

IAG Commission 4 – Positioning & Applications

The Terms of Reference (TOR) of Commission 4 are to *promote research into the development of a number of geodetic tools that have practical applications to engineering and mapping*. The Commission carries 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 Sister Organisations such as FIG, ISPRS and the U.S. ION. Recognising the central role that Global Navigation Satellite Systems (GNSS) plays in many of these applications, the Commission's work focuses on several GPS-based techniques. These include precise positioning, but extending beyond the applications of reference frame densification and geodynamics, to address the demands of precise, real-time positioning of moving platforms. Several Sub-Commissions deal with precise kinematic GPS positioning technology itself (alone or in combination with other positioning sensors) as well as its applications in surveying and engineering. Recognising the role of continuously operating GPS reference station network, research into non-positioning applications of such geodetic infrastructure is also pursued, such as ionospheric and tropospheric sensing. The Commission also monitors developments in the general area of GNSS, in particular the next generation ('modernized') GPS and GLONASS, as well as the EU's GALILEO.

The Commission has the following Steering Committee:

Chris Rizos – President
Pascal Willis – Vice President
Dorota Brzezinska – Chair SC4.1
Heribert Kahmen – Chair SC4.2
Susan Skone, Hans van der Marel – Co-Chairs SC4.3
Xiaoli Ding – Chair SC4.4
Yang Gao – Chair SC4.5
Marcelo Santos – Member at Large
Ruth Neilan – IAG services representative

The Commission web site URL is: http://www.gmat.unsw.edu.au/iag/iag_comm4.htm.

Commission 4 is organised around five Sub-Commissions (SC):

- SC4.1 “Multi-sensor Systems”
- SC4.2 “Applications of Geodesy in Engineering”
- SC4.3 “GNSS Measurement of the Atmosphere”
- SC4.4 “Applications of Satellite & Airborne Imaging Systems”
- SC4.5 “Next Generation RTK”

Each SC has several Working Groups (WG) dealing with specific scientific issues.

In addition there are several Study Groups (SG):

- IC-SG1.1 “Ionospheric Modelling & Analysis” (joint with IAG Commission 1)
- IC-SG1.2 “Use of GNSS for Reference Frames” (joint with IAG Commission 1)
- SG4.1 “Pseudolite Applications in Positioning & Navigation”
- SG4.2 “Statistics and Geometry in Mixed Integer Linear Models, with Applications to GPS & InSAR” (joint with the IAG ICCT)

Since the establishment of Commission 4 in July 2003 the Steering Committee has met four times: “16th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, Portland, Oregon, 9-12 September 2003; “10 Years IGS: Workshop & Conference”, Bern, Switzerland, 1-5 March 2004; “17th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, Long Beach, California, 21-24 September 2004; and “U.S. Institute of Navigation National Tech. Meeting”, San Diego, California, 24-26 January 2005. However, not all Steering Committee members could make these meetings. The next meeting is scheduled to be held at the “Dynamic Planet” joint IAG/IAPSO/IABO Scientific Assembly, Cairns, Australia, 22-26 August 2005.

Given the “practical” nature of the Commission’s TOR, much importance is placed on developing strong links with Sister Organisations. Most of the chairs of SCs, SGs and WGs also hold positions within Entities of Sister Organisations that also deal with the topics of Commission 4. In particular, close links exist with the FIG, ISPRS, and U.S. Institute of Navigation (ION). It is especially pleasing to report that Commission 4 has been playing a central role in reinvigorating the IAG-FIG linkage, where there is already a Memorandum of Understanding (MoU) (<http://www.gmat.unsw.edu.au/iag/mou-fig-iag.pdf>). For example, joint sponsorship of two symposium series (one on “mobile mapping”, and the other on “deformation monitoring”) has assured that these symposia are held in alternate years, and a rationalisation of conferences in these topic areas has been achieved through the merger of the IAG-organised “Symposium on Geodesy for Geotechnical & Structural Applications” and the FIG-organised “Symposium on Deformation Measurements”, commencing in 2006.

An outcome of the renewed interest in IAG-FIG cooperation has been a paper prepared by the President of FIG Commission 5 (Matt Higgins) outlining the “mapping” of the IAG structure to the FIG-structure. The President of IAG (Gerhard Beutler) was invited to make a keynote speech at the FIG Working Week, in Athens, Greece, 22-27 May 2004. This paper explains the common interests of the two Organisations in the fields of Surveying and Geodesy (<http://www.gmat.unsw.edu.au/iag/fig-iag-athens2004.pdf>). Gerhard Beutler was also an invited speaker at the FIG Regional Conference, in Jakarta, Indonesia, 3-7 October 2004. Further concrete actions that FIG and IAG can take to strengthen their linkages will be explored at a roundtable meeting of the Presidents of FIG and IAG, at the “Dynamic Planet” conference in Cairns, Australia, 22-26 August 2005.

Commission 4 has also played a central role in developing a MoU between IAG and the U.S. ION (<http://www.gmat.unsw.edu.au/iag/mou-ion-iag.pdf>). This will lead to joint promotion of symposia, as well as more IAG-organised sessions at ION conferences. There is already a close working relationship between some Sub-Commissions and equivalent working groups within the ISPRS. The following summarises the linkages with Sister Organisations, and outcomes arising from them, as well as plans for further collaboration:

- The Chair of FIG Commission 5 “Positioning & Measurements” (Matt Higgins) has developed a document indicating the potential linkages between IAG and FIG Entities (and not just between the IAG Commission 4 and the FIG Commission 5) (<http://www.gmat.unsw.edu.au/iag/fig-iag-structures2003.pdf>).
- The FIG Commission 5 will assist in organising sessions of relevance to its Commission at “Dynamic Planet”, Joint Assembly of IAG/IAPSO/IABO, Cairns, Australia, 22-26 August 2005.
- The Chair of SC4.1 (Dorota Brzezinska) has facilitated an IAG-ION MoU similar to the one the IAG already has with the FIG.

