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DIVISION A
COMMISSION 19

ROTATION OF THE EARTH
ROTATION DE LA TERRE

PRESIDENT	**Chengli Huang**
VICE-PRESIDENT	**Richard Gross**
SECRETARY	**Florian Seitz**
PAST PRESIDENT	**Harald Schuh**
ORGANIZING COMMITTEE	**Christian Bizouard, Ben Chao, Wieslaw Kosek, David Salstein, Vladimir Zharov**
IVS representative:	**Oleg Titov**
IERS representative:	**Bernd Richter**
IAG representative:	**Zinovy Malkin**

Abstract. The activities and some research progress of IAU Commission 19 (C19) - Rotation of the Earth - in the past triennial term (2012-2015) is reported in this paper, including the scientific session and business meeting of C19, as well as a business meeting of the IAU/IAG Joint Working Group of "Theory of Earth Rotation" (JWG_ThER) during the XXIX IAU General Assembly in Hawaii, USA. Three reports of JWG_ThER progress, IERS and IAG, eleven reports of national projects and individual institutions, a short summary of the history and heritage of C19, and an Overview of the status and outlook of new Commission A2 are also presented.

1. Introduction

During the XXIX IAU General Assembly in Honolulu, Hawaii, USA, Commission 19 (C19) - Rotation of the Earth - hosted 3 sessions. The first was a scientific session composed of the scientific meeting of Division A, the second was a business meeting of the IAU/IAG Joint Working Group of "Theory of Earth Rotation" (JWG_ThER), and the third was a business meeting of C19.

IAU Division A - Fundamental Astronomy - held a science meeting (called Division Meeting, similar to Joint Discussions in previous IAU GAs) that lasted two full days on 7 and 10 August 2015. C19 hosted session VI (10:30 - 12:30, 10 Aug.) "Earth rotation and geodynamics". It received 19 oral plus 4 poster abstracts related to Earth rotation, almost 1/3 of total received abstracts for the Div. A Meeting. This session, attended by roughly 70 participants, consisted of 3 invited and 6 oral presentations, while all others were presented as posters in the corresponding time slot. A summary of this Session is given in Section 3 below.

The business meeting of the IAU/IAG Joint Working Group of "Theory of Earth Rotation" was held on 11 August 2015 from 17:00 - 18:00. It was attended by about 40 participants, and five reports were given. A summary of the reports can be found in Section 4.1.

The business meeting of Commission 19 and the new Commission A2 was held on 12 August 2015 from 10:30 - 12:30. It was attended by about 40 participants, and six reports were given. It began with a report by the President on the C19 activities during the triennium 2012-2015 and our new commission C.A2 in the IAU reform process. Then, a report of JWG_ThER progress, and two reports of related services: the International Earth Rotation and Reference Systems Service (IERS) and International VLBI Service for Geodesy and Geodynamics (IVS). A report of IAG activities, especially the activity of IAG SC1.4 (Theory and coordination of astrometric observation for reference frame purposes), and the issues on IAG General Assembly at Prague during June 2015 was also presented. The last presentation was given by designated president on Outlook into the upcoming triennium (2015-2018). At the end, some discussion on the start-up of the new Commission C.A2 and other topics were made. Summary of these reports can be found in Sections 2 and 4.

Eleven reports of national projects and/or individual institutions are given in Section 5. A short summary of the history and heritage of C19 is presented in Section 6. Overview of the status and outlook of new Commission A2 are also presented in Section 7.

2. Activities of IAU Commission 19 during 2012-2015

by Chengli Huang, Richard Gross, Florian Seitz

The most important achievement related to the objectives of the Commission was the creation of a new IAU/IAG Joint Working Group "Theory of Earth rotation" (JWG_ThER) in 2013. This JWG is active in organizing its members to promote study on earth rotation. Its progress was reported in several international conferences and is summarized in section 4.1.

Other organizational activities include: updating the C19 membership list, maintaining the C19 website (www.iau-comm19.org/), renewing Commission 19 in the reconstruction of commissions in IAU Reform, and organizing science sessions, themes, and C19 Business Meetings on "Earth rotation" in related conferences.

In the past 3 years, C19 (co-) organized more than ten science sessions or themes of "Earth rotation" in: AGU Fall Meetings (2012, 2013, 2014), EGU General Assemblies (2013, 2014, 2015), Journées Systèmes de Référence Spatio-Temporels (JSR, 2013, 2014), IAG General Assembly (2013), IUGG General Assembly (2015), Asia Oceania Geosciences Society (AOGS) Annual Meeting (2015), etc. We also organized six C19 Business Meetings at IAG General Assembly (2013), JSR (2013, 2014), AGU Fall Meetings (2014), EGU General Assembly (2014) and IAU General Assembly (2015).

The GGOS of the IAG and the IAU C19 jointly organized a workshop on "Observing and Understanding Earth Rotation" that was held at the Shanghai Astronomical Observatory in Shanghai, China, during Oct. 25-28, 2010. Over 90 participants from 12 countries took part in the workshop. The proceedings of this workshop were published as a special issue (Vol.62, No.1) of Journal of Geodynamics on "Observing and Understanding Earth Rotation" in 2012. In all, 20 papers were submitted and 13 papers were accepted and published after rigorous review.

The next conference dedicated to Earth rotation study will be a Symposium "Geodesy, Astronomy and Geophysics in Earth Rotation" (GAGER2016, http://main.sgg.whu.edu.cn/gager2016), jointly organized by IAU C19/A2, IAG C3 and IERS, that is to be held during 18-23 July 2016 at Wuhan, China. All are welcome.

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C19 in the IAU Construction Reform:

According to the arrangement of the IAU, all commissions needed to submit a Letter-of-Intent (LoI) to continue or change their status. C19 took part in this reorganization starting in 2014. The reviewing and voting processes lasted half a year, including submission of LoI, members' voting, submission of full proposal, recommendation by Division President/SOC sent to IAU Executive Committee, approval of commissions announced by the EC, and sign-up for the approved commissions. As a result, C19 is kept with the same name "Rotation of the Earth" but with a new assigned commission number "A2". With the support of commission members, the participation in our Commission (C.A2) Organization Committee vote (86.4 %) is the highest in all IAU Commissions.

The new C.A2 Organization Committee structure (total OC number of seats is 6) is:

- President: Richard Stewart Gross (USA)
- Vice President: Florian Seitz (Germany)
- Co-proposers: Jose Ferrandiz (Spain), Vladimir Zharov (Russia)
- At-large members (elected): Alberto Escapa (Spain, also serve as Secretary), Daniela Thaller (Germany)

The representatives from IAG/IERS/IVS are still under discussion and yet to be determined.

