NOTE ON THE DETERMINATION OF THE NEARLY DIURNAL FREE NUTATION (CORE NUTATION) AND THE PRINCIPAL TERM OF NUTATION BASED ON THE ASTROMETRIC DATA

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1. INTRODUCTION

Due to the highly accurate determination of the corrections to the nutation terms (the IAU-1980 nutation theory) by VLBI observations, the proposal for adoption of the new nutation theory or standard model of nutation is being discussed. At this point there are two unsolved problems:

(a) VLBI observations can't provide reliable estimates of the principal nutation term. The reason is that the correlation between this term and the precession constant is high due to the insufficient time span of these observations (about 10 years).
(b) period of free core nutation (FCN) which depends on the ellipticity of the mantle-core boundary has not been, so far, reliably determined from direct observations.

In the present paper, we would like to draw attention to the results of the analysis of astrometric latitude and time observations which could be useful for resolving these problems.

2. SEARCH FOR THE NEARLY DIURNAL FREE NUTATION

From the papers by Yatskiv et al., 1975; Yatskiv, 1979; Kovbasyuk, 1984, 1985, 1988; and by some other authors, it is clearly seen that the spectra of the nearly diurnal variations of latitudes and longitudes of the observatories have a complicated and time-stable structure. The frequency and amplitude characteristics of the spectra don't depend on the observatory location and method of observation. The values of the amplitudes of main oscillations vary from 0.003 to 0.010 arcseconds. (These values exceed by one order of magnitude the amplitude of the FCN derived from the VLBI observations.) Moreover, the phase characteristics seem to indicate the existence of both the retrograde (predicted by the theory) and prograde (suggested by Yatskiv et al.,1975) components of nearly diurnal polar motion.

Thus, for the most general model of the nearly diurnal variations of the astronomical coordinates we take

$$\sum_j A_{ji} \cos[\pm\sigma_j (S_i - S_{0i}) + \beta_{ji} \pm \sigma_j \lambda_i], \quad (1)$$

where A_{ji} is the amplitude of the j-th harmonic derived from observations of the i-th observatory; $\sigma_j = 2\pi/\tau_j$ is the frequency of the j-th harmonic, where τ_j is the period of the nearly diurnal variation expressed in mean or sidereal days; the "+" sign corresponds to the clockwise retrograde wobble; S_i is the local sidereal or mean time reckoned from the origin of this time, S_{0i}; β_{ji} is the initial phase of the harmonic (west longitude of the nearly diurnal free wobble, reckoned from Greenwich meridian $\lambda_G=0$ at a moment S_{0G}); λ_i is the west longitude of the i-th observatory.

Depending on the type of observations, one can determine either separate harmonics of (1) or their combination. We would note that there are three different modes of observations involved in the search for FCN:

(a) the day-and-night observations of the bright zenith stars and pairs of stars (program of station at Gorky, USSR);
(b) the observations of selected bright zenith stars at constant moment of sidereal time (program of observatory at Poltava, USSR);
(c) the observations of stars and groups of stars at constant (or nearly constant) moments of mean time (the ILS program).

All these methods have their own limitations. In case (a), it is impossible to determine separately the prograde and retrograde wobble components from the observations of a single station. In the other two cases, one can determine only the transformed oscillations with frequencies $(\sigma_0-\sigma_j)$, where σ_0 is the sampling frequency which is equal to 1 cycle per sidereal day or 1 cycle per mean day for cases (b) and (c), respectively. The amplitudes and phases of transformed oscillations are the combinations of the amplitudes and phases of the nearly diurnal variations of astronomical coordinates given in eq. (1).

Comparing the results of analysis of different observational data allowed us to make the above-mentioned conclusions on the spectra of the nearly diurnal latitude variations.

Let us consider some examples.

2.1. EXAMPLE 1

Given the spectrum of the nearly diurnal variations of latitude at the Gorky station, calculate a spectrum convolved about the frequency $\sigma_0=1$ cycle per sidereal day and compare it with the observed spectrum of latitude variation at Poltava (Popov and Yatskiv, 1979).

Based on the latitude observations at Gorky from 1961 to 1976, the spectrum of nearly diurnal variations was derived in the frequency domain $\sigma_j = 2\pi(1-0.000058K)$, where K is equal to ±1, ±2, ±3, etc. The initial phases of harmonics were converted to the initial epoch of the Poltava observations, i.e., $S_{op} = 0^h$ of sidereal time on March 1, 1950.

The symmetric harmonics in eq. (1) (for the case of the theoretically predicted retrograde component) were summed up:

$$A'_j \cos[(\sigma_o+\Delta\sigma_j)(S-S_o)+\beta'_j] + A''_j \cos[(\sigma_o-\Delta\sigma_j)(S-S_o)+\beta''_j], \qquad (2)$$

where $\Delta\sigma_j = (\sigma_o - \sigma_j)$ is the frequency of the transformed oscillation. After that, the amplitudes and phases of the resulting oscillations $\tilde{A}_j$ and $\tilde{\beta}_j$ were derived.

When summing up the symmetric harmonics in the case of the prograde nearly diurnal wobble, the difference between the longitudes of the Gorky and Poltava stations has to be taken into account.

