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International Laser Ranging Service

International Doris Service

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Time Section of the Int. Bureau of Weights and Measures

International Gravity Field Service

International Gravimetric Bureau

International Geoid Service

International Center for Earth Tides

Permanent Service for Mean Sea Level

International Center for Global Earth Models

International DEM Service

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International Association of Geodesy (IAG)

IAG-Commission 1 – Reference Frames

Bulletin No. 19

Mid-Term Report 2005

Edited by

Hermann Drewes, President

Helmut Hornik, Redaction

Munich 2005

Deutsches Geodätisches Forschungsinstitut

International Association of Geodesy (IAG)

IAG-Commission 1 – Reference Frames

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http://www.iag-aig.org/

IAG Commission 1 – Reference Frames

http://iag.dgfi.badw.de/

Deutsches Geodätisches Forschungsinstitut (DGFI) – German Geodetic Research Institute

http://www.dgfi.badw.de/

This series of **IAG Commission 1 – Reference Frames Bulletins** continues the series of the former **IAG Commission on International Coordination of Space Techniques for Geodesy and Geodynamics (CSTG) Bulletins**, cf. *http://www.dgfi.badw.de/cstg/WWW/cstg_bull_list.html*

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Preface

The present volume of the IAG Commission 1 Bulletins is the mid-term report on the Commission's activities from its establishment in July 2003 to the mid of 2005. The presidents and chair persons of the sub-commissions, projects, study groups and working groups, respectively, give a summary of the research work done during the last two years and the main results achieved. The great effort of all scientists associated with the Commission is gratefully acknowledged.

Munich, Summer 2005

Hermann Drewes
President
IAG Commission 1 – Reference Frames

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IAG-Commission 1 – Reference Frames

Mid-Term Report 2005

H. DREWES[1]

Introduction

Commission 1 "Reference Frames" of the International Association of Geodesy (IAG) was established within the new IAG structure (adopted by the IAG Council at the IAG Scientific Assembly in Budapest, 2001) during the XXIII General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Sapporo, Japan July 2003. The principal objectives of the scientific work focus on basic research related to

- Definition, establishment, maintenance, and improvement of geodetic reference frames;
- Advanced development of terrestrial and space geodetic observation techniques for this purpose;
- Analysis and processing methods for parameter estimation related to reference frames;
- Theory and coordination of astrometric observations for reference frame purposes.

The research work shall be done in very close cooperation with the IAG Services relevant for reference frames. These are in particular

- International Earth Rotation and Reference Systems Service (IERS)
- International GNSS Service (IGS)
- International Laser Ranging Service (ILRS)
- International VLBI Service for Geodesy and Astrometry (IVS)
- International DORIS Service (IDS).

To some extent, Commission 1 integrates and continues the work of the previous IAG Commissions VIII "International Coordination of Space Techniques for Geodesy and Geodynamics (CSTG)" and X "Global and Regional Geodetic Networks" which were discontinued in 2003 with the establishment of the new IAG Structure. For this reason, Commission 1 continues as the Sub-Commission B2 "CSTG" of the ICSU Committee on Space Research (COSPAR).

Structure of Commission 1

The Commission was structured in Sapporo, July 2003, into four Sub-Commissions (SC), two Inter-Commission Projects (IC-P), two Inter-Commission Study Groups (IC-SG), and three Inter-Commission Working Groups (IC-WG). These are:

SC1.1	Coordination of Space Techniques (President: M. ROTHACHER, Germany)
SC1.2	Global Reference Frames (President: C. BOUCHER, France)
SC1.3	Regional Reference Frames (President: Z. ALTAMIMI, France)
SC1.3a	Europe (Chair: J. A. TORRES, Portugal)
SC1.3b	South and Central America (Chair: L. P. FORTES, Brazil)
SC1.3c	North America (Chairs: M. CRAYMER, Canada, R. SNAY, USA)
SC1.3d	Africa (Chair: R. WONNACOTT, South Africa)
SC1.3e	Asia-Pacific (Chair: J. MANNING, Australia)
SC1.3f	Antarctica (Chair: R. DIETRICH, Germany)
SC1.4	Interaction of Celestial and Terrestrial Reference Frames (Pres.: S. Y. ZHU, Germany)
IC-P1.1	Satellite Altimetry (jointly with Commissions 2 and 3, Chair: W. BOSCH, Germany)
IC-P1.2	Vertical Reference Frames (jointly with Commission 2, Chair: J. IHDE, Germany)
IC-SG1.1	Ionosphere Modelling and Analysis (jointly with Commission 4 and COSPAR, Chair: C. BRUNINI, Argentina)
IC-SG1.2	Use of GNSS for Reference Frames (jointly with Commission 4 and IGS, Chair: R. WEBER, Austria)
IC-WG1	Quality Measures, Quality Control, and Quality Improvement (jointly with ICC on Theory, Chair: H. KUTTERER, Germany)
IC-WG2	Integrated Theory for Crustal Deformation (jointly with Commission 3 and ICCT, Chair: K. HEKI, Japan)
IC-WG3	Satellite Gravity Theory (jointly with Commission 2 and ICCT, Chair: N. SNEEUW, Canada, in future Germany)

The Sub-Commissions are sub-divided into Working Groups for specific research topics. While the Sub-Commissions are designed for a longer time of activity, the Working Groups may be discontinued after a two or four years period in the same way as the Projects and Study Groups.

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The Commissions's Steering Committee consists of

- President: H. DREWES
- Vice President: C. K. SHUM
- President SC1.1: M. ROTHACHER
- President SC1.2: C. BOUCHER
- President SC1.3: Z. ALTAMINI
- President SC 1.4: S. Y. ZHU
- Representatives of Services: W. GURTNER, C. MA, J. RIES
- Members at large: J. MANNING, R. WONNACOTT

Main Activities 2003-2005

The Commission's work during the period 2003 to 2005 was determined by the set-up of the internal structure and the implementation of the work plan of the individual entities. The first meeting of the Steering Committee (StC) was held in Sapporo, Japan, 7 July 2003, immediately after the establishment of the Commission. Six members of the StC were present. As the meeting was declared an open Commission 1 assembly, also five of the other officers and several guests participated. The main point of discussion was the structure of the Commission as well as the Terms of Reference and Objectives of the individual entities (Sub-Commissions, Projects, Study Groups, Working Groups). A major topic was the link to and the cooperation with the IAG Services and other scientific bodies (e.g., IUGG, COSPAR).

The second Steering Committee meeting took place during the General Assembly of the European Geoscience Union (EGU) in Nice, France, 28 April 2004. It was again held as an open assembly with a total of 24 participants, 8 of them members of the Steering Committee and 5 other Commission 1 officers. There were detailed reports and discussions on the initiated work of the Sub-Commissions, Projects, and Study Groups. The planned activities of the Commission within the IAG Project "Global Geodetic Observing System (GGOS)" and COSPAR were drafted. It was agreed to continue the former CSTG Bulletin as the Commission 1 Bulletin for presentation of the research work.

Highlights of the Commissions Research Work

The current work of the Commission is, in general, in a good shape. There are some excellent results obtained by Sub-Commissions, Projects, and Study Groups. They are presented in detail in the corresponding sections in the sequel and may be highlighted here briefly.

Sub-Commission 1.1 "Coordination of Space Techniques" studies in particular effects that influence in a similar way the different space techniques, e.g., caused by the satellite orbits or by the atmosphere. The work has been done in close cooperation with the IAG Services. An advantage in the organizational structure is that there are several scientists active in Sub-Commission 1.1 and in the services, first of all the SC President. A number of activities (pilot projects and studies) were initiated, mainly together with the IERS.

Sub-Commission 1.2 "Global Reference Frames" is very close to the work of the IERS Product Center for the International Terrestrial Reference Frame (ITRF). It is in permanent contact with the three ITRF Combination Centers at IGN Paris, DGFI Munich, and NRCan, Ottawa. In particular the datum definition and the surveys (localties) at co-location sites have intensively been discussed.

Sub-Commission 1.3 "Regional Reference Frames" is engaged in the coordination of the establishment and maintenance of reference frames in the different continents. It was focusing on the African Reference Frame (AFREF) which is on the way for ist initial phase. Good progress has been made in Europe, North and South America. The unification of the vertical (height) reference frames was a major point of discussion.

Sub-Commission 1.4 "Interaction of Celestial and Terrestrial Reference Frames" is mainly focusing on the consistency between the reference frames. The transformation of the new IAU 2000 resolution concerning the precession and nutation model into the geodetic conventions is a major challenge. The work was done in connection with the outcome of the IERS Workshop on the "Implementation of the new IAU Resolutions", Paris 2002.

Inter-Commission Project 1.1 "Satellite Altimetry" is on the way of the installation of an International Altimetry Service (IAS). An interdisciplinary planning group was set up and met several times. The major objective is to identify the scientific requirements to provide a consistent long-period time series of altimeter observations to the broad users community.

Inter-Commission Project 1.2 "Vertical Reference Frames" concentrates on the establishment of a unified global vertical reference frame (height system). The very close cooperation between European (EUREF, EVRS) and American (SIRGAS) groups presents encouraging results towards a successful work. First ideas of the realization have been published.

Inter-Commission Study Group 1.1 "Ionosphere Modelling and Analysis" aims at a physical model of the ionosphere that presents the complete 3 D electron density rather than the total electron content (TEC) normally used in geodesy. Existing models like IRI and NeQuick have been studied with the objective to improve the parameter estimation of these physical models from geodetic observations.

Inter-Commission Study Group 1.2 "Use of GNSS for Reference Frames" is a joint effort with IGS. A major activity is the implementation of the European Galileo System into reference frame realizations. The work is very close to the United Nations' newly installed International Committee on GNSS (ICG) where several officers of Commission 1 participated.

The Inter-Commission Working Groups are all part of the Inter-Commission Committee on Theory (ICCT) and will be reported there in detail. We include a summary in this Bulletin for information.

Selected literature

Angermann, D., M. Krügel, B. Meisel, H. Müller, V. Tesmer: Time evolution of the terrestrial reference frame, Sanso F (Ed): A Window on the Future of Geodesy, IAG Symposia, Vol. 128, Springer, 2005.

Altamimi, Z.: Towards a dense European velocity field. Mitteilungen des BKG (33) 84-88, 2004.

Blewitt, G., P. Clarke: Inversion of Earth's changing shape to weigh sea level in static equilibrium with surface mass redistribution. J. Geophys. Res. (108) B6, 13, 22pp, 2003.

Bosch, W.: Geodetic application of satellite altimetry. In: Hwang, C., C.K. Chum, J. Li (Eds.): Satellite Altimetry for Geodesy, Geophysics and Oceanography, IAG Symposia, Vol. 126, 3-22, Springer, 2003.

Boucher, C., Z. Altamimi, P. Sillard, M. Feissel-Vernier: The ITRF 2000. IERS Technical Note No. 31, 2004.

Bursa, M., S. Kenyon, J. Kouba, Z. Sima, V. Vatrt, M. Vojtiskova: A global vertical reference frame based on four regional vertical datums. Studia geoph. et geod. (48) 493-502, 2004.

Clarke, P.J., D.A. Lavallee, G. Blewitt, T.M. van Dam, J.M. Wahr: Effect of gravitational consistency and mass conservation on seasonal mass loading models. Geophys. Res. Lett. (32) L08306 (4pp), 2005.

Dong, D., T. Yunck, M. Heflin: Origin of the International Terrestrial Reference Frame. J. Geophys. Res. (108) B4, 8, 10pp, 2003.

Drewes, H., B. Meisel: An actual plate motion and deformation model as a kinematic terrestrial reference system. Geotechnologien Science Report No. 3, 40-43, 2003.

Kaniuth, K., S. Huber: Modelling vertical site displacements due to atmospheric pressure loading with the Bernese software - A demonstation using EUREF data. Mitteilungen des BKG (33) 89-95, 2004.

Munekane, H., S. Matsuzaka: Nontidal ocean mass loading detected by GPS observations in the tropical Pacific region. Geophys. Res. Lett. (31) L08602, 4pp, 2004.

Petrov, L., J.-P. Boy: Study of the atmospheric pressure loading signal in VLBI observations. J. Geophys. Res. (109) B7, 1-13, 2004.

Rothacher, M., J. Campbell, A. Nothnagel, H. Drewes, D. Angermann, D. Grünreich, B. Richter, Ch. Reigber, S.Y. Zhu: Integration of space techniques and establishment of a user center in the framework of the International Earth Rotation and Reference Systems Service (IERS). Geotechnologien Science Report No.3, 137-141, 2003.

Tregoning, P., T. van Dam: Effects of atmospheric pressure loading and seven-parameter transformations on estimates of geocenter motion and station heights from space geodetic observations. J. Geophys. Res. (110) B03408, 1-12, 2005.

Zhu, S.Y., F.-H. Massmann, Ch. Reigber: Satellite antenna phase center offsets and scale errors in GPS solutions. J. Geodesy (76) 668-672, 2003.

Sub-Commission 1.1
Coordination of Space Techniques

Mid-Term Report 2005

M. ROTHACHER[2], H. BOOMKAMP[3], D. ANGERMANN[4], J. BÖHM[5]

Introduction

Objectives

Sub-Commission 1.1 coordinates efforts that are common to more than one space geodetic technique. It studies combination methods and approaches concerning the links between techniques co-located onboard satellites, common modeling and parameterization standards, and performs analyses from the combination of a single parameter type up to a rigorous combination on the normal equation (or variance-covariance matrices) or even the observation level. The list of parameters includes site coordinates (e.g. time series of positions), Earth orientation parameters, satellite orbits, atmospheric refraction (troposphere and ionosphere), gravity field coefficients (primarily the low-degree harmonic coefficients), geocenter coordinates, etc.

The work of Sub-Commission 1.1 is done in close cooperation with the IAG Services, namely the International Earth Rotation and Reference Systems Service (IERS), its Working Groups on Combination and on Site Co-locations, the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), the International VLBI Sevice for Geodesy and Astrometry, the International DORIS Service (IDS), the IAG project "Global Geodetic Observing System" (GGOS), and with COSPAR.

For more details see the Sub-Commission description at *http://www.iag-aig.org*.

General Remarks

Within Sub-Commission 1.1 three working groups have been established in order to make progress towards the goals described above:

- SC1.1-WG1 on "Comparison and combination of precise orbits derived from different space geodetic techniques"
- SC1.1-WG2 on "Interactions and consistency between Terrestrial Reference Frame, Earth rotation, and gravity field"
- SC1.1-WG3 on "Comparison and combination of atmospheric information derived from different space geodetic techniques"

All these working groups are very important as preparatory steps towards GGOS, the Global Geodetic Observing System, the only project of the IAG. They have the task to (1) compare and combine precise orbits, to (2) study the interactions between the three pillars of geodesy, namely the Earth's geometry, Earth rotation and the Earth's gravity field as well as the temporal variations of these three parts, and to (3) compare and combine the atmospheric information derived from different space geodetic techniques. Through the activities of the IERS considerable progress has been made towards a rigorous combination of site coordinates and Earth orientation parameters. The next step will be the inclusion of quasar coordinates, thus consistently linking the celestial and terrestrial reference frame. Not much attention has been put on the gravity field, be it the comparison and combination of global gravity field models or be it the combination of the gravity field parameters with geometry and Earth rotation or the combination of the space geodetic techniques onboard satellites. Here the Sub-Commission sees its most important tasks: to encourage research groups to work in this field in order to finally develop a consistent set of products ranging from the reference frames over Earth orientation parameters and the gravity field to information on the atmosphere.

That these topics of the Sub-Commission 1.1 are indeed important can be seen from the following exemplary activities:

- Completion of the interesting Ph.D. thesis of GERALDINE BOURDA at the Observatoire de Paris with the title "Rotation terrestre et variations du champ de gravité" (Earth Rotation and Gravity Field Variations).
- A project called GGOS-D (German part of GGOS) recently funded in Germany to consider the combination of site coordinates, Earth rotation parameters, and low-degree gravity field coefficients.

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– Various institutions developing software packages capable to process most of the space geodetic techniques on the observation level.

The objectives and activities of the three working groups of Sub-Commission 1.1 are summarized below.

Outlook

An important goal of Sub-Commission 1.1 will be the development of a much better understanding of the interactions between the parameters describing geometry, Earth rotation, and the gravity field, as well as the study of methods to validate the combination results, e.g., by comparing them with independent geophysical information. A session chaired by the chair of this Sub-Commission will take place at the EGU Meeting 2006, addressing exactly this issue. To the extent possible SC1.1 will also encourage research groups to develop new observation techniques connecting or complementing the existing set of space geodetic observations.

SC 1.1-WG 1: Comparison and combination of precise orbits derived from different space geodetic techniques (IAG Orbit Group)

Organisation and objectives

By the time of its establishment under the new IAG organizational structure, the Working Group 1 of Sub-Commission 1.1 was labeled *Comparison and combination of precise orbits derived from different space geodetic techniques*, with the addendum *joint with the IGS LEO WG*. Apart from the elaborate name and an arranged marriage to the IGS LEO Working Group, the WG 1.1.1 also had to somehow reconcile two earlier IAG commissions with similar names and objectives, namely the CSTG Sub-Commission on Precise Orbit Determination of Low Earth Orbiting Satellites, and the IAG Special Study Group 2.162 on Precise Orbits Using Multiple Space Techniques. The first task of WG 1.1.1 was therefore to solve an apparent identity crisis: without creating clarity about its organization and its objectives, a working group can hardly be expected to be effective.

To put things on the right track, the IAG WG 1.1.1 started by using the more pragmatic name "*IAG Orbit Group*", which covers the contents just as well. The use of the IAG acronym automatically implies state-of-art geodetic science, and makes most of the official name conveniently redundant. The full name will of course be maintained as a subtitle in all formal environments.

The connection to the IGS LEO Working Group is indeed natural, because this group has been active in the area of interest for some years, albeit with much more limited objectives related to IGS product improvements. Nonetheless, most findings of the IGS LEO WG can be incorporated in the work of the IAG Orbit Group. For practical reasons the two groups now have the same chair, and are bound to operate in close harmony in mutual interest. This does not mean that the IGS LEO WG has been dissolved into IAG WG 1.1.1, because the overlap between their objectives is not complete from either side.

The ambiguous past of the two precursor commissions has been eliminated in an equally straightforward way: the member lists of the earlier groups have been merged with each other as well as with that of IGS LEO. After removing duplications and outdated information, an initial member list for the IAG Orbit Group appeared. Reflecting this list against the objectives of the IAG Orbit Group led to the addition of several further members from areas of research that were not adequately covered by the initial list.

The Working Group objectives have meanwhile been formulated in a revised and extended Working Group Charter. Rather than iterating these objectives in this report, it may be sufficient to mention that the charter can be found on the main IAG Orbit Group website at *http://nngs.esoc.esa.de/iag_wg111.html*. The Working Group is in fact in the process of installing a *webring* that connects the websites of contributing centers, and at the same time keeps them more involved with the wider IAG activities.

Working Group activities

The IAG Orbit Group has started by making a survey of available satellite missions and tracking data, resulting in a set of core satellites that, with a few exceptions, share some essential properties that make them interesting to the IAG Orbit Group:

– Routine precise orbits are being produced by at least two independent centers. This ensures that good reference orbits are available over long periods of time, and provides adequate expertise with POD for these satellites.
– Each core satellite carries at least two independent tracking systems. This ensures that different datasets can be constrained to each other *via* the satellite orbits.
– The appearing orbital heights and inclinations are shared by at least two satellites.
– The quality of orbit determination is good enough to allow estimation of station coordinates within the orbit determination processes. This supports the analysis of systematic frame offsets between tracking data types on the basis of orbit comparisons.

The selection of core satellites does not in any way exclude analysis related to other satellite missions, but helps to focus the limited resources on the main issues. A careful assessment of centers with particular expertise in one or more of the core satellite missions allows for a practical distribution of tasks in achieving the analysis objectives of the IAG Orbit Group, without requesting any centre for unrealistic additional efforts outside their nominal activities.

With this minimum basis for analysis established, the principle long-term objective has been selected to arrive at a generic exchange format for orbit estimation

information at the level of normal equations. This can one day allow global multi-satellite orbit solutions, based on multiple data types and long arc lengths. Global orbit solutions based on normal equation recombination can guarantee their internal consistency, so that they form a tool to identify systematic offsets between data types or solution methods.

As a first step, the conditions to achieve this long-term objective are currently under investigation. So far there seem to be many practical problems, like exchange formats and proper definition of initial conditions and problem descriptions. The improvement of modeling standards – which has been set as a generic goal of the Working Group – may improve such matters. There are no fundamental objections against global recombination of normal matrix information, and many POD systems already support such solutions.

In summary: the IAG Orbit Group has been formally established, has a clear mission, and has started to work towards its goals. For more information, please refer to the central web page mentioned above, or to the websites of any of the participating centres.

SC 1.1-WG 2: Interaction and consistency between Terrestrial Reference Frame, Earth rotation, and gravity field

Organization and main research topics

The Working Group 2 of Sub-Commission 1.1 "Coordination of Space Techniques" has been established within the new IAG organizational structure as a joint WG together with Commission 2, Commission 3, and GGOS.

The main research topics are:

- Study the theoretical and practical interactions/relationships between parameters and models describing the terrestrial reference frame (TRF), Earth rotation, and the gravity field (e.g., low-degree spherical harmonic coefficients of the gravity field, etc.).
- Analyses of different space techniques concerning the sensitivity for the estimation of the relevant paramter types of these three fields and the correlations between them, and assess systematic biases between different techniques.
- Assess and investigate the consistency between space geodetic solutions (products) of geometry, Earth rotation and the gravity field.
- Investigate methods and techniques to combine these three fields by using different space geodetic techniques (VLBI, SLR, GNSS, DORIS) and by including Low Earth Orbiting (LEO) satellites (e.g., JASON-1, CHAMP, GRACE).

Interaction of WG2 with the IERS

Within the IERS, which is directly involved in two of the mentioned fields (geometry and Earth rotation), the interactions and the consistency between the relevant parameters and products (station positions and their temporal variations), Earth orientation parameters (EOPs), and the celestial reference frame (CRF) were studied. Up to now, the core IERS products (ITRF, ICRF, EOPs) are generated almost independently of each other, leading to inconsistencies betweem them. The IERS Combination Pilot Project has been initiated in 2004, aiming at more consistent, routinely generated IERS products.

Working Group activities

The key issue of this working group is the interaction of geometry and Earth rotation with the gravity field, which goes far beyond the mission of IERS. Towards this aim various activities have been initiated, which are among others:

- Analysis of the strengths (and weaknesses) of different space techniques concerning the estimation of parameters of Earth rotation (e.g., pole coordinates, length of day, etc.), of the gravity field (primarily the low-degree spherical harmonic coefficients) and of the terrestrial reference frame.
- Assessment and study of systematic biases between different techniques and products, which can be considered as a major error source for the parameter estimation.
- Investigations towards the development of an optimum methodology for the combined adjustment (e.g., modelling, spatial and temporal resolution for the parameter estimation, weighting of the techniques, realization of a consistent datum).
- Studies related to the connection of the different techniques, e.g. by terrestrial measurements ("local ties"), on the satellite level (e.g. LEOs) or by combining common parameters (EOPs or tropospheric parameters).

SC 1.1-WG 3: Comparison and combination of atmospheric information derived from different space geodetic techniques

Since the installation of Working Group 3 (WG3) in Nice 2004 at the 1st General Assembly of the European Geophysical Union and the selection of the chair on 26 May 2004, mainly preparatory tasks have been worked on.

At first, members for WG3 have been chosen who are experts in the fields that are addressed by this working group. In particular, special care has been taken to include persons who are representing the IGS Troposphere WG (P. FANG, M. ROTHACHER), IGS Ionosphere WG (M. HERNANDEZ-PAJARES) and IVS (R. HAAS, A. NIELL, TH. HOBIGER).

As a second step the Terms of Reference and the Program of Activities have been discussed by the members of WG3, and they were finally accepted in December 2004. The Terms of Reference, the list of members of WG3, and the Program of Activities were put on the webpage which has been installed by the chair of WG3. The address of the webpage is *http://www.hg.tuwien.ac.at/~sc1-1wg3*.

In the last months a questionnaire has been prepared which covers important topics and open questions that have to be addressed by the members of WG3. It is divided into 4 sections (neutral part of the atmosphere, ionosphere, local ties and CONT02), and each section is filled with questions and tasks that either have already been answered and are of importance to the group or that are still pending and have to be dealt with in future.

In case they have already been answered or addressed, references to literature will be collected and the most important results (with tables and figures) will be summarized in a special report.

On the other hand open tasks and questions will be clearly formulated and distributed to the members of WG3 or other scientists involved in this research field.

Sub-Commission 1.2
Global Reference Frames

Interim report submitted to the IAG Scientific Meeting, Cairns, 2005

C. BOUCHER[5]

Sub-Commission 1.2 is engaged in scientific research and practical aspects of the global reference frames. It investigates the requirements for the definition and realization of the terrestrial reference systems, addresses fundamental issues of multi-technique global geodetic observatories (local ties, site effects) and studies methods and approaches for the combined processing of heterogeneous observation data.

The work is done in close cooperation with the International Earth Rotation and Reference Systems Service (IERS), the other relevant IAG services (IGS, ILRS, IVS, IDS), and the IAG Project "Global Geodetic Observing System (GGOS)". Theoretical aspects (e.g., quality measures, relativistic modeling) are investigated in cooperation with the Inter-Commission Committee on Theory.

Objectives

The following research topics were adopted as fundamental objectives during this t period:

- Definition of the global terrestrial reference frame (origin, scale and orientation, time evolution, standards, conventions, models);
- Fundamentals of the realization of the global terrestrial reference frame (e.g., co-location problems: local ties, datum problems: coordinates origin, geocentre, time evolution: linear and non-linear velocities, time series approach, long-term consistency with EOPs and ICRF);
- Analysis of strengths, weaknesses and systematic differences (biases) of individual techniques (VLBI, SLR, GPS, DORIS) and their contribution to specific TRF parameters;
- Combination methodology of individual techniques' solutions and analysis of the underlying models, parameters datum definitions etc.;
- Definition of common standards and models for all techniques.
- Practical implementation of the concept of Global Geodetic Observatory

Major achievements for the 2003-2005 period.

There has been numerous activities during this period a detail reporting of which will be found in the final report of the sub-commission.

A major activity was done in the frame of *IERS*. Two joint WG were considered:

- *WG 1 on Datum Definition of Global Terrestrial Reference Frames*, for which the charter was defined, which provides a broad research program :
  - to clarify the different types of possible reference system definitions that might be important for different research fields (sea level, geoid, deformation, Earth- orientation, geocenter motion, ...) and for what measurements they are important.
  - to study the differences between these systems
  - to assess the uncertainties and quality of the various realizations, how they are affected by geophysical processes, and how the effect of these processes can be modelled in time and space to allow a refined realization of the frames
  - to assess how a stable and consistent reference frame can be realized over decades with the limited number of stations and observations.
  - to study datum definition in a relativistic framework, in particular in view of the CRS/TRS transformation
  - to study the impact of IAU non-rotating origin on TRS, if any.
- *WG 5 on Site Surveys and Colocations*, which is now fully in operation (see report below)

The actual implementation needed some hard work, especially to balance between specificities of an IAG commission and a service. The WG 1 is still not fully defined for several reasons, but clearly its research program is actively investigated. Other IERS bodies play a leading role in these issues, namely:

- the *ITRS Product Center*, that I chaired myself up to the end of 2004, followed by ZUHEIR ALTAMIMI, who submitted a report to the Sub-Commission (given below).
- The newly created *IERS Conventions Advisory Board* chaired by JIM RAY. Most of the WG 1 research topics

[5] Claude Boucher, President Sub-Commission 1.2 – Global Reference Frames, claude.boucher@espace.gouv.fr

are taken in consideration by this group, in which Geoff Blewitt (and his co-workers) is active.

– The *IERS Working Group on combination*, chaired by MARKUS ROTHACHER

Besides IERS, other issues are noticeable:

1. IAU has established a *Working Group on Nomenclature for Fundamental Astronomy (NFA)* chaired by NICOLE CAPITAINE. I took part to their work in order to try to ensure a complete and consistent terminology concerning TRS. One of the significant new terminology is to adopt the term of *Geocentric Terrestrial Reference System (GTRS)* defined as « a system of geocentric space-time coordinates within the framework of General Relativity., co-rotating with the Earth and related to the GCRS by a spatial rotation which takes into account the Earth orientation parameters. It replaces the previously defined CTRS » ITRS and ITRF are also explicitly included into the NFA terminology list.
2. TRS/TRF issues has also been considered in several *GNSS activities*:
   – activities of the IAG/IGS Working group on GNSS, chaired by Robert Weber, with several meetings jointly with the ESA GalileoSat project team
   – formal recognition of ITRS/ITRF as common frame for both GPS and Galileo, as stated in the US-EU agreement
   – work in the Galileo project related to the implementation of the GTRF, Galileo realization of the ITRS. A project called GGSP has been approved and implies several IAG members from Europe.
   – establishment within United Nations of an International Committee on GNSS

Contributing Reports

IAG SC1.2 Working Groups

SC1.2-WG Datum Definition of Global Terrestrial Reference Frames (jointly with IERS and ICCT); Chairman: Geoff Blewitt (USA)

Objectives

The objectives of IERS WG1 are:

– to assist the IERS by providing recommendations on datum conventions for future realizations of ITRS.
– to assist the ICCT in drafting conventional definitions of technical terms that refer to the various possible components of GTRFs
– to identify the needs of potential user groups of GTRFs and address issues of datum definition that might benefit those groups.
– to conduct research and periodically update a collaborative working document on the current status of WG1 with respect to datum definition issues, clearly identifying which issues are resolved by common consensus, which issues remain a topic of debate or further research, which issues are speculative, and which issues remain relatively unexplored.
– to compile a short summary document that references all recent published journal articles (not just those of the WG) relevant to datum definition of GTRFs, including a summary of the findings, conclusions, and significance of each paper, and to keep such a document updated as a reference document to assist research and informed discussion.

Research Agenda

The research agenda of IERS WG1 will include:

– to clarify the different types of possible reference system definitions that might be important for different research fields (sea level, geoid, deformation, Earth orientation, geocenter motion, ...) and for what measurements they are important.
– to study the differences between these systems
– to assess the uncertainties and quality of the various realizations, how they are affected by geophysical processes, and how the effect of these processes can be modelled in time and space to allow a refined realization of the frames
– to assess how a stable and consistent reference frame can be realized over decades with the limited number of stations and observations.
– to study datum definition in a relativistic framework, in particular in view of the CRS/TRS transformation
– to study the impact of IAU non-rotating origin on TRS, if any.

SC1.2-WG ITRS/ITRF propagation to national and international organizations; Chairman: CLAUDE BOUCHER (France)

This WG is starting its work. The topic is investigated along to several tracks

– in the general frame of GGOS
– in connection with GNSS activities and specifically the new UN group

More detailed informations will be released soon.

SC1.2-WG Site Surveys and Colocations (jointly with IERS); Chairman: JOHN DAWSON (Australia)

IAG Sub-Commission 1.2 – Working Group (WG) on Site Survey and Co-location (*jointly with the IERS Working Group on Site Survey and Co-location, IERS WG 2*) was established in February 2004. The major goals and objectives of the WG are:

– Site Survey and Standards
   – Develop, test, compare and set standards on site survey methods, including observational techniques, network design, classical adjustment, geometrical modelling and/or direct measurement techniques for invariant point determination, reference frame alignment, software implementation and SINEX generation. This will include the

development of a standards document for undertaking site surveys;
  - Preparation and coordination of a Pilot Project (PP) on site survey. The PP will include a test campaign(s) to be used for the comparison of different approaches to local tie surveys addressing each of the technical elements;
  - Develop standards for the documentation of site surveys, including survey report content and format; and
  - Suggest a pool of expertise to provide advice to survey teams, as required, on standards for site surveys.
- Coordination
  - Liaise with local and international survey teams undertaking site surveys at important co-location sites;
  - Liaise with the technique combination groups to ensure WG site survey products meet user requirements;
  - Coordinate as required and make recommendations to observatories as to survey scheduling and re-survey frequency;
  - Develop and distribute software tools to the community to assist in the generation of site survey products, including SINEX generation software; and
  - Provide a forum to raise the profile of site survey as a critically important independent geodetic technique.
- Site Survey Research
  - Investigate new site survey methodologies, including observational techniques, observational modelling, invariant point definition, geometrical modelling and/or direct measurement techniques for invariant point determination, reference frame alignment and structural deformation analysis.
- Future Planning
  - The WG will make recommendations and prepare for the future in respect to the ongoing site survey needs of the community and how these needs will be met in the long term (to address issues outside of the scope of this WG).

Working Group Meetings

Working group meetings to date include:

- April 2004, EGU in Nice;
- April 2005, EGU in Vienna; and
- August 2005 IAG General Assembly in Cairns (*planned*).

As a result of these meeting WG members have agreed:

- To undertake a Pilot Project (PP) in site survey and co-location;
- To draft survey standards document is to be revised in parallel with the WG2 pilot project activities. This document will provide more details and explanatory content and include a full site survey report example – it will be useful to those new to site surveys at co-located observatories;
- To draft a brief explanation for the need of precise terrestrial ties (to be included in site survey documentation);
- To establish a Working Group web site. The web site will initially provide links to the template survey documents and example survey reports;
- To collate all existing site survey reports for the WG2 web site (or provide web links to them);
- To clearly define output products including a detailed explanation of the SINEX requirements;
- To address the issue of VLBI antenna deformation including its observation and to quantify its impact on VLBI results; and
- To attempt to quantify the impact of antenna domes and other GPS antenna modelling issues at co-located observatories.

Working Group Web Site

The IERS has established a web site at *http://www.iers.org/iers/about/wg/wg2*. The web site provides links to relevant Working Group documents, including the draft survey report format document. It is the Working Groups intention to use the web site as a forum for discussions related to local tie survey.

Site Survey and Co-location Pilot Project (SSCPP)

The dissemination of a Call for Participation in the Site Survey and Co-location Pilot Project (SSCPP) was made in November, 2004. A review of the SSCPP activities was undertaken in April 2005 at the EGU meeting in Vienna. The SSCPP will broadly address the following technical issues: observational techniques; survey network design and monumentation; classical geodetic adjustment; indirect geometrical modelling and/or direct measurement techniques for invariant point determination; reference point definition and access; local to global reference frame alignment; structural and network deformation modelling; and SINEX generation.

Four groups have responded to the Call for Participation in the SSCPP, namely:

- Geoscience Australia;
- Natural Resources Canada;
- IRA - Istituto Nazionale di Astrofisica and University of Bologna, Italy; and
- Telespazio, Italy.

IERS ITRF Product Center

This report summarizes the activities of the IERS ITRS Product Center during the period 2003-2004.

The main activities of the ITRS Product Center during 2003-2004 are:

- Surveys of co-location sites

– Relation with IGS
– Contribution to the IERS Workshop on site surveys and Co-locations, Matera, Italy, October, 2003
– Maintenance of the IERS network

Surveys of Co-location Sites

The Institut Géographique National participated on complete surveys of the following co-location sites:

– Hartebeesthoek, South Africa, comprising the 4 techniques: VLBI, SLR, GPS and DORIS
– Shanghai, China, comprising 3 techniques: VLBI, SLR and GPS
– Wuhan, China, comprising 3 techniques: VLBI, SLR and GPS

For each one of the above 3 sites, 3 IGN surveyors were participated in the survey. The total cost of these 3 surveys is around 100 K-Euros.

Relation With the IGS

The ITRS PC contributes to specifications for ITRF densification, initiated by the IGS for its part (regional solutions of weekly permanent GPS station positions). Work is still in progress for evaluation/comparison of the different proposed densification approaches.

Maintenance of the IERS network

This activity includes update of the IERS network database in terms of new sites and stations, assignment of DOMES numbers, local ties, availability of IERS network information and ITRF products on the web and ftp server, as well as assisting the ITRF users for a proper use of ITRF products.

Moreover, a new ITRS WEB site was developed and it is now open to the ITRF users: ***http://itrf.lareg.ensg.fr*** This new WEB site allows the users to interactively:

– retrieve site information
– on-line request DOMES number assignment
– select positions (at any epoch) and velocities in any ITRF version for any sub-set of stations, in SINEX or/and table list.

Contribution to the IERS Workshop on site surveys and Co-locations, Matera, Italy

The ITRS PC contributed to the IERS Workshop held in Matera on October 2003. A Position Paper (Altamimi et al., 2003) was prepared by the ITRS PC with contribution from the technique services. The Position paper was extensively discussed during its devoted session and focussed on Co-location sites and their importance for the ITRF, and in particular:

– Definition of a co-location site in terms of accuracy and distance between co-located stations
– Requirements of the IERS combination centers concerning local ties: SINEX files, accuracy
– Current status of local ties in co-location sites:
  – distribution of currently operating stations of the 4 techniques
  – quality of the currently available local ties
  – list of missing local ties
  – priority list of problematic sites

ITRF Combination and Research Center at Institut Géographique National (IGN)

The IGN ITRF Combination and Research Center concentrates its activity on software enhancement, new combination strategy development and regular analysis of Global TRF solutions as well as time series (weekly/monthly) solutions of TRF and EOP. The experience gained in time series analysis leads to the conclusion that the upcoming ITRF solution should combine TRF and EOPs, based on times series (weekly or monthly) of TRF and EOP of the individual techniques. It is preferable to use weekly solutions in order to better monitor station non linear motions. The EOP parameters resulted from this combination would be used then to recalibrate the current IERS C04 series, so that ITRF and IERS EOP consistency will be ensured.

Publications

ALTAMIMI Z., SILLARD P., BOUCHER C., *The Impact of a No-Net-Rotation Condition on ITRF2000*, GRL, 30(2), 1064, doi:10.1029/2002GL016279, 2003.

ALTAMIMI Z., MOORE A., NOTHNAGEL A., HUSSON V., FAGARD H., *ITRF and Collocation Sites*, IERS Workshop on site co-locations, Matera, Italy, 2003.

ALTAMIMI Z., BOUCHER C., WILLIS P., *Terrestrial Reference Frame Requirements within GGOS Perspective*, Accepted for publication, J. Geodynamics, 2004.

ALTAMIMI Z., C. BOUCHER, GAMBIS D., 2005, *Long-term Stability of the Terrestrial Reference Frame*, Adv. Space Res., In press.

Sub-Commission 1.3
Regional Reference Frames

Mid-Term Report for the Period 2003-2005

Z. ALTAMIMI[6]

President: Zuheir Altamimi (France)

Regional Sub-commissions:

- SC1.3a Europe (EUREF)
  Chair: JOÃO AGRIA TORRES (Portugal)
- SC1.3b South and Central America (SIRGAS)
  Chair : LUIZ PAULO FORTES (Brazil)
- SC1.3c North America (NAREF)
  Co-Chairs: MICHAEL CRAYMER (Canada), RICHARD SNAY (USA)
- SC1.3d Africa (AFREF)
  Chair: RICHARD WONNACOTT
- SC1.3e South-East Asia and Pacific
  Chair: JOHN MANNING (Australia)
- SC1.3f Antarctica (SCAR)
  Chair: REINHARD DIETRICH (Germany)

This mid report gathers the contributions of the above regional sub-commissions covering the period 2003-2005. As stated in the Terms of Reference, IAG Sub-commission SC1.3 is concerned with definitions and realizations of regional reference frames and their connection to (and the densification of) the global International Terrestrial Reference Frame (ITRF). It offers a home for service-like activities addressing theoretical and technical key common issues of interest to regional organisations.

The main Sub-Commission 1.3 objectives are the following:

- Develop specifications for the definition and realization of regional reference frames, including vertical datums, with full interaction with the Inter-Commission Project ICP 1.2 on Vertical Reference Frames.
- Develop and promote operation of GPS permanent stations, in connection with IGS whenever appropriate, to be the basis for the long-term maintenance of regional reference frames.
- Coordinate activities of the regional subcommissions focusing on exchange and share of competences and results.
- Encourage and stimulate the emerging development of the AFREF project with close cooperation with IGS.
- Encourage and assist, within each regional Sub-Commission, countries to re-define and modernize their national geodetic systems, compatible with the ITRF.

The reports of the individual Sub-commissions are presented in the sequel.

[6] Zuheir Altamimi, President IAG Sub-Commission 1.3 – Regional Reference Frames, altamimi@ensg.ign.fr

Sub-Commission 1.3a
Reference Frame for Europe (EUREF)

– Status Report for the Period 2003-2005 –

J. AGRIA TORRES, Z. ALTAMIMI, H. HORNIK[7]

1. Introduction

The EUREF Sub-Commission was constituted at the IUGG *(International Union of Geodesy and Geophysics)* General Assembly held in Vancouver, 1987, under the umbrella of Commission X - Global and Regional Geodetic Networks of Section 1 – Positioning. As a result of the implementation of the new IAG (*International Association of Geodesy*) structure at the IUGG General Assembly held in Sapporo, 2003, EUREF was integrated within Sub-Commission 1.3, Regional Reference Frames, under Commission 1 – Reference Frames, with the designation *Sub-Commission 1.3a, Reference Frame Sub-Commission for Europe (EUREF)*. The present report covers the activities carried out in the period August 2003 – March 2005 and is focussed on the following topics:

- Overview and organisation
- EUREF Permanent Network (EPN)
- Improvements and extensions of ETRS89
- European Vertical Reference System (EVRS)
- Symposia
- Outreach and external liaisons
- Publications

2. Overview and organisation

At the annual Symposium held in Bratislava (June 2004), the Terms of Reference (ToR) of EUREF were adopted. The ToR contain the description of EUREF, its objectives, activities, organization and the rules for membership according to the general rules expressed in the Statutes and By-laws of IUGG and, consequently, of IAG. The complete text can be found in *http://www.euref-iag.net/html/Overview_of_EUREF_Terms_of_reference.html*.

The long-term objective of EUREF is the definition, realization and maintenance of the European Reference Systems. All the work is done in close cooperation with the pertinent IAG components and EuroGeographics, the consortium of the European NMCA (*National Mapping and Cadastre Agencies*).

The forum where the activities are discussed and decisions are taken is the annual symposium. A fundamental element in the structure is the EUREF Technical Working Group (TWG), with the task to govern current activities, such as:

- to coordinate and develop the EPN;
- to evaluate and classify results of GNSS campaigns as EUREF densification or extension;
- to coordinate the actions for the realisation of a European Height System;
- to identify the relevant actions for the continuation and development of EUREF, with respect to innovation and the changing user needs;
- to set up the working groups to run the projects defined by the plenary;
- to prepare the recommendations for the EUREF plenary.

The TWG is composed by 17 members. It met 5 times in the period covered by the report. Information about TWG membership, agenda of the meetings and some contributions are available at *http://www.euref-iag.net/html/twg.html*.

3. EUREF Permanent Network (EPN)

During the period between June 2003 and March 2005, about 30 continuously operating GPS stations were integrated into the EUREF Permanent Network (EPN) bringing the total number of EPN stations to more than 160.

The number of stations providing hourly data has increased from 58% to 70%. Half of the EPN stations also submits data to the International GNSS Service. 16 of these stations provide GLONASS data and 11 contribute to the TIGA (Tide Gauge Benchmark monitoring) Pilot Project of the IGS.

The "Procedure for becoming an EPN station" has been completely revised. The new procedure is effective since Dec. 2 2003, and can be downloaded via the EPN Central Bureau (CB) web site *http://www.epncb.oma.be/*. The most important change concerns the new requirement to submit a commitment letter guaranteeing that

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the station will be operated following EPN guidelines for a minimal duration of 5 years.

In addition, the 'Guidelines for EPN Stations and Operational Centres' have also been reviewed. The new guidelines were issued mainly in order to improve the data flow within the EPN and to guarantee the availability of the EPN data at the regional (European) level. This will be achieved by making all EPN data available to two regional data centres: BKG (Federal Office of Cartography and Geodesy, Germany) and OLG (Space Research Institute, Department of Satellite Geodesy Austrian Academy of Sciences, Austria).

The web site of the CB has added some new web pages showing the results of the monitoring of the long-term quality of the GPS observations. These pages have proven to be a valuable tool for indicating tracking changes. The web pages contain:

- a yearly plot displaying the long-term tracking performance based on the daily percentage of GPS observations (refreshed daily);
- yearly and 45-day average plots displaying the number of observations and cycle slips, and the RMS due to the multipath on the observed L1 and L2 (refreshed daily);
- monthly snapshots of the satellite tracking (one plot each month).

As a complement to the "Station latency reports" distributed monthly through EUREF mail, the EPN CB web site is now also displaying in graphical form the results of the monitoring of the delays of the hourly data files.

On September 17-18, 2003, the Fourth EUREF Analysis Workshop was held in Graz, Austria. The minutes of this meeting are available at *http://www.epncb.oma.be/_newsmails/workshops/EPNLACWS_2003/minutes.html*.

Following the request to contribute to the computation of ITRF2004 as a regional densification, the relevant information is being prepared by the EPN CB and Analysis Centers in order to fulfil the requirements.

