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

IERS
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2010

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IERS Annual Report 2010

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1 Foreword

In 2010 the IERS achieved several important milestones in the evolution of its key products for scientific and societal uses. The IERS Conventions (2010) were finalized and published as IERS Technical Note 36. It is widely understood that the IERS Conventions are the basis for the underlying analysis and interpretation of the ITRF, EOP and ICRF and require continual updating as geophysical and astronomical models are improved. Through the coordinated efforts of the ITRS Center, the ITRS Combination Centers and the four Technique Centers the ITRF2008 was released along with the companion DTRF2008. It remains the goal of the IERS to encourage other ITRS combination activities and continued investigation of the combination process. Using ITRF2008 the Earth Orientation Center generated a new, consistent series C04_08 to replace C04_05. As the ICRF2 became the fundamental celestial reference frame on 1 January 2010 according to IAU Resolution B3, 2010 saw the renewal of all the essential IERS products.

In other areas the Rapid Service/Prediction Center improved the use of AAM data and began a pilot project on EOP prediction. The new structure of the GGFC became effective on 1 January 2010 with a new Special Bureau for Combination and new product centers. It is expected that the GGFC products will improve the analysis supporting the main IERS products. Looking back in history, the Central Bureau digitized IERS Technical Notes Nos. 1 – 28, published between 1989 and 2000, which are now available at the IERS web site.

The achievements of the IERS in 2010 mark progress toward the vision articulated by Markus Rothacher, the IERS Analysis Coordinator whose term completed in 2010. The new Analysis Coordinator Tom Herring will bring a fresh pair of eyes on the framework and practices of the IERS as it continues its necessary service work and plans its next steps.

Chopo Ma
Chair, IERS Directing Board (2005–2012)

2 The IERS
2.1 Structure

From 2010 to 2013, the IERS had the following components. For their functions see the Terms of Reference (Appendix 1), for addresses and electronic access see Appendices 3 and 4. Dates are given for changes between 2010 and 2013.

Analysis Coordinator

Markus Rothacher (until 9 October 2010),
Thomas Herring (since 10 October 2010)

Central Bureau

Director: Bernd Richter (1 January 2001 to 31 March 2013),
Daniela Thaller (since 1 April 2013)

Technique Centres

International GNSS Service (IGS)
IGS Representatives to the IERS Directing Board:
Steven Fisher (until May 2010, since 1 January 2013),
Urs Hugentobler (from May 2010 to April 2011),
Tim Springer (since May 2011)
IERS Representative to the IGS Governing Board: Claude Boucher

International Laser Ranging Service (ILRS)
ILRS Representatives to the IERS Directing Board:
Jürgen Müller, Erricos C. Pavlis
IERS Representative to the ILRS Directing Board:
Bob E. Schutz

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

International DORIS Service (IDS)
IDS representatives to the IERS:
Frank G. Lemoine, Bruno Garayt (from December 2009 to December 2012), Jérôme Saunier (since 1 January 2013)
IERS Representative to the IDS Governing Board:
Chopo Ma

Product Centres

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

Rapid Service/Prediction Centre
Primary scientist and representative to the IERS Directing Board: Brian J. Luzum

Conventions Centre
Primary scientists: Brian J. Luzum, Gérard Petit
Representative to the IERS Directing Board:
Gérard Petit (from 1 January 2010 to 31 December 2012)
Brian J. Luzum (since 1 January 2013)

ICRS Centre
Primary scientists: Ralph A. Gaume, Jean Souchay
Current representative to the IERS Directing Board:
Jean Souchay (until 31 December 2012),
Ralph A. Gaume (since 1 January 2013)

ITRS Centre
Primary scientist and representative to the IERS Directing Board: Zuheir Altamimi

Global Geophysical Fluids Centre
Head and representative to the IERS Directing Board:
Tonie van Dam

Special Bureau for the Oceans
Chair: Richard S. Gross

Special Bureau for Hydrology
Chair: Jianli Chen

Special Bureau for the Atmosphere
Chair: David A. Salstein

Special Bureau for Combination (since 1 January 2010)
Chair: Tonie van Dam

ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)
Primary scientist: Hermann Drewes (until April 2010)
Manuela Seitz (since May 2010)

Institut Géographique National (IGN)
Primary scientist: Zuheir Altamimi

Natural Resources Canada (NRCan)
(until 31 December 2009)
Primary scientist: Remi Ferland

Jet Propulsion Laboratory (JPL)
(established in December 2012)
Primary scientist: Richard S. Gross

Working Groups

Working Group on Site Survey and Co-location
Chair: Pierguido Sarti

IERS/IVS Working Group on the Second Realization of the ICRF
Chair: Chopo Ma

Working Group on Combination at the Observation Level
Chair: Richard Biancale

Working Group on SINEX Format
(established in April 2011)
Chair: Daniela Thaller

Working Group on Site Coordinate Time Series Format
(established in April 2012)
Chair: Laurent Soudarin

(*Status as of March 2013*)

2.2 Directing Board

In 2010 to 2013, the IERS Directing Board had the following members (for addresses see Appendix 2):

Chair	Chopo Ma (until 31 December 2012) Brian J. Luzum (since 1 January 2013)
Analysis Coordinator	Markus Rothacher (until 9 October 2010) Thomas Herring (since 10 October 2010)
Product Centres Representatives	
Earth Orientation Centre	Daniel Gambis
Rapid Service/Prediction Centre	Brian J. Luzum
Conventions Centre	Gérard Petit (1 January 2010 to 31 December 2012), Brian J. Luzum (since 1 January 2013)
ICRS Centre	Jean Souchay (until 31 December 2012), Ralph A. Gaume (since 1 January 2013)
ITRS Centre	Zuheir Altamimi
Global Geophysical Fluids Centre	Tonie van Dam
Central Bureau	Bernd Richter (1 January 2001 to 31 March 2013, Daniela Thaller (since 1 April 2013)
Technique Centers Representatives	
IGS	Steven Fisher (until May 2010, since 1 January 2013), Urs Hugentobler (May 2010 to April 2011), Tim Springer (since May 2011)
ILRS	Jürgen Müller, Erricos C. Pavlis
IVS	Chopo Ma, Rüdiger Haas
IDS	Frank G. Lemoine, Bruno Garayt (until 31 December 2012), Jérôme Saunier (since 1 January 2013)
Union Representatives	
IAU	Aleksander Brzezinski
IAG / IUGG	Clark R. Wilson
GGOS (since March 2012)	Bernd Richter

2.3 Associate Members

Andersen, Ole Baltazar
Appleby, Graham
Arias, Elisa Felicitas
Behrend, Dirk
Biancale, Richard
Boucher, Claude
Bruyninx, Carine
Capitaine, Nicole
Carter, William E.
Chao, Benjamin F.
Chen, Jianli
Fagard, Hervé
Feissel-Vernier, Martine
Fisher, Steven
Garayt, Bruno
Gendt, Gerd
Gross, Richard S.
Hugentobler, Urs
Kolaczek, Barbara
McCarthy, Dennis D.
Melbourne, William G.
Moore, Angelyn W.
Neilan, Ruth E.
Noomen, Ron
Nothnagel, Axel
Pearlman, Michael R.
Petit, Gérard
Pugh, David
Ray, Jim
Reigber, Christoph
Rothacher, Markus
Salstein, David
Sarti, Pierguido
Schuh, Harald
Schutz, Bob E.
Shelus, Peter J.
Seitz, Manuela
Souchay, Jean
Soudarin, Laurent
Thaller, Daniela
Veillet, Christian
Vondrák, Jan
Weber, Robert
Willis, Pascal
Wooden, William H.
Yatskiv, Yaroslav S.
Yokoyama, Koichi
Zhu, Sheng Yuan

Ex officio Associate Members:
IAG Secretary General: Hermann Drewes
IAU General Secretary: Thierry Montmerle
IUGG General Secretary: Alik Ismail-Zadeh
President of IAG Commission 1: Tonie van Dam
President of IAG Subcommission 1.1: Tom Herring
President of IAG Subcommission 1.2: Claude Boucher
President of IAG Subcommission 1.4: Johannes Böhm
President of IAG Commission 3: Richard S. Gross
President of IAG Subcommission 3.1:
President of IAG Subcommission 3.2: Markku Poutanen
President of IAG Subcommission 3.3: Maik Thomas
President of IAU Commission 8: Norbert Zacharias
President of IAU Commission 19: Cheng-Li Huang
President of IAU Commission 31: Mizuhiko Hosokawa
President of IAU Division A: Sergei A. Klioner

(*Status as of March 2013*)

3 Reports of IERS components
3.1 Directing Board

The IERS Directing Board (DB) met twice in the course of the year 2010. Summaries of these meetings are given below.

Meeting No. 50

May 1, 2010, Technical University of Vienna, Vienna, Austria

Introduction and approval of agenda

The agenda was accepted. The Chair, Chopo Ma, welcomed the guests and the members of the IERS Directing Board. Urs Hugentobler is the new IGS representative in the IERS DB. As the status and schedule of the ITRF2008 are discussed more external experts were invited than usual.

Formalities

Besides minor formal changes the Central Bureau received no further comments for the minutes of IERS DB No. 49.

Earth orientation products

Status and function of current and new / changed EO products

Daniel Gambis presented the report of the Earth Orientation Centre:

- Combination: short-term: GPS, long-term: VLBI.
- GPS has a constant offset.
- Two analyses have been done:
    1. Simultaneous study of annual and Chandler variations for GPS, VLBI and SLR. There is a good agreement between GPS and SLR, less with VLBI (higher discrepancies).
    2. Allan variance analysis of long term behaviour of EOP series (GPS flicker noise, VLBI white noise, SLR between flicker noise and white noise)
- An individual analysis of IGN and DGFI solutions can be found in their respective presentation.

IERS pilot project on prediction

Brian J. Luzum presented the pilot project set up to investigate the feasibility of initiating the operational ensemble EOP predictions and the participants' role within the project. The participants can either get involved with prediction series (daily data, prediction period is equal) or with combined prediction series (daily data, 1-day to 90-day predictions). Documentation of algorithms is mandatory in both cases.

The pilot project:

- Collection of all individual and combined predictions for archival, backup, and evaluation.
- Provide near-real-time feedback for all predictions.
- C04 as standard, predictions of different methods will be

compared to this standard.

- Expecting ~10 participants, comparison will be done in every case.
- Participants can bring in their solution or take them out to compare/combine.
- A later participation will be possible at any time.

The goal of the pilot project is to provide recommendations on the feasibility of producing operational ensemble EOP products. The estimated timeline envisages:

- Call for participation: June 2010 (notification of participants: July 2010).
- Providing sample data file and documentation of the participants: August 2010.
- Providing predictions operationally: September 2010 (October 2010 for combined predictions).
- Interim reports to IERS DB: 2010–2012 and a final report and recommendations in fall 2012.

Decision: The DB agreed on the pilot project.

New Action Items:

#50.01 Schedule for updating EOP XX C04 according to ITRF2008

#50.02 Prepare the call for proposals to participate in the EOP prediction pilot project, CB will distribute

Status of the new GGFC components

Tonie van Dam reported about construction of the new GGFC website: the skeleton structure is ready but some inputs are missing. The Special Bureaus for the Atmosphere and for the Oceans still have their old websites, the 6-month accreditation period is to be finished by summer.

She also presented the GGFC Status Report as of 1 April 2010. Short reports of the Special Bureaus for the Oceans and for the Atmosphere were received about their work, products, and the progress of the new web pages. There was no reply from the SB for Hydrology. An overview of the SBs concerning available new products and links to data server/websites was given. D. MacMillan, who continues to run the atml_load at NASA/GSFC, is a potential contributor and was asked for a proposal.

R. Koenig sent in a proposal concerning site displacements due to atmospheric pressure loading computed at GFZ.

New Action Items:

#50.03 Send the GFZ proposal by R. Koenig to SB chairs for review, GGFC chair should give a recommendation to IERS DB

#50.04 Complete the actions described in the GGFC report (improve website, invite other contributors)

Urs Hugentobler presented results of IGS products: final orbits

Reports from the Technique Centres

International GNSS Service (IGS)

and clocks, rapid orbits and clocks, ultra rapid orbits and clocks. There were 9 ACs between 1994 and 2007. Starting in 2011 decisions on new models and new reprocessing will be made. A real time pilot project on real time clocks was set up and will be combined at ESOC.

There is an issue on equipment change because there seem the be observed changes in data attributed to instrumental effects. An infrastructure committee set up by S. Fisher will handle numerous changes in the 400-station network detected big discrepancies due to frequent equipment changes at stations. On-site calibration of the stations, especially for radome covered antennas, could provide useful information.

The combination activities have been moved from NRCan to IGN.

New satellite antenna offsets will be updated in a new SINEX version.

GRGS (Groupe de Recherche de Géodésie Spaciale) will become a new AC, but this is not yet official.

There are only a few ACs for the ultra rapid orbits and ultra rapid clocks. IGS needs more ACs for the case that an AC fails.

International Laser Ranging Service (ILRS)

Erricos Pavlis presented a summary of the ILRS report. The are 8 ACs: ASI, BKG, GA, GFZ, GRGS, JCET, and NSGF. Concerning the ITRF2008P Tests, 4 ACs responded, 2 have provided some input so far:

- JCET report (E. Pavlis): ITRFP combination improves the a priori fits of the two LAGEOS data sets for the entire data period, there is a significant overall improvement to fits over the period 2006 to 2010 (collected data did not contribute to ITRF2005), and an even more significant improvement of data from 2009 which are not contributing to either combination.
- ASI report (V. Luceri): comparison of ILRSA vs. SLRF2005 and ITRF2008P, core sites gave a residual WRMS of ~4mm in the mean.

International VLBI Service for Geodesy and Astrometry (IVS)

Rüdiger Haas gave a short report on the IVS. The VLBI 2010 project is ongoing, some new telescopes have been approved for Spain and requested for Onsala, Sweden. The EO has potential low latency for UT1 but the ultra rapid sessions are not in the EOP products because they are not reduced operationally. He gave an overview of the analysis of a real-time correlated ultra rapid R&D session with respect to a rapid session and a priori and predicted UT series, showing a good agreement to the predicted values. The objective is to obtain the UT1 result within the shortest possible time. A recorded session Onsala – Tsukuba was correlated in 2–3 minutes with a new software correlator at GSI and the UT1 result was available with a latency of 45 min. Making it operational will need coordination.

ITRS/ITRF

Reports and decision on ITRF 2008

Zuheir Altamimi presented the status of ITRF2008, but no final consensus was reached with the DGFI solution. However, differences are not considered to be significant. ITRF2008 is already outdated for all South-American sites because of the Chile earthquake.
Summary of TC opinions after first tests:

- 75% of TCs favour the release of the ITRS Centre (IGN) solution for evaluation without additional delay.
- IVS, ILRS and IDS propose extensive evaluation of the two solutions.
- ITRF2008P was released to the TCs for evaluation on March 31, 2010.
- ITRF2008D solution is also available at the ITRS Centre server.

IVS did extensive evaluations, all IVS concerns will be satisfied for the final ITRF2008 solution.

Z. Altamimi proposed to the IERS DB:

- A final ITRF2008 solution will be ready and can be released before the end of May, 2010.
- Set up an extensive campaign of evaluation and comparison of the DGFI and IGN approaches and solutions until October 2010.

Concerning the evaluation/comparison campaign, the following data should at least made available for both solutions:

Combination procedure and starting assumptions, like frame definition handling of each technique, adjusted parameters, usage of local ties, method for relative technique weighting, discontinuity handling and velocity constraints, frame definition of the final combination. Full solutions and files for the 4 techniques. Local ties used and their weighting. Full post-fit residuals of technique solutions (positions, velocities, EOPs) and local ties. Additional test combinations must be provided.

Hermann Drewes presented a summary of the ITRF computation strategy at DGFI and the differences with respect to the combination technique at IGN. The principal difference is the accumulation of NEQs, followed by fixing the datum on the basis of normal equations (DGFI) and a final inversion of the normal equations, versus stacking the weekly inverted NEQs by similarity transformations, fixing the datum crust-fixed (IGN) for a final solution. There is a fundamental question of whether a “crust-fixed” reference frame takes into account the IERS. H. Drewes analysed a difference of 1 ppb for SLR/VLBI (corresponding to 6mm) and a moving geocentre of 1 mm/year.

H. Drewes is interested in discussing the two solutions and not only presenting them. He presented Manuela Seitz as his successor as director of the combination centre at DGFI for the next ITRF.

In addition to the DGFI report given at the IERS DB meeting, M. Seitz prepared a detailed presentation about the aspects of ITRF2008 computation and investigations at DGFI. Details are given concerning scale analysis and scale definition of ITRF2008 and the selection of local ties. In the chapter comparison with IGN solution station coordinates, datum parameters and EOPs are investigated and finally suggestions for improvements are given. Due to a lack of time it was not possible that M. Seitz gave the presentation, which is available on request from the author or the CB.

Recommendations for the next ITRF:

Markus Rothacher: keep all solutions open and accessible for all interested groups and persons.

Chopo Ma: better schedule for the next ITRF, giving more time for evaluation (problem: late response of ACs).

M. Rothacher: understanding the differences between the two solutions before the next ITRF will be computed.

H. Drewes proposed a new ITRF in 2012 in order to collect enough data within a minimum of 2 years after the earthquake in South America in 2010.

Z. Altamimi will author a short booklet as a technical note for the ITRF2005 (no technical note existing so far). For ITRF2008 a technical note is foreseen with a comparison and a note on DGFI solution.

IERS Working Group on on Site Survey and Co-location

As Pierguido Sarti could not participate in this IERS DB meeting, his report was distributed with the minutes, covering the following subjects:

- WG meetings: 1st WG meeting was held on December 16th, 2009 at San Francisco (detailed minutes can be found in the report). Next meeting on May 4, 2010 at EGU in Vienna. Agenda: Site survey standards, tie vector estimation, site survey activities, coordination and research, miscellaneous.
- EGU2010 session: A session covering all aspects relevant to the WG activity, “The Global Geodetic Observing System: Tying and Integrating Geodetic Techniques for Research and Applications”, covering the large inter-technique residuals in combinations of the different space-based and ground-based techniques. These discrepancies have to be reduced by modernising the

geodetic infrastructure and homogeneous processing of geodetic data.

IERS Working Group on Combination at the Observation Level

Daniel Gambis presented the report of the IERS WG for Richard Biancale:

A comparison campaign on combination at the observation level was set up to analyse the strategy of SINEX files processing at GRGS. The SINEX to GINS conversion was tested for AIUB SINEX files and the GRGS EOP determination was analysed and proposals given. A benchmark was established August, 10 to 30, 2008, the file exchange format is SINEX. Participating ACs are: AIUB, DGFI, ESOC, GFZ, GRGS. Showing a diagram he explained the strategy of SINEX files processing at GRGS. SINEX to GINS conversion: keep identified elements (parameter names), convert units used for EOP into GINS format, convert ASCII files into binary files. Solution estimation by NEQ inversion: adapt director files with the SINEX signalled elements, extract solutions from Dynamo solution files. Conversion of solution from GINS to SINEX: make SINEX files available via ftp. Summary: Homogenous SINEX format.

Decision: ITRF2008 of IGN will be the official ITRF2008, but in the Technical Note publication both solutions will be presented.

New Action Items:

#50.05 Send information of local survey in O'Higgins to Z. Altamimi

#50.06 Complete ITRF2008 according to proposed schedule

#50.07 Make available the DGFI final result for examination

New version of IERS Conventions

Brian J. Luzum presented for Gérard Petit the new reference edition of the IERS Conventions covering the updates of the different chapters highlighting the achieved points concerning:

- Ch. 3 Conventional dynamical realization of the ICRS
- Ch. 4 Terrestrial reference systems and frame
- Ch. 5 Transformation between ITRF and GCRS (rewritten, FCN model, introduction of librations)
- Ch. 6 Geopotential (ocean pole tide, new conventional geopotential model)
- Ch. 7 Displacement of reference points (conventional ocean tide loading. Ocean pole tide loading, technique-dependent effects, new conventional mean pole)
- Ch. 8 Tidal variations in the Earth's rotation (new model for zonal tides)
- Ch 9 Atmospheric propagation (optical: new model, radio: new conventional mapping functions, new section on ionosphere)
- CH. 10 General relativistic models for space-time

coordinates and equations of motion (new section, implementation of IAU recommendations)

and the still-under-work points concerning:

- Ch. 2 Conventional celestial reference system and frame (new ICRF)
- Ch. 6 Geopotential (ocean tides)
- Ch. 7 Displacement of reference points (diurnal/ semidiurnal atmospheric pressure loading effect, non tidal) loading effect, technique-dependent effects
- Ch. 4 [possibly] Terrestrial reference systems and frames (ITRF2008)
- Ch. 8 [possibly] Tidal variations in the Earth's rotation (new model for diurnal and semidiurnal EOP variations)

Other work: Software associated with conventional models, conventions document to be fully cross-referenced, glossary under development, web page on "additional material".

A new mean pole model was defined as the old model was not sufficient. For Ch. 8 the current high frequency ERP model is deficient, especially for GPS. Updated software was implemented and additional material added. The IERS Conventions 2010 are to be available in the near future.

C. Ma proposed to look at the high frequency EOP model and the description in June and to look for specific points with R. Ray in the beginning of July. E. Pavlis mentioned that the Technique Centres are not informed from when the Conventions should be used and implemented. Also for multiple models some evaluation is needed on the level of model differences compared to level of accuracy.

The final version of the conventions for print should be finished in December, the latest, or in October. The Directing Board should endorse major change, goal of Sept. 2010.

New Action Item:

#50.08 Model for diurnal/subdiurnal variations: choose a new model for high frequency earth orientation

Reports on GGOS, GIC and GEO

GGOS

Markus Rothacher presented the GGOS Portal and the GGOS Book and gave a report on GGOS activities since IERS DB meeting #49 including:

New components in GGOS: Established new components (January 2009), GGOS portal (January 2009), GGOS2020 Book (published in summer 2009), GGOS Coordination Office (January 2010)

Frankfurt meeting on GGOS Intergovernmental Committee (GIC):

- Goals: coordination of resources, promotion for GGOS in international entities, link GGOS to higher intergovernmental bodies

- Past meetings: Frankfurt Meeting in November 2–3, 2009 (Frankfurt Declaration), FIG 2010 in Sydney on April 15, 2010
- Next meeting: EGU in Vienna on May 7, 2010
- Problem: long-term support and sustainability of IAG Services
- White paper and inter-agency agreement to be prepared

3 GGOS themes to make progress towards integrated GGOS products:

- Theme 1: Global Unified Height System
- Theme 2: Geohazards
- Theme 3: Sea-Level Change, Variability and Forecasting
- Global GGOS network of core sites (GGCN): Call for participation in preparation
  GEO Committee Representatives from GGOS, GEO task representation from GGOS

Past meetings and workshops:

- Workshop on Infrastructure of IAG Services, November 2–3, 2009 in Frankfurt
- GEO VI Plenary/IGOS Symposium, November 17–18, 2009 in Washington
- AGU Fall Meeting, GGOS Session, December 14–18, 2009 in San Francisco
- GGOS Retreat on Implementation Plan, February 1–4, 2010 in Miami
- FIG 2010, April 12–16, 2010 in Sydney; GGOS session

Next meetings and workshops:

- GGOS session at EGU meeting, May 5, 2010 in Vienna
- 18^{th} GGOS Steering Committee meeting at EGU, May 3, 2010 in Vienna
- IGS Workshop 2010, June 28 – July 2 in Newcastle, UK
- Wegener meeting, September 14–17, 2010 in Istanbul
- Reference Frame Symposium, October 4–8. 2010 in Paris
- GGOS Science Workshop on “Earth Rotation”, October 25–29, 2010 in Shanghai, China
- GEO Ministerial Summit, November 3–5, 2010 in Beijing, China

Next major steps: Follow-up on the three themes and action items, implementation plan for GGOS2020, GGOS Portal and official GGOS web pages, update of GGOS ToR, GEO tasks: GEO VI and

IGOS, call for participation for GGCN, GGOS "strategy" document.

GIC

Bernd Richter presented the GGOS Intergovernmental Committee (GIC):

Strengths: IAG Services are the backbones of GGOS, delivering the products related to high precision reference frames, fundamental science and infrastructure for global geodetic tasks, functional community of international voluntary cooperation and scientifically based strategy plan for the enhancement of the geodetic product. Weaknesses: the products of IAG Services currently "best effort", suboptimal global observing networks, infrastructure custodians are missing long-term stable financial resources, replacement of aging infrastructure (allow new technical challenges) and suffering of the global geodetic network of several debilitating closures.

Meetings:

- Meeting of Governmental, IAG, GOOS and IAG Services on November 2 and 3, 2009 in Frankfurt
- 1st meeting of the GIC Planning Team on February 2–4, 2010 during GGOS Retreat in Miami
- 2nd meeting at FIG Congress on April 12–16, 2010 in Sydney
- 3rd meeting at EGU on May 7, 2010 at Vienna

GIC supporting GGOS: providing a forum for the coordination of resources, promotion of GGOS in international entities, examining options for aligning the activities of GGOS with some higher intergovernmental oversight

Membership of GIC: representatives of organisations contributing resources to the existing activities of the IAG services; other organisations may be invited as observers.

Goals: strengthen GGOS structurally and administratively and the infrastructure they are based on, secure long-term operation.

Tasks: Identifying the resources needed for the basic GGOS operations, maintain liaison with IAG/GGOS, government representation, maintenance of the liaison with GGOS (new GGOS governance structure).

GEO

Bernd Richter made a presentation of the GEOSS (Global Earth Observation System of Systems) Architecture and Data Committee (ADC) Activities, showing the GCI (GEOSS Common Infrastructure) operational view including its nine social benefit areas and the Earth observations contributions. The goal of GCI is to strengthen GGOS (+its infrastructure) and to secure their long-term operation. From 2010 to 2015 the operational scenario is changing from multiple (three Web Portals and three Clearing Houses) to single

GCI components (one Web Portal and one Clearing House). BR presented the GEO Sub-Task AR-09-02c (Global Geodetic Reference Frames) showing the Work Plan, organizational changes (Lead Zuheir Altamimi, point of contact Bernd Richter), objectives and progresses made (GGOS2020, WG on ITRS ISO standards, CfP for Unified Height System) and GEO Sub-Task AR-09-03e (Global Geodetic Observing Systems) by M. Pearlman showing the target (operational ground network of space geodetic sites satisfying Sub-Task DA-09-02c (Global Reference Frame Systems), the Work Plan, schemata with the proposed elements of the Data Strategy (including ADC, UIC, STC and CBC) and the strategy from a functional perspective.

Consequences for IERS out of UAW

Markus Rothacher gave a report on the GGOS Unified Analysis Workshop (UAW) 2009: the goal was to increase the common understanding of all techniques for each individual technique contributing to GGOS and to make concrete progress. The four workshop sessions covered: (1) products by the Services, GGOS Portal and Metadata, (2) modelling deficiencies and modelling based on external data, (3) combination strategies, common parameters and combined products, (4) network simulations and analyses. The major action items concern benchmarking of software packages, SINEX format update, working group on SINEX and data base of daily SINEX files, troposphere combination campaign, sub daily ERPs, IERS WG on parameterisation and modelling standards for IERS201x, unified documentation of AC modelling and parameterisation, reference pressure for atmospheric loading, sub daily ERP tidal model, consistent ERP parameterisation, SLR tracking of GLONASS, survey for products.

One point was also the SINEX update to version 2.10, with the introduction of new blocks (e.g. a FILE/METADATA block) and extended parameterisation (e.g. piece-wise linear representation) amongst others.

Next UAW: in late 2011 at ETH Zürich, Switzerland.

M. Rothacher proposed the foundation of a working group on SINEX format with involvement of TCs, Daniela Thaller as chair as SINEX format expert, including AC Coordinators, involving GGOS and the gravity field service of they are interested. He will ask D. Thaller and Carey Noll.

New Action Item:
#50.09 Write draft charter and membership list for WG on SINEX and contact D. Thaller as prospective chair

Jean Souchay presented a report on ICRS Centre activities.

ICRS/ICRF

Current status/news of the ICRS-dedicated tasks:

- Task 1: Maintenance and extension of the ICRF (contribution to ICRF2).
- Task 2: Investigation of future VLBI realisations of the ICRS (ICRF2 as new fundamental astronomic reference frame, details in IERS Technical Note 35, WG meeting held on February 10, 2010 in Hobart, development of future reference frames).
- Task 3: Investigation of future non VLBI realisations of the ICRS (L.Q.R.F. , Large Quasar Reference Frame).
- Paris Observatory VLBI Group (radio source monitoring).
- Astro-photometric study of the variability of quasars.
- Task 6: Maintenance of link to Hipparcos (UCAC-USNO CCD Astrograph Catalogue – version 3 released.
- Task 10: Maintenance of link to the dynamical system through LLR.
- Corrections to the celestial pole coordinates (VLBI, LLR and combination).
- Recovery of lost lunar reference point Lunokhod 1, VLBI with constant bias, no real drift between VLBI and LLR.

IAU-related issues

Alexander Brzezinski gave a summary:

- Division I “Fundamental astronomy” – discussing possibility of quasi-permanent bodies within IAU and re-examination of Commissions. IAU agreed to co-sponsor the GGOS meeting in Shanghai and the Journées 2010.
- Commission 19 “Rotation of the Earth”: Harald Schuh and Florian Seitz working on commission member list, new web site: <http://www.iau-comm19.org/>
- Commission 4 “Ephemerides”: Message to the IERS DB from George Kaplan, President of the IAU Commission 4, concerning the adoption of JPL’s DE421 ephemeris in Conventions without sufficient study and the comparison of the three major independent ephemeris centres JPL, IAA and IMCCE.

Meetings of interest:

- Journées 2010 Système de référence spatio-temporels on September 20–22, 2010 in Paris (see IERS Message No. 160 and <http://syrte.obspm.fr/journees2010/ >)
- Joint GGOS/IAU Science Workshop on October 25–28, 2010 in Shanghai, China (see IERS Message No. 162 and <http://GGOS-C19.shao.ac.cn/>)

Tom Herring approached as possible IERS AC, but has to accept

Renewal of the IERS Analysis Coordinator

(agreed in principle). A description of the role and tasks of IERS Analysis Coordinator is needed.

Reports on ICSU activities

For lack of time the report on ICSU activities was left out and sent out with the minutes.

The presentation by Bernd Richter reported on the World Data System (WDS) and the Strategic Coordinating Committee on Information and Data (SCCID) of the ICSU (International Council for Science):

WDS: construction structure: ICSU -> Strategic Coordinating Committee -> World Data System Scientific Committee -> Data centres and services. The WDS Common Data Portal Prototype is built on 4 layers: the producers (related projects, data efforts, institutes, monitoring, services) feeding the WDC as long-term data archiving and publishing facilities, dissimilation of WDC catalogue via offline products, WDC and other portals, DOI registry and library catalogues to the community.

WDS Components: World Data Centres, International Data Analysis Services, National Data Centres and Analysis Services, disciplinary data organisations (e.g. IRIS, Intermagnet, Virtual Observatories, etc.), Data publishers.

SCCID: leadership role on behalf of the global scientific community (policies, management and stewardship), expertise and advice to ICSU, coordination among ICSU activities, training and capacity enhancement focused on least developed countries, strategic advice and guidance of the implementation of new ICSU WDA structure, work with relevant ICSU bodies and key partners.

