International Earth Rotation and Reference Systems Service (IERS)
Service International de la Rotation de la Terre
et des Systèmes de Référence

IERS
Annual Report
2002

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IERS Annual Report 2002

Edited by Wolfgang R. Dick and Bernd Richter

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1 Foreword

The IERS Annual Report for 2002 roughly follows the same scheme as that for 2001 – the parts devoted to the Technique and Product Centres are relatively short since it is assumed that they produce their own, more detailed, reports. The changes therefore reflect only minor changes in the organisational structure of the IERS that took place since 2001:

- There is a new part describing the activity of the newly created GGFC Special Bureau for Loading (Section 3.5.6.8);
- In addition to existing German and French ITRS Combination Centres, there is a new one in Canada (Section 3.6.1.2).

The life of the IERS in 2002 was much affected by an exceptionally high number of IERS Workshops. There were two of them: one in April in Paris (devoted to the implementation of the new IAU resolutions), and one in November in Munich (devoted to combinations and geophysical fluids). The immediate impact of the first one on IERS products as published since the beginning of 2003 (new precession-nutation model and new transformation between the celestial and terrestrial reference frames) is evident, the impact of the second one will hopefully appear on a long run, and will be reflected in an improved consistency of the products. The detailed results of these Workshops are published separately, in IERS Technical Notes No. 29 and 30.

The attentive reader might notice, on the cover of this report and elsewhere, that the traditional abbreviation IERS now stands for somewhat changed name of the Service – International Earth rotation and Reference systems Service. It is the consequence of the decision of the IERS Directing Board, taken at its meeting in Paris Observatory on April 2, 2003, to reflect better the real activities and products of the Service.

Jan Vondrák

2 The IERS
2.1 Structure

In 2002 and the beginning of 2003, the IERS had the following components. For their functions see the Terms of Reference (Appendix 1), for addresses and electronic access see Appendices 3 and 4. Dates are given for new components and for other changes in 2002 and 2003.

Analysis Coordinator

Markus Rothacher

Central Bureau

Director: Bernd Richter

Technique Centres

International GPS Service (IGS)
IGS Representatives to the IERS Directing Board:
Carine Bruyninx, Robert Weber (until March 2003), Gerd Gendt (since April 2003)
IERS Representative to the IGS Directing Board: Claude Boucher

International Laser Ranging Service (ILRS)
ILRS Representatives to the IERS Directing Board:
Ron Noomen, Peter J. Shelus
IERS Representative to the ILRS Directing Board: Bob E. Schutz

International VLBI Service (IVS)
IVS Representatives to the IERS Directing Board:
Chopo Ma, Axel Nothnagel
IERS Representative to the IVS Directing Board: Chopo Ma

International DORIS Service (IDS) - planned
DORIS representative to the IERS with observing status:
Pascal Willis

Product Centres

Earth Orientation Centre
Primary scientist and representative to the IERS Directing Board: Daniel Gambis

Rapid Service/Prediction Centre
Primary scientist and representative to the IERS Directing Board: Jim Ray (until May 2002), William Wooden (since February 2003)

Convention Centre
Primary scientists: Dennis D. McCarthy, Gérard Petit
Current representative to the IERS Directing Board:
Dennis D. McCarthy

ICRS Centre
Primary scientists: Ralph A. Gaume, Jean Souchay
Current representative to the IERS Directing Board: Jean Souchay

ITRS Centre
Primary scientist and representative to the IERS Directing Board: Claude Boucher

Global Geophysical Fluids Centre
Head and representative to the IERS Directing Board: Benjamin F. Chao

Special Bureau for the Atmosphere
Chair: David A. Salstein

Special Bureau for the Oceans
Chair: Richard S. Gross

Special Bureau for Tides
Chair: Richard D. Ray

Special Bureau for Hydrology
Chair: Clark R. Wilson

Special Bureau for the Mantle
Chair: Benjamin F. Chao

Special Bureau for the Core
Chair: Veronique Dehant (until June 2002),
Tim van Hoolst (since July 2002)

Special Bureau for Gravity/Geocenter
Chair: Michael M. Watkins

Special Bureau for Loading (established on 1 February 2002)
Chair: Tonie van Dam, *Vice-chair*: Hans-Peter Plag

Combination Centres

ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)
Primary scientist: Hermann Drewes

Institut Géographique National (IGN)
Primary scientist: Zuheir Altamimi

Natural Resources Canada (NRCan)
(established in February 2002)
Primary scientist: Remi Ferland

Combination Research Centres

CRC representative to the IERS Directing Board:
Sheng Yuan Zhu

Agenzia Spaziale Italiana (ASI)
(established in March 2003)
Primary scientist: Giuseppe Bianco

Astronomical Institute, Academy of Sciences of the Czech Republic, and Department of Geodesy, Czech Technical University, Prague
Primary scientist: Jan Vondrák

Deutsches Geodätisches Forschungsinstitut (DGFI)
Primary scientist: Detlef Angermann

Forschungseinrichtung Satellitengeodäsie, Technical University Munich (FESG)
Primary scientist: Markus Rothacher

Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment)
Primary scientist: Per Helge Andersen

GeoForschungsZentrum Potsdam (GFZ)
Primary scientist: Sheng Yuan Zhu

Geodetic Institute of the University of Bonn (GIUB)
Primary scientist: Axel Nothnagel

Groupe de Recherches de Géodésie Spatiale (GRGS)
Primary scientist: Richard Biancale

Institute of Applied Astronomy, St. Petersburg (IAA)
Primary scientist: Zinovy M. Malkin

Institut Géographique National (IGN)
Primary scientist: Patrick Sillard (until October 2002), Zuheir Altamimi (since November 2002)

Jet Propulsion Laboratory (JPL)
Primary scientist: Richard S. Gross

2.2 Directing Board

In 2002 and 2003, the IERS Directing Board had the following members (for addresses see Appendix 2):

Chair	Jan Vondrák
Analysis Coordinator	Markus Rothacher
Product Centres Representatives	
Earth Orientation Centre Representative	Daniel Gambis
Rapid Service/Prediction Centre Representative	Jim Ray (until May 2002) William Wooden (since March 2003)
Conventions Centre Representative	Dennis D. McCarthy
ICRS Centre Representative	Jean Souchay
ITRS Centre Representative	Claude Boucher
Global Geophysical Fluids Centre Representative	Benjamin F. Chao
Central Bureau Representative	Bernd Richter
Combination Research Centres Representative	Sheng Yuan Zhu
Technique Centers Representatives	
IGS Representatives	Carine Bruyninx Robert Weber (until March 2003) Gerd Gendt (since April 2003)
ILRS Representatives	Ron Noomen Peter J. Shelus
IVS Representatives	Chopo Ma Axel Nothnagel
IDS Representative (observing status)	Pascal Willis
Union Representatives	
IAU Representative	Jan Vondrák
IAG / IUGG Representative	Clark R. Wilson
FAGS Representative	David Pugh

2.3 Associate Members

Altamimi, Zuheir
Andersen, Per Helge
Andersen, Ole Baltazar
Angermann, Detlef
Arias, Elisa Felicitas
Biancale, Richard
Carter, William E.
Dam, Tonie van M.
Dow, John M.
Drewes, Hermann
Feissel-Vernier, Martine
Ferland, Remi
Gaume, Ralph A.
Gross, Richard S.
Gurtner, Werner
Herring, Thomas
Hoolst, Tim van
Kolaczek, Barbara
Kostelecký, Jan
Larson, Kristine M.
Malkin, Zinovy M.
Melbourne, William G.
Neilan, Ruth E.
Pearlman, Michael R.
Petit, Gérard
Plag, Hans-Peter
Ray, Richard D.
Ray, Jim
Reigber, Christoph
Salstein, David
Schlüter, Wolfgang
Schutz, Bob E.
Tavernier, Gilles
Vandenberg, Nancy
Veillet, Christian
Watkins, Michael M.
Weber, Robert
Wilkins, George A.
Yatskiv, Yaroslav S.
Yokoyama, Koichi

Ex officio Associate Members:
IAG General Secretary: Carl Christian Tscherning
IAU General Secretary: Hans Rickmann
IUGG General Secretary: Jo Ann Joselyn
President of FAGS: David Pugh
President of IAG Section II: C. K. Shum
President of IAG Commission VIII: Hermann Drewes
President of IAG Section V: Clark R. Wilson
President of IAU Commission 19: Nicole Capitaine
President of IAU Commission 31: Gérard Petit
Head of IAU Division I: Nicole Capitaine

(*Status as of May 2003*)

3 Reports of IERS components
3.1 Directing Board

The IERS Directing Board (DB) met twice in the course of the year 2002. Short summaries of these meetings are given below.

Meeting No. 35 *Saturday, April 20, 2002, Observatoire de Paris, Paris, France*

J. Vondrak welcomed the participants of the meeting, and the minutes of the DB Meeting No. 34 were approved. J. Vondrak announced that the GGFC Special Bureau for Loading was created in February 2002.

Concerning the proposed Working Group on the ITRS, M. Rothacher reported that he contacted several colleagues. There is already an ITRS WG, so that there is no need to have another group. The present group should act as advisor for the ITRS Centre.

J. Vondrak reported that he corresponded with R. Ferland concerning an ITRS Combination Centre at the Geodetic Survey Division of Natural Resources Canada/Geomatics Canada. An official letter from N. Beck was received by the Chairman, accepting the ITRS Combination Centre under certain conditions.

G. Beutler as invited guest gave an overview on the main elements of the new structure of IAG, which will be introduced at the 2003 IAG General Assembly. The DB voted for the IERS to become an IAG element.

G. Beutler reported also about the “Integrated Global Geodetic Observing System (IGGOS)”, which will be the first IAG Project. The DB decided that the IERS will take part in the planning of IGGOS.

N. Capitaine as invited guest reported about the IERS Workshop on the Implementation of the New IAU Resolutions, held at Observatoire de Paris, France, 18-19 April 2002. (See also her report in IERS Message No. 28, June 12, 2002.) Several action items were defined during the Workshop, the dates for which were specified by the DB at this meeting. It should be underlined in all documents that IERS will not stop the old products on 1 January 2003.

M. Rothacher reported on his activities as the IERS Analysis Coordinator: the present status and future perspective of IERS products as well as plans for improvements, the coordination of the IERS Combination Research Centres activities, the IERS EOP Alignment Campaign, the SINEX 2.0 Format, the IERS SINEX Campaign, and the proposed IERS Combination Research Workshop.

J. Ray gave a short overview on the NASA Proposal “Integration of Space Geodesy”, which is similar to IGGOS.

B. Richter reported that the *IERS Annual Report 2000* was available as PDF file at the IERS web site in mid-December. The DB decided that starting with the Annual Report for 2001, the report will mainly contain summaries of activities, results and publications of the IERS components. Extended results will be published in IERS Technical Notes or in other publications by the IERS centres.

The DB decided that IERS Associate Members will receive the IERS Messages, Annual Reports and Technical Notes as well as the minutes of the DB meetings. Minor changes in the Terms of Reference concerning the definition of IERS Associate Members and Correspondents were accepted. The Central Bureau (CB) was asked to compile a list of IERS Associate Members, which will be approved by the DB members. Also selected persons from IERS components who do not have official representation functions may become IERS Associate Members.

B. Richter reported on the planned EU Networks of Excellence and Integrated Projects. The DB decided that the CB should prepare in the name of all European partners of the IERS an Expression of Interest for a Network of Excellence related to the thematic area Space with its two components Galileo and GMES.

D. Gambis gave a status report on UTC, with additions by D. McCarthy.

Meeting No. 34

Friday, November 22, 2002, Bavarian Academy of Sciences, Munich, Germany

J. Vondrak welcomed the participants of the meeting, and the minutes of the DB Meeting No. 35 were approved. J. Vondrak announced the following: A letter by the IAU General Secretary, H. Rickman, was sent to the General Secretaries of IAG and IUGG, asking for support of the IAU resolutions. J. Ray resigned from the DB in May 2002 because he left USNO. The election of a candidate for IAG representative by e-mail among the DB members nominated M. Rothacher. P. Sillard, who left IGN, was replaced by Z. Altamimi as the Responsible Scientist of the CRC at IGN. T. van Hoolst replaced V. Dehant as Chair of the GGFC Special Bureau for the Core in July 2002. A proposal for a new CRC was received from the Italian Space Agency.

B. Chao and M. Rothacher gave reports on the IERS Workshop in Munich, which was very successful. As one of the major results of the workshop M. Rothacher proposed an IERS Retreat (see below). The Proceedings of the Workshop will be published as an IERS Technical Note.

B. Richter reported that the *Technical Note 29* with the Proceedings of the Paris Workshop has been printed and distributed right before the Workshop in Munich. The *Annual Report 2001* is in print and will also be available as PDF file at the IERS web site. The CB compiled a list of IERS Associate Members.

D. Gambis reported on the Earth Orientation Centre's survey on the redefinition of the UTC scale, which showed that most users do not wish any change. D. McCarthy added that however most probably the Working Group draft recommendation will be to remove the leap second. The final decision will be made by ITU.

N. Capitaine as invited guest reported on the status of the material available to users for the implementation of the IAU 2000 Resolutions. The revised version of Chapter 5 of the IERS Conventions, together with the associated electronic Tables, which are posted on the website of the IERS Convention Centre, provide the full IAU 2000 expressions necessary to implement Resolution B1.6 (IAU 2000 precession-nutation model), B1.7 (definition of the CIP) and B 1.8 (new transformation between the TRS and the CRS, including a new definition of UT1). This is provided both for the new transformation (CEO-based) and the classical transformation (equinox-based). The available expressions and Tables for the IAU 2000 models for the motion of the CIP in the GCRS, for the position of the CEO in the GCRS and for GST ensure the equivalence between the two transformations at any date at a microarcsecond level after a century and ensure continuity in the EOP on 1 Jan 2003. The different methods which are described in the document are implemented in the software package provided by P. Wallace.

P. Wallace as invited guest described a set of additions to the SOFA software library that implement IAU 2000 models. These Fortran routines, about 40 in number, include support for both the classical (equinox-based) and new (CEO-based) methods, and for both IAU 2000A and B nutation models. They include GST implementations adjusted to satisfy the requirement of no UT1 jump on 2003 January 1.0. The URL for SOFA is <www.iau-sofa.rl.ac.uk>. The present collection of Fortran routines deals with pre-2000 models and techniques. The new "draft" routines will be added if and when the SOFA has accepted them for inclusion in the SOFA collection. Because SOFA has a "no beta-release" policy, it would not be possible to distribute copies of the draft routines before approved by the SOFA Board. However, equivalents of the key routines, specially designed for IERS use, had been prepared and would be posted on the draft IERS Conventions Chapter 5 website at USNO. These IERS versions gave essentially identical results to the SOFA routines.

An IERS Message will be prepared for the information of users. Also Chapter 5 of the IERS Conventions which is nearly ready will contain information. The next Bulletins A will contain announcements of the forthcoming changes.

To implement the Resolution of the 24th IAU General Assembly the IERS Publications will:

1. Publish in Bulletin A & B
   a. location of software to implement the resolutions
   b. availability of products in Bulletins A & B

2. Produce in Bulletins A & B
   a. x, y, UT1-UTC
      $\psi_{obs} - \psi_{IAU\ 1976/1980}$
      $\varepsilon_{obs} - \varepsilon_{IAU\ 1976\ /\ 1980}$
   b. $x_{obs} - x_{IAU\ 2000\ A}$
      $y_{obs} - y_{IAU\ 2000\ A}$
   c. $\psi_{obs} - \psi_{IAU\ 2000\ A}$
      $\varepsilon_{obs} - \varepsilon_{IAU\ 2000\ A}$

3. Notice that references to $\psi_{IAU\ 1976/1980}$ and $\varepsilon_{IAU\ 1976\ /\ 1980}$ will be removed after December 31, 2005.

B. Richter and M. Rothacher presented a proposal for an addition on Working Groups in the IERS Terms of Reference. After discussion, a revised text was approved by the DB. The existing WG on ITRF Datum should be re-established. A WG on Collocation was proposed.

G. Beutler as invited guest reported about INDIGO, a proposal by JPL prepared by R. Neilan. The intention of this project is to integrate the independent space geodesy data services of ILRS, IVS and IGS. J. Vondrák will sign the letter prepared by G. Beutler in reply to this proposal.

On suggestion of the CB, the DB decided on the following change in the Terms of Reference: In the section on IERS Associate Members, add “IAU General Secretary, IUGG General Secretary, President of FAGS” as ex officio members.

The CB decided that an IERS Retreat will be held on Monday and Tuesday, 31 March – 1 April 2003 in Paris. Together with the representatives of all components of the IERS some external experts will be invited to discuss the present status of the IERS and future requirements with the aim to find answers to:
- What is the IERS,
- What does the IERS want in the future,
- What does it NOT want,
- How we can realize this (action items and schedule).

Bernd Richter, Wolfgang R. Dick

3.2 Central Bureau

The IERS Central Bureau (CB), hosted and funded by Bundesamt für Kartographie and Geodäsie (BKG), organized and documented two IERS Directing Board (DB) meetings: No. 35, April 20, 2002, Observatoire de Paris, Paris, France; No. 36, November 22, 2002, Bavarian Academy of Sciences, Munich, Germany. Between these meetings the CB coordinated the work of the DB.

The CB contributed to the discussion of the role of IERS in the new IAG structure and in the framework of the IAG Project “Integrated Global Geodetic Observing System (IGGOS)”. New possibilities of funding were searched through the Sixth Framework Programme of the European Community for Research, Technological Development and Demonstration activities for the period 2002 to 2006. The CB prepared in the name of all European partners of the IERS an Expression of Interest for a *Network of Excellence* related to the thematic area Space with its two components Galileo and GMES. EU received far more proposals (171) than anticipated. As most of the proposals for a NoE, the IERS proposal EPISTAGE has been declined because the applications were targeting rather in the direction of “cooperation” than of “integration” as expected by the EU. The CB compiled a list of IERS Associate Members, which was approved by the DB (see section 2.3).

In 2002, the CB organized two Workshops in cooperation with other IERS components:

- IERS Workshop on the Implementation of the New IAU Resolutions, Observatoire de Paris, Paris, France, 18–19 April 2002;
- IERS Workshop on Combination Research and Global Geophysical Fluids, Bavarian Academy of Sciences, Munich, Germany, 18–21 November 2002.

About 80 participants took part in each of these workshops. The Proceedings have been published or are in preparation as IERS Technical Notes (see below). The CB participated also in the organisation of a splinter meeting of the Combination Research Centres held during the EGS General Assembly in Nice in April 2002.

The CB presented the activities of IERS with oral and poster presentations at the EGS General Assembly in Nice, the AGU Spring Meeting in Washington and the WEGENER General Assembly in Athens.

IERS components maintain individually about 20 separate web sites. The central IERS site <www.iers.org>, established by the CB, gives access to all other sites, offers information on the structure of the IERS, its products and publications and provides contact addresses as well as general facts on Earth rotation studies. It contains also electronic versions of IERS publications, a list of meetings related to the work of the IERS, and a large link list for IERS, Earth rotation in general and related fields. Throughout 2002 the web site was regularly enlarged and updated. All changes are documented in a “What was new” page.

IERS Technical Note (TN) No. 29, containing the Proceedings of the Paris Workshop (see above), appeared as an online version in July and in printed form in November 2002. It was edited by the CB together with the members of the Workshop’s Organizing Committee, mainly with Nicole Capitaine. Work started on TN 30, which will contain the Proceedings of the Munich Workshop.

The IERS Annual Report 2000, prepared as an online version in 2001, was printed in May 2002. The CB edited and published also the IERS Annual Report 2001 in online and printed form. It appeared in November (online) and December 2002. Besides the reports of the IERS components, it contains information on the IERS compiled by the CB. Funds for printing the Technical Note and the Annual Report were provided by BKG and by FAGS.

During the year 2002, 17 IERS Messages (Nos. 20 – 37) were edited and distributed by the CB. They contain news from the IERS and from related services as well as announcements of conferences.

The CB continued to maintain its address database of IERS users. There were about 2000 users in 2002 with valid addresses who subscribed to IERS publications for e-mail and regular mail distribution. A considerable number of new users were added. Address and subscription information has regularly been updated.

In March 2002 the IERS database project started at the CB. A scientific position for this project is funded for 3 years by the German Ministry of Education and Sciences within the “Geotechnologien-Programm”. The goal of the project is to build a dynamic and database-driven information system to coordinate the data and information flow between all institutions within the IERS. Therefore, all relevant IERS data and products should be archived at the CB. The metadata information of all products should be modelled within a database to allow the users to search for specific data with respect to space, time and contents. As a first step the results of a product review done by the IERS Analysis Coordinator have been compiled and put into new Web pages of the IERS products. Their structure – now more concise and uniform – can be regarded as a starting point for the data modelling for the IERS database. In parallel, the concept for the new database system has been developed. All components of the system, the database management system as well as the methods to access and display the data through a Web based interface, are based on open source software. First applications have been implemented to evaluate the efficiency of the proposed concept with respect to its software components.

Bernd Richter, Wolfgang R. Dick, Wolfgang Schwegmann

3.3 Analysis Coordinator

Introduction

This annual report of the IERS Analysis Coordinator (AC) will concentrate on the following topics:

- List of IERS products on the Web pages
- IERS Analysis Campaign to align EOPs to ITRF2000 / ICRF
- IERS SINEX Combination Campaign
- SINEX Format Version 2.00

Besides these major topics considerable effort was put into the scientific preparation of the IERS Workshop 2002 in Munich with the themes “combination” and “global geophysical fluids”.

List of IERS Products on the Web Pages

A complete list of the IERS products was compiled by Daniela Thaller during the end of 2001 and finalized in the first few months of 2002. In mid 2002 the detailed information for all products was added in a uniform way to the IERS Web pages at the IERS Central Bureau by Wolfgang Schwegmann (see <http://www.iers.org/iers/products/>). This list will serve as the “status quo”, i.e., as the starting point for improving the IERS product consistency and accuracy. In view of the fact, that only a rigorous combination of station coordinates, EOP and quasar coordinates can guarantee a consistent IERS product palette, the emphasis of the IERS AC work was put on stimulating the combination efforts and the development of appropriate software algorithms. On the long run this strategy will be more efficient than trying to improve individual products (e.g., improving EOP series independent of the reference frame).

IERS Analysis Campaign to Align EOPs to ITRF2000 / ICRF

The intention of this EOP Alignment Campaign is to achieve an overall accuracy of 0.1 mas for Earth Orientation Parameters and to create EOP series with highest possible consistency with ICRF and ITRF2000. Therefore, this EOP Alignment Campaign deals with the analysis and understanding of the origin of systematic errors resulting from the reference frame or its realisation.

At the end of September 2001 the IERS Alignment Campaign was started by the IERS AC with an initial Call for Participation (CfP). The Campaign has been subdivided into two parts. In a first step the Analysis Centres of the various space geodetic techniques were asked to produce EOP series with the reference frame fixed to the ITRF2000 / ICRF coordinates and velocities. In addition, they were asked to produce solutions with different levels of constraining to ITRF2000 (ICRF). The second step consisted of the analysis of the submitted EOP series by comparing individual series with the official IERS solutions (C04, Bulletin A) and by studying the consistency between the series. The final results should be a set of recommendations on how the ITRF2000 reference frame should be realised in the routine solutions generating EOP series.

Until May 2002, 21 proposals were received (see also the Web pages <http://alpha.fesg.tu-muenchen.de/iers/eop/campaign.html>). 12 of them contributed to the first step and produced more than 40 different EOP series from all four techniques (VLBI, SLR, GPS, DORIS) with various constraints (fixed site coordinates, significant or minimum constraints on the site coordinates) to realise the ITRF2000 reference frame. The series are publicly available at the ftp archive <ftp://alpha.fesg.tu-muenchen.de/iers/eop/>. In addition to the EOP series themselves, a detailed description file about the constraints, the reference frame, the reference sites and the combination approach used is available for each individual series. A first overview was given by Robert Dill at the EGS General Assembly 2002 in Nice.

As a second step of the campaign, 12 groups are now analysing the submitted EOP series.

These groups have to deal with many special problems coming from the pooling of EOP series from different techniques. In order to be able to compare the series, these need to be reformatted and resampled into one common format. Problems occur with data gaps, different interpolation schemes and different or wrong signs. In a first comparison of the EOP series against each other, the three EOP parameters x-pole, y-pole, and UT1-UTC were studied by a simultaneous estimation of an offset, a drift and a scale factor. Additionally, possible time lags (shifts in time) were detected. In polar motion (x-pole, y-pole) most series show offsets that agree within about ± 0.5 mas and almost no drifts, except IGN 01 (Doris) and ASI 01 (about 1.5 mas/a). Drifts result mainly between the long VLBI series (IAA, GAUS, GSFC), where the ITRF2000 velocities are used over long time intervals. The VLBI series show a good agreement in UT1-UTC. The comparison of UT1-UTC estimates from satellite techniques (GPS, SLR, DORIS) with those from VLBI is known to be a problem because of systematic effects coming from the orbit modelling. Until now there is no significant indication that fixed constraints are better than loose or minimum constraints. Only the ASI 01 series differs very much from the other series, probably due to the extremely loose constraints used. The poster from the EGS 2002 in Nice and the total set of most recent results are available on the Web pages <http://alpha.fesg.tu-muenchen.de/iers/eop/results.html>. More results were presented at the IERS Combination Workshop 2002 in Munich by

- Dill, R.: Comparison of EOP series from the IERS analysis campaign to align EOPs to the ITRF2000/ICRF.
- Carlucci, T., Gambis, D., Bizouard, C., Francou, G.: Comparative Study of EOP Series Derived for the IERS Alignment Campaign.

- Messerer, E., Boehm, J., Schuh, H.: Comparison and combination of the EOP submitted to the IERS Alignment Campaign 2002.

The IERS Combination Workshop in Munich adopted the following recommendations concerning the EOP Alignment Campaign:

- Solve problems that occur from reformatting, resampling and interpolation
- Create a new database with comparable EOP series until the end of the year 2002
- Analysis of offsets and drifts in x-pole, y-pole; find relations to the type of ITRF realisation
- Develop strategies to combine / compare UT1 and LOD of satellite techniques and VLBI
- Call to the analysis groups, to finish their studies until February 2003
- Conclusion and presentation of final results until EGS General Assembly, April 2003

After removing all obvious error sources like interpolation and sample errors further investigations by the FESG group in Munich are concentrating on the smaller differences between subsets of the submitted EOP series, like, e.g., the 13 GPS series from IGS. Now the influences of the choice of stations realizing the ITRF2000 reference frame or the constraints used can be seen. The analysis of the remaining residuals shows systematic errors like biases and/or periodic signals. The interpretation of these results will be finished in the beginning of 2003. The presentation of final results is expected at the EGS 2003 in Nice.

IERS SINEX Combination Campaign

After some preparations the IERS SINEX Combination Campaign was started with a Call for Participation (CfP) in May 2002 and eleven groups sent back a proposal. The campaign has been divided into two parts:

- as a first step, solution series of the space geodetic techniques were to be produced by several analysis centres for the whole year of 1999, including at least station coordinates and EOPs as parameter types in the SINEX files;
- as a second step, these solution series in SINEX format were then to be combined by several groups with the goal to develop appropriate combination software and to assess systematic biases between the individual space geodetic techniques.

The first step could be finished by the end of the year 2002 and all solution series were added to the SINEX data pool, which was already prepared in 2001. The combination step is still ongoing and first results, presented at the IERS Workshop in November 2002 in Munich, look very promising. Further results are expected for the EGS General Assembly 2003 in Nice in April 2003.

All necessary information concerning the campaign can be found on the Web site of the IERS Analysis Coordination, which is updated whenever new information becomes available:

<http://alpha.fesg.tu-muenchen.de/iers/sinex/sinex_campaign.html>.

Concerning the SINEX files, you can retrieve all solutions for the combination tests from the Web page on the SINEX data pool:

<http://alpha.fesg.tu-muenchen.de/iers/sinex/datapool.html>.

SINEX files containing local tie information are also available in the data pool.

As one result of the IERS Workshop 2002 in Munich, all analysis centres that were contributing solution series were asked to fill in a form about the modelling and parameterisation characteristics of their solutions. These forms will be archived together with the solution series in the SINEX data pool, but this step has not yet been completed.