- “Cross-chairing” arrangements between IAG SC4.1 “Multi-sensor Systems” and the FIG WG5.3 “Integrated Positioning, Navigation and Mapping Systems” (i.e. Chair/Vice-Chair of these two entities are reversed).
- An agreement has been reached that the biannual FIG-IAG-ISPRS “Mobile Mapping Technology” symposia will be held during the “odd” years, commencing with the next one in May 2007.
- There is a long tradition of IAG, FIG & ISPRS joint sponsorship of conferences going back to the predecessor of SC4.2, the “IAG Special Commission 4” (1995-2003), and this continues with the recently held “6th Conference on Optical 3-D Measurement Techniques”, in Zurich, Switzerland, 22-25 September 2003, and the 7th conference planned for Vienna, Austria, 3-5 October 2005.
- “Cross-chairing” arrangements between IAG SC4.2 “Applications of Geodesy in Engineering” and the FIG WG6.4 “Engineering Surveys for Construction Works & Structural Engineering” (i.e. Chair/Vice-Chair of these two entities are reversed). One outcome of which was the co-sponsoring of the “1st FIG Int. Symp. on Engineering Surveys for Construction Works & Structural Eng.” (Nottingham, U.K., 28 June – 1 July 2004).
- An agreement has been reached that the biannual FIG-IAG “Deformation Measurement” symposia will be held during the “even” years, commencing with the next one in May 2006. This represents a merger of two independently run symposia into one event.
- “Cross-chairing” arrangements between IAG SC4.4 “Applications of Satellite & Airborne Imaging Systems” and the FIG Task Force 6.1.2 “Use of Satellite Radar Interferometry for Deformation Measurement” (i.e. Chair of these two entities is the same person!).
- SC4.5 is currently working on a cooperative agreement with the relevant FIG Entity.
- There are several joint conferences/symposia being (or have been) organised, in addition to the organisation of individual sessions (see below).

Linkages have been made with other IAG Entities, some formal, others still not yet formalised:

- A joint symposium of SC4.1, SC4.2 and SC4.4 (together with the FIG Working Group 6.1) “3rd IAG Symp. on Geodesy for Geotechnical & Structural Engineering and 12th FIG Symp. on Deformation Measurements”, will be held in Baden, Austria, 22-24 May 2006.
- SC4.3 has pursued formal collaboration with the IGS Ionosphere Working Group.
- SC4.5 has pursued formal collaboration with the IGS RT Products Working Group.
- There is an Inter-Commission SG1.1 “Ionospheric Modelling & Analysis” (with IAG Commission 1 and COSPAR). One of the Chairs of SC4.3 (Susan Skone) is Vice-Chair of SG1.1.
- There is an Inter-Commission SG1.2 “Use of GNSS for Reference Frames” (with IAG Commission 1 and also the IGS GNSS Working Group), which has resulted in the formation of an “umbrella” IAG-IGS Joint WG on GNSS. The Chair of SG1.2 (Robert Weber) is also Chair of the IGS GNSS WG.

Conferences or symposia in which Commission 4 SCs, SGs or WGs and members are (or were) actively involved in their organisation and promotion include:

- “16th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, Portland, Oregon, 9-12 September 2003.
- “6th Conference on Optical 3-D Measurement Techniques”, Zurich, Switzerland, 22-25 September 2003.
- “10 Years IGS: Workshop & Conference”, Bern, Switzerland, 1-5 March 2004.
- “4th Int. Conference on Mobile Mapping Technology”, Kunming, China, 29-31 March 2004.
- “European Navigation Conference GNSS 2004”, Rotterdam, The Netherlands, 16-19 May 2004.
- “1st FIG Int. Symp. on Engineering Surveys for Construction Works & Structural Eng.”, Nottingham, U.K., 28 June – 1 July 2004.
- “Western Pacific Geophysics Meeting”, Hawaii, USA, 16-20 August 2004.
- “17th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, Long Beach, USA, 21-24 September 2004.
- “3rd FIG Regional Conference – Spatial Information for Economic & Environmental Development”, Jakarta, Indonesia, 3-7 October 2004.
- “Int. Symp. on GPS/GNSS”, Sydney, Australia, 6-8 December 2004.
- “Hydro Society Conference”, Ireland, November 2004.
- “7th Conference on Optical 3-D Measurement Techniques”, Vienna, Austria, 3-5 October 2005.
- “Int. Symp. on GPS/GNSS”, Hong Kong, 8-10 December 2005.
- “13th Int. Conf. on Geoinformatics”, Toronto, Toronto, Canada, 17-19 August 2005.
- “3rd IAG Symp. on Geodesy for Geotechnical & Structural Engineering and 12th FIG Symp. on Deformation Measurements”, Baden, Austria, 22-24 May 2006.
- “VI Hotine-Marussi Symp. on Theoretical & Computational Geodesy”, Wuhan, China, 29 May – 2 June 2006.
- “5th Int. Conference on Mobile Mapping Technology”, Padua, Italy, 7-10 May 2007.

