THE SHORT PERIOD NUTATIONS OF THE EARTH

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ABSTRACT

Facing the drastic improvements of VLBI and GPS observations which lead to a very high accuracy in the determination of the EOP (Earth Orientation Parameters), it was necessary to develop further the theoretical calculations of nutation coefficients, noticably by lowering the truncation threshold of the amplitude of these coefficients. Thus, we show that at the microarsecond level, a significant amount of coefficients of nutation with sub-diurnal period are present. After describing their origin from the non-zonal harmonics of the geopotential, we explain their global effect on the modelization of the pole direction in space, discussing also the influence of the model of Earth chosen (rigid or non-rigid).

1. THE ORIGIN OF THE SHORT PERIOD NUTATIONS.

The non-rigid Earth nutation series adopted by the IAU (International Astronomical Union) in 1980 are based on the works of Kinoshita (1977) and Wahr (1979). In the first one, the rigid Earth nutation series were calculated by the application of the Hamiltonian canonical equations to the rotation of the rigid and elliptical Earth. In the second one, the transfer function for the nutations of an elliptical, elastic and oceanless Earth with fluid outer core and a solid inner core was obtained. The non-rigid Earth nutation coefficients were derived from the convolution between Wahr's transfer function and Kinoshita's rigid Earth nutation series.

The improvement in the accuracy of the techniques as Very Long Baseline Interferometry (VLBI), Lunar Laser Ranging (LLR) and Global Positining System (GPS) have led in this decade to the extension of Kinoshita's theory and more precise determination of Wahr's transfer function.

The new transfer function are based on new models for Earth's interior and takes into account other geophysical effects as changes in the boundary shapes due to the non-hydrostatic equilibrium, changes in the density, the inelasticity of the mantle, etc. (Dehant and Defraigne, 1997), (Mathews et al., 1998), (Dehant et al., 1999).

In Kinoshita's work, the coefficients of nutation up to 0.1 *mas* (milliarcsecond) have been taken into account. The extension of this work was principally due to the better precision reached by the observations. Such extension has been carried out in several steps:

- 0.1 *mas* → 0.005 *mas*

  This step made necessary the introduction of the direct and indirect planetary effects, of the influence of the second-order parts of the potential and some improvements due to an extension of the theory at the second order as the coupling effect between the rotational motion of the Earth and the orbital motion of the Moon: (Kinoshita and Souchay, 1990).

- 0.005 *mas* → 0.1 *μas* (microarcsecond)

  In this step, the calculations of the planetary tilt-effect, the second order effects due to crossed-nutations and spin-orbit coupling and the influence of non-zonal harmonics of third and fourth degree was carried out: (Souchay and Kinoshita, 1996; 1997), (Folgueira et al., 1998a;b), (Souchay et al., 1999).

The short period nutations have their origin in the non-zonal harmonic coefficients of the geopotential. That is, they come from the harmonics C_{nm} and S_{nm} (with $m \neq 0$). Kinoshita (1977) studied theoretically the influence due to the Earth is not an axially symmetrical body (originated by C_{22} and S_{22} coefficients) and also proved numerically that such harmonics had no appreciable effect on the rotational motion of the Earth, at a level of 0.1 *mas*. The new level of truncation for the coefficients of nutation considered by Kinoshita and Souchay (1990) provided 7 terms in longitude and 3 terms in obliquity above 0.005 *mas* due to the triaxiality of the Earth. The new tables REN-2000 of the nutation for a rigid Earth model have included all the quasi-diurnal and sub-diurnal nutations above 0.1 *μas*. The number of short period nutations considered is 252 terms in longitude and 190 in obliquity. This appreciable amount of new coefficients comes from the harmonics C_{22}, C_{31}, C_{32}, C_{33}, C_{41}, S_{22}, S_{31}, S_{32}, S_{33} and S_{41}.

In the last years, new rigid Earth nutation series, calculated using different analytical methods, have come forth. These are SMART97, Bretagnon et al.'s series, and RDAN97, Roosbeek and Dehant's series (Bretagnon et al., 1997;1998), (Roosbeek and Dehant, 1998). In the next section, we evaluate the differences between these two series and REN-2000.

2. TEMPORAL EVOLUTION OF REN-2000 SHORT PERIOD NUTATIONS. COMPARISON WITH OTHER SERIES.

The figures 1 and 2 show the temporal evolution for 1 century of REN-2000 short period nutations for $\Delta\psi \sin\varepsilon$ and $\Delta\varepsilon$. As we can see, these contributions vary between -60 *μas* and +50 *μas* for longitude component and between -50 *μas* and +50 *μas* for obliquity component. The figures 3 and 4 present the temporal evolution for 1 century of the differences between SMART97 and REN-2000, for longitude and obliquity quasi-diurnal and sub-diurnal nutations. Finally, in the figures 5 and 6, we show the time domain comparison between RDAN97 and REN-2000, for longitude and obliquity components, when considering a 100 years time span.

