1 General Definitions and Numerical Standards

This chapter provides general definitions for some topics and the values of numerical standards that are used in the document. Those are based on the most recent reports of the appropriate working groups of the International Association of Geodesy (IAG) and the International Astronomical Union (IAU).

1.1 Permanent Tide

Some geodetic parameters are affected by tidal variations. The gravitational potential in the vicinity of the Earth, which is directly accessible to observation, is a combination of the tidal gravitational potential of external bodies (the Moon, the Sun, and the planets) and the Earth's own potential which is perturbed by the action of the tidal potential. The (external) tidal potential contains both time independent (permanent) and time dependent (periodic) parts, and so does the tide-induced part of the Earth's own potential. Similarly, the observed site positions are affected by displacements associated with solid Earth deformations produced by the tidal potential; these displacements also include permanent and time dependent parts. On removing from the observed site positions/potential the time dependent part of the tidal contributions, the resulting station positions are on the "mean tide" (or simply "mean") crust; and the potential which results is the "mean tide" potential. The permanent part of the deformation produced by the tidal potential is present in the mean crust; the associated permanent change in the geopotential, and also the permanent part of the tidal potential, are included in the mean tide geopotential. These correspond to the actual mean values, free of periodic variations due to tidal forces. The "mean tide" geoid, for example, would correspond to the mean ocean surface in the absence of non-gravitational disturbances (currents, winds). In general, quantities referred to as "mean tide" (*e.g.* flattening, dynamical form factor, equatorial radius, *etc.*) are defined in relation to the mean tide crust or the mean tide geoid.

If the deformation due to the permanent part of the tidal potential is removed from the mean tide crust, the result is the "tide free" crust. As regards the potential, removal of the permanent part of the *external* potential from the mean tide potential results in the "zero tide" potential which is strictly a geopotential. The permanent part of the deformation-related contribution is still present; if that is also removed, the result is the "tide free" geopotential. It is important to note that unlike the case of the potential, the term "zero tide" as applied to the *crust* is synonymous with "mean tide."

In a "tide free" quantity, the total tidal effects have been removed with a model. Because the perturbing bodies are always present, a truly "tide free" quantity is unobservable. In this document, the tidal models used for the geopotential (Chapter 6) and for the displacement of points on the crust (Chapter 7) are based on nominal Love numbers; the reference geopotential model and terrestrial reference frame, which are obtained by removal of tidal contributions using such models, are termed "conventional tide free." Because the deformational response to the permanent part of the tide generating potential is characterized actually by the secular (or fluid limit) Love numbers, which differ substantially from the nominal ones, "conventional tide free" values of quantities do *not* correspond to truly tide free values that would be observed if tidal perturbations were absent. The true effect of the permanent tide could be estimated using the fluid limit Love numbers for this purpose, but this calculation is not included in this document because it is not needed for the tidal correction procedure.

Resolution 16 of the 18th General Assembly of the IAG (1983), "recognizing the need for the uniform treatment of tidal corrections to various geodetic quantities such as gravity and station positions," recommended that "the indirect effect due to the permanent yielding of the Earth be not removed," *i.e.* the use of "zero-tide" values for quantities associated with the geopotential and "mean-tide" values for quantities associated with station displacements. This recommendation, however, has not been implemented in the algorithms used for tide modeling by the geodesy community in the analysis of space geodetic data in general. As a consequence, the station coordinates that go with such analyses (see Chapter 4) are "conventional tide free" values.

The geopotential can be realized in the three different cases (*i.e.*, mean tide, zero tide or tide free). For those parameters for which the difference is relevant, the values given in Table 1.1 are "zero-tide" values, according to the IAG Resolution.

The different notions related to the treatment of the permanent tide are shown pictorially in Figures 1.1 and 1.2.

