SF2A 2009
M. Heydari-Malayeri, C. Reylé and R. Samadi (eds)

GRGS COMBINATION OF THE TERRESTRIAL FRAME AND EARTH ORIENTATION PARAMETERS AT THE OBSERVATION LEVEL. CONTRIBUTION TO ITRF2008 REALIZATION

Richard, J-Y.[1], Bizouard, C.[1], Bourda, G.[2], Deleflie, F.[3], Gambis, D.[1], Loyer, S.[4] and Soudarin, L.[4]

Abstract. A new version of ITRF (ITRF2008) is planned and requests combination of the various astro-geodetic techniques over a period of several years. In the framework of the " Groupe de Recherches de Godsie Spatiale ", GRGS, we are combining normal equations derived from the processing of four techniques on a regular weekly basis (GPS, VLBI, SLR and DORIS). Observations of these techniques are separately processed at different analysis centers of GRGS using the software package GINS-DYNAMO, developed and maintained by GRGS. The strength of the method is the use of a set of identical up-to-date models and standards in unique software. The datum-free normal equation matrices weekly derived from the analysis of each technique are stacked to derive solutions of Station Space Coordinates, and Earth Orientation Parameters (EOP). In this presentation, we explain the process to obtain weekly combined normal equations and validate the EOP global solutions with respect to C04 series and the SSC with respect to the ITRF2005.

1 Introduction

In this paper, we propose a combination process of geodetic observations to estimate both EOP and terrestrial frame (Coulot et al. 2007; Gambis et al. 2009). To have an overview of combination of geodetic techniques see Rothacher (2002). From 2007 until the end of 2008 normal equations (NEQ) concerning the four techniques VLBI, GPS, DORIS and SLR were processed to contribute to the new realization of the TRF, ITRF2008, whereas the former terrestrial frame ITRF2005 was published in 2007 (Altamimi et al. 2007). The process consists in using the NEQ produced by the Analysis Centers of VLBI (LAB Bordeaux Observatory), GPS and DORIS (CLS) and SLR (OCA Geoazur). Each Analysis Center produces weekly datum-free normal equations containing EOP and SSC, processed with the GINS/DYNAMO package. Other method of combination is presented in Pesek & Kostelecky (2006). The five EOP are pole coordinates (X,Y) and UT1-TAI (sampling 6 hours), nutation parameters ϵ and ψ (sampling 12 hours) and station coordinates (weekly measurement). Other parameters such as the gravity field coefficients, ocean tides, quasar coordinates, troposphere zenithal delay, orbital bias, satellite orbits, non gravitational forces, station shift coordinates are eliminated from stacked NEQ. The common geophysical models included within the GINS software, insure the consistency of observations, especially for EOP. In future, LLR observations could be included in these combinations, but the lack of LLR measurements between 2005 and 2009 disqualifies this technique.

The datum free normal equations generated by each analysis center are deposited on the ftp web site at the Paris Observatory (ftp://dynamo.obspm.fr/data/). Processes are then applied to construct the weekly combined normal equations. In the call for participation in ITRF2008, it was proposed to submit solutions resulting from a combination of various techniques at the observation level. The main requirements of ITRF2008 are to avoid any correction for geophysical fluid loading effects, except for tidal ocean loading, and to provide time series solutions in SINEX version 2.0 format in two classes: (1) Free singular normal equations (2) Solutions with TRF minimum/inner constraints.

[1] Observatoire de Paris SYRTE, 61 av. de l'Observatoire, 75014 Paris, France (jean-yves.richard@obspm.fr, +33 1 40 51 23 67)
[2] Université de Bordeaux LAB CNRS, Bordeaux, France
[3] Observatoire de la Côte d'Azur / Geoazur - GRGS, Grasse, France
[4] Collecte Localisation Satellite, Ramonville Saint Agne, France

2 Combination process

The working plan for constructing the ITRF2008 weekly normal equations is explicitly summarized in figure 1.

