

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

IERS Annual Report 2012

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IERS Annual Report 2012

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1 Foreword

In 2012 the IERS took steps to prepare for its future goals and products. The Analysis Coordinator set in motion plans for an IERS Retreat to “focus on maintaining the IERS’s core role of the generation of regular, high accuracy products ... [and] to establish directions for IERS over next decade that will ensure this core role is met.” Along with the publication of IERS Technical Note 37 on the analysis and results of ITRF2008, the ITRS Centre began preparations for ITRF2013. To strengthen this work the IERS Directing Board accepted the proposal from JPL to become an ITRS Combination Centre.

The GGFC organized a workshop in Vienna “with the goal of allowing the Special Bureau Chairs, the GGFC Product Centers, and the GGFC user community to review the structure and data holdings of the GGFC and to make suggestions for new products”. Several proposals were received in response to a GGFC call, demonstrating the interest of the community in continuing refinement of IERS products.

To provide improved latency the Rapid Service / Prediction Centre began operational distribution of EOP combination and prediction solutions four times per day. In response to a need to facilitate comparison of products the IERS established a new working group on site coordinate time series format to define a common exchange format for coordinate time series of all geodetic techniques.

Two developments of potential importance to the IERS should be noted. The ITU Radiocommunication Assembly held in Geneva decided to defer the development of a continuous time standard in order to address the concerns of countries that use the current system of the leap second in Coordinated Universal Time (UTC). The IERS should be prepared with the products and processes to proactively address the changes that may be decided in the future. The IAU General Assembly in Beijing established under Division A the working group for the Third Realisation of International Celestial Reference Frame. The IERS should have an active role in the preparation and adoption of future realizations of the ICRF.

Finally, the IERS Directing Board elected Brian Luzum to be its new Chair beginning in 2013. His expertise and experience in the work of the IERS will provide a firm foundation for the future.

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

2 The IERS

2.1 Structure

From 2012 to 2014, 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 2012 and 2014.

Analysis Coordinator Thomas Herring

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 (since 1 January 2013),
Tim Springer
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 (until December 2012),
Jérôme Saunier (since 1 January 2013)
IERS Representative to the IDS Governing Board:
Chopo Ma (until 31 December 2012),
Brian J. Luzum (since 1 January 2013)

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

2.1 Structure

Conventions Centre

Primary scientists: Brian J. Luzum, Gérard Petit

Representative to the IERS Directing Board:

Gérard Petit (until 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

Chair: Tonie van Dam

ITRS Combination Centres

Deutsches Geodätisches Forschungsinstitut (DGFI)

Primary scientist: Manuela Seitz

Institut Géographique National (IGN)

Primary scientist: Zuheir Altamimi

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 (until 31 December 2013), Sten Bergstrand (since 1 January 2014)

Co-Chair: John Dawson (since April 2012)

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

Chair: Daniela Thaller

Working Group on Site Coordinate Time Series Format

(established in April 2012)

Chair: Laurent Soudarin

(Status as of April 2014)

2.2 Directing Board

In 2012 to 2014, 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	Thomas Herring
<i>Product Centres Representatives</i>	
Earth Orientation Centre	Daniel Gambis
Rapid Service/Prediction Centre	Brian J. Luzum
Conventions Centre	G�rard Petit (until 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)
<i>Technique Centers Representatives</i>	
IGS	Steven Fisher (since 1 January 2013), Tim Springer
ILRS	J�rgen M�ller, Erricos C. Pavlis
IVS	Chopo Ma, R�diger Haas
IDS	Frank G. Lemoine, Bruno Garayt (until 31 December 2012), J�r�me Saunier (since 1 January 2013)
<i>Union Representatives</i>	
IAU	Aleksander Brzezinski
IAG / IUGG	Clark R. Wilson
GGOS (since March 2012)	Bernd Richter

2.3 Associate Members

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

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: Spiros Pagiatakis
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 April 2014)

3 Reports of IERS components

3.1 Directing Board

The IERS Directing Board (DB) met twice in the course of each of the year 2012. Summaries of these meetings are given below.

Meeting No. 54

April 22, 2012, Technical University of Vienna, Gusshausstr. 27, 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.

Formalities

The minutes of IERS DB Meeting #53 were distributed together with the agenda of DB Meeting #54.

Reports from the Technique Centres

International GNSS Service (IGS)

Tim Springer gave an overview on IGS activities:

- The real-time project is developing very well and is now routinely producing a combined product. There is also routine usage of the products in real time using the precise point positioning method.
- The IGS has started a Multi-GNSS EXperiment (MGEX) in order to prepare the IGS for the upcoming new systems and signals like QZSS, GALILEO, and COMPASS. In a first stage the focus is on gathering data from the new systems, in particular the first QZSS satellite and the first two GALILEO In Orbit Validation (IOV) satellites. With these new systems and signals the format version 3 of the Receiver Independent Exchange format (RINEX) changes significantly which is a non-trivial change/move for the IGS. The MGEX experiment should pave the way towards this new format.
- The bi-annual IGS Workshop will be held from July 23 to 27 in Olsztyn, Poland.

The Astronomical Institute of the University of Berne is taking care of the generation of a, long overdue, IGS technical report.

International Laser Ranging Service (ILRS)

Erricos Pavlis gave a presentation on ILRS activities:

1. Network and Operations

The DC harmonization was improved and data flow problems are now resolved. ILRS will finally switch to new data format on May 2. Several new and old international stations joined/returned to operations. ILRS adopted a new procedure in collecting full rate (FR) data to form normal points (NP).

2. Missions

New GLONASS satellite; Chinese Topography Mapping mission ZY-3; Galileo/IOVE Constellation successfully tracked; RadioAstron (SPEKTR-R) is poorly tracked; LARES (new cannonball satellite) launched.

3. Analysis

Operational products (weekly & daily) delivered routinely and on time from all nine ACs; new CoG model for LAGEOS & ETALON; ILRS AWG will switch official product on May 2; PPs schedule shifted to accommodate ITRS/GGFC PP for testing atmospheric corrections at observation level; re-analysis for 1983 to present planned; AWG held a meeting on April 21, 2012.

4. Publications

2009–2010 Annual Report is in preparation; ILRS Special Issue in the Journal of Geodesy is progressing slowly.

5. Future Meetings

WPLTN Technical Workshop, September 24–28, 2012, St. Petersburg, Russia; ILRS Technical Workshop in Frascati, Italy, on November 3, 2012; 18th International Workshop on Laser Ranging to be held in Tokyo, fall of 2013.

International VLBI Service for Geodesy and Astrometry (IVS)

Rüdiger Haas presented the IVS report:

1. Recent and upcoming VLBI meetings

VLBI2010 TecSpec in Bad Kötzting, March 1&2, 2012; 7th IVS GM in Madrid, March 5–8, 2012; E-VLBI meeting, October 22–24, 2012, Haystack; IVS EGU Training school for VLBI in Geodesy and Astrometry, March 2–5, 2013, in Helsinki; 21st EVGA Working Meeting, March 6–8, 2013, in Helsinki.

2. IVS operations and analysis

Problems with station outages (Tigo Concepcion, Tsukuba); attempts to provide time series of station positions for EOP analysis (GSFC); too few IVS analysis centers, too few different software packages; timeliness of submissions has improved; preparations for VLBI contribution to ITRFxx have started; interesting web pages concerning IVS: IVS live (Bordeaux), IVS tools page at IVS Combination Center at BKG.

3. IVS Intensives

Quality issues for INT-sessions; IVS Task force on Intensives; Ultra-rapid sessions.

4. VLBI2010 technical development (feed developments; digital backends; recording)

5. VLBI2010 projects

There are projects at 11 sites for new telescopes from 12 to 22 m, to be finished between 2012 and 2017.

Zuheir Altamimi asked about the inclusion of radio source positions in SINEX files. Chopo Ma replied that this is for studies only, not for ITRF combination.

New Action Items:

#54.01 Gather high-frequency EOP models currently available

#54.02 Test high-frequency EOP models with GPS

Report on GGFC activities

Tonie van Dam presented the status of the new GGFC components:

1. Evaluation of products

The following products were evaluated and are recommended as official products: Loading: GLDAS, ECCO, NCEP, Grace AOD (T. van Dam); Tropospheric delays (J. Böhm); Combination momentum (M. Thomas)

2. GGFC workshop

30 participants, 21 presentations; presentations to be put on the IERS website; short summary, recommendations, and action items being developed

3. Call for proposals

Following the GGFC Call for new products and for Chair of Science Support Component, distributed on February 3, the following proposals were received: GLDAS and NCEP: D. MacMillan; ECMWF and MOG2D: J.P. Boy; ECMWF: J. Böhm; Grace AOD: R. König; tropospheric delay NCEP: M. Santos

4. Call for participation

The UAW initiated a call for participation to evaluate using ATML at the observation level.

5. Response from the VLBI and from laser communities; no response so far from GPS community.

Data have been available since mid-Feb. Deadline for contributions is July 1.

Decision:

The DB accepted the current provisional products as operational ones.

New Action Items:

#54.03 Inform responsible persons that provisional products were accepted as operational ones

#54.04 Assess the impact of temporal variations in the amplitudes and phase of the S1 and S2 thermal tide loading signals.

#54.05 Reconcile differences between the CM S1 S2 tidal loading coefficients in the IERS conventions and those being used by the GGFC.

ITRS/ITRF <i>Report from ITRS Center</i>	The report was presented by Zuheir Altamimi. 1. Activities Maintenance of the ITRF database and website; preparation of the joint GGFC/ITRS Call for NT-ATML corrected solutions from the 4 techniques; article on ITRF2008 Plate Motion Model; ITRF2008 Technical Note in preparation; development/organization of an operational entity for local surveys and co-locations (see below); evaluation of the NT-ATML solutions. 2. Next ITRF solution (ITRF2013) To be ready in mid 2014; CfP for ITRF2013 will be issued by Fall 2012; outcome of the ITRS/GGFC call solutions evaluation; all techniques to submit solutions by Jan–Feb 2014. Expected Improvements & Developments: reprocessed solutions; revisiting the weighting of Local Ties and Space Geodesy solutions included in the ITRF combination; improving the process of detection of discontinuities in the time series; modeling the post-seismic station motion.
<i>IERS Working Group on SINEX Format</i>	A short written report was submitted by Daniela Thaller before the meeting. Besides a change in WG membership, it contained mainly the topics of the WG meeting on 23 April 2012.
<i>IERS Working Group on Combination at the Observation Level</i>	Christian Bizouard presented this report on behalf of Richard Biancale. The first action of the COL WG was to organize an inter-comparison campaign in order to homogenize the software packages used. The period chosen is the one corresponding to the three week of the intensive CONT08 VLBI campaign. The combination has been performed for common parameters: station coordinates, Earth Orientation Parameters, orbit parameters and troposphere parameters. The multi-technique approach gives the opportunity to compare in a coherent way the solutions obtained from various techniques. This was demonstrated for the case of ZDT. In order to ease the task, the COL WG has created an ftp server for exchanging data and a Web site for describing the state of the art and its last upgrade. Prospects of work: • Multi-technique processing by reinforcing the consistency of standards, parameters, and a-priori references • Search for optimal weighting on station coordinates • Introduction of space ties as constraints • Exploring sub-diurnal EOP variations by using hourly to bi-hourly parameters • Low degree spherical harmonic coefficients of the gravity field

IERS Working Group on on Site Survey and Co-location

Pierguido Sarti gave a critical overview on the activities and the success of the WG during the last years and analyzed, whether its general goals have been achieved.

1. *Coordinate research on Local Tie procedures and Tie Vectors estimation*

There is scarce feedback from WG members. The WG is not serving as a liaising entity.

2. *Define procedures, standards, guidelines*

It is questionable whether this goal can be achieved at all.

3. *Stimulate discussion and interaction between surveyors, SG technique experts, combination experts*

This could partially be reached.

4. *Investigate precision, accuracy and repeatability of TVs and their discrepancies with SG solutions (ITRF residuals)*

The best results were gained in this direction.

The following proposals were made by P. Sarti:

- Re-write the TOR and revise the list of members
- Stimulate the IAG Services to focus on technique biases
- Stringent need of a permanent entity that goes beyond the prerogatives of a WG to ensure temporal continuity and services
- Establishment of a “Service” for local ties and tie vectors (intended as the fifth technique) was suggested at the last WG meeting in SF (Dec. 2011) but did not find supporters
- Creation of an Action Group within the ITRS Centre and supported by IGN

Establishing of a survey operational entity within the ITRS Center

Xavier Collileux explained the IGN plans to support the international activity related to local ties based on an analysis of the current situation.

IGN proposes to establish a “survey operational entity” that will interact with an “advisory group” composed of international local tie survey experts. Its mission would be to supply local tie data and products as well as recommendations to surveyors and users.

Actions foreseen are:

1. Creation and maintenance of a Survey Data Archive: Observations (data), metadata (pictures, reports) and products (SINEX, reports). Availability through a web site.
2. Establishment of Survey Data Format conversion document and software.
3. Development of a document “Survey Guidelines/Specifications”.

Decisions:

WG on Combination at the Observation Level will be continued.

DB approved the activity to establish a “survey operational entity” within the ITRS Center.

New Action Item:

#54.06 Send a thank-you message to NGS

Establishing of an IERS Working Group on Time Series Format

Laurent Soudarin offered the plan of establishing this WG, based on the proposal of the UAW 2011 in Zurich to establish an IERS Working Group on site coordinates time series to define a common exchange format for coordinates time series for the geodetic techniques.

The major goals and objectives of the WG are:

- Define a common exchange format for coordinate time series of all geodetic techniques (DORIS, GNSS, SLR, VLBI ...).
- Examine what type of time series is required (geocentric, detrended, reference frame, ...)
- Define the data and meta-data that should be included in the format
- Ensure that the format contains the necessary information to be easily used or converted for the web tools of the IAG Services (GGOS, IERS, IDS, IGS, ILRS, IVS)

A draft charter, a schedule for work, and a preliminary list of members was presented.

Decision:

DB agrees for establishing this WG.

**Earth orientation products
Report from Earth Orientation
Centre**

Christian Bizouard reported about the work of the Earth Orientation Centre. Since December 2011 only final values of the C04 EOP series values are provided. DORIS IGN series is now included in C04 combination.

**Report from Rapid Service/
Prediction Centre**

Brian Luzum summarized the recent changes and the near-term investigations at the Rapid Service / Prediction Centre.

1. Recent Changes
4x/day EOP Combination and Prediction solutions operational; pertinent information for solutions; improved functionality of the EO calculator
2. Near-term Investigations
Improved polar motion prediction; use of VLBA-derived UT1–UTC estimates; increased frequency of USNO UTGPS

**IERS products: Comments on
Unified formats**

Tom Herring initiated a discussion on the formats of EOP.

After analyzing the current situation, he presented the following suggestions:

- A concise summary of how each product is generated, what its nominal purpose is and measures of accuracies of the input contributions.
- Clear indication of date of generation of the product when this is not clear in file name.
- File naming convention that is clear and can be machine generated.
- Comparison statistics and graphics in an easily accessible and marked location.

These topics and implementation plans will be discussed at the retreat and with the new leadership of the IERS.

New Action Item:

#54.07 Update Bulletin B including all Analysis Centers

Report on GGOS

Chopo Ma gave a short report from GGOS, announcing that there will be a GGOS Retreat at the end of June in Frankfurt am Main.

Status of ICRS/ICRF

Richard Gaume presented summaries of the work on the following selected tasks of the ICRS Center:

1. Maintenance and extension of the ICRF
USNO Cooperation ongoing, ICRF maintenance observations continue
2. Investigation of future VLBI realizations of the ICRS
Discussion started at IVS GM about ICRF 3; plan to establish a IAU Division 1 Working Group on ICRF 3 at the upcoming IAU GA
3. Investigation of future non VLBI realizations of the ICRS
LQAC-2 (Large Quasar Astrometric Catalog v.2) was published; GIQC-3 (Gaia Initial Quasar Catalog v.3) and USNO CCD Astrograph Catalog V4 in preparation; description of the USNO Robotic Astrometric Telescope (URAT)
4. Maintenance of the time stability of ICRF
Regular update of coordinate time series; diffusion via <http://ivsopar.obspm.fr>
5. Maintenance of the link to the Hipparcos catalog
Way forward study for Joint Milliarcsecond Arcsecond Pathfinder Survey (JMAPS) underway
6. Maintenance of the link to the solar dynamical reference frame through planets & asteroids
ASETEP (Asteroid Effects on The Terrestrial Planets) since 2012 available
7. Maintenance of the link to the solar dynamical reference frame through LLR (Lunar laser ranging)

New Apollo Station (Apache Point/ New Mexico); Meo Station (Caussols / France) modernized; reduction improvements

IERS Conventions Gérard Petit reported about the work on updating the IERS Conventions (2010). So far, only detected errors were corrected, and respond to users requests for clarification etc. was given. The updates are listed at the website. There is regular traffic with >1000 visits / month (on http, not counting ftp). Work on technical updates to the Conventions (2010) was started, with updates of existing content, expansion of models, and introducing new topics (non-tidal loading, SINEX format for modeling, ...).

New Action Item:

#54.08 Include version numbers in updates of IERS Conventions

Report from IAU Aleksander Brzezinski reported the following from IAU.
A message from Dennis MacCarthy, President of the IAU Division I, stated:

- At the upcoming IAU General Assembly, Joint Discussion 7 “Space-time Reference Systems for Future Research” will be of interest to the IERS.
- At business meetings at the IAU General Assembly there is likely to be discussion regarding the future arrangements between IAU Division I and the IERS, particularly because of the proposed reorganization of the structure of the IAU.
- President of IAU Division I hopes that the IERS will have a formal report to Division I covering the past 3 years of operation to present for discussion by the time of the General Assembly.
- Plans for the next ICRF will be discussed at the General Assembly and IERS should be an important contributor in working toward that goal.

The report of Harald Schuh, President of the IAU Commission 19, prepared for IAU GA 2012, contain also the following topics:

- Establishing a Commission’s Secretary
- Update of the Commission 19 member list
- Setting up and maintaining new C19 website, including new web page about history of C19
- Organizing the C19 OC elections for the term 2012–2015
- President: Cheng-li Huang; Vice-President: Richard Gross; OC Members: Christian Bizouard, Ben Chao, Wieslaw Kossek, David Salstein, Vladimir Zharov, representatives of IVS, IERS, IAG, t.b.d.
- Co-organization of workshops and other meetings

3.1 Directing Board

- Co-organization of a Special Issue on Earth Rotation in the Journal of Geodynamics
- Preparation of the IAU General Assembly in Beijing, including two own Scientific Sessions

General tasks and future plans of Commission 19 are:

- follow new technological achievements with relevance for EOP research (e.g. optical clocks, ...) and make proposals on applications
- establish even better collaboration with neighboring disciplines (oceanography, meteorology, hydrology, ...)
- encourage interdisciplinary endeavors with the aims of improving the understanding of processes and interactions in the Earth system in view of global change
- establishment of new IAU/IAG Working Group "Theory of Earth rotation" (not started yet)
- update Comm. 19's Terms of Reference

A message from George Kaplan, President of the IAU Commission 4, stated:

- With the leap-second question delayed by the ITU for another three years, there is probably nothing of any urgency on the agenda for us. If leap seconds had been eliminated, we would have been interested in having the IERS (or one of its contributing organizations) develop a regular service of best-available predictions of UT1–UTC for up to 3 years in advance, along with reliable uncertainty estimates.
- The error estimates for the long-range UT1–UTC predictions that now appear in Bulletin A are surely too small; that issue should be reviewed. The paper by Gambis and Luzum (Metrologia 48, S165) seems to be more realistic on the issue of predictions and their uncertainties several years in advance.

New Action Item:

#54.10 Contact D. MacCarthy concerning report to IAU Div. I

Discussion on IERS DB Chair elections

Chopo Ma reminded that his second term will end on 21 December 2012. According to the IERS ToR, the Chairperson is one of the members of the DB elected by the Board for a term of four years. All DB members are asked to propose candidates. The proposed DB members will be contacted whether they are willing to stand candidate.

New Action Item:

#54.09 Send message to DB members asking for candidates

IERS Retreat / Next DB Meeting

Due to several problems (uncertain successor for B. Richter as representative of the Central Bureau, new DB Chair by the beginning of 2013, short preparation time and problematic travel situation at NASA), the retreat will be postponed to 2013.

The DB agreed on the following date: Thursday and Friday, 4–5 April 2013. The DB meeting could then be held on Saturday, 6 April.

Decision:

Next DB meeting on Sunday morning before the AGU Fall Meeting, i.e. on 1 December 2012.

Annual Reports

The annual reports for 2008 and 2009 were published online as a biennial report in December 2011. The printed issue will follow asap.

Contributions for Annual Reports 2010 and 2011 have been received; several reports of components are still missing.

The DB proposed to consider introducing a “highlights” section into the annual reports.

Decision:

Publish annual reports for 2010 and 2011 separately.

New Action Item:

#54.11 Send reminders for contributions to AR 2010

New director of the Central Bureau

Chopo Ma expressed his thanks to Bernd Richter for his work as Director of the IERS Central Bureau from 2001 to 2012. B. Richter thanked the DB members for their cooperation. The work in IERS was a very interesting one. This will be his last DB meeting as Director of the CB, but he will be back as representative of GGOS to the IERS DB.

The new director of the Central Bureau will be known in about August this year.

Meeting No. 55

December 1, 2012, Hotel Westin, 50 Third Street, San Francisco, USA

Introduction and approval of agenda

The agenda was accepted. The Chair, Chopo Ma, welcomed the guests and the members of the IERS Directing Board.

Formalities

The minutes of IERS DB Meeting #53 were distributed together with the agenda of DB Meeting #54.

IERS DB Chair election Brian Luzum is the only candidate: His qualifications have been presented in a short CV.

The board accepted Brian as new DB Chair. His period starts at January 01, 2013.

IERS Retreat Tom Herring presented the objectives of the IERS retreat. The aims of the retreat are to establish the directions for IERS over next decade. Main objectives should be:

- “Real-time” products (products that support low latency (1-sec) applications of geodetic data; VLBI incorporation).
- Rigorous combined products (e.g., services are generating EOP and terrestrial RF simultaneously; IERS is simply averaging EOP values).
- Long-term stability and parameterization of the reference frame.
- Center-of-Mass products.
- EOP prediction improvements.
- Next generation of models needed and how to establish need (improvements needed in diurnal/semi-diurnal EOP, tidal loading).

IERS evolution: Last re-organization in 2003 with last retreat. Establish mechanisms that allow changing contributions.

Other possible subjects:

- 1) Definition and integration of Local Ties in the ITRF generation and
- 2) How to integrate the Techniques in the generation of ITRF.
- 3) Establish an evaluation plan for upcoming ITRF generation.
- 4) Gaia reference frame discussion.
- 5) IUGG resolution 2011 on rigorously processing EOP.

Local Ties:

The local ties are not the problem for the collocation. Problematic are the accessibility of the technique-specific reference point and the systematic errors/biases of the techniques.

P. Sarti plans a workshop on local ties. Expectations:

Techniques have to work on their own systematic errors (such as thermal deformations of VLBI telescopes, models, etc.) and their impact on the tie vector.

All surveyors may introduce biases (esp. VLBI), GPS-based tie discrepancies are known and described in the paper of P. Steigenberger. Furthermore feedback from services regarding e.g. radomes for GPS, gravitation for VLBI, etc. is expected.

Proposal: Combining the workshop on local ties and the IERS Retreat; and organizing a combined meeting in Paris in mid-May.

The DB agreed to postpone the retreat from April to mid-May for university teaching responsibility reasons. The retreat will take place in Paris. Zuheir Altamimi is willing to make the arrangements.

The retreat will be held in conjunction with a preceding 2-days workshop on local ties organized by P. Sarti.

New Action Items:

#55.02 Organize workshop on local ties

#55.03 Agree on date for the retreat

#55.04 Make arrangements for IERS Retreat in Paris

#55.05 Update and distribute draft retreat topics and invitees

Report on GGFC activities

Xavier Collilieux and Tonie van Dam made the call for participation concerning tidal and non-tidal loading studies in May 2012 with a good response. The submitted data are available and can be used. The contributions and their impact on the combination have to be validated by Zuheir Altamimi (see item “ITRS/ITRF”).

IAU WG on ICRF3 Activities and US NSF issue on NRAO VLBA

Ralph Gaume presented the status of the IAU Working Group on ICRF 3.

A steering committee has been organized to form an IAU Division A WG on ICRF3. The WG charter as well as the membership has been finalized. Chris Jacobs has been selected to chair the WG. Currently, the approval is about to be decided by IAU.

Status of NRAO VLBA

The US National Science Foundation (NSF) may divest itself of the VLBA (Very Long Baseline Array) by 2017. The VLBA consists of eight continental radio telescopes and one telescope each on Hawaii and on the Virgin Islands.

Closing the VLBA after 2017 would have a major impact on the generation of the ICRF3, as the VLBA accounted for ~28% of ICRF2 observations in total. In order to ensure the operability of the VLBA (or of parts of the VLBA) the IERS DB Chair sent a VLBA letter of support to the NSF in October as well as the IVS DB Chair and the IAU Div. A President in order to convince the NSF to continue the operation of the VLBA.

The NSF decision is expected to be made in 2013.

Report on GGOS

Hansjörg Kutterer reported on the status of GGOS:

- The elections for GGOS components were finalized and the transition phase was successfully finished in April 2012. A list of the members for the Coordinating Board (CB), the Executive Committee (EC) and the science panel can be found in the presentation.

- A GGOS Retreat took place in June 2012 in Frankfurt with plenary discussions and breakout groups. The results of the retreat have been formulated in the Frankfurt Matrix. The Frankfurt Matrix summarizes the strategic/project activities: review the existing action plan, document the user requirements, improve the interaction and the communication amongst GGOS, IAG services and commissions (e.g., inter-service forum), maintain relationship with GIAC, better integrate gravity experts, formulate standardized GGOS review processes, etc.
- GGOS participations in GEO, CEOS and UN GGIM (Global Geospatial Information Management Initiative of the United Nations).

A UN High Level Forum meeting took place in Seoul, October 24–26, 2011. The next meeting of UN Committee of Experts took place in New York on August 13–15, 2012. Participants: Nations represented by national mapping and cadastral authorities, international organizations.

Global Geodetic Reference System: Sustainable global geodetic observation and data infrastructure sessions in Seoul and New York.

Upcoming High Level Forum in Doha, Qatar, 2013, Feb 4–6 (H. Kutterer as session keynote speaker).

Reports from the Technique Centres

International DORIS Service (IDS)

Frank Lemoine reported on IDS activities in 2012:

- **Satellite Constellation Status:**
6 active spacecrafts currently in use, 4 future missions are foreseen for 2013 and 2014.
- **Network Status:**
88% of the 57 DORIS stations are operating. The 4th generation beacon development phase is planned for 2014–2015. The deployment is planned to start in 2016.
- **DORIS data and Data Center Status:**
Envisat Data Reissue: Error in ionosphere correction field for early data; Data reissued early May 2012; DORIS time bias has also been corrected.
All DORIS ACs deliver at least quarterly. The IDS has an active combination center in Toulouse, which is also generating the data for the next ITRF.
- **DORIS Ground Antenna RF Characterization:**
The results of a characterization of the phase center offset and variations of DORIS Ground Antennas showed a discrepancy of 17mm in the 2 GHz phase center compared to the manufacturer specification. The impact on DORIS solutions will be analyzed.

- SPOT-5 SAA Data Issues:
Perturbation of the oscillator by high-energy protons (e.g. in SAA) in SPOT-5 and Jason-1.
Solutions:
 - 1) No mitigation (perturbed positions and velocities of these stations – this happened in ITRF2008).
 - 2) Delete data from affected stations (degrade orbits for SPOT-5).
 - 3) Adjust SPOT-5 stations but exclude SPOT-5 SAA stations from weekly combination.
 - 4) Apply correction model as for Jason-1.
- IDS Analysis Summary:
7 active DORIS analysis centers (ESA, GAU, GOP, GSC, IGN, INA, LCA). GFZ has also expressed interest and has attended DORIS AWG meetings; DORIS ACs routinely submit SINEX solutions each quarter (e.g. 3/30, 6/30, 9/30, 12/30) which are now processed by IDS Combination Center by Guilhem Moreaux, CLS Toulouse; Campaigns have been conducted to analyze the contributions of individual satellites and to analyze the EOP contributions of DORIS data.
- ITRF2013 Preparations:
Require all ACs to reprocess data with updated geophysical models; Conduct test combinations over discrete periods for validation; Conducted orbit intercomparison between ACs which revealed each AC had individual modeling problems on at least one satellite.
- Elections to IDS GB:
Analysis Center Representative: Pascal Willis.
Data Center Representative: Carey Noll.
At Large member: Richard Biancale.
- Past meetings:
AWG meetings took place in Prague (June 2012) and Venice (with IDS workshop, September 2012).
- Future IDS meetings:
The next IDS GB meeting: Tuesday December 4, 2012 in San Francisco.
IDS AWG meetings: Toulouse, March–April 2013 (before EGU) and in Washington DC, NASA GSFC in October 2013.

IERS designated Brian Luzum (the new IERS DB chair) as new representative for the IDS Governing Board (as Chopo Ma leaves IERS Chair at the end of 2013).

IDS will start the reprocessing in January and the full times series will be available at the end of the year.

International GNSS Service (IGS)

Steve Fisher reported on IGS activities:

- **IGb08 Release:**
The new IGb08 replaced IGS08 in GPS week 1709 (October 7, 2012). Coordinates were re-estimated at 33 IGS08 stations to account for discontinuities since the IGS08 release, see <<http://igsceb.jpl.nasa.gov/pipermail/igsmail/2012/007853.html>>.
- **Repro2 Project:**
A second IGS reprocessing campaign has been initiated, which will form the basis of the IGS contribution to ITRF2013.
- **Uncalibrated Radome Experiment:**
Thus far 6 of the 21 un-calibrated radomes have been removed for a planned two-month observation phase. Data analysis is in progress. <<https://sites.google.com/a/igs.org/igsnet/infrastructure-committee/radome-experiment-2011>>
- **Site Guidelines:**
IGS Site Guidelines have been revised to add procedures to map discontinuities while introducing new equipment.
- **Real-time project:**
The strategy for an IGS real-time service has been developed with introduction of an initial service targeted by early 2013.
- **M-GEX Project:**
A focused Multi-GNSS experiment was initiated to establish a data set of new GNSS signals, including the new GPS signals, new Russian GLONASS signals, the Japanese QZSS, the Chinese Beidou and the E.U.'s Galileo, for experimentation.
- **Combination Software:**
Revision of the IGS combination software has been initiated by the CODE and ESOC analysis centers and TU Vienna.
- **Strategic Planning:**
The IGS Strategic Plan is being updated with new goals and objectives for the period 2013–2017.
- **Past Meetings and Workshops:**
The IGS organized several meetings and workshops and participated in others: IGS Bias and Calibration Workshop in Bern; RTCM Meetings, Bern and Nashville; GGOS Coordinating Board meeting, Vienna; IGS Real-time Workshop, Frankfurt; IGS Community Workshop, Olsztyn; United Nations International Committee on GNSS, Beijing; ICSU World Data System Scientific Committee, Taiwan; GGOS Strategic Retreat, Frankfurt; IGS Governing Board Meetings, Olsztyn, San Francisco; IGS Business Meeting, Vienna

- Publications:
IGS 2011 Technical Report; IERS 2011 Report; GPS World Article on the IGS Real-time Project; 2008–2012 IGS Progress Report; Community Workshop Proceedings, <<http://igs.org/presents/poland2012/>>

There are currently 440 stations in IGS network; analysis continues to be improved.