Miscellaneous

ITRF standardization: Zuheir Altamimi gave a report from C. Boucher working on ISO standards and ISO products within GGOS that France is willing to host the secretariat and provide the 100.000 Euro needed to do the ISO standardization. This would be done by AFNOR; the proposal has to be ready in October/November 2010. DB members, countries and organisations should support the proposal. Bernd Richter reminded that support is through the national standardization organisation of each country. Z. Altamimi proposed that IAG national representatives should be asked to work with their standards organizations.

Next IERS Directing Board meeting

The DB discussed whether the next meeting should be held in Europe (e.g. during the IAG Commission I Symposium 2010 in Marne-La-Vallée, France) or in USA.

New Action Item:

#50.13 Set the next DB meeting after consulting T. Herring

Meeting No. 51

October 10, 2010, Observatoire de Paris, Paris, France

Introduction and approval of agenda

The agenda was accepted. Jean Souchay as representative of Observatoire de Paris, and the Chair, Chopo Ma, welcomed the guests and the members of the IERS Directing Board.

Formalities

Besides minor formal changes the Central Bureau received no further comments for the minutes of IERS DB No. 50.

Status of the new GGFC

Tonie van Dam gave an overview on the status of GGFC concerning the reorganization, the combination products, the web site and the how to proceed in the near future.

The reorganization of the GGFC was approved in October 2009. New product centres are:

- TUV gridded Vienna mapping functions 1 and zenith delay,
- GFZ (Maik Thomas) contributes AAM (SBA), OAM (SBO) and HAM (SBH).

Loading has been calculated by:

- NCEP atm pressure contributing to SBA,
- GLDAS hydrology contributing to SBH, and
- ECCO bottom pressure contributing to SBO.

Concerning the combination products: AOD (Atmosphere and Ocean De-aliasing) loading still needs to be generated, the web site is still under construction (mainly the download area), but will be set up by the AGU meeting.

The web site will be reachable under <http://geophy.uni.lu> and will be online in 2 weeks.

The tasks for the near future are mainly the accreditation of SBO, SBA and SBH. Furthermore, missing products have to be identified and a call for new products prepared, especially cryosphere observations or models, solid earth models (post glacial rebound core mantle) and GRACE products.

One question to answer is how external products (i.e. new products of the IERS services) can be validated and accredited to be consistent with the already existing, well defined, standard products.

A meeting is envisaged in 2011, probably at EGU2011.

New Action Items:

#51.01 Get GGFC web site operational.

#51.02 Survey of community, products → how to validate new products?

Earth orientation products

Generating IERS EOP series consistent with ITRF2008

Christian Bizouard presented some results and comparisons carried out with C04_05 series and the new C04_08 series. Remarkable is a pole coordinates shift of 40 mas in the IVS EOP compared to the C04_05 series.

Tom Herring proposed a reprocessing of the EOP with ITRF2008 pointing out, that the IGS solution is too smooth, causing the C04 solution being too smooth too.

Zuheir Altamimi argued that there is no problem to reprocess the solution more precisely using all data available until 2009.5 to be consistent with C04_08. The user will use the EOP and the reference frame together (provide to OPAR).

Christian Bizouard might ask the services to provide the solution between 2009.5 up to now.

Proposal: make C04_08 solution public, and stop C04_05 solution at a given date (e.g. December 1, 2010), notifying the users in November 2010.

Noise and stability of pole coordinate series: the offset between the various time series reflects the precision of pole coordinates. The Allan variance of this offset quantifies their stability at different time scale (the smaller the Allen variance for time lag τ, the larger is the precision of these time series).

Clues for the future combination: stability of time series differences depends on time scale. The present weighting of techniques is not satisfactory (it does not account for technique dependency on time scale).

IERS pilot project on prediction

Chopo Ma made the presentation of the WG (as Brian Luzum was excused) showing the status of the pilot project on EOP combination of prediction.

The pilot project collects all individual predictions and combined predictions for archival, backup and evaluations. The project provides near-real-time feedback for all predictions using the C04 solution as metric. The goal is to provide recommendations on feasibility of producing operational ensemble EOP predictions.

The project started in June 2010 with the call for participation. When the project will be operational (this is scheduled for October 2010) the participants will provide predictions and combined predictions operationally (list of participants see below).

Interim reports to the IERS DB are envisaged for 2010–2012 and a final report for fall 2012.

List of participants:

- Jet Propulsion Laboratory (R. Gross)
- Paris Observatory (D. Gambis)
- Pulkovo Observatory (Z. Malkin) (combined products)
- Shanghai Astronomical Observatory (Xu X.)
- Siberian Scientific Research Institute of Metrology and Siberian State Geodetic Academy (V. Tissen)

- Space Research Centre (W. Kosek, T. Niedzielski) (combined products)
- Ulyanovsk State Technical University (S. Valeev)
- U.S. Naval Observatory (B. Luzum) (combined products)

Auxiliary data will come from the IERS Special Bureau for the Atmosphere (AAM data), from IGS (ultra EOP predictions) and from GFZ (AAM/OAM/HAM data).

Information concerning the pilot project and its contributing participants can be found at <http://maia.usno.navy.mil/eopcppp>, with a mirror site available at <http://www3.cbk.waw.pl/eopcppp>.

New Action Items:

#51.03 Make C04_08 solution public, and stop C04_05 solution a.s.a.p. at a given date. Notify the users, coordinate the transition to the C04_08

#51.04 TCs should provide data consistent with ITRF 2008

#51.05 When is the IGS ready to regenerate polar motion consistent with ITRF2008?

#51.06 IERS Technical Note for C04_08

Reports from the Technique Centres

International DORIS Service (IDS)

Frank Lemoine presented the IDS report 2010 covering the following subjects:

1. Satellite constellation status:
   Current missions are Cryosat-2, Jason-2, Envisat, Spot5, Jason-1 and Spot4, future missions will be Saral/Alti-Ka, Hy2a, Sentinel3a, Jason-3 and Swot. This constellation ensures that there are always 5 or 6 satellites in orbit.
2. Network status:
   A world map showing the DORIS stations can be found in the presentation. Several changes on stations have been done in 2009 and 2010 (beacons, equipment, etc.). For some stations a remote management system has been installed, the stations configuration has been standardized and the beacon model 3.0 deployment is almost completed.
3. DORIS data and data centre status:
   DORIS measurements are available in RINEX format (see <http://www.ids-doris.org/pub/ids/data/RINEX_DORIS.pdf> for further information). Measurements are dated in two ways: in On Board Time and in International Atomic Time scale. The directory structure at data centres can be found in the presentation. New satellite data from Jason-2 and CryoSat-2 in DORIS and RINEX format. Data reissue for Jason-2 and SPOT4 data.

4. Central Bureau report:
   There is a new version of the IDS web site since March 2010 at <http://ids-doris.org>. The Central Bureau's ftp site is available under <ftp.ids-doris.org>.
5. DORIS special issue:
   This will be published in two volumes (volumes 45 and 46) of Advances in Space Research (Elsevier).
6. There us a new IDS citation.
7. Analysis centre activities (post-ITRF2008):
   An IDS Analysis Working Group meeting took place on May 26–27, 2010 at ESOC, Darmstadt, Germany. Guilhem Moreaux (CLS) is new IDS Combination Centre Coordinator.

International GNSS Service (IGS)

Urs Hugentobler presented an overview on the IGS activities. A workshop in Newcastle in June/July 2010 was held with ~235 participants, covering the following topics:

- infrastructure and network
- new GNSS signals
- real time
- reprocessing
- modelling, and
- atmosphere

Concerning the product quality: 2.5 cm consistency for final and rapid orbits, 5 cm for ultras in first 12h prediction. There are too large numbers in the discontinuities.

The Infrastructure Committee made a revision of the site guidelines. The GRGS in Toulouse became a new AC within the IGS, so that there are now 8 ACs providing products for the final combination, the reference frame coordinate transition from NRCan to IGN was performed by Bruno Garayt and there is a new working group on orbit modelling under Marek Ziebart.

The IGS is furthermore involved in RTCM (RINEX), the ICG (geodetic references, time references, alignment to international standards and retro-reflectors on GNSS satellites), and in demonstration campaigns QZSS and CONGO.

A data reprocessing contributing to the ITRF2008 took place from February 2008 until November 2009. All products are available except time scale; currently models are updated according to the updated IERS conventions. Next reprocessing is planned after the new standards have been successfully implemented and tested (~end of next year).

In the field of real time point positioning, there are some 130 stations and several casters, 7 agencies are providing RT solutions (mainly clocks), a conversion to experimental service will be possible in spring 2011.

C. Ma asked about the infrastructure committee. Is it necessary to renew the infrastructure and to calibrate radoms? U. Hugentobler mentioned that this should be a data operation issue.

International Laser Ranging Service (ILRS)

Erricos Pavlis presented the news of the ILRS Analysis Working Group (AWG).

ESA became a new AC of the ILRS, so that there are presently nine ACs contributing products to the ILRS. The operational products (weekly and daily) are delivered routinely and on time (daily: data from the prior week until the day of yesterday). One of the AWG projects was the evaluation of ITRF2008 and ITRF2008D (see "ITRS/ITRF – Summary of the TC services in the use of ITRF2008" in the next section for details). Other projects are the adoption of improved modelling and IERS C&S2010 (starting in early 2011), the re-analysis for the period from 1983 to present, and beginning once all improvements have been checked and validated by all ACs.

The daily product becomes operational in early 2011 and the weekly product becomes "definitive" product with 1–1.5 month latency (to be able to take advantages of global fields for environmental modelling).

The USNO evaluation of the daily product was completed successfully.

Concerning new products, there are some pilot projects in progress covering:

- orbit products (SP3C files)
- weekly 2x2 gravitational harmonic solutions
- CRD data format validation process (new format by January 2011)
- new NP generation procedure, and a
- Special issue of Journal of Geodesy.

Some potential projects are the use of Starlette, BLITS and Ajisai (EOP and TRF) and the near real-time analysis of SLR data for "station health".

A comparison of the daily EOP product – polar motion (ILRS daily vs. USNO finals) – was carried out. The de-aliasing product test shows no obvious differences between the use of a static vs. a daily changing gravity model, differences in mean RMS is 0.5 mm (consistent with prior tests using a de-aliasing product based on ECMWF 6-hr fields only).

AWG meetings: two meetings in 2010 (EGU 2010, Vienna and REFAG 2010, Paris); another meeting possibly at AGU fall meeting. Next meeting: May 14, 2011, Bad Kötzting, Germany.

International VLBI Service for Geodesy and Astrometry (IVS)

Rüdiger Haas presented the IVS report:

Since October 2009 the routine IVS combination is at BKG and works fine. In the analysis, the XY-partials and IAU2006 precession are now used in Solve by GSFC and BKG, the older $d\psi$/$d\varepsilon$ are only achieved by backward calculation. Some telescope problems in 2010 caused a lot of changes in the IVS schedule in this time: Wettzell is out of operation because of bearing repair since September 1, but should be back operationally in the middle of November this year; Tsukuba was out of operation since July 26 because of repair and is now back since the beginning of October; HartRAO is re-operating since September (was not operating since October 2008), and Fortaleza will be back soon, after being repaired. Concerning the intensive sessions INT-1/2/3: during the time for repair, Westford replaces Wettzell, and Kashima replaces Tsukuba.

The IVS Task Force for Intensives is working on unifying analysis strategy for INT: the ultra-rapid solution is automated with a very low latency; the rapid solution is generated interactively with a low latency, and the final solution is a combined solution. The automated ultra-rapid UT1 observations are interactively analysed with Calc/Solve (USNO) and with C5++ under evaluation of Nick Stamatakos (USNO). Results: differences of max. 75 µsec for UT1 between the two solutions for all sessions. The comparison of the Calc/Solve solution and the C5++ solution for one 24h IVS-session (Onsala – Tsukuba) shows slight differences.

VLBI2010:

- *System development*
  There are several feed-horn, Dewar and data acquisitions developments ongoing at Haystack, Onsala and Göteborg.
- *Network*
  In near future there are some changes in the VLBI network: the Twin Telescope Wettzell (TTW) is under construction; within RAEGE, three or four new telescopes will be built on the Azores, the Canary Islands and in Yebes. Furthermore there are new sites GGAO, Arecibo, and Auscope (three telescopes) and projects in Korea and China. Some submitted project proposals coming from Norway (Twin Telescope Ny-Ålesund – TTN), France (Tahiti), India, Brazil and Saudi Arabia. Projects are in preparation in the USA (10 antennas), Russia (4–10 antennas), Finland and Japan.
- *Simulations*
  VLBI2010 simulations with ‘realistic’ networks are previewed to be available in 2015, consisting of VLBI2010 antennas and upgraded legacy antennas (network size:

18 telescopes). Scheduling tests are carried out at GSFC and TU Wien, source structure simulations at Observatoire de Bordeaux.

New Action Item:

#51.07 Information about IGS change to ITRF2008

ITRS/ITRF

Report from IAG Commission 1 Symposium – REFAG2010

Zuheir Altamimi gave an overview on the 6 sessions that were held during the Commission 1 Symposium in Marne-La-Vallée (October 4 – 8, 2010):

- *Session 1*: Theory and realization of global terrestrial reference systems
  The main topics were the computation and the quality assessment of both ITRF solutions, the TRF activities of the space techniques (SLR, VLBI, GNSS, DORIS) and their contribution to ITRF2008. Furthermore local ties, site stability and the IERS Conventions were discussed.
- *Session 2*: Strengths, weaknesses, modelling standards and processing strategies of space geodetic techniques
  The topics of this session were: the increasing use of external data (like ECMWF data for mapping functions) that do not cause a problem for reprocessing but for near real-time products (on time availability); DORIS improvements: reached the precision level of SLR and VLBI, GRGS IGS AC achieve a performance comparable to other IGS ACs; combination on the observation level (COL), as well as multi-technique combination, space ties and other related topics.
- *Session 3*: Definition, establishment, maintenance and integration of regional reference Frames
  Most regional sub-commissions are currently in reprocessing mode, except some few institutions (AFREF & APREF, SIRGAS). The recommendation is to minimize the "network effect" by using a global network to realize regional reference frames.
- *Session 4*: Interaction between the celestial and the terrestrial reference frame
- *Session 5*: Definition and establishment of vertical reference systems
  Main conclusion: the vertical datum problem has been studied by many groups using different kind of data, analysis strategies and perspectives. The combination of geometrical and physical parameters makes the vertical datum unification reliable, but the vertical datum problem is still a big challenge for the geodetic community.

- *Session 6*: Usage and applications of reference frames in Geosciences
  This session had shown that reference frames are fundamental to Earth science (sea level change), planetary science (interplanetary spacecraft navigation) and the society (precision agriculture). Co-located measurement techniques on the Moon are previewed to improve the terrestrial reference frame.

Z. Altamimi presented the summary of the REFAG2010 symposium; no decisions have been made so far.

The proceedings of the symposium will be published by Springer as an IAG Symposia volume. Paper submission deadline is January 8, 2011.

C. Boucher pointed out that the task now is to transform the scientific activities into operational services.

Lessons from ITRF2008 and considerations for the future

Zuheir Altamimi presented some technical considerations and some structural considerations.

- Technical considerations
  ITRF2008 accuracy: origin: 1cm over the time-span of SLR observations; scale: 1.2 ppb (8mm) over the common time-span of VLBI and SLR observations.
  Local ties in ITRF: Regarding the uncertainties of the transfer of SLR origin and SLR&VLBI mean scale to GPS frame the presentation shows that the uncertainties of TX, TY, TZ and scale components are 2–3 times larger when using “good” (small sub-set of) ties only, compared to using all available ties, properly weighted (see presentation for details).
  Conclusion: all available weighted ties should be used (the more ties used the more precise is the estimation); technique specific errors are e.g. GPS uncalibrated radomes, VLBI antenna gravitational deformations, SLR range/timing biases and DORIS beacon reference point behaviour.
  Schedule: observe and respect reasonable and agreed schedule for next ITRF solution
- Structural considerations
  ITRS Centre role: enforce role to improve the IERS image; ITRS Centre solution is the official IERS standard solution, but encourage DGFI and other groups to do combination in order to create active competition; IERS label should be unique.

M. Rothacher prefers to see all solutions available and proposed to draw a list of criteria as a basis for tests by the (ACs and) TCs.

T. Herring proposes to publish recommendations by the IERS regarding (among others) the ties, the scale between the techniques and the linear motion.

The proposal came up to name the combination solution of the Combination Centres as a composition of the name of the CC and the reference year (e.g. IGN2008, DGFI2008). The DB voted on this issue and the proposal was accepted without opposition.

M. Rothacher proposed the formation of an ITRF evaluation group within the IERS, composed by several people of the technique centres. The members of this group should be the ACs of IERS, the ACs of the different services and the CB.

C. Ma added that this group won't exist permanently, rather epoch-wise in parallel with ITRF generations.

The DB accepts this proposal, but details have to follow.

F. Lemoine added that the evaluation group should also be open for everyone who is willing to make contributions.

C. Ma: The IERS DB should accept the membership in the evaluation group by appointment.

Summary of the Technical Services in the use of ITRF2008

- *IGS*
  U. Hugentobler: IGS needs time to switch completely to ITRF2008 as it is not usable immediately.
- *IVS*
  R. Haas: Generally good experiences, but some stations with smaller problems (e.g. Zelenchukskaya)
- *IDS*
  F. Lemoine: IDS sees no difficulties or problems so far, but some DORIS stations are missing
- *ILRS*
  E. Pavlis: ILRS sees no problems using the new ITRF and presented the results of the WG meeting including a detailed analysis of both ITRF solutions:
  LAGEOS 1 & 2 data have been re-analysed from 1983 to present using ITRF2008 (IGN2008) and ITRF2008D (DGFI2008) as apriori. Furthermore comparisons of the site coordinate residuals, Helmert translation parameter Tx, Ty and Tz, as well as the scale have been carried out, without showing significant differences between SLRF2005, ITRF2008 and ITRF2008D. Only the scale comparison is slightly different in ITRF2008 (scale slope ~–0.2mm/yr) and ITRF2008D (scale slope <–0.1mm/yr). Also the 3D site residuals wrms fit quite well between ITRF2008 and ITRF2008D.

IERS Working Group on on Site Survey and Co-location

C. Ma summarised the report from P. Sarti:

A WG meeting took place before the EGU 2010 meeting in Vienna (minutes are under preparation). Ongoing activities:

- Local tie surveying: possibility to write guidelines for surveyors resumed in a reference manual, as the methods are highly site dependent. The objective is a harmonization of the different surveying methods. Furthermore the WG sees the need to inter-compare and test the different software which is used to calculate the local ties coming from field measurements.
- Tie vector residuals are currently being investigated for assessing critical situations at the co-location sites.
- A close cooperation with the Product and Combination Centres is compulsory and part of the ongoing investigation.

The WG needs closer cooperation with the single technique services (particularly IVS, IDS and ILRS) to investigate the role of PCV connecting the electronic and conventional reference points of the different geodetic instruments.

Z. Altamimi proposed to put discrepancies of ties on the web site to facilitate the identification of survey problems.

Decision: The name of the combination product of each Combination Centre will be composed by the name of the CC and the reference year (e.g. IGN2008, DGFI2008). Build an evaluation group.

New Action Items:

#51.08 Information when TCs switch to ITRF2008

#51.09 Write Technical Note on ITRF2008

New IERS Conventions

Gérard Petit presented the new version of the IERS conventions. At present, the new IERS Conventions (2010) are online – <http://tai.bipm.org/iers/conv2010/conv2010.html> – and comments will be accepted until October 18, 2010.

Several chapters have been rewritten, introducing new numerical standards, models (geopotential model, model for zonal tides) or references (ICRF-2, ITRF2008, mean pole), beside other conventions.

Some chapters will be revised afterwards, like Chapter 7.2 (loading effects): for this chapter volunteers and collaboration are needed or Chapter 8 (Tidal Variations in the Earth's Rotation): new model for diurnal and semidiurnal EOP variations.

Furthermore the IERS Conventions also support software associated with conventional models by providing documentation and test cases, including IERS Conventions Software License.

The web page on “additional material” is under construction and expanded as needed: <http://tai.bipm.org/iers/convupdt/convupdt_aux.html>

New Action Items:

#51.10 Implementation and publishing of schedule for new Conventions by Conventions Centre

#51.11 Prioritize the changes

#51.12 Estimate the implementation schedule

Reports on GGOS, GIC and WDS

GGOS

Markus Rothacher presented the GGOS activities since the last DB meeting (#50):

The activities have been:

- The GGOS Web pages
  The web pages are ready, presently reviewed by the GGOS EC and then opened for the GGOS SC
- The 3 GGOS Themes to make progress towards integrated GGOS products
  1. Global Unified Height System (GUHS):
     Capability of ITRF and GUHS (standards, models); tide gauge referenced to ITR collocated with GNSS; time series for tide gauge stations and GIA sites; GGOS core sites (connection to tide gauges wherever possible); co-location of ITRF sites with gravity sites.
  2. Geohazards
     Continued refinement of the accuracy/stability of the ITRF; improved ultra-rapid GNSS orbits and clocks for PPP
  3. Sea-Level Change, Variability and Forecasting
     High-precision ITRF is crucial (geocenter); time series of vertical motion; new format for time series of station coordinates
- Tasks and Action Plans for GGOS2020
  Task 1 – Recommendations in the GGOS2020 Book: step-by-step realization; list of action items from the recommendations
  Task 2 – Work on the three Themes identified in Miami (see above).
  Task 3 – Write down implementation plans for the various GGOS components: core network, data handling, analysis, Earth system model
- GGOS Inter-Agency Committee (GIC)
  The major problem is the long-term support and sustainability of the IAG Services and the global GGOS infrastructure. To support GGOS, the GIC attains its goals by: Forum for the coordination of resources, promotion of GGOS in international entities (UN, etc.), and options to link GGOS to higher intergovernmental bodies.
  The first step is a white paper and an inter-agency

agreement (prepared by GIC Planning Group).
Past meetings of the GIAC: Frankfurt, Germany (Nov, 2009), GGOS Retreat Miami, USA (2010), FIG Sydney, Australia (April, 2010), EGU Vienna, Austria (May, 2010). Next meeting possibly at AGU2010 in San Francisco, USA (December, 2010)

- Meetings, sessions, workshops
  Past meetings:
  GGOS Session at EGU Meeting May, 2010, Vienna and 18th GGOS SC also in Vienna; IGS Workshop in Newcastle, June, 2010; Wegener Meeting in Istanbul, September 2010 and at the Reference Frame Symposium (IAG Comm. 1 Symposium), in Paris, October, 2010.
  Next meetings and workshops:
  GGOS Science Workshop on "Earth Rotation" in Shanghai, China (October 25–29, 2010), GEO Plenary VII Meeting and Ministerial Summit in Beijing, China (November 3–5, 2010), 19th GGOS Steering Committee Meeting in San Francisco (December 11, 2010), AGU Fall Meeting (GGOS session) in San Francisco (December 13–17, 2010), IUGG General Assembly 2011 in Melbourne, Australia (June 28 – July 7, 2011)

The next major steps of GGOS are the follow-up on the three themes and the action items of the GGOS Planning Meeting and SC Meeting, action plans for GGOS2020, GGOS Portal and GGOS web pages, update of the GGOS ToR, contribution to GEO tasks (GEO VII and Ministerial Summit), GGOS "strategy" document, recognition of GGOS by ICSU and other organizations.

GIC and WDS

Bernd Richter added to the remarks given above: a letter to invite the agencies to sign the Frankfurt Declaration, recognize the White Paper and become member of the GIAC was sent out to 15 agencies as a first initiative.

The old World Data Centres and the Federation of Astronomical and Geophysical Services (FAGS) are dissolved and will be reorganised under a new structure (World Data Services, WDS) by ICSU. The new structure has been set up; soon the applications to become a WDS member will be sent out.

New IERS Analysis Coordinator

C. Ma thanked Markus Rothacher for being the AC for the last eight years and proposed Tom Herring as the new AC.

Statement from the new IERS Analysis Coordinator

Tom Herring gave an overview of the tasks of the AC:

As described in the IERS ToR the AC is responsible for the consistency of the IERS reference frame and other products. Furthermore, he is responsible to ensure the appropriate combination of the TC products into the single set of official IERS products. T. Herring proposed to possibly change the ToR in that way that the AC's role covers the monitoring of the TC and PC activities to ensure that the IERS objectives are carried out.

Some specific tasks of the AC are: coordinate and stimulate the generation of the combined and consistent IERS products of different latencies and improve the consistency of the techniques among each other. Therefore, he has to work closely together with ACs of the different techniques. The AC should also be the chair of the working group on parameterization/modelling of ITRF20xx/IERS20xx (to be established); he should serve in the "ITRF datum evaluation" working group, support GGOS in organizing the biennial UAW.

Concerning the ITRS Centre and the ITRS Combination Centres, T. Herring pointed out the current complication that the product centre is one of the two combination centres and that there is a need of more combination centres (possibility to provide ITRF coordinate and velocities but not all EOPs). Desirable is a more open access to intermediate results during their generation.

Other issues concerning the AC's role are: current status and use of the Global Geophysical Fluids Centre (non-tidal loading, VMF), current study groups, roles of IERS and GGOS and their interaction as well as the interaction between the AC and the DB. Z. Altamimi proposed regular discussions between the ACs and the IERS AC to bring in more interaction between them.

Changes in IERS Terms of Reference

Bernd Richter proposed some changes in the IERS Terms of References (ToR):

IERS DB members

Old: "The Directing Board consists of the following members: [...] Representatives of IAU, IAG/IUGG and FAGS."

New: "The Directing Board consists of the following members: [...] Representatives of IAU, IAG/IUGG and GGOS, and Representative of IGFS with observing status."

IERS Analysis Coordinator

Old: "The AC serves for a four-year term, renewable once by the DB. [...]"

New: "The AC is elected by the DB for a term of four years with the possibility of re-election for one additional term. [...] This is accomplished through direct contact with the independent TC Analysis Coordinators *and PC chairs* or equivalent. […]"

Decisions:

The changes of ToR were accepted by the DB.

T. Herring was elected as new AC under the new ToR.

New Action Item:

#51.13 The IAG Executive Committee has to be contacted to inform about the proposed changes in the IERS DB membership (representative of GGOS). GGOS should delegate a representative.

IERS Annual Reports

There are still a non-negligible number of reports missing for the AR 2008, so that the DB decided to publish a bi-annual report 2008/2009 which should be finished by the end of this year.

New Action Item:

#51.14 Send out informational email concerning missing reports for AR 2008/09

Miscellaneous

Election of the new IAG Executive Committee: The IAG services are represented by 3 members.

G. Beutler sent out an email asking for nominations (deadline November 5, 2010). At present H. Schuh, R. Neilan and M. Rothacher are nominated. For the election C. Ma proposed T. Herring as one of the candidates of the three service representatives.

Decision: The IERS DB accepted the proposal to nominate T. Herring as a candidate for the IAG EC.

Next IERS Directing Board meeting

B. Richter proposed to meet before/after EGU2011 in Vienna (April 3 or April 9, 2010).

New Action Item:

#51.15 Coordinate the meeting with the IAG EC

Sabine Bachmann, Wolfgang R. Dick, Bernd Richter

3.2 Central Bureau

General activities

The IERS Central Bureau (CB), hosted and funded by Bundesamt für Kartographie and Geodäsie (BKG), organized and documented the IERS Directing Board (DB) Meetings No. 50, May 1, 2010, at Technical University Vienna, Austria, and No. 51, October 10, 2010, at Observatoire de Paris, France. Between the meetings the CB coordinated the work of the DB.

The CB represented the IERS at the following meetings: European Geosciences Union General Assembly, IAG Commission 1 Symposium 2010 (Reference Frames for Applications in Geosciences – REFAG2010); Statusseminar DFG Forschergruppe FOR 584 “Erdrotation und globale dynamische Prozesse”, AGU 2010 Fall Meeting.

IERS components maintain individually about 20 separate web sites. The central IERS site <www.iers.org>, established by the CB, gives access to all other sites, offers information on the structure of the IERS, its products and publications and provides contact addresses as well as general facts on Earth rotation studies. It contains also electronic versions of IERS publications, a list of meetings related to the work of the IERS, and an extended link list for IERS, Earth rotation in general and related fields. Throughout 2010 the web site was regularly updated, several new pages and documents were added.

The IERS Annual Report 2007 and the IERS Technical Note No. 35 “The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry” appeared in print and were distributed to libraries and subscribers. The CB continued to prepare the IERS Annual Report 2008 and started work on the report for 2009 for publication. The Directing Board decided to combine both reports. Along with the reports of the IERS components, the Annual Reports contain information on the IERS compiled by the CB. The CB gave technical support for editing the IERS Technical Note No. 36 “IERS Conventions (2010)” and published it electronically at the IERS web site.

The digitization of the IERS Technical Notes Nos. 1 – 28, published between 1989 and 2000, was finished. These publications are now available in PDF format at the IERS web site. Each page consists of two layers: the visible image of the scanned page and the searchable text, obtained with OCR, in background, related to each other with high precision.

During the year 2010, 24 IERS Messages (Nos. 156 – 179) were edited and distributed. They include news from the IERS and of general type as well as announcements of conferences.

Address and subscription information has regularly been updated in the IERS user database. There were about 2500 users in

2010 with valid addresses who subscribed to IERS publications for e-mail and regular mail distribution. A concept for migration this database into a new system was developed. The improved database should allow easier and automated maintenance and use.

Many questions from IERS users and journalists concerning IERS publications and products as well as Earth rotation and reference frames in general were answered or forwarded to other specialists. Several German radio stations and newspapers reported about the work of IERS based on information from the CB.

IERS Data and Information System (DIS)

The IERS Data and Information System (IERS DIS), which was developed by the Central Bureau between 2002 and 2005, is in the operational mode since 2006. The system is continuously being adapted and extended by new components in order to fulfill the requirements for a modern data management and for the access to the data by the users. In this context international and interdisciplinary projects like the Global Geodetic Observing System (GGOS) or the Global Earth Observation System of Systems (GEOSS) are demanding special requirements with respect to the standardization of the data and applications on the data.

Besides routine work like maintenance of the data bases of users, products and web pages, in 2010 further developments of the IERS DIS concentrated on the following aspects:

- acquisition of data from IERS services and institutions,
- conversion of the data into uniform formats as well as extraction and creation of ISO 19115-conform metadata,
- integration of new data sources,
- development of tools for the visualization of time series,
- updating the data structure, e.g. by adopting to the new structure of the Global Geophysical Fluids Center.

Many of these developments were made in close cooperation with another research project at BKG, the project ERIS. The aim of ERIS (Earth Rotation Information System) as a part of the research unit FOR 584 “Earth Rotation and Global Dynamic Processes” was the development of a virtual Earth rotation system for geodetic and geoscience applications. The central part of the electronic infrastructure of the research unit is the common Web portal <http://www.erdrotation.de>. The project provided an information, communication, and database system as a central interface between the research partners and their applications and fields of interest.

During the year 2010 the focus was on the improvement and development of tools for the visualization of time series. The data analysis tool, developed in previous years, was improved and enlarged. It provides methods like spectral analyses, different filters and approximations, which may be applied to existing time series from IERS as well as to user data. The interaction between the different methods was considerably improved. The results are provided in standardized data formats and in graphic form. All intermediary steps and the final results may now be exported in XML format. A connection was made with the IERS plot tool developed at BKG, which allows improved graphical displaying. These tools together with instructions can be found at <http://www.erdrotation.de/ida>.

Also a simulation tool was developed during 2010. It allows to combine different model data on Earth rotation, to analyze them and to compare with observed Earth rotation parameters. Currently selected models of excitation functions of the atmosphere, oceans and hydrology are available. For this, existing and tested methods, functions and structures of the data analysis tools could be used. The simulation will be finally tested and made available at the ERIS web portal.

