AGU2019: G21C-0748
American Geophysical Union
Fall Meeting 2019
09–13 December 2019, San Francisco, CA

CODE Contribution to IGS Repro3 Campaign

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Introduction

CODE (Center for Orbit Determination in Europe) is a joint venture of the following four institutions:

- Astronomical Institute, University of Bern (AIUB), Bern, Switzerland
- Federal Office of Topography swisstopo, Wabern, Switzerland
- Federal Agency of Cartography and Geodesy (BKG), Frankfurt a. M., Germany
- Institut für Astronomische und Physikalische Geodäsie, Technische Universität München (IAPG, TUM), Munich, Germany

It is acting as a global Analysis Center of the IGS, the International GNSS Service (Johnston et al. 2017). The operational computations are performed at AIUB, whereas IGS–related reprocessing activities are usually carried out at IAPG, TUM. All solutions and products are generated with the latest development version of the Bernese GNSS Software (Dach et al. 2015).

Previous Reprocessing Efforts

CODE already contributed to the previous reprocessing efforts of the IGS, e.g., repro2 (Steigenberger et al. 2014) providing GPS and GLONASS orbits, Earth rotation parameters, and coordinate solutions up to the end of 2014.
In the frame of the H2020 funded project European Gravity Service for Improved Emergency Management (EGSIEM, Jäggi et al. 2019), among others, another reprocessing effort was performed in order to obtain the following products:

	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. 2016) is available at `ftp://ftp.aiub.unibe.ch/REPRO_2015/`.
The EGSIEM-repro does include additional periodic terms in the *D*-component of the solar radiation pressure model pointing from the satellite to the Sun – the so-called ECOM2 (empirical CODE orbit model, Arnold et al. 2015) whereas for the IGS-repro2 the classical ECOM without periodic terms in the *D*-component was used.

Model Update for the Current Reprocessing Effort

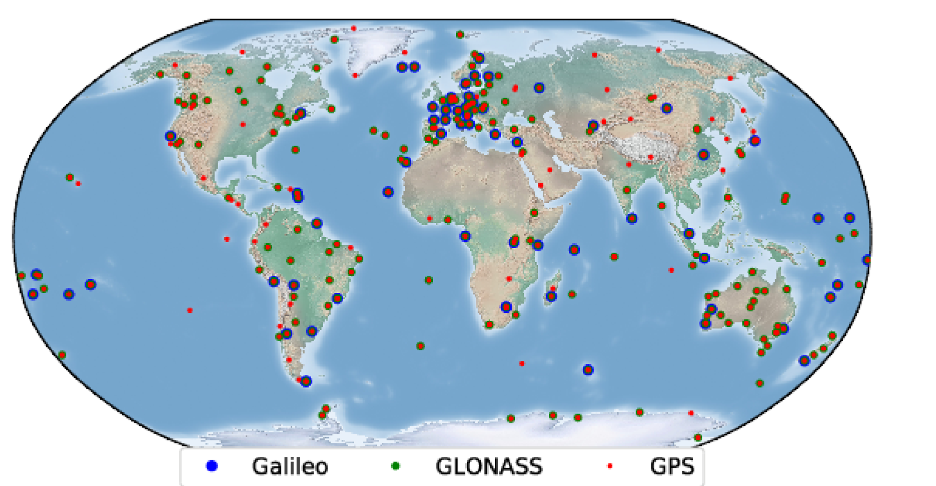

Figure 1: Station network as selected by CODE for the current reprocessing effort. Stations with antennas and radom combinations (“COPY FROM NONE”) are not used as far as possible.

Some important model updates are planned to be introduced with the current reprocessing effort with respect to the current final product generation at CODE:

- IERS-convention related: new mean pole (R. Ray) and high frequency pole model (Desai and Sibois 2016)
- Inclusion of Galileo as the third GNSS constellation: requires an update of receiver and satellite antenna corrections as well as Galileo-specific orbit models
- Orbit modelling: shift pulses from noon to orbit midnight; requires long-arc solution (72 hours)

Poster compiled by Rolf Dach, December 2019
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Scheduling of Stochastic Pulses

