Commission 2 – Gravity Field

President: **Roland Pail** (Germany)
Vice President: **Shuanggen Jin** (China)

http://alpha.fesg.tu-muenchen.de/IAG-C2/

Terms of Reference

The accurate determination of the gravity field and its temporal variations is one of the three fundamental pillars of modern geodesy (besides of geometry/kinematics and Earth rotation). This is essential for applications in positioning and navigation, civil engineering, metrology, geophysics, geodynamics, oceanography, hydrology, cryospheric sciences and other disciplines related to the Earth's climate and environment. IAG Commission 2 was established at the IUGG in Sapporo in summer 2003 for promoting, supporting, and stimulating the advancement of knowledge, technology, and international cooperation in the geodetic domain associated with Earth's gravity field.

Since most of the scientific themes are of long-term interest, large parts of the structure of Commission 2 are continued on the same basis as in the previous period 2011-15. Main focus points for the present period 2015-19 are related to the IUGG and IAG resolutions adopted at the XXVI IUGG General Assembly 2015 in Prague, addressing the topics global geodetic reference frames, future satellite gravity mission constellations, and the role of oceans in the climate system (IUGG), as well as definition and realization of an International Height Reference System (IHRS) and the establishment of an absolute gravity reference system (IAG). The structure of Commission 2 has been adopted to address these objectives and tasks, and joint working and study groups have been implemented accordingly.

Commission 2, at the start of the new period, consists of six sub-commissions (SCs), plus several Joint Study Groups (JSG) and Joint Working Groups (JWG), all of them jointly with other Commissions and/or services. The sub-commissions cover the following scientific topics:

- Terrestrial (land, marine, airborne) gravimetry and relative/absolute gravity networks;
- Methodology for geoid and physical height systems;
- Satellite gravity missions;
- Regional geoid determination;
- Satellite altimetry;
- Gravity and mass transport in Earth system.

Commission 2 has strong links to other commissions, GGOS, IGFS, ICCT and other components of IAG. Connections to these components are created through joint working groups (JWGs) and joint study groups (JSGs) that provide a cross-disciplinary stimulus for work in several topics of interest to the commission, and the joint organization of meetings.

The main tasks of Commission 2 in the period 2015-19 are among others:

- Establishment of a global absolute gravity reference system (GAGRS) to replace the International Gravity Standardization Net 1971 (IGSN71), which no longer fulfills the requirements and accuracy of a modern gravity reference; especially to include time-dependent gravity variations;
- Supporting the realization of an International Height Reference System (IHRS);
- Supporting the realization of an Global Geodetic Reference System (GGRS);
- Analysis of current and future satellite data (CHAMP, GRACE, GOCE, GRACE-FO) and the release of improved global Gravity field models (satellite only models and in combination with terrestrial data and satellite altimetry);
- Promoting future gravity mission constellations for assuring the continued monitoring of global gravity and mass transport processes in the Earth system;
- Assuring the future of the comparison campaigns of absolute gravimeters;

- Investigating modern relativistic methods and geodetic metrology with special focus on gravity field and height determination;
- Fostering regional gravity and geoid determination and integration of regional models into a global reference
- Assisting the regional sub-commissions in establishing contacts and in acquiring data;
- Understanding of physics and dynamics of the Earth sub-systems and mass transport processes in the Earth system;
- Providing contributions to operationalization of mass transport modelling and stimulation of new applications
- Fostering communication with user communities;
- Assisting the IGFS and its components in improving their visibility and their services;

The necessary WGs and SGs can be established at any time and they can be dissolved when they reached their goals or if they are not active.

Objectives

The main objectives of Commission 2 are as listed in the IAG by-laws:

- Terrestrial, marine and airborne gravimetry
- Satellite gravity field observations
- Gravity field modeling
- Time-variable gravity field
- Geoid and height determination
- Satellite orbit modeling and determination
- Satellite altimetry for gravity field modeling

Structure

Sub-Commissions

SC 2.1: Gravimetry and Gravity networks
Chair: Leonid F. Vitushkin (Russia)

SC 2.2: Methodology for Geoid and Physical Height Systems
Chair: Jonas Ågren (Sweden)

SC 2.3: Satellite Gravity Missions
Chair: Adrian Jäggi (Switzerland)

SC 2.4: Regional Geoid Determination
Chair: Maria Cristina Pacino (Argentina)
SC 2.4a: Gravity and Geoid in Europe
Chair: Heiner Denker (Germany)
SC 2.4b: Gravity and Geoid in South America
Chair: Maria Cristina Pacino (Argentina)
SC 2.4c: Gravity and Geoid in North and Central America
Chair: Marc Véronneau (Canada)
SC 2.4d: Gravity and Geoid in Africa
Chair: Hussein Abd-Elmotaal (Egypt)
SC 2.4e: Gravity and Geoid in Asia-Pacific
Chair: Jay Hyoun Kwon (Korea)
SC 2.4f: Gravity and Geoid in Antarctica
Chair: Mirko Scheinert (Germany)

SC 2.5: Satellite Altimetry
Chair: Xiaoli Deng (Australia)

SC 2.6: Gravity and Mass Transport in the Earth System
Chair: Jürgen Kusche (Germany)

Joint Study Groups

JSG 0.11: Multiresolution aspects of potential field theory
(joint with ICCT, Commission 3, see ICCT)
Chair: Dimitrios Tsoulis (Greece)

JSG 0.12: Advanced computational methods for recovery of high-resolution gravity field models
(joint with ICCT, GGOS, see ICCT)
Chair: Robert Čunderlík (Slovak Republic)

JSG 0.13: Integral equations of potential theory for continuation and transformation of classical and new gravitational observables
(joint with ICCT, GGOS, see ICCT)
Chair: Michal Šprlák (Czech Republic)

JSG 0.15: Regional geoid/quasi-geoid modelling – Theoretical framework for the sub-centimeter accuracy
(joint with ICCT, GGOS, see ICCT)
Chair: Jianliang Huang (Canada)

JSG 0.16: Earth's inner structure from combined geodetic and geophysical sources
(joint with ICCT, Commission 3, see ICCT)
Chair: Robert Tenzer (China)

JSG 0.18: High resolution harmonic analysis and synthesis of potential fields
(joint with ICCT, GGOS, see ICCT)
Chair: Sten Claessens (Australia)

JSG 0.21: Geophysical modelling of time variations in deformation and gravity
(joint with ICCT, Commission 3, see ICCT)
Chair: Yoshiyuki Tanaka (Japan)

JSG 3.1: Intercomparison of Gravity and Height Changes (joint with IGFS, Commissions 1 and 3, description see Commission 3)

Joint Working Groups

JWG 0.1.2: Strategy for the Realization of the International Height Reference System (IHRS)
(joint with GGOS, Commission 1, ICCT, IGFS, description see GGOS)
Chair: Laura Sánchez (Germany)

JWG 2.1**:** Relativistic Geodesy: First steps towards a new geodetic technique
(joint with Commission 1)
Chair: Jakob Flury (Germany)

Program of Activities

The Gravity Field Commission fosters and encourages research in the areas of its sub-entities by facilitating the exchange of information and organizing Symposia, either independently or at major conferences in geodesy. The activities of its sub-entities, as described below, constitute the activities of the Commission, which will be coordinated by the Commission and summarized in annual reports to the IAG Bureau.

