

REPORT ON ACTIVITIES OF THE IAU/IAG JOINT WORKING GROUP ON THEORY OF EARTH ROTATION

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ABSTRACT. This report of progress on the activities of the IAU/IAG Joint Working Group on Theory of Earth Rotation (JWG_ThER) has a twofold purpose. First, providing a short introduction to the JWG_ThER dedicated sub-session, recalling the purpose, structure and operation of the JWG and the main activities developed so far. Second, summarizing the discussion scheduled at the end of the sub-session after the presentation of the reports, by giving a brief account of the topics submitted by the Chairs of the JWG and its three Sub Working Groups as well as the argumentations and the reached agreements.

1. INTRODUCTION

Purpose. The International Association of Geodesy (IAG) and the International Astronomical Union (IAU) set up a new Joint Working Group on Theory of Earth Rotation in April 2013. The purpose of this JWG is promoting the development of theories of Earth rotation that are fully consistent and that agree with observations and provide predictions of the EOP (Earth Orientation Parameters) with the accuracy required to meet the needs of the near future as recommended by, e.g., GGOS, the Global Geodetic Observing System of the IAG. Let us recall that GGOS accuracy and stability goals are 1 mm in position and 0.1 mm/yr in velocity on global scales for the reference frame realizations, especially the ITRF (International Terrestrial Reference Frame) – see, e.g., Plag and Pearlman, 2009; Plag et al., 2009. The accuracy in position corresponds roughly to 30 μ as and 3 μ as/yr in the angles measured from the Earth's centre.

Desired Outcomes.

- Contribute to improving the accuracy of Precession-Nutation and UTPM (Universal Time, Polar Motion) theoretical models by proposing both new models or additional corrections to existing models.
- Clarify the issue of consistency among conventional EOP, their definitions in various theoretical approaches, and their practical determination.
- Establish guidelines or requirements for future theoretical developments with improved accuracy.

The overall goals of the JWG cannot be achieved within only two years and the first term should be used to develop a solid concept of how to reach its aims. Reports must be concluded and presented at the next General Assemblies of IAU and IAG to be held in 2015.

Structure. The structure of this JWG follows the characteristics of the current set of EOP as well as the fields of specialization of researchers. The people in charge are: José M. Ferrándiz (Chair, mainly IAU) and Richard Gross (Vice-Chair, mainly IAG). The WG is structured in three Sub-Working Groups (SWG):

1. Precession/Nutation (Chair¹: Juan Getino)
2. Polar Motion and UT1 (Chair: Aleksander Brzeziński)
3. Numerical Solutions and Validation (Chair: Robert Heinkelmann)

SWG 3 is dedicated to 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. The three SWG should work in parallel for the sake of efficiency and they should be coordinated and linked together as closely as the needs of consistency demand. The JWG is intended on an open basis and the cooperation of non-members is welcome. All people interested in Earth rotation are invited to contribute; it suffices contacting directly any of the chair-persons or visiting the JWG web site hosted by the Institution of the Chair (University of Alicante, Spain), at <http://web.ua.es/en/wgther>. That site contains the full terms of reference (ToR), member lists and a brief account of the activities to be described in the next section, including the corresponding memorandums and presentations.

2. PREVIOUS ACTIVITIES AND MEETINGS

The JWG serves as a forum for the exchange of ideas and information on the contemporary and prospected future advances in the theory of Earth rotation, resulting from the activity of its ordinary or correspondent members and the community of researchers interested in this matter. A selection of the investigations carried out recently in different aspects of Earth rotation is collected in the reports of each SWG, therefore we do not reiterate them here.

At the initial stages of operation some invited talks introducing the JWG and its goals were delivered at conferences of special relevance for our subject, namely the *IAG Scientific Assembly* (Potsdam, September 2013) and shortly afterwards the *Journées 2013 Systèmes de Référence Spatio-Temporels* (JSR2013, Paris, September 2013) – Ferrándiz and Gross, 2014a, 2014b. Besides, a number of business or science meetings of opportunity were organized on occasion of those two and of later conferences, generally open to their attendants. Among the main scientific topics discussed at the JSR2013 splinter meeting, we can remark:

- The need of agreeing on a common background among the three SWG to encompass the development of the tasks of each SWG and keep the main issue of consistency.
- The convenience of preparing a first catalogue of potential sources of inconsistency among theory and the series of EOP determined from the data obtained by the various observational techniques. Inconsistencies may result from many causes: differences among reference systems used in theories and data analyses, realizations of frames, geophysical models, etc. Assessing their magnitudes would help to ascertain which effects may be not negligible at the pursued accuracy level.
- Revising Earth models used in different theoretical approaches to EOP since they exhibit large variations. Some possibilities, as adopting triaxial models or taking into account other new geophysical effects, should be addressed in future.
- Studying further and testing new effects or corrections to nutations proposed in the last few years.
- Considering the role of theoretical predictions in a scenario in which observational accuracy goes ahead of theory, etc.

An additional presentation dedicated to the JWG_ThER scope and its initial activities was performed at the *AGU Fall Meeting 2013* held in San Francisco, December 2013 (Ferrándiz and Gross, 2013).

