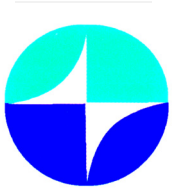

International Association of Geodesy (IAG)

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

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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.

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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.

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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 georeferencing 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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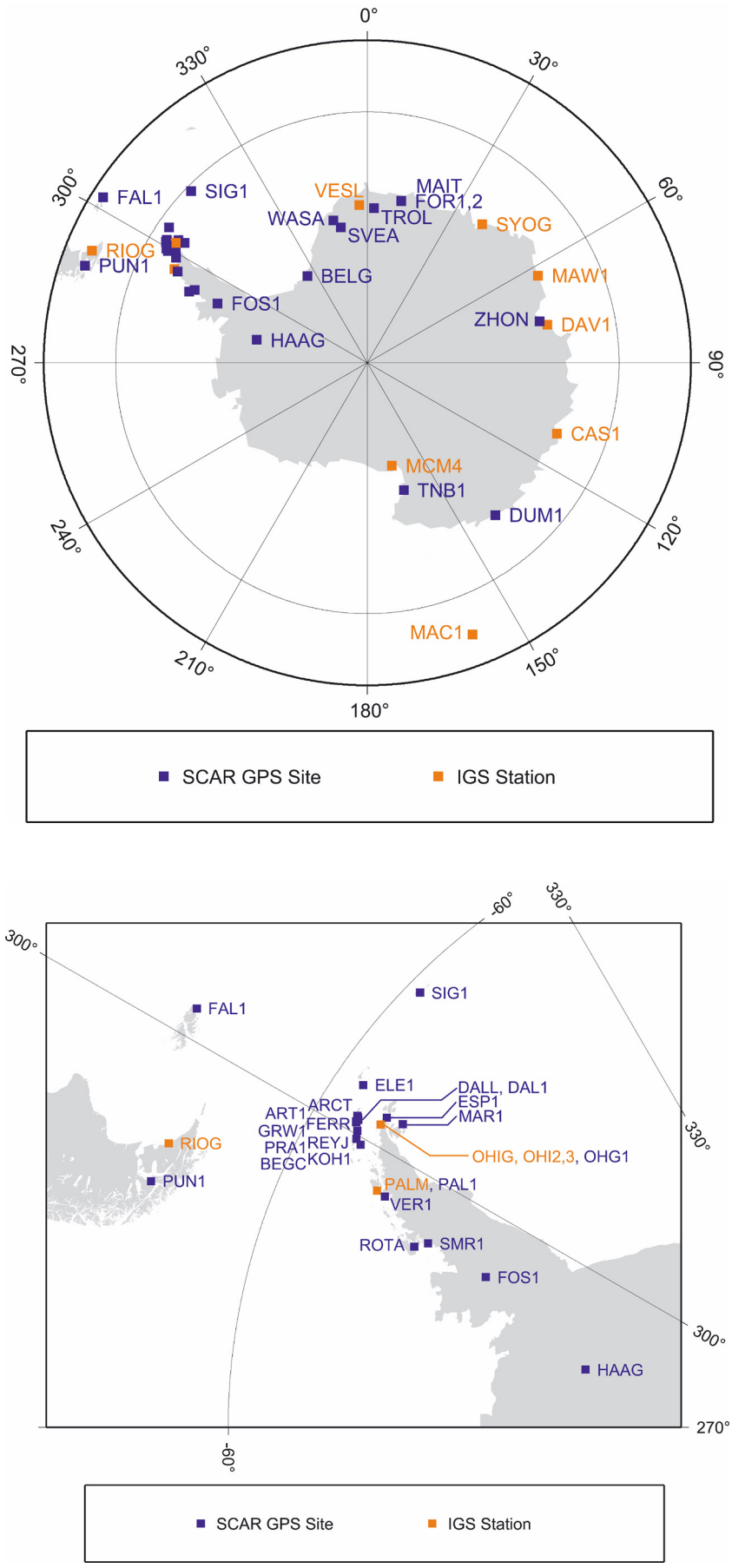

Figure 1: Station distribution of the SCAR GPS network and of the IGS network in Antarctica (April 2005).

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.

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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.

Membership

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Benada Robert	NASA/ JPL	Jules.R.Benada-III@ jpl.nasa.gov
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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.