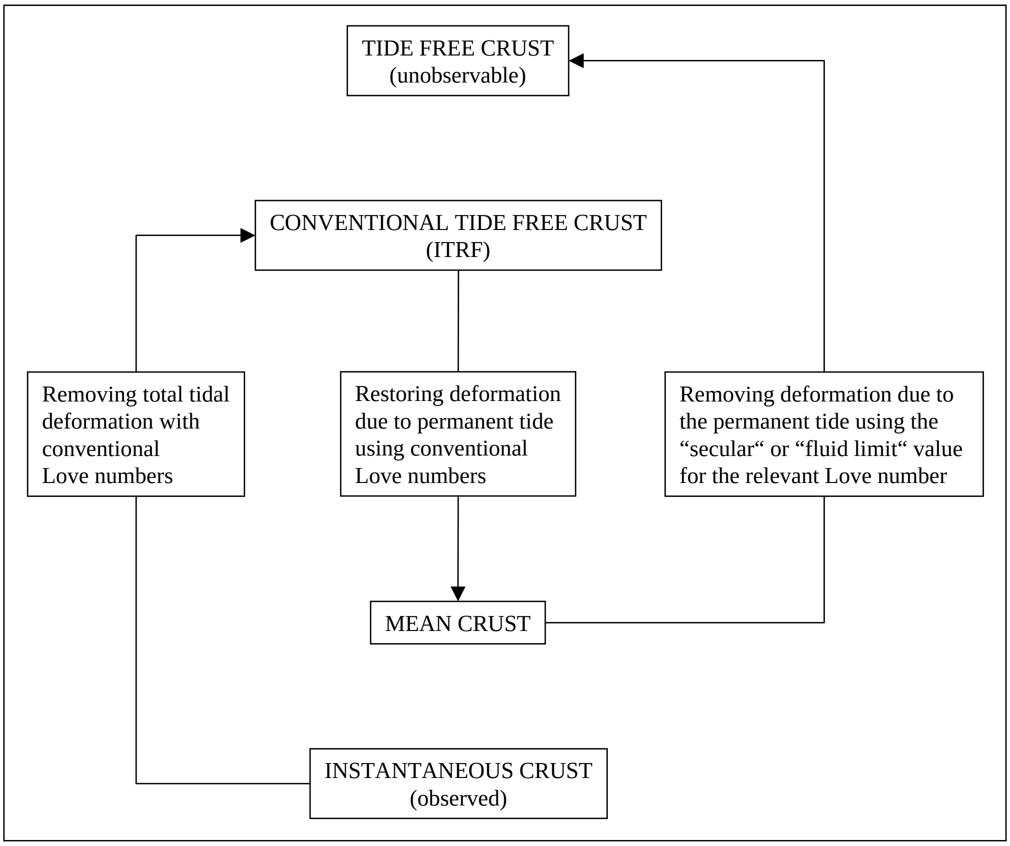

Fig. 1.1 Treatment of observations to account for tidal deformations in terrestrial reference systems (see Chapters 4 and 7).

