

Commission 4 – Positioning and Applications

http://enterprise.lr.tudelft.nl/iag/iag_comm4.htm

President: Sandra Verhagen (The Netherlands)
Vice President: Dorota Grejner-Brzezinska (USA)

Structure

Sub-commission 4.1:	Multi-Sensor Systems
Sub-commission 4.2:	Applications of Geodesy in Engineering
Sub-commission 4.3:	Remote Sensing and Modelling of the Atmosphere
Sub-commission 4.4:	Applications of Satellite and Airborne Imaging Systems
Sub-commission 4.5:	High-Precision GNSS
Study Group 4.2:	GNSS Remote Sensing and Applications
Study Group 4.3:	IGS Products for Network RTK and Atmosphere Monitoring

Steering committee

President	: Sandra Verhagen (The Netherlands)
Vice-president	: Dorota Grejner-Brzezinska (USA)
Chair SC 4.1	: Dorota Grejner-Brzezinska (USA)
Chair SC 4.2	: Günther Retscher (Austria)
Chair SC 4.3	: Marcelo Santos (Canada)
Chair SC 4.4	: Xiaoli Ding (Hong Kong)
Chair SC 4.5	: Yang Gao (Canada)
Member-at-large	: Pawel Wielgosz (Poland)
IAG representative	: Ruth Neilan (USA)

Overview

Terms of reference

To promote research into the development of a number of geodetic tools that have practical applications to engineering and mapping. The Commission 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 Sister Organisations.

Recognising the central role that Global Navigation Satellite Systems (GNSS) plays in many of these applications, the Commission's work will focus on several Global Positioning System (GPS)-based techniques, also taking into account the expansion of GNSS with Glonass, Galileo and Beidou. These techniques 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 will deal with precise kinematic GNSS 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 will

also be pursued, such as atmospheric sounding. Thereby, other geodetic techniques such as VLBI will be considered as well.

The commission will also deal with geodetic remote sensing, using (differential) InSAR, and GNSS as a remote sensor with land, ocean and atmosphere applications.

Objectives

The main objectives of Commission 4 are:

- Research into (integration of) new navigation and deformation measurement / sensor technologies, and their applications.
- Encourage research and development into new applications in e.g. “precise navigation”, “geodetic remote sensing”, “engineering geodesy”.
- Collaboration with geodetic organizations and services to promote and enable the use of GNSS and geodetic infrastructure for positioning as well as non-positioning applications.

The following activities were planned to reach these objectives:

- Interface with IAG sister organisations and other organizations - e.g. FIG, ISPRS, IEEE, ION
- Promote Geodesy and GGOS to a wide (professional) community
- Offer outreach opportunity through its conferences and seminars (jointly organised with other organisations)
- Forums, collaborative research, and exchange of data through the various sub-components.

Linkages between IAG Commission 4 and FIG, ION, ISPRS

Commission 4, by its rather more “practical” nature than other IAG commissions, has stronger links with sister organisations such as FIG, ISPRS and the U.S. ION. This is reflected in the broad activity of its members, who tend to support conferences organised by these other organisations. Often the officers of Commission 4 are also members of WGs, SGs and committees of the sister organisations. Hence there are a lot of cross-links between organisations. The links with the FIG Commission 5 (“Positioning and Measurements”), FIG Commission 6 (“Engineering Surveys”), ISPRS Commission I (“Image Data Acquisition – Sensors & Platforms”), and ISPRS Commission V (“Close Range Sensing – Analysis and Applications”) are now particularly strong, as evidenced by a permanent series of joint symposia (see below).

Memorandum of Understandings between IAG and FIG initiated and prepared by Chris Rizos and Matt Higgins (FIG); Memorandum of Understanding between IAG and U.S. ION facilitated by Dorota Grejner-Brzezinska.

Joint conferences / sessions

- FIG Working Week 2008
 - Sandra Verhagen chaired a joint IAG – FIG session on Geodetic Networks, Reference Frames and Systems
 - Sandra Verhagen gave a presentation on behalf of IAG Commission 4 on New Positioning Technologies
 - discussion forum chaired by Sandra Verhagen, Chris Rizos ...
- ISPRS Congress 2008, Beijing
 - Dorota Grejner-Brzezinska chaired a special session SS-4: Modern Navigation and Earth Observation that is jointly sponsored by IAG and ISPRS
- ION International Technical Meeting, 26-29 January 2009, Anaheim CA
 - session on "Applications in Surveying, Geodesy, Science and Timing", organized and chaired by Dorota Grejner-Brzezinska
- 2009 6th International Mobile Mapping Symposium
 - co-sponsored/co-organized by IAG, ISPRS and FIG
 - Dorota Grejner-Brzezinska is Science Chair
- IAG 2009 Scientific Assembly “Geodesy for Planet Earth”
 - session 4 “Positioning and remote sensing of land, ocean and atmosphere” convened by Sandra Verhagen and Pawel Wielgosz, with the following sub-sessions:
 - Session 4.1 “Technology and land applications” convened by Dorota Grejner-Brzezinska and Xiaoli Ding (related to SC 4.1, SC 4.4, SC 4.5 a.o.)
 - Session 4.2 “Modelling and remote sensing of the atmosphere” convened by Marcelo Santos and Jens Wickert (related to SC 4.3 and SG 4.3)
 - Session 4.3 “Multi-satellite ocean remote sensing” convened by Shuanggen Jin and Ole Andersen (related to SG 4.2)
 - session 6 “Joint IAG/FIG/ION/ISPRS session on Navigation and Earth Observation”, convenors: Dorota Grejner-Brzezinska and Charles Toth
- 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 13th FIG Deformation Measurement Conference, May 12-15, 2008 in Lisbon, Portugal
- 5th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 14th FIG Deformation Measurement Conference, 2010, most likely in Hong Kong, P.R. China

Linkages with other IAG commissions and services

Commission 1

- IC-WG 1.1: Environment Loading: Modelling for Reference Frame and positioning applications, Chairs: Tonie van Dam (Luxembourg), Jim Ray (USA) [Joint with Commission 4 and IERS]
- IC-SG1.2 Quality of geodetic multi-sensor systems and networks, Chair: H-G. Kutterer (Germany) [Joint with ICCT, Commission 4]

GGOS

- Sandra Verhagen in steering committee, and participated in the SC meeting in December 2008. Dorota Grejner-Brzezinska is substitute delegate.
- Chris Rizos and Dorota Grejner-Brzezinska contributed to the GGOS Reference document (chapter 4)

ICCT

- IC-SG2: Quality of geodetic multi-sensor systems and networks (see Commission 1, IC-SG1.2)
- IC-SG6: InSAR for tectonophysics, Chair: M. Furuya (Japan) [Joint with Commission 3 and 4]
- IC-SG9: Application of time-series analysis in geodesy, Chair: W. Kosek (Poland) [Joint with Commission 1, 2, 3 and 4]
- Organization of Hotine-Marussi 2009 symposium on Theoretical Geodesy:
 - Sandra Verhagen in scientific committee
 - Session 2 “Geodetic sensors and sensor networks” convened by Sandra Verhagen
 - Poster on behalf of commission 4 “Geodetic sensors and sensor networks – IAG’s perspective”

IGS

- Third meeting of International Committee on GNSS: contributions by Chris Rizos and Ruth Neilan.
- IGS is linked to SG 4.3 (see report)

Commission 4 sponsorships

- International Conference on Geo-Spatial Solutions for Emergency Management to be held September 14-16, 2009, Beijing, P. R. China, to celebrate CASM's 50th anniversary.
 - Chris Rizos is member of the Steering Committee
- ION International Technical Meeting, January 26-29, Anaheim CA
 - Session on "Applications in Surveying, Geodesy, Science and Timing", organized and chaired by Dorota Grejner-Brzezinska.

- IEEE International Geoscience & Remote Sensing Symposium (IEEE IGARSS 2009), Cape Town, Africa, 13-17 July 2009
 - Session on GNSS Remote Sensing Applications in Atmosphere, Ocean and Land, see SG4.2 report.
- International Workshop on Geodetic Theory-IWGT 2009, 1-3 June 2009 at Tongji University, Shanghai, China.
 - Yanming Feng was in the technical program committee, see WG 4.5.4 report
- 2nd International Colloquium – Scientific and Fundamental Aspects of the Galileo Programme, October 14-16, 2009, Padua, Italy

Highlight: publications

Commission 4 will publish two papers which are the result of a collaborative effort (co-authored by the different SC and SG chairs), and represent the views, activities, and objectives of the Commission:

- “Geodetic sensors and sensor networks – IAG’s perspective” to be presented at Hotine-Marussi 2009 symposium on Theoretical Geodesy, July 2009, Rome, Italy
- “Positioning and applications for planet Earth” to be presented at the IAG2009 Scientific Assembly “Geodesy for planet Earth”, September 2009, Buenos Aires, Argentina

Sub-Commission 4.1: Multi-Sensor Systems

President: Dorota Grejner-Brzezinska (USA)

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

Terms of Reference

To coordinate research and other activities that address 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 platforms. The primary sensors of interest will be GNSS and inertial navigation systems; however the important role of other techniques used for indoor and pedestrian navigation environmental monitoring is also recognized. The Sub-commission 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, IEEE, ION.

