Real-time multi-GNSS products for the Precise Point Positioning

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INTRODUCTION

The process of developing and improving already existing Global Navigation Satellite Systems (GNSS) is a great opportunity to improve performance of PPP, a technique that uses a single receiver for positioning. PPP takes advantage of precise products that are considered as fixed parameters in the normal equation system. To use capabilities of PPP as a measurement technique it is important to use real-time precise corrections. Precise products are provided by several institutions, e.g. by the International GNSS Service (IGS) or CNES. This study verifies the accuracy of the CNES real-time products in comparison to the final CODE products and their availability. In this work BKG NTRIP Client (BNC) v2.12 was used as a decoder of precise real-time stream that contains the following corrections: orbits, clocks, differential code bias (DCB), differential phase bias (DPB) and vertical total electron contents (VTEC). All computations were conducted using GNSS-WARP software (Wroclaw Algorithms for Real-time Positioning) which is developed in the Institute of Geodesy and Geoinformatics (IGiG) at Wroclaw University of Environmental and Life Sciences (WUELS).

METHODOLOGY

In this work we were focused on orbit and clock corrections provided by CNES, their availability and quality. As a testing period we selected dates from 1 to 30 April 2016 (doy 92 - 121). Calculation was performed in postprocessing mode using corrections and broadcast ephemerides which are stored on the hard disc server using BNC software. In our work we calculated coordinates and clocks of GPS, GLONASS, Galileo and BeiDou satellites on the basis of broadcast ephemerides which were corrected in the second step using precise products. The major issue during real-time corrections application is to join broadcast ephemeris with appropriate correction for it. It is possible to do it on the basis of IOD (Issue of Data) number. It is the unique number that is included in the navigation message. IODs are directly available in broadcast message only for GPS and Galileo while for GLONASS and BeiDou there is the necessity to compute it using ephemeris parameters. After applying the corrections satellite coordinates are referred to the antenna phase centre (APC). Thus, to compare the obtained coordinates using real-time products with final products, that refer to the centre of mass (CoM), we need to use absolute IGS antenna correction file. Both orbit and clocks were compared in 15 min interval. Each difference was reduced in each epoch using median of differences for each system separately in order to remove systematic error caused by the analysis centre. Center for Orbit Determination in Europe (CODE) final products were used as a reference.

Table 1 Precise CNES real-time orbit and clock corrections availability in % for period 1-30.04.2016 (stream CLK93)

	GPS	GLONASS	Galileo	BeiDou
max	94 (G15)	92 (R06)	91 (E12)	85 (C07)
min	52 (G32)	50 (R16, R17)	12 (E08)	80 (C08)
median	93	91	90	83

RESULTS

Figure 1 shows availability of precise products while the numeric values are stored in Table 1. For some epochs from testing period there is lack of information for all satellites. Gaps may be caused by a failed internet connection on the server that stores information, improper BNC performance or no data transmission. It is also visible that there are gaps only for part of satellites. It is probably connected with the fact that no precise products were provided for those satellites in some epochs or IOD matching was incorrect. Gaps in days 94, 101,108 and 115 for BeiDou are connected with wrong dates and hours in corrections headers in the files saved by BNC. This may refer to the improper BNC working or to some errors in streams transmitted by CNES. Generally, GPS has the highest availability while the lowest one is proven by BeiDou. In the second step of works the obtained coordinates and clocks of satellites were compared to the reference products. The results are presented in Figure 2. It is visible that the most accurate satellite coordinates were obtained for GPS excluded satellite G32 for which there was a more serious error in radial and along-track component. GLONASS coordinates are slightly less accurate, especially for satellites from the first orbital plane (R01-R08) where lots of outliers occurred. It may be related to the satellite eclipsing on this orbital plane. The less accurate position was obtained for R01 for which some scheduled works were conducted during the testing period (7-8.04.2016). These works may affect future correction performance. Galileo satellites coordinates have bigger errors and for some satellites systematic biases appear. It is demanding to find clear border differences between In-Orbit Validation (IOV) and Full Operational Capability (FOC). There is also visible systematic bias for satellites E24 and E30 in cross-track component which are the only satellites from the C orbital plane. BeiDou satellites coordinates are less accurate, especially if we consider Inclined geosynchronous orbit (IGSO- C06-C10) in along and cross-track components. Medium Earth Orbits (MEO) are slightly more precisely determined and are comparable to the Galileo satellites coordinates accuracy. Additionally, for Galileo and BeiDou we removed IOV and IGSO satellites respectively and then a slight improvement occured for Galileo position components and almost twice better results for BeiDou. Clocks for GPS are estimated the most accurately (0.37ns) while clocks for Galileo and BeiDou are at the level of 1ns, when GLONASS clocks are estimated almost triple less accurate than Galileo and BeiDou. Removing IOV improves Galileo clocks calculation accuracy to 0.58ns while BeiDou clocks RMSE calculated without IGSO satellites remain at the same level. The summary plot of RMSE for each analyzed component is presented in Figure 3, while its tabular summary is listed in Table 2.

