Real Time Multi-GNSS Processing at ESOC

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Introduction

Over the last 12 years, ESOC has embarked on a program to build a Real Time GNSS software infrastructure. RETINA (system for REal TIme NAvigation) has been modelled after ESOC's experiences in Real Time satellite control systems and includes many of the elements for data processing, archiving and visualisation that are common to such systems. Originally developed to support the GPS constellation, RETINA capabilities have now been extended to cover Galileo, GLONASS, QZSS and SBAS. In addition, processing capabilities have been extended to include all new GNSS signals and frequencies.

The poster shows the RETINA capabilities and results from multi-GNSS processing, assessing the performance in the orbit and clock domain, as well as the enhanced performance in Precise Point Positioning compared to the GPS-only solution

Software Overview

The ESOC software includes Visualisation, Infrastructure and Algorithmic components.

A large effort has been invested into generating highly portable code for data and processing visualisation. The code has been developed using Java and allows Real Time, as well as historical monitoring of the Real Time processes. Figure 1 shows a snapshot of the processing status of the MGEX real time observation streams, with a world map graphical display of the station and satellite locations. Also shown are the number of "live" links for each satellite and station, with the actual links displayed as coloured lines for selected elements. Colour-coding is used to display the processing status of each station(red=no data, yellow=intermittent data, green=nominal). Alphanumeric displays show the satellites tracked by each receiver and the receiver IDs tracking each satellite.

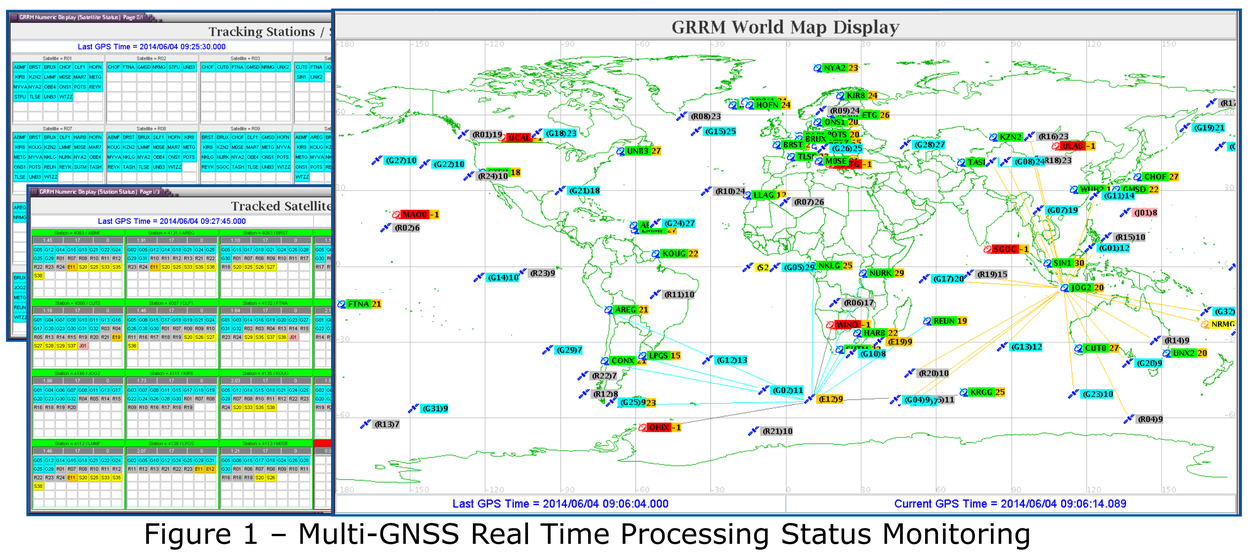

Figure 1 – Multi-GNSS Real Time Processing Status Monitoring

The Infrastructure components are written in C++ and provide a middleware layer for a number of diverse functions, including filing and archiving Real Time data and products in specially designed circular History Files, job scheduling and control and event logging.

Algorithmic components are written in Fortran 90 or C++ and include tasks for Real Time multi-GNSS observation and ephemeris processing and filing, satellite and receiver Real Time clock estimation and Real Time product dissemination via RTCM messages. The latest version of the software can accommodate all observation signals and frequencies and Broadcast Ephemeris structures for GPS, Galileo, GLONASS, QZSS and SBAS. Beidou functionality is currently being added.

MGEX Real Time Processing Setup

The software is now running in an experimental mode, processing 1 Hz Real Time streams from the BKG MGEX caster. Combined with the latest version of the NAPEOS orbit determination software, which produces precise orbits every 2 hours, RETINA generates Real Time orbit and clock products for all the available GPS, GLONASS and Galileo satellites.

The stations used in the routine processing are shown in Figure 1 above. There are typically 45 stations and the data latencies for these stations are plotted in Figure 2 over two 24-hour intervals. A wait threshold of 7.5 seconds is applied before the clock solution is attempted, in order to ensure that all the data have arrived. Figure 2 shows that this is clearly sufficient.

