Sauber (USA)

JSG T.47: Height datum: Definition, New Concepts, and Standardization

Chair: Xiaopeng Li (USA)
Vice-Chair: Marcelo Santos (Canada)
Affiliations: Commissions 2, IGFS

Terms of Reference

Since geometric heights above the reference ellipsoid (as obtained by transformation of geocentric Cartesian coordinates estimated routinely by GNSS) have no physical meaning, the concept of various physical heights, such as orthometric and normal, has been developed in geodesy. All physical heights use a height reference surface (height datum) the geoid defined as a reference equipotential surface of the Earth's gravity field.

To transform geometric heights into orthometric heights, the geoid height defined as ellipsoidal normal separation of the geoid and the reference ellipsoid, must be precisely known. However, given the definition of normal heights using an analytic model of the Earth's gravity field (known as the normal field in geodesy), the so-called height anomaly must alternatively be estimated. Thus, local or global models of the geoid height/height anomaly must be estimated with high precision (1 cm or better).

Through the past decades, various definitions of the height datums for physical heights have been used, both officially and unofficially. For example, a classical textbook definition of the geoid reads as "equipotential surface of the Earth's gravity field approximated by the temporal mean sea level over the oceans". This definition is easy to understand; however, the estimation of such a surface over the continents leaves some theoretical issues to be resolved. Moreover, the concept of the normal heights based on the quasi-geoid has even some serious theoretical issues as some recent studies reported.

The main goal of this joint study group is to establish new or to extend existing international cooperation of researchers within the physical geodesy community in order to review and specify the definition of the height reference surfaces used in connection with physical heights in geodesy. The ultimate goal of the group is to provide a clear, rigorous, and manageable guideline for their precise (1 cm or better) realization.

The updated or new concepts for the height datum realization will consider data from various observation systems, including modern ones such as those based on precise clocks (chrono-geodesy using relativistic effects). Additionally, it will be investigated how to link seamlessly and errorlessly the geoid height/height anomaly models with local high-resolution and accurate spirit levelling observations as the concept and realization of height datums must serve real world applications of physical heights.

Objectives

The scope of this JSG will cover theoretical aspects of the geoid height or height anomaly modelling. In particular, the group will focus on:

- physical parameters such as GM and W_0
- geo-center conventions with respect to the International Terrestrial Reference Frame (ITRF)
- Geodetic Reference System
- tide system conventions
- combination of various gravity field data
- new geodetic boundary-value problems
- consolidate the theory of physical heights

Program of Activities

The JSG will achieve its objectives through:

- Specifying height datum definitions and providing official documentation to IAG.
- Suggesting recommendations regarding the practical use of normal heights related to the geoid.
- Updating and unifying required systems and parameters (which sea surface and which epoch).
- New convention of atmospheric correction
- Seamless connection of local, regional, marine datums, and global datum
- Circulating and sharing information, ideas, progress reports, papers, presentations.
- Organizing a session at the Hotine-Marussi Symposium 2026.
- Supporting and cooperating with IAG Commission 2, ISG, and IGFS, namely their working groups and other entities related to gravity field and height systems.

Members

Xiaopeng Li (USA); Chair
Marcelo Santos (Canada); Vice-chair
Ana Cristina Matos (Brazil)
David Avalos (Mexico)
Elena Osorio-Tai (Mexico)
Fabio Albarici (Brazil)
Gabriel Guimarães (Brazil)
Georgios Vergos (Greece)
Hussein Abd-Elmotaal (Egypt)

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Laura Sanchez (Germany)
Miao Lin (China)
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Pavel Novák (Czech Republic)
Riccardo Barzaghi (Italy)
Robert Kingdon (Canada)
Yanming Wang (USA)

Associate members

Fernando Sansò (Italy)
Rachelle Winefield (New Zealand)

JSG T.48: Theoretical foundations of Machine & Deep Learning in Geodesy

Chair: Lotfi Massarweh (The Netherlands)
Vice-chair: Mostafa Kiani Shahvandi (Switzerland)
Affiliations: Commissions 2,3,4, GGOS (AI4G)

Terms of Reference

The new Joint Study Group is dedicated to a rigorous investigation of Artificial Intelligence/Machine Learning state-of-the-art techniques in the context of current and/or future geodetic applications.