The principal symposia that will be organized jointly by Commission 2 and the IGFS in the next period will be held in Thessaloniki in September 2016 and in 2018 (location TBD). The other two symposia where a Commission 2 meeting will be held are the IAG Scientific Assembly 2017 in Kobe, Japan, and the IUGG General Assembly 2019 in Montréal.

The status of Commission 2, including its structure and membership, as well as links to the internet sites of its sub-entities and parent and sister organizations and services, will be updated regularly and can be viewed on the web site: http://alpha.fesg.tu-muenchen.de/IAG-C2.

Steering Committee

President Commission 2:	Roland Pail (Germany)
Vice President Comm. 2:	Shuanggen Jin (China)
Chair Sub-Comm. 2.1:	Leonid F. Vitushkin (Russia)
Chair Sub-Comm. 2.2:	Jonas Ågren (Sweden)
Chair Sub-Comm. 2.3:	Adrian Jäggi (Switzerland)
Chair Sub-Comm. 2.4:	Maria C. Pacino (Argentina)
Chair Sub-Comm. 2.5:	Xiaoli Deng (Australia)
Chair Sub-Comm. 2.6:	Jürgen Kusche (Germany)
Representative of IGFS:	Riccardo Barzaghi (Italy)
Representative of ICCT:	Pavel Novák (Czech Republic)
Member-at-Large:	Laura Sanchez (Germany)
Member-at-Large:	Urs Marti (Switzerland)

The steering committee will meet at least once per year. These meetings are open for all interested IAG members.

Sub-Commissions

SC 2.1: Gravimetry and Gravity Network

Chair: Leonid F. Vitushkin (Russia)
Vice-chair: Akito Araya (Japan)

Terms of Reference

IAG Sub-commission 2.1 "Gravimetry and gravity networks" promotes scientific studies of the methods and instruments for terrestrial (on the land, airborne, shipboard) gravity measurements, establishment of gravity networks and improvement of strategy in the measurement of gravity networks provided by growing number of absolute gravity determinations and the sites for such determinations. The Sub-commission provides the geodesy-geophysics community with the means to access the confidence in gravity measurements at the well-defined level of accuracy through organizing, in cooperation with metrology community, Consultative Committee on Mass and Related Quantities and its Working Group on Gravimetry (CCM WGG), Regional Metrology Organizations (RMO) the international comparisons of absolute gravimeters on continental scale. The Sub-commission proceeds from such point-wise gravimetry to precise gravimetry/gradiometry which should cover, in particular, the land-sea border areas to resolve still existing problem of significant biases and errors in determination.

Objectives

The Sub-commission promotes such research and development by stimulating airborne and shipboard gravimetry and gradiometry. It encourages and promotes special absolute/relative gravity campaigns, techniques and procedures for the adjustment of the results of gravity surveys on a regional scale. It promotes the research in the linking of satellite and terrestrial gravity measurements.

In the frame of realization of the “CCM-IAG Strategy for Metrology in Absolute Gravimetry” the Sub-commission in collaboration with metrology community promotes the implementation of the system of metrological support (calibration, verification, comparisons) of absolute gravimeters belonging to geodesy-geophysics community.

For the realization of these goals, the SC 2.1 sets up the Study Group SG 2.1.1 on techniques and metrology in terrestrial (land, marine, airborne) gravity measurements and the joint with IGFS and IGETS Working Group JWG2.1.1. SC2.1 appoints the Steering Committee consisted of the members experienced in the fields of gravimetry related to the activities of SC2.1 and the contact persons for European, East Asia and Western Pacific, South America and North America Gravity Networks.

According to the Resolution 2 of IAG adopted at the IUGG General Assembly in Prague in 2015 the Sub-commission supports through its JWG2.1.1 in collaboration with IGFS and IGETS the development of the Global Absolute Gravity Reference System (GAGRS) for GGOS technically and works on the standardization of absolute gravity data, software for absolute gravity measurement and appropriate information. The Sub-commission will encourage regional meetings or workshops dedicated to specific problems, where appropriate.

Program of Activities

- Selection (JWG 2.1.1) in collaboration with CCM WGG of the sites for regional comparisons of absolute gravimeters, as the basis for GAGRS,
- providing the results of comparisons of absolute gravimeters to data base AGrav at BKG-BGI,
- supporting the scientific investigations of absolute and relative (including the superconducting) gravity measurements on static and moving platforms,
- organizing the IAG Commission 2 Symposiums "Terrestrial Gravimetry. Static and mobile measurements – TGSMM-2016 and TGSMM-2019".

Study Groups of Sub-Commission 2.1

SG 2.1.1: Techniques and metrology in terrestrial (land, marine, airborne) gravimetry

Chair: Derek van Westrum (USA)
Vice-chair: Christoph Förste (Germany)

Terms of Reference

The SG 2.1.1 is concentrated on the scientific studies of the techniques and methods of the measurements of terrestrial gravity field on static and moving platforms (on the land, shipboard and airborne gravimetry and gravity gradiometry). It encourages and coordinates special absolute and relative gravity campaigns, development of the techniques, gravimetry sites and networks for the monitoring of temporal variations of gravity field using in particular the superconducting gravimetry. It promotes the improvements of the strategy in the measurement of gravity for such applications as hydrogeology, studies of volcanoes, technical geology, etc.

The SG2.1.1 promotes the studies of the techniques and procedures for the adjustment of the results of gravity surveys on a regional scale. It promotes the research in the linking of satellite and terrestrial gravity measurements and the studies of the use of terrestrial gravity data for the calibration of the satellite gravity measurements.

The SG2.1.1 aims to deal with the technical and metrological aspects in terrestrial absolute and relative gravity measurements in collaboration with metrology community.

Objectives

- Promotion and coordination of scientific studies of the techniques and methods of absolute and relative terrestrial gravity measurements on static and moving platforms.
- Promotion and coordination in the establishment and measurements of regional gravity networks.
- The collaboration with metrology community for the implementation of the system of calibration and verification of absolute gravimeters.
- Organization of scientific workshops and meetings for the discussion of actual subjects in techniques and methods of terrestrial gravity measurements.

Members

Derek van Westrum (USA), Chair
Christoph Förste (Germany), Vice-chair
Matthias Becker (Germany)
Mirjam Bilker (Finland)
Nicholas Dando (Australia)
Andreas Engfeld (Sweden)
Reinhard Falk (Germany)
Olivier Francis (Luxemburg)
Alessandro Germak (Italy)
Filippo Greco (Italy)
Joe Henton (Canada)
Jeff Kennedy (USA)
Anton Krasnov (Russian Federation)
Nicolas LeMoigne (France)
Sebastien Merlet (France)
Oleg Orlov (Russian Federation)
Vojtech Palinkas (Czech Republic)
Vladimir Schkolnik (Germany)
Sergiy Svitlov (Ukraine)
Ludger Timmen (Germany)
Michel Van Camp (Belgium)

Corresponding Members

Martin Amalvict (France)
Jan Krynski (Poland)
Chiungwu Lee (China-Taipei)
Shigeki Mizushima (Japan)
Jan Mrlina (Czech Republic)
Andrzej Pachuta (Poland)
Alfredo Esparza Ramires (Mexico)
René Reudink (The Netherlands)
José Manuel Serna Puente (Spain)
Yury Stus (Russian Federation)
Simon Williams (UK)

Joint Working Groups of Sub-Commission 2.1

JWG 2.1.1: Establishment of a global absolute gravity reference system
(joint with IGFS, IGETS)

Chair: Hartmut Wziontek (Germany)
Vice-chair: Sylvain Bonvalot (France)

Terms of Reference

One task of IAG's Commission 2 "Gravity Field" is the establishment of an absolute gravity reference system to replace the International Gravity Standardization Net 1971 (IGSN71). At the IUGG General Assembly in Prague 2015, Resolution No. 2 for the establishment of a global absolute gravity reference system was adopted by the IAG.