Objectives

- To follow the technical advances in navigation sensors and algorithms, including autonomous vehicle navigation, based on
 - positioning sensors and techniques such as GPS (and pseudolites), INS, including MEMS IMU, wheel sensors, ultrasonic and magnetic sensors, and
 - positioning methods based on cellular networks and their hybrid with GPS
- To follow the technical advances in mapping sensors, such as CCD cameras, laser range finders, laser scanners and radar devices
- To standardize definitions and measurements of sensor related parameters
- To study and report on the performance of stand alone and integrated navigation systems
- Report on the development, possibilities and limitations of new multi-sensor system technologies.
- To stimulate new ideas and innovation in
 - navigation algorithms, sensor calibration, synchronization and inter-calibration
 - real-time sensor information processing and georeferencing
 - sensor and data fusion
 - automation techniques for information extraction from multi-sensor systems using expert systems
- To study and monitor the progress in new applications (not limited to conventional mapping) of multi-sensor systems (transportation, engineering, car navigation, environmental monitoring personal navigation, indoor navigation, etc.)
- To promote research collaboration and to organize and to participate in professional workshops, seminars, meetings
- To promote research and collaboration with countries with no or limited access to modern multi-sensor technology
- To establish a web page providing information on the SC 4.1 activities, technology updates, and professional meeting calendar.

WG 4.1.1: Alternative integration algorithms

Chair: Dr. Aboelmagd Noureldin (Canada)

Ongoing Research Activities

1. Particle filtering based modules for non linear INS/GPS integration (Dr. Kornberg and Dr. Noureldin).
2. Spectral analysis modules for both GPS and inertial sensor signals using fast orthogonal search (FOS) algorithms to enhance system accuracy and improve INS/GPS integration. (Dr. Noureldin, Dr. McGaughey and Capt. Armstrong).
3. AI modules to fuse data from mobile multi-sensor systems for indoor navigation applications and in denied GPS environments (Dr. Chiang and Dr. Noureldin).
4. Exploring the enhancement of multi-sensor system integration using spectral estimation techniques employing robust orthogonal search methods (Dr. Kornberg and Dr. Noureldin).
5. Augmented KF / NN modules for reliable INS/GPS integration for airborne navigation (Dr. Noureldin and Capt. Armstrong).
6. Parallel cascade identification for INS/GPS integration and for modelling inertial sensor errors (Dr. Kornberg and Dr. Noureldin).

Publications (April 08 – April 09):

1. Iqbal U., Karamat T., Okou A., Noureldin A. "Experimental Results on an Integrated GPS and Multi Sensor System for Land Vehicle Positioning" International Journal of Navigation and Observation, Hindawi. (Online) (In Print)
2. Noureldin A., Karamat T., Eberts M. and El-Shafie A. "Performance Enhancement of MEMS Based INS/GPS Integration for Low Cost Navigation Applications" IEEE Transactions on Vehicular Technology, V58 (3), pp: 1077 – 1096, March 2009.
3. Perreault J., Iqbal U., Okou A. and Noureldin A. "RISS/GPS Integration Utilizing an Augmented KF/NN module" European Journal of Navigation, V6 (3), pp: 15-21, November 2008.
4. Chiang K-W, Noureldin A., and El-Sheimy N: "Developing a Low Cost MEMS IMU/GPS Integration Scheme Using Constructive Neural Networks;" IEEE Transactions on Aerospace and Electronic Systems, V44 (2), pp: 582 – 594, April 2008.
5. Georgy J., Noureldin A. and Bayoumi M.: "Mixture Particle Filter for Low Cost INS/Odometer/GPS Integration in Land Vehicles" In Proc. IEEE Vehicular Technology Conference, Barcelona, April 27 – 30, 2009. (Peer Reviewed – Full Paper)
6. Georgy J., Iqbal U. and Noureldin A.: "Quantitative Comparison between Kalman Filter and Particle Filter for Low Cost INS/GPS Integration" In Proc. Of the 6th International

WG 4.1.2: Indoor Navigation Systems

Chair: Günther Retscher (Austria)

The IAG WG 4.1.2 on Indoor Navigation Systems has currently 13 members from 8 different countries.

In 2007 the WG has jointly organized with the ICA Commission on Ubiquitous Cartography and ISPRS WG V TC2 the 4th symposium on Location Based Services and Telecartography which was held in Hong Kong, P.R. China, in end of November. In one oral session on 'Indoor Positioning' and one session on 'Positioning in LBS' 8 papers were presented also from some of the members of WG 4.1.2. In addition, 5 papers on Positioning were presented as posters. The conference proceedings have been published as CD Rom.

Several WG members met again and presented their research work at the ION GNSS conference, which was held in Savannah, Georgia, USA, in September 2008. In the same year the working group was also actively involved in the organization of the 5th symposium on Location Based Services and Telecartography held in Salzburg, Austria, in end of November 2008. At this conference two sessions on 'Positioning' within total 9 presentations were held with participation of WG members. The participating WG members also discussed the future work and collaboration in the working group at this meeting.

In 2009 the working group WG 4.1.2 is involved in the organization of the 6th International Symposium on Mobile Mapping Technology (MMT'09) which will take place in Presidente Prudente, São Paulo, Brazil, from 21-24 July 2009 (see <http://www4.fct.unesp.br/simposios/mmt09/ingles/>). The WG 4.1.2 is also one of the organizers of the 6th International Symposium on Location Based Services and TeleCartography to be held at the University of Nottingham, UK, from September 2-4, 2009. The co-organizers of the conference are the ICA Commission on Maps and Internet and Ubiquitous Cartography and our working group together with the Center of Geospatial Science of the University of Nottingham, UK, and the Research Groups of Cartography and Engineering Geodesy of the Vienna University of Technology, Austria. The call for contributions can be found at <http://www.lbs2009.org/>.

Another opportunity for a meeting and exchange of ideas of WG members is the upcoming ION GNSS conference which will be held in Savannah, Georgia, USA, from 22-25 September 2009 (see <http://www.ion.org/meetings/#gnss>). WG members are strongly involved in the organization of the conference; e.g. Dr. Allison Kealy is representing the WG as technical chair of Track B and Dr. Guenther Retscher is co-chairing a session on 'Multi-sensor Navigation'. Other relevant sessions in track B include 'Algorithms for Multi-sensor Fusion', 'Alternatives and Backups to GNSS' and 'GNSS – Inertial Navigation Systems'.

For the future work of WG 4.1.2 co-organization of upcoming conferences in the field of GNSS and LBS is planned. In addition, networking and knowledge exchange between members of the WG will be continued.

WG 4.1.3: Multi-sensors systems for environmental monitoring applications

No report submitted.

Sub-Commission 4.2: Applications of Geodesy in Engineering

President: Günther Retscher (Austria)

Vice-president: Gethin Roberts (UK)

Secretary: Michaela Haberler-Weber (Austria)

Member-at-large: Wolfgang Niemeier

Terms of reference

The main tasks of the SC 4.2 are to study and enhance technologies for applications of engineering geodesy in order to address the objectives set in the Terms of References. To start with, a website has been set up to provide information on SC4.2 activities, a professional meeting calendar, contact information of the WG members, etc. The address of the website is <http://info.tuwien.ac.at/ingeo/sc4/sc42.html>.

Initially it was planned to establish the following four Working Groups

- **WG 4.2.1: Measurement Systems for the Navigation of Construction Processes**
Chair: Wolfgang Niemeier (Technical University Braunschweig, Germany)
- **WG 4.2.2: Dynamic Monitoring of Buildings**
Chair: Gethin Roberts (IESSG, Nottingham University, UK)
- **WG 4.2.3: Application of Artificial Intelligence in Engineering Geodesy**
Chair: Alexander Reiterer (Vienna University of Technology, Austria)
Co-Chair: Uwe Egly (Vienna Univ. of Technology, Austria)
- **WG 4.2.4: Monitoring of Landslides and System Analysis**
Chair: Gyula Mentes (Geodetic and Geophysical Research Institute of HAS, Hungary)
Co-Chair: Paraskevas Savvaidis (University of Thessaloniki, Greece)

The reports of the activities of WG 4.2.3 and WG 4.2.4 can be found below. These two WGs are very active. WG 4.2.3 has currently 8 members and WG 4.2.4 23 members. WG 4.2.4 has changed its title recently to “Investigation of Kinematic and Dynamic Behavior of Landslides and System Analysis”.

WG 4.2.1 and WG 4.2.2, however, are still in the process of establishment. We have received a proposal of Dr. Jose Bittencourt for the establishment of a new WG on Pavement Mapping. This proposed WG will be merged with the WG 4.2.1 under a new chair. Jose Bittencourt has started recently to invite people to join the new working group. He is planning to have a first meeting of WG members at the upcoming 6th International Symposium on Mobile Mapping Technology (MMT'09) which will take place in Presidente Prudente, São Paulo, Brazil, from 21-24 July 2009 (see <http://www4.fct.unesp.br/simposios/mmt09/ingles/>).

Dr. Gethin Roberts is very active in FIG and will take over as a chair of FIG Commission 6 in 2010. He found it to be difficult to work actively in IAG as well. Therefore he has asked use these days to be replaced by someone else in his role of Vice-Chair of SC4.2 and Chair of WG 4.2.2.

The secretary of SC 4.2 Dr. Michaela Haberler-Weber has left Vienna University of Technology recently and does not want to continue her work in our commission. Hopefully a new Secretary can overtake her role soon.

In the last two years SC 4.2 was involved in the organization of the following conferences

1. **8th Conference on Optical 3-D Measurement Techniques**

July 9-12, 2007 in Zurich, Switzerland, <http://www.photogrammetry.ethz.ch/optical3d/>

2. **4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 13th FIG Deformation Measurement Conference**

May 12-15, 2008 in Lisbon, Portugal, <http://measuringchanges.lnec.pt/>

The established WG's have supported these two conferences and were represented by WG members and/or chairs.

