GLOBAL NAVIGATION SATELLITE SYSTEM

GLONASS

Open Service Performance Standard (OS PS)

APPENDIX C
ESTIMATION OF CURRENT PERFOMACE AND FAILURE RATE

Edition 2.2

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C.1 GLONASS Open Service Performance Estimation

C.1.1 Software and Hardware Facilities Used for Performance Estimation

The estimation was performed using the input data, generated by the nominal adaptable AKVAPAS hardware and software tool developed and operated by the Information and Analysis Center for PNT (www.glonass–center.ru) under the IAC–EKS contract. The AKVAPAS tool is used for analysis of orbit and clock data and SIS parameters of navigation satellite systems. The GLONASS and GPS performance estimation includes the analysis of their nominal orbit and clock data against the reference orbit determination and clock correction data obtained by IAC. The AKVAPAS tool is registered with the Government Register under the number 46393–11 and is authorized to use in the Russian Federation (Certificate RU.E.27.018.№42157 for Approval of Measurement Tool). As recommended by the Appendix to the above Certificate, the AKVAPAS tool shall be used "for estimation and assessment of industrial products and other objects against the requirements, set by the legal acts of the Russian Federation, as well as for government supervision". SIS URE estimations were obtained based on the statistical processing of the differences between the satellite broadcast ephemeris and clock data and the post–processed ephemeris and clock data.

When processing navigation files we assume that the GLONASS ephemeris can be used only within ±15 min of its reference time. It is assumed that ephemeris and clock data can be refreshed only when transferring to the next set of data, which is at 0 and 30 minutes of each hour. Health status indications can change anytime. The instant for changing the health status indication is selected as the earliest of all the available frame starting instants. When integrating the GLONASS broadcast ephemeris, the cutoff of the least significant bits is taken into account instead of the rounding, which results in some smaller ephemeris propagation errors. These errors can reach as much as 1 m over 15 min.

The IAC post–processed ephemeris and clock data is corrected once per day with a 5–day delay based on the measurements of 70 measurement stations. The correction of the final ephemeris and clock data is carried out over a 2–day interval based on the direct code and phase measurements for all the GLONASS and GPS satellites using processing models recommended by the IERS Standards 2010. The set of the parameters being corrected includes: initial conditions in GCRF, radiation pressure force parameters, empirical accelerations, the pseudopulses of the GPS satellites, coordinates of all the measurement stations, the tropospheric zenith errors, the estimations of the GLONASS and GPS time difference for all combined receivers, the instantaneous corrections for all measurement stations' and satellites' clocks, and also the ambiguities of all series of phase measurements. The typical dimensions of the solution include about 80,000 of parameters. The generation of the final ephemeris and clock data is performed over of the central 24–hour interval for each everyday solution. The RMS error of the final post–processed orbits as against the IGS data is about 8 cm, according to the IAC. According to the IGS Coordinator, the RMS error of the final post–processed orbits as against the IGS data is 2.5–3 cm. The difference in results is primarily predetermined by the use of parameters for coordinating reference frames (realized by different analysis centers in individual solutions) to ITRF (realized by IGS).

In principle, that the IGS analysis center coordinator does not estimate precise satellite clock corrections when computing final solutions. It is predetermined by the significant systematic errors of the code measurements due to the Frequency Division Multiple Access signals. According to the IGS recommendations, the abstract receiver directly performing P1 and P2 measurements averaged over the receiver network is selected for zero.

Thus, the GLONASS clock corrections, obtained directly in the IAC solutions are tied to the ionosphere–free combination of the P1 and P2 code measurements averaged over the receiver network. The direct application of these data for the estimation of the GLONASS broadcast ephemeris and clock performance results in significant systematic errors in the estimation of clock corrections due to the presence of the systematic errors in measurements attributable to the command and control subsystem which are different from those attributable to an averaged receiver. Unlike GLONASS, GPS is almost free of such errors due to the code division multiple access nature of its signals. Moreover, based on the measurements over long–term intervals, there are no reasons to assume that such systematic errors (attributable to the GLONASS command and control subsystem) are stable on the level of better than 1 nsec. These can be due to the ground facilities upgrade, temperature fluctuations or other reasons. That is why IAC performs the estimations of the clock corrections against the final IAC data obtained over the previous 24–hour interval within each loop of the final ephemeris and clock corrections estimation. These current systematics are used in all loops of the IAC ephemeris and clock corrections estimation in order to coordinate the post–processed clock corrections to the broadcast data. Corrections estimation results in the exclusion of clock errors induced by non–calibrated receivers.

The difference between the post–processed and the broadcast ephemeris and clock data is estimated without employing reference systems coordination parameters. The corresponding error is insignificant as compared to the broadcast ephemeris errors. For GLONASS the nominal displacement of the PZ–90.11 origin relative to ITRF in the equatorial plane is not broadcast in satellite ephemeris. The displacement along X axis is 3 cm which is not significant as compared to the real ephemeris errors.

C.1.2 Estimation of Coverage

The standard (100%) in this OS PS is established without verification.

C.1.3 Estimation of CSA SIS Accuracy

C.1.3.1 Estimation of CSA SIS URE

C.1.1 demonstrates estimation of the 95% Global Average SIS URE for every SV over the 30-day ergodic interval. The sampling interval is 10 min. The step of the data delivery is 24 hours.

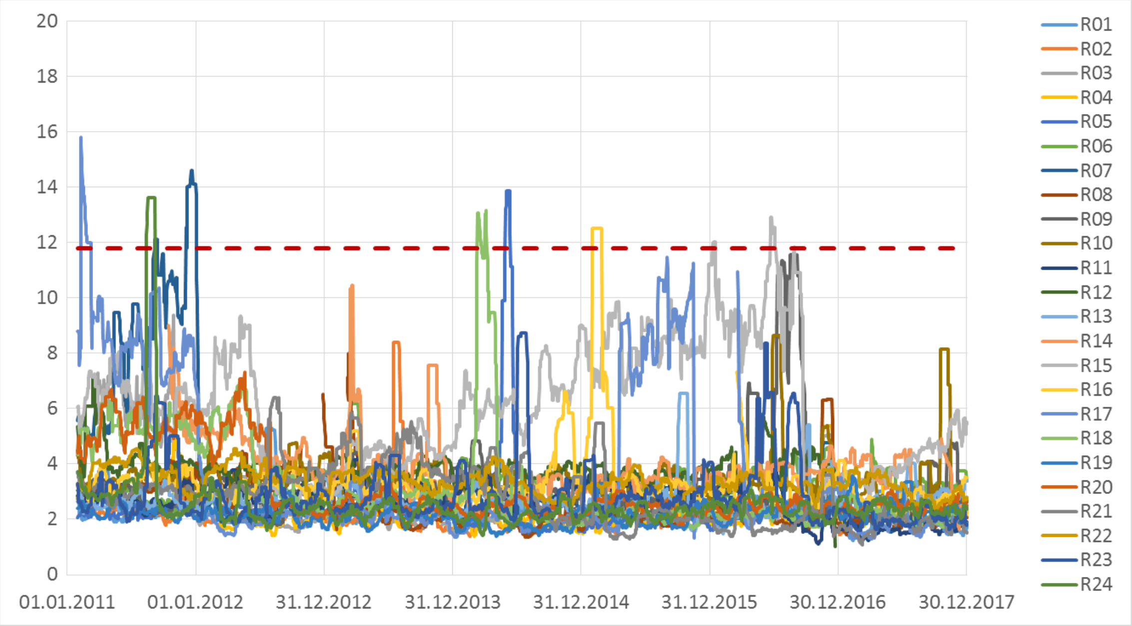

Figure C.1.1 — 95% Global Average SIS URE for every SV over a 30-day interval

C.1.2 gives the estimation of the 95% Global Average SIS URE averaged for the constellation. 95%-threshold is used for statistics. The sampling interval is 10 min. The step of the data delivery is 30 min.

