COMBINATION OF GEODETIC TECHNIQUES TO DETERMINE THE EARTH ORIENTATION PARAMETERS

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ABSTRACT. In the framework of the IERS Combination Research Centers, the Groupe de Recherche de Geodesie Spatiale (GRGS) from CNES has proposed to study the combination of five techniques (SLR, LLR, VLBI, GPS and DORIS) in order to obtain a global and homogeneous solution of the Earth Orientation Parameters (EOPs) : universal time UT1, pole motion and nutation corrections in longitude and obliquity, as well as stations coordinates. Advantages and inconvenient of three of these techniques (SLR,VLBI and GPS) are discused in terms of precision and resolution, and solutions for the EOPs are given. A combined solution is undertaken over three months and compared to the IERS products.

1. INTRODUCTION

Each geodetic technique has his own advantages and failings in the determination of precise geophysics parameters. Our motivation in this work is to exploit the benefit of each one of them to form the best possible combination to obtain precise parameters of the Earth rotation. In order to reach this goal, a preliminary work was undertaken last year. It concerned the comparison and the combination of Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) (Yaya, 2000) over one month. The next step described in this paper consists in adding the Global Positioning System (GPS) technique, which now plays a significant role in the combination of individual series used to obtain IERS pole motion series. We also extend our time span to three months. For example, this has multiplied by four our number of VLBI session (from three to thirteen) and should give more reliable results.

2. DATA PROCESSING

2.1 Models and data

We adopt, as far as possible, the same models for all the techniques. They are either derived from GRSG GRIM5 gravity models or taken from IERS Conventions (McCarthy, 1996). With those environmental models, we will be able to process the distinct data, synthesized in figure 1.

SLR data come from Lageos1 and Lageos2 measurements. They can be found at CDDIS web site and range from 5 July 2000 to 26 September 2000. We analyzed approximately 2000 observations per week coming from about 30 stations, localised for the majority in the northern hemisphere. The inherent bias coming from this unbalanced distribution should be solved by the combination.

For VLBI, we used all the "NEOS" data (USNO program) available between 1 July 2000 and 30 September 2000, *i.e.* thirteen principal 24-hour sessions, and four additionaly 24-hour sessions from the NASA "CORE" program. VLBI programs for Earth rotation are not continuously carried out, introducing problems for an optimum combination. The number of observations are about 1000 per session (half time less numerous than SLR observations) involving about 4 to 6 stations.

GPS data consist of about 700,000 observations (5 minute normal points) per week, from a main network of 40 stations collecting data from the 24 satellite constellation. The important number of GPS observation is able to compensate the relatively poor precision of the measurements.

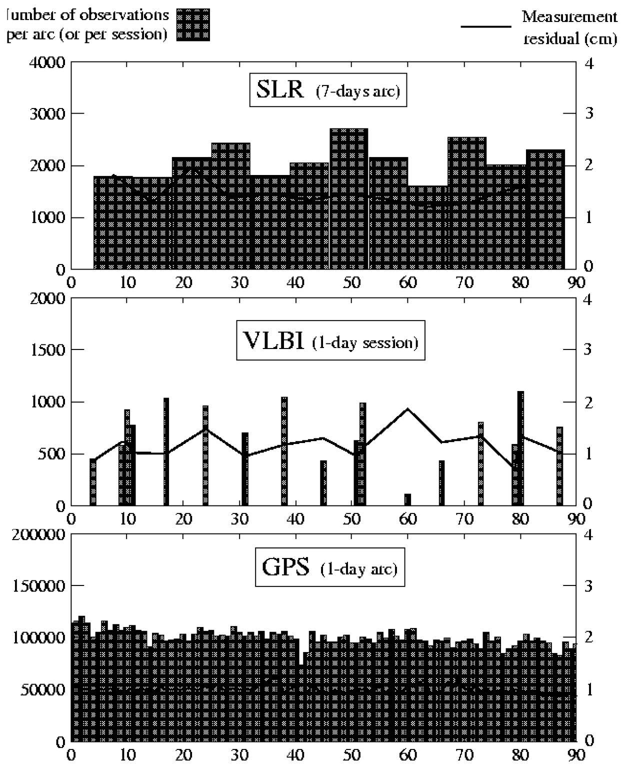

Figure 1: Number of observations and measurements residuals after GINS processing (abscissa : days from 1 July 2000)

2.2 Processing with GINS/DYNAMO software

GINS/DYNAMO was developed at CNES (the French spatial agency, in Toulouse) about twenty years ago. It was initially dedicated to earth satellite orbitography, giving also parameters related to gravity field, geophysics or Earth rotation. New routines have been implemented in the software in 1999 in order to process VLBI data (Meyer *et al.*, 2000). Although there is no orbit integration for VLBI, the first results seemed to be encouraging in comparison with the JPL MODEST software.

