Earth's free core nutation from the IERS data

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I use the various nutation series submitted to the International Earth rotation and Reference systems Service (IERS) Earth Orientation Center at the Paris Observatory and the daily combined series IERS EOP 14 C 04 data set computed by the same organisation to obtain empirical models of the free core nutation (FCN). The series provide values for celestial pole offsets dX and dY referred to the MHB expansion (Mathews et al. 2002). I consider that the free motion associated with the FCN can be seen as an oscillation of period -430.21 days in a spaced-fixed frame of reference. This period corresponds to the resonance period which is function of various geophysical parameters like the core flattening and the deformability at the core-mantle boundary. The free motion exhibits significant variations in amplitude and in phase whose origins remain unclear at this time. Moreover, the oscillation is considered as circular, ignoring any possible asymmetry in the distribution of mass in the core.

The computation is based on a weighted least-squares fit of a circular term plus a constant to the complex-valued quantity $dX + \mathrm{i}\, dY$. The model is expressed as

$$dX + \mathrm{i}\, dY = A\mathrm{e}^{\mathrm{i}\,\sigma t} + X_0 + \mathrm{i}\, Y_0, \tag{1}$$

where A is the complex amplitude, σ the FCN frequency, and t is the time measured from J2000.0. When the nutation series do not provide the non-diagonal covariance information, the data is simply weighted by the inverse of the squared standard error as provided in the data file. Otherwise, the full covariance information is used. This leads to

$$\begin{aligned} dX &= A_c \cos\sigma t - A_s \sin\sigma t + X_0, \\ dY &= A_c \sin\sigma t + A_s \cos\sigma t + Y_0, \end{aligned} \tag{2}$$

allowing the estimation of four parameters: A_c and A_s and the constant offsets X_0 and Y_0. The offsets account for the long-term variations appearing in the nutation residuals and are not physically related to the core nutation. Apart a slight correction to the precession, the offsets include reference frame biases and contributions to the 18.6-yr nutation and other prominent terms mismodeled in MHB. The contribution of the FCN only to the celestial pole offsets is given by

$$X_{\mathrm{FCN}} = X_s \sin\sigma t + X_c \cos\sigma t, \tag{3}$$

$$Y_{\rm FCN} = Y_s \sin \sigma t + Y_c \cos \sigma t,$$

where

$$X_s = Y_c = A_s, \quad X_c = -Y_s = A_c. \tag{4}$$

To account for the time variability of the amplitude and the phase, the estimates are done over a sliding window. The tabulated epoch for each window is the middle date of the window. The window width must be sufficiently large to separate the FCN from the retrograde annual oscillation expected to show up at about 0.1 mas. The demodulation period is 6.7 years. I chose 7 years.

Adjusted coefficients can be found at http://syrte.obspm.fr/∼lambert/fcn in the file table-asc-XXX.txt together with a FCN time series table-ser-XXX.txt computed for the nutation epochs and a FORTRAN subroutine fcnnut.f that is able to compute the FCN amplitude at any epoch. This subroutine takes as argument the yearly amplitudes and uncertainties adjusted above and that can be found in the file table-asc-XXX.txt.

It can be noticed that the formal error on these amplitudes varies between 10 μas in the early years down to less than 1 μas for the most recent years. As already mentioned, the reader must keep in mind that a more realistic error estimated through statistical tests might replace these formal errors.

A mean prediction error has been introduced in the FORTRAN routine to account for the degradation of the uncertainty in predictive mode (forward or backward). It is estimated through the average of a thousand predictions over past time intervals. The prediction error is fitted with a first-order polynomial whose slope gives the degradation in forward or backward predictive mode starting from any given epoch. For the routine implementation, I adopt the value of 0.08 μas/day.

The data is updated regularly, typically every week. Note that unless the nutation data set is strongly modified (e.g., due a complete reanalysis after changing the IERS combination strategy or introducing a new ITRF), the amplitudes for past years will remain the same or very close. Only the coefficient relative to the present year can be affected significantly.

References

[1] Mathews, P. M., Herring, T. A., & Buffett, B. A. 2002, J. Geophys. Res., 107, 10.1029/2001JB000390