GNSS orbit validation activities at the Astronomical Institute in Bern

ILRSWS2016

International Laser Ranging Service Workshop 2016
9 - 14 October, 2016
Potsdam, Germany

A. Grahsl[1], A. Sušnik[1], Lars Prange[1], D. Arnold, R. Dach[1], A. Jäggi[1]

[1]Astronomical Institute, University of Bern, Switzerland

Introduction

Orbits from Global Navigation Satellite Systems (GNSS) are typically based on microwave observations. Satellite Laser Ranging (SLR) is therefore a fully independent technique to validate these orbits. All GLONASS, Galileo, BeiDou, and QZSS spacecraft carry retroreflectors and can thus be tracked via SLR. The two GPS satellites equipped with reflectors are meanwhile both decommissioned.

Principle of SLR validation

The SLR observations ('observed') are directly compared to the geometry based on the coordinates of the SLR stations and the microwave-based orbit ('computed') without estimating any parameter. The residuals ('observed minus computed') contain thus potential range biases, inconsistencies between the GNSS and SLR reference frame coordinates, and reflector offset uncertainties. Nevertheless, SLR residuals are capable to indicate the quality of the orbits. Since 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 the GNSS orbits.

Validation of reprocessed GPS and GLONASS orbits

The most recent reprocessing campaign at CODE is called Repro15 (Sušnik et al. 2016). The main difference w.r.t. previous product series is the extension of the Empirical CODE Orbit Model (ECOM) by periodic terms in the satellite-Sun direction according to Arnold et al. (2015). The additional terms are in particular important for satellites with elongated bodies (e.g., GLONASS). The influence of this orbit model improvement is demonstrated in Fig. 1. The dependency of the residuals on the elongation angle of the Sun is clearly reduced when the extended ECOM is used.

