3.5.2 Rapid Service/Prediction Centre

Rapid Service Techniques

The algorithm used by the IERS Rapid Service/Prediction Centre for 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 Earth Orientation Centre (EOC). 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 an 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 2001. Units are milliseconds of arc for x, y, dψ, and dε and milliseconds of time for UT1-UTC and LOD.

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*			
USNO AAM UT**			0.036**			

* All satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodeled orbit node motion. VLBI-based results have been used to correct for LOD biases and to minimize drifts in UT estimates.
** Estimated accuracy at time of solution epoch for issues after 14 August 2001.

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 the spline coefficients for every data point which are then used to interpolate the Earth orientation time series so that x, y, UT1-UTC, dψ, and dε values are computed at the epoch of zero hours UTC for each day. The only data points that 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 than 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).

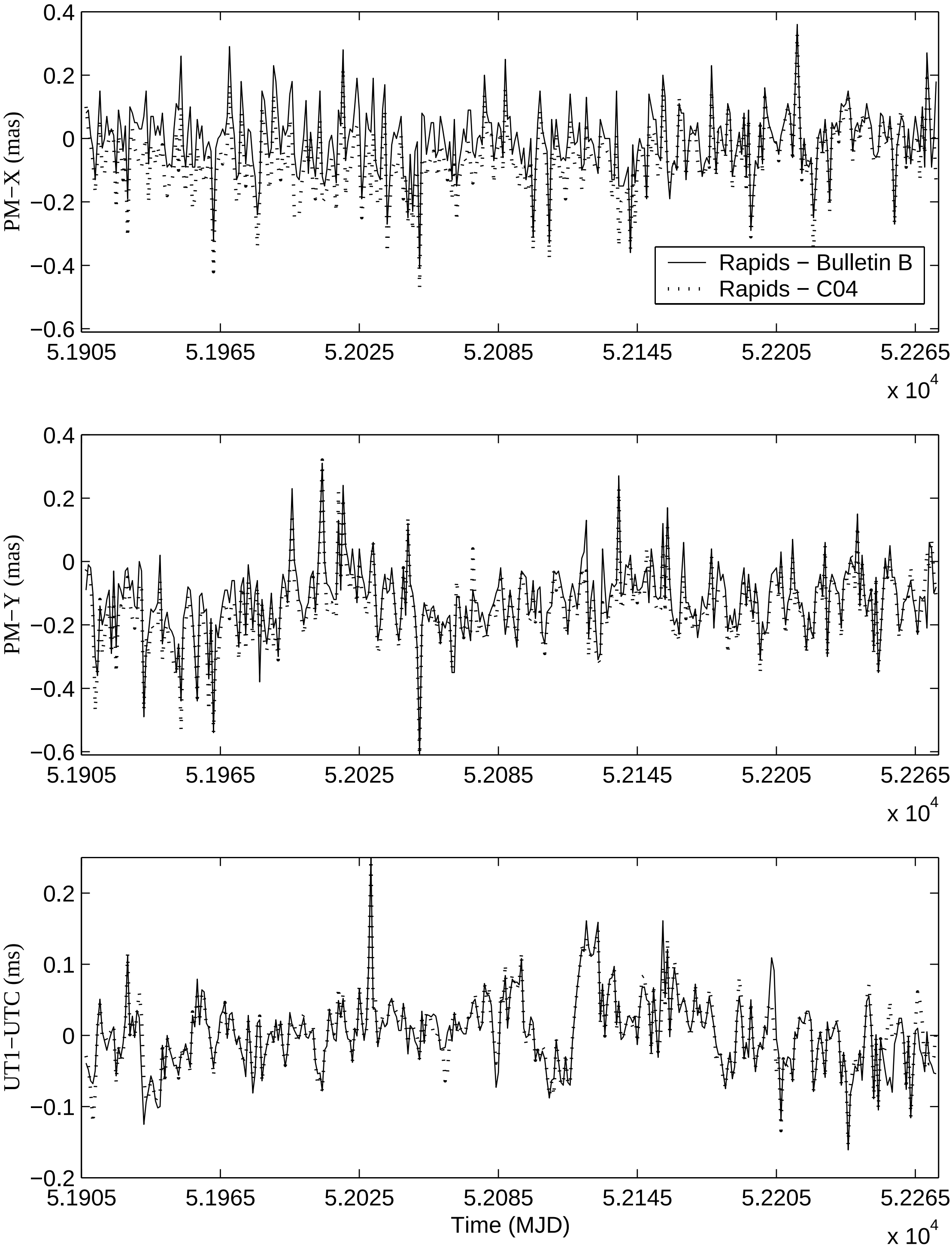
Table 2. Mean and standard deviation of the differences between the various Rapid/Prediction Centre solutions and IERS Bulletin B and C04 EOP solutions for 2001. Polar motion X and Y values are in units of mas and UT1-UTC values are in units of ms.

