International Earth Rotation Service (IERS)
Service International de la Rotation Terrestre

Member of the Federation of the Astronomical and Geophysical data analysis Service (FAGS)

IERS Annual Report 2000

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IERS Annual Report 2000

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Table of Contents

I. Forewords

The IERS in 2000

As in previous years the IERS routinely provided in 2000 homogeneous celestial and terrestrial reference frame and Earth orientation parameter information with a precision approaching the few centimeters level. This information provided to the users through various media is derived from observations of near Earth orbiting satellites, the moon and extragalactic radio sources, involving Satellite Laser Ranging (SLR), Lunar Laser Ranging (LLR), DORIS Doppler Positioning and Very Long Baseline Interferometry (VLBI). The daily monitoring of the Earth orientation parameters and the estimation of the celestial and terrestrial reference frame parameters are the result of the international tracking efforts coordinated by the International GPS Service (IGS), the International Laser Ranging Service (ILRS) and the International VLBI Service (IVS) as well as of the joint analysis efforts of more than 30 expert groups. Besides the provision of these routine IERS products, the IERS Global Geophysical Fluids Product Center (GGFC) provided data and products related to the atmosphere, the oceans, the hydrological cycle and the Earth core through the data bases of its Special Bureaus and a mirror site in Strasbourg. The ITRF section of the service came up with a considerably improved preliminary solution for the terrestrial reference frame (ITRF2000) which will improve all research and application activities requiring the link to the global terrestrial reference frame.

Apart from the routine processing, the continuing activities for the delivery of a final ITRF2000 and the preparations for the draft version of the Conventions 2000, the major focus of the service was the finalization of its own reorganization.

After having received 24 individual proposals from 13 different institutions until March 23, 2000 as a response to the 1999 Call for Participation, the Proposal Review Board (RB) under the leadership of Prof. Ivan I. Mueller immediately resumed its evaluation work. After two RB meetings in April (Nice) and June (Washington) the RB chairman presented the board's recommendations to the IERS Directing Board (DB) at its 30th meeting in Washington D.C. on June 3/4, 2000. The Directing Board voted separately on each recommendation for the various components of the new service. The DB chairman informed all parties on the outcome of the voting and asked the International GPS, VLBI and SLR Services to nominate two representatives each as members in the new IERS DB.

After a special DB meeting in September 2000 in Frankfurt, where representatives of all components of the new service were present and where the Review Board chairman presented the board's final recommendations, the transition phase from the old to the new

IERS was initiated with an extended board membership for the interim.

Daniel Gambis as director of the old Central Bureau (CB) and Bernd Richter as the designated director of the new CB managed a smooth transfer of the Central Bureau from the Paris Observatory to the Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt in this period. At the 32nd DB meeting in San Francisco on December 18, 2000, the new Directing Board elected – as one of its very first important duties – a new chairman out of the candidates provided by the Nominating Committee. Jan Vondrak got the majority vote and will lead the new IERS into its new phase of operation.

Many organisations and experts all over the world contributed to the successful operation of the IERS in this very eventful year 2000. Their contributions are highly appreciated.

In appreciation of their help in making the transformation of the IERS into a more efficient service possible, I would like to mention namely the directors of the Central Bureau during the transition period from 1996 to 2000 Martine Feissel (until end of 1997) and Daniel Gambis (until end of 2000), the members of the old Directing Board Felicitas Arias, Claude Boucher, Dennis McCarthy, Ben Chao, Chopo Ma, William Melbourne, Jim Ray, Bob Schutz, Peter Shelus, Pascal Willis, the members of the Proposal Review Committee Gerhard Beutler, Francoise Barlier, Erwin Groten, Tom Herring, Jan Kouba, Chopo Ma, William Melbourne, Paul Paquet, Harald Schuh, Bob Schutz, Pascal Willis, Clark Wilson. In particular, Ivan Mueller, as facilitator in various planning meetings, as chairman of the Proposal Review Committee, and as chairman of the Nominating Committee, has demonstrated extraordinary skills in ensuring that all the discussed targets for the IERS in its new structure were met and realized in the new Terms of Reference.

It was difficult to introduce a new order of things, but it was worth the efforts for the benefit of Earth Sciences.

Christoph Reigber
(until December 2000 Chairman, IERS Directing Board)

Prospects for IERS

The IERS Annual report for 2000 is the last one prepared in the 'old' format, or at least formally resembling its structure; the volumes to come will necessarily reflect all changes in the organizational structure of the service that have recently been implemented. The year 2000 concludes the first, very important stage in more than one decade old history of the International Earth Rotation Service. Since 1988 when it was created the IERS evolved into one of the most complex services supported by the IAU and IUGG, and become a real multidisciplinary international service. The year 2000 was the year of transition from the 'old' to the 'new' IERS, during which it was substantially reorganized into a sort of 'federation' of de-centralized components like Product Centers, Combination Research Centers and Technique Centers (International VLBI Service – IVS, International GPS Service – IGS, International Laser Ranging Service – ILRS, and hopefully also International DORIS Service in the future) having well defined and distributed responsibilities. Newly formulated Terms of Reference (http://www.iers.org/iers/about/tor) reflect all these changes.

Probably the most important changes are the new Central Bureau (located at BKG, Frankfurt a.M. and directed by Bernd Richter) that became administrative center organizationally separated from other components, the Analysis Coordinator (Markus Rothacher) who is responsible for internal consistency of the products, ten Research Combination Centers (represented and coordinated by Sheng Yuan Zhu) that are supposed to do the research and propose new methods of combining the observations by different techniques, and Global Geophysical Fluids Center (under the guidance of Ben Chao), responsible for monitoring the changes of fluid layers of the Earth and their relations with Earth dynamics. Novelty is also that the ITRF Product Center will be supported in its work by (hopefully more than) two ITRF Combination Centers, in order to ensure competition and independent comparisons.

Although the new structure promises positive results, only the time will show to which extent these changes will help increase the effectiveness of the whole service and the accuracy/mutual consistency of all IERS products. I would like to take this opportunity to thank all members of the IERS Directing Board who concluded their functions in 2000, and namely to my predecessor in the chair, Chris Reigber, for all excellent work they have done during the difficult period of reorganization of the IERS. A special gratitude should go to Ivan Mueller who helped the IERS to go smoothly through this period by his efficient chairmanship of different meetings and bodies that were responsible for implementing the changes.

Jan Vondrák
(Chairman, IERS Directing Board)

II. Organisation of the IERS in 2000

Centers and bureaus

In 2000, the main centers of IERS and the persons in charge of them were as follows.

CENTRAL BUREAU
Daniel Gambis
Observatoire de Paris, Paris, France

Terrestrial Frame Section
Claude Boucher
Institut Geographique National, ENSG/LAREG,
Marne la Vallee, France

Earth Orientation Section
Daniel Gambis
Observatoire de Paris, Paris, France

Celestial Frame Section
Felicitas Arias
Bureau International des Poids et Mesures,
Sevres Cedex, France

SUB-BUREAU FOR RAPID SERVICE AND PREDICTIONS
Jim Ray
National Earth Orientation Service
U.S. Naval Observatory
Washington DC, USA

GGF COORDINATING CENTER
Benjamin F. Chao
Laboratory for Terrestrial Physics, Space Geodesy Branch,
NASA Goddard Space Flight Center, Greenbelt, USA

VLBI COORDINATING CENTER
Chopo Ma
Goddard Space Flight Center, Geodynamics Branch,
Greenbelt, USA

LLR COORDINATING CENTER
Peter J. Shelus
University of Texas at Austin, Department of Astronomy
McDonald Observatory, Austin, USA

GPS COORDINATING CENTER
William G. Melbourne
Jet Propulsion Laboratory, Pasadena, USA

SLR COORDINATING CENTER
Bob E. Schutz
Center for Space Research, Austin, USA

DORIS COORDINATING CENTER
Pascal Willis
Institut Geographique National, ENSG/LAREG,
Marne la Vallee, France

CONVENTIONS
Dennis McCarthy
National Earth Orientation Service, U.S. Naval Observatory,
Washington, DC, USA

The IERS Directing Board in 2000

IAU representative:
J. Vondrak, Astronomical Institute, Prague, Czech Republic

IUGG representative:
C. Reigber, Chairman (1995–2000), GFZ, Potsdam, Germany

FAGS representative:
D. Pugh, Natural Environment Research Council,
Southampton Oceanography Centre,
Southampton, United Kingdom

Central Bureau representative: D. Gambis, France

VLBI Coordinating Center representative: C. Ma, USA

LLR Coordinating Center representative: P.J. Shelus, USA

GPS Coordinating Center representative: W.G. Melbourne, USA

SLR Coordinating Center representative: B.E. Schutz, USA

DORIS Coordinating Center representative: P. Willis, France

GGF Coordinating Center representative: B.F. Chao, USA

Central Bureau, TRF representative: C. Boucher, France

Central Bureau, CRF representative: F.E. Arias, Argentina

Central Bureau, EOP representative: D. Gambis, France

Sub-bureau for rapid service and predictions: J. Ray, USA

Conventions representative: D.D. McCarthy, USA

Products and Publications

The IERS products are described in the reports of the IERS Bureaus, Centres and Representatives (chapters IV.2 to IV.7). All products are available under anonymous ftp and World Wide Web (Appendix 2).

IERS also maintains a series of publications, with Bulletins devoted to the Earth's rotation, Reports and Technical Notes for general results. In 2000, the following publications were issued:

Sub-Bureau for Rapid Service

Twice weekly Bulletin A

Earth orientation parameters (x, y, UT1, $d\psi$, $d\varepsilon$): Rapid Service, prediction.

Central Bureau of IERS

Monthly Bulletin B

Earth orientation parameters (x, y, UT1, $d\psi$, $d\varepsilon$) combined solution and individual series. Information on UTC time scale. *First issue in January 1988.*

EOP(IERS) C 04

Earth orientation parameters (x, y, UT1, $d\psi$, $d\varepsilon$) combined solution. Updated twice weekly. *Available electronically only.*

Special Bulletin C

Announcement of the leap seconds in UTC.

Special Bulletin D

Announcement of the value of DUT1 to be transmitted with time signals.

IERS Annual Report

Activities of the coordinating centers and bureaus. Results and analyses concerning the Earth orientation and the terrestrial and celestial frames of the IERS reference system. In 2000, the 1999 Annual Report appeared. For availability of back issues see Appendix 3.

IERS Technical Note

Reports and complementary information of relevance to the work of IERS. In 2000, issue 28 appeared:

B. Kolaczek, H. Schuh, D. Gambis (eds.): High frequency to subseasonal variations in Earth Rotation. Observatoire de Paris, September 2000. v, 90 p.

For availability of back issues see Appendix 3.

IERS Gazette

General information on IERS. In 2000, Nos. 50 to 55 appeared. *Available electronically only.*

III.1 VLBI Coordination Centre

IVS Organization

The year 2000 was the first full year of operation for the International VLBI Service for Geodesy and Astrometry (IVS). IVS was recognized as a service of the International Astronomical Union (IAU). In 1999 IVS had been recognized as a service of the International Association of Geodesy (IAG). IVS held its first General Meeting in 2000, with more than 120 participants representing almost all components of the IVS.

Network Stations

A total of 740 station days were used in 125 geodetic sessions during the year, for an average of 2.4 days per week observing. Observing was reduced compared to 1999 because we had to accommodate the phase-in of the new Mark IV correlators. The major observing programs during 2000 were:

NEOS-A

Weekly 24-hour measurements of EOP were continued by the U.S. National Earth Orientation Service (NEOS), a joint effort of USNO and NASA. The Green Bank (USA, operated by USNO) station was closed mid-year and was replaced by Algonquin Park (Canada, operated by Natural Resources, Canada). Daily 1.5-hour UT1 Intensive measurements continued on the other four days of the week. As of July 1, 2000, Kokee Park (USA, operated by USNO and NASA) replaced Green Bank in the Intensive measurements, and the starting time of the Intensives was fixed at 18:30 UT instead of shifting by a sidereal amount each day.

CORE

The CORE (Continuous Observations of the Rotation of the Earth) program, coordinated by NASA, observed monthly CORE-A sessions simultaneous with NEOS for the first half of the year and then began the “true” CORE observations with CORE-1 (Mondays) and CORE-3 (Wednesdays) as monthly sessions. CORE-1 and CORE-3 recorded at 128 Mb/s, double the standard bandwidth. These modes can only be processed by the Mark IV correlators.

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. Additional 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 its series at a reduced level of seven sessions. These sessions were aimed at studies of vertical motions within Europe.

IRIS-S Monthly 24-hour sessions were continued to be coordinated and correlated by the Geodetic Institute of the University of Bonn with observatories in South Africa (Hart RAO), Brazil (Fortaleza), Europe (Wettzell) and North America (Westford, Gilcreek) for stabilization of EOP and TRF determinations. The IRIS-S series (International Radio Interferometric Surveying - South) started in early 1986 and is now the longest running VLBI observing series.

APSG The Asia-Pacific Space Geodynamics (APSG) Project sponsored two sessions.

JADE The JApanese Dynamic Earth observation by VLBI (JADE) experiments began in February and had quarterly sessions. These sessions include the dedicated 32-m dish at Tsukuba and were designed to fix 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.

COHIG BKG continued its sessions involving the O'Higgins station in Antarctica. Two campaigns were held, one in February and the other in October. Equipment and antenna problems plagued the latter campaign.

JPNTI The Geographical Survey Institute (GSI), Japan, sponsored five "ties" sessions designed to provide precise geodetic ties between the Tsukuba station and the Keystone network.

Correlators

The new Mark IV correlators at Haystack Observatory (USA), the U.S. Naval Observatory (USA), and at Max-Planck Institute for Radioastronomy (Germany) became operational in early 2000. The start-up period for the new correlators was slow: the initial processing of a 24-hour session took nearly a week. Software enhancements and some clever work on the problem-plagued station units steadily reduced the processing time to about three days as of the end of the year. Additional significant enhancements and improvements are anticipated during the next year, with the goal being 1–2 days processing for each 24-hour session.

Data Centers

The IVS Data Centers continued to receive new data bases throughout the year. The Data Centers increased their VLBI data holdings in 2000, although all of the historical data bases had not been submitted to the Data Centers as of the end of the year. This project should be completed during 2001.

Analysis Products

The first IVS Analysis Workshop was held on the last day of the first General Meeting. The Analysis Coordinator led discussions of standards, models, and contributions of the various Analysis Centers.

The objective of providing high-quality EOP derived by VLBI is met by regular VLBI data analysis by IVS Analysis Centers and by rigorous combination of their results by the IVS Analysis Coordinator. In late 2000, the U.S. Naval Observatory ceased submission of VLBI analysis products and Goddard Space Flight Center took over this responsibility. As of year end, there were regular submissions of EOP results from 24-hour and from 60-minute sessions to the IVS Data Centers by four IVS Analysis Centers: Bundesamt für Kartographie und Geodäsie, Leipzig, Germany; Institute of Applied Astronomy, St. Petersburg, Russia; St. Petersburg University, St. Petersburg, Russia; and NASA Goddard Space Flight Center, USA. The Analysis Coordinator began a routine service to compare and later combine the four contributions into a combined IVS product.

Starting on October 1, 2000 the individual EOP results from weekly 24-hour network sessions (NEOS network) are processed further in a combination procedure at the IVS Analysis Coordinator's office in order to generate a combined IVS EOP product. For polar motion and UT1-UTC series, it is intended that long term consistency is maintained with the C04 series of the International Earth Rotation Service (IERS). The results of the combinations are regularly updated. They are available both graphically and numerically on the IVS Analysis Coordinator's web page via the IVS Home page at <http://ivscc.gsfc.nasa.gov> or directly from <http://giub.geod.uni-bonn.de/vlbi/IVS-AC>. The combined EOP series may also be retrieved by anonymous FTP from one of the IVS Data Centers (e.g. <ftp://hpiers.obspm.fr/ivs/ivsproducts/eops>).

Outlook

During 2001, IVS will hold its second Analysis Workshop and publish the 2000 Annual Report. The first Technical Operations Workshop will be held at Haystack Observatory with the purpose of training operations staff. IVS will actively participate in ongoing discussions about VLBI observing programs and support by the international community for increasing observing in the CORE program.

Nancy Vandenberg, Chopo Ma, Axel Nothnagel

III.2 GPS Coordination Centre

General

The primary objective of the IGS is to provide a Reference System for a wide variety of GPS applications. To fulfil this role the IGS produces a large number of different combined products which constitute the practical realization of the IGS Reference System. Table 1 gives a brief overview of the estimated quality of these different IGS Reference Frame products at the begin of the year 2001.

Table 1: Quality of the IGS Reference Frame products as of March 2001 (for details see <http://igscb.jpl.nasa.gov/components/prods.html>)

Products Delay	Predicted Real Time	Ultra-Rapid Real Time	Rapid 17 hours	Final 13 days	Units
Orbit	50.0	25.0	5.0	< 5.0	cm
Clock	150.0	5.0	0.2	0.1	ns
Polar Motion	(note: delivery		0.2	0.1	mas
LOD	of IGP products		30.0	20.0	µs/d
Stations h/v	terminated in			3.0/6.0	mm
Troposphere	March 2001)			4.0	mm ZPD

Orbit Quality, New Products

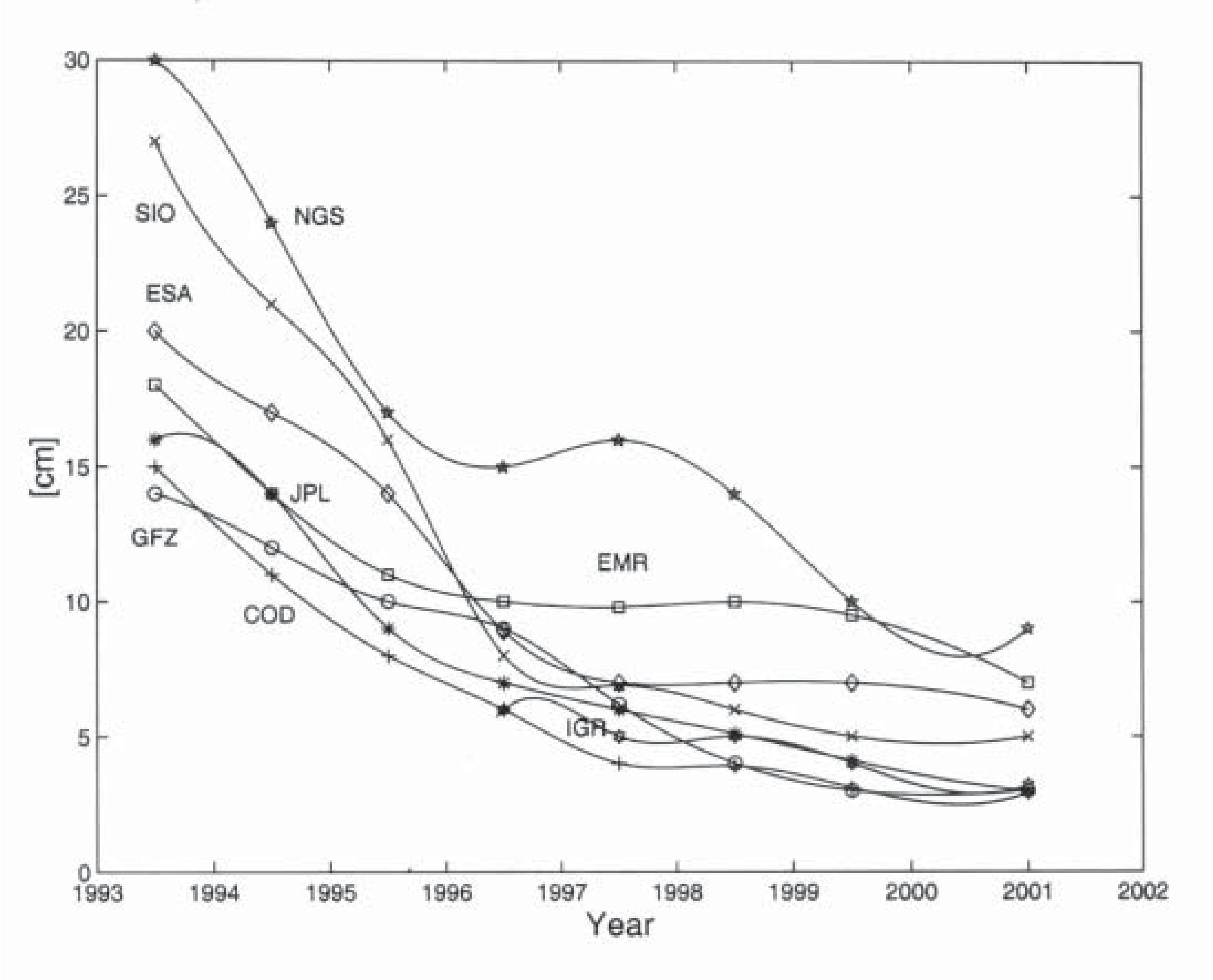
Table 2 as well as Figure 1 demonstrate the quality improvement of the IGS orbits since 1994. Figure 1 shows the weighted orbit RMS (WRMS) for the final Analysis Centre solutions with respect to the combined IGS final orbit products. Several Analysis Centres and also the IGS rapid orbit products have reached the 3 centimeter orbit precision level, also indicated by the IGS 7-day arc orbit analysis.

Table 2: Yearly average weighted orbit RMS (cm) of the Analysis Center and the IGS Rapid (IGR) orbit solutions with respect to the IGS final orbits.

Year	COD	EMR	ESA	GFZ	JPL	NGS	SIO	IGR
1994	11	14	17	12	14	32	21	-
1995	8	10	14	10	9	17	16	-
1996	6	10	9	9	7	15	8	6
1997	4	10	7	6	6	16	7	5
1998	4	10	7	4	5	14	6	5
1999	3	10	7	3	4	9	5	4
2000	3	7	6	3	3	9	5	3

Concerning new products the IGS Analysis Center Workshop 2000, hold at the U.S. Naval Observatory in Washington D.C., discussed as a major topic the quality of the recently implemented Ultra-Rapid products as well as their applications, e.g. for the derivation of ground-based GPS meteorological parameters used in numerical weather prediction. These products, which are delivered every 12 hours (two times per day), contain a 48 hour orbit arc from which 24 hours are real orbit estimates and 24 hours are orbit predictions. The latency of this product is 3 hours. The generation of a combined 'ultra-rapid' product (IGU) has started in March 2000 based on contributions from up to five different Analysis Centres. This product has been made available for real-time usage, like the IGS predicted orbits (IGP), but the quality is significantly better because the average age of the predictions is reduced from 36 to 9 hours. The next months the quality and the reliability of the IGS Ultra rapid (IGU) orbits was assessed against the IGS Predicted (IGP) and the IGS Rapid (IGR) products. During the second half-year of 2000 the individual orbit submissions reached a consistency of about 25 cm. In November 2000 the IGU products became an official IGS product and subsequently the submission of predicted orbits (IGP) could be terminated in March 2001 (Week 1105). Currently seven different Analysis Centres deliver contributions to the Ultra-Rapid products.

Figure 1: Weighted orbit RMS (WRMS) of the Analysis Center and the IGS Rapid (IGR) orbit solutions with respect to the IGS final orbits. WRMS values were smoothed for graphical representation.



A new station and satellite clock combination, which is based on the RINEX clock format, has been implemented in November 2000. This combination provides the normal combined satellite clocks in the orbit (SP3) format and it also provides both satellite and station clocks in the RINEX clock format. These clock products have a sampling rate of 5 minutes, compared to the 15 minutes in SP3. Some Analysis Centres even provide higher sampled clock products, e.g., JPL provides clocks with a sampling rate of 30 sec. The new clock combination distinguishes by a high quality of the provided clocks and it has improved the robustness of the combination process tremendously.

Outlook

The presently active and the upcoming LEO missions have the potential to fundamentally change the IGS as we know it today. It is therefore necessary that the IGS takes an active role in this field if it does not want to loose its position as the service which delivers the reference system for all GPS applications. In this context the generation of more frequent IGS products for near real-time use is an urgent need. Therefore the next IGS Analysis workshop in Ottawa is dedicated to real-time requirements and IGS real-time products. Also the potential interactions between the IGS and various GNSS systems (GPS, GLONASS, Galileo) and the remarkable progress achieved by the various IGS Project groups within the past year have to be considered.

At the end of 2001 IGS will implement the IGS Reference Frame 2000 (IGS 2000) realization. Similar to IGS 1997, the combined orbits will be made consistent to the combined IGS SINEX solution by using the combined ERPs and applying the same transformation parameters as used in the SINEX combination.

Robert Weber, Carine Bruyninx

III.3 SLR and LLR Coordination Centre

Introduction

The year 2000 has been a remarkable one for the Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) technique, since important contributions have been made for the generation of the ITRF2000 solution. In addition, the SLR/LLR community is heavily involved in an organizing process, with the aim of assuming a more coordinated role of the laser technique and providing for further improvements of the quality of results.

Activities in 2000

In principle, the SLR/LLR community has made contributions to the IERS in the same way as has been done in previous years. In general, three types of contributions can be distinguished:

(1) operational Earth Orientation Parameters
(2) final Earth Orientation Parameters
(3) station coordinates and velocities

The operational Earth Orientation Parameters (EOPs) are computed by a number of analysis institutes, and are submitted for inclusion in the IERS Bulletin A on a weekly or even more frequent basis. An overview of the various contributions as determined from the laser range technique is given in the table below. It is clearly visible that the frequency of the contributions, both in terms of number of submissions per week and in terms of length of data intervals, are diverse. At this moment, the same holds for the computation models and strategies and for the quality of the results.

Table 1. Overview of operational SLR/LLR EOP solutions.

institute	products	data interval per EOP solution [days]	submission frequency [days]
CSR	xpole, ypole, UT	3	7
DEOS	xpole, ypole	3	7
IAA	xpole, ypole, UT	1	1
MCC	xpole, ypole, UT	3	7

It is recognized, both by the IERS and the various SLR/LLR analysis groups, that the various products are not homogeneous. The International Laser Ranging Service (ILRS; cf. next section) will be instrumental in improving this situation.

Second, the various analysis institutes have contributed EOP solutions based on SLR/LLR observations for inclusion in the C04 series, which is a final EOP product produced by IERS. In some cases these contributions are merely a merged set of operational EOP products, whereas other contributions were obtained from a full re-analysis.

The SLR/LLR technique has also contributed to the most recent model for station coordinates: ITRF2000. This model basically provides the position of a large number of stations at a certain reference epoch and the individual velocity of each station. In total, 10 SLR and 2 LLR solutions were included in the ITRF2000 solution, provided by the following institutes: AUSLIG, CGS, CLG, CRL, CSR (twice), DEOS, DGFI, GSFC and JCET (all SLR) and FESG and UTexas (LLR). For comparison, ITRF2000 also included 18 GPS solutions, 3 VLBI solutions, 3 DORIS solutions and 2 multi-technique solutions.

The SLR/LLR solutions played a very important role in the ITRF2000 solution. Because of the unique characteristics of the observations (the laser range measurements are absolute, and in principle unbiased), the technique is capable of providing absolute coordinates and velocities (at least for the north-south and vertical components; the east-west component is connected to the ascending node of the satellites and/or moon, and is therefore not 100% absolute), and also of determining the absolute scale of the network with unprecedented accuracy. In its computation of ITRF2000, the IERS has exploited this feature by having the ITRF2000 origin fully defined by the SLR/LLR solutions, and by having the latter contribute with 50% weight to the absolute scale of the network model (the other 50% of information was determined by the VLBI solutions). This choice clearly underlines the unique capabilities and role of the laser range technique, and illustrates its changing role in space geodetic investigations.

ILRS

The ILRS was established in 1998 in Deggendorf, Germany. Amongst others, the purpose of the ILRS is to coordinate the satellite missions using SLR and the tracking of these spacecraft, stimulate, improve and coordinate the analyses and, in general terms, promote the laser ranging technique as a whole. To this aim, the ILRS organization includes a Central Bureau, Analysis and Associate Analysis Centers, Data Centers, Operations Centers and Stations and Networks.

In addition, the ILRS has established 4 working groups, notably on

(1) Missions,
(2) Data Formats & Procedures,
(3) Networks & Engineering, and
(4) Analysis.

The total organization is headed by a Governing Board.

In principle, all ILRS elements affect the IERS, directly or indirectly. The most intensive interaction is with the analysis groups, of course, which are represented by the Analysis Working Group (AWG) and the Analysis Coordinator. The AWG is tasked with the coordination of the various analysis and research activities of the laser ranging community, and one of the direct goals is to develop a number of unique analysis products. To this aim, the AWG has defined a number of pilot projects, in essence all with the aim of improving the analysis products computed at individual research institutions. In addition, some of the pilot projects (on station coordinates and earth orientation, in particular) aim at the generation of unique analysis products. This is in line with the envisioned data and products flow of the IERS, following its reorganization in 2000.

To achieve the goals, the ILRS AWG has organized a number of workshops in which various analysis aspects are under discussion and in development. Specific items which are worth mentioning here are the interpretation and use of the SINEX format, the generation of test datasets with satellite observations, the definition of parameter representations, and the development of pilot projects.

The latter make use of specific test cases, and are instrumental in understanding the individual analysis products and the development of official combination products. The response from the SLR/ LLR analysis community has been quite good, both in terms of attendance (about 15-20 analysts, typically) and in terms of number of contributions (about 10).

Ron Noomen, Bob E. Schutz, Peter J. Shelus

III.4 DORIS Coordination Centre

Overview

DORIS was developed for precise orbit determination and precise positioning on Earth.

Following the inclusion of DORIS as a new technique in IERS, six groups have been participating as Analysis Centers: CNES/SOD, GRGS, and IGN in France, UT/CSR in the USA, DUT in the Netherlands and MCC in Russia. The first four groups have submitted regular results to IERS either for polar motion determination or for tracking stations coordinates and velocities. Other groups are still developing their processing capabilities. Two IERS Data Centers have been providing the scientific community with DORIS measurements for several years: NASA/CDDIS and IGN/LAREG.

In 1999, following the recent IERS reorganization, it has been decided at the IAG General Assembly (Birmingham, UK, August 1999) to create a DORIS Pilot Experiment. Such a Pilot Experiment would give time to all groups to coordinate and improve their operationability in order to create on the long term an International DORIS Service (IDS). In the future, this scientific service would structure the DORIS community in order to provide scientific products for a broad range of potential users, starting by the IERS itself. This is done as common activity of the IERS and the IAG/CSTG (Commission on International Coordination of Space Techniques for Geodesy and Geodynamics of the International Association of Geodesy). This is very similar to what is done for GPS by the IGS, or for VLBI by the IVS or for SLR and LLR by the ILRS.

The International DORIS Pilot Experiment

For the DORIS Pilot Experiment an international Call for Participation has been issued in September 1999. A steering Committee has been set up and is composed of the following individuals:

Gilles Tavernier	CNES	Chairperson
Kristine Larson	University of Colorado	Stations Selection Group chairperson
Carey Noll	NASA/CDDIS	Data Flow coordinator
John Ries	University of Texas CSR	Data and Products formats Working Group chairperson
Laurent Soudarin	CLS	
Pascal Willis	IGN LAREG	DORIS representative and Coordinating Center to IERS

CNES, CLS and IGN perform the operational tasks of the Central Bureau. A specific Web site has been created presenting the Pilot Experiment organization, the proposals, the members of the different groups, the DORIS Mails, the Site logs, a lot of new information on the DORIS system and also links to all DORIS groups Web sites: <http://ids.cls.fr>

The DORIS Days, organised by CNES in partnership with the IGN, CLS and GRGS, and with the sponsorship of the INSU, the IERS and the CSTG, were held in Toulouse on May 2 and 3, 2000. About 130 people, representing various contributors and users of the DORIS system attended them: the host agencies (stations), the Data and Analysis Centres, the project partners and the scientific community.

This second version of the DORIS Days was in particular devoted to a review of the start-up of the Doris Pilot Experiment and of presenting the technological changes which have been made to the system (Jason, Envisat and SPOT5 missions, 3rd generation beacons). Two workshops gave the opportunity to discuss on:

- the organization of the Experiment and the interaction between scientific research and services
- the DORIS system and performances evolutions as planned as well as needed by the users

The Data and Products formats Working Group chaired by John Ries (Jean-Paul Berthias, Werner Gurtner, Carey Noll, Jean-Jacques Valette and Pascal Willis) is analyzing possible formats for:

- DORIS measurements: either raw or preprocessed, taking future dual channel second generation receivers into account
- High accuracy satellite ephemeris
- Three-dimensional coordinates and velocities of stations
- Earth rotation parameters
- Time-varying geocenter coordinates
- Static and time varying coefficients of the Earth's gravity field
- Surface meteorology, troposphere and ionosphere information

The activity of the group in 2000 was mainly related to measurements and the two first products.

Two Data Centers archive and distribute DORIS measurements and ancillary data. They will also archive and distribute products as soon as they are available, with the help of Carey Noll (Data Flow coordinator):

NASA GSFC / CDDIS	USA	Carey Noll
IGN / LAREG	France	Pascal Willis

There are eleven candidate Analysis Centers willing to process DORIS measurements:

AUSLIG	Australia	Ramesh Govind
CNES	France	Jean-Paul Berthias
CSR / Univ. of Texas	USA	John Ries
ESA ESOC Darmstadt	Germany	John Dow
Geod. Observ. Pecny	Czech Rep.	Jan Kostelecky

IAA St Petersbourg	Russia	George Krasinsky
IGN LAREG	France	Pascal Willis
INASAN Moscow	Russia	Suriya Tatevian
LEGOS / CLS	France	Jean-François Crétaux
Royal Obs. of Belgium	Belgium	René Warnant
University of Newcastle	UK	Phil Moore

The Stations Selection Group chaired by Kristine Larson includes scientists involved in various applications such as geodesy, geophysics, altimeter calibration, tide gauges, ITRF collocation and a representative of the DORIS Stations Installation and Maintenance Service (IGN/SIMB): Eric Calais, Chuck DeMets, Herve Fagard, Ramesh Govind, Bruce Haines, Frank Lemoine, Seth Stein, Simon Williams.

Existing stations were candidates to IDS:

Orbitography Network CNES/IGN – France	Hervé Fagard
Yarragadee, Mount Stromlo AUSLIG – Australia	Ramesh Govind
Badary, IAA – Russia	Zinovy Malkin
Kauai, Fairbanks NASA GSFC – USA	John Bosworth
Metsahovi, Finnish Geodetic Institute – Finland	Matti Paunonen
Syowa, National Institute of Polar Research – Japan	Kazuo Shibuya

The group defined site criteria taking DORIS site constraints into account and prepared a Station Response Form to be sent to candidate sites:

Cape York, Burnie and Lambert (Antartica), AUSLIG – Australia	Ramesh Govind
Dome C, Antartica	Christian Vincent
Grasse, Ajaccio – France	Pierre Exertier
Gavdos TU Crete – Greece	Stelios Mertikas
Herstmonceux – UK	Phil Moore
India	Vinod Gaur
Iran	Faramarz Nilforoushan
Irkutsk VS NIIFTRI – Russia	Vjacheslav Zalutsky
Geodetic Observatory Pecny – Czech Republic	Jan Kostelecky
San Fernando – Spain	Jose Martin Davila
Svetloe, Zelenchukskaya , IAA – Russia	Zinovy Malkin
Terra Nova Bay – Italy/Antartica	Alessandro Capra
Warsaw University of Technology – Poland	Janusz Sledzinski
Wettzell, TIGO (Chile), O'Higgins (Antartica) – Germany	Wolfgang Schlüter
Wousi, New Hebrides	Stéphane Calmant

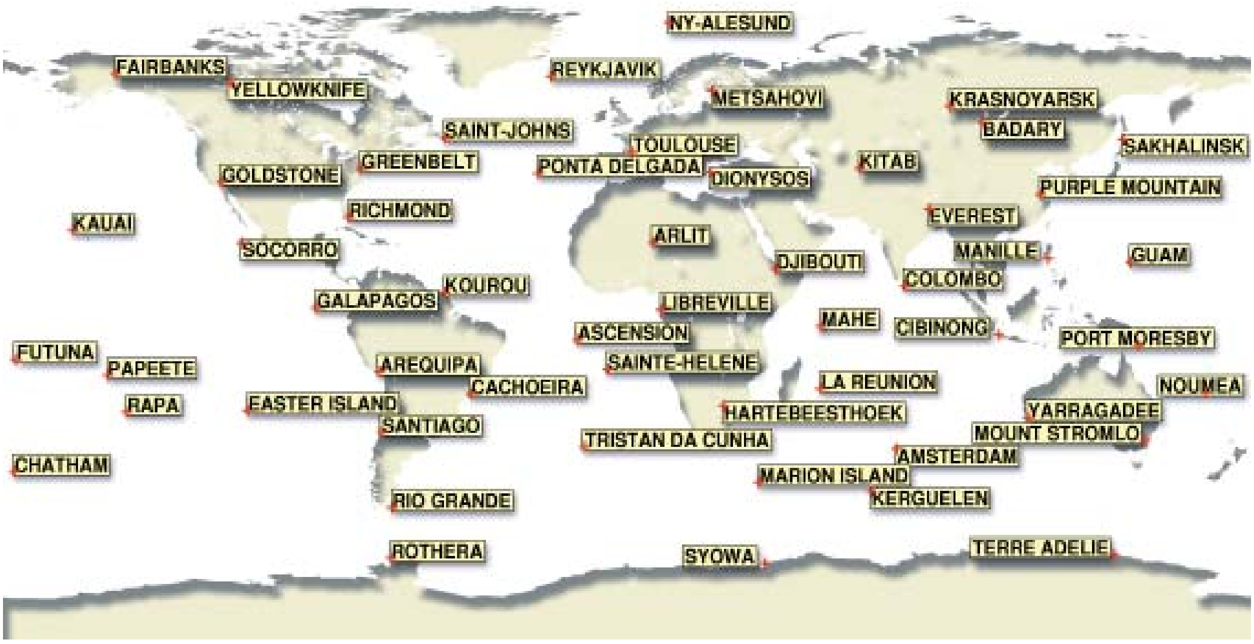
The proposals are going to be analyzed for a first selection.

Complete information about the activities of the Stations Selection Group are available on its web page which can be fond on the IDS web site or directly at the following address:
<http://phys-geophys.colorado.edu/~kristine/doris.html>

DORIS Network

As in the past years, the DORIS network has been very stable (see Figure 1). The installation and maintenance activities are realized by the IGN/SIMB.

Figure 1. The DORIS Network



In order to reach new accuracy goals for JASON 1 and ENVISAT, it was decided to improve the long-term stability of the antennas when necessary. This network renovation action started in 2000 with the stations of Cibinong, Djibouti, Hartebeesthoek and Metsahovi. Two new stations were installed in Greenbelt, replacing Ottawa (antenna on a concrete pillar instead of a high building) and in Futuna (antenna on an iron tube + concrete), replacing Wallis. Several new local ties with other geodetic techniques were realized and transmitted to the IERS Central Bureau.

It was also decided to develop third generation beacons to improve DORIS system accuracy and capacity, with possible frequency shift avoiding jamming by nearby stations, higher transmitted power, a modulated 2 GHz channel and possible remote control through a telephone line or an Argos terminal.

Sites logs have been created by the SIMB for all DORIS sites and are available at the IGN Web site (<http://www.ign.fr>). This includes information concerning the changes in the DORIS ground equipment (antenna, beacon, ...) and also precise local ties with other precise space technique of the IERS.

