LATEST BEST ESTIMATES OF ASTRONOMICAL CONSTANTS

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1. Abstract

Systematic errors caused by the use of inconsistent models and constants currently limit the accuracy of the most precise astro-geodetic observations. It is important, therefore, to provide conventional estimates of astronomical constants for general use in astronomy and geodesy. Establishment of such a set raises issues involving the accuracy of the constants, their internal consistency, and the reference system in which they are expressed. Future sets of constants will be updated at regular intervals to provide the most accurate values at that instant. Careful consideration must be given to their internal consistency. It is likely that they will be provided only in electronic format with references to their determination and to procedures for their use.

2. Introduction

Establishment of a conventional set of astronomical constants involves consideration of several issues.

Accuracy - Generally researchers require the most accurate estimates available. However, in some instances it may be more desirable to make use of estimates which may not be the most accurate but may be "conventional."

Consistency - Internal consistency of a set of constants is a desirable, if not critical, quality of a set of constants. Some researchers may require constants which are consistent with themselves but may not be the most accurate.

Frequency of updates - The question of how often the conventional set of constants should be updated is particularly important for researchers when it is now possible to make "best" estimates available instantaneously by electronic means. In some cases it is also possible to re-analyze large amounts of data rather quickly using revised constants and models. On the other hand, some may require constants which will be "stable" over an extended period of time.

Availability - Particularly for current best estimates, users need to have easy and fast access. It may also be useful to have access to explanatory information regarding the constants available at the same location.

Minimal Set - Rather than update a large set of constants, it may be more logical to provide a minimum set from which a more extensive set could be derived. If this course is followed it would be useful to provide proper procedures to be used in these derivations.

3. Requirement for constants

Modern observations making use of the most precise techniques such as very long baseline interferometry, laser ranging to satellites or the Moon, and GPS provide valuable information for astronomical reference systems, geodesy, and geophysics. Unfortunately, the analyses of these ob-

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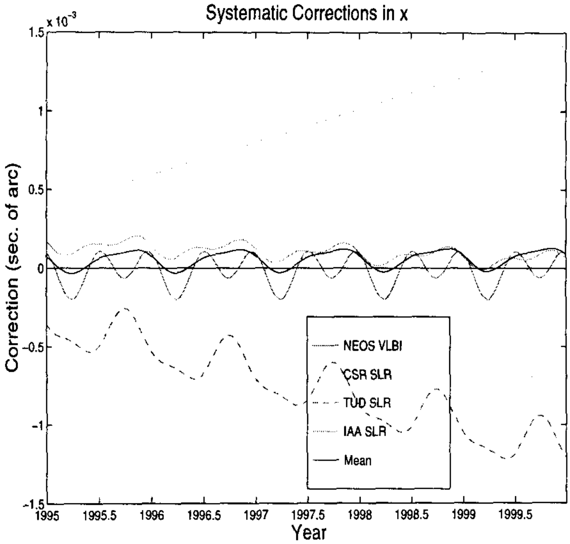
Figure 1. Systematic Errors in x.



servations are limited by discrepancies in the models and constants used. One example of this fact is shown in Figure 1 which shows the large systematic differences among the estimates of the polar coordinate x by different analysis centers.

4. Relevant Constants

Version 1.3 of the 1986 CODATA Recommended Values of Physical Constants (Cohen and Taylor, 1986) is currently in widespread use. It is available electronically at

http://physics.nist.gov/funcon.html.

A new general adjustment of these values is currently in progress. This 1997 Adjustment is anticipated to be available after September, 1998.

The International Association of Geodesy (IAG) has established a Special Commission on Fundamental Constants (Burša, 1995). Its mission is to provide a set of current best estimates of geodetic parameters for the 1999 General Assembly of the International Union of Geodesy and Geophysics (IUGG). The IUGG has had a long tradition of quadrennial updates to the current best estimates of geodetic parameters.

The International Earth Rotation Service (IERS) has continued its publication of constants in its IERS Conventions (McCarthy, 1996). MERIT standards (Melbourne *et al.*, 1983) were the first in a series which has been continued with the publication of the IERS Standards in 1987, (McCarthy, 1989), 1992 (McCarthy, 1992) and the IERS Conventions in 1996. They are available electronically at

http://maia.usno.navy.mil/conventions.html.

