Validation of GNSS orbits using Satellite Laser Ranging data

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Introduction

The Center for Orbit Determination in Europe (CODE) is a global analysis center of the International GNSS Service (IGS) and an Associate Analysis Center of the International Laser Ranging Service (ILRS). CODE delivers products such as precise satellite orbits, station coordinates, Earth rotation parameters as well as satellite and receiver clock corrections. Starting from January 4, 2015, the orbit products generated at CODE are based on an extended version of the original Empirical CODE Orbit Model (ECOM, Arnold et al. (2015)). In this contribution we quantify the impact of the new ECOM on the computed GNSS orbits using four years of reprocessed data (2010 to 2013). Since all GLONASS and two GPS satellites are equipped with retroreflector arrays, Satellite Laser Ranging (SLR) provides a powerful tool to validate microwave-based GNSS orbits. Because the maximum angle of incidence of a laser pulse to a GNSS satellite does not exceed 14°, SLR data are mainly sensitive to the radial component of microwave-based GNSS orbits.

Recent Reprocessing Campaign

The current reprocessing is mainly motivated by the shortcomings of the original ECOM regarding the solar radiation pressure modeling (Arnold et al., 2015). This deficiency is especially apparent in case of GLONASS satellites, whose shapes differ significantly from cubes. Table 1 presents the estimated parameters for the original and the extended ECOM.

Table 1: Empirical parameters estimated in D (satellite-Sun direction), Y (direction along the satellite's solar panels axes), and B (completes the orthogonal right-handed system) for the original ECOM and the extended ECOM (cycle-per-revolution is denoted as cpr).

	Parameters estimated in		
	D	Y	B
Original ECOM	constant	constant	constant, 1-cpr
Extended ECOM	constant, 2-cpr, 4-cpr	constant	constant, 1-cpr

The second reason for the recent reprocessing campaign is the establishment of a new reference frame within the European Gravity Service for Improved Emergency Management (EGSIEM) project. The campaign will cover the period from 1994 using data from 40 stations (in 1994) and up to more than 250 stations per day for the recent years. We present the progress from this ongoing activity (years 2010 to 2013 are finished so far). The number of all considered stations in the 1-day solutions is presented on the left side of Fig. 1, whereas the right side shows the number of satellites (black color represent GPS, red GLONASS and blue GPS+GLONASS).

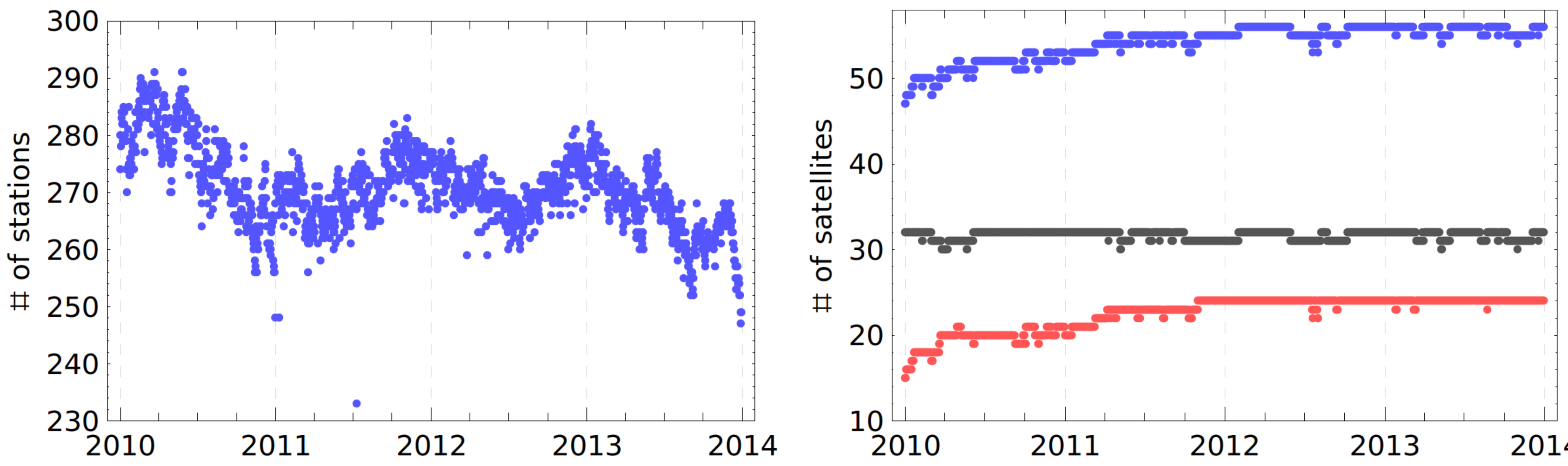

Figure 1: (Left) Number of GPS+GLONASS tracking stations used in the reprocessing of microwave-based data and (right) number of satellites used in the analysis (black color represents GPS, red GLONASS and blue GPS+GLONASS).