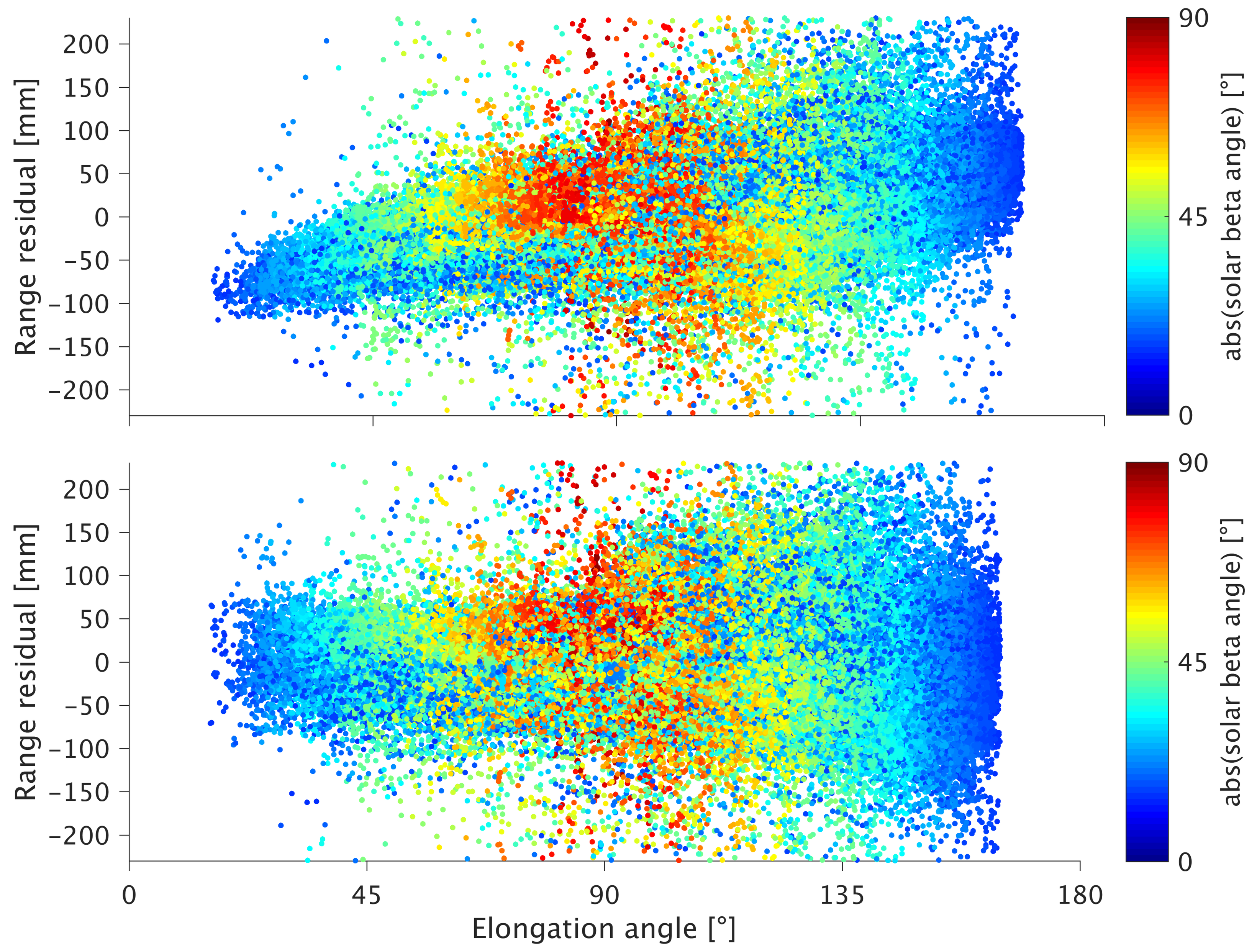

Figure 1: SLR residuals for 3-day GLONASS-M orbits between January 2003 and December 2014 using the classical ECOM (top) and the extended ECOM (bottom). The residuals are shown as a function of the elongation angle (i.e., the angle between Sun and satellite as seen from the geocenter) and of the solar beta angle (i.e., the elevation of the Sun above the orbital plane). Furthermore, all residuals having an absolute beta angle smaller than 15° have not been taken into account.

In Fig. 1 the SLR residuals to the orbits of GLONASS satellites with SVN 723, 725, 736, and 737 are excluded due to their anomalous behavior. As Fig. 2 demonstrates, the residuals of these GLONASS satellites increase after a certain time after launch. The four mentioned satellites belong to the same orbital plane. Other satellites in the same orbital plane (e.g, SVN 716, 724, 729) do not show this effect. The reason for this abnormal behavior is so far not understood.