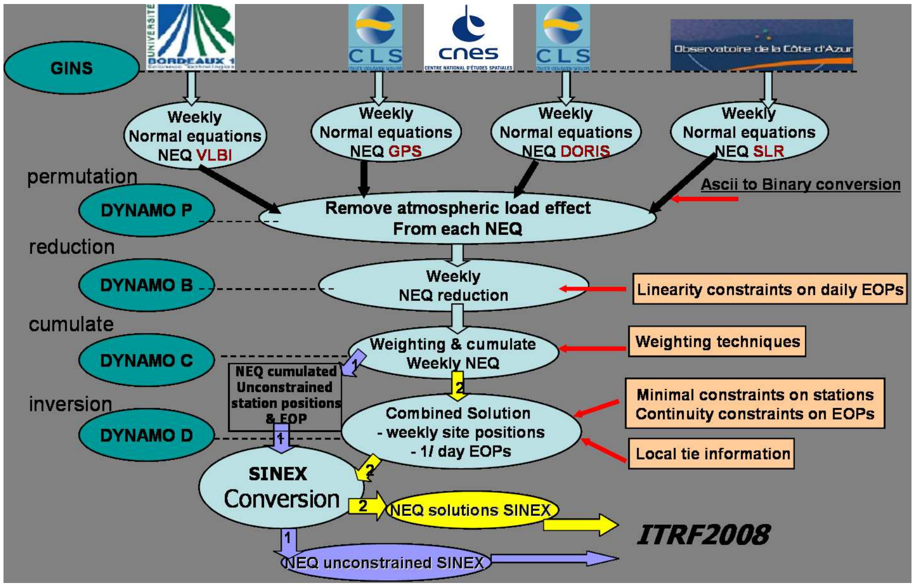

Fig. 1. Two steps are applied: 1- Production of NEQ solutions contributing to ITRF2008 and 2 -NEQ stacking using ITRF2005 and C04 as a priori for solution validation

2.1 Common process

EOP are sampled every 6h for X and Y pole coordinates and for UT and every 12h for nutation ϵ and ψ. To produce NEQ with daily EOP at 12pm as required, we introduce a linear piecewise constraint over each day and reduce the resulting EOP at 12pm. Equation system (1) express the linear constraint applied. P_j is the unknown parameter at the j date. $P_j(t)$ value (t=0,6,12,18) is forced to be on a line with an uncertainty $\sigma_P = 0.5$ for pole coordinates and for Universal Time. This linearity constraint is applied either on the corrections dP_j or on the solution plus corrections $P_j(t) + dP_j(t)$. In our case the linearity is applied on the EOP corrections with respect to the a priori EOP C04 series. These constraints on EOP are introduced while reducing all parameters not used and keeping the station coordinates as fixed to ITRF2005.

$$\begin{cases} P_j(6h) = \frac{3}{4}P_j(0h) + \frac{1}{4}P_{j+1}(0h) \\ P_j(12h) = \frac{1}{2}P_j(0h) + \frac{1}{2}P_{j+1}(0h) \\ P_j(18h) = \frac{1}{4}P_j(0h) + \frac{3}{4}P_{j+1}(0h) \end{cases}$$

Weekly resulting NEQ are weighted with a scaling factor depending on the techniques, and cumulated. The cumulated NEQ when reduced and unconstrained are produced on a weekly basis and available for steps 1 or 2.

2.2 Step 1: Unconstraint EQN in SINEX format

The non constraint normal equations are converted in SINEX format and sent to the ITRS Center (figure 1).

2.3 Step 2: Generating solutions in SINEX format

This second step consists in inverting the unconstrained weekly NEQ by introducing different constraints as explained by Sillard & Boucher (2001). First continuity constraints on daily EOP are applied with an uncertainty of 1.3mm for polar coordinates (X,Y) and for nutation (ϵ,ψ) and 1μs for Universal Time. Second systematic constraints are applied to stabilize the station positions. The station space coordinates corrections with respect to the a priori terrestrial frame ITRF2005 are limited to 1m for the three cartesian coordinates (X,Y,Z). The local ties information concerning 26 collocated stations are introduced and minimal constraints on transformation parameters are fixed to zero with a correction less than 10m. That forces the four technical networks to the a priori terrestrial frame ITRF2005 with a loose constraint. Earth orientation parameters and station space coordinates are estimated altogether in these weekly NEQ inversions. The daily EOP solutions and weekly station positions produced are deposited at the web site http://syrte.obspm.fr/~richard/ITRF2008/ (in ASCII format, SINEX format is now not available).

