Commission 4 – Positioning and Applications

President: **Marcelo Santos** (Canada)
Vice President: **Allison Kealy** (Australia)

http://IAG-Comm4.gge.unb.ca

Terms of Reference

IAG Commission 4 intends to bring together scientists, researchers and professionals dealing with the broad area of positioning and its applications. For this purpose, it will promote research that leverages current and emerging positioning techniques and technologies to deliver practical and theoretical solutions for engineering and mapping applications, GNSS technologies, sensors fusion, and atmospheric sensing, modelling, and applications, based on geodetic techniques. Commission 4 will carry out its work in close cooperation with the IAG Services and other IAG entities, as well as via linkages with relevant entities within scientific and professional organizations.

Recognizing the central role of Global Navigation Satellite Systems (GNSS) in providing high accuracy positioning information today and into the future, Commission 4 will focus on research for improving models and methods that enhance and assure the positioning performance of GNSS-based positioning solutions for a range of geodetic applications.

The Sub-Commissions will develop theory, strategies and tools for modeling and/or mitigating the effects of interference, signal loss and atmospheric effects as they apply to precise GNSS positioning technology. They will address the technical and institutional issues necessary for developing backups for GNSS, integrated positioning solutions, automated processing capabilities and quality control measures.

Commission 4 will also deal with geodetic remote sensing, using Synthetic Aperture Radar (SAR), Light Detection and Ranging (LiDAR) and Satellite Altimetry (SA) systems for geodetic applications.

Additional WGs and SGs can be established at any time, and existing can be dissolved, if they are inactive.

Objectives

The main topics dealt by Commission 4 are as listed in the IAG By-laws:

- Terrestrial and satellite-based positioning systems development, including sensor and information fusion;
- Navigation and guidance of platforms;
- Interferometric laser and radar applications (e.g., Synthetic Aperture Radar);
- Applications of geodetic positioning using three dimensional geodetic networks (passive and active networks), including monitoring of deformations;
- Applications of geodesy to engineering;
- Atmospheric investigations using space geodetic techniques.

Structure

Sub-Commissions

SC 4.1: Emerging Positioning Technologies and GNSS Augmentation
Chair: Vassilis Gikas (Greece)

SC 4.2: Geo-spatial Mapping and Geodetic Engineering
Chair: Jinling Wang (Australia)

SC 4.3: Atmosphere Remote Sensing
Chair: Michael Schmidt (Germany)

SC 4.4: Multi-constellation GNSS
Chair: Pawel Wielgosz (Poland)

Joint Study Groups

JSG 0.10: High rate GNSS
Chair: Mattia Crespi (Italy)
(joint with ICCT, description see ICCT)

JSG 0.14: Fusion of multi-technique geodetic data
Chair: Krzysztof Sośnica (Poland)
(joint with ICCT, description see ICCT)

JSG 0.17: Multi-GNSS theory and algorithms
Chair: Amir Khodabandeh (Australia).
(joint with ICCT, description see ICCT)

JSG 0.20: Space weather and ionosphere
Chair: Klaus Börger (Germany)
(joint with ICCT, description see ICCT)

Joint Working Groups

JWG 1.3: Troposphere Ties
Chair: Robert Heinkelmann (Germany)
Vice-Chair: Jan Douša (Czech Republic)
(joint with Commission 1, description see Commission 1)

Steering Committee

President Commission 4: Marcelo Santos (Canada)
Vice-President Comm. 4: Allison Kealy (Australia)
Chair Sub-Comm. 4.1: Vassilis Gikas (Greece)
Chair Sub-Comm. 4.2: Jinling Wang (Australia)
Chair Sub-Comm. 4.3: Michael Schmidt (Germany)
Chair Sub-Comm. 4.4: Pawel Wielgosz (Poland)
Representative of IVS: Robert Heinkelmann (Germany)
Member-at-Large: Jens Wickert (Germany)
Member-at-Large: João F. Galera Monico (Brazil)

Representative of External Bodies

ISPRS: Charles Toth (USA)
FIG: Allison Kealy (Australia)
ION: Larry Hothem (USA)
UN International Committee on GNSS: Ruth Neilan (USA)

Sub-Commissions

SC 4.1: Emerging positioning technologies and GNSS augmentation

Chair: Vassilis Gikas (Greece)
Vice-chair: Günther Retscher (Austria)
Secretary: Harris Perakis (Greece)

Terms of Reference

To undertake, promote and report on research that leverages emerging positioning techniques and technologies aiming to address practical and theoretical solutions for positioning, navigation and guidance, including spatio-temporal monitoring and tracking of objects at various scales. The focus will be on multi-sensor cooperative systems operating in adverse GNSS conditions for transportation, personal mobility, industrial and indoor positioning applications and to a lesser extent environmental monitoring. Except GNSS, the primary sensors of interest include inertial and wireless technologies as well as vision-based systems and laser scanning. SC 4.1 will foster linkages and pursue its goals in close collaboration with other IAG Entities, as well as sister scientific and professional organizations, primarily the ISPRS, FIG, ION and IEEE.

Objectives

- To address and evaluate new algorithms and multi-sensor systems for cooperative and ubiquitous positioning for land and airborne navigation applications including UAV systems;
- To examine the potential and capabilities of low-cost sensors including GNSS systems and smartphone navigation sensors;
- To follow the technical advances in wireless systems such as RFID, UWB, WiFi, LED, DSRC for personal mobility and road applications;
- To evaluate the usability of emerging positioning technologies for urban traffic navigation and improved routing using collaborative driving systems and crowdsourcing traffic information;
- To study vision-based and optical systems including cameras and laser scanning both for navigation and object tracking and monitoring purposes;
- To contribute in research that depends on big data handling, sensor synchronization, data fusion, real-time processing as well as to support standardization activities;
- To study and monitor the progress of new multi-sensor applications, as well as, to support and promote knowledge exchange and reporting on the development trends, possibilities and limitations of emerging positioning technologies;
- To work closely, promote and present through publications and workshops the SC work at IAG events and those of sister organizations including the FIG, ISPRS, IEEE, ION, as well as, in collaboration with more specialized initiatives such as the EU COST Action SaPPART.