IAG Sub-Commission 2.1 "Gravimetry and Gravity Networks" promotes scientific investigations of gravimetry and gravity networks and terrestrial (on the land, airborne, marine) and planetary gravity measurements. One of the outputs of the SC 2.1 activities is the result of gravity measurements, i.e. the gravity data. The International Gravity Field Service IGFS coordinates the servicing of the geodetic and geophysical community with gravity field related data, software and information. A modern and precise absolute gravity reference system will not only contribute to the establishment of the Global Geodetic Reference Frame (GGRF) of UN but will serve as a long-term and precise gravity reference for GGOS, the IAG Global Geodetic Observing System.

Objectives

In the frame of IAG Sub-Commission 2.1 "Gravimetry and Gravity Networks" the necessary steps to realize this new reference system will now be prepared by the JWG 2.1.1. It will focus on the preparation of a roadmap for establishment of the GAGRS taking into account:

- Repeated international comparisons of absolute gravimeters under guidance of the International Committee for Weights and Measures (CIPM) and Regional Metrology organizations which define both measurement standards in gravimetry (absolute gravimeters) and absolute gravity standards for metrology and geodesy;
- A set of distributed gravity reference stations where the repeated absolute gravity measurements and the monitoring of temporal gravity changes with superconducting gravimeters for the realization of an absolute gravity reference function;
- The transfer of international comparison results to other absolute gravimeters and reference stations, as outlined in the document "CIPM – IAG Strategy for Metrology in Absolute Gravimetry";
- The definition of standard models for the correction of absolute gravity data in cooperation with the GGOS Bureau of Standards and Conventions.

The absolute gravity database "AGrav", which already became a fixed part of the BGI (International Gravimetric Bureau) services, will be used as a registry for the global absolute gravity reference system. The extension for storage and distribution of comparison results will be an essential task.

Cooperation with the new International Geodynamics and Earth Tide Service (IGETS) of IAG (former Global Geodynamics Project, GGP) should be established to realize the continuous monitoring at the gravity reference stations.

Members

Hartmut Wziontek, Chair (Germany),
Sylvain Bonvalot, Vice-chair (France),
Jonas Ågren (Sweden), Henri Baumann (Switzerland),
Mirjam Bilker Koivula (Finland), Jean-Paul Boy (France),
Nicholas Dando (Australia), Reinhard Falk (Germany),
Olivier Francis (Luxembourg), Domenico Iacovone (Italy),
Jan Krynski (Poland), Jacques Liard (Canada),
Urs Marti (Switzerland), Vojtech Palinkas (Czech Republic),
Diethard Ruess (Austria), Victoria Smith (UK),
Ludger Timmen (Germany), Michel van Camp (Belgium),
Derek van Westrum (USA), Leonid Vitushkin (Russia),
Shuqing Wu (China).

Corresponding Members

Mauro Andrade de Sousa (Brazil), In-Mook Choi (Korea),
Andreas Engfeldt (Sweden), Yoichi Fukuda (Japan),
Alessandro Germak (Italy), Joe Henton (Canada),
Jacques Hinderer (France), Juraj Janak (Slovak Republic),
Shuanggen Jin (China), Janis Kaminskis (Latvia),
Jeff Kennedy (USA), Jakub Kostelecky (Czech Republic),
Jaakko Mäkinen (Finland), J.N. Markiel (USA),
Emil Nielsen (Denmark), Tomasz Olszak (Poland),
Bjørn Ragnvald Pettersen (Norway), Rene Reudink (The Netherlands), Jose Manuel Serna Puente (Spain),
Manuel Schilling (Germany), Heping Sun (China),
V.M. Tiwari (India), Christian Ullrich (Austria).

SC 2.2: Methodology for Geoid and Physical Height Systems

Chair: Jonas Ågren (Sweden)
Vice-chair: Artu Ellmann (Estonia)

Terms of Reference

A global height reference frame with high accuracy and stability is required to determine the global changes of the Earth. A major step towards this goal was taken by the IAG resolution (No. 1) for the definition and realization of an international Height Reference System (IHRS), adopted at the IUGG 2015 meeting in Prague. It is now the intention that the IHRS will be globally realized using geometric satellite methods, like GNSS, in combination with gravimetrically determined geopotential values. The latter can be derived using a global geopotential model originating from the dedicated satellite gravity missions, complemented with terrestrial gravity and other information to reduce the omission error. Traditional levelling might also be integrated on a regional or local scale. The IAG SC 2.2 aims at bringing together scientists and geodesists concerned with methodological questions in geoid and height determination, who in different ways contribute to reach the above mentioned goal of a global height system realisation and unification. It includes topics ranging from regional gravimetric geoid determination to the realization and implementation of IHRS in view of the existing regional/local/national height system realisations.

Objectives

The IAG Sub-Commission 2.2 (SC2.2) promotes and supports scientific research related to methodological questions in geoid and height determination, both from the theoretical and practical perspectives, concentrating particularly on methodological questions contributing to the realization of IHRS with the required sub-centimetre accuracy. This includes for instance:

- Realization of the International Height Reference System (support of Joint Working Group 0.1.2)
- Implementation of the International Height Reference Frame, height system unification.
- Studies on $W0$ determination.
- Studies on data requirements, data quality, distribution and sampling rate to reduce the omission error to the sub-centimetre level in different parts of the world.
- Investigation of the theoretical framework required to compute the sub-centimetre geoid (support of JSG 0.15)
- Investigation and benchmarking of alternative regional geoid determination methods and software.
- Studies on theoretical and numerical problems related to the solution of the geodetic boundary value problems in geoid determination,
- Studies on time variations of the gravity field and heights due to Glacial Isostatic Adjustment (GIA) and land subsidence.
- Development of relativistic methods for potential difference determination using precise atomic clocks (support of Joint Working Group 2.3)
- Investigating the role of traditional levelling in future regional/local height system realisations.

Program of activities

- Organizing meetings and conferences.
- Inviting the establishment of Special Study Groups on relevant topics.
- Reporting activities of SC2.2 to the Commission 2.
- Communication/interfacing between different groups/fields relevant to the realization of IHRS.