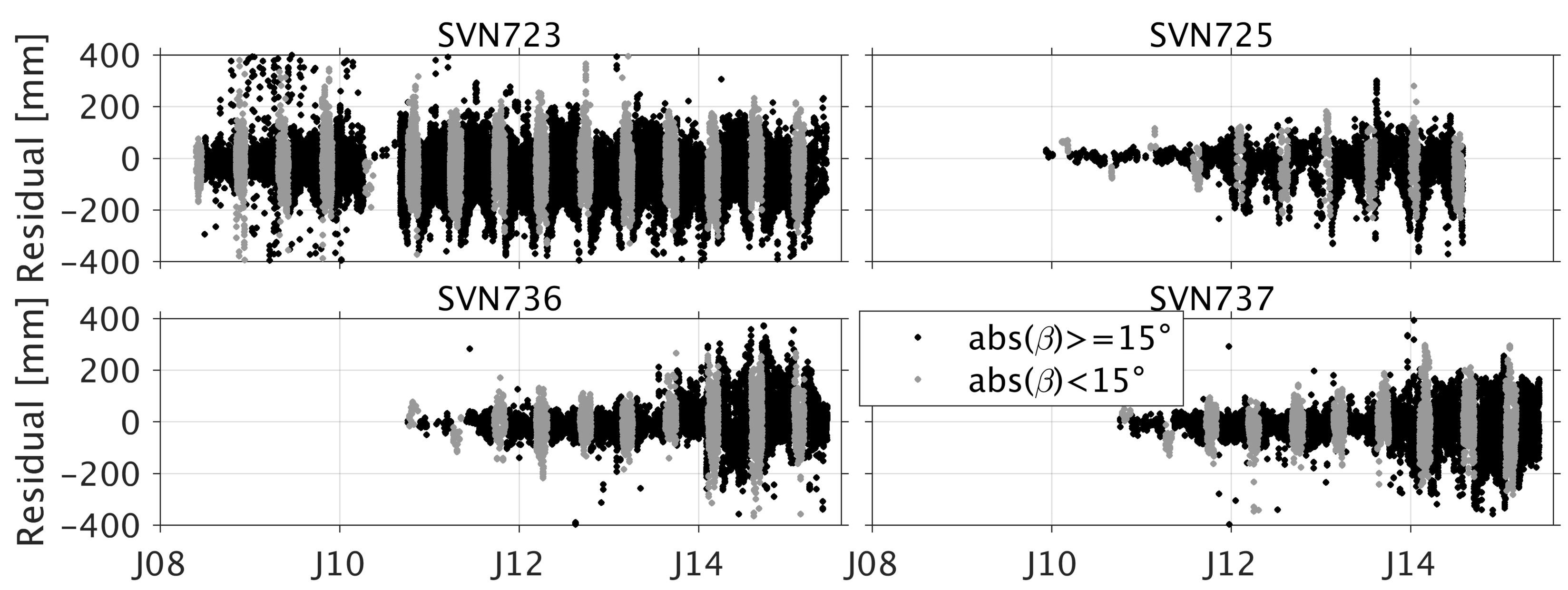

Figure 2: SLR residuals w.r.t. 3-day GLONASS orbits between January 2008 and May 2015 using the extended ECOM. Observations during satellite eclipses (solar beta angle smaller than 15°) are depicted in gray.

Validation of MGEX orbits

CODE has been contributing to the Multi-GNSS Extension (MGEX) of the International GNSS Service (IGS) since the beginning of MGEX in 2012 (Prange et al., 2016). The quality assessment of this product series is essential because of new signals to a new fleet of GNSS satellites. Within the IGS a comparison of different orbit products is the currently used practice. No quality parameter is considered. Instead, a majority voting approach is used. Since all new GNSS satellites (apart from GPS) are equipped with reflectors, SLR provides an independent quality control. We downloaded the MGEX orbits from six analysis centers (ACs), see Table 1. From the beginning of 2015 to mid of 2016, 38 000, 8400, and 2200 normal points are available to Galileo satellites, BeiDou satellites, and QZS-1, respectively. Fig. 3 gives an impression how well these satellites are tracked by SLR stations.

Table 1: ACs providing MGEX products (**com**: Center for Orbit Determination in Europe, **gbm**: Deutsches GeoForschungsZentrum Potsdam, **grm**: CNES/CLS, **qzf**: Japan Aerospace Exploration Agency, **tum**: Technische Universität München, **wum**: Wuhan University)

AC/GNSS	GPS	GLONASS	Galileo	BeiDou	QZSS
com	√	√	√	√	√
gbm	√	√	√	√	√
grm	√	√	√	×	×
qzf	√	×	×	×	√
tum	×	×	√	×	√
wum	√	√	√	√	√