International Laser Ranging Service (ILRS)

Erricos Pavlis reported on ILRS activities:

- New data format since May 2012.
- New ILRS website released: <<http://ilrs.gsfc.nasa.gov>>
- Meetings in 2012:
WPLTN Technical Workshop, September 24–28, 2012, St. Petersburg, Russia;
ILRS Technical Workshop in Frascati, Italy, November 5–9, 2012.
- Upcoming meetings:
All-day ILRS AWG meeting on Sunday, April 7, 2013 at TUW;
18th International Workshop on Laser Ranging to be held in Tokyo area, November 11–15, 2013;
All-day AWG meeting on Saturday, November 9, 2013.
- 4 GGOS “Core” sites with SLR planned.
- ILRS AWG:
Operational products (weekly & daily) delivered routinely and on time from all nine ACs:
ASI (AC & CC), BKG, DGFI, ESA, GA, GFZ, GRGS, JCET (AC & CC), & NSGF.
Five AC contributed to ITRS/GGFC PP for testing atmospheric corrections at observation level (using GGFC input data): ASI, GA, GFZ, JCET, NSGF.
- Reprocessing for data from 1983 until now.

International VLBI Service for Geodesy and Astrometry (IVS)

Axel Nothnagel reported on the latest IVS activities:

- A first VLBI School will be held in March 2013 in Helsinki.
- Research and Development sessions (R&D sessions) in mixed mode, VLBI 2010 sessions with legacy antennas, will be initiated in early 2013.
- Continuous 14 days sessions in early 2014 (CONT2014).
- Twin-telescopes will be built in Onsala, Sweden and the inauguration of the Wettzell Twin Telescope will be held on April 26, 2013.

Zuheir Altamimi and Axel Nothnagel agreed to reprocess VLBI data without atmospheric models for the ITRF2013.

ITRS/ITRF <i>Report from ITRS Center</i>	Zuheir Altamimi presented the status: • <i>Preparation for the ITRF2013</i> Planned to be ready in mid 2014. The call for participation is planned for January 2013; solution submission by the Techniques by Jan–Feb 2014. • <i>Analysis of solutions</i> submitted to the joint call of ITRS/GGFC, w/o NT-ATML corrections. Preliminary analysis results have been discussed within the IAG WG JWG1.2 (see presentation for details of the analysis results). Some open analysis and comparisons still have to be done. • <i>Proposal for ITRF2013</i> NT-ATML Solutions at the observation level Z. Altamimi proposed to put a full description of DTRF2008 on the IERS web site to give all information to users and to print the Technical Note without additions. The DB decided that future Technical Notes on ITRF will contain results and comparisons of the solutions of the different ITRS Combination Centers (IGN, DGFI, JPL and future Combination Centers).
<i>JPL Proposal to become ITRS Combination Center</i>	Richard Gross gave a presentation of this proposal. The DB accepted JPL as new ITRS Combination Center. Chopo Ma informed that NRCan will formally withdraw their work for the ITRS Combination Center.
<i>IERS Working Group on on Site Survey and Co-location</i>	Pierguido Sarti gave the following information: • A Workshop on local ties is planned for May 2013. • The IDS representative nomination is still pending.
<i>IERS Working Group on SINEX Format</i>	Daniela Thaller reported on WG activities: • Last meeting took place during EGU in Vienna and the next WG meeting is foreseen during EGU 2013 in Vienna. • Modifications in the SATELLITE/ID block and revision of Appendix II (mathematical background). • Parameterization for EOPs still under discussion. • Next steps: finalize version 2.03, finalize the DISCONTINUITY block and start preparation of a modeling block.
<i>IERS Working Group on Time Series Format</i>	Laurent Soudarin presented the first activities of the WG: • WG has been established in April 2012 by IERS DB. • WG charter and member list are available at <http://www.iers.org/WGSCTSFSF>.

- Objectives:
User friendly format with data and metadata by definition of a common exchange format for coordinate time series for all geodetic techniques (DORIS, GNSS, SLR, VLBI) with all necessary information (data and metadata)
- Next meeting: during AGU 2012 in San Francisco.
- An exchange format is planned to be proposed at EGU in Vienna.

New Action Items:

#55.06 Prepare call for participation in ITRF2013

#55.07 Prepare one page with information and references on DTRF2008 to put on the website with the TN on ITRF2008.

#55.08 Print TN on ITRF2008

**IERS Retreat /
Next IERS DB Meeting**

The IERS Retreat has been rescheduled and is planned to be held in May in Paris.

The next DB meeting is planned to be held after the Retreat.

New Action Item:

#55.09 Arrange next DB meeting.

IERS Annual Report

Bernd Richter informed that the Annual Report 2010 is in preparation at the CB. Some reports are still in preparation by the contributors.

New Action Item:

#55.10 Send reminders for contributions for AR 2010.

**Miscellaneous / New director of the
Central Bureau**

Representative for IDS Governing Board: Brian Luzum will follow Chopo Ma as IERS representative to the IDS Governing Board.

The new director of the Central Bureau will probably be designated for the next IERS DB meeting.

Wolfgang R. Dick, Sabine Bachmann, Bernd Richter

3.2 Central Bureau

General activities

The IERS Central Bureau (CB), hosted and funded by Bundesamt für Kartographie und Geodäsie (BKG), organized and documented the IERS Directing Board (DB) Meetings No. 54, April 22, 2012, at Technical University Vienna, Austria, and No. 55, December 1, 2012, at Westin Hotel, San Francisco, California, USA. Between the meetings the CB coordinated the work of the DB.

The CB participated in organizing the GGFC Workshop, held April 20, 2012, at Vienna, by preparing the web site of this meeting. For a summary see Section 4. The CB represented the IERS in the ICSU World Data System (WDS) and at the following meetings: European Geosciences Union General Assembly, 28th General Assembly of the International Astronomical Union, and AGU 2012 Fall Meeting.

IERS components maintain individually about 10 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, as well as link lists for IERS, Earth rotation in general and related fields. Throughout 2012 the web site was continually updated, several new pages and documents were added. New link lists for VLBI and DORIS were created, other link lists were extensively updated. An extended list of meetings related to the work of the IERS was maintained. The CB maintains also the web pages of the IERS working groups and added several new documents to these pages. A web page for the new IERS Working Group on Site Coordinate Time Series Format was created.

IERS Technical Note No. 37 “Analysis and results of ITRF2008” was published online.

The CB started to edit the IERS Annual Reports 2010 and 2011. Along with the reports of the IERS components, provided by them, the annual reports contain general information on the IERS compiled by the CB. For both reports, the CB provided also summaries of DB meetings and its own reports, as well as a report about the Third GGOS Unified Analysis Workshop.

A report about the activities of the IERS during 2009 to 2012 was compiled for IAU Division I.

During the year 2012, 21 IERS Messages (Nos. 201–221) 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 2012 with valid addresses who subscribed to IERS publications

for e-mail and regular mail distribution. The development of a new system of address management was started in cooperation with a software company. The improved system, which will be related to the Content Management System “Government Site Builder” used for the IERS web site, will allow easier maintenance and will give access for users to register as well as to check and update their data through the IERS web pages.

Questions from IERS users concerning IERS publications and products as well as Earth rotation and reference frames in general were answered or forwarded to other specialists.

A member of the CB continued to work in the Control Body for an ISO Geodetic Register Network, which will contain standardized and proved data on reference systems, and became member of the ISO project “Geodetic references”.

IERS Data and Information System (DIS)

The IERS Data and Information System (IERS DIS) 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 2012 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,
- start of the test phase of a new data management system.

The previous data management system has been in use since 2006. An analysis made in 2010/11 showed that a completely new software system is needed to fulfill future demands. Such a new system was developed during 2012 by a software company in cooperation with the CB. The new system should be easier to handle and be more flexible and expandable for new products. It is also no longer connected with the address management for better data security.

Earth Rotation Information System (ERIS)

ERIS has been executed at BKG since June 2006 as part of the research unit FOR 584 “Earth Rotation and Global Dynamic Processes” supported by the German Research Foundation (DFG). ERIS served as a development and testing platform for new interactive

data access tools as well as an information portal. Furthermore, it was used as an exchange platform within the research unit.

The internet portal <<http://www.erdrotation.de>> developed in the framework of ERIS integrates data, models as well as scientific information and procedures in due consideration of state-of-the-art technology. It is addressed to both experts and the interested public.

The project ERIS ended on 14 March 2012.

Staff in 2012

Dr. Bernd Richter, Director

Sabine Bachmann, scientist

Dr. Wolfgang R. Dick, scientist

Sonja Geist, technician

Carola Helbig, secretary

Michael Lösler, technician

Anja Niederhöfer, scientist (until 14 March 2012)

Sandra Schneider, technician

Wolfgang R. Dick

3.3 Analysis Coordinator

1. Introduction

In this report we outline the activities of the Analysis Coordinator during 2012. The main activities were continued planning for the IERS Retreat to be held in May 2013, activities in the Sub-Commission 1.1 Coordination of Space Geodetic Techniques, and discussions of the future of leap seconds.

2. Planning for the 2013 IERS Retreat

The theme of the retreat will be to focus on maintaining the IERS's core role of the generation of regular, high accuracy products. The aims of the retreat are to establish directions for IERS over next decade that will ensure this core role is met. Initial planning had been to hold the retreat in Vienna in association with the EGU meeting in April. For a variety of logistical reasons this was not possible and now the retreat is planned to held in conjunction with the IERS Workshop on Local Surveys and Co-locations at University Paris-Diderot, Amphitheatre Alan Turing Paris, France, May 21–22, 2013 with the retreat being held May 23–May 25 at the same venue.

2.1 Retreat organization

Retreat will be held over two days during which 7 topics and a summary and recommendations session will be covered. There will be 4 sessions per day with 2 session in the morning and 2 sessions in the afternoon. Each session will 1.5 hours. The sessions will start with a 30-minute presentation that will address the issues associated with each topic. The remaining hour of the session will be discussions and the development of recommendations that will be presented at the board meeting immediately following the retreat. Each session will be organized by two people, one of whom will make the presentation and the other will take notes during the discussions. Both organizers will write the final report and present the recommendations from their session. As the plan for the retreat develops in more detail, some of the lengths of the sessions may be altered to allow more discussion of the most critical topics.

The target of the workshop is to determine what can be done, determine if it is necessary and, if necessary, how do we proceed. The overall theme has to be maintaining the quality and regularity of the IERS' products and to ensure that the service continues to meet the needs of all of its users. The path forward will be developed in detail outside of the retreat. Most likely a set of working groups will be established that will determine how to implement the recommendations of the retreat. These working groups are likely to meet over the next year.

2.2 Sessions

1. *Move towards “real-time” products* (products that support low latency (1-sec) applications of geodetic data; eVLBI incorporation). The theme to be addressed here is the need for low latency high accuracy EOP for the real-time GNSS applications being developed. A current trend in these applications is the use of precise point positioning methods, as opposed to differential positioning, and these PPP methods need to define the terrestrial reference frame through the orbits and clocks on the GNSS satellites. Currently this is a challenging task and this session will examine how to best deploy IERS resources to achieve these aims.

Chaired by Harald Schuh and Jens Wickert

2. *Rigorous combined products* (e.g., services are generating EOP and terrestrial RF simultaneously; IERS is simply averaging EOP values). This topic is considered critical to the future of the IERS and will occupy two sessions because of its great impact potentially on the service. Of importance here is the consideration of inclusion of both the terrestrial (ITRF) and celestial reference frames (ICRF). The discussion here will focus on how to assess the need for rigorous combination, how best to achieve such combinations, and how to determine whether we need to proceed with such techniques. It is possible that different methodologies would be used for different levels of service. The rapid service for example due to speed requirements might retain the current types of combinations while the Bulletin B products might be generated through a rigorous combination. The impact of this type of combination on the ICRF and nutation must be considered. The implementation of a rigorous combination approach also has major impact on the services contributing to the IERS and the path forward will need to establish the impact on the services as well. It will also need to be established how we blend pre-spaced geodesy measurements with the conventional astronomical ones. This session will be allotted two time slots.

Chaired by Zuheir Altamimi and Manuela Seitz

3. *Long-term stability and parameterization of the reference frame*. This session will address how to parameterize the ITRF. With the GGOS aims of defining an ITRF accurate to 1 mm and 0.1 mm per year, serious consideration has to be given to precisely how to define such a system when there are unknown non-secular components to the motions of all of the ITRF sites. The session will outline the steps that need to be taken in understanding how to incorporate such phenomena as earthquake co-seismic and post-seismic deformations, anthropogenic and natural loading phenomena, and other deviations from secular motion. Also to be addressed is how

to approach the appropriate parameterization of variations in the ICRF. Consideration of source structure variation and source evolution needs to be addressed. The impact on the services will need to be assessed.

Chaired by Daniela Thaller and Xavier Collilieux

4. *Next Generation of models and Center-of-Mass products.* How to establish need (improvements needed in diurnal/semi-diurnal EOP, tidal loading)? This session will address the types of model updates that should be included in the IERS conventions, and how to determine the need for these updates. The inclusion of new IERS products such as a center of mass product will also be discussed. Models and new products should also consider the celestial component of the reference systems as well.

Chaired by Richard Gross and Tonie van Dam

5. *EOP prediction improvements.* This session will address the need for EOP prediction accuracy and how best to achieve these accuracies and determine the timescales over which predictions need to be made. The users of these prediction products will also need to be determined and their requirements established.

Chaired by Brian Luzum and Christian Bizouard

6. *Unification of product formats.* This session will cover two broad areas. One will be the unification of the IERS product formats to allow easy comparison and combination. The other area will be establishing modern standards for product formats such as the metadata content and how to express that.

Chaired by Thomas Herring and Laurent Soudarin.

7. *Establish mechanisms that allow changing contributions.* The aim of this session is to provide a mechanism for evolving the IERS as time goes on and needs change. During the last retreat, over a decade ago, new components of the IERS were established. Since then these components have stayed in place and there is no formal mechanism for changing the components of the IERS. This session will look at how best to establish such procedures so that the IERS can evolve more quickly between retreats.

Chaired by Bernd Richter and Chopo Ma

8. *Summary and Recommendations.* The final session will summarize the retreat and develop a set of synthesized recommendations to be passed on to the full board at the IERS board meeting immediately following the retreat. All members of the retreat will be involved in this discussion and the Chair of the IERS and the Director of its Central Bureau will lead it.

Plans are in place for the retreat to held and next year's report will summarize the out come of the retreat.

3. International Association of Geodesy (IAG) Activities

The IERS Analysis Coordinator has been involved in the IAG Sub-Commission SC 1.1 Coordination of Space Techniques. The space geodetic observation techniques, including Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS) such as GPS, GLONASS, GALILEO, and COMPASS, and the DORIS system, as well as altimetry, InSAR, LIDAR, and the gravity missions, contribute significantly to the knowledge about and the understanding of the three major pillars of geodesy: the Earth's geometry (point coordinates and deformation), Earth orientation and rotation, and the gravity field as well as its time variations. These three fields interact in various ways and they all contribute to the description of processes in the Earth System. Each of the space geodetic techniques contributes in a different and unique way to these three pillars and, therefore, their contributions are critical to the Global Geodetic Observing System (GGOS).

Sub-Commission 1.1 coordinates efforts that are common to more than one space geodetic technique, such as models, standards and formats. It shall study combination methods and approaches concerning links between techniques co-located at fundamental sites, links between techniques co-located onboard satellites, common modeling and parameterization standards, and perform analyses from the combination of a single parameter type up to a rigorous combination on the normal equation (or variance-covariance matrices) as well as at the observation level. The list of interesting parameters includes site coordinates (e.g. time series of combined solutions), Earth orientation parameters, satellite orbits (combined orbits from SLR, GPS, DORIS, altimetry), atmospheric refraction (troposphere and ionosphere), gravity field coefficients, geocenter coordinates, and others. One important goal of SC 1.1 will be the development of a much better understanding of the interactions between the parameters describing geometry, Earth rotation, and the gravity field as well as developing methods to validate combination results, e.g., by comparing them with independent geophysical information.

To the extent possible SC 1.1 should also encourage research groups to develop new observation techniques connecting or complementing the existing set of measurements.

Sub-Commission 1.1 has the task to coordinate the activities in the field of the space geodetic techniques in close cooperation with GGOS, all of the IAG Services, and with COSPAR.

3.1 SC 1.1 Objectives

The principal objectives of the scientific work of Sub-Commission 1.1 in collaboration with GGOS are the following:

- Study systematic effects of and between space geodetic techniques.
- Develop common modeling standards and processing strategies.
- Comparison and combination of orbits derived from different space geodetic techniques.
- Explore and develop innovative combination aspects such as, e.g., GPS and VLBI measurements based on the same high-accuracy clock, VLBI observations to GNSS satellites, and the combination of atmospheric information (troposphere and ionosphere) of more than one technique.
- Establish methods to validate the combination results (e.g., with global geophysical fluids data).
- Explore, theoretically and practically, the interactions between the gravity field parameters, EOPs, and reference frames (site coordinates and velocities plus extended models), improve the consistency between these parameter groups, and assess, how a correct combination could be performed.
- Study combination aspects of new geodetic methods such as Synthetic Aperture Radar (InSAR), LIDAR and optical image analysis methods.

Additional objectives of Sub-Commission 1.1 are:

- Promotion of international scientific cooperation.
- Coordination of common efforts of the space geodetic techniques concerning standards and formats (together with the IERS and GGOS).
- Organization of workshops and sessions at meetings to promote research.
- Establish bridges and common activities between SC1.1 and the IAG Services.

3.2 Links to Services

Sub-Commission 1.1 will establish close links to the relevant services for reference frames, namely Global Geodetic Observing System (GGOS), International Earth Rotation and Reference Systems Service (IERS), International GPS Service (IGS), International Laser Ranging Service (ILRS), International VLBI Service for Geodesy and Astrometry (IVS), and International DORIS Service (IDS) and the International gravity services.

3.3 Working Groups

WG 1.1.1: Creation of common geodetic coordinate time series

Chair: Laurant Soudarin (Laurent.Soudarin@cls.fr)

This working group, formed in collaboration with the IERS, will explore methods for creating position time series for the different geodetic techniques so that they can be displayed in a common format and consistent reference frame. The working group will explore, in the format and interfaces for time series. A common tool that can be used to display and compare these results will also be developed. The working group will have a representative from each technique combination center, a representative from the ITRS Center, and from the GGOS portal. There should also be representatives from the geophysics/geodynamics and oceanography communities who are seen as the primary users of this product. The final product of this working group will be recommendations on how the geodetic community should proceed in developing common positional time series and making such results readily available to the broad scientific community.

WG 1.1.2: Investigate methods for merging geodetic imaging systems (InSAR, LIDAR and optical methods) into a geodetic reference system

Chair: Sebastian Le Prince

With the development of new methods for studying surface deformations, such as InSAR, LIDAR and optical methods, this working group will explore the methods that should be used to ensure that these deformation measurements are made in a well-defined geodetic reference frame. Issues to be addressed include how to establish the reference frame for these classes of measurements, how to ensure the long-term stability of the reference frame, and to make recommendations for changes in future systems that would allow more robust reference frame realization.

4. Discussions of the future of Leap Seconds

Brian Luzum has reported the conclusion of the conference on UT1 redefinition. His report has been included in the IERS April 2012 directing board meeting. Participants mainly came from the International Telecommunication Union and its relevant Study Groups and Working Parties and from other international organizations with interests in this subject. The presentations are available at <http://futureofutc.org/program/>.

Wolfgang Dick summarized the consequences of an UT1 redefinition for the IERS:

- The outcome of the official ITU-R vote in January 2012 is not certain. 70% of Yes-votes necessary of attending people on national base. If successful, there would be no more leap seconds after 2019.

- XML format was suggested for the IERS products to make them more user friendly and more compatible with modern software applications.
- It could be possible to continue to publish pseudo-leap-seconds at IERS if the leap seconds were to be abolished. These pseudo-leap-seconds would show how far UTC had drifted from the conventional definition of UT1.
- UTC will continue to be linked to the rotation of the Earth since the difference UT1–UTC will be available at the level of microseconds from IERS.
- IERS needs to make its products better known and understood.

A press release should be prepared to inform the IERS community about the result of the vote. In the case that leap seconds are to be abolished, the IERS should establish an IERS leap second service. At this time the future of leap seconds is unresolved with the status quo of introducing leap seconds to keep UTC with ~0.5 seconds of UT1 will continue. Future international agreements will be needed if the leap seconds are to be eliminated and for UTC to become a continuous time series.

Thomas Herring

3.4 Technique Centres

3.4.1 International GNSS Service (IGS)

International Global Navigation Satellite Service 2012

The International Global Navigation Satellite System Service (IGS) was established in 1994 with a mission to provide the highest quality Global Navigation Satellite System (GNSS) data and products for scientific use. The IGS products, including Earth rotation parameters and global tracking station coordinates and velocities, are provided to IERS as the GNSS technique contribution to the realization of the International Terrestrial Reference Frame (ITRF). IGS activities and developments in 2012 that are of interest to IERS are summarized within this report. The information herein was compiled from the 2012 IGS Technical Report, which includes detailed report sections by the heads of all of the IGS Components and Working Groups. The Technical Report should be consulted for more detailed information regarding the IGS activities in 2012. It is available for download from the publications section of the IGS website <www.IGS.org>.

Summary of Routine Operational Activities

IGS network stations are maintained and operated globally by many institutions, making tracking data available at different latencies from daily RINEX files to real-time streams for free public use. IGS tracking data held by each of the four global Data Centers on permanently accessible servers increased in volume over last year by over 1 Tb (15 million files). Many of these data are redundantly provided through the IGS regional Data Centers. The IGS Analysis Centers and Associate Analysis Centers utilize tracking data from 70 up to more than 350 stations to generate and control the quality of highest-precision products up to four times per day. Product Coordinators combine these products on an operational basis and assure their quality. Nearly 700 IGS final, rapid, ultra-rapid and GLONASS-only product files as well as 140 ionosphere files are made available per week as well as daily troposphere files for more than 300 stations. The interest of users in IGS products is documented by the download statistics that records typically over 150 000 file (25 Gb) downloads per day (CDDIS statistics). The Central Bureau assumes responsibility for day-to-day management of the service, interaction with station operators, and answering to a typical number of 150–200 questions and requests from users per month. All these activities are performed all year and day-by-day, with high redundancy and reliability based on the pooled resources of more than 200 institutions worldwide.

Network Status

The Central Bureau monitors a globally distributed network of 440 select GNSS tracking stations that operate according to the IGS guidelines. In addition to GPS, 196 provide tracking data

from the Russian GLONASS satellites. Approximately 107 IGS stations provide real-time data streams so support the IGS Real Time Pilot Project activities.

Three new stations have been added to the IGS network in 2012, all providing real-time and multi-GNSS observation data:

- BRUX Brussels, Belgium
- KAT1 Katherine, North Territory, Australia
- MGUE Malargue, Argentina

Integration into IGS of the 18 NGA monitoring stations that was initiated last year is still being worked on. Two issues must still be addressed before these stations are useful to the IGS Analysis Centers, requiring this activity to be continued in 2013:

1. Antennas must be calibrated by an IGS certified calibration lab.
2. A firmware induced quarter cycle phase ambiguity must be removed from the previous data sets and fixed in the receiver firmware going forward.

Due to number of reference frame stations retiring from service and position discontinuities, IGB08 was adopted on GPS week 1709 (07 Oct 2012). IGB08 includes 33 stations affected by position discontinuities from IGS08 and 3 new stations co-located with decommissioned IGS08 stations. This update increases the number of usable reference frame stations by about 36 and the number of usable core stations by about 15.

Analysis and Core Product Generation

The IGS core products have continued to be routinely combined and delivered to users in a timely manner through 2012. To ensure continued production of high-quality IGS products, the Analysis Center Coordinator (ACC) performed high-level oversight and quality control of Analysis Center (AC) products, combination performance, and maintenance of the ACC website with updated plots. Also performed was coordination among ACs to assimilate changes made by them and to ensure that the best analysis models and procedures are used, along with coordination among the other relevant IGS components, preparation of component reports, and coordination of the IGS 2nd reprocessing campaign.

Despite a few minor delivery delays caused by power or network outages of the combination server, all of the IGS core products met availability targets (Table 1). The addition of new ACs to the IGS Ultra-rapid and Rapid products has improved product reliability. However, the overall high quality of those two products was unchanged from 2011. Product quality was effected by a number of factors, including 1) introduction of Ultra-rapid products by two

3.4.1 International GNSS Service (IGS)

Table 1: IGS core products and availability targets. Availability is defined as the percentage of time that accuracy, latency and continuity of service meet target specification.

		Sample Interval	Accuracy	Latency	Continuity	Target Availability
GPS Satellite Ephemerides / Satellite and Station Clocks						
Broadcast (for comparison)	Orbits	1s	~100 cm	real time	Continuous	99.99%
	Sat. Clocks		~5 ns RMS; ~2.5 ns Sdev			
Ultra-Rapid (predicted half)	Orbits	15 min	~5 cm	predicted	4x daily, at 03, 09, 15, 21 UTC	95%
	Sat. Clocks		~3 ns RMS; ~1.5 Sdev			
Ultra-Rapid (observed half)	Orbits	15 min	~3 cm	3-9 hours	4x daily, at 03, 09, 15, 21 UTC	95%
	Sat. Clocks		~150 ps RMS; ~50 ps Sdev			
Rapid	Orbits	15 min	~2.5 cm	17-41 hours	daily, at 17 UTC	95%
	Sat. & Stn. Clocks	5 min	~75 ps RMS; ~25 ps Sdev			
Final	Orbits	15 min	~2 cm	12-18 days	weekly, every Thursday	99%
	Sat. & Stn. Clocks	Sat: 30 s; Stn.: 5 min	75 ps RMS; 20 ps Sdev			
Real-time	Orbits	5-60 s	~5 cm	25 seconds	Continuous	95%
	Sat. Clocks	5 s	300 ps RMS; 120 ps Sdev			
GLONASS Satellite Ephemerides						
Final		15 min	~3 cm	12-18 days	weekly, every Thursday	99%
Geocentric Coordinates of IGS Tracking Stations (over 250 Sites)						
Positions of Real-time Stations	Horizontal Vertical	daily	3 mm 6 mm	1-2 hours	daily	99%
Final Positions	Horizontal Vertical	weekly	3 mm 6 mm	11-17 days	weekly, every Wednesday	99%
Final Velocities	Horizontal Vertical	weekly	2 mm/yr 3 mm/yr	11-17 days	weekly, every Wednesday	99%
Earth Rotation Parameters						
Ultra-Rapid (predicted half)	Polar Motion Polar Motion Rate Length-of-day	daily integrations at 00, 06 12, 18 UTC	~200 μas ~300 μas/day ~50 μs	real time	4x daily, at 03, 09, 15, 21 UTC	99%
Ultra-Rapid (observed half)	Polar Motion Polar Motion Rate Length-of-day	daily integrations at 00, 06, 12, 18 UTC	~50 μas ~250 μas/day ~10 μs	3-9 hours	4x daily, at 03, 09, 15, 21 UTC	99%
Rapid	Polar Motion Polar Motion Rate Length-of-day	daily integrations at 12 UTC	~40 μas ~200 μas/day ~10 μs	17-41 hours	daily at 17 UTC	99%
Final	Polar Motion Polar Motion Rate Length-of-day	daily integrations at 12 UTC	0.03 mas ~150 μas/day 0.01 ms	~11-17 days	weekly, every Wednesday	99%
Atmospheric Parameters						
IGS Final Tropospheric Delay: zenith path delay (ZPD) plus north, east gradients		5 min	~4 mm for ZPD	~ 3 weeks	daily	99%
Ionosphere TEC Grid		2 hours; 5 deg (Lon.) x 2.5 deg (Lat.)	2-8 TECU	~11 days	weekly	99%
Rapid ionosphere TEC Grid		2 hours; 5 deg (Lon.) x 2.5 deg (Lat.)	2-9 TECU	<24 hours	daily	95%

Analysis Centers, 2) a switch to daily SINEX combinations, 3) Adoption of IGB08, and 4) Studies of the Rotational Offset between IGU and IGR and of the Final Orbit Misalignment. Details regarding the effects of these factors on the IGS products are described within the Analysis Coordinator Section of the IGS Technical Report.

Second Reprocessing Campaign (IG2)

Preparations for the second reprocessing campaign (IG2) are underway. The past year was spent establishing a set of minimum analysis standards (see items delineated in black on the IG2 web page at <http://acc.igs.org/reprocess2.html>), which was finalized at the 2012 Workshop. Since then, the ACs have worked to implement nearly all of these minimum standards. A few Analysis Centers still need to adopt models for 2nd-order ionosphere effects, Earth radiation (visible and infrared) and satellite thrusting due to signal transmission along the antenna bore site. In addition to the minimum analysis standards, other models are proposed and can be adopted as each AC chooses. These are shown in red at the IG2 website.

Multi-GNSS Experiment

The Multi-GNSS Experiment (MGEX), considered a key project that will enhance IGS capabilities to support the emerging satellite navigation systems, has proceeded with high priority since its launch in February 2012. The focus of this cornerstone experiment is the data flow, the understanding of observables, the characterization of the tracking equipment, and the generation of products. The very successful Workshop on GNSS Biases held in Bern from January 18–19 addressed very significant issues related to the implementation of multi-GNSS within IGS. The launch of a Multi-GNSS Pilot Project is targeted in 2015.

Real-time Service

The real-time Working Group is proceeding toward launch of an Initial Operating Capability (IOC) Real-Time Service (RTS) in the first half 2013. The initial service will provide real-time GPS orbit and clock corrections, as well as experimental GLONASS corrections. Other satellite systems will be included within the service as they become available. The service is focused on supporting geophysical applications, e.g., natural hazards monitoring in the framework of GGOS, but it will support a large variety of applications in positioning, navigation, time transfer, system monitoring and others. More information and an updated status of the service can be found on the RTS website at rts.igs.org.

Formats and Standards

The joint IGS/RTCM RINEX Working Group is preparing a plan for the transition from RINEX 2.11 to RINEX 3.0x over the next few years. While tracking data from GNSS-capable equipment shall

be solely available in RINEX 3 after a target date to be specified, tracking data from legacy receivers will continue to be available in RINEX 2 for the foreseeable future. The IGS GB affirmed the transition to RINEX 3 and the further elaboration of the transition plan.

The Infrastructure Committee has completed a thorough review and revision of the IGS Site Guidelines. The guidelines were publicly reviewed and were approved at the July Governing Board meeting subject to final comments being integrated. In particular, a real-time section is to be added prior to the Guidelines being fully adopted.

Governance

The IGS Governing Board met a total of four times in 2012: April 25 business meeting during the EGU General Assembly in Vienna; July 22 regular meeting and July 22 post workshop meetings associated with the IGS Workshop in Poland; and December 2 regular end-of-year meeting prior to the AGU Fall Meeting in San Francisco. The IGS Executive Committee – consisting of Urs Hugentobler, Chuck Meertens, Ruth Neilan, Chris Rizos, Tim Springer and with regular participation of John Dow and Steve Fisher and of WG Chairs as required – has met ten times in 2012 by teleconference.

None of the current Governing Board member's terms expired in 2012, thus no election took place. The GB membership of Steve Fisher as IGS CB Secretariat was approved by the Board. Given the successful review of the work of the IGS Working Groups and Pilot Projects documented with the very successful IGS Workshop in Olsztyn, the GB extended the terms of those WG and PP Chairs whose terms terminated end of 2012 by another two years. The current Governing Board Members are listed in the organization section of the IGS website.

Strategic Planning

The new IGS Strategic Plan 2013–2016 was developed in 2012 by the IGS CB and EC as an updated version of the current Strategic Plan 2008–2012, defining IGS goals and objectives and including elements that allow for a better monitoring and reporting of progress. At the same time the CB prepared a Progress Report for the period 2008–2012 that records and quantifies, based on the annual implementation plans, the progress made by the IGS in the different fields addressed by the Strategic Plan. The final version of the two documents are available for download from the publications section of the IGS website.