Our software uses a classical least-square method to get the parameters, which are estimated by minimizing the differences (the residuals) between the observed and the calculated quantities. For satellite technique those quantities are the distances between a station and the satellite (in fact a time, changing in distance using a precise model of wave propagation). As for VLBI, the equivalent quantities are the time delays between two stations observing a same quasar.

The minimization of the residuals is done by GIN module, which finally gives a normal equation for each technique, with the partial derivatives of the parameters we want to solve for (orbital elements, as well as stochastic forces, tropospherics parameters, and, of course, the EOPs). The second module of our software, DYNAMO, is able to mix these equations, with a special weighting, to add new parameters if necessary, to reduce some of them, and to finally obtain the parameters we are interesting in, by inversion of the grouped normal equation.

3. RESULTS AND ANALYSIS

3.1 Processing results

The measurement residuals obtained by GINS module are shown in figure 1 for each technique, in comparison with the number of observations, showing some correlations between them, especially for VLBI where the number of observations is not as regular as the other technique.

The processing of SLR observations with GINS has proven itself for years at GRGS. The orbits residuals obtained for the 3-months period of this study have a root mean square (rms) of about 1.5cm for 7-day arcs, which is a common value for that kind of measurements.

As for VLBI, the usual value for the delay residuals rms - obtained with MODEST (JPL) or GLORIA (Gontier, 1992) - is about 40 picoseconds (ps) for a daily estimation. Our processing leads to the same value, between 30 and 60 ps, with a 40ps mean rms over the 3 months. We increased our precision by a factor 4, comparing to our last study (Yaya, 2000) thanks to a better estimation of tropospheric parameters (estimations each 2 hours). In figure 1 we convert our rms in distance value, multiplying them by the speed of light.

GPS has regular residuals during the test period : the range rms present a small variation around 1cm, which is a common number for range value. Our internal precision in then quite good. But the comparison of our orbits with IGS (International GPS Service) ones highlight clearly a lack of precision (about 10cm rms).

The three techniques present almost the same residuals, varying between 1 and 2 cm. This value is in accordance wih the precision we want to reach for the EOPs.

3.2 Results of EOPs estimates

Figure 2 compares, for each technique and for the combination, our daily series of pole motion and universal time with the reference IERS series EOPC04. SLR estimates present a usual rms *w.r.t* EOPC04 of 0.4 mas and no exageratted bias. For UT, we seem to detect a linear trend, althought satellite techniques are not adequate to estimate the Earth rotation rate (due to the correlation with the orbit node precession).

The GPS rms *w.r.t* EOPC04 is twice higher than those of other groups determining EOPs with GPS. It is surely due to the deficiency of precision in the orbits, as shown previously. This orbital trouble also probably causes the bias and trend in the estimates, especially for the Xp coordinate. We seems to observe a 2-months period signal in the Yp coordinate but further work need to be undertaken to confirm it. As SLR, GPS cannot precisely solve for UT1.