3. Summary of the presentations in the science session "Earth rotation and geodynamics" in Division Meeting

by Chengli Huang

C19 hosted the session "Earth rotation and geodynamics" in the Division A Meeting during this IAU GA. It received 19 oral plus 4 poster abstracts related to Earth rotation, almost 1/3 of the total abstracts received for the Div. A Meeting. These abstracts cover almost all related topics in Earth rotation studies including new observation techniques, data analysis, geophysical excitation and modelling, theory of the precession and nutation, prediction, tidal model, and constraint on the physics of the Earth interior from Earth rotation, etc.

Three invited and six oral presentations were given in this session, they are:

- Mass Transport and Dynamics in the Earth System: Unsolved Scientific Questions and Observational Requirements (by R. Gross)
- Development of a new model for short period ocean tidal variations of Earth rotation (by H. Schuh)
- Recent developments in the theory of the Earth's precession and nutation (by J. Ferrándiz)
- On the use of ring laser gyroscope data for monitoring diurnal and semidiurnal signals in Earth rotation (by A. Brzeziński)
- The statistical properties and possible causes of polar motion prediction errors (by W. Kosek)
- Effects of density stratification on the frequencies of the inertial modes of the Earth's fluid core (by B. Seyed-Mahmoud)
- Earth orientation parameters: excitation by atmosphere, oceans and geomagnetic jerks (by J. Vondrák)
- Medium- and Long-term Prediction of LOD Change by the Leap-step Autoregressive Model (by Q.J. Wang)
- The analysis of monthly STRF and EOPs based on CERS results (by X.Y. Wang)

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4. Summary of presentations in C19 BM

4.1. *Report of the IAU/IAG Joint Working Group on Theory of Earth Rotation*

by José M. Ferrándiz and Richard S. Gross

The purpose of the International Astronomical Union / International Association of Geodesy (IAU/IAG) Joint Working Group (JWG) on Theory of Earth Rotation is to promote the development of theories of Earth rotation that are fully consistent and that agree with observations and provide predictions of the Earth orientation parameters (EOPs) with the accuracy required to meet the needs of the near future as recommended by, for example, IAG's Global Geodetic Observing System. Its activities will be continued by the new IAU/IAG JWG on Theory of Earth Rotation and Validation.

A main objective of the JWG is to assess and ensure the level of consistency of EOP predictions derived from theories with the corresponding EOPs determined from analyses of the observational data provided by the various geodetic techniques. Consistency must be understood in its broader meaning, referring to models, processing standards, conventions etc. In addition, clearer definitions of polar motion and nutation are needed for both their separation in observational data analysis and for use in theoretical modelling. The derivation of comprehensive theories accounting for all relevant astronomical and geophysical effects and the ability to predict all EOPs is sought. In case more than one theory is needed to accomplish this, their consistency should be ensured. Searching for potential sources of systematic differences between theory and observations is encouraged, including potential effects of differences in reference frame realization. Theoretical approaches must be consistent with IAU and IAG Resolutions concerning reference systems, frames and time scales. There are no a priori preferred approaches or methods of solution, although solutions must be suitable for operational use and the simplicity of their adaptation to future improvements or changes in background models should be considered. The incorporation into current models of corrections stemming from newly studied effects or improvements of existing models may be recommended by the JWG when they lead to significant accuracy enhancements.

Since the subject of the JWG is quite broad, three Sub-Working Groups (SWGs) have been formed: (1) Precession/Nutation chaired by Juan Getino, (2) Polar Motion and UT1 chaired by Aleksander Brzeziński, and (3) Numerical Solutions and Validation chaired by Robert Heinkelmann. The subjects of SWG 1 and 2 are self-explanatory. The subject of SWG 3 is numerical theories and solutions, relativity and new concepts, and validation by comparisons among theories and observational series. Each SWG is entrusted with its own tasks and goals, but the three SWG must work in parallel for the sake of consistency. To facilitate the coordination a number of people were affiliated with more than one SWG. More details including the full terms of reference and member list are given in Ferrándiz and Gross (2014, 2015b).

The JWG was established in April 2013. The overall goals not being achievable within only two years, the first term was intended to develop a solid concept of how to reach the JWG aims. The desired outcomes were set to: (1) Contribute to improving the accuracy of precession-nutation and Earth orientation parameters (EOP) theoretical models; (2) Clarify the issue of consistency among conventional EOP, their definitions in various theoretical approaches, and their practical determination; and (3) Establish guidelines or requirements for future theoretical developments. Guidelines for the operation of the JWG were drafted, and since the initial stage its activity has been understood on an open basis, welcoming the co-operation of non-members.

Presentations about the JWG and reports on its activities have been given at the: (i) 2013 IAG Scientific Assembly*; (ii) 2013 Journées Systèmes de Référence

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Spatio-Temporels (JSR)*; (iii) 2013 AGU Fall Meeting; (iv) 8th IVS General Meeting; (v) 2014 EGU General Assembly (GA)*; (vi) 2014 JSR*; (vii) 2014 AGU Fall Meeting*; (viii) 2015 EGU GA*; (ix) 2015 IUGG General Assembly*; (x) 2015 IAU General Assembly*. Besides, open splinter meetings of the JWG have been held in conjunction with the congresses marked with * in the former list. Reports of many of the meetings and copies of the presentations can be found on-line on the JWG's web site at http://web.ua.es/en/wgther. Mid-term reports of progress of the JWG and its three SWGs have been published in the JSR 2014 Proceedings (available at http://syrte.obspm.fr/jsr/journees2014/pdf/).

Because of space limitations, it is not possible to describe all the contributions of members and correspondents here, but a brief summary of facts and ideas to be addressed in the future can be outlined. The accuracy of the observations has improved to the point that the current theory of the Earth's rotation is no longer adequate. For example, the theory is for an axisymmetric Earth whereas triaxial effects on the Earth's rotation are currently being observed. Therefore, current Earth rotation theories should be improved. A number of different approaches are being taken to improve the theories of the Earth's rotation including: addressing deficiencies and inconsistencies among components of theories and/or realizations of reference frames and EOP; revision of the present basic Earth model, complementary geophysical models, and second order corrections used in the theory of nutation and precession; preparing for upcoming advances in observation techniques, etc.

