IV.5 Sub-Bureau for Rapid Service and Predictions

Rapid Service Activities

The algorithm used by the IERS Sub-bureau for Rapid Service and Predictions (starting 2001 the Sub-bureau is now known as the Rapid Service/Prediction Centre) in the determination of the quick-look Earth orientation parameters is based on a weighted cubic spline with adjustable smoothing fit to contributed observational data (McCarthy & Luzum, 1991a). Contributed data are corrected for possible systematic differences. Biases and rates are determined with respect to the C04 system of the IERS EOP Section.

Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques. Minimal smoothing is applied, consistent with the estimated accuracy of the observational data.

Weights in the algorithm may be either a priori values estimated by the standard deviation of the residual of the techniques or based on the internal precision reported by contributors. Estimated accuracies of data contributed for rapid service estimates of Earth orientation are shown in Table 1.

Table 1. Estimated accuracies of the techniques in 2000. Units are milliseconds of arc for x, y, dψ, and dε, and milliseconds of time for UT1-UTC.

Contributor	Estimated Accuracy					
	x	y	UT1	lod	dψ	dε
CSR 3-day SLR	0.5	0.5	0.12 *			
DUT 3-day SLR	0.4	0.4				
IAA 1-day SLR	0.2	0.2				
MCC 1-day SLR	0.2	0.2				
GSFC daily VLBI			0.028			
SPbU daily VLBI			0.027			
GSFC weekly VLBI	0.3	0.3	0.010		0.4	0.1
IAA weekly VLBI	0.2	0.2	0.007		0.4	0.1
Texas LLR (CERGA)			0.15			
Texas LLR (MLRS2)			0.15			
IGS Final	0.06	0.06				
IGS Rapid	0.08	0.08		0.02 *		
USNO GPS UT *			0.015 *			
EMR GPS UT *			0.03 *			

* All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to correct for lod biases and to minimize drifts in UT estimates.

Operationally the weighted spline uses as input the epoch of observation, the observed value, and the weight of each individual data point. The software computes spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, $d\psi$, and $d\varepsilon$ values are computed at the epoch of zero hours UTC for each day. The only data points which are excluded from this process are points whose errors, as reported by the contributors, are greater than three times their average reported precision or those points that have a residual that is more that four times the associated a priori error estimate. Since all of the observations are reported with the effects of sub-daily variations removed, no processing is done to account for these effects (see IERS Gazette No. 13, 30 January 1997).

The errors for the daily values listed in Bulletin A are derived from the quality of the fit of the spline in the neighborhood of the day in question. Table 2 shows a comparison of Bulletin A with the series Bulletin B and C04 maintained by the IERS EOP Section at the Paris Observatory.

Table 2. Mean and standard deviation of the differences between various IERS solutions for 2000.

	Bulletin A - Bulletin B		Bulletin A - IERS C04	
	mean	std. deviation	mean	std. deviation
x	0.00 mas	0.05 mas	-0.02 mas	0.06 mas
y	-0.02 mas	0.06 mas	-0.03 mas	0.07 mas
UT1-UTC	0.005 ms	0.035 ms	0.007 ms	0.031 ms

During 2000, several substantial changes have occurred which affect the performance of IERS Bulletin A. Beginning 29 June, the near-term polar motion predictions were modified slightly to rely more heavily on the latest observed polar motion rates from the IGS Rapid combination. The latest IGS polar motion rates have been included since 11 February 1999, but their improved quality and reliability warrants placing a greater weight on them for the Bulletin A polar motion predictions. Beginning 21 July, the near-term UT1-UTC predictions were modified to include a contribution from model predictions of the atmospheric angular momentum (AAM) excitation. The AAM results come from the National Centers for Environmental Prediction (NCEP), using both their analysis products (tabulated at 6-hr intervals) and forecast fields (at 12-hr intervals) for excitation of length of day (LOD). A procedure was developed for smoothly merging each set of daily updates into a continuous time series extending 5 days into the future. This series is then assimilated into Bulletin A by first integrating the LOD values then matching the last 5 days before the predictions to the geodetic observations of UT1R-UTC and LODR. Starting the beginning of July, Kokee Park (Hawaii, USA) replaced Green Bank (West Virginia, USA) in the quasi-daily UT1 Intensive VLBI sessions which run with Wettzell (Germany). While this change was forced by the ending of geodetic operations at Green Bank, there is good reason to believe that the UT1 performance of the Kokee-Wettzell baseline may be better than the previous Green Bank-Wettzell baseline. Both baselines are oriented nearly East-West and are very sensitive to variations in UT1, but the Kokee baseline is about 50% longer. Beginning 28 November, a new version of the series of variations in Universal Time based on observed GPS orbits was included in Bulletin A. This series, developed at USNO, uses more satellites and covers a longer time span (beginning 03 December 1995) than the previous version. The method of calibrating the GPS-based UT values by comparing to VLBI determinations of UT1 was not changed. Beginning 12 December, the data analyses provided by the NASA/GSFC VLBI group was incorporated into the Bulletin A combination. These include results for both the 24-hour sessions and the short Intensive UT1 sessions. The previous VLBI analyses made at USNO („NEOS") were discontinued (on 14 November for the 24-hour sessions; 04 December for the Intensives).