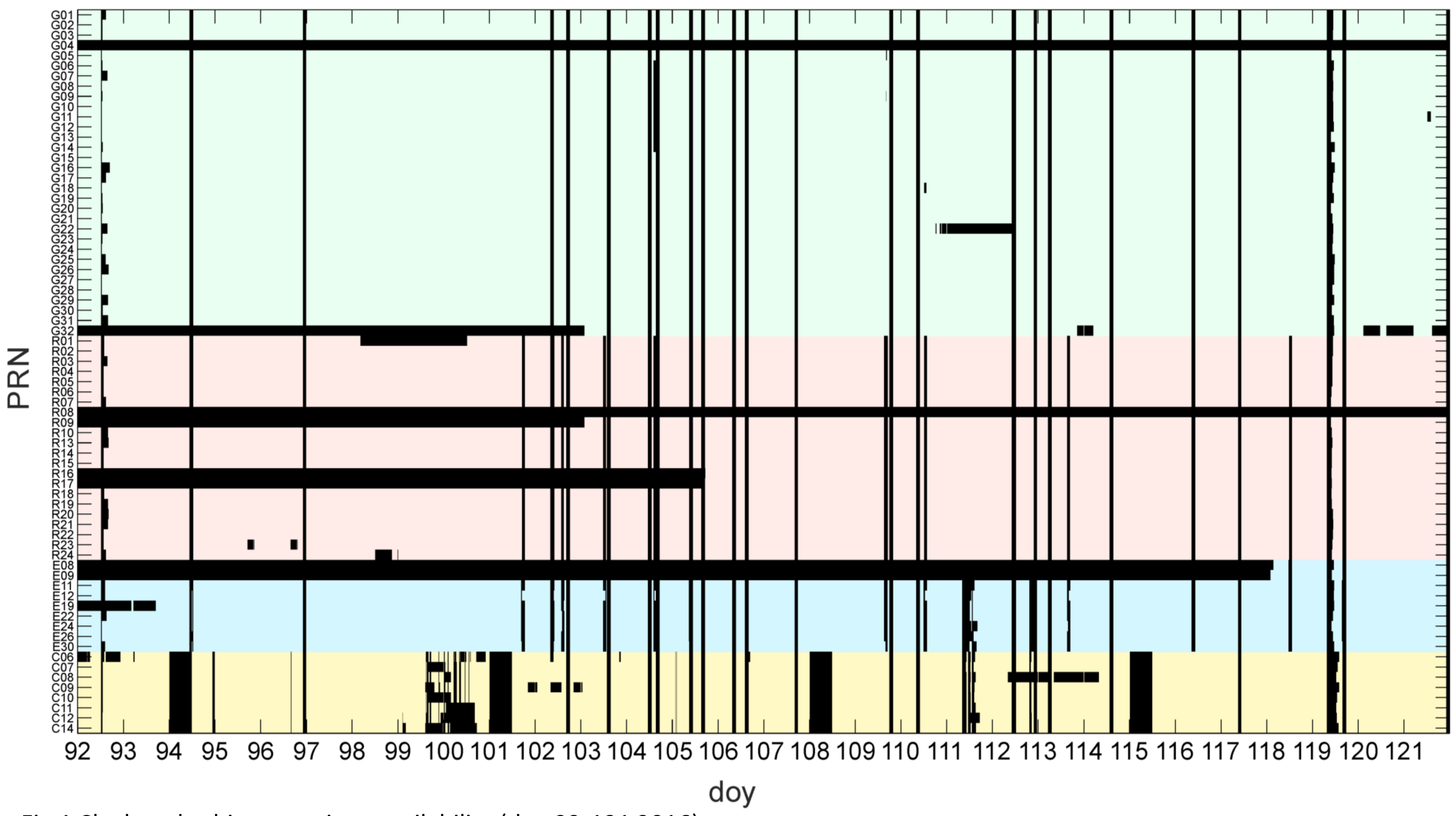

Fig.1 Clock and orbit corrections availability (doy 92-121 2016)

