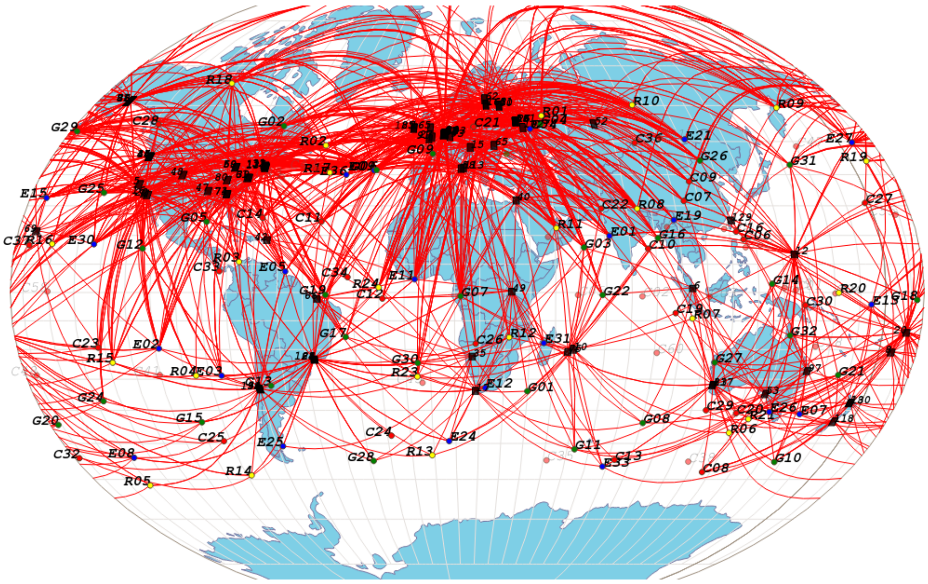
The *unofficial* Galileo Weekly Performance Report
Sat, 26 Sep 2020 23:59:42 +0000 - Sat, 03 Oct 2020 23:59:42 +0000
(WN 1101)

The galmon.eu project



Monday 5th October, 2020

contact: bert@hubertnet.nl

Abstract

Performance this week was 57% nominal, which means that close to 43% of the time at least a single SV was unavailable.

This week saw maintenance of E24 and a prolonged marginal (unavailable) period from E02.

In addition, there were severe uplinking problems leading many SVs to broadcast older ephemerides. For most satellites this was not a problem, but E11's unruly clock diverged by +15 and -15 nanoseconds during the week. No NAGU or SISA update was issued for this 5 meter error.

The cause of the uplinking problem is an under-resourced Galileo ground segment, as elaborated in this week's summary in chapter 2.

In happier news, we previously reported an odd situation where the two combined clock signals from E24 were remarkably different, which caused hard to understand realtime corrections for this satellite. When properly understood, this was not a problem. But, after the maintenance, the two E24 clocks are now very close together, making life simpler for everyone.

This week, on average 0.1% of the earth's surface violated the PDOP performance level for 5 degree elevation satellites, while 1.0% was violated for 10 degree elevation. See 1.2 for finer definitions of these metrics.

See chapter 2 for further details.

Contents

Chapter 1

Introduction

The galmon.eu project strives to publish a weekly unofficial Galileo Performance Report every week. In good weeks, this report will have been processed manually, removing measurement anomalies and other oddities. If we are too busy, there will be an automated report that might for example show bad behaviour of satellites undergoing planned maintenance.

Automated reports will clearly be flagged as such.

Despite this, it should be noted that even manually processed reports only show what we can see. If we report on a problem, it is entirely possible we are misunderstanding a situation.

In addition, even when we show problems for individual Galileo satellites, this in no way means Galileo performance was impaired. We have separate graphs for that.

Finally, we do report on global metrics such as "x% of the Earth's surface not having Galileo coverage, as defined by being able to see 4 satellites more than 5 degrees above the horizon".

These metrics are defined in the Galileo Service Definition Document, but the SDD also states that the defined Minimum Performance Level is not breaching such a metric for more than 7 days in a row.

Our reports only talk about instantaneous breaches of such performance levels. Readers can determine for themselves if a 6 day breach of a performance level also constitutes a breach of the Minimum Performance Levels.

Official Galileo Performance Reports are published on the site of the Galileo Service Centre.

1.1 Intended use

These reports are provided in the hope that these will be useful for the Galileo project. The same goes for our live dashboard on `https://galmon.eu`.

If anything in these reports is found to be incorrect, or in need of explanation, feedback is most welcome (bert@hubertnet.nl). Similarly, suggestions for additional graphs or metrics are much appreciated.

1.2 Performance levels

As noted, the Galileo SDD contains many performance definitions. We try to align to metrics also present in the SDD, but also provide additional numbers that may be more operationally relevant on a per-week basis.

The SDD defines a Positional Dilution of Precision (PDOP) of more than 6.0 as a performance level threshold, measured for a receiver able to see satellites more than 5 degrees above the horizon.

In addition, the SDD requires visibility of 4 or more satellites more than 5 degrees above the horizon.

Beyond the SDD's 5 degree limit, we also report on a more realistic 10 degree limit (which is closer to what users would encounter).

Galileo currently has a constellation of 22 healthy satellites. This is two less than the design, but for reporting purposes, we consider 22 to be the nominal constellation size.

1.3 Data sources, acknowledgments

This report is based on many data sources, and we are very grateful for all the data that is being made public. Such transparency enables great reporting.

We specifically acknowledge the following great data sources:

- DLR and Spaceopal provide a realtime RTCM State Space Representation feed, which we use to plot orbit errors
- CNES provides a similar but independent feed, which makes it possible to separate measurement problems from Galileo problems
- GFZ Potsdam provides excellent post-processed orbit data (SP3) which provide even more authoritative orbit data
- ESA/ESOC provides similar data, calculated independently
- The International GNSS Service (IGS) who distribute and coordinate a vast network of files and realtime streams
- The galmon.eu volunteer receiver network, using over 80 stations around the world to receive each and every Galileo (and BeiDou, GLONASS and GPS) message

Galmon.eu would not be possible without the many many volunteer station operators around the world.

In addition, we thank the Galileo Service Centre and the Spaceopal NAVCAST helpdesks for patiently answering our many questions.

We also thank the European Commission's Joint Research Centre for authoring the NeQuick G model used in this report.

Finally, a large cast of mostly anonymous engineers, researchers, scientists, operators and Galileo customers have provided very valuable insights that made this report possible, and hopefully useful.

1.4 About us

We are an independent project, not affiliated with any Galileo vendor or organization.

The galmon.eu network is described in this post by Bert Hubert.

A presentation about our technologies is here.

The source code to our project can be found on GitHub.

Chapter 2

Weekly summary & open items

This week saw maintenance of E24 and a prolonged marginal (unavailable) period from E02.

In addition, there were severe uplinking problems leading many SVs to broadcast older ephemerides. For most satellites this was not a problem, but E11's unruly clock diverged by +15 and -15 nanoseconds during the week. No NAGU or SISA update was issued for this 5 meter error.

The root cause appears to be that one uplink station was unavailable for a large part of the week, meaning Galileo uplink capacity was significantly impaired.

If a Galileo satellite is out of reach, it does not know if its clock is off, and it can not update its own Signal In Space Accuracy. E11 was out of communications for two stretches of 3.5 hours each, during which time the clock diverged 15 nanoseconds, once in the positive direction, once in the negative.

The eccentric testing satellites E14 and E18 have received a software upgrade that causes them to flag themselves as unhealthy if they haven't received an update from the ground in 60 minutes. Given the nature of the E11 clock, it seems it would be very wise if it too would autonomously set its "Working Without Guarantee" flag after an hour. This may prove difficult because E11 is a very different satellite than E14 and E18 though, which means new software may have to be developed.

I continue to not understand how 10 billion euros was spent on Galileo and then we struggle to get sufficient ground segment antennas working to reliably talk to all Galileo satellites at the same time. With the advent of OSNMA and HAS (both of which need realtime ground communications), plus the upcoming launch of new satellites, this is becoming ever weirder.

Nominally, there should be 20 working satellite dishes to talk to the 24 active Galileo SVs. This number 20 has not been reached in ages, and is unlikely to be reached soon. I am told an earlier design goal was 10, which is even stingier.

If we equip the satellites with four different clocks, redundant computers, controllers and everything, why do we then have less than one satellite dish per SV? Why not have 40 dishes? As seen above in this picture by Galmon.eu operator Théophile from Réunion, the antennas are not particularly special.

In happier news, we previously reported an odd situation where the two combined clock signals from E24 were remarkably different, which caused hard to understand realtime corrections for this satellite. When properly understood, this was not a problem. But, after the maintenance, the two E24 clocks are now very close together, making life simpler for everyone.

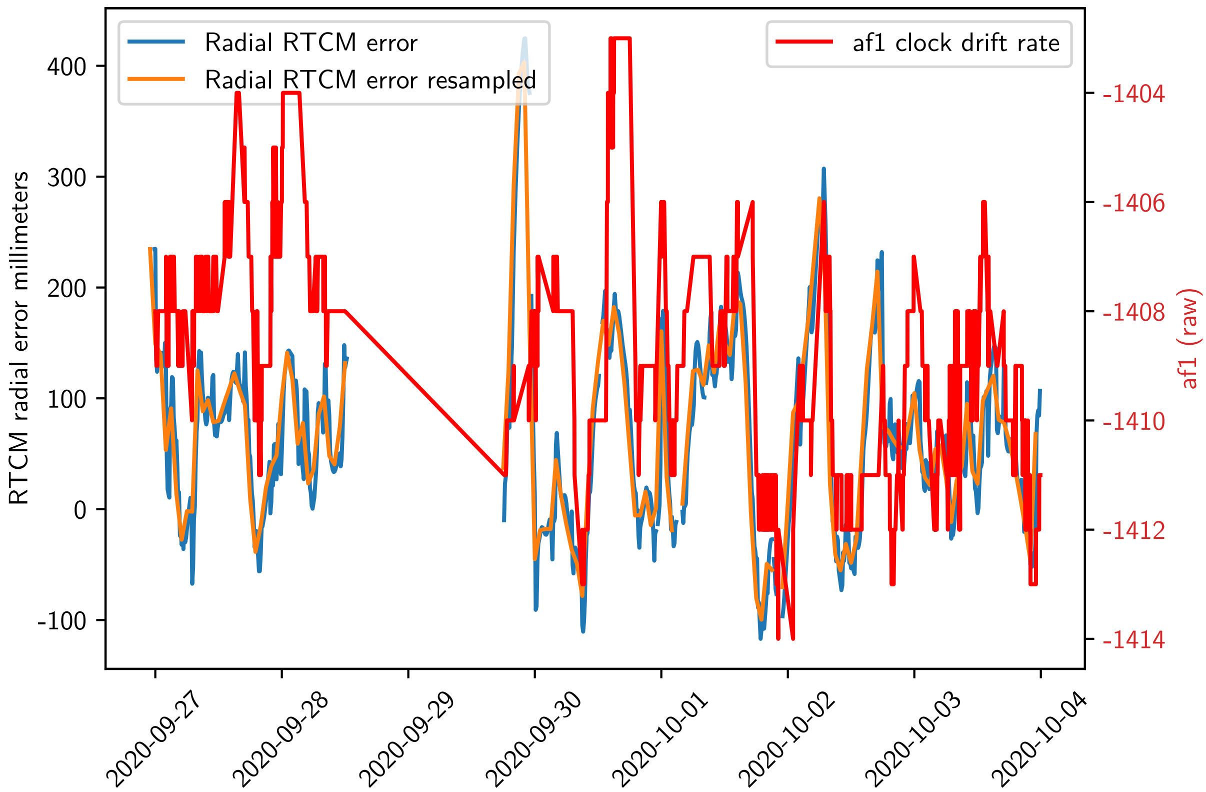
It is still not clear why the difference was so large in the first place.

This week, on average 0.1% of the earth's surface violated the PDOP performance level for 5 degree elevation satellites, while 1.0% was violated for 10 degree elevation. See 1.2 for finer definitions of these metrics.

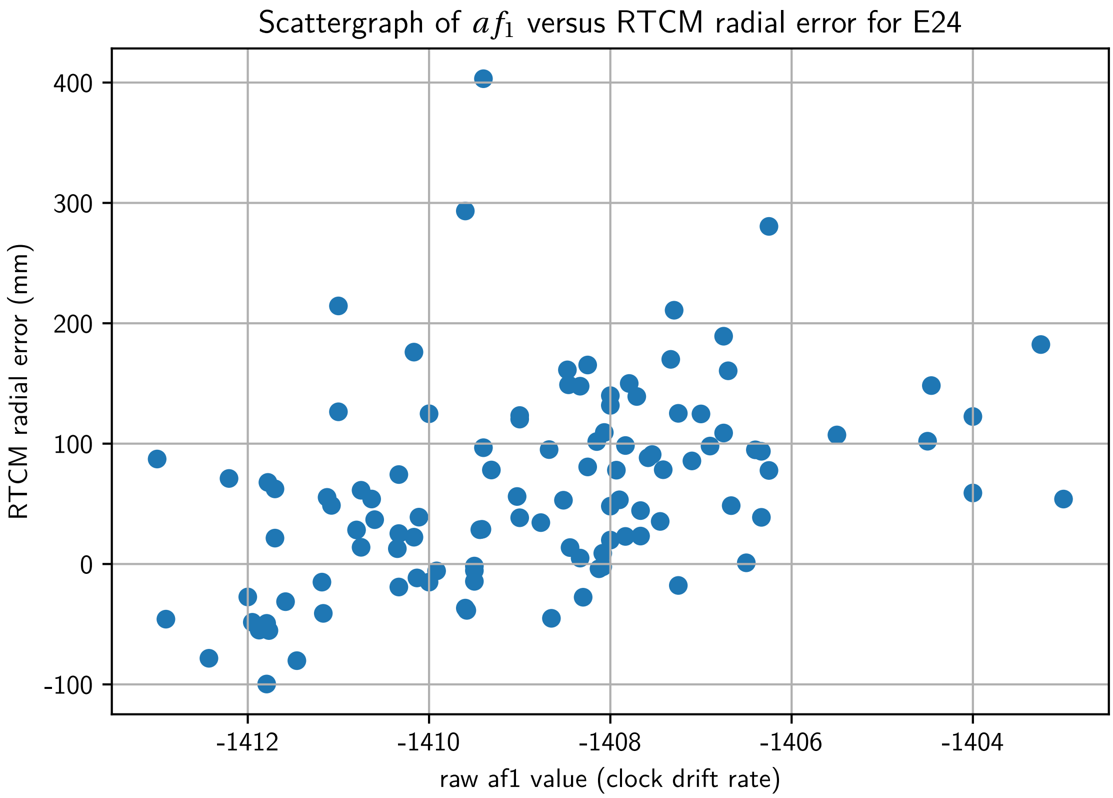
2.1 Ongoing oscillatory oddity

As observed in the rest of this report, most measured errors show an oscillation with a period that seems similar to the Galileo orbital period.

Here is a graph of the E24 RTCM radial error (left axis) and the raw af_1 clock drift parameter (right axis).



There appears to be a strong correlation between these two metrics:



This correlation is strong enough that Galileo orbit errors can meaningfully be improved by applying a correction based on the reported af_1. We also observe however that there is a corresponding and inverse signal in the clock error. As such the impact on the SISE (see below) is not as pronounced.

The oscillation may indicate a transfer of uncertainty from the space to the time component.

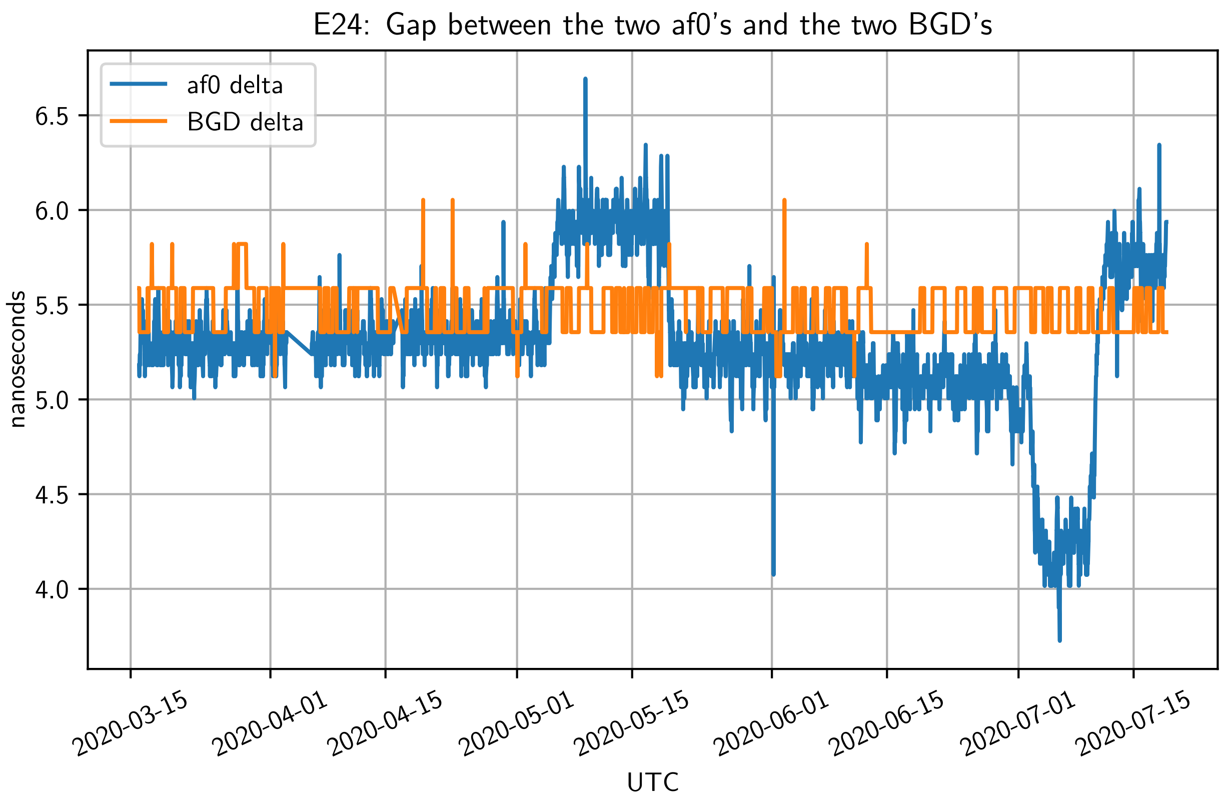
2.2 Broadcast Group Delay and clock parameters

As elaborated in the earlier blog post "Multi-Signal GNSS & the Curious Case of Galileo E24: Part 1", Galileo is defined in terms of two ionosphere-free clock combinations: E1/E5a (F/NAV) and E1/E5b (I/NAV).

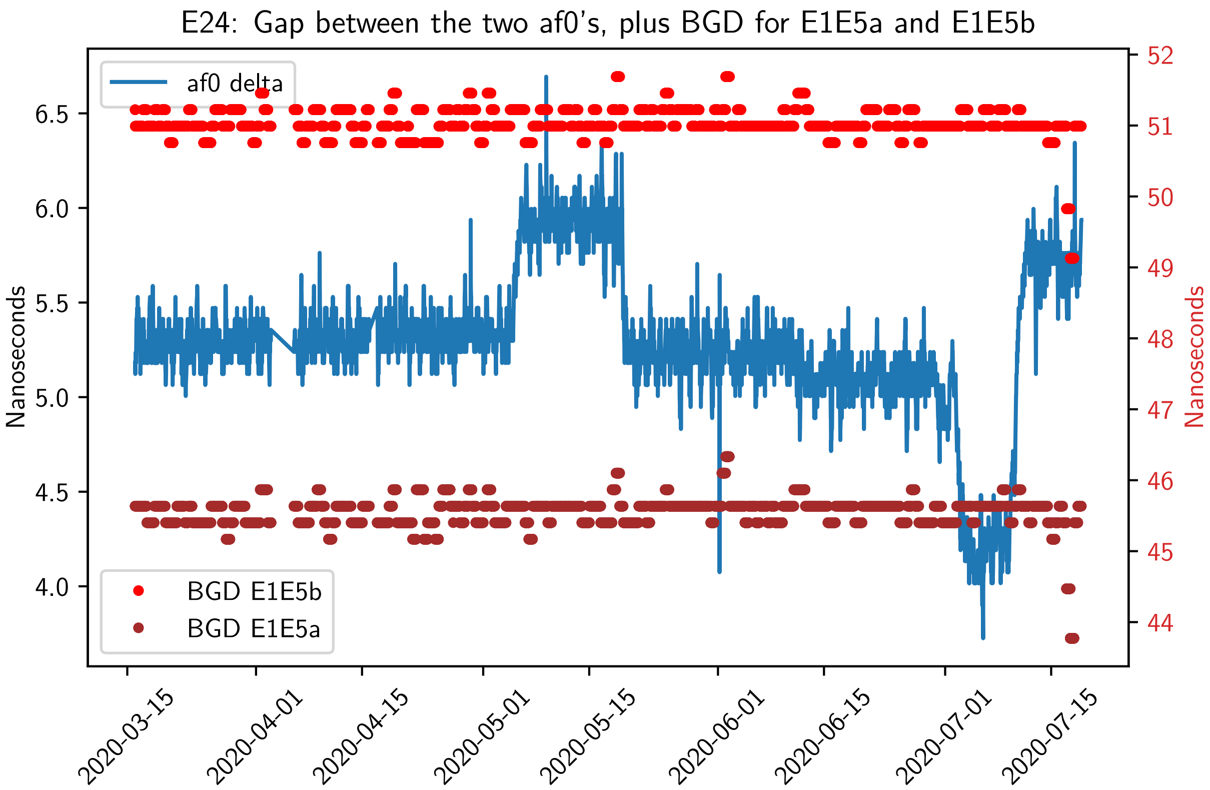
These two clocks are usually very similar, except for E24 which sports a 5 nanosecond gap, likely because of delays within spacecraft RF systems.

In studying an oddity in the RTCM SSR data for E24, we ran into a slight mismatch between the gaps between the two af_0 parameters, and the gap between BGDE1E5a and BGDE1E5b. On first reading we think these gaps should be identical, modulo quantization effects. But it appears they aren't.

This graph is based on ephemeris data from DLR BRDM series:



From the following graph we can see that both the Broadcast Group Delay parameters shift, sometimes in unison:



It appears that since the maintenance performed on E24 last week (29th of September), the gap between the I/NAV and

F/NAV clock has been reduced to almost zero, meaning this issue has likely disappeared.

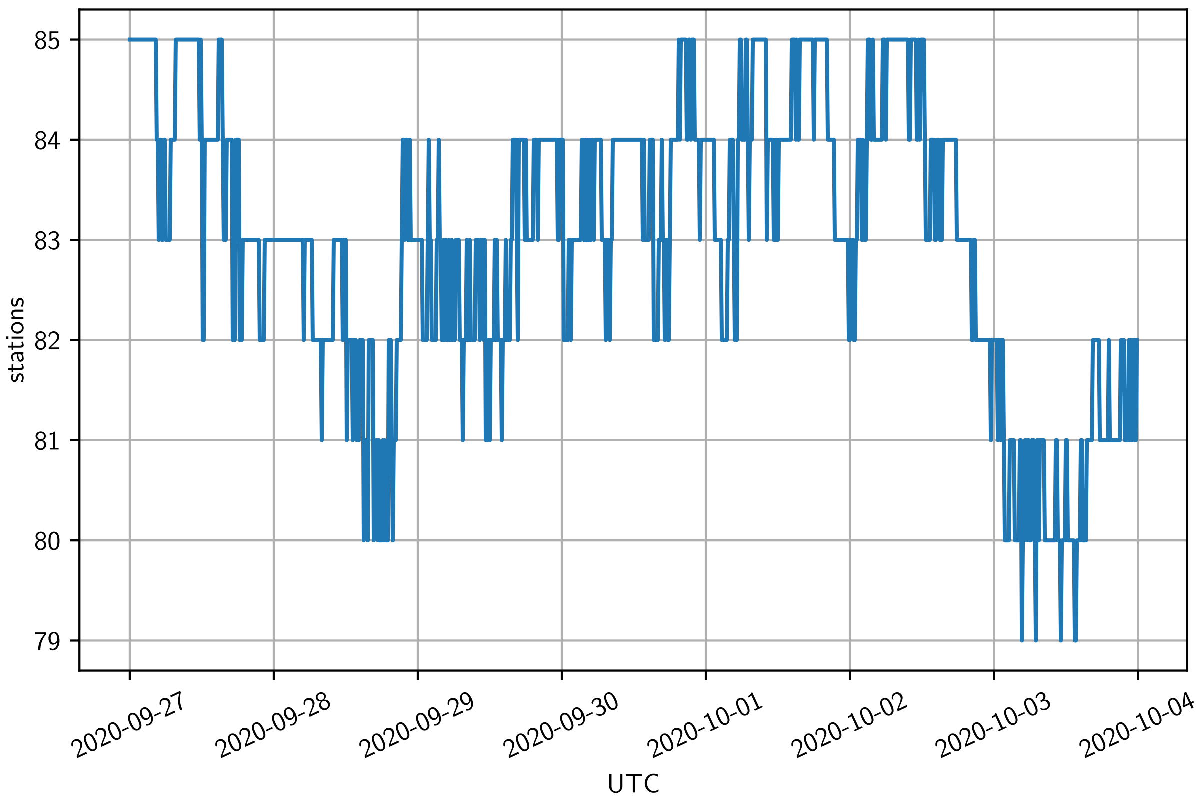
Chapter 3

Availability

3.1 The galmon.eu network

Nominally there are around 85 stations active in the galmon.eu network. Because many of our stations are in faraway places, connectivity and power sometimes suffer. This graph shows if we had any problems over the reporting period.

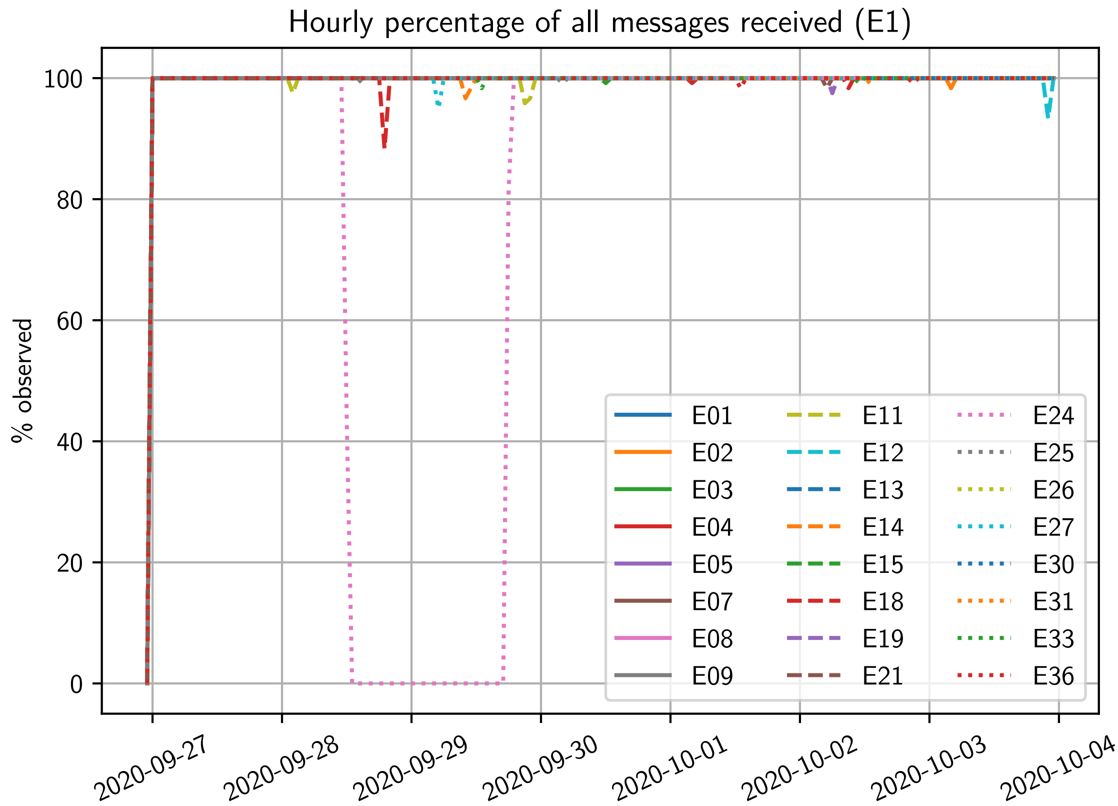
Note that most stations only see the E1 band, some see E5b and one sees E5a and E6. We're working on expanding this coverage.