Sub-Commission 4.1: Multi-sensor Systems

<http://www.ceegs.ohio-state.edu/IAG-SC41>

Terms of Reference

To coordinate research and other activities that address the broader areas of multi-sensor system theory and applications, with a special emphasis on integrated guidance, navigation, positioning and orientation of airborne and land-based platform. The primary sensors of interest will be Global Navigation Satellite Systems (GNSS) and inertial navigation systems; however the important role of other techniques used for indoor and pedestrian navigation is also recognised. The SC will carry out its work in close cooperation with other IAG entities, as well as via linkages with relevant scientific and professional organisations such as ISPRS, FIG, IEEE, ION.

Steering Committee

Chair: Dorota Grejner-Brzezinska (OSU, USA)
Vice-Chair: Naser El-Sheimy (Univ. of Calgary, Canada)
Secretary: Jinling Wang (UNSW, Australia)
Member-at-Large: Guenther Retscher (Vienna Univ. of Technology, Austria)
Joao Fernando Silva (UNESP, Brazil)

To strengthen the linkage between IAG and FIG it is noteworthy that there is “cross-chairing” of relevant entities within these two organisations. That is, the Chair/Vice-Chair of SC4.1 are reversed in the case of FIG WG5.3 “Integrated Positioning, Navigation and Mapping Systems”, allowing for close collaboration between the IAG and FIG in this SC. An excellent example of this collaboration is the joint organisation of the “Mobile Mapping Technology” conferences, the next one to be held in May 2007. The Vice-Chair of the SC is also chair of the ISPRS SPRS IC WG I/V “Integrated Mobile Mapping Systems”. The Chair of the SC is also a member of the Council of the U.S. ION (Land Applications representative), and has negotiated the IAG-ION Memorandum of Understanding between the two organisations.

WG4.1.1 Advances in Inertial Navigation and Error Modelling Algorithms

Chair: Sameh Nassar (Univ. of Calgary, Canada)
Co-Chair: Jay Kwon (Sejgon Univ., Korea)

Terms of Reference: To study and report the performance of the currently used inertial error modelling algorithms, and to promote the development of new methods and techniques for modelling inertial sensor errors. To implement innovative ideas for processing inertial data and integrating inertial systems with other sensors. To report the advances in the development of new inertial sensor technologies.

WG4.1.2 Indoor and Pedestrian Navigation

Chair: Guenther Retscher (Vienna Univ. of Technology, Austria)
Co-Chair: Bertrand Merminod (Swiss Federal Institute of Technology, Switzerland)

Terms of Reference: To promote research and development in the area of indoor and pedestrian navigation using multi-sensor integrated systems, based on medium to low-accuracy small-sized inertial systems, including micro-electro-mechanical systems (MEMS), and other positioning sensors, such as wheel sensors, ultrasonic and magnetic sensors, integrated with imaging sensors. To report progress on positioning methods based on cellular networks and their combination with GPS.

WG4.1.3 Advances in MEMS Technology and Applications

Chair: Mikel Miller (Sensors Directorate, Wright Patterson Air Force Base, USA)

Co-Chair: Jan Skaloud (Swiss Federal Institute of Technology, Switzerland)

Terms of Reference: To promote research into the development and integration of MEMS-based IMU that have practical applications to engineering and mapping. To promote research and development into precise, low-cost, low-power, small-sized, and high reliability IMU's for integration with other position, navigation, attitude, and time systems.

News & Linkages

- “4th Int. Conference on Mobile Mapping Technology”, Kunming, China, 29-31 March 2004. MMT represents a substantial joint activity between IAG, FIG & ISPRS. Naser El-

Sheimy (Vice-Chair of SC4.1) is the co-convenor and chair of the Science Committee and Dorota Brzezinska (Chair of SC4.1) is the co-chair of the Science Committee for the 5th MMT Padua, Italy, 7-10 May 2007.

- “3rd IAG Symposium on Geodesy for Geotechnical & Structural Engineering and 12th FIG Symposium on Deformation Measurements”, Baden, Vienna, 22-24 May 2006, is a joint symposium of IAG (SC4.1, SC4.2 and SC4.4) and FIG (WG6.1).
- IAG/FIG co-sponsored the session TS SS 3 “Mobile multi-sensor mapping systems” at the “XXth ISPRS Congress”, Istanbul, Turkey, 12-22 July 2004.
- SC4.1 participated in the development of the science program for “*Dynamic Planet*”, joint assembly of IAG, IAPSO & IABO, through a joint session with SC4.2 & SC4.4: G6 “Systems and Methods for Airborne Mapping, Geophysics and Disaster Monitoring”.
- Dorota Brzezinska is Track Chair for the “18th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, Long Beach, USA, 13-16 September 2005.
- Dorota Brzezinska is Program Chair and Naser El-Sheimy is General Chair of the “U.S. Institute of Navigation National Tech. Meeting”, Monterey, California, 18-20 January 2006, where there will be two sessions chaired by Commission 4 members.
- Chris Rizos and Dorota Brzezinska were invited participants at the “Workshop on Geolocation Technology to Support UXO Geophysical Investigations”, organised by the Strategic Environmental Research and Development Program (SERDP), and sponsored by DoD, EPA, and DOE, in Annapolis, Maryland, 1-2 June 2005.
- Guenther Retscher (Chair of WG4.1.2) was invited by the European Commission to present the research conducted by his research group and WG 4.1.2 at the workshop on “Location-based Technologies, Services and Applications”, Brussels, Belgium, 8 March 2004.
- Two members of WG4.1.2 also participated at the “2nd Workshop on Positioning, Navigation and Communication 2005 (WPNC'05)” and the “1st Ultra-Wideband Expert Talk 2005 (UET'05)”, Hannover, Germany, March 2005.
- WG4.1.2 will co-sponsor the “3rd Symp. on LBS & TeleCartography”, Vienna, Austria, 28-30 November 2005.