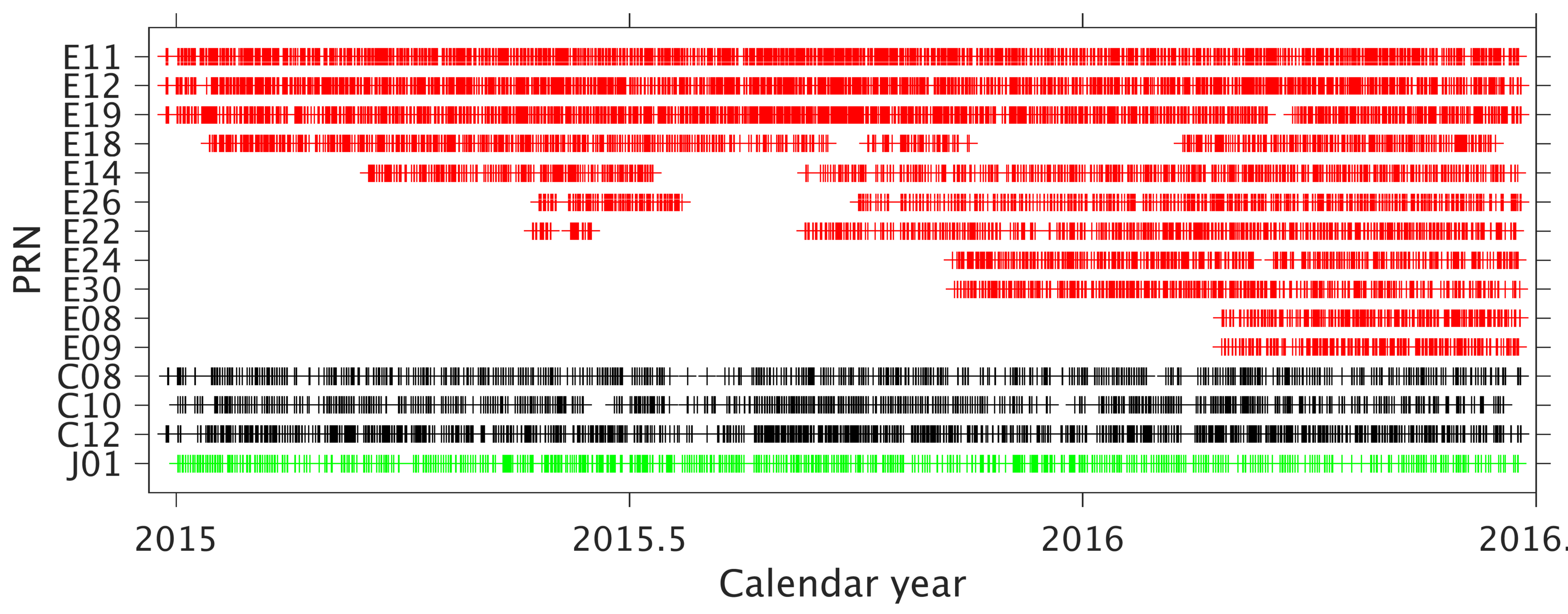

Figure 3: SLR observations to Galileo satellites (red color), BeiDou satellites (black color), and QZS-1 (green color).

Fig. 4 shows the mean value and standard deviation of SLR residuals for each MGEX AC. In general, the SLR residuals for the MGEX ACs agree very well. For QZS-1 the discrepancy of both the mean values and the respective standard deviations is largest. The standard deviation is smallest for the com orbits.

