RIGOROUS COMBINATION TO ENSURE ITRF AND EOP CONSISTENCY

Z. ALTAMIMI[1], D. GAMBIS[2], C. BIZOUARD[2]
[1]Institut Géographique National, LAREG
6-8 Avenue Blaise Pascal, 77455 Marne-la-Vallée, France
e-mail: altamimi@ensg.ign.fr
[2]Observatoire de Paris; 61 Avenue de l'Observatoire, 75014 Paris
e-mail: daniel.gambis@obspm.fr; christian.bizouard@obspm.fr

ABSTRACT. The ITRF2005 is the first rigorous combination ensuring ITRF and EOP consistency, based on time series of station positions and Earth Orientation Parameters (EOPs). The objective of the presentation is the development of a combination strategy allowing to ensure the ITRF2005 and IERS 05 C04 consistency with time. Combining additional input time series after the release of ITRF2005 from the four techniques (VLBI, SLR, GPS and DORIS) allows the assessment of two main procedures: (1) using CATREF combination model and (2) using EOP-only combination method. The main features of the two combination strategies are presented together with numerical application. Comparisons of results obtained by the two procedures will be discussed in an attempt to evaluate the current accuracy of EOP determination by space geodesy techniques and to guide our conclusion for future development.

1. ITRF2005 INPUT DATA

For the first time of the ITRF history, the ITRF2005 input data are under the form of time-series solutions, provided in a weekly production by the IAG International Services of satellite techniques (the International GNSS Service, IGS, the International Laser Ranging Service, ILRS and the International Doris Service,IDS) and in a daily (VLBI session-wise) basis by the International VLBI Service, IVS. Each per-technique time series is indeed a combination, on a weekly basis, of the individual Analysis Center (AC) solutions of the technique, except for DORIS for which two individual analysis center time series were submitted for the ITRF2005 computation. Local tie vectors at about 87 sites were used in the ITRF2005 combination allowing the connection between the four techniques. The ITRF2005 is composed of 608 stations located at 338 sites as illustrated on Figure 1, with an imbalanced distribution between the northern (268 sites) and the southern hemisphere (70 sites).

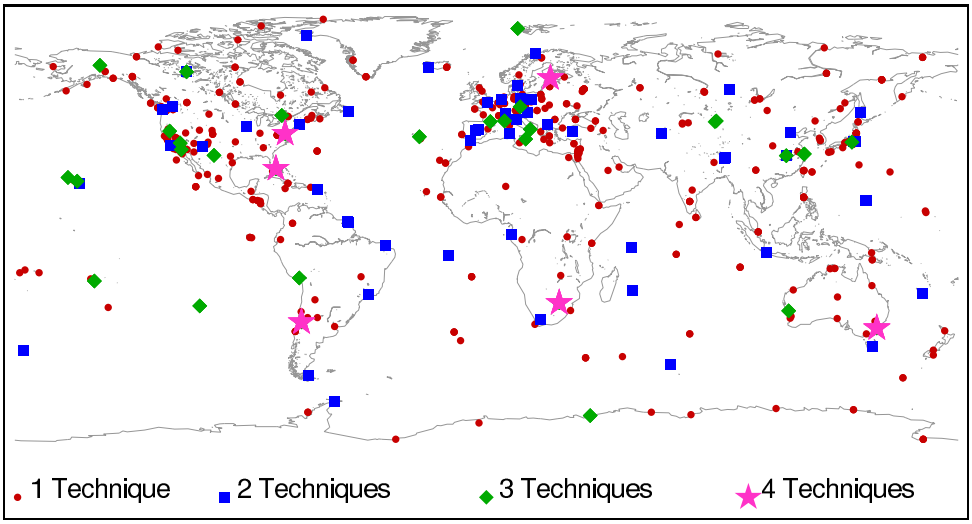

Figure 1: ITRF2005 sites with co-located techniques

2. ADVANTAGES OF USING TIME SERIES

The main advantages of using time series as input data for the construction of the ITRF2005 solutions are:

- to monitor non-linear motion of stations and all kind of discontinuities in the time series. This allows in fact to (1) ensure an optimal velocity field determination and consequently to (2) rigorously define the time evolution of the frame orientation,
- to examine the temporal behavior of the physical parameters of the frame, namely the origin and the scale. The analysis of the temporal behavior of these parameters are of great importance since it helps guiding our choice on how to define the origin and the scale of the ITRF2005 that need to be optimally stable over time, i.e. they should not exhibit temporal discontinuities in order to avoid any internal frame distortion, in order to ensure an optimal temporal stability of a secular frame like the ITRF,
- to ensure a rigorous combination of EOP and ITRF and so to enforce their mutual consistency.

3. ITRF2005 DATA ANALYSIS

The strategy adopted for the ITRF2005 generation follows the following steps:

- Remove original constraints (if any) and apply minimum constraints equally to all solutions
- Use as they are minimally constrained solutions
- Form per-technique combinations (TRF + EOP)
- Identify and reject (de-weight) outliers and properly handle discontinuities using a piece-wise approach
- Combine (if necessary) all solutions of a given technique into a unique solution
- Combine per-technique combination adding local ties in co-location sites

The final step yields the ITRF2005 global solution comprising a full time series of EOPs consistent with the combined frame in addition to the station positions and velocities. For a detailed description of the ITRF2005 data analysis, refer to Altamimi et al. (2007).

4. EOP SERIES ASSOCIATED TO ITRF2005

One of the primary tasks of the IERS is to ensure consistency between the ITRF, the International Celestial Reference Frame (ICRF) and EOPs connecting the two frames. The ITRF2005 provides a major step towards this consistency by providing a consistent series of polar motion and its daily rate, Universal Time (UT1) and Length of Day (LOD). Note that UT1 and LOD values included in the ITRF2005 combination are provided by VLBI only. Biased LOD values from satellite techniques were not included in order to avoid contaminating the VLBI estimates. In a presentation at the GRF2006 Symposium, October 2006, Munich, Germany, J. Ray proposed a multi-step procedure to derive complete UT1/LOD time series consistent with the ITRF2005 making use of UT1 determination from one-hour single-baseline VLBI sessions that were not included in the ITRF2005 combination.

As results from the global ITRF2005 combination, Figure 2 shows Polar Motion differences between the ITRF2005 combination and the IERS C04 series. The mean of these differences indicates a significant bias of about 200 mas in the Y component between the two EOP series. Therefore the ITRF2005 was a good opportunity to reset the IERS C04 to make it consistent with the ITRF2005. The new calibrated series is now called IERS 05 C04 (Bizouard and Gambis, 2008).

In order to evaluate the performance of the solutions used in the ITRF2005 generation in terms of polar motion, Figure 3 illustrates the post fit residuals in x and y components. As an indication of the EOP quality, we computed the WRMS of these residuals resulting in the following approximate numbers: 130μas for VLBI and SLR, 50μas for GPS and 700μas for DORIS.

5. RE-COMPUTATION OF THE EOP 05C04

5.1. Upgrade of the C04 code

For the first time a terrestrial reference frame, i.e. ITRF2005 was available with an associated EOP system. This was a good opportunity to recompute the C04 series since 1962 in a frame consistent with ITRF2005. By the way, the combination code leading to the C04 combined solution was upgraded.

