COMBINATION OF SPACE GEODESY TECHNIQUES FOR MONITORING THE KINEMATICS OF THE EARTH

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Abstract

In the framework of activities of the International Earth Rotation and Reference Systems Service (IERS) Combination Research Centres (CRC), the french Groupe de Recherche en Géodésie Spatiale (GRGS) studies the benefit of combining four geodetic techniques (SLR, VLBI, GPS and DORIS) at the measurement level in order to obtain a global and consistent solution for Earth Orientation Parameters (EOPs): polar motion x_p and y_p, universal time UT and celestial pole offsets in longitude and obliquity $d\psi$ and $d\varepsilon$ with a six-hour sampling, as well as weekly station positions. A one-year test period (the year 2002) has been chosen to prove the power of such a combination moreover worked out in a homogeneous global terrestrial reference frame. All techniques were processed with the same computational framework (GINS/DYNAMO) so with the same a priori models and a priori values for parameters. The optimal relative weights between each geodetic technique were obtained with an optimal variance component estimation method. The aim of this paper is to describe the processing and the precision level of each individual technique for EOPs, to show how we handled with the combination of techniques and to discuss some results.

Introduction

The International Earth Rotation and Reference Systems Service (IERS) is an interdisciplinary service responsible for the definition, the production and the maintenance of the International Terrestrial and Celestial Reference Frames (ITRF and ICRF) and Earth Orientation Parameters (EOPs). This service also provides users with conventions (physical constants and models) which should especially be used by the IERS analysis centres to derive the IERS products. Concerning Earth orientation, IERS provides daily EOPs since 1962 (time series *EOPC04*, for example). These series are derived from VLBI measurements and spatial geodetic measurements (such as SLR, GPS and DORIS). VLBI provides absolute but sparse reference for the determination of the universal time and the celestial pole offsets. The geodetic techniques provide the short-period variations of these quantities and provide the polar coordinates as well. The production of EOP time series consists in combining solutions of each individual technique which have been computed by different IERS analysis centres. The inaccuracies of such a combination come from (i) the heterogeneity of the reference frames in which individual EOP solutions have been derived and (ii) the diversity of the softwares (algorithms, constants and models) developed and used by IERS analysis centres. Furthermore, the different products of IERS (ITRF, ICRF and EOPs) are still computed independently and it can cause inconsistencies between them. Even if inaccuracy due to (ii)

should be reduced thanks to the IERS conventions, subtle differences may still lead to systematic effects. In order to fully cancel these sources of inaccuracy and these inconsistencies, we combine VLBI, SLR, GPS and DORIS techniques at the measurement level in order to obtain a global and consistent solution for EOPs (polar coordinates, universal time and celestial pole offsets with a six-hour sampling), as well as weekly station positions. All techniques are processed with the same softwares (GINS/DYNAMO), so with the same fundamental constants, the same physical models and the same *a priori* values for parameters of interest. EOPs and Terrestrial Reference Frames (TRFs) are computed together during the same processing in order to avoid for inconsistencies between them. The processing and the main results for EOPs are presented in this paper. After having described the method of the global combination carried out at the measurement level (Sect. 2), we analyse and discuss the results (Sect. 3).

Method of combination

The test period chosen for the combination is the year 2002. More precisely, this period begins on December 30, 2001 (Julian Date 2 452 273,5) and ends on January 01, 2003 (Julian Date 2 452 643,5). The GINS software provides the sensitivity of measurements with respect to parameters of interest, through weekly normal matrices per technique. In our case, these parameters are EOPs and positions of GPS, SLR, DORIS and VLBI stations. Each week, normal matrices of the four techniques are used to obtain a "four-technique" normal matrix. This processing is carried out in two steps. In the first step, the four matrices are used to compute the relative weights between techniques with an optimal variance component estimation method [Sahin and Sellers 1992]. These four relative weights are used in the second step to gather the four individual normal matrices in a global weekly normal matrix taking into account the quality of each technique. The weekly normal system so obtained can not be solved for without any additional information on parameters (EOPs every six hours and station positions every week). We so give these supplementary informations as constraints on parameters ("continuity constraints" on EOPs acting as a filter and minimum constraints for station positions [Sillard and Boucher 2001]) which allow us to invert the normal system and to obtain the final solutions. The EOP offsets are computed with respect to the IERS time series *EOPC04* [EOP PC] corrected with the diurnal and sub-diurnal model of [Ray et al. 1994]. The station position offsets are computed with respect to ITRF2000 positions [Altamimi et al. 2002] corrected with models of IERS conventions [Mc Carthy 1996].