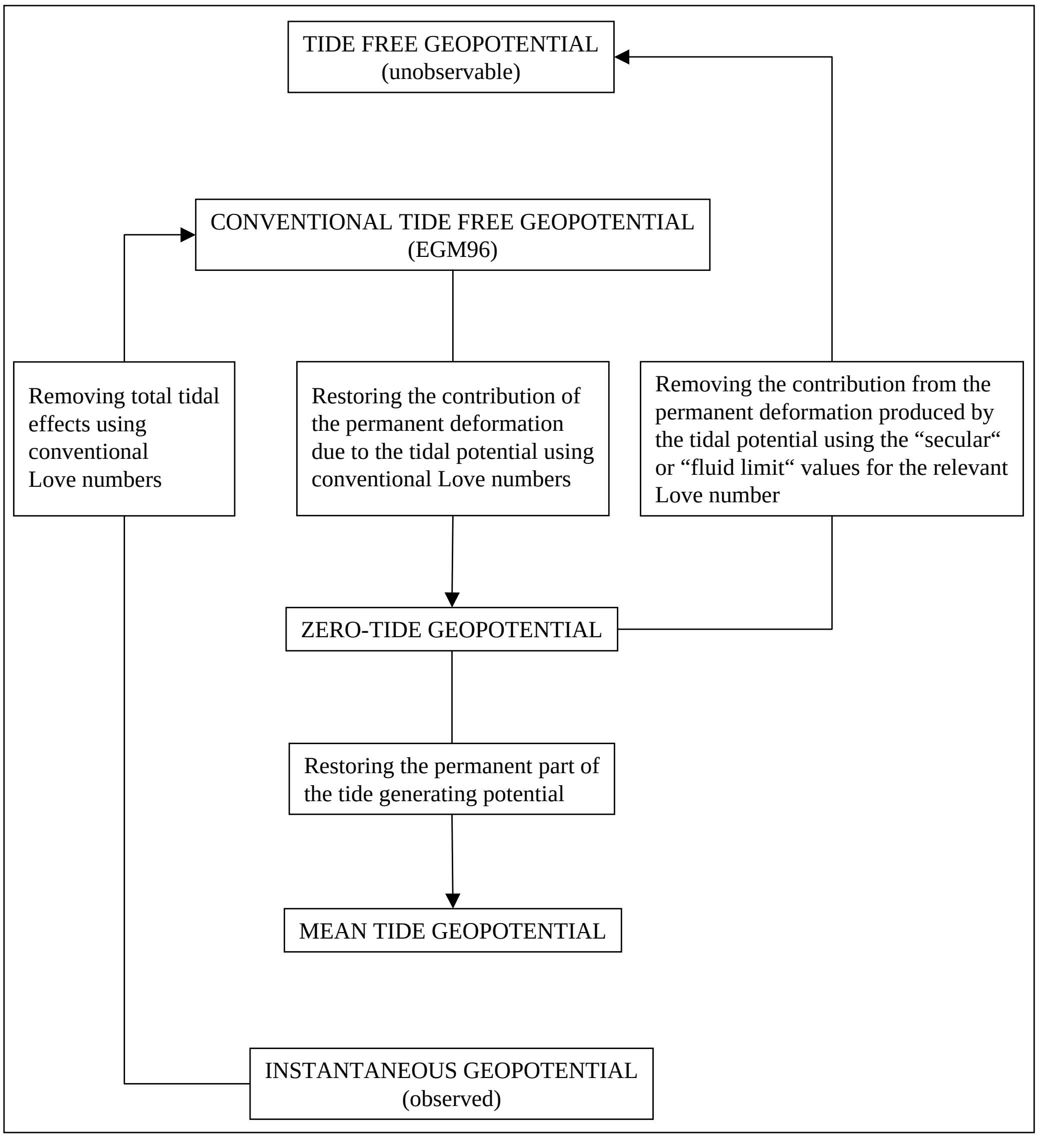

Fig. 1.2 Treatment of observations for tidal effects in the geopotential (see Chapter 6).

1.2 Numerical Standards

Table 1.1 listing numerical standards is organized into 5 columns: item, value, uncertainty, reference, comment. Most of the values are given in terms of SI units (*Le Système International d'Unités (SI)*, 1998), *i.e.* they are consistent with the use of Geocentric Coordinate Time TCG as a time coordinate for the geocentric system, and of Barycentric Coordinate Time TCB for the barycentric system. The values of τ_A, $c\tau_A$, and ψ_1, however, are given in so-called "TDB" units, having been determined previously using Barycentric Dynamical Time TDB as a time coordinate for the barycentric system. In this book some quantities are also given in so-called "TT" units, having been determined using Terrestrial Time TT as a time coordinate for the geocentric system. See Chapter 10 for further details on the transformations between time scales and Chapter 3 for a discussion of the time scale used in the ephemerides.

TDB and TCB units of time, t, and length, ℓ, may be easily related by the expressions (Seidelmann and Fukushima, 1992)

$$t_{TDB} = t_{TCB}/(1 - L_B), \quad \ell_{TDB} = \ell_{TCB}/(1 - L_B),$$

where L_B is given in Table 1.1. Therefore a quantity X with the dimension of time or length has a numerical value x_{TCB} when using "TCB" (SI) units which differs from its value x_{TDB} when using "TDB" units by

$$x_{TDB} = x_{TCB} \times (1 - L_B).$$

Similarly, the numerical value x_{TCG} when using "TCG" (SI) units differs from the numerical value x_{TT} when using "TT" units by

$$x_{TT} = x_{TCG} \times (1 - L_G)$$

where L_G is given in Table 1.1.

The IAU 1976 System of Astronomical Constants (*Astronomical Almanac for the Year 1984*) is adopted for all astronomical constants which do not appear in Table 1.1.

Table 1.1 IERS Numerical Standards.

