

International Earth Rotation and Reference Systems Service (IERS)

<http://www.iers.org>

Chair of the Directing Board: Chopo Ma (USA)
Director of the Central Bureau: Bernd Richter (Germany)

Overview

The International Earth Rotation and Reference Systems Service continued its operation as in previous years. It provided Earth orientation data, terrestrial and celestial references frames, as well as geophysical fluids data to the scientific and other communities.

Earth orientation data have been issued on a daily, weekly, and monthly basis, and new global geophysical fluids data were added. Work on new realizations of the International Terrestrial Reference System (ITRF2008) and the International Celestial Reference System (ICRF2) was finished. The IERS Conventions (i.e. standards etc.) have been updated regularly, a new revised edition was published at the end of 2010.

The IERS continued to issue Technical Notes, Annual Reports, Bulletins, and Newsletters. It held Workshops on Conventions (September 2007) and on EOP Combination and Prediction (October 2009) and organized two GGOS Unified Analysis Workshops and a follow-up meeting (December 2007, April 2008, December 2009).

The IERS Data and Information System (DIS) at the web site www.iers.org, maintained by the Central Bureau, has been updated, improved and enlarged continually. It presents information related to the IERS and the topics of Earth rotation and reference systems. As the central access point to all IERS products it provides tools for searching within the products (data and publications), to work with the products and to download them. The DIS provides also links to other servers, among these to about 20 web sites run by other IERS components.

Activities

Publications

The following IERS publications and newsletters appeared between mid-2007 and 2011:

- IERS Technical Note No. 35: The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry
- IERS Technical Note No. 36: IERS Conventions (2010)
- IERS Annual Reports 2005, 2006, and 2007
- IERS Bulletin A, B, C, and D (weekly to half-yearly)
- IERS Messages Nos. 115 to 190

Workshops

The IERS organized the following Workshops:

- *Workshop on Conventions (Sèvres, France, September 20–21, 2007)*. The main conclusions of the workshop include the classification of models, the criteria for choosing

models for conventional station displacements, the treatment of non-tidal loading effects, existing and proposed new models for S1/S2 atmospheric loading, the troposphere, a conventional model for the effect of ocean tides on geopotential, a model for diurnal and semidiurnal EOP variations, and recommendations for handling technique-dependent effects.

- *GGOS Unified Analysis Workshops (Monterey, CA, USA, December 5–7, 2007)*. It was intended to be a forum to exchange information and results and thus increase the common understanding of all the technique representatives for each of the individual techniques as they contribute to GGOS. The participants decided the following action items and recommendations: extension of the SINEX format for other parameter types and representations; tests on atmospheric loading: application on the observation or solution level?; generation of daily SINEX files (IVS Intensives and IGS Rapids); parameterisation and modelling for the next ITRF; benchmark tests for models common to several techniques; documentation of AC modelling standards and parameterisation; definition of meta data standards (e.g. SINEX meta data block).
- *GGOS Unified Analysis Workshop, Follow-Up Meeting (Vienna, Austria, April 15, 2008)*. The status of the action items from the previous workshop, SINEX issues, a proposal for reference pressure, and a common analysis description form were discussed.
- *Workshop on EOP Combination and Prediction (Warsaw, Poland, October 19–21, 2009)*. Its main goal was to provide the current state-of-the-art for EOP predictions in terms of data sets and algorithms as well as to discuss recommended actions for improving EOP predictions, including improving the IERS rapid combined series. The Workshop was attended by about 50 participants and about 40 papers and 5 posters were presented. The 20 concluding recommendations concerned e.g. EOP tidal models, the IERS precession/nutation model, a priori tropospheric gradient models, the latency of IVS intensive and IGS rapid EOP products, systematic errors in EOP, EOP + TRF consistency, modern Earth rotation theory, fluid excitation functions time series and their forecasts as well as required EOP prediction length and accuracy. The proceedings of this Workshop were published in a special issue of *Artificial Satellites* Vol. 45, No. 2, 2010.
- *Second GGOS Unified Analysis Workshop (Grand Hyatt, San Francisco, CA, USA, December 11–12, 2009)*. This workshop was intended to be a forum for the exchange of information and results concerning both problems common to more than one service and problems specific to an individual service. It was organized in the following four sessions: 1. Products by the Services, GGOS Portal and Metadata (including portal and meta data). 2. Modelling Deficiencies and Modelling Based on External Data (Atmosphere, Ocean, ...). 3. Combination Strategies, Common Parameters and Combined Products. 4. Network Simulations and Analyses. Among the action items and recommendations were the following: Introduce benchmarking of diverse models in the software packages, that are common to all techniques; distribute new version 2.10 of the SINEX format; create an IERS Working Group for the maintenance and updating of the SINEX format; establish a data base of daily SINEX files from reprocessing activities; accomplish a Troposphere Combination Campaign; work towards a subdaily resolution and a representation of EOPs; establish an IERS Working Group on Parameterization and Modeling for IERS201x (ITRF/EOP/ICRF); work on documentation of modeling and parameterization standards; investigate reference pressure for atmospheric loading, atmospheric loading on the observation level, subdaily ERP tidal model, combination of SLR range biases, EOP parameterization, solar radiation pressure models.

