

IERS Retreat Summary

Dates: Retreat Thursday/Friday, May 23-24, 2013
Directing board meeting Saturday May 25, 2013

Location: University Paris-Diderot, 35 Rue Hélène Brion, Paris, France

Session 1: *Move towards “real-time” products*

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

Discussion items:

Initial part of the sessions and the presentations focused on the evolution of systems eVLBI, GNSS real-time and the potential interaction between these two systems. IVS performance improvements are expected in terms of geodetic parameters estimated as the VLBI2010 systems are deployed. With these new systems there is the potential for multi-station 1-hr solutions of EOPs in near real-time. Currently the ILRS has a two-day latency for EOP estimates but 95% of data are available within one hour and the possibility of developing a near real-time SLR EOP product could be investigated. The discussion also suggested that there is the potential for significant improvements to near real-time UT1 determination by combining IGS ultra-rapid polar motion values and VLBI intensives. Berne and BKG have plans to investigate the gains from a GNSS/VLBI coupled analyses.

It was also decided that there should be an assessment of the IGS requirements for real-time EOP to allow real-time precise-point-positioning (PPP) with millimeter accuracy. The IGS real-time service could potentially return accurate EOP in real-time and the IGS should be asked to look at this possibility. This new product type will require a data format that allows for real-time dissemination. For the daily VLBI intensive sessions, there are concerns about poor EOP estimates due to the short duration (1h) and different baselines involved affecting the EOP predictions made by the IERS Rapid Service/Prediction Center.

Recommendations and studies:

- (1) Assess accuracy and latency of near real-time eVLBI and SLR EOP products.
- (2) Carry out studies into the potential improvements in EOP products through coupled VLBI/GNSS analyses.
- (3) Assess the sensitivity of real-time GNSS results to EOP prediction errors.
- (4) Start investigating a possible data format and dissemination method for real-time EOP products.

Session 2: Rigorous combined products

2. *Rigorous combined products* (e.g., services are generating EOP and terrestrial RF simultaneously; IERS is simply averaging EOP values). This topic is considered critical to the future of the IERS and will occupy two sessions because of its great impact potentially on the service. Of importance here is the consideration of inclusion of both the terrestrial (ITRF) and celestial reference frames (ICRF). The discussion here will focus on how to assess the need for rigorous combination, how best to achieve such combinations, and how to determine whether we need to proceed with such techniques. This session will be divided into two basic discussions. One will deal with the long-term product generation, the combined ICRF and ITRF product, and the other discussion will focus on the day-to-day generation of IERS products. The implementation of a rigorous combination approach also has major impact on the services contributing to the IERS and the path forward will need to establish the impact on the services as well. It will also need to be established how we blend pre-spaced geodesy measurements with the conventional astronomical ones. This session will be allotted two time slots.

Organizers: Zuheir Altamimi, Manuela Seitz and Richard Biancale

Discussion items:

ICRF consistency issues (adherence to IAG/IAU resolutions)

The issue was raised whether the ICRF is consistent with the ITRF and EOPs. One question that needs to be addressed is: are radio sources needed in operational generation of ITRF. The consensus of the discussion was that the ICRF is decoupled enough from the ITRF that radio sources do not need to be included but this question should be more fully addressed. ICRF working group should clarify issues associated with consistency implementation and quantify level of consistency needed. Additional studies evaluate impact of using polar motion from IGS instead of IVS when the ICRF is determined. The impact on estimates and sigma should be quantified. Groups that can do these studies are encouraged to do this.

Rigorous combination for day-to-day EOP determination

Rapid service: Consensus was that the rapid EOP estimates are generated with such slow latency (4-times per day, 10 minute run times) that not enough time (with current systems) would be available for a rigorous SINEX-based approach to be used in their generation. For the non-rapid EOP estimates, the Earth Orientation Center should evaluate the impact of rigorous combination. An initial study would compare C04 and ITRF recovered EOP during the overlap period.

Alignment of EOP series:

The discussion showed that there was a need for better analysis and reporting of biases between techniques to see how large they are currently with all techniques using ITRF2008. The VLBI Intensives could have more consistent biases because a single baseline is used as opposed to 24-hr VLBI sessions, which use different stations on different days (impact on biases is likely to be from non-linear station motions). The most appropriate source for polar motion values for analysis of the intensives (e.g., fixed to Bulletin-A) should be determined. There should be a study to evaluate the impact of adding GPS gradient and atmospheric delays to the analysis of the VLBI intensives to how this processing

effects biases and noise in the intensive UT1 estimates. There are differences between IGS ultras and finals EOP and these differences cause problems with blend in the rapid products. The magnitude and origin of these differences between final and ultra EOP estimates should be looked at IGS.