DORIS Control Center

SSALTO, the new DORIS and altimetry multimission Control Center is operational since December 2000. Thanks to its links with the Control Centers of the different satellites fitted out with a DORIS receiver, it is able to collect DORIS measurements, preprocess and send them to the DORIS Data Centers as well as ancillary data such as maneuvers, attitude, meteorological data.

SSALTO also produces preliminary and precise orbits, which will be sent to the Data Centers as soon as a format is adopted. The AVISO component will ensure archiving.

DORIS Satellite Constallation

DORIS data from four satellites are currently available in the two Data Centers and used by the Analysis groups: SPOT 2 (launched in 1990), TOPEX/POSEIDON (launched in 1992), SPOT 3 (1993–1996) and SPOT 4 (launched in 1998).

Three new satellites will be launched in the near future, carrying an improved second generation DORIS receiver: JASON 1, ENVISAT and SPOT 5. Other missions are already decided, such as CRYOSAT (ESA) or Pleïade (SPOT follow-on). The new DORIS receivers will have a dual channel capability, allowing multiple stations positioning in the same area, an improved accuracy and a real autonomy thanks to DIODE navigator: self start, self programming and real time on-board orbit determination.

Furthermore, in its proposal CNES has offered such receivers for possible new missions outside France. The number of available DORIS satellites is still a limiting factor in the accuracy of the DORIS results for IERS (stations positions and velocities), polar motion. It is then very important to increase the present number of satellites.

Gilles Tavernier, Kristine Larson, Carey Noll,
John Ries, Laurent Soudarin, Pascal Willis

IV.1 Central Bureau

The IERS began operation in January 1988. After a decade, its structure was reorganized by the Directing Board for the following reasons:

Firstly the various techniques GPS, Laser tracking to the Moon and to artificial satellites and also VLBI into international Services had already been reorganized into international services IGS, ILRS and IVS, respectively in 1994, 1998 and 1999.

Secondly to give more visibility to the different components of the IERS.

Thirdly in order to open the service to new scientific groups which had developed in various countries in the meantime.

Following discussions which took place at the IERS workshop in Paris in Fall 1996 and during the “IERS retreat” held in Potsdam in September 1998, new Terms of Reference were formulated and adopted by the IERS Directing Board in March 1999. The IAG, IAU and FAGS were acknowledged of these new Terms of Reference in 1999.

The Call for Participation in the new IERS was disseminated on 16 November 1999 via the IERS Gazette 46 and also more officially through hard copies directly sent to 34 different institutions of various countries. After reviewing the various submitted proposals, a Review Board lead by Ivan Mueller presented recommendations to the Directing Board which then voted separately on each recommendation. The list of institutions in charge of the different activities are presented in the present annual report. The new structure of the IERS began operation on January 1, 2001.

During the course of 2000 the Central Bureau activities were smoothly transferred from Paris Observatory to the Bundesamt für Kartographie und Geodäsie (BKG) with Bernd Richter as its director designee.

During 2000, the former Central Bureau in Paris performed the general management and daily coordination of its activities involving the relationships with users, the archival and dissemination of products, IERS gazettes and relevant documentation and information. Several publications were made, including in particular an Annual Report for 1999 and the Technical Note No. 28 (High-frequency to subseasonal variations in

Earth Rotation, B. Kolaczek, H. Schuh and D. Gambis (eds.)).

The former and the forthcoming Central Bureau organised the following directing board meetings:

No. 30, June 3-4, 2000, US Naval Observatory, Washington D.C.,

No. 31, September 14-15, 2000, Bundesamt für Kartographie und Geodäsie, Frankfurt am Main,

No. 32, December 18, 2000, Moscone Centre, San Francisco, California, USA.

On request of the IERS Directing Board the forthcoming Central Bureau organized a meeting on an IERS Data Base. The meeting took place in Paris, October 31, 2000. The goal was to find out 1) how the data flow inside the IERS, as well as between its product centers and the technique/analysis centers on the one hand, and the users on the other hand, works at present and how it should be organized in the future, 2) which data/products should be collected, archived and displayed at a central place (IERS Data Base/ Data Centre).

Daniel Gambis, Bernd Richter, Wolfgang R. Dick

IV.2 Celestial System Section of the Central Bureau

Introduction

The IAU 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 Product Center (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 International Celestial Reference System. The present report was prepared by the Paris Observatory component of the ICRS Product Center, in cooperation with the ICRF section of the IERS Central Bureau that was in charge until the end of 2000.

The International Celestial Reference System (ICRS) is materialized by coordinates of extragalactic radio sources derived from VLBI observations. The access to ICRS in radio wavelengths is given by the 667 extragalactic radio sources in ICRF-Ext.1 (IERS, 1999). This extension of the initial ICRF was elaborated as a part of the maintenance process of the conventional celestial system and its frame (Ma *et al.*, 1997, 1998). While the set of the 212 defining sources and their respective coordinates remain unchanged with respect to the first realization of the frame, more precise coordinates for sources classified as “candidate” and “other” in ICRF are provided in ICRF-Ext.1; 59 “new” sources that were not included in the initial ICRF increase the number of objects in the conventional frame.

Concerning the ICRS monitoring, the location of the ICRS origin of right ascensions relative to the dynamical equinox is monitored using Lunar Laser Ranging (LLR) solutions. The location of the ICRS pole relative to the Celestial Ephemeris Pole is monitored using VLBI-derived celestial frames and time series of the celestial pole offsets.

Various investigations concerning ICRF-Ext.1 are presented, based on the contributions from VLBI analysis centers: additional sources since the construction of ICRF-Ext.1, stability analyses based on time series of source coordinates, and comparisons of the ICRF with newly computed radio source catalogues. Notice that some of these catalogues were generated from the TRF/EOP solutions rather than specifically for the CRF.

The ICRS Product Center at Paris Observatory organizes and updates a database which contains VLBI celestial frame realizations achieved during the last 15 years. Different files provide information to characterize the objects involved (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 Product Center (<icrs-pc@hpopa.obspm.fr>).

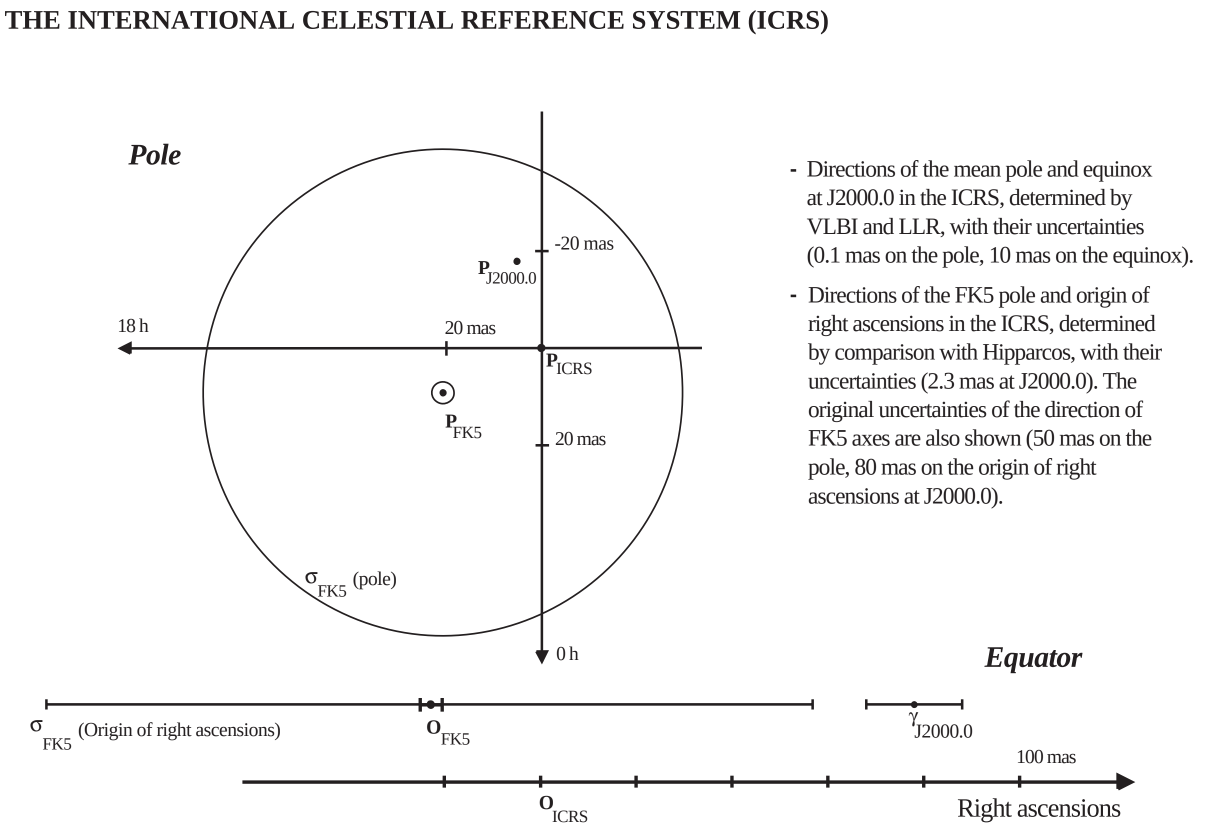
The International Celestial Reference System

The kinematical definition of ICRS

Since 1998 January 1st, the International Celestial Reference Frame (ICRF), materialized by a set of extragalactic directions, replaced the Fifth Fundamental Catalogue (FK5) that gave star coordinates in a reference system (referred to as equator and equinox J2000.0) based primarily on the dynamics of the solar system (see Feissel and Mignard, 1998). The current definition of this conventional celestial reference system is based on a kinematical concept. In this concept, the axes of the system will remain fixed with respect to distant matter in the Universe. For the sake of continuity, the FK5 conventional directions at J2000.0 were retained in the new definition.

Figure IV-2.1 shows the positions of the mean pole and equinox at J2000.0 ($P_{J2000.0}$, $\gamma_{J2000.0}$) and those of the pole and the right ascensions origin of the FK5 catalogue (P_{FK5}, o_{FK5}) with respect to the ICRS pole and right ascensions origin ($P_{ICRS,}$ o_{ICRS}).

Fig. IV-2.1: The ICRS pole and right ascensions origin.



The origin of the coordinate axes in the ICRS is at the barycenter of the Solar System. The principal plane of the ICRS is close to the mean equator at J2000.0; it was defined by the equatorial plane implied in the IAU(1976) and IAU(1980) conventional precession and nutation models (Lieske *et al*., 1977; Seidelmann, 1982). In consistency with the IAU recommendations, the ICRS celestial pole agrees with that of the FK5 within the uncertainty of the latter (Fig. IV-2.1).

The right ascensions origin of the ICRS represents very closely the dynamical equinox at J2000.0, and agrees with the FK5 origin. It was implicitly defined in its first realization by adopting the mean of the J2000.0 right ascensions of 23 radio sources in a group of VLBI catalogues. These catalogues were compiled by fixing the right ascension of the quasar 1226+023 (3C273B) to its conventional FK5 value (obtained by Kaplan *et al.*, 1982 from the FK4 value derived by Hazard *et al.,* 1971), a usual procedure at that time.

Ecliptic directions in ICRS

The combined analysis of VLBI and LLR observations (Folkner *et al.,* 1994) is one of the most efficient ways to determine the position of the planetary frame relative to the extragalactic reference frame. The series of Earth Orientation Parameters (EOP) adjusted in the analysis of VLBI observations provide the accurate relationship between the terrestrial reference system and the extragalactic celestial reference system. The LLR technique is sensitive to the orientation of the Earth with respect to the lunar orbit, providing fundamental information about the tie between the Earth-fixed frame and the dynamical frame materialized by the motion of the Moon as determined from semi-analytical theories or numerical integrations.

Thus knowing the station locations and the time-dependent rotation transformations involving the EOP, it is possible to infer the position of the planetary ephemeris frame with respect to the extragalactic reference frame. The orientation of the dynamical ecliptic and the location of the dynamical equinox in the ICRS are obtained from the combined analysis of the two techniques.

The definition of the ecliptic itself has been a subject of discussion (Standish, 1981; Kinoshita and Aoki, 1983). Following Le Verrier's definition, the ecliptic is the mean orbital plane of the Earth as determined from the secular part of the motion of the ascending node and the declination of the Sun with respect to an inertial reference plane.

The ecliptic can also be defined so that in the expression of the Sun's latitude there is no term containing the sine or the cosine of the argument of the latitude. Moreover, Standish (1981) pointed out that there can be two different definitions of the dynamical equinox and of the mean obliquity according to the way they are computed, that is, with respect to an inertial frame or to a rotating frame. The definition in a rotating frame is equivalent to Newcomb's one.

Monitoring the ICRS

Orientation of the celestial dynamical ecliptic reference frame from LLR results

In practice, the position of the inertial dynamical ecliptic at a given epoch with respect to the ICRS can be obtained from LLR observations. It must be emphasized that the lunar ephemerides (as ELP2000, DE405 etc...) provide the position of the inertial dynamical ecliptic with respect to the Moon, whereas the position of the equator of J2000.0 is implicitly given by its orientation with respect to the instantaneous equator at a given date by means of the nutation-precession matrix. In order to get the position of the dynamical ecliptic above, the complementary necessary parameters are the coordinates of the Celestial Ephemeris Pole (CEP), the Greenwich Sidereal Time (GST), the geocentric coordinates of the LLR stations (Folkner *et al.*, 1994) and the selenocentric coordinates of the receivers on the Moon. These last parameters can be subject to adjustment during the analysis.

The basic definitions concerned here are:

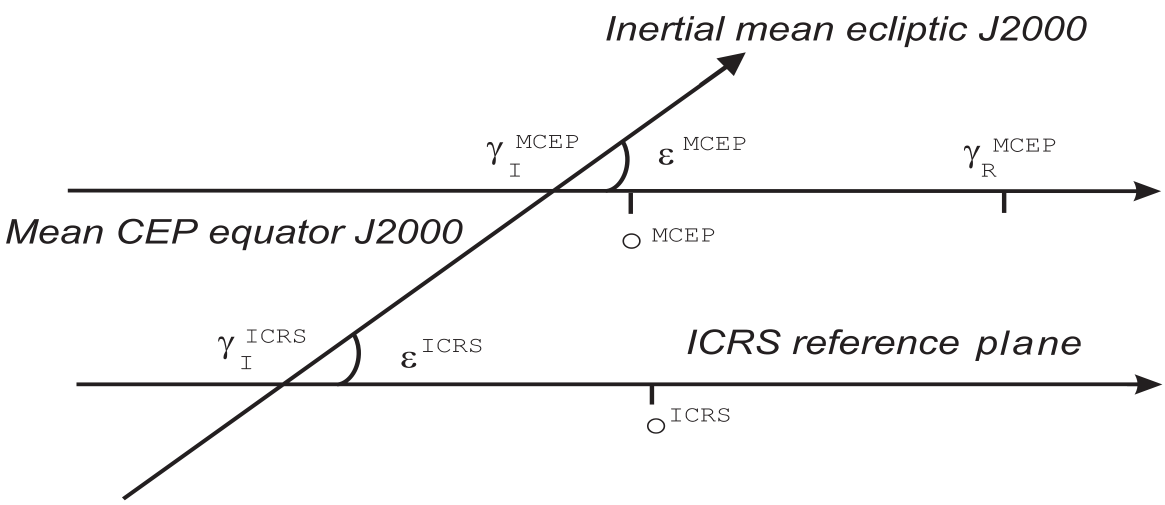
· the inertial dynamical ecliptic of J2000.0

· the J2000.0 mean equator (E) and origin of right ascensions (o)

· the inertial mean equinox of J2000.0 (γ_I) defined as the ascending node of the inertial ecliptic on the mean equator of J2000.0

The J2000.0 mean equator (E) and origin of right ascensions (o) are defined starting from both the rectangular coordinates of the LLR stations in the terrestrial reference frame and the adopted transformation from terrestrial coordinates to the celestial J2000.0 equatorial coordinates, with two realizations, according to the solutions OPA 01 M 01 and OPA 01 M 02 which are explained below (Fig. IV-2.2). The method is described in Chapront *et al.* (1999a).

Fig. IV-2.2: Position angles of the inertial mean ecliptic of J2000.0 according to the solutions OPA 01 M 01 and OPA 01 M 02



Solution OPA 01 M 01 gives the position of the inertial mean ecliptic of J2000.0 with respect to a celestial reference frame tied to the mean CEP equator of J2000.0. Solution OPA 01 M 02 gives the position of the inertial mean ecliptic of J2000.0 with respect to the ICRS.

These solutions result from weighted fits of the semi-analytical theory ELP 2000-96 of the orbital motion of the Moon (Chapront and Chapront-Touzé, 1997) and the improved Moon's analytical theory for the libration with numerical complements (Chapront *et al.*, 1999b). The numerical complements have been recently updated (Chapront, 2000).

These determinations are based on weighted fits of a lunar analytical solution to a set of 14 754 LLR observations (normal points) from McDonald (2.7 m telescope, MLRS1, MLRS2), Haleakala (Hawaii), and Grasse (CERGA), covering the time span from January 1972 till March 2001. A correction of 0.7 *ns* has been added to CERGA observations from 1997, January 13th till 1998, June 24th, in order to take into account a calibration offset mentioned by F. Mignard and J.-F. Mangin (CERGA). The adopted coordinates of McDonald 2.7 m, MLRS1, Haleakala transmitter and Grasse are those of ITRF94. The separations between MLRS2 and MLRS1, and Haleakala receiver and transmitter are constrained to JPL 1991 values. The velocities (plate motion) are given by ITRF94. The other corrections to the station coordinates are computed according to the IERS Standards (McCarthy, 1992). EOP values x, y, and UT1 are given by the IERS series EOP(IERS) C 04 and the short period variations are taken into account using Ray's developments in the IERS Conventions (McCarthy, 1996).

We present hereafter the two solutions: OPA 01 M 01 and OPA 01 M 02. The errors mentioned in these solutions represent the formal uncertainties resulting from the least squares adjustment. Realistic uncertainties can be estimated between five and ten times these values.

Analysis of the LLR solution OPA 01 M 01

In this solution, the precession is given by the expressions of Williams (1994) with corrections to the precession and obliquity constants introduced by means of the derivatives of Simon *et al.* (1994). The nutation adopted is from Herring (McCarthy, 1996). The conclusions by Williams and Melbourne (1982) are taken into account by means of a correction to the sidereal time. The resulting J2000.0 celestial equator and origin of right ascensions are denoted as J2000.0 mean CEP equator and CEP origin of right ascensions. The notation for this origin is o^{MCEP}.

The solution yields the fitted values of the inertial mean obliquity of J2000.0 ε_I^{MCEP}, the arc $o^{MCEP}\gamma_I^{MCEP}$ along the equator, and the correction Δp to the IAU 1976 precession constant:

ε_I^{MCEP} = 23° 26' 21".405 62 ± 0.000 05"

$o^{MCEP}\gamma_I^{MCEP}$ = –14.5 ± 0.2 *mas*

Δp = –3.36 ± 0.03 *mas/yr*

Usually, γ_I^{MCEP} is named the «inertial dynamical mean equinox» of J2000.0. The separation from γ_I^{MCEP} to the «rotational dynamical mean equinox» of J2000.0 γ_R^{MCEP} is 93.66 *mas* (Standish, 1981). γ_R^{MCEP} is the same as $\gamma_{J2000.0}$ in Fig. IV-2.1.

Analysis of the LLR solution OPA 01 M 02

In this solution, the precession-nutation resulted from the corrections $d\psi$ and $d\varepsilon$ given by the series EOP(IERS) C 04. The resulting J2000.0 celestial equator and origin of right ascensions stand for the ICRS equator and origin of right ascensions. The latter origin is denoted as o^{ICRS}.

The solution yields the fitted values of the mean obliquity ε_I^{ICRS} and the arc $o^{ICRS}\,\gamma_I^{ICRS}$ along the equator:

ε_I^{ICRS} = 23° 26' 21".411 08 ± 0.000 05"

$o^{ICRS}\,\gamma_I^{ICRS}$ = –55.3 ± 0.1 *mas*

The difference between the two lunar mean longitudes at the weighted mean epoch of observations gives the arc $\gamma_I^{ICRS}\,\gamma_I^{MCEP}$ separating the two inertial equinoxes in the dynamical ecliptic of J2000.0:

$\gamma_I^{ICRS}\,\gamma_I^{MCEP}$ = 44.5 ± 0.4 *mas*

Orbital parameters of the Moon and of the Earth-Moon barycenter, free libration parameters, tidal secular acceleration, corrections to the theoretical values of the mean motions of the lunar perigee and of the node have also been fitted in both solutions (Chapront *et al.*, 2001).

Direction of the mean pole at J2000.0 in the ICRS from VLBI results

Until 2000, the IERS Conventions (McCarthy, 1996) provided a rate correction to the IAU (1976) precession in longitude and a rate in obliquity which was ignored in the current IAU models as well as a state of the art nutation model that was implicitly referred to the mean pole at J2000.0. In 2000, the IAU recommended the use of a new nutation model, MHB2000 (Mathews *et al.*, 2001), starting from 2003, January 1st. On the other hand, the ICRS pole was defined in 1988 by using the then current IAU models (Lieske *et al.,* 1977; Seidelmann, 1982). To the extent that the IERS(1996) nutation model or the MHB2000 are accurate, VLBI time series of the celestial pole offsets $d\psi$, $d\varepsilon$, referred to the ICRF pole, can be used to estimate the direction of the mean pole at J2000.0 in the ICRS ($P_{J2000.0}$ in Fig. IV-2.1).

The IERS series of $d\psi$, $d\varepsilon$ (e.g. EOP(IERS) C 04) are referred to the ICRS. If we correct them by the IERS(1996) precession-nutation model, or if we use the MHB2000 model and the corresponding precession and obliquity rates corrections (resp. –2.997 mas/year and –0.255 mas/year), the expected remaining signal, apart from the Free Core Nutation, is a pair of biases $d\psi_0$, $d\varepsilon_0$ that reflect the misalignment of the mean pole at J2000.0 with the ICRS pole. Defining the rotation around the ICRS X-axis as P_18h and the rotation around the ICRS Y-axis as P_0h, one gets:

$$P\_18h = -\,d\varepsilon_0; \qquad P\_0h = d\psi_0 \sin \varepsilon_0$$

In the case of a VLBI solution that includes both a series of $d\psi$, $d\varepsilon$ and a celestial reference frame (CRF), the same information can be derived after taking into account the corrections that bring the results into the IERS system. Using the VLBI solutions submitted for this Annual Report, the angles between individual CRF and the ICRF and the consistency corrections, estimations of P_18h and P_0h, are given in Table IV-2.1.a, using the IERS(1996) precession-nutation model, and in Table IV-2.1.b, using the MHB2000 model.

Table IV-2.1.a: Coordinates of the mean pole at J2000.0 in the ICRS, based on individual solutions and on the IERS results, using the nutation series EOP(IERS) C 04, corrected by the IERS(1996) precession-nutation model

EOP		RSC		Time span	P_0h	P_18h
BKGI	01 R 01	BKGI	01 R 01	1984.0-2001.0	-17.15±0.02	5.10±0.02
GSFC	01 R 01	GSFC	01 R 01	1979.0-2001.0	-17.12±0.01	5.09±0.01
IAA	01 R 01	IAA	01 R 02	1984.0-2001.0	-17.15±0.03	5.06±0.03
SHA	01 R 01	SHA	01 R 01	1979.0-2001.0	-17.13±0.03	5.10±0.03
IERS	C 04	ICRF-Ext.1		1984.0-2001.0	-16.94±0.08	5.07±0.01

Unit: 0.001"

Table IV-2.1.b: Coordinates of the mean pole at J2000.0 in the ICRS, based on individual solutions and on the IERS results, using the nutation series MHB2000

EOP		RSC		Time span	P_0h	P_18h
BKGI	01 R 01	BKGI	01 R 01	1984.0-2001.0	-16.63±0.02	6.80±0.02
GSFC	01 R 01	GSFC	01 R 01	1979.0-2001.0	-16.60±0.01	6.76±0.01
IAA	01 R 01	IAA	01 R 02	1984.0-2001.0	-16.59±0.03	6.81±0.03
SHA	01 R 01	SHA	01 R 01	1979.0-2001.0	-16.61±0.03	6.77±0.03
IERS	C 04	ICRF-Ext.1			-16.41±0.02	6.80±0.02

Unit: 0.001"

In order to evaluate the position of the mean pole at J2000.0 with respect to the ICRF, we calculated the mean value of the coordinates P_18h and P_0h given by the tables above. We conclude that the direction of the mean pole at J2000.0 in the ICRS is 5.0 *mas* in the direction 18h and 17.1 *mas* in the direction 12h, when we adopt as a nutation model the IERS(1996) one, and respectively 6.8 *mas* and 16.6 *mas*, when we adopt the MHB2000 nutation model. Note that the difference of determinations between the two models are not detectable at the scale of Fig. IV-2.1. As a consequence, in order to predict $d\psi$ and $d\varepsilon$ in the ICRS by means of the IERS(1996) precession-nutation model or by means of the MHB2000 model, one must use a pair of additive constants, which are:

– in longitude : $d\psi_0 = -0.0431''$ [IERS(1996)];
$d\psi_0 = -0.0417''$ (MHB2000).
– in obliquity : $d\varepsilon_0 = -0.0051''$ [IERS(1996)];
$d\varepsilon_0 = -0.0068''$ (MHB2000).

These constants will be absorbed in the expressions for precession/nutation to be used after 2003, January 1st.

Investigations concerning ICRF-Ext.1

Additional sources

In the frames submitted this year to IERS, 21 extragalactic radio sources not present in ICRF-Ext.1 are found. Most of these sources have a short observational history and in consequence only preliminary ICRS coordinates can be obtained from the individual catalogues by using the parameters of Tables IV-2.-6 and IV-2.7 to transform individual frames into ICRS. The Table IV-2.2 gives ICRF designations and the source information available in each frames.

Table IV-2.2: Additional sources with respect to ICRF-Ext.1

ICRF Designation	IERS Des.	Frame	Mean MJD	First of observation	Last span	Nb ses.	Nb Delay
J024031.6+611345	0236+610						
		RSC(BKGI) 01 R 01	50492.2	49693.8	51736.8	22	62
		RSC(GSFC) 01 R 01	50262.4	49690.0	51975.7	28	87
		RSC(IAA) 01 R 02	50798.5	49980.1	51674.7	13	40
		RSC(SHA) 01 R 01	50493.2	49694.8	51961.8	26	62
J032536.8+222400	0322+222						
		RSC(BKGI) 01 R 01	51614.6	51323.8	51813.8	16	170
		RSC(GSFC) 01 R 01	51492.9	51324.8	51814.8	19	742
		RSC(IAA) 01 R 02	51563.0	51323.8	51814.4	14	184
		RSC(SHA) 01 R 01	51470.5	51324.8	51814.8	17	491
J032754.1+023341	0325+023						
		RSC(IAA) 01 R 02	51492.3	51492.1	51492.4	1	4
		RSC(SHA) 01 R 01	51492.8	51492.8	51787.8	2	4

J033647.3+003519	0334+004							
		RSC(IAA)	01 R 02	49987.3	49987.3	49987.4	1	2
		RSC(SHA)	01 R 01	49992.8	49987.8	50064.8	3	3
J041821.2+380135	0415+379							
		RSC(GSFC)	01 R 01	51534.1	51464.8	51681.7	5	135
		RSC(IAA)	01 R 02	51538.2	51464.1	51681.7	4	46
		RSC(SHA)	01 R 01	51538.3	51464.8	51681.7	4	47
J065917.9+081330	0656+082							
		RSC(IAA)	01 R 02	51584.9	51520.2	51688.6	4	39
		RSC(SHA)	01 R 01	51583.6	51520.8	51688.8	4	38
J094014.7+260329	0937+262							
		RSC(BKGI)	01 R 01	51407.8	51407.8	51407.8	1	13
		RSC(IAA)	01 R 02	51408.0	51407.8	51408.6	1	13
		RSC(SHA)	01 R 01	51408.8	51408.8	51408.8	1	13
J094538.1+353455	0942+358							
		RSC(GSFC)	01 R 01	50854.6	50854.6	50854.6	1	100
J124129.5+602041	1239+606							
		RSC(IAA)	01 R 02	51367.9	51352.0	51352.7	2	9
		RSC(SHA)	01 R 01	51368.3	51352.8	51380.7	2	9
J141604.1+344436	1413+349							
		RSC(GSFC)	01 R 01	51684.3	51646.8	51687.6	2	63
		RSC(IAA)	01 R 02	51646.3	51645.8	51646.7	1	4
		RSC(SHA)	01 R 01	51646.8	51646.8	51646.8	1	4
J143853.6+371035	1436+373							
		RSC(GSFC)	01 R 01	51687.6	51687.6	51687.6	1	65
J143923.6+325354	1437+331							
		RSC(GSFC)	01 R 01	51687.6	51687.6	51687.6	1	35
J181657.0+530744	1815+531							
		RSC(BKGI)	01 R 01	51703.5	51703.5	51703.5	1	11
		RSC(SHA)	01 R 01	51704.5	51704.5	51704.5	1	11
J192218.6+084157	1919+086							
		RSC(SHA)	01 R 01	50700.6	50700.6	50700.6	1	9
J192439.4+154043	1922+155							
		RSC(GSFC)	01 R 01	50654.8	50654.8	50654.8	1	339
J200210.4+472528	2000+472							
		RSC(BKGI)	01 R 01	51703.5	51703.5	51703.5	1	27
		RSC(GSFC)	01 R 01	51704.5	51704.5	51704.5	1	27
		RSC(SHA)	01 R 01	51704.5	51704.5	51704.5	1	27
J210841.0+143027	2106+143							
		RSC(GSFC)	01 R 01	50800.8	50800.8	50800.8	1	296
J212313.3+100754	2120+099							
		RSC(BKGI)	01 R 01	50699.6	50699.6	50699.6	1	38
		RSC(GSFC)	01 R 01	50700.6	50700.6	50700.6	1	31
		RSC(SHA)	01 R 01	50700.6	50700.6	50700.6	1	56
J214518.7+111527	2142+110							
		RSC(GSFC)	01 R 01	50654.8	50654.8	50654.8	1	124
J214755.2+083011	2145+082							
		RSC(GSFC)	01 R 01	50654.8	50654.8	50654.8	1	26
J214935.2+075625	2147+077							
		RSC(BKGI)	01 R 01	50699.6	50699.6	50699.6	1	24
		RSC(SHA)	01 R 01	50700.6	50700.6	50700.6	1	30

Source stability analyses

The astrometry data set used here is a time series of session-per-session source positions computed in a homogeneous reference frame by T. M. Eubanks, then at USNO, from VLBI observations going back to August 1979. For the most regularly observed sources, quasi continuous time series of weighted average coordinates at one-year intervals are shown on the ICRS-PC website: <http://hpiers.obspm.fr/icrs-pc/timeseries/presentation.html>.

Figure IV-2.3 shows source stability plots under the form of the envelopes of the standard deviation of 0.5 year averages in the source declinations and right ascensions. The figure presents separately the sources with high or moderate stability and those with low stability, measured over 1987–1999.

Table IV-2.3 gives the distribution of the maximum variance directions as a function of declinations for the two classes of sources shown in Fig. IV-2.3.

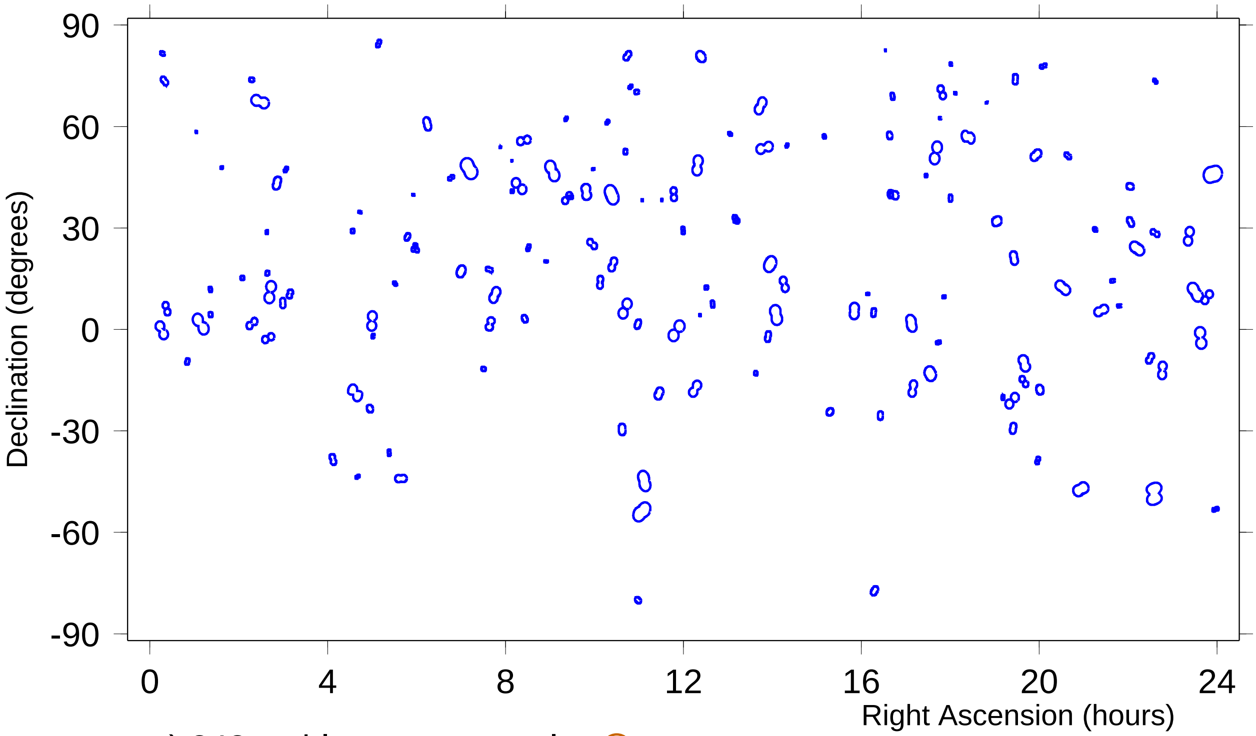
Table IV-2.4 gives the amplitude and direction of the maximum standard deviations over 1994–1999 for 258 sources with a good observational history over that time span.

The most stable sources show a quite even distribution of the local directions of maximum variability in the declination zones north of +20° and south of –20°, suggesting that the observed variability corresponds to real local effects in the sources. A detailed study of the 16 best observed sources north of declination +20° (Feissel *et al.*, 2000) shows that the VLBI results are precise enough to allow the spectral characterization of the source variability. However, the results in the declination zone [–20°,+20°] show an excess of the variability in the direction of declinations, probably reflecting tropospheric mismodelling. This excess is much stronger for the more variable sources, for which an even distribution is reached only north of +20°. An extensive analysis of the time stability of nearly 300 ICRF sources is being published (Gontier et *al.*, 2001).

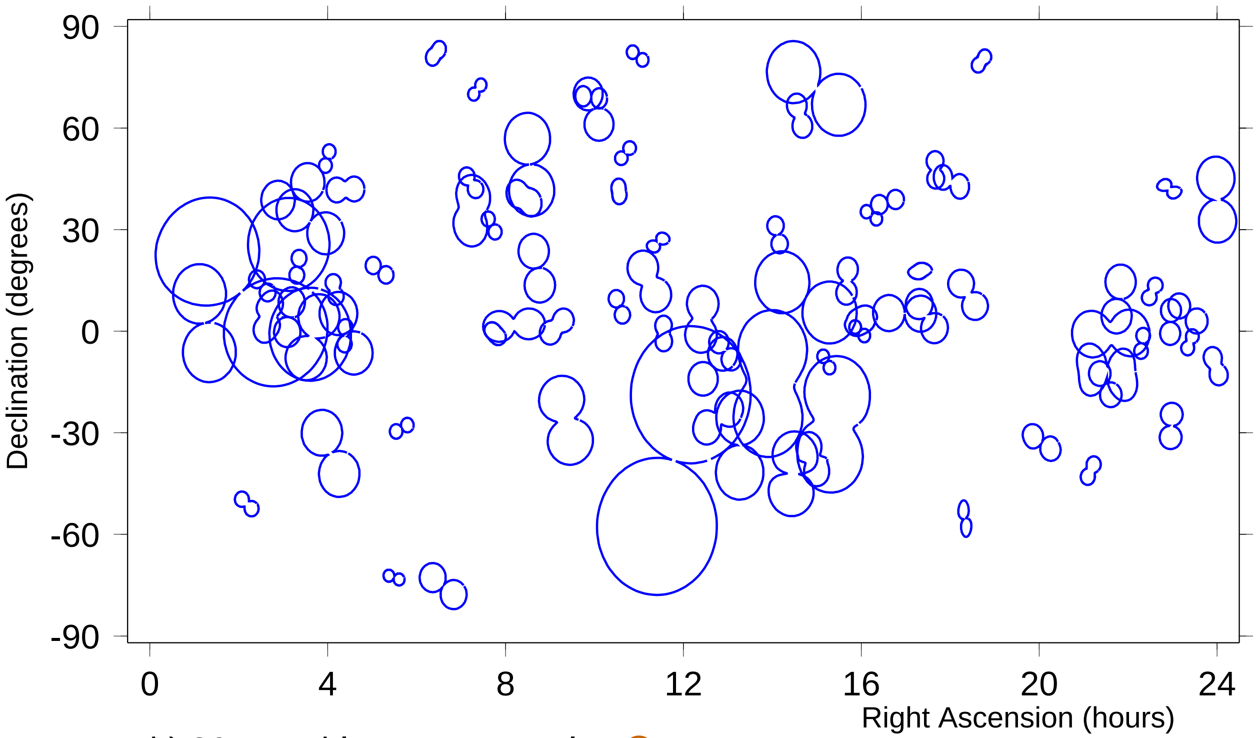
Table IV-2.3: Distribution of the angles of axes of maximum variability with respect to the declination axis, for sources shown on Fig. IV-2.3.

Declinations in degrees	Inclination bins (absolute values) Stable sources			Unstable sources		
	0°-30°	30°-60°	60°-90°	0°-30°	30°-60°	60°-90°
+20 to +90	35%	42%	23%	32%	45%	23%
0 to +20	55%	27%	18%	55%	31%	14%
-20 to 0	55%	30%	15%	67%	20%	13%
-90 to -20	42%	26%	32%	70%	18%	12%

Fig. IV-2.3: Envelopes of the 1987–1999 standard deviations of 0.5 year averages in equatorial coordinates. Sources with a) high or moderate stability, b) with low stability.



a) 243 stable sources, scale: (Diameter = 0,001")



b) 86 unstable sources, scale: (Diameter = 0,001")

Table IV-2.4:
Stability criteria of ICRS sources

Struc: The ICRF-Ext.1 structure indices in the S and X bands (1->4, in decreasing order of astrometric suitability).
Sigmax: Standard error of average residuals at 0.5 year intervals, in direction Dir.
Dir: Direction of the maximum variance relative to the local parallel (90° ~ declinations axis, 0 & 180° ~ right ascensions axis).
Data span: Dates of the first and last average points considered (years-1900).
Np: Number of average points at 0.5 year intervals available in the data span.
Ns: Number of sessions having the source over 1980.00-1999.25.