IGS Workshop

The 2012 biennial IGS Workshop was hosted by the University of Warmia and Mazury in Olsztyn, Poland, and was attended by about 230 participants. The scientific program included sessions where a wide range of activities associated with the IGS were

presented and discussed. Session topics included the status and achievements of the IGS Multi-GNSS Experiment; the IGS network infrastructure and real-time activities; modeling of observations and station motions; modeling of atmosphere delays and applications; space vehicle dynamics and attitude; clock modeling and time scale realization; antenna calibration; geodetic applications of IGS products; the relevance of the IGS for the geodetic and wider community. Jointly with the IGS Workshop a meeting of the “Compatibility and Interoperability Working Group” of the United Nations International Committee on GNSS (ICG) took place, which provided an opportunity for interaction and exchange between IGS and representatives from the different GNSS operators (GPS, GLONASS, Galileo and Biedou). A short workshop summary may be found in IGSMAIL #6635. The workshop presentations, posters and recommendations can be found on the IGS website at <<http://www.igs.org/presents/poland2012/>>.

Outreach

The IGS is well represented on the GGOS Coordinating Board. It plays a leadership role in the International Committee on GNSS (ICG), in particular by co-chairing Working Group D on Reference Frames, Timing and Applications, and by participating in the planning for the international GNSS Monitoring and Assessment System (iGMAS). The IGS is also well represented in the International Earth Rotation and Reference Systems Service (IERS) and in IAG Sub-Commission 1.2 on Global Reference Frames, in the RTCM SC104, and others.

IGS has been involved with many outreach activities in 2012. The following list provides a selection of presentations at international meetings and articles in geospatial magazines. In addition the IGS CB together with the RT WG prepared a statement citing the reasons for the IGS involvement in real-time activities. The IGS was also given visibility as session organizers of, or presenters in, IGS-related sessions at conferences such as those of the EGU in Vienna and AGU in San Francisco. Additional IGS related publications, citations and presentations are listed within the IGS bibliography in the publications section of the IGS website.

Presentations at International Meetings

- PPP-RTK Symposium, March 12–13, Frankfurt/Main, U. Hugentobler: “From GPS to GNSS – Challenges and Prospects”.
- FIG Working Week, May 6–10, Rome, R. Neilan: “The IGS in Support of Science and Society – new Roles, New Challenges, New Products”.
- 3rd China Satellite Navigation Conference, May 15–19, Guangzhou, C. Rizos: “The IGS in the Multi-GNSS Era: New Roles, New Products, New Challenges”.

3.4.1 International GNSS Service (IGS)

- Asia Oceania Geoscience Society, August 13–17, C. Rizos and R. Neilan: “New Roles, New Challenges and New Products for the International GNSS Service (IGS)”.
- 3rd Colloquium Galileo Science, August 31–September 2, Copenhagen, R. Weber: “The IGS Multi-GNSS Global Experiment”.
- INTERGEO, October 9–11, Hannover, C. Rizos: “The International GNSS Service (IGS): Supporting the Geospatial Industry”.
- ICG-7, November 5–9, Beijing, C. Rizos: “The IGS: A Multi-GNSS Service”.

Articles

- Caissy, M., L. Agrotis, G. Weber, M. Hernandez-Pajares, U. Hugentobler: “Coming Soon: The IGS Real-Time Service”, GPS World, June 2012.
- Rebischung, P., J. Griffiths, J. Ray, R. Schmid, X. Collilieux, B. Garayt: “IGS08: the IGS realization of ITRF2008”, GPS Solutions, 16(4):483–494.
- Rizos, C.: “GNSS Service Analysis Workshop Held in Poland”, GIM International Magazine, November 2012.
- Weber, R., U. Hugentobler, R. Neilan: “IGS M-GEX – The IGS Multi-GNSS Global Experiment”, Proceedings of the 3rd International Colloquium on Scientific and Fundamental Aspects of the Galileo Program.
- J. Griffiths, J. and J. Ray: Sub-daily Alias and Draconitic Errors in IGS Orbits, GPS Solutions, doi: 10.1007/s10291-012-0289-1, (2012).

Position Statement

- “Why Is IGS Involved in Real-Time GNSS?”
<ftp://igs.org/pub/resource/pubs/IGS_why_in_RT.pdf>

Steven Fisher

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 2012.

Network The network of SLR/LLR stations (Figure 1), 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. The single-shot precision of an average station today is better than 10 mm (for the best stations this number is a few millimeters, Figure 2). The absolute quality of the individual observations is at the 10 mm level, with a significant number of stations doing significantly better. Most of the stations deliver normal points with a precision of 1 mm, a firm requirement for the GGOS-era network as outlined in the GGOS2020 docu-



Fig. 1: The global network of SLR stations (status early 2013).

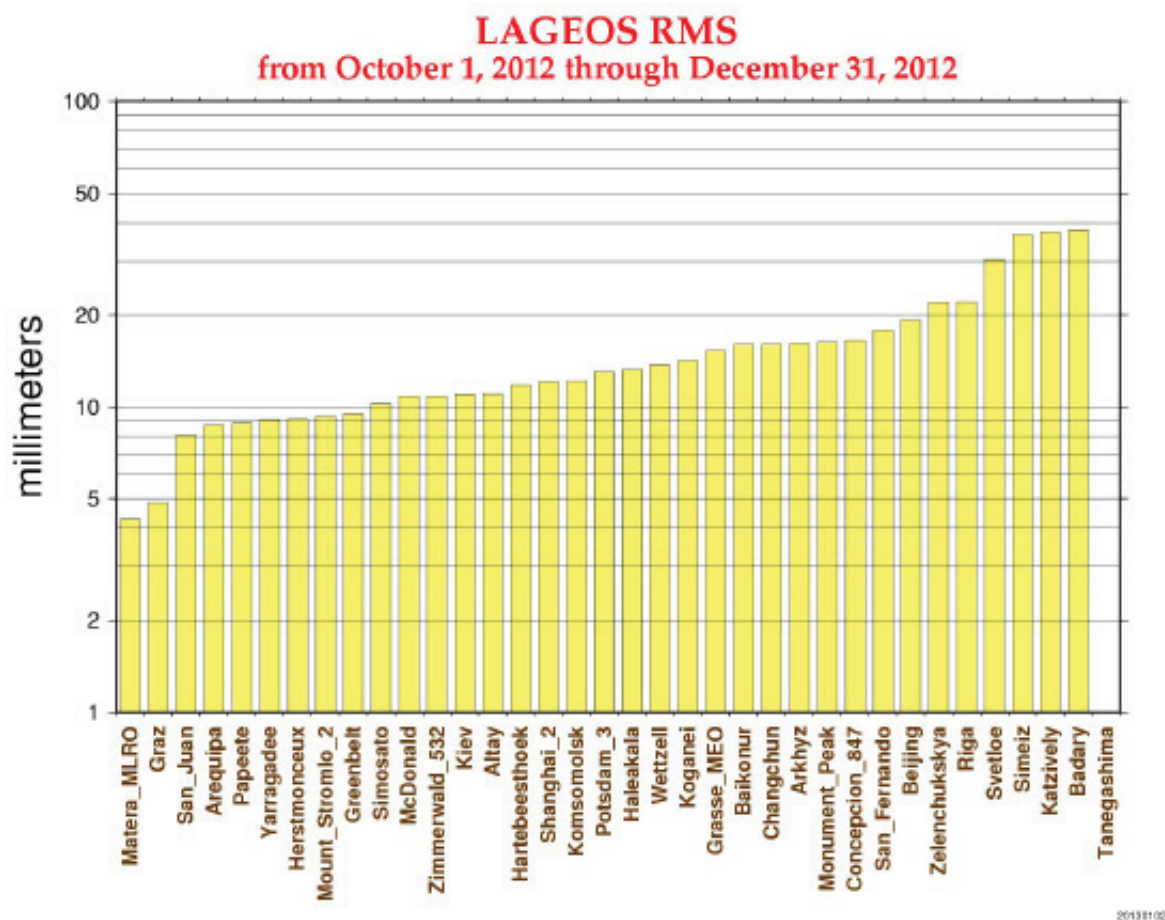


Fig. 2: Performance of the global network of SLR stations on LAGEOS (status end of 2012).

ment and several stations (6) have upgraded to high repetition rate systems to meet such requirements. NASA's next generation SLR system is in the final stages of development, demonstrating successful tracking of LEO to HEO targets at night and in daylight. The switching to high repetition rate systems at a number of sites has increased productivity and improved data quality. This evolution of the network led to the need for a revision of the definition of the way SLR normal points (NP) are constructed. A task force worked on an improved NP definition that increases productivity. The new rule allows for collection of many more data on various targets when automated pass interleaving is exercised. This is achieved by limiting inactivity for high repetition rate systems that meet the NP precision requirement long before they exhaust the time interval that is assigned for the target being tracked. So far a limited number of stations have implemented the new approach. Since the beginning of the year three new Russian sites started contributing data. These sites are located in areas void of coverage up to this time, and they are co-located with VLBI systems that are part of the IVS network for a long time now (Badary, Zelenchuks-

Table 1: ILRS Network Tracking Statistics for 2012.

Site Name	Station	Number of Passes			Total
		Low	LAGEOS	High	
Altay	1879	173	259	630	1,062
Arequipa	7403	3,251	771	0	4,022
Arkhyz	1886	251	116	214	581
Badary	1890	496	213	65	774
Baikonur	1887	169	532	495	1,196
Beijing	7249	845	199	176	1,220
Changchun	7237	5,166	1,053	3,241	9,460
Concepcion	7405	1,763	852	367	2,982
Grasse	7845	885	568	882	2,335
Graz	7839	3,566	1,138	2,704	7,408
Greenbelt	7105	5,262	1,259	1,162	7,683
Haleakala	7119	2,170	1,023	0	3,193
Hartebeesthoek	7501	2,799	1,018	788	4,605
Herstmonceux	7840	3,018	1,056	1,777	5,851
Katzively	1893	1,666	460	340	2,466
Kiev	1824	733	192	43	968
Koganei	7308	425	203	367	995
Komsomolsk-Na-Amure	1868	33	161	420	614
Matera	7941	4,081	2,209	2,703	8,993
McDonald	7080	967	493	254	1,714
Monument Peak	7110	3,196	959	905	5,060
Mount Stromlo	7825	5,873	1,495	667	8,035
Potsdam	7841	2,678	774	313	3,765
Riga	1884	223	12	0	235
San Fernando	7824	2,719	259	7	2,985
San Juan	7406	2,787	1,131	1,385	5,303
Shanghai	7821	892	213	580	1,685
Simeiz	1873	870	381	80	1,331
Simosato	7838	1,069	562	130	1,761
Svetloe	1888	116	115	15	246
Tahiti	7124	506	211	126	843
Tanegashima	7358	125	15	13	153
Wettzell	8834	4,663	1,402	1,626	7,691
Yarragadee	7090	14,602	3,851	8,464	26,917
Zelenchukskaya	1889	177	126	411	714
Zimmerwald	7810	6,451	1,846	4,383	12,680
Totals:	36 stations	84,666	27,127	35,733	147,526

3.4.2 International Laser Ranging Service (ILRS)

kaya, and Svetloe). By late 2012 the three sites were validated according to ILRS procedures and were accepted as operational sites of the ILRS network. This addition will eventually improve tremendously the tie between the SLR- and VLBI-implied frames, and since they all have GNSS receivers, the GNSS frame as well.

Statistics of the data collected as pass segments during the calendar year 2012 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), GPS, GLONASS, ETALON, GIOVE-A/B, GALILEO, and BeiDou satellites, part of the Chinese Navigation Constellation BeiDou (COMPASS).

Of all the active ILRS observatories (~35), very few are technically equipped to track retro-reflector arrays on the surface of the moon or spacecraft orbiting around the moon. The situation did actually improve in 2012, and the active Lunar Laser Ranging (LLR) sites were: the McDonald Observatory in Texas, USA (generating 17 NP), the Observatoire de la Côte d'Azur, France (351 NP), the APOLLO site in New Mexico, USA (201 NP) and the Matera Laser Ranging station in Italy (28 NP). The measurement statistics of 2012 (Figure 3) shows that about one third of the data have been collected at the APOLLO site, almost 60% of the data at the French MeO site near Grasse. Figure 4 illustrates the statistics for the observed reflectors, where – thanks to APOLLO and the upgraded French system – a much better coverage of all reflectors could be achieved than in the previous years. Figure 5 shows the entire LLR data set 1970–2012, indicating the amount of data collected by each of the active LLR sites in each year. It is about 17,700 normal points in total. A steady increase of LLR NP in the last years is obvious.

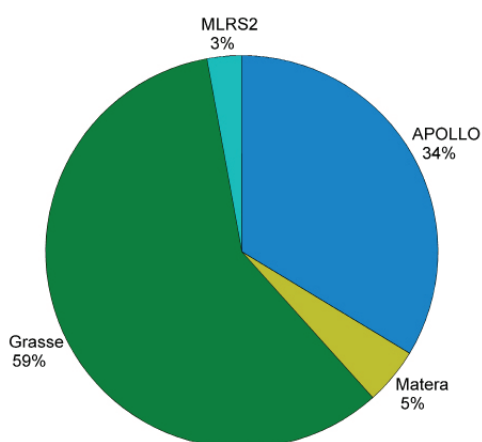


Fig. 3: Observatory statistics in 2012.

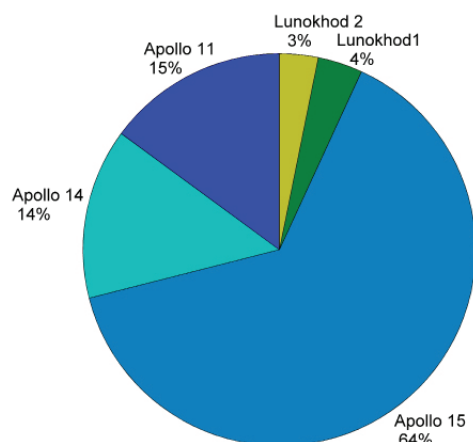


Fig. 4: Reflector statistics in 2012.

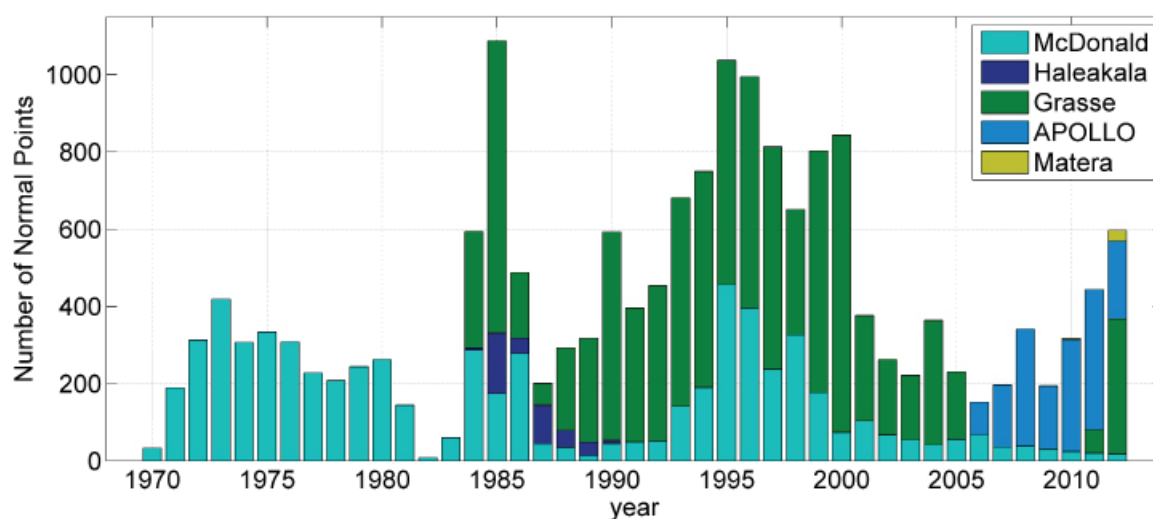


Fig. 5: Data yield of the global LLR network of stations (up to 2012). Note the significant contribution of Grasse's MeO system upon its return to operations.

LLR data analysis is mainly carried out by four major LLR analysis centers: Jet Propulsion Laboratory (JPL), Pasadena, USA; Center for Astrophysics (CfA), Cambridge, USA; Paris Observatory Lunar Analysis Center (POLAC), Paris, France; Institute of Geodesy (IfE), University of Hannover, Germany.

One general objective is to achieve the mm level of accuracy for LLR data analysis (e.g. Müller et al. 2012b). The four analysis centers have started a comparison initiative to mutually improve the various codes.

LLR remains one of the best tools to test General Relativity in the solar system. It allows for constraining gravitational physics parameters related to the strong equivalence principle, geodetic precession, preferred-frame effects, or the time variability of the gravitational constant, cf. Müller et al. (2012a), Murphy et al. (2012), Williams et al. (2012).

In 2012, the International Space Science Institute (ISSI) workshop series on "Theory and model for the new generation of the Lunar Laser Ranging data" has been finalized with a short spring meeting in Berne, Switzerland.

Missions

In 2012, a total of ~34 satellites (including the Moon) were being tracked by laser (Figure 6). 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. There were four successful launches in 2012, of satellites carrying LRAs, listed in Table 2, and three missions which were launched in previous years, initiated SLR tracking in 2012. The first two satellites are GLONASS spacecraft launched in 2011, which were tracked by ILRS for the first time in 2012. The next mission, LARES, is an

3.4.2 International Laser Ranging Service (ILRS)

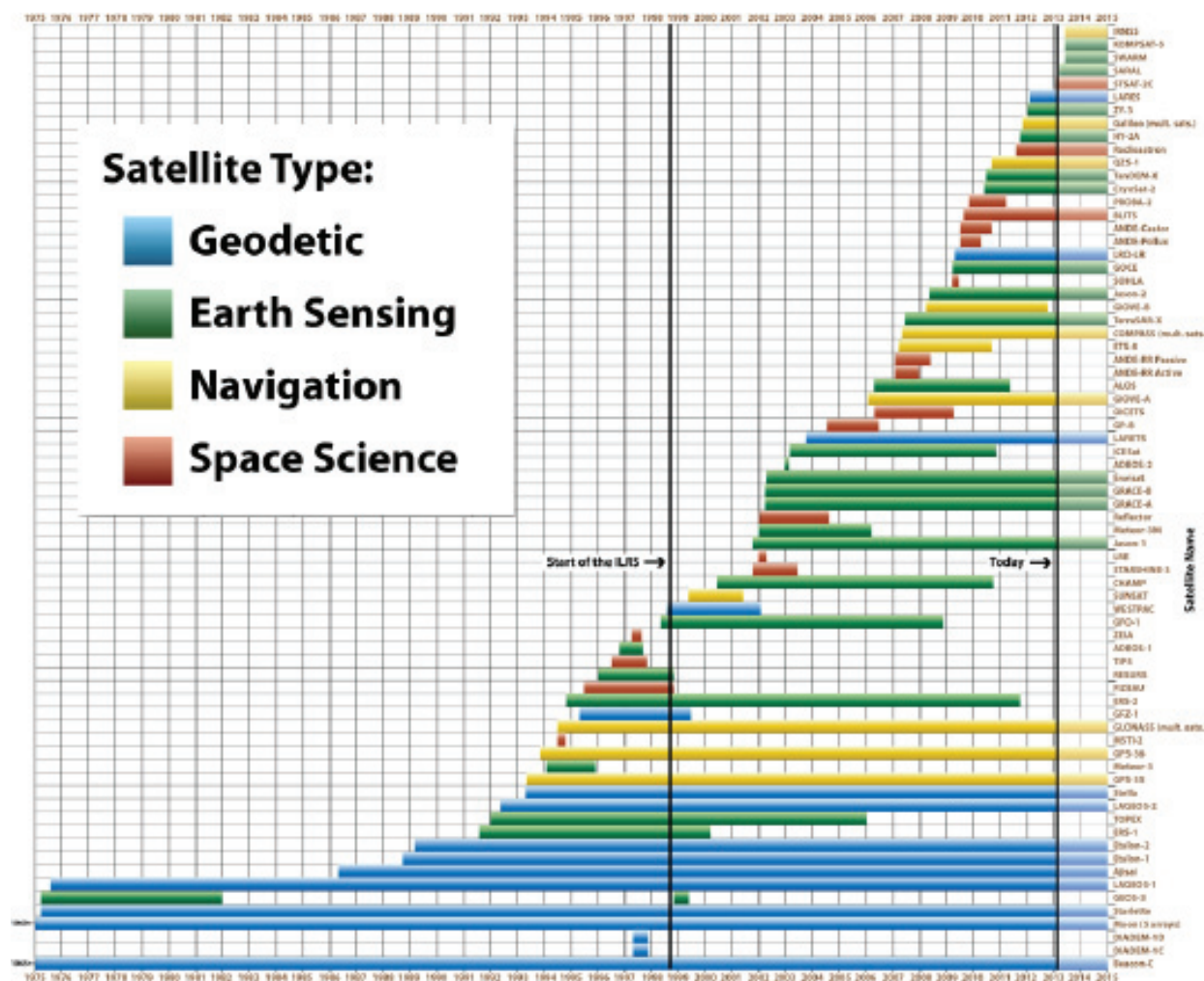


Fig. 6: The currently tracked SLR missions (status early 2013).

ASI mission, designed at the Univ. of Rome “La Sapienza” and launched on ESA’s VEGA rocket, in its maiden, demonstration launch from Kourou, French Guiana. LARES is a cannonball satellite similar to LAGEOS in design, however, it is made of a single piece of Tungsten alloy so that despite its smaller size (~36 cm diameter compared to 60 cm for LAGEOS), it has almost three times a smaller area-to-mass ratio, making it a perfect test particle even if in a lower than LAGEOS’ orbit. The following three s/c, COMPASS-I3, COMPASS-G1, and COMPASS-I5, are part of the BeiDou/COMPASS Constellation, launched in prior years by China, however, tracking was requested only in 2012. COMPASS-M3 is another member of the BeiDou/COMPASS Constellation that was launched in 2012 and was tracked by the ILRS network since mid-2012. The last two satellites which were launched in 2012, are the second two of four operational satellites designed to validate the Galileo concept in both space and on Earth. This In-Orbit Validation (IOV) phase will be followed by additional

satellite launches to reach Initial Operational Capability (IOC) by mid-decade.

During 2012 the ILRS ceased tracking COMPASS-M1, there were no other missions that were removed from the list of active missions and no missions were de-orbited over 2012.

Although the ILRS network has lost a number of stations since an all-time high in 2000 (red line in Figure 7), the productivity of

Table 2: ILRS Supported Missions Launched or Initiating Tracking in 2012.

Satellite Name	Satellite ID	SIC Code	NORAD Number	NP Indicator	Bin Size (sec)	Altitude (Km)	Inclination (deg)	First Data Date
GLONASS-129	1106402	9129	37868	9	300	19,140	65	02-Jan-12
GLONASS-130	1107101	9130	37938	9	300	19,140	65	01-Jan-12
LADES	1200601	5987	38077	5	30	1,450	69.5	17-Feb-12
COMPASS-I3	1101301	2003	37384	9	300	42,161	55.5	27-Apr-12
COMPASS-G1	1000101	2002	36287	9	300	42,164	55.5	28-Apr-12
COMPASS-I5	1107301	2005	37948	9	300	42,161	55.5	6-Jul-12
COMPASS-M3	1201801	2004	38250	9	300	21,528	55	11-Jul-12
Galileo-103	1205501	7103	38857	9	300	23,220	56	7-Nov-12
Galileo-104	1205502	7104	38858	9	300	23,220	56	7-Nov-12

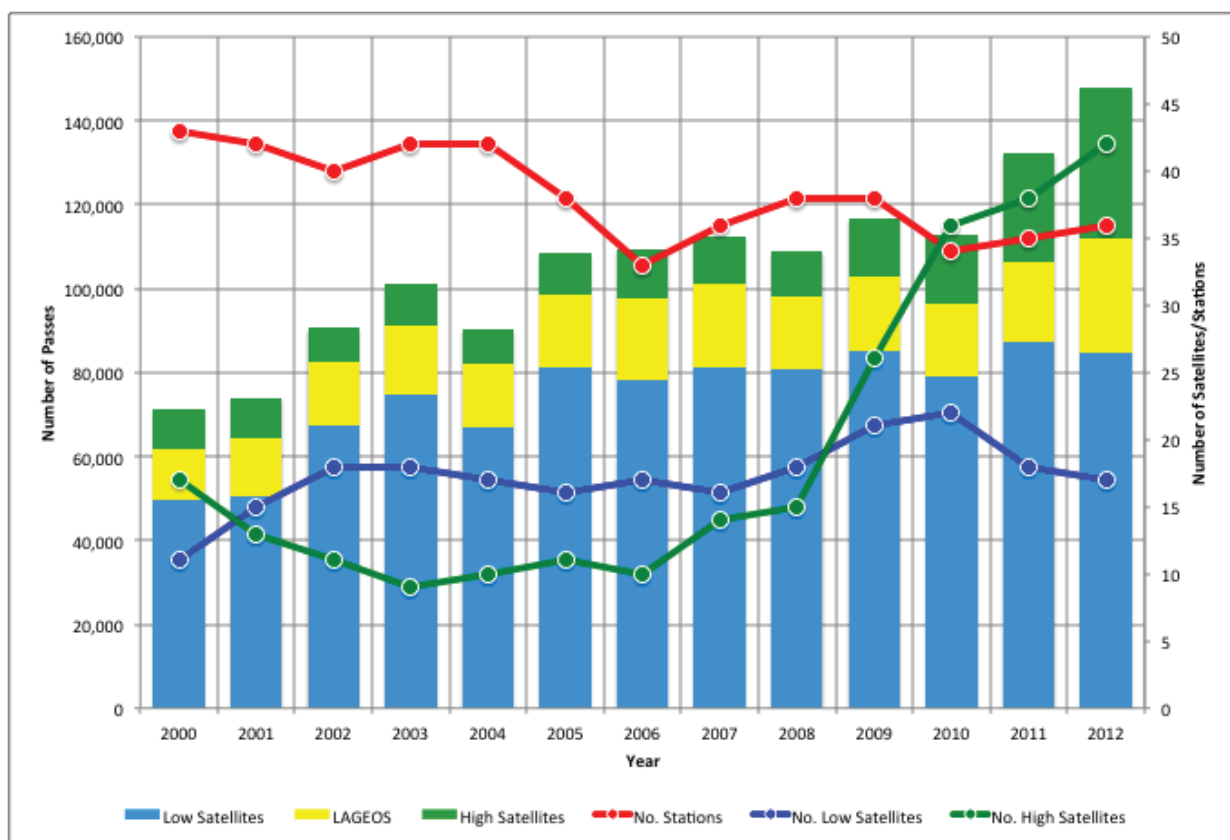


Fig. 7: ILRS network data yield over the past decade (status late 2012).

3.4.2 International Laser Ranging Service (ILRS)

the remaining sites has increased tremendously to not only make up for that loss but rather double the data yield by 2012 (Figure 7). A major contributor in the recent years' data yield increase is the fact that several stations have started tracking all GLONASS satellites as of 2010. This resulted in tripling the number of HEO satellites tracked between 2008 and 2012 (note the green line in the graph of Figure 7). This demonstrates the ability of the current network to deal with such increases in the demand for tracking HEO orbits and indicates that with the expected system upgrades for the realization of the GGOS-era network, we should be in very good shape to deal with increasing demand for mission support.

The ILRS implemented the new data format (CRD) on May 1, 2012, after a long delay since the initial attempt at the end of 2010 beginning of 2011 due to Data Center issues that had to be resolved prior to this format switch. The delay was however quite beneficial for the ILRS, as the two DC emerged from this process as nearly mirror images of each other. This ensures in the future that users will find the same data at either DC at any time. As part of this improvement in data handling, EDC implemented also a very helpful website for visualization of metadata from their data base.

Another significant improvement of the ILRS resources is the accelerated development of a new website for the Service, a project that was under the aegis of the ILRS CB. The new website became operational in late 2012, during the Frascati workshop. There are several sections of the website which are still being improved and the entire website is maintained current through the efforts of the CB and the ILRS associates' comments and suggestions.

Analysis and science

The Analysis Working Group (AWG), in an effort to accommodate the Pilot Project of the IERS/ITRS and the GGFC on "Non-tidal atmospheric loading corrections" at observation level, postponed its own similar PP and tried to provide GGFC with as many submissions from our ACs as it was possible in the tight timeline that was agreed during the 2011 UAW meeting in Zurich. For this GGFC PP the input data were requested to be the ones provided by GGFC, something that not all ACs were ready to make use of due to formatting and other issues. In the end, six ACs were able to participate in the first step, with more providing results at a much later stage. Initial examination of these submissions indicated that there was a varied success in the implementation of the corrections and left several questions unanswered. It was agreed to re-examine the submissions and compile a report to be presented and discussed during the coming year (EGU).

In regards to modeling improvement in SLR data analysis, the newly released target signature model of Appleby and Otsubo, a time dependent version of their original "center-of-mass" (CoM)

offset correction for the LAGEOS and ETALON satellites, was put under test by all ACs. The newly proposed CoM model was to be validated by the end of the year and the AWG to determine the level of improvement in the final product from its implementation. Due to the slow response of several ACs, the results of these tests will likely be available not earlier than spring of 2013. The AWG will then adopt the new model and proceed with the execution of a number of Pilot Projects for testing new products such as orbital files, low degree harmonics, station-dependent systematics monitoring, inclusion of new targets in the analysis, e.g. LARES, Starlette, etc.

It is hoped that these PP will be completed in time to benefit the reprocessing effort of the entire data set from 1983 to present, in support of the development process of the next ITRF realization, ITRF2013. Based on the latest ITRS draft CfP, the Services who will participate in ITRF2013 should have their contributions ready by early 2014.

Meetings

The ILRS held an international technical workshop in Frascati, Italy, November 5–9, with the title “Satellite, Lunar and Planetary Laser Ranging: characterizing the space segment”, (ITLW-12). The Western Pacific Laser Tracking Network (WPLTN) held a Technical Workshop, “One-way and two-way SLR for GNSS co-located with RF techniques” (WPLTN-2012), on September 24–28, 2012, at St. Petersburg, Russia. The AWG held two meetings in 2012, one prior to the EGU General Assembly, on April 21, and one prior to the Frascati workshop, on November 3. Other meetings of direct interest to ILRS were the final meeting of the ISSI-sponsored study group “Theory and Model for the New Generation of the Lunar Laser Ranging Data”, in Bern Switzerland, March 22–23, 2012, and the “Second International LARES Science Workshop” in Rome, Italy, September 17–19, 2012. The ILRS Governing Board met twice during 2012, once during the EGU General Assembly, and a second time during the Frascati workshop. In 2012 the ILRS released its newly designed website, on the occasion of the Frascati workshop. Everyone was encouraged to visit the site and submit comments and suggestions to the ILRS CB and/or the relevant Working Groups.

Publications

Biskupek, L., Müller, J., Hofmann, F.: Determination of nutation coefficients from Lunar Laser Ranging. In: *Geodesy for Planet Earth*, eds. Kenyon, S., Pacino, M.C. and Marti, U., IAG Symposia Series, Vol. 136, Springer, p. 521–526, 2012.

Müller, J., Hofmann, F., Biskupek, L.: Testing various facets of the equivalence principle using Lunar Laser Ranging. *Classical and quantum gravity*, Vol. 29, 184006 (9pp), 2012a, doi:10.1088/0264-9381/29/18/184006

3.4.2 International Laser Ranging Service (ILRS)

Müller, J., Hofmann, F., Fang, X., Biskupek, L.: Lunar Laser Ranging – recent activities at Institut für Erdmessung (IfE). Proceedings of the 17th International Workshop on Laser Ranging, May 16–30, 2011, Bad Kötzting, Germany, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Vol. 48, p. 227–231, 2012b.