Working Groups of Sub-Commission 4.1

WG 4.1.1: Multi-Sensor Systems

Chair: Allison Kealy (Australia)
Vice-Chair: Günther Retscher (Austria)

Description

This group is a joint working group between IAG and FIG. It focuses on the development of shared resources that extend our understanding of the theory, tools and technologies applicable to the development of multi-sensor systems. It has a major focus on:

- Performance characterization of positioning sensors and technologies that can play a role in augmenting core GNSS capabilities;
- Theoretical and practical evaluation of current algorithms for measurement integration within multi-sensor systems;
- The development of new measurement integration algorithms based around innovative modeling techniques in other research domains such as machine learning and genetic algorithms, spatial cognition etc.;
- Establishing links between the outcomes of this WG and other IAG and FIG WGs (across the whole period);
- Generating formal parameters that describe the performance of current and emerging positioning technologies that can inform IAG and FIG members.

Specific projects to be undertaken include:

- International field experiments and workshops on a range of multi sensor systems and technologies;
- Evaluation of UAV capabilities and the increasing role of multi-sensor systems in UAV navigation;
- Investigation of the role of vision based measurements in improving the navigation performance of multi-sensor systems;
- Development of shared resources to encourage rapid research and advancements internationally.

WG 4.1.2: Indoor Positioning and Navigation

Chair: Kefei Zhang (Australia)
Vice-Chair: R. Chen (USA)

Description

The needs for indoor positioning and navigation have experienced unprecedented growth in the past decade due to the proliferation and ubiquitous usages of mobile devices and the rapid development of Internet of Things. Location information of people and objects in indoor environments becomes a key issue for many emerging and innovative applications. The primary aims of this working group are:

- To investigate emerging sensor technologies (e.g. LED, magnetometers), integrated techniques and protocols for indoor positioning and tracking;
- To discuss, investigate and develop new algorithm and smart solutions;
- To bring key researchers and developers in this area together;
- To disseminate effectively the state-of-the-art knowledge and new discoveries in the geospatial communities.

Specific projects to be undertaken include:

- Smart tracking based hybrid indoor positioning and GIS techniques;
- Third generation of positioning system for underground mine environments;
- Tracking indoor information and people's behaviour;
- Development of intelligent device-finder and location-finder;
- Multi-sensor Navigation with low-cost;
- Positioning in 5G cellular communication system.

WG 4.1.3: 3D Point Cloud Based Spatio-temporal Monitoring

Chair: Jens-Andre Paffenholz (Germany)
Vice-Chair: Corinna Harmening (Austria)

Description

The WG will focus on spatio-temporal monitoring of artificial and natural objects with the aid of 3D point clouds acquired by means of multi-sensor-systems (MSS). The emphasis will primarily be placed on laser scanning technology and to certain extend on digital cameras. In general, monitoring applications over a certain period of time require a geo-referencing of the acquired data with respect to a known datum. Also, a kinematic MSS requires the determination of the time-dependent seven degrees of freedom (translation, rotation and scale) with regard to a referencing.

Objectives

- Performance characterization of laser scanners and cameras and their fusion in MSS with respect to spatio-temporal monitoring of artificial and natural objects in different scales. Potential objects or scenarios can range from plant phenotyping to the monitoring of infrastructure buildings;
- Evaluate the object's abstraction for epochal comparison by means of discrete point-wise, area-based and shape-based approaches. One suitable method to investigate will be B-spline surfaces;
- Investigate and develop suitable algorithms for change tracking over time in 3D point clouds, for instance by means of feature point tracking or shape matching;
- Evaluate the fusion of heterogeneous data like 3D point clouds and ground-based synthetic aperture radar (GB-SAR) data with respect to structural health monitoring applications including infrastructure buildings;
- Algorithms will be implemented in Python, Matlab, C++ whereas for basic 3D point cloud operations open source libraries should be used, such as point cloud library (PCL);
- Establishing links to colleagues from civil and mechanical engineering to benefit from each other in terms of structural health monitoring, for instance loading tests of structural elements in lab and real conditions;
- Establishing working links between this working group and similar national and international working groups such as DVW, ISPRS, IAG and FIG working groups.

Specific projects to be undertaken include:

- Comparative study of different laser scanners in a plant phenotyping scenario in a greenhouse environment. The focus should be on low-cost laser scanners rather than on high-end triangulation sensors (link to plant scientists);
- Loading tests of a concrete structures in laboratory environments (link to civil engineers);
- Simultaneous observations and cross-comparisons using laser scanner, camera and GB-SAR of suitable objects.

WG 4.1.4: Robust Positioning for Urban Traffic

Chair: Laura Ruotsalainen (Finland)
Vice-Chair: Fabio Dovis (Italy)

Description

The Work Group will focus on the navigation challenges on the urban environments for greener, safer and more comfortable traffic. At present, navigation is mainly based on the use of Global Navigation Satellite Systems (GNSS), providing good performance in open outdoor environments. However, navigation solution with sufficient accuracy and integrity is needed in urban canyons, where GNSS is significantly degraded or unavailable. For overcoming the aforementioned navigation challenges, research has been very active for decades for finding a suitable set of other methods for augmenting or replacing the use of GNSS in positioning for urban traffic.

Objectives

- Specification and characterization of the system requirements, especially from the environmental and safety viewpoints;
- Evaluation of the usability of emerging technologies for the urban traffic navigation, including vision-aiding and collaborative driving systems;
- Selection of best set of technologies fulfilling the system requirements;
- Performance analysis of the selected system both for vehicles and pedestrians in urban areas;
- Selecting the most suitable algorithms for map matching and routing.

Specific projects to be undertaken include reporting on and/or establishing links between:

- The specification and characterization of the system requirements;
- recommendations on the best set of sensors and technologies to be used;
- The performance analysis of the selected system;
- The most suitable algorithms for map matching and routing in urban environments.

