Evaluating orbits from the EGSIEM reprocessing

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Introduction

In the frame of the H2020 funded project European Gravity Service for Improved Emergency Management (EGSIEM, Jäggi et al., 2018), among others, also a reprocessing of GNSS data from the network of the IGS (International GNSS Service, Dow et al., 2009) has been performed for the following intervals

	GPS	GLONASS
GNSS satellite orbits:	since 1994	since 2002
GNSS satellite clocks, sampling 30 s:	since 2000	since 2008
GNSS satellite clocks, sampling 5 s:	since 2003	since 2010

The full dataset of results (Sušnik et al., 2017) is available at `ftp://ftp.aiub.unibe.ch/REPRO_2015/`.

In preparation of the planned next reprocessing of the IGS, we have carefully evaluated the orbit products. Some aspects might be interesting also for a wider audience are presented on this poster.

Summary on the GNSS Data Processing

The reprocessing follow ed mainly the strategy as applied by the Center for Orbit Determination in Europe (CODE) in Summer 2015 (Dach et al., 2016). The station selection has not changed with respect to the 2nd reprocessing of the IGS. Because still the antenna corrections related to IGS08 (Schmid et al., 2016) were used, the solution is consistent to the GNSS-part of the ITRF2014 (Altamimi et al., 2016).

A detailed description of the reprocessing results can be found in Sušnik et al. (2017). The only difference with respect to the solution published in the frame of the EGSIEM project is that the number of periodic terms in the *D*-component of the solar radiation pressure model pointing from the satellite to the Sun was changed that only the twice per revolution terms have been estimated (see Arnold et al., 2015, for more details on the ECOM, the empirical CODE orbit model).

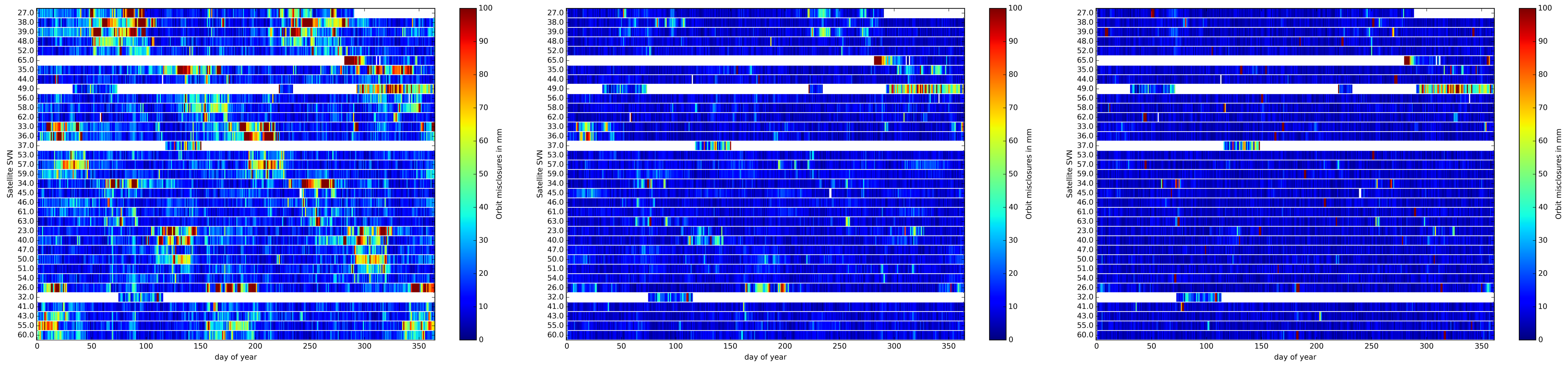
Scheduling of Stochastic Pulses

CODE orbits are generated by extracting the middle part of a long-arc solution covering 3 days. In order to compensate for potential deficiencies in the orbit modeling, empirical, instantaneous velocity changes – so called stochastic pulses – are added every 12 hours (Beutler et al., 1994).

With the recent improvements in the orbit model the question came up whether these stochastic pulses are still needed as they are small most of the time. For that reason an additional solution without any pulses was computed.