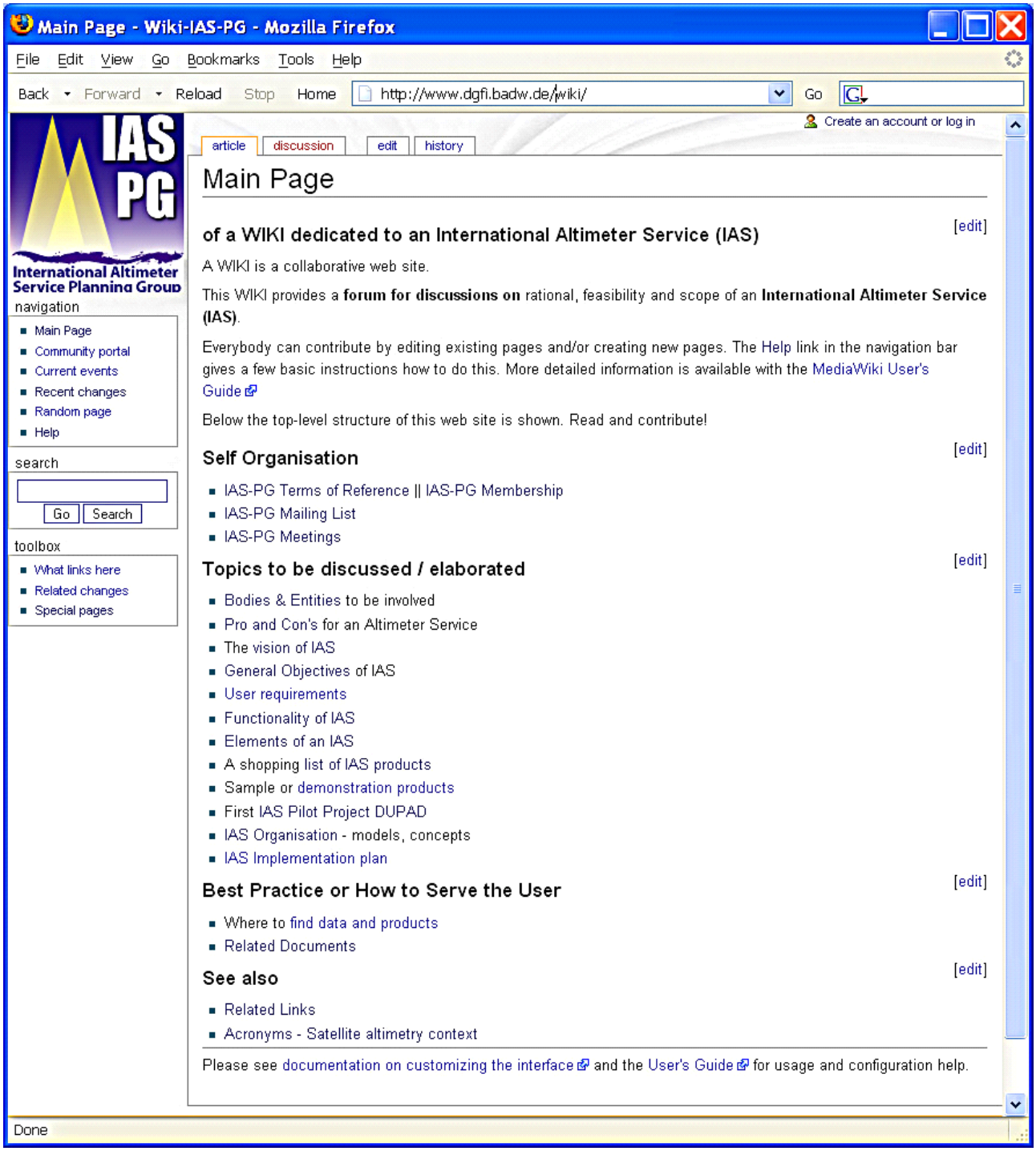

Fig.1: Screenshot of IAS-PG WIKI, a collaborative web site, that serves as a forum for discussion on the envisaged International Altimeter Service and is used to compile and synthesize contribution from the members of the IAS-Planning Group.

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.

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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

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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
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- R. GREBENITCHARSKY, University of Calgary Canada, grebski@ucalgary.ca
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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.

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