The outcomes of this WG, other IAG and FIG WGs, the EU COST action SaPPART addressing the satellite positioning performance assessment for road transport, as well as different actors having interest in urban traffic, e.g. transport authorities and car manufacturers.

SC 4.2: Geo-spatial mapping and geodetic engineering

Chair: Jinling Wang (Australia)
Vice-Chair: Michael J. Olsen (USA)
Secretary: Hsiu-Wen Chang (China-Taipei)

Terms of Reference

Geodesy provides foundations for geospatial mapping and engineering applications. Modern geospatial mapping as a massive point positioning process has been evolving towards automatic operations, and at the same time, various engineering areas are increasingly relying on highly developed geospatial technologies to deliver improved productivities and safety with minimised negative environment impact. This Sub-Commission (SC) 4.2 will therefore endeavour to coordinate research and other activities that address the broad areas of the theory and applications of geodesy tools in geospatial mapping and engineering, ranging from construction work, geotechnical and structural health monitoring, mining, to natural phenomena such as landslides and ground subsidence. The SC4.2 will carry out its work in close cooperation with other IAG Entities, as well as via linkages with relevant scientific and professional organizations such as ISPRS, FIG, ISM, ICA, IEEE, ION, OGC.

Objectives

- To develop and promote the use of new geospatial mobile mapping technologies for various applications;
- To develop and report the modelling and quality control framework for geo-referencing procedures;
- To monitor research and development into new technologies that are applicable to the general field of engineering geodesy, including hardware, software and analysis techniques;
- To study advances in geodetic methods for engineering applications, such as mining operations, and large construction sites;
- To study advances in monitoring and alert systems for local geodynamic processes, such as landslides, ground subsidence, etc.;
- To study advances in Structural Health Monitoring (SHM) systems and geospatial mapping applications in SHM;
- To study advances in Building Information Modelling (BIM) and geospatial mapping applications in BIM;
- To document the body of knowledge in the field of geospatial mapping and engineering geodesy, and to present such knowledge in a consistent frame work at symposia and workshops;
- To promote research into several new technology areas or applications through the SC4.2 Working Groups.

Working Groups of Sub-Commission 4.2

WG 4.2.1: Mobile Mapping Technologies and Applications

Chair: J. Skaloud (Switzerland)
Vice-Chair: K.-W. Chiang (China-Taipei)

Description

Mobile mapping technologies have been widely used to collect geospatial data for a variety of applications, for example, navigation and online geospatial information services. As mobile mapping sensors are becoming cheaper and easier to access, modeling and quality control procedures for major steps of mobile mapping should be further developed to ensure the reliability of geospatial data from mobile mapping systems. This working group will conduct its work through coordinated activities among the members of the group as well as in collaborations with other professional organizations, such as ISPRS/FIG.

Objectives

- To monitor new trends in mobile mapping technologies, such as UAV/UAS mapping;
- To evaluate the performance of geo-referencing and mapping sensors, such as IMU, GNSS, 3D cameras, optical vision sensors;
- To develop realistic mathematical and functional models for geo-referencing procedures;
- To develop a framework to evaluate the quality of geo-referencing and mapping results;
- To promote the use of geospatial mapping systems for various applications.

WG 4.2.2: Applications of Geodesy in Mining Engineering

Chair: Jian Wang (China)
Vice-Chair: Frederick Cawood (South Africa)

Description

Geodesy has been playing an important role in mining operations from geospatial mapping, modern navigation and guidance technologies used in automation at various mine sites to special orientation and location procedures used in underground operations. This working group will conduct its activities in close collaborations with other relevant international professional organizations, such as the International Society of Mining Surveying (ISM) and FIG.

Objectives

Major objectives of this WG are to study, and report the use of:

- Modern geodesy in various mining sites;
- 3D mapping for mining;
- Positioning, navigation and guidance of mining machinery;
- Miner location technologies in underground mining operations;
- Mine CORS and its synergized hazard monitoring (e.g. deformation, landslides and ground subsidence).

WG 4.2.3: Mobile Structural Health Monitoring Systems

Chair: Christian Eschmann (Germany)
Vice-Chair: Johnson Shen (Australia)

Description

Structural health monitoring (SHM) is an issue of increasing importance when looking at more and more aging and critical infrastructure around the world. In order to perform safety-related infrastructure inspections, robotic solutions are required to allow an automatic and reliable geospatial data acquisition for a comprehensive building database suitable for SHM analysis. Here the investigation of new mapping and navigation methods as well as non-destructive testing (NDT) sensors forms the basis for these mobile SHM systems. To develop such reliable autonomous systems, this working group will focus on current challenges such as the reproducibility and traceability of mobile NDT sensor data as well as the precise localization and navigation operations inside and/or in the areas close to infrastructures.

Objectives

- To monitor new approaches in terms of mobile structural health monitoring;
- To promote the use of unmanned mobile platforms, such as RPAs, UGVs and ROVs, for remote inspection and monitoring applications;
- To develop new methods for autonomous precise geospatial data acquisition and inspection tasks;
- To evaluate the applicability of miniaturized navigation and non-destructive testing sensors, such as LiDAR, radar or ultrasound, in mobile SHM systems.

WG 4.2.4: Building Information Modelling (BIM)

Chair: Mohsen Lalantari (Australia)
Vice-Chair: Michael J. Olsen (USA)

Description

Developed and promoted by Architecture, Engineering and Construction (AEC) industry, Building Information Models (BIM) provides the most detailed 3D spatial and semantic information about every building element during the lifecycle of a building. BIM is a 3D digital data space for sharing building information to enable multi-disciplinary collaboration among different actors involved in the development process of buildings. Recent surveys indicate that the BIM-based paradigm brings more productivity gains and long-term benefits. Therefore, this working group aims to promote BIM in IAG and encourage and report innovation in integrating BIM with geospatial engineering. This working group will conduct its activities in close collaborations with other relevant international professional organizations, such as GSDI, ISPRS and FIG.