The sub-commission is also involved in the organization of the following upcoming meetings

1. **9th Conference on Optical 3-D Measurement Techniques**

July 1-3, 2009 in Vienna, Austria; <http://info.tuwien.ac.at/ingeo/optical3d/o3d.htm>

2. **6th International Symposium on Mobile Mapping Technology (MMT'09)**

July 21-24, 2009 in Presidente Prudente, São Paulo, Brazil; <http://www4.fct.unesp.br/simposios/mmt09/ingles/>

3. **5th IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 14th FIG Deformation Measurement Conference**

2010, most likely in Hong Kong, P.R. China

The sub-commission will continue its work in the next two years and will encourage the active members to participate in the upcoming meetings to present and discuss their research.

WG 4.2.3: Application of Artificial Intelligence in Engineering Geodesy

Chair: Alexander Reiterer

In the last years, Artificial Intelligence (AI) has become an essential technique for solving complex problems in Engineering Geodesy. AI is an extremely broad field – the topics range from the understanding of the nature of intelligence to the understanding of knowledge representation and deduction processes, eventually resulting in the construction of computer programs which act intelligently. Especially the latter topic plays a central role in applications.

Current applications using AI methodologies in engineering geodesy are:

- geodetic data analysis,
- deformation analysis,
- navigation,
- deformation network adjustment,
- optimisation of complex measurement procedure.

The work of the WG 4.2.3 in 2008 can be summarized as follows

- networking and knowledge exchange between members of the WG,
- organisation of a first meeting (in form of an international workshop),

- public relation in form of a website
(http://info.tuwien.ac.at/ingeo/sc4/wg423/wg_423.html).

In 2009 the WG is organizing a special session at the 9th Conference on “Optical 3-D Measurement Techniques” in Vienna. The session “Applications of Artificial Intelligence in Optical 3D-Systems“ will present research work of different origin and content, e.g. basic research, application oriented research, etc.

Furthermore, WG has begun to plan the “Second International Workshop on Application of Artificial Intelligence in Engineering Geodesy – AIEG” which will be organized at the end of 2009 / begin of 2010.

For an easy communication within the WG a central data exchange unit (ftp-server) and a mailing list have been installed. The existing website will be extended to a WIKI.

Publications

Reiterer, Egly (Eds.): Application of Artificial Intelligence in Engineering Geodesy. Proceedings for the First Workshop on AIEG, 2008.

WG 4.2.4: Investigation of Kinematic and Dynamic Behaviour of Landslides and System Analysis

Chair: Gyula Mentés

In the frame of the working group the participants laid a great stress on multi-scale monitoring landslide prone areas [1]. For the investigations several test site were used in China (Baota test site), in Hungary (High Danube banks at Dunaföldvár and Dunaszekcső), in Greek (Touzla overpass, Kristallopigi landslide, Basilikos landslide, Gkrika Cuts, Prinotopa site, Anthohori entrance, the Big Cut), in Italy (Corvara test site). The different types of landslide areas make it possible to investigate the influence of geological, geomorphological, hydrological, meteorological, etc. factors and their role in triggering landslides. All the participants collect all data in GIS [e.g. 3, 4, 5] and use these data to develop Spatial Decision Support Systems (SDSS) [e.g. 2] and Early warning systems. Such systems consist of the following main modules

- Extended multi-sensor deformation measurement system based on geodetic, geophysical, geotechnical, hydrological, meteorological instrumentation.
- A knowledge-based system that analysis all data and makes a rough risk assessment, triggering the alarm for possible immediate failures.
- An alarm system to ensure the instant/direct authority action.
- The overall assessment of the results and the final decision level due to geo-informatics solutions.

The extended multi-sensor deformation measurement system consists of terrestrial geodetic and geotechnical measurements completed by InSAR technique. This latter is used for large-scale detection of landslide prone areas as well as for deformation measurements of the investigated landslide area. This complete measurement system is very suitable for the investigation of the kinematic behaviour of landslides and together with other (e.g. hydrological, meteorological, etc.) parameters for study the dynamics of landslides [4] In the frame of a

close cooperation between the Wuhan University of Technology (China) and the University of Braunschweig (Germany) the Baota test site [8, 9], and in a co-operation between University of Braunschweig and the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences in Hungary the Dunaföldvár test site is monitored by terrestrial and InSAR measurement techniques. Berlin University of Technology, Institute of Applied Geosciences, Department of Hydrogeology and Bureau of Applied Geoscientific Remote Sensing takes also intensively part in the investigation of the Dunaföldvár test site using remote sensing data. In the frame of the latter cooperation the role of tectonic movements in triggering of slope failures was also revealed [7].

In this period of the activity of the working group the most characteristic test site was the high loess bank of the Danube at Dunaszekcső in Hungary. The high bank on this area was sliding slowly with increasing velocity since September of 2007 till 12 of February 2008. On this day there was an abrupt sliding. About 500.000 m³ loess was sliding toward to the Danube. The whole sliding process was monitored. The study of the movement is a good possibility to understand the kinematics and dynamics of the slope. The monitoring will be continued in the future to study the after-sliding processes [10, 11].

The University of Thessaloniki developed very intensively Spatial Decision Support Systems and applied it on several test sites [2, 3].

The Institute of Geodesy and Geophysics of the Vienna University of Technology works on development of multi-sensor measurement systems [1] and in co-operation with the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences develops measurement methods and their mathematical background for detecting very small displacements [5, 6].

The working group participants are in connection with each other via internet and if it is necessary a workshop will be organised in spring of 2010 to discuss the problems and results.

Publications

1. Kahmen, H., Eichhorn, A. and Haberler-Weber, M.: A Multi-Scale Monitoring Concept for Landslide Disaster Mitigation. In: Tregoning, P. and Rizos, C. (Eds.): Dynamic Planet Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools. IAG Symposium, Cairns, Australia, 22-26 August, 2005 Series, International Association of Geodesy Symposia. 2007, Vol. 130, 769-775.
2. Lakakis, K., Charalampakis, M., Savaidis, P.: A Spatial Decision Support System for Highway Infrastructure. Fifth International Conference on Construction in the 21st Century (CITC-V), "Collaboration and Integration in Engineering, Management and Technology. May 20-22, 2009, Istanbul Turkey. pp. 1-8.
3. Lakakis, K., Charalampakis, M., Savaidis, P.: A Landslide Definition by an Integrated Monitoring System. Fifth International Conference on Construction in the 21st Century (CITC-V), "Collaboration and Integration in Engineering, Management and Technology. May 20-22, 2009, Istanbul Turkey. pp. 1-8.
4. Mentés G.: Investigation of different possible agencies causing landslides on the high loess bank of the river Danube at Dunaföldvár, Hungary. Proceedings of the Measuring the Changes, 13th FIG International Symposium on Deformation Measurements and Analysis, 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering, LNEC, Lisbon, Portugal, CD, May 12-15, 2008, pp. 1-10.
5. Mentés G.: Investigation of Micro-Movements by Borehole Tiltmeters on the High Loess Bank of the River Danube at Dunaföldvár in Hungary. Proceedings of the INGEO 2008 – 4th International Conference on Engineering Surveying, Slovak University of Technology, ISBN 978-80-227-2971-0, Bratislava 2008, p. 11.

6. Mentés G.: A new method for dynamic testing of accelerometers. INGENEO 2008 – 4th International Conference on Engineering Surveying, Slovak University of Technology, ISBN 978-80-227-2971-0, Bratislava 2008, p. 10.
7. Mentés, G., Theilen-Willige, B., Papp, G., Síkhégyi, F., Újvári, G.: Investigation of the relationship between subsurface structures and mass movements of the high loess bank along the River Danube in Hungary. *J. Geodyn.* (2008), doi:10.1016/j.jog.2008.07.0005.
8. Riedel, B., Heinert, M.: An adapted support vector machine for velocity field interpolation at the Baota landslide. AIEG 2008 – First Workshop on Application of Artificial Intelligence in Engineering Geodesy. pp. 1-13.
9. Riedel, B., Walther, A.: InSAR Processing for the recognition of landslides. *Advances in Geosciences*. 2008, 14, 189-194.
10. Újvári, G., Mentés, G., Bányai L., Kraft, J., Gyimóthy, A. Kovács, J.: Evolution of a bank failure along the River Danube at Dunaszekcső, Hungary. *Geomorphology*, 2009, 109, 197-209. (doi:10.1016/j.geomorph.2009.03.002).
11. Újvári, G., Mentés, G., Theilen-Willige, B.: Detection of landslide prone areas on the basis of geological, geomorphological investigations, a case study. Proceedings of the Measuring the Changes, 13th FIG International Symposium on Deformation Measurements and Analysis, 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering, LNEC, Lisbon, Portugal, CD, May 12-15, 2008, pp. 1-9.

Sub-Commission 4.3: Remote Sensing and Modelling of the Atmosphere

President: Marcelo Santos (Canada)

Vice-President: Jens Wickert (Germany)

Terms of Reference

The objective of Sub-Commission 4.3 (SC 4.3) is to coordinate research dealing with the treatment, interpretation and modelling of measurements collected in the atmosphere for the purpose of improvements in geodetic positioning as well as for better understanding the atmosphere itself. Even though GNSS techniques are seen here as the primary research tools, other sensors also bring important information on the atmosphere and as such should be considered in the context of this Sub-Commission. Dedicated satellites, having on-board GNSS receivers, can also contribute to atmospheric studies by exploring the atmosphere-induced bending of GNSS signals while propagating through the atmosphere, to furnish round-the-clock weather data, monitor climate change, and improve space weather forecasts. Geodetic positioning can benefit and contribute to atmospheric models, such as Numerical Weather Prediction (NWP) models. Novel advancements in modelling the atmosphere as applied to positioning, error sources, instrumentation, dedicated missions, and real- or near real-time data access should also be contemplated. SC4.3 will foster linkages with sister scientific and professional organizations, such as IAG, ISPRS, FIG, IEEE and ION.