Joint Working Groups of Sub-Commission 2.2

JWG 2.2.1: Integration and validation of local geoid estimates
(joint with ISG, IGFS, ICGEM)

Chair: Mirko Reguzzoni (Italy)
Vice-chair: Georgios Vergos (Greece)

Terms of Reference

Regional geoid estimates (in areas having e.g. extension of some degrees) can give a detailed description of the high frequency geoid features. They are based on local gravity databases and high resolution DTMs that allow to reconstruct the high frequency spectrum of the gravity field, thus improving the global geopotential model representation. Local geoid estimates are computed following well-defined estimation methods that can give reliable results. These estimates are frequently used in engineering applications to transform GPS derived ellipsoidal heights into normal or orthometric heights.
Despite the fact that methodologies in geoid estimation have a sound basis, there are still some related issues that are to be addressed.

In comparing local geoid estimates of two adjacent areas inconsistencies can occur. They can be caused by the different global geopotential models used in representing the low frequency part of the gravity field spectrum and/or the method that has been adopted in the geoid estimation procedure. Biases due to a different height datum can also be present. Thus proper procedures should be proposed and assessed to homogenize the two local solutions.

Validation of regional geoid is another issue that is to be better standardized. Usually the validation is based on GPS/levelling data that are compared with the geoid estimates. Differences between GPS/levelling and geoid/quasi-geoid values are then fitted with polynomial surfaces to account for reference frames discrepancies. Statistics of the post-fit residuals are then considered as the estimates of the geoid precision. In this respect, some issues related to the fitting procedure could be better defined and standardized.

Finally, another question to be investigated is the definition of procedures for local geoid estimates in areas with sparse gravity data. The interactions existing among the maximum degree of the global geopotential model, the DTM resolution, the local gravity database mean spatial density, the estimation geoid grid step should be studied to define some general best-practice rules.

Goals and Objectives

The objectives of the Working Group are to:
- Study and define methodologies for merging local geoid solutions
- Discuss and define proper procedure to assess the geoid estimation precision
- Compare different geoid estimation methods
- Define general rules for geoid estimation in areas with sparse gravity data

Program of Activities

The Working Group activities will be developed following the objective stating above. Particularly, based on the geoid solution available at ISG, numerical tests will be carried out. Members will be required to participate in these tests with their own software/methodologies. Results of these tests will be discussed through the ISG website and in face-to-face meeting to be held in connection with major geodesy related congresses.

Members

Mirko Reguzzoni (Italy), Chair
Georgios Vergos (Greece), Vice-chair
Hussein A. Abd-Elmotaal (Egypt)
Franz Barthelmes (Germany)
Riccardo Barzaghi (Italy)
T. Bašić (Croatia)
Will Featherstone (Australia)
Gabriel Guimaraes (Brazil)
Jianliang Huang (Canada)
Cheinway Hwang (China-Taipei)
Shuanggen Jin (China)
Norbert Kühtreiber (Austria)
Marie-Françoise Lalancette (France)
Giovanna Sona (Italy)
Hasan Yildiz (Turkey)

Corresponding Member

Heiner Denker (Germany)

SC 2.3: Satellite Gravity Missions

Chair: Adrian Jäggi (Switzerland)
Vice-chair: Frank Flechtner (Germany)

Terms of Reference

Sub-commission 2.3 promotes scientific investigations concerning the dedicated satellite gravity field missions CHAMP, GRACE, GOCE, and the future GRACE Follow-On mission, the development of alternative methods and new approaches for global gravity field processing also including complementary gravity field data types, as well as interfacing to user communities and relevant organizations.

Objectives

The successful launches of the German CHAMP (2000), the US/German GRACE (2002) and the ESA GOCE (2009) missions have led to a revolution in global gravity field mapping by space-borne observation techniques. Due to the fact that they are the only measurement system which can directly observe mass and mass transport in the Earth system, they provide valuable contributions to many geoscientific fields of application, such as geodesy, hydrology, oceanography, glaciology, and solid Earth physics. These missions have proven new concepts and technologies, such as high-low satellite-to-satellite tracking (SST) using the GPS constellation, low-low SST based on micro-wave ranging, and satellite gravity gradiometry (SGG), as well as space-borne accelerometry. GRACE has produced consistent long- to medium-wavelength global gravity field models and its temporal changes. GOCE provided high-accuracy and high-resolution static gravity field models. In combination with complementary gravity field information from terrestrial data, satellite altimetry, an even higher spatial resolution can be achieved. Additionally, based on challenging user requirements, concepts of future gravity field missions are developed and investigated.

Program of Activities

The focus of this sub-commission will be to promote and stimulate the following activities:

- Generation of static and temporal global gravity field models based on observations by the satellite gravity missions CHAMP, GRACE, GOCE, and the future GRACE Follow-On mission, as well as optimum combination with complementary data types (SLR, terrestrial and air-borne data, satellite altimetry, etc.);
- Investigation of alternative methods and new approaches for global gravity field modelling, with special emphasis on functional and stochastic models and optimum data combination;
- Identification, investigation and definition of enabling technologies for future gravity field missions: observation types, technology, formation flights, etc.;
- Communication / interfacing with gravity field model user communities (climatology, oceanography / altimetry, glaciology, solid Earth physics, geodesy, ...);
- Communication/interfacing with other IAG organizations, especially the GGOS Working Group for Satellite Missions and the GGOS Bureau for Standards and Conventions

SC 2.4: Regional Geoid Determination

Chair: Maria Cristina Pacino (Argentina)
Vice-chair: Hussein Abd-Elmotaal (Egypt)

Terms of Reference and Objectives

Sub-Commission 2.4 is concerned with the following areas of investigation:

- Regional gravity and geoid sub-commissions: data sets, involved institutions, comparison of methods and results, data exchange, comparison with global models, connection of regional models
- Gravimetric geoid modelling techniques and methods, available software, new alternative geoid determination techniques
- GPS/levelling geoid determination: methods, comparisons, treating and interpretation of residuals, common treatment of gravity and GPS/levelling for geoid determination
- Geoid applications: GPS heights, sea surface topography, integration of geoid models in GPS receivers, vertical datums.
- Other topics: topographic effects, downward and upward continuation of terrestrial, airborne, satellite data specifically as applied to geoid modelling.

Program of Activities

Sub-Commission 2.4 is going to initiate and coordinate regional gravity and geoid sub-commissions. It will encourage and support the data exchange between agencies and will assist local, regional and national authorities in their projects of gravity field determination. It will help in organizing courses and symposia for gravity field determination.

SC 2.4a: Gravity and Geoid in Europe

Chair: Heiner Denker (Germany)

Terms of Reference

The primary objective of the sub-commission is the development of improved regional geoid and quasigeoid models for Europe, which can be used for applications in geodesy, oceanography, geophysics and engineering, e.g., height determination with GNSS techniques, vertical datum definition and unification, dynamic ocean topography estimation, geophysical modelling, and navigation. Another emerging field is related to the development of new optical clocks in physics with projected relative accuracies at the level of 10^{-18}, as in accordance with the laws of general relativity, such clocks are sensitive to the gravity potential at the level of 0.1 m^2/s^2, equivalent to 1 cm in height.

The geoid and quasigeoid modelling will be based mainly on terrestrial gravity and terrain data in combination with state-of-the-art global geopotential models. In this context, upgraded terrestrial data sets as well as the utilization of new GRACE and GOCE based global geopotential models led to significant improvements. The evaluation of the latest European Gravimetric Geoid 2015 (EGG2015) by GNSS and levelling data indicates an accuracy potential of 1 – 2 cm on a national basis, and 2 – 4 cm at continental scales, provided that high quality and resolution input data are available within the area of interest. Further improvements can be expected from the inclusion of upgraded gravity field data sets, especially in areas with hitherto insufficient input data.