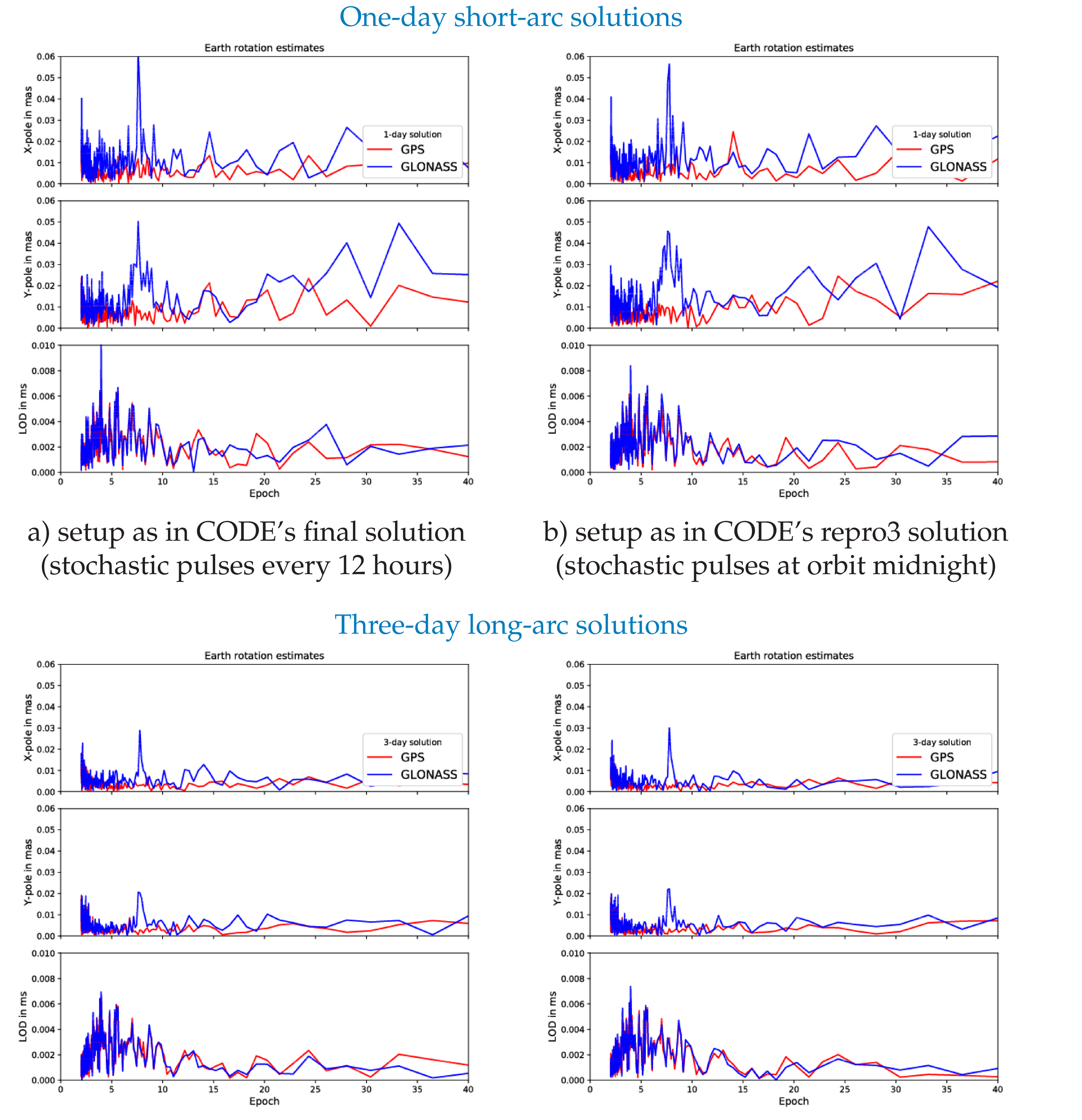
CODE orbits are generated by extracting the middle part of a long-arc solution covering 3 days. In order to compensate for potential deficiencies in the orbit modeling, empirical, instantaneous velocity changes – so called stochastic pulses – are added every 12 hours (Beutler et al. 1994).
In Figure 2a) there are some planes with bigger, others with lower magnitude of the orbit misclosures during the eclipse season. For those with the lower values the eclise period was 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 2b). As Figure 2c) shows, this results in a reduction of the misclosures by about 10%.

a) stochastic pulses every 12 hours
b) stochastic pulses at orbit midnight
c) difference (green: better for orbit midnight)

Figure 2: Orbit misclosures for GPS satellites during year 2014. The satellites are listed according to their PRN and the orbital planes.