SINEX Format Version 2.00

The new version of the SINEX format description, called SINEX 2.00, could be finished after intensive discussions with the groups that are doing the analysis of the space geodetic techniques. Since May 2002, the final description is available on the Web site of the IERS Analysis Coordination (including an example and a set of formulas):

<http://alpha.fesg.tu-muenchen.de/iers/sinex/sinex_v2.pdf>.

Acknowledgement: The IERS AC work is partly funded by the Geotechnologien-Projekt of the German BMBF (Bundesministerium für Bildung und Forschung) .

Markus Rothacher, Robert Dill, Daniela Thaller

3.4 Technique Centres

3.4.1 International GPS Service (IGS)

General

Since 1994, the International GPS Service is committed to provide the highest quality data and products as the standard for global navigation satellite systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. Based on GPS+GLONASS observation data, the IGS offers a large number of consistent products which constitute the practical realization of the International Reference System and allow for an easy access to the most recent ITRF (ITRF2000 since end of December 2001-GPSWeek 1143).

Table 1 gives an brief overview of the estimated quality of these data sets at the end of the year 2002.

Table 1: Quality of the IGS Reference Frame products as of December 2002 (for details see <http://igscb.jpl.nasa.gov/components/prods.html>)

Products / Delay	Ultra-Rapid/ Real Time	Rapid/ 17 hours	Final/ 13 days	Units
Orbit (GPS)	15.0	5.0	3.0	cm
SatelliteClocks	5.0 (predicted)	0.1	0.05	ns
Station Clocks		0.1	0.05	ns
Polar Motion		0.1	0.05	mas
LOD		30.0	20.0	µ s/d
Stations h/v			3.0/6.0	mm
Troposphere			4.0	mm ZPD

To ensure enhanced reliability all products are outcome of a combination of the individual IGS Analysis Center (AC) solutions.

Tracking Network

In support of the GLONASS stations and to improve the geophysical information available in the site logs, the IGS switched to a new GNSS site log format in June 2002. At the same time, combined GPS/GLONASS stations have become an integral part of the IGS network.

IGS Working Groups/Pilot Projects

Within IGS a number of Working Groups focus on selected topics related to the IGS components. Furthermore Pilot Projects have been launched to develop new products and services. A few of them are briefly presented below. For a complete list and descriptions see <http://igscb.jpl.nasa.gov/projects/projindex.html>.

Time Transfer Pilot Project

The Time Transfer Pilot Project has further refined its internally realized IGS time scale (IGST; loosely steered to GPS-time). At the end of 2002, the WG was terminated and a new "Clock Product

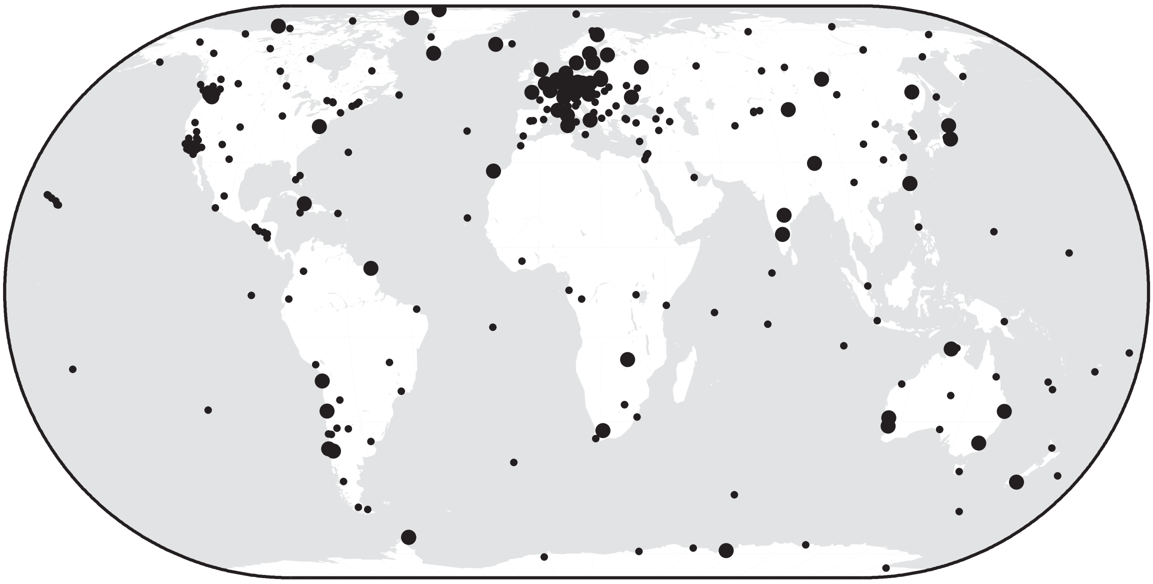

Figure 1: The IGS tracking network as of January 2003

Centre" was set up. This is in recognition of the IGST and IGRT (Rapid) time products as one of the IGS core products next to the orbits.

Galileo/GNSS Working Group

In response to the emerging GALILEO system and the upcoming GPS modernization a Galileo/GNSS Working Group was set up at the end of 2002. The Terms of Reference highlight the objectives of this WG which are, among others, to explore potential contributions of the IGS to reference frame establishment and maintenance for Galileo and to prepare a consolidated feedback for Galileo developments based on relevant IGS experience.

Real-time Working Group

The Real-Time working group has been steadily developing data format, routing, compression, and 1Hz data collection software in support of the growing real-time applications.

LEO Working Group

The LEO working group focuses on demonstrating the impact of processing LEO data on IGS-like products of individual analysis centres as well as on IGS combination products. Currently 4 IGS and 3 special LEO centres process data from the CHAMP and JASON missions under the umbrella of this WG. It is planned to issue the first combined LEO orbits for research purposes mid of 2003. The inclusion of GRACE and ICESAT data, as soon as released, will certainly enhance the overall quality of the analysis centre products. The WG maintains a website at <http://nng.esoc.esa.de/gps/igsleo.html>.

TIGA Working Group

The TIGA network, consisting of IGS receivers collocated with tide gauges is steadily growing and comprises now 26 observing stations. Addressing the height component in routine computation and establishing and maintaining new geodetic ties to tide gauge systems will be further an important contribution to climate change studies. Several analysis centres process the data and the preparations for a combined solution is under way.
(<http://op.gfz-potsdam.de/tiga/>)

Data Center Working Group

A new Data Center working group has been set up in 2002. Among the topics to be addressed by this group are an effective data flow redundancy/backup plan, reliability, security and consistency issues at data centres, and the timely archive and dissemination of data as the IGS moves into a real-time mode for selected products.
(<http://cddisa.gsfc.nasa.gov/igsdc/>)

Data and Analysis Center Workshop, April 8-11, Ottawa

This IGS workshop was organized around the central theme “Towards Real Time”. A variety of applications including weather prediction, ionospheric weather monitoring, satellite and terrestrial navigation, earthquake and volcano monitoring, positioning of structures, surveying, timing and earth orientation would benefit from the availability of Real-Time (RT) GPS raw data products and from RT or Near Real-Time (NRT) products computed from them. In view of this trend workshop participants decided to go ahead with the development of:

- the infrastructure needed to transfer in real time raw GPS data
- the software needed to generate, quality check and disseminate in RT and NRT orbit and clock information and further products like Global Ionospheric Maps (GIM) or Total Zenith Delay estimates

Strategies to implement the upcoming GPS modernization were also discussed at this workshop as the combination of regional network solutions with the IGS global network solutions and the application of absolute antenna phase centre values.

Concerning the IGS products the participants agreed on the following recommendations:

- Time Scale
  Adopt a new time scale for IGS Final and Rapid Products to achieve continuity at day boundaries and allow for a direct link to UTC.
- SP3 Format
  Review and adopt a new version of the SP3 format. To serve the user community keep both the old and the new

format in parallel for a period of at least 1 year. *As recommended the new format, labelled SP3c, has been established in December 2002. The format offers a significant enhanced flexibility e.g. in characterizing the variable accuracy of the given data points within the IGU orbits.*

- GLONASS data processing
  Intensify the ability to process data from combined GPS/GLONASS tracking sites. ACs and AACs are encouraged to provide orbit and clock submissions in order to ensure a reliable combined IGS/GLONASS orbit and clock product.

- IGS Ultra Rapid products
  In view of upcoming NRT- needs explore and implement a more frequent update of the IGU Ultra Rapid Products. An update cycle of 3 hours (currently 12 hours) for IGU products is envisaged. Investigate the option of different update cycles for orbits (6 hours) and clocks (3 hours). In addition, explore the possibility of decreasing the latency of IGU products from currently 3 hours to 2.5 hours as well as the submission of 5-minutes RINEX clock files.

Summary

In 2002, as in previous years, the IGS contributed significantly to a number of core activities of the IERS like the maintenance and extension of the International Terrestrial Reference Frame or in establishing highly accurate Earth Rotation Parameter series. For a more detailed information on further activities of the IGS, please refer to IGS Annual and Technical Reports as well as to the IGS Strategic Plan issued by the Central Bureau at JPL.

Robert Weber and Carine Bruyninx

3.4.2 International Laser Ranging Service (ILRS)

Introduction

The International Laser Ranging Service (ILRS), established in 1998, is responsible for the coordination of SLR/LLR missions, technique development, operations, analysis and scientific interpretation. Within the organizational structure of the IERS, the ILRS is one of several Technique Centres, having accompanying responsibilities for the generation and quality assurance of Earth Orientation and related products that are generated within the laser technique. A clear example is the contribution to the implementation of the terrestrial reference system (i.e. the ITRF), where the laser technique provides unique information on the exact location of the earth's geocentre and (shared with VLBI) absolute scale. Another area, where SLR plays an important role, is gravity field development. Although the solutions rely heavily on radiometric observations, the SLR measurements by virtue of their absolute, unbiased character provide a unique tool to validate the orbital and gravity field solutions and independently assess their quality. As an illustration, Figure 1 shows the SLR support of the GRACE satellites, launched in March 2002, clearly indicating that the ILRS community has been able to pick up these dedicated and critical satellites in their operational configuration shortly after launch and with an impressive and consistent monthly data yield.

Activities in 2002

Although the ILRS activities cover a broad spectrum, this overview concentrates on analysis activities, for obvious reasons. The ILRS Analysis Working Group (AWG) is the entity which is responsible for the coordination of these activities, including the development of quality control procedures as well as official ILRS analysis products. Two AWG workshops were held in 2002, notably in Nice/France (April) and in Lanham/USA (October). Here, analysts and program managers meet to discuss analysis and data product issues, initiate projects and/or campaigns and evaluate their results.

With the development of (an) official ILRS product(s) and the quality control (QC) issue (of observations and products) in mind, the AWG has initiated a number of pilot projects. They are clearly developing with time. One pilot project concerns the harmonization of semi real-time QC results, the quality assessment of the SLR observations in particular. In 2001 it was recognized that the model for station coordinates plays a major role in the diversity of quality "verdicts" that are generated and distributed to the stations each week. To better unify this, the AWG has strongly recommended to use the ITRF2000 solution as a common element in the weekly (or more frequent) analyses. At the time of writing, almost all of the relevant analysis centres have switched to this model. Although no a posteriori evaluation has been made yet, it is expected that this

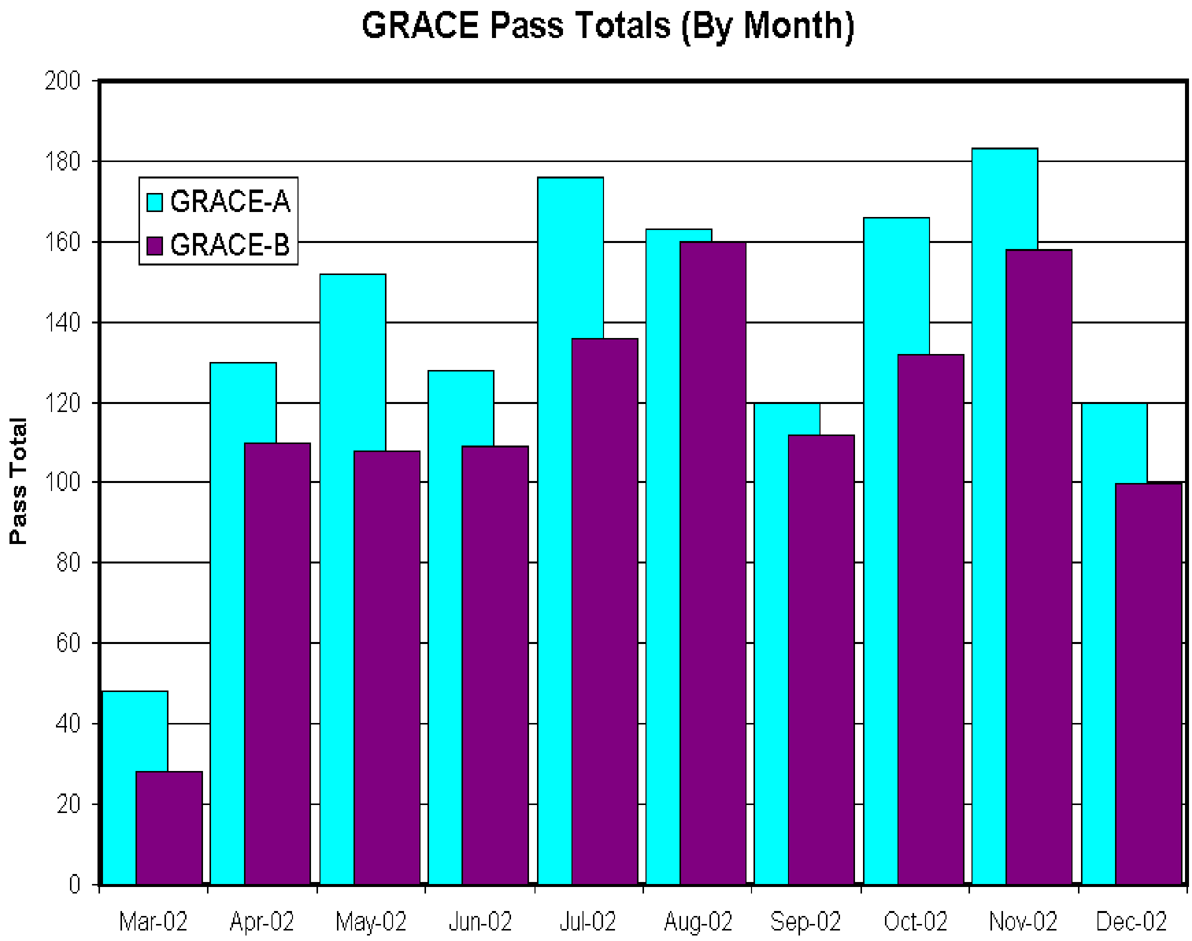

Figure 1: Overview of the monthly number of SLR passes on the GRACE satellites (courtesy Van Husson).

will also have consequences for the semi real-time EOP solutions which are generated and submitted to IERS.

The second project is aimed at quality control of the software that is used within the SLR/LLR community. Its purpose is to benchmark the various computer programs and to detect blunders and other possible problems. It focuses on satellite orbits and specific parameter solutions, which may evolve into (the development of) an official ILRS product for satellite orbits. This project has seen first results in 2002, and is in the process of setting acceptance/rejection criteria as a contribution to a third project.

This third project focuses on two traditional products, i.e. station coordinates and EOPs. The purpose here is to develop an official ILRS solution, currently for EOPs and station coordinates (the former to be included in the IERS Bulletin A). In the future, the analysis system may evolve further to provide official “full rate” EOPs, station coordinates and other parameter solutions.

At the moment, an official Call for Participation has been released and about 10 reactions have been received, either for the role as an official analysis centre (responsible for the direct computation of solutions for EOPs and station coordinates, following specific guidelines) or for the role of official combination centre (individual solutions coming from various analysis groups have to be combined into one singe official ILRS product). An overview of the reactions is given in Table 1. It must be emphasized, however, that its content just reflects the response to the Call for Participation, and no selection and/or screening has been applied yet.

Table 1: Overview of the various reactions to the ILRS Call for Participation for contributions to the official ILRS operational product on EOPs and other parameters.

institute	analysis contribution	combination contribution
ASI	+	+
DGFI	+	+
Geosciences Australia	+	
NASA/JCET	+	+
NCL		+
NERC	+	

Related to this and to the interests of the IERS, it has been decided to consider solutions for the x-pole and y-pole coordinates and excess Length of Day (LOD) as the prime products of the ILRS analysis activities concerning EOPs. This deviates from the historic situation, where solutions for UT1-UTC were submitted as representative parameters. However, it must be realized that the UT time difference is directly correlated with the right ascension of the ascending node of the satellites(s), so by definition it cannot be observed by any of the satellite techniques. To improve the quality of the EOP results, the ILRS is pursuing a dedicated tracking campaign of the Etalon satellites (which are analysed in addition to the (standard) LAGEOS spacecraft). Analyses have convincingly shown that the quality of the EOP solutions improves dramatically if even a small amount of Etalon data is included in the data reduction process. In principle, the Etalon campaign is open-ended.

The analysis activities within the ILRS, related to the IERS, are not restricted to just these pilot projects. The ILRS community is providing input to other projects, like the SINEX Campaign, the EOP Alignment Project and the future (IAG) IGGOS Project. Results on these projects can be found elsewhere.

Outlook

The AWG pilot projects, that can be considered as the focal point of the ILRS analysis activities, will proceed with the momentum that they have shown so far. The harmonization project is expected to show significant convergence from 2002 onwards. The benchmarking/orbits project has embarked upon a strict and ambitious scheme. A first round of results revealed a number of shortcomings, and the current activities will undoubtedly yield a better consistency of the results. The project on station positions and Earth orientation is entering the phase of official product combination. By the time of writing, analysis groups and combination centres are gearing up to serve the IERS community with a consistent and high-quality product on EOPs as a beginning. The ILRS AWG expects this official product to be available in mid-2003.

Ron Noomen and Peter J. Shelus

3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

As of 2002, IVS changed from the institution-driven observing programs and related products to its own programs and products which are expected from the IVS as an IAG and IAU service. As a direct result of the IVS Working Group 2 document, which in 2001 reviewed the products and proposed related observing programs, IVS started in January 2002 its own observing program (see Network Station section of this report for details).

In February 2002 IVS held its second General Meeting in Tsukuba, Japan, generously hosted by the Communications Research Laboratory and the Geographical Survey Institute. Proceedings of the meeting were published in April 2002. The third IVS Analysis Workshop was also held in Tsukuba, with major topics being the SINEX extension for VLBI and the Platform Independent VLBI Exchange Format (PIVEX). Two IVS Directing Board meetings were held, one in February in Tsukuba, and the other in October at Haystack Observatory, USA. The first e-VLBI Workshop was held at Haystack Observatory, bringing together geodetic/astrometric and astronomical users and experts in wideband networks. IVS published its 2001 Annual Report in March 2002 and published three newsletter issues which keep the community informed about IVS activities.

Network Stations

A total of 1130 station days were used in 183 geodetic sessions during the year. Observing sessions coordinated by IVS increased from an average of 3.0 to 3.5 days per week, compared to 2001. The number of station days increased by 25%. The major observing programs during 2002 were:

IVS-R1, IVS-R4

Weekly (Mondays and Thursdays) 24-hour, rapid turnaround measurements of EOP. Data bases are available within 15 days after each session. These sessions, coordinated by NASA Goddard Space Flight Center (R1) and the U. S. Naval Observatory (R4), are the descendents of the former CORE and NEOS sessions.

Intensive

Daily 1-hour UT1 Intensive measurements were made on four days of the week on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA). A test intensive series using the Japanese K4 technology with weekly 1.5-hour sessions was observed during the second half of the year.

IVS-T2

Monthly sessions coordinated by the Geodetic Institute of the University of Bonn, observed monthly to monitor the TRF.

IVS-E3

Monthly sessions using the Canadian S2 technology, coordinated by Natural Resources, Canada, designed to measure EOP and monitor TRF. The Canadian mobile antenna occupied locations at St. John’s (Newfoundland) and Shirley’s Bay (near Ottawa).

VLBA The Very Long Baseline Array (VLBA), operated by the National Radio Astronomy Observatory (NRAO), continued to allocate six observing days for astrometry/geodesy. These sessions included the 10 VLBA stations plus up to 10 geodetic stations, providing state-of-the-art astrometry as well as information for mapping ICRF sources. An additional five sessions were scheduled for maintenance of the ICRF in the southern hemisphere.

Europe The European geodetic network, coordinated by the Geodetic Institute of the University of Bonn, continued with four sessions in 2002.

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions.

JADE The JApanese Dynamic Earth observation by VLBI (JADE) had seven sessions. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

Syowa The National Institute for Polar Research (NIPR) continued its sessions that included the Syowa station in Antarctica. The data were recorded with K4 and S2 and processed at the Mitaka (Japan) correlator.

CONT02 A 15-day continuous campaign observed in October, 2002 with eight stations, designed to demonstrate the state-of-the-art in geodetic VLBI.

IVS-R&D Seven sessions were observed with ultra-high SNR targets with the goal of enabling investigations of instrumental effects which dominate VLBI error sources.

The Network Coordinator’s data base of station performance showed data loss of about 12%. The most significant problem in 2002 continued to be RFI (radio frequency interference), which occurs mostly at S-band and is becoming more severe and widespread as expected.

Correlators

The Mark IV correlators at Haystack Observatory (USA), the U.S. Naval Observatory (USA), and at Max Planck Institute for Radioastronomy (Germany) continued operation. Two significant software bugs were fixed during 2002 resulting in less re-processing and improved processing factors.

Data Centers

The IVS Data Centers continued to receive data bases throughout the year and make them available for analysis within one day of correlation. The Data Centers also continued to receive solutions from Analysis Centers. All data and results holdings are mirrored several times per day among the three primary IVS Data Centers.

Analysis Coordinator

Routine analysis and combination of the EOP series submitted by the six IVS Analysis Centers has continued. Due to a change in the general IVS observing program two sessions per week are now being observed and processed in a rapid turnaround mode. As a consequence the IVS Analysis Centers are now able to produce EOP twice per week for the IVS combined EOP product. The EOP of both days are included in the IVS Rapid EOP Series (e.g. ivs02r1e.eops).

As of summer 2002 the IVS Analysis Coordinator's office has started to regularly compute a combined EOP series containing all VLBI network sessions suitable for the determination of EOP from 1979 onwards. This combined series is updated quarterly with all sessions processed by the IVS Analysis Centers at that time (ivs02q1e.eops). Currently combined EOP are still listed by session even though there may be more than one on a single day.

Technology Development Centers

The major effort in 2002 was deployment and testing of Mark 5P disk-based recording systems as a direct replacement for the Mark IV/VLBA tape recorders. The new recorders enable e-VLBI, in which data is transmitted electronically from the stations to the correlator. Full deployment of the Mark 5 systems is planned by mid-2004. Demonstration e-VLBI experiments were conducted on single baselines between stations in the USA, Japan, and Finland. The VSI-S (software) specification was completed; the document will be published in the 2002 IVS Annual Report. Separate experiments were conducted in the US and in Japan demonstrating 1 Gb/s and 2 Gb/s data rates. These high data rates are expected to be employed regularly by 2004.

Nancy Vandenberg, Axel Nothnagel, Chopo Ma

3.4.4 International DORIS Service (IDS)

The activity related to DORIS is conducted as a worldwide cooperation within a Pilot Project of the International Association of Geodesy. After a pre-operational phase, it should become a full IAG Service (tentatively in Sapporro in 2003).

The DORIS Pilot project includes a Steering Committee, a Central Bureau, Data Centers and Analysis Centers.

The Steering Committee is composed of the following individuals: M. Feissel-Vernier (France, Analysis Coordinator), F. Lemoine (USA, stations selection group), C. Noll (USA, Data flow coordinator), J. Ries (USA), L. Soudarin (France, Central Bureau), G. Tavernier (France, chairman) and P. Willis (France, representative to IERS). With the help of the Central Bureau (CNES/CLS/IGN) it defines the orientation of the Pilot Experiment.

In particular, there is a dedicated DORIS Web site at <http://ids.cls.fr> for the Pilot Experiment and another one at <http://lareg.ensg.ign.fr/IDS/> for the Analysis coordination aspects as well as a DORISMail facility at <http://list.ensg.ign.fr/wws/arc/dorismail> to allow easy information between all groups (59 messages in 2002).

In 2002, only one Data Center was operational at NASA/CDDIS (anonymous ftp access at cddisa.gsfc.nasa.gov). It contains DORIS data from all DORIS satellites, DORIS products (see below) and general DORIS information (satellite models description, attitude files, information on satellites maneuvers or data gaps). However, another Data Center (IGN) was under rejuvenation in 2002 and effectively started in 2003.

Several DORIS Analysis groups have participated to the DORIS Pilot project. The table below summarizes their contributions :

Table 1: DORIS Pilot Experiment Analysis Centers (O = Operational, P = Planned)

Analysis Center	Country	Global Sinex	Time series Sinex	Geocenter	EOP	ionosphere
CNES	France		P		O	
CNES/SSALTO	France		O			
IGN/JPL	France/USA	O	O	O	O	
LEGOS/CLS	France	O	O	O		
INASAN	Russia	O	O	O	O	
UT/CSR	USA	O				
AUSLIG	Australia	P	P	P	P	
ESA/ESOC	Germany				P	
G.O. Pecny	Czech Rep.	P	P	P		
IAA	Russia	P	P	P		
ROB	Belgium					P
U. Newcastle	UK	P	P	P	P	

To review the results obtained by the different groups, an IDS Workshop has took place in Biarritz on June 13-14. Attendance (90 people in total), agenda and presentations in PDF format can still be found at <http://ids.cls.fr/html/report/ids_workshop_2002/programme.html>.

In 2002, data from 3 more DORIS satellites became available (JASON, SPOT5 and ENVISAT). Consequently the current DORIS constellation increased drastically from 3 to 6 satellites in 2002. Furthermore, the new satellites carry improved DORIS receivers (increased accuracy and multi-channel capability allowing tracking of 2 tracking beacons simultaneously). They also carry new DIODE software to allow improved on-board real-time orbit computation (<20 cm radially). Results from all analysis groups have been improved and were recently presented at an IDS Analysis Workshop, held in Paris on February 20 and 21, 2003 (agenda, attendance and presentation in PDR format can be found at <http://lareg.ensg.ign.fr/IDS/events/wkshp_2003.html>).

In 2002, an important effort has been made in the DORIS community for inter-comparison of results. Within the scope of an international analysis campaign, DORIS analysis groups were asked to submit times series of coordinates and EOP and several groups submitted results (some for the campaign time period like INASAN, others already for all available DORIS data from 1993 to 2002 like IGN/JPL and LEGOS/CLS). Other groups were in charge of the inter-comparison and the merging of solutions provided in SINEX format (CLS, DGFI and IGN). Additional information can be found on the organization of this campaign as well as on the results obtained at <http://lareg.ensg.ign.fr/IDS/events/camp_2002.html>. A complete workshop was organized in early 2003 to discuss the results. This Analysis Campaign can be considered as a pre-operational DORIS Service.

In 2002, the DORIS network has been very stable (around 50 stations). However, the task initiated in 2000 by the IGN/SIMB continued in order to improve the stability of the antennas (better support structures) and the quality of the local ties with other techniques (35 collocations in total). Information on any individual DORIS station is regularly updated and can be found on the Web at <http://www.ign.fr/fr/PI/activites/geodesie/DORIS/stations-en.html>.

With the launch of the new DORIS instruments on the recent satellites (dual-channel), the limitation of beacons in the same area is much looser. CNES has proposed to install new DORIS beacons for densification, and an international group has been created to select between the different proposals received (12 in total). In February 2002, a specific DORIS campaign has been conducted in Antartica on the Sorsdall glacier, following the observations made in December 2001. This continued also in early 2003 by observations on the Lambert glacier.

