A MODEL AND PREDICTION OF EARTH'S POLE MOTION

L.D. AKULENKO[1], S.A. KUMAKSHEV[1], Y.G. MARKOV[2]

[1] Institute for Problems in Mechanics
pr. Vernadskogo 101-1, Moscow, 119526, Russia
e-mail: kumak@ipmnet.ru

[2] Moscow Aviation Institute
Volokolamskoe sh. 4, Moscow, 125872, Russia

Perturbed rotatory/oscillatory motions of Earth under the action of the gravitational forces due to Sun and Moon are studied. In this study, Earth is regarded as a linear viscoelastic body. It has been established that the excitation of oscillations of the poles (more precisely, the vector of angular velocity of Earth in the Earth-fixed reference frame) has a tidal nature and can be accounted for by the rotatory/translatory motion of the Earth-Moon baricenter about Sun [1, 2]. It is shown that basic characteristics of these oscillations are rather stable and do not change during time intervals that substantially exceed the precession period of Earth's axis. Using methods of celestial mechanics, we construct a simple mathematical model governing these oscillations. This model involves two frequencies (natural (Chandler's) frequency and yearly frequency) and provides predictions that agree with IERS astrometric data. The parameters of this model were identified on the basis of the spectral analysis of the IERS data and least squares method. Using this model, we obtained statistically reliable interpolation data for time intervals from several months to 15–20 years. For the first time, a high-precision prediction of the motion of the poles for a term of 0.5 to 1 year and a fairly reliable 1 to 3 year prediction are presented. These predictions have been validated by observations during several recent years. The results obtained are of great importance for geodynamics and celestial mechanics, as well as for applications in astrometry, navigation, and geophysics.

Analysis of the power spectrum density of the oscillations shows that the Chandler and annual components are the basic ones. The motion of the pole on considerable time intervals ($\tau \sim 10 - 15$ years) can be represented by the expressions

$$x(\tau) = c_x - a_x^c \cos 2\pi N\tau + a_x^s \sin 2\pi N\tau - N d_x^c \cos 2\pi\tau - d_x^s \sin 2\pi\tau \equiv (\xi, f_\xi),$$

$$y(\tau) = c_y + a_y^c \cos 2\pi N\tau + a_y^s \sin 2\pi N\tau - N d_y^c \cos 2\pi\tau + d_y^s \sin 2\pi\tau \equiv (\eta, f_\eta),$$

$$N = 0.845 - 0.850, \quad c_{x,y} = c_{x,y}^0 + c_{x,y}^1 \tau + \ldots; \quad \tau = \tau_i, \quad i = 1, 2, \ldots, i^*,$$

where the term $c_{x,y}$ account for slow trend. On short time intervals ($\tau \leq 6$ years), these coefficients can be considered constant ($c_x \approx 0.03''$, $c_y \approx 0.33''$) or linearly dependent on τ. The unknown parameters c^0, c^1, $a^{c,s}$, $d^{c,s}$ for x and y, i.e., the vectors ξ and η and the Chandler frequency N can be identified on the basis of the dispersion analysis by means of least squares. The basis functions f_ξ and f_η involve polynomial and trigonometric components. The choice of these function depends on the purpose of the utilization of the model, specifically, whether this model is utilized for the interpolation or prediction of the motion on short, medium or long

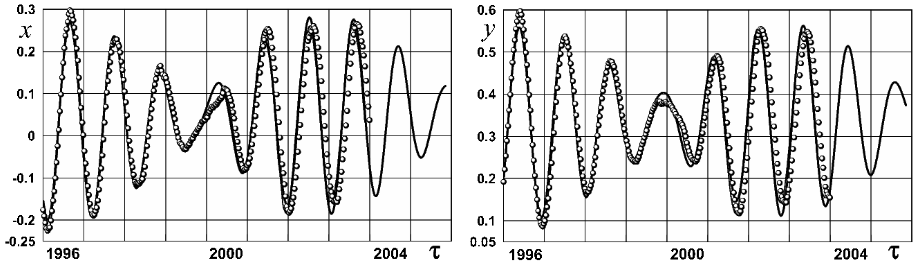

Figure 1: Eight-year (1996–2003) interpolation and 2-year (2004–2005) prediction; the dots correspond to IERS data

time intervals. It should be noted that the coefficients $a_{x,y}^{c,s}$ and $d_{x,y}^{c,s}$ are not independent. The relationship between these coefficients is determined by the structural properties of the model. In the beginning of 2004, we constructed a 6-parameter interpolation of the pole motion ($x(\tau)$ and $y(\tau)$) for an 8-year time interval (1996–2003). On the basis of this interpolation, we gave a 2-year prediction (up to the end of 2005). These results are shown in Fig. 1, where the dots correspond to IERS data. Note that during a period of 1999–2000, abnormal oscillations of the pole accounted for by the parade of planets were observed. This perturbation affected the accuracy of the prediction. Figure 2 presents a segment of the prediction for 2004 (smooth curve)

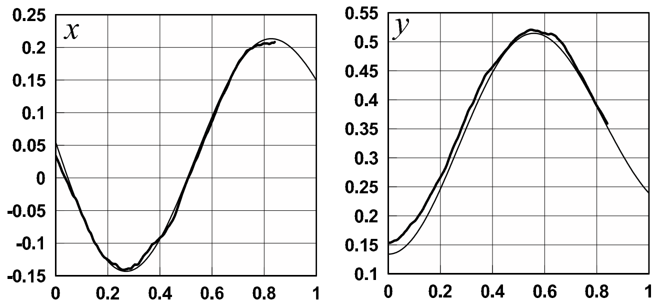

Figure 2: Comparison of the prediction for 2004 with the measurements from January 1 to November 2, 2004.

and the actual motion of the pole on the interval from January 1 to November 2, 2004 (thin irregular curves). A comparison of these curves shows that the prediction provides acceptable degree of accuracy (the maximum error does not exceed $0.02''$ or 60 cm).

A short-term prediction (≤ 0.5 year) with an appropriate interpolation depth enables one to attain higher accuracy ($0.005''$ or 15 cm) on the basis of the 5-parameter model in which c_x^1 and c_1^y are equal to zero. The prediction error in this case coincides in order of magnitude with the perturbing influence of the Moon and some other tidal torques the frequency of which is higher than those taken into account in the model. The further increase of the accuracy of the theoretical and computational models requires a broader frequency spectrum and more precise IERS data to be utilized.

REFERENCES

Akulenko L.D., Kumakshev S.A., Markov Yu.G., 2002, Motion of the Earth's Pole, *Doklady Physics*, **47**, N 1, 78-84.

Akulenko L.D., Kumakshev S.A., Markov Yu.G., and Ryhlova L.V., 2002, Forecasting the Polar Motions of the Deformable Earth, *Astronomy Reports*, **46**, N 10, 858-865.