Earth Rotation Parameters

One-day short-arc solutions



a) setup as in CODE’s final solution (stochastic pulses every 12 hours)
b) setup as in CODE’s repro3 solution (stochastic pulses at orbit midnight)

Three-day long-arc solutions

c) setup as in CODE’s final solution (stochastic pulses every 12 hours)
d) setup as in CODE’s repro3 solution (stochastic pulses at orbit midnight)

Figure 3: Amplitude spectra of the differences between system-specific polar motion estimates and the CO4-series during the year 2014.

The Earth rotation parameters (daily offset and rates for X- and Y-component as well as Length of day, LOD) are estimated in a global solution individually per GNSS (GPS, GLONASS, Galileo; as proposed by Scaramuzza et al. 2018). The difference with respect to the CO4-series is computed and the related spectra are shown in Figure 3.
In repro3 solution series (right hand plots) a new high-frequency pole model (Desai and Sibois 2016) is used. In the operational final solution (as for all other space geodetic techniques where the CO4-series is based on) still the old IERS2010 model (left hand plots) is applied. For that reason the direct interpretation of these differences is difficult.
As Abraha et al. (2017) have shown, deficiencies in tidal effect modelling may map in different ways for individual GNSS because of different resulting aliasing periods due to the orbit revolution periods. To check the consistency of the Earth rotation solutions obtained with different GNSS may thus be used as a quality measure.
In particular in the one-day short arc solution (top plots in Figure 3) some differences due to the model changes are visible. Which of them is caused by the change in the high-frequency pole model and which by the change of the orbit model can be discussed in detail when adding a third solution where only one of the two models is changed.
Increasing the length of the orbit arcs helps to reduce the noise and all amplitudes in the spectra significantly (already reported, e.g., by Lutz et al. 2016) when comparing the top and bottom plots. The estimation of the polar motion parameters becomes only possible from satellite techniques because of the oblateness of the Earth (otherwise only the rates would be accessible). This fact introduces a direct relation between the stability of the orbits and the quality of the obtained Earth rotation parameters.
It is clearly visible in all the plots that the Earth rotation parameters obtained from GLONASS show a particular peak at (nearly) eight days that is not visible for the GPS-based series. The period of eight sidereal days is known as the repetition rate of the GLONASS ground tracks. The similar period for GPS is one sidereal day.

Station Coordinate Series

The datum definition of the daily solutions have been realized by No-Net-Rotation conditions (NNR) with respect to the currently used IGS14 reference frame. A verified list of reference frame sites has been used for the datum definition.
The station coordinates from the daily three-day long-arc solutions are more consistent to the reference frame because of the related smoothing effect (see Figure 4).
When the different models are enabled step by step, the consistency of the three-day solution with the IGS14 reference frame is improved by the updated antenna corrections (see Figure 5).

