RECENT IMPROVEMENTS IN THE IERS RAPID SERVICE PREDICTION CENTER PRODUCTS FOR 2010 AND 2011

N. STAMATAKOS[1], B. LUZUM[1], B. STETZLER[1], N. SHUMATE[1],
M.S. CARTER[2], J. TRACEY[1]

[1] USNO, 3450 Massachusetts Avenue, N. W., Washington, D. C. 20392
e-mail: nick.stamatakos@usno.navy.mil

[2] NOFS, 10391 West Naval Observatory Road, Flagstaff, Arizona 86001-8521

ABSTRACT. The International Earth Rotation and Reference Systems Service (IERS) Rapid Service/Prediction Center (RS/PC) has made improvements to its products and has also updated a web-based Earth Rotation matrix calculator to be compliant with IERS Tech Note (TN) 36 equinox-based theory. The improvements to the Earth Orientation Parameters (EOP) products include updating the RS/PC EOP system to the 08C04 from the 05C04 system (the official long-term IERS EOP series), using the Geospatial Information Authority of Japan (GSI) Intensives in generating operational EOPs, and making the 2x daily EOPs available publicly. Also, being investigated on beta test software development systems is generating a 4x daily EOP solution, using new Universal Time-like GPS (UTGPS) updates based on more recent IGS (International GNSS Service) Ultras, and using a Kalman Filter (KF) in place of a cubic spline for generating EOPs.

1. OVERVIEW OF RS/PC SOLUTION

The daily EOP combination and prediction (CP) solution (finals.daily) is produced at approximately 17:00 UTC each day; the weekly version (Bulletin A) is produced on Thursdays at approximately 17:30 UTC. Both provide EOP values which include polar motion, UT1-UTC, and celestial pole offsets (CPO), with results located at `http://maia.usno.navy.mil`. These EOP values are used in determining the terrestrial to celestial transformation matrix. Data from Very Long Baseline Interferometry (VLBI), the Global Positioning System (GPS), Satellite Laser Ranging (SLR), and Atmospheric Angular Momentum (AAM) are used in these solutions. Further details about inputs, processes, numbers of users, and results can be obtained in Stamatakos et al. (2011) and references provided therein.

2. CHANGE OF REFERENCE SYSTEM FROM 05C04 to 08C04

To maintain consistency with the official IERS long-term EOP solution, which was officially changed on February 1, 2011, adjustments were made to the RS/PC EOP products by early February 2011. The IERS long-term EOP solution, called the C04, is produced by the IERS Earth Orientation Center, Observatoire de Paris (OP), and on February 1, 2011, they made changes to Polar Motion and UT1-UTC portions of the EOP set, and renamed the series from 05C04 to 08C04.

Prior to the official February 1, 2011 switch-over, OP had provided the new C04 series to the RS/PC. New systematic corrections (a bias and/or slope) were computed relative to the new 08C04 for each input data series and for the weekly, updated RS/PC EOP solution, finals.data. During this period before February 1, several test combination solutions were run, wherein the input data series weights and smoothing parameters were adjusted to attempt to improve the RS/PC root mean squared RMS residuals in Polar Motion and UT1-UTC relative to the new 08C04 series. Once the systematic corrections, weights, and smoothing parameters were determined, a new weekly solution file (finals.data) was produced, which contained a new combination solution based on these new parameters, going back to February, 2010.

The RS/PC made a new updated daily (finals.daily) and updated weekly (Bulletin A and finals.data) solution available to users on Tuesday, February 1, and Thursday February 3, respectively, both adjusted to the new C04 system. However, based on user comments after February 3, it was shown that the Polar Motion Y solution could be improved further, and the entire process for Polar Motion Y was repeated,

with a better resulting RS/PC daily and weekly solution produced on February, 10, 2011.