Combination at observation level (COL):

Progress has been slow in the implementation of combinations at the observation level (COL). The sense was that progress will continue to be slow. A clear summary of the impact of observation level combinations (mainly common tropospheric parameters, orbits for altimeter satellites) would be useful. There was a suggestion that ITRF2013 submission of COL solutions should be compared to regular ITRF solutions to allow an assessment of the potential of COL improvements over current combination methods.

Recommendations and Studies:

- (1) The ICRF working group to clarify consistency implementation and quantify level of consistency needed.
- (2) Earth Orientation Center should evaluate the impact of rigorous combination of EOP estimated using a SINEX/ITRF based approach. An initial study could be carried out comparing C04 with the ITRF2008 EOP estimates during the overlap interval.
- (3) There should be a study to evaluate the impact of adding GPS gradient and atmospheric delays to the analysis of the VLBI intensives to how this processing effects biases and noise in the intensive UT1 estimates.
- (4) The magnitude and origin of the differences between final and ultra EOP estimates should be looked at IGS.
- (5) ITRF2013 submission of COL solutions should be compared to the regular ITRF solutions so that an assessment of the potential of COL improvements to the combined results.

Session 3: Long-term stability and parameterization of the reference frame

3. This session will address how to parameterize the ITRF. With the GGOS aims of defining an ITRF accurate to 1 mm and 0.1 mm per year, serious consideration has to be given to precisely how to define such a system when there are unknown non-secular components to the motions of all of the ITRF sites. The session will outline the steps that need to be taken in understanding how to incorporate such phenomena as earthquake co-seismic and post-seismic deformations, anthropogenic and natural loading phenomena, and other deviations from secular motion. Also to be addressed is how to approach the appropriate parameterization of variations in the ICRF. Consideration of source structure variation and source evolution needs to be addressed. The impact on the services will need to be assessed.

Organizers: Xavier Collilieux and Daniela Thaller

ITRF parameterization:

There was consensus that there needed to be consistency between the different technique analyses in the parameterization of the ITRF especially in terms of breaks due to earthquakes even if it is not clear for some techniques that they are able to directly detect these effects (e.g. jumps due to earthquakes and

anthropogenic effects). As a treatment for non-linear site motions (other than simple offsets), it was decided that these sites would not be included in the ITRF solution but that they would be retained in the time series analysis. The ITRF reference sites would be limited to sites with largely linear motion and a few as possible offsets in the time series. The parameterization need to be consistent between techniques and the users must understand the nature of these parameterizations. New parameterizations for SINEX (e.g. log post-seismic functions) will be needed and these should be developed in consultation with the SINEX WG. Mean loading corrections, atmospheric and hydrologic, should be added to the SINEX file and the method through which this is done needs to be defined (SINEX WG). The IERS GGFC should compare existing loading models to assess the level of difference between the different centers.

There needs to be a discontinuities analysis to assess which equipment generates the best geodetic result. These studies would focus mainly on GNSS and DORIS sites (less so for the later which are better controlled). The IERS should request the IGS examine antenna effects and assess the level of systematic phase residuals at GNSS site.

There was consensus that methods should be developed to allow easy access position residuals from the individual centers contributing to the ITRF combinations. The technique center (TC) and analysis centers (ACs) should examine this from each of the techniques. Ideally overlaying results from different techniques and different analysis centers within the same technique should be easily done by users.

Recommendations and Studies:

- (1) New parameterizations for SINEX (e.g. log post-seismic functions) will be needed these should be developed in consultation with the SINEX WG.
- (2) Methods of incorporating mean loading models should be studied by the SINEX WG.
- (3) The IERS GGFC should compare existing loading models to assess the level of difference between the different centers and report back the community on the outcome of these studies.
- (4) The IERS should request the IGS examine antenna effects and assess the level of systematic phase residuals at GNSS site.
- (5) Developed methods to allow easy comparison of time series from different analysis centers and techniques contributing to the ITRF.

Session 4: *Next Generation of models and Center-of-Mass products*

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

Organizers: Tonie van Dam and Richard Gross

Studies should be carried out to determine at your center motion model that can be used to relate the center of figure the center of mass. It was not clear that such a model can be generated but such models are being developed on at the

moment. The GGFC should review current status of these models. LEO orbits are effected by these motions. The Conventions center (CC) is currently developing this class of model. Much of the discussion focused on the need for careful bookkeeping so that processes are not accounted for twice. These analyses apply loading corrections and center of mass variations are both considered.

The current models used for polar motion and UT1 diurnal and semidiurnal variations still need improvement (ocean current contribution). There was discussion on how to best combine oceanographic models with geodetic measurements of these diurnal and semi diurnal variations. There was concern of potential aliasing effects, particularly arising from GNSS estimates of these variations.