5. IERS Conventions

The IERS Conventions are designed to be used in transforming between celestial and terrestrial reference frames. Accuracy is the foremost consideration for the models and constants which are included. As a result there may be small inconsistencies between the chapters of this publication. The values of the constants contained in Chapter 4 are listed in Table 1. It is organized into 5 columns: item, value, uncertainty, reference, comment. All values are given in terms of SI units (Le Système International d'Unités (SI), 1991). The SI second, the basic unit of the TT time scale, is

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specifically assumed. If the TDB time scale is used, new units of time, t_{TDB}, and length, ℓ_{TDB}, are implicitly defined by the expressions (Seidelmann and Fukushima, 1992)

$t_{TDB} = t/(1\text{-}L_B)$, and

$\ell_{TDB} = \ell/(1\text{-}L_B)$,

where t and ℓ are the SI units and LB is a derived constant given in Table 1. The 1976 IAU System of Astronomical Constants (Astronomical Almanac for the Year 1984) is adopted for all astronomical constants which do not appear in Table 1.

Some geodetic parameters are affected by tidal variations. The values given above are in the zero-tide system so that they correspond to a realistic time-averaged crust. This is done to be consistent with XVIII IAG General Assembly Resolution 16.

TABLE 1. IERS Numerical Standards.

ITEM	VALUE	UNCERTAINTY	REF.	COMMENTS
c	299 792 458 ms^{-1}	Defining	[2]	Speed of light
L_B	1.550 519 748$\times10^{-8}$	4×10^{-17}	[4]	Average value of d(TCB)/d(TT)-1
L_C	1.480 826 845 7$\times10^{-8}$	1×10^{-17}	[4]	Average value of d(TCB)/d(TCG)-1
L_G	6.969 290 3 $\times$ 10^{-10}	1×10^{-17}	[4]	Average value of d(TCG)/d(TT)-1
W_0	626 368 56.85m^2s^{-2}	1.0 m^2s^{-2}	[1]	Potential of the geoid
τ_A	499.004 783 8061s	0.000 000 02s	[7]	Astronomical unit in seconds
$c\tau_A$	149 597 870 691m	30m	[7]	Astronomical unit in meters
P	5 029$''.$0965/century	0$''.$3/century	[5]	General precession in longitude at J2000.0
ϵ_0	84 381$''.$412	0$''.$005	[7]	Obliquity of the ecliptic at J2000.0
a_E	6 378 136.49m	0.10 m	[1]	Equatorial radius of the Earth
1/f	298.256 42	0.00001	[1]	Flattening factor of the Earth
$J_{2\oplus}$	1.082 635 9$\times10^{-3}$	1.0×10^{-10}	[1]	Dynamical form-factor of the Earth
G	6.672 59$\times10^{-11}m^3kg^{-1}s^{-2}$	$8.54\times10^{-15}m^3kg^{-1}s^{-2}$	[3]	Constant of gravitation
$GM_\oplus$	3.986 004 418$\times10^{14}m^3s^{-2}$	$8\times10^5m^3s^{-2}$	[1]	Geocentric gravitational constant
μ	0.0123 000 345	5×10^{-10}	[7]	Moon-Earth mass ratio
ω	7.292 115$\times10^{-5}$rad s^{-1}	variable	[1]	Nominal mean angular velocity of the Earth
$GM_\odot$	1.327 124$\times10^{20}m^3s^{-2}$		[6]	Heliocentric gravitational constant
g_e	9.78 0327 ms^{-2}	$1\times10^{-6}ms^{-2}$	[1]	Mean equatorial gravity
$R_0=GM_\oplus/W_0$	6 363 672.461 m	0.1 m	[1]	Geopotential scale factor

6. Future Maintenance

A three to four year cycle in the updating of a conventional set of astronomical constants appears to be appropriate. The IERS plans to update its Conventions using one editor, an editorial board, and subject matter experts. Constants will be included in this document and these estimates should be carefully coordinated with the International Astronomical Union. Efforts should be made to make the constants internally consistent but not at the expense of accuracy. Ever improving observational precision demands the most accurate constants and models. An issue remaining to be resolved is the reference frame in which to express these parameters. This largely involves issues of relativity related to geocentric or barycentric reference frames. A logical solution is to provide useful transformations between systems along with the adopted values. Future sets of constants may also include relationships between the constants, perhaps in the form of a user manual. In this way users may make use of a minimal set to derive more extensive sets.

Future issues of the latest best estimates of the astronomical constants will most likely be provided as a world wide document for easy access by users. Hopefully this could then provide links to references involving the constants, software to be employed in the use of the constants and the relationships to other constants.

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