International Earth Rotation and Reference Systems Service (IERS)

http://www.iers.org

Chair of the Directing Board: Brian Luzum (USA)
Director of the Central Bureau: Daniela Thaller (Germany)

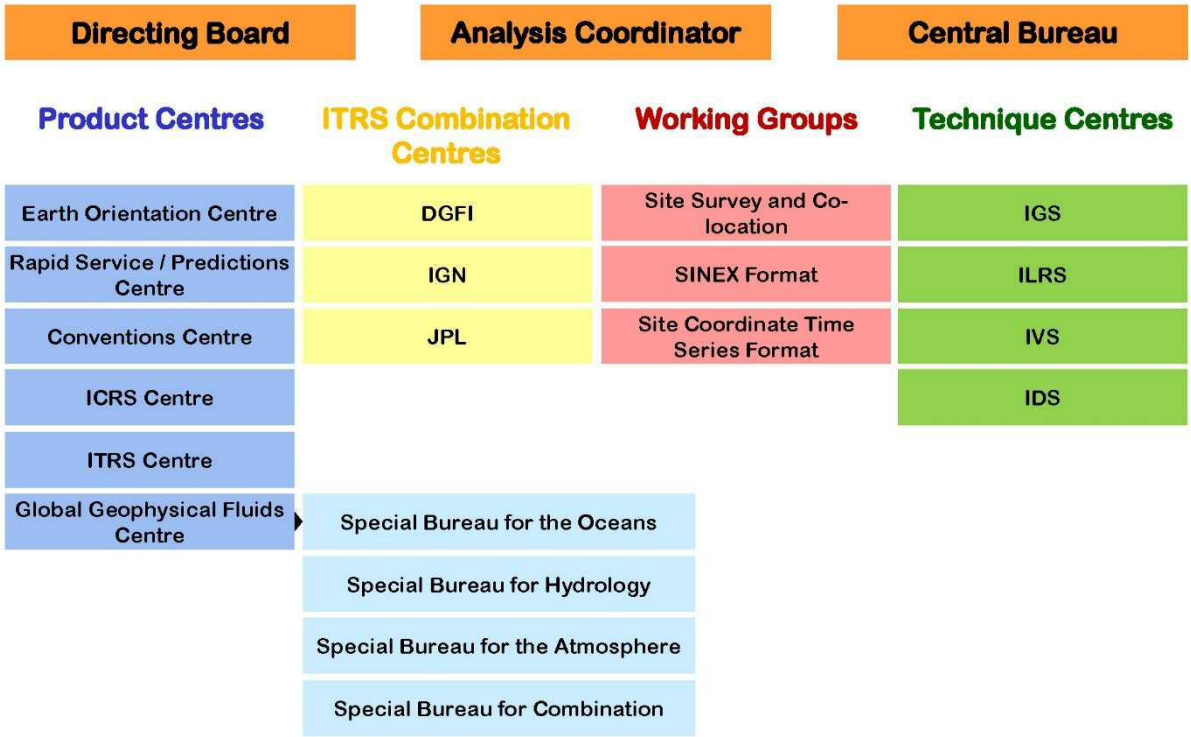
Structure

According to the Terms of Reference, the IERS consists of the following components:

- Directing Board
- Technique Centres
- Product Centres
- ITRS Combination Centre(s)
- Analysis Coordinator
- Central Bureau
- Working Groups

The Technique Centres are autonomous operations, structurally independent from the IERS, but which cooperate with the IERS.

As of May 2019, the IERS consists of the following components:

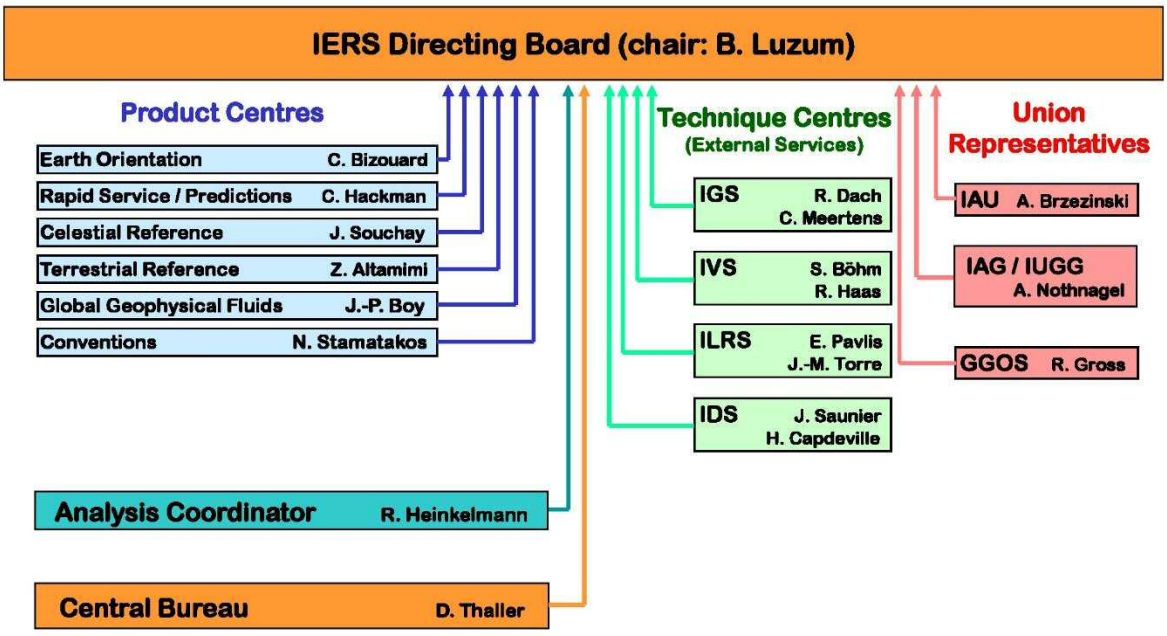


Responsible persons are (as of May 2019):

- Product centres
  - Earth Orientation Centre: *Christian Bizouard (France)*
  - Rapid Service/Prediction Centre: *Christine Hackman (USA), Nick Stamatakos (USA)*

    - Conventions Centre: *Christian Bizouard (France), Nick Stamatakos (USA)*
    - ICRS Centre: *Bryan Dorland (USA), Jean Souchay (France)*
    - ITRS Centre: *Zuheir Altamimi (France)*
    - Global Geophysical Fluids Centre: *Jean-Paul Boy (France), Tonie van Dam (Luxembourg)*
        - Special Bureau for the Oceans: *Richard Gross (USA)*
        - Special Bureau for Hydrology: *Jianli Chen (USA)*
        - Special Bureau for the Atmosphere: *David Salstein (USA)*
        - Special Bureau for Combination: *Tonie van Dam (Luxembourg)*
- ITRS Combination Centres
    - Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM): *Manuela Seitz (Germany)*
    - Institut National de l'Information Géographique et Forestière (IGN): *Zuheir Altamimi (France)*
    - Jet Propulsion Laboratory (JPL): *Richard Gross (USA)*
- Analysis Coordinator: *Robert Heinkelmann (Germany)*
- Central Bureau: *Daniela Thaller (Germany)*
- Working groups
    - Working Group on Site Survey and Co-location: *Sten Bergstrand (Sweden), John Dawson (Australia)*
    - Working Group on SINEX Format: *Daniela Thaller (Germany)*
    - Working Group on Site Coordinate Time Series Format: *Laurent Soudarin (France)*

The current members of the Directing Board (representatives of scientific unions and of IERS' components) are:



Overview

The International Earth Rotation and Reference Systems Service continues to provide Earth orientation data, terrestrial and celestial references frames, as well as geophysical fluids data to the scientific and other operationally oriented communities.

Earth orientation data have been issued on a sub-daily, daily, weekly, and monthly basis, and new global geophysical fluids data were added. A new realization of the International Terrestrial Reference System (ITRF2014) was released in January 2016 and was adopted by the IERS product and technique centres in early 2017. Ongoing documentation of the ITRF2014 resulted in the release of the Journal of Geophysical Research: Solid Earth paper in 2016 and the first of the IERS Technical Notes being released in early 2017. A new realization of the International Celestial Reference System (ICRF3) was published in mid-2018 and officially adopted by IAU on January 2019. The IERS Conventions (i.e. standards etc.) have been updated regularly, and a fully revised release of the IERS Conventions is in preparation. The Bureau de Poids et Mesures (BIPM) phased out their support of the IERS Conventions Centre in 2016. In response, the Observatoire de Paris joined with the U.S. Naval Observatory in co-directing the IERS Conventions Centre. The IERS Working Group on Combination at the Observation Level finished its activities in 2016.

The IERS continued to issue Technical Notes, Annual Reports, Bulletins, and electronic newsletters. It co-sponsored the symposium "Geodesy, Astronomy, and Geophysics in Earth Rotation (GAGER2016)", which was held 18–23 July 2016 in Wuhan, Hubei, China, and co-organised the IAG/GGOS/IERS Unified Analysis Workshop (UAW), July 10–12, 2017 in Paris.

The IERS Data and Information System (DIS) at the web site www.iers.org, maintained by the Central Bureau, has been updated, improved and enlarged continually. It presents information related to the IERS and the topics of Earth rotation and reference systems. As the central access point to all IERS products it provides tools for searching within the products (data and publications), to work with the products and to download them. The DIS provides links to other servers, among these to about 10 web sites run by other IERS components.