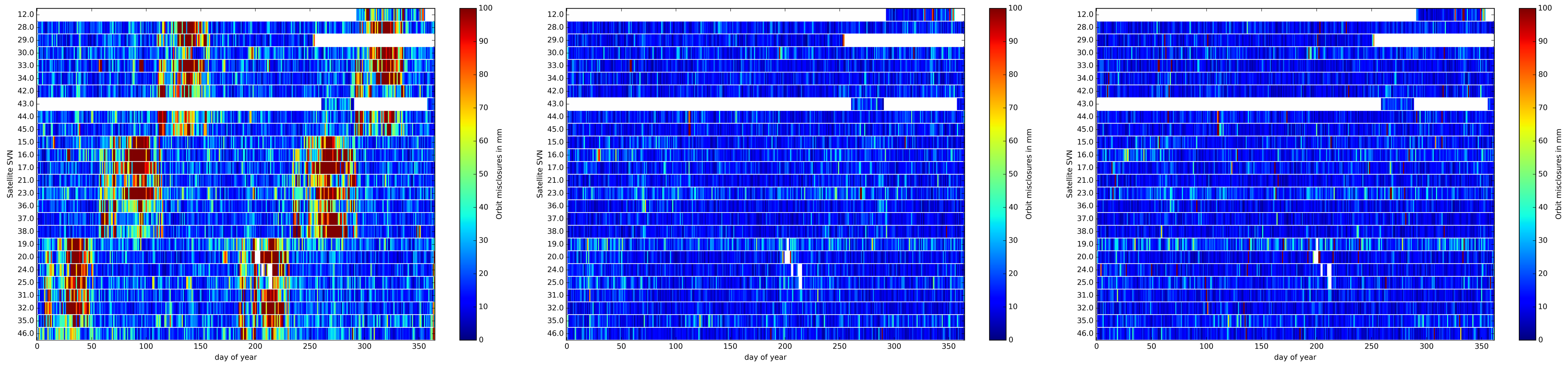
The solution without pulses in Figure 1a) clearly shows deficiencies in periods where the satellites are in eclipse. Because the ECOM parameters are an empirical representation of the solar radiation pressure affecting a satellite, observations during the shadow transition time do not contribute to their estimation. Related aspects are discussed by Sidorov et al. 2018 in Session G1.3 (EGU2018-16750): *Advancing the orbit model for Galileo satellites during eclipse seasons*.

In Figure 1b) the pulses (at noon and midnight UTC) are efficient to reduce the size of the orbit misclosures in particular when the shadow period is close to noon. For that reason another solution was computed where the pulses are scheduled at the biggest distance of the satellite from the Sun (orbit midnight, Figure 1c) resulting in a further reduction of the misclosures by 10% with respect to the solution in Figure 1b.



a) without stochastic pulses — b) stochastic pulses every 12 hours — c) stochastic pulses at orbit midnight

Figure 1: Orbit misclosures for GPS satellites during year 2012. The satellites are listed according to their SVN and the orbital planes.



a) without stochastic pulses — b) stochastic pulses every 12 hours — c) stochastic pulses at orbit midnight

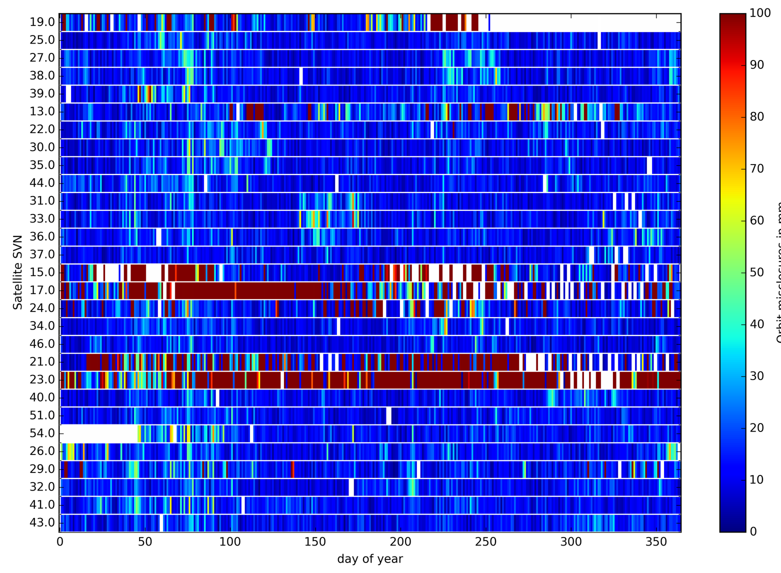
Figure 2: Orbit misclosures for GLONASS satellites during year 2012. The satellites are listed according to their SVN and the orbital planes.

