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

IERS Annual Report 2011

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IERS Annual Report 2011

Edited by Wolfgang R. Dick

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1 Foreword

The IERS in 2011 built upon the foundation laid in the previous year from the renewal of all the essential IERS products and the reorganization of the GGFC. On 1 February 2011, the EOP system was changed from 05 C04 to 08 C04. This change was made in order to improve the consistency between EOP data and the underlying ITRF2008. From December 2011, only final values are provided in the C04 series. The original two-year validation of GGFC Provisional Products was completed and these were upgraded to GGFC Operational Products.

As part of the ongoing work to continually improve the IERS products, the IERS co-organized the Third GGOS Unified Analysis Workshop, Zurich, Switzerland, 16 – 17 September 2011 with goal of improving the integration of modeling and data analysis among the space geodetic techniques. The ITRS Combination Center at DGFI demonstrated for the first time the realization of the ITRS and the ICRS consistently in one common adjustment. Input data were time series of normal equations derived from the analysis of the space geodetic techniques VLBI (a combined series of DGFI and IGG, Bonn), SLR (DGFI), and GPS (TU München). To further such combination analysis a new Working Group on SINEX Format was established.

Starting in September 2011, the IERS Rapid Service/Prediction Center began the operational generation of two solutions per day. The additional solution is part of an ongoing progression to improve the accuracy of the EOP solutions by reducing their latency.

It is essential for the mission of the IERS to continue to improve the quality, consistency and utility of the IERS products. There are certainly challenges in the future as the scientific and societal expectations for accuracy, stability, coverage, latency and distribution increase, and IERS should be in the vanguard as well as the solid foundation.

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

2 The IERS
2.1 Structure

From 2011 to 2013, the IERS had the following components. For their functions see the Terms of Reference (Appendix 1), for addresses and electronic access see Appendices 3 and 4. Dates are given for changes between 2011 and 2013.

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),
Urs Hugentobler (until April 2011),
Tim Springer (since May 2011)
IERS Representative to the IGS Governing Board: Claude Boucher

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

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

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

Product Centres

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

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

Conventions Centre
Primary scientists: Brian J. Luzum, Gérard Petit
Representative to the IERS Directing Board:
Gérard Petit (until 31 December 2012)
Brian 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

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

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

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

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

(*Status as of October 2013*)

2.2 Directing Board

In 2011 to 2013, the IERS Directing Board had the following members (for addresses see Appendix 2):

Chair	Chopo Ma (until 31 December 2012) Brian Luzum (since 1 January 2013)
Analysis Coordinator	Thomas Herring
Product Centres Representatives	
Earth Orientation Centre	Daniel Gambis
Rapid Service/Prediction Centre	Brian J. Luzum
Conventions Centre	Gérard 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)
Technique Centers Representatives	
IGS	Steven Fisher (since 1 January 2013), Urs Hugentobler (until April 2011), Tim Springer (since May 2011)
ILRS	Jürgen Müller, Erricos C. Pavlis
IVS	Chopo Ma, Rüdiger Haas
IDS	Frank G. Lemoine, Bruno Garayt (until 31 December 2012), Jérôme Saunier (since 1 January 2013)
Union Representatives	
IAU	Aleksander Brzezinski
IAG / IUGG	Clark R. Wilson
GGOS (since March 2012)	Bernd Richter

2.3 Associate Members

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

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

(*Status as of October 2013*)

3 Reports of IERS components
3.1 Directing Board

The IERS Directing Board (DB) met twice in the course of the year 2011. Summaries of these meetings are given below.

Meeting No. 52

April 3, 2011, 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

Besides minor formal changes the Central Bureau received no further comments for the minutes of IERS DB No. 51.

Reports from the Technique Centres

International DORIS Service (IDS)

L. Soudarin gave the IDS report:

1. Satellite constellation: 6 satellites currently in orbit, in future: HY2A, SARAL/ALTI-KA, SENTINEL3A, JASON-3, JASON-CS, SWOT, GRASP
2. Network: new station at Cold Bay and equipment upgrading at some stations. For the future, major renovations are planned at several stations.
3. DORIS/VLBI compatibility: an experiment is planned to find out how to safely co-locate DORIS and VLBI at VLBI locations. A DORIS/VLBI compatibility status can be found here: <http://ivscc.gsfc.nasa.gov/publications/gm2010/ilin.pdf>
4. Analysis activities: ACs submit 3 months of weekly SINEX solutions every 3 month with a 3-month delay; Combination Center: the IDS 2010 analysis campaign analyses each satellite to determine its contribution to the geocenter and the scale and to determine discrepancies between the ACs; A working group DPOD2008 (chair: Pascal Willis) has been initiated to include new stations in the set of ITRF2008.
5. IDS events: Last event: IDS workshop in Oct. 2010; Next event: analysis WG meeting May 2011 (subject: switch to ITRF2008 and discuss IERS conventions).

Concerning the combination: the Jason-1 satellite is sensitive to radiation at the area of the South Atlantic Anomaly (SAA) and is therefore not included in combination.

International GNSS Service (IGS)

U. Hugentobler announced that Tim Springer will take over the responsibility for IGS activities. A report will be finished this month. He gave a presentation with the following subjects:

1. Network: 700 stations are used for IGS products in 2010, from that 91 are core stations.
2. Analysis: calls for next Analysis Center Coordinator, as well as the calls for the next-generation IGS combination system, are still open; Currently 10 ACs are contributing to the IGS; Real time product combined at ESA; Reprocessing campaign starting in ~1 year.
3. IGS08: 232 well performing IGS stations from ITRF2008, information to users is distributed via IGS mail and available on the IGS web site; IGS08 core network: sub-network of IGS08 with 91 core stations.
4. Iterative Calibration of Antenna Offsets: IGS08 has to be consistent with igs08.atx, but ITRF2008 coordinates are consistent with igs05.atx. Due to a scale jump from ITRF2005 to ITRF2008 the antenna calibrations have to be recomputed; IGS08 will be implemented on April 14, 2011.
5. ITRFxx scale wrt. ITRF2008 Scale: IGS recommendation: fix the scale for future ITRF realizations to ITRF2008 scale to avoid scale jumps seen between ITRFxx and ITRF2008 until now.
6. Radome experiment: a campaign to measure the effects of uncalibrated radomes on the realization of IGS reference frame (lasting for several months) is underway. The objective is the calibration for old data.
7. UT1–UTC: comparing the techniques to the rapid service in UT1–UTC, differences to C04 in March 10–30 can be seen.
8. Meetings and Publications. IGS 2010 Workshop Summary Recommendations; Implementation Plan for 2011.

Z. Altamimi mentioned that in ITRF2008 critical sites with discrepancies are probably coming from GPS.

International Laser Ranging Service (ILRS)

E. Pavlis presented a report on the ILRS Analysis Working Group, with the following subjects:

1. ILRS Governing Board Elections
2. ILRS News: Christian Schwatke is the new person under EDC, several NASA stations are undergoing repairs/upgrades.
3. ILRS AWG News: JCET AC beginning end of October 2011; Implementation of ITRF2008 and IERS 08 C05; Adoption of IERS Conventions 2010 after AWG meeting in May; USNO evaluation of daily product completed successfully; ILRS annual report 2009/2010 in preparation.
4. AWG Current Projects: a) Pilot Projects: Orbit products; CRD data format validation; Special issue in Journal of Geodesy;

b) New projects: Use of Starlette, BLITs and Ajisai for EOP (eventually for TRF products); Near real time analysis for SLR data for “station health”.

5. ILRS Meetings: 2 meetings in 2010 (EGU and REFAG 2010); Next meeting at 17th ILRS WS in May, 2011 in Bad Kötzting.

The focus is on improvements and products of IERS.

International VLBI Service for Geodesy and Astrometry (IVS)

R. Haas first transmitted the latest news from the IVS meeting in the past week:

Elections: new representatives from China and Spain in DB, re-elected chair of IVS became Harald Schuh.

The last meeting took place at the end of March in Bonn, Germany. The next meeting will take place in 2012 in Madrid.

R. Haas then gave a short overview on the latest changes within the IVS:

1. IVS operations:
   - Network stations; Japanese stations affected by earthquake. Tsukuba will restart on April 4, Mizusawa telescope damaged, Kashima probably not damaged. New 12m telescopes at Arecibo and Goddard.
   - Correlators and data: Bonn software correlator DiFX fully compatible with geodetic VLBI; New VLBI data structure “OpenDB” based on NetCDF (official use starts January 1, 2010; prepared for VLBI2010)
2. Analysis: New software: VieVS, c5++, nSolve; Upgrade to IERS Conventions 2010 ongoing (remarks on drift observed due to pole coordinate model change from cubic linear model).
3. IVS operations: Intensives. C. Ma proposed to replace Tsukuba by Kokee indefinitely, discussion with IERS Rapid Service/Prediction Center using the results; IVS Task Force on Intensives: Intensive strategy/scheduling, Unified analysis strategy, three levels of INT products.
4. Observing plan 2011; CONT11 on September 15–30, 2011 with 16 stations; Baseline Onsala-Tsukuba for ultra-rapid UT1-UTC for 15 days; Connect VLBI, GNSS and DORIS to an external maser (request from L. Soudarin to connect also DORIS).
5. VLBI2010 development: 20 new telescopes at 17 sites by 2017; 3 stations plan for fully VLBI2010 compliant twin-telescopes (Wettzell, Ny-Ålesund, Onsala), not all will fulfil the VLBI2010 requirements.
6. Simulations: with realistic networks; Mix of VLBI2010 antennas; Source structure simulations at Bordeaux Observatory.

Status of the new GGFC components

T. van Dam presented the status of the new GGFC components:

- Update of GGFC ULUX file server installed.
- New products available through the websites (center of mass, figure, earth); Completion estimated for end of June 2011.
- DB meeting No. 51: generation of AOD loading incomplete; SBA, SBO and SBH accreditation incomplete.
- GGFC meeting/workshop was proposed: perhaps before the AGU 2011.
- GGFC site: operational.
- Validation process of new products incomplete.
- New proposal for AAM products from J. Böhm.

Z. Altamimi proposed to ask the Techniques Centers on used loading models and to study the impact of the models on the results. Testing the models may take a long time for GPS; For SLR at least one year to see first results.

New Action Items:

#52.01 Test loading models

#52.02 Validation procedures

#52.03 Organize Workshop

Earth orientation products

Generating IERS EOP series consistent with ITRF2008

D. Gambis gave a presentation on the EOP series C04:

- Situation before: 70–80 µas in pole difference between EOP(ITRF2008) and 05C04
- Differences between IGS05 and EOP(ITRF2008) and CATREF and EOP(ITRF2008).
- Bias= EOP (ITRF2008) – 08C04 = 0.
- Studies on interpolation methods, study inconsistency between CATREF(IGS) and 08C04.
- UT1 differences with IVS – 08C04 from 24h sessions and intensives; Outliers in intensive session (a combination of intensive sessions may reduce outliers).
- UT1 from 08C04 differences wrt. NEOS, SPACE, IVS combination (intensives from different ACs, 24h sessions combined) and OPA are shown.
- Nutation offsets: T. Herring noted that nutation only comes from IVS within the C04 series, therefore it is unclear from where these offsets come.
- Differences of polar motion due to interpolation method: Lagrange vs Fourier, Spline, Linear
- Practical issues: 08C04 available since February 1, 2011.
- 05C04 available until June 2011.

- Technical documentation on 08C04 can be found in <http://hpiers.obspm.fr/iers/eop/eopc04/C04.guide.pdf>.

C. Ma proposed more points of EOP for next ITRF. T. Herring added that subdaily EOP would be favourable, because EOP rates absorb subdaily effects.

D. Gambis will stop the preliminary version in June.

C. Ma proposed to update the C04 series every day instead of twice per week (every day a point for 30 days back).

IERS Rapid Service/Prediction Center Status Report

A report about the IERS Rapid Service/Prediction Center status was presented by B. Luzum:

1. Recent changes:
   - Adopt 08C04 series.
   - Backup site at <http://toshi.nofs.navy.mil/> (independent site) for combined solution.
   - Use of AAM.
   - Incorporate GSI intensives.
   - More frequently use of eVLBI.
   - Improvements in UT1 predictions.
2. Near-term improvements:
   - IGU LODs into combination.
   - Accuracy check wrt C04 and SPACE.
   - EOP update twice per day (eVLBI data more quickly available).
   - CIO-based EO matrix calculator.
   - Investigate use of AAM/OAM.

Pilot project on EOP Combination and prediction

B. Luzum reported also about this pilot project:

- Pilot Project's objective: collect individual predictions and combined predictions; Near-real-time feedback for all predictions; C04 solution as metric; Goal: recommendations on feasibility of producing EOP predictions.
- Timeline: last issue: interim report to IERS DB; Final report previewed for fall 2012.
- 9 participants.
- Auxiliary data: IERS SB for Atmosphere AAM data; IGS Ultra EOP prediction; GFZ AAM/OAM/HAM.
- Information on web site with contact infos, etc.: <http://maia.usno.navy.mil/eopcppp/> (USNO PP web site); <http://www.cbk.waw.pl/eopcppp/> (SRC, PAS web site).

Near future: additional prediction series/ensemble prediction series, analysis of statistical properties of prediction series.

Decision: Earliest date in the C04 series of an EOP is 31 days in the past.

New Action Items:

#52.04 Announce change

#52.05 Communicate to the user to take EOP from rapid service.

#52.06 Update C04 series every day instead of twice a week.

#52.07 Write Technical Note on 08C04.

ITRS/ITRF

International Committee on GNSS (ICG)

The International Committee on GNSS (ICG) should ensure interoperability between the systems for the users: time and geodetic reference system. Chair of WG D: John Dow and Matt Higgins, 2 Taskforces: time Felicitas Arias, reference frames: Zuheir Altamimi, WG D for geodetic reference: provider agree to be interoperable to ITRF, consensus how to make this possible, IERS' official representative in ICG: Z. Altamimi

C. Ma: DB agrees that Z. Altamimi should be representative. Is a letter from DB requested? Z. Altamimi will ask the secretariat and inform the DB. Next meeting in October.

Status of ITRF2008

Main activities since ITRF2008 release:

- Open access article published in Journal of Geodesy.
- Article on ITRF2008 plate motion model in preparation.
- Technical note of ITRF2008 in preparation (ready by summer).
- Contribution for IERS AR 2009 almost ready.
- Maintenance of ITRF website <http://itrf.ensg.ign.fr/GIS/>.

ITRF2008: Consistency between local ties and space geodesy discrepancies

- GPS co-location improvements necessary.
- Velocity spherical errors for (IDS, IVS and ILRS).
- PMM – Plate Motion Model, comparison to geological models: NNR-Morvel65: most sites on most plates if one wants to compare with ITRF2008, but highest rotations (goal is less than 3 mm/year).

C. Ma asked Z. Altamimi to make a forecast for the services concerning a start for input for next ITRF20xx. Z. Altamimi: wait for two years (probably prepare next ITRF in about 1.5 years).

IERS Working Group on on Site Survey and Co-location

As Perguido Sarti was excused for this DB meeting, B. Richter gave a short overview of his written report:

1. WG meeting: the last meeting took place during EGU 2010 in Vienna, the next meeting is foreseen in December 2011

during AGU Fall meeting in San Francisco.

2. Ongoing activities: the WG and its chairmanship were confirmed by the IERS DB for additional two years. Required actions to push the activity of the WG:
   - A co-chair.
   - Revision of the WG members.
   - Revision of WG charter.

IERS Working Group on Combination at the Observation Level

D. Gambis presented activities of the WG:

1. Charter of the WG and on overview on the last meeting in December 2010.
2. Kick-off Meeting December 2010 in Munich, Germany: (the minutes can be found at the web site <www.iers.org/WGCOL>). CONT08 campaign to compare results
   a. Roadmap: 5 points which should be fulfilled:
      i. Review the approach for the various groups.
      ii. Elaborating benchmarks.
      iii. Ensuring SINEX compatibility.
      iv. Establishing common processing standards.
      v. Optimizing and unifying parameterization.
   b. Activity reports from the Analysis Centers.
   c. Activity reports from the Combination Centers.
   d. Discussion on SINEX format.
   e. Discussion on models.
   f. Discussion on parameters.
   g. Next tasks.
3. Next meeting Tuesday April 5, 2011, 16:30 – 18 h at TU Vienna.

IERS Working Group on SINEX

B. Richter presented the report from D. Thaller who did not participate in DB meeting:

- A First meeting is scheduled for April 6, 2011 during EGU Vienna.
- The list of members contains representatives from the IERS, the Technique Services, the ITRF Combination Centers, the IERS WG on Site Survey and Co-location as well as the GGOS Bureau for Standards and Conventions.
- Goals and objectives:
  - o Maintenance and update of the SINEX format.
  - o Handle request for SINEX format changes.
  - o Mechanism on how the SINEX format is changed and agreed upon.

- o Introduction of new parameterizations and models.
- o Format description with up-to-date information technology.

T. Herring proposed to better document what models should be used. Z. Altamimi requested that there should be a defined block for models (machine readable, not as a comment).

New Action Items:

#52.08 Contact the ICG secretary and DB will write a letter if necessary.

#52.09 Re-organize the WG on Site Survey and Co-location.

Statements from the IERS Analysis Coordinator

T. Herring gave a short summary about his major tasks as Analysis Coordinator:

1. Work with SINEX definition working group to better define a model specification block in SINEX files. The idea of this block is that when models change, the block written by the analysis software of the different groups contributing to the IERS will need to be changed to reflect the new processing methods. When the IERS conventions are changed, such a block will allow the monitoring of the implementation of new models.
2. Work closely together with the Analysis Coordinators of the individual techniques (e.g., common meetings among the ACs) to achieve better consistency in the models used to generate the results for the IERS products.
3. Work to resolve the C04/rapid EOP product overlap.
4. Start a review of the IERS EOP product availability and consistency.

Status of IERS Conventions

Gérard Petit reported about the status of IERS Conventions:

The Conventions 2010 have been electronically published on December 15, 2010. The printed version is planned to be available at the beginning of May, 2011.

G. Petit presented some results of a survey proposed on the Conventions web site:

- The value of some new features of the Conventions (2010) and of the technical content is found to be high by users.
- Future Conventions: Users favor continuing the same process for gathering information and publishing the Conventions.
- Other comments: Accent on software availability, cover all existing techniques; remove inconsistencies.

The role of the Advisory Board (established 2005 and chaired by J. Ray) was discussed. C. Ma indicated that it is up to the Conventions Center to determine the form in which it continues. Z. Altamimi asked whether the Convention’s glossary is suited to serve as an official document for definition for the IERS Conventions.

New Action Item:

#52.10 Include a survey letter when the printed version of the Conventions will be distributed.

ICRS/ICRF

R. Gaume presented ICRS-related issues. The tasks of the ICRS Center are:

A) Reference system and frame:

1. Maintenance and extension of the ICRF: ICRF 2.
2. Investigation of future VLBI realizations of the ICRS: High frequency reference frame: Q-Band = 33-50GHz. Radio source monitoring on <http://ivsopar.obspm.fr>, astro-photometric observations of quasar visibility.
3. Investigation of future non VLBI realizations of the ICRS: Joint MilliArcsecond Pathfinder Survey (JMAPS) and Large Quasar Astrometric Catalogue (LQAC).

B) Extragalactic radio-sources:

4. Monitor structure to assess astrometric quality.
5. Maintenance of the time stability of ICRF.

C) Link of other reference frames to the ICRS:

6. Maintenance of the link to the Hipparcos catalog: USNO CCD Astrograph Catalogue (UCAC) – UCAC4 as final UCAC – and USNO Robotic Astrometric Telescope (URAT) with new camera (10.660x10.660pixel).
7. Information concerning the ICRF objects at other wavelengths.
8. Maintenance of the link to the solar dynamical reference frame through millisecond pulsar analysis.
9. Maintenance of the link to the solar dynamical reference frame through observation of asteroids.
10. Maintenance of the link to the solar dynamical reference frame through LLR. Recent improvements of LLR: New Apollo Station; Meo station.
11. Maintenance of the link to the ITRF.

D) Informational Service:

12. Dissemination of ICRS products.

VLBI intensive series: single baseline: Mk (Hawaii) – Pt (Mexico); intensives start FY12 (fiscal year).

Reports on GGOS and ICSU

Markus Rothacher gave an overview on the GGOS activities.

GGOS

- Retreat in February 2011
- GGOS Vision and Mission (Why GGOS? What is GGOS? Link to the users.)
- GGOS Working Groups: Satellite and Space Missions; Outreach; Data and Information Systems; ITRS Standardization; Contribution to Earth System Modeling.
- Modular 4D Earth System Model (ESM)
- GGOS WG on ESM: Schedule and Milestones; Member list
- GGOS Portal: Lot of progress; Next step is to fill the portal with products, metadata, etc.
- Web Pages: First release finished by GGOS Coordinating Office: <http://www.ggos.org/>
- Outreach: Mention GGOS once in any of your presentation; Promote GGOS.
- Book published “Sea-level rise and variability” and “System Earth via Geodetic-Geophysical Space Techniques”
- Recognition by ICSU as 4th Global Observing System; GGOS then supervised by ICSU and not by IAG.
- GGOS chair selection and appointment.
- Contribution of GGOS to the 3 GGOS Themes:
  1. Global Unified Height System:
  2. Geohazards
  3. Sea-Level Change, Variability and Forecasting
- GIC and GIAC: May 2010: First go for GGOS Inter-Agency Committee (GIAC) supporting GGOS; December 2011: First GIAC meeting; Furthermore: Election of new chair, vice-chair, secretariat.
- IAG/GGOS Declaration.
- GEO development of work plan 2012-2015: 5 task where GGOS should be present:
  - o IN-02 Earth Observation Systems
  - o IN-05 Gap Analysis
  - o DS-01 Disaster Risk Reductions and Early Warning
  - o DS-03 Climate Information
  - o DS-05 Integrated Water-Cycle Information

  Workshop GEO Work Plan 2012–2015 on May 4–6, 2011 in Geneva.
- Next Meetings and Workshop: GIAC Meeting on Aril 4, 2011 during EGU in Vienna; Unified Analysis Workshop in Zurich on September 16/17, 2011; GEO Plenary 2011 on November 16/17, 2011 in Istanbul.

C. Ma: selection of chair: no official announcement sent out so far, CB distribute to DB; DB members think of possible candidates (no limited number), deadline by end of April 2011.

ICSU

Bernd Richter reported about the newly established World Data System (WDS) which is a follow up of the old World Data Services and the Federation of Astronomical and Geophysical Services (FAGS). The WDS has a new structure; details are published under <http://www.icsu-wds.org/> . To become a member, an application form has to be filled which will be reviewed in a formal process by the WDS Scientific Committee. Certain specifications have to be fulfilled but there should be no problems for the existing IAG services. Ruth Neilan (IGS) and Lesley Rickards (PLMSL) are members of the WDS Scientific Committee.

New Action Item:

#52.11 CB will change the ToR according to the decision made at the IERS DB meeting #51, and ask for nominations for a GGOS representative out of the DB members. The election will be made electronically, later the IAG Executive Committee will be informed.

Report from IAU

Alexander Brzezinski gave an overview on IAU-related activities:

- 2 important publications in 2010: 1) IAU Highlights of Astronomy Vol. 15, 2) IAU Transactions XXVIIB.
- Final report on International Year of Astronomy 2009.
- General Assemblies: XXVIIIth IAU GA on August 20–31, 2012 in Beijing, China, and XXIXth IAU GA on August 3–14, 2015 in Honolulu, Hawaii, USA.
- Division 1 “Fundamental Astronomy”: report currently under discussion by Organizing Committee; Implementation of IERS 08 C04.
- Commission 19 “Rotation of the Earth”: Co-organization of joint GGOS/IAU Science Workshop 2010 in Shanghai; upcoming events: organization of the Journées 2011 in Vienna; Preparation of IAU GA in Beijing, China; Co-organization of Special Issue on Earth Rotation in Journal Geodynamics (deadline end of April 2011).
- Commission 4 “Ephemerides”: WG on Standardizing Access to the ephemerides (see web pages <www.iaucom4.org>)
- Other commissions and Working Group: Brian Luzum chairman of IAU Div. I WG “Numerical Standards in Fundamental Astronomy”: WG report will be published in “Celestial Mechanics and Dynamical Astronomy”.

Meeting of interest: Journées 2011 Système de référence spatio-temporels, September 19–21, 2011 Vienna, Austria.

Annual Report

B. Richter gave an overview on the current status of the contributions to the Annual Report 2008–2009, pointing out missing and incomplete reports. The AR will be printed together with the Technical Note on ITRS2008.

Next IERS DB meeting / workshop

The next IERS DB meeting will take place in the Washington area in October 2011, e.g. Thursday + Friday at the end of October. The Third GGOS Unified Analysis Workshop will be held right before the Journées which will take place in Vienna.

New Action Item:

#52.13 Ask NGS to provide a meeting room.

Meeting No. 53

December 3, 2011, Westin Hotel, 50 Third Street, San Francisco, California, 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

Besides minor formal changes the Central Bureau received no further comments for the minutes of IERS DB No. 52.

Reports from the Technique Centres

International DORIS Service (IDS)

Frank Lemoine was not able to attend the meeting. B. Richter gave a short report on IDS activities based on notes from Frank Lemoine:

1. Stations/Network
   Some stations were not operational for various reasons; ongoing problems with US authorities concerning the use of 2 GHz frequency; VLBI/DORIS interference tests are underway or planned.
2. Satellite constellation
   Currently seven satellites used.
3. ACs/Combination Center
   Combination Center producing a quarterly combination with contributions of all ACs; GFZ is a possible candidate for a new AC; the next IDS AWG meeting will be in Prague in May/June 2012.
4. Modeling
   Issues to be resolved for next ITRF: Possible SAA (South Atlantic Anomaly) effect on Spot5; Phase Center Variations; Need of Phase Windup correction will be evaluated; Software by Oscar Colombo to evaluate the 2nd order correction on DORIS measurement; A single-satellite analysis campaign has been conducted; A campaign is underway to assess

   the fidelity of the solar radiation pressure (SRP) modeling for current satellites.

5. Atmospheric Loading
   Integration of new geometric correction in the ACs software.

IDS will not be ready for ITRF reprocessing before 2013.

International GNSS Service (IGS)

Rolf Dach gave an overview on IGS activities:

- The real time pilot project will become a product. Data stream including clock and orbit corrections will be distributed via Internet. Two streams: one relying on ITRF coordinates and one on EUREF coordinates.
- The ACC term will end by the end of 2011.
- NGS will continue the combination work for the next 4 years.
- Repro2 campaign will need at least two years.
- An IGS workshop will be held in summer 2012 in Poland.
- An improved sub-daily pole model is necessary.
- A SINEX format update is needed to include CODE into IGS combination.

International Laser Ranging Service (ILRS)

E. Pavlis gave a presentation on ILRS activities:

1. Governing Board Elections
2. Network and Operations
   New responsible person for EDC at DGFI; NASA Network contractor change; Returning stations: Potsdam, Riyadh; New stations: Arkhyz, Komsomolsk, Badari, Zelenchukskaya and Svetloe.
3. New & Upcoming Sites
   GGOS core sites with SLR: San Juan (Argentina), Yebes (Spain), NyAlesund (Norway), Metsahovi (Finnland), Sejong (South Korea).
4. Missions
   New GLONASS satellites, Chinese Altimetry mission HY-2A, new Galileo satellites, RadioAstron, LARES (January 2012).
5. Analysis
   Operational products delivered routinely and on time from nine ACs; New Center of Gravity models for LAGEOS & ETALON; Daily analysis product will become the “official” ILRS product; All pilot projects are expected to be finalized by spring 2012; Switching to new data format (CRD) in early 2012.
6. Last and Future Meetings
   Brief meeting held at the 17th ILRS workshop in Bad Kötzting and before a one day meeting before the Third GGOS Unified

Analysis Workshop in Zürich; Next meeting: prior to EGU 2012 in Vienna (Saturday, April 21, 2012); 18^{th} International Workshop on Laser Ranging will be held in Tokyo in fall 2013.

International VLBI Service for Geodesy and Astrometry (IVS)

C. Ma presented the IVS report:

1. IVS operations
   - Network stations
   - Fortaleza resumed observations in May; AuScope network with new VLBI2010 antennas; Warkworth commenced observing; New telescope in Korea, Arecibo and Goddard under construction; Japanese stations affected by earthquake in March, 2011.
   - Intensives
   - Tsukuba replacements for Int2 and Int3: Int2: Kokee Park and Int3: Seshan; Successful ultra-rapid.
   - Analysis and related topics
   - New software packages: VieVs, C5++, nuSolve; IVS combination operational at BKG with six ACs contributing; CONT11 in September 2011 with 13 participating stations.
2. VLBI2010 development

   eVLBI transfer protocol under development; DiFX correlator fully applicable for geodetic VLBI; discussion on "network cloud"; 3 stations plan for fully VLBI2010-compliant twin-telescopes (Wettzell, Ny-Alesund, Onsala); 14 stations plan to build one fully VLBI2010-compliant telescope each; 11 stations plan VLBI2010 upgrade.

Hansjörg Kutterer informed about the status of TIGO in Chile: Chile is not able to pay for Chilean co-workers at the site (these have to be paid by BKG for the next years); the station will probably be moved to another site in South America.

ITRS/ITRF

IERS Working Group on on Site Survey and Co-location

WG Meetings

A short WG meeting will probably take place during the AGU2011 fall meeting in San.

Ongoing activity

Revision, update of WG members and finalization of co-chairship under progress (planned to be submitted for next DB Meeting).
A draft of the new charter was prepared.

Next ITRF solution issues

Z. Altamimi plans an ITRF2013. IGS reprocessing will take approximately 1 ½ to 2 years. The techniques should provide a test solution as soon as possible.

ISO standardization of ITRS

Claude Boucher presented the current status and background on the ISO standardization. A proposal for an ISO standard on ITRS within ISO TC (Technical Committee) 211 “Geographic information/ Geomatics” is currently developed and a New Work Item Proposal (NWIP) on geodetic references has been submitted. The aim is to establish a permanent structure on geodetic references and to create an ISO standard on ITRS.

New Action Item:

#53.01 Provide unique loading model for the Techniques.

Report on GGFC activities

T. van Dam presented the status of the GGFC.

UAW Action Items:
A project to test the effects on applying atmospheric loading corrections at observation level has been proposed. Status: the displacement data is ready, gravity data still under development.

GGFC:
Reorganization in progress since 2010. First product centers have been recognized; A new call has been drafted and will be distributed to the DB before January 01, 2012 and then distributed in January (deadline mid/end March).

Workshop:
Next workshop on April 20–21, 2012 (Friday and Saturday) before EGU GA in Vienna.

New Action Item:

#53.02 Prepare call for GGFC product centers.

Discussion on IERS Working Group on UT1 distribution

B. Luzum reported about the conclusions from the conference on UT1 redefinition.

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 provided a summary of 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.
- The idea came up to continue to publish pseudo-leap-seconds at IERS.

- If proposal concerning the redefinition of UT1 is adopted, it would provide legal standing to represent civil time by atomic time for concerned countries (e.g. UK).
- 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 a decision to abolish leap seconds is reached, the IERS should establish an IERS leap second service.

Decision:

Issue a press release, if decision has been made, to inform the IERS community that the IERS is already informed about this issue.

New Action Item:

#53.03 Prepare press release.

