Expressions for the Coordinates of the CIP and the CEO using IAU 2000 Precession-Nutation

Nicole Capitaine,[1] Jean Chapront,[1]
Sébastien Lambert,[1] Patrick Wallace [2]

[1] *Observatoire de Paris, SYRTE/UMR8630-CNRS*
[2] *H.M. Nautical Almanac Office, CLRC/Rutherford Appleton Laboratory*

1 Introduction

Expressions for the position of the Celestial Intermediate Pole (CIP) and the Celestial Ephemeris Origin (CEO) in the Geocentric Celestial Reference System (GCRS) have been computed using the IAU 2000A precession-nutation. These expressions are for use in the new transformation between the GCRS and the International Terrestrial Reference System (ITRS) which is recommended by IAU Resolution B1.8. Various comparisons and numerical checks have been performed between the classical and the new transformations based on the IAU 2000A precession-nutation. These comparisons revealed necessary improvements to be applied to the classical form of the transformation in order to achieve the required level of accuracy. Once these improvements are applied, the consistency between the positions of the CIP in the GCRS corresponding to the classical and the new transformations is at a level of a few microarcseconds after one century. This paper summarizes the main points of this work, which will be described in more detail in a paper in preparation (Capitaine *et al.* 2002).

2 Expressions for the position of the CIP and the CEO in the GCRS

The expressions for the position of the CIP and the CEO in the GCRS are based on the definitions and formulations described in Capitaine *et al.* (2000). The position of the CIP in the GCRS is provided by the coordinates X and Y which are expressed as function of combined quantities for precession and nutation; these coordinates include precession, nutation, the coupling effects between precession and nutation and the offsets at J2000. The quantity s is used along with X and Y to predict the position of the CEO as a function of time. It is computed by an integration along the CIP path, from J2000.0 to t. The developments of X, Y and s can be provided at microarcsecond accuracy as a polynomial form of t plus a series of Poisson terms, valid over an interval of several centuries, the expression for s being derived from those obtained for X and Y. The precession and nutation quantities used in these computations are the MHB 2000 nutation series and IAU 1976 precession corrected for the rates in longitude and obliquity (Mathews *et al.* 2002), and the associated values for the celestial pole offsets at J2000.0, with respect to the pole of the GCRS. The quantity ($d\alpha_0$ =14 mas) used for the offset in right ascension (opposite of the right ascension of the mean equinox at J2000) results from simultaneous analysis of VLBI and LLR data (Chapront *et al.* 2002). The manipulation of the Fourier and Poisson series have been performed using the software package GREGOIRE, which handles Fourier and Poisson series and allows a rapid manipulation of large series. The resulting expressions for X,

Y and s are given in the IERS Conventions 2000 (McCarthy and Capitaine, session 3.2, this Volume).

3 Comparison between new and classical transformations

3.1 Internal checks of the developments for X and Y

In order to check the developments as function of time of the quantities X and Y, an internal comparison in the time domain over 4 centuries around J2000 has been performed (see Figure 1) between ephemerides using the developments as functions of time for X and Y (index a) and the values at the same dates based on the analytical formulation as functions of the classical precession and nutation quantities (index b). The differences are less than five microarcseconds over the considered interval. Spectra of the differences show no amplitude greater than 0.3 μas.

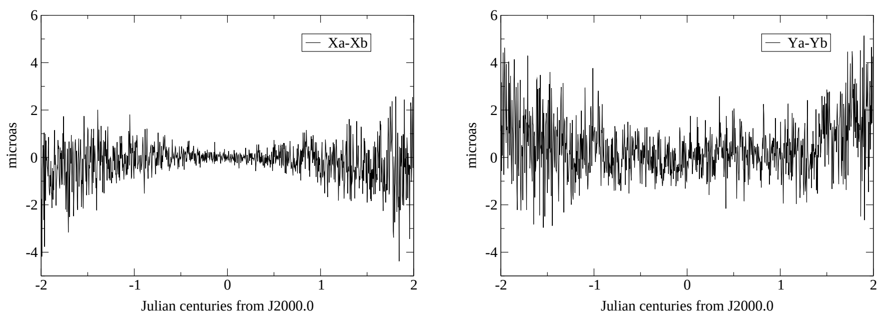

Figure 1: *Comparison between the development of the quantity X (left) and Y (right) and ephemerides for the analytical formulation as functions of the combined IAU 2000A precession-nutation quantities*

3.2 Comparisons with the classical formulation

Comparison of the series for X, Y with a classical formulation, in which elements (3,1) and (3,2) of the NP matrix are the CIP X, Y, revealed differences at one milliarcsecond level after two centuries. These differences have been explained by the following effects appearing in the classical transformation when the IAU 2000A nutation code is used (Wallace, session 5.1, this Volume) :

- disagreement (at 1 mas level over 2 centuries) between the two ways of forming the precession matrix using the angles of Lieske *et al.* (1977): the 3-rotation transformation based on the quantities ζ_A, θ_A, z_A and the 4-rotation one based on the quantities ϵ_0, ψ_A, ω_A and χ_A,

- cross terms becoming significant after a few decades (see Figure 2) due to the use of the IAU 2000A precession contributions rather than applying the changes directly to ψ_A, ω_A and ϵ_A,

- cross terms becoming significant after a few decades due to the effect of using the IAU 2000A bias contributions rather than applying this offset at J2000 rigorously, as a separate rotation,

- cross-terms of non-negligible amplitudes over long periods of time appearing in X, Y, due to the effect of omitting the offset in right ascension, $d\alpha_0$.

After correcting these effects, agreement to a few microarcseconds is achieved between classical and new transformations (see Figure 3), but only because, in the classical transformation, the "total" $d\psi$, $d\epsilon$ from IAU 2000A have been rejected in favour of rigorous precession and bias corrections.

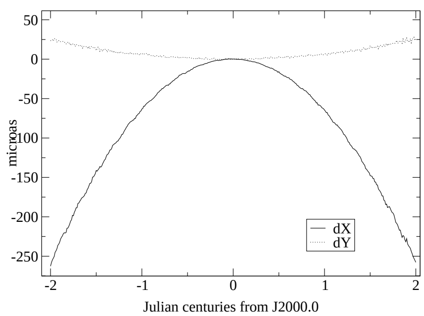

Figure 2: *Effect of using the IAU 2000 precession contribution rather than applying directly to ψ_A and ω_A*

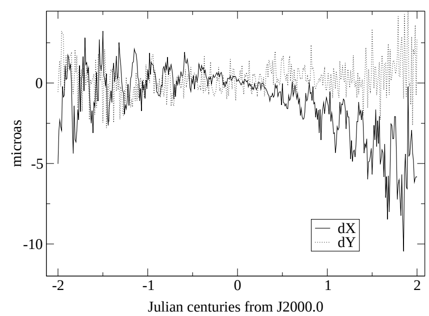

Figure 3: *Comparisons with the series for X, Y elements (3,1) and (3,2) of the classical NP matrix*

These comparisons have demonstrated that the new method is more simple, compact and direct than the classical formulation, predicting the position of the CIP to accuracies of a few microarcseconds with greatly reduced scope for misuse. The clean separation between precession-nutation of the equator from Earth rotation is a further advantage of the new method.

References

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