The EPN runs two special projects using the installed infra-structure: 'Monitoring of the EPN to produce coordinate time series suitable for geokinematics' and 'Generation of an EUREF-troposphere product'.

The goal of the first one is to support the use of the EPN products for geokinematics The activity involves the time series monitoring and correction, preparations for kinematic analysis, quality assessment and monitoring of site configuration and identification of stations with unreliable behaviour.

The goal of the second one is to derive tropospheric parameters as part of the estimation. The basic task within this activity is to produce a combined troposphere solution with input from the individual troposphere solutions of all Analysis Centers, which contribute to the coordinate solution.

Information about these projects and further information about the EPN can be found at *http://www.epncb.oma.be*.

Another project based on the EPN structure is EUREF-IP (*Internet Protocol*), with the goal to disseminate GNSS data using Internet. Under this project the software Ntrip (*Networked Transport of RTCM via Internet Protocol*) was developed. The Ntrip protocol as been included in the standards of RTCM104 (*Radio Technical Committee for Maritime Services*). EUREF-IP established a specific IP address for its Ntrip Broadcaster service at *www.euref-ip.net*.

The total number of known Ntrip Broadcasters is approximately 25. The total number of reference stations in the world available via Ntrip technology amounts to approximately 650.

The current EUREF-IP efforts focus on developing a real-time Ntrip Monitoring/Notification system to reach and maintain a professional level of service availability, develop Ntrip towards full HTTP compatibility and introduce UPD as an additional option for IP multicast, and encourage more EPN station operators to participate in EUREF-IP with real-time raw or RTK data (in addition to differential corrections).

4. Improvements and extensions of ETRS89

The ETRS89 (*European Terrestrial Reference System*) is being adopted as the official system for geo-referencing by several organisations in Europe and most of the European countries.

The establishment and maintenance of the European Reference Frame is achieved by a network of geodetic reference sites determined at national and multi-national level by GPS campaigns. In the last 2 years, the following campaigns have been validated by the TWG and accepted as class B standard (about 1 cm at the epoch of observation):

- EUREF-Slovakia-2001 campaign in Slovakia;
- EUREF-Pol-2001 campaign in Poland;
- EUREF-Austria-2002 campaign in Austria;
- EUREF-Hungary-2002 campaign in Hungary;
- EUREF-Armenia-2002 campaign in Armenia;
- EUREF-GB-2001 (re-computation of the campaign in Great Britain).

The majority of these recent campaigns had the purpose to improve the accuracy of the former national reference frames expressed in ETRS89, as well as the densification of the existing network and/or replacement of old markers by GPS permanent stations.

Detailed information about the EUREF campaigns can be found at *http://www.geo.tudelft.nl/mgp/euref/*.

For the long-term maintenance of the European Reference Frame, the project European Velocity Field (EVF) aiming at the establishment of a dense velocity field model in Europe was started.

5. European Vertical Reference System (EVRS)

The definition of the **European Vertical Reference System 2000 (EVRS)**, including a European Vertical Datum and related parameters as realisation, is being revised, considering that the progress in global gravity models will soon make possible the realization of EVRS as a genuine World Height System.

The UELN (*Unified European Levelling Network*) is being densified and extended with new levelling observations. Contacts are being established with Russia for the inclusion of new levelling data in the Baltic area. The existence of repeated observations in some areas presents the chance to take a first step on the way to a geokinematic height network.

The projects EUVN_DA (*European Vertical GPS Reference Network Densification Action*) and ECGN (*European Combined Geodetic Network*) are under development.

Further information about the European Vertical Reference System can be found at *http://crs.bkg.bund.de/evrs/*.

6. Symposia

Following the symposium held in Toledo in June 2003, one more symposium took place in Bratislava (Slovakia) in June 2004. The 2005 symposium that will take place in Vienna (Austria) in June 2005 is in preparation.

These meetings are usually attended by more then 100 participants from more than 30 countries in Europe. The web portal contains the contributions presented at the symposia, as well as the full set of resolutions of all the EUREF symposia since 1990 (*http://www.euref-iag.net/html/symposia.html*).

7. Outreach and external liaisons

The old web portal address was replaced by the new one *http://www.euref-iag.net*. This portal links to all the EUREF structures and projects; its main contents are information about the EUREF structure and documentation related with the symposia and TWG meetings.

The liaison with EuroGeographics, the consortium of the National Mapping and Cadastre Agencies (NMCA) in Europe, continues through its Expert Group on Geodesy (ExGG). This liaison is concretized by the support of EuroGeographics to the organization of EUREF symposia, where a special session of ExGG is usually included.

Furthermore, contacts are being established in order to find possible ways of co-operation with the organizations responsible for EGNOS and GALILEO, as well as with EUMETNET for the co-operation between the meteorological and geodetic communities.

8. Publications

The proceedings of the EUREF symposia are the main source of information concerning the EUREF activities. In the period covered by this report were published:

- EUREF Publication No. 12, 2003
  - Report on the Symposium of the IAG Sub-commission for Europe (EUREF) held in Ponta Delgada, 5 – 8 June 2002.
  - Reports of the EUREF Technical Working Group.

  Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 29, Frankfurt am Main; ISBN 3-89888- 873-8, 425 pages.
- EUREF Publication No. 13, 2004
  - Report on the Symposium of the IAG Sub-commission for Europe (EUREF) held in Toledo, 4 – 7 June 2003.
  - Reports of the EUREF Technical Working Group

  Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 33, Frankfurt am Main; ISBN 3-89888- 885-1, 451 pages.

The proceedings of the symposium held in Bratislava, 2004, are under preparation.

For enabling the early access to the contributions presented to symposia and TWG meetings for the interested geodetic community, the original presentations are also pre-published in the EUREF homepage.

Sub-Commission 1.3b
Reference Frame for South and Central America (SIRGAS)

Report July 2003 – April 2005

L. P. FORTES[8]

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Vice-Chair: E. LAURÍA (Argentina); elauriaigm.gov.ar

SC1.3b-WG1: Reference Frame – C. BRUNINI (Argentina); mgende@fcalgp.fcaglp.edu.ar

SC1.3b-WG2: Geocentric Datum – A. HERNANDEZ (México); anavarro@dgg.inegi.gob.mx

SC1.3b-WG3: Vertical Datum – L. SÁNCHEZ (Colombia); lsanchez@igac.gov.co / sanchez@dgfi.badw.de

Sub-commission 1.3b (South and Central America) encompasses the activities developed by the "Geocentric Reference System for the Americas" project (SIRGAS). As such, it is concerned with the definition and realization of a unified reference frame for South and Central America, consistent with ITRF, besides promoting the definition and establishment of a unique vertical reference system in this region.

After July 2003, when the term of the elected project president and vice-president was initiated, they contacted the countries and institutions represented in the SIRGAS executive committee (10 – out of a total of 13 - from South America, two from North America – Canada and Mexico - and three from the sponsoring entities – International Association of Geodesy, Pan-American Institute of Geography and History, and National Geospatial-Intelligence Agency) in order to select and/or confirm the names of the Working Groups (WG) presidents. Based on this contact, CLAUDIO BRUNINI, from the University of La Plata, Argentina, was appointed to the position of president of the Working Group 1 "Reference Frame" (SC1.3b-WG1), ANTONIO HERNANDEZ, from the National Institute of Statistics, Geography and Informatics (INEGI), Mexico, was appointed as president of the Working Group 2 "Geocentric Datum" (SC1.3b-WG2), whereas LAURA SANCHEZ was confirmed as president of the Working Group 3 "Vertical Datum" (SC1.3b-WG3). The SIRGAS executive committee would like to thank the former WG1 and WG2 presidents, respectively MELVIN HOYER, from the University of Zulia, Venezuela, and RODRIGO BARRIGA, from the Military Geographic Institute, Chile, for their contribution and dedication to the project.

Concerning the SIRGAS 2000 GPS campaign, the official coordinates of 184 GPS stations covering the entire Americas, referred to ITRF2000, epoch 2000.4, along with their covariance information, had been released in February 2003. A velocity field for South America was released in November 2003, after combining least-squares collocation and finite elements solutions (DREWES and HEIDBACH, 2003). All information is available at the project website (*http://www.ibge.gov.br/sirgas*). It must be mentioned the work that has been carried out by DGFI, Germany, as the IGS Regional Network Associate Analysis Center RNAAC-SIR for SIRGAS in terms of computing weekly coordinate solutions for the continuous GPS stations in the region as well as velocity values for those stations.

During the last project meeting, held at the INEGI facilities, in Aguascalientes, Mexico, in December 2004, the status of each working group activities was discussed. Representatives from El Salvador and Costa Rica attended the meeting, as an effort to involve countries of that region in SIRGAS. It terms of SC1.3b-WG1, it was decided to establish regional processing centers in the region to carry out a task analogous to that currently performed by the IGS RNACC-SIR. Preliminarily, University of La Plata, Argentina, the Brazilian Institute of Geography and Statistics (IBGE), Brazil, and INEGI, Mexico, were identified as potential candidates to carry out this task. It was also decided to coordinate efforts towards starting a pilot project on ionospheric mapping in the continent.

Regarding SC1.3b-WG2, the status of the connection of the national geodetic networks to SIRGAS was surveyed amongst the representatives attending the meeting (Table 1). This table is going to be complemented with information related to the remaining countries of the region. Recommendations for integrating new geodetic stations of each country to SIRGAS frame have also been issued during the meeting.

Concerning SC1.3b-WG3, the status of the ongoing efforts for establishing a unified vertical reference system in the continent has been presented. In terms of computing physical heights, every country continued with the compilation of the spirit leveling and gravity data in digital format in order to enable a unique continental adjustment of geopotential numbers. In addition, the connection of the first order leveling networks between neighboring countries was almost completed. For the estimation of the unified height reference surface, there were considerable improvements in

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the combination of terrestrial gravity data with those coming from the new satellite missions in order to obtain a highly precise (quasi)geoid model. In this sense, the computation of W_0 has been evaluated using the Mean Sea Surface (MSS) Model CLS01 in combination with different gravity models, such as EGM96, TEG4 and GMM01. As a complement for the connection of the classical height systems with the new vertical system, several tide gauges in South America are being observed continuously or periodically with GPS. The variations of the ellipsoidal heights are compared with the variations coming from the tide gauge registrations to determine the actual sea surface during the definition period of the classical height systems. For details about discussions and presentations during this last SIRGAS meeting, please see the SIRGAS Newsletter #8, available at the project webpage. The project president and vice-president would like to thank the International Association of Geodesy and the Pan-American Institute of Geography and History, for sponsoring the meeting, and INEGI, for kindly hosting it.

Reference

Drewes, H; Heidbach, O. (2003): *Deformation of the South American crust estimated from finite element and collocation methods*. IAG Symposia (128), Springer (In press).

Table 1. Current status of SIRGAS adoption in South and Central America

Country	Geodetic System	Datum	Reference Epoch	Is going to adopt SIRGAS?
Argentina	POSGAR 94	WGS84	19938	Yes
Brazil	SIRGAS2000	SIRGAS2000	20004	Adopted
Chile	SIRGA/CHILE	SIRGAS2000	20020	Adopted
Colombia	MAGNA/SIRGAS	SIRGAS95	19954	Adopted
Costa Rica	NAD27			Yes
El Salvador	NAD27/ITRF97		19989	Yes
México	ITRF2000	ITRF2000	2004.0	Adopted
Uruguai	SIRGAS ROU 98	SIRGAS95	19954	Adopted
Venezuela	SIRGAS/REGVEN	SIRGAS95	19954	Adopted

Sub-Commission 1.3c
Reference Frame for North America (NAREF)

Report July 2003 – April 2005

M. CRAYMER, R. SNAY[9]

Chair : MICHAEL CRAYMER (Canada), RICHARD SNAY (USA)

This sub-commission has 3 active working groups. The following summarizes the recent activities of each.

SC1.3c-WG1: North American Reference Frame (NAREF)

The objective of this WG is to densify the ITRF and IGS global networks in the North American region. Work continued on the production of weekly GPS coordinate solutions for over 400 continuously operating ITRF/IGS densification stations in North America. These solutions are a combination of five different regional solutions using three different GPS processing software. The combined solutions are being contributed to the IGS, together with weekly processing reports, with a latency of approximately 4 weeks. Most recent improvements since 2003 have been the incorporation of a weekly regional solution for over 350 US CORS stations using the PAGES processing software. The Plate Boundary Observatory solution from Scripps was also expanded from 50 to 75 points. In the past year, a cumulative solution has been computed based on the weekly combinations to provide velocity estimates for all sites with a data span of at least one year. This solution is being combined with a ten year solution computed by NGS for approximately 200 of the better CORS sites and will be contributed to the densification of the ITRF2004.

SC1.3c-WG2: Stable North American Reference Frame (SNARF)

Significant efforts began under this newly created joint working group with UNAVCO, Inc. The goal is to define a plate-fixed regional reference frame for North America stable at the mm-level to provide a standardized and consistent reference frame in support of geodynamics studies throughout the continent. Three workshops to define the reference frame been held in 2004 and 2005. The frame is being defined via a no net rotation condition for a set of stable frame sites with respect to ITRF2004. The first version of the reference frame will be delivered at the UNAVCO Annual Meeting in June 2005. This version will include coordinates and velocities (with uncertainties) for all frame sites, a model for glacial isostatic adjustment, and rotation rates with respect to ITRF2000. Further versions will follow as the reference frame is improved. More information about the working group is available from the UNAVCO web site (follow the links at <*http://www.naref.org/*>).

SC1.3c-WG3: Reference Frame Transformations

This sub-commission is concerned with the definition and maintenance of the relationships between international and North American reference frames/datums. This primarily involves maintaining the officially adopted (in Canada and the U.S.) relationship between ITRF and NAD83, the later which is now defined in terms of a fourteen parameter transformation from ITRF. There has been no recent activity since the updating of the transformation between NAD83 and ITRF2000. However, it was agreed in 2002 to update the reference epoch of published NAD83 coordinates from 1997.0 to 2002.0 for continuously operating GPS stations in both Canada and the U.S. to avoid the accumulation of small bias in the NNR-NUVEL1A plate motion model used to define the motion of NAD83 in ITRF. In addition, the transformation between the new SNARF reference frame and ITRF2000 will be made public as part of the SNARF frame.

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Sub-Commission 1.3d
Reference Frame for Africa

Report July 2003 – April 2005

R. WONNACOTT[10]

Introduction

The activities of IAG Sub-Commission 1.3d (Africa) are focused on the unification of a geodetic reference frame for Africa in a project commonly known as AFREF (Africa Reference Framework). The outcome of the project, which includes both the horizontal and vertical components of the reference frame, will be a uniform reference frame consistent with the International Terrestrial Reference Frame (ITRF) and will form the basis of all continental, regional and national planning and development projects in support of the ideals of the programmes of NEPAD (New Partnership for Africa's Development). The project faces numerous logistic challenges in that there are over 50 countries in Africa each with its own reference frame and, in some cases, two or more reference frames in one country which makes the task even more challenging.

Objectives of AFREF

A fundamental principle of the project is that it is an African initiative and will be designed, managed and executed by African countries with the scientific and technical assistance of the International community. The objectives of the AFREF project have been defined as:

- Define the continental reference system of Africa. Establish and maintain a unified geodetic reference network as the fundamental basis for the national 3-d reference networks fully consistent and homogeneous with the global reference frame of the ITRF;
- Realize a unified vertical datum and support efforts to establish a precise African geoid, in concert with the African Geoid project activities;
- Establish continuous, permanent GPS stations such that each nation or each user has free access to, and is at most 1000 km from, such stations;
- Provide a sustainable development environment for technology transfer, so that these activities will enhance the national networks, and numerous applications, with readily available technology;
- Understand the necessary geodetic requirements of participating national and international agencies; and
- Assist in establishing in-country expertise for implementation, operations, processing and analyses of modern geodetic techniques, primarily GPS.

Progress

Most of the activities to date have been of an organizational nature to establish a steering committee and garner support for the project from the International geodetic and surveying communities, Non-Governmental Organizations (NGO's) such as UN Office for Outer Space Affairs (UNOOSA) and the UN Economic Commission for Africa's Committee on Development Information - Geo-information Subcommittee (CODI-Geo).

In August 2004, the UNECA CODI accepted the objectives of the AFREF project and established a Working Group on AFREF with the structures of the CODI-Geo sub-committee. At the same time an AFREF Steering Committee was established with representation from the IAG Sub-Commission 1.3d. The broader structure and provisional terms of reference of the Steering Committee were proposed at a workshop hosted by the African Association Sensing of the Environment (AARSE) held in Nairobi in October 2004. The UNOOSA hosted a Workshop of GNSS experts in November 2004 at which the International Federation of Surveyors (FIG) invited the AFREF Steering Committee to hold business and information meetings during the FIG/GSDI Working Week to be held in Cairo between 16 and 21 April 2005. Besides the support provided by FIG, the UNOOSA has also provided some travel support for these meetings. It is planned to review the Steering Committee structure and solicit further support for the project within the International community as well as appropriate equipment manufacturers and vendors. It is further planned to propose that a technical workshop be held in Cape Town late in 2005 or early in 2006 that will bring together geodesists from African countries who will be directly involved in the project and international experts to guide and train participants.

Conclusion

The project is showing slow but steady progress. Once the organizational issues and structures have been resolved and supporting organizations officially commit to the project, the current Steering Committee is confidant that the first phase of the project to establish a network of permanent GPS base stations throughout Africa will gain momentum.

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Sub-Commission 1.3f
Reference Frame for Antarctica

Mid-Term Report – April 2005

R. DIETRICH[11]

1. Observation Campaigns

The SCAR GPS Campaigns 2004 and 2005 were carried out in the austral summers 2004 and 2005. All together, the data of 36 sites are now collected in the SCAR GPS database beginning with the year 1995.

2. Data Analysis

The new as well as the existing data were reanalysed with the Bernese Software, version 5.0.

First results were presented at the XXVIII. SCAR Meeting in Bremen/Germany in July 2004.

For the ITRF2004 a densification solution for Antarctica was determined and submitted to the IERS Central Bureau at February 28th, 2005. The solution contains 31 IGS sites and 27 SCAR Campaign sites. The station distribution is shown in Fig.1.

3. Meetings

During the XXVIII SCAR Meeting in Bremen the members of SC1.3f met and discussed the working plan of the SCAR Group of Experts on Geodetic Infrastructure in Antarctica (GIANT) was discussed and fixed for the years 2004-2006. R. Dietrich (Germany) was elected as the new chairman of GIANT. The members of GIANT represent the SC1.3f.

4. Plans for the International Polar Year 2007/2008

The International Polar Year 2007/2008, which follows the 1st International Polar Year after 125 years and the International Geophysical Year after 50 years will be an intensive period of scientific activities in the polar regions. It is organized jointly by ICSU and WMO, and a broad range of coordinated, international projects are in preparation.

The SC1.3f will actively participate in the frame of the project POLENET (Polar Earth Observing Network).

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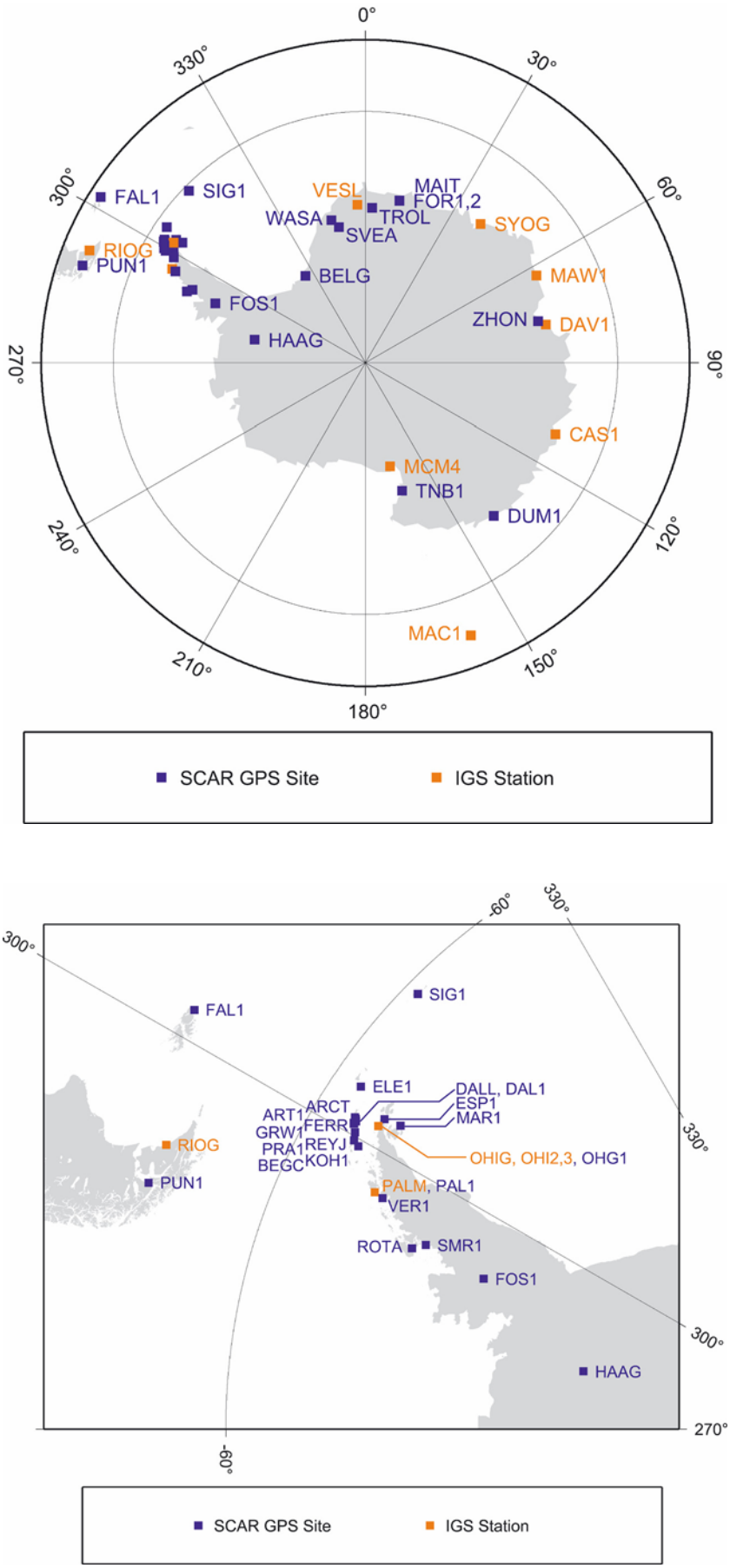

Figure 1: Station distribution of the SCAR GPS network and of the IGS network in Antarctica (April 2005).

Sub-Commission 1.4
Interaction of Celestial and Terrestrial Reference Frames

Mid-Term Report – April 2005

S.-Y. ZHU[12], B. RICHTER[13], V. TESMER[13]

The main objective of the IAG Sub-commission 1.4 is the study of the interaction of the celestial and the terrestrial reference frames. The terrestrial reference frames of different space geodetic techniques are materialised by monuments, which can relatively easy be connected via direct local measurements under the assumption that nearby monuments have equal motions. Such a straightforward link is in general not available for the celestial reference frames, because the inertial frames of the space geodetic techniques have different physical natures. This makes comparisons very difficult. Common for all techniques is only the orientation of the Earth's crust in space. Exceptions are some satellites, equipped with different technique antennas / reflectors, which can be used as co-locations between satellite techniques.

The signals we are searching for (tiny variations in gravity and site positions, e.g. to monitor sea level fluctuations) are very small, and the parameters of terrestrial reference frames, realised by each technique, are significantly connected with the diversely realised celestial reference frames. Therefore, even though geodesists generally are interested in earth related parameters, it is very important to understand the interactions between the frames, to promote the investigation of systematic error sources in the modelling of the techniques and to find approaches to reduce them.

WG 1.4.1: Theoretical Aspects of the Celestial Reference Systems

Scheduled activities:

- Study of the effect of the new IAU definitions of the relations between the celestial and the terrestrial reference systems

An essential progress was the appearance of the new IERS Conventions 2003, which in Chapter 5 fulfilled the IAU resolutions of 2000 by introducing the new IAU 2000 precession and nutation model and the celestial and terrestrial ephemeris origins into common use. The new concept of the celestial ephemeris origin combines precession and nutation into one transformation so that the mean equinox and the equation of equinoxes are no longer used. Compared with the formerly used Greenwich apparent sidereal time, the new earth rotation angle has a much simpler relation to universal time, which is free of certain inconsistencies in the old relation. The new nutation model considerably reduces the nutation corrections (apart from free core nutation), which have to be determined from observations.

Another new precession model was presented by FUKUSHIMA (2003). It models both the precession of the ecliptic (on the basis of the DE405 ephemeris) and the precession of the mean equator (on the basis of observed nutation corrections with respect to the old precession/ nutation model). He introduces an optimal parameterisation in which the whole transformation from the ICRF to the true equatorial system of date is performed by the minimum number of four elementary rotations, taking into account that the nutation parameters refer to the ecliptic of date. Other precession models compatible with IAU 2000 that provide an improved dynamical consistency were published by BRETAGNON et al. (2003) and CAPITAINE et al. (2003).

WG 1.4.2: Realisation of Celestial Reference Frames (CRF and Transformations)

Scheduled activities:

- Survey of the current status of CRF realisation (different techniques)
- Review of the implementation of IERS Conventions and IAG Fundamental Parameters

In April 2002, an IERS Workshop on the "implementation of the new IAU Resolutions" was held at the Observatoire de Paris. The proceedings of this workshop (published as IERS Technical Note 29, CAPITAINE et al., 2002) summarise explanations of the resolutions and their practical consequences, report on comparisons between "old" and "new" concepts, describe existing procedures and software and give account of the consequences on the future IERS products complying with the IAU Resolutions and the compatibility of the resolutions with past observations.

Since 2003, the IERS has been obliged to publish EOP values in the new transformational system. In parallel, products according to the old transformation are still

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provided. Although the IVS proceeds the same way, not all of the existing VLBI software are able to directly estimate parameters following the new transformations. It is unclear if any of the software used for analysis of geodetic satellite observations allows to transform according to the new Resolutions.

WG 1.4.3: Systematic Effects in the CRF Determination

Scheduled activities:

– Definition of pilot projects regarding CRF determination (different groups with different software) to identify inconsistencies causing systematic effects or models that have to be refined

The aim of this working group was to develop and implement a systematic observing program for astrometric sources. Beginning in the spring of 2004, a small part of some of the regularly scheduled geodetic VLBI sessions has been dedicated to observing ICRF defining sources and other sources that are stable or potentially stable, based on an analysis of source position time series (Feissel-Vernier, 2003 and 2004). The goal is to observe these sources at least twice a year to build up the data set for selecting the defining sources of the next radio ICRF. An overview of ICRF related discussions can be found in the IVS 2004 General Meeting proceedings: FEY (2004) reports on the status of the ICRF, MA (2004) presents considerations for generating a new ICRF and the necessary areas of refinement, and CHARLOT (2004) discusses future challenges for ICRF after 2010.

Another aspect was to coordinate and develop the CRF analysis capability of the IVS analysis centres. In a first step, source catalogues generated by eight analysis centres were submitted, which are currently being analysed and compared by four centres. Preliminary status reports were presented at the IVS analysis workshop in Noto, April 2005: Although no definite conclusions could be drawn, it became clear, that most of the catalogues coincided quite well in the positions of the regularly observed sources. But it also turned out that much care has to be taken to find out the optimum procedure to set up a new ICRF, e.g. which parts of the analysis procedures and data sets have to be adapted in the different contributions. The topic to be studied next shall be comparisons of source position time series, computed by the different analysis centres.

WG 1.4.4: Interaction between Celestial and Terrestrial Reference Frames

Scheduled activities:

– Identification of the effect of errors in the CRF on the TRF and related products (EOP) and vice versa
– Identification of the effect of deformations on the realisation of the NNR condition and its effect on EOP determination
– Comparisons of the EOP with geophysical models and the interaction with the gravity field

Due to various reasons (technical, theoretical, models, etc.) the CRF, realised by the individual techniques have systematic differences. The terrestrial frames thus realised are also affected. E.g., it was found that terrestrial frames realised by GPS have different scales within different time periods. This is caused mainly by the antenna phase error of the Block IIR satellites. By estimating antenna phase centre offsets together with the station coordinates, this scale error can be largely removed (see ZHU et al., 2003).

A lot of LEO satellites have multi-tracking techniques on-board. These are, e.g., TOPEX/POSEIDON, which has three techniques (SLR, DORIS and GPS), CHAMP and GRACE, which have two (SLR and GPS). This co-existence can be used as another kind of co-location. Methods and procedures are developed to use this to complement the usual ground co-locations. Thus the link between various satellite techniques is strengthened. One can even use this type of co-location to study the systematic differences between various (especially GPS and SLR) reference frames.

Some research groups are expanding their standard software in such a way that it can be used for all kinds of space geodetic techniques. This will ensure the consistency of the various reference frames, orbits and variable gravity. All these efforts shall provide more accurate, consistent and homogeneous reference frames.

GAMBIS (2004) gave a description how the IERS series of earth rotation parameters (EOP) are presently obtained by combining the results of different geodetic space techniques, and he analysed the long-term consistency of the EOP system with respect to terrestrial and celestial reference frames. He found that the present accuracy of the IERS-C04 series amounting to 0.2 mas for the pole position and 0.02 ms for UT1 is much lower that its internal precision of 0.01 mas and 0.005 ms respectively, owing to inconsistencies in the two reference frames.

Chao (2003) reviews on our understanding of the geophysical and climatic causes, the excitations for length-of-day change, polar motion and nutation. It is described, how measurements of time-variable gravity, geo-centre motion and Earth rotation variations can on a wide range of spatial and temporal scales be used as a remote-sensing tool for the integral of all mass transports.

In GROSS et al. (2003), the effectiveness of atmospheric and oceanic processes in exciting the Earth's wobbles during 1980-2000 is evaluated. The authors compare the EOP series "COMB2000", derived from geodetic observations, with estimates from atmospheric and oceanic angular momentum models. In spite of low statistical significance, they draw the intermediate conclusion that on pentadal and longer levels, atmospheric and oceanic processes do not appear to have enough power to excite the Earth's wobbles to their observed levels.

BOURDA and CAPITAINE (2004) discuss the connection between precession, nutation and space geodetically determined J2 coefficients. The second degree zonal coefficient of the geopotential is closely related to the Earth's dynamical flattening H, and thus to the expressions for precession and nutation. They conclude that the monitoring of periodic variations in J2 can be used for predicting periodic effects in precession-nutation. But realistic results, especially for the secular trend, can only be achieved by also using geophysical models and data as well as a refined and more realistic Earth model than that used for the study.

References

Bourda G., Capitaine N.: Precession, nutation and space geodetic determination of the Earth's variable gravity field. Astronomy and Astrophysics, 428, 691-702, doi: 10.1051/0004-6361:20041533, 2004

Bretagnon, P., Fienga A., Simon J.-L.: Expressions for precession consistent with the IAU 2000A model. Considerations about the ecliptic and the Earth Orientation Parameters. Astronomy and Astrophysics, 400, 785-790, 2003

Capitaine N., Gambis D., McCarthy D., Petit G., Ray J., Richter B., Rothacher M., Standish M.,. Vondrak J (Eds.): Proceedings of the IERS Workshop on the Implementation of the New IAU Resolutions. Observatoire de Paris, Paris, France, 18.-19. April 2002. IERS Technical Note 29, Frankfurt a.M., Verlag des Bundesamts für Kartographie und Geodäsie, ISBN 3-89888-866-5, 2002

Capitaine N., Wallace P., Chapront J.: Improved expressions for precession quantities consistent with MHB2000. Astronomy and Astrophysics, 412, 567-586, 2003

Chao B.: Earth Rotational Variations Excited by Geophysical Fluids. In: Vandenberg, N., K. Baver (Eds.): IVS 2004 General Meeting Proceedings, NASA/CP-2004-212255, 38-46, 2004

Charlot P.: The ICRF: 2010 and Beyond. In: Vandenberg, N., K. Baver (Eds.): IVS 2004 General Meeting Proceedings, NASA/CP-2004-212255, 12-21, 2004

Fukushima T.: A new precession formula. The Astronomical Journal 126, 494-534, 2003

Feissel-Vernier M.: Selecting stable extragalactic compact radio sources from the permanent astrogeodetic VLBI program, Astronomy and Astrophysics, 403, 105, 2003

Feissel-Vernier M.: Stability of the VLBI-Derived Celestial Reference Frame. In: Vandenberg, N., K. Baver (Eds.): IVS 2004 General Meeting Proceedings, NASA/CP-2004-212255, 346-350, 2004

Fey A.: Status of the International Celestial Reference Frame. In: Vandenberg, N., K. Baver (Eds.): IVS 2004 General Meeting Proceedings, NASA/CP-2004-212255, 341-345, 2004

Gambis D.: Monitoring Earth orientation using space-geodetic techniques: state-of-the-art and prospective. Journal of Geodesy, 78, 295-303, 2004

Gross R., Fukumori I., Menemenli D. s: Atmospheric and oceanic excitation of the Earth's wobbles during 1980-2000, Journal of Geophysical Research, 108, B8, 2370, doi: 10.1029/2002JB002143, 2003

Ma C.: Refinement of the ICRF. In: Vandenberg, N., K. Baver (Eds.): IVS 2004 General Meeting Proceedings, NASA/CP-2004-212255, 337-340, 2004

Zhu S., Massmann F.-H., Reigber Ch.: Satellite antenna phase center offsets and scale errors in GPS solutions. Journal of Geodesy, 76, 668-672, 2003

Inter-Commission Project 1.1
Satellite Altimetry

Mid-Term Report 2005

W. BOSCH[14]

Introduction

The Intercommission Project 1.1 'Satellite Altimetry' was created in August 2003 at the IUGG General Assembly in Sapporo, Japan. Due to the interdisciplinary relevance of satellite altimetry and overlap of research areas this project is joined between IAG commission 1, 2 and 3.

Objectives of ICP1.1

The primary objective of the joined commission project is to identify the scientific requirements to ensure a long and precise time series of utmost consistent altimeter observations with up-to-date geophysical corrections, consolidated geocentric reference and long-term stability. It has to be elaborated, how satellite altimetry is going to contribute to a global observing system, how the data of different missions is to be harmonized and how fast updates of orbits and geophysical parameters can be achieved in order to support scientific and operational applications.

More specific, it is required to obtain precise knowledge about the inherent vertical reference system of altimetry and the long-term stability of the altimeter sensors itself, and of ancillary sensors (radiometer). It is also envisioned that this project will provide a forum to foster innovative ideas for research and applications of satellite altimetry relevant to strengthen the realisation of vertical component of the ITRF and to diverse areas of geosciences.

Planned Activities

- Investigate by an interdisciplinary working group the rationale, feasibility and scope of an International Altimeter Service in order to serve scientific and operational applications of satellite altimetry. The group shall strive for a broad support by other scientific entities.
- Study the contribution of satellite altimetry to the realisation and stability of the vertical component of the ITRF implied by precise orbit determination, geocenter variations, mis-centering of reference frame, as well as long-term performance of altimeter - and ancillary sensors.

The first topic has been immediately taken up and led to the creation of the International Altimeter Service Planning Group (IAS-PG), see below. The second topic is to be addressed later on and will be subject to a dedicated session within an IAG, Commission 1 symposium.

The International Altimeter Service Planning Group (IAS-PG)

In October 2003 a Call for Participation to a Planning Group for the International Altimeter Service was initiated by CHE-KWAN SHUM, PHIL WOODWORTH, G. MITCHUM and WOLFGANG BOSCH. There were more than 45 positive responses. Among the suggested comments, the initiators were encouraged to form a group representing all space agencies, processing centres, and other expert groups, which are providing, processing, analysing or applying altimeter data – a request difficult, if not impossible to realize. To keep the size of the group manageable the invited members (see below) were asked to act as representatives for other individuals.

Terms of References of IAS-PG

The IAS Planning Group (IAS-PG) studies the rational, feasibility and scope of an International Altimeter Service (IAS) and develops a detailed implementation plan for an IAS serving the altimeter user community with an utmost long time series of harmonized multi-mission altimeter observations with up-to-date geophysical corrections and consolidated geocentric reference and with related sea level products.

- Collaborate, as appropriate, with space agencies, processing centres, data and product archives, other existing or emerging (global) observing systems as well as with scientific organisations and expert groups,
- identify categories of altimeter users and compile their requirements, considering already available key documents from previous studies and projects,
- elaborate the basic functionality, an IAS should provide and compile a list of data and products the IAS should consider to serve their users,
- identify and describe the components, necessary or recommended to fulfil the IAS objectives and functionality,

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– propose an organisational structure for the IAS taking into account the responsibilities of space agencies and the possible contribution of other entities, able to host or support components of the envisaged service,
– report to IAG, GLOSS, IAPSO and other bodies related to satellite altimetry on the state of planning and implementation of an IAS.

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Self Organisation of the IAS-Planning Group

As the IAS-PG is not funded, discussions have to be organized by business meetings which are attached to scientific conferences or general assemblies or by electronic mail. To facilitate the email exchange a mailing list has been created. Any email, sent to *ias-pg@dgfi.badw.de* is sent to subscribed members of the list. In addition, all emails – distributed this way – are archived (see *http://www.dgfi.badw.de/lists/ias-pg*) and may be viewed in different ways – sorted according to threads, date, and author. All members of the IAS-PG were initially subscribed to receive the messages posted to the mailing list. The list is however open and unmoderated. Anyone who is interested may subscribe to the mailing list and receive then all messages posted to the list. In addition, anyone who is interested may contribute to the discussion by posting his own emails.

Several requests for comments (RFC) were used by the chair of the IAS-PG to push forward discussions on particular topics.

It was soon recognized that the email list is a necessary tool, but not well suited to synthesize different contribution of the IAS-PG members. It was therefore decided to install in addition a so called 'WIKI', a collaborative web site, see *http://www.dgfi.badw.de/wiki*. This WIKI allows everybody to edit existing pages or to create new pages within the web site dedicated to the objectives of the IAS-PG. A very simple syntax is used to do this and to create headings, lists, internal, as well as external links. After its creation, most of the contributions of the mailing list were compiled and synthesized to the IAS-PG WIKI. The main page auf the WIKI web site is shown in figure 1.

Fig.1: Screenshot of IAS-PG WIKI, a collaborative web site, that serves as a forum for discussion on the envisaged International Altimeter Service and is used to compile and synthesize contribution from the members of the IAS-Planning Group.

Meetings

Initial Meeting during 8th Meeting of GLOSS Experts at IOC, Paris, 13-17 October 2003

The idea of an International Altimeter Service was introduced, followed by a general discussion on the rational of an International Altimeter Service. There is a general accepted requirement to serve users with a long and precise time series of utmost consistent altimeter observations. This is an international, multi-disciplinary, mission overlapping and agency independent task, providing the general rational for an International Altimeter Service. Additional rationales are based on more technical issues (different data format, data with increasing size and complexity, delayed update of corrections ...). Several suggestions for the realisation of the IAS were given: the organization of ESEAS and OCCC were recommended as examples. It was emphasized that any altimeter service has to rely on the space agencies. On the other hand the envisaged service

should address and support scientist working with the altimeter data.

Later on the GLOSS Experts passed a letter of endorsement for the IAS Planning Group.

Business Meeting at the EGU2004 General Assembly, NICE, 27 April 2004

The Terms of References were presented and opened for discussion. It was suggested to extend the list of products and to include explicitly products over land and lakes as well as over ice surfaces. An introduction to the email list (see above) was given and it was decided to create in addition a 'WIKI' web site. Two work statements with request for comments were then discussed: one concerning the compilation of space agencies, processing centres, other existing or emerging observing systems as well as scientific organizations and expert groups that work on satellite altimetry, should be part of it, or interface the envisaged altimeter service. The second work statement was on the general objectives and the functionality of the altimeter service. Result of these discussions have been compiled to the WIKI web site, see *http://www.dgfi.badw.de/wiki/index.php/Bodies_&_Entities* and *http://www.dgfi.badw.de/wiki/index.php/Functionality_of_IAS*.

For the assessment of user categories and user requirements it was referred to previous studies, in particular the final reports of the GAMBLE (Global Altimeter Measurements by Leading Europeans) project. The meeting was supplemented by status reports on the reprocessing of ERS-1 data, the Pathfinder project and information about ESA's Oxygen O_2 programme.

Business Meeting at the EGU2005 General Assembly, Vienna, 27 April 2005

The last meeting focused on the organisation of the envisaged altimeter service, on first IAS demonstration products and the GRID technology.

For the future IAS organization it was suggested to use the already existing services of IGS, ILRS, and IVS as an example. It has to be recognized, however, that the data delivery situation in altimetry is different from the situation in these space techniques. Altimeter data is provided by the space agencies which operate altimeter satellites. They have their own data policy – fortunately in most cases completely open. For IGS, ILRS and IVS data is taken by the services itself. Therefore, IAS can not be build without essential contribution and support of the space agencies.

JPL supports a project dedicated to the "re-tracking" (the re-analysis of the radar echo's) of the complete TOPEX/Poseidon data – a rather demanded processing task. Unfortunately, there are no additional resources to update simultaneously orbits, ocean tide corrections, to replace the geoid and the mean sea surface and to create a full GDR-product. It was suggested that re-computation and merging of additional corrections could be performed by a first IAS pilot project. This pilot project could realise a distributed upgrade procedure and give an impressive demonstration of the IAS functionality.

Finally, a suggestion was made to consider GRID technology for the International Altimeter Service.

GRID technology is a new but emerging and promising technique which allows to coordinate resources (e.g. processing power or data storage) without a centralized control. The technology is based on standard, open, general-purpose protocols and interfaces and is capable to deliver a non-trivial quality of services. GRID technology seems to be extremely well suited to coordinate a virtual network of processing centres already providing service functions to altimeter users.

Conclusions

The following conclusions summarize the most important results of the work performed within the IAS Planning Group:

- There is a general agreement that an International Altimeter Service (IAS) is necessary and should be created as soon as possible.
- The IAS shall integrate the envisaged altimetry service into the Global Earth Observing System of Systems (GEOSS) and let altimetry become an essential element of Global Ocean and Geodetic Observing Systems (GOOS, GGOS).
- IAS shall provide a unique point-of-contact for altimeter users and support all applications of satellite altimetry, including, for example, applications for oceanography, coastal zones, hydrology, geodesy, cryosphere.
- IAS shall support calibration and validation activities, assess data and product quality, and recommend improvements for generation and delivery of data and products.
- IAS will not replace but build on the voluntary contribution of the many existing data, analysis, and product centres already providing service functions. Thus, IAS will have to coordinate a network of centres. User request are to be re-directed to and resolved by these centres which keep the desired data.
- IAS must ensure that intellectual property rights remain with, and proper referencing is made to the generating node, whenever data, products or algorithms are provided or used in publications.
- A unification of data formats is neither feasible nor desirable. Instead, IAS shall provide generic tools, which keep the necessary metadata to inform about data content and allow extracting data with content and format upon user request.
- IAS shall integrate and share distributed resources (data bases) from multiple institutions, each with their own policy and mechanism on the bases of standard, open, and general-purpose protocols and interfaces.

Inter-Commission Project 1.2
Vertical Reference Frames

Mid-Term Report April 2005

J. IHDE[15]

Based on the classical and modern observations, the ICP1.2 on Vertical Reference Frames shall study the consistent modelling of both, geometric and gravimetric parameters, and provide the fundamentals for the installation of a unified global vertical reference frame.

Objectives

- To elaborate a proposal for the definition and realization of a global vertical reference system (World Height System – WHS);
- To derive transformation parameters between regional vertical reference frames;
- To establish an information system describing the various regional vertical reference frames and their relation to a world height frame (WHF).

Program of Activities

- Harmonization of globally used height data sets;
- Study of combination procedures for height data sets from different techniques;
- Study of information on regional vertical systems and their relations to a global vertical reference system for practical applications;
- Unification of regional (continental) height systems.

Activities since 2003

(1) Realization of the European Combined Geodetic Network (ECGN) as case study for further global activities (Project of EUREF - IAG SC1.3a)

ECGN is a terrestrial network for the combination of different techniques: GPS/GLONASS positioning, gravity measurements, levelling, tide gauge observations.

- 1st Call for Participation: Implementation of ECGN Stations in April 2003
- Decision about the criteria to evaluate the proposals of the 1st Call and discussion of the individual proposals in September 2003
- Information of the ECGN organizations/ institutions about the status in November 2003 (*http://www.ifag.de/ecgn/index.htm*)
- Preparation of the 2nd Call relating methodical investigations for the combination of spatial observation data with gravity field data.

(2) European Vertical Reference System Workshop April 5-7, 2004

- Preparation of a common European Vertical Reference System (EVRS) and its relation to a WHS till 2007
- Revision of the present EVRS conventions in agreement with the WHS/WHF conventions of ICP1.2
- Realization and maintenance of the EVRS by the ECGN till 2007.

