RECENT IMPROVEMENTS IN IERS RAPID SERVICE/PREDICTION CENTER PRODUCTS

N. STAMATAKOS[1], B. LUZUM[2], B. STETZLER[3], N. SHUMATE[4], M. S. CARTER[5]

[1 2 3 4] USNO
3450 Massachusetts Avenue, N. W.
Washington, D. C. 20392

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

e-mail: [1] Stamatakos.Nick@usno.navy.mil [2] Brian.Luzum@.usno.navy.mil
[3] Beth.Stetzler@usno.navy.mil [4] Nathan.Shumate@usno.navy.mil [5] MSC@nofs.navy.mil

ABSTRACT. The International Earth Rotation and Reference Systems Service (IERS) Rapid Service/Prediction Center (RS/PC) has made several improvements to its products and has also developed a web-based Earth Rotation matrix calculator. The improvements include a correction to the Universal Time Atmospheric Angular Momentum (UTAAM) implementation in the combination. Also, use of the International GNSS Service (IGS) Ultras for UT1-UTC and a twice daily Earth Orientation Parameter (EOP) solution are being investigated on testing computers. The web-based calculator returns the Earth rotation matrix at specified user input times based on the IERS 2003 Conventions models.

1. OVERVIEW OF RS/PC SOLUTION AND IMPROVEMENTS

The daily EOP combination and prediction (CP) solution (finals.daily) is produced at approximately 1700 UTC each day; the weekly version (Bulletin A) is produced on Thursday at approximately 1700 UTC. Both provide EOP values which include polar motion, UT1-UTC, and celestial pole offsets, 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), Global Positioning System (GPS), Satellite Laser Ranging (SLR), and AAM are used in these solutions. Observations from the past are combined with appropriate weighting factors and used, along with AAM forecast data, to predict EOP values into the future. It is estimated there are 700 users who receive IERS RS/PC data each week, and roughly 60000 ftp downloads are made per month. Most uses of the data are for practical, non-research purposes with many users — *85 to 90%* — having limited EOP knowledge. Details on the inputs, processes, and results of the RS/PC solution can be found in Stamatakos et al. (2008).

A change in the UTAAM processing within the EOP combination has resulted in improved UT1-UTC short-term predictions. Test computer runs which a) use the IGS Ultra-Rapid observed data (also known as the IGS Ultras) for UT1-UTC and b) generate a twice daily EOP solution are discussed. Lastly, a web-based Earth rotation matrix calculator developed at the RS/PC is presented.

2. UTAAM PROCESSING CHANGE

One of the users of EOP data reported systematic errors in the 1 to 10 day UT1-UTC predictions, and EOP personnel had previously observed a related issue with the last combination day. These errors are shown for the year 2009 in Figure 1 and were computed by differencing the finals.daily with the finals.data UT1-UTC solution produced at a much later date. Salient features to observe are the fortnightly and the quasi-annual periodicity. Since predictions are greatly influenced by the last combination value and since the last combination and 1-day prediction errors show a correlation, our investigation quickly focused on the UTAAM because it greatly influences the last day combination and short term predictions. Fifteen days of previous AAM values had been used in the combination; however, the weighting was small since there were other more accurate data sets from VLBI and GPS at those epochs. At the last combination day epoch, the AAM influence grows rapidly since only Universal Time-like GPS (UTGPS), integrated IGS Rapids, and occasional e-VLBI results were available on the same day. For short term UT1 predictions, the AAM influence grows even more rapidly since the USNO UT1 predictions out to 7 days are based on AAM forecasts.

In the past, Johnson et al. (2005), observed an occasional and possibly erroneous low-frequency signal in the combination results caused by the AAM input, and so this input had been modified and down-weighted to reduce the problem. However, the implemented down-weighting method might not have worked as intended, and it was discovered, in early 2010, that simply removing the AAM from the combination (but not from the predictions) greatly improved the results. In Figure 2, one can observe the improvement in the 1-day prediction error obtained over the range of dates from July 28, 2009 through January 20, 2010, when the AAM was removed from the combination. The green curve is the 1-day prediction error using the AAM in the combination and the red curve is the prediction error with the AAM removed (on a test computer), and the resulting reduction in error was approximately 20 to 30%.