4.2. *Report of the International Earth Rotation and Reference Systems Service*

by Brian Luzum, Wolfgang R. Dick, and Daniela Thaller

The International Earth Rotation and Reference Systems Service continued to provide Earth orientation data, terrestrial and celestial references frames, as well as geophysical fluids data to the scientific and other communities. The Earth Orientation Centre made the generation of the C04 series fully automated with daily quality checks and comparisons. The EOPs are now available also in XML format. A format for a file with leap second information was proposed. The Rapid Service / Prediction Centre started to provide solutions of ultra rapids 4 times per day and improved the short-term UT1-UTC predictions by 25%. It worked out a proposal for distributing UT1 with the Network Time Protocol. The ITRS Centre issued a call for participation for ITRF2013, but later it was decided to expand the time span of data used until the end of 2014 and to create an ITRF2014. All Technique Centres provided combined SINEX files by February/March 2015, which are being analyzed by three ITRS Combination Centres (DGFI, IGN, JPL). The ITRS Centre participated also in surveys of co-located sites. Together with the IAU Division A Working Group on ICRF3, the ICRS Centre started work to prepare the next ICRF. Work on technical updates to the IERS Conventions (2010) was continued, with updates of existing content, expansion of models, and introducing new topics (non-tidal loading, SINEX format for modelling, ...). New product centres of the Global Geophysical Fluids Centre (GGFC) were recognized, and new GGFC products have been proposed and evaluated for latency and reliability. In 2013, the Central Bureau moved to a new data management system of retrieval, check, metadata extraction, format conversions, storage, and presentation of IERS products. A new IERS User and Address Management System was introduced in 2014 with login areas for IERS members and for users. New tools for analysis and visualization of data products have been developed.

The Working Group (WG) on Site Survey and Co-location issued a resolution on the nomenclature of space-geodetic reference points and local tie measurements. The WG on Combination at the Observation Level worked on homogenized processing of VLBI

CONT08 and CONT11 campaigns solving all parameters together simultaneously; a long-term combination is expected in the ITRF2014 framework. The WG on SINEX Format developed modifications in the SATELLITE/ID block and other revisions. The WG on Site Coordinate Time Series Format is working on the definition of a common exchange format for coordinate time series for all geodetic techniques.

The following IERS publications and newsletters appeared between 2012 and 2015: Z. Altamimi, X. Collilieux, and L. Métivier: Analysis and results of ITRF2008 (IERS Technical Note No. 37, 2012); IERS Annual Reports 2010, 2011, 2012, and 2013; IERS Bulletins A, B, C, and D (weekly to half-yearly); ca. 70 IERS Messages. The central IERS web site www.iers.org and about 10 individual web sites of IERS components have been updated, improved and enlarged continually.

The following workshops were held: IERS Workshop on Local Surveys and Co-locations (Paris, France, 21-22 May 2013); IERS Retreat (Paris, France, 23-24 May 2013); 4th Unified Analysis Workshop (Pasadena, California, USA, 27-28 June 2014). Abstracts and presentations of all these workshops are available at the IERS web site.

4.3. *Report of the IVS Activity Highlights 2012 - 2015*

by Oleg Titov and Dirk Behrend

The International VLBI Service for Geodesy and Astrometry (IVS) continued to fulfill its role as a service within the IAU by providing necessary products for the densification and maintenance of the celestial reference frame as well as for the monitoring of Earth orientation parameters (EOP). Here we report on highlights of the service work during the report period focusing on governance, products, and special campaigns/programs.

Governance: In 2013, Dr. Axel Nothnagel (University of Bonn) was elected as new IVS Chair succeeding Dr. Harald Schuh (GFZ Potsdam). Dr. John Gipson succeeded Dr. Nothnagel as IVS Analysis Coordinator. Dr. Dirk Behrend (NVI Inc., NASA GSFC) continued to serve as Director of IVS Coordinating Center. There were three active committees: Observing Program Committee (chaired by D. Behrend), VGOS Technical Committee (chaired by B. Petrachenko), and Committee on Training and Education (chaired by R. Haas). A new Working Group on Satellite Observations with VLBI (WG7) was established (chaired by R. Haas). A Working Group on Galactic Aberration (to be chaired by D. MacMillan) was proposed.

Observing program: The IVS continued the observation of 24-hour, rapid turnaround sessions (IVS-R1 and IVS-R4), which were run two times per week, for a total of 104 sessions per year. These sessions provided the full set of EOP parameters (i.e., polar motion, UT1-UTC, and nutation). Daily 1-hour Intensive measurements were made for the operational estimation and dissemination of UT1-UTC values. A Continuous VLBI Campaign (CONT14) was observed 6?20 March 2014. The campaign included 17 VLBI radio telescopes at 16 sites recording observations at a data rate of 512 Mbit/s. All data were correlated at the Bonn Correlator within two months. About half of the raw VLBI data were electronically transferred. The resulting data set is the best that the legacy S/X VLBI system has produced to date.

Gaia: The IVS initiated an observing program for 195 radio sources (identified by Bordeaux Observatory) as possible transfer sources between the ICRF2 (radio frame) and Gaia (optical frame). The dedicated program commenced in mid-2013 with an accuracy target for the source positions of 0.1 mas and a monitoring target of 12 sessions per year. The targets were achieved for most sources; however, weaker sources need special attention. The program will be continued for a few more years.

VGOS: The development of the next generation VLBI system (VLBI Global Observing System, VGOS) was continued. Implementation plans for the broadband system were established with the VGOS Observing Plan and the VGOS Data Transmission and Correlation Plan. A VGOS Analysis Plan is being worked on. It is anticipated that by the year 2017 sixteen VGOS stations will become operational.

4.4. *Report of IAG activities*

by Harald Schuh

A highlight of the IAG activities in the last period was its General Assembly held within the 26th General Assembly of the International Union of Geodesy and Geophysics (IUGG) from 22 June to 2 July, 2015 in Prague, Czech Republic. IUGG is comprised of the following eight semi-autonomous Associations: International Association of Cryospheric Sciences (IACS), International Association of Geodesy (IAG), International Association of Geomagnetism and Aeronomy (IAGA), International Association of Hydrological Sciences (IAHS), International Association of Meteorology and Atmospheric Sciences (IAMAS), International Association for the Physical Sciences of the Oceans (IAPSO), International Association of Seismology and Physics of the Earth's Interior (IASPEI), and International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI).