(3) Meeting of ICP1.2, August 31, 2004, Porto

Main items of the discussion were the

- view to ICP1.2 strategy
- principles for conventions, open questions
- Information of local reference frames needed for transformation in a regional and global vertical system
- importance of W_0 in the definition of a global vertical reference system, and adoption of a new number for W_0, respectively the acceptance of existing conventions,
- importance of tide gauge observations and satellite altimetry for the realization of the global vertical reference system as well as the unification of regional vertical reference frames.

Next actions

A result of the discussion of the members of ICP1.2 about the definition and realization of a global vertical reference system was the composition of two work packages.

The first work package will address

- convention and standards for a Conventional Height System, a World Height System and a World Height Frame
- relationships to the CTRS, CTRF and gravity standards

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– datum realization (handling of information of the satellite altimetry, possible role of the TIGA project, mean earth ellipsoid versus W_0)

This work package will be in executed in collaboration of J. IHDE, J. KRYNSKI (chair), J. MÄKINEN and V. VATRT.

The second work package is related to the unification of height systems and the collection and distribution of information about the different national height systems including transformation parameters. Members of the group are M. AMOS, A. KASENDA, BILL KEARSLY, G. LIEBSCH, D. ROMAN (chair) and MARC VERONNEAU.

All ICP1.2 members are asked to contribute to the work packages. Both groups shall present first results till end of March 2005.

The next ICP 1.2 meeting is planned for spring 2005 during the EGS Conference in Vienna on 24.-29.04.2005. First results of our project shall be presented on the IAG Scientific Symposium in Cairns, Australia on 22.-26 August 2005.

Inter-Commission Study Group 1.1
Ionosphere Modelling and Analysis

Mid-Term Report July 2005

M. SCHMIDT[16]

The ionospheric delay constitutes the main error source for Global Navigation Satellite Systems (GNSS). Although as a result of many years of research the climatology of the ionosphere is today quite well known, 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 mean ionospheric conditions. The development of sophisticated high technological systems for navigation, telecommunication, space missions, etc., require accurate prediction models of the space weather conditions. For more than ten years scientific organizations and industry have been developing so-called Satellite Based Augmentation Systems (SBAS), which are networks of ground relay stations and geostatic satellites designed to receive satellite navigation signals and to transmit corrected time and distance measurements that greatly improve accuracy. Among other items SBAS corrects satellite navigation signals for ionospheric delays. SBAS is vital to providing the reliability and precision required by aviation and other precision-critical applications.

The Earth's ionosphere has been studied for more than one hundred years using different observation techniques. In the last years the new possibility to estimate the global distribution of ionospheric free electrons by means of GPS has opened a very active and promising field of research. To be more specific, ground- and space-based dual-frequency P-code GPS receivers provide P-code and carrier phase measurements on both frequencies of the system. Linear combinations of the dual-frequency GPS observations have been discussed extensively in the literature. The so-called geometry-free linear combination of simultaneous carrier phase observations on both frequencies provides informations about the so-called slant total electron content (STEC) along the ray-path between a satellite and a receiver at a certain observation time. Usually STEC is transformed into the so-called vertical total electron content (VTEC) by means of a certain mapping function. There are today a variety of approaches for processing dual-frequency GPS observations and to produce global ionospheric maps of VTEC with a temporal resolution of two hours or less.

While ground-based two-dimensional ionospheric maps mean a substantial progress in ionosphere weather research, applications and forecast, the radial geometry of the ground-based observations limits their capability for providing information on the vertical electron distribution. Using simulated data it was demonstrated that this limitation can be overcome by introducing more or less horizontal cuts through the ionosphere, performed by space-borne GPS receivers flying on low-Earth orbiting (LEO) satellites such as GPS-Met, CHAMP, GRACE or SAC-C. Two- and three-dimensional snapshots representing the global ionosphere were obtained combining ground- and space-based observations.

The planned activities of this study group in the first years should concentrate on the collection and validation of existing empirical and physical ionospheric models. In this context the empirical ionospheric NeQuick model was subject of investigation in order to derive a three-dimensional model of the electron density of the ionosphere. In general, STEC is defined as the integral of the space- and time-dependent electron density along the ray-path between satellite and receiver. Three-dimensional modelling of the electron density is mostly related to tomography. One promising non-tomographic approach was performed by adjusting the electron density of the peak of an oxygen Chapman profile to GPS observations. A new approach provides a methodology for three-dimensional ionospheric imaging by replacing the rather simple Chapman model by the more complex but realistic NeQuick model. The NeQuick model is a ionospheric electron density model developed by the Aeronomy and Radio Propagation Laboratory of the International Centre of Theoretical Physics (ARPL-ICTP) in Trieste/Italy and by the Institute for Geophysics, Astrophysics and Meteorology (IGAM) of the University of Graz in Austria. The model is being used by the ESA EGNOS project for assessment analysis and has been proposed for GALILEO single-frequency operation. It describes the electron density distribution in a given point and for any time by a function, that depends – among others parameters - on the electron density NmF2 and the height hmF2 of the F_2 peak of the profile. These values are usually computed as a function of position and time, using the climatologic data base from the International Union of Radiosciences Recommendations (ITU-R). Since the ITU-R provides monthly averaged values, significant day-to-day deviations between the actual and the predicted values can be expected. Therefore, it seems suitable to determine appropriate corrections for the ITU-R values from GPS geometry-free observations. These corrections can be

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modelled each by a series expansion in terms of regional base functions such as spherical wavelets or spline functions. Whereas this kind of modelling, which essentially means a multi-resolution representation (MRR), is well-known in gravity field modelling, it obviously can be used also in space weather applications. The basic idea of the MRR is to split a given input signal into a smoothed version and a certain number of band-pass signals by successive low-pass filtering. In the context of wavelet theory, this procedure consists of the decomposition of the signal into wavelet coefficients and the (re)construction of the (modified) signal by means of detail signals. The latter are the spectral components of the MRR because they are related to certain frequency bands.

The coefficients of the series expansions mentioned before are the unknown parameters of the linear model which can be solved by applying suitable adjustment procedures using terrestrial and/or space-borne GPS observations. The resulting normal equation system has to be regularized because of the data gaps caused by the GPS observation networks. An appropriate method to solve such an ill-conditioned problem is given by the estimation of variance components of both the observations and the prior information for the unknown parameters. Estimators of the corresponding covariance matrices can be computed and used for hypothesis tests in order to check the observations for outliers and the parameters on significance. This method, successfully applied in regional gravity field modelling within the last years, was now adapted to ionospheric modelling.

The described approach provides an appropriate combination of physics – by means of the NeQuick model – as well as mathematical and statistical modelling, respectively. Of course the concept can be adapted in a similar way to other empirical or physical ionospheric models like IRI. Since TEC is modelled along the ray-path, the results of the presented approach will not be falsified by a deficient mapping function to transform STEC data into VTEC. This way, an update of the climatological parameters of the physical models should provide a better representation of the ionospheric conditions and a better understanding of specific ionospheric phenomena like the equatorial anomaly.

The Institute of Communications and Navigation of the German Aerospace Center (DLR) continued the regional TEC monitoring activities over the European (*http://www.kn.nz.dlr.de/daily/tec-eu/*) and Northern polar area (*http://www.kn.nz.dlr.de/daily/tec-np/*).

Ionospheric radio occultation (IRO) measurements re carried out onboard the German CHAMP satellite since 11 April 2001 on a routine basis. At present about 100-150 vertical profiles of electron density are derived per day by an operational CHAMP data processing system. More than 150000 vertical electron density profiles have been derived so far.

The achieved accuracy of the retrieved electron density profiles is estimated in particular by comparing the IRO results with independent data obtained from vertical sounding stations on Earth and from the Langmuir probe onboard CHAMP. The GPS navigation data received with the topside antenna are used to reconstruct the 3D electron density structure of the ionosphere by data assimilation techniques. Progress has been made in tomographic reconstruction of the ionospheric density by combining ground GPS data and space based radio occultation data.

A systematic comparison was carried out with ionospheric models NeQuick and IRI. IRI estimations revealed systematic deviations indicating that IRI generally overestimates the upper part of the ionosphere whereas it underestimates the lower part of the ionosphere under high solar activity conditions.

Within the frame of the space weather pilot project of ESA an operational ionosphere data service (SWIPPA) was established at DLR (*http://www.kn.nz.dlr.de/swippa*) that provides a warning message and various TEC derived ionospheric data products for European users with update rates of 5 minutes. The 1Hz sampled GPS data are provided by the Bundesamt für Kartographie und Geodäsie (BKG).

IGS GNSS WG / Inter-Commission Study Group 1.2 Use of GNSS for Reference Frames

Mid-Term Report

R. Weber, C. Bruyninx[17]

Introduction

Recognizing the importance of the upcoming new European satellite navigation system (GALILEO) and of the modernization programs planned for GPS and GLONASS the IGS (International GPS Service) decided to set up a GNSS-Working Group begin of 2003. A major goal of this WG is to prepare a consolidated feedback to GNSS system engineering based on relevant IGS experience of providing highest accuracy products for the existing systems. Special emphasis should be laid on calibration characterization issues such as the role of SLR for orbit determination, estimation of inter-system and inter-frequency biases, clock and orbit prediction as well as reference frame definition and realization. End of 2003 this items were addressed by a short list of recommendations from the IGS-WG to the GALILEO System Design.

After the past IUGG Meeting in Sapporo 2003 the president of IAG Commission I on 'Reference Frames' decided to set up a Study Group entitled 'Use of GNSS for Reference Frames'. Goal is to evaluate and support the use of Global Navigation Satellite Systems for the definition and densification of the International Terrestrial Reference Frame (ITRF). According to the new statutes of IAG it has been agreed by the IAG president, the Commission I president and the IGS Governing Board that the IGS-GNSS WG and IAG IC-SG1.2 should be closely coordinated. Furthermore the group is closely linked to IAG Commission IV on 'Positioning & Applications'.

The membership list has been broadened according to the new topics. One of the overlapping goals clearly is how to take advantage of the IGS product suite for the definition and densification of the International Terrestrial Reference Frame (ITRF).

The revised Terms of Reference of both sub-groups may be accessed via *http://www.hg.tuwien.ac.at/research/GNSS/GNSS_WG_IGS/GNSS_WG_IGS.htm* and *http://www.gps.oma.be/IAG-study-group/workprogram.php*.

General Activities

Discussions and scientific work of the group are carried out by email, via bi-lateral meetings of individual members or via scheduled meetings of the whole groups (see list of meetings below). Meeting reports are made available to the public via the web-links mentioned above.

- Open WG-Meeting during ION2003, Portland

  Topics: Galileo/GPS Frequency Overlay, Tie of Galileo Reference Frame to ITRF
- Open WG/SG-Meeting during IGS Workshop & Symposium, March 2004, Berne

  Topics: Formal Organisation of the Joint IAG/IGS Study Group; Recommendations to Systems Design, GPS and GLONASS Modernization
- Meeting SC-,WG- and SG-chairs of Commission IV during ION 2004

  Topics: Organisational Issues and Relation of IGS GNSS WG / IAG IC-SG 1.2 to Commission IV
- First Meeting of WG/SG members with Galileo Project Team at ESOC (Darmstadt) (June 29th ,.2004)

  Topics: Satellite Phase Center Definition, on-board retro-reflector arrays, GSTB-V1
- Second Meeting of WG/SG members with Galileo Project Team at ESOC (Darmstadt) (March 17th, 2005)

  Topics: Laser Ranging on-going activities, GNSS Biases (intra- and intersystem), Relation Galileo Reference Frame Provider – IGS, GSTB-V2 Mission Status

In order to improve the quality of the contribution of the global GNSS station network to the ITRF2004, a discontinuity table containing the epochs with discontinuities in the IGS station coordinates, has been created. In addition, regional sub-commission chairs of commission 1 have been asked to review and complete this discontinuity table.

EGNOS has agreed to open its GNSS observation data to the IGS. On the short term the ESTB station data will be made available and on the medium term the EGNOS Data Server and EGNOS RIMS data will be opened, giving to the IGS about 15 additional stations in Africa which will improve the stability of the GNSS reference frame.

Members of the Working Group are part of the consortium that was chosen by the European Commission to carry out the project "Galileo Geodesy Service

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Provider (GGSP)". The GGSP will be responsible for providing the Galileo terrestrial reference frame and also for the links between the Galileo ground segment and the IAG services (IGS, ILRS, IERS). Since the Galileo project does not want to/cannot deal with the individual services, the GGSP will be the intermediary.

Future Activities

In the near future the Study Group will try to explore an optimal set of signals (from GPS, Galileo, Glonass) to be tracked by future geodetic GNSS receivers. Furthermore the interaction with entities involved in the technical set up of modernized GPS (GPS III) and modernized GLONASS should be intensified, preferably to a level similar to the current interaction with the Galileo project team.

In addition, based on the agreed reference network design we will investigate the quality of the tie and anticipated time evolution of the GALILEO Reference Frame with the ITRF. In addition the group will concentrate on expected synergies using a real GNSS observation network covering three satellite navigation systems for reference frame maintenance.

References

WEBER R. et al., *The IGS-GNSS Working Group – Charter and Plans*, Presentation at the IGS Workshop & Symposium, March 2004, Berne

WEBER R. et al., *Activities of the IGS GNSS Working Group*, Presentation at the EGU 2005, April 2005, Vienna

WEBER R.,*The IGS Participation in the long term exploitation of the next generation of GNSS*. Proceedings of the European Navigation Conference GNSS 2004, The Institute of Navigation, Netherlands, Paper 117, pp.1-8, 2004.

Inter-Commission Working Group 1
Quality Measures, Quality Control and Quality Improvement
(Joint WG of Commissions 1 and 2 and Inter-Commission Committee on Theory)

Mid-Term Report 2005

H. KUTTERER[18]

General remarks

The scope of the WG is both on theory and applications. The theoretical part covers issues from statistical analysis, Bayesian theory, interval mathematics and fuzzy theory, respectively. The applications are mainly in the field of space-geodetic techniques (GPS, VLBI). One big issue is the development of a more or less comprehensive concept of quality in Geodesy.

Presentations by members

Publications

Hewitson S., Lee H.K., Wang J.: Localizability Analysis for GPS/Galileo Receiver Autonomous Integrity Monitoring. Journal of Navigation , 57, 1–15, 2004.

Kutterer H.: The role of parameter constraints in VLBI data analysis. In: Schwegmann W., Thorandt V. (Eds.): Proc. 16th Working Meeting on European VLBI. BKG, Leipzig, 171-180, 2003.

Kutterer H.: Reliability measures for geodetic VLBI products. In: Vandenberg N., Beaver K. (Eds.): IVS 2004 General Meeting Proceedings, 301-305, 2004.

Kutterer H.: Statistical hypothesis tests in case of imprecise data. In: Sanso F. (Ed.): V Hotine-Marussi Symposium on Mathematical Geodesy, Springer, Berlin, 49-56, 2004.

Kutterer H.: Moderne Ansätze zum Umgang mit der Unsicherheit geodätischer Messungen. Mitteilungen DVW-Landesvereins Baden-Württemberg, Heft 2, Oktober 2004, 28-53, 2004.

Kutterer H., Heinkelmann R., Tesmer V.: Robust outlier detection in VLBI data analysis. In: Schwegmann W. Thorandt V. (Eds.): Proc. 16th Working Meeting on European VLBI. BKG, Leipzig, 247-256, 2003.

Kutterer H., Schön S.: Alternativen bei der Modellierung der Unsicherheit beim Messen. ZfV, 6/2004, 389-398, 2004.

Lehmann R.: Qualitätskontrolle geodätischer Messungen am Beispiel des Lagepunktvergleichs. In: Sroka A., Wittenburg R. (eds.): 5. Geokinematischer Tag 13. und 14. Mai 2004, Schriftenreihe des Institutes für Markscheidewesen und Geodäsie an der Technischen Universität Bergakademie Freiberg, Freiberg, 2004.

Schön S., Kutterer H.: Realistic uncertainty measures for GPS observations. In: Sanso F. (Ed.): A Window on the Future, Proceedings of the 36th IAG General Assembly, 23rd IUGG General Assembly, Sapporo, Japan, 2003, IAG Symposia series, No. 128, 54-59, in print, 2005.

Schön S., Kutterer H.: Using Zonotopes for Overestimation-Free Interval Least-Squares - Some Geodetic Applications. Reliable Computing, Vol. 11, Issue 2, 137-155, in print, 2005.

Tesmer V., Kutterer H.: An advanced stochastic model for VLBI observations and its application to VLBI data analysis. In: Vandenberg N., Beaver K. (Eds.): IVS 2004 General Meeting Proceedings, 296-300, 2004.

Wieser A.: Reliability checking for GNSS baseline and network processing. GPS Solutions 8: 55–66, 2004.

Wieser A., Petovello M. G., Lachapelle G.: Failure Scenarios to be Considered with Kinematic High Precision Relative GNSS Positioning. In: Proc ION GNSS 2004, September 21–24, Long Beach, California, pp 1448–1459, 2004.

Schön S., Kutterer H.: Remaining systematics in GPS heights: Impact of the troposphere. (to be submitted to Journal of Geodesy, 2005). *In preparation*

Stewart M.P., Penna N.T., Lichti D. D.: Impact of unmodelled systematic errors on coordinate time series estimated using least squares (to be submitted to Journal of Geodesy, February 2005). *In preparation*

Oral Presentations

Kutterer H.: Alternativen bei der Modellierung der Unsicherheit beim Messen. Geodätische Woche 2004, Stuttgart, 12.10.2004.

Tanir E.: "Detection of Outliers from The Bayesian Point of View in Temperature Time Series at „NRAO85 3" VLBI Station". Geodätische Woche 2005, Stuttgart, Germany, 12.10.2004.

Poster Presentations

Schön S., Kutterer H.: Towards a realistic uncertainty budget for GPS heights. AGU Fall Meeting 2003, San Francisco, 12.12.2003.

Present activities

Up to now, there were neither workshops, nor conference sessions nor group meetings. This is mainly due to the chairmans`s move to the University of Hannover. Nevertheless, the WG has been active as indicated by the list of presentation. There is a web-site of the WG at DGFI in Munich, Germany (*http://iag.dgfi.badw.de/index.php?ic-wg1&type=3*). There are some written contributions of WG members available.

[18] Hansjörg Kutterer Chair Inter-Commission Working Group 1 – Quality Measures, Quality Control and Quality Improvement (since April 2004), kutterer@gih.uni-hannover.de

Future plans

It is planned to intensify the WG's work significantly in 2005 including e-mail discussions as well as presentations at the EGU Assembly in Vienna, Austria, the IAG Assembly in Cairns, Australia, and the Geodetic Week in Düsseldorf, Germany. The WG's web-site will be moved to the Geodetic Institute, University of Hannover, and updated. There is some on-going discussion concerning a WG meeting (probably in Cairns) and a workshop (probably in Hannover), respectively.

Inter-Commission Working Group 3
Satellite Gravity Theory
(Joint Working Group of Commissions 1 and 2 and Inter-Commission Committee on Theory)

Report 2003 – 2004

N. SNEEUW[19]

Joint WG Meeting

During the GGSM2004 meeting, August/September 2004, Porto, Portugal, a joint meeting was organized between ICWG2.1 and the ICCT WG on Inverse Problems (chair: J Kusche). The participation level was high, about 70%. Individual members briefly presented their research plans for the next few years. This meeting can be regarded as a kick-off for both working groups. One of the main discussions at the joint meeting was about a publication plan; see below.

Special issue Journal of Geodesy

It was proposed and agreed at the joint meeting that the two WG chairs will organize a special issue of the Journal of Geodesy, dedicated to the combined areas of the two working groups. The authorship is mostly drawn from the combined WG membership, although authors from outside will participate as well. Further details:

- The Editor-in-Chief of JoG, Will Featherstone, has agreed.
- The two WG chairs will act as guest editors (though N Sneeuw is regular JoG editor already).
- To date, about 16 papers have been announced.
- Deadline for submission is end of June 2005.
- Papers will have to pass the normal editorial and review process.
- Depending on the speed of the review process, the special issue may be expected end of 2005, or rather early 2006.

Further activities

All WG members are actively involved in aspects of spaceborne gravimetry using CHAMP, GRACE, GOCE and/or future missions. In this reporting period it is too early to extensively document all publications, papers, poster presentations, etc. For the upcoming reporting timeframe it is planned to monitor relevant activities and stimulate participation in workshops and conferences, in close agreement with the chairs of SC2.3 on Dedicated Gravity Field Missions (.P VISSER) and the Inter-Commission-Committee on Theory (PL Xu), to which this WG is answerable.

Members

The initial members of the working group (addresses at start of WG activities) are:

- N. SNEEUW (chair), University of Calgary Canada, sneeuw@ucalgary.ca
- P. DITMAR, TU Delft Netherlands, ditmar@geo.tudelft.nl
- C. GERLACH, TU Munich Germany, gerlach@bv.tum.de
- R. GREBENITCHARSKY, University of Calgary Canada, grebski@ucalgary.ca
- S. C. HAN, Ohio State University USA, han.104@osu.edu
- M. KERN, TU Graz Austri,a kern@geomatics.tu-graz.ac.at
- C. KOTSAKIS, University of Calgary Canada, ckotsaki@ ucalgary.ca
- J. KUSCHE, TU Delft Netherlands, j.kusche@citg.tudelft.nl
- J. LI Wuhan, University China, jcli@wtusm.edu.cn
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- R. PAIL, TU Graz Austria, pail@geomatics.tu-graz.ac.at
- N. PAVLIS, Raytheon ITSS Corp. USA, npavlis@atlas.stx.com
- T. PETERS, TU Munich Germany, peters@bv.tum.de
- H. SCHAUB, Virginia Tech USA, schaub@vt.edu
- Y. SHEN, Tongji University China, yzshen@mail.tongji.edu.cn
- I. VELICOGNA, University of Colorado USA, isabella@ colorado.edu
- P. VISSER (ex officio), TU Delft Netherlands, pieter.visser@ lr.tudelft.nl
- F. WILD, University of Karlsruhe Germany, wild@gik.uni-karlsruhe.de
- D. N. YUAN, JPL USA, dah-ning.yuan@jpl.nasa.gov

At the GGSM2004 meeting in Porto, Portugal, PAVEL NOVÁK (Research Institute of Geodesy, Czech Republic, pnovak@ pecny.asu.cas.cz) was added to the membership. C .KOTSAKIS has since moved to the Aristotle University of Thessaloniki, Greece. R. GREBENITCHARSKY has moved to TU Delft, The Netherlands.

[19] Nico Sneeuw, Chair Inter-Commission Working Group 3 – Satellite Gravity Theory, sneeuw@ucalgary.ca / in future sneeuw@ gis.uni-stuttgart.de

Interim Activity Report for IAG Commission 2, The Gravity Field

by

Christopher Jekeli
Commission President

September 2005

Executive Summary

Commission 2 consists of four sub-commissions, seven projects, and six study groups, organized in the following structure:

1. Sub-Commission SC2.1: Gravimetry and Gravity Networks (president: Shuhei Okubo)
    a) Commission Project CP2.7: Gravity in South America (María Cristina Pacino)
    b) Study Group SG2.1: Comparison of Absolute Gravimeters (Leonid Vitushkin)
    c) Study Group SG2.4: Aerogravimetry and Gradiometry (Uwe Meyer)

2. Sub-Commission SC2.2: Spatial and Temporal Gravity Field and Geoid Modeling (president; Martin Vermeer)
    a) Study Group SG2.2: Forward Gravity Field Modeling Using Global Databases (Michael Kuhn)
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    d) Inter-Commission Study Group IC-SG2.6 (Joint with ICCT): Multiscale Modeling of the Gravity Field (Willi Freeden)

3. Sub-Commission SC2.3: Dedicated Satellite Gravity Mapping Missions (president: Pieter Visser)

4. Sub-Commission SC2.4: Regional Geoid Determination (president: Urs Marti)
    a) Commission Project CP2.1: European Gravity and Geoid (Heiner Denker)
    b) Commission Project CP2.2: North American Geoid (Marc Véronneau)
    c) Commission Project CP2.3: African Geoid (Charles Merry)
    d) Commission Project CP2.4: Antarctic Geoid (Mirko Scheinert)
    e) Commission Project CP2.5: South American Geoid (Denizar Blitzkow)
    f) Commission Project CP2.6: Southeast Asian Geoid (Bill Kearsley)

In addition, there are a number of Inter-Commission working groups and projects, as follows.

a) Inter-Commission Working Group IC-WG1 (Joint with ICCT & Commission 1):

Quality Measures, Quality Control, and Quality Improvement (H. Kutterer)

b) Inter-Commission Working Group (proposed) IC-WG2 (Joint with IGFS): Evaluation of Global Earth Gravity Models (Jianliang Huang)

c) Inter-Commission Working Group IC-WG3 (Joint with ICCT & Commission 1): Satellite Gravity Theory (Nico Sneeuw)

d) Inter-Commission Project IC-P1.1: (Joint with Commissions 1 & 3): Satellite Altimetry (Wolfgang Bosch)

e) Inter-Commission Project IC-P1.2: (Joint with Commission 1) Vertical Reference Frames: (Johannes Ihde)

f) Inter-Commission Project IC-P3.1: (Joint with Commissions 1 & 3): Global Geodynamics Project (David Crossley)

These entities have their primary affiliation as indicated and the reporting of their activities is contained in other corresponding documents.

This report covers the period of activity of the entities in Commission 2 for the year 2004. Each of the chairs of the entities was asked to summarize activities in seven general areas:

1) publications of members, including journal papers, conference papers and presentations, and bulletin reports;
2) organizations of workshops, conference sessions, group meetings;
3) participation in observation campaigns and major computational efforts;
4) other noteworthy accomplishments, including significant interaction with groups outside the Commission;
5) future plans and activities;
6) issues and concerns, and recommended improvements in the Commission.

Reporting for the Commission was organized by Sub-Commission, with entities submitting activity summaries to their corresponding Sub-Commission. Each president of a Sub-Commission then collected and submitted a brief report to the Commission President. This report then summarizes these for the Executive Committee of the IAG.

It is clear that some entities of the Commission were significantly more active than others, but most if not all made progress in their stated objectives. A large majority of entities now maintains a web page with links to publications, meetings, reports, and other items of relevance. All of these web pages can now be accessed through the main web page for the Commission (www.ceegs.ohio-state.edu/iag-commission2). Important highlights of the Commission are represented by the following.

1. The International Symposium on Gravity, Geoid, and Space Missions 2004 (GGSM2004), held in the beautiful city of Porto, Portugal, from 30 August to 3 September 2004. It was expertly organized by members of the Faculty of Science, University of Porto. GGSM2004 brought together 234 scientists from 39 countries to discuss the state-of-the-art in nine topical areas of interest to the Commission. These included gravity field modeling from satellite missions; airborne and satellite gravimetry instrumentation; regional geoid modeling; radar and laser surface mapping from

satellites; topographic data bases and gravity modeling; satellite altimetry, oceanography, and the geoid; terrestrial gravity instrumentation, networks, and geodynamics; Temporal gravity variations: modeling and measurements; and Planetary gravity fields and models. All components of the Commission were well represented at the symposium not only in terms of participants but also by attracting a total of 258 papers. A Proceedings of the Symposium was published in the form of a CD with most of the oral and poster presentations, as well as many corresponding journal-style papers. A Springer-Verlag volume of a selected number of peer-reviewed papers (approximately 55) is also being published.

2. The various geoid projects under Sub-Commission 2.4 are proceeding well for the most part, especially the European, South American, and Antarctic projects. The greatest effort at the moment pertains to the coordination of collecting, validating, and bringing consistency to existing data sets from among the many participating groups (countries and/or organizations). Details may be found in the Appendices 7-12.

3. The gravity field satellite missions, CHAMP and GRACE, have already had a profound effect on geoid modeling and time-variable gravity investigations. Significant improvements over the global standard, EGM96, have been documented (e.g., one-meter differences in parts of Africa). The identification of the intensive hydrological signal over the Amazon basin in the GRACE data was particularly convincing evidence and confirmation of the exquisite precision of these satellite data. It gives investigators much hope even further improvement and applications for the future mission GOCE and potential follow-on projects to GRACE. Extensive references and more details on the activities of the Sub-Commission 2.2 are found in Appendices 3 and 4. Another area of significant development concerns the re-tracking of satellite altimetry data. This has led to improved geoid and gravity determination in shallow waters and inland lakes (see also Appendix 4).

4. Extensive absolute gravity networks are being established in eastern Asia and the western Pacific under the auspices of the Geographical Survey Institute of Japan and several institutions of the participating countries (Appendix 1). Work is continuing to organize comparison of absolute gravimeters under the auspices of the BIPM. Further details are found in Appendix 2. Discussions are under way to bring together a wider group of investigators and scientist involved in the metrology of gravity, adding to the topic of absolute gravimetry also airborne and shipborne gravimetry, both absolute and relative, as well gravity gradiometry.

5. Additional activities were reported by entities that have a joint interest between Commission 2 and other groups within the IAG. These are contained in Appendices 13, 14, 15, and 16, and include reports from IC-P1.2:(Vertical Reference Frames), showing significant progress toward a world vertical datum; from IC-P3.1: (Global Geodynamics Project), describing activities of workshops and particular efforts to increase absolute gravimetry data collection; from IC-WG3 (Satellite Gravity Theory), which has launched a special issue of the Journal of Geodesy on satellite gravity theory and inverse problems; and from IC-SG2.6 (Multiscale Modeling of the Gravity Field), reporting on extensive

cooperation and publications with various groups in wavelet and multiscale applications. Special mention should also be made of the new International Gravity Field Service (IGFS) with which a close collaboration is expected. Details of its inauguration are found in Appendix 17. A joint working group has also been established on the evaluation of earth gravity models (Appendix 18).

A few Study Groups unfortunately have not reported significant activity. This undoubtedly is not due to apathy but rather a lack of time to coordinate and assimilate relevant studies. Nevertheless, a decision to discontinue these study groups (namely, SG2.4, IC-SG2.5) is under consideration of the Commission.

In summary, the Commission 2 appears to have survived the major re-structuring of the IAG that occurred in 2003 and is carrying on with geodetic and gravity-related activities in the high-quality tradition of the Association.

The Appendices are reports provided by the sub-commission presidents and chairs of individual entities and form a part of this report. They provide the details of activities within the sub-structure of the Commission.

Appendix 1: Report of **Sub-Commission SC2.1**, by S. Okubo
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Appendix 17: Report of **IGFS**, by R. Forsberg
Appendix 18: Terms of Reference of **Joint Working Group**, by J. Huang

Interim Activity Report for IAG Commission 2, The Gravity Field

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April 2005

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A few Study Groups unfortunately have not reported significant activity. This undoubtedly is not due to apathy but rather a lack of time to coordinate and assimilate relevant studies. Nevertheless, a decision to continue or re-direct the activities of these study groups (namely, SG2.4, IC-SG2.5, IC-SG2.6) may be needed in order to streamline the pursuits of the Commission.

In summary, the Commission 2 appears to have survived the major re-structuring of the IAG that occurred in 2003 and is carrying on with geodetic and gravity-related activities in the high-quality tradition of the Association.

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Appendix 17: Proposal for **Joint Working Group**, by J. Huang

Appendix 1

Activity Report of Sub-Commission 2.1

(Gravimetry and Gravity Networks)

Compiled by S. Okubo, President of SC 2.1

Absolute Gravity Network in East Asia and Western Pacific:
Reported by Y. Fukuda, Member of SC2.1.

Absolute gravity measurements provide nationwide fundamental basis for local and regional gravity surveys and consequently a reference for the height system of the nation as well. Moreover the absolute gravity measurements very much contribute to the studies of crustal movements, sea level changes as well as secular gravity changes due to various phenomena in and on the Earth. Therefore, to establish/enhance the absolute gravity standard station network, we have been conducting absolute gravity measurements in East Asia and Western Pacific under the collaboration with Geographical Survey Institute of Japan and several institutions of the countries. So far, using FG-5 absolute gravimeters, we successfully finished the measurements at the stations of

1) Wuhan, Shanghai, Nanning, Beijing, Kunming, Lhasa and Hong Kong in China,
2) Bandung, Yogyakarta and Cibinong in Indonesia;
3) Kuala Lumpur and Kota Kinabalu in Malysia,
4) Hsinchu in Taiwan,
5) Perth and Canberra in Australia, and
6) Syowa Station in Antarctica.

During the period of 2005-2006, we will conduct the absolute gravity measurements in Urumqi, Xi'an, Xining and Changchun in China, Pontianak in Indonesia, Chiang Mai and Bangkok in Thailand and Manila in the Philippines. Addition to these new measurements, we are also planning to reoccupy at some of the stations in Indonesia, Malysia and Australia within a few years.

Study Group 2.1.1: Study Group on Comparisons of Absolute Gravimeters
Reported by Leonid Vitushkin (Chairperson of SG 2.1.1 and CCM WGG).

A separate report is included as Appendix 2.

Gravity in South America.
Reported by M. C. Pacino (Chair of Commission Project 2.7)

The report of this Project is included in the report for Commission Project 2.5, Appendix 12.

Appendix 2

file: SG2-1-1_report_to_S_Okubo_170205.doc
BIPM, 17 February 2005

Sub-Commission 2.1
(Gravimetry and Gravity Networks)
Study Group 2.1.1
(Study Group on Comparisons of Absolute Gravimeters)

Activity report
(May 2004 – February 2005)

1. The First Joint Meeting of the SG 2.1.1 and Working Group on Gravimetry of the Consultative Committee on Mass (CCM WGG) was organized on 26-27 May 2004 at the Bureau International des Poids et Mesures (BIPM), Sevres. Twenty five participants from fourteen countries and the BIPM have attended the meeting.
The meeting discussed the problems related to metrology in absolute gravimetry and organization of the International Comparisons of Absolute Gravimeters (ICAGs) under the auspices of the CCM, BIPM and IAG.
1.1 For the first time the project of the Technical Protocol for the ICAGs was discussed. This project was developed by the Discussion Group 2 (moderator Alessandro Germak, IMGC, Italy) following the rules for the key comparisons in the frame of the Mutual Recognition Arrangement signed by the directors of the National Metrology Institutes from more than 50 countries.

1.2 The draft requirements to the sites for the regional international comparisons were prepared by Discussion Group 1 (moderator Jacques Liard, NRCan, Canada) and also discussed at the meeting. Sites in Canada, China, Finland, Luxemburg, Slovakia, Russia and USA have been proposed for regular regional comparisons and, probably, future calibrations of the absolute gravimeters.

1.3 The meeting proposed to organize the 7th ICAG (ICAG-2005) in 2005 at the BIPM. The steering committee of the ICAG-2005 was nominated. It consists of L.Vitushkin (BIPM), M.Becker (IPG DTU, Germany), O.Francis (ECGS, Luxemburg), A.Germak (IMGC, Italy), Z.Jiang (BIPM), Wangxi Ji (NIM, China).

2. The first meeting of the steering committee was held on 29 November 2004 at the IMGC (Turin, Italy). It was decided to organize the absolute measurements of the ICAG-2005 at the BIPM in September 2005 and the relative measurements (gravity

gradients, links between the sites) in July 2005. Proposals on the programme of absolute and relative (gravity gradients and links between the sites of the BIPM) measurements have been discussed.

3. The Circular Letter 1 on the ICAG-2005 was prepared by the chairman and steering committee, and distributed on 23-24 December 2004.
Currently more than 15 participants plan to take part in the absolute measurements of the ICAG-2005 at the BIPM.

4. The Circular Letter 2 on the ICAG-2005 will be distributed in March 2005. Taking into account the decisions of the institutes - members of the CCM WGG and SG2.1.1 the steering committee proposed to organize the ICAG-2005 as a pilot study.

The working documents of the 1st CCMWGG-SG2.1.1 are available for the members of CCM WGG and SG2.1.1 on the website of the BIPM www.bipm.org (see Consultative Committees; CMM; Working Group on Gravimetry).

Leonid Vitushkin
Chairman of SG 2.1.1 and CCM WGG.

Appendix 3

Activities of IAG Subcommission 2.2: Spatial and Temporal Gravity Field and Geoid Modelling

Martin Vermeer

18th March 2005

1 Reporting period

This report covers the Subcommission's history from its official creation in Sapporo, Japan in 2003.

2 Terms of Reference

The subjects of study that the Sub-commission supports and promotes can be summarized, without claim to completeness, as follows. Research work in the spatial domain concentrates on:

- Global and regional gravity modelling
- Topographic/isostatic modelling
- Downward and upward continuation problems
- Boundary value problem approaches
- Spectral techniques like (but not limited to) spherical harmonics
- Height theory and height systems
- Geodetic aspects of satellite radar altimetry

Studies in the temporal domain of the gravity field include, among others, the following:

- Tides
- The effect of postglacial land uplift
- Time derivatives of the J_n
- Short/medium term gravity change due to movements of air and water
- Anthropogenic gravity changes.

3 Steering Committee and membership

Martin Vermeer (Chair) – Finland	marti.vermeer@hut.fi
Bernard Ducarme – Belgium	bernard@ksb-orb.oma.be
Michael Kuhn – Australia	kuhnm@vesta.curtin.edu.au
Dimitrios Tsoulis – Germany... Greece	tsoulis@topo.auth.gr
Bernhard Heck – Germany	heck@gik.uni-karlsruhe.de
Zdenek Martinec – Germany	zdenek@gfz-potsdam.de
Christopher Kotsakis – Canada	kotsakis@geomatics.ucalgary.ca

As for the Subcommission's members, we have a mailing list of interested people in which no distinction is being made between full and corresponding members. These are almost 40 people that your chairman knows to be or have been active in the field of the Subcommission. During the reporting period only part of these people actually responded to the initial invitation or otherwise participated in the work.

4 Activities

4.1 Subcommission

The main activity was undoubtedly our participation in the Porto International IAG Symposium GGSM "Gravity, Geoid and Space Missions" in 2004. At this meeting, we organized a splinter meeting of the Subcommission, which was well attended.

A website has been set up:

`http://www.hut.fi/~mvermeer/IAGSC2.2.html`

but is still incomplete.

The current report includes contributions by Michael Kuhn, Dan Roman, Dimitris Tsoulis, Heiner Denker, Artu Ellmann and Frank Lemoine.

- Dan Roman of the National Geodetic Survey, Washington DC, reported on the national geoid determination effort [RWHH04], which includes airborne gravity missions in collaboration with Naval Research Lab in the seas surrounding the country.
- Dimitris Tsoulis, who is involved with a number of colleagues in finding ways of assessing available gravity field models by connecting them with known structures in the Earth's interior. This work relates to IAG Study Group 2.2, but also the the new satellite gravity missions.
- Heiner Denker, who reported [DBB+05] on the European Gravity and Geoid Project, a regional application in practice of the subject area of our Subcommission. The ambitious effort is envisaged to exploit many different data types and several different techniques, but with a focus on gravimetric-topographic geoid determination using remove-restore.

  For the first time, also satellite mission data is included: already improvements by up to 60% are seen when using GRACE data compared to the previous European geoid model EGG97, while also systematic errors are substantially less. Accurate determination of W_0will make it possible to contribute to the establishment of a new, globally defined European vertical datum.
- Artu Ellmann reported on ongoing work of the Vancouver group, on subjects like gravity field studies, e.g., the Stokes-Helmert method of solving the geodetic BVP, and the rigorous determination of orthometric heights. A number of publications are included below.
- Frank Lemoine provided a draft of an upcoming article[RLK+05] on the GRACE work also presented in Porto, where seasonal ground water variations in the Amazone and similar river basins can actually be monitored gravimetrically from space.

4.2 Scientific results

As Frank Lemoine also pointed out, the big development in the field of study covered by the Subcommission was the explosion of scientific studies prompted by the becoming available of the first CHAMP and GRACE mission results. A synthesis is represented by the publication of the combination geopotential model EIGEN-CG01C, comprising 860 days of CHAMP data, 200 days of GRACE data, and terrestrial gravimetry and satellite radar altimetry, cf.

`http://www.gfz-potsdam.de/pb1/op/grace/results/index_RESULTS.html`.

We should mention:

- The determination of ever more precise global geopotential and geoid models (e.g., [RSF+05, TBWR04])
- Their validation against, e.g., GPS and DORIS results[WH04]
- The measurement by GRACE satellite gravimetry of ground and ocean water level variations of various kinds[TBR+04]

- The validation of these measurements against hydrological and ocean circulation models [AHL04, AH05, RFC+04, RCB04, RCR+04] and satellite altimetry [CWN04]
- Other methodogical studies [HJS04, GTS05, MTGD04, CWTR04].

It appears that today, global geoid models can be robustly determined at cm-level accuracy up to harmonic degree 150, and seasonal ground water variations studied on the several-mm level on subcontinental (river basin) scales.

Let us place this in historical perspective: those scientists preparing for and planning missions like the now succesful CHAMP and GRACE — and hopefully, GOCE — have thus been amply vindicated already.

4.3 IAG Study Group 2.2

This study group, "Forward Gravity Field Modelling Using Global Databases", chairman Michael Kuhn, reported separately. This section presents his report, slightly edited. The below publications list contains references from that report. It covers the period from the creation of the group in August 2003 and does not claim completeness.

4.3.1 Primary Objectives of the SG

The primary objective of the SG is to investigate the use of different global datasets describing the Earth's mass distribution for gravity field recovery and interpretation, using forward gravity field methods (direct application of Newton's integral). Special focus is the employment of high-resolution digital elevation models as well as datasets on the structure of crust and mantle to recover high-frequency information of the Earth's gravity field. Furthermore, these data can be used to study the behaviour of gravity inside the (topographic) masses. Summarising, the SG will mainly focus on the following generic items:

- Construction of forward gravity field models using geophysical data
- Interpretation of forward gravity field modelling results
- Application of forward modelling results in gravity field determination

4.3.2 SG Membership, full members (active)

Michael Kuhn (Australia) (Chair) M.Kuhn@curtin.edu.au
Dimitris Tsoulis (Germany) (Vice-Chair) tsoulis@topo.auth.gr
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4.3.3 SG membership, corresponding members

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4.3.4 Activities of the SG

Discussion of the terms of references: After the creation of the SG in late 2003 the group's members discussed the current terms of references as well as expressed their personal views and ideas on the subject of this SG. The result of this discussion led to the final version of the terms of references.

Installation of a web-page: A web-page of the group's activities has been created, which summarises the activities of the SG as well as a list of relevant publications. Two mirrored versions of the web-page are located at Curtin University of Technology, Perth, Western Australia, as well as Aristotle University of Thessaloniki, Greece.

Addresses:

http://www.cage.curtin.edu.au/~kuhnm/IAG_SG2.2/intex.html

and

http://users.auth.gr/~tsoulis/IAG_SG2.2/index.html.

Meeting at the GGSM2004 conference: The first meeting of the Study Group was held at the GGSM2004 Symposium in Porto, Portugal. It was open for members as well as nonmembers. The meeting had mostly two objectives:

1. Introduction of the group's members in order to present their interests. Each participant of the meeting got the possibility to give a brief introduction as well as to provide some information on his or her research area and interest in the SG.
2. How to focus the group's resources on one particular study area. An extensive and lengthy discussion took place regarding a smart use of the group's resources. The background to this point was the proposal of a more intense focus on one particular aspect of the SG, which might be an achievable goal. However, all participants are strongly encouraged to continue their own research and if possible sharing their results with the SG.

It could be seen that most participants either directly deal with forward gravity field modelling or consider it as an important/helpful tool in gravity field modelling. Two main categories of use could be identified:

1. Use of forward gravity modelling results for data smoothing in order to get better data properties (e.g. interpolation and downward continuation of gravity data).
2. Use of forward gravity modelling results for geophysical interpretations of the Earth s interior (e.g. topographic/isostatic models).

The group agreed that the development of software/algorithms in forward gravity field modelling is a suitable subject to be studied by the SG in more detail. It has been identified that most group members use an algorithm, which is somehow based on prism formulae, which is very time consuming. Therefore, this point is central for forward gravity field modelling as all studies depend on fast and reliable software algorithms. Focus should be given on different ways to obtain fast and reliable forward gravity modelling results. Briefly discussed was the approach using spherical shell elements (tesseroids) rather than prisms as well as the development of fast space domain forward modelling algorithms with an optimal way of handling the required computer memory.

5 Publications

Below we list some publications by members of the Subcommission (and others) that are relevant to the field of the Subcommission according to the Terms of Reference. The list includes the presentations at the Porto Symposium in Session 8: "Temporal gravity variations: modeling and measurements".

This reference list is also found, in richly cross-refererenced form, on the Subcommission's web site, at `http://www.hut.fi/~mvermeer/bib2html/index.html`.

References

[AE04] H Abd-Elmotaal. Long-period temporal variation of the gravity field. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Proceedings-CD, 2004.

[AH05] OB Andersen and J Hinderer. Global inter-annual gravity changes from GRACE: Early results. *Geophys. Res. Lett.*, 32(1), 2005. L01402.

[AHL04] OB Andersen, J Hinderer, and FG Lemoine. Seasonal gravity field variations from GRACE and hydrological models. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[BCF+04] I Baran, SJ Classens, WE Featherstone, SA Holmes, M Kuhn, and P Vanícek. First Results of Australian Synthetic Earth Gravity Model (AUSSEGM). In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Proceedings-CD, 2004. Poster presentation.

