ON THE COMPARISON OF DIURNAL NUTATION DERIVED FROM SEPARATE SERIES OF LATITUDE AND TIME OBSERVATIONS

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Abstract. Several authors tried to derive the period, amplitude and initial phase of the free diurnal nutation using separate series of latitude and time observations. The results obtained by them are compaired and discussed in the present paper.

From the investigations by Sludsky, Hough, Poincaré, Jeffreys and others on the rotation of the Earth with liquid compressed core it follows that besides the Chandler wobble, there must exist another free nutation with an almost diurnal period between 23^h54^m and 23^h57^m sidereal time.

The accurate value of this period as calculated by Molodensky for two models of the internal constitution of the Earth is about 3 min shorter than a sidereal day, and the difference between the two models is approximately 2 s. It was Pariisky who confirmed the existence of this nutation from analysis of terrestrial tides and directed the attention of astronomers to the possibility of observing the diurnal nutation with the period indicated by Molodensky. Then many attempts were made to reveal the diurnal nutation from astronomical observation.

In the sequence of latitudes obtained from observations of bright zenith stars (for example, the observations at Poltava) this nutation produce a harmonic variation with amplitude $\mathscr{A}$ and a period about $T_1 = 463.5$ sidereal days (s.d.). In the customary latitude observations (for example, the ILS program) Molodensky's diurnal nutation would manifest itself as a variation with the same amplitude and period about $T_2 = 204.0$ mean days (m.d.).

The effect of this nutation on the time observations is similar, with a phase change of 90°.

It seems very important to obtain the values of T from the long series of astronomical observations and to compute the diurnal periods

$$\tau_i = \frac{T_i}{T_i + 1}, \quad i = 1, 2, \tag{1}$$

where τ_1 and τ_2 are expressed in units of sidereal and mean days respectively. τ_1 and τ_2 are linked by the following relations

$$\tau_1 = 1.002738\, \tau_2 \,\text{s.d.}$$
$$\tau_2 = 0.997270\, \tau_1 \,\text{m.d.}$$

Analysing observations of two bright zenith stars at Poltava, Popov found a value of τ_1, which fully agrees with that calculated by Molodensky for the second model.

P. Melchior and S. Yumi (eds.), Rotation of the Earth, 200–205.

Débarbat (1969) found in latitude and time observations at Paris observatory several periodic terms.

Yatskiv and Emetz dealt with latitude observations at Pulkovo from 1905 to 1941 and Washington from 1916 to 1940. The power spectrum analysis of these data was made using Tukey's method in order to find the period T_2. A suitable band-pass filter was applied to get the best estimate of the power spectrum in the vicinity of the frequency of the free diurnal nutation. The results are shown in Figures 1 and 2.

Instead of only one period predicted by the theory (204 m. d.) there are three significant periods in observations at Pulkovo (219, 208, 194 m. d.) and three in observations at Washington (234, 219, 206 m. d.).

On the other hand Popov and Yatskiv (1970) found the following periodic variation of the amplitude of the diurnal nutation

$$\mathscr{A}(t) = \underset{\pm 2}{0\overset{''}{.}013} + \underset{\pm 4}{0\overset{''}{.}013} \sin\left(\frac{2\pi}{10.5}\,t + \underset{\pm 30}{145^\circ}\right) \tag{2}$$

where t is the number of years elapsed from the initial epoch 1939.0.

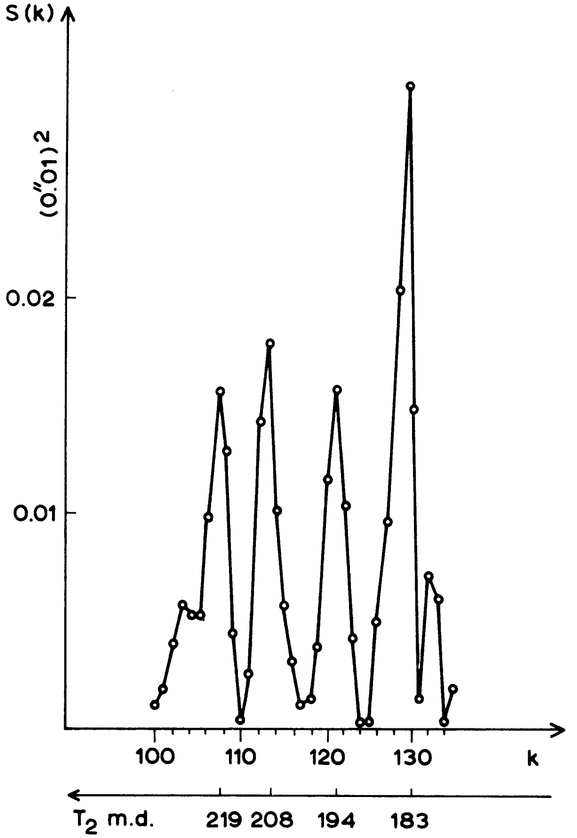

Fig. 1.