IUGG holds General Assemblies at four-year intervals, the Prague conference with more than 4300 participants - of which 532 were from IAG - was a big success. The IUGG General Assembly consisted of three important parts: (i) an open Scientific Assembly, (ii) a Council Meeting of the duly accredited Delegates of the IUGG Member Countries; and (iii) business meetings of the IUGG, Union Associations, and their scientific groupings. The Scientific Program of the General Assembly consisted of 202 symposia and workshops and 639 sessions in total. Among more than 5300 presentations at the General Assembly were 9 Union lectures, 476 invited presentations, 2682 oral presentations, and 2211 poster presentations. For IAG, Harald Schuh gave a well-noted Union Lecture on "Contributions of Geodesy to Monitoring Natural Hazards and Global Change".

It should be emphasized here that several research activities are common to IAU and IAG. One example is IAG's Commission 3 "Earth Rotation and Geodynamics" which has strong links with IAU Commission A2 and a joint Working Group on "Theory of Earth Rotation and Validation" chaired by José-Manuel Ferrándiz. Other common interests are related to reference frames, in particular via the International Celestial Reference Frame, ICRF, which is needed for many astronomical applications and mainly realized by geodetic infrastructure in terms of geodetic VLBI radio telescopes. Within IAG the relation between the ITRF (International Terrestrial Reference Frame) and the ICRF is treated in Commission 1 and there mainly in Sub-Commission 1.4.

The IUGG Council approved 8 Resolutions, of which several are most important for IAG, e.g. the resolutions on Future Satellite Gravity and Magnetic Mission Constellations, on the Global Geodetic Reference Frame, and on Real-time GNSS Augmentation of the Tsunami Early Warning System. In Prague, new IUGG and Association Officers were elected. Thus, for the period 2015-2019, Harald Schuh (Germany) was elected IAG President, and Zuheir Altamimi (France) was elected IAG Vice-President. The 27th IUGG General Assembly will be held in Montréal, Canada, in 2019.

5. Reports of national projects and/or individual institutions:

5.1. *Report on activity in the field of the Earth Rotation in Australia during 2012-2015*

by Oleg Titov

New VLBI network included three AuScope radio telescopes (Hobart, Yarragadee, Katherine) started operation in 2011, particularly, in IVS-R1, R4 sessions. All three stations actively participated in all IVS programs, and run a separate geodetic observing program in the southern hemisphere along with HartRAO (South Africa) and Warkworth (New Zealand).

The observational program for identification of the reference sources in radio/optics has continued at several large optical facilities (PI: Oleg Titov). This program focuses on the future link between the radio reference frame produced by VLBI and the optical reference frame that will be produced by GAIA, and comprises several large optical facilities: 3,58-meter New Technology Telescope (NTT, ESO) in Chile; 2,5-meter Nordic Optical Telescope at Canary Islands (NOT) in Spain; two 8-meter Gemini Telescopes in Chile and Hawaii. Spectroscopic observations in optics of the reference radio sources to determine redshifts, and, thus, confirm their extragalactic nature are undertaken. Redshifts of 300 reference radio sources have been measured to date (Titov *et al.*, 2013).

An alternative formulation of the general relativity effect in VLBI observation has been proposed. It is shown that the traditional gravitational delay is linked to the formula of the light deflection angle with a simple analytical equation (Titov & Girdiuk, 2015).

The last four years has seen the completion of a phase of federally funded expansion of the ground GNSS infrastructure. Australian government funding provided through the AuScope initiative saw the installation of 100 new Continuously Operating Reference Station (CORS) sites throughout Australia. New CORS have also been installed within some state and territory jurisdictions at a rapid pace, with input from both government agencies and private industry. This infrastructure has augmented Australia's national geodetic infrastructure and significantly increased the quantity of data used to improve the accuracy of Australia's Reference Frame.

The GNSS data are made available from the Australian GNSS network to national and international researchers and has supported a range of research including next generation GNSS-based precise positioning services (Teunissen Khodabandeh, 2015), real-time precise point positioning (PPP) services, multi-GNSS studies (Feng *et al.*, 2013) and GNSS signal errors. The data are also being provided to the International GNSS Service which contributes to the IGS Earth Orientation parameter estimates and the IGS's Multi-GNSS Experiment.

5.2. *Report on activities during 2012 - 2015 in Austria*

by Robert Weber and Johannes Böhm

The research Advanced Geodesy at TU Wien is carrying out research on measuring and interpreting Earth orientation parameters (EOP). One key element is the development of the Vienna VLBI Software (VieVS; BÖhm *et al.*, 2009) which is used for scheduling and analysing Very Long Baseline Interferometry (VLBI) observations. In terms of scheduling, Sun *et al.* (2014) have implemented new features in VieVS, which are used by Mayer *et al.* (2014) for the assessment of the importance of individual VLBI stations for the EOP determination or for the routine generation of observation plans for the Australian and other VLBI networks. In terms of interpretation of VLBI-derived EOP, long time series of celestial pole offsets have been used by Krásná *et al.* (2013) to derive Free Core

Nutation parameters or by Schindelegger (2015; personal communication) to assess the atmospheric contribution. Along those lines, a special research focus is on the influence of atmospheric tides on polar motion and UT1-UTC and Schindelegger *et al.* (2013) have investigated the agreement of the angular momentum and torque approach as derived from different numerical weather models. In another study empirical ocean tide models have been used to derive a model for the high-frequency variations in Earth rotation parameters (Madzak *et al.*, 2014). Furthermore the impact of the new European GNSS Galileo on the determination of EOP parameters is currently under investigation with special focus on the improved ability to derive LOD and nutation rates.

5.3. *Report on activities during 2012 - 2015 in Belgium*

by Véronique Dehant

V. Dehant and P.M. Mathews have written a book entitled "Precession, Nutation and Wobble of the Earth", published by Cambridge University Press (ISBN: 9781107092549).

The European Research Council (ERC) has announced the award of its prestigious Advanced Grants, which will enable senior researchers and their teams to pursue groundbreaking ideas. One of these researchers is Dr. Véronique Dehant of ROB, with the project RotaNut: Rotation and Nutation of a wobbly Earth. Mixing different approaches from astronomy, geophysics, geodesy and fluid dynamics, the project aims to improve the model for the rotation and orientation of the Earth, and to make use of VLBI measurements with sub-centimeter precision. At the same time, it will allow scientists to learn much more about the interior of the Earth. The kick-off of Dehant's ERC RotaNut was held on 1 October 2015. ROB in that frame has hired 5 new scientists, specialists of experiment and modeling of rotating fluids mimicking the Earth core, of magneto-hydrodynamics, of Earth rotation modelling, and of ocean and atmosphere loading. These new people will mainly work on coupling mechanisms at the core-mantle boundary for explaining the presently observed differences between the observation and the models for nutation and rotation of the Earth. This includes topographic, gravitational, viscous, and electromagnetic torques.