Sub-Commission 4.2: Applications of Geodesy in Engineering

<http://info.tuwien.ac.at/ingeo/sc4/sc42.html>

Terms of Reference

Rapid developments in engineering, microelectronics and the computer sciences have greatly changed both instrumentation and methodology in *engineering geodesy*. To build higher and longer, on the other hand, have been key challenges for engineers and scientists since ancient times. Now, and for the foreseeable future, engineers confront the limits of size, not merely to set records, but to meet the real needs of society minimising negative environmental impact. Highly developed engineering geodesy techniques are needed to meet these challenges. The SC will therefore endeavour to coordinate research and other activities that address the broad areas of the theory and applications of engineering geodesy tools. The tools range from

conventional terrestrial measurement and alignment technology (optical, RF, etc.), GNSS, geotechnical instrumentation, and software systems such as GIS, decision support systems, etc. The applications range from construction engineering and structural monitoring, to natural phenomena such as landslides and ground subsidence that have a local effect on structures and community infrastructure. The SC carries out its work in close cooperation with other IAG Entities, as well as via linkages with relevant scientific and professional organisations such as ISPRS, FIG, IEEE, ION.

Steering Committee

Chair: Heribert Kahmen (Vienna Univ. of Technology, Austria)
Vice-Chair: Gethin Roberts (IESSG, Nottingham University, UK)
Secretary: Guenther Retscher (Vienna Univ. of Technology, Austria)
Member-at-Large: Wolfgang Niemeier (Tech. Univer. Braunschweig, Germany)

To strengthen the linkage between IAG and FIG it is noteworthy that there is “cross-chairing” of relevant entities within these two organisations. That is, the Chair/Vice-Chair of SC4.2 are reversed in the case of FIG WG6.4 “Engineering Surveys for Construction Works & Structural Engineering”, allowing for close collaboration between the IAG and FIG in this SC. An example of this collaboration is the IAG involvement/sponsorship of the “*1st FIG Int. Symp. on Engineering Surveys for Construction Works & Structural Eng.*” (Nottingham, U.K., 28 June – 1 July 2004), and the FIG (& ISPRS) sponsorship of the IAG-initiated conference series on “Optical 3-D Measurement Techniques”.

WG4.2.1 Measurement Systems for the Navigation of Construction Processes

Chair: Wolfgang Niemeier (Technical Univ. Braunschweig, Germany)
Co-Chair: Guenther Retscher (Vienna Univ. of Technology, Austria)

Terms of Reference: To study and report the performance of the currently used navigation/guidance systems for construction machinery, and to promote the development of new methods and techniques for controlling construction processes.

WG4.2.2 Dynamic Monitoring of Buildings

Chair: Matthew Tait (Univ. of Calgary, Canada)
Co-Chair: Gethin Roberts (IESSG, Nottingham University, UK)

Terms of Reference: To study and report the performance of currently used building monitoring systems, including techniques based satellite and terrestrial measurements, and to promote new the application of new sensor technology.

WG4.2.3 Application of Knowledge-based Systems in Engineering Geodesy

Chair: Klaus Chmelina (GeoData, Austria)
Co-chair: John Bosco Miima (Technical Univ. Braunschweig, Germany)

Terms of Reference: To study and report on topics such as control of measurement- and guidance-systems, deformation analysis, control of alert systems, and the evaluation of their complex data stream through the use of knowledge-based systems. To implement new research outcomes in Artificial Intelligence for deformation analysis and measurement system control.

WG4.2.4 Monitoring of Landslides & System Analysis

Chair: Gyula Mentés (Geodetic & Geophysical Research Institute of HAS, Hungary)
Co-chair: Zhenglu Zhang (Wuhan University, China)

Terms of Reference: Worldwide landslides are one of the major types of natural hazards killing or maiming many people, and causing considerable damage to infrastructure. There has already been done a wide range of research work on landslides. Most of this work had a bias towards one discipline, such as remote sensing or geology. The proposal of the WG is to promote multi-disciplinary integration of different methods. The main goal is to establish an integrated workflow for landslide hazard management.

News & Linkages

- There is a long tradition of IAG, FIG & ISPRS joint sponsorship of conferences going back to the predecessor of SC4.2, the “IAG Special Commission 4” (1995-2003).
- Such linkages were responsible for the successful “6th Conference on Optical 3-D Measurement Techniques”, Zurich, Switzerland, 22-25 September 2003. The “7th Conference on Optical 3-D Measurement Techniques” is scheduled for Vienna, Austria, 3-5 October 2005.
- There was IAG/FIG co-sponsorship of the “1st FIG Int. Symp. on Engineering Surveys for Construction Works & Structural Eng.” (Nottingham, U.K., 28 June – 1 July 2004), which involved SC4.2.
- “3rd IAG Symposium on Geodesy for Geotechnical & Structural Engineering and 12th FIG Symposium on Deformation Measurements”, Baden, Vienna, 22-24 May 2006, is a joint symposium of the IAG (SC4.1, SC4.2 and SC4.4) and FIG (WG6.1).
- SC4.2 participated in the development of the science program for “Dynamic Planet”, joint assembly of IAG, IAPSO & IABO, through a joint session with SC4.1 & SG4.4: G6 “Systems and Methods for Airborne Mapping, Geophysics and Disaster Monitoring”.