Study Group 4.3.1 - Ionosphere Modelling and Analysis

Chair: Michael Schmidt (Deutsches Geodätisches Forschungsinstitut, Munich, Germany)

Co-Chair: Mahmut O. Karlioglu (Middle East Technical University, Ankara, Turkey)

Terms of Reference

The general objective of this study group is the development of strategies for establishing ionosphere models which can be used for both, the correction of electromagnetic measurements and the study of ionospheric features and their spatial-temporal evolution. Thus, our overall intention is the combination of physics, mathematics and statistics to derive a high-resolution multi-dimensional ionosphere model.

Research Activities

- At DGFI a multi-dimensional ionosphere model was developed within the last years which can be used for modelling ionospheric target functions such as the electron density and the vertical total electron content (VTEC) globally, regionally or locally. Depending on the chosen area spherical harmonics, endpoint-interpolating B-splines, trigonometric B-splines, Chapman functions, etc. can be used for the spatial representation. For the temporal representation empirical orthogonal functions, B-splines, a Fourier series, etc. can be chosen. The unknown coefficients of the resulting spatio-temporal multi-dimensional ionosphere model based on tensor products of the different kinds of base functions are estimable from a combination of ground-based GNSS measurements, dual-frequency altimetry and COSMIC/FORMOSAT-3 GPS measurements; data gaps can be handled efficiently by a regularization procedure using prior information.

- Much of the ionospheric modelling efforts in South Africa have been concentrated on practical applications and for contributions towards improvements to the International Reference Ionosphere (IRI). The main areas that the group has concentrated on in the last 2 years are (1) improvements to the South African Bottomside Ionospheric Model (SABIM), (2) the development of a neural network based global foF2 model, (3) the variability of F1 and F2 layer parameters and (4) the development of an ionospheric map for South Africa.
- The research work on ionosphere at NCU is to carry out studies of the structure and dynamics of near-Earth space plasma distribution and investigation of space weather under different solar-geophysical conditions. The proposed research will be carried out by ionosphere profiling and modeling and on the base of ionosondes, low-orbital (American TRANSIT and Russian TSIKADA/PARUS) and high-orbital (American GPS and Russian GLONASS) navigational satellite systems.
- The DLR at Neustrelitz is establishing an ionosphere weather service via the project SWACI (<http://swaciweb.dlr.de>) which is essentially supported by the German state government of Mecklenburg-Vorpommern. The service includes the provision of data products deduced from ground- and space-based GNSS measurements. Whereas ground-based GNSS measurements provide VTEC maps and corresponding derivatives, spaced-based measurements provide vertical electron density profiles and 3D reconstructions of the topside ionosphere/plasmasphere systems. All retrieval techniques are model assisted:
 - The DLR model NTCM is used as a background model for creating TEC maps by data assimilation.
 - A Chapman layer based model is assisting the retrieval of vertical electron density profiles from radio occultation measurements onboard CHAMP and GRACE satellites.
 - The PIM model is used as a background model for 3D reconstructions of the topside ionosphere/plasmasphere systems using navigation data from the CHAMP satellite
- With its standard X/S-band dual frequency observing sessions Very Long Baseline Interferometry (VLBI) provides consistent ionospheric delays from 1979 until today. The network of geodetic/astrometric VLBI guided by the International VLBI Service of Geodesy and Astrometry (IVS) consists of sites with a globally distribution, which take part in routine observing sessions more or less sparsely. At DGFI first considerations have been carried out evaluating a potential contribution of slant total electron content (STEC) from IVS data to a combined model of the ionosphere.
- In the last 2 years the Institute of Geodesy and Geophysics (IGG) of TU Vienna has successfully accomplished the development of combined global VTEC models from GNSS and altimetry. To achieve this goal spherical harmonics of degree 15 were used. Global Ionosphere Maps (GIMs) with spatial resolution of 2.5° latitude, 5° longitude and temporal resolution of 2 hours are estimated. Next VTEC measurements derived from FORMOSAT-3/COSMIC occultation data were combined with the GIMs by recursive parameter estimation. Different empirical weighting methods were applied. The results clearly show improvement of VTEC maps in the time when occultation measurements are carried out in regions with low number of GNSS stations, i.e. mainly on ocean.
- At the Middle East Technical University (METU) B-spline functions were used to model VTEC on the basis of real GPS observations collected over Turkey. For 2D case, VTEC is modelled in sun-fixed reference frame while 3D approach including the time to represent

the temporal variations the modelling was performed in an Earth-fixed reference frame. Iteratively re-weighted least squares (IRLS) with a bi-square weighting function as a robust regression algorithm was carried out for the parameter estimation procedure in order to reduce the effects of outliers. Another iterative method, i.e. Conjugate Gradient Least Squares (CGLS) method was performed to bring about regularization effect for ill-conditioned problems in large equations.

- In a second project at METU an efficient algorithm with Multivariate Adaptive Regression Splines (MARS) was developed for regional spatio-temporal mapping of the ionospheric electron density using ground-based GPS observations. MARS is able to handle very large datasets and is an adaptive and flexible method, which can be applied to linear and non-linear problems. The base functions are directly obtained from the observations and have space partitioning properties resulting in an adaptive model that provides solutions in region with rare observations without regularization. Since the fitting procedure is additive it does not require gridding and is able to process large amounts of data with large gaps. The performance and adaptivity of the MARS algorithm were applied to real GPS data over Europe.
- The work at Goddard Space Flight Center (NASA/GSFC) was concentrating on the validation of the International Reference Ionosphere (IRI) using in situ measurements from GRACE K-Band ranging and CHAMP planar langmuir probe (PLP). The ionospheric delay derived by combination of dual frequency K-Band ranging measurements of GRACE infers the electron density integrated between the two satellites along the orbit with a baseline length of approximately 220 km at the altitude of around 450 km. We compared the GRACE KBR and PLP measurements with the electron density derived from IRI and validated the recent advances in IRI.

Meetings

- TUJK, Annual Scientific Meeting, 2007-11-14/16, Ankara, Turkey (Karslioglu, Nohotcu, Schmidt, Heinkelmann)
- EGU 2008, General Assembly, 2008-04-14/18, Vienna, Austria (Schmidt, Alizadeh, Heinkelmann)
- URSI 2008, General Assembly, 2008-08-07/16, Chicago, USA (Schmidt, Tsai, Bilitza, McKinnell)
- EGU 2009, General Assembly, 2009-04-19/24, Vienna, Austria (Schmidt, Dettmering, Tsai, Alizadeh, Bilitza, Krankowski, Wielgosz, Han)
- Splinter Meeting of IAG SG 4.3.1, 2009-04-23, TU Vienna, Austria (Schmidt, Dettmering, Tsai, Alizadeh, Bilitza, Krankowski, Wielgosz)
- Real-time IRI Task Force Workshop, 2009-05-04/06, Colorado Springs, USA (Schmidt, Bilitza)

List of Publications

Adewale A.O., Oyeyemi E.O., and McKinnell L.A., "Comparisons of observed ionospheric F2 peak parameters with IRI-2001 predictions over South Africa", *Journal of Atmospheric and Solar Terrestrial Physics*, 71(2), doi:10.1016/j.jastp.2008.10.014, pp. 273-284, 2009.

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- Hoque, M.M., and N. Jakowski, Mitigation of higher order ionospheric effects on GNSS users in Europe”, *GPS Solutions*, DOI 10.1007/s10291-007-0069-5
- Hsiao, T. Y., L.-C. Tsai, and C. H. Liu, The initial results of coherent beacon radio receiving systems of transit satellites for low-latitude scintillation near Taiwan, *Terrestrial, Atmospheric and Oceanic Sciences*, 20 (1), 261-271, 2009
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- Oyeyemi E.O., McKinnell L.A. and Poole A.W.V., “Neural network based prediction techniques for global modeling of M(3000)F2 ionospheric parameter”, *Advances in Space Research*, doi:10.1016/j.asr.2006.09.038, 39, 5, pp. 643 – 650, 2007.
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Tsai, L.-C., C.H. Liu, and T. Y. Hsiao, Profiling of ionospheric electron density based on the FormoSat-3/COSMIC data: results from the intense observation period experiment, *Terrestrial, Atmospheric and Oceanic Sciences*, 20 (1), 181-191, 2009.

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Tsai, L.-C., C. H. Liu, T. Y. Hsiao, and J. Y. Huang, A near real-time phenomenological model of ionospheric electron density based on GPS radio occultation data, accepted by *Radio Science*, 2009

Uwamahoro J, McKinnell L.A., and Cilliers P.J., "Forecasting Solar Cycle 24 using Neural Networks", *Journal of Atmospheric and Solar Terrestrial Physics*, 71, doi:10.1016/j.jastp.2008.12.003, pp. 569-574, 2009.

Zeilhofer, C.: Multi-dimensional B-spline modeling of spatio-temporal ionospheric signals. German Geodetic Commission, series A, 123, München, 2008.

Zeilhofer, C., M. Schmidt, D. Bilitza, and C.K. Shum: Regional 4-D modeling of the ionospheric electron density from satellite data and IRI. *Adv. Space Res.*, in press, 2008.