ITEM	VALUE	UNCERTAINTY	REF.	COMMENTS
c	$299792458 ms^{-1}$	Defining	[2]	Speed of light
L_B	$1.55051976772 \times 10^{-8}$	2×10^{-17}	[4]	Average value of 1-d(TT)/d(TCB)
L_C	$1.48082686741 \times 10^{-8}$	2×10^{-17}	[4]	Average value of 1-d(TCG)/d(TCB)
L_G	$6.969290134 \times 10^{-10}$	Defining	[4]	1-d(TT)/d(TCG)
G	$6.673 \times 10^{-11} m^3 kg^{-1} s^{-2}$	$1 \times 10^{-13} m^3 kg^{-1} s^{-2}$	[2]	Constant of gravitation
$GM_\odot$	$1.32712442076 \times 10^{20} m^3 s^{-2}$	$5 \times 10^{10} m^3 s^{-2}$	[from 3]	Heliocentric gravitational constant
$\tau_A{}^\dagger$	$499.0047838061 s$	$0.00000002 s$	[3]	Astronomical unit in seconds
$c\tau_A{}^\dagger$	$149597870691 m$	$6 m$	[3]	Astronomical unit in meters
$\psi_1{}^\dagger$	$5038.47875''/c$	$0.00040''/c$	[6]	IAU(1976) value of precession of the equator at J2000.0 corrected by $-0.29965''$. See Chapter 5.
ϵ_0	$84381.4059''$	$0.0003''$	[5]	Obliquity of the ecliptic at J2000.0. See Chapter 5 for value used in IAU precession-nutation model.
$J_{2\odot}$	2×10^{-7}	(adopted for DE405)		Dynamical form-factor of the Sun
μ	0.0123000383	5×10^{-10}	[3]	Moon-Earth mass ratio
$GM_\oplus$	$3.986004418 \times 10^{14} m^3 s^{-2}$	$8 \times 10^5 m^3 s^{-2}$	[1]	Geocentric gravitational constant (EGM96 value)
$a_E{}^\ddagger$	$6378136.6 m$	$0.10 m$	[1]	Equatorial radius of the Earth
$1/f^\ddagger$	298.25642	0.00001	[1]	Flattening factor of the Earth
$J_{2\oplus}{}^\ddagger$	1.0826359×10^{-3}	1.0×10^{-10}	[1]	Dynamical form-factor
ω	$7.292115 \times 10^{-5} rad s^{-1}$	variable	[1]	Nominal mean angular velocity of the Earth
$g_e{}^\ddagger$	$9.7803278 ms^{-2}$	$1 \times 10^{-6} ms^{-2}$	[1]	Mean equatorial gravity
W_0	$62636856.0 m^2 s^{-2}$	$0.5 m^2 s^{-2}$	[1]	Potential of the geoid
$R_0{}^{\dagger\dagger}$	$6363672.6 m$	$0.1 m$	[1]	Geopotential scale factor

† The values for τ_A, $c\tau_A$, and ψ_1 are given in "TDB" units (see discussion above).

‡ The values for a_E, $1/f$, $J_{2\oplus}$ and g_E are "zero tide" values (see the discussion in section 1.1 above). Values according to other conventions may be found from reference [1].

†† $R_0 = GM_\oplus / W_0$

[1] Groten, E., 1999, Report of the IAG. Special Commission SC3, Fundamental Constants, XXII IAG General Assembly.

[2] Mohr, P. J. and Taylor, B. N., 1999, *J. Phys. Chem. Ref. Data*, **28, 6**, p. 1713.

[3] Standish, E. M., 1998, JPL IOM 312-F.

[4] IAU XXIV General Assembly. See Appendix 1.

[5] Fukushima, T., 2003, Report on astronomical constants, *Highlights of Astronomy*, in press.

[6] Mathews, P. M., Herring, T. A., and Buffett, B. A., 2002, Modeling of nutation-precession: New nutation series for nonrigid Earth, and insights into the Earth's interior, *J. Geophys. Res.* **107, B4**, 10.1029/2001JB00390.

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Astronomical Almanac for the Year 1984, U.S. Government Printing Office, Washington, DC.

Le Système International d'Unités (SI), 1998, Bureau International des Poids et Mesures, Sèvres, France.

Seidelmann, P. K. and Fukushima, T., 1992, "Why New Time Scales?" *Astron. Astrophys.*, **265**, pp. 833–838.