Publications

The following IERS publications and newsletters appeared between mid-2015 and May 2019:

- IERS Technical Note No. 38 (2017): Z. Altamimi, P. Rebischung, L. Métivier, X. Collilieux: Analysis and results of ITRF2014
- IERS Technical Note No. 39 (2017): Jean-Claude Poyard, with contributions by Xavier Collilieux, Jean-Michael Muller, Bruno Garayt and Jérôme Saunier: IGN best practice for surveying instrument reference points at ITRF co-location sites
- IERS Annual Reports 2014, 2015, 2016, and 2017
- IERS Bulletins A, B, C, and D (weekly to half-yearly)
- IERS Messages Nos. 270 to 377

IERS Directing Board

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

- Meeting No. 61 in San Francisco, December 13, 2015;
- No. 62 in Vienna, April 17, 2016;
- No. 63 in San Francisco, December 10, 2016;
- No. 64 in Vienna, April 23, 2017;

- No. 65 in New Orleans, December 8, 2017;
- No. 66 in Vienna, April 8, 2018;
- No. 67 in Washington, D.C., December 8, 2018;
- No. 68 in Vienna, April 7, 2019.

Among the most important decisions made by the DB in 2015–2019 were the following:

- New list of IERS Associate Members confirmed and annually updated.
- Two IERS Technical Notes should be prepared on ITRF2014.
- Nutation series dEps / dPsi should be maintained.
- ITRS Combination Centres should compare the 9 co-located sites of the single technique solutions and the combined solution.
- Extend antenna serial number in SINEX format.
- Confirmed roadmap to switch to ITRF2014.
- Publish a Technical Note on site survey guidelines.
- Closed the IERS Working Group on Combination at the Observation Level.
- Elected Brian Luzum for a second term (2017–2020) as Chair of the Directing Board.
- An external evaluation of ITRF should be done.
- Publish a Technical Note on 14 C04 series.
- Establish an IERS Working Group to investigate possible improvements related to the distribution of the IERS products.
- Issue Call-for-Experts for next major revision of IERS Conventions.
- Issue Call for Participation in ITRF2020.
- Endorsed ICRF3.
- Elected Robert Heinkelmann as new Analysis Coordinator (succeeding Tom Herring on 1 January 2019).
- Establish a Working Group on Geocenter motion.

Technique Centres

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

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

For details about the work of the TCs, see their individual reports to IAG.

Product Centres

Earth Orientation Centre

Primary scientist: Christian Bizouard (France)

Overview

According to the IERS Terms of Reference, the IERS Earth Orientation Centre (EOC) is responsible for monitoring Earth Orientation Parameters including long-term consistency, publications for time dissemination (DUT1) and leap second announcements. Earth Rotation Parameters (ERPs: 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. ERPs are initially collected in the form of combined solutions derived by the Technique Centres (IGS, IVS, ILRS and IDS). Two main solutions are computed: a long-term solution (IERS C01) that starts in 1846 and extends until the end of the previous year and the Bulletin B / C04 given at one-day intervals, which is published monthly with a 30-day delay (Gambis, 2004; Bizouard and Gambis, 2009; Gambis and Luzum, 2011). The EOC is located at Paris Observatory.

Activities and publications during the period 2015–2019

During the period 2015–2019 the EOC issued two leap seconds through Bulletin C (2015 July 1 and 2017 January 1).

An important issue is the maintenance of the consistency between the EOP system and both the International Terrestrial and Celestial Reference Frames (ITRF and ICRF). So far, Earth Orientation Parameters and the terrestrial frame are separately computed. This led in the past to increasing inconsistencies between both systems. All IERS reference solutions (C01, Bulletin B, C04 as well as Bulletin A derived by the Rapid Service/Predictions Centre, US Naval Observatory) were recomputed and aligned to the EOP solution associated with the new version of the ITRF (ITRF2014) in March 2017. Inconsistencies are now negligible compared to the current accuracies, i.e. limited to about 10 microarcseconds for polar motion and a few micro-seconds for UT1.

Recently C04 software and data base procedures have been upgraded. The celestial pole offsets are combined directly with respect to the IAU 2000 precession-nutation model. If IVS analysis centres provide them with respect to the IAU 1980 model, they are transformed into IAU 2000 consistent offsets according to a rigorous procedure based upon Standards of Fundamental Astronomy software libraries (SOFA). Moreover uncertainties are directly estimated from the formal uncertainties of the individual series and their weights reflecting the intra-technique dispersion (Bizouard et al., 2017).

The C04 series were updated to provide EOP series consistent with the set of station coordinates of the ITRF 2014. The new C04, referred to as IERS EOP 14C04, is aligned onto the most recent versions of the conventional reference frames (ITRF 2014 and ICRF2). Additionally, the combination algorithm was revised to include an improved weighting of the intra-technique solutions (Bizouard et al., 2018).

