Compatibility with Past Observations

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This topic addresses the issue of the compatibility of observations made in the past with observations made using the new system. It is not likely that there would any requirement to adjust past observations to put them into a system that complies with the newly adopted IAU Recommendations. However, it may be important to look at the specifics of each case.

Recall that, in the new system, the ICRS is realized by the ICRF (Hipparcos Celestial Frame, HCRF, in the visual) and that those positions can be considered as being analogous to a catalog of positions and motions related to the equinox and equator of J2000.0. The definitions have been made more rigorous and it has now been made clear that the ICRS is a barycentric system with the time tags in TCB. The direction of the x axis of this system (ICRS) is very close to that of the dynamical mean equinox of J2000, the offset being 78±10 mas (Folkner *et al.*, 1994; Arias, *et al.*, 1995). Note that the FK5 origin of right ascension is only known with a precision of ± 80 mas. According to Mignard & Froeschle (1997), this origin is offset by -22 mas from the ICRS. The ICRF provides positions with respect to a fixed equator that does not move. To treat the effects of proper motion correctly, the epoch related to each star position should be noted.

The procedure to be followed in transforming from the celestial (ICRS) to the terrestrial (ITRS) systems has been clarified to be consistent with the improving observational accuracy. See Figure 1 for a diagram of the new and old procedures to be followed. As before, we make use of an intermediate reference system in transforming to a terrestrial system. In this case we call that system the Intermediate Celestial Reference System. The Celestial Intermediate Pole (CIP) that is realized by the IAU2000A/B Precession-Nutation model defines its equator. Previously we made use of the Celestial Ephemeris pole that was defined by the IAU1976 precession and the IAU1980 Nutation. The Conventional Ephemeris Origin replaces the concept of the equinox in this system. Whereas the CEP did not address high-frequency nutation the definition of the CIP makes it clear that the effects of nutation terms with periods less than 2 days are to be included in the polar motion.

The position in this reference system is called the intermediate right ascension[1] and declination and is analogous to the previous designation of "apparent right ascension and declination." After the new procedures are fully implemented in the national almanacs, it is expected that they would provide positions of stars and solar system information in these geocentric apparent positions for the appropriate TCG epoch.

The relationships between the coordinates X and Y and the traditional precession-nutation quantities to first order in offset quantities are (Capitaine, 1990)

$$\mathrm{X} = \overline{\mathrm{X}} + \xi_0 - \mathrm{d}\alpha_0\, \overline{\mathrm{Y}},$$

$$\mathrm{Y} = \overline{\mathrm{Y}} + \eta_0 + \mathrm{d}\alpha_0\, \overline{\mathrm{X}},$$

where ξ_0 and η_0 are the celestial pole offsets at the J2000.0 and $\mathrm{d}\alpha_0$ the right ascension of the mean equinox of J2000.0 in the CRS. The traditional precessional angles θ and ζ can be expressed in the context of the IAU 2000 recommendations (see Hilton 2002, this Volume).

[1] Please note that the terminology used in this paper to refer to the system of coordinates in this intermediate reference system has not been sanctioned officially by the IAU.

The mean equinox of J2000.0 to be considered is not the "inertial dynamical mean equinox of J2000.0" (Standish 1981) but the origin of right ascension in the mean equatorial system of the CIP at J2000.0. The numerical value for $d\alpha_0$ as provided by Chapront *et al.* (1999) is -14 mas. The quantities $\overline{X}$ and $\overline{Y}$ are given by

$$\overline{X} = \sin\omega \sin\psi,$$

$$\overline{Y} = -\sin\varepsilon_0 \cos\omega + \cos\varepsilon_0 \sin\omega \cos\psi,$$

where ε_0 is the obliquity of the ecliptic at J2000, ω is the inclination of the true equator of date on the fixed ecliptic of epoch and ψ is the longitude, on the ecliptic of epoch, of the node of the true equator of date on the fixed ecliptic of epoch. These quantities are such that