Murphy, T., Adelberger, E., Battat, J., Hoyle, C., Johnson, N., McMillan, R., Stubbs, C., Swanson, H.: APOLLO: millimeter lunar laser ranging. Classical and quantum gravity, Vol. 29, 184005 (11pp), 2012, doi: 10.1088/0264-9381/29/18/184005

Williams, J.G., Turyshev, S., Boggs, D.: Lunar Laser Ranging Tests of the Equivalence Principle. Classical and quantum gravity, Vol. 29, 184004 (13pp), 2012, doi: 10.1088/0264-9381/29/18/184004

Additionally, an extensive publications list of interest to ILRS can be found at the ILRS website:

<<http://ilrs.gsfc.nasa.gov/about/reports/biblio/bibliography.2012.html>>

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3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2012, 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:

- The VLBI2010 Workshop on Technical Specifications (Tec-Spec) was held on March 1–2, 2012 in Bad Kötzting, Germany.
- During March 4–9, 2012, the 7th IVS General meeting was held at the Royal Observatory of Madrid, Spain.
- The 13th IVS Analysis Workshop was held in Madrid (Spain) on March 8, 2012.
- The spring 2012 IVS Directing Board meeting (IVS DB #27) was held on March 9 in Madrid (Spain).
- The fall 2012 IVS Directing Board meeting (IVS DB #28) was held on October 20, 2012, at MIT Haystack Observatory, Westford, MA, USA.
- The 1st International VLBI Technology Workshop was held on October 22–24, 2012, at MIT Haystack Observatory, Westford, MA, USA.
- In the summer of 2012 the IVS published the 2011 Annual Report. Furthermore, three IVS newsletters were published in April, August and December to keep the community informed about IVS activities.

Network Stations

The IVS network operated well for most of 2012. The average single station data loss (scheduled versus correlated) is estimated to have been at the 10% level for stations that participated in 20 or more sessions; this loss number is similar to the ones for previous years. It should be noted that this number not only includes lost observing time due to interrupted or missed operations at the station, but it also factors in lost recording bits because of warm receivers or poor pointing that are subsequently converted into lost observing time (e.g., recordings with a warm receiver result in a two-third loss of the nominal observing time). In the analysis stage additional data may be edited out following quality-control criteria established at the analysis centers.

A total of 170 geodetic/astrometric 24-hour sessions were observed during the year 2012. The number of observing sessions coordinated by IVS was about ~3.3 days per week, similar to previous years. The major observing programs during 2012 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.

3.4.3 International VLBI Service (IVS)

- Intensive** 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). Kokee replaced Tsukuba in the Int2 Intensives from the end of February to mid-April during the repair of the support pillars of the sub-reflector at Tsukuba.
- IVS-T2** Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with on average 17.5 stations per session. Seven of these sessions were observed 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. Sixteen sessions were observed for the maintenance of the ICRF in 2012.
- 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 2012.
- IVS-OHIG** The purpose of the IVS-OHIG (Southern Terrestrial Reference Frame) sessions is to tie together optimally the sites in the southern hemisphere. In 2012 six OHIG sessions were observed.
- APSG** The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2012.
- AUSTRAL** In 2012 four Austral sessions were observed. The purpose is to determine the station coordinates and their evolution in the Australia (AuScope) and New Zealand geodetic VLBI network.
- JADE** The Japanese Dynamic Earth observation by VLBI (JADE) had eight sessions during 2012. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

IVS-R&D Ten research and development sessions were observed in 2012. The goal of the 2012 R&D sessions was to determine the best choice for the minimum-angular-distance-to-the-sun scheduling parameter and to test the scheduling software VIE_SCHED in an operational setting.

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 majority of the 24 hour sessions were processed by the Bonn and Washington correlators. The Bonn correlator used the DiFX software correlator and processed, e.g., the R1, EURO, T2, Int3, and OHIG sessions. The Washington correlator still used the Mark IV hardware correlator and processed, e.g., the R4, Int1, and CRF sessions. The Haystack correlator processed RD sessions and some T2 sessions. The Int2 and JADE sessions were processed at the Tsukuba correlator.

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

Since October 1, 2009, the operational combination has been carried out by the IVS Combination Center at the German Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt a.M. The input to these combinations is datum-free (constraint-free) normal equation systems in SINEX format (Solution INdependent EXchange format) containing elements for radio source positions, Earth orientation parameters, and radio telescope coordinates.

The 13th IVS Analysis Workshop was held at the Royal Observatory of Madrid, Spain, on March 8, 2012, in connection with the 7th IVS General Meeting. In this workshop, the coordination of IVS routine data analysis was discussed as well as a number of individual items concerning geodetic and astrometric data analysis in the framework of the IVS. Due to personnel limitations at some of the analysis centers, the progress in improving the analysis software packages was slow. This is important for the necessary changes following the IERS Conventions 2010 in particular.

Concerning atmospheric gradient modeling, a decision was made by the attendees that the Chen and Herring (1997) model

should be the conventional model of the IVS, using the constant $C = 0.0031$ for estimating the hydrostatic gradient. Since the hydrostatic contribution is the biggest one and the coefficient for the total gradient contribution is only slightly different ($C = 0.0032$), no noticeable effect on the estimates is expected. The MacMillan (1995) model produces essentially the same results, but for consistency with the analyses of the IGS, the Chen and Herring (1997) model was adopted.

An unsolved problem is the issue of the sidelobe ambiguities resulting from loss of channels, e.g., due to radio frequency interference (RFI). For certain stations and sessions, this causes a loss of many observations. The only way to overcome this problem is by re-fringing the correlator output with a narrow search window (± 10 ns).

Technology Development

The annual international e-VLBI workshop, the 10th of which was convened in 2011 in South Africa, was expanded in 2012 to include a broader scope of technical VLBI developments and was renamed 1st International VLBI Technology Workshop. It was held at Haystack Observatory 22–24 October 2012 and attended by 68 participants from 17 countries. The three-day workshop included sessions on antennas, receivers, digital backends, phase-calibration, recording, and e-VLBI, as well as some recent VLBI science achievements, and it was judged to be highly successful by all. The program and presentations from the workshop are available on-line at

<<http://www.haystack.mit.edu/workshop/ivtw/program.html>>.

The 2nd International VLBI Digital-Backend Intercomparison Workshop was held at Haystack Observatory immediately following the VLBI technical workshop. Participants from China, Europe, Japan, and the U.S. spent two days preparing equipment, recording wide-bandwidth correlated noise, and processing through the Haystack DiFX correlator to test the proper operation and intercompatibility of all the units under test.

At the end of 2012, IVS Technology Coordinator Alan Whitney stepped down from his position because of his retirement from MIT. He will be succeeded by Bill Petrachenko from Natural Resources Canada as the new IVS Technology Coordinator in 2013.

The Mark 6 VLBI data system is entering service at 8 Gbps. Several successful experiments have been conducted, and the system continues to be made more robust. Routine service at 8 Gbps is expected in the first half of 2013, with expansion to 16 Gbps by the end of 2013.

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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). In a first step, we will present the current status of the DORIS system (available satellites and tracking network). In a second step, we will present the activities of the IDS Central Bureau (IDS Web site management and DORIS-related email distributions). We will 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

1.1 DORIS satellites

During this report period (2012), the number of DORIS satellites has decreased to six (see Table 1).

Just one week after celebrating its tenth year in orbit, communication with the Envisat satellite was suddenly lost on April 8, 2012. The end of the Envisat satellite operations was declared on May.

Note that in 2012, the CNES-NASA Joint Steering Group directed the Jason-1 Project to move the satellite to a geodetic orbit. Jason-1 maneuver operations were started on April 23rd, and the first operations to lower the orbit were performed on April 25th. The mission was resumed on May 7.

In the near future, several new DORIS satellites are already planned (and approved): SARAL/Altika, Sentinel-3A, Jason-3 ... This should increase or at least stabilize the number of DORIS satellites in the 2013–2016 time period.

1.2 DORIS network

DORIS network still provided this year a reliable service with annual network availability mean of 89 % of operating stations. This performance is the result of the joint effort of CNES, IGN and all host agencies.

Main events of the year: Futuna and Tristan da Cunha stations back to operation after more than three years of inactivity; Mahé

Table 1: DORIS data available at IDS Data Centers. As of December 2012

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	08-APR-12	Altimetry, Environment
Jason-2	12-JUL-08	–	Altimetry
Cryosat-2	30-MAY-10	–	Altimetry
HY-2A	1-OCT-11	–	Altimetry

Table 2: Composition of the IDS Governing Board (from January 2013)

Name	Institution	Country	Mandate
Richard Biancale	CNES	France	Member at large
Pascale Ferrage	CNES	France	System representative
Frank Lemoine	GSFC	USA	Analysis Coordinator
Brian Luzum	USNO	USA	IERS representative
Guilhem Moreaux	CLS	France	Combination Center representative
Carey Noll	GSFC	USA	Data flow Coordinator
Michiel Otten	ESOC	Germany	IAG representative
John Ries	U. Texas/CSR	USA	Member at large
Jérôme Saunier	IGN	France	Network representative
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 (CB) maintains the IDS web (<<http://ids-doris.org>>) and ftp (<<ftp://ftp.ids-doris.org/pub/ids>>) sites. The main updates of 2012 are reported hereafter.

- In February, a new set of tools, we called Plot tools, has been implemented on the IDS website to interactively build and display graphs of DORIS station coordinates time series and orbit residuals (see Section 3.3)
- The presentations of the AWG meeting held on May 31 & June 1, 2012, in Prague, Czech Republic, were put on line on a dedicated page (<<http://ids-doris.org/report/meeting-presentations/ids-awg-05-2012.html>>).
- The presentations of the IDS Workshop and of the AWG meeting held in Venice on September 2012 have been made available (<<http://ids-doris.org/report/meeting-presentations/ids-workshop-2012.html>>)
- Several activity reports were added (IDS Activity report for 2011, 2010 and 2011 Reports for IERS) as well as the minutes of the IDS GB meetings held in 2012 (<<http://ids-doris.org/report/governing-board.html>>).
- The list of the peer-reviewed publications related to DORIS has been enriched with 6 new references of articles published in 2012 (<<http://ids-doris.org/report/publications/peer-reviewed-journals.html#2012>>). With the exception of a few number of articles, they can be accessed directly or with their DOI link.
- A new version of the site logs has been provided by IGN, with coordinates expressed in ITRF2008. They can be seen on the IDS website (<<http://ids-doris.org/network/sitelogs.html>>).

New documents and files were put on the IDS ftp site, in particular a new version of the document describing the DORIS satellite models implemented in CNES POE processing. It includes HY-2A. (<ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf>)

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/emails.html>.

3.3 Plot tools

The CB implemented on the IDS web site new plot tools to provide time series browsing in an interactively way (<http://ids-doris.org/plot-tools.html>).

This family of tools named Plot tools is composed of:

- STCD tool for station position time series (North, East, Up residuals).
- POE tool for CNES/POE statistics time series (satellite orbit residuals, amount of station measurements).

STCD tool and POE tool contain utilities for selecting sites or satellites, displaying time series, editing data, changing plot appearance, specifying scaling, downloading data, plots and graph statistics in several formats. They are equipped with statistic tools for the calculation of mean, slope and weighted rms with respect to the slope (WRSD). Several series can be viewed and compared on the same graph. Complementary data about station and satellites events can also be displayed. A help online is available for both tools.

Station coordinates time series are generated from the STCD files provided by IDS Analysis Centers and available on the IDS Data Centers. STCD format description can be seen at:

http://ids-doris.org/documents/report/CB_STCD_format_v1.0.pdf.

Orbit performance time series are outputs of the CNES POE processing for the DORIS missions.

Satellite events are extracted from the list of the main events that occurred on the DORIS system elements with the exception of the station network.

Station events are extracted from the list of the main events that occurred on the DORIS station network (new sites, new antennae, removed sites, failures ...) with information on data gaps, invalidated data ...

Information about recent earthquakes are also obtained from USGS survey service and added to the station events data available for the Plot tools.

3.4.4 International DORIS Service (IDS)

Fig. 2: Example of a position time series displayed with STCDtool: evolution of the North component of the DORIS station in Santiago with discontinuity due to the 2010 Chile Earthquake.



4 IDS Data Centers

The IDS data flow organization remains the same. 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.).

The main events of the year are listed hereafter:

- Data from HY-2A launched in 2011 are now archived in the IDS Data Centers, in data format 2.1 and in RINEX version 3.0 (phase data), as it is the case for the DGXX receivers on Jason-2 and Cryosat-2.
- Taking advantage of the recent GDR-C and GDR-D orbit reprocessing campaigns, CNES POD team redelivered the Envisat measurements to the IDS. This redelivery concerns arcs 001-255 (as since arc 256 the ionospheric field is corrected) and arcs 901-907, 910 (measurements available prior to arc 001, never delivered before).
- In the fall of 2012, the IDS Analysis Working Group requested a test data set where data from stations in the South Atlantic Anomaly (SSA) were reprocessed by applying corrective models. Data from 2011 in DORIS V2.2 format from the Jason-1 satellite (cycles 331 through 368) were submitted to the IDS data centers in late 2012; a set of 2011 SPOT-5 data (cycles 322 through 358) will be provided in early 2013. These files were submitted to the IDS data centers and archived in dedicated directories.

- A solution (designated “ids”) produced by the IDS combination center from the individual IDS AC solutions started production in 2012.

5 IDS Analysis Centers

All seven analysis centers that participated in ITRF2008 continue to remain active, participating in the IDS activities, with a very important commitment in the Analysis Working Group (AWG).

The IDS held AWG meetings in Prague (Czech Republic, May 31–June 1, 2012), and in Venice (Italy, September 26, 2012). The meeting in Prague was hosted by the Czech Office for Surveying, Mapping, and Cadastre (COSMC), while the AWG meeting in Venice took place at the conclusion of the bi-annual DORIS workshop which was associated with the NASA ESA conference on satellite altimetry. At both meetings, the overarching concern was the planning for the data reprocessing to take place for the next ITRF. It is anticipated that the IERS will release a call for submissions in early 2013, with submission of the final SINEX files by the technique centers in early 2014. This would require the IDS ACs to finish their reprocessing of most of the 20-years of DORIS data by the end of 2013. Therefore, the decision on the models to use and what improvements to make in the modeling standards and analysis procedures were constant themes in both meetings.

The Prague AWG included 15 participants from the CNES, GFZ, GOP, GSFC, IGN, IPGP, LCA and the University of Luxembourg. The primary issues discussed included:

- (1) A review of the first orbit determination results with HY-2A;
- (2) A report on the ground calibration of the Starec DORIS antennae;
- (3) Updates on the SAA models for SPOT-5 and Jason-1;
- (4) A presentation of the results of a comparison campaign between the analysis centers for orbits and the values of the empirical accelerations;
- (5) A review of the effect of atmospheric loading and its impact on geodetic data, and a discussion of a call to DORIS ana-

Table 3: List of IDS Analysis Centers routinely participating in the analysis activities in 2012.

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	GINSD/DYNAMO

lysis centers to participate in an IERS analysis campaign to apply atmospheric loading at the observation level.

At both AWG meetings, updates were presented on the ground antenna calibration of the Starec antenna. The reports, presented by Cédric Tourain (CNES) showed that based on actual measurements of multiple Starec antennae in an anechoic chamber, the actual 2 GHz phase center differed from the phase center stipulated in the documentation by 17 mm. In addition the phase law – or phase variation vs. elevation was measured and also compared with manufacturer specifications. All previous DORIS analyses have used the old specification of the phase center and have not applied a phase law. The implications of this drastic change are unclear – and it seems that testing is required by the DORIS analysis centers. Although the DORIS scale did not contribute to the ITRF2008, a discrepancy of 17 mm (~3ppb) was not observed between DORIS and the other geodetic techniques.

6 IDS Combination

IDS combination activities in 2012 were devoted to i) the pursuit of the IDS combination and the improvement of the operational chain, ii) preliminary studies for ITRF2013, and iii) the analysis of first series including HY-2A.

6.1 Routine combination

The main evolution in 2012 of both the evaluation and combination chains concerns the inclusion of EOPs. Therefore, every three months, in addition to stations positions, IDS Combination Center evaluates single EOPs series from Analysis Centers (X and Y pole as well as LOD). EOPs are evaluated with respect to 2 criteria: a) differences between DORIS EOPs and IERS C04 series and b) in terms of EOPs formal errors.

The last quarter of 2012 was also devoted to the elaboration of a stacking chain to produce mean station positions and velocities over a time period. Some validation tests still remain, especially to check that internal ties are correctly handled.

6.2 Preliminary studies for ITRF2013

In preparation to the next ITRF (2013), the most complete time series provided by each Analysis Center were evaluated. The objectives of this exercise were to functionally test the new evaluation and combination chains with data before 2008, to size memory and CPU for ITRF2013 and to give first feedbacks to all the Analysis Centers.

Analysis of DORIS stations positions time series from IDS combined solution over time period 2000–2012 has revealed discontinuities not linked with geophysical phenomenon, but correlated with beacons frequency shifts. Indeed, some DORIS Analysis Centers did not handle properly the frequency offsets between the actual frequency of the transmitted signal at 2GHz

by the beacons and its nominal value (2.03625 GHz). The error, which resulted from using standard station frequency value, was corrected by modifying the partial derivatives for bias estimation. This error mostly affected the estimated station height, introducing discontinuities in some of the Analysis Center solutions, which were consequently propagated into the combined solution as well as in the ITRF2008. This problem is now solved and consequently should affect neither the IDS combination, nor the future ITRF2013 solution.

6.3 First HY-2A analyses

At the end of 2012, 3 Analysis Centers (ESA, GOP and LCA) delivered multi satellites solutions including HY-2A. HY-2A which was launched on August 15th, 2011 is the third DORIS satellite with the new DGXX DORIS receiver onboard (after Jason-2 and Cryosat-2). The analyses of these new series shown that adding HY-2A has no major impact on the series in terms of transformation parameters as well as on EOPs.

6.4 Future Plans

The activity of the IDS Combination Center in 2013 will be mainly devoted to the elaboration of the DORIS contribution to the next ITRF.

7 Meetings

In 2012, the IDS organized a DORIS Analysis Working Group (AWG) meeting in Prague, Czech Republic, on May 31 and June 1st, as well as the IDS Workshop and a second AWG meeting held in Venice in September.

All the presentations from the meetings are made available by the Central Bureau on the IDS website at:

<<http://ids-doris.org/report/meeting-presentations/ids-awg-05-2012.html>>

<<http://ids-doris.org/report/meeting-presentations/ids-workshop-2012.html>>

<<http://ids-doris.org/report/meeting-presentations/ids-awg-09-2012.html>>

8 Publications

IDS published a 2011 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 2012. The IDS has started several validation studies in preparation for ITRF2013, involving the Analysis Centers and the Combination Center. A few problems were detected and most of them are now

3.4.4 International DORIS Service (IDS)

solved. Improvements in the accuracy of the DORIS-derived geodetic products are expected for the future combined solution, at least for the polar motion determination and also most probably for station positioning.

The IDS noted with regret the demise of Envisat in April 2012, after 10 years of operation (since March 2002). This means that the DORIS operational combination relies on four satellites (SPOT-4, SPOT-5, Jason-2, and Cryosat-2) after April 2012, pending the assessment of the utility of the HY-2A DORIS data. However, several new satellites equipped with DGXX instruments should be launched in the near future, starting with SARAL in 2013.

Jérôme Saunier, Laurent Soudarin

3.5 Product Centres

3.5.1 Earth Orientation Centre

This section presents the activities and main results of the Earth Orientation Centre located at Paris Observatory over the year 2012. 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 available to a broad community of users in various domains such as astronomy, geodesy, geophysics, space sciences and time.

EOPs are firstly collected in the form of combined solutions derived by the Technique Centers (IGS, IVS, ILRS and IDS). Two main solutions are computed: a long-term solution (IERS C01) since 1846 and the Bulletin B/ C04 given at one-day intervals published monthly with a 30 day delay (Gambis, 2004; Bizouard and Gambis, 2009; Gambis and Luzum, 2011).

An important issue is the maintenance of the consistency between the EOP system and both the terrestrial and celestial reference frames. So far, Earth Orientation Parameters and the terrestrial frame are separately computed. This leads to increasing inconsistencies between both systems. At the end of 2009, these inconsistencies were small but significant for polar motion (negligible for the x-pole component and about 50 microarcseconds for the y-pole component). All IERS reference solutions (C01, Bulletin B, C04 as well as Bulletin A derived by the Rapid Service/ Prediction Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008. Inconsistencies are now limited to about 10 microarcseconds for polar motion and a few microseconds for UT1.

Combined daily series: Bulletin B and C04, statistics over 2011–2012

Tables 1 to 3 present statistics in term of formal errors and Weighted Root Mean Square (WRMS) of the combined technique centres and individual solutions with respect to the combined solution Bulletin B / C04 over the period 2011–2012. Combined solutions derived by the various technique centres (IGS, ILRS, and IVS) are mostly used in the IERS combinations with the additions of some VLBI series for Universal Time (intensive for UT1 and standards for nutation). Statistics concerning individual series are given as a feedback to the analysis centres.

New format of Bulletin B since January 2010

A new presentation is available since January 2010. The new Bulletin B and its content description are available at ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.dat and ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.pdf.

3.5.1 Earth Orientation Centre

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B / C04 over 2011–2012. 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. Solutions contributing to Bulletin B /C04 combined solutions are referred with a star ().*

Individual solutions	Estimated uncertainties			
	Time sampling	Terrestrial Pole μas	UT1 LOD μs	Celestial Pole μas
VLBI – 24 h				
EOP (AUS)	3–4d	340	15.4	200
EOP (BKG)	1–4d	125	10.6	86
EOP (GSFC)	1–4d	120	10.9	75
EOP (IAA)	1–4d	140	12.0	86
EOP (MAO)	1–4d	160	21.6	109
EOP (OPA)	1–4d	154	12.7	82
EOP (USNO)	1–4d	130	9.0	75
EOP(IVS) *	1–4d	125	7.6	47
VLBI – Intensive				
EOP (BKG) *	1–3 d		21.4	
EOP (GSFC) *	1–3 d		22.6	
EOP (PUL) *	1–3 d		21.0	
EOP (USNO) *	1–3 d		20.7	
SLR				
EOP (CGS)	1d	205		53.3
EOP (IAA)	1d	174		20.2
EOP (MCC)	1d	180		–
EOP (ILRS)*	1d	180		36.5
GPS				
EOP (CODE)	1d	42		13.3
EOP (EMR)	1d	54		22.0
EOP (ESOC)	1d	92		13.8
EOP (GFZ)	1d	50		11.5
EOP (IAA)	1d	280		53.5
EOP (JPL)	1d	60		22.0
EOP (NOAA)	1d	69		9.1
EOP (SIO)	1d	55		21.6
EOP (IGR) *	1d	40		7.5
EOP (IGS) *	1d	28		7.6

Table 2: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions entering the combination and Bulletin B/ C04 over 2011–2012

EOP	IGS Comb – IERS 08C04		ILRS Comb – IERS 08C04		IVS Comb – IERS 08C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	–7	29	68	173	65	151
Y (μas)	17	26	81	187	99	107
UT1 (μs)					0	7.6
LOD (μs)	–10	8	–5	36		
$D\psi\sin\epsilon$ (μas)					1	50
$D\psi$ (μas)					–20	43

Table 3: Mean and standard deviation for Pole components and UT1 of the differences between various solutions and Bulletin B/ C04 over 2011–2012

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard Deviation	Mean	Standard Deviation
X	μas	0	21	0	47
Y	μas	0	17	1	32
UT1	μs	2.0	14.2	–4.1	10.9

The content of Bulletin B is:

1 – DAILY FINAL VALUES AND PRELIMINARY VALUES OF x , y , UT1–UTC, dX , dY

and their respective uncertainties. Angular unit is milliarcsecond (mas), time unit is millisecond (ms).

2 – DAILY SMOOTHED VALUES OF CELESTIAL POLE OFFSETS ($d\psi_{1980}$, $d\epsilon_{1980}$)

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

Content of Bulletin B / C04

According to the IERS Message 198 (http://data.iers.org/products/2/14873/orig/message_198.txt) and starting on 1 December 2011, the EOP C04 series is now delivered with 30-day latency. In other words, only final definitive values are included in it.

Users needing a long-term continuous series extending up to a recent date (including rapid solution over the most recent 30 days) have two possibilities:

1) Getting the C04 solution extending until the date 30 days back and available at

ftp://hpiers.obspm.fr/iers/eop/eopc04/eopc04_IAU2000.YY, where YY is current two digit year,

and concatenate it with the Rapid solution (Bulletin A) issued from the Rapid Service/Prediction Center available at: <ftp://maia.usno.navy.mil/ser7/finals2000A.daily>

Due to differences in the delivery times of the two products, users should exercise caution in blending the files to ensure that there is continuity between Bulletin B/ C04 and Bulletin A.

2) Getting the new OPA EOP solution consisting of a continuous series derived from the concatenation of the C04 series and the OPA rapid solution available at:

ftp://hpiers.obspm.fr/iers/series/opa/eopc04_IAU2000

Long-term series: C 01 (1846–2013)

EOP(IERS) C 01 is a series of Earth Orientation Parameters given at 0.1 year intervals 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, 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 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.

1962–2013: BIH and IERS solutions (BIH and IERS annual reports).

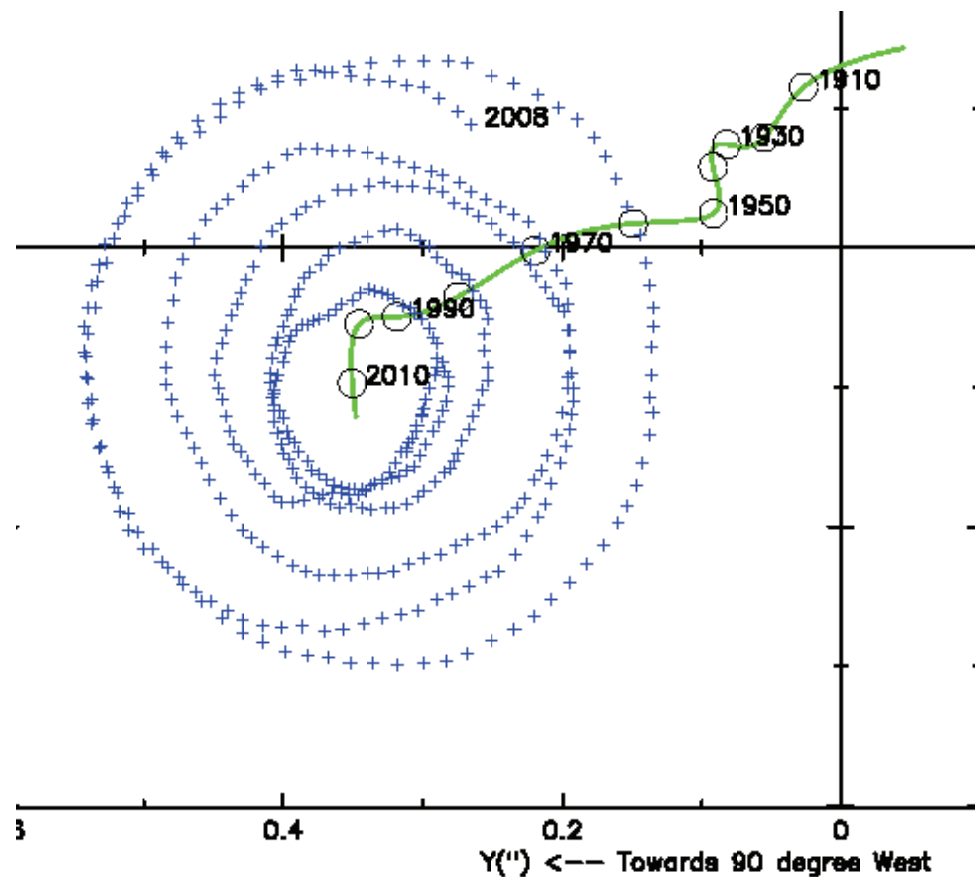


Fig. 1: Mean polar motion (1900–2013) and IERS C04 polhody over 2008–2013

Mean Pole with respect to the IERS reference origin

Gravity field models include the tesseral coefficients C_{21} and S_{21} 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 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 2012 (Shiskin et al., 1965). Figure 1 represents the polar motion over 2008–2012 and the path of the mean pole since 1900. Until the 2000's the mean polar motion was affected by a long-term drift westward (direction 70.7 degree West, rate: 4.2 mas/yr). It appears clearly that since that epoch, the mean pole is directed to Greenwich direction.

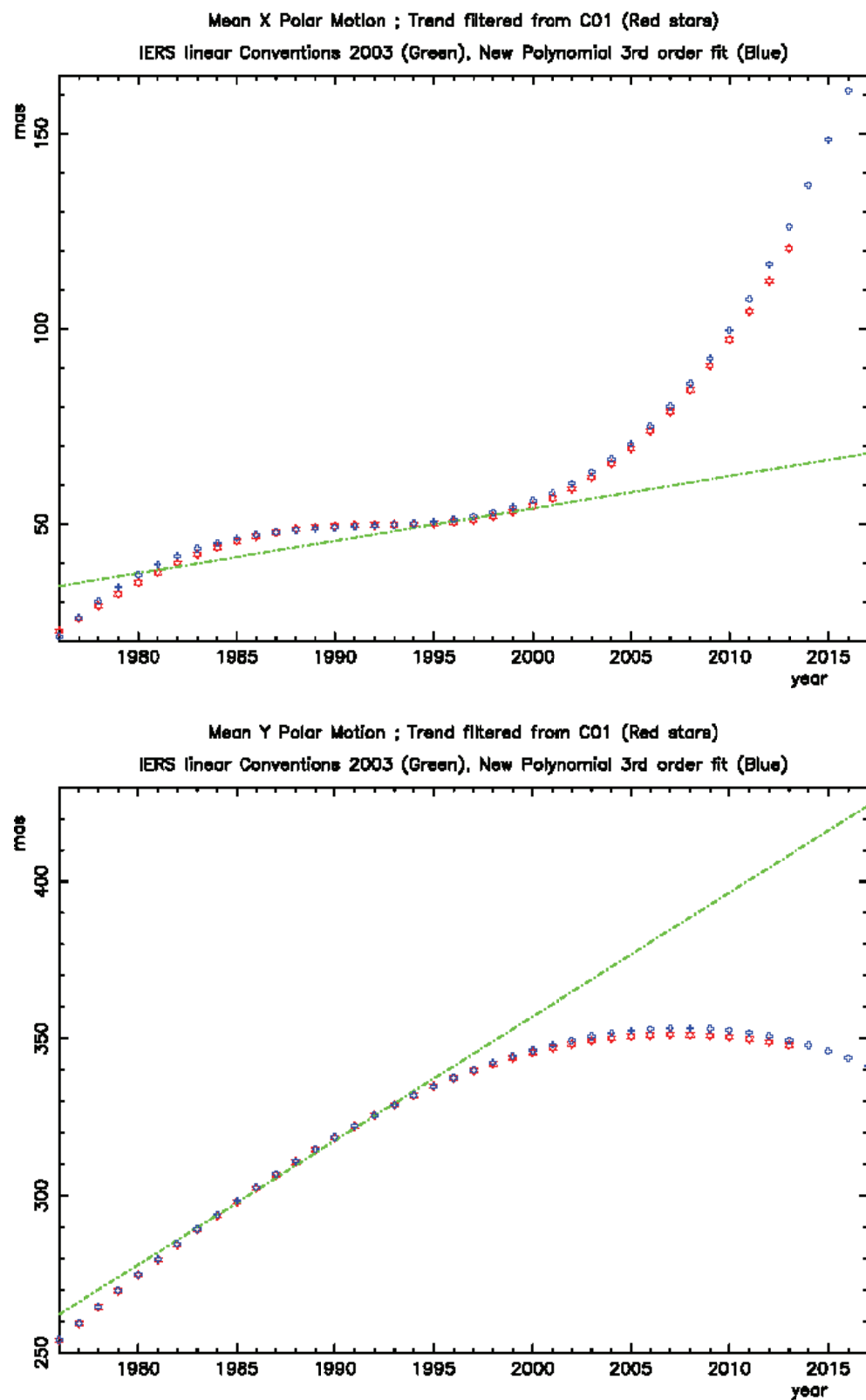
The mean pole is described by a third order polynomial. Its coefficients are published in IERS Conventions 2010 (Petit and Luzum, 2010). The corresponding table is also available at the following address: <http://hpiers.obspm.fr/eop-pc/>.

3.5.1 Earth Orientation Centre

After two years, it was interesting to match the extrapolated polynomial values and the updated mean pole time series. Table 4 and Figures 2a and 2b thereafter give the IERS mean pole components compared to the fitted polynomial and their differences which appear to remain roughly limited to a couple of mas over the extrapolated period 2010–2013 .