Program of Activities

- Utilization of state-of-the-art global geopotential models.
- Identification and acquisition of new terrestrial data sets, including gravity, terrain, and GPS/levelling data.
- Merging and validation of all data sets.
- Investigation of refined mathematical modelling techniques and numerical tests.
- Computation of new geoid and quasigeoid models.
- Evaluation of the results by GNSS/levelling data.
- Study of applications, such as vertical datum definition and unification, dynamic ocean topography estimation, ground truth for optical clocks, etc.

Delegates

The SC2.4a cooperates with national representatives from most of the countries in Europe. The existing contacts and successful cooperation with the respective persons and national and international agencies shall be continued and extended.

SC 2.4b: Gravity and Geoid in South America

Chair: Maria Cristina Pacino (Argentina)
Vice-chair: Denizar Blitzkow (Brazil)

Terms of Reference and Objectives

The Sub Commission 2.4b entitled Gravity and Geoid in South America, as part of the Commission 2 of IAG, was established as an attempt to coordinate efforts to establish a new Absolute Gravity Network in South America, to carry out gravity densification surveys, to derive a geoid model for the continent as a height reference and to support local organizations in the computation of detailed geoid models in different countries.

Besides, a strong effort is being carried out in several countries in order to improve the distribution of gravity information, to organize the gravity measurements in the continent and to validate the available gravity measurements.

The main objectives of the project are:

- To re-measure existent absolute gravity stations and to encourage the establishment of new stations.
- To validate fundamental gravity network from different countries in order to establish a single and common gravity network for South America.
- To adjust national gravity networks and to link them together.
- To obtain and to maintain files with data necessary for the geoid computation like gravity anomalies, digital terrain models, geopotential models and satellite observations (GPS) on the levelling network of different countries.
- To provide a link between the different countries and the IGFS in order to assure access to proper software and geopotential models for local geoid computation.
- To compute a global geoid model for South and Central America using the available data. To encourage countries to cooperate by releasing data for this purpose.
- To encourage and eventually support local organizations in different countries endeavouring to increase the gravity data coverage, to improve the existing digital terrain models, to carry out GPS observations on the levelling network and to compute a high resolution geoid.
- To organize and/or encourage the organization of workshops, symposia or seminars on gravity and geoid determination in South America.
- To test and to use future geopotential models derived from the modern missions (GRACE and GOCE) as well as any new combined model (e.g. EGM2008).
- To support the IAG Sub-Commission 1.3b (Reference Frame for South and Central America, SIRGAS) in the activities related to the unification of the existing vertical datums.
- Establish close connections with SC2.4c (Gravity and Geoid in North and Central America) to have a good overlap of data coverage in Central America and the Caribbean.

Delegates

Denizar Blitzkow (Brazil)
Oscar Carranco (Ecuador)
Henry Montecino Castro (Chile)
Eduardo Andrés Lauría (Argentina)
Roberto Teixeira Luz (Brasil)
Silvia Alicia Miranda (Argentina)
Ana Crisitina Oliveira Concoro de Matos (Brasil)
Maria Cristina Pacino (Argentina)
Ivonne Gatica Placencia (Chile)
Norbertino Suárez (Uruguay)
Jorge Faure Valbi (Uruguay)

SC 2.4c: Gravity and Geoid in North and Central America

Chair: Marc Véronneau (Canada)
Vice-chair: David Avalos (Mexico)

Terms of Reference and Objectives

The primary objective of this Sub-commission is the development of a regional gravity field and geoid model covering the region of North America and Central America by 2022 in order to achieve a common vertical datum. The region involved will encompass Iceland, Greenland, Canada, the U.S.A. (including Alaska and Hawaii), Mexico, countries forming Central America, the Caribbean Sea and the northern parts of South America. This model will serve as the official realization of the vertical datum for countries that want to adopt it.

The intention is to ensure that a suitable North American Geoid is developed to serve as a common datum for every-one in the region. All countries in the region would be served by having access to a common model for translating oceanographic effects to terrestrial datums for various scientific, commercial, engineering and disaster prepared-ness applications. Likewise, it shall serve as the basis for the forthcoming International Great Lakes Datumin 2022 (IGLD 2020).

The achievement of a geoid model for North and Central America will be accomplished by coordinating activities among agencies and universities with interest in geoid theory, gravity, gravity collection, gravity field change, geophysical modelling, digital elevation models (DEM), digital density models (DDM), altimetry, dynamic ocean topography, levelling and vertical datums. Of particular interest will be relating geoid and ocean topography models to ocean topography and tidal benchmarks, taking advantage of the recent satellite altimetry and geopotential field products.

The determination of a geoid model for North and Central America is not limited to a single agency, which will collect all necessary data from all countries. The Sub-commission encourages theoretical diversity in the determination of a geoid model among the agencies. Each agency takes responsibility or works in collaboration with neighbouring countries in the development of a geoid model for their respective country with an overlap (as large as possible) over adjacent countries. Each solution will be compared, the discrepancies will be analyzed, and the conclusions will be used to improve on the next model.

Program of Activities

The Sub-commission will support geoid activities in countries where geoid expertise is limited by encouraging more advanced members to contribute their own expertise and software. The Sub-commission will encourage training and education initiative of its delegates (e.g., IGeS geoid school, graduate studies and IPGH technical cooperation projects). Starting 2011 the Sub-commission will organize regular meetings with representatives of Central American and Caribbean countries to promote an increase of expertise as well as to create a wide network of specialists.

The chair (or a delegate representative) of the Sub-commission will meet with the equivalent European and South American projects to discuss overlap regions and to work towards agreements to exchange data. The delegates of the Sub-commission will keep close contact with all related Study Groups of the IAG. The Sub-commission is open to all geodetic agencies and universities across North and Central America with an interest in the development of a geoid model for the region. The meetings of the Sub-commission 2.4c are open to everyone with interests in geodesy, geophysics, oceanography and other related topics.

The delegates will communicate primarily using e-mail. In addition, starting on November 9, 2015, Canada (CGS), USA (NGS) and Mexico (INEGI) will organize audio / video conferences every four weeks to discuss activity plans and present results. The sub-commission also plans to organize annual meetings if enough delegates can be present. Preferably, these meetings will be held during international conferences;. Minutes of meetings will be prepared and sent to all delegates of the Sub-commission.

Delegates

Alvaro Alvarez (Costa Rica)
David Avalos (Mexico)
Christopher Ballesteros (Panama)
Carlos E. Figueroa (El Salvador)
Rene Forsberg (Denmark)
Jianliang Huang (Canada)
Wilmer Medrano (Nicaragua)
Oscar Meza (Honduras)
Laramie Potts (USA)
Vinicio Robles (Guatemala)
Dan Roman (USA)
Marc Véronneau (Canada)
Yan Min Wang (USA)
Anthony Watts (Cayman Islands)

SC2.4d: Gravity and Geoid in Africa

Chair: Hussein Abd-Elmotaal (Egypt)

Terms of Reference

The African Gravity and Geoid sub-commission (AGG) belongs to the Commission 2 of the International Association of Geodesy (IAG). The main goal of the African Gravity and Geoid sub-commission is to determine the most complete and precise geoid model for Africa that can be obtained from the available data sets. Secondary goals are to foster cooperation between African geodesists and to provide high-level training in geoid computation to African geodesists.