	Bulletin A – Bulletin B		Bulletin A – C04	
	Mean	Std. Deviation	Mean	Std. Deviation
Bulletin A Rapid Solution (Twice Weekly)				
X	0.00	0.11	-0.06	0.11
Y	-0.12	0.11	-0.15	0.11
UT1-UTC	0.002	0.051	0.004	0.049
Bulletin A Daily Solution				
X	-0.01	0.16	-0.07	0.16
Y	-0.10	0.18	-0.13	0.18
UT1-UTC	0.004	0.077	0.005	0.076
Running Solution (finals.data)				
X	0.00	0.06	-0.06	0.06
Y	0.00	0.05	-0.03	0.04
UT1-UTC	-0.004	0.022	0.002	0.021

The daily values errors listed in Bulletin A are derived from the quality of the spline fit in the neighborhood of the day in question. Table 2 shows the accuracies of three different Rapid/Prediction Centre products compared to the series Bulletin B and C04 maintained by the IERS EOC at the Paris Observatory. The agreement between the twice weekly Bulletin A Rapid solution and the daily Bulletin solution with the IERS EOC solutions are quite good, except for the large mean values for the Y-component of polar motion. An examination of the differences between the twice weekly rapid solutions also indicates that the Y-component of polar motion has an offset from the both the Bulletin B and C04 solutions (Figure 1). This offset, for the Y-component of polar motion, appears to be the result of IGS EOP files being used in the combination solution software. Fortunately, the introduction of the new IGS

Final EOP file corrected this problem, as described later in this section. This error does not exist in the Rapid Service/ Prediction Centre's running EOP solution. Overall, the EOP estimated for both the Bulletin A rapid solution and daily solution have similar accuracies at the time of solution epoch.

Figure 1: Differences between Bulletin A Rapid Solutions and the Earth Orientation Parameters available in Bulletin B and C04



Prediction Techniques

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 that 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 prediction 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, $(UT1R\text{-}TAI)_o$.

$$(UT1\text{-}TAI)_n = 2(UT1R\text{-}TAI)_o - <(UT1R\text{-}TAI)_{-n}>.$$

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 are published in Bulletin A to extend the tabular data. The prediction of $d\psi$ and $d\varepsilon$ is based on the KSV_1996_3 model (McCarthy, 1996). Table 3 and 4 show the mean magnitude and the standard deviation of the differences between the daily solution and C04 solution, respectively, for 2001. Recent prediction performance in UT1-UTC has been improved by 42% at 10 days into the future by the addition of a UT1-like data product derived from NCEP AAM (UTAAM) to the combination and prediction routine. This estimate of improvement was determined by examining one year of daily solutions that used UTAAM in the combination and prediction solutions.

Table 3. Mean magnitude of the differences between the Daily solutions with respect to C04 Earth Orientation Solutions for 2001.

Days in Future	X 0.001"	Y 0.001"	UT1-UTC ms	ψ 0.001"	ε 0.001"
1	.17	.11	.002	.14	.11
5	.85	.03	.031	.14	.11
10	2.15	.12	.025	.14	.12
20	5.42	.75	.356	.14	.12
40	12.2	3.25	1.36	.14	.12
90*	21.1	16.4	5.02		

* ψ and ε not predicted to 90 days into future in daily solutions.

Table 4. Standard Deviation of the differences between the Daily solutions with respect to C04 Earth Orientation Solutions for 2001.

Days in Future	X 0.001"	Y 0.001"	UT1-UTC ms	ψ 0.001"	ε 0.001"
1	.51	.47	.145	.59	.25
5	2.22	1.76	.732	.61	.26
10	3.99	2.93	1.88	.63	.27
20	6.86	5.21	4.21	.64	.28
40	11.1	10.6	5.45	.70	.29
90	18.9	21.2	10.47		

* ψ and ε not predicted to 90 days into future in daily solutions.

The predictions of ψ and ε are based solely on VLBI data. If no new data is available, a new prediction of these nutation angles cannot be determined. Therefore, the length of the prediction into the future for ψ and ε can and does vary in the daily solution files.

Predictions, of UT1-TAI up to 2010 January 1, are given in Table 5 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.

Table 5. Predicted values of UT1-TAI, 2002-2010. Note that TT-UT1 can be obtained from this table. Using the expression TT-UT1=32.186s – (UT1-TAI).