[BH04] RJ Bingham and K Haines. Decadal Ocean Bottom Pressure Variability and its Associated Gravitational Effects in a Coupled Ocean–Atmosphere Model. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[BKC+05] I Baran, M Kuhn, S Claessens, WE Featherstone, SA Holmes, and P Vanícek. A synthetic Earth gravity model specifically for testing regional gravimetric geoid determinations. *Journal of Geodesy*, 2005. Submitted February 2005.

[CWN04] DP Chambers, J Wahr, and RS Nerem. Preliminary observations of global ocean mass variations with GRACE. *Geophys. Res. Lett.*, 31(13), July 2004. L13310.

[CWTR04] JL Chen, CR Wilson, BD Tapley, and JC Ries. Low degree gravitational changes from GRACE: Validation and interpretation. *Geophys. Res. Lett.*, 31(22), 2004. L22607.

[DBB+05] H Denker, J-P Barriot, R Barzaghi, R Forsberg, J Ihde, A Kenyeres, U Marti, and IN Tziavos. Status of the European Gravity and Geoid Project EGG. In *Proceedings GGSM2004*, Porto, 2005.

[Den04] H Denker. Evaluation of SRTM3 and GTOPO30 terrain data in Germany. In *Proceedings GGSM2004, Porto*, 2004.

[GTS05] C Gruber, D Tsoulis, and N Sneeuw. CHAMP accelerometer calibration by means of the equation of motion and an a-priori gravity model. *Zeitschrift für Vermessungswesen*, 2005. In press.

[HJS04] S-C Han, C Jekeli, and CK Shum. Time-variable aliasing effects of ocean tides, atmosphere, and continental water mass on monthly mean GRACE gravity field. *J. Geophys. Res.*, 109 (B4)(B04403), 2004. doi:10.1029/ 2003JB002501.

[JMPS04] F Jarecki, J Müller, S Petrovic, and P Schwintzler. Temporal gravity variations in GOCE gradiometric data. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[JV05] J Janak and P Vanicek. Mean free-air gravity anomalies in the mountains. *Studia Geophysica et Geodaetica*, 49:31 – 42, 2005.

[KF02a] M Kuhn and WE Featherstone. On the construction of a synthetic Earth gravity model. In IN Tziavos, editor, *Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission*, pages 189–194. Ziti Editions, Greece, 2002.

[KF02b] M Kuhn and WE Featherstone. On the optimal spatial resolution of crustal mass distributions for forward gravity field modelling. In IN Tziavos, editor, *Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission*, pages 195–200. Ziti Editions, Greece, 2002.

[KF05] M Kuhn and WE Featherstone. Construction of a synthetic Earth gravity model by forward gravity modelling. In *The Proceedings of the International Association of Geodesy: A Window on the Future of Geodesy*, volume 128 of *IAG Symposia*, pages 350–355. Springer Berlin, Heidelberg, New York, 2005.

[KS04a] JF Kirby and CJ Swain. Global and local isostatic coherence from the wavelet transform. *Geophys. Res. Lett.*, 31(24), 2004. L24608, doi: 10.1029/2004GL021569.

[KS04b] J Kusche and EJO Schrama. Mass redistribution from global GPS timeseries and GRACE gravity fields; inversion issues. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[KS05] M Kuhn and K Seitz. Evaluation of Newton's integral in space and frequency domain. In F Sansó, editor, *The Proceedings of the International Association of Geodesy: A Window on the Future of Geodesy*, volume 128 of *IAG Symposia*. Springer Berlin, Heidelberg, New York, 2005.

[KVS+04] R Kingdon, P Vanicek, M Santos, A Ellmann, and R Tenzer. Toward an improved height system for Canada. *Geomatica*, 2004. submitted Oct. 2004.

[MEH+04] J Mäkinen, A Engfeldt, BG Harsson, H Ruotsalainen, G Strykowski, T Oja, and D Wolf. The Fennoscandian Land Uplift Gravity Lines 1966-2003. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[MTGD04] J Müller, L Timmen, O Gitlein, and H Denker. Gravity changes in the Fennoscandian land uplift area to be observed by GRACE and absolute gravimetry. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[NKSH03] P Novák, M Kern, K-P Schwarz, and B Heck. Evaluation of band-limited topographical effects in airborne gravimetry. *Journal of Geodesy*, 76:597–604, 2003.

[NVMV01] P Novák, P Vanícek, Z Martinec, and M Véronneau. Effects of the spherical terrain on gravity and the geoid. *Journal of Geodesy*, 75:491–504, 2001.

[R+04] Ch Reigber et al. Earth gravity field and seasonal variability from CHAMP. In *Earth Observation with CHAMP*, pages 25–30. Springer Verlag, 2004.

[RCB04] G Ramillien, A Cazenave, and O Brunau. Global time variations of hydrological signals from GRACE satellite gravimetry. *Geophysical Journal International*, 158(3):813–826, Sep. 2004.

[RCR+04] G Ramillien, A Cazenave, Ch Reigber, R Schmidt, and P Schwintzer. Recovery of global time-variations of surface water mass by GRACE geoid inversion. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[RFC+04] M Rodell, JS Famiglietti, J Chen, SI Seneviratne, P Viterbo, S Holl, and C Wilson. Basin scale estimates of evapotranspiration using GRACE and other observations. *Geophys. Res. lett*, 31(20), 2004. L20504.

[RLK+05] DD Rowlands, SB Luthcke, SM Klosko, FGR Lemoine, DS Chinn, JJ McCarthy, CM Cox, and OB Andersen. Resolving mass flux at high spatial and temporal resolution using GRACE intersatellite measurements. *Geophys. Res. Lett*, 32(L04310), 2005. doi:10.1029/2004GL021908.

[RSF+05] C Reigber, R Schmidt, F Flechtner, R Konig, U Meyer, KH Neumayer, P Schwintzler, and SY Zhu. An Earth gravity field model complete to degree and order 150 from GRACE: EIGEN-GRACE02S. *Journal of Geodynamics*, 39(1):1–10, Jan. 2005.

[RWHH04] DR Roman, YM Wang, W Henning, and J Hamilton. Assessment of the New National Geoid Height Model - GEOID03. *Surveying and Land Information Systems*, 64(3):153–162, 2004.

[SK03a] CJ Swain and JF Kirby. The coherence method using a thin anisotropic elastic plate model. *Geophys. Res. Lett.*, 30(19):2014, 2003. doi: 10.1029/2003GL018350.

[SK03b] CJ Swain and JF Kirby. The effect of noise on estimates of the elastic thickness of the continental lithosphere by the coherence method. *Geophys. Res. Lett.*, 30(11):1574, 2003. doi:10.1029/2003GL017070.

[SO04] W Sun and S Okubo. Methods to study co-seismic deformations detectable by satellite gravity mission GRACE. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[ST03] F Sansó and CC Tscherning. Fast spherical collocation: theory and examples. *Journal of Geodesy*, 77:101–112, 2003.

[SW04] K-W Seo and CR Wilson. Estimating GRACE Aliasing Errors. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[TÓ4] Gy Tóth. The gravimetric-geodynamic boundary value problem. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[TBR+04] BD Tapley, S Bettadpur, JC Ries, PF Thomson, and MM Watkins. GRACE measurements of mass variability in the Earth system. *Science*, 305(5683):503–505, 2004. doi:10.1126/science.1099192.

[TBT04] PF Thomson, SV Bettadpur, and BD Tapley. Impact of short period, non-tidal, temporal mass variability on GRACE gravity estimates. *Geophys. Res. Lett.*, 31(L06619), 2004. doi:10.1029/2003GL019285.

[TBWR04] BD Tapley, S Bettadpur, M Watkins, and C Reigber. The gravity recovery and climate experiment: Mission overview and early results. *Geophys. Res. Lett.*, 31(9), May 2004. L09607.

[TGS04] D Tsoulis, C Gruber, and N Sneeuw. A method for the estimation of bias and scale parameters for the CHAMP accelerometer. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Proceedings-CD, 2004.

[TGS05] D Tsoulis, C Gruber, and N Sneeuw. A novel approach for the calibration of the champ accelerometer using short data spans. *Bollettino di Geodesia e Scienze Affini*, 2005. In press.

[TS05a] D Tsoulis and B Stary. First results towards an isostatically compensated reference Earth model. In F Sansó, editor, *A Window on the Future of Geodesy*, volume 128. IAG Symposia Series, 2005. In press.

[TS05b] D Tsoulis and B Stary. An isostatic compensated gravity model using spherical layer distributions. *Journal of Geodesy*, 2005. In press.

[Tso03a] D Tsoulis. Numerical investigations in the analytical and semi-analytical computation of gravimetric terrain effects. *Studia geophysica et geodaetica*, 47(3):481–494, 2003.

[Tso03b] D Tsoulis. Potential field determination due to the given masses of a Digital Terrain Model for a system of target points. *Bollettino di geofisica teorica ed applicata*, 44(2):129–138, 2003.

[Tso03c] D Tsoulis. Principles and the scientific use of current and planned dedicated satellite gravity field missions. In A Dermanis, editor, *From Stars to Earth and Culture, Volume in honour of the memory of Professor Alexandros Tsioumis*, pages 259–266. Ziti Editions, Thessaloniki, 2003.

[Tso03d] D Tsoulis. Terrain modeling in forward gravimetric problems: a case study on local terrain effects. *Journal of Applied Geophysics*, 54(1/2):145–160, 2003.

[Tso03e] D Tsoulis. The use of generally shaped polyhedra in gravity field modeling and geophysical interpretation. In A Dermanis, editor, *From Stars to Earth and Culture, Volume in honour of the memory of Professor Alexandros Tsioumis*, pages 267–272. Ziti Editions, Thessaloniki, 2003.

[Tso04a] D Tsoulis. Band-limited investigations of some isostatic Earth models. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, 2004, Porto*, page 6 pp. Proceedings-CD, 2004. Session 5: Topographic data bases and gravity modeling.

[Tso04b] D Tsoulis. Recent developments in modelling the gravitational signal of known mass distributions and their implications in geodetic and geophysical applications of different scales. In *Proceedings of the FIG Symposium on Modern technologies, education and professional practice in geodesy and related fields, November 4-5*, pages 151–158, Sofia, 2004.

[Tso04c] D Tsoulis. Spherical harmonic analysis of the CRUST 2.0 global crustal model. *Journal of Geodesy*, 78(1/2):7–11, 2004.

[Tso04d] D Tsoulis. Two Earth gravity models from the analysis of global crustal data. *Zeitschrift für Vermessungswesen*, 129(5/2004):311–316, 2004.

[Tso05] D Tsoulis. The derivation and analysis of topographic/isostatic gravity models up to degree and order 1082. *Bollettino di Geodesia e Scienze Affini*, 2005. In press.

[TT03] D Tsoulis and IN Tziavos. Comparison of some existing methods for the computation of terrain corrections in local gravity field modelling. In IN Tziavos, editor, *Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission*, pages 156–160. Ziti Editions, Greece, 2003.

[TVN03] R Tenzer, P Vanícek, and P Novák. Far-zone contributions to topographical effects in the Stokes- Helmert method of the geoid determination. *Studia geophysica et geodaetica*, 47(3):467–480, 2003.

[TVS+05] R Tenzer, P Vanicek, M Santos, WE Featherstone, and M Kuhn. Rigorous orthometric heights. *Journal of Geodesy*, 2005. in press.

[TWP03] D Tsoulis, H Wziontek, and S Petrovic. A bilinear approximation of the surface relief in terrain correction computations. *Journal of Geodesy*, 77(5/6):338–344, 2003.

[VCS04] L Völgyesi, G Csapó, and Z Szabó. Relation between time variation of gravity field and vertical surface movements in the Pannonian Basin. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[VNM04] P Vanicek, P. Novak, and B Meurers. On the evaluation of Newton integrals in geodetic coordinates: Exact and in spherical approximation. *Contributions to Geophysics and Geodesy*, 34(4), 2004.

[VT04] L Völgyesi and Gy Tóth. Modelling gravity gradient variation due to water mass fluctuations. In *IAG-Meeting Geoid and Space Missions GGSM2004, August 30 – September 3, Porto*. Springer Verlag, 2004.

[VTS+04] P Vanicek, R Tenzer, LE Sjöberg, Z Martinec, and WE Featherstone. New views of the spherical Bouguer gravity anomaly. *Journal of Geophysics International*, 159(2):460 – 472, 2004.

[VV05] P Vajda and P Vanicek. Input for the TFM technique for gravity interpretation. *Studia Geophysica et Geodaetica*, 2005. submitted Aug. 2004.

[VVM04] P Vajda, P Vanicek, and B Meurers. On the removal of the effect of topography on gravity disturbance in gravity data inversion or interpretation. *Contributions to Geophysics and Geodesy*, 34(4), 2004.

[VVNM04] P Vajda, P Vanicek, P Novak, and B Meurers. On some numerical aspects of primary indirect topographical effect computation in the Stokes-Helmert theory of geoid determination. *Revista Cartografica*, 76 – 77:71 – 77, 2004.

[WH04] P Willis and MB Heflin. External validation of the GRACE GGM01C gravity field using GPS and DORIS positioning results. *Geophys. Res. Lett*, 31(13), July 2004. L13616.

[WSZV04] J Wahr, S Swenson, V Zlotnicki, and I Velicogna. Time-variable gravity from GRACE: First results. *Geophys. Res. Lett.*, 31(L11501), 2004. doi:10.1029/2004GL019779.

Appendix 4

Activity Report of the IAG Study Group 2.2 Forward Gravity Field Modelling Using Global Databases

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February 2005

Period Covered

This activity report gives a summary of the work undertaken by the IAG SG 2.2 since its creation in August 2003. Importantly, it summarises only the contributions of some members. Our apologies to all whose results are omitted in this report.

Primary Objectives of the SG

The primary objective of this study group (SG) is to investigate the use of different global datasets describing the Earth's mass distribution for gravity field recovery and interpretation, using forward gravity field methods (direct application of Newton's integral). Special focus of the SG is the employment of high-resolution digital elevation models as well as datasets on the structure of crust and mantle to recover high-frequency information of the Earth's gravity field. Furthermore, these data can be used to study the behaviour of gravity inside the (topographic) masses. Summarising, the SG will mainly focus on the following generic items:

- Construction of forward gravity field models using geophysical data
- Interpretation of forward gravity field modelling results
- Application of forward modelling results in gravity field determination

Current Member List

We have to acknowledge that the background of the group's members is very different ranging from geodesy, geophysics to mathematics.

FULL MEMBERS (active)

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Activities of the SG

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See html addresses:
http://www.cage.curtin.edu.au/~kuhnm/IAG_SG2.2/intex.html
http://users.auth.gr/~tsoulis/IAG_SG2.2/index.html

Meeting at the GGSM2004 conference: The first meeting of the SG was held at the GGSM2004 meeting at Porto, Portugal. It was open for members as well as non-members. The meeting had mostly two objectives:

(i) Introduction of the group's members in order to present their interests. Each participant of the meeting got the possibility to give a brief introduction as well as to provide some information on his or her research area and interest in the SG.

(ii) How to focus the group's resources on one particular study area. An extensive and lengthy discussion took place regarding a *smart* use of the group's resources. The background to this point was the proposal of a more intense focus on one particular aspect of the SG, which might be an achievable goal. However, all participants are strongly encouraged to continue their own research and if possible sharing their results with the SG.

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The group agreed that the development of software/algorithms in forward gravity field modelling is a suitable subject to be studied by the SG in more detail. It has been identified that most group members use an algorithm, which is somehow based on prism formulae, which is very time consuming. Therefore, this point is central for forward gravity field modelling as all studies depend on fast and reliable software algorithms. Focus should be given on different ways to obtain fast and reliable forward gravity modelling results. Briefly discussed was the approach using spherical shell elements (tesseroids) rather than prisms as well as the development of fast space domain forward modelling algorithms with an optimal way of handling the required computer memory.

Publications of SG members as well as others related to the SG's aim

This is a summary of publications (obtained by the chair up until the date of the report) related to the objectives of the SG published by group members as well as others.

Allasia G (2004): Recursive and parallel algorithms for approximating surface data on a family of lines or curves. In P. Ciarlini et al. (eds.): Advanced mathematical and computational tools in metrology VI, World Scientific, 2004, pp. 137—148

Baran, I., Kuhn, M., Claessens, S., Featherstone, W.E., Holmes, S.A., Vaníček, P. (submitted February 2005): A synthetic Earth gravity model specifically for testing regional gravimetric geoid determinations. Journal of Geodesy.

Denker H. (2004). Evaluation of SRTM3 and GTOPO30 terrain data in Germany. Proceed. GGSM2004, Porto.

De Rossi A (2004): Spherical interpolation of large scattered data sets using zonal basis functions. Proceedings of the sixth International Conference on Mathematical Methods for Curves and Surfaces, July 1-6, 2004, Tromsø, Norway.

Gruber C, Tsoulis D (2003) Kalibrierung des CHAMP Akzelerometers mittels der Kräftebilanzmethode, Presented at the *Geodätische Woche 2003, Hamburg, Session 5: Geodätische Aspekte neuartiger Satellitenmissionen: Gravitationsfeld, Bahnberechnung, Altimetrie, SAR, neue Sensoren*

Gruber C, Tsoulis D, Sneeuw N (2004) CHAMP kinematic orbit processing for use in gravity field determination, Oral Presentation at the Joint CHAMP/GRACE Science Meeting, Geoforschungszentrum Potsdam, July 5-8, 2004

Gruber C, Tsoulis D, Sneeuw N (2005) CHAMP accelerometer calibration by means of the equation of motion and an a-priori gravity model, *Zeitschrift für Vermessungswesen*, in press

Kirby, J.F., and C.J. Swain (2004). Global and local isostatic coherence from the wavelet transform, *Geophysical Research Letters*, 31(24), L24608, doi: 10.1029/2004GL021569.

Novák P, Vaníček P, Martinec Z, Véronneau M (2001): Effects of the spherical terrain on gravity and the geoid. JoG 75: 491-504.

Novák P, Kern M, Schwarz K-P, Heck B (2003): Evaluation of band-limited topographical effects in airborne gravimetry. JoG 76: 597-604.

Kuhn M, Featherstone WE (2003): On the optimal spatial resolution of crustal mass distributions for forward gravity field modelling. In: Tziavos I.N. (ed) Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission, Ziti Editions, Greece, 195-200.

Kuhn M, Featherstone WE (2003): On the construction of a synthetic Earth gravity model. In: Tziavos I.N. (ed) Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission, Ziti Editions, Greece, 189-194.

Kuhn M, Featherstone WE (2005): Construction of a synthetic Earth gravity model by forward gravity modelling. In F. Sansò (ed.): The Proceedings of the International Association of Geodesy: A Window on the Future of Geodesy, IAG Symposia 128:350-355, Springer Berlin, Heidelberg, New York.

Kuhn M, Seitz K (2005): Evaluation of Newton's integral in space and frequency domain. In F. Sansò (ed.): The Proceedings of the International Association of Geodesy: A Window on the Future of Geodesy, IAG Symposia 128:, Springer Berlin, Heidelberg, New York.

Roman D.R., Y.M. Wang,, W. Henning, and J Hamilton (2004): Assessment of the New National Geoid Height Model - GEOID03, Surveying and Land Information Systems, 64, 3, 153-162.

Swain, C.J., and J.F. Kirby (2003). The effect of 'noise' on estimates of the elastic thickness of the continental lithosphere by the coherence method, *Geophysical Research Letters*, 30(11), 1574, doi:10.1029/2003GL017070.

Swain, C.J., and J.F. Kirby (2003). The coherence method using a thin anisotropic elastic plate model, *Geophysical Research Letters*, 30(19), 2014, doi: 10.1029/2003GL018350.

Tenzer R, Vaníček P, Novák P (2003): Far-zone contributions to topographical effects in the Stokes-Helmert method of the geoid determination. *Studia geophysica et geodaetica*, 47 (3), pp 467 – 480

Tsoulis D (2003) Potential field determination due to the given masses of a Digital Terrain Model for a system of target points, *Bollettino di geofisica teorica ed applicata*, 44 (2), pp 129 – 138

Tsoulis D (2003) Numerical investigations in the analytical and semi-analytical computation of gravimetric terrain effects, *Studia geophysica et geodaetica*, 47 (3), pp 481 – 494

Tsoulis D (2003) Terrain modeling in forward gravimetric problems: a case study on local terrain effects, *Journal of Applied Geophysics*, 54 (1/2), pp 145 – 160

Tsoulis D (2003) Principles and the scientific use of current and planned dedicated satellite gravity field missions, In: *From Stars to Earth and Culture*, Volume in honour of the memory of Professor Alexandros Tsioumis (Ed: A Dermanis), pp 259 – 266, Ziti Editions, Thessaloniki

Tsoulis D (2003) The use of generally shaped polyhedra in gravity field modeling and geophysical interpretation, In: *From Stars to Earth and Culture*, Volume in honour of the memory of Professor Alexandros Tsioumis (Ed: A Dermanis), pp 267 – 272, Ziti Editions, Thessaloniki

Tsoulis D (2003) Validierung verschiedener isostatisch kompensierten Gravitationsfelder anhand einer globalen harmonischen Synthese und Vergleich mit existierenden Modellen, Presented at the *Geodätische Woche 2003, Hamburg, Session 1: Geoid, Randwertaufgaben, Quasi-Geoid*

Tsoulis D, Wziontek H, Petrovic S (2003) A bilinear approximation of the surface relief in terrain corection computations, *Journal of Geodesy*, 77 (5/6), pp 338 – 344

Tsoulis D, Tziavos IN (2003): A comparison of some existing methods for the computation of terrain corrections in local gravity field modelling. In: Tziavos I.N. (ed) Gravity and Geoid 2002. 3rd Meeting of the International Gravity and Geoid Commission, Ziti Editions, Greece, 156-160.

Tsoulis D (2004) Spherical harmonic analysis of the CRUST 2.0 global crustal model, *Journal of Geodesy*, 78 (1/2), pp 7 – 11

Tsoulis D (2004) Two Earth gravity models from the analysis of global crustal data, *Zeitschrift für Vermessungswesen*, 129 (5/2004), pp 311 – 316

Tsoulis D (2004) Band-limited investigations of some isostatic Earth models, Oral presentation at the IAG-Meeting *Geoid and Space Missions GGSM2004*, August 30 – September 3, Porto, 2004, Session 5: Topographic data bases and gravity modeling. Proceedings-CD, 6 pp

Tsoulis D (2004) Recent developments in modelling the gravitational signal of known mass distributions and their implications in geodetic and geophysical applications of different scales, Proceedings of the FIG Symposium on „*Modern technologies, education and professional practice in geodesy and related fields*", Sofia, November 4-5, 2004, 151-158 pp

Tsoulis D, Gruber C, Sneeuw N (2004) A method for the estimation of bias and scale parameters for the CHAMP accelerometer, Poster presented at the IAG-Meeting *Geoid and Space Missions GGSM2004*, August 30 – September 3, Porto, 2004, Session 1: Gravity field modeling from satellite missions. Proceedings-CD, 6 pp

Tsoulis D (2005) The derivation and analysis of topographic/isostatic gravity models up to degree and order 1082, *Bollettino di Geodesia e Scienze Affini*, in press

Tsoulis D, Stary B (2005) An isostatic compensated gravity model using spherical layer distributions, *Journal of Geodesy*, in press

Tsoulis D, Stary B (2005) First results towards an isostatically compensated reference Earth model, presented at the XXIII General Assembly of the International Union of Geodesy and Geophysics, 30.06-11.07.03, Sapporo, Japan, In: A Window on the Future of Geodesy (Ed: F Sanso), IAG Symposia Series, Volume 128, in press

Tsoulis D, Gruber C, Sneeuw N (2005) A novel approach for the calibration of the CHAMP accelerometer using short data spans, *Bollettino di Geodesia e Scienze Affini*, in press

Vaníček P, Novák P, Martinec Z (2001): Geoid, topography, and the Bougouer plate or shell. JoG 75: 21-215.

Vajda P, Vaníček P, Novák P, Meures, B (2004): On the evaluation of Newton integral in geodetic coordinates: exact formulation and spherical approximation. Contributions to Geophysics and Geodesy 34/4: 289-314.

Wolf, KI, Denker, H (2004): Upward continuation of ground data for GOCE callibration/validation purposes. Presentation at the IAG-Meeting *Geoid and Space Missions GGSM2004*, August 30 – September 3, Porto, 2004, Session 5: Topographic data bases and gravity modeling. To appear in the Proceedings-CD, 6 pp

Future Work

- The next official meeting of the SG has been scheduled for the IAG/IASPO meeting 2005, at Cairns, Australia.
- During the first meeting of the SG (during the GGSM2004 conference, Porto, Portugal) the group agreed to organise a session at the IGFS meeting at Istanbul, Turkey in 2006. Apart from being a platform for the group's members to present their actual results this session gives the opportunity to all others to present their latest research in this field. The chair is in contact with the local organising committee.
- As a main outcome of the group's meeting at Porto should be mentioned, that the SG will focus in more detail on software/algorithms used in forward gravity field modelling. Special intention will be given on different ways (other than prism integration) to obtain fast and reliable forward gravity modelling results. All SG members are encouraged to collect available information on this subject (literature research). The information will be collocated on the SG's web-page. Much information should be found in the relevant geophysical literature. After this step it will be attempted to identify suitable study areas, which can be tackled by small groups of few SG members.
- Apart from the modelling and computing issues (algorithm & software) an equally important issue is the interpretation of the obtained gravity models. As the global databases offer now a geometrical means of modelling the different mass distributions in the Earth's interior, it should be feasible to correlate different bandwidths of the available or the newly developed Earth gravity models with the potential contributions due to these fairly well known mass distributions. This line of reasoning should lead eventually to the compilation of Synthetic Earth Gravity Models for which we will possess a better understanding of their geophysical interpretation.

Appendix 5

Midterm Report

IAG Special Group 2.3: Satellite altimetry: data quality improvement and coastal applications

Chair: Cheinway Hwang,
Department of Civil Engineering, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan

1. Introduction

Coastal applications of satellite altimetry in geodesy, geophysics and oceanography have become increasingly important. However, shallow-water altimeter data are prone to errors in range itself, environmental and geophysical corrections. If shallow-water altimeter data are to be useful, the first problem on has to confront is data quality. For example, retracking waveforms of altimetry can produce improved results in altimetric applications. Retracked altimetry will be first used to improve tide modeling and in turn improve coastal gravity field modeling and determination of ocean dynamic topography. The densely distributed Geosat/GM and ERS-1/GM will be the biggest contributors to high frequency components of parameters extracted from altimeter data. Another dense data set, namely, Geosat/GM, has not been retracked for coastal applications. One of the objectives of this current SSG will be to freely provide a database of retracked ERS-1 and Geosat/GM for members interested in applications of these retracked altimeter data. Exchange of data and idea will be also encouraged to maximize the use of improved shallow-water altimeter data.

2. Current activities

1) Retracking Geosat and ERS-1 waveforms
2) Developing improved data processing techniques over shallow waters
3) Developing new theories and computational techniques for gravity modeling from satellite altimetry over shallow waters
4) Evaluation of gravity field models by means of long-term averaged single satellite altimetry crossovers (SSC), derived from altimetry of ERS 1, 2 and Geosat
5) Examination of global ocean laser altimetry in support of cal/val efforts for ICESat (40 Hz, 70 m footprint, 170 m separation). Some specific coastal, river, wetland and lake areas have been examined.

3. Current achievements of members

1) Retracked Geosat and ERS-1 waveforms and improved gravity determination from such data
2) Improved procedure of gravity anomaly computations over shallow waters
3) Calibration factors of the covariance matrices of recent gravity field models checked or corrections suggested.
4) Estimating noise level of 40 Hz laser altimetry to be about 3 cm over quiet waters. Have identified regions of specular reflection over some areas which require further analysis. Have developed several methods for elevation calibration using ocean data.

4. Future activities

1) Distributions of waveform retracking algorithms and retracked altimetry data to SG 2.3 members

2) Continue the current works on retracking, data processing and theory development
3) Organize a satellite altimetry workshop for shallow-water applications of altimetry in 2006.
4) Use of the SSC data and LLC method to explain significantly lower accuracy of recent (mostly only CHAMP-based) models for the lowest degrees and orders.
5) Continue ICESat cal/val, including coastal examinations. Recover data from areas of specular reflection.

5. Publications of members

Hwang, C. and H.Y. Hsu, Gravity anomaly over shallow waters from satellite altimetry: applications of filtering and differenced heights, Proceedings of the 21th Conference on Surveying, Hsinchu, 2002.

Hwang, C., H.Y. Hsu and R.J. Jang, Global mean sea surface and marine gravity anomaly from multi-satellite altimetry: applications of deflection-geoid and inverse Vening Meinesz formulae International Workshop on Satellite Altimetry for Geodesy, Geophysics and Oceanography, Wuhan, Sep 8-13, 2002.

Hwang, C., and H.Y. Hsu, Shallow-water gravity anomaly from satellite altimetry: applications of filters and differenced heights, Third meeting of International Gravity and Geoid Commission, Thessaloniki, Greece, Aug 26-30, 2002.

Hwang C., H.Y. Hsu and R. Jang, Global mean sea surface and marine gravity anomaly from multi-satellite altimetry: applications of deflection-geoid and inverse Vening Meinesz formulae, J. Geod., 76, pp. 407-418, 2002.

Hwang, C., and H. Y. Hsu, Global and local derivations of gravity from satellite altimetry, IUGG2003, Sapporo, June 30- July 11, 2003.

Hwang, C., and H.Y. Hsu, Improved determination of shallow-water gravity from altimetry: use of differenced heights and optimal parameters, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004.

Hwang C., H.Y. Hsu and X. Deng, Marine Gravity Anomaly from Satellite Altimetry: a Comparison of Methods over Shallow Waters. International Association of Geodesy Symposia, 126, pp. 59-66, 2004.

Hwang C., and H.-Y. Hsu, Marine gravity from satellite altimetry over shallow waters: data processing and data types, 2005. (will be submitted to J. Geodyn.)

Klokocnik, J., C.H. Reigber, P. Schwintzer, C.A. Wagner, and J. Kostelecky, Evaluation of pre-CHAMP gravity models GRIM5-S1 and C1 with satellite crossover altimetry, J. Geod., 76, pp. 189-198, 2002.

Klokocnik, J., C.A. Wagner, and J. Kostelecky, Accuracy assessment of Earth gravity field models by means of independent satellite crossover altimetry, 3rd meeting of IGGC Thessaloniki, Greece, August, 2002.

Klokocnik J., J. Kostelecky, C.A. Wagner, and M. Kocandrlova, Geometry and accuracy of bistatic satellite altimetry, IUGG 2003, Sapporo, Japan, July, 2003.

Klokocnik J., J. Kostelecky, C.A. Wagner, and M. Kocandrlova, Geometry and accuracy of bistatic satellite altimetry, 30th Interntl. Symp. on. Remote Sensing of

Environment (SRSE), Honolulu, Hawaii, November, 2003.

Klokocnik, J., C.A. Wagner, and J. Kostelecky, Accuracy assessment of Earth gravity field models by means of independent satellite crossover altimetry, International Association of Geodesy Symposia, 126, pp. 161-165, 2004.

Klokocnik J., J. Kostelecky, and M. Kocandrlova, Geometry, accuracy, and position of ocean reflecting points in bistatic satellite altimetry, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004.

Klokocnik J., J. Kostelecky, C.A. Wagner, P. Schwintzer, C. Foerste, and R. Scharroo, Evaluation of the accuracy of the EIGEN-1S and -2 CHAMP-derived gravity field models by satellite crossover altimetry, J. Geod., 2004. (on line already publ)

Kostelecky J., and J. Klokocnik, Geometry and accuracy of reflecting points in bistatic satellite altimetry, J. Geod., 2005. (in review)

Lillibridge, J.L., W.H.F. Smith, R. Scharroo, and D.T. Sandwell, The Geosat Geodetic Mission Twentieth Anniversary Edition Data Product, AGU Fall meeting, 2004.

Smith,W.H.F. and D.T. Sandwell, Improved Global Marine Gravity Field From Reprocessing of Geosat and ERS-1 Radar Altimeter Waveforms, AGU Fall meeting, 2004.

Sandwell, D.T., and W.H.F. Smith, Transform Faults, Gravity Lineaments, and Seamounts, AGU Fall meeting, 2004.

Tziavos, I.N., G.S. Vergos, V. Kotzev, and L. Pashova, Mean sea level and sea surface topography studies in the Black Sea and the Aegean, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004.

Vergos, G.S., I.N. Tziavos, and V.D. Andritsanos, On the Determination of Marine Geoid Models by Least-Squares Collocation and Spectral Methods Using Heterogeneous Data, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004.

Vergos, G.S., I.N. Tziavos, and V.D. Andritsanos, Gravity Data Base Generation and Geoid Model Estimation Using Heterogeneous Data, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004. (accepted for publication to the conference proceedings).

Vergos, G.S., and I.N. Tziavos, A geodetic perspective to the estimation of the quasi-stationary sea surface topography and current velocities in a closed sea area, IAG Intertnl. Symp., GGSM2004, Porto, Portugal, Aug 31- Sep 5, 2004.

Wagner, C.A., J. Klokocnik, and J. Kostelecky, Reflection altimetry for oceanography and geodesy, Joint Assemblies of IAPSO-IABO-IAG, Mar del Plata, October, 2001.

Wagner, C.A., and J. Klokocnik, The value of ocean reflections of GPS signals to

enhance satellite altimetry: data distribution and error analysis, J. Geod., 77, pp. 128-138, 2003.

Appendix 6

Sub-Commission 2.3 – Dedicated Satellite Gravity Mapping Missions
Commission 2 (Gravity Field)
International Association of Geodesy (IAG)

Report 2003-2004

http:/www.deos.tudelft.nl/~pieter/IAG/sc23.htm

Pieter Visser (chair)

Activities:

- Organization of Session 1 of The International Symposium on Gravity, Geoid, and Space Missions (GGSM2004), 30 August – 3 September, 2004, Porto, Portugal (19 oral/27 poster presentations, 17 fully reviewed papers for proceedings).
- Proposal for a Joint Working Group between the International Gravity Field Service (IGFS) and IAG Commission 2 by Dr. Jianliang Huang (Geodetic Survey Division, CCRS, Nrcan, Canada) and Dr. Christopher Kotsakis (Aristotle University of Thessaloniki, Greece).

Future plans and activities:

- The sub-commission members are all actively involved in the analysis of CHAMP and GRACE data and are preparing for missions like GOCE and COSMIC (and even for GRACE and GOCE follow-ons). It is planned to monitor relevant activities and stimulate participation in workshops and conferences, and support/propose dedicated sessions.

Members:

Pieter Visser (DEOS/Netherlands, chair)
Srinivas Bettadpur (CSR/U.S.A.)
Thomas Gruber (IAPG/Germany)
Cheinway Hwang (NCKU/Taiwan)
Radboud Koop (SRON/The Netherlands)
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Appendix 7

Activity Report of Sub-Commission 2.4 "Regional Geoid Determination" for the period: August 2003 - March 2005-03-29

General organization, overview

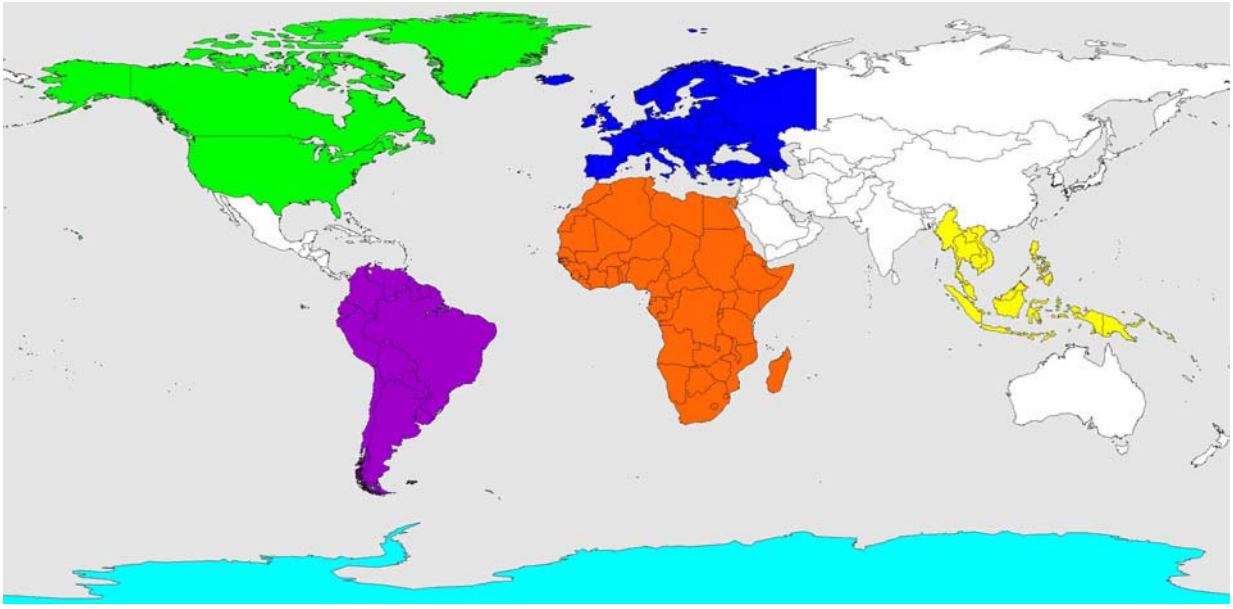
Sub-Commission 2.4 was initiated after the IUGG General Assembly in Sapporo (2003) and covers the following principal objectives:

- coordination of regional geoid projects
- comparison of methods and results, data exchange, comparison with global models
- gravimetric geoid modeling techniques and methods, available software
- GPS/leveling geoid determination:
- methods, comparisons, treating and interpretation of residuals
- common treatment of gravity and GPS/leveling for geoid determination
- geoid applications: GPS heights, sea surface topography, integration of geoid models in GPS receivers, vertical datums
- other topics: topographic effects, downward and upward continuation of terrestrial, airborne, satellite data specifically as applied to geoid modeling

The steering committee of SC 2.4 is formed by the chair and the leaders of the Sub-Commission projects:

Urs Marti	chair
Heiner Denker	CP 2.1: European Gravity and Geoid Project (EGGP)
Marc Véronneau	CP 2.2: North American Geoid Project
Charles Merry	CP 2.3: African Geoid Project
Mirko Scheinert	CP 2.4: Antarctic Geoid Project (AntGP)
Denizar Blitzkov	CP 2.5: Gravity in South America and South American Geoid
Bill Kearsley	CP 2.6: Southeast Asian Geoid

There has been no official meeting of the steering committee until now but there have been many informal contacts especially during the IAG Symposium " Gravity, Geoid and Space Missions" (GGSM2004) in Porto (August 30 - September 3 2004).
The web-site of SC2.4 can be found at http://www.swisstopo.ch/um/sc24.htm, where the reports of the projects and several other information can be found.



Areas covered by the Commission 2 Projects

Meetings, Workshops

The principal meeting of SC2.4 during the reporting period was the GGSM 2004 symposium in Porto (http://www.fc.up.pt/ggsm2004/) where session 3 "Regional Geoid Modeling" was one of the largest sessions with more than 60 oral and poster contributions. The status of some of the SC projects was presented there.
Most of the project leaders used the GGSM2004 to organize a meeting. Some other meetings of the Commission projects are the following:

CP2.1:	Feb. 2004, Milan
CP2.2:	May 2004, Montreal
CP2.3:	Dec 2003, Marrakech
CP2.4:	Sep 2003, Potsdam
	Jul 2004, Potsdam
	Jul 2004, Bremen
	Sep 2004, Herndon VA
	Dec 2004, Hanover
CP2.5:	Sep 2004, Buenos Aires

Measuring Campaigns, computational efforts

Most of the Projects are more involved in collecting available data than in measuring. Exceptions are until now only the AntGP with several activities in Antarctica and the South American project, where several gravity campaigns have been performed in various countries. Most other projects are in the stage of contacting national representatives and in collecting, testing and validating available data (mostly gravity, but also GPS/Leveling, DTM's and global models). For all projects the release of the new global geopotential models from CHAMP and GRACE and the SRTM3 digital elevation model are of enormous help and allowed the computation of some preliminary regional geoid models.

Future plans

The **European** Geoid project advances well. In 2005, a major effort will be undertaken to further update the gravity and terrain data sets, and new preliminary geoid computations will be done based on these data. The project should finish until the next IUGG General Assembly in 2007.
In **North America**, the main goal is to converge the national geoid solutions of the USA and of Canada to one single North American geoid model. Until now, some larger discrepancies are mainly caused because the two agencies do not have the same data holding. A better data exchange process between the agencies is the focus of 2005.
In **Africa,** data collection is very difficult and there still exist large data gaps which could be very efficiently filled by airborne gravimetry. One main problem is to find funding for such surveys.
The **Antarctic** Geoid Project is advancing well. One main goal is to carry out new gravity surveys and to close the polar gap. The most promising method is airborne gravimetry. A second main activity is the built-up of a gravity database for Antarctica.
In **South America,** the collection of gravity data is almost completed. Now, GPS/Leveling data is collected all over the continent in order to derive a set of geoid undulations that will be compared to the gravimetric model. A new gravimetric geoid will be computed as soon as new data sets for Ecuador and Columbia are available.
For the **Southeast Asian** Geoid project, it is rather hard to collect data. First contacts have been established with most relevant agencies in the region. In some countries, the tsunami disaster stopped much of the activities.

Some publications (see also proceedings of the GGSM2004)

Abd-Elmotaal, H. (2003) The Egyptian Geoid EGGG2003. Presented at the 23rd General Assembly of the International Union of Geodesy and Geophysics IUGG, Sapporo, Japan, June 30 – July 11, 2003.

Abd-Elmotaal, H. (2004) The AFH04 Digital Height Models for Africa. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions "GGSM2004", Porto, Portugal, August 30 – September 3, 2004.

Aleshkova, N., V. Masolov, G. Leitchenkov, V. Mandrikov, S. Alyavdin, A. Golynski, and R. Kurinin (2004). Russian Antarctic Gravity Dataset. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Bell, R. (2004). International Polar Year 2007-2008. Presentation at SCAR XXVIII Open Science Conference, IPY Discussion Forum, Bremen, July 28, 2004.

Benahmed Daho, S.A. (2003) Orthometric height computation from GPS observation: case of study - North of Algeria. Proceedings, 2nd Regional Conference of the Fédération Internationale des Géomètres, Marrakech, Morocco, December 2003. CD-ROM publication, paper TS9.3

Benahmed Daho, S.A., Fairhead, J.D., Kahlouche, S. (2004) A procedure for modelling the differences between the gravimetric geoid model and GPS/Levelling data with an example in the North part of Algeria. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions "GGSM2004", Porto, Portugal, August 30 – September 3, 2004.

Benahmed Daho, S.A. (2004) A computer program for the adjustment of combined GPS/levelling/geoid networks: case of study - North of Algeria. *Newton's Bulletin,* 2.

Benahmed Daho, S.A., Fairhead, J.D. (2004) A new quasigeoid computation from gravity and GPS data in Algeria. *Newton's Bulletin,* 2.

Blankenship, D. D., D. L. Morse, I. W. D. Dalziel, L. A. Lawver, J. W. Holt, J. M. Brozena, V. A. Childers, M. J. Siegert, J. L. Bamber, and A. J. Payne (2004). Investigating the crustal elements of the central Antarctic Plate (Icecap): how long-range aerogeophysics is critical to understanding the evolution of the East Antarctic ice sheet. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Coren, F., P. Sterzai, A. Capra, and G. Bitelli (2004). Local gravimetric geoid determination in North Victoria Land (Antarctica). Presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Damaske, D. and M. McLean (2004). Airborne Geophysical Data Acquisition South of the Prince Charles Mountains, East Antarctica. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Denker, H. (2004a). Evaluation of SRTM3 and GTOPO30 terrain data in Germany. Proceed. GGSM2004, Porto.

Denker, H. (2004b). Improved European geoid models based on CHAMP and GRACE results. Proceed. GGSM2004, Porto.

Denker, H., J.-P. Barriot, R. Barzaghi, R. Forsberg, J. Ihde, A. Kenyeres, U. Marti, I.N. Tziavos (2004). Status of the European Gravity and Geoid Project EGGP. Proceed. GGSM2004, Porto.

Denker, H., M. Roland (2003). Compilation and evaluation of a consistent marine gravity data set surrounding Europe. Proceed., IUGG2003, Sapporo, Japan, June30-July11, 2003.

Dietrich, R., H. Miller, and M. Wiehl (2004, Juli). Mass distribution and mass changes in Antarctica: The role of recent and upcoming satellite missions. Oral presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Forsberg, R., S. Kenyon (2004). Gravity and geoid in the Arctic Region – The northern GOCE polar gap filled. Proceed. 2nd Internat. GOCE Workshop, Esrin, March 8-10, 2004.

Kahlouche, S., Rami, A., Benahmed Daho, S. (2004) Topex altimetric mean sea level and gravimetric geoid in the North of Algeria. In: *Satellite Altimetry for Geodesy, Geophysics and Oceanography* (Eds: Hwang, C., Shum, C.K., Li, J.), Springer Verlag, Berlin.