When one examines Figure 3, the rationale for removing the AAM from the combination becomes clear. The error in the operational combination which uses AAM in both the combination and prediction (blue), the UTGPS (cyan), a test version of the combination which used AAM only in prediction (green), and another test version of the combination which used no AAM in combination or prediction (black) are plotted together from August 9 to September 28, 2010. Also included in the plot are vertical line markers (red) which indicate the epochs in which e-VLBI results were available to the combination on the same day as the observation. For most days shown, the combination with AAM only in predictions results in a reduced error. Even for the days when both e-VLBI and UTGPS results are available, one would have expected a very low error in the blue curve; however, on days 270, 278 and 298, the error is larger than expected. However, once the AAM was removed (green) from the combination, the errors on these dates decreased significantly — indicating even when the more accurate e-VLBI data were available, the AAM errors and weights were large enough to cause large combination errors. Note that although only 50 days of 2009 are shown in Figure 3, it is representative of what was seen throughout 2009.

The removal of the AAM from the operational combination (but not prediction) was implemented on February 25, 2010. Figure 4 is a comparison of the 1-day UT1-UTC prediction results from January 1, 2009 to February 24, 2010 with results from February 25, 2010 through August 24, 2010, and one can clearly see the reduction in error after the change. Before the change, the mean was -1.30 μsec and standard deviation was 112.34 μsec; after the change, the mean was -18.20 μsec and standard deviation was 71.14 μsec. Thus, so far, there has been a 25 to 30% reduction in 1-day prediction error due to using the AAM input data only in the predictions, and not in the combination.

3. EOP SOLUTION MULTIPLE TIMES PER DAY

A second, automatic, EOP CP solution is run at 03:00 UTC each day on a test computer, and additional manual runs can be made at most other times. Currently this solution can accommodate updates to any VLBI and IGS input data. With some additional effort, the software could be made to accommodate multiple-times-per-day updates to SLR, UTGPS, and AAM once more frequent updates are available. So far, only multiple-times-per-day updates to the IGS Ultras have been available. Once the Wettzell and Tsukuba radio antennas come back on-line in late 2010, it is hoped that multiple-times-per-day updates to VLBI will be available.

4. USE OF IGS ULTRA DATA IN THE UT1-UTC COMBINATION

Another test case EOP CP solution, running since early September 2010, includes the IGS Ultra data in the UT1-UTC combination, which provide additional useful UT1-UTC estimates beyond the last available VLBI intensive and UTGPS data. These ultras provide LOD and UT1-UTC information for the 0, 6, 12, and 18-hour UTC observations each day with only a few hours of latency between the observations and processing. When the daily solution is run at 17:00 UTC, the previous day 18-hour and current day 0-hour observations (beyond the last IGS Rapid) are available. This additional data could provide a reduction in the last combination and short-term prediction errors for UT1-UTC.

When the 03:00 UTC second EOP CP solution (discussed in section 3 above) is run, the 6 and 12-hour IGS Ultras from the previous day are available to the combination — providing two additional epochs. It is anticipated that if one could use the EOP CP solution produced at this time, instead of waiting for the next daily run at 17:00 UTC, then there would be an additional reduction in last combination and short term prediction errors.

5. EO MATRIX WEB-BASED CALCULATOR

A transformation matrix calculator was added at the USNO EOP server, located at `http://maia.usno.navy.mil/t2crequest/t2crequest.html`; although, a dedicated server for the calculator may be coming soon to USNO. The calculator is based on the IERS Conventions (2003), Technical Note 32 using the equinox-based International Terrestrial Reference Frame (ITRF) to Geocentric Celestial Reference System (GCRS) transformation. The code is written in FORTRAN and relies heavily on code provided at `http://tai.bipm.org/iers/conv2003/conv2003_c5.html` and by the Standards of Fundamental Astronomy (SOFA) organization. Observable quantities are from a version of the finals2000A.data or finals.daily files provided at the EO Department server listed above. Polar motion and UT1 observables are interpolated when needed, with long-period tidal terms removed before the interpolation and then, long-period tidal, diurnal, and sub-diurnal tidal terms are added back into the observables. Adding sub-diurnal and diurnal tides is a user option, which provides additional accuracy. Outputs include the ITRF to GCRS and several intermediate transformation quantities.

Figure 5 contains a picture of the user interface to the calculator. The user chooses date and time intervals. The code produces an output page containing the ITRF to GCRS transformation and desired intermediate quantities. The user is restricted to 100 intervals or less; however, once the dedicated server is available, this restriction limit will be raised considerably. The standard output, observed in Figure 6, is the transformation and requested intermediate matrices at the epochs corresponding to the user specified start and stop time intervals. Optional quaternion (also known as Euler parameters) output can be chosen. The available intermediate quantities are polar motion, Greenwich Mean Sidereal Time (GMST), equation of the equinoxes, precession, nutation, and combined bias-precession-nutation.