Working Group 4.3.1: Atmospheric refractivity, TEC and Ionospheric Scintillation

Chair: Lucilla Alfonsi (INGV, Italy)

Co-Chair: Sybille Vey (TU Dresden)

Terms of Reference

To collect experimental data to derive information on precipitable water vapour, TEC and ionospheric scintillation by means of GPS monitors/receivers, at high and mid latitudes, and to study the tropospheric and ionospheric impact on precise positioning operations, during both quiet and disturbed conditions at middle and high latitudes.

Report on activities

During the first months of the WG the work has been mainly dedicated to the first attempts of exchange data and expertise on ionospheric imaging and mitigation of ionospheric effects on GNSS signals. A feasibility study on the use of Antarctic measurements, run by both geodetic and ionospheric teams, for water vapour reconstruction is currently in progress by using the GPS data collected at the Italian station "Mario Zucchelli" (Terra Nova Bay, Antarctica).

Recently available, global tropospheric models for water vapour retrieval were implemented in the analysis of geodetic observations with the purpose of improve the estimation process of zenith total delay with GPS data. Comparisons with old models are being carried out and alternative techniques for water vapour content estimation, such as radiosonde. In particular, common data sets from different techniques and overlapping observations periods have been identified and adopted as test benchmarks on which cross checking can be performed and integrated water vapour can be computed. Analysis is currently in progress.

A collaboration with the geodetic groups dealing with Mediterranean GPS data is planned to start multidisciplinary studies also at middle latitudes.

Papers/posters presentation

L. Alfonsi, Y. Ping, C.N. Mitchell, G. De Franceschi, V. Romano, P. Sarti, M. Negusini, A. Capra, GPS Imaging of the Antarctic Ionosphere: A First Attempt. Presentation during the *SCAR Open Science Conference (St. Petersburg, July 2008)*. The work presents the potentialities of using the geodetic data also for producing ionospheric imaging, for the first time, over Antarctica.

M. Negusini, P. Sarti, Precipitable Water Vapour at VLNDEF GPS Network Sites: An Example of Multi-disciplinary Investigation. Poster at the *SCAR Open Science Conference (St. Petersburg, July 2008)*. The work presents the potentialities of geodetic GPS Antarctic data for multidisciplinary applications.

P. Sarti, M. Negusini, C. Lanconelli, A. Lupi, C. Tomasi, GPS and Radiosonde Derived Precipitable Water Vapour Content and its Relationship with 5 Years of Long-Wave Radiation Measurements at “Mario Zucchelli” Station, Terra Nova Bay, Antarctica. Poster at the *SCAR Open Science Conference (St. Petersburg, July 2008)*. The work presents the long time series of water vapor content computed with GPS at Terra Nova Bay and its relation with long wave radiation.

A. W. Wernik, A. Lucilla, M. Aquino, G. De Franceschi, A. Dodson, C. N. Mitchell, V. Romano, GPS Ionospheric Scintillations Monitoring and Studying: Bipolar Capabilities During Ipy. *Poster at XXIXth URSI General Assembly, Chicago, USA, 9-16 August 2008*. The state of art of GPS network is presented over Arctic and Antarctica for scintillation studies.

Luca Spogli, Lucilla Alfonsi, Giorgiana De Franceschi, Vincenzo Romano, Marcio Aquino, Alan Dodson, Climatology of the Ionospheric Scintillations: First Results over the Auroral and Cusp European Regions. Poster at *V European Space Weather Week (Brussels, 17-21 November, 2008)*. The work deals with the use of GPS high rate data to investigate the scintillation scenario due to irregularities of perturbed ionosphere from cusp to auroral region during high solar activity.

Vincenzo Romano, Silvia Pau, Michael Pezzopane, Enrico Zuccheretti, Stefano Locatelli, Liudmila Kurylovich, Luca Spogli, The Electronic Space Weather Upper Atmosphere (ESWUA) System. *Poster at V European Space Weather Week (Brussels, 17-21 November, 2008)*. The state of the art is presented of a proper data base designed and developed to manage high latitude GPS high rate experimental observations from Antarctica and Arctic (<http://eswua.ingv.it>).

G. De Franceschi, L. Alfonsi, V. Romano, L. Spogli, M. Aquino, A. Dodson. GPS Ionospheric Scintillation Monitoring and Investigation at High Latitude. *Invited talk to the AGU Fall Meeting (San Francisco, 15-19 December 2008), Session G44A: Synergy between GNSS/GPS Observation Systems and Climate, Meteorological, and Ionospheric Applications II*. A review on scintillation and plasma dynamics deduced by ionospheric imaging over polar regions is presented.

Publications

GPS Imaging of the Antarctic Ionosphere: a First Attempt, by L. Alfonsi, Y. Ping, C.N. Mitchell, G. De Franceschi, V. Romano, P. Sarti, M. Negusini, A. Capra, submitted to *Journal of Atmospheric and Solar-Terrestrial Physics*, 2008.

Improving the GNSS Positioning Stochastic Model in the Presence of Ionospheric Scintillation, M Aquino, JFG Monico, AH Dodson, H Marques, G De Franceschi, L Alfonsi, V Romano and M Andreotti, submitted to *Journal of Geodesy*, 2008. The work focuses on the introduction of a novel technique to mitigate the effects of corruption on GNSS signals due to scintillations and it is based on the cooperation between the ionospheric and the geodetic communities in UK, Brazil and Italy.

Probing the High Latitude Ionosphere from Ground-Based Observations: The State of Current Knowledge and Capabilities during IPY (2007–2009), L. Alfonsi, A. Kavanagh, Amata E., P. Cilliers, E. Correia, Freeman M., Kauristie, K., Liu R., Luntama J-P, Mitchell, C.N, Zherebtsov, G.A, *Journal of Atmospheric and Solar-Terrestrial Physics*, 70, 18, December, 2008. The review includes also information on the international cooperation, in progress and planned, among the different communities handling GPS data at polar latitudes.

Validation of the Atmospheric Water Vapour Content from NCEP Using GPS Observations over Antarctica, Vey, S. and Dietrich, R. (2008). In Capra, A. and Dietrich, R., *Geodetic and Geophysical Observations in Antarctica, An Overview in the IPY Perspective* p. 125-135., Springer Berlin Heidelberg, ISBN: 978-3-540-74881-6, DOI10.1007/978-3-540-74882-3.

Working Group 4.3.3 – Numerical Weather Predictions for Positioning

Terms of Reference

To study various technical aspects of using Numerical Weather Prediction (NWP) model data to map the effect of troposphere on space geodetic signals. To concatenate the terminology used by both meteorological and geodetic communities. To test and sediment procedures related to ray-tracing through NWP data layers. To suggest quality control criteria to be used for assessing the quality of tropospheric data and results obtained from them. To evaluate state of the art and report the progress achieved during the time-life of the WG on the use of NWP for positioning.

Report on activities

In order to draw conclusions about the best way for ray-tracing based on numerical weather data, two radiosonde profiles (kindly provided by A. Niell) were selected as basis for all investigations. At first, the focus was set on zenith hydrostatic (ZHD) and wet delays (ZWD) whereas six independent solutions were submitted for comparison. As for the hydrostatic components all solutions agreed within 1 mm, including the model by Saastamoinen (1972), which has been computed additionally. The wet delays showed larger scattering between the different solutions, likely caused by different interpolation strategies of the water vapour constituents. Some groups linearly interpolate relative humidity before converting it to water vapor pressure, other groups prefer to interpolate water vapor pressure levels using an exponential scheme. Nevertheless, all submitted solutions were found to be within +/- 1 mm from the average over all results.

After comparison of zenith delays, a second call was made to submit ray-traced dry and wet slant delays, based on the same profiles under the assumption of spherical symmetry. In total, four WG members followed this call and submitted their results for elevations angles ranging from 3 to 90 degrees, in steps of one degree. In general, all solutions agreed well with each other, having only larger differences (~1 cm) at the very low elevation angles (i.e. below 10 degrees). These differences are thought to be caused by the different ray-tracing operators used for the calculation of the ray-path. In general, it could be stated that smaller integration steps are preferred rather than ray-tracing in coarse steps. Better modeling of asymmetric delays due to the Earth's ellipticity as well as proper consideration of bending angle effects have been pointed out as well.

Meetings and communication:

A kick-off meeting was held during AGU Fall Meeting 2007 and a mailing list was established to distribute information between the WG members. Additionally, the WG homepage¹ has been set-up in “wiki” style, allowing the members to modify the content and upload results directly.

Relevant papers

Boehm, J., B. Werl, and H. Schuh (2006), Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium Range Weather Forecasts operational analysis data, *J. Geophys. Res.*, 111, B02406, doi:10.1029/2005JB003629 [download](#).

1 <http://www.hobiger.org/wg433/tiki-index.php>

Boehm, J., A. Niell, P. Tregoning, and H. Schuh (2006), Global Mapping Function (GMF): A new empirical mapping function based on numerical weather model data, *Geophysical Research Letters*, Vol. 33, L07304, doi:10.1029/2005GL025546 [download from AGU](#)

Boehm, J., R. Heinkelmann, and H. Schuh (2007), Short Note: A global model of pressure and temperature for geodetic applications, *Journal of Geodesy*, doi:10.1007/s00190-007-0135-3 [download from JoGeod](#)

Ghoddousi-Fard R., P. Dare and R.B. Langley (2009), Tropospheric delay gradients from numerical weather prediction models: effects on GPS estimated parameters, *GPS Solutions*, [download from GPSSol](#)

Hobiger T., R. Ichikawa, T. Kondo, and Y. Koyama (2008), Fast and accurate ray-tracing algorithms for real-time space geodetic applications using numerical weather models, *Journal of Geophysical Research*, vol. 113, no. D203027, pp. 1–14, [download from AGU](#)

Hobiger T., R. Ichikawa, T. Takasu, Y. Koyama, and T. Kondo (2008), Ray-traced troposphere slant delays for precise point positioning, *Earth, Planets and Space*, vol. 60, no. 5, pp. e1–e4 [download from EPS \(free e-paper\)](#).

