ON THE ACCURACY OF THE 1980 IAU NUTATION SERIES

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I. INTRODUCTION

At the Seventeenth IAU General Assembly in Montreal, Canada, in 1979, the resolution was passed adopting the 1979 Nutation Series, which was based on : - the development of the rigid theory by Kinoshita (1977); - the modifications to this theory allowing for the effects of a fluid core and an elastic shell (Molodensky, 1961). The purpose of this action has been nothing but the adoption of a working Standard on Nutation. The details that follow are well known (Seidelmann, 1980). After a discussion at IAU Colloquium N°56 in Warsaw, Poland, in 1980, the Working Group on Nutation decided to recommend a change to the 1980 IAU Nutation Series, which is based on the theory developed by Wahr (1980). The differences between the above mentioned Series are within the limits of $\pm 0\overset{''}{.}002$ and are not detectable with the present observational accuracy. As an example, we summarized in Table 1 the observed amplitudes of circular nutation component ($2L_{☾}-\alpha$) which were determined from astronomical observations with best accuracy. The effect of O_1-tide on this component is taken into account by using the theoretical tide with $\Lambda=1+k-l=1.2$. The theoretical amplitudes of this component were reduced to the mean epochs of observations.

Thus, both of the nutation series satisfy the requirements for astronomical observations. However, new techniques, such as laser ranging and VLBI, promise to achieve an accuracy more than ±0.002 in the near future. Therefore, the adopted working standard has to describe the actual nutation motion as accurate as possible.

O. Calame (ed.), High-Precision Earth Rotation and Earth-Moon Dynamics, 287–292.

TABLE 1. Observed and theoretical amplitudes of the nutational component ($2L_{☾}-\alpha$)

Author	Observational data	Amplitude
Orlov (1961)	Pulkovo, 1915-1928	0".0940
McCarthy (1976)	Washington, 1930-1976	0.0945
O'Hora and Griffin (1980)	Herstmonceux, 1958-1976	0.0928 (lat.)
		0.0919 (time)
Gubanov and Yagudin (1979)	U.S.S.R., Time Service, 1955-1974	0.0909
Taradij et al (1980)	I.L.S., 1899-1966	0.0961
Manabe et al (1980)	I.L.S., 1899-1977	0.0936
Mean value		0.0934
IAU (rigid Earth)		0.0847
IAU 1979		0.0935
IAU 1980		0.0940

II. ON THE CAUSES OF INACCURACY OF NUTATIONAL SERIES

The possible sources of inaccuracy of the modern nutation series, in particular the 1980 IAU Nutation Series, are :

(a) internal inconsistency of the theory;
(b) inaccuracy of the IAU System of Astronomical Constants (1976);
(c) deficiency of the Earth's model;
(d) dynamical effects of the oceans;
(e) effect of core-mantle dissipative coupling;
(f) other non-modelling effects.

We have tried to estimate the contribution of the effects to inaccuracy of nutation series. As an estimator, we used the average value (<S>) of mean-root-square errors of amplitudes of nutation components with frequencies ±1/13.7, ±1/183 and ±1/6798^d.

From the available observational data collected by one of the authors (Yatskiv, 1980), we have found that $\langle S\rangle_{obs} = \pm 0''.0014$. One can consider $\langle S\rangle_{theor.} \leqslant \pm 0''.001$ as an a priori estimate of <S> which will meet the modern requirements for coordinate systems for the Earth's dynamics.

II.1 The effects of internal inconsistency of the theory and of inaccuracy of adopted astronomical constants.

The computation of nutation for the total angular momentum of the Earth (H_E) by Wahr (1980) offers the means of testing for internal consistency of the theory. From the H_E results shown in Table 3 of

Wahr's paper (1980), one can find $<S>_a \leqslant 0''.0001$. In spite of the additional theoretical assumptions, the effect of internal consistency of Molodensky's theory (1961) is of the same order.

The present accuracies of the ratio (μ) of the masses of the Moon and the Earth and of the luni-solar precession (f_{2000}) are sufficient to determine nutation coefficients for a rigid Earth within $\pm 0''.0001$ (Duncombe et al, 1976).

