# Reprocessing campaign in the framework of the EGSIEM project at AIUB

IGSWS2016
International GNSS Service
Workshop 2016
8 - 12 February, 2016, Sydney, Australia

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## Introduction

In the framework of the European Gravity Service for Improved Emergency Management (EGSIEM) project, monthly gravity field solutions derived from the Gravity Recovery and Climate Experiment (GRACE) mission will be combined. Since an improved reference frame is a prerequisite for precise orbit and gravity field determination, a reprocessing campaign (Repro15) was initiated at the Astronomical Institute of the University of Bern (AIUB), with more than 250 globally distributed tracking stations of the International GNSS Service (IGS), homogeneously processed for the interval between 2003 to the end of 2014.
Since the Low Earth Orbiting satellites (LEOs) are tracking with a higher sampling than the usual 30 s of the IGS tracking stations, we included the 1 Hz dataset provided by the IGS real-time pilot project/service. The procedures established by the Center for Orbit Determination in Europe (CODE, hosted at AIUB), have been applied for the reprocessing. The new Empirical CODE Orbit Model (extended ECOM) has been applied to model the GNSS orbits. The procedure to densify the satellite clock corrections down to 5 s is applied to the GLONASS satellites for the first time.

## Processing scheme

In order to provide within the EGSIEM project the best reference frame products, the latest GNSS orbit model (extended ECOM) was used. It significantly improves the accuracy of the GNSS orbits (in particular for the GLONASS satellites) and reduces the deficiencies in the geodynamical parameters. Fig. 1 shows the working flow in the current reprocessing campaign, where on the left 1-day and 3-day processing strategy of CODE from March 2015 is shown, while the right side is presenting generation of GNSS satellite clock products. The figure also indicates the different levels of validation procedures applied for quality control of the products (indicated with blue colour).