Pascal Willis

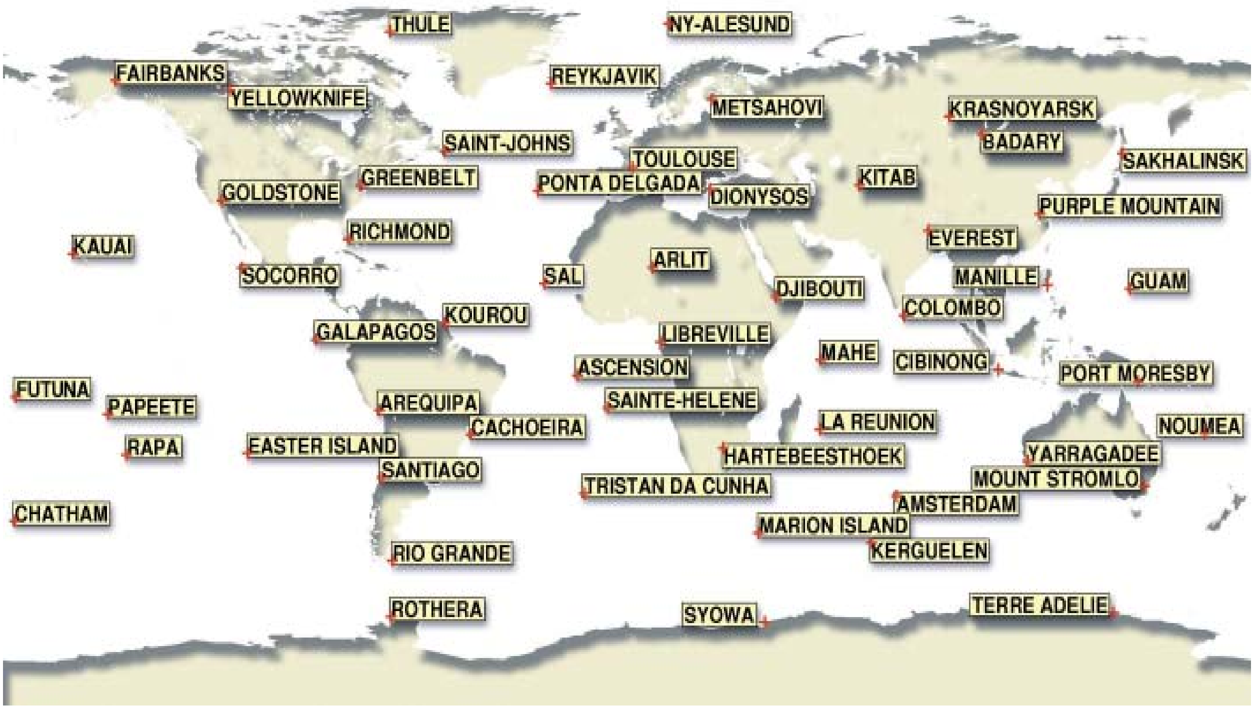

Figure 1 : Current DORIS network in 2002

3.5 Product Centres
3.5.1 Earth Orientation Centre

This section presents activities and main results concerning the Earth Orientation Centre located in Paris Observatory over 2002. General presentation of the IERS Earth Orientation Parameters (EOP), operational activities and yearly analyses are presented at the web site (<http://hpiers.obspm.fr/eop-pc>). According to the IERS Terms of Reference, the Earth Orientation Centre is responsible for monitoring Earth orientation parameters including long term consistency, publications for time dissemination and leap second announcements. It is making available to users different products: long-term and operational series of Polar motion, Universal Time (UT1), Length of Day (LOD) and Celestial pole offsets.

Determination of EOP is in the form of combined solutions derived by the analysis centres of the different techniques. Various solutions are computed: long-term solution (IERS C01), normal values at five and one-day intervals (IERS C02 and C03) and the operational smoothed solution Bulletin B at one-day intervals published monthly and providing EOP with a delay of 30 days with respect to the date of publication. Bulletin B is updated in an operational mode in the IERS C04 which is computed twice weekly.

Combined daily series: Bulletin B and EOP(IERS) C 04

Description of Bulletin B is available in the IERS Explanatory Supplement for Bulletin A and Bulletin B (Gambis and Ray, 2002). Since formal uncertainties reported by the contributors are often underestimated, they are calibrated by statistical assessment using the Allan variance analysis in order to reflect the real quality of the data (Gray and Allan, 1974; Gambis, 2002). This procedure leads to an optimal weighting of the individual series entering the combinations. Table 1 gives the estimated accuracy with respect to IERS C04 of these series over 2002-2003 after removal of systematic variations, mainly a bias.

Predictions

Different methods are used for prediction of the Earth rotation parameters.

Polar Motion

The formalism uses at first a floating period fit (Bevington, 1969) for both the Chandler and annual components estimation over a past time interval of several years. An autoregressive filter is then applied on the short-term residuals series and used for the prediction. The predictions of the celestial pole offsets $\Delta\psi$ and $\Delta\varepsilon$ are based on an empirical model (McCarthy, 1996).

Universal Time

The present formalism used is based on the assumption that the long-term fluctuations (annual and semi-annual) of the preceding

Table 1: Estimated accuracies of individual solutions entering the combined solutions in 2002-2003.

Individual solutions		Time	Estimated uncertainties Terrestrial Pole 0.001"	UT1 0.0001s	LOD 0.0001s	Celestial Pole 0.001"
VLBI - 24 h						
EOP (GAUS)	01 R 01	7d	0.28	0.12		0.09
EOP (BKG)	01 R 03	7d	0.25	0.12		0.09
EOP (GSFC)	02 R 04	7d	0.13	0.09		0.08
EOP (IAA)	02 R 01	7d	0.19	0.09		0.07
EOP (SPBU)	01 R 02	7d	0.70	0.15		0.12
VLBI - Intensive						
EOP (BKG)	01 R 02	1-3 d		0.14		
EOP (GSFC)	02 R 03	1-3 d		0.13		
EOP (IAA)	02 R 02	1-3 d		0.12		
EOP (SPBU)	02 R 01	1-3 d		0.10		
Satellite Laser Trackin						
EOP (CGS)	97 L 02	3d	0.54	1.40 *		
EOP (CSR)	95 L 01	3d	0.40	0.90 *		
EOP (DUT)	98 L 01	3d	0.60	0.09 *		
EOP (IAA)	98 L 02	1d	0.20	0.19 *	0.03	
EOP (MCC)	97 L 01	3d	0.17		0.47	
GPS						
EOP (CODE)	98 P 01	1d	0.07		0.25	
EOP (EMR)	96 P 03	1d	0.08		0.29	
EOP (ESOC)	96 P 01	1d	0.11		0.62	
EOP (GFZ)	96 P 02	1d	0.09		0.29	
EOP (JPL)	96 P 03	1d	0.07		0.46	
EOP (NOAA)	96 P 01	1d	0.20		0.65	
EOP (SIO)	96 P 01	1d	0.08		0.32	

** The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates*

Table 2: Uncertainty of the current solution and the estimated accuracies of the predictions for horizons of 5 days to 1 year for 2002.

Solutions		Terrestrial Pole 0.001"	UT1 0.0001s	Celestial Pole 0.001"
Analysis	1-d	0.15	0.20	0.10
Prediction				
	5-d	3.	15.	0.10
	10d	6.	21.	0.10
	30d	12.	35.	0.10
	90d	40.	45.	0.10
	180d	60.	75.	0.10
	1-yr	50.	120.	0.10

year are valid over the next few months. For short-term variations prediction, an autoregressive process is used. Table 2 shows the accuracy of the current EOP solutions and also the skills of the predictions. New procedures for prediction are under investigation, they are based on Singular Spectrum Analysis SSA and Neuronal networks.

Table 3 gives the agreement and consistencies of the IERS C04 solution with two combined solutions obtained by the IERS Rapid Service/Prediction Centre at USNO (Bulletin A) and the JPL. These values reflect the mean precision reached i.e. about 0.05 mas for polar motion and 10 microseconds for UT1. The overall accuracy taking into account the consistency between the terrestrial and celestial frames is in the range of 0.1 mas and 20 microseconds, respectively for Polar motion and UT1.

Table 3: Mean and standard deviation of the differences between various IERS solutions for 2002.

EOP	Unit	Comb JPL - IERS C04		BullA - IERS C04	
		Mean	Standard deviation	Mean	Standard deviation
X	mas	-0.19	0.07	-0.03	0.05
Y	mas	0.03	0.04	0.05	0.05
UT1	0.1 ms	-0.07	0.16	-0.05	0.20

Long-term series: C 01 (1846-2002)

EOP(IERS) C 01 is a series of the Earth Orientation Parameters given at 0.1 year interval from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole offsets; UT1-UTC since 1962). For many decades, the observations were made using mostly visual and photographic zenith telescopes. Since the advent of the space era in the 1960s, new geodetic techniques were used for geodynamics. Now, the global observing activity involves Very Long Baseline Radio Interferometry (VLBI), Lunar (LLR) and Satellite Laser Ranging (SLR), Global Positioning System (GPS) and more recently DORIS.

The C 01 series was recomputed in the course of 2002. It is a composite series based on following temporal solutions:

1846-1899: Fedorov *et al*. (1972) polar motion solution derived from three series of absolute declination programs (Pulkovo, Greenwich, Washington).

1900-1961: Vondrak *et al.* (1995) solution derived from optical astrometry analyses based on the Hipparcos reference frame The series gives polar motion, celestial pole offsets and Universal Time (since 1956).

1962-2003: BIH and IERS solutions (BIH and IERS Annual Reports).

Mean Pole with respect to the IERS reference origin

The analyses of the observations of space geodesy require to perform the transformation between both terrestrial and celestial frames via the Earth orientation parameters. Gravity fields models include the tesseral coefficients C21 and S21 coefficients. These terms describe the position of the Earth's figure axis with respect to the Terrestrial Reference Frame. This axis should coincide with the observed position of the rotation pole averaged over the same time period.

The mean polar motion is affected by a long-term drift westward (direction 70.7 deg West, rate: 4.2 mas/yr). The mean rotation axis with respect to the IERS Terrestrial Reference Frame, can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2000 (Shiskin *et al.*, 1965). Figure 1 represents the polar motion over 2001-2002 and the path of the mean pole since 1900. The table is available in Conventions 2000 (McCarthy, 2003) and at the following address: <http://hpiers.obspm.fr/eop-pc/>.

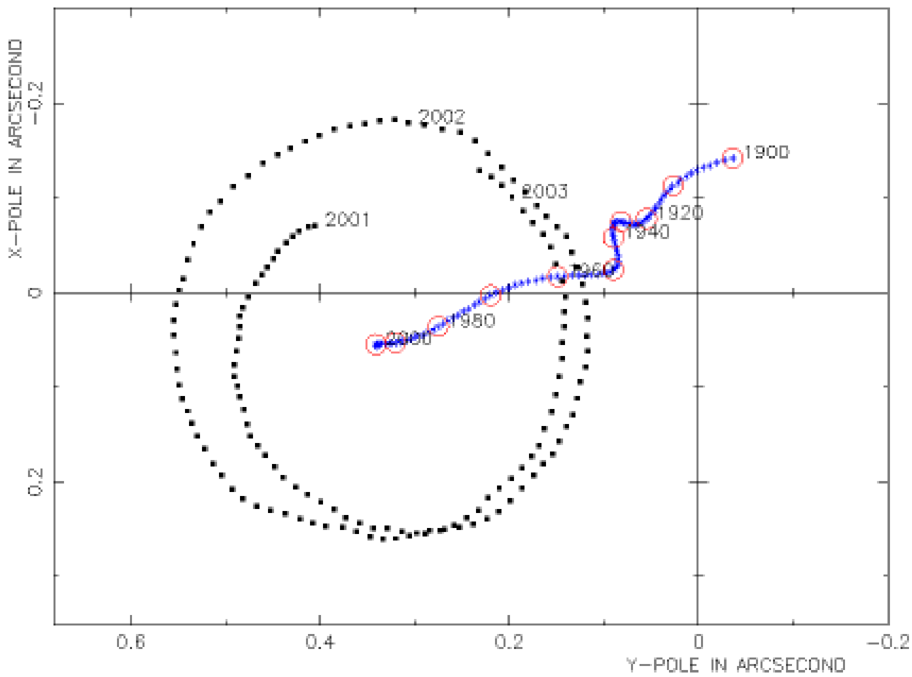

Figure 1 Mean polar motion (1900-2002) and IERS C04 polhody over 2001 - 2003.

Normal Point Solutions: C 02 (1962-2002), C 03 (1993-2002)

Other series, based on normal points solutions given at various time intervals, are also proposed to users, i.e. C 02 (5-day intervals, polar motion, UT1-UTC, dψ, dε), C 03 (one-day intervals, polar motion, UT1-UTC) (Gambis, 1996; Eisop and Gambis, 1997). These series are respectively consistent one to another. They use the full correlation matrix when available. Recently there were new developments in the normal point series C 02 and C 03 in which the estimation of the solution given at the central dates of the n-day interval is made using a least-square fit for all EOP components. Although the L2 estimation has been extensively used for data analysis, it has some drawbacks linked to problems of ill-conditioning and in the non-detection of outliers. Alternative methods based on robust estimators like M-Huber can be used. These estimators are a generalization of both the L1 and L2 class. They have been implemented in our analyses and are now currently used (Bougeard *et al.*, 2000). Table 4 reflects the evolution of the mean uncertainties of C02 solution since 1962.

Table 4: EOP(IERS) C 02 : Evolution of the mean uncertainty of the normal point solution given at five-day intervals

Years -- Unit	σ(X) -- 0.001"	σ(Y) -- 0.001"	σ(UT1) -- 0.0001s	σ(dψ) -- 0.001"	σ(dε) -- 0.001"
1962-1967	30	30	20	-	-
1968-1971	25	25	17	-	-
1972-1979	11	11	10	-	
1980-1983	2	2	3	2	1
1984-1989	.40	.40	.20	.5	.2
1990-2000	.20	.20	.20	.3	.1
2001-2003	.15	.15	.1	.3	.1

Impact of IAU2000 Resolutions on EOP

Resolutions adopted at the 24th General Assembly of the International Astronomical Union recommend the implementation of new procedures concerning the transformation between the celestial and terrestrial reference systems: adoption of a new precession-nutation model (IAU 2000), of a new celestial pole (the Celestial Intermediate Pole) and of a new transformation between the terrestrial and celestial systems defining UT1 as directly proportional to the Earth Rotation Angle.

The IERS Workshop held in Paris in April 2002 had the objective to discuss the impact of these resolutions on the various IERS Products (Capitaine *et al.*, 2002). The description of all these changes for the IERS is presented in Rothacher (2002). Complete expressions and tables are described in Chapter 5 of the IERS Conventions 2000 (McCarthy, 2003).

To comply with these resolutions, effective on 1 January 2003, Bulletin B and IERS C04 are providing new products in addition to those already published. These products include the celestial pole offsets relatively to the new precession-nutation model IAU2000A and using the new formulation described in the following.

The changes in the EOP

New parameterisation of the Earth orientation

The most important changes are those introduced by IAU Resolutions B1.6 (IAU 2000 Precession-Nutation Model), B1.7 (Definition of Celestial Intermediate Pole) and B1.8 (Definition and Use of Celestial and Terrestrial Ephemeris Origins). Although it is not directly mentioned in the Resolutions, the new precession-nutation model is accompanied by a new formulation for the transformation between the celestial (*CRS*) and terrestrial (*TRS*) reference systems in the form recommended in the IERS Conventions 2000:

$$[CRS] = Q(t) \cdot R_3(-\theta) \cdot W(t) \cdot [TRS],$$

in which $Q(t)$, $R_3(-\theta)$ and $W(t)$ are time-dependent transformation matrices to account for the precession-nutation, proper rotation of the Earth about the axis corresponding to CIP and polar motion, respectively:

$$Q(t) = \begin{pmatrix} 1 - aX^2 & -aXY & X \\ -aXY & 1 - aY^2 & Y \\ -X & -Y & 1 - a(X^2 + Y^2) \end{pmatrix} \cdot R_3(s),$$

$$a = \tfrac{1}{2} + \tfrac{1}{8}(X^2 + Y^2)$$

$$W(t) = R_3(-s') \cdot R_2(x) \cdot R_1(y).$$

The Earth Rotation Angle (ERA) between the CEO and TEO is given as function of UT1 by a simple linear relation:

$$\theta(T_u) = 2\pi\,(0.779\,057\,273\,264\,0 + 1.002\,737\,811\,911\,354\,48\,T_u)$$

where T_u= JD(UT1) - 2 451 545.0 .

Here X, Y, s and x, y, s' describe the position of the Celestial Intermediate Pole (CIP) and the Celestial/Terrestrial Ephemeris Origins (CEO, TEO) in the Geocentric Celestial Reference System (GCRS) and International Terrestrial Reference System (ITRS), respectively (see <http://maia.usno.navy.mil/ch5tables.html>). The novelty are the quantities X, Y, s whose developments into Poisson series, based on the IAU 2000A precession-nutation model, are published by Capitaine *et al*. (2003). Expressions for the classical transformation based on the new IAU 2000 model have been developed to be equivalent in the new transformation (McCarthy, 2003).

Celestial pole offsets

Precession-nutation is referred to CIP that exhibits, by definition, only long-periodic motions with periods of two days and longer in space. The IERS is now publishing the celestial pole offsets δX_{2000}, δY_{2000}, referred to the new model IAU 2000 following the new formalism and the quantity s. Classical nutation angles, the celestial pole offsets in longitude and obliquity $\delta\Delta\psi_{2000}$, $\delta\Delta\varepsilon_{2000}$, respectively, referred to the new model can be easily derived from (δX_{2000}, δY_{2000}) using equations 23 of Chapter 5 of the IERS2000 Conventions or the relative Fortran subroutine dXdY_dpsideps included in the package uai2000.package (see next paragraph for its availability). These values δX, δY are now smaller than 1 mas, reflecting mostly the effect of the Free Core Nutation (FCN) that is not predictable and therefore not incorporated into the new model. The position of the CEO, given by *s*, is insensitive to any small change of the precession-nutation at the level of one mas, so only its model values are to be used (<http://maia.usno.navy.mil/ch5tables.html>). Parallel to these values, the values of 'classical' celestial pole offsets $\delta\Delta\psi_{1980}$, $\delta\Delta\varepsilon_{1980}$, referred to the old IAU 1976 precession and 1980 nutation model, are also being published for a limited period in Bulletin B and in the operational combined series C04.

Polar motion

Polar motion is not affected by adopting the IAU 2000 resolutions. Polar motion contains (relatively small) diurnal and sub-diurnal terms, due to ocean tides and high-frequency nutation terms. These are *not* part of the polar motion values published by the IERS at daily intervals; they are represented by a model (IERS Conventions 2000, Chapters 5 and 8) and should be added after interpolation. The Earth Orientation Centre makes available a Fortran subroutine for such an interpolation (<ftp://hpiers.obspm.fr/eop-pc/models/interp.f>). The position of the TEO, given by *s'*, depends on the actual polar motion but the value of *s'* is so small that a simple linear approximation (Lambert and Bizouard, 2002) is sufficient:

$s' = -47\ \mu as\ (t - 51544.5) / 36525$

where t is expressed in Modified Julian Days (MJD).

Universal Time

UT1-UTC is theoretically not affected by the resolutions. Although UT1 is now directly linked to the Earth rotation angle through the linear relation above, the positioning of CEO (represented by the quantity *s*) and IAU2000 expressions between sidereal time and universal time UT1 are such that continuity in UT1 is ensured at the epoch of change from the old system.

There are short-periodic (diurnal, semi-diurnal) variations in UT1 due to ocean tides that are treated similarly to polar motion (the IERS publishes the daily values from which these terms have been removed, and they are to be added back after the interpolation).

Availability of new products and models

Series of the EOC, in particular BULLETIN B and C04 are being duplicated since January 2003 to give δX and δY in the new formulation in addition to the current issue containing $(\delta psi, \delta eps)_{1980}$.

The new files are available at the following Web/ftp sites:

– Web:
http://hpiers.obspm.fr/eoppc/eop/eopc04/eopc04_IAU2000.02
http://hpiers.obspm.fr/eoppc/eop/eopc04/eopc04_IAU2000.03

– anonymous ftp: hpiers.obspm.fr
files: /eop-pc/eop/eopc04/eopc04_IAU2000.02
/eop-pc/eop/eopc04/eopc04_IAU2000.03

Fortran subroutines

1) Transformation of $(\delta X, \delta Y)_{2000}$ to $(\delta psi, \delta eps)_{1980}$ or $(\delta psi, \delta eps)_{2000}$ and inversely are available in Fortran 77/90 at:

– Web:
http://hpiers.obspm.fr/eop-pc/models/models.html#software
files:
ftp://hpiers.obspm.fr/eop-pc/models/uai2000.package
ftp://hpiers.obspm.fr/eop-pc/models/uai2000.package.readme

– anonymous ftp: hpiers.obspm.fr
files: /eop-pc/models/uai2000.package
/eop-pc/models/uai2000.package.readme

2) Interpolation of Polar Motion at hourly scale
– Web: http://hpiers.obspm.fr/eop-pc/models/models.html#software
files: ftp://hpiers.obspm.fr/eop-pc/models/interp.f
ftp://hpiers.obspm.fr/eop-pc/models/interp.readme

Consistency of IERS EOP series with ITRF and ICRF

Earth Orientation Parameters (EOP) provide the transformation between the International Celestial Reference Frame (ICRF) and International Terrestrial Reference Frame (ITRF) of which the last realization is the ITRF2000 (Altamimi *et al.*, 2002). The IERS reference series, labeled IERS C04 is obtained from the combination of individual EOP series derived from the various astro-geodetic techniques, mostly VLBI, GPS and SLR. These individual EOP series present mutually systematic errors, generally limited to biases and drifts which can be attributed to the adoption of different references frames CRF and TRF in the analyses of observations. It is thus essential that the reference series C04 be not affected by these individual systematic errors to ensure a long-term stability. However, as the C04 is independently maintained, it is expected that small inconsistencies could appear after some time. This fact already lead in the past to a small re adjustment of polar motion (biases and drifts) in 1997. In order to assess whether a correction should again be applied to C04, various consistency studies were carried on, using the IVS pilot project 2001 (Bizouard and Gambis, 2002, Gambis *et al.*, 2002) and the IERS alignment campaign in 2000 (Gambis and Bizouard, 2003).

IERS alignment campaign

The idea of the campaign (Rothacher, 2002) is to create EOP series with highest possible consistency with ITRF2000 / ICRF and investigate the ultimate achievement of the overall accuracy. The main objectives are to study and understand systematic discrepancies, long-term trends and biases, within techniques due to software differences and also between techniques due to sub-network effects and to investigate long-term consistency, trends and biases, between techniques and the reference IERS C04.

We limited our analyses to long-term EOP series derived by analysis centres in which both references frames were fixed to ITRF2000 (Altamimi *et al.*, 2002) and ICRF in the course of the calculations (i.e. 5 VLBI, 3 SLR and one GPS series). Table 5 presents systematic errors between individual solutions obtained within same techniques, same or different software, and IERS C04 for all parameters.

Table 5: Systematic errors between individual solutions and IERS C04 for all EOP parameters. Units: µas for pole and nutation bias, µs for UT1, µas/yr for pole drift and nutation drift, µs/yr for UT1 drift. CSR solution, computed in a different reference frame than ITRF2000 was transformed using the correction given for the 1997 correction (IERS Gazette 8).

	Institute	Software	X bias	X drift	Y bias	Y drift	UT1 bias	UT1 drift	DΨ bias	DΨ drift	Dε bias	Dε drift
VLBI	BKG	CALC	-114	20	143	37	-1	2	-27	-5	6	-1
	GSFC	CALC	-103	16	148	31	-1	2	-62	-14	5	-3
	DGFI	OCCAM	-135	12	134	41	1	2				
	GAUS	OCCAM	-200	37	133	36	1	2				
	IAA	OCCAM	-138	3	116	38	3	3	-39	-10	27	-1
SLR	CGS	GEODYN	-235	3	110	8						
	IAA	GROSS	-59	11	58	-3						
	CSR	UTOPIA	-360	-101	27	24						
GPS	CODE	BERNESE	44	-17	-35	49						

In conclusion, it appears that the C04 series is for pole components inconsistent with ITRF2000 at a level of 50–200 µas for biases and 40 µas/yr for drifts. It is still premature to apply any correction to it since there are inconsistencies between the different techniques at the same level.

More investigations are needed to identify the reasons of the discrepancies within same techniques, same or different packages used and between the different techniques.

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3.5.2 Rapid Service/Prediction Centre

Processing Techniques

The algorithm used by the IERS Rapid Service/Prediction Centre for the determination of the quick-look Earth orientation parameters (EOP) is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy & Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases and rates are determined with respect to the C04 system of the IERS Earth Orientation Centre (EOC). Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques. Minimal smoothing is applied, consistent with the estimated accuracy of the observational data.

Weights in the algorithm may be either a priori values estimated by the standard deviation of the residual of the techniques or values based on the internal precision reported by contributors. Estimated accuracies of data contributed to the IERS Rapid Service/Prediction Centre are given in Table 1. These estimates are based on a random sampling of the statistical reports that were generated weekly as part of the Bulletin A Rapid Service EOP solution for 2002.

Table 1. Estimated accuracies of the techniques in 2002. Units are milliseconds of arc for x, y, $\delta\psi$, and $\delta\varepsilon$ and milliseconds of time for UT1-UTC and LOD.

Contributor	Estimated Accuracy					
	X	Y	UT1	LOD	$\delta\psi$	$\delta\varepsilon$
CSR 3-day SLR	0.3	0.5	0.11*			
DUT 3-day SLR	0.3	0.3				
IAA 1-day SLR	0.3	0.3				
MCC 1-day SLR	0.2	0.2				
GSFC daily VLBI			0.020			
SpbU daily VLBI			0.021			
GSFC weekly VLBI	0.1	0.1	0.008		0.4	0.1
IAA weekly VLBI	0.1	0.1	0.005		0.4	0.1
IGS Final	0.02	0.05				
IGS Rapid	0.03	0.06		0.02*		
USNO GPS UT*			0.018*			
EMR GPS UT*			0.04*			
USNO AAM UT			0.030			

**All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to correct for LOD biases and to minimize drifts in UT estimates.*

Operationally, the weighted spline uses as input the epoch of observation, the observed value, and the weight of each individual data point. The software computes the spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, $\delta\psi$, and $\delta\varepsilon$ values are computed at the epoch of zero hours UTC for each day. The only data points that are excluded from this process are points whose errors, as reported by the contributors, are greater than three times their average reported precision or those points that have a residual that is more that four times the associated a priori error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, no processing is done to account for these effects (see IERS Gazette No. 13, 30 January 1997).

Table 2. Mean and standard deviation of the differences between the Rapid Service/Prediction Centre solutions and IERS Bulletin B and C04 EOP solutions for 2002. Polar motion X and Y values are in milliseconds of arc and UT1-UTC values are in units of milliseconds of time.

