CCTF 2012: Report of the Royal Observatory of Belgium

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Clocks and Time scales:

The Precise Time Facility (PTF) of the Royal Observatory of Belgium (ROB) contains presently 5 Cesium clocks HP5071A, two with standard tubes (since 1993 and 1995), and three with High Perf. Tubes (since 2012), plus one active H-maser CH1-75A (since 2006). UTC(ORB) is generated from the CH1-75A frequency, steered monthly upon circular T, and more recently (2012) upon the rapid UTC values, associated with a comparison between the UTCr results of other laboratories.

The behavior of UTC(ORB) with respect to UTC is shown in Figure1.

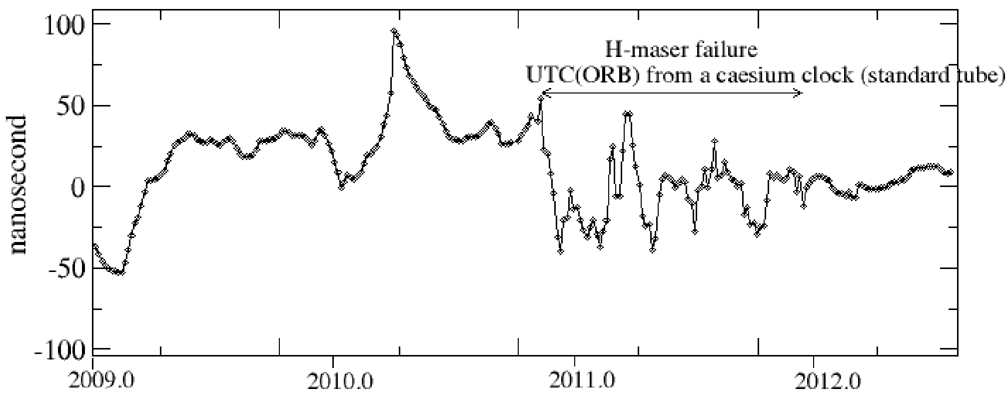

Figure 1. UTC-UTC(ORB) from 2009.0 to 2012.5

- A new PTF design was defined and is gradually being implemented. This new PTF setup focuses on automatic health status monitoring, as well as on automatic control, of all operational devices (see [9].)

- A new GNSS station is used for time transfer to TAI, it is the IGS station BRUX, while BRUS was decommissioned. The new hardware delays were computed so that the new solution based on BRUX can be aligned on the solution based on BRUS. The receiver, a PolaRx4_TR, was calibrated in August 2012 using the traveling GTR50 receiver from BIPM.

- A new service for monitoring atomic clocks connected to a GNSS receiver is available at ROB, based on PPP computation using the Atomium software and a webpage where the solutions are plotted at each request. The clock comparisons are provided with a delay of less than 1 hour using IGS real time products. After 2 hours, the solutions in the database (and hence in the pictures appearing on the web page) are replaced by new solutions computed with the ultra rapid products EMU produced by the NRCan IGS analysis center. This new solution is very close to the IGS rapid solution, the std. dev. of the differences is between 0.2 and 0.5 ns. Two days later the solutions obtained with the ultra rapid products EMU are replaced by the solutions computed with the rapid IGS orbits. No significant bias exist between our solutions obtained using the IGR and the IGS solutions, and the standard deviation of the differences between both is at the level of 100 ps (see [10]).