$$\omega = \omega_A + \Delta\varepsilon_1, \quad \psi = \psi_A + \Delta\psi_1,$$

where ψ_A and ω_A are the precession quantities in longitude and obliquity (Lieske, *et al.,* 1977) referred to the ecliptic of epoch and $\Delta\psi_1$, $\Delta\varepsilon_1$ are the nutation angles in longitude and obliquity referred to the ecliptic of epoch. $\Delta\psi_1$, $\Delta\varepsilon_1$ can be obtained from the nutation angles $\Delta\psi$, $\Delta\varepsilon$ in longitude and obliquity referred to the ecliptic of date. The following formulation from Aoki and Kinoshita (1983) provides accuracy better than one microarcsecond after one century:

$$\Delta\psi_1 \sin\omega_A = \Delta\psi \sin\varepsilon_A \cos\chi_A - \Delta\varepsilon \sin\chi_A,$$

$$\Delta\varepsilon_1 = \Delta\psi \sin\varepsilon_A \sin\chi_A + \Delta\varepsilon \cos\chi_A,$$

ω_A and ε_A being the precession quantities in obliquity referred to the ecliptic of epoch and ecliptic of date respectively and χ_A the precession quantity for planetary precession along the equator (Lieske, *et al.,* 1977).

In transforming from this intermediate system to the terrestrial system in which observations are made, there should be no systematic shifts in polar motion or in UT1-UTC. While UT1 will now be defined differently by using the stellar angle, θ, between the CEO and the meridian origin of the ITRS (or ITRF), where

$$\theta(T_u) = 2\pi\,(0.779\,057\,273\,2640 + 1.002\,737\,811\,911\,354\,48\,T_u),$$

and T_u = (Julian UT1 date 2451 545.0) (Capitaine *et al.*, 2000),

no "jumps" in UT1-UTC will be seen. This definition replaces the use of Greenwich Mean Sidereal Time as the basis for the definition of UT1.

The numerical expression for Greenwich Sidereal Time consistent with the IAU 2000 precession and nutation model can be obtained using computations similar to those used to obtain the expression for s (Capitaine, *et al.*, 2002).

$$\mathrm{GST} = \theta + 4612.\text{"}157482t + 1.\text{"}39667841t^2 - 0.\text{"}00009344t^3 + 0.\text{"}0000188t^4 + \Delta\psi\cos\varepsilon_A - \sum_k C_k \sin\alpha_k - 0.\text{"}002106$$

where t = (TT-2000 January 1d 12h TT) in days / 36525. GST - θ provides the right ascension of the CEO. $-\sum_k C_k \sin\alpha_k - 0.\text{"}002106$ contains the complementary terms to be added to the current "equation of the equinoxes"', $\Delta\psi\cos\varepsilon_A$, to provide the relationship between GST and θ at a microarcsecond accuracy. This replaces the two complementary terms provided in the IERS Conventions 1996. (see McCarthy and Capitaine 2002, this Volume, Table 1, for more detail on the periodic terms appearing in $\Sigma_k C_k \sin\alpha_k$). A secular term similar to that appearing in the quantity s is included. The change in the polynomial part of GST due to the correction in the precession rates and offset in obliquity at J2000 corresponds to a change dGMST (see Williams, 1994) in the current relationship between GMST and UT1 (Aoki , *et al.*, 1982) which can be written in microarcseconds as:

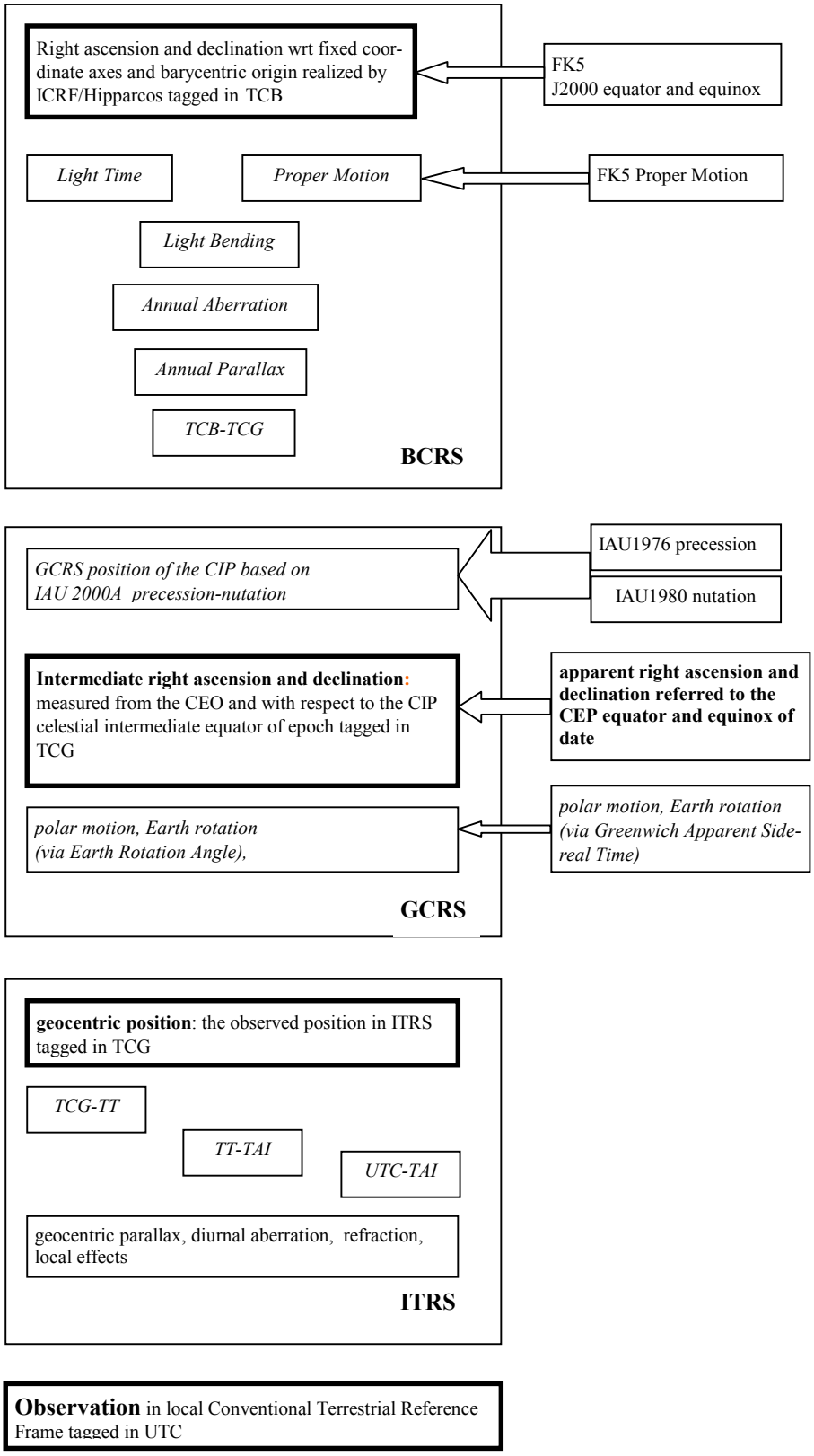

Figure 1. Process to transform from celestial to terrestrial systems. Differences with the past process are shown on the right of the diagram.

$dGMST = GMST_{NEW} - GMST_{OLD} = - 274868\ t + 118\ t^2 + 19\ t^4$.

The convention for the constant term in GST will be such that it provides for no discontinuity in UT1 on 01/01/2003.

In the newly adopted system, the ecliptic remains as the mean plane of the Earth's orbit. In practice it is realized by an ephemeris of the Earth. Analogous with previous definitions, the equinox is either of two points where the ecliptic intersects the celestial intermediate equator.

A conventional ecliptic can be defined at an epoch (Seidelmann and Kovalevsky, 2002) as a fixed plane in the ICRF with a fixed inclination ε_0 equal to the mean obliquity at J2000.0. The transformation from the ICRS (x, y, z) coordinates to the ecliptic fixed coordinates (X_e, Y_e, Z_e) is then

$X_e = x$,
$Y_e = y \cos \varepsilon_0 + z \sin \varepsilon_0$,
$Z_e = -y \sin \varepsilon_0 + z \cos \varepsilon_0$,

$\varepsilon_0 = 23^\circ\ 26'\ 21.''4059$ (IERS Conventions 2000). This conventional ecliptic plays no role in the transformation between the ICRS and the ITRS. It may be useful for some specialized purposes.

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