Table 4: IERS mean pole components compared to the fitted polynomial and their differences which remain limited to a couple of mas over the extrapolated period.

Year	X-Pole (mas)			Y-Pole (mas)		
	IERS data	Polynomial	diff(X-pole)	IERS data	Polynomial	diff(Y-pole)
1976	22.494	21.157	1.337	253.915	254.139	-0.224
1977	25.835	25.966	-0.131	259.294	259.467	-0.173
1978	29.050	30.173	-1.123	264.564	264.706	-0.142
1979	32.106	33.822	-1.716	269.720	269.850	-0.130
1980	34.973	36.954	-1.981	274.756	274.894	-0.138
1981	37.622	39.611	-1.989	279.668	279.832	-0.164
1982	40.028	41.836	-1.808	284.455	284.660	-0.205
1983	42.169	43.671	-1.502	289.118	289.370	-0.252
1984	44.032	45.157	-1.125	293.661	293.959	-0.298
1985	45.606	46.337	-0.731	298.088	298.420	-0.332
1986	46.891	47.254	-0.363	302.404	302.749	-0.345
1987	47.898	47.948	-0.050	306.607	306.939	-0.332
1988	48.646	48.463	0.183	310.694	310.985	-0.291
1989	49.164	48.841	0.323	314.653	314.882	-0.229
1990	49.491	49.123	0.368	318.470	318.625	-0.155
1991	49.674	49.352	0.322	322.128	322.207	-0.079
1992	49.768	49.570	0.198	325.608	325.624	-0.016
1993	49.833	49.819	0.014	328.892	328.870	0.022
1994	49.931	50.141	-0.210	331.964	331.940	0.024
1995	50.128	50.579	-0.451	334.813	334.827	-0.014
1996	50.486	51.175	-0.689	337.431	337.527	-0.096
1997	51.067	51.970	-0.903	339.814	340.035	-0.221
1998	51.926	53.006	-1.080	341.964	342.344	-0.380
1999	53.114	54.327	-1.213	343.883	344.450	-0.567
2000	54.677	55.974	-1.297	345.574	346.346	-0.772
2001	56.655	57.989	-1.334	347.042	348.028	-0.986
2002	59.083	60.415	-1.332	348.290	349.490	-1.200
2003	61.990	63.293	-1.303	349.319	350.726	-1.407
2004	65.402	66.666	-1.264	350.130	351.731	-1.601
2005	69.337	70.575	-1.238	350.724	352.500	-1.776
2006	73.812	75.064	-1.252	351.102	353.027	-1.925
2007	78.836	80.174	-1.338	351.266	353.307	-2.041
2008	84.416	85.947	-1.531	351.219	353.335	-2.116
2009	90.553	92.425	-1.872	350.966	353.104	-2.138
2010	97.247	99.651	-2.404	350.510	352.609	-2.099
2011	104.497	107.667	-3.170	349.855	351.845	-1.990
2012	112.304	116.514	-4.210	349.002	350.807	-1.805
2013	120.666	126.236	-5.570	347.953	349.489	-1.536



Figs. 2a and 2b: Plots showing the good agreement between the data and the fitted polynomial. Their differences remain limited to a couple of mas over the extrapolated period 2010–2013.

Long term UT1/LOD (EOP C02: 1830–now)

For geophysical study, we propose a new product: a long term UT1/LOD series (with the label EOP C02). This series is extending from 1830 until now and is monthly updated.

This series is composite and is available at <http://hpiers.obspm.fr/eoppc/series/longterm/eopc02.1830-now>; it is composed of the following series series:

- 1) 1830–1955: $\Delta T = TE - UT = TE - TAI - (UT - TAI)$ from Jordi et al. (1994), and obtained from the analysis of lunar occultations – mean sampling time of 120 days.
- 2) 1955–1962: from Vondrak et al. (1995) UT1 time series from optical astrometry.
- 3) 1962–now: Combined C04 time series free from short term zonal tides (< 2 years).

The characteristics of the combination are:

- For optical astrometric data (Jordi et al., AICAS), prior to 1962, UT–TE / UT1–TAI series are smoothed by gaussian filter with 365 day interpolation step.
- C04 series are smoothed using a gaussian filter with a 200 day interpolation step.
- After filtering the total series, composed of UT–TE (prior to 1958) and UT1–TAI (after 1958), are interpolated by cubic spline at 100 days step.
- Variation of the length of day LOD, given by $LOD / D = -dUT1/dt$ where $D = 86400$ s is the duration of the day, is then obtained from a two point time derivative of the 100 day UT1 time series.

Dissemination of UT1–UTC through the use of virtual observatory

Information concerning UT1–UTC and the occurrence of the leap seconds are currently made available via IERS Bulletin D and C. However, this old-fashioned procedure does not satisfy automatic systems. We have investigated the way to develop a new service based on the concept of Virtual Observatory (VO). This concept, provided by the International Virtual Observatory Alliance (IVOA), allows scientists and the public to access and retrieve UT1–UTC information using on-line distributed computational resources. We derived the concept, using the XML-based VO Table format to build this UT1–UTC dedicated new service (Deleflie et al., 2011).

The scientific community working in different field and requiring in particular UT1–UTC on a regular and reliable basis can benefit from the VO concept. The concept of metadata allows making available a single file with a description. Such tools can enhance the visibility of earth orientation parameters as well as UT1–UTC derived by the IERS.

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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. Offsets and rates with respect to the 08 C04 system of the IERS Earth Orientation Centre (EOC) at the Paris Observatory are determined using a robust linear estimator (Matlab function 'regstats'). 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 Center are given in Table 1. These estimates are based on the residuals between the series and the combined RS/PC EOP solution for 2012.

Table 1: Estimated accuracies of the contributors in 2012. Units are milliseconds of arc for x , y , $d\psi$, $d\epsilon$, dX , and dY and milliseconds of time for UT1–UTC.

Contributor Information Name, Type	Estimated Accuracy				
	x	y	UT1	$\delta\psi$ (dX)	$\delta\epsilon$ (dY)
ILRS SLR	0.19	0.17			
IAA SLR	0.22	0.21			
MCC SLR	0.15	0.22			
GSFC VLBI Intensives			0.020		
USNO VLBI Intensives			0.018		
GSI Intensives			0.015		
GSFC VLBI	0.13	0.12	0.004	0.51	0.20
IAA ¹ VLBI	0.22	0.13	0.007	(0.07)	(0.08)
IVS ¹ VLBI	0.17	0.17	0.003	(0.03)	(0.04)
USNO VLBI	0.18	0.14	0.004	0.20	0.08
IGS Final	0.01	0.01			
IGS Rapid	0.03	0.03			
IGS Ultra*	0.04	0.05	0.007*		
USNO GPS UT*			0.017*		

*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 (see Petit and Luzum, 2010).

Table 2: Mean and standard deviation of the differences between the Rapid Service/Prediction Center combination solutions and the 08 C04 EOP solutions for 2012. Polar motion 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	0.00	0.02
y	0.00	0.03
UT1-UTC	0.004	0.018
Bulletin A Weekly Solution (finals.data)¹		
x	0.03	0.04
y	0.02	0.04
UT1-UTC	0.002	0.023
Bulletin A Daily Solution (finals.daily)		
x	0.02	0.05
y	0.03	0.05
UT1-UTC	-0.001	0.035

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

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 $\delta\epsilon$ 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 $\delta\epsilon$ or dX and dY, for historical reasons, it uses $\delta\psi$ and $\delta\epsilon$. Therefore, IAA and IVS VLBI dX and dY values are converted to $\delta\psi$ and $\delta\epsilon$ in the combination process. The LOD for the combination 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 08 C04 series maintained by the IERS EOC. The running solution is the combination solution over the past 366-day period. The statistics for the running solution at year's end show the agreement between the Bulletin A running combination solution and the C04 series.

The comparison of the 52 weekly solutions to the 08 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 08 C04 and presents the data used in Table 2 for the determination of the daily solution statistics. In 2012, the mean residuals between the daily solution and the 08 C04 were essentially the same as in 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 that 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, 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). A deficiency with the current implementation of this algorithm occasionally causes poor quality short-term polar motion predictions. Mitigation strategies are currently being investigated.

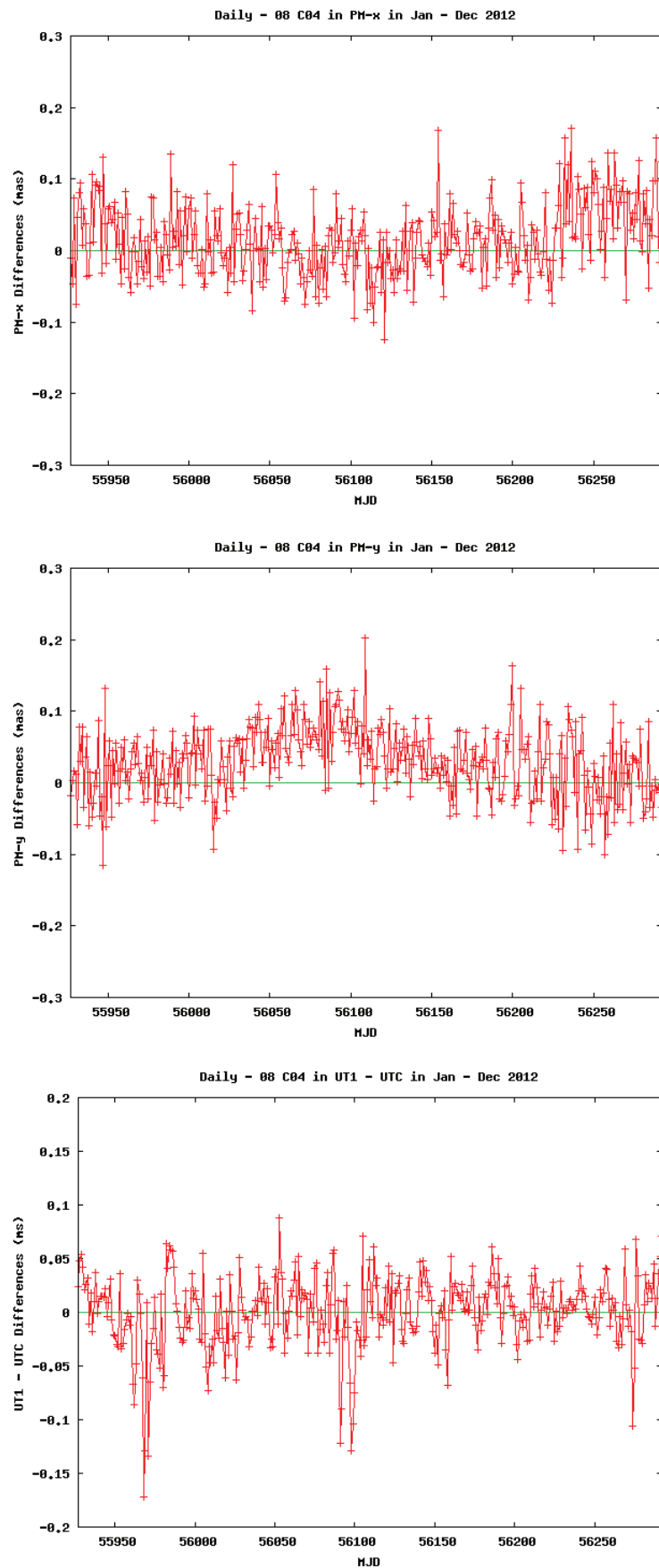


Fig. 1: Differences between the daily rapid solutions at each daily solution epoch for 2012 and the Earth orientation parameters available in the 08 C04 series produced in April 2013.

The UT1–UTC prediction 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 7.5 days. For longer predictions, the LOD excitations are combined smoothly with the longer-term UT1 predictions described below. For more information on the use of the UT AAM data, 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, $(\text{UT2R}-\text{TAI})_n$, the smoothed time value from n days in the past, $\langle (\text{UT2R}-\text{TAI})_{-n} \rangle$ is subtracted from the most recent value, $(\text{UT2R}-\text{TAI})_0$

$$(\text{UT2R}-\text{TAI})_n = 2(\text{UT2R}-\text{TAI})_0 - \langle (\text{UT2R}-\text{TAI})_{-n} \rangle.$$

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 restore the 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 also strongly influenced by the observed daily Universal Time estimates derived at USNO from the motions of the GPS orbit planes reported by the IGS Rapid service (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.

Errors of the prediction 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, but predictions derived from these formulas are significantly less accurate than the tabular predictions and are not recommended for operational use. The predictions of $\delta\psi$ and $\delta\epsilon$ are based on the IERS Conventions (McCarthy, 1996; McCarthy and Petit, 2004).

For 2012, the polar motion prediction errors were roughly the same accuracy as compared to the 2011 values. Figure 2 provides a plot of the prediction error as a function of polar motion value. The improvement over the last few years in UT1–UTC short-term prediction is due to the improved availability of rapid turnaround e-VLBI intensives. Table 3a shows the root mean square of the differences between the daily solution predictions and the 08 C04 solution for 2012.

Daily – 08 C04 Pole Path with Absolute 1-day Prediction Accuracy
January – December 2012

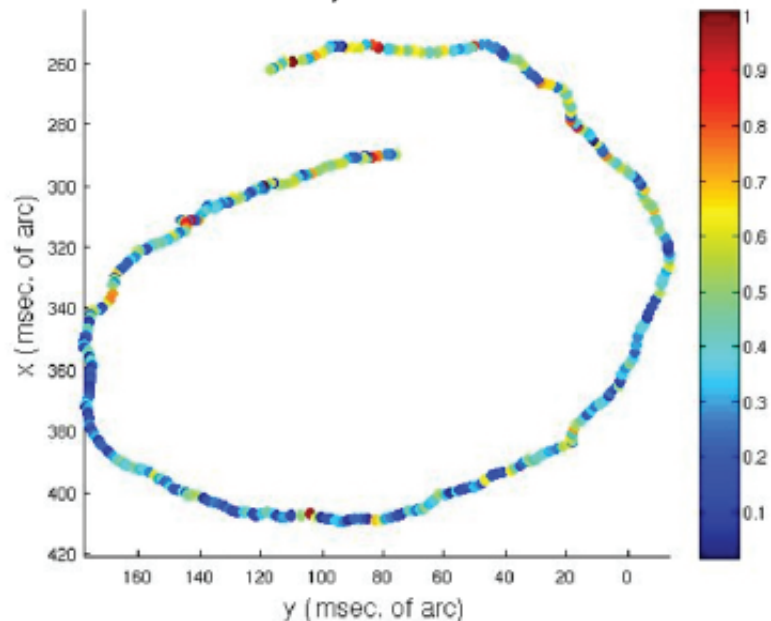


Fig. 2: Plot of the prediction error as a function of polar motion. The prediction error is in units of milliseconds of arc.

Table 3a: Root mean square of the differences between the EOP time series predictions produced by the daily solutions and the 08 C04 combination solutions for 2012. Note that the prediction length starts counting from the day after the last available observation is made for polar motion or UT1–UTC (or UT-like data).

Days in	PM-x	PM-y	UT1-UTC
Future	mas	mas	ms
1	.35	.25	.063
5	2.01	1.35	.256
10	3.92	2.76	.662
20	7.52	5.66	2.22
40	13.7	11.3	5.77
90	22.1	24.4	10.8

The predictions of celestial pole offsets (both dX/dY and $\delta\psi/\delta\epsilon$ representations) are produced through the use of the KSV1996 model (McCarthy, 1996). In addition, a bias between the model and the last 20 days of celestial pole offset observations is computed. Correcting for this bias allows for a seamless transition between the observed and predicted celestial pole offsets. This bias 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 08 C04 for 2012 are given in Table 4.

Table 4: Root mean square of the differences between the nutation prediction series produced by the daily solutions and the 08 C04 combination solutions for 2012.

Days in Future	dX mas	dY mas	$\delta\psi$ mas	$\delta\epsilon$ mas
1	.13	.14	.32	.13
5	.13	.15	.34	.14
10	.15	.16	.38	.15
20	.17	.18	.44	.17
40	.22	.23	.57	.22

Predictions of TT–UT1, up to 1 April 2023, 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 errors 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; Stamatakos *et al.*, 2010).

Center Activities in 2012

During 2012, a number of significant changes occurred in the RS/PC products. On 29 November 2012, the zonal tide model was changed to be compliant with the IERS Conventions (2010). There are no statistical differences between solutions with the two zonal tide models.

For 2012, the IERS RS/PC computed four EOP solutions each day — the original solution at 17:10 UTC and new solutions at 21:10, 03:10, and 09:10 UTC. These solutions are collectively referred to as the Nxdaily solutions. The original solution at 17:10 UTC has been produced by the IERS RS/PC each day for over 10 years. The additional solutions are part of an ongoing effort to improve the accuracy of the EOP solutions by updating EOP solutions soon after new observational data are available, thereby reducing the latency between observations and EOP solution updates. Examples of these new observational input data are eVLBI intensives and IGS Ultra-Rapid solutions (IGS ultras). Tables 6a and 6b illustrate the relationship between the EOP solution times and these input data.

Table 5: Predicted values of TT–UT1, 2013–2023. 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)
2013 Jul 1	67.121	0.008
2013 Oct 1	67.16	0.01
2014 Jan 1	67.27	0.02
2014 Apr 1	67.38	0.02
2014 Jul 1	67.5	0.2
2014 Oct 1	67.6	0.3
2015 Jan 1	67.7	0.4
2015 Apr 1	67.8	0.4
2015 Jul 1	67.9	0.5
2015 Oct 1	68.1	0.7
2016 Jan 1	68.2	0.8
2016 Apr 1	68.3	0.9
2016 Jul 1	68.	1.
2016 Oct 1	69.	1.
2017 Jan 1	69.	1.
2017 Apr 1	69.	1.
2017 Jul 1	69.	2.
2017 Oct 1	69.	2.
2018 Jan 1	69.	2.
2018 Apr 1	69.	2.
2018 Jul 1	70.	2.
2018 Oct 1	70.	2.
2019 Jan 1	70.	2.
2019 Apr 1	70.	3.
2019 Jul 1	70.	3.
2019 Oct 1	70.	3.
2020 Jan 1	70.	3.
2020 Apr 1	70.	3.
2020 Jul 1	71.	3.
2020 Oct 1	71.	3.
2021 Jan 1	71.	4.
2021 Apr 1	71.	4.
2021 Jul 1	71.	4.
2021 Oct 1	71.	4.
2022 Jan 1	71.	4.
2022 Apr 1	71.	5.
2022 Jul 1	71.	5.
2022 Oct 1	72.	5.
2023 Jan 1	72.	5.
2023 Apr 1	72.	5.

At each Nxdaily UTC solution time listed in Tables 6a and 6b, major contributors are listed with an associated “epoch at midpoint”. IGS and VLBI solutions are determined from a span of observations and the EOP estimate is provided at the midpoint of this span. Typically IGS orbits are integrated over a 24-hour period and VLBI intensives observations of quasars are integrated over a 1-hour period. The Contributor column contains the most recently available input at the time of each UTC solution.

Table 6a lists the most recent major input contributors for each polar motion Nxdaily solution. For example, by the polar motion 17:10 UTC <MJD> solution time, the most recently computed IGS Rapid solution, which has an epoch at midpoint of 12:00 UTC noon from the previous day, <MJD-1>, is available. In addition, there are two IGS ultras available that contain an epoch at midpoint after the IGS rapid. By 21:10 UTC <MJD>, the IGS has produced an updated IGS ultra, the 18-hr solution, and the corresponding EOP solution will use this latest data. Similarly, the 03:10 UTC and 09:10 UTC solutions will have later IGS ultra data available as shown in the table. Finally, for the next day, <MJD+1>, the sequence of IGS Rapids and Ultras will repeat — the 17:10 UTC <MJD+1> solution will have the next IGS rapid solution whose midpoint was at 12:00 UTC <MJD> along with the next 6-hr and 12-hr Ultras.

In Table 6b, a similar pattern for UT1-UTC to what was described above for polar motion is shown. In addition to the IGS contributions, the VLBI intensives series and AAM contributions are included. VLBI intensives are not available as regularly as the IGS observations, and so the contributors shown for each solution are only an ideal case that occurs roughly 70% of the time. The INT1 intensives are typically only observed on weekdays, the INT2 intensives on weekends, and the INT3 intensives on Mondays. For more information about the relation of the INT1, INT2, and INT3 VLBI intensives observation times to the EOP solution see Stamatakis *et al.*, *AGU poster G51A-1084*.

Within each Nxdaily EOP solution file — each called finals.daily and finals2000A.daily, but located in separate sub-directories — there are EOP solutions for polar motion, UT1–UTC and celestial pole offsets. Each has an identical format to the original 17:10 UTC solution.

Tables 3a through 3d contain the RMS for the 1- to 90-day prediction errors for the 17:10, 21:10, 03:10, and 09:10 UTC EOP solutions for 2012. The polar motion short-term prediction solutions should improve at each later EOP update (starting from the 17:10 UTC <MJD> to the 09:10 UTC <MJD+1> solution) since the later EOP solution will have more recent observations. The 2012 one and five day polar motion prediction results shown in Tables 3a and 3d confirm this improvement. The 1-day polar motion prediction

Table 6a and 6b: Tables describing the data available for each of the NXdaily solutions.

Table 6a: Major Contributors for the Polar Motion EOP solution at the Nxdaily Solution Times

1700 UTC solution		2110 UTC solution		0310 UTC solution		0910 UTC solution	
Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*
IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00	IGS 0 hr Ultra	+12:00	IGS 6 hr Ultra	+18:00
IGS 6 hr Ultra	-06:00	IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00	IGS 0 hr Ultra	+12:00
IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00	IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00
		IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00	IGS 12 hr Ultra	00:00
				IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00
						IGS Rapid	-12:00

Table 6b: Major Contributors for the UT1-UTC EOP solution at the Nxdaily Solution Times

1700 UTC solution		2110 UTC solution		0310 UTC solution		0910 UTC solution	
Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*	Contributor	Epoch at Midpoint*
AAM LOD ³		AAM LOD ³		AAM LOD ³		AAM LOD ³	
INT2 / 3 VLBI intensive ¹	+08:00	INT2 / 3 VLBI intensive ¹	+08:00	IGS 0 hr Ultra	+12:00	IGS 6 hr Ultra	+18:00
IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00	INT2 / 3 VLBI intensive ¹	+08:00	IGS 0 hr Ultra	+12:00
INT1 VLBI intensive ²	-05:00	IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00	INT2 / 3 VLBI intensive ¹	+08:00
IGS 6 hr Ultra	-06:00	INT1 VLBI intensive ²	-05:00	IGS 12 hr Ultra	00:00	IGS 18 hr Ultra	+06:00
IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00	INT1 VLBI intensive ²	-05:00	IGS 12 hr Ultra	00:00
		IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00	INT1 VLBI intensive ²	-05:00
				IGS Rapid	-12:00	IGS 6 hr Ultra	-06:00
						IGS Rapid	-12:00

* IGS and VLBI solutions are determined by integrating a period of observation times. The EOP reported is the observation mid-point.

¹ INT2 and INT3 intensives are normally observed Saturday through Monday with an epoch at midpoint at approximately 08:00 UTC.

² INT1 intensives are normally observed Monday through Friday with an epoch at midpoint at approximately 19:00 UTC.

³ The AAM LOD inputs contain 7.5 days of forecast data from 00:00 to 180:00 hours.

from the 17:10 UTC <MJD> EOP solution will make a prediction of the polar motion at 00:00 UTC <mjd+1>. The 1-day polar motion prediction from the 09:10 UTC <MJD+1> EOP solution will make a prediction of the polar motion at 00:00 <MJD+1>. The percentage decrease in error was significant — 21% for PM_x and 24% for PM_y. Improvements of a consistently smaller magnitude are made between the 17:10 and 21:10 UTC and between the 17:10 and 03:10 UTC solutions, as can be seen by comparing results among Tables 3a, 3b, 3c, and 3d.

Table 3b, 3c, and 3d: Root mean square of the differences between the EOP time series predictions produced by the 4x daily solutions and the 08 C04 combination solutions for 2012. Note that the prediction length starts counting from the day after the last available observation is made for polar motion or UT1–UTC/LOD.

Table 3b: RMS for the 21:10 UTC EOP solution for 2012.

Days in Future	PM-x mas	PM-y mas	UT1-UTC ms
1	.30	.22	.062
5	1.93	1.31	.257
10	3.86	2.74	.666
20	7.48	5.67	2.22
40	13.7	11.4	5.77
90	22.2	24.1	10.8

Table 3c: RMS for the 03:10 UTC EOP solution for 2012.

Days in Future	PM-x mas	PM-y mas	UT1-UTC ms
1	.28	.19	.057
5	1.88	1.27	.261
10	3.84	2.71	.669
20	7.49	5.64	2.22
40	13.7	11.3	5.74
90	22.1	23.9	10.7

Table 3d: RMS for the 09:10 UTC EOP solution for 2012.

Days in Future	PM-x mas	PM-y mas	UT1-UTC ms
1	.27	.19	.055
5	1.84	1.28	.263
10	3.83	2.74	.675
20	7.50	5.0	2.22
40	13.8	11.4	5.73
90	22.4	23.9	10.7

For the 5-day polar motion predictions, the percentage decrease in error was significant (but smaller than for the 1-day predictions) — 8% for PMx and 5% for PMy. For the 10-, 20-, 40-, and 90-day predictions, there is no statistically significant change in prediction accuracies among the various Nxdaily solutions.

The UT1–UTC 1-day predictions also show improvements from the 17:10 UTC <MJD> to the 09:10 UTC <MJD+1> solutions; however, the percentage decrease is much smaller than it was for polar motion — a decrease in error of 12%. The 5-day predictions do not show an improvement. There also was improvement in the 1-day predictions when comparing the 17:10 UTC to the 21:10 and 03:10 UTC solutions; yet, as to be expected the improvement was less than 12%.

There are no rapid turnaround estimates of celestial pole offsets; only 24-hour VLBI solutions provide celestial pole offsets. These 24-hr solutions can be latent by one to two weeks, and therefore, it is anticipated that there will be no statistically significant difference between celestial offset prediction solutions. No tables of statistics for celestial pole offsets are presented in this report.

Each of the Nxdaily EOP solutions are updated daily at approximately 17:10 UTC, 21:10 UTC, 03:10 UTC, and 09:10 UTC, respectively. They are located in subdirectories of the following URLs:

<<http://maia.usno.navy.mil/>> or <<http://toshi.nofs.navy.mil/>>

Time (UTC)	Sub-directory
17:10	ser7
21:10	eop2100utc
03:10	2xdaily
09:10	eop0900utc

For, example, the EOP USNO DC solution produced at 03:10 UTC is located at <<http://maia.usno.navy.mil/2xdaily/finals.daily>> or [finals2000A.daily](#).

An identical process has been implemented for 2013 to what was implemented for 2012. Solution names and locations have remained the same from 2012 to 2013.

New global solutions were received from the GSFC VLBI Analysis Center (gsf2012a) and the USNO VLBI Analysis Center (usno2012a and usno2012b). These new solutions were examined and new slopes and biases were computed before being incorporated into operations.

The IERS RS/PC now provide the same operational EOP products generated at USNO DC at an offsite location at the Naval Observatory Flagstaff Station (NOFS). The solutions at the USNO DC and NOFS are checked on a daily basis to ensure that there

are no discrepancies between the two. This redundancy provides an alternative location from which to obtain a solution should the primary facility at USNO DC be unable to deliver its EOP product due to internet outage, power outage, etc.

The EO transformation calculator was maintained throughout the year. The calculator can now produce rotation matrix elements calculated using the IERS Technical Note 36 equinox-based algorithm (Petit and Luzum, 2010). This web-based product will provide both the transformation matrices as well as quaternion representations of the rotations between terrestrial and celestial reference frames.

Availability of Rapid Service

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

Other data sets are available that include: UT from NRC Canada (EMR) GPS; UT0–UTC from University of Texas at 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 $\delta\epsilon$ from IRIS VLBI.

The data described above are available from the Center 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>` or

`<ftp://toshi.nofs.navy.mil/ser7>`

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

Center Staff The Rapid Service/Prediction Center staff consisted of the following members:

Brian J. Luzum	Director
Nick Stamatakos	Operational program manager, research, and software maintenance
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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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 2012, the work accomplished or in progress is the following:

1. Technical content of the IERS Conventions

After the publication of the new reference edition, the IERS Conventions (2010), in electronic form (<http://tai.bipm.org/iers/conv2010/>) and as IERS Technical Note 36, work started on the updates to the Conventions (2010). The list below summarizes the changes in 2012. See <http://tai.bipm.org/iers/convupdt/convupdt.html> (or the site at <http://maia.usno.navy.mil/conv2010/convupdt.html>) for details.

- Corrected typos or other numerical errors, or completed information, in Chapter 5 (Transformation between the International Terrestrial Reference System and Geocentric Celestial Reference System), Chapter 6 (Geopotential), Chapter 7 (Displacements of reference points), Chapter 9 (Models for atmospheric propagation delays), and the Appendices.
- Provided the yearly update of the free core nutation model.

2. Conventions software

The most significant updates to the Conventions software were the modifications to HARDISP and DEHANTTIDEINEL to account for the 2012 insertion of the leap second.

3. Planned Changes

Discussions initiated to update the conventional geopotential model (Chapter 6), notably its time-varying part (low degree coefficients, seasonal variations). Associated topics such as conventional models for the geocenter motion in the ITRF and the IERS mean pole are also covered. Investigation into non-tidal displacement of reference markers continues and may lead to a new section for Chapter 7. In response to concerns regarding the quality of existing models for diurnal and semi-diurnal EOP variations in Chapter 8, efforts to identify improved models has begun. In addition to improvements in content, the IERS Conventions Center is considering the electronic content of the document, version control, and other ways to improve the quality and usability of the IERS Conventions.

3. Dissemination of information

The Conventions web pages at the BIPM (<<http://tai.bipm.org/iers/>>) and the USNO (<<http://maia.usno.navy.mil/conv2010/>>) were maintained.

Past updates to the IERS Conventions (2003), from 2004 until the release of the IERS Conventions (2010), were archived separately from the current updates, at <<http://tai.bipm.org/iers/conv2010/convupdt/convupdt.html>>.

A survey has been carried out to gather comments on the technical content of the Conventions (2010), the process of elaboration, as well as ideas for future evolution (<http://maia.usno.navy.mil/conv2010/Conventions_Survey.html>). A summary of the replies may be found at <http://tai.bipm.org/iers/conv2010/conv2010_surveyreplies.pdf>.

5. Conventions Center staff

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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](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 2012. 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. Preliminary results of these high frequency reference frame observations can be found in Charlot et al. (2010) and Lanyi et al. (2010). Results of observations to determine the position/structure stability of four ICRF2 quasars can be found in Fomalont et al. (2011).

At the IAU General Assembly in Beijing in August 2012, ICRS Center personnel organized an effort to establish an IAU Working Group on ICRF-3. The effort was well received by the IAU. A steering committee was established which met in Beijing and subsequently in October 2012 in Bordeaux. The steering committee wrote a charter for the working group, established Working Group membership, and selected a Working Group chair. The IAU subsequently accepted all these, and formally established the Working Group. The ICRF-3 Working Group will immediately pursue new observations that will fill gaps and improve weaknesses of ICRF2, present a progress report to the IAU General Assembly in 2015, and pursue the completion of ICRF-3 in 2018.

In the coming decades, there will be significant advances in the area of space-based optical astrometry. Missions such as the European Space Agency’s (ESA) Gaia mission are expected to

achieve astrometric positional accuracies beyond that presently obtained by ground-based radio interferometric measurements. In 2012, ICRS Center personnel worked on development of a micro-satellite based astrometric mission, called the Joint Milli-Arcsecond Pathfinder Survey (JMAPS), to produce milliarcsecond level astrometry for all of the bright stars up to 12th magnitude (limiting magnitude ~15–16) (see Gaume et al. 2009). Unfortunately, due to budget limitations, toward the end of 2011 the U.S. Navy cancelled the JMAPS program however, funding was allocated for two additional years (2012 and 2013) to complete the JMAPS instrument. Whether or not the JMAPS instrument will be utilized astrometrically, was unresolved at the end of 2012.