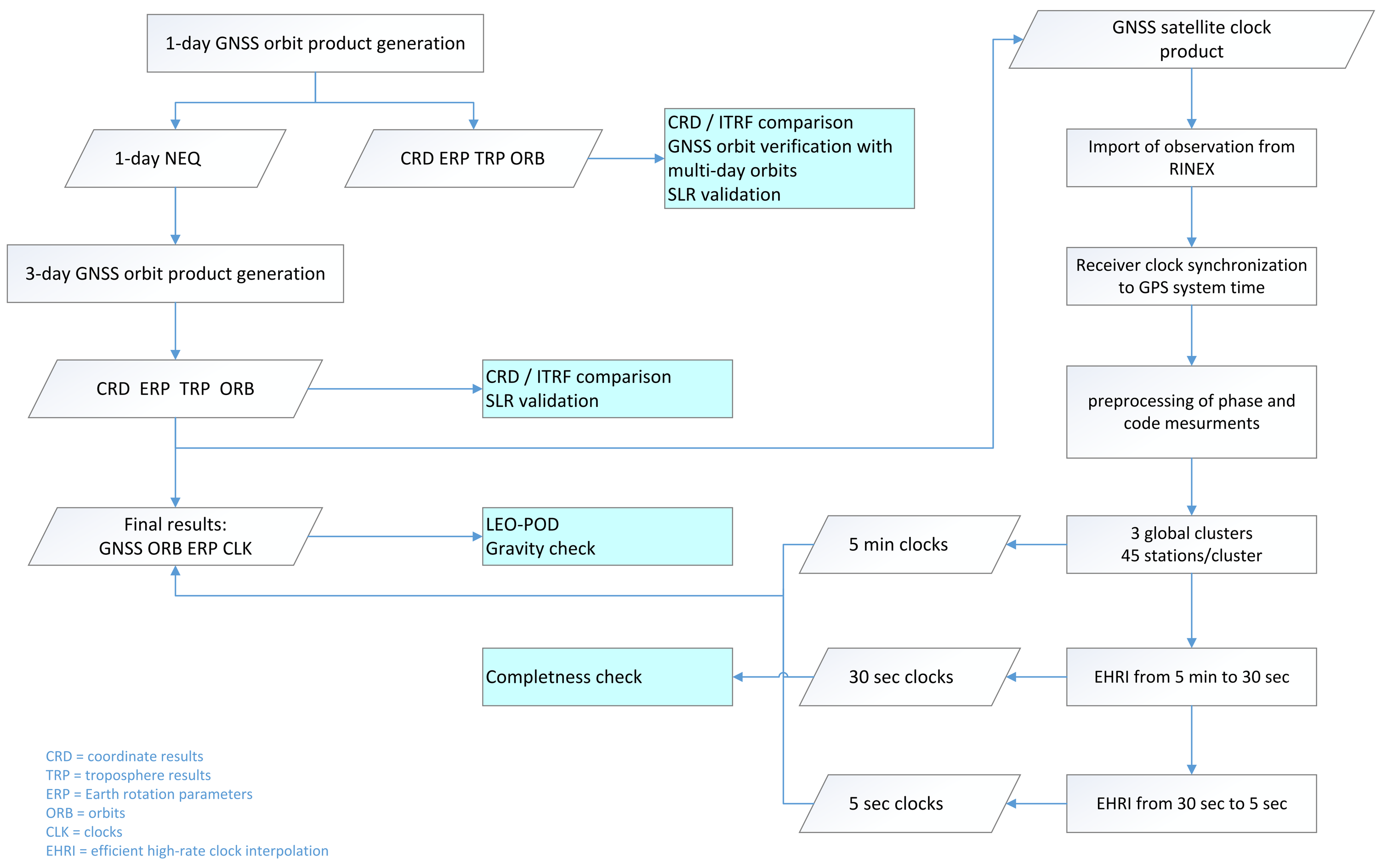


**Figure 1:** Schematic presentation of the working flow in the current reprocessing campaign, and the related quality control steps.

## Validation of GNSS orbits with SLR

Since all GLONASS and two GPS satellites are equipped with laser retro-reflector arrays, Satellite Laser Ranging (SLR) provides an independent tool to validate microwave-based GNSS orbits. The SLR residuals w.r.t. all GLONASS-M orbits from 2003 and 2014 are shown in Fig. 2 as a function of the elongation angle (i.e. the angle Sun-geocenter-satellite). The systematic pattern, which is visible for orbits generated with the original ECOM, has been successfully reduced when generating the orbits with the extended ECOM.