6. FUTURE DIRECTIONS

The 2x-daily EOP solution will be evaluated in 2010 and then made operational in early 2011. Eventually, an Nx-daily solution will be made to re-evaluate a new EOP solution any time a new input data series is detected. Also, Celestial Pole Offsets published by the IERS RS/PC will be with respect to the P03 series. The use of the Geospatial Information Authority (GSI) of Japan VLBI intensives in the operational EOP CP solution has begun recently and is being evaluated. Finally, the use of the IGS Ultra data in the UT1-UTC CP solution on a test computer will be evaluated.

7. REFERENCES

Johnson T.J., Luzum B.L., Ray J.R., “Improved near-term Earth rotation predictions using atmospheric angular momentum analysis and forecasts”, Journal of Geodynamics 39 2005, pp 209-221.

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.

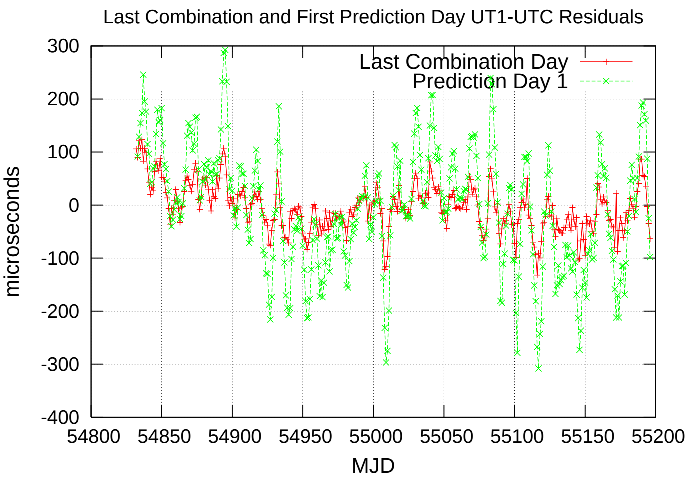

Figure 1: Last Combination and 1-Day Prediction Errors

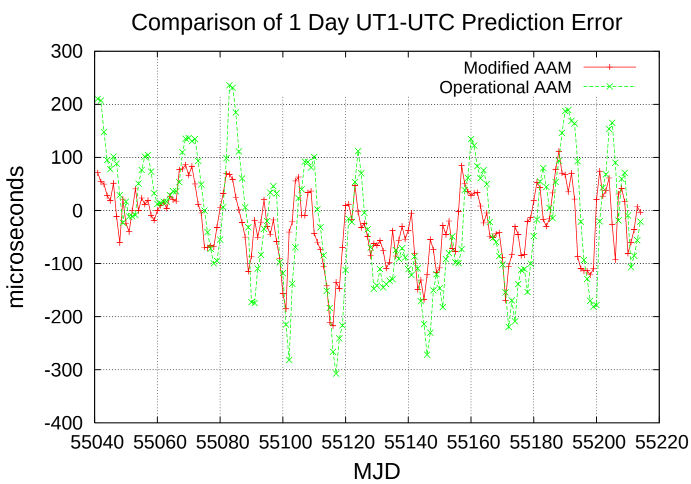

Figure 2: 1-Day prediction error with (green) and without (red) AAM in the Combination