References

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

Bizouard C., S. Lambert, C. Gattano, O. Becker, and J.Y. Richard, 2018, The IERS EOP 14C04 solution for Earth orientation parameters consistent with ITRF 2014. Journal of Geodesy Vol. 93, pp. 621–633, DOI 10.1007/s00190-018-1186-3

Bizouard C., S. Lambert, J.Y. Richard, and O. Becker, 2017, Combined solution C04 for Earth Rotation Parameters consistent with International Terrestrial Reference Frame 2014, Technical Note, http://hpiers.obspm.fr/iers/eop/eopc04/C04.guide.pdf

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

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

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

Rapid Service/Prediction Centre

Primary scientist: Christine Hackman (USA)
Production director and lead project scientist: Nick Stamatakos (USA)

Overview

The Rapid Service/Prediction Centre (RS/PC) provides high-quality Earth orientation estimates/predictions on a rapid turnaround basis, primarily for real-time-users. It issues the weekly IERS Bulletin A and corresponding data files, as well as daily and four-times-daily EOP estimate/prediction values. The centre also conducts research toward improving the accuracy and/or production robustness of its products. Lastly, the centre maintains a web-based Earth orientation matrix calculator that provides the full direction cosine matrix between celestial and terrestrial reference frames based on IERS conventions and given calendar date and time inputs.

Activities and publications during the period 2015–2019

The RS/PC successfully implemented the 30 June 2015 and 31 December 2016 leap seconds. It also successfully transitioned its products to the ITRF 2014 reference frame in March 2017. The RS/PC provided input to the National Institute of Standards and Technology (NIST; USA) in the NIST development of a Network Time Protocol UT1–UTC server, and set up an additional ftp download site for RS/PC products at the National Aeronautics and Space Administration (NASA; USA) Crustal Dynamics Data Information System (CDDIS) data archive. The cooperation of NIST and NASA is gratefully acknowledged.

The RS/PC continued to study the effects of implementing atmospheric angular momentum (AAM) and oceanic angular momentum (OAM) values/predictions in its EOP estimation/prediction algorithms, presenting results at the 2015 to 2018 American Geophysical Union (AGU) Fall Meetings and at the 2016, 2018, and 2019 European Geosciences Union General Assemblies. The RS/PC provided support to the IERS Conventions Centre regarding issues associated with the definition of mean pole, presenting its findings at the 2016 AGU Fall Meeting and spurring discussion that was continued in a technical session at the July 2017 Global Geodetic Observing System (GGOS) Unified Analysis Workshop. The RS/PS also developed an improved simulation program allowing it to more easily pre-test the impact of modelling/data changes under consideration on its results.

Finally, the RS/PC implemented changes to its software to use the dX dY celestial pole offset observations for its core processing consistent with IERS Conventions 2010 precession and

nutation models; this change will replace core processing done with the older $d\psi$ and $d\varepsilon$ paradigm.

Conventions Centre

Primary scientists: Christian Bizouard (France), Nick Stamatakos (USA)

Overview

The Conventions Centre is continuing work on technical updates to the IERS Conventions (2010), with updates of existing content, expansion of models, and introducing new topics as needed.

Activities and publications during the period 2015–2019

In 2016, the Paris Observatory (OP) took over responsibility for the co-chairmanship that was previously held by the Bureau International des Poids et Measures (BIPM); the other co-chairmanship is held by the US Naval Observatory (USNO). The Centre has created new web and ftp sites containing updated Conventions versions and associated software. Those sites are located at:

http://iers-conventions.obspm.fr/ and http://maia.usno.navy.mil/conventions
(The same information can be found at both the Obervatoire de Paris and U.S. Naval Observatory Conventions websites.)

ftp site ftp://maia.usno.navy.mil/conventions .

A versioning system has been implemented to handle intermediate updates of the conventions. The centre has also begun preparing for a future IERS Conventions update. In February 2018, it issued a Call for Participation in the next IERS Conventions.

ICRS Centre

Primary scientists: Bryan Dorland (USA), Jean Souchay (France)

Overview

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.

Activities and publications during the period 2015–2019

Involvement by ICRS Centre personnel in the construction of the celestial reference frame from VLBI programs has continued, in particular from the participation in extensive observing programs. The ICRS Centre has fulfilled various tasks devoted to the monitoring of ICRF sources, the link with the dynamical system (in particular through LLR), the construction of new updates of the LQAC (Large Quasar Astrometric Catalogue) and of the LQRF (Large Quasar Reference Frame). The first Gaia data release in September 2016 provided the possibility of extensive comparisons between the preliminary Gaia optical reference frame and the ICRF, the results of which are very promising. Together with the IAU Division 1 Working Group on ICRF3, the ICRS Centre prepared the next ICRF, which was published in mid-2018.

Comparisons were made between the ICRF and the Gaia Data Releases 1 and 2 optical reference frame.