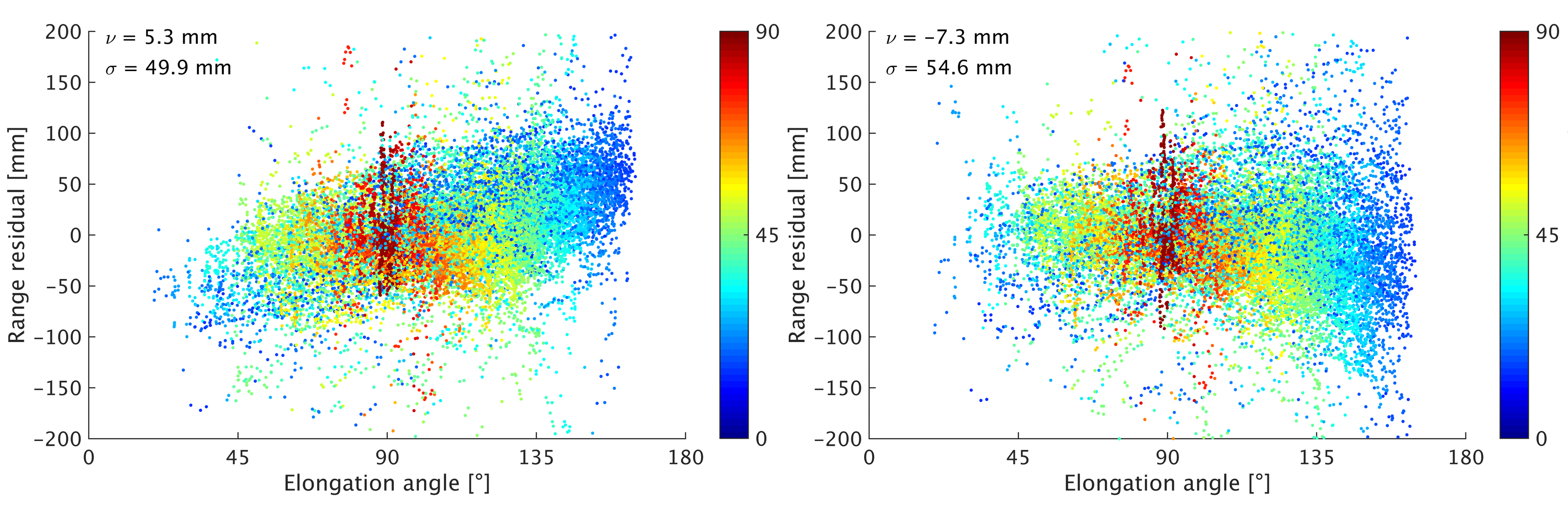


**Figure 2:** SLR residuals w.r.t. GLONASS-M orbits using the original ECOM (left) and the extended ECOM (right). Mean value ($\nu$) and standard deviation ($\sigma$) are based on all residuals whose absolute value is smaller than 150 mm. Observations to four GLONASS satellites (SVN 723, 725, 736, 737) have been excluded due to anomalous patterns. Furthermore, all residuals having an absolute beta angle smaller than 15° have been not taken into account due to unmodeled attitude during eclipses.

## GNSS Clock Products

Fig. 3 shows the percentage of completeness of the satellite clock products with 30 s (left side) and 5 s sampling (right side) over the period 2006-2007. It can be noticed that for the period shown, the overall completeness is 100% for both sampling rates, however there are some GPS satellites (namely G12, G15, G29, G32 and G32) for which both, 30 s and 5 s clock corrections are not complete. These data gaps are mainly due to reduced tracking of (unhealthy) satellites.

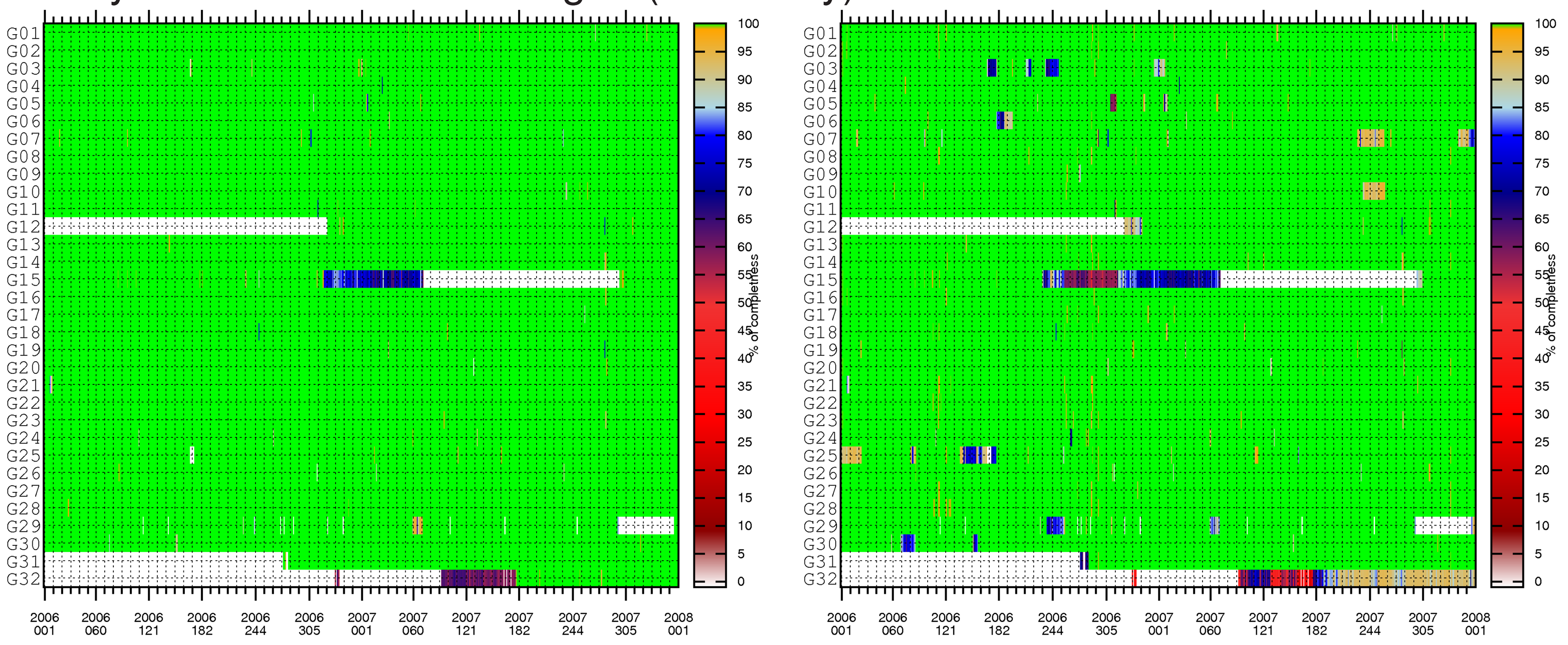

**Figure 3:** Completeness of 30 s (left) and 5 s (right) GPS clock corrections for the time period between 2006 and 2007.