Objectives

- Promote BIM and raise awareness in geospatial engineering applications;
- Integrate 3D mapping technologies and BIM;
- Investigate interoperability between and other geospatial formats;
- Use BIM in indoor navigation, indoor positioning, and 3D cadasters

SC 4.3: Atmosphere remote sensing

Chair: Michael Schmidt (Germany)
Vice-Chair: Jaroslaw Bosy (Poland)
Secretary: Mahmut O. Karslioglu (Turkey)

Terms of Reference

The Earth's atmosphere can be structured into various layers depending on physical parameters such as temperature or charge state. From the geodetic point of view the atmosphere is nowadays not only seen as a disturbing quantity which has to be corrected but also as a target quantity, since almost all geodetic measurement techniques provide valuable information about the atmospheric state.

Space weather and especially its impacts and risks are gaining more and more importance in politics and sciences, since our modern society is highly depending on space-borne techniques, e.g., for communication, navigation and positioning. Coupling processes between different atmospheric layers and inter-relations with climate change are other contemporary issues.

The general objectives of this SC are to coordinate research on the one hand side in understanding processes within and between the different atmospheric layers using space-geodetic measurements and observations from other branches such as astrophysics and on the other hand in developing new strategies, e.g., for prediction and real-time modelling.

Since GNSS is characterized as a highly precise observation technique it covers a wide range of applications and allows for a huge number of research topics. Besides GNSS based atmosphere sounding and studying space weather effects by modern evaluation methods, the promising GNSS reflectometry technique (GNSS-R) is another innovative research topic within this Sub-Commission.

Objectives

- Bridging the gaps between modern geodetic observation techniques such as GNSS radio occultations or GNSS-R and measurements from other scientific branches such as astrophysics and geophysics with the geodetic community;
- Exploration of the synergies between geodesy and other scientific branches such as astrophysics and geophysics;
- Improvement of the understanding of space weather with respect to the whole cause and effect chain;
- Investigation of the impact of solar events such as CMEs and solar flares on technical systems and satellite observation techniques;
- Investigation of ionosphere phenomena such as currents or scintillations;
- Investigation of coupling processes between different atmospheric layers;
- Estimation of thermosphere target parameters and studying their influences on satellite missions;
- Support of atmosphere prediction models based on the combination of data from different observation techniques, e.g., by developing sophisticated estimation procedures;
- Improvement of precise positioning and navigation on the basis of new atmosphere models;
- Development of real- and near real-time techniques for atmosphere monitoring;
- Study of climatological variations of the atmosphere.

Program of activities

- To promote research collaboration among groups from geodesy and other disciplines worldwide dealing with atmosphere research and applications;
- To organize and/or participate in scientific and professional meetings (workshops, conference sessions, etc.);
- To maintain a web page concatenating the Sub-Commission activities and reports;
- To encourage special issues, e.g. of Journal of Geodesy, on research, applications, and activities related to the topics of this Sub-Commission.

Study Groups of Sub-Commission 4.3

SG 4.3.1: Ionospheric and Atmospheric Coupling Processes and Phenomena: Modeling and Measurements

Chair: Lucie Rolland (France)
Vice-Chair: Attila Komjathy (USA)

Description

This SG aims at better understanding the coupling processes within the Earth's atmosphere and more generally between the solid Earth and its external envelopes including oceans, neutral atmosphere and the ionosphere using the help of geodetic techniques. Ionospheric disturbances from disruptive phenomena such as – but not limited to – large earthquakes, volcanic eruptions, tsunamis, meteorological or geomagnetic storms are now routinely observed using total electron content (TEC) measurements from GNSS indicating that the Earth's internal and external processes are closely coupled.

Objectives

- The development of new detection capabilities (e.g., multi-GNSS, radar imagery, etc.);
- The characterization and classification of ionospheric signatures, transients or traveling ionospheric disturbances (TID), in terms of amplitude, duration, frequencies, wavelengths, etc., as they relate to the source of the phenomena (natural or hand-made, telluric, atmospheric or ionospheric, etc.);
- The development of algorithms and methods for quantitative modeling of acoustic-gravity waves and novel designs of inversion strategies of physical parameters defining the source;
- Further developing data collection techniques along with establishing geodetic databases of coupled phenomena using non-geodetic observations (airglow, infrasound, etc.).

Working Groups of Sub-Commission 4.3

WG 4.3.1: Real-time Ionosphere Monitoring

Chair: Alberto Garcia-Rigo (Spain)
Vice-Chair: David Roma Dollase (Spain)

Description

Currently, near real-time or even real-time procedures are under development to monitor and analyse the state of the ionosphere and to predict ionosphere target parameters such as the electron density or the vertical total electron content.

Objectives

- Summary of the current status of real-time Ionosphere Monitoring;
- Comparison of existing RT Ionosphere Monitoring approaches from different perspectives for a specific event, such as the recent St. Patrick's Day 2015 Geomagnetic Storm;
- Procedure to automatically compare on a daily basis a subset of real time ionosphere data products providing the results in a common compatible IONEX format. Potential validation with external data sources, such as JASON2;
- Open discussion towards new concept(s) on RT Ionosphere Monitoring (through common mailing list).
- Dissemination activities (publications in international congresses and in international journals).

This WG aims to work in close scientific collaboration with IGS RT-WG, URSI and COSPAR IRI, among others.