Because of the close cooperation between ERIS and the IERS Central Bureau, ERIS has direct access to the data archive of the IERS and to applications developed for the IERS. In return, techniques and software developed in ERIS will be used after a phase of testing also by the IERS. One of the most important tasks in both projects deals with the data preparation and data networking. To ensure interoperability all data series are transformed into standardized data formats. Based on the XML versions developed for the IERS the XML schemata and the transformation routines are revised to harmonize the data structure and to enhance the machine readability.

Additionally metadata are stored to describe the content of the series, how the data are produced, the authorship, the availability of the data, parameterization etc. To ensure interoperability of the metadata with respect to international and interdisciplinary metadata catalogues, the IERS and ERIS specific metadata are conform to the ISO 19115 “Geographic Information – Metadata” profile. Routines have been established for automatic generation of metadata.

Staff

Dr. Bernd Richter, *Director*

Sabine Bachmann*, scientist (since March 1, 2010)*

Dr. Wolfgang R. Dick, *scientist*

Carola Helbig, *secretarian*

Alexander Lothhammer, *technician (until 31 January 2011)*

Anja Niederhöfer, *scientist*

Peter von Rappard, *technician (until 31 December 2010)*

Sandra Schneider-Leck, *technician (on leave until 31 Dec. 2010)*

Dr. Wolfgang Schwegmann, *scientist (until March 31, 2010)*

Publications

Nothnagel, A.; Angermann, D.; Börger, K.; Dietrich, R.; Drewes, H.; Görres, B.; Hugentobler, U.; Ihde, J.; Müller, J.; Oberst, J.; Pätzold, M.; Richter, B.; Rothacher, M.; Schreiber, U.; Schuh, H.; Soffel, M.: Space-time reference systems for monitoring global change and for precise navigation; Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Nr. 44, Verlag des Bundesamtes für Kartographie und Geodäsie, 2010, 142 p., ISBN 978-3-89888-920-9

Rothacher, Markus; Drewes, Hermann; Nothnagel, Axel; Richter, Bernd: Integration of Space Geodetic Techniques as the Basis for a Global Geodetic-Geophysical Observing System (GGOS-D): An Overview. In: F. Flechtner et al. (eds.), System Earth via Geodetic-Geophysical Space Techniques (Advanced Technologies in Earth Sciences), Berlin, Heidelberg: Springer, 2010, p. 529–537, DOI: 10.1007/978-3-642-10228-8_43

Schwegmann, Wolfgang; Richter, Bernd: GGOS-D Data Management – From Data to Knowledge. In: F. Flechtner et al. (eds.), System Earth via Geodetic-Geophysical Space Techniques (Advanced Technologies in Earth Sciences), Berlin, Heidelberg: Springer, 2010, p. 539–544, DOI: 10.1007/978-3-642-10228-8_44

Wolfgang R. Dick, Anja Niederhöfer, Bernd Richter

3.3 Analysis Coordinator

Overview of responsibilities

As the new Analysis Coordinator (AC), appointed in October 2010, I see my role in the IERS as one of coordination of the efforts of the analysis centers of the IERS to ensure that the IERS continues to provide the highest possible quality Earth orientation parameters and associated materials to the community. The role of the AC from the IERS Terms of Reference is: "*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 Technique Center (TC) products into the single set of official IERS products and the archiving of the products at the Central Bureau or elsewhere.*" This core responsibility should be modified somewhat to reflect the role of the IERS Product Centers (PC) as well as the Technique Centers. My first task as AC would be to pose my role as: "*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.*"

To achieve the responsibilities as AC, some specific tasks to be undertaken are:

1) Coordinate and stimulate the generation of a palette of combined and consistent IERS products of different latencies,
2) Improve the consistency of the techniques among each other and the synergies (e.g. reduction of technique-specific biases, common parameterization, adherence to standards, etc)

To achieve these tasks, my plan is to

1) Work closely together with the Analysis Coordinators of the individual techniques (e.g., common meetings between the ACs)
2) Chair of the working group on Parameterization/Modeling of ITRF20xx/IERS20xx to be established (decision at the last IERS DB Meeting).
3) Serve on "ITRF datum evaluation" Working group established by IAG Commission 1. (Xavier Collilieux, Chair).
4) Support GGOS in organizing the biannual Unified Analysis Workshop (UAW).

Analysis of the IERS core products

Some of my initial thoughts on the IERS core products and how they should evolve include the IERS product quality. How are the products used? And the procedures used to generate current products with emphasis on use of SINEX and combined results from Technique Centers. Other questions that can be addressed are: Should IERS generate a Center of Mass product? How do we evaluate the ITRF? Do we have the needed blend of latency and accuracy of products? Further analysis of the parameterization of earth orientation parameters can be considered. Should we generate higher time resolution products on a regular basis? Is the current offset and rate parameterization adequate or should we consider piecewise linear models? With the current accuracies of GPS orbit determinations and the potential leakage of diurnal and semidiurnal signals into the (semidiurnal) GPS orbits, the current diurnal and semidiurnal models of both EOP and loading should be evaluated.

The AC will also look at the IERS product centers as well. There are currently two ITRF Product Centers and there have been some complications associated with how these two centers interact. I would be useful if the IERS had additional ITRF product centers and a means to allow other centers to become involved in the IERS. It could be possible to allow less stringent ITRF product centers that allow for EOP variations in their ITRF/ICRF generation but not explicitly compute all the covariance between all EOP and ITRF parameters. This less stringent approach would allow Kalman and square-root-information filters to be used that can generate all the EOPS in a smoothing filter but cannot easily compute all the covariances between all the EOP parameters.

The IERS Global Geophysical Fluid Center has been recently updated with many new loading and atmospheric products to be delivered and I will work closely with the product center to ensure we have high quality products.

I see many challenges in the coming years to ensure that the IERS continues to maintain its very high standards and products. I would like to thank the outgoing AC, Markus Rothacher, for leaving the analysis state of the IERS in such very good condition.

Thomas Herring

3.4 Technique Centres
3.4.1 International GNSS Service (IGS)

The International Global Navigation Satellite System Service (IGS) is a federation of more than 200 organizations from around the world that operate a cooperative global infrastructure to provide the highest quality Global Navigation Satellite System (GNSS) data products for scientific users. The IGS is a service of the International Association of Geodesy (IAG), one of the associations of the International Union of Geodesy and Geophysics (IUGG). It is also a service of the World Data System of the International Council for Science (ICSU/WDS).

The IGS data products are openly available to all users. They include GNSS satellite ephemerides, Earth rotation parameters, global tracking station coordinates and velocities, satellite and tracking station clock information, zenith troposphere path delay estimates, and global ionosphere information. These products contribute to IERS objectives of realizing the International Terrestrial Reference Frame (ITRF) and monitoring Earth orientation parameters.

IGS Tracking Network Status

At the end of 2010, there were 424 GNSS tracking stations within the IGS network (Figure 1). Approximately 85% of these provide data on a weekly or more frequent basis and are included in IGS weekly combination solution.

The number of IGS stations co-located with other geodetic techniques has remained unchanged since 2009; 25 stations are collocated with VLBI, 37 with SLR, and 55 with DORIS. 221 IGS stations were used to compute the IGS08 reference frame. 179 were considered core stations because they exhibit long-term stable time series'.

Many IGS stations have multiple capabilities to support a range of applications. At the end of 2010, 121 stations deliver GLONASS data to support the generation of the IGS GLONASS orbit product. 134 stations are co-located with external high-precision frequency standards and are used in production of the IGS clock products. A subset of the network provides meteorological data used in the generation of the IGS troposphere product. Many IGS stations stream data in real-time to support the IGS Real-time Working Group activities, which is developing procedures and methodologies for delivering the IGS products on Real-time.

IGS Products Quality

The Analysis Centers have implemented a number of advancements in 2010 that have improved the quality of the IGS products. Table 1 gives an overview of the estimated quality of the IGS core products at the end of 2010.

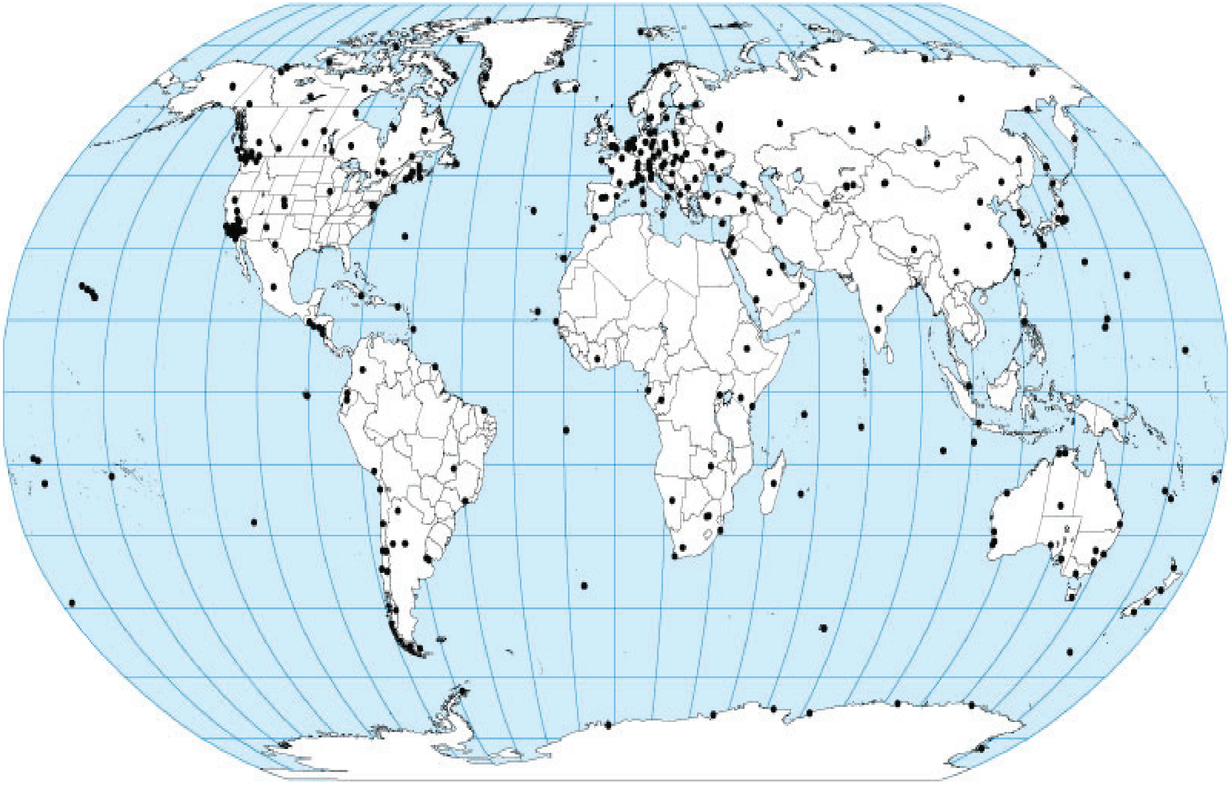

Fig. 1: IGS Global Tracking Network consisting of 424 GNSS stations as of December 2010.

Details related to the IGS products and enhancements implemented in 2010 are available on the IGS web site at <http://igs.org/components/compindex.html>. Various evaluations of the IGS product quality can be found in the Analysis Coordinator section of the IGS website at <http://acc.igs.org/>.

2010 Activity Summary

Repro1 Campaign

Details relating to the reprocessing campaign (Repro1, covering the period 1994–2007) are available online at <http://acc.igs.org/reprocess.html>. The combined SINEX orbit/clock solution was completed and posted for user access at the CDDIS Global Data

Table 1: Quality of the IGS core products at end of 2010.

Product	IGS Final	IGS Rapid	IGS Ultra Rapid	
			Adjusted	Predicted
Updates	Weekly	Daily	Every 6 h	Every 6 h
Delay	~13 days	17 hours	3 hours	Real-time
GPS Orbits	2.5 cm	3 cm	3 cm	5 cm
GPS Satellite Clocks	0.05 ns	0.1 ns	~0.2 ns	~3 ns
Station Clocks	0.05 ns	0.15 ns		
Polar Motion	0.03 mas	<0.04mas	0.2 mas	
LOD	0.02 ms/day	0.03 ms/day	0.03 ms/day	
Station Coordinates (h/v)	3 mm/6 mm			
GLONASS Orbits	~5 cm			

Center. Long-term GNSS station stability, uncalibrated radome effects and site tie errors were identified as factors limiting the IGS reference frame products accuracy that should be urgently addressed. A number of analysis improvements identified in Repro1 are being carried forward as planning for Repor2 commences.

IGS08 Adoption

The IGS08 definition was finalized, including the updated ground antenna model (igs08.atx), and circulated to Analysis Centers for their final comments. At year-end, preparations were in progress to implement IGS08 in early 2011.

Working Group Activities

The IGS Working Groups responsible for the various IGS products have progressed in 2010:

- The TIGA Pilot Project has transitioned into the TIGA Working Group with introduction of an official IGS tide gauge product.
- A new Space Vehicle Orbit Dynamics Working Group has been formed to develop an advanced GNSS satellite force model for use within IGS.
- The Multi-GNSS Working Group activities are increasing in response to the Newcastle workshop recommendations. The WG is cooperating with the CONGO Network and JAXA/QZSS Demonstration Experiment to assemble a multi-GNSS data set for experimental use within IGS.
- The Real-time Working Group began producing a combined real-time orbit and clock product on an experimental basis. The RT WG is also pursuing establishment of standards for real-time GNSS messages in cooperation with the Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS (RTCM/SC104), which is the principal international standards organization for real-time GNSS services.
- The Antenna Working Group has compiled igs08.atx, updated the ANTEX format, and coordinated with calibration centers and GNSS manufacturers to include new calibrations within the IGS equipment definition files.
- The Ionosphere Working Group introduced a new predicted ionosphere product.
- The Data Center Working Group began implementation of daily data status summary files at all the Global Data Centers. The file summarizes the daily data holdings and extracts key metadata and data quality information from all files.

International Coordination and Outreach

The IGS coordinates extensively with many external organizations to promote the IGS and develop relations with stakeholders around the world. 2010 was highlighted by coordination with projects involving multiple GNSS to develop cooperation in implementing new

GNSS signals within IGS. Also in 2010, IGS involvement in the International Committee on GNSS (ICG) was elevated to co-chair (along with the International Federation of Surveyors) of a newly formed task force on Reference Frames, Timing and Applications (formerly Working Group D).

Governance

Significant governance items in 2010 include:

- Urs Hugentobler of TU Munich was elected Chairman of the Governing Board to replace John Dow whose term ended at the end of 2010.
- The IGS Terms of Reference were fully reviewed and updated by the Governing Board to better reflect the current organization.
- A new IGS Associates Committee was formed to review the Associate Membership.

Meetings

IGS conducted the following meetings in 2010:

36th Governing Board (GB)	Newcastle-upon-Tyne	27 June 2010
IGS Newcastle Workshop 2010	Newcastle-upon-Tyne	28 June – 2 July 2010
Closing 36th GB	Newcastle-upon-Tyne	2 July 2010
37th GB	San Francisco	12 Dec 2010

The next IGS Workshop will take place in 2012. The dates and location will be selected by early 2011.

Publications

Many papers, articles and presentations relating to IGS were published or presented in 2010. A partial listing of these is posted online at <http://tinyurl.com/IGS-bibli>.

Summary

The IGS has continued its delivery of high quality products to the IERS, which represent a significant contribution to the realization of the ITRF. The quality of the IGS results continue to improve. More information regarding the IGS and related activities can be found on the IGS Central Bureau website < http://www.igs.org/>.

Steven Fisher
on behalf of all IGS participants
who supported this body of work

3.4.2 International Laser Ranging Service (ILRS)

Introduction

The International Laser Ranging Service (ILRS), established in 1998, is responsible for the coordination of SLR/LLR missions, technique development, network operations, data analysis and scientific interpretation. Here we summarize the status and developments in 2010.

Network

The network of SLR/LLR stations, under the aegis of the ILRS, has been subject to change over the years. From a technical perspective, the quality of the observations has improved drastically during the past decade. At this moment, the single-shot precision of an average station is better than 10 mm (for the best stations this number is a few millimeters). The absolute quality of the individual observations is at the 10 mm level, with a significant number of stations doing significantly better. The geometry of the SLR network has been a point of concern over the years (cf. Figure 1). However, the network has improved slightly in recent

Fig. 1: The global network of SLR stations (status early 2011).

years. NASA's next generation SLR system is in the final stages of development, and it is expected to reach completion by next year. The switching to high repetition rate systems at a number of sites has increased productivity and improved data quality. This evolution will slowly lead us to the GGOS-era network as described in their GGOS2020 document.

The network sustained a major disruption on February 27, when a "megaquake" of magnitude 8.8 with a duration of about 2.5 minutes, hit the Concepción area in Chile. All geodetic instruments at the site were affected and SLR operations were suspended. The coseismic relocation of the site by more than 3 m required tremendous effort from the local crew to bring the systems back up to normal operations. Surprisingly, SLR was up by mid-April and tracking successfully by late April in operational mode. Because of the ILRS network's poor station distribution, particularly in the southern hemisphere, the loss of this site was reflected immediately in the quality of the products delivered while the Concepción SLR was inoperable.

Statistics of the data collected as pass segments during the calendar year 2010 are summarized in Table 1. For each of the contributing stations the tracked passes are broken down in three categories of tracked targets: Low Earth Orbiters (LEO), LAGEOS 1 & 2, and the High Earth Orbiters (HEO) which include the GPS, GLONASS, ETALON and GIOVE-A/B satellites (GALILEO test s/c), as well as a number of recently launched Beidou satellites, part of the Chinese Navigation Constellation COMPASS/Beidou.

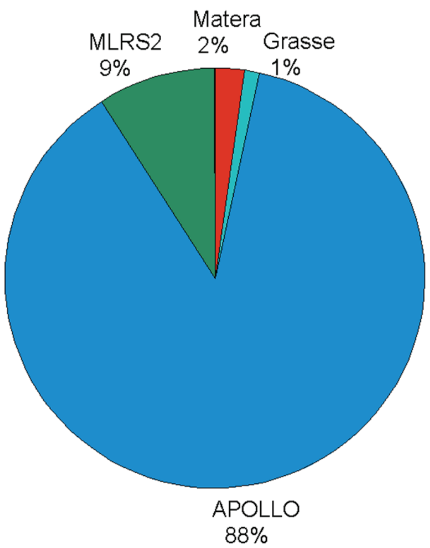

Fig. 2: Observatory statistics in 2010.

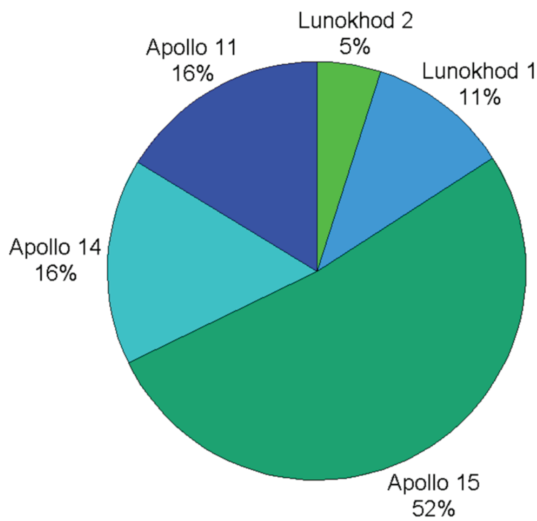

Fig. 3: Reflector statistics in 2010.

3.4.2 International Laser Ranging Service (ILRS)

Table 1: ILRS Network Tracking Statistics for 2010.

Site Name	Station	Number of Passes			Total
		Low	LAGEOS	High	
Altay	1879	137	176	238	551
Arequipa	7403	1,503	91	0	1,594
Beijing	7249	341	51	30	422
Borowiec	7811	61	11	0	72
Changchun	7237	6,474	817	455	7,746
Concepcion	7405	1,873	591	273	2,737
Grasse	7845	1,534	658	1,148	3,340
Graz	7839	4,757	670	546	5,973
Greenbelt	7105	1,510	334	322	2,166
Haleakala	7119	1,413	404	0	1,817
Hartebeesthoek	7501	1,196	262	168	1,626
Herstmonceux	7840	3,862	754	1,306	5,922
Katzively	1893	1,288	203	151	1,642
Kiev	1824	680	129	30	839
Koganei	7308	1,058	291	374	1,723
Koganei	7328	38	18	0	56
Komsomolsk-Na-Amure	1868	43	139	120	302
Matera	7941	4,266	1,686	2,018	7,970
McDonald	7080	1,142	446	247	1,835
Monument Peak	7110	2,781	829	1,013	4,623
Mount Stromlo	7825	6,420	1,068	521	8,009
Potsdam	7841	2,319	390	58	2,767
Riga	1884	1,187	133	4	1,324
Riyadh	7832	843	220	73	1,136
San Fernando	7824	2,709	288	44	3,041
San Juan	7406	2,739	492	839	4,070
Shanghai	7821	1,905	343	409	2,657
Simeiz	1873	1,103	333	9	1,445
Simosato	7838	871	345	28	1,244
Tahiti	7124	553	168	8	729
Tanegashima	7358	362	162	91	615
Wettzell	8834	1,598	330	198	2,126
Yarragadee	7090	15,289	3,329	4,733	23,351
Zimmerwald	7810	5,151	1,009	1,112	7,272
Totals	34 stations	79,006	17,170	16,566	112,742

From all of the ILRS observatories (about 35), only a few laser ranging systems are technically equipped to track retro-reflector arrays on the surface of the Moon or spacecraft orbiting around the Moon. The active Lunar Laser Ranging (LLR) sites in 2010 were the three well-known observatories: the McDonald Observatory in Texas, USA, the APOLLO site in New Mexico, USA, and the Observatoire de la Côte d' Azur, France. In addition, the Matera Laser Ranging station in Italy showed its lunar capability for the first time providing a few normal points. Finally, the German Geodetic Observatory at Wettzell worked on its system to soon join the LLR tracking network. The measurement statistics of 2010 (Figure 2) clearly shows that most of the data have been collected at the APOLLO site.

Figure 3 illustrates the statistics for the observed reflectors: The good distribution among all reflectors is mainly due to the APOLLO site contribution, which gets a relatively strong signal even from the smaller reflectors. The most remarkable event on the LLR reflector side was the re-discovery of the Lunokhod 1 reflector that was taken to the Moon by the unmanned Soviet mission Luna 17 (Figure 4). The exact position of the Lunokhod 1 rover was unknown for nearly 39 years, before it was observed by LRO in March 2010. Initial laser measurements were a few days later carried out by the APOLLO site. The LLR data showed the reflector in a good condition with a strong signal. Due to its close position to the lunar limb, the Lunokhod 1 reflector has a high sensitivity to the orientation of the Moon, it helps to obtain a better determination of lunar libration in longitude and latitude.

Today, the LLR results are considered among the most important science return of the Apollo era. It has continuously provided range data for about 40 years, generating about 16800 normal points by 2010. Based on appropriate modeling and sophisticated data analysis, LLR determines many parameters of the Earth–Moon dynamics like lunar ephemeris, lunar physics, the Moon's interior, reference frames and Earth orientation parameters.

LLR has also become a strong tool for testing Einstein's theory of general relativity in the solar system. By extending the standard solution, it is possible to solve for parameters related to gravitational physics, like the temporal variation of the gravitational constant, metric parameters as well as the strong equivalence principle and preferred-frame effects. As one example of a recent study see Hofmann et al. (2010). So far, all LLR-based relativity tests have confirmed Einstein's theory of gravitation.

In 2010, an ISSI (International Space Science Institute, Berne, Switzerland) workshop series has been started dedicated on "Theory and model for the new generation of the Lunar Laser Ranging data", where experts from various disciplines discuss future challenges in LLR observation, modeling and analysis.

3.4.2 International Laser Ranging Service (ILRS)

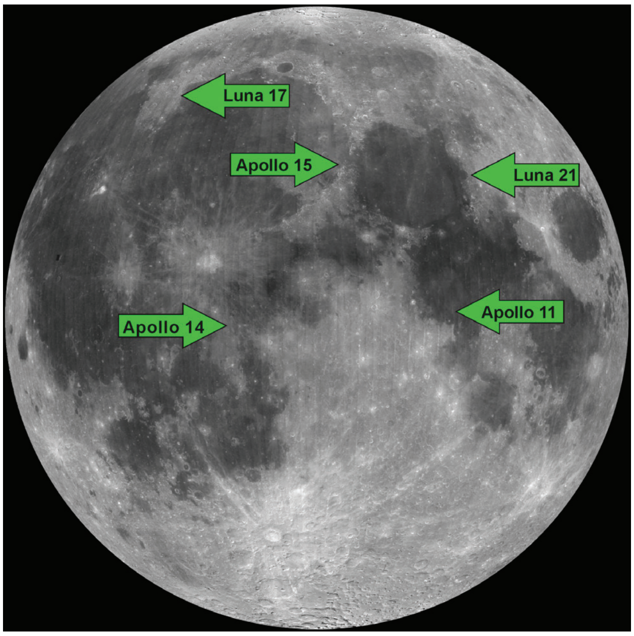

Fig. 4: Retro-reflector sites on the Moon, Luna 17 has not been successfully tracked until 2010.

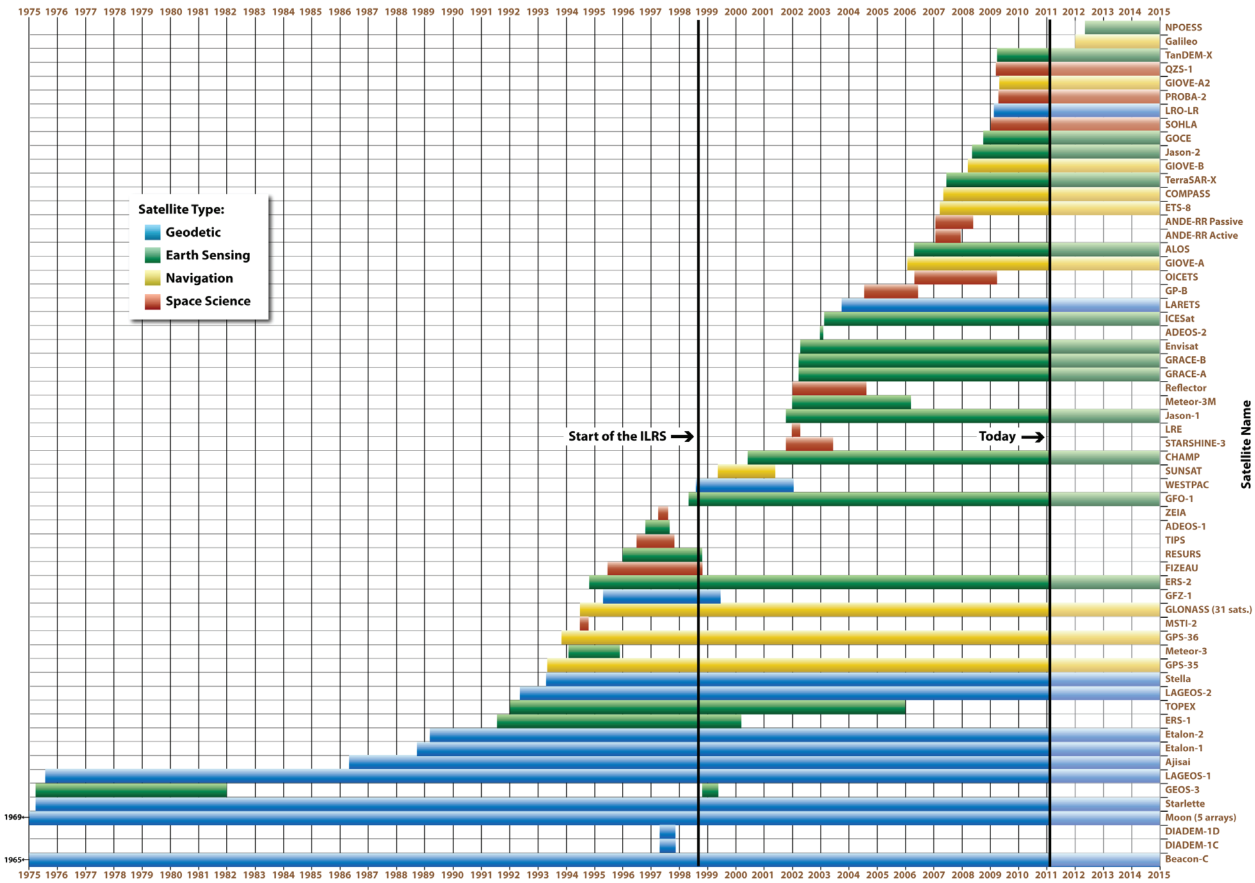

Fig. 5: The currently tracked SLR missions (status early 2011).

Missions

In 2010, a total of ~30 satellites (including the Moon) were being tracked by laser (Figure 5). Of these, only about 1/3 are geodetic type targets (cannonball satellites), the rest are mainly Earth Observation missions and navigation satellites, along with a small number of experimental space science missions. During 2010 we had six successful launches of satellites carrying LRAs, listed in Table 2. The first one, COMPASS-G1 is a geostationary member of the COMPASS/Beidou Constellation, launched by China. Cryosat-2, the second launch, is an ESA mission for observation of the cryosphere and the oceans with radar altimeters and Synthetic Aperture Radar (SAR). The third mission, TanDEM-X, is a German DLR mission to complete the imaging pair with TerraSAR-X, launched back in 2007. QZS-1 is the fourth mission and the first of a Japanese Navigation Constellation that intends to improve navigation in urban areas of Japan and the surrounding regions. There were also two multi-payload launches from Russia, each one placing in orbit three new GLONASS satellites, 119-120-121 and 122-123-124. The new GLONASS-M satellites carry improved LRAs and ILRS initiated tracking campaigns to evaluate the effectiveness of the new design. The group of GLONASS spacecraft tracked by ILRS was changed to substitute older spacecraft with the recently launched. Some ILRS stations begun tracking a larger number of GLONASS satellites in order to gain experience in handling a large number of HEO targets, something ILRS will have to contend with once GLONASS, Galileo, COMPASS/Beidou, etc. become fully operational and request tracking support.

A number of missions completed their operations in 2010 (Table 3). The pair of ANDE spacecraft Pollux and Castor completed successfully their mission in late March. ETS-8 collected its last observations in late July, and ICESat in the beginning of August. The first geopotential mapping mission CHAMP collected its last observation on September 4, and after a successful 10-year

Table 2: ILRS Supported Missions Launched in 2010.

Satellite Name	Satellite ID	SIC Code	NORAD Number	NP Indicator	Bin Size (Seconds)	Altitude (Km)	Inclination (deg)	First Data Date
COMPASS-G1	1000101	2002	36287	9	300	42,164	55.5	28-Apr-12
Cryosat-2	1001301	8006	36508	3	15	720	92	20-Apr-10
TanDEM-X	1003001	6202	36605	1	5	514	97.44	21-Jun-10
QZS-1	1004501	1581	37158	9	300	32,000-40,000	45	11-Sep-10
GLONASS-119	1000701	9119	36400	9	300	19,140	65	
GLONASS-121	1000702	9121	36401	9	300	19,140	65	12-Apr-10
GLONASS-120	1000703	9120	36402	9	300	19,140	65	12-Apr-10
GLONASS-124	1004101	9124	37137	9	300	19,140	65	11-Oct-10
GLONASS-123	1004102	9122	37138	9	300	19,140	65	7-Oct-10
GLONASS-122	1004103	9122	37139	9	300	19,140	65	6-Oct-10

Table 3: Missions that ended their operations in 2010.