References

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Fey, A.L., Gordon, D., Jacobs, C.S., et al., 2015, The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry, Astr. J. 150, 58F

Souchay, J., Andrei, A.H., Barache, C., et al., 2015, The third release of the Large Quasar Astrometric Catalogue (LQAC-3): a compilation of 321 957 objects, A&A 583A, 74S

Souchay, J., Gattano, C., 2016, The large catalogues of quasars and the LQAC-3 compilation, Romanian Astronomical Journal, vol. 26, No. 1, pp. 47–55

Taris, F., Andrei, A.H., Roland, J., et al., 2016, Long Term R and V band monitoring of some suitable targets for the link between ICRF and the future Gaia celestial reference frame, A&A, 587A, 112T

ITRS Centre

Primary scientist: Zuheir Altamimi (France)

Overview

The main activities of the ITRS Centre during the period 2015–2019 include the maintenance of the ITRF network, database and website. The ITRS Centre, according to the IERS ToR, is responsible, among other duties, for the maintenance and update of the ITRF network database and its provision to the users through the ITRF website. 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 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 online; 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.

Activities and publications during the period 2015–2019

The main activities of the ITRS Centre during this period include:

- The ITRF network database, which contains the descriptions of the sites and points, is continually updated as DOMES numbers are assigned. DOMES number request form can be found on the ITRF web site <http://itrf.ign.fr>, and should be sent to domes@ign.fr. An updated list of all available DOMES numbers is available at <http://itrf.ign.fr/doc_ITRF/iers_sta_list.txt>. The IERS site information is available to the users through the ITRF website interface (see below). As a result of the ITRF2014 analysis, several new stations, mainly GNSS permanent stations where added to the ITRF network and database.
- The ITRS Centre has started 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 is finalized and the development started in 2013.

- 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.
- In preparation for the ITRF2014 analysis, several new local tie SINEX files and corresponding reports were submitted to the ITRS Centre. These new survey results were made available via the ITRF website after the release of the ITRF2014.
- The operational entity of the ITRS Centre at the IGN Survey department has prepared a document describing the IGN current practice of local survey that could help surveyors who do not know how to proceed and are not accustomed to working at mm precision. The document was published as IERS Technical Note 39.
- Producing and publishing the ITRF2014, with a dedicated website: http://itrf.ign.fr/ITRF_solutions/2014/. See also the report of the ITRS Combination Centre at IGN France.

Altamimi, Z., Rebischung, P., Métivier, L., and Collilieux, X. (2016), ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, J. Geophys. Res. Solid Earth, 121, 6109–6131, doi: 10.1002/2016JB013098

Altamimi, Z., L.Métivier, P. Rebischung, H. Rouby, and X. Collilieux (2017) ITRF2014 plate motion model, Geophysical Journal International, Volume 209, Issue 3, 1 June 2017, Pages 1906-1912, doi: 10.1093/gji/ggx136

Altamimi Z., P. Rebischung, and X. Collilieux (2017) The International Terrestrial Reference Frame: Lessons from ITRF2014, Rend. Fis. Acc. Lincei (2017). doi: 10.1007/s12210-017-0660-9

Global Geophysical Fluids Centre

Primary scientist: Jean-Paul Boy (France)
Co-chair: Tonie van Dam (Luxembourg)

Overview

The Global Geophysical Fluid Centre (GGFC) of the International Earth Rotation and Reference Systems Service (IERS) provides the community with models of geodetic effects (Earth rotation, gravity and deformation) due to the temporal redistribution of the Earth geophysical fluids. These include fluid motions with the solid Earth (core and mantle) as well as motions at the Earth's surface (ocean, atmosphere and continental hydrology).

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

Activities and publications during the period 2015–2019

The Special Bureau for the Atmosphere (SBA) is concerned with the atmospheric information that is needed for a number of geodetic issues. During the period of this report, the SBA updated all fields from atmospheric angular momentum (AAM).

The Special Bureau for the Oceans (SBO) is responsible for collecting, calculating, analysing, archiving, and distributing data relating to nontidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocentre. Products from the ECCO/JPL ocean model were updated.

The Special Bureau for Hydrology (SBH) provides access to data sets of terrestrial water storage (TWS) variations from major climate and land surface models and GRACE (Gravity Recovery and Climate Experiment) satellite gravity measurements. The NASA GLDAS and GRACE data products are updated on a regular basis.

At the beginning of 2017, GFZ Potsdam as one of the providers of combinational products introduced major changes to their data series (atmospheric, oceanic and hydrological loading).

GGFC organized sessions on global geophysical fluids at AGU Fall Meetings and EGU General Assemblies.

ITRS Combination Centres

Three ITRS Combination Centres (CCs) are responsible for providing ITRF products by combining ITRF inputs. Within the time frame covered by this report the CCs focused on the computation of the new ITRS realization 2014.

ITRS CC at DGFI-TUM

Primary scientist: Manuela Seitz (Germany)

Overview

DGFI-TUM has been acting as one of the ITRS Combination Centres within the IERS since 2001. The related activities are embedded into DGFI-TUM's research on the realization of Global Terrestrial Reference Frames within the research area Reference Systems.