Source	Struc S X	Sigmax (mas)	Dir (deg)	Data span	Np	Ns
0003-066	3 1	.169	92.	94.5-99.0	8	200
0013-005	2 1	.467	110.	96.0-99.0	7	30
0014+813	1 1	.080	58.	94.0-99.0	11	269
0016+731	2 1	.302	136.	94.0-98.5	9	401
0019+058	1 1	.341	106.	95.0-98.0	5	13
0048-097	1 1	.117	84.	94.0-99.0	11	709
0055+300		.961	92.	96.5-99.0	5	8
0059+581	2 1	.052	122.	94.0-99.0	11	622
0104-408		.225	110.	94.0-99.0	11	265
0106+013	2 1	.501	114.	94.0-99.0	11	1017
0111+021	3 1	.180	46.	94.5-99.0	10	94
0119+041	2 1	.101	106.	94.0-99.0	11	1208
0119+115	2 1	.134	104.	95.5-99.0	8	141
0133+476	2 1	.050	24.	94.0-99.0	10	286
0146+056	3 1	.585	30.	96.0-99.0	7	30
0201+113	2 1	.175	102.	94.0-99.0	11	215
0202+149	2 2	.092	44.	94.0-99.0	11	338
0202+319	2 2	.200	64.	95.0-99.0	6	18
0202-172	3 1	.661	116.	94.5-98.0	5	11
0208-512		.819	138.	94.0-99.0	11	212
0212+735	2 2	.190	40.	94.0-99.0	8	1122
0215+015	1 1	.220	20.	94.0-98.5	8	18
0220-349		.684	54.	94.0-98.5	6	9
0221+067	2 2	.527	40.	95.5-98.0	6	9
0229+131	2 1	.088	148.	94.0-99.0	11	1578
0234+285	3 2	.081	110.	94.0-99.0	9	877
0235+164	1 1	.131	98.	94.0-99.0	11	212
0236+610		2.114	26.	95.0-99.0	5	9
0237+040	2 1	1.020	62.	94.5-98.5	5	11
0237-027	1 1	.330	16.	94.5-99.0	6	11
0238-084	4 2	.270	36.	94.5-99.0	10	165
0239+108	2 2	.568	78.	95.5-99.0	8	29
0256+075	2 1	.109	94.	95.5-98.0	5	31
0300+470	2 1	.173	88.	94.0-98.5	8	662
0302-623		.240	32.	94.0-96.5	5	14
0305+039		.268	20.	96.5-99.0	5	12
0306+102	3 1	.224	64.	96.0-98.5	6	22
0308-611		.191	118.	94.0-96.5	6	55
0317+188	2 1	.826	78.	96.0-98.5	6	22
0333+321	3 3	.112	174.	94.0-99.0	7	57
0336-019	2 1	.136	162.	94.0-99.0	11	512
0338-214		.699	108.	94.0-99.0	9	21
0341+158	2 1	.160	124.	95.0-97.5	5	9

Table IV-2.4 (cont.)

Source	Struc S	Struc X	Sigmax (mas)	Dir (deg)	Data span	Np	Ns
0355+508	2	3	.679	84.	94.0-98.0	5	358
0402-362			2.223	114.	94.0-99.0	11	154
0405-385			.249	112.	95.5-99.0	6	34
0420-014	3	1	.658	76.	94.0-99.0	9	1168
0422+004	2	1	.536	84.	95.0-98.5	5	12
0430+052	4	3	.788	98.	94.5-99.0	8	51
0430+289			.111	90.	96.0-99.0	7	26
0434-188	3	1	.643	124.	94.0-98.5	8	48
0437-454			.649	72.	94.0-98.0	6	10
0440+345	2	1	.099	166.	94.5-98.5	6	14
0440-003	1	1	.657	4.	94.5-98.0	5	15
0454+844	2	1	.178	64.	94.0-98.5	8	21
0454-234	2	1	.191	144.	94.0-99.0	11	1302
0457+024	4	1	.470	80.	94.0-99.0	10	43
0458-020	2	1	.102	58.	94.0-99.0	11	906
0507+179	2	2	.156	68.	94.5-98.5	5	23
0521-365			.335	110.	94.5-99.0	8	44
0528+134	1	1	.124	148.	94.0-99.0	11	2118
0528-250			.658	102.	94.0-98.5	6	14
0530-727			.322	150.	94.0-97.0	7	34
0537-441	3	1	.318	0.	94.0-98.5	10	268
0539-057	2	1	.396	52.	94.0-98.0	6	9
0544+273	1	1	.198	54.	95.0-98.5	7	21
0552+398	2	1	.043	166.	94.0-99.0	11	2488
0554+242			.201	30.	96.0-98.5	5	17
0556+238	1	1	.210	112.	95.5-99.0	8	112
0605-085	3	1	.390	0.	94.5-98.0	5	10
0607-157	2	2	.238	146.	94.0-97.0	5	8
0615+820	3	1	.397	150.	94.0-97.0	5	19
0620+389			.349	52.	94.0-97.0	5	8
0636+680	1	1	.344	158.	94.0-96.5	5	26
0637-752			.231	0.	94.0-99.0	11	222
0642+449	1	1	.056	38.	94.0-99.0	11	277
0648-165	2	1	.696	158.	94.5-97.0	5	7
0657+172	2	1	.270	74.	94.0-98.5	9	86
0716+714	1	1	.167	136.	94.0-98.0	6	79
0718+792	2	1	.114	142.	94.0-99.0	11	223
0723-008	3	2	.522	18.	94.0-98.5	6	19
0727-115	1	1	.112	148.	94.0-99.0	11	1666
0735+178	3	1	.129	164.	94.0-98.5	9	463
0736+017	3	3	.333	58.	95.5-99.0	8	23
0742+103	4	1	.462	82.	94.0-98.5	8	268
0743+259	1	1	.364	2.	94.5-98.0	5	7
0745+241	3	2	.179	52.	96.0-99.0	7	100
0749+540	1	1	.055	30.	94.0-99.0	11	152
0804+499	2	1	.042	118.	94.0-99.0	11	450
0805+410	2	1	.098	58.	94.0-99.0	11	115
0814+425	2	1	.152	0.	94.0-97.5	7	109
0818-128	3	1	1.562	94.	94.5-98.5	6	14
0820+560	2	1	.390	10.	94.0-99.0	6	48
0821+394	2	2	.224	166.	94.0-98.5	5	12
0821+621			.473	30.	94.0-99.0	6	8
0823+033	2	1	.151	114.	94.0-99.0	11	547
0826-373			1.258	106.	94.5-98.5	5	9
0827+243	2	2	.161	64.	94.5-98.5	5	30
0839+187	4	3	1.716	98.	94.0-98.5	7	16

Table IV-2.4 (cont.)

Source	Struc S X	Sigmax (mas)	Dir (deg)	Data span	Np	Ns
0851+202	2 1	.077	170.	94.0-99.0	11	2222
0906+015	3 2	.309	104.	94.5-98.0	5	14
0917+624	2 1	.107	54.	94.5-99.0	10	59
0919-260	3 2	1.272	74.	94.0-99.0	11	223
0920+390		.341	46.	95.0-99.0	9	34
0920-397		.870	90.	95.0-98.5	7	32
0923+392	2 1	.100	30.	94.0-99.0	11	2279
0951+693		.905	168.	94.0-99.0	11	42
0952+179	3 3	.269	76.	94.5-98.5	5	25
0953+254	2 1	.341	136.	94.0-99.0	11	388
0954+658	2 1	1.747	110.	94.0-99.0	11	236
0955+476	1 1	.069	30.	94.0-99.0	11	707
1004+141	3 2	.316	84.	94.0-99.0	11	161
1014+615		.141	42.	94.0-98.5	7	13
1022+194	2 2	.355	66.	95.0-98.5	6	12
1032-199		1.388	130.	95.0-98.5	5	8
1034-293	1 1	.238	92.	94.0-99.0	11	810
1038+064	3 1	.403	56.	95.0-98.5	7	31
1038+528		.137	76.	94.0-99.0	11	121
1039+811	2 1	.169	32.	94.0-97.5	5	12
1044+719	1 1	.124	36.	94.0-99.0	11	313
1053+704	1 1	.130	68.	94.0-99.0	8	23
1053+815	1 1	.690	144.	94.0-99.0	9	90
1055+018	2 2	.202	48.	94.5-98.5	6	205
1057-797		.158	134.	94.0-99.0	11	189
1101+384	1 1	.060	106.	94.5-99.0	10	90
1101-536		.539	42.	94.0-99.0	7	26
1104-445		.431	94.	94.0-98.0	8	160
1123+264	2 1	.225	82.	94.0-97.0	6	84
1124-186	1 1	.205	54.	94.5-99.0	10	214
1128+385	1 1	.061	82.	94.0-99.0	11	480
1130+009	2 1	.793	86.	94.0-98.5	7	14
1144+402	1 1	.269	94.	94.0-99.0	8	96
1144-379		.170	122.	94.5-99.0	10	212
1145-071	3 1	.194	36.	94.0-98.5	10	81
1156+295	2 2	.191	90.	94.0-99.0	11	376
1213-172	1 1	.434	52.	94.0-98.5	5	11
1219+044	2 1	.056	80.	94.0-99.0	11	554
1219+285	3 2	.135	158.	95.5-99.0	5	13
1221+809	2 1	.281	146.	94.0-98.5	7	14
1222+037	4 2	.262	4.	94.0-98.5	6	44
1222+131		.781	76.	96.5-99.0	5	10
1226+373	1 1	.554	50.	94.0-98.5	7	10
1228+126	3 3	.139	54.	95.0-99.0	9	220
1236+077	2 1	.169	86.	94.5-99.0	6	12
1237-101		1.641	46.	94.0-99.0	7	13
1243-072	2 1	.192	90.	94.5-98.5	7	23
1244-255		.130	128.	94.0-98.5	7	51
1253-055	3 2	1.500	142.	95.0-98.5	7	187
1255-316		1.350	106.	94.5-99.0	10	68
1300+580	1 1	.119	148.	94.0-99.0	11	91
1302-102	2 1	.973	120.	94.0-99.0	9	22
1308+326	1 1	.137	58.	94.0-99.0	11	1138
1308+328		.247	130.	95.0-99.0	8	23
1313-333	1 1	2.720	88.	94.5-99.0	10	86
1334-127	2 1	.083	66.	94.0-99.0	11	1323

Table IV-2.4 (cont.)

Source	Struc S X	Sigmax (mas)	Dir (deg)	Data span	Np	Ns
1349-439		2.731	56.	94.0-99.0	5	7
1351-018	1 1	.252	92.	94.0-99.0	11	213
1354+195	3 2	.167	158.	94.0-98.5	8	60
1354-152	1 1	.325	4.	95.0-99.0	5	67
1357+769	1 1	.037	104.	94.0-99.0	11	527
1402+044	2 1	.389	74.	94.0-99.0	9	36
1404+286	3 1	.431	102.	94.5-99.0	10	1024
1406-076	2 1	.113	26.	94.0-99.0	7	19
1413+135	1 3	.432	116.	95.5-99.0	7	16
1418+546	2 2	.071	54.	95.5-99.0	8	193
1424-418		.330	146.	94.0-99.0	11	191
1442+101	3 3	2.992	150.	94.0-98.0	5	27
1451-375		1.451	108.	95.0-99.0	7	50
1451-400		.786	64.	94.0-98.5	7	22
1458+718	3 3	.436	84.	94.0-98.0	6	13
1504-166	3 1	4.454	20.	95.0-99.0	7	22
1508+572		.101	130.	94.5-99.0	10	39
1510-089	3 1	.588	104.	94.0-99.0	9	250
1511-100	1 1	.706	110.	94.0-98.0	6	8
1514-241		.209	32.	94.5-99.0	9	93
1519-273		.481	52.	94.0-99.0	10	89
1546+027	2 1	.344	58.	95.5-98.5	5	16
1548+056	2 2	.166	64.	94.0-98.5	7	209
1555+001	1 1	.652	134.	95.0-99.0	7	80
1557+032		.937	18.	94.5-99.0	9	23
1600+335	3 1	.095	14.	95.0-98.5	6	9
1606+106	2 1	.089	4.	94.0-99.0	11	893
1610-771		.271	50.	94.0-99.0	11	202
1611+343	3 1	.088	108.	94.0-99.0	11	899
1614+051	2 1	.186	128.	94.0-99.0	11	68
1622-253	1 1	.208	64.	94.0-99.0	11	931
1622-297		.367	70.	94.0-99.0	10	33
1624+416	3 2	.175	120.	94.0-99.0	8	19
1633+382	3 1	.440	16.	94.0-99.0	10	399
1637+574	2 1	.190	108.	94.0-98.5	9	156
1638+398	1 1	.092	18.	94.0-99.0	11	552
1641+399	4 1	.276	12.	94.5-99.0	7	901
1642+690	3 2	.075	108.	94.0-98.5	8	107
1652+398	3 2	.148	84.	94.5-99.0	10	103
1656+053	3 2	1.510	0.	94.0-98.0	6	33
1657-261		.520	140.	95.0-98.0	5	19
1705+018	2 1	.434	114.	94.0-99.0	11	39
1706-174	2 1	.411	78.	95.5-98.0	5	15
1726+455	2 1	.066	140.	94.0-99.0	11	450
1730-130	2 2	.230	108.	94.5-98.5	7	542
1738+476	2 1	.717	144.	94.0-99.0	5	11
1739+522	2 1	.116	56.	94.0-99.0	11	1135
1741-038	1 1	.134	18.	94.0-99.0	11	1753
1744+557		.191	166.	96.5-99.0	5	9
1745+624	1 2	.069	154.	94.0-99.0	11	252
1749+096	1 1	.094	8.	94.0-99.0	11	1145
1749+701	2 2	.421	76.	94.0-97.0	5	16
1758+388		.176	88.	94.0-99.0	10	17
1803+784	2 1	.071	142.	94.0-99.0	11	1686
1807+698	3 2	.064	154.	94.5-99.0	10	88
1815-553		.959	90.	94.0-98.5	10	96

Table IV-2.4 (cont.)

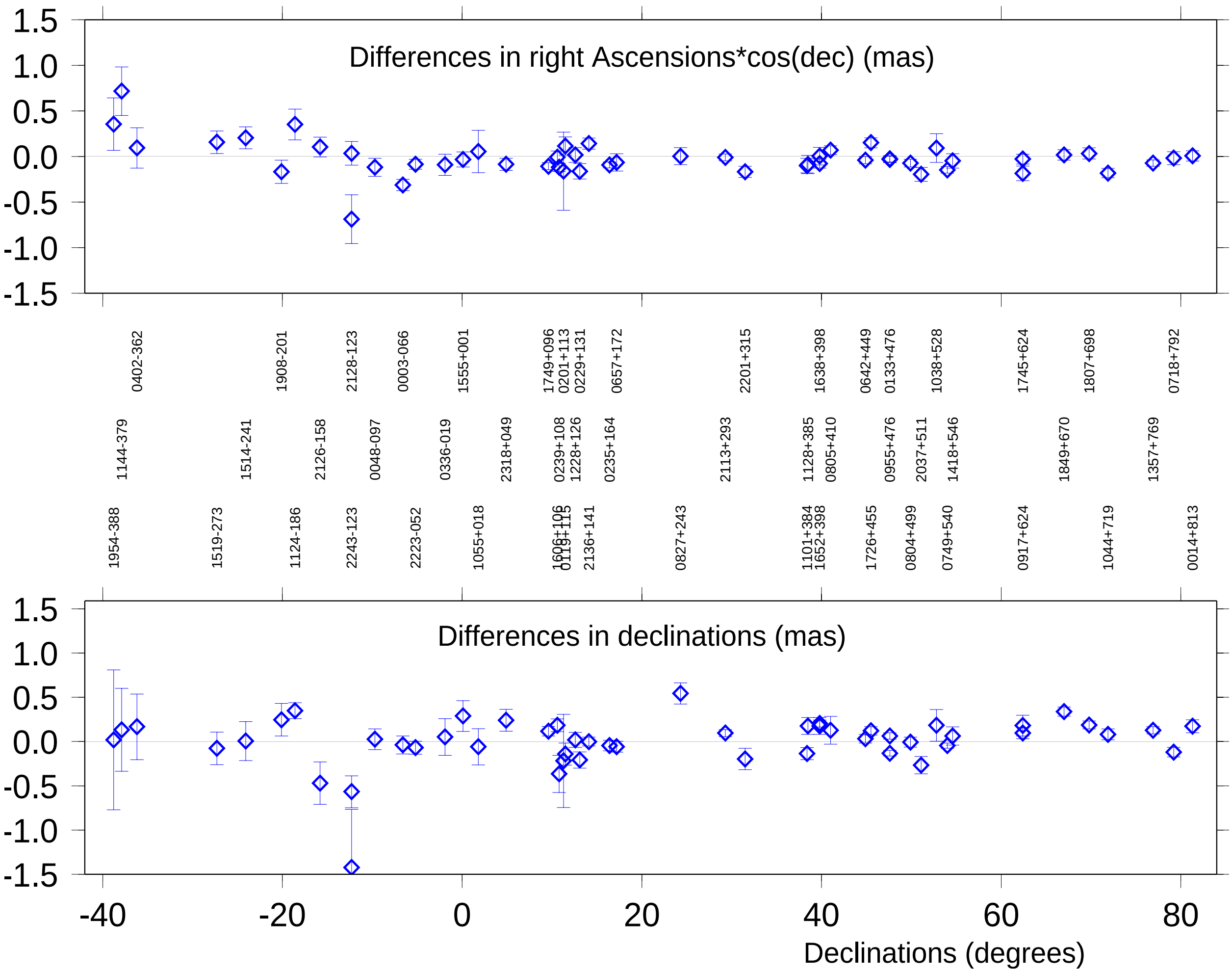
Source	Struc S X	Sigmax (mas)	Dir (deg)	Data span	Np	Ns
1817-254		.775	90.	94.0-98.5	5	7
1823+568	1 1	.241	104.	94.0-99.0	10	133
1845+797	4 2	.543	38.	95.0-98.5	6	21
1849+670	1 2	.047	44.	94.5-99.0	6	61
1901+319	4 3	.236	26.	94.5-98.5	8	20
1908-201		.123	74.	94.0-99.0	9	126
1920-211		.447	46.	96.0-99.0	6	29
1921-293	2 1	.252	84.	94.0-99.0	11	1084
1928+738	3 2	.277	74.	94.0-98.5	6	97
1936-155	1 1	.344	148.	95.5-99.0	7	21
1937-101	3 1	.387	116.	94.0-98.5	7	11
1954+513	2 1	.361	34.	94.0-98.0	5	18
1954-388		.196	68.	94.5-99.0	10	189
1958-179	1 1	.214	146.	94.0-99.0	11	637
2000-330		1.278	144.	95.5-98.0	5	18
2007+777	3 1	.130	6.	94.0-98.5	9	232
2008-159	1 1	1.198	132.	96.0-98.5	6	31
2037+511	3 3	.056	128.	95.0-99.0	7	208
2052-474		.495	46.	94.0-98.5	9	42
2109-811		.627	152.	94.0-96.5	6	12
2113+293	1 1	.085	92.	94.0-99.0	9	62
2121+053	2 1	.303	38.	94.0-99.0	10	674
2126-158	2 1	1.558	114.	94.0-99.0	10	87
2128-123	3 2	.278	122.	94.0-99.0	11	566
2134+004	4 1	2.040	8.	94.0-99.0	8	708
2136+141	1 1	.113	6.	95.5-99.0	7	113
2145+067	1 1	.125	2.	94.0-99.0	11	1372
2149+056	2 1	.119	138.	96.0-98.5	6	23
2155-152	3 1	.639	114.	95.0-98.0	5	31
2200+420	3 1	.176	104.	94.0-99.0	10	708
2201+315	3 1	.265	120.	94.0-99.0	11	206
2216-038	3 1	.684	86.	94.5-98.5	8	390
2223-052	2 3	.233	76.	94.0-99.0	9	86
2227-088	1 1	.259	52.	94.5-98.5	7	24
2230+114	4 2	.613	16.	94.5-98.5	7	96
2232-488		.574	60.	94.0-98.0	7	11
2234+282	2 1	.213	154.	94.0-99.0	11	1380
2243-123	3 1	.418	84.	94.5-99.0	10	255
2254+074	1 1	.654	92.	95.0-99.0	5	15
2255-282	1 2	.376	68.	94.0-99.0	11	709
2318+049	2 1	.102	156.	95.0-99.0	8	60
2319+272	3 1	.464	78.	94.5-99.0	6	14
2320-035	3 2	.680	68.	95.0-99.0	6	31
2335-027	3 1	.576	94.	96.0-98.5	5	10
2344+092	3 2	.321	50.	94.0-98.0	6	13
2355-106	1 1	.386	70.	94.0-99.0	9	101
2356+385		4.010	90.	94.5-99.0	5	66

OPA time series of source coordinates

A time series of source coordinates was provided by OPA for 52 sources observed in 1999.

Figure IV-2.4 shows the mean difference of coordinates with ICRF-Ext.1 for these sources.

Fig. IV-2.4: Mean coordinate differences with ICRF-Ext.1 over 1999 for 52 sources, derived from OPA time series of right ascensions and declinations.



Validation of individual celestial reference frames

The reference frames analyzed

Four extragalactic reference frames obtained from VLBI analysis were submitted to the IERS for inclusion in this report. The analysis strategies used for their calculation are summarized hereafter. The frames have been studied and compared to the ICRF-Ext.1. Notice that some of these catalogues were not optimized for the determination of source positions or for consistency with ICRF or ICRF-Ext.1.

RSC(BKGI) 01 R 01

The celestial reference frame RSC(BKGI) 01 R 01 was elaborated jointly by the Geodetic Institute of the University of Bonn (GIUB) and the Federal Agency for Cartography and Geodesy (BKG). A world-wide set of VLBI observations over the period January 1984 – December 2000 has been analysed with the software *CALC 9.12* and *SOLVE* release *2001.03.07* to obtain from a global solution, radio source positions among other parameters. The celestial frame is aligned to ICRF-Ext.1 by constraining the sum of the right ascension and declination adjustments for the 209 defining sources present in the frame to be zero. Tropospheric gradients have been estimated in the solution.

RSC(GSFC) 01 R 01

Radio source coordinates at the Goddard Space Flight Center have been estimated with *CALC 9.12* and *SOLVE* release *2001.04.20*. The celestial reference frame is attached to the ICRF by a no-net-rotation condition using ICRF defining sources. Positions of the 552 radio sources in RSC(GSFC) 01 R 01 were estimated as global parameters. Quality criteria have been applied for generating the list of sources: either the source has been observed in two or more sessions, in which it had two or more good observations; or the source had at least 25 good observations in the only session it has been observed. 138 sources, which did not fit these criteria, were excluded from the global parameters. Tropospheric gradients have been estimated in the solution for a set of stations.

RSC(IAA) 01 R 02

This celestial reference frame has been obtained with the package ERA v.7 at the Institute of Applied Astronomy of the Russian Academy of Sciences. VLBI sessions of NEOS-A, IRIS-A, IRIS-S, CORE-A and CORE-B networks in the span 1984–2000 were analysed to elaborate a three-step solution.

In a first step, parameters have been adjusted from yearly, one-program solutions. The celestial system is aligned to ICRS by fixing the radio source coordinates to ICRF-Ext.1. At the following step, improved local parameters have been used to perform a similar re-adjustment. RSC(IAA) 01 R 02 results from averaging these yearly, one-program solutions. Tropospheric gradients have been estimated.

RSC(SHA) 01 R 01

MARK III VLBI observations over the period August 1979 – February 2001 were analyzed by the Shanghai Astronomical Observatory. The CALC – SOLVE software was used to produce, from a global solution, the full set of radio source coordinates RSC(SHA) 01 R 01 among other parameters. The celestial reference frame is attached to the ICRF-Ext.1 by applying a no net rotation constraint to the position adjustments of the 212 defining sources with a weighting proportional to the precision of the source positions. Sources with comparatively insufficient observations, so they have large uncertainties, were included in the frame. Tropospheric gradients have been estimated.

Table IV-2.5 gives some characteristics of the four analyzed reference frames. The larger median value for the candidate sources appears in RSC(SHA) 01 R 01.

Table IV-2.5: Analyzed Celestial Reference Frames

Frame	Total	Defining		Candidate		Other		New		Add.	d(°)
	n	n	m	n	m	n	m	n	m	n	
RSC(BKGI) 01 R 01	578	209	0.14	216	0.15	102	0.05	44	0.26	7	-81,+84
RSC(GSFC) 01 R 01	552	202	0.09	201	0.09	101	0.03	35	0.11	13	-81,+84
RSC(IAA) 01 R 02	331	86	0.13	112	0.12	79	0.07	45	0.32	9	-80,+84
RSC(SHA) 01 R 01	675	211	0.15	275	0.23	102	0.04	58	0.28	14	-85,+84

(n) : Number of sources,
(m) : Median of the formal position uncertainty (unit: 0.001"),
(d) : Declination interval (unit: degree).
The column "Add." gives the number of sources in each catalogue not present in ICRF-Ext.1.

Comparison of individual celestial frames with ICRF-Ext.1

Under the assumption that ICRF is free from deformations, we adopt it as a reference to determine systematic effects coming from the current VLBI catalogues.

The comparison algorithm in equations (1) models the global relative orientation between two frames by three angles A_1, A_2, A_3, and the systematic effects by three deformation parameters representing a slope in right ascension as a function of the declination (D_α), a slope in declination as a function of the declination (D_δ), and a bias in declination (B_δ):

$$\begin{aligned} A_1 \,\mathrm{tg}\,\delta \cos\alpha + A_2 \,\mathrm{tg}\,\delta \sin\alpha - A_3 + D_\alpha(\delta - \delta_0) &= \alpha_1 - \alpha_2 \\ -A_1 \sin\alpha + A_2 \cos\alpha + D_\alpha(\delta - \delta_0) + B_\delta &= \delta_1 - \delta_2 \end{aligned} \qquad (1)$$

All individual solutions have been compared to ICRF-Ext.1 by using the model represented in equations (1). Only defining sources common to each frame and ICRF-Ext.1 (or ICRF) were used in the comparisons. The transformation parameters were evaluated by a weighted least squares fit; the equations were weighted using the inverse of the variance of the coordinate differences (α_1–α_2) and (δ_1–δ_2).

Formal uncertainties smaller than 0.01 mas in the individual catalogues have been set to this value. The adjusted parameters serve to transform individual frames into ICRS; the relative global orientation and the deformation parameters are given in Tables IV-2.6 and IV-2.7 respectively.

Table IV-2.6: Relative orientation between individual frames and ICRF

A_1, A_2, A_3 are the rotation angles which transform coordinates from the individual VLBI frames to ICRF. They are calculated on the basis of the defining sources only.
N is the number of common defining sources.
r_α and r_δ are the weighted rms residuals in $\alpha\cos\delta$ and δ respectively.

Frame		N	A_1	A_2	A_3	r_α	r_δ
RSC(BKGI)	01 R 01	209	+0.030 ±0.016	+0.000 ±0.016	-0.050 ±0.021	0.18	0.23
RSC(GSFC)	01 R 01	202	+0.008 ±0.017	+0.001 ±0.017	-0.030 ±0.022	0.18	0.23
RSC(IAA)	01 R 02	86	-0.011 ±0.025	-0.019 ±0.025	-0.032 ±0.039	0.18	0.22
RSC(SHA)	01 R 01	211	+0.032 ±0.015	-0.011 ±0.015	-0.042 ±0.020	0.17	0.22

Unit: 0.001"

Table IV-2.7: Slopes and biases evaluated in the comparisons between individual frames and ICRF

D_α, D_δ are the slopes in right ascension and declination respectively,
B_δ is the bias in declination. They are evaluated in a global solution together with the rotation angles in Table IV-2.5.

Frame		D_α	D_δ	B_δ
RSC(BKGI)	01 R 01	-0.001 ±0.001	+0.000 ±0.000	+0.003 ±0.017
RSC(GSFC)	01 R 01	-0.001 ±0.001	+0.000 ±0.000	+0.043 ±0.018
RSC(IAA)	01 R 02	+0.000 ±0.001	-0.001 ±0.001	+0.013 ±0.032
RSC(SHA)	01 R 01	-0.001 ±0.001	+0.000 ±0.000	-0.011 ±0.016

Units: 0.001"/degree for the slopes, 0.001" for the biases.

In the four submitted frames constraints were applied to align the respective celestial frames to ICRF. The origins of right ascensions in the individual frames agree with the ICRS origin at a few tens of microarcseconds (see values in Table IV-2.6).

The parameters in Table IV-2.7 indicate that there are no slopes in right ascension and declination detected in any individual frames. No strong declination biases are observed; efforts in the modelling in IAA solution and the extension of the frame to lower southern declinations reduced by a factor of ten the bias in declination that was present in previous realizations (catalogues RSC(IAA) 00 R 02 and RSC(IAA) 00 R 03 analysed in the 1999 IERS Annual Report, Table VI-4). The largest bias B_δ (+0.043 mas) appears in RSC(GSFC) 01 R 01. This discrepancy of the GSFC principal plane relative to that of ICRS is removed by the model, as shown when comparing plots IV-2.6 (b) and IV-2.6 (c).

Figures IV-2.5 (a) through IV-2.8 (a) show, for the defining sources common to each analysed frame and ICRF, the postfit residuals in right ascension and in declination as a function of the declination after adjusting the transformation parameters. In all frames compared, the postfit residuals remain at the sub-milliarcsecond level with the exception of a few sources, mainly below the equator.

Figures IV-2.5 (b) through IV-2.8 (b) plot the normalized residuals (ratio of the postfit residual to the uncertainty of the coordinate difference between frames) in declination as a function of right ascension when deformations between frames are not adjusted. Ideally, in absence of deformations, all points should remain within the circle with unit radius shown in the figures.

Figures IV-2.5 (c) through IV-2.8 (c) plot the same parameters when the frames have been freed from the deformations relative to ICRF by the use of the parameters in Table IV-2.7.

In all (b and c) plots the three ICRF categories of sources are shown; filled circles represent the defining sources in each comparison, open circles represent the candidate and other sources.

These plots indicate that the four catalogs are not inconsistent with the ICRF, at its expected level of accuracy (~0,25 mas).

This report was completed by people belonging to the staff of the Paris Observatory component of ICRS-PC, with contributions of three Paris Observatory staff members. They are named below.

Members of the Paris Observatory component of the ICRS-PC:

Souchay[1]	Jean	Co-Director
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Chapront[1]	Jean	Astronomer
Essaïfi[1]	Najat	Engineer
Feissel[1,3]	Martine	Astronomer
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Other Paris Observatory staff members :

Carlucci	Teddy	Engineer
Francou	Gérard	Astronomer
Jean-Alexis	Didier	Engineer

For contact information see Section V.3, for electronic access see Appendix.

Fig. IV-2.5: RSC(BKGI) 01 R 01 – ICRF-Ext.1

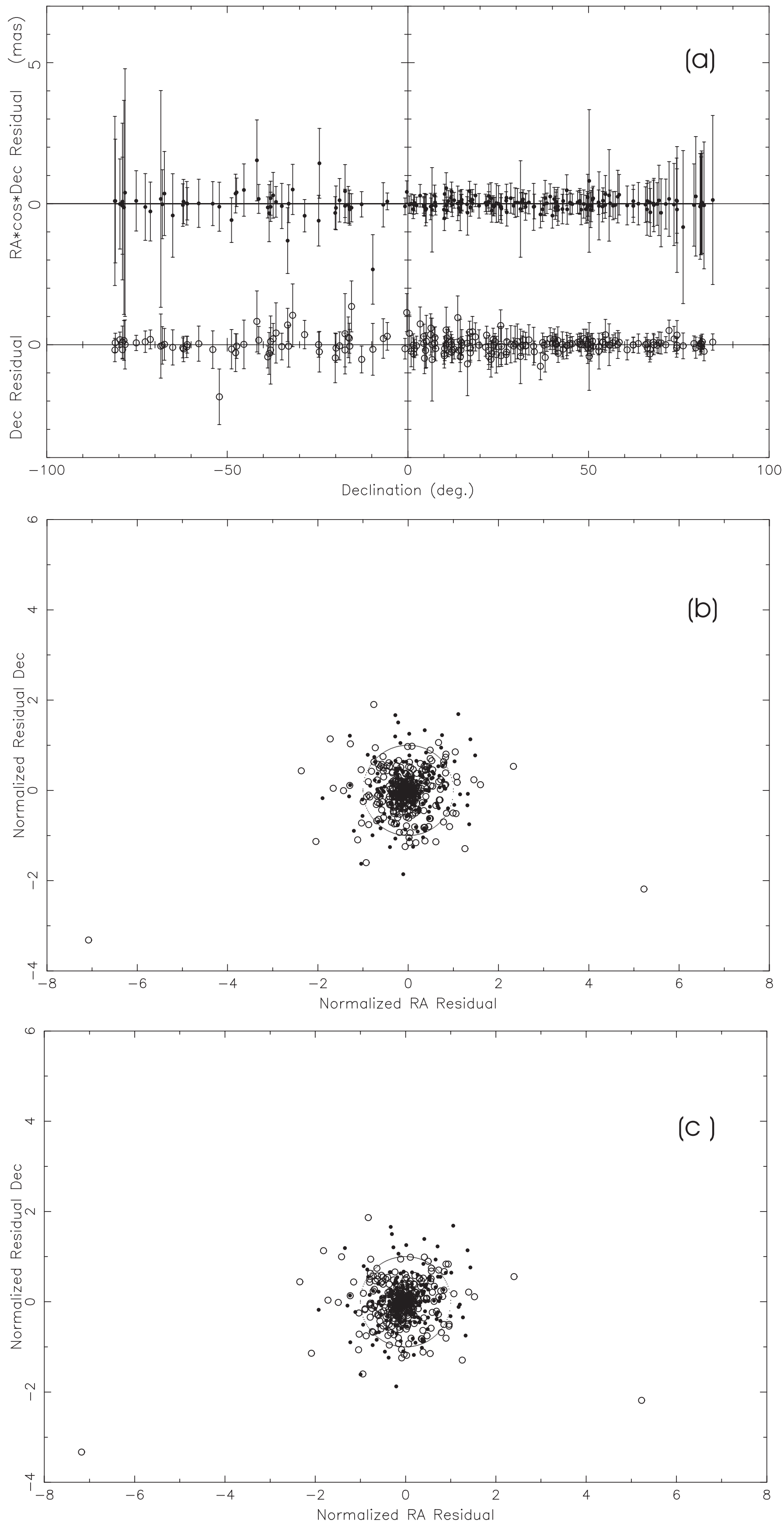
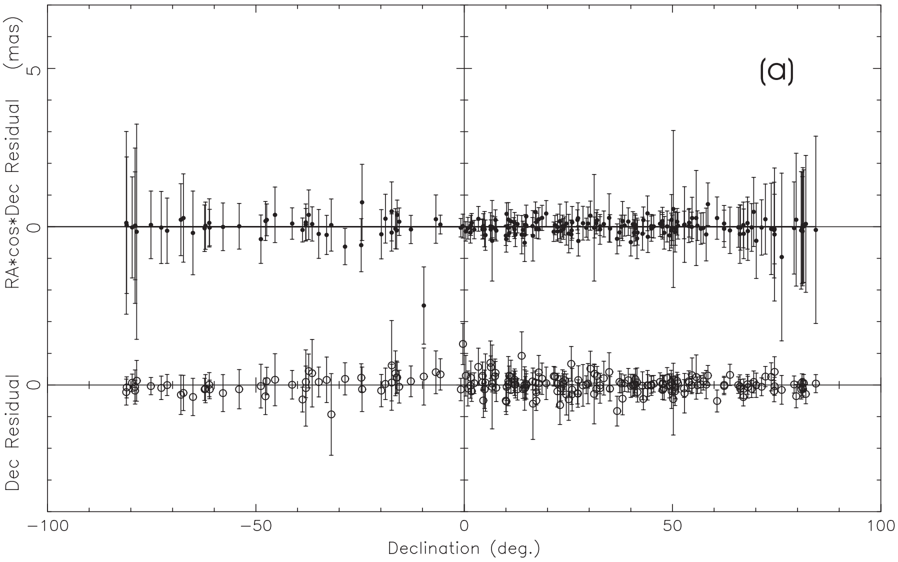
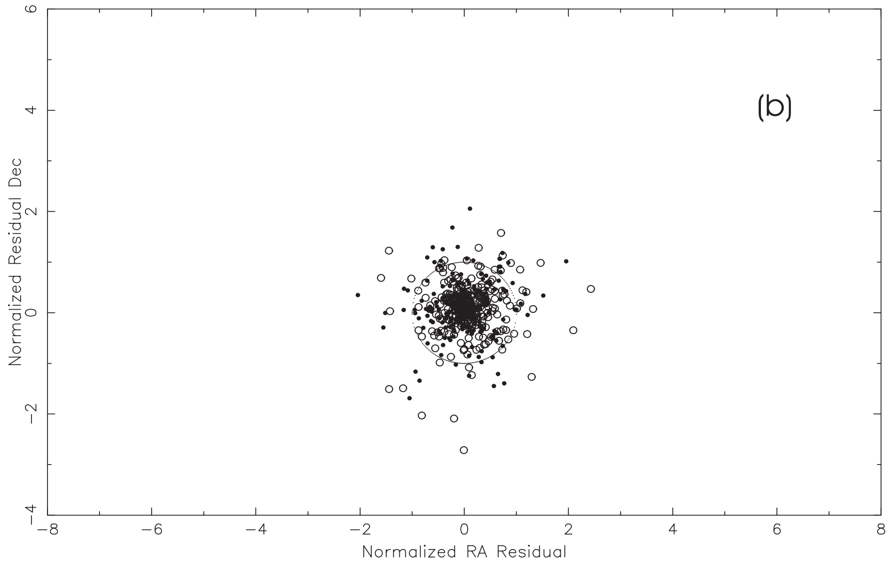