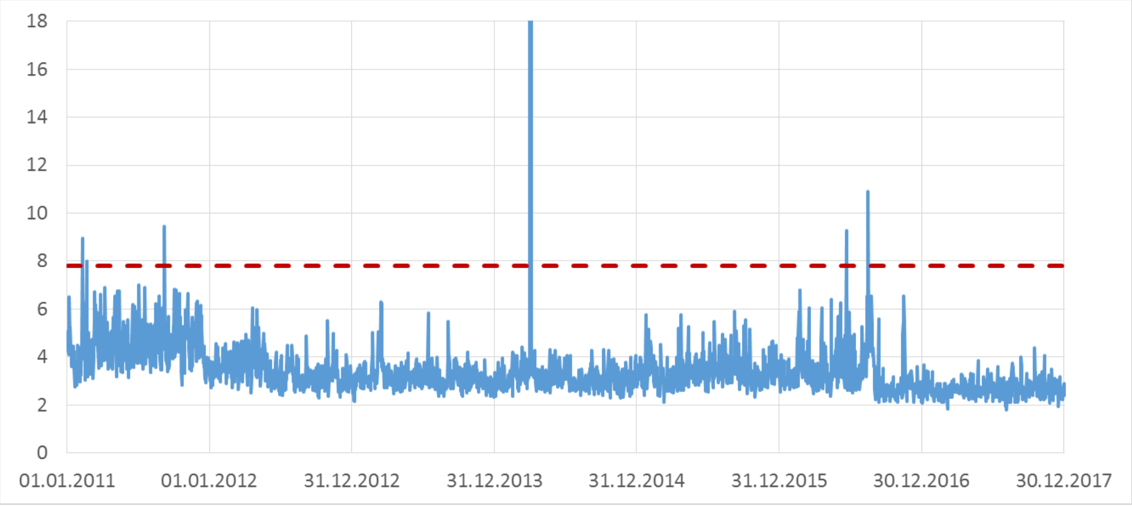

Figure C.1.2 — 95% Global Average SIS URE averaged for the constellation

C.1.3.1.1 Estimation of CSA SIS URE Reliability

C.1.3, C.1.4 shows estimations of the Global Average Reliability and the Worst Case Single Point Average Reliability. These characteristics were estimated over one year interval. The sampling interval and the step of the data delivery is 10 min.

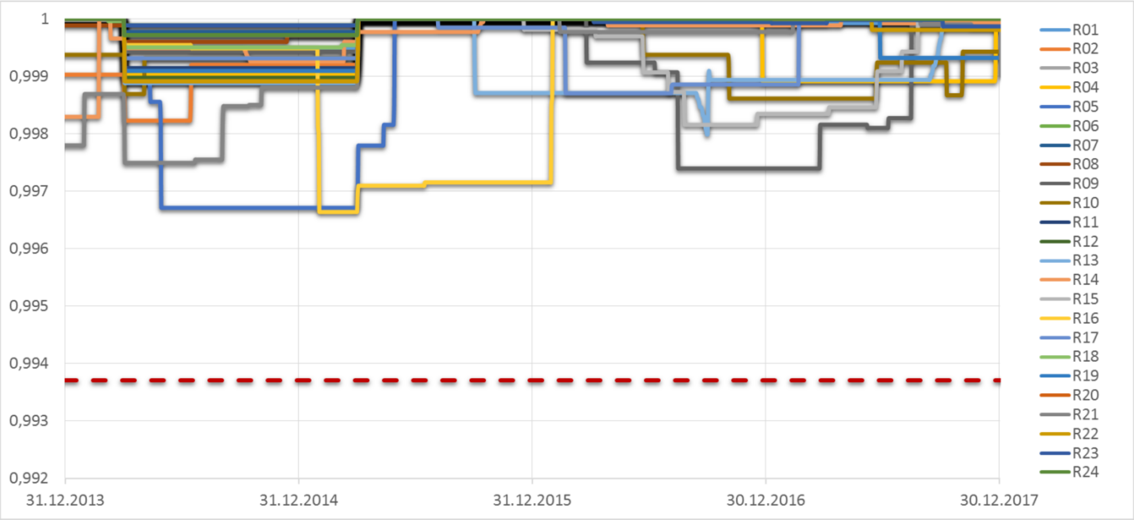

Figure C.1.3 — Global Average Reliability for every SV over one year interval with every 24 hour averaging

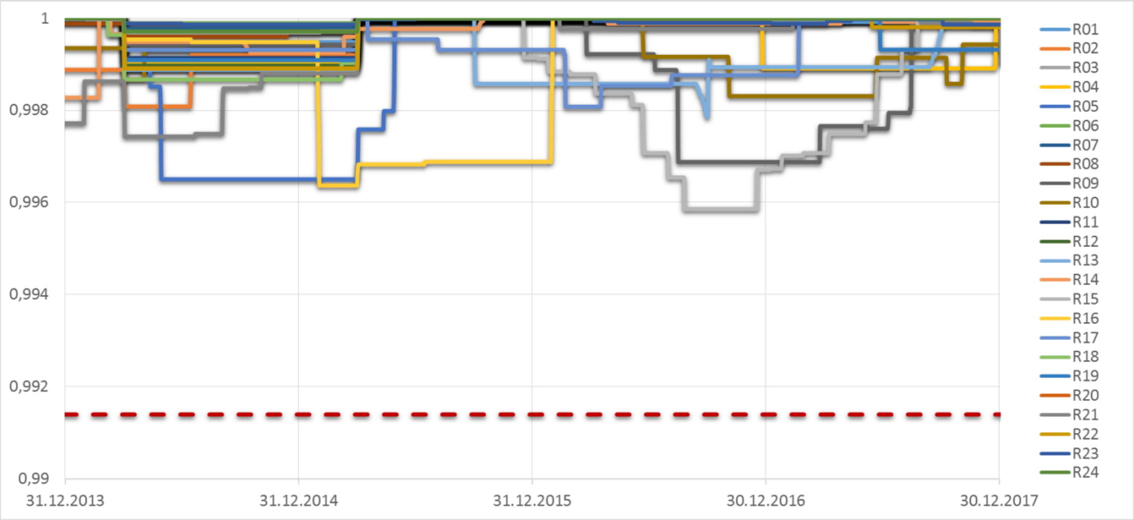

Figure C.1.4 — Worst Case Single Point Average Reliability for every SV over one year interval with every 24 hour averaging

C.1.3.2 Estimation of CSA SIS URRE

C.1.3.2.1 Estimation of CSA SIS URRE Based on Sampling Users in the Per-slot Coverage Area

The method was not used because of the lack of the network of the distributed reference receivers which can properly rule out all the components of additional errors (including receiver induced systematic errors and troposphere delay).

C.1.3.2.2 Estimation of CSA SIS URRE based on a Rough Calculation of CSA SIS URRE Based on Approximate Derivations from Satellite AFS Short-term Stability

C.1.5 provides 95% Global Average SIS URRE for every SV over the 23-day interval. The sampling interval is 3 sec. The step of the data delivery is 24 hours.

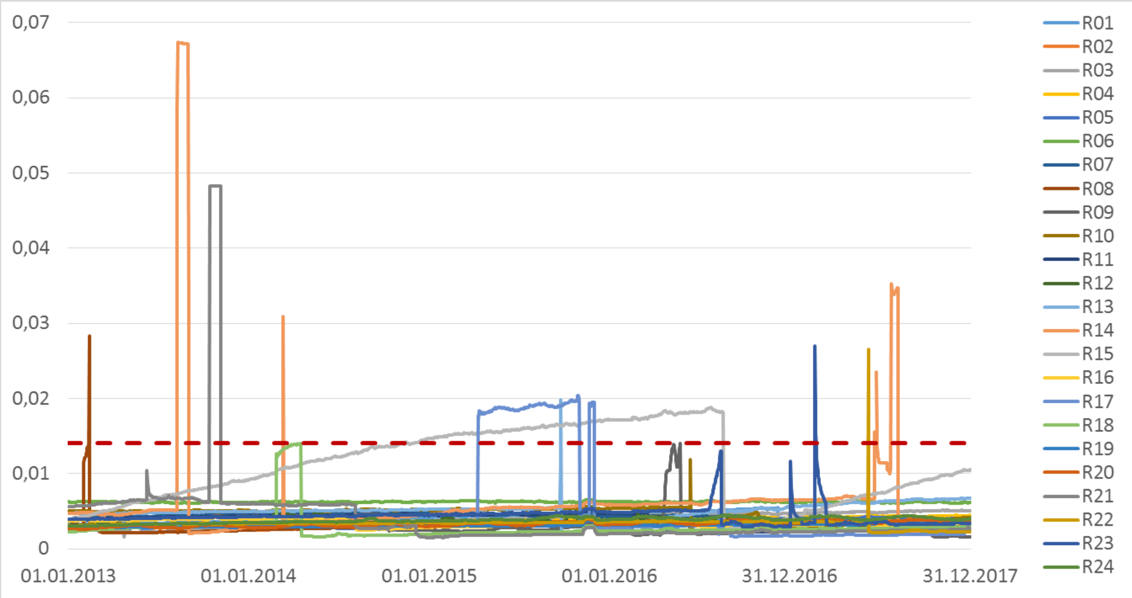

Figure C.1.5 — 95% Global Average SIS URRE for every SV over the 23-day interval

C.1.3.3 Estimation of CSA SIS URAE

C.1.3.3.1 Estimation of CSA SIS URAE Based on Sampling Users in the Per–slot Coverage Area

The method was not used because of the lack of the network of the distributed reference receivers which can properly rule out all the components of additional errors (including receiver induced systematic errors and troposphere delay).

C.1.3.3.2 Estimation of CSA SIS URAE Based on Approximate Derivations from Satellite AFS Short–term Stability

C.1.6 provides 95% Global Average SIS URAE for every SV over the 23–day interval. The sampling interval is 3 sec. The step of the data delivery is 24 hours.