Satellite Name	Satellite ID	SIC Code	NORAD Number	NP Indicator	Bin Size (Seconds)	Altitude (Km)	Inclination (deg)	First Data Date	Last Data Date
ANDE Pollux	903805	1074	35693	1	5	350	51.6	4-Aug-09	16-Mar-10
ANDE Castor	903806	1073	35694	1	5	350	51.6	4-Aug-09	1-Apr-10
ETS-8	605901	1579	29656	9	300	36,000	0	10-Mar-07	29-Jul-10
ICESat	300201	8201	27642	1	5	600	94	5-Mar-03	2-Aug-10
CHAMP	3902	8002	26405	1	5	474	87	1-Jan-00	4-Sep-10

mission, it entered the atmosphere for a final trajectory on September 20.

Analysis and science

The main topic on which most of the Analysis Centers focused their work during 2010 was the evaluation and validation of ITRF2008 candidate models. Two such TRFs were produced and delivered to the Services for evaluation: ITRF2008P from the French/IGN ITRS CC and ITRF2008D from the German/DGFI CC. The two models were made available in early April and the intention was to complete their evaluation by the Services so that a final model could be adopted for official release during a dedicated meeting (REFAG 2010) in Paris, in early October 2010. The general consensus amongst the Analysis Working Group (AWG) was that the two models performed very similarly and were both an improvement upon ITRF2005. When compared in 3-D station positions and network scale, we can see a slight (but throughout consistent) preference for the ITRF2008D model, at the few tenths of a millimeter level (Fig. 6).

	vs SLRF2005		vs ITRF2008		vs ITRF2008D	
	<WRMS> [mm]	σWRMS [mm]	<WRMS> [mm]	σWRMS [mm]	<WRMS> [mm]	σWRMS [mm]
All Sites	**13.21**	***18.80***	**10.93**	***18.43***	**10.48**	***18.54***
Core Sites	**8.44**	***5.79***	**7.13**	***4.99***	**6.89**	***5.12***

Fig. 6: Weighted RMS statistics of X, Y, and Z coordinates of stations in the ILRS network with respect to the old ITRF2005 (SLRF2005 version of ILRS) and the two new candidate models ITRF2008 (IGN) and ITRF2008D (DGFI). Statistics are shown for the entire network (top line) and the Core sites only (bottom line). The comparison spans the entire period covered by SLR observations (1983.0 – 2009.0).

The most significant difference between the two candidate models was their scale definition. Although ITRF2008P is a clear improvement over the ITRF2005, the SLR data clearly prefer the scale

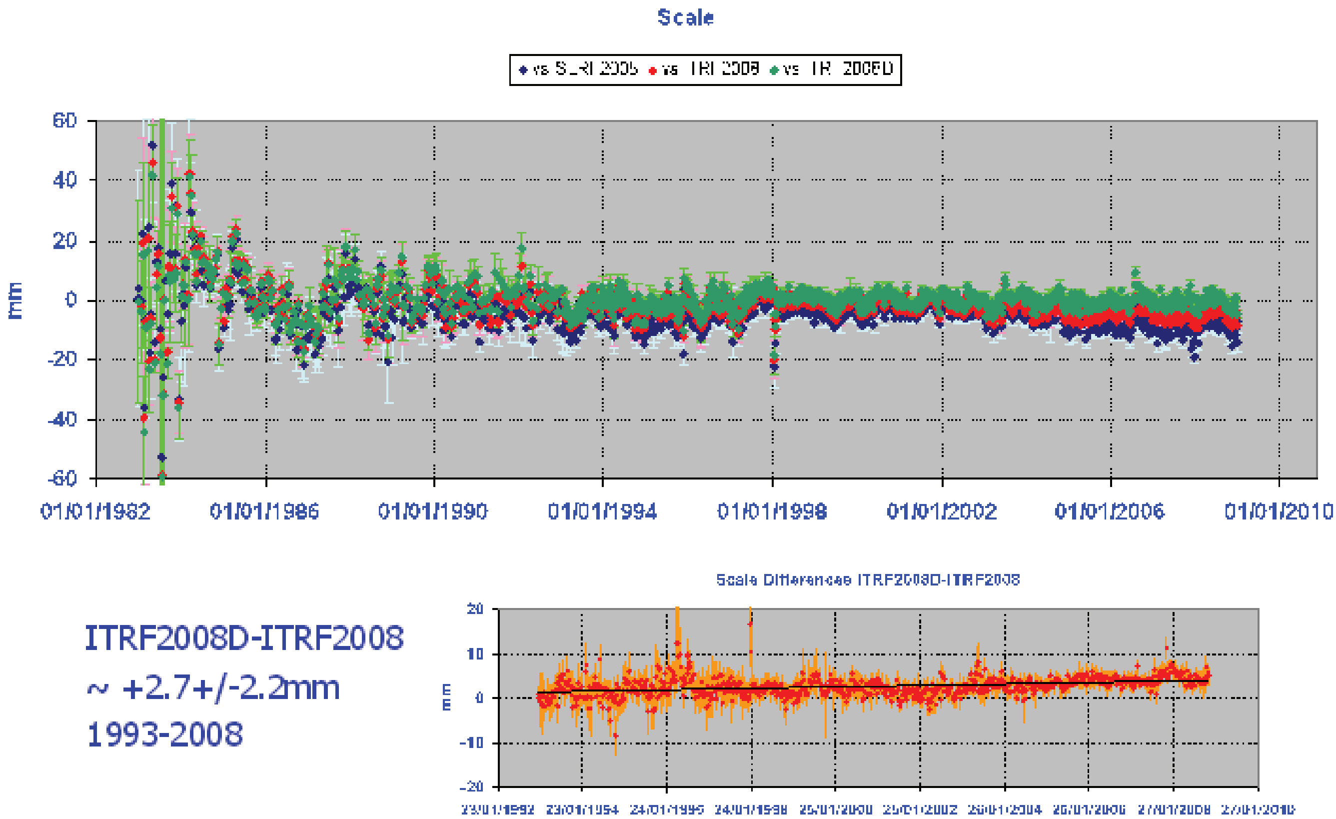

Fig. 7: Weekly ILRS product comparison in scale with respect to the old ITRF2005 (SLRF2005 version of ILRS) and the two new candidate models ITRF2008 (IGN) and ITRF2008D (DGFI). The systematic difference between ITRF2008 and ITRF2008D is shown in the second graph.

definition of ITRF2008D. This results in a trendless evolution of the scale as seen from the weekly ILRS products for the 1983.0 to 2009.0 period (Fig. 7). The two frames differ in scale systematically by 2.7 ± 2.2 mm/y over the 1993–2008 period, when the SLR data are of the highest quality. While the stability (rate) of the scale is –0.18 mm/y for ITRF2008P, for ITRF2008D is only –0.04 mm/y, both having a sigma of 0.01 mm/y.

Following the development of ITRF2005 ILRS' AWG took extreme care to eliminate systematic effects in the data, by resolving their source and correcting for them or by allowing for the estimation of appropriate parameters during the data reduction process. The primary concern of all AC analysts treating the same data with exactly the same measurement biases was also addressed and the AWG adopted the establishment and the maintenance of a "Data Handling" file in a quasi-SINEX format (machine readable), either known from engineering tests or detected during the analysis. With the accuracy of the results reaching a few millimeters at worst, even small biases of comparable magnitude cause discontinuities in the TRF and force the introduction of ad hoc "breaks" in the series which must be avoided at all costs since they cause instability in the end-product. The “Data Handling” must be interrogated every time one analyzes SLR data since it is updated frequently. To aid users a “version” and date of last update are included in the file, and they are changed when a new entry is inserted. This file is maintained by DGFI and can be accessed from:

<http://ilrs.dgfi.badw.de/data_handling/
ILRS_Data_Handling_File.snx>

A similarly formatted file called the “Discontinuities File” has been established in order to keep track of the various events at each site of the network that mark the different periods of operation of each site between changes (that result in a functionally/operationally different system). This file is also maintained by DGFI and can be accessed from:

<http://ilrs.dgfi.badw.de/data_handling/
ILRS_Discontinuities_File.snx>

The “Discontinuities File” is of more interest to the ITRF developers and users, rather than to the SLR analysts.

During 2009 the European Space Agency Space Operations Center (ESOC) underwent benchmark activities to become an official ILRS Analysis Center under the codename “ESA”. Most of the testing formalities were successfully completed at the end of 2009, and ESA joined the ILRS AWG as the ninth AC in early 2010.

Meetings

The ILRS held a number of meetings in 2010. The first one was the Governing Board meeting at the EGU in Vienna, Austria, followed by meetings of various Working Groups including the AWG. There was no International Laser Workshop in 2010, nor a Technical Workshop, however, in the fall, in conjunction with the IAG Commission 1 Symposium on Reference Frames for Applications in Geosciences, in Marne-la-Vallee, France, October 04–08, 2010, we held a second ILRS Analysis Working Group Meeting, on October 01, 2010. In addition to these two main events, the ILRS participated in several international meetings and held several internal meetings of its Central Bureau (<http://ilrs.gsfc.nasa.gov/about_ilrs/meetings.html>).

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3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2010, the IVS continued to fulfill its role as a service within the IAG and IAU by providing necessary products for the maintenance of global reference frames: TRF, CRF, and EOP. Some highlights of the IVS organization and activities were:

- During February 7–11, 2010, the 6th IVS General Meeting was held at the University of Tasmania in Hobart, Tasmania, Australia.
- The 11th IVS Analysis Workshop and the VLBI2010 Developers Workshop were also held at the University of Tasmania on February 12, 2010.
- The spring 2010 IVS Directing Board meeting (IVS DB meeting #23) was held on February 13, 2010, also at the University of Tasmania in Hobart.
- The fall 2010 IVS Directing Board meeting (IVS DB meeting #24) was held at Shanghai Astronomical Observatory, Shanghai, China on October 23, 2010.
- The 9th International e-VLBI Workshop was held in Perth, Western Australia, Australia on October 19–20, 2010.
- In 2010, the Politecnico di Milano DIIAR (PMD) (Italy) was accepted as a new IVS Associate Analysis Center.
- In the summer of 2010 the IVS published the 2009 Annual Report. Furthermore, three IVS newsletters were published in April, August and December 2010 to keep the community informed about IVS activities.
- A dynamic Web site was set up at the Laboratoire d'Astrophysique de Bordeaux that allows users to follow IVS sessions in real-time (<http://ivslive.obs.u-bordeaux1.fr>).
- The VLBI2010 Project Executive Group (VPEG) sent out support letters for several international VLBI projects.

Network Stations

The IVS network operated well for most of 2010. The average single station loss is estimated to have been in the range of 10–20%, similar to previous years. One of several positive developments this year was the increased usage of e-transfer. This speeds data transfer and reduces shipping costs. Another positive development was that Mark 5B recorders were installed at several stations. This will improve correlator efficiency. A third development is that digital back-ends are starting to be used for operations. The DBBC developed by the EVN is being used at Hobart in Australia and will be used at Katherine and Yarragadee as well and in New Zealand. The Haystack/NRAO developed RDBE is nearing readiness for observations and is expected to start being used in 2011. There were a few notable issues with IVS antennas:

- Fortaleza could not observe throughout 2010.
- Kokee Park had problems with the azimuth drive.
- Matera operated with a warm receiver for the whole year.
- Medicina had problems with a warm receiver since November.
- Noto started observing again in April after a bearing repair.
- Ny-Ålesund had high SEFD values since May.
- The O'Higgins burst campaign had to be cancelled due to illness of personnel.
- Svetloe started observing after repair in July.
- Tigo Concepción was strongly affected by the 2010 Maule earthquake on February 27. Two weeks later the station started to observe again.
- The Tsukuba telescope was hit by lightning and could not observe in August and September.
- Wettzell had reduced operations during April through August due to problems with telescope bearings, and was out of operations during September through November because of bearing repair.
- The new 12-m telescope at Hobart was completed and started operations in 2010.

A total of 151 geodetic/astrometric 24-hour sessions were observed during the year 2010. The number of 24-hour sessions coordinated by IVS remained at an average of ~3 days per week, similar to previous years. The major observing programs during 2010 were:

IVS-R1, IVS-R4

Weekly (Mondays and Thursdays) 24-hour, rapid turnaround measurements of EOP. Databases are available no later than 15 days after each session. The NASA Goddard Space Flight Center (R1) and the U. S. Naval Observatory (R4) coordinate these sessions.

Intensive

Daily 1-hour UT1 Intensive measurements are made on five days (Monday through Friday, Int1) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA), on weekend days (Saturday and Sunday, Int2) on the baseline Wettzell (Germany) to Tsukuba (Japan), and on Monday mornings (Int3) in the middle of the 36-hour gap between the Int1 and Int2 Intensive series on the network Wettzell (Germany), Ny-Ålesund (Norway), and Tsukuba (Japan). During 2010 Kashima and replaced Tsukuba in Int2/Int3-sessions, and Ny-Ålesund and Westford replaced Wettzell in Int1- and Int2-sessions, respectively, during the times these stations were under repair.

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with at least 12 stations per session. Seven of these sessions were observed in 2010 to monitor the TRF with all IVS stations.

IVS-CRF The Celestial Reference Frame (CRF) sessions, coordinated by the U.S. Naval Observatory, provide astrometric observations that are required for improving the current CRF and in extending the CRF by observing 'new' sources. Four sessions were observed for the maintenance of the ICRF in 2010.

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 7 geodetic stations, providing state-of-the-art astrometry as well as information for mapping ICRF sources.

Europe The European geodetic network, coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, continued with six sessions in 2010.

IVS-OHIG The purpose of the IVS-OHIG (Southern Terrestrial Reference Frame) sessions is to tie together optimally the sites in the southern hemisphere. The participating sites include all the sites available in the south. In 2010 three OHIG sessions were observed

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2010.

JADE The JApanese Dynamic Earth observation by VLBI (JADE) had eight sessions during 2010. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

IVS-R&D Five research and development sessions were observed in 2010.

TC-Quake Five dedicated sessions were observed to determine the position of Tigo Concepción after the Maule earthquake on February 27, 2010.

Correlators

The correlator at Haystack Observatory (USA), the correlator at the U.S. Naval Observatory in Washington (USA), the BKG/MPIfR correlator at the Max Planck Institute for Radioastronomy in Bonn (Germany) and the correlator at the Geographical Survey Institute (GSI) in Tsukuba, Japan continued their efficient processing of the data recorded for the IVS. The Bonn and Washington correlators processed the majority of the experiments. The Washington correlator processed all R4 and Int1 sessions. The Bonn correlator used its high-speed optical fiber connections for e-transfer from several network stations in Europe and Japan and processed, e.g., all R1, Europe, OHIG, and Int3 sessions. The MkIV hardware correlator at Bonn failed in December 2010 and since then the Bonn correlator uses the DiFX software correlator. The Tsukuba correlator processed all Int2 and domestic Japanese sessions and continued to process ultra-rapid 24-hour dUT1 sessions on the baseline Onsala–Tsukuba. The Haystack correlator processed primarily RD and T2 sessions.

Data Centers

The IVS Data Centers continued to receive databases throughout the year and made them available for analysis within one day of correlation. The Data Centers also continued to receive solutions from Analysis Centers. All data and results holdings are mirrored several times per day among the three primary IVS Data Centers at BKG (Germany), Paris Observatory (France), and Goddard Space Flight Center (USA).

IVS Operational Data Analysis and Combination

The combination process for the two IVS EOP series (rapid and quarterly solutions) has been continued exclusively on the basis of datum-free normal equations in SINEX format. In 2010, six IVS Analysis Centers (BKG, DGFI, GSFC, IAA, OPA, and USNO) contributed to the IVS combined products by providing input in the correct format. The rapid solutions contain only R1 and R4 sessions and new data points are added twice a week as soon as the SINEX files of at least five IVS Analysis Centers are available. The SINEX file submissions should not be later than 48 hours after the correlation is completed. A Web page is automatically updated which lists the timeliness of the latest submissions of the R1 and R4 sessions (see <http://ida.bkg.bund.de/IVS/data/timeliness_2.html>).

Every three months the quarterly solution is updated. For this solution almost all available data of 24-hour sessions from 1984 onwards are used. Since this series is designed for EOP determinations, those sessions are excluded that are observed with networks of limited extension or which are scheduled for a different purpose like radio source monitoring.

The results are reported in two EOP time series: the rapid solution file and the quarterly solution file, both in the IVS EOP Exchange format. Solution files are available in two forms, expressed with nutation offsets dX, dY referred to the IAU2006 precession-nutation model excluding free core nutation, and with nutation offsets dPsi, dEps referred to the IAU2000A precession-nutation model excluding free core nutation.

Technology Development

During 2010 progress continued towards the goal of a next-generation VLBI2010 system, e-VLBI, and other technical aspects. Some important highlights were:

- Two broad-band feed horns for VLBI2010, the Swedish ‘Eleven’ feed and the American ‘QRFH’ feed were tested.
- The work on digital backends continued with the European DBBC and the American RDBE development.
- The recording system Mark 5C was successfully tested with 4 Gbps recording speed.
- The installation of the Twin-Telescope Wettzell started in 2010.
- New 12-m telescopes were installed at NASA Goddard Space Flight Center (USA), at Arecibo (USA), and Katherine and Yarragadee (Australia).
- Several VLBI2010 projects were started and funding proposals prepared and submitted.
- Work continued to test technical equipment developed for VLBI2010 involving the Westford telescope and the new antenna at NASA/GSFC.
- A VLBI Standards Web Site was established (<http://www.vlbi.org).
- The VEX2 Task Force continued to work on the VEX (VLBI Experiment Documentation) file format.

Rüdiger Haas, Dirk Behrend, Axel Nothnagel

3.4.4 International DORIS Service (IDS)

Overview

The current report presents the different activities held by all components of the International DORIS Service (IDS). First, we present the current status of the DORIS system (available satellites and tracking network). Second, we present the activities of the IDS Central Bureau (IDS Web site management and DORIS-related email distributions). We then focus on the most recent activities conducted by the Analysis Centers (ACs) and the Analysis Coordination. Finally, we will present other activities related to meetings and publications.

1 DORIS system

The DORIS system celebrates in 2010 its 20^{th} anniversary. It was first tested on the Spot-2 satellite, launched on the 22nd January 1990.

1.1 DORIS satellites

During this report period (2010), the number of DORIS satellites has remained between five and six (see Table 1).

On April 8, 2010, a new DORIS satellite (Cryosat-2) was launched including the newest-generation receiver (DGXX). The new receiver is digital, can track up to 7 beacons simultaneously, and allows direct phase measurement like GPS (instead of Doppler data).

In the near future, several new DORIS satellites are already planned (and approved): HY-2A, SARAL, Sentinel-3A, Jason-3, … This should increase or at least stabilize the number of DORIS satellites in the 2011–2016 time period.

Table 1: DORIS data available at IGN. As of December 2010

Satellite	Start	End	Type
SPOT-2	31-MAR-90 04-NOV-92	04-JUL-90 15-JUL-09	Remote sensing
TOPEX/Poseidon	25-SEP-92	01-NOV-04	Altimetry
SPOT-3	01-FEB-94	09-NOV-96	Remote sensing
SPOT-4	01-MAY-98	–	Remote sensing
SPOT-5	11-JUN-02	–	Remote sensing
Jason-1	15-JAN-02	–	Altimetry
ENVISAT	13-JUN-02	–	Altimetry, Environment
Jason-2	12-JUL-08	–	Altimetry
Cryosat-2	30-MAY-10	–	Altimetry

1.2 DORIS tracking network

The DORIS permanent tracking network remains very stable (Figure 1). About 50% of the DORIS stations are in co-location with other geodetic space techniques: GPS (38), SLR (9) and VLBI (6). A new station was installed in Cold Bay (Alaska peninsula) on November 2010. It replaced the Fairbanks station which has been down since July 2010 and was removed on October 7^{th}.

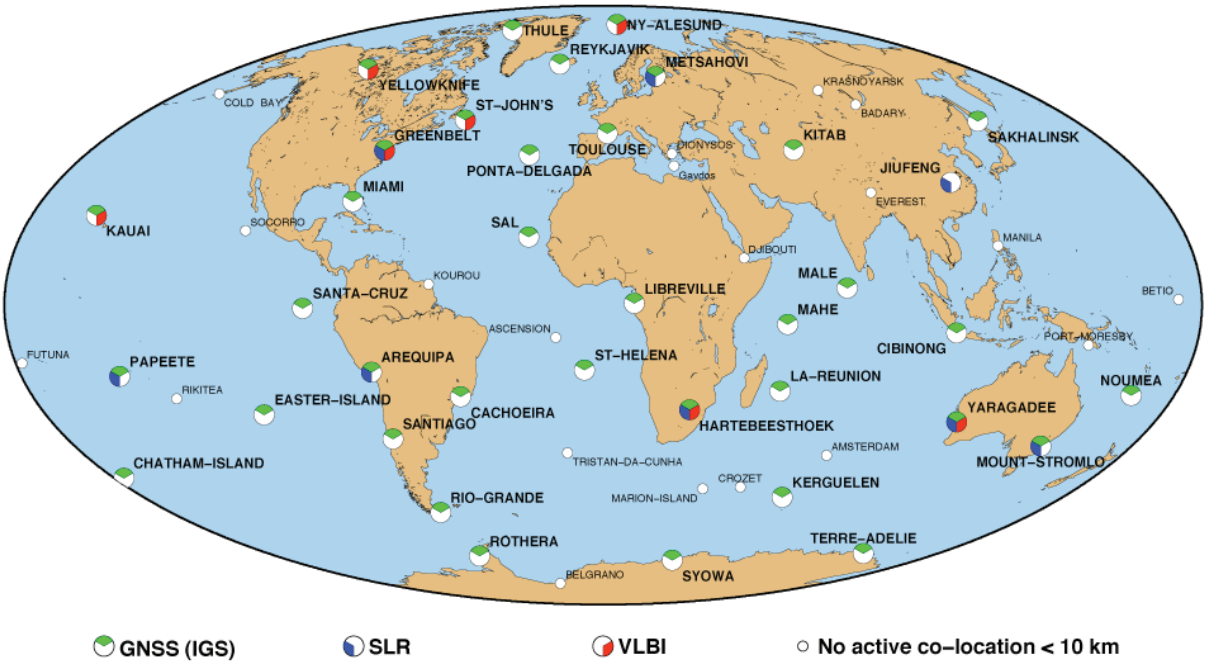

Fig. 1: DORIS stations co-located with other techniques (VLBI, SLR, GNSS) (as of Nov. 2010).

In Santiago, the station has undergone a shift of 30 cm caused by the magnitude 8.8 Chile/Maule earthquake of February 27th, 2010. At Monument Peak, broadcasts were permanently halted on February 6th, 2010, due to conflict in frequency of transmission between the DORIS beacon and a nearby US TV 2GHz micro-wave relay system. This conflict arose because of a reallocation of frequency use in the United States that took affect in 2009. The 2 GHz channel used by DORIS now overlaps that used by mobile television relay.

2 IDS Governing Board

The current Governing Board was elected at the end of 2008 (see Table 2). In 2010, Hervé Fagard resigned as network representative and was replaced by Bruno Garayt (IGN). Activities related to DORIS tracking network is now performed by Jérôme Saunier who becomes a member of the Central Bureau.

Table 2: Composition of the IDS Governing Board (since January 2010)

Name	Institution	Country	Mandate
Pascale Ferrage	CNES	France	Member at large
Bruno Garayt	IGN	France	Network representative
Frank Lemoine	GSFC	USA	Analysis Coordinator
Chopo Ma	GSFC	USA	IERS representative
Carey Noll	GSFC	USA	Data flow Coordinator
Michiel Otten	ESOC	Germany	IAG representative
John Ries	U. Texas/CSR	USA	Member at large
Laurent Soudarin	CLS	France	Director IDS Central Bureau
Pascal Willis (chair)	IGN/IPGP	France	Analysis Center representative

3 IDS Central Bureau

3.1 IDS Web and ftp sites

The IDS Central Bureau maintains the IDS web and ftp sites. In 2010, a new version of the web site was made available at <http://ids-doris.org> (DORISmail 654). It is developed with a CMS (Content Management System) which offers new capabilities for the management and the update of the site. The structure stays the same but the system address has changed. New pages were developed: site updates (history of the main page updates), station events (new sites, new antennas, removed sites, data gaps, invalidated data...), list of the main events that occurred on each DORIS mission impacting the data delivered to the Data centers.

The ftp site has been moved to a new server. All the documents are now available at <ftp://ftp.ids-doris.org/pub/ids> (DORISmail 647).

Access to the IDS website has been steadily increasing from month to month since Spring 2000. In early 2010, this website was accessed about 2000 times each month on a regular basis.

3.2 IDS Mail system

Several types of emails are distributed by the IDS Central Bureau:

- DORISMail: general DORIS interest
- DORISReports: reports related to DORIS data and products
- AWG and IDS Analysis Forum: technical discussion between analysis centers, combination and coordination
- DORISstations: information about station events (data gap, positioning discontinuities)

Everyone is welcome to subscribe to any of these emails. See more details on <http://ids-doris.org/report/mails.html>.

4 IDS Data Centers

The IDS data flow organization remains the same, but is now more robust. It is based on two data centers: one on the East Coast of the U.S. (CDDIS at NASA GSFC) and one in Europe (IGN in France). They are both exact mirrors of each other, and so, are able to continue on an operational basis, even if one of them is inaccessible due to a temporary failure.

These two data centers archive the DORIS data as well as the IDS products (station coordinates and velocity, geocenter motion, earth orientation parameters, ionosphere data, etc.).

5 IDS Analysis Centers

Like the other technique services in IAG, IDS has now a large number of independent Analysis Centers.

All seven analysis centers that participated in ITRF2008 continue to remain active, participating in the IDS activities. In addition TU Delft (E. Schrama) participated in the IDS AWG in 2010 with his evaluation of the POD performance of Cryosat-2 with SLR and DORIS data. The CNES POD center (L. Cerri, A. Couhert) was also an active IDS participant in all POD analyses, including the ITRF2008 station coordinate evaluation.

Table 3: List of IDS Analysis Centers routinely participating in the analysis activities in 2010.

Acronym	Analysis Center	Country	Software package
ESA	ESOC	Germany	NAPEOS
GAU	Geoscience Australia	Australia	GEODYN
GOP	Geodetic Observatory Pecny	Czech Rep.	Bernese
GSC	GSFC	USA	GEODYN
IGN	IGN	France	GIPSY/OASIS
INA	INASAN	Russia	GIPSY/OASIS
LCA	CNES/CLS	France	GINS/DYNAMO

The analysis activities consisted of: (1) follow-up activities related to the development of ITRF2008, including the extension of the data processing to include data in 2009; (2) the development of satellite-only time series of SINEX solutions as part of an analysis campaign to try and ascertain the causes of scale and Tz variations in IDS solutions; (3) the evaluation of the IDS3 solution with respect to ITRF2008 and the EOP performance for the cumulative solution and per Analysis Center (AC); (4) the assessment of the Jason-2 contribution to the IDS combination (Jason2 was not included in the IDS combination solution created for ITRF2008); (5) the first assessment of the Cryosat2 DORIS data; (6) the evaluation of the DORIS and SLR complements of the ITRF2008 solution using POD and other tests.

6 IDS Combination

In line with the successful DORIS contribution to ITRF2008, IDS decided to extend the combination process to an operational service.

At this stage of the service development, the ACs agreed to deliver every three months, with three months of delay, three months of their latest combined SINEX series. Then, a few days after the submission deadline, the Combination Center will download the ACs solutions and will start to evaluate each SINEX series. This evaluation step has been designed to check the internal continuity of the individual solutions and will be used to create weekly lists of ACs contribution to the combined solution. After delivery of an evaluation report to the ACs, combination of weekly SINEX series will be performed.

At the end of 2010, the routine combination is still in development. Meanwhile, evaluation of the first two deliveries (first six months of 2010) has been done and associated evaluation report is available for all the contributing ACs (ESA, GAU, GOP, GSC, INA, IGN and LCA).

7 Meetings

In 2010, the IDS organized the following meetings:

- DORIS Analysis Working Group Meeting, Darmstadt, Germany, 26–27 May, 2010

- DORIS Analysis Working Group Meeting, Lisbon, Portugal, 22 October, 2010
- IDS Workshop, Lisbon, Portugal, 21–22 October, 2010

All presentations from these meetings are made available by the Central Bureau on the IDs website at <http://ids-doris.org/meetings/ids-meetings.html>.

8 Publications

In 2006, a DORIS Special Issue was published in the Journal of Geodesy 80(8-11), including 17 peer-reviewed articles.

A second DORIS Special Issue was published in 2010 in Advances in Space Research (volumes 45 and 46, issue 12). It included 22 manuscripts written by a large number of authors and co-authors from different countries.

IDS published a 2010 activity report that was broadly distributed to all DORIS participants and relevant services (see <http://ids-doris.org/report/governing-board.html#activity>).

All DORIS related articles published in international peer-reviewed journals are available on the IDS Web site <http://ids-doris.org/report/publications/peer-reviewed-journals.html>.

Conclusions

In conclusion, the DORIS community had a productive year in 2010. Seven analysis centers routinely participated in the analysis activities. The combination process has been extended to an operational service. The ACs were asked to continue their series in so far as was possible to be consistent with their ITRF2008 submissions.

A second DORIS/DGXX has been placed in orbit on board the Cryosat-2 satellite. This new receiver generation brings more data (7-channel receiver), better quality (equivalent to 0.3 mm/s) and the possibility to process these data using a GPS-type technique (access to raw DORIS phase measurement instead of Doppler data). In the near future several new satellites equipped with DGXX instruments should be launched, insuring a minimum of four DORIS satellites for the 2011–2016 time period.

Laurent Soudarin

3.5 Product Centres

3.5.1 Earth Orientation Centre

This section presents the activities and the main results of the Earth Orientation Centre located at Paris Observatory over the year 2010. According to the IERS Terms of Reference, the Earth Orientation Centre is responsible for monitoring Earth orientation parameters including long term consistency, publications for time dissemination (DUT1) and leap second announcements. Earth Orientation Parameters (EOP: Polar motion, Universal Time (UT1), Length of Day (LOD) and Celestial pole offsets) are made available to a broad community of users in various domains such as astronomy, geodesy, geophysics, space sciences and time.

EOPs are given in the form of combined solutions obtained from the Technique Centers (IGS, IVS, ILRS and IDS). Various solutions are computed: a long-term solution (IERS C01) since 1846 and the Bulletin B given at one-day intervals published monthly with a 30 day delay. Bulletin B is updated in the operational C04.

Another issue is the maintenance of the consistency between the EOP system and the terrestrial reference frame. So far, Earth Orientation Parameters and the terrestrial frame are separately computed. This leads to increasing inconsistencies between both of them. At the end of 2009, these inconsistencies were small but significant for polar motion (about 100 μas). All IERS reference solutions (C01, Bulletin B, C04 as well as Bulletin A derived by the Rapid Service/Predictions Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008 (Altamimi et al., 2011)

Combined daily series: Bulletin B and 05 C04, statistics over 2009–2010

This section gives statistics (Tables 1 to 3) in term of formal errors and WRMS of the combined technique centres and individual solutions with respect to the combined solution Bulletin B and 08C04 over the year 2010. The procedure to achieve the Bulletin B and IERS C04 combined solution is described in Gambis (2004) and Bizouard and Gambis (2009). Only combined solutions derived by the various technique centres are used in the combinations. Statistics concerning individual series are only given as a feedback to the analysis centres.