Abstracts and presentations of these workshops are available at the IERS web site.

Activities of the IERS components

Central components

The *IERS Directing Board* (DB) met twice each year to decide on important matters of the Service like structural changes, overall strategy, creating working groups, launching projects, changing Terms of Reference, etc:

- Meeting No. 45 in San Francisco, December 11, 2007;
- No. 46 in Vienna, April 13, 2008;
- No. 47 in Washington D.C., October 27–28, 2008;
- No. 48 in Vienna, April 19, 2009;
- No. 49 in Warsaw, October 22–23, 2009;
- No. 50 in Vienna, May 1, 2010;
- No. 51 in Paris, October 10, 2010;
- No. 52 in Vienna, April 3, 2011.

Among the most important decisions made by the DB in 2007–2011 were the following:

- Terminate the present CRCs at the end of 2008.
- Revitalise the present GGFC Special Bureaus by new calls.
- Add a new Special Bureau for Propagation Delays.
- IERS will work for membership in the newly structured ICSU World Data System.

The *Central Bureau* coordinated the work of the Directing Board and the IERS in general, organized meetings and issued publications. It further developed the IERS Data and Information System based on modern technologies for internet-based exchange of data and information like the application of the extensible Markup Language (XML) and the generation and administration of ISO standardised meta data. The system provides general information on the structure and the components of the IERS and gives access to all products. A plot tool was developed and installed which allows visualizing some of the Earth orientation data provided by the IERS. The data include pole coordinates, UT1–UTC, LOD, and celestial pole offsets. For most IERS products, meta data according to ISO 19115 were produced as well as a proposal for SINEX file meta data. The move to a new Content Management System was finished and the web site was re-launched in February 2010.

The work of the *Analysis Coordinator* focused on coordinating the Combination Pilot Project, to prepare the GGOS Unified Analysis Workshops, and to propose a new version of the SINEX data format.

Technique Centres

The Technique Centres are autonomous independent services, which cooperate with the IERS:

- *International GNSS Service* (IGS)
- *International Laser Ranging Service* (ILRS)
- *International VLBI Service for Geodesy and Astrometry* (IVS)
- *International DORIS Service* (IDS)

For the work of the Technique Centres, see their individual reports to IAG.

Product Centres

The *Earth Orientation Centre* is responsible for monitoring of long-term earth orientation parameters, publications for time dissemination and leap second announcements. It issues IERS Bulletins B, C, and D and corresponding data files. An extended EOP Web Service was developed that offers the Earth orientation parameters and the Earth orientation matrix at a given date. The tool allows the computation of the excitation function of the Earth rotation and the comparison with the geophysical excitation functions. Since June 2007 a new IERS EOP reference series, IERS 05 C 04 consistent with ITRF2005 was available. In May 2009, Bulletin B was revised following a survey which was made among the community. In order to be consistent with ITRF2008, the IERS EOP C04 was revised again in 2011. The new solution 08 C04 is the reference solution which started on 1 February 2011. Relative to 05 C04, changes in the EOP series consisted of a negligible bias in x-pole and a bias of about -50 ± 25 microarcseconds in y-pole in the sense of $y(08C04) - y(05C04)$; and changes in UT1–TAI and celestial pole offsets are respectively on the order of 2 microseconds, 1, and 17 microarcseconds which are at the level of the WRMS between IVS individual solutions. Other IERS EOP series (Bulletin B, C01) are also expressed in this new system.

The *Rapid Service/Prediction Centre* 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 before the IERS final values are available. It issues IERS Bulletin A and corresponding data files. Further work has been dedicated to improvement of the centre's products. The system of the Bulletin A was changed to match the system of the new IERS 05 C 04 and 08 C 04 series. In January 2009, the centre moved its web site to a new address and changed its style considerably.

The *Conventions Centre* prepared a large number of updates to the IERS Conventions (2003). A Conventions Workshop was held in September 2007 (see above) in preparation for a new registered edition, which was finished in October 2010 and published online as an IERS Technical Note in December 2010. The Centre maintains a web site including pages for the Conventions updates.

