NUTATION AND HIGH PRECISION ASTROMETRY OBSERVATION TECHNIQUES

K. YAO, N. CAPITAINE, S. LAMBERT
SYRTE, Observatoire de Paris, CNRS, UPMC
61, Ave. de l'Observatoire, 75014 Paris, France
e-mail: kunliang.yao@obspm.fr, n.capitaine@obspm.fr, sebastien.lambert@obspm.fr

ABSTRACT. The purpose of this paper is to compare the principles and potentials of the best high accuracy astrometry/geodetic techniques for the determination of the Earth's nutation. Nutation estimation is currently dominated by VLBI observations. The GNSS satellite orbits are not stable celestial references due to the discrepancies in the models for various perturbations and are correlated with Earth's rotation. But the high precision and the high time resolution of the GNSS observations give them the possibility to be used to estimate short-period nutation terms. In this work, based on observations from 2002 to 2010, we make an evaluation of the precision and resolution that can be achieved by each of these techniques for the estimation of the amplitudes of nutation as functions of the period. We report on the accuracy of the IAU 2006/2000 precession-nutation model as compared to VLBI observations and on some preliminary tests for possible GNSS contribution for improving that model.

1. DETERMIMATION OF NUTATION BY VLBI AND GPS

VLBI is currently the most important technique to estimate the Earth rotation angle, ERA, (or length of day, or UT1) as well as precession-nutation; IVS analysis centers currently provide celestial pole offsets, i.e. corrections ($\mathrm{d}X$, $\mathrm{d}Y$) to the IAU 2006/2000 precession-nutation model (Wallace & Capitaine, 2006), X, Y being the coordinates of the Celestial intermediate pole (CIP) in the Geocentric Celestial Reference System (GCRS).

GPS is the most important technique to estimate the pole coordinates x_p, y_p, but does not provide celestial pole offsets. However, it has been shown (Rothacher et al. 1999, Weber & Rothacher, 2001) that GPS can contribute to nutation estimation for short term nutations.

In both techniques, the effect of precession-nutation appears through the transformation between coordinates [ITRS] in the International Terrestrial Reference System and [GCRS] in the GCRS by the following equation:

$$[GCRS] = Q(t) * R(t) * W(t) * [ITRS], \tag{1}$$

where Q(t) is a matrix determined by (X, Y), R(t) is a matrix determined by the rotation angle ERA, and W(t) is a matrix determined by (x_p, y_p).

1.1. Analysis of VLBI solutions

We have applied a least-squares method, based on Equation (2), to different VLBI solutions for estimating the largest corrections to nutation :

$$dX + \mathrm{i} * dY = \sum (A_{retro} * e^{retro} + A_{pro} * e^{pro}). \tag{2}$$

The results shown in Table 1 are all consistent for terms with periods greater than 27.6 days, but large discrepancies appear between those corresponding to shorter periods. This implies that VLBI is able to estimate corrections to the IAU 2000 nutation; it can detect a small signal corresponding to the long period nutation terms, but is not efficient for estimating short period terms.