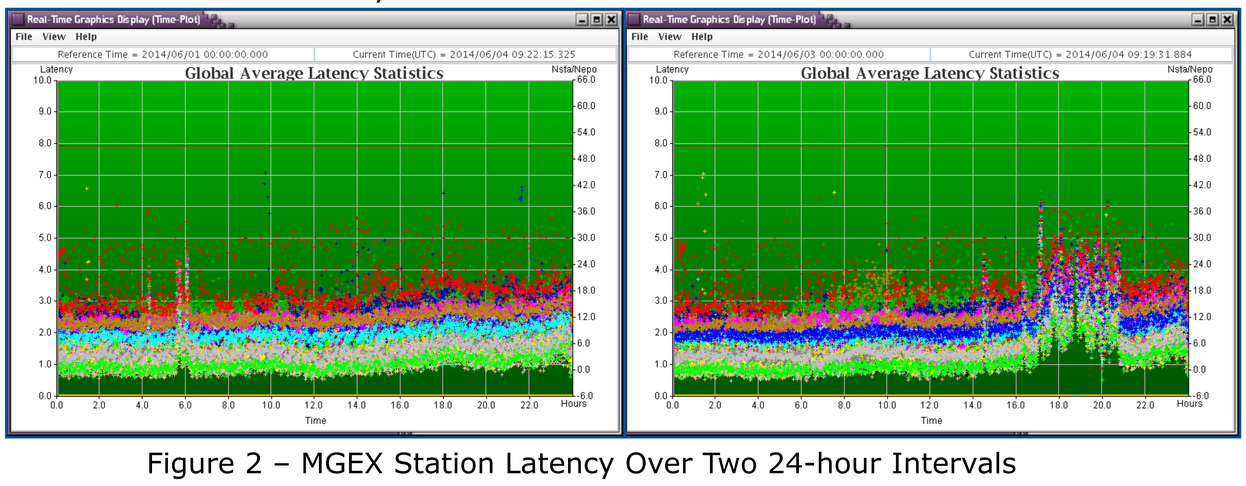

Figure 2 – MGEX Station Latency Over Two 24-hour Intervals

RT Solution Orbit and Clock Performance

The assessment of orbit and clock performance was performed using MGEX archived Real Time observations. RINEX 3.02 files were generated using the BKG BNC tool, to be used in precise obit determination with the NAPEOS software. This is the latest version of NAPEOS with the ability to process all available signals and to estimate signal and Inter-System biases. A span of 14 days from August-September 2013 was used to estimate daily precise orbits and bias values.

The NAPEOS products were then used in the RETINA Real Time filter in order to test the new software in simulated Real Time mode using an observation interval of 10 sec. The first row of Table 1 shows typical 1-day averaged results of the performance of the Real Time solution against reference products.

The NAPEOS bias products computed during the 2-week test campaign are now used in routine Real Time processing of the MGEX streams, along with predicted orbits from NAPEOS which are updated every 2 hours. Typical results are shown in the last two rows of Table 1.

Table 1 – MGEX Real Time Solution Results

Case	GPS Orbit 1-D RMS[1] (mm)	GPS Clock SD[1] (ns)	GLONASS Orbit 1-D RMS[2] (mm)	GLONASS Clock SD[2] (ns)	Galileo Orbit 1-D RMS[3] (mm)	Galileo Clock SD[3] (ns)
MGEX testing 31/8/2014	21.3	0.09	35.4	0.15	10.5	0.06
RT MGEX 21/5/2014	39.9	0.10	62.5	0.21	87.6	0.07
RT MGEX 22/5/2014	42.6	0.13	65.1	0.21	81.7	0.13

[1]Against IGS Rapids [2]Against ESA Rapids [3]Against MGEX NAPEOS Solution

As expected, the Real Time clock results are somewhat worse than the results obtained during testing. The main reason is the use of predicted orbit information, rather than precise orbits that were used in testing. A further reason is the age of the NAPEOS bias solution, which is approximately 9 months old.

RT Solution PPP Performance

The RETINA Real Time MGEX solution is streamed to an internal caster in the form of RTCM SSR messages generated using the BKG BNC software. This allows access to the solution using the BNC PPP client, in much the same way as if the solution was provided over the Internet. As the BNC functionality is currently limited to GPS and GLONASS, the impact of Galileo is not assessed in these tests.

Figure 3 is a plot of the kinematic PPP results from the BNC client, showing on the left the GPS-only solution from the ESOC CLK53 IGS stream and on the right the RETINA MGEX solution. Observations from the same station, FFMJ1 in Frankfurt, are used in both cases. The plots were generated using RTKLIB.