Report on GGOS

H. Kutterer gave an overview on latest GGOS activities:

He was elected as GGOS chair after the IUGG 2011 in Melbourne. Ongoing transfer/redefinition from the old GGOS structure to the new structure (new ToR, redefinition of GGOS Vision, Mission, Goals and Tasks, implementation of the new structure).

Components

1. GGOS Consortium (GGOS matters with two representatives from each GGOS component).
2. Election of GGOS Coordination Board: call for nominations has been sent out in November 2011.
3. Executive Committee: GGOS Science Panel (recommendation from GGOS community); Two members of each service to the consortium.

Organization

The objective is to make GGOS operational with the three GGOS themes (Unified Global Height System, Natural Hazards and Understanding Sea-level Rise). The aim is to make the community aware of what GGOS may provide.

Other activities

1. GGOS has established partnership with CEOS.
2. A call for participation for a core system has been sent out.
3. The GGOS Portal has been set up and is now reachable via <www.ggos-portal.org>.

A GGOS retreat is planned for early 2012.

Earth orientation products

T. Herring gave an overview of EOP data within the IERS.

Two aspects of EOP products:

1. Location and access of products

   Access through iers.org or through the product centers?
   Difficult automation due to unclear naming convention (also via ftp access).
   These aspects lead to the assumption that users get products directly from the product centers (and not from the central IERS web site).

2. Content of products

   Three main bulletins:

   - Bulletin A: Rapid service, available in two forms (weekly and daily updates)
   - Bulletin B: monthly updates
   - C04 series: recently changed

   Different formats, units, file naming schemes.

Suggestions (to be discussed at the IERS Retreat):

- A concise summary for each product useful (how produced, nominal purpose, measures of accuracies of the input contributions).
- Clear indication of date of generation of the product.
- Generation of sets of products in the same machine friendly format and standard comparison statistics (no need to change existing products).
- Introduce a clear file naming convention.
- Comparison statistics and graphics in an easily accessible and marked location.

IERS Retreat and next IERS DB meeting

The IERS Retreat could take place on Wednesday and Thursday before EGU2012 (April 18–19, 2012). A survey should be drafted and sent out to IERS users in order to point out possible topics to be discussed during the Retreat. A problem is to get information from non-scientific users.

B. Richter: External experts should be invited.

C. Ma: A template of self-assessment to be filled out by DB members should be prepared.

New Action Items:

#53.04 Draft a survey to be sent out to IERS users.

#53.05 Draft a template for self-assessment within the IERS DB.

IERS Annual Reports

The annual reports for 2008 and 2009 will be published as a biennial report by end of December 2011. The printed reports will follow as soon as possible.

The annual reports for 2010 and 2011 should be finished as soon as enough reports are available. The digital versions will contain separate volumes for each year, the printed versions will be published together.

Decisions:

Publish AR 2008–2009 as soon as possible.

Start AR 2010 and 2011.

New Action Items:

#53.07 Publish AR for 2010 as soon as there are enough reports.

#53.08 Send out call for AR 2011.

Miscellaneous

B. Richter informed that he changed to the Geoinformation Section of BKG. In conjunction with this new position he will no longer be the Director of the IERS Central Bureau. He will continue working for the IERS Central Bureau until his successor at BKG is found.

Sabine Bachmann, Wolfgang R. Dick, Bernd Richter

3.2 Central Bureau

General activities

The IERS Central Bureau (CB), hosted and funded by Bundesamt für Kartographie and Geodäsie (BKG), organized and documented the IERS Directing Board (DB) Meetings No. 52, April 3, 2011, at Technical University Vienna, Austria, and No. 53, December 3, 2011, at Westin Hotel, San Francisco, California, USA. Between the meetings the CB coordinated the work of the DB.

Together with the Global Geodetic Observing System (GGOS), the CB prepared the Third GGOS Unified Analysis Workshop, held September 16–17, 2011, at the ETH Centre main building, Zurich, Switzerland. The programme and the presentations were published at the IERS web site. For a summary see Section 4. The CB represented the IERS at the following meetings: European Geosciences Union General Assembly, IUGG XXV General Assembly, Journées 2011 “Systèmes de référence spatio-temporels”, Colloquium “Decoupling Civil Timekeeping from Earth Rotation”, and AGU 2011 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 2011 the web site was continually updated, several new pages and documents were added. An extended list of meetings related to the work of the IERS was maintained, and a new list of publications about the IERS and its work including links to online versions was compiled. The CB maintains also the web pages of the IERS working groups.

The IERS Annual Report 2008–2009 was finished and published online at the end of 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 the 2008–2009 report, the CB provided also summaries of DB meetings and its own report, as well as reports about the GGOS Unified Analysis Workshop Follow-Up Meeting and the Second GGOS Unified Analysis Workshop.

The IERS Technical Note No. 36 “IERS Conventions (2010)” was printed and distributed to libraries and subscribers.

A report about the activities of the IERS during 2007 to 2011 was compiled for IAG, and a triennial report 2009–2011 was provided to IAU Commission 19.

During the year 2011, 21 IERS Messages (Nos. 180–200) 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 2011 with valid addresses who subscribed to IERS publications for e-mail and regular mail distribution. A proof-of-concept for a new system of address management was successfully developed by a software firm in cooperation with the CB. The improved system will allow easier maintenance and will give access for users to register as well as to check and update their data.

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 became involved in the Control Body for an ISO Register of Geodetic Codes and Parameters.

IERS Data and Information System (DIS)

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

Besides routine work like maintenance of the data bases of users, products and web pages, in 2011 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,
- visualization of time series,
- updating the data structure, e.g. by adopting to the new structure of the Global Geophysical Fluids Center,
- development of a concept for a new data management system.

Earth Rotation Information System (ERIS)

Many of these developments were made in close cooperation with another research project at BKG, the project ERIS (Earth Rotation Information System). Since June 2006 ERIS is executed at BKG. ERIS is a part of the research unit FOR 584 “Earth Rotation and Global Dynamic Processes” which is supported by the German Research Foundation (DFG). ERIS serves as a development and testing platform for new interactive data access tools as well as an information portal. Furthermore, it is used as an exchange platform within the research unit.

The aim of ERIS is the development of a portal, which 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 internet portal <http://www.erdrotation.de> has been continuously upgraded and completed. Besides the information portal the activities of the research unit are presented and internal web pages for data and information exchange are provided.

In 2011 the work focused on the completion and extension of tools for visualizing and processing of time series. Thus, the data analysis tool, developed in the year before, was improved and completed. This tool provides analysis procedures like spectral analyses, various filters and approximations. These procedures can be operated on implemented time series but also on user's local data. The usability was improved by linking the data with their metadata. This allows a direct access to information like production date, underlying models and data as well as responsible persons and institutions. Additionally operation instructions were integrated. The access to this tool, hints for use and a user manual are found on ERIS portal at <http://www.erdrotation.de/ida>.

As a further application a visualization tool was developed in the last year and continuing in this year. Within this tool different model data concerning earth rotation can be combined, processed and compared to measured earth rotation parameters. At this time models for excitation functions of the atmosphere, oceans and hydrology are available. For this application existing and tested methods, functions and structures of the data analysis tools were reused reducing and simplifying administration. The visualization tool was finally tested and is now available on the ERIS portal along with a user guide.

Beside these tools the data availability was expanded in close cooperation with the IERS Central Bureau. This includes creation of schemata for standardized data formats for geophysical fluids data as well as standardized metadata formats. Especially the reorganization of the GGFC (Global Geophysical Fluid Center) results in restructuring data structures and databases.

Staff in 2011

Dr. Bernd Richter, *Director*
Sabine Bachmann*, scientist*
Dr. Wolfgang R. Dick, *scientist*
Sonja Geist, *technician (since 1 February 2011)*
Carola Helbig, *secretarian*
Michael Lösler, *technician (since 1 January 2011)*
Alexander Lothhammer, *technician (until 31 January 2011)*
Anja Niederhöfer, *scientist*
Sandra Schneider-Leck, *technician*

Publications

Dick, Wolfgang R.: The IERS, the Leap Second, and the Public. In: John H. Seago, Robert L. Seaman, Steven L. Allen (eds.), Decoupling of Civil Timekeeping from Earth Rotation. Proceedings of a Colloquium Exploring Implications of Redefining Coordinated Universal Time (UTC), held October 5–7, 2011 at Analytical Graphics, Inc., Exton, Pennsylvania. (American Astronautical Society, Science and Technology Series; 113) San Diego, Cal.: Univelt, 2011, p. 117–121 (Discussion on p. 122)

Dick, Wolfgang R.; Richter, Bernd (Eds.): IERS Annual Report 2008–09. Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, 2012. 237 p.

Wolfgang R. Dick, Anja Niederhöfer

3.3 Analysis Coordinator

1. Introduction

In this report we outline the activities of the Analysis Coordinator during 2011. The main activities were clarifying the distribution of rapid EOP products; examining the distribution and formats of the IERS EOP products; initial planning for the IERS Retreat and the IERS action items from the 3rd GGOS Unified Analysis workshop.

2. Rapid product delivery clarification

A review of the product delivery by the IERS revealed that there was confusion about the official IERS rapid Earth Orientation Parameters (EOP) product. This product delivered with 24-hour latency and including predicted values is generated by the IERS Rapid Service/Prediction Centre hosted at the US Naval Observatory (USNO). This product is the official IERS product however the IERS center responsible for the long-term IERS series was also delivering a rapid and predicted product as part of its “definitive” C04 product. The two rapid products, while similar in value, are not the same and this difference could cause confusion among the users of the IERS services. The IERS Directing Board directed the IERS Earth Orientation Center, hosted at the Paris Observatory, to remove their rapid product from the long-term series distribution. The Paris Observatory rapid product could still be made available through the Paris Observatory itself rather than as an official IERS product. With this change bulletin A, the rapid product, is available solely through the rapid product center, hosted at the US Naval Observatory.

The following announcement was sent to users of IERS data on November 3, 2011:

```
************************************************************************
IERS Message No. 198                                   November 03, 2011
************************************************************************

Note to IERS C04 and Bulletin A users

According to the IERS Directing Board resolution (DB52), and starting on
1 December 2011, the EOP C04 series will be delivered with a 30-day
latency. In other words, only final definitive values will be 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) will have
two solutions:

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 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 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

3) The OPA files are now available at this location for users wishing to
  test the new file locations.

If users expect problems with this new arrangement, please contact
central_bureau@iers.org with their concerns. Subject line should include
"C04 transition".

Christian Bizouard and Daniel Gambis
IERS Earth Orientation Center
Observatoire de Paris
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As noted in the announcement, users still could continue to obtain the Paris Observatory rapid product if they wished directly from the Paris Observatory FTP site.

3. IERS product format unification

An early activity of the Analysis Coordinator was to look at the IERS product distribution. Of concern here was the variety of formats and information content in the products. Initial thoughts on these topics are given below and ultimately these will be addressed at the IERS Retreat. Figure 1 shows the IERS EOP products page.

The layout of the IERS product page is very nice for users browsing the page, but when links are revealed the pattern of the links is not clear (and thus difficult to automate).

For example to download C04 for 2011 from the IERS web site a user would need to use the command wget from a terminal in the form:

```
wget <http://data.iers.org/products/211/14461/orig/
eopc04_08_IAU2000.11>
```

Also the file name used at the product centers differ from those at iers.org and therefor the correspondence of the files is not obvious. Also in the link above, the values of 211 and 14461 are not clear and are different for each product and change between products (e.g. Bulletin B each month). One question to raise is where users get their products? Do they download them directly from product centers or from the IERS http or ftp sites? Where do we want users to download products? The ftp servers at IERS.org (which is an easily overlooked link) has many layers and products with file names with bulletin “numbers” which are need to be converted to dates.

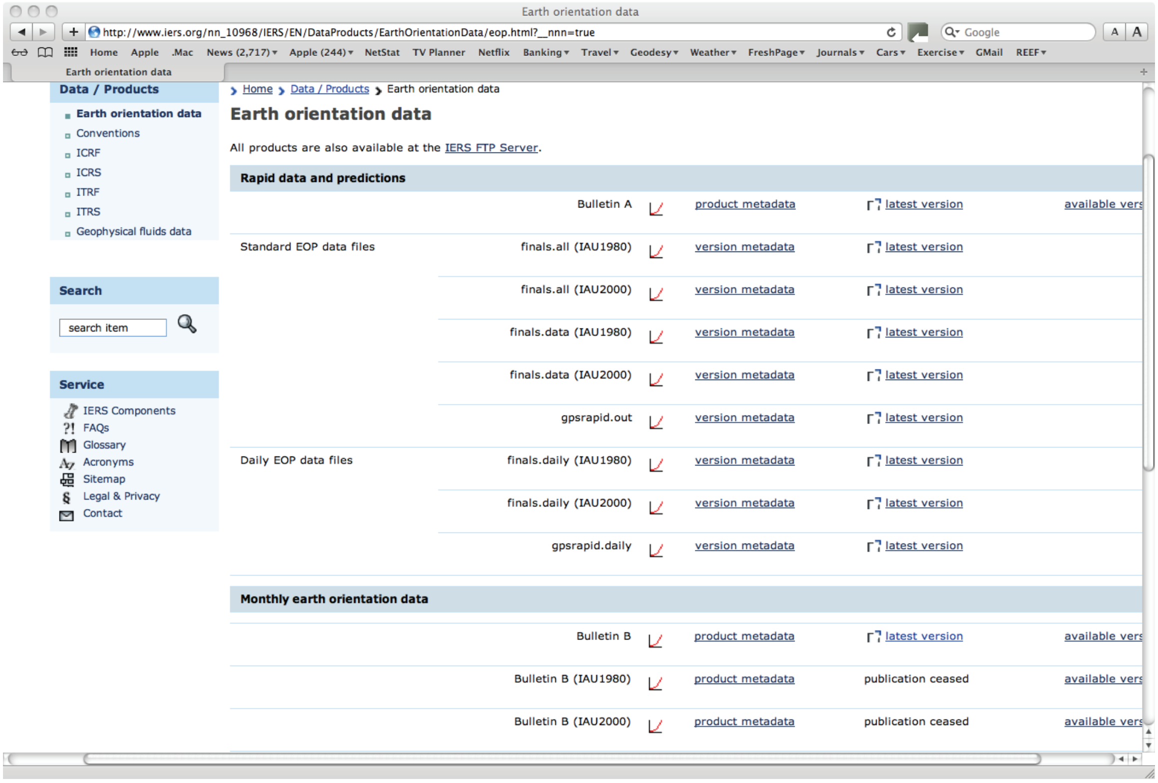

Fig. 1: IERS products page, shortcut URL <http://www.iers.org/EOP>

Also to be considered other uses of the products. There are three main EOP bulletins/series:

Bulletin A: Rapid service, available in two forms finals2000A.data (updated weekly) and finals2000A.daily (updated daily).

Bulletin B: Monthly updates.

C04: Monthly updates (recently changed (Dec 1, 2011) to have only definitive values).

Who is using which products? IGS analysis centers use Bulletin A files (downloaded from USNO). There are small differences between the EOP estimates in USNO files labeled “data” and “daily” for the most recent observed values. There are small differences between C04 and Bulletin B and in recent years, the use of Bulletin B as opposed to C04 has not been clear. C04 is meant to be the definitive IERS series whose values do not change accept from major revisions of the terrestrial reference system. Is Bulletin B still useful or should C04 be used in its place? It is not clear why all years of C04 seem to be updated regularly if this is the definitive series that should not change except for the addition of new values.

Possibly most problematic with the current products is that each one of the EOP series has different formats and different information content. In some cases units have different between the different bulletins. The IERS needs to develop a common format for all of its EOP products. This format might be generated from the current series input by each of the product centers or the product centers themselves might change that formats. For users of the IERS products, the existing formats should be retained for backwards compatibility.

Some of the other differences in the products have to do with whether headers are included which describe the columns in the format or whether the user needs to consult the metadata information at the IERS website in order to decode the data format. Current IERS EOP products are not uniform in format, units or locations. A concise summary of how each product is generated, what its nominal purpose is (e.g., Bulletin B versus C04 for post-processing) and measures of accuracies of the input contributions. These summaries can be found searching around ftp areas etc but should be made more prominent. There should be clear indication of the date of generation of the product when this is not clear in file name. Generation of a set of products in the same (machine friendly) format would allow easy comparison of the products and the generation of statistics for each product. Most likely existing products would not be eliminated (for backwards compatibility with existing user software) but new formats would be made available.

Some thought needs to be given to the file naming conventions. For example, finals.2000A.daily is easily generated but age of product is not clear. Bulletin number NNN indicates an age but it is not clear how to generate date from the number.

These topics and implementation plans will be discussed at the IERS Retreat.

4. Initial planning for IERS Retreat

Initial planning for the IERS Retreat was started with the basic questions to be addressed. The general concept of the retreat is to ensure that the IERS products continue to be timely, high quality, and meet the needs of the IERS users. The initial discussions of the retreat focused on questions such as: Who are the current and potential future users of IERS products? Which products are required to meet the demands of these users? How to organize the IERS to produce them?

Other possible topics for the retreat are the changes and updates to the distribution of IERS products (data format and data access). Is there a need for new products? For example, should IERS start to develop a product giving the offset between the center of figure and the center of mass of the Earth system?

The IERS generates products on a regular basis. As these products have become routine, we need to consider approaches for handling discontinuities in the coordinates of sites used to determine EOP values. Specifically within the last few years there have been large earthquakes that generate significant co-seismic offsets at a large fraction of the IERS reference sites. In addition to the co-seismic offsets, there are also post seismic deformations that continue to affect the reference frame for potentially many years after the earthquakes. How the IERS should accommodate rapid updates to the reference frame used for the EOP values needs to be addressed.

Other topics to be considered include: How to assure the best results of the IERS products? And how well is the organization working in its structure and in individual parts?

The retreat plans initially targeted early 2012 as the likely time to hold the retreat. However, based on trying to find a time for the retreat and the time needed for preparation before the retreat, it is more likely that the retreat will be held in 2013.

5. Unified Analysis Workshop Action Items

The 3rd Global Geodetic Observing System (GGOS) Unified Analysis Workshop (UAW) was held September 16–17, 2011 at ETH Zurich, Switzerland (see also the report in Section 4 below). The presentations from the workshop are on-line at <http://www.iers.org/UAW2011>. Presentations made at the workshop are available under the *programme* link. There were a number of action items for the IERS that are being worked on (Table 1).

Progress has been made on all these action items with some of them to be more fully addressed at the IERS Retreat. Specifically, the IERS Working Group on Site Coordinate Time Series Format, chaired by Laurent Soudarin, has been formed and is active; the study of loading effects at the observation level has been performed and the results collected by the Global Geophysical Fluids Center and the analysis of the center of mass products will be addressed at the IERS Retreat.

Thomas Herring

Table 1: Action Items from the 3rd Global Geodetic Observing System Unified Analysis Workshop

AI	Description	Responsible	Deadline
6	Establish an IERS WG on site coordinate time series: Common format/interfaces for coordinate time series of all techniques. Common tool for display? What type of coordinate time series are required (geocentric, de-trended, reference frame, …) Members: - Chair: Laurant Soudarin - One representative from each technique combination center - One representation from ITRS CCs - GGOS portal manager - Representatives from geophysics/geodynamics, oceanography, …	Chair: Laurent Soudarin; IERS sets up the working group.	02-DEC-11 WG group formed and active
7c	Atmospheric loading corrections on the observation level: Decision not yet taken. Check which IGS ACs can apply atmospheric loading. IGS ACs should get prepared to apply atmospheric loading (recommendation) All services to process the years 2006–2010 with and without atmospheric loading. 1–3 AC solutions per Service would be sufficient for this test. Services identify the ACs. The GGFC model should be used. Tonie van Dam will make this data available for the various formats. Assess the impact on ITRF.	IGS Chair or IGS AC 1-3 ACs from each Service: IVS, ILRS, IDS,IGS GGFC ITRS CC	05-OCT-11 29-FEB-12 30-NOV-11 31-MAR-12
11b	Should there be again a Sub-bureau for geocenter motion in GGFC? Yes. A plan will be developed by Tonie van Dam	GGFC, IERS	15-APR-12

3.4 Technique Centres
3.4.1 International GNSS Service (IGS)

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

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

This report highlights IGS activities of interest to the IERS during 2011.

IGS Tracking Network

At the end of 2011, there were 436 GNSS tracking stations within the IGS network (Figure 1). Approximately 70% of these provide data on a weekly or more frequent basis and are included in IGS weekly combination solution.

A number of IGS stations are co-located with other geodetic techniques to promote combination and inter-comparisons of products and systems. The number of these has remained unchanged since 2010; 25 stations are collocated with VLBI, 37 with SLR, and 55 with DORIS. Accuracy of the tie surveys between the different observing systems remains a limiting factor in the ITRF realization. This is being addressed within the International Association of Geodesy, Global Geodetic Observing System (IAG/GGOS) Bureau for Network and Communications (BNC) and by a number of IGS participating agencies.

Many IGS Network stations have multiple capabilities to support a range of applications. 141 stations deliver GLONASS data in addition to GPS to support the generation of the IGS GLONASS orbit product. 134 stations are co-located with external high-precision frequency standards and are used in production of the IGS clock products. A subset of the network provides meteorological data used in the generation of the IGS troposphere product. Many IGS stations provide data in real-time to support emerging low latency applications.

A complete listing of IGS network stations and related information can be found online at: <http://igs.org/network/netindex.html>.

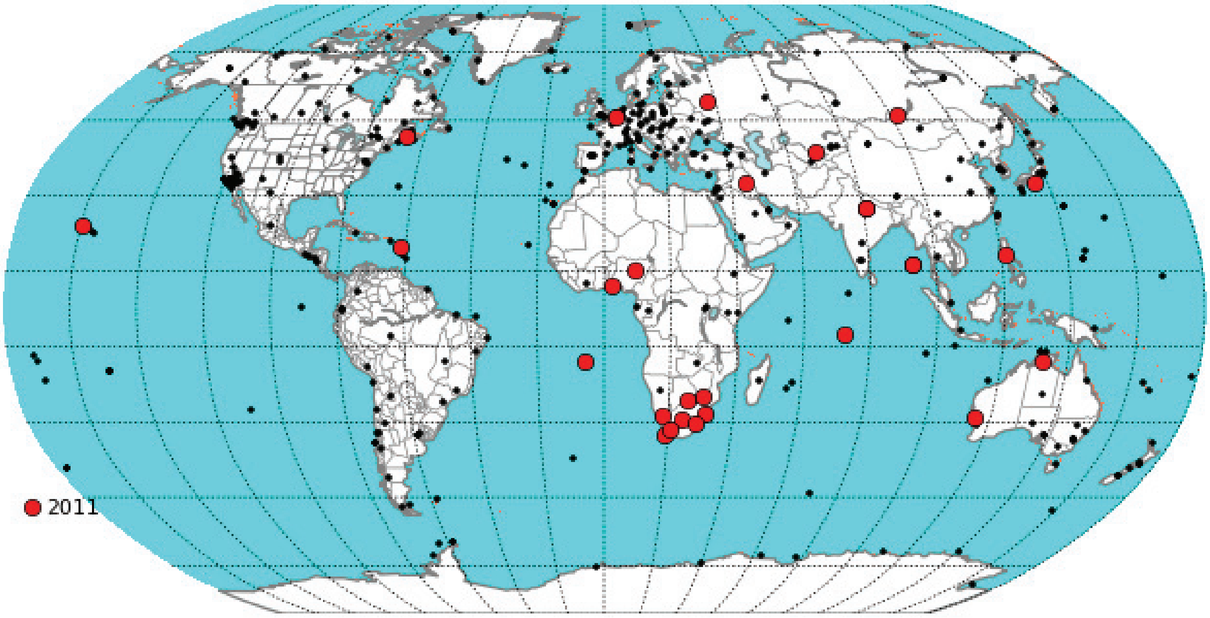

Fig. 1: IGS Global Tracking Network as of December 2011. New stations introduced during 2011 are depicted in RED.

IGS Products Quality

The IGS Analysis Centers (see <http://igs.org/organization/centers.html#ac>) have continued to improve product precision and consistency. Table 1 gives an overview of the estimated quality of the IGS core products at the end of 2011.

Table 1: Quality of the IGS core products at end of 2011.

Product	IGS Final	IGS Rapid	IGS Ultra Rapid	
			Adjusted	Predicted
Updates	Weekly	Daily	Every 6 h	Every 6 h
Delay	~13 days	17 hours	3 hours	Real-time
GPS Orbits	2.0 cm	2.5 cm	3 cm	5 cm
GPS Satellite Clocks	0.05 ns	0.1 ns	~0.2 ns	~5 ns
Station Clocks	0.05 ns	0.1 ns		
Polar Motion	0.05 mas	<0.1 mas	0.1 mas	
LOD	0.02 ms/day	0.03 ms/day	0.03 ms/day	
Station Coordinates (h/v)	2 mm/6 mm			
GLONASS Orbits	~5 cm			

IGS orbit and clock quality is depicted in Figure 2, which shows a significant improvement of these products over time. Final orbits agreed at a level of approximately 2 cm at end of year 2011. Final satellite clock solutions agreed at approximately 5 ns. IGS is expecting an improved IERS diurnal and semi-diurnal EOP tide

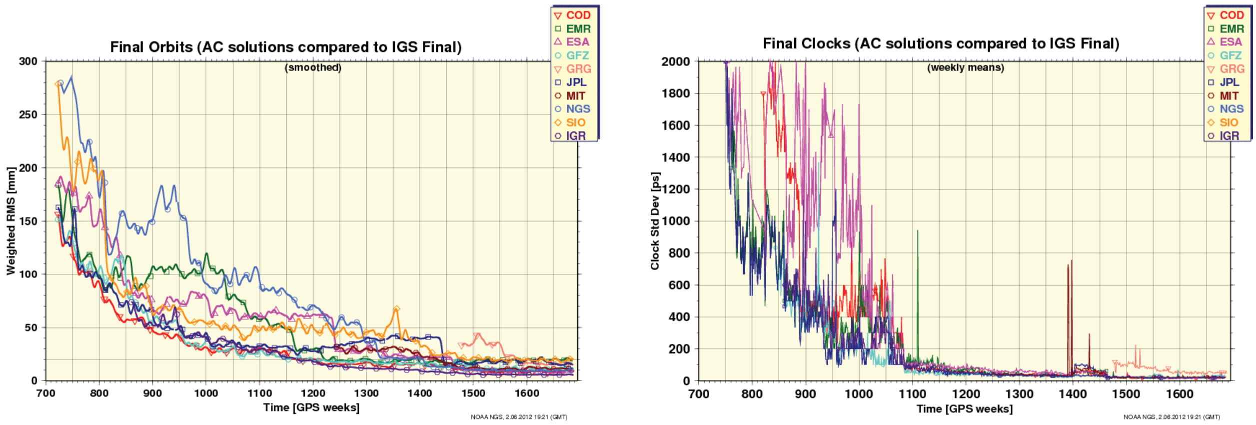

Fig. 2: (a) Weighted RMS differences of all AC's and IGS final orbits to the IGS final combined orbit. (b) Standard deviation of IGS final clock solutions.

model and is developing improved radiation pressure models in order to further improve orbit quality.

Historical quality of the IGS Final Earth Rotation Parameters is shown in Figures 3 and 4. The Final X and Y-Pole solutions agreed at approximately 0.05 mas in 2011. The Final Length of Day Solutions agreed at approximately 0.02 ms/day.

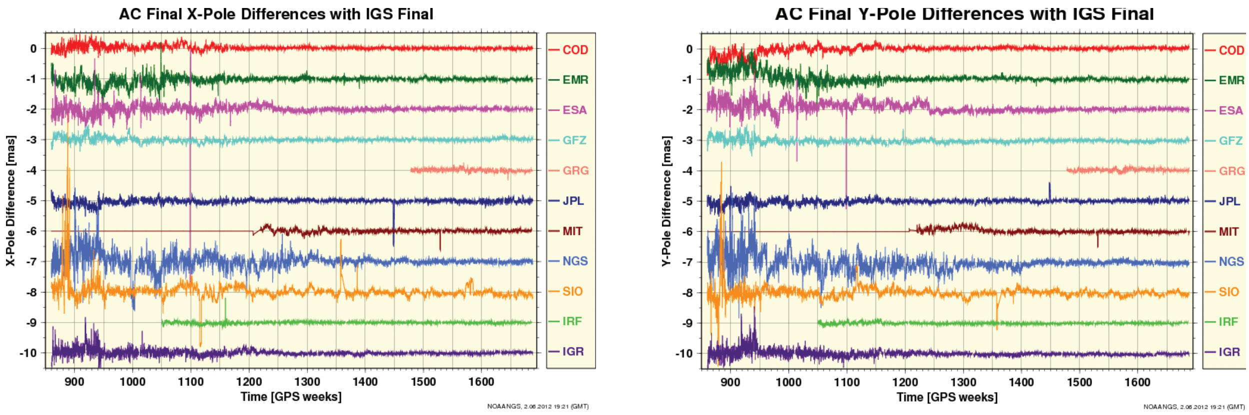

Fig. 3: (a) X-pole differences between IGS Analysis Centers. (b) Y-pole differences between IGS Analysis Centers.

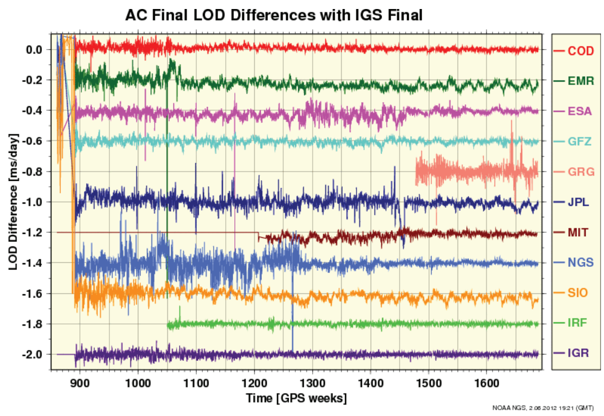

Fig. 4: Length of Day differences between IGS Analysis Centers.

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

IGS08 Reference Frame Introduced

Effective April 17, 2011 the IGS adopted the new IGS08 reference frame, which is closely related to ITRF08. The IGS08 computations were based on a selected globally distributed subset of 232 well performing ITRF08 ground stations. Coincidentally, the IGS also adopted a new ground antenna calibration model (IGS08.atx) based on absolute calibration of the antennas. Satellite phase center offsets were also re-estimated based on ITRF05 to ITRF08 scale differences. Details relating to IGS08 and the IGS08.atx antenna model are contained in IGSMAIL-6354 and IGSMAIL-6355 respectively. Effects on ground station coordinates arising from the IGS05 to IGS08 datum shift, as well as the change over to the new antenna models are discussed in IGSMAIL-6356 and IGSMAIL-6401. The IGSMAIL archive is available online at <http://igscb.jpl.nasa.gov/pipermail/igsmail/>.

2010 Reprocessing Campaign Results Finalized

Results of the first IGS reprocessing campaign (Repro1) covering the period 1994–2007 were announced in April 2010 (see IGSMAIL-6136). Since that time, a number of important details have been resolved (see IGSMAIL-6445). Related product files have now been finalized and distributed to the IGS Global Data Centers for access by users. Details relating to the Repro1 Campaign are available online at <http://acc.igs.org/reprocess.html>.

Radome Experiment in Progress

Radomes at 21 IGS stations that are co located at SLR or VLBI sites have not been calibrated to IGS standards. Station operators were asked to participate in an experiment to assess the effects of these radomes by removing them for a two-month period during 2011. Four stations have been able to respond in 2011, though the experiment will continue into 2012 to allow more time for additional stations to participate. Results are anticipated in 2012.

Multi-GNSS Global Experiment (M-GEX)

A call to participate in a focused Multi-GNSS experiment was circulated in June by the GNSS Working Group (see IGSMAIL-6459 and <ftp://igs.org/pub/resource/pubs/IGS M-GEX VF.pdf>). This was developed to establish a data set of new GNSS signals, including the Russian GLONASS, the Japanese QZSS and European Galileo, available for experimentation. The project is to run from February to August 2012. Participating stations are anticipated to eventually form the core of a multi-GNSS IGS network and service. Details relating to the M-GEX project are available online at <http://igs.org/mgex/>.

Table 2: IGS Stations asked to participate in Radome Experiment.

Agency	Station ID	Antenna Type*	Radome Type	Schedule
JPL	AREQ	AOAD/M_T	JPLA	2011
JPL	CRO1	ASH701945G_M	JPLA	2011
JPL	FAIR	ASH701945G_M	JPLA	2012
JPL	GODE	AOAD/M_T	JPLA	TBD
JPL	MDO1	AOAD/M_T	JPLA	2012
JPL	SANT	AOAD/M_T	JPLA	2012
JPL	SHAO	AOAD/M_T	JPLA	TBD
JPL	TIDB	AOAD/M_T	JPLA	Not Possible
SIO	MONP	ASH701945B_M	SCIS	TBD
NICT	KGNI	ASH701945C_M	SCIS	TBD
NICT	KSMV	ASH700936E	SCIS	TBD
BKG	LHAZ	ASH701941.B	SNOW	TBD
NMA	NYA1	ASH701941.B	SNOW	TBD
NMA	NYAL	AOAD/M_B	DOME	TBD
LMV	ONSA	AOAD/M_B	OSOD	TBD
GSI	SYOG	AOAD/M_T	DOME	TBD
GSI	TSKB	AOAD/M_T	DOME	2011
GSI	TSK2	AOAD/M_T	DOME	2011
WHU	WUHN	ASH700936E	ENCL	TBD
GA	YARR	ASH701073.1	DOME	TBD
GA	YAR2	AOAD/M_T	JPLA	2012

**See IGS08.atx for antenna and radome definitions.*

Real-time Pilot Project Update

The strategy for an official IGS real-time product is being developed, and is expected to be introduced in 2012. Rational for the IGS real-time product is articulated in the statement entitled "Why Is IGS Involved in Real-time GNSS?," which is available online at <ftp://igs.org/pub/resource/pubs/IGS_why_in_RT.pdf>.

There were 188 stations participating in the Real Time Pilot Project at the end of 2011 (see <http://igs.org:2101/home>). Real-time protocols and station standards are being addressed by Real-time Project participants in coordination with the Data Center Working Groups and the Infrastructure Committee. Standards for the real-time GNSS messages are being developed in cooperation with the Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS (RTCM/SC104), which is the principal international standards organization for real-time GNSS services.

Receiver Independent Exchange Format (RINEX)

IGS established in December 2011 a joint IGS/RTCM-SC104 RINEX Working Group chaired by IGS in order to underlined the importance of RINEX for IGS and to assume leadership in maintenance and further development of RINEX. Main tasks are the establishment of RINEX 3 as a standard for new signals and GNSS systems, to develop and implement a transition plan to the new format and to encourage and support the development of open software tools for data handling and quality control.

Troposphere Product in Production

As of July 2011, the responsibility for the production of the IGS troposphere product has transitioned from JPL to USNO (see IGSMAIL-6443). Daily zenith path delay estimates will continue to be generated with an approximate three-week latency for all active IGS sites based on Precise Point Positioning. The resulting product files will continue to be available through the CDDIS Global Data Center at <ftp://cddis.gsfc.nasa.gov/gps/products/troposphere/zpd>.

Combination Software Upgrade

An effort to update the IGS combination software is being jointly planned by the CODE and ESOC analysis centers together with TU Vienna. The first major revision of this software since IGS began generating combination products in 1994 is envisioned to allow for Multi-GNSS product combination and to improve traceability of the IGS products and maintainability of the software. The upgrade project will be initiated in 2012 and is anticipated to take 1–2 years depending on availability of resources to complete the work.

Site Guidelines Revised

IGS Site Guidelines have been revised to reflect currently recommended best practices. The new Guidelines include procedures for upgrading station equipment, prescribing periods of operation where old and new equipment are operated simultaneously to assure that discontinuities are properly mapped. In addition, stricter antenna requirements have been introduced as recommended during the 2008 IGS Workshop, and guidelines for real-time stations were added. The IGS Governing Board has provisionally accepted the new guidelines and plans to formally adopt them by mid-2012 after comments by the broad IGS community are integrated. Once completed, the new guidelines will be posted on the IGS website.

Network Information System Improved

IGS network information systems are being upgraded to improve information content and consistency. A prototype IGS network interface, which provides better access to station data and quality control (QC) information, is now operating at <http://network.igs.org/>. In addition, site log metadata are now contained in a relational database, which is operating in parallel to the current site log system. This is already facilitating improvements in site metadata accuracy and accessibility. Network performance monitoring reports will be derived from metadata and quality control information that give an aggregate view of the network's performance, including threshold compliance with IGS guidelines, data availability and quality parameters. These will soon be available on the IGS website.

International Coordination and Outreach

The CB coordinates extensively with many external organizations to promote the IGS and develop key partnerships with participants and users. This has continued as a hallmark activity in 2011, which was highlighted by these activities:

- International Association of Geodesy/Global Geodetic Observing System (IAG/GGOS): The IGS coordinated extensively with GGOS, including participating on the Coordinating Board and within the Bureau for Networks and Communications.
- United Nations/International Committee on GNSS (ICG): Working Group D on reference frames and timing applications is chaired by the IGS CB Director. IGS representatives are participating in planning of the International GNSS Monitoring and Assessment System (iGMAS). The 6th ICG Meeting in Tokyo was attended by several IGS participants.
- International Earth Rotation & Reference Systems Service (IERS): IGS and IERS have continued to extensively cooperate in the realization of ITRF, as well as reciprocally participate on each other's Boards.
- Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS (RTCM/SC104): The IGS holds voting membership on this international standards organization for Differential GNSS.
- International Federation of Surveyors (FIG): FIG represents the single largest user community of IGS products, and is also a potential channel for extending the IGS network. IGS and FIG are coordinating to reach out to users, as well as to advocate for precision geodesy within organizations such as ICG. A number of IGS participants attended FIG Working Week in Marrakech, Morocco (May 2011).

Additionally, IGS reached out to a number of user communities by participating in scientific workshops and conferences, including: AfricaGEO in Capetown, the International Council of Science/World Data System Meeting in Paris, the European Geophysical Union Meeting in Vienna, the International Union of Geodesy and Geophysics Meeting in Melbourne, the Institute of Navigation in Portland and the American Geophysical Union Meeting in San Francisco.

Publications and Meetings

The 2011 IGS Technical Reports containing summaries of all of the principal IGS activities will be available online by mid-2012 at <ftp://igs.org/pub/resource/pubs/2011_techreport.pdf>.

Many papers, articles and presentations relating to IGS were published or presented in 2011. A partial listing of these is available online at <http://tinyurl.com/IGS-bibli>.

A significant number of meetings and workshops were attended by IGS participants in 2011. A listing of these is available online at <http://igs.org/events/>. The next IGS Workshop will take place from July 23 to 27, 2012, at University of Warmia and Mazury in Olsztyn, Poland.

Summary

The IGS has continued its delivery of high quality products to the IERS, which represent a significant contribution to the realization of the ITRF. The quality of the IGS results continue to improve analysis methodologies are constantly refined, historical data reprocessed and GNSS technologies evolve. More information regarding the IGS and related activities can be found on the IGS Central Bureau website (see: <http://www.igs.org/>).

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

3.4.2 International Laser Ranging Service (ILRS)

Introduction

The International Laser Ranging Service (ILRS), established in 1998, is responsible for the coordination of SLR/LLR missions, technique development, network operations, data analysis and scientific interpretation. Here we summarize the status and developments in 2011.

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 document

Fig. 1: The global network of SLR stations (status early 2012).

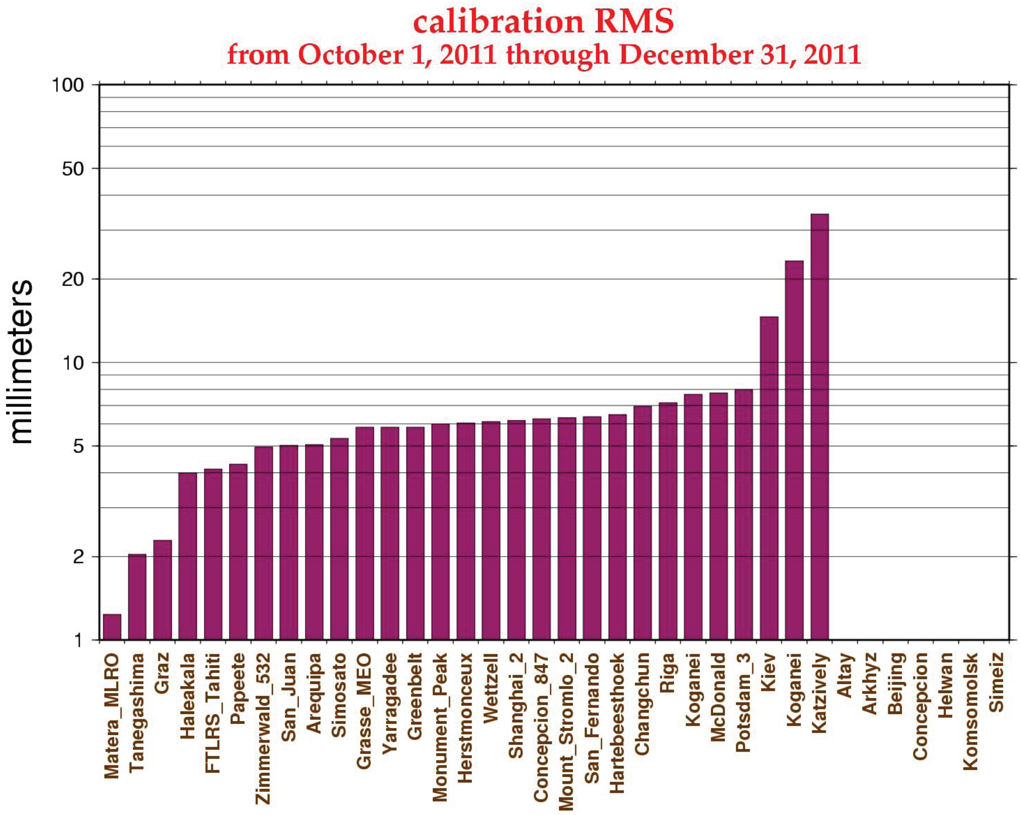

Fig. 2: The global network of SLR stations (status early 2012).

and several stations 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. Near the end of the year the Russian agencies indicated an interest in contributing a significant number of new, high repetition rate systems, most of which are located in areas void of coverage at the moment, and three of which are co-located with VLBI systems that are part of the IVS network for a long time now (Badary Zelenchukskaya, and Svetloe). These sites will have to be validated before they can become part of the ILRS network, early next year, however, 3.4.2 International Laser Ranging Service (ILRS)

Table 1: ILRS Network Tracking Statistics for 2011.

Site Name	Station	Number of Passes			Total
		Low	LAGEOS	High	
Altay	1879	214	243	773	1,230
Arequipa	7403	1,998	166	0	2,164
Arkhyz	1886	72	189	184	445
Beijing	7249	569	45	1	615
Changchun	7237	5,202	544	1,020	6,766
Concepcion	7405	1,049	573	111	1,733
Grasse	7845	877	550	764	2,191
Graz	7839	4,784	708	1,841	7,333
Greenbelt	7105	4,301	593	684	5,578
Haleakala	7119	1,654	493	0	2,147
Hartebeesthoek	7501	2,875	970	992	4,837
Helwan	7831	3	0	0	3
Herstmonceux	7840	3,931	760	1,673	6,364
Katzively	1893	1,449	244	213	1,906
Kiev	1824	935	165	89	1,189
Koganei	7308	439	169	356	964
Koganei	7328	129	34	0	163
Komsomolsk-Na-Amure	1868	59	135	439	633
Matera	7941	4,924	2,036	2,933	9,893
McDonald	7080	1,164	427	213	1,804
Monument Peak	7110	3,303	949	1,166	5,418
Mount Stromlo	7825	6,217	971	386	7,574
Potsdam	7841	2,217	331	86	2,634
Riga	1884	1,427	106	2	1,535
San Fernando	7824	1,674	185	19	1,878
San Juan	7406	2,794	608	831	4,233
Shanghai	7821	1,741	270	516	2,527
Simeiz	1873	1,143	308	10	1,461
Simosato	7838	1,233	431	124	1,788
Tahiti	7124	538	189	0	727
Tahiti	7822	96	50	0	146
Tanegashima	7358	274	33	107	414
Wettzell	8834	3,938	917	902	5,757
Yarragadee	7090	15,330	2,918	5,142	23,390
Zimmerwald	7810	9,152	1,732	4,489	15,373
Totals:	35 stations	87,705	19,042	26,066	132,813

they will 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 2011 are summarized in Table 1. For each of the contributing stations the tracked passes are broken down in three categories of tracked targets: Low Earth Orbiters (LEO), LAGEOS 1 & 2, and the High Earth Orbiters (HEO) which include the GPS, GLONASS, ETALON and GIOVE-A/B satellites (GALILEO test s/c), as well as a number of recently launched Beidou satellites, part of the Chinese Navigation Constellation COMPASS/Beidou.