Amplitudes (uas)	solution YAO		bkg00013		iaa2007a		opa2010d	
periods	Real	imag	real	imag	real	imag	real	imag
-6798.4	26.8 ±1.8	-31.1 ±1.8	59.1 ± 2.2	-16.0± 2.2	22.5 ± 2.2	-42.8 ± 2.2	28.5 ± 1.3	-27.2 ± 1.3
6798.4	18.4 ±1.8	-34.8± 1.8	30.3± 2.2	-23.8± 2.2	21.9± 2.2	-35.2± 2.2	24.3± 1.3	-28.6±1.3
-182.6	-11.3± 1.6	5.5± 1.6	-13.3± 2.1	7.9± 2.1	-15.6± 2.1	5.3± 2.1	-11.8± 1.1	6.0± 1.1
-27.6	-15.0± 1.6	-3.4± 1.6	-14.7± 2.1	-4.4± 2.1	-17.7± 2.0	-2.9± 2.0	-14.7± 1.0	-6.8± 1.1
-13.7	-14.9± 1.6	-12.3± 1.6	-9.5± 2.1	-9.1± 2.1	-14.3± 2.0	-10.9± 2.0	-10.6± 1.0	-11.9± 1.0
13.7	-7.6± 1.6	11.5± 1.6	-8.3± 2.1	12.4 ±2.1	6.1± 2.0	-5.9± 2.0	-4.9± 1.0	12.8± 1.0
-9.13	-5.3± 1.8	2.8± 1.8	-7.2± 2.2	3.7± 2.2	-4.3± 2.2	-0.5± 2.2	-5.5± 1.1	0.7± 1.1
7.10	7.0± 1.6	-0.2± 1.6	7.6± 2.1	-1.4± 2.1	6.3 ±2.0	-1.2± 2.0	-2.8± 1.1	0.0± 1.1
6.86	5.1± 1.9	-1.2± 1.9	5.8± 2.4	5.3± 2.4	1.7± 2.3	7.3± 2.3	2.8± 1.2	1.1± 1.2
WRMS (mas)	dX	dY	dX	dY	dX	dY	dX	dY
pre-fit	0.618	0.886	0.177	0.191	0.176	0.217	0.231	0.219
FCN removed	0.604	0.823	0.142	0.140	0.141	0.144	0.181	0.184
post-fit	0.579	0.767	0.122	0.123	0.118	0.121	0.133	0.133

Table 1: Amplitudes of a few nutation terms estimated by least-squares analyses of VLBI solutions and WRMS

1.2. Satellite orbital elements and nutation

By investigating the ITRS satellite position, we can obtain from Equation (1) and (Rothacher & Beutler 1999), the following relations between the $\dot{X}$, $\dot{Y}$, $\dot{\text{ERA}}$ and satellite orbital parameters rates (Ω: ascending node, i: inclination, u_0: argument of latitude at the osculation epoch):

$$\dot{\text{ERA}} = -\dot{\Omega} - \cos i \cdot \dot{u}_0, \quad \dot{X} = -\sin\Omega \cdot \dot{i} + \sin i \cos\Omega \cdot \dot{u}_0, \quad \dot{Y} = \cos\Omega \cdot \dot{i} + \sin i \sin\Omega \cdot \dot{u}_0. \tag{3}$$

Due to strong correlations, the $\dot{X}$, $\dot{Y}$, $\dot{\text{ERA}}$ estimates are affected by the systematic errors in the orbital elements coming from deficiencies in the gravitational and non gravitational forces. Therefore, in order to use Equation (3) with the real GPS satellite orbital elements (see Figure 1), the main sources of perturbations (listed in Table 2) need to be modeled as best precise as possible.

Main sources of perturbation	acceleration magnitude ($m * s^{-2}$)
Non-sphericity of the Earth	$5 * 10^{-5}$
Moon attraction	$5 * 10^{-6}$
Sun attraction	$2 * 10^{-6}$
Direct and indirect Sun radiation pressure	$1 * 10^{-7}$
Relative effect	$3 * 10^{-9}$

Table 2: Perturbation on the GPS satellite orbital elements

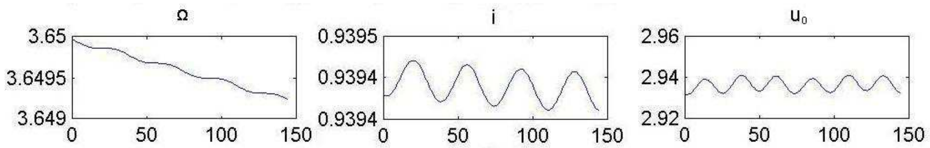

Figure 1: GPS satellite angular orbital elements during 1 day, sample rate: 10 min

The numerical values of the rates of (X, Y) and ERA can be compared with the semi-analytical series for the time derivatives derived from the IAU 2006/2000 model for X and Y (see Yao & Capitaine 2011). This would be a new method to estimate discrepancies in the nutation model. Preliminary tests have been done with GPS observations during a 3-month period in 2011.

2. REFERENCES

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