5.4. *Report on Chinese activities during 2012 - 2015*

by Ben Chao and Chengli Huang

Most of the space geodesy observations (VLBI/SLR/GNSS) in China spread in several observatories belonging to Chinese Academy of Sciences: Shanghai Astron. Obs. (SHAO), Xinjiang Astron. Obs. (Urumqi), National Time Service Center (Xi'an), Natinal Astron. Obs. (Beijing and its SLR station at San Juan, Argentina), Changchun SLR station, Yunnan Obs. (Kunming), etc. All of these facilities join CMONOC (Crustal Movement Observation Network of China) and provide it with a regional terrestrial reference frame and link to the global terrestrial reference frame.

Most of the research in Earth rotation and reference frames are predominantly in SHAO.

SHAO developed a new multiple layer spectral method, as well as a linear operator method, and applied it to the computation of normal modes including free core nutation (FCN). Our primary result is the determination that the FCN period is 435 sidereal days, very close to observation, i.e., 430 days, without any unconfirmed assumptions like increasing flattening of core-mantle-boundary, geomagnetic coupling with nutation at the core boundaries, viscous contribution, etc. (Huang & Zhang, 2014, 2015; Zhang & Huang, 2014, 2015).

SHAO employed a combination of the autoregressive (AR) model and Kalman filter (AR+Kalman) in making short-term EOP prediction (Xu *et al.*, 2012), as well as proposing an artificial neural network technique for long-term EOP prediction (Liao *et al.*, 2012), and took part in the EOP prediction comparison campaign (EOP_PCC)

Polar motion excitations for an Earth model with frequency-dependent responses, with numerical tests of the meteorological excitations, were studied (Chen *et al.*, 2013a,b).

The non-linear geocenter motion observed by SLR after 1998 and its impact on the origin of the TRF was studied. The geocenter motion derived from the loading model can explain about 42% of the Tz rate in the SLR series. It suggests that the non-linear geocenter motion is at least partly real signal and it should be modeled to achieve a reference frame with stability precision of 0.1mm/yr (Dong *et al.* 2014).

SHAO had been a VLBI/SLR/GNSS data analysis center of IERS through 1980s to 2000s, and we are trying to recover this work to continue this contribution to IERS and provide the country with regular service of Earth rotation and reference system products.

Work related to the Earth rotation in the Academia Sinica, Taiwan, has resulted in new findings on two fronts: (1) The dynamics of the free-core nutation (FCN) is revisited and (re)derived from basic principles using normal-mode theory (in a rotating frame). The behavior of the observed FCN by VLBI can be explained in terms of the convolution. Conversely, a deconvolution approach is used to reach an estimate of the FCN period of 441 ± 4.5 sidereal days (Chao and Hsieh, 2015). (2) A wavelet analysis finds (and confirms), among other things, the clean and robust presence of the 6-year signal in LOD and the 26-year Markowitz wobble up to the present in the polar motion excitation (Chao *et al.*, 2014).

5.5. *Report of activities in the Czech Republic*

by Jan Vondrák

A new solution of Earth orientation parameters from optical astrometry in 1900–1992, based on the Earth Orientation Catalog EOC-4 and linked to ICRF and ITRF was made (Vondrák *et al.* 2012). In close collaboration with our Bulgarian colleague Ya. Chapanov, we studied the long-term interactions between the Earth rotation and solar activity (Chapanov *et al.*, 2012; Ron *et al.*, 2012), and mean sea level (Chapanov *et al.*, 2015). We also studied the systematic jumps in polar motion (Chapanov *et al.*, 2014). Using the numerical integration of Brzeziński's broad-band Liouville equations, we demonstrated that the free core nutation (FCN) is most probably excited by the combined effect of the atmosphere, oceans and geomagnetic jerks, the latter being responsible for sudden changes of FCN amplitude and phase (Ron *et al.*, 2014, 2015; Vondrák & Ron, 2014). Later on, we showed (Vondrák & Ron 2015a,b) that similar effects of geomagnetic jerks are present in all Earth orientation parameters (polar motion, length-of-day, nutation). In all these cases, the agreement between the integrated and observed values of Earth orientation parameters significantly improved when additional impulse-like excitations were applied at the epochs of geomagnetic jerks.

5.6. *Report on activities during 2012 - 2015 in Paris Observatory, France*

by Christian Bizouard

General scientific theme of Paris Observatory/ SYRTE department is Space-time Reference system (https://syrte.obspm.fr).

One team is "Space Geodesy and Earth rotation" (Christian Bizouard, Pascal Bonnefond, Olivier Becker, Jean-Yves Richard, Sébastien Lambert (associate), Nicole Capitaine

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(Emeritus), Daniel Gambis (retired)) whose activity is devoted to the determination of the Earth rotation irregularities and their modelling in light of geophysical and astronomical causes.

Determination of Earth rotation is reflected by routine Earth Orientation Parameters (EOP) solutions done in the framework of the IERS: daily C04 since 1962 ; 0.05 year C01 since 1846 ; 100 day C02 (LOD, UT1) since 1830. This is completed by the development of multi-technique combination in close partnership with the teams belonging to the French group of space geodesy (Groupe de Recherche en Géodésie Spatiale, GRGS). Hourly determinations are scheduled, especially by processing DORIS measurements.

Since 2012 this team, in collaboration with Moscow State University, has published different results pertaining to polar motion: asymmetric effects caused by triaxiality and ocean pole tide (Bizouard and Zotov 2013), Chandler excitation its modulation (Zotov and Bizouard, 2012, Zotov and Bizouard 2015) and related climatic effects. Atmospheric excitation of the nutation has been revisited, revealing a striking lunar effect for periods below than 30 days (Bizouard *et al.*2014). See related publications. Skills in "Global Fluid" has been considerably reinforced these last years. In particular, we have an increasing collaboration with the French Private Company MERCATOR OCEAN producing Ocean Angular Momentum from French Ocean Global Circulation Model NEMO.

Another team of SYRTE, "Atom Interferometry and Inertial Sensors", is developing a matter wave interferometer, which might become an alternative to space geodetic technique, on a 20-year horizon, for monitoring Earth's rotation change. A giant Matter-wave laser Interferometric Gravitation Antenna (MIGA) will be built in "Laboratoire Souterrain Sans Bruit" (Rustrel, France) before 2018 and its applicability for geoscience will be investigated before 2020 (http://arxiv.org/abs/1505.07137).