Of all the active ILRS observatories (35), only a few laser-ranging systems are technically equipped to track retro-reflector arrays on the surface of the Moon or spacecraft orbiting around the Moon, where the Lunar Reconnaissance Orbiter (LRO) could be tracked successfully by several SLR sites with one-way ranging. The active dedicated Lunar Laser Ranging (LLR) sites in 2011 were the following observatories: the McDonald Observatory in Texas, USA (generating 20 NP), the Observatoire de la Côte d' Azur, France (60 NP), the APOLLO site in New Mexico, USA (366 NP) and the Matera Laser Ranging station in Italy (3 NP). The German Geodetic Observatory at Wettzell is still working on its system hoping to soon join the LLR tracking network. The measurement statistics of 2011 (Figure 3) clearly shows that most of the data have been collected at the APOLLO site, that however needed a long time span for re-processing and calibration correction, before the data could be released by end of 2012.

Figure 4 illustrates the statistics for the observed reflectors, where – thanks to APOLLO – a much better coverage of all reflectors could be achieved than in the previous years. Figure 5 shows the entire LLR data set 1970–2011, indicating the amount of data collected by each of the active LLR sites in each year. It is about 17,200 normal points in total.

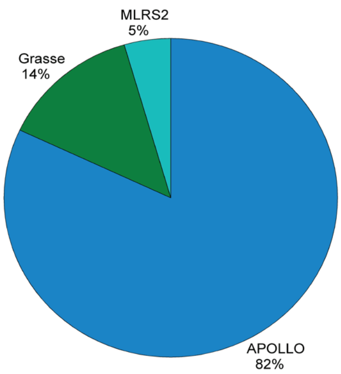

Fig. 3: Observatory statistics in 2011.

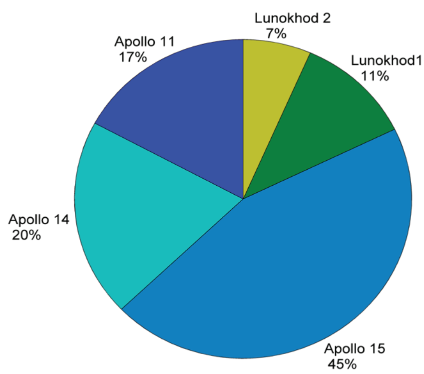

Fig. 4: Reflector statistics in 2011.

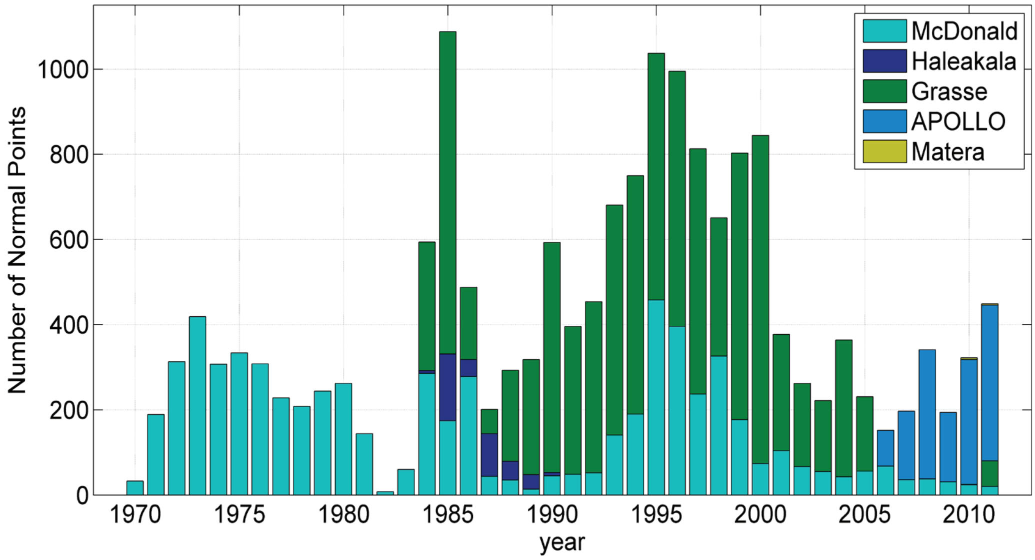

Fig. 5: Data yield of the global LLR network of stations (up to 2011)

The LLR results are considered among the most important science return of the Apollo era. To enable data analysis at the mm level of accuracy, all elements of the tracking process have to be modeled at appropriate (relativistic) approximation, i.e. the orbits of the major bodies of the solar system, the rotation and deformation of Earth and Moon, the signal propagation, but also the involved reference and time systems. This is mainly done 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.

By analysing the 42-year record of range data, LLR is 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. In 2011, the ISSI (International Space Science Institute) workshop series on “Theory and model for the new generation of the Lunar Laser Ranging data” has been continued with a spring meeting in Berne, Switzerland.

Missions

In 2011, a total of ~38 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 twelve successful launches in 2011, of satellites carrying LRAs, listed in Table 2. The first one, COMPASS-I3 is a geostationary

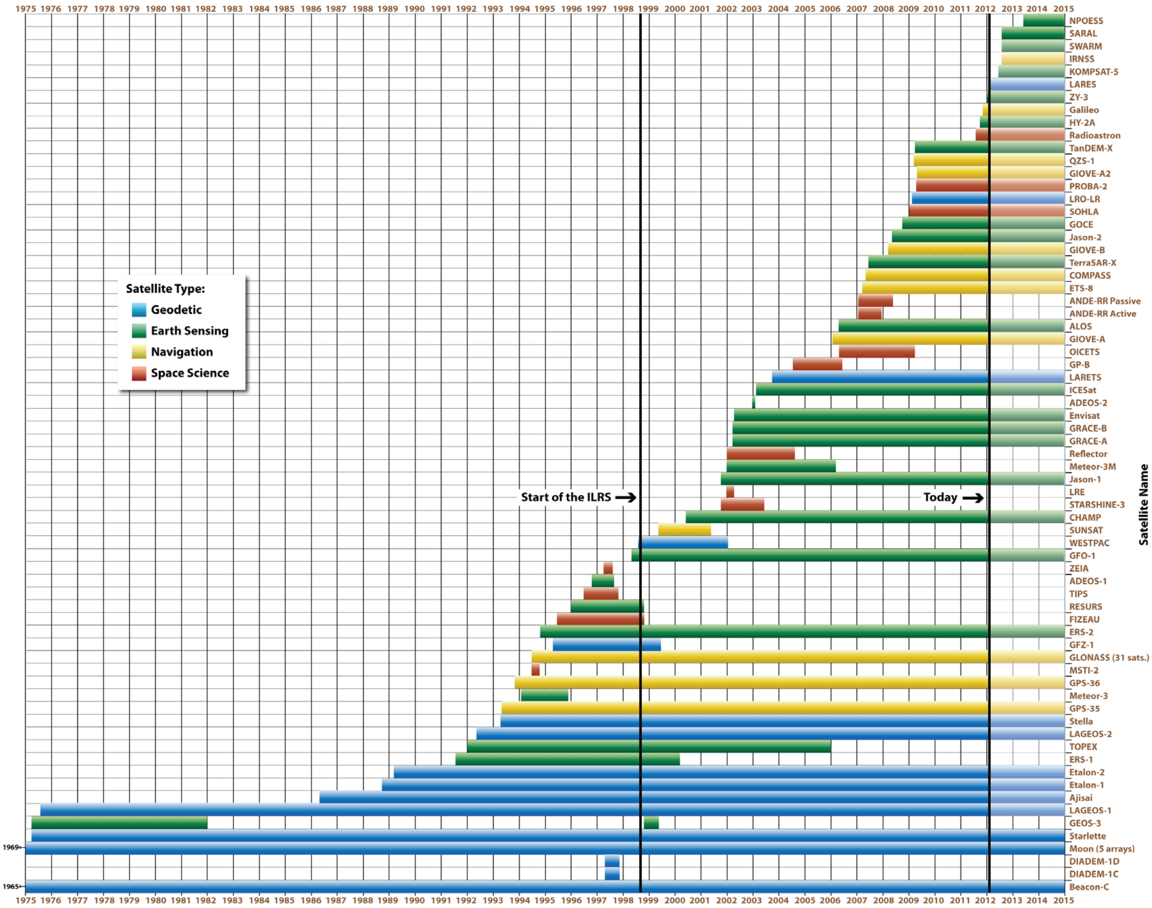

Fig. 6: The currently tracked SLR missions (status early 2012).

member of the COMPASS/Beidou Constellation, launched by China. RadioAstron is a mission of the Russian Academy of Sciences, carrying a large radio telescope into a challenging highly eccentric orbit, with a very low perigee and an apogee that is almost at the distance to the Moon. Tracking such a mission will be very challenging for the network and it is expected that only stations with lunar capability will be able to achieve that. The third mission is an oceanographic mission from China with a collaboration with the French space agency CNES. The next two satellites were launched together on 21 October 2011, they are the first 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. The following six satellites from Russia were put in four different launches. Six new GLONASS satellites, 125-130, completed the GLONASS Constellation, all of which carry improved LRAs. The group of GLONASS spacecraft tracked by ILRS was changed to substitute older spacecraft with the recently launched ones. Several ILRS stations though have decided to increase the number of GLONASS satellites they track, in preparation of future requests for regular support of the complete constellation. The last entry of Table 2 corresponds to another geostationary member of the COMPASS/ Beidou Chinese navigation constellation that has accelerated the pace of populating their orbital slots in recent years.

Table 2: ILRS Supported Missions Launched in 2011.

Satellite Name	Satellite ID	SIC Code	NORAD Number	NP Indicator	Bin Size (sec)	Altitude (Km)	Inclination (deg)	First Data Date
COMPASS-I3	1101301	2003	37384	9	300	42,161	55.5	27-Apr-12
RadioAstron	1103701	5559	37755	6	60	500-350,000	51.4	22-Jan-12
HY-2A	1104301	2201	37781	5	30	971	99.35	2-Oct-11
Galileo-101	1106001	7101	37846	9	300	23,220	56	29-Nov-11
Galileo-102	1106002	7102	37847	9	300	23,220	56	29-Nov-11
GLONASS-125	1100901	9125	37372	9	300	19,140	65	9-Mar-11
GLONASS-126	1105501	9126	37829	9	300	19,140	65	15-Nov-11
GLONASS-127	1106403	9127	37869	9	300	19,140	65	
GLONASS-128	1106401	9128	37867	9	300	19,140	65	
GLONASS-129	1106402	9129	37868	9	300	19,140	65	
GLONASS-130	1107101	9130	37938	9	300	19,140	65	9-Mar-11
COMPASS-I5	1107301	2005	37948	9	300	42,161	55.5	6-Jul-12

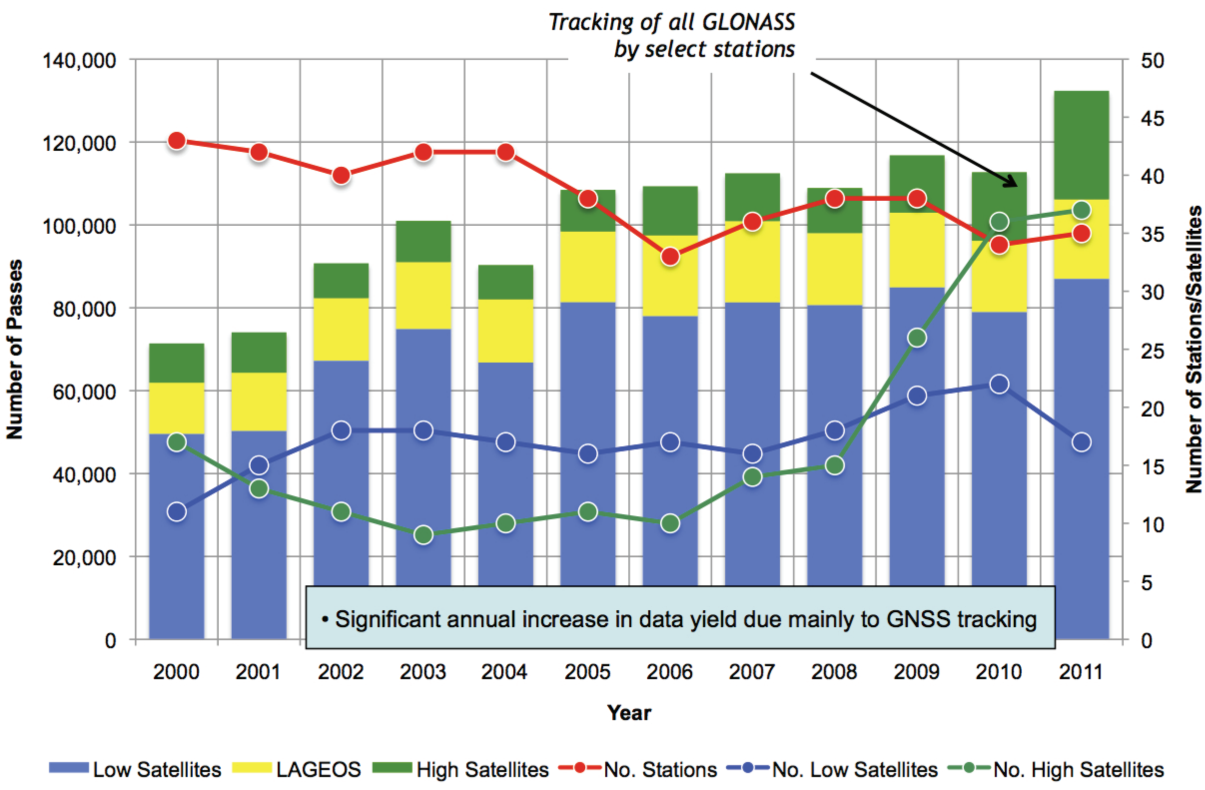

Fig. 7: ILRS network data yield over the past decade (status late 2011).

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 the remaining sites has increased tremendously to not only make up for that loss but rather nearly double the data yield by 2011 (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 more than doubling the number of HEO satellites tracked between 2008 and 2011 (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.

An area of concern for the entire community was the change of hands of the operations for the NASA network during early 2011. It turns out that this change came at some cost, primarily in the prompt data flow of the collected data. This however gave the ILRS an incentive to pursue a more systematic overhaul of the data flow and the archival of the data at its two Data Centers (DC), CDDIS at Goddard SFC, Greenbelt and EDC at DGFI, München. The harmonization of the two DCs caused severe delays in the implementation plan of the new data format (CRD), with the initial attempt at the end of 2010 beginning of 2011 to be aborted and a quick return to the old format. 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 will ensure 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 is under the aegis of the ILRS CB. The new website is expected to become operational for user comments sometime in 2012. At the Kötzting workshop all WGs were encouraged to work on the updating of their pages for inclusion in the new website.

Analysis and science

The Analysis Working Group (AWG) concentrated on the integration of ITRF2008 within the system maintained by ILRS for all sites that hosted SLR tracking at any time in the past. The new TRF, titled "SLRF2008", was released in mid-2011, at the AWG meeting in Kötzting, Germany, for evaluation and validation by the Analysis Centers (AC). At the same time, the AWG decided to improve the feedback of the QC services provided by a number of ACs to the stations, by instituting a new type of official ILRS email, the "Rapid Service Mail". Use of this tool will ensure that anomalies observed by any of the participating ACs will be communicated immediately to the entire group and the station(s) involved, in a brief message indicating the nature of the observed anomaly. It is expected that the stations will respond with an explanation, if available, or indicate that they will undertake measures to resolve the anomaly and report back to the AWG when the issue has been resolved.

In regards to modeling improvement of the SLR data, the task force on target signature released a new, time dependent version of their "center-of-mass" (CoM) offset correction for the LAGEOS and ETALON satellites. This new version is no longer in tabular form and comprises a data base that requires regular updates and a s/w package that users can use to interrogate the data base. Based on the mode in which a site operated at different times, the CoM offset can be quite different for each target, a difference that has a range in some cases as much as 10 mm. This is a huge variation given that the goal for the accuracy of the ITRF is at or below the 1 mm, with 0.1 mm/y stability! The newly proposed CoM model was put to test in an AWG Pilot Project (PP) to validate the model and determine the level of improvement in the final product. Results are expected in early 2012.

The ILRS AC members of the AWG begun to look into the ability of their s/w to model the application of atmospheric corrections in the calculated station positions and on the orbit. This is in anticipation of an ITRS request that was discussed during the second AWG meeting in Zürich, Switzerland and the IERS Unified Analysis Workshop in the same venue. The ITRS expressed an interest in testing the application of the atmospheric corrections at the level of the contributions of the Services rather at the observation level, so a PP that would compare the final results from these two approaches seemed a reasonable approach. The ITRS indicated that they would work together with the IERS/GGFC to formulate the proposed PP to the Technique Services.

Meetings

The ILRS held three meetings in 2011. The 17th International Workshop on Laser Ranging was held in Bad Kötzting, Germany, May 16–20, 2011. This workshop was originally intended to take place in Concepcion, Chile, however, the disastrous earthquake of 2010 forced a change of plans. A Governing Board (GB) meeting was held during the workshop. In acknowledgement of the loss of two of our closest associates over the past year, Dr. W. Seemüller and Dr. Y. Fumin, the GB recognized their contribution to the success of the ILRS with two plaques that were sent to their families. A brief meeting of the AWG also followed the end of the workshop, where plans were made for the agenda of the subsequent AWG meeting that took place in Zürich, Switzerland, on September 15, 2011 in conjunction with the IERS Unified Analysis Workshop. A second GB meeting took place during the Fall AGU on Tuesday, December 6, 2011. During this meeting Carey Noll gave a demonstration of the new ILRS website at the stage it reached at that time. Everyone was encouraged to visit the site and submit commends and suggestions to the ILRS CB.

Publications

Appleby, G., G. Kirchner, Jan McGarry, C. Noll, E. C. Pavlis, and M. Pearlman (2011), “High Quality Products from Satellite Laser Ranging”, Geophysical Research Abstracts, Vol. 13, EGU2011-11370, EGU General Assembly 2011, Vienna, Austria, 3–8 April.

Ciufolini, I., A. Paolozzi, E. C. Pavlis, J. Ries, R. König, and R. Matzner, (2011), “LARES, Laser-Ranged Satellite for Testing General Relativity”, Space Research Today, Volume 182, December 2011, pp. 11–25, ISSN 1752-9298, 10.1016/j.srt.2011.11.005.

Ciufolini I., A. Paolozzi, E. C. Pavlis, J. C. Ries, R. Koenig, R. Matzner, G. Sindoni, and H. Neumayer, (2011), Testing Gravitational Physics with Satellite Laser Ranging, European Physics Journal Plus 126 72, 10.1140/epjp/i2011-11072-2.

Ciufolini, I., E. C. Pavlis, A. Paolozzi, J. Ries, R. König, R. Matzner, G. Sindoni, K.-H. Neumayer (2011), “Phenomenology of the Lense-Thirring effect in the Solar System: Measurement of frame-dragging with laser ranged satellites”, doi:10.1016/j.newast.2011.08.003, New Astronomy 17, pp. 341–346.

Dell’Agnello, S., G.O. Delle Monache, D.G. Currie, R. Vittori, C. Cantone, M. Garattini, A. Boni, M. Martini, C. Lops, N. Intaglietta, R. Tauraso, D.A. Arnold, M.R. Pearlman, G. Bianco, S. Zerbini, M. Maiello, S. Berardi, L. Porcelli, C.O. Alley, J.F. McGarry, C. Sciarretta, V. Luceri, T.W. Zagwodzki (2011), Creation of the new industry-standard space test of laser retroreflectors for the GNSS and LAGEOS, Advances in Space Research, Volume 47, Issue 5, Scientific applications of Galileo and other Global Navigation Satellite Systems - II, pp. 822–842, ISSN 0273-1177, DOI: 10.1016/j.asr.2010.10.022.

Kuzmicz-Cieslak, M. and E. C. Pavlis, (2011), “Space Geodetic Technique Co-location in Space: Simulation Results for the GRASP Mission”, Abstract G53B-0897 presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5–9 Dec.

Lucchesi, D.M., The LAGEOS satellites orbit and Yukawa-like interactions, Advances in Space Research, Volume 47, Issue 7, 1 April 2011, pp. 1232–1237, ISSN 0273-1177, DOI: 10.1016/j.asr.2010.11.029.

Murphy T.W. Jr., Adelberger E.G., Battat J.B.R., Hoyle C.D., Johnson N.H., McMillan R.J., Michelsen E.L., Stubbs C.W., Swanson H.E. (2011),”Laser ranging to the lost Lunokhod 1 reflector”, Icarus, Volume 211, pp. 1103–1108.

Pavlis, E. C., (2011), “ILRS Products, Standards, Modeling”, 2011 Unified Analysis Workshop of the IERS, Zürich, Switzerland, September 16–17, 2011.

Pavlis, E. C., (2011), “GGOS Global Geodetic Networks: Their Impact on WEGENER”, (INVITED), Geophysical Research Abstracts, Vol. 13, EGU2011-9002, EGU General Assembly 2011, Vienna, Austria, 3–8 April.

Pavlis, E. C. (2011), “Improved Modeling and Data Analysis for Laser Ranging Data”, 2nd Workshop on *“Theory and Model for the New Generation of the Lunar Laser Ranging Data”*, ISSI, Bern, Switzerland, 15–17 February 2011.

Pavlis, E. C., I. Ciufolini and A. Paolozzi, (2011), “LARES: A new mission to improve the measurement of Lense-Thirring effect with Satellite Laser Ranging”, Journées 2011, Vienna, Austria, September 19–21, 2011.

Pavlis, E. C. and M. Kuzmicz-Cieslak (2011), “Multi-satellite Mission Products for GGOS”, Abstract G53A-0877 presented at 2011 Fall Meeting, AGU, San Francisco, CA, 5–9 Dec.

Pavlis, E. C. and M. Kuzmicz-Cieslak, (2011), “Improvements in SLR Data Modeling and Reduction for POD”, Ocean Surface Topography Mission Science Team Meeting, San Diego, CA, October 19–21, 2011.

Pavlis, E. C., M. Kuzmicz-Cieslak and P. M. Hinkey, (2011), “Forthcoming Improvements in SLR Data Analysis: Towards the mm SLR”, Journées 2011, Vienna, Austria, September 19–21, 2011.

Pavlis, E. C., M. Kuzmicz-Cieslak, and P. M. Hinkey (2011), “GGOS Products from Multiple Mission SLR Data Analysis”, Geophysical Research Abstracts, Vol. 13, EGU2011-14124, EGU General Assembly 2011, Vienna, Austria, 3–8 April.

Pearlman, M. R., E. C. Pavlis, Chopo Ma, Zuheir Altamimi, Carey E. Noll, and David A. Stowers (2011), “Space Geodesy Networks to Improve the ITRF”, (INVITED) Geophysical Research Abstracts, Vol. 13, EGU2011-4786, EGU General Assembly 2011, Vienna, Austria, 3–8 April.

Riepl S. and E. C. Pavlis, (2011), “Position paper on: Refraction - Modeling and Remote Sensing Approach”, 17th Int. Laser Workshop, Bad Kötzting, Germany, May 16–20, 2011.

Rambaux, N., Williams, J. G., (2011), “The Moon’s physical librations and determination of their free modes”, Celestial Mechanics and Dynamical Astronomy, Volume 109, pp. 85–109.

Ries, J., I. Ciufolini, E. C. Pavlis, A. Paolozzi, R. König, R. Matzner, G. Sindoni, and K-H. Neumayer (2011), “The Earth’s frame-dragging via laser-ranged satellites: A Response to “Some considerations on the present-day results for the detection of frame-dragging after the final outcome of GP-B” by Iorio L.”, EPL, 96, 10.1209/0295-5075/96/30002.

Schuh, H., M. Pearlman and E. C. Pavlis, (2011), "Position paper on: Co-location on Ground and in Space, GGOS Core Sites", 2011 Unified Analysis Workshop of the IERS, Zürich, Switzerland, September 16–17, 2011.

Schreiber, U., M. Pearlman, and G. Appleby (eds.) (2011), Proceedings of the 17th International Workshop on Laser Ranging, Bad Koetzing, Germany, May 16–22, 2011, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 48, BKG, Frankfurt am Main.

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3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2011, 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 20th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting was held in Bonn (Germany) March 29–31, 2011.
- The 12th IVS Analysis Workshop was held in Bonn (Germany) on March 31, 2011.
- The spring 2011 IVS Directing Board meeting (IVS DB #25) was held on April 1st in Bonn (Germany). At this meeting Harald Schuh was elected chair of the IVS DB for another four years.
- The 6th IVS Technical Operations Workshop (TOW) was held at Haystack Observatory (USA), May 9–12, 2011.
- The continuous VLBI campaign 2011 (CONT11) was observed on September 15–29, 2011, including 13 participating stations.
- An IVS retreat was held on September 21–22, 2011, at Hohe Wand, Austria.
- The fall 2011 IVS Directing Board meeting (IVS DB #26) was held on September 23, 2011, at Hohe Wand, Austria.
- The 10th International e-VLBI Workshop was held on November 13–16, 2011, at Broederstroom, South Africa.
- In the summer of 2011 the IVS published the 2010 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 2011. The average single station loss is estimated to have been in the range of 10–20%, similar to previous years. One of several positive developments was increased use of e-transfer with data from Ny-Ålesund, Fortaleza, AuScope, and Warkworth now being largely e-transferred. This speeds data transfer and reduces shipping costs. Another positive development was that Mark 5B recorders were installed at several stations improving correlator efficiency. A third development is that digital back-ends are starting to be used at more stations for operations. The DBBC developed by the EVN is being used at Hobart, Katherine, Yarragadee, and Warkworth. The Haystack/NRAO developed RDBE is nearing readiness for observations and is expected to start being used in 2012. There were a few notable issues with IVS antennas:

- On March 11, 2011, a major earthquake and Tsunami affected the east coast of Japan, impacting the VLBI stations at Tsukuba and Kashima. Also the VERA station at Mizusawa was affected and severely damaged.
- Several stations had problems with warm receivers.
- Noto was not operating due to a rail repair.
- The AuScope stations had some problems with recording devices.
- The use of the Chinese stations Seshan25 and Urumqi was restricted due to obligations in connection with the Cheng'E mission.
- The station Warkworth participated in one of the CONT11 sessions.

A total of 171 geodetic/astrometric 24-hour sessions were observed during the year 2011. The number of observing sessions coordinated by IVS was about ~3.3 days per week, similar to previous years. The major observing programs during 2011 were:

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

Intensive Daily 1-hour UT1 Intensive measurements are made on five days (Monday through Friday, Int1) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA), on weekend days (Saturday and Sunday, Int2) on the baseline Wettzell (Germany) to Tsukuba (Japan), and on Monday mornings (Int3) in the middle of the 36-hour gap between the Int1 and Int2 Intensive series on the network Wettzell (Germany), Ny-Ålesund (Norway), and Tsukuba (Japan). Since Tsukuba was affected by the Tohoku earthquake in March 2011 and exhibited continued, post-seismic nonlinear motion, back-to-back Int2 sessions were organized where a Wettzell–Kokee Intensive was immediately followed by a Wettzell–Tsukuba Intensive. This program was continued until the Tsukuba motion could be properly modeled. Also, when possible, Seshan25 was added to the Int3 sessions.

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with at least 12 stations per session. Seven of these sessions were observed 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. Twelve sessions were observed for the maintenance of the ICRF in 2011.

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 2011.

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 2011 six OHIG sessions were observed.

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2011.

AUSTRAL In 2011 two 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 2011. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

IVS-R&D Seven research and development sessions were observed in 2011. The goal of the 2011 R&D sessions was to test and validate the observing mode to be used during the CONT11 campaign.

CONT11 The continuous VLBI campaign CONT11 was observed September 15–29, 2011, and involved 13 stations worldwide. The data were correlated at the Washington correlator.

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 CONT11 sessions. The Haystack correlator processed RD sessions and some T2 sessions. The Int2 and JADE sessions were processed at the Tsukuba correlator that also processed the baseline Onsala–Tsukuba during the whole CONT11 campaign in ultra-rapid mode.

Data Centers

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

IVS Operational Data Analysis and Combination

The combination process for the two IVS EOP series (rapid and quarterly solutions) has been continued exclusively on the basis of datum-free normal equations in SINEX format. In 2011, six IVS Analysis Centers (BKG, DGFI, GSFC, IAA, OPA, and USNO) contributed to the IVS combined products by providing input in the correct format. The rapid solutions contain only R1 and R4 sessions and new data points are added twice a week as soon as the SINEX files of at least five IVS Analysis Centers are available. The SINEX file submissions should not be later than 48 hours after the correlation is completed. A Web page is automatically updated which lists the timeliness of the latest submissions of the R1 and R4 sessions (see <http://ida.bkg.bund.de/IVS/data/timeliness_2.html>).

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

CONT11

The continuous VLBI campaign CONT11 was observed September 15–29, 2011 and involved 13 participating stations on six continents. The goals of CONT11 were to address the discrepancies seen between the theoretical models (ocean tidal and atmospheric) and the observations at the M2 and S1 frequencies as well as between long-term and short-term values of tidal amplitudes. The Tsukuba correlator processed the Onsala–Tsukuba baseline in ultra-rapid mode during the whole CONT11 campaign, thus producing dUT1 results during the ongoing campaign.

Technology Development

During 2011 progress continued towards the goal of a next-generation VLBI system, e-VLBI, and other technical aspects. Some important highlights were:

- The VLBI2010 prototyping work continued with, e.g., test of broadband feed horns and digital backends.
- The Mark 5C VLBI data system is now used routinely at 2 Gbps to a single 8-disk module and will enter service at 4 Gbps in early 2012.
- A 16 Gbps COTS-based Mark 6 system is under development at Haystack Observatory; a successful 16 Gbps VLBI experiment using an early Mark 6 development system was conducted in November 2011. The Mark 6 is projected to enter service in mid/late 2012.
- A number of VLBI2010 data-taking sessions between Westford and NASA/GSFC were undertaken during 2011. Most were recorded onto four Mark 5C units at each station using RDBE backend units as data sources, at an aggregate data rate of 8 Gbps/station. More of the processing of VLBI2010 data continues to be moved from the Mark 4 correlator to the DiFX correlator at Haystack Observatory.
- The DiFX software correlator was prepared for a 16-station VLBI2010 operational mode.

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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 (2011), the number of DORIS satellites has increased up to seven (see Table 1).

On August 15, 2011, a new DORIS satellite (HY-2A) was launched including the last generation receiver (DGXX) on-board: digital, 7-channel, allowing direct phase measurement like GPS (instead of Doppler data).

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 2012–2016 time period.

1.2 DORIS network

The station at Monument Peak, CA, USA was closed in 2010 because of conflicts in frequency with a nearby TV relay station. Since then, 56 stations make up the DORIS permanent network and two additional stations are dedicated to experimentation: Gavdos (Crete, Greece) and Grasse (France).

Two new models of beacon came out this year:

Model 3.1 with mainly software improvement, becoming more simple and strong. Two stations have been equipped this year: Toulouse and Yarragadee.

Table 1: DORIS data available at IDS Data Centers. As of December 2011

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

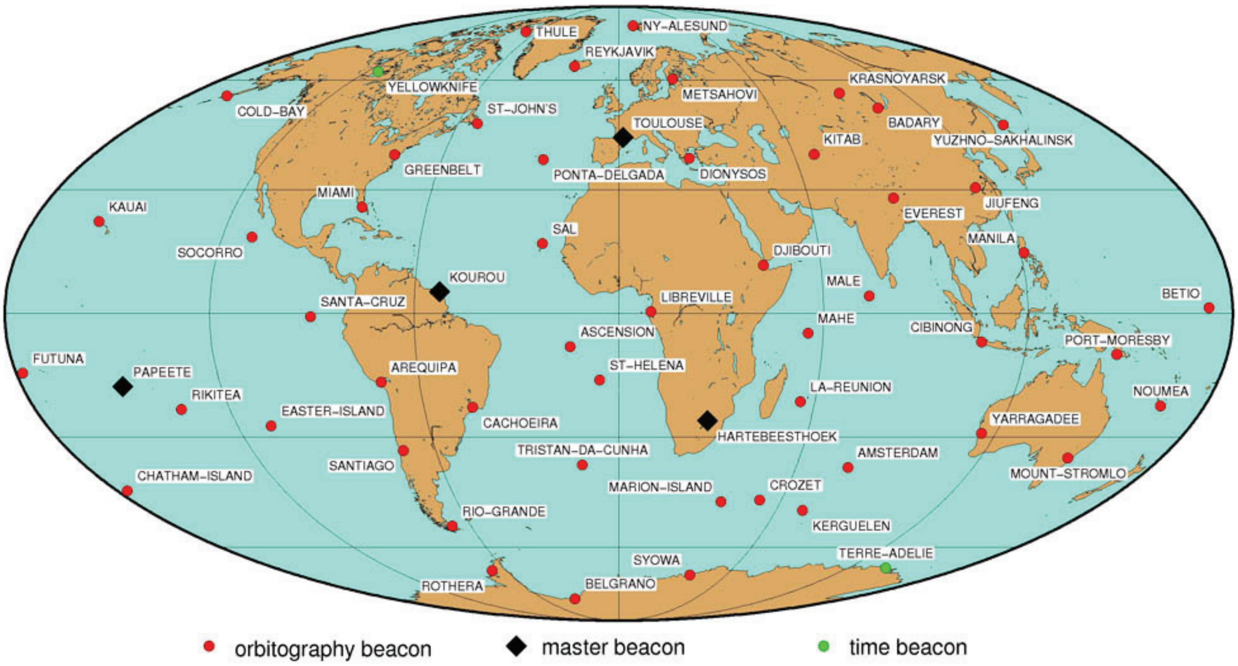


Fig. 1: DORIS stations co-located with other techniques (VLBI, SLR, GNSS) (as of December 2011).

Model 3.2 is more interesting with regard to the station configuration. This beacon works with optic cables and requires an extend amplifier. This allows till 80m distance between the beacon and the antenna, compared with 15m for regular cables. It will be easier to meet the sky view and stability requirements for DORIS antenna.

The remote control system allowing distance settings on the beacon is still being deployed: 23 stations are now equipped.

2 IDS Governing Board

The current Governing Board (GB) was elected at the end of 2008 (see Table 2).

On GB's request, a Working Group was formed in September 2010 to review and update the IDS Terms of Reference. The WG, chaired by Mike Pearlman, proposed a revised version, which was first adopted by the GB, then by the IAG Executive Committee

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

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

at the XXVth IUGG General Assembly in July 2011. The main evolutions of the text are:

- Revision of the election process of the GB members; the members at large are elected by the Associate Members, and not by the GB.
- Addition of a representative for the Combination Center.
- Addition of a DORIS system representative appointed by CNES.
- Appointment of the network representative by IGN.

The new Terms of Reference will be applied for the renewal of the GB whose term is ending in December 2012.

3 IDS Central Bureau

3.1 IDS Web and ftp sites

- The IDS Central Bureau maintains the IDS web (<http://ids-doris.org>) and ftp (<ftp://ftp.ids-doris.org/pub/ids>) sites. In 2011, the web site was enriched with:
- a photo gallery (http://ids-doris.org/gallery.html) proposing pictures from some local teams of agencies hosting the DORIS stations, as well as photos taken during AWG meetings, IDS workshops, and GB meetings;