Sub-Commission 4.3: GNSS Measurement of the Atmosphere

http://www.gmat.unsw.edu.au/iag/iag_sc43.htm

Terms of Reference

Over the past decade, significant advances in GPS technology have enabled the use of GPS as an atmospheric remote sensing tool. With the growing global infrastructure of GPS reference stations, the capability exists to derive high-resolution estimates of total electron content and precipitable water vapour in near real-time. Recent advances in tomographic modelling and the availability of spaceborne GPS observations has also allowed 3-D profiling of electron density and atmospheric refractivity. Future plans for the GALILEO system will allow further opportunities for exploiting GNSS as an atmospheric remote sensing tool. Many countries have initiated efforts in this area of research and application. The focus of this Sub-Commission is to facilitate collaboration and communication, and support joint research efforts, for GNSS measurement of the atmosphere. Collaboration with the International GPS Service (IGS), the SG1.1, and other IAG Entities and agencies will be promoted through, for example, joint sponsorship of workshops and conference sessions.

Steering Committee

Chair: Susan Skone (Univ. of Calgary, Canada)
Co-Chair: Hans van der Marel (TU Delft, The Netherlands)
Vice-Chair: Jens Wickert (GFZ, Germany)

Members-at-Large: Anthea Coster (MIT Haystack Observatory, USA)

The co-chairing of this SC was deemed appropriate as it deals with two quite distinct atmospheric sensing topics: the Ionosphere and the Troposphere. Susan Skone is also Vice-Chair of SG1.1 “Ionospheric Modelling & Analysis”.

WG4.3.1 Ionospheric Scintillation

Chair: B. Fortes (Abdus Salam International Centre for Theoretical Physics)

Co-Chair: TBA

To collect experimental data on ionospheric scintillation, by means of

Terms of Reference: The goal could be the study of scintillation impact on precise positioning operations, during both quiet and disturbed conditions, as well as during low to high solar activity, at high latitudes. Moreover, efforts could be devoted to the analysis of scintillation impact on satellite navigation and generic positioning operations.

WG4.3.2 Ionosphere Modelling Algorithms & Evaluation

Chair: Z. Liu (Univ. of Calgary, Canada)

Co-Chair: A. Komjathy (JPL, USA)

Terms of Reference: The ionosphere tomographic modelling method based on GNSS measurements is an interesting research topic and recently has increasingly drawn attention from a wide range of researchers. A systematic evaluation of the performances of ionosphere tomographic models will provide a good summary of the accuracy and predictability that ionosphere tomographic models can achieve. The performance of tomographic models will be assessed through comparisons against other available ionospheric models and calibration with different ionospheric data sets, under both ionospheric benign and severe conditions.

News & Linkages

- The SC has pursued formal collaboration with the IGS Ionosphere Working Group. The nature of this collaboration will likely take the form of a co-sponsored working group. This group will focus on defining space weather products (and methods of delivery) for ionospheric researchers.
- There will also be a link with a working group within URSI (International Union of Radio Science), of which the Chair of SC4.3 (Susan Skone) and several other members of IAG SC4.3 are members.
- Members of SC4.3 participated in the “*Workshop on Atmospheric Remote Sensing using Satellite Navigation Systems*” in Matera, Italy, 13-15 October 2003 (a workshop sponsored by the URSI working group “Atmospheric Remote Sensing using Satellite Navigation Systems”). Joint sponsorship of a future workshop with URSI is currently under consideration.
- SC4.3 co-sponsored a session on “GPS moisture retrieval” at the annual meeting of the *Canadian Meteorological and Oceanographic Society*, 31 May - 3 June 2004.
- SC4.3 participated in the development of the science program for “*Dynamic Planet*”, joint assembly of IAG, IAPSO & IABO, Cairns, Australia, 22-26 August 2005, through session G7 “Atmospheric Studies Using Space Geodetic Techniques”.

Sub-Commission 4.4:

Applications of Satellite & Airborne Imaging Systems

http://www.gmat.unsw.edu.au/iag/iag_sc44.htm

Terms of Reference

Satellite and airborne imaging systems, primarily Synthetic Aperture Radar (SAR) and Light Detection And Ranging (LiDAR) systems, are increasingly being used for geodetic applications such as ground deformation monitoring due to seismic and volcanic activity and man-induced subsidence due to fluid extraction, underground mining, etc. This SC will endeavour to promote and report on hardware/software research into these imaging systems that is relevant to geodetic applications. The SC will also facilitate communications and exchange of data, information and research results, in order to encourage wider application of these technologies, particularly in less developed countries. The SC carries out its work in close cooperation with other IAG Entities, as well as via linkages with relevant scientific and professional organisations such as ISPRS, FIG, IEEE.

Steering Committee

Chair: Xiaoli Ding (The Hong Kong Polytechnic Univ., Hong Kong)
Vice-Chair: Linlin Ge (UNSW, Australia)
Secretary: Makoto Omura (Kochi Womens University, Japan)
Member-at-Large: Ramon F. Hanssen (TU Delft, The Netherlands)

Xiaoli Ding is also chair of the FIG Task Force 6.1.2 “Use of Satellite Radar Interferometry for Deformation Measurement”.

WG4.4.1 Permanent Scatterer / Corner Reflector / Transponder InSAR

Chair: Fabio Rocca (Politecnico di Milano, Italy)
Co-Chair: Chao Wang (Institute of Remote Sensing Applications, Chinese Academy of Sciences)

Terms of Reference: To study and report on the use of permanent scatterers, corner reflectors and active transponders to enhance the quality and the scope of applicability of InSAR.

