Amplitude-frequency analysis of the Earth orientation parameters and the variation of the second zonal harmonic of the geopotential

V.V. Bondarenko, Yu. G. Markov, V.V. Perепелкин, A. S. Filippova
Moscow aviation institute, department of theoretical mechanics, Moscow, Russia

Abstract. Modeling temporal variations of the geopotential caused by the oscillatory-rotational processes of the Earth’s motion is of a significant interest for some satellite navigation applications and geophysics problems. Observed variations of the Earth orientation parameters (EOP), the variations of the Earth’s gravitational field and oscillations in the large-scale geophysical events appear to be in a considerable correlation. Based on the celestial mechanics’ methods namely the spatial version of the problem of the Earth-Moon system in the gravitational field of the Sun a mathematical model of the rotational-oscillatory motion of the elastic Earth is developed. A comparison between the real and theoretically obtained Earth’s pole motion trajectory as well as between real and derived variations of the length of the day demonstrate the adequacy of the derived model to the International Earth Rotation and Reference System Service (IERS) observations data.

Based on the amplitude-frequency analysis of the oscillation processes in the motion of the Earth’s pole and on the observations’ data of the SLR a modeling of the second zonal harmonic of the geopotential has been carried out. Its functional dependence on the amplitude and phase of the Earth’s pole oscillatory process is shown by the means of periodic functions of time.

\[
X_v, X_\pi, \kappa, \kappa_i \text{ correspond to tidal humps and cusps, respectively; } M(\Omega, I, \pi) \text{ are specific lunar and solar gravitational tidal torques depending on the Euler variables (the nutation } \theta, \text{ precession } \psi, \text{ and proper rotation } \varphi \text{ and the mean motions of the Earth and the Moon; } \Omega \text{ is the longitude of the ascending node of the lunar orbit; } \pi \text{ is the longitude of perigee of the lunar orbit; and } I \text{ is the inclination between the Moon’s orbital plane and the ecliptic.}
\]

Let adduce the results of simulations of variations \( \Delta \overline{C}_{20} \) based on amplitude-frequency analysis of the Earth Pole oscillations and SLR data. The equations for amplitude and phase variables of the Earth Pole modulation motion have the following form assumed \( \overline{C}_{20} = c \cos \psi + c \sin \psi \) (the values \( c, c_i \) are determined by choice of ITRF system): \( a = \mu \cos(\psi - \nu), \psi = N - a' - \mu \sin(\psi - \nu), \) where \( \mu = \mu(t), v = v(t) \) are the functions of time which are expanded into a sum of periodical components; the values \( \mu \cos \nu, \mu \sin \nu \) are perturbations which lead to the observed oscillations of the Earth Pole and which have the dimensions of specific moment of force. The solution of system is represented as follows:

\[
a(v, \xi, \alpha) = a_0 + \sum_i \xi_i \cos(2\pi v + \alpha_i),
\]

\[
\psi(\beta, \eta, \beta) = \psi_0 + 2\pi N \tau + \sum_j \eta_j \sin(2\pi \delta \tau + \beta_j),
\]

\[a, \psi_i = \text{const},\]

Here \( f \) is the function of amplitude and phase of the Pole oscillation; dimensioned coefficient \( \varepsilon \) is refined from SLR observations and has the order \( 10^{-4} \) (the amplitude \( a \) of the Earth Pole oscillations is expressed in angular milliseconds).

The interpolation of expression \( \Delta \overline{C}_{20} \) along SLR measurements data from 1984 till 2008 including is presented on fig. a and extrapolation for six years with the forecast for two years is given there. The contrast line on the figure is obtained theoretical curve, the connected by line stars are the measurements data. The component with oscillations corresponded to expansion of function \( f(\alpha, \psi) \) for harmonic components is released during interpolation. The coefficients of these oscillations (amplitudes and phases) are considered as unknown and must be determined based on the least square method on the interval of interpolation of SLR observations and measurements data. The observed curve is shown on fig. b with comparison of function \( f(\alpha, \psi) \) that built directly from observations of the Earth Pole oscillations. For these the amplitude and the phase of the Earth Pole oscillations are extracted from IERS observations and measurements data preliminarily.

Figure a

Figure b