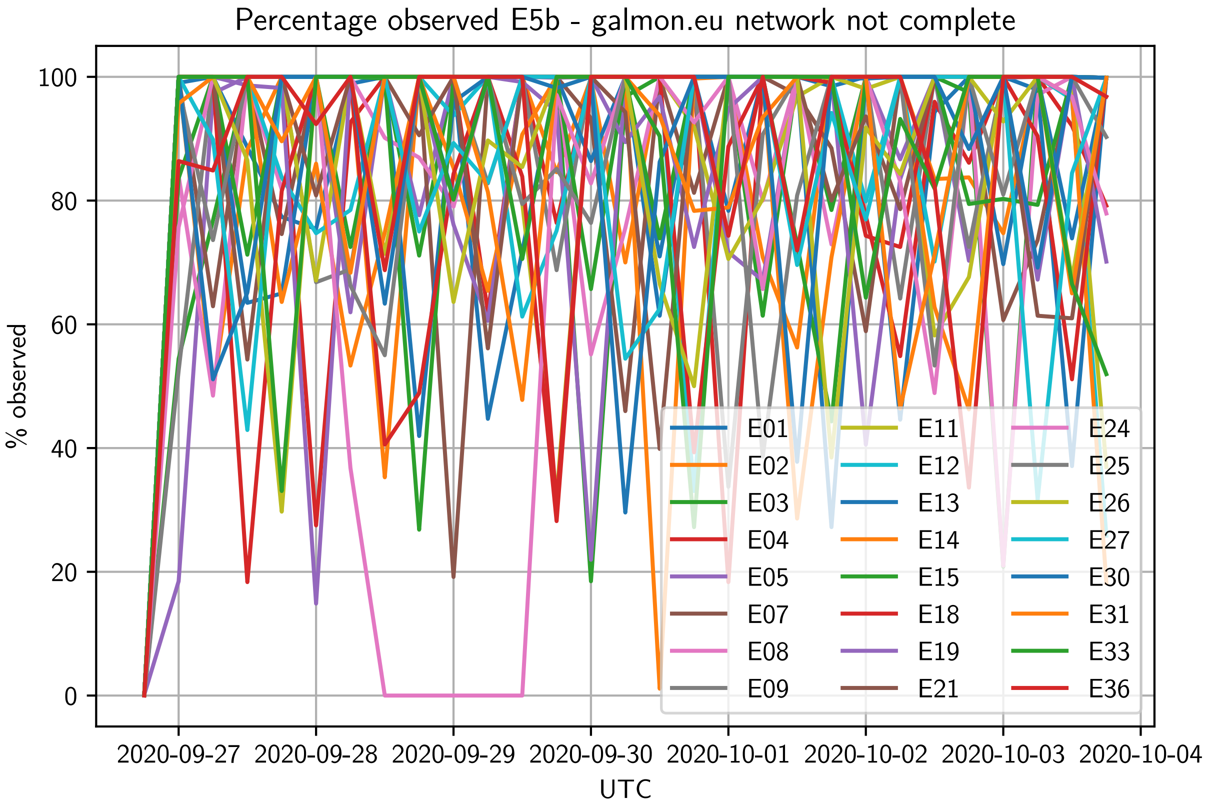
3.2 Percentage observed

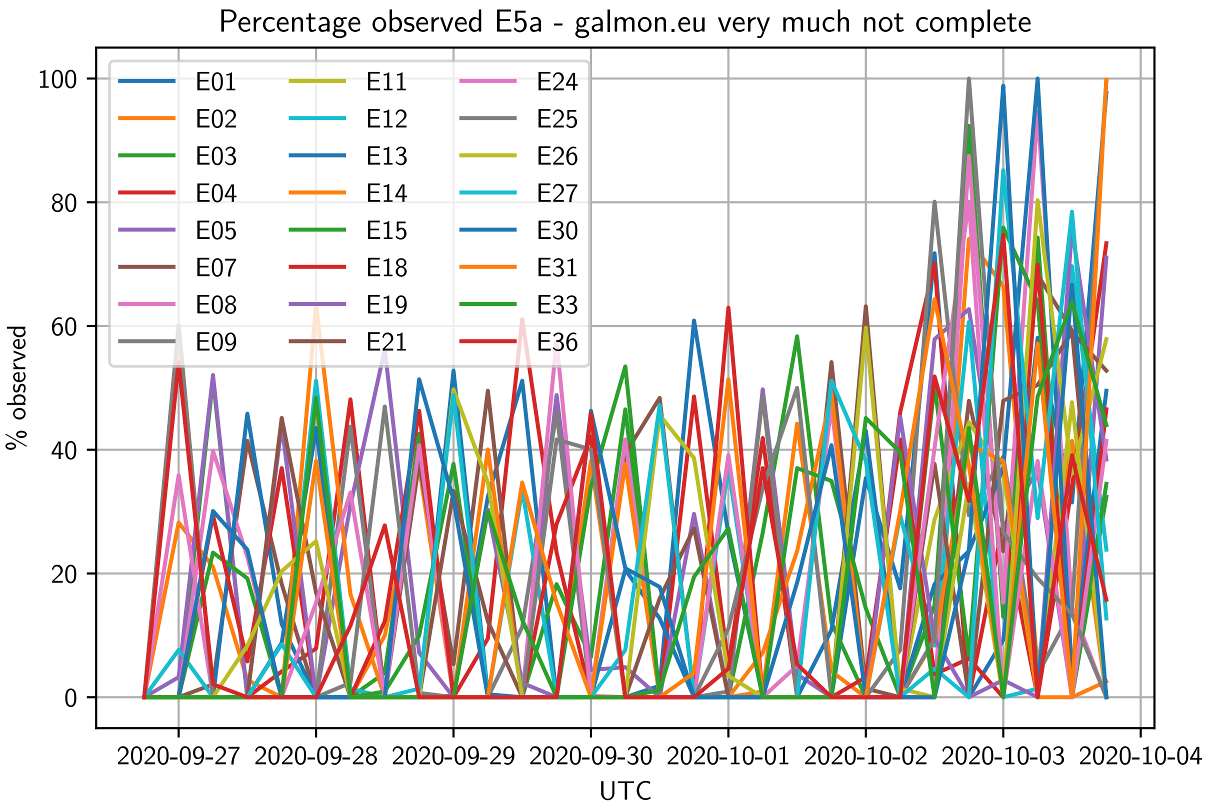
The galmon.eu network strives for 100% coverage of all Galileo transmissions. This is not an easy bar to reach since many receivers will miss double percentage fractions of transmissions. We compensate for this by having a large number of receivers.

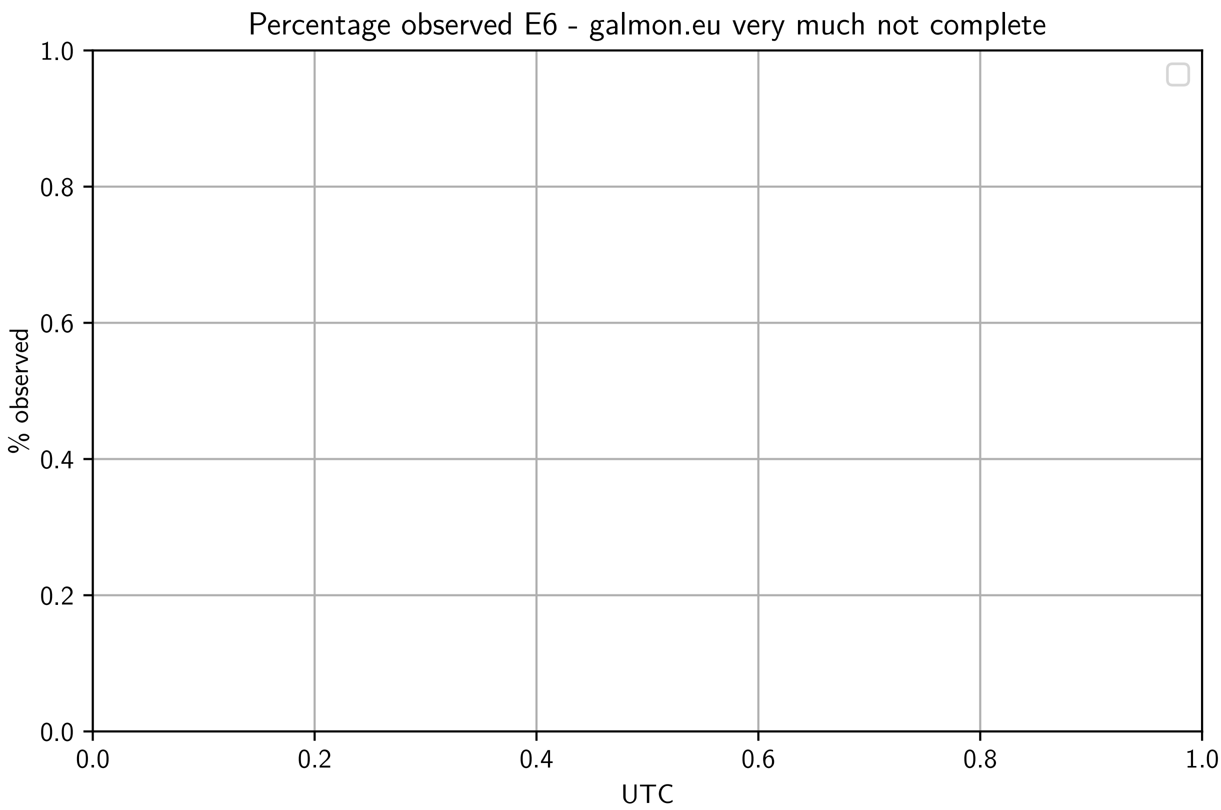
Despite this, some messages are not received. If some messages are missed briefly, this likely indicates a deficiency of the galmon.eu network. If there is a more prominent dip, this likely indicates a problem with the satellite. Note that it is normal for this graph to go to zero at the end or beginning of the reporting period.



Our network also covers the E5b, E5a and even the E6 bands, but our coverage is far less complete:


Percentage observed E5b - galmon.eu network not complete
% observed
UTC
0
20
40
60
80
100
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E13 E14 E15 E18 E19 E21 E24 E25 E26 E27 E30 E31 E33 E36

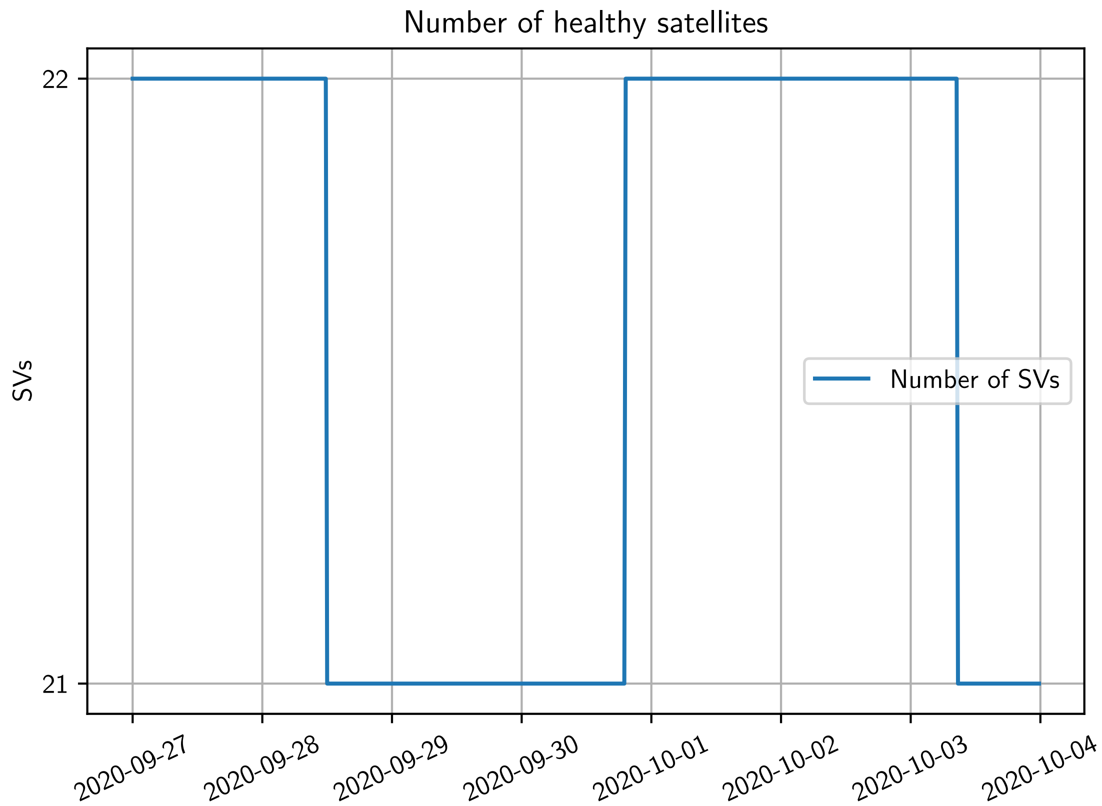

Percentage observed E5a - galmon.eu very much not complete
% observed
UTC
0
20
40
60
80
100
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E13 E14 E15 E18 E19 E21 E24 E25 E26 E27 E30 E31 E33 E36



If you can spare us an SBF feed from your Septentrio device, this would be most helpful!

3.3 Healthy satellites

Satellites can be healthy, unhealthy or marginal. The difference between the last two categories is academic since no marginal satellites should be used.



In the following table, the distribution of status of all non-testing SVs can be observed:

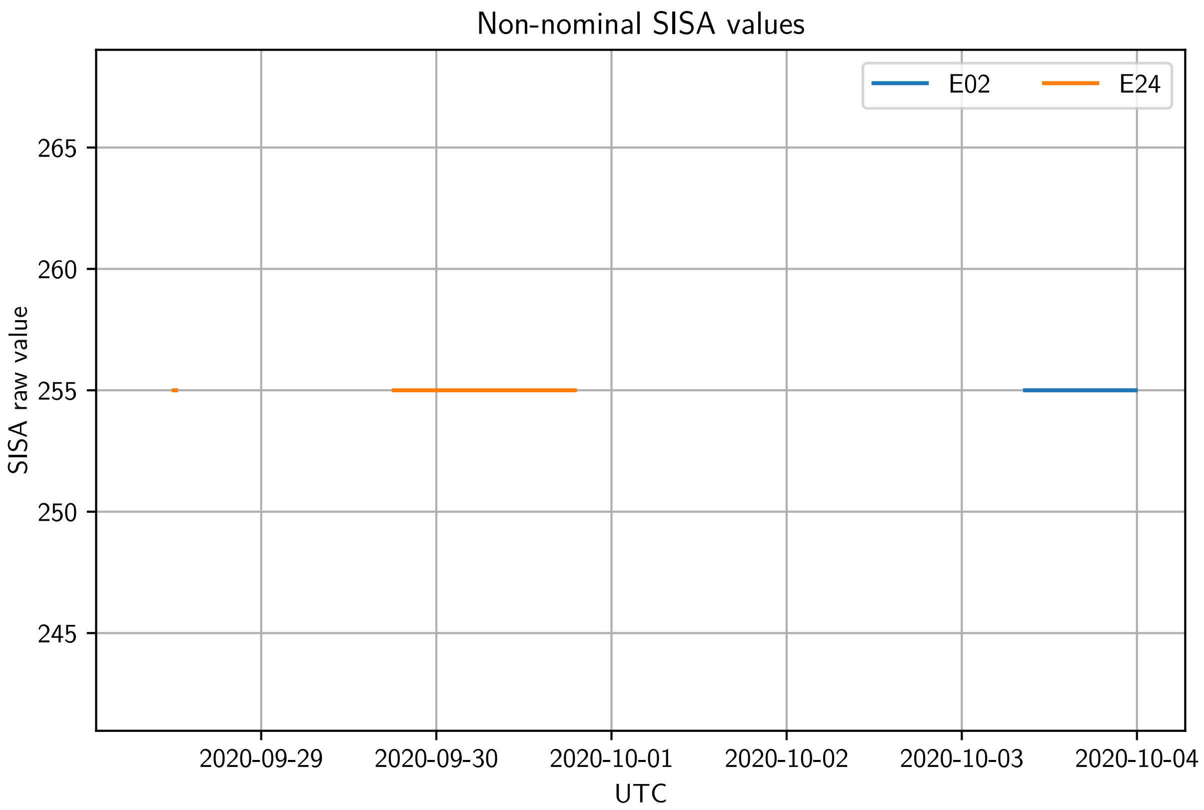
SV	unobserved	unhealthy	healthy	testing	napa	ripe	expired
E01	0.00%	0.00%	100.00%	0.00%	0.00%	9.82%	0.00%
E02	0.00%	0.00%	90.87%	0.00%	9.13%	5.56%	0.00%
E03	0.00%	0.00%	100.00%	0.00%	0.00%	8.63%	0.00%
E04	0.00%	0.00%	100.00%	0.00%	0.00%	9.82%	0.00%
E05	0.00%	0.00%	100.00%	0.00%	0.00%	7.24%	0.00%
E07	0.00%	0.00%	100.00%	0.00%	0.00%	6.65%	0.00%
E08	0.00%	0.00%	100.00%	0.00%	0.00%	5.65%	0.00%
E09	0.00%	0.00%	100.00%	0.00%	0.00%	8.04%	0.00%
E11	0.00%	0.00%	100.00%	0.00%	0.00%	8.33%	0.00%
E12	0.00%	0.00%	100.00%	0.00%	0.00%	9.23%	0.00%
E13	0.00%	0.00%	100.00%	0.00%	0.00%	9.72%	0.00%
E15	0.00%	0.00%	100.00%	0.00%	0.00%	6.94%	0.00%
E19	0.00%	0.00%	100.00%	0.00%	0.00%	5.85%	0.00%
E21	0.00%	0.00%	100.00%	0.00%	0.00%	8.53%	0.00%
E24	17.66%	0.30%	67.26%	0.00%	14.78%	8.04%	0.00%
E25	0.00%	0.00%	100.00%	0.00%	0.00%	8.93%	0.00%
E26	0.00%	0.00%	100.00%	0.00%	0.00%	8.33%	0.00%
E27	0.00%	0.00%	100.00%	0.00%	0.00%	7.64%	0.00%
E30	0.00%	0.00%	100.00%	0.00%	0.00%	6.15%	0.00%
E31	0.00%	0.00%	100.00%	0.00%	0.00%	9.13%	0.00%
E33	0.00%	0.00%	100.00%	0.00%	0.00%	9.82%	0.00%
E36	0.00%	0.00%	100.00%	0.00%	0.00%	6.05%	0.00%
Tot	0.80%	0.01%	98.10%	0.00%	1.09%	7.91%	0.00%

Table 3.1: Satellite status table for E1/E5b I/NAV

This table defines a "ripe" ephemeris as one older than 100 minutes, and an expired one as older than 4 hours (in accordance with the Galileo Service Definition document).

3.4 Signal In Space Accuracy (SISA) and NAPA

The nominal Signal In Space Accuracy value for Galileo is currently 312 centimeters. This graph shows occasions where Galileo satellites broadcast a different SISA value. If everything is operating as planned, this graph is empty.

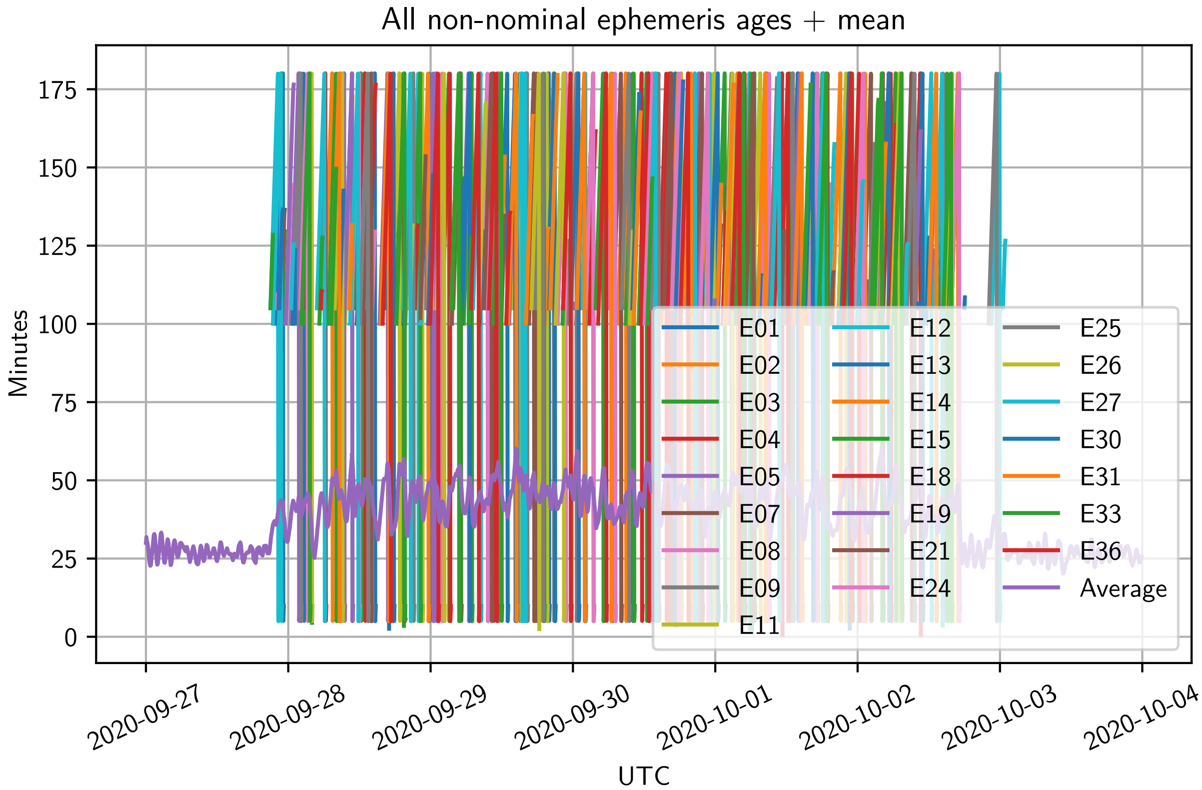


Chapter 4

Ephemerides

4.1 Ephemeris age

This graph shows the average ephemeris age, defined as time passed since t_{0e}. In addition, any non-nominal ephemerides ages, defined as more than 100 minutes old, will also be shown.



Chapter 5

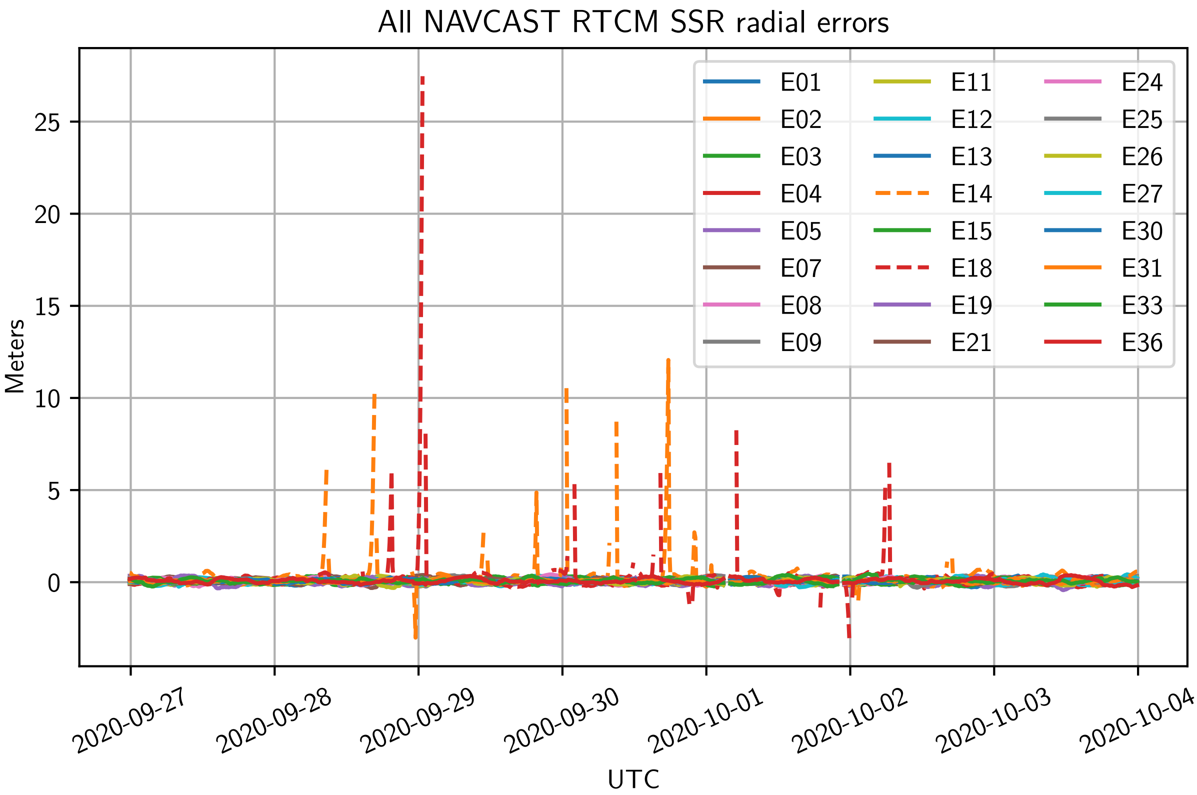
Accuracy

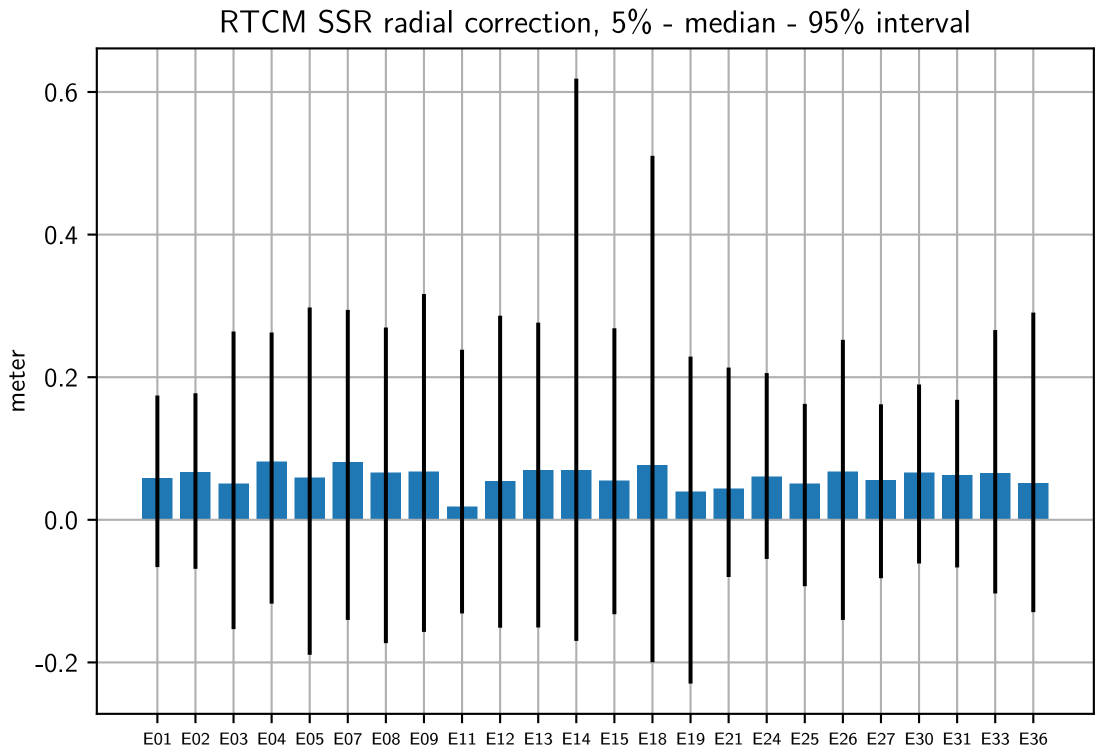
5.1 Radial error

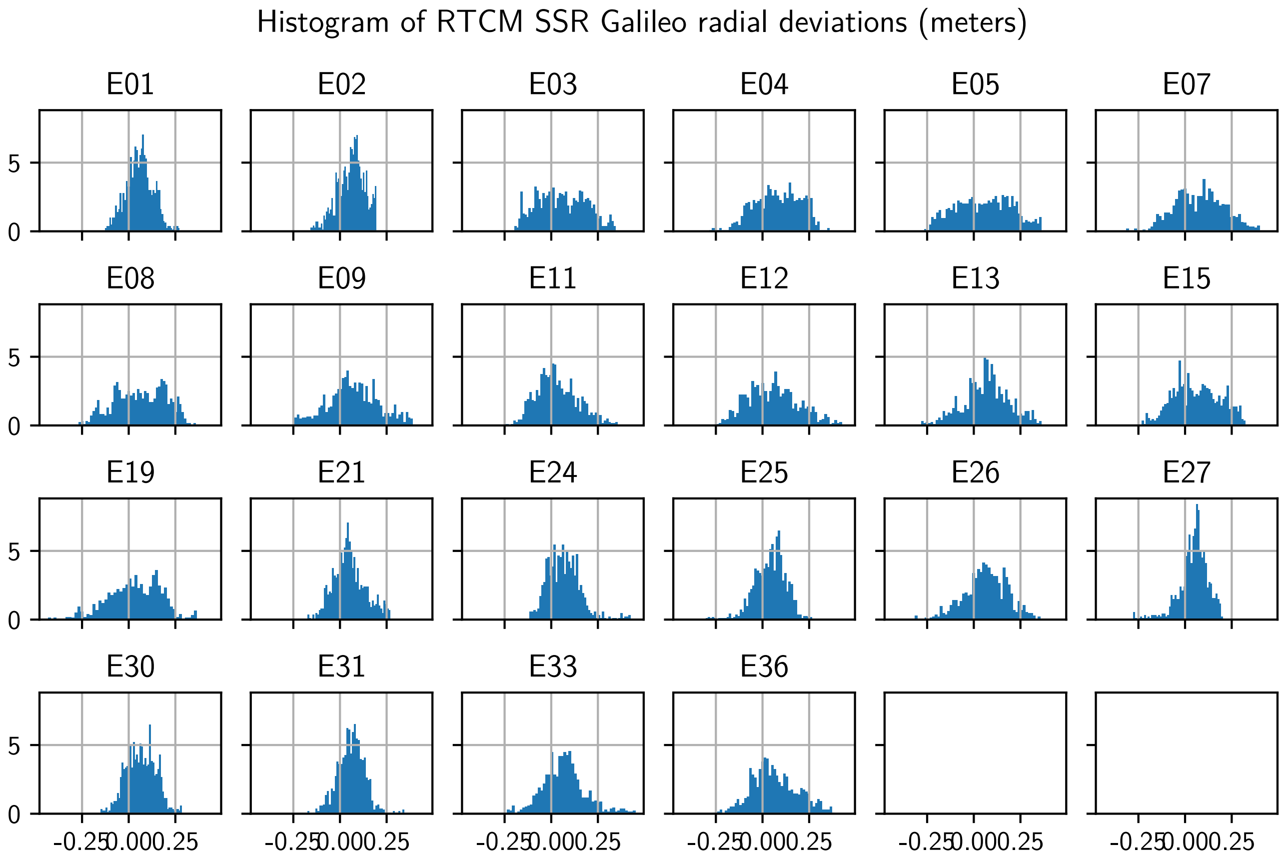
In a nominal situation, this graph shows many overlapping lines all clustered around 0 meters error. If any SV deviates significantly, this shows up in subsequent graphs.

