1. CLOCK SOLUTIONS
Four solutions were used as a combination of the two different solar radiation pressure (SRP) models from CODE (see Sec. 2) and two orbital arc lengths as described in Tab. 1.

2. CODE SOLAR RADIATION PRESSURE MODELS
The old Empirical CODE Orbit Model (ECOM, Beutler et al., 1994) used in its reduced form (Springer et al., 1999) only 5 empirical parameters for modelling solar radiation pressure (SRP): one bias in the direction D of the Sun, one bias in the direction of the solar panel axis and one bias plus once per revolution terms in the direction completing the orthogonal system. The new ECOM (Arnold et al., 2015) adds twice and a second order per revolution terms to the bias in the D direction. The new parameterization compensates for deficiencies of the old ECOM to represent the periodic variations of the cross-section of the satellite illuminated by the Sun. While this was not an issue with for the GPS satellites (due to their cubic shape), the deficiencies became relevant for the GLONASS satellites, which are of elongated shape. Therefore the new ECOM is also more suitable for Galileo and QZSS precise orbit determination (Prange et al., 2015).

Table 2: Sub-GNSS-wise yearly statistics on satellite clock linear fit RMS over 2014. Best in red, second best in blue.

3. SATELLITE CLOCKS STABILITY
Tab. 2 presents statistics (mean and associated standard deviation) on the daily linear clock fit RMS of the satellite clocks from all five GNSS computed over year 2014 for all four solutions. It highlights several points:

(1) generally speaking, there is not much difference between the 1-day and the 3-day solutions, apart for QZSS where the 3-day arc solution looks better.

(2) as expected (see Sec. 2), a significant improvement is obtained when switching to the new ECOM for the Galileo and QZSS satellites (apart from eclipsing/nominal altitude mode periods).

(3) For the GLONASS satellites no tangible improvement was obtained with the new ECOM.

(4) Using the old ECOM, the lowest RMS were obtained for the GPS block IIF satellites (running on improved Rub clocks compared to the other GPS satellites) followed by the Galileo satellites, with similar numbers obtained using either the 1-day or the 3-day arcs.

(5) Using the new ECOM, Galileo shows the most linear clock time series, followed by the QZSS and GPS IIF (sub-)systems. QZSS shows however less consistency over time, as reflected by its 3 times higher standard deviation. Note that periods with orbit normal mode enabled were not considered in the computation.

4. INTER-SYSTEM BIASES STABILITY
In a multi-GNSS zero-difference processing, inter-system biases (ISB, see Sec. 3) are used to connect adjacent days; and (3) a second order polynomial was removed from the weekly time series. With the new ECOM, the bulge centered at half a revolution period for Galileo and QZSS satellites with the old ECOM is clearly reduced. Note that for assessing the very short-term stability of the satellite clocks, daily time series will be performed on the weekly reconstructed ones used here as they depend on the quality of the ISB estimates and of their reference unification (see next section).

5. CONCLUSIONS
The updated CODE SRP model has a significant positive impact for Galileo and QZSS clock estimation. Overall similar results are obtained with the 1-day and 3-day arcs orbits. Only QZSS seems to benefit from longer arcs. Finally, the system-wise ISB stabilities are better for the Galileo and QZSS systems.

References:

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In the processing, an ISB is set up for each station and GNSS other than GPS, with a zero-mean condition set for each GNSS. To study the station-wise ISB stability over a certain period, their references need first to be unified. This was accomplished by selecting as the reference (i.e. with constant zero ISB assumed) the station that was minimizing the cumulative RMS of all stations over the given period. Fig. 2 shows an example. It also shows that ISB time series are subject (among other things) to firmware upgrade, but not systematically. Some cleaning had to be performed in order to also exclude potentially huge outliers. Fig. 3 presents the cleaned ISB for all GNSS over 2014, with ISBs references unified over 15-day periods over 2014.

Fig. 4 presents in the form of box-and-whiskers plots the distribution of the station-wise ISB stabilities over 2014 for all systems. It appears that apart from the GLONASS R_715 satellite, all systems have their median ISB close to the overall median value (green line in Fig. 4). It is noticeable that the Galileo and QZSS systems have 75 % of their tracking stations below the overall median value, indicating more stable ISBs compared to those of BeiDou and QNSS. However, Fig. 4 also suggests that a similar highest level of ISB stability can be reached for all systems, as all 0 % values are (still apart from R_715) on a similar level, which is not the case for the maximum (100 %) values. The spread of the ISB stabilities varies between 0.77 ns for R_742 up to 2.23 ns for R_736 if we exclude GLONASS R_714 from the comparison since it was not active over the full year 2014.

The updated CODE SRP model has a significant positive impact for Galileo and QZSS clock estimation. Overall similar results are obtained with the 1-day and 3-day arcs orbits. Only QZSS seems to benefit from longer arcs. Finally, the system-wise ISB stabilities are better for the Galileo and QZSS systems.