A NEW SYSTEM OF THE U.S.S.R. STANDARD TIME FOR 1955 - 1974 AND ITS APPLICATION IN THE STUDY OF THE EARTH'S ROTATION

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For the study of the Earth's rotation and geodetic measurements the longest possible series of homogeneous Universal Time (UT) data is required. For various reasons this remains a difficult problem. Periodically it is necessary to revise past observations and redetermine the UT scale. This was done by the Bureau International de l'Heure (BIH) in 1968 when the FK 4 catalog, revised values of astronomical longitudes, and new techniques were standardized for the reduction of astronomical observations. This system known as the 1968 BIH System has been in use since 1968 and has also been used for the re-reduction of observations back to 1962.0.

The U.S.S.R. Time Service, while participating in the BIH, also produces an independent UT scale, "Standard Time of U.S.S.R." (ST), for use in scientific and conventional geodetic work in the U.S.S.R. Since 1 January 1975 a new technique for the calculation of UT(ST) has been used. This involved the adjustment of longitudes as well as other measures to bring the new scale into agreement with UT(BIH) for the epoch 1975.0. Until now no attempt has been made to revise the data previous to 1975. These observations were essentially non-homogeneous due to past changes in origin, coordinate systems, and reference catalogs.

REVISION OF THE TIME SCALE

In the present work the data from 1955 through 1974 were used. During this period 26 observatories of the Soviet Union and other socialist countries participated in the U.S.S.R. United Time Service. The observations were made with 83 instruments including 40 visual instruments, 31 photoelectric transit instruments, eight astrolabes, three circumzenithals, and one photographic zenith tube. Approximately 78,000 clock corrections were determined by 300 observers. These initial data are the differences between the observed clock corrections and those adopted in the old system. The procedure followed in this revision was as follows:

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1. All clock corrections were reduced to the KCB Catalog of Time Services (Pavlov, et al., 1971). Systematic as well as individual corrections were applied to the star coordinates.

2. The new value of the aberration constant (20".496) was used.

3. Observations made after 1962 were referred to the CIO and the BIH system. Data previous to 1962 were treated using the polar motion data of Fedorov and Korsun (1972) reduced to the BIH system by Brandt (Afanas'eva, et al., 1976).

4. A new method for deriving the new ST time scale from the data was used. Suppose that within the time interval, T, the time scale UT(ST) is defined by N adopted corrections to the reference clock, u_i, i = 1 to N. During this interval there exist M observational values, $u_{i,k}$, k = 1 to M. The observational values are in different systems of "instrument + observer" (IO). If we assume that during T the systematic errors of the IO systems are constant, then

$$u_{i,k} - \bar{u}_i = u_{j,k} - \bar{u}_j; \quad i,j = 1 \text{ to } N. \tag{1}$$

The values $\bar{u}_i$, $\bar{u}_j$ represent the true values of the corrections to the reference clocks for the new UT(ST) time scale corresponding to the times t_i and t_j.

Equation (1) can be written in the form

$$\Delta u_i - \Delta u_j = (u_{i,k} - u_i) - (u_{j,k} - u_j), \tag{2}$$

where $\Delta u_i = \bar{u}_i - u_i$, and $\Delta u_j = \bar{u}_j - u_j$. A system of MN(N+1)/2 equations of type (2) could be constructed for the interval T if the IO systems were not changed. This system of equations would have N unknowns Δu_i. The matrix of the resulting normal equations can not be inverted. Therefore it is necessary to adopt one value of the unknowns, for example, u_1, as an origin.

In reality the IO systems are constantly changing. The actual system of equations may then be constructed as follows:

4.1. Fortnightly means of the $u_{i,k}$ were formed for an interval of T = 2 years. The matrix of the resultant normal equations was of the order N = 48. The observations from 1955 - 1974 were then reduced by successive solutions of the matrices. Each successive solution overlapped the previous one by T/2 = 1 year.

4.2. The intervals, T_k, over which the IO system could be considered constant were found by studying the smoothed systematic errors, D_k. If there were no gaps in D_k during the interval T, and D_k was less than three times the mean square error of D_k, then T_k = T. Otherwise the interval was subdivided into segments of different duration.

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4.3. Each equation (2) was assigned a weight to account for accidental errors and instability in D_k. The method is given by Yagudin (1978a).

4.4. The origin of the new UT(ST) scale was adjusted to that of the BIH by computing the systematic difference UT1(ST) - UT1(BIH) for the period 1962 - 1974.

The systematic differences between the old (ST_0) and the new ST scales and the BIH are shown in Figure 1. For comparison the new official scale of the U.S.S.R. Universal Time, UT1(SU) since 1968 using Kaufmann's