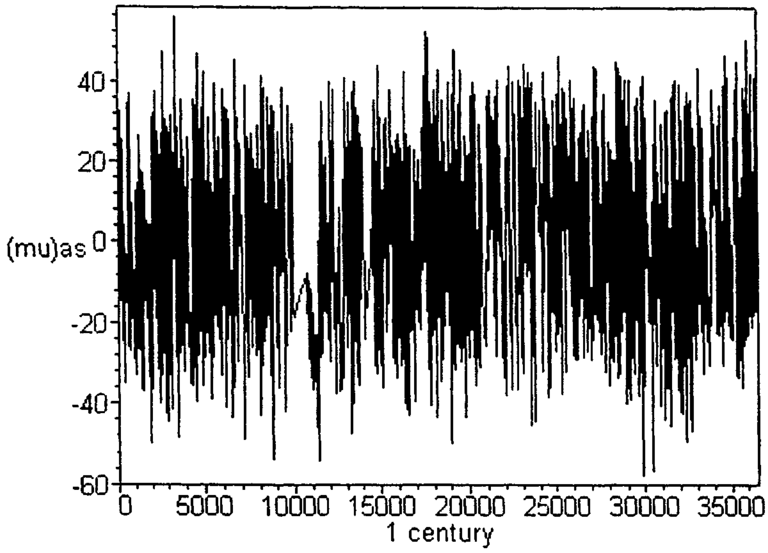

Figure 1: REN-2000 short period nutations in longitude.

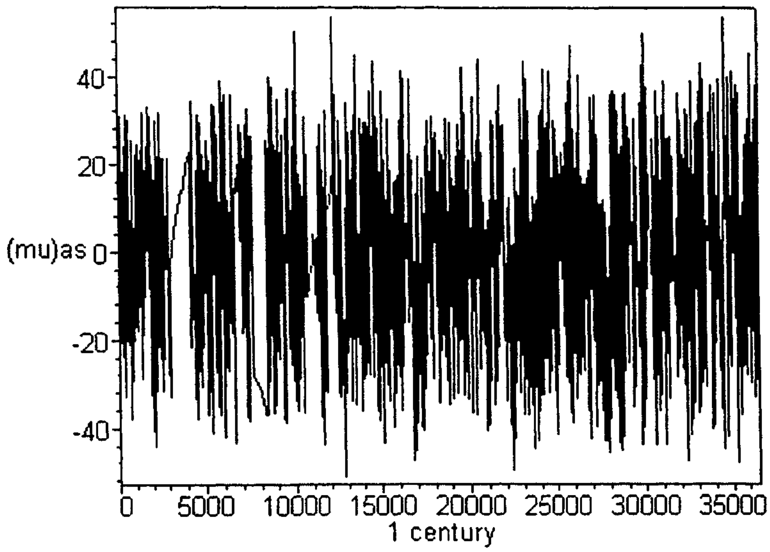

Figure 2: REN-2000 short period nutations in obliquity.

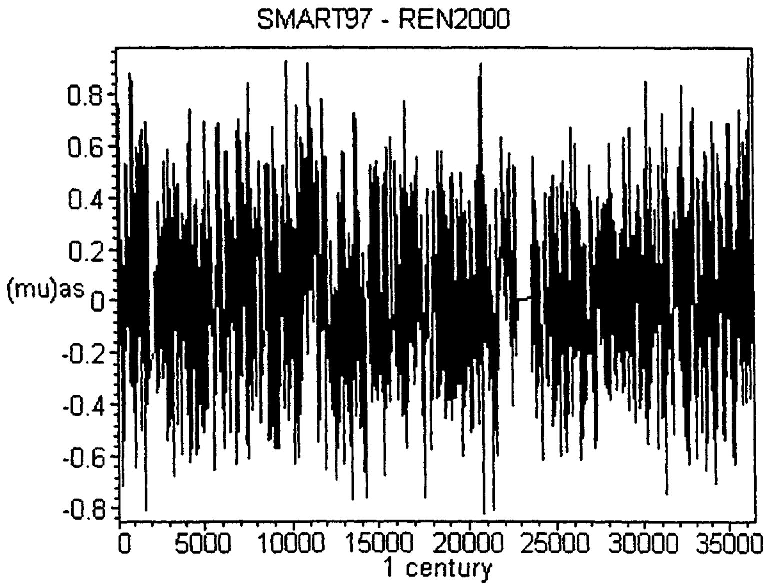

Figure 3: Time domain comparison between SMART97 and REN-2000, longitude part.