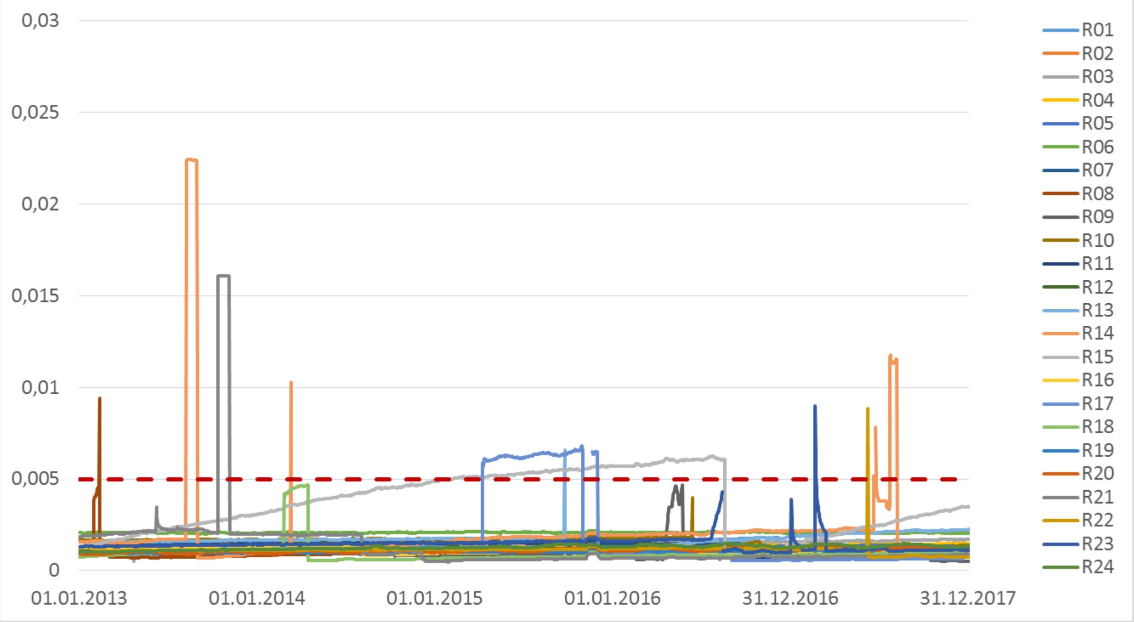

Figure C.1.6 —95% Global Average SIS URAE for every SV over the 23 day interval

The charts on C.1.5 and C.1.6 show that SIS URRE and URAE values, measured approximately based on Satellite AFS Short–term Stability fall within the established threshold obtained based on the assumed AFS stability of 1×10^{-13}. It worth noting, that the method allows determining performance characteristics with a rough approximation. The lack of technical facilities to collect measurements globally with a second periodicity and sufficient reliability when processing large amount of measurement data from various types of receivers doesn't allow opting for the more accurate method.

C.1.3.4 Estimation of CSA SIS UTCOE

C.1.7 provides the 95% Global Average UTCOE. The characteristic was measured over the 24–hour interval and is shown for the most representative period from 1 August 2014 to 8 August 2014.

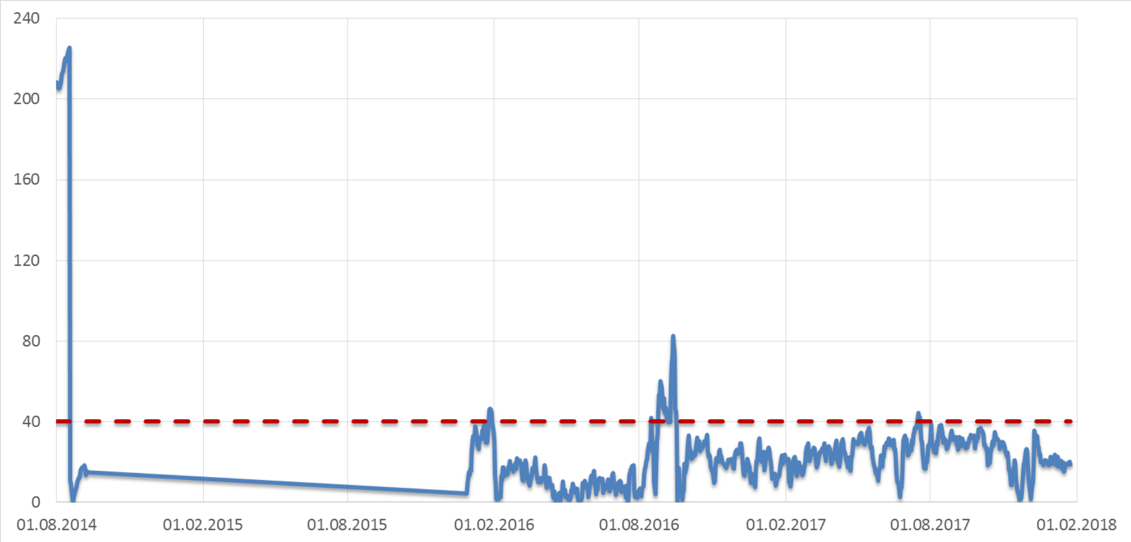

Figure C.1.7 — 95% Global Average UTCOE over the 24-hour interval averaged over the constellation

For the time being the demonstrated characteristic is somehow different from that described in the Calculation Methods. It is represented by the difference between the 24-hour expected offset value determined by the facilities used to physically compare ground-based clock references, and the 24-hour expected offset averaged over the constellation as broadcast in the navigation message. The use of this characteristic for the first approximation is predetermined by the relatively small RMS of 1–2 ns.

The significant decrease of the error as seen on C.1.7 is related to the maintenance efforts aimed at improving the accuracy of the broadcast offset (τ_c parameter). When performing further estimation of CSA characteristics it is necessary to monitor UTCOE for each satellite individually.

C.1.4 Estimation of Probability of CSA Major Service Failure

Figure C.1.8 provides the GLONASS CSA Major Service Failure over one year interval averaged for the constellation. The sampling interval and the step of the data delivery are 10 min. The Figure gives the CSA Major Service Failure for single independent loss. Every value is measured over the previous 1 year interval.

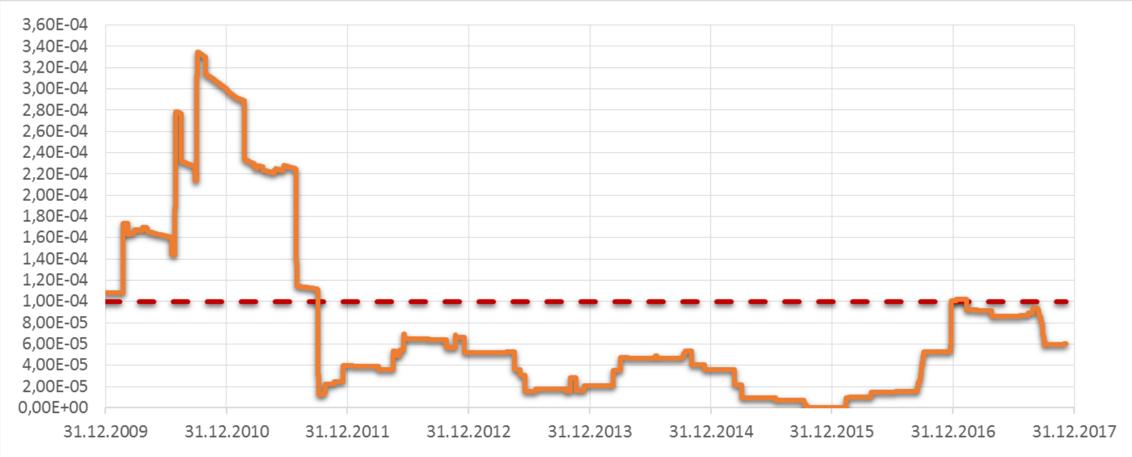

Figure C.1.8 — GLONASS CSA Major Service Failure for Single Independent Loss

C.1.5 Estimation of CSA SIS Continuity

Figure C.1.9 provides the GLONASS CSA SIS Continuity over one year interval averaged for the constellation. The sampling interval and the step of the data delivery are 10 min.