Further analysis is also needed of long period and/or secular motion of the Z-component of center of mass than has been observed. The interpretation of cause of the secular motion is not clear currently (curvature over 20-years in similar to annual amplitude).

The model for long period motion of the mean pole for use in the pole tide correction needs updating for recent mean pole deviation. The historical motion is based on observed polar motion but the prediction into the future is always a simple linear trend. As data is collected the models need to be updated. A method for systematically doing these updates should be developed. The mean pole motion issue is also related to C21/S21 changes with time that also need to be incorporated into orbit determination.

Recommendations and Studies:

- (1) The GGFC in coordination with the convention center should review current status of models of the relative motion between the center of mass and center of figure.
- (2) Develop methods for improved diurnal and semidiurnal models of EOP variations with particular attention paid after blending oceanographic and geodetic measurements while minimizing potential aliasing effects.
- (3) Assess quantitatively the secular motion of the center of mass of the Earth relative to center of figure and investigate possible origins of such motion.
- (4) Establish methodologies for treating the secular motion uphold and its consequence to the pole tide correction.

Session 5: EOP prediction improvements

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

Organizers: Brian Luzum and Christian Bizouard

Many issues were raised in this session concerning how to best deliver real-time EOP estimates and predicted values. There needs to be developed a real-time transfer data protocol that can be used in the future. The current flat ASCII file formats will not work. There should also be greater emphasis on machine readability of the files. There was a general sense but for improved predictions they should be reduced latency to the last data point and this last data point should have the highest accuracy possible. Some improvement in EOP prediction would be possible improved AAM

and OAM update schedules i.e., updates with 6 hour versus 24 hour latency. The GGFC will be asked to look into these rapid updates.

Studies should be carried out to examine the being in prediction accuracy by using ensemble averages of different prediction algorithms that already exist. Initial studies into such averages suggest that the ensemble would perform better than the individual series.

One aspect of long-term predictions is their potential application to estimating when leap seconds will be needed. The possible impacts of not correctly predicting when a leap second will occur should also be investigated.

Recommendations and Studies:

- (1) Develop formats that would be appropriate for real-time delivery of EOP values.
- (2) In collaboration with the DG FC, investigate the improvement expected in prediction values by using more frequent AAM and OAM updates.
- (3) Study the benefits of ensemble averaging of current prediction.

Session 6: Unification of product formats

6. This session will cover two broad areas. One will be the unification of the IERS product formats to allow easy comparison and combination. The other area will be establishing modern standards for product formats such as the metadata content and how to express that. The target products here are the EOP products that are used by wider IERS community.

Organizers: Thomas Herring and Laurent Soudarin

Benefits of common formats and data types to be included were discussed. For the IERS there are several data products that could benefit from common formats. Primary among these are position time-series and EOP estimates.

For EOP series: Polar motion rate estimates (LOD is already present) are not in every analysis. When rates are included, correlation between epoch value and rate should be included and this would allow effective mean epoch of pole determination to be determined. The distribution of data within the interval of the EOP determinations is an issue for DORIS and SLR and this knowing the effective epoch of the determination would allow more accurate comparison of results. VLBI and GNSS data tend to be more uniformly collected during the interval over which EOPs are determined but even for these techniques, correlation estimates would be useful.

Date style and resolution: Currently dates are given on day boundary and this will need to change for higher temporal resolution EOP and time systems (UTC vs GPST).

The contents of the EOP files for different systems (e.g., rapid, Bulletin B and C04) and between the different geodetic techniques are the same. Not all EOPs are available for all systems and this makes comparison more difficult. Use of a common format and content for input series and combined EOP would allow easy comparison of the input series from different techniques with the final combined products. Consideration should be given to evolving the formats to web 2.0 standards to allow web service access and analysis of data.

The leap second file should be made available in a machine-readable form. Paris Observatory has such files but these can not be found on the Leap second page of

the Paris Observatory web site <http://hpiers.obspm.fr/eop-pc/index.php?index=leapsecond&lang=en>

There was discussion of a common position time series format but the IERS and IAG already have a working group developing this format and investigating methods for web access to these files (including graphical presentations).

Recommendations and Studies:

- (1) The IERS AC along with the ACC for each of the techniques contributing to the IERS should determine a mutually acceptable common format for EOPs. This format would be in addition to existing formats that users are familiar with.
- (2) Work should start on developing web 2.0 based standards for EOPs (XML format)
- (3) A machine-readable leap second format should be made available as soon as possible.
- (4) The IERS working group on developing a position time series format should continue its activities.

Session 7: *Mechanisms for IERS evolution*

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

Organizers: Bernd Richter and Chopo Ma

Recommendations and Studies:

- (1) Current terms of reference were reviewed and update to these will need to be addressed by the DB.