With the revolution period of 11 h 15 m the effect of the traditionally used 12 hour sampling of the stochastic pulses should be less efficient for GLONASS satellites. An adequate distribution of the stochastic pulses at orbit midnight is expected to have at least the same impact as for GPS.

When comparing the Figures 2b and 2c with the pulses scheduled every 12 hours or at orbit midnight no significant difference can be found. The reason for that different behavior between GPS and GLONASS is currently not understood and under investigation in a dedicated study.

Orbit Modeling Problems for old GPS Satellites

In the early years of the series, there are numerous GPS satellites where the orbit misclosures are significantly larger than for the others. Figure 3 shows the situation for the year 2001 as an example. The satellites SVN 21, 23, and 17 are affected most of the time. During shorter periods also SVN 15 shows similar problems. It is in particular noticeable that between days 30 and 100 all four satellites are degraded at the same time. This even impacts the quality of the other satellite orbits.

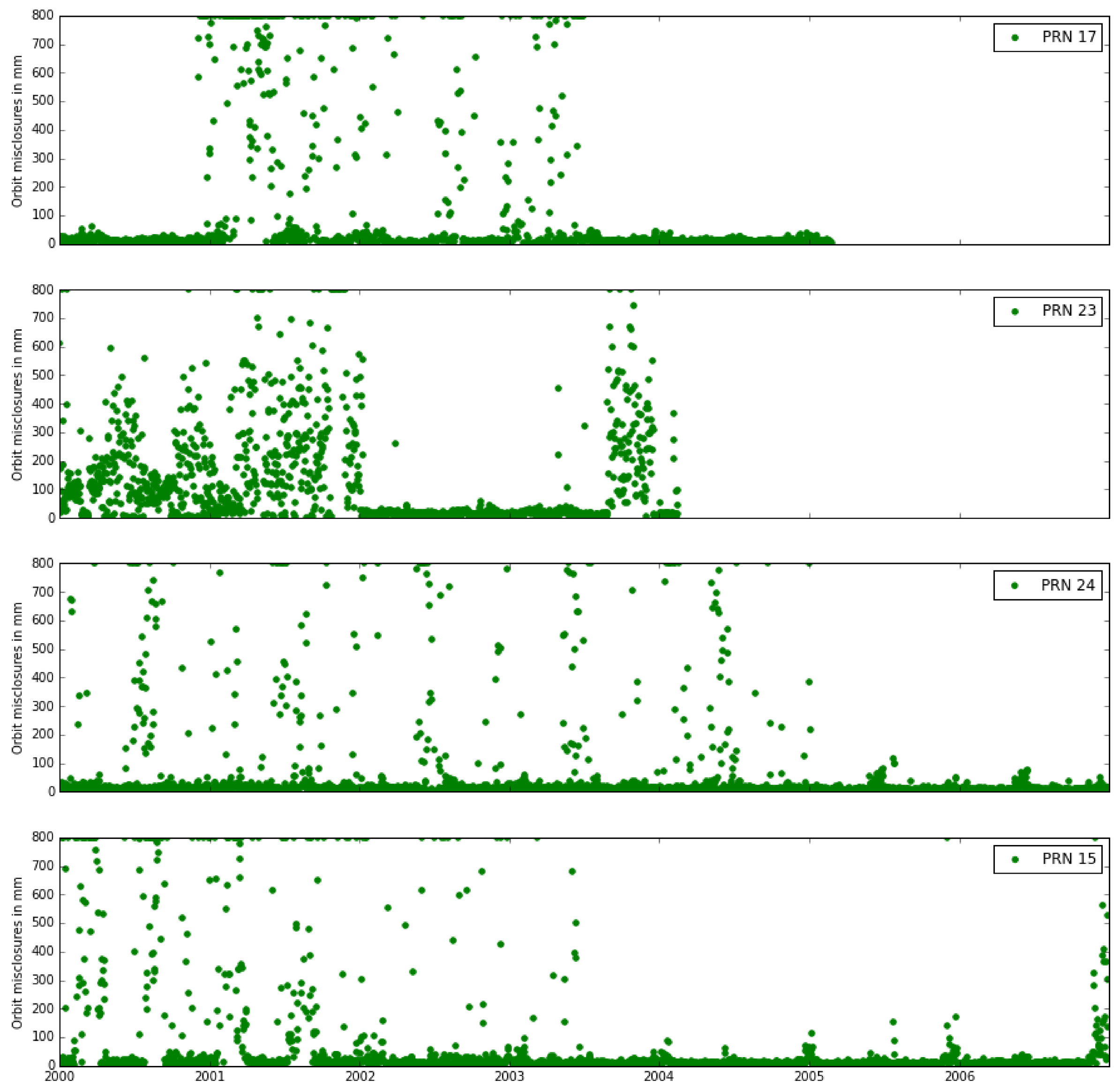


stochastic pulses every 12 hours

Figure 3: Orbit misclosures for GPS satellites during year 2001. The satellites are listed according to their SVN and the orbital planes.

Checking the affected satellites for a longer time interval (see Figure 4) it turns out that the magnitude of the exceptionally large orbit misclosures depends on the elevation angle of the Sun above the orbital plane. Only selected satellites from the BLOCK II and BLOCK IIA are affected. It is in particular noticeable that the problem can be resolved after a few years and the satellite comes back to a usual behavior (e.g., PRN 24 is still active until end of 2011 without repeated problems). On the other hand, satellite PRN 15 was decommissioned in early 2007, directly after the end of the second problematic period. The last satellites affected by this type of problems was PRN 29, which was affected between mid of 2002 until it has been decommissioned by the end of 2008.

Whether the effect is related to the attitude management or any other issue at the satellite cannot be concluded from these results.