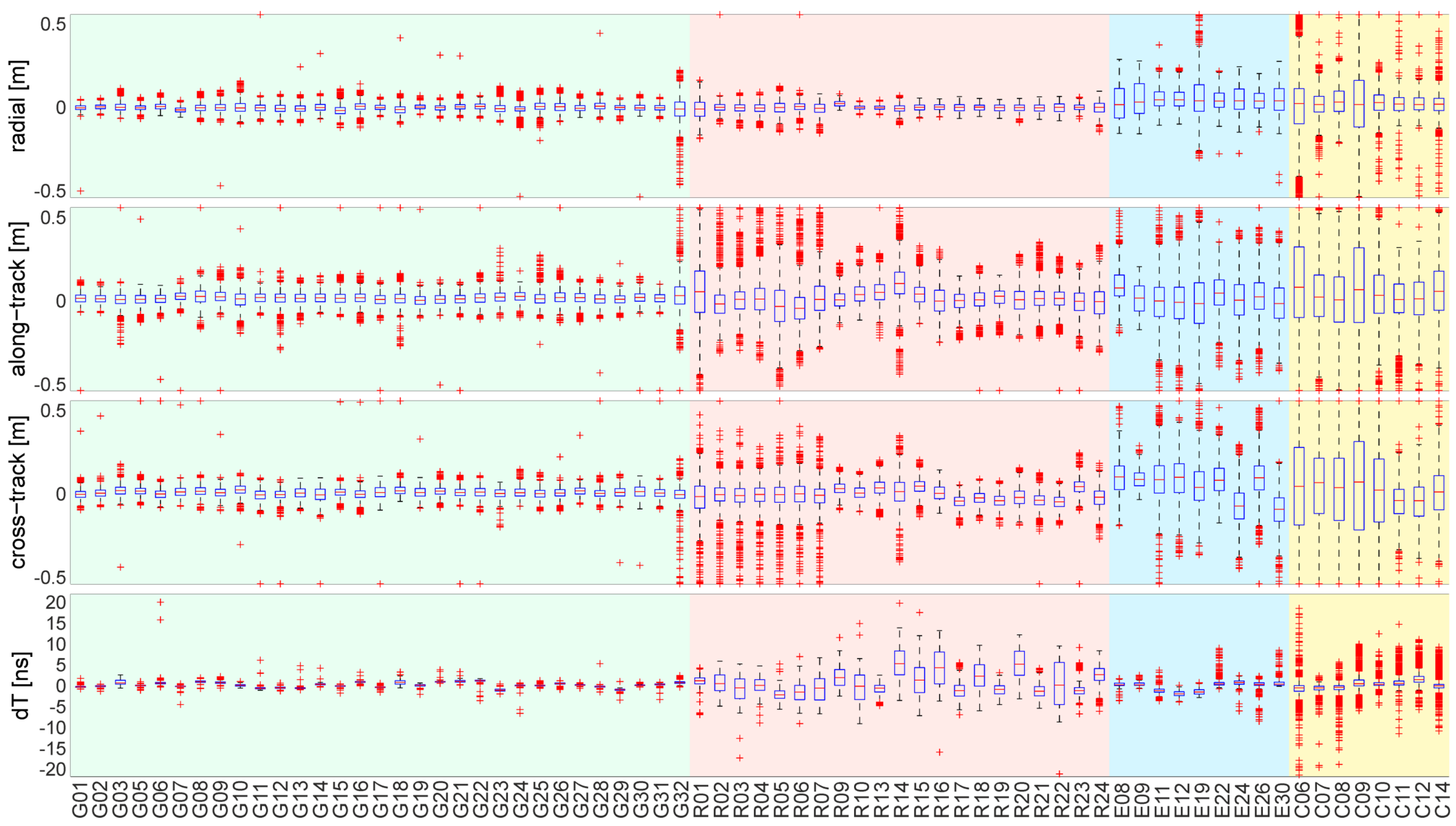

Fig.2 Differences boxplot for the analyzed period (doy 92-121 2016)