In Table 1, the values of the amplitudes and phases of the transformed harmonics which are in common for the Gorky and Poltava stations are given. To each value of aliasing period T_j, corresponds two values of the nearly diurnal periods τ_j. The agreement of results, except for the harmonic with the period T=454 sidereal days, is satisfactory, taking into account the standard errors of amplitude and phase which are ±3 marcsec and ±30 degrees, respectively. As for the harmonic T=454 sidereal days, the phase difference could be explained partly by the presence of the prograde nearly diurnal wobble.

Table 1. Amplitudes (in marcsec) and phases (in degrees) of the nearly diurnal latitude variations of the Gorky and Poltava stations.

Period (sidereal days)		Poltava		Gorky	
T_j	τ_j	$\tilde{A}_j$	$\tilde{\beta}_j$	$\tilde{A}_j$	$\tilde{\beta}_j$
321	0.996894 1.003125	12	113	9	160
391	0.997449 1.002564	19	290	7	350
454	0.997802 1.002207	10	190	7	308
961	0.998960 1.001042	8	177	6	200

2.2. EXAMPLE 2

Given the spectrum of the nearly diurnal latitude variations of the Gorky station, calculate a spectrum convolved about the frequency σ_o=1 cycle per mean day and compare it with the observed spectrum of variations of the ILS stations (Yatskiv et al.,1975).

For this purpose, we have adopted the values of aliasing periods as well as the direction of polar motion given in Yatskiv et al.,1975. The results are summarized in Table 2.

Table 2. Amplitudes (in marcsec) and phases (in degrees) of the nearly diurnal latitude variations of the Gorky and ILS stations.

Period (mean days)		ILS		Gorky	
T_j	τ_j	$\tilde{A}_j$	$\tilde{\beta}_j$	$\tilde{A}_j$	$\tilde{\beta}_j$
retrograde component					
169.1	0.994121 1.005948	3	33	3	5
192.1	0.994822 1.005232	4	95	5	69
209.6	0.995253 1.004793	6	266	9	235
235.6	0.995773 1.004263	5	348	12	282
prograde component					
186.3	0.994660	7	208+2λ	8	255+2λ
204.4	0.995169	7	204+2λ	7	216+2λ
246.9	0.995966	10	298+2λ	5	253+2λ

The agreement of results is remarkable. Similar results based on the data of other observatories were given in Kovbasyuk, 1980.

2.3. DISCUSSION

From the results presented above, we can conclude that the nearly diurnal variations of the latitudes really exist. They can be explained by:

(a) variations of meteorological conditions of observatory sites;
(b) variations of vertical lines of observatories;
(c) motion of the pole (within the Earth body and in space) which is due to the existence of the Earth's liquid core.

The first reason seems to be unreal because we have used the data of different observatories (with different conditions and methods of observation). As for the second reason, it has some physical meaning, but it has to be excluded, otherwise the corresponding changes of gravity would be observed. Finally, the third reason at the present time can't be confirmed because of the lack of theoretical modelling of the wave motions in the Earth's core (Dehant, 1988; Melchior et al.,1988). If we suppose that the oscillations with periods of 0.994822 and 0.995253 mean days (see Table 2) result from amplitude variations (damping) of theoretically predicted FCN, we find the average value of the period of this nutation is 446 sidereal days and the damping factor Q~2500 (the value of the average period, 0.995038 mean days, corresponds to a period of 23h 56m 46.5s of sidereal time). These estimates of period and Q-factor are in agreement with estimates based on recent observations.

Now the question arises, why do FCN based on the VLBI observations show amplitudes one order of magnitude smaller than the amplitudes derived from astronomical observations? To answer this question, it is necessary to consider the problem of the VLBI observables and search for FCN. First of all, the prograde nearly diurnal wobble will result in the time delay observable as the semidiurnal variation. Such variation was never searched for before. In the case of retrograde, nearly diurnal wobble (and corresponding long-period FCN), the effect of correlation of this wobble with other solved-for parameters has to be investigated for different observational programs.

3. DETERMINATION OF CORRECTIONS TO THE COEFFICIENTS OF THE PRINCIPAL TERM OF NUTATION

In Table 3, the most accurate (from our point of view) astrometric determinations of corrections to the amplitudes of the prograde and retrograde circular nutations with a period of 18.6 years are given.

Taking the average values of these amplitudes, we find the values of the coefficients of the principal term of nutation to be:

in longitude $-\Delta\psi \mathrm{SIN}\theta = 6.8444 \pm 0.0006$ arcsec,
in obliquity $\Delta\theta = 9.2052 \pm 0.0006$ arcsec.

These values agree, within the errors, with the modern determinations of correction to nutation by VLBI observations and Lunar Laser Ranging (LLR) (Charlot et al.,1990).

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So, the necessity of adopting corrections to coefficients of the principal term of nutation is evident.

Table 3. Amplitudes (in 0.0001 arcsec) of the retrograde and prograde circular nutations with a period of 18.6 years at J 2000.0

Author and reference	Mean epoch of observations	Retrograde	Prograde
Yatskiv (1980, 1989) The mean values from the astrometric determinations carried out before 1980	1950	80250±10	11790±10
Capitaine et al., (1988) Z-term based on the BIH data from 1962 to 1982	1972	80245±09	11813±09
Glebova et al,(1990) Observations of the latitude at Pulkovo from 1948 to 1989	1968	80236±29	11792±29
Lapaeva (1988) Observations of the latitude at the Engelhardt observatory from 1957 to 1976	1967	80238±22	11766±22
Mean values	1965	80248±06	11804±06
IAU-1980 theoretical values		80220	11804

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