- the presentations of the AWG meeting held on May 23–24, 2011, in Paris, France (<http://ids-doris.org/report/meeting-presentations/ids-awg-05-2011.html>);
- a new page about the next IDS Workshop to be held in Venice on September 2012 (<http://ids-doris.org/report/meeting-presentations/ids-workshop-2012.html>);
- several activity reports (IDS Activity report for 2010, 2007–2011 Report for the International Association of Geodesy, 2008–2009 Report for IERS) as well as the minutes of the IDS GB meetings held in 2011 (<http://ids-doris.org/report/governing-board.html>);
- 7 new references of articles published in 2011. See the list of the peer-reviewed publications related to DORIS (<http://ids-doris.org/report/publications/peer-reviewed-journals.html#2011>);
- 7 updated versions of site logs provided by IGN for Amsterdam Island, Easter Island, Chatham Island, Cibinong, Crozet, Kerguelen, Male, Marion Island, Monument Peak, Mount Stromlo, Rikitea (<http://ids-doris.org/network/sitelogs.html>);
- new pictures and fish-eye views of the visibility obstruction for Nouméa, Rothera, Dionysos, Djibouti, Marion Island, Toulouse, Fairbanks, Amsterdam Island, Crozet, Rikitea, Cold Bay, Greenbelt, Ascension, Krasnoyarsk (<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 clarifications on Spot-5 solar panel offset. (<ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf>)

Access to the IDS website is still steadily increasing from month to month since spring 2000. In late 2011, this website was accessed about 2000 times each month on a regular basis.

3.2 IDS Mail system

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

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

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

4 IDS Data Centers

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

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.

5 IDS Analysis Centers

Like the other technique services in IAG, IDS has now a large number of independent Analysis Centers. All seven analysis centers that participated in ITRF2008 continue to remain active, participating in the IDS activities.

An Analysis Working Group (AWG) meeting was held this year at the Bureau des Longitudes, Paris, France, May 23–24, 2011, with 19 participants from all the active analysis centers (ESA, GAU, GSC, GOP, IGN, INA, LCA), as well as the CNES, GRGS, CLS, TU Delft, and UCL (University College London) and the GFZ. The principal themes concerned:

(1) the status of the IDS Combination;

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

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

(2) the presentation of the first results concerning analysis of Cryosat-2 data;

(3) a detailed report concerning analysis and use of the RINEX phase data for DORIS data analysis;

(4) plans for the operational update to ITRF2008 (DPOD2008);

(5) future plans for improved modeling of the nonconservative forces on the DORIS satellites by UCL;

(6) tests regarding attempts to implement a DORIS phase center correction as a station correction;

(7) analysis of a hypothesis concerning a phase center offset between the Alcatel and Starec antennae.

In addition GFZ (S. Rudenko) presented the capabilities of the EPOS software to process LEO satellite data, including DORIS data.

6 IDS Combination

In line with the successful DORIS contribution to ITRF2008, IDS decided to extend the combination process to an operational service. In 2011, the combination procedure has been upgraded and consists now in 3 steps:

1) evaluation of ACs SINEXs w.r.t. ITRF2008

2) combination of all ACs series

3) evaluation of ACs SINEXs w.r.t. the IDS combined series.

The IDS combined series has been extended since last delivery for ITRF2008. At the end of 2011, this multi-ACs series stops at the end of the first quarter of 2011.

The Combination Center also analysed the so-called Jason-2 Jason-1 like series (i.e. Jason-2 2DFCs) provided by LCA. That series, which has been designed to better understand the impact of the 7 DORIS frequency channels (DFCs) of the new DORIS DGXX receiver, used the Jason-1, 2 tandem period (September to December 2008). The analysis shows that the increase of DFCs on the DGXX receiver has a positive impact on the Tz parameter.

7 Meetings

In 2011, the IDS organized a DORIS Analysis Working Group meeting in Paris, France, on May 23–24, 2011.

All the presentations from the meeting are made available by the Central Bureau on the IDS website at <http://ids-doris.org/report/meeting-presentations/ids-awg-05-2011.html>.

8 Publications

Two DORIS Special Issues were published in the past few years, the first one in the Journal of Geodesy 80(8–11), 2006, the second one in Advances in Space Research (volumes 45 and 46, issue 12), 2010.

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 2011. Seven analysis centers routinely participated in the analysis activities. The combination process has been extended to an operational service. The ACs were asked to continue their series in so far as was possible to be consistent with their ITRF2008 submissions.

A third DORIS/DGXX has been placed in orbit on board the HY-2A satellite. This new receiver generation brings more data (7-channel receiver), better quality (equivalent to 0.3 mm/s) and the possibility to process these data using a GPS-type technique (access to raw DORIS phase measurement instead of Doppler data). In the near future several new satellites equipped with DGXX instruments should be launched, insuring a minimum of four DORIS satellites for the 2012–2016 time period.

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 2011. 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 by the Earth Orientation Center: 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. Bulletin B is updated in the operational OPA solution.

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/Predictions Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008.

Combined daily series: Bulletin B and 05 C04, statistics over 2010–2011

This section gives statistics (Tables 1 to 3) in term of formal errors and WRMS of the combined technique centres and individual solutions with respect to the combined solution Bulletin B and 08C04 over the period 2010–2011. Only combined solutions derived by the various technique centres (IGS, ILRS, and IVS) are used in the IERS combinations. Statistics concerning individual series are given as a feedback to the analysis centres.

New format of Bulletin B since January 2010

Bulletin B issued by the IERS EOP Centre was more than 20 years old. Following a survey which was made in 2007 among the scientific community, 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>.

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B and 05 C04 over 2010–2011. 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.

Individual solutions		Estimated uncertainties				
		Time	Terrestrial Pole	UT1	LOD	Celestial Pole
			µas	µs		µas
VLBI – 24 h						
EOP (AUS)	01 R 01	3–4d	280	12.5		160
EOP (BKG)	03 R 02	1–4d	145	9.7		76
EOP (GSFC)	07 R 01	1–4d	115	9.8		70
EOP (IAA)	05 R 02	1–4d	150	11.9		73
EOP (MAO)	03 R 01	1–4d	160	9.7		110
EOP (OPA)	07 R 01	1–4d	345	14.2		74
EOP (USNO)	06 R 02	1–4d	171	8.4		70
EOP(IVS) *	02 R 01	1–4d	170	4.6		30
VLBI – Intensive						
EOP (BKG) *	03 R 02	1–3 d		18.0		
EOP (GSFC) *	06 R 01	1–3 d		17.3		
EOP (SPBU) *	05 R 01	1–3 d		14.3		
EOP (USNO) *	05 R 01	1–3 d		19.1		
SLR						
EOP (ASI)	03 L 02	1d	230		54.1	
EOP (IAA)	02 L 01	1d	190		20.6	
EOP (MCC)	97 L 01	1d	200		–	
EOP (ILRS)*	05 L 01	1d	170		38.4	
GPS						
EOP (CODE)	98 P 01	1d	45		11.6	
EOP (EMR)	96 P 03	1d	60		20.9	
EOP (ESOC)	96 P 01	1d	75		13.9	
EOP (GFZ)	96 P 02	1d	57		12.4	
EOP (IAA)	01 P 01	1d	240		34.6	
EOP (JPL)	96 P 03	1d	60		22.1	
EOP (NOAA)	96 P 01	1d	88		12.5	
EOP (SIO)	96 P 01	1d	55		19.2	
EOP (IGR) *	07 P 01	1d	45		7.5	
EOP (IGS) *	96 P 02	1d	25		7.2	

Table 2: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions and IERS 08C04 over 2010–2011

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**	27	12	169	**–40**	181
Y (μas)	16	23	-22	173	71	170
UT1 (μs)					4	4.4
LOD (μs)	0	7	-6	38		
Dψsinε (μas)					1	24
Dψ(μas)					**–18**	27

Table 3: Mean and standard deviation for Pole components and UT1 of the differences between various solutions and Bulletin B over 2010–2011

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard deviation	Mean	Standard deviation
X	μas	**–8**	38	**0**	58
Y	μas	**16**	39	**1**	36
UT1	μs	**–1**	11.6	**–4**	11.9

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 (dPsi1980, dEps1980)
with respect to IAU 1980 precession-nutation model and their uncertainties.

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

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

5 – SUMMARY OF CONTRIBUTED EARTH ORIENTATION PARAMETERS SERIES

Reset of Bulletin B and C04 to the new system consistent to ITRF2008, new reference solution since 1 February 2011

Maintaining a high level of consistency between the current EOP solutions with the ITRF is essential in the field of geodynamics and satellite orbit computation. The ITRF2005 was the first rigorous combination ensuring ITRF and EOP consistency, based on time series of station positions and Earth Orientation Parameters (Altamimi et al., 2008). The ITRF2008 has the same characteristics than ITRF2005. Its release was the opportunity to re-align the C04 to the ITRF2008 system. Relative to 05C04, changes in the EOP series consisted in:

1) A negligible bias in x-pole and a bias of about –50 ± 25 microarcseconds in y-pole in the sense of y (08C04) – y (05C04);

2) Changes in UT1–TAI were on the order of 2 microseconds; celestial pole offsets respectively 1, and 17 microarcseconds which are at the level of the WRMS between IVS individual solutions.

Other IERS EOP series (Bulletin B, C01) have been expressed in this new system consistent with ITRF2008. The Rapid Service/Prediction Center solutions (Bulletin A and daily) are as well expressed in the new reference system.

Content of the 08C04 as of 1 December 2011

According to the IERS Message 198 (<ftp://ftp.iers.org/products/publications/messages/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 will be 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 solutions:

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 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 (1846–2012)

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 was recomputed in the course of 2011 to be consistent with the reference system associated with ITRF2008. It is a composite series based on following temporal solutions:

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

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

1962–2012: BIH and IERS solutions (BIH and IERS annual reports).

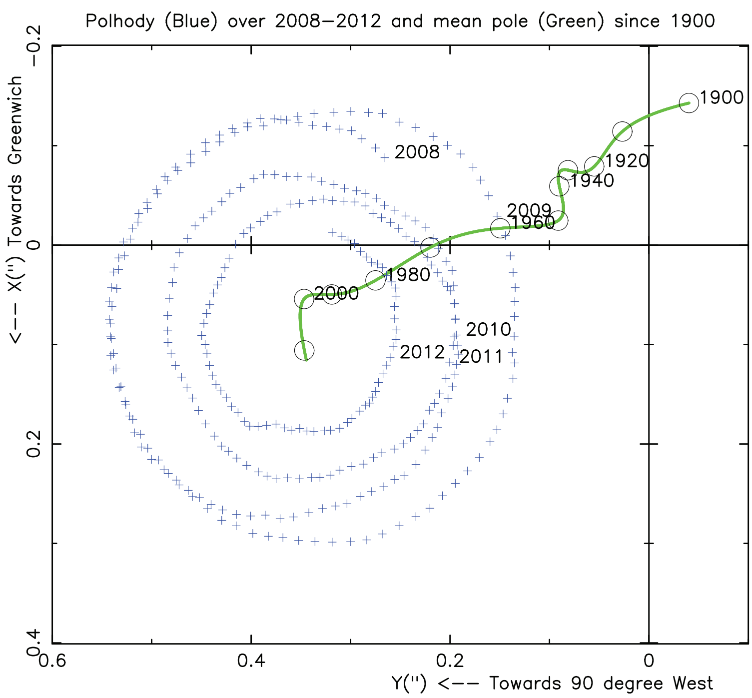


Fig. 1: Mean polar motion over 1900–2012 and IERS C04 polhody over 2008–2012

Mean Pole with respect to the IERS reference origin

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

The mean polar motion is affected by a long-term drift westward (direction 70.7 degree West, rate: 4.2 mas/yr). The mean rotation axis with respect to the IERS Terrestrial Reference Frame can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2012 (Shiskin et al., 1965). Figure 1 represents the polar motion over 2008–2012 and the path of the mean pole since 1900. The coefficients of the IERS (2010) mean pole model are available in Conventions 2010 (Petit and Luzum, 2010). The corresponding table is also available at the following address: <http://hpiers.obspm.fr/eop-pc/>.

After two years, it was interesting to match the extrapolated 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 limited to a couple of mas over the extrapolated period 2010–2012 .

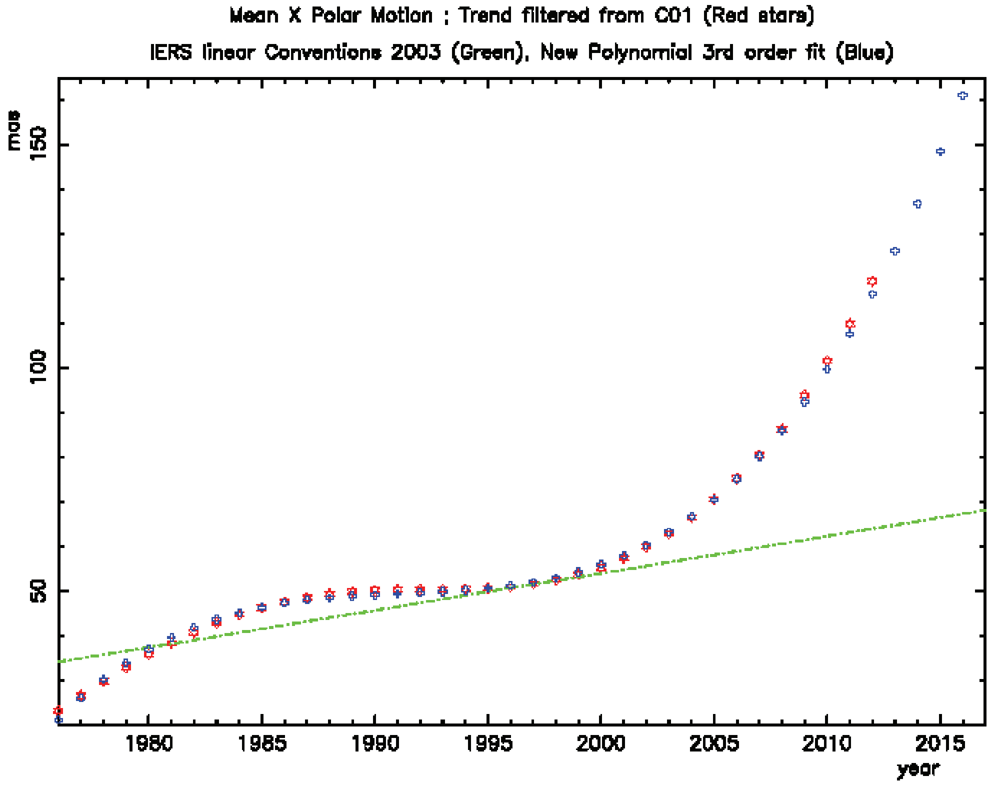
Leap second issue. Results of the IERS survey made in summer 2011 about a possible UTC re-definition

The Earth Orientation Center is responsible for the prediction and announcement of the leap second (Bulletin C) as well as the announcement of the value of DUT1 truncated at 0.1s for transmission with time signals. This system introduced in 1972, is a good compromise to maintain UTC coupled with UT1 (Earth rotation). However some communities are arguing that this system is becoming increasingly problematic for a vast range of modern navigational and communication systems, such as satellite navigation, financial services, air traffic control and the internet.

A first survey made in 2002 within the IERS showed that 89% of users were satisfied by the current determination of UTC, including leap seconds introductions. With the increasing number of users belonging to the various communities, it was felt necessary to make a new survey to find out the strength of opinion for maintaining or changing the present system before the proposal of redefining UTC be discussed at the ITU-R meeting held in Geneva in January 2012 (Gambis et al., 2012).

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)		
	Data	Polynomial fit	Difference in mas	Data	Polynomial fit	Difference in mas
1976	23.257	21.157	2.100	254.129	254.139	-0.010
1977	26.603	25.966	0.637	259.513	259.467	0.046
1978	29.817	30.173	-0.356	264.787	264.706	0.081
1979	32.868	33.822	-0.954	269.946	269.850	0.096
1980	35.725	36.954	-1.229	274.981	274.894	0.087
1981	38.360	39.611	-1.251	279.891	279.832	0.059
1982	40.751	41.836	-1.085	284.672	284.660	0.012
1983	42.876	43.671	-0.795	289.326	289.370	-0.044
1984	44.719	45.157	-0.438	293.858	293.959	-0.101
1985	46.274	46.337	-0.063	298.273	298.420	-0.147
1986	47.540	47.254	0.286	302.575	302.749	-0.174
1987	48.528	47.948	0.580	306.765	306.939	-0.174
1988	49.256	48.463	0.793	310.839	310.985	-0.146
1989	49.755	48.841	0.914	314.789	314.882	-0.093
1990	50.064	49.123	0.941	318.601	318.625	-0.024
1991	50.232	49.352	0.880	322.261	322.207	0.054
1992	50.312	49.570	0.742	325.751	325.624	0.127
1993	50.366	49.819	0.547	329.055	328.870	0.185
1994	50.458	50.141	0.317	332.160	331.940	0.220
1995	50.655	50.579	0.076	335.056	334.827	0.229
1996	51.020	51.175	-0.155	337.737	337.527	0.210
1997	51.617	51.970	-0.353	340.202	340.035	0.167
1998	52.502	53.006	-0.504	342.450	342.344	0.106
1999	53.731	54.327	-0.596	344.486	344.450	0.036
2000	55.349	55.974	-0.625	346.312	346.346	-0.034
2001	57.400	57.989	-0.589	347.931	348.028	-0.097
2002	59.919	60.415	-0.496	349.344	349.490	-0.146
2003	62.939	63.293	-0.354	350.549	350.726	-0.177
2004	66.487	66.666	-0.179	351.543	351.731	-0.188
2005	70.583	70.575	0.008	352.322	352.500	-0.178
2006	75.244	75.064	0.180	351.881	353.027	-1.146
2007	80.481	80.174	0.307	351.918	353.307	-1.389
2008	86.302	85.947	0.355	351.830	353.335	-1.505
2009	93.908	92.425	1.483	351.516	353.104	-1.588
2010	101.602	99.651	1.951	350.905	352.609	-1.704
2011	109.902	107.667	2.235	350.105	351.845	-1.740
2012	119.502	116.514	2.988	348.925	350.807	-1.882



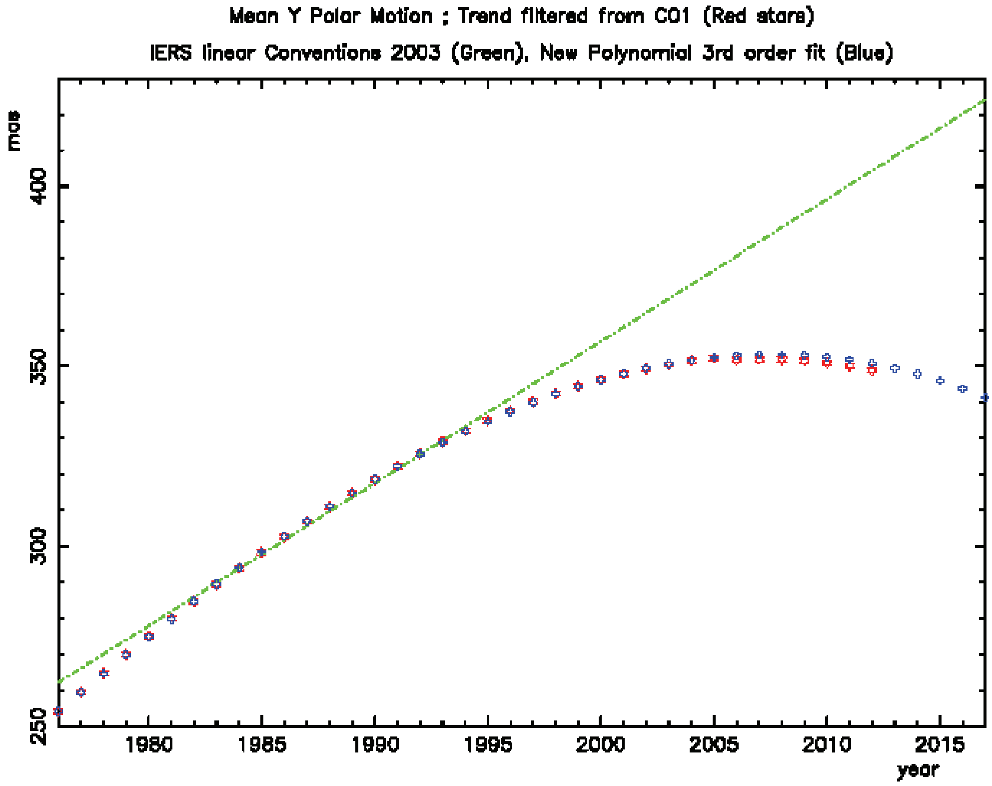


Fig. 2a and 2b: Plots showing the good agreement between the data and the fitted polynomial. Their differences remain limited to a couple of mas over the extrapolated period 2010–2012.

Questionnaire to survey opinion concerning a possible redefinition of UTC

Universal Time, the conventional measure of Earth rotation is the traditional basis for civil timekeeping. Clocks worldwide are synchronized via Coordinated Universal Time (UTC), an atomic time scale recommended by the Radiocommunications Sector of the International Telecommunications Union (ITU-R) and calculated by the Bureau International des Poids et Mesures (BIPM) on the basis of atomic clock data from around the world.

UTC is computed from TAI by the introduction of leap seconds such that UTC is maintained within 1 second of UT1. Since 1972, these leap seconds have been added on December 31 or June 30, at the rate of about one every 18 months. Since 1 July 2012, 0:00 UTC, UTC–TAI= –35s.

The objective of the survey was to find out the strength of opinion for maintaining or changing the present system.

The options

1. I am satisfied with the current definition of UTC which includes leap second adjustments
2. I prefer that UTC be redefined as a uniformly increasing atomic timescale without leap seconds and constantly offset from TAI. Consequently, UTC would increasingly diverge from the Earth's rotation.
3. I have another preference
4. I have no opinion or preference
5. Comments

Results

Figures 3a to 3d give respectively the global results and statistics concerning the domains of activities as well as the number of answers per country.

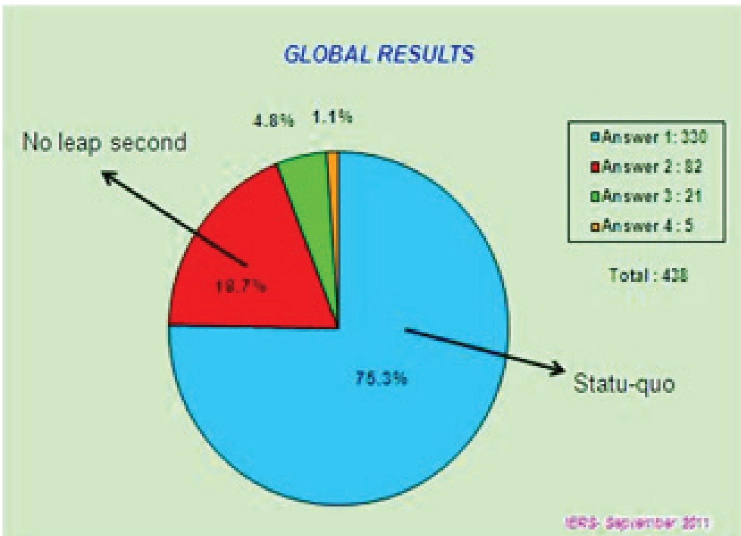


Fig. 3a: Global results

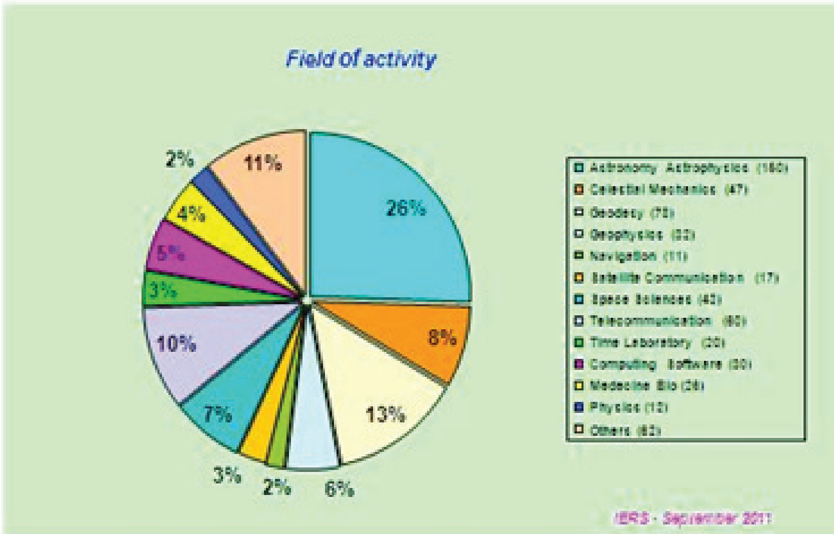


Fig. 3b: Field of activities

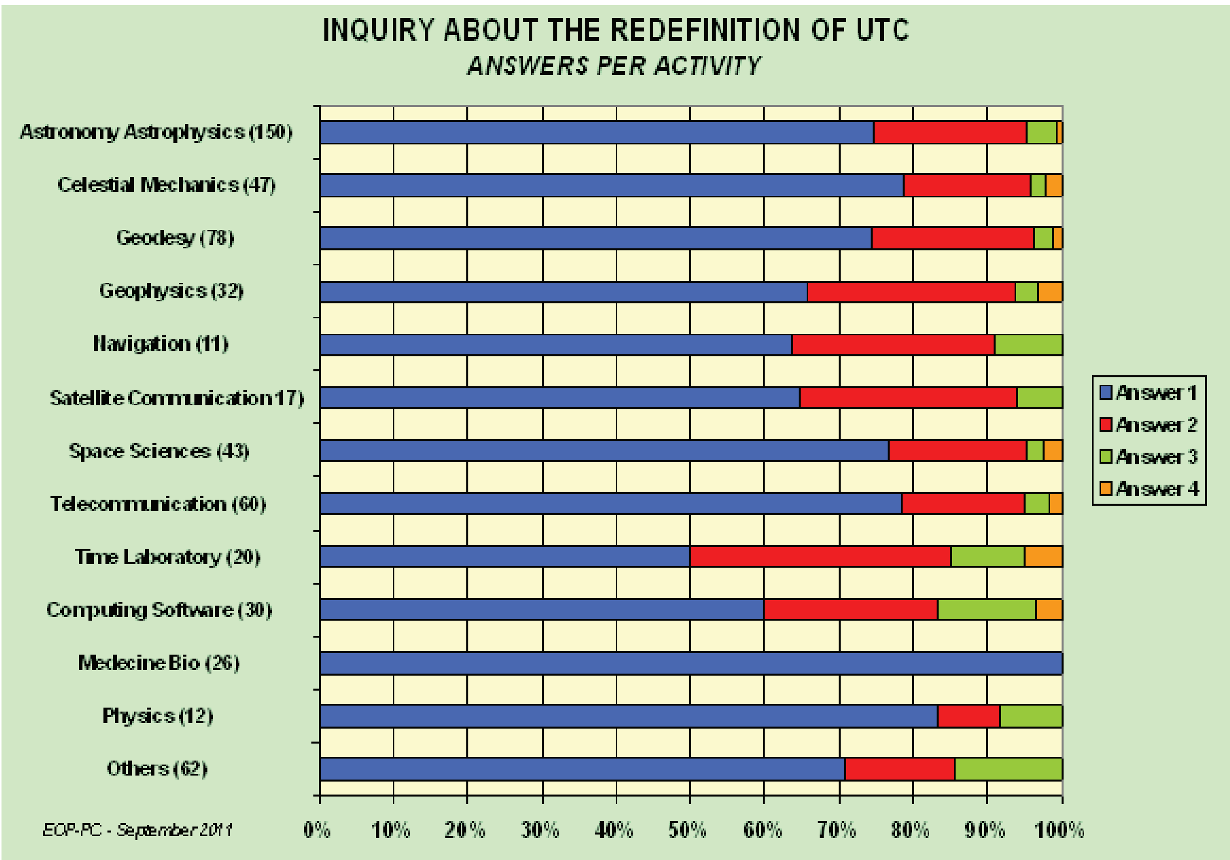


Fig. 3c: Answers per field of activity

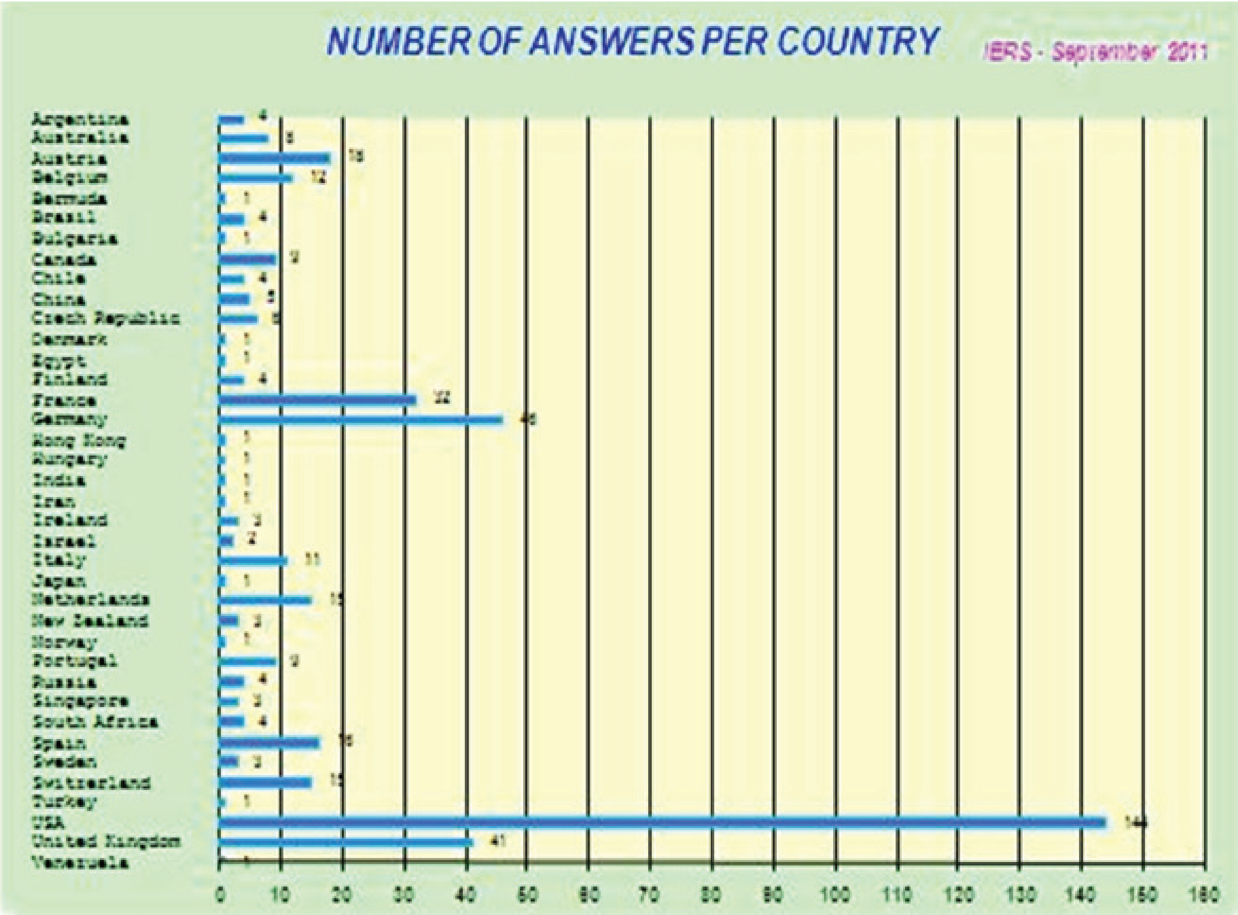


Fig. 3d: Statistics concerning the number of answers per country

Summary The statistics mostly reflect the statements of communities of time scales users. Over the 447 answers, about 75 % are for the statu quo, i.e. no change in the current definition including leap seconds. 19 % for switching to the new UTC definition, i.e. continuous time scale no leap second, 5% for another solution mostly requiring the prediction of the leap second with a longer schedule in advance. Let us note that globally and except for the time community where 50% are for the statu quo, the rate of users for and opposite to the statu quo is similar with a majority for statu quo and this whatever the domain of activity. More details are given in Gambis et al. (2011).

Answers and comments to the questionnaire are still available at the following web site:

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

Redefinition of UTC. January 2012: the leap second decision is postponed to 2015

After years of discussions within the scientific community, a proposal to fundamentally redefine UTC without leap second was discussed in January 2012 at the International Telecommunication Union (ITU) in Geneva. Delegates of 103 countries over a total of 193 countries were unable to reach a consensus, so moving the matter to a meeting in 2015. Japan, Italy, Mexico and France all supported the United States' stance on losing the leap second, while Germany and Canada, like the UK, wanted the extra second to stay.

As a result of the discussions which took place, the ITU decided that more research was needed to consider the broader social implications of losing the leap second before a decision could be taken.

More understanding on the consequences of ending the link between UTC (Coordinated Universal Time) and solar time is needed before a final decision be taken.

The ITU suggested that a study group should investigate the issue, before presenting any proposal at the next World Radio Conference in 2015. It means that for now, the world's time will continue to be linked to the Earth's rotation.

The last leap second was added on 30 June 2012.

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 bulletins (Bulletin D and C) sent to users in ASCII format. 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 derive 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 mainly through two points. On the one hand, the concept of metadata allows to make available a single file with a description. Such tools can give a good visibility of earth orientation parameters as well as UT1–UTC derived by the IERS.

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References

Abarca del Rio, D. Gambis and D. Salstein, 2012, Interdecadal oscillations in the Atmospheric Angular Momentum variations, Journal of Geodetic Science, Volume 2, 1, pp. 42–52. Doi:10.2478/v10156-011-0025-8

Abarca del Rio, R., Gambis D., 2011, Solar activity and atmospheric angular momentum variability (and length of day) reanalyses, in Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.), pp. 194–195.

Altamimi, Z., Collilieux X., Legrand J., Garayt B., Boucher C., 2008, ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters, J. Geophys. Res. 112, B09401, doi: 10.1029/2008JB004949.

Altamimi, Z., Gambis, D., Bizouard, Ch., 2008, Rigorous combination to ensure ITRF and EOP consistency, Proc. Journées Systèmes de Référence 2008, N. Capitaine (ed.), p. 151

Bizouard, C. and D. Gambis, 2009, the combined solution C04 for Earth Orientation Parameters, recent improvements, Springer Verlag series, Series International Association of Geodesy Symposia, Vol. 134, Drewes, Hermann (ed.), pp. 265–270, DOI 10.1007/978-3-642-00860-3

Bizouard C., Lambert S., Remus F., Seoane L., Gambis D., 2011, Source of the variable Chandler wobble, in Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.), pp. 196–197.

Bizouard C, F. Rémus, S. Lambert, L. Seoane and D. Gambis, 2011, The Earth variable Chandler wobble, A&A, Vol. 526, A106.

Chapanov Y. and D. Gambis, 2011, Variations of the Earth main moments of inertia due to glacial cycles for the last 800Ka, in Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.), pp. 198–199.

Deleflie F., D. Gambis, C. Barache, J. Berthier, 2011, Dissemination of UT1–UTC through the
use of virtual observatory VO, in AAS Proceedings, AAS 11-680

Fedorov, E.P., Korsun, A.A., Mayor, S.P., Pantscheenko, N.I., Tarady, V.K., Yatskiv, YA. S., 1972, Dvizhenie polyusa Zemli s 1890.0 po 1969.0. Naukova dumka, Kiev (English translation of the text available).

Finkleman, D., Seago, J.H., and Seidelmann, P. K. The Debate over UTC and Leap Seconds. Proceedings of the AIAA/AAS Astrodynamics Specialist Conference, Toronto, Canada,

Gambis, D., 2004: Monitoring Earth Orientation at the IERS using space-geodetic observations. J. of Geodesy 78, pp. 295–303.

Gambis,D and Luzum B., 2011, Earth rotation monitoring, UT1 determination and prediction, Metrologia 48, S165–S170

Gambis, D., Salstein D., Lambert S., 2011, Use of Atmospheric Angular momentum forecasts for UT1 predictions, J. of Geodesy, Vol. 85, 7, pp. 435–441, DOI: 10.1007/s00190-011-0479-6

Gambis D., G. Francou, T. Carlucci, 2011, Results of the IERS survey made in summer 2011 about a possible UTC re-definition, AAS Proceedings. AAS 11-668

Kalarus M., Schuh, Kosek W., Akyilmaz O., Bizouard Ch., Gambis D., Gross R., Jovanovic B., Kumakshev S., Kutterer H., Ma L., Mendes Cerveira P.J., Pasynok S, Zotov L., 2010, Achievements of the Earth Orientation Parameters Prediction Comparison Campaign, J. of Geodesy, Vol. 84, number 10, pp. 587–596.

Nelson, R.A., McCarthy, D.D., Malys, S., Levine, J., Guinot, B., Fliegel, H.F., Beard, R.L., and Bartholomew, T.R., 2001, The leap second: its history and possible future. Metrologia, Vol. 38, pp. 509–529

Petit, G. and B. Luzum (eds.), 2010, IERS Conventions (2010), BKG, Frankfurt am Main (IERS TN36; Website: <http://www.iers.org/TN36>).

Richard J.Y., Gambis D., Bizouard Ch, 2011, Earth rotation parameters determined over CONT08 VLBI campaign by the GRGS from the combination of space geodetic techniques, in Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.), pp. 219–220.

Savoie D., D. Gambis, 2011, The consequences of decoupling UTC on sundials, in AAS Proceedings. AAS 11-670.

Seoane L., Nastula J., Bizouard C. and D. Gambis, 2011, Hydrological excitation of polar motion derived from GRACE gravity field solutions, Intern. J. of Geophysics, vol. 2011, 174396, 10 p, doi:10.1155/2011/174396.

Seoane L., R. Biancale and D. Gambis, 2011, Agreement between Earth's rotation and mass displacements as detected by GRACE, J. of Geodynamics, http://dx.doi.org/10.1016/j.jog.2012.02.008

Shiskin, J., Young, A.H., Musgrave J.C., 1965, The X-11 variant of the Census Method II seasonal adjustment program, U.S. Dept. of Commerce, Bureau of the Census (Technical Paper No 15).

Vondrak J., Ron C., Pesek I., Cepek A., 1995, New global solution of Earth orientation parameters from optical astrometry in 1900–1990, Astron. Astrophys. 297, 899–906.

Daniel Gambis, Christian Bizouard, Jean Yves Richard,
Teddy Carlucci, Olivier Becker, Pascale Baudoin

3.5.2 Rapid Service/Prediction Centre

Processing Techniques

The algorithm used by the IERS Rapid Service/Prediction Center (RS/PC) for the determination of the quick-look Earth orientation parameters (EOP) is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy and Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases or offsets and rates with respect to the 05 C04 (1–31 January 2011) and 08 C04 (1 February–31 December 2011) systems 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 Ser-

Table 1: Estimated accuracies of the contributors in 2011. Units are milliseconds of arc for x, y, dψ, dε, dX, and dY and milliseconds of time for UT1–UTC. Note that EMR discontinued its UT series on 2 June 2011.

Contributor Information	Estimated Accuracy				
Name, Type	x	y	UT1	dψ (dX)	dε (dY)
ILRS SLR	0.21	0.22			
IAA SLR	0.22	0.21			
MCC SLR	0.18	0.23			
GSFC VLBI Intensives			0.020		
USNO VLBI Intensives			0.022		
GSI Intensives			0.018		
GSFC VLBI	0.13	0.15	0.006	0.40	0.16
IAA[1] VLBI	0.23	0.26	0.008	(0.07)	(0.06)
IVS[1] VLBI	0.20	0.19	0.004	(0.06)	(0.06)
USNO VLBI	0.17	0.16	0.004	0.20	0.08
IGS Final	0.01	0.02			
IGS Rapid*	0.08	0.10	0.014		
IGS Ultra*	0.09	0.10	0.004		
USNO GPS UT*			0.017*		
EMR GPS UT*[2]			0.048*		

*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).

[2] Input series discontinued on 2 June 2011.

Table 2: Mean and standard deviation of the differences between the Rapid Service/Prediction Center combination solutions and the 05/08 C04 EOP solutions for 2011. 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)[2]		
x	0.01/0.00	0.07/0.04
y	0.00	0.05
UT1-UTC	-0.001	0.013
Bulletin A Weekly Solution (finals. data)[1]		
x	0.04	0.09
y	0.02	0.06
UT1-UTC	-0.001	0.020
Bulletin A Daily Solution (finals.daily)[2]		
x	0.00/0.02	0.04/0.05