Assessment of VLBI Realisations of the ICRF

In 2012, new celestial reference frames were produced at different IVS analysis centers by the reanalysis of the full VLBI observational database and submitted to the IVS data center. The aus2012b catalog was produced at Geoscience Australia (Canberra), using the OCCAM geodetic VLBI analysis software package. Both bkg2012a and opa2012a were produced with the NASA Goddard Space Flight Center's package SOLVE, at the Federal Agency for Cartography and Geodesy (BKG Leipzig) and Institute of Geodesy and Geoinformation of the University of Bonn (IGGB), and at the OPAR IVS analysis center of the Paris Observatory, respectively. Technical descriptions of the solutions are available at the IVS data center. The VLBI group of the NASA Goddard Space Flight Center also provided a catalog along with the gsf2012a solution.

We evaluate the consistency of the four catalogs with the ICRF2 by modelling the coordinate difference between the ICRF2 defining source coordinates in both the submitted catalog and the

Table 1: The characteristics and transformation parameters relevant to the four catalogs submitted to the IVS in 2012.

	No. Sources		Difference to ICRF2				Transformation parameters			
	All	Def.	Mean $\alpha \cos \delta$ μas	δ μas	Rms $\alpha \cos \delta$ μas	δ μas	A1 μas	A2 μas	A3 μas	B δ μas
aus2012b	2895	288	4	-7	78	84	-23	4	3	-14
±							5	5	5	5
bkg2012a	3253	287	-1	22	51	66	7	15	1	18
±							5	5	4	4
gsf2012a	3708	295	2	-8	46	54	-2	7	-3	-14
±							5	5	4	4
opa2012a	3526	295	6	10	53	52	-4	12	-7	10
±							5	5	4	4

3.5.4 ICRS Centre

ICRF2. The coordinate difference was modelled by a 6-parameter transformation as used at the IERS in previous comparisons (see, IERS Annual Report 1995, p. II-32). The results are reported in Table 1. The 6 parameters were fitted to the coordinate difference of the defining sources present in the catalogs. The drifts in right ascension and declination (noted $D\alpha$ and $D\delta$, respectively) have been omitted in the Table 1 since they do not exceed $0.6 \mu\text{as}$ with formal error of $0.2 \mu\text{as}$. Figures 1–4 below represent the residual (i.e., after alignment onto the ICRS) differences between each catalog and the ICRF2.

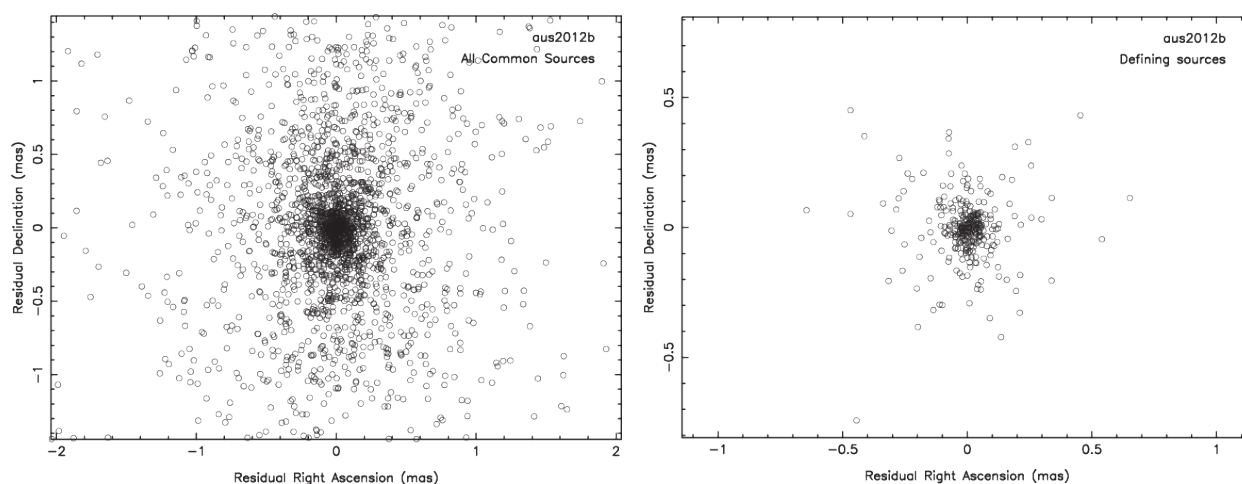


Fig. 1: The residual difference between the *aus2012a* catalog and the ICRF2 for all sources (Left) and defining sources only (Right).

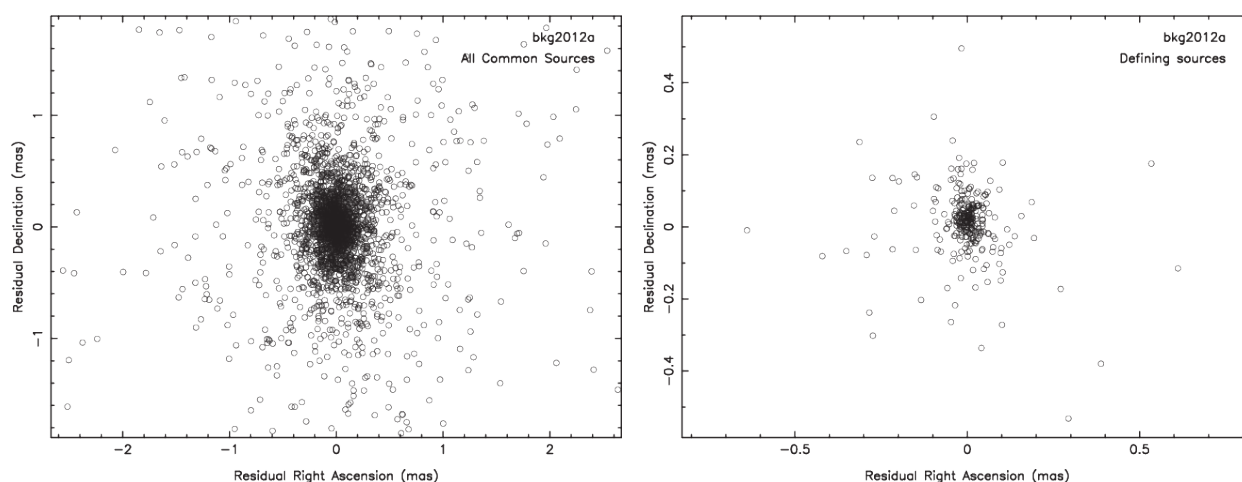


Fig. 2: The residual difference between the *bkg2012a* catalog and the ICRF2 for all sources (Left) and defining sources only (Right).

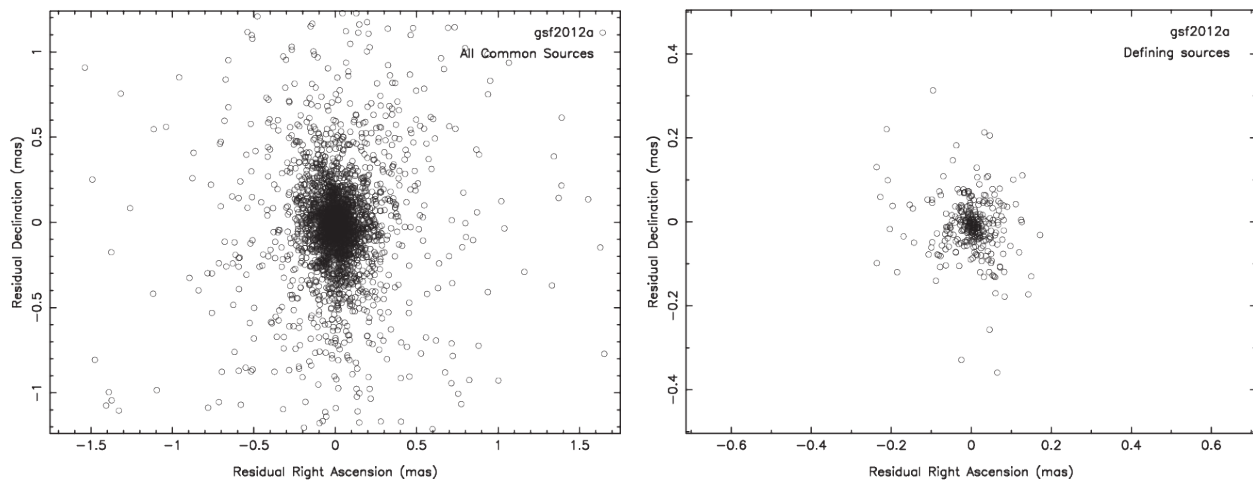


Fig. 3: The residual difference between the *gsfc2012a* catalog and the ICRF2 for all sources (Left) and defining sources only (Right).

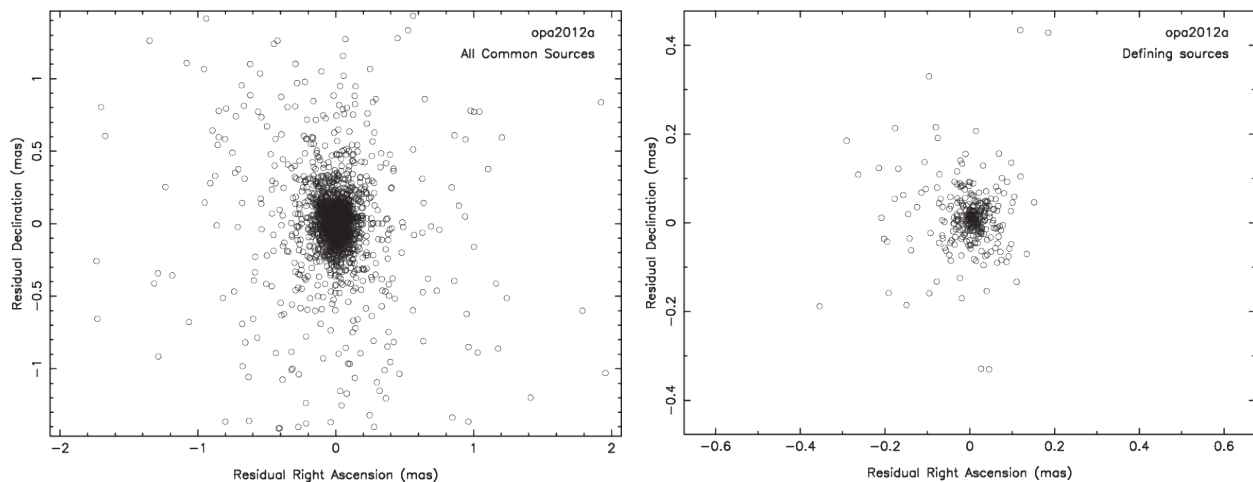


Fig. 4: The residual difference between the *opa2012a* catalog and the ICRF2 for all sources (Left) and defining sources only (Right).

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 2012. 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 2012, a total of six VLBA RDV experiments were observed.

Monitor source structure to assess astrometric quality

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 2012, ICRS Center personnel imaged sources from two high frequency (K-band) VLBA experiments. 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 1867 images of 285 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 3517 Very Long Baseline Array (VLBA) images of 1100 sources mostly at radio frequencies of 2.3 GHz and 8.4 GHz, but includes images for some sources at 24 GHz and 42 GHz. The BVID can be accessed from the Analysis Center web page or directly at <http://www.obs.u-bordeaux1.fr/BVID/>.

Linking the ICRF to frames at other wavelengths

The link between the ICRF and other celestial reference frames is fundamental to prepare the future ICRF as well the future connection between the ICRS and the GCRS (Gaia Celestial Reference System). During the reporting period (2012) ICRS Center personnel continued to make progress with several astrometric star catalogs (e.g. UCAC and URAT), the extragalactic link to ICRF sources, and in preparation for the Gaia astrometric space mission.

Optical Representation of the ICRS: Gaia

The ICRS/ICRF paradigm is based on a frame formed by very distant extragalactic sources which are thus assumed to have no global rotation. By definition this frame is considered to be kinematically non-rotating. To present date the versions of the ICRF (IERS Tech. Notes 23/1997 and 35/2009) were formed by VLBI positions of selected radio loud quasars. The ESA satellite Gaia, to be launched on end 2013, astrometric solution will be referred to a kinematically non-rotating frame thanks to the global zero-proper motion constraint set on the clean subset of quasars detected by Gaia. The positional accuracy of the individual sources will depend on their magnitude, but at least for the (forecasted) 30,000 QSOs brighter than $G=18$ this would be better than 80 μ as and 60 μ as/yr. This astrometric solution should supersede the VLBI based versions of the ICRF, and bring the primary representation of the ICRS to the optical wavelength at the time of issuing of the Gaia final solution, to be published around 2020 (Mignard, 2012).

In preparation for what is currently called the Gaia Celestial Reference Frame (GCRF), the Gaia Initial QSO Catalog has been prepared (Andrei et al., 2012a).

Gaia Initial QSO Catalog (GIQC)

QSOs will define the GCRF, and accordingly on Gaia board means are capable of classifying them. The QSO classification will possess three major orientations: getting the cleanest QSO sample to determine the GCRF; deriving the most complete QSO sample based on the full Gaia data; and determining the astrophysical parameters for each QSO. The determination itself of a Gaia source as a QSO is planned to rely primarily on comparison of the photometric output against a template of spectral energy distributions (SED), and secondarily on astrometric observables, variability analysis and a reliable initial list of known QSOs. A sample as small as 10,000 quasars can stabilize the GCRF to a residual rotation of less than 0.5 μ as per year, provided they are well distributed over the sky. The relatively small number of points actually required to constitute a robust GCRF brings particular relevance for the initial list of known QSOs, the GIQC. It aims to obtain a clean sample of at least 10,000 quasars, distributed all-sky above $|20^\circ|$ of galactic latitude, with magnitude brighter than $V=20$ and point-like PSF. This bona fide initial clean sample is useful both for the actual orientation of the GCRF and to enlarge the templates of the recognition scheme. For that, catalogue and published QSO determinations were inspected (Taris et al., 2012a). The 4th version of the GIQC, presented at the Gaia CU3 meeting (Coordination Unit 3, Core Processing) in Porto, Portugal (2012), contains 187,505 objects, divided in three categories – defining, candidates, and other (Andrei et al., 2012b). The defining objects are 136,643 well documented QSOs, being 103,422 from the SDSS/DR8 (Schneider et al., 2010). The catalog brings reliable redshift for 183,543 objects (97.87%), and there are reliable optical images for 159,701 objects (85.17%).

The morphology indexes

In the GIQC morphological indexes were assigned to each object on basis of the departure of the images from a purely stellar PSF, defined by the stars nearby to each quasar. A morphological departure indicates that the isophotes from the host galaxy must be considered in order to reach maximum precision in the determination of the centroid of the target. A pilot study compared 1,343 quasars in images from the SDSS (r images) and the DSS (R plates). The outcome has shown that the DSS images were able to detect quasars for which the host galaxy signature was sensed in the SDSS images, using the SHARP, SROUND, and GROUND, PSF parameters in IRAF's DAOFIND task. Thus the images of all quasars in the GIQC were searched for in the B, R, and I plates of the DSS. For each of the 3 DAOFIND parameters, in each of the 3 colors, a morphological index was produced as the z-ratio of the parameter value for the quasar to the mean parameter ratio for the surrounding stars, normalized by the standard deviation in that mean. Thus, in all, there are up to 9 morphological indexes for

each quasar. Typically about 10% of the quasars are found with departures larger than 2 in the z-ratio. The departures are clearly more important in the R plates than in the B plates (Souchay et al., 2012).

The variability indexes

Variability is a prominent characteristic of quasars due to the violent processes of infall of matter to the massive central black hole (Taris et al., 2012b). As the objects that will materialize the GCRF will be those with the most accurate and stable positions (which are therefore critical, defining, properties), there is evidence that flux variations at different time scales correlate with variations of the astrometric location of their photocentres. Therefore, photocentre angular variations at different wavelengths are possibly the results of common phenomena occurring in the vicinity of the central engine of QSOs: the base of relativistic jets, the broad emission line regions, or accretion disks (Popovic et al., 2012).

Typically Gaia will take about 80 measurements of each quasar during the five years mission, a couple of times in successive fields (or slightly more if the quasar happens to occupy the nodus of a transit great circle), and then come back to the target after a month and a half. Such cadence is very well suited to single out the peculiar quasar variability in comparison to other variable sources (Kelly et al., 2009, Andrei et al., 2012c). At the same time, if an associated astrometric jitter is not accounted for, the error budget of the quasar increases beyond what can be attributed to photon noise.

Accordingly variability indexes were produced on basis of the mass of the central black hole and the absolute luminosity of the quasar. With these elements the radius of the accretion disk and of the dust torus region were calculated, as apparent angular sizes accounting for the cosmological redshift correction. Those two radii, the accretion disk one in micro-arcseconds and the torus one in milli-arcseconds, are given as the indexes to indicate the likeness of an astrometric jitter that would impact the stability of the centroid during the Gaia mission.

Optical monitoring of extragalactic radiosources to ensure the link between ICRF and the future Gaia celestial reference frame

After two years of observation, a huge amount of optical images of some AGN's selected to ensure the link between the ICRF and the future Gaia celestial reference frame have been gathered (without taking into account the data mining). They come from small robotic telescopes, medium size or large optical facilities spread all over the world.

In 2012 four large telescopes (CFHT, NOT, MPG 2.2 and Rozhen 2m) provided high resolution optical images dedicated to morphology analysis while four smaller ones (OHP, the two TAROT and Zadko) provided images dedicated to photometry. Work is also in progress to add three other medium size telescopes for the mag-

nitude monitoring and the Subaru Telescope in collaboration with a Japanese team for the morphology studies (late 2012 early 2013).

The first results of the optical monitoring campaign have been submitted to “Astronomy and Astrophysics” (Fig. 5). A part of them have been also published in the proceedings of the GREAT ESF meeting held in Porto in June 2011 (Mem. S.A.It. Vol. 83-3, 986, 2012).

All the optical images will be made available to the astronomers by the mean of a database currently under construction in the frame of the ICRS Center. These observations will be also of interest in the frame of the Gaia Initial QSO Catalogue (GIQC) and for astrophysical studies (emission regions, gravitational lensing, photocenter scattering, constraints for binary black holes models).

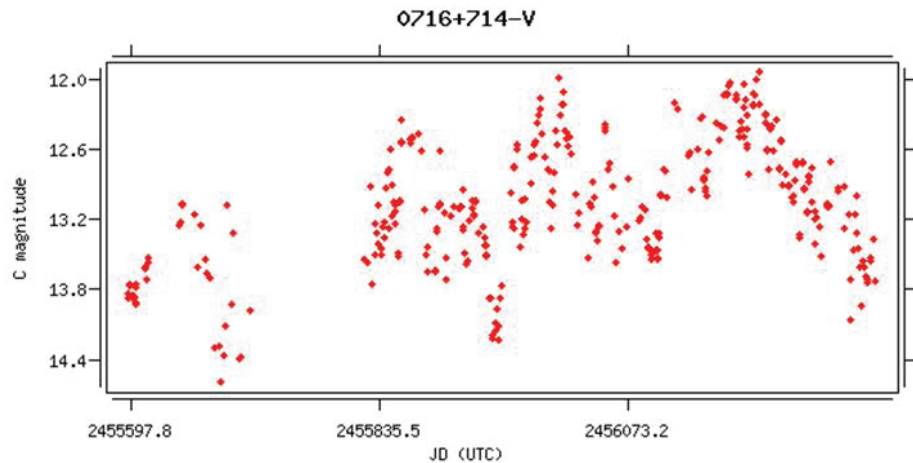


Fig. 5: The target ICRF J072153.4+712036 monitored by one of the TAROT telescope in the filter V

The Large Quasar Astrometric Catalog

The ICRS Center is in charge of the LQAC (Large Quasar Astrometric Catalog), a whole sky compilation of information on known QSOs, as well as of its regular up-dates. The second version of the LQAC, named as LQAC-2 (Souchay et al., 2012) was published as a CDS catalog. The LQAC-2 now contains 187 504 quasars. It delivers complete information (when available) as a set of optical magnitudes and radio fluxes, the redshift, original and consolidated equatorial coordinates, together with re-calculated absolute magnitudes and morphological indexes (see IERS Annual Report, 2010).

Spectroscopic observations of ICRF sources

We continued in 2012 our program of optical spectroscopic observations of ICRF sources. The targets were selected from the International VLBI Service (IVS) candidate International Celestial Reference Catalogue which forms part of an observational VLBI program to strengthen the celestial reference frame. New redshifts

of 120 objects were obtained with five telescopes: the 3.58m ESO New Technology Telescope (NTT), the two 8.2m Gemini telescopes (Chile and Hawaii), the 2.5m Nordic Optical Telescope (NOT), and the 6.0m Big Azimuthal Telescope (BTA) of the Special Astrophysical Observatory in Russia. We obtained spectra of the potential optical counterparts of more than 150 compact flat-spectrum radio sources, and measured redshifts of 120 emission-line objects, together with 19 BL Lac objects. These identifications add significantly to the precise radio-optical frame tie to be undertaken by Gaia, due to be launched in 2013. A few cases of close alignment of the reference radio sources and foreground galactic stars were reported. Fig. 6 shows two images of the quasar IVS B2300-307 obtained under different weather conditions with the 3.58-meter New Telescope Technology (NTT) in 2010 and 2011 years. Fig. 7 shows a sample of spectra of 12 quasars obtained with different telescopes.

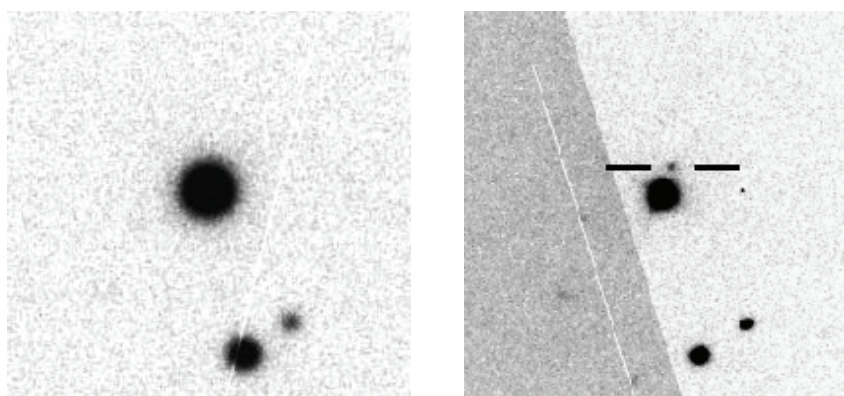


Fig. 6: Two acquisition images of the sky field around the quasar IVS B2300–307 made at the NTT in 2010 August (left: seeing 2") and 2011 December (right: seeing 0".6). Each image is 50" on a side; north is up and east to the left. The foreground star in the centre of the left image completely obscures the quasar due to its large seeing disk. In the right image the much better seeing reveals the faint quasar (marked between the bars), separated by 3".7 from the star. (The diagonal step in contrast in the right image is an artifact of fast readout using two amplifiers for the acquisition image).

Link Between HCRS and Extragalactic Frame

Re-reductions of Cerro Tololo Interamerican Observatory (CTIO) 0.9m telescope data taken of over 400 ICRF optical counterparts between 1997 and 2001 were completed using UCAC4 type reductions of contemporary astrograph observations. The astrograph data provides a strong link between the Hipparcos/Tycho-2 primary reference stars of the Hipparcos Catalog Reference Frame (HCRF) and the faint QSO optical counterparts without impact of proper motion uncertainties of link stars in the 12 to 16 mag range.

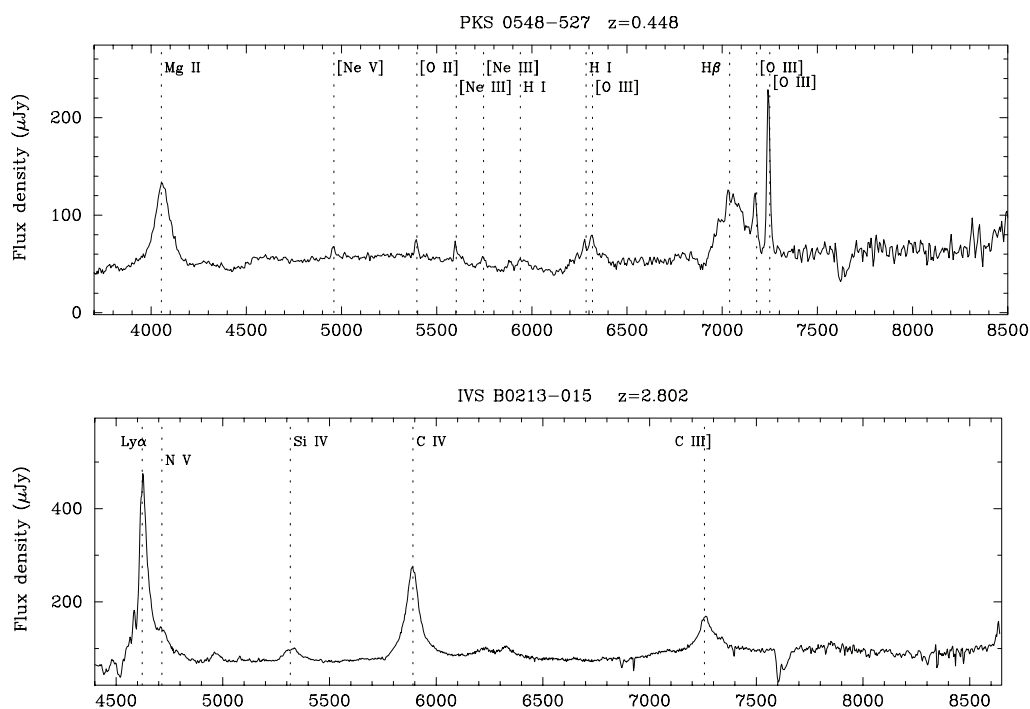


Fig. 7: A sample of spectra of quasars obtained with different telescopes. (GS – Gemini South, BTA – Big Telescope Azimuthal, NTT – New Technology Telescope).

A journal paper is in preparation. First results were presented at the IAU GA (Zacharias, Zacharias & Finch, 2012).

Recent epoch observations with a new generation CMOS detector of Hipparcos stars were performed and first results presented at an AAS meeting (Hennessy et al., 2012). Observed radio-optical position offsets of ICRF sources were discussed in connection with Gaia mission requirements (Makarov et al., 2012).

UCAC 4 The final USNO CCD Astrograph Catalog (UCAC4) was released at the IAU General Assembly in August 2012 (Zacharias et al., 2012). DVDs were sent to previous customers and the catalog is served by CDS. UCAC4 contains accurate positions of over 113 million objects (mostly stars). About 110 million of these have proper motions and 2MASS near-IR photometry. About 50% of stars in UCAC4 could be supplemented with accurate APASS 5-band optical photometry. Bright stars were added from FK6, Hipparcos and Tycho-2 to make UCAC4 a complete catalog down to about 16th magnitude. Meanwhile UCAC3 data were used to discover new high proper motion stars (Finch et al., 2012a).

Quasar position shifts Monitoring of a sample of 12 ICRF optical counterparts continued at the 1.55m telescope at NOFS to investigate possible centroid shifts as a function of time (photometric activity).

URAT The USNO Robotic Astrometric Telescope (URAT) was installed at the Naval Observatory Flagstaff Station (NOFS) where it achieved first light on March 26, 2012. Regular survey observing began on April 24 (Finch et al., 2012b). Several technical issues had to be worked out, like dome shutter failure and lightning protection mitigation upgrades causing interruptions of regular survey observing. Nevertheless over 13,000 exposures were obtained with URAT by the end of 2012, each covering 28 sq.deg of sky. A long (240 sec) and short (60 sec) exposure are taken on each telescope pointing with a 15-fold overlap pattern of the sky to be completed within a year.

During periods of full moon a very short exposure survey (30 and 10 sec) is performed with a grating mounted in front of the lens to provide 1st order diffraction images of bright stars attenuated by about 4.5 mag. The combination of regular and grating survey allows URAT to cover the magnitude range of about 3.5 to 17.5 in a bandpass between R and I. While operations software reached a stable production level by end of 2012, development of reduction code had just begun. For latest information see

[<www.usno.navy.mil/usno/astrometry/optical-IR-prod/urat>](http://www.usno.navy.mil/usno/astrometry/optical-IR-prod/urat) .

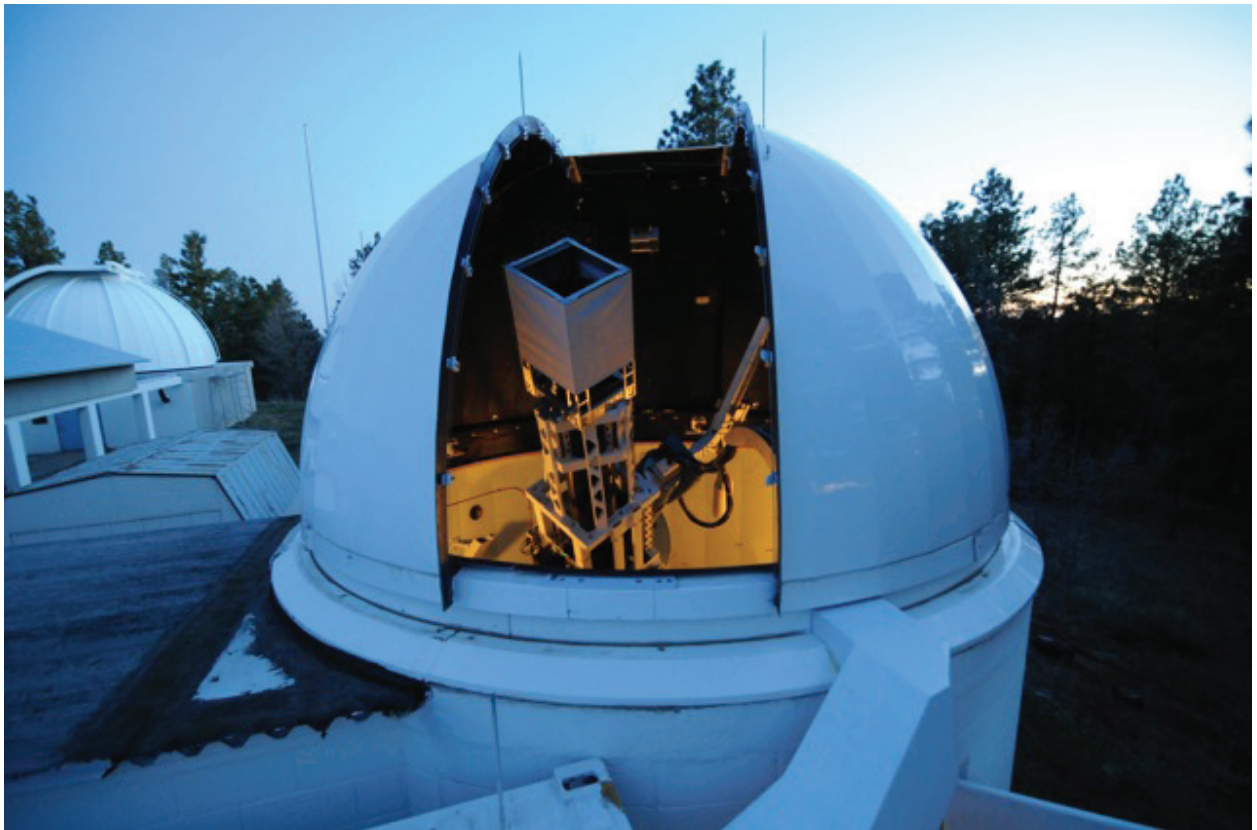


Fig. 8: The URAT dome at NOFS at the beginning of a night of observations in April 2012, as seen from the roof of the control room container.



Fig. 9: The URAT telescope at NOFS with heads of instrument shops Mike DiVittorio (NOFS, left) and Gary Wieder (Washington DC, right). The movable counterweight is seen on the top right to keep the telescope mount in balance depending on liquid nitrogen fill level inside the dewar.