WG4.4.2 Atmospheric Effects in InSAR / InSAR Meteorology

Chair: Linlin Ge (UNSW, Australia)
Co-Chair: Chinatsu Yonezawa (Miyagi University, Japan)

Terms of Reference: To characterise the spatial and temporal variations of atmospheric effects, especially heterogeneous tropospheric delay, on InSAR and LiDAR measurements, and to study methods for the mitigation of the effects as well as the possibility of using these effects in numerical weather forecast.

WG4.4.3 InSAR for Polar Regions

Chair: Makoto Omura (Kochi Womens Univ., Japan)
Co-Chair: TBA

Terms of Reference: To generate high resolution and high accuracy digital elevation models for the polar regions using InSAR and Lidar and to monitor the movements of ice sheets.

WG4.4.4 Imaging Systems for Ground Subsidence Monitoring

Chair: Andrew Manu (Iowa State Univ., USA)
Co-Chair: TBA

Terms of Reference: To study and report on ground surface deformation monitoring using satellite and airborne imaging systems, especially ground subsidence associated with, e.g.,

city development, mining and ground liquid withdrawal, land reclamation and seismic activities.

News & Linkages

- SC4.4 participated in the *European Space Agency (ESA) "FRINGE 2003 Workshop: SAR Interferometry"* in Frascati, Italy, 1-5 December 2003.
- SC4.4 was responsible for organising a session "Applications of Satellite & Airborne Imaging Systems for Crustal Deformation Monitoring", at the "*Western Pacific Geophysics Meeting*", Hawaii, USA, 16-20 August 2004.
- There was IAG/FIG co-sponsorship of the "*1st FIG Int. Symp. on Engineering Surveys for Construction Works & Structural Eng.*" (Nottingham, U.K., 28 June – 1 July 2004), which involved SC4.4.
- SC4.4 members participated in the European Space Agency (ESA)'s "*ENVISAT Symposium*" in Salzburg, Austria, 1 – 6 September 2004.
- SC4.4 members participated in the "*XXth ISPRS Congress*" in Istanbul, Turkey, 12-23 July 2004.
- SC4.4 co-sponsored the "*Asia Pacific Geodynamics Program (APSG) Workshop: Geodynamics and Natural Hazards*" in Hong Kong, 15-17 June 2005.
- SC4.4 will participate in the "*International Geoscience and Remote Sensing Society (IGARSS)*" Meeting in Seoul, Korea, 25-29 July 2005.
- SC4.4 will participate in the "*1st International Symposium on Cloud-Prone & Rainy Areas Remote Sensing*" in Hong Kong, 6-8 October 2005.
- "*3rd IAG Symposium on Geodesy for Geotechnical & Structural Engineering and 12th FIG Symposium on Deformation Measurements*", Baden, Vienna, 22-24 May 2006, is a joint symposium of the IAG (SC4.1, SC4.2 and SC4.4) and FIG (WG6.1).
- SC4.4 participated in the development of the science program for "*Dynamic Planet*", joint assembly of IAG, IAPSO & IABO, through a joint session with SC4.1 & SG4.2: G6 "Systems and Methods for Airborne Mapping, Geophysics and Disaster Monitoring".
- SC4.4 will participate in ESA's "*FRINGE 2005 Workshop: Advances from Envisat and ERS Missions*" in Frascati, Italy, 28 November – 2 December 2005.
- SC4.4 is encouraging, and members are leading, regional collaborative research that involve InSAR research groups from several countries. This will prove to be beneficial to the participating research groups.
- SC4.4 is working closely with the FIG Task Force 6.1.2 (the Chair of SC4.4 and the Chair of TF6.1.2 is the same person). Discussions on formal collaboration with ISPRS and IEEE are underway.
- SC4.4 submitted a proposal to the International Polar Year 2007-2008: "Monitoring movements of Antarctic Ice Sheet and Glaciers on Coastlines by SAR".
- Vice-Chair of SC4.4 (Linlin Ge) was an invited speaker at the "*International Workshop on Earth Observation Technology and Application (CEOS 2004)*" in Beijing, China, 16-17 November 2004.

Sub-Commission 4.5: Next Generation RTK

<http://www.ucalgary.ca/~ygao/iag.htm>

Terms of Reference

Current carrier phase-based Real-Time Kinematic (RTK) positioning at the centimetre accuracy level requires the combination of observations from two GPS receivers, with one serving as the base station with known coordinates and another as the mobile/user station. One significant drawback for this approach, however, is the practical constraints imposed by the requirement that simultaneous observations be made at the user and reference stations, and that the user station be within the vicinity of the reference station typically up to 20 kilometres. Development of methods and algorithms to eliminate such constraints for increased flexibility and accessibility using RTK therefore presents a current trend. This SC will identify, encourage investigation into the important research issues and problems for the development of next generation RTK technologies, report on such developments, and will promote international collaborations among researchers and organisations from academia, government and private sectors. The latter will be done through linkages with sister scientific and professional organisations, and especially with the IGS.

Steering Committee

Chair: Yang Gao (Univ. of Calgary, Canada)
Vice-Chair: Lambert Wanninger (Ingenieurbüro Wanninger, Germany)
Secretary: Wu Chen (The Hong Kong Polytechnic Univ., Hong Kong)
Member-at-Large: Mark Caissy (Natural Resources Canada, Canada)
Member-at-Large: John Raquet (Air Force Institute of Technology, USA)
Member-at-Large: Sunil Bisnath (Harvard-Smithsonian Center for Astrophysics, USA)

WG4.5.1 Network RTK

Chair: Lambert Wanninger (Ingenieurbüro Wanninger, Germany)
Co-Chair: Ola Ovstedal (Agricultural Univ. of Norway, Norway)

Terms of Reference: To study the various technical aspects of network RTK positioning and to stimulate further research work in this field. To report progress on the development of GNSS reference station networks for RTK positioning.