3 Earth Orientation Parameters solutions by combination at the observation level

Earth orientation parameters are determined throughout step 2. The combined NEQ solutions for pole coordinates are obtained by weighting GPS to 5.2, SLR to 1.7, VLBI to 1.9, and DORIS to 1.1 as obtained from the Helmert process (Sahin et al. 1992). The constraints mentioned in step 2 are applied. Since nutation and polar motion are correlated, retrograde polar motion corresponds to nutation, we choose as a first step to fix nutation to the a priori EOP C04 series. Station coordinates have been fixed to the a priori ITRF2005. The combined NEQ solutions for nutation (ϵ,ψ) are computed in cumulating the four techniques with the same weighting (GPS to 5.2, SLR to 1.7, VLBI to 1.9, and DORIS to 1.1) and by fixing the pole coordinates (X,Y) and UT to the a priori EOP C04 series. Although UT1 from VLBI is completed by GPS, DORIS and SLR UT1 measurements, their combinations do not improve UT1 estimation. This is due to the drift on UT1 issued from GPS measurements. Other approaches to combine GPS and VLBI were investigated by Thaller et al. (2006) and Gambis & Bizouard (2009). This approach is to be investigated to study the improvement of UT1 estimation by combination of VLBI UT1 and LOD from other geodetic techniques. The series of daily corrections for polar motion (X, Y) and solutions with their associated corrections for nutation (ϵ,ψ) are shown figure 2 as illustrations of the quality realized with respect to a priori EOP C04. To compare EOP solutions obtained for each geodetic technique to the combination series we have proceeded by cumulating the weekly NEQ separately for each technique with unit weighting. The estimation of EOP from cumulated NEQ of one technique consists to proceed in the same manner than step 2 mentioned above. The EOP solutions estimated by each technique are compared to EOP estimated by the multi-technique combination. RMS values weighted on inverse uncertainties are reported in Table 1. It appears that the combination leads to a small degradation of the pole component quality if we compare to GPS. This is probably due to the weighting of the different techniques for which the weight of GPS is under estimated in the combination. We can also note that nutation parameters have been better estimated by multi-technique combination in comparison with VLBI technique. It shows that nutation parameters are slightly improved by the multi-technique combination probably due to the density geodetic satellite for nutation measurements every 6h that contribute to stabilize these parameters.

EOP	VLBI	GPS	DORIS	SLR	Combination
X pole (μas)	352	72	435	271	90
Y pole (μas)	332	82	330	206	105
ϵ (μas)	388	X	504	548	291
ψ (μas)	341	276	359	690	281
UT1 (μs)	17.7	X	47	26.3	X

Table 1. Weighted RMS values on inverse uncertainties in μs (X: inconsistent)

4 Conclusions

The development of these processes allows computing simultaneously Earth Orientation Parameters and a terrestrial frame by combination at the normal equation level. The second aspect concerns the capability to compare our combination products (EOP and station positions) to others combination of intra techniques such as IVS, ILRS, IGS or IDS which contributes to the ITRF2008. The weekly weighting NEQ of each geodetic technique is worth being followed to optimize EOP measurements in order to benefit better from multi technique combination. Concerning analysis of transformation parameters and station space coordinates solutions, we invite to see Gambis Richard et al. (2009). For station positions it will be interesting to evaluate other sites