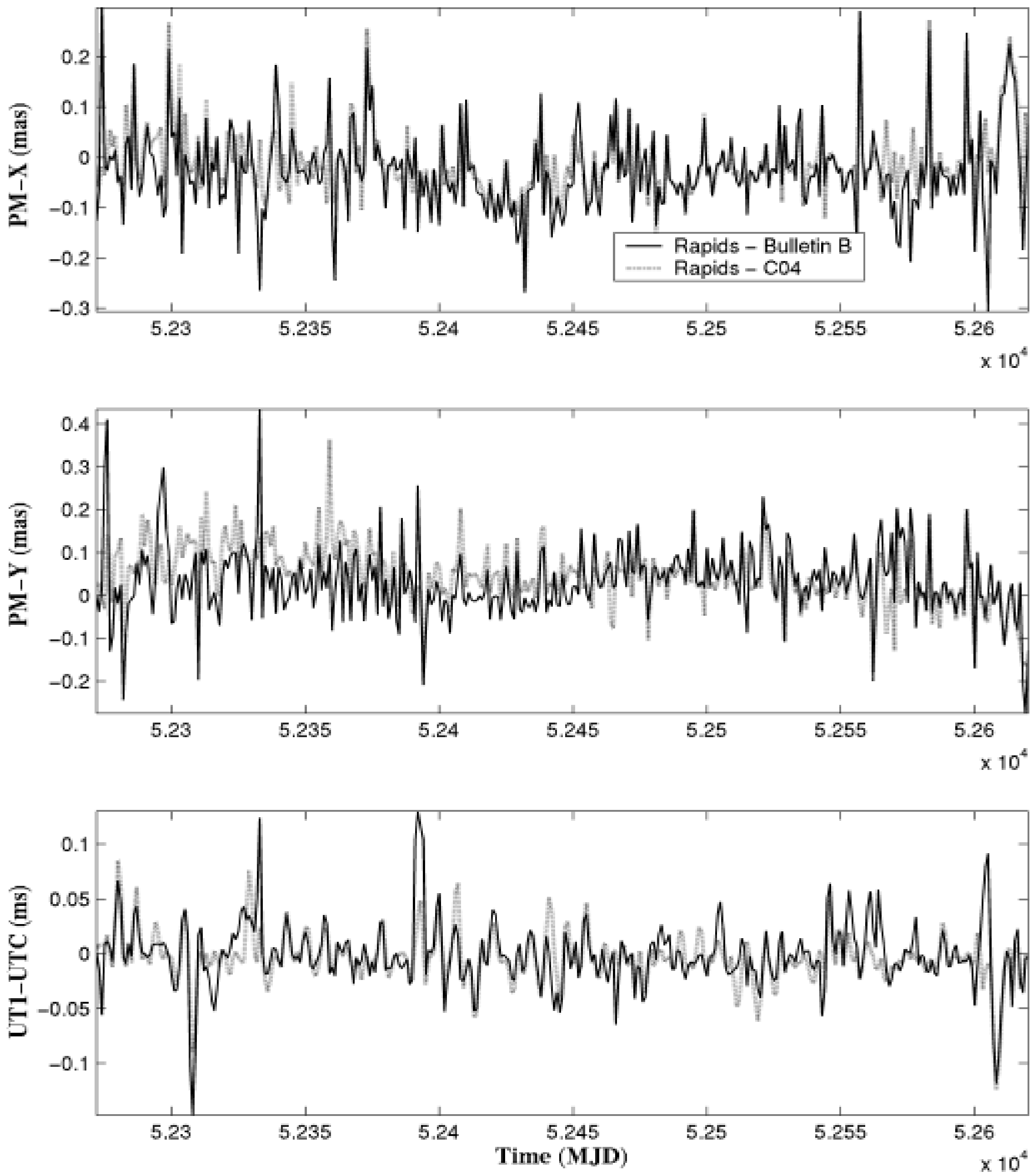
	Bulletin A – Bulletin B		Bulletin A – C04	
	Mean	Std. Deviation	Mean	Std. Deviation
Bulletin A Rapid Solution (finals.data)				
X	0.03	0.09	–0.01	0.07
Y	0.03	0.08	0.05	0.07
UT1-UTC	0.001	0.030	–0.004	0.023
Bulletin A Daily Solution (finals.daily)				
X	0.01	0.15	0.02	0.15
Y	–0.04	0.14	–0.03	0.13
UT1-UTC	0.011	0.060	0.015	0.056

The uncertainties in the daily values listed in Bulletin A are derived from the quality of the spline fit in the neighbourhood of the day in question. Table 2 shows the accuracies of two different Rapid Service/Prediction Centre products compared to the Bulletin B and C04 series maintained by the IERS EOC at the Paris Observatory. The agreement between the Bulletin A solutions and the IERS EOC solutions is quite good. In addition the EOP accuracies for the Bulletin A rapid solution and daily solution are similar at the time of solution epoch.

Prediction Techniques

Polar motion predictions are based on the extrapolation of an annual and semiannual ellipse and a Chandler circle fit to the previous 400 days of observed values of x and y (McCarthy and Luzum, 1991b; Johnson, 2002). The differences between the last observed pole position and rate and those of the curve are computed. These differences are then used to adjust the extrapolated curve by an amount that decreases with the length of the forecast. In February 1998, the near-term polar motion predictions (less than about 30 days) were improved significantly by modifying the transition proc-

Figure 1: Differences between Bulletin A Rapid Solutions and the Earth Orientation Parameters available in Bulletin B and C04 for 2002.



ess from the last observed polar motion result to the long-term predictions. Continuity in the first derivatives was enforced placing great weight on the observed polar motion rate reported by the IGS in their Rapid series. The improvement was most pronounced for the shortest prediction intervals. The procedure for UT1-UTC involves a simple technique of differencing (McCarthy and Luzum, 1991b). All known effects such as leap seconds, solid Earth zonal tides, and seasonal effects are first removed from the observed values of UT1-UTC. Then, to determine a prediction of UT1-UTC n days into the future, $(UT1\text{-}TAI)_n$, the smoothed time value from n days in the past, $<(UT1R\text{-}TAI)_{-n}>$ is subtracted from the most recent value, $(UT1R\text{-}TAI)_o$.

$(UT1\text{-}TAI)_n = 2(UT1R\text{-}TAI)_o - <(UT1R\text{-}TAI)_{-n}>$.

The amount of smoothing used in this procedure depends on the length of the forecast. Short-term predictions with small values of n make use of less smoothing than long-term predictions. Once this value is obtained, it is possible to account for known effects in order to obtain the prediction of UT1-UTC. This process is repeated for each day's prediction.

The very near-term UT1-UTC prediction is strongly influenced by the observed daily Universal Time estimates derived at USNO from the motions of the GPS orbit planes reported by the IGS Rapid service. The IGS estimates for LOD are combined with the GPS-based UT estimates to constrain the UT1 rate of change for the most recent observational day. For the 5 days after the latest observed day, AAM-based predictions of LOD excitation are combined smoothly with the longer-term UT1 predictions described above.

Errors of the estimates are derived from analyses of the past differences between observations and the published predictions. Formulas published in Bulletin A are used to extend the tabular data. The prediction of $\delta\psi$ and $\delta\varepsilon$ is based on the IERS Conventions (McCarthy, 1996). Table 3 shows the standard deviation of the differences between the daily solution and C04 solution, respectively, for 2002. Recent prediction performance in UT1-UTC has been improved by 42% at 10 days into the future by the addition of a UT1-like data product derived from NCEP AAM (UTAAM) to the combination and prediction routine (Johnson et al., 2003). This estimate of improvement was determined by examining one year's worth of daily solutions that used UTAAM in the combination and prediction.

Table 3. Standard Deviation of the differences between the Daily solutions and the C04 EOP solutions for 2002.

Days in Future	X mas	Y mas	UT1-UTC ms	$\delta\psi$ mas	$\delta\varepsilon$ mas
1	.47	.37	.118	.39	.17
5	2.15	1.51	.445	.40	.18
10	3.69	2.57	1.09	.41	.18
20	6.41	4.46	3.59	.42	.19
40	10.2	8.23	7.00	.46	.21
90	15.1	18.5	13.8		

* *$\delta\psi$ and $\delta\varepsilon$ not predicted to 90 days into future in daily solutions.*

The predictions of δψ and δε are based solely on VLBI data. If no new data are available, a new prediction of these nutation angles cannot be determined. Therefore, the length of the prediction into the future for δψ and δε can and does vary in the daily solution files.

Predictions, of UT1-TAI up to 2010 January 1, are given in Table 4 below. They are derived using a prediction algorithm similar to that employed in the Bulletin A predictions of UT1-UTC. Up to twenty years of past observations of UT1-TAI are used. Estimates of the expected one-sigma error for each of the predicted values are also given. These are based on analyses of the past performance of the model with respect to the observations.

Table 4. Predicted values of UT1-TAI, 2003–2012. Note that TT-UT1 can be obtained from this table using the expression TT-UT1=32.186s – (UT1-TAI).

DATE	UT1-TAI (s)	Uncertainty (s)
2003 Jan 1	–32.27	.02
2003 Apr 1	–32.33	.02
2003 Jul 1	–32.68	.03
2003 Oct 1	–32.89	.04
2004 Jan 1	–33.10	.06
2004 Apr 1	–33.31	.1
2004 Jul 1	–33.6	.2
2004 Oct 1	–33.8	.2
2005 Jan 1	–34.1	.3
2005 Apr 1	–34.3	.4
2005 Jul 1	–34.5	.4
2005 Oct 1	–34.7	.5
2006 Jan 1	–34.9	.6
2006 Apr 1	–35.2	.8
2006 Jul 1	–35.4	.9
2006 Oct 1	–36.	1.
2007 Jan 1	–36.	1.
2007 Apr 1	–36.	1.
2007 Jul 1	–36.	1.
2007 Oct 1	–36	2.
2008 Jan 1	–36.	2.
2008 Apr 1	–36.	2.
2008 Jul 1	–36.	2.
2008 Oct 1	–37.	2.
2009 Jan 1	–37.	2.
2009 Apr 1	–37.	2.
2009 Jul 1	–37.	3.
2009 Oct 1	–37.	3.
2010 Jan 1	–37.	3.
2010 Apr 1	–37.	3.
2010 Jul 1	–37.	3.
2010 Oct 1	–38.	3.
2011 Jan 1	–38.	3.
2011 Apr 1	–38.	4.
2011 Jul 1	–38.	4.
2011 Oct 1	–38.	4.
2012 Jan 1	–38.	4.

Please contact the IERS Rapid Service/Prediction Centre for details on how to obtain these data. Further information on recent improvements to IERS Bulletin A and the significance for predictions of GPS orbits for real-time users is provided in the paper by Luzum et al. (2001).

Centre Activities in 2002

During 2002 a few changes occurred which affect the performance of IERS Bulletin A. In January software formats were modified to handle the new IVS VLBI data formats. In February the software was modified to allow the editing of all data techniques used in polar motion and UT1 combination solutions. In addition data editing was introduced into the nutation software.

Due to the improved accuracy of the Bulletin A daily solutions, the weekly nature of VLBI 24-hour sessions, and personnel limitation, the frequency of the Bulletin A rapid solution was reduced from twice weekly to weekly on 1 July 2002.

In September a study to evaluate the potential improvements by introducing USNO and IVS Combination 24-hour VLBI products into the Bulletin A rapid service/prediction EOP series was initiated. By November the results clearly indicated that the robustness of the Bulletin A could be improved by the addition of these two VLBI series, especially for the nutation angles. It was decided that the USNO and IVS Combination 24-hour VLBI products would be introduced into the operational Bulletin A solution in early January 2003.

On 9 November 2002 the software script that produces the finals.daily data file failed to produce a data file over the correct period. The software produced the file as if the solution epoch was 52586 (8 November 2002). This problem continued until 13 November 2002. The results of this error caused the solution published in the finals.daily to be given ±90 days with respect to 52586 and not with the appropriate epoch of the solution even though the values stored in the files appear to be correct. This problem was corrected by the 14 November 2002 solution.

In late 2002 the Centre prepared for the implementation of the IAU 2000 resolutions by creating a dX and dY series with respect to the IAU 2000A Precession/Nutation Theory. The complete replacement of the IAU 1980 Theory of Nutation and the IERS Precession/Nutation Theory should be completed by mid- to late-2003.

The Centre is currently investigating improvement of the current methods employed to estimate the biases between the different Analysis Centre datasets and C04.

Availability of Rapid Service

The data available from the IERS Rapid Service/ Prediction Centre consist mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from IAA VLBI; x, y, UT1-UTC, $\delta\psi$ from GSFC VLBI; UT1-UTC from Saint Petersburg University 1-day

Intensives; UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from CSR LAGEOS 3-day SLR; x, y from Delft University of Technology 3-day SLR; x, y from Institute of Applied Astronomy 1-day SLR; x, y from the Russian Mission Control Centre 1-day SLR; x, y, LOD from the International GPS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from the IERS Rapid Service/Prediction Centre; x, y, UT1-UTC, $\delta\psi$, $\delta\varepsilon$ from the IERS Earth Orientation Centre; and predictions of x, y, UT1-UTC from the IERS Rapid Service/ Prediction Centre.

In addition to this published information, other data sets are available. This includes: UT0-UTC from University of Texas as Austin LLR, UT0-UTC from JPL LLR; UT0-UTC from CERGA LLR; UT0-UTC from JPL VLBI; latitude and UT0-UTC from Washington PZTs 1,3,7; latitude and UT0-UTC from Richmond PZTs 2,6; x and y from CSR LAGEOS 5-day SLR; x and y from Delft 5-day SLR; x, y, UT1-UTC, $\delta\psi$, and $\delta\varepsilon$ from IRIS VLBI.

The data described above are available from the Centre in a number of forms. You may request a weekly machine-readable version of the IERS Bulletin A containing the current ninety day's worth of predictions via electronic mail from

<ser7@maia.usno.navy.mil> or <http://maia.usno.navy.mil/>.

Internet users can also direct an anonymous FTP to

<maia.usno.navy.mil>

and change to the ser7 directory where the IERS Bulletin A and more complete databases can be accessed including the daily Bulletin solutions.

World Wide Web access is available at

<http://maia.usno.navy.mil/>.

Centre Staff

For most of 2002, the Rapid Service/Prediction staff consisted of the following members.

Jim R. Ray	director and program manager
Thomas Johnson	research, software maintenance and support
Merri Sue Carter	assists in daily operations and support
Jerry Josties	assists in operations and support

Jim Ray resigned from USNO in May 2002 and Jerry Josties retired in October 2002, after 42 years of service to USNO. Thomas Johnson managed the program for the remainder of 2002. William Wooden is the new director of the Centre as of February 2003.

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William Wooden, Thomas Johnson

3.5.3 Convention Centre

The IERS Conventions Centre is provided jointly by the U.S. Naval Observatory (USNO) and the Bureau International des Poids et Mesures (BIPM). The work accomplished in 2002 is the following:

Chapter 1 – General Definitions and Numerical Standards
The chapter has been updated for consistency of notation and concepts with other sections according to IAG and IAU working groups.

Chapter 2 – Conventional Celestial Reference System and Frame
The chapter has been updated to incorporate the effects of the IAU 2000 24th General Assembly.

Chapter 3 – Conventional Dynamical Reference Frame
The chapter has been updated to be consistent with notation and concepts of other sections.

Chapter 4 – Conventional Terrestrial Reference System
The Chapter has been updated for ITRF2000.

Chapter 5 – Transformation Between the Celestial and Terrestrial Systems
The chapter was modified to be consistent with resolutions adopted at the 24th IAU General Assembly and the 2002 IERS Workshop. Nicole Capitaine and Patrick Wallace have provided a major revision.

Chapter 6 – Geopotential
The chapter has been updated to include the EGM96 conventional geopotential model and the treatment of tides.

Chapter 7 – Site Displacement
The chapter has been updated to account for models used in IERS analysis centers and to ensure consistency with chapters 4 and 6.

Chapter 8 – Tidal Variations in the Earth's Rotation
The chapter has been updated to be consistent with resolutions adopted at the 24th IAU General Assembly.

Chapter 9 – Tropospheric Model
The chapter has been updated.

Chapter 10 – General Relativistic Models for Time, Coordinates and Equations of Motion
The chapter has been updated for consistency of notation and con-

cepts with other sections. New software for the TCB-TCG transformation, developed by Harada and Fukushima, has been checked against existing programs and added to the list of such standards.

Chapter 11 – General Relativistic Models for Propagation
The chapter has been updated for consistency of notation and concepts with other sections.

Appendix – Resolutions of the 24th IAU General Assembly

New versions of chapters and accompanying software are posted on the web as they become available, see
<http://maia.usno.navy.mil/conv2000.html>.

Gérard Petit, Dennis D. McCarthy

3.5.4 ICRS Centre

Introduction

The IAU has charged the IERS with the responsibility of monitoring the International Celestial Reference System (ICRS) and maintaining its current realization, the International Celestial Reference Frame (ICRF), and links with other celestial reference frames. Starting in 2001, these activities are run jointly by the ICRS Centre (Observatoire de Paris and US Naval Observatory) of the IERS and the International VLBI Service for Geodesy and Astrometry (IVS), in coordination with the IAU Working Group on the Reference System. The present report was jointly prepared by the Paris Observatory and U.S. Naval Observatory components of the ICRS Centre.

Different files provide information to characterize the objects involved in the construction of the ICRF (radio source nomenclature, physical characteristics of radio sources, astrometric behaviour of a set of sources, radio source structure). The database is available at URL <http://hpiers.obspm.fr/icrs-pc>, by anonymous ftp (<hpiers.obspm.fr/icrs-pc>), and on request to the ICRS Centre (<icrs-pc@hpopa.obspm.fr>).

In the following, we explain the contents of the various tasks which are devoted to the ICRS Centre, by explaining for each of them the studies which were developed in 2002.

Maintenance and Extension of the ICRF : Validation of Individual Celestial VLBI Reference Frames

Three individual celestial frames obtained from VLBI analysis and a compiled one had been submitted to the IERS for their validation. The four frames had been analysed and compared to the ICRF-Ext.1.

The reference frames analysed

RSC (BKGI) 02 R 01: This VLBI global combined solution was computed by the BKG VLBI Analysis Centre in cooperation with the VLBI group at the University of Bonn. For this solution, a worldwide set of VLBI observations over the period January 1984 – December 2001 has been processed with the software CALC 9.12/SOLVE release 2001.12.21. The orientation of the celestial frame has been defined by constraining to zero the sum of the right ascension and declination adjustments of the ICRF defining sources in RSC (BKGI) 02 R 01. Tropospheric gradients have been estimated in the solution.

RSC (GAOUA) 01 C 01: This frame has been elaborated at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine. Radio source coordinates have been calculated by the combination of the four individual VLBI solutions submitted to the IERS and analyzed in the IERS Annual Report for 2000 (IERS, 2001). The Kyiv arclength method (Yatskiv and Kur'yanova, 1990) has been applied for the catalogue compilation. The axes of the compiled frame are aligned to the ICRS with an accuracy of 0.01 mas by the 202 ICRF defining sources present in RSC (GAOUA) 01 C 01.

RSC (IAA) 02 R 03: This celestial frame has been elaborated by the VLBI research group of the IAA Laboratory of New Methods in Astrometry and Geodynamics (NMAG) in St. Petersburg. The solution has been obtained with the new software QUASAR (version QUASAR_LSC) for VLBI data analysis by Least Squares Collocation Technique. NEOS-A VLBI data for the period 1993–2001 has been analysed for this solution. RSC (IAA) 02 R 03 has been aligned to the ICRS by not-net translation and no-net rotation constraints applied to source positions with respect to ICRF-Ext.1. Tropospheric gradients have been adjusted in the solution.

RSC (GSFC) 02 R 01: This VLBI solution has been elaborated at the Goddard Space Flight Centre, it has been constrained to be aligned to ICRF-Ext.1.

Table 1 gives the characteristics of the reference frames analyzed. Four categories of sources appear in the table: “defining”, “candidate” and “other” sources correspond to the classification of ICRF sources, “new” are the sources added in ICRF-Ext.1, “additional” is for sources not present in ICRF-Ext.1 and observed in VLBI programs.

Table 1: Analysed VLBI celestial reference frames. N = number of sources, m = mean standard error (Unit: mas).

Frame	Total	Defining		Candidate		Other		New		Addit.		
	n	n	m	n	m	n	m	n	m	n	m	(°)
RSC (BKGI) 02 R 01	594	209	0.13	216	0.13	102	0.04	44	0.24	23	0.76	–81;+84
RSC (GSFC) 02 R 01	552	202	0.07	201	0.08	101	0.03	35	0.11	13	0.17	–81;+84
RSC (IAA) 02 R 03	323	85	0.11	115	0.10	68	0.06	47	0.23	8	0.45	–44;+84
RSC (GAOUA) 01 C 01	670	211	0.06	277	0.09	102	0.02	59	0.14	21	0.22	–85;+84

Comparison of individual celestial frames to ICRF-Ext.1

All submitted individual VLBI frames have been compared to ICRF-Ext.1. Under the assumption that ICRF-Ext.1 is free from deformations, the systematic effects detected in the comparisons indicate the existence of deformations in the individual frames.

The algorithm of comparison is the one currently used at the ICRS Centre; the coordinate difference between two frames is modelled by a global rotation of the axes, represented by the angles A_1, A_2, A_3, and by a deformation represented by three parameters: one is a slope in right ascension as a function of the declination (D_α), another is a slope in declination as a function of the declination (D_δ), and the third one is a bias of the principal plane of the frame relative to that of the ICRF-Ext.1 (B_δ).

$$A_1 \,\mathrm{tg}\,\delta \cos\alpha + A_2 \,\mathrm{tg}\,\delta \sin\alpha - A_3 + D_\alpha(\delta - \delta_0) = \alpha_1 - \alpha_2$$

$$-A_1 \sin\alpha + A_2 \cos\alpha + D_\delta(\delta - \delta_0) + B_\delta = \delta_1 - \delta_2$$

Only defining sources common to each individual frame and the ICRF-Ext.1 have been used for the comparison. The parameters have been evaluated by a weighted least squares fit; the equations have been weighted using the inverse of the variance of the coordinate differences.

Formal uncertainties in radio source positions listed in the individual frames smaller than 0.01 mas were set to this value for the assignation of weights. The six fitted parameters allow to transform coordinates in the individual frames into ICRS.

Table 2 gives the global orientation between axes of the individual catalogues and those of the ICRS. Table 3 shows the systematic effects in the individual frames detected by their comparison to ICRF-Ext.1.

Table 2: Relative orientation between individual frames and the ICRF. A_1, A_2, A_3 are the small angles which transform coordinates from the individual frames into ICRF; N is the number of the common defining ICRF sources used for the comparison; r_α and r_δ are the weighted mean residuals in $\alpha \cos\delta$ and δ respectively. Unit: 0.001".

Frame	N	A_1	A_2	A_3	r_α	r_δ
RSC (BKGI) 02 R 01	209	+0.036±0.016	+0.004±0.016	–0.053±0.021	0.17	0.23
RSC (GSFC) 02 R 01	202	+0.000±0.018	–0.023±0.017	–0.044±0.023	0.18	0.24
RSC (IAA) 02 R 03	85	–0.009±0.024	+0.018±0.025	–0.023±0.036	0.15	0.23
RSC (GAOUA) 01 C 01	211	–0.003±0.016	–0.020±0.016	–0.022±0.021	0.17	0.22

Following the usual practice in VLBI work, constraints are applied to align the axes of the individual frames to ICRF. The origin of right ascensions of the individual frames agrees with the ICRF origin at a few tens of mas.

No deformations are detected in the individual frames when compared to ICRF. The principal plane of RSC (GSFC) 02 R 01 is bi-

Table 3: Slopes and biases evaluated in the comparisons between individual VLBI frames and ICRF. D_α, D_δ are the slopes in right ascension and in declination, respectively. B_δ is the bias in declination. Units: 0.001"/degree for the slopes, 0.001" for the biases.

Frame	D_α	D_δ	B_δ
RSC (BKGI) 02 R 01	–0.001±0.001	+0.000±0.000	+0.002±0.017
RSC (GSFC) 02 R 01	–0.001±0.001	+0.000±0.000	+0.028±0.018
RSC (IAA) 02 R 03	+0.001±0.001	–0.001±0.001	–0.005±0.038
RSC (GAOUA) 01 C 01	–0.001±0.001	+0.000±0.000	+0.014±0.017

ased by +0.028 mas from that of the ICRF; this bias is smaller than the value reported for RSC (GSFC) 01 R 01 in the IERS Annual Report 2000 (IERS, 2001).

E. Felicitas Arias, Sébastien Bouquillon, Anne-Marie Gontier

Investigation of Future Realisations of the ICRS

Involvement by ICRS Centre personnel in the celestial reference frame VLBI program continued in 2002, significantly increasing the number of observations of ICRF quasars in the southern celestial hemisphere and continuing an extensive observing program in the northern hemisphere. These observations are directed towards the elaboration of a second extension to the ICRF, expected to be issued in the following years.

In the coming decades, there will be significant advances in the area of space-based optical astrometry. Proposed and scheduled missions such as the National Aeronautics and Space Administration's (NASA) Space Interferometry Mission (SIM) and the European Space Agency's GAIA mission will achieve positional accuracies well beyond that presently obtained by any ground-based radio interferometric measurements.

During 2002, ICRS Centre personnel were involved in the Full-sky Astrometric Mapping Explorer (FAME) mission; an astrometric space mission to measure the position, parallax and proper motions of 40 million stars between 5th and 15th magnitude. In January 2002, NASA announced their decision to withdraw financial support for the FAME mission, citing continued uncertainty surrounding the development of the FAME Charged Coupled Devices (CCDs) and optics, instrument software development, and operations algorithm development, while noting a significant anticipated mission cost growth significantly exceeding the NASA mission cost cap. With the conclusion of NASA support for the FAME mission, no new NASA funds were received by the project, however, NASA did support project CCD technology development in 2002 through the funding of a secondary supplier with already disbursed FAME funds. In addition to the very successful procurement of CCDs, ICRS Centre personnel made important progress in optical system analysis, developing systems engineering tools to connect science requirements to engineering requirements. Using these tools ICRS Centre personnel developed a model of a three mirror anastigmat (TMA) telescope design that will satisfy FAME science requirements, costed out a newer version of the instrument, and developed a data simulator and analysis pipeline which helps further define system requirements. A systems engineering analysis of the PDR design of FAME, using CCDs from the secondary supplier and the TMA optics design, shows that a cumulative astrometric mission accuracy of 100 µas can be attained for 9th magnitude stars in the first 2 years of a FAME mission, with no radiation mitigation. As the FAME mission progress toward its planned 5 year duration, an astrometric accuracy of 50 µas can be achieved using radiation mitigation techniques available with the recently fabricated CCDs.

In October 2002 ICRS Centre personnel met with members of the DIVA project team, and were highly impressed with the DIVA mission design. DIVA, a German led astrometric space mission, is in many respects quite similar to the USNO led FAME mission, but with somewhat relaxed astrometric requirements for mission position, parallax and proper motion (150 µas, 200 µas, and 250 µas yr^{-1}, respectively) for a 2 year mission. Facing a significant budget shortfall, the DIVA project team and the FAME project team explored the potential for a collaborative merger of the DIVA and FAME programs. It was determined that the most promising avenue for closing the DIVA funding gap was for USNO to submit a funding proposal to NASA for a Mission of Opportunity. The next proposal opportunity is May 02, 2003.

Ralph Gaume

Monitor Source Structure

Observations of ICRF sources using the Very Long Baseline Array (VLBA), together with up to 10 geodetic antennas, continued. These VLBA RDV observations constitute a joint program between the U.S. Naval Observatory (USNO), Goddard Space Flight Center (GSFC) and the National Radio Astronomy Observatory (NRAO) for maintenance of the celestial and terrestrial reference frames. During each 24 hour VLBA RDV session, about 80 ICRF sources are observed at S/X-band (2.3/8.4 GHz). The VLBA observations taken under this program provide data suitable for imaging of the intrinsic structure of the extragalactic radio sources which make up the ICRF. Images are made at the USNO and are made available for use by anyone from the USNO Radio Reference Frame Image Database (RRFID). The RRFID can be accessed on the World Wide Web at <http://www.usno.navy.mil/RRFID/>. During the reporting period (2002), a total of 332 new images of 167 sources were added to the RRFID, including images of 7 sources not previously imaged.

Very Long Baseline Array observations to extend the ICRF to K-band (24 GHz) and Q band (43 GHz) (Jacobs et al. 2002, in International VLBI Service for Geodesy and Astrometry 2002 General Meeting Proceedings, edited by Nancy R. Vandenberg and Karen D. Baver, NASA/CP-2002-210002) began in May 2002. These observations are part of a joint program between NASA, the USNO, NRAO and Bordeaux Observatory. Images are produced from these observations by the USNO and made available through the RRFID. During the reporting period (2002), two VLBA high frequency experiments were calibrated and imaged adding 260 images of 65 sources to the RRFID.

The resulting intrinsic source structure information from the RRFID provides a valuable resource for evaluating the astrometric suitability of the extragalactic sources used to define the ICRF. Fey and Charlot (2000, Astrophysical Journal Supplement Series, Vol. 128, pp. 17–83) used RRFID data to quantify the magnitude of the expected effect of intrinsic source structure on astrometric bandwidth synthesis VLBI and presented their results in the form of a “Structure Index” for the observed sources. The “Structure Index” ranges from a value of 1 for the least contribution (best astrometric sources) to a value of 4 for the most contribution (worst astrometric sources). The “Structure Index” can be used as an estimate of the astrometric quality of the sources based on intrinsic structure. The distribution of “Structure Index” calculated from the first epoch of K/Q-band images (Charlot 2002, private communication) is shown in Figure 1. Also shown are values for the 28 sources observed in VLBA RDV31 at X-band which overlap with these sources. Note the shift toward lower values as the frequency of observation increases suggesting that structure contamination will be less pronounced at these higher frequencies.