DATE	UT1-TAI (s)	Uncertainty (s)
2002 Jan 1	-32.115	.001
2002 Apr 1	-32.189	.001
2002 Jul 1	-32.229	.001
2002 Oct 1	-32.24	.01
2003 Jan 1	-32.30	.01
2003 Apr 1	-32.36	.02
2003 Jul 1	-32.57	.03
2003 Oct 1	-32.80	.04
2004 Jan 1	-33.02	.06
2004 Apr 1	-33.25	.08
2004 Jul 1	-33.4	.1
2004 Oct 1	-33.7	.2
2005 Jan 1	-33.9	.2
2005 Apr 1	-34.1	.3
2005 Jul 1	-34.4	.4
2005 Oct 1	-34.6	.4
2006 Jan 1	-34.8	.5
2006 Apr 1	-35.0	.6
2006 Jul 1	-35.3	.8
2006 Oct 1	-35.5	.9
2007 Jan 1	-36.	1.
2007 Apr 1	-36.	1.
2007 Jul 1	-36.	1.
2007 Oct 1	-36.	1.
2008 Jan 1	-37.	2.
2008 Apr 1	-37.	2.
2008 Jul 1	-37.	2.
2008 Oct 1	-37.	2.
2009 Jan 1	-37.	2.
2009 Apr 1	-37.	3.
2009 Jul 1	-38.	3.
2009 Oct 1	-38.	3.
2010 Jan 1	-38.	3.

Please contact the IERS 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).

Centre Activities in 2001

During 2001 several substantial changes have occurred which affect the performance of IERS Bulletin A. In December of 2000, it was determined that the contributions of the National Centers for Environmental Prediction (NCEP) model estimates of Atmospheric Angular Momentum (AAM) excitation of Length of Day (LOD) were actually degrading the near-term UT1-UTC predictions. Therefore, the contributions of AAM were removed from the Bulletin A solution and the usefulness of the NCEP model to the prediction of UT1-UTC was reevaluate. This reevaluation indicated the presence of quasi-periodic variability in the AAM-derived LOD that was not present in the UT1-UTC time series. It was determined that this variability could be reduced and that the resulting AAM-derived LOD time series could improve the centre's near-term UT1-UTC predictions (Johnson et al., 2002). Therefore, beginning with 14 August, the AAM-derived LOD time series was re-introduced into the combination of datasets used in the solution of IERS Bulletin A (Rapid Service and Predictions of EOP).

Beginning with the 1 May 2001 issue of IERS Bulletin A, we have adopted the system of our Annual Report submission. This involves changing the systematic corrections and weights of the contributing series. We have also removed the USNO VLBI reductions from the combination procedure. For recent data, the RMS differences in polar motion are less than 50 µas and in UT1-UTC are less than 5 µs.

Starting 22 May, the number of past data points used to estimate polar motion predictions was changed from 1100 days to 400 days. In testing the two prediction lengths since 1995, the new algorithm produced significantly better results for all prediction intervals. While the shorter time span makes separating the Chandler and annual oscillations more difficult, the advantage is that time-varying characteristics of the oscillations change less year-to-year than they do over the course of four years. This change has caused a larger-than-normal change in the polar motion prediction coefficients and in the long-term polar motion predictions.

Beginning 9 October, the IGS Final EOP file is being used. The new file is a concatenation of several originally inhomogeneous segments, all of which have been transformed to be consistent with the ITRF97 realization. The affect of this change on IERS Bulletin A polar motion values is generally less than about 0.1 mas. For the period since 51601.5 (27 Feb 2000), when the SINEX combination officially replaced the previous orbit combination series, the mean and RMS difference for Bulletin A polar motion are nearly zero and 0.036 mas, respectively, for each component. However, the differences are not entirely random. For the most recent period, the previous difference of about 0.1 mas between IERS Bulletins A and B for PM-y has been reduced almost to zero.

Availability of Rapid Service

The data available from the IERS Rapid Service/ Predictions Centre consists mainly of the data used in the IERS Bulletin A. This includes: x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from NEOS VLBI; x, y, UTC1-UTC $d\psi$, $d\varepsilon$, from IAA VLBI; x, y, UT1-UTC, $d\psi$, 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 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 Centre 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, $d\psi$, $d\varepsilon$, from the IERS Rapid Service/Predictions Centre; x, y, UT1-UTC, $d\psi$, $d\varepsilon$ from the IERS Earth Orientation Centre; predictions of x, y, UT1-UTC, from the IERS Rapid Service/Predictions Centre.

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 and UT0-UTC from Washington PZTs 1,3,7; latitude and UT0-UTC from Richmond PZTs 2,6; x and y from CSR LAGEOS 5-day SLR; x and y from Delft 5-day SLR; x, y, UT1-UTC, $d\psi$, and $d\varepsilon$ from IRIS VLBI.

The data described above are available from the Centre 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 form

<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/>.

Centre Staff

For most of 2001, the Rapid Service/Prediction staff consisted of the following members.

Jim R. Ray	program manager
Brian Luzum	daily operations & software manager
Thomas Johnson	research, software maintenance and support
Meri-Sue Carter	assists in daily operations and support
Jerry Josties	assists in operations and support

In December of 2001, Brian Luzum resigned from USNO and the program. Currently, Thomas Johnson is managing the program.

References

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Thomas Johnson