Fig. 10: The URAT "red lens" enabling accurate astrometry in a bandpass between R and I. In this picture the lens is seen without the shutter box.

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*Ralph Gaume, Jean Souchay, Alexandre Andrei,
E. Felicitas Arias, Christophe Barache, Sébastien Bouquillon,
Alan Fey, Agnès Fienga, Gérard Francou, Sébastien Lambert,
François Taris, Oleg Titov, Norbert Zacharias*

3.5.5 ITRS Centre

This report summarizes the activities of the IERS ITRS Centre during the year 2012.

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.

Preparation for a new ITRF web site

The ITRS Centre has started in 2011 the initial study analysis and preparation for a new design of the ITRF web site. It will be designed to provide more ITRF-related information to the users using more user-friendly interfaces. The specification document will be ready in 2012 and the development will start in 2013. The new web site is expected to be operational beginning 2014.

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.

IERS Technical Note on ITRF2008

A technical note on ITRF2008 analysis and results was prepared in 2012 and published by the IERS Central Bureau:

Altamimi, Z., X. Collilieux and L. Métivier (2012), Analysis and Results of ITRF2008, IERS Technical Note No. 37, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main, 2012. Online version: <<http://www.iers.org/TN37>>

Other activities

- Participation in most meetings of the analysis working groups of the Technique Centres (in 2012: IDS, IGS, ILRS);
- Convening and organizing an EGU session: The next International Terrestrial Reference Frame and an update on geocenter motions;
- Participation in the 7th meeting of the International Committee on GNSS held in Beijing, 5 – 9 November 2012.

*Zuheir Altamimi, Xavier Collilieux,
Bruno Garayt, Laurent Métivier*

3.5.6 Global Geophysical Fluids Center (GGFC)

The International Earth Rotation and Reference Systems Service (IERS)'s Global Geophysical Fluids Center (GGFC) provides the geodetic community with models of geodetic effects (earth rotation, gravity, and deformation) driven by the temporal redistribution of the Earth geophysical fluids. These include fluid motions within the Earth system such as the core and mantle, as well as the motions of surface fluids (e.g. oceans, atmospheres, and continental water).

A GGFC workshop was held in Vienna on 20 April, 2012 (see Section 4 of this report). It is our hope, that over the next few years the GGFC and its user community can make progress on many of issues raised at the Workshop and in its recommendations.

In 2012, a call was sent out for proposals for new products. The products accepted as GGFC Provisional Products are shown in Table 1. The procedure for certifying the products requires an analysis of the latency and reliability over a two-year period. In 2014, the original two-year validation will be complete, with certified products upgraded to GGFC Operational Products.

These and all other GGFC Operational and Provisional products can be found through the GGFC website: <<http://geophy.uni.lu/>>, and links to the Special Bureau sites therein.

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.vandam@uni.lu).

Tonie van Dam

Table 1: New GGFC Provisional Products

Proposed GGFC Product	Principal Investigator	Proposed GGFC Operational Center
UNB Vienna Mapping Function Service	M. Santos	University of New Brunswick
• AAM series from 6-hourly operational analysis data starting in 1980, • AAM series from 3-hourly delayed cut-off analysis data starting in 2004, • AAM series from 10-day forecast data, • Cartesian coordinates of the center of mass of the atmosphere and total mass of the atmosphere at 6-hourly intervals • Atmospheric loading ECMWF • Atmospheric gravity coefficients : thin layer approach and vertical integration approach	J. Boehm	Technical University of Vienna
• Atmospheric loading: NCEP • Continental water loading: GLDAS	D. MacMillan	Goddard Space Flight Center
• Site displacements due to atmospheric pressure loading • Low degree harmonic time series from LAGEOS	J.-C. Raimondo R. Koenig	University of Luxembourg
• High resolution atmospheric loading (3-hr; 0.5 deg): ECMWF+IB and ECMWF+MOG2D • atmospheric loading ECMWF reanalysis • Continental water loading: GLDAS, EWMWF reanalysis (soil moisture+snow) • Effects on gravity and surface displacement	J.-P. Boy	Ecole et Observatoire des Sciences de la Terre; University of Strasbourg

3.6 ITRS Combination Centres

3.6.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

In 2012, the focus of the work of the ITRS Combination Centre at DGFI was on continuing the research activities regarding a common realization of the ITRS and ICRS and the computation of epoch reference frames.

Simultaneous computation of CRF and TRF

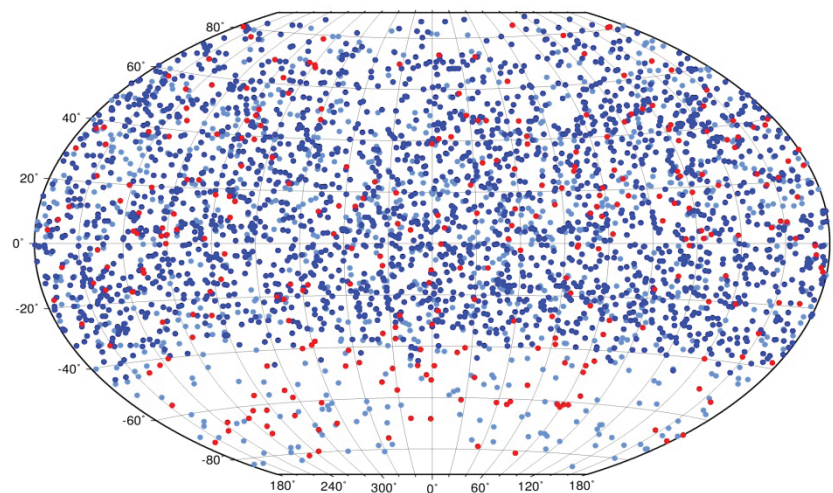
At present, ITRF and ICRF are computed separately by different institutions which apply different software packages. Additionally, the used input data are not the same. Consequently, the two frames and the respective EOP series are not fully consistent. The main inconsistencies are:

- The input data for ICRF are data resulting from the analysis of VLBI observations at one IVS Analysis Center, AC (Goddard Space Flight Center). The input data for ITRF are time series, computed by combining the results of the different ACs for each of the geodetic space techniques VLBI, SLR, GNSS and DORIS. The data are provided by the technique services of the IAG. In case of VLBI, the data of six ACs are combined.
- The ITRF and the VLBI-only terrestrial reference frame VTRF – computed consistently to the ICRF – differ with respect to the network scale. It is realized from VLBI data only in case of VTRF and as a mean of the VLBI and the SLR scale in case of ITRF. Additionally, the network geometry of VTRF and ITRF differ slightly, as the geometry is marginally changed in the combination.
- The EOP derived from ICRF computation are VLBI-only EOP series. Due to the fact, that VLBI does not provide continuous observations, the EOP series are also not continuous. The EOP solved consistently to the ITRF are combined EOP series of VLBI, SLR, GNSS and DORIS, which are continuous for the satellite era.

A consistent computation of TRF and CRF from long time series of VLBI, SLR and GNSS input data (normal equations) was performed at DGFI. While the combination of the station coordinates does not have a systematic effect on the CRF, the EOP combination leads to changes in the standard deviations and positions of the source coordinates:

- The combination of the EOP leads to a general decrease of the standard deviations of the source positions. As expected, the VCS sources (Fig. 1), usually showing standard deviations which are about 5 times larger than those of the non-VCS

Fig. 1: Celestial reference frame (CRF): VCS sources (dark blue) observed by the VLBA station network (Fig. 2), non-VCS sources (light blue), defining sources (red).

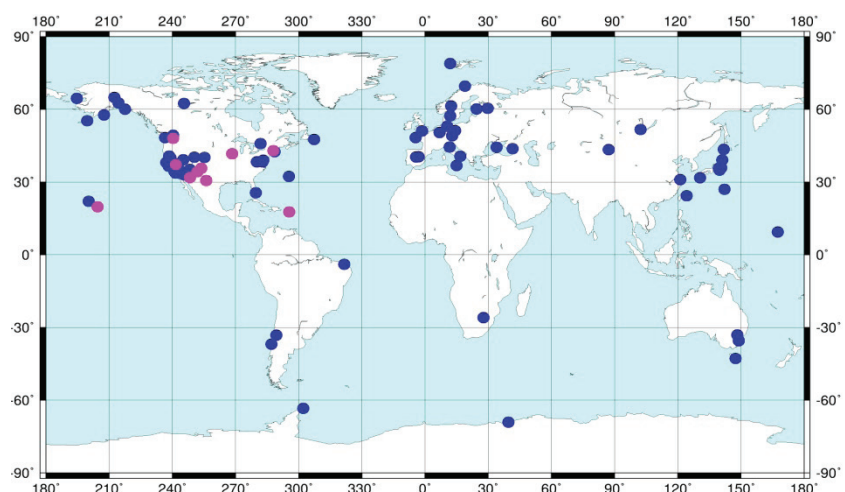


sources, benefit most. About 90% of the effect can be related to the combination of the terrestrial pole coordinates.

- The source positions are also changed by the combination of the EOP. While no systematic effect is found in the declination, some of the VCS sources show systematics in the right ascension, mainly caused by LOD combination. But also the combination of the terrestrial pole coordinates lead to small systematics (see Fig. 3).

Figure 4 displays the correlation matrix of the source positions. While the non-VCS sources show correlations of up to 0.9, the correlations between the VCS sources are very small. It's interesting that the group of VCS sources is better linked to the non-VCS sources than the VCS sources among themselves. A re-observation for the VCS sources in new constellations would help to link the VCS sources much better and would lead to a homogeneous CRF, which is not split into several groups of sources.

Fig. 2: Global VLBI station network. The stations of the VLBA network are magenta-colored.



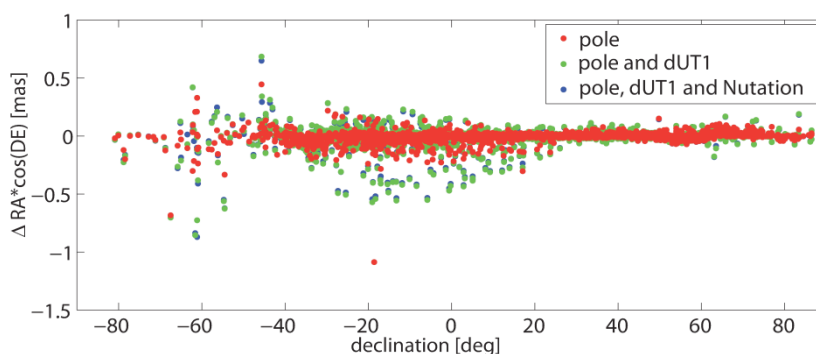


Fig. 3: Effect of the combination on the CRF: Change of right ascension due to different kinds of EOP combination: only terrestrial pole coordinates are combined (red), terrestrial pole coordinates and UT1–UTC parameters are combined (green), all EOP, i.e. coordinates of the terrestrial and the celestial pole and UT1–UTC are combined (blue).

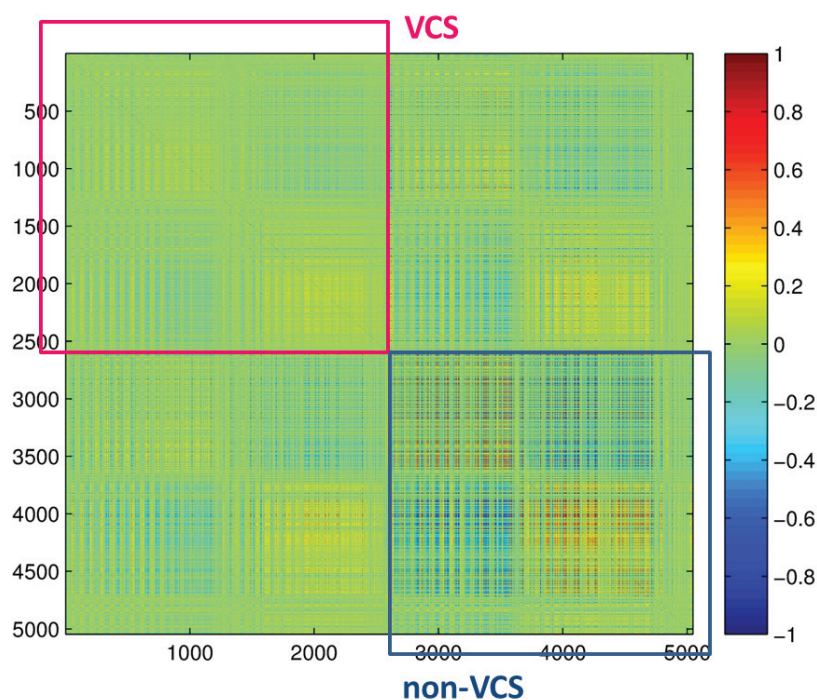


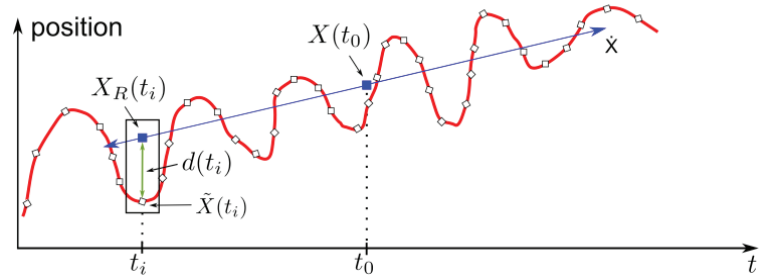
Fig. 4: Correlation matrix of source positions sorted by VCS and non-VCS sources. In each of the two blocks the sources are sorted by right ascension. This leads to the small block structure. Sources with a right ascension between 0 and 12h are positive correlated. The same holds for sources with a right ascension between 12h and 24h. Correlations between the two groups are negative.

Epoch reference frames (ERFs)

State-of-the-art realizations of terrestrial reference frames (TRFs) realize the motion of a reference point, connected with the Earth's crust, by a constant velocity. Global and environmental deformations of the crust (e.g., due to tides and loading effects) affect the short-term and long-term motion in a periodic manner. Additionally, aperiodic motions are caused by earthquakes or by man-made changes, such as technical updates of a station. Since these variations cannot be taken perfectly into account by models, the residual variations propagate into the observation residuals

or falsify other consistently estimated parameters such as the Earth Orientation Parameters (EOP). To study the impact of non-linear station motions on the EOP, one possibility is to estimate the station position frequently (e.g., weekly). In this alternative station parameterization, the station motions are approximated by a time-discrete signal. Figure 5 shows the differences $d(t_i)$ between the conventional parameterization $X_R(t_i)$ used for e.g., the International Terrestrial Reference Frame 2008 (ITRF2008) and the parameterization $\tilde{X}(t_i)$, used for the most recent realization of the DGFI ERFs.

Fig. 5: Different station motion parameterization in the conventional reference frame realizations (such as ITRF2008), $X_R(t_i)$, and DGFI ERFs, $\tilde{X}(t_i)$.



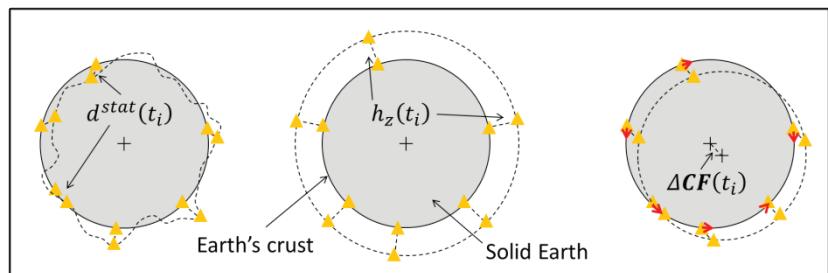
The differences can be separated into three constituents (Fig. 6):

$$d(t_i) = d^{stat}(t_i) + [\Delta CF(t_i) + h(t_i)], \quad (1)$$

with the *individually performed* non-linear station motion $d^{stat}(t_i)$ caused by local environmental effects (e.g., groundwater withdrawal), the non-linear height variation $h(t_i)$ *common to all stations* which not affects the Center of Frame (CF) but the network scale and the non-linear variation of the CF w.r.t. the Center of Mass of the whole Earth ($CM \equiv 0$) caused by non-linear motions *common to all stations*.

The CF is defined not to be the barycenter of the station network but the Center of the best-fitting ellipsoid through the station coordinates. Depending on the network geometry (station distribution), the origin of the network is correlated with the orientation of the network (Fig. 6). Since the network orientation in x- and y-direction and the terrestrial pole coordinates y and x are complementary parameters, variations in the origin of the network affect the terrestrial pole coordinates.

Fig. 6: The three constituents of $d(t_i)$. Common translations $\Delta CF(t_i)$ can cause rotations (red arrows in right panel) common to all stations (triangles) in the conventional parameterization.



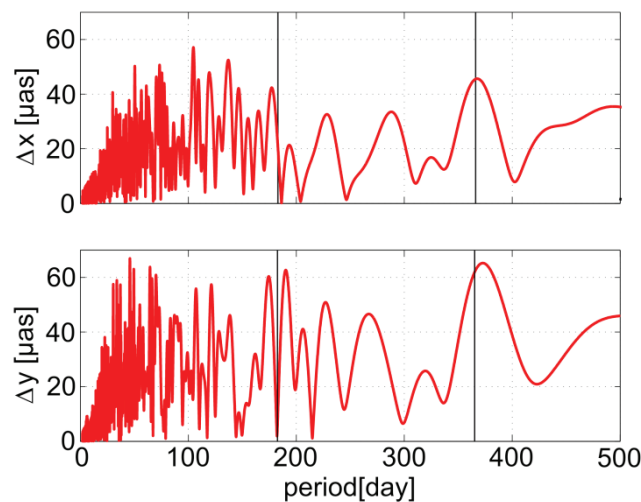


Fig. 7: Amplitude spectra of the x- and y-pole difference time series using the conventional and the ERF station parameterization (Fig. 5). Amplitudes of $10.0 \mu\text{as}$ are equal to a distance of 0.3 mm at the Earth's surface.

The above described relationship plays an important role especially for SLR. Since this technique is sensitive to the CM and the global station distribution is not homogeneous, the differences $d(t_i)$ excite a clear seasonal variation (Fig. 7) with amplitudes of 1.43 mm in the x-pole and in the y-pole, respectively. The seasonal period is caused by the mainly seasonal character of the differences $d(t_i)$ since in this analysis, the loading displacements due to the atmosphere and the hydrology are not considered. The signals with periods lower than the seasonal frequency band reach still amplitudes of up to 2.0 mm and are influenced to a larger extend by the individual station motions $d^{\text{stat}}(t_i)$.

The results of this analysis show that the EOP of the conventional TRF realization are affected by the not-parameterized non-linear station motions. Nevertheless, the TRF realizations are, due to their high long-term stability, fundamental for monitoring long-term changes within the Earth's system.

Acknowledgements

We thank Peter Steigenberger (FESG, TU Munich) and Thomas Artz (IGG, University Bonn) for providing the GNSS and VLBI input data, respectively.

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3.6.2 Institut National de l'Information Géographique et Forestière (IGN)

This report summarizes the activities of the ITRS Combination Centre at IGN during the year 2012. These research activities are mainly related to the ITRF2008 results.

ITRF2008 Plate Motion Model

For various geophysical and geodetic users' applications, we estimated a plate motion model derived from and consistent with ITRF2008, for 14 major tectonic plates, and published in Journal of Geophysical Research (Altamimi et al., 2012). The analysis we adopted to estimate the ITRF2008 Plate Motion Model (ITRF2008-PMM) consisted in the simultaneous estimation of angular velocities of the 14 plates, together with a global translation rate parameter representing an Origin Rate Bias (ORB) of the selected velocity field of 206 sites, far from plate boundaries and deformation zones. The results of this study indicated that we were able to determine an ITRF2008-PMM with an RMS of 0.3 mm/yr. In addition to the precise estimation of the plate angular velocities, we also evaluated the ORB and compared our results to the most used geophysical models, namely NNR-NUVEL-1A and NNR-MORVEL56 elaborated by Donald Argus from JPL, in 1991 and 2011, respectively. The components of the evaluated ORB are (in mm/yr): 0.41 ± 0.27 , 0.22 ± 0.32 , 0.41 ± 0.30 over the three axes (XYZ). In addition, we observed a large angular residual velocity of the order of 4 mm/yr of the Australian plate between ITRF2008-PMM and NNR-MORVEL56, as illustrated by Figure 1. This bias is not observed when comparing ITRF2008-PMM to NNR-NUVEL-1A, suggesting that it is originated from the new model NNR-MORVEL56.

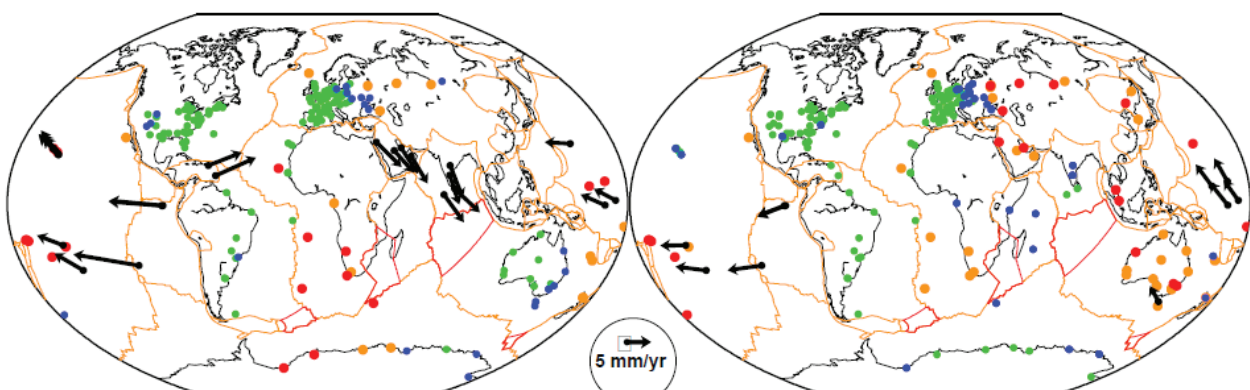


Fig. 1: Velocity differences after rotational transformation between ITRF2008 and NNR-NUVEL-1A (left) and NNR-MORVEL56 (right). In mm/yr: green: less than 2; blue: between 2 and 3; orange between 3 and 4; red between 4 and 5; black larger than 5.

Research and development activities

The members of the IGN CC, often in cooperation with other scientists, conduct research and developments activities relating to the ITRF in particular and reference frames in general. R&D activities include ITRF accuracy evaluation, mean sea level, loading effects, combination strategies, and maintenance and update of CATREF software. Scientific results of specific data analysis and combination are published in peer-reviewed journals, as listed in the references' section, but also presented at international scientific meetings.

Publications

Altamimi, Z., L. Métivier and X. Collilieux (2012), ITRF2008 plate motion model, *J. Geophys. Res.*, 117, B07402, doi:10.1029/2011JB008930.

Altamimi, Z., X. Collilieux and L. Métivier (2012), Analysis and Results of ITRF2008, IERS Technical Note 37, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main, 2012.

Chen, Q., T. van Dam, N. Sneeuw, X. Collilieux and M. Weigelt (2012) Singular spectrum analysis for modeling seasonal signals from GPS time series, *Journal of Geodynamics*, in review

Métivier, L., X. Collilieux, and Z. Altamimi (2012), ITRF2008 contribution to glacial isostatic adjustment and recent ice melting assessment, *Geophys. Res. Lett.*, 39(L01309), doi:10.1029/2011GL049942.

Santamaría, Á., M. Gravelle, X. Collilieux, M. Guichard, B. Martín Míguez, P. Tiphaneau and G. Wöppelmann (2012) Mitigating the effects of vertical land motion in tide gauge records using a state-of-the-art GPS velocity field, *Global and Planetary Change*, 98–99, p. 6–7, doi:10.1016/j.gloplacha.2012.07.007

van Dam, T., X. Collilieux, J. Wuite, Z. Altamimi and J. Ray (2012) Nontidal ocean loading effects in GPS height time series, *Journal of Geodesy*, DOI 10.1007/s00190-012-0564-5

Zuheir Altamimi, Xavier Collilieux, Laurent Métivier

3.7 IERS Working Groups

3.7.1 Working Group on Site Survey and Co-location

After the positive response of the IERS Directing Board to P. Sarti's proposal to initiate a co-chair of the working group with Dr. John Dawson (Geoscience Australia), from January 2012 the co-chair became effective. The Charter of the working group was revised by the new chairs and the Terms of Reference and goals were re-written as follows.

Terms of Reference

The combination of space geodetic solutions is critically reliant on the availability of local tie vectors, which are the relative positions of the reference points of co-located space geodetic instruments determined by some survey technique. Tie vectors enter the combination of space geodetic solutions effectively as a fifth technique and are not only necessary for rigorous terrestrial reference frame realization but also serve to highlight the presence of technique- and/or site-specific biases.

With the ultimate objective of improving the accuracy of tie vectors as well as the consistency of space geodetic solutions, the Working Group (WG) will provide an authoritative source of surveying methodology advice, promote technical discussion, provide a forum for the evaluation of existing and new procedures and analysis strategies, and support the exchange of relevant information across GGOS and between the IAG technique services. The WG will also support new survey activities with advice and advocate for re-survey where necessary.

Goals and objectives

Research:

- Revise existing local tie procedures
- Revise existing tie vector estimation processes
- Develop and define new methods

Coordination:

- Liaise with IERS combination centres
- Liaise with IAG technique services
- Direct research towards the investigation of technique specific systematic effects

Outreach:

- Remotely support local tie operations and tie vector estimation
- Spread the know-how
- Set guidelines

2012 WG Meeting

The annual meeting of the *IERS Working Group on Site Survey and Co-location* took place on April 25th, 2012 at the Vienna International Centre, room SM6, during the EGU2012, 13:30-15:00. As it is usual, the meeting was very well attended: the list of 38 participants is given in Table 1.

The large number of attendees evidently confirmed the strong interest related to the investigations promoted by the working group.

A presentation given by Pierguido Sarti summarized the last three years of activity of the WG, highlighting the major achievements and the problems that still remain unsolved. The presentation can be found at the WG web site in the “documents” section and in the 2012 meeting sub-section.

A long standing goal is the preparation of a handbook containing local tie procedures and tie vectors computation guidelines, easy to use for surveyors and other interested users. The task is far from being trivial as the procedures implemented at each observatory are usually site dependent and largely rely on the know-how of the local surveyors. Though, a document containing general guidelines is still highly desirable and should be prepared and endorsed by the WG.

The IERS DB has approved the creation of an action group (AG) to actively face some stringent requirement related to the archiving, standardization and availability of the local tie data. The AG will be operatively supported by the IGN (France) and will be formed by people working at IGN with an advisory board created by a selection of members of the WG. IGN also aims at continuing the local tie survey activity once per year. Additionally, NGS (USA) has the same commitment for the future years.

A presentation was given by X. Collilieux to illustrate the design of the web site developed at IGN to archive and format the local survey data. IGN aims at establishing a permanent service to access the relevant information and the metadata for each co-location site. The presentation is available on the IERS web page dedicated to the WG activities, under the “documents” section and in the 2012 meeting sub-section.

A major shortcoming in the magnitude of the discrepancies between tie vectors and space geodetic solutions is related to space geodetic techniques systematic errors. Jim Ray presented a comprehensive overview of the state of the art on this topic. It is obvious that an improvement of the combination residuals requires a tight cooperation between all four IAG space geodetic services and the agencies/surveyors in charge of the local ties. The WG can serve here as efficient common forum.

It was proposed to organize a new workshop/school on local ties and tie vector computation after 10 years from the first one held in 2003. Proposed locations were Matera (Italy) or Paris (France) in a period shortly before or after the IERS Directing Board retreat.

3.7 IERS Working Groups

Table 1: 2012 working group meeting participants list.

Participant name	Institution	e-mail
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Web site The WG's web site <<http://www.iers.org/WGSiteSurvey>> is maintained by the IERS Central Bureau with input from the WG Chair. In 2012, new documents were added.

Pierguido Sarti

3.7.2 Working Group on Combination at the Observation Level

Introduction

The IERS “Combination at the Observation Level” (COL) Working Group was created in 2009. Its main objective is to bring together groups able to perform combinations of space geodetic techniques (DORIS, GNSS, SLR and VLBI) at the level of observations searching for an optimal strategy to simultaneously solve for geodetic parameters, in particular Earth Orientation Parameters, terrestrial and celestial reference frames. This implies to improve the accuracy, the time resolution and the overall consistency of the geodetic products derived.

Progress of the project

A Working Group meeting took place at the DGFI in Munich in May 2012. Its objective was first to review the Analysis and Combination Centres activity (AIUB, ASI, DGFI, ESOC, GRGS, GSFC) concerning the two inter-comparison benchmarking campaigns corresponding to the VLBI CONT08 and CONT11 intensive projects.

Discussions developed about the following points:

Use of the defined standards and a priori recommended models over both test periods, on the data sets to be used (list of stations, number of data rejected per technique and per week), number of satellites to be processed (for instance Etalon, Starlette, Stella, Jason, ...). This can be particularly of interest for multisatellite processing as it is done at ESOC. The way Pole and UT1 parameters had to be parameterized was as well discussed.

SINEX file compatibility. Most of discrepancies which were still present are now solved.

Supply by the combination center OP of variance factors obtained by the Helmert’s variance component estimation method for all normal equation, this in the objective of weighting.

Minutes of the meeting and presentations from ACs and CCs are available on the following site:

<<http://www.iers.org/WGCOL>> (see “Activities” section).

Combination processing at the GRGS Combination Center

Implementation of the No Net Rotation (NNR) condition for the Celestial Reference frame

In order to align positions of radio sources to the a priori catalog (ICRF2) we introduce a constraint so that the global transformation, i.e. three rotations, between the a priori and the estimated catalogue is zero. This no net rotation condition for the celestial frame was developed and introduced in the combination package DYNAMO. The variations of the three angular parameters which were estimated with respect to the ICRF2 are shown for each period CONT08 and CONT11 on Figure 1. As expected, values are small.

Handling systematic effects before combination

Combining reference frames of various geodetic techniques requires expressing them in a unique homogeneous frame. However, this is not perfectly realized. Due to inaccuracies in coordinates,

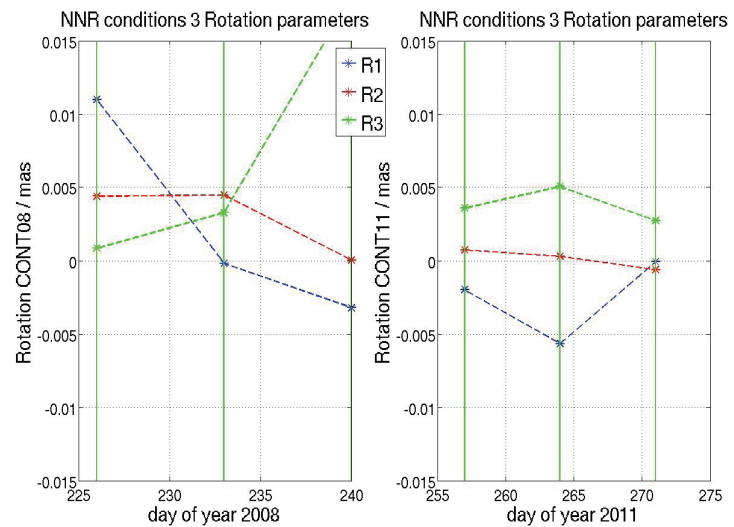


Fig. 1: NNR parameters variations over CONT08 and CONT11 periods

individual reference frames are affected by systematic effects. Consequently, before their combination, it is necessary for each technique to identify, calculate and remove these effects with respect to a standard reference frame such as ITRF2008.

For each technique, the a priori station coordinates expressed in the ITRF reference frame are transformed into a common reference frame by the introduction of the Helmert parameters. Systematic effects estimated over CONT08 and CONT11 periods are shown on Figure 2. Table 1 summarizes the rank deficiency of the geodetic techniques used and the Helmert parameters added.