5.7. *Report on activities during 2012 - 2015 in Germany*

by Florian Seitz

Coordinated research activities related to Earth rotation in Germany have been performed during the past triennium predominantly in the frame of two Research Units (RU) of the German Research Foundation (DFG).

The RU 578 "Earth Rotation and Global Dynamic Processes" (2006 - 2014) with 10 inter-related sub-projects (comprising 12.5 inter-disciplinary positions for young scientists from 11 universities and research institutions) aimed at the investigation of physical phenomena that contribute to variations of Earth rotation (www.erdrotation.de). In particular the interactions and coupling mechanisms of different sub-systems (e.g. geosphere, atmosphere, oceans, continental hydrosphere) were studied, and their joint influence on Earth rotation was assessed on the basis of newly developed numerical models. Space-geodetic observation data were analyzed in detail, and approaches for the joint application of model and observation data including assimilation procedures were developed. The RU focused on the thematic complexes (a) high frequent and episodic processes, (b) decadal and secular processes, and (c) Earth rotation as indicator of climate change. The integrated analysis and modeling of processes and data led to significant new information about the diverse excitation mechanisms of changes of Earth rotation on various temporal scales. The activities also resulted in a joint description of the Earth's rotation, gravity field and surface geometry as an important contribution to IAG's Global Geodetic Observing System (GGOS) that requires highest consistency between these parameter groups.

The RU 1503 "Space-Time Reference Systems for Monitoring Global Change and for Precise Navigation in Space" (started in 2012) with 7 inter-related sub-projects

(comprising 12 inter-disciplinary positions for young scientists from 9 universities and research institutions) aims to develop integrative methods and procedures for a consistent definition and realization of geodetic reference systems on Earth and in space as well as to accomplish computations for their establishment and maintenance (www.referenzsysteme.de). One of the core products of the RU will be a state-of-the-art simultaneous estimate of a multi-frequency celestial reference frame together with Earth orientation parameters and a terrestrial reference frame from all observing techniques (VLBI, SLR, LLR, GNSS, DORIS). This goal is in line with IUGG Resolution R3 (2011) that urges that the highest consistency between the ITRF and the ICRF as well as the Earth Orientation Parameters (EOP) should be a primary goal in all future realizations. Further topics covered within the RU deal, e.g., with the consistency of reference systems, the integration of all space-geodetic and astrometric observations, and the realization of next generation reference systems.

5.8. *Report on activities during 2012 - 2015 in Poland*

by Aleksander Brzeziński

The scientific activities in Poland during the triennium 2012 - 2015 concentrated on several important aspects of Earth rotation including evaluation and prediction of the Earth orientation parameters (EOP) and analysis of the related excitation data as well as research on associated geodynamic phenomena such as geocenter motion and global sea level change. We continued investigations on diurnal and subdiurnal variations in Earth rotation by the use of the complex demodulation technique; see the review paper (Brzeziński, 2012) and the associated work done in cooperation with Austrian colleagues (Böhm *et al.*, 2012). We also studied different aspects of modeling the observed free oscillations in Earth rotation, the Chandler wobble (Brzeziński and Rajner, 2014, Nastula and Gross, 2015) and the free core nutation (Brzeziński *et al.*, 2014). Further progress has been achieved in the computation of EOP predictions (Kosek, 2012, Niedzielski and Kosek, 2012). The regional contributions to the excitation of polar motion have been studied in details by considering the atmospheric pressure, ocean bottom pressure and land hydrology data (Nastula *et al.*, 2012, Nastula *et al.*, 2014). A new field of research which is closely associated with the Earth rotation studies, concerns the geocenter motion (Kosek *et al.*, 2014). A more extensive report on research activities carried out in Poland in 2011-2014 in the field of Earth rotation and geodynamics, including complete list of references, is a part of the Polish national report for IAG (Bogusz *et al.*, 2015).

5.9. *Report on activities during 2012 - 2015 in Russia*

by Zinovy Malkin

Several institutes in Russia have been working on the processing of space geodesy observations: Institute of Applied Astronomy, Institute of Astronomy, Institute of Time and Space Metrology (VNIIFTRI), Pulkovo Observatory, Sobolev Astronomical Institute of the St. Petersburg State University, and Sternberg Astronomical Institute of the Moscow State University. The primary derived results are EOP, terrestrial and celestial reference frames. More than 20 Russian permanent VLBI, GPS, and SLR stations are included in the IVS, IGS, EPN and IDS networks and used for derivation of IERS, IVS, IGS, EUREF, and IDS products and TRF densification. Institute of Applied Astronomy provides daily UT1 and weekly full EOP determinations from the Russian VLBI network "Quasar" (Finkelstein *et al.*, 2012). VNIIFTRI maintains the Russian State EOP Service (Kaufman and Pasynok, 2012; Koshelyaevsky *et al.*, 2015).

Several groups have been working on theoretical investigations of the Earth rotation and EOP variation studies at different time scales from intra-day to decadal and their geophysical causes (Akulenko *et al.*, 2012, 2013; Klimov, 2014; Skurikhina *et al.*, 2014; Zharov, 2013; Gubanov and Kurdubov, 2015). Several authors studied the interconnection between Earth rotation variations and other geophysical and cosmophysical processes, such as crustal movements, solar activity, atmospheric and climate change, and geomagnetic jerks (Bizouard *et al.*, 2014; Gorshkov *et al.*, 2012; Malkin, 2013a, 2013b; Krasna, *et al.*, 2015; Zotov *et al.*, 2014). A new method for EOP prediction was analyzed by Malkin and Tissen (2012). Accuracy and consistency of the celestial pole offset series were studied by Malkin (2012a, 2014a). Malkin (2014c) analyzed the detectability of the free inner core nutation.

Russian groups actively participated in ICRF improvement, mostly in the framework of the activity of the IAU Division A Working Group "Third Realization of the International Celestial Reference Frame" (Jacobs *et al.*, 2012, 2014; Malkin 2012b, 2014b; Sokolova and Malkin, 2012; Gubanov and Kurdubov, 2013; Voronkov and Zharov, 2013; Zharov, 2013; Malkin *et al.*, 2015). Implications of the Galactic aberration for the EOP and reference frames were analyzed by Liu *et al.* (2012) and Malkin (2014b).