Kahlouche, S., Haddad, M., Rami, A., Benahmed Daho, S.A. (2004) A high precision altimetric determination of the geoid over the Mediterranean Basin using the TOPEX/Poseidon data. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions "GGSM2004", Porto, Portugal, August 30 – September 3, 2004.

Mäkinen, J., H. Koivula, and J. Ahola (2004). Absolute gravity measurements in Dronning Maud Land. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

McAdoo, D., V. Childers, S. Laxon, C. Wagner, and J. Brozena (2003). High Accuracy Gravimetric Geoid for Arctic Research from GRACE. GRACE Science Meeting, October 8-10, 2003.

McAdoo, D., S. Farrell, S. Laxon, C. Wagner, and V. Childers (2004). GRACE-based Arctic Ocean Geoids for Oceanographic and Sea-Ice Investigations. Joint CHAMP/GRACE Science Meeting, July 6-8, 2004, Potsdam.

Merry, C.L, Blitzkow, D., Abd-Elmotaal, H., Fashir, H., John, S., Podmore, F. and Fairhead, J. (2003) A Preliminary Geoid Model for Africa. Presented at the 23rd General Assembly of the International Union of Geodesy and Geophysics IUGG, Sapporo, Japan, June 30 – July 11, 2003.

Merry, C.L. (2003) DEM-Induced Errors in Developing a Quasi-Geoid Model for Africa. *Journal of Geodesy*, **77**(9), 537:542

Merry, C.L. (2003) The African Geoid Project and its relevance to the unification of African vertical reference frames. Proceedings, 2nd Regional Conference of the Fédération Internationale des Géomètres, Marrakech, Morocco, December 2003. CD-ROM publication, paper TS9.3.

Merry, C.L. (2004) The African Geoid Project: Establishing a vertical reference. *GEOInformatics*, **7**(7),6:9.

Merry, C.L. 2004) Vertical reference frames and the geoid. Presented, Workshop on Control Networks, Johannesburg, November 2004.

Müller, J., R. Dietrich, M. Scheinert, and M. Wiehl (2004). About the Role of Subglacial Topography on Geoid Determination from Airborne Gravimetry in Antarctica. Poster presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Müller, J., M. Scheinert, and R. Dietrich (2003). About the role of the subglacial topography on regional geoid determination in Antarctica. Oral presentation at GOCE/CryoSat-Workshop, Immenstaad, November 4-5, 2003.

Müller, J., M. Scheinert, and R. Dietrich (2004). Progress in gravity _eld determination for Antarctica from global gravity _eld models. Poster presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Nixdorf, U., J. Müller, S. Riedel, M. Scheinert, D. Steinhage, M. Wiehl, W. Jokat, R. Dietrich, and H. Miller (2004). Airborne gravity measurements in Dronning Maud Land for the validation, densification and interpretation of new satellite data. Oral presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Sansò, F., C.C. Tscherning (2003). Fast spherical collocation: theory and examples. Journal of Geodesy 77:101-112.

Scheinert, M. (2004b). The Antarctic Geoid Project: Status Report and Next Activities. In C. Jekeli (Ed.), Proc. IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Scheinert, M., H. Anschütz, G. Rotschky, S. Roemer, A. Senatorov, J. Brovkov, D. Steinhage, R. Dietrich, H. Miller, A. Yuskevich, W. Jokat, and U. Nixdorf (2004). VISA 2003/04 - Geodetic,

Glaciological and Geophysical Observation Campaign in Dronning Maud Land, Antarctica, for the Validation and Interpretation of New Satellite Data. Poster presentation at IAG International Symposium “Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Scheinert, M., H. Anschütz, G. Rotschky, A. Senatorov, S. Roemer, H. Miller, R. Dietrich, A. Yuskevich, W. Jokat, U. Nixdorf, H. Oerter, J. M uller, and M. Wiehl (2004, Juli). Geodetic-glaciological Fieldwork in Dronning Maud Land for the validation and interpretation of new satellite data. Poster presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Scheinert, M., E. Ivins, R. Dietrich, and A. Rülke (2003). Vertical Crustal Deformations in Dronning Maud Land, Antarctica: Observations versus Model Predictions. In D. Fütterer (Ed.), Antarctic Contributions to Global Earth Sciences, Proc. of ISAES IX, Potsdam, September 8-12, 2003, Berlin - Heidelberg. Springer.

Shibuya, K., K. Doi, Y. Fukuzaki, and M. Iwata (2004). Local geodetic ties among geodesy reference points at Syowa station, Antarctica. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Shum, C. K., C. Jekeli, B. Csatho, M. Bevis, S. Han, C. Kuo, L. Potts, R. von Frese, Y. Yi, A. Braun, R. Forsberg, L. Hotem, S. Kenyon, J. Manning, M. Scheinert, R. Dietrich, and K. Shibuya (2004). Interdisciplinary Antarctic Research in Geodesy Using an Instrumented, Long-Range Aircraft. Poster presentation at NSFWorkshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research, Herndon VA, USA, September 27-29, 2004.

Studinger, M., R. Bell, W. Buck, G. Karner, and D. Blankenship (2004). Sub-ice geology inland of the Transantarctic Mountains in light of new aerogeophysical data. Earth Plan. Sci. Letters 220, 391-408.

Studinger, M., D. Bromwich, B. Csatho, R. Muench, T. Parish, and J. Stith (2005). Science Opportunities for a Long-Range Antarctic Research Aircraft. EOS Trans. American Geophys. Union 86(4), 39-40.

Studinger, M., G. D. Karner, R. E. Bell, V. Levin, C. A. Raymond, and A. A. Tikku (2003). Geophysical models for the tectonic framework of the Lake Vostok region, East Antarctica. Earth Plan. Sci. Letters 216, 663-677.

Wiehl, M., R. Dietrich, M. Scheinert, and M. Thomas (2004). Separation of temporal gravity signals in Antarctica: a regional case study in Dronning Maud Land. Oral presentation at IAG International Symposium \Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Appendix 8

European Gravity and Geoid Project (EGGP)
Status Report, February 2005

Heiner Denker (denker@ife.uni-hannover.de)

The project started with the setup of a steering committee (SC), consisting of H. Denker (Chair), J.P. Barriot, R. Barzaghi, R. Forsberg, J. Ihde, A. Kenyeres, U. Marti, I.N. Tziavos. A first meeting of the SC was held in Milan, Feb. 3-4, 2004 (kick-off meeting). During the meeting, the status and possible improvements of the European Geoid, the project structure, the input data sets, the methodology, and the time schedule were discussed. It was decided to have national correspondents/delegates from all countries as project members, which have access to the relevant data sets or are engaged in geoid computations. The primary input data sets for the geoid computation will be gravity and terrain data supplemented by a state-of -the-art global geopotential model. In addition, GPS/levelling, bathymetry, altimetry, and density data were discussed. Due to confidentiality reasons, it was decided to have only one data and computation centre within the project, which is the Institut für Erdmessung (IfE), University of Hannover. In addition, if the data owners agree, the project gravity data shall also be stored within a separate confidential data base at the Bureau Gravimétrique International (BGI), Toulouse. The confidential data base of BGI will not have any connections to the public BGI data base and will not be connected to a network. The main reason for the 2nd gravity data centre is to use the expertise of BGI in the validation and cleaning of large gravity data sets. With respect to terrain data, national models will be merged with the global models SRTM3 and GTOPO30. GPS/levelling data are collected worldwide at the International Geoid Service (IGeS) in Milan and will be made available. The general strategy for the geoid/quasigeoid calculation will be the remove-restore technique, where a global model and terrain reductions are taken into account, before applying the modelling techniques. From the discussion it turned out that IfE will start with the spectral combination and integration technique (later on IfE may also investigate other techniques, e.g., collocation or wavelets), while the Milan group intends to test the fast collocation procedure (e.g., Sansò and Tscherning, 2003). Regarding the time line, the project should finish until the next IUGG General Assembly in Perugia, 2007, and intermediate results should be generated in 2005 and 2006 (IGFS meeting in Istanbul).

After the SC meeting, the project members were approached and about 50 national delegates (project members) from most of the countries in Europe agreed to join the project. At the GGSM2004 symposium in Porto, a meeting of the project members was held and about 30 people participated. Information was given on the project organization and status. The main discussion concentrated on possible improvements of the relevant data sets. Several problem areas were identified and discussed (e.g., the Mediterranean Sea), and several project members offered their support. Furthermore, a complete project status report was presented by H. Denker at the GGSM2004 symposium (oral and poster) and will be published in the proceedings (Denker et al., 2004).

Since the start of the project, significant improvements of the gravity database were made, including new data sets for several countries, e.g., Belgium, Luxemburg, Germany, Slovenia, Switzerland, and Netherlands. Moreover, positive responses, indicating a data update in the near future, were received from Austria, the Baltic States, Croatia, France, Greece, Poland, Serbia, Russia, the Scandinavian countries, etc. In addition to this, the public domain data set from the Arctic Gravity Project became available (Forsberg and Kenyon, 2004). In addition,

the older gravity data sets were revised regarding the underlying reference systems, the target systems being ETRS (European Terrestrial Reference System), UELN (United European Levelling Network) and absolute gravity. Within the EGGP, only data which can be related without any doubts to the target reference systems will be included in the primary data base. Significant progress was also made in the collection and reprocessing of ship gravity data (Denker and Roland, 2003). The ship gravity data, collected from several institutions for the European Seas, were crossover adjusted using a bias per track error model in order to reduce instrumental and navigational errors, incorrect ties to harbour stations, and other error sources. An "original" and an "edited" data set were considered, where the edited data set excluded data affected by ship turns, data in the Red Sea, data from short tracks (< 3 points), and tracks with large crossover differences. The editing of some bad observations resulted already in an improvement of the crossover differences by a factor of two, while the crossover adjustment again reduced the crossovers by a factor of two. Before the adjustment, the RMS crossover difference is 15.5 mgal for the original and 8.4 mgal for the edited data set; the corresponding values after the adjustment are 7.0 mgal and 4.7 mgal, respectively.

Improvements were also made regarding the digital elevation models (DEMs). Switzerland has released a 1" × 1" DEM, and Austria has indicated the release of a corresponding model. However, especially in Eastern Europe and some other areas, fill-ins from global public domain databases have to be used, either because high-resolution DEMs do not exist or are not released for confidentiality reasons. For this purpose, the SRTM3 model with a resolution of 3" × 3" (JPL, 2004) and the public domain global model GTOPO30 with a resolution of 30" × 30" (LP DAAC, 2004) were investigated (Denker, 2004a). The national DEMs, augmented by the SRTM3 and GTOPO30 data will allow the creation of DEMs for entire Europe with a resolution of at least 30" × 30", which is a significant improvement compared to the previous EGG97 computation.

Regarding the global geopotential models, the CHAMP and GRACE missions have led to significant improvements in the modelling of long wavelength gravity signals. This is documented, e.g., by the accumulated formal geoid error, which does not exceed 0.01 m for spherical harmonic degrees up to about 25 for the CHAMP models (e.g., Reigber et al., 2004a) and 75 for the GRACE models (e.g., Reigber et al., 2004b). On the other hand, the limit of 0.01 m is already exceeded at degree 8 for the EGM96 model.

Updated European geoid/quasigeoid models were computed based on the new CHAMP and GRACE geopotential models (Denker, 2004b). The computations were done using the EGG97 terrestrial gravity data set as well as an updated data set (see above). All computed quasigeoid models were evaluated by GPS/levelling data from the European EUVN data set (Ihde et al., 2000) and by national campaigns. The comparisons show clearly that the long wavelength discrepancies over Central Europe almost disappear for the solutions based on the GRACE models. The largest discrepancies remain at coastal stations, especially around the Mediterranean Sea where the gravity data quality is weak. In the GPS/levelling comparisons of the European and national data sets, the RMS differences reduce up to about 60 % when using the GRACE models and up to 30 % for the solutions based on CHAMP, as compared to the previous EGG97 model relying on EGM96. In addition, the tilts, existing in EGG97, were reduced to typically below 0.1 ppm. Furthermore, with the updated solutions based on the GRACE models, accurate determinations of W_0 (reference geopotential of the vertical datum) and vertical datum unifications become possible. Thus, contributions can be made to the definition of a European Vertical Reference System (EVRS).

In summary, significant progress was made within the framework of the European Gravity and Geoid Project EGGP regarding the collection and homogenization of high-resolution gravity and terrain data. Several new data sets became available, and especially the new geopotential models from the CHAMP and GRACE missions improved the geoid/quasigeoid modelling very much. Further details on the progress made so far are documented in Denker et al. (2004).

In my opinion, the project is running well so far. In 2005, a major effort will be undertaken to further update the gravity and terrain data sets, and new geoid computations will be done based on these data.

References:

Denker, H. (2004a). Evaluation of SRTM3 and GTOPO30 terrain data in Germany. Proceed. GGSM2004, Porto.

Denker, H. (2004b). Improved European geoid models based on CHAMP and GRACE results. Proceed. GGSM2004, Porto.

Denker, H., J.-P. Barriot, R. Barzaghi, R. Forsberg, J. Ihde, A. Kenyeres, U. Marti, I.N. Tziavos (2004). Status of the European Gravity and Geoid Project EGGP. Proceed. GGSM2004, Porto.

Denker, H., M. Roland (2003). Compilation and evaluation of a consistent marine gravity data set surrounding Europe. Proceed., IUGG2003, Sapporo, Japan, June30-July11, 2003.

Forsberg, R., S. Kenyon (2004). Gravity and geoid in the Arctic Region – The northern GOCE polar gap filled. Proceed. 2nd Internat. GOCE Workshop, Esrin, March 8-10, 2004.

Ihde, J. et al. (2000). The height solution of the European Vertical Reference Network (EUVN). Verö ff. Bayer. Komm. für die Internat. Erdmessung, Astronom. Geod. Arb., Nr. 61: 132-145, München.

JPL (2004). SRTM – The Mission to Map the World. Jet Propulsion Laboratory, California Inst. of Techn., http:// www2.jpl.nasa.gov/srtm/index.html.

LP DAAC (2004). Global 30 Arc-Second Elevation Data Set GTOPO30. Land Process Distributed Active Archive Center, http://edcdaac.usgs.gov/gtopo30/gtopo30.asp.

Reigber, Ch., et al. (2004a). Earth gravity field and seasonal variability from CHAMP. Earth Observation with CHAMP: 25-30, Springer Verlag.

Reigber, Ch., et al. (2004b). An Earth gravity field model complete to degree and order 150 from GRACE: EIGEN-GRACE02S. J. of Geodynamics, accepted June 25, 2004.

Sansò, F., C.C. Tscherning (2003). Fast spherical collocation: theory and examples. Journal of Geodesy 77:101-112.

Appendix 9

The activities for the North American Geoid project consisted of two meetings. The first meeting was held in Montreal during the Canadian Geophysical Union annual scientific meeting back in back in May 2004 while the second meeting was held in Porto during the Geoid and Gravity conference back in September 2004. Furthermore, Natural Resources Canada's Geodetic Survey and U.S. National Geodetic Survey Division maintain channel of communication in the development of a geoid model for North America. This development is especially important for Canada because the future vertical datum for Canada (~2008) will be define by an equipotential surface and realized by a geoid model.

Latest geoid models developed in the USA and Canada are continuously compared in order to converge towards a single solution. Currently, the largest discrepancies are principally due to the facts that the two agencies do not have the same data holding. A better data exchange process is required between the two agencies. This process will be the focus for this coming year.

Appendix 10

REPORT OF COMMISSION PROJECT 2.3: AFRICAN GEOID PROJECT
(part of Sub-Commission 2.4: Regional Geoid Determination)

For the period: June 2003 - June 2005

General:

The working group on this project has not made as much progress as had been hoped. Members have found it difficult to obtain time, funds and data. Nevertheless data collection has continued and most of the BGI gravity data holding for Africa have been obtained, as well as some additional data sets for a few specific regions. Nevertheless, there are still large data gaps in many parts of Africa; particularly in those regions that have been or are in a state of conflict. Airborne gravimetry would be a very efficient way to fill these gaps, but it is difficult to find sources of funding for such surveys.

The new satellite-based data sets from Grace and from the SRTM should improve both the long wavelength and short wavelength modelling of the geoid for Africa. Time constraints have prevented much work being done with these data, but preliminary testing indicates that the SRTM30 DEM is a significant improvement over earlier 1km DEM's for Africa, and that there are significant differences between the Grace geopotential model and EGM96 (up to one metre in geoid height) over parts of southern Africa.

Publications:

Abd-Elmotaal, H. (2003) The Egyptian Geoid EGGG2003. Presented at the 23rd General Assembly of the International Union of Geodesy and Geophysics IUGG, Sapporo, Japan, June 30 – July 11, 2003.

Abd-Elmotaal, H. (2004) The AFH04 Digital Height Models for Africa. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions “GGSM2004”, Porto, Portugal, August 30 – September 3, 2004.

Benahmed Daho, S.A. (2003) Orthometric height computation from GPS observation: case of study - North of Algeria. Proceedings, 2nd Regional Conference of the Fédération Internationale des Géomètres, Marrakech, Morocco, December 2003. CD-ROM publication, paper TS9.3

Benahmed Daho, S.A., Fairhead, J.D., Kahlouche, S. (2004) A procedure for modelling the differences between the gravimetric geoid model and GPS/Levelling data with an example in the North part of Algeria. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions “GGSM2004”, Porto, Portugal, August 30 – September 3, 2004.

Benahmed Daho, S.A. (2004) A computer program for the adjustment of combined GPS/levelling/geoid networks: case of study - North of Algeria. *Newton's Bulletin,* 2.

Benahmed Daho, S.A., Fairhead, J.D. (2004) A new quasigeoid computation from gravity and GPS data in Algeria. *Newton's Bulletin,* 2.

Kahlouche, S., Rami, A., Benahmed Daho, S. (2004) Topex altimetric mean sea level and gravimetric geoid in the North of Algeria. In: *Satellite Altimetry for Geodesy, Geophysics and Oceanography* (Eds: Hwang, C., Shum, C.K., Li, J.), Springer Verlag, Berlin.

Kahlouche, S., Haddad, M., Rami, A., Benahmed Daho, S.A. (2004) A high precision altimetric determination of the geoid over the Mediterranean Basin using the TOPEX/Poseidon data. Presented at the IAG International Symposium on Gravity, Geoid and Space Missions "GGSM2004", Porto, Portugal, August 30 – September 3, 2004.

Merry, C.L, Blitzkow, D., Abd-Elmotaal, H., Fashir, H., John, S., Podmore, F. and Fairhead, J. (2003) A Preliminary Geoid Model for Africa. Presented at the 23rd General Assembly of the International Union of Geodesy and Geophysics IUGG, Sapporo, Japan, June 30 – July 11, 2003.

Merry, C.L. (2003) DEM-Induced Errors in Developing a Quasi-Geoid Model for Africa. *Journal of Geodesy*, **77**(9), 537:542

Merry, C.L. (2003) The African Geoid Project and its relevance to the unification of African vertical reference frames. Proceedings, 2nd Regional Conference of the Fédération Internationale des Géomètres, Marrakech, Morocco, December 2003. CD-ROM publication, paper TS9.3.

Merry, C.L. (2004) The African Geoid Project: Establishing a vertical reference. *GEOInformatics*, **7**(7),6:9.

Merry, C.L. 2004) Vertical reference frames and the geoid. Presented, Workshop on Control Networks, Johannesburg, November 2004.

Appendix 11

Report of Commission Project 2.4 "Antarctic Geoid" (AntGP)

Mirko Scheinert
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Short Review

This group was initiated in the course of the IUGG General Assembly in Sapporo 2003 and the adoption of the new structure of the IAG. It is the first time, that within IAG a special group is dedicated to the determination of the gravity field in Antarctica. Therefore, substantial time has to be taken to get into and to deepen contacts. Because of the special conditions in Antarctica, cooperation is possible only in an interdisciplinary way, especially in the fields of geodesy, geophysics and glaciology. This is reflected in the membership of the group (cf. below).
Thus, considerable work has been done in establishing communication, in disseminating the idea of closing the gravity gap in Antarctica and in investigating what gravity (and auxiliary) datasets do already exist for Antarctica.
For communication various conferences played an important role (cf. below). At the Porto symposium (GGSM2004), a short meeting of the AntGP group could be carried out. In between, communication was maintained by circular letters. The most comprehensive report on the status of the project was given by an invited talk of M. Scheinert at the IAG International Symposium on Gravity, Geoid and Space Missions (GGSM2004) in Porto (Scheinert 2004a). This paper is due to publication in a respective Springer volume (Scheinert 2004b).
To present AntGP to a wider audience, a website has been established and will be maintained under `http://www.tu-dresden.de/ipg/antgp/antgp.html`

An important linkage could be maintained to the Scientific Committee on Antarctic Research (SCAR), which represents Antarctic sciences in a broad sense. Within the "SCAR Standing Scientific Group on GeoSciences" the "Expert Group on Geospatial Information - Geodesy" adopted a new work plan for Geodetic Infrastructure of Antarctica (GIANT) for the period 2004 - 2006. Project 3 of this work plan "Physical Geodesy" is chaired by A. Capra and co-chaired by M. Scheinert. A close linkage to SCAR is also very important envisaging the International Polar Year 2007/08, which offers unique possibilities for internationally and interdisciplinarily coordinated initiatives and thus also for geodetic-geophysical campaigns aiming at gravity surveys in Antarctica.

Specific activities have been undertaken by the AntGP members when carrying out or planning observation campaigns in Antarctica in the time period 2003 - 2005 (cf. below).

Future plans and activities

Future activities can be well defined following the "Terms of Reference". Activities of the group should be focussed in the following sense:

(a) Promotion and carrying-out of new gravity surveys in Antarctica

Here, the upcoming IPY plays an important role for the international coordination of such surveys. Airborne gravimetry is the most promising technique to close the polar gap in the global gravity data coverage. Due to the huge logistic efforts of Antarctic (and especially airborne) surveys, coordination has to be set up well in advance and on a broad (national/international) basis.

(b) Built-up of databases

An overview of already existing data is given in (Scheinert 2004b). The built-up and maintainance of Antarctic gravity databases should be supported. Within AntGP, methods and rules of data exchange have to be elaborated.

Upcoming conferences will be important to further communicate the goals of AntGP and to coordinate the work between the group members and the different communities (especially: Joint Assembly of IAG/IAPSO/IABO, Cairns 2005; Intl. Symp. on Antarctic Earth Sciences, Hobart 2006; IUGG General Assembly, Perugia 2007). It is also intended to organize a workshop dedicated to AntGP (possibly in 2006).

Membership (as of January 2005)

Active members

Mirko Scheinert (chair)	TU Dresden, Germany
Alessandro Capra	Politechnico di Bari, Italy
Detlef Damaske	BGR Hannover, Germany
Reinhard Dietrich	TU Dresden, Germany
René Forsberg	KMS Copenhagen, Denmark
Larry Hothem	USGS, USA
Wilfried Jokat	AWI Bremerhaven, Germany
Gary Johnston	Geoscience Australia
A.H. William Kearsley	University of New South Wales, Australia
Steve Kenyon	NIMA, USA
Christopher Kotsakis	University of Calgary, Canada
German L. Leitchenkov	VNIIOkeangeologia, Russia
Jaakko Mäkinen	FGI, Finland
Kazuo Shibuya	NIPR, Japan
C.K. Shum	OSU Columbus, USA
Dag Solheim	Statens Kartverk, Norway
Michael Studinger	Lamont-Doherty Earth Observatory, USA

Corresponding members

Robin Bell	Lamont-Doherty Earth Observatory, USA
Graeme Blick	LINZ, New Zealand
John Brozena	Naval Research Lab, USA
Cheinway Hwang	National Chiao Tung University, Taiwan
John Manning	University of New South Wales, Australia
Dave McAdoo	NOAA, USA

Selected conferences and workshops with participation of AntGP members

IX International Symposium on Antarctic Earth Sciences (ISAES IX)
Potsdam, Germany, September 8-12, 2003

Joint CHAMP/GRACE Science Meeting (JCG)
Potsdam, Germany, July 6-8, 2004

XXVIII SCAR Meeting and Open Science Conference (SCAR 28)
Bremen, Germany, July 25-31, 2004

IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004)
Porto, Germany, August 30 - September 3, 2004

NSF Workshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research, Herndon VA, USA, September 27-29, 2004
co-organized by Michael Studinger, member of AntGP

Workshop Geosciences on HALO (High-Altitude and Long-Range Research Aircraft)
Hannover, Germany, December 14, 2004

Selected activities in Antarctic observation campaigns

Joint project of TU Dresden and AWI Bremerhaven (Germany) "Validation, Densification and Interpretation of Satellite Data for the Determination of the Magnetic Field, Gravity Field, Ice Mass Balance and Crustal Structure in Antarctica by Means of Airborne and Terrestrial Measurements" (PIs: R. Dietrich and W. Jokat): Antarctic campaigns in Dronning Maud Land in the seasons 2003/04 (head of field group: M. Scheinert) and 2004/05

Projects of VNIIOkeangeologia (Russia) in Antarctica (G. Leitchenkov)

Finnish Antarctic Research Programme (FINNARP): Absolute gravity measurements in Dronning Maud Land, season 2003/04 (J. Mäkinen)

Observatory programme (superconducting gravimeter and others) at Japanese Syowa station, East Antarctica (K. Shibuya)

Selected publications and presentations of members

Aleshkova, N., V. Masolov, G. Leitchenkov, V. Mandrikov, S. Alyavdin, A. Golynski, and R. Kurinin (2004). Russian Antarctic Gravity Dataset. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Bell, R. (2004). International Polar Year 2007-2008. Presentation at SCAR XXVIII Open Science Conference, IPY Discussion Forum, Bremen, July 28, 2004.

Blankenship, D. D., D. L. Morse, I. W. D. Dalziel, L. A. Lawver, J. W. Holt, J. M. Brozena, V. A. Childers, M. J. Siegert, J. L. Bamber, and A. J. Payne (2004). Investigating the crustal elements of the central Antarctic Plate (Icecap): how long-range aerogeophysics is critical to understanding

the evolution of the East Antarctic ice sheet. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Coren, F., P. Sterzai, A. Capra, and G. Bitelli (2004). Local gravimetric geoid determination in North Victoria Land (Antarctica). Presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Damaske, D. and M. McLean (2004). Airborne Geophysical Data Acquisition South of the Prince Charles Mountains, East Antarctica. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Dietrich, R., H. Miller, and M. Wiehl (2004, Juli). Mass distribution and mass changes in Antarctica: The role of recent and upcoming satellite missions. Oral presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Mäkinen, J., H. Koivula, and J. Ahola (2004). Absolute gravity measurements in Dronning Maud Land. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

McAdoo, D., V. Childers, S. Laxon, C. Wagner, and J. Brozena (2003). High Accuracy Gravimetric Geoid for Arctic Research from GRACE. GRACE Science Meeting, October 8-10, 2003.

McAdoo, D., S. Farrell, S. Laxon, C. Wagner, and V. Childers (2004). GRACE-based Arctic Ocean Geoids for Oceanographic and Sea-Ice Investigations. Joint CHAMP/GRACE Science Meeting, July 6-8, 2004, Potsdam.

Müller, J., R. Dietrich, M. Scheinert, and M. Wiehl (2004). About the Role of Subglacial Topography on Geoid Determination from Airborne Gravimetry in Antarctica. Poster presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Müller, J., M. Scheinert, and R. Dietrich (2003). About the role of the subglacial topography on regional geoid determination in Antarctica. Oral presentation at GOCE/CryoSat-Workshop, Immenstaad, November 4-5, 2003.

Müller, J., M. Scheinert, and R. Dietrich (2004). Progress in gravity field determination for Antarctica from global gravity field models. Poster presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Nixdorf, U., J. Müller, S. Riedel, M. Scheinert, D. Steinhage, M. Wiehl, W. Jokat, R. Dietrich, and H. Miller (2004). Airborne gravity measurements in Dronning Maud Land for the validation, densification and interpretation of new satellite data. Oral presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Scheinert, M. (2004a). The Antarctic Geoid Project: Status Report and Next Activities. Oral presentation (invited talk) at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Scheinert, M. (2004b). The Antarctic Geoid Project: Status Report and Next Activities. In C. Jekeli (Ed.), *Proc. IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004*. Springer. (accepted for publication).

Scheinert, M., H. Anschütz, G. Rotschky, S. Roemer, A. Senatorov, J. Brovkov, D. Steinhage, R. Dietrich, H. Miller, A. Yuskevich, W. Jokat, and U. Nixdorf (2004). VISA 2003/04 – Geodetic, Glaciological and Geophysical Observation Campaign in Dronning Maud Land, Antarctica, for the Validation and Interpretation of New Satellite Data. Poster presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Scheinert, M., H. Anschütz, G. Rotschky, A. Senatorov, S. Roemer, H. Miller, R. Dietrich, A. Yuskevich, W. Jokat, U. Nixdorf, H. Oerter, J. Müller, and M. Wiehl (2004, Juli). Geodetic-glaciological fieldwork in Dronning Maud Land for the validation and interpretation of new satellite data. Poster presentation at XXVIII SCAR Meeting and Open Science Conference (SCAR 28), Bremen, July 25-31, 2004.

Scheinert, M., E. Ivins, R. Dietrich, and A. Rülke (2003). Vertical Crustal Deformations in Dronning Maud Land, Antarctica: Observations versus Model Predictions. In D. Fütterer (Ed.), *Antarctic Contributions to Global Earth Sciences, Proc. of ISAES IX, Potsdam, September 8-12, 2003*, Berlin – Heidelberg. Springer. (accepted for publication).

Shibuya, K., K. Doi, Y. Fukuzaki, and M. Iwata (2004). Local geodetic ties among geodesy reference points at Syowa station, Antarctica. Poster presentation at SCAR XXVIII Open Science Conference, Bremen, July 26-28, 2004.

Shum, C. K., C. Jekeli, B. Csatho, M. Bevis, S. Han, C. Kuo, L. Potts, R. von Frese, Y. Yi, A. Braun, R. Forsberg, L. Hotem, S. Kenyon, J. Manning, M. Scheinert, R. Dietrich, and K. Shibuya (2004). Interdisciplinary Antarctic Research in Geodesy Using an Instrumented, Long-Range Aircraft. Poster presentation at NSF Workshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research, Herndon VA, USA, September 27-29, 2004.

Studinger, M., R. Bell, W. Buck, G. Karner, and D. Blankenship (2004). Sub-ice geology inland of the Transantarctic Mountains in light of new aerogeophysical data. *Earth Plan. Sci. Letters 220*, 391–408.

Studinger, M., D. Bromwich, B. Csatho, R. Muench, T. Parish, and J. Stith (2005). Science Opportunities for a Long-Range Antarctic Research Aircraft. *EOS Trans. American Geophys. Union 86*(4), 39–40.

Studinger, M., G. D. Karner, R. E. Bell, V. Levin, C. A. Raymond, and A. A. Tikku (2003). Geophysical models for the tectonic framework of the Lake Vostok region, East Antarctica. *Earth Plan. Sci. Letters 216*, 663–677.

Wiehl, M., R. Dietrich, M. Scheinert, and M. Thomas (2004). Separation of temporal gravity signals in Antarctica: a regional case study in Dronning Maud Land. Oral presentation at IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004), Porto, August 30 - September 3, 2004.

Appendix 12

Projects: Gravity in South America (M.C. Pacino) and South American Geoid (D. Blitzkow).
Report to Commission II: Gravity Field.

This is a joint report of "Gravity in South America" (SC2.1 - CP2.7) and "South American Geoid" (SC2.4 - CP2.5) projects. Their members are organized in a coordinated effort to develop activities related to both projects, under the coordination of Maria Cristina Pacino and Denizar Blitzkow respectively. The two projects were established as part of the Commission II: Gravity Field, in order to organize the activities of gravity measurements in the continent and to provide the necessary information for the height system in association with the geoid determination.

Gravity meeting:

The first meeting of the "Gravity in South America" project took place at the headquarters of Instituto Geográfico Militar de Argentina, during the XXII Scientific Assembly of the AAGG (Argentine Association of Geodesy and Geophysics), on September 9th, 2004, and was attended by the following members:

- M. Cristina Pacino (chairman)
- Eduardo Lauría (Argentina)
- Rubén Ramos (Argentina)
- Mauro Andrade de Sousa (Brazil)
- Wilfredo Rubio Díaz (Chile)
- Héctor Rovera (Uruguay)
- Eugen Wilderman (Venezuela)

The following objectives and actions regarding gravity measurements were approved:

- To collect and to send to Dr. M. Cristina Pacino for validation and technical evaluation, all the existent information regarding Absolute Gravity Measurements in South America, in special those performed from 1988 to 1991 by Dr. W. Torge;
- To define sites for absolute gravity determinations in order to establish a new Absolute Gravity Network in South America with a medium distance between the stations on the order of 1,000 km, with the re-observation of the existent absolute gravity stations to assure internal consistency in precision, reference system, method of measurement, etc;
- To adopt the absolute gravitymeter Micro-G Solution Inc, FG5 model, property of the Observatorio Nacional – Río de Janeiro – Brasil to perform the measurements;
- Adjust national gravity networks at a continental level;
- To maintain and to promote international relationships between National Geographic Institutes and similar Institutions;
- To apply for national and international support;
- To cooperate with the "South American Geoid" Project;
- To encourage international seminars and short courses ;

Activities accomplished:

The documents related to Absolute Gravity Measurements (1988-1991) in Venezuela, Brazil, Uruguay and Argentina were collected. Besides, several gravity stations were reoccupied in Brazil and Uruguay and a budget was approved for the reoccupation of absolute gravity stations in Argentina. In Chile it has been reported a set of new absolute measurements carried out with the support of France.

In the last two years a strong effort was carried out in order to improve the distribution of gravity information in the South American continent (Figure 1). It includes Argentina, Brazil, Chile, Colombia, Ecuador and Paraguay. Many new surveys were carried out and an intense process of validation was also carefully realized in different countries. The contribution of many organizations in South America and other countries is very much appreciated: IBGE, EPUSP and many universities and research institutes (Brazil), IGM (Chile), IGM and University of Rosario (Argentina), DISERGEMIL (Paraguay), IGAC (Colombia), IGM and INOCAR (Ecuador), GETECH (UK), NGA (USA), Dr. Goetze (Germany), IRD and BGI (France).

New Fundamental Gravity Networks were established in Chile, Ecuador and Paraguay (Figures 2 - 3). A least squares adjustment of the networks is in progress.

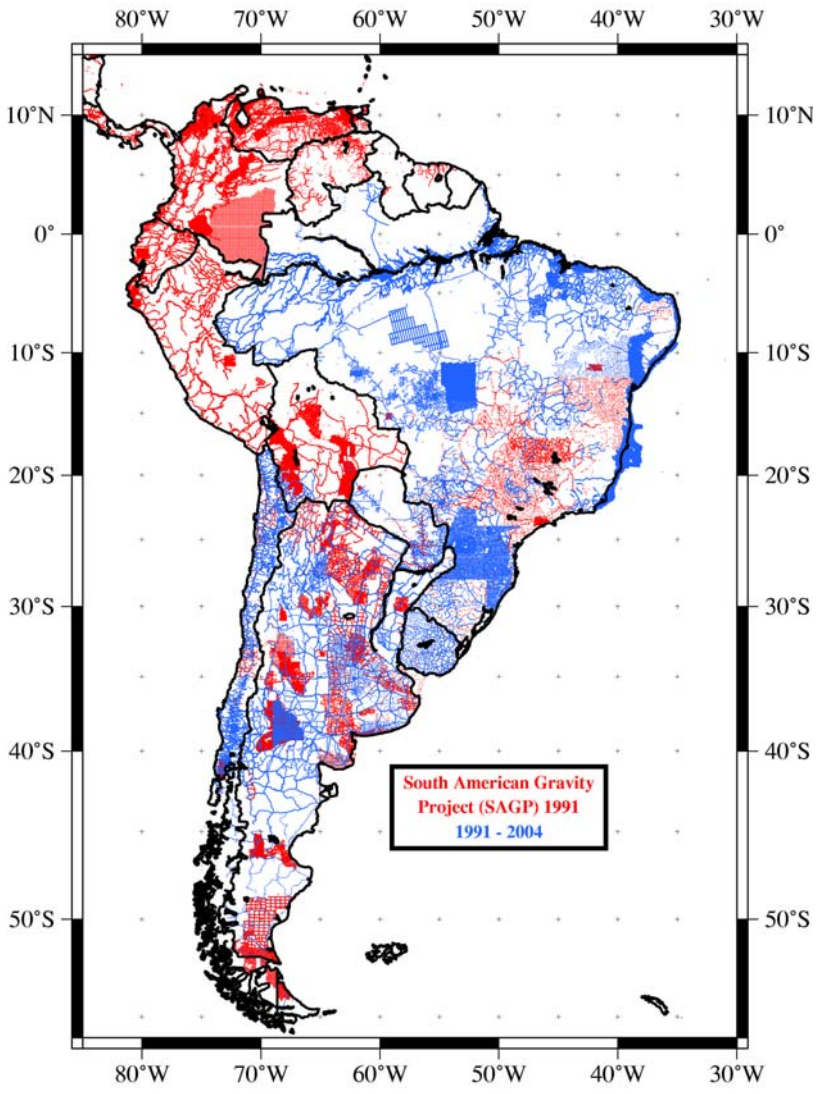

Figure 1 – Gravity data distribution in South America.

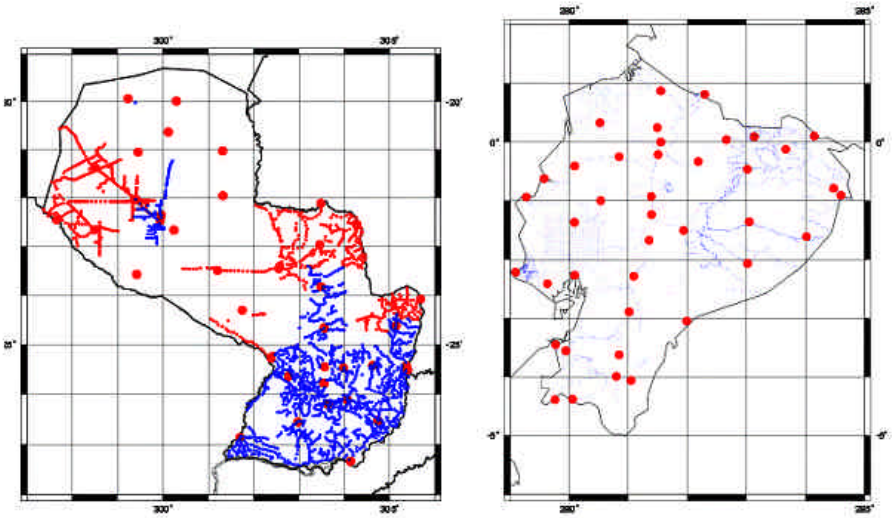

Figure 2 – Fundamental Gravity Network in Paraguay and Ecuador.

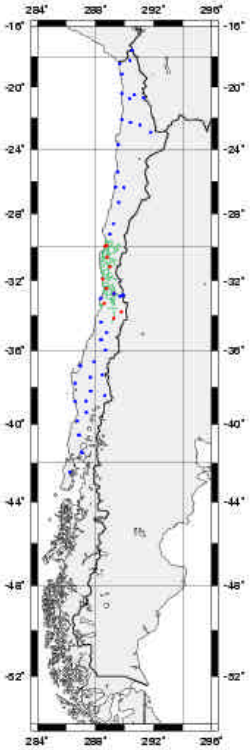

Figure 3: Fundamental Gravity Network in Chile.

<u>DTM initiative:</u>

A great effort has been done to analyse the different DTM available (DTM2002, GLOBE, GTOPO30, ETOPO2, JGP95E, TERRAINBASE, ETOPO5), with a special emphasis to Endeavour mission, Shuttle Recovery Topography Mission (SRTM). The models were compared with heights on Bench Marks (BM) derived from spirit leveling throughout Brazil and Argentina. Topographic maps have been digitized in many areas in the continent (Figure 4 - black). Special bathymetric information has been recovered from different sources in the coast of Brazil (nautical maps, profiles of specific surveys, point measurements) and Argentina (nautical maps) (Figure 4 – orange). The blue color in the figure 4 is DTM2002 and the green is SRTM.

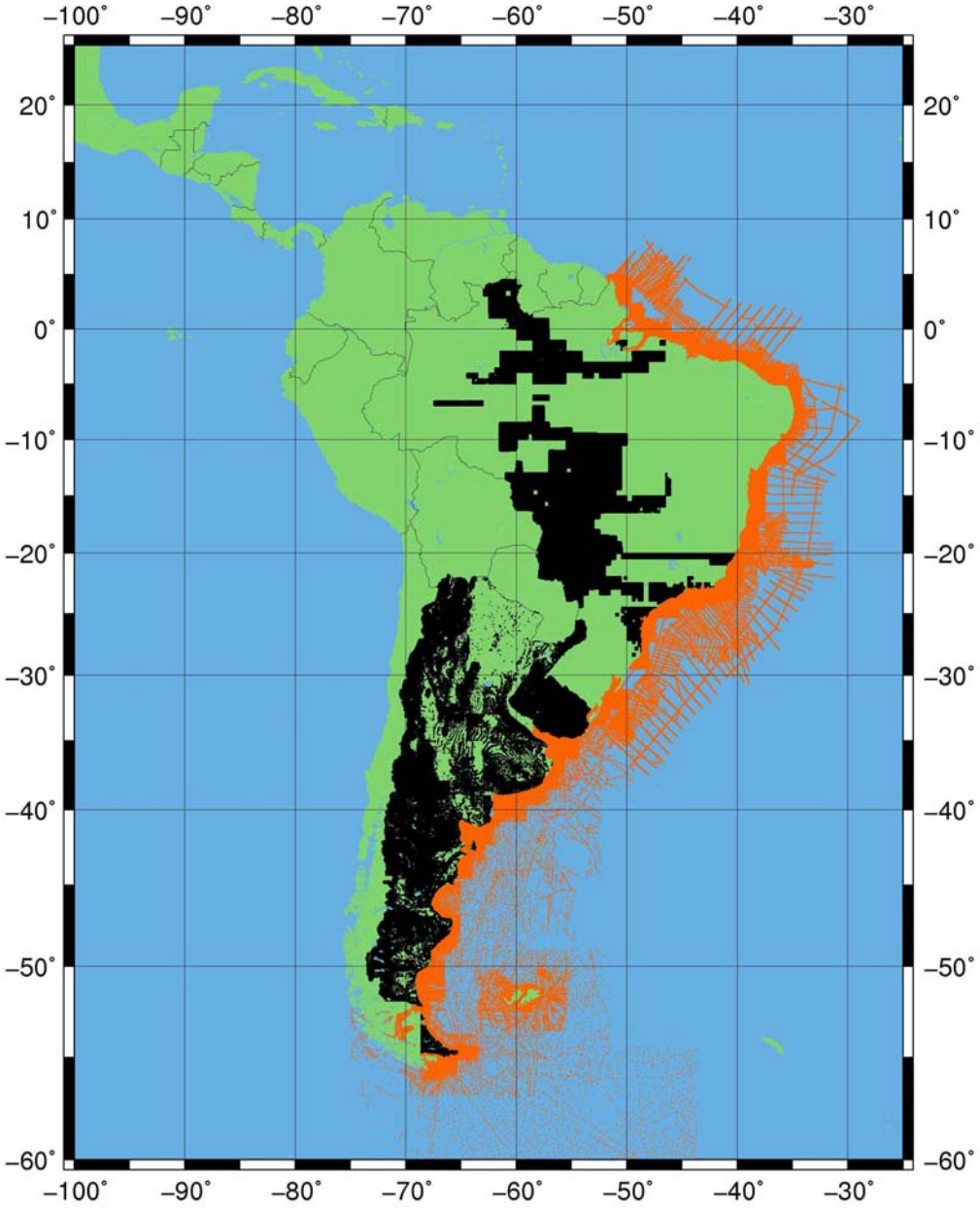

Figure 4: Distribution of different data used in the DTM.

As a result, three DTM models were generated for South America: DTM-ver1, DTM-ver2, DTM-ver3. The first one has a resolution of 1' and was generated from data of Figure 4. The second has also a resolution of 1'. It differs from ver1because it used SRTM instead of topographic maps. The ver3 is a 30" resolution; it is SRTM only in the continent and in the ocean is DTM2002. Figure 5 represent the DTM with ver2. This important and time consuming work was carried out at EPUSP by the student Ana C. Cancorro de Matos.