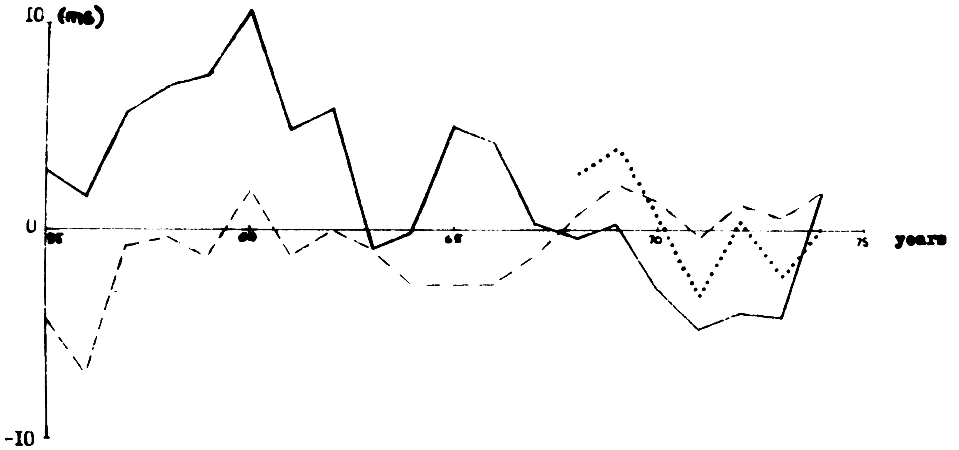

Figure 1. Systematic differences in UT1 time scales: ———— $UT1(ST_0)$ - UT1(BIH); - - - - UT1(ST) - UT1(BIH); ········ UT1(SU) - UT1(BIH).

method is also shown in Figure 1. Monthly differences in $UT1(ST_0)$ - UT1(BIH) and UT1(ST) - UT1(BIH) were examined and found to be due mainly to the influence of different reference catalogs on the respective time scales.

CORRECTIONS OF LONGITUDES

The revision of these observations in a homogeneous system permits us to revise the longitudes of the contributing observatories. The corrections to the previously assumed longitudes were computed in relation to the UT(ST) time scale and the BIH scale. Both methods resulted in longitudes in excellent agreement (Yagudin, 1978b).

LONG-PERIOD VARIATIONS IN THE RATE OF ROTATION

Variations of the rate of rotation relative to the BIH atomic time scale were calculated using unsmoothed fortnightly values of UT1(ST) in the form τ_i = (UT1 - AT)$_i$, and

$$\left(\frac{d\tau}{dt}\right)_i = \frac{\tau_{i+1} - \tau_{i-1}}{AT_{i+1} - AT_{i-1}}.$$

The data from 1956 to 1974 were divided into three seven-year periods, and the spectra of $d\tau/dt$ were treated separately to obtain independent evaluations. The significant periodic terms are shown in Table 1. These results are determined from the entire data set from 1956 to 1974. The seasonal variation (UT2 - UT1) was found to be

$$\Delta T_S = 0^s\!.016 \sin 2\pi t - 0^s\!.012 \cos 2\pi t - 0^s\!.003 \sin 4\pi t + 0^s\!.008 \cos 4\pi t,$$

where t is the fraction of the Besselian year.

Table 1. Variation in $d\tau/dt$ and τ in the form A sin $(2\pi/P + \phi)$ using UT1(ST) from 1956 to 1974. Errors are 90% probable errors.

	$d\tau/\tau dt$		τ	
P (years)	A (10^{-9})	ϕ (degrees)	A ($0^s\!.001$)	ϕ (degrees)
1.00 ± 0.01	4.0 ± 0.3	59 ± 4	20 ± 2	149 ± 4
0.50 ± 0.01	3.4 ± 0.3	213 ± 5	8 ± 1	303 ± 5
2.9 ± 0.2	0.9 ± 0.3	236 ± 19	13 + 4	329 ± 19
3.7 + 0.4 − 0.3	0.6 ± 0.3	244 ± 26	11 ± 6	334 ± 26
2.0 ± 0.1	0.5 ± 0.3	87 ± 31	5 ± 3	177 ± 31
6.9 + 1.0 − 0.8	2.3 ± 0.3	316 ± 7	80 ± 10	46 ± 7
11 + 5 − 3	1.4 ± 0.3	54 ± 12	77 ± 17	144 ± 12

SHORT-PERIOD VARIATIONS IN THE RATE OF ROTATION

Residuals of the form $\Delta u_{t,k} = u_{t,k} - \bar{u}_t - D_{t,k}$ were analyzed for short-period variations. Values of u_t and $D_{t,k}$ were derived by smoothing normal values for every 15 days using Whittaker's method (Yusupov) with a smoothing factor $\varepsilon = 0.1$. Amplitude spectra computed with the Fast Fourier Transform show periods which can be identified with the M_m, M_f, O_1, and M_2 tides. The details are given by Gubanov and Yagudin (1978). Values of the Love number k derived from these results are:

$k(M_m) = 0.31 \pm 0.02$, and
$k(M_f) = 0.30 \pm 0.02$.

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These are in good agreement with the predictions of Molodenskij Earth Model II (Molodenskij, 1961). These results can also be used to derive estimates for the combination of Love and Shida numbers $\Lambda = 1+k-l$. For the M_2 wave $\Lambda = 1.10 \pm 0.05$, and for the O_1 wave $\Lambda = 1.39 \pm 0.10$. The latter result was derived using the theoretical value of the forced luni-solar polar motion. If a value for Λ is assumed to be 1.20 an improved value for the fortnightly nutation in obliquity is found to be $0\overset{''}{.}0897 \pm 0\overset{''}{.}0007$.

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DISCUSSION

S. Debarbat: Was it your intention to produce a time scale as close as possible to that of the BIH?

V. S. Gubanov: Our scale has been adjusted to that of the BIH only in the average over the entire time interval.

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