Objectives and Activities

The objectives and activities of the sub-commission are summarized as follows:

- Identifying and acquiring data sets - gravity anomalies, DTMs, GPS/levelling.
- Training of African geodesists in geoid computation.
- Merging and validating gravity data sets.
- Computing African geoid models**.**
- Evaluating the computed geoid models using GPS/levelling data.
- Updating the geoid models using new data/strategies to obtain better geoid accuracy (dynamic process).

Delegates

Hussein Abd-Elmotaal (Egypt)
Mostafa Abd-Elbaky (Egypt)
Ahmed Abdalla (Sudan)
Francis Aduol (Kenya)
Mostafa Ashry (Egypt)
Jose Almeirim (Mozambique)
Joseph Awange (Kenya)
Ludwig Combrinck (South Africa)
Benahmed Daho (Algeria)
Tsegaye Denboba (Ethiopia)
Hassan Fashir (Sudan)
Walyeldenn Godah (Sudan)
Godfrey Habana (Botswana)
Ayman Hassan (Egypt)
Bernhard Heck (Germany)
Addisu Hunegnaw (Ethiopia)
Saburi John (Tanzania)
Adekugbe Joseph (Nigeria)
J.B.K. Kiema (Kenya)
Norbert Kühtreiber (Austria)
Ismail Ateya Lukandu (Kenya)
Atef Makhloof (Egypt)
Charles Merry (South Africa)
Albert Mhlanga (Swaziland)
Peter Nsombo (Zambia)
Karim Owolabi (Namibia)
Francis Podmore (Zimbabwe)
Solofo Rakotondraompiana (Madagascar)
Kurt Seitz (Germany)
Prosper Ulotu (Tanzania)

SC 2.4e: Gravity and Geoid in the Asia-Pacific

Chair: Jay Hyoun Kwon (Korea)
Vice-chair: Cheinway Hwang (China-Taipei)

Context

Depending on one's definition of the Asia-Pacific (AP) region, this SC could cover as many as 48 counties. Moreover, these countries are very diverse in terms of language, political persuasions, governments and wealth. This poses a significant challenge for the exchange of gravity and geoid data and expertise.

Not only unique to the AP region, the management and administration of gravity and the geoid can be vastly different in each country, making the coordination of such a group challenging. Taking Australia as an easy example, the gravity database is administered by a different government division to the administration of the national quasigeoid model.

Terms of Reference and Objectives

Promote the cooperation in and knowledge of gravity, geoid and closely related studies in the Asia-Pacific region.

A group of delegates comprises one member from each participating country. Because of the need to carry national authority, the national member is logically the officer in the country's geodetic authority responsible for its quasi/geoid and/or vertical datum matters.

Because of the synergy that exists between the objectives of this SC and those of the Working Group of the United Nations Global Geospatial Information Management for Asia and the Pacific ((UNGGIM-AP), it is logical to liaise with this working group.

Program of Activities

Liaise with the Geodesy Working Group of the UNGGIM-AP and other nations in the Asia-Pacific region, initially through the production of a flier that outlines the benefits of cooperation and data sharing.

Audit, document and catalogue the gravity and geoid-related that exists – including airborne campaigns. It is also important to establish a protocol for sharing the data. National authorities may be reluctant to give all the data available and at the precision available. It should be possible for geoid evaluation purposes, however, to decrease the resolution and accuracy of data shared along common borders without either comprising the precision of the geoid significantly, or the security of the national data shared.

a) Gravity and Related Data

Explore ways in which we may

- Share available gravity data (e.g. via International Gravity Bureau)
- Share available DEMs along common borders (National Geodetic Authorities)
- Combine resources for terrestrial gravity surveys along common borders
- Combine resources for airborne gravity surveys in the region.

b) Quasi/geoid Control

Explore ways in which countries of the region may cooperate by

- Sharing geometric (GNSS/levelling and vertical deflections) geoid control data
- Combining efforts in global GNSS campaigns
- Undertaking joint campaign for the connection of regional vertical datums.

c) Education & Research

Encourage and sponsor, for the region,

- Meetings and workshops, in cooperation with the International Geoid Service, to foster understanding in the evaluation and use of gravimetric quasi/geoids, and in their application to efficient height determination with GNSS.
- Technical sessions in scientific and professional conferences
- Research into matters of common concern/interest.

Delegates

John Dawson (Australia)
Will Featherstone (Australia)
Wen Hanjiang (Chaina)
Cheinway Hwang (China-Taipei)
Jay Hyoun Kwon (Korea)
Basara Miyahara (Japan)
Kamaludin Omar (Malaysia)
Ibnu Sofian (Indonesia)
Chalermchon Satirapod (Thailand)

SC 2.4f: Gravity and Geoid in Antarctica

Chair: Mirko Scheinert (Germany)

Terms of Reference and Objectives

Antarctica is the region that still features the largest data gaps in terrestrial gravity. Global gravity field solutions suffer from the lack of terrestrial data in Antarctica as well as from the polar data gap originating from the orbit inclination of dedicated satellite gravity field missions (esp. GOCE with a polar data gap of 1,400 km diameter).
However, a certain coverage of terrestrial gravity data in Antarctica coverage exists. These data are heterogeneous and exhibit inconsistencies. Nevertheless, these are needed for the global high-resolution determination of the Earth's gravity field and/or for a validation of global gravity field models. Finally, terrestrial gravity data need to be applied for a regional improvement of the Antarctic geoid.
Due to the vast extension of the Antarctic continent, its hostile environment and the difficult logistic conditions it is a long-lasting task to close the Antarctic data gaps in terrestrial gravity. AntGG shall pursue this objective and shall facilitate the necessary coordination to release gridded gravity datasets for Antarctica. It plays an important role to improve the cooperation between all interested scientists of geodesy and of neighboring disciplines, mainly geophysics.

Program of Activities

- Promoting the collection of surface and airborne gravity data in Antarctica;
- Promoting new gravity surveys in Antarctica, especially airborne gravimetry;
- Promoting the establishment and (re-)measurement of reference gravity stations utilizing absolute gravity meters;
- Promoting the scientific exchange of latest developments in technology (esp. airborne gravimetry) and data analysis;
- Evaluation of existing and new surface and airborne gravity data, validation of global gravity field models in Antarctica;
- Investigation of optimum strategy for the combination of gravity data of different sources;
- Release of gridded gravity anomaly dataset(s) for Antarctica to the scientific public (first release planned for 2015/2016, subsequent updates are planned when data availability improves adequately);
- Organization of special workshop on airborne geodesy and geophysics (especially aerogravimetry) with focus on Antarctica;
- Focus group for all scientists interested in Antarctic gravity and geoid, and cooperation with similar data initiatives, especially within the Scientific Committee on Antarctic Research (SCAR);