II.2 The effect of deficiency of adopted structural models.

Comparing the results by Molodensky (1961), Shen and Mansinha (1976) and Wahr (1980), we have found the effects of deficiency of Model 2 by Molodensky $<S>_C^M = \pm 0''.0011$ and those of Model 1066A by Gilbert and Dziewonsky (1975) $<S>_C^{GD} = \pm 0''.0001$.

II.3 The dynamical effect of the oceans.

This effect has been studied by one of the authors (Molodensky, 1981). The systematic effect of the ocean tide on nutation can be written in the form :

$$\frac{\delta\tilde{\varepsilon}(\theta)}{\varepsilon_r} = \tilde{k}\ a(\theta) \qquad (1)$$

where $\mathrm{Re}\,\delta\varepsilon(\theta)$ and $\mathrm{Im}\,\delta\varepsilon(\theta)$ are the corrections to the amplitude and the phase of nutation component with the frequency θ; ε_r is the amplitude of nutation of the rigid Earth; $\tilde{k}$ is the complex Love number; $a(\theta)$ are dimensionless coefficients, which depend on the adopted Earth's model.

For the Model 508 by Gilbert and Dziewonsky (1975), the value of $a(\theta)$ are given in the first line of Table 2.

TABLE 2. Values of coefficients $a(\theta)$ for Gilbert and Dziewonsky Model 508.

Coefficient	Frequency							
	-1/13.7	-1/183	-1/365	-1/6800	1/6800	1/365	1/183	1/13.7
$a(\theta) \times 10^3$	200	140	310	-5.9	5.1	40	47	-4.1
$-\delta\varepsilon(\theta) \times 10^3$	0''.0	0''.1	0''.2	-0''.9	0''.1	0''.0	0''.5	0''.0

The accurate value of $\tilde{k}$ has only been determined for the equilibrium tide (Dahlen, 1976)

$$\mathrm{Re}\ \tilde{k}\Big|_{\theta=0} = 0.05 \qquad \mathrm{Im}\ \tilde{k}\Big|_{\theta=0} = 0 \qquad (2)$$

However, for our purpose, it is necessary to take into account the non-equilibrium behavior of the oceans.

Using the chart by Bogdanov and Magarik (1969), Pertzev (1980) has found the following results for the K_1-tide :

$$\mathrm{Re}\ \tilde{k} \sim -0.02 \qquad \mathrm{Im}\ \tilde{k} \sim 0.007 \tag{3}$$

Using these values, we have computed the corrections to the amplitudes of nutation components given in the second line of Table 2, and the corresponding estimate $\langle S \rangle_d = \pm 0\overset{''}{.}0004$.

II.4 The effect of core-mantle dissipative coupling.

The most remarkable corrections for this effect are expected to appear in the principal and annual terms. This problem was studied by Sasao et al (1977) and Sasao et al (1980), who gave the preliminary estimates of corrections to the amplitude and phase of nutation. The actual value of $\langle S \rangle_c$ appears to be within the limits of $\pm 0\overset{''}{.}0001$ to $\pm 0\overset{''}{.}0010$. The effects mentioned above are listed in Table 3.

TABLE 3. Estimates of S for different effects in nutation.

Effect	Nutation series IAU 1979	IAU 1980
(a) internal inconsistency of theory	$\pm 0\overset{''}{.}0001$	$\pm 0\overset{''}{.}0001$
(b) inaccuracy of astronomical constants	±0.0001	±0.0001
(c) structural model	±0.0011	±0.0001
(d) dynamical effect of the oceans	±0.0005	±0.0005
(e) core-mantle dissipative coupling	±0.0001 to ±0.0010	±0.0001 to ±0.0010
Total	±0.0012 to ±0.0016	±0.0005 to ±0.0011

III. CONCLUSION

1. The 1980 IAU Nutation Series is based on the best Earth model, available presently. The accuracy of this series is of the order of $\pm 0\overset{''}{.}001$, which is better than those that have been obtained from long series of astronomical observations.