stochastic pulses every 12 hours

Figure 4: Orbit misclosures for selected GPS satellites during the years 2000 to 2006.

Effect of GPS Orbits on Other Parameters

The issue in the orbit modeling for the GPS satellites has an impact on the other parameters that are relevant, e.g., for the geoscience. In Figure 5 the obtained station coordinates are compared with the coordinates from the ITRF2014 (Altamimi et al., 2016) after applying seven parameters from a Helmert transformation. Alternatively a solution has been generated where the problematic satellites have been identified and down-weighted. An improvement in the coordinate solution in particular in March (compare to Figure 3) is visible.

Similar improvements can be identified for other parameters, e.g., Earth rotation parameters, due to down-weighting of the affected satellites.

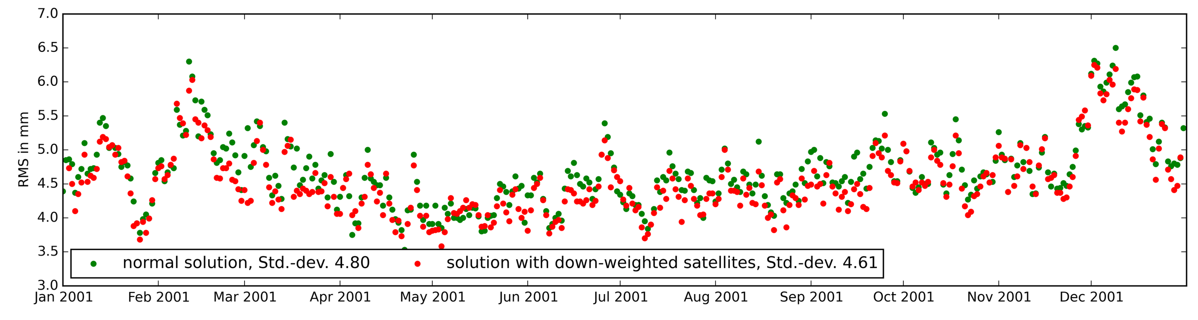


Figure 5: RMS of the residuals from a Helmert transformation between the coordinate solution and the ITRF2014 during 2001.

Summary and Conclusions

Before starting a new reprocessing of the GNSS data history (e.g., for the next ITRF) the previous ones should be carefully studied. Some examples from the analysis of our most recent reprocessing effort follow:

- A change in the schedule to setup stochastic pulses in the CODE solution that is more related to the orbit characteristic did show an improvement for GPS satellites of 10%. Because the difference between the old and new scheme for GLONASS satellites is even bigger, it is surprising that they show no benefit. Obviously their orbit quality is limited by other effects that need to be understood.
- A series of GPS satellites in the early years has been identified where the orbit modeling is significantly degraded. The source of this behavior is not known from the analysis so far.
- It is better to understand and model the behavior of these GPS satellites. At least a down-weighting of their observations should be implemented for the next reprocessing to improve the quality of the products also in the early years of the IGS/GNSS series.

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