Involvement by *ICRS Centre* personnel in the celestial reference frame VLBI program has continued, increasing the number of observations of ICRF quasars in the southern celestial hemisphere and continuing an extensive observing program in the northern hemisphere. This observing program eventually resulted in a new realization of the ICRS, called ICRF2. It contains precise positions of 3414 compact radio astronomical sources, more than five times the number as in the first ICRF (ICRF1). Further, the ICRF2 was found to have a noise floor of approximately 40 microarcseconds, some 5–6 times better than ICRF1, and an axis stability of approximately 10 microarcseconds, nearly twice as stable as ICRF1. Alignment of ICRF2 with the International Celestial Reference System (ICRS) was made using 138 stable sources common to both ICRF2 and ICRF-Ext2. Documentation about ICRF2 was published online as IERS Technical Note 35 in July 2009 and was distributed in printed form in 2010. A “Resolution on the Second Realization of the International Celestial Reference Frame” was prepared for the IAU General Assembly in August 2009. In addition to these activities, the ICRS Centre has continued the various tasks devoted to the monitoring of ICRF2 sources, the link with the dynamical system (through LLR, pulsar timing, and observation of asteroids), the construction of the LQAC (Large Quasar Astrometric Catalogue) and of the LQRF (Large Quasar reference Frame).

The *ITRS Centre* participated in complete surveys of some co-location sites, contributed to specifications for ITRF densification, developed the tools and methodology for generating the

ITRF from SINEX inputs from the various space geodesy techniques (in cooperation with the ITRS Combination Centres), and maintained the IERS network. The ITRS Centre, together with the ITRS Combination Centres, generated a new ITRF solution (ITRF2008, release May 2010). A detailed article on ITRF2008 was published online in *Journal of Geodesy*.

The *Global Geophysical Fluids Centre* (GGFC) consisted of eight Special Bureaus (SB) for Atmosphere, Core, Gravity/Geocentre, Hydrology, Loading, Mantle, Oceans, and Tides. These provided data related to global geophysical fluids such as co-seismic excitation of Earth rotational and gravitational changes, glacial isostatic adjustment, core angular momentum changes, geocentre variations, oceanic tidal angular momentum, oceanic tidal variations in earth rotation, low-degree spherical harmonics of ocean and atmospheric tides, models for global oceanic angular momentum, models for oceanic centre-of-mass, a model for ocean bottom pressure, measurements of ocean bottom pressure, continental water storage and water flux, effective atmospheric angular momentum functions, spherical harmonic coefficients of surface pressure, global friction torque and global mountain torque, and Earth surface deformation due to surface mass loading. In May 2009 the IERS released a Call for Proposals, whose purpose was to restructure the GGFC. The structural changes were instituted to 1) allow for the establishment of operational products, i.e., those products, which are provided with regularity and which have been evaluated as being reliable and precise; and to 2) allow for inclusion of new operational products. The new structure is the following: The GGFC was first broken up into an Operational and a Non-operational component. The operational component would house data that is required for other IERS (non-GGFC) product Centers to generate their products. The Non-operational component, entitled GGFC Science and Support Products, would consist of products and/or models (environmental fluids or solid Earth) that do not change frequently, e.g. ocean and solid Earth tide models, or models of post-glacial rebound. The SB Atmospheres, Hydrology and Oceans were already firmly established in the previous GGFC structure. A new operational SB, Combination Products, was established to house the new data sets that model the mass movement of combined environmental fluids such as oceans+atmosphere.

Combination Centres and Working Groups

Nine *Combination Research Centres* (CRC) have been working on the development of methods and software for the combination of data and products from different techniques. The CRCs were terminated by December 31, 2008. They will be replaced by *Research Centres* which will be responsible for carrying out research on a specific subject, related to a corresponding Product Centre and limited to a term of 4–5 years. Three *ITRS Combination Centres* are responsible for providing ITRF products by combining ITRF inputs.

Areas of work of the *Working Group on Site Survey and Co-location* are standards and documentation (guidelines, survey reports, etc.), coordination (share know-how and join efforts between survey teams), research (investigate discrepancies between space geodesy and tie vectors, alignment of tie vectors into a global frame), and cooperation. In 2009 the working group updated its Charter, changed the list of its members and presented a new schedule for work. The major task of the *Working Group on Combination* was the coordination of the IERS Combination Pilot Project. The working group was terminated by December 31, 2008. A new *Working Group on Combination at the Observation Level* was established at a kick-off meeting in October 2009. Its major task is to study methods and advantages of combining techniques at the observation level, searching for an optimal strategy to solve for geodetic parameters. Demonstration will be based on weekly combined SINEX files (containing unconstrained normal equations of station coordinates, EOPs, nutation parameters and eventually quasar coordinates) from all space geodetic techniques together.

The new products resulting from these combination procedures will be compared to the current IERS products routinely produced. The working group maintains an online “Forum Multi-technique Combinations”. The *Working Group on Prediction* existed from December 2005 to October 2009. It was designed to build upon the foundation laid by the Prediction Comparison Campaign (PCC) and also investigate the new data sets from the Combination Pilot Project. The objectives of the PCC were the comparison of the various methods, models, techniques and strategies, which can be applied for EOP prediction with equal rules. In total 12 scientists participated with 20 prediction techniques in four categories: ultra short-term (10 days), short-term (30 days), medium term (500 days) and long term (20 years). The purpose of the *IERS/IVS Working Group on the Second Realization of the ICRF* was to generate the second realization of the ICRF from VLBI observations of extragalactic radio sources, consistent with the current realization of the ITRF and EOP data products.