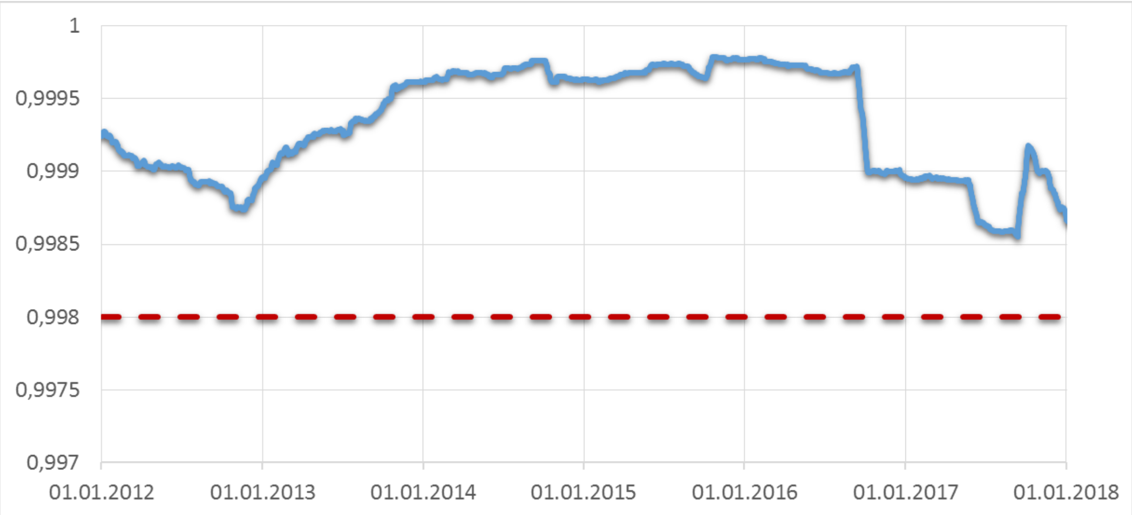

Figure C.1.9 — CSA SIS Continuity during one hour, averaged over the constellation, based on measurement interval of 1 year without prior notice

Currently CSA SIS interruptions are announced by way of the System Control Center issuing a "Notice Advisory to GLONASS Users" (NAGU) – on-line bulletins published on the official websites of the Roscosmos State Corporation — www.glonass-center.ru, and the Russian Ministry of Defense — www.glonass-svoevp.ru. At the same time, following the recommendations of ICAO the GPS and GLONASS Constellations Monitoring Center has been established in the Russian Federation. The Center is put into service and operated by the State Unitary Enterprise "The State Corporation for Air Traffic Management". The Monitoring Center performs the following functions (for GPS and for GPS–GLONASS combined):

- RAIM availability prediction for various flight operations, including for en–route, en–route terminal and NPA,
- GNSS accuracy monitoring including real–time,
- generating advisory notices on GNSS SIS interruptions and on changes in performing flight operations (NOTAM, NOtice To AirMen), and delivering NOTAMs to the Center of the Air Navigation Information of the Russian Federation for further publication,
- reception, register and archiving information on GNSS, GBAS, and SBAS status,
- estimation of GNSS SIS in the airspace of the Russian Federation.

C.1.6 Estimation of CSA SIS Availability

C.1.6.1 Estimation of CSA SIS Per–slot Availability

C.1.10 provides the GLONASS CSA SIS Per–slot Availability (an average over all slots in the constellation, based on measurement interval of 1 year). The sampling interval and the step of the data delivery are 10 min.

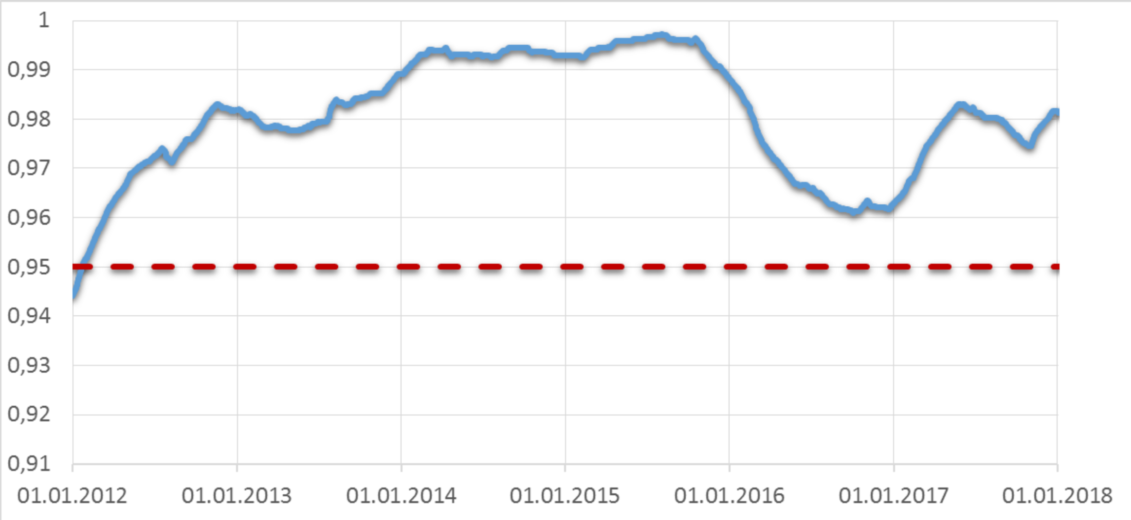

Figure C.1.10 — CSA SIS Per–slot Availability (an average over all slots in the constellation, based on measurement interval of 1 year)

C.1.6.2 Estimation of CSA SIS Constellation Availability

C.1.11 provides the GLONASS CSA SIS Constellation Availability for 21 healthy satellites based on measurement interval of 1 year. The sampling interval and the step of the data delivery are 10 min.

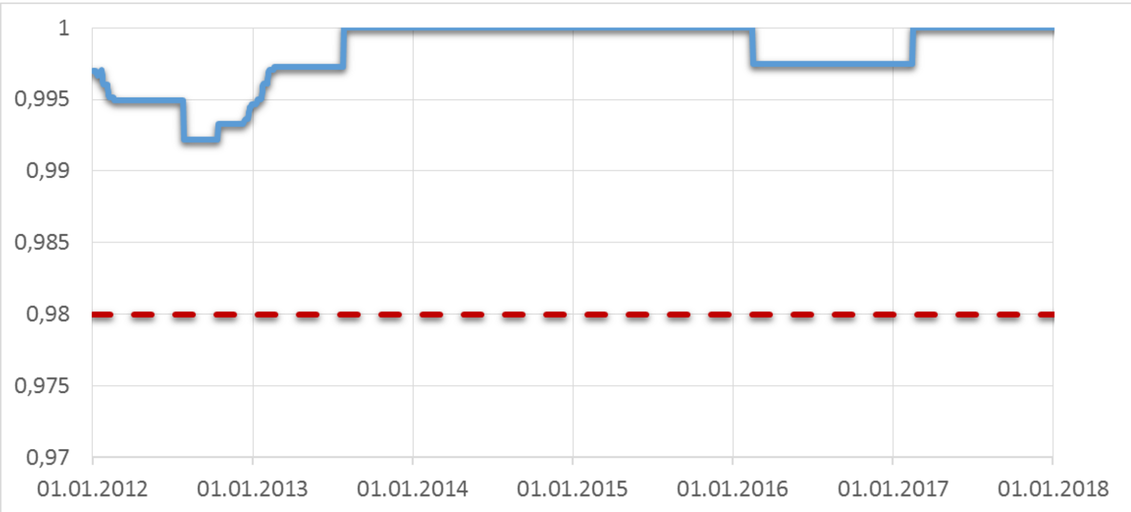

Figure C.1.11 — CSA SIS Constellation Availability (based on measurement interval of 1 year)

C.1.7 Estimation of CSA SIS Performance Characteristics in Position/Time Domain

C.1.7.1 Estimation of CSA PDOP Availability

C.1.12 provides the GLONASS CSA PDOP Availability (average and worst site).

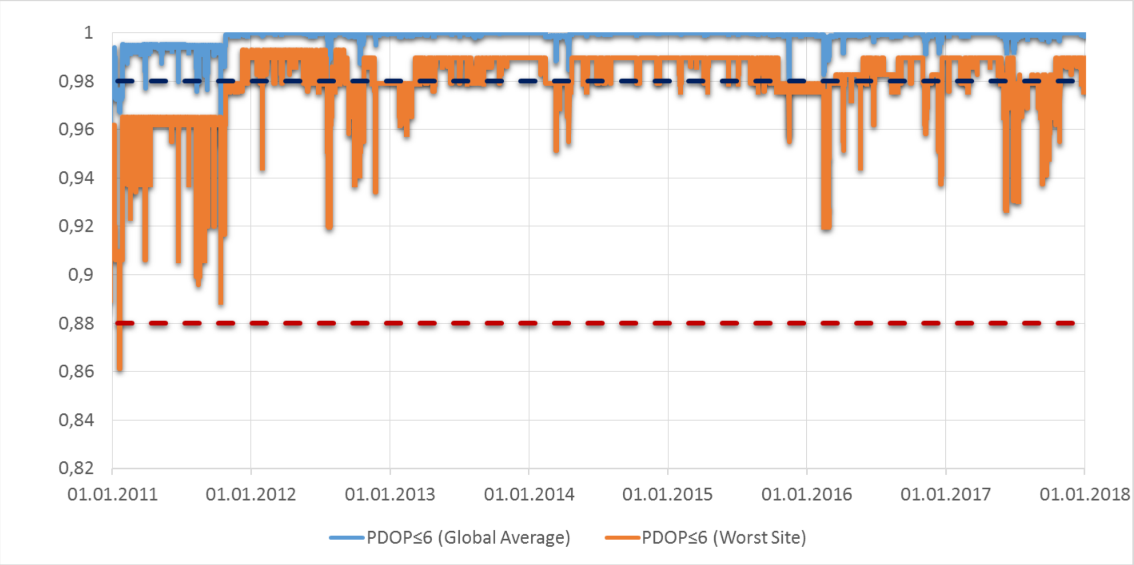

Figure C.1.12 — Average location and Worst-site PDOP Availability over 24-hour interval

C.1.7.2 Estimation of CSA Positioning Error

The data necessary for the estimation of the GLONAS CSA Positioning Error (vertical and horizontal, for PDOP≤6) has been generated starting 6 June 2014. The results of the estimation are provided on C.1.13, Figure C.1.14.