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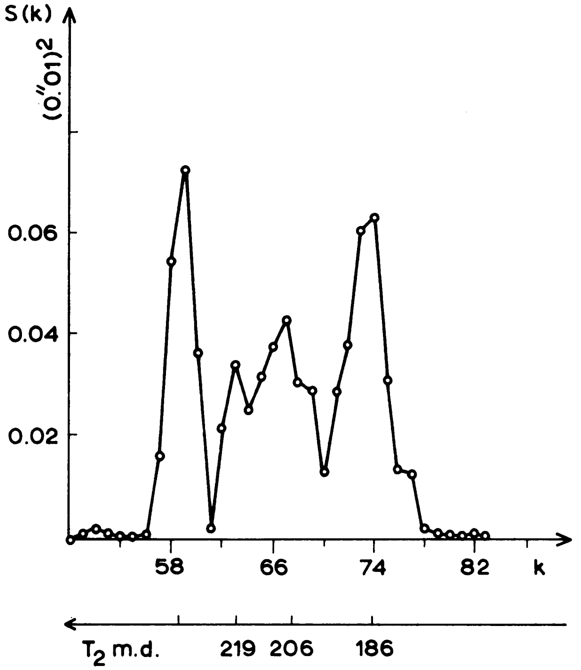

Fig. 2.

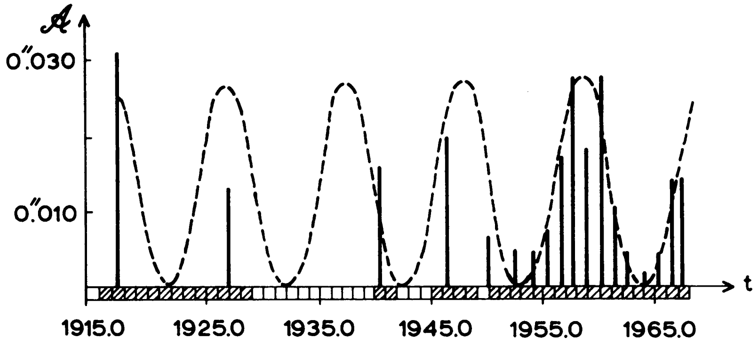

Fig. 3.

In Figure 3 the straight lines represent the observed values of the amplitude, derived by Popov and Yatskiv, and the dotted line those computed by means of (2).

Thus, it may be concluded that either in the frequency region near the free diurnal nutation there exist several oscillations or the parameters of the new nutation are not constant. It hampers the comparison of the diurnal nutation parameters derived from separate series of observations.

We have decided to compare only those nutational terms whose periods are close enough to the theoretical value $23^h56^m54^s$ given by Molodensky.

Let x, y be the usual coordinate system.

O is the origin of coordinates coinciding with the mean nutational position of the north pole.

P_1 is the position of the instantaneous pole at initial epoch E_1, namely at 0^h Greenwich sidereal time at a certain date.

β_1 is the longitude of the pole west of the meridian through Greenwich and the mean position of the pole, at initial epoch E_1, $\theta_1 = (2\pi/\tau_1)$ is the angular frequency of the nutational term. P'_1 is the position of the instantaneous pole at the epoch E'_1, namely, at S^h Greenwich sidereal time of certain date.

It follows from theoretical considerations that we shall have for clockwise nutational rotation of the north pole

$$\begin{aligned} x &= \mathscr{A} \cos\left[\theta_1 (E'_1 - E_1) + \beta_1\right] \\ y &= \mathscr{A} \sin\left[\theta_1 (E'_1 - E_1) + \beta_1\right]. \end{aligned} \tag{3}$$

Then for a station with longitude $\lambda°$ we may write

$$\Delta\varphi_1 = \mathscr{A} \cos\left[\theta_1 (E'_1 - E_1) + \beta_1 - \lambda°\right] \tag{4}$$

where $\Delta\varphi_1$ is the latitude variation due to diurnal nutation, since

$$E'_1 - E_1 = N_1 + s/24 = N_1 + \bar{s}/24 + \lambda/24,$$

where N_1 denotes the number of sidereal days elapsed since the initial epoch E_1; $\bar{s}$ is the local sidereal time, the Equation (4) becomes

$$\Delta\varphi_1 = \mathscr{A} \cos\left[\theta_1 (N_1 + \bar{s}/24) + \theta_1 \cdot \lambda/24 + \beta_1 - \lambda°\right].$$

The term $(\theta_1 \cdot \lambda/24 - \lambda°)$ is negligible with respect to $\theta_1 (N_1 + \bar{s}/24)$.