5.10. *Report on activities during 2012-2015 in Spain*

by J. M. Ferrándiz, J. Getino and A. Escapa

The groups of the Universities of Alicante and Valladolid have carried on with the theoretical investigation of second order effects on the Earth rotation along this term. The effects of the tidal mass redistribution on the Earth's precession and nutation have been derived using the Hamiltonian method (Baenas *et al.*, 2015) under various assumptions. A survey of the main features of that approach to the Earth's rotation was published by Ferrándiz *et al.* (2015c). The consistency of the current IAU theories of precession and nutation has been considered in detail, unveiling that the available corrections to the IAU2000A nutation series stemming from the differences between the IAU2006 and IAU1976 precession models must be completed with some additional terms of similar magnitude (Escapa *et al.*, 2015a, 2015b). Other indirect effects on nutations arising from the changes of the values of the dynamical ellipticity are also pointed out in the last reference. In cooperation with colleagues from the GeoForschungsZentrum (GFZ) we addressed the consistency of the conventional celestial and terrestrial reference frames and the Earth orientation parameters (Heinkelmann *et al.*, 2015a, 2015b) by VLBI data analyses. We also dealt with some supplementary problems like minimization properties of the Tisserand reference systems (Escapa *et al.*, 2015c), existence of periodic orbits in self-excited rigid-body motion (Ferrándiz *et al.*, 2014), the Slichter oscillation mode of Mercury (Escapa and Fukushima, 2015) and a canonical theory of the physical librations of the Moon with a liquid core (Barkin *et al.*, 2015).

On the observational side, we must emphasize the deployment of the RAEGE network by the National Geographic Institute (IGN) of Spain, together with the Regional Government of Açores, Portugal. This set of four VGOS radio telescopes located in three tectonic plates (Eurasian, African, and North American) is a main Spanish contribution to GGOS (Gómez-González *et al.*, 2014 and http://www.raege.net/). The new Yebes instrument is already collecting data and the Santa María one will be soon. The whole network is expected to be operative in 2017.

5.11. *Report on activities during 2012 - 2015 in Jet Propulsion Laboratory (JPL), USA*

by Richard Gross

During the past triennium, JPL continued to investigate Earth orientation variations including their excitation by just atmospheric fluctuations (de Viron and Dickey, 2012), just oceanic fluctuations (Marcus *et al.*, 2012; Nastula *et al.*, 2012) and by the combination of atmospheric, oceanic, and hydrologic variations (Nastula *et al.*, 2014). In addition, models and observations of the excitation of the Chandler wobble have been used to estimate its period and quality factor Q (Gross and Nastula, 2015; Nastula and Gross, 2015), the possibility of improving predictions of UT1 with forecasts of atmospheric, oceanic, and hydrologic angular momentum was investigated (Gross, 2012), the need for an improved theory of the Earth's rotation was discussed (Gross, 2015a), and the second edition of a review paper on the theory of Earth orientation variations, the techniques used to measure them, and their causative mechanisms was prepared (Gross, 2015b). JPL also continued to support tracking and navigation of interplanetary spacecraft by acquiring and reducing very long baseline interferometry, global positioning system, and lunar laser ranging data and by using a Kalman filter to both combine these with other Earth orientation measurements in order to produce optimal estimates of past variations in the Earth's orientation and to predict its future evolution (Ratcliff and Gross, 2013a, 2013b, 2015).

6. On the history and heritage of C19

by Zinovy Malkin

The IAU Commission 19 starts its history in 1919 at the Brussels Conference where the IAU was established along with its 32 Standing Committees on different branches of astronomy. One of them was the Standing Committee 19 on Latitude Variations chaired by Hisashi Kimura, Director of the International Latitude Observatory, Mizusawa, Japan. In 1922, at the 1st IAU General Assembly all the IAU Standing Committees became Commissions, and thus the IAU Commission 19 "Variation of Latitude" was established.

During its first years, the main topic of the Commission was investigation of polar motion, primarily using observations at stations located on the North parallel 39°08′ coordinated by the International Latitude Service (ILS). According to the first Commission 19 Charter, the main tasks were: continuation of observations on the North parallel, compilation of programs of observations, unification of reduction methods, providing financial support for the latitude works, and development of new instruments and methods for future observations. The main scientific problems discussed at the Commission meetings were non-polar latitude variations, station motion, atmospheric impact on the results of latitude observations, improvement of astronomical models affecting the ILS results, such as nutation, precession and aberration, and improvement of star positions used for computation of latitudes. One can see that many of these tasks remain important today despite revolutionary changes in observational techniques used for Earth rotation studies!

It should be noted that in the beginning of the XX century, polar motion was the only irregularity in the Earth's rotation that could be reliably measured. Later, the field of Commission activities expanded due to several factors. Among them were the increasing number of stations performing latitude and then time observations and developments in the theory of Earth rotation. The connection between variations in the Earth's rotation and various geophysical phenomena also came to be one of the most important topics of Commission discussions. As a result, in 1964 at the XIIth IAU General Assembly

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the Commission was renamed "Rotation of the Earth" and included several functions of Commission 31 "Time" related to determination of Universal Time.

The investigation of the Earth's rotation is primarily based on observations of natural and artificial celestial bodies, such as stars, extragalactic radio sources, and satellites. Therefore, the accuracy of the coordinate transformation between terrestrial and celestial systems is of ultimate importance. For this reason, improvement of the model of precession/nutation was always amongst the Commission discussion topics. During its first decades, latitude observations were used to improve the nutation constant. In the 1970s, IAU Commission 19 and the IERS jointly promoted the new IAU 1980 nutation model. In the 2000s, the IAU2000/2006 model of precession/nutation was adopted. This model currently provides the best accuracy in ITRF/ICRF transformations.

Description of the Earth's rotation requires clear and accurate definitions of terrestrial and celestial coordinate systems, in which all the motions under investigation are given. The Commission was always active in this field and plays a leading role in maintenance of the international terrestrial and celestial reference frames, usually in partnership with the IERS and IAG. For example, in 1967 the concept of Conventional International Origin (CIO) was accepted by the IAU and IUGG. Later, the IAU mainly concentrated on the maintenance of the celestial coordinate system. In 1997, the new celestial reference system ICRS and celestial reference frame ICRF were adopted by the IAU, followed by ICRF2 which was adopted in 2009. The work on realizing ICRF3 is currently underway. Now the Commission Charter includes such items as developing collaborations in observation and theoretical studies of Earth orientation, linking the astronomical community to the official organizations providing the International Terrestrial and Celestial Reference Systems and Frames (ITRS/ITRF and ICRS/ICRF) and Earth orientation parameters (EOP): IAG, IERS, IVS, IGS, ILRS, IDS, developing methods for improving the accuracy and understanding of Earth orientation and related reference systems/frames, ensuring agreement and continuity of the reference frames used for Earth orientation with other astronomical reference frames and their densification, providing means of comparing observational and analysis methods and results to ensure accuracy of data and models.

