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Abstract

In 2003 the OPAR Analysis Center activities focused, on the one hand, on the compliance of GLORIA software with the IAU 2000 resolutions. Various tests were performed to compare different ways of implementing the classical expression of the transformation from a geocentric frame to a celestial one. On the other hand, we analyse the impact of the celestial frame stability on the monitoring of the EOP.

1. Implementation of IAU 2000 Resolutions in VLBI Analysis

The analysis of an Earth based observation of celestial objects requires an astrometric model to express the transformation from a geocentric terrestrial frame to a geocentric celestial one. One of the resolutions adopted by the XXIV General Assembly of the IAU (Manchester, August 2000) recommends the use of a new approach referring to the non-rotating origin on the equator of date, proposed by Guinot in 1979 [10], and using the celestial coordinates of the CIP [3], instead of the classical transformation which refers to the equinox of date and uses classical precession and nutation quantities. In GLORIA software the update of the new paradigm and the classical one, based on the IAU 2000 A model for precession-nutation was made and compare together last year [7], [8]. Different ways of implementing the classical transformation have been investigated and tested with GLORIA this year.

Based on Chapter 5 of IERS Conventions 2003 [11], we have implemented two different ways of computing the Greenwich Sideral Time GST:

- version *a*: implementation of the numerical relation between GST and the Earth rotation angle θ referred to the Celestial Ephemeris Origin ([11] chapter 5, equation 35) which includes an update of the "equation of the equinoxes".
- version *b*: modification of the current relationship between Greenwich Mean Sideral Time (GMST) and UT1 [1] to include dGMST ([11] chapter 5, equation 37 with a constant term of 14600μas) due to the correction in the precession rate, together with an update of the "equation of the equinoxes" ([11] chapter 5, second line of equation 35).

In order to study the impact of the frame bias at J2000 (especially the equinox offset dα_0), we have also implemented a so-called VLBI version. It includes the usual precession parameter ([11] chapter 5, equation 31), Herring's routine for nutation "IAU2000A.f" [11] and the computation of GST using version b together with equation 47 of [4].

Various tests have been performed to verify the level of agreement between those three classical versions using the 1999 NEOS sessions. The analyses showed differences less than 0.5μas on polar motion, 0.1μs on UT1 with a slope of 3μs/century between the a version and the others. For dψ $sin\epsilon$, dϵ the differences are less than 0.5μas between a and b version but could reach 3.5μas between a and the VLBI version. For the EOP the mean value of the standard errors is about 53μas.

2. Improved EOP Determination

The study of long time series of radio source coordinates gives the possibility to detect unstable sources that are not suitable for the maintenance of the frame. Statistical schemes to select a subset of objects that would be used for the maintenance of the ICRF and the monitoring of the Earth's rotation have been studied in the Feissel-Vernier [6] paper. The impact of such selection on various applications of the celestial reference frame is described in Gontier et *al.* [8] and Gontier and Feissel-Vernier [9]. The investigation of the use of the stable sources in the determination of EOP is presented hereafter.

The stability of time series of EOP of various origins can be compared by the Allan variance. The Allan variance of a time series x_i with N items and sampling time τ is defined as:

$$\sigma_A^2(\tau) = \frac{1}{2N}\sum_i (x_{i+1} - x_i)^2$$

The Allan variance analysis allows one to characterize the power spectrum of the variability in time series, for sampling times ranging from the initial interval of the series to 1/4 to 1/3 of the data span, in our case one year through four years. This method allows one to identify white noise (spectral density S independent of frequency f), flicker noise (S proportional to f^{-1}), and random walk (S proportional to f^{-2}). Note that one can simulate flicker noise in a time series by introducing steps of random amplitudes at random dates. When several series of measurements of the same phenomenon are available, it is possible not only to derive the level of measurement noise, but also its spectrum by the three-corner-hat method [2], assuming that their measurement errors are independent. The slope of the graph giving the Allan variance as a function of sampling time, both in logarithmic scale, points to white noise (slope = -1), flicker noise (slope = 0), or random walk noise (slope = +1).

Figure 1 shows measurement stability graphs for polar motion and universal time determinations over 1990-2002 based on either all sources or on the stable sources only. The results shown here involve both GPS and VLBI for polar motion, and only VLBI solutions for universal time. The set of VLBI solutions considered are based on seven different source selections, considering various sources characteristics, e.g. defining, stable, unstable, etc [12].