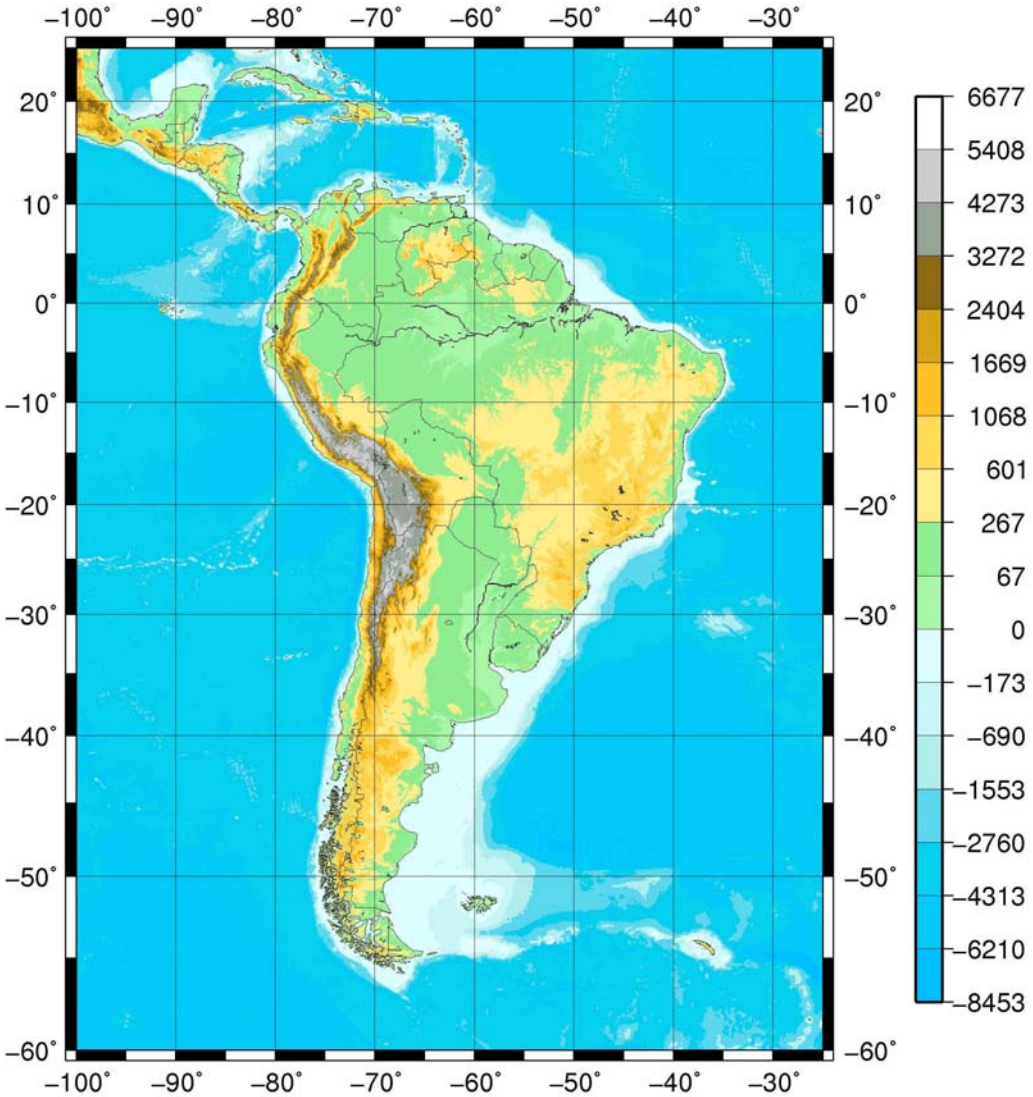

Figure 5: DTM representation (ver2).

Using ver2 of the DTM, the terrain correction and the indirect effect were estimated for South America (Figure 6).

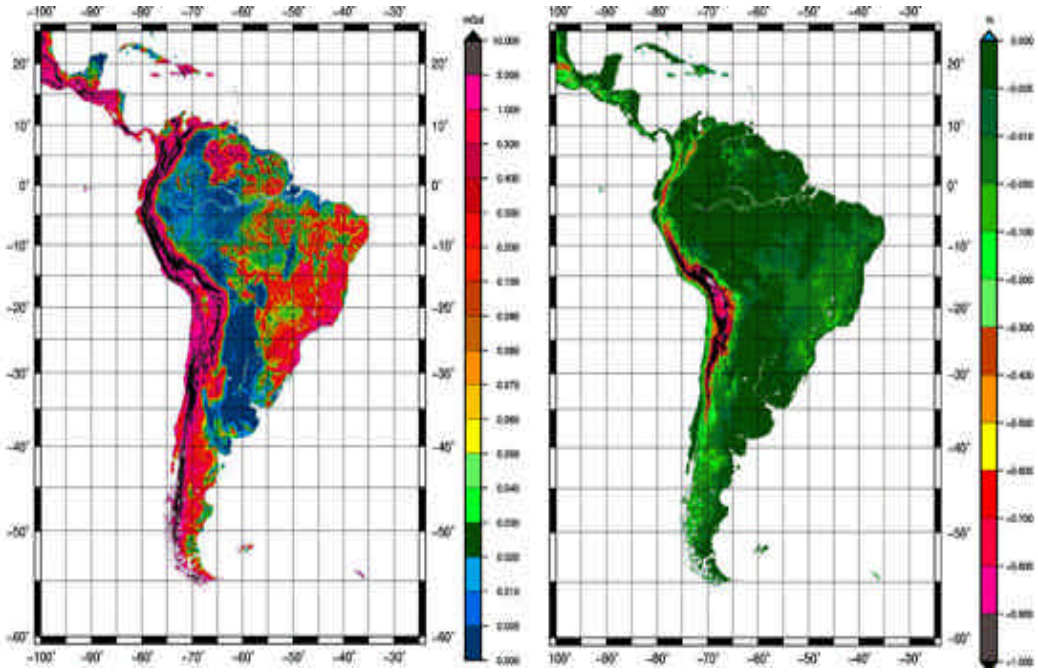

Figure 6: Terrain correction (left) and indirect effect (right).

<u>GPS/leveling:</u>

GPS/leveling stations data are being collected all over the continent to derive a set of geoid undulations that will be used for comparisons with the gravity geoid model.

<u>Geoid computations:</u>

All the above data collected, validated and organized are being used for geoid computations by numerical integration and FFT-1D. The geopotential models available, specially those from dedicated satellite missions CHAMP and GRACE, are being compared with terrestrial data. A new geoid computation will be done as soon as the new data from Ecuador and Colombia be replaced on the 5’ x 5’ mean gravity anomalies grid. The last version was derived with fft (Figure 7).

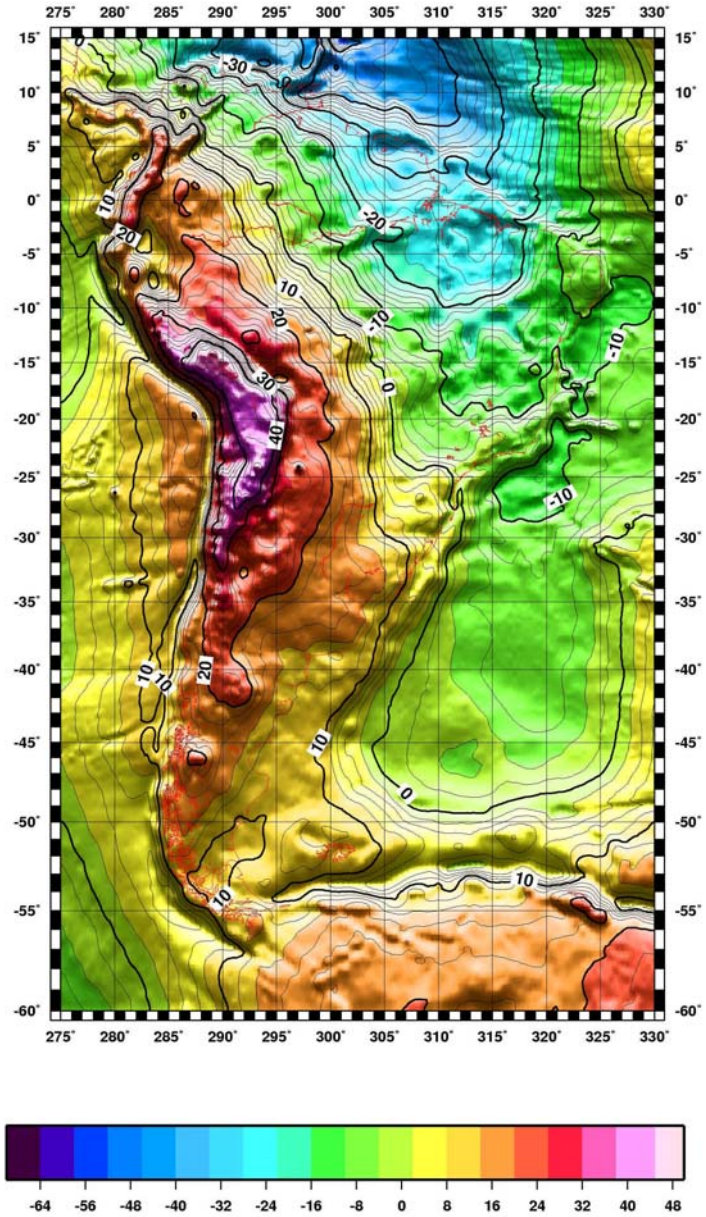

Figure 7. Geoid model computed with fft-1d – version 2004.

Bibliography:

Matos, A.C.C.de, Campos, I.O., Castro Jr., C.A.C., Blitzkow, D. (2004). Height analysis in Amazon área using different methods. Symposium on Gravity, Geoid and Space Missions (GGSM2004). Aug 30 – Sep 3, 2004. Porto, Portugal.

Lobianco, M.C.B., Castro Jr., C.A.C., Blitzkow, D. (2004). The last ten years of progress on the geoid in South América. Symposium on Gravity, Geoid and Space Missions (GGSM2004). Aug 30 - Sep 3, 2004. Porto, Portugal.

Blitzkow, D., Lobianco, M.C.B., Castro Jr., C.A.C.,Leiva, C., Centurión, L., Morales, W. (2004). Hacia un sistema de altura normal para Sudamérica: Los esfuerzos en Paraguay. Poster. 18 a 22 de outubro de 2004. Santiago, Chile.

Matos A.C. de, Blitzkow, D., Cintra, J.P. (2004) Avaliação do SRTM e SAM para a Argentina. XXII Reunión Científica de la Associacion Argentina de Geofísicos y Geodestas. Buenos Aires, 6 - 10 de setembro.

Appendix 13

IAG Inter-Commission Project
ICP1.2 Vertical Reference Frames

Progress Report 2004

Based on the classical and modern observations, the ICP1.2 on Vertical Reference Frames shall study the consistent modelling of both, geometric and gravimetric parameters, and provide the fundamentals for the installation of a unified global vertical reference frame.
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Objectives

- To elaborate a proposal for the definition and realization of a global vertical reference system (World Height System – WHS);
- To derive transformation parameters between regional vertical reference frames;
- To establish an information system describing the various regional vertical reference frames and their relation to a world height frame (WHF).

Program of Activities

- Harmonization of globally used height data sets;
- Study of combination procedures for height data sets from different techniques;
- Study of information on regional vertical systems and their relations to a global vertical reference system for practical applications;
- Unification of regional (continental) height systems.

Activities since 2003

(1) Realization of the European Combined Geodetic Network (ECGN) as case study for further global activities (Project of EUREF - IAG SC1.3a)
ECGN is a terrestrial network for the combination of different techniques: GPS/GLONASS positioning, gravity measurements, levelling, tide gauge observations.

- 1st Call for Participation: Implementation of ECGN Stations in April 2003
- Decision about the criteria to evaluate the proposals of the 1st Call and discussion of the individual proposals in September 2003
- Information of the ECGN organizations/institutions about the status in November 2003 (http://www.ifag.de/ecgn/index.htm)
- Preparation of the 2nd Call relating methodical investigations for the combination of spatial observation data with gravity field data.

(2) European Vertical Reference System Workshop April 5-7, 2004

- Preparation of a common European Vertical Reference System (EVRS) and its relation to a WHS till 2007
- Revision of the present EVRS conventions in agreement with the WHS/WHF conventions of ICP1.2
- Realization and maintenance of the EVRS by the ECGN till 2007.

(3) Meeting of ICP1.2, August 31, 2004, Porto

Main items of the discussion were the

- view to ICP1.2 strategy
- principles for conventions, open questions
- Information of local reference frames needed for transformation in a regional and global vertical system
- importance of W_0 in the definition of a global vertical reference system, and adoption of a new number for W_0, respectively the acceptance of existing conventions,
- importance of tide gauge observations and satellite altimetry for the realization of the global vertical reference system as well as the unification of regional vertical reference frames.

Next actions

A result of the discussion of the members of ICP1.2 about the definition and realization of a global vertical reference system was the composition of two work packages.

The first work package will address

- convention and standards for a Conventional Height System, a World Height System and a World Height Frame
- relationships to the CTRS, CTRF and gravity standards
- datum realization (handling of information of the satellite altimetry, possible role of the TIGA project, mean earth ellipsoid versus W_0)

This work package will be in executed in collaboration of J. Ihde, J. Krynski (chair), J. Mäkinen and V. Vatrt.

The second work package is related to the unification of height systems and the collection and distribution of information about the different national height systems including transformation parameters. Members of the group are M. Amos, A. Kasenda, Bill Kearsly, G. Liebsch, D. Roman (chair) and Marc Veronneau.

All ICP1.2 members are asked to contribute to the work packages. Both groups shall present first results till end of March 2005.

The next ICP 1.2 meeting is planned for spring 2005 during the EGS Conference in Vienna on 24.-29.04.2005. First results of our project shall be presented on the IAG Scientific Symposium in Cairns, Australia on 22.-26 August 2005.

January 7, 2005-01-06 Johannes Ihde (Chair of IAG ICP1.2)

Appendix 14

IAG Commission 2 – The Gravity Field
Report on the Activities of the
Global Geodynamics Project (GGP)

by

David Crossley,
GGP Chairman

In 2004 the main GGP activity was the project session held at the 15th International Symposium on Earth Tides, in Ottawa, August 2-6. The associated Newsletter #14 appeared in the Fall of 2004 and was posted on the GGP website (http://www.eas.slu.edu/GGP/ggphome.html). Important points noted in the Newsletter were:

1. Station Review. We have seen the closing down of the Boulder stations (BO) due to a hardware malfunction that also required a software upgrade that has not yet been implemented. For the moment the only North America SG station still recording is in Cantley Canada, and recently we heard that this station is also in imminent danger of disappearing, unless funding can be arranged through the Geological Survey of Canada. Contrary to the NA situation, a new station has come on line in Korea, and a new installation in Taiwan is in the planning phase. We are pleased that station BH (Bad Homberg, Germany) is now providing data to GGP and the remote station in Concepcion, Chile is working well.
2. Updated GGP agreements now require a delay of no more than 6 months between members and within 1 calendar year after its collection, all reporting SG stations are required to send their data to the International Center for Earth Tides (ICET)in Brussels.
3. GGP is moving towards more timely release of earthquake (rapid sample data), see below.
4. GGP is also working out the details of collecting AG (absolute gravimeter) data at the SG station sites. The purpose if to provide AG data for (a) the calibration of the SGs, and (b) to determine the secular changes in gravity at a station so that the SH drift can better be monitored. The reason GGP is considering thi development is due to the reservations some members of the community seem to have with the current procedures for collecting absolute gravimeter data through the BGI database.

Since the August GGP Workshop, and spurred on by the very large earthquakes in Sumatra on December 26 2004 and March 28 2005, GGP has move to make raw data available online (http://www.eas.slu.edu/GGP/sumatra.html). The format for the data has been standardized as modified PRETERNA format, just as for the 1 minute data, and now about 15 datasets are available for December 2004 and January 2005. It is hoped this will be expanded in future to permit more continuous data to be sent to the IRIS (seismology)

database. Some differences of approach exists within GGP as to whether to go directly to IRIS or work through our normal ICET procedures, now managed from GFZ (Potsdam).

The special issue of the Journal of Geodynamics (vol 38, Nos. 3-5, 2004) was devoted to papers arising from the previous years' Sapporo GGP Workshop, on the occasion of the first 6 year period of GGP (1997-2003). This special issue contained 19 papers from about 60 authors. At the present time, papers are being assembled from the 2004 Earth Tides meeting and will again be published in a future issue of the Journal of Geodynamics.

The next GGP Workshop is scheduled to be held during the imminent EGU meeting in Vienna, April 2005. Issues to be addressed remain those largely on the table last year. GGP has now successfully completed its first year as an interdisciplinary project of the newly organized IAG.

Of particular interest the gravity community at large is the need to create an absolute gravity database. GGP will continue to seek a viable means to collect AG data from the SG station sites, and this should be a good point of intersection for the combined resources of GGP and Commission 2.

St. Louis,
April 11, 2005.

Appendix 15

Inter-Commission Working Group 2.1
International Association of Geodesy (IAG)

Satellite Gravity Theory

Commission 2 (Gravity Field)
&
InterCommission Committee on Theory

Report 2003-2004

Nico Sneeuw (chair)

Joint WG Meeting

During the GGSM2004 meeting, August/September 2004, Porto, Portugal, a joint meeting was organized between ICWG2.1 and the ICCT WG on Inverse Problems (chair: J Kusche). The participation level was high, about 70%. Individual members briefly presented their research plans for the next few years. This meeting can be regarded as a kick-off for both working groups. One of the main discussions at the joint meeting was about a publication plan; see below.

Special issue Journal of Geodesy

It was proposed and agreed at the joint meeting that the two WG chairs will organize a special issue of the Journal of Geodesy, dedicated to the combined areas of the two working groups. The authorship is mostly drawn from the combined WG membership, although authors from outside will participate as well. Further details:

- The Editor-in-Chief of JoG, Will Featherstone, has agreed.
- The two WG chairs will act as guest editors (though N Sneeuw is regular JoG editor already).
- To date, about 16 papers have been announced.
- Deadline for submission is end of June 2005.
- Papers will have to pass the normal editorial and review process.
- Depending on the speed of the review process, the special issue may be expected end of 2005, or rather early 2006.

Further activities

All WG members are actively involved in aspects of spaceborne gravimetry using CHAMP, GRACE, GOCE and/or future missions. In this reporting period it is too early to extensively document all publications, papers, poster presentations, etc. For the upcoming reporting timeframe it is planned to monitor relevant activities and stimulate participation in workshops and conferences, in close agreement with the chairs of SC2.3 on Dedicated Gravity Field Missions (P Visser) and the InterCommission Committee on Theory (PL Xu), to which this WG is answerable.

Members

The initial members of the working group (addresses at start of WG activities) are:

N Sneeuw (chair)	University of Calgary	Canada	sneeuw@ucalgary.ca
P Ditmar	TU Delft	Netherlands	ditmar@geo.tudelft.nl
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R Grebenitcharsky	University of Calgary	Canada	grebski@ucalgary.ca
SC Han	Ohio State University	USA	han.104@osu.edu
M Kern	TU Graz	Austria	kern@geomatics.tu-graz.ac.at
C Kotsakis	University of Calgary	Canada	ckotsaki@ucalgary.ca
J Kusche	TU Delft	Netherlands	j.kusche@citg.tudelft.nl
J Li	Wuhan University	China	jcli@wtusm.edu.cn
P Moore	Newcastle University	UK	philip.moore@ncl.ac.uk
R Pail	TU Graz	Austria	pail@geomatics.tu-graz.ac.at
N Pavlis	Raytheon ITSS Corp.	USA	npavlis@atlas.stx.com
T Peters	TU Munich	Germany	peters@bv.tum.de
H Schaub	Virginia Tech	USA	schaub@vt.edu
Y Shen	Tongji University	China	yzshen@mail.tongji.edu.cn
I Velicogna	University of Colorado	USA	isabella@colorado.edu
P Visser (ex officio)	TU Delft	Netherlands	Pieter.Visser@lr.tudelft.nl
F Wild	University of Karlsruhe	Germany	wild@gik.uni-karlsruhe.de
DN Yuan	JPL	USA	dah-ning.yuan@jpl.nasa.gov

At the GGSM2004 meeting in Porto, Portugal, Pavel Nová k (Research Institute of Geodesy, Czech Republic, pnovak@pecny.asu.cas.cz) was added to the membership. C Kotsakis has since moved to the Aristotle University of Thessaloniki, Greece. R Grebenitcharsky has moved to TU Delft, The Netherlands.

Appendix 16

Report of IAG ICCT Joint Working Group with Commission on Gravity:

JWG 5: Multiscale Modelling of the Gravity Field

Introduction

During the last decades technological progress has changed completely the observational methods in all fields of geosciences with a trend to achieve immediate results, thus reducing time and costs. A reconstruction of the gravity field from data material coming from satellite as well as airborne and terrestrial measurements requires a careful multiscale analysis of the gravity potential, fast solution techniques, and a proper stabilization of the solution by regularization. While global long-wavelength modelling can be adequately done by use of spherical harmonic expansions, harmonic splines and/or wavelets are most likely candidates for medium and short-wavelength approximation. The working group intends to bring together scientists concerned with the diverse areas of geodetically relevant wavelet theory in general and its applications. An essential field of research is the specific character of geodetic multiresolution methods used in addition or in contrary to standard spectral techniques based on spherical harmonic framework.

Objectives

- Theoretical research in the field of spherical and ellipsoidal wavelets as well as wavelet introduction and modelling on geodetically relevant surfaces (like spheroid, geoid, (actual) Earth's surface).
- Studies of harmonic wavelets in geodetic boundary-value problems (e.g., Runge-Walsh wavelets, layer potential wavelets, etc).
- Studies on spline/wavelet kernel modelling, multiscale pyramid algorithms via kernel functions known from (least squares) collocation and spline approaches, noise cancellation, least-squares adjustment and spline smoothing vs. multiscale thresholding, etc.
- Development of specific numerical methods: fast wavelet transform, tree algorithms, data compression, domain decomposition techniques, fast multipole methods, panel clustering, data transmission, etc.
- Comparison of spherical harmonic and/or wavelet modelling: Combined spectral and multiscale expansion of the gravitational potential, degree variances vs. local wavelet variances, spectral and/or multiscale signal to noise thresholding, etc.
- Investigation of different wavelet types in geodetic pseudodifferential equations (using numerical methods such as collocation, Galerkin method, least-squares approximation, etc).
- Regularization of inverse problems by multiresolution, locally reflected multiscale vs. globally reflected spectral regularization, multiscale parameter choice strategies, multiscale modelling in SST, SGG.
- Time dependent multiscale modelling in boundary value and inverse problems, numerical implementation and application to GRACE-, GOCE-data.

Members and Correspondent Members

W. Freeden, Germany (chair)

M. J. Fengler (Germany), T. Gervens (Germany), E. W. Grafarend (Germany), M. Gutting (Germany), K. Hesse (Australia), C. Jekeli (USA), W. Keller (Germany), J. Kusche (Netherlands),

D. Michel (Germany), V. Michel (Germany), J. Otero (Spain), S. Pereverzev (Austria), F. Sacerdote (Italy), F. Sanso (Italy), M. Schreiner (Switzerland), J. Schröter (Germany), W.-D. Schuh (Germany), I. H. Sloan (Australia), N. Sneeuw (Canada), L. Svensson (Sweden), C. C. Tscherning (Denmark)

Past Activities

- Oberwolfach conference on Geomathematics in May 2004, organised by W. Freeden, E. W. Grafarend, I. H. Sloan, L. Svensson.
- Presentations at several conferences:
  - 2nd CHAMP Science Meeting in Potsdam, September 2003.
  - Minisymposium about Inverse Problems at DMV Jahrestagung Rostock, September 2003.
  - Geodetic Week Hamburg, September 2003.
  - GOCE-CryoSat-Workshop at EADS Astrium in Friedrichshafen, November 2003.
  - 2nd GOCE User Workshop at ESRIN, Frascati, March 2004.
  - General Assembly of the European Geoscience Union (EGU) in Nice, April 2004.
  - Geodetic Week Stuttgart, October 2004.
  - General Assembly of the European Geoscience Union (EGU) in Vienna, April 2005.
  - SIAM Conference on Mathematical and Computational Issues in the Geosciences, Avignon, June 2005.
- Cooperation between the groups in Kaiserslauten (W. Freeden) and Munich (R. Rummel) about multiscale modelling of temporal changes of the gravitational field measured by GRACE (see: M.J. Fengler, W. Freeden, A. Kohlhaas, V. Michel, T. Peters, "Wavelet Modelling of Regional and Temporal Variations of the Earth's Gravitational Potential Observed by GRACE", submitted to Journal of Geodesy, 2005).
- Cooperation between the groups in Kaiserslautern (W. Freeden) and Stuttgart (E. W. Grafarend) in form of a joint DFG-project: Inverse Multiscale Geoid Computation (IMGC).
- Cooperation between the groups in Delft (J. Kusche) and Kaiserslautern (W. Freeden) about Wavelet Modelling of satellite data and its combination with regional terrestrial data. (see: M. J. Fengler, W. Freeden, V. Michel: "The Kaiserslautern Multiscale Geopotential Model SWITCH-03 from Orbit Perturbations of the Satellite CHAMP and Its Comparison to the Models EGM96, UCPH2002_02_0.5, EIGEN-1s, and EIGEN-2." Geophysical Journal International, Vol. 157, pp. 499-514, 2004; and: M. J. Fengler, W. Freeden, J. Kusche: "Multiscale Geopotential Solutions from CHAMP Orbits and Accelerometry." C. Reigber, H. Lühr, P. Schwintzer, J. Wickert (Eds.), Proceedings of the 2nd CHAMP Science Meeting, Springer Berlin, Heidelberg, New York, pp. 139-144, 2004.).

Literature

In addition to many papers the following books about wavelets and multiscale techniques in geosciences have been published during the last 2 years:

- W. Keller, "Wavelets in Geodesy and Geodynamics", de Gruyter, Berlin, 2004.
- W. Freeden, V. Michel, "Multiscale Potential Theory (With Applications to Geoscience)", Birkhäuser, Boston, 2004.
- "Geomathematics, Oberwolfach Conference Report No. 27/2004", in: Oberwolfach Reports, Vol. 1, No. 2, European Mathematical Society, 2004.

Planned Activities

- Organisation of a workshop "Inverse Problems in Geosciences" together with the Group of R. Rummel (Munich, Germany) and ESA representatives in Kaiserslautern in fall 2005.
- Further Email discussion and electronic exchange.
- Launch of an extended web-page for dissemination of information, expressing aims, objectives, and providing a bibliography.
- Further monitoring and presentation of activities, either of working group members or interested external individuals.

Appendix 17

Report of the International Gravity Field Service – Feb. 2005

Chairman: Rene Forsberg, Danish National Space Center
rf@spacecenter.dk

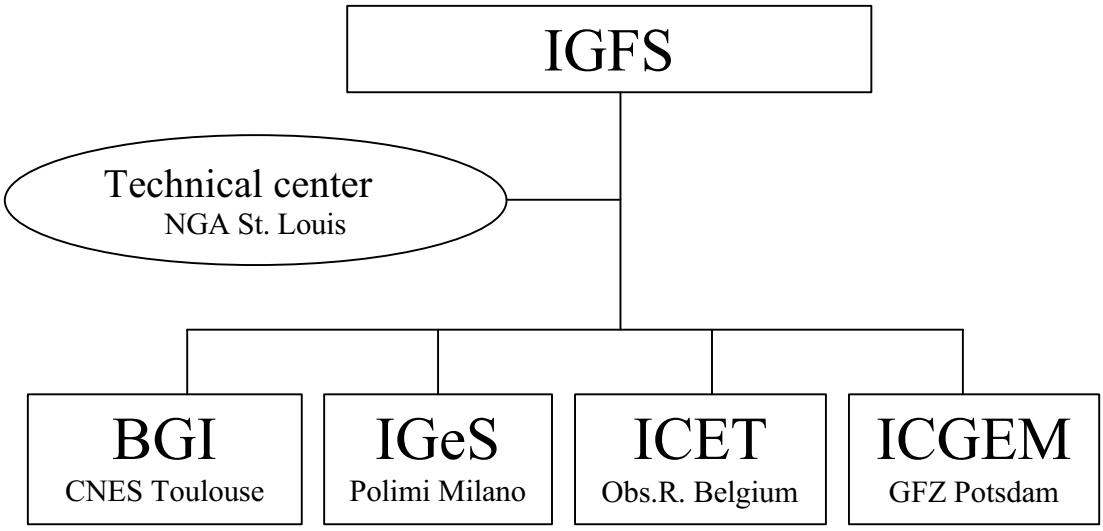
The International Gravity Field Service (IGFS) is an "umbrella service", coordinating the gravity-related services under the International Association of Geodesy (IAG). The IGFS was approved by IAG at the IUGG General Assembly in Sapporo 2003. The primary purpose of the IGFS is - in addition to the service coordination - to represent gravity field geodesy more unified in relation to other parts of geodesy, notably in connection with the IAG project GGOS – Global Geodetic Observing System. The IGFS is presently still under formation ("in statu nascendi"), and the active cooperation and communication between existing services under the IGFS umbrella could be somewhat improved. It is not presently not the idea that the IGFS should serve the scientific community directly, but focus on the inter-service coordination, aid in the data collection, establish new service elements ads required, and – to some degree – participate in outreach of more general gravity field nature.

Current structure of the IGFS

The following service entities are presently active under the IGFS umbrella:

- International Gravimetric Bureau (BGI) – *director G. Barriot*
- International Geoid Service (IGeS) – *director R. Barzagi*
- International Center for Earth Tides (ICET) – *director B. Ducarme*
- International Center for Global Earth Model (ICGEM) – *director t.b.a.*

In addition the Geodesy and Geophysics Department at National Geospatial-Intelligence Agency (NGA, *chief geodesist S. Kenyon*), serve a special role as an IGFS Technical Center, interacting both with the IGFS services and directly with the scientific community, supplementing especially BGI and IGeS activities in terms of collecting and disseminating gravity and geoid data. A proposed service to collect and provide digital terrain models (DEMs) for gravity field modelling purposes (De Montfort University, UK, *P. Berry)* is not yet operational. The activities of the IGFS is governed by an Advisory Board, consisting of the service directors, IAG representatives (*C. Jekeli, M. Sideris*) and two members of the IGFS affiliates (*D. Blitzkow and H. Denker).*



Ongoing activities of the IGFS

1st Advisory Board meeting: Nice, April 2004. Agenda and structure of the IGFS confirmed. Next advisory board planned for Cairns, August 2005.

Preparations for 1st International Symposium of the IGFS in Istanbul, Turkey, September 2006, is under way. The IGFS Symposium will partially carry on the activities of the earlier joint Gravity and Geoid symposia under the auspices of the former International Gravity and Geoid Commission. A scientific steering group has been appointed and a technical program is being prepared. The Geodetic Department of the Turkish Military Mapping Agency will be leading the local organization committee (*chairman A. Kilicoglu).*

A joint IAG Commission 2 / IGFS working group for validation of new EGM05 ultra-high resolution (n_{max} = 2160) global gravity field model (NGA/NASA) have been established. The EGM05 will likely serve as a de facto standard for global gravity field and geoid information for a long period after 2005, equivalent to the success of EGM96. The IGFS will actively support the release of regional gravity field data for various regions of the world to enhance the overall quality of EGM05.

Other main activities:
* Joint service schools: Microgravimetry school, BGI and ICET, Canary Islands, planned for fall 2005.
* Joint bulletin: Newton's Bulletin – joint electronic journal of the BGI and IGeS.
* Geoid schools: New IGeS Geoid School successfully held in Budapest, Feb. 2005 (with approx. 60 participants).

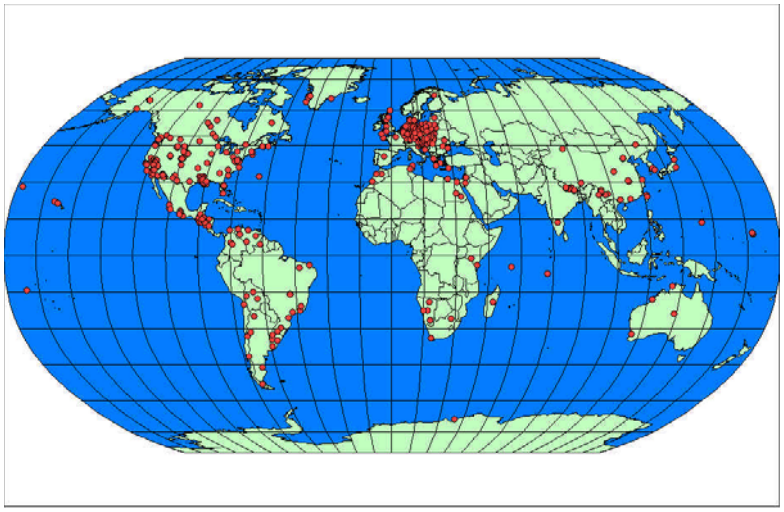
Web sites of the IGFS services:
BGI – http://bgi.cnes.fr
IGeS – http://www.iges.polimi.it
ICET – http://www.astro.oma.be/ICET
ICGEM – http://icgem.gfz-potdam.de/ICGEM/ICGEM.html

The IGFS own website has not yet been established (available a.s.a.p. at the new DNSC premises of the chairman).

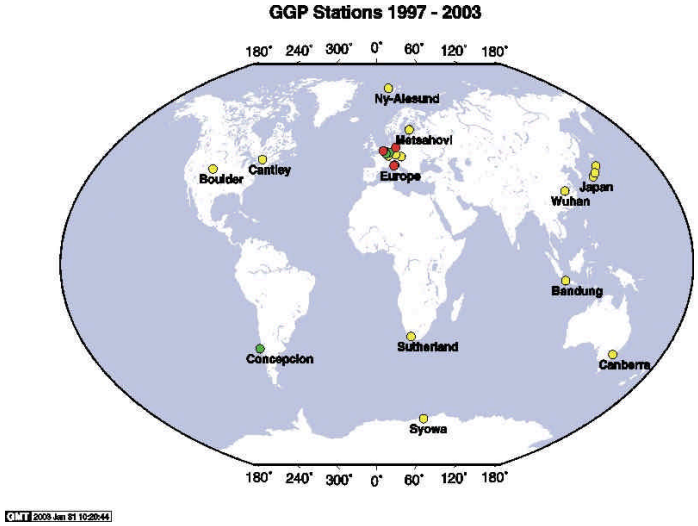
Outlook

The IGFS should in cooperation with the gravity-related services provide gravity field input, standardization and outreach to the GGOS, including such activities as

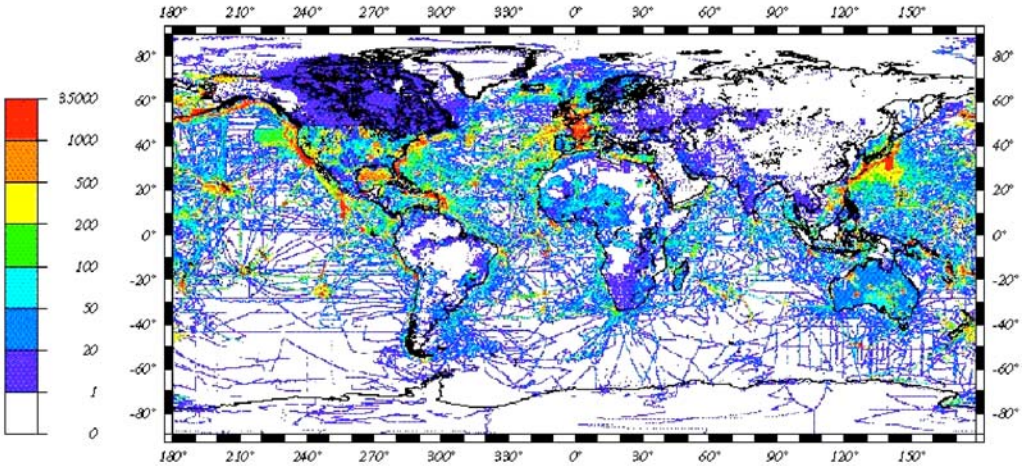
- encourage fundamental gravity field observation networks (e.g., a global absolute reference net, co-located with satellite stations and other geodetic observation techniques);
- encourage the data collection and release of marine, surface and airborne gravity data for improved global model development (e.g, EGM05);
- encourage the use of consistent standards for gravity field models across the services, and for combination of satellite and terrestrial gravity field data;
- encourage timely release of satellite gravity field data from space agencies;
- encourage establishment of new IAG service "homes" for new science applications (e.g., time-varying gravity).



Absolute gravity measurement coverage (NGA)



Coverage of superconducting gravimeters (ICET/Global Geodynamics Project)



Coverage of unclassified surface gravimetry (BGI; approx 12 mio points)

Appendix 18

Proposal for a Joint Working Group (JWG)
Between International Gravity Field Service (IGFS) and the IAG Commission 2

Evaluation of Global Earth Gravity Models

Chair: Dr. Jianliang Huang (Geodetic Survey Division, CCRS, NRcan, Canada)
Vice-chair: Dr. Christopher Kotsakis (Aristotle University of Thessaloniki, Greece)

Terms of Reference

The CHAMP and GRACE satellite gravity missions, along with the upcoming GOCE mission, are and will be mapping the Earth's gravity field with significantly increasing accuracy and spatial resolution. The data obtained from these missions are being and will be used to develop a series of new static satellite-only gravity models down to 150 – 200 km wavelength, as well as combined Earth Gravity Models (EGMs) down to about 20 km wavelength. The evaluation of such global EGMs is commonly based on comparisons with other "external" data sets that depend on the same gravity field. The various centers responsible for the development of these models routinely perform such comparisons using a variety of validation data sets such as geoid heights from GPS and leveling heights, airborne and surface gravity measurements, marine geoid heights from mean oceanographic sea surface topography models and altimetry observations, orbits from other geodetic and altimetry satellites etc.

In response to the call of having an independent and coordinated initiative for the evaluation of the new EGMs, a new Joint Working Group (JWG) has been established between IGFS and the IAG Commission 2. The main objective of the JWG is to develop standard validation/calibration procedures, and to perform the quality assessment of GRACE-, CHAMP- and GOCE-based satellite-only and combined solutions for the static Earth's gravity field. The external data sets that will be used for such purposes include mainly GPS-leveling data, airborne and surface gravity data, mean oceanographic sea surface topography models and altimetry data, orbit data from other geodetic and altimetry satellites and astro-geodetic deflection data etc.

Another equally important evaluation is with respect to temporal variation of the Earth's gravity field derived from the GRACE monthly gravity solutions. The repeated absolute/relative gravity measurements and super-conducting gravity observations provide the most accurate temporal variation on the ground. As part of the initiative, validation/calibration methods for temporal gravity variation will be explored.

Program of Activities

1. The JWG creates opportunities through communication and workshops/conferences for international cooperation to develop and propose standard methods for evaluating global EGMs using external geodetic and oceanographic data. A specific research area of interest will be the issue of how to handle the different spectral content of satellite-based global gravity field models and terrestrial gravity data.
2. The JWG defines a set of synthetic data to test the feasibility and the performance of various evaluation methods for EGMs.
3. The JWG conducts evaluation of new global EGMs.
4. The JWG explores evaluation methods for temporal gravity variation.
5. The JWG encourages active participation and contribution from its members through email contact, conferences/meetings, scientific presentations and publications.
6. A WWW site will be created to facilitate communication, information and data exchanges.

The Joint Working Group reports to IGFS and the Commission 2.

Membership:

Dr. Hussein Abd-Elmotaal, Minia University, Egypt
Dr. Min Kang Cheng, CSR, University of Texas & Austin, USA
Dr. Heiner Denker, University of Hannover, Germany
Prof. Will Featherstone, Curtin University of Technology, Australia
Dr. Rene Forsberg, National Space Centre, Denmark
Dr. Thomas Gruber, IAPG, TUM, Germany
Dr. Jianliang Huang, Geodetic Survey Division, CCRS, NRcan, Canada
Dr. Jaroslav Klokocníc , Astronomical Institute of the Acad. of Sciences, Czech Republic
Dr. Christopher Kotsakis, Aristotle University of Thessaloniki, Greece
Prof. Jiancheng Li, Wuhan University, P. R. China
Prof. Charles Merry, University of Cape Town, South Africa
Prof. Phil Moore, Newcastle University, UK
Dr. Pavel Novák, Research Institute of Geodesy, Czech Republic
Dr. Niko K Pavlis, Raytheon ITSS Corporation, USA
Dr. Dan Roman, National Geodetic Survey, USA

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Mr. S. C. Kenyon, National Geospatial-Intelligence Agency, USA

Prof. Ch. Reigber, GeoForschungsZentrum, Potsdam, Germany
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Prof. R. Rummel, IAPG, TUM, Germany
Prof. M.G. Sideris, University of Calgary, Canada
Dr. N. Sneeuw, University of Calgary, Canada
Prof.. B.D. Tapley, CSR, University of Texas & Austin, USA
Prof. I.N. Tziavos, Aristotle University of Thessaloniki, Greece
Mr. M. Véronneau, Geodetic Survey Division, CCRS, NRCan, Canada
Dr. P. Visser, Delft University of Technology, The Netherlands

Commission 3: Earth Rotation and Geodynamics

REPORT OF ACTIVITIES
(2003–2005)

President: Véronique Dehant (Belgium) Vice President: Mike Bevis (USA)

1. Overview

The reorganization of the IAG took effect at the IUGG meeting in Sapporo in 2003. The new Commission 3 is dealing with Earth rotation and geodynamics activities.

An Advisory Board of Commission 3 has been created to serve during the period 2003-2007 in order to provide comments and advices to the officers (President and Vice-President) and to represent the interests within the commission. The Advisory Board confers via email, and has no formal meetings. The Advisory Board consists of the following members (their responsibilities is also given below):

President: Véronique Dehant
Vice-President: Mike Bevis
Past Presidents: Clark R. Wilson and Martine Feissel-Vernier

Heads of Sub-commissions:
Sub-commission 3.1 Earth Tides: G. Jentzsch (Germany)
Sub-commission 3.2 Crustal Deformations: M. Poutanen (Finland)
Sub-commission 3.3 Geophysical Fluids: R. Gross (USA)

Head of Inter-commission Project:
Inter-commision project 3.1 GGP: D. Crossley (USA)
Inter-commision project 3.2 WEGENER: S. Zerbini (Italy)

Commission 3 representatives:
To inter-commision commitee on Theory: T. Van Hoolst (Belgium)
To inter-commision commitee on Planetary Geodesy: O. Karatekin (Belgium)
To inter-commision project 3.1 GGP: D. Crossley (USA)
To inter-commision project 3.2 WEGENER: T. Van Dam (Luxembourg)
To IERS: C. Wilson (USA)
To IAU commission 19: M. Rothacher (Germany)

Member at large:
Kosuke Heki (Japan)

The commission is co-sponsoring two WGs

1. on "Theory of crustal deformations" of ICC on Theory (Chair: Heki Sensei),

2. on “Differential INSAR” of Commission 4 (Chair: Xiaoli Ding).

The objectives of Commission 3 are:

- To develop cooperation and collaboration in computation, in theory, and in observation of Earth rotation and geodynamics, and to ensure development of research in geodynamics and Earth rotation by organizing meetings, symposia, and general assemblies, by creating working groups on specific topics, and by encouraging exchange of ideas and data, comparisons of methods and results improving the accuracies, content, methods, theories, and understanding of Earth rotation and geodynamics.
- To serve the geophysical community by linking them to the official organization providing the International Reference Systems/Frames and Earth orientation parameters (IERS and related bodies), and organizations providing all the other data on which geodynamics and Earth rotation studies can be performed.

The activities in scientific research related to Commission 3 are mostly developed in the sub-commission report, with one important exception, the new research in the frame of precession and nutation. This research has been initiated by the Descartes Prize received by the Nutation Consortium in 2003. The money (300 000 €) has been dedicated to young scientist proposals. A call for proposals has been sent out at the beginning of 2004 and 15 proposals have been selected for either PhD students or postdocs. Additionally, money has been dedicated to travel support for participation in meetings for disfavored countries.

In addition to this, the activities of these last two years include
1. Participation in special meetings related to geodynamics and Earth rotation, such as Journées Systèmes de Références Spatio-temporels in Paris, ECGS Chandler Wobble Workshop in Luxembourg (on ‘Forcing of polar motion in the Chandler frequency band: a contribution to understanding interannual climate variations’).
2. Participation in the IAG Project Global Geodetic Observing System (GGOS). Some of the Descartes fellows have a GGOS flag on their project.
3. Linking the Sub-Commission together: we have encouraged joint sub-commission meetings. The three Presidents of the sub-commissions have agreed to have a common Symposium in 2008 in Jena, Germany.
4. Linking Commission 3 with its sister commission of the IAU, Commission 19 on ‘Earth Rotation’. This link has been done using the website of both commissions and through the sharing of information, easy to do for this term as the presidents of both commissions are the same person (V. Dehant).
5. Encouraging and stimulating the services related to Commission 3. This has again been performed by using money of Descartes Prize as several proposals have the objectives to help the IERS Product Center on Global Geophysical Fluids.

In addition to this, following the adoption of new resolutions on the definition of the way to pass from the terrestrial reference frame to the celestial reference frame, using the Non Rotating Origin (NRO), the Royal Observatory of Belgium has decided to dedicate some money to perform 3D representations which explain it. These 3D representations

are on the web. Still some explanations must be added. The new link between the frames takes full advantage of precision available with modern VLBI and other space techniques. The new precession-nutation models are an important element of high precision geodesy that enables the study of geodynamics.