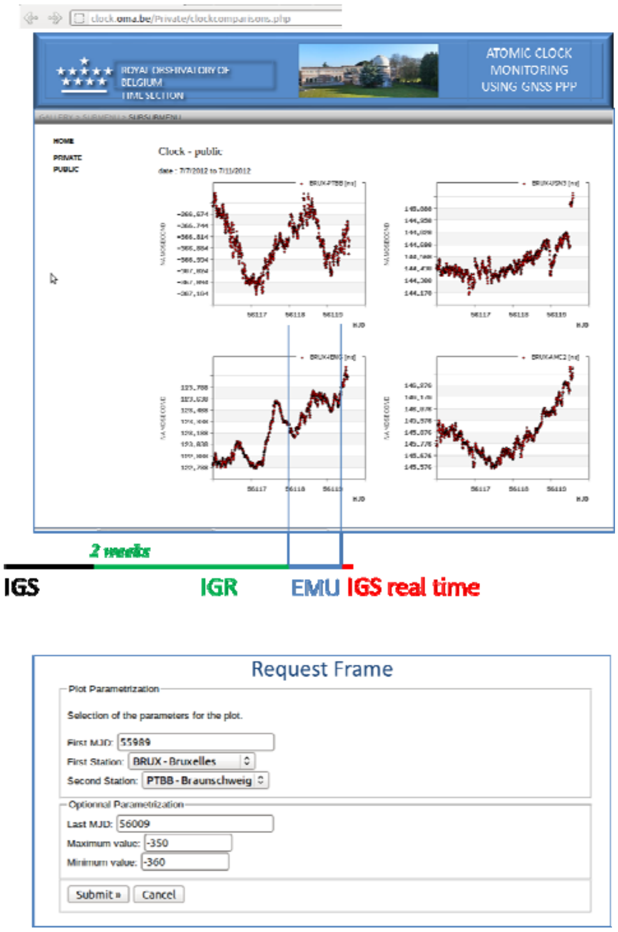

Figure 2. Web page for near-real time clock monitoring, available upon request at the royal Observatory of Belgium.

- The ORB participated to the Working Group for Galileo FOC Timing Interface, which provided a white paper to ESA and EC concerning the recommendations of the European Timing Community concerning the architecture, GST steering and products of the future Galileo Time Service Provider.

GNSS time and frequency transfer

- A new version (V4.3_R3) of the R2CGGTTS was developed in order to adapt the software to the new RINEX format (RINEX 3.0) dedicated to common GPS-GLONASS-GALILEO observations. In order to test the application to Galileo data, first tests were performed with the signals from the two experimental satellites GioveA and GioveB signals (see Figure 3 and [6]).

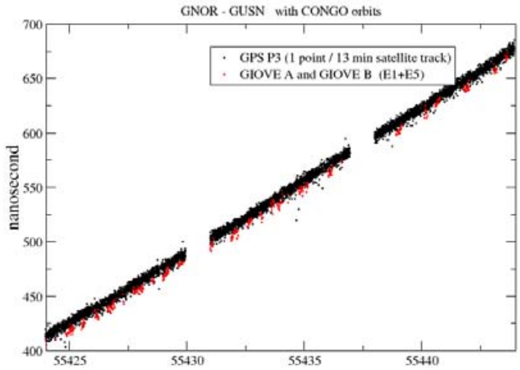

Figure 1: Time transfer between GNOR (ESTEC, the Netherlands) and GUSN (USNO) obtained via common view from CGGTTS results**.**

- In collaboration with A. Harmegnies BIPM, the R2CGGTTS was upgraded towards a new version (v5.1) able to produce results for both GPS and GLONASS satellites. The CGGTTS data are corrected for orbits and clocks using ESOC rapid products, which now provide combined products for satellite orbits and clocks in which both GLONASS and GPS clocks are given with respect to the same reference. A procedure was then setup to correct the GLONASS results for inter-frequency biases (IFB's). These corrected CGGTTS data for GPS and GLONASS can therefore be combined in one unique GPS+GLONASS All-In-View solution. The stability of this combined solution is not significantly different from the stability of the solution based on GPS data only (see [7,8]).

- The combination of GPS and GLONASS was also developed in Atomium, i.e. PPP analysis. The results have shown that it is important to determine the IFB's of the GLONASS satellites as these can include some multipath effects which vary with time (see Figure 4). A second important result was that the use of GLONASS satellites in the solution does not modify the GPS-only solution, except for short data batches where the additional GLONASS code data helps in the determination of the ambiguities, and hence improves the solution (see Figure 5 and [5])

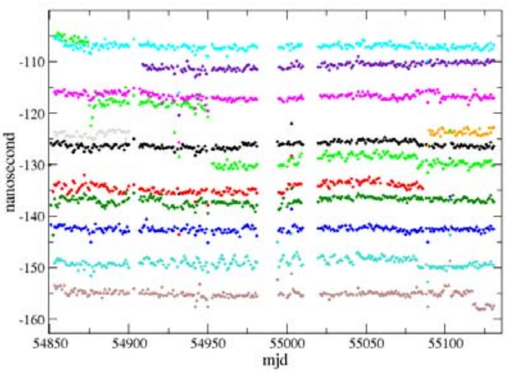

Figure 4: Values of the inter-frequency hardware delays computed with Atomium for the link ONSA-WTZR during 6 months. Som periodic variations appear for some frequencies, probably dut to multipath**.**