Realizations of the ITRS are based on the combination of space geodetic observations of the four techniques VLBI, SLR, GNSS, and DORIS at globally distributed geodetic observatories. Respective input data are provided by the corresponding technique services (IVS, ILRS, IGS, IDS). The combination strategy developed at DGFI-TUM bases on the combination of normal equation systems, which allows for a pure physically realization of the origin and scale of the reference frames.

Activities and publications during the period 2015–2019

The CC DGFI-TUM computed the realization DTRF2014, which for the first time considers non-linear station motions caused by atmospheric and hydrological loading. The corrections are derived from the atmosphere model NCEP and the hydrology model GLDAS, respectively, and are provided by Tonie van Dam. The final DTRF2014 product comprises besides the solution SINEX files and the EOP file (including terrestrial and celestial pole coordinates, the rates of the terrestrial pole coordinates, UT1–UTC and LOD values) also the model values introduced for non-tidal loading correction, the residual time series of station positions and translation time series of the DTRF2014 origin. The time series allow for a computation of the real station positions at each epoch of observation.

Furthermore, DGFI-TUM researched a consistent realization of ITRS, ICRS and the EOP. In particular the impact of the combination of station coordinates and of the combination of EOP on the CRF was investigated.

ITRS CC at IGN

Primary scientist: Zuheir Altamimi (France)

See the report of the ITRS Centre above.

ITRS CC at JPL

Primary scientist: Richard Gross (USA)

Overview

The ITRS Combination Centre at JPL focused on research regarding the representation of terrestrial reference frames by time series of smoothed positions of reference stations rather than by a parameterized model of the station positions. A Kalman filter and smoother for reference frames (KALREF) has been developed and used to determine time series representations of terrestrial reference frames. In addition, a square-root information filter for reference frames (SREF) is currently being developed that can be used to not only determine time series representations of terrestrial reference frames but that can also be used to jointly determine time series representations of terrestrial and celestial reference frames.

Activities and publications during the period 2015–2019

KALREF was used to determine trial solutions using the same input SINEX files that were used to determine ITRF2005 and ITRF2008 (Wu et al., 2015). KALREF was also used to determine JPL's official JTRF2014 solution that was determined from the ITRF2014 input SINEX files (Abbondanza et al., 2017). Soja has compared terrestrial reference frames determined by Kalman filters to other realizations (Soja et al., 2016) and has explored the stability and the effect of process noise on reference frames determined by Kalman filters (Soja et al., 2018a, 2018b). He has also estimated a celestial reference frame using a Kalman filter (Soja et al., 2017).

Abbondanza, C., T. M. Chin, R. S. Gross, M. B. Heflin, J. W. Parker, B. S. Soja, T. van Dam, and X. Wu (2017), JTRF2014, the JPL Kalman filter and smoother realization of the International Terrestrial Reference System, J. Geophys. Res. Solid Earth, 122(10), 8474–8510, doi:10.1002/2017JB014360.

Soja, B., T. Nilsson, S. Glaser, K. Balidakis, M. Karbon, R. Heinkelmann, R. Gross, and H. Schuh (2016), Comparison of a VLBI TRF solution based on Kalman filtering and recent ITRS realizations, in *International VLBI Service for Geodesy and Astrometry 2016 General Meeting Proceedings*, edited by D. Behrend, K. D. Baver, and K. L. Armstrong, pp. 256–260, NASA/CP-2016-219016.

Soja, B., R. Gross, C. Jacobs, T. Chin, C. Abbondanza, M. Heflin, J. Parker, X. Wu, M. Karbon, T. Nilsson, R. Heinkelmann, and H. Schuh (2017), A celestial reference frame based on Kalman filtering, in *Proceedings of the 23rd Working Meeting of the European VLBI Group for Geodesy and Astrometry (EVGA)*, Gothenburg, Sweden, May 15–19, 2017.

Soja, B., R. S. Gross, C. Abbondanza, T. M. Chin, M. B. Heflin, J. W. Parker, X. Wu, T. Nilsson, S. Glaser, K. Balidakis, R. Heinkelmann, and H. Schuh (2018a), On the long-term stability of terrestrial reference frame solutions based on Kalman filtering, J. Geodesy, 92(9), 1063–1077.

Soja, B., R. S. Gross, C. Abbondanza, T. M. Chin, M. B. Heflin, J. W. Parker, X. Wu, K. Balidakis, T. Nilsson, S. Glaser, M. Karbon, R. Heinkelmann, and H. Schuh (2018b), Application of time-variable process noise in terrestrial reference frames determined from VLBI data, Adv. Space Res., 61(9), 2418–2425, doi:10.1016/j.asr.2018.02.023.

Wu, X., C. Abbondanza, Z. Altamimi, T. M. Chin, X. Collilieux, R. S. Gross, M. B. Heflin, Y. Jiang, and J. W. Parker (2015), KALREF—A Kalman filter and time series approach to the International Terrestrial Reference Frame realization, J. Geophys. Res. Solid Earth, 120(5), 3775–3802, doi:10.1002/2014JB011622.