One important concern related to our commission is the impact of the 2005 tsunami on geodynamics. Sessions at AGU and EGU meetings have been totally dedicated to that subject. The IAG General Assembly in Cairns contains as well many papers on that subject.

The web pages of Commission 3 are: http://www.astro.oma.be/IAG/

2. Report of Sub-commission 3.1 on 'Earth Tides'

Author: G. Jentzsch

After taking over the presidency from Shuzo Takemoto in July 2003, Gerhard Jentzsch asked Spiros Patiatakis to become Vice-President of ETsC, and Olivier Francis to continue as the secretary. They prepared the 15th International Symposium in Ottawa, August 2004. The symposium was a successful event, although only about 80 participants took part. Currently, they are preparing the proceedings which will appear as a special volume of the Journal of Geodynamics, scheduled for the last volume in 2005.

In April 2004, Gerhard Jentzsch participated in the celebration of the 70th birthday of Houtze Hsu in Wuhan, China. He was invited to present a talk which was printed in a comprehensive volume on 'Progress in Geodesy and Geodynamics' (1100 pages), already completed at the event. H.T. Hsu was a former president of the ETC, and he opened China for Earth tide research. He especially tied strong connections to European scientists and their institutions.

The Earth Tides sub-commission had three working groups which continue:
- Earth Tides in Geodetic Space Techniques, co-chaired by H. Schuh and Wu Bin,
- Analysis of Environmental Data for the Interpretation of Gravity Measurements, co-chaired by C. Kroner and G. Jentzsch, and
- Gravitational Physics, chaired by L. Mansinha.

A new working group was created:
- Precise Tidal Prediction, chaired by Y. Tamura

During the last EGU General Assembly in Vienna, April 2005, the sub-commission had a joint GGP and ETsC meeting. There we decided that between March 27 and 31, 2006, (during the week prior to the EGU conference) a combined meeting of the working group on 'Environmental Data ...' and the new WG on 'Tidal Prediction' together with a GGP workshop should be organized in Jena. The sub-commission will apply for funding of this meeting.

The 16th International Symposium on Earth Tides will be held in Jena in 2008. Taking into account that more than 50% of all presentations were not on Earth tides, but on geodynamics and environmental effects as well as on instrumental topics, the sub-commission already agreed in Ottawa to extend the scope of the next symposium: there will be a joint symposium of the three sub-commissions of commission 3 (Earth Tides, Crustal Deformation, Geophysical Fluids) and the inter-commission project GGP (Global Geodynamics Project).Other inter-commission study groups can be included if possible. This symposium is scheduled for the first week in September 2008.

3. Report of Sub-commission 3.1 on 'Crustal Deformation'

Author: M. Poutanen

Members of the directing board:
Markku Poutanen (Chair)
Jim Davis
Kosuke Heki
John Manning
Janusz Sledzinski
Susanna Zerbini

General objectives of the Sub-Commission 3.2 include:

- to study tectonic motions, including plate deformation;
- to study postglacial rebound, but also glacial dynamics and glacial isostatic adjustment in the currently glaciated area of the Earth, as well as the water and ice mass balance;
- to study local crustal movements, some of which could be potentially hazardous
- to study sea-level fluctuations and changes in relation to vertical tectonics along many parts of the coastlines and in relation to environmental fluctuations/changes affecting the geodetic observations;
- to promote, develop and coordinate international programs related to observations, analysis and data interpretation for the three fields of investigation mentioned above;
- to promote the development of appropriate models.

The SC3.2 comprises sub-entities or working groups corresponding either to different geographical regions or different important and actual topics involved in the field of the SC studies. These sub-entities are dealing with main scientific objectives having common general aspects and, in parallel to these objectives, follow the development of technology and measurement techniques capable to best fulfill the scientific objectives. Sub-entities or working groups will be established by the directing board according to the needs or activities. Currently, there exists the Permanent Working Group on 'Geodynamics of the Central Europe'.

Permanent Working Group on '*Geodynamics of the Central Europe'*, (reported by Janusz Sledzinski, Poland) has continued studies on geotectonic regions of Central Europe. The formal membership list of the WG includes 29 scientists from 12 European countries. The programme of the WG (Plan of Action for 2003-2006) includes the following subjects:

- Geodetic and geodynamic programmes

European programmes:

  - CERGOP = Central Europe Regional Geodynamics Project,
  - CEGRN = (Central European GPS Reference Network) Consortium,
  - Post-UNIGRACE action (Unification of gravity system in Central and Eastern Europe).

Local geodynamic projects:

  - Projects realized by the subgroups of the CERGOP Study Group CSG.5 on "Geotectonic Analysis of the Region of Central Europe"; they concern the following regions: Eastern Alps and the North and Eastern Adriatic Sea, Romania Plate, Pannonian Basin, Plitvice Lakes, Croatia, Tatra Mountains, Northern Carpathians, and Balkan Peninsula;
  - Projects realized in bilateral/multilateral agreements of CEI countries, e.g. Czech-Polish-Slovak Cross-Border Studies of Regional Geodynamics (Sudetes, Beskydy, Tatra, Pieniny Mts).

- Working Group on University Education Standards;
- Working Group on Satellite Navigation Systems;
- Cooperation CEI Section C "Geodesy"– European Geophysical Society (EGS) / European Geosciences Union (EGU).

CEI WGST Section C "Geodesy" declares further close cooperation with the International Association of Geodesy in any form that would be considered as the most effective. The research and interpretation of recent crustal movements detected by satellite techniques are recognized as most important and urgent action within the mentioned workpackages of the CERGOP-2. The Section C "Geodesy" will provide the velocity vectors (displacement vectors) from the regions of Central Europe covering the area of CEI countries. The results of the CERGOP and other CEI projects will be release for the IAG scientific groups dealing with geodynamic investigations. The full report can be found on SC3.2 web page (see below).

Contacts between SC3.2 and WEGENER (Working group of European Geoscientists for the Establishment of Networks for Earth science Research, chaired by L. Bastos) continued. Zerbini is also a member of the WEGENER governing board. Zerbini and Poutanen participated in the board meeting of WEGENER held in Vienna in April 2005.

Discussions and planning on a joint symposium of SC3.1, 3.2 and 3.3 started. Preliminarily, the meeting is planned to be held in September 2008 in Jena. Chairman of the SC3.1, Gerhard Jentzsch is the chairman of the organizing committee.

Markku Poutanen participated on the planning of the Antarctic geodynamics plan POLENET: Polar Earth Observing Network for IPY. It is an international plan, chaired

by Terry Wilson of OSU, and proposed as an IPY project for the International Polar Year programme. One of the goals is to study present-day motions on Antarctica.

Markku Poutanen is the chairman of the Task Force set by Presidium of the Nordic Geodetic Commission to prepare the plan for the NGOS – Nordic Geodetic Observing System. The plan will follow the guidelines and principles of the GGOS (Global Geodetic Observing System) of IAG. NGOS will be a regional implementation of GGOS. The report of the NGOS task force can be found in http://www.nkg.fi.

Web pages of the IAG SC3.2 are under construction. Current version of the pages can be found in http://IAGSC32.fgi.fi.

4. Report of Sub-commission 3.1 on 'Geophysical Fluids'

Author: R. Gross

Directing Board

President: Richard Gross (USA)
Vice President: Aleksander Brzezinski (Poland)
Member: Ben Chao (USA)

Terms of Reference

Mass transports in the atmosphere-hydrosphere-solid Earth-core system, or the "global geophysical fluids", will cause observable geodynamic effects on a broad time scale. Although relatively small, these global geodynamic effects have been measured by space geodetic techniques to increasing, unprecedented accuracy, opening up important new avenues of research that will lead to a better understanding of global mass transport processes and the Earth's dynamic responses. Angular momentums and the related torques, gravitational coefficients, and geocenter shift for all geophysical fluids are the relevant quantities. They are studied theoretically and observed based on global observational data, and/or products from state-of-the-art models some of which assimilate such data.

The objective of the Sub-Commission is to serve the scientific community in providing research and data analysis associated with the geophysical fluids, in areas related to the variations in Earth rotation, gravitational field and geocenter that are caused by mass transport in the geophysical fluids. The geophysical fluids of the Earth system include the atmosphere, ocean, solid Earth, and core, and geophysical processes associated with ocean tides and hydrological cycles.

Report

Investigating the impact of geophysical fluids on the Earth's gravity, rotation, and shape continues to be a very active area of research as judged both by the number of special sessions devoted to this topic at the major EGS, EGU, and AGU conferences that were held during 2003 to 2005 and by the successful Chandler wobble workshop that was held during April 21–23, 2004 in Luxembourg at which geophysical fluid excitation of the Chandler wobble was a major topic of discussion. Special sessions on geophysical fluids will continue to be organized at future EGU and AGU conferences. In addition, at the invitation of Gerhard Jentzsch, President of IAG Sub-Commission 3.1 on Earth Tides, Sub-Commissions 3.2 and 3.3 and the Inter-Commission Project on the Global Geodynamics Project will participate in and co-organize the next Earth Tide Symposium to be held in Jena, Germany in 2008. Holding such a joint symposium will strengthen interactions between these Sub-Commissions and Inter-Commissions of the IAG.

Sub-Commission 3.3 continues to be a very active participant in the Global Geophysical Fluids Center (GGFC) of the IERS. The President of Sub-Commission 3.3 (R. Gross) is the head of the GGFC Special Bureau for the Oceans, and a member of its Directing Board (B. Chao), who was the former head of the GGFC, is the head of the GGFC Special Bureau for the Mantle. The data sets archived at the GGFC Special Bureaus continue to expand, providing a continuing source of data for present and future investigations of the impact of geophysical fluids on the Earth's gravity, rotation, and shape.

5. Report of intercommission project 3.1 on 'GGP'

Author: D. Crossley

Directorate

D. Crossley (Chair), J. Hinderer (Secretary).

Terms of Reference

The GGP project began on 1 July 1997 and Phase 1 ended on 1 July 2003. A continuation of the project, GGP Phase 2, was approved to continue until July 1, 2007. The main purpose of GGP was, and remains, to record the Earth's gravity field with high accuracy at a number of worldwide stations using superconducting gravimeters (SGs). An important requirement is the frequent monitoring of absolute gravity at each site to co-determine secular changes. Phase 2 envisages project in which SGs are deployed in regional arrays for limited time periods.

A list of publications related to GGP and SGs is available at the GGP website, as are a number of newsletters published for the benefit of the community. The main website is http://www.eas.slu.edu/GGP/ggphome.html.

The data is being used in an extensive set of studies of the Earth, ranging from global motions of the whole Earth such as the Chandler wobble to surficial gravity effects such as atmospheric pressure and groundwater. The SG stations are run independently by national groups of scientists who send data each month to the GGP database at the International Centre for Earth Tides (ICET) in Brussels.

GGP data is recorded and processed to standards agreed between the SG groups. For some of the GGP sites, the most recent data is temporarily restricted and will become available one or two years after collection. For other GGP sites, the data is available as soon as it has been sent to ICET, without restriction. Interested scientists can contact ICET, or the GGP website, for details. Useful site links and some technical terms involved in gravimetry are also on this site.

GGP has recently endorsed a joint operation between ICET and GFZ as a means of developing the database of SG measurements. ICET provides the front-end organization to which the data is sent, and GFZ provides the technical aspects of maintaining and developing the database. GGP will thereby contribute data to ICET, for as long as ICET remains a service of the Earth Tide Commission and FAGS.

Organization

The activities of the GGP are coordinated by a directorate consisting of a Chairman (Crossley) and Secretary (Hinderer). The directorate guides the members who are responsible for all aspects of the GGP such as setting the timetable for the project, setting standards for the data acquisition systems and data exchange protocols and recommending procedures for the database operations. The membership agrees to meet at least once a year, either independently of in conjunction with an appropriate scientific meeting.

Recent Evolution

GGP (the Global Geodynamics Project) is currently an inter-union, interdisciplinary project endorsed by SEDI (Study of the Earth's Deep Interior). We have conducted a survey of its members on possible affiliation with IAG, as discussed at the GGP Business Meeting in Sapporo, Japan, on July 6, 2003. Only 15 of approximately 80 members on the mailing list replied to our survey. We interpret this response to indicate that the majority of members do not object to the ideas proposed in our survey.

The following items constitute GGP Proposal to Commissions 2 and 3 of the IAG:

1. Identity. GGP considers itself to be an unrestricted international scientific *project* that also provides a *service* to the community. Therefore any affiliation with IAG needs to preserve these two aspects and to allow GGP to continue its current scientific and administrative structure.
2. Affiliation. GGP would like to be affiliated with IAG as an Inter-Commission *project*, on the understanding that the definition of project (IAG Bylaw 1.2.3) in no way limits the time period over which GGP can operate. We have voted to seek affiliation under the general scientific directives of both Commission 2 (the Gravity Field) and Commission 3 (Earth Rotation) because the mandate of GGP encompasses the terms of reference of both Commissions.

3. Reporting. GGP prefers a mechanism whereby it reports only to one commission, in this case Commission 3 (Earth Rotation), on the assumption that there will be close communication between the commissions on matters concerning GGP.
4. GGOS. GGP would like to establish a membership within the GGOS framework and to participate in that organization for the purpose of the exchange of worldwide gravity data.

Scientific Objectives

GGP monitors changes in the Earth's gravity field at periods of seconds and longer. The GGP is named to indicate the application of gravity data to the solution of a number of geodynamic problems; additionally GGP may become a source for absolute gravimeter data as well as other geodynamic data.

The measurements were originally planned over a time span of 6 years at a small number of permanent observatories where a superconducting gravimeter (SG) had been installed. The 6-year period was chosen as the minimum length of data required to separate annual and 14 month Chandler wobble components in the gravity record. A pilot phase of GGP commenced 2 years earlier, in July 1995, so GGP is effectively in its 9'th year of operation.

The SG has been, for the past two decades, the most sensitive, stable instrument for the measurement of the vertical component of the Earth's gravity field. Each of the currently operating SGs is the focus of a national effort to provide a continuous gravity record for geodetic and geophysical research. The GGP is an opportunity for the various SG groups to participate in a global campaign to monitor the gravity field and to exchange the raw data.

Precise global measurements of the Earth's gravity field are essential to answer a number of important questions in geophysics, which we outline in more detail in the next section: (a) Do internal gravity waves (inertial waves if the fluid is neutrally stratified) exist in the Earth's liquid core and are their gravitational effects at the Earth's surface detectable? (b) What is the gravity effect of the global atmospheric loading and mass re-distribution on the solid Earth? (c) Through global tidal analysis, can we refine estimates of the nearly diurnal free wobble of the Earth and models of oceanic loading on the solid Earth? (d) What changes in gravity are associated with slow and silent earthquakes, tectonic motions, sea-level changes and post-glacial rebound? (e) Can we monitor the location of the rotation pole of the Earth on a time scale of minutes? (f) Can SG recordings of the earth's normal modes enhance the global long period seismic and spring gravimeter networks?

Benefits

The aims of GGP are twofold:

- To reassure users of SG data that extreme care has been taken in the sampling and pre-processing of the available data and that all pre-processing steps and other

site-specific information such as atmospheric pressure, environmental data and a record of all site disturbances are available to users, and
- To enable global signals to be extracted by various stacking procedures that would not be possible with single station recordings.

Study Groups

The GGP is open to all organizations with access to the appropriate instrumentation, i.e. a SG. Each independent organization that manages a SG will be called a SG group; there may be several SG groups in any one country. SG groups seek their own sources of financing.

The GGP Agreements encourage SG groups to (a) upgrade existing SG facilities to a common standard of data acquisition, (b) participate in continuous gravity observations by maintaining the SGs in good operating conditions at fixed locations and (c) exchange raw gravity (and other important supplemental) data through the Internet.

Global Data Acquisition and Distribution

As described later, the scientific goals of the GGP include a wide range of signals from periods of seconds to years, covering seismic normal modes, tides, core modes and wobble modes of the Earth to other long period variations in Earth's gravity field such as tectonic deformation.

Many of the Earth parameters of critical interest in global dynamics exist in gravimetric signals at or below the ambient noise level. Examples include internal gravity waves in the fluid core and post-glacial uplift and plate motions. The SG has a frequency-domain sensitivity at the nanogal level and many periodic signals of interest are expected to be in this range. Because the time-domain variability of gravity ‘noise’ is usually two to three orders of magnitude greater than this, global signals identified on the record of an individual instrument at the nanogal level cannot be considered reliable until confirmed with similar signals from other instruments. For many purposes, these instruments must be distributed widely around the Earth because global gravimetric signals have theoretically predictable spatial and temporal global variations.

Access to worldwide gravimetric data is essential for progress in global geodynamics for several reasons. First, SG data can be used to recover long-period free oscillations of the Earth with unprecedented precision. In real time, an array of SG instruments, as considered in GGP Phase 2, would provide a means for detection of slow and silent earthquakes, co-seismic slip, and tectonic signals. Second, sub-milliarcsecond orientation can be obtained through measurement by an SG network for space-based measurements such as Satellite Laser Ranging and the US-proposed GLRS project to position points on the Earth's surface to the sub-centimeter level through the use of Earth-based retro-reflectors and satellite-based lasers. Third, Earth models that incorporate core resonances require access to gravimetric data at the nanogal level to successfully account for motion in the deep interior in all of the orientation calculations. GGP is striving to

make such data available as rapidly as possible to the scientific community, so that all the above tasks can be accomplished.

A number of tectonics-related problems require global gravity field data for their resolution. In particular the problems of long-term secular changes in elevation, caused not only by post-glacial rebound and sea level changes but also by active plate-tectonic related deformation, need long-term gravity variations at continental scales. The long-period stability of SGs is variable, with the best instruments having instrument drift as low as about 1 microgal per year. Wherever this level of stability can be maintained by even a small number of SG stations in a regional network, particularly where confirmed with absolute gravimeters, then GGP will provide useful data for these tectonic problems.

In the past an individual with access to his/her local instrument and a computer could make major progress in the solution of both analytical and data analysis problems. However, the complexity of many problems in global geodynamics is such that measurements on a global scale are needed to make even minimum progress. Concerted effort by cooperating scientists is needed to make any significant advance. Without uniform high precision global data it will be impossible to move toward the solution of the problems of the Earth's deep interior. GGP has responded to this need by agreeing to a monthly transfer of data from all instruments to the ICET / GFZ database in Brussels. This data represents the success of the overall project.

Specific Tasks of GGP

The SG is capable of recording temporal gravity variations from seconds to years and thus the GGP has application to large number of scientific tasks. As indicated above, at long periods (months - years), we highly recommend the use of a SG supplemented by an absolute gravimeter to fully characterize secular trends in gravity.

1. Earth tides and the nearly diurnal free wobble: the estimation of precise tidal parameters (e.g. gravitational delta factors) can contribute to the development of better models for correcting for ocean loading phenomena. In addition, the stacking of global delta factors provides important information on the diurnal free wobble of the Earth which is essential for theoretical work on the structure of the Earth's core.
2. Core modes: the search for internal gravity waves in the Earth's liquid core necessitates global, long-period, long-duration recordings to separate local gravity variations from a global coherent signal. If we are able to detect these waves, this will give direct information on the mechanical equilibrium of the fluid in the core, and thus information on the operation of the geodynamo.
3. Atmospheric interactions: stacking global gravity and pressure data is essential to clarify the nature of the long period phenomena in the atmosphere and for evaluating the effects of global atmospheric surface pressure and mass redistribution on the Earth's gravity field.

4. Hydrology: it has become clear during the first phase of GGP that rainfall, soil moisture, snow cover, and groundwater variations can all affect local gravity. The study of hydrology is therefore a fruitful area for GGP. With the advent of new satellite missions (CHAMP, GRACE, GOCE) it is possible to look at common signals in both ground and satellite data sets, particularly using the European stations of the GGP array.
5. Earth rotation and polar motion: the measurement of the gravity effect of polar motion (orientation of the Earth's rotation axis) requires a global coverage of stations. It should be possible to continuously monitor the location of the rotation pole on the time scale of minutes and therefore provide an independent verification of the same measurement now made with space techniques; connections with the International Earth Rotation Service (IERS) service here will be valuable.
6. Gravity changes due to tectonic motions: the monitoring of long-term changes due to tectonic motions, sea-level changes affecting the survival of coastal cities, post-glacial uplift and the deformation associated with active tectonic events.
7. Enhancing absolute gravity measurements: SGs are a valuable aid to international programs for the determination of absolute gravity values on a global scale as they provide a short-term, relative gravity reference level and they 'fill in' the gravity field behavior between AG measurements.
8. General research tool: GGP provides a high quality continuous global data set that will be a valuable resource for future geodetic and geophysical studies that involve the Earth's gravity.

GGP and Geodesy

There are important connections between the above goals and other scientific programs of national concern. In particular, the geodetic community clearly recognizes the importance of simultaneous geodetic (positional) information and gravity changes at fiducial stations that contain very high quality instrumentation. There are two primary areas in common between GGP and other geodetic programs:

1. Space techniques. Two space techniques that require detailed models of Earth deformation are satellite tracking and Very Long Baseline Interferometry (VLBI). At the proposed sub-centimeter level of accuracy, for projects in the 1990's such as the current Satellite Laser Ranging (SLR) and the proposed Geodynamics Laser Ranging System (GLRS) mission, precise knowledge of the Earth's dynamics, including resonances in the liquid core, are required. A global net of SGs will give the required information on dynamics of the liquid core.
2. Sea level changes. A satisfactory solution to the problem of defining the origins of sea-level changes requires input from different sources. The necessity of differentiating between the effects of height variations caused by post glacial rebound or plate tectonics and changes in sea level resulting from global warming demands the establishment of a global geodetic/geophysical observatory network, such as FLINN (Fiducial Laboratories for an International Natural Science Network), an IUGG-sponsored project initiated at the Coolfront Workshop in

1989. A central feature of such a network is the monitoring of the gravity field at a smaller group of fiducial stations equipped with SGs as well as precise positioning instrumentation (e.g. SLR, VLBI or GPS) and having accurate connections to the reference tide gauges.

Report

In 2004 the main GGP activity was the project session held at the 15th International Symposium on Earth Tides, in Ottawa, August 2-6. The associated Newsletter #14 appeared in the fall of 2004 and was posted on the GGP website (http://www.eas.slu.edu/GGP/ggphome.html). Important points noted in the Newsletter were:

1. Station Review. We have seen the closing down of the Boulder stations (BO) due to a hardware malfunction that also required a software upgrade that has not yet been implemented. For the moment the only North America SG station still recording is in Cantley Canada, and recently we heard that this station is also in imminent danger of disappearing, unless funding can be arranged through the Geological Survey of Canada. Contrary to the NA situation, a new station has come on line in Korea, and a new installation in Taiwan is in the planning phase. We are pleased that station BH (Bad Homberg, Germany) is now providing data to GGP and the remote station in Concepcion, Chile is working well.
2. Updated GGP agreements now require a delay of no more than 6 months between members and within 1 calendar year after its collection, all reporting SG stations are required to send their data to the International Center for Earth Tides (ICET) in Brussels.
3. GGP is moving towards more timely release of earthquake (rapid sample data), see below.
4. GGP is also working out the details of collecting AG (absolute gravimeter) data at the SG station sites. The purpose if to provide AG data for (a) the calibration of the SGs, and (b) to determine the secular changes in gravity at a station so that the SH drift can better be monitored. The reason GGP is considering this development is due to the reservations some members of the community seem to have with the current procedures for collecting absolute gravimeter data through the BGI database.

Since the August GGP Workshop, and spurred on by the very large earthquakes in Sumatra on December 26 2004 and March 28 2005, GGP has move to make raw data available online (http://www.eas.slu.edu/GGP/sumatra.html). The format for the data has been standardized as modified PRETERNA format, just as for the 1 minute data, and now about 15 datasets are available for December 2004 and January 2005. It is hoped this will be expanded in future to permit more continuous data to be sent to the IRIS (seismology) database. Some differences of approach exists within GGP as to whether to go directly to IRIS or work through our normal ICET procedures, now managed from GFZ (Potsdam).

The special issue of the Journal of Geodynamics (vol 38, Nos. 3-5, 2004) was devoted to papers arising from the previous years' Sapporro GGP Workshop, on the occasion of the first 6 year period of GGP (1997-2003). This special issue contained 19 papers from about 60 authors. At the present time, papers are being assembled from the 2004 Earth Tides meeting and will again be published in a future issue of the Journal of Geodynamics.

The next GGP Workshop is scheduled to be held during the imminent EGU meeting in Vienna, April 2005. Issues to be addressed remain those largely on the table last year. GGP has now successfully completed its first year as an interdisciplinary project of the newly organized IAG.

Of particular interest the gravity community at large is the need to create an absolute gravity database. GGP will continue to seek a viable means to collect AG data from the SG station sites, and this should be a good point of intersection for the combined resources of GGP and Commission 2.

6. Report of intercommission project 3.2 on 'WEGENER'

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Members

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Representative of Commission 1 (to be assigned);
Representative of Commission 3: Tonie van Dam.

Terms of reference

The evolution of geodetic techniques in the past decade, with unprecedented achievements in the precise detection and monitoring of 3D movements at the millimeter level has opened new prospects for the study of Earth kinematics and hence dynamics. However, those achievements also raised new issues that have to be properly taken into account in the processing and analysis of the data, demanding a careful inter-disciplinary approach.

Areas in Europe, primarily in the broad collision zone between Europe, Africa and Arabia, provide natural laboratories to study crucial and poorly understood geodynamic processes. These have been systematically monitored in the last decade by different research groups using a variety of space geodetic and other techniques. However, in general data analysis has been done from the perspective of one discipline and processing procedures have not always followed a standard approach.

The existence of these geodata, never completely explored, justifies a new insight by using a really integrated approach that combines data from different observational techniques and input from other disciplines in the Earth Sciences. This should lead to the development of interdisciplinary work in the integration of space and terrestrial techniques for the study of the Eurasian/African/Arabian plate boundary deformation zone, and adjacent areas, and contribute to the establishment of a European Velocity Field.

With that purpose it is important to promote stronger international cooperation between Earth-Scientists interested in the study of that plate boundary zone. Towards that goal the WEGENER project aims to:

• Actively encourage the cooperation of all geoscientists Eurasian/African/Arabian plate boundary deformation zone, by promoting the exploitation of synergies;
• Be a reference group for the integration of the most advanced geodetic and geophysical techniques by developing the adequate methodologies for a correct data integration and interpretation;
• Act as a forum for discussion and scientific support for geoscientists from all over the world interested in unraveling the kinematics and mechanics of the Eurasian/African/Arabian plate boundary deformation zone;
• Promote the use of standard procedures for geodetic data, in particular GPS data, quality evaluation and processing.

The need to involve different research areas demands for collaboration with different IAG Commissions and in particular with Commission 1 and Commission 3. Commission 1 is responsible for regional and global reference frames, for the coordination of space techniques and for satellite dynamics. WEGENER can contribute significantly to each one of these areas and, in particular, to regional and global reference frames by making available, in its study area, quality-tested regional data sets acquired with different space and terrestrial techniques, as well as relevant quality-tested solutions. Additionally WEGENER can contribute by carrying out studies, already being developed by WEGENER member groups, on the definition of effective integrated observational strategies. Commission 3, is responsible for earth rotation and geodynamics. WEGENER will provide its main contribution in the field of geodynamics by studying, regionally, both short and long-term crustal motions.

Objectives

The primary goals of the WEGENER project are:

• Continue as a framework for geodetic/geophysical/geological cooperation in the study of the Eurasian/African/Arabian plate boundary zone;
• Foster the use of space-borne, airborne and terrestrial hybrid techniques for earth observation;
• Define effective integrated observational strategies for these techniques to reliably identify and monitor crustal movements and gravity field variations over all time-scales;
• Facilitate and stimulate the integrated exploitation of data from different techniques in the analysis and interpretation of geoprocesses;
• Organize periodic meetings with special emphasis on interdisciplinary research and interpretation and modeling issues;

• Reinforce cooperation with African and Arabian countries and colleagues, which can both contribute to understanding the kinematics and dynamics of the Eurasian/African/Arabian plate boundary zone and promote the growth of such research in these countries.

Activities

• We have begun to establish a GEO Data and Analysis Center (GEODAC) at the University of Porto (http://geodac.fc.up.pt). The main objective of GEODAC is to provide a platform to the whole interested scientific community for European GPS data archiving/linking, reprocessing of old data series in a unique reference frame, and an open data bank which will include, when available, environmental parameter series. GEODAC is promoting the use of state-of-the-art methodologies and latest results/solutions by supporting the scientific community when requested. Although in a testing phase (access only by password), GEODAC already contains most of the functions that were planned to be implemented. Examples are the computation of atmospheric loading corrections for stations that are not provided by the IERS Special Bureau for Loading, and realistic error bars for the trends in continuous GPS data analysis. At present, GEODAC is processing data of the GPS stations of the Iberian area. GPS data from episodic campaigns performed in Iberia, Italy and Morocco are already stored and available for access.. Log utilities to describe the properties of the GPS stations according to the IGS template were implemented. A forum where the GEODAC users can post questions and suggestions was also created. A link to other geodata sources, namely NEIC (National Earthquake Information Center) was already established. Additionally, GEODAC can support teams that do not have many processing capabilities. -
• Standards for GPS networks establishment, data acquisition and guidelines for data processing and reliability checks have been defined;
• Strategies for a full exploitation of different geodata (GPS, gravimetry, seismic, etc.) have been defined;
• We have organized every two years General Assemblies to serve as high-level international forum, in which scientists from all over the world can look at a multidisciplinary interpretation of geodynamics, and strengthen the collaboration between countries. The last conference took place in September 2004 in Tangier (Morocco). The next one will be in June 2006 in France.

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 carrys 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, Oregan, 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, Oregan, 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, Totonto, 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",* Padau, 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-convener 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 Novemeber 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 endevour to coordinate research and other activities that address the broad areas of the theory and applications of engineering geodesy tools. The tools range from

convenional 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 phnemona 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 Mentes (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 Ionspheric 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 be 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 ionospherically 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 endevour 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 scatters, 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, Turdey, 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-ar-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 Geoinfomatics",* 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, Oregan, 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.

Report on the Intercommission Committee on Theory

When the Intercommission Committee on Theory (ICCT) was established at the 2003 IUGG General Assembly in Sapporo, we stated our missions as follows:

(1) strongly encourages frontier mathematical and physical research, directly motivated by geodetic need/practice, as a contribution to science/engineering in general and the foundations for Geodesy in particular;
(2) provides the channel of communication amongst the different IAG entities of commissions, services, and/or projects, on the ground of theory and methodology, and directly cooperate with and support these entities in the topics-oriented work;
(3) helps the IAG in articulating mathematical and physical challenges of geodesy as a subject of science and in attracting young talents to geodesy. The ICCT should certainly try to attract and serve as home to mathematically motivated geodesists and to applications-oriented applied mathematicians; and
(4) encourages closer research ties with and directly gets involved with relevant areas of the Earth Sciences, bearing in mind that geodesy has been playing an important role in understanding the physics of the Earth.

In order to advance our missions, the ICCT strongly encourages research on precise ocean bottom geodetic deformation measurement, GPS mathematics and mathematical modeling of highly precise space geodetic measurements, which are believed either as one of the most important directions for geodesy in the next decade(s) or so, or as one of the most possible contributions to mathematics from geodesists, or in order to meet the need and challenge of modern space geodesy. However, we have always kept in mind that new theory/methods can be borne out of "old practical problems". Thus we never forget encouraging giving new insights into "old-fashioned or traditional problems". Obviously, our missions will also have to be realized in another way via the activities of our working groups, some of which have been very active, for example, the working group headed by Dr Wolf has successfully held a workshop as one of the most important activity of his group.

More practically, the ICCT has been working on two projects. As the first project, we asked two of our working groups to work together in order to collect all the most recent progress on gravity field modeling and inverse problem theory and get it published as a special issue of J Geod. The project is working very well and will soon be undergoing the review process; As the second project, the ICCT is preparing the VI Hotine-Marussi Symposium to be held at Wuhan University, PR China, 29 May – 2 June 2006. The first phase for the Symposium has been well prepared and basically finished. The Symposium will serve two purposes: (i) to summarize important theoretical progress achieved; and (ii) to provide an opportunity for theoretically-oriented and practically-oriented geodesists to exchange ideas/opinions on any issues/problems of common interest. In particular, we hope that theoretically-oriented geodesists could gain new insights from "seemingly" practical problems for new inventions and practically-oriented geodesists could find new ideas/methods to retreat more or better physical information from geodetic measurements. The Symposium will focus on the following five topics: (1). Satellite gravity missions: open theoretical problems and their future application; (2). Earth-environmental, disaster monitoring and prevention by Geodetic methods; (3). GNSS: Mathematical theory, engineering applications, reference system definition and monitoring; (4). Deterministic and Ramdon fields analysis with application to BVP, approximation theory and inverse problems; and (5). Statistical estimation and prediction theory, quality improvement and data fusion. We will be planning other activities at the Committee level if necessary and if certain resources would be available.

Bi-annual Report on the Contribution of the Communication and Outreach Branch (COB)

1. Introduction

In the past period (since July 2003, Sapporo, the foundation of the COB), the infrastructure investment indicated in our proposal for the Executive Committee Meeting in Nice (April 2003) has been fully realized. Thus the technological background of the COB at the Department of Geodesy and Surveying of the Budapest University of Technology and Economics (BME) has been fully realized and is supported by the department and the Research Group for Physical Geodesy and Geodynamics of the Hungarian Academy of Sciences. All administrative work for registration of the new IAG Website address (www.iag-aig.org) has been done.

The Terms of Reference and program activities of the COB and a short report on the IAG website were published in the Geodesist's Handbook 2004 (pp. 677-678, pp. 576-577. respectively).

The COB's Steering Committee held meetings four times in the last two years:

a) Sapporo, Japan, 8 July, 2003;
b) Nice, France, 29 April, 2004;
c) Budapest, Hungary, 1 February, 2005;
d) Cairns, Australia, 23 August, 2005.

2. Status of the new IAG website

A new Compaq server has been purchased and the backend of the website has been developed. Hence all of the documents can be edited and maintained through a simple web browser. The documents are stored in a MySQL database, which enables fast data retrieval and also searching in documents. The graphical front-end is also ready.

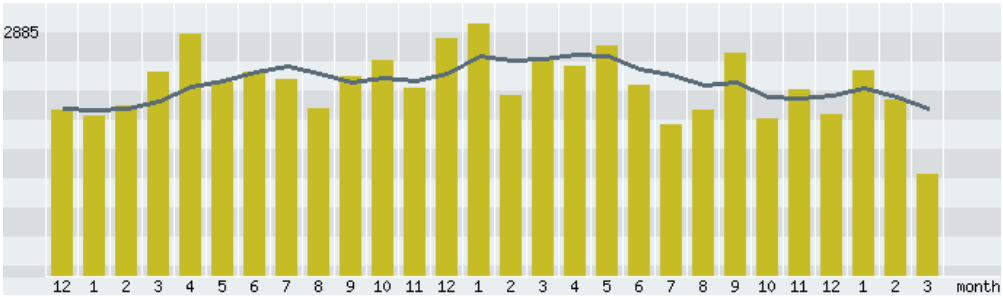
After providing the IT background for creating and maintaining the web content, the editing of the old web content has been started. All the old documents must have been partially re-edited in order to fit into the new structure of the IAG website. Due to this, the migration of the old website to the new one was going a bit slower than previously expected. The Geodesist's Handbook (1999, 2000) have also been migrated to the new website.

The layout of the website has been changed a few times according to the proposals accepted at the Steering Committee Meetings. Direct links to services, old sections, commissions, etc. have been added to the front page. The event calendar has been shortened, it contains only the next five important events. Additional advertisements have been also added to the front page. The recent Membership Application Form as well as the IAG Newsletters can be downloaded for the opening page.

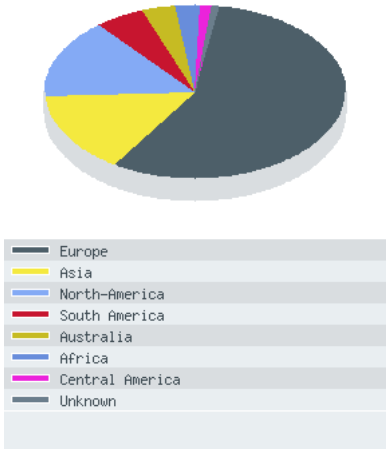
The number of visitors is steady. The weekly number of visitors is about 600. The geographical distribution of the visitors shows that the webpage is mostly visited from Europe (37159), Asia (10100) and North-America (9880) out of the total 66239 visits since May 28 2003. Only 1774 visits came from the African Continent.

Visitors could be registered from 142 countries worldwide. The list can be found at http://www.webstats4u.com/s?tab=1&link=3&id=2359395&cou=all.

The IAG website includes the Members' Section, which can be accessed by IAG Members only. IAG Members have received a password to enter this restricted area. Each IAG Member is entitled to read articles in this area as well as to query the contact database of the IAG members. The Members may update their own contact details, and specify their fields of interests, too.



Monthly number of visits



Geographical Distribution of visitors

3. The IAG Newsletters

Altogether 19 IAG Newsletters have already been published till July 2005 and can be accessed on the IAG new website in HTML, HTML print version and in PDF formats. The web addresses in the text can now be reached also from the PDF file. The IAG Individual

Members received it monthly in PDF and text attachments, with a link in the e-mail message to access the actual HTML Newsletter on the IAG website. A new subscriber list of the Newsletter for developing countries was set up in a web-based database, independently from the IAG Individual Members' subscriber list for promoting interest in the activities of IAG. Now the electronic IAG Newsletter is distributed to these e-mail addresses as well. Selected content of the electronic Newsletters were compiled and have been sent to Springer for publication for already 9 issues of the Journal of Geodesy (Vol 77/12-79/4-5).

4. Membership development and outreach activities

The Membership Application form (MAF) has been updated and put in the new IAG website. It contains all the information for the credit card payments and it can be filled using Adobe Acrobat Reader.

Initially about 2600 e-mail addresses were stored in a database. The validation of e-mail addresses as well as web integration for future mailing lists management tasks is currently taking place. Unfortunately many duplicate and invalid e-mail addresses had to be removed from the aforementioned database.

The COB designed a brochure for promoting the IAG to the geoscientific community. The main objective of this brochure is to introduce the activities of IAG to the geoscientific community and to encourage individuals to be a member of the Association. In the first run 1500 copies have been printed. The brochure was available at the IAG, AGU, EGU Assemblies and at different IAG Symposia.

The Communication and Outreach Branch in cooperation with the Department of Geodesy and Surveying, Budapest University of Technology and Economics and the Research Group for Physical Geodesy and geodynamics of the Hungarian Academy of Sciences organized the 6th International IGeS School on "The Determination and Use of the Geoid", Budapest, Hungary, 31 January- 4 February, 2005.

József Ádám, Szabolcs Rózsa, Gyula Tóth
IAG Communication and Outreach Branch

Minutes of the IAG COB Steering Committee Meeting
Sapporo, Japan, 8 July, 2003.

1. Attendance
    - József ÁDÁM (President)
    - Szabolcs RÓZSA (Secretary, IAG Webmaster)
    - Carl-Christian TSCHERNING (Secretary General of IAG)
    - Michael G. SIDERIS (IAG Vice-President of IAG)
    - Will FEATHERSTONE (Editor-in-chief of JoG)
    - Christina SCHNEIDER-PEDERSEN
    - Markku POUTANEN
    - Gyula TÓTH (IAG Newsletter Editor)
    - Ole B. ANDERSEN (Guest, Assistant Secretary General of IAG)

2. Discussed topics

2.1. Organizational structure of the COB

The president of the Steering Committee introduced the members of the committee, accepted by the new Executive Committee of IAG:

▪ József ÁDÁM	Hungary	President
▪ Christina SCHNEIDER-PEDERSEN	Denmark	
▪ Markku POUTANEN	Finland	
▪ Szabolcs Rózsa	Hungary	Secretary, IAG webmaster
▪ Michael G. SIDERIS	Canada	IAG Vice-President
▪ Gyula TÓTH	Hungary	IAG Newsletter Editor

Ex-officio:

▪ Carl-Christian TSCHERNING	Denmark	IAG Secretary General
▪ Will FEATHERSTONE	Australia	Editor-in-chief of the JoG

2.2. Membership development

The current Membership Application Form (MAF) should be improved according to the proposal of Prof. Sideris and Ms. Schneider-Pedersen. The MAF should include additional credit card information (security code) and the form fields should be resized to provide enough room for the card number, etc. Moreover the fields should be activated to enable the applications to fill in the form electronically.

2.3. The IAG website

The structure of the official IAG website has been discussed and some modifications have been decided. The event calendar on the website should be more concise. Sue to the low number of events, the daily calendar is not required. On the other hand direct links to the IAG Services, Commissions and to the IUGG website should be included on the first page of the website.
The layout of the website should be modified, in order to follow the various screen size and resolution of the viewers.
The Committee discussed the possibility of letting each unit (Service, Commission, etc.) to add articles directly to the webpage, and decided not to provide this option due to security and managements reasons.
The migration of the files from the old website to the new one has been discussed, too. Due to security reasons O. B. Andersen offered to archive the old website to CD and send the CD via regular mail to the COB.
In order to express the fact that the IAG Services and Commissions belong to the IAG, the websites of the units should follow some rules concerning the graphical layout of their own websites. These rules should be specified by the COB.

2.4. Clarification of the information flow between the Central Bureau and the COB

The Committee discussed the information flow on new members between the Central Bureau and the COB. Although the applications are submitted to the Central Bureau, and accepted by the EC, the contact information database will be created and maintained by the COB. This database is going to have an interface on the website,

where each member can update their own contact information, and they will be able to specify which information should be viewable by other users. Therefore the Central Bureau should notify the COB about the new members, in order to be able to create required account (login name and password) for the members. The details of this procedure will be discussed later.

2.5. Edition of the IAG Newsletters

The Committee discussed the layout of the IAG Newsletter. O.B. Andersen proposed to design a special header of the IAG Newsletter. In this way, the readers of the Journal of Geodesy could easier distinguish between the scientific articles and the Newsletter.
The Newsletter should be published monthly. The articles should be published on the website, and in the e-mail version of the Newsletter, the link to the website should also be present in the e-mail version. In this way the mailbox of the members will not be overloaded.
The Committee decided that the president of the SC is responsible for the contents of the Newsletter.

2.6. Outreach Activities

The members discussed the possibility of an Outreach Lecture series at the EGS/EUG Meeting in Nice, 2004. The aim of these lectures would be to promote the activities in the science of geodesy to other geoscientists. However additional negotiations with the organizers and possible lecturers are required to be able to decide the question.
On the other hand, the design procedure of the IAG brochures should be started, too. First of all, a brochure promoting the Association should be created.

Budapest, 12.08.2003
Compiled by Szabolcs Rózsa

Minutes of the IAG COB Steering Committee Meeting
Nice, France, 29 April, 2004

1. Attendance
    - József ÁDÁM (President)
    - Szabolcs RÓZSA (Secretary, IAG Webmaster)
    - Carl-Christian TSCHERNING (Secretary General of IAG)
    - Michael G. SIDERIS (Vice President of IAG)
    - Markku POUTANEN
    - Christina SCHNEIDER-PEDERSEN
    - Gerhard BEUTLER (Guest, President of IAG)

2. Discussed topics

2.1 IAG Website

Prof. Sideris proposed to change the layout of the opening page of the website in order to provide some information on the purpose of IAG. The Steering Committee (SC) agreed on that the opening page should also contain the latest articles added to the website because most of the visitors come back to read new information.
Prof. Sideris also proposed to add a link to the newly founded service of the IAG called Reference Model Service (hosted by the GFZ Potsdam). Moreover the links to the IAG services should be emphasized on the webpage. A possible solution would be to add the links to the menu system.
It was also proposed to add the links section to the menu system as permanent menu item.
The SC discussed the possibility of developing a joint membership database between the Central Bureau (CB) and the Communication and Outreach Branch (COB). The proposed solution was to create an interface between the MySQL server, which powers the website and the FileMaker Pro, which is used by the CB. It is not recommended to create a common database, because both of the systems has different capabilities. Moreover financial information should be kept confidential, therefore they should not be stored in the MySQL database.
The MySQL database should contain the personal details of the members (address, fax, tel, e-mail, affiliation, etc.). The members should be able to change their own contact information, thus they're going to be responsible for keeping their contact information always up to date.
The papers presented at the General Assembly in Sapporo 2003 should be added to the website. However first of all the Secretary General of IAG contacts Springer Verlag in order to get their approval for publishing the unreviewed papers on the web. In case of a rejection by Springer Verlag the papers could be published temporarily on the web until they are published in hard copies by Springer. The SC agreed on that the access to the publications on the web would be an important service to the members.