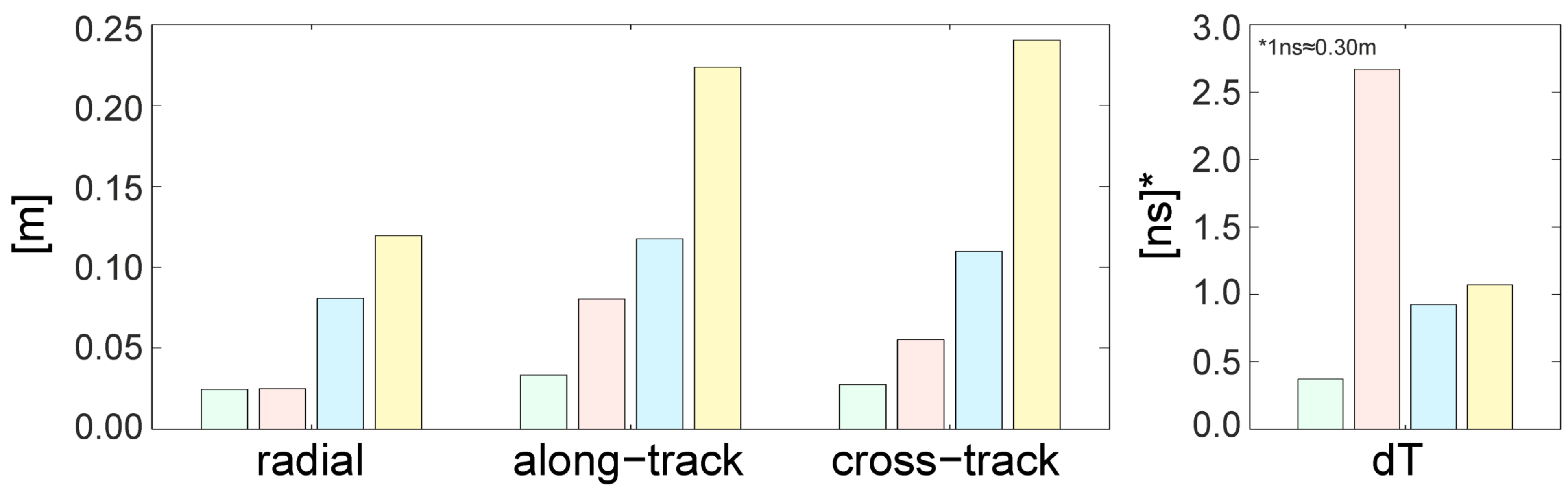

Fig.3 RMSE of analyzed real-time products for period 92-121 2016

GPS | GLONASS | Galileo | BeiDou

Table 2 RMSE of analyzing real-time products for period 92-121 2016

		GPS	GLONASS	Galileo (IOV excluded)	BeiDou (IGSO excluded)
radial	[m]	0.025	0.025	0.081 (0.081)	0.120 (0.051)
along-track	[m]	0.033	0.080	0.118 (0.109)	0.224 (0.144)
cross-track	[m]	0.028	0.055	0.110 (0.105)	0.240 (0.120)
clock		0.111	0.801	0.277 (0.174)	0.321 (0.317)
	[ns]	0.370	2.670	0.920 (0.580)	1.070 (1.060)

CONCLUSIONS

Conducted works allow to assess the availability and accuracy of the newly available real-time multi-GNSS stream provided by CNES. The products availability for the analyzed period is at the level of 80% for BeiDou while for the other system at the level of 90%. The most accurate parameters are estimated for GPS (3cm for orbits and 11cm for clocks). GLONASS satellite coordinates do not extend 10cm level of accuracy and the radial component is estimated as precisely as for GPS. GLONASS clocks have the lowest accuracy - at the level of 80cm. Galileo coordinates are computed at the level of 11cm while BeiDou satellites coordinates computation accuracy is below 24cm, or even 15cm when excluding IGSO satellites. All BeiDou clocks are at the comparable level of accuracy (1ns) while Galileo IOV clocks excluding led to the improvement of their accuracy for about 10cm (0.34ns). The above results show that the application of real-time products allows to calculate satellite parameters at different levels of accuracy depending on the selected system. Thus, it is necessary to appropriately weigh observation during the processing. The obtained results show also that corrections still have some gaps what may lead to PPP outcomes instability.