y	-0.04/0.03	0.03/0.05
UT1-UTC	0.003/-0.002	0.029/0.029

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

[2] The first set of statistics refers to values computed from 1 – 31 Jan 2011 with respect to the 05 C04. The second set of statistics refers to values computed from 1 Feb – 31 Dec 2011 with respect to 08 C04.

vice/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 2011.

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, dψ, and dε values are computed at the epoch of zero hours UTC for each day. While the celestial pole offset combination software can combine either dψ and dε or dX and dY, for historical reasons, it uses dψ and dε. Therefore, IAA and IVS VLBI dX and dY values are converted to dψ and dε in the combination process. The LOD are derived directly from the UT1–UTC data. The analytical expression for the first derivative of a cubic spline passing through the UT1–UTC data is used to estimate the LOD at the epoch of the UT1–UTC data.

The only data points that are excluded from the combination process are the points whose errors, as reported by the contributors, are greater than three times their average reported precision, or those points that have a residual that is more than four times the associated *a priori* error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, the input data are not corrected for these effects (see IERS Gazette No. 13, 30 January 1997).

The uncertainties in the daily values listed in Bulletin A are derived from the quality of the spline fit in the neighborhood of the day in question. Table 2 shows the accuracies of Rapid Service/Prediction Center's combination solution for the running, weekly, and daily products compared to the 05/08 C04 series maintained by the IERS EOC. The running solution is the combination solution over the past 365-day period. The statistics for the running solution at year's end show the agreement between the Bulletin A running combination solution and the C04 series. Two sets of statistics are computed for PM-x: a) one from 1 January 2011 through 31 January 2011 which compares the Bulletin A made at the end of January 2011 to the 05 C04 series and b) another from 1 February 2011 through 31 December 2011 which compares the Bulletin A made at the end of December 2011 to the 08 C04 series. The Bulletin A running solution was updated to be on the new 08 C04 series on 1 February 2011. It appears that the reason that the standard deviations for PM-x are larger for January than for February–December is that there are unusually large residuals between the IERS RS/PC and 05 C04 at the end of January. These large differences do not appear when comparing the IERS RS/PC solution to the JPL SPACE solution.

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 2011, the mean residuals between the daily solution and the 08 C04 were essentially the same as in 2010. The small bias differences in the polar motion components appear to be related to the use in the IERS RS/PC solution of the IGS Ultra series which is systematically biased with respect to the IGS Final series used in the 08 C04 solution. There has been a significant improvement in the UT1–UTC results due to the greater availability of the electronically transferred VLBI data in the IERS RS/PC solution.

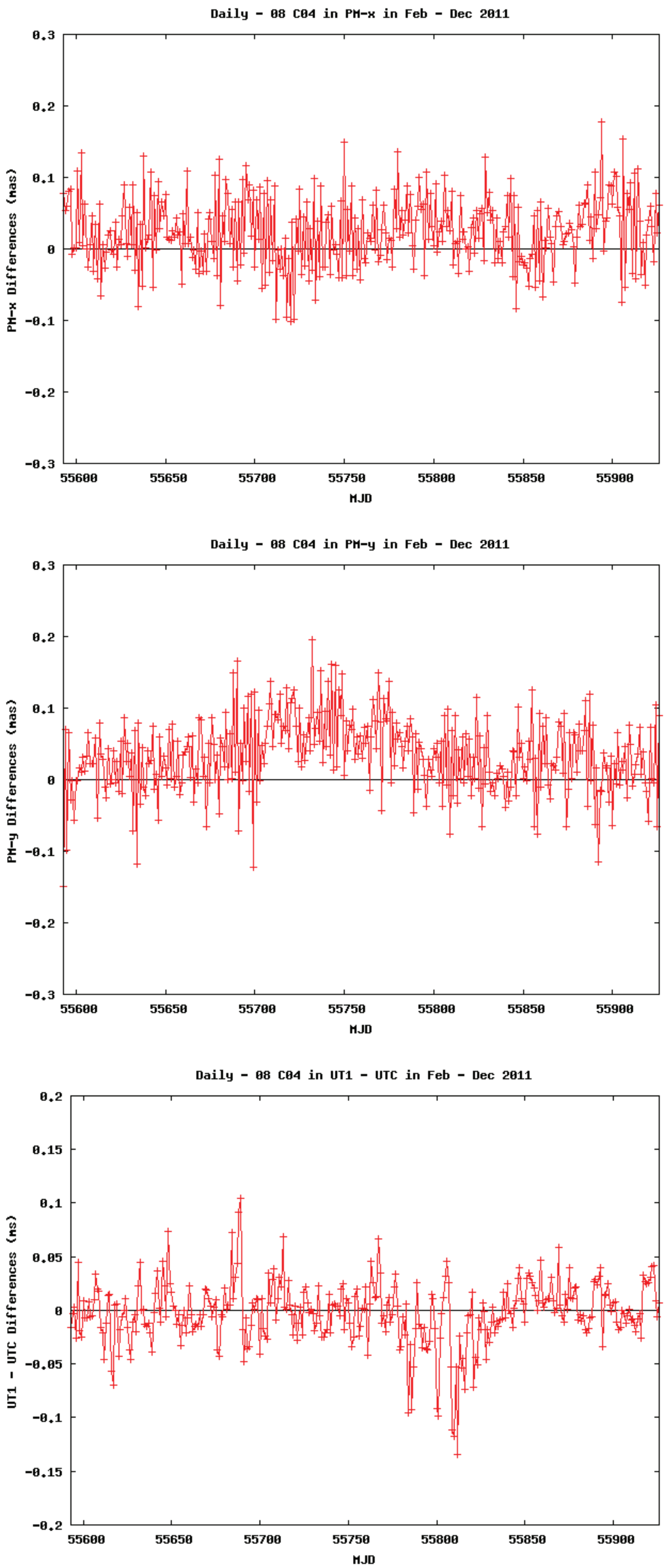

Fig. 1: Differences between the daily rapid solutions at each daily solution epoch for Feb–Dec 2011 and the Earth orientation parameters available in the 08 C04 series produced in September 2012.

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).

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 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, $(UT2R-TAI)_n$, the smoothed time value from n days in the past, $\langle (UT2R-TAI)_{-n} \rangle$ is subtracted from the most recent value, $(UT2R-TAI)_0$

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

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. The predictions of $d\psi$ and $d\varepsilon$ are based on the IERS Conventions (McCarthy, 1996; McCarthy and Petit, 2004).

For 2011, the polar motion prediction errors were roughly the same accuracy as compared to the 2010 values. Figure 2 provides a plot of the prediction error as a function of polar motion value. The UT1–UTC prediction showed a significant improvement, especially over the latter part of the year. The improvement in UT1–UTC is due to the improved availability of rapid turnaround e-VLBI intensives. Table 3 shows the root mean square of the differences between the daily solution predictions and the 05/08 C04 solution for 2011.

The predictions of celestial pole offsets (both dX/dY and $d\psi/d\varepsilon$ 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

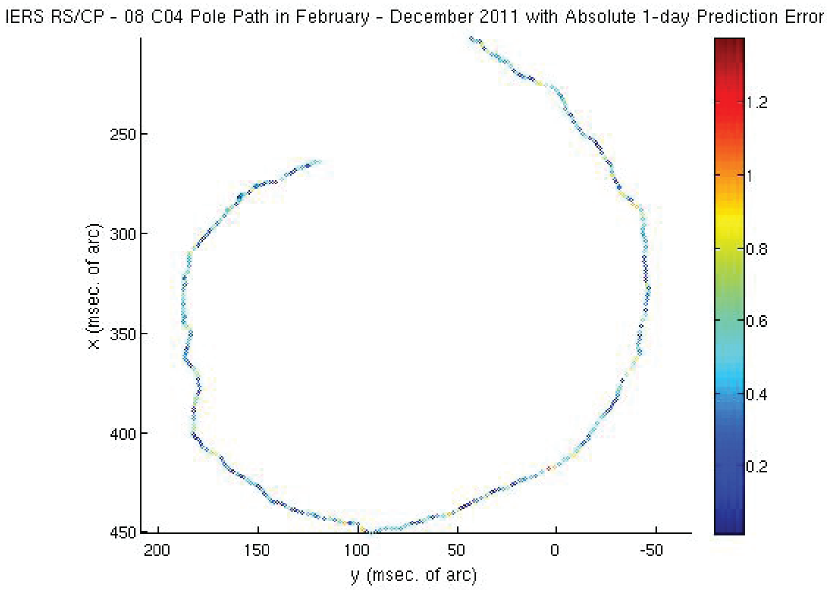

Fig. 2: Plot of the prediction error as a function of polar motion. The prediction error is in units of milliseconds of arc.

Table 3: Root mean square of the differences between the EOP time series predictions produced by the daily solutions and the 05/08 C04 combination solutions for 2011. 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 Future	PM-x mas	PM-y mas	UT1-UTC ms
1[1]	.74	.30	.069
1[2]	.39	.28	.054
5	2.22	1.37	.305
10	4.01	2.49	.776
20	6.72	4.71	1.99
40	11.9	9.13	3.62
90	26.6	17.7	13.6

[1] Statistics computed for data from 1 – 31 January 2011 against the 05 C04.
[2] Statistics computed for data from 1 February – 31 December 2011 against the 08 C04.

not determined. Therefore, the predictions of celestial pole offsets start before the solution epoch and the length of the prediction into the future can and does vary in the daily solution files. The differences between the daily predictions and the 05/08 C04 for 2011 are given in Table 4.

Predictions of TT–UT1, up to 1 January 2020, 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.

Table 4: Root mean square of the differences between the nutation prediction series produced by the daily solutions and the 05/08 C04 combination solutions for 2011.

Days in Future	dX mas	dY mas	$d\psi$ mas	$d\varepsilon$ mas
1	.16	.15	.44	.13
5	.17	.15	.46	.13
10	.18	.16	.48	.14
20	.20	.19	.53	.18
40	.25	.24	.65	.24

Table 5: Predicted values of TT–UT1, 2012–2020. Note that UT1–TAI can be obtained from this table using the expression UT1–TAI = 32.184s – (TT–UT1).

DATE	TT-UT1	Uncertainty
	(s)	(s)
2012 Jul 1	66.771	0.000
2012 Oct 1	66.810	0.000
2013 Jan 1	66.910	0.003
2013 Apr 1	67.02	0.01
2013 Jul 1	67.10	0.02
2013 Oct 1	67.13	0.02
2014 Jan 1	67.2	0.4
2014 Apr 1	67.3	0.5
2014 Jul 1	67.4	0.7
2014 Oct 1	67.5	0.8
2015 Jan 1	67.6	0.9
2015 Apr 1	68.	1.
2015 Jul 1	68.	1.
2015 Oct 1	68.	1.
2016 Jan 1	69.	1.
2016 Apr 1	69.	2.
2016 Jul 1	69.	2.
2016 Oct 1	69.	2.
2017 Jan 1	69.	2.
2017 Apr 1	69.	2.
2017 Jul 1	69.	2.
2017 Oct 1	69.	2.
2018 Jan 1	69.	3.
2018 Apr 1	70.	3.
2018 Jul 1	70.	3.
2018 Oct 1	70.	3.
2019 Jan 1	70.	3.
2019 Apr 1	70.	3.
2019 Jul 1	70.	3.
2019 Oct 1	70.	4.
2020 Jan 1	70.	4.
2020 Apr 1	71.	4.
2020 Jul 1	71.	4.
2020 Oct 1	71.	4.
2021 Jan 1	71.	4.

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 2011

During 2011, a number of significant changes occurred in the RS/PC products. On 1 February 2011, the EOP system was changed from 05 C04 to 08 C04 in coordination with the IERS EOC. This change was made in order to improve the consistency between EOP data and the underlying ITRF2008.

Starting in September 2011, the IERS RS/PC began the operational generation of two solutions per day: the original solution at 1700 UTC and a new solution at 0310 UTC. The additional solution is part of an ongoing progression to improve the accuracy of the EOP solutions by reducing their latency. Ultimately, the goal is achieve the generation of real-time EOP estimates. These twice-daily solutions take advantage of additional input data that have become available since the previous solution, such as eVLBI intensives and additional IGS Ultra data. The accuracy of these solutions is similar to the 1700 UTC daily solutions, but the 1-day predictions for UT1–UTC, as indicated in Table 3b and shown in Stamatakos *et al.* (2012) do show an improvement of 10% or greater. Revised versions of Table 2, 3, and 4, labeled Table 2b, 3b, and 4b, respectively, are shown below. These tables provide the relevant statistics for the last third of a year, 1 September 2011 – 31 December 2011, for the 0310 UTC solution.

On 21 April 2011, the IERS RS/PC procedures were modified to utilize the IGS Ultra LOD information in the operational combination and prediction procedures instead of the IGS Rapid LOD. The data are used in a fashion similar to how the IGS Rapid LOD were; the LODs are integrated to form UT-like data, calibrated and incorporated into the cubic spline. Like the IGS Rapids, only data extending beyond the last VLBI data are used.

Table 2b: Mean and standard deviation of the differences between the Rapid Service/Prediction Center 0310 UTC combination solutions and the 08 C04 EOP solutions for 2011. 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 Daily Solution (finals.daily)[1]		
x	0.02	0.05
y	0.03	0.06
UT1–UTC	–0.000	0.030

[1] The statistics were computed from 1 Sep – 31 Dec 2011 with respect to the 08 C04.

Table 3b: Root mean square of the differences between the EOP time series predictions produced by the 0310 UTC daily solutions and the 08 C04 combination solutions for 2011. Note that the prediction length starts counting from the day after the last available observation is made for polar motion or UT1–UTC/LOD.

Days in Future	PM-x mas	PM-y mas	UT1-UTC ms
1	.36	.26	.049
5	1.85	1.52	.245
10	3.55	2.93	.608
20	6.08	6.30	2.21

The statistics were computed from 1 Sep – 31 Dec 2011 with respect to the 08 C04.

Table 4b: Root mean square of the differences between the nutation prediction series produced by the 0310 UTC daily solutions and the 08 C04 combination solutions for 2011.

Days in Future	dX mas	dY mas	$d\psi$ mas	$d\varepsilon$ mas
1	.17	.10	.48	.12
5	.19	.10	.53	.12
10	.21	.11	.56	.14
20	.23	.15	.62	.19

The statistics were computed from 1 Sep – 31 Dec 2011 with respect to the 08 C04.

New global solutions were received from the GSFC VLBI Analysis Center (gsf2011a and gsf2011b), the USNO VLBI Analysis Center (usno2011a), and the GSI Analysis Center (gsi2011a). These new solutions were examined and new slopes and biases were computed before being incorporated into operations.

The IERS RS/PC now runs EOP additional solutions off site 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.

Additional capabilities for the EO transformation calculator were implemented. 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, $d\psi$ and $d\varepsilon$ from GSFC VLBI; x, y, UT1–UTC, $d\psi$ and $d\varepsilon$ from USNO VLBI; x, y, UT1–UTC, dX and dY from IVS combination VLBI; UT1–UTC from GSFC 1-day Intensives; UT1–UTC from USNO 1-day Intensives; UT1–UTC from GSI 1-day Intensives; x, 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 NRCanada (EMR) GPS; LOD from NCEP AAM; LOD from NAVY NOGAPS AAM; x, y, UT1–UTC, $d\psi$ and $d\varepsilon$, and dX and dY from the IERS Rapid Service/Prediction Center; x, y, UT1–UTC, $d\psi$ and $d\varepsilon$ from the IERS Earth Orientation Centre; and predictions of x, y, UT1–UTC, $d\psi$ and $d\varepsilon$, and dX and dY from the IERS Rapid Service/Prediction Center.

Other data sets are available that include: UT0–UTC from University of Texas as Austin LLR, UT0–UTC from JPL LLR; UT0–UTC from CERGA LLR; UT0–UTC from JPL VLBI; latitude and UT0–UTC from Washington PZTs 1,3,7; latitude and UT0–UTC from Richmond PZTs 2,6; LOD from ILRS 1-day SLR; x, y, UT1–UTC from CSR LAGEOS 3-day SLR; x and y from CSR LAGEOS 5-day SLR; x and y from Delft 1-, 3- and 5-day SLR; and x, y, UT1–UTC, $d\psi$ and $d\varepsilon$ 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 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

References

Johnson, T.J., 2002, Rapid Service/Prediction Centre, *IERS Annual Report 2001*, 47–55.

Johnson, T.J., Luzum, B.J., and Ray, J.R., 2005, Improved near-term Earth rotation predictions using atmospheric angular momentum analysis and forecasts, *J. Geodynamics*, **39**(3), 209–221.

Kammeyer, P., 2000, A UT1-like Quantity from Analysis of GPS Orbit Planes, *Celest. Mech. Dyn. Astr.*, **77**, 241–272.

Luzum, B.J., Ray, J.R., Carter, M.S., and Josties, F.J., 2001, Recent Improvements to IERS Bulletin A Combination and Prediction, *GPS Solutions,* **4**(3), 34–40.

McCarthy, D.D. and Luzum, B.J., 1991a, Combination of Precise Observations of the Orientation of the Earth, *Bulletin Geodesique,* **65**, 22–27.

McCarthy, D.D. and Luzum, B.J., 1991b, Prediction of Earth Orientation, *Bulletin Geodesique,* **65**, 18–21.

McCarthy, D.D. (ed.), 1996, IERS Conventions (1996), *IERS Technical Note* No. 21, Paris Observatory, France.

McCarthy, D.D. and G. Petit (eds.), 2004, IERS Conventions (2003), *IERS Technical Note* No. 32, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main, Germany.

Petit, G. and Luzum (eds.), 2010, IERS Conventions (2010), *IERS Technical Note* No. 36, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main, Germany.

Stamatakos, N., Luzum, B., Wooden, W., 2008, “Recent Improvements in IERS Rapid Service/Prediction Center Products,” in *Proc. Journées Systèmes de Référence Spatio-Temporels*, Paris, 17–19 Sept. 2007, 163–166.

Stamatakos, N., Luzum, B., Stetzler, B., Wooden, W., and Schultz, E., 2009, “Recent Improvements in IERS Rapid Service/Prediction Center Products,” in *Proc. Journées Systèmes de Référence Spatio-Temporels*, Dresden, 22–24 Sept. 2008, 160–163.

Stamatakos, N., Luzum, B., Stetzler, B., Shumate, N., and Carter, M.S., 2011, “Recent Improvements in IERS Rapid Service/Prediction Center Products,” in *Proc. Journées Systèmes de Référence Spatio-Temporels*, Paris, 20–22 Sept. 2010, 184–187.

Stamatakos, N., Luzum, B., Stetzler, B., Shumate, N., Carter, M.S., and Tracey, J., 2012, “Recent Improvements in IERS Rapid Service/Prediction Center Products for 2010 and 2011,” in *Proc. Journées Systèmes de Référence Spatio-Temporels*, Vienna, 19–21 Sept. 2011, 125–129.

Stamatakos, N., Luzum, B., Zhu, S., and Boboltz, D., 2012, “Further Analysis of a New Geodetic VLBI Data Source and its Applications,” G51A-1084, AGU Fall Meeting, San Francisco, 3–7 Dec. 2012.

Wooden, W.H., Johnson, T.J., Carter, M.S., and Myers, A.E., 2004, Near Real-time IERS Products, *Proc. Journées Systèmes de Référence Spatio-Temporels*, St. Petersburg, 22–25 Sept 2003,160–163

Wooden, W.H., Johnson, T.J., Kammeyer, P.C., Carter, M.S., and Myers, A.E., 2005, Determination and Prediction of UT1 at the IERS Rapid Service/Prediction Center, *Proc. Journees Systemes de Reference Spatio-Temporels*, Paris, 20–22 Sept 2004, 260–264.

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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 2011, 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 2011, see <http://tai.bipm.org/iers/convupdt/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 8 (Tidal variations in the Earth's rotation), Chapter 9 (Models for atmospheric propagation delays) and the Glossary. The most significant corrections concern data files for the FES2004 ocean tides model.
- Provided the yearly update of the free core nutation model.

2. Conventions software

Some of the updates included changes to the Conventions software, in general affecting only the test cases. However the update included functional changes for the routine ARG2.F which computes the angular astronomical argument for 11 tidal waves.

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/>) have been maintained.

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

A survey (<http://maia.usno.navy.mil/conv2010/Conventions_Survey.html>) 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. A summary of the replies may be found at <http://tai.bipm.org/iers/conv2010/conv2010_surveyreplies.pdf>.

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Beth Stetzler (USNO)

Gérard Petit, Brian Luzum

3.5.4 ICRS Centre

Introduction

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

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

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

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

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

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

In the coming decades, there will be significant advances in the area of space-based optical astrometry. 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 2011, 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 the U.S. Navy cancelled the JMAPS program toward the end of 2011, although funding was allocated for 2012 to complete the JMAPS instrument.

Assessment of VLBI Realisations of the ICRF

In 2011, new celestial reference frames were produced at different IVS analysis centers by the re-analysis of the full VLBI observational database and submitted to the IVS data center. The aus2011a and aus2011b catalogs were produced at Geoscience Australia (Canberra), using the OCCAM geodetic VLBI analysis software package. Both bkg2011a and opa2011a were produced by the NASA Goddard Space Flight Center's package SOLVE, respectively 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.

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 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 the Table hereafter. The 6 parameters were estimated on 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 since they do not exceed 0.6 μas with formal error of 0.2 μas. Figures below represent the residual (i.e., after alignment onto the ICRS) differences between each catalog and the ICRF2.

Table 1: The characteristics and transformation parameters relevant to the four catalogs submitted to the IVS in 2011.

Catalog	No. Sources		Difference to ICRF2				Transformation parameters			
			Mean		Rms					
	All	Defining	αcosδ μas	δ μas	αcosδ μas	δ μas	A1 μas	A2 μas	A3 μas	Bδ μas
aus2011a	2848	280	47	19	138	183	-228	-42	-32	21
±							11	10	9	10
aus2011b	2881	291	48	22	167	166	-192	-32	-35	26
±							10	10	9	9
bkg2011a	3226	287	8	26	59	68	26	22	-8	26
±							5	5	4	4
opa2011a	3720	295	9	9	46	50	-6	9	-6	8
±							5	5	4	4

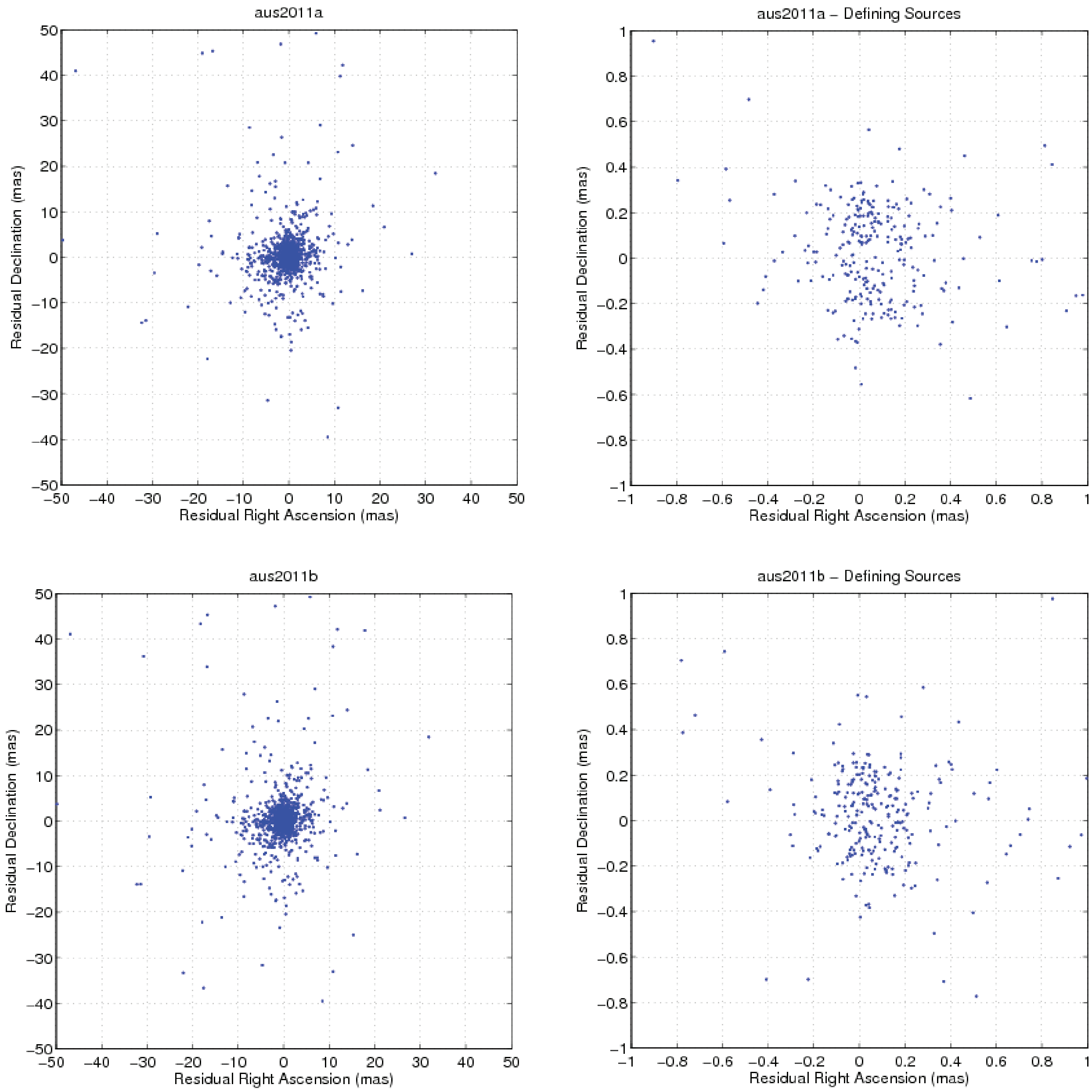

Fig. 1: The residual difference between the four catalogs and the ICRF2 for all sources (Left) and defining sources only (Right).

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 2011. 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 2011, a total of six VLBA RDV experiments were observed.

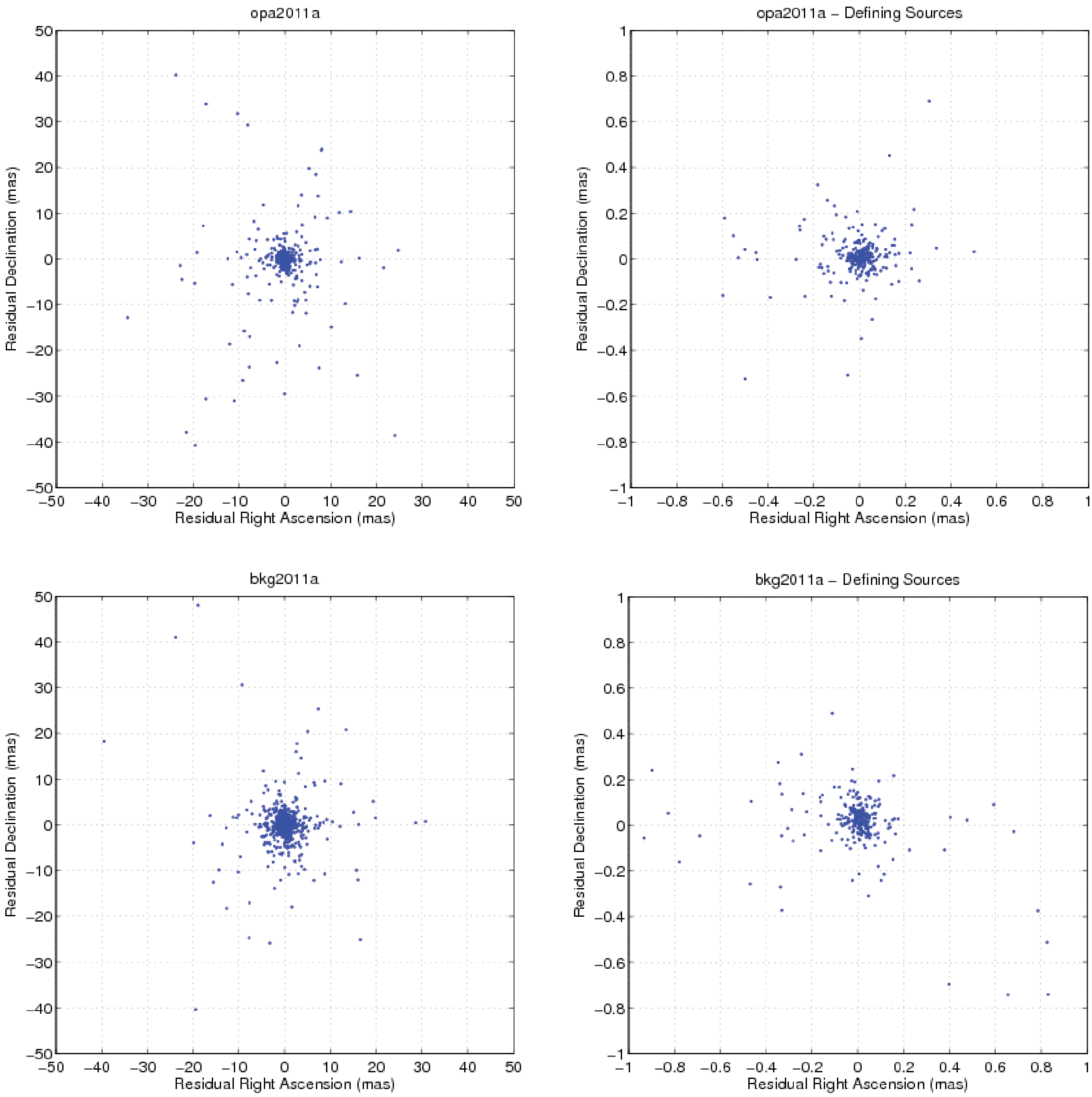

Fig. 1 (continued)

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 2011, ICRS Center personnel imaged sources from three VLBA RDV experiments and from one high frequency (K-band) VLBA experiment. The RRFID currently contains 7279 Very Long Baseline Array (VLBA) images of 782 sources at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 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 various 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). In 2011 several actions were taken by the ICRS Center in order to facilitate and improve the link between the ICRF and other celestial frames.

Optical Representation of the ICRS

The astrometric precision for the observation of the constituent sources and maintenance of the ICRF is steadily increasing in VLBI observations, hand in hand with increasing sensitivity. In the optical domain a precision leap will be achieved by the European mission Gaia, perhaps shifting the ICRF dominion from the radio back to optical wavelengths. In the ground segment, large synoptic surveys as the SDSS and the forthcoming DES, Pan-STARRS, and LSST complement Gaia by deeper surveying, larger numbers, and multi-band observations. All this asks for a careful cataloguing of each object’s astrometry and main outcomes from every observation. Such outcomes enable the relating of the astrometry to the photometry with astrophysics, in order to define the appropriateness or shortcomings of any given object as an element of the ICRF. To consider all these different aspects, that are progressively becoming relevant, a major meeting was held in 2011 in Porto, Portugal, sponsored by Gaia/Great.

The Large Quasar Astrometric Catalog

The ICRS Center is in charge of the LQAC, a whole sky compilation of information on known QSOs, as well as of its regular up-dates. The second version of the LQAC was published as a CDS catalog (Souchay et al., 2011). The LQAC2 now contains 187 504 quasars, observed optical and radio flux and redshift, original and consolidated equatorial coordinates, plus calculated absolute magnitudes and morphological indexes (see IERS Annual Report, 2010). A more precise description of the LQAC-2 will be given in the IERS Annual Report 2012.

Investigation on the QSO optical/ radio centroid reconciliation

This issue is central to the representation of the ICRS in the optical band. It also is being actively revised for the onset of Gaia. For the reconciliation between the ICRF and the GCRF, given the limited number of sources that are anticipated to be suitable to this end, the question of individual coincidence of the optical and radio centroids must be addressed on a case by case basis whenever possible. One such investigation was conducted by Camargo et al. (2011) observing 22 ICRF sources with the wide field CCD imager of the SOAR telescope.

Quasar Variability

Variability is a distinct feature of quasars, in all time, band, and regions domains. It hampers the astrometric precision which is signal-to-noise dependent, and may increase the photocenter jitter and detection of spurious proper motion. Taris et al. (2011) investigated photometric and astrometric variability of 41 quasars from the CFHT Deep Field 2, followed during 4.5 years.

Stellar Proper Motions

A milestone was reached with the publication of absolute proper motions (SPM4) of the southern proper motion program based on 2 epoch data (Girard et al. 2011). The positions were put on the Tycho2 system while the proper motion system is anchored by galaxies and QSOs.

UCAC 4

Data for the final USNO CCD Astrograph Catalog (UCAC4) was prepared and a beta version sent out to testers. All-sky plots of UCAC4 proper motion distribution look good, a significant improvement over UCAC3. First feedback from the testers was received and the catalog improved.

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 entire dewar system and electronics of the USNO Robotic Astrometric Telescope (URAT) was delivered by Semiconductor Technology Associates (STA) and the telescope with its new focal plane array achieved first light on September 25, 2011 in Washington DC. The 4 monolithic CCDs with 10,560 by 10,560 pixels of 9 micron square size image 2.65 by 2.65 deg of sky each, with a total of 28 square degrees of sky coverage in a single exposure. All outputs are functional in 8 channel per CCD readout mode. The clocked anti-blooming mode is functional. The dewar almost got destroyed while sitting on a wooden box in preparation for mounting at the astrograph backend when an earthquake hit the Washington DC area.

Later in 2011 the telescope was prepared for shipment to the Naval Observatory Flagstaff Station (NOFS) while the camera and dewar was sent to STA for minor upgrades (e.g. removing the glow at the amplifiers, and obtaining a new neutral density spot on the dewar window). A status report was presented at the

AAS meeting (Zacharias et al. 2011). For latest information see <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/urat/usno-robotic-astrometric-telescope-urat>.

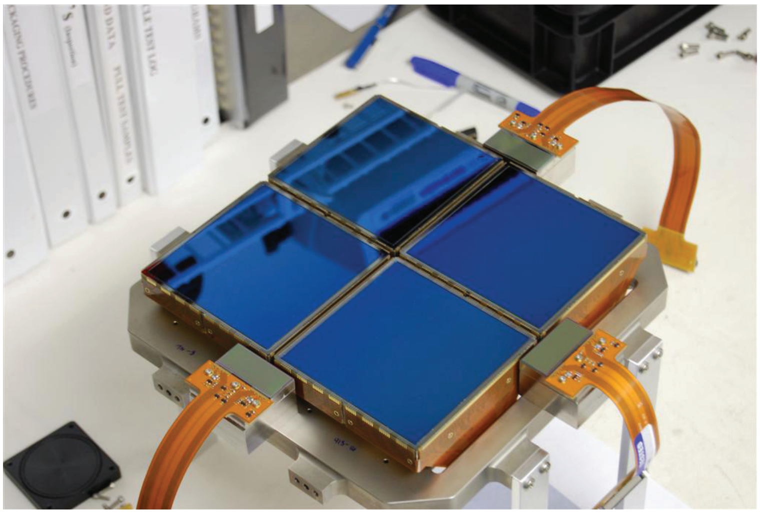

Fig. 2: The URAT focal plane at STA: 4 big CCDs (95 mm by 95 mm each) and 3 guide CCDs.

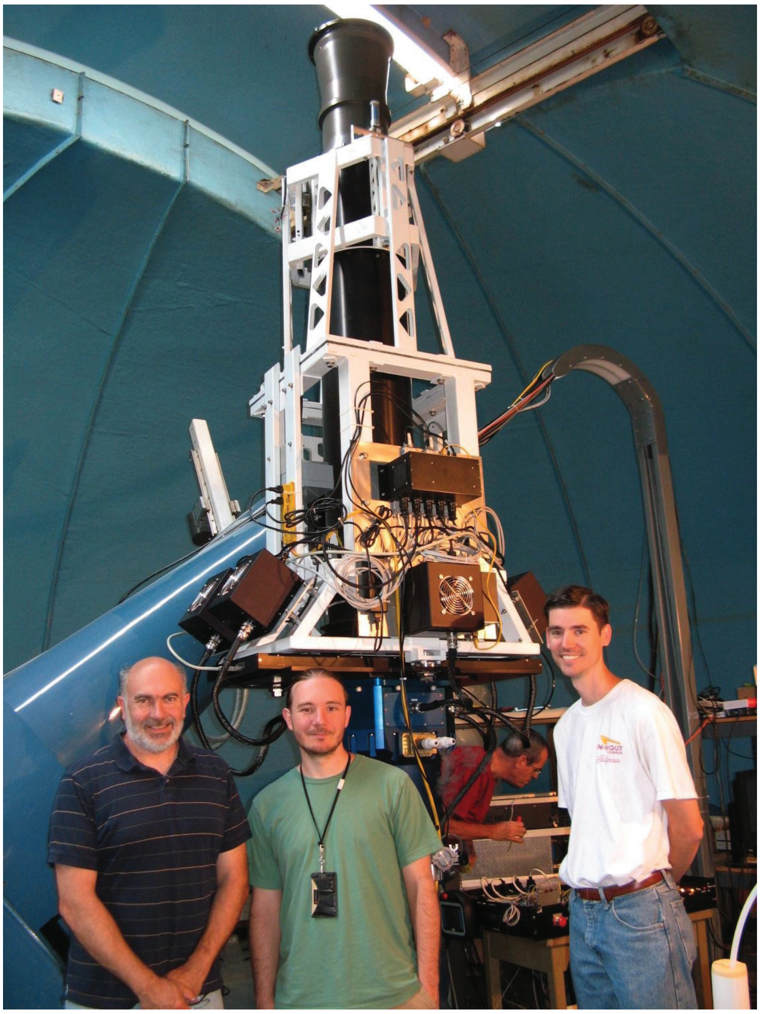

Fig. 3: Setup of the URAT telescope with the dewar and camera electronics in September 2011. From left to right: Norbert Zacharias, Charlie Finch, Ted Rafferty (retired, in the background), and Greg Bredthauer (STA).

Maintenance of the link to the solar system dynamical reference frame

Using Planetary Ephemeris: the ASETEP database

The link between the ICRS and the Dynamical System is one of the important tasks devoted to the ICRS Center. This can be done through the ephemerides of the planets and asteroids: each orbital motion of these bodies can be considered as a representation, a materialization of the Dynamical System, at least by defining implicitly the basic plane from which it is defined (generally the fixed ecliptic and equinox of the epoch J2000.0).

In that topic recent high precision ephemerides as INPOP (from Paris Observatory, cf. Fienga et al. (2010)), DE (from JPL, cf. Standish et al., 1998) and EPM (from IAA) compete to give the best determinations of the planetary motions. Nevertheless, their accuracy is limited by the lack of knowledge concerning the masses of the largest asteroids which exert significant gravitational perturbations.

In 2011, a database was constructed in order to give a clear view of the specific influence of a set of 43 asteroids whose mass is known with a relatively good accuracy (better than ± 60% of relative uncertainty), on the terrestrial planets : Mercury, Venus , the Earth (in fact the EMB : Earth-Moon Barycentre) and Mars. This database is called ASETEP (Asteroidal Effects on the Terrestrial Planets).

In addition to basic tables where the masses of the 43 asteroids above are given, together with their nominal value, their uncertainty, the origin of their determination, the ASETEP database provides mainly three kinds of information:

- It gives the specific influence of each of the 43 selected asteroids on each of the 6 orbital elements of any of the 4 terrestrial planets (Mercury, Venus, the EMB and Mars), leading to the presentation of 43 x 6 x 4 = 1032 curves.