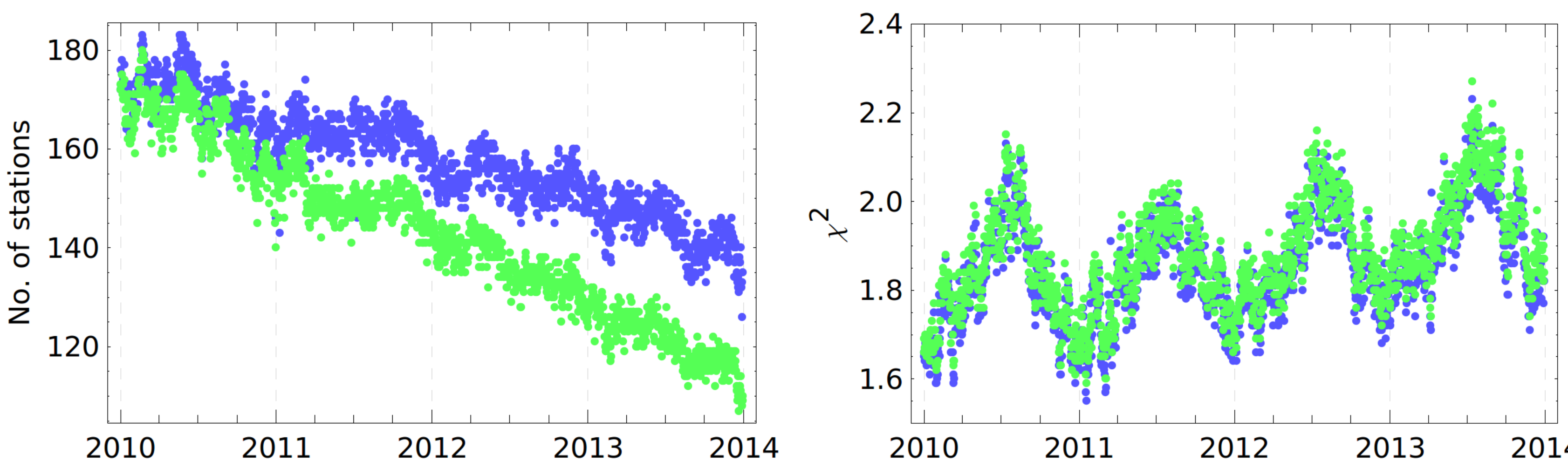

Figure 2: The number of stations used for datum definition (left) and χ^2 value of the 1-day solution (right). Green denotes the second reprocessing campaign and blue the recent reprocessing campaign. It can be noticed that in the recent reprocessing campaign more stations are considered in the datum definition.

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EGSIEM European Gravity Service for Improved Emergency Management

AIUB

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The number of SLR observations per year to each GLONASS-M satellite is presented in Fig. 3. From 2011 on, when the GLONASS system became fully operational, a larger number of stations participated in tracking.