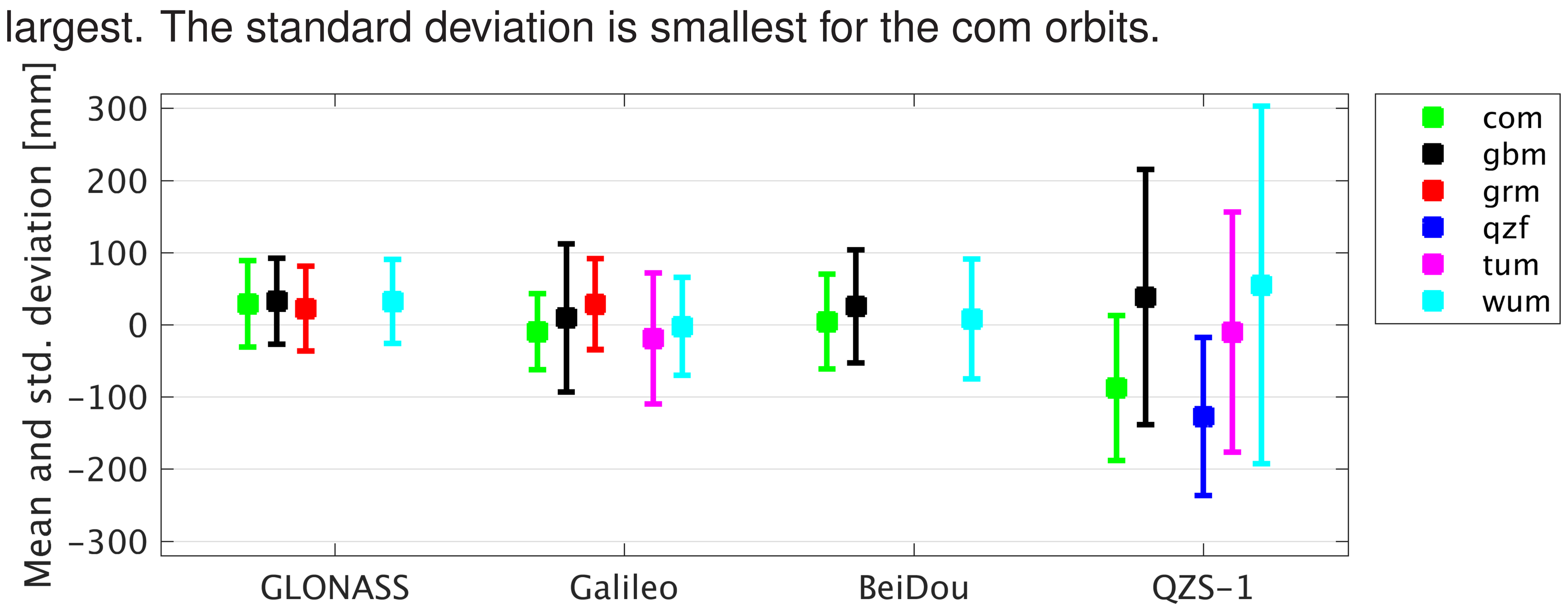

Figure 4: For each AC, mean value and standard deviation [mm] of SLR residuals with respect to GLONASS, Galileo, BeiDou, and QZS-1 satellites is shown. Note that all residuals larger than 300 mm (GLONASS), 500 mm (Galileo), 300 mm (BeiDou), and 1500 mm (QZS-1) were regarded as outliers. In addition, SLR observations during eclipses for GLONASS and during intervals with solar beta angle smaller than 20° for QZS-1 were not taken into account. For the description of acronyms see caption of Table 1.

Summary

The validation of the reprocessed GNSS orbits showed that the elongation-dependency of the SLR residuals could be significantly diminished by using the extended ECOM. When focusing on other than GPS systems SLR can provide an independent quality measure for microwave-based orbits. This information could potentially used by the IGS for the orbit combination.

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

Prange L., Orliac E., Dach R., Arnold D., Beutler G., Schaer S., Jäggi A. (2016). CODE's five-system orbit and clock solution—the challenges of multi-GNSS data analysis. J Geod. (submitted)

Sušnik A., Dach R., Villiger A., Maier A., Arnold D., Schaer S., Jäggi A. (2016). CODE reprocessing product series. Published by Astronomical Institute, University of Bern. DOI: 10.7892boris.80011.

Contact address

Andrea Grahsl
Astronomical Institute, University of Bern
Sidlerstrasse 5
3012 Bern (Switzerland)
andrea.maier@aiub.unibe.ch

Poster compiled by A. Grahsl, October 2016
Astronomical Institute, University of Bern, Bern
andrea.maier@aiub.unibe.ch

Posters and other publications from the AIUB Satellite Geodesy Group:
http://www.bernese.unibe.ch/publist