Delegates

Don Blankenship (USA)
Alessandro Capra (Italy)
Koichiro Doi (Japan)
Graeme Eagles (Germany)
Fausto Ferraccioli (UK)
Christoph Förste (Germany)
René Forsberg (Denmark)
Larry Hothem (USA)
Wilfried Jokat (Germany)
Gary Johnston (Australia)
Steve Kenyon (USA)
German L. Leitchenkov (Russia)
Jaakko Mäkinen (Finland)
Yves Rogister (France)
Mirko Scheinert (Germany)
Michael Studinger (USA)

Associates

Matt Amos (New Zealand)

SC 2.5: Satellite Altimetry

Chair: Xiaoli Deng (Australia)
Vice-chair: C.K. Shum (USA)

Terms of Reference

The long-term time series of altimeter measurements has revolutionised the knowledge of many interdisciplinary scientific research fields including the marine gravity field, oceanic dynamics, terrestrial hydrology, ice sheet mass balance, sea level changes, and solid Earth geodynamics. Conventional Ku-band altimetry is now a mature technique after more than 24 years of continuous observations and will be further applied in Jason-3. New missions employing Ka-band radar (SARAL/AltiKa), delay Doppler SAR altimetry (CryoSat-2, Sentinel-3 and Jason-CS) and laser altimetry (ICEsat-1/-2 including a photon counting instrument) are providing and will provide higher resolution observations of the cryosphere, sea-ice, ice-covered oceans, open oceans and inland water bodies. The future Surface Water and Ocean Topography (SWOT) altimeter mission, to be launched in 2020, is expected to substantially improve our understanding of ocean circulation and surface water hydrology at finer scales. Another altimetry technology under development is GNSS-R altimetry or reflectometry, which also has applications in the remote sensing of ocean wind retrieval, soil moisture, land cover, snow depth, and ocean surface topography.

With these existing and new technological advances in altimetry, novel observations are and will be driving technological leaps forward for satellite geodesy and oceanography. At the same time, they will bridge an observational gap on a spatio-temporal domain critical for solving interdisciplinary problems of considerable societal benefit. Therefore, the purpose of this IAG sub-commission is to promote innovative research using historic and future altimeter observations to study local, regional, and global geophysical processes, with emphasis on emerging cross-disciplinary applications using satellite altimetry, and in combination with other *in situ* data sets and techniques including hydrography data, SAR/InSAR and GRACE/GOCE. The research results and potential data products will benefit IAG's Global Geodetic Observing System.

Objectives

Sub-Commission 2.5 will:

- Establish a close link between this sub-commission and the International Altimeter Service (IAS) and data product providers, in order to (1) organise scientific forums to discuss new results, (2) bring new algorithms from expert research into data production, and (3) encourage development of data products that more directly facilitate cross-disciplinary applications using satellite altimetry;
- Promote innovative applications of satellite altimetry, including evaluations and cross-disciplinary applications of future satellite altimetry;
- Continue developing techniques to improve altimeter data quality, aiming towards new data products in coastal zones including coastal ocean, estuaries and inland water bodies;
- Focus on capabilities of the very high along-track spatial resolution from new SAR and SARAL altimeters for precisely modelling the marine gravity field, the mean sea surface, bathymetry and ocean mean dynamic topography, as well as temporal variations of sea level induced by solid Earth processes, climate change and the global terrestrial water cycle;
- Promote cross-disciplinary research on the shapes and temporal variations of land/ice/ocean surfaces, such as studies of long-term ocean variability, regional and global sea level changes, mountain glaciers/ice-sheet ablations/accumulations, permafrost degradation, coastal and ice-shelf ocean tides, vertical displacements at major tectonic-active zone, land subsidence and other geophysical processes; and
- Establish a specific connection with relevant altimetry observing systems in IAG's GGOS.

Program of Activities

This sub-commission will organize independent workshops or special sessions in major meetings to promote altimetric applications in interdisciplinary earth sciences, and to increase the visibility of IAG in altimetric science. Special study groups may be established to investigate important issues.

SC 2.6: Gravity and Mass Transport in the Earth System

Chair: Jürgen Kusche (Germany)
Vice-chair: Isabelle Panet (France)

Terms of Reference

Spatial and temporal variations of gravity are related to the dynamics of the Earth's interior, land surface, oceans, cryosphere, and atmosphere. The geoid maps equilibrium dynamic processes in the ocean and in the Earth's mantle and crust, and large-scale coherent changes in gravity result from mass transports in atmosphere, hydrosphere, cryosphere, and the ocean, and across these. The gravity field, derived from terrestrial and space gravimetry (SLR, GRACE, GOCE, …) with unprecedented accuracy and resolution, provides a unique opportunity to investigate gravity-solid earth coupling, the structure of the globe from the inner core to the crust, and mass transports such as those associated within the global water cycle. Gravimetry also contributes to a better understanding of the interactions in the Earth system, and to its response to climate change and the anthropogenic fingerprint.

Objectives

- To further the understanding of the physics and dynamics of the Earth's interior, land surface, cryosphere, oceans and atmosphere using gravity and other geophysical measurement techniques.
- To promote the study of solid Earth mass (re-)distribution from gravity and gravity gradient tensor variations, e.g. crust thickness, isostatic Moho undulation, mass loadings, basin formation, thermal effects on density, deformations, as well as interactions with the Earth's interior.
- To advance the investigation of mass transports in the Earth system, and, in particular, to contribute to the understanding of the global water cycle, of the storage of water in cryosphere and hydrosphere, of the fluxes across these sub-systems and the atmosphere, and of sea level.
- To contribute to the operationalization of mass transport monitoring, e.g. for water resource monitoring
- To stimulate new applications of gravimetry and mass transport monitoring, e.g. in climate model validation and detection of anthropogenic effects
- To aid in method benchmarking and reconciliation of conflicting results
- To communicate with gravity-related communities in oceanography, hydrology, cryosphere, solid Earth, geodesy...)

Program of Activities

The sub-commission will establish Work Groups (WGs) on relevant topics. The Steering Committee will work closely with members and other IAG commissions and sub-commissions to obtain mutual goals. Also it will promote and jointly sponsor special sessions at IAG Symposia and other workshop/conferences.

Joint Working Groups of Sub-Commission 2.6

JWG 2.6.1: Geodetic observations for climate model evaluation
(joint with Commission 1)

Chair: Annette Eicker

Terms of Reference

Spatio-temporal variations of gravity are related to the dynamics of the Earth's interior, land surface and hydrosphere, oceans, cryosphere, and atmosphere. Due to its large signal, in particular the variations of continental water storage have been observed and analyzed in recent years from space gravimetry. In addition, the temporal change of gravity has been successfully related to net flux at the land-atmosphere interface, the sum of precipitation, evapotranspiration and runoff/discharge. Another powerful geodetic technique is microwave remote sensing of the atmosphere; in particular global and regional water vapor trends can be determined from GNSS measurements and other space-geodetic data and, e.g. radiosonde information.

Global and regional climate models simulate the coupled atmosphere-land surface- ocean system on decadal to century-long time scales. Since the water cycle is coupled to the energy and carbon cycles and critically controls biomass evolution, their ability of correctly simulating variability, frequency and trends of climate variables like land and sea surface temperature and precipitation and their response to anthropogenic forcing depend critically on their skills in representing the water cycle. As a result, the representation of the water cycle, including groundwater and human modifications like pumping and irrigation, has gained much attention in recent years. This holds also for climate monitoring activities that rather focus on assessing the current state of the Earth's climate than on the future. Initialization of climate model runs, detection and attribution of the anthropogenic fingerprint, or reanalysis of atmospheric/land surface modelling all depend on accurate observations of the current water cycle.