Thus, the effect of the diurnal nutation on the observed latitude is the same for each station

$$\Delta\varphi_1 = \mathscr{A} \cos\left[\theta_1 (N_1 + \bar{s}/24) + \beta_1\right]. \tag{5}$$

When counting time in units of a mean day after 0^h UT of the initial epoch E_2 we can get, in analogy to (5)

$$\Delta\varphi_2 = \mathscr{A} \cos\left[\theta_2 (N_2 + m/24) + \beta_2\right], \tag{6}$$

where m is the local mean time, $\theta_2 = 2\pi/\tau_2$ denotes the angular frequency of the nutational term, β_2 is the west longitude of the north pole at the epoch E_2, N_2 denotes the number of mean days elapsed since the initial epoch E_2. As the initial epoch E_2, one can choose the origin of the tropical years, for example, 1960.0. In any case when comparing the values of phase β derived from the separate series of the observation it is necessary to reduce β to the common initial epoch E.

In this connexion we face the following problem: should we use for the reduction the empirical estimates τ_i of the period or its theoretical value τ_0? It is not easy to decide.

For $E'_1 - E_1 \gg 1$ these estimates would lead to different values of β at initial epoch E.

As an example we consider the comparison of the nutational terms derived from observations at Pulkovo during 1915–1928 (Yatskiv, 1969)

$$\Delta\varphi_0 = \underset{\pm 3}{0''\!.010} \cos\left[\frac{2\pi}{\tau_0}(N + m/24) + \underset{\pm 17}{353^\circ}\right], \tag{7}$$

where a phase 353° refers to the initial epoch, namely, 0^h UT 1 December, 1915, and from the observations at Pulkovo during 1904–1941

$$\Delta\varphi_2 = \underset{\pm 1}{0''\!.004} \cos\left[\frac{2\pi}{\tau_2}(N + m/24) + \underset{\pm 7}{209^\circ}\right], \tag{8}$$

where $\tau_2 = 0.99522$ m. d., the phase 209° refers to 0^h UT 16 January, 1907. (The determinations of the terms (7) and (8) are independent). Reducing the phase of the term (8) to 0^h UT 1 December, 1915 by means of the empirical period τ_2 and Molodensky's theoretical value τ_0, we have found respectively

$$\beta_\text{I} = 209^\circ + 205^\circ = 54^\circ$$
$$\beta_\text{II} = 209^\circ + 318^\circ = 167^\circ.$$

The difference $\beta_\text{I} - \beta_\text{II}$ is significant. All the available estimates of the parameters of nearly diurnal nutation are given in Table I, in which we use the theoretical period of nutation (τ_0) when reducing the longitudes of the pole β to initial epoch 1960.0.

TABLE I

No.	Authors	τ_1	$\mathscr{A}$	β	The period of observation	Observatory
			Latitude observation			
(1)	Popov	0.99784	$0''\!.012 \pm 3$	$164^\circ \pm 12$	1939–1969	Poltava
(2)	Kulagin, Kovbasjuk	–	$0''\!.020 \pm 10$	$226^\circ \pm 26$	1953–1962	Gorky
(3)	Thomas	–	$0''\!.006 \pm 3$	$221^\circ \pm 24$	1958–1961	Greenwich
	Thomas	–	$0''\!.010 \pm 3$	$232^\circ \pm 13$	1958–1961	Greenwich
(4)	Yatskiv	0.99785	$0''\!.010 \pm 3$	$87^\circ \pm 17$	1915–1929	Pulkovo
(5)	Débarbat	0.99793	$0''\!.008 \pm 3$	$299^\circ \pm 18$	1956–1963	Paris
(6)	Kulagin, Kovbasjuk	0.99786	$0''\!.013 \pm 5$	$53^\circ \pm 22$	1961.5–1965.5	Gorky
(7)	Yatskiv, Emetz	0.99794	$0''\!.004 \pm 1$	$149^\circ \pm 7$	1905–1941	Pulkovo
(8)	Yatskiv, Emetz	0.99789	$0''\!.009 \pm 1$	$294^\circ \pm 4$	1916–1940	Washington
(9)	Sugawa, Ooe	0.99786	$0''\!.005 \pm 3$	262°	1955–1967	ILS
			Time observation			
(1)	Thomas	-	$0''\!.008 \pm 5$	$25^\circ \pm 40$	1958–1961	Greenwich
(2)	Débarbat	0.99775	$0''\!.006 \pm 5$	$53^\circ \pm 47$	1956–1963	Paris

References

Débarbat, S.: 1969, *Astron. Astrophys.* **1**, 3.
Popov, N. A. and Yatskiv, Ya. S.: 1970, *Bull. Inform. Bruxelles*, No. 57.
Yatskiv, Ya. S.: 1969, *Bull. Inform. Bruxelles*, No. 54.

DISCUSSION

S. Débarbat: The results I obtained from latitude are a little different from the results you have from Washington and Pulkovo Observations but I think that it will be better to speak about that after my paper which is on the same subject.