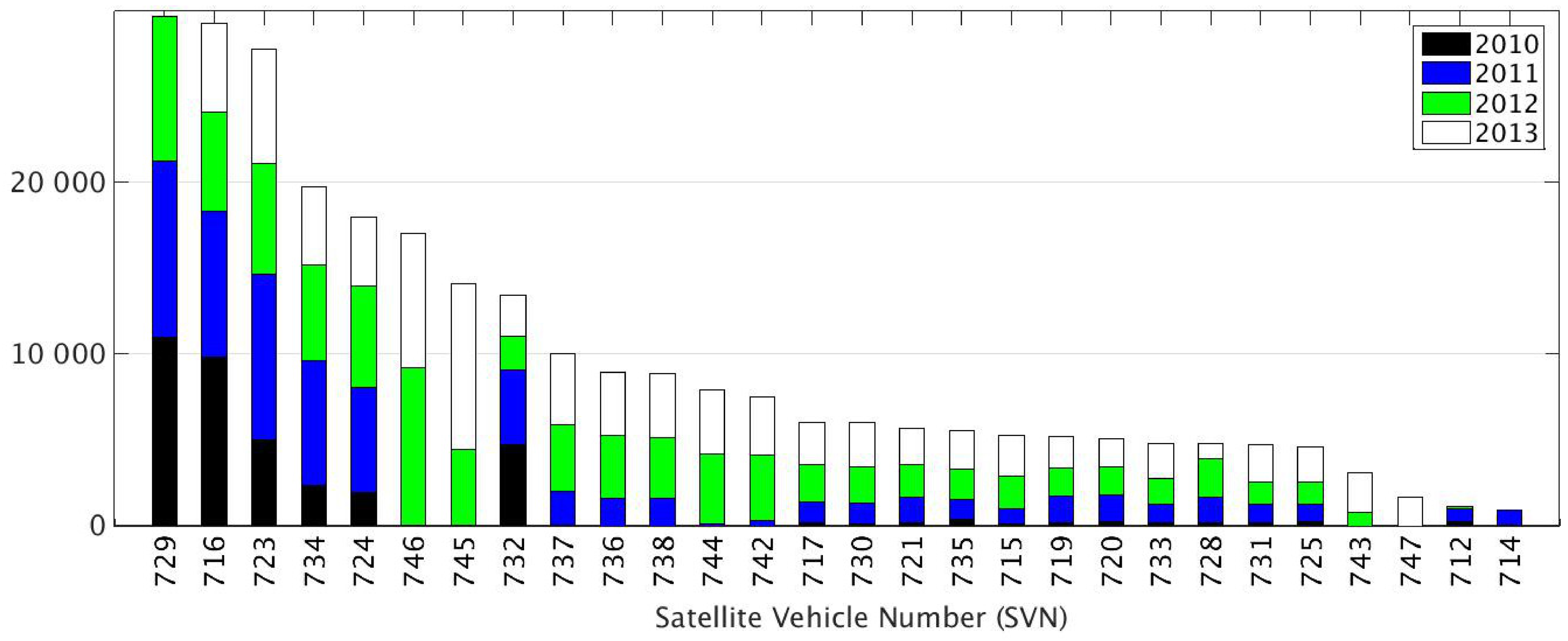

Figure 3: Number of SLR observations per GLONASS-M satellite and year.

The SLR residuals w.r.t. the microwave-based GNSS orbits using the original ECOM on the one hand and the extended ECOM on the other hand are shown depending on the elongation angle. Hence, Fig. 4 shows the definition of the elongation angle E', i.e. the angle Sun-geocenter-satellite. It depends on the elevation of the Sun above the orbital plane (β_0), and on the angle Δu, which is the difference between the argument of latitude of the satellite and the argument of latitude of the Sun. The elongation angle can be expressed as