Results for EOPs

There is no absolute method to evaluate the quality of EOP time series. Usually, the quality assessment of time series is done through comparisons with other series and/or with theoretical models. In our case, we choose to compare the one-day and six-hour sampling combined time series with each individual series through the RMS of the estimated offsets (Table 1). The dx_p, dy_p and dUT series with a six-hour sampling are also analysed in the frequency domain (Figure 1).

Table 1. Root Mean Squares of the individual and combined EOP time series. Units are mas for x_p and y_p and ms for UT. The names C_{1D} and C_{6H} correspond respectively to the combined series with a one-day and a six-hour sampling.

Technique	dx_p	dy_p	dUT	Technique	dx_p	dy_p	dUT
GPS	0,107	0,101	0,0175	SLR	0,182	0,180	0,0198
DORIS	0,650	0,552	0,153	VLBI	0,150	0,230	0,0056
C_{1D}	0,108	0,106	0,0131	C_{6H}	0,423	0,423	0,0177

The RMS of the individual series are in good agreement with those usually obtained by the IERS analysis data centres. The C_{1D} series present a RMS of 0.1mas for the pole coordinate offsets in agreement with the GPS series whereas the RMS of dUT is strongly reduced. This shows that our combination process takes advantage of the characteristics of each technique. So the dUT series seem to be mainly influenced by the VLBI technique which is known as the best one for this parameter, even if the RMS for UT of the combined series is more than two times greater than those of the VLBI series. This is probably explained by the different kind of constraints applied for the VLBI series. Indeed the VLBI technique can not give a continuous daily sampling for EOPs. For this reason, we use constraints to zero for EOPs and not continuity constrains as for other techniques or combinations.
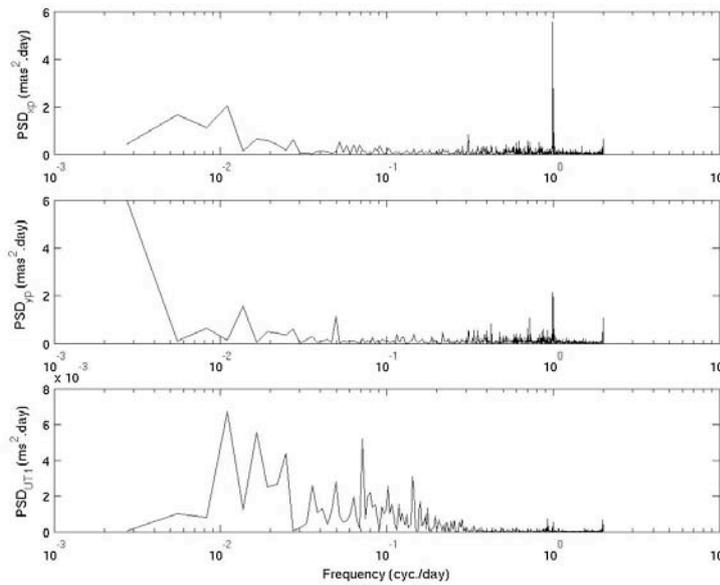
Figure 1. Power Spectral Densities (PSDs) of the x_p, y_p and UT offsets

As shown on Figure 1, the pole coordinate offset time series present an harmonic with a frequency of 1 cycle/day. This diurnal term in polar motion is retrograde and has an amplitude of 140 ⇐as. It is probably associated with orbit computation deficiencies (correlation between a daily retrograde polar motion and the right ascensions of the ascending nodes and the inclinations [Hefty et al. 2000]). Besides the three PSDs present low frequency harmonics. Their associated periods are mainly multiples of one week. The week is the characteristic period of our combination process since EOPs are estimated week per week. Therefore these low frequency harmonics seem to be mainly due to our processing method and to have no physical sense in terms of Earth rotation.

Conclusion

The analysis of the combined series of EOPs with a six-hour sampling shows that our method of combination at the measurement level is working. Furthermore this method provides a global and consistent solution of EOPs and station positions simultaneously with a satisfactory sampling. This kind of computation seems to be the future for Reference System realization and maintenance.

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