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a continuing VLBI research program in Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the southern hemisphere through repeated high quality astrometry and imaging. Observations from this program are still under analysis.

Alan Fey

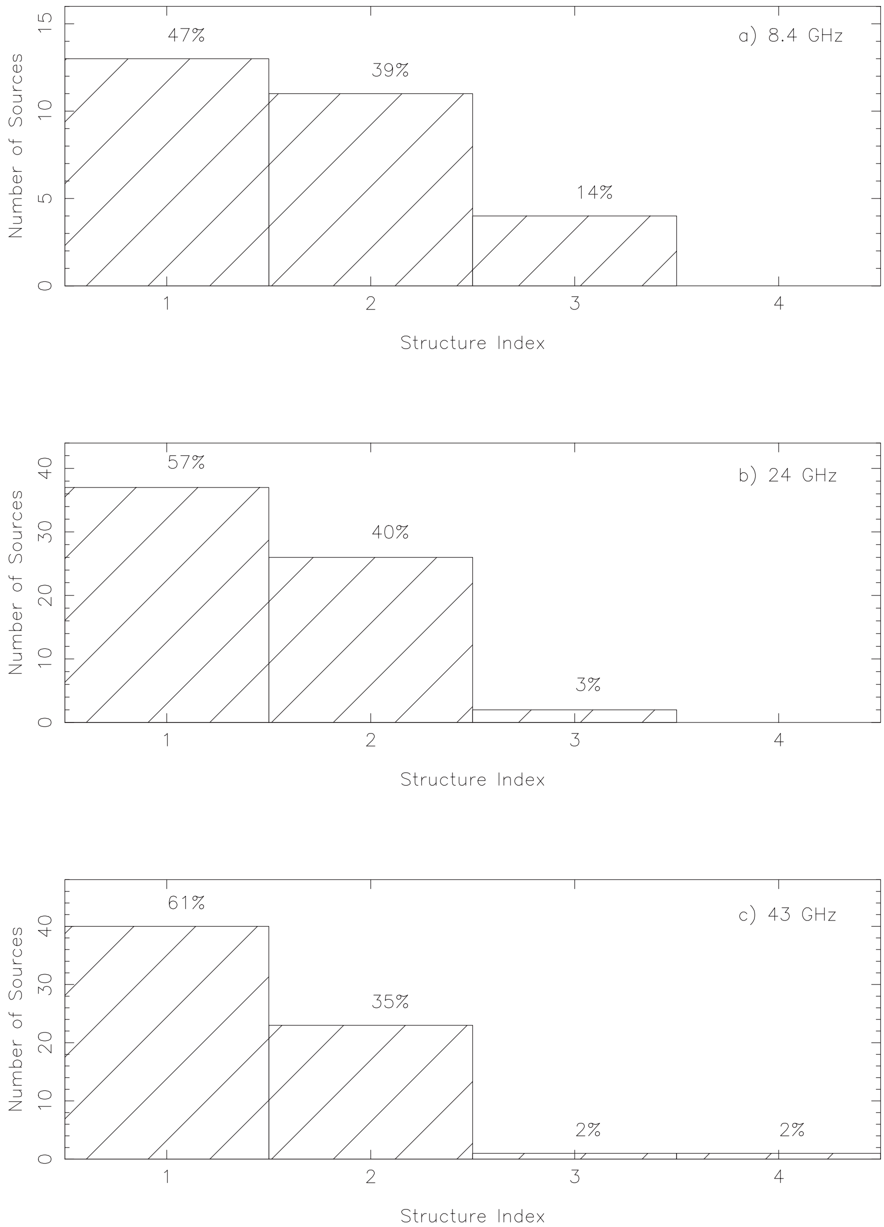

Figure 1: Distribution of "Structure Index" for sources at a) 8.4 GHz, b) 24 GHz, and c) 43 GHz. A total of 65 sources were observed at 24 and 43 GHz on 2002 May 15. Also shown are the values for the 28 overlap sources observed at 8.4 GHz on 2002 Jan 16.

Maintenance of the Time Stability of ICRF : Monitor Coordinates to Assess Astrometric Quality

In a paper submitted to Astronomy and Astrophysics, we propose a statistical scheme to select a subset of objects that would be used for the maintenance of the ICRF and the monitoring of the Earth's rotation.

The study is based on the series of individual source coordinates derived by A. Fey (USNO) over 1979–2002. The time series of source coordinates were obtained in three parallel analyses of the VLBI observing sessions up to May 2002. Each of the analysis derives time series of coordinates per session, for one third of the sources, the other two thirds being treated as “global”, i.e. with fixed positions over the total observation span. Each analysis includes a no-net-rotation (NNR) condition with respect to ICRF. To avoid inconsistencies that are due to the NNR condition realization in the three analyses, and that reach the level of 50 mas, we consider here for each source the time series of its coordinates referred to its global weighted mean.

The improvements in VLBI technology, the development of the observing network and the extension of the set of observed objects that took place in operational astrogeodetic VLBI brought the astrometric results to its current precision level towards the end of the eighties. Therefore, the proposed selection scheme is applied to data after 1989.5, i.e. 3.1 million observations of 707 sources, representing 87% of the total data set.

A set of stable sources is selected in a two-step process, as follows.

– A first selection is made on the basis of continuity criteria for one-year weighted average coordinates.

a) Length of observation period longer than five years.
b) More than two observations of the source in a given session.
c) One-year average coordinates based on at least three observations.
d) Not more than two successive years with no observations, given conditions (b), (c) are met.
e) At least half of the one-year averages available.

– The time series of yearly values are then analysed in order to derive

f) a linear drift (least squares estimation) and its normalized absolute value,
g) the Allan standard deviation of a one-year sampling time.

For each local coordinate ($\alpha \cos \delta$ and δ), two partial indices are defined, based on the values of the above statistics. The partial stability indices range from 1 (most stable) through 3 (least stable), with a rejection value (10) associated to very large drifts or standard deviations. The global stability index is defined as the average of the partial indices for $\alpha \cos \delta$ and δ, i.e. four values per source. The stable sources are those which get a stability index smaller than 2.5.

Out of the 362 pre-selected sources the stability scheme detects 199 stable ones, a number to be compared to the 212 defining sources in the ICRF. Table 4 gives the relationship of the global stability index with two ICRF qualifiers: the source status (defining/candidate/other) and ICRF structure index computed on the basis of source mapping. The structure qualifies the level of expected position disturbance (1 for the less disturbed, 4 for the most disturbed). The proposed list of selected sources is only poorly correlated with he current ICRF ones.

Table 4: Stability index and ICRF source qualifiers

Stability	Source status			Structure index		
Index	Def.	Can.	Oth.	1	2	3–4
1	33	26	15	53	21	12
2	48	42	34	83	33	14
3	2	1	4	17	12	8
4	58	61	34	79	32	19

To test their efficiency with respect to the maintenance of the axes of the celestial reference frame that they materialize, we consider the 13 yearly differential reference frames (1990.0 – 2002.0) that are formed by the set of stable sources observed for that year. The yearly differential rotation around the axes of the equatorial coordinate system are then computed for the 13 years. Table 5 lists efficiency estimates for the selected sources, and for the ICRF defining sources. These estimates are the usual standard deviation that characterizes the scatter of the sets of rotation angles, and their Allan standard deviations for one-year and four-year sampling times that characterize their stability in time. Note that if the time series of the rotation angles has white noise, the four-year Allan standard deviation will be equal to half the one-year one (square root of one fourth in sampling time). In the case of flicker noise, both values will be equal.

Table 5: Stability of the celestial reference frame orientation definition. Rms standard deviation and Allan standard deviation of the 1990–2002 yearly rotation angles. Unit: mas

212 defining sources			199 stable sources		
Std. Dev.	Allan Std. Dev. 1-yr	Allan Std. Dev. 4-yr	Std. Dev.	Allan Std. Dev. 1-yr	Allan Std. Dev. 4-yr
25.6	26.6	27.6	10.8	9.4	5.9

When compared to the current ICRF defining sources, the proposed selection scheme achieves improved time stability of yearly reference frames. The improvement is particularly striking in the long term. This stability implies enhanced internal consistency in time.

Martine Feissel-Vernier

Maintenance of the Link to Hipparcos and to Frames at Other Wavelengths

During the report period (2002) progress has been achieved by ICRS Centre personnel in 3 areas related to the maintenance of the Hipparcos link: UCAC project, comparison to 2MASS data and extragalactic link.

For the densification of the optical reference frame the UCAC project (USNO CCD Astrograph Catalog) continued. This all-sky survey will give 20 mas positions for stars in the 10 to 14 mag range, with a limiting magnitude of about R=16. From its current location at the Naval Observatory Flagstaff Station, 9263 more fields have been completed, now giving 87% total sky coverage. The 2nd data release (UCAC2) will become available in early 2003. Positions for about 50 million stars have been obtained. Proper motions are being derived from re-measurements of AGK2, NPM and SPM plates. In September 2002 the USNO B1 catalog was released, containing positions (on 150 mas level) and proper motions of about 1 billion stars, obtained from PMM measures of all major Schmidt surveys.

In December 2002 a comparison of UCAC2 positions with the infrared 2MASS catalog pre-release data was made. Both catalogs were taken at about the same epoch (around 2000) and both were independently reduced with respect to Tycho-2 stars. Only very small systematic differences (10 to 20 mas) between the 2 catalogs were found, depending on magnitude, color and declination zone. The precision of the 2MASS positions was confirmed to be about 80 mas.

Independantly, systematic positional differences between HIPPARCOS and the second incremental data release of the 2MASS catalogues were analysed (Damljanovic and Souchay, A & A to be subm.). After a cross-identification procedure leading to a total of 37 940 stars among the 117 955 Hipparcos stars (the second 2MASS incremental release covers only 47% of the sky), zonal differences were found with respect to equatorial coordinates, by applying linear regressions.

During his sabbatical stay at USNO, M.Assafin (Brazil) evaluated 4 CTIO observing runs of ICRF counterparts plus corresponding 1.6m LNA telescope data. The mean optical-radio position differences for 170 sources are –6 mas and –15 mas for RA and Dec, respectively, using preliminary UCAC survey data as reference stars. The additional astrograph calibration observations, not used in this pilot investigation, are needed to reduce systematic errors. In preparation for NASA's Space Interferometry Mission (SIM) a dozen ICRF sources were imaged at the NOFS 61-inch. This is the beginning of a long-term project to monitor possible optical centroid wandering of selected ICRF counterparts.

Norbert Zacharias

Link to the Dynamical Reference Frame and Specific Pulsar Astrometric Catalog Through Pulsar Analysis

The ephemerides of the Earth orbiting around the sun are necessary for the reduction of pulsar observations. Therefore the idea of associating pulsar timing technique with differential VLBI astrometry should provide high quality information about the position and motion of the equator, the ecliptic, the origin point of the ICRS.

Moreover, the sole analysis of signals of various pulsars should enable to construct an astrometric catalog containing the positions and the proper motions of a good number of pulsars (more than 30 observed at Nançay radiotelescope). The possibility of using high precision accumulated data coming from intensive campaigns for more than 10 years (Cognard et al., 1995) in that aim is more and more seriously investigated. In 2002 the campaign was very active, with a number of about 25 pulsars observed on a regularly basis.

Ismaël Cognard, Jean Souchay

Orientation of the Celestial Dynamical Ecliptic Reference Frame by Analysing Lunar Laser Ranging Data

The position of the inertial dynamical ecliptic at a given epoch with respect to the ICRS can be obtained from Lunar Laser Ranging (LLR) observations. The basic definitions concerned here are:

- the inertial dynamical ecliptic of J2000 and the ICRS reference equatorial plane;
- the inertial mean equinox of J2000 $\gamma_I^{(ICRS)}$ and the origin of right ascensions $o^{(ICRS)}$;
- the inclination of the inertial mean ecliptic on the ICRS equator $\varepsilon^{(ICRS)}$.

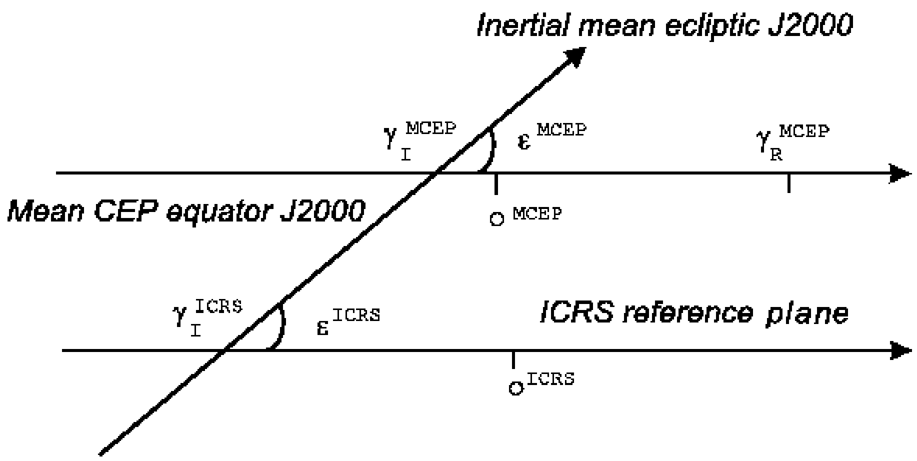

Figure 2: Position angles of the inertial mean ecliptic of J2000.

The ICRS equator and origin of right ascensions $o^{(ICRS)}$ are involved in the transformation of the rectangular coordinates of the LLR stations in the terrestrial reference frame to the celestial J2000 equatorial coordinates. This transformation has been realized according to the lunar solution which results from weighted fits of the semi-analytical theory ELP2000-96 (orbital motion of the Moon) to the LLR observations provided between 1970 and 2002. The precession-nutation matrix PN is computed via the conventional set of values recommended by IERS (1996), in particular the nutation corrections $\delta\varepsilon$ and $\delta\psi$ of the series EOP(C04) produced by the Earth Orientation Centre. The position of the inertial dynamical ecliptic of J2000 with respect to the ICRS is defined by the angles:

$$\varepsilon^{(ICRS)} = 23° \, 26' \, 21.411\,00'' \pm 0.000\,05''$$
$$o^{(ICRS)}\gamma_I^{(ICRS)} = -55.4 \pm 0.1 \text{ mas}$$

By the same way, the position of the inertial dynamical ecliptic of J2000 can be obtained with respect to the reference frame linked to the mean Celestial Ephemeris Pole (CEP), noted here MCEP. In this case, we used another lunar solution, also issued from ELP2000-96 fitted to LLR data, where the precession-nutation is provided by analytical solutions: polynomial expressions of the precession and theory of nutation. Then, the position of the inertial dynamical ecliptic of J2000 with respect to the MCEP is defined by the angles:

$$\varepsilon^{(MCEP)} = 23° \, 26' \, 21.405\,64'' \pm 0.000\,09''$$
$$o^{(MCEP)}\gamma_I^{(MCEP)} = -14.6 \pm 0.2 \text{ mas}$$

From the 2 solutions linked to ICRS and MCEP, we also determine the correction Δp to the IAU 1976 precession constant and the value of the distance between the two inertial mean equinox of J2000 $\gamma_I^{(ICRS)}$ and $\gamma_I^{(MCEP)}$:

$$\Delta p = -3.02 \pm 0.03 \text{ mas/a}$$
$$\gamma_I^{(ICRS)}\gamma_I^{(MCEP)} = 44.5 \pm 0.4 \text{ mas}$$

Orbital parameters of the Moon and of the Earth-Moon barycentre have also been fit, in particular the tidal component of the secular acceleration of the lunar longitude Γ which is related to a decrease in the Earth's rotation rate and an increase of the length of the day. The most recent determination is:

$$\Gamma = -25.858 \pm 0.003 \text{ ''/cy}^2$$

Remarks:

- The uncertainties mentioned in the above evaluations represent formal uncertainties resulting from the least square fitting. Realistic uncertainties can be estimated between five and ten times these values.

- Usually $\gamma_I^{(MCEP)}$ is named the "inertial" dynamical mean equinox of J2000. The separation from $\gamma_I^{(MCEP)}$ to the "rotational" dynamical mean equinox of J2000 $\gamma_R^{(MCEP)}$ is 93.66 mas.

Jean Chapront, Michelle Chapront-Touzé, Gérard Francou

Staff

Souchay	Jean	Director	(OP)
Gaume	Ralph	Co-director	(USNO)
Arias	Felicitas	Assoc. Astronomer	(BIPM / OP)
Boboltz	David	Astronomer	(USNO)
Bouquillon	Sébastien	Post-doc	(OP)
Chapront	Jean	Astronomer	(OP)
Chapront-Touzé	Michelle	Astronomer	(OP)
Cognard	Ismaël	Astronomer	(LPCE Univ. Orléans / OP)
Damljanovic	Goran	Astronomer	(Univ. Belgrade)
Feissel-Vernier	Martine	Astronomer	(ENSG / OP)
Fey	Alan	Astronomer	(USNO)
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Gontier	Anne-Marie	Astronomer	(OP)
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3.5.5 ITRS Centre

ITRF Working Groups Activities

- Working Group on ITRF Datum: This group, chaired by Kristine Larson, continues its activities under a discussion forum between the members, essentially on the ITRF datum definition, in terms of rotational datum (sub-group chaired by Geoff Blewitt) and Geocentre Motion (sub-group chaired by Mike Watkins).
- Working Group on Local Ties: This group is created under the IAG/CSTG, chaired by Jim Long, taking over the activities of John Bosworth. Progress is made on documentation local survey specification as well as on new surveys on some collocation sites.

Relation With the IGS

The ITRS Centre 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 is developed and it is under its validation phase. This new Web site will provide site information, station positions (at any epoch) and velocities in any ITRF version in SINEX or/and table list.

Contribution to the IERS Workshop 2002

The ITRS Centre contributed to the IERS Workshop held in Munich in November 2002. A Position Paper (Altamimi et al., 2002) was prepared by the ITRS Centre with contribution from the ITRF CCs, Analysis Coordinator, chair of the Working Group on ITRF Datum and Jim Ray. The Position Paper was extensively discussed during its devoted session and focused mainly on combination of station positions and velocities. 9 recommendations were proposed and discussed regarding the Terrestrial Reference Frame datum definition, quality and distribution of collocation sites as well as future goals and improvement. These recommendations will be synthesized with the other Workshop recommendations in order to avoid redundancy and overlap.

For further information, see also the report of the ITRS Combination Centre at IGN (section 3.6.1.2).

Zuheir Altamimi, Claude Boucher, Martine Feissel-Vernier

3.5.6 Global Geophysical Fluids Center (GGFC)

Established by the International Earth Rotation Service (IERS) on January 1, 1998, the Global Geophysical Fluids Centre (GGFC) has the responsibility of supporting, facilitating, and providing services to the worldwide research community in areas related to the variations in Earth rotation, gravitational field and geocentre that are caused by mass transport in the geophysical fluids and the induced loading effects.

Under the GGFC, eight Special Bureaus (SB) were established. They are SB for Atmosphere, Oceans, Hydrology, Tides, Mantle, Core, Loading, and Gravity/Geocentre (see below). Angular momenta and the related torques, gravitational coefficients, geocentre shift, and surface loading deformation fields will be computed for all geophysical fluids based on global observational data, and/or products from state-of-the-art models some of which assimilate such data. The computed quantities, algorithm and data formats will be standardized. The data products are, and additional ones will be, archived and made available to the scientific research community.

During 2002, GGFC participated in the following activities:

The 2002 International Earth Rotation (IERS) Workshop on Combination Research and Global Geophysical Fluids was held in the Bavarian Academy of Sciences, Munich, Germany, November 18 – 21, 2002, participated by over 100 scientists. The GGFC portion was organized into 8 Special Bureau sub-sessions during two full days of intensive presentations and discussions, followed by an all-hands meeting discussing future prospects of GGFC.

A dedicated Geodesy special session, entitle “Geodesy at the Solid-Fluid Interface”, was held at the Fall AGU’2002 meeting, San Francisco, Dec. 9, 2002, co-chaired by R. Gross and C. Wilson. In addition to oral presentations, all 8 Special Bureaus of GGFC gave invited posters.

Two open GGFC “business” meetings were held in 2002:

April 24, 2002, Nice, France, during the European Geophysical Society General Assembly; and November 21, 2002, Munich, Germany, in conjunction with the 2002 IERS Workshop.

The Websites given in Appendix 4 contain detailed information of GGFC and the SBs, including description and availability of archived data, useful graphics, members/associates list, call for participation, planned activities, and bibliography, etc.

Detail reports from each SB follow.

Benjamin F. Chao

3.5.6.1 Special Bureau for the Atmosphere

In conjunction with the U.S. National Oceanic and Atmospheric Administration (NOAA), the SBAtmosphere has produced data from 4 different operational meteorological centres. We have also produced data from atmospheric reanalyses, spanning back to 1948. SBAtmosphere organized a system to operate in two modes. In the first, it supplies the data in near-real time through the service at NOAA, including analysis and forecast terms. In the second mode, it updates monthly archives of the data on the FTP server at the Atmospheric and Environmental Research, Inc. (AER).

The principal data prepared relate to atmospheric excitations of Earth rotation vector, as forced by changes in the winds and surface pressure of the atmosphere, known respectively also as the motion and mass terms of the atmospheric angular momentum AAM. For the axial component, related to length of day, the stronger term is the motion one, and for the equatorial term, related to polar motion, the mass term dominates. An "inverted barometer" correction is produced to the mass terms, designed to model an equilibrium condition of the oceans in which the ocean depresses in response to a higher atmospheric pressure and rises in response to a lower one.

SBAtmosphere also computes the AAM terms locally, in a number of equal-area sectors distributed around the globe, as well as globally. In addition, SBAtmosphere computes the mean atmospheric surface pressure over the globe, and various spherical harmonics, which are related to the Stokes coefficients of the Earth gravity field. SBAtmosphere archives torques from the NCEP-NCAR reanalyses that relate to the angular momentum transfer from atmosphere to solid Earth, including topographic (mountain), friction (stress) and gravity wave drag torques. Users log in to our ftp sites to obtain the desired information.

David A. Salstein

3.5.6.2 Special Bureau for the Oceans

Introduction

The oceans have a major impact on global geophysical processes of the Earth. Nontidal changes in oceanic currents and ocean-bottom pressure have been shown to be a major source of polar motion excitation and also measurably change the length of the day. The changing mass distribution of the oceans causes the Earth's gravitational field to change and causes the centre-of-mass of the oceans to change which in turn causes the centre-of-mass of the solid Earth to change. The changing mass distribution of the oceans also changes the load on the oceanic crust, thereby affecting both the vertical and horizontal position of observing stations located near the oceans. As part of the IERS Global Geophysical Fluids Centre, the Special Bureau for the Oceans (SBO) is responsible for collecting, calculating, analyzing, archiving, and distributing data relating to nontidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocentre. The oceanic products available through the IERS SBO web site at <http://euler.jpl.nasa.gov/sbo> are produced primarily by general circulation models of the oceans that are operated by participating modeling groups and include oceanic angular momentum, centre-of-mass, and bottom pressure.

Data Products

The data sets currently available through the IERS SBO web site are: (1) two different oceanic angular momentum (OAM) series, namely, ponte98.oam which spans 1985–1996 at 5 day intervals, and johnson01.oam which spans 1988–1997 at 3 day intervals; and (2) two different oceanic centre-of-mass (COM) series, namely, dong97_mom.com and dong97_micom.com, both of which span 1992–1994 at 3 day intervals but which are produced by different ocean models. In addition, a link is provided to the Estimating the Circulation and Climate of the Ocean (ECCO) web site at <http://ecco.jpl.nasa.gov> from which two different ocean-bottom pressure data sets can be obtained, both of which are given at 12-hour intervals but with one spanning 1993 to the present produced by a data-assimilating ocean model and the other spanning 1980 to the present produced by an ocean model that does not assimilate any data. A link is also provided to the GLObal Undersea Pressure (GLOUP) data bank of ocean-bottom pressure measurements at <http://www.pol.ac.uk/psmslh/gloup/gloup.html>. A subroutine to compute oceanic angular momentum, centre-of-mass, and bottom pressure from the output of general circulation models can also be downloaded from the IERS SBO web site along with a bibliography of related articles.

Richard Gross

3.5.6.3 Special Bureau for Tides

The IERS Special Bureau for Tides collects datasets related to the effects of tides on Earth rotation and geocentre motions. Like the other special bureaus of the GGFC, the Bureau for Tides generates most of its own product datasets by analyzing the results of numerical computer models of the relevant geophysical fluids, in this case of both ocean tides and atmospheric tides. For example, as more realistic numerical hydrodynamic models of ocean tides are developed, the Bureau endeavors to obtain the tidal elevation and current velocity data from these models and to determine and tabulate the implied Earth-rotation effects. The data archive that the Bureau maintains has slowly grown as individual tidal investigators contribute their modeling results.

During 2002 most activity was devoted to obtaining updated models of diurnal and semidiurnal ocean tides and to deducing the tidal angular momentum from atmospheric circulation models. Efforts have also been devoted to improving models of the small long-period ocean tides (periods between 5 days and 18.6 years). Particularly noteworthy is the recent improvement in models of the fortnightly tide Mf, where clear phase lag differences are seen between the Atlantic and Pacific Oceans. Atmospheric tide estimates have been deduced from the products of several meteorological centres, and it appears that recent operational models produce more accurate tidal signals than do reanalysis products. The Earth-orientation predictions from these improved models will be computed and released over the coming year.

The data collected by the Special Bureau are publicly available via the internet. The web site of the Special Bureau (<bowie.gsfc.nasa.gov/ggfc/tides>) continues to see a slow but steady growth in the number of “hits” per day. The figure below shows the daily hits on one particular web page during October 2002. (This particular web page is the site’s tutorial page that presents an introductory overview of the effects of tides on Earth rotation.)

Richard D. Ray

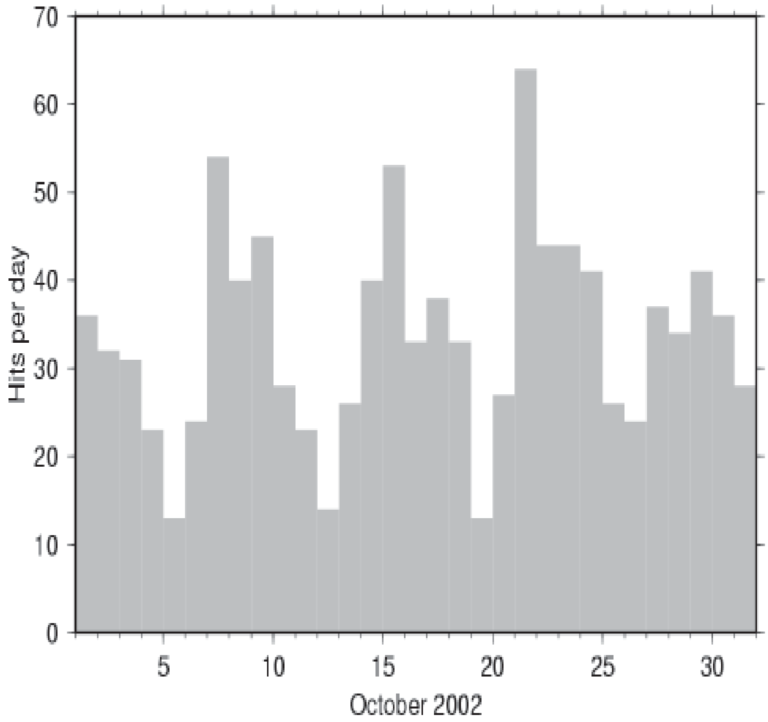

Fig. 1: Number of unique daily hits on one particular page of the Special Bureau for Tides web site during October 2002. The minima all occur on Saturdays. Highest activity occurs either Tuesdays or Mondays.