In the context of generation GLONASS satellite clock products, we have been confronted with the limitation of available GLONASS tracking data in early years of the IGS real-time network. The number of available stations providing 5 s data is shown on the left side of Fig. 4, where grey colour presents GPS only, green GPS/GLONASS and white no data available. On the right side of the Fig. 4 the percentage of completeness of the GLONASS satellite clock products is shown for the 30 s sampling rate.

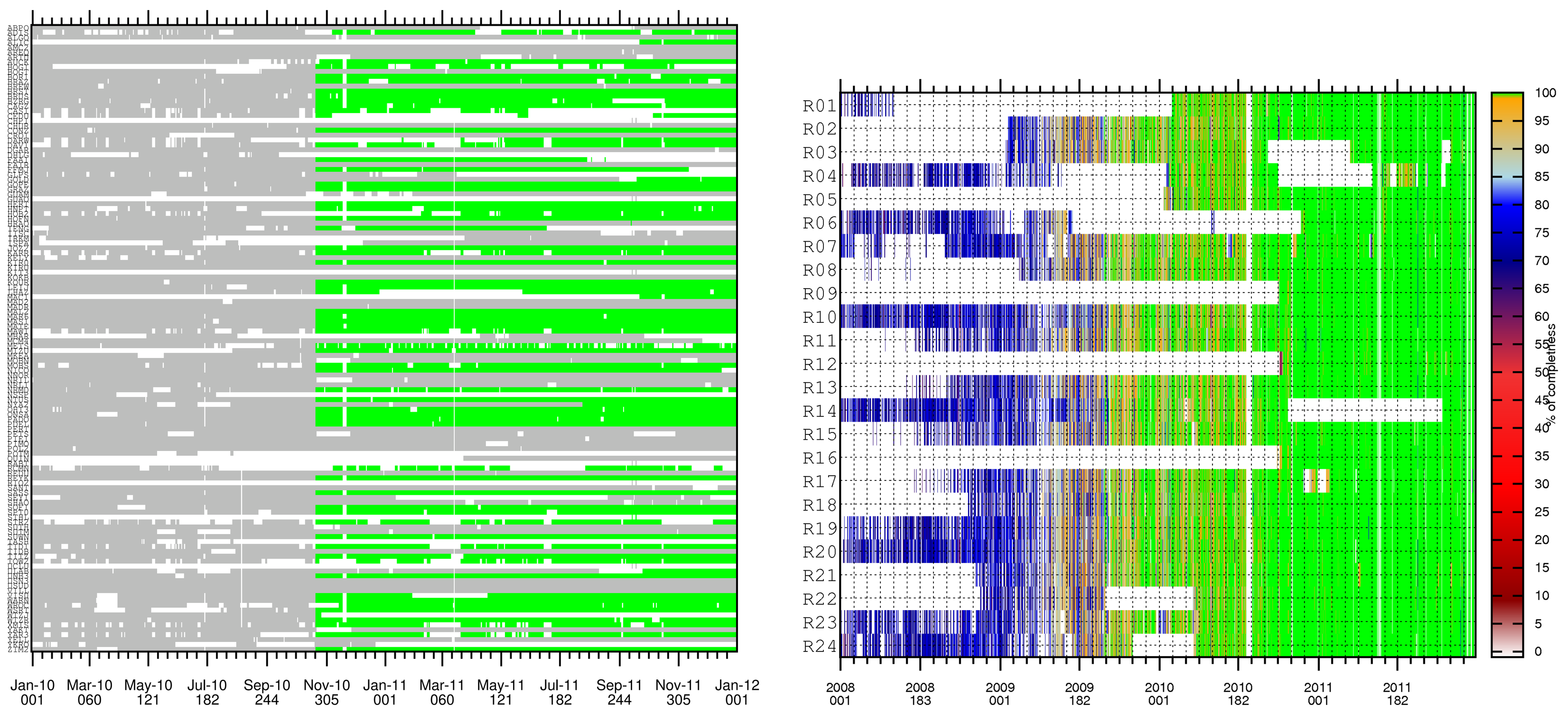

**Figure 4:** Left: number of stations delivering 5 s RINEX2 files, where grey colour presents GPS only, green GPS/GLONASS and white no data available. Right: completeness of 30 s GLONASS clock corrections for the 2008-2011 period.