In preparing for this 2000 IERS Annual Report, a number of additional changes have been made for the Bulletin A combination. The annual and semiannual systematic corrections that were previously applied were discontinued since they appear to be unnecessary. The reference epoch for the linear rate corrections has been shifted to 1 January 2000. The weightings of all of the input polar motion series were updated to match current estimates of the accuracies.

Prediction Activities in 2000

Polar motion predictions are based on the extrapolation of an annual and semiannual ellipse and a Chandler circle fit to the previous 1100 days of observed values of x and y (McCarthy and Luzum, 1991b). The differences between the last observed pole position and rate and those of the curve are computed. These differences are then used to adjust the extrapolated curve by an amount which decreases with the length of the forecast.

In February 1998, the near-term polar motion predictions (less than about 30 days) were improved significantly by modifying the transition process from the last observed polar motion result to the long-term predictions. Continuity in the first derivatives was enforced placing great weight on the observed polar motion rate reported by the IGS in their Rapid series. The improvement was most pronounced for the shortest predictions intervals.

The procedure for UT1-UTC involves a simple technique of differencing (McCarthy and Luzum, 1991b). All known effects such as leap seconds, solid Earth zonal tides, and seasonal effects are first removed from the observed values of UT1-UTC. Then, to determine a prediction of UT1-UTC n days in the future, $(UT1\text{-}TAI)_n$, the smoothed time value from n days in the past, $<(UT1R\text{-}TAI)_{-n}>$, is subtracted from the most recent value, $(UT1R\text{-}TAI)_0$.

$$<UT1R\text{-}TAI)_n> = 2(UT1R\text{-}TAI)_0 - <(UT1R\text{-}TAI)_{-n}>.$$

The amount of smoothing used in this procedure depends on the length of the forecast. Short-term predictions with small values of n make use of less smoothing than long-term predictions. Once this value is obtained, it is possible to account for known effects in order to obtain the prediction of UT1-UTC. This process is repeated for each day's prediction.

The very near-term UT1-UTC prediction is strongly influenced by the observed daily Universal Time estimates derived at USNO from the motions of the GPS orbit planes reported by the IGS Rapid service. The IGS estimates for LOD are combined with the GPS-based UT estimates to constrain the UT1 rate of change for the most recent observational day. For the 5 days after the latest observed day, AAM-based predictions of LOD excitation are combined smoothly with the longer-term UT1 predictions described above.

Errors of the estimates are derived from analyses of the past differences between observations and the published predictions. Formulas published in Bulletin A to extend the tabular values are determined from a least-squares fit to the tabular data. The prediction of $d\psi$ and $d\varepsilon$ is based on the KSV_1996_3 model (McCarthy, 1996). Table 3 shows the errors to be expected in the predictions based on results since the beginning of 1998. Recent prediction performance in UT1-UTC has been degraded by the effects of the most recent El Niño/La Niña cycle, particularly for longer intervals.

Table 3. Errors for different prediction

Days in future	Terr. Pole 0.001"	UT1-UTC 0.001s	Celest. Pole 0.001"
1	0.2	0.05	0.3
4	1.8	0.46	0.3
10	3.9	1.6	0.3
40	11.2	7.7	0.3
90	19.7	17.8	0.3

Predictions of UT1-TAI up to 2009 January 1 are given in Table 4 below. They are derived using a prediction algorithm similar to that employed in the Bulletin A predictions of UT1-UTC. Up to twenty years of past observations of UT1-TAI are used. Estimates of the expected one-sigma error for each of the predicted values are also given. These are based on analyses of the past performance of the model with respect to the observations. Predicted values of UT1-TAI up to 2020 are available on request. Please contact the IERS Sub-bureau for Rapid Service and Predictions (now the Rapid Service/Prediction Centre) for details on how to obtain these data.