2. The effects of the oceans and core-mantle dissipative coupling

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appear to be remarkable and should be a subject of further study with using the new observational techniques.

REFERENCES

Bogdanov, K. T. and Magarik, V. A., 1969, *Numerical solution of the problem of distribution of tidal waves in ocean.* Physics of atmospheric and ocean, Nauka, 5, N 12 (in Russian).

Dahlen, F. A., 1976, *Ocean influence upon the rotation of the Earth.* Geophys. J. Roy. Astr. Soc., 46, 363.

Duncombe, R. L. et al., 1976, *Report of joint meeting of Commission 4, 8 and 31 on the new system of astronomical constants.* Trans. IAU XVI B, 49.

Gubanov, V. S. and Yagudin, L. I., 1979, *A new system of the USSR Standard Time for 1955-1974.* Proc. IAU Symp. N°82 "Time and the Earth's Rotation", D. Reidel, 47.

Gilbert, F. and Dzeiwonski, A. M., 1975, *An application of normal mode theory to the retrieval of structural parameters and source mechanisms from seismic spectra.* Phil. Trans. Roy. Soc. Lond., A 278, 187.

Kinoshita, H., 1977, *Theory of the rotation of the rigid Earth.* Celest. Mech., 15, 277.

Manabe S., Sakai, S. and Sasao, T., 1980, *Declination corrections and short periodic latitude variation derived from the recalculated past ILS data.* Publ. Intern. Lat. Obs. Mizusawa, 13, 53.

McCarthy, D. D., 1976, *Observations of the fortnightly nutation terms and the dynamical variation of latitude with PZT.* Astron. J., 81, 482.

Molodensky, M. S., 1961, *The theory of nutation and diurnal Earth tides.* Commun. Obs. Roy. Belgique, 188, 25.

Molodensky, C. M., 1981, *Effects of the ocean and viscosity of the shell on nutation.* Physics of the Earth, Nauka (in Russian).

O'Hora, N. P. and Griffin, S. F., 1980, *Short-period terms in time and latitude observations made with the Herstmonceux PZT.* Proc. IAU Symp. N°78 "Nutation and the Earth rotation", D. Reidel, 53.

Orlov, A. Ya., 1961, *Analysis of Pulkovo observations made with ZT from 1915 to 1928.* Selected papers by Orlov, Vol. 1, Kiev, 234 (in Russian).

Pertsev, B. P. (private communication).

Sasao,T., Okamoto, T. and Sakai, S., 1977, *Dissipative core-mantle coupling and nutational motion of the Earth.* Publ. Astr. Soc. Japan, 29, 83.

Sasao, T., Okubo, Sh. and Saito, M., 1980, *A simple theory of the dynamical effects of a stratified fluid core upon nutational motion of the Earth.* Proc. IAU Symp. N°78 "Nutation and the Earth's rotation", D. Reidel, 171.

Seidelmann, P. K., 1980, *The 1980 IAU theory of nutation.* Memorandum to the members of the IAU Working Group on Nutation. (See Trans. IAU Vol. XVII B, 1980).

Shen Po-Yu and Manshina, L., 1976, *Oscillation, nutation and wobble of an elliptical rotating Earth with liquid outer core.* Geophys. J. Roy. Astr. Soc., 46, 467.

Taradij, B. K., Korsun, A. A. and Yanovitskaja, G. T., 1980, *Fortnightly nutation from the ILS data.* (Private communication).

Wahr, J., 1981, *The forced nutation of an elliptic, rotating, elastic and oceanless Earth.* Geophys. J. Roy. Astr. Soc., 64, 705.

Yatskiv, Ya. S., 1980, *Nutation in the IAU System of Astronomical Constants.* Preprint of the Institute for Theoretical Physics, Kiev.

DISCUSSION

Anderle : Have solid Earth measurements determined which model is better ?

Yatskiv : It is clear now that the Wahr model is better, because it is based on the Gilbert & Jablonsky structural model, which better satisfies the observed eigenfrequencies of the Earth. Neither theory yet adds the effects of the oceans or of core-mantle coupling.

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