$$\cos E' = \cos\beta_0 \cos\Delta u.$$

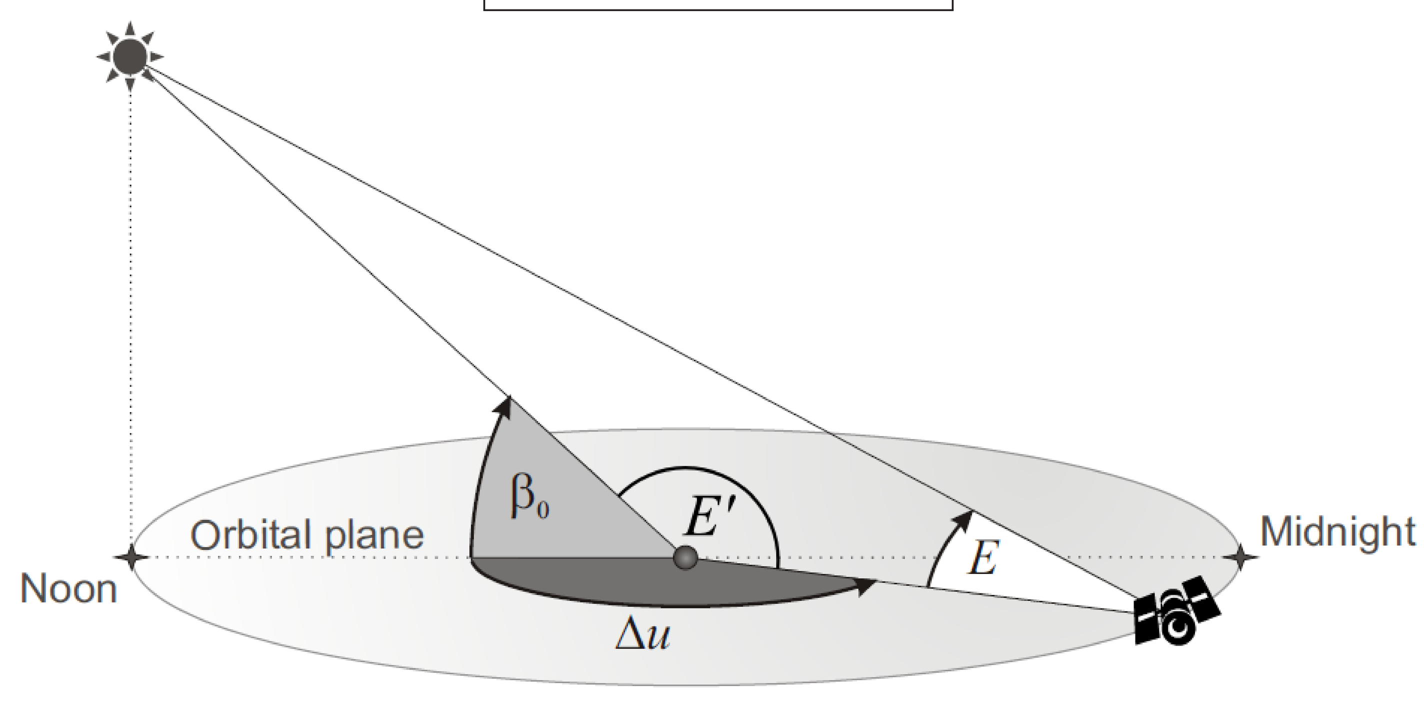

Figure 4: Geometry of the Sun, the geocenter, and the satellite.

In Fig. 5 the SLR residuals w.r.t. the microwave-based GLONASS-M orbits from January 2010 to December 2013 are shown depending on the elongation angle. The systematic pattern, which is visible for orbits generated with the original ECOM, has been successfully reduced in case the orbits are generated with the extended ECOM.

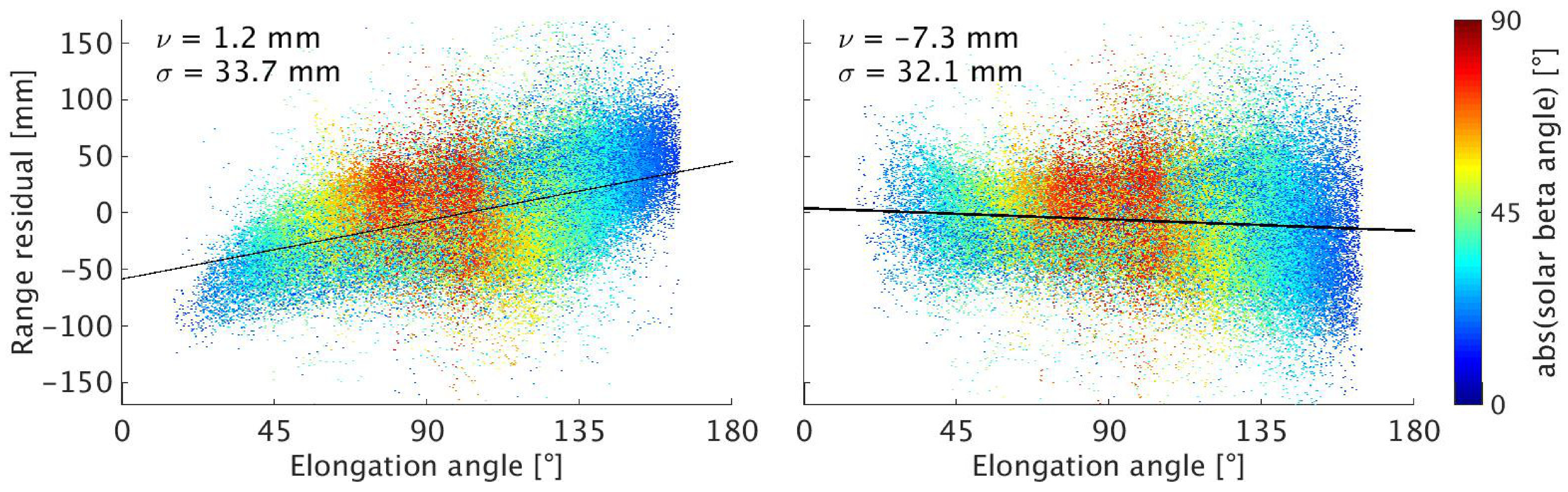

Figure 5: SLR residuals w.r.t. microwave-based GLONASS-M orbits of the (1) second reprocessing using the original ECOM (left) and (2) recent reprocessing using the extended ECOM (right). Mean value (ν) and standard deviation (σ) are based on all residuals whose absolute value is smaller than or equal to 300 mm. Observations to four satellites (SVN 723, 725, 736, 737) have been excluded due to anomalous patterns. Both illustrations have the same scale.

Summary

The validation of GNSS orbits (second reprocessing) using SLR data reveals deficiencies in the solar radiation pressure modeling. Extending the original ECOM with 2-cpr and 4-cpr terms in the satellite-Sun direction removes these systematics. Comparing the results of the recent reprocessing campaign with the second reprocessing campaign one can notice that the extended ECOM slightly reduces the χ^2 value.

References

Arnold D., Meindl M., Beutler G., Dach R., Schaer S., Lutz S., Prange L., Sośnica K., Mervart L., Jäggi A. (2015). CODE's new solar radiation pressure model for GNSS orbit determination. J Geod. doi:10.1007/s00190-015-0814-4