The adoption of Machine Learning (ML) in various domains of Geodesy has become more popular in the past decade. In particular, the rise of Deep Learning (DL) techniques has further increased the adoption of Artificial Intelligence (AI) methods for tackling several complex problems. This widespread use has become possible by a greater availability of computing power, but it has also been motivated by the vast amount of geodetic data that is currently accessible. The latter not only concerns fields such as the Global Navigation Satellite System (GNSS) and Interferometric Synthetic Aperture Radar (InSAR), but also the Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) data.

However, most of research works still focus on applying promising AI/ML algorithms as a black box system, which is viewed in terms of its inputs/outputs without any knowledge of its internal processing or any clear ‘uncertainty quantification’ of the solutions. However, the lack of ‘explainability’ might hinder the accurate analysis of real-world problems and thus, one of the goals of the study group is to address this problem. A second issue is related to the ‘reproducibility’ of results, a fundamental aspect of the scientific method for real-world datasets. Often, AI/ML algorithms fail in achieving outcomes that can easily be reproduced by others and therefore, a part of the joint study will be devoted to this aspect.

One of the primary goals of this Joint Study Group is to identify machine learning use cases in Geodesy, as well as best practices, methods, and algorithms when applying machine learning to geodetic data. In particular, the group focuses on addressing – from a theoretical viewpoint – both 'explainability' and 'reproducibility' aspects in scientific research. This will include methodologies for better understanding underlying assumptions of each model, while also providing a clear quantification of the uncertainty of AI/ML outcomes. In this way, we aim at enhancing the reliability of algorithms and methods, while combining these ones with known physical models and well-established geodetic theories. We recognize the great potential of this AI/ML revolution in Geodesy, whereas a more rigorous theoretical approach is still necessary to fully integrate such novel techniques into the current body of knowledge.

Objectives

- To rigorously investigate, from a theoretical perspective, both methods and assumptions related to machine learning algorithms in different areas of Geodesy.
- To provide a better quantification of the uncertainty for ML/DL techniques, including a more comprehensive statistical description of the solutions.
- To address the problems of 'explainability' and 'reproducibility' in machine learning methods, bridging the gap with traditional data analysis approaches.
- To closely collaborate with the GGOS Focus Area 'AI4G (Artificial Intelligence for Geodesy)' in order to identify open problems in the processing and generation of geodetic products, and therefore including the potential issues of reliability.
- To develop best practices in the adoption of ML/DL techniques, meanwhile further consolidating a standardized terminology for the geodetic community.

Program of Activities

The Joint Study Group will achieve its objectives through:

- To create a web page about machine learning in geodesy, thus providing technical information and raising awareness about the topic in our community. This page will include:
  - an inventory of AI/ML algorithms and their methodology;
  - benchmark datasets to test the performance of AI/ML solutions,
  - a comprehensive record of all previous activities/publications related to machine learning and deep learning in geodesy,
  - a description of key activities performed by the JSG members
- To work toward a comprehensive literature review paper about machine learning in geodesy coauthored by the JSG members, while also addressing traditional data analysis approaches.
- To promote sessions and presentation of the research results at international scientific assemblies (IAG/IUGG, EGU, AGU), technique-specific meetings (IGS, IVS, ILRS, IDS) and the next Hotine-Marussi Symposium in 2026.
- To enhance collaborations with GGOS "AI4G", along with IAG Commissions.