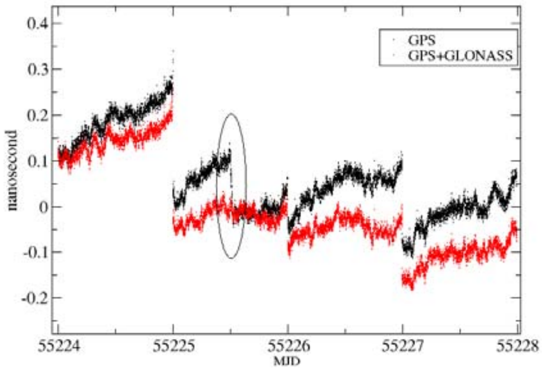

Figure 5: Differences between the Atomium PPP solution and the IGS solution for the time link ONSA-WTZR, with GPS data only or with GPS+GLONASS data, showing the improvement thanks to the GLONASS data when there is a tracking interruption as in WTZR during the MJD 55225.

- The ORB investigated new analysis procedures based on the E5 code-plus-carrier (CPC) combination for time transfer. Tests with simulated Galileo data showed that while providing a noise level 10 times lower than the ionosphere-free combination of Galileo E1 and E5, the use of the CPC combination with E5 does not improve the medium-and long-term stability of time transfer with respect to the ionosphere-free combination of Galileo E1 and E5 codes, due to the need of a second frequency signal to correct for the ionospheric delays and ambiguities (see [1]).

- The *ORB* developed, the computation of a combined GPS+TWSTFT solution for time transfer, combining all observations in a common least square analysis. For little noisy TWSTFT links, the combination improves the stability of the solution, reducing the day boundary discontinuities due to the noise of the GPS noise as illustrated in Figure 6 for the link NIST-OP; the accuracy is then given by the TWSTFT data and the short term frequency stability and high sampling is given by the carrier phase data (see Figure 6 and [4]).

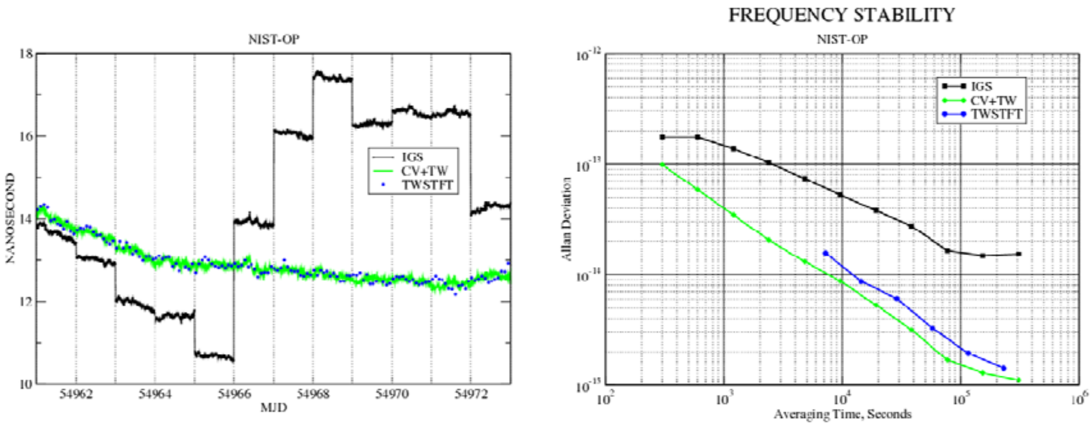

Figure 6. Comparisons between the combined CV+TW, the TW data and the GPS-only solutions for the time link NIST-OP (left), and frequency stability analysis of the data analyzed (right). A linear drift was removed to all curves on the left plot ($y = -6.36 \cdot 10^{5} + 11.699x$) in order to improve the visibility.