WG4.5.2 Carrier Phase based Precise Point Positioning

Chair: Sunil Bisnath (Harvard-Smithsonian Center for Astrophysics, USA)
Co-Chair: Maxim Kechine (Delft Univ. of Technology, The Netherlands)

Terms of Reference: To address and investigate issues and problems related to the development of a new RTK positioning technology based on the processing of un-differenced carrier phase (and pseudo-range) observations without the need of a reference station.

WG4.5.3 High Precision Positioning on Buoys and Moving Platforms

Chair: Wu Chen (The Hong Kong Polytechnic Univ., Hong Kong)
Co-Chair: Mark Dumville (IESSG, Nottingham Univ., UK), Oscar Colombo (NASA, USA)

Terms of Reference: To study precise positioning in marine environment including precise positioning algorithms on moving platforms, multipath effects off water surfaces, and data fusion of GNSS and other ocean environment sensors. To promote the collaboration of

researchers from different research areas, including geodesy, navigation, oceanography, and meteorology.

WG4.5.4 Multiple Carrier Ambiguity Resolution Methods & Applications

Chair: Yanming Feng (Queensland University of Technology, Australia)

Co-Chair: Hiro Ishiki (Institute of Mathematical Analysis, Japan)

Terms of Reference: The next generation Global Navigation Satellite Systems (GNSS), such as modernized GPS and Galileo systems, offer three and more carriers for civilian use. The full potential of the three and more signals, however, are yet to be exploited. To develop efficient approaches to carrier phase ambiguity resolutions with three and multiple GNSS signals, namely Three Carrier Ambiguity Resolution (TCAR) or generally Multiple Carrier Ambiguity Resolution (MCAR). To investigate the technical benefits for the global, regional and local GNSS services.

News & Linkages

- SC4.5 organised a technical session “Precise Point Positioning” at “*17th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation*”, Long Beach, California, 21-24 September 2004. This will be repeated at the next ION-GNSS, Long Beach, California, 13-16 September 2005.
- SC4.5 organised a technical session “Network RTK” at “*17th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation*”, Long Beach, California, 21-24 September 2004. This will be repeated at the next ION-GNSS, Long Beach, California, 13-16 September 2005.
- SC4.5 will co-sponsor the “*13th Int. Conf. on Geoinformatics*”, Toronto, Canada, 17-19 August 2005, and organise technical sessions.
- WG4.5.1 has been interfacing with RTCM SC104, through WG members who also contribute to the work of RTCM.
- WG4.5.2 has been working in collaboration with the IGS Real-Time Products Working Group to make real-time GPS satellite and clock information available over the Internet.
- WG4.5.3 organised technical sessions at the “*Hydro Society Conference*”, Ireland, November 2004.
- WG4.5.3 will organise technical sessions at the “*Int. Symp. on GPS/GNSS*”, Hong Kong, 8-10 December.

Study Group 4.1: Pseudolite Applications in Positioning and Navigation

<http://www.gmat.unsw.edu.au/pseudolite/>

Terms of Reference

In satellite-based precise positioning, the dominant factors are the number *and* geometric distribution of the satellites tracked by the receivers. In the case of GNSS such as GPS, GLONASS, and the planned GALILEO system, four visible satellites are the minimum requirement for precise three-dimensional positioning. In general, the more satellites that are tracked, the more reliable the positioning solutions. However, in some situations, such as in downtown urban canyons, engineering construction sites, and in deep open-cut pits and

mines, the number of visible satellites may not be sufficient. In the worst situations, such as in underground tunnels and inside buildings, the satellite signals may be completely absent. Such problems with existing GNSS systems can be addressed by the inclusion of additional ranging signals transmitted from ground-based “pseudo-satellites” (pseudolites). Pseudolites are an exciting technology that can be used for a wide range of positioning and navigation applications, either as a substantial augmentation tool of spaceborne systems, or as an independent system for indoor positioning applications.

Steering Committee

Chair: Jinling Wang (UNSW, Australia)
Vice-Chair: Gethin Roberts (Univ. of Nottingham, UK)
Vice-Chair: Dorota Grejner-Brzezinska (OSU, USA)

News & Linkages

- The Chair of SG4.1 (Jinling Wang) organised the “*Int. Symp. on GPS/GNSS*”, Sydney, Australia, 6-8 December 2004, where there were several presentations focusing on pseudolite research.
- SG4.1 has developed a comprehensive website on pseudolite research:
<http://www.gmat.unsw.edu.au/pseudolite/>.
- Chris Rizos presented an invited paper on “Pseudolite Augmentation of GPS” at the “*Workshop on Geolocation Technology to Support UXO Geophysical Investigations*”, Annapolis, Maryland, 1-2 June 2005.

Study Group 4.2: Statistics and Geometry in Mixed Integer Linear Models, with Applications to GPS and InSAR

(joint with Inter-Commission Committee on Theory)
<http://der.topo.auth.gr/icct/WGS/7-Dermanis.htm>

Terms of Reference

The presence of an unknown number of cycles in GPS observations of phase differences has generated a new challenging theoretical problem, which in its utmost generality may be described as the solution of over-determined equations with both real-valued and integer unknowns. Within this problem these particular issues emerge: (a) the selection and design of an optimality criterion that leads to a unique solution, (b) the development of computationally efficient algorithms for obtaining the optimal solution, especially with respect to the integer unknowns which require search within a discrete set, (c) the new types of distributions of the estimated real-valued and integer parameters, (d) particular geometry in connection with the estimated integer parameters, (e) the assessment of the accuracy of the solution in the presence of both random and systematic errors affecting the observations, and (f) new statistical hypothesis testing techniques.