Fig. IV-2.6: RSC(GSFC) 01 R 01 – ICRF-Ext.1





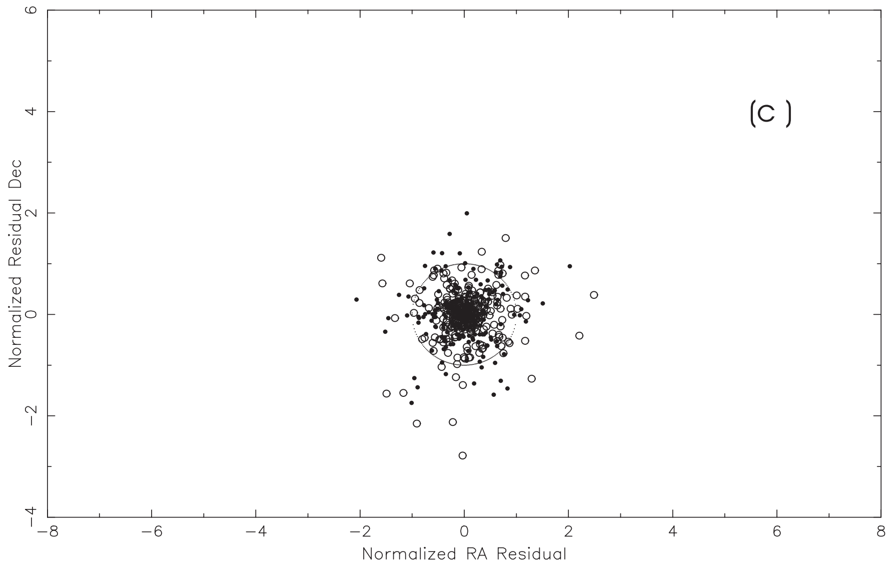


Fig. IV-2.7: RSC(IAA) 01 R 02 – ICRF-Ext.1

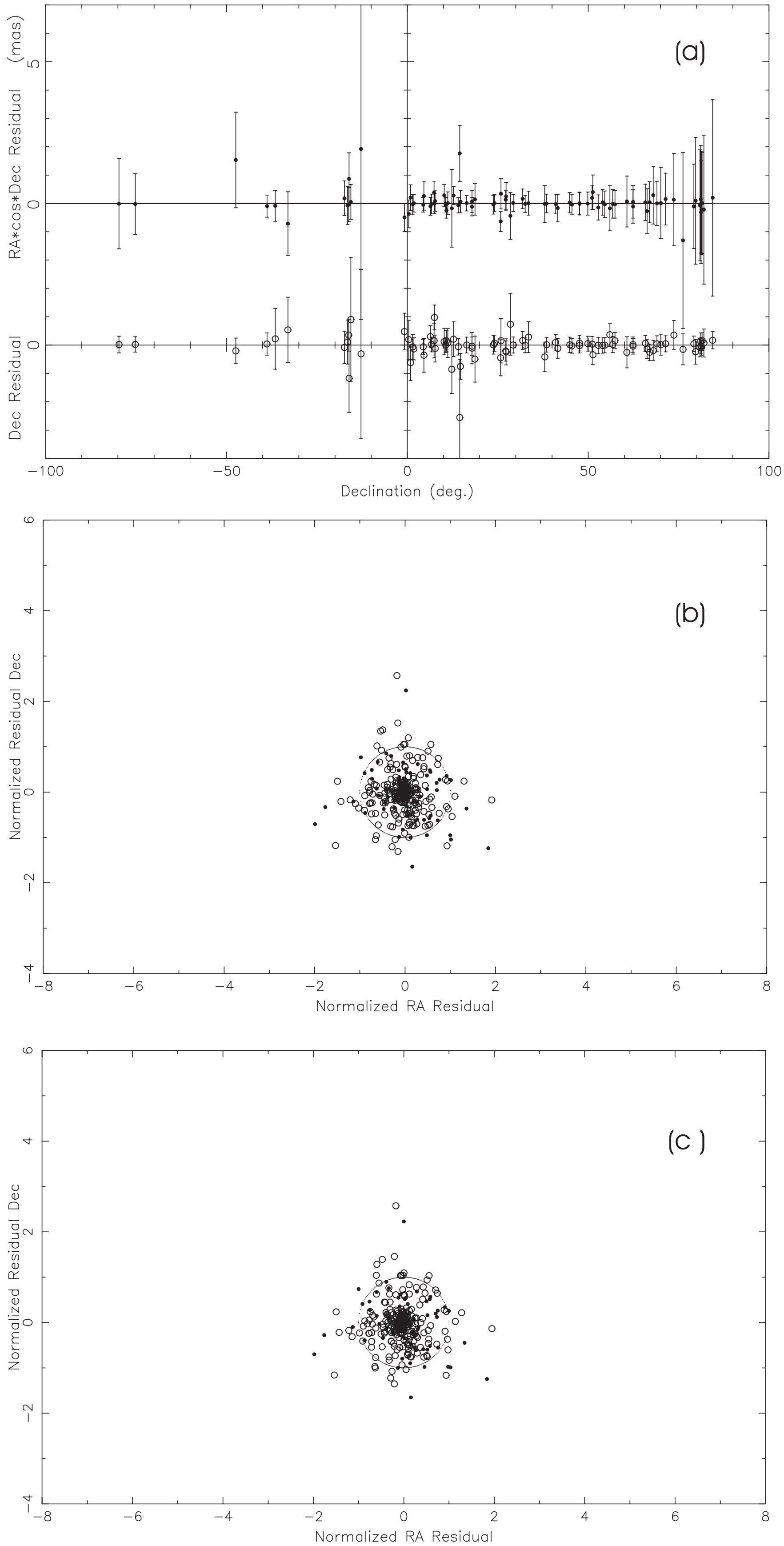
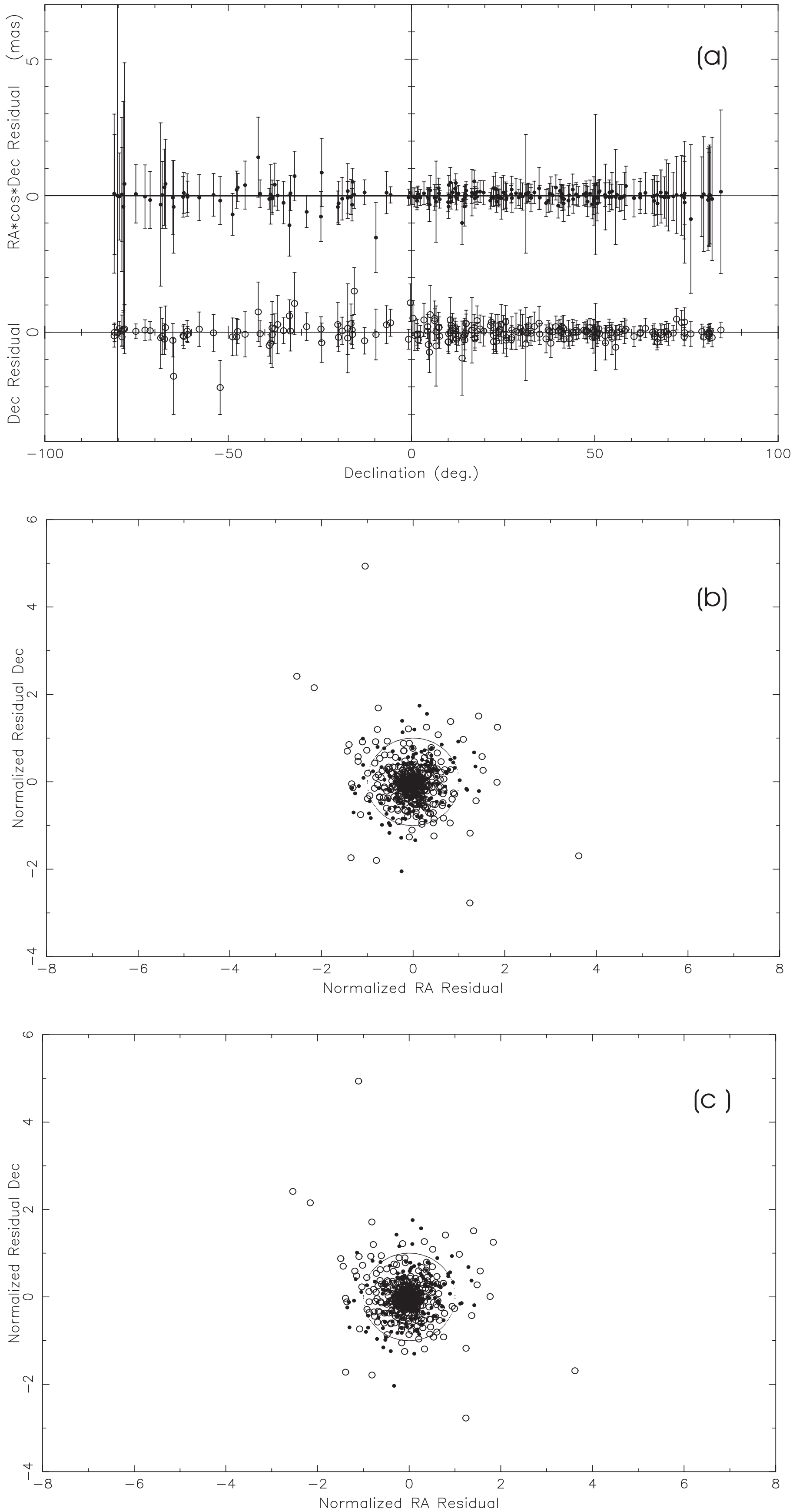


Fig. IV-2.8: RSC(SHA) 01 R 01 – ICRF-Ext.1



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IV.3 ITRF Section of the Central Bureau

This report summarizes the activities of the former Terrestrial Reference Frame Section of the IERS Central Bureau.

The main activities of the ITRF Section during the year 2000 are:

· Maintenance of the IERS network
· Data analysis and Software enhancement
· ITRF2000 project

Maintenance of the IERS network

This activity includes update of the IERS network data base 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.

Data analysis and Software enhancement

With interaction of IERS Analysis Centers (AC), individual solutions from the different techniques are frequently evaluated and tested, in order to improve the individual analysis as well as ITRF combination. Thus both the individual AC's as well as the ITRF Section regularly test new analysis strategies. This cooperation between the IERS AC's and the ITRF Section 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 ITRF Section, is regularly updated and enhanced in order to perform proper analysis of the different solutions performed by the IERS AC's.

ITRF2000

A great part of the year 2000 was devoted to the preparation of the ITRF2000 solution. Interaction between the ITRF Section and the individual IERS AC's was regularly maintained in order to provide specific individual solutions for this Standard solution. The ITRF2000 is intended to be a Standard and densified solution for a wide application community (geodesy, cartography, navigation, etc.).

Before the generation of this solution, a specific Workshop was organized by the ITRF section gathering all the contributing IERS AC's. During this Workshop, the individual AC's presented their analysis and description of their solutions. Preliminary analyses of these solutions performed by the ITRF Section were discussed. The Working Group on ITRF Datum issued specific recommendations for the final ITRF2000 combination in terms of datum definition (see <http://lareg.ensg.ign.fr/ITRF/ITRF2000/ITRF2000.RECOM>).

The ITRF2000 solution is the most dense and accurate frame ever developed, containing about 800 stations located on about 500 sites. It has been achieved by simultaneous combination of positions and velocities using full variance/covariance matrices of the individual solutions provided by the IERS Analysis Centers. It includes core stations observed by VLBI, LLR, SLR, GPS and DORIS (usually used in previous ITRF versions) as well as regional GPS networks for its densification (Alaska, Antarctica, Asia, Europe, North and South Americas and Pacific) . Figure 1 shows the distribution of the primary sites of ITRF2000 highlighting the collocated techniques.

The ITRF2000 is intended to have an accurate datum definition, achieved as follows:

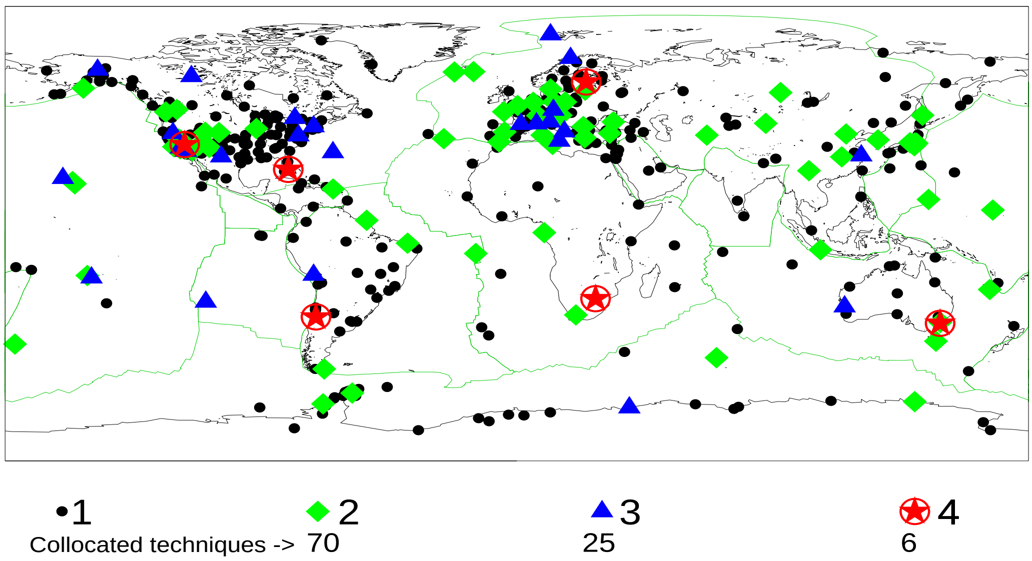
- The origin and its rate are defined by a weighted average of most consistent SLR solutions.
- The scale and its rate are defined by a weighted average of VLBI and most consistent SLR solutions. Unlike the ITRF97 scale, expressed in the Geocentric Coordinate Time-frame, that of the ITRF2000 is expressed in Terrestrial Time-frame. The effect of this change on the scale factor is 0.70 ppb (10^{-9}).
- The orientation is aligned to that of ITRF97 at 1997.0 epoch and its rate to be such that there is no-net-rotation rate with respect to NNR-NUVEL-1A. Note that the orientation as well as its rate are defined upon a selection of ITRF sites with high geodetic quality.

The ITRF2000 long-term stability, evaluated over 10 years, is estimated to be better than 4 mm in origin and better than 0.5 ppb in scale, equivalent to a shift in station heights of approximately 3 mm over the Earth's surface.

All the ITRF2000 related files are available via Internet at: <http://lareg.ensg.ign.fr/ITRF/ITRF2000>

Zuheir Altamimi, Claude Boucher,
Patrick Sillard, Martine Feissel

Figure 1. ITRF2000 Primary Network



IV.4 EOP Section of the Central Bureau

This section presents the activities and results concerning the former EOP Section of the Central Bureau of the IERS in Paris. Starting from 1 January 2001, the Earth Orientation Parameters Product Center (EOP-PC) is replacing this section. The text was written under the responsibility of Daniel Gambis (Observatoire de Paris). Figures and Tables are available at the web site: <http://hpiers.obspm.fr/eop-pc>.

4.1 General Description

The IERS Conventions

Reference systems

The International Celestial and Terrestrial Reference Systems (resp. ICRS, ITRS) are defined by their origins, directions of axes and, in the case of the ITRS, length unit.

ICRS: The ICRS is described by Arias *et al.* (1995). Its origin is at the barycenter of the solar system. The directions of its axes are fixed with respect to the quasars to better than ± 20 microarcseconds; they are aligned with those of the FK5 within the uncertainty of the latter (± 80 milliarcseconds). The ICRS is realized by estimates of the coordinates of a set of quasars, the International Celestial Reference Frame, ICRF (Ma and Feissel, 1997). The maintenance of the ICRS/ICRF is under the responsibility of ICRS Product Center (<http://hpiers.obspm.fr/icrs-pc>).

ITRF: The ITRS origin is at the center of mass of the whole Earth, including the oceans and the atmosphere. Its length unit is the *meter* (SI), defined in a local Earth frame according to the relativistic theory of gravitation. The orientation of its axes is consistent with that of the BIH System at 1984.0 within ± 3 milliarcseconds. Its time evolution in orientation is such that it has no residual rotation relative to the Earth's crust. The ITRS is realized by estimates of the coordinates and velocities of a set of observing stations, the International Terrestrial Reference Frame, ITRF. A new ITRF realization (ITRF2000) is now available at the web site: <http://lareg.ensg.ign.fr/ITRF/>.

IERS constants and models

The values of the constants are adopted from recent analyses; in some cases they differ from the current IAU and IAG conventional ones. The models represent, in general, the state of the art in the field concerned. The IERS conventions used in this report are the IERS Conventions (1996), published as IERS Technical Note 21. New IERS Conventions 2000 will be published in the course of 2001. Two key aspects concern a new nutation model which will be adopted as of 1 January 2003 and the definition of Celestial Intermediate Pole (IAU Commission 19 web site: <http://danof.obspm.fr/iaucom19/>).

The Earth Orientation Parameters

The IERS Earth Orientation Parameters (EOP) describe the transformation between both the ITRS and the ICRS, including the conventional Precession-Nutation model.

Coordinates of the pole

The parameters x and y are the coordinates of the Celestial Ephemeris Pole (CEP) relative to the IERS Reference Pole (IRP). The CEP differs from the instantaneous rotation axis by quasi-diurnal terms with amplitudes under 0.01" (Seidelmann, 1982). The x-axis is in the direction of the IERS Reference Meridian (IRM); the y-axis is in the direction 90 degrees West longitude. The need for accurate definition of reference systems brought about by unprecedented observational precision requires the adoption of a new reference: the Celestial Intermediate Pole (CIP); see definition in IAU Resolution B1.7 at the web site: <http://danof.obspm.fr/iaucom19>. The implementation of the CIP will be on 1 January 2003.

Celestial pole offsets

VLBI and LLR observations have shown the existence of deficiencies in the IAU 1976 Precession and in the IAU 1980 Theory of Nutation; however, these models are kept as a part of the IERS standards, and the observed differences with respect to the conventional celestial pole position defined by the models are monitored and reported by the IERS. The celestial pole offsets, $d\psi$, $d\varepsilon$, are the offsets in longitude and in obliquity of the celestial pole with respect to its position defined by the conventional IAU precession/nutation models. A conventional correction model is available in the IERS Conventions (1996). It matches the observations within ± 0.001". The implementation of the new nutation model in January 2003 is assumed to lead to an agreement of 0.2 milliarcsecond (mas) with the VLBI observations.

Universal time and duration of the day

UT1 is related to the Greenwich mean sidereal time (GMST) by a conventional relationship (Aoki *et al*., 1982); it gives access to the direction of the IRM in the ICRS, reckoned around the CEP axis. It is expressed as the difference UT1–TAI or UT1–UTC.

TAI is the atomic time scale derived by the BIPM; its unit interval is exactly one SI second at sea level. The origin of TAI is such that UT1–TAI ≈ 0 on 1958 January 1. The instability of TAI is about 6 orders of magnitude smaller than that of UT1. The Terrestrial Time TT is realized in practice as TAI + 32.184s (McCarthy, 1996, chapter 11, p. 83). Observed values of UT1–TAI over 1962–2001 are given in *Table 1*.

UTC is defined by the CCIR (International Radio Consultative Committee) Recommendation 460-4 (1986), it differs from TAI by an integer number of seconds, in such a way that UT1–UTC remains smaller than 0.9 s in absolute value. The decision to introduce a leap second in UTC to meet this condition is the responsibility of IERS. According to the CCIR Recommendation, first preference is given to the opportunities at the end of December and June, and second preference to those at the end of March and September. Since the system was introduced in 1972 only dates in June and December have been used. The relationship of UTC with TAI is given in *Table 2*; the corresponding offsets and step adjustments of UTC are given in *Table 3*.

The "leap second" procedure is affecting the activities of modern communication and navigation systems. In order to envisage the possibility to redefine the Coordinated Universal Time (UTC), various working groups were created within the IAU and the ITU (International Telecommunication Union). During the ITU meetings discussions developed on the implication of changes on scientific, governmental, commercial and regulatory interests. Resolutions will be proposed at the CCTF (Comité Consultatif des Temps et Fréquences) in the course of 2003.

DUT1 is the difference UT1–UTC, expressed with a precision of 0.1 s, which is broadcasted with the time signals. The changes in DUT1 are decided by the EOP Product Center of the IERS. In the past, UT2 was used; it was derived from UT1 by adding the following conventional annual and semi annual terms:

$$\mathrm{UT2{-}UT1} = 0.0220 \sin 2\pi t - 0.0120 \cos 2\pi t - 0.0060 \sin 4\pi t + 0.0070 \cos 4\pi t$$

the unit being the second and t being the date in Besselian years:

$$t = 2000.000 + (\mathrm{MJD} - 51544.03) / 365.2422.$$

The difference between the astronomically determined duration of the day and 86400s of TAI, is also called excess on the length of day and designed by D or LOD. Its relationship with the angular velocity of the Earth ω is:

$$\omega = \Omega\,(1 - D/T),$$

with T = 86 400 s and Ω the mean pole rate.

$$\omega = 72\,921\,151.467\,064 - 0.843\,994\,803\,D,$$

where ω is in picoradians/s and D in milliseconds.

It is useful to differentiate in some details the various forms of universal time series that can be derived from different observing systems. UT1 can be obtained only from inertial technique like VLBI. Other techniques (e.g. LLR) may estimate the Earth's orientation relatively to a dynamical frame which is different of ICRS.

UT1, hence D and ω, are subject to variations under the effect of zonal tides. The model which is a part of IERS Conventions (1996) includes 62 periodic components, with periods ranging from 5.6 days to 18.6 years. UT1R, DR, and ωR are the values of UT1, D, and ω corrected for the short-term part of the model, i.e., the 41 components with periods under 35 days. The model is listed in *Table 4a* and *Table 4b*. A new model taking into account oceanic effects and recommended to users will be published in the IERS Conventions 2000.

Table 1. Observed values of UT1–TAI, 1962–2001

The uncertainty of UT1–TAI is smaller than 2 units of the last digit listed.
TT–UT1 can be obtained from this table using the expression: TT–UT1 = 32.184s – (UT1–TAI).

Date	UT1-TAI (s)	Date	UT1-TAI (s)	Date	UT1-TAI (s)	Date	UT1-TAI (s)
1962 JAN 1	-1.813	1972 JAN 1	-10.045	1982 JAN 1	-19.983	1992 JAN 1	-26.1252
APR 1	-1.936	APR 1	-10.347	APR 1	-20.184	APR 1	-26.3562
JUL 1	-2.058	JUL 1	-10.638	JUL 1	-20.391	JUL 1	-26.5569
OCT 1	-2.142	OCT 1	-10.888	OCT 1	-20.550	OCT 1	-26.7146
1963 JAN 1	-2.289	1973 JAN 1	-11.189	1983 JAN 1	-20.773	1993 JAN 1	-26.9378
APR 1	-2.407	APR 1	-11.489	APR 1	-21.036	APR 1	-27.1734
JUL 1	-2.551	JUL 1	-11.771	JUL 1	-21.250	JUL 1	-27.4010
OCT 1	-2.659	OCT 1	-12.016	OCT 1	-21.400	OCT 1	-27.5748
1964 JAN 1	-2.847	1974 JAN 1	-12.301	1984 JAN 1	-21.6042	1994 JAN 1	-27.8004
APR 1	-3.043	APR 1	-12.553	APR 1	-21.7603	APR 1	-28.0202
JUL 1	-3.217	JUL 1	-12.814	JUL 1	-21.9018	JUL 1	-28.2171
OCT 1	-3.350	OCT 1	-13.023	OCT 1	-22.0074	OCT 1	-28.3738
1965 JAN 1	-3.558	1975 JAN 1	-13.292	1985 JAN 1	-22.1587	1995 JAN 1	-28.6014
APR 1	-3.761	APR 1	-13.554	APR 1	-22.3058	APR 1	-28.8437
JUL 1	-3.964	JUL 1	-13.799	JUL 1	-22.4516	JUL 1	-29.0614
OCT 1	-4.139	OCT 1	-13.999	OCT 1	-22.5333	OCT 1	-29.2196
1966 JAN 1	-4.360	1976 JAN 1	-14.274	1986 JAN 1	-22.6872	1996 JAN 1	-29.4447
APR 1	-4.586	APR 1	-14.545	APR 1	-22.8157	APR 1	-29.6292
JUL 1	-4.817	JUL 1	-14.812	JUL 1	-22.9292	JUL 1	-29.8129
OCT 1	-5.006	OCT 1	-15.054	OCT 1	-23.0058	OCT 1	-29.9362
1967 JAN 1	-5.248	1977 JAN 1	-15.336	1987 JAN 1	-23.1382	1997 JAN 1	-30.1110
APR 1	-5.476	APR 1	-15.595	APR 1	-23.2788	APR 1	-30.2914
JUL 1	-5.700	JUL 1	-15.850	JUL 1	-23.3972	JUL 1	-30.4731
OCT 1	-5.871	OCT 1	-16.062	OCT 1	-23.4816	OCT 1	-30.6087
1968 JAN 1	-6.111	1978 JAN 1	-16.351	1988 JAN 1	-23.6356	1998 JAN 1	-30.7818
APR 1	-6.344	APR 1	-16.651	APR 1	-23.7823	APR 1	-30.9622
JUL 1	-6.573	JUL 1	-16.917	JUL 1	-23.9100	JUL 1	-31.1004
OCT 1	-6.775	OCT 1	-17.123	OCT 1	-23.9771	OCT 1	-31.1582
1969 JAN 1	-7.021	1979 JAN 1	-17.402	1989 JAN 1	-24.1159	1999 JAN 1	-31.2833
APR 1	-7.274	APR 1	-17.670	APR 1	-24.2443	APR 1	-31.3840
JUL 1	-7.521	JUL 1	-17.918	JUL 1	-24.3857	JUL 1	-31.4801
OCT 1	-7.734	OCT 1	-18.112	OCT 1	-24.4899	OCT 1	-31.5307
1970 JAN 1	-7.997	1980 JAN 1	-18.355	1990 JAN 1	-24.6713	2000 JAN 1	-31.6445
APR 1	-8.271	APR 1	-18.582	APR 1	-24.8631	APR 1	-31.7235
JUL 1	-8.526	JUL 1	-18.792	JUL 1	-25.0386	JUL 1	-31.7959
OCT 1	-8.722	OCT 1	-18.970	OCT 1	-25.1803	OCT 1	-31.8253
1971 JAN 1	-8.985	1981 JAN 1	-19.196	1991 JAN 1	-25.3813	2001 JAN 1	-31.9068
APR 1	-9.237	APR 1	-19.414	APR 1	-25.5871	APR 1	-31.9744
JUL 1	-9.503	JUL 1	-19.629	JUL 1	-25.7735		
OCT 1	-9.741	OCT 1	-19.777	OCT 1	-25.9204		

Table 2. Relationship between TAI and UTC

Limits of validity (at 0h UTC)	TAI − UTC
1961 Jan. 1 - 1961 Aug. 1	1.422 818 0s + (MJD - 37 300) x 0.001 296s
Aug. 1 - 1962 Jan. 1	1.372 818 0s + ""
1962 Jan. 1 - 1963 Nov. 1	1.845 858 0s + (MJD - 37 665) x 0.001 123 2s
1963 Nov. 1 - 1964 Jan. 1	1.945 858 0s + ""
1964 Jan. 1 - April 1	3.240 130 0s + (MJD - 38 761) x 0.001 296s
April 1 - Sept. 1	3.340 130 0s + ""
Sept. 1 - 1965 Jan. 1	3.440 130 0s + ""
1965 Jan. 1 - March 1	3.540 130 0s + ""
March 1 - Jul. 1	3.640 130 0s + ""
Jul. 1 - Sept. 1	3.740 130 0s + ""
Sept. 1 - 1966 Jan. 1	3.840 130 0s + ""
1966 Jan. 1 - 1968 Feb. 1	4.313 170 0s + (MJD - 39 126) x 0.002 592s
1968 Feb. 1 - 1972 Jan. 1	4.213 170 0s + ""
1972 Jan. 1 - Jul. 1	10s
Jul. 1 - 1973 Jan. 1	11s
1973 Jan. 1 - 1974 Jan. 1	12s
1974 Jan. 1 - 1975 Jan. 1	13s
1975 Jan. 1 - 1976 Jan. 1	14s
1976 Jan. 1 - 1977 Jan. 1	15s
1977 Jan. 1 - 1978 Jan. 1	16s
1978 Jan. 1 - 1979 Jan. 1	17s
1979 Jan. 1 - 1980 Jan. 1	18s
1980 Jan. 1 - 1981 Jul. 1	19s
1981 Jul. 1 - 1982 Jul. 1	20s
1982 Jul. 1 - 1983 Jul. 1	21s
1983 Jul. 1 - 1985 Jul. 1	22s
1985 Jul. 1 - 1988 Jan. 1	23s

Limits of validity (at 0h UTC)	
1988 Jan. 1 - 1990 Jan. 1	24s
1990 Jan. 1 - 1991 Jan. 1	25s
1991 Jan. 1 - 1992 Jul. 1	26s
1992 Jul. 1 - 1993 Jul 1	27s
1993 Jul. 1 - 1994 Jul. 1	28s
1994 Jul. 1 - 1996 Jan. 1	29s
1996 Jan. 1 - 1997 Jul. 1	30s
1997 Jul. 1 - 1999 Jan 1	31s
1999 Jan. 1 -	32s

Irregularities of the Earth's Rotation

Polar motion

The main components of polar motion are a free oscillation (Chandler wobble) with a period of 1.2 year and an oscillation which is forced by the seasonal mass redistribution in the atmosphere and oceans. The beating period of the two terms is approximately 6 years. A slow, irregular drift towards the west is superimposed to the cyclic variation.

Figures IV-4-1 and *IV-4-2* show a filtering of x and y coordinates of the pole since 1890 obtained by CENSUS X-11 (Shiskin *et al.,* 1965) modified to take into account two main periodic components. The series shown is EOP(IERS) C 01. The residual motion in the lower part of the figures includes irregularities with recurrence times ranging from days to years that are forced by the atmosphere, as shown on *Figure IV-4-3* for EOP(IERS) C 04.

Table 5 gives yearly coordinates of the mean rotation axis in the IERS Terrestrial Reference Frame, obtained by filtering the Chandler and seasonal terms. Their uncertainty is about 0.010".

Table 3. Offsets and step adjustments of UTC

Date (at 0h UTC)	Offsets	Steps
1961 Jan. 1	$- 150\text{x}10^{-10}$	
Aug. 1	"	+ 0.050s
1962 Jan. 1	$- 130\text{x}10^{-10}$	
1963 Nov. 1	"	- 0.100s
1964 Jan. 1	$- 150\text{x}10^{-10}$	
Apr. 1	"	- 0.100s
Sept. 1	"	- 0.100s
1965 Jan. 1	"	- 0.100s
March 1	"	- 0.100s
Jul. 1	"	- 0.100s
Sept. 1	"	- 0.100s
1966 Jan. 1	$- 300\text{x}10^{-10}$	
1968 Feb. 1	"	+ 0.100s
1972 Jan. 1	0	- 0.1077580s

Date (at 0h UTC)	Steps
1972 Jul. 1	- 1s
1973 Jan. 1	- 1s
1974 Jan. 1	- 1s
1975 Jan. 1	- 1s
1976 Jan. 1	- 1s
1977 Jan. 1	- 1s
1978 Jan. 1	- 1s
1979 Jan. 1	- 1s
1980 Jan. 1	- 1s
1981 Jul. 1	- 1s
1982 Jul. 1	- 1s
1983 Jul. 1	- 1s
1985 Jul. 1	- 1s
1988 Jan. 1	- 1s
1990 Jan. 1	- 1s
1991 Jan. 1	- 1s
1992 Jul. 1	- 1s

Date (at 0h UTC)	Steps
1993 Jul. 1	- 1s
1994 Jul. 1	- 1s
1996 Jan. 1	- 1s
1997 Jul. 1	- 1s
1999 Jan. 1	- 1s

Celestial motion of the pole

The variations in $d\psi$ and $d\varepsilon$ reflect the difference of the actual celestial motion of the pole with the one modeled by the conventional IAU precession and nutation models. *Figure IV-4-4* shows the observed variations of $d\psi$ and $d\varepsilon$. These variations reflect the errors in several terms of the IAU models: secular term, periodic terms (mainly 18.6 yr, 1.0 yr, 0.5 yr, 14 d). These terms are included in the IERS Conventions (1996) correction model. *Figure IV-4-5* shows the residual variations when the corrective model is applied. In order to refer to the ICRF pole, a bias both in longitude and obliquity should be added (see ICRS Section).

Universal time and excess of the duration of the day over 86400s

Universal time and the duration of the day are subject to variations mainly due to the zonal tides (*Tables 4a and 4b*), the atmospheric circulation, the internal effects and the transfer of angular momentum to the Moon orbital motion. *Figure IV-4-6* shows a decomposition of the variations in the duration of the day. The residual oscillation in the middle of the figure includes transient sub-seasonal oscillations that are forced by the atmosphere.

Table 4a. Earth rotation variations due to zonal tides with periods up to 35 days

UT1R, DR, ωR represent the corrected values of UT1, of the duration of the day D and of the angular velocity of the Earth ω, according to IERS Conventions (1996).
The units are 10^{-4} s for UT, 10^{-5} s for D, and 10^{-14} rad/s for ω.

N	ARGUMENTS					PERIODS	COEFFICIENTS		
	l	l′	F	D	Ω	DAYS	UT1-UT1R	D-DR	ω-ωR
							sin	cos	cos
1	1	0	2	2	2	5.64	-0.024	0.26	-0.22
2	2	0	2	0	1	6.85	-0.040	0.37	-0.31
3	2	0	2	0	2	6.86	-0.099	0.90	-0.76
4	0	0	2	2	1	7.09	-0.051	0.45	-0.38
5	0	0	2	2	2	7.10	-0.123	1.09	-0.92
6	1	0	2	0	0	9.11	-0.039	0.27	-0.22
7	1	0	2	0	1	9.12	-0.411	2.83	-2.39
8	1	0	2	0	2	9.13	-0.993	6.83	-5.76
9	3	0	0	0	0	9.18	-0.018	0.12	-0.10
10	-1	0	2	2	1	9.54	-0.082	0.54	-0.45
11	-1	0	2	2	2	9.56	-0.197	1.30	-1.10
12	1	0	0	2	0	9.61	-0.076	0.50	-0.42
13	2	0	2	-2	2	12.81	0.022	-0.11	0.09
14	0	1	2	0	2	13.17	0.025	-0.12	0.10
15	0	0	2	0	0	13.61	-0.299	1.38	-1.17
16	0	0	2	0	1	13.63	-3.208	14.79	-12.48
17	0	0	2	0	2	13.66	-7.757	35.68	-30.11
18	2	0	0	0	-1	13.75	0.022	-0.10	0.08
19	2	0	0	0	0	13.78	-0.338	1.54	-1.30
20	2	0	0	0	1	13.81	0.018	-0.08	0.07
21	0	-1	2	0	2	14.19	-0.024	0.11	-0.09
22	0	0	0	2	-1	14.73	0.047	-0.20	0.17
23	0	0	0	2	0	14.77	-0.734	3.12	-2.64
24	0	0	0	2	1	14.80	-0.053	0.22	-0.19
25	0	-1	0	2	0	15.39	-0.051	0.21	-0.17
26	1	0	2	-2	1	23.86	0.050	-0.13	0.11
27	1	0	2	-2	2	23.94	0.101	-0.26	0.22
28	1	1	0	0	0	25.62	0.039	-0.10	0.08
29	-1	0	2	0	0	26.88	0.047	-0.11	0.09
30	-1	0	2	0	1	26.98	0.177	-0.41	0.35
31	-1	0	2	0	2	27.09	0.435	-1.01	0.85
32	1	0	0	0	-1	27.44	0.534	-1.22	1.03
33	1	0	0	0	0	27.56	-8.261	18.84	-15.90
34	1	0	0	0	1	27.67	0.544	-1.24	1.04
35	0	0	0	1	0	29.53	0.047	-0.10	0.08
36	1	-1	0	0	0	29.80	-0.055	0.12	-0.10
37	-1	0	0	2	-1	31.66	0.118	-0.23	0.20
38	-1	0	0	2	0	31.81	-1.824	3.60	-3.04
39	-1	0	0	2	1	31.96	0.132	-0.26	0.22
40	1	0	-2	2	-1	32.61	0.018	-0.03	0.03
41	-1	-1	0	2	0	34.85	-0.086	0.15	-0.13

Table 4b. Earth rotation variations due to zonal tides with periods longer than 35 days

UT1R', DR', ωR' represent the corrected values of UT1, of the duration of the day D and of the angular velocity of the Earth ω, based on Yoder *et al.* (1981), with K/C = 0.94.
The units are 10^{-4} s for UT, 10^{-5} s for D, and 10^{-14} rad/s for ω.