New format of Bulletin B since January 2010

Bulletin B issued by the IERS EOP Centre was more than 20 years old in 2009. Following a survey among the scientific community, a new presentation is available since January 2010. The new Bulletin B and its content description are available respectively at

<ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.dat>

and

<ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.pdf>.

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B and 08 C04 over 2009–2010. The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to non modelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates. The star (*) is attributed to series entering the final combination.

Individual solutions		Estimated uncertainties				
		Time	Terrestrial Pole µas	UT1 µs	LOD µs	Celestial Pole µas
VLBI – 24 h						
EOP (AUS)	01 R 01	3–4d	225	11.4		125
EOP (BKG) *	03 R 02	1–4d	146	8.9		70
EOP (GSFC) *	07 R 01	1–4d	110	9.2		64
EOP (IAA)	05 R 02	1–4d	170	9.6		100
EOP (MAO)	03 R 01	1–4d	155	7.8		110
EOP (OPA)	07 R 01	1–4d	345	10.5		155
EOP (USNO)	06 R 02	1–4d	115	7.8		70
EOP(IVS) *	02 R 01	1–4d	149	4.6		38
VLBI – Intensive						
EOP (BKG) *	03 R 02	1–3 d		18.0		
EOP (GSFC) *	06 R 01	1–3 d		17.3		
EOP (SPBU) *	05 R 01	1–3 d		11.8		
EOP (USNO)	05 R 01	1–3 d		19.1		
SLR						
EOP (ASI)	03 L 02	1d	168		39.4	
EOP (IAA)	02 L 01	1d	189		19.6	
EOP (MCC)	97 L 01	1d	200		–	
EOP (ILRS)*	05 L 01	1d	170		38.4	
GPS						
EOP (CODE)	98 P 01	1d	27		13.1	
EOP (EMR)	96 P 03	1d	48		22.8	
EOP (ESOC)	96 P 01	1d	62		16.8	
EOP (GFZ)	96 P 02	1d	38		14.4	
EOP (IAA)	01 P 01	1d	177		30.7	
EOP (JPL)	96 P 03	1d	45		19.5	
EOP (NOAA)	96 P 01	1d	84		13.2	
EOP (SIO)	96 P 01	1d	45		19.2	
EOP (IGR) *	07 P 01	1d	32		7.7	
EOP (IGS) *	96 P 02	1d	25		8.7	
DORIS						
EOP (IGN)	05 D 01	1d	485			

Table 2: Mean and standard deviation of the differences between various combined techniques solutions and Bulletin B over 2009–2010

EOP	IGS Comb – IERS 08C04		ILRS Comb – IERS 08C04		IVS Comb – IERS 08C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	–4	26	–2	166	–1.7	133
Y (μas)	16	24	–23	119	130	168
UT1 (μs)					–1.1	4.1
LOD (μs)	0	8.7	9.6	39.4		
Dψsinε (μas)					4	32
Dψ(μas)					–45	38

Table 3: Mean and standard deviation for Pole components and UT1 of the differences between various combined solutions and Bulletin B over 2009–2010

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard deviation	Mean	Standard deviation
X	μas	–37	40	–2	38
Y	μas	67	39	3	27
UT1	μs	–1	10.9	–4	12.7

The content of Bulletin B is:

1 – DAILY FINAL VALUES AND PRELIMINARY VALUES OF x, y, UT1–UTC, dX, dY
and their respective uncertainties. The angular unit is milliarcsecond (mas), time unit is millisecond (ms).

2 – DAILY SMOOTHED VALUES OF CELESTIAL POLE OFFSETS (dPsi1980, dEps1980)
with respect to IAU 1980 precession-nutation model and their uncertainties.

3 – EARTH ANGULAR VELOCITY: DAILY VALUES OF LOD, OMEGA AT 0hUTC
LOD: Excess of the Length of Day – 86400 s TAI
OMEGA: Earth angular velocity

4 – INFORMATION ON TIME SCALES: TAI–UTC, leap second announcements

5 – SUMMARY OF CONTRIBUTED EARTH ORIENTATION PARAMETERS SERIES

Long-term series: C 01 (1846–2010)

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

The C 01 series was recomputed in the course of 2010 to be consistent with the reference system associated with ITRF2008. It is a composite series based on following temporal solutions:

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

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

1962–2008: BIH and IERS solutions (BIH and IERS annual reports).

Mean Pole with respect to the IERS reference origin

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

The mean polar motion is affected by a long-term drift westward (in the direction 70.7 deg West, rate: 4.2 mas/yr). The mean rotation axis with respect to the IERS Terrestrial Reference Frame can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2009 (Shiskin et al., 1965). Figure 1 represents the polar motion over 2006–2010 and the path of the mean pole since 1900. The coefficients of the IERS (2010) mean pole model are available in Conventions 2010 (Petit and Luzum, 2010). The table is regularly updated and is available at the following address:

<http://hpiers.obspm.fr/eop-pc/>

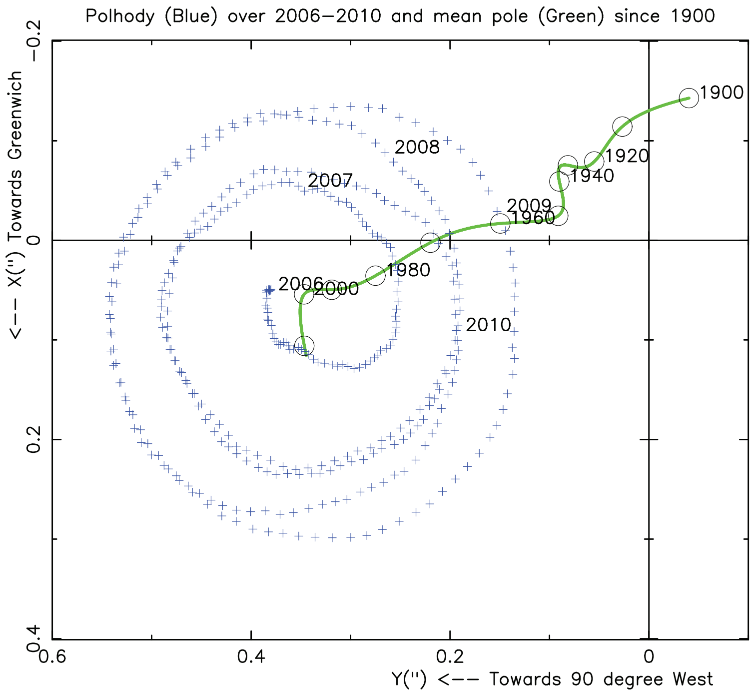

Fig. 1: Mean polar motion (Green line) over 1900–2010 and Bulletin B polhody over 2006–2010 (Blue dots)

Staff

Daniel Gambis	Astronomer, Head
Christian Bizouard	Astronomer
Teddy Carlucci	Engineer
Jean Yves Richard	Engineer
Olivier Becker	Engineer
Pascale Baudoin	Secretary

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3.5.2 Rapid Service/Prediction Centre

Processing Techniques

The algorithm used by the IERS Rapid Service/Prediction Center (RS/PC) for the determination of the quick-look Earth orientation parameters (EOP) is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy and Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases and rates with respect to the 05 C04 system of the IERS Earth Orientation Centre (EOC) at the Paris Observatory are determined using a robust linear estimator. Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques. Minimal smoothing is applied, consistent with the estimated accuracy of the observational data.

Weights in the algorithm may be either *a priori* values estimated by the standard deviation of the residual of the techniques or values based on the internal precision reported by contributors. Estimated accuracies of data contributed to the IERS Rapid Service/Prediction Centre are given in Table 1. These estimates are

Table 1: Estimated accuracies of the techniques in 2010. Units are milliseconds of arc for x, y, $\delta\psi$, $\delta\varepsilon$, dX, and dY and milliseconds of time for UT1–UTC. Note that AAM results are no longer provided since the AAM data are now only used for predictions and the previous statistics were misleading.

Contributor Information	Estimated Accuracy				
Name, Type	x	y	UT1	$\delta\psi$ (dX)	$\delta\varepsilon$ (dY)
ILRS SLR	0.34	0.31			
IAA SLR	0.20	0.24			
MCC SLR	0.21	0.22			
GSFC VLBI Intensives			0.019		
USNO VLBI Intensives			0.018		
GSI Intensives			0.015		
GSFC VLBI	0.12	0.11	0.004	0.31	0.12
IAA[1] VLBI	0.19	0.17	0.007	(0.18)	(0.17)
IVS[1] VLBI	0.13	0.16	0.004	(0.15)	(0.07)
USNO VLBI	0.11	0.12	0.003	0.64	0.10
IGS Final	0.01	0.02			
IGS Rapid	0.08	0.10			
IGS Ultra	0.09	0.11			
USNO GPS UT*			0.016*		
EMR GPS UT*			0.069*		

*All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodeled orbit node motion. VLBI-based results have been used to correct for LOD biases and to minimize drifts in UT estimates.
[1] IAA and IVS VLBI nutation values are in terms of dX/dY using IAU 2000A Nutation Theory.

Table 2: Mean and standard deviation of the differences between the Rapid Service/Prediction Centre solutions and the 05 C04 EOP solutions for 2010. Polar motion values x and y values are in milliseconds of arc and UT1–UTC values are in units of milliseconds of time.

	Bulletin A – C04	
	Mean	Std. Deviation
Bulletin A Rapid Solution (finals.data)		
x	-0.02	0.03
y	-0.08	0.04
UT1–UTC	0.005	0.011
Bulletin A Weekly Solution (finals.data)[1]		
x	0.02	0.04
y	-0.10	0.04
UT1–UTC	0.000	0.017
Bulletin A Daily Solution (finals.daily)		
x	-0.01	0.04
y	-0.06	0.04
UT1–UTC	-0.006	0.031

[1] Statistics computed over the 7-day combination solution period prior to solution epoch.

based on the residuals between the series and the combined RS/PC EOP solution for 2010.

Operationally, the weighted spline uses as input the epoch of observation, the observed value, and the weight of each individual data point. The software computes the spline coefficients for every data point, which are then used to interpolate the Earth orientation parameter time series so that x, y, UT1–UTC, $\delta\psi$, and $\delta\varepsilon$ values are computed at the epoch of zero hours UTC for each day. While the celestial pole offset combination software can combine either $\delta\psi$ and $\delta\varepsilon$ or dX and dY, for historical reasons, it uses $\delta\psi$ and $\delta\varepsilon$. Therefore, IAA and IVS VLBI dX and dY values are converted to $\delta\psi$ and $\delta\varepsilon$ in the combination process. The length of day (LOD) data are derived directly from the UT1–UTC data. The analytical expression for the first derivative of a cubic spline passing through the UT1–UTC data is used to estimate the LOD at the epoch of the UT1–UTC data.

The only data points that are excluded from the combination process are the 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 than four times the associated *a priori* error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, the input data are not corrected for these effects (see IERS Gazette No. 13, 30 January 1997).

The uncertainties in the daily values listed in Bulletin A are derived from the quality of the spline fit in the neighborhood of the day in question. Table 2 shows the accuracies of Rapid Service/ Prediction Center's combination solution for the running, weekly, and daily products compared to the 05 C04 series maintained by the IERS EOC. The running solution is the combination solution over the past 365-day period. The statistics for the running solution at year's end show the agreement between the Bulletin A running combination solution and the 05 C04 series for the entire year ("Bulletin A Rapid Solution" statistics). The comparison of the 52 weekly solutions to the 05 C04 series gives the statistics of the residuals computed over the new combination results for the 7-days prior to the solution epoch ("Bulletin A Weekly Solution" statistics). The statistics for the daily solution are determined from a series of differences spanning one year where each element of the series is the difference for the day of the solution epoch ("Bulletin A Daily Solution" statistics). EOP accuracies for the Bulletin A rapid weekly solution for the new combination for the day of the solution run and daily solution at the time of solution epoch are similar and, therefore, not included in the table.

Figure 1 shows the residuals between the daily rapid solution and the 05 C04 and presents the data used in Table 2 for the determination of the daily solution statistics. The most notable feature in these plots is the significant bias in the polar motion y (PM-y) component. Analysis indicates that a significant portion of this bias is due mainly to a similar bias in the IGS Ultra PM-y data, which are a significant contributor to the Rapid Service/Prediction Center's polar motion solution. The periodic differences in the UT1–UTC residuals that had been seen in past Annual Report submissions appear to be greatly reduced with the change in the use of Atmospheric Angular Momentum (AAM) analysis data in the combination solution and the increasingly common use of electronically transferred VLBI (e-VLBI) data. These changes have produced a significant improvement in the UT1–UTC results (Stamatakos *et al.*, 2011).]

Prediction Techniques

In 2007, the algorithm for polar motion predictions was changed to incorporate the least-squares, autoregressive (LS+AR) method created by W. Kosek and improved by T. Johnson (personal communication, 2006). This method solves for a linear, annual, semiannual, 1/3 annual, 1/4 annual, and Chandler periods fit to the previous 400 days of observed values for x and y. This deterministic model is subtracted from the polar motion values to create residuals, which are more stochastic in nature. The AR algorithm is then used to predict the stochastic process while a deterministic model consisting of the linear, annual, semiannual,

3.5.2 Rapid Service/Prediction Centre

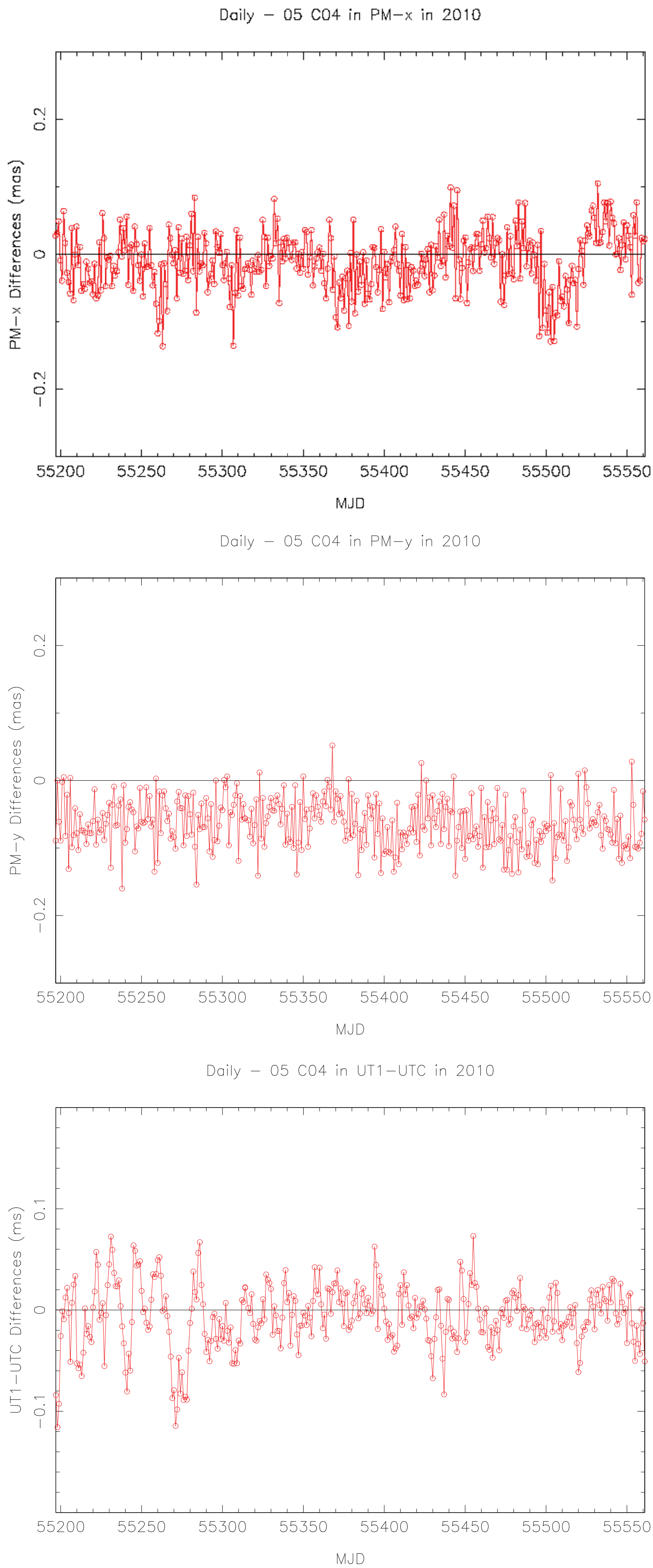

Fig. 1: Residuals between daily rapid solutions at each daily solution epoch for 2010 and the Earth orientation parameters available in 05 C04 series produced in April 2011.

and Chandler terms is used to predict the deterministic process. The polar motion prediction is the addition of the deterministic and stochastic predictions. The additional unused terms in the deterministic solution help to absorb errors in the deterministic model caused by the variable amplitude and phase of the deterministic components (T. Johnson, personal communication, 2006). For more information on the implementation of the LS+AR model, see Stamatakos *et al.* (2008).

The procedure for UT1–UTC involves a simple technique of differencing (McCarthy and Luzum, 1991b). All known effects such as leap seconds, solid Earth zonal tides, and seasonal effects are first removed from the observed values of UT1–UTC. Then, to determine a prediction of UT1–UTC n days into the future, $(UT2R–TAI)_n$, the smoothed time value from n days in the past, $<(UT2R–TAI)_{–n}>$ is subtracted from twice the most recent value, $(UT2R–TAI)_0$

$$(UT2R–TAI)_n = 2(UT2R–TAI)_0 – <(UT2R–TAI)_{–n}>.$$

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 UT1–UTC prediction out to a few days is strongly influenced by the observed daily Universal Time estimates derived at USNO from the Earth motion relative to the GPS orbit planes reported by the IGS Rapid service (Kammeyer, 2000). The IGS estimates for LOD are combined with the GPS-based UT estimates to constrain the UT1 rate of change for the most recent observation.

The UT1–UTC prediction also makes use of a UT1-like data product derived from a combination of the operational National Centers for Environmental Prediction (NCEP) and U.S. Navy's Operational Global Atmospheric Prediction System (NOGAPS) model's AAM analysis and forecast data (UTAAM). AAM-based predictions are used to determine the UT1 predictions out to a prediction length of 7 days. For longer predictions, the LOD excitations are combined smoothly with the longer-term UT1 predictions described above. The AAM data used are the combined northern and southern hemisphere data (winds+pressure, inverted barometer). For more information on the use of the UT AAM data, see Stamatakos *et al.* (2008).

Errors of the estimates are derived from analyses of the past differences between observations and the published predictions. Formulas published in Bulletin A can be used to extend the tabular data. The predictions of $\delta\psi$ and $\delta\varepsilon$ are based on the IERS Conventions (McCarthy, 1996; McCarthy and Petit, 2004). Table 3

Table 3: Root mean square of the differences between the EOP time series predictions produced by the daily rapid solutions and the 05 C04 combination solutions for 2010. Note that the prediction length starts counting from the day after the last available observation is made for polar motion or UT1–UTC/LOD. (Note that for all of 2010, the last observation for polar motion and UT1–UTC was made on the last combination day and so the first prediction day always occurred the following day.)

Days in Future	PM-x mas	PM-y mas	UT1–UTC ms
1	.46	.29	.075
5	2.20	1.35	.308
10	4.49	2.33	.718
20	8.33	4.26	2.17
40	14.7	9.11	5.09
90	21.0	23.3	7.90

shows the standard deviation of the differences between the daily solution predictions and the 05 C04 solution for 2010. Initial estimates indicated that the UT1–UTC prediction performance would be improved by 42% at 10 days into the future by the addition of UTAAM to the combination and prediction process (Johnson et al., 2005). However, comparisons of the UT1–UTC prediction performance from 2003 to those estimated in 2001 (before UTAAM was introduced) indicated a better than 50% reduction in prediction error with the updated method at both 10 days and 20 days into the future.

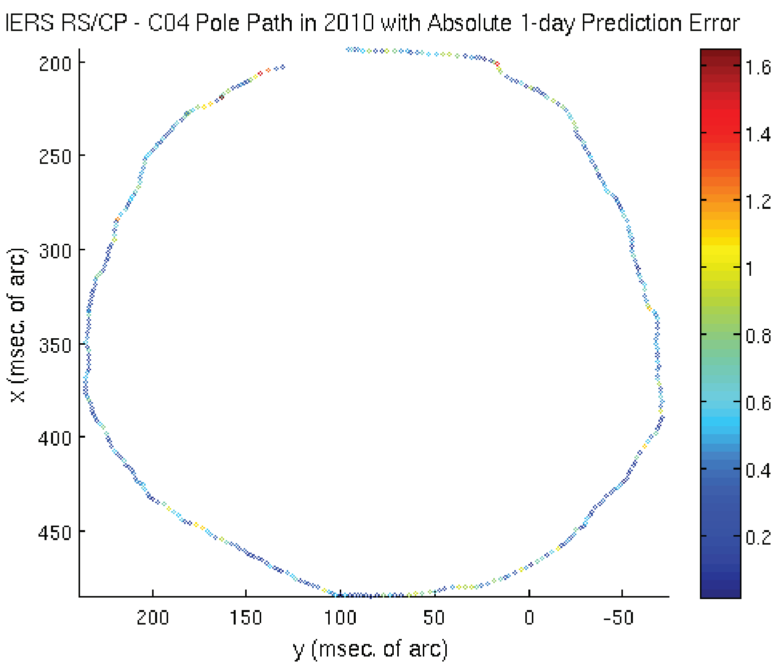

Fig. 2: Errors in polar motion prediction, denoted by the color of the plotting symbol, as a function of polar motion. The units of the polar motion error are mas.

Table 4: Root mean square of the differences between the nutation prediction series produced by the daily solutions and the 05 C04 combination solutions for 2010.

Days in Future	dX mas	dY mas	$\delta\psi$ mas	$\delta\varepsilon$ mas
1	.15	.17	.40	.16
5	.15	.16	.41	.16
10	.16	.17	.42	.17
20	.18	.18	.47	.18
40	.20	.20	.52	.20

For 2010, the polar motion prediction errors were slightly worse in x, better in the shorter y predictions, but worse in the long-term y predictions as compared to 2009. A plot of the polar motion error (shown as color codes of the plotting symbol) as a function of pole path is provided in Figure 2. The UT1–UTC prediction showed a significant improvement (~30%) to the prediction errors from 2009. As mentioned above, the improvement in UT1–UTC is likely due to changes in the use of AAM analysis data and the more frequent availability of rapid turnaround e-VLBI intensives.

The predictions of celestial pole offsets (both dX/dY and $\delta\psi/\delta\varepsilon$ representations) are produced through the use of the KSV1996 model (IERS Conventions (1996)). In addition, a bias between the model and the last 20 days worth of celestial pole offset observations is computed. This bias, used to correct the predictions, is tapered so that as the prediction length is extended, the bias becomes progressively smaller. Since celestial pole offsets are based solely on VLBI data, if no new VLBI 24-hour session observations are available, a new rapid combination/prediction of these angles is not determined. Therefore, the predictions of celestial pole offsets start before the solution epoch and the length of the prediction into the future can and does vary in the daily solution files. The differences between the daily predictions and the 05 C04 for 2010 are given in Table 4.

Predictions of TT–UT1, up to 1 January 2019, are given in Table 5. 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 TT–UT1 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.

Additional information on improvements to IERS Bulletin A and the significance for predictions of GPS orbits for real-time users is available (Luzum *et al.*, 2001; Wooden *et al.*, 2005; Stamatakos *et al.*, 2008; Stamatakos *et al.*, 2009).

Table 5: Predicted values of TT–UT1, 2011–2020. Note that UT1–TAI can be obtained from this table using the expression UT1–TAI = 32.184s – (TT–UT1).

DATE	TT-UT1 (s)	Uncertainty (s)
2011 Apr 1	66.396	0.000
2011 Jul 1	66.475	0.000
2011 Oct 1	66.506	0.000
2012 Jan 1	66.61	0.01
2012 Apr 1	66.70	0.02
2012 Jul 1	66.8	0.2
2012 Oct 1	66.9	0.3
2013 Jan 1	67.1	0.2
2013 Apr 1	67.2	0.3
2013 Jul 1	67.3	0.4
2013 Oct 1	67.5	0.4
2014 Jan 1	67.6	0.5
2014 Apr 1	67.7	0.7
2014 Jul 1	67.8	0.8
2014 Oct 1	68.0	0.9
2015 Jan 1	68.	1.
2015 Apr 1	68.	1.
2015 Jul 1	68.	1.
2015 Oct 1	68.	1.
2016 Jan 1	68.	2.
2016 Apr 1	69.	2.
2016 Jul 1	69.	2.
2016 Oct 1	69.	2.
2017 Jan 1	69.	2.
2017 Apr 1	69.	2.
2017 Jul 1	69.	2.
2017 Oct 1	69.	3.
2018 Jan 1	70.	3.
2018 Apr 1	70.	3.
2018 Jul 1	70.	3.
2018 Oct 1	70.	3.
2019 Jan 1	70.	3.
2019 Apr 1	70.	3.
2019 Jul 1	70.	4.
2019 Oct 1	70.	4.
2020 Jan 1	70.	4.

Center Activities in 2010

In early 2010, a revised method of processing AAM data was implemented, resulting in a significant improvement in the combination and short-term prediction of UT1–UTC. The AAM analysis data were removed from the UT1–UTC combination except for the one data point corresponding to the last combination point. It should be noted that the AAM forecasts are still a valuable part of the UT1–UTC prediction process.

In June 2010, a new web-based transformation calculator was added to the RS/PC web site. This calculator provides both the transformation matrices as well as quaternion representations of the rotations between terrestrial and celestial reference frames. This calculator was tested against the IERS Earth Orientation Center calculator and the rms difference between the two was less than 0.5 mas. This difference is expected to be an upper bound on the error of the rotation matrices. Additional work in 2011 is expected to make this calculator IERS Conventions (2010) compliant.

In August 2010, the automated VLBI intensive solution generated by GSI was added to the combination procedure. This solution has improved the RS/PC combination and prediction products particularly on the weekends where there had been a dearth of new VLBI results.

New global solutions were received from the GSFC, IAA, IVS, and USNO VLBI analysis centers. These new solutions were examined and new slopes and biases were computed.

Availability of Rapid Service

The data available from the IERS Rapid Service/ Prediction Center consist mainly of the data used in the IERS Bulletin A. These data include: x, y, UT1–UTC, dX, and dY from IAA VLBI; x, y, UT1–UTC, $\delta\psi$, and $\delta\varepsilon$ from GSFC VLBI; x, y, UT1–UTC, $\delta\psi$, and $\delta\varepsilon$ from USNO VLBI; x, y, UT1–UTC, dX, and dY from IVS combination VLBI; UT1–UTC from GSFC 1-day Intensives; UT1–UTC from USNO 1-day Intensives; UT1–UTC from GSI 1-day Intensives; x and y from International Laser Ranging Service 1-day SLR; x and y from Institute of Applied Astronomy 1-day SLR; x and y from the Russian Mission Control Centre 1-day SLR; x, y, and LOD from the International GNSS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; UT from NCEP AAM; UT from NAVY NOGAPS AAM; x, y, UT1–UTC, $\delta\psi$, $\delta\varepsilon$, dX, and dY from the IERS Rapid Service/Prediction Center; x, y, UT1–UTC, $\delta\psi$, and $\delta\varepsilon$ from the IERS Earth Orientation Centre; and predictions of x, y, UT1–UTC, $\delta\psi$, $\delta\varepsilon$, dX, and dY from the IERS Rapid Service/ Prediction Center.

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

The data described above are available from the Centre in a number of forms. You may request a weekly machine-readable version of the IERS Bulletin A containing the current 365 days' worth of predictions via electronic mail from

ser7@maia.usno.navy.mil or through

<http://www.usno.navy.mil/USNO/earth-orientation>.

Internet users can also direct an anonymous FTP to

<ftp://maia.usno.navy.mil/ser7>

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

Center Staff

The RS/PC Center staff consisted of the following members:

Brian J. Luzum	Director
Nick Stamatakos	Chief, Earth Orientation Parameters Combination and Prediction Division
Merri Sue Carter	Assists in daily operations and support
Beth Stetzler	Assists in daily operations and support, research, and software maintenance
Nathan Shumate	Assists in daily operations and support, research, and software maintenance

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Brian J. Luzum, Nicholas Stamatakos, Merri Sue Carter, Beth Stetzler, Nathan Shumate

3.5.3 Conventions Centre

The Conventions Center is operated jointly by the Bureau International des Poids et Mesures (BIPM) and the U.S. Naval Observatory (USNO).

The Conventions Center provides updated versions of the IERS Conventions in electronic form, after approval of the IERS Directing Board. In the meantime, work on interim versions is also available by electronic means. In addition to the electronic releases, printed versions of the Conventions will be provided at less frequent intervals or when major changes are introduced.

Over 2010, the work accomplished or in progress is the following:

1. Technical content of the IERS Conventions

The new reference edition has been finalized as the IERS Conventions (2010) on 15 December 2010 in electronic form (<http://tai.bipm.org/iers/conv2010/>). This has since been published as Technical Note 36 of the IERS. This completes the work initiated after the 2007 IERS Workshop. In addition to the background work of keeping track of typos, corrections and cosmetic modifications, nearly every chapter has undergone substantial change in 2010 and the list below presents the most important of them.

1.1 Introduction

The introduction reflects the conclusions of the 2007 IERS Workshop. Tables synthesizing the information on the IERS reference frames and on the models in the IERS Conventions (2010) have been created.

1.2 Numerical standards (Chapter 1)

The section “Numerical standards” has been rewritten and the list of constants ensures consistency with the IAU (2009) system of astronomical constants.

1.3 Celestial reference frame (Chapter 2) and its dynamical realization (Chapter 3)

Chapter 2 has been significantly rewritten, with F. Arias, S. Bouquillon, A. Fey, G. Francou, and N. Zacharias as primary contributors. It describes ICRF2, the second realization of the ICRF, recommended as the fundamental realization of the ICRS by Resolution B3 of the IAU (2009).

Chapter 3 has been rewritten (with W.M. Folkner as the primary contributor) and provides information on recently released ephemerides.

1.4 Terrestrial reference frame (Chapter 4)

A presentation of ITRF2008, the current reference realization of the ITRS, has been included (from Z. Altamimi).

1.5 Transformations between terrestrial and celestial reference systems (Chapter 5)

The chapter has been revised by N. Capitaine and A. Brzezinski to include the effects of libration on the motion of the celestial intermediate pole in the ITRS and the Earth rotation angle. The subroutine UTLIBR.F has been provided to calculate the effects on UT1 and LOD. In addition, numerous less significant modifications occurred.

1.6 Geopotential (Chapter 6)

A new conventional geopotential model, based on the EGM2008 model, is proposed. The section on Ocean tides has been completely rewritten, and describes the tide model FES2004. The principal contributors to this effort are S. Bettadpur, R. Biancale, F. Flechtner, F. Lemoine, N. Pavlis, J. Ray, and J. Ries.

1.7 Models for the displacement of reference points (Chapter 7)

The chapter has been reorganized to consider three types of displacement: Conventional that must be accounted at the observation level; other non-tidal motions associated with changing environmental loads (not treated yet); technique dependent effects.

A new conventional mean pole, to be referenced as IERS (2010) mean pole, is to be used to model pole tide effects.

A conventional model is provided for the loading due to surface pressure oscillations at mostly diurnal and semidiurnal periods caused by heating of the atmosphere. The principal contributors to this effort are T. van Dam and R. Ray.

1.8 Tidal variations in Earth's rotation (Chapter 8)

The model to evaluate the effects of zonal Earth tides on the Earth's rotation has been updated, with software included, and a model to evaluate tidal variations in polar motion and polar motion excitation due to long period ocean tides has been added (from R. Gross).