2.2 Newsletter

The Steering Committee discussed the way of acquiring material for the IAG newsletter. It has been proposed to contact the Commission Presidents and ask them to publish regularly in the newsletter. This could be managed on a rotational basis. Moreover a short summary of PhD Thesises, Technical reports, Projects could also be included in the IAG newsletter.
Announcements on new books could also be included in the newsletter. However acquiring information on new books might be difficult. Prof. Tscherning proposed to use the webpage of Physics Today, which has a list of new publications. Moreover the websites of the big publication companies can also be visited regularly to get this information.
The scientific paper of the month could be also introduced in the newsletter. These papers should also be selected by the Commission Presidents. Moreover the results of Executive Committee (EC) and SC meetings could be also published.
An important topic could be the list of promotions, retirements etc.

2.3 Membership Development

The membership application form should be updated, a checkmark should be added for a permission to handle the data of the members.

The website should include a login for the members and electronic publications should be available only for the members. Moreover an expertise database could also be created. The members should also be able to specify a few keywords of their interests in the contact information field.
The Geodesists' Database should be available only for the members of IAG. No manual update is going to be made by either the COB or the CB after the membership database is available.

2.4 Outreach Activities

The possibility of giving a discount on the membership fee for members of other scientific organizations has been discussed. It was proposed that the Secretary General tries to get some information how it has been solved between other associations.

2.5 Brochure

The IAG brochure for the geoscientists has been introduced to the Steering Committee. It has been discussed to create another brochure for the wider community (decision makers, politicians etc.). To start this project Markku Poutanen has been asked to create a draft on a more general brochure. Prof. Sideris proposed that some additional funding could be received from various agencies like NGIA (NIMA).

2.6 Varia

Rules for IAG Schools

It has been discussed that according to the By-Laws the IAG Schools are accepted by the EC, therefore the COB should only assist in advertising these schools.

History of Geodesy

An important task of the COB is to document the history of IAG. The SC discussed the possibility of creating a working group for documenting the history of IAG. It has been decided not to create a working group or other entity for this purpose. However some more information should be added to the website on this topic. The material could be acquired from Past presidents' Reports, Geodesists' Handbooks and the Bulletin Geodesique.

Nice, 29.04.2004
Compiled by Szabolcs Rózsa

Minutes of the IAG COB Steering Committee Meeting
Budapest, Hungary, 1 February, 2005.

3. Attendance
    - József ÁDÁM (President)
    - Szabolcs RÓZSA (Secretary, IAG Webmaster)
    - Carl-Christian TSCHERNING (Secretary General of IAG)
    - Michael G. SIDERIS (Vice President of IAG)
    - Christina SCHNEIDER-PEDERSEN
    - Gyula TÓTH (IAG Newsletter Editor)
    - Gerhard BEUTLER (Guest, President of IAG)
    - Fernando SANSÓ (Guest, Immediate Past President of IAG)

4. Discussed topics

2.1. IAG Website

Sz. Rózsa has made a report on the current status of the IAG website. The latest developments, such as the restricted members' area and the contact database have been introduced to the IAG COB Steering Committee (SC).
Prof. Sideris proposed that the IAG Services should be present on the top page of the website with their active links.
The SC discussed how the restricted members' area should be filled with information. The members' area should provide additional value for the IAG members only. Therefore the aim of COB should be to put electronic publications, existing electronic information, proceedings etc. to the members' area. As this information is available only for the IAG members, it could provide value for them. The possibility of putting electronic papers available for the IAG members only, could be promoted in the IAG newsletter as well as in a circular e-mail. Digital datasets could also be published here. The unreviewed version of the Sapporo papers could also be put to the private section of the IAG website. It has been also discussed whether the lecture notes of the IGeS Geoid Schools could be put on the private section of the IAG website. In order to clarify the copyright issues, COB will contact the lecturers to get their permission.
The SC decided to ask conference organizers to keep the right of electronic publications.

2.2. IAG Newsletter

The SC discussed the information flow between the IAG entities and the IAG COB. It is still a problem to get enough material to the IAG Newsletter. Therefore IAG COB should encourage the leaders of other IAG entities to provide information for the IAG Newsletter. Moreover some major agencies could be contacted with the newsletter (ESA, NASA, USGS, Geodetic Survey of Canada, etc.), moreover the Presidents and Secretary Generals of the IUGG Associations.
Obituaries are made usually by the IAG National Correspondents.

2.3. IAG Brochures

The SC decided that the present IAG Brochure should remain up to the IUGG General Assembly in Perugia. However another IAG Brochure for the wider public is needed, and should be prepared. It should focus on the project and applications, should not be more than 16 pages, and should be written on a highschool level. It should give an overview of the historical development. Some material could be found on the NASA, NIMA homepages. The Brochure should also review the IAG Services.
The brochure should be available for download and printing.

2.4. Membership Development

The SC has discussed the form of the new Membership Application From (MAF). It has been decided that the MAF should include a cell, where students can enter the expected end of their PhD studies. It has also been decided that a Membership Renewal Form also should be available for download.
The COB should also contact the National Correspondents, and advertise the benefits of becoming a member.

Other community building actions could also be carried out by the IAG COB. This could include such as automatic Birthday Congratulations using the IAG contact database, etc. Moreover the Merchandising (pens, T-shirts, tie, cups, etc.) could also be planned and started in the next future.

2.5. Outreach Activities

The Outreach Activities should focus on the EGU Meeting in Vienna and on the IAG Scientific Assembly in Cairns. On both of the events, the IAG Brochure should be distributed, moreover the merchandising could also be started on the Scientific Assembly.
Links should also be put on the webpage, which point to information resources for geodesy related presentations.
The topic of IAG Booth in Cairns has also been discussed. According to the decision of the SC, the IAG Booth would be linked with the Office of the IAG Bureau.

Compiled by Szabolcs Rózsa

Minutes of the IAG COB Steering Committee Meeting
Cairns, Australia, 23 August, 2005.

5. Attendance

- József ÁDÁM (President)
- Szabolcs RÓZSA (Secretary, IAG Webmaster)
- Carl-Christian TSCHERNING (Secretary General of IAG)
- Gyula TÓTH (IAG Newsletter Editor)
- Markku POUTANEN
- Ole B. ANDERSEN (Guest, Assistant Secretary General of IAG)

6. Discussed topics

2.1. IAG Website

Sz. Rózsa gave a short report on the current status of the website. The Steering Committee (SC) discussed how the restricted members' area of the website could be filled with information. The SC agreed that the reviewed Sapporo Proceedings could be uploaded to the this area as well as the lecture notes of the Geoid School held in Budapest 2005.

Moreover listing of new PhD Thesises and a list of useful internet sites could also be added to the IAG website.

2.2. IAG Newsletter

The SC discussed some questions regarding the Newsletters. C.C. Tscherning proposed that a short summary of some interesting PhD thesises could also be included in the newsletter.

2.3. IAG Brochures

The IAG COB SC decided that the present IAG Brochure should remain up to the IUGG General Assembly in Perugia. However it seems that the brochure will run out before the GA, therefore a slightly updated version should be prepared. The lately created IAG services should be introduced to the list of services (IGFS, Geopotential Models Service).

M. Poutanen introduced a first version of the new IAG brochure for the wider public. The SC agreed on that the brochure should be no longer than 16 pages, and should contain an introduction of the IAG Services in a 'layman' language. The brochure should be also available in PDF format on the web. J.Ádám proposed that an introduction written by I. I. Mueller for the IAG Scientific Assembly in Budapest, 2001 could also be used in the brochure.

2.4. Travaux

The SC agreed that until end of September 2005 all of the IAG entities should send their report to O. B. Andersen. Afterwards the Travaux will be posted to the IAG website.

2.5. Membership Development

Sz. Rózsa proposed that the upcoming conferences and IAG Symposia should give a certain reduction on the registration fee for IAG members. The SC agreed on a 10% reduction and C.C. Tscherning agreed to contact the LOC of upcoming conferences (IGFS 1st Meeting, etc.) as well as to promote the need for such a reduction in the EC meeting.

Compiled by Szabolcs Rózsa

INTERNATIONAL GEOID SERVICE
at DIIAR (Sezione del Rilevamento)
P.zza Leonardo da Vinci, 32
20133 Milano
(Italy)

International Geoid Service Report (2003-2005)

Since the IAG/IUGG General Assembly held in Sapporo, IGeS actively continued its educational and research mission on geoid estimation.
IGeS promoted a new school on geoid determination which was held at the beginning of 2005.
The School on "The determination and Use of Geoid" took place from January 31st to February 4th, 2005.
It was hosted by the Department of Geodesy and Surveying of the Budapest University of Technology and Economics (BUTE) in cooperation with the Research Group for Physical Geodesy and Geodynamics of the Hungarian Academy of Science (HAS).
This School continued the tradition of IGeS which, has organized five geoid Schools: Milano (Italy - 1994), Rio de Janeiro (Brasil - 1997), Milano (Italy -1999), Johor (Malesia - 2000), Thessaloniki (Greece - 2002).
The courses have been given by Fernando Sansò (A compendium of physical geodesy in view of geoid computation and related height questions), Riccardo Barzaghi (The Global Geopotential Models) Christian C. Tscherning (Geoid Determination by least-squares collocation using GRAVSOFT), Michael G. Sideris (Geoid Determination by FFT Techniques) and Ilias N. Tziavos (The Terrain Effects in Geoid Estimation). One seminar on "Present Day Activities of the International Gravimetric Bureau (BGI)" was presented by M. Abbasi and Th. Fayard from BGI, France.
The Lecture Notes on Global Geopotential Models was prepared by Peter Schwintzer (GeoForschungsZentrum, Potsdam), who passed away before the School. His Lecture Notes titled as "The gravity field of the Earth: global gravitational potential models" is dedicated in memory of Peter Schwintzer.
As done in the previous schools, lecture notes and software for geoid computation have been distributed to the students.
All courses, but for the first one, have been followed by computer exercises based on the available software programs. 49 participants attended the School. They come from 19 countries: Canada (3), Croatia (3), Czech Republic (1), Denmark (3), France (3), Germany (3), Greece (1), Hungary (5), Italy (3), Malaysia (1), Pakistan (8), Poland (4), Portugal (1), Saudi Arabia (3), Slovakia (1), Slovenia (1), Spain (2), Turkey (2) and Ukraine (1).
On the scientific side, IGeS is participating to the project aimed at estimating the new European geoid, a Commission Project which is chaired by Heiner Denker. In this framework, IGeS has carried out the validation of the SRTM DTM and of the NOAA 1'× 1' bathymetry in the Mediterranean area. Also, the gravity data base covering the Western/Central part of the Mediterranean has been checked using the collocation filtering technique and will be used in the

European geoid project. Furthermore, within this project, IGeS is in charge for the computation of the terrain effect (using an original approach) and for the estimation of the residual geoid component by means of Fast Collocation.
IGeS is also stongly involved as a member of the European GOCE Gravity Consortium (EGG-C) in the GOCE High-level Processing Facility (GOCE HPF) whose activities started in April 2004.
Within the GOCE Ground Segment, the HPF is one of the Core Elements (ESA-controlled), and it is charged with the generation of L2 products and acquisition of the external (auxiliary) data needed to generate these products, the delivery of these products (auxiliary, intermediate and final) to the PDS/DPA (Payload Data Segment/Data Processing Archive) and/or the LTA (Long Term Archive) and the generation of QLP (Quick Look Products) and ECP (External Calibration Products) for the purpose of the activities of the CMF (Calibration and Monitoring Facility).

Members of the GOCE HPF are:
- IAPG Institute of Astronomical and Physical Geodesy, Technical University Munich, Germany (Principal Investigator);
- AIUB Astronomical Institute, University of Bern, Switzerland;
- CNES Centre National d'Etudes Spatiales, Groupe de Recherche de Géodésie Spatiale, Toulouse, France;
- FAE/A&S Faculty of Aerospace Engineering, Astrodynamics & Satellite systems, Delft University of Technology, Delft, The Netherlands;
- GFZ GeoForschungsZentrum Potsdam, Department 1 Geodesy and Remote Sensing, Potsdam, Germany;
- ITG Institute of Theoretical Geodesy, University Bonn, Germany;
- IGeS- POLIMI, DIIAR – Sezione Rilevamento, Politecnico di Milano, Italy;
- SRON National Institute for Space Research , Utrecht, The Netherlands;
- TUG Institute of Navigation and Satellite Geodesy, Graz University of Technology;
- UCPH Department of Geophysics, University of Copenhagen, Denmark.

Within the GOCE HPF, the establishment of a sub-processing facility for GOCE data and the retrieval of the gravity field with the space-wise approach is under responsibility of IGeS-POLIMI as contractor, with UCPH as sub-contractor. In addition ITG is participating as science consultant. The sub-processing facility will be developed at two sites, namely at IGeS-POLIMI and UCPH, and operated at one facility at IGeS-POLIMI.
The software to perform the space-wise approach will be made up of already existing modules developed at UCPH (GRAVSOFT) and modules developed at IGeS-POLIMI for the purpose (based on existing routines). This software will be integrated and tested as a whole, so that the data stream from GOCE will flow smoothly through it, in a unique processing chain implemented in a Sub-Processing Facility (SPF) located at IGeS-POLIMI.
IGeS web has been also updated and renewed during the last two years and contains at present 25 geoid data files and a collection of 11 global geopotential models. Furthermore, the CD containing the software on geoid computation (the same distributed at the geoid schools) can be requested through the IGeS web. It is available under the same restrictions applied when distributing it during the geoid schools (freely available after a declaration stating for non commercial use of this software).
The editorial activity, which started in 1993, is now continuing in a new form. From December 2003, the IGeS and the BGI Bulletins have been merged in the new Newton's Bulletin. The Newton's Bulletin is a reviewed scientific journal collecting paper on geoid and gravity. Two

issues are available, in electronic form, on the IGeS web page, together with 13 issues of the previous IGeS Bulletin.
IGeS also promoted, together with BGI, NIMA, ICET and GFZ, the creation of a new IAG service named International Gravity Field Service (IGFS). IGFS is a unified IAG service aiming at collecting, validating and distributing data and software for the purpose of determining, with various degrees of accuracy and resolution, the gravity potential of the Earth, or any of its functional, and the surface of the Earth. This new service has been approved by the IAG Executive Committee during the last IAG-IUGG Assembly in Sapporo.
IGFS is actively organizing its first international symposium which will be held in Istanbul in August, 2006.
On the national Italian side, IGeS has estimated the new high precision Italian geoid and it is cooperating with the Italian Space Agency (ASI), the Istituto Geografico Militare (IGM), the Agenzia del Territorio (Italian National Cadastre), the Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS).

International VLBI Service for Geodesy and Astrometry (IVS)
— Status Report 2003-2005 —

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Abstract

This report reviews the activities and the progress made in the time span from 2003 to 2005. It summarizes and qualifies the products generated continuously by IVS. The efforts for improving the TRF, CRF, and EOP are shortly described. Special emphasis is put on the future vision for a next generation VLBI system.

1. General remarks and the key role of geodetic VLBI

The Very Long Baseline Interferometry (VLBI) technique has been employed in geodesy for nearly 40 years. Covering intercontinental baselines with highest accuracy, monitoring Earth rotation at the state of the art and providing the quasar positions as the best approach to an inertial reference frame, VLBI significantly contributed to the tremendous progress made in geodesy over the last decades. VLBI was a primary tool for understanding the global phenomena changing the "solid" Earth. Today VLBI routinely monitors Earth rotation and its variations and also crustal movements in order to maintain global reference frames, coordinated within the International VLBI Service for Geodesy and Astrometry (IVS) – a Service of the IAG and IAU. Science and applications set the requirements for the realization and maintenance of global reference frames at VLBI's technical limitations. VLBI, as the unique technique for providing a celestial reference frame and for deriving the full set of Earth rotation parameters, plays the fundamental role of generating the basis for many applications and research in the geosciences.

VLBI today is the key technique for monitoring and realizing global reference frames. The importance of global reference frames has increased as space and satellite technologies, e.g. satellite navigation systems, are employed for many applications in research, in particular in geosciences and in all kinds of surveying and navigation. For the description of satellite orbits a "quasi" inertial system is required, which does not rotate with the Earth – a celestial reference frame (CRF). Such a system is realized by positions of radio sources and is internationally available as the International Celestial Reference Frame (ICRF). Point positioning on the surface of the earth needs an Earth fixed system – a terrestrial system (TRF). The terrestrial reference frame is realized through stations for which the positions and velocities are determined and known. The most recent realization (the adopted international realization) is the ITRF2000. Both TRF and CRF systems are needed and the relation between both must be known to the highest accuracy possible, in order to meet the broad spectrum of applications. The relation between the CRF and TRF is described by the Earth Orientation Parameters, which fix the Earth rotation axis with respect to the CRF ($d\varepsilon$, $d\varphi$) and by the polar motion parameters x_p and y_p which fix the Earth's crust. The rotation is described by the parameter DUT1 as the difference between the time scale provided by the Earth rotation itself (Universal Time, UT1) and the time

scale generated by atomic clocks (Universal Time Coordinated, UTC).

As all the parameters are changing with time and no model is precise enough for prediction, the parameters have to be derived continuously from observations. Among the geodetic space techniques (Satellite/Lunar Laser Ranging and GPS etc.), VLBI plays a unique role, as it is the only technique which is capable of realizing and maintaining the CRF, of providing the complete set of Earth orientation parameters and in particular of observing DUT1. Due to superior accuracy in the determination of long baselines VLBI dominates in the determination of the ITRF scale. Because sub-daily variations in Earth rotation occur, it is important to observe regularly with adequate resolution in time and accuracy. Regular and more dense observations will become a demand with the request for mm-precise reference frames, consistent for decades, that is set by the IAG within its project Global Geodetic Observing System (GGOS).

2. International VLBI Service for Geodesy and Astrometry

The International VLBI Service for Geodesy and Astrometry (IVS) is a Service of the International Association of Geodesy (IAG) and of the International Astronomical Union (IAU) and a member of the Council of Astronomical and Geophysical Data Analysis Services (CAGS). The charter and the basis for international collaboration is given by the Terms of Reference (ToR) accepted by IAG and IAU and by the proposals provided by individual agencies in response to the call for participation.

IVS is an international collaboration of organizations that operate or support Very Long Baseline Interferometry (VLBI) components. The goals are

- to provide a service to support geodetic, geophysical and astrometric research and operational activities;
- to promote research and development activities in all aspects of the geodetic and astrometric VLBI technique;
- to interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system.

As IVS has no funds of its own, but is tasked by IAG and IAU for the provision of timely, highly accurate products (Earth Orientation Parameters (EOPs), Terrestrial Reference Frame (TRF), Celestial Reference Frame (CRF), etc.), IVS is dependent on the support of individual agencies. Figure 1 shows the global distribution of the IVS components.

In order to maintain the strong requirement for consistency, which is the basis for realizing and maintaining global reference frames such as the CRF and TRF, IVS coordinates the VLBI infrastructure from the network stations to the analysis centers. Currently the IVS consists of

- 30 Network Stations, acquiring VLBI data;
- 3 Operations Centers, coordinating the activities of a network of Network Stations;
- 6 Correlators, processing the acquired data;
- 6 Data Centers, distributing the products to users, providing storage, and archiving functions;
- 21 Analysis Centers, analyzing the data, processing the results and products;
- 7 Technology Development Centers, developing new VLBI technology;
- 1 Coordinating Center, coordinating the daily and long term activities.

In total, there are 74 Permanent Components, representing 37 institutions in 17 countries with ~250 Associate Members.

Activities of the past two years are documented in the Annual Reports of the IVS for the years 2003 and 2004 [Vandenberg and Baver, 2004; Behrend and Baver, 2005]. The third General Meeting was held in Ottawa, Canada in February 2004 and several technical meetings concerning analysis and technology aspects

were conducted. Proceedings of the General Meeting are available [Vandenberg and Baver, 2004].

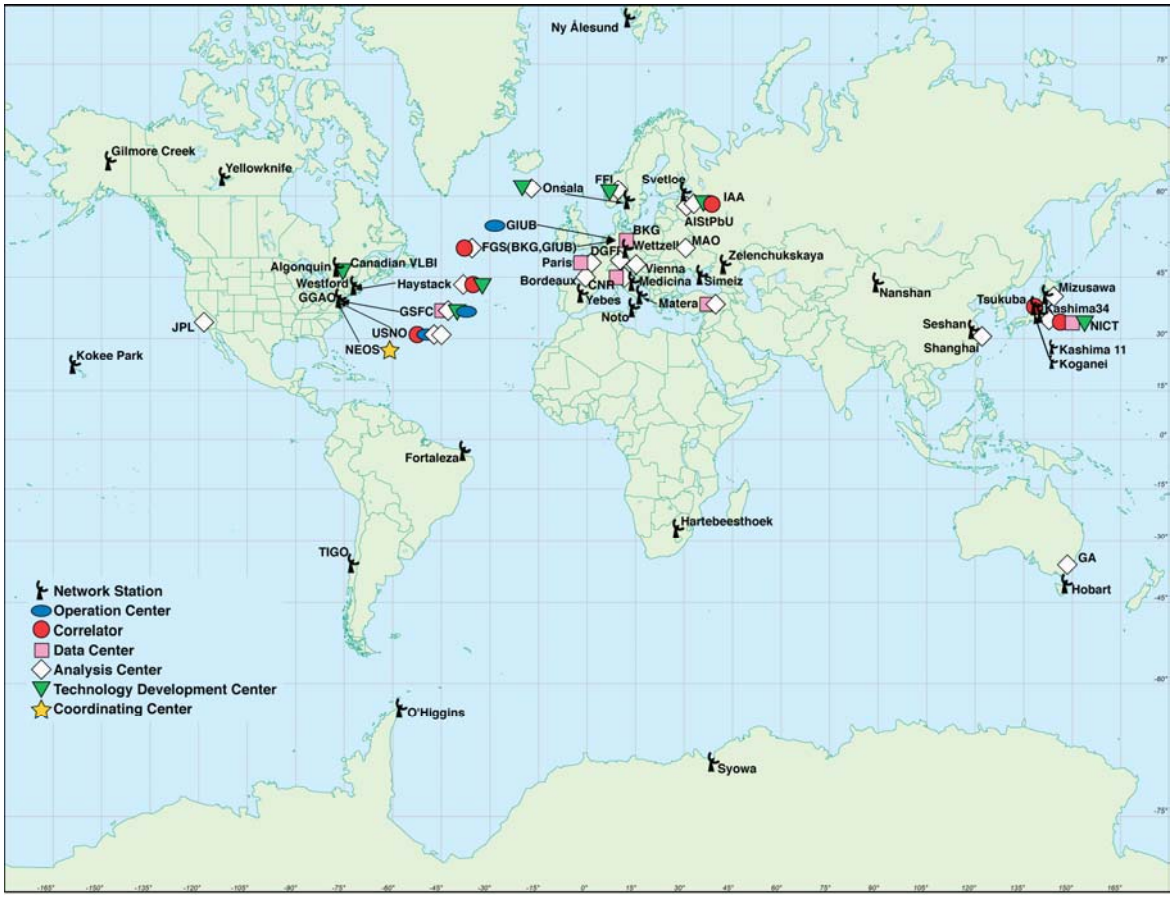

Figure 1: IVS components and their global distribution

3. IVS Products and Goals

In 2001 the IVS Working Group 2 (WG2) reviewed the IVS products and the corresponding observing programs in terms of meeting the service requirements. The WG2 report [Schuh et al., 2002] proposed a development of the products and the observing programs up to the year 2005. Even if, due to the limited resources, the proposed goals cannot be achieved in the expected period, the general view remains valid for years to come. The IVS products are summarized in Table 1. The demands on a next generation VLBI system need to be based on the requirements imposed on the products IVS has to provide. With respect to accuracy and latency, IAG's project GGOS will drive the future demands. The categories summarized in Table 1 have different requirements and conditions in terms of operation and timeliness. Some of the products, such as the EOP or TRF (partly), have to be provided operationally and in near-real time. Other products, in particular scientific products for CRF and TRF (partly), necessitate individual studies. Here the accuracy is of primary interest, whereas timeliness is not. The various requirements will be reflected in the specifications for the IVS components and in the demands for the observing programs and the data handling. Combinations of VLBI, GNSS (Global Navigation Satellite Systems), and SLR products will significantly improve the overall accuracy of all products. Systematic errors will be detected if time series of comparable precision are made available by all techniques. For the combination of all techniques to be useful, a reasonably timely delivery of products will be required. By making use of the technical potential of the Internet, timely solutions will become more economical.

Table 1: IVS products and goals for the coming years in terms of accuracy, frequency of solutions, resolution

and timeliness

Category	Products	Accuracy	Frequency of solutions	Resolution	Timeliness
CRF	α,δ	0.25 mas for as many sources	yearly		1 month
	α,δ time series	0.5 mas	monthly	1 month	1 month
	source structure		monthly	1 month	3 months
	flux density		7 days/week	1 hour	near real time
TRF	x,y,z time series (1 solution/session)	2…5 mm	7 days/week	1 day	1 day
	episodic events	2…5 mm	7 days/week	< 1 day	near real time
	annual solution coordinates velocities	 1…2 mm 0.1…0.3 mm/y	yearly	-	1 month
EOP	DUT1	5 μs	7 days/week continuous	10 min	near real time
	$D\varphi,d\varepsilon$	25…50 μas	7 days/week	1 day	near real time
	x_P,y_p	25…50 μas	7 days/week	10 min	near real time
	$dx_P/dt,y_p/dt$	8…10 μas/day	7 days/week	10 min	-
Geodynamic parameters	solid Earth tides h,l	0.1%	1 year	1 year	1 month
	ccean loading A, φ	1%	1 year	1 year	1 month
	Atmoshere loading	10%	1 year	1 year	1 month
Physical parameters	tropospheric parameters zenith delay gradients	 1…2 mm 0.3…0.5 mm	 7 days/week 7 days/week	 10 min 2 hours	near real time
	ionospheric mapping	0.5 TEC units	7 days/week	1 hour	near real time
	light deflection parameter	0.1%	1 year	all sessions used	1 month

The observing program for 2003–2005 included the following sessions:

- EOP: Two rapid turnaround sessions each week, mostly with 7 stations, some with 6 or 8 stations depending on station availability. These networks were designed with the goal of having comparable x_p and y_p results. Data bases are available no later than 15 days after each session. Daily 1-hour UT1 Intensive measurements on five days (Monday through Friday) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA) and on weekend days (Saturday and Sunday) on the baseline Wettzell (Germany) to Tsukuba (Japan). The daily sessions are recorded using Mark 5 (Wettzell-Kokee) and K5 (Wettzell-Tsukuba) technology. Comparisons of the two series showed good agreement with the IERS C04 series.
- TRF: Monthly (2003, 2004) and bi-monthly (2005) TRF sessions with 16 stations using all stations at least two times per year. The increase from 8 stations in the observing years 2002/2003 to 16 stations in 2004/2005 is largely due to the deployment of the Mark 5 technology, which sped up the correlator processing time significantly. The limiting factor has shifted from correlator to station availability.
- CRF: Bi-monthly RDV sessions using the Very Long Baseline Array (VLBA) and 10 geodetic stations, plus astrometric sessions to observe mostly southern sky sources where the sessions were increased from 8 in 2003, over 10 in 2004, to 16 in 2005.
- Monthly R&D sessions to investigate instrumental effects, research the network offset problem, and study ways for technique and product improvement.
- Bi-annual, or annual if resources are available, 14-day continuous sessions to demonstrate the best

results that VLBI can offer, aiming for the highest sustained accuracy.

Although certain sessions have primary goals, such as CRF, all sessions are scheduled so that they contribute to all geodetic and astrometric products. Sessions in the observing program that are recorded and correlated using S2 or K5 technology will have the same accuracy and timeliness goals as those using Mark 5. On average, a total of more than 1000 station days per year were used in about 180 geodetic sessions during the year increasing the average days per week which are covered by VLBI network sessions to 3.5.

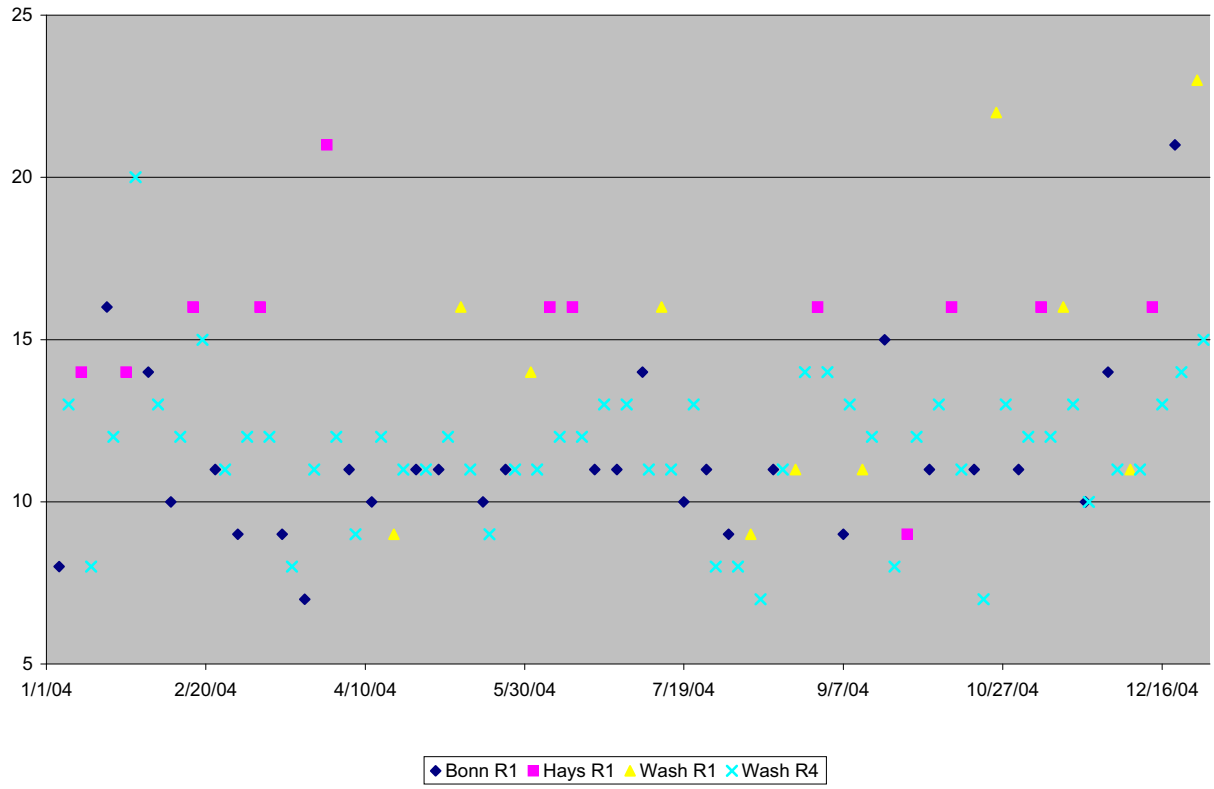

Figure 2: Delay (in days) between the observation and the availability of the results of the rapid turnaround sessions IVS R1 and IVS R4 as performed in the observation year 2004

The objective of the rapid turnaround observation sessions is to minimize the delay between the observations and the availability of the results. As shown in Figure 2 the delay from the observation to the results is better than two weeks (12 days average) for the chosen observation year 2004. The current observation year (2005) has followed through with the same performance. Though the WG2 goal of only 4 days has not been achieved, a clear improvement was made as compared to the year 2002 where the average was 15 days. In addition, now several sessions have single digit time delay values, which was not the case two years earlier. The limiting factor is still the data transmission that is mostly done via physically shipping the digital recording disks from the stations to the correlator. A significant improvement will occur when the e-VLBI capability of the Mark 5 digital recording system can be fully exploited. Currently, only very few stations have high speed Internet connections for fast data transmission.

Many hardware components for VLBI (such as radio telescopes) supporting IVS were constructed three to four decades ago; some are badly worn and inefficient in operation and in urgent need of an upgrade or replacement. The increase of radio interference, particularly at S-band (2.0-2.4 GHz), caused by modern wireless technology (cell phones and satellite radio, among others) severely degrades the quality of many current observations and will force a move to higher frequencies. Additionally, the increasing demand for higher-quality global reference frames requires better global coverage. All these factors led the IVS to

establish a Working Group, WG3, at the 10th Directing Board Meeting in September 2003 with the objective to develop future visions.

Work has begun that should ultimately lead to a redetermination of the ICRF. In February 2004 the IVS began a program to systematically monitor 307 sources. These include the non geodetic ICRF defining sources as well as astrometric sources identified by Martine Feissel-Vernier as stable or potentially stable based on analysis of position time series. The goal of this monitoring program is to observe each source at least twice a year using a small part of the time of the geodetic networks. A database was developed to track when these sources are observed and the number of successful observations. The procedure for including these sources in schedules is largely automatic. At present only the R1 and RDV sessions are used, but it is anticipated that other geodetic observing programs will be included in the future.

In terms of increasing the number of observations of poorly observed sources, the monitoring program has been a success. Prior to the start of the program approximately 160 sources had not been successfully observed in the preceding twelve months. Now all sources have been observed successfully. Prior to the program only 70 of the sources had been observed at least twice in the same period. This has been reduced to a very few sources. The data gathered by the source monitoring program should permit the selection of better defining sources for a redetermined ICRF.

In parallel to improving the astrometric data set work started to coordinate the IVS analysis centers for the ICRF redetermination. The first step in February 2005 was the generation of source catalogues in a configuration similar to the 1995 ICRF analysis, i.e., source positions as global parameters and station positions are arc parameters. The analysis centers participating in this effort are:

- U. S. Naval Observatory, U.S.A.
- Jet Propulsion Laboratory, U.S.A.
- Geoscience Australia, Australia
- Deutsches Geodätisches Forschungsinstitut, Germany
- Institute of Applied Astronomy, Russia
- Main Astronomical Observatory, Ukraine
- Bundesamt für Kartographie und Geodäsie, Germany
- Shanghai Observatory, China
- Space Geodesy Center Matera, Italy
- Goddard Space Flight Center, U.S.A.

The catalogues will be compared by the analysis centers at JPL, Paris Observatory, USNO and IAA. Over the next several years it is anticipated that many test catalogues will be made, compared, and analyzed to identify systematic errors, to try methods for treating source position instabilities, to determine the real size of position errors, and to decide on the analysis configuration for the final result. One goal will be the consistent estimate of VLBI CRF, TRF and EOP. Another area of work will be the generation of position time series and analysis of these series to decide on the defining sources of the redetermined ICRF.

The IVS also contributes to the effort to determine a combined TRF solution which will eventually become the ITRF2004. IVS provided a consistent set of combined TRF, EOP and CRF estimates based on solutions from five analysis centers. This set will be combined at the IERS with the solutions of the other geodetic space techniques. Since the ITRF2000 was based on data up to the end of the year 2000, the quality of this TRF deteriorated in the subsequent years. In order to provide a TRF for operational VLBI determinations of EOP and atmospheric water vapor content, a new conventional VLBI TRF (VTRF2005) was compiled from a combination of five VLBI TRF realizations. The complete list of VTRF2005 coordinates at epoch 1997.0 and their velocities can be found at http://vlbi.geod.uni-bonn.de/IVS-AC.

Data of the 15-day Continuous VLBI Campaign 2002 (CONT02) were used to perform combination studies with other techniques. Thaller et al. (2005) investigated, among other things, the effect of combining estimates for UT1-UTC (DUT1). VBLI is the only technique to fully determine DUT1, as the satellite

techniques GPS and SLR only yield the rate terms. Figure 3 shows hourly UT1-UTC values estimated by VLBI and GPS w.r.t. the official C04-series and the IERS2000 sub-daily model. Despite the large drift in the GPS estimates, the combined solution aligns very well with the VBLI-only solution. The combined solution appears to be an improvement over the VLBI solution as the RMS of the remaining differences to C04/IERS2000 reduces from 0.015 ms for VLBI to 0.011 ms for the combined solution demonstrating the advantage of an inter-technique combination.

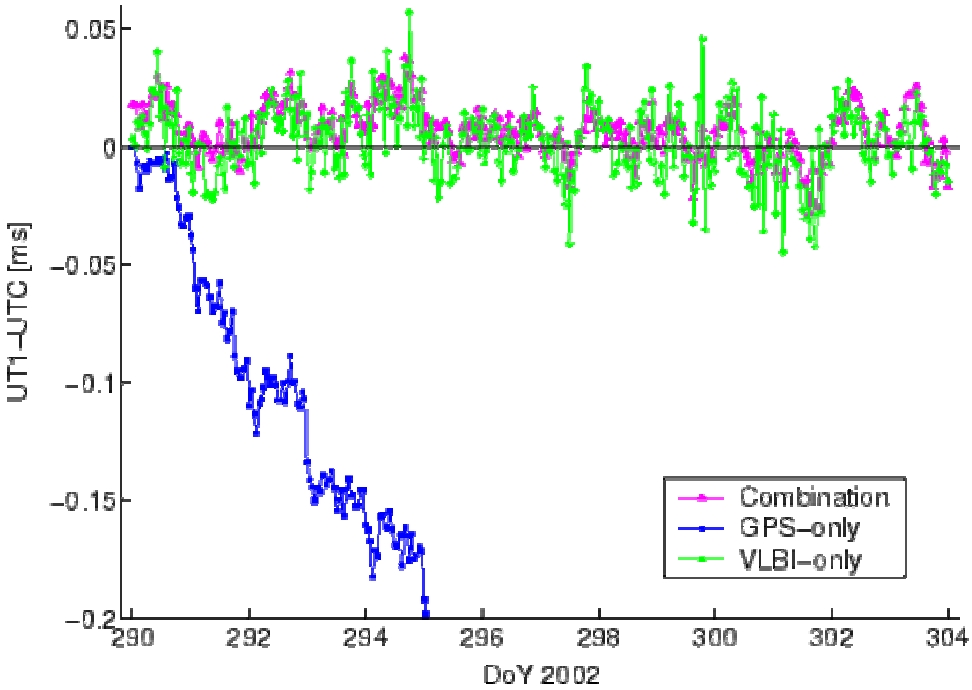

Figure 3: Hourly UT1-UTC estimates w.r.t. C04/IERS2000 derived from VLBI, GPS, and a combined solution.

4. Next Generation VLBI System

Geodetic VLBI stands at the brink of a new era. Such societally relevant issues as climate change and natural hazards are placing ever increasing demands on performance. This comes at a time when problems with aging antennas, a deteriorating RFI environment, obsolete electronics, and high operating costs are making current levels of accuracy, reliability, and timeliness difficult to sustain. Attaining modern requirements for significantly greater accuracy, continuous data flow, and shortened times to product delivery challenge the continuing progress made by geodetic VLBI over the past 30 years. Fortunately, recent advances in antenna manufacture, digital electronics, and data transmission technology are enabling modes of operation unimaginable only a few years ago. Furthermore, the capital investment and reduced operating costs associated with the new technology make complete renewal of present infrastructure appear cost effective. A new instrument that will meet requirements for decades to come can now be envisioned.

4.1 Future Requirements for VLBI

IVS Working Group 3 (WG3) was asked to examine current and future requirements for geodetic VLBI, including all components from antennas to analysis, and to create recommendations for a new generation of VLBI systems. To constrain these recommendations, a new set of criteria by which to measure the next generation geodetic VLBI system was established based on the recommendations for future IVS products detailed in the IVS Working Group 2 Report [Schuh et al., 2002], on the requirements of the Global Geodetic Observing System (GGOS) project of the International Association of Geodesy, and on the science driven

geodetic goals outlined in the NASA Solid Earth Science Working Group Report (SESWG, http://solidearth.jpl.nasa.gov/seswg.html). These criteria are:

- 1 mm measurement accuracy on global baselines,
- continuous measurements for time series of station positions and Earth orientation parameters,
- turnaround time to initial geodetic results of less than 24 hrs.

While the new requirements are significant challenges, it is vital to continue the measurements for which VLBI is the unique space geodetic technique:

- UT1 and nutation,
- the celestial reference frame (CRF).

UT1 and the CRF are currently defined by VLBI, and there is no alternative for the foreseeable future. It is recognized that achieving long term accuracy at the level of 1 mm or better is a daunting task.

4.2 Strategies and Recommendations

From the outset WG3 sought approaches for the design of the new system that would enable the following performance enhancing strategies:

- Reduce the random component of the delay-observable error, i.e., the per-observation measurement error, the stochastic properties of the clocks, and the unmodeled variation in the atmosphere,
- Reduce systematic errors,
- Increase the number of antennas and improve their geographic distribution,
- Reduce susceptibility to external radio-frequency interference,
- Increase observation density, i.e. the number of observations per unit time,
- Develop new observing strategies.

All of the above considerations, along with the need for low cost of construction and operation, required a complete examination of all aspects of geodetic VLBI, including equipment, processes, and observational strategies. The results of this examination have led WG3 to make the following recommendations:

- <u>Design a new observing system based on small antennas</u>. The new system will be automated and operate unattended and will be based on small (10-12 m diameter), fast-moving, mechanically reliable antennas that can be replicated economically. The observing should be done over a broad, continuous frequency range, perhaps 1-14 GHz, which includes both the current S-band and X-band frequencies for backwards compatibility, but allows much more agility to avoid RFI and more bandwidth to significantly improve delay measurement precision. At the same time, the best of the existing large antennas will be updated for compatibility with the new small-antenna system; this will allow them to co-observe with the small-antenna systems to preserve continuity with the historical record, as well as to improve the CRF measurements made primarily by the large antennas.
- <u>Transfer data with a combination of high-speed networks and high data-rate disk systems</u>. Data recording rates and transmission rates are rapidly increasing courtesy of vast investments by the computer and communications industries.
- <u>Examine the possibilities for new correlator systems</u> to handle the anticipated higher data rates, including correlation based on commodity PC platforms, possibly widely distributed.
- <u>Automate and streamline the complete data-analysis pipeline</u>, enabling rapid turnaround and consistent TRF, CRF, and EOP solutions.

Because the new systems should be fully backwards compatible with the existing systems, the transition from the old to the new systems can be gradual and deliberate, maintaining important continuity of geodetic results and measurements series while dramatically upgrading the quality, precision, and timeliness of new observations. Furthermore, with more of the new VLBI systems co-located with the suite of complementary

space-geodetic techniques, the space-geodetic program as a whole will be greatly strengthened.

4.3 Next Steps

The above recommendations describe a system that can begin to become reality very soon. The IVS WG3 report (Niell et al., 2005) identifies specific steps that need to be taken next in order to develop, deploy, and bring the system into operation. The next steps include two broad categories of efforts:

- System studies and simulations: error budget development, decisions on observing frequencies, optimal distribution of new sites, number of antennas per site, new observing strategies, and a transition plan.
- Development projects and prototyping: small antenna system, feed and receiver, cost and schedule, higher data rate system, correlator development, backend development, and data management and analysis software.

Almost all of the recommended next steps can be done in parallel, and WG3 hopes that various IVS components will find the resources to support one or several of these studies and development projects. Results of these studies and projects should be well communicated within the community and coordinated by IVS so that common goals for the new vision are recognized and met.

It is important that IVS make a strong recommendation that some of the resources dedicated today to routine product generation and technology development be directed to address the studies and projects recommended in this report. These studies must move forward so that a detailed plan can be generated, including defensible costs and schedules. Building on the efforts of WG3, the results of these studies and projects will provide the final element required for IVS members to move forward with requests for augmented funding to implement the new vision. We believe that this vision will renew the interest of current funding resources and inspire new interest from universities, industry, and government, based on the exciting possibilities for a more accurate and data-rich geodetic VLBI system.

A report of the WG3 was presented in September 2005. The IVS Directing Board reviewed the final version and accepted it for publication. It is available under http://ivscc.gsfc.nasa.gov/wg/wg3 and will be published in the Annual Report 2005.

At the 14th Directing Board meeting held in September 2005 in Washington, DC, a Committee was formed, VLBI2010 Committee, whose primary function is to promote and guide research into the improvement of the "technique" of geodetic VLBI. The committee will take an integrated view of VLBI and will evaluate the effectiveness of proposed system changes based on the degree to which they improve IVS' final products. In addition, the committee will take responsibility for encouraging the implementation of the WG3 recommendations.

5. References

Behrend, D., Baver K.D. (editors): Annual Report 2004, NASA/TP-2005-212772, Greenbelt, MD; March 2005

Thaller, D., Krügel, M., Angermann, D., Rothacher, M., Schmid, R., Tesmer, V.: Combination Studies Using the CONT02 Campaign, in: Behrend, D., Baver K.D. (editors): Annual Report 2004, pages 13–21, NASA/TP-2005-212772, Greenbelt, MD; March 2005

Schuh, H. et al.; IVS Working Group 2 for Product Specification and Observing programs, Final Report, in: Vandenberg, N. R., Baver K.D. (editors), Annual Report 2001, pages 13–45, NASA/TP-2002-210001, Greenbelt, MD; February 2002

Vandenberg, N. R., Baver K.D. (editors): Annual Report 2003, NASA/TP-2003-211619, Greenbelt, MD; May 2003

Vandenberg, N. R., Baver K.D. (editors): 2002 General Meeting Proceedings, NASA/CP-2002-210002, Greenbelt, MD; June 2002

Vandenberg, N. R., Baver K.D. (editors): 2004 General Meeting Proceedings, NASA/CP-2004-212255, Greenbelt, MD; July 2004