3.5.6.4 Special Bureau for Hydrology

The Special Bureau for Hydrology provides internet access to data sets of water storage load variations for all land areas of the world. The web site contains results from two numerical models. The NCEP (National Center for Environmental Prediction) reanalysis model is a fixed data-assimilating global numerical model, designed mainly for atmospheric studies. It has been run for a period exceeding 50 years, starting in 1948. The hydrologic part of this model is primitive, and reflects a combination of an imposed (non data-assimilating) hydrologic cycle, and some interaction with the atmosphere and climate. The NCEP hydrologic time series and load variations are probably representative of real Earth variations, but probably not accurate in detail. Notably, they lack the level of interannual variability expected in the real hydrologic cycle. In addition, there are evident flaws over Antarctica and Greenland, and we interpret these in part to be a combination of sea ice and land ice. While sea ice is not significant geodetically, because it is part of the oceans, its appearance in the gridded files means that we must exclude Antarctica and Greenland from geodetic calculations. Nevertheless, the NCEP results are valuable for their global coverage and long duration. The web site includes daily NCEP water storage in Gaussian grid (T62) form for 1979–2001. In addition NCEP CDAS-1 monthly results are available for 1993–1998 for a 1 x 1 degree grid format, and there are daily excitations for polar motion and length of day for 1948–2001, as well.

The other model results are from ECMWF (European Center for Medium Range Weather Forecasting), a data-assimilating reanalysis model, similar to NCEP, also with a surface hydrologic cycle. We find that it appears more realistic than NCEP, showing greater interannual variability. In addition, its seasonal cycle resembles long-term average results based on local budget (Precipitation, Evaporation, Runoff) calculations. The web site includes 2.5 degree gridded values at daily intervals for the period 1979–1993.

At the moment there is no test on a global scale of the accuracy of either NCEP or ECMWF results. Estimates from both NCEP and ECMWF models are derived from atmospheric general circulation models, and lack primary data (such as river discharge and actual precipitation) to constrain their results. We are communicating with other data centres (notably NASA) and have acquired a new data-assimilating hydrologic model gridded time series. The assimilated data in the NASA model is largely from remote sensing, and not primary observations of precipitation or river discharge. We are currently processing and analyzing a 15 year series 1979–1993 from the NASA GSFC land surface model (LSM), sampled every 3 hours on a 2 x 2.5 degree grid. In addition, we plan to process the newly released 50-year (1950–1999) monthly terrestrial water budget (soil moisture and snow) data provided by Willmott's group at the University of Delaware. The LSM and Willmott gridded data will be available on the SBH homepage in similar formats as those of the NCEP and ECMWF data.

Clark R. Wilson

3.5.6.5 Special Bureau for the Mantle

As with any geophysical processes that involve mass transports, large-scale motions in the mantle produce variations in Earth's rotation, gravity field, and geocentre. Among them, however, currently only two topics have been extensively investigated:

(1) The co-seismic effects on various geodynamic parameters, including low-degree gravitational Stokes coefficients, Earth rotation parameters (length-of-day and polar motion excitation), and Earth's moments of inertia changes. They are shown as cumulative effects for 19,050 earthquakes spanning Jan 1977 through May 2002. The computation is based on Chao & Gross, 1987 (Chao, B. F. and Gross, R. S., Changes in the Earth's rotation and low-degree gravitational field induced by earthquakes, *Geophys. J. Roy. Astron. Soc., 91,* 569-596, 1987) using the centroid-moment tensor solutions of all major earthquakes larger than magnitude 5 as published in the Harvard CMT catalogue.

(2) Post-glacial rebound, or glacial isostatic adjustment (GIA) modelling output from Erik Ivins (JPL). This set of data consists of graphics and spherical harmonic geopotential rates complete through degree 12 for each of three different cases. The geopotential rates are provided as a function of the lower mantle viscosity ranging from 10^{21} to 10^{23} Pa-sec. The first case uses ICE3G and a standard (Tushingham and Peltier, 1991) Earth model. The second case has an upper mantle viscosity of 3.2 x 10^{20} Pa-sec (Johnston and Lambeck, 1999) and lithosphere thickness = 80 km. The third case has a fixed deepest mantle (CMB to 650 km above) viscosity at eta = 7 x 10^{22} Pa-sec, variable mantle viscosity from 650 km above the CMB to the 670 km seismic discontinuity, an upper mantle viscosity of 5 x 10^{20} Pa-sec and a lithospheric thickness of 100 km. Also posted are a set of GIA modelling data from Prof. Richard Peltier (University of Toronto). This set consists primarily of the graphics from chapter 4 in the recent book “Sea Level rise: History and Consequences” (ed. B. Douglas, M. Kearney, and S. Leatherman, Academic Press, San Diego, 2001).

Further improvements of the GIA models and other parallel model output from other authors are to be surveyed and incorporated. Also under preparation is a model scenario of the mantle tectonic movements and resultant geodynamic effects over geological timescales by M. Greff-Lefftz (IPGP).

Benjamin F. Chao

3.5.6.6 Special Bureau for the Core

Flow in the fluid outer core, and also motion of the inner core with respect to the outer core, can result in various geodetic phenomena observable from the Earth's surface or space. These phenomena include variations in the Earth's rotation and orientation, surface gravity changes, geocentre variations, and surface deformations. Although small, these variations can or could be observed by very precise space geodetic techniques. Observation of these effects yields unique insight into the core, which cannot be observed directly, and the resulting better understanding of the core will lead to improved models and predictions for the geodetic observables. The Special Bureau for the Core is responsible for collecting, archiving, and distributing data related to the core and plays a role in promoting and coordinating research on this topic. In particular, the SBC focuses on theoretical modelling and observations related to core structure and dynamics (including the geodynamo), and on inner core – outer core – mantle interactions. The SBC has about twenty members from the fields of geomagnetism, Earth rotation, geodynamo modelling (numerical and experimental), and gravimetry.

The SBC has set up a web site (<www.astro.oma.be/SBC/main.html>) as the central mechanism for providing services to the geophysical community. The web site presently contains nine different sets of model data on core flow and core angular momentum. The data are based on the observed surface geomagnetism field, and various hypotheses and physical assumptions are used to determine the flow and the angular momentum of the core. The core flows and angular momentum variations are all very similar and agree remarkably well with the observed decadal LOD variations. In addition to the data, a description is given of the relevant theories and of the dynamical assumptions used for constructing the flows.

A further goal of the SBC is to distribute general information on the core, to make the geophysical community aware of the various geodetic effects that could be linked with the core, and to stimulate, support and facilitate core research. We therefore present on our website concise explanations on topics as core convection, core flow, geomagnetism, core-mantle boundary torques, inner core differential rotation, Earth's rotation changes due to the core, and core composition. Additionally, we have built and continuously update a bibliography of articles relevant to the core that at present contains more than a thousand references.

Within the multidisciplinary spirit of the SBC, a book has been prepared by V. Dehant, K. Creager, S. Karato, and S. Zatman (eds.) and published in December 2002 by the American Geophysical

Society as “Earth’s Core: dynamics, structure, rotation”. In July 2002, the chair of the SBC was turned over from V. Dehant to T. Van Hoolst.

Members

Dehant, Veronique[1] (Chair until June 2002)
Van Hoolst, Tim[1] (Chair since July 2002)
and by alphabetic order
Cardin, Philippe[2]
Chulliat, Arnaud[3]
Defraigne, Pascale[1]
de Viron, Olivier[1]
Dormy, Emmanuel[3]
Greff-Lefftz, Marianne[3]
Hinderer, Jacques[4]
Holme, Richard[5]
Hulot, Gauthier[3]
Jackson, Andrew[6]
Jault, Dominique[2]
Kuang, Weijia[7]
Legros, Hilaire[4]
Le Mouel, Jean-Louis[3]
Noir, Jerome[2]
Pais, Alexandra[8]

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[3] Institut de Physique du Globe de Paris (IPGP), Laboratoire de Géomagnétisme, France
[4] Ecole et Observatoire de Physique du Globe de Strasbourg (EOPGS), France
[5] University of Liverpool, United Kingdom
[6] School of Earth Sciences, University of Leeds, United Kingdom
[7] Goddard Space Flight Center (GSFC), USA
[8] University of Coimbra (UMBC), Portugal

Tim Van Hoolst and Véronique Dehant

3.5.6.7 Special Bureau for Gravity/Geocenter

Web site

A major redesign and upgrade of the SBGG website began in October 2002 to be completed in the first quarter of 2003. At that time, the additional datasets described below will be included.

Gravity

During 2002, most of the attention of the SBGG staff was dedicated to GRACE mission data analysis, archiving, and documentation. Recall that the SBGG website will serve as a portal for access to the GRACE Level-1 data and Level-2 gravity field products archived at the Physical Oceanography Distributed Active Archive Center and at the GeoForschungsZentrum Potsdam. The SBGG will provide not only links to these archives, but provide a forum for understanding the formats and standards of the data products, provide access to gravity solutions from other satellites including CHAMP and the SLR satellites, and links to access the geophysical data needed to interpret these changes. SBGG staff have continued to contribute significantly to the preparation of GRACE Product Specification Document and the User Guide, which will be made publicly available in early 2003.

In addition, the SBGG staff have been heavily involved in setting up the systems that generate gravity dealiasing products for GRACE (and CHAMP) data analysis. These dealiasing products involve the generation of time series of gravity changes due to the atmosphere, nontidal ocean mass changes, and ocean tides. Currently, for a variety of reasons, these products are not the same as those produced in the other IERS Geophysical Fluids special bureaus. In 2003, we intend to work with the IERS to understand if merging these activities is feasible.

Concurrent with the launch of the new website, and recognizing the renewed interest in the SLR-based determination of the Earth's oblateness due to the apparent anomalous changes beginning in the late 90's, a new call for SLR-based J-even and J-odd time series will take place. We encourage all solution providers to actively participate in making solutions available to the analysis community through the SBGG website.

Geocenter

After some years of reduced community interest in the geocenter relative to gravity, there has been recent increased interest due both to renewed recognition that of its critical role in reference frame definition, and to a series of papers with alternate methodologies for tracking degree one changes in the Earth through loading effects. Based on a number of internal discussions in 2002, the SBGG has decided, with strong support from the IERS, to significantly increase activities in this area in 2003.

Michael M. Watkins

3.5.6.8 Special Bureau for Loading

On 1 February, 2002 the Special Bureau for Loading (SBL) was formally established. Eventually, the SBL is expected to provide in near real-time a consistent global solution data set describing the surface deformation, gravity signal and geocentre variations due to various surface loading processes, in reference frames relevant for direct comparison with existing geodetic observing techniques.

The accuracy of the products provided through the SBL should, as much as model limitations allow, match the precision of the space-geodetic and gravimetric observing techniques. Achieving this ambitious goal requires major scientific advances with respect to the earth model, the theory and the algorithms used to model deformations of the earth and improvement of the surface loading data themselves. Consequently, a scientific agenda has been established to perform the research necessary for the improvement of the models and algorithms, in parallel with an operational agenda which is directed towards establishing a service which provides validated loading products to the IERS community.

SBL has made significant progress during this year to attain the goal of becoming operational. We have addressed a number of issues related to determining loading products from variations in atmospheric mass. (For more information please download a copy of the SBL position paper). The knowledge gained from this research will allow us to implement new surface loading data sets and produce the appropriate products more quickly.

One major accomplishment of the SBL this year, was the creation of the web site (<http://www.gdiv.statkart.no/sbl/>). A mirror site will be established soon. We expect to have the historical loading effects (1995 - 2002) computed using the NCEP Reanalysis data on the web by June 2003. Results from the ECMWF data set will immediately follow.

Tonie van Dam and Hans-Peter Plag

3.6 Combination Centres
3.6.1 ITRS Combination Centres
3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

Background and major activities

The work of the ITRS Combination Centre (ITRS CC) at DGFI is being funded by the Geotechnologien-Projekt of the German BMBF (Bundesministerium für Bildung und Forschung), Verbundprojekt: FE: IERS, Forschungsvorhaben: 03F0336C. The activities are closely related to the IERS Combination Research Centre at DGFI (see 3.6.2.2, this issue). This ensures that the state-of-the-art combination strategies, algorithms, software packages, etc. can be applied for the computation of the ITRS products.

This report summarizes the activities of the ITRS CC during the year 2002. They can be divided into two major topics:

- Software enhancement and further developments of the combination procedure of the ITRS CC;
- Data analysis and computation of a combined TRF solution.

Software enhancement and further developments of the ITRS CC

During the year 2002 a major part of the work was related to further developments of the ITRS Combination Centre, including software enhancement, refinements of the combination methodology, further automation of the processing and data flow, as well as improvements of tools and software for quality control and validation of the combination results. The combination procedure, the processing flow and the relevant software packages are shown in Figure 1.

The relevant software and tools of the ITRS Combination Centre can be structured in two parts:

- Validating, unconstraining and reformatting software:
  - SNXCHK: Checking of SINEX files
  - SNX2DOGS: Reformatting of SINEX format into DOGS format and generation of unconstrained (free) normal equations
  - DOGS2SNX: Reformatting of DOGS into SINEX format
- Relevant packages and modules of the software DOGS (DGFI Orbit & Geodetic Parameter Estimation Software):
  - DOGS-AS (**A**nalysis of **S**olutions): This program package delivers tools for the analysis of individual and combined space technique solutions and/or normal equations (e.g. rank defect analysis, deconstraining normal equation matrices, variance component estimation for inter-technique combination).
  - DOGS-CS (**C**ombination & **S**olution): This software package consists of various programs to combine and solve normal equation systems obtained from the same and/or different observation types (e.g. VLBI, SLR, GPS, DORIS). DOGS-CS enables a number of features for the combination of space geodetic data and/or solutions (e.g. elimination or reduction of param-

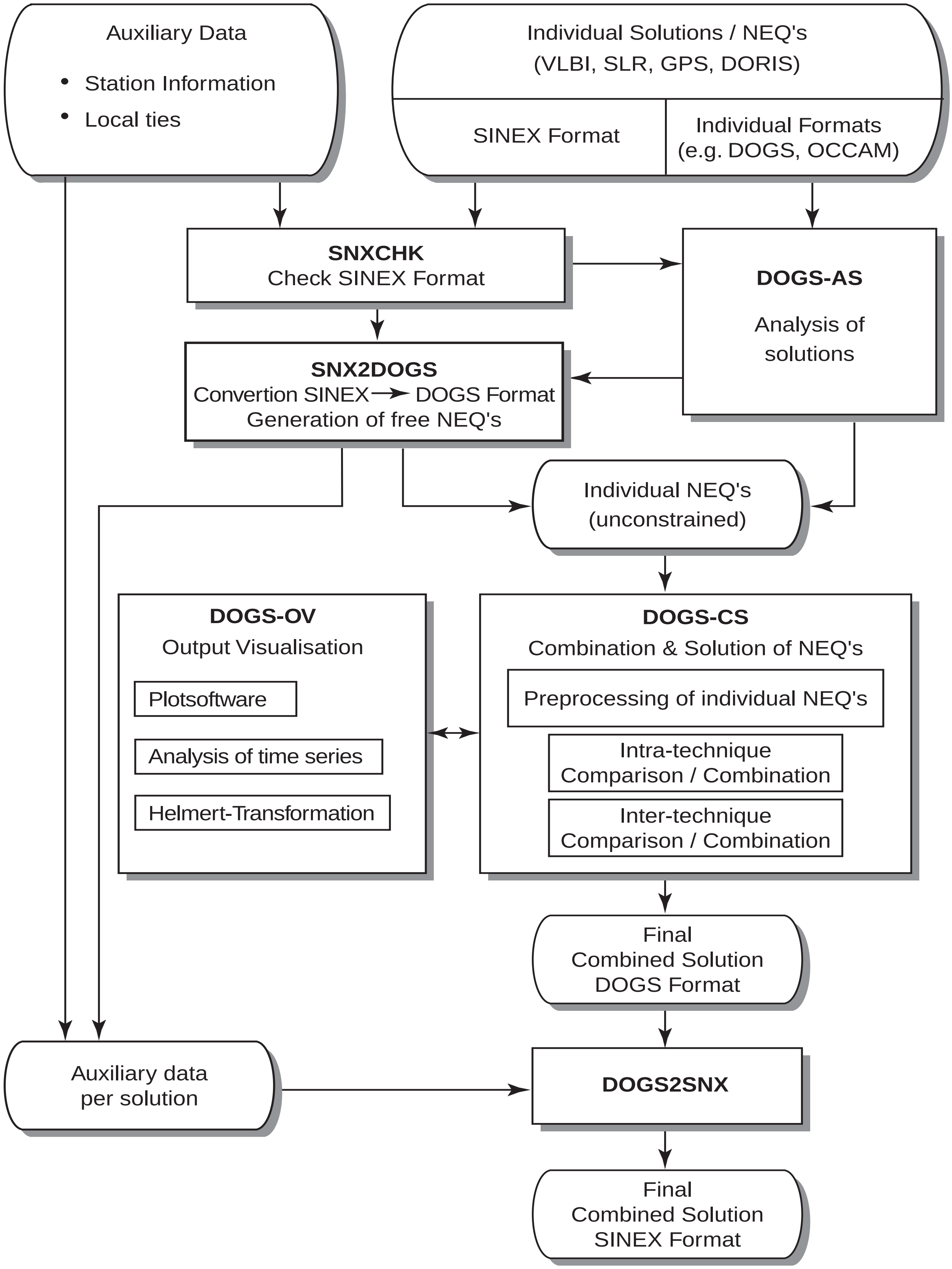

Figure 1: Data flow and combination procedure of the ITRS Combination Centre at DGFI.

eters, equating parameters, parameter transformations, flexible handling of local tie information and datum conditions).
- DOGS-OV (**O**utput **V**isualisation): This software package consists of various programs and tools for the analysis, validation, quality control and graphical representation of the combination results (e.g. Helmert transformation, plot software, analysis of time series).

The combination methodology of the ITRS Combination Centre at DGFI is based on the following major steps (see Figure 1):

- Validation and analysis of individual solutions: The available solutions are checked concerning various aspects, such as format and the suitability for a rigorous combination.
- Reconstruction of unconstrained (free) normal equations: According to our combination strategy on the level of free normal equations we have to remove the datum constraints which are applied to the solutions.
- Preprocessing of individual solutions: For some of the input solutions it may be necessary to perform preprocessing, e.g. transformation of a particular solution (normal equation) to the reference epoch of the combined solution, a-priori reduction of stations with very poor observations (e.g. < 1 yr), which should not be included in the TRF computation.
- Intra-technique comparison/combination: The input for it are individual unconstrained normal equations of the same observation techniques. Before combining them, a dedicated comparison is essential to identifiy possible problems, which could cause systematic effects (biases) onto the combined result. Unremovable datum biases are overcome by introducing Helmert parameters for the individual solution. In order to generate comparable individual and intra-technique solutions we define the datum for each of them in a consistent way by applying minimum constraints. Other important tasks are the computation of relative weighting factors for the individual solutions and the identification and reduction of outliers. Finally, the individual normal equations are added by applying the previously estimated relative weighting factors.
- Inter-technique comparison/combination: The input for it are the combined intra-technique normal equations (unconstrained) resulting from the previous processing step. Similar to the intra-technique case, a dedicated comparison of the solutions of the different techniques (especially at colocation sites) is necessary to identify possible problems. Other important tasks include the estimation of relative weighting factors (e.g. variance component estimation), handling of local ties, equating velocities of different occupations and/or techniques on the same

site, and the datum definition. The combined intra-technique normal equations are added by applying relative weighting factors between the different techniques. The resulting free normal equations are completed by pseudo-observation equations for local ties and for equating velocities (at one site).

- Final combined solution: To generate the final combined solution we add datum conditions and invert the resulting normal equation system. We define the geodetic datum by no-net-rotation conditions for the orientation and its rate with respect to ITRF2000 station positions and velocities. The origin (translation and their rates) is defined by SLR, and the scale and its rate by SLR and VLBI. Currently, we do not use GPS and DORIS solutions to define the datum of the combined solution.

Data analysis and computation of a combined TRF solution

The purpose of that exemplary TRF solution was the verification of our combination procedure. We used a number of multi-years solutions with station coordinates and velocities, e.g. input solutions submitted by several analysis centres for ITRF2000 computation (see <http://lareg.ensg.ign.fr/ITRF/ITRF2000/submissions.html>). Based on various criteria we performed a pre-selection of all these available solutions, and in addition we included some newer solutions containing more recent observations. According to our combination strategy (see Figure 1) several steps were performed (e.g. checking of individual solutions, removing constraints, reformatting from SINEX into DOGS format, reduction of stations with too few observations, epoch transformations for some of the solutions), before the individual normal equations (unconstrained) could be used for the intra-technique and/or inter-technique combination, and for the computation of the final combined TRF solution. A detailed description of the combination methodology, a summary of the results of this TRF computation and external comparisons (e.g. with ITRF2000) will be published soon.

Status and recommendations for the future

From our experiences regarding the analysis and combination of space geodetic observations we identified a number of deficiencies regarding current ITRF realizations, e.g.:

- One serious problem of the combination is the reduction of a-priori datum constraints which normally are included in the solutions.
- Systematic differences (biases) between different techniques and/or solutions are considered as one major limiting factor for the accuracy of the combined solution.
- The position time series reveal non-linear motions for a large number of sites, which are inconsistent with the conventional ITRF realization adapting cartesian coordinates and constant velocities for all IERS sites.
- Several stations are observed over short time intervals or in

early times of space geodesy (the eighties) only. Their inclusion does not only yield bad coordinates and velocities of the particular stations but might deform the network by systematic effects.

Recommendations for future ITRF realizations:

- To overcome the problems concerning the reduction of constraints, we recommend for future ITRF submissions, that unconstrained normal equations in addition to/or instead of solutions with variance-covariance matrices should be provided.
- Another important issue is to investigate the existing inconsistencies between different techniques and/or solutions regarding various aspects (e.g. modeling, parameterization, datum definition, analysis strategy) and to identify their origin.
- For the definition of the kinematic datum of the ITRF we propose to use kinematic models based on geodetic observations (e.g. APKIM) instead of geophysical models (e.g. NNR NUVEL-1A) to ensure that the no-net-rotation condition is more accurately fulfilled.
- The assumption of constant site velocities is not true in reality, since several geophysical phenomena may vary as a non-linear function of time (e.g. seismic or volcanic effects, deformations at plate boundary zones, local effects). Therefore, alternative – and probably more realistic – representations for the time evolution of the ITRS should be developed (e.g. time series of station positions).

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3.6.1.2 Institut Géographique National (IGN)

The IGN ITRS Combination Centre and the IGN Combination Research Centre concentrate their activities 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.

Data analysis and Software enhancement

With interaction between IGN ITRS CC and Technique Centers as well as their individual Analysis Centers (AC), individual VLBI, SLR, GPS and DORIS solutions are frequently evaluated and tested, in order to improve the individual analyses as well as the ITRF combination. Thus both the individual ACs as well as the IGN ITRS CC regularly test new analysis strategies. This cooperation between the individual ACs and the ITRS Center is vital for quality control and improvement of IERS products. To achieve this goal, the software package Combination and Analysis of Terrestrial Reference Frames (CATREF), developed by the ITRS Center, is regularly updated and enhanced in order to perform proper analysis of the different solutions performed by the ACs. In particular modeling of the Earth Orientation Parameters (EOP) is now included in the CATREF software, to be able to combine concisely and coherently station positions/velocities and EOPs.

Contribution to the IERS Workshop 2002

The contribution of our centre to the IERS Workshop was concentrated on multi-technique combination of time series of station positions and Earth Orientation Parameters. Time series of TRF and EOP solutions for the year 1999 submitted to the SINEX combination campaign were analysed:

- SLR: ILRS Pilot Project Monthly Solutions provided by ASI, CSR, DGFI and JCET analysis centres
- GPS: IGS weekly combined solutions
- VLBI: GSFC and BKG 24h-session SINEX files
- DORIS: IGN/JPL weekly solutions

The strategy adopted for TRF and EOP time series analysis is basically to:

- Apply minimum constraints equally to all loosely constrained solutions (all SLR solutions)

- Use as they are the minimally constrained solutions (GPS, VLBI, DORIS)
- Perform per-technique combinations (TRF + EOP), all expressed in ITRF2000 using equations of minimum constraints
- Combine the per-technique combinations adding Local ties
- Estimate variance components and iterate as necessary

Figure 1 illustrates the polar motion post fit residuals, per technique, as result from the combinations for the year 1999.

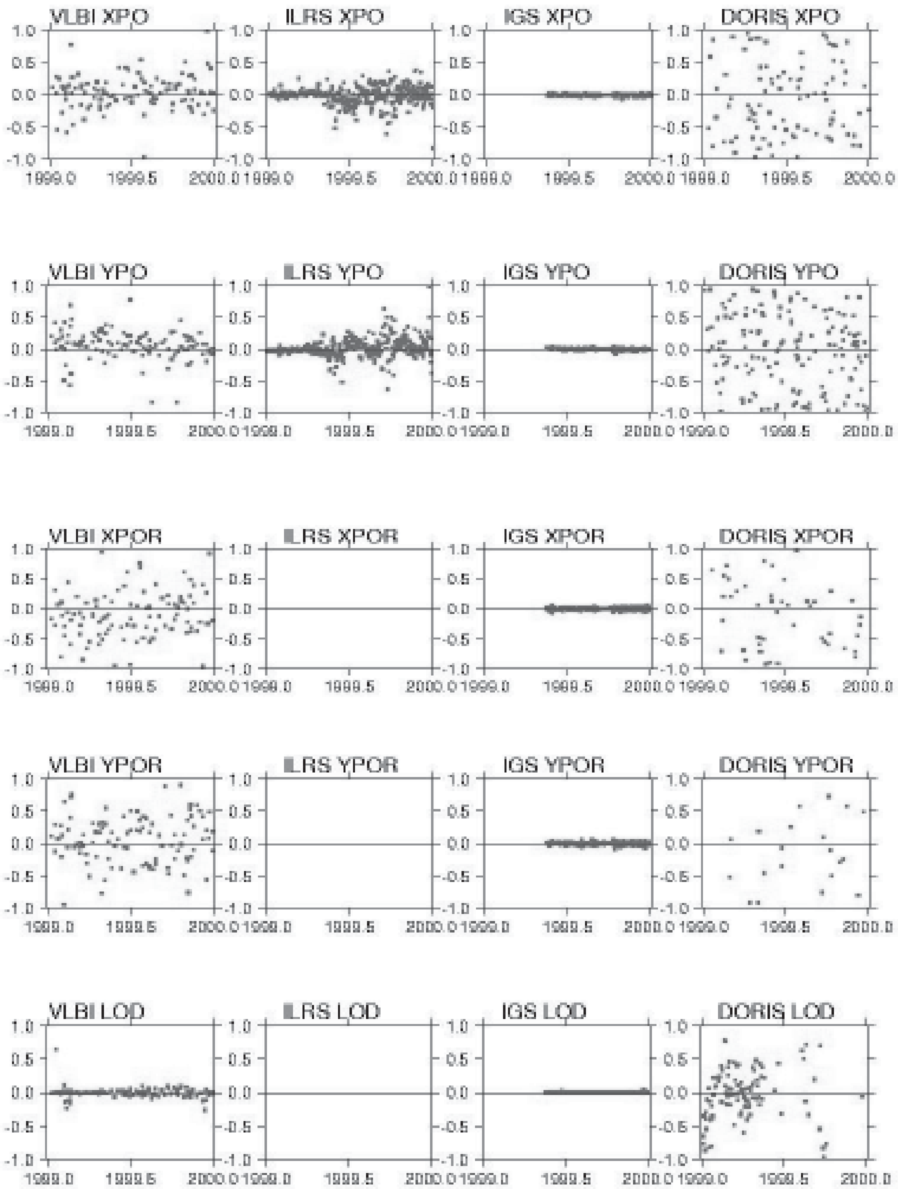

Figure 1: Post fit residuals as results from 1999 TRF and EOP multi-technique combination

For further information, see also the report of the ITRS Centre at IGN (section 3.5.5).

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Zuheir Altamimi, Claude Boucher, Martine Feissel-Vernier, Patrick Sillard

3.6.1.3 Natural Resources, Canada (NRCan)

NRCan is an ITRS Combination Centre for the International Earth Rotation Service (IERS). The IERS objective for the TRF combination project is to have independent combinations of the TRF realizations thus providing some quality control. Since the late 1980's, IGN has been the sole agency responsible for determining the ITRF realizations. At NRCan, the capability to combine GPS solutions has been developed. Extending this capability to combine solutions containing station coordinates and velocity determined with the DORIS, GPS, SLR and VLBI techniques, was a natural step forward.