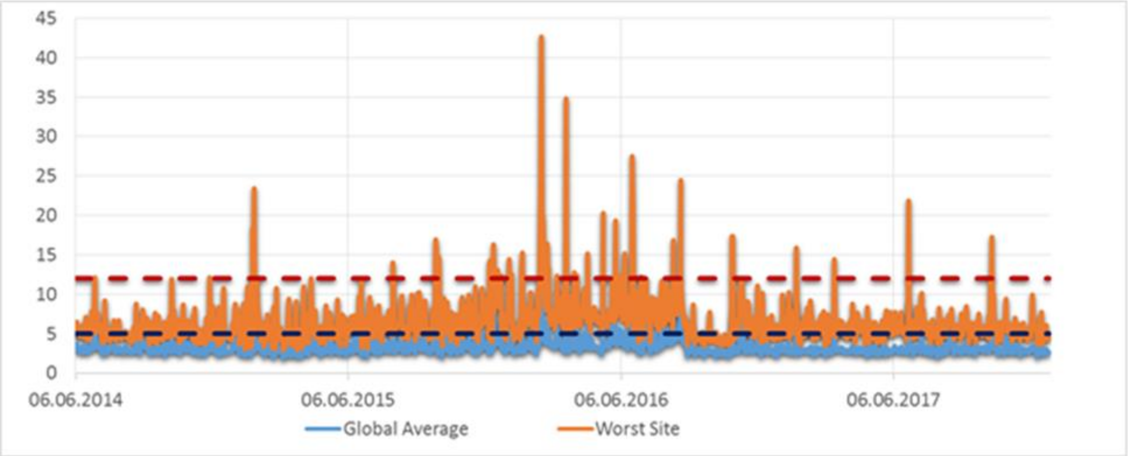

Figure C.1.13 — Global Average (RMS) and Worst-site Horizontal for PDOP≤6

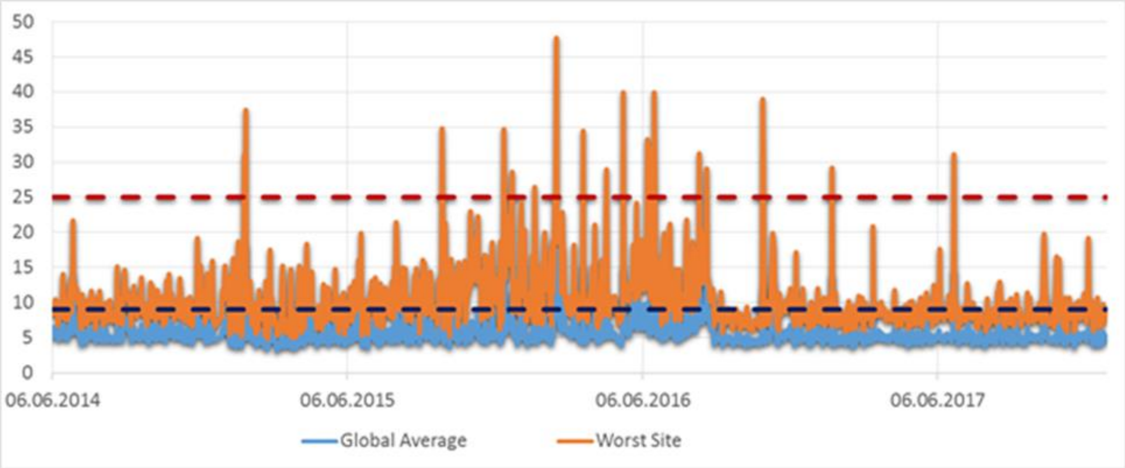

Figure C.1.14 — Global Average (RMS) and Worst-site Vertical for PDOP≤ 6

The lack of the direct correspondence of the 3D positioning error (10.3 m, 0.95) to the multiplying of the global average SIS URE (7.8 m, 0.95) by the average PDOP of 2, can be explained by the inconsistency of the peak SIS URE values and the local PDOP values in any instant of time, as well as by the fact, that not all the satellites of the constellation are taken into the solution when estimating the real statistical GLONASS performance in local sites, but only those visible. When estimating the global average SIS URE, even one satellite affects the overall system performance. The correspondence of the observed statistical SIS URE estimates and the positioning error estimates to the standards established in this OS PS is provided in the respective sections of this Appendix.

C.1.7.3 Estimation of CSA Service Availability

Figures C1.16 – C.1.18 provide the GLONASS CSA Service Availability Estimation (horizontal and vertical, global average and worst-site). The threshold values of 95% positioning errors are 12 m horizontal and 25 m vertical (SIS only), respectively.

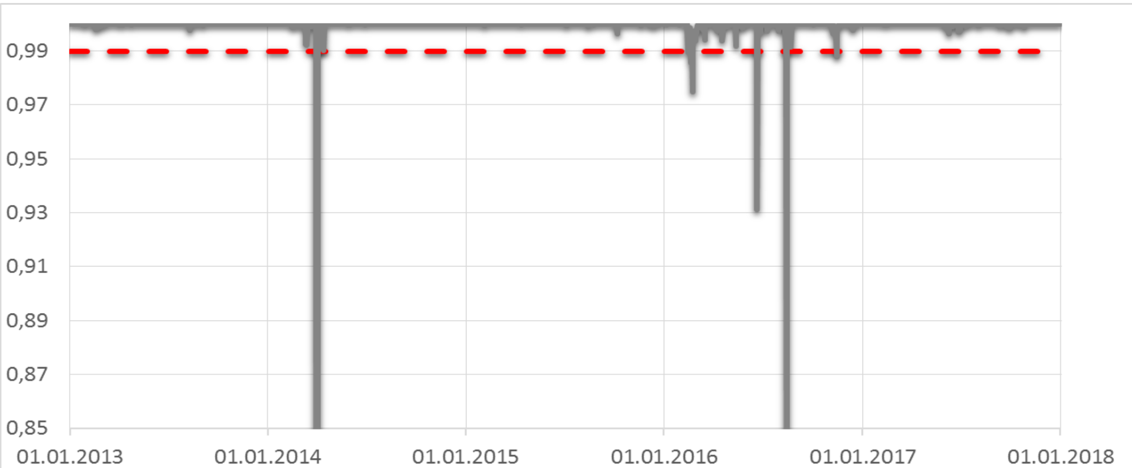

Figure C.1.15 — Global Average CSA Service Availability (12 m horizontal (SIS only) 95% threshold)

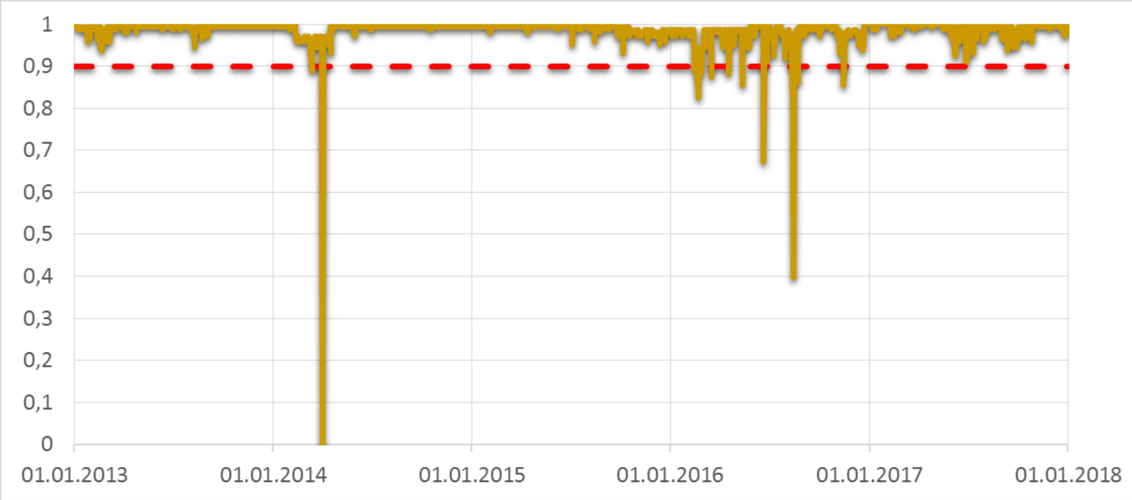

Figure C.1.16 — Worst-site CSA Service Availability (12 m horizontal (SIS only) 95% threshold)