1.9 Models for atmospheric propagation (Chapter 9)

A mean *a priori* model for tropospheric gradients is given along with information on its use for radio techniques (provided by J. Boehm).

1.10 General relativistic models (Chapters 10 and 11)

The wording has been changed to follow the recommendations of the IAU Commission 52 on relativity. Information on the time coordinate transformations has been updated.

2. Conventions software

Following discussions at the 2007 Conventions Workshop, work has been carried out to provide standardized software. A software template has been developed, analogous to the IAU Standards of Fundamental Astronomy (SOFA) software template, to provide information to users, documentation, test cases and a distribution license. This template has been implemented on all software provided on the Conventions web site.

3. Dissemination of information

The Conventions web site (<http://tai.bipm.org/iers/>) has been maintained.

The USNO has established web pages (<http://maia.usno.navy.mil/conv2010/>) that ensure an exact duplication of the information.

Following the release of the IERS Conventions (2010), the web sites will be reorganized in order to provide access to the reference editions, the most recent updates as well as the history of updates between reference editions.

4. Conventions Center staff

Felicitas Arias (BIPM)
Brian J. Luzum (USNO), co-director
Dennis McCarthy (USNO)
Gérard Petit (BIPM), co-director
Beth Stetzler (USNO)

Gérard Petit, Brian J. Luzum

3.5.4 ICRS Centre

Introduction

The IAU has charged the IERS with the responsibility of monitoring the International Celestial Reference System (ICRS), maintaining its current realization, the International Celestial Reference Frame (ICRF), and maintaining and improving the links with other celestial reference frames. Starting in 2001, these activities have been run jointly by the ICRS Centre (Observatoire de Paris and US Naval Observatory) of the IERS and the International VLBI Service for Geodesy and Astrometry (IVS), in coordination with the IAU. The present report was jointly prepared by the Paris Observatory and US Naval Observatory components of the ICRS Centre. The ICRS Centre web site (<http://hpiers.obspm.fr/icrs-pc>) provides information on the characterization and construction of the ICRF (radio source nomenclature, physical characteristics of radio sources, astrometric behaviour of a set of sources, radio source structure). This information is also available by anonymous ftp (<hpiers.obspm.fr/icrs-pc>), and on request to the ICRS Centre (icrspc@hpopa.obspm.fr).

Maintenance and extension of the ICRF and investigation of future realizations of the ICRS

The International Celestial Reference System (ICRS), adopted by the International Astronomical Union (IAU) in 1997, forms the underlying basis for all astrometry by defining the reference directions of a quasi-inertial celestial coordinate system that are fixed with respect to the most distant objects in the universe. Since 1 January 1998, the ICRS has been realized by the International Celestial Reference Frame (ICRF), which is based on the radio wavelength astrometric positions of compact extragalactic objects determined by the technique of very long baseline interferometry (VLBI).

At the XXVII General Assembly of the IAU held in Rio de Janeiro, Brazil, a second realization of the International Celestial Reference Frame (ICRF2; Fey, Gordon and Jacobs 2009) was adopted as the fundamental celestial reference frame as of 1 January 2010. ICRF2 is again based on the radio wavelength astrometric positions of compact extragalactic objects determined by the technique of VLBI. Significant developments and improvements in geodetic/astrometric VLBI observing and analysis have been made since the initial generation of the ICRF, hereafter ICRF1. Sensitivity of VLBI observing systems to weaker sources and overall data quality have improved significantly due to advances in VLBI receiver and recording systems and due to better observing strategies coordinated by the International VLBI Service for Geodesy and Astrometry (IVS). The use of newer and more modern radio telescopes, such as the 10 station Very Long Baseline Array (VLBA) of the National Radio Astronomy Observatory, has also greatly improved the sensitivity and quality of recent data. Further, enhanced geophysical modeling and computers with faster processors have allowed significant improvements in data analysis techniques and astrometric position estimation.

ICRF2 contains precise positions of 3414 compact extragalactic sources, more than five times the number as in ICRF1. The ICRF2 has a noise floor of approximately 40 micro-arcseconds, some 5–6 times better than ICRF1, and an axis stability of approximately 10 micro-arcseconds, nearly twice as stable as ICRF1. Alignment of ICRF2 with the ICRS was made using 138 stable sources common to both ICRF2 and ICRF1. Future maintenance of ICRF2 will be made using a set of 295 new “defining” sources selected on the basis of positional stability and the lack of extensive intrinsic source structure. The stability of these 295 defining sources, and their more uniform sky distribution eliminates the two largest weaknesses of ICRF1.

ICRS Center personnel are involved in a program to extend the ICRF to higher radio frequencies than those currently used. At these higher radio frequencies, e.g., K-band (24 GHz) and Q-band (43 GHz), contributions to source position uncertainties from intrinsic source structure and from the Earth’s Ionosphere will be less than that at the radio frequencies currently used for astrometric/geodetic VLBI. VLBA observations to extend the ICRF to K-band and Q-band continued in 2010. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO) and Bordeaux Observatory. Results of these high frequency reference frame observations can be found in Charlot et al. (2010) and Lanyi et al. (2010). Ongoing observations to determine the position stability of four ICRF2 quasars continued in 2010. Results of these observations can be found in Fomalont et al. (2011).

In the coming decades, there will be significant advances in the area of space-based optical astrometry. Proposed and scheduled missions such as the European Space Agency’s (ESA) Gaia mission will achieve astrometric positional accuracies well beyond that presently obtained by any ground-based radio interferometric measurements. In 2010, ICRS Center personnel worked on development of a micro-satellite based astrometric mission, called the Joint Milli-Arcsecond Pathfinder Survey (J-MAPS), to produce milliarcsecond level astrometry for all of the bright stars up to 12th magnitude (limiting magnitude ~15–16) (see Gaume et al. 2009)

Monitor source structure to assess astrometric quality

VLBA RDV observations and analysis

Observations of International Celestial Reference Frame (ICRF) sources at radio frequencies of 2.3 GHz and 8.4 GHz using the Very Long Baseline Array (VLBA), together with up to 10 geodetic antennas, continued in 2010. These VLBA RDV observations constitute a joint program between the U.S. Naval Observatory

(USNO), Goddard Space Flight Center (GSFC) and the National Radio Astronomy Observatory (NRAO) for maintenance of the celestial and terrestrial reference frames. During the calendar year 2010, a total of six VLBA RDV experiments were observed.

The Radio Reference Frame Image Database

The Radio Reference Frame Image Database (RRFID) is a web accessible database of radio frequency images of ICRF sources. In 2010, ICRS Center personnel imaged sources from three VLBA RDV experiments and from one high frequency (K-band) VLBA experiment. The RRFID currently contains 7279 Very Long Baseline Array (VLBA) images of 782 sources at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 1706 images of 282 sources at frequencies of 24 GHz and 43 GHz. The RRFID can be accessed from the Analysis Center web page or directly at <http://rorf.usno.navy.mil/rrfid.shtml>.

The Bordeaux VLBI Image Database

The Bordeaux VLBI Image Database (BVID) is a web accessible database of radio frequency images of ICRF sources. The BVID currently contains 1898 Very Long Baseline Array (VLBA) images of 824 sources at radio frequencies of 2.3 GHz and 8.4 GHz. The BVID can be accessed from the Analysis Center web page or directly at <http://www.obs.u-bordeaux1.fr/BVID/>.

Investigation on the QSO optical/ radio centroid reconciliation

This issue is central to the representation of the ICRF in the optical band. It has being the object of several early investigations (e.g., Silva Neto et al., 2002) and it is actively revised for the onset of the Gaia Celestial Reference Frame (GCRF) as optical materialization of the ICRS (Bourda et al., 2010, 2011). A space astrometric mission of the Space Agency (ESA) Gaia will be launched in October 2013. It is anticipated that 500 000 QSOs would be detected. Optical positions will be determined with Gaia with an unprecedented accuracy, ranging from a few tens of μas at magnitude 15−18 to about 200 μas at magnitude 20. Simulations show that the residual spin of the Gaia frame can be determined to 0.5 μas/yr with a “clean sample” of at least 10 000 of these sources (Mignard, 2002). A preliminary Gaia catalog is expected to be available by 2015 with the final version released by 2020. In the future, aligning the Gaia frame and the VLBI frame (i.e. the ICRF2, or any successor introduced by 2015) will be crucial for ensuring consistency between measured radio and optical positions. This alignment will be important not only for guaranteeing a proper transition if the fundamental reference frame is moved from the radio to the optical domain, but also for registering the radio and optical images of any celestial target with the highest accuracy. Such a registration will allow one, for example, to pinpoint the relative location of the optical and radio emission in active galactic nuclei (AGN) to a few tens of μas, placing constraints on the overall AGN geometry. Gaia will permit the realization of the extragalactic reference frame directly at optical bands, based on the QSOs which have the most accurate positions; possibly those with magnitudes brighter than 18, but also the aspects of variability and pointlikeness in the optical band must be considered. For the reconciliation between the ICRF and the GCRF, given the limited number of sources that are anticipated to be suitable to this end, the question of individual coincidence of the optical and radio centroids must be addressed on a case by case basis whenever possible. One such investigation was conducted by Camargo et al. observing 22 ICRF sources with the wide field CCD imager of the SOAR telescope.

Observations at OHP

In 2010 QSO observations began with a 1.2m telescope located in France (OHP). The goal of these observations is to monitor the magnitude of sources in order to have information about the physical processes that could produce displacements of their optical photocenter. Such displacements, if they exist, would be of critical importance in the framework of the link of reference systems (ICRF and the future Gaia Celestial Reference Frame). The T120 (telescope of 1.2m) of the OHP (Observatoire de Haute Provence, <http://www.obs-hp.fr/guide/t120.shtml>) is located in the South East of France. It was used from March 2010 to February 2011 during 17 nights. It is equipped with a 1.2m mirror of 7.2m focal length. It uses a 1024x1024 px2 CCD camera with a pixel scale in the focal plane of 0.69 arcsec/px given a field of view of 10 arcmin^2. The seeing during the observations was relatively poor, with a mean value of 3.4 arcsec. The filters used were the V and R Cousins filters. A first list of targets that could be used for the link between ICRF and the future Gaia Celestial Reference Frame has been given by Bourda et al. (2008). First preliminary observations of these targets have been done with the T120 to verify that all of them are observable by small aperture telescopes. They are the basis to other extended programs (in term of the frequency of observations) that are scheduled to begin in February 2011 with small robotic telescopes. The figure below gives an example of the data obtained.

Maintenance of the time stability of the ICRF

The astrometric position time series of quasars as derived from VLBI delays at OPAR IVS analysis center were used in two research projects which involved persons of the ICRS Center.

Use of VLBI astrometric position time series for research

Titov, Lambert, & Gontier (2011) used position time series produced with a very loose constraint in order to detect the effect of the Solar System acceleration in the Universe in the distant body proper motion. They showed that the small systematic proper motion of ~5 microseconds of arc per year is indeed detectable in the VLBI observations. (The systematic shows up as a degree-2,

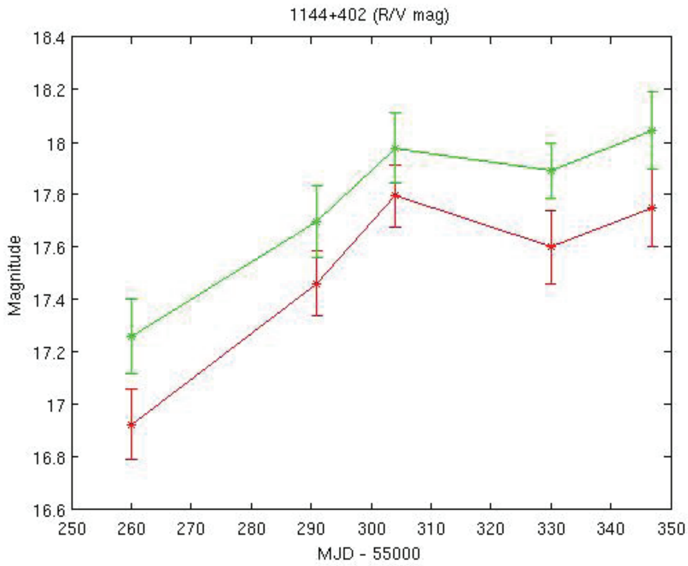

Fig. 1: Optical variability in V and R bands of a quasar observed at OHP

zero-order, deformation of the quasar velocity field, oriented towards the Galactic center. This confirms that the main component of the Solar System acceleration is due to the rotation around the Galactic center.) Higher order harmonics (quadrupolar deformation of the velocity field) were investigated, but the various systematics detected were not fully explained and need more research.

The time series used in this study are pretty different from those published on the IVS OPAR web site, obtained with a tighter constraint and aiming at describing mid-term (typically interannual) variations of the position of the centroid. However, it appears that the tight constraint biases significantly the slopes and impeaches the detection of the dipole.

Moór et al. (2011) assessed whether the direction of the centroid motion as derived from the time series was consistent with the relevant direction derived from source structure maps. On a sample of 62 sources, they compared the characteristic direction of the extended jet structure and the direction of the apparent proper motion. They concluded that there is indeed a correlation between the two characteristic directions. However, there are cases where the ~ 1–10 mas scale VLBI jet directions are significantly misaligned with respect to the apparent proper motion direction.

Linking the ICRF to frames at various wavelengths

The Large Quasar Astrometric Catalog

The Large Quasar Astrometric Catalog (LQAC) is a whole sky compilation of information on known QSOs. It complements the existing catalogues, which are dedicated on confined zones of the sky, wavelength, selection criteria, by providing the most precise astrometry and completeness of tabular data currently available. The LQAC presently contains entries for 113,666 objects (Souchay et al., 2009). Along the year it was introduced at several meetings (e.g., Barache et al., 2009, 2010, at the ASPC and SF2A) to explain and discusses its contents and get comments and demands from the users.

The second version of the LQAC is being prepared. For this the database aspect will be emphasized, bringing in calculated quantities – namely absolute magnitudes, an additional set of coordinates to consistently represent the ICRF for all objects for which there is optical counterpart, and morphological indexes on the DSS optical bands. A coherent set of absolute magnitudes, computed according to rigorous relativistic space-time precepts, is a key point for astrophysics investigation, being a quantity free from theoretical modeling. It also provides elements to size up the accretion disk region in views of estimating optical variability likeness during the five years of the forthcoming Gaia mission. The morphological indexes have similar role in what concerns the signature of the host galaxy and the methodology will be that from the Gaia Initial QSO Catalog. The optical equatorial coordinates will follow the methodology used in the LQRF, by which both products can be embedded. The enlarged, second version of the LQAC in this way will also brings to the user the latest version of the Gaia Initial QSO Catalog.

Maintenance of the link to the Hipparcos catalog

During the reporting period (2010) USNO continued to make progress in the areas of astrometric star catalogs, the extragalactic link to radio frame sources, URAT, and JMAPS.

Papers describing the details of the USNO CCD Astrograph Catalog 3rd release (UCAC3) were published (Finch et al. 2010, Zacharias, 2010) and work toward the final UCAC4 release begun. Detections on individual CCD frames were cleaned up, bugs in matching software fixed, and the conventional astrometric reduction of all applicable frames was repeated with improved modeling. Code was developed for an iterative overlap solution and simulations run, showing a slow convergence due to the only 2-fold pattern of UCAC observational data.

The new version of the Northern Proper Motion (NPM) plate reductions was obtained from T. Girard (Yale Univ.) which forms the basis for UCAC4 proper motions for the majority of stars north of Dec = –20 deg, with expected, formal errors of 3 to 5 mas/yr. The Brorfelde Schmidt CCD Catalog (BSCC) was published (Zacharias et al. 2010) as a joint effort between USNO and Copenhagen Observatory, giving precise positions of 13.7 million stars mainly north of 70 deg on the Tycho-2 reference system.

Monitoring a sample of 12 ICRF optical counterparts continued at the 1.55m telescope at NOFS, while the Space Interferometry Mission, SIMLite project was canceled by NASA.

Hardware construction of the USNO Robotic Astrometric Telescope (URAT) continued (Zacharias, Gaume 2010). See also

<www.usno.navy.mil/USNO/astrometry/optical-IR-prod/urat> . The URAT mount in Washington DC is now controlled by a computer. All 4 STA1600B CCD chips (10560 x 10560 pixels) were characterized and accepted. All 3 guide CCDs were produced, tested and accepted. The construction of the dewar is delayed and delivery of the complete 4-shooter camera will be in 2011.

The Joint Milli-arcsecond Pathfinder Survey (JMAPS) space mission was ramping up at USNO in 2010 including more detailed simulations and reduction code development. First hardware parts were built by contractors.

Maintenance of the link to the solar system dynamical reference frame using Lunar Laser Ranging analyses

Lunar Laser Ranging (LLR) analyses provide scientific results in various domains (astronomy, gravitational physics, geodynamics, selenophysics). They contribute also to the positioning of the dynamical reference frame with respect to ICRS. The LLR technique is particularly sensitive to the orientation of the dynamical ecliptic materialized by the Earth's orbit. Figures LLR1 and LLR2 show the distribution of the LLR observations performed by the different

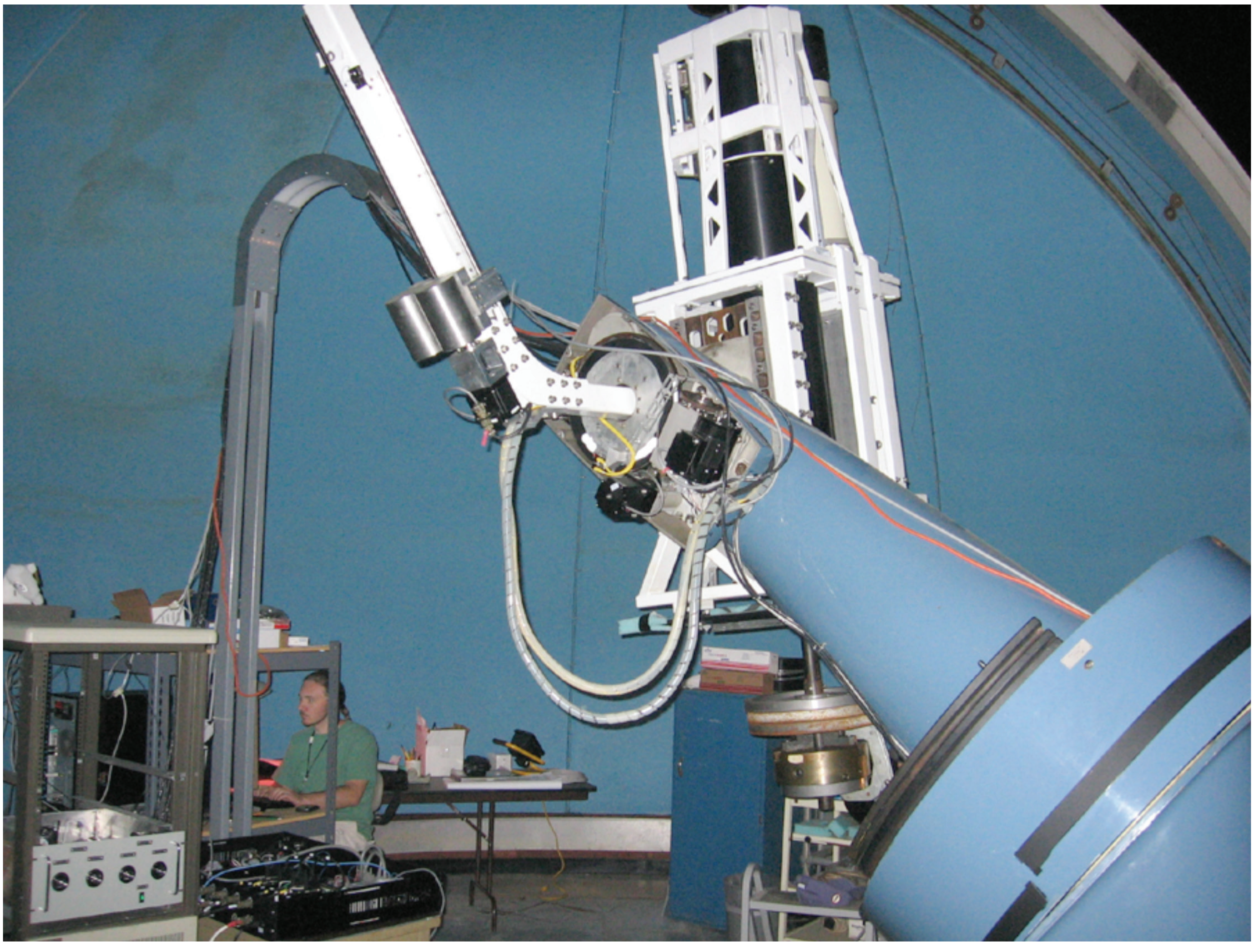

Fig. 2: The URAT telescope sans camera

terrestrial stations with the five retro-reflectors placed on the lunar ground. About 20000 LLR normal points have been taken by the tracking stations between 1969 and 2010.

At the Paris Observatory Lunar Analysis Center (POLAC), the dynamical reference frame of the solar system is defined as the dynamical mean ecliptic and equinox J2000 related to the orbit of the Moon given by the solution ELP (Chapront et al., 1999). Figure 5 shows the evolution of the residual between models and observations obtained by POLAC during the forty last years. The post-fit residuals are now around 300 picoseconds for the round-trip travel time of the light, that is to say less than 5 cm for the distance station–reflector.

The position of the inertial dynamical mean ecliptic of J2000.0 with respect to an equatorial frame chosen as reference is oriented by two angles: ε, the inclination of the ecliptic to the equator and φ, the angle between the origin of the right ascension (o) on the equator and the ascending node (γ^{I}_{2000}) of the ecliptic on the equator (Figure 6). Thus, the link with ICRS is defined by the angles $\varepsilon^{(ICRS)}$ and $\varphi^{(ICRS)}$. In the same way, the angles $\varepsilon^{(Eq2000)}$ and $\varphi^{(Eq2000)}$ define the link of the inertial dynamical mean ecliptic of J2000.0 with the mean equator of J2000.

The evaluations made by POLAC give the following values:

$\varepsilon^{(ICRS)} = 23°26'21''.4110 \pm 0.1$ mas; $\varphi^{(ICRS)} = -55.4 \pm 0.1$ mas;

$\varepsilon^{(Eq2000)} = 23°26'21''.4056 \pm 0.1$ mas; $\varphi^{(Eq2000)} = -14.6 \pm 0.1$ mas,

and the arc between $\gamma^{I}_{2000}{}^{(ICRS)}$ and $\gamma^{I}_{2000}{}^{(Eq2000)}$ on the ecliptic is estimated at 44.5 ± 0.3 mas.

These results have some applications for the astronomical community.

In the IAU 2009 System of Astronomical Constants (IAU, 2009), the obliquity at J2000.0 (given under the notation ε_{J2000}) is equal to the value of $\varepsilon^{(Eq2000)}$ (8.4381406×10^{4}”). It is a component of the IAU 2006 precession model.

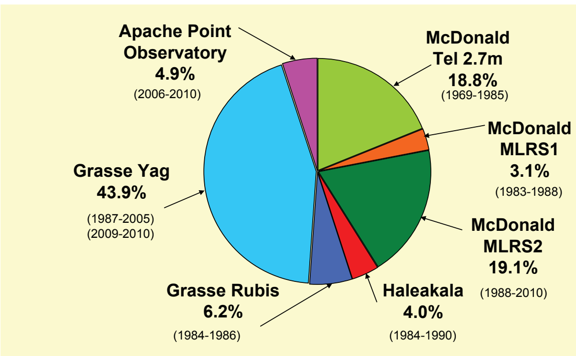

Fig. 3: Percentage of LLR normal points for each ground-based station during the 1969–2010 time interval

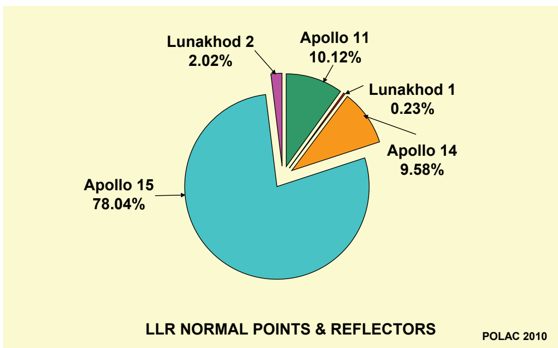

Fig. 4: Percentage of LLR normal points for each lunar reflector during the 1969–2010 time interval

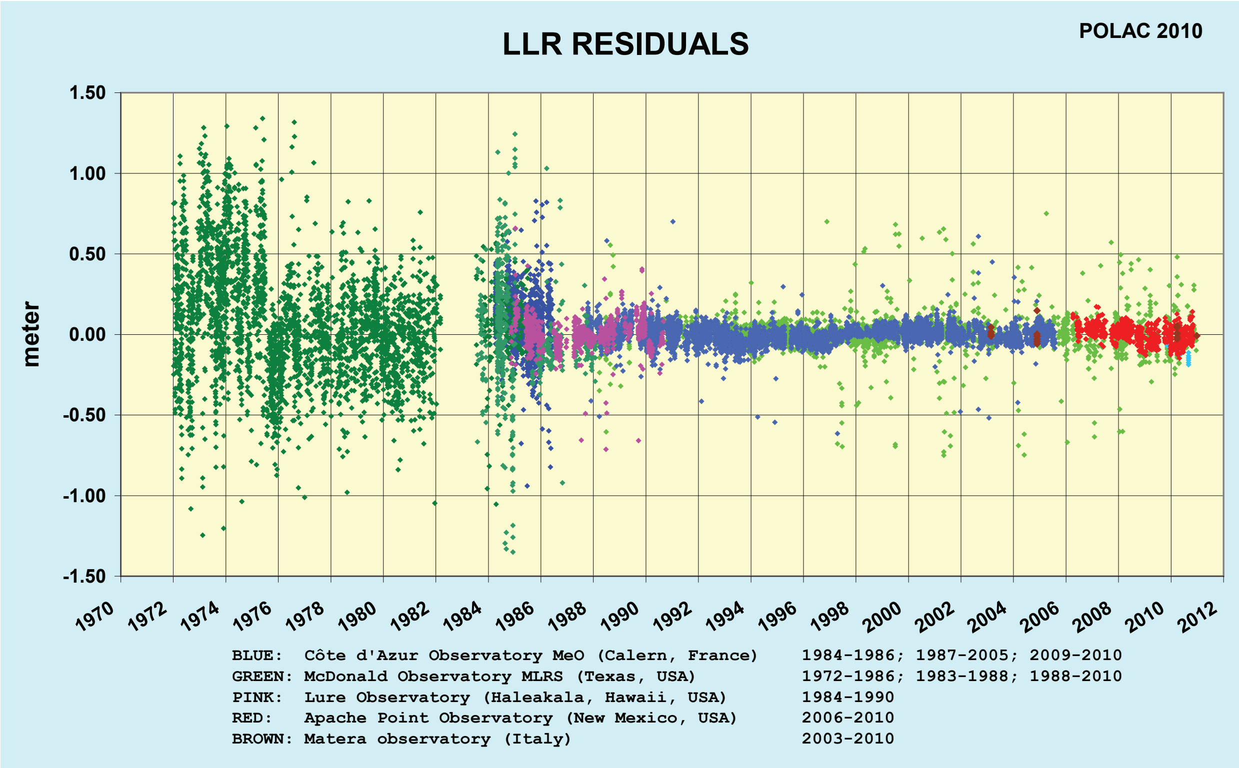

Fig. 5: Amplitude of LLR residuals from 1970 to 2010

The IAU recommends also that the origin of right ascension of the ICRS be close to the dynamical equinox at J2000.0. The shift $\varphi^{(ICRS)}$ of –55.4 mas (direct rotation around the polar axis) on the ICRS equator corresponds to the shift $\varphi^{(Eq2000)}$ of –14.6 mas on the mean equator of J2000.0 that is noted $d\alpha_0$ in the IERS Conventions (IERS, 2010).

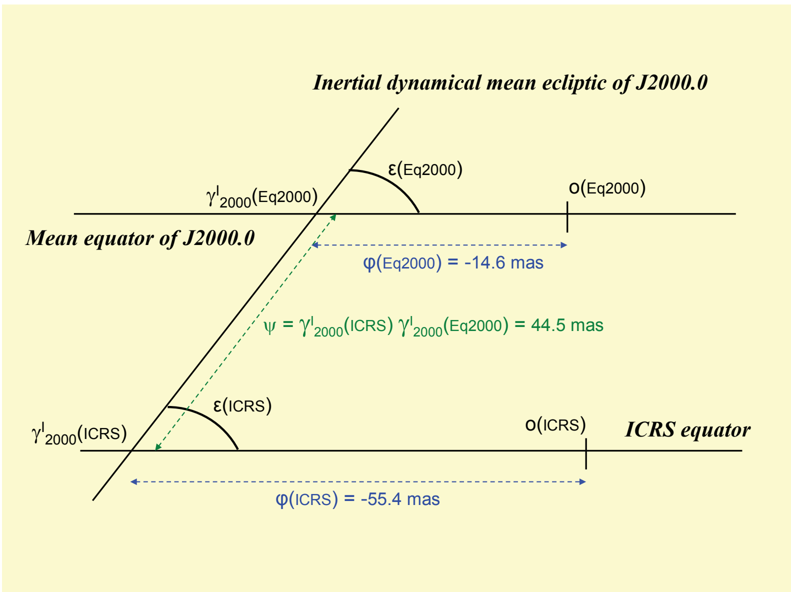

Fig. 6: Relative orientation of the fundamental planes (ecliptic, equator) from LLR observations

Maintenance of the link to the solar system dynamical reference frame using asteroid observations

The link between the ICRF and the dynamical reference frame realized by the ephemeris of the Solar System bodies is made simultaneous observations of the latter and QSOs. For the inner Solar System this link was directly investigated by VLBI observations of planet-orbiting spacecrafts and angularly nearby quasars (Newhall et al. 1986). In the case of the outer Solar System, simultaneous CCD observations of planets and quasars during apparent close approaches were obtained for Neptune and Uranus (da Silva Neto et al. 2005). In the framework of the forthcoming Gaia space mission, the close approaches of Jupiter with a large sample of quasars from the catalog were investigated in the time interval 2005–2015 (Souchay et al. 2007). Another approach was taken by Nedelcu et al. (2010) that determined between near Earth asteroids (NEAs), representing the dynamical reference frame by means of their ephemeris, and QSOs. Besides the large number these asteroids are generally bright and thus the astrometry is of good quality. Also, when planets are used, either there is a problem to define the center of an extended object, or satellites are used and the results must be later transported to the planet's ephemeris. This study, in the period 2010–2018, found respectively 2,924, 14,257, and 6,972 close approaches (within 10arcmin) between asteroids with a minimum solar elongation value of 60deg and quasars from the ICRF-Ext2, the Very Large Baseline Array Calibrator Survey (VLBA-CS), and the Very Large Array (VLA).

Maintenance of the link to the solar system dynamical reference frame using Pulsar Timing analyses

In 2010, activities related to VLBI observations of millisecond pulsars (MSP) and the link between dynamical reference frames and ICRF based on millisecond pulsar observations have been maintained and used with new planetary ephemerides, INPO10A (Fienga et al., 2010). As explained in the IERS Annual Report 2008–2009, radio timing and VLBI astrometry of millisecond pulsars is used to estimate rotation matrices between the reference frames of planetary ephemerides and ICRF. We used 18 MSP observed by radio timing at the NRT (Desvignes, 2009) and VLBI astrometry of 4 MSP extracted from Chaterjee et al. (2009) and Deller et al. (2009). More details about the used procedure as well as the MSP used to estimate the rotation matrixes can be found in Fienga et al. (2010) and Fienga et al. (2010b).