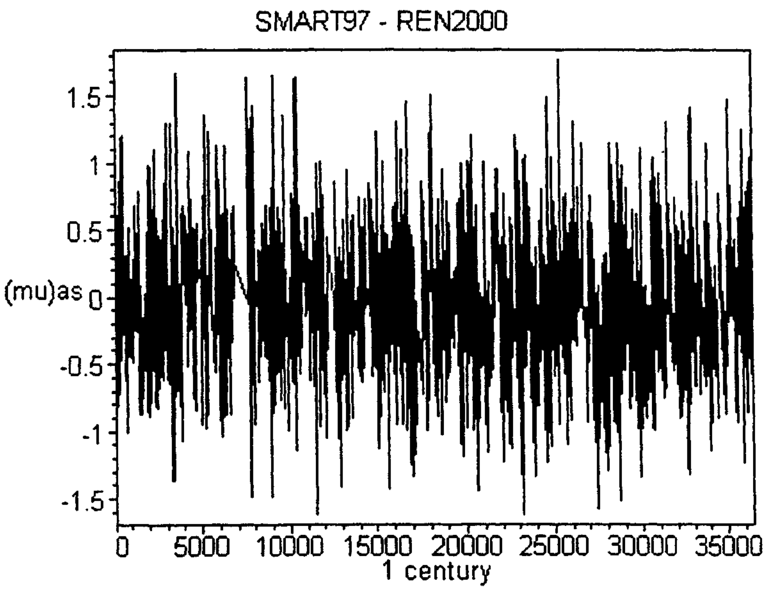

Figure 4: Time domain comparison between SMART97 and REN-2000, obliquity part.

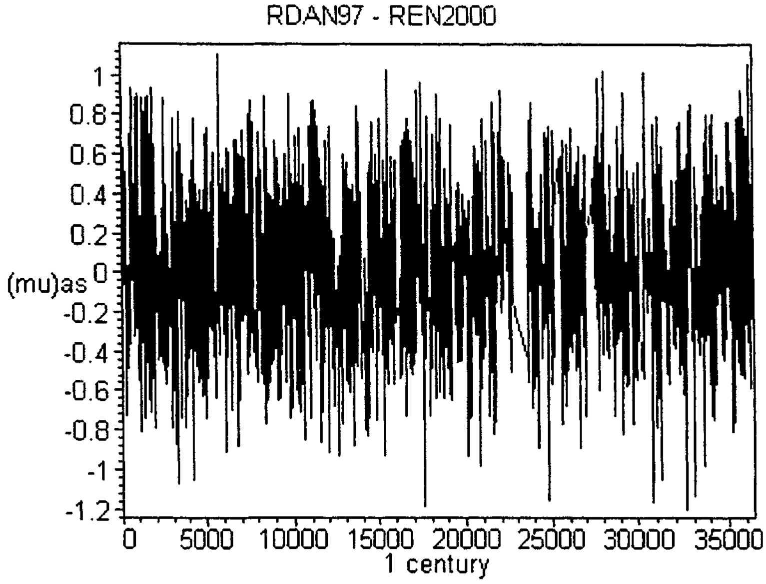

Figure 5: Time domain comparison between RDAN97 and REN-2000, longitude part.

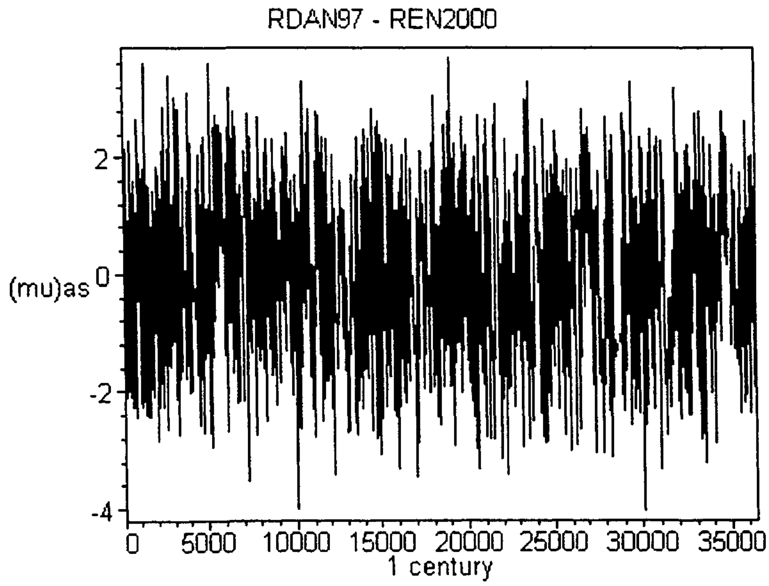

Figure 6: Time domain comparison between RDAN97 and REN-2000, obliquity part.

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