3. ADDITION OF GSI VLBI INTENSIVES TO THE RS/PC EOP SOLUTION

In August 2010, UT1-UTC results produced by GSI, from VLBI Intensives observed on the weekends, were added as inputs to the operational RS/PC EOP solution. (The term, VLBI Intensives, is discussed in Kronschnabl, 2009.) Each of these weekend observations are made well before noon UTC, and the GSI process is automated and can generate an EOP solution within an hour of the observation; thus making the input available to the 17:00 UTC RS/PC solution.

GSI is not always able to produce a UT1-UTC result on the same day as the observations. For instance, from early May to the end of October 2011, GSI produced same day results 65% of the time. In the earlier months of GSI EOP generation, the automated analysis process caused some failures to produce a same day result, but lately, the automated process has improved – the last reported automated analysis failure was on June 11, 2011; lately, any failures have been due to other reasons, such as data transfer problems.

To show the improvement in UT1-UTC 1-day predictions when using GSI Intensives in the RS/PC solution, daily EOP results were regenerated on a test computer for several past months. For each Saturday and Sunday from February to October, 2011 when a GSI Intensive was available, the EOPs were regenerated on a test computer with that Saturday or Sunday GSI Intensives removed. The results shown in Figure 1 indicate that with the GSI Intensives (shown with blue "X" symbols), the UT1-UTC RMS error was 52 μseconds (μs), and without (shown with green "O" symbols), the error was 65 μs.

4. TWICE-DAILY EOP SOLUTION

A second RS/PC EOP solution, computed at 03:10 UTC, is available at `http://maia.usno.navy.mil/2xdaily`. Normally, the integrated IGS length-of-day (LOD) and Polar Motion inputs produced from "18-hour" and "0-hour" IGS Ultra-Rapid orbit solutions (IGS Ultras) – which contain the LOD and Polar Motion results reported for 06:00 and 12:00 UTC, respectively – are the only additional inputs beyond those inputs used in the 17:00 UTC daily solution; however, when VLBI Intensives processing is occasionally late and misses the 17:00 UTC daily solution it will be added to the next 03:10 UTC solution. Also, this solution is not as closely monitored by RS/PC personnel as the 17:00 UTC daily solution. Users who notice problems with the solution may contact the RS/PC at ser7@maia.usno.navy.mil.

5. IMPROVEMENTS OF UT1-UTC PREDICTIONS IN RECENT YEARS

The UT1-UTC 1 to 10 day prediction errors have been decreasing over the last decade, as shown in Figure 2. Prediction errors are the differences between the daily produced EOP predictions and the combination solution computed several weeks later for the same epochs; e.g., a 1-day UT1-UTC prediction error (of -0.0188 seconds) produced at MJD 55700 is the difference between UT1-UTC at MJD 55701 in finals.daily (-0.286607) and the combination value at MJD 55701 produced several weeks later in finals.data (-0.2677922). The 1-day RMS prediction errors for UT1-UTC were 110 μs in 2009, 75 μs in 2010, and, for the first 10 months of 2011, it was 57 μs. The reduced latency of Int1 and Int2 VLBI Intensives (Stamatakos et al., 2008), the removal of AAM LOD from the EOP combination (but not from the prediction) (Stamatakos et al., 2011), and the addition of the integrated IGS Ultras in April 2011 have decreased the short term UT1-UTC errors. In 2009, latencies of 1 day or less, between observation to inclusion of VLBI inputs in the EOP solution, occurred only 30% of the time; by 2011, the percentage had increased to 70%. The 5 and 10 day prediction errors for 2011 have been slightly worse than for 2009 and 2010, and the reasons are still under investigation.

6. A NEW UTGPS SOLUTION BASED ON IGS ULTRAS

The USNO GPS Analysis Division has produced a new UTGPS Ultras solution, a UT1-like solution based on IGS Ultras orbits. The solution is produced daily around 09:00 UTC, just after the "6-hour" IGS Ultra solution becomes available. A special EOP solution is being generated around 09:15 UTC each day on a test computer using this new input. From February to the end of October, 2011, a 15% improvement in the "0-day prediction" of UT1-UTC has been observed when using this new input versus the operational solution produced at 17:00 UTC on the previous day. Figure 3 contains a plot of the 0-day prediction error for both the new UTGPS Ultras solution and for the operational solution since February, 2011. The new UTGPS Ultras solution had an rms error of 24.8 μs, versus 29.4 μs for the

operational solution. It is hoped that with new changes to the filtering of the provided UTGPS Ultras solution (Stamatakos et al., 2009), the error can be further decreased.