N	ARGUMENTS					PERIODS	COEFFICIENTS		
	l	l′	F	D	Ω	DAYS	UT1-UT1R′	D-DR′	ω-ωR′
							sin	cos	cos
42	0	2	2	-2	2	91.31	-0.057	0.04	-0.03
43	0	1	2	-2	1	119.61	0.033	-0.02	0.01
44	0	1	2	-2	2	121.75	-1.885	0.97	-0.82
45	0	0	2	-2	0	173.31	0.251	-0.09	0.08
46	0	0	2	-2	1	177.84	1.170	-0.41	0.35
47	0	0	2	-2	2	182.62	-48.247	16.60	-14.01
48	0	2	0	0	0	182.63	-0.194	0.07	-0.06
49	2	0	0	-2	-1	199.84	0.049	-0.02	0.01
50	2	0	0	-2	0	205.89	-0.547	0.17	-0.14
51	2	0	0	-2	1	212.32	0.037	-0.01	0.01
52	0	-1	2	-2	1	346.60	-0.045	0.01	-0.01
53	0	1	0	0	-1	346.64	0.092	-0.02	0.01
54	0	-1	2	-2	2	365.22	0.828	-0.14	0.12
55	0	1	0	0	0	365.26	-15.359	2.64	-2.23
56	0	1	0	0	1	386.00	-0.138	0.02	-0.02
57	1	0	0	-1	0	411.78	0.035	-0.01	0.00
58	2	0	-2	0	0	1095.17	-0.137	-0.01	0.01
59	-2	0	2	0	1	1305.47	0.422	-0.02	0.02
60	-1	1	0	1	0	3232.85	0.040	0.00	0.00
61	0	0	0	0	2	3399.18	7.900	0.15	-0.12
62	0	0	0	0	1	6790.36	-1617.268	-14.95	12.62

Mean anomaly of the Moon $l = 134°.96 + 13°.064993(MJD-51544.5)$

Mean anomaly of the Sun $l' = 357°.53 + 0°.985600(MJD-51544.5)$

Mean longitude of the Moon from the node of the Moon $F = 93°.27 + 13°.229350(MJD-51544.5)$
$F = L - \Omega$
L : Mean longitude of the Moon

Mean elongation of the Moon from the Sun $D = 297°.85 + 12°.190749(MJD-51544.5)$

Mean longitude of the ascending node of the Moon $\Omega = 125°.04 - 0°.052954(MJD-51544.5)$

Fig. IV-4-1. X-coordinate of the pole (EOP(IERS) C 04)

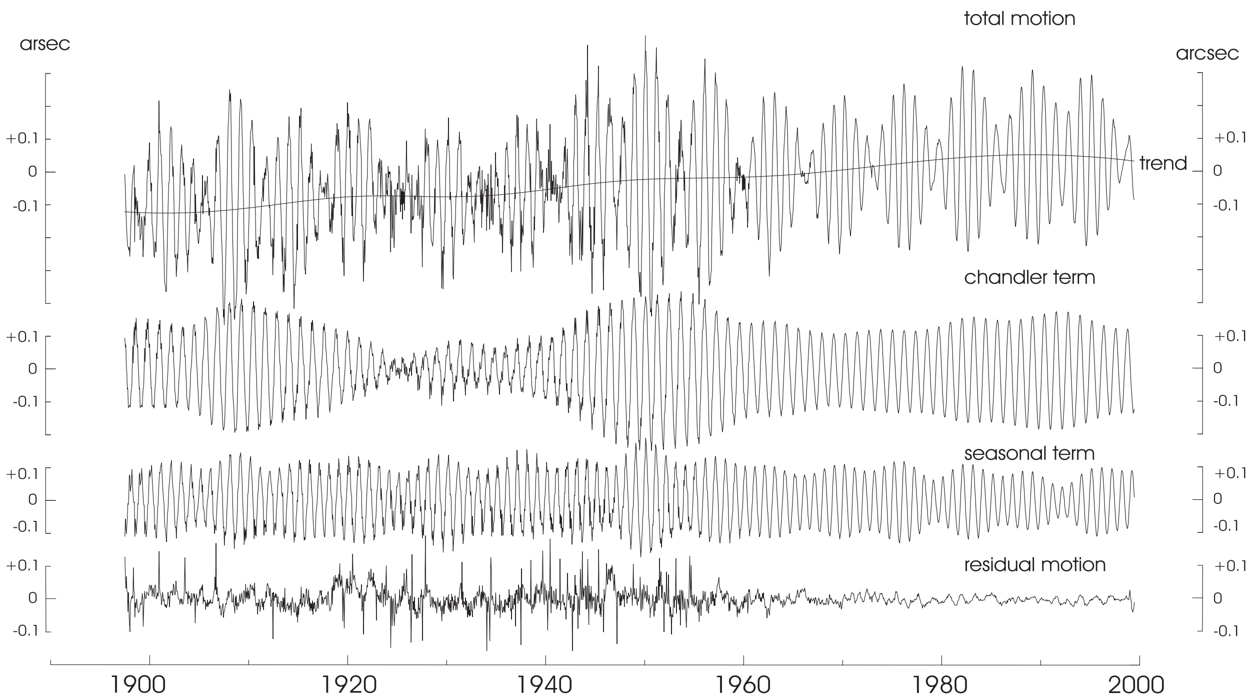


Fig. IV-4-2. Y-coordinate of the pole (EOP(IERS) C 04)

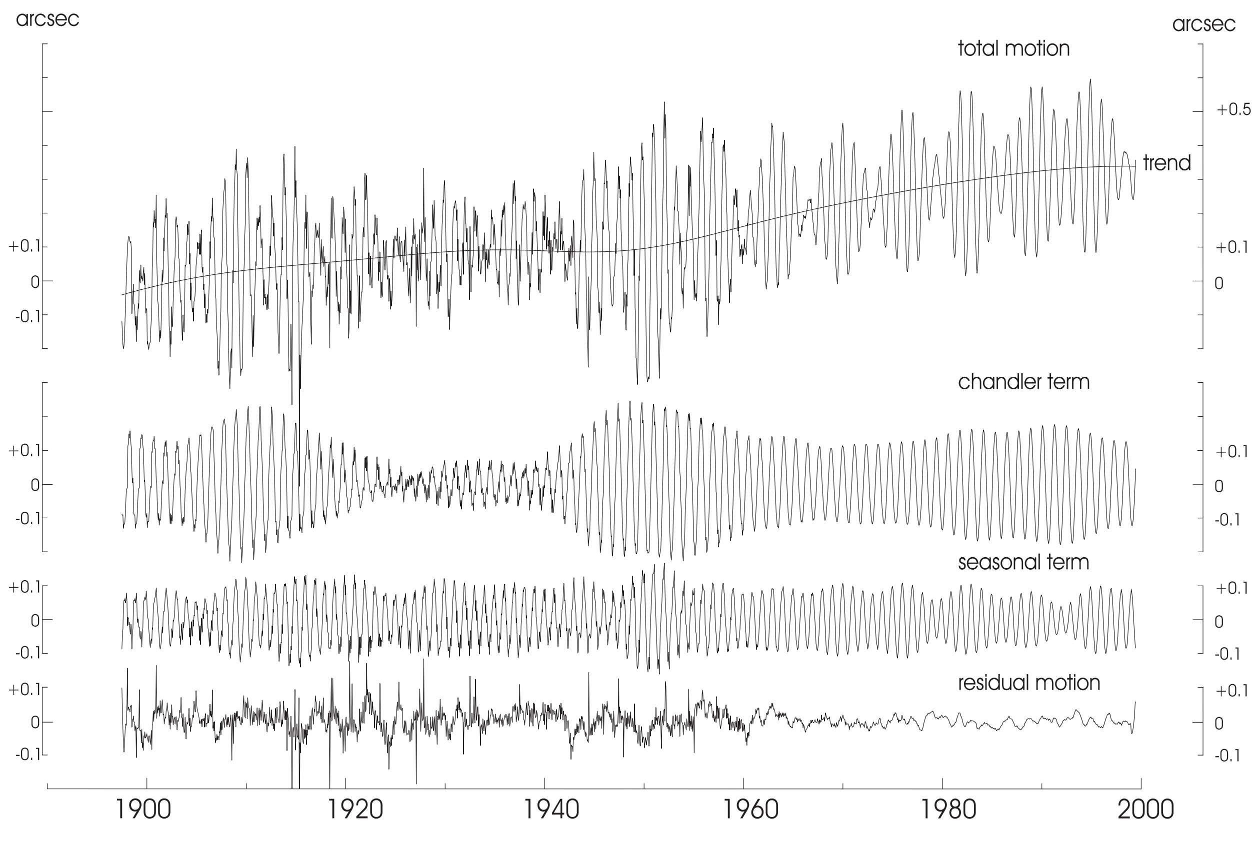


Fig. IV-4-3. Irregular variations in polar motion (EOP(IERS) C 04 filtered by CENSUS X-11)

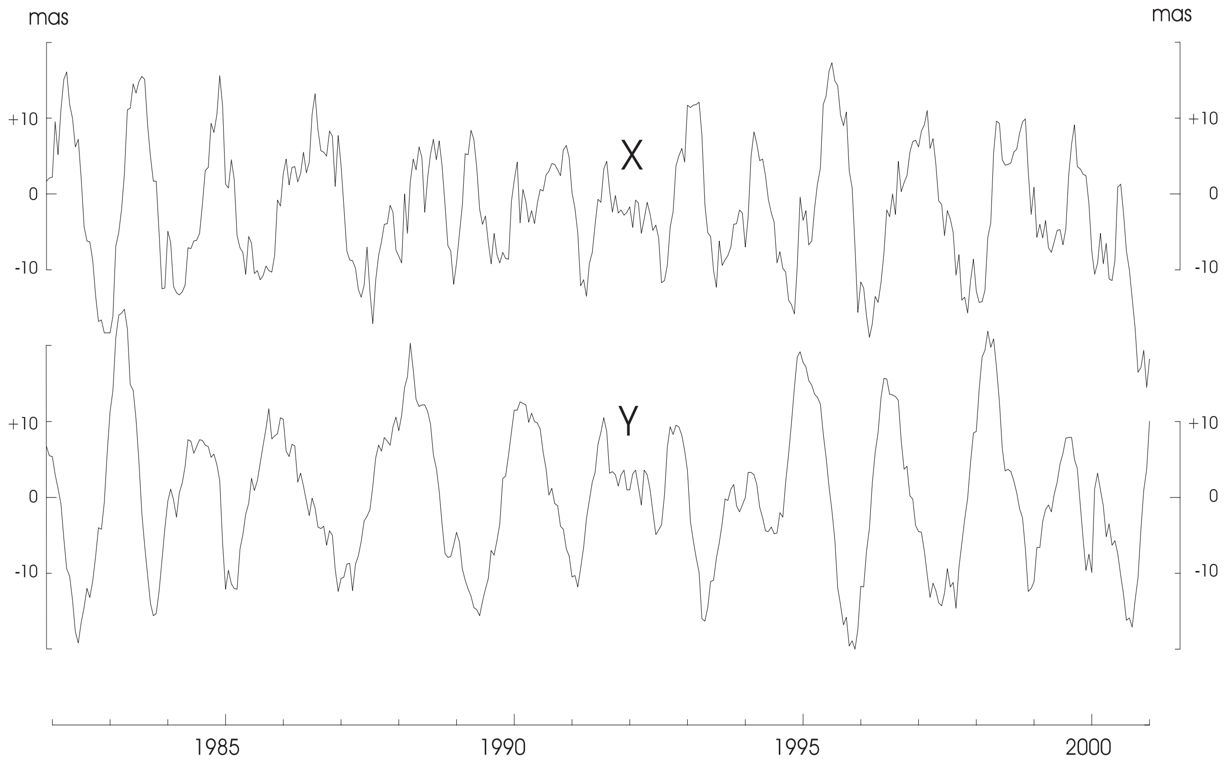


Table 6 gives mean annual values of the excess of the duration of the day D, which are available for the last four centuries. For the interval 1623–1955, the data are those provided by L.V. Morrison, Royal Greenwich Observatory, interpolated for the middle of the year. The mean solar time has been referred to the dynamical time scale derived from the time argument of the lunar ephemeris. The duration of the day has been obtained:

– from 1623 to 1860, by derivative of cubic splines fitted on individual values of the difference between mean solar time and dynamical time,
– from 1861 to 1955, by a 5-point quadratic convolute.

More information on the computation of the duration of the day is available in Stephenson and Morrison (1984), with an estimation of the accuracy of these evaluations. From 1956 up to present, the duration of the day has been obtained from the BIH/IERS values of UT1–TAI; the table gives annual averages. At the level of precision of these values of the duration of the day, the unit of the dynamical time and the unit of TAI can be considered as having the same duration. Thus D is expressed in present SI units. The table gives also the values of the angular velocity of the Earth's rotation ω derived from the listed values of D.

Table 5. Coordinates of the mean rotation axis since 1900 (EOP(IERS) C 01)

Date (year)	x (")	y (")	Date (year)	x (")	y (")	Date (year)	x (")	y (")
1900.	-.122	-.033	1934.	-.074	.090	1968.	-.003	.208
1901.	-.124	-.026	1935.	-.072	.091	1969.	.000	.214
1902.	-.124	-.018	1936.	-.070	.091	1970.	.003	.220
1903.	-.125	-.011	1937.	-.068	.091	1971.	.006	.227
1904.	-.125	-.005	1938.	-.065	.091	1972.	.009	.233
1905.	-.124	.001	1939.	-.062	.091	1973.	.012	.239
1906.	-.123	.007	1940.	-.059	.090	1974.	.016	.244
1907.	-.121	.012	1941.	-.055	.089	1975.	.019	.250
1908.	-.119	.017	1942.	-.051	.088	1976.	.023	.256
1909.	-.117	.022	1943.	-.047	.087	1977.	.026	.261
1910.	-.114	.026	1944.	-.043	.086	1978.	.029	.266
1911.	-.111	.030	1945.	-.039	.086	1979.	.033	.272
1912.	-.107	.033	1946.	-.035	.085	1980.	.036	.277
1913.	-.104	.036	1947.	-.032	.086	1981.	.039	.282
1914.	-.100	.039	1948.	-.029	.087	1982.	.042	.286
1915.	-.096	.042	1949.	-.026	.088	1983.	.044	.291
1916.	-.092	.045	1950.	-.024	.091	1984.	.046	.296
1917.	-.088	.047	1951.	-.022	.094	1985.	.048	.300
1918.	-.085	.050	1952.	-.021	.098	1986.	.050	.304
1919.	-.081	.053	1953.	-.020	.102	1987.	.052	.309
1920.	-.079	.055	1954.	-.019	.108	1988.	.053	.313
1921.	-.076	.058	1955.	-.018	.114	1989.	.054	.316
1922.	-.074	.061	1956.	-.018	.120	1990.	.054	.320
1923.	-.073	.063	1957.	-.017	.127	1991.	.054	.323
1924.	-.072	.066	1958.	-.017	.134	1992.	.054	.326
1925.	-.072	.069	1959.	-.017	.142	1993.	.053	.329
1926.	-.072	.072	1960.	-.016	.149	1994.	.052	.332
1927.	-.073	.074	1961.	-.015	.157	1995.	.051	.334
1928.	-.073	.077	1962.	-.014	.165	1996.	.049	.336
1929.	-.074	.080	1963.	-.013	.172	1997.	.047	.337
1930.	-.074	.082	1964.	-.012	.180	1998.	.044	.338
1931.	-.075	.084	1965.	-.010	.187	1999.	.041	.339
1932.	-.075	.086	1966.	-.008	.194	2000.	.038	.339
1933.	-.074	.088	1967.	-.006	.201			

Fig. IV-4-4. Celestial pole offsets: motion of the celestial pole relative to the IAU 1980 Theory of Nutation and the IAU 1976 Precession (EOP(IERS C 04)

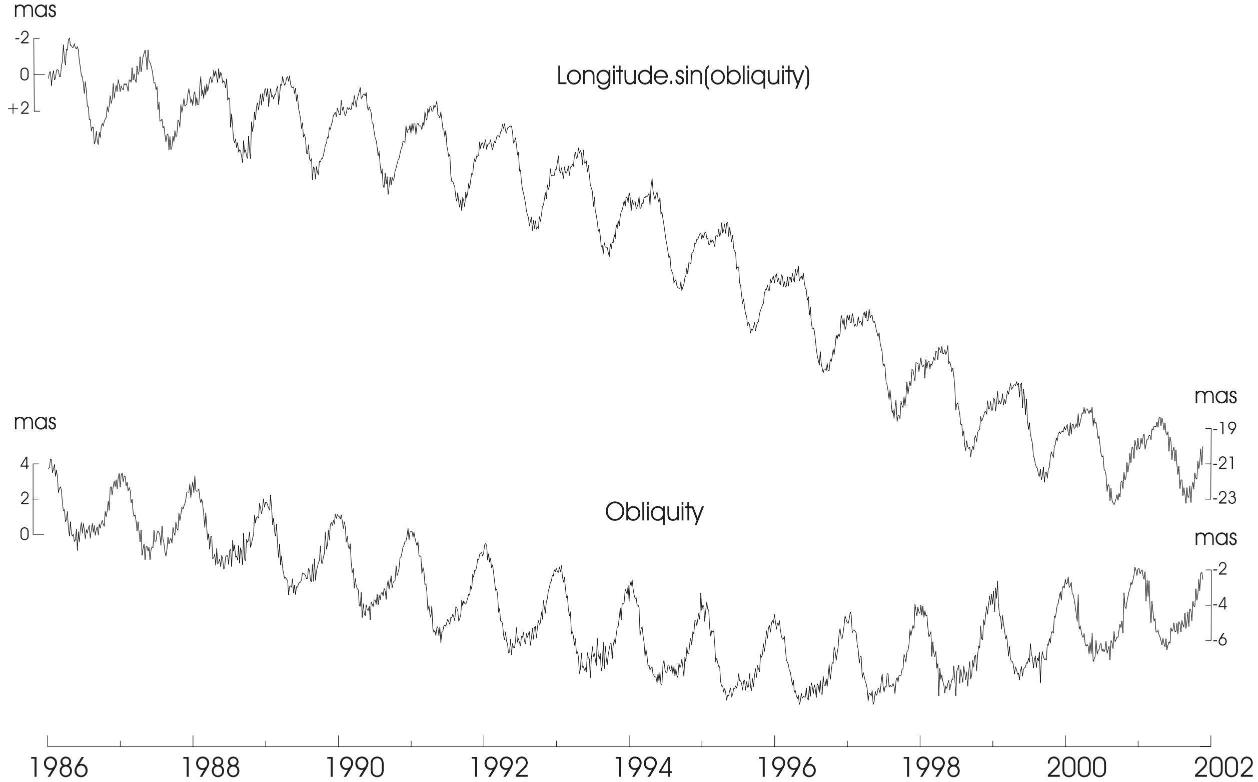


Fig. IV-4-5. Celestial pole offset corrected by the IERS Conventions (1996) precession-nutation corrective model (EOP(IERS C 04)

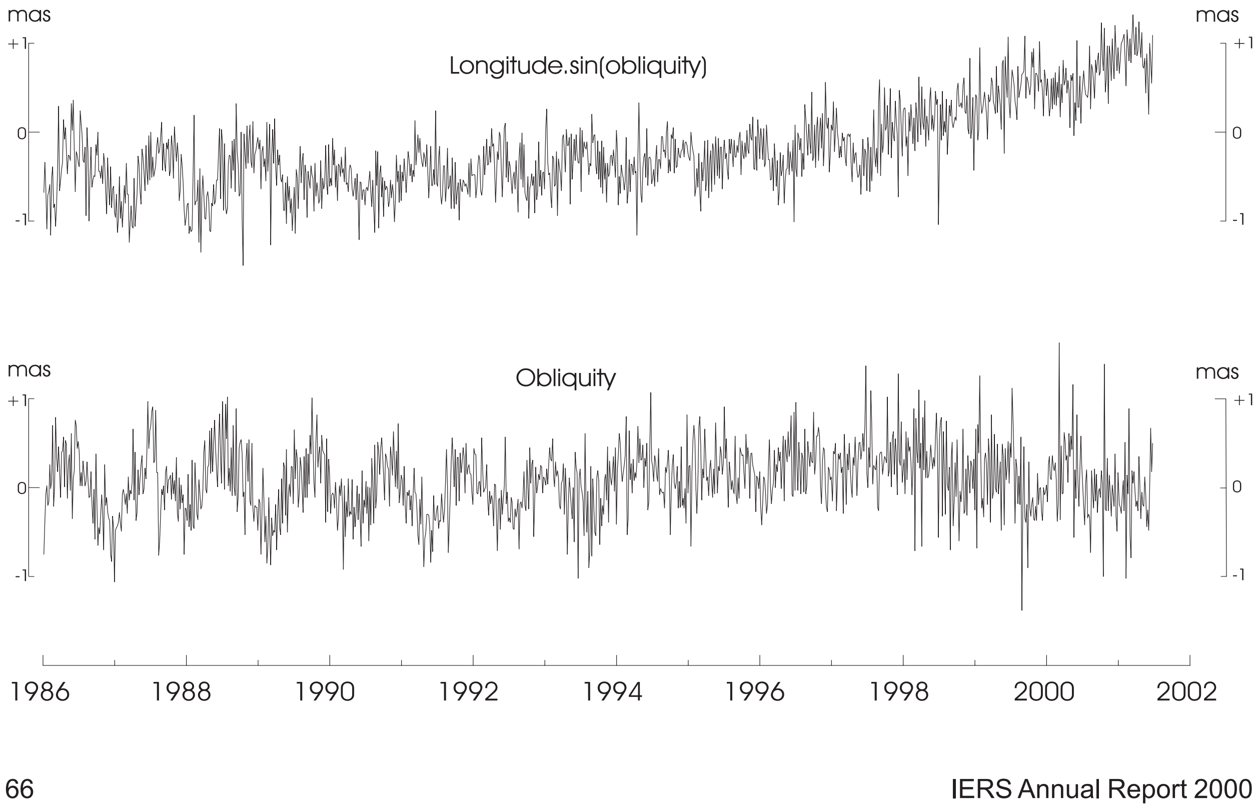


Fig. IV-4-6. Variation in the duration of the day (EOP(IERS C 04)

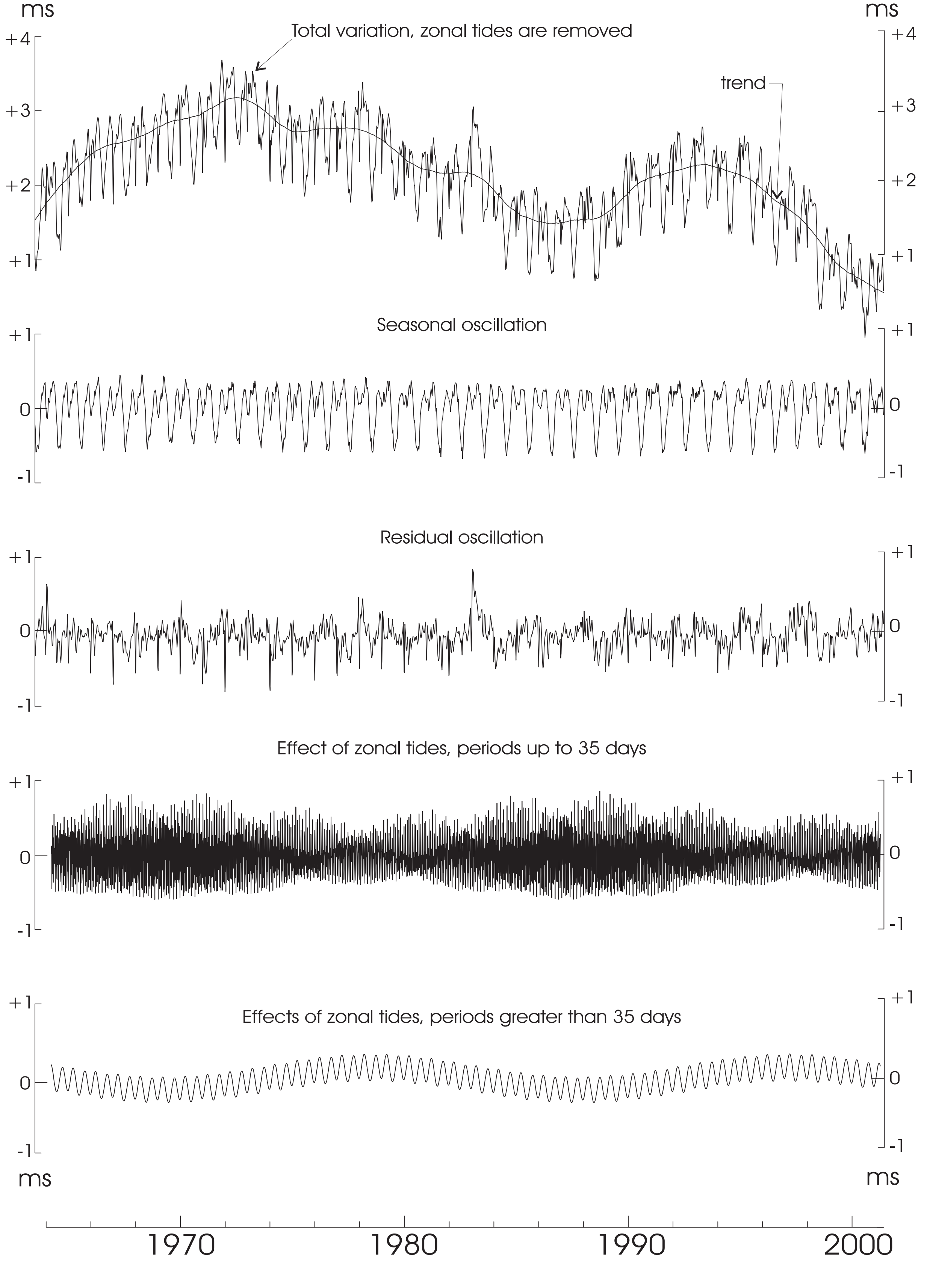


Table 6. Excess of the duration of the day to 86400s and Angular velocity of the Earth's rotation, since 1623

DATE (years)	D (ms)	ω (prad/s)	DATE (years)	D (ms)	ω (prad/s)	DATE (years)	D (ms)	ω (prad/s)
		72 921..			72 921..			72 921..
			1671.5	-3.	154.	1721.5	0.2	151.3
			1672.5	-3.	154.	1722.5	0.2	151.3
1623.5	-11.	161.	1673.5	-3.	154.	1723.5	0.1	151.4
1624.5	-11.	161.	1674.5	-3.	154.	1724.5	0.1	151.4
1625.5	-10.	160.	1675.5	-3.	154.	1725.5	0.1	151.4
1626.5	-10.	160.	1676.5	-3.	154.	1726.5	0.1	151.4
1627.5	-9.	159.	1677.5	-3.	154.	1727.5	0.1	151.4
1628.5	-9.	159.	1678.5	-3.	154.	1728.5	0.2	151.3
1629.5	-8.	158.	1679.5	-2.	153.	1729.5	0.2	151.3
1630.5	-8.	158.	1680.5	-2.	153.	1730.5	0.2	151.3
1631.5	-8.	158.	1681.5	-2.	153.	1731.5	0.2	151.3
1632.5	-7.	157.	1682.5	-2.	153.	1732.5	0.2	151.3
1633.5	-7.	157.	1683.5	-2.	153.	1733.5	0.2	151.3
1634.5	-7.	157.	1684.5	-2.	153.	1734.5	0.2	151.3
1635.5	-6.	157.	1685.5	-2.	153.	1735.5	0.2	151.3
1636.5	-6.	157.	1686.5	-1.	152.	1736.5	0.3	151.2
1637.5	-6.	157.	1687.5	-1.	152.	1737.5	0.3	151.2
1638.5	-5.	156.	1688.5	-1.	152.	1738.5	0.3	151.2
1639.5	-5.	156.	1689.5	-1.	152.	1739.5	0.3	151.2
1640.5	-5.	156.	1690.5	-1.	152.	1740.5	0.3	151.2
1641.5	-4.	155.	1691.5	-1.	152.	1741.5	0.3	151.2
1642.5	-4.	155.	1692.5	-1.	152.	1742.5	0.3	151.2
1643.5	-4.	155.	1693.5	0.	151.	1743.5	0.4	151.1
1644.5	-4.	155.	1694.5	0.	151.	1744.5	0.4	151.1
1645.5	-4.	155.	1695.5	0.	151.	1745.5	0.4	151.1
1646.5	-3.	154.	1696.5	0.	151.	1746.5	0.4	151.1
1647.5	-3.	154.	1697.5	0.	151.	1747.5	0.4	151.1
1648.5	-3.	154.	1698.5	0.	151.	1748.5	0.4	151.1
1649.5	-3.	154.	1699.5	0.	151.	1749.5	0.4	151.1
1650.5	-3.	154.	1700.5	0.1	151.4	1750.5	0.4	151.1
1651.5	-3.	154.	1701.5	0.2	151.3	1751.5	0.4	151.1
1652.5	-3.	154.	1702.5	0.2	151.3	1752.5	0.4	151.1
1653.5	-3.	154.	1703.5	0.3	151.2	1753.5	0.4	151.1
1654.5	-3.	154.	1704.5	0.3	151.2	1754.5	0.4	151.1
1655.5	-3.	154.	1705.5	0.3	151.2	1755.5	0.4	151.1
1656.5	-3.	154.	1706.5	0.3	151.2	1756.5	0.4	151.1
1657.5	-3.	154.	1707.5	0.3	151.2	1757.5	0.4	151.1
1658.5	-3.	154.	1708.5	0.4	151.1	1758.5	0.4	151.1
1659.5	-3.	154.	1709.5	0.3	151.2	1759.5	0.4	151.1
1660.5	-3.	154.	1710.5	0.3	151.2	1760.5	0.4	151.1
1661.5	-3.	154.	1711.5	0.3	151.2	1761.5	0.4	151.1
1662.5	-3.	154.	1712.5	0.3	151.2	1762.5	0.3	151.2
1663.5	-3.	154.	1713.5	0.3	151.2	1763.5	0.3	151.2
1664.5	-3.	154.	1714.5	0.3	151.2	1764.5	0.3	151.2
1665.5	-3.	154.	1715.5	0.2	151.3	1765.5	0.3	151.2
1666.5	-3.	154.	1716.5	0.2	151.3	1766.5	0.3	151.2
1667.5	-3.	154.	1717.5	0.2	151.3	1767.5	0.3	151.2
1668.5	-3.	154.	1718.5	0.2	151.3	1768.5	0.3	151.2
1669.5	-3.	154.	1719.5	0.2	151.3	1769.5	0.3	151.2
1670.5	-3.	154.	1720.5	0.2	151.3	1770.5	0.3	151.2

Table 6 (cont.).

DATE (years)	D (ms)	ω (prad/s)	DATE (years)	D (ms)	ω (prad/s)	DATE (years)	D (ms)	ω (prad/s)
		72 921..			72 921..			72 921..
1771.5	0.3	151.2	1821.5	-0.81	152.15	1871.5	-2.59	153.65
1772.5	0.2	151.3	1822.5	-0.99	152.30	1872.5	-2.55	153.62
1773.5	0.2	151.3	1823.5	-1.16	152.45	1873.5	-2.10	153.24
1774.5	0.2	151.3	1824.5	-1.32	152.58	1874.5	-2.03	153.18
1775.5	0.2	151.3	1825.5	-1.42	152.67	1875.5	-1.77	152.96
1776.5	0.2	151.3	1826.5	-1.49	152.72	1876.5	-1.37	152.62
1777.5	0.2	151.3	1827.5	-1.50	152.73	1877.5	-1.24	152.51
1778.5	0.2	151.3	1828.5	-1.48	152.72	1878.5	-0.90	152.23
1779.5	0.2	151.3	1829.5	-1.41	152.66	1879.5	-0.49	151.88
1780.5	0.2	151.3	1830.5	-1.30	152.56	1880.5	-0.23	151.66
1781.5	0.2	151.3	1831.5	-1.14	152.43	1881.5	-0.06	151.52
1782.5	0.1	151.4	1832.5	-0.94	152.26	1882.5	-0.15	151.59
1783.5	0.1	151.4	1833.5	-0.73	152.08	1883.5	-0.33	151.75
1784.5	0.1	151.4	1834.5	-0.52	151.91	1884.5	-0.24	151.67
1785.5	0.0	151.5	1835.5	-0.34	151.75	1885.5	-0.15	151.59
1786.5	0.0	151.5	1836.5	-0.18	151.62	1886.5	-0.05	151.51
1787.5	-0.1	151.6	1837.5	-0.04	151.50	1887.5	-0.04	151.50
1788.5	-0.2	151.6	1838.5	0.09	151.39	1888.5	-0.18	151.62
1789.5	-0.3	151.7	1839.5	0.19	151.31	1889.5	-0.25	151.68
1790.5	-0.5	151.9	1840.5	0.27	151.24	1890.5	-0.48	151.87
1791.5	-0.6	152.0	1841.5	0.33	151.19	1891.5	-0.58	151.96
1792.5	-0.7	152.1	1842.5	0.37	151.15	1892.5	-0.42	151.82
1793.5	-0.9	152.2	1843.5	0.39	151.14	1893.5	-0.13	151.58
1794.5	-0.9	152.2	1844.5	0.40	151.13	1894.5	0.33	151.19
1795.5	-1.0	152.3	1845.5	0.41	151.12	1895.5	0.86	150.74
1796.5	-1.0	152.3	1846.5	0.41	151.12	1896.5	1.53	150.18
1797.5	-1.0	152.3	1847.5	0.40	151.13	1897.5	2.16	149.64
1798.5	-1.0	152.3	1848.5	0.39	151.14	1898.5	2.64	149.24
1799.5	-1.0	152.3	1849.5	0.38	151.15	1899.5	3.00	148.94
1800.5	-0.87	152.20	1850.5	0.36	151.16	1900.5	3.31	148.67
1801.5	-0.75	152.10	1851.5	0.33	151.19	1901.5	3.60	148.43
1802.5	-0.61	151.98	1852.5	0.30	151.21	1902.5	3.70	148.34
1803.5	-0.46	151.86	1853.5	0.26	151.25	1903.5	3.69	148.35
1804.5	-0.34	151.75	1854.5	0.23	151.27	1904.5	3.55	148.47
1805.5	-0.23	151.66	1855.5	0.20	151.30	1905.5	3.40	148.60
1806.5	-0.14	151.59	1856.5	0.17	151.32	1906.5	3.48	148.53
1807.5	-0.06	151.52	1857.5	0.15	151.34	1907.5	3.57	148.45
1808.5	-0.01	151.48	1858.5	0.11	151.37	1908.5	3.65	148.39
1809.5	0.03	151.44	1859.5	-0.02	151.48	1909.5	3.71	148.34
1810.5	0.05	151.42	1860.5	-0.34	151.75	1910.5	3.77	148.29
1811.5	0.05	151.42	1861.5	-0.81	152.15	1911.5	3.86	148.21
1812.5	0.04	151.43	1862.5	-1.19	152.47	1912.5	3.89	148.18
1813.5	0.01	151.46	1863.5	-1.35	152.61	1913.5	3.62	148.41
1814.5	-0.04	151.50	1864.5	-1.61	152.83	1914.5	3.18	148.78
1815.5	-0.11	151.56	1865.5	-2.13	153.26	1915.5	2.92	149.00
1816.5	-0.18	151.62	1866.5	-2.76	153.80	1916.5	2.74	149.15
1817.5	-0.28	151.70	1867.5	-2.89	153.91	1917.5	2.35	149.48
1818.5	-0.39	151.80	1868.5	-2.60	153.66	1918.5	2.05	149.74
1819.5	-0.51	151.90	1869.5	-2.59	153.65	1919.5	1.76	149.98
1820.5	-0.65	152.02	1870.5	-2.51	153.59	1920.5	1.48	150.22

Table 6 (cont.).

DATE (years)	D (ms)	ω (prad/s) 72 921..	DATE (years)	D (ms)	ω (prad/s) 72 921..
1921.5	1.51	150.19	1971.5	2.90	149.02
1922.5	1.28	150.39	1972.5	3.13	148.83
1923.5	0.98	150.64	1973.5	3.05	148.89
1924.5	0.93	150.68	1974.5	2.72	149.17
1925.5	0.81	150.78	1975.5	2.69	149.20
1926.5	0.56	150.99	1976.5	2.91	149.01
1927.5	0.18	151.32	1977.5	2.77	149.13
1928.5	-0.22	151.65	1978.5	2.88	149.04
1929.5	-0.35	151.76	1979.5	2.61	149.26
1930.5	-0.19	151.63	1980.5	2.30	149.53
1931.5	-0.10	151.55	1981.5	2.16	149.64
1932.5	-0.07	151.53	1982.5	2.16	149.64
1933.5	-0.06	151.52	1983.5	2.28	149.54
1934.5	-0.08	151.53	1984.5	1.52	150.18
1935.5	0.00	151.47	1985.5	1.45	150.24
1936.5	0.08	151.40	1986.5	1.23	150.43
1937.5	0.22	151.28	1987.5	1.36	150.32
1938.5	0.47	151.07	1988.5	1.32	150.35
1939.5	0.78	150.81	1989.5	1.53	150.18
1940.5	1.09	150.55	1990.5	1.94	149.83
1941.5	1.25	150.41	1991.5	2.04	149.75
1942.5	1.31	150.36	1992.5	2.22	149.59
1943.5	1.35	150.33	1993.5	2.37	149.47
1944.5	1.41	150.28	1994.5	2.17	149.64
1945.5	1.41	150.28	1995.5	2.31	149.52
1946.5	1.35	150.33	1996.5	1.83	149.92
1947.5	1.30	150.37	1997.5	1.84	149.91
1948.5	1.25	150.41	1998.5	1.37	150.31
1949.5	1.20	150.45	1999.5	0.99	150.63
1950.5	1.15	150.50	2000.5	0.72	150.86
1951.5	1.10	150.54			
1952.5	1.05	150.58			
1953.5	0.99	150.63			
1954.5	0.92	150.69			
1955.5	0.86	150.74			
1956.5	0.89	150.72			
1957.5	1.34	150.34			
1958.5	1.37	150.31			
1959.5	1.31	150.36			
1960.5	1.19	150.46			
1961.5	1.09	150.55			
1962.5	1.30	150.37			
1963.5	1.54	150.17			
1964.5	1.92	149.85			
1965.5	2.21	149.60			
1966.5	2.41	149.43			
1967.5	2.37	149.47			
1968.5	2.48	149.37			
1969.5	2.67	149.21			
1970.5	2.71	149.18			

4.2 Operational Activity

Overview

One of the tasks of the Earth Orientation Parameters Product Center (EOP-PC) is to perform combined EOP series from the individual techniques, VLBI, SLR, GPS, LLR and DORIS. Various solutions, namely Bulletin B, EOP(IERS) C 01, C 02, C 03 and C 04 are thus published to fulfill the requirements of users, operational and scientific. They are available at the ftp/web site: hpiers.obspm.fr/eop-pc. The continuous improvement of the results derived from these geodetic techniques and the development of new methods of combination made possible the improvement of combined solutions; precisions of about 0.15 mas in polar motion and 15 microseconds for UT1 are currently obtained.

Combination of EOP Series

The maintenance of the reference systems consistency and its long-term stability require long and homogeneous EOP series. The realization of combined solutions must take advantage of the availability and the qualities of the independent series at the various time scales. They are assumed to contain no jump and negligible systematic errors.

General Combination Procedure

The first step in the general procedure for deriving the multi-technique combined solutions is the evaluation for each series of the systematic errors corrections, bias and drift, in order to translate it to the IERS system. A known source of relative drifts in x, y and UT1–UTC is the variety of processes chosen by the analysis centers to control the time evolution of the adjusted terrestrial reference frames, complicated by the sampling of the tectonic plates and plate margins. The formal uncertainties given by the analysis centers being an internal consistency estimate, usually an external calibration has to be made in order to reflect the real external uncertainty. This is done using the Allan variance analysis (Gray and Allan, 1974; Gambis, 2001) of the differences between series without any reference to a combined series. When three or more series of similar quality and time resolution can be differenced, the pair variance of the noise of each series can be evaluated, provided that their errors are considered statistically independent. The pair variance thus obtained is used as an estimate of the uncertainty of a single determination in a given series; its ratio with the rms formal uncertainty over the same period provides a scaling factor, from which the weighting of the combined individual results is based. Weighting of the series entering into the combined solution are thus estimated. The combined C 04 is now permanently updated on a near real-time basis.

Long-term Solution: C 01 (1846–2001)

EOP(IERS) C 01 is a series of the Earth Orientation Parameters given at 0.1 year interval from 1846 to 1889 and 0.05 year interval from1890 until now. 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 applied for geodynamics. Now, the global observing activity involves Very Long Baseline Radio Interferometry (VLBI), Lunar and Satellite Laser Ranging (LLR, SLR), Global Positioning System (GPS) and more recently DORIS.

The C 01 series is based on the following 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–now: BIH and IERS solutions (BIH and IERS annual reports).

Middle-term Solution: C 02 (1962–2001), C 03 (1993–2001)

Other series, based on normal points solutions given at various time intervals, are also proposed to users, i.e. C 02 (5-day intervals), C 03 (one-day intervals) (Gambis, 1996a and 1996b; 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 M.L., Gambis D. and R. Ray, 1999; Gambis *et al.*, 2000).

Operational Solution: EOP(IERS) C 04

Taking advantage of the recomputations of various individual series, EOP(IERS) C 04 is currently recomputed. In the course of the analyses the determination of the systematic corrections of individual series entering into the combination and the weighting procedure are re-examined. *Table 7* and *Table 8* give the characteristics of the smoothing adopted for each time interval. The variations with periods shorter than the value in the table are smoothed out, except the short term variations in UT1 due to zonal tides and the 14 d terms in celestial pole offsets which are first removed using a model then added back at the end of the series combination process. *Table 9* shows the uncertainty of one daily value of EOP for each period. *Table 10* shows the agreement and consistencies of the current solutions. The Bulletin B is issued on a monthly basis and is "frozen", contrarily to NEOS Bulletin A and IERS C 04 which are permanently updated.

Predictions

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

- Polar Motion: The formalism uses at first a floating period fit 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 nutation offsets $d\psi$ and $d\varepsilon$ 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 year are valid over the next few months. For short-term variations prediction, an autoregressive process is used. The following *Table 11* shows the current accuracy of the EOP solutions and also the skills of the predictions.

Table 7. Frequency filtering characteristic of smoothing for polar motion and celestial pole offsets, [EOP(IERS) C 04]

Epsilon	PERIOD FOR REMAINING AMPLITUDE 5%	50%	95%	Years
$10^{-0.6}$	3.2d	10.0d	17.0d	1983-1985
$10^{+0.6}$	2.0d	6.3d	10.7d	1986-1989
$10^{+1.0}$	1.7d	5.4d	9.2d	1990-1991
$10^{+1.4}$	1.5d	4.5d	7.9d	1992
$10^{+1.6}$	1.4d	4.2d	7.3d	1993
$10^{+2.0}$	1.2d	3.7d	6.3d	1994-2000

Table 8. Frequency filtering characteristic of smoothing for Universal Time, [EOP(IERS) C 04]

Epsilon	PERIOD FOR REMAINING AMPLITUDE 5%	50%	95%	Years
$10^{-0.5}$	3.0d	9.6d	16.3d	1983-1987
$10^{+0.2}$	2.3d	7.4d	12.5d	1988-1989
$10^{+1.0}$	1.7d	5.4d	9.2d	1990-1991
$10^{+1.5}$	1.5d	4.5d	7.6d	1992-1993
$10^{+2.0}$	1.2d	3.7d	6.3d	1994-2000

Table 9. Uncertainty of one daily value, [EOP(IERS) C 04]

EOP	Unit	1962-67	1968-71	1972-79	1980-83	1984-95	1996-2000
X	mas	30	20	15	2	0.5	0.2
Y	mas	30	20	15	2	0.5	0.2
UT1-UTC	0.1ms	20	15	10	4	0.4	0.2
LOD	0.1ms	14	10	7	2	0.3	0.2
dPsi.sin(Eps)	mas	-	-	-	3	0.6	0.3
dEps	mas	-	-	-	2	0.6	0.3

Table 10. Mean and standard deviation of the differences between different solutions over 2000

EOP	Unit	SPACE 2000 - IERS C04		NEOS final - IERS C04	
		mean	std deviation	mean	std deviation
X	mas	-0.03	0.09	0.02	0.05
Y	mas	0.01	0.07	0.01	0.05
UT1-UTC	0.1ms	0.00	0.11	0.04	0.22
dPsi.sin(Eps)	mas	-	-	-0.15	0.48
dEps	mas	-	-	-0.04	0.31

Table 11. Assessment of the predictions precision over 2000

Solutions	Sample Time	Terrest. Pole 0.001"	UT 0.0001s	Celest. Pole 0.001"
Smoothed	1-d, 5-d	0.2	0.2	0.3
Raw	5-d	0.2	0.2	0.3
Prediction	10d	5.0	20.0	0.3
	30d	11.0	77.0	0.3

4.3 Analysis Centers Global Solutions

The data analyzed in the present Annual Report were provided by the various analysis centers together with their solutions. *Table 12* gives the earth orientation and reference frames results submitted in 2001.