Hobiger T., Ichikawa R., Koyama Y., Kondo T. (2009), Computation of troposphere slant delays on a GPU, *IEEE Transactions of Geoscience and Remote Sensing*, accepted, doi10.1109/TGRS.2009.2022168.

Kouba, J. (2007), Implementation and testing of the gridded Vienna Mapping Function 1 (VMF1), *Journal of Geodesy*, doi:10.1007/s00190-007-0170-0 [download from JoGeod](#)

Nievinski F.G., Ray-tracing Options to Mitigate the Neutral Atmosphere Delay in GPS (MSc. thesis), [download](#).

Sub-Commission 4.4: Applications of Satellite and Airborne Imaging Systems

President: Xiaoli Ding (Hong Kong)
Vice-President: Dr. Linlin Ge (Japan)
Secretary: Dr. Makoto Omura (Australia)

Objectives

The main objectives of the Sub-Commission are to promote collaborative research in the development of satellite and airborne imaging systems, primarily including Synthetic Aperture Radar (SAR) and Light Detection and Ranging (LiDAR) systems, for geodetic applications, and to facilitate communications and exchange of data, information and research results through coordinated efforts.

Terms of Reference

- (1) Development of methods, models, algorithms and software for geodetic applications of satellite and airborne imaging systems;
- (2) Study of effects of field and atmospheric conditions on satellite and airborne imaging systems;
- (3) Integration of satellite and airborne imaging systems with other geodetic/geospatial technologies such as GPS and GIS;
- (4) Development and promotion of new geodetic applications of satellite and airborne imaging systems; and
- (5) Development of collaboration with sister organisations such as FIG and ISPRS, and liaison with image data providers.

Working Groups

The SC has currently the following Working Groups:

WG 4.4.1: Quality Control Framework for InSAR Measurements

Chair: Prof. Xiaoli Ding

Terms of Reference

To study quality measures and quality control procedures and formulate a quality control framework for InSAR measurements.

WG 4.4.2: Imaging Systems for Monitoring Local Area Surface Deformation

Chair: Prof. Makoto Omura

Terms of Reference

To study satellite and airborne imaging systems such as InSAR and LiDAR for monitoring local area ground surface deformations such as volcanic and seismic activities, and ground subsidence associated with city development, mining activities, ground liquid withdrawal, and land reclamation.

Research Activities of the Working Groups

InSAR is a very active field of research in the geodetic research communities. The current research issues that the members of the SC are working on include

- The development of more effective methods/algorithms for InSAR solutions;
- The quality control and assurance of InSAR measurements;
- The study and mitigation of biases in InSAR measurements such as the atmospheric effects;
- Integration of InSAR and other geodetic technologies such as GPS and GIS; and
- New and innovative applications of the technology in geodetic studies.

Examples of some of the major research projects that the SC is working on include mine site and city area deformation monitoring and earthquake studies. Prof. Makoto Omura has been leading a research project that focuses on studying ground deformations associated with mining activities and urban subsidence in many parts of the world. The work involves collaborations between researchers from a number of countries.

Dr. Linlin Ge and some other members of the SC have been working on ground deformations associated with the devastating Wenchuan earthquake in Sichuan, China that occurred on 12 May 2008. The work supported by ERSDAC (Earth Remote Sensing Data Analysis Center) of Japan has contributed significantly to the efforts of emergency response in the affected area by providing rapid D-InSAR results from the ALOS/PALSAR L-band SAR data.

Conferences

Members of the SC have been active in both participating and organizing scientific meetings/conferences relevant to the activities of the SC. The following represent a sample of the meetings organized (or co-organized):

- A session on InSAR at the 13th FIG Symposium on Deformation Measurements and Analysis and 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering in Lisbon, Portugal, 12-15 May 2008.
- A special session on SAR at the Japanese Geosciences Union Meeting 2008 in Chiba city, Japan, 25-30 May 2008.
- A session on Earth Observation at the 26th ISTS (International Symposium on Space Technology and Science) in Hamamatsu, Japan, 1-8 June 2008.

- A special session on InSAR, Geodetic Remote Sensing, at the AOGS (Asia Oceana Geophysics Society) conference in Busan, South Korea, 16-20 June 2008.
- A special session, Modern Geodetic Techniques for Surface Deformation Monitoring, at the WPGM (Western Pacific Geophysics Meeting) in Cairns, Australia, 29 July – 1 August 2008.
- 2008 Earthquake Research Institute, University of Tokyo, Workshop on Monitoring and Analyzing Earthquakes, Volcanoes and Ground movements by using SAR and Infra-red Sensors in Tokyo, Japan, 16-17 September 2008.
- A session on SAR at the Japanese Geosciences Union Meeting 2009 in Chiba, Japan, 16-21 May 2009.
- A session on Earth Observation at the 27th ISTS (International Symposium on Space Technology and Science) in Tsukuba city, Japan, 5-12 July 2009.
- Sessions at the IAG Scientific Assembly, Buenos Aires, Argentina, 31 August – 4 September 2009.
- A conference on Satellite and Airborne Imaging Systems for Geodetic Studies in Beijing, China in 2010.
- IEEE International Geoscience and Remote Sensing Symposium (IGARSS) in Sendai, Japan, 1-5 August 2011.

Special Issue in Journal of Geodesy

The SC is currently working on a special issue on InSAR and LiDAR in Journal of Geodesy.

Sub-Commission 4.5: High-Precision GNSS

President: Yang Gao (Canada)

www.ucalgary.ca/~point/iag.html

Working Groups

WG4.5.1 Quality Measures for Network Based GNSS Positioning

- Chair: Xiaolin Meng (The University of Nottingham, UK)

WG4.5.2 Precise Point Positioning and Network-RTK

- Chair: Sunil Bisnath (York University, Canada); <http://www.yorku.ca/sbisnath/iag/>

WG4.5.3 Correction Models for Ultrahigh-Precision GNSS Positioning

- Chair: Wu Chen (The Hong Kong Polytechnic Univ., Hong Kong)

WG4.5.4 Data Processing of Multiple GNSS Signals

- Chair: Yanming Feng (Queensland University of Technology); <http://www.gnss.com.au/iagwg454.html>

Academic Activities:

- WG4.5.2. “Precise Point Positioning and Network-RTK” forms a small, active, global group of members from academia and the public and private industry.
- A white paper “Current state of Precise Point Positioning and future prospects and limitations” presented at IUGG 24th General Assembly IAG Commission 4 session.
- A paper on “Precise Point Positioning: Past, Present, and Future” published in GPS World’s Innovation.
- A working group website created for WG4.5.2: <http://www.yorku.ca/sbisnath/iag/>.
- A number of PPP and closely associated network RTK papers were presented at the ION GNSS 2008 conference in Savannah, Georgia, USA.
- Members at The University of Calgary has published and presented several papers on their research progress made in the area of GNSS biases and PPP ambiguity resolution central to the development next generation RTK technology
- Research results on Precise Point Positioning at The University of Calgary have been transferred in the form of software system to academic and industry sectors to support research activities and product development.
- Members at the University of New Brunswick have created a PPP software comparison website: <http://gge.unb.ca/Resources/PPP/>.
- WG4.5.1. “Quality Measures for Network Based GNSS Positioning” forms a membership with members from academia and the private industry.
- A link to previous WG of IAG has been set up to integrate existing findings with this group: www.network-rtk.info/

- Members at The University of Nottingham conducted systematic studies on the quality issues of network RTK positioning and a systematic approach has been designed to quantify the quality of the RTK corrections in real time and relevant data processing and quality assessment platform has been developed. A number of papers have been published in journals (e.g. Journal of Applied Geodesy, GPS World) and international conferences (e.g. ION, ENC and FIG).
- Members at The University of Newcastle upon Tyne have conducted a series of field tests using the Ordnance Survey's facility aiming at creating best practice guidance to the surveyors using NRTK.
- Around 200 people attended the ground breaking Launch Day of the Network RTK Best Practice Guidelines that was organised by the University of Newcastle upon Tyne. This report can be downloaded from the website of The Survey Association (TSA) at <http://www.tsa-uk.org.uk/guidance.php>.
- Member at in Position worked on the combination of different GNSS into one seamless positioning network and solution. The use of observations of different GNSS constellations is relatively straight-forward as long as similar receiver types are used throughout the network configuration. Especially for an arbitrary mix of receivers of different manufacturers the overall concepts for processing GNSS observations in real-time need adaptation.
- New concepts for processing multiple receiver observation information and quality control techniques are desperately required. The publications concentrate the options for optimal use of a multi-GNSS receiver together with other GNSS receivers not supporting the complete set of GNSS. The computation scheme developed allows an arbitrary mix of GNSS receivers. Results based on post-processing and real-time processing have been published on various conferences (see literature list)
- WG4.5.4 "Data Processing of Multiple GNSS Signals" forms a membership with members from academia and the private industry.
- A website has been created for WG4.5.4 "Data Processing of Multiple GNSS Signals": <http://www.gnss.com.au/iagwg454.html>
- WG4.5.4 Chair Yanming Feng gave a keynote speech on "Three carrier Ambiguity Resolution: Generalized Problems, Models, Solutions and Performance" at International Workshop on Geodetic Theory 2009.
- WG4.5.4 members present four papers at ION GNSS 2008 session 6D "Multiple-frequency GNSS algorithms".
- WG4.5.4 members published nine papers journals and seven conference papers.