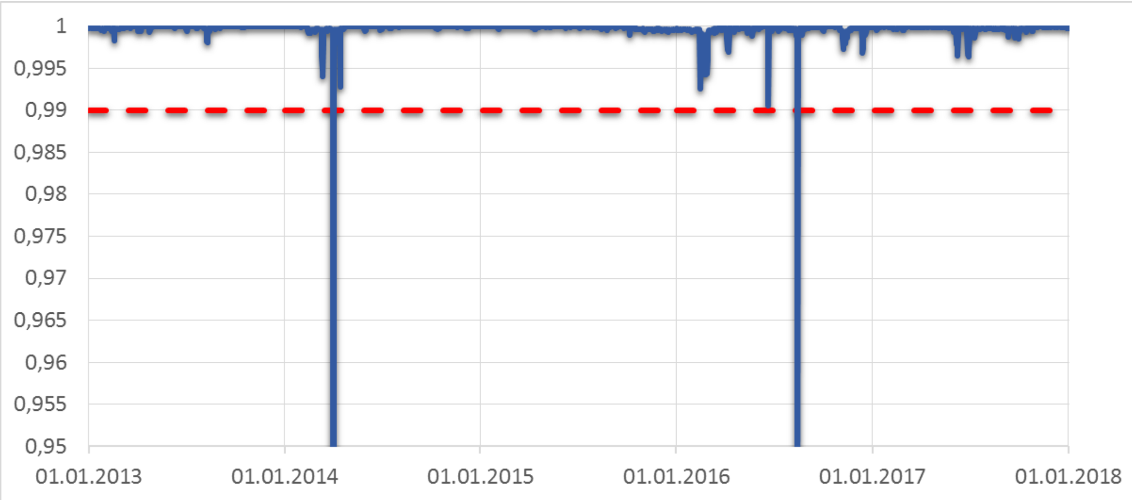

Figure C.1.17 — Global Average CSA Service Availability (25 m vertical (SIS only) 95% threshold)

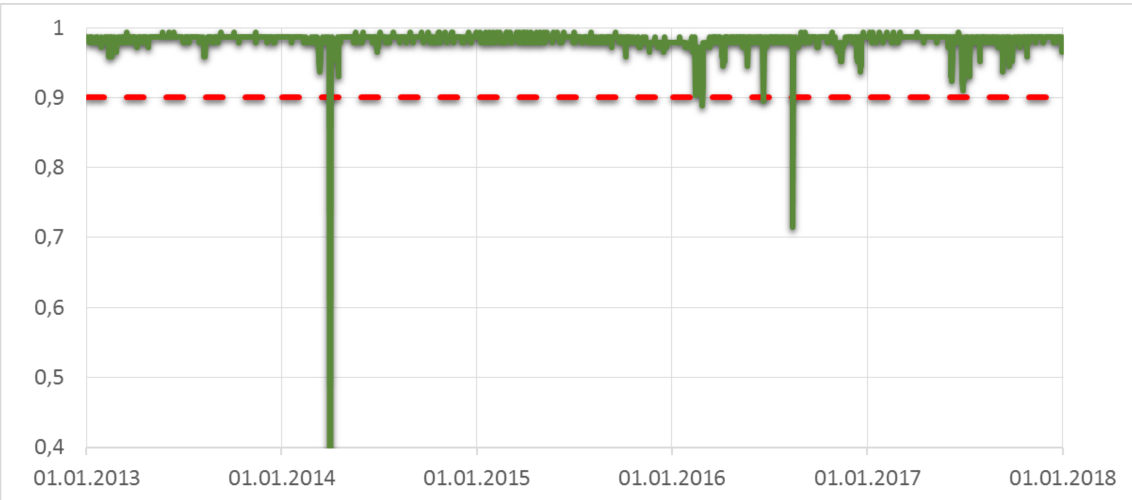

Figure C.1.18 — Worst-site CSA Service Availability (25 m vertical (SIS only) 95% threshold)

C.1.7.4 Estimation of CSA Time Transfer Accuracy)

C.1.19 provides estimation of the GLONASS Global Average Time Transfer Error (UTC(SU) Transfer Error).

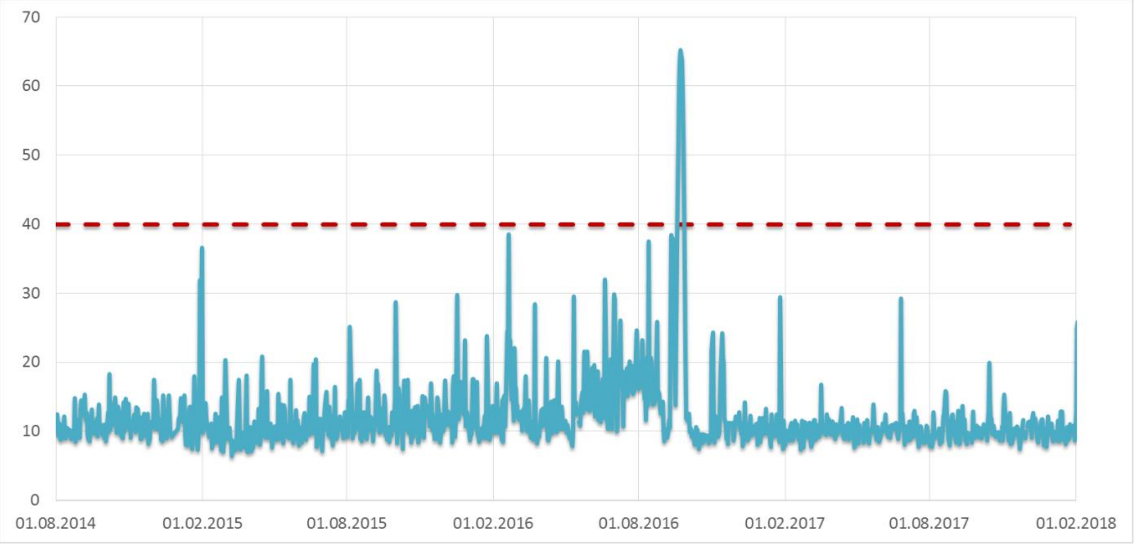

Figure C.1.19 — Global Average Time Transfer Error

C.1.20 provides the final estimation of the Global Average UTC(SU) Transfer Error, accounted for the SIS URE and the UTC(SU) to GLONASS Time Broadcast Offset.

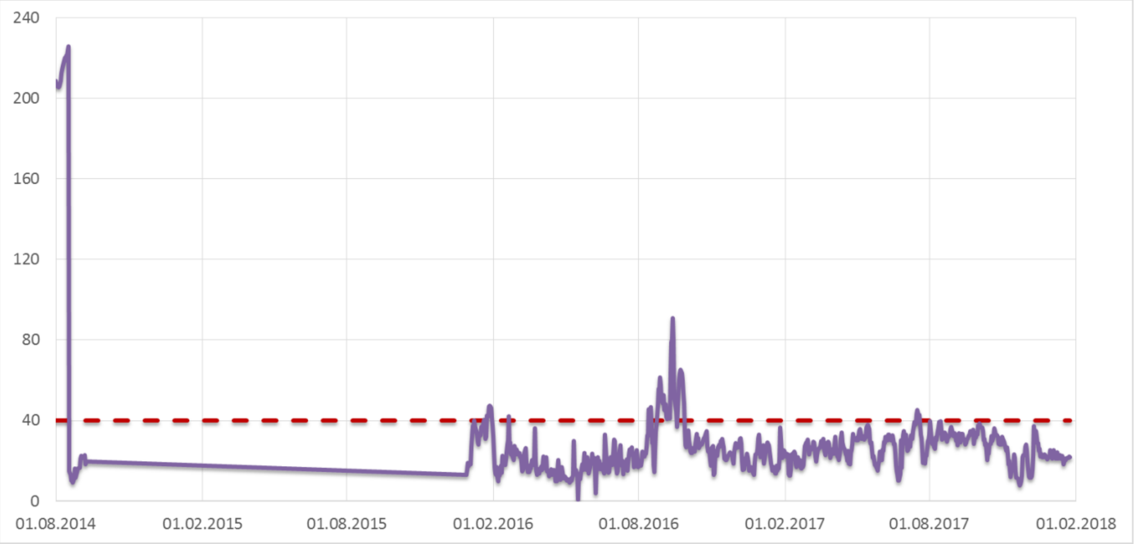

Figure C.1.20 — Global Average Time Transfer Error based on a measurement interval of 24 hours

C.2 Estimation of Failure Rate based on Monitoring Results

As a result of processing the real 2009–2014 data the estimation of the GLONASS Failure Rate was made using the criteria of instantaneous worst–site URE exceeding 70 m (SIS URE NTE Tolerance) and 18 m (threshold for reliability). C.2.1 provides the chart for GLONASS Failures in the period of 2009–2015. The failures are divided into two groups: ephemeris related and clock–related. C.2.1 gives an overview of the total number and the duration of the failures.

