NEW SERIES OF RIGID AND NON RIGID EARTH NUTATION. COMPARISON WITH OBSERVATIONS

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Abstract. After analysing the recent developments of the theory of the nutation for a simplified rigid Earth model (Kinoshita and Souchay,1990) with new corrections and new contributions (Williams,1994; Souchay and Kinoshita,1996), we will study the effect of these developments on the calculation of the coefficients of nutation for a non rigid Earth model, based on the transfer function given by Wahr (1979). The relative improvements characterized by the residuals with the observations are explained in the following.

1. Introduction

Because of the high accuracy obtained by the VLBI observations in the recent years, the conventional IAU1980 nutation series (Wahr,1979; Seidelmann,1982) can no more be available, mainly because only the coefficients up to 0.1 milliarcsecond (mas) were retained, whereas the precision of the observational individual determination of nutation coefficients by VLBI (Herring *et al.*, 1991) falls far below this limit.

In view of this remark it was necessary to reconstruct the tables of the nutation for a rigid Earth model by taking into account all the coefficients up to 0.005 mas. This was done both by Zhu and Groten (1989) and Kinoshita and Souchay (1990). For some reasons explained by Souchay (1993), this last work is more complete than the former one, especially because planetary effects (direct and indirect) have been considered. Notice also that some important corrections to large coefficients (among them the corrections at the level of 1 mas of coefficients of argument Ω and 2Ω) were

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done by Kinoshita and Souchay (1990), which characterize an interaction between the orbital motion of the Moon and the motion of rotation of the Earth.

Williams (1994) as well as Souchay and Kinoshita (1996) pointed out corrections and new contributions which were not included in the series of Kinoshita and Souchay (1990). In the following we present all the improvements to these last series related to the remarks above.

2. Corrections and new contributions in rigid earth nutation

Since the tables of the nutation for a rigid Earth model were established by Kinoshita and Souchay (1990), many authors have shown that a correction to the value of the general precession in longitude p_A, that is to say: $p_A =$ 5029.0966"/cy (Lieske *et al.*, 1977), was necessary. The values found for the correction δp_A are in agreement one to each other (Herring,1991; Herring*et al.*, 1991; Mc Carthy and Luzum,1991; Miyamoto and Soma,1993; Williams *et al.*, 1993) and close to : $\delta p_A = -0.3$"/cy. Notice that they are coming from the reductions of various kinds of observations (LLR, VLBI, optical catalogue).

Souchay and Kinoshita(1995), by choosing the value $\delta p_A = -0.3266$ "/cy, as suggested by Williams (1994), show that this correction leads to a correction to the dynamical ellipticity of the Earth H_d as calculated by Kinoshita and Souchay (1990). Their new value: $H_d = 0.0032737548$, is different from the value in this last paper:$H_d = 0.0032739567$, by a relative amount of 6×10^{-5}. This change in the value of H_d affects in a significant manner the largest trems of nutation as calculated by Kinoshita and Souchay (1990), at the level of 1 mas for the 18.6y component. Notice that the value of H_d recently calculated by Williams (1994) by taking the same correction $\delta p_A = -0.3266$"/cy, that is to say: $H_d = 0.0032737634$, is close to the new value calculated by Souchay and Kinoshita (1996).

Williams (1994) pointed out a planetary tilt effect on nutation not taken into account in the tables of Kinoshita and Souchay (1990). They are characterized by out of phase components for the terms of argument Ω and 2Ω. Souchay and Kinoshita (1996) calculated the total amplitudes of these terms. They found:

$$\Delta\Psi = -17283.977 \sin\Omega + 0.135 \cos\Omega + 209.077 \sin 2\Omega + 0.005 \cos 2\Omega$$

$$\Delta\varepsilon = 9228.910 \cos\Omega - 0.030 \cos\Omega - 90.360 \cos 2\Omega + 0.003 \sin 2\Omega$$

to be compared with the respective amounts in Kinoshita and Souchay (1990):

$$(\Delta\Psi)_{out-of-phase} = -17285.201 \sin\Omega + 209.095 \sin 2\Omega$$

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$$(\Delta\varepsilon)_{out-of-phase} = 9229.578\cos\Omega - 90.368\cos 2\Omega$$

Their value for the new out-of-phase contributions are very close to those of Williams (1994) who found:

$$\Delta\Psi = 0.137\cos\Omega + 0.006\cos 2\Omega$$

$$\Delta\varepsilon = -0.028\cos\Omega + 0.003\sin 2\Omega$$

Moreover, Souchay and Kinoshita (1996) found new terms not included in the tables of Kinoshita and Souchay (1990), due to the oscillations of the true ecliptic with respect to the mean ecliptic of the date. They are characterized by 9 coefficients larger than the level of truncation of the series (0.005 mas).

They also summarized in their tables all the corrections and new contributions explained above, with respect to the results of Kinoshita and Souchay (1990). Notice that they concern the luni-solar part of the nutation for a rigid Earth model, the indirect planetary effects being included. Moreover, their tables include also all the sign errors, omissions or misprints in the tables of Kinoshita and Souchay (1990).

3. VKSNRE95.1 Series for non rigid earth nutation

The conventional IAU80 nutation series (Seidelmann,1982) are based on the rigid Earth nutation series established by Kinoshita (1977) to which the transfer function calculated by Wahr (1979) has been applied, to determine the coefficients for a non rigid Earth model. In order to evaluate the improvement in nutation theory due to the reconstruction of the tables of nutation for a rigid Earth model by Kinoshita and Souchay (1990), the same transfer function as above has been applied to these reconstructed tables. Souchay *et al.* (1995 a) have compared the nutation given by resulting series, called KSNRE (Kinoshita and Souchay Non Rigid Earth) with VLBI observations (Ma *et al.*, 1994). By comparing the KSNRE nutation with 10 years of VLBI data, they have shown that the weighted rms post fit residuals are 1.16 mas in longitude and 1.18 mas in obliquity. If the comparison with IAU80 series is done, the rms post fit residuals becomes respectively 1.27 mas and 1.44 mas. This improvement is undoubtedly due to the new level of truncation of the KSNRE series (0.005 mas instead of 0.1 mas).

In a similar way, Souchay *et al.* (1995 b) have shown that after fitting only the linear trend, the FCN (Free Core Nutation) term and 9 among the 10 largest terms of the KSNRE series, which are affected by the geophysical modeling, the residuals after comparison with 15 years VLBI observational data falls below 0.1 mas for the total amplitude of the nutation. This leads

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them to construct new series, called VKSNRE95.1, consisting in adopting the empirical fitted value for the 9 terms above (both in longitude and obliquity), all the other terms being those of KSNRE analytical series. Among the fitted terms are the 18.6 y, the annual, semi-annual monthly and fortnightly components. Even if there is clearly a need to explain the relatively big differences between the theory and the observations for the 9 fitted terms above, the VKSNRE95.1 series can be of very useful help for users needing to use analytical series characterized by a very good agreement with the observations.

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