Table 1: Rank deficiency and Helmert parameters of geodetic techniques

	Satellite techniques DORIS, GNSS, SLR	VLBI
Rank deficiency	Orientation imperceptible Rx, Ry, Rz	Frame orientation undefined Rx, Ry, Rz & Origin imperceptible Tx, Ty, Tz
Helmert parameters	Tx, Ty, Tz, Scale	Scale

Retrograde diurnal oscillation cancelled for sub-diurnal EOP

There is some ambiguity in the respective definition of nutation and polar motion in the diurnal band. These parameters are separated in the conventional parameterization. Thus theoretically, there is no retrograde diurnal component to polar motion; however, when estimating the polar motion in the diurnal/sub-diurnal band, an oscillation appears. This oscillation should not exist, and consequently has to be put to zero by adding constraints. The corresponding procedure was implemented in the DYNAMO package.

3.7.2 Working Group on Combination at the Observation Level

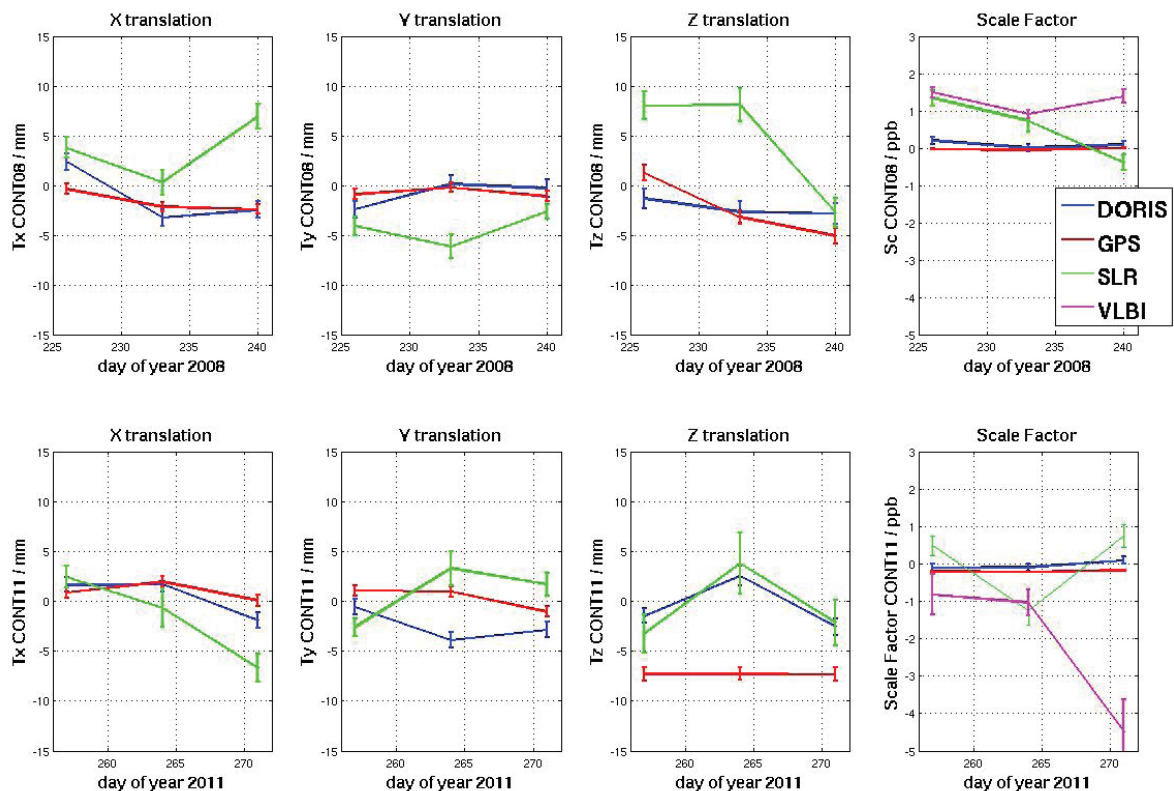


Fig. 2: Systematic effects over CONT08 and CONT11

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*Daniel Gambis, Jean-Yves Richard
and the members of the COL Working Group*

3.7.3 Working Group on SINEX Format

The IERS Working Group (WG) on SINEX Format was established in early 2011, with a kick-off meeting during EGU General Assembly 2011 in Vienna.

In 2012, one WG meeting was held on April 23, in conjunction with the EGU General Assembly 2012 in Vienna. The agenda and the minutes are available on the website <<http://www.iers.org/WGSINEX>>.

WG Members

The list of WG members was changed only slightly during 2012: Jim Ray handed over the IGS Analysis Center Coordination (ACC) to Jake Griffiths. He will be the representative of the IGS ACC in the SINEX WG, and Jim Ray will continue his participation in the WG.

- Chair: Daniela Thaller
- IERS Analysis Coordinator (ex officio): Tom Herring
- IERS Central Bureau (ex officio): Bernd Richter
- IDS Analysis Coordination: Laurent Soudarin
- IDS Combination: Guilhem Moreaux
- IGS Analysis Center Coordination: Jake Griffiths (replaced Jim Ray)
- IGS Reference Frame Working Group: Paul Rebischung
- ILRS Analysis Coordination: Erricos Pavlis
- ILRS Combination: Cecilia Sciaretta
- IVS Analysis Coordination: Axel Nothnagel
- IVS Combination: Sabine Bachmann
- ITRS Center and ITRS Combination Center at IGN: Zuheir Altamimi
- ITRS Combination Center at DGFI: Manuela Seitz
- IERS Co-location Working Group: Pierguido Sarti
- IERS Conventions Center: Gérard Petit
- GGOS Bureau for Standards and Conventions: Peter Steigenberger

Revision of SINEX Format

A list of topics to be revised or added to the SINEX format description was compiled and discussed in conjunction with the kick-off meeting (see IERS Annual Report 2011). Several topics out of this list were further discussed and worked on by members of the SINEX WG during 2012:

- Mathematical background (Appendix II)
- Phase center issues, antenna offsets and SATELLITE/ID block for satellite techniques
- Weighting of satellites, techniques, etc.
- DISCONTINUITY block

Appendix II containing the mathematical background on how to handle the information given in the SINEX file was revised under

the leadership of Manuela Seitz (DGFI). The new version was circulated within the working group. Only minor remarks were suggested by the WG members and subsequent changes made. Therefore, Appendix II is finalized.

The phase center issues and antenna offsets were discussed among the WG members representing the analysis of the satellite techniques' observations. The goal is to make the block SATELLITE/ID also applicable for non-GNSS solutions and satellites, and to define how the antenna phase center models (for GNSS and DORIS) or the SLR reflector offsets (for SLR) should be specified in a SINEX file. It was agreed that the format itself will not be changed, but a dedicated remark will be added to the format description in order to explicitly define the satellite numbers in the SATELLITE/ID block. The specification of the antenna / reflector model will be considered in a new block on modelling issues.

The IDS representatives brought up the request to provide information on satellite-specific weighting in the SINEX file. Two proposals were prepared together with the chair of the WG: Add this information to the SATELLITE/ID block, or define a new block for weighting issues. In the latter case, the weighting could be extended from satellite-specific only to, e.g., technique-specific or station-specific weighting. The WG decided that the satellite-specific weighting should be separated from the SATELLITE/ID block in order to have more flexibility. A final decision regarding how the new block for weighting issues should be defined has not been made yet.

The group at IGN (Institut Géographique National) provided a document with pros and cons for different ways of defining the block DISCONTINUITY and related information stored in other blocks. It was proposed that the best way of storing all information related to discontinuities in SINEX will be evaluated during the computation of ITRF2013. The ITRF combination centers then will provide a proposal to the WG.

The third Unified Analysis Workshop (UAW) that took place in Zurich, September 2011 brought up another important topic to be clarified in the SINEX format description: the parameterization, especially for the Earth orientation parameters (EOPs). This request is supported by the IVS, too. Parameterizations as piece-wise linear polygons (that are especially needed if highly resolved time series are estimated, e.g., 1 hour) on the one hand and piece-wise constant offsets on the other hand cannot be represented unambiguously in SINEX. Therefore, the parameter definition for EOPs has to be revised in the SINEX format description. The discussion on this topic is still ongoing.

Daniela Thaller (on behalf of all WG members)

3.7.4 Working Group on Site Coordinate Time Series Format

Charter	The temporal variations of the position of points on the Earth's surface are useful observations to monitor geophysical process (land deformation, post-glacial rebound, seismic activity ...). The IAG services that distribute GNSS, SLR, VLBI and DORIS data and products proposes plots and/or files of coordinates time series for the stations of the tracking networks, as well as web services to display these time series. However, the time series, when available, are proposed in different formats and give position series under various forms (residuals, trended or detrended, cartesian or geographic coordinates ...).
Introduction	One of the outcomes of the Unified Analysis Workshop 2011 (UAW 2011) in Zurich was the action item to establish an IERS Working Group on site coordinates time series to define a common exchange format for coordinates time series for the geodetic techniques. The format should provide a user-friendly presentation of co-ordinate time-series results for a potentially broader community of users. One of the objectives of the group is to define the data and meta-data to be included so that the format is self-described and can be easily used or converted for, at least, the existing web tools of the IAG Services (GGOS, IERS, IDS, IGS, ILRS, IVS). The group will ensure that comparisons of time series can so be possible between GNSS, SLR, VLBI and DORIS, but also with other techniques such as tide gauges records. Some of the issues that should also be addressed are, e.g., reference system, time unit, content description ...
Goals and objectives	The major goals and objectives of the WG are: 1. Define a common exchange format for coordinate time series of all geodetic techniques (DORIS, GNSS, SLR, VLBI ...). 2. Examine what type of time series is required (geocentric, detrended, reference frame, ...). 3. Define the data and meta-data that should be included in the format. 4. Ensure that the format contains the necessary information to be easily used or converted for the web tools of the IAG Services (GGOS, IERS, IDS, IGS, ILRS, IVS).
Members	Laurent Soudarin (CLS) Chair Bernd Richter (BKG) GGOS portal manager Thomas Herring (MIT) IERS Analysis Coordinator Xavier Collilieux (IGN) ITRS Combination Center Manuela Seitz (DGFI) ITRS Combination Center

3.7.4 Working Group on Site Coordinate Time Series Format

Laurent Soudarin (CLS) IDS representative

Paul Rebischung (IGN) IGS representative

Erricos Pavlis (Univ. of Maryland, Baltimore County) ILRS representative

Alexis Nothnagel (Uni. Bonn) IVS representative

Médéric Gravelle (Uni. La Rochelle) user (SONEL)

Yehuda Bock (Scripps Institution of Oceanography) user (SOPAC GPS webservice)

Simon Williams (Proudman Oceanographic Laboratory) user (CATS software)

Xiaoping Wu (JPL) user

Summary of the activity in 2012

The WG has been established in April 2012 by the IERS Directing Board.

The first meeting of the WG was organized in San Francisco at AGU, on December 6th, 2012 with nine attendees: Detlef Angermann (DGFI), Daniela Thaller (AIUB), Sabine Bachman (BKG), Paul Rebischung (IGN), Samuel Namahni (IGN), Claudio Abbondanza (JPL), Xiaoping Wu (JPL), Thomas Herring (MIT), Laurent Soudarin (CLS). Despite a very short time of meeting, we had rich discussions on some important issues concerning the data: time scale, reference system, coordinate system ... The metadata are of prime importance in the format because they will give the necessary information to identify the time series and to make them easily used. They were briefly discussed. S. Bachman informed us of the existence of ISO standards for Geospatial metadata, and of the metadata search engine included in the GGOS portal.

Laurent Soudarin

4 GGFC Workshop

A GGFC Workshop was held in Vienna on 20 April 2012 with the goal of allowing the Special Bureau Chairs, the GGFC Product Centers, and the GGFC user community to review the structure and data holdings of the GGFC and to make suggestions for new products. Thirty scientists from the geodetic community attended the workshop with an agenda of 20 presentations! In addition to presentations by the SB chairs, there were presentations 1) reviewing some of the newly proposed GGFC Provisional Products, 2) comparing models with geodetic observations, 3) showing geodetic observations driven by fluid redistribution, and 4) providing a statement of current issues and future challenges for the GGFC and geodetic community.

Program

The following presentations were given at the workshop:

- | | |
|--|--|
| 1) GGFC: Current Status | The GGFC Special Bureau for the Oceans: Providing Ocean Products for Geodesy
Richard S. Gross

Special Bureau for Hydrology
Jianli Chen

Combination Products
Tonie van Dam, Mike Thomas

Global Geophysical Fluids: an IERS RS/PC Perspective
Brian Luzum et al. |
| 2) GGFC: Proposed new Products | Mass Loading Products at NASA GSFC
D. MacMillan, D. Erikson; Chopo Ma (presenter)

High-resolution models of surface displacements caused by atmospheric, oceanic and hydrological loads
Jean-Paul Boy

Atmospheric effects in space geodesy: plans and perspectives
Johannes Boehm et al.

The GRACE AOD product release 05
H. Dobsław et al.; Rolf König (presenter) |
| 3) Comparison of Models with Observations | Consistency of Crustal Loading Signals Derived from Models & GPS: Inferences for GPS Positioning Errors
Jim Ray et al.

SLR Test Products Using ECMWF Atmospheric Loading and Gravity
Erricos C. Pavlis, Magdalena Kuzmicz-Cieslak |

Evaluations of Global Geophysical Fluid Models Based on Broad-band Geodetic Excitations

Wei Chen, Jim Ray

How well can we estimate the displacements associated to loading?

Pierre Valtý et al.

4) Observations Degree 2 and Geocenter Variations from Satellite Laser Ranging

Minkang Cheng

Low degree harmonic series from LAGEOS

Rolf König

Global Mass Balance Effects on the Earth's Rotation Rate

Haoming Yan, Ben F. Chao

5) Issues and Future Challenges On the challenges of developing a mass conserving system model

Maik Thomas et al.

How to deal with coordinate systems in numerical weather models? - Goals of the newly formed IAG SSG12

Thomas Hobiger et al.

Mitigation of unmodelled non-tidal atmospheric pressure loading into parameters of a global GNSS solution

Rolf Dach et al.

Call for space geodetic solutions corrected for non-tidal atmospheric loading (NT-ATML) at the observation level

Xavier Collileux et al.

Uncertainties in models for glacial isostatic adjustment

Wouter van der Wal, Valentina Barletta

Satellite Gravity Measurements and the Global Water Cycle

Jianli Chen

The detailed workshop program and copies of most of the presentations are available at <<http://www.iers.org/Workshop2012>>.

Recommendations The highlights of the meeting are summarized in the following recommendations:

1. Special bureaux should investigate forming intra-fluid/intra-model weighted combined products of available models (including forecasts), in part to investigate ways to quantify (relative) errors of each model. However, this might complicate efforts to form multi-fluid products with full internal consistency (see below).

2. The GGFC should promote the development and use of dynamic barometer models and products, especially for short-period (less than ~ 10 d) applications.
3. Greater availability of sub-daily product sampling should be sought for all surface fluids (down to 3 hr or shorter).
4. Special bureaux should consider ways to move towards adoption of common product formats (and delivery modes), at least for load grids.
5. Efforts should be made to reduce the latency of the availability of the products required for operational use (for example especially when oceanic forcing is used). This might be addressed by provision of suitable forecast products if their accuracy is sufficient.
6. The GGFC should lead a community effort to review and elaborate recommended procedures and algorithms to compute EOP excitations from geodetic time series, especially to ensure the best fidelity for the high-frequency regime.
7. Apparent large discrepancies in surface hydrology EOP excitations should be investigated in view of the relatively better performance of such models in computing local surface load displacements than for global angular momentum variations. It seems likely that large-scale time-variable biases in the hydrology models might degrade globally integrated products, like EOP excitations.
8. Working with the Technique Services and the greater geodetic community, the utility of load corrections in geodetic data reductions needs to be much better quantified and put on a sound statistical basis taking account of actual SNR values for the loads as a function of sampling intervals.
9. Global mass conservation is one of the biggest issues facing the community. Mass conserving system models (i.e. atmosphere+ocean +water storage) do not exist for geodetic applications. The current solution is to sum different models. This leads to inconsistencies. Recommendation: Only models (for example ocean and hydrology) that are forced by the same atmospheric model and consider continental discharge into the oceans should be combined to compute total effects.
10. At the same time, a much better understanding of the nature and magnitude of internal measurement errors by all the space geodetic techniques is needed, especially at short temporal samplings, if these are to be used to evaluate fluid-based load models.

Tonie van Dam, Wolfgang R. Dick

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 Subcommittee 1.1
President of IAG Subcommittee 1.2
President of IAG Subcommittee 1.4
President of IAG Commission 3
President of IAG Subcommittee 3.1
President of IAG Subcommittee 3.2
President of IAG Subcommittee 3.3
President of IAU Commission 8
President of IAU Commission 19
President of IAU Commission 31
Head of IAU Division I

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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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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 <code>ser7</code> Monthly earth orientation data Web access: http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins ftp access: hpiers.obspm.fr - directory <code>iers/bul/bulb_new</code> Long term earth orientation data Web access: http://hpiers.obspm.fr/eop-pc/index.php?index=eoptable ftp access: hpiers.obspm.fr - directory <code>iers/eop</code> Leap second announcements Web access: http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins ftp access: hpiers.obspm.fr - directory <code>iers/bul/bulc</code> Announcements of DUT1 Web access: http://hpiers.obspm.fr/eop-pc/index.php?index=bulletins ftp access: hpiers.obspm.fr - directory <code>iers/bul/buld</code>
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 <code>iers/icrs-pc</code>
International Terrestrial Reference Frame	Web access: http://itrf.ensg.ign.fr/ ftp access: lareg.ensg.ign.fr - directory <code>pub/itrf</code>
Geophysical fluids data	Web access: 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

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IERS Annual Reports

<http://www.iers.org/AnnualReports>

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IERS Components

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Earth Orientation Centre

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ICRS Centre

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ITRS Centre

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Global Geophysical Fluids Centre

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Special Bureau for Hydrology

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	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>>.

2MASS	Two Micron All Sky Survey	CDDIS	NASA Crustal Dynamics Data Information System
AAM	Atmospheric Angular Momentum	CDS	Centre de Données astronomiques de Strasbourg
AAS	American Astronomical Society	CEOS	Committee on Earth Observation Satellites
AC	Analysis Centre	CERGA	Centre d'Etudes et de Recherches Géodynamiques et Astronomiques
AC	Analysis Coordinator	CF	Center of Frame [origin of ITRF]
ACC	[IGS] Analysis Center Coordinator	CfA	Harvard-Smithsonian Center for Astrophysics
AG	action group	CFHT	Canada-France-Hawaii Telescope
AGU	American Geophysical Union	CfP	Call for Participation/Proposals
AIUB	Astronomical Institute, University of Bern	CLS	Collecte Localisation Satellites
AOD	atmospheric and oceanic dealiasing	CM	[instantaneous] centre of mass of the whole Earth
APASS	AAVSO Photometric All-Sky Survey	CMOS	complementary metal-oxide-semiconductor
APSG	Asia-Pacific Space Geodynamics	CNES	Centre National d'Etude Spatiale
AR	[IERS] Annual Report	CODE	Centre for Orbit Determination in Europe
AR	autoregressive	CoG	center of gravity to effective reflection surface
asap	as soon as possible	COL	combination at/on the observation level
ASETEP	Asteroidal Effects on the Terrestrial Planets	CoM	centre-of-mass
ASI	Agenzia Spaziale Italiana	CONT	continuous VLBI session/campaign
ATML	atmospheric loading	Corp.	Corporation
AUS	= AUSLIG	COSMC	Czech Office for Surveying, Mapping, and Cadastre
AUSLIG	Australian Surveying and Land Information Group (now: Geoscience Australia)	CRD	Consolidated Laser Ranging Data Format
AWG	Analysis Working Group	CRF	Celestial Reference Frame
BIH	Bureau International de l'Heure	CSR	Center for Space Research, University of Texas
BIPM	Bureau International des Poids et Mesures	CTIO	Cerro Tololo Inter-American Observatory
BKG	Bundesamt für Kartographie und Geodäsie	CV	Curriculum Vitae
BTA	Big Telescope Azimuthal	DB	Directing Board
BVID	Bordeaux VLBI Image Database	DC	Data Center
Caltech	California Institute of Technology	DC	District of Columbia
CATREF	Combination and Analysis of Terrestrial Reference Frames	deg	degree
CATS	Time Series Analysis Software	DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
CB	Central Bureau		
CB	Coordinating Board		
CC	Combination Centre		
CCD	Charge-Coupled Device		

Appendices

DGFI	Deutsches Geodätisches Forschungsinstitut	FGI	Finnish Geodetic Institute
DiFX	Distributed FX	FIG	Fédération Internationale des Géomètres (International Federation of Surveyors)
DIS	IERS Data and Information System		
Div.	Division	FK6	Sixth Catalogue of Fundamental Stars
DOI	Digital Object Identifier	FR	full rate
DOMES	Directory Of MERIT Sites (originally; now of more general use)	FTP, ftp	File Transfer Protocol
DORIS	Doppler Orbit determination and Radiopositioning Integrated on Satellite	GA	General Assembly
DPOD	DORIS terrestrial reference frame for precise orbit determination	GA	Geoscience Australia
DSS	Digitized Sky Survey	GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
DTRF	ITRS realization by DGFI	Gb	gigabyte
DUT1	= UT1–UTC	GB	Governing Board
DVD	digital video disc	Gbps	Gigabit(s) per second
EC	Executive Committee	GCRF	Gaia Celestial Reference Frame
ECCO	Estimating the Circulation and Climate of the Ocean	GCRS	Gaia Celestial Reference System
ECMWF	European Center for Medium Range Weather Forecasting	GEO	Group on Earth Observations
EDC	EUROLAS Data Center	GEOSS	Global Earth Observation System of Systems
EGU	European Geosciences Union	GEST	Goddard Earth Science and Technol- ogy Center
EMR	Energy, Mines and Resources Canada (replaced by NRCan)	GFZ	GeoForschungsZentrum Potsdam
EO	Earth orientation	GGFC	Global Geophysical Fluids Centre
EOC	Earth Orientation Centre	GGIM	= UN GGIM
EOP	Earth Orientation Parameters	GGOS	Global Geodetic Observing System
ERF	epoch reference frame	GGOS-D	GGOS – Deutschland (Germany)
ERIS	Earth Rotation Information System	GHz	gigahertz
ESA	European Space Agency	GIAC	GGOS Inter-Agency Committee
ESF	European Science Foundation	GINS	Geodesy by Simultaneous Digital Integration [software]
ESOC	European Space Operations Center, ESA	GIOVE	Galileo In-Orbit Validation Element
E.U.	European Union	GIQC	Gaia Initial Quasar Catalogue
EUROLAS	European [Satellite] Laser [Ranging] Consortium	GLDAS	NASA's Global Land Data Assimilation System
EVGA	European VLBI [Group] for Geodesy and Astrometry	GLONASS	GLObal'naya NAVigatsionnay Sputnikovaya Sistema [Global Orbiting Navigation Satellite System, Russia]
eVLBI, e-VLBI, E-VLBI	Electronic transfer VLBI	GM	General Meeting
FAGS	Federation of Astronomical and Geophysical Data Analysis Services	GNSS	Global Navigation Satellite System
FESG	Forschungseinrichtung Satellitengeodäsie, TUM	GOP	Geodetic Observatory Pecny
		GPS	Global Positioning System
		GRACE,	
		Grace	Gravity Recovery and Climate Experiment
		GREAT	Gaia Research for European Astronomy Training

5 Acronyms

GRGS	Groupe de Recherches de Géodésie Spatiale	IOC	Initial Operational Capability
GSC	GSFC Analysis Center	IOV	In-Orbit Validation
GSFC	Goddard Space Flight Center	IPGP	Institut de Physique du Globe de Paris
GS	Gemini South [telescope]	IR	infrared
GSI	Geographical Survey Institute	IRA	Istituto di Radioastronomia
HCRF	Hipparcos Catalog Reference Frame	IRIS	International Radio Interferometric Surveying
HEO	High Earth Orbiter	ISO	International Organization for Standardization
hr	hour, hours	ISSI	International Space Science Institute
IAA	Institute of Applied Astronomy, St. Petersburg	ITLW	International Technical Laser Workshop
IAG	International Association of Geodesy	ITRF	International Terrestrial Reference Frame
IAU	International Astronomical Union	ITRS	International Terrestrial Reference System
ICG	International Committee on Global Navigation Satellite Systems	ITU	International Telecommunication Union
ICRF	International Celestial Reference Frame	ITU-R	ITU Radiocommunication Sector
ICRS	International Celestial Reference System	IUGG	International Union of Geodesy and Geophysics
ICSU	International Council for Science	IVOA	International Virtual Observatory Alliance
IDS	International DORIS Service	IVS	International VLBI Service for Geodesy and Astrometry
IERS	International Earth Rotation and Reference Systems Service	JADE	Japanese Dynamic Earth observation by VLBI
IfE	Institut für Erdmessung [Institute of Geodesy], University of Hannover	JCET	Joint Center for Earth System Technology, GSFC
IG2	IGS second reprocessing campaign	J-MAPS,	
IGG, IGGB	Institute of Geodesy and Geoinformation of the University of Bonn	JMAPS	Joint Milli-Arcsecond Pathfinder Survey
iGMAS	International GNSS Monitoring and Assessment System	JPL	Jet Propulsion Laboratory
IGN	Institut National de l'Information Géographique et Forestière (formerly: Institut Géographique National)	JWG	Joint Working Group
IGR	IGS rapid [products / satellite orbits]	KACST	King Abdulaziz City for Science and Technology
IGS	International GNSS Service	LAREG	Laboratoire de Recherche en Géodesie
IGU	IGS 'ultra-rapid' [products / satellite orbits]	LARES	Laser Relativity Satellite
ILRS	International Laser Ranging Service	Lat.	latitude
INA	= INASAN	LCA	LEGOS in cooperation with CLS
INAF	Istituto Nazionale di Astrofisica	LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
INASAN	INstitut ASTRonomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)	LEO	Low Earth Orbit(er)
InSAR	Interferometric Synthetic Aperture Radar	LIDAR	Light Detection And Ranging
INT	Intensive [VLBI session]	LLR	Lunar Laser Ranging
		LOD	Length of Day
		Lon.	longitude
		LQAC	Large Quasar Astrometric Catalog
		LRA	Laser Retroreflector Array

Appendices

LS	least-squares	ns	nanosecond(s)
MAO	= GAOUA	NSF	US National Science Foundation
mas	milliarcsecond(s)	NSGF	NERC Space Geodesy Facility
μ as	microarcsecond(s)	NT-ATML	non-tidal atmospheric loading
MCC	Russian Mission Control Centre	NTT	New Technology Telescope
MeO	Métrologie Optique [Grasse SLR /LLR system]	Obs.	Observatory, Observatoire
MERIT	Monitoring Earth Rotation and Inter-comparison of Techniques	OC	Organizing Committee
MGEX,		OHIG	O'Higgins [station]
M-GEX	Multi-GNSS Global Experiment	OHP	Observatoire de Haute Provence
MIT	Massachusetts Institute of Technology	OP, OPA	Observatoire de Paris
MLRS	McDonald Observatory Laser Ranging Station	OPAR	Paris Observatory IVS Analysis Center
MOG2D	2 Dimensions Gravity Waves model	ORB	Origin Rate Bias
MPIfR	Max-Planck-Institut für Radioastronomie / Max Planck Institute for Radio Astronomy	OSO	Onsala Space Observatory
ms	millisecond(s)	PC	Product Centre
μ s	microsecond(s)	PM	Polar Motion
NASA	U.S. National Aeronautics and Space Administration	PMM	Plate Motion Model
Nat.	National, Nacional	POD	Precise [or Precision] Orbit Determination
NCEP	U.S. National Centers for Environmental Prediction	POE	Precise Orbit Comparison
NERC	Natural Environment Research Council, UK	POLAC	Paris Observatory Lunar Analyses Center
NERC-SGF	NERC Space Geodesy Facility	PP	Pilot Project
NGA	National Geospatial-Intelligence Agency	ppb	parts per billion (10^{-9})
NGS	U.S. National Geodetic Survey	PPP	Precise Point Positioning
NGSLR	[NASA's] Next Generation SLR	PPP-RTK	Precise Point Positioning Real-Time Kinematics
NNR	No-net-rotation	PSF	point spread function
NOAA	U.S. National Oceanic and Atmospheric Administration	PZT	Photographic Zenith Tube [or Telescope]
NOFS	[U.S.] Naval Observatory Flagstaff Station	QSO	Quasi-Stellar Object [or quasar]
NOGAPS	[U.S.] Navy's Operational Global Atmospheric Prediction System	QZSS	Quasi-Zenith Satellite System
NOT	Nordic Optical Telescope	R&D	Research and Development
NP	SLR normal point(s)	RDV	Research and Development (sessions) with the VLBA
NRAO	[U.S.] National Radio Astronomy Observatory	REFAG	Reference Frames for Applications in Geosciences
NRCan	Natural Resources, Canada (formerly: EMR)	REGINA	Regional glacial isostatic adjustment and CryoSat elevation rate corrections in Antarctica
		RF	radio frequency
		RF	Reference Frame
		RFI	radio frequency interference
		RINEX	Receiver INdependent EXchange format
		rms, RMS	Root Mean Square

5 Acronyms

RRFID	USNO Radio Reference Frame Image Database	TN	Observatory [IERS] Technical Note
RS/PC	IERS Rapid Service/Prediction Center	ToR, TOR	Terms of Reference
RT WG	IGS Real Time Working Group	TRF	Terrestrial Reference Frame
RTCM	Radio Technical Commission for Maritime Services	TT	Terrestrial Time
RTS	IGS Real-Time Service	TU	Technical University
SAA	South Atlantic Anomaly	TUM	Technical University of Munich
Sat.	satellite	TUW	Technische Universität Wien (Vienna University of Technology)
SB	Special Bureau	TV	tie vector
SC	Special Committee	U.	University
SC	Sub-Commission	UAW	GGOS Unified Analysis Workshop
Sdev	standard deviation	UCAC	USNO CCD Astrograph Catalog
SDSS	Sloan Digital Sky Survey	UK	United Kingdom
SDSS/DR8	Eighth SDSS Data Release	UMBC	University of Maryland, Baltimore County
SED	spectral energy distribution(s)	UN	United Nations
sec	second(s) [of time]	UN GGIM	Global Geospatial Information Management Initiative of the UN
SF	San Francisco	Univ.	University
SG	space geodesy	URAT	USNO Robotic Astrometric Telescope
SGF	= NERC-SGF	URL	Uniform Resource Locator
SINEX	Solution (Software/technique) INdependent EXchange Format	U.S.	United States
SIO	Scripps Institution of Oceanography	USNO	United States Naval Observatory
SLR	Satellite Laser Ranging	UT, UT0,	
SONEL	Système d'Observation du Niveau des Eaux Littorales	UT1	Universal Time
SOPAC	Scripps Orbit and Permanent Array Center	UT	University of Texas
sq.deg	square degree	UTAAM	NOAA AAM analysis and forecast data
SSA	South Atlantic Anomaly	UTC	Coordinated Universal Time
SSG	Special Study Group	VCS	VLBA Calibrator Survey
STCD	STation Coordinates Difference	VLBA	Very Long Baseline Array, NRAO
Stn.	station	VLBI	Very Long Baseline Interferometry
SYRTE	(Laboratoire) Systèmes de Référence Temps-Espace	VO	Virtual Observatory
TAI	Temps Atomique International (International Atomic Time)	VTRF	VLBI terrestrial reference frame
TAROT	Télescopes à Action Rapide pour les Objets Transitoires	WDS	ICSU World Data System
Tb	terabyte	WG	working group
t.b.d.	to be defined	w/o	without
TC	Technique Centre	WPLTN	Western Pacific Laser Tracking Network
TEC	total electron content	WRMS	Weighted Root Mean Square
TecSpec	Workshop on Technical Specifications	XML	eXtensible Markup Language
Tigo	Transportable Integrated Geodetic	yr	year
		ZPD	zenith path delay
		ZTD	zenith total delay