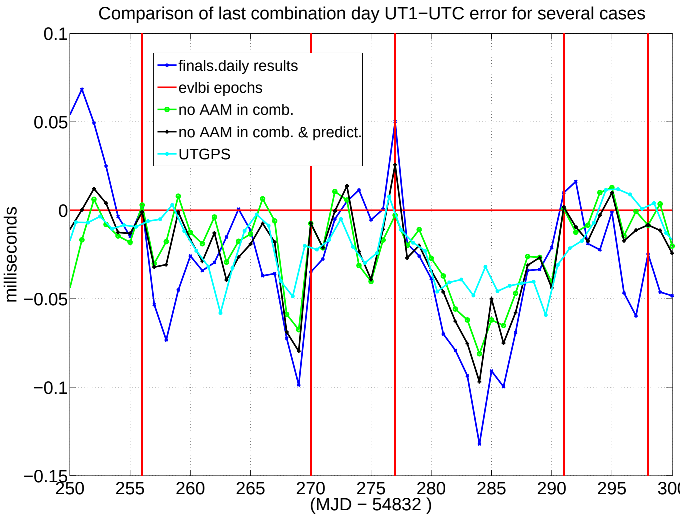

Figure 3: Comparison of Input Data Sets to finals.data for UT1-UTC

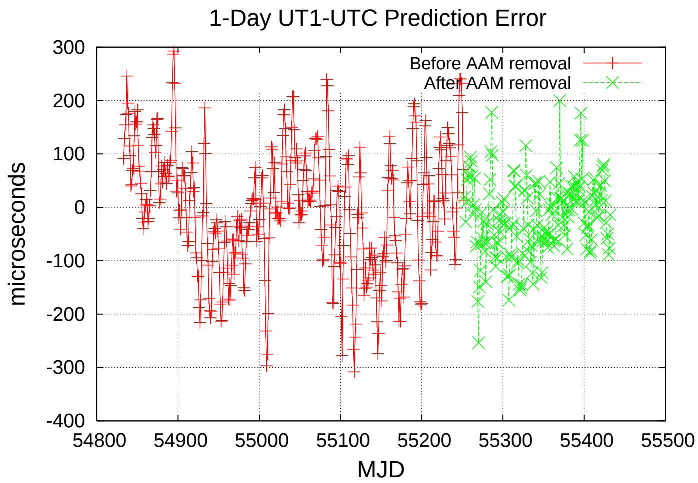

Figure 4: 1-Day UT1-UTC Prediction Error before and after AAM Removal from the Combination

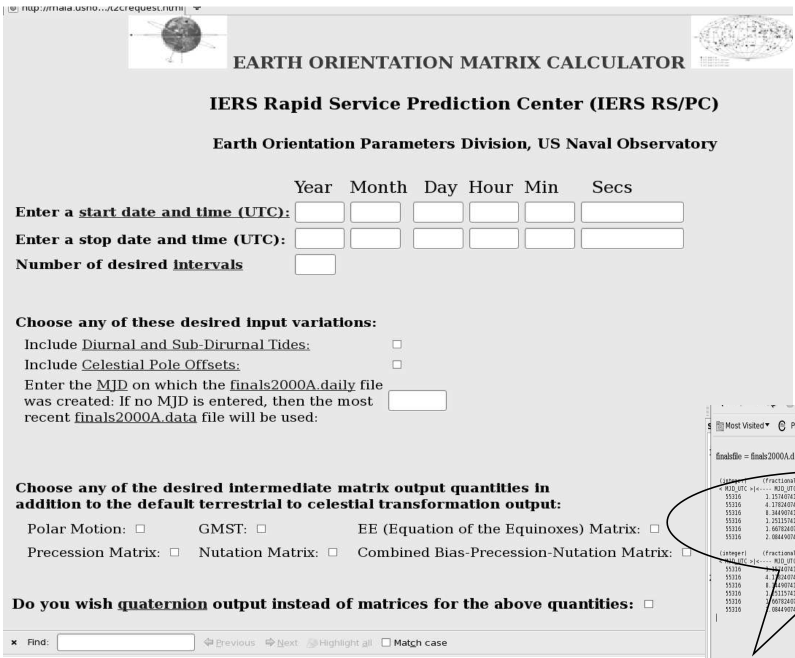

Figure 5: EO Matrix Calculator: User Interface

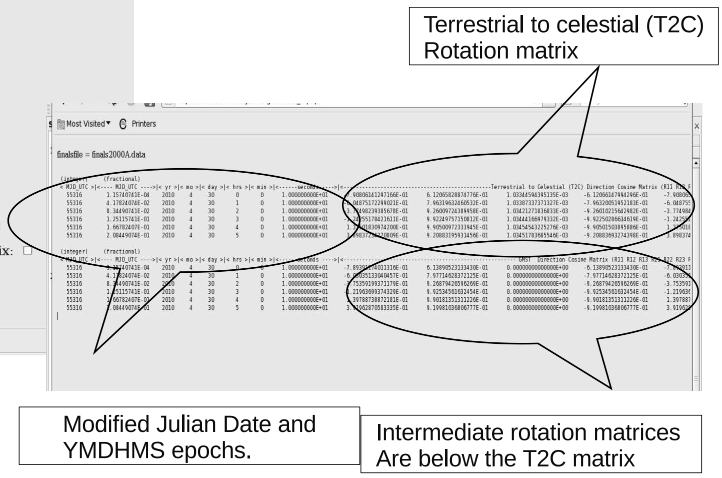

Figure 6: EO Matrix Calculator: Output