OBSERVED AND THEORETICAL VALUES OF THE NUTATIONS

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We are here concerned with the nutations that appear in the motion of the Earth because of the existence of the external forces due to the Sun and Moon, that is, the forced nutations.

We can consider the nutations divided in two groups from the point of view of their values and the precision attained by astronomical observations. The first group comprises the nutations that have values greater than 1″ and in this group we have the nutation of period 18.6 yr called the principal nutation and the value of this nutation in obliquity is called the constant of nutation. The second group comprises the nutations with values smaller than 1″ and corresponds to the great majority of all other nutations.

Grouping the nutations in this way we can see immediately the great difficulties we have in determining their observed values because the great majority of them have values inferior to one second of arc and therefore can only be determined by astronomical observations of high precision.

The observed values of the nutations correspond to the behaviour of the real Earth considered as a body with a layered structure and where exists an irregular distribution of the oceans and continents.

The observations of the principal nutation have been specially concerned with the value in obliquity, that is, the so called constant of nutation. There is a lack of observations made in a convenient way in order to obtain the value in longitude. Some of the values computed from the observations are:

Principal nutation in obliquity

Newcomb (1895)	9″.210 ±0″.008
Przybyllok (1920)	9.2069±0.0030
Spencer Jones (1939)	9.2066±0.0055
Morgan (1943)	9.206 ±0.007
Kulikov (1956)	9.2108±0.0019
Hattori (1951)	9.1985±0.0051
Fedorov (1958)	9.1980±0.0018

These values have been obtained employing different observational methods and computational procedures, but a certain number of them have relied on the values obtained at the stations of the International Latitude Service (ILS) nowadays called the International Polar Motion Service (IPMS).

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We can see that Newcomb's value adopted as one of the fundamental constants of astronomy since 1896, does not show great differences when compared with the other values considering their stated errors, and one must remember that the errors indicated were derived from each series of observations employed.

Another source of imprecision derives from the fact that the results of the observations made at the ILS do not correspond to the same method of reduction of the observations throughout the 70 yr that this service has operated. There is therefore a lack of homogeneity in the published results for the different years and for the coordinates of the pole (Vicente and Yumi, 1969).

Most of the published values of the constant of nutation do not cover a sufficient interval of time compared with the period of this nutation which is 18.6 yr.

Considering all the difficulties and imprecisions that appear in the determination of the observed values of the principal nutation, we cannot have any grounds for changing the adopted value of this nutation.

The other group of nutations with values smaller than 1″ are still more difficult to determine from the observations, the above reasons applying more strongly in this case. The difficulty in determining their values is shown by the few reliable determinations made till the present time.

The values obtained by Fedorov (1958) are

	Obliquity	Longitude
Fortnightly	0″.0949 ± 0″.0010	0″.0918 ± 0″.0010
Semi-annual	0.578 ± 0.004	0.533 ± 0.004

The main difficulties here are to have astronomical observations of high precision and to have employed homogeneous series of observations in order to be able to derive the values of these nutations.

We have now to consider the theoretical values of the nutations obtained from the theory of the rotation of the Earth around its centre of mass. This theory has been developed considering the Earth as a homogeneous and rigid body and the values obtained have been employed in all ephemeris calculations that appear in the several national almanacs published in different countries. As an example of the lack of uniformity in the formulae adopted we can see that the values used by the *Astronomical Ephemeris* have been different before and after 1960 (Explanatory Supplement, 1961). Even prior to 1960 the number of long and short period terms of the nutations included in the calculations have varied from time to time.

This fact is also a good example for the need of not having too many changes in the adopted values of the nutations because they introduce another possible source of error due to the fact that people are not aware of these changes and therefore do not take them into consideration if they are not specialists in this field of research.

The theoretical expressions adopted for the nutations since 1960 have been based on the research carried out by Woolard (1953). This research considers the Earth as a rigid and homogeneous body and the values obtained show discrepancies when

compared with the observed values of the nutations (Vicente, 1969). The explanation of this discrepancy has only been possible since the seismological studies revealed a layered structure for the Earth, specially the division of the Earth in two main parts corresponding to the mantle and core; another important fact is the existence of a liquid core for the Earth.

The development of a theory of the nutations considering the Earth as a heterogeneous and elastic body (Jeffreys and Vicente, 1957; Molodensky, 1961) has led to the possibility of explaining the disagreements between the observed and theoretical values of the nutations.

This theory has revealed the complexity of the subject and specially the influence that the liquid core has on the values of the nutations. It is therefore essential to have a good knowledge of the internal structure of the Earth and this subject has been pursued vigorously in the last few years, leading to the setting up of many Earth models. This is one of the difficulties of the present time because one does not know which Earth model should be adopted in the calculations for determining the theoretical values of the nutations.

Another difficulty derives from the fact that the theory of nutations is closely connected with the bodily tides of the Earth (Jeffreys and Vicente, 1957), that is, the theory of the tides, and therefore it would also be convenient to have a more uniform agreement with the theoretical expressions adopted in tidal theory.

These subjects are being studied at the moment and we shall probably get an internationally agreed model for the structure of the Earth within the next few years. This is essential for the determination of the theoretical values of the nutations.

The observed values of the nutations, most of them computed from the results of the IPMS, can only be better determined after the observations of latitude variations are reduced to a more homogeneous system for the reasons given by Vicente and Yumi (1969).

Another great advantage in not changing the adopted values of the nutations, besides the reasons given above, derives from the fact that frequent changes in the values of the fundamental constants of astronomy introduce difficulties and complications in the construction of astronomical ephemerides and also many scientists working in related subjects are not aware of these changes, so that they may sometimes adopt wrong values for these constants.

The theoretical relations connecting the constants of nutation and precession, the dynamical ellipticity of the Earth, the mass of the Moon and the solar parallax (Vicente, 1965) show the importance of the modern methods of determining some of these values, for instance, by satellite and radar observations, and therefore we shall have more reliable values that will give us an improved knowledge of some of these quantities in the near future.

These facts justify the opinion expressed in 1963 (Vicente, 1965; p. 113) that a change in the system of astronomical constants should wait till it is possible to have a critical discussion of the results obtained by the modern methods of observation of the masses and motions of the bodies of the solar system.

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