Members

Lotfi Massarweh (The Netherlands); Chair
Mostafa Kiani Shahvandi (Switzerland); Vice-Chair
Michela Ravanelli (Italy)
Kyriakos Balidakis (Germany)
Alireza Amiri-Simkooei (The Netherlands)
Junyang Gou (Switzerland)
Andrea Nardin (Italy)
Mohammad Mahdi Kariminejad (Iran)
Amir Khodabandeh (Australia)

JSG T.49: High-resolution Probing of the Troposphere and Ionosphere

Chair: Michela Ravanelli (Italy)
Affiliations: Commission 4, GGOS (Geohazards Monitoring, GSWR)

Terms of Reference

Nowadays, geodetic measurements are routinely used to probe the Earth's atmosphere both from space and ground. In detail, tropospheric and ionospheric sounding is more and more essential in a variety of applications.

Tropospheric sounding has an important role both in meteorology, in weather forecasting and nowcasting. Global Navigation Satellite Systems (GNSS), GNSS Radio Occultation (GNSS-RO) and Interferometric Synthetic Aperture Radar (InSAR) are the most common used techniques. GNSS and InSAR can be used in complementary way, whereas the GNSS-RO and GNSS can act in a synergistic way.

Through the integration of the afore-mentioned techniques, this JSG aims to improve the high resolution of tropospheric sounding in both zenith and slant directions. In this background, our goals involve studying of severe weather events, the impact of lowcost instrumentations and/or moving platform observations on assimilation approaches, numerical modelling and tomography. The final outcome will help to enhance the real-time capability of models for severe weather nowcasting. To this point, the use of highperformance computing platforms should be encouraged. Furthermore, tropospheric observations could increase the knowledge on the effects and monitoring of climate change.

GNSS-TEC and GNSS-RO offer complementary insights into the ionosphere. The former provides horizontal information on electron content, while the latter offers altitude-wise profiles of electron contents. These observations play a fundamental role in the analysis of natural and man hazard-related ionospheric perturbations, being useful to enhance early warning systems. In this direction, this JSG fosters the improvement of real-time ionospheric monitoring. Data-driven and model-based methodologies for realtime detection of earthquakes and tsunamis should be also improved and integrated into operating tools. The sharing of local GNSS data coming from regional network and private space company (Spire, CubeSats) as well and from moving platform and low-cost instrumentations (smartphones, single-frequency receivers) should be bolstered, going towards a denser ionospheric coverage especially over the oceans. These denser ionospheric observations are necessary to improve the reliability of ionospheric maps (both regional and global) for TEC forecasting and nowcasting, being useful for space weather monitoring, as the 2022 Starlink satellite loss event showed.

The opportunity to reconstruct the 3D ionospheric structure (ionospheric tomography) is increasing thanks to LEO nanosatellites equipped with GNSS (e.g., Astrocast).

Furthermore, studies related to the impact of tropospheric events such as lightning and severe convective weather in the ionosphere should be encouraged. Indeed, these events are about to increase in frequency due to climate change variability. Nonetheless, these investigations should also be fostered to overcome the compartmental use of geodetic observations, typical of the academic world, to gain a holistic and comprehensive angle on the lower/upper atmosphere coupling.

Ultimately, machine learning plays an increasingly significant role in forecasting and nowcasting parameters in tropospheric sounding, as well as in detecting natural hazards for early warning systems. In this regard, fostering interrelation and collaboration with JSG 48 about foundations of machine and deep learning in geodesy is crucial to harness the expertise from both fields.

Finally, it is clear that this unprecedented dense coverage of troposphere and ionosphere sounding enabled by commercial all available ground and spacebased geodetic techniques represents a great opportunity for future investigations in Earth sciences. This underscores the importance of integrating different techniques and products to fully harness their potential and extract optimal information. This is the reason why it is worth having a JSG about highresolution probing of the troposphere and ionosphere using geodetic techniques within the ICCT.