Details for individual satellites can be found at the end of this report.

Note that the RTCM radial data appears to have a 5 centimeter bias. This may reflect a transposition to a different coordinate system.




RTCM SSR radial correction, 5% - median - 95% interval
meter
0.6
0.4
0.2
0.0
-0.2
E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E13 E14 E15 E18 E19 E21 E24 E25 E26 E27 E30 E31 E33 E36

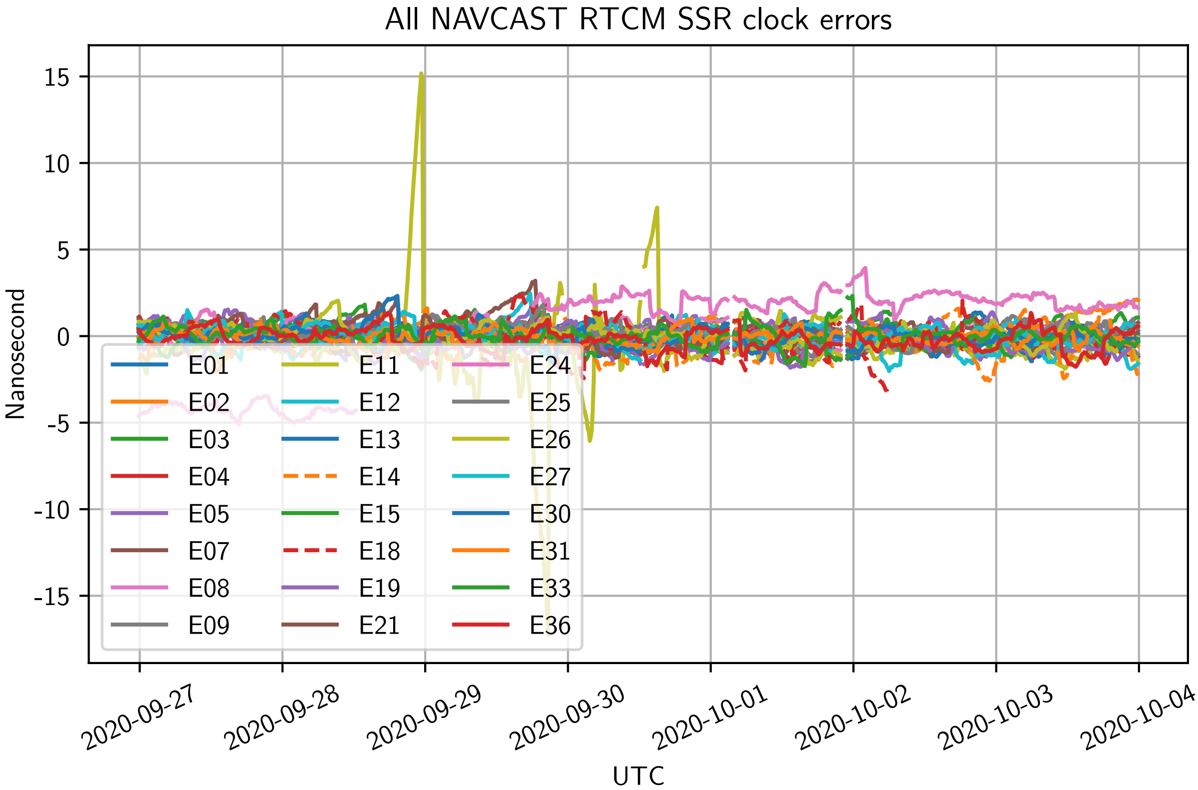

Histogram of RTCM SSR Galileo radial deviations (meters)
E01 E02 E03 E04 E05 E07
E08 E09 E11 E12 E13 E15
E19 E21 E24 E25 E26 E27
E30 E31 E33 E36
5
0
-0.25 0.00 0.25

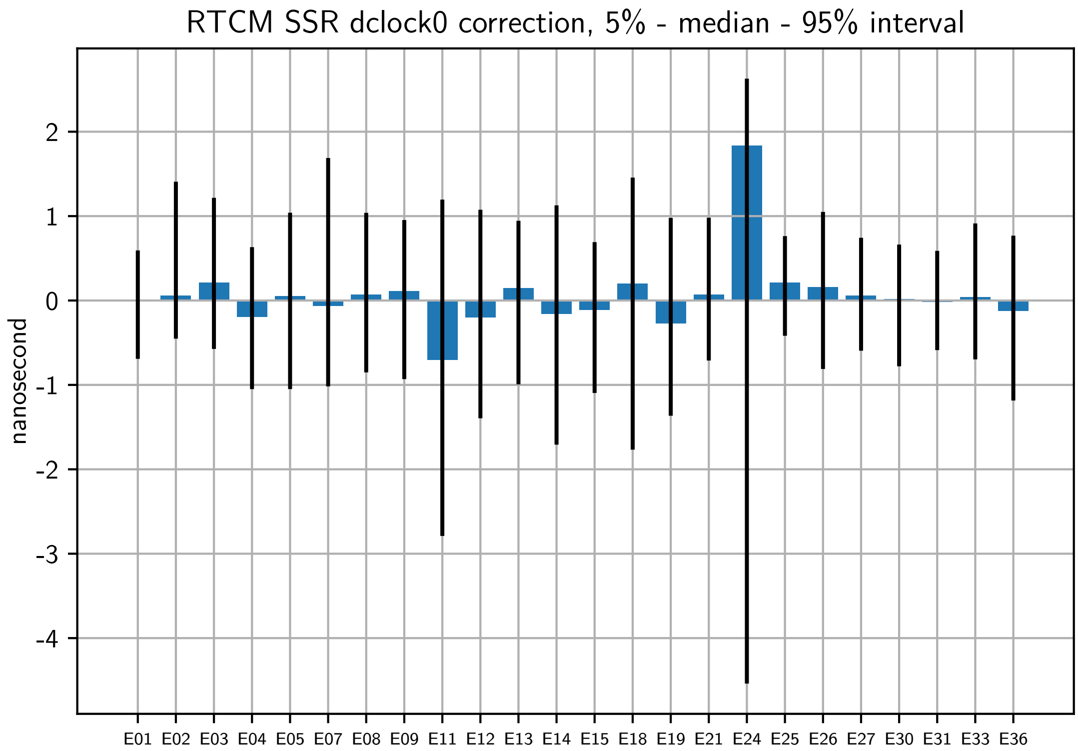
5.2 Clock error

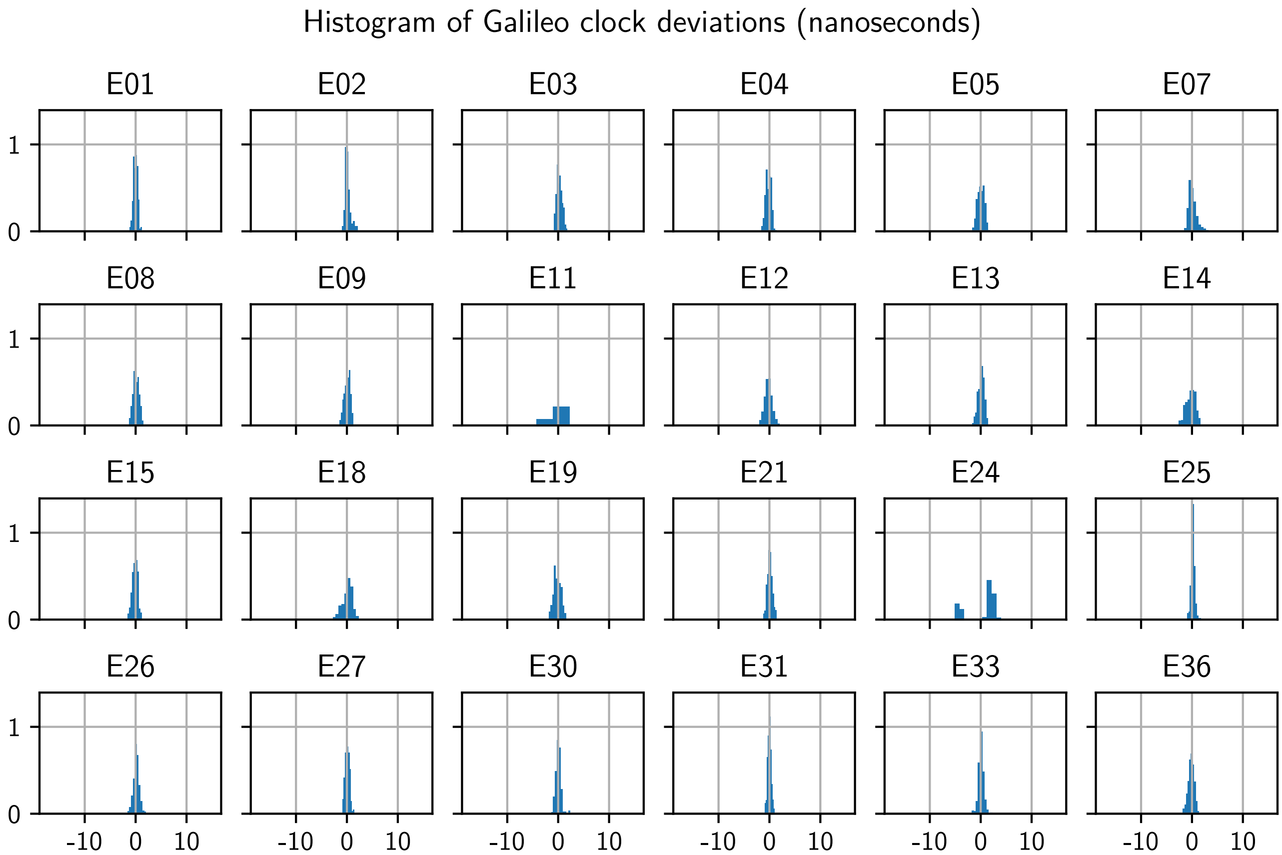
In a nominal situation, this graph shows many overlapping lines all clustered around 0 nanosecond error. If any SV deviates significantly, this shows up in subsequent graphs.

Details for individual satellites can be found at the end of this report.

Note that the RTCM clock error data as provided by DLR/NAVCAST and CNES is expressed in terms of a metric which corrects the F/NAV clock to the I/NAV clock. This creates non-physical corrections. To compensate, the data as presented in this report undoes the I/NAV-F/NAV transition. Further details on this situation can be found in two blogposts by independent researcher Daniel Estévez, "About Galileo BGDs" and "RTCM clock corrections for Galileo E24".




RTCM SSR dclock0 correction, 5% - median - 95% interval
nanosecond
2
1
0
-1
-2
-3
-4
E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E13 E14 E15 E18 E19 E21 E24 E25 E26 E27 E30 E31 E33 E36

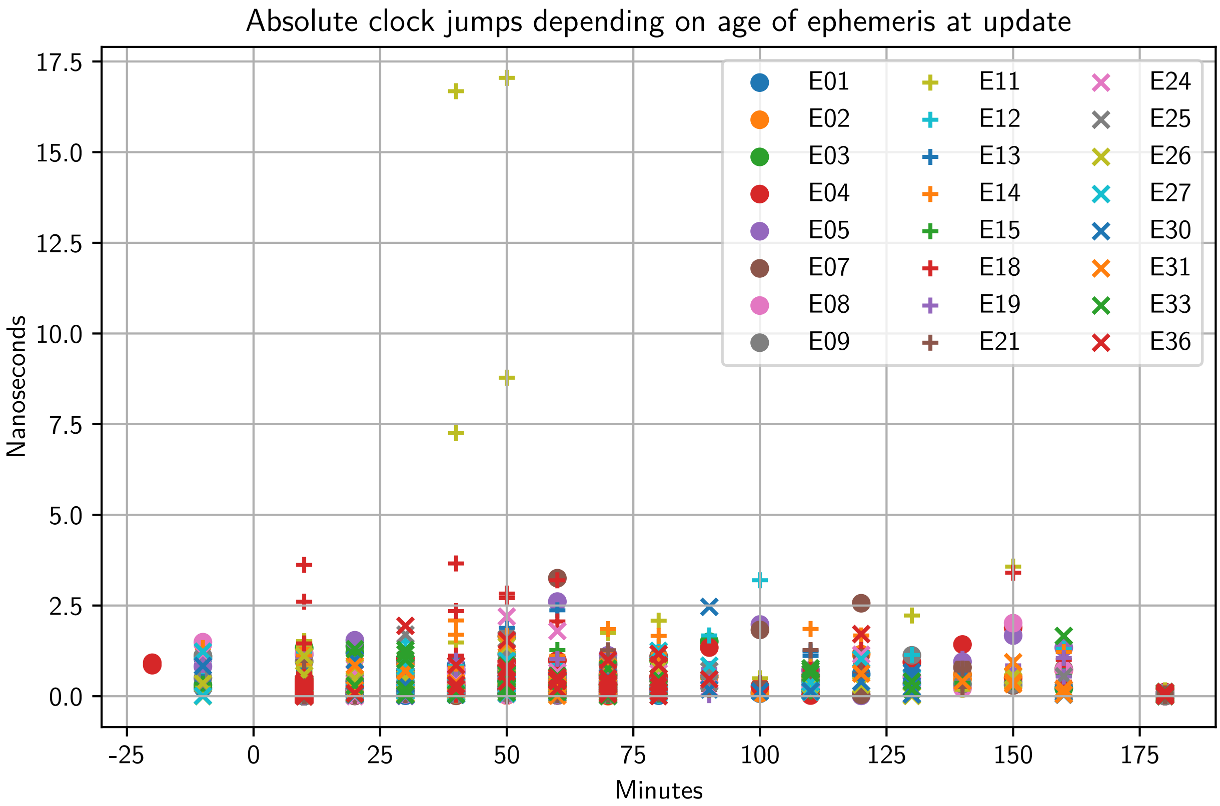

Histogram of Galileo clock deviations (nanoseconds)
E01 E02 E03 E04 E05 E07
E08 E09 E11 E12 E13 E14
E15 E18 E19 E21 E24 E25
E26 E27 E30 E31 E33 E36
1
0
-10 0 10

5.3 Clock stability

The Galileo clocks are monitored from the ground to determine their offset from Galileo System Time (GST), as well as their drift rate. Periodically, mostly every ten minutes, new parameters are uplinked. Occasionally however updates may appear only after 90 minutes. This is all nominal behaviour.

However, such delayed updates can lead to larger shifts in clock corrections, which are indicative of clock behaviour not being modeled well (enough).

The scatterplot below shows update latency versus absolute clock jumps for all Galileo satellites.



Chapter 6

Global performance

The performance for average and worst user locations features large in the Galileo Service Definition Document. Of specific note is availability (coverage, visibility of 4 or more satellites) with an elevation more than 5 degrees above the horizon.

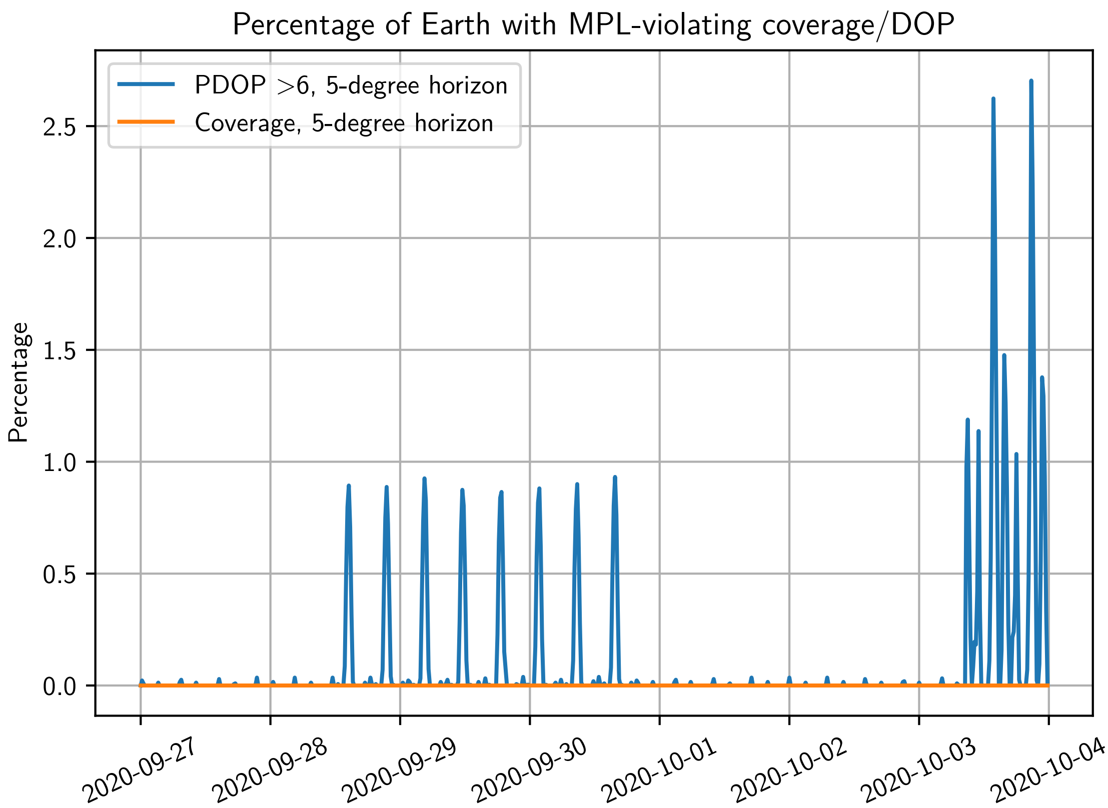
In addition, we plot the perhaps more meaningful similar measure with a view of more than 10 degrees above the horizon.

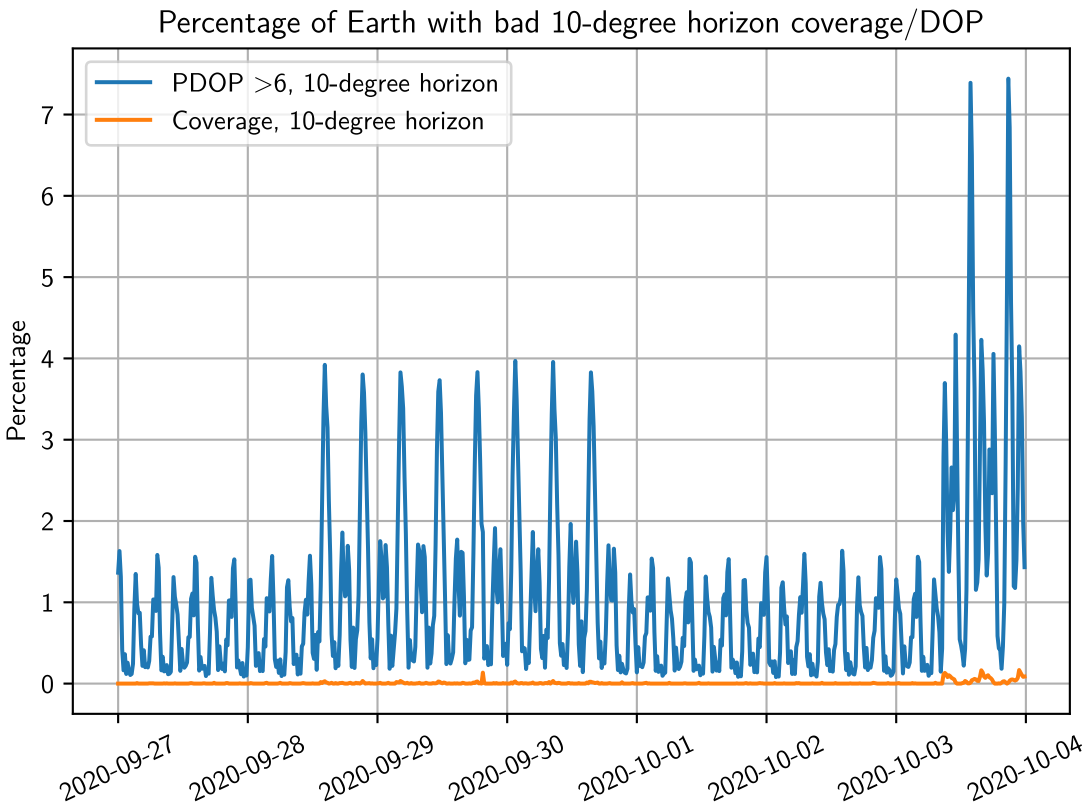
Note that these graphs show minute variations, where sometimes only tiny fractions of the Earth's surface are impacted.

6.1 PDOP and coverage

This week, on average 0.1% of the earth's surface violated the PDOP performance level for 5 degree elevation satellites, while 1.0% was violated for 10 degree elevation.

In addition, 0.0% did not see at least 4 satellites more than 5 degrees above the horizon, while 0.0% did not do so for more than 10 degrees above the horizon.



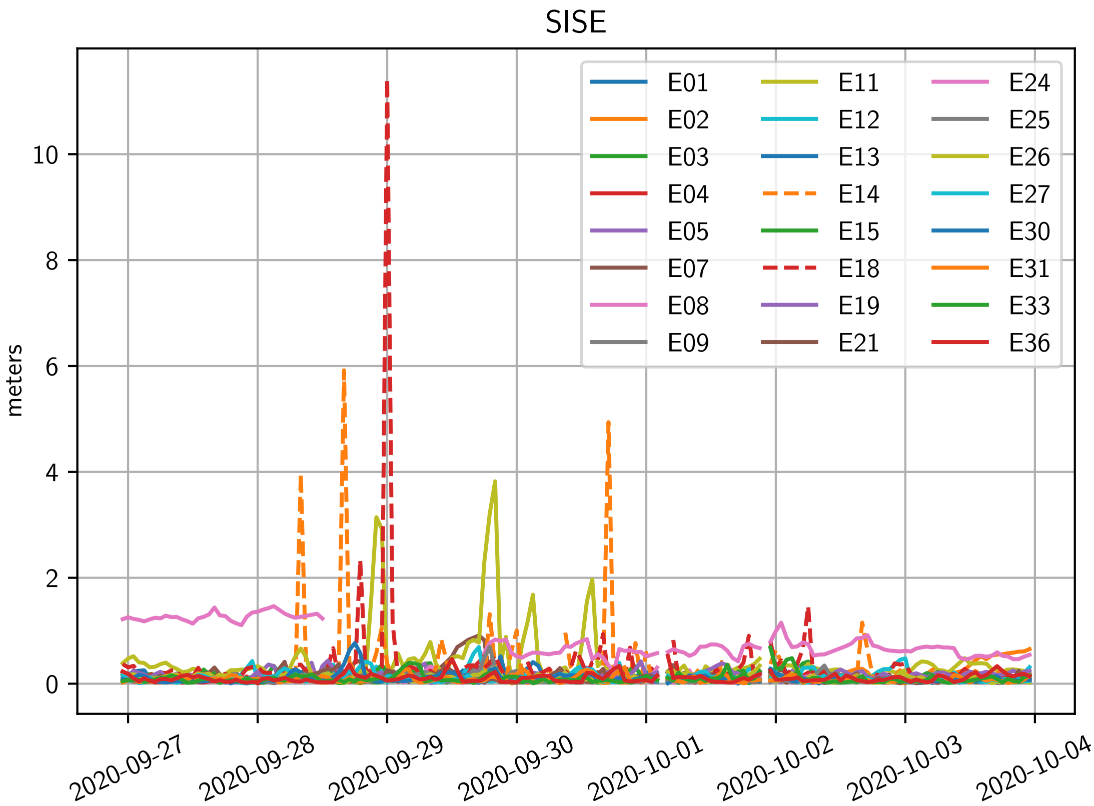


6.2 Signal In Space Error (SISE)

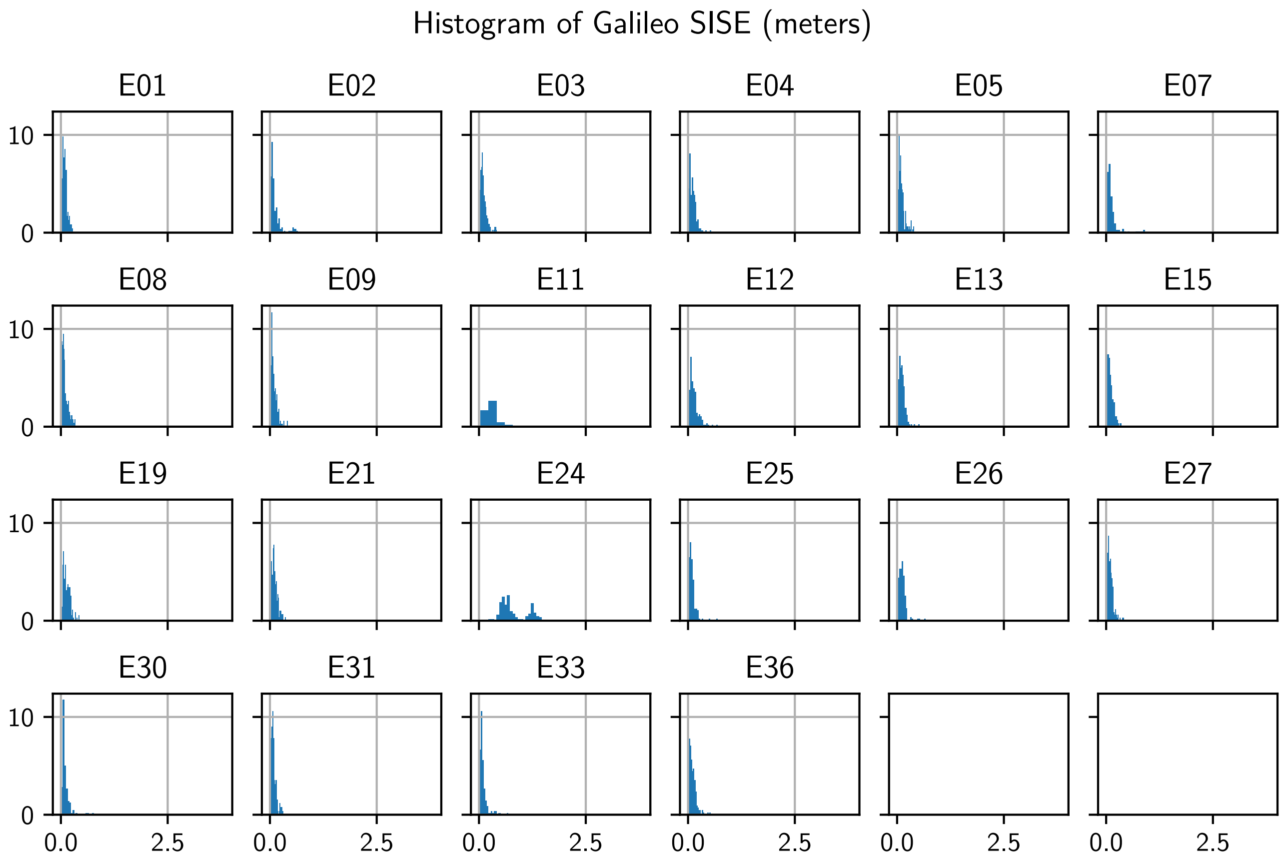
The data in this section is based on the approximation formula from section C.4.3.2 from the Galileo Service Definition Document.

The source of the corrections is the realtime NAVCAST data from Spaceopal/DLR. This data has, as usual, been adjusted for the F/NAV-I/NAV clock situation. In addition, an observed bias of around 5 centimeters has been deducted from the radial error.

The first graph shows all SISE values for all SVs, and should show a lot of data quite close to 0 meters (usually 10 centimeters).



This second graph shows a histogram of Signal In Space Errors for all Galileo SVs:

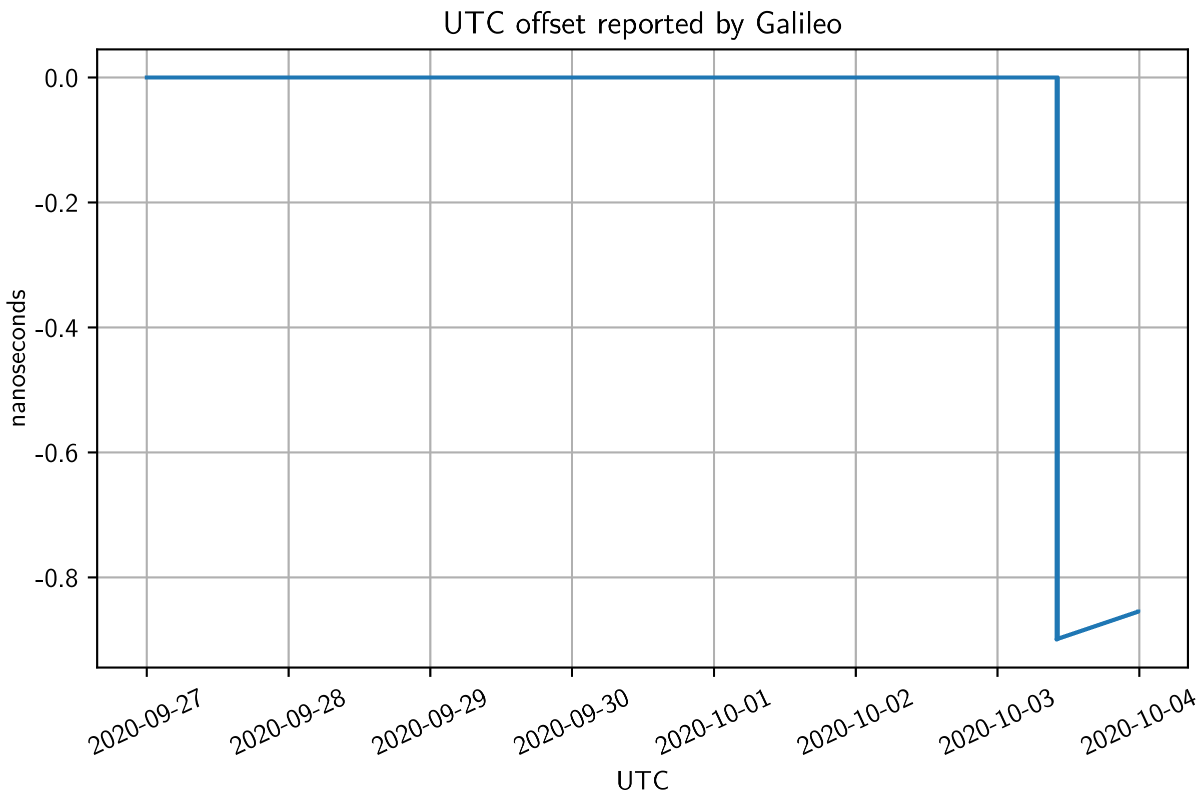


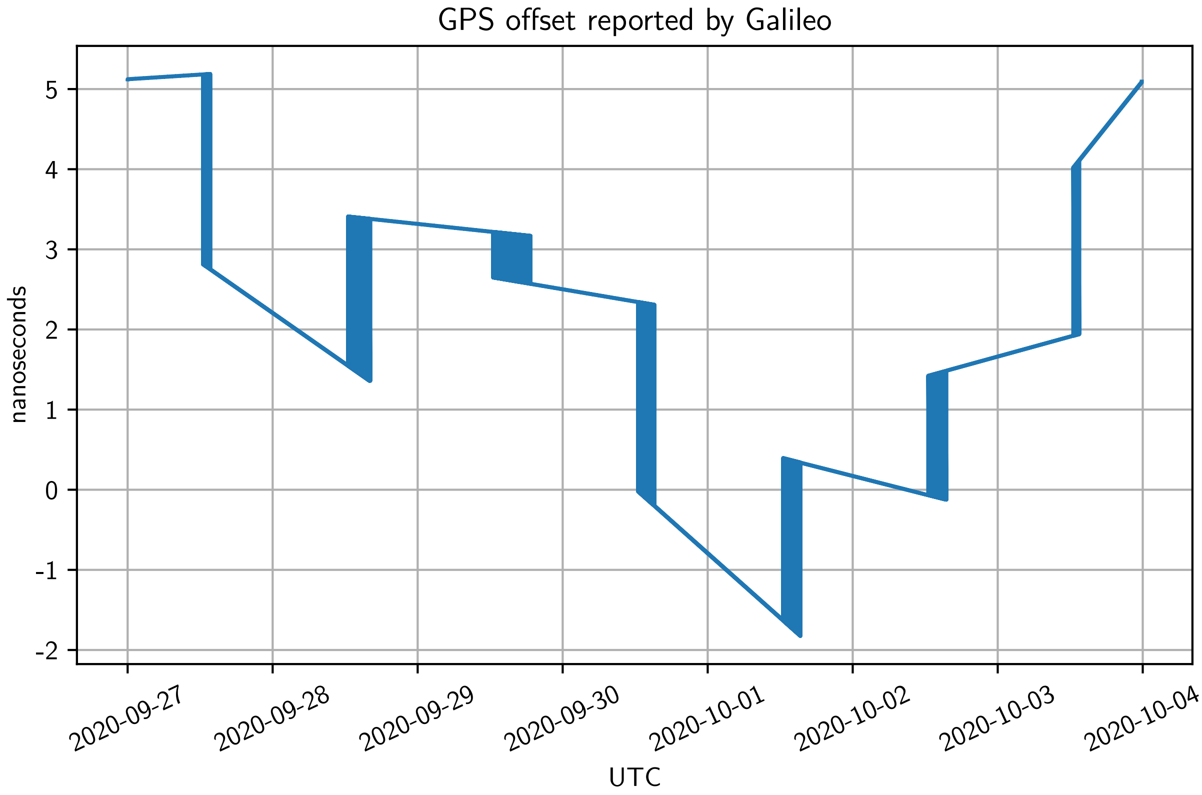
Chapter 7

UTC offset, GPS offset (GGTO)

7.1 Broadcast offset parameters

Galileo satellites broadcast their offset between "Galileo Time" (GST), UTC and GPS Time. These graphs show what offsets are transmitted.



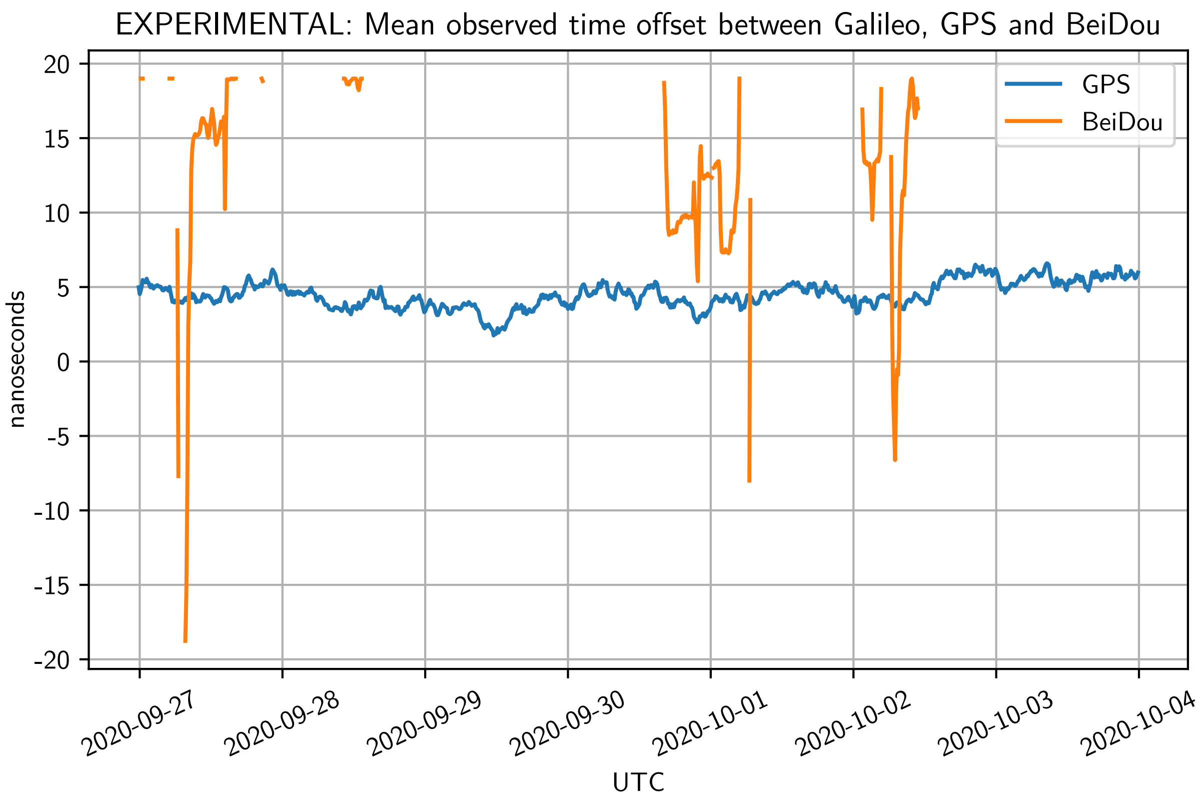


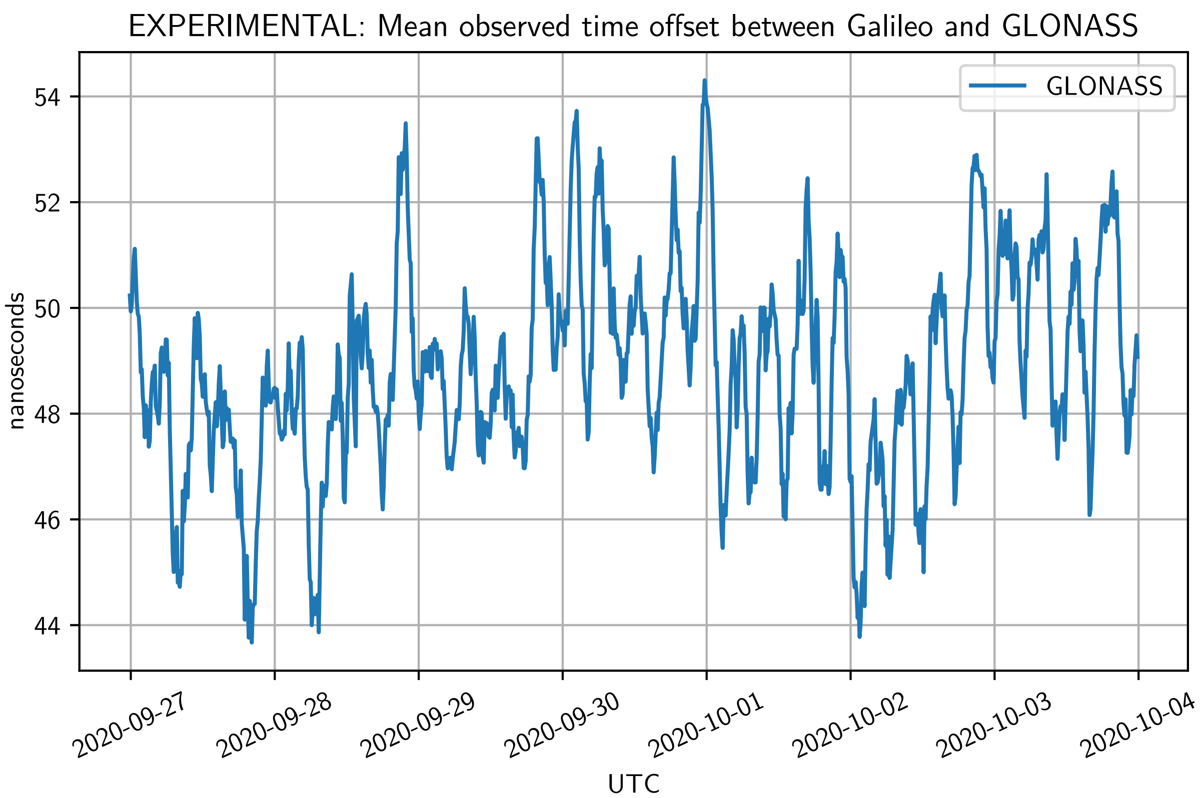
7.2 Measured time offsets between constellations

Since early July, the Galmon.eu networks attempts to measure the offset between the system times of Galileo, GPS, BeiDou and GLONASS.

Our individual receivers report offsets that appear to be distributed normally around the "actual" offset.

From UTC midnight of the 10th of July and onwards, sufficient receivers are participating that the offsets average out to something that might be real.

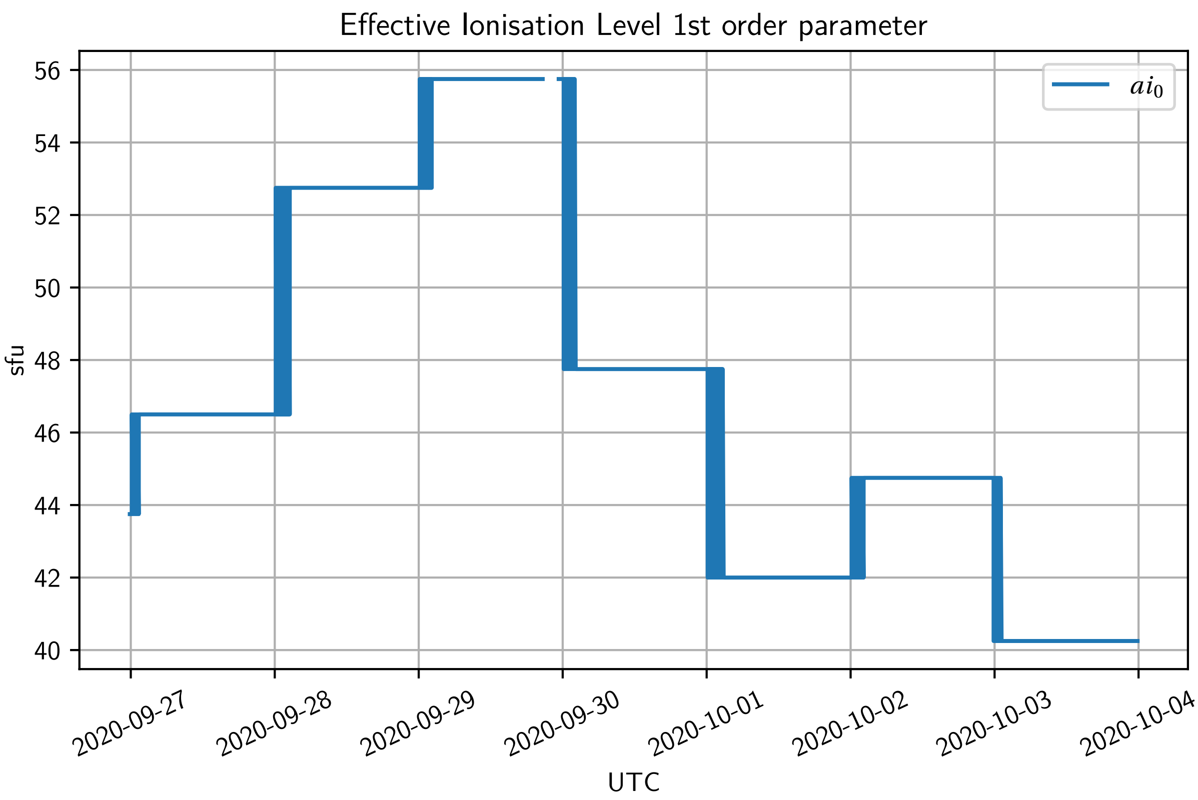

EXPERIMENTAL: Mean observed time offset between Galileo, GPS and BeiDou
GPS
BeiDou
nanoseconds
20
15
10
5
0
-5
-10
-15
-20
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

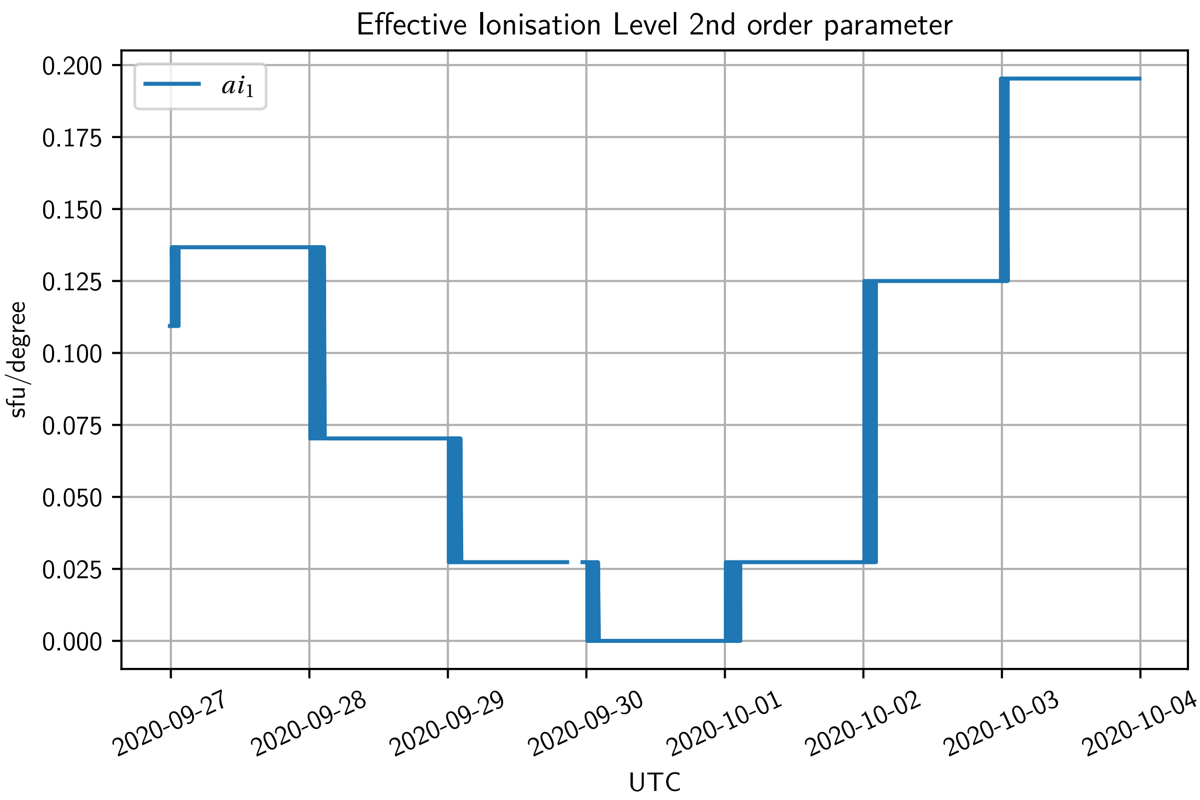

EXPERIMENTAL: Mean observed time offset between Galileo and GLONASS
GLONASS
nanoseconds
54
52
50
48
46
44
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

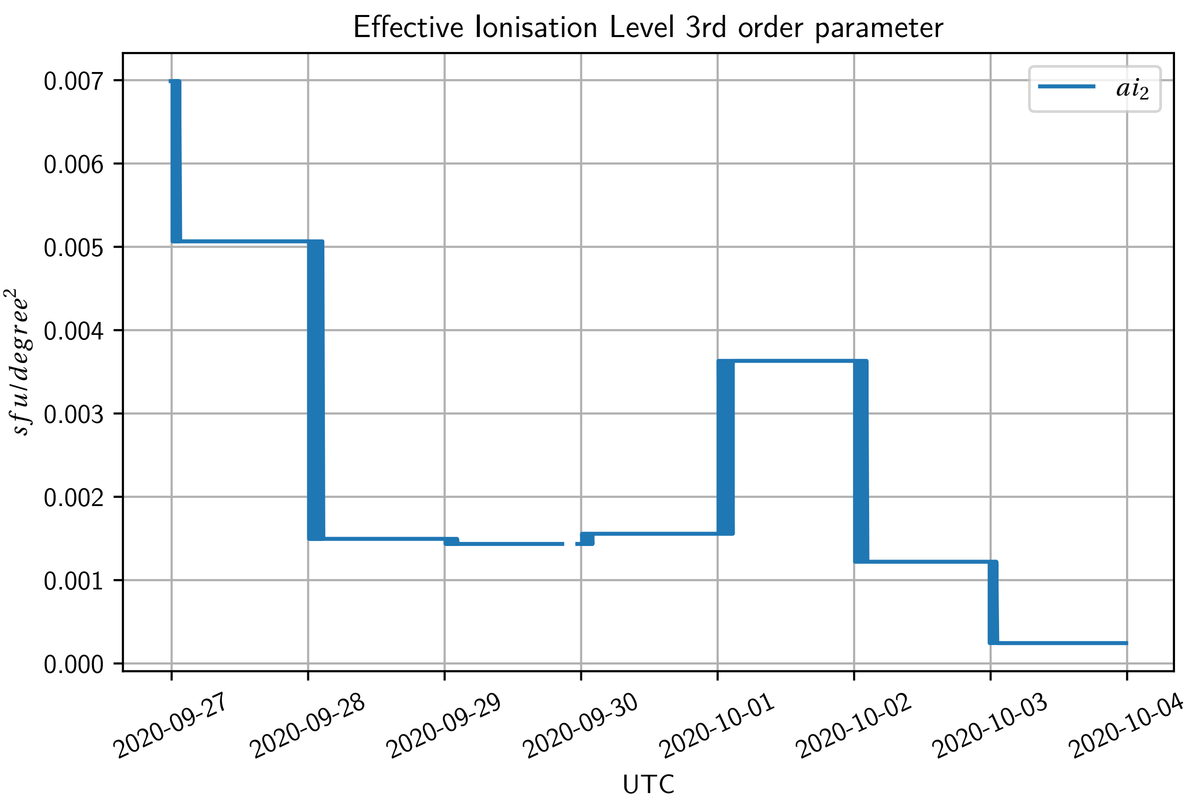
Chapter 8

Ionosphere

For the benefit of single-frequency receivers, Galileo transmits parameters for an ionospheric delay model called "NeQuick G". The ai_0, ai_1 and ai_2 parameters describe the solar flux inputs for this model.







In these three graphs, a "thick" transition from one parameter level to another shows the time needed to propagate the new value to the entire constellation.

Dual-frequency receivers have no need for an ionospheric model since they can eliminate the ionosphere by combining multiple signals.

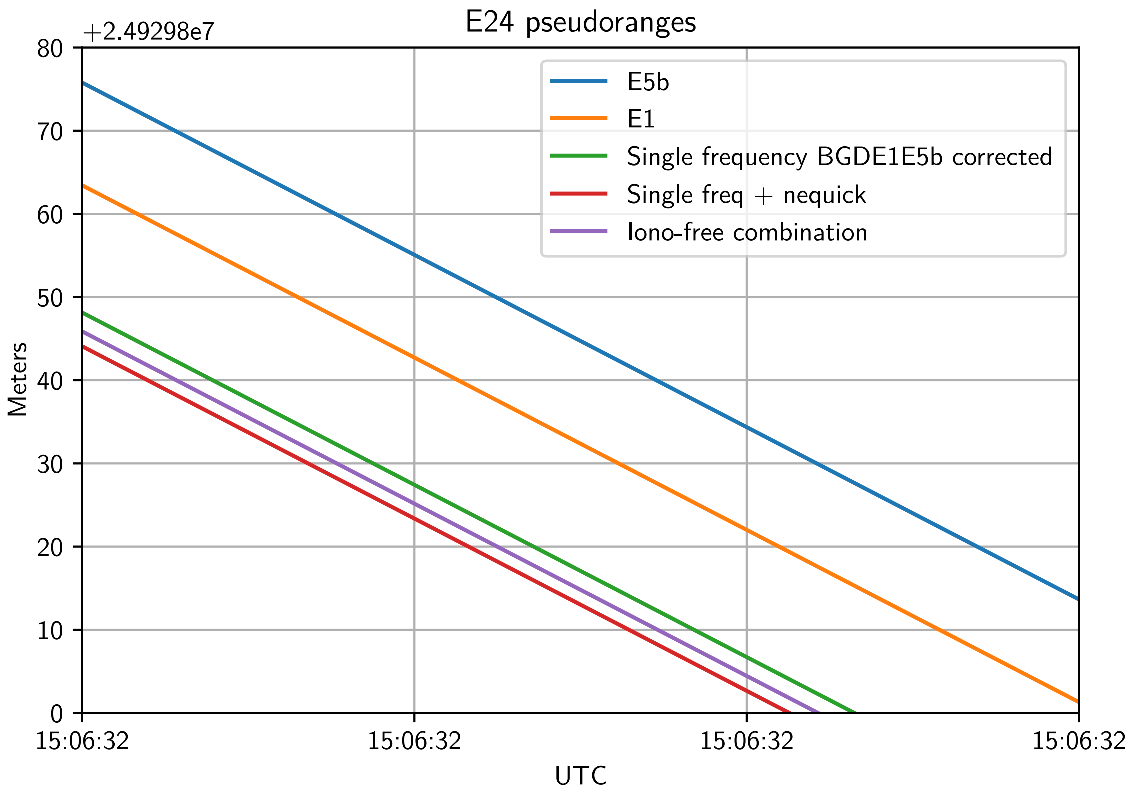
Future editions of this report will contain a graph that compares the the NeQuick G ionospheric delay model and the actual delays observed by our multi-frequency receivers.

8.1 NeQuick G analysis

This analysis is very preliminary and mostly shown to gather feedback, some of which has arrived already.

The NeQuick G code used was supplied by the Galileo Service Desk, and authored by the European Commission's Joint Research Centre. While open source, the code must be requested through a form. Those in a hurry may also find the code on GitHub, but it might be outdated.

For the analysis, a Ublox F9P receiver with an excellent reference center grade antenna is used, hosted in Delft, The Netherlands. This is the data we start with:



The top line represents the pseudorange of the E5b signal. The pseudorange is often close to the actual range to the satellite, but it must not be read this way. It is a measure of the relative Time of Receipt of the signal. Pseudoranges can be compared usefully, even if they are not absolute ranges.

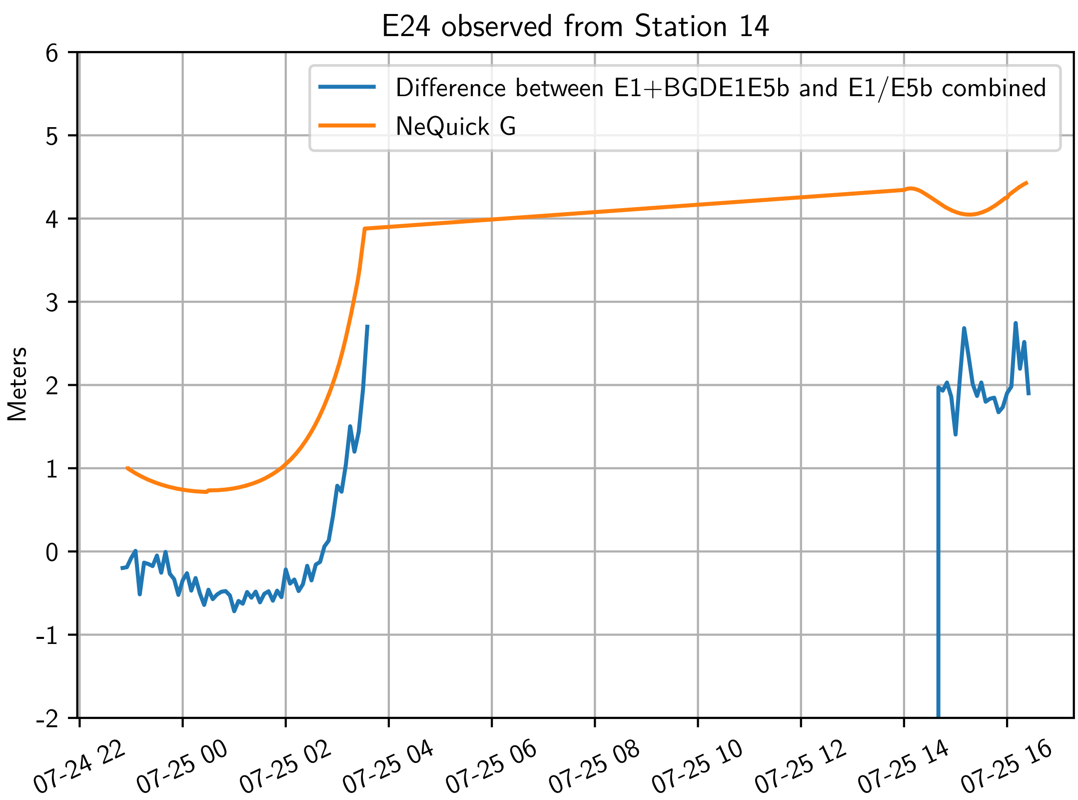
Below E5b is the E1 signal - it has a higher frequency, so it arrives earlier since it is delayed less by the ionosphere. This is explained at some length in this blog post. E24 also has an unusually large transmission gap between E1 and E5b making this graph visually very useful (thanks).

The E1 and E5b delays are combined to derive the ionosphere-free arrival time, which is the purple line. This is the "official clock", the one that a single-frequency receiver hopes to derive with the NeQuick G model.

A single-frequency receiver does so by adding the BGDE1E5b delay to the E1 pseudorange, and then it ends up at the green line, which is already quite close to the purple line (which is the goal).

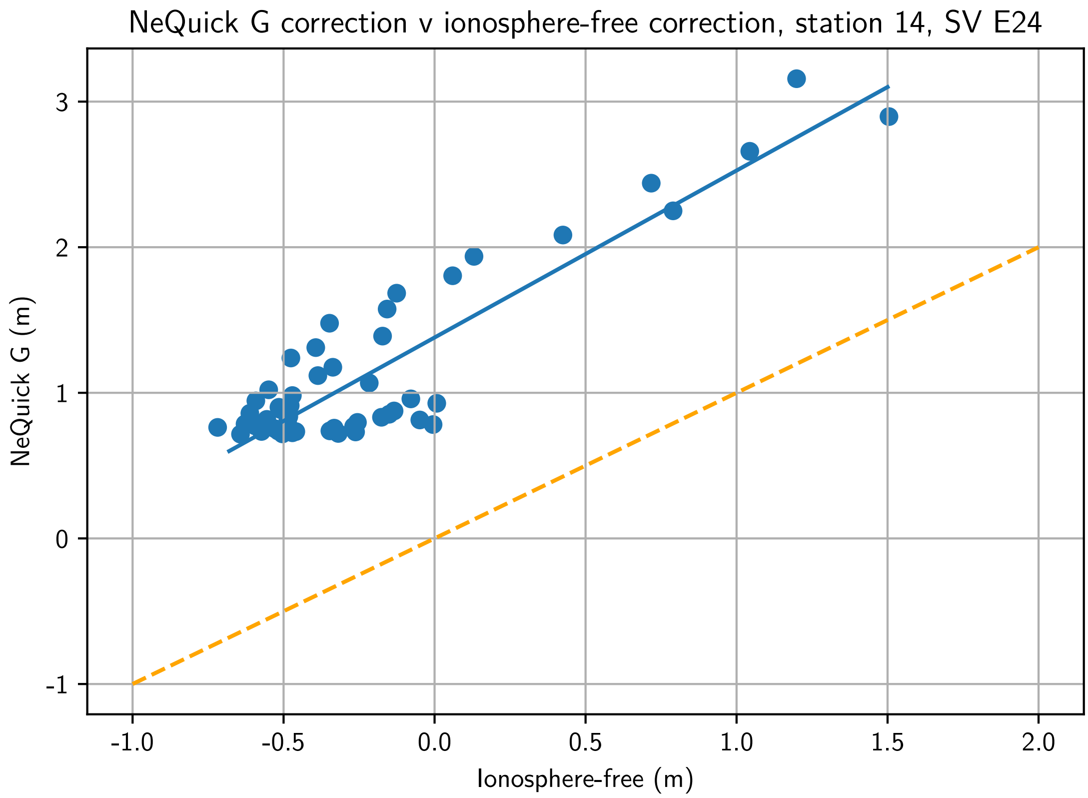
The receiver then calculates the ionospheric delay parameter using the NeQuick G model and supplied parameters, and uses that delay to end up at the red line, which is indeed quite close to the goal.

In this graph, the NeQuick G adjustment is compared to the 'calculated' ionospheric adjustment:



Note that E24 was measured during two disjoint periods. Model and "reality" clearly move in the same direction, with a gap. Note that the measured ionospheric correction is *negative* at times, which should not be possible.

In histogram form:



This shows great correlation between NeQuick G and the measured ionospheric correction, albeit at an offset.

Combined with our observed negative ionospheric correction, this likely means our data, measurements and processing still has errors in there.

It is however already good to see the great correlation between measurement and model.

Chapter 9

COSPAS-SARSAT Return Link Messages

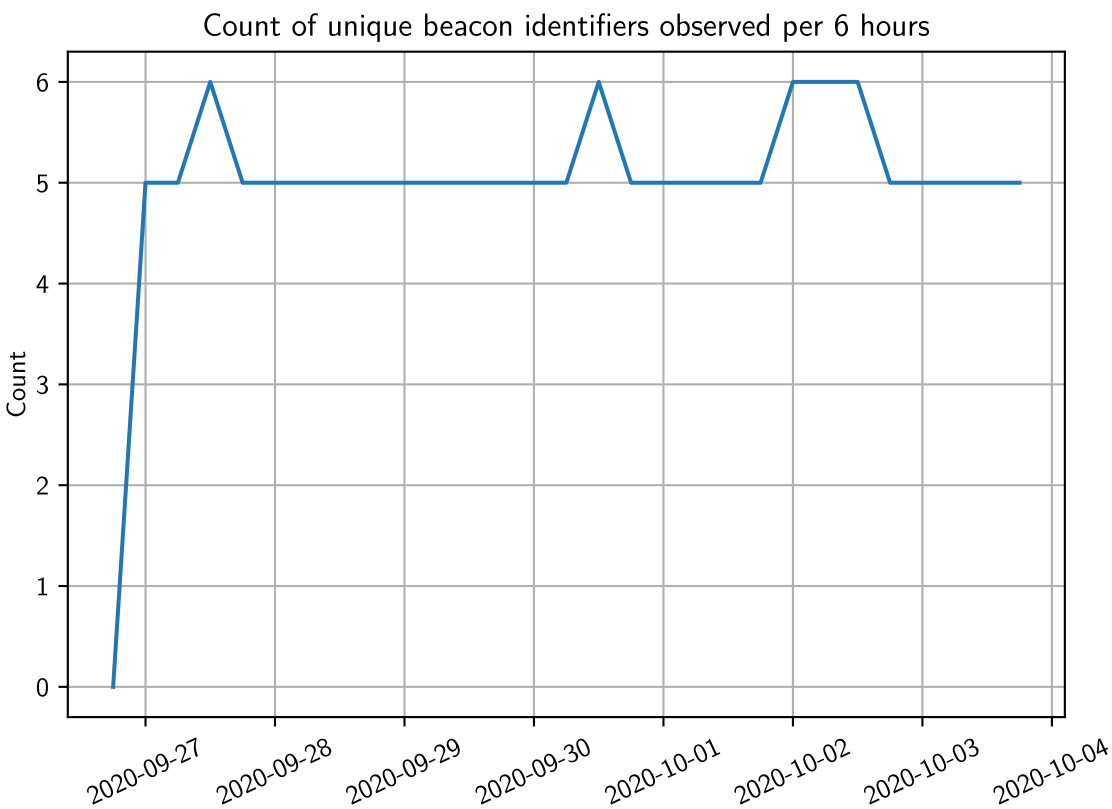
Galileo satellites carry a Search And Rescue beacon payload which can pick up distress signals and alert authorities. Uniquely, Galileo also provides a Return Link Service by which the beacon can receive confirmation its request for help has been processed.

The Galmon.eu network sees Return Link Messages (RLMs), but does not report on the associated beacon identifiers, as these identify people and vessels with actual emergencies.

We can however publish statistics of RLM traffic. It is known that five test beacons are used to verify correct operations, and these five are normally always observed.

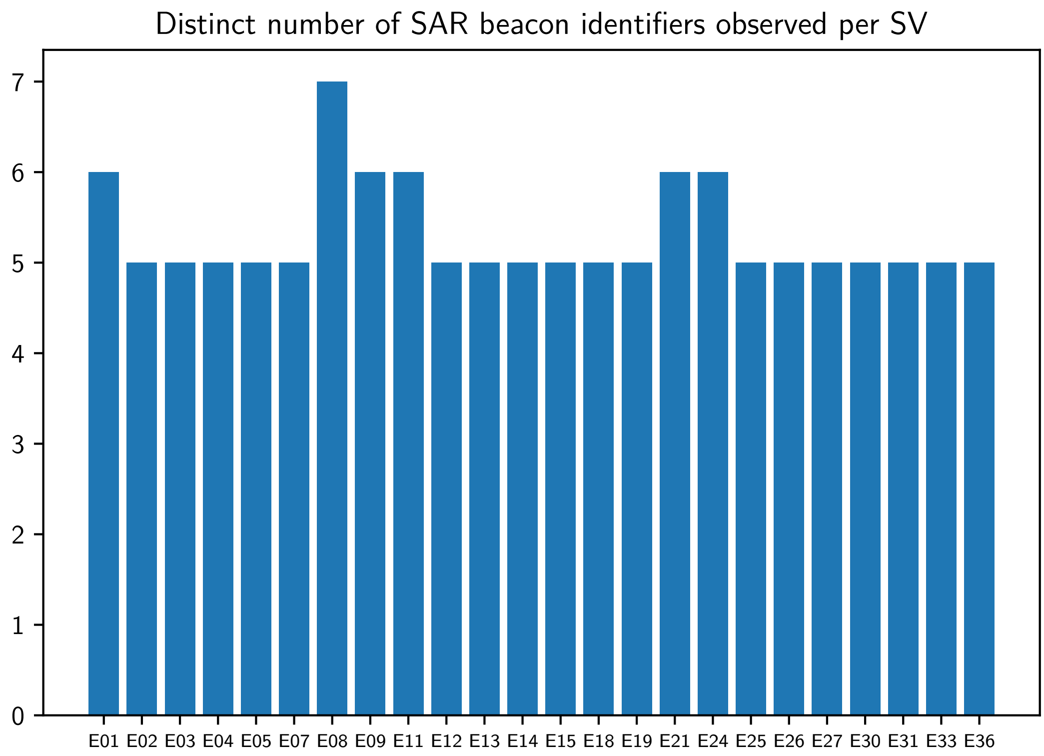
RLM frames are frequently received by dozens of our receivers, so it does not make sense to plot the raw number of received messages, since it is hard to tell which are duplicates.

This graph shows the number of unique beacon identifiers identified per six hour period, which normally always includes the five known testing beacons:



It is normal for this graph to drop off near the right, where the reporting period ends.

Not all satellites appear to have equal SAR RLM capabilities, here is a graph of number of unique beacon identifiers seen per SV over the reporting period:



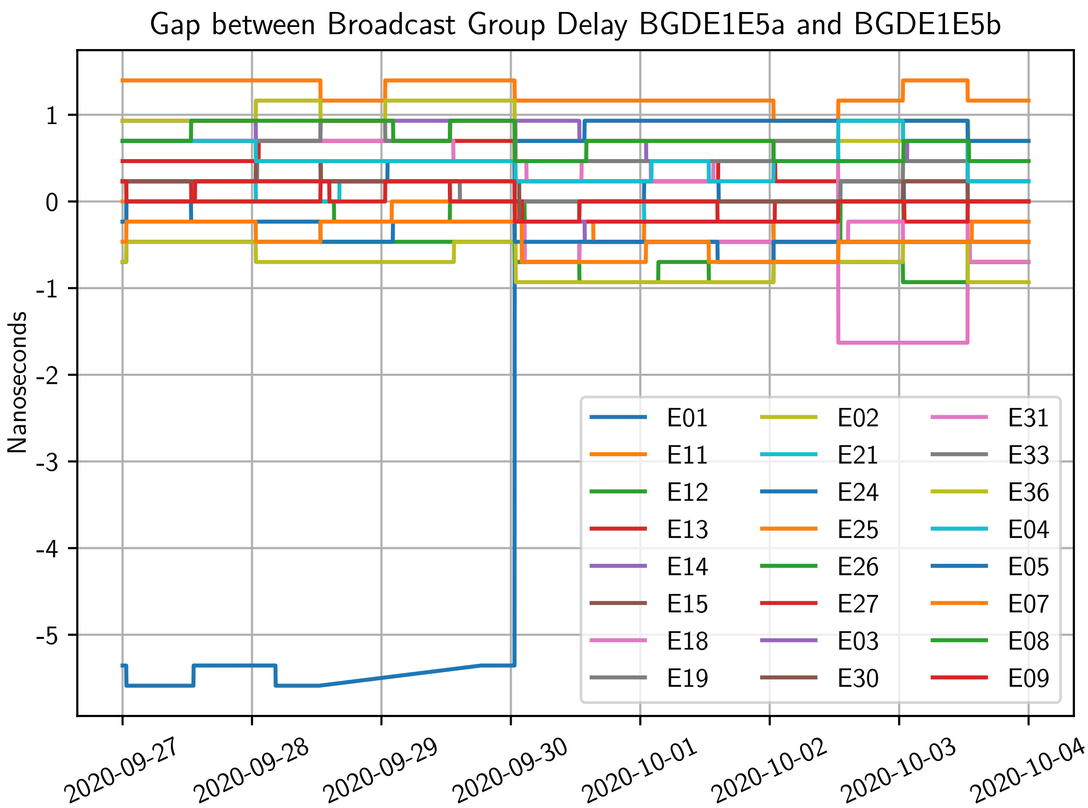
Chapter 10

Other parameters

10.1 BGD E1E5a, E1E5b

This plots the difference between the E1E5a and E1E5b parameters, which should correspond to the gap between the af_0 values broadcast over E1/E5b (I/NAV) and E5a (F/NAV).

This graph incidentally also describes the correction this report applies to the NAVCAST RTCM SSR data to undo the I/NAV-F/NAV modification.



Chapter 11

Per SV

The SP3 data as provided by GFZ Potsdam and ESOC refers to the Center of Mass (CoM) coordinates. The broadcast ephemerides however describe the trajectory of the Antenna Phase Centre (APC).

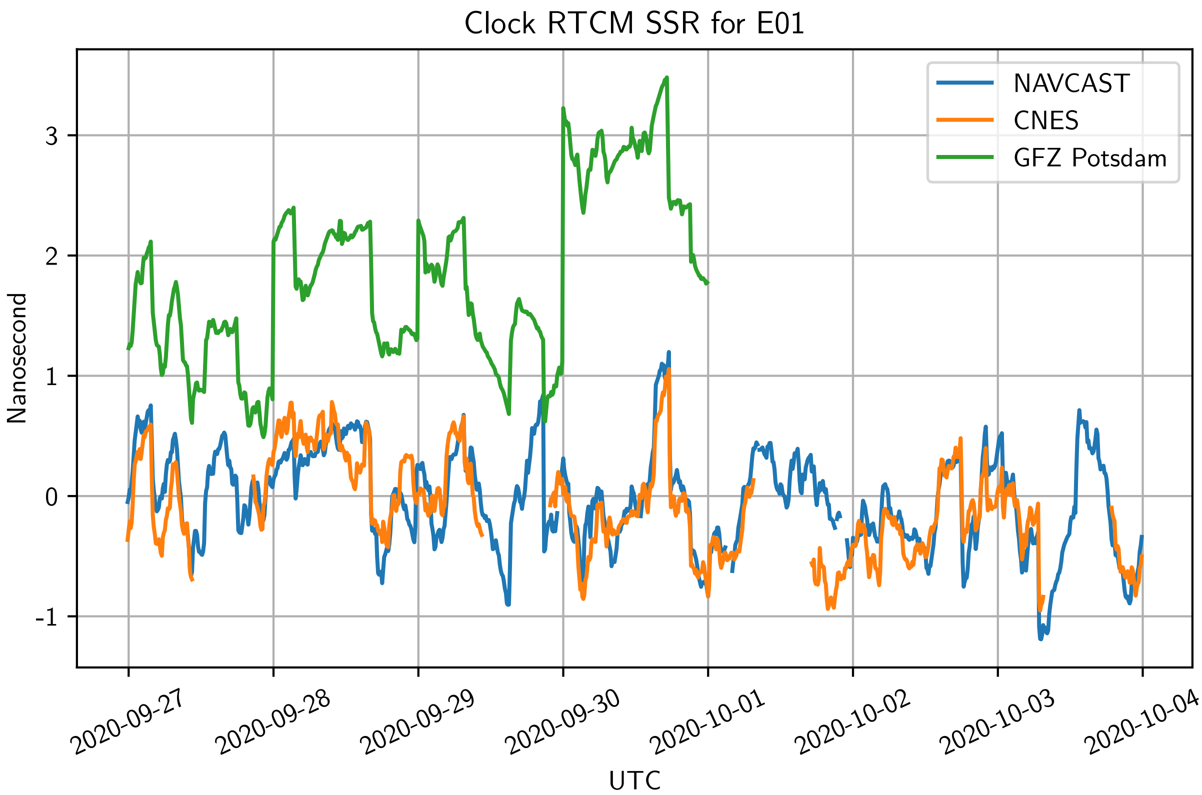
There is a measurable distance between CoM and APC, typically of around 80 centimeters.

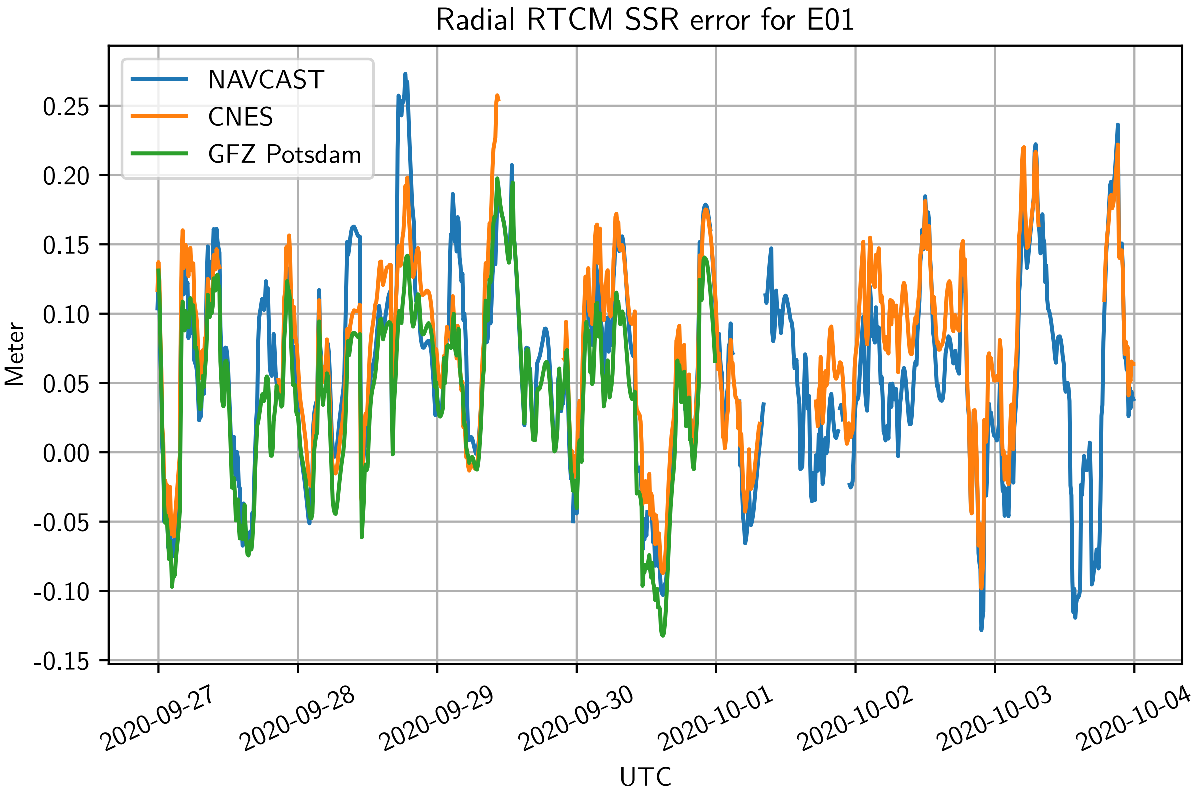
By using metrics provided by ESA for the Galileo satellites, it is possible to transpose the APC to the CoM via the Antenna Reference Point.

This transposition has so far proved to be too difficult for the authors of this report, but we have found the correction in the z-axis is 80 centimeters for most but not all SVs.

In future editions of this report, a more sophisticated correction will be applied. But for now, if SP3 data (GFZ or ESOC) is offset somewhat from the APC RTCM SSR data, this is why.

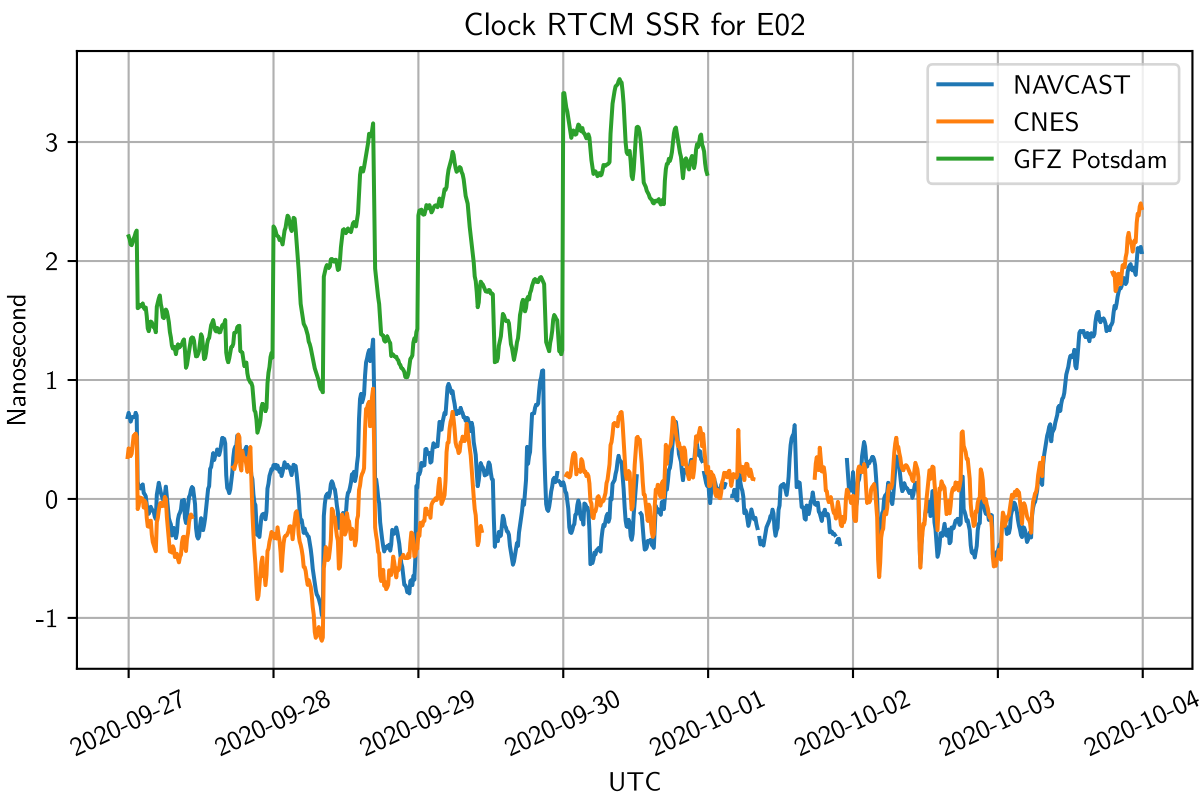
E01

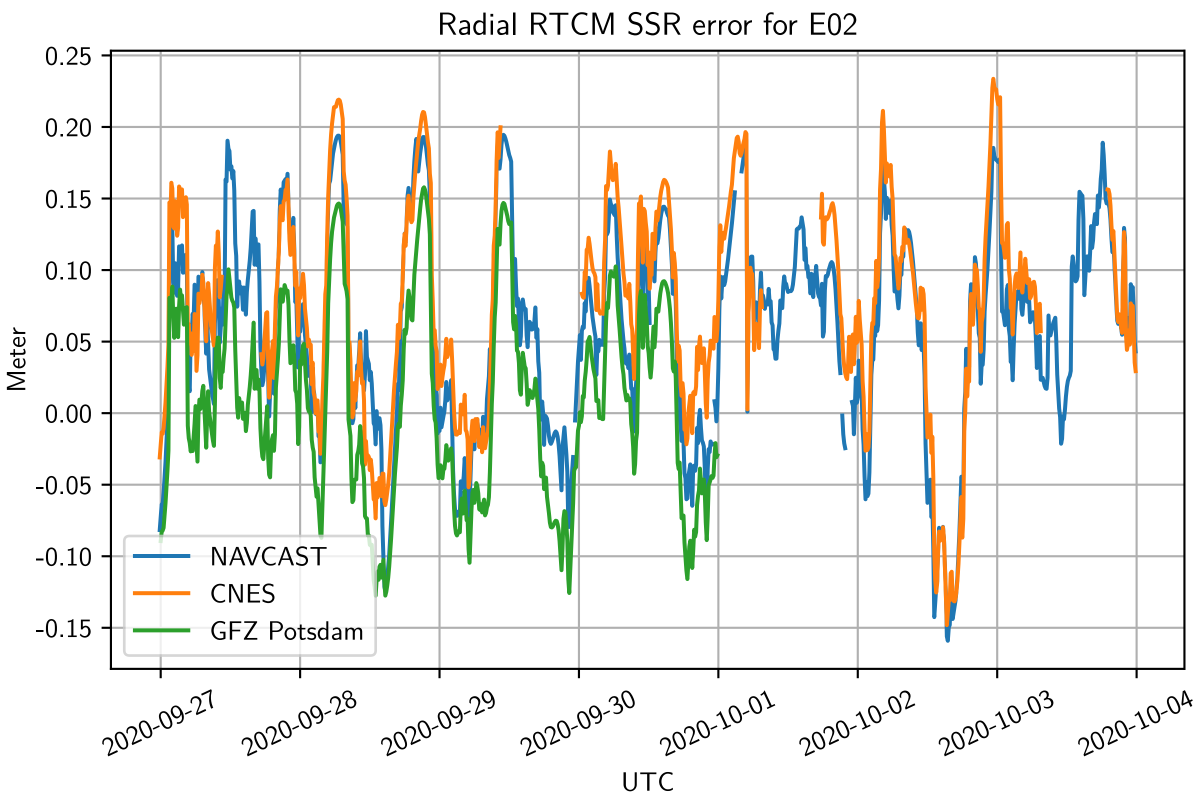




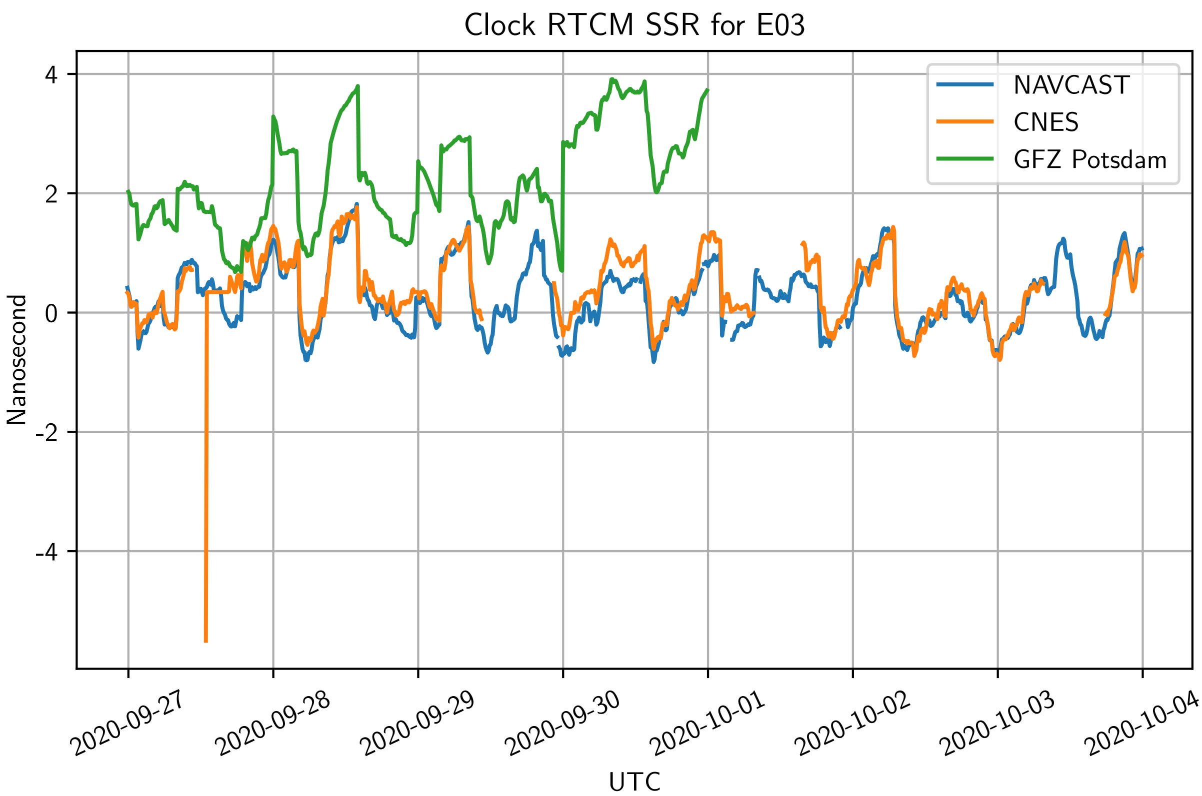
Radial RTCM SSR error for E01
NAVCAST
CNES
GFZ Potsdam
Meter
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

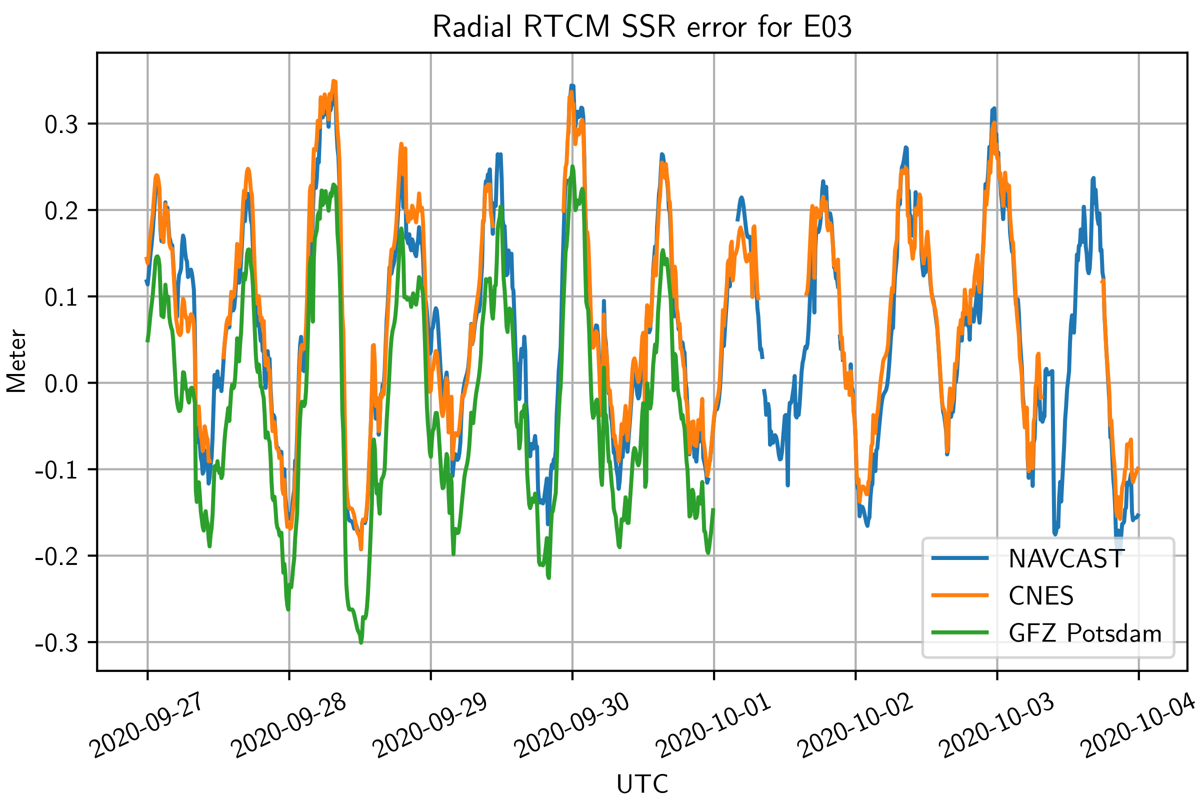
E02


Clock RTCM SSR for E02
NAVCAST
CNES
GFZ Potsdam
Nanosecond
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

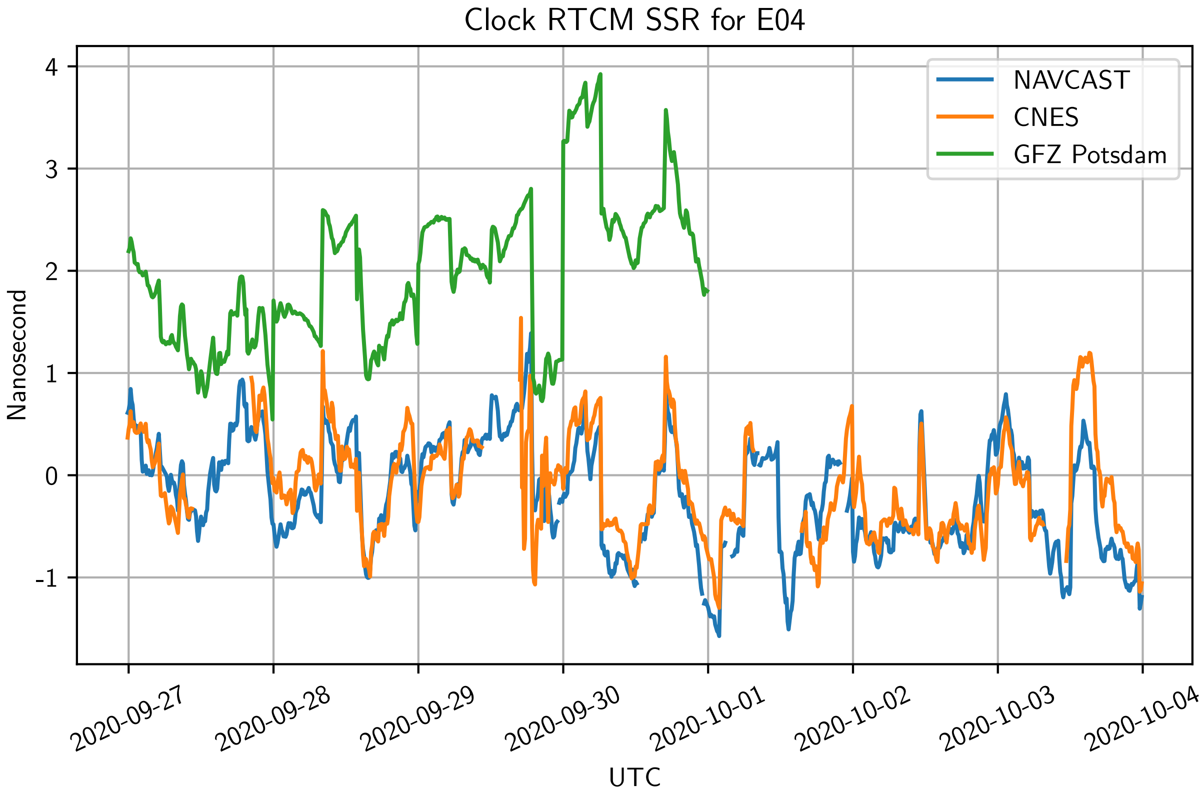

Radial RTCM SSR error for E02
NAVCAST
CNES
GFZ Potsdam
Meter
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E03

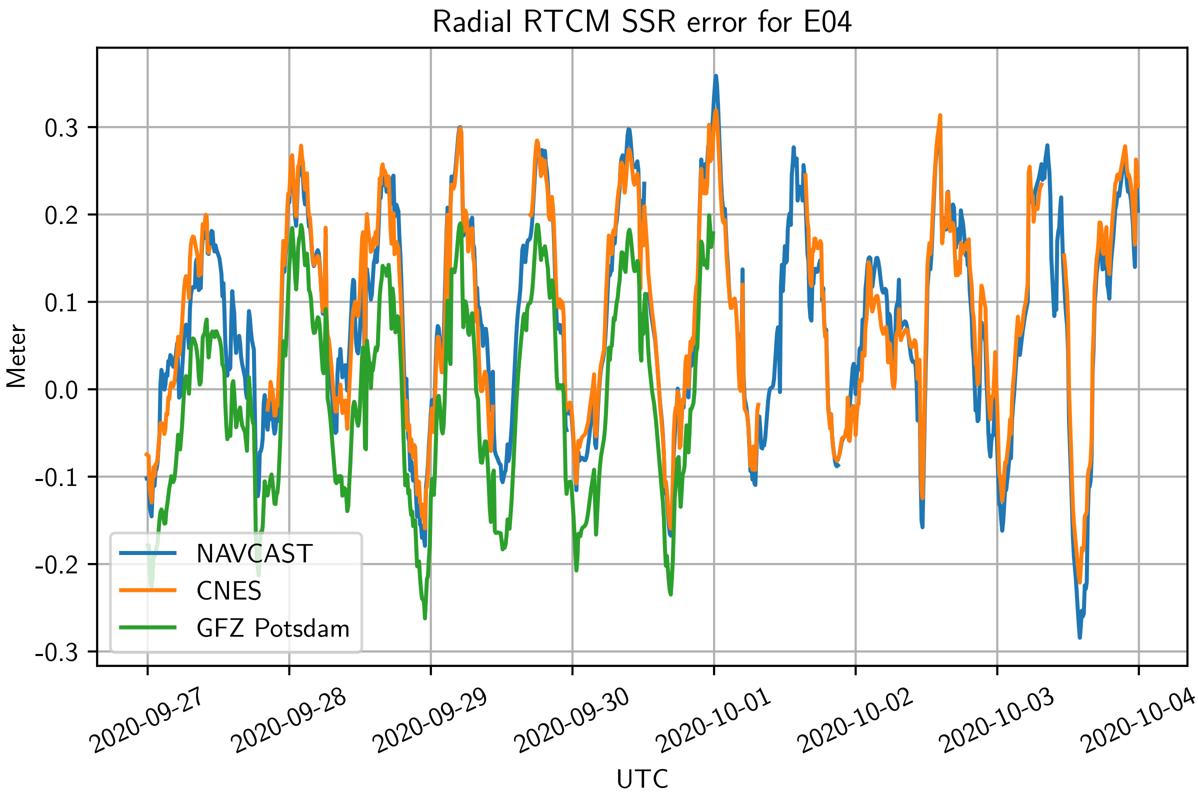

Clock RTCM SSR for E03
Nanosecond
4
2
0
-2
-4
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam


Radial RTCM SSR error for E03
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

E04

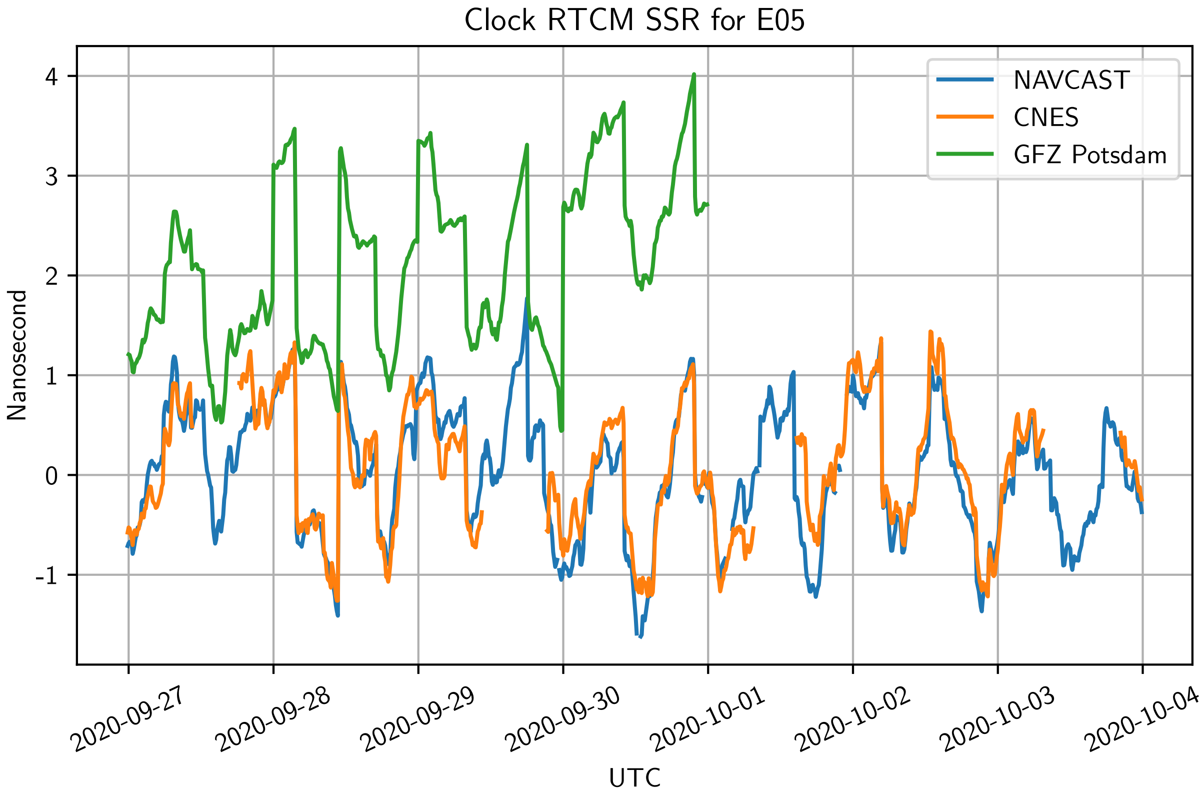


Clock RTCM SSR for E04
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

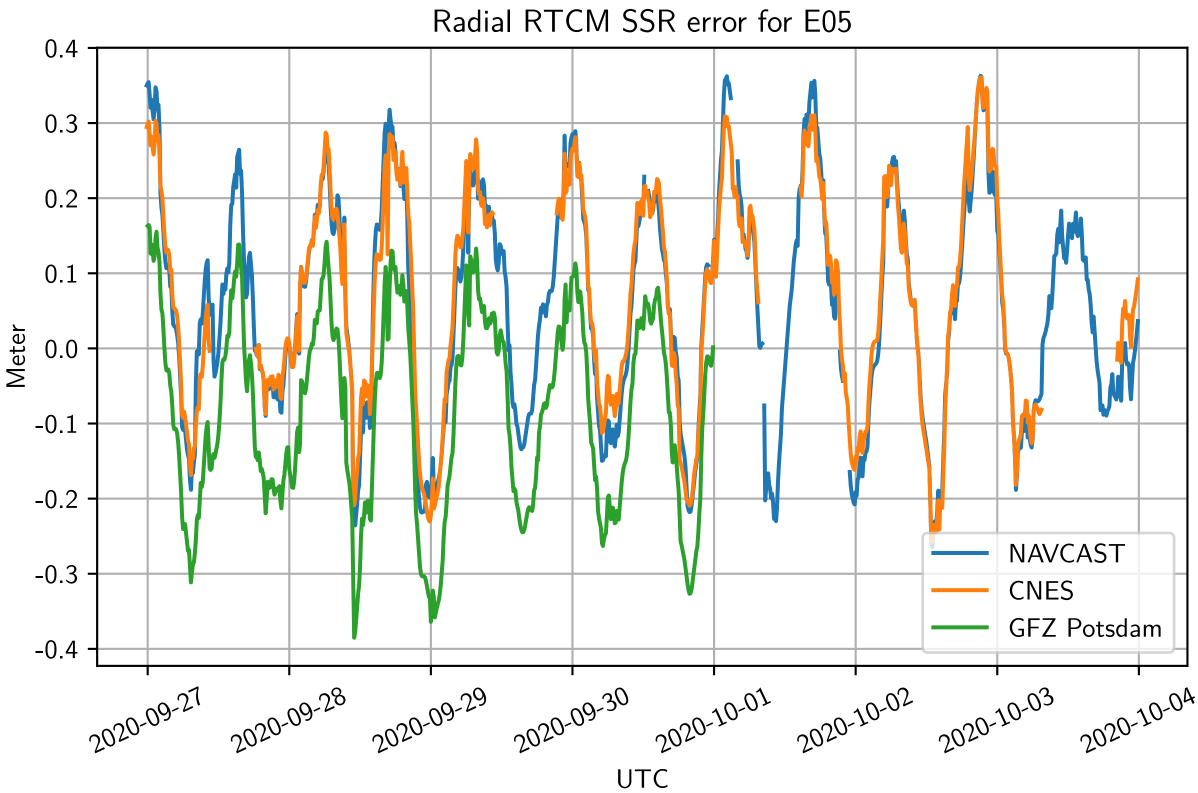


Radial RTCM SSR error for E04
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E05

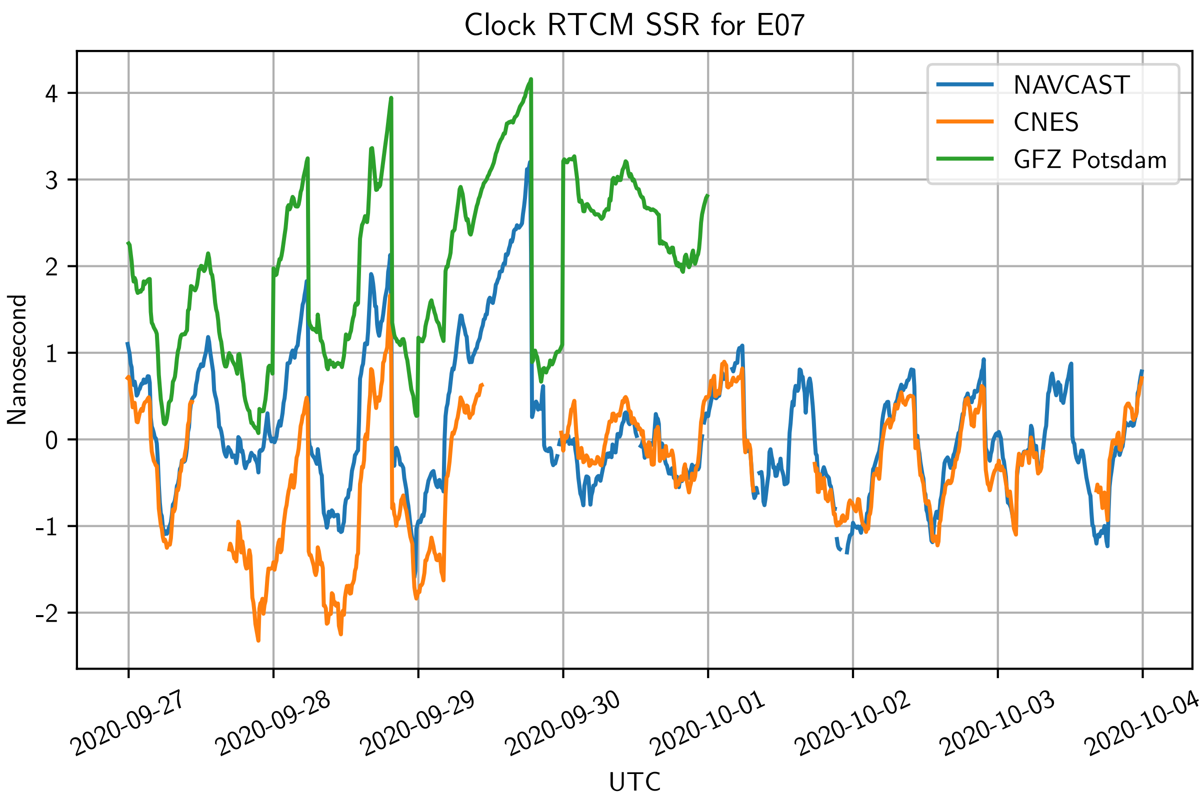


Clock RTCM SSR for E05
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

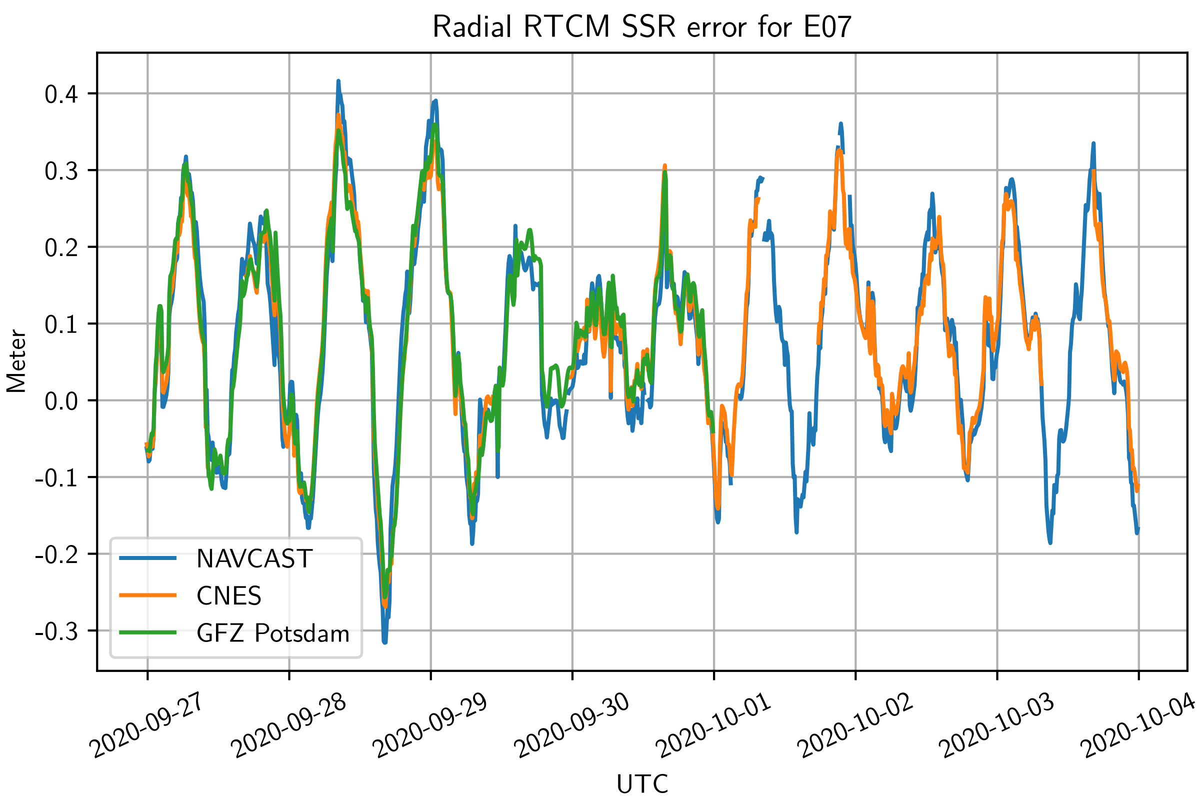


Radial RTCM SSR error for E05
Meter
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

E07

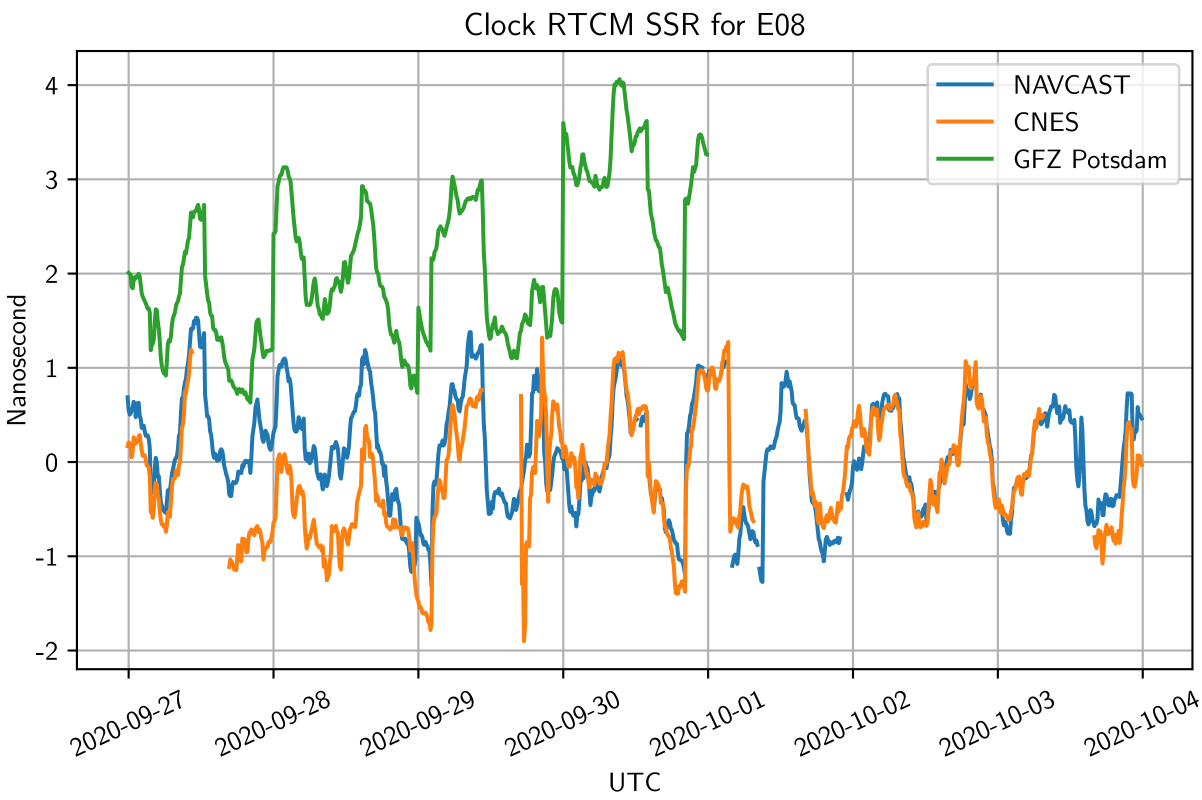


Clock RTCM SSR for E07
Nanosecond
UTC
NAVCAST
CNES
GFZ Potsdam
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04

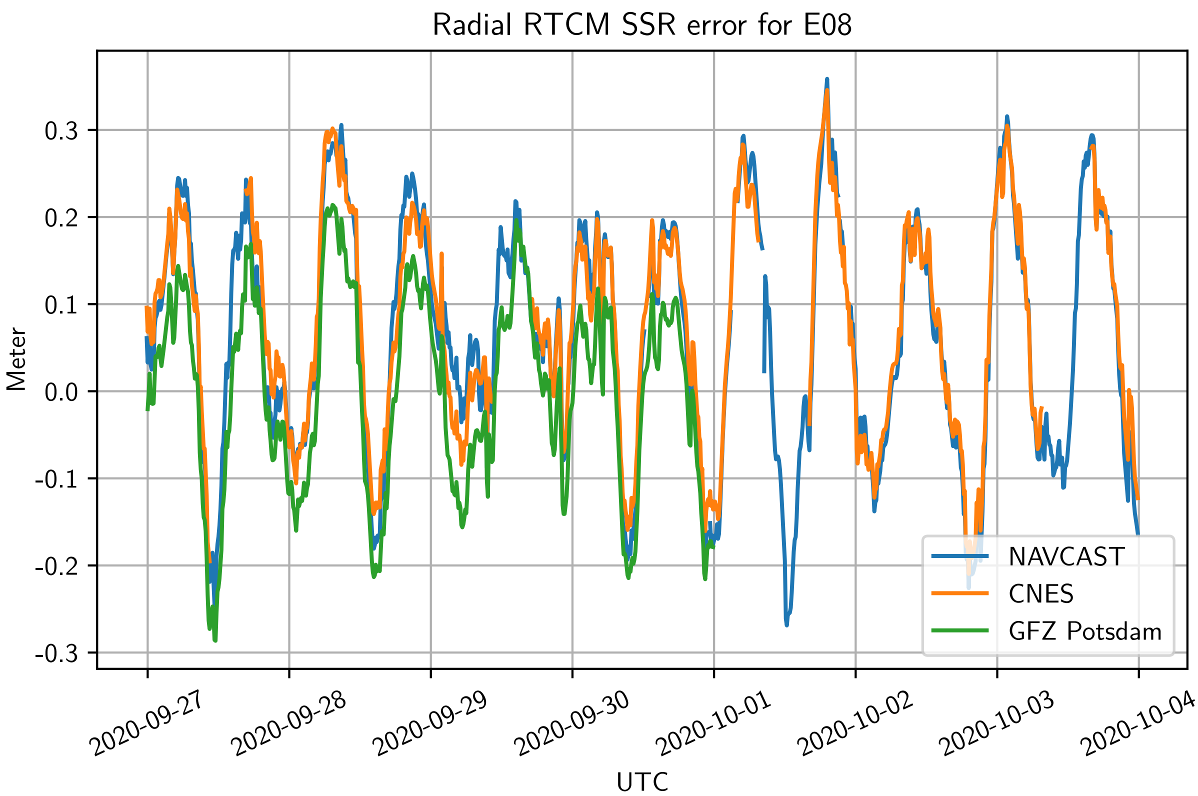


Radial RTCM SSR error for E07
Meter
UTC
NAVCAST
CNES
GFZ Potsdam
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04

E08

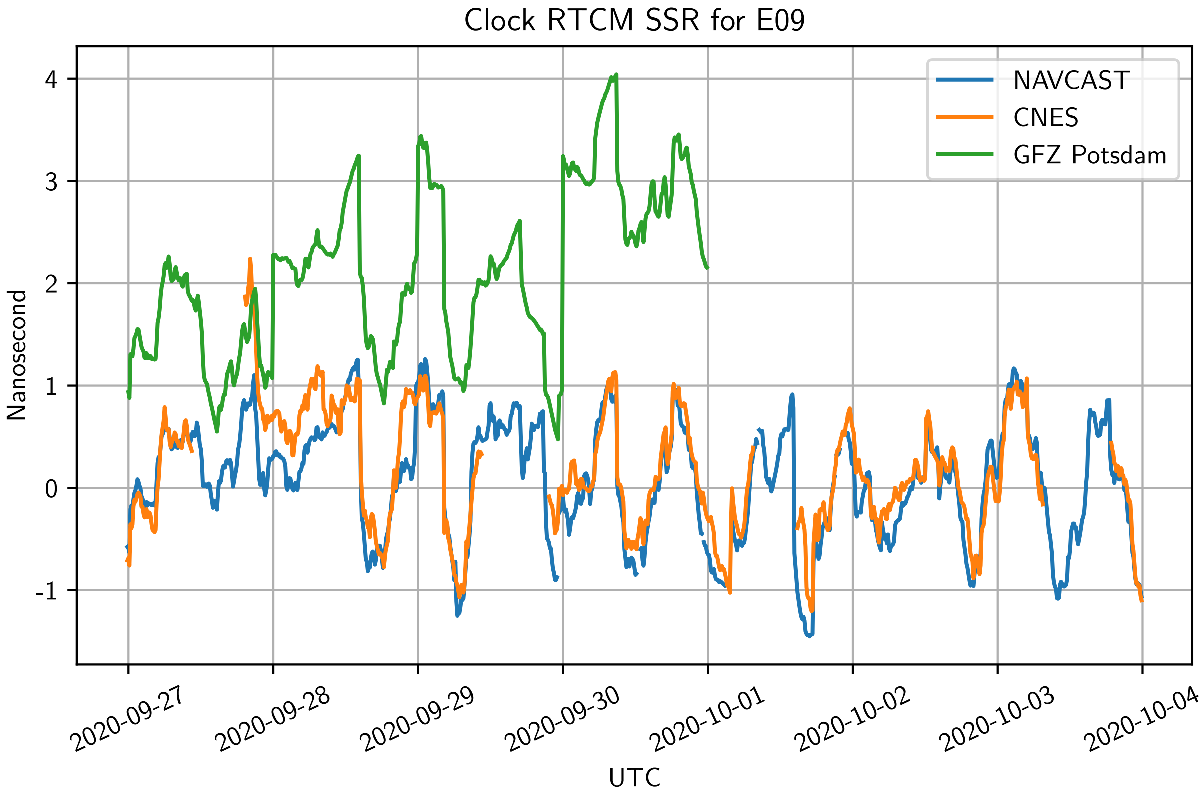


Clock RTCM SSR for E08
Nanosecond
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam



Radial RTCM SSR error for E08
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

E09


Clock RTCM SSR for E09
Nanosecond
UTC
NAVCAST
CNES
GFZ Potsdam
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
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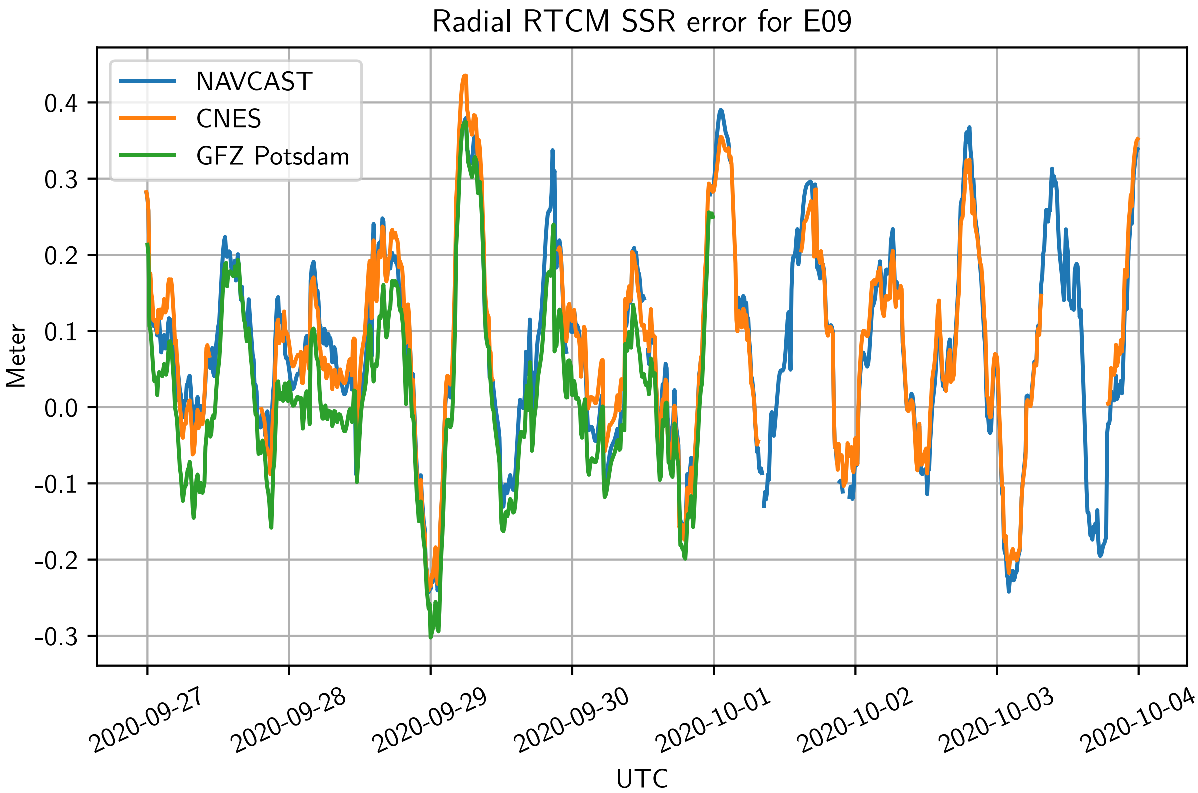
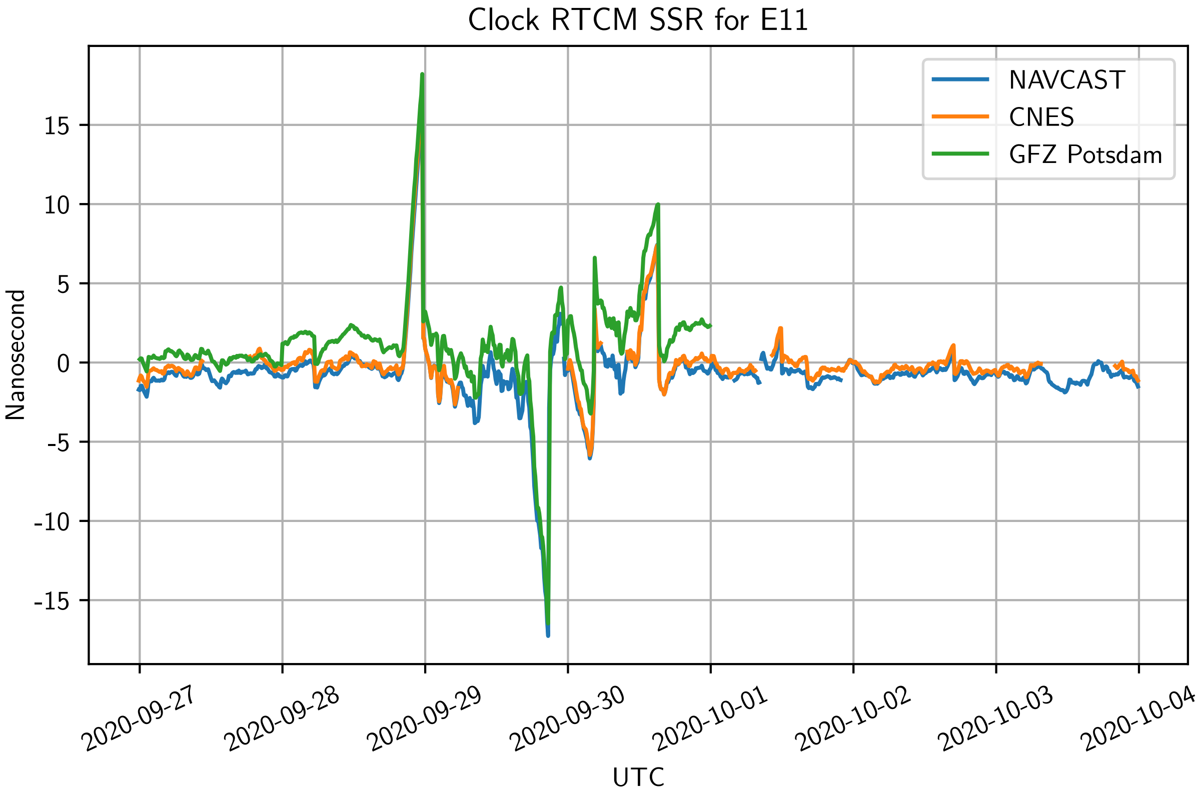
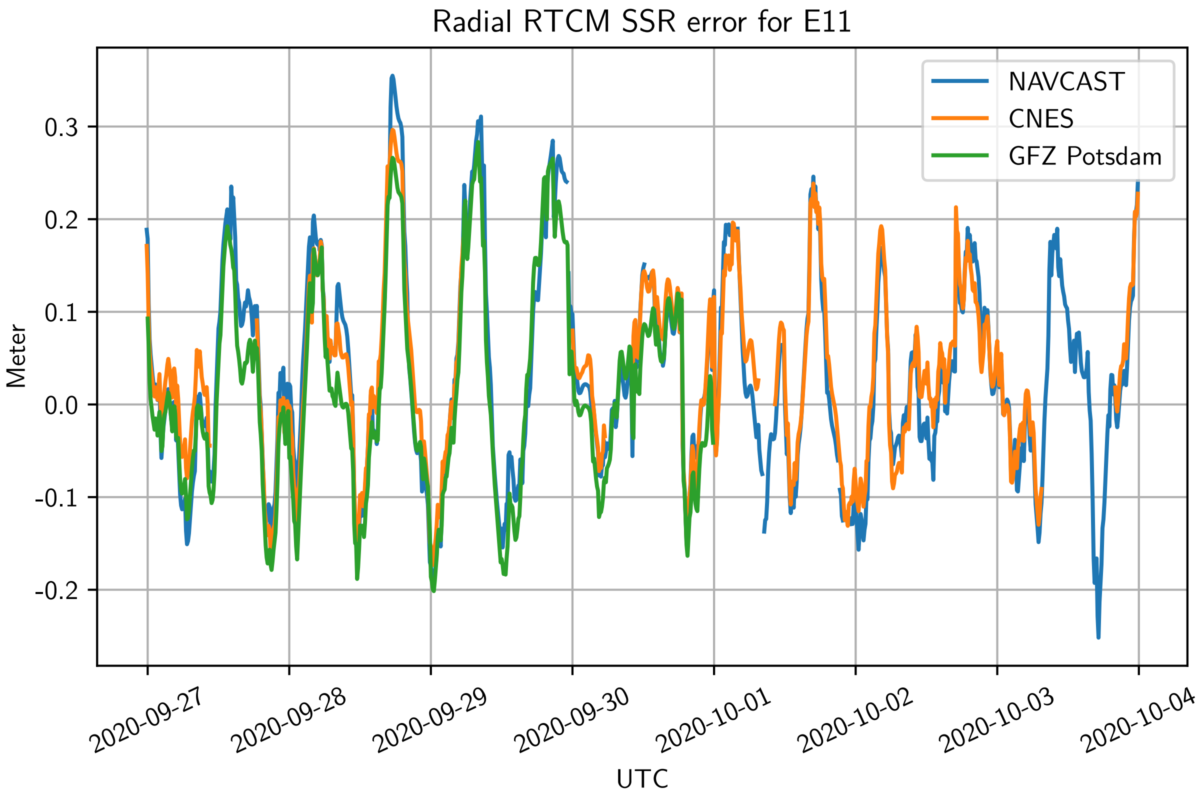
2020-10-01
2020-10-02
2020-10-03
2020-10-04


Radial RTCM SSR error for E09
Meter
UTC
NAVCAST
CNES
GFZ Potsdam
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04

E11

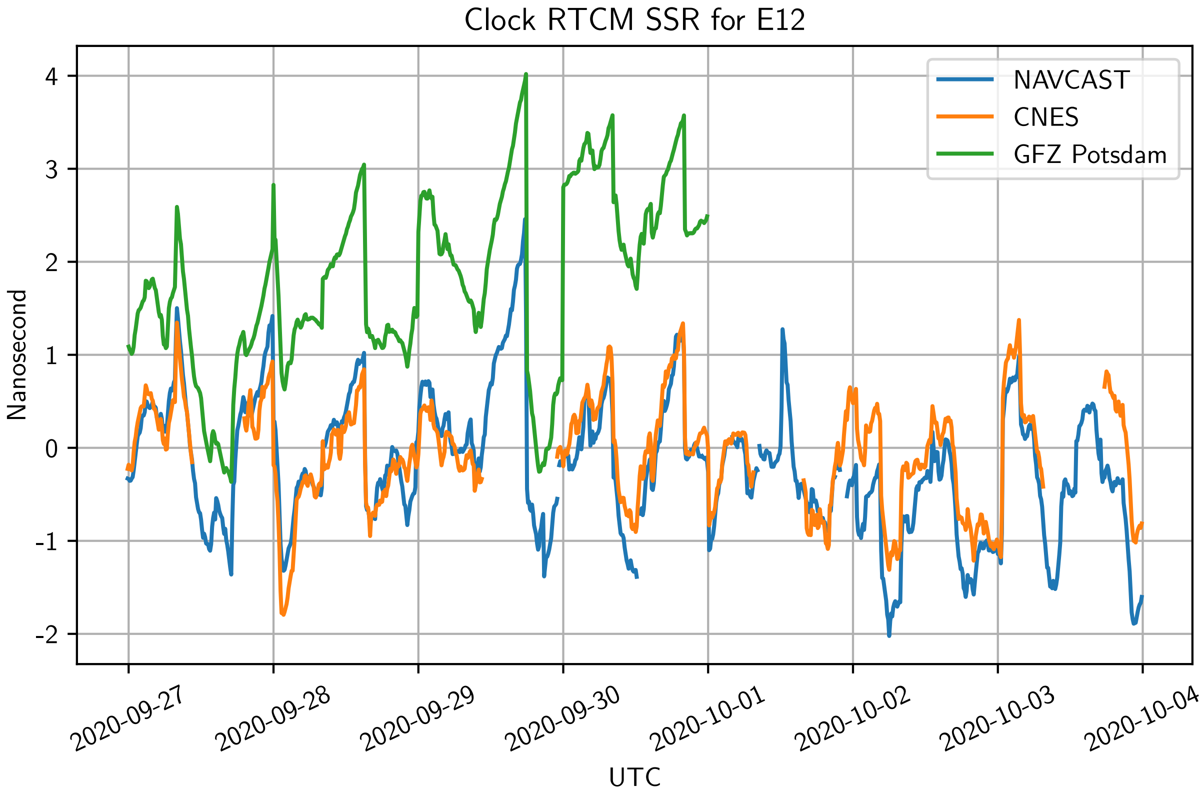


Clock RTCM SSR for E11
NAVCAST
CNES
GFZ Potsdam
Nanosecond
15
10
5
0
-5
-10
-15
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

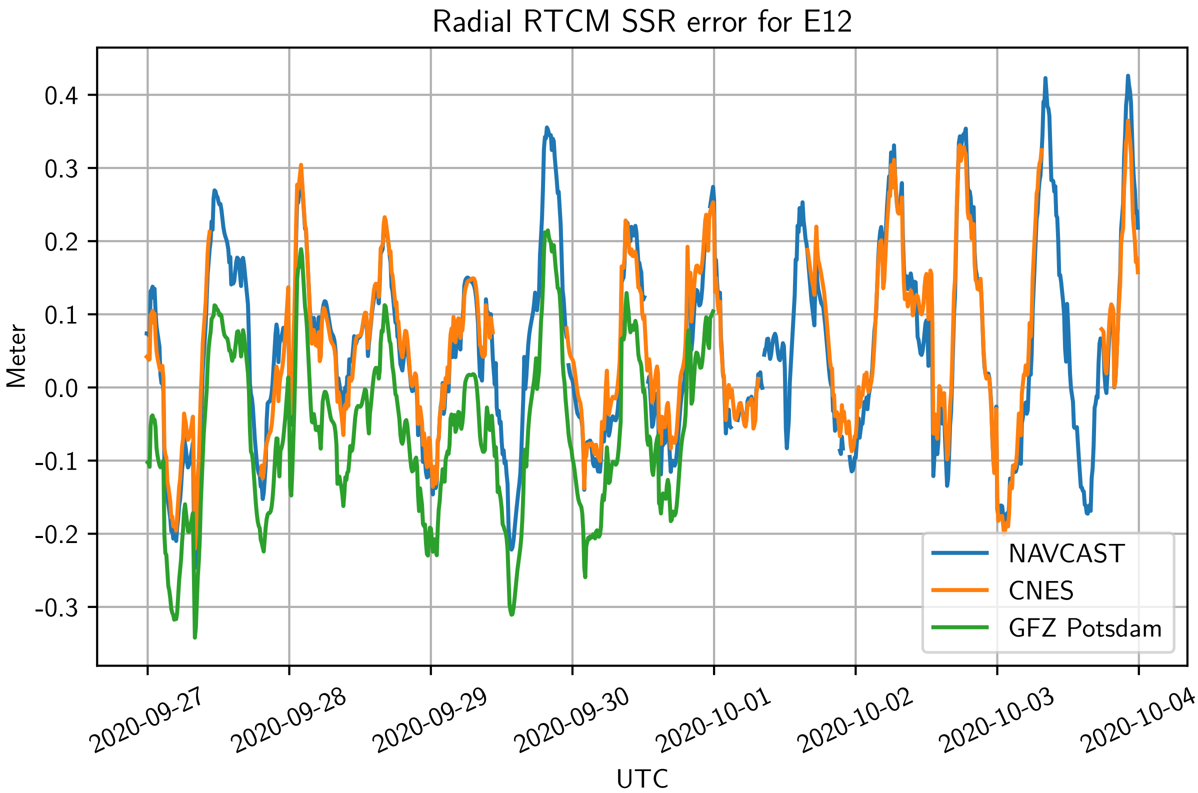


Radial RTCM SSR error for E11
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E12

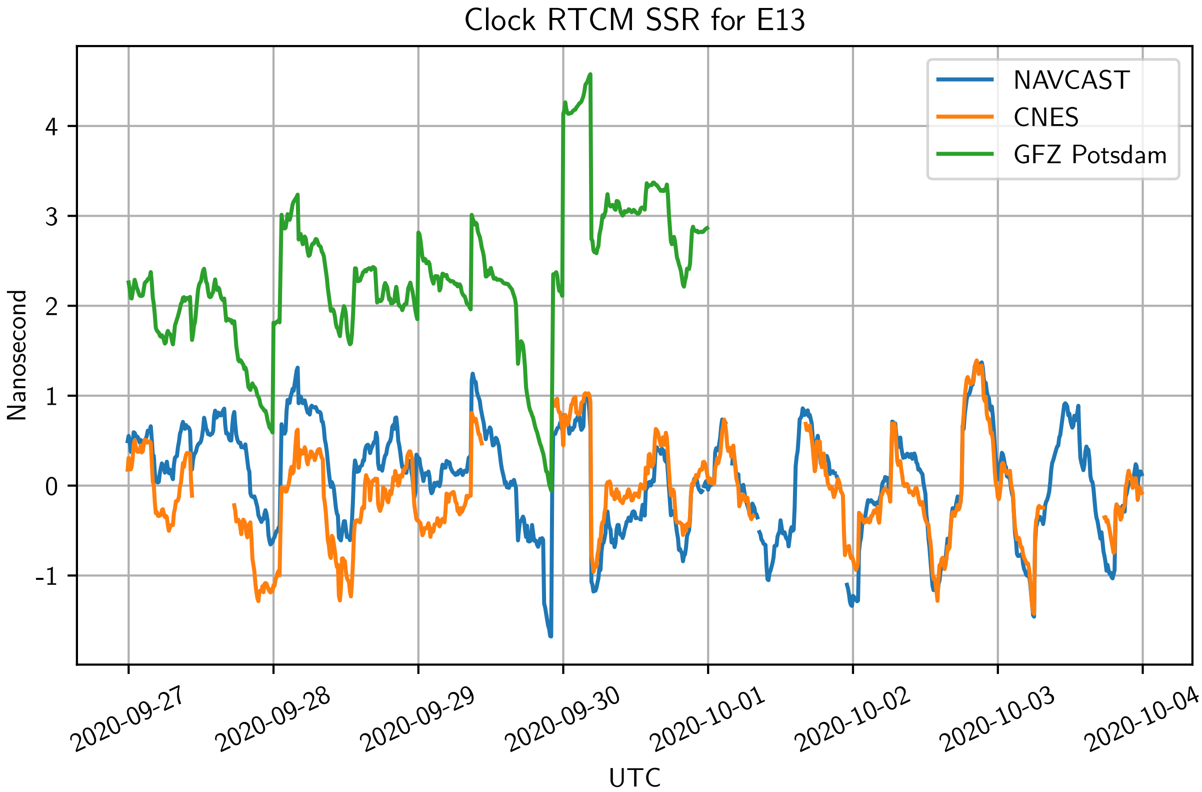


Clock RTCM SSR for E12
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

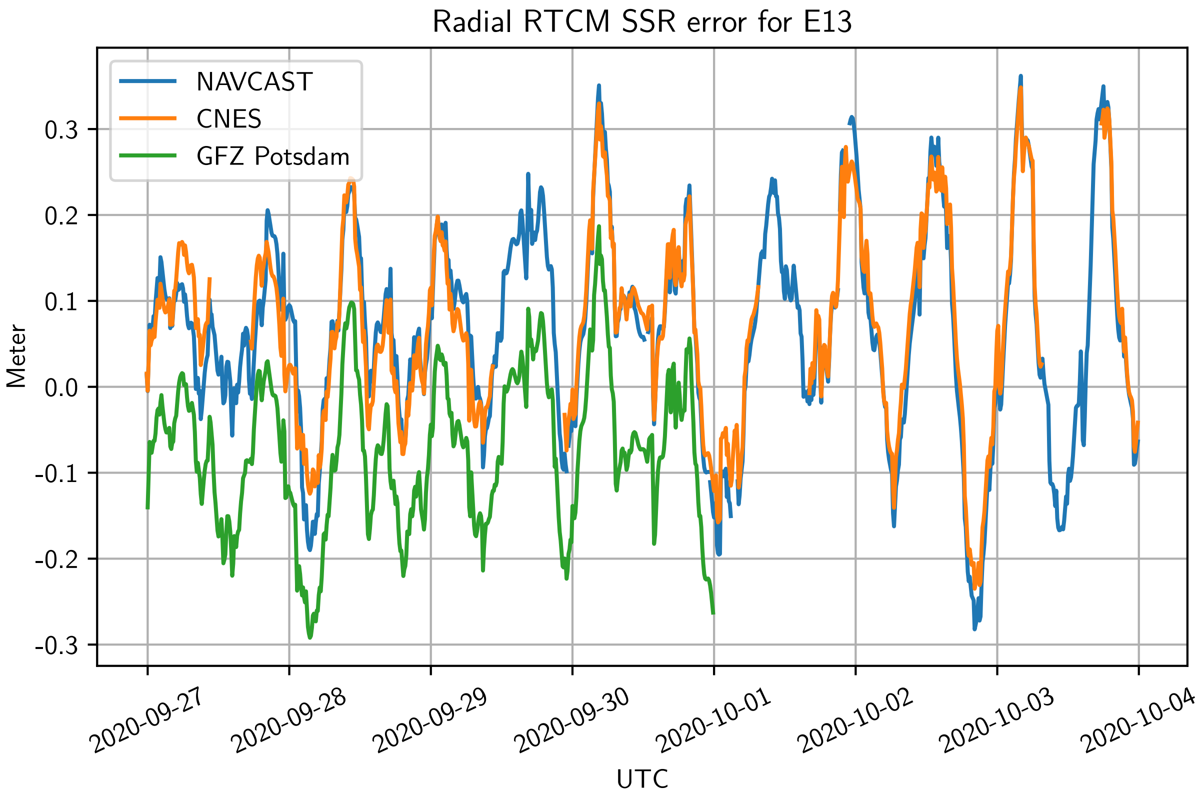


Radial RTCM SSR error for E12
NAVCAST
CNES
GFZ Potsdam
Meter
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E13

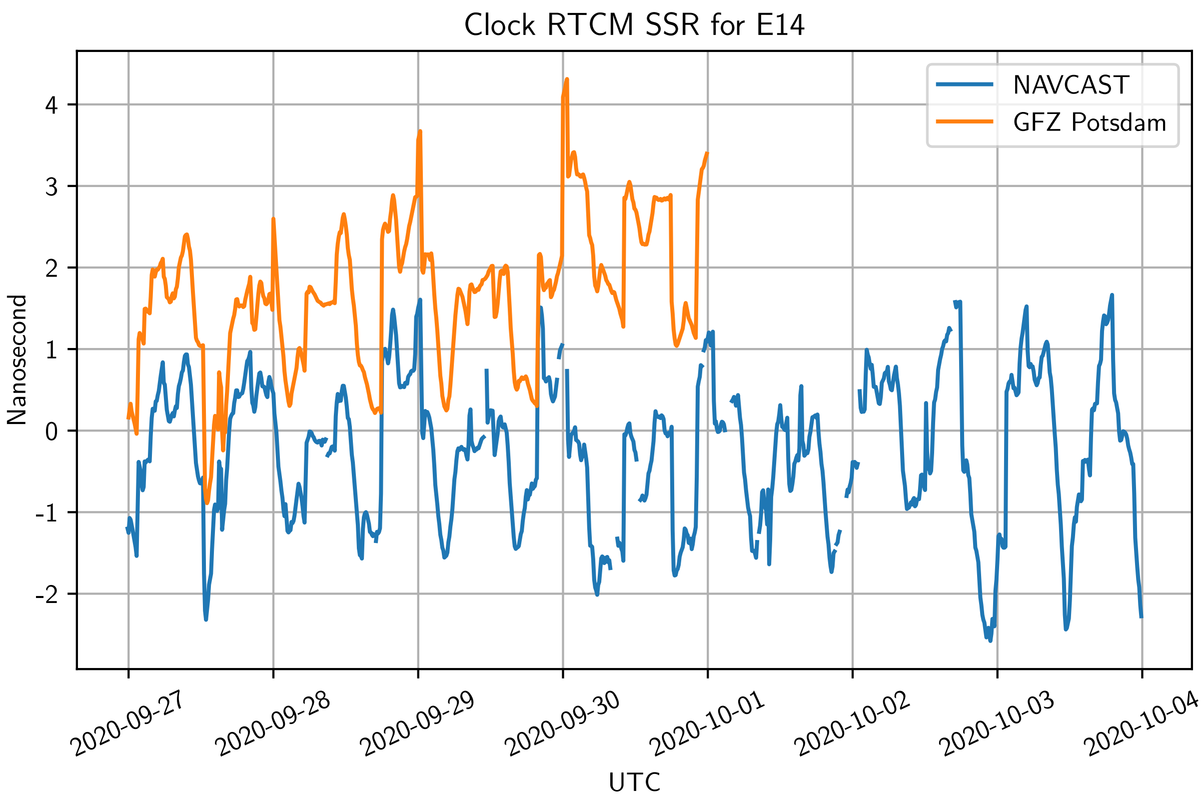


Clock RTCM SSR for E13
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

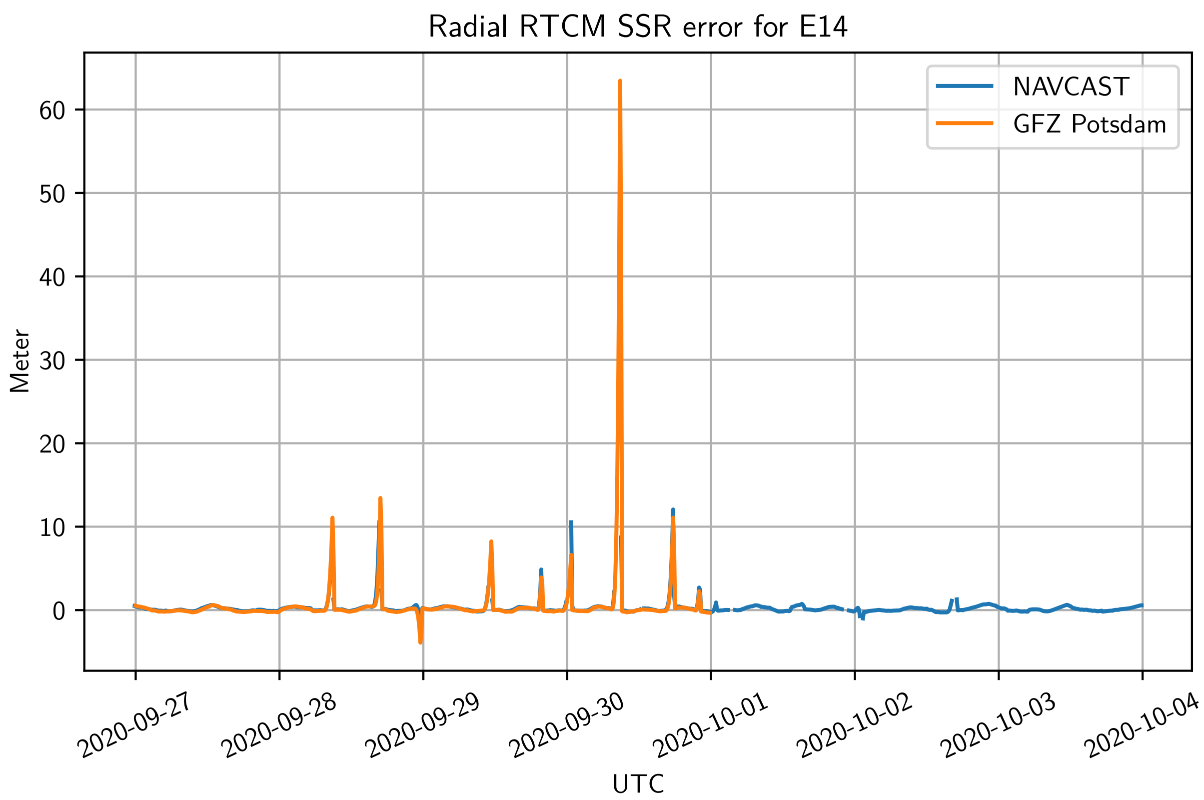


Radial RTCM SSR error for E13
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E14

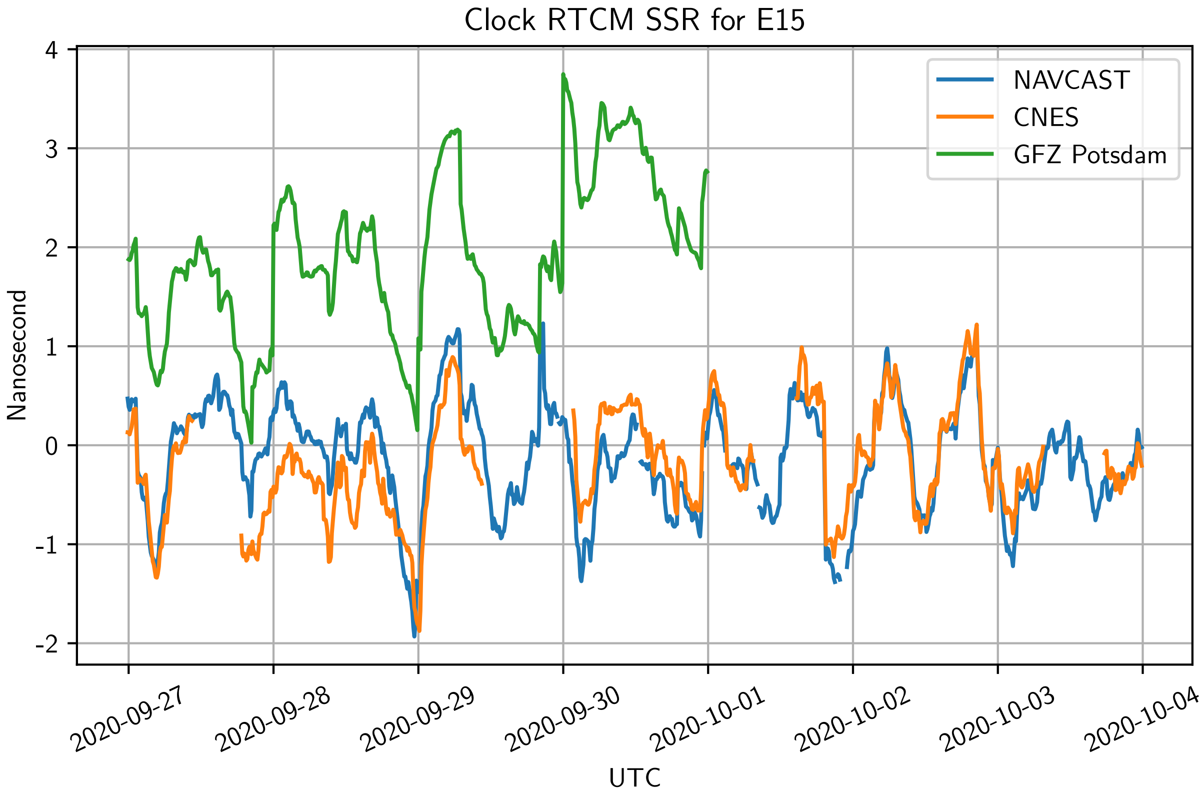


Clock RTCM SSR for E14
NAVCAST
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

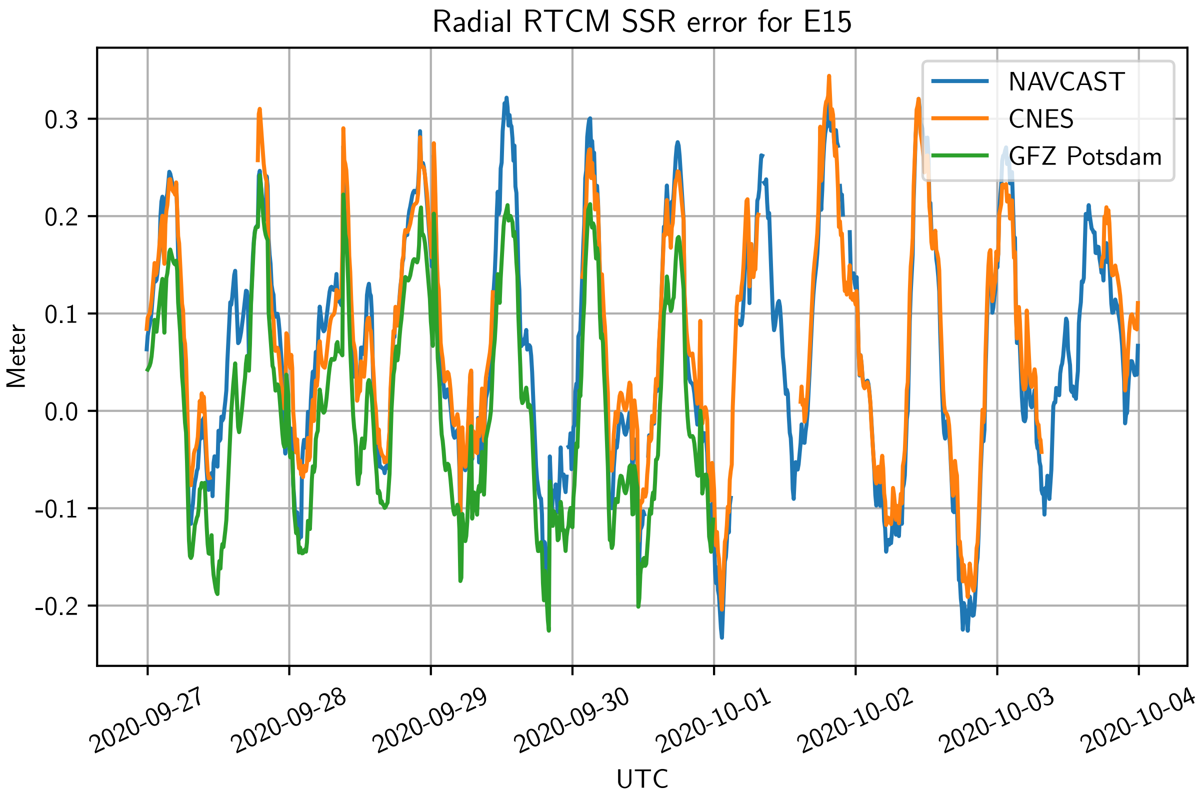


Radial RTCM SSR error for E14
NAVCAST
GFZ Potsdam
Meter
60
50
40
30
20
10
0
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E15

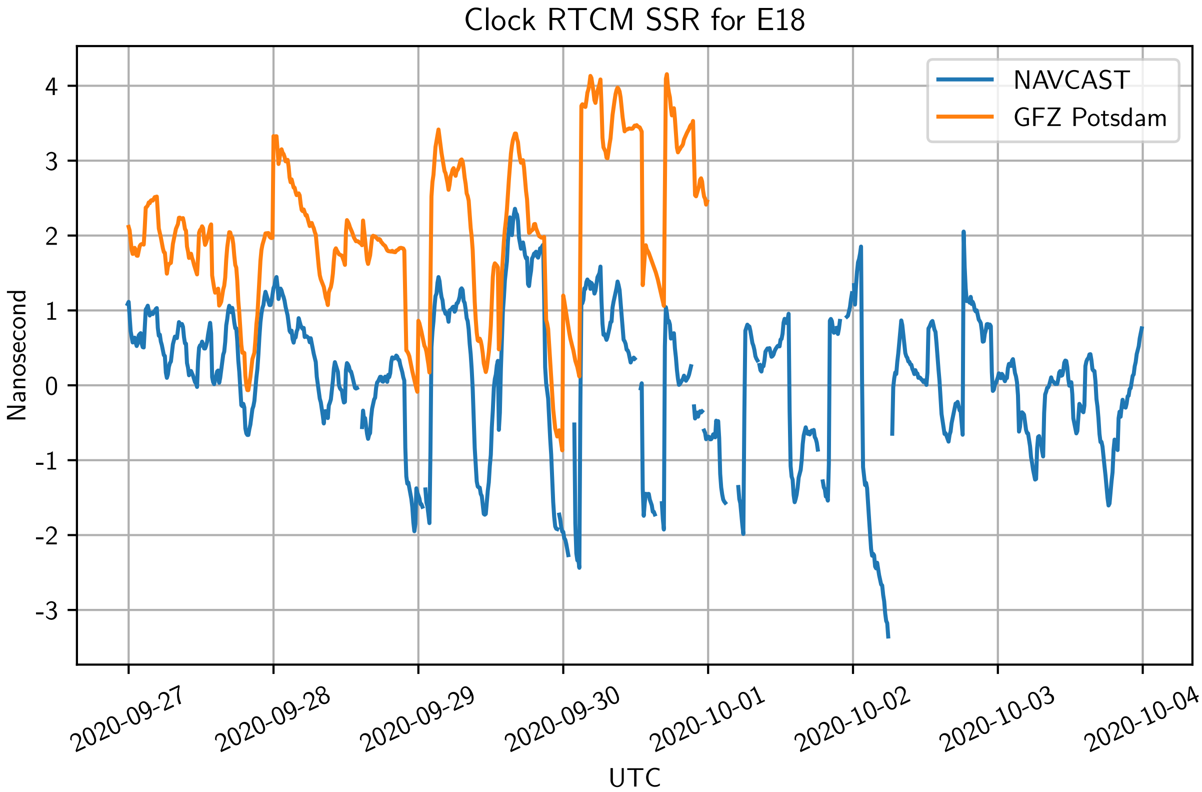


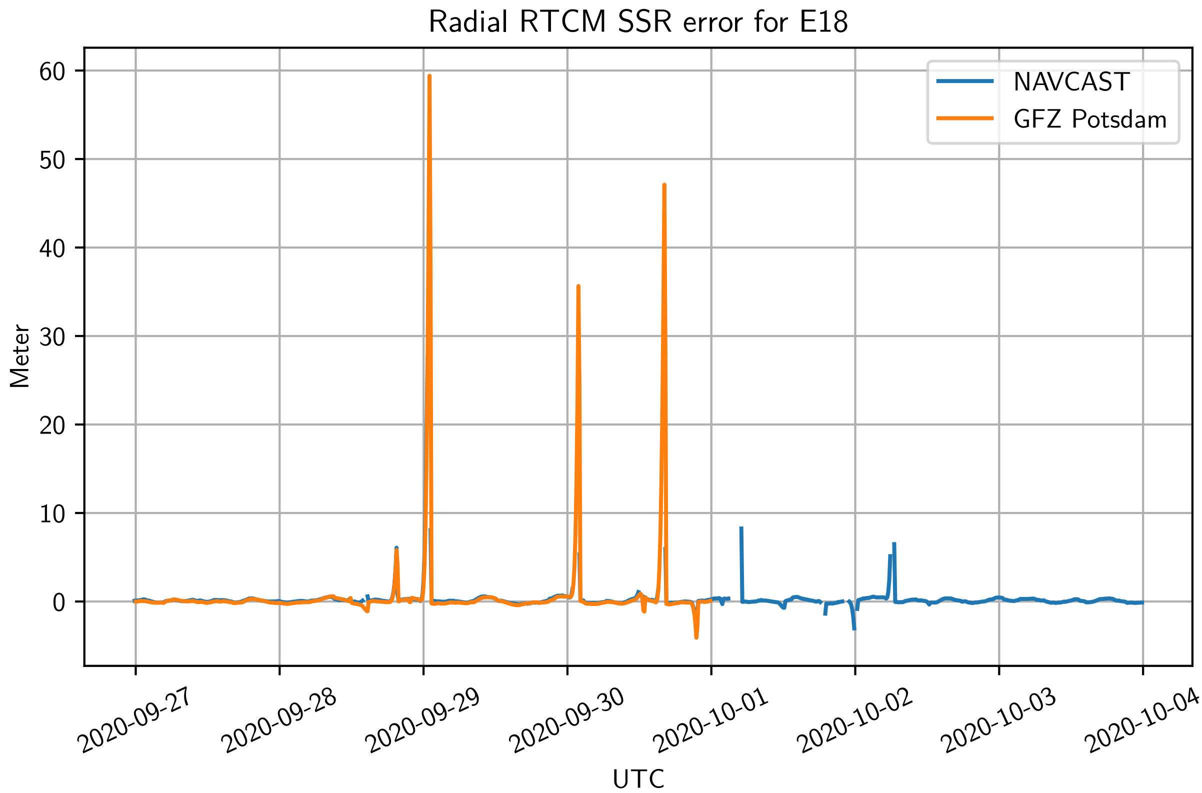
Clock RTCM SSR for E15
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC



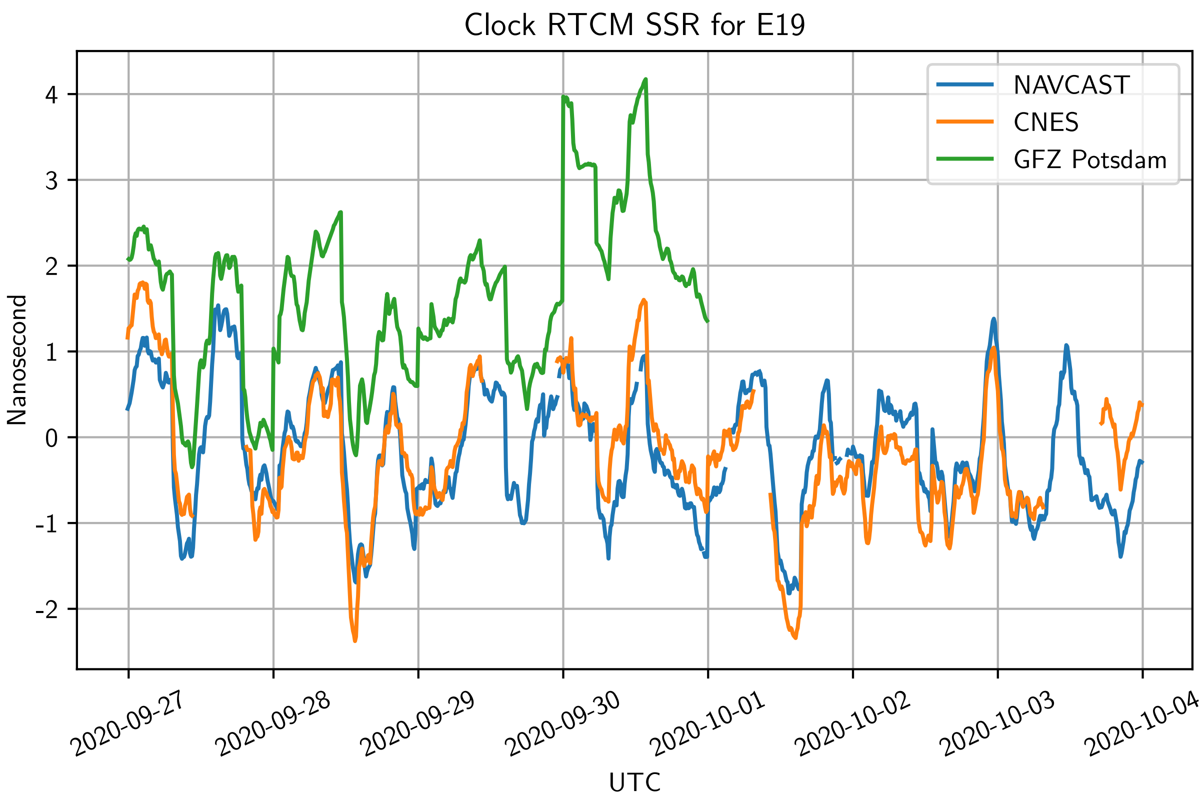
Radial RTCM SSR error for E15
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E18

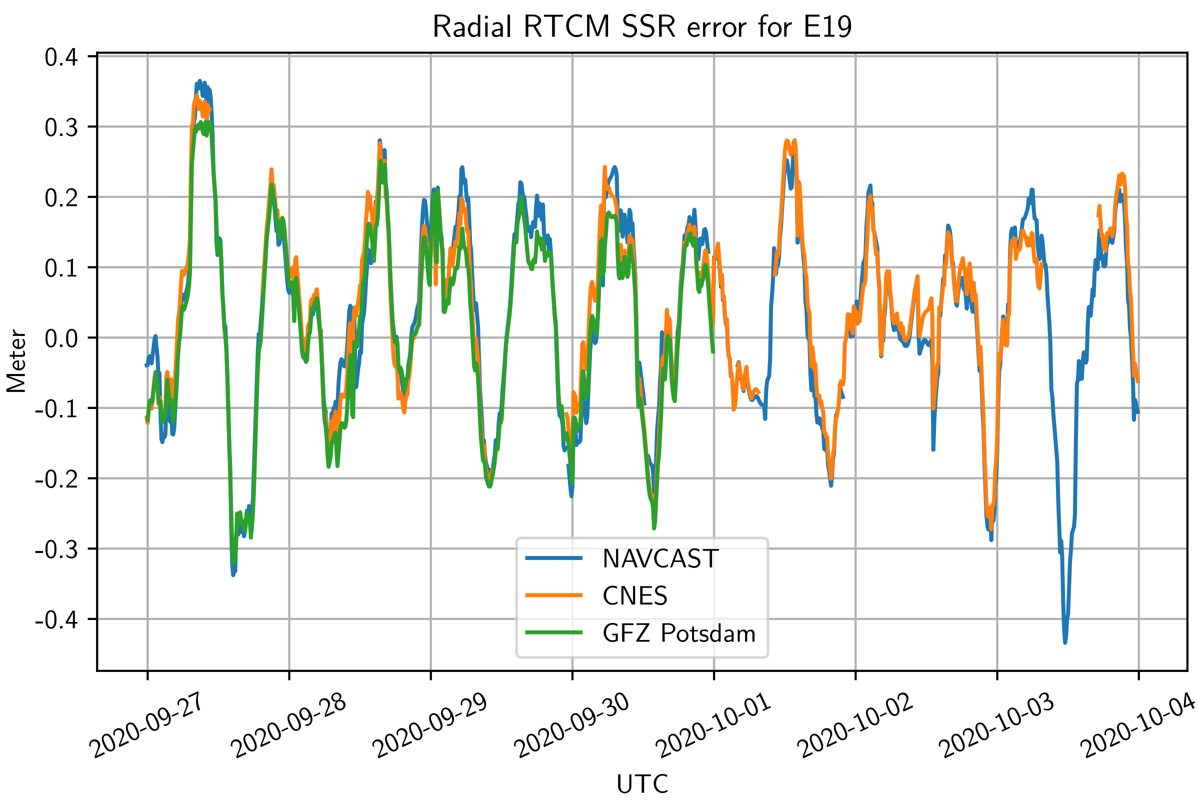

Clock RTCM SSR for E18
NAVCAST
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
-2
-3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC


Radial RTCM SSR error for E18
NAVCAST
GFZ Potsdam
Meter
60
50
40
30
20
10
0
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E19

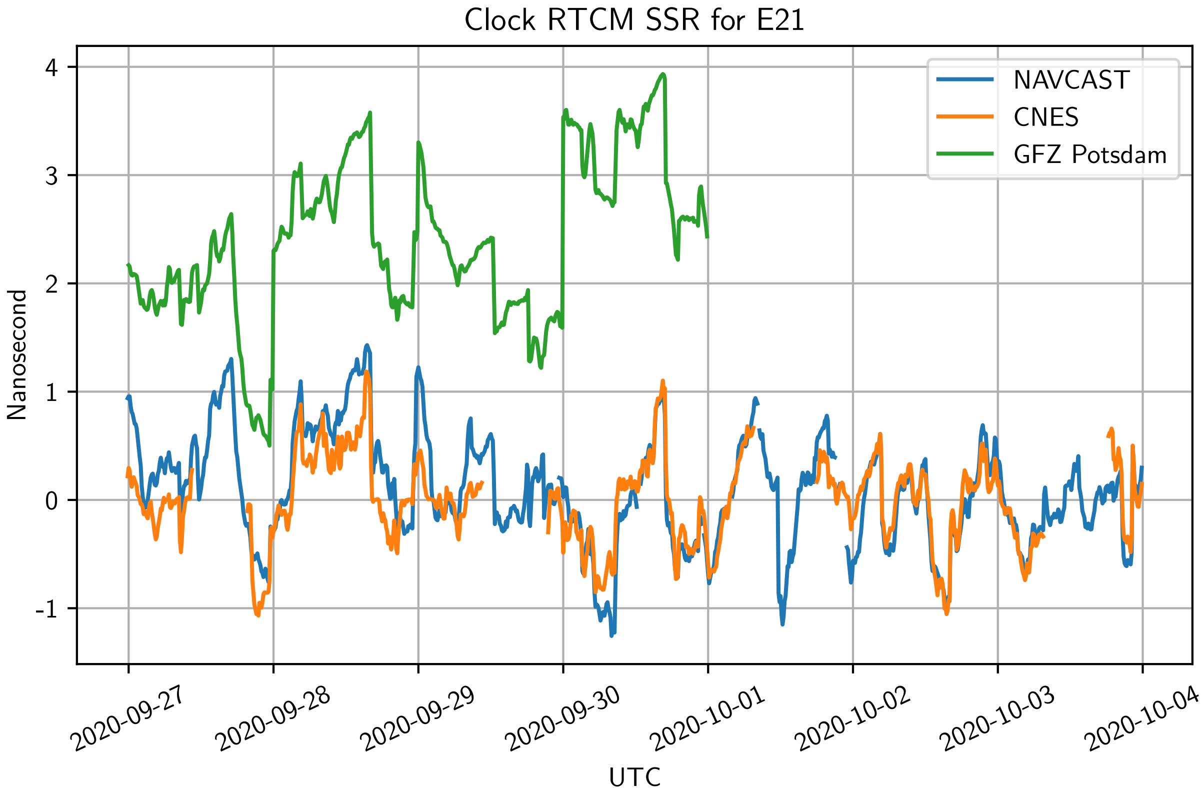


Clock RTCM SSR for E19
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

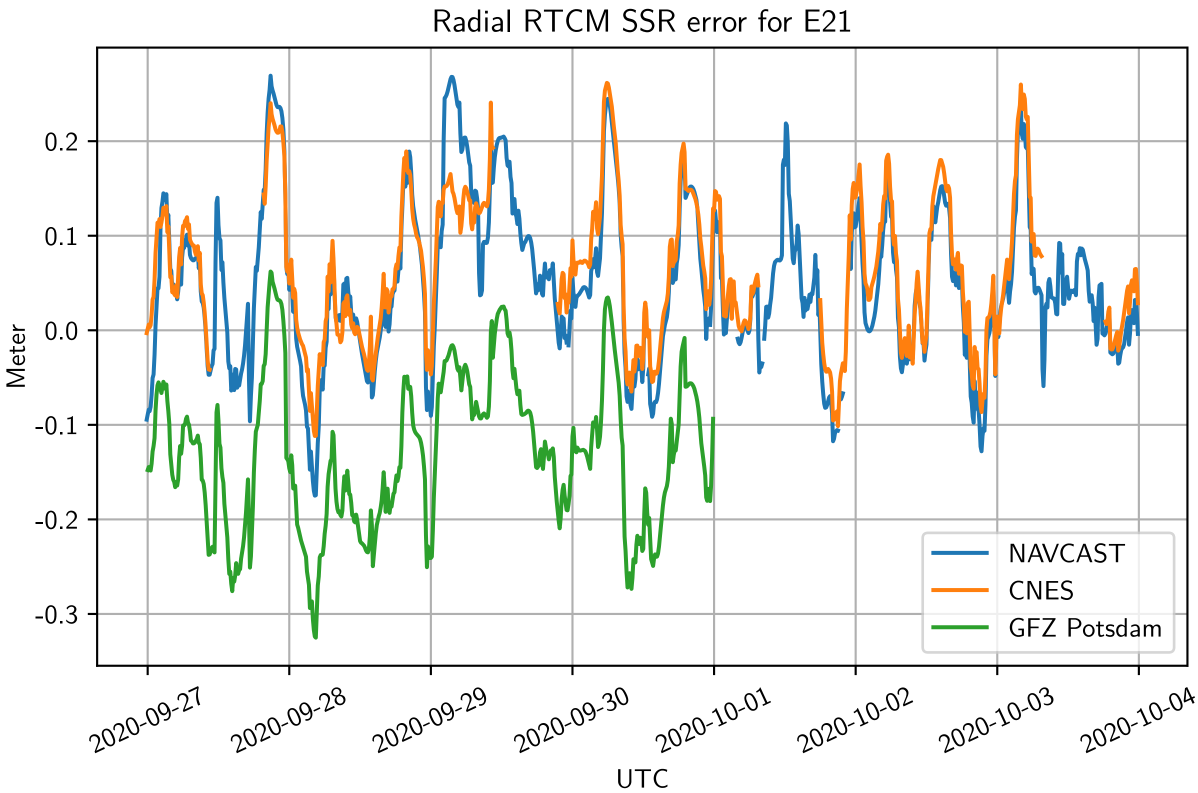


Radial RTCM SSR error for E19
Meter
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
NAVCAST
CNES
GFZ Potsdam
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E21

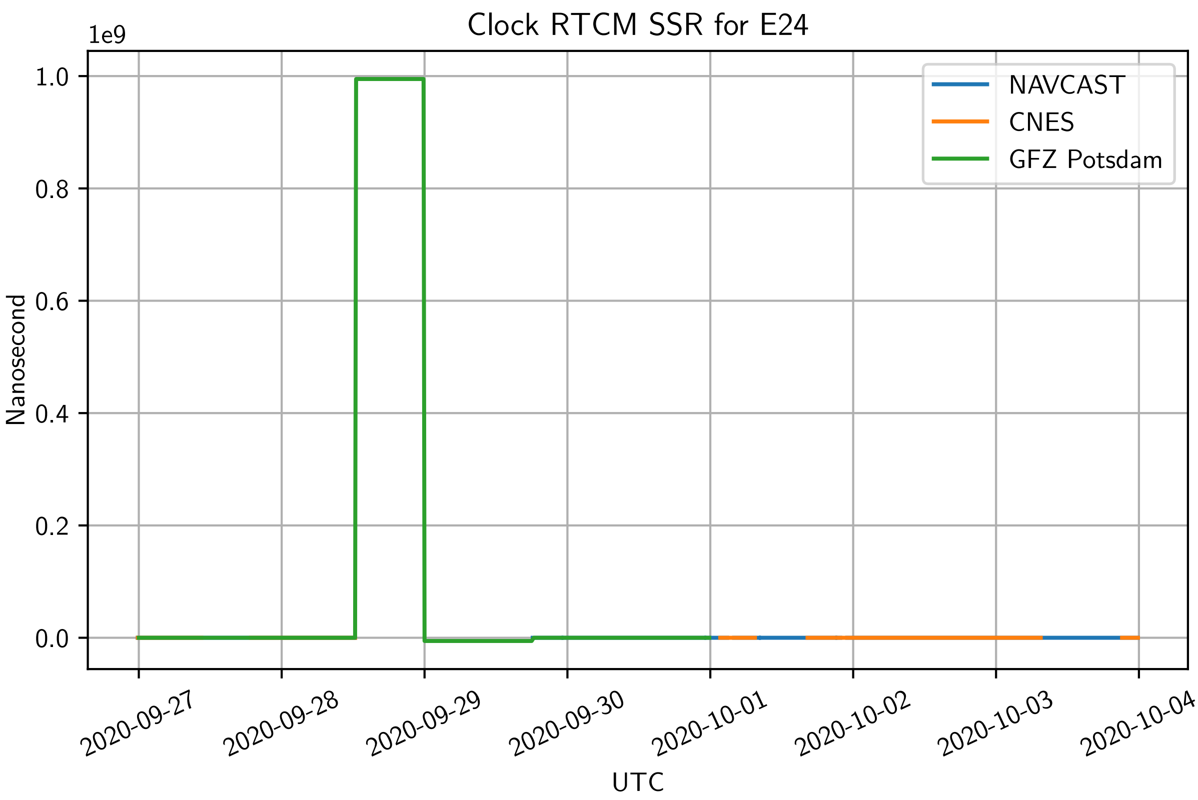