Astrometry

AICAS

This is an updated version of our previous solution of 1997, with slightly more observed data used and a different approach to observatories where more instruments were active. The observations of latitude and universal time variations made at 33 observatories all over the world with 47 instruments of different types are used to derive Earth Orientation Parameters (EOP) in the interval 1899.7–1992.0. To this end, all available results (latitude, universal time, star altitude) based on individual star or star pair observations (that were originally referred to local star catalogs) are re-reduced to the HIPPARCOS Catalogue and the present IAU standards. In cases when two or more instruments of the same type were active at an observatory (Mizusawa, Poltava, Pulkovo, Richmond, Shanghai and Washington), the observations were merged into a single series with the estimated steps removed.

The apparent places of the observed stars are calculated using relevant parts of the IERS Conventions (1996). About four thousand different Hipparcos stars were observed throughout the interval in question. Special care is devoted to double and/or multiple stars whose proper motions (and sometimes also positions) are corrected in order to be consistent with the other observations. These corrections are derived from the trends in the residuals of the respective star observations. They are applied only when sufficiently long series of ground-based observations are available and the corrections themselves are statistically significant; about twenty per cent of the observed Hipparcos stars are corrected. Additional corrections are also applied before the solution is made, such as the secular motions of the instruments (due to plate tectonics, using the geophysical model NNR NUVEL1), certain instrumental constants (plate scale, micrometer value), deformations of the apparent almucantar (due to anomalous refraction), oceanic tide-loading effects in the direction of the local verticals of the observatories. Short-periodic zonal tide variations in the speed of rotation of the Earth (due to deformations of the solid Earth) are removed from the observed values of universal time but they are added back to the values of UT1–TAI estimated from the solution.

From more than four million observations, almost thirty thousand unknown parameters are estimated in a single least-squares solution with constraints. Such a large system of linear equations is solved using a modified Cholesky decomposition of the sparse matrix of normal equations, taking into account their specific form. The estimated parameters comprise polar motion (i.e. motion of the spin axis in terrestrial reference frame) and celestial pole offsets (motion of the same axis in celestial reference frame), at five-day intervals in the whole time span. After 1956, when the International Atomic Time scale (TAI) became available, the differences between universal time UT1 and TAI are also determined, again at five-day intervals. In addition to these, combinations of Love numbers Lambda = 1 + k – l (governing the solid Earth tidal variations of the local verticals) are estimated, together with the small corrections of station coordinates and the seasonal effects in latitude/longitude (i.e. a constant, secular trend, semi-annual and annual terms) at each observatory. The latter are mutually tied by 18 constraints (these are meant to fix the terrestrial reference frame to the one defined by initially chosen station coordinates and to reduce the systematic deviations of individual instruments due to seasonal effects of refraction).

Very Long Baseline Radio Interferometry

BKG

Observing technique: VLBI, group delay observables. Data span: January 1984 – December 2000 (2376 sessions), worldwide set of VLBI observations, 24 hours sessions. Number of sites: 71. Number of radio sources: 730

Type of results: EOP, RSC, SSC/SSV; – Station coordinates and velocities; – Right ascension and declination of radio sources; – Earth orientation parameters (x,y,UT1–UTC,dpsi,deps) corrected for short periodic variations according to Gipson (1996); – Reference epochs for UT1–UTC and polar motion: midnight epochs; – Reference epochs for nutation offsets: beginning of each session.

Connection between systems: – The orientation of CRF is defined by no-net-rotation constraints for 209 ICRF defining sources; – Definition of initial translation and rotation of the TRF: condition that the sum of adjustments of 12 sites with respect to ITRF97 is zero; – The evolution of the TRF velocity field is defined by introducing the condition that the sum of adjustments of the velocities of five sites with respect to ITRF97 is zero.

GSFC

Solution *gsf2001b* estimates station position and velocity parameters to define TRF/CRF for computing EOP time series. Source positions are also estimated. The TRF is attached to ITRF2000 by imposing no-net-rotation and no-net translation conditions for the positions of a subset of stations and to NUVEL1-A NNR by similar conditions from velocities of a subset of stations. The CRF is attached to the ICRF by a no-net-rotation condition using the 212 ICRF defining sources. All available dual-band Mark-3/Mark-4 VLBI observations from 03-AUG-1979 through 03-APR-2001, 3051999 measurements of group delays were used in a combined solution.

Parameters are split onto three groups: 1) global parameters estimated over all sessions; 2) local parameters estimated for each 24-hour session individually; 3) segmented parameters estimated over 20–60 minutes time span.

Positions and velocities of all stations were estimated as global parameters. Positions of 552 sources were estimated as global parameters. Criteria for generating the list of these 552 sources: either 1) the source was observed during 2 or more sessions, in which it had 2 or more good observations, and the source had 40 or more good observations; or 2) the source was observed only during one session and had 25 or more good observations. Sources which were observed less than 2 times in any session were excluded. Positions of the other 138 sources were estimated for each session individually.

Two source catalogues are provided, *gsf2001b.crfg* – catalogue of 552 sources estimated as global parameters; *gsf2001b.crfl* – catalogue of 138 sources estimated as local parameters. Mean site gradients were computed from GSFC Data Assimilation Office

(DAO) model for met data from 1990–95. Atmospheric gradient delay is modeled as:

*tau = m_grad(el,az) * [GN*cos(az)+GE*sin(az)]*,

where el and az are the elevation and azimuth of the observation and the gradient mapping function is m_grad. The gradient vector has east and north components GE and GN.

IAA The solution was obtained from analysis of 2155 VLBI observation sessions since Sep-1980 till 13-Mar-2001 (among them 410 – NEOS-A, 589 – IRIS-A, 72 – IRIS-P, 142 – IRIS-S, 76 – CORE-A, 52 – CORE-B and the others). Model of reduction follows IERS Conventions (1996) except relativistic correction which was computed according to IERS Standards (1992). Celestial reference frame was fixed to ICRF-Ext.1. The solutions were obtained by using OCCAM software version 3.6. Wet tropospheric delays and clock offsets were modeled as random walk stochastic process and estimated using Kalman filter technique. Pole coordinates, UT1–UTC and nutation angles have been estimated. Terrestrial reference frame ITRF97 with the associated velocity field was used for station coordinates.

OPA The solution EOP(OPA) 01 R 02 consists in a series of estimated EOP (x, y, UT1–UTC, dPsi, dEpsilon) based on 24-hour observing sessions available in the IVS Data Centers for 1999 and 2000. The data analysis uses as adopted references the ITRF97 and its velocity field for the terrestrial frame and ICRF-Ext.1 for the celestial frame. The x, y, and UT1 results have no diurnal/semi diurnal variations (taken off by using the Ray 1995 model).

SHA The VLBI analysis center at the Shanghai Observatory of Chinese Academy of Sciences analyze in this year the MKIII VLBI group delay observations between Aug 1979 and Feb 2001. The solutions produce the full set of RSC, SSC, SSV and EOP. Using almost all geodetic and astrometric experiments from the NASA Crustal Dynamics Project, POLARIS/IRIS organized by NOAA, the Communications Research Laboratory (Japan), the Geographical Survey Institute (Japan), the University of Bonn Geodetic Institute, the National Astronomical Observatory (Japan), the Naval Research Laboratory Reference Frame Program, the USNO NAVNET/NAVEX, the NASA Space Geodesy Program-GSFC, the National Earth Orientation Service (USA), CORE project, and APSG VLBI observations, the data include 2928 sessions and 2,534,349 group delay observations. There are 113 sites and 675 sources in the analysis. The origin and orientation of the TRF are connected to ITRF97 at 1997.0 by applying no-net-horizontal-translation and no-net-rotation constraints to the position adjustments of 12 stations with uniform station weighting for both constraints. The evolution of the TRF is connected to NNR-NUVEL1A by applying no-net-horizontal-translation and no-net-rotation constraints to the velocity adjustments of five stations with uniform station weighting for both constraints. The right ascension origin and orientation of the CRF are connected to ICRF-Ext.1 by applying a no-net-rotation constraint to the position adjustments of the 212 ICRF95 defining sources with weighting proportional to the precision of the source positions. Three-dimensional velocities are adjusted for all sites with constraints for those sites with insufficient data. EOP values from 24-hr sessions are available at minimum weekly, and there are continuous periods up to two-weeks duration.

Lunar Laser Ranging

FSG

The solution is based on the LLR data acquired since the beginning of the observations (1970) until December 2000. The cartesian station coordinates of five sites and their velocities using weak constraints, are estimated. Differences between the three McDonald sites are constrained to local surveys. The model for calculating the station coordinates comprises of tidal displacements due to solid earth and polar tides, ocean loading, variations of latitude in agreement with IERS Conventions (1996). Diurnal and semidiurnal tidal variations in UT1 and relativistic contraction in the geocentric frame have been regarded as well. Corrections to precession and some nutation terms are applied or estimated. Input Earth rotation values are taken from a solution of R. Gross (JPL). This solution is called COMB2000 and is aligned with the IERS system. Daily corrections for UT0 and VOL are determined after the global fit. A total number of 1566 values have been computed. The ephemeris of the major solar system bodies are computed with the FSG ephemeris program, the lunar librations were integrated simultaneously. The initial values for the integration are essentially taken from the ephemeris DE200.

OPA

Paris Observatory Lunar Analysis Center presents two solutions for the orientation of the celestial dynamical ecliptic reference frame (OPA 01) M 01 & M 02 and two series for UT0–UTC and variation of latitude VOL (OPA 01) M 03 & M 04.

Solution OPA 01 M01 gives the position of inertial mean ecliptic of J2000.0 with respect to a celestial coordinate system tied to the mean CEP of J2000.0, and solution OPA 01 M02 gives it with respect to the IERS celestial reference system (ICRF). These solutions result from weighted fits of the Moon orbital motion theory ELP2000-96 and the improved Moons' theory of libration to 14754 LLR normal points provided by McDonald, Haleakala and Grasse observatories between January 1972 and March 2001. The fits used the values of parameters x, y, and UT1–UTC provided by the series EOP(IERS) C 04 and the LLR stations coordinates from ITRF94.

For OPA 01 M01 the fit involves an analytical representation of precession-nutation. For OPA 01 M 02 we used the IERS numerical corrections dPsi and dEpsilon.

Values of UT0–UTC and variation of latitude VOL have been determined by analyzing LLR observations from 1995 till 2000 for nights with four normal points at least. We used the results of the previous fit given by the solution OPA 01 M 01. Series OPA 01 M 03 contains 282 values of UT0–UTC and VOL from the observations provided by Grasse and series OPA 01 M 04 contains 178 values from McDonald.

UTXMO

The University of Texas McDonald Observatory (UTXMO) has submitted SSC and EOP results for the 2000 IERS Annual report. The analysis used the total set of lunar laser ranging data available. A total of 14803 normal points were acquired between September, 1969 and December, 2000 from the following stations: McDonald Observatory 2.7m telescope (which ceased operation in 1985), the McDonald Laser Ranging Station (saddle site and Mt. Fowlkes site) near Fort Davis, Texas, the Haleakala Observatory on Maui, Hawaii (which ceased operation in 1990), the Observatoire de Côte d'Azur station in Grasse, France were used in this solution. The node of the EMbary orbit was fixed to the MIT ITR-78 ephemeris to tie the longitude of the celestial reference frame. The orientation of the terrestrial reference frame was fixed to the EOP(CSR) 95 L 01 EOP series at 11 Jan 1985. There were sufficient data for 1514 station/reflector pair estimates of UT0–UTC including 99 UT0 estimates on 69 nights in 2000. The time interval between EOP values varied due to the phase of the Moon and to weather but the average interval was about 4 days.

Global Positioning System

CODE

The solution made available to the IERS by the CODE Analysis Center of the IGS for the 2000 submission was produced using as observations 7.5 years of GPS data of the global IGS network and fixing 50 stations to the corresponding ITRF2000 site coordinates and velocities. The UT1–UTC series was obtained by integration of the estimated LOD values (the first UT1–UTC value fixed to the corresponding C04 value). The time interval covered by the solution starts on day 200 of the year 1993 (July 19, 1993) and ends on day 135, 2001 (May 15, 2001). The spacing between subsequent EOP values is one day. The number of daily global IGS stations processed at CODE grew from about 35 (in 1993) to about 140 (in 2001). Regarding the satellite orbits the series is not homogeneous because the satellite orbit modeling was changed (improved) a few times. Concerning the EOP series we have to mention that subdaily EOP variations were modeled (Ray model) starting with January 1, 1995.

GFZ Earth Orientation Parameters (EOP(GFZ)01P01) have been estimated from the analysis of the global GPS data spanning 8 years from January 1993 to March 2001 using the GFZ analysis software package EPOS.P.V2. The daily EOP results (EOP(GFZ)01P01 with x, y, LODR, UT1R–TAI) are consistent with the global Set of Station Coordinates (SSC(GFZ) 00 P 01) computed for the year 2000 ITRF submission. The orientation of the system was defined by applying no-net-rotation constraints both for the site coordinates and the site velocities, as a reference the ITRF97_IGS_RS51.SNX reference frame including velocities was used.

Data: The initial data acquired at the GFZ IGS Analysis Center are the 30 sec RINEX data from the IGS Core stations collected at the global IGS data centers. For the analysis itself undifferenced ionospheric free phases were used. Starting with February 8, 1998 (GPS week 944) the elevation cut-off was changed from 20 to 15 degrees and the sample rate was changed from 6 minutes to 5 minutes. P-code data entered into the analysis to preset the ambiguities. The identified ambiguities were constrained to the expected P-code accuracy. We use 24 hour data segments in the analysis. Starting from the GPS week 971 (16 August 1998) we have introduced the so-called ambiguity fixing in our analysis.

Analysis: The solutions were obtained by using GFZ EPOS.P.V2 Software package, which is adapted to the IERS Standards. The adjusted parameter set results from a HELMERT blocking. For each parameter the time resolution can be chosen freely. The orbital elements are adjusted independently from day to day.

The Earth Rotation Parameters (pole coordinates and length of day) were adjusted as daily values independent from day to day. Since June 30, 1996 the daily and sub-daily polar motion and UT1 are modeled according to the IERS 1996 Standards. To get a stable reference for the pole parameter determination a set of core stations was fixed. Their number and nominal values vary from year to year. The whole series is homogenized to compensate for jumps originating from the changes in the reference frame and is aligned to our coordinate solution SSC(GFZ) 00 P 01. The orientation of the system was defined by applying loose no-net-rotation constraints both for the site coordinates and the site velocities, as a reference the ITRF97 (ITRF97_IGS_RS51.SNX) reference frame including velocities was used (the alignment is of the order of (0.2 mas).

JPL The most recent velocity and position solution from JPL is based on nearly ten years of data from 91jan22 through 00oct28. Position and velocity estimates were included for 168 sites with two or more years of data and official site log information. Sixty extra sites which lacked sufficient site log data were included in the stacov file but not in the sinex file. Daily estimation was carried out with JPL's

GIPSY software using strategies which generally adhered to IERS/ IGS standards. Antenna height corrections were applied directly while uncalibrated offsets due to equipment changes or co-seismic motion were estimated as necessary. Each daily coordinate and EOP was aligned with ITRF97 by estimation and application of three rotations, three translations, and one scale. The translation and scale time series represent the daily offsets between the GPS implied origin and scale and those of ITRF97. Positions, velocities, and time series of latitude, longitude, height, polar motion, length of day, geocenter, and scale estimates are also available via the internet at <http://sideshow.jpl.nasa.gov /mbh/series.html>.

USNO 01

By about 17h each UTC day, the U.S. Naval Observatory (USNO) determines the UT1-like quantity UTGPS for UTC noon the previous day. This quantity is determined from the combined Rapid GPS satellite orbits produced by the International GPS Service (IGS). The IGS combined Rapid orbits for 12 to 16 GPS satellites are considered in producing each day's UTGPS. These combined Rapid orbits are, in turn, produced from the Rapid orbits submitted to the IGS by the Analysis Centers of the IGS, including USNO.

The software which determines UTGPS finds, for each satellite it considers, the relation between the satellite's Earth-referenced IGS orbit and a model of this satellite's orbit plane in inertial space. The software propagates each orbit-plane model using standard models of gravitational accelerations and an empirical model representing the radiation-pressure acceleration observed during several past years of in-flight experience. From the relation between the IGS and modeled orbits, the software finds a single-satellite estimate of Universal Time. Taking the median of these estimates gives UTGPS.

USNO 02

This submission is derived from solution EOP(USNO) 01 P 02. However the long-term variations which are not related to UT1 (due to orbit modeling errors and to nodal excitations induced by geophysical fluid motions) have been removed by applying a high-pass filter based on a comparison to less frequent VLBI determinations. The calibration process interpolates the GPS-based UT series to the epochs of all available VLBI determinations of UT1 (24-hour and Intensive sessions) using a cubic spline. These splined residuals are then high-passed smoothed using a Gaussian filter, fully transmitting variations with periods less than 10 days and attenuating by 50% those at about 26 days. The resulting low-pass curve is treated as a calibration trend and subtracted from the GPS UT. This creates a high-passed GPS UT1-like series that should not suffer from the long-term systematic effects seen in most GPS series based on integrated LOD. In this way, this submission is intended to provide quasi-independent estimates of high-frequency UT1 variations.

Satellite Laser Ranging

CGS

The SLR solution CGS 01 L 01 provides SSC/SSV at the reference epoch 970101 and 3-day EOP derived from Lageos I (Jan 1984 – Dec 2000) and Lageos II (Nov 1992 – Dec 2000) data.

The solution is obtained using the NASA/GSFC GeodynII/Solve software for the analysis of 30-day arcs and their combination to derive estimates of three dimensional site coordinates and 3-D velocities, 30-day C20 zonal coefficients and 3-day EOP (x,y,UT1–UTC) and with loose constraints on SSC/SSV.

The normal points collected from the worldwide network are analyzed using ITRF97 as a priori site coordinates and velocities, IERS Bulletin B for a priori EOP values, EGM96 geopotential (up to degree 70) and its own tides model. The secular drift and the influence of the dynamical pole on C21 and S21 coefficients, all the major planets perturbations as well as the relativistic effects have been applied. Residual unmodeled effects on the satellite orbit in the along-track direction are minimized by the estimation of fortnightly empirical accelerations.

CLG

The solution provided by the Central Laboratory for Geodesy SC/SSV/EOP 01 L 01 is based on the analysis of 1 389 906 Lageos-1 and Lageos-2 normal points covered the time span April 1984 – December 2000 and January 1993 – December 2000 respectively.

The analyses are made using the revised version 4.0 of the Satellite Laser Ranging Processor (SLRP) software developed at the CLG. Monthly arcs for the period are first analyzed and then combined to obtain the global solution. The gravity field model used is JGM3. The orientation of the terrestrial frame is defined by constraining three latitudes – Haleakala (7210), Greenbelt (7105) and Matera (7939) and two longitudes – Greenbelt and Matera to their ITRF97 values. The time evolution is constrained by adopting the 3-D ITRF97 velocities of Haleakala and Greenbelt. Estimates of 3-D site coordinates of 94 sites and 3-D velocities of 63 sites with good tracking history were derived using ITRF97 as a priori values. Earth orientation parameters (x, y, UT1) were estimated at 1 day interval keeping UT1R–UTC fixed at the IERS values at the end of each monthly arc and using IERS Bulletin B as a priori values. Length of the day (LOD) series were calculated by differencing the estimated UT1 series. A few more parameters were obtained in the global solution like geogravitational constant, selected sets of geopotential coefficients and ocean loading parameters, dynamic orbital parameters.

GAOUA

The GAOUA 01 L 01 solution is obtained by processing the SLR global network data of Lageos-1 acquired since September 1, 1983 through January 23, 2001 and Lageos-2 since October 24, 1992 through January 23, 2001. The data consists of 1.090.776 normal points for Lageos-1 and 515.485 normal points for Lageos-2 that have been processed using Kiev-Geodynamics-5.2 software. The solution include the ERP (x, y, UT–UTC) sets at three-day intervals since MJD 45583 till MJD 51952, coordinates of 100 stations at epoch January 1, 1997 (MJD 50449) and velocities of 70 stations located at 49 sites with good observing histories. The terrestrial reference frame is attached to ITRF96 by fixing the latitude of stations 7105 (Washington) and 7210 (Maui) and longitude of station 7105. The station velocities are linked to NNR-NUVEL1A by fixing the rates of these parameters to the values given by the NNR-NUVEL1A model. The velocities of 30 stations which velocities were not estimated were modeled using the NNR-NUVEL1A model. Transformation between the Celestial and Terrestrial Reference Frames is modeled using IAU (1976) precession model, IAU (1980) nutation model and a priori values of celestial pole offsets and ERP taken from the EOP(IERS) C 04 series.

IAA

The solution EOP(IAA) 01 L 01 is based on the SLR observations of Lageos since Jan 1983 till Feb 2001, the solution EOP(IAA) 01 L 02 is based on the SLR observations of Lageos and Lageos2 since Oct 1992 till Feb 2001. The model IERS Conventions 1996 with small exceptions was used for the reduction of observations. The length of arc was equal to five days (increasing of arc was applied when necessary). UT–UTC was estimated from free-running UT series computed summarizing of LOD and corrected for high-frequency variations obtained from comparison with EOP(IERS) C 04. To densify series overlapping arcs with one day shift was used. Station coordinates and velocities was not adjusted and was adopted from ITRF97. The analysis was done using the GROSS program package.

Combination

JPL01

A Kalman filter has been used to combine independent measurements of the Earth's orientation taken by the space-geodetic techniques of LLR, SLR, VLBI, and GPS. Prior to their combination, each series was adjusted to have the same bias and rate, the stated uncertainties of the measurements were adjusted, and data points considered to be outliers were deleted. The resulting combination, EOP(JPL) 01 C 01, also known as SPACE2000, spans September 28, 1976 to January 6, 2001 at 1-day intervals and has been aligned with the IERS combination EOP(IERS) C 04 during 1987–2000. Diurnal and semidiurnal tidal variations are not included in the reported polar motion (PMX, PMY) and UT1–UTC values since they have not been added back after having been removed (when necessary) from the measurements prior to their combination.

JPL02 & JPL03 A Kalman filter has been used to combine the space-geodetic Earth orientation series comprising SPACE2000 (EOP(JPL) 01 C 01; see description) with the BIH (Li, BIH Annual Report for 1984, pp. D31-D63) and ILS optical astrometric series. Prior to their combination with SPACE2000, the optical astrometric series were corrected to have the same bias, rate, and annual term as SPACE2000, the stated uncertainties of the optical astrometric series were adjusted to be consistent with the scatter of their residuals, and outlying data points were deleted. The adjusted optical astrometric series were then combined with SPACE2000 in two steps: (1) the BIH series was combined with SPACE2000 to form COMB2000 (EOP(JPL) 01 C 02), a combined series of smoothed, interpolated polar motion and UT1–UTC values spanning January 20, 1962 to January 5, 2001 at 5-day intervals, and (2) the ILS series was combined with COMB2000 to form POLE2000 (EOP(JPL) 01 C 03), a combined series of smoothed, interpolated polar motion values spanning January 20, 1900 to December 21, 2000 at 30.4375-day intervals. As with SPACE2000, both COMB2000 and POLE2000 have been aligned with the IERS combined EOP series EOP(IERS) C 04 during 1987–2000, and diurnal and semidiurnal tidal variations are not included in either the COMB2000 or POLE2000 reported polar motion (PMX, PMY) or UT1–UTC values.

USNO The description of the EOP (NEOS) 1 C01 is available in the Explanatory Supplement for Bulletins A and B or in the Sub-bureau report in the present Annual Report volume, section IV.5.

Notes to Table 12

Note (1): EOP headings.
Tp: coordinates of the pole,
T : universal time,
Cp: celestial pole offsets.

Note (2): Station velocities.
Es: estimated together with the SSC,
A : adopted from the same SSC,
I6: adopted from the ITRF96 velocity field,
I7: adopted from the ITRF97 velocity field,
N1: adopted from the Nuvel NNR-1 model,
NA: adopted from the Nuvel NNR-1A model,
A2: adopted from the AM0-2 model,
No: not considered.

Table 12. Earth orientation and reference frames results submitted in 2001

Centers & Data span	Earth orientation Nb of date (1)	Celestial frames Nb of sources	Terrestrial frames Nb of sites	Vel.(2)
VLBI				
BKG 1984-2000	EOP(BKG) 01 R 01 2280 Tp T Cp	RSC(BKG) 01 R 01 667	SSC(BKG) 01 R 01	Es
GSFC 1979-2000	EOP(GSFC) 01 R 01 2744 Tp T Cp	RSC(GSFC) 01 R 01 552	SSC(GSFC) 01 R 01	Es
GSFC 1980-2000	EOP(GSFC) 01 R 02 367 Tp T	RSC(GSFC) 01 R 02 137	SSC(GSFC) 01 R 02	Es
IAA 1980-2000	EOP(IAA) 01 R 01 2155 Tp T Cp	RSC(WGRF) 99 R 01 667	SSC(IERS) 97 C 01	I7
OPA 1999-2000	EOP(OPA) 01 R 02 106 Tp T Cp	RSC(WGRF) 99 R 01 667	SSC(IERS) 97 C 01	I7
SHA 1979-2000	EOP(SHA) 01 R 01 2928 Tp T Cp	RSC(SHA) 01 R 01 467	SSC(SHA) 01 R 01	Es
LLR				
FSG 1970-2000	EOP(FSG) 01 M 01 1566 .. T ..	- -	SSC(FSG) 01 M 01	Es
UTXMO 1970-2000	EOP(UTXMO)01 M 01 1514 .. T ..	- -	SSC(UTXMO)01 M 01	Es
OPA 1995-2000	EOP(OPA) 01 M 03 282 .. T ..	- -	EPH(OPA) 01 M 01	I6
OPA 1995-2000	EOP(OPA) 01 M 04 178 .. T ..	- -	EPH(OPA) 01 M 01	I6
GPS				
CODE 1993-2000	EOP(CODE) 01 P 01 2858 Tp . ..	- -	SSC(CODE) 01 P 01	Es
GFZ 1993-2000	EOP(GFZ) 00 P 01 2986 Tp . ..	- -	SSC(GFZ) 00 P 01	Es
JPL 1992-2000	EOP(JPL) 01 P 01 2854 Tp . ..	- -	SSC(JPL) 01 P 01	Es
SLR				
CGS 1984-2000	EOP(CGS) 01 L 01 2060 Tp . ..	- -	SSC(CGS) 01 L 01	I7
CLG 1984-2000	EOP(CLG) 01 L 01 6119 Tp . ..	- -	SSC(CLG) 01 L 01	Es
GAOUA 1983-2000	EOP(GAOUA)01 L 01 2115 Tp . ..	- -	SSC(GAOUA)01 L 01	Es
IAA 1983-2000	EOP(IAA) 01 L 01 6151 Tp . ..	- -	SSC(IERS) 97 C 01	I7
IAA 1992-2000	EOP(IAA) 01 L 02 3030 Tp . ..	- -	SSC(IERS) 97 C 01	I7
COMBINED				
JPL 1976-2000	EOP(JPL) 01 C 01 8867 Tp T ..	- -	- -	- -
JPL 1962-2000	EOP(JPL) 01 C 02 2847 Tp . ..	- -	- -	- -
JPL 1900-2000	EOP(JPL) 01 C 03 1212 Tp . ..	- -	- -	- -
USNO 1973-2000	EOP(USNO) 01 C 01 10226 Tp T Cp	- -	- -	- -

Table 13. Series of Orientation Parameters available for analysis

Analysis Centers by technique	Years	Number of measurements x,y	UT1	UT0	UT	LOD	$\Delta\psi$ $\Delta\varepsilon$
ASTROMETRY							
EOP (AICAS) 01 A 01	1899 - 1991	6693	6693	-	-	-	6693
VLBI							
EOP (BKG) 00 R 01	1999 - 2001	-	602	-	-	-	-
EOP (BKG) 01 R 01	1984 - 2000	2280	2280	-	-	-	2280
EOP (GSFC) 00 R 01	1999 - 2001	-	596	-	-	-	-
EOP (GSFC) 01 R 01	1979 - 2001	2744	2744	-	-	-	2744
EOP (IAA) 01 R 03	1984 - 2001	-	3846	-	-	-	-
EOP (IAA) 01 R 04	1980 - 2001	2232	2232	-	-	-	2232
EOP (OPA) 01 R 02	1999 - 2000	106	106	-	-	-	106
EOP (SHA) 01 R 01	1979 - 2001	2928	2928	-	-	-	2928
EOP (SPBU) 99 R 01	1997 - 2001	-	866	-	-	-	-
EOP (SPBU) 00 R 03	1983 - 2001	1009	1009	-	-	-	1009
LLR							
EOP (FSG) 01 M 01	1970 - 2000	-	-	1566	-	-	-
EOP (OPA) 01 M 03	1995 - 2000	-	-	282	-	-	-
EOP (OPA) 01 M 04	1995 - 2000	-	-	178	-	-	-
EOP (UTXMO) 01 M 01	1970 - 2000	-	-	1514	-	-	-
GPS							
EOP (CODE) 01 P 01	1993 - 2001	2858	-	-	2858	2858	-
EOP (EMR) 96 P 03	1996 - 2001	1820	-	-	1820	1820	-
EOP (ESOC) 96 P 01	1996 - 2001	1824	-	-	1824	1824	-
EOP (GFZ) 00 P 01	1993 - 2001	2986	-	-	2986	-	-
EOP (JPL) 01 P 01	1992 - 2000	2854	-	-	-	2854	-
EOP (NOAA) 96 P 01	1996 - 2001	1821	-	-	1821	1821	-
EOP (SIO) 96 P 01	1996 - 2001	1756	-	-	1756	1756	-
EOP (USNO) 01 P 02	1995 - 2001	-	-	-	1953	-	-
EOP (USNO) 01 P 01	1995 - 2001	-	-	-	1946	-	-
SLR							
EOP (CGS) 01 L 01	1984 - 2000	2060	-	-	2060	-	-
EOP (CLG) 01 L 01	1984 - 2000	6119	-	-	6119	-	-
EOP (CSR) 95 L 01	1976 - 2001	2831	-	-	2831	-	-
EOP (DUT) 98 L 01	1993 - 2001	1034	-	-	1034	-	-
EOP (GAOUA) 01 L 01	1983 - 2001	2115	-	-	2115	-	-
EOP (IAA) 01 L 02	1992 - 2001	3030	-	-	3030	3030	-
EOP (IAA) 01 L 01	1983 - 2001	6151	-	-	6151	6151	-
COMBINED							
EOP (IERS) C 04	1962 - 2001	14877	14877	-	-	14877	14877
EOP (IERS) C 03	1998 - 1999	2556	2556	-	-	2556	-
EOP (IERS) C 02	1962 - 2001	2886	2886	-	-	2886	-
EOP (JPL) 01 C 01	1976 - 2001	8867	8867	-	-	-	-
EOP (JPL) 01 C 02	1962 - 2001	2847	-	-	-	-	-
EOP (JPL) 01 C 03	1900 - 2001	1212	-	-	-	-	-
EOP (USNO) 01 C 01	1973 - 2001	10300	10300	-	-	10300	-

4.4 Yearly Analyses

The Earth orientation series available for analysis are described in *Table 13*. They include the 38 series received from 27 Analysis Centers.

General Combination of Series

A known source of relative drifts in x, y and UT1–UTC is the variety of processes chosen by the analysis centers to control the time evolution of the adjusted terrestrial reference frames, complicated by the sampling of the tectonic plates and plate margins in the actual observing networks. The NNR-NUVEL1A model (DeMets *et al.*, 1990; DeMets *et al*., 1994) is recommended in the IERS Conventions (1996). The various ways in which the time evolution is globally constrained to follow a reference model reflect themselves in the EOP time series.

The calibration of the formal uncertainties associated with the EOP determinations which are combined is derived from the pair variance analysis of the differences between series, without considering any combined series in the process. The analysis follows the method of Gray and Allan (1974) extended to the case of correlated errors. When three or more series of similar quality and time resolution can be differenced, the pair variance of the noise of each series can be evaluated. In the case of series based on the same data set, the estimation model includes consideration of their possible correlation whenever permitted by the information available. The pair variance thus obtained is referred to as the estimated uncertainty of a single determination in a given series; its ratio with the *rms* formal uncertainty over the same period provides a scaling factor.

The weighting of the combined individual results is based on the quadratic sum of *estimated uncertainties,* obtained by multiplying the formal uncertainty of the original determination by the previously described scale factors of the series to which they belong, and of a term which reflects the uncertainty of the systematic correction applied. The effective weighting of the individual series obtained from the same data set (VLBI, GPS, SLR) is appropriately modified to take into account the resulting redundancy.

In the case of satellite techniques (SLR, GPS), the numbers in the columns labeled “UT-UTC” refer to the high frequency content of the results, i.e. for periods shorter than about 60 days.

Presentation of the Combined Solutions

Reference series of EOP at 0.05 year interval, EOP(IERS) C 01: Tables 14, 15, 16

EOP(IERS) C 01 is under the form of normal values at 0.05 year intervals since 1846 with associated formal uncertainties. It serves as a reference for the evaluation of systematic differences of the compared series. This solution is intended for long term studies. *Figure IV-4-7* represents the pole path over 1996 until 2001. The mean pole path since 1900 is represented in solid line. EOP (IERS) C 01 is based on the following data.

– 1980 – now: IERS solution of x, y, UT1–TAI, dψ, dε, based on VLBI, LLR, GPS (from 1992) and SLR.
– 1962 – 1979: IERS and BIH solutions, giving x, y, UT1–TAI. Space techniques are introduced starting with 1969 (LLR for UT) and 1972 (Doppler for polar motion).

The 1996–2000 interval of EOP(IERS) C 01 is re-computed with this year's analysis. It is obtained as the series of the weighted mean of the three intra-techniques solutions (VLBI, SLR and GPS) under the form of normal values at 0.05 year interval. The individual values are weighted by means of their formal uncertainties, scaled to match the pair variance of each series at 0.05 year interval, with added variance derived from the uncertainties in the estimation of the systematic corrections. The relative contribution of these solutions to the EOP(IERS) C 01 solution are listed in *Table 14*.

Fig. IV-4-7. Polar motion, 1996–2000 (EOP(IERS) C 04). Solid line: mean pole displacement, 1900–2000

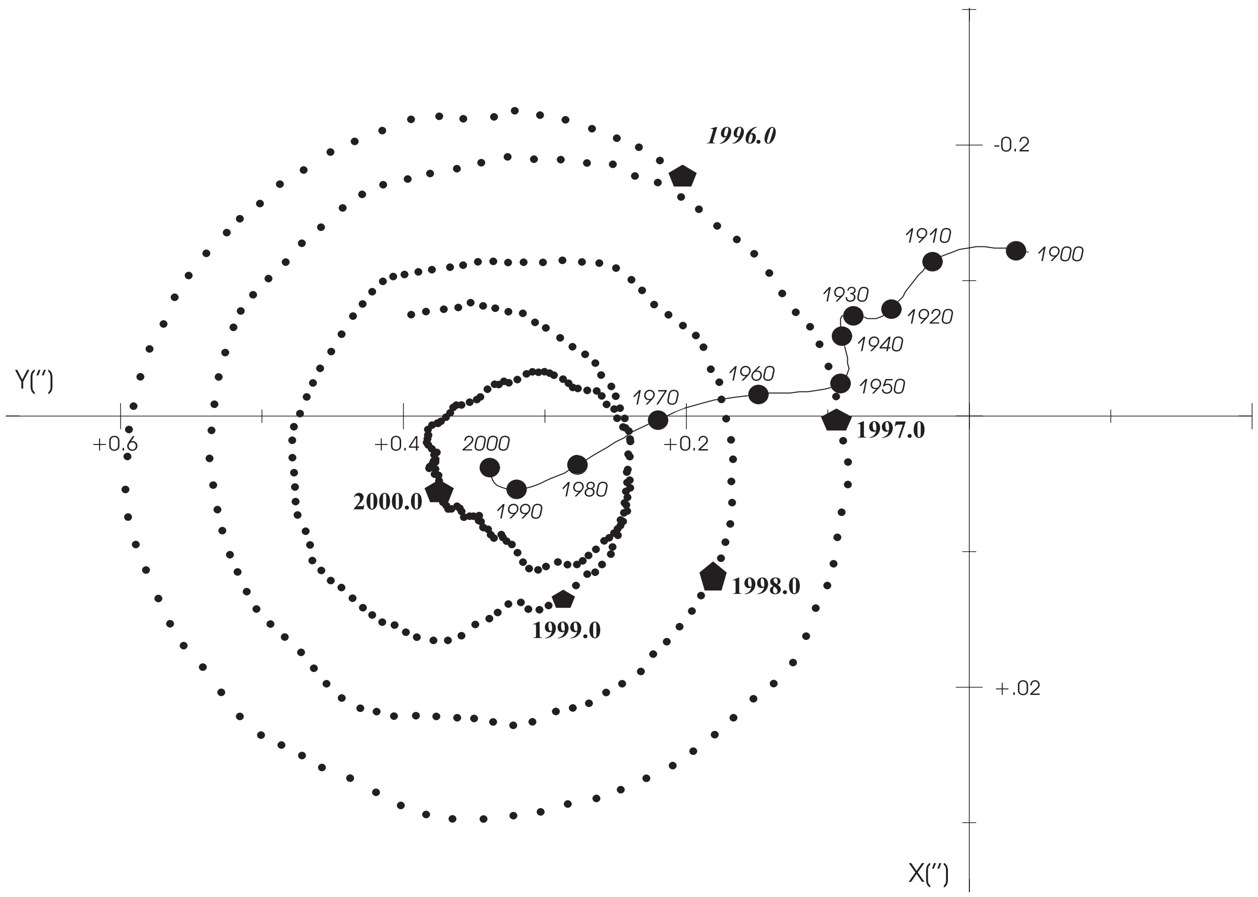


Table 14. EOP(IERS) C 01: Percentage of the contribution of various techniques in the final solution

TECHNIQUE	POLAR MOTION	UT1-UTC	LOD	NUTATION OFFSET
IERS VLBI	20	100	10	100
IERS SLR	10	-	-	-
IERS GPS	70	-	90	-

Table 15. EOP(IERS) C 01: Evolution of the mean uncertainties

YEARS	X		Y		UT1-UTC		dψ		dε	
	Nb /year	σ (mas)	Nb /year	σ (mas)	Nb /year	σ (0.1ms)	Nb /year	σ (mas)	Nb /year	σ (mas)
1846-1889	10	80.	10	90.	-	-	-	-	-	-
1890-1900	20	50.	20	70.	-	-	-	-	-	-
1900-1961	20	30.	20	40.	-	-	-	-	-	-
1962-1972	20	15.	20	15.	20	15.	-	-	-	-
1973-1979	20	10.	20	10.	20	5.	-	-	-	-
1980-1983	20	1.2	20	1.1	20	1.2	20	2.0	20	0.5
1984-1987	20	0.16	20	0.15	20	0.11	20	0.20	20	0.10
1988-1995	20	0.11	20	0.11	20	0.08	20	0.16	20	0.08
1995-2000	20	0.08	20	0.08	20	0.04	20	0.06	20	0.04

Table 16. EOP(IERS) C 01: Earth orientation parameters at 0.05 yr interval

Date	Normal values						Uncertainties					
Bessel. year	x "	y "	UT1-UTC s	LOD s	dψ 0.001"	dε 0.001"	x 0.001"	y 0.001"	UT1 0.0001s	LOD 0.0001s	dψ 0.001"	dε 0.001"
2000.00	.043240	.377693	.3554825	.0009023	-50.46	-2.44	.009	.012	.016	.002	.05	.02
2000.05	.052402	.375673	.3413541	.0008776	-51.51	-2.92	.008	.010	.011	.002	.04	.02
2000.10	.060578	.372437	.3250566	.0008094	-50.23	-3.48	.008	.010	.012	.002	.04	.02
2000.15	.068039	.365452	.3071142	.0009868	-49.81	-4.66	.010	.010	.016	.005	.06	.02
2000.20	.074497	.357951	.2899853	.0008020	-49.55	-5.15	.010	.011	.010	.003	.03	.01
2000.25	.075411	.345975	.2762529	.0008396	-47.65	-5.71	.010	.012	.020	.003	.06	.02
2000.30	.082297	.343177	.2552617	.0012363	-47.61	-6.21	.007	.010	.014	.005	.04	.02
2000.35	.088037	.331942	.2358645	.0008132	-47.54	-6.58	.008	.010	.018	.002	.05	.03
2000.40	.096328	.321422	.2198827	.0006230	-48.98	-7.18	.006	.008	.014	.002	.04	.02
2000.45	.113551	.304341	.2064849	.0004528	-51.74	-6.51	.009	.008	.020	.002	.06	.02
2000.50	.110095	.279075	.2040671	.0000078	-54.23	-6.58	.010	.007	.024	.002	.09	.03
2000.55	.096143	.261651	.2004162	-.0001027	-56.25	-6.15	.007	.008	.011	.002	.04	.02
2000.60	.083051	.248520	.1987965	.0000841	-58.40	-6.31	.011	.012	.017	.005	.08	.03
2000.65	.058367	.242754	.1949480	.0004127	-60.77	-6.56	.008	.011	.015	.004	.06	.02
2000.70	.025943	.239566	.1871300	.0002841	-59.88	-5.77	.007	.008	.012	.002	.06	.02
2000.75	-.005736	.246950	.1747323	.0008476	-60.10	-5.05	.007	.007	.020	.004	.08	.02
2000.80	-.035990	.262843	.1599588	.0008995	-57.11	-3.77	.007	.009	.014	.002	.04	.02
2000.85	-.059984	.292223	.1391539	.0010610	-54.98	-3.79	.007	.008	.012	.002	.06	.02
2000.90	-.076903	.325406	.1205417	.0009176	-55.13	-2.77	.009	.009	.019	.002	.09	.03
2000.95	-.082693	.357049	.1045876	.0006411	-53.18	-1.91	.010	.010	.017	.002	.06	.03

Combined series at 5-day intervals, EOP(IERS) C 02: Table 17

This series is available from 1962. For each date at 5-day intervals, individual determinations available within ±2.5 days are brought to the central date by a modeled time variation of each of the EOP. The combined normal values are obtained by a weighted least square adjustment taking into account the covariance matrices of the individual determinations. The *a priori* standard deviations are based on the formal uncertainties associated with the individual values of the EOP, scaled to match the pair variance of the series, with added variances. The GPS series were first combined prior to the compilation of EOP(IERS). The uncertainties given in *Table 17* represent the short-term instability of the normal values.

