NEARLY DIURNAL FREE POLAR MOTION DERIVED FROM ASTRONOMICAL LATITUDE AND TIME OBSERVATIONS

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1. Introduction

The first attempts to take into account the dynamic effect of a liquid core on the rotation of the Earth were made as far back as the end of the 19th century.

Improved knowledge of the internal constitution of the Earth acquired during the past few decades has led both to extensions of the theory of the Earth's rotation by Jeffreys and Vicente (1957a,b) and by Molodensky (1961) and to theoretical calculations of the period of the nearly diurnal free wobble. The general first-order theory of the rotation of the Earth with a liquid core has been recently constructed by Shen and Mansinha (1976). On the basis of that theory, the spectrum of free spheroidal core oscillations of degree 2 and order 1 (S_2^1) associated with polar motion has been computed. The spectrum of S_2^1 depends on a parameter determining the core stability, the so-called β-parameter. The only core mode independent of β is the one with a nearly diurnal period. It was designated by Shen and Mansinha as $S_2^1\ T_1$, the inertial oscillation mode.

The periods of nearly diurnal free polar motion calculated for different models of the Earth's core are given in Table 1, where J-V 1 means the central particle model of the core by Jeffreys and Vicente (1957a); M1 and M2 stand for the first and second core models of Molodensky (1961); and Sh-M designates the Pekeris-Accad model (Pekeris and Accad, 1972) adopted by Shen and Mansinha (1976) in numerical calculations.

Current knowledge about the influence on polar motion due to the dynamic effects of the Earth's core can more or less be summarized as follows:

(1) the existence of the liquid outer core induces a spectrum of polar motion;

E. P. Fedorov, M. L. Smith and P. L. Bender (eds.), Nutation and the Earth's Rotation, 59–66.

(2) there is only one distinct inertial oscillation with a nearly diurnal period;
(3) no upper limit to the periods of core nutation has been detected.

Table 1. Predicted Periods of Nearly Diurnal Free Polar Motion

Models	τ (sidereal time)
J-V 1	$23^h56^m47^s$
M 1	23 56 55
M 2	23 56 53.5
Sh-M	23 56 54

2. What can be derived from astronomical latitude and time observations?

Let $\vec{e}_3$, $\vec{H}$ and $\vec{\omega}$ be the unit vector along the maximum moment of inertia axis of the Earth, the total angular momentum vector, and the instantaneous angular velocity vector, respectively. The relative positions of $\vec{e}_3$, $\vec{H}$, $\vec{\omega}$ are represented by the well-known Poinsot scheme for the Chandler polar motion and nearly diurnal polar motion (see, for example, Rochester et al., 1974). Motion of the rotation axis within the Earth, i.e., the polar motion or wobble, is accompanied by a motion of the rotation axis in space, the so-called "sway." Toomre (1974) has demonstrated that in the case of the theoretically predicted nearly diurnal free polar motion the amplitude of the motion of the rotation axis in space must be hundreds of time larger than the amplitude of the polar motion. Rochester et al. (1974) derived the amplitude ratio (ν) of these two motions on the basis of a simplified Earth model

$$\nu \simeq A_o/Ae_1 \quad ,$$

where A and A_o are the equatorial moments of inertia of the entire Earth and of the shell (or mantle) alone. e_1 is the dynamical ellipticity of the core.

On the other hand, Ooe and Sasao (1974) showed that the value of ν can be easily determined from the simple kinematical relation

$$\nu = \delta/(\delta+\omega) \quad ,$$

where δ is the frequency of nearly diurnal polar motion, and ω is the diurnal frequency.

It had been believed previously that latitude and time observations allow a determination of the motion of the rotation axis within the Earth, i.e., the angle between $\vec{\omega}$ and $\vec{e}_3$. As a matter of fact, these observations are capable of giving nothing but the relative positions of the vectors $\vec{e}_3$ and $\vec{H}$, provided the adopted star catalog and the coefficients of nutation are free from errors.

Jeffreys (1963) was the first to pay attention to the astronomically observed values. Further consideration of this problem was made by Fedorov et al. (1972) and Ooe and Sasao (1974). It follows that the astronomers can derive the combination of the effects of polar motion and sway. In the case of the theoretically predicted nearly diurnal free polar motion, the observed motion would be sway, since the amplitude of the wobble is very small. In the case of the prograde (direct) nearly diurnal polar motion indicated by Yatskiv et al. (1975), the amplitude ratio of sway to wobble will be $\nu \simeq 1/2$. For the sake of brevity these facts will not be repeatedly emphasized, and the term "nearly diurnal polar motion" will be used with an understanding that in every case it includes the motion of rotation axis in space.

Now we briefly review the effect of nearly diurnal polar motion on the astronomical latitude and time observations. The retrograde nearly diurnal polar motion manifests itself as a nearly diurnal latitude variation, for which the initial phase is the same for different stations. The effect of the prograde nearly diurnal polar motion depends on twice the longitude of the station, provided time is expressed in units of local time. The effects of nearly diurnal polar motion on the time observations are similar, with a phase change of 90° and the amplitude multiplied by tan ϕ, where ϕ is latitude of the station.

3. Is there any possibility of observing the nearly diurnal polar motion?

The possibility of observing the nearly diurnal polar motion depends upon careful selection of both the program of observations and the method of data reduction. To study the nearly diurnal variations of latitude or time, twenty-four-hour astronomical observations would be desirable. Until now these observations have not been made anywhere. Nevertheless, many attempts have been made to find the nearly diurnal free polar motion in astronomical observations.