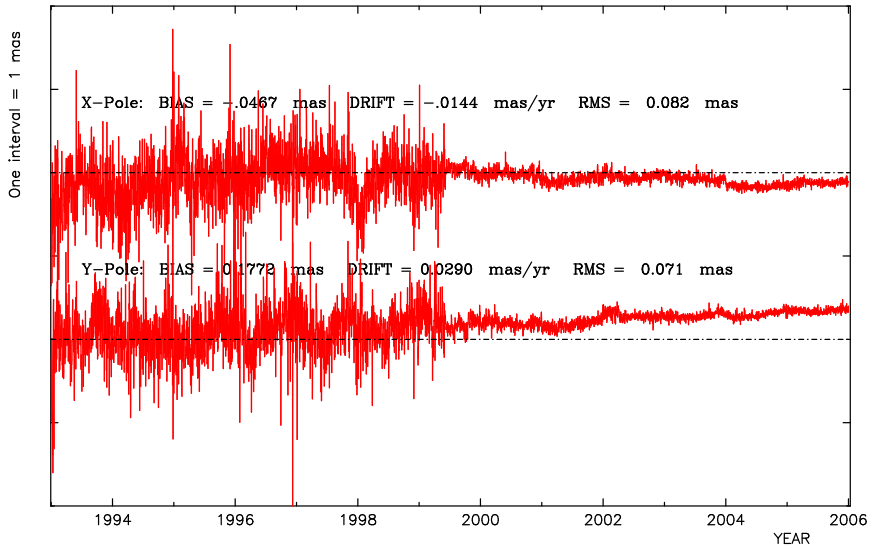

Figure 2: Polar Motion Differences Between ITRF2005 and the IERS C04

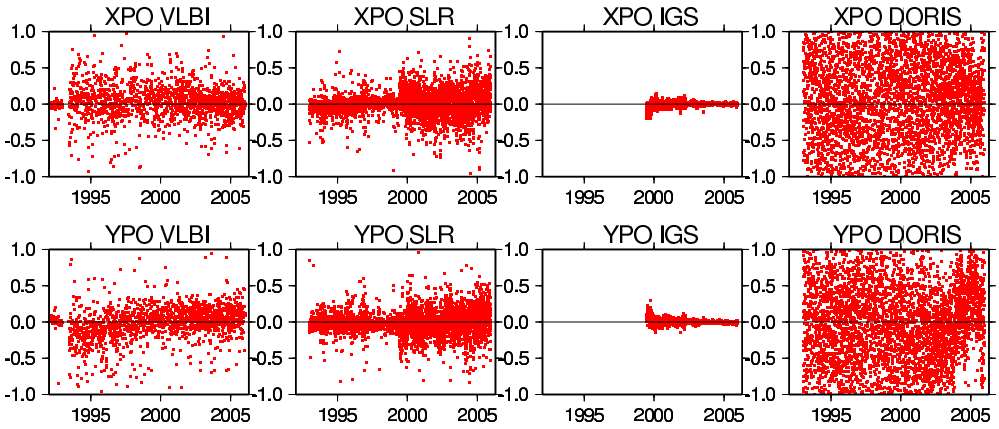

Figure 3: Polar motion residuals per technique resulting from the ITRF2005 combination

The description of the algorithm leading to the combined C04 EOP series is presented in Gambis (2004). The numerical code was recently upgraded to take advantage of the evolution of the precision of EOP derived from the various techniques as well as to benefit of the dramatic improvement of computational resources (Bizouard and Gambis, 2008). The nutation model IAU 2000 was implemented. Solution can now be performed over 20 years in one run. Formal errors associated with the computed EOPs are estimated.

5.2. Performance of the new combination code

The C04 solution has been significantly improved : on one hand it is consistent with the current ICRF and ITRF 2005, on the other hand its parameters present an improved accuracy (50 μas for polar motion, 20 μas for LOD). The parameters $UT1$ and $d\psi * \sin\varepsilon_0$ and $d\varepsilon$ are in better agreement with VLBI series than the official IVS official combined VLBI solution, especially for UT1. Their present accuracy is about 5 μs for $UT1$ and 60 μas for nutation offsets.