Conference, Workshop, Technical Session

- SC4.5 helped organize several technical meetings and workshops including International Technical Meeting on GNSS – "The Next Generation GNSS - Innovation and Applications" to be held in Beijing, August 7-9, 2009; Chinese Technical Application Association for GPS (CTAAGPS) on New Navigation Technologies and Innovations, Beijing, December 18-20, 2008; Scientific Workshop on Hazard Monitoring by Geosciences, Wuhan, China, May 22, 2008.
- SC4.5 President Yang Gao gave invited talks at several technical meetings such as IGS Workshop 2008, Florida, USA, 2-6 June 2008; CTAAGPS Annual Meeting on

New Navigation Technologies and Innovations, Beijing, China, December 18-20, 2008.

- A session on PPP vs DGPS central to IAG Commission 4 "Positioning and Applications" held at the International Union of Geodesy and Geophysics 24th General Assembly, Perugia, Italy, 2-13 July 2007.
- WG4.5.2 organized a PPP workshop in June 2008, Niagara Fall, Canada: <http://gge.unb.ca/Research/GRL/GNSS/NiagaraFallsPPP2008.htm>.
- WG4.5.1 co-organised LBS 2009 Workshop in Nottingham
- WG4.5.4 co-organized International Workshop on Geodetic Theory 2009, Tongji University on behalf of AIG Commission IV, 1-2 June 2009.
- WG4.5.2 organized a PPP and network RTK session at the upcoming ION GNSS 2009 conference in Savannah, USA.
- WG4.5.1 plans to organise a dedicated NRTK QC workshop in 2010.

Publications

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Euler, H.-J., Wirth, J., Novel Concept in Multiple GNSS Network RTK Processing, ION GNSS 2007, September 25-28, 2007, Fort Worth, TX

Lück, Th., Winkel, J., Göhler, E., Falk, N., Consoli, A., Piazza, F., Gerna, D., Granger, R., Readman, P., Simpson, S., Euler, H.-J., Artus – A Second Generation Galileo/GPS Receiver, ION GNSS 2007, September 25-28, 2007, Fort Worth, TX.

Euler, H.-J., Wirth, J., Advanced Concept in Multiple GNSS Network RTK processing, ENC GNSS 2008, April 22-25, 2008, Toulouse, France.

Euler, H.-J., Wirth, J., Advanced Concept in Multiple GNSS Network RTK processing, 1st International Conference on Machine Control & Guidance, ETH Zürich, June 24-26, 2008, Zürich, Switzerland (reformatted ENC GNSS 2008 version)

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Euler, H.-J., Comparison of different Network RTK Concepts – Status and Developments, 83. DVW-Seminar. GNSS 2009: Systeme, Dienste, Anwendungen. 18. und 19. März 2009. TU Dresden.

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Yang, L., Hill, C. and Meng, X. (2008). Evaluation of RTK GPS Correction Transmission Delay and Loss, ENC-GNSS 2008, 22-25 April, 2008, Toulouse, France.

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P.J.G. Teunissen and S. Verhagen, GNSS Carrier Phase Ambiguity Resolution: Challenges and Open Problems, *Observing our Changing Earth, Proceedings of the 2007 IAG General Assembly, Perugia, Italy, July 2 - 13, 2007, Series: International Association of Geodesy Symposia*, Vol. 133. Sideris, Michael G. (Ed.), p785-792.

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Chen W., Ji S., Ding X., Chen Y., Hu C. (2008) Towards Single Epoch Ambiguity Resolution with Galileo Multiple Frequency using Improved Cascading Ambiguity Resolution (CAR) Method, ION GNSS 2008, 16–19 Sept., Savannah GA

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Feng Y. M., Rizos C., Higgins M. (2007) Multiple Carrier Ambiguity Resolution and Performance Benefits for RTK and PPP Positioning Services in Regional Areas Proceedings of ION GNSS 2007, 25-28 Sept, Fort Worth, TX, pp668-677.

Feng, Y. and Wang, J. (2007) Exploring GNSS RTK Performance Benefits with GPS and Virtual Galileo Measurements, Proceedings of ION-NTM 2007, pp 218-226, San Diego, CA, USA

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Study Group 4.2: GNSS Remote Sensing and Applications

Chair: Shuanggen Jin (South Korea)

Introduction

Nowadays, the Global Navigation Satellite System (GNSS), which is a very powerful and important contributor to all scientific questions related to high precision positioning on Earth's surface, has been widely used as a mature technique in geodesy and geodynamics. Recently, the versatility and availability of reflected and refracted signals from GNSS gave birth to many new GNSS applications for various environmental remote-sensing in atmosphere, ocean and land. Many countries have initiated efforts in this area of researches and applications. The focus of this Study Group (SG4.1) is to facilitate collaboration and communication, and to support joint researches with new GNSS remote sensing techniques. Specific objectives will be achieved through closely working with members and other IAG Commissions/Sub-Commissions. Meanwhile, close collaboration with the International GNSS Service (IGS), Institute of Navigation (ION) and IEEE Geoscience and Remote Sensing Society (IGRASS) will be promoted, such as joint sponsorship of international professional workshops and conferences.

Website:

<http://www.gnss.googlepages.com/iag-sg4.1>

Activities

2009

- 31 August-4 September 2009, Shuanggen Jin attended the International Association of Geodesy (IAG) Scientific Assembly, Buenos Aires, Argentina and Chaired one sub-session "Multi-satellite Ocean Remote Sensing" as well as presented two papers.
- 8-10 August 2009, Shuanggen Jin attended International Technical Meeting on GNSS (ITM-GNSS)-Innovation and Application, Beijing, China with one presentation and Chaired one session.
- 13-17 July 2009, Shuanggen Jin and Attila Komjathy Chaired one Joint IAG/IEEE/ION/ISPRS session "GNSS Remote Sensing of Atmosphere, Ocean and Land" at the IEEE Geoscience and Remote Sensing Symposium (IGARSS), Cape Town, South Africa and presented two papers.
- 19-24 April 2009, Shuanggen Jin Chaired one session "GPS/Gravity Applications in Active Tectonics and Geophysics" and Co-Convened one session "Secular changes of the Planetary Earth system and its Physical Mechanism" at the European Geosciences Union (EGU) General Assembly, Vienna, Austria.

2008

- 15-19 December 2008, Shuanggen Jin Chaired one session "High-Rate and Low-Latency Data for Earth Science Applications", American Geophysical Union (AGU) Fall Meeting, San Francisco, USA.

- 24-25 September 2008, GNSS Reflectometry Course and Workshop organized by the European Space Agency was held at ESTEC in Noordwijk, The Netherlands.
- 29 July-1 August 2008, Dr. Shuanggen Jin Co-Convened one session “Towards the synergy of geodesy, environment and atmosphere” at the Western Pacific Geophysics Meeting (WPGM) of American Geophysical Union (AGU), Cairns, Australia and presented one paper.
- 5-12 July 2008, Dr. Attila Komjathy Convened one session "Ionospheric Remote Sensing by GPS" at the joint 2008 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting (Commission G, Ionospheric Radio and Propagation), San Diego, CA, USA.
- June-July 2008, Shuanggen Jin had worked as Research Scientist at the Department of Reference Systems and Geodynamics, Royal Observatory of Belgium, Brussels, Belgium.
- 16-20 June 2008, Shuanggen Jin participated in the fifth Annual Assembly of Asia Oceania Geosciences Society (AOGS), Busan, South Korea and Chaired one session “GPS/Gravity and Applications in Active Tectonics and Geophysics” and Co-chaired on session "Geodetic Techniques (GNSS, VLBI, SLR...) and Its Applications on Atmosphere/Geodynamics" as well as presented two papers.
- 5-8 May 2008, Dr. Susan Skone of SG4.1 member Chaired one session “Earth Observation & Remote Sensing” at the Position Location and Navigation Symposium 2008 (PLANS2008), Monterey, California, USA.
- 13-18 April 2008, Dr. Shuanggen Jin attended the European Geosciences Union (EGU) General Assembly, Vienna, Austria, where he Chaired one session “Monitoring of the lower atmosphere and ionosphere by space geodetic techniques” and presented one paper “Retrieval of Ionospheric slab thickness and its variations from 3-D GPS observations”.
- 28-30 January, 2008, Dr. Susan Skone of SG4.1 member Co-Chaired one session “Atmospheric Effects” at the 2008 National Technical Meeting, San Diego, CA, USA.
- 5-7 January 2008, Dr. Shuanggen Jin attended the Second CPGPS Youth Forum on “The Next Generation GNSS - Opportunities and Challenges”, Guangzhou, China as member of Technical Committee and Co-Chaired one session as well as presented the paper "GPS models/combinations and its applications: Progresses and Challenges".