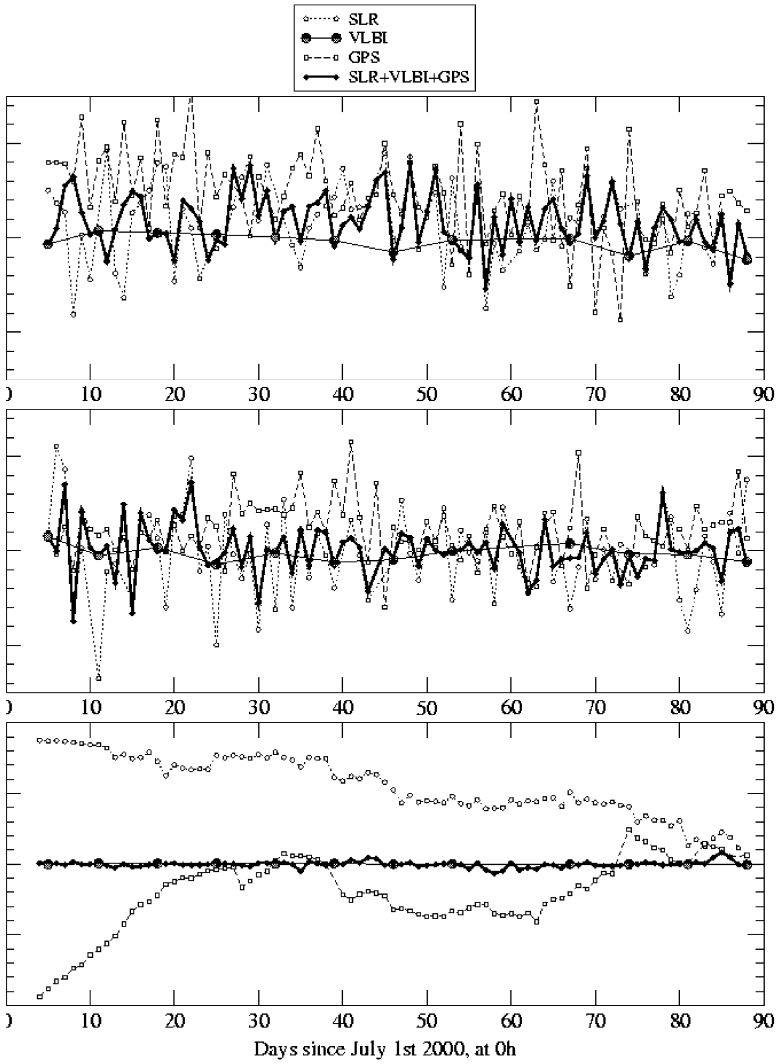

Figure 2: EOP differences between the IERS EOPC04 series and LAGEOS/VLBI solution series

Table 1: Comparison with EOP C04

		rms	bias	mean error
	SLR	0.45	0.12	0.14
Xp	VLBI	0.21	0.04	0.21
(mas)	GPS	0.47	0.49	0.08
	SLR+VLBI+GPS	**0.31**	**0.19**	**0.03**
	SLR	0.54	0.01	0.14
Yp	VLBI	0.16	-0.03	0.29
(mas)	GPS	0.37	0.22	0.08
	SLR+VLBI+GPS	**0.33**	**0.03**	**0.03**
UT	VLBI	0.17	0.02	0.14
(*0.1ms)	**SLR+VLBI+GPS**	**0.57**	**-0.14**	**0.03**

Concerning VLBI, the quality of the estimates are really excellent. The modelling of the measurement processing in GINS has been realized with success. Both pole coordinates and UT1 are determined with a great precision and a nice rightness. This is encouraging if we keep in mind that VLBI plays an important role in the IERS estimates of all EOPs, including nutation.

Finally, the results of the combination is shown in both table 1 and figure 2. We have applied a simple combination with the a-priori weights used in the GINS processing. DYNAMO software simply add the normal equation from each technique. The resulting series presents a stable (no bias) and a lower noise than the individual satellite series. Of course VLBI keeps its first rank due to its correspondance with a very-stable reference frame, but 7-days estimates introduce smoothness of the values.

4. CONCLUSION

This study has pointed out the advantage of combining VLBI to satellite techniques, such as GPS and SLR. The addition of other techniques like DORIS or LLR should improve our combination, or in the worst case would not introduce any regression of quality, as we just add some new measurements. The problem of weighting each technique with respect to others is a very important problem and will be our next step in our combination work. Nevertheless we could go further with the present data : for example, evaluate nutation will be a interesting test for VLBI goodness. We can also improve our final series quality with a combination processing of 24h and intensive VLBI sessions. Another way of study would be to estimate the stations positions, this could point out the problem of collocation, and maybe solve some of them. To conclude, our combination method seems to be very encouraging for the future and competitive in the framework of the Combination Research Centers studies.

6. REFERENCES

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