Further information on recent improvements to IERS Bulletin A and the significance for predictions of GPS orbits for real-time users is provided in the paper by Luzum et al. (2001).

Availability of Rapid Service

The data available from the IERS Sub-bureau for Rapid Service and Predictions consists mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, dψ, dε from NEOS VLBI; x, y, UT1-UTC, dψ, dε from IAA VLBI; x, y, UT1-UTC, dψ, dε from GSFC VLBI; UT1-UTC from NEOS 1-day Intensives; UT1-UTC from SPbU 1-day Intensives; UT1-UTC from GSFC 1-day Intensives; x, y, UT1-UTC from CSR LAGEOS 3-day SLR; x, y from Delft University of Technology 3-day SLR; x, y from Institute of Applied Astronomy 1-day SLR; x, y from the Russian Mission Control Center 1-day SLR; UT0-UTC from University of Texas LLR; x, y, LOD from the International GPS Service; UT from USNO GPS; UT from NRCanada (EMR) GPS; x, y, UT1-UTC, dψ, dε from the IERS Sub-bureau for Rapid Service and Predictions (now Rapid Service/Predictions Centre); x, y, UT1-UTC, dψ, dε from the IERS EOP Section (now Earth Orientation Centre); predictions of x, y, UT1-UTC, from the IERS Sub-bureau for Rapid Service and Predictions.

In addition to this published information, other data sets are available. This includes: UT0-UTC from JPL LLR; UT0-UTC from CERGA LLR; UT0-UTC from JPL VLBI; latitude, UT0-UTC from Washington PZTs 1, 3, 7; latitude, UT0-UTC from Richmond PZTs 2, 6; x, y from CSR LAGEOS 5-day SLR; x, y from Delft 5-day SLR; x, y, UT1-UTC, dψ, dε from IRIS VLBI.

The data described above are available from the Sub-bureau in a number of forms. You may request a semiweekly machine readable version of the IERS Bulletin A containing the current ninety days worth of predictions via electronic mail from

<ser7@maia.usno.navy.mil> or <http://maia.usno.navy.mil/>.

Internet users can also direct an anonymous FTP to

<maia.usno.navy.mil>

and change to the ser7 directory where they can access the IERS Bulletin A or more complete databases.

World Wide Web access is available at

<http://maia.usno.navy.mil/>.

Table 4. Predicted values of UT1-TAI, 2001-2009. Note that TT-UT1 can be obtained from this table using the expression TT-UT1 = 32.184s - (UT1-TAI).

DATE		UT1-TAI (s)	Uncertainty (s)
2001	Jan 1	-31.907	.001
	Apr 1	-31.974	.001
	Jul 1	-32.01	.01
	Oct 1	-32.01	.02
2002	Jan 1	-32.08	.02
	Apr 1	-32.16	.03
	Jul 1	-32.7	.3
	Oct 1	-32.8	.4
2003	Jan 1	-33.0	.4
	Apr 1	-33.1	.5
	Jul 1	-33.3	.6
	Oct 1	-33.4	.8
2004	Jan 1	-33.6	.9
	Apr 1	-34.	1.
	Jul 1	-34.	1.
	Oct 1	-34.	1.
2005	Jan 1	-34.	1.
	Apr 1	-35.	2.
	Jul 1	-35.	2.
	Oct 1	-35.	2.
2006	Jan 1	-35.	2.
	Apr 1	-35.	2.
	Jul 1	-35.	2.
	Oct 1	-36.	2.
2007	Jan 1	-36.	3.
	Apr 1	-36.	3.
	Jul 1	-36.	3.
	Oct 1	-36.	3.
2008	Jan 1	-36.	3.
	Apr 1	-37.	3.
	Jul 1	-37.	3.
	Oct 1	-37.	4.
2009	Jan 1	-37.	4.

References

Luzum, B.J., Ray, J.R., Carter, M.S., and Josties, F.J., 2001, „Recent Improvements to IERS Bulletin A Combination and Prediction," GPS Solutions, 4(3), 34.

McCarthy, D.D. and Luzum, B.J., 1991a, „Combination of Precise Observations of the Orientation of the Earth," Bulletin Géodésique, 65, 22.

McCarthy, D.D. and Luzum, B.J., 1991b, „Prediction of Earth Orientation," Bulletin Géodésique, 65, 18.

McCarthy, D.D., 1996, „IERS Conventions," IERS Technical Note, 21, Paris Observatory.

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