7. UPGRADE OF EO MATRIX CALCULATOR TO TN 36 EQUINOX-BASED

The terrestrial to celestial (T2C) transformation matrix calculator was upgraded on the USNO EOP server at `http://maia.usno.navy.mil/t2c36e/t2c36e.html`. The T2C transformation relates the orientation of the International Terrestrial Reference Frame (ITRF) to the Geocentric Celestial Reference System (GCRS). An earlier version of the T2C calculator based on TN 32 is described in Stamatakos et al. (2011), and the upgraded version (which is slightly more accurate) is based on TN 36 using the equinox-based equations listed therein. The reference, just listed, provides details about the user-interface, observable inputs, optional intermediate outputs, and output formats for the TN 32 option. Many details between the two versions are similar, and Table 1 provides a list of changes made.

Item	TN 32	TN 36
User Interface:		
Input option for librations	NO	YES
Intermediate outputs option for Greenwich Apparent Sideral Time (GAST) and Bias matrix	NO	YES
Special user-requested output format	YES	NO
Tidal models:		
Long period tides	DS_ZONT.F	RG_ZONT2.F
Subdiurnal/diurnal tides	ORTHO_EOP.F	ORTHO_EOP.F
SOFA software at `http://www.iausofa.org/`	`2007_0810_F.html`	`2010_1201.html`

Table 1: Summary of changes from TN 32 to TN 36 T2C transformation matrix calculator.

8. FUTURE DIRECTIONS

Four EOP solutions will be produced each day starting in 2012, and sometime in the next several years, an EOP solution will be regenerated any time a new input data series is available. Also, an EOP combination based on a Kalman Filter approach is under study – results for UT1-UTC are similar to those obtained from the USNO EOP operational solution. More testing and development of this Kalman Filter approach will be done in the future. Finally, improvements in Polar Motion predictions using combined AAM plus Ocean Angular Momentum (OAM) are under investigation by RS/PC personnel.

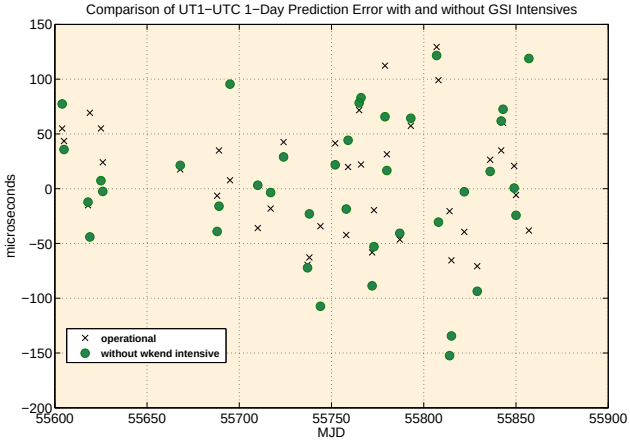
9. REFERENCES

Kronschnabl G., "Experiences with regular e-transer of geodetic INTENSIVE data at Wettzell", Proceedings of Science, 2009, The 8th International e-VLBI Workshop, EXPReS09, June 22-26, 2009, Madrid, Spain, pp. 1-5; (`http://pos.sissa.it/archive/conferences/082/034/EXPReS09_034.pdf`)

Stamatakos N., Luzum B., Stetzler B., Shumate, N., Carter, M. S., (2011) "Recent improvements in the IERS Rapid Service/Prediction Center Products", *Journées Systèmes de Référence Spatio-Temporels* 2010, pp. 184-187

Stamatakos N., Luzum B., Stetzler B., Wooden W., Shultz E., (2009) "Recent improvements in the IERS Rapid Service/Prediction Center Products", *Journées Systèmes de Référence Spatio-Temporels* 2008, pp. 160-163

Stamatakos N., Luzum B., Wooden W., (2008) "Recent improvements in the IERS Rapid Service/Prediction Center Products", *Journées Systèmes de Référence Spatio-Temporels* 2007, pp 163-166.