## Validation by LEO Precise Orbit Determination (POD)

LEO Precise Orbit Determination (POD) provides an efficient validation method for global GNSS solution, since it covers all regions of the Earth by processing the data from one receiver only. Fig. 5 is presenting the daily RMS of the L1 carrier phase residuals of a kinematic orbit determination for GRACE-A (left side) and GRACE-B (right side) over the 2006-2007 period. The values in red were obtained when using the old GPS orbits and clocks from Repro 01, while the use of the new products of (Reporo 15) results in the green values. For most of the days a clear reduction of the phase RMS is observed, indicating a better fit of the GPS observations when using the new products.

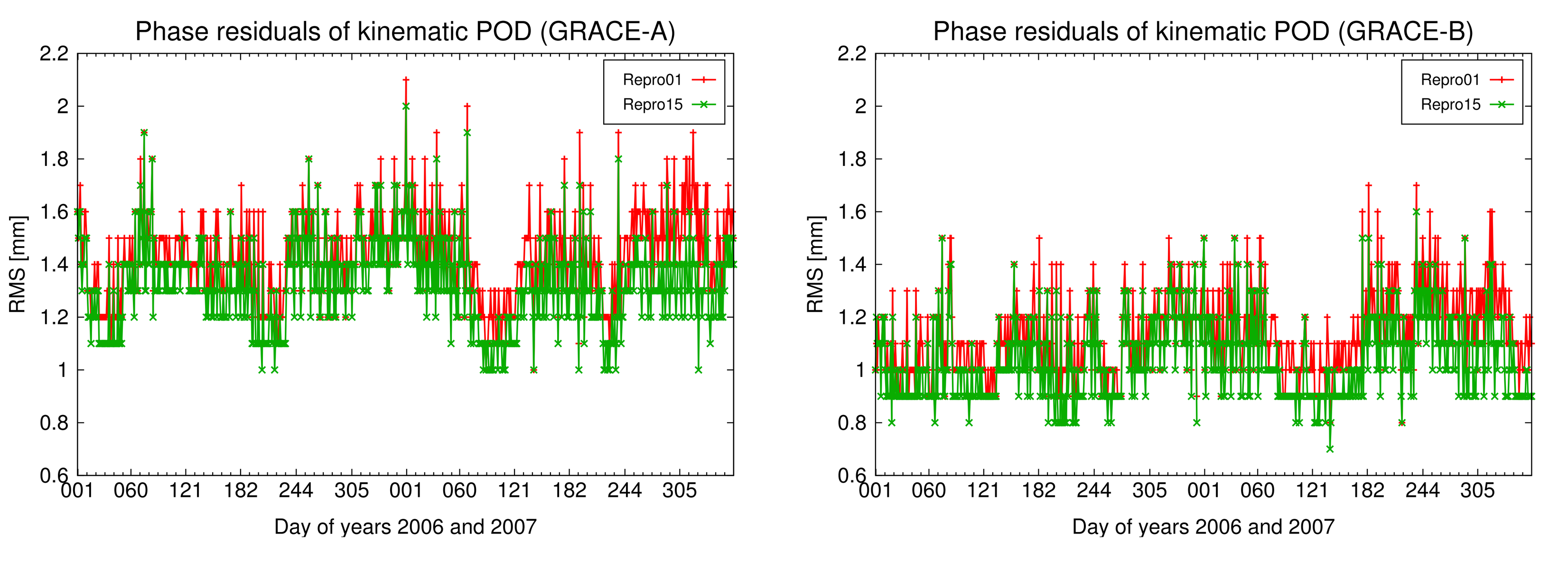


**Figure 5:** Daily RMS of the L1 carrier phase residuals of a kinematic orbit determination for GRACE-A (left) and GRACE-B (right).

## Summary

The validation of the GNSS orbits using SLR data shows that the dependency of the SLR residuals on the elongation angle is significantly reduced in the case of the extended ECOM. From the GNSS clock products side, it was shown that for the period presented the products have in overall 100% completeness. For the cases with incomplete clock corrections an investigation revealed the presence of a large number of stations with missing data. Validation of the final GNSS orbit and clock products, performed by GRACE POD showed a clear reduction of the phase RMS when using the new products.

This research was supported by the European Union's *Horizon 2020 research and innovation program* under the grant agreement No. 637010.

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