To check the procedure, we have estimated rotation matrices between planetary ephemerides reference frames themselves. Based only on radio timing observations, the angles presented in the left-hand side part of Table 1 and obtained in using the all sample of pulsars available with a good accuracy are quite compatible with previous determinations of rotation matrices between planetary frames or the estimation one can expect. For example, the rotation angles between DE405 and DE200 obtained with the 18 most accurate TOAs give results consistent with Standish (1998). The accuracy of the presented results is a factor 10 better than this last paper.

Furthermore, DE405 and the other modern ephemerides (INPOPs, DE414) have rotation matrices quite stable indicating a very similar behavior between INPOP08, INPOP10A and DE414 in one hand and DE405 in the other hand. The rotations between these ephemerides are less than 2 mas which corresponds to the present mean accuracy of the VLBI tracking observations used to link the planetary ephemerides to ICRF (Folkner et al., 2008; Fienga et al., 2008).

In the right hand side of Table 1, one can find the rotation angles obtained between planetary ephemerides frames and the ICRF as deduced from pulsar timing and VLBI astrometry. The rotations obtained are more important than expected for all the ephemerides. However to get these rotation angles, only 4 pulsars were used in the fit with one pulsar (J2145-07) severally down-weighted due to its high uncertainties in timing and VLBI astrometry. Furthermore, the spatial distribution of the 4 MSPs is not optimized. One should wait for new VLBI observations of pulsars to obtain a more definitive conclusion. An important set of VLBI observations of MSP is now proceeded by Chatterjee et al. as a ground follow-up program to the FERMI mission. From this intensive VLBI program, 22 pulsars should be observed. Among them, at least 3 targets are tracked by the NRT regularly and can be used for reference frame ties.

Table 1: Angles of rotation deduced from adjustment of rotation matrices between ICRF and planetary reference frames obtained by comparisons of MSP positions deduced from radio timing and VLBI astrometry. The angles are given in milliarcseconds and the uncertainties are the formal 1-sigma deduced from the least squares.

	θ mas	η mas	ζ mas
18 MSPs with TOA $(\sigma_\alpha,\sigma_\delta) < 10$ mas			
DE405 → DE200	-0.4 ± 0.3	-13 ± 0.4	-13 ± 0.3
DE405 → DE200 [22]	-1 ± 2	-14 ± 3	-10 ± 3
DE414 → DE405	1.5 ± 0.3	-1.0 ± 0.4	-0.9 ± 0.3
INPOP08 → DE405	1.3 ± 0.3	-0.3 ± 0.4	-1.1 ± 0.3
INPOP10A → DE405	1.6 ± 0.3	-0.7 ± 0.4	-0.7 ± 0.3
Only 4 MSPs with TOA $(\sigma_\alpha,\sigma_\delta) < 10$ mas			
DE405 → DE200	-0.5 ± 0.2	-12 ± 0.3	-13 ± 0.18
INPOP08 → DE405	1.4 ± 0.03	-0.03 ± 0.05	-1.4 ± 0.03
INPOP10A → DE405	1.7 ± 0.01	-0.03 ± 0.02	-1.0 ± 0.01

	θ mas	η mas	ζ mas
Only 4 MSPs with TOA + VLBI $(\sigma_\alpha,\sigma_\delta) < 10$ mas			
DE405 → ICRF	6 ± 5	15 ± 11	-4 ± 6
INPOP08 → ICRF	4 ± 5	15 ± 11	-2.5 ± 6
INPOP10A → ICRF	4 ± 5	15 ± 11	-3.0 ± 6
DE200 → ICRF	6 ± 5	28 ± 11	9 ± 6
DE200 → ICRF [1]	2 ± 2	12 ± 3	6 ± 3
DE200 → ICRF [25]	-1 ± 3	10 ± 3	4 ± 5

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3.5.5 ITRS Centre

This report summarizes the activities of the IERS ITRS Centre during the year 2010.

ITRF2008 publication

The ITRF2008 solution was released in May 2010. A dedicated website has been established (<http://itrf.ign.fr/ITRF_solutions/2008/>) providing full description of ITRF2008 solution, together with all associated products: station positions and velocities of the 920 stations (located at 580 sites) in SINEX as well as in simple table formats; Earth Orientation Parameters in different formats; plots of technique origin and scale time variations and station position residuals. The website also provides synthetized summary descriptions of the IERS Technique Centres (TC) solutions used in the ITRF2008 elaboration. All the submitted solutions were combined solutions by the Combination Centre of each TC and based on reprocessed individual solution generated by the Analysis Centres of each one of the four techniques (VLBI, SLR, GNSS/GPS and DORIS). The submitted solutions cover the full history of observations, except for the GNSS/GPS series which start in 1997. These solutions are archived by the ITRS Centre and the Central Bureau and were analysed by the two IERS Combination Centres (IGN and DGFI). Interaction and communication between the IERS Centre and the TCs were operated as necessary and as a function of the ITRF2008 analysis conducted by the IERS CCs. A summary of the ITRF2008 results are presented in the IGN CC section of this report, see 3.6.1.2. The following table summarizes the final time series of station positions and EOPs submitted by the TCs.

TC	Span	Solution type	EOPs
IVS	1980.0–2009.0	Normal Equation	Full set
ILRS	1983.0–2009.0	Variance-Covariance	Polar Motion, LOD
IGS	1997.0–2099.5	Variance-Covariance	Polar motion, rate, LOD
IDS	1993.0–2009.0	Variance-Covariance	Polar motion, rate, LOD

Maintenance of the IERS network

The ITRS Centre assigns DOMES numbers to geodetic tracking stations or markers as unambiguous identifications of points in space, independently from the technique of their tracking instruments.

The IERS network database, which contains the descriptions of the sites and points, is continuously updated as DOMES numbers are assigned. DOMES number request form can be found on the ITRF web site <http://itrf.ign.fr>, and should be sent to domes@

ign.fr. An updated list of all available DOMES numbers is available at <http://itrf.ign.fr/doc_ITRF/iers_sta_list.txt>. The IERS site information is available to the users through the ITRF website interface (see below).

ITRF web site

The ITRF web site, available at <http://itrf.ign.fr>, provides an interface to consult the IERS network database. Site and point information can be requested on line; it contains approximate coordinates of the sites, the list of their points as well as their descriptions, their DOMES numbers and the list of ITRF versions in which they have been computed. Subsets of points can be selected and their ITRF coordinates can be requested at any epoch in any ITRF version if their coordinates are provided in the requested ITRF version.

The maps of the ITRF networks can be displayed depending of the measurement techniques and of the ITRF realization. Velocity vectors can be displayed as well as tectonic plates. The dynamical map can help users to familiarize with ITRF products and can be used for educational purpose. It can also be an interesting tool to select IERS sub-network depending on the measurement techniques, co-located hosted instruments or ITRF versions. ITRF94, ITRF96, ITRF97, ITRF2000, ITRF2005 and ITRF2008 solutions are available for download.

Local ties of ITRF co-location sites

The ITRS Centre collects all new surveys operated by either IGN or the hosting agencies of ITRF co-location sites. The reports of these surveys are posted at the ITRF web site and available to users at <http://itrf.ign.fr/local_surveys.php>. The local ties SINEX files used in the ITRF combinations are also available on that web site.

In preparation for the ITRF2008 combination, the IGN survey department has conducted a re-adjustment of all surveys in DORIS sites co-located with the other 3 techniques. Other few non-DORIS co-located sites for which IGN detains the raw survey data were also adjusted. The local ties generated from this re-adjustment are provided in SINEX format with full variance-covariance information.

Zuheir Altamimi, Xavier Collilieux,
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3.5.6 Global Geophysical Fluids Center (GGFC)

The International Earth Rotation and Reference Systems Service's (IERS) Global Geophysical Fluid Center (GGFC) provides the geodetic community with data and models of geodetic effects (rotation, gravity, and deformation) driven by the temporal redistribution of the Earth fluids, as well as information needed for geodetic observations that are reliant on the state of the fluids. These include fluid motions within the Earth, such as the core and mantle, as well as the motions of surface fluids, e.g. oceans, atmospheres, and continental water.

The GGFC is composed of four operational entities: the Special Bureau for the Atmosphere (SBA, Chair, D. Salstein), the Special Bureau for the Oceans (SBO, Chair, R. Gross), the Special Bureau for Hydrology (SBH, Chair, J.-L.. Chen), and the Special Bureau for the Combination Products (SBCP, Chair, T. van Dam). The Atmosphere, Hydrology and Oceans SBs have been firmly established since the creation of the GGFC in 1998. A new operational SB, Combination Products, was established in 2009 to house the new data sets that model the mass movement of combined environmental fluids such as oceans+atmosphere. There is a GGFC non-operational component, the GGFC Science and Support Products. This component serves as a repository for models and data used regularly in data processing but that do not change often. The GGFC is actively searching for a Chair for this component.

In 2010, the newly reorganized GGFC website was established, <http://geophy.uni.lu/>. Users can now connect to all SB's and download data from this starting location. The SB Atmosphere provides atmospheric angular momentum and related data derived from various analyses produced by the U.S. National Centers for Environmental Prediction, the U.K. Meteorological Office, the Japanese Meteorological Agency, and the European Centre for Medium Range Weather Forecasts (ECMWF). Atmospheric delays of radio signals emitted by satellites or distant astronomic sources and 3-D surface displacements from NCEP reanalysis data can also be accessed from the SBA. SB Oceans provides oceanic angular momentum, oceanic center of mass, and bottom pressure derived from various ocean models. The data used to derive these products can also be accessed from this site. The SB Hydrology provides hydrological data from a number of sources including GRACE, the NASA Global Land Data Assimilation System (GLDAS), and the ECMWF. Surface loading from the GLDAS model can also be found here. Operational and historic atmospheric (AAM), oceanic (OAM), and hydrologic angular momentum (HAM) time series and 3-D loading time series from the combined ocean+atmosphere model used for GRACE dealiasing can also be found here.

In 2010, the AAM products provided by D. Salstein at Atmospheric and Environmental Research, the Hydrology Products provided by J.-L. Chen at the University of Texas, Austin and the OAM products and excitation functions provided by R. Gross at JPL were evaluated as being reliable and provided to the public with a minimum of delay. These data sets include products from earlier in the history of the special bureaus. As a result, these products were upgraded from provisional to operational by the IERS Directing Board in one year versus the normal 2 year provisional period. Other products at the GGFC will remain provisional until they can be reviewed in 2011.

For information on submitting proposals for GGFC operational products, please go to <http://geophy.uni.lu/ggfc-about/to-submit-new-proposals-for-products.html> or contact T. van Dam.

Tonie van Dam, David Salstein, Richard Gross, Jianli Chen

3.6 ITRS Combination Centres

3.6.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

In 2010, the focus of the ITRS Combination Centre at DGFI was on the finalization of the ITRS realization DTRF2008, internal validations of the DTRF2008 solution as well as the comparisons of the realizations DTRF2008 and ITRF2008 in order to assess their accuracy.

One of the most challenging issues to be solved in the context of ITRF realization are seasonal signals in station position time series, which are neglected so far. Thus, different model combinations for atmospherical and hydrological loading are compared in order to investigate their potential to reduce the seasonal signals and hence to improve future ITRS realizations.

Computation of DTRF2008

In the IERS Annual Report 2008/2009 the computation strategy for the ITRS realization was described. The solution was finished and provided to the IERS community in May 2010. The solution contains station coordinates, coordinates of the terrestrial and the celestial pole, UT1–UTC and LOD parameters. The time range of the EOP is from 1983.0 to 2009.0. Figure 1 shows the distribution of the stations. In Fig. 2 the horizontal station velocities of the solution are displayed. The solution is available in different file

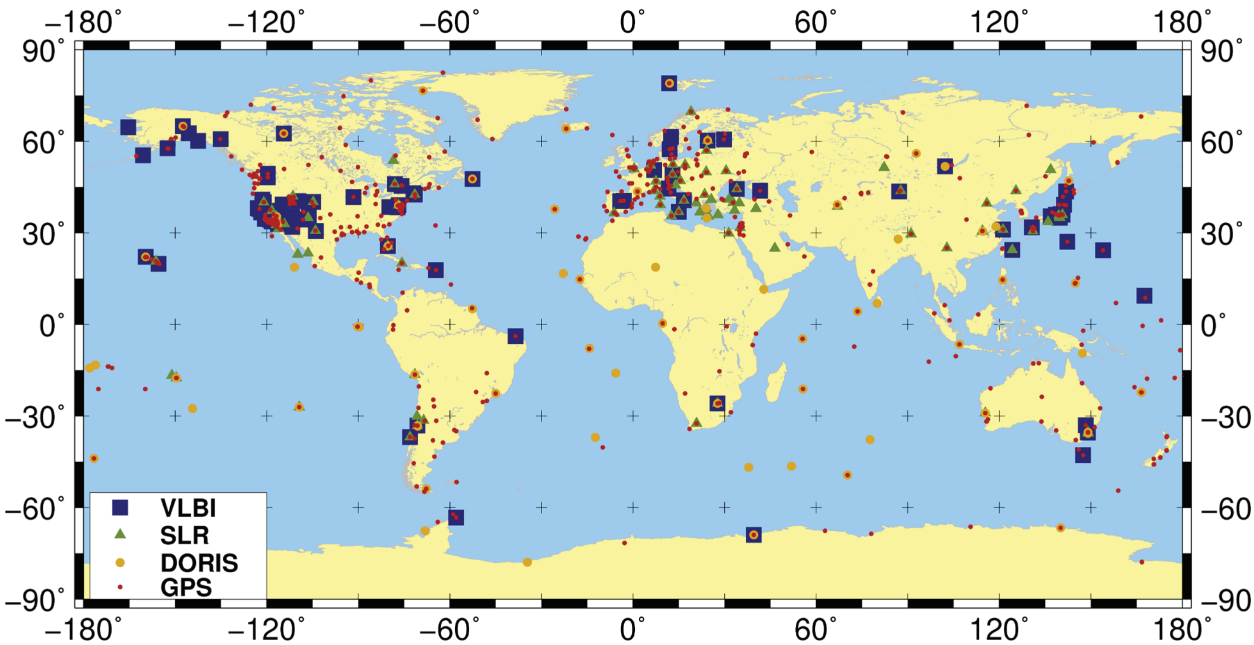

Fig. 1: Global station distribution of DTRF2008.

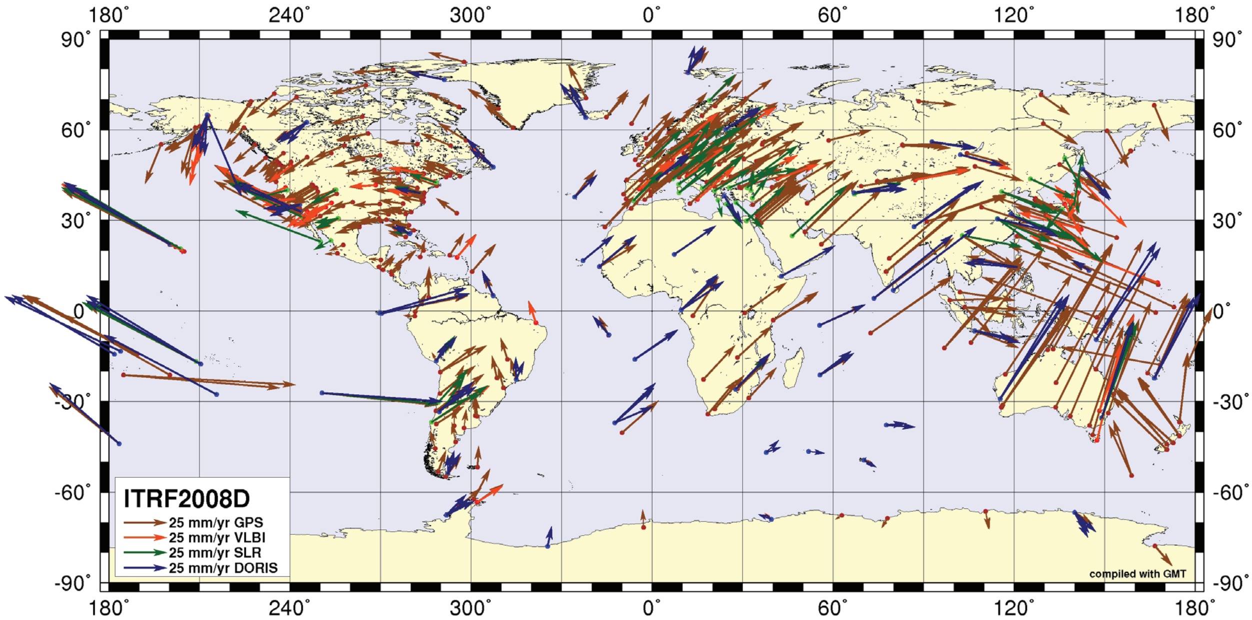

Fig. 2: Horizontal station velocities of DTRF2008.

formats under <ftp.dgfi.badw.de/pub/DTRF2008>, a short description of the solution on the website <http://www.dgfi.badw.de/index.php?id=258>. A detailed publication is given by Seitz et al. (2012).

Internal validation of DTRF2008

In order to assess the accuracy of DTRF2008, internal validation procedures are performed with respect to the network geometry and the geodetic datum, in particular the origin and the scale which are realized from the observations of the space geodetic techniques. Figure 3 shows exemplarily the time series of SLR and VLBI scale. The SLR time series shows a long-term systematic behavior at the beginning when only LAGEOS1 was in orbit. But because of the periodic character of the effect and the larger standard deviations at this time, the mean scale of SLR is not affected. In case of VLBI a drift can be seen at the beginning. But the noise is quite high and the mean scale is also not affected. Thus, the complete SLR and VLBI input data series are used for determining the scale of DTRF2008.

The origin of the DTRF2008 is realized from SLR data only. In order to assess the stability of the origin, also the translation time series are investigated. Especially, for z-translation a periodic effect for the LAGEOS1-only era was detected, which is in its characteristic very similar to the effect in the scale series. But also the effects in translation do not affect the mean origin significantly.

Furthermore, the conservation of the datum within the combination process was investigated. For this, the DTRF2008 was compared to the single-technique solutions. Table 1 and 2 summarize

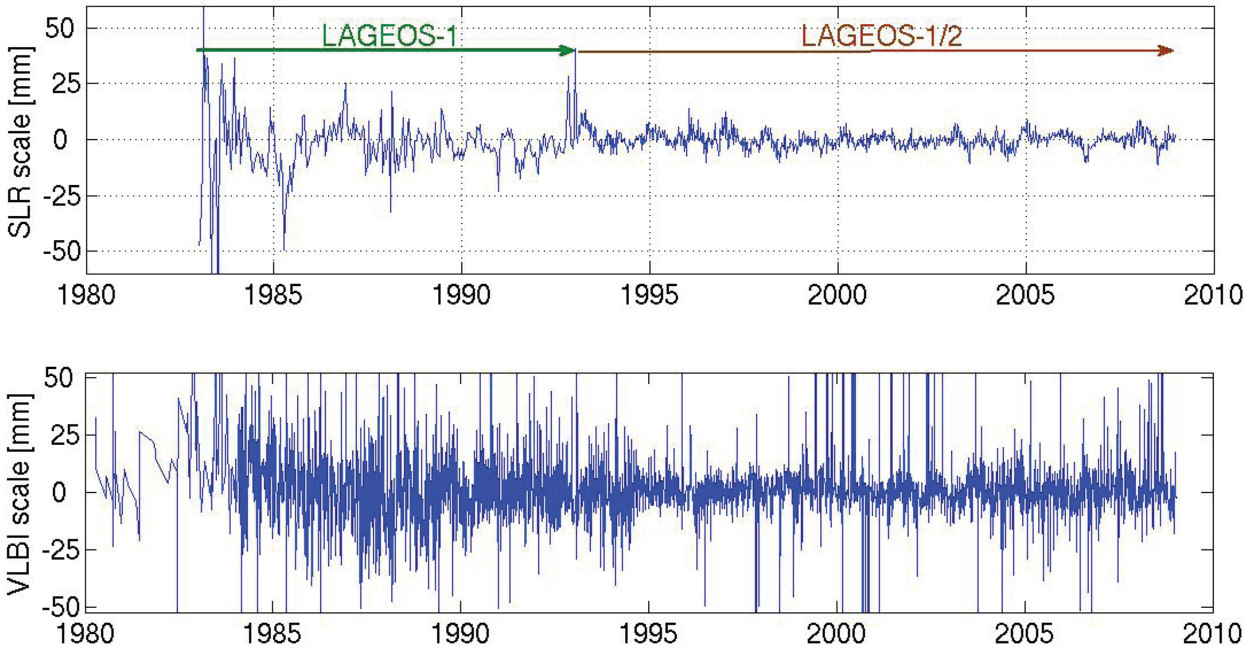

Fig. 3: Time series of SLR (upper plot) and VLBI scale (lower plot) for ITRF2008/DTRF2008 input series.

the results for origin and scale. The results show that the origin and the scale are not significantly affected by the combination. The estimated values are not larger than 0.3 mm and 0.1 mm/a for the origin and in maximum 0.02 mm and 0.02 mm/a for the scale.

Tab. 1: Translation parameters of DTRF2008 w.r.t. SLR-only multi-year solution.

SLR	tx	ty	tz
pos [mm]	0.1 ± 0.21	-0.3 ± 0.21	0.2 ± 0.21
vel [mm/a]	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05

Tab. 2: Scale parameters of DTRF2008 w.r.t. SLR- and VLBI-only multi-year solution. The scale is expressed as a radial distance [mm] at the Earth's surface.

SLR	scale	VLBI	scale
pos [mm]	0.02 ± 0.03	pos [mm]	0.01 ± 0.03
vel [mm/a]	-0.02 ± 0.008	vel [mm/a]	0.00 ± 0.002

A measure of the change of the network geometry due to the combination is the RMS of the transformation between DTRF2008 and the single-technique solutions (see Tab. 3). The RMS values are small for GPS and VLBI and reach a few millimetres for SLR and DORIS because of the larger variance level of these two techniques.

Tab. 3: RMS values of the similarity transformation between DTRF2008 and the technique specific multi-year solutions.

	position [mm]	velocity [mm/a]
GPS	0.6	0.09
VLBI	0.3	0.05
SLR	1.9	0.42
DORIS	3.3	0.83

Comparison of DTRF2008 and ITRF2008

The comparison of the DTRF2008 and the ITRF2008 is a validation step, which is important in order to assess the accuracy of the solutions (Seitz et al. 2013). Figure 4 shows the transformation parameters between the two solutions. The transformations are performed technique-wise. The results indicate, that DTRF2008 and ITRF2008 agree within 4–5 mm (rotation and scale change are transformed into distances at the Earth's surface). However, the difference between the values derived for the techniques are partly larger. E.g. in case of z-orientation, there is a difference between SLR and VLBI of about 7 mm. It can be summarized that the agreement of the DTRF2008 and ITRF2008 w.r.t. the geodetic datum is within one centimetre per component.

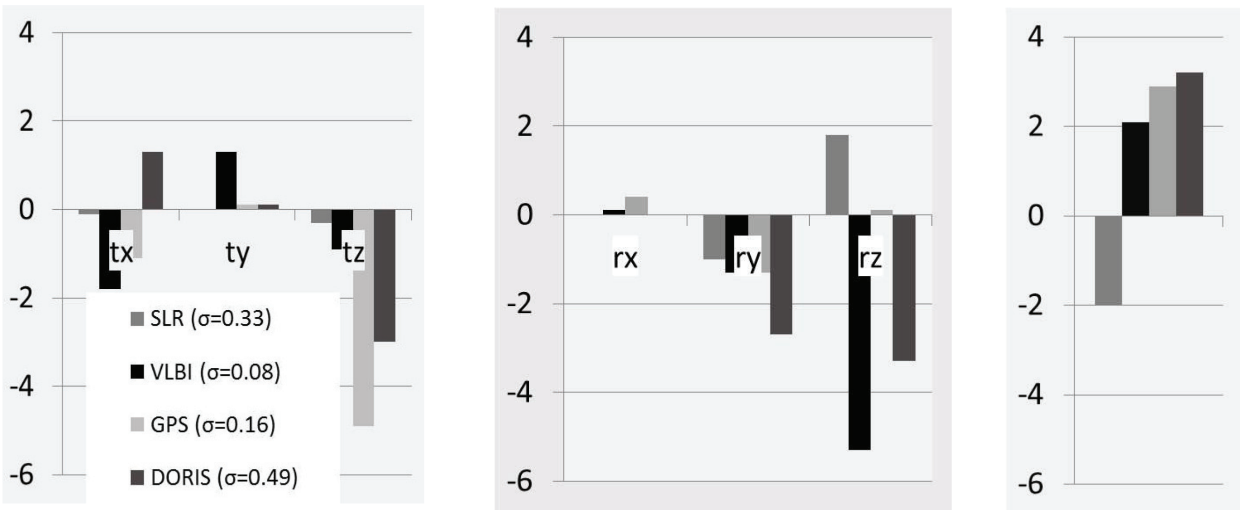

Fig. 4: *Translation (left), rotation (middle) and scale (right) parameters [mm] for the transformation from DTRF2008 to ITRF2008. The transformation epoch is 2000.0.*

In order to compare the network geometry of the two frames, the RMS values of the transformation are analyzed. Table 4 summarizes the corresponding values. While the agreement for the GPS and the VLBI part of the network is very good, for SLR and DORIS differences of 2–3 mm and 1 mm/a are obtained. The reason for the larger differences is the larger standard deviation for most of the SLR and DORIS station positions and velocities.

Tab. 4: RMS values of the 14 parameter similarity transformation between DTRF2008 and ITRF2008. Core stations are used for the transformation.

	position [mm]	velocity [mm/a]	# core stations
GPS	1.33	0.19	66
VLBI	0.38	0.09	25
SLR	2.00	0.82	37
DORIS	3.20	0.98	43

Comparison of different model combinations for atmospherical and hydrological loading

One of the most important challenges for future ITRS realizations is the handling of annual variations of station position time series (especially of the height component), which are mainly caused by atmospherical, non-tidal oceanic or hydrological mass load changes. We compared the RMS values of station height positions obtained for GPS stations (i) without applying loading models, (2) corrected by different geophysical model combinations and (3) corrected by an estimated annual and semi-annual signal. The models used for the approach (2) are NCEP and ECMWF for atmospheric mass load changes, ECCO for non-tidal oceanic contributions and LAD, GLDAS and WGHM for the hydrological component. Figure 5 shows the RMS values derived from the different approaches (1), (2) and (3). The solid line connects the RMS values of the original (non-corrected) series. It becomes apparent, that the reduction by an annual+semi-annual sinus fit leads to the largest reduction of the RMS for all stations. This leads to the conclusion, that the geophysical models used might not provide loading signals with very high accuracy. With respect to the geophysical models it can be seen, that the consideration of hydrological loading (solutions NEL, NEG and EEW) leads to a reduction of the RMS compared to a solution for which only atmospherical and non-tidal oceanic loading are applied.

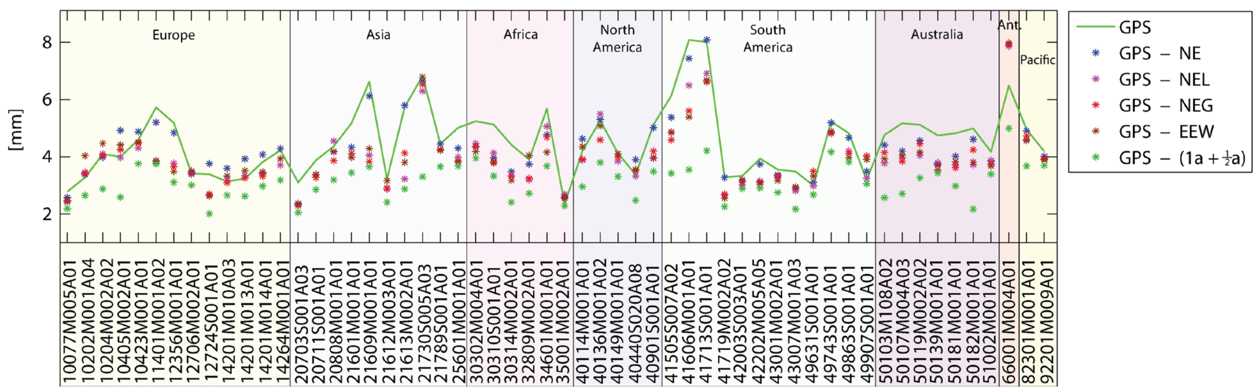

Fig. 5: RMS values for GPS station height position time series for series without loading correction (solid line) and for series corrected by different combinations of atmospherical, non-tidal oceanic and hydrological loading models (NE: NCEP-ECCO, NEL: NCEP-ECCO-LAD, NEG: NCEP-ECCO-GLDAS, EEW: ECMWF-ECCO-WGHM) and corrected by an annual plus semi-annual sinus fit.

Acknowledgements

We thank the ITRS Centre/ITRS Combination Centre at IGN for the team work and the fruitful discussions around the ITRF2008/DTRF2008 computation. We thank the IGN group also for providing the infrastructure for the ITRF computation and the large effort to provide all the data and information necessary.

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Manuela Seitz, Detlef Angermann, Mathis Bloßfeld,
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3.6.2 Institut National de l‘Information Géographique et Forestière (IGN)

This report summarizes the activities of the IGN combination centre during the year 2010. These activities are mainly related to the ITRF2008 analysis and its final combination.

ITRF2008 data analysis

With interaction and communication with the Combination Centers of the TCs, the IERS IGN Combination Center operated continuous analysis of the individual TC solutions submitted to the ITRF2008. As the ITRF2008 pre-analyses showed some deficiencies in some TC solutions, the Combination Centers of the TCs generated updated solutions which caused a certain delay in the ITRF2008 production process. The first step consists in operating data analysis of each individual technique solution, which allowed evaluating the individual station behaviour regarding linear and non-linear station motions. Discontinuities in the station position time series are then localised and introduced in the accumulation (rigorously stacking) of the time series. Sites with multiple stations and discontinuities are then constrained to have a unique velocity, except sites where Earthquakes have taken place. This first step is also an efficient tool to evaluate the temporal behaviour of the frame parameters, especially the physical ones: origin and scale. The two ITRS CCs have also operated comparisons between their intra-technique cumulative solutions.

ITRF2008 combination

A preliminary combination test was generated in early 2010, called ITRF2008P and made available to the TCs for evaluation. After the evaluation period, and taking into account comments from the TCs (e.g. discontinuities and velocity constraints for some sites), the final ITRF2008 solution was released in May 2010. As results of the first step of the ITRF2008 combination, Figure 1 illustrates an assessment of the ILRS SLR origin temporal behaviour. This figure shows that the origin components around the three axes are much more scattered between the start of SLR data in 1983 and 1993, compared to the period afterward. This feature is to be related to the use of one satellite (LAGEOS I) data in the first period, whereas the second period makes use of the two LAGEOS satellites data. For comparison with SLR, Figure 2 illustrates the origin components of the IDS DORIS time series where we can see that the Z-translation is the most scattered component.

The assessment of the scale agreement between VLBI and SLR submitted solutions is illustrated by Figure 3. From this figure we can see that the level of agreement between the two solutions is about 1 ppb. The figure also shows the scale of the IDS DORIS solution, which is situated in between VLBI and SLR scales, although it is closer to VLBI than to SLR.