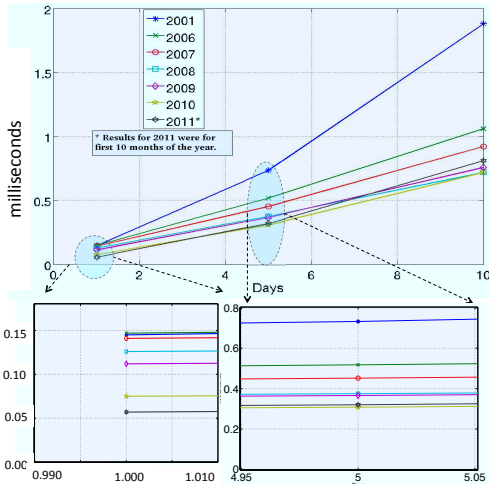


Figure 1 (left): Comparison of UT1-UTC 1-day prediction error with and without GSI Intensives.
Figure 2 (right): UT1-UTC 1 to 10 day prediction error from 2001 to 2011.

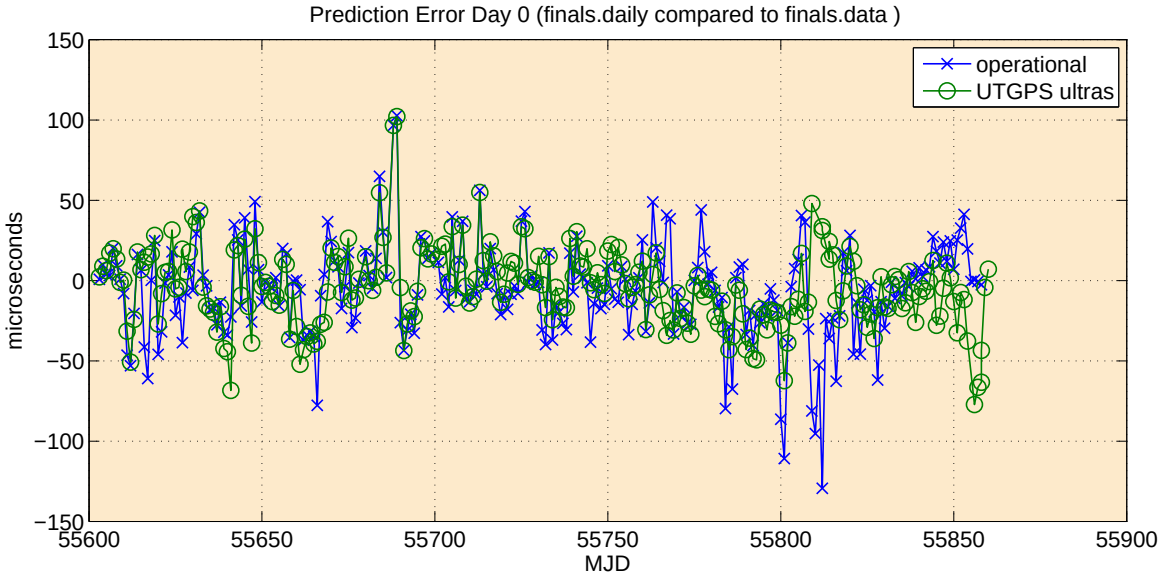


Figure 3: Comparison of last combination epoch errors using UTGPS-Ultras input and the current operational EOP solution. RMS error for UTGPS Ultras solution was 24.8 μseconds. RMS error for the operational solution was 29.4 μseconds.