IAU Commission 19 has always worked in close cooperation with the IAG and the IERS and its predecessors. At the very beginning, IAU Commission 19 on latitude variations was established simultaneously with analogous IAG commission, and both organizations supported the highly successful activities of the ILS. This cooperation continued during the entire Commission 19 history. Besides the works described above, the most important projects developed during recent years were creation of the ICRF2 (2006-2009) and the IAU/IAG Joint Working Group on Theory of Earth Rotation. Also during recent years, the IAU Commission 19 jointly with the IERS plays a leading role in maintenance of the IERS Conventions.

Table 1 lists all the Presidents of IAU Commission 19 during its 96-year history:

Table 1. Presidents of Commission 19

1922-1935	Hisashi Kimura	1973-1976	Chikara Sugawa	1994-1997	Jan Vondrák
1936-1948*	Harold Spencer Jones	1976-1979	Raimundo Vicente	1997-2000	Dennis McCarthy
1948-1955	Paul Sollenberger	1979-1982	Paul Paguet	2000-2003	Nicole Capitaine
1955-1961	Eugeniy Fedorov	1982-1985	Yaroslav Yatskiv	2003-2006	Veronique Dehant
1961-1967	Bernard Guinot	1985-1988	William Klepczynski	2006-2009	Aleksander Brzeziński
1967-1970	Paul Melchior	1988-1991	Martine Feissel	2009-2012	Harald Schuh
1970-1973	Humphry Smith	1991-1994	Barbara Kolaczek	2012-2015	Chengli Huang

* 1936-1948: President d'Honneur: Hisashi Kimura

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At the XXIX GA, 2015, Hawaii, Commission 19 was abolished, and a new Commission A2 "Rotation of the Earth" was established. Its first Chair is Richard Gross.

7. The new Commission A2: Status and Outlook

by Richard Gross

The Earth rotates about its axis once a day, but does not do so uniformly. Instead, the rate of rotation fluctuates by as much as a millisecond a day, the Earth wobbles as it rotates because the Earth's mass is not balanced about its rotation axis, and the Earth's rotation axis precesses and nutates in space. These variations in the Earth's rotation are caused by processes acting within the interior of the Earth such as core-mantle interaction torques and glacial isostatic adjustment, by processes acting at the surface of the Earth such as fluctuations in the transport of mass within the atmosphere and oceans, and by processes acting external to the Earth such as torques due to the gravitational attraction of the Sun, Moon, and planets. Studying the Earth's time varying rotation can therefore be used to gain greater understanding of these and other global-scale processes of the Earth.

Knowledge of the Earth's time varying rotation is also needed to connect the terrestrial and celestial reference frames to each other. The terrestrial reference frame is attached to the solid Earth and its orientation with respect to the celestial frame changes as the Earth rotates. Knowing the relative orientation of the terrestrial and celestial reference frames and how it varies in time allows the positions of objects such as interplanetary spacecraft tracking stations to be known in both frames.

Earth rotation is therefore an interdisciplinary topic that bridges astronomy and geodesy. Precise Earth rotation parameters are needed for positioning and navigating objects on Earth and in space and the analysis of Earth rotation variations provides important information about the interactions between the various components of the Earth system and about global change phenomena.

Commission A2 has a long and proud history of active involvement in the IAU. During 1919-1922 it was known as "Standing Committee" 19 on Latitude Variation with Hisashi Kimura as its President. During 1922-1964 it became IAU Commission 19 on "Latitude Variation" and during 1964-2015 it was IAU Commission 19 on "Rotation of the Earth". Following the reorganization of the IAU in 2015, Commission 19 became Commission A2 but retained its name "Rotation of the Earth". The objectives of the Commission are to:

(1) Encourage and develop cooperation and collaboration in observation and theoretical studies of Earth orientation variations (the motions of the pole in the terrestrial and celestial reference systems and rotation about the pole).

(2) Serve the astronomical community by linking it to the official organizations that provide the International Terrestrial and Celestial Reference Systems/Frames (ITRS/ITRF and ICRS/ICRF) and Earth orientation parameters (EOP): International Association of Geodesy (IAG), International Earth Rotation and Reference Systems Service (IERS), International VLBI Service for Geodesy and Astrometry (IVS), International GNSS Service (IGS), International Laser Ranging Service (ILRS), International DORIS Service (IDS).

(3) Develop methods for improving the accuracy and understanding of Earth orientation variations and related reference systems/frames.

(4) Ensure agreement and continuity of the reference frames used for studying Earth orientation variations with other astronomical reference frames and their densification.

(5) Provide means of comparing observational and analysis methods and results to ensure accuracy of data and models and encourage the development of new observation techniques.

The Commission meets its objectives by fostering research and discussion on Earth rotation and reference frames, by organizing topical symposia and workshops, and by forming relevant Working Groups. During the upcoming triennium, the Commission is co-sponsoring the "Geodesy, Astronomy and Geophysics in Earth Rotation" (GAGER2016) Symposium that will be held in Wuhan, China during 18-23 July 2016 (http://main.sgg.whu.edu.cn/gager2016/). And the Commission is planning on organizing an IAU Symposium on Earth rotation in early 2018.

During the upcoming triennium the Commission currently has just one Working Group, an IAU/IAG Joint Working Group (JWG) on "Theory of Earth Rotation and Validation". The purpose of the JWG is to promote the development of theories of Earth rotation that are fully consistent and that agree with observations and provide predictions of the Earth orientation parameters with the accuracy required to meet the needs of the near future as recommended by, for example, GGOS, the Global Geodetic Observing System of the IAG.

The Commission will work closely with the Services, Commissions, Inter-Commission Committees, and Global Geodetic Observing System of the IAG as it has in the past. In this manner, the astronomy community is kept abreast of progress being made by the geodetic community in observing and understanding the Earth's rotation, and vice versa.

8. Closing remarks

The President of Commission 19 thanks C19 members for their cooperation in conferences especially their support in the voting of new commission A2. He appreciates all the members of the current Organizing Committee of C19 and several C19 past Presidents (e.g., Aleksander Brzeziński, Nicole Capitaine, Véronique Dehant, Paul Paquet, Jan Vondrák) for their active work and service. He also congratulates the new President, Vice-President, and the OC members on their election in new Commission A2 and wishes them successful activities during their new term.

Chengli Huang
President of Commission 19

Reference

Due to page limit, all the cited references are not listed here, but can be found in the webpage of Commission A2

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