Table C.2.1 — Number and duration of failures in 2009–2015

	Clock Failure	Ephemeris Failure	Clock Failure	Ephemeris Failure
	(URE > 70 м)	(URE > 70 м)	(URE > 18 м)	(URE > 18 м)
	Total Number of Failures			
2009	2 (+1 system–level)	5	168 (+1 system–level)	30
2010	3	2	6	1
2011	4	7	26	3
2012	3	2	25	3
2013	2	2	6	2
2014	5	(+1 system–level)	10	0
2015	0	0	8	0
	Total duration of Failures, hour			
2009	18.16	4.33	1075.69	129.32
2010	20.00	30.00	26.00	16.19
2011	5.50	2.33	132.49	0.83
2012	7.00	3.65	178.67	11.36
2013	0.67	3.67	33.84	13.67
2014	5.00	9.83	29.68	0.00
2015	0.00	0.00	45.83	0.00

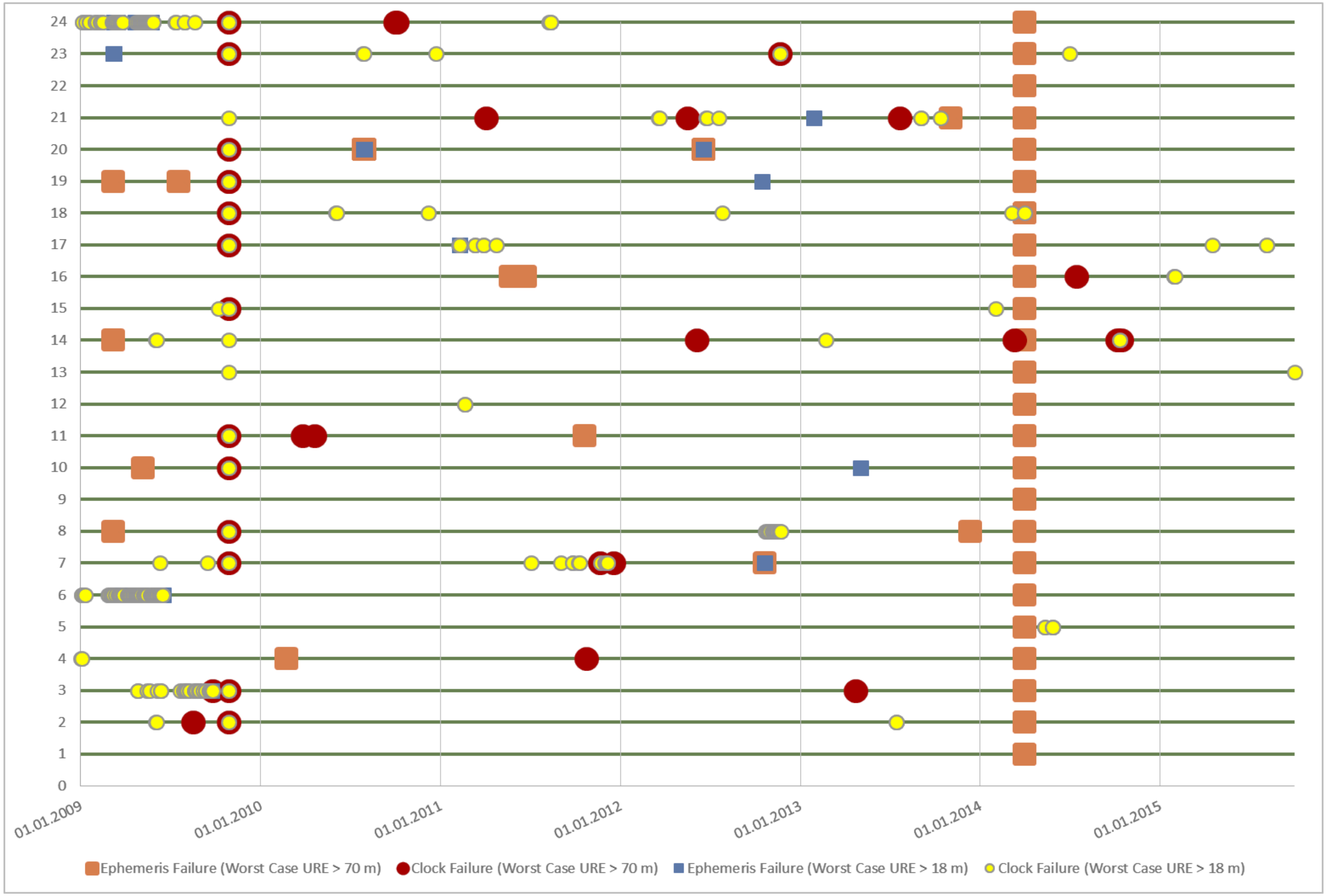

Figure C.2.1 — 2009–2015 GLONASS Failures (for every satellite of the 24-sat constellation)

C.2.2 and C.2.3 give the details of the major service failures (70 m threshold) and reliability failures (18 m threshold) in 2009–2015.

Table C.2.2 — Details of Major Service Failures of Glonass–M Sats (Worst–case SIS URE > 70 m), 2009–2015

Type of failure	URE behaviour	Number of Failures	Total duration, hour	Probability, 1e–6 /h/Sat	Probability, 1e–6 /Sat
Single (1 Sat)	Linear increase <0.01 m/s	2	3	1.36	2.04
Single (1 Sat)	Linear increase 0.01–0.05 m/s	–	–	–	–
Single (1 Sat)	Linear increase 0.05–0.25 m/s	–	–	–	–
Single (1 Sat)	Linear increase 0.25–0.50 m/s	–	–	–	–
Single (1 Sat)	Noise 70–300 m	2	23.65	1.36	16.07
Single (1 Sat)	Jump 70–300 m	3	5	2.04	3.40
Single (1 Sat)	Jump 300–700 m	6	32.34	4.08	21.97
Single (1 Sat)	Jump > 700 m	24	26.99	16.31	18.34
System–level (>1 Sat)	Jump 70–300 m	1	9.33	0.68	6.34
System–level (>1 Sat)	Jump 300–700 m	–	–	–	–
System–level (>1 Sat)	Jump > 700 m	1	9.83	0.68	6.68
	Total	39	110.14	26.50	74.84

Table C.2.3 — Details of reliability failures (Worst–case SIS URE > 18 m) of Glonass–M sats, 2009–2015

Type of failure	URE behaviour	Number of Failures	Total duration, hour	Probability, 1e–6 /h/Sat	Probability, 1e–6 /Sat
Single (1 Sat)	Linear increase <0.01 m/s	266	157.02	180.75	1068.86
Single (1 Sat)	Linear increase 0.01–0.05 m/s	11	72.84	7.47	49.49
Single (1 Sat)	Noise 20–70 m	2	17.38	1.36	11.81
Single (1 Sat)	Jump 40–70 m	9	29.16	6.12	19.81
System–level (>1 Sat)	Jump 40–70 m	1	1	0.68	0.68
	Total	289	1693.4	196.37	1150.66

The analysis of the provided data shows, that the number and the duration of failures have been decreasing, excluding the major system–level failure in April, 2014. In 2015 there were no major service failures. It is also supported by the estimation of the probability of a major service failure and reliability as provided in C.1.4 and C.1.3.1.1. As it can be seen on C.1.8, starting from 2011, the probability of single independent failures does not exceed 10^{-4}. The additional reliability tolerance for major service failures is due to the fact, that the probability is defined irrespective of the type of the failure and includes, among others, the failures resulting in URE exceeding 700 m. Receiver algorithms can handle such errors using step detector; they shall not be accounted for by FDE algorithms.

In 2009 the duration of failures of two and more satellites was 9.33 hours, in 2014 — 9.83 hours. Over the last 8 year interval, from the beginning of 2010 to the end of 2017 the probability of a major service failure is as per the formula:

$$Pconst = \frac{D_{2014}}{31.12.2017 - 01.01.2010} = \frac{9{,}83}{70104} = 1.4 \cdot 10^{-4}.$$

Taking into account that the calculation method does not account for the prompt elimination of the consequences of such rare events as well as for the significant ease of error burden in a multi–system receiver, the above provided value seems very pessimistic, however close enough that we can assume Pconst = 10^{-4}.

Table C.2.4 provides the general summarized list and details of the GLONASS failures in 2013–2015.