The recent work related to the ITRF combination was mainly dedicated to solution analysis and software upgrades. In principle, all contributing solutions are combined simultaneously to generate the final solution. The data combination is currently done using a two-step procedure. In the first step, the solutions within each technique are combined. In the second step, all the intra-technique solutions obtained in the first step are combined to generate the final solution. This approach has been chosen because it is less demanding on the available resources, namely, existing software is usable with minimal upgrade requirements. Splitting the combination activities, however, introduces some approximations.

In the intra-technique combination, the following activities are performed: 1) standardization of the solutions to a consistent "flavour" of SINEX; 2) removal of the constraints and rescaling of the covariance (iterative); 3) removal of the outliers (also iterative); 4) alignment of all solutions to a reference using 14 or less transformation parameters (rotation, translation, scale & rates) as appropriate; 5) combination (addition of normals); 6) analysis of the results. For a few solutions, the removal of the constraints caused a significant degradation of the relative station coordinates/velocities. In some cases it is not possible to remove the a-priori constraints, suggesting some incompatibilities between a-priori and estimated matrices for some solutions. Numerical problems are also not ruled out. Some intra-technique combinations are almost ready.

During the second step, the results from the first step are combined along with the local ties. The ties at each site are allowed 3 degrees of freedom in translation (TX, TY, TZ) during the adjustment. The combined solution currently includes the DORIS, GPS, SLR and VLBI. The 3-D RMS of the residuals vary from 8 mm to 29 mm in position, and from 2 to 9 mm/y in velocity. The realization of the origin (SLR), scale and rate (VLBI & SLR), orientation and rates (ITRF97 & NNR) needs further investigation and should be further resolved as the intra- and inter-technique combinations are integrated. Table 1 summarizes the 3-D RMS statistics for each technique after the intra- and inter-technique combinations. In the intra-technique columns, the RMS residuals are between each solution and the combined intra-technique solution. Similarly, the inter-technique RMS are between the technique combination and the inter-technique combination. Position RMS are determined from the position residuals at the minimal position variance. In the table, the GPS-D technique refers to the GPS densification solutions. Since in this case there is little or often no overlap between the solutions, they were compared to the IGS combined solutions to extract meaningful statistics; those solutions haven't yet been included in the inter-technique combination. There were also two (GRIM5, CSR) multi-techniques solutions. Those haven't been included yet.

Table 1: 3-D RMS position and velocity statistics for the intra-technique and inter-technique combinations.

	Intra-technique		Inter-technique	
Techniques	Position 3-D RMS (mm)	Velocity 3-D RMS (mm/y)	Position 3-D RMS (mm)	Velocity 3-D RMS (mm/y)
DORIS	35	11	33	10
GPS-D	8	6	-	-
GPS	13	6	4	2
Multi	-	-	-	-
SLR	26	10	24	5
VLBI	16	2	6	3

A few more iterations of the combination process are needed to produce the final solution. Analysis of the quality and consistency of the origin and scale determinations also remain to be done. Comparisons with the official ITRF 2000 will also be performed.

Remi Ferland

3.6.2 Combination Research Centres

3.6.2.1 Astronomical Institute, Academy of Sciences of the Czech Republic, and Department of Geodesy, Czech Technical University, Prague

Introduction

The CRC works principally in two different directions that would hopefully converge to a single combination method in future. On the one hand, we combine some of the Earth Orientation Parameters using the 'combined smoothing' algorithm that we recently proposed, without changing the underlying reference frames (terrestrial, celestial). On the other hand, we follow the direction of combining particular solutions of different techniques for the simultaneous determination of EOP and station coordinates.

Combination of EOP only

The algorithm used in 2001 was further improved – GPS observations of length-of-day and celestial pole offset rates proved to suffer from long-periodic (30 days and longer) systematic errors, most probably due to orbit mismodeling. Therefore the calibration of GPS against VLBI becomes necessity on these time scales, prior to their combination. The new algorithm was used to combine Universal time observed by VLBI (IVS) with length-of-day changes observed by GPS (IGS) in the interval 1999.0 – 2002.0, and to combine the celestial pole offsets by VLBI (IVS+ IERS C04) with their rates by GPS (CODE) in the interval 1994.3 – 2000.4 (Vondrák & Ron 2002a). Later on, when more recent celestial pole offset rates from CODE were obtained, the latter study was repeated on a longer time span (1994.3 – 2002.0) and the solution was compared with the new IAU model of precession-nutation (Vondrák et al. 2003). The agreement is on the level of 0.2 mas, the dominant difference between the two series having the period of about 450 days (free core nutation). Finally, when a more recent IVS combined solution appeared (in September), it was used to repeat both combinations (i.e. UT1/LOD and celestial pole offsets/rates) with GPS in the interval 1994.3 – 2002.0 (Vondrák & Ron 2002b). It is demonstrated that the *a priori* and *a posteriori* uncertainties are almost equal for both methods of observation when UT1 is combined with LOD. However, it is not the case of combining celestial pole offsets/rates – in case of GPS the *a posteriori* uncertainties are about two times larger than the *a priori* values.

Combination of EOP and station coordinates

We continued in developing a method for combining non-sinex data to obtain simultaneously station coordinates and Earth orientation parameters. The method is based on combining position vectors of the stations as obtained from different techniques, in the celestial reference frame. Input EOP are referred to a single epoch so that celestial pole offset cannot be separated from polar motion. Thus, two auxiliary fictitious "observations" shifted by

±6 hours from the basic epoch should be introduced to separate the unknowns.

The tie between EOP at different epochs is realized by introducing constraints (assured by means of special “condition” observation equations) whose weights can control smoothness of the result. The combination was stabilized substantially by deriving transformation parameters of individual input solutions rather than increments to the individual station coordinates, in addition to the constraint of no-net rotation. Sample tests show that dispersion of station coordinates decreases by 40-50% after adjustment (Kostelecký & Pešek 2002).

Staff

Astronomical Institute:
Dr. Jan Vondrák (Primary scientist)
Dr. Cyril Ron
Department of Geodesy:
Prof. Jan Kostelecky (head of CEDR)
Dr. Ivan Pesek
Prof. Ales Cepek (Department of Mapping and Cartography)

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Jan Vondrák, Cyril Ron, Jan Kostelecký, Ivan Pešek

3.6.2.2 Deutsches Geodätisches Forschungsinstitut (DGFI)

Background and research activities

Within the Forschungsgruppe Satellitengeodäsie (FGS), DGFI cooperates with GIUB (Geodätisches Institut, University Bonn, Germany) and FESG (Forschungseinrichtung Satellitengeodäsie, Technical University of Munich, Germany) in a joint IERS Combination Research Centre (CRC). The work is done in close cooperation with the GFZ (GeoForschungsZentrum Potsdam, Germany). The major activities are being funded by the Geotechnologien-Projekt of the German BMBF (Bundesministerium für Bildung und Forschung), Verbundprojekt: FE: IERS, Forschungsvorhaben: 03F0336C. The work of the CRC at DGFI is closely related to the ITRS Combination Centre (see 3.6.1.1, this issue).

The research activities of the CRC at DGFI during the year 2002 can be divided into four major topics:

- Investigations related to ITRF relevant issues
- Studies related to variance component estimation
- Intra-technique combination within ILRS
- Contributions for the IERS SINEX Combination Campaign

ITRF related investigations

In relation with the ITRS Combination Centre at DGFI we performed various investigations related to ITRF relevant issues, including:

- Analysis of individual multi-years solutions on station coordinates and velocities with regard to several aspects (e.g. constraints, rank deficiencies, datum definition);
- Reviewing and studying systematic differences between different solutions to understand their origin (e.g. software-related aspects, model differences, parameterisation, processing strategies, etc.);
- Analysis of station position time series with respect to nonlinear effects, periodic signals and systematic differences and comparison of the results obtained by different techniques at collocation sites;
- Concerning the datum definition of the ITRF we analysed time series of the scale and origin obtained from different space technique solutions. For the definition of the kinematic datum of the ITRF we propose to use kinematic models based on geodetic observations (e.g. APKIM2000) instead of geophysical models (e.g. NNR NUVEL-1A) to ensure that the no net rotation condition is more accurately fulfilled;
- Investigations related to the weighting for the intra- and inter-technique combination (e.g. variance component estimation, see below) and to the handling of local ties.

Variance component estimation

Within the inter-technique combination it may be useful to apply the variance component estimation for the weighting of the heterogeneous input solutions from the different space geodetic observations, such as VLBI, SLR, GPS and DORIS. From various applications in different fields of geodesy it is well known that this quadratic estimation method may lead to useless results. Hence intensive investigations for the feasibility of this method have started under the specific conditions of the inter-technique combination. First results proof that at least three input solutions have to be inserted to the variance component estimation in order to obtain convergence. The investigations have to be continued.

Combination of SLR solutions for ILRS

In response to the call for participation „Positioning & Earth Orientation“ of the ILRS, DGFI expressed the willingness to contribute as analysis and combination centre. The role of an ILRS combination centre is to perform a quality control of the individual SLR solutions (daily earth orientation parameters and 28-day global station coordinates) and to provide a single combined solution on a weekly basis. For this purpose DGFI has developed software and tools to get the input solutions from the global ILRS data centres (CDDIS and EDC), to analyse and to combine them, and to put the final solution back to the data centres, within an automated process. Only those input solutions are included in the combination which pass an eigenvalue analysis and which fulfil rms difference criteria to internal and external parameter values. Because the official SLR input solutions are not yet available, solutions of ILRS pilot projects and of the data pool of the IERS SINEX Combination Campaign are used within a first test phase. The necessary fine-tuning will follow when getting the official SLR solutions from individual ILRS analysis centres.

IERS SINEX Combination Campaign

DGFI has provided SLR, VLBI and GPS solutions and/or free normal equations and concentrates on the analysis of combination strategies. In view of the goals of the SINEX Combination Campaign the available solutions were checked concerning various aspects, such as format and suitability for a rigorous combination. The scientific studies include:

- o Assessment of the quality of local tie information and the impact of local ties on the combination
- o Investigations related to the weighting of solutions in the intra- and inter-technique case
- o Study datum definition issues for individual space-techniques and combined solutions
- o Study systematic biases between the techniques

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3.6.2.3 Forschungseinrichtung Satellitengeodäsie, Technical University of Munich (FESG)

Introduction

At the FESG as a Combination Research Centre (CRC) mainly the following four research topics were covered during 2002:

- Analyses of EOP series from the IERS Campaign to align EOPs to ICRF/ITRF2000,
- Studies for the IERS SINEX Combination Campaign,
- Determination of the local tie between VLBI and GPS at Wettzell,
- Analyses of subdaily ERPs and nutation offsets/rates from VLBI and GPS.

The emphasis of the work performed was put on the two campaigns, the IERS SINEX Combination Campaign and the IERS EOP Alignment Campaign.

IERS Campaign to Align EOPs to ICRF/ITRF2000

Quite some effort of the FESG CRC was put into analyses of the EOP time series available through the IERS Campaign to Align EOPs to the ICRF/ITRF2000. The campaign itself is described in more detail in section 3.3 of this Annual Report and on the Internet (<http://alpha.fesg.tu-muenchen.de/iers/eop/campaign.html>). The Web pages also contain all the major results achieved by the FESG in the course of the analyses.

IERS SINEX Combination Campaign

The campaign itself started in May 2002 (see section 3.3, this volume) and the analysis and research related to this campaign is still going on. After some modifications, the Bernese GPS Software can now process not only the variance-covariance information but also the files with normal equation blocks, an option made possible by the new version 2.00 of the SINEX format. For such solution series, a matrix inversion for retrieving the normal equation systems is not necessary. We started testing the VLBI SINEX solutions from DGFI, because these are the only solutions that directly include the normal equations. To see if a solution can be exactly reproduced, the coordinates were fixed on ITRF2000 coordinate values and the resulting EOPs were compared to the results from the EOP Alignment Campaign, because both results, being produced from exactly the same normal equation information, should be identical. The generation of GPS solutions was already implemented in the course of a diploma thesis. The next step will be the incorporation of SLR solutions and thorough tests of the combination algorithms that handle both, station coordinates and EOPs. A first presentation of combination results will be given at the EGS General Assembly 2003 in Nice.

Local Tie Between VLBI and GPS at Wettzell

The local tie between the VLBI reference point (intersection of axes) and the GPS reference point called WTZA (Ashtech), at Wettzell, was analysed. The data for this analysis were obtained from a GPS antenna that was installed on the top of the radio telescope (above the secondary reflector). Measurements were performed with different azimuth and elevation positions of the radio telescope. Afterwards, the L1 and L2 baselines to the permanent point WTZA - the Ashtech antenna point WTZA was chosen, because it is equipped with exactly the same antenna type as the one put onto the radio telescope - were used to determine the local tie. The results for the baseline vector between the GPS point WTZA and the VLBI reference point were compared to the terrestrial survey results and show an agreement for the local tie on the 1 mm level, giving an additional confirmation of the quality of the local tie in Wettzell. This type of experiments and checks are extremely important in view of the fact, that today, the accuracy of the global ITRF reference frame is mainly limited by the accuracy of the local tie information for the co-location sites (and systematic biases between the individual space geodetic techniques).

Analyses of Subdaily ERPs and Nutation Offsets/Rates from VLBI and GPS

Detailed analyses of the subdaily ERP series from VLBI, generated by the Goddard Space Flight Center, and from GPS, generated by the CODE Analysis Center of the IGS, have shown that both, the VLBI and GPS series, are dominated by the noise of the subdaily ERP estimates after removing the low-frequency part and the variations due to ocean tides (e.g. using the model of Ray, 1996, given in the IERS Conventions 1996). Therefore, it should be possible to obtain an improved subdaily ERP time series by combining the VLBI and GPS results. At present, the program, that allows the combined estimation of the amplitudes for the ERP variations due to ocean tides, is modified to also generate a combined subdaily ERP series. Before a combined subdaily ERP series can be routinely generated as a new IERS (research) product, however, the two analysis centres (GSFC and CODE) presently generating subdaily ERP solutions have to agree to a routine production and delivery of these solutions. It is clear that in the long run, the combination of the subdaily solutions should be performed on the SINEX level, i.e. also including the site coordinates.

Not much work was dedicated in 2002 to the analysis of nutation offsets and rates from VLBI and GPS. A new analysis of the complete series of nutation rates from GPS (CODE Analysis Center) over the last 8 years and comparisons/combinations with VLBI results is foreseen for the IUGG General Assembly in 2003.

Acknowledgement: The FESG CRC work is funded by the Geotechnologien-Projekt of the German BMBF.

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3.6.2.4 Forsvarets forskningsinstitutt (FFI)

Introduction

FFI has during the last 19 years developed a software package called GEOSAT (Andersen, 1995) for the combined analysis of VLBI, GPS, SLR and other types of satellite tracking data (GLONASS, DORIS, PRARE and altimetry). The observations are combined at the observation level with a consistent model and consistent analysis strategies. The data processing is automated except for some manual editing of the SLR observations.

In the combined analysis of VLBI, GPS and SLR observations the data are processed in arcs of 24 hours defined by the duration of the VLBI session. The result of each analyzed arc is a state vector of estimated parameter corrections and a Square Root Information Filter array (SRIF) containing parameter variances and correlations. The individual arc results are combined into a multi-year global solution using a Combined Square Root Information Filter and Smoother program called CSRIFS. With the CSRIFS program any parameter can either be treated as a constant or stochastic parameter between the arcs. The estimation of multi-day stochastic parameters is possible and extensively used in the analyses.

Analysis strategy

Presently, the most important stochastic parameters of the global level state vector are the following: Radio source coordinates (1d resolution) of sources with structure index 3 or 4, geocentre coordinates (3d resolution), Earth orientation parameters (1d), the C21 and S21 gravity coefficients (6d), satellite independent SLR ranging biases (15d), Solar radiation pressure scaling and empirical drag of the Lageos satellites (3d), and GPS receiver antenna eccentricity vectors (station dependent time resolution to account for instrumental changes). The reason for including the two gravity coefficients is to account for the fact that errors in the gravity field will map into the estimates of polar motion derived from satellite tracking data. In order to be consistent with VLBI, which is almost independent of gravity, these parameters must be estimated.

The main constant parameters of the global state vector are monument coordinates and velocities, GPS and/or SLR eccentricity vectors relative to the station monument if it's a collocated station, radio source coordinates, relative zenith delay between VLBI and GPS at collocated stations (to account for differences in antenna heights), VLBI antenna axis offsets, and GPS satellite transmitter phase centre z-coordinate offset and nadir-dependent variation (relative to the satellite body-fixed reference frame). Results show that the z-coordinate offset can be determined to a formal precision of some centimetres (1 sigma). Using the IGS z-coordinate values will result in a scale inconsistent with SLR and

VLBI by several ppb. This means that most, but not all, of the error in the GPS phase centre offset is absorbed by the estimated clock and ambiguity parameters. However, the phase centre variation as a function of the nadir angle is not absorbed by the estimates of any of the parameters. The phase centre variation is within approximately 20 mm. One value is estimated for each of the Block II/IIA and Block IIR satellite types. Individual estimates for the different satellites of a specific type show remarkable similarities regarding the nadir dependency.

The status of the analyses is that approximately 3500 daily SLR arcs (with Lageos I & II data from 1 Jan 1993 to 31 Dec 2002) have been processed where approximately 800 arcs are combinations with VLBI and approximately 200 arcs are combinations with VLBI, GPS and SLR. Typically, 60 GPS stations are included in each arc. These arcs have been combined into a global solution using the CSRIFS program. A program called CSRIFS-IERS reads the output of CSRIFS and estimates a time dependent transformation from the internal terrestrial and celestial reference frames to an ITRF (presently ITRF2000) and an IERS Celestial Reference Frame (presently ICRF-95.ext). Since the estimated Earth Orientation Parameters in principle are 100 % consistent with the internal reference frames the time dependent transformation parameters can be applied to transform the EOP estimates to IERS for comparison with the IERS EOP products. A possible inconsistency between the IERS reference frames and the IERS EOP estimates should in principle be detectable. The CSRIFS-IERS automatically generates SINEX files for the terrestrial and celestial reference frames and the EOPs. These files can be directly submitted to the IERS Product Centres.

During the last year the following improvements/extensions have taken place in the GEOSAT software:

- Inclusion of GLONASS analysis and combined VLBI/GPS/GLONASS/SLR analysis. This was done as a preparation for a combined VLBI/GPS/GALILEO/SLR analysis.
- Automatic editing of poor GPS satellites.
- Improved GEOSAT robustness with automated combined VLBI/GPS/SLR analysis. Only a few % of runs are aborted mostly due to badly formatted GPS data or multiple VLBI clock jumps.
- Spherical harmonic coefficients to account for Earth's surface mass redistribution (Blewitt and Clarke, 2002) can be estimated with the newest version of GEOSAT.

Problems and possible advantages of combining individual VLBI sessions taken at the same day into one daily session have been investigated. There are a few complications that can be handled and the results show that the improvements are marginal in most cases, although the results for sessions with a small number of participating stations improve.

The FFI project covering IERS, IVS, ILRS, and IGS related activities has been approved until the end of 2005. The GEOSAT software has recently been converted to PC/LINUX. The computation time per combined VLBI/GPS/SLR session has been reduced from 16 hours to 6-7 hours going from a HP J7000/UNIX computer to a 2.8 GHz PC/LINUX computer. We plan to set up a network of 5 to 20 PCs over the next three years to process combined VLBI/GPS/SLR sessions. With such a computation power it should be possible to process daily GPS/SLR or VLBI/GPS/SLR sessions in addition to frequent recalculation of historical data for research purposes. Some years ago the idea was to demonstrate and investigate the problems and possible advantages with a combined analysis of VLBI, GPS and SLR observations. With the new increased computation power we plan to go from a demonstration phase towards a production phase where it is realistic to process on routine basis observations from a large network of VLBI, GPS and SLR stations.

References

Andersen, P. H. High-precision station positioning and satellite orbit determination. Ph.D. Thesis, NDRE/publication-95/01094. FFI/E, Box 25, N-2007, Kjeller, Norway.

Blewitt, G., Clarke, P. Inversion of Earth's Changing Shape to Weigh Sea Level in Static Equilibrium with Surface Mass Redistribution. Manuscript submitted to JGR, 4 Nov. 2002.

Per Helge Andersen

3.6.2.5 Geodetic Institute of the University of Bonn (GIUB)

The Geodetic Institute of the University of Bonn (GIUB) and the Deutsches Geodätisches Forschungsinstitut (DGFI), both members of the German Forschungsgruppe Satellitengeodäsie (FGS), jointly form an IERS Combination Research Centre. The group at GIUB concentrates on VLBI related combination topics making use of its long-standing experience in VLBI network operation, correlation and data analysis. The work is funded by the German Bundesminister für Bildung und Forschung (BMBF) under the Geotechnologien Project "IERS - 03F0336B".

The research and development project at the Geodetic Institute of the University of Bonn related to combination aims at a rigorous combination of the three elements needed to describe the kinematics of System Earth: the celestial reference frame, Earth rotation, and the terrestrial reference frame. In order to achieve this goal a number of fields have been identified which have to be investigated individually before a complete combination can be tackled.

As all IVS Analysis Centers mostly define their celestial reference frame by using ICRF coordinates, a number of new sources have to be incorporated in a consistent way into a combined CRF catalogue. As a first step towards combined radio source positions, existing cataloques have been compared. It has become obvious that the use of atmospheric gradients in the VLBI refraction modelling plays an important role in these investigations.

The combination of Earth orientation parameters from VLBI analyses and the related research and development activities are being carried out in the framework of the responsibilities of the IVS Analysis Coordinator which is hosted by the GIUB. The official IVS Earth orientation parameter products are generated by a rigorous combination of input series produced by the IVS Analysis Centre. The results of the current combinations and more information are also available at the IVS home page <http://ivscc.gsfc. nasa.gov> with a link to the IVS Analysis Coordinator's page.

Realizations of terrestrial reference frames from VLBI analyses are being generated in two different ways: Either as simple ASCII files of coordinates and velocities with their standard deviations or as SINEX files containing the full variance-covariance matrix of the estimated coordinates and velocities. In order to combine individual solutions the input systems should ideally be datum-free and the datum should only be introduced after the combination process. In this context the validation of datum-free (singular) normal equations from VLBI analysis centres plays an important role.

Axel Nothnagel, Dorothee Fischer, Christoph Steinforth

3.6.2.6 GeoForschungsZentrum Potsdam (GFZ)

Research activities

GFZ has investigated the error sources which may cause systematic differences in the reference frames realized by different techniques and/or computed by various Analysing Centres. A few related papers have been published.

IERS SINEX Combination Campaign

A new software has been developed at GFZ to combine the SINEX files of different ACs from various space-geodesy techniques. Its functions are:

1) validation;
2) de-constraining (remove the a priori constraints);
3) adjust the weighting factors for different SINEX files;
4) combine SINEX normal equations, including TRF and EOP parameters;
5) using local tie data;
6) add systematic parameters for per technique, per AC, or per SINEX file;
7) datum definition, add the global constraint into the combined normal equation;
8) solution, residual check, statistical information.

Final results will be presented at the EGS (2003) meeting.

Study the possible impact of LEO missions on IERS basic products

For some years now quite a number of low altitude satellites have been launched, which are equipped with instruments of more than one technique. Examples are: ENVISAT (SLR + DORIS); Jason and T/P (GPS receiver + SLR + DORIS); CHAMP and GRACE (GPS receiver + SLR). Firstly, they provide a kind of ‘collocation (of multi-techniques) on board satellites’, which, in addition to the ground collocations, can be used to strengthen the link between the terrestrial reference frames of the related techniques. Secondly, if one uses the on-board GPS data together with the ground GPS data to determine simultaneously LEO orbits, GPS orbits, ground station positions and EOP, the geocentre and scale of the GPS reference frames could be more stable due to the contribution of the LEO. Geocentre and scale are actually the two weak points of the GPS reference frame.

In order to fully exploit the usefulness of LEOs for the IERS basic products, the method of combination at the observation level is necessary. This requires more complicated software and larger CPU time. The EPOSOC software at GFZ is therefore revised in order to meet this requirement. The tests results which will be published in the forthcoming IERS Technical Note No. 30 has shown encouraging potential.

Shengyuan Zhu and Chuang Shi

3.6.2.7 Groupe de Recherches de Géodésie Spatiale (GRGS)

In the framework of the IERS Combination Research Centres, the "Groupe de Recherches de Géodesie Spatiale" (GRGS) has proposed from year 2000 to study the combination of five techniques (SLR, LLR, VLBI, GPS and DORIS) in order to obtain a global and homogeneous solution of the Earth Orientation Parameters (EOPs): universal time UT1, polar motion, nutation corrections in longitude and obliquity, as well as station coordinates.

The adopted strategy consisted in combining with the GRGS's DYNAMO software the normal equations resulting from processing the GRGS's GINS orbitography software for individual techniques. The optimal relative weights between each technique were obtained by using the Helmert's optimal variance-covariance method.

From a three-months period (July to September 2000), results not only emphasise the interest of combining satellites for the same technique (DORIS or SLR), but also use the advantages of each technique in a global combination. Precision for SLR, inertial system for VLBI, data redundancy for GPS are the main benefits of the combination process. Resolutions of one day as well as of six hours in order to better fit the VLBI intensive campaigns were attempted. Compared to the EOPC04 series, our final solution shows discrepancies in the order of 0.25 mas for the pole motion and 0.015 ms for UT1.

However some problems remain on the processing of individual techniques like GPS which is not yet on the level of the international service. Moreover the chosen period is too short for drawing a definitive conclusion.

This is why a next step is already planned. It will consist in a one-year (probably year 2002) global estimation including the EOPs, as well as station coordinates and using upgraded models and improved processing for each technique. It should demonstrate the merits of such a global and homogeneous processing.

This work was leaded at GRGS in the framework of the doctorate of Philippe Yaya.

Reference

Ph. Yaya: Apport des combinaisons de techniques astrométriques et géodésiques à l'estimation des paramètres d'orientation de la Terre, Thèse de Doctorat, Observatoire de Paris, July 2002.

Richard Biancale

3.6.2.8 Institut Géographique National (IGN)

Please see the joint report of the ITRS Combination Centre and the Combination Research Centre at IGN (section 3.6.1.2).

3.6.2.9 Institute of Applied Astronomy (IAA)

Research groups and staff

Two research groups of the Institute of Applied Astronomy of the Russian Academy of Sciences (IAA) are involved in the IERS CRC related activity:

1. Laboratory of Space Geodesy and Earth Rotation (LSGER)

   Dr. Zinovy Malkin (Head), Natalia Panafidina, Elena Skurikhina
   Contact: malkin@quasar.ipa.nw.ru

2. Laboratory of Ephemeris Astronomy (LEA)

   Prof. George Krasinsky (Head), Nadejda Shuygina
   Contact: kra@quasar.ipa.nw.ru

Activities

LSGER group

Comparison and combination of EOP series

During the last year we continued to develop software for comparison and combination of EOP series. This software is routinely used in the framework of every-day IAA EOP Service activity for control of data and result quality and study of systematic errors of various EOP series.

Several special studies were performed: investigation of accuracy of VLBI EOP rate estimations, comparison of results obtained with the IVS R1 and R4 observational programs, analysis of the VLBI nutation series and comparison with model, and others. Most of these investigations will be continued.

One of the nearest goals of this investigations is the computation of combined EOP series from VLBI, SLR and GPS solutions routinely computed at the IAA. We expect the quality of such a combination to be close to the quality of the JPL SPACE series based on combination of similar data. We are going to compute also an operational solution with an expected delay 1.5-2 days. Prediction will be also provided. Beginning of the experimental computation is planned for 2003 if we could find needed resources for this activity.

Comparison and combination of TRF realizations

During the last year we continued to develop software for comparison of station coordinates time series and combination of TRF realizations. At the moment this software is primarily used for analysis of the VLBI TRF and EPN (European Permanent GPS Network) GPS results.

The VLBI TRF solution which is used for comparison and combination with GPS data is computed from all available VLBI sessions (both 24h and intensives can be used). Final coordinates and velocities are obtained from analysis of session solutions. Software for computation of EOP+TRF session solution is in progress.