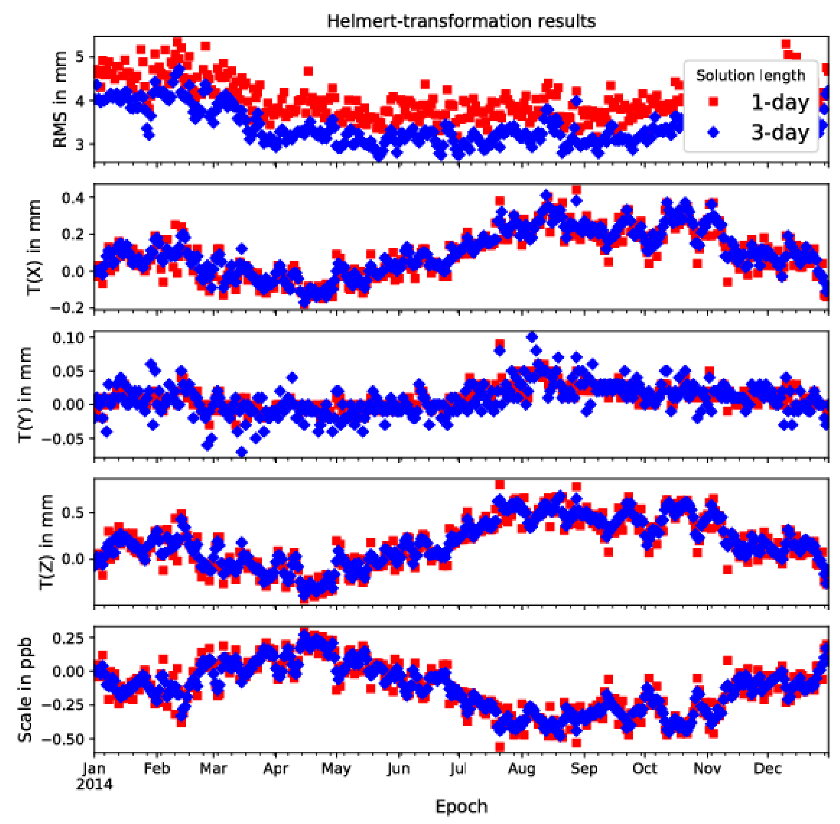


Figure 4: Results of a Helmert–transformation from daily solutions with respect to the IGS14 reference frame during the year 2014 from the repro3-style solution.

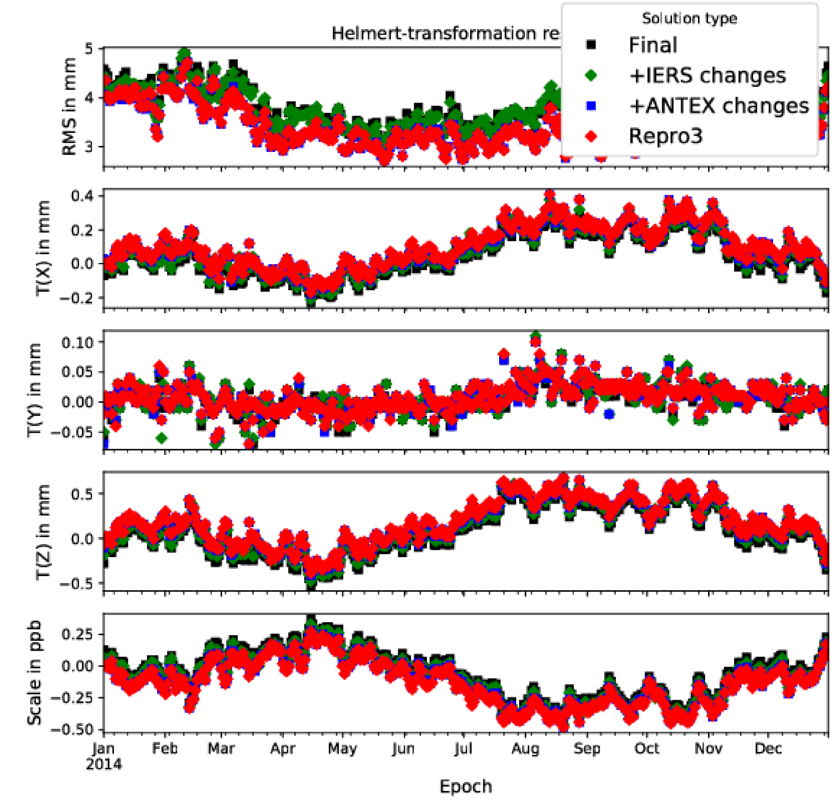


Figure 5: Results of a Helmert–transformation from a series of three-day solutions with respect to the IGS14 reference frame where the different model changes are enabled step-by-step during the year 2014.

Summary

- CODE will contribute to the current reprocessing effort of the IGS with a multi-GNSS solution including GPS, GLONASS, and Galileo.
- The change of the scheduling of stochastic orbit parameters is beneficial for the resulting orbits. This procedure requires long-arc solutions (72 hours).
- The longer orbit arcs are also beneficial for the noise in the Earth rotation series. System-specific (GPS and GLONASS) series become more consistent than in one-day short-arc solutions.

The inclusion of Galileo requires updated receiver and antenna corrections that have extensively been tested within the IGS, see Villiger et al. (G12A-06) or Rebischung et al. (G11A-03) at this conference.

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