Objectives

- To produce inventories of:
  - commercial and publicly space and groundbased geodetic techniques, with a distinction between troposphere and ionosphere observations, and a classification based on the different acquisition parameters (e.g., sampling rate, vertical or temporal resolution, altitude range of acquisition, tracking mode),
  - present and desired applications of dense troposphere and ionosphere sounding for science and engineering, with a special concern to the estimated physical quantities (e.g., temperature, pressure and TEC), in order to focus on related problems (still open and possibly new) and draw future challenges.
- To address known problems related to dense troposphere and ionosphere sounding using geodetic observations as (not an exhaustive list): natural-hazard anomalies detection, localization and classification; revision and refinement of inversion techniques; temporal variability of receivers DCBs and evaluation of their impact in the calibrated process; data quality assessment and validation; outlier detection and removal; in-situ sensors evaluation, cross-calibration and integration.
- To describe the different analytical and physical implications of combining observations collected with different observational geometries, such as: ground-based receivers tracking signals transmitted by GNSS satellites in MEO and GEO orbits;

space-based receivers tracking GNSS signals at different elevation angles (from positive to negative and vice versa). Furthermore, investigate different ways of combining these remote sensing observations to retrieve fundamental atmospheric parameters, and disentangle the spatial and temporal variability of the atmosphere.

Program of Activities

- To participate at IAG assembly in 2025 in Rimini
- To organize a session at the forthcoming Hotine- Marussi symposium in 2026
- To convene at international conferences such as IAG/IUGG, EGU, AGU
- Interacting with JSG T.48 on foundations of machine and deep learning in geodesy

Members

Michela Ravanelli (Italy); Chair
Elvira Astafyeva (France)
Gregor Moeller (Austria)
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JSG T.50: High-precision GNSS theory and algorithms

Chair: Dimitrios Psychas (The Netherlands)
Affiliations: Commissions 1,4

Terms of Reference

The family of modernized and recently-developed global and regional navigation satellite systems is being further extended by plentiful Low Earth Orbit (LEO) navigation satellites that are almost 20 times closer to Earth as compared to current GNSS satellites. This namely means that navigation sensory data with much stronger signal power will be abundantly available, being in particular attractive in GNSS-challenged environments. Next to the development of new navigation signal transmitters, a rapid growth in the number of mass-market GNSS and software-defined receivers would at the same time demand efficient ways of data processing in terms of computational power and capacity.

Such a proliferation of multi-system and multi-frequency measurements, that are transmitted and received by mixed-type sensing modes, raises the need for a thorough research into the future of next-generation navigation satellite systems, thereby appealing rigorous theoretical frameworks, models and algorithms that enable such GNSS-LEO integration to serve as a high-accuracy and high-integrity tool for Earth-, atmospheric- and space sciences.

Objectives

- Identify, investigate, and tackle challenges that are posed by the integration and processing of multi-GNSS data with heterogeneous sensory measurements, like LEO observations, that are sensed by, e.g., next generation navigation-oriented and communication-oriented constellations.
- Develop and study theory for multi-GNSS integrity and quality control, taking into account the combination of parameter estimation and statistical testing.
- Conduct an in-depth analysis of low-cost, low-power and mass-market GNSS sensory data, such as those of smartphones, and investigate their performances in geoscience applications, considering also fusion with other sensors.
- Develop algorithmic frameworks and strategies to deal with computational challenges encountered in parameter estimation and testing in the presence of a huge number of GNSS and LEO sensing nodes.
- Articulate theoretical developments and findings through journals, conference proceedings, and online and in-person workshops.

Program of Activities

While the investigation will strongly be based on the theoretical aspects of the GNSS-LEO 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 output of the group study is to provide the geodesy and GNSS communities with well-documented models and algorithmic methods through the journals, conference proceedings, and workshops, primarily including IAG assembly in Rimini in 2025, Hotine-Marussi symposium in 2026, and the annual EGU and AGU assemblies.

Members

Dimitrios Psychas (The Netherlands); Chair
Andreas Brack (Germany)
Pengyu Hou (China)
Amir Khodabandeh (Australia)
Lotfi Massarweh (The Netherlands)
Nacer Naciri (USA)
Robert Odolinski (New Zealand)
Jacek Paziewski (Poland)
Sandra Verhagen (The Netherlands)
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