GPS coordinate time series is computed from analysis of available EPN weekly solutions. The basis of this project is using a non-fiducial (free network) strategy for computation of station coordinates. This strategy has some evident advantages:

- Such a solution does not cause a distortion of the network.
- More stations can be used for orientation of a network which makes final orientation of the solution more reliable and dependant to a lesser degree on unmodelled errors in coordinates of fiducial stations.
- Such a solution can be easily transformed to any reference system and re-transformed to another one using a much simpler procedure than that needed for removing constraints.

Two approaches to obtain an homogeneous coordinate time series have been tested. The first one is based on re-processing of available combined weekly EPN solutions produced at CODE and BKG. This processing is made in three steps:

- Removing constraints from the official EPN solutions.
- Re-scaling of covariance matrix to obtain homogeneous solution in sense of errors.
- Transformation of obtained quasi-free-network solution to ITRF.

The first solution obtained using this strategy was computed in two steps only (1 and 3). The results showed that this method allows us to obtain independent homogeneous coordinate time series close to computed at the ROB. However, analysis of errors of our solution showed several significant jumps in errors of several mm in coordinates which most probable are caused by episodic changes in processing options during computation of the official EPN combined solution. Introducing of step 2 gave us a possibility to solve this problem.

The second solution (which is now under development) is based on independent combination of individual EPN Analysis Centres' solutions using a three step approach:

- Removing the Analysis Centre specific constraints when necessary.
- Computation of a weekly free network solution.
- Final orientation of the weekly free network solution w.r.t. ITRF2000.

We are going to submit our EPN solutions to the EPN Central Bureau on a regular basis when available.

VLBI+GPS analysis of European baselines

This project is directed toward investigation of crust deformations in the European region on the basis of comparison and combination of results obtained with VLBI and GPS observations at European stations. The first results showed a good agreement between baseline length rates (except Ny Alesund), however analysis of seasonal variations in baseline length revealed some problems. This investigation will be continued with new GPS and VLBI results obtained with updated versions of software.

Results of researches are available on the Lab web site at <http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/>.

LEA group

The main topic of investigations of the LEA group is combining of space geodesy and other astronomical observations at the observational level in single processing using ERA software. Combined processing of VLBI and SLR observations with the goal to obtain dense UT1 and nutation series is under development. DORIS observation processing is also underway.

During the last year this group concentrated on the improvement of the processing software.

Zinovy Malkin, Natalia Panafidina, George Krasinsky, Nadejda Shuygina

3.6.2.10 Jet Propulsion Laboratory (JPL)

Introduction

The uncertainty in our knowledge of the Earth's changing orientation in space is a major source of error in tracking and navigating interplanetary spacecraft. Because the Earth's orientation changes rapidly and unpredictably, measurements must be acquired frequently and processed rapidly in order to meet the near-real-time Earth orientation requirements of the interplanetary spacecraft navigation teams. These requirements are currently met at JPL by using the Global Positioning System (GPS) to provide daily determinations of polar motion and length-of-day within 24 hours of acquisition. Single baseline Very Long Baseline Interferometry (VLBI) measurements are taken twice-per-month by the Time and Earth Motion Precision Observations (TEMPO) project in order to provide the benchmark Universal Time (UT) measurements between which the GPS length-of-day measurements are integrated. The Kalman Earth Orientation Filter (KEOF) is then used to combine the GPS polar motion and length-of-day measurements with the TEMPO VLBI variation-of-latitude and UT0 measurements, along with other publicly available Earth orientation measurements including proxy measurements such as atmospheric angular momentum, in order to generate and deliver the required polar motion and UT1 Earth orientation parameters to the spacecraft navigation teams.

Data Products

Reference series of Earth orientation parameters are generated annually at JPL. During 2002, three such reference series were generated: (1) SPACE2001, consisting of values and rates for polar motion and UT1 spanning September 28, 1976 to January 19, 2002 at daily intervals, was generated by combining Earth orientation measurements taken by the space-geodetic techniques of Lunar and Satellite Laser Ranging, VLBI, and GPS; (2) COMB2001, consisting of values and rates for polar motion and UT1 spanning January 20, 1962 to January 15, 2002 at either 1-day or 5-day intervals, was generated by additionally including the BIH optical astrometric measurements with the space-geodetic measurements used to generate SPACE2001; and (3) POLE2001, consisting of values and rates for just polar motion spanning January 20, 1900 to December 21, 2001 at monthly intervals, was generated by additionally including the ILS optical astrometric measurements with the other optical astrometric and space-geodetic measurements used to generate COMB2001. These reference series can be obtained by anonymous ftp to <ftp://euler.jpl.nasa.gov/keof/combinations/2001>. A report describing the generation of these series [Gross, 2002] is also available at this site.

The near-real-time Earth orientation requirements of the interplanetary spacecraft navigation teams are met by twice-per-week updating the annually generated reference series. The updated Earth orientation series are generated by additionally incorporating measurements that are rapidly available such as the GPS measurements from the JPL Analysis Centre of the IGS and the atmospheric angular momentum measurements from NCEP that are used as proxy length-of-day measurements. In addition, short-term predictions of the EOPs are produced in order to provide the navigation teams with an uninterrupted series of Earth orientation parameters. The updated and predicted EOP series can be obtained by anonymous ftp to
<ftp://euler.jpl.nasa.gov/keof/predictions>.

Research activities

Research activities during 2002 were largely concerned with exploring methods of improving the accuracy of the combined and predicted Earth orientation parameters. The feasibility of producing daily updates was explored, Earth orientation measurements from alternate sources were evaluated including the JCET/GSFC SLR polar motion series, and methods to improve the accuracy of short-term predictions of the EOPs were investigated [Chin *et al.*, 2003].

References

Chin, T. M., R. S. Gross, and J. O. Dickey, Modeling and forecast of the polar motion excitation functions for short-term polar motion prediction, *J. Geodesy*, submitted, 2003.

Gross, R. S., Combinations of Earth orientation measurements: SPACE2001, COMB2001, and POLE2001, Jet Propulsion Laboratory Publ. 02-08, 27 pp., Pasadena, Calif., 2002.

Richard Gross

Appendix 1: IERS Terms of Reference

The International Earth Rotation Service (IERS) was established in 1987 by the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG) and it began operation on 1 January 1988. In 2003 it was renamed to International Earth Rotation and Reference Systems Service. IERS is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS).

The primary objectives of the IERS are to serve the astronomical, geodetic and geophysical communities by providing the following:

- The International Celestial Reference System (ICRS) and its realization, the International Celestial Reference Frame (ICRF).
- The International Terrestrial Reference System (ITRS) and its realization, the International Terrestrial Reference Frame (ITRF).
- Earth orientation parameters required to study earth orientation variations and to transform between the ICRF and the ITRF.
- Geophysical data to interpret time/space variations in the ICRF, ITRF or earth orientation parameters, and model such variations.
- Standards, constants and models (i.e., conventions) encouraging international adherence.

IERS is composed of a broad spectrum of activities performed by governmental or selected commercial organizations.

IERS collects, archives and distributes products to satisfy the objectives of a wide range of applications, research and experimentation. These products include the following:

- International Celestial Reference Frame.
- International Terrestrial Reference Frame.
- Monthly earth orientation data.
- Daily rapid service estimates of near real-time earth orientation data and their predictions.
- Announcements of the differences between astronomical and civil time for time distribution by radio stations.
- Leap second announcements.
- Products related to global geophysical fluids such as mass and angular momentum distribution.
- Annual report and technical notes on conventions and other topics.

- Long term earth orientation information.

The accuracies of these products are sufficient to support current scientific and technical objectives including the following:

- Fundamental astronomical and geodetic reference systems.
- Monitoring and modeling earth rotation/orientation.
- Monitoring and modeling deformations of the solid earth.
- Monitoring mass variations in the geophysical fluids, including the atmosphere and the hydrosphere.
- Artificial satellite orbit determination.
- Geophysical and atmospheric research, studies of dynamical interactions between geophysical fluids and the solid earth.
- Space navigation.

The IERS accomplishes its mission through the following components:

- Technique Centers.
- Product Centers.
- Combination Center(s)
- Analysis Coordinator.
- Central Bureau.
- Directing Board.
- Working Groups.

Some of these components (e.g., Technique Centers) may be autonomous operations, structurally independent from IERS, but which cooperate with the IERS. A participating organization may also function as one or several of these components (except as a Directing Board).

TECHNIQUE CENTERS (TC)

The TCs generally are autonomous independent services, which cooperate with the IERS.

The TCs are responsible for developing and organizing the activities in each contributing observational technique to meet the objectives of the service. They are committed to produce operational products, without interruption, and at a specified time lag to meet requirements. The products are delivered to IERS using designated standards. The TCs provide, as a minimum, earth orientation parameters and related reference frame information, as well as other products as required.

The TCs exercise overall control of observations from their specific techniques, archiving, quality control and data processing including combination processing of data and/or products received from their participating organizations. TCs are the various international technique specific services: IGS, ILRS, IVS and possible future TCs e.g. DORIS.

PRODUCT CENTERS (PC)

PCs are responsible for the products of the IERS.

Such centers are the following:

- Earth Orientation Center, responsible for monitoring earth orientation parameters including long term consistency, publications for time dissemination and leap second announcements.
- Rapid Service/Prediction Center, responsible for publication of semiweekly (possibly daily?) bulletins of preliminary and predicted earth orientation parameters.
- Convention Center, under the guidance of the IERS Conventions Editorial Board, responsible for the maintenance of the IERS conventional models, constants and standards.
- ICRS Center, responsible for the maintenance of the ICRS/ICRF.
- ITRS Center, responsible for the maintenance of the ITRS/ITRF, including network coordination (design collocation, local ties, and site quality). For this purpose the Center is also responsible to provide the ITRS Combination Centers (see below) with specifications, and to evaluate their respective results.
- Global Geophysical Fluids Center, responsible for providing relevant geophysical data sets and related computational results to the scientific community.

COMBINATION CENTER(S)

- Combination Research Center(s) are responsible for the development of combinations from data and/or products emanating from the different techniques (TCs). These research combination solutions are provided to the Analysis Coordinator.
- ITRS Combination Center(s) are responsible to provide ITRF products by combining ITRF inputs from the TCs and others. Such products are provided to the ITRS Product Center.

IERS ANALYSIS COORDINATOR (AC)

The AC is responsible for the long-term and internal consistency of the IERS reference frames and other products. He is responsible for ensuring the appropriate combination of the TC products into the single set of official IERS products and the archiving of the products at the Central Bureau or elsewhere.

The AC serves for a four-year term, renewable once by the DB. The responsibility of the AC is to monitor the TC and PC activities to ensure that the IERS objectives are carried out. This is accomplished through direct contact with the independent TC Analysis Coordinators or equivalent. Specific expectations include quality control, performance evaluation, and continued development of appropriate analysis methods and standards. The AC interacts fully with the Central Bureau, the Product Centers and the Combination Research Center(s).

CENTRAL BUREAU (CB)

The Central Bureau is responsible for the general management of the IERS consistent with the directives and policies set by the Directing Board, i.e., acts as the executive arm of the Directing Board. The CB facilitates communications, coordinates activities, monitors operations, maintains documentation, archives products and relevant information and organizes reports, meetings and workshops.

Although the Chairperson of the Directing Board is the official representative of the IERS at external organizations, the CB is responsible for the day-to-day liaison with such organizations. The CB coordinates and publishes all documents required for the satisfactory planning and operation of the Service, including standards/conventions/specifications regarding the performance, functionality and configuration requirements of all elements of the Service including user interface functions.

The CB operates the communication center for the IERS. It distributes and/or maintains a hierarchy of documents and reports, both hard copy and electronic, including network information, standards, newsletters, electronic bulletin board, directories, summaries of performance and products, and an Annual Report.

DIRECTING BOARD (DB)

The Directing Board consists of the following members appointed for four-year terms, renewable once:

- Two representatives from each Technique Center to be selected by the Technique Center's governing board or equivalent. The two representatives will represent that technique regarding
    a. its network and coordination with other techniques,
    b. the details of the technical analyses.

It is desired that, as part of reciprocity agreements, IERS representatives are to become members of the Technique Centers' directing boards.

- One representative from each Product Center.
- One representative from the Combination Research Center(s).
- Representative of the Central Bureau.

- IERS Analysis Coordinator.
- Representatives of IAU, IAG/IUGG and FAGS.

The Chairperson is one of the members of the DB elected by the Board for a term of four years with the possibility of re-election for one additional term. The Chairperson does not vote, except in case of a tie. He/she is the official representative of IERS to external organizations.

The DB exercises general control over the activities of the service and modifies the organization as appropriate to maintain efficiency and reliability, while taking full advantage of the advances in technology and theory.

Most DB decisions are to be made by consensus or by a simple majority vote of the members present, provided that there is a quorum consisting of at least one half of the membership. In case of a lack of a quorum, the voting is by correspondence. Changes in the Terms of Reference and Chairperson of the DB can be made by a two third majority of the members of the DB.

For the DB to effectively assess the value of IERS services to the user communities, and to ensure that the service remains up to date and responsive to changing user needs, the DB will organize reviews of the IERS components at appropriate intervals. The DB will decide, on an annual basis, those components that are to be reviewed and from time to time may select other activities for review, as it deems appropriate. The Central Bureau provides the secretariat of the DB.

The Board shall meet at least annually and at such other times as shall be considered appropriate by the Chairperson or at the request of five members.

WORKING GROUPS

Working Groups may be established by the DB to investigate particular topics related to the IERS components. Working groups are limited to a term of two years with a possible one-time re-appointment. The IERS Analysis Centre Coordinator and the Director of the Central Bureau are ex officio members of each working group, and may send official representatives to meetings which they are unable to attend. Working groups may also collaborate with other scientific organizations like, e.g., IAG, CSTG.

The chair of a working group must prepare, at least annually, a report about the activities of the group to be included in the IERS Annual Report. Working group chairs are invited to participate in DB meetings.

Individuals or groups wishing to establish an IERS Working Group must provide the following at least two weeks prior to the IERS Directing Board Meeting where DB approval is requested.

- Draft charter clearly specifying:
    - Proposed goals (two pages at maximum),
    - Proposed structure of the group or project,
    - Working plan including schedule / deadlines including the anticipated end of work,
- Candidate for a chairperson to be appointed by the DB (optional),
- Initial list of members,
- Proposed plans for an operational phase (if applicable),
- Draft IERS message to inform the IERS community.

IERS ASSOCIATE MEMBERS

Persons representing organizations that participate in any of the IERS components, and who are not members of the Directing Board, are considered IERS Associate Members. Ex officio IERS Associate Members are the following persons:

IAG General Secretary

IAU General Secretary

IUGG General Secretary

President of FAGS

President of IAG Section II

President of IAG Commission VIII

President of IAG Section V

President of IAU Commission 19

President of IAU Commission 31

Head of IAU Division I

IERS CORRESPONDENTS

IERS Correspondents are persons on a mailing list maintained by the Central Bureau, who do not actively participate in the IERS but express interest in receiving IERS publications, wish to participate in workshops or scientific meetings organized by the IERS, or generally are interested in IERS activities.

April 2, 2003

Appendix 2: Contact addresses of the IERS Directing Board

Chair

Jan Vondrák
(address see below)

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ITRS Combination Centres

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Appendix 4: Electronic Access to IERS Products, Publications and Components

Central IERS web site

http://www.iers.org/

Please note that all other products, publications and centres may be accessed via this web site.

Products

For a complete list of all IERS products see <http://www.iers.org/iers/products/>.

Earth orientation data

Rapid data and predictions
Web access: http://maia.usno.navy.mil/
ftp access: `maia.usno.navy.mil` - directory `ser7`

Monthly earth orientation data
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulb`

Long term earth orientation data
Web access: http://hpiers.obspm.fr/eop-pc/products/eopcomb.html
ftp access: `hpiers.obspm.fr` - directory `iers/eop`

Leap second announcements
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulc`

Announcements of DUT1
Web access: http://hpiers.obspm.fr/eop-pc/products/bulletins.html
ftp access: `hpiers.obspm.fr` - directory `iers/bul/buld`

Conventions

Web access:
IERS Conventions 1996: http://maia.usno.navy.mil/conventions.html
IERS Conventions 2000: http://maia.usno.navy.mil/conv2000.html

International Celestial Reference Frame

Web access: http://hpiers.obspm.fr/icrs-pc/
ftp access: `hpiers.obspm.fr` - directory `iers/icrf`

International Terrestrial Reference Frame

Web access: http://lareg.ensg.ign.fr/ITRF/
ftp access: `lareg.ensg.ign.fr` - directory `pub/itrf`

Geophysical fluids data

Web accesss: http://bowie.gsfc.nasa.gov/ggfc/

Publications

IERS Messages
http://www.iers.org/iers/publications/messages/

IERS Bulletins
http://maia.usno.navy.mil/ (Bulletin A)
http://hpiers.obspm.fr/eop-pc/products/bulletins.html
(Bulletins B, C, D)
http://www.iers.org/iers/publications/bulletins/

IERS Technical Notes
http://www.iers.org/iers/publications/tn/

IERS Annual Reports
http://www.iers.org/iers/publications/reports/

ITRF Mail
http://list.ensg.ign.fr/wws/arc/itrfmail

IERS Components

Directing Board
Web page: http://www.iers.org/iers/about/db/

Central Bureau
Web site: http://www.iers.org/

Analysis Coordinator
Web site: http://alpha.fesg.tu-muenchen.de/iers/

Product Centres

Earth Orientation Centre
Web site: http://hpiers.obspm.fr/eop-pc/

Rapid Service/Prediction Centre
Web site: http://maia.usno.navy.mil/

Convention Centre
Web page: http://www.iers.org/iers/pc/conv/

ICRS Centre
Web site: http://hpiers.obspm.fr/icrs-pc/

ITRS Centre
Web site: http://lareg.ensg.ign.fr/ITRF/

Global Geophysical Fluids Centre
Web site: http://bowie.gsfc.nasa.gov/ggfc/
Special Bureaus:
Special Bureau for the Atmosphere
Web site: http://www.aer.com/groups/diag/sb.html
Special Bureau for the Oceans
Web site: http://euler.jpl.nasa.gov/sbo/
Special Bureau for Tides
Web site: http://bowie.gsfc.nasa.gov/ggfc/tides/
Special Bureau for Hydrology
Web site: http://www.csr.utexas.edu/research/ggfc/
Special Bureau for Mantle
Web site: http://bowie.gsfc.nasa.gov/ggfc/mantle.htm
Special Bureau for the Core
Web site: http://www.astro.oma.be/SBC/main.html
Special Bureau for Gravity/Geocenter
Web site: http://sbgg.jpl.nasa.gov/
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Technique Centres

International GPS Service (IGS)
Web site: http://igscb.jpl.nasa.gov/

International Laser Ranging Service (ILRS)
Web site: http://ilrs.gsfc.nasa.gov/

International VLBI Service (IVS)
Web site: http://ivscc.gsfc.nasa.gov/

International DORIS Service (IDS) - planned
Web site: http://ids.cls.fr/

Combination Centres
ITRS Combination Centres

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Institut Géographique National (IGN)
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National Resources Canada (NRCan)
Web page: http://www.iers.org/iers/itrscc/geocan/

Combination Research Centres

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Astronomical Institute, Academy of Sciences of the Czech Republic, Prague
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Deutsches Geodätisches Forschungsinstitut (DGFI)
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Forschungseinrichtung Satellitengeodäsie, Technical University Munich (FESG)
Web page: http://www.iers.org/iers/crc/fesg/

Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment)
Web page: http://www.iers.org/iers/crc/ffi/

GeoForschungsZentrum Potsdam (GFZ)
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Jet Propulsion Laboratory (JPL)
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Appendix 5: Acronyms

2MASS	Two Micron All Sky Survey
AAC	Associated Analysis Centre
AAM	Atmospheric Angular Momentum
AC	Analysis Centre
AC	Analysis Coordinator
AER	Atmospheric and Environmental Research Inc.
AGK2	Zweiter Katalog der Astronomischen Gesellschaft
AGU	American Geophysical Union
APKIM	Actual Plate Kinematic Models
APSG	Asia-Pacific Space Geodynamics
ASI	Agenzia Spaziale Italiana
ATNF	Australia Telescope National Facility
AUSLIG	Australian Surveying and Land Information Group (now: Geoscience Australia)
AWG	Analysis Working Group
BIH	Bureau International de l'Heure
BIPM	Bureau International des Poids et Mesures
BKG	Bundesamt für Kartographie und Geodäsie
BKGI	BKG in cooperation with GIUB
BMBF	Bundesministerium für Bildung und Forschung
CATREF	Combination and Analysis of Terrestrial Reference Frames
CB	Central Bureau
CC	Combination Centre
CCD	Charge-Coupled Device
CDDIS	NASA Crustal Dynamics Data Information System
CEDR	Center for Earth Dynamics Research
CEO	Celestial Ephemeris Origin
CEP	Celestial Ephemeris Pole
CERGA	Centre d'Etudes et de Recherches Géodynamiques et Astronomiques
CGS	Centre di Geodesia Spatiale, ASI
CIP	Celestial Intermediate Pole
CLS	Collecte, Localisation, Satellites
CMB	core-mantle boundary
CNES	Centre National d'Etude Spatiale
CODE	Centre for Orbit Determination in Europe
COM	centre-of-mass
CORE	NASA Continuous Observations of the Rotation of the Earth
CPU	central processing unit
CRC	Combination Research Centre
CRF	Celestial Reference Frame
CRS	Celestial Reference System
CSR	Center for Space Research
CSTG	Commission on International Coordination of Space Techniques for Geodesy and Geodynamics
CTIO	Cerro Tololo Inter-American Observatory
DANOF	Département d'Astronomie Fondamentale
DB	Directing Board
Dec	declination
DEOS	Delft Institute for Earth-Oriented Space Research
DGFI	Deutsches Geodätisches Forschungsinstitut
DIODE	Détermination Immédiate d'Orbite par Doris Embarqué
DOGS	DGFI Orbit & Geodetic Parameter Estimation Software
DOMES	Directory Of MERIT Sites (originally; now of more general use)
DORIS	Doppler Orbit determination and Radiopositioning Integrated on Satellite
DUT	Delft University of Technology
DUT1	= UT1-UTC
ECCO	Estimating the Circulation and Climate of the Ocean
ECMWF	European Center for Medium Range Weather Forecasting
EDC	EUROLAS Data Center
EGS	European Geophysical Society
EMR	Energy, Mines and Resources Canada (replaced by NRCan)
ENSG	Ecole Nationale de Sciences Geographiques
EOC	Earth Orientation Centre
EOP	Earth Orientation Parameters
EOPGS	Ecole et Observatoire de Physique du Globe de Strasbourg
EPN	European Permanent GPS Network

ERA	Earth Rotation Angle
ERP	Earth Rotation Parameters
ESA	European Space Agency
ESOC	European Space Agency Operational Center
EU	European Union
EUROLAS	European Laser Consortium
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FAME	Full-sky Astrometric Mapping Explorer
FCN	Free Core Nutation
FESG	Forschungseinrichtung Satellitengeodäsie, Technical University of Munich
FFI	Forsvarets forskningsinstitutt
FGS	Forschungsgruppe Satellitengeodäsie
FTP	File Transfer Protocol
GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
GAUS	Geoscience Australia
GCRS	Geocentric Celestial Reference System
GFZ	GeoForschungsZentrum Potsdam
GGFC	Global Geophysical Fluids Centre
GIA	glacial isostatic adjustment
GIM	Global Ionospheric Maps
GIUB	Geodetic Institute of the University of Bonn
GLONASS	Global Orbiting Navigation Satellite System
GLOUP	GLObal Undersea Pressure
GMES	Global Monitoring of Environment and Security
GNSS	Global Navigation Satellite System
G.O.	Geodetic Observatory
GPS	Global Positioning System
GRGS	Groupe de Recherches de Géodésie Spatiale
GSFC	Goddard Space Flight Center
GST	Greenwich Sidereal Time
IAA	Institute of Applied Astronomy, St. Petersburg
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IDS	International DORIS Service
IERS	International Earth Rotation and Reference Systems Service (formerly: International Earth Rotation Service)
IGGOS	Integrated Global Geodetic Observing System
IGN	Institut Géographique National
IGRT	IGS rapid time (products)
IGS	International GPS Service
IGST	IGS time scale
IGU	IGS ‘ultra-rapid’ satellite orbits
ILRS	International Laser Ranging Service
INASAN	INstitut AStronomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)
INDIGO	Inter-service Data Integration for Geodetic Operations
IPGP	Institut de Physique du Globe de Paris
IRIS	International Radio Interferometric Surveying
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
ITU	International Telecommunication Union
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JCET	Joint Center for Earth System Technology, GSFC
JPL	Jet Propulsion Laboratory
KEOF	Kalman Earth Orientation Filter
LAREG	Laboratoire de Recherche en Geodesie
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LEA	Laboratory of Ephemeris Astronomy, IAA
LEO	Low Earth Orbit
LGIT	Laboratoire de Géophysique Interne et Tectonophysique
LLR	Lunar Laser Ranging
LNA	Laboratório Nacional de Astrofísica
LOD	Length of Day

LPCE	Laboratoire de Physique et Chimie de l'Environnement
LSGER	Laboratory of Space Geodesy and Earth Rotation, IAA
LSM	land surface model
mas	milliarcsecond(s)
MCC	Russian Mission Control Centre
MCEP	mean Celestial Ephemeris Pole
MJD	Modified Julian Day
NASA	U.S. National Aeronautics and Space Administration
NCAR	U.S. National Center for Atmospheric Research
NCEP	U.S. National Centers for Environmental Prediction
NCL	University of Newcastle upon Tyne
NEOS	U.S. National Earth Orientation Service
NEQ	normal equation
NERC	Natural Environment Research Council
NIPR	National Institute for Polar Research
NNR	No-net-rotation
NOAA	U.S. National Oceanic and Atmospheric Administration
NoE	Network of Excellence
NOFS	USNO Flagstaff Station
NPM	Lick Northern Proper Motion Program
NRAO	U.S. National Radio Astronomy Observatory
NRCan	Natural Resources, Canada (formerly: EMR)
NRT	Near Real-Time (products)
NUVEL	Northwestern University Velocity Model
OAM	oceanic angular momentum
OP	Observatoire de Paris
PC	Product Centre
PIVEX	Platform Independent VLBI Exchange Format
ppb	parts per billion (10^{-9})
PRARE	Precise RAnge and Range-Rate Equipment
PZT	Photographic Zenith Tube (Telescope)
QC	quality control
RA	right ascension
RFI	radio frequency interference
RINEX	Receiver INdependent EXchange format
rms, RMS	Root Mean Square
ROB	Royal Observatory of Belgium
RRFID	USNO Radio Reference Frame Image Database
RT	Real-Time (products)
SB	Special Bureau
SIM	NASA's Space Interferometry Mission
SIMB	Service d'Installation et de Maintenance des Balises DORIS
SINEX	Solution (Software/technique) INdependent EXchange Format
SIO	Scripps Institution of Oceanography
SLR	Satellite Laser Ranging
SNR	signal-to-noise ratio
SOFA	Standard Objects For Astronomy
SPBU	St Petersburg University
SPM	Yale/San Juan Southern Proper Motion Program
SRIF	Square Root Information Filter array
SSALTO	Segment Sol multi-mission d'ALTimétrie, d'Orbitographie et de localisation précise
TAI	Temps Atomique International (International Atomic Time)
TC	Technique Centre
TCB	Barycentric Coordinate Time
TCG	Geocentric Coordinate Time
TEMPO	Time and Earth Motion Precision Observations
TEO	Terrestrial Ephemeris Origin
TIGA	GPS Tide Gauge Benchmark Monitoring
TMA	three mirror anastigmat
TN	IERS Technical Note
TRF	Terrestrial Reference Frame
TRS	Terrestrial Reference System
U., Univ.	University
UCAC	USNO CCD Astrograph Catalog
URL	Uniform Resource Locator
USNO	United States Naval Observatory
UT	University of Texas
UT, UT0/1	Universal Time
UTC	Coordinated Universal Time
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VSI	VLBI Standard Interface
WG	working group
ZPD	zenith path delay