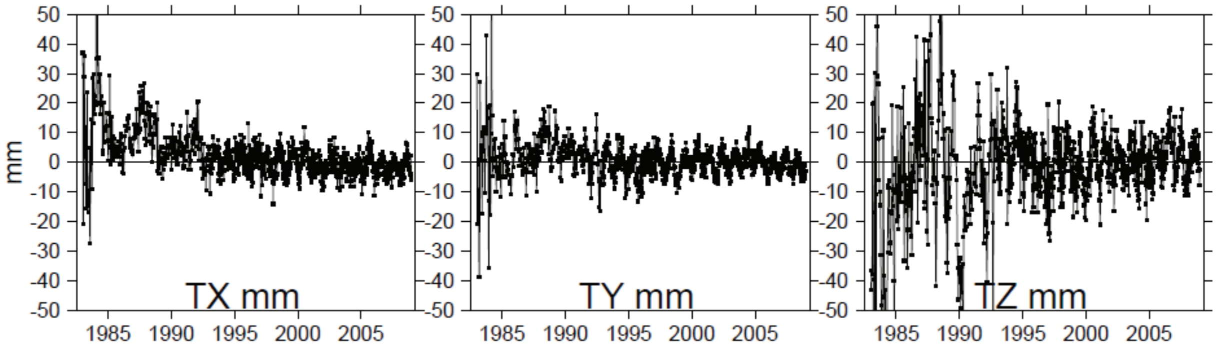

Fig. 1: ILRS SLR origin components with respect to ITRF2008

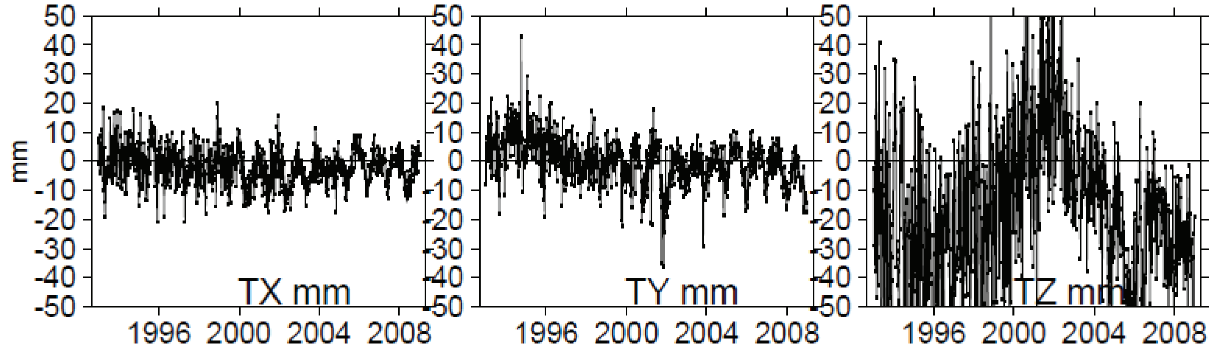

Fig. 2: IDS DORIS origin components with respect to ITRF2008

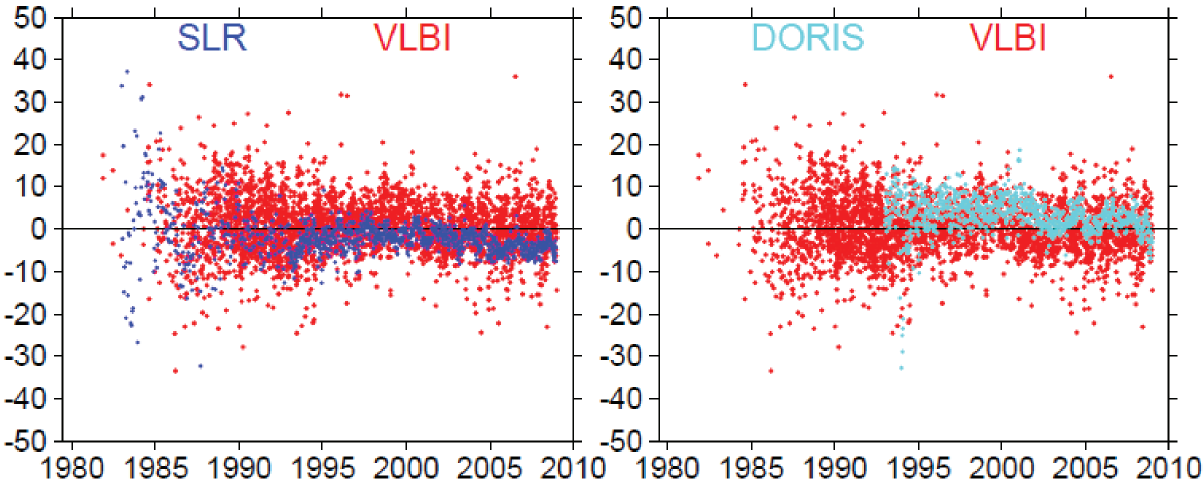

Fig. 3: VLBI, SLR and DORIS scale temporal variations with respect to ITRF2008 in millimetres

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Zuheir Altamimi, Xavier Collilieux, Laurent Métivier

3.7 IERS Working Groups
3.7.1 Working Group on Site Survey and Co-location

The Charter, Goals and Objectives and the list of members of the IERS Working Group on co-location and local ties – Jointly with IAG Sub-Commission 1.2 – can be found at the IERS WG web site: <http://www.iers.org/WGSiteSurvey>

WG Meeting

A meeting of the WG took place in Vienna, during the EGU 2010 meeting, May 4th, 2010, 19.00 h-20.00 h at the Vienna International Centre venue, Meeting Room SM3, with the following agenda:

1. **Site survey standards:**
   1. *Guidelines for surveyors* – Set up a group of experts for the compilation of a reference manual for site survey observation methods and standards. Appoint members and deadlines.
2. **Tie vector estimation:**
   1. *Software* – Identify groups capable to exchange tie vector estimation software and data sets for cross-checking and testing. Define a road map toward tie vector estimation software diffusion.
   2. *Software output* – Tie vector components in the native topocentric frame (prior to alignment) must be saved as part of the routine output.
   3. *Tie vector alignment* – The approach adopted to align the tie vector into the global frame (topocentric to global transformation) has to be specified in the output. Optimal procedures must be investigated further.
3. **Site Surveys activities:**
   1. *Critical co-location sites (Z. Altamimi)* – Identification of critical co-location sites/tie vectors based on ITRF2008 combination.
4. **Coordination and research:**
   1. *PCV & technique-dependent biases* – VLBI technique: identify surveying groups capable of investigating gravitational deformation of VLBI telescopes and producing AGD files for investigation of VLBI height and scale biases. Other techniques: status on PCV and related biases in SLR and DORIS.
   2. *Alignment* – See previous 2.3.
5. **Miscellaneous**

Participants:
C. Abbondanza, Z. Altamimi, J. Dawson, R. Haas, M. Pearlman, J. Ray, R. Schmid, P. Sarti, M. Seitz, L. Vittuari
Invitees:
D. Angermann, T. Kluegel, C. Ma, M. Pouttanen, S. Boeckmann,

J. Pietzner, B. Richter, M. Rothacher
Excused:
G. Bianco, X. Collilieux, B. Garayt, C. Meertens, M. Hennes, M. Loesler, J. Long, V. Michel, A. Nothnagel, J.-C. Poyard, J. Saunier, A. Woods

The interest on the topics covered by the WG chart is high in the geodetic community, as shown by the remarkable number of invitees that participated to the WG meeting. The discussion partially focussed on the possibility to write *guidelines for surveyors* to be resumed *in a reference manual* for practical on field operations. Although time consuming, a drafting of such document is feasible and would be useful under certain circumstances. Nevertheless, as chair of the working group, I have to stress the *complete lack of agreement on the methods to be adopted for tie vector surveying* among the groups involved in local tie surveying. This certainly jeopardizes the efforts spent on the preparation of a reference manual and it compromises its significance and validity.

As the *local ties* are performed mostly by local on-site surveyors, the *methods are highly site dependent* and may differ considerably one another. Nevertheless, a *harmonization* of the different surveying method *is needed to* dominate and *control* several factors that impact on the *accuracy of* the *tie vector*. In addition, the different *homemade software* which are used specifically to reduce and condition indirect terrestrial observations *must be inter-compared* and tested. To my knowledge, *only one test* was successfully carried out inter-comparing two indirect-method software and it *proved* their *consistency* (Dawson et al. 2007, J Geodesy). *This* mandatory *phase* of the harmonization process was identified as *crucial* during the San Francisco WG meeting *but* had *no follow up*.

Tie vectors residuals were recently released as a *by-product* of the recent *ITRF2008 combination*. Their values *are currently* being *investigated* for assessing critical situations at the co-location sites. A close *cooperation* with the *ITRS Centre* and the *ITRS Combination Centres* is compulsory and is part of the ongoing investigation. The *WG needs closer cooperation with the single technique services* in order to investigate further the role of PCV to connect the Electronic and Conventional reference points of the different geodetic instruments and remove the possible biases. *Particularly,* the cooperation with *IVS, IDS and ILRS must be strengthened.*

EGU2010 sesion

During the EGU2010, the session “The Global Geodetic Observing System: Tying and Integrating Geodetic Techniques for Research and Applications” attracted contributions that covered several aspects relevant to the WG activity.

3.7.1 Working Group on Site Survey and Co-location

Convener: Pierguido Sarti; *Co-Conveners*: Richard Gross, Erricos C. Pavlis, Manuela Seitz

Session details: IAG's Global Geodetic Observing System (GGOS) provides the means for integrating ground- and spaced-based observations of geodetic techniques. Nowadays, large inter-technique residuals are found in combinations and they reflect the presence of discrepancies whose nature and origin are not well understood. Modernization of geodetic infrastructures and homogeneous processing of geodetic data are essential to reduce discrepancies and support consistent observations of Earth's time-variable surface geometry (including ocean and ice surfaces), ocean currents, mass and volume changes.

This session was a forum to discuss integration of geodetic techniques, the actual discrepancies highlighted by the combinations, their possible causes and corrections, as well as novel plans and strategies for development of infrastructures and their application to Earth's surface monitoring.

Twelve oral and twenty one poster contributions were eventually presented and helped outlining the state-of-the-art on the WG activities.

Pierguido Sarti

3.7.2 Working Group on Combination at the Observation Level

The IERS Working Group "Combination at the Observation Level" (COL) was created in the course of 2009. Its charter is available at <http://www.iers.org/WGCOL>. A major task of the WG COL is to study methods and advantages of combining space geodetic techniques (DORIS, GNSS, SLR, VLBI), searching for an optimal strategy to solve for geodetic parameters and to intercompare the solutions obtained by the software packages of the different institutes involved in the Working Group.

Its main objective is to bring together groups able to perform combinations of space geodetic techniques at the observation level, this in order to improve the accuracy, the time resolution and the overall consistency of the geodetic products derived, i.e. Earth Orientation Parameters, terrestrial and celestial reference frames. The road map is summarized as follows:

1) review the approach of the various groups and their capability to process two or more space geodetic techniques,

2) elaborating benchmarks to intercompare results between groups from the same data set,

3) insuring SINEX compatibility between techniques, the international technique centers and IERS,

4) establishing common processing standards for all techniques in order to guarantee homogeneity and consistency,

5) optimizing and unifying parameterization.

Meetings

Two meetings were organized in 2010. The first one was held in May 2010 during the EGU meeting. Its main objective was to organize a benchmark campaign over a dedicated interval for inter-comparison. Several analyses centres took part: AIUB from Bern, DGFI from Munich, ESOC from Darmstadt, GFZ from Potsdam, GRGS from Toulouse, GSFC from Greenbelt, and JPL from Pasadena. A period of test of benchmarking was adopted corresponding to the VLBI CONT08 campaign extending from 10th to 30th August 2008.

Over this period, each analysis centre had to deliver weekly normal equations derived from the processing of the different geodetic techniques. Parameters to be estimated include daily EOP, weekly station coordinates, weekly quasar coordinates for VLBI and in addition hourly troposphere delays. The format for all normal equations spanning the three weeks is the normalised SINEX format. This format was upgraded to take into account additional types of formats of normal equations. This had to be validated at the following step.

The IERS WG COL organized another meeting at the Bavarian Academy of Sciences of Munich on 9 and 10 December 2010. New Analysis Centres joined the Working Group: TU Vienna and ASI/e-GEOS of Matera and MAO Kiev Observatory. An important part of the meeting concerned the activity reports of the various analyses centres: SLR and GNSS processed using Bernese software by AIUB, SLR processed with DOGS software and VLBI using OCCAM software by DGFI, combined SLR GNSS and SLR DORIS with NAPEOS software by ESOC. The combination centres DGFI and GRGS reported about their analyses concerning the station coordinates and EOP solutions obtained by combination of the results derived by the different analysis centres. A discussion on the models used by each analyses centre was summarized and a consensus was adopted concerning the following models: gravity field, the ocean tides FES2004 and atmospheric loading. The terrestrial reference frame chosen as the a priori is ITRF2008 and for EOP is EOPC04_08 consistent with ITRF2008. Additional parameters such as troposphere delays in collocated stations and radio-sources coordinates relative to the ICRF2 reference frame are also considered in the process of multi-technique combinations. The next step consisted in computing normal equations delivered using homogenized standards and parameters over the three week period and new set of data by LEO satellites such as Jason-2 with multi-technique (SLR, DORIS, GPS) or GRACE-A/B (SLR, GPS).

Schedule deadlines

- At the end of January 2011 the a priori models and information were put on the COL forum <http://grgs.obspm.fr/forum/>.
- SINEX files had to be delivered through the ftp server <ftp://hpiers.obspm.fr/iers/eop/grgs/>.

Contributors for 2010

The following people contributed to the work of the WG COL in the year 2010:

Daniel Gambis, Jean-Yves Richard, Christian Bizouard, Observatoire de Paris/GRGS
Richard Biancale, Jean-Michel Lemoine, CNES/GRGS
Manuela Seitz, Robert Heinkelmann, Michael Gerstl, Horst Müller, Mathis Blossfeld, DGFI
Ralf Schmid, TUM
Sylvain Loyer, Laurent Soudarin, CLS
Daniella Thaller, AIUB
Maria Mareyen, Sabine Bachmann, BKG
Rolf König, Daniel König, GFZ
Tim Springer, Drazen Svehla, ESA/ESOC
Hana Krasna, Kamil Teke, TUW

Sciarretta Cecilia, ASI/e-GEOS
Maria Kudryashova, ORB
Florent Deleflie, IMCCE

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Richard J.-Y., Bizouard C., Bourda G., Deleflie F., Gambis D., Loyer S., Soudarin L., 2009, GRGS combination of the terrestrial frame and Earth orientation parameters at the observation level. *Contribution to ITRF2008 realization, SF2A Proceedings, GRAAPH session*, pp. 115–119

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Appendix 1: IERS Terms of Reference

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

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

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

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

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

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

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

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

The IERS accomplishes its mission through the following components:

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

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

TECHNIQUE CENTERS (TC)

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

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

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

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.
- Conventions 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.

ITRS COMBINATION CENTER(S)

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 Center.

RESEARCH CENTER(S)

Research Center(s) are responsible for carrying out research on a specific subject. They are established by the DB and are related to a corresponding Product Center. Research Center(s) are limited to a term of 4–5 years.

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 is elected by the DB for a term of four years with the possibility of re-election for one additional term. 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 and PC chairs 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:

- 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.
- Representative of the Central Bureau.
- IERS Analysis Coordinator.
- Representatives of IAU, IAG/IUGG and GGOS.

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

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

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

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

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

WORKING GROUPS

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

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

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

- Draft charter clearly specifying:
  - Proposed goals (two pages at maximum),
  - Proposed structure of the group or project,
  - Working plan including schedule / deadlines including the anticipated end of work,
- Candidate for a chairperson to be appointed by the DB (optional),

- Initial list of members,
- Proposed plans for an operational phase (if applicable),
- Draft IERS message to inform the IERS community.

IERS ASSOCIATE MEMBERS

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

IAG General Secretary
IAU General Secretary
IUGG General Secretary
President of FAGS
President of IAG Commission 1
President of IAG Subcommission 1.1
President of IAG Subcommission 1.2
President of IAG Subcommission 1.4
President of IAG Commission 3
President of IAG Subcommission 3.1
President of IAG Subcommission 3.2
President of IAG Subcommission 3.3
President of IAU Commission 8
President of IAU Commission 19
President of IAU Commission 31
Head of IAU Division I

IERS CORRESPONDENTS

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

October 10, 2010

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(*Status as of April 2013*)

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

Central IERS web site

http://www.iers.org/
Please note that all other products, publications and centres may be accessed via this web site.

Products

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

Earth orientation data

Rapid data and predictions
Web access:
http://www.usno.navy.mil/USNO/earth-orientation/eo-products
ftp access: `maia.usno.navy.mil` - directory `ser7`

Monthly earth orientation data
Web access:
http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulb_new`

Long term earth orientation data
http://hpiers.obspm.fr/eop-pc/index.php?index=eoptable
ftp access: `hpiers.obspm.fr` - directory `iers/eop`

Leap second announcements
Web access:
http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins
ftp access: `hpiers.obspm.fr` - directory `iers/bul/bulc`

Announcements of DUT1
Web access:
http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins
ftp access: `hpiers.obspm.fr` - directory `iers/bul/buld`

Conventions

Web access:
IERS Conventions 2010:
http://tai.bipm.org/iers/conv2010/conv2010.html

International Celestial Reference Frame

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

International Terrestrial Reference Frame

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

Geophysical fluids data

Web accesss: http://geophy.uni.lu/

Publications

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

IERS Bulletins
http://www.usno.navy.mil/USNO/earth-orientation/eo-products/weekly/bulla (Bulletin A)
http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins (Bulletins B, C, D)
http://www.iers.org/Bulletins

IERS Technical Notes
http://www.iers.org/TechnicalNotes

IERS Annual Reports
http://www.iers.org/AnnualReports

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

IERS Components

Directing Board
Web page: http://www.iers.org/DB

Analysis Coordinator
Web page: http://www.iers.org/AC

Central Bureau
Web page: http://www.iers.org/CB

Product Centres

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

Rapid Service/Prediction Centre
Web site: http://www.usno.navy.mil/USNO/earth-orientation

Conventions Centre
Web site: http://tai.bipm.org/iers/

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

ITRS Centre
Web site: http://itrf.ensg.ign.fr/

Global Geophysical Fluids Centre
Web site: http://geophy.uni.lu/
Special Bureaus:
Special Bureau for the Oceans
Web site: http://euler.jpl.nasa.gov/sbo/
Special Bureau for Hydrology
Web site: http://www.csr.utexas.edu/research/ggfc/
Special Bureau for the Atmosphere
Web site: http://www.aer.com/scienceResearch/diag/sb.html
Special Bureau for Combination
Web site: http://geophy.uni.lu/

Technique Centres

International GNSS 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)
Web site: http://ids-doris.org/

ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)
Web site: http://www.dgfi.badw.de/index.php?id=122

Institut Géographique National (IGN)
Wep site: http://itrf.ensg.ign.fr/

Jet Propulsion Laboratory (JPL)
Web page: http://www.iers.org/ITRSCC-JPL

Working Groups

Working Group on Site Survey and Co-location
Web site: http://www.iers.org/WGSiteSurvey

IERS/IVS Working Group on the Second Realization of the ICRF
Web site: http://www.iers.org/WGICRF

Working Group on Combination at the Observation Level
Web site: http://hpiers.obspm.fr/combinaison/

Working Group on SINEX Format
Web site: http://www.iers.org/WGSINEX

Working Group on Site Coordinate Time Series Format
Web page: http://www.iers.org/WGSCTSF

Appendix 5: Acronyms

The following acronyms and other abbreviations are used in this report. For more acronyms related to IERS see <http://www.iers.org/Acronyms>.

AAM	Atmospheric Angular Momentum
AAS	American Astronomical Society
AC	Analysis Centre
AC	Analysis Coordinator
ADC	GEO Architecture and Data Committee
AFNOR	Association Française de Normalisation
AFREF	African Geodetic Reference Frame
AGD	AgileGraph Data
AGN	Active Galactic Nucleus [or Nuclei]
AGU	American Geophysical Union
ANDE	Atmospheric Neutral Density Experiment
ANTEX	Antenna Exchange (format)
AOD	atmospheric and oceanic dealiasing
APREF	Asia-Pacific Reference Frame
APSG	Asia-Pacific Space Geodynamics
AR	[IERS] Annual Report
AR	autoregressive
ASCII	American Standard Code for Information Interchange
ASI	Agenzia Spaziale Italiana
AUS	= AUSLIG
AUSLIG	Australian Surveying and Land Information Group (now: Geoscience Australia)
AWG	Analysis Working Group
BIH	Bureau International de l'Heure
BIPM	Bureau International des Poids et Mesures
BKG	Bundesamt für Kartographie und Geodäsie
BLITS	Ball Lens In The Space [spacecraft]
BSCC	Brorfelde Schmidt CCD Catalog
BVID	Bordeaux VLBI Image Database
CB	Central Bureau
CBC	GEO Capacity Building Committee
CC	Combination Centre
CCD	Charge-Coupled Device
CDDIS	NASA Crustal Dynamics Data Information System
CERGA	Centre d'Etudes et de Recherches Géodynamiques et Astronomiques
CfP	Call for Participation/Proposals
CHAMP	CHAllenging Minisatellite Payload
CLS	Collecte Localisation Satellites
CMS	Content Management System
CNES	Centre National d'Etude Spatiale
CODE	Centre for Orbit Determination in Europe
COL	combination at/on the observation level
CONGO	Cooperative Network for GIOVE Observation
CONT	continuous VLBI session
CRD	Consolidated Laser Ranging Data Format
CRD	CRF deepsouth [sessions]
CRF	Celestial Reference Frame
CSR	Center for Space Research, University of Texas
DB	Directing Board
DBBC	Digital Base Band Converter
DE	JPL Development Ephemeris
DGFI	Deutsches Geodätisches Forschungsinstitut
DiFX	Distributed FX
DIS	IERS Data and Information System
DOGS	DGFI Orbit & Geodetic Parameter Estimation Software
DOI	Digital Object Identifier
DOMES	Directory Of MERIT Sites (originally; now of more general use)
DORIS	Doppler Orbit determination and Radiopositioning Integrated on Satellite
DSS	Digitized Sky Survey
DTRF	ITRS realization by DGFI
DUT1	= UT1–UTC
EC	Executive Committee
ECCO	Estimating the Circulation and Climate of the Ocean
ECMWF	European Center for Medium Range Weather Forecasting
EGU	European Geosciences Union
ELP	Ephemeride Lunaire Parisienne
EMR	Energy, Mines and Resources Canada

	(replaced by NRCan)
ENSG	Ecole Nationale de Sciences Géographiques
EO	Earth orientation
EOC	Earth Orientation Centre
EOP	Earth Orientation Parameters
ERIS	Earth Rotation Information System
ERP	Earth Rotation Parameters
ESA	European Space Agency
ESOC	European Space Operations Center, ESA
ETH	Eidgenössische Technische Hochschule
ETS	Engineering Test Satellite
e-VLBI	Electronic transfer VLBI
EVN	European VLBI Network
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FCN	Free Core Nutation
FIG	Fédération Internationale des Géomètres (International Federation of Surveyors)
FTP, ftp	File Transfer Protocol
GA	Geoscience Australia
GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
GB	Governing Board
Gbps	Gigabit(s) per second
GCI	GEOSS Common Infrastructure
GCRF	Gaia Celestial Reference Frame
GCRS	Geocentric Celestial Reference System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GFZ	GeoForschungsZentrum Potsdam
GGAO	Goddard's Geophysical and Astronomical Observatory
GGCN	Global GGOS network of core sites
GGFC	Global Geophysical Fluids Centre
GGFC-OC	GGFC Operational Component
GGOS	Global Geodetic Observing System
GGOS-D	GGOS – Deutschland (Germany)
GIA	glacial isostatic adjustment
GIAC	GGOS Inter-Agency Committee
GIC	GGOS Intergovernmental Committee
GINS	Geodesy by Simultaneous Digital Integration [software]
GIOVE	Galileo In-Orbit Validation Element
GLDAS	NASA's Global Land Data Assimilation System
GLONASS	GLObal'naya NAvigatisionnay Sputnikovaya Sistema [Global Orbiting Navigation Satellite System, Russia]
GNSS	Global Navigation Satellite System
GOOS	Global Ocean Observing System
GOP	Geodetic Observatory Pecny
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRGS	Groupe de Recherches de Géodésie Spatiale
GSC	GSFC Analysis Center
GSFC	Goddard Space Flight Center
GSI	Geographical Survey Institute
GUHS	Global Unified Height System
HAM	Hydrologic[al] Angular Momentum
HartRAO	Hartebeesthoek Radio Astronomy Observatory
HEO	High Earth Orbiter
hr	hour
h/v	hight/vertical
IAA	Institute of Applied Astronomy, St. Petersburg
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICESat	Ice, Cloud, and land Elevation Satellite
ICG	International Committee on Global Navigation Satellite Systems
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
ICSU	International Council for Science
IDS	International DORIS Service
IERS	International Earth Rotation and Reference Systems Service (formerly: International Earth Rotation Service)
IGFS	International Gravity Field Service
IGN	Institut National de l'Information Géographique et Forestière (formerly: Institut Géographique National)
IGOS	Integrated Global Observing Strategy

IGR	IGS rapid (orbit)
IGS	International GNSS Service (formerly: International GPS Service)
ILRS	International Laser Ranging Service
ILRSA	ILRS official solution
IMCCE	Institut de Mécanique Céleste et de Calcul des Éphémérides
INA	= INASAN
INAF	Istituto Nazionale di Astrofisica
INASAN	INstitut AStronomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)
INPOP	Intégrateur Numérique Planétaire de l'Observatoire de Paris
IPGP	Institut de Physique du Globe de Paris
IRA	Istituto di Radioastronomia
IRIS	International Radio Interferometric Surveying
ISO	International Organization for Standardization
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JAXA	Japan Aerospace Exploration Agency
JCET	Joint Center for Earth System Technology, GSFC
J-MAPS, JMAPS	Joint Milli-Arcsecond Pathfinder Survey
JPL	Jet Propulsion Laboratory
LAD	Land Dynamics
LAREG	Laboratoire de Recherche en Geodesie
LCA	LEGOS in cooperation with CLS
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LEO	Low Earth Orbit(er)
LLR	Lunar Laser Ranging
LOD	Length of Day
LQAC	Large Quasar Astrometric Catalog
LQRF	Large Quasar Reference Frame
LRA	Laser Retroreflector Array
LRO	Lunar Reconnaissance Orbiter
LS	least-squares
MAO	= GAOUA
mas	milliarcsecond(s)
μas	microarcsecond(s)
MCC	Russian Mission Control Centre
MeO	Métrologie Optique [Grasse SLR /LLR system]
MERIT	Monitoring Earth Rotation and Intercomparison of Techniques
MPIfR	Max-Planck-Institut für Radioastronomie / Max Planck Institute for Radio Astronomy
MSP	millisecond pulsar(s)
ms	millisecond(s)
μs	microsecond(s)
NASA	U.S. National Aeronautics and Space Administration
Nat.	National, Nacional
NCEP	U.S. National Centers for Environmental Prediction
NEQ	normal equation
NERC	Natural Environment Research Council, UK
NOAA	U.S. National Oceanic and Atmospheric Administration
NOFS	USNO Flagstaff Station
NOGAPS	[U.S.] Navy's Operational Global Atmospheric Prediction System
NP	SLR normal point(s)
NPM	Lick Northern Proper Motion Program
NRAO	[U.S.] National Radio Astronomy Observatory
NRCan	Natural Resources, Canada (formerly: EMR)
NRT	Nançay Radio Telescope
ns	nanosecond(s)
NSGF	NERC Space Geodesy Facility
OAM	oceanic angular momentum
Obs.	Observatory, Observatoire
OCR	optical character recognition
OHP	Observatoire de Haute Provence
OP, OPA	Observatoire de Paris
OPAR	Paris Observatory IVS Analysis Center
ORB	Observatoire Royal de Belgique

PC	Product Centre
PCV	Phase-Center Variations
PM	Polar Motion
PMD	Politecnico di Milano, Dipartimento di Ingegneria Idraulica, Ambientale, Infrastrutture Viarie, Rilevamento
POD	Precise [or Precision] Orbit Determination
POLAC	Paris Observatory Lunar Analyses Center
ppb	parts per billion (10^{-9})
QRFH	Quadruple-ridged flared horn / Quad-ridge Feed Horn
QSO	Quasi-Stellar Object [quasar]
QZSS	Quasi-Zenith Satellite System
RAEGE	Red Atlantica de Estaciones Geodinamicas y Espaciales
R&D	Research and Development
RDBE	Roach Digital Backend
RDV	Research and Development (sessions) with the VLBA
REFAG	Reference Frames for Applications in Geosciences
RINEX	Receiver INdependent EXchange format
rms, RMS	Root Mean Square
RRFID	USNO Radio Reference Frame Image Database
RS/PC	IERS Rapid Service/Prediction Center
RT	real-time
RTCM	Radio Technical Commission for Maritime Services
SAR	Synthetic-aperture radar
SB	Special Bureau
SBA	Special Bureau for the Atmosphere
SBCP	Special Bureau for the Combination Products
SBH	Special Bureau for Hydrology
SBO	Special Bureau for the Oceans
SC	Steering Committee
SC	Subcommittee
SCCID	Strategic Coordinating Committee for Information and Data
SDSS	Sloan Digital Sky Survey
SEFD	System Equivalent Flux Density
SIMLite	Space Interferometry Mission
SINEX	Solution (Software/technique) INdependent EXchange Format
SIO	Scripps Institution of Oceanography
SIRGAS	Sistema de Referencia Geocéntrico para Las Américas
SLR	Satellite Laser Ranging
SOAR	Southern Astrophysical Research
SOFA	Standards Of Fundamental Astronomy
SPBU	St Petersburg University
STC	GEO Science & Technology Committee
SYRTE	(Laboratoire) Systèmes de Référence Temps-Espace
TAI	Temps Atomique International (International Atomic Time)
TanDEM-X	TerraSAR-X add-on for Digital Elevation Measurement
TC	Technique Centre
TIGA	Tide Gauge Benchmark Monitoring
TN	[IERS] Technical Note
TOA	time of arrival
ToR	Terms of Reference
TRF	Terrestrial Reference Frame
TT	Terrestrial Time
TTW	Twin Telescope Wettzell
TU	Technical University
TUM	Technical University of Munich
TUV, TUW	Technische Universität Wien (Vienna University of Technology)
U.	University
UAW	GGOS Unified Analysis Workshop
UCAC, UCAC3, UCAC4	USNO CCD Astrograph Catalog
UFRJ	Universidade Federal do Rio de Janeiro
UIC	GEO User Interface Committee
U.K.	United Kingdom
URAT	USNO Robotic Astrometric Telescope
URL	Uniform Resource Locator
U.S.	United States
USNO	United States Naval Observatory
UT, UT0, UT1, UT1R	Universal Time
UTAAM	NOAA AAM analysis and forecast data
UTC	Coordinated Universal Time

VEX	VLBI Experiment Documentation
VLA	Very Large Array
VLBA	Very Long Baseline Array, NRAO
VLBA-CS	Very Large Baseline Array Calibrator Survey
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Function
VPEG	VLBI2010 Project Executive Group
WDC	World Data Centre(s)
WDS	ICSU World Data System
WG	working group
WGHM	WaterGAP [Global Assessment and Prognosis] Global Hydrology Model
WRMS, wrms	Weighted Root Mean Square
XML	eXtensible Markup Language
yr	year