Table C.2.5 — List and Details of the GLONASS Failures in 2013–2015

Sat	Date	Durat., h	Reason	Consequences	GA URE, m	WC URE, m	SVOEVP (integrity failure in daily bulletins)	SDCM (max error)
3	23.04.2013	0.17	wrong health status (delay) for clock failure	(URE > 70 m)	663,109	–664,232	>50 m	1,92E+08
21	21.07.2013	0.5	wrong health status (time of initiation) for clock failure	(URE > 70 m)	423,589	423,91		429,23
14	11.03.2014	3	wrong health status (delay) for clock failure	(URE > 70 m)	3097,268	3097,675	>50 m	5248,23
16	15.07.2014	0.5	wrong health status (time of initiation) for clock failure	(URE > 70 m)	2389,032	2389,961	>50 m	2388.21
14	07.10.2014	0.5	Clock jump	(URE > 70 m)	12597,48	12597,946	>50 m	9,7
14	09.10.2014	0.5	Clock jump	(URE > 70 m)	1153,006	1153,147		4080,27
14	15.10.2014	0.5	Clock jump	(URE > 70 m)	378,089	378,753		9,25
21	02.11.2013	2.67	wrong health status (delay) for ephemeris jump	(URE > 70 m)	265,044	331,408		270,41
8	12.12.2013	1	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41225235	45427026	>50 m	8,03
1	01.04.2014	4.5	wrong health status (delay) for ehemeris failure	(URE > 70 m)	37855,263	50010,382	>50 m	4,00E+05
2	01.04.2014	7	wrong health status (delay) for ephemeris failure	(URE > 70 m)	40671,829	53804,209	>50 m	4,00E+05
3	01.04.2014	8.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41384,333	54771,062	>50 m	4,00E+05
4	01.04.2014	8.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41397,871	54778,426	>50 m	4,00E+05
5	01.04.2014	9.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	37988,564	50189,375	>50 m	4,00E+05
6	01.04.2014	1	wrong health status (delay) for ephemeris failure	(URE > 70 m)	40839,06	54030,649	>50 m	4,00E+05
7	01.04.2014	2	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41482,33	54898,865	>50 m	4,00E+05
8	01.04.2014	2.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41485,532	54891,593	>50 m	4,00E+05

Sat	Date	Durat., h	Reason	Consequences	GA URE, m	WC URE, m	SVOEVP (integrity failure in daily bulletins)	SDCM (max error)
9	01.04.2014	5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	30687.712	40437.364	>50 m	4.00E+05
10	01.04.2014	6	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41469.404	54876.596	>50 m	4.00E+05
11	01.04.2014	7.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41418.535	54803.311	>50 m	4.00E+05
12	01.04.2014	9	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41503.421	54916.309	>50 m	4.00E+05
13	01.04.2014	9.83	wrong health status (delay) for ephemeris failure	(URE > 70 m)	30765.696	40542.102	>50 m	4.00E+05
14	01.04.2014	1.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41398.268	54781.341	>50 m	4.00E+05
15	01.04.2014	2.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41421.51	54806.081	>50 m	4.00E+05
16	01.04.2014	4	wrong health status (delay) for cephemeris failure	(URE > 70 m)	41362.925	54731.837	>50 m	4.00E+05
17	01.04.2014	6	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41335.542	54693.782	>50 m	4.00E+05
18	01.04.2014	4	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41143.758	54436.695	>50 m	4.00E+05
19	01.04.2014	8	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41429.577	54800.897	>50 m	4.00E+05
20	01.04.2014	9.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	39293.666	51925.54	>50 m	4.00E+05
21	01.04.2014	10.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41295.988	54643.681	>50 m	4.00E+05
22	01.04.2014	9.5	wrong health status (delay) for ephemeris failure	(URE > 70 m)	41552.694	54997,913	>50 m	4.00E+05
23	01.04.2014	1	wrong health status (delay) for ephemeris failure	(URE > 70 m)	38056.882	50290.494	>50 m	4.00E+05
24	01.04.2014	2.33	wrong health status (delay) for ephemeris failure	(URE > 70 m)	38458.764	50802.994	>50 m	4.00E+05
14	21.02.2013	15.17	Smooth increase of clock parameters	(URE > 18 m)	36.853	–37.941	>50 m	40.11

Sat	Date	Durat., h	Reason	Consequences	GA URE, m	WC URE, m	SVOEVP (integrity failure in daily bulletins)	SDCM (max error)
2	14.07.2013	3.33	Smooth increase of clock parameters	(URE > 18 m)	20.252	-21.,279	>50 m	n/a
2	15.07.2013	6.5	Smooth increase of clock parameters	(URE > 18 m)	24.001	-25.039	>50 m	5.39
21	02.09.2013	6.17	Smooth increase of clock parameters	(URE > 18 m)	23.415	24.707	>50 m	21.09
21	03.09.2013	2.5	Smooth increase of clock parameters	(URE > 18 m)	26.936	28.284	>50 m	25.42
21	13.10.2013	0.17	wrong health status (delay) for clock failure	(URE > 18 m)	59.911	60.268		61.16
15	02.02.2014	0.17	8 ns clock jump followed by smooth increase	(URE > 18 m)	16.496	18.285	>50 m	17.9
18	07.03.2014	3.17	15 ns clock jump	(URE > 18 m)	18.083	19.4	>50 m	23.54
18	01.04.2014	4.5	Clock failure	(URE > 18 m)	17.746	-20/293	>50 m	37900.39
5	12.05.2014	0.17	Smooth increase of clock parameters	(URE > 18 m)	20.822	20.863	>50 m	20.19
5	12.05.2014	3.33	Smooth increase of clock parameters	(URE > 18 m)	20.822	20.863	>50 m	20.19
5	28.05.2014	0.17	п Smooth increase of clock parameters	(URE > 18 m)	20.678	21.532	>50 m	18.45
5	28.05.2014	4.17	Smooth increase of clock parameters	(URE > 18 m)	20.678	21.532	>50 m	18.45
5	29.05.2014	13.33	Smooth increase of clock parameters	(URE > 18 m)	32.923	34.587	>50 m	4.32E+08
23	01.07.2014	0.17	Smooth increase of clock parameters	(URE > 18 m)	17.419	-18.127	>50 m	21,19
14	11.10.2014	0.5	clock parameters failure	(URE > 18 m)	56.689	56.924	>50 m	9,95
16	29.01.2015	12	Smooth increase of clock parameters	(URE > 18 m)	28.345	29.023	>50 m	27.4
16	30.01.2015	3.33	Smooth increase of clock parameters	(URE > 18 m)	19.338	-22.054	>50 m	16.26

Sat	Date	Durat., h	Reason	Consequences	GA URE, m	WC URE, m	SVOEVP (integrity failure in daily bulletins)	SDCM (max error)
16	31.01.2015	12	Smooth increase of clock parameters	(URE > 18 m)	34.534	–35.984	>50 m	36.81
17	17.04.2015	4	Smooth increase of clock parameters	(URE > 18 m)	16.605	19.564	>50 m	n/a
17	05.08.2015	1.83	Smooth increase of clock parameters	(URE > 18 m)	19.223	19.56	>50 m	n/a
17	06.08.2015	0.17	Smooth increase of clock parameters	(URE > 18 m)	18.031	18.204		n/a
13	01.10.2015	8	Smooth increase of clock parameters	(URE > 18 m)	28.534	28.926	>50 m	n/a
13	02.10.2015	4.5	Smooth increase of clock parameters	(URE > 18 m)	25.13	26.312		n/a
21	29.01.2013	8	Ephemeris accuracy drop (R,N)	(URE > 18 m)	53.55	64.71	>50 m	53.57
10	03.05.2013	5.67	Ephemeris accuracy drop (R,N)	(URE > 18 m)	32.82	48.937	n/a	35.2

The comparison with the data provided by SDCM and SVOEVP (www.glonass–svoevp.ru) in Table C.2.4 supports the .... of the GLONASS failure estimation in 2013–2015. The analysis of the input data shows that some of the failures can be connected with the heterogeneity of receivers used by the IGS stations. It is worth mentioning, that these receivers differ by type, manufacturer, software, and output data. These all lead to the significant differences of systematic errors in every single receiver. Moreover, as IGS was established as a voluntary organization based on international cooperation, its receiver output data can not be fully supervised with respect to the relevance of satellite health indications, processing of the reference time of the ephemeris and clock, etc.

The above mentioned errors can not be fully traced by the autonomous facilities, that is why every failure shall be approached individually.

The situation can be changed for better for GLONASS by establishing Russia's own global network of sensor stations employing several units of single–type receivers. While there is no such a network, the alternative could be promotion in the ICG of the idea to generate files incorporating the full set of navigation message digital data along with the RINEX files. The GRIL format used in JAVAD and Topcon receivers can serve as an example. The significant amount of such receivers currently in use within the IGS network can facilitate building the sub–network of receivers capable of providing the maximum set of data.