The issues of accuracy and consistency of EOP and the relationships between theory and observations were addressed in a talk made at the *8th General Meeting of the IVS* (International VLBI Service) held in Shanghai from 2-9 March 2014 (Ferrándiz et al., 2014a) Other activities of the JWG on Theory of Earth Rotation which took place at that meeting are:

A - JWG business meeting. The Chair and Vice-Chair of the JWG and the Chair of SWG3 got together with the President and Past-President of IAU C19 (Ferrándiz, Gross, Heinkelmann, Huang, Schuh, respectively) and had an informal business meeting to discuss about the agenda. It was agreed: The Splinter Meeting scheduled at the EGU 2014 would provide an opportunity to each SWG Chair

¹Due to some health problems of J. Getino, A. Escapa is temporarily acting as Co-Chair of Sub-WG1.

to make a presentation concerning his SWG (Ferrándiz et al., 2014b; Brzeziński, 2014; Getino, 2014; Heinkelmann, 2014) and it would help to organize its work according to the ToRs. The only SWG Chair attending the IVS GM was Heinkelmann, who also supported the idea, so Getino and Brzeziński were invited to do it. The next milestone to be considered were the Journées 2014, that would take place half year later. It was expected that reports of progress of all the SWG could be presented in this conference too, that usually gathers many experts on various Earth rotation topics.

B - Participation in the Analysis Workshop. The SWG3 Chair contributed to the discussion with a short presentation during the IVS Analysis Workshop (Heinkelmann et al., 2014b). A keen discussion started immediately following the presentation. It mainly was about the interpretation of the GGOS goals for accuracy (1 mm, 0.1 mm/year), whether the accuracy applies on the session or on the reference frame level and about how these accuracy goals are forwarded to the linking EOP. The significance of the EOP quality reported by IERS (International Earth Rotation Service) was seriously questioned. A number of topics and questions concerning the numerical determination of EOP by VLBI and the effects of Earth rotation theory on VLBI was addressed and was forwarded to the VLBI community by making the presentation available on the website of the IVS Analysis Coordinator, which was under development.

Finally, the aforesaid Splinter Meeting of the IAU/IAG JGW_ThER (SPM1.49) took place at the General Assembly of the European Geosciences Union (EGU) held in Vienna in April 2014. It was open to all interested EGU attendants and timely announced by means of an IERS message (No. 247). It was intended for the presentation of reports of progress on the activities of the three SWG and the whole JWG as well as for discussion. Its agenda was very similar to the one of this dedicated sub-session at the JSR 2014 and the presentations made by Getino, Brzeziński, and Heinkelmann are posted on the JWG web site, as well as a poster that summarize them. Links to all of them are provided in the References section.

3. DISCUSSION

The Sub-Session on the “IAU/IAG Joint Working Group on Theory of Earth Rotation” ended with a general discussion according to the program. It was organized around a block of five questions posed by the JWG Chair, after consulting the Chairs of the Sub-Working Groups:

1. *Should the scope of SWG1 and SWG2 be split based on geophysical/astronomical mechanisms rather than solely by frequency?*

The previous agreement of the Chairs of both SWGs was ratified: Astronomical components of polar motion associated with the multipole structure of the Earth’s inertia tensor, having amplitudes as large as 0.1 mas, should be included in the scope of SWG1 *Precession/Nutation*; but geophysical effects in nutation, primarily the Free Core Nutation and S1 tidal signals that have amplitudes as large as 0.5 mas, should be included in the scope of SWG2 *Polar Motion and UT1*. Of course, SWG1 and SWG2 will continue to work together to coordinate their activities and ensure consistency of their results.

The next two questions were put forward by the Chair of SWG1, and the respective technical details are provided in his report.

2. *Should the JWG recommend that the IAU2000A nutation theory be corrected to be fully consistent with the IAU2006 precession theory?*

It was agreed that a Group of Experts be formed to study this issue and make a proposal.

3. *Should the JWG recommend a terminology to be used to make clear the different IAU2000A nutation and IAU2006 precession theories being used with or without consistency corrections?*

It was agreed that suggestions concerning the terminology would be solicited from the community.

4. *Why are models behind data in terms of accuracy? What are the remaining key limiting factors in of Earth rotation modeling? Should model validation be done using “official” series or is it sufficient to use individual solutions? Should the JWG recommend that EOP be determined as part of a joint determination of ITRF, ICRF, and EOP?*

Because of time constraints, there was no real discussion of these topics, raised by the Chair of SWG3 as well as the next.

5. *How should the individual improvements to the theory of the Earth's rotation that have been obtained so far be integrated into a consistent theoretical framework?*

It was agreed that this should be a topic of discussion at future meetings of the JWG.

Finally, it was suggested that the JWG start email discussions of its work in order to increase participation in its activities. Meetings-of-opportunity should still be held at the major conferences (EGU, AGU, IAG, IUGG) but since not everyone can attend these, it would be beneficial if JWG discussions could also be conducted by email.

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