Combined series of EOP (normal points) at 1-day interval, EOP(IERS) C 03: Table 18

This series is available from 1993. It is only continuous for polar motion. For each date at one-day interval, all individual determinations of universal time available within ± 0.5 days are brought to the central date by a modeled time variation of UT and corrected for their difference with the IERS System. A weighted mean is then performed; the *a priori* standard deviations of the individual values are based on the formal uncertainties, scaled to match the pair variance of the series, with added variances.

Combined daily series, EOP(IERS) C 04: Table 19

This series continues the one available since 1962. After being homogenized and merged, the contributing series of each of the EOP are slightly smoothed by the Vondrak algorithm. The filter characteristics, given in *Table 23*, are selected so that the weighted *rms* residuals of the original EOP series in a given time interval match their estimated precision. The series are given at one-day intervals and can be interpolated linearly; the oscillations in UT and in duration of the days due to zonal tides for periods under 35 days, as well as the 14d terms in $d\psi$ and $d\varepsilon$ are present in the series.

EOP(IERS) C 04 series and its continuation until the current date is available at the web site: <http://hpiers.obspm.fr/eop-pc>.

Table 17. EOP(IERS) C 02: Average uncertainty of the normal point solution given at five-day intervals

YEARS	σ(X)	σ(Y)	σ(UT1)	σ(dψ)	σ(dε)
	0.001"		0.0001s	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	0.4	0.4	0.2	0.5	0.3
1990-2000	0.2	0.2	0.1	0.3	0.2

Table 18. EOP(IERS) C 03: Number of values and average uncertainty

YEAR	X (mas)		Y (mas)		UT1-UTC (0.1ms)		dψ (mas)		dε (mas)	
	Nb	σ	Nb	σ	Nb	σ	Nb	σ	Nb	σ
1993	365	0.41	365	0.38	236	0.26	70	0.23	70	0.11
1994	365	0.32	365	0.32	194	0.17	52	0.17	52	0.08
1995	365	0.28	365	0.26	216	0.14	52	0.17	52	0.08
1996	366	0.28	366	0.27	215	0.15	53	0.17	53	0.08
1997	365	0.28	365	0.27	257	0.15	53	0.17	53	0.08
1998	365	0.25	365	0.12	257	0.15	53	0.17	53	0.08
1999	365	0.10	365	0.10	259	0.08	88	0.17	88	0.08
2000	366	0.10	365	0.10	259	0.08	88	0.17	88	0.08

Table 19. EOP(IERS) C 04: Uncertainty of a daily value

EOP	Unit	1962-67	1968-71	1972-79	1980-83	1984-95	1996-2000
X	mas	30	20	15	2	0.7	0.2
Y	mas	30	20	15	2	0.7	0.2
UT1-UTC	0.1ms	20	15	10	4	0.4	0.2
LOD	0.1ms	14	10	7	1.5	0.3	0.2
dPsi.sin(Eps)	mas(1)	12	9	5	3	0.6	0.3
dEps	mas(1)	2	2	2	2	0.6	0.3

Note (1): Prior to 1984, dψ, dε are evaluated by an empirical model.

Comparison of Series with the EOP(IERS) C 04

The combination of series of EOP which is described in the above sections is based on two major hypotheses:

- the high frequency behaviors of the series combined are statistically independent,
- the applied corrections (bias and drift) appropriately model their systematic differences.

The high frequency correlation of the individual series has been investigated. Each series is first corrected for known effects (effects of zonal tides in UT, 14d term in $d\psi$ and $d\varepsilon$), and high pass filtered by a Vondrak smoothing (Bulletin B degree of smoothing, *Table 23*). The series of residuals are then correlated two by two, considering only dates less than 0.25 day apart. The correlations are lower than +0.3 across techniques and lower than +0.5 within the same technique.

Systematic differences: when estimating by weighted least squares the systematic differences between pairs of series under the form of a bias and a linear drift over common time intervals, the weighted *rms* postfit residuals found are consistent with the *a priori* uncertainties used in the computation of EOP(IERS) C 01.

Series used in the computation of EOP(IERS) solutions

The individual series used in the computation of EOP(IERS) C 01, C 02, C 03, C 04 are compared with EOP(IERS) C 04 over 1999–2000 in *Table 20*.

The *formal uncertainties* are the averages of those given by the analysis centers after removing the spurious values (values > 3 sigma). The *rms* is the root mean square residual obtained from the comparison to EOP(IERS) C 04.

Consistency of daily combined EOP series

Two daily combined EOP series obtained by JPL and NEOS are compared with EOP(IERS) C 04 and between themselves. The main features of the implementation of the three series are quite similar. They are based on a limited number of VLBI and SLR series, GPS being introduced mid-1992. The unification of the systems is obtained by correcting the individual series for a bias and a linear drift. The weighting of individual values is based on their original standard error, multiplied by a scaling factor specific to each series. They are low-pass filtered, with a frequency cutoff corresponding to a few days.

Table 21 gives the systematic long term differences between the three series. The standard deviations are consistent with the estimated quality of EOP(IERS) C 04.

Table 22 gives an estimation of the stability of the IERS, JPL and NEOS series, based on their intercomparison, for sampling times of 1 through 64 days. The three series have similar characteristics.

Table 20. Formal uncertainties and rms residuals of individual determinations of the EOP, 1999–2000

Individual Series	Errors	X 0.001"	Y 0.001"	UT1-UTC 0.0001s	dPsi 0.001"	dEps 0.001"	D 0.0001s	sample time
VLBI								
EOP (BKG)	formal:	0.17	0.13	0.09	0.25	0.10	-	1d
00 R 02	rms:	0.17	0.13	0.15	0.28	0.12	-	
EOP (BKG)	formal:	-	-	0.18	-	-	-	0.05d
00 R 01	rms:	-	-	0.19	-	-	-	
EOP (GSFC)	formal:	0.14	0.12	0.07	0.24	0.09	-	1d
00 R 01	rms:	0.14	0.10	0.14	0.40	0.15	-	
EOP (GSFC)	formal:	-	-	0.17	-	-	-	0.05d
01 R 01	rms:	-	-	0.15	-	-	-	
EOP (IAA)	formal:	0.12	0.10	0.06	0.21	0.08	-	1d
01 R 03	rms:	0.17	0.16	0.12	0.37	0.16	-	
EOP (IAA)	formal:	-	-	0.15	-	-	-	0.05d
01 R 04	rms:	-	-	0.15	-	-	-	
EOP (OPA)	formal:	0.09	0.07	0.04	0.06	0.06	-	1d
01 R 02	rms:	0.22	0.32	0.12	0.29	0.15	-	
EOP (SHA)	formal:	0.14	0.12	0.07	0.20	0.08	-	1d
01 R 01	rms:	0.16	0.11	0.14	0.29	0.13	-	
EOP (SPBU)	formal:	0.09	0.08	0.04	0.20	0.08	-	1d
00 R 03	rms:	0.14	0.13	0.09	0.30	0.14	-	
EOP (SPBU)	formal:	-	-	0.19	-	-	-	0.5d
99 R 01	rms:	-	-	0.16	-	-	-	
GPS								
EOP (CODE)	formal:	0.01	0.02	-	-	-	0.01	1d
01 P 01	rms:	0.09	0.08	-	-	-	0.24	
EOP (EMR)	formal:	0.06	0.06	-	-	-	0.10	1d
96 P 03	rms:	0.21	0.27	-	-	-	0.92	
EOP (ESOC)	formal:	0.03	0.03	0.04	-	-	0.03	1d
96 P 01	rms:	0.16	0.15	0.52	-	-	0.32	
EOP (GFZ)	formal:	0.01	0.01	-	-	-	0.01	1d
01 P 01	rms:	0.07	0.08	-	-	-	0.32	
EOP (JPL)	formal:	0.06	0.06	-	-	-	0.16	1d
01 P 01	rms:	0.11	0.11	-	-	-	0.32	
EOP (NOAA)	formal:	0.03	0.03	-	-	-	0.19	1d
96 P 01	rms:	0.27	0.27	-	-	-	0.80	
EOP (SIO)	formal:	0.06	0.07	-	-	-	0.16	1d
96 P 01	rms:	0.16	0.10	-	-	-	0.36	
EOP (USNO)	formal:	-	-	-	-	-	-	1d
01 P 01	rms:	-	-	0.30	-	-	-	
SLR								
EOP (CGS)	formal:	0.12	0.12	-	-	-	-	3d
00 L 01	rms:	0.58	0.55	-	-	-	-	
EOP (CSR)	formal:	0.35	0.35	0.29	-	-	-	3d
95 L 01	rms:	0.44	0.30	1.13	-	-	-	
EOP (CLG)	formal:	0.29	0.28	-	-	-	-	3d
01 L 01	rms:	1.51	1.45	-	-	-	-	
EOP (DUT)	formal:	0.11	0.11	-	-	-	-	3d
98 L 01	rms:	0.35	0.37	-	-	-	-	
EOP (GAOUA)	formal:	0.18	0.16	-	-	-	-	3d
01 L 01	rms:	0.30	0.28	-	-	-	-	
EOP (IAA)	formal:	0.07	0.07	0.04	-	-	0.04	5d
00 L 01	rms:	0.22	0.19	0.37	-	-	0.22	
EOP (IAA)	formal:	0.05	0.05	0.03	-	-	0.03	5d
00 L	rms:	0.19	0.16	0.29	-	-	0.18	
LLR								
EOP (FSG)	formal:	-	-	0.62	-	-	-	0.05d
01 M 01	rms:	-	-	1.46	-	-	-	
EOP (UTXMO)	formal:	-	-	3.32	-	-	-	0.05d
01 M 01	rms:	-	-	1.21	-	-	-	
EOP (OPA)	formal:	-	-	0.27	-	-	-	0.05d
01 M 03	rms:	-	-	0.56	-	-	-	
EOP (OPA)	formal:	-	-	0.44	-	-	-	0.05d
01 M 04	rms:	-	-	0.41	-	-	-	

Table 21. Differences between combined daily series of EOP over 1996–2000

The differences are expressed under the form: A + A'(t–1997.0), where t is the date in Besselian years. R is the rms residual after the adjustment of A and A'.

Units: x, y, dψ, dε: A and R in 0.001", A' in 0.001"/yr
UT1–UTC: A and R in 0.0001s, A' in 0.0001s/yr

SOLUTIONS		JPL – IERS	NEOS – IERS	NEOS – JPL
X	A	0.052 ± 0.004	-0.021 ± 0.004	-0.073 ± 0.002
	A′	-0.033 ± 0.002	-0.080 ± 0.002	0.028 ± 0.001
	R	0.109	0.091	0.063
Y	A	-0.033 ± 0.004	-0.037 ± 0.004	-0.016 ± 0.003
	A′	0.020 ± 0.002	0.004 ± 0.002	-0.010 ± 0.001
	R	0.102	0.091	0.060
UT1-UTC	A	0.019 ± 0.006	0.013 ± 0.008	0.002 ± 0.003
	A′	-0.012 ± 0.003	0.007 ± 0.004	0.010 ± 0.002
	R	0.191	0.240	0.093
dPsi	A	- -	-0.206 ± 0.019	- -
	R	- -	0.557	- -
dEps	A	- -	-0.011 ± 0.012	- -
	R	- -	0.339	- -

JPL: series 01 C 01
NEOS: series 01 C 01
IERS: series C 04

Table 22. Allan variance analysis of the combined series of EOP for sampling times of 1 through 64 days based on the 1996–2000 data

Combined EOP Series	Sampling time	X (0.001")	Y (0.001")	UT1-UTC (0.0001s)
IERS C 04	1 d	0.10	0.18	0.04
	8 d	0.03	0.07	0.07
	32 d	0.02	0.04	0.04
	64 d	0.01	0.03	0.03
JPL 01 C 01	1 d	0.09	0.18	0.03
	8 d	0.04	0.07	0.01
	32 d	0.02	0.04	0.01
	64 d	0.02	0.03	0.01
NEOS 01 C 01	1 d	0.09	0.18	0.09
	8 d	0.03	0.06	0.06
	32 d	0.02	0.03	0.02
	64 d	0.02	0.02	0.01

IERS Bulletin B

An advanced version of EOP(IERS) C 04 is distributed monthly in IERS Bulletin B. The time series of EOP issued in Bulletin B are based on the annual analysis described in the above sections, applied to the series provided weekly or monthly by the operational analysis centers. Each of the series available is referred to the IERS System considering a bias and a linear drift derived from previous analyses. The formal uncertainties are scaled to reflect the real uncertainty of the data. All series of determinations of the same parameters are then merged, and the five resulting series (x, y, UT1, $d\psi$, $d\varepsilon$) are smoothed with the adopted degree of smoothing. UT1 is treated under the form of UT1R (effect of zonal tides with periods under 35 d removed), and $d\psi$, $d\varepsilon$ are treated under the form of residuals to a modeled correction; these modeled corrections are added back at the end of the processing. The degrees of smoothing used in 2000 are given in *Table 23*. They are chosen as allowed by the precision of the input series. The *rms* differences between the Bulletin B series and EOP(IERS) C 04 in 2000 are 0.2 mas on x, y, 0.02 ms on UT1, and 0.0003" on $d\psi \sin\varepsilon$ and $d\varepsilon$.

Table 23. Bulletin B: Transfer functions of smoothings by Vondrak algorithm

Epsilon	Period for Remaining amplitude 5%	50%	95%	Parameters involved
10^{-2}	6d	15d	25d	$d\psi$, $d\varepsilon$ through B96 (Dec 1995)
$10^{-0.5}$	6d	8d	12d	x, y, UT1, LOD through B96 (Dec 1995)
10^{+2}	2d	3d	5d	all parameters starting with B97 (Jan 1996)

Two different approaches are used for prediction of the Earth rotation parameters.

- Universal Time: The formalism used is based on the assumption that the long-term fluctuations (annual and semi-annual) of the preceding year are valid over the next few months. For short-term variations prediction, an autoregressive process is used.

- Polar Motion: The formalism uses at first a floating period fit for both Chandler and annual components estimation. An autoregressive filter is then applied on the short-term variations.

Table 24. Bulletins A and B: Individual series contributing to IERS, January 2000

The formal uncertainties are those which are reported by the contributors. They are used in the combinations for Bulletins A and B after being calibrated by statistical assessment.

INDIVIDUAL SERIES CONTRIBUTING TO IERS BULLETINS A AND B		SAMPLING TIME	FORMAL UNCERTAINTIES BASED ON 1999-2000 DATA			
			Terrest.Pole 0.001"	UT 0.0001s	LOD 0.0001s	Celest.Pole 0.001"
VLBI						
EOP(GSFC)	00 R 01	7d	--	0.21	--	--
EOP(GSFC)	00 R 02	7d	0.64	0.29	--	0.15
EOP(BKG)	00 R 01	7d	--	0.22	--	--
EOP(BKG)	00 R 02	7d	0.16	0.09	--	0.08
EOP(IAA)	98 R 01	7d	0.10	0.04	--	0.10
EOP(IAA)	00 R 04	7d	--	0.18	--	--
EOP(USNO)+	99 R 01	7d	0.14	0.06	0.20	0.13
EOP(USNO)+	99 R 02	1-3 d	--	0.23	--	--
EOP(SPBU)	99 R 01	1-3 d	--	0.22	--	--
SLR						
EOP(CGS)	97 L 02	3d	0.28	0.25 *	--	--
EOP(CSR)	95 L 01	3d	0.39	0.31 *	--	--
EOP(DUT)	98 L 01	3d	0.11	0.10 *	--	--
EOP(IAA)	98 L 02	1d	0.05	0.04 *	0.04	--
EOP(MCC)	97 L 01	3d	0.05	--	0.10	--
GPS						
EOP(CODE)	98 P 01	1d	0.05	--	0.10	--
EOP(EMR)	96 P 03	1d	0.07	1.05 *	0.13	--
EOP(ESOC)	96 P 01	1d	0.02	0.03 *	0.03	--
EOP(GFZ)	96 P 02	1d	0.01	0.01 *	0.01	--
EOP(JPL)	96 P 03	1d	0.04	0.14 *	0.14	--
EOP(NOAA)	96 P 01	1d	0.03	0.10 *	0.19	--
EOP(SIO)	96 P 01	1d	0.07	0.45 *	0.16	--
EOP(IGS)	95 P 02	1d	0.05	0.17 *	0.08	--
EOP(IGS)	96 P 02	1d	0.08	0.29 *	0.14	--

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

The content of Bulletin B is as follows (7 sections):

1. Smoothed values of x, y, UT1R–UTC, UT1R–TAI, dψ, dε, sampled at five-day interval. Final Bulletin B values over one month and provisional extension over the next four months. The smoothings are based on the Vondrak (1977) algorithm, with degrees of smoothing indicated in the legend (see also Feissel and Lewandowski, 1984). However, the oscillations in UT and in duration of the day due to zonal tides with periods under 35

days, as well as the 14 days term in dψ, dε, are present in full size in the series.

2. Daily values of x, y, UT1–UTC, UT1–UT1R, D, dψ, dε, same series as in section 1.
3. Five-day normal values of x, y, UT1–UTC, dψ, dε, and their uncertainties based on a combination of the series of section 6.
4. Smoothed values of DR and ωR, with the same degree of smoothing than for UT1R–UTC.
5. Current values of UTC–TAI and DUT1, reproducing IERS Bulletins C and D.
6. Statistics on the data used.
7. Data of IERS analysis centers (available only in electronic distribution). In this section, the original results received from the IERS analysis centers and used for the solution listed in sections 1 to 3 are reproduced. These results are those which are available one to five weeks after the observation dates. Updated results received later are stored, but as a general rule, they are not printed in Bulletin B. The series used in January 2000 are listed in *Table 24*.

4.5 Consistency of IERS Results

Consistency of IERS EOP Series with ITRS and ICRS at a Reference Epoch

Let us consider two series of EOP (x, y, UT1, dψ, dε) and (x', y', UT1', dψ', dε') respectively. Each of them is referred to a celestial frame defined by the adopted Radio Source Coordinates (RSC) and to a terrestrial frame defined by the adopted Set of Station Coordinates (SSC). The celestial reference frames, respectively denoted CRF and CRF' present systematic differences, which can be described by an elementary rotation matrix A. The coordinates in both system, [CRF] and [CRF'] respectively, are linked by the relation:

$$[CRF] = A\,[CRF']$$

In the same way the terrestrial reference frames, TRF and TRF' respectively, are linked through an elementary rotation:

$$[TRF] = R\,[TRF']$$

If the EOP series were consistent, then the systematic differences in the pole coordinates, Δx and Δy, in the universal time, ΔUT1, and in the celestial pole offsets, Δdψ and Δdε would be only due to the rotation angles (A_1, A_2, A_3) between the two celestial frames and the rotation angles (R_1, R_2, R_3) between the two terrestrial frames, with:

$$\begin{aligned}
\Delta x &= x' - x\\
\Delta y &= y' - y\\
\Delta UT1 &= UT1' - UT1\\
\Delta d\psi &= d\psi' - d\psi\\
\Delta d\varepsilon &= d\varepsilon' - d\varepsilon
\end{aligned}$$

It can be shown that these systematic differences would satisfy the following relationships with an accuracy of a few microarcseconds:

$$
\begin{aligned}
\Delta x &= R_2 \\
\Delta y &= R_1 \\
\Delta \mathrm{UT1} &= (-R_3 + A_3)/ f \\
\Delta \mathrm{d}\psi &= A_2/\sin\varepsilon \\
\Delta \mathrm{d}\varepsilon &= -A_1
\end{aligned}
\qquad (1)
$$

where f is the conversion factor from Universal Time to sidereal time, and ε is the obliquity of the ecliptic.

It is worthwhile to know to which extent the relationships (1) are satisfied. Each comparison will be made naturally with respect to the same data set (CRF, TRF, EOP), that is the ICRF, the ITRF and the corresponding EOP series of the IERS.

The closure of relationships (1) characterizes the internal consistency of the set of IERS results, time series and reference frames. In this objective the quantities:

$$
\begin{aligned}
C(x) &= \Delta x - R_2 \\
C(y) &= \Delta y - R_1 \\
C(UT1) &= f.\,\mathrm{UT1} - (-R_3 + A_3) \\
C(\mathrm{d}\psi) &= \Delta\, \mathrm{d}\psi - A_2/\sin\varepsilon \\
C(\mathrm{d}\varepsilon) &= \Delta\, \mathrm{d}\varepsilon - (-A_1)
\end{aligned}
$$

are computed.

Time evolution of the IERS EOP series relative to ITRF

We consider two terrestrial frames, each one having its own velocity field. The corresponding series of EOP, the relative drifts $\Delta\dot{x}, \Delta\dot{y}, \Delta\dot{U}T1$ between the series of EOP can be predicted by relationships (2), obtained as the time derivatives of the first three relationships (1):

$$\Delta\dot{x} = \dot{R}_2 \quad ; \Delta\dot{y} = \dot{R}_1 \quad ; \Delta\dot{U}T1 = -\dot{R}_3 \qquad (2)$$

where $\dot{R}_1$, $\dot{R}_2$, $\dot{R}_3$ are the rates of change of the rotation angles between the two terrestrial reference frames. These relationships are used to compare the drifts of the EOP series relative to EOP(IERS) C 01 with their predicted values based on the definition of the corresponding terrestrial velocity field.

Results for the EOP Series (2000)

The present consistency analysis consists in two steps. The first step is the computation of the biases and slopes of the individual EOP parameters (nutation in longitude, nutation in obliquity) with respect to the combined parameters of the series EOP(IERS) C 01. The second step is the comparison, given hereafter, between these biases and slopes, and those theoretically produced by the rotations between the reference frames, as already explained.

Consistency analysis extends over the period 1988–2001, except for the recent VLBI series produced by the Paris Observatory since 1999 (OPA). The data before 1988 were not involved, because they are considered to be of less quality. Bias and trend have been computed with respect to the epoch 1997.0 expressed in Julian year.

Actually since the year 1998, the angles between the individual TRF and the ITRF have not been computed by the ITRF Product Center of the IERS (located at the Institut Géographique National, France, formerly known as the ITRF Section of the Central Bureau) for some technical reason. In turn consistency analyses of the last long term series up to 2001.0, collected by the IERS EOP Product Center in the framework of the Annual Report 2000, cannot be made systematically for polar motion and UT1, because the angles R_1, R_2, R_3 are not available for computing the corresponding closure relations.

For this reason the analysis has been restricted to 7 series, 5 of them derived from VLBI processing, and 2 from SLR processing. *Table 25* gives the evaluations of the internal consistency for EOP series, involving SSC or RSC, of which the orientation is known. The celestial frames angles can be found in Celestial System Section.

Nutation offsets consistency

For VLBI series, the associated radio-source catalogue either corresponds to the ICRF (zero angles, case of IAA, OPA and SHA series) or to celestial frame departing from the ICRF at the level of 50 microarcseconds (case of BKG and GSFC series). In turn consistency of nutation offsets of these series can be fully investigated. Acceptable consistency, less than 100 microarcseconds, is obtained for celestial pole offset ($d\psi\sin\varepsilon$, $d\varepsilon$) of the BKG, GSFC, IAA and SHA series. Celestial pole offsets of OPA series present inconsistencies, which may be caused by the shortness of the time span (two years).

Polar motion and UT1 consistency

Polar motion and UT1 consistencies have been investigated in the case of two VLBI series (IAA, OPA), and two SLR series from LAGEOS observations (IAA L 01, IAA L 02). These 4 series are referred either to ITRF 2000 or to terrestrial frames, which do not present any net rotation with respect to ITRF 2000. Let us notice that for other VLBI series the rotation matrix with respect to ITRF 2000 remains unknown. Polar motion consistency smaller than 100 microarcseconds is reached only for SLR series IAA L 01. UT1 consistency is under this threshold for (IAA) VLBI series and the 2 (IAA) SLR series.

Table 25: Consistency of VLBI EOP series with celestial reference frames, based on the rotation angles relative to ICRF at the epoch 1997

SERIES		R2 / Δx / C(x)	R1 / Δy / C(y)	A3-R3 / ΔUT1 / C(UT1)	A2/sinε / Δdψ / C(dψ)	-A1 / Δdε / C(dε)
	1	R2	R1	A3-R3	A2/sinε	-A1
	2	Δx	Δy	ΔUT1	Δdψ	Δdε
	3	C(x)	C(y)	C(UT1)	C(dψ)	C(dε)
EOP(BKG)	1	-	-	-	0.000±0.040	-0.030±0.016
01 R 01	2	-0.090±0.009	0.055±0.008	-	-0.091±0.018	-0.008±0.013
1988-2000	3	-	-	-	-0.091±0.044	0.022±0.021
EOP(GSFC)	1	-	-	-	0.003±0.043	-0.008±0.017
01 R 01	2	-0.122±0.008	0.189±0.007	-	-0.047±0.021	0.000±0.013
1988-2000	3	-	-	-	-0.050±0.048	0.008±0.021
EOP(IAA)	1	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
01 R 04	2	-0.148±0.009	0.157±0.008	-0.020±0.035	-0.054±0.022	0.089±0.014
1988-2000	3	-0.148±0.009	0.157±0.008	-0.020±0.035	-0.054±0.022	0.089±0.014
EOP(OPA)	1	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
01 R 02	2	0.057±0.126	0.201±0.205	0.280±0.334	0.253±0.084	0.116±0.046
1999-2000	3	0.057±0.126	0.201±0.205	0.280±0.334	0.253±0.084	0.116±0.046
EOP(SHA)	1	-	-	-	0.000±0.000	0.000±0.000
01 R 01	2	-0.115±0.008	0.102±0.007	-	-0.059±0.020	0.002±0.013
1988-2000	3	-	-	-	-0.059±0.020	0.002±0.013
EOP(IAA)	1	0.000±0.000	0.000±0.000	0.000±0.000	-	-
01 L 01	2	-0.077±0.032	-0.102±0.018	0.057±0.084	-	-
1992-2000	3	-0.077±0.032	-0.102±0.018	0.057±0.084	-	-
EOP(IAA)	1	0.000±0.000	0.000±0.000	0.000±0.000	-	-
01 L 02	2	-0.102±0.032	-0.148±0.025	0.002±0.087	-	-
1992-2000	3	-0.102±0.032	-0.148±0.025	0.002±0.087	-	-

Unit: 0.001"

IERS Earth Orientation Centre

For the address of the IERS Earth Orientation Centre and for electronic access see Chapter V.4 and Appendix 2.

Staff:

Gambis	Daniel,	Director
Baudouin	Pascale ,	Secretary
Bizouard	Christian,	Astronomer
Bougeard	Mireille,	Mathematician
Carlucci	Teddy,	Engineer
Essaïfi	Najat,	Engineer
Francou	Gérard,	Astronomer
Jean-Alexis	Didier,	Engineer

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IV.5 Sub-Bureau for Rapid Service and Predictions

Rapid Service Activities

The algorithm used by the IERS Sub-bureau for Rapid Service and Predictions (starting 2001 the Sub-bureau is now known as the Rapid Service/Prediction Centre) in the determination of the quick-look Earth orientation parameters 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 EOP Section.

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 based on the internal precision reported by contributors. Estimated accuracies of data contributed for rapid service estimates of Earth orientation are shown in Table 1.

Table 1. Estimated accuracies of the techniques in 2000. Units are milliseconds of arc for x, y, $d\psi$, and $d\varepsilon$, and milliseconds of time for UT1-UTC.

Contributor	Estimated Accuracy					
	x	y	UT1	lod	$d\psi$	$d\varepsilon$
CSR 3-day SLR	0.5	0.5	0.12 *			
DUT 3-day SLR	0.4	0.4				
IAA 1-day SLR	0.2	0.2				
MCC 1-day SLR	0.2	0.2				
GSFC daily VLBI			0.028			
SPbU daily VLBI			0.027			
GSFC weekly VLBI	0.3	0.3	0.010		0.4	0.1
IAA weekly VLBI	0.2	0.2	0.007		0.4	0.1
Texas LLR (CERGA)			0.15			
Texas LLR (MLRS2)			0.15			
IGS Final	0.06	0.06				
IGS Rapid	0.08	0.08		0.02 *		
USNO GPS UT *			0.015 *			
EMR GPS UT *			0.03 *			

* 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 spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, dψ, and dε values are computed at the epoch of zero hours UTC for each day. The only data points which 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).

The errors for the daily values listed in Bulletin A are derived from the quality of the fit of the spline in the neighborhood of the day in question. Table 2 shows a comparison of Bulletin A with the series Bulletin B and C04 maintained by the IERS EOP Section at the Paris Observatory.

Table 2. Mean and standard deviation of the differences between various IERS solutions for 2000.

	Bulletin A - Bulletin B		Bulletin A - IERS C04	
	mean	std. deviation	mean	std. deviation
x	0.00 mas	0.05 mas	-0.02 mas	0.06 mas
y	-0.02 mas	0.06 mas	-0.03 mas	0.07 mas
UT1-UTC	0.005 ms	0.035 ms	0.007 ms	0.031 ms

During 2000, several substantial changes have occurred which affect the performance of IERS Bulletin A. Beginning 29 June, the near-term polar motion predictions were modified slightly to rely more heavily on the latest observed polar motion rates from the IGS Rapid combination. The latest IGS polar motion rates have been included since 11 February 1999, but their improved quality and reliability warrants placing a greater weight on them for the Bulletin A polar motion predictions. Beginning 21 July, the near-term UT1-UTC predictions were modified to include a contribution from model predictions of the atmospheric angular momentum (AAM) excitation. The AAM results come from the National Centers for Environmental Prediction (NCEP), using both their analysis products (tabulated at 6-hr intervals) and forecast fields (at 12-hr intervals) for excitation of length of day (LOD). A procedure was developed for smoothly merging each set of daily updates into a continuous time series extending 5 days into the future. This series is then assimilated into Bulletin A by first integrating the LOD values then matching the last 5 days before the predictions to the geodetic observations of UT1R-UTC and LODR. Starting the beginning of July, Kokee Park (Hawaii, USA) replaced Green Bank (West Virginia, USA) in the quasi-daily UT1 Intensive VLBI sessions which run with Wettzell (Germany). While this change was forced by the ending of geodetic operations at Green Bank, there is good reason to believe that the UT1 performance of the Kokee-Wettzell baseline may be better than the previous Green Bank-Wettzell baseline. Both baselines are oriented nearly East-West and are very sensitive to variations in UT1, but the Kokee baseline is about 50% longer. Beginning 28 November, a new version of the series of variations in Universal Time based on observed GPS orbits was included in Bulletin A. This series, developed at USNO, uses more satellites and covers a longer time span (beginning 03 December 1995) than the previous version. The method of calibrating the GPS-based UT values by comparing to VLBI determinations of UT1 was not changed. Beginning 12 December, the data analyses provided by the NASA/GSFC VLBI group was incorporated into the Bulletin A combination. These include results for both the 24-hour sessions and the short Intensive UT1 sessions. The previous VLBI analyses made at USNO („NEOS“) were discontinued (on 14 November for the 24-hour sessions; 04 December for the Intensives).

In preparing for this 2000 IERS Annual Report, a number of additional changes have been made for the Bulletin A combination. The annual and semiannual systematic corrections that were previously applied were discontinued since they appear to be unnecessary. The reference epoch for the linear rate corrections has been shifted to 1 January 2000. The weightings of all of the input polar motion series were updated to match current estimates of the accuracies.

Prediction Activities in 2000

Polar motion predictions are based on the extrapolation of an annual and semiannual ellipse and a Chandler circle fit to the previous 1100 days of observed values of x and y (McCarthy and Luzum, 1991b). 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 which 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 process 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 predictions 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 in 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, $(UT1R\text{-}TAI)_0$.

$$<UT1R\text{-}TAI)_n> = 2(UT1R\text{-}TAI)_0 - <(UT1R\text{-}TAI)_{-n}>.$$

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 to extend the tabular values are determined from a least-squares fit to the tabular data. The prediction of $d\psi$ and $d\varepsilon$ is based on the KSV_1996_3 model (McCarthy, 1996). Table 3 shows the errors to be expected in the predictions based on results since the beginning of 1998. Recent prediction performance in UT1-UTC has been degraded by the effects of the most recent El Niño/La Niña cycle, particularly for longer intervals.

Table 3. Errors for different prediction

Days in future	Terr. Pole 0.001"	UT1-UTC 0.001s	Celest. Pole 0.001"
1	0.2	0.05	0.3
4	1.8	0.46	0.3
10	3.9	1.6	0.3
40	11.2	7.7	0.3
90	19.7	17.8	0.3

Predictions of UT1-TAI up to 2009 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. Predicted values of UT1-TAI up to 2020 are available on request. Please contact the IERS Sub-bureau for Rapid Service and Predictions (now the 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).

Availability of Rapid Service

The data available from the IERS Sub-bureau for Rapid Service and Predictions consists mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from NEOS VLBI; x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from IAA VLBI; x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from GSFC VLBI; UT1-UTC from NEOS 1-day Intensives; UT1-UTC from SPbU 1-day Intensives; 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 Center 1-day SLR; UT0-UTC from University of Texas LLR; x, y, LOD from the International GPS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from the IERS Sub-bureau for Rapid Service and Predictions (now Rapid Service/Predictions Centre); x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from the IERS EOP Section (now Earth Orientation Centre); predictions of x, y, UT1-UTC, from the IERS Sub-bureau for Rapid Service and Predictions.

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

The data described above are available from the Sub-bureau in a number of forms. You may request a semiweekly machine readable version of the IERS Bulletin A containing the current ninety days 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 they can access the IERS Bulletin A or more complete databases.

World Wide Web access is available at

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

Table 4. Predicted values of UT1-TAI, 2001-2009. Note that TT-UT1 can be obtained from this table using the expression TT-UT1 = 32.184s - (UT1-TAI).

DATE	UT1-TAI (s)	Uncertainty (s)
2001 Jan 1	-31.907	.001
Apr 1	-31.974	.001
Jul 1	-32.01	.01
Oct 1	-32.01	.02
2002 Jan 1	-32.08	.02
Apr 1	-32.16	.03
Jul 1	-32.7	.3
Oct 1	-32.8	.4
2003 Jan 1	-33.0	.4
Apr 1	-33.1	.5
Jul 1	-33.3	.6
Oct 1	-33.4	.8
2004 Jan 1	-33.6	.9
Apr 1	-34.	1.
Jul 1	-34.	1.
Oct 1	-34.	1.
2005 Jan 1	-34.	1.
Apr 1	-35.	2.
Jul 1	-35.	2.
Oct 1	-35.	2.
2006 Jan 1	-35.	2.
Apr 1	-35.	2.
Jul 1	-35.	2.
Oct 1	-36.	2.
2007 Jan 1	-36.	3.
Apr 1	-36.	3.
Jul 1	-36.	3.
Oct 1	-36.	3.
2008 Jan 1	-36.	3.
Apr 1	-37.	3.
Jul 1	-37.	3.
Oct 1	-37.	4.
2009 Jan 1	-37.	4.

References

Luzum, B.J., Ray, J.R., Carter, M.S., and Josties, F.J., 2001, „Recent Improvements to IERS Bulletin A Combination and Prediction," GPS Solutions, 4(3), 34.

McCarthy, D.D. and Luzum, B.J., 1991a, „Combination of Precise Observations of the Orientation of the Earth," Bulletin Géodésique, 65, 22.

McCarthy, D.D. and Luzum, B.J., 1991b, „Prediction of Earth Orientation," Bulletin Géodésique, 65, 18.

McCarthy, D.D., 1996, „IERS Conventions," IERS Technical Note, 21, Paris Observatory.