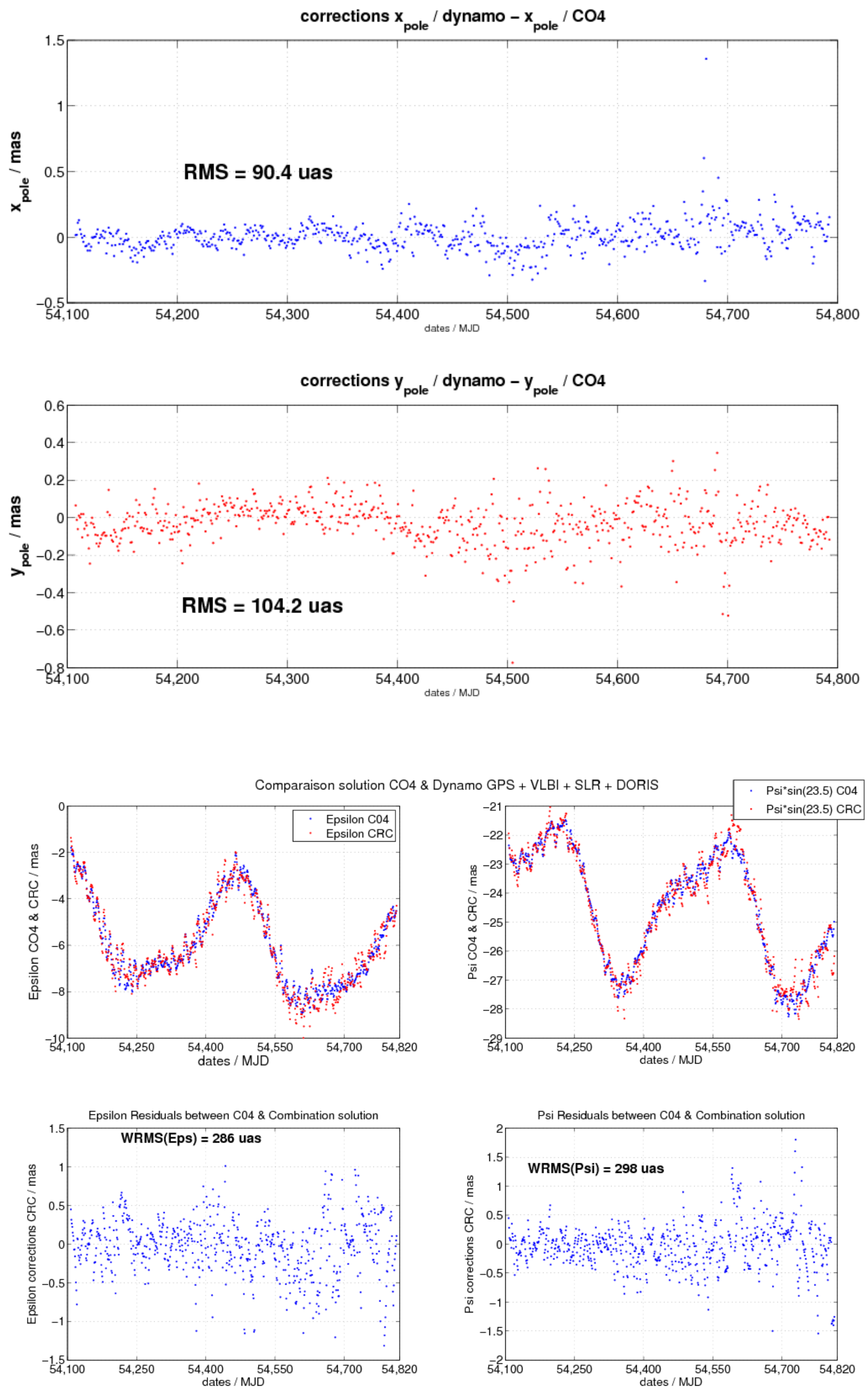

Fig. 2. Daily X and Y pole corrections, nutation solutions and corrections

with collocated stations to observe and compare the station motions with official ITRF2008. . Other method of combination is presented in Pesek & Kostelecky (2006) and should be compared to this one. Forthcoming papers will evaluate our combination products with others techniques over a longer period and to product solutions in order to participate to the future realization of ITRF.

The authors are grateful to H. Capdeville, J.M. Lemoine, T. Carlucci, for their assistance during this study. The authors express their thanks to CNES for making available GINS/DYNAMO package.

References

Altamimi, Z., Collilieux, X., Legrand, J., Garayt, B., Boucher, C. 2007, *ITRF2005, a new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters*. JGR, Vol. 112, B09401

Bizouard, Ch., Gambis, D., Becker, O., Richard, J.Y. 2009, *Combination of EOP from different techniques*. Proceedings of the "JSR spatio-temporels", 153

Coulot, D., Berio, P., Biancale, R., Loyer, S. et al 2007, *Toward a direct combination of space-geodetic techniques at the measurement level: Methodology and main issues*. JGR, Vol. 112, B05410

Gambis, D., Biancale, R., Carlucci, T. et al 2009, *Combination of Earth Orientation Parameters and terrestrial frame at the observation level*. Springer Verlag series, Series International Association of Geodesy Symposia, Vol. 134, Drewes (Ed), 3, DOI 10.1007/978-3-642-00860-3

Gambis, D., & Bizouard, C. 2009, *Monitoring UT1 using VLBI and GPS estimates*. Proceedings 19th European VLBI for Geodesy and Astrometry and EVGA Bourda, Charlot, Collioud (eds), 107

Pesek, I., & Kostelecky, J. 2006, *Simultaneous determination of earth orientation parameters and station coordinates from combination of results of different observation techniques*. Stud Geophys Geod 50, 537

Rothacher, M. 2002, *Towards a Rigorous Combination of Space Geodetic Techniques*. Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids, IERS TN. No.30, Munich, Germany

Sahin M., Cross P. A., Sellers P. C. 1992, *Variance component estimation applied to Satellite Laser Ranging*. Bull. Geod., 66, 284

Sillard, P., & Boucher, C. 2001, *A review of algebraic constraints in terrestrial reference frame datum definition*. JGR, 75, 63

Thaller, D., Krgel, M., Rothacher, M., Tesmer, V., Schmid, R., Angermann, D. 2006, *Combined Earth orientation parameters based on homogeneous and continuous VLBI and GPS data*. JGR, Springer-Verlag, DOI 10.1007/s00190-006-0115-z