2007

- 1 November 2007, Dr. Shuanggen Jin’s paper “Ionospheric slab thickness and its seasonal variations observed by GPS” was published in the Journal of Atmospheric and Solar-Terrestrial Physics, 69(15), 1864-1870, doi: 10.1016/j.jastp.2007.07.008.
- 29 October-4 November, 2007, Shuanggen Jin visited/collaborated with the University of Bath and University of Oxford, and attended the International Navigation Conference & Exhibition, Royal Institute of Navigation (RIN), London, UK.
- 10 October 2007, Dr. Y. T. Song of SG4.1 member published the recent result “Detecting tsunami genesis and scales directly from coastal GPS stations” at Geophys. Res. Lett., 34, L19602, doi: 10.1029/2007GL031681.
- **1-4 October 2007**, The GNSS Remote Sensing Session was held at the 1st Colloquium Scientific and Fundamental Aspects of the Galileo Programme, Toulouse,

France. Dr. J. Garrison of SG4.1 member presented the paper “Considerations in Utilizing Galileo Signals for GNSS-R Ocean Sensing” and Prof. G. Ruffini of SG4.1 member presented the paper “Soil Moisture Monitorization Using Galileo Reflected Signals”.

- October-November 2007, Report initial activities of SG4.1 to Commission 4.
- October-November 2007, Expand members to join the Study Group (SG4.1).
- September-November 2007, Made a website for the SG4.1 to show the terms of reference, objectives and members list, report activities and progress as well as related linkage, etc.: <http://www.gnss.googlepages.com/IAG-SG4.1>
- 14-16 September 2007, Dr. Shuanggen Jin invited Prof. Dr. Jeffrey T. Freymueller (University of Alaska, Fairbanks, USA) to visit the Korea Astronomy & Space Science Institute, Daejeon, South Korea and then he attended 21st COE conference at the University of Tokyo, Japan.
- 31 July-4 August 2007, Dr. Shuanggen Jin attended the 4th Assembly of Asia Oceania Geosciences Society (AOGS), Bangkok, Thailand and chaired one session “Geodesy, Geodynamics and Geohazards” as well as presented three papers.
- 1-9 July 2007, Dr. Shuanggen Jin attended the IUGG XXIV General Assembly, Earth: Our Changing Planet, Perugia, Italy and presented three papers with two oral presentations.

Journal publications with SG4.2 members

Cardellach E, A. Rius (2008) A new technique to sense non-Gaussian features of the sea surface from L-band bistatic GNSS reflections, *Remote Sensing of Environment*, 112(6), 2927-2937

Gleason S, Hodgart S, Sun Y, Gommenginger C, Mackin S, Adjrak M, Unwin M (2005) Detection and Processing of Bistatically Reflected GPS Signals from Low Earth Orbit for the Purpose of Ocean Remote Sensing. *IEEE Transactions on Geoscience and Remote Sensing*, 43(6): 1229- 1241.

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Jin S.G., O.F. Luo, and S. Gleason (2009), Characterization of diurnal cycles in ZTD from a decade of global GPS observations, *J. Geodesy*, 83(6), 537-545, doi: 10.1007/s00190-008-0264-3.

Jin S.G., O.F. Luo, and J. Cho (2009), Systematic errors in VLBI precipitable water vapor estimations from 5-year GPS measurements, *J. Atmos. Sol.-Terr. Phys.*, 71(2), 264-272, doi: 10.1016/j.jastp.2008.

Jin S.G., O.F. Luo, and P. Park (2008), GPS observations of the ionospheric F2-layer behaviour during the 20th November 2003 geomagnetic storm over South Korea, *J. Geodesy*, 82(12), 883-892, doi: 10.1007/s00190-008-0217-x.

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Larson, K.M., E.E. Small, E. Gutmann, A. Bilich, J. Braun, V. Zavorotny (2008), Use of GPS receivers as a soil moisture network for water cycle studies, *Geophys. Res. Lett.*, 35, L24405, doi: 10.1029/2008GL036013.

Nogués, O., Cardellach, E., Sanz Campderros, J., Rius, A.(2007) A GPS-Reflections Receiver That Computes Doppler/Delay Maps in Real Time, *IEEE Transactions on Geoscience and Remote Sensing*, 45, 1, pp. 156-174, doi: 10.1109/TGRS.2006.882257.

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Study Group 4.3: IGS Products for Network RTK and Atmosphere Monitoring

Chair: Robert Weber (Austria)

The IAG Study Group 4.2 on the 'Use of IGS Products for Network RTK and Atmosphere Monitoring' has been established end of 2007

Study Groups Web-site:

http://www.hg.tuwien.ac.at/Research/SatelliteTechniques/IAG_Study_Group_42/iag_study_group_42.html

Objectives

- To promote the use of IGS products for Network RTK and Atmosphere Monitoring
- To identify the current needs of near real-time atmospheric monitoring and Network-RTK in terms of IGS product quality, delivery time and spatial resolution
- To investigate options how to provide IGS products in standard real-time formats

Terms of Reference

The International GNSS Service (IGS) provides GPS & GLONASS station data and derived products like satellite orbits, clock corrections, electron content models and tropospheric delays of superior quality and within different time frames in support of Earth science research and multidisciplinary applications. Special applications like Network RTK in order to allow for fast access of a globally consistent reference frame for all position applications and near/real-time atmospheric monitoring for weather prediction require GNSS products with greatly reduced delays. Soon these products will be made available to the user community by means of the IGS RT Project in near-real via Internet and other available streaming technologies.

This Study Group shall identify the needs of near real-time atmospheric monitoring in terms of orbit and clock-correction quality and investigate if the suite of IGS real-time products match the requested quality and spatial resolution necessary for correction data within regional RTK networks. Another topic deals with the coding of IGS products and models to be useful as a state space representation of error sources within the real-time standard formats RTCM and RTCA.

This Study Group is directly linked to IAG Sub-commissions 4.3 and 4.5 as well as to the International GNSS Service (IGS).

According to work program proposed at the set up phase of this study-group the topics to be studied in 2008/09 can be summarized as

2008 – Investigate deficiencies of current IGS products for Near Real-time atmosphere Monitoring

2008/2009 – Use of IGS Real-Time products for regional RTK-networks

Accomplished and upcoming tasks

Over the past year the influence of IGU (IGS Ultra Rapid) products on the fast calculation of Zenith Wet delays has been studied in depth. An operational system to provide ZWD-estimates to the Austrian Meteorological Office has been set up. In conclusion the predicted part of the IGU orbits can be used for close to real time ZWD estimation. IGU satellite clock corrections are usually not suitable for this purpose due to their low resolution (15 minutes) and the 6h –update rate accompanied by frequent clock mis-modelling. It is recommended to obtain real-time clock corrections delivered by the upcoming IGS RT project. Several publications and presentations were issued (see list of publications below). Close to Real-Time Ionospheric Models have not been handled in 2008 but will be investigated in 2009.

In spring 2009 modified professional RTK software offered by the Geo++ company will be installed at TU-Vienna to study in more detail the use of IGU products for ambiguity resolution and the effect on the issued corrections at different scales within two different RTK networks. Of special interest will be to merge IGS tropospheric and ionospheric quasi-realtime products as well as clock-corrections with regional models obtained by data of the RTK Reference Station Network (Steady State Representation merging global and regional Models).

Publications and Presentations of SG members related to the goals of the Study Group (time frame end 2007/2008, selection)

V. Bröderbauer, M. Opitz, R. Weber: "Automated quasi-realtime prediction of GNSS clock corrections"; Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), begutachteter Spezialband, Heft 2 (2007), 95. Jahrgang; S. 53 -58.

T. Hobiger, T. Kondo, Y. Koyama, R. Ichikawa, R. Weber: *Effect of the Earth's oblateness on the estimation of global vertical total electron content maps*; Geophysical Research Letters, **34** (2007), 11.

A. Karabatic, R. Weber: "Near real-time zenith wet delay estimation"; Analysis Center Workshop 2008, Miami; 02.06.2008 - 06.06.2008.

A. Karabatic, R. Weber: "Potential contribution of GNSS data based tropospheric zenith delay to weather forecasts in alpine areas"; Poster: AGU Fall Meeting San Francisco, San Francisco; 10.12.2007 - 14.12.2007.

A. Karabatic, R. Weber, S. Leroch, Th. Haiden: "GNSSMET - Contribution of tropospheric zenith delays derived from GNSS data for weather forecast in alpine areas"; EGU 2008, Vienna; 13.04.2008 - 18.04.2008.

M. Opitz, R. Weber: "Real Time Monitoring of IGS Products within the RTIGS Network"; in: "Proceedings of the IGS Analysis Center Workshop, Darmstadt", Proceedings of the IGS Analysis Center Workshop, 2008, S. 5 - 13

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R. Weber, S. English: "Scientific Applications in Geodesy and Geodynamics - Innovations offered by the new Galileo signals"; 1st Colloquium Scientific and Fundamental Aspects of the Galileo Program, Toulouse, France; 01.10.2007 - 04.10.2007; Proceedings of Colloquium.

R. Weber, A. Karabatic, S. Leroch, Th. Haiden: "GNSSMET – Quasi Real tropospheric zenith delays derived from GNSS data for weather forecast"; Final Report, 120 pages, University of Technology, Vienna.

Scientific sessions in close relation to the goals of the Study Group chaired/co-chaired by R. Weber

AGU 2007; Session G11A on 'Future of Global Navigation Satellite Systems and Their Impact on Geodetic and Geophysical Applications'

EGU 2008; Session G7 on 'GNSS new capabilities for geosciences'

AGU 2008: Session G41C on 'The Future of Global Navigation Satellite Systems (GNSS) and Their Impact on Geodetic, Geophysical, and Environmental Applications'

According to the published work program the group will focus in the period 2009-2010 on the topics

2009/2010 – Investigate formulation of IGS Real-Time Products as State Space Representation

2009/2010 – Investigate formulation of IGS Products as Real-Time RTCM and/or RTCA Corrections