Jim Ray, Brian Luzum

IV.6 Conventions

Activity in 2000 was threefold:

- Continue the editing of the new version of the IERS Conventions;
- Incorporate changes brought about by the Resolutions adopted at the IAU2000 24^{th} General Assembly and interact with the working groups involved in the preparation of these resolutions;
- Prepare the program of work of the Conventions Product Center (CPC) in the new IERS organization

At the time of this writing, the new organization of the IERS is installed and the CPC is provided jointly by the U. S. Naval Observatory (USNO) and the Bureau International des Poids et Mesures (BIPM), who are working on the new edition of the IERS Conventions. The organization of this new edition is still based on the plan of Conventions 1996, with numerous updates. The work accomplished or in progress is the following:

Chapter 1 - Conventional Celestial Reference Frame
Update to incorporate the effects of the IAU 2000 24^{th} General Assembly
Chapter 2 - Conventional Dynamical Reference Frame
Consistency of notation and concepts with other sections
Chapter 3 - Conventional Terrestrial Reference Frame.
Update for ITRF2000. A complete rewriting is in progress.
Chapter 4 - Numerical Standards
Update for consistency of notation and concepts with other sections. Update values according to IAG and IAU working groups.
Chapter 5 - Transformation Between the Celestial and Terrestrial Systems.
Modify to be consistent with the resolutions adopted at the 24^{th} IAU General Assembly.
Chapter 6 – Geopotential
Update conventional geopotential model. Update treatment of tides.
Chapter 7 - Site Displacement
Update to account for models used in IERS analysis centers and ensure consistency with chapters 3 and 6.
Chapter 8 - Tidal Variations in the Earth's Rotation
Update to be consistent with resolutions adopted at the 24^{th} IAU General Assembly
Chapter 9 - Tropospheric Model
Update model
Chapter 10 - Radiation Pressure Reflectance Model
This chapter is being deleted.

Chapter 11 - General Relativistic Models for Time, Coordinates and Equations of Motion
Update for consistency of notations and concepts with other sections.
Chapter 12 - General Relativistic Models for Propagation
Update for consistency of notations and concepts with other sections.
Appendix - Resolutions from 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

IV.7 Global Geophysical Fluids Center

Introduction

The Global Geophysical Fluids Center (GGFC) was established by the International Earth Rotation Service (IERS) on IERS's 10th anniversary day January 1, 1998, in an effort to expand IERS's services to the scientific community, which had already included those of the Sub-Bureau for Atmospheric Angular Momentum since 1989. Under the GGFC, seven Special Bureaus (SB) were established, each to be responsible for research activities relating to a specific Earth component or aspect of the geophysical fluids of the Earth system.

The geophysical fluids of the Earth system include the atmosphere, ocean, solid Earth, and core, and geophysical processes associated with tides and hydrological cycles. Mass transports in the atmosphere-hydrosphere-solid Earth-core system, or the "global geophysical fluids", will cause observable geodynamic effects on a broad time scale. The GGFC and the SBs have 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 geocenter that are caused by mass transport in the geophysical fluids. Under GGFC/SBs, angular momenta and the related torques, gravitational coefficients, and geocenter shift 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.

Present Organization

The following overview gives the heads of the GGFC and of the Special Bureaus as well as their host institutions. For addresses and details on electronic access see Chapter V.4 and Appendix 2.

GGFC

Head: Benjamin F. Chao
Space Geodesy Branch, NASA's Goddard Space Flight Center
Greenbelt, USA

Special Bureaus

ATMOSPHERE (SBAtmosphere)
Head: David A. Salstein
Atmospheric and Environmental Research, Inc.
Lexington, USA

OCEANS (SBOceans)
Head: Richard S. Gross
Jet Propulsion Laboratory
Pasadena, USA

TIDES (SBTides)
Head: Richard D. Ray
Space Geodesy Branch, NASA's Goddard Space Flight Center
Greenbelt, USA

HYDROLOGY (SBHydrology)
Head: Clark R. Wilson
Department of Geological Sciences, University of Texas, Austin
Austin, USA

MANTLE (SBMantle)
Head: Benjamin F. Chao
Space Geodesy Branch, NASA's Goddard Space Flight Center
Greenbelt, USA

CORE (SBCore)
Head: Veronique Dehant
Royal Observatory of Belgium/Observatoire Royal de Belgique
Brussels, Belgium

GRAVITY/GEOCENTER (SBGravity/Geocenter)
Head: Michael M. Watkins
Jet Propulsion Laboratory
Pasadena, USA

The GGFC Website is located at NASA's Goddard Space Flight Center, at URL <http//bowie.gsfc.nasa.gov/ggfc/>. The Special Bureaus can be readily linked from this portal site. The Websites 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. In particular, the following article defining GGFC, published in 2000, is posted on the GGFC website, courtesy of the American Geophysical Union:

Chao, B. F., V. Dehant, R. S. Gross, R. D. Ray, D. A. Salstein, M. M. Watkins, and C. R. Wilson, Space geodesy monitors mass transports in global geophysical fluids, *EOS, Trans. Amer. Geophys. Union*, *81,* 247-250, May 30, 2000.

Activities Update

Below is a list of activities during 2000-2001:

GGFC

Two GGFC meetings were conducted: (1) December 15, 2000, San Francisco, USA, during the American Geophysical Union's 2000 Fall Meeting; (2) March 29, 2001, Nice, France, during the European Geophysical Society General Assembly. The first meeting was an "invitation-only" small business meeting attended by the SB Heads and several interested scientists. The second meeting was a well attended open discussion by 30 scientists. SB Heads all made reports, and some lively discussions led to a proposal to establish a new Special Bureau for Loading, the process of which is now underway and expected to be completed in the beginning of 2002.

Two GGFC collective papers were presented by B. Chao at: (1) EGS2000 General Assembly, Nice, France, March, 2000; (2) Ocean Hemisphere Project Symposium, Japan, January 2001.

SBGravity/Geocenter

Archiving of the previous Geocenter Campaign informationdata (from J. Ray) is completed. They are now available at the SBGravity/ Geocenter website (see above).

SBCore

The members of the SBCore have organized AGU and EGS sessions and have participated actively in the SEDI meeting (Study of the Earth Deep Interior). Following an AGU Union session, V. Dehant has been organizing and editing a new AGU monograph entitled "Core dynamics, structure and rotation", ed. V. Dehant, K. Creager, S. Karato, S. Zatman. It contains an impressive list of authors.

SBCore has sent out a call for participation for getting data, comments, and bibliography inputs through the SEDI email list. The ROB (Royal Observatory of Belgium) staff has updated the SBCore website and its bibliography, with new links to other sites of interest to the scientific community, and in particular with the websites of new satellites undergoing magnetic measurements including Oersted and Champ. A USA mirror site has been set up by B. Chao at Goddard.

New data series are available in the website, which brings the total number of data series to six. Apart from numerical geodynamo simulations, only indirect calculations using geomagnetic data can be performed to estimate core angular momentum as there are no direct observations of the core flow to lead to well-constrained models as in the case of the oceans and atmosphere. The hypotheses used for these computations are detailed on the website.

SBMantle

In addition to seismic effects time series that have been archived since last year, the SBMantle has received two sets of post glacial rebound modeling data. The first set is from Eric Ivins (JPL). This set of data consists 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 1 x 10^{21} to 1 x 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 η = 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.

The second set of data is from Prof. 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). Web/presentation friendly forms will be made available, in addition to the full postscript files. For both sets of data, we are in the process of preparing the data for inclusion on the website, and expect to have it available online in the very near future.

SBTides

SBTides continues to add tidal datasets to its primary web site. Recent additions include tabulations of spherical harmonic expansion coefficients for several ocean tide models and at least one atmospheric tide model. Such expansions are useful for satellite orbitography and other space geodetic applications, in addition to Earth rotation study applications. The Special Bureau's web site receives roughly two dozen hits per day, excluding hits from web crawlers. The most popular page is the short tutorial explaining the effects of tides on the Earth's rotation. This page is linked from a number of other web sites related to tides, which no doubt helps account for its popularity.

SBHydrology

The near-term goal of the SBHydrology is to provide internet access to water storage datasets that provide estimates of surface load variations for all land areas of the world. A trial dataset is on the website <http://www.csr.utexas.edu/research/ggfc/>. The website format was improved during the summer of 2001. A web site format for selecting individual river basin load time series is under development. A new member of the advisory group, Anny Cazenave, has been added, and a member of her research group, Marie-Claude Gennero, has begun efforts to establish a parallel website for providing internet access to related datasets, as reported at the EGS meeting, Nice, 2001. The URL for this effort is <http://www.obs-mip.fr/omp/gos/resultats/geofluid.htm>.

SBOceans

Two OAM (Oceanic Angular Momentum) series, one spanning 1985-1996 at 5-day intervals, and the other spanning 1990-1993 at 15-day intervals, have been archived and can be downloaded from the SBOceans web site.

A bibliography of over 150 papers relating to oceanic processes and their influence on the solid Earth continues to be updated and expanded. The most recent version can be downloaded from the SBOceans web site. Information packets about the SBOceans continue to be distributed to potential customers at scientific conferences. More than 100 packets have been distributed to date.

A fortran program that computes the SBOceans core products (OAM, oceanic center-of-mass, and ocean-bottom pressure) has been written and is available upon request to <Richard.Gross@jpl.nasa.gov>.

A meeting for the Joint IAG/IAPSO Working Group on Geodetic Effects of Non-tidal Oceanic Processes was held on March 29, 2001, Nice, France, during the European Geophysical Society General Assembly.

SBAtmosphere

In conjunction with the U.S. National Oceanic and Atmospheric Administration (NOAA), the SBAtmosphere has produced data from 4 different operational meteorological centers. 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. 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. Users log in to our ftp sites to obtain the desired information. Having kept track of our data usage during a recent period, for example, the data were accessed by 35 different IP (Internet Protocol) addresses between March and October 2000.

Two reports have been prepared:

Salstein, D. A., O. de Viron, M. Yseboodt, and V. Dehant, 2001; High-frequency geophysical fluid modeling necessary to understand Earth rotation variability, in press, EOS.

Salstein, D. A., and A. J. Miller, 2001: The special bureau for the atmosphere of the International Earth Rotation Service, submitted, IERS Technical Note, ed. B. F. Chao, International Earth Rotation Service.

Benjamin F. Chao, Veronique Dehant, Richard S. Gross, Richard D. Ray, David A. Salstein, Michael M. Watkins, Clark R. Wilson

V.1 Call for Participation in the New IERS (1999)

Dear colleague,

The International Earth Rotation Service (IERS) is near to completeits 12th year of operation, an operation which has provided continuous improvements in the quality and time resolution of user products andin theaccessibility of those products for science and application. This was achieved thanks to new developments in space, computer and communications technology, but to a large extent also thanks to the outstanding efforts of many institutions and individuals contributing to the service.

Nevertheless, new developments in technology and modeling have significantly changed the situation from 1988 - when the service was created and the old Terms of Reference were established - until now. As a result and based on a general public evaluation and intensive discussions with the involved community, the IERS Directing Board decided in 1998 to reorganize the current operation and to come up with new Terms of Reference, satisfying current and near future requirements and taking into account new organizational structures of the space-observing techniques. These new Terms of Reference were approved by the Directing Board in March 1999 and the Board decided in a follow-on meeting to solicit proposals for participation in the various elements of the new IERS. A detailed description of the functions and duties of these elements is given in the attached material.

Your institution has directly or indirectly contributed to the activities of the IERS in the past and the importance of these contributions is herewith acknowledged and highly appreciated. We hope that the extended importance of the new IERS will encourage you to participate in one or even more elements of the service by responding to the attached Call for Participation.

Thanking you for your contributions to date and awaiting with interest your response to the Call for Participation I remain.

Yours sincerely,

Christoph Reigber
Chairman IERS Directing Board

CALL FOR PARTICIPATION IN THE NEW INTERNATIONAL EARTH ROTATION SERVICE (IERS)

Background

The International Earth Rotation Service (IERS), created by the IAU and the IUGG in 1987, started its activities in January 1988. IERS was given the mission to define and maintain a terrestrial reference system based on the most precise space geodesy techniques, to define and maintain a celestial reference system based on the directions of extragalactic radio sources and its tie to other celestial reference frames and to monitor the Earth's orientation. After ten years of activity it became necessary to reorganize it for various reasons: the re-organization of the new space techniques SLR, Lunar Laser Ranging, VLBI, and GPS into International Services (DORIS being now organized as a pilot program) and the development of a new component: the Global Geophysical Fluids (GGF) dealing with motions of the various fluid layers and their relationship with reference frames and earth dynamics.

Following discussions which took place at the IERS workshop in Paris in fall 1996 and during the "IERS retreat" held in Potsdam in September 1998, new Terms of Reference were formulated and adopted by the IERS Directing Board in March 1999.

The IAG and IAU were informed of these new Terms of Reference in Spring 1999.

Call for Proposals

The present IERS Directing Board solicits proposals for the various components of the new structure as laid down in the March 99 Terms of Reference. These Terms of Reference (ToR) and a more detailed description of the duties and functions of the various elements of the service are enclosed. The ToR can also be accessed via the IERS homepage at the following address:

http://hpiers.obspm.fr/webiers/general/iersq/TREF.html

This call for participation is open to all interested organizations or institutes. Proposals are being sought for:

- Product Centers:
  Earth Orientation
  Rapid Service, Prediction
  Conventions
  International Celestial Reference System (ICRS)
  International Terrestrial Reference System (ITRS)
- Combination Research Center(s)

– Analysis Coordinator

– Central Bureau

The IERS has no proper financial resources. Proposers must provide their own financial resources to support their proposal. The commitment of their organization will be an important consideration in the proposal review.

Proposal Instructions

Proposals for IERS Components should be submitted not later than 28 February 2000 to:

Christoph Reigber
GeoForschungsZentrum Potsdam
Telegrafenberg A 17
D-14473 Potsdam, Germany
phone:+49-331-288-1100
fax: +49-331-288-1111
e-mail: <reigber@gfz-potsdam.de>

with a copy to:

Daniel Gambis
Central Bureau of IERS
Observatoire de Paris
61 avenue de l'Observatoire
F-75014 Paris, France
phone: +33-1-4051-2229
fax: +33-1-4051-2291
e-mail: <gambis@obspm.fr>

The Proposal should be structured as follows:

– Cover Page (details below)
– Proposal Summary
– Description of Proposed Activities
– Management Proposal
– Financial Arrangements
– Curriculum Vitae of Proposer(s) with Relevant Publications

The Cover Page should contain the following information:

– IERS component referred to
– parent/funding organization
– name and title of authorizing official
– name and title of primary scientist
– mailing address
– phone/fax/email

– cooperating organisations/institutes
– signatures (the cover page should be signed both by the Authorizing Official committing the organization/institution to the IERS activity and the primary scientist involved)

Please send your proposal via postal mail to the above addresses. For easier distribution to the reviewers, an additional e-mail version should be made available (in ASCII or attached Word or WordPerfect file). Please send the email version to Christoph Reigber reigber@gfz-potsdam.de and Daniel Gambis gambis@obspm.fr

Proposals should not exceed approximately 20 pages.

Letter of Intent

A non-binding Letter of Intent is due by 10 December 1999. The Letter of Intent - use the form provided at the end - should state that you intend to submit a proposal. This letter should be addressed to Christoph Reigber, Directing Board Chairman, with a copy to Daniel Gambis, Central Bureau.

Proposal Schedule:

15 November 1999:	Dissemination of the Call for Participation
10 December 1999:	Deadline for letter of intent
28 February 2000:	Due date for the proposals
April/May 2000:	Evaluation of the proposals

Proposal Review

The IERS Directing Board augmented by external experts will review the proposals and make the selection at its Board Meeting in April/May 2000.

All proposers will be notified after this meeting.

ELEMENTS OF THE NEW IERS ORGANIZATION

[The sections concerning the Technique Centers are only included for information]

IGS Technique Center

The International GPS Service (IGS) acts as the Technique Center for the IERS in matters pertaining to the Global Positioning System (GPS), GLONASS and other global navigation satellite systems (GNSS) planned for the next decade. The IGS, which is supported on a volunteer basis by an international consortium of agencies, research institutions and universities, is comprised of a global network of roughly 200 GPS tracking stations, a number of ground communication complexes, several network centers, three global data centers, seven analysis centers, and an analysis coordinating center for comparing and assessing data products from the analysis centers, and for improving and disseminating official IGS products. IGS scientific products include ephemerides for GPS satellites with both final and short-latency products, GPS tracking station positions, velocities and other ITRF-related products, Earth rotation parameter information, tropospheric water vapor distributions, ionospheric electron density distributions, and GPS satellite clock epoch and related timing information. The governance of the IGS is accomplished through the oversight provided by its 22-member Governing Board, the policies and standards of which are executed by the IGS Central Bureau (ICB). The ICB acts as the information center for the IGS. The ICB maintains documents relating to IGS standards and it publishes IGS technical reports and workshop proceedings. It also provides coordination for the operations and development of the IGS global network and for the ground communications and data systems infrastructure. Additional information is available at the IGS homepage http://igscb.jpl.nasa.gov

ILRS Technique Center

The International Laser Ranging Service (ILRS) provides global satellite and lunar laser ranging data and their related products to support geodetic and geophysical research activities as well as IERS products important to the maintenance of an accurate ITRF. For the IERS activities, the ILRS focuses on the tracking collected on Lageos-I, Lageos-II and the Moon. The ranging measurement is based on the time required for a laser pulse to make the round trip from the transmit site to the target and return. The ILRS uses the IERS Conventions. The ILRS collects, merges, archives and distributes Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) observation data sets of sufficient accuracy to satisfy the objectives of a wide range of scientific, engineering and operational applications and experimentation. The ILRS consists of about 50 tracking stations, four Operations Centers, three Analysis Centers, four Lunar Analysis Centers, 18 Associate Analysis Centers, two Global Data Centers and one Regional Data Center. Additional information is available at the ILRS homepage http://ilrs.gsfc.nasa.gov

IVS Technique Center

The Technique Center for VLBI is the IVS (International VLBI Service for Geodesy and Astrometry). Established in 1999 to intensify international VLBI cooperation and to assure delivery of high quality data products for Earth orientation and reference frames, the IVS comprises 30 network stations, 3 operation centers, 7 correlators, 6 data centers, 18 analysis centers, 9 technical centers and a coordinating center. Because of the unique access of VLBI to the celestial reference frame, the IVS is recognized by the IERS as having singular responsibility to provide radio source positions for updating the ICRF and for defining new realizations of the ICRS. Similarly, the IVS provides unique measurements of long term UT1 and the coordinates of the celestial pole (nutation and precession). The IVS is responsible for coordinating global VLBI observations for geodesy and astrometry and assuring that analysis centers follow documented standards and data formats for the results to be used by the IERS. In future, the IVS shall provide self-consistent, combined EOP and reference frame products for the IERS and other users. Additional information is available at the IVS homepage http://ivscc.gsfc.nasa.gov

DORIS Technique Center

DORIS receivers are presently flying on three low Earth orbiting satellites. More DORIS-equipped satellites are expected in 2000, carrying upgraded equipment. The DORIS tracking network consists of 52 well-distributed permanent stations, a large number of them collocated with other IERS equipment, primarily GPS.

The DORIS system is presently managed by CNES, with the global data center at the CDDIS.

A Technique Center for DORIS is currently being organized as a Pilot Experiment within Commission VIII (CSTG) of the International Association of Geodesy. The purpose of this experiment is to initiate a large international cooperation on DORIS, providing in particular all IERS data necessary for obtaining IERS products and for conducting related scientific studies on station coordinates and velocities, station coordinate time series (weekly solutions), polar motion and length of day determinations. The long-term goal of this experiment is to create an International DORIS Service based on world-wide cooperation.

Additional information can be obtained at the following Web page: http://lareg.ensg.ign.fr/DORIS

Earth Orientation Product Center

The Earth Orientation Center is responsible for:

(1) Monitoring of long-term Earth orientation,

(2) Publications for time dissemination, and
(3) Leap second announcements

(1) Long-term Earth Orientation

Long-term Earth orientation parameters series are derived from the combination and integration of all available data in a consistent way. For recent data, this combination will be made using data which are made available after all of the final data are received from the Technique Centers. It is expected that this center would receive the final observational estimates from the Technique Centers, examine them for adherence to the IERS Reference Systems and Conventions, combine the data using state-of-the-art techniques, and make the final result available for publication. Results should also be sent to the Central Bureau which will make them available to users via its web/ftp site. A monthly schedule for the EOP computation process is envisioned but other cycles could be considered. The Center will be required to publish a detailed description of its procedure and document any changes.

(2) Time Dissemination

Publications for time dissemination refer to the announcements of the differences between astronomical and civil time (DUT1) for time distribution by radio stations. The Earth Orientation Center is expected to make available for publication the notices when appropriate.

(3) Leap second announcements

Similarly the notice of insertion of (or lack of) a leap second in UTC will be made by this Center. The Earth Orientation Center will evaluate the predicted behaviour of UT1-UTC and, using the guidelines provided by the CCIR, make announcements regarding leap second insertion as appropriate.

The Earth Orientation Center would be expected to interact closely with the Analysis Coordinator to guarantee long-term internal consistency of the Earth orientation data with the ITRF and the ICRF. The center will work together with the Analysis Coordinator and the Combination Research Centers to ensure that the operational combination procedure is optimal. Routine interaction with the Rapid Service/Prediction Center will be necessary to provide consistency of IERS Earth orientation data.

Exchanges between the center and the Technique Coordinators are commonly required in order to assure timely delivery of data to the Earth Orientation Center and to notify the Technique coordinators of any potential data problems. Direct contacts with Operational Analyses Centers providing individual solutions may take place in case of specific problems in their contributions.

A representative of the Earth Orientation Center will serve on the Directing Board for up to two four-year terms.

Rapid Service/Prediction Product Center

The IERS Product Center for Rapid Service/Prediction is responsible for providing Earth orientation parameters on a rapid turnaround basis, primarily for real-time users and others needing the highest quality EOP information sooner than that available in the final series published by the IERS Earth Orientation Product Center. The publications of the Rapid Service/Prediction Center must be fully consistent with and complement the publications of the Earth Orientation Center. It is expected that this center will receive observational estimates from the Technique Centers, especially rapid and preliminary series, examine them for adherence to the IERS Reference Systems and Conventions, combine the submissions using state-of-the-art techniques, and make the results available in a timely fashion. It is also necessary to develop reliable and robust prediction algorithms to extend the rapid service EOP series to future epochs. For the convenience of users requiring only modest accuracy, predictions should be made available up to one year in advance.

A regular publication schedule for EOP time series is envisioned for the Rapid Service/Prediction Center, with bulletins at least twice weekly. To satisfy the highest accuracy user requirements, such as for GPS orbit prediction, updated bulletins may be published as frequently as daily (or as often as justified by available observations). The Center will be required to provide detailed documentation of its procedures and to report any changes.

The Rapid Service/Prediction Center will be expected to interact closely with the IERS Analysis Coordinator to guarantee long-term internal consistency of the Earth orientation series with the ITRF and the ICRF, and with EOP series published by the Earth Orientation Center. This center will work together with the Analysis Coordinator and the Combination Research Centers to ensure that the operational combination procedure is optimal. Routine interaction with the Earth Orientation Center will be necessary to provide consistency of IERS Earth orientation results. Exchanges between this center and the Technique Centers are commonly required in order to assure timely delivery of data to the IERS and to notify the Technique Centers of any potential data problems.

A representative of the Rapid Service/Prediction Center will serve on the Directing Board for up to two four-year terms.

Conventions Product Center

The IERS Conventions Center is responsible for the maintenance of the IERS conventional models, constants and standards. The Center works under the guidance of the IERS Editorial Board that is selected by the IERS Directing Board. The Conventions Center must interact closely with experts in the fields related to the appropriate models, constants and standards to propose new versions of the IERS Conventions to the Editorial and Directing Boards for approval and make them available for printed and electronic mail distribution. It is expected that a new version will be published approximately every three years and that updates, corrections, etc. will be maintained electronically. The Center will maintain electronically accessible files containing any software available for distribution to users.

A representative of the Conventions Center will serve on the Directing Board for up to two four-year terms.

ICRS Product Center

The IERS Terms of Reference specify that one of the primary objectives of the IERS is to provide the International Celestial Reference System (ICRS) and its realization, the International Celestial Reference Frame (ICRF).

In the future IERS structure, a Technique Center and a Product Center will share the task of maintaining the ICRS and the ICRF: the International VLBI Service for Geodesy and Astrometry (IVS) and the ICRS Center. There will be a close interaction between the Analysis Coordinator and the ICRS Center. Being an IERS Product Center, the ICRS Center will be represented in the Directing Board.

While the IVS is fully responsible for providing VLBI radio source coordinates for updating the celestial reference frame, the ICRS Center will be organized assuming the following responsibilities:

- In coordination with the IVS, the ICRS Center will maintain and extend the current ICRF. From astrometric results provided by the IVS as new data and analysis become available, the ICRS Center will periodically issue updated catalogs of the current ICRF. It will provide J2000 names for new sources and assure that such catalogs are consistent with the ICRF and the ICRS.

- The ICRS Center together with the IVS will provide parameters to quantify the astrometric quality of sources.

- The ICRS Center will have the responsibility of monitoring the links to other frames that permit the access of all users to the ICRS.

- In coordination with the IVS and the IAU Working Group on the International Celestial Reference System, the ICRS Center will prepare recommendations for each future ICRS realization, which upon adoption by the IAU would replace the then current ICRF. These recommendations would be on the basis of studies developed at the ICRS Center and conducted jointly with the IVS.

- In coordination with other IERS Product Centers and the Analysis Coordinator, the ICRS Center will maintain the long-term consistency of the ICRF, ITRF and Earth orientation time series.

- The ICRS Center will coordinate with the IVS the data and information to be provided to the IERS Central Bureau and to the IERS Data Center for archiving and distribution.

A representative of the ICRS Product Center will serve on the Directing Board for up to two four-year terms.

ITRS Product Center

The ITRS Center is responsible for the maintenance of the ITRF as the realization of the ITRS.To fulfil this function, the ITRS Center must have a broad overview of the entirety as well as the constituent networks that form the ITRF. It promotes the connection and integration of these networks through technique collocations and accurate, documented local surveys. From geodetic input provided by the Technique Centers and/or individual Analysis Centers, the ITRS Center forms a combined ITRF, evaluates the results globally and at each individual point, and analyses discrepancies. The ITRS Center distributes the ITRF for public use and provides feedback to the Technique Centers, Analysis Centers, and local survey organizations. To advance the state of the art, the ITRS Center develops and evaluates rigorous combination algorithms and refines the conceptual basis of the ITRS. The ITRS Center works under the guidance of the IERS Analysis Coordinator to ensure the consistency of IERS reference frames and EOP.

A representative of the ITRS Product Center will serve on the Directing Board for up to two four-year terms.

Combination Research Center(s)

Combination Research Center(s) are required to develop combination procedures at two different levels: a) observation of the various techniques and b) data provided by the techniques contributing to the IERS. The center(s) develop recommended method(s), provide detailed description(s), and make the necessary software available to the Analysis Coordinator. The Center(s) provide recommendations regarding the implementation of the combination procedure to the Analysis Coordinator. The center(s) are expected to work closely together with each other and with the Analysis Coordinator. Suggested combination procedures must be well documented and thoroughly tested. Centers may assume that the Technique Centers will provide the necessary data for analyses and demonstrations although innovations in analysis proceedings may also be necessary.

A person chosen from the representatives of the selected proposals will serve on the Directing Board for up to two four-year terms.

Global Geophysical Fluids Product Center

[This section is only included for information. No call for participation is issued at this time for the GGF as its structure is already in place.]

The Global Geophysical Fluids (GGF) Center was established by IERS on its 10th anniversary day January 1, 1998, in an effort to expand its services to the scientific community. Under the GGF Center, seven Special Bureaus (SB) were selected, each to be responsible for research activities relating to a specific Earth component or aspect of the geophysical fluids of the Earth system. They are: Atmosphere, Ocean, Ocean Tides, Hydrology, Mantle, Core, and Gravity/Geocenter. The GGF Center and the SBs have 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 geocenter that are caused by mass transport in the geophysical fluids. The angular momenta and the related torques, gravitational coefficients, and geocenter shift 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, algorithms and data formats are standardized. The results are archived and made available to the scientific research community.

Analysis Coordinator

The Analysis Coordinator is responsible for the long-term and internal consistency of the IERS products. He/she is responsible for ensuring the appropriate combination of the Technique Center products into the single set of official IERS products and the archiving of the products at the Central Bureau or elsewhere.

The Analysis Coordinator will monitor the Technique Center and Product Center activities to ensure that the IERS objectives are carried out. This is accomplished through direct contact with the independent Technique Center Analysis Coordinators or equivalent. Specific expectations include quality control, performance evaluation, and continued development of appropriate analysis standards. The Analysis Coordinator may commission in concert with the Technique and Analysis Center Coordinators certain measurement and analysis programs for the purpose of improving the accuracy and consistency of IERS products. The Analysis Coordinator interacts fully with the Central Bureau and the Product Centers. The tasks of the Analysis Coordinator require at least a full-time position.

The Analysis Coordinator is a voting member of the IERS Directing Board and is generally selected every four years by the majority vote of the Technique Center's representatives.

Central Bureau

The IERS Terms of Reference specify that the Central Bureau (CB) is responsible for the general management and the coordination of the IERS. It collects data from the Technique Centers and also the products resulting from the Combination Research Center(s) and Product Centers to users via its Web/ftp site and electronic procedures. The CB disseminates to the user community the appropriate information on Earth-orientation and the terrestrial and celestial reference systems.

The Central Bureau manages the IERS activities in conjunction with the Analysis Coordinator, the Product Centers and the Combination Research Center(s). The CB coordinates the activities of the different IERS groups. It makes analyses of all IERS products in close cooperation with the Analysis Coordinator. Via its Web/ftp site and electronic mailing, it ensures the day-to-day interface with the user Community. It organizes and publishes an Annual Report, Technical Notes, Conventions and various other documents. It distributes by e-mail information on the daily activity of the IERS via mailing, newsletters, gazettes... It organizes dedicated campaigns, meetings and workshops. It acts as the executive arm of the Directing Board (DB), provides the secretariat for the DB, organizes the Board meetings and edits the meeting minutes. It is in charge of the interface with associate and corresponding members.

A representative of the Central Bureau will serve on the Directing Board for up to two four-year terms.

V.2 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. 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.

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.

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.

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. Ex officio IERS Correspondents are the following persons:

IAG General Secretary

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

December 18, 2000

V.3 Members of the IERS Directing Board in 2001

Chair

Jan Vondrák
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V.4 Organisation of the IERS in 2001

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ITRS Combination Centres

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President of IAU Division I	N. Capitaine
President of IAU Commission 19	N. Capitaine
President of IAU Commission 31	G. Petit
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General Secretary of IAG	C. Tscherning
President of IAG Section II	C.K. Shum
President of LAG Section V	C. Wilson
President of IAG Commission 8 (CSTG)	H. Drewes

Appendix 2: Electronic Access to IERS Products, Publications and Centres

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

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 (in preparation):
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://bowie.gsfc.nasa.gov/ggfc/geo_grav.htm (under construction)

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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Web site: http://dgfi.badw-muenchen.de/dgfi/WWW/D/d1_en.html

Combination Research Centres

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

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Web site: http://dgfi.badw-muenchen.de/dgfi/WWW/D/d1_en.html

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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)
Web page: http://www.iers.org/iers/crc/gfz/

Geodätisches Institut der Universität Bonn (GIUB)
Web page: http://www.iers.org/iers/crc/giub/

Groupe de Recherches de Géodésie Spatiale (GRGS)
Web page: http://www.iers.org/iers/crc/grgs/

Institute of Applied Astronomy, St. Petersburg (IAA)
Web page: http://www.iers.org/iers/crc/iaa/

Institut Géographique National (IGN), Ecole Nationale des Sciences Géographiques (ENSG), Laboratoire de Recherche en Géodésie (LAREG)
Web page: http://www.iers.org/iers/crc/ign/

Jet Propulsion Laboratory (JPL)
Web page: http://www.iers.org/iers/crc/jpl/

Appendix 3: IERS Technical Notes and Annual Reports

IERS Technical Notes

Back issues still available:

No. 14: P. Charlot (ed.): Earth orientation, reference frames and atmospheric excitation functions submitted for the 1992 IERS Annual Report. *(Available for libraries only)*

No. 16: J. O. Dickey and M. Feissel (eds.): Results from the SEARCH'92 Campaign. *(Available for libraries only)*

No. 17: P. Charlot (ed.): Earth orientation, reference frames and atmospheric excitation functions submitted for the 1993 IERS Annual Report.

No. 19: P. Charlot (ed.): Earth orientation and reference frames submitted for the 1994 IERS Annual Report.

No. 21: D. D. McCarthy (ed.): IERS Conventions (1996).

No. 22: C. Reigber and M. Feissel (eds.): IERS missions, present and future. Report on the 1996 IERS Workshop.

No. 24: C. Boucher, Z. Altamimi, P. Sillard (eds.): Results and Analysis of the ITRF96.

No. 25: J. Ray (ed.): Analysis Campaign to Investigate Motions of the Geocenter.

No. 26: D. Salstein, B. Kolaczek, D. Gambis (eds.): El Nino, earth rotation, and related phenomena.

No. 27: C. Boucher, Z. Altamimi, P. Sillard (eds.): The 1997 International Terrestrial Reference Frame (ITRF97).

No 28: B. Kolaczek, H. Schuh, D. Gambis (eds.): High frequency to subseasonal variations in Earth Rotation.

IERS Annual Reports

Back issues still available:

1989 *(Available for libraries only)*
1990 *(Available for libraries only)*
1992
1993
1994
1995
1996 *(Available for libraries only)*
1997
1999

For a free copy of these publications, please write to the IERS Central Bureau (address see Chapter V.4).

Appendix 4: Acronyms

AAM	Atmospheric Angular Momentum
AC	Analysis Centre
AC	Analysis Coordinator
AER	Atmospheric and Environmental Research Inc.
AGU	American Geophysical Union
AICAS	Astronomical Institute, Academy of Sciences of the Czech Republic
APSG	Asia-Pacific Space Geodynamics
AUSLIG	Australian Surveying and Land Information Group (now: GEOSCIENCE AUSTRALIA - National Mapping Division)
AVISO	Archiving, Validation and Interpretation of Satellites Oceanographic data
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
CB	Central Bureau
CEP	Celestial Ephemeris Pole
CERGA	Centre d'Etudes et de Recherches Géodynamiques et Astronomiques
CCIR	International Radio Consultative Committee
CCTF	Comité Consultatif des Temps et Fréquences
CDDIS	NASA Crustal Dynamics Data Information System
CGS	Centre di Geodesia Spatiale
CIP	Celestial Intermediate Pole
CLG	Central Laboratory for Geodesy
CLS	Collecte, Localisation, Satellites
CMB	core-mantle boundary
CNES	Centre National d'Etude Spatiale
COD	Centre for Orbit Determination
CODE	Centre for Orbit Determination in Europe
CORE	NASA Continuous Observations of the Rotation of the Earth
CRC	Combination Research Centre
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory
CSR	Center for Space Research
CSTG	Commission on International Coordination of Space Techniques for Geodesy and Geodynamics
DANOF	Département d'Astronomie Fondamentale
DAO	GSFC Data Assimilation Office
DB	Directing Board
DEOS	Delft Institute for Earth-Oriented Space Research
DGFI	Deutsches Geodätisches Forschungsinstitut
DIODE	Détermination Immédiate d'Orbite par Doris Embarqué
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
EGS	European Geophysical Society
EMR	Energy, Mines and Resources Canada (replaced by NRCan)
ENSG	Ecole Nationale de Sciences Geographiques
EOP	Earth Orientation Parameters
ERP	Earth Rotation Parameters
ESA	European Space Agency
ESOC	European Space Agency Operational Center
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FESG	Forschungseinrichtung Satellitengeodäsie, Technical University Munich
FFI	Forsvarets forskningsinstitutt
FK5	Fifth Fundamental Catalogue
FSG	Forschungsgruppe Satellitengeodäsie
GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
GFZ	GeoForschungsZentrum Potsdam
GGFC	Global Geophysical Fluids Center
GIUB	Geodetic Institute of the University of Bonn

GLONASS	Global Navigation Satellite System
GMST	Greenwich Mean Sidereal Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRGS	Groupe de Recherches de Géodésie Spatiale
GSFC	Goddard Space Flight Center
GSI	Geographical Survey Institute
GST	Greenwich Sidereal Time
IAA	Institute of Applied Astronomy, St. Petersburg
IAG	International Association of Geodesy
IAPSO	International Association for the Physical Sciences of the Ocean
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IDS	International DORIS Service
IERS	International Earth Rotation Service
IGN	Institut Géographique National
IGR	IGS rapid (orbit)
IGS	International GPS Service
ILRS	International Laser Ranging Service
ILS	International Latitude Service
INASAN	INstitut AStronomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)
INSU	Institut des Sciences de l'Univers
IRIS	International Radio Interferometric Surveying
IRM	IERS Reference Meridian
IRP	IERS Reference Pole
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
LAREG	Laboratoire de Recherche en Geodesie
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LEO	Low Earth Orbit
LLR	Lunar Laser Ranging
LOD	Length of Day
mas	milliarcsecond(s)
MCC	Russian Mission Control Centre
MJD	Modified Julian Day
MLRS	McDonald Observatory Laser Ranging Station
NASA	U.S. National Aeronautics and Space Administration
NAVEX	NAVNET Experiment
NAVNET	U.S. Navy VLBI Network
NCEP	U.S. National Centers for Environmental Prediction
NEOS	U.S. National Earth Orientation Service
NGS	National Geodetic Survey
NIPR	National Institute for Polar Research
NNR	No-net-rotation
NOAA	National Oceanic and Atmospheric Administration
NRAO	U.S. National Radio Astronomy Observatory
NRCan	Natural Resources, Canada (formerly: EMR)
NUVEL	Northwestern University Velocity Model
OAM	Oceanic Angular Momentum
OPA	Observatoire de Paris
PC	Product Centre
POLARIS	Polar motion Analysis by Radio Interferometry
ppb	parts per billion (10^{-9})
PZT	Photographic Zenith Tube (Telescope)
RA	Right ascension
RINEX	Receiver INdependent EXchange format
rms	Root Mean Square
ROB	Royal Observatory of Belgium
RSC	Radio Source Coordinates
SB	Special Bureau
SEDI	Study of the Earth Deep Interior
SHA	Shanghai Observatory
SI	Systeme International (International System of Units)

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
SOD	CNES Service d'Orbitographie DORIS
SPBU	St Petersburg University
SSALTO	Segment Sol multi-mission d'ALTimétrie, d'Orbitographie et de localisation précise
SSC	Sets of Stations Coordinates
SSV	Sets of Stations Velocities
TAI	Temps Atomique International (International Atomic Time)
TC	Technique Centre
TIGO	Transportable Integrated Geophysical Observatory
TRF	Terrestrial Reference Frame
TT	Terrestrial Time
TU	Technical University
USNO	United States Naval Observatory
UT	University of Texas
UT, UT1	Universal Time
UTC	Coordinated Universal Time
UTexas	University of Texas
UTXMO	University of Texas McDonald Observatory
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VOL	Variations of Latitude
VS NIIFTRI	East-Siberian Research Institute for Physics-technical and Radio-technical Measurements
WGRF	IAU Working Group on Reference Frames
wrms	Weighted Root Mean Square
ZPD	zenith path delay