6. ENSURING THE CONSISTENCY OVER TIME

From the user point of view of the ITRF and EOP results, it is fundamental to ensure the consistency over time between ITRF2005 and the IERS 05 C04. Therefore it is agreed between the two IERS product centers to assess the extension of the series in two ways: using (1) the EOP PC upgraded procedure and (2) CATREF combination incorporating the routinely available SINEX files by the technique services. The procedure of the EOP Product Center at Paris Observatory is routinely performed whereas the CATREF combination is to be done at regular interval (let us say every 6 months). Both results should then be compared on this time scale in order to evaluate the level of their consistency. In order to illustrate the current level of consistency between the two computations, Figure 4 shows the polar motion differences, including the extended period of about two years of data after the end of ITRF2005 series (i.e. epoch 2006.0). A particular feature could easily be seen from Figure 4 that is, the small but distinguishable jump around the end of 2006. This jump curiously coincides with the time where the IGS switched from relative to absolute model of antenna phase center variations which normally impacts mostly station vertical components. Still, this jump is largely within the current GPS polar motion performance estimated to be at the level of 50μas.

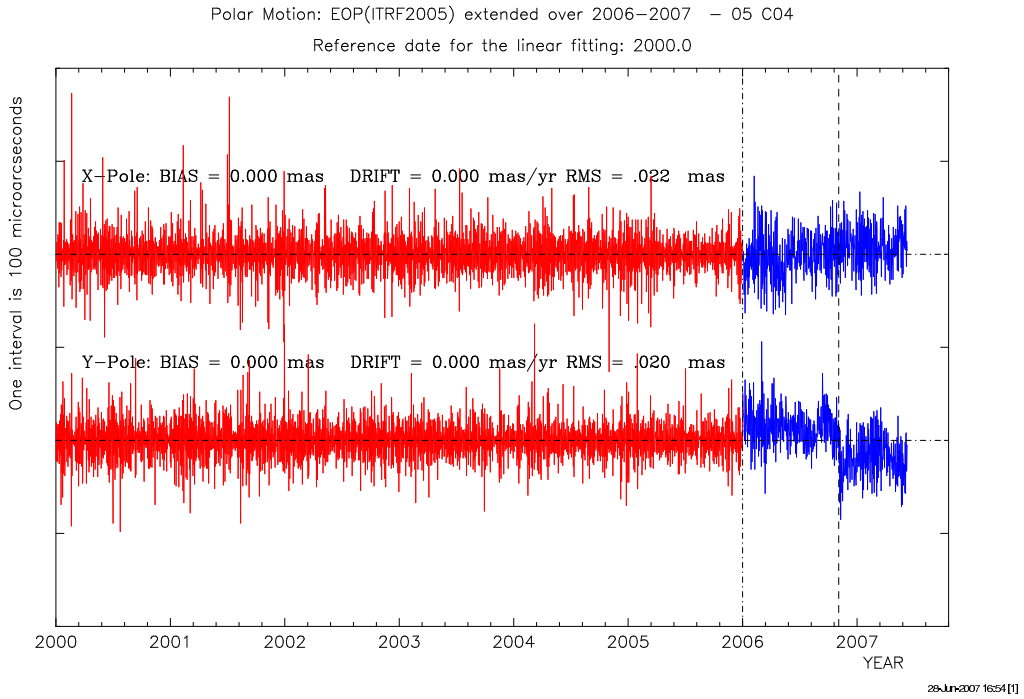

Figure 4: Polar motion differences between ITRF2005 and IERS 05 C04, the time interval was extended over 2 more years after epoch 2006.0

7. CONCLUSION

The ITRF history and evolution demonstrates the continuous improvement of the ITRF solutions, since the BIH era, in the 1980's. It is now fundamental to use time series analysis for ITRF implementation, a major step for improving quality and consistency. The ITRF2005 is a starting point of rigorous unification of ITRF and EOPs. This paper shows that the overall consistency between ITRF2005 and the IERS EOP series 05 C04 is now ensured at the level of 20-30 μas.

8. REFERENCES

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