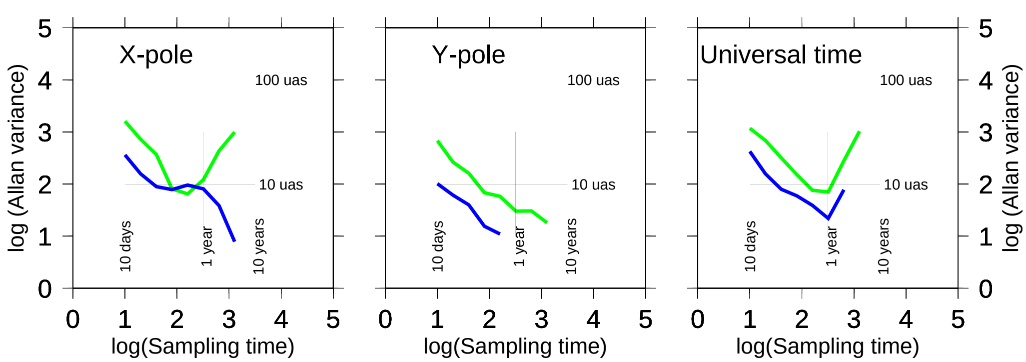

Figure 1. Stability of pole coordinates and universal time over 1990-2002 according to source selection. All sources: green(light); stable sources only: blue (dark).

In addition to the fact that the Allan variance is always lower when using the stable sources only, a striking feature for x-pole is that the use of the stable sources cancels the random walk noise appearing beyond one-year sampling time when using all sources. The reference to the stable sources ensures or strengthens white noise in the long term for the measurement of polar motion. The measurement of universal time involves the stability of both the terrestrial and the celestial reference frames. The possible influence of the terrestrial frame on the remaining random walk signature beyond one year should be investigated.

Nutation is the motion of the Earth's axis in space in response to the torque exerted by the Moon, Sun and planets. The state of the art model recommended by the IAU in 2000 [13], is based on *i*) the modelling of the astronomical external torque at the 0.1 μas accuracy level [14] [15], *ii*) the modelling of the response of the non rigid Earth to this external torque, and *iii*) the VLBI observations relative to extragalactic directions materialized by the quasars. When observed at the current level of precision (a fraction of a milliarcsecond), no object is really point-like. Apparent motions, if existing, may be related to the existence of jets originating in the sources. Such motions may give rise to time varying inhomogeneities in the celestial reference frame that, in turn, could mimic nutation signals.

Studying the influence on nutation of the variable torque exerted by the atmosphere and the ocean, Dehant et al. [5] showed that apparent variability in the celestial frame can lead to changes in estimates of precession or long period nutation coefficients at a level comparable to that of the variable nutation excited by the Earth's fluid layers (a few tens of μas).

Figure 2 shows the celestial frame effect on precession and obliquity rate and on the 18.6 year nutation term. The precession and obliquity rates changed by 20 μas/year and the 18.6 year prograde component by 30 μas.

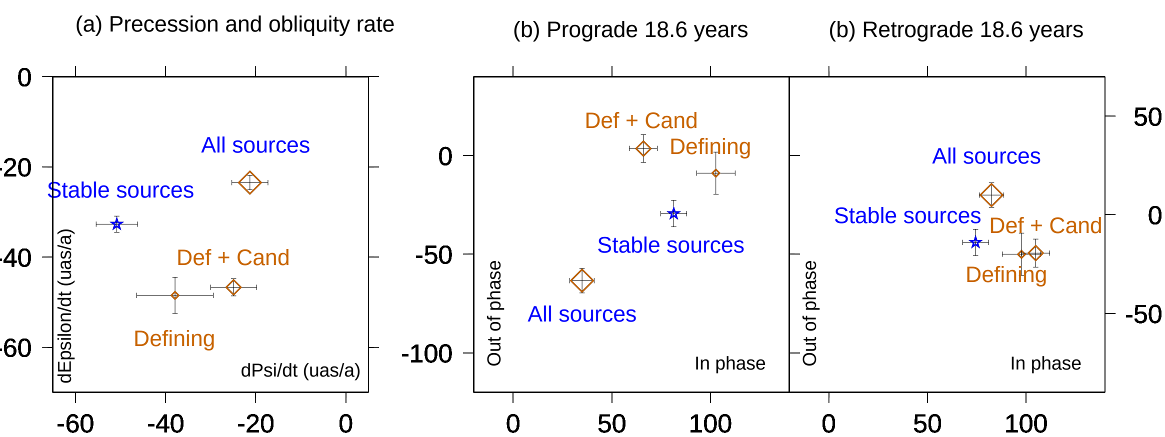

Figure 2. Precession and obliquity rate corrections (left graph) and prograde and retrograde corrections to the 18.6 year nutation term in μas (right graph).

3. Summary

The update of the GLORIA software to comply with the IAU 2000 resolutions was made. The comparisons between the different implementations of the classical transformation showed an agreement better than 4μas on estimated EOP.

M. Feissel-Vernier [6] proposed a source selection scheme based on time series analysis of source coordinates that gives the possibility to detect unstable sources. The consideration of the stable sources strengthens white noise in the long term for the measurements of polar motion. The impact on UT1 is less sensible as the measurement involves also the stability of the terrestrial frame. The improved stability and internal consistency of the frame impacts positively the determination of Earth orientation parameters.

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