- Using GNSS data from US stations during the storm of the Halloween day in 2003, the second-order ionospheric effects were pointed. These can be due to either the delays in the signals or (or in combination with) errors in the satellite clocks computed by the IGS without correction of the 2nd-order ionospheric delays. In Figure 7, we clearly see that all the satellite tracks have the same shape during the first part of the day, i.e. before the storm, while they show different shapes during the storm. In Figure 8, the associated Slant TEC is plotted with the corresponding colors. As we know that for some stations the STEC can reach 600 TECU, the effect observed for station ALGO (Canada) could be amplified by a factor 4 for other stations (see also [2,3]).

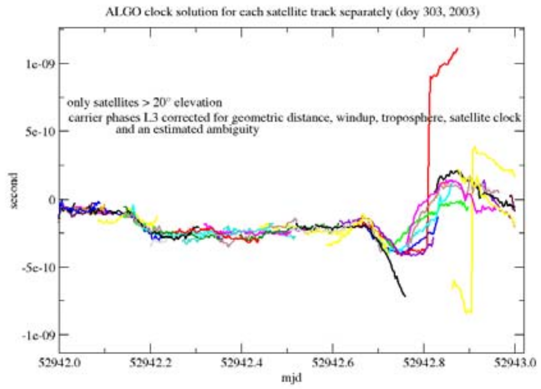

Figure 7. Clock solutions obtained with the different satellite tracks separately during the day of the Halloween storm in 2003.

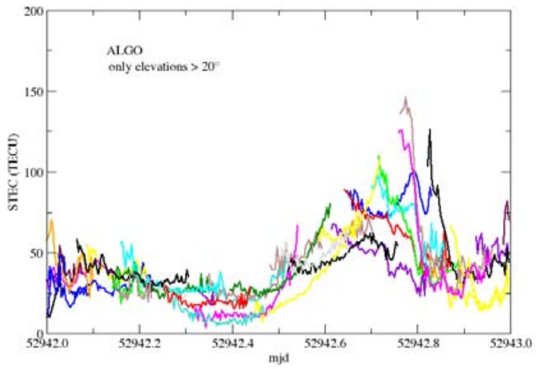

Figure 8. STEC corresponding to the satellite tracks depicted in the clock solutions.

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Some Associated Publications:

[1] M C. Martinez,; P. Defraigne, C. Bruyninx,
On the Potential of Galileo E5 for Time Transfer,
In press in IEEE UFFC, 2012

[2] S. Pireaux, P. Defraigne, L. Wauters, N. Bergeot, Q. Baire, and C. Bruyninx,
Influence of ionosphere perturbations in GPS time and frequency transfer,
Journal of Advances in Space Research, doi:10.1016/j.asr.2009.07.011, vol 45 (9), pp. 1101-1112, 2010.

[3] P. Defraigne, S. Pireaux,
Ionospheric perturbations in GNSS time transfer,
in: Proc. 2nd colloquium Scientific and Fundamental Aspects of the Galileo Programme, CD-rom, 2009.

[4] M.-C. Martinez, and P. Defraigne
Combination of TWSTFT and GPS data for time transfer,
Metrologia, 47 (3), 305-319, 2010.

[5] P. Defraigne and Q. Baire,
Combining GPS and GLONASS for Time and Frequency Transfer,
Journal of Advances in Space Research, accepted (June 2010),
doi: 10.1016/j.asr.2010.07.003.

[6] P. Defraigne, M.C. Martinez, A. Mudrak, and S. Binda
Galileo Common View: format, processing and tests with GIOVE,
in: Proc. 42th PTTI, CD-rom , 2010.

[7] P. Defraigne, A. Harmegnies, G. Petit,
Time and frequency transfer combining GLONASS and GPS data,
proc. EFTF-IFCS, CD-rom 2011.

[8] A. Harmegnies, P. Defraigne

Upgrade of R2CGGTTS for GLONASS P3 use
BIPM Time section Technical Memorandum TM 190 du BIPM

[9] W. Aerts, P. Defraigne
Ongoing Renewal of the ROB PTF
Proc. EFTF, CD-rom 2012.

[10] P. Defraigne, G. Cerretto, F. Lahaye, Q. Baire, D. Rovera,
Near real-time comparison of UTC(k)'s through a Precise Point Positioning approach
Proc. EFTF, CD-rom 2012.