There are two different modes of observation for deriving the variations of astronomical latitude and time. The first one consists of taking observations at constant moments of sidereal time (bright star observations), and the second one of taking observations at constant moments of mean time (for example, the ILS-program). The nearly diurnal polar motion would manifest itself as a harmonic variation with aliasing periods T_1 and T_2 for these two cases respectively. The periods derived for the different models mentioned above are given in Table 2.

Table 2. Aliasing periods, in days, for latitude and time observations

Models	T_1 s.d.	T_2 m.d.
J-V 1	447	201
M 1	466	205
M 2	462	204
Sh-M	463	204

The use of digital (rather than continuous) records of observations with sampling interval $\Delta t = 1$ day introduces a troublesome ambiguity when studying the power spectra of latitude and time observations. Harmonic oscillations with frequencies

$$(\Delta t)^{-1} k \pm \delta \quad , \quad k = 0,1,2...$$

all look alike.

Thus the aliasing period T can result from several nearly diurnal, semi-diurnal and other variations. Table 3 presents these "identical" periods for digital records with two intervals Δt=1 s.d. and Δt=1 m.d.

Table 3. "Identical" periods, in days, for digital records with sampling interval Δt

k	Δt = 1 s.d.	Δt = 1 m.d.
0	0.99784	0.99512
1	0.49946 462.0	0.49878 204.0
2	0.33309 1.00217	0.33228 1.00493
3	0.24986 0.50054	0.24969 0.50123

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By analyzing the daily or monthly mean values of latitude or time, we reduce the high frequency oscillations. For nearly diurnal variations, the values of periods that are longer and shorter than a day cannot be distinguished. The latitude observations using a number of bright stars at the Gorky station appear to be most conclusive for solving this problem.

4. What results have been obtained?

The following two methods may be used to search for the nearly diurnal free polar motion:

i) an estimation of the power spectra of latitude and time variations with the purpose of a search for aliasing period of T,

ii) an estimation of the amplitude and phase of harmonic variation with the period predicted theoretically.

The necessary first step in this analysis is filtering out the long-period polar motion components. For this purpose one can take the difference of the evening and the morning values of latitude or time. This is a very simple and most effective method of reducing the data used for determining the nearly diurnal polar motion.

Here we present a summary of some results of the spectral analysis of astronomical data in the frequency domain under consideration. Aliasing periods found are given in Tables 4 and 5. For the convenience of comparison of the results given in Tables 4 and 5, we have calculated the values of τ_j and T_{2j} corresponding to T_{1j}.

Table 4. Aliasing periods T_2, in mean days, found in latitude and time observations

Yatskiv (1975)	Pulkovo (1915-1929)	168	194	203	214	232
Yatskiv (1976)	Greenwich (1911-1935)	170	197	206	---	240
Capitaine (1975)	Paris (1956-1973)	164	---	208	---	237
	Latitude, time	160	190	---	---	---
Yatskiv, Wako, Kaneko (1975)	ILS-stations (1955-1973)	164	---	204	---	241

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Table 5. Periods, in days, found in latitude variations Poltava, 1950-1968 (Popov and Yatskiv, 1977)

T_{1j}	τ_j	T_{2j}
117	0.99152	88
	1.00862	171
190	0.99474	125
	1.00526	396
390	0.99744	189
	1.00256	5650
455	0.99780	203
	1.00220	1892
536	0.99814	217
	1.00187	1152
707	0.99859	242
	1.00142	759

As one can see from Tables 4 and 5, the structure of the nearly diurnal latitude variations is the same for different stations. The fact that the latitude observations in Poltava have confirmed the existence of oscillations with periods of about 190, 204 and 240 m.d. is of interest. The period of 204 m.d. has been predicted theoretically and studied by different authors. The amplitude of this oscillation is in the range 0".004-0".020. The phase referred to a common initial epoch differs significantly, showing the 2λ dependence for the ILS-stations (Yatskiv, 1972; Yatskiv et al., 1975). The last was the reason for the separation of the effects of the retrograde and prograde components of nearly diurnal polar motion performed by Yatskiv et al. (1975). The results are given in Table 6.

Table 6. Aliasing periods and amplitudes for nearly diurnal polar motion

	Prograde component	
18 6	20 6	247
0".007 ± 0".003	0".007 ± 0".003	0".011 ± 0".003
	Retrograde component	
192	210	---
0".004 ± 0".006	0".006 ± 0".003	---

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The inconsistencies of the estimates of the parameters of nearly diurnal polar motion greatly exceed the formal errors. Hence, there is a tendency for skepticism on the possibility of the determination of nearly diurnal polar motion from the conventional latitude and time observations.

In this paper I have tried to show how astronomical observations can be used to yield a satisfactory practical solution to the problem of nearly diurnal polar motion determination. The question is whether or not the oscillations with the aliasing periods mentioned above are due to the dynamic effect of a liquid core of the Earth. Answering this question is hampered by the following:

(1) There is an ambiguity in interpretation of the aliasing periods T_1 and T_2.
(2) A meteorological origin of the nearly diurnal latitude and time variations cannot be ruled out.
(3) There is no physical interpretation of prograde nearly diurnal polar motion (Sasao and Yatskiv, 1975).
(4) The theoretical calculations of the spectra of free core oscillations which are associated with polar motion are still approximate.

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