The gravity field, derived from GRACE and in the near future from GRACE-FO and other missions with unprecedented accuracy and resolution, provides a unique opportunity to validation of global and regional climate models. Different from 'GRACE-Hydrology', the focus of this WG would be on the observation, analysis and validation of fluxes across the land-atmosphere interface, and not on water resources. We would also aim at developing synergies between gravimetric, microwave-based, and other geodetic climate model validation efforts.

Objectives:

- To further the understanding of the potential of gravity and other geodetic measurements for the observation, analysis and validation of fluxes across the land-atmosphere continuum.
- To promote the cross-disciplinary study of these fluxes through comparison and possibly integration of gravimetric and hydro-meteorological measurements such as soil moisture, precipitation, water vapor, or evapotranspiration (e.g. latent and sensible heat flux)
- To advance the improvement of climate models (including land surface models), climate monitoring systems and analyses/reanalyses through space-based measurements of gravity
- To stimulate discussion between the gravity community and the land surface modelling, atmospheric modelling and climate communities

Program of Activities

- The WG will create opportunities for communication and discussion through suggesting/organizing sessions at international meetings and conferences
- The WG will develop reference (best-practice) methods for evaluating/improving climate models from geodetic data and publish these methods (e.g. in a 'white paper')
- The WG will seek to organize a special issue on its topic in an appropriate international journal

Members

Carmen Böning (USA)
Marie-Estelle Demory (UK)
Albert van Dijk (Australia)
Henryk Dobslaw (Germany)
Annette Eicker (Germany)
Wei Feng (China)
Vincent Humphrey (Switzerland)
Harald Kunstmann (Germany)
J.T. Reager (USA)
Anne Springer (Germany)
Paul Tregoning (Australia)

Working Groups of Sub-Commission 2.6

WG 2.6.1: Potential Field modeling with Petrophysical support

Chair: Carla Braitenberg (Italy)

Terms of Reference

The WG is concentrated on developing and promoting methods and software that are needed for a full understanding of the Earth static and variable gravity and gradient field. Due to the similarity in the gravity and magnetic potential field equations and the recent SWARM mission, the magnetic field modeling is also considered. At the present stage of knowledge it is recognized that a petrologic modeling of density should be considered in order to reduce ambiguity of the density models of crust and mantle. The group will seek petrological support to assist in developing a geophysically oriented petrological software for density, magnetic susceptibility and seismic velocity modeling. The output should be usable for further modeling as input for 3D lithosphere and mantle modeling. The working group intends to validate potential field modeling software that is free-share. Herefore a series of benchmark models will be collected.

The WG promotes studies and research of potential field terrestrial and satellite data for crust and mantle modeling.

Objectives:

- Validation of potential field modelling software
- Promote development of geophysical oriented petrological software for density, magnetic susceptibility, seismic velocity modeling. Output should be usable for further modeling as input for 3D lithosphere and mantle modeling.
- Define benchmark models for validation of software
- Organization of scientific workshops and meetings for the discussion of up to date modeling methods of potential fields and their time variations

Members

Orlando Alvarez (Argentina)
Valeria Barbosa, (Brazil)
Carla Braitenberg (Italy)
Jörg Ebbing, (Germany)
Christian Hirt (Germany)
Erik Ivins (USA)
Juanggen Jin (China)
Jon Kirby (Australia)
Rezene Mahatsente (USA)
Daniele Sampietro, (Italy)
Sabine Schmidt (Germany)
Holger Steffen (Sweden)
Leonardo Uieda (Brazil)
Xiapoping Wu (USA)

Joint Working Groups of Commission 2

JWG 2.1: Relativistic Geodesy: Towards a new geodetic technique
(joint with Commission 1, ICCT)

Chair: Jakob Flury (Germany)
Vice-chair: Gerard Petit (France)

Terms of Reference

In recent years major technology breakthroughs on the fields of optical frequency standards and optical frequency transfer have been achieved, which provide a new basis for relativistic geodesy. Optical frequency standards at the leading National Metrology Institutes today have relative frequency inaccuracies in the order of 10-17 to 10-18 range, and long-distance optical frequency transfer through phase-stabilized optical fiber has been demonstrated even with a relative frequency inaccuracy at the 10-19 level. The current, very dynamic activities on the field of optical frequency transfer are expected to pave the way towards continental or even global clock networks. This development will contribute to a redefinition of the SI second based on optical standards, and it could allow tying height reference and height networks to atomic standards. In addition, upcoming space missions such as Microscope and GRACE Follow-On will provide measurements at an accuracy level that is very relevant for relativistic geodesy. The Joint Working Group 2.1 will foster the exchange on concepts and methods in relativistic geodesy and will promote the development of clock networks and their use for relativistic geodesy. This requires strong links with time and frequency metrology and, in this aim, the JWG will establish liaisons with the Consultative Committee on Time and Frequency (CCTF) of BIPM to enhance communication and coordination. Within IAG, the group is joint and with IAG Sub-Commission 1-2 on Global Reference Frames to enhance communication and coordination.

Goals and Objectives

- Act as interface between groups in geodesy (gravity fields, reference frames…) and in time and frequency metrology (clock development, clock comparisons …);
- Provide a platform to promote the further development and application of relativistic geodesy, e.g. in physics, astronomy and other fields of geodesy and metrology;
- Foster the geodetic interests in the realization of the concept of relativistic geodesy;
- Develop an optimal strategy for the installation and analysis of clock networks and for the combination of clock data with classical geodetic data (e.g. for height systems);
- Advocate the implementation of a clock network of sufficient capability to obtain data products essential for geodetic applications;
- Study the use of clock networks in space;
- Provide relevant information for the geodetic community including key contacts and links;
- Organize meetings and sessions on relativistic geodesy;
- Prepare a document on the perspectives and applications of relativistic geodesy.

Program of Activities

The JWG 2.1 will work on meeting these objectives. In particular, the group will meet regularly during major conferences on geodesy and on time and frequency metrology, such as IAG Scientific Assembly, IUGG General Assembly, IFCS, EFTF. If needed, dedicated meetings will be organized. The group will exchange information and discuss questions on measurement techniques, standards, and analysis methods. The group will foster communication and coordination related to measurement campaigns and infrastructure in clock networks and Relativistic Geodesy. If appropriate, the group will make recommendations on methods of measurement and analysis.

Members

Jakob Flury (Germany), Chair
Gerard Petit (France), Vice-chair
Geoff Blewitt (US)
Claude Boucher (France)
Pascale Defraigne (Belgium)
Pacome Delva (France)
Gesine Grosche (Germany)
Claus Lämmerzahl (Germany)
Christian Lisdat (Germany)
Jürgen Müller (Germany)
Pavel Novak (Czech Republic)
Paul Eric Pottie (France)
Bijunath Patla (US)
Nikos Pavlis (US)
Stefan Schiller (Germany)
Piet Schmidt (Germany)
Pieter Visser (The Netherlands)
Peter Wolf (France)