- It gives the influence of each of the 43 selected asteroids on the geocentric coordinates (α, δ, distance) of the centre of mass of each of the 3 terrestrial planets (Mercury, Venus, Mars), leading to the presentation of 43 x 3 x 3 = 387 curves.
- It presents information tables related to the asteroids (mass estimation with uncertainty, amplitude of the oscillations characterizing the perturbations etc…).

The ASETEP database will be up-dated regularly at each time a new and more precise estimation of the masses of the asteroids involved will be given. They will be also extended by including more and more asteroids, according to their mass uncertainty.

Using Lunar Laser Ranging analyses

Between 1969 and 2011, about 20 000 observations (LLR normal points) have been performed by the following LLR tracking stations:

LLR tracking station	Time span	No. of observations
McDonald – Tel 2.7m (Texas)	1969–1985	3604
McDonald – MLRS1 (Texas)	1983–1988	592
McDonald – MLRS2 (Texas)	1988–2011	3931
Grasse OCA (Laser Rubis)	1984–1986	1187
Grasse OCA (Laser YAG)	1987–2005	8357
Grasse OCA (Station MeO)	2009–2011	125
Haleakala – LURE (Hawaii)	1984–1990	770
Matera (Italie)	2003–2011	36
Apache Point Obs. (New Mexico)	2006–2011	1370

Lunar Laser Ranging (LLR) analyses provide scientific results in various domains (astronomy, gravitational physics, geodynamics, selenophysics). They contribute also to the positioning of the dynamical reference frame with respect to ICRS.

At the Paris Observatory Lunar Analysis Center (POLAC), the dynamical reference frame of the solar system is defined as the dynamical mean ecliptic and equinox J2000 related to the orbit of the Moon given by the solution ELP (Chapront et al., 1999).

The position of the inertial dynamical mean ecliptic of J2000.0 with respect to an equatorial frame chosen as reference is oriented by two angles: ε, the inclination of the ecliptic to the equator and φ, the angle between the origin of the right ascension (o) on the equator and the ascending node (γI2000) of the ecliptic on the equator.

The link with ICRS is defined by the angles ε(ICRS) and φ(ICRS) and the evaluations made by POLAC with the LLR observations, performed between 1969 and 2011, give the following values:

ε (ICRS) = 23°26'21".411 ± 0.001"
φ (ICRS) = –55.4 ± 0.1 mas

Using Pulsar Timing analyses

In 2011 a large program of VLBI observations of pulsars organised by a large international consortium was launched. About 20 pulsars have been selected for a 4 year observational session in order to estimate their parallaxes but also the variability with time of their physical characteristics. This survey is also a complementary session of VLBI observations for objects observed by FERMI in X. Pulsars selected for their interest for liking reference frames such as J0751+1801, J1744-1134 and J0613+0200 were also included. These observations will help for the densification and the improvement of the VLBI pulsar observations when improvement in radio timing of these objects will be ensure by new analysis of the timing data sets.

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References

Camargo, J.I.B., Andrei, A.H., Assafin, M., Vieira-Martins, R., da Silva Neto, D.N., 2011, A&A 532, 115.

Chapront, J., Chapront-Touzé, M., Francou, G. , 1999, Determination of the lunar orbital and rotational parameters and of the ecliptic reference system orientation from LLR measurements and IERS data, A&A, 343, 624–633.

Charlot, P.; Boboltz, D. A.; Fey, A. L.; Fomalont, E. B.; Geldzahler, B. J.; Gordon, D.; Jacobs, C. S.; Lanyi, G. E.; Ma, C.; Naudet, C. J.; Romney, J. D.; Sovers, O. J.; Zhang, L. D., 2010, AJ, 139, 1713

Fey, A.L., Gordon, D., and Jacobs, C.S., (eds.), 2009, The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry, IERS Technical Note 35.

Fienga,A., Laskar,J., Kuchynka, Manche, H., Desvignes, G., Gastineau, M., 2010, The INPOP10a planetary ephemeris and its applications in fundamental physics, Celest. Mech. Dy. Astr., 111, 361–367

Fomalont, E. , Johnston, K., Fey, A., Boboltz, D., Oyama, T. & Honma, M. 2011, AJ, 141, 91

Gaume,R., Dorland,B,. Hennessy,G., Dudik,R., Bartlett,J., Dugan,N., Zacharias,N., Johnston,K., Barrett,P., Makarov,V., 2009, "The Joint Milli-Arcsecond Pathfinder Survey (J-MAPS) Mission", 213th AAS meeting, Long Beach, California, January 2009 Bull. Amer. Astron. Soc. 41, No. 1, 344, #451.01

Girard, T.M., van Altena, W.F., Zacharias, N., Viera, K., Casetti-Dinescu, D.I., Castillo, D., Herrera, D., Lee, Y.S., Beers, T.C., Monet, D.G., Lopez, C.E., 2011, The Southern Proper Motion Program IV. The SPM4 Catalog, AJ 142, 15

Lanyi, G. E.; Boboltz, D. A.; Charlot, P.; Fey, A. L.; Fomalont, E. B.; Geldzahler, B. J.; Gordon, D.; Jacobs, C. S.; Ma, C.; Naudet, C. J.; Romney, J. D.; Sovers, O. J.; Zhang, L. D., 2010, AJ, 139, 1695

Standish, E.M., 1998, JPL Planetary and lunar ephemerides, DE405/LE405, IOM,312.F-98-048

Souchay, J., Andrei, A. H., Barache, C., Bouquillon, S., Suchet, D., Taris, F., Peralta, R., 2011; LQAC2 CDS catalog 33379099

Taris, F., Souchay, J., Andrei, A. H., Bernard, M., Salabert, M., Bouquillon, S., Anton, S., Lambert, S. B., Gontier, A.-M., Barache, C., 2011, A&A 526, 25.

Zacharias, N., Finch, C., Zacharias, M.,I., Girard, T., 2011, «UCAC4 Status», 218th AAS meeting, Boston, Massachusetts, 2011AAS...21840909Z

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

3.5.5 ITRS Centre

This report summarizes the activities of the IERS ITRS Centre during the year 2011.

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 number 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 Website 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.

Other activities

- Participation in most meetings of the analysis working groups of the Technique Centres (in 2011: IDS, IGS, ILRS);
- Convening and organizing an EGU session: Improved Terrestrial Reference Frames for Higher-Accuracy Applications;
- Participation and contribution to the IERS Unified Analysis Workshop held in Zurich, 16–17 September, 2011;
- Participation in the 6th meeting of the International Committee on GNSS held in Tokyo, 5–9 September, 2011.

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).

The GGFC is composed of four operational entities, the Special Bureau for the Atmosphere (Chair D. Salstein), the Special Bureau for the Oceans (Chair R. Gross), the Special Bureau for Hydrology (Chair J.-L. Chen), and the Special Bureau for the Combination Products (Chair T. van Dam). There is also a GGFC non-operational component, the GGFC Science and Support Products. This component serves as a repository for models and data used regularly in data processing but that do not change often. The GGFC is actively searching for a chair for this component.

In 2009, the newly reorganized GGFC sent out a call for proposals. The responses to the call are shown in the table below. The products were all accepted as GGFC Provisional Products. The procedure for certifying the products requires an analysis of the

Proposed GGFC Product	**Principal Investigator**	**Proposed GGFC Operational Center**
VMF1 atmospheric delays; wet and dry zenith hydrostatic delays all computed (ECMWF)	J. Boehm	Vienna University of Technology
GRACE Atmosphere Ocean Dealiasing products (ECMWF atmosphere driving the OMCT ocean model)	F. Flechtner	GFZ
Consistent atmosphere, ocean, land water storage angular momentum (ECMWF atmosphere driving the OMCT ocean and LSDM land hydrology models)	M. Thomas	GFZ
Atmospheric loading (NCEP reanalysis model) Non-tidal ocean loading (ECCO/JPL model) Continental water storage loading (GLDAS) Atmosphere+ocean loading (GRACE AOD product)	T. van Dam	University of Luxembourg

latency and reliability over a two-year period. In 2011, the original two-year validation was complete and the provisional products were 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/>

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

3.6 ITRS Combination Centres
3.6.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

In 2011, the focus of the work of the ITRS Combination Centre at DGFI was on research regarding a common realization of the ITRS and ICRS. ITRF and ICRF are computed separately and by different institutions today. Hence, the two frames and the respective EOP series are not fully consistent (see Fig. 1).

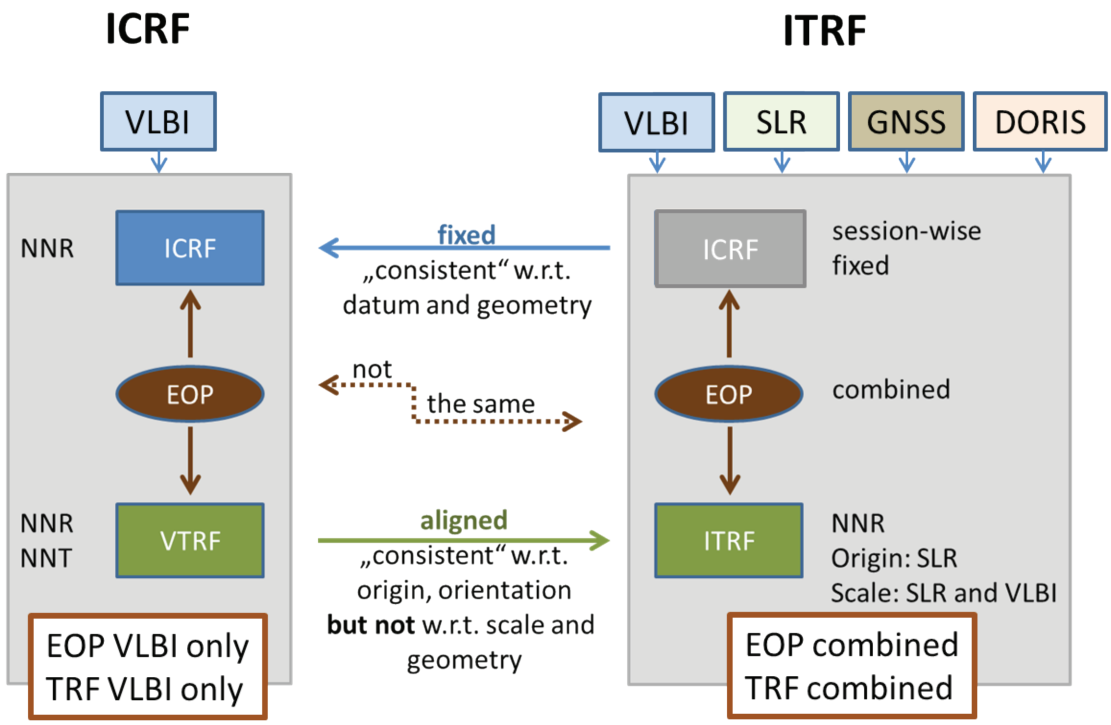

Fig. 1: Current situation for the realization of the ITRS and ICRS.

DGFI realizes for the first time the ITRS and the ICRS consistently in one common adjustment (see Fig. 2). Input data are time series of weekly or session-wise normal equations derived from the observation of VLBI, SLR and GNSS. Table 1 gives an overview of the input data. The parameters, which are included in the solution, are station coordinates, source coordinates and the EOP, i.e. the coordinates of the terrestrial and the celestial pole, UT1-UTC and the time derivatives of these parameters. Altogether, about 45,000 parameters are solved. The geodetic datum of the reference frames is realized according to the IERS Conventions: the origin is realized from SLR observations and the scale as a weighted mean of the SLR and the VLBI scale. The orientation of the CRF is realized by a no-net-rotation condition w.r.t. ICRF2 and the orientation of the TRF by no-net-rotation conditions w.r.t. DTRF2008.

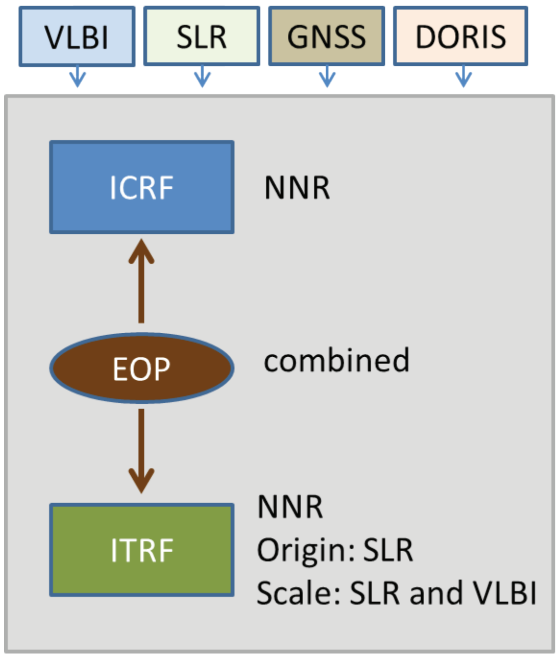

Fig. 2: Consistent realization of the ITRS and ICRS performed at DGFI.

ITRF solutions and the IERS C04 series demonstrate that the terrestrial reference frame and the EOP benefit from a combination of different space geodetic techniques. Thus, also an improvement for the CRF could be expected. Our investigations focused on the effect of the combination of space techniques on the CRF, which has not been investigated so far. Two different impacts on the CRF can be distinguished: (i) the effect of the combination of the terrestrial reference frames (station coordinates) introducing local ties and (ii) the effect caused by the combination of the EOP. While the combination of the station coordinates has only a very small impact (< 40 µas), the combination of the EOP shows a clear effect on the CRF.

Figure 3 shows the differences between the standard deviations of the declination of the sources resulting from a combined and a VLBI-only solution. The standard deviations decrease in general due to the combination. In particular, the standard deviations of the VCS sources (sources observed by so called VLBA Calibra-

Tab. 1: Input data for the consistent computation of TRF and CRF.

Technique	Time span	Resolution	Institution
VLBI	1984–2007	session-wise (24 h)	Combined: IGG+DGFI
GNSS	1997–2007	daily	GFZ/TUM
SLR	1993–2007	weekly	DGFI

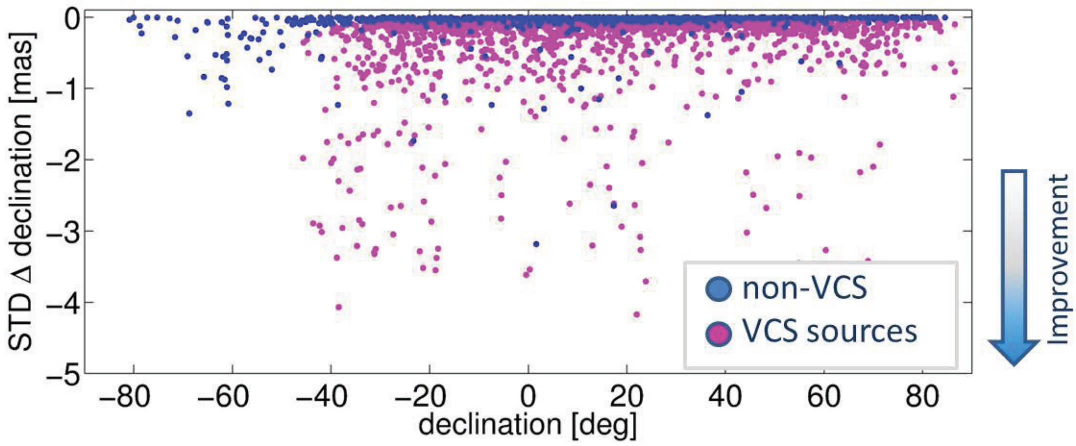

Fig. 3: Change of standard deviation of declination angles due to the combination (combined minus VLBI-only).

tor Survey (VCS) sessions only) become smaller. This could be expected, because the standard deviations of the VCS source positions are larger than of the non-VCS sources. The reason is, that the VCS sources are observed by the VLBA network (a regional network) only and most of the VCS sources are observed in only one session.

In Fig. 4 the source positions resulting from the CRF-TRF solution are compared to the VLBI-only solution. For both, declination and right ascension, it comes out that the position changes are larger for VCS sources than for non-VCS sources. In the right ascension, a systematic effect was found for some of the VCS sources between +30° and -40° of declination. It can be related to the combination of LOD (see Fig. 5). However, even if the effect is systematic, it is not significant w.r.t. the standard deviation of a single source position (0.4 mas or larger).

Acknowledgements

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

References

Angermann D., Drewes H., Seitz M.: Global terrestrial reference frame within the GGOS-D project. In: Kenyon, S.; Pacino, M.C.; Marti, U. (Eds.): Geodesy for Planet Earth, IAG Symposia, Vol. 136, pp 87-93, 2011, DOI: 10.1007/978-3-642-20338-1_11

Bloßfeld M., Müller H., Angermann D.: Adjustment of EOP and gravity field parameters from SLR observations. Proceedings of the 17th ILRS Workshop, 2011

Seitz M., Heinkelmann R., Steigenberger P., Artz T.: Common Realization of Terrestrial and Celestial Reference Frame. In: Alef W., Bernhard S. and Nothnagel A. (Eds.) Proceedings of

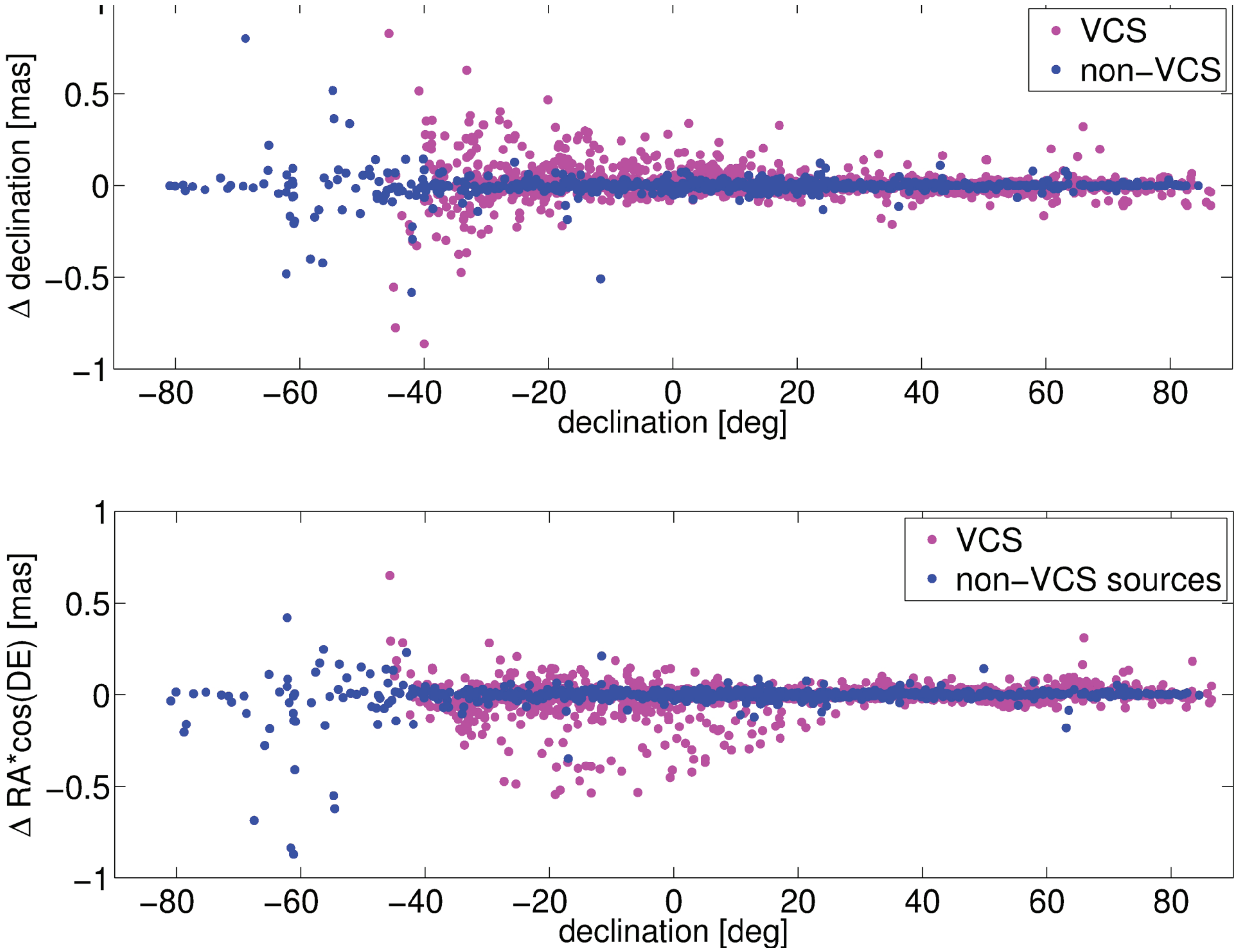

Fig. 4: Change of sources positions due to the combination.

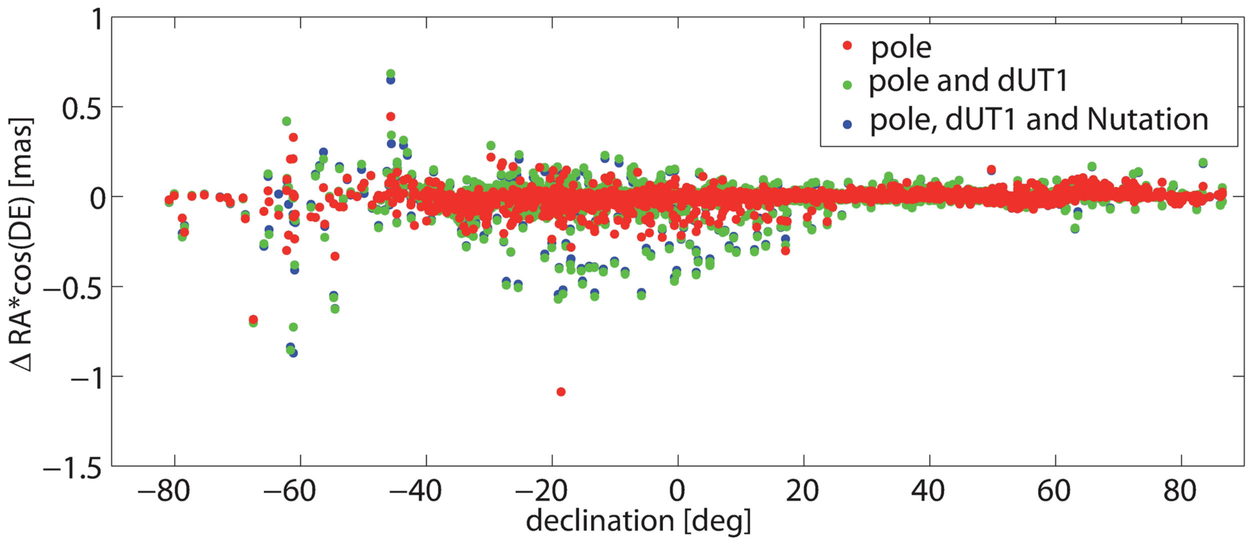

Fig. 5: Change of right ascension due to different kinds of EOP combination: only terrestrial pole coordinates are combined (red), terrestrial pole coordinates and UT1-UTC parameters are combined (green), all EOP, i.e. coordinates of the terrestrial and the celestial pole and UT1-UTC are combined (blue).

the 20th Meeting of the European VLBI Group for Geodesy and Astronomy, Schriftenreihe des Instituts für Geodäsie und Geoinformation der Universität Bonn, 22, 2011

Manuela Seitz, Detlef Angermann, Mathis Bloßfeld,
Michael Gerstl, Robert Heinkelmann, Horst Müller

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

This report summarizes the activities of the IGN combination centre during the year 2011. These activities are mainly related to the publication of the ITRF2008 results.

ITRF2008 publications

A detailed article on ITRF2008 results was prepared and published in Journal of Geodesy with the “open access” option so that the ITRF2008 users have full and free access to the details of the ITRF2008 analysis and results.

During 2011, detailed analyses of the ITRF2008 velocity field were undertaken in order to estimate a plate motion model consistent with ITRF2008. Indeed, for various geodetic and geophysical applications of ITRF2008, the aim of this study is to provide users with the most precise plate motion model derived from and consistent with the ITRF2008. An article with the title “ITRF2008 Plate Motion Model” was submitted to Journal of Geophysical Research in October 2011. More details about the results of this study will be summarized in the IERS Annual Report 2012.

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.

References

Altamimi, Z., X. Collilieux, and L. Métivier (2011), ITRF2008: an improved solution of the International Terrestrial Reference Frame, Journal of Geodesy, doi:10.1007/s00190-011-0444-4

Collilieux, X. and G. Wöppelmann (2011), Global sea-level rise and its relation to the terrestrial reference frame, *Journal of Geodesy*, 85(1), pp 9–22, doi:10.1007/s00190-010-0412-4

Collilieux X., van Dam T., Ray J., Coulot D., Métivier L., Altamimi Z. (2011), Strategies to mitigate aliasing of loading signals while estimating GPS frame parameters, *Journal of Geodesy*, published online, doi: 10.1007/s00190-011-0487-6.

Collilieux, X., L. Métivier, Z. Altamimi, T. van Dam, and J. Ray (2011), Quality assessment of GPS reprocessed Terrestrial Reference Frame, *GPS Solutions*, vol. 15, n. 3, pp. 219–231, doi:10.1007/s10291-010-0184-6

Wu, X., X. Collilieux, Z. Altamimi, B. Vermeersen, R.S. Gross, and I. Fukumori (2011), Accuracy of the International Terrestrial Reference Frame origin and Earth expansion, *Geophysical Research Letters*, 38(L13304), doi:10.1029/2011GL047450

Zuheir Altamimi, Xavier Collilieux, Laurent Métivier

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

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

2011 WG Meeting

The third meeting of the *IERS WG on site surveys and co-location sites* took place on Dec. 7th at the Westin St. Francis, 3rd Market Street in San Francisco; h: 17.30. The meeting was very well attended, with a total of 27 participants (Table 1). The large number of attendees confirmed the strong interest related to the investigations promoted by the working group.

Table 1: Working group meeting participants list. Names of the IERS working group members are highlighted.

Participant name	Institution	e-mail
Claudio Abbondanza	JPL-Caltech	claudio.abbondanza[at]jpl.nasa.gov
Zuheir Altamimi	IGN-France	altamimi[at]ensg.ign.fr
Andria Bilich	NOAA-NGS	andria.bilich[at]noaa.gov
Bud Donovan	Honeywell-NASA NGSLR	Howard.Donovan[at]honeywell.com
Mark Eckl	NOAA-NGS	mark.eckl[at]noaa.gov
Charles Geoghegan	NOAA-NGS	charles.geoghegan[at]noaa.gov
Jake Griffiths	NOAA-NGS	jake.griffiths[at]noaa.gov
Richard Gross	JPL	richard.gross[at]jpl.nasa.gov
Gary Johnston	Geoscience Australia	gary.johnston[at]ga.gov.au
Johan Löfgren	OSO-Chalmers Univ	johan.lofgren[at]Chalmers.se
Chopo Ma	NASA Goddard	chopo.ma[at]nasa.gov
Stephen Merkowitz	NASA	Stephen.Merkowitz[at]nasa.gov
Monia Negusini	IRA-INAF	negusini[at]ira.inaf.it
Ruth Neilan	JPL-IGS	rneilan[at]igs.org
Arthur Niell	MIT Haystack Observatory	aniell[at]haystack.mit.edu
Mike Pearlman	Center for Astrophysics	mpearlman[at]cfa.harvard.edu
Paul Rebischung	IGN-France	paul.rebischung[at]ign.fr
Jim Ray	NOAA-NGS	jim.ray[at]noaa.gov
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Pierguido Sarti	IRA-INAF	p.sarti[at]ira.inaf.it
Harald Schuh	TU Wien	harald.schuh[at]tuwien.ac.at
Dru Smith	NOAA-NGS	dru.smith[at]noaa.gov
Tonie van Dam	Univ Luxembourg	tonie.vandam[at]uni.lu
Scott Wetzel	Honeywell	scott.wetzel[at]honeywell.com
Pascal Willis	IGN-IPGP France	willis[at]ipgp.fr
Dan Winester	NOAA-NGS	daniel.winester[at]noaa.gov
Xiaoping Wu	JPL	xiaoping.wu[at]jpl.nasa.gov

The meeting started with a presentation given by Pierguido Sarti summarizing the most recent investigations about the assessment of the accuracy of the tie vectors; the presentation is available on the WG web page.

In addition, the discussion also focussed on the possibility to infer/relate the tie vector accuracies from/to the ITRF combination residuals.

Paul Rebischung and Gary Johnston kindly contributed giving additional presentations that focussed on Tsukuba (VLBI-GPS) and Yaragadee (SLR-GPS-DORIS) co-location sites, respectively. They offered a deeper insight in the relationship between the space geodetic solutions, the ITRF combination residuals and the GPS radome effects (presentations are also available on the WG web page at the 2011 Dec. 7th meeting section).

During the meeting, Pierguido Sarti suggested the establishment of a service for tie vectors and local ties, similar to what is currently done for the space geodetic techniques. The proposal aimed at highlighting the urgent need of establishing a central, international entity in charge of i) setting the guidelines and harmonizing the survey process, ii) prioritizing the surveys iii) coordinating the tie vector computation, iv) defining central repositories to store raw and reduced data, results, parameters and metadata. The proposal boosted a vivid discussion about the possibility to create a permanent agency about local tie surveys and co-location sites.

Activity

The list of WG members has been revised and prepared for approval at the 2012 IERS DB meeting to be held in Vienna, during the EGU2012.

In addition, a new WG charter has been drafted. With possible integrations and updates, it will also be submitted for approval, along with the new list of members and schedule, to the IERS DB meeting in Vienna during EGU2012.

Proposal for a co-chair

In 2011, a co-chair of the working group was proposed by the current chair P. Sarti. Since the very beginning of its activity, the WG was established by the IERS DB envisaging a possible co-chair between Dr. John Dawson (Geoscience Australia, former WG chair during 2004–2005) and P. Sarti. This possibility would now be very appropriate. Such co-chair could efficiently support the activity of the WG and spread its results and decisions with a higher level of penetration and credibility. A co-chair in this particular moment would certainly allow a maximization of the number of meetings of the WG and a better exploitation of its activities.

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 the course of 2009. Its charter is available at <http://www.iers.org/WGCOL>. 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. The COL road map has been defined as follows:

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

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

3) insuring SINEX compatibility between techniques and with the international technique services and IERS.

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

5) optimizing and unifying parameterization for instance for tropospheric parameters in order to minimize globally the degree of freedom of the whole inverse system and to reach consistency.

6) studying the appropriate weighting between techniques and the use of local ties or identical satellites tracked by several techniques.

7) studying stabilization methods and looking for high temporal resolution of parameters.

8) evaluating and comparing results to search for compatibility between groups.

9) organizing routine operations for a new TRF realization, either in the framework of the next ITRF or as ITRF assessment.

Points 1 to 5 have been treated so far.

Progress of the project

Two meetings were organized in 2011. The first one was held during the EGU meeting period. Its objective was first to review the strategy to be applied and standard models to be adopted for the inter-comparison benchmarking campaign corresponding to the VLBI CONT08 intensive campaign extending from 10^{th} to 30^{th} August 2008. The actions to carry out were:

- Make available the a priori gravity field
- Make available FES2004 model with a list of additional side band waves for interpolation and extrapolation

- Implement IERS Conventions 2010 in the various software packages

A list of satellites to consider in the processing was set up:

- SLR: Lageos and Lageos 2
- DORIS: SPOT 4, SPOT 5, JASON, ENVISAT
- GNSS: GPS and GLONASS
- Multitechnique SLR+DORIS+GPS: JASON 2

Specifications concerning parameters to be estimated in the processing:

- EOP, daily sampling, parameterization for polar motion: piece-wise linear or offset + drift
- Station coordinates: 1 set per week in Cartesian coordinates
- Tropospheric zenith biases per pass or 2hrs + horizontal gradients per day
- Antenna phase centres estimates for DORIS and GPS
- No atmospheric loading are applied

The IERS COL-WG organized another meeting at Paris Observatory on 21–22 November 2011. Activity reports were presented by the various analyses centres taking part in the activities: AIUB / BKG, DGFI, ESOC, GFZ, GRGS, ASI, GSFC, TUW and by the two Combination centers: GRGS and DGFI. Discussions followed on the road map and a proposal to iterate the test period. The pertinence of the strategy adopted was discussed as well as the objectives to be reached in the future planning of the work.

Demonstration is now based on weekly combined modified SINEX files containing unconstrained normal equations of station coordinates, Earth rotation parameters from all space geodetic techniques (SLR/LLR, GNSS, VLBI, DORIS) and in addition nutation parameters, quasars coordinates for VLBI, and this over 3 weeks including CONT08 period.

Combinations and validations were performed by the combination centres: SLR by AIUB, DGFI and GRGS. VLBI by DGFI, OPA and TUW. GNSS by AIUB and GRGS. DORIS is at present only provided by GRGS. Multi-technique combination results were compared to DTRF2008 and EOP 08 C04.

The future planning of the project was extensively discussed. Technical points as listed thereafter were addressed.

- *Test period*
  The COL-WG decided to extend the tests to the CONT11 period (11 September to 1 October 2011).

- *Data set*
  Rather than providing the exact same data set per technique to all groups (what does happen to be difficult, mainly for GNSS), it was recommended that groups use the same station set per technique. These lists of stations provided by the ACs have been made available via the COL-forum.
- *A priori models*
  An updated gravity field model to be used for the CONT11 campaign period was provided.
  As for the model delivered for the CONT08 period, it includes some averaged departures from atmospheric gravitational effect (from ECMWF) as well as from oceanic circulation effect (from MOG2D) over the 3 weeks of the campaign. The Ray-Ponte atmospheric tide model should be used. It should be compared to the Bode-Biancale model used by GRGS and GFZ. Rolf Koenig provided the ocean tide loading model (by Scherneck). The GPT/GMF tropospheric delay models should be used for the electromagnetic techniques and the Mendes-Pavlis model for light. All these models were made available through the COL forum.
- *Parameterization*
  Daily EOP and nutation parameters can be either piece-wise linear (at 0hr) or offset + drift (at 12hr). The NRO nutation corrections in X and Y should be implemented and used in all software packages.
  A priori values for wet tropospheric zenithal delays should be present every 2 hours and northward/eastward gradients per day, at least for a few co-located stations whose list is put on the forum (Hartebeesthoek, Concepcion, Greenbelt, Mount Stromlo, Tahiti, Kokee Park, NyAlesund, …). Antenna phase centres for DORIS and GPS should be present as well.
- *SINEX files compatibility*
  Most of discrepancies are now solved. However it can still be improved by satellite names, processing description (e.g. models).
- *Interpolation*
  As proposed in 2010 meeting the Gerstl's paper on interpolation methods was provided by DGFI and put onto the forum.
- *Weighting*
  OP provided variance factors obtained by the Helmert's variance component estimation method for all normal equations.
- *Comparison strategy*
  It was proposed that ACs check the SINEX files per technique from now on.

- *Miscellaneous*
  The discussion of the COL participation in the next ITRF2013 proposal was delayed.

Participants in working group activities

D. Gambis, J.-Y. Richard, C. Bizouard, Observatoire de Paris/GRGS
R. Biancale, Jean-Michel Lemoine, CNES/GRGS
M. Seitz, R. Heinkelmann, M. Gerstl, H. Müller, M. Blossfeld, DGFI
R. Schmid, TUM
S. Loyer, L. Soudarin, CLS
D. Thaller, AIUB
M. Mareyen, S. Bachmann, BKG
G. Bourda, Observatoire de Bordeaux
R. Koenig, D. König, GFZ
T. Springer, D. Svehla, ESA/ESOC
H. Krasna, K. Teke, TUW
C. Sciarretta, ASI/e-GEOS
M. Kudryashova, ORB
F. Deleflie, IMCCE
F. Lemoine, GSFC

References

Gambis D. and C. Bizouard, 2010, Monitoring UT1 from astro-geodetic techniques at the EOP Center of the IERS, Highlights of Astronomy, Volume 15, pp 207–208

Gambis D., 2012, Global Combination of techniques, 7th IVS meeting, Madrid, March 2012.

Gambis D. and R. Biancale, 2012, Combination at the observation level, Colloquim TOSCA/CNES, Paris, 20–21 mars 2012.

Gambis D., Richard J.Y., Biancale R., Bizouard C., 2013, Why combining at the Observation Level Reference Frame for Applications in Geodesy (REFAG), *in Proc REFAG (2010), (Altamimi and Collilieux, eds) IAG series, Vol. 138*, pp 111–117.

Richard J.Y., D. Gambis, R. Biancale, 2010, Combination of Space Geodetic Techniques at the Normal Equation Level, EGU 2010.

Richard J.Y., Gambis D., Bizouard C., 2010, Earth rotation parameters determined over CONT08 VLBI campaign by the GRGS from the combination of space geodetic techniques, subm. to *Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.)*.

Richard J.Y., Gambis D., Biancale R., Bizouard C., “Earth rotation parameters determined over CONT08 from the combination of space geodetic techniques”, AGU 2010 13–17 December.

Richard J.Y., Gambis D., Bizouard Ch., 2011, Earth rotation parameters determined over CONT08 VLBI campaign by the GRGS from the combination of space geodetic techniques, *in Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.)*, pp 219–220.

Richard, J.Y., Gambis, D., 2011, Multi-technique combination for Earth Orientation, DORIS Analysis Working Group meeting (AWG) of the International DORIS Service, May 23–24, 2011

Richard J.Y., Seitz M., Biancale R., Gambis D., Loyer L., Soudarin L., Thaller D., Springer T., Koenig R., Sciarretta C., Spicakova H., Lytvyn M., 2011, IERS Working group on Combination of Space Geodetic Techniques at the Observation Level, IUGG, Earth on the Edge, Science for a sustainable planet, Melbourne, 28 June – 7 July.

Daniel Gambis, Richard Biancale, Jean-Yves Richard

3.7.3 Working Group on SINEX Format

The SINEX (Solution INdependent EXchange) format is a well-established format used by the technique services of the IERS since several years. Since 2001 the IERS Analysis Coordinator has been taken care of the SINEX format updates (see, e.g., IERS Annual Reports 2001, 2002, and 2006). One of the outcomes of the Unified Analysis Workshop 2009 (UAW 2009) held in San Francisco was the action item to establish an IERS Working Group for the maintenance and update of the SINEX format and format description. The IERS Working Group (WG) on SINEX Format was finally established in early 2011. The official announcement was sent as IERS Message No. 188 on April 15, 2011.

The Kick-Off meeting of the WG took place on April 6, 2011 during the EGU General Assembly in Vienna.

A website for the WG has been established at the IERS Central Bureau:

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

The latest version of the SINEX format description is accessible via this website. Additionally, the charter of the WG, the actual list of members, as well as the minutes of the WG meetings are available.

Goals and objectives

The aim of the working group is to maintain the SINEX format according to the needs of the IERS, the technique services (IDS, IGS, ILRS, IVS) and GGOS. The working group should be the point of contact if any modifications or extensions are required.

The major goals and objectives of the WG are:

1. Maintenance and update of the SINEX format.
2. Handle request for SINEX format changes.
3. Mechanism on how the SINEX format is changed and agreed upon.
4. Introduce new parameterizations and model variables as required.
5. Description of the format with up-to-date information technology.

Members

In order to have the best possible interaction with the groups working with the SINEX format (either as output or as input), the analysis and combination groups of all the technique services as well as the relevant components of the IERS and GGOS are represented within the working group. The members are in detail:

- 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: 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

Format updates

During the kick-off meeting the requests and needs for updates and changes of the SINEX format from all groups of the IERS and related services were collected.

The major topics are:

- Inclusion of the list of station discontinuities into the official format description. The block SOLUTION/DISCONTINUITIES – which is already in use for the ITRF combination – should be revised and adapted to the actual needs.
- Clarification of GNSS-specific antenna phase center issues (at the moment, only the antenna offsets for GPS and Galileo are defined).
- Definition how the offsets of the laser reflector arrays or the center-of-mass values for spherical SLR satellites should be reported in SINEX.
- Revision of the block SATELLITE/ID in order to make it applicable for all satellite techniques.
- Extension of Appendix II in order to cover the whole mathematical background relevant for the SINEX format.
- Inclusion of a standardized and machine-readable modelling block.
- Inclusion of information about satellite-specific weighting used to generate the solution provided in the SINEX file.

The update of the SINEX format description considering these requests is currently under development.

Daniela Thaller

4 Third GGOS Unified Analysis Workshop

After the GGOS Unified Analysis Workshop (UAW) in Monterey, California, USA, in December 2007, a Follow-Up Meeting in Vienna in April 2008, and the Second UAW in San Francisco, California, in December 2009, a Third GGOS Unified Analysis Workshop was organized at the ETH Centre main building in Zürich, Switzerland, September 16–17, 2011. As in the case of the other UAWs, the participation in the UAW 2011 was based on invitation, i.e., the IAG Services decided on the persons to represent them during the workshop.

Workshop Scope and Goals

An important goal of GGOS is to advance the combination and integration of the various space and in-situ geodetic techniques. This goal can only be achieved with the help of all the IAG Services, and especially the IERS and IGFS.

Even if considerable progress has been made in the effort to rigorously combine the various space geodetic techniques (e.g. with the realization of ITRF2008, making use of a new approach based on time series of weekly/session SINEX files), there are still many deficiencies, inconsistencies and systematic effects to be addressed.

The workshop was intended to be a forum for the exchange of information and results concerning both,

- problems common to more than one service and
- problems specific to an individual service.

For a successful combination of the space geodetic techniques, experts of a certain technique have to be familiar with the critical issues of the other techniques. Therefore, the workshop was aimed at increasing the common understanding of the individual techniques as they contribute to GGOS.

The workshop was organized in four sessions. Their titles, chairs, and goals were the following:

Session 1: Products by the Services, Filling the GGOS Portal

Chaired by B. Richter and C. Noll

Goals:

- Approach to fill the GGOS Portal with service products: methods and metadata
- Imbedding of GGOS portal into international programs like GEOSS Data-Core

Presentations:

- Position paper / introduction (B. Richter, C. Noll)

- IDS, products and service status (L. Soudarin)
- ILRS products, standards, modeling (E. Pavlis)
- ILRS data QC, data flow, ... (H. Müller)

Session 2: Modelling Based on External Data (Atmosphere, Ocean, ...), Modelling Deficiencies and Standards

Chaired by T. van Dam, J. Böhm, and D. Angermann

Goals:

- Data from atmosphere, hydrology, ocean, ...
- Biases of individual techniques, systematic effects
- Standards and conventions

Presentations:

- Position paper / introduction (T. van Dam, J. Böhm, D. Angermann)
- VLBI atmospheric loading comparison: observation level versus daily; reference pressure for atmospheric loading (J. Böhm)
- Reference pressure used for pressure loading computation (D. MacMillan)
- Atmospheric pressure loading (R. Dach)
- Hydrological loading (D. MacMillan)
- Update on ray-traced delays (J. Böhm)
- Correcting met data in VLBI data analysis (D. MacMillan)
- Vertical deformations from homogeneously processed GRACE and global GPS long-term series (P. Steigenberger)
- Geophysical fluids modeling (R. König)
- GGOS Bureau on Standards (D. Angermann)
- SLR Systematics (C. Luceri)
- VLBI telescopes and gravitation effects (A. Nothnagel)
- Impact of orbit modeling deficiencies (U. Hugentobler, C. Rodríguez)

Session 3: ITRF 20xx and Other Combined Products

Chaired by Z. Altamimi, M. Seitz, and R. Biancale

Goals:

- SINEX issues: development of SINEX for more complex combination strategies
- ITRF20xx: modelling and parameterization for the next ITRF solution
- Combination strategies: observation level, weighting, ...
- Other combined products

Presentations:

- Position paper / introduction (Z. Altamimi, M. Seitz, R. Biancale)
- SINEX (D. Thaller)
- ITRF combination issues (Z. Altamimi)
- Recent validation of the ITRF (X. Wu)
- Seasonal geocenter motion from space geodesy and models (J. Ries)
- Consistent modeling/estimation of Earth rotation, gravity, and geometry (R. Gross)
- Simultaneous Adjustment of TRF and CRF (M. Seitz)
- LLR contribution to long-term EOP variations and celestial reference frames (J. Müller)
- ILRS combination products (C. Sciarretta)
- Status, results, challenges of the Combination on the Observation Level (COL) (R. Biancale)

Session 4: Co-location on Ground and in Space, GGOS Core Sites

Chaired by H. Schuh, M. Pearlman, and E. Pavlis

Goals:

- Co-location on ground: new technologies, twin telescopes, GNSS antenna arrays
- Co-location on satellites: problems with existing co-location, new satellite missions (GRASP), co-location on GNSS
- Discrepancies in local ties
- GGOS core sites
- Twin telescopes, kHz laser, multi-frequency GNSS

Presentations:

- Position paper / introduction (H. Schuh, M. Pearlman, E. Pavlis)
- GRASP mission status and insights (Y. Bar-Sever)
- The next generation timing system at the Geodetic Observatory Wettzell (goals and prospects) (U. Schreiber)
- VLBI for Space Applications (H. Schuh, L. Plank, C. Schönberger, J. Böhm)
- GNSS/SLR combination with co-location on satellites (D. Thaller)
- SLR target signature model improvements, SLR and co-locations with gravity measurements (G. Appleby)
- Observation of GLONASS satellites with VLBI (R. Haas)

- NASA Space Geodesy Program at GGAO (C. Ma)
- New options with twin telescopes in VLBI (A. Nothnagel)

A discussion with a wrap-up and outlining Action Items, chaired by M. Rothacher, concluded the workshop.

The detailed programme, the position papers of the sessions, the presentations, and the Action Items are available at <http://www.iers.org/UAW2011>.

Markus Rothacher, 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 Subcommission 1.1

President of IAG Subcommission 1.2

President of IAG Subcommission 1.4

President of IAG Commission 3

President of IAG Subcommission 3.1

President of IAG Subcommission 3.2

President of IAG Subcommission 3.3

President of IAU Commission 8

President of IAU Commission 19

President of IAU Commission 31

Head of IAU Division I

IERS CORRESPONDENTS

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

October 10, 2010

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

Central IERS web site

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

Products

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

Earth orientation data

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

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

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

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

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

Conventions

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

International Celestial Reference Frame

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

International Terrestrial Reference Frame

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

Geophysical fluids data

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

Publications

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

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

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

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

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

IERS Components

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

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

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

Product Centres

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

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

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

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

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

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

Technique Centres

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

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

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

International DORIS Service (IDS)
Web site: http://ids-doris.org/

ITRS Combination Centres

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

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

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

Working Groups

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

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

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

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

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

Appendix 5: Acronyms

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

AAM	Atmospheric Angular Momentum
AAS	American Astronomical Society
AC	Analysis Centre
AC	Analysis Coordinator
ACC	[IGS] Analysis Center Coordinator
AGU	American Geophysical Union
AOD	atmospheric and oceanic dealiasing
APSG	Asia-Pacific Space Geodynamics
AR	[IERS] Annual Report
AR	autoregressive
ASCII	American Standard Code for Information Interchange
ASETEP	Asteroidal Effects on the Terrestrial Planets
ASI	Agenzia Spaziale Italiana
AUS	= AUSLIG
AUSLIG	Australian Surveying and Land Information Group (now: Geoscience Australia)
AWG	Analysis Working Group
BIH	Bureau International de l’Heure
BIPM	Bureau International des Poids et Mesures
BKG	Bundesamt für Kartographie und Geodäsie
BNC	[GGOS] Bureau for Networks and Communications
BVID	Bordeaux VLBI Image Database
CATREF	Combination and Analysis of Terrestrial Reference Frames
CB	Central Bureau
CC	Combination Centre
CCD	Charge-Coupled Device
CDDIS	NASA Crustal Dynamics Data Information System
CDS	Centre de Données astronomiques de Strasbourg
CEOS	Committee on Earth Observation Satellites
CERGA	Centre d’Etudes et de Recherches Géodynamiques et Astronomiques
CfA	Harvard-Smithsonian Center for Astrophysics
CFHT	Canada-France-Hawaii Telescope
CIO	Conventional International Origin
CLS	Collecte Localisation Satellites
CNES	Centre National d’Etude Spatiale
CODE	Centre for Orbit Determination in Europe
COL	combination at/on the observation level
CoM	centre-of-mass
CONT	continuous VLBI session/campaign
CRD	Consolidated Laser Ranging Data Format
CRF	Celestial Reference Frame
CSR	Center for Space Research, University of Texas
DB	Directing Board
DBBC	Digital Base Band Converter
DC	Data Center
DE	JPL Development Ephemeris
DES	Dark Energy Survey
DFC	DORIS frequency channel
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DGFI	Deutsches Geodätisches Forschungsinstitut
DiFX	Distributed FX
DIS	IERS Data and Information System
Div.	Division
DOI	Digital Object Identifier
DOMES	Directory Of MERIT Sites (originally; now of more general use)
DORIS	Doppler Orbit determination and Radiopositioning Integrated on Satellite
DPOD	DORIS terrestrial reference frame for precise orbit determination
DTRF	ITRS realization by DGFI
DUT1	= UT1–UTC
ECCO	Estimating the Circulation and Climate of the Ocean
ECMWF	European Center for Medium Range Weather Forecasting
EDC	EUROLAS Data Center

EGU	European Geosciences Union
ELP	Ephemeride Lunaire Parisienne
EMB	Earth-Moon Barycentre
EMR	Energy, Mines and Resources Canada (replaced by NRCan)
EO	Earth orientation
EOC	Earth Orientation Centre
EOP	Earth Orientation Parameters
EPM	Ephemerides of Planets and the Moon
ERIS	Earth Rotation Information System
ESA	European Space Agency
ESM	Earth System Model
ESOC	European Space Operations Center, ESA
ETH	Eidgenössische Technische Hochschule
EUREF	IAG Reference Frame Sub-Commission for Europe
EUROLAS	European [Satellite] Laser [Ranging] Consortium
EVGA	European VLBI [Group] for Geodesy and Astrometry
eVLBI, e-VLBI	Electronic transfer VLBI
EVN	European VLBI Network
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FESG	Forschungseinrichtung Satelliten-geodäsie, TUM
FIG	Fédération Internationale des Géomètres (International Federation of Surveyors)
FTLRS	French Transportable Laser Ranging Station
FTP, ftp	File Transfer Protocol
GA	General Assembly
GA	Geoscience Australia
GAOUA	Main Astronomical Observatory of the Ukrainian Academy of Sciences
GB	Governing Board
Gbps	Gigabit(s) per second
GCRF	Gaia Celestial Reference Frame
GCRS	Gaia Celestial Reference System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GFZ	GeoForschungsZentrum Potsdam
GGAO	Goddard's Geophysical and Astronomical Observatory
GGFC	Global Geophysical Fluids Centre
GGOS	Global Geodetic Observing System
GGOS-D	GGOS – Deutschland (Germany)
GIAC	GGOS Inter-Agency Committee
GIC	GGOS Intergovernmental Committee
GINS	Geodesy by Simultaneous Digital Integration [software]
GIOVE	Galileo In-Orbit Validation Element
GLDAS	NASA's Global Land Data Assimilation System
GLONASS	GLObal'naya NAvigatisionnay Sputnikovaya Sistema [Global Orbiting Navigation Satellite System, Russia]
GMF	Global Mapping Function
GNSS	Global Navigation Satellite System
GOP	Geodetic Observatory Pecny
GPS	Global Positioning System
GPT	Global Pressure and Temperature
GRACE	Gravity Recovery and Climate Experiment
GRASP	Geodetic Reference Antenna in Space
GRGS	Groupe de Recherches de Géodésie Spatiale
GSC	GSFC Analysis Center
GSFC	Goddard Space Flight Center
GSI	Geographical Survey Institute
HAM	Hydrologic[al] Angular Momentum
HEO	High Earth Orbiter
hr, hrs	hour, hours
h/v	hight/vertical
IAA	Institute of Applied Astronomy, St. Pe-tersburg
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICG	International Committee on Global Navigation Satellite Systems
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference Sys-tem
ICSU	International Council for Science
IDS	International DORIS Service
IERS	International Earth Rotation and Ref-

	erence Systems Service (formerly: International Earth Rotation Service)
IfE	Institut für Erdmessung [Institute of Geodesy], University of Hannover
IGFS	International Gravity Field Service
IGG, IGGB	Institute of Geodesy and Geoinformation of the University of Bonn
iGMAS	International GNSS Monitoring and Assessment System
IGN	Institut National de l'Information Géographique et Forestière (formerly: Institut Géographique National)
IGR	IGS rapid (orbit)
IGS	International GNSS Service (formerly: International GPS Service)
ILRS	International Laser Ranging Service
IMCCE	Institut de Mécanique Céleste et de Calcul des Éphémérides
INA	= INASAN
INAF	Istituto Nazionale di Astrofisica
INASAN	INstitut AStronomii Rossijskoj Akademii Nauk (Institute of Astronomy of the Russian Academy of Sciences)
INPOP	Intégrateur Numérique Planétaire de l'Observatoire de Paris
INT	Intensive [VLBI session]
IOC	Initial Operational Capability
IOV	In-Orbit Validation
IPGP	Institut de Physique du Globe de Paris
IRA	Istituto di Radioastronomia
IRIS	International Radio Interferometric Surveying
ISO	International Organization for Standardization
ISSI	International Space Science Institute
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
IUGG	International Union of Geodesy and Geophysics
IVOA	International Virtual Observatory Alliance
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JCET	Joint Center for Earth System Technology, GSFC
J-MAPS, JMAPS	Joint Milli-Arcsecond Pathfinder Survey
JPL	Jet Propulsion Laboratory
LAREG	Laboratoire de Recherche en Geodesie
LARES	Laser Relativity Satellite
LCA	LEGOS in cooperation with CLS
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LEO	Low Earth Orbit(er)
LLR	Lunar Laser Ranging
LMV	Lantmäteriet (formerly: Lantmäteriverket) [Swedish National Land Survey]
LOD	Length of Day
LQAC	Large Quasar Astrometric Catalog
LRA	Laser Retroreflector Array
LRO	Lunar Reconnaissance Orbiter
LS	least-squares
LSDM	Land Surface Discharge Model
LSST	Large Synoptic Survey Telescope
MAO	= GAOUA
mas	milliarcsecond(s)
µas	microarcsecond(s)
MCC	Russian Mission Control Centre
MeO	Métrologie Optique [Grasse SLR /LLR system]
MERIT	Monitoring Earth Rotation and Intercomparison of Techniques
M-GEX	Multi-GNSS Global Experiment
MIT	Massachusetts Institute of Technology
MLRO	Matera Laser Ranging Observatory
MLRS	McDonald Observatory Laser Ranging Station
MOG2D	2 Dimensions Gravity Waves model
MPIfR	Max-Planck-Institut für Radioastronomie / Max Planck Institute for Radio Astronomy
ms	millisecond(s)
µs	microsecond(s)
NASA	U.S. National Aeronautics and Space Administration
Nat.	National, Nacional

NCEP	U.S. National Centers for Environmental Prediction
NERC	Natural Environment Research Council, UK
NetCDF	Network Common Data Form
NGS	U.S. National Geodetic Survey
NGSLR	[NASA's] Next Generation SLR
NICT	National Institute of Information and Communications Technology
NMA	Norwegian Mapping Authority [Statens kartverk / Kartverket]
NNR	No-net-rotation
NOAA	U.S. National Oceanic and Atmospheric Administration
NOFS	USNO Flagstaff Station
NOGAPS	[U.S.] Navy's Operational Global Atmospheric Prediction System
NP	SLR normal point(s)
NRAO	[U.S.] National Radio Astronomy Observatory
NRCan	Natural Resources, Canada (formerly: EMR)
NRO	Non-Rotating Origin
ns	nanosecond(s)
NWIP	New Work Item Proposal
OAM	oceanic angular momentum
Obs.	Observatory, Observatoire
OHIG	O'Higgins [station]
OMCT	Ocean Model for Circulation and Tides
OP, OPA	Observatoire de Paris
OPAR	Paris Observatory IVS Analysis Center
ORB	Observatoire Royal de Belgique
OSO	Onsala Space Observatory
Pan-STARRS	Panoramic Survey Telescope And Rapid Response System
PAS	Polish Academy of Sciences
PC	Product Centre
PM	Polar Motion
PMM	Plate Motion Model
POD	Precise [or Precision] Orbit Determination
POE	Precise Orbit Comparison
POLAC	Paris Observatory Lunar Analyses Center
PP	Pilot Project
PSMSL	Permanent Service for Mean Sea Level
PZT	Photographic Zenith Tube [*or* Telescope]
QC	quality control
QSO	Quasi-Stellar Object [*or* quasar]
QZSS	Quasi-Zenith Satellite System
R&D	Research and Development
RDBE	Roach Digital Backend
RDV	Research and Development (sessions) with the VLBA
REFAG	Reference Frames for Applications in Geosciences
RINEX	Receiver INdependent EXchange format
rms, RMS	Root Mean Square
RRFID	USNO Radio Reference Frame Image Database
RS/PC	IERS Rapid Service/Prediction Center
RTCM	Radio Technical Commission for Maritime Services
SAA	South Atlantic Anomaly
SB	Special Bureau
SBA	Special Bureau for the Atmosphere
SBCP	Special Bureau for the Combination Products
SBH	Special Bureau for Hydrology
SBO	Special Bureau for the Oceans
SC	Subcommittee
SDSS	Sloan Digital Sky Survey
SINEX	Solution (Software/technique) INdependent EXchange Format
SIO	Scripps Institution of Oceanography
SLR	Satellite Laser Ranging
SOAR	Southern Astrophysical Research
SPBU	St Petersburg University
SPM	Yale/San Juan Southern Proper Motion Program
SRC	Space Research Centre of the PAS
SRP	solar radiation pressure
STA	Semiconductor Technology Associates
SYRTE	(Laboratoire) Systèmes de Référence Temps-Espace
TAI	Temps Atomique International (International Atomic Time)
TBD	to be defined
TC	Technical Committee

TC	Technique Centre
TIGO	Transportable Integrated Geodetic Observatory
TN	[IERS] Technical Note
ToR	Terms of Reference
TOW	Technical Operations Workshop
TROS	Transportable Ranging Observation System
TRF	Terrestrial Reference Frame
TT	Terrestrial Time
TU	Technical University
TUM	Technical University of Munich
TUW	Technische Universität Wien (Vienna University of Technology)
U.	University
UAW	GGOS Unified Analysis Workshop
UCAC	USNO CCD Astrograph Catalog
UCL	University College London
UK	United Kingdom
ULUX	Utsteinen LUXemburg [Luxemburg station in Antarctica]
Univ.	University
URAT	USNO Robotic Astrometric Telescope
URL	Uniform Resource Locator
U.S.	United States
USNO	United States Naval Observatory
UT, UT0, UT1, UT1R	Universal Time
UTAAM	NOAA AAM analysis and forecast data
UTC	Coordinated Universal Time
VCS	VLBA Calibrator Survey
VLBA	Very Long Baseline Array, NRAO
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Function
VO	Virtual Observatory
VTRF	VLBI terrestrial reference frame
WDS	ICSU World Data System
WG	working group
WHU	Wuhan University, China
WRMS	Weighted Root Mean Square
WS	Workshop
XML	eXtensible Markup Language
yr	year