Analysis Coordinator

Analysis Coordinator: Thomas Herring (USA, until 2018), Robert Heinkelmann (Germany, since 2019)

Overview

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

Activities and publications during the period 2015–2019

The work of the Analysis Coordinator focused on an analysis of the ITRF2014 extended model presentation of post-seismic deformation after large earthquakes and a comparison of recent diurnal and semidiurnal EOP models with the IERS Conventions (2010). He has also been looking at the scale differences between the SLR and VLBI systems that persist in ITRF2014 and coordinating with the IERS combination centres to better understand the origin of the difference. He organized and developed recommendations from the 2014 Unified Analysis Workshop held in Pasadena, CA (USA) and participated in preparing the 2017 Unified Analysis Workshop held in Paris, France.

Central Bureau

Director: Daniela Thaller (Germany)

Overview

The Central Bureau coordinates the work of the Directing Board and the IERS in general, organizes meetings and issues publications. It replies to questions of users regarding IERS products and general topics of Earth rotation and reference systems. It maintains an IERS Data and Information System (DIS) based on modern technologies for internet-based exchange of data and information like the application of the Extensible Markup Language (XML) and the generation and administration of ISO standardised metadata. The system provides general information on the structure and the components of the IERS, serves as a portal to websites of all IERS components and gives access to all products.

Activities and publications during the period 2015–2019

For most of the IERS products, metadata according to ISO 19115 were produced and are available through the IERS web pages on products and now also at the IERS ftp server ftp.iers.org.

Several tools for visualization and analysis of IERS data and products, developed in the framework of the German research unit "Earth Rotation and Global Dynamic Processes", were improved and added to the IERS website. These are: Plot tool; EOP of today; Timescales; EOP Reader. Furthermore links to tools of other IERS components were added.

Based on the EOP Reader and on the Timescales tools, web services for Earth Orientation Parameters, leap seconds and time scales were developed.

It became apparent that the internal processes of the data management component of the IERS DIS are in need of improvements. The requirements were formulated and a contract was concluded. The optimized system was tested and implemented.

The Central Bureau published and distributed IERS Technical Notes Nos. 38 and 39, IERS Annual Reports 2014, 2015, 2016, and 2017, as well as IERS Messages Nos. 270 to 377. It compiled reports by IERS to IAU Commission 19/A2, IAG, and the ICSU World Data System.

Dick, W. R.: How to Talk to the Public About the Leap Second? The Experience of the IERS Central Bureau. In: The Science of Time 2016. Time in Astronomy & Society, Past, Present and Future. E. F. Arias, L. Combrinck, P. Gabor, C. Hohenkerk, P. K. Seidelmann (eds.). Cham: Springer International Publishing, 2017, pp. 277–286

Thaller, D. and S. Bachmann: The IERS Retreat: How to improve Earth Rotation products? In: N. Capitaine (ed.), Proceedings of the Journées 2013 "Systèmes de Référence Spatio-Temporels". Paris: Observatoire de Paris, 2015, pp. 175–180

Working Groups

Reports, meeting summaries, presentations and other documents of all working groups are available at the IERS web site.

Working Group on Site Survey and Co-location

Chair: Sten Bergstrand (Sweden)
Co-chair: John Dawson (Australia)

Overview

Areas of work of the Working Group on Site Survey and Co-location are standards and documentation (guidelines, survey reports, etc.), coordination (share know-how and join efforts between survey teams), research (investigate discrepancies between space geodesy and tie vectors, alignment of tie vectors into a global frame), and cooperation.

Activities and publications during the period 2015–2019

Due to different national surveying procedures, local constraints etc., a detailed plan, handbook or instruction for how to perform a local survey has previously been disregarded. However, for the benefit of future surveying work the operational entity of IGN worked on local survey guidelines. These were published as IERS Technical Note 39 "IGN best practice for surveying instrument reference points at ITRF co-location sites".

Local survey campaigns were performed at Onsala space observatory, at Australian observatories (Katherine VLBI Observatory, Mt Stromlo Observatory and Kiribati), on Mauna Kea, Hawaii, and at many other sites.

Working Group on Combination at the Observation Level

Chair: Richard Biancale (France)
Co-Chairs: Daniel Gambis (France), Manuela Seitz (Germany)

Overview

The Working Group on Combination at the Observation Level (WG COL) reviewed the interest in combining techniques at the observation level for EOP and reference frames. Its main goal was to bring together groups capable to do combinations on the observation level and to improve the homogeneity, precision and resolution of the products. After 7 years of activities concluded its efforts in 2016.

Activities and publications during the period 2015–2016

The WG COL contributed to the ITRF2014 realization by combining geodetic techniques (DORIS, GNSS, SLR, and VLBI) at the Normal Equation Level. Twelve years of daily Normal Equations (NEQs) from 2002 to 2013 have been processed for each technique (Tab. 1). The combined Normal Equations at weekly bases in SINEX format has been produced and delivered to IGN for comparisons of the Earth Orientation Parameters solutions (EOP) and station positions with respect to the new reference frame ITRF2014.