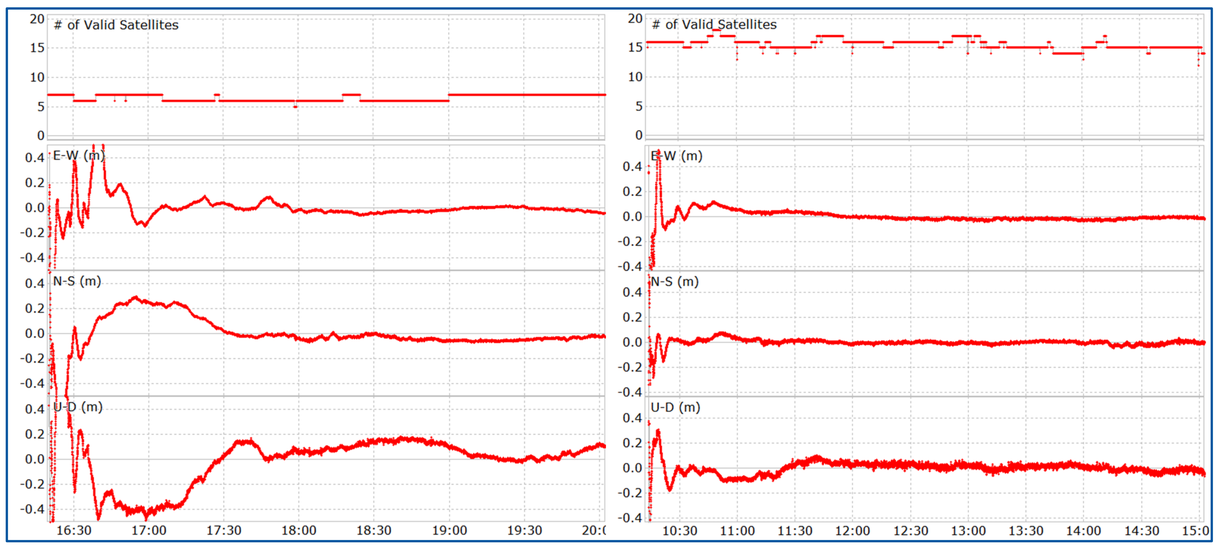

Figure 3 – PPP Solution Performance (Left =GPS-only, Right=GPS+GLONASS)

Figure 3 shows that there is a very significant improvement in the PPP performance with the addition of GLONASS as a result of the roughly 100% increase to the number of visible satellites. This is seen in both the speed of convergence and in the stability of the kinematic PPP solution. If a convergence threshold of 20 cm is used, it can be seen that the GPS-only solution needs 50 minutes to reach that level, while the GPS+GLONASS solution converges in under 5 minutes. It should be noted that the solutions solve for float ambiguities, so they can be further improved with integer ambiguity resolution. The convergence behaviour is further demonstrated in Figure 4, where two restarts of the solution show 2-D convergence at the 20 cm level in approximately 5 minutes.

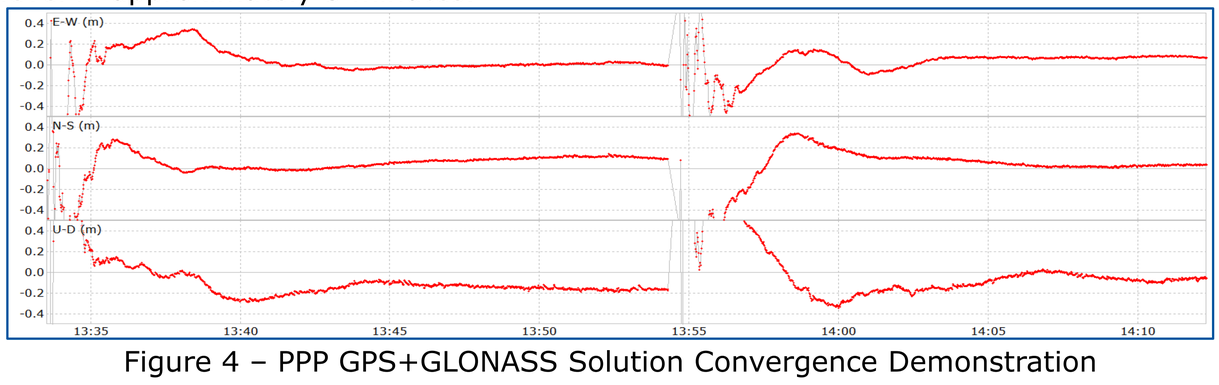

Figure 4 – PPP GPS+GLONASS Solution Convergence Demonstration

CONCLUSIONS

The latest release of the RETINA software allows multi-frequency multi-GNSS processing of Real Time GNSS data. GPS+GLONASS results using data from the MGEX observation caster demonstrate a significant improvement in performance over GPS-only results, with convergence times reduced to a few minutes. Further improvements are expected with the addition of Galileo and Beidou in the test chain.