Chair

Athanasios Dermanis (Aristotle Univ. of Thessaloniki, Greece)

News & Linkages

- An extensive literature has been prepared on Ambiguity Resolution (available separately), and the preparation of its critical presentation has been initiated.
- A state-of-the-art monograph on the subject is under preparation with contributions from SG members.
- A joint workshop on the subject with statistician and mathematicians, is currently in its organisation stage. Participation at the “*VI Hotine-Marussi Symp. on Theoretical & Computational Geodesy*”, Wuhan, China, 29 May – 2 June 2006, is planned.

Inter-Commission Study Group 1.1: Ionospheric Modelling and Analysis

(Jointly Commission 1 and 4 in cooperation with IGS and COSPAR)

Terms of Reference

As a result of many years of research the climatology of the ionosphere is today quite well known. However, variations of the solar activity and emissions of plasma from the solar corona change the conditions of the Sun-Earth environment and can dramatically disturb the ionospheric mean conditions. The development of sophisticated high technological systems for navigation, telecommunication, space missions, etc., created the need of predicting the meteorological conditions of the space around the Earth, giving rise to a branch of knowledge that today is called space weather. Disruptions of the ionosphere caused by massive solar flares can interfere with or even destroy communication systems, Earth satellites and power grids on Earth. A stringent application of ionospheric models would be to provide real-time corrections and integrity information for aircraft navigation and precision approach.

Ionospheric models are important for many space geodesy observing techniques to correct the delay caused by the ionosphere on the propagation of electromagnetic wave, typical applications being single-frequency GPS and GLONASS positioning or real time ambiguity resolution. The Earth's ionosphere has been studied for more than one hundred years using different observational techniques. A large contribution to the knowledge of the bottom-side ionosphere was done by a global network of 100-200 vertical incidence ionosondes, that started operation during the International Geophysical Year 1957-1958. Incoherent backscatter radars were used after 1958 to extend the exploration of the ionosphere to its topside. In 1957 the space age began enabling topside ionosondes onboard satellites, observations of Faraday rotation on transionospheric signals emitted by geostationary satellites, Doppler method with rockets and satellites and in situ techniques aboard spacecrafts.

Using large data bases of classical observations covering different geographical regions and different solar and geomagnetic conditions, several empirical ionospheric models were established. Among them, the International Reference Ionosphere (IRI) is probably the most widely used. IRI is continuously revised and updated through international cooperative effort of different type sponsored by the Working Group created by the Committee on Space Research (COSPAR) and the Union of Radio Sciences (URSI). Today ground-based and space-based GPS observations, and in a less extent observations of other space geodetic dual-frequency observing techniques, e.g., satellite altimetry, bring an unprecedented opportunity for ionospheric studies and may well revolutionize science and technology of the ionospheric

meteorology. They provide high quality ionospheric information, with global coverage, simultaneity and time continuity and are easy and free available for ionospheric scientists.

Structure

Chair: Claudio Brunini (Argentina)
Vice-Chair: Susan Skone (Univ. of Calgary, Canada)

Inter-Commission Study Group 1.2: Use of GNSS for Reference Frames

(Jointly Commission 1 and 4 in cooperation with IGS & IERS)

http://www.hg.tuwien.ac.at/research/GNSS/GNSS_WG_IGS/GNSS_WG_IGS.htm

Terms of Reference

Up to now the operating satellite navigation systems GPS and GLONASS allow a huge user community easy access to reference frames very close to the most recent realization of the ITRS. The IAG Services IERS (International Earth Rotation and Reference Systems Service) and IGS (International GPS Service) provide the necessary products to tie these frames to the ITRF, which is based upon a set of estimated coordinates and velocities of stable stations observed by all space techniques. The design of the upcoming GALILEO system - its envisaged accuracy and the long-term stability implies - that also GALILEO will become a highly valuable technique for the definition and maintenance of the ITRF. The modernization of GPS and the completion of the GLONASS system will further improve the situation. The goal of SG1.2 is to evaluate and support the use of GNSS for the definition and densification of the International Terrestrial Reference Frame (ITRF).

Structure

Chair: Robert Weber (Tech. Univ. of Vienna, Austria)
Co-Chair: C. Bruyninx (Royal Observatory Belgium)

Robert Weber is also the Chair of the IGS GNSS WG.

News & Linkages

- Several meetings of the SG have been held, including at “16th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation” (Portland, Oregon, 9-12 September 2003), “10 Years IGS: Workshop & Conference” (Bern, Switzerland, 1-5 March 2004), and “17th Int. Tech. Meeting of the Satellite Division of the U.S. Institute of Navigation”, (Long Beach, USA, 21-24 September 2004).
- SG1.2 presentation of IGS Plans concerning upcoming and modernization of GNSS Systems at the *EGU* (Nice, France, 26-30 April 2004).
- SG1.2 presentation at the “*European Navigation Conference GNSS 2004*”, Rotterdam, The Netherlands, 16-19 May 2004.
- First Meeting of SG1.2 members with Galileo Project Team at ESOC (Darmstadt), 29 June 2004. Topics discussed included Satellite Phase Centre definition, on-board retro-reflector arrays, and the GSTB-V1. Second Meeting of SG1.2 members with Galileo Project Team at ESOC, 17 March, 2005.