Members

Alberto Garcia-Rigo (Chair, Spain)
David Roma Dollase (Vice-Chair, Spain)
Louikis Agrotis (UK), David Altadill (Spain)
Jens Berdermann (Germany), Nicolas Bergeot (Belgium)
Yannick Béniguel (France), Denise Dettmering (Germany)
Joachim Feltens (Germany), Tim Fuller-Rowell (USA)
Ivan A. Galkin (USA), Alberto Garcia-Rigo (Spain)
Tamara Gulyaeva (Russia), Haris Haralambous (Cyprus)
Manuel Hernández-Pajares (Spain)
Attila Komjathy (USA), Andrzej Krankowski (Poland)
Anna Krypiak-Gregorczyk (Poland)
Raul Orús (The Netherlands), David Roma Dosalle (Spain)
Michael Terkildsen (Australia), Li Zishen (China)

WG 4.3.2: Ionosphere Predictions

Chair: Mainul Hoque (Germany)

Description

The general objective of this study group is the development of ionosphere prediction algorithm/models based on the dependence of ionospheric characteristics on solar and magnetic conditions as well as on the region of the Earth. Ionospheric disturbances can affect technologies in space and on Earth disrupting satellite and airline operations, communications networks, navigation systems. As the world becomes ever more dependent on these technologies, ionospheric disturbances as part of space weather poses an increasing risk to the economic vitality and national security. Therefore, having the knowledge of the ionospheric state in advance during space weather events is becoming more and more important.

As part of the working group activities we will arrange splinter meetings during international conferences (e.g., EGU, ION GNSS) depending on the availability of members.

Within the next four years we will focus on

- the development of algorithms for estimating and forecasting ionospheric parameters worldwide based on data from geodetic observation systems, (e.g., GNSS) – the approach may take advantage of the ionospheric movement from east to west,
- performing first steps by introducing physics-motivated functions into the ionospheric parameters estimation process with respect to the inclusion of Sun and magnetic observations,
- combining data from different sensors to improve the spatial and temporal resolution and sensitivity taking advantage of different sounding geometries and latency.

Members

Mainul Hoque (Chair, Germany)
Aliaa Abd-Elnasser (Egypt)
Mahdi Alizadeh (Germany)
Claudia Borries (Germany)
Marta Cueto (Spain)
Nada Ellahony (Egypt)
Eren Erdogan (Germany)
Adria Rovira Garcia (Spain)
Abraham Stern (USA)

WG 4.3.3: Combination of Observation Techniques for Multi-dimensional Ionosphere Modelling
(joint with GGOS)

Chair: Mahdi M. Alizadeh (Germany)

Description

The general objective of this working group is the development of regional and global ionosphere maps of VTEC and electron density in 2D, 3D, and 4D; based on the combination of various observation techniques. Several observation techniques including space geodetic techniques allow monitoring and modelling of the ionosphere parameters, such as the electron density or the vertical total electron content (VTEC), but each technique has its specific characteristics which influence the derived parameters. Combining measurements from different techniques will provide more homogeneous maps with higher reliability and improved accuracy.

This JWG will contribute extensively to the aims of GGOS, which is integrating different geodetic techniques, different models, and different approaches in order to ensure a long-term, precise monitoring of the geodetic observables in agreement with the Integrated Global Observing Strategy (IGOS).

Objectives

- To investigate new space geodetic techniques suitable for providing information about the ionosphere, e.g. GNSS radio occultation aboard the Formosat-7/COSMIC-2 mission;,
- To focus on the development of appropriate parameter estimation and assimilation techniques based on the combination of different observation techniques;
- To study the integration of measurements from other sources into the combination procedure, e.g. ionosonde data;
- To further investigate on empirical, mathematical, and physical weighting schemes, with respect to the weighting of different techniques;
- To validate the combined maps through comparison with raw data from various space geodetic techniques;
- To evaluate the global ionosphere maps with global models such as IRI and NeQuick and the regional maps with regional ionosphere models such as LPIM and TWIM model.

Thus, this JWG will provide integrated global and regional maps of VTEC and peak ionosphere parameters from the combination of various space geodetic techniques. These products are interpretable as GGOS products following the strategy defined at the GGOS days 2015 in Frankfurt.

Members

Mahdi M. Alizadeh (Germany)
Dieter Bilitza (USA)
Janina Boisits (Austria)
Eren Erdogan, Eren (Germany)
Robert Heinkelman (Germany)
Mainul Hoque (Germany)
Jian Kong (China)
Ernest P. Macalalad (Philippines)
Anthony J. Mannucci (USA)
David Minkwitz (Germany)
Lung-Chih Tsai (China-Taipei)
Robert Weber (Austria)
Dudy D. Wijaya (Indonesia)
Yibin Yao (China)

WG 4.3.4: Ionosphere and Troposphere Impact on GNSS Positioning

Chair: Tomasz Hadas (Poland)

Description

Atmosphere effects are still one of the major factors limiting GNSS precise positioning. One possibility to overcome this limitation is to augment the positioning with precise external model. The ionosphere information is particularly important for processing long baselines, single frequency data and ambiguity resolution. The troposphere model can improve the convergence time and height estimation, particularly in real-time kinematic positioning. Further research is needed in detailed analysis of the atmosphere impact on GNSS positioning.

Objectives

- Specify the requirements for atmosphere models supporting GNSS positioning;
- Study the potential of NWM to support GNSS positioning with troposphere information;
- Investigate the impact of higher-order ionosphere effects on GNSS precise positioning;
- Final product: Recommendation on atmosphere models quality for application in GNSS positioning.

Members

Tomasz Hadas (Chair, Poland)
Simon Banville (Canada)
Mainul Hoque (Germany)
Amir Khodabande (Australia)
Thaleia Nikolaidou (Canada)
Junbo Shi (China)
Toshiaki Tsujii (Japan)
Pavel Vaclavovic (Czech Republic)
Duojie Wenig (China)

WG 4.3.5: Ionosphere Scintillations

Chair: Lung-Chih Tsai (China-Taipei)
Vice-Chair: Jens Berdermann (Germany)

Description

Ionospheric scintillation has significant impacts on satellite radio communication and navigation system performance. The main effects of scintillation on transionospheric radio systems are signal loss and phase cycle slips, causing difficulties in the signal lock of receivers. There is no doubt that scintillation of satellite radio signals is a consequence of the existence of random electron density fluctuations within the ionosphere. There could be different sources for ionospheric instabilities/irregularities at different areas and geophysical conditions.

Objectives

- Understanding the climatology of ionospheric scintillations, namely, its variation with latitude, season, local time, magnetic activity and solar cycle;
- Understanding the primary instability sources;
- Forecasting scintillations.

Members

Lung-Chih Tsai (Chair, China-Taipei)
Jens Berdermann (Vice-Chair, Germany)
Suvorova Alla (China-Taipei)
Chi-Kuang Chao (China-Taipei)
Kai-Chien Cheng (China-Taipei)
Alexei V. Dmitriev (China-Taipei)
Rui Fernandes (Portugal)
Yoshihiro Kakinami (Japan)
Chinmaya Kumar Nayak (India)
Ernest Macalalad (Philippines)
Charles L. Rino (USA)
Michael Schmidt (Germany)
Kuo-Hsin Tseng (China-Taipei)
Sudarsanam Tulasiram (India)

WG 4.3.6: Troposphere Tomography

Chair: Witold Rohm (Poland)

Description

GNSS troposphere tomography technique is gradually gaining interest around the world as new researchers start to investigate this concept, with new implementations being announced quite frequently. In the coming years we will see dramatic increase of number of available observations from dense GNSS networks and new satellite constellations such as Galileo, Beidou, QZSS or IRSS. As the slant troposphere delay estimation strategies are being intensively reinvestigated, the number and quality of standard tomography observations will be tripled or quadrupled.

This poses an opportunity for tomography application in the field of meteorology for monitoring, nowcasting and forecasting. The tomography models could be applied to independently resolve vertical and horizontal structure of weather phenomenon, if this could be done with high temporal resolution it would be an important input for nowcasting systems. On the other hand a number of STDs might overload the assimilation systems and the assimilation algorithms might not be optimal for exploiting the information provided by slants. An intermediate tomography step might solve these problems. However, successful implementation of tomography models in the weather services is hampered by several factors, such as (1) the unknown retrieval accuracy, (2) an unstable solution that may vary from epoch to epoch, and (3) a low vertical and horizontal resolution.

Objectives

- Quality assurance factors in GNSS tomography processing, investigating new mapping techniques, operator monitoring schemes and use (in the early stage) synthetic observations,
- Optimal combination of GNSS observations with other troposphere measurements in GNSS tomography models, [COMBINATION]
- Use of tomography retrievals in severe weather investigation, [SEVERE]
- Use of tomography retrieval in weather system assimilation. [ASSIMILATION]

Members

Witold Rohm (Chair, Poland)
Hugues Brenot (Belgium)
Michael Bender (Germany)
Michal Kacmarik (Czech Republic)
Toby Manning (Australia)
Alain Gaiger (Switzerland)
Zhizhao (George) Liu (Hong Kong, China)
Zohre Adavi (Iran)
Laurent Morel (France)
Gregor Moeller (Austria)
Krzysztof Kroszczynski (Poland)
Cédric Champollion (France)
Yan Xin (Austria)
Andre Sa (Portugal)

WG 4.3.7: Real-time Troposphere Monitoring

Chair: Jan Dousa (Czech Republic)
Vice-Chair: Eric Pottiaux (Belgium)

Description

The main objective of this WG is to develop, optimize and assess new real-time or ultra-fast tropospheric products using data from GNSS permanent networks. Tropospheric zenith total delays, tropospheric linear horizontal gradients, slant delays, integrated water vapour (IWV) maps or other derived products in sub-hourly fashion are foreseen for future exploitation in numerical and non-numerical weather nowcasting or severe weather event monitoring.

The use of Precise Point Positioning (PPP) processing strategy will play a key role in developing new products because it is an efficient and autonomous method, it is sensitive to absolute tropospheric path delays, it can effectively support real-time or ultra-fast production, it may optimally exploit data from all GNSS multi-constellations, it can easily produce a full variety of parameters such as zenith total delays, horizontal gradients or slant path delays and it may also support as reasonable as high temporal resolution of all the parameters. Last, but not least, the PPP is supported with the global orbit and clock products provided by the real-time service of the International GNSS Service (IGS).

Objectives

- Develop optimal strategies for real-time/ultra-fast tropospheric products suitable for numerical or non-numerical weather nowcasting applications or severe weather event monitoring.
- Stimulate development of application software for supporting routine production.
- Demonstrate real-time/ultra-fast production, assess applied methods, software and precise orbit and clock products.
- Evaluate tropospheric parameters and their potential for applications in meteorology
- Setup a link to the potential users, review product format and requirements.

Members

Jan Dousa (Chair, Czech Republic)
Eric Pottiaux (Vice-Chair, Belgium)
John Braun (USA)
Junping Chen (China)
Galina Dick (Germany)
Siebren de Haan (Netherlands)
Tomasz Hadaś (Poland)
Fabian Hinterberger (Austria)
Jonathan Jones (UK)
Min Li (China)
Xingxing Li (Germany)
Thaleia Nikolaidou (Canada)
Rosa Pacione (Italy)
Yoshinory Shoji (Japan)
Felix Norman Teferle (Luxembourg)
Pavel Václavovic (Czech Republic)
Henrik Vedel (Denmark)
Xiaoming Wang (Australia)
Kefei Zhang (Australia)

JWG 4.3.8: GNSS tropospheric products for Climate
(joint with Commission 1)

Chair: Rosa Pacione (Italy)
Vice-Chair: Eric Pottiaux (Belgium)

Description

In many parts of the world, huge efforts are ongoing for providing homogeneously reprocessed GNSS solutions that are the basis for deriving very precise coordinates, velocities and troposphere parameters (namely Zenith Total tropospheric Delays and Horizontal Gradients). These regional and global reprocessing campaigns are possible thanks to the availability of 19+ years of observations from permanently observing GNSS stations located worldwide (e.g. the IGS network), their regional densifications (e.g. the EPN network), and of reprocessed global orbit and clock products (e.g. those provided by the IGS Analysis Centers). These long-term time series of homogeneously reprocessed troposphere parameters will provide a GNSS climate data record with high potential for climate monitoring. Unfortunately, these time series still suffer from inhomogeneities (for example instrumental changes, changes in the station environment) which can affect the analysis of the long-term variability.

Objectives

The main objective of the working group is to assess existing reprocessed GNSS tropospheric products, foster the development of forthcoming reprocessing activities and promote their use for climate research.
The objectives of this WG are:

- Assess existing reprocessed troposphere solutions and provide recommendations for the forthcoming reprocessing activities.
- Set-up a common GNSS climate dataset on which different homogenization methodologies can be tested. The homogenized common long-term dataset can then be reused for climate trends and variability studies within the community.
- Stimulate the data assimilation of GNSS troposphere products in Climate Models.
- Review and update GNSS-based product requirements and exchange format for climate.
- Strengthen the cooperation between geodesists and climatologists.

Members

Rosa Pacione (Chair, Italy)
Eric Pottiaux (Vice-Chair, Belgium)
Fadwa Alshawaf (Germany)
Andrzej Araszkiewicz (Poland)
Olivier Bock (France)
Galina Dick (Germany)
Jan Douša (Czech Republic)
Gemma Halloran (United Kingdom)
Robert Heinkelmann (Germany)
Tong Ning (Sweden)
Felix Norman (Luxembourg)
Marcelo Santos (Canada)
Roeland Van Malderen (Belgium)
Sibylle Vey (Germany)
June Wang (USA)

WG 4.3.9: GNSS-R

Chair: Felipe Nievinski (Brazil)
Vice-Chair: Thomas Hobiger (Sweden)

Description

Global Navigation Satellite Systems (GNSS) have not only revolutionized positioning, navigation, and timing but also lead to the development of many other applications which were not anticipated when those satellite systems were designed decades ago. The most prominent example for a novel application from recent years is the usage of reflected GNSS signals as a new tool for remote sensing. GNSS-R enables us to derive geometric and physical characteristics of the reflecting surface by analysing and interpreting features of the received signals. GNSS-R has started to make an impact in the discipline of remote sensing but it still has not reached the focus of a broader geodetic community although topics like sea-level monitoring, hydrological loading, and water cycle and drought/flooding observations are highly relevant to the goals of the Global Geodetic Observing System (GGOS). Thus, the overall aim of this working group is to bridge the gap between GNSS-R and the geodetic community, by seeking to raise the awareness of its relevance to several geodetic problems as well as opportunities.

Objectives

- Identify GNSS-R data products which have a strong relation to IAG services and goals.
- Foster and establish interactions with neighbouring societies (such as the IEEE Geoscience and Remote Sensing Society, IGARSS) and cooperate with technological, engineering, and operational entities related to GNSS (e.g., the International GNSS Service, IGS), identifying common goals and detecting potential synergies.
- Provide an online inventory of GNSS-R products relevant to geodesy and point to corresponding data archives.
- Evaluate the possibility to obtain formal errors for GNSS-R products in order to enable better combination with other datasets.
- Provide guidelines and define formats for GNSS-R products being used for geodetic purposes.
- Organize working meetings with GNSS-R experts, while also inviting stakeholders from the geodetic community to participate in such events.
- Extend IGS Site Guidelines so as to maximize the shared usefulness of new GNSS site installations for reflectometry applications.
- Supplement the GNSS-R Campaign Spreadsheet (initiated by the IEEE GARSS) so as to list existing GNSS tracking stations that can be leveraged for reflectometry purposes.
- Evaluate the feasibility of a pilot project on GNSS-R for coastal sea level monitoring, demonstrating its current level of maturity towards an operational service; possibly in cooperation with the IGS Tide Gauge WG (IGS-TIGA).
- Plan future inter-comparison campaigns for the validation of theoretical model simulations as well as parameter retrievals based on measured data.

Members

Felipe Nievinski (Chair, Brazil)
Thomas Hobiger (Vice-Chair, Sweden)
Estel Cardellach (Spain)
Rüdiger Haas (Sweden)
Kosuke Heki (Japan)
Yukihito Kitazawa (Japan)
Kristine Larson (USA)
Manuel Martín-Neira (ESA)
Miguel Angel Ribot (Switzerland)
Nicolas Roussel (France)
Maximilian Semmling (Germany)
Joakim Strandberg (Sweden)
Kegen Yu (China)
Sibylle Vey (Germany)
Wei Wan (China)
Jens Wickert (Germany)
Simon Williams (UK)

SC 4.4: Multi-constellation GNSS

Chair: Pawel Wielgosz (Poland)
Vice-Chair: Yang Gao (Canada)
Secretary: George Liu (China)

Terms of Reference

Multi-GNSS Constellation is rapidly growing extending the number of satellites and available signals/frequencies. In addition to two already operational GPS and GLONASS systems, the new Galileo and BDS systems are under construction. Both GPS and GLONASS are currently undergoing a significant modernization, which adds more capacity, more signals, better accuracy and interoperability, etc. These new developments in GNSS provide opportunities to create new high-precision GNSS technologies and applications and also to open new research areas. This, however, results in new challenges in multi-GNSS data processing. Recognizing the central role of GNSS in providing high accuracy positioning information, the SC4.4 will foster research that address standards, theory and applications of Multi-GNSS Constellation. SC4.4 will coordinate activities to deliver practical and theoretical solutions for engineering and scientific applications and also will stimulate strong collaboration with the IAG Services (IGS) as well as with relevant entities within scientific and professional sister organizations (FIG, IEEE and ION).

Objectives

The major objective of SC4.4 is to promote collective research on Multi-Constellation GNSS methods and technologies and their novel applications to facilitate timely dissemination of scientific findings, to stimulate strong collaborations among researchers and international organizations and the industry.

Program of activities

- to identify and investigate important scientific and technical issues in Multi-Constellation GNSS applications,
- to stimulate strong collaborations among researchers,
- to organize international conferences and workshops,
- to promote the use of multi-GNSS techniques and products in interdisciplinary scientific research and engineering applications.

Study Groups of Sub-Commission 4.4

SG 4.4.1: Integrity Monitoring for Precise Positioning

Chair: Ahmed El-Mowafy (Australia).
Vice-Chair: Aboelmagd Noureldin (Canada).

Description

The use of GNSS for real-time precise positioning, defined here as positioning at cm to sub-meter accuracy level, relays on GNSS signals that have well-known vulnerabilities and the use of supplementary systems to calibrate measurement biases. In addition, when working in urban environment or in case of a break in receiving the reference station data, GNSS need to be integrated with other sensors such IMU and speed sensors. For a user, such as driverless cars, intelligent transport systems (ITS) and UAVs, with such vulnerabilities and mixture of systems, integrity monitoring is important for protection from faults and to alert the user in case that the system cannot reach the target performance.

This Study Group (SG) will endeavour to research and develop a framework, including theory and algorithms, for integrity monitoring of precise positioning in a number of applications. It will include precise positioning from GNSS in a stand-alone mode, e.g. in Precis Point Positioning (PPP), Real-Time Kinematic (RTK) or Network RTK processing, and when being integrated with other sensors such as IMU and speed sensors. The study group will carry out its work in close cooperation with other IAG and integrity monitoring groups, as well as via linkages with relevant scientific and professional organizations such as IGS, FIG, IEEE and ION**.** The SG will document the body of knowledge in the proposed field and present such knowledge at symposia and workshops.

Members

Ahmed El-Mowafy (Chair, Australia)
Aboelmagd Noureldin (Vice-Chair, Canada)
Slawomir Cellmer (Poland).
Naser El-Sheimy (Canada)
Per Enge (USA)
Pedro Francisco Navarro Madrid (Spain).
Allison Kelley (Australia),
Samer Khanafseh (USA)
Nobuaki Kubo (Japan).
Ilaria Martini (Germany),

SG 4.4.2 Modernized GNSS for Crustal Motions

Chair: Jianghui Geng (China)
Co-Chair: Diego Melgar (USA)

Description

The evolution of GNSS has been driving the advancement of Earth sciences. This Study Group will focus on the technical advancement of multi-GNSS positioning techniques and their applications in Earth sciences, especially in seismology and tectonics where high-precision positions over a wide frequency band are appreciated. Modernized GNSS provides new data such as L5, L2C and many others, which are expected to improve satellite positioning techniques, and benefit the identification of transient and minor crustal motion signals.

Objectives

- Identification of requirements for accuracy and frequency bands to detect crustal motion signals, such as slow earthquakes, etc.;
- Investigation of multi-GNSS positioning techniques utilizing new code measurements and the third civilian frequency;
- Evaluation of integrated high-rate GNSS and strong-motion sensors in co-seismic displacement identification;
- Workshops and meetings at AGU, EGU and IGS conferences to gather together international researchers in this field to discuss the improvement by multi-GNSS positioning in crustal motion sensing.

Specific projects to be undertaken include:

- Suppression of multipath errors in a multi-GNSS environment, and the reduction of spurious signals in long-term GNSS position time series;
- Study how the fusion of GNSS and seismological sensors can be improved to reduce low-frequency noise;
- Study the benefits of multi-GNSS position time series and relevant approaches in identifying and extracting transient and minor crustal motion signals.

Members

Junbo Shi (China)
Brendan Crowell (USA)
Peng Fang (USA)
Yehuda Bock (USA)
Dana Caccamise (USA)
Norman Teferle (Luxembourg)
Yong Zheng (China)
Xiaopeng Tong (USA)
Radoslaw Baryla (Poland)
Bob Wang (USA)
Jennifer Haase (USA)
Adrian Borsa (USA)

Working Groups of Sub-Commission 4.4

WG 4.4.1: Biases in Multi-GNSS data processing

Chair: Xingxing Li (Germany)
Vice-Chair: Jan Dousa (Czech Republic)

Description

To address and investigate issues related to the various biases in multi-GNSS data processing. The main research focus will include the definition and mathematical representation of various biases in multi-GNSS, their spatiotemporal characters and the related mechanism, precise bias modeling and the estimability, the development of rigorous multi-GNSS algorithms, to improve positioning performance and to enhance computational efficiency (especially for real-time orbit and clock determination) through proper bias estimation and correction. The continuous effort is to tightly integrate multi-GNSS signals together through precise determination and application of the biases for the best positioning performance.

Members

Xingxing Li (Chair, Germany)
Jan Dousa (Vice-Chair, Czech Republic)
Ahmed El-Mowafy (Australia)
Yang Gao (Canada)
Fei Guo (China)
Haibo He (China)
Shuanggen Jin (China)
Richard Langley (Canada)
Bofeng Li (China)
Zishen Li (China)
Yidong Lou (China)
Felipe Nievinski (Brazil).
Jacek Paziewski (Poland)
Nigel Penna (UK)
Chris Rizos (Australia)
Pavel Vaclavovic (Czech Republic)
Jinling Wang (Australia)
Ningbo Wang (China)
Xiaoming Wang (Australia)
Robert Weber (Austria)
Suqin Wu (Australia)
Tianhe Xu (China)

WG 4.4.2: Integer Ambiguity Resolution for Multi-GNSS PPP and PPP-RTK

Chair: Xiaohong Zhang (China)
Vice-Chair: Sue Lynn Choy (Australia)

Description

To study the methodology of integer ambiguity resolution for Multi-GNSS PPP and investigate issues and problems of Multi-GNSS PPP related to ambiguity initialization time, success rate, accuracy and reliability etc. The research will focus on the following areas: the development of methods and algorithms for integer ambiguity resolution in Multi-GNSS precise point positioning; the development of new ionospheric correction model to speed up PPP ambiguity initialization time, and the real-time implementation and standardization of PPP-based Multi-GNSS RTK systems. The working group will carry out its work in close cooperation with other IAG groups and FIG to promote the use of multi-GNSS techniques and products in interdisciplinary scientific research and engineering applications

Members

Xiaohong Zhang (Chair, China)
Sue Lynn Choy (Vice-Chair, Australia)
Simon Banville (Canada)
Maorong Ge (Germany)
Jianghui Geng (China)
Marco Mendonça (Canada)
Baocheng Zhang (Australia)