Table 1: Parameters to estimate for comparison with ITRF2014 and added parameters for further studies

Parameters	SINEX format	GINS format	Sampling	Initial values
Polar motion	**XPO, YPO**	PX, PY	PWL @ 12Hr	IERS EOP 08-C04 series Interpolated @12h
Delta time UT1-TAI	**UT1**	PT	PWL @ 12Hr	IERS EOP 08-C04 series Interpolated @12h
Nutation angles X, Y corrections to the IAU2000A/2006 model	**NUT_X, NUT_Y**	NX, NY	PWL @ 12Hr	Set to 0.0
Station coordinates	**STAX, STAY, STAZ**	SX, SY, SZ	1/w @ mid epoch	ITRF2008
Radio sources coordinates right ascension & declination	**RS_RA, RS_DE**	QRA, QDE	1/w @ mid epoch	ICRF2
Added parameters not used for ITRF2013 purposes but proposed for GRGS studies				
Zenithal Troposphere Delay for wet component limited for stations (*)	**ZBIAS**: Adjustment of the wet component to the model	MZB	Every 2-hours: 00, 02, 04, ...20, 22hr per day	GPT/GMF model for radio waves and Mendles/Pavlis for optical waves
Troposphere gradient north & east limited for stations (*)	**TGETOT, TGNTOT**	MGE, MGN	1 pt/d @ 00Hr	gradient troposphérique per Day and per station
Possible parameters for future investments				
Polar motion rate	**XPOR, YPOR**	PXR, PYR	1pt/d @ 12Hr	Set to 0.0
Length of Day LOD	**LOD**	PTR	1pt/d @ 12Hr	IERS EOP 08-C04 LOD Interpolated @12h
Rate for nutation angle	**NUTR_X, NUTR_Y**	NXR, NYR	1pt/d PWL @ 12Hr	Set to 0.0

Conclusions about the COL activities have been presented during the closure meeting at the BKG in Frankfurt, February 19, 2016. The main result consists in having developed a new method to homogenize the terrestrial frame, Earth Orientation and celestial frame in a global solution. Further developments have been pursued in the context of the Earth Orientation Centre to produce and analyse the EOP solutions using this method and to maintain efforts studying this combination technique and analysing products.

Jean-Yves Richard, Daniel Gambis, Christian Bizouard, Sébastien Lambert, Olivier Becker, Teddy Carlucci, Sylvain Loyer, Laurent Soudarin, Géraldine Bourda, Antoine Bellanger, Florent Deleflie, David Coulot, Arnaud Pollet, Jean-Michel Lemoine, Richard Biancale, Jean-Charles Marty, Felix Perozanz, "GRGS Solutions EOP, TRF, CRF by multi technique Combination DORIS, GPS, SLR, VLBI at normal equation level, period 2002–2013", presented at COL meeting Federal Agency for Cartography and Geodesy (BKG), Frankfurt am Main, Germany, 19 February 2016.

Poster presentation: Jean-Yves Richard, Christian Bizouard, Sébastien Lambert, Olivier Becker, Richard Biancale, "A combined GNSS/VLBI solution for EOP and TRF", EGU2016, Vienna, 17–22 April 2016.

Working Group on SINEX Format

Chair: Daniela Thaller (Germany)

Overview

The SINEX (Solution INdependent EXchange) format is a well-established format used by the technique services of the IERS for several years. 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 is the point of contact if any modifications or extensions are required. 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.

Activities and publications during the period 2015–2019

The Working Group on SINEX Format has been working on modifications for representations of non-linear station motions due to post-seismic movements, of parameters describing radio source positions and of the antenna serial number, as well as on other topics. Also, there have been activities for setting up a more user-friendly SINEX description as a web interface for each block, which will be easier to maintain and to update and will be more user-friendly to implement or check.

Working Group on Site Coordinate Time Series Format

Chair: Laurent Soudarin (France)

Overview

The objectives of the Working Group on Site Coordinate Time Series Format, a joint WG of IERS and IAG, are a user-friendly format with data and metadata by definition of a common exchange format for coordinate time series for all geodetic techniques (DORIS, GNSS, SLR, VLBI) with all necessary information (data and metadata). The goal is to access products via web interfaces.

Activities and publications during the period 2015–2019

A meeting of the WG took place in Vienna, on April 15, 2015, during the EGU General Assembly week. Based on a non-exhaustive list of existing formats at IAG services and GPS time series providers, metadata and data have been examined. The content of existing formats have been listed and compared, regarding the metadata and the data. The examination allows to identify three types of metadata (file information, site information, and product information) as well as a list of variables forming the data block. The next step is to define the necessary elements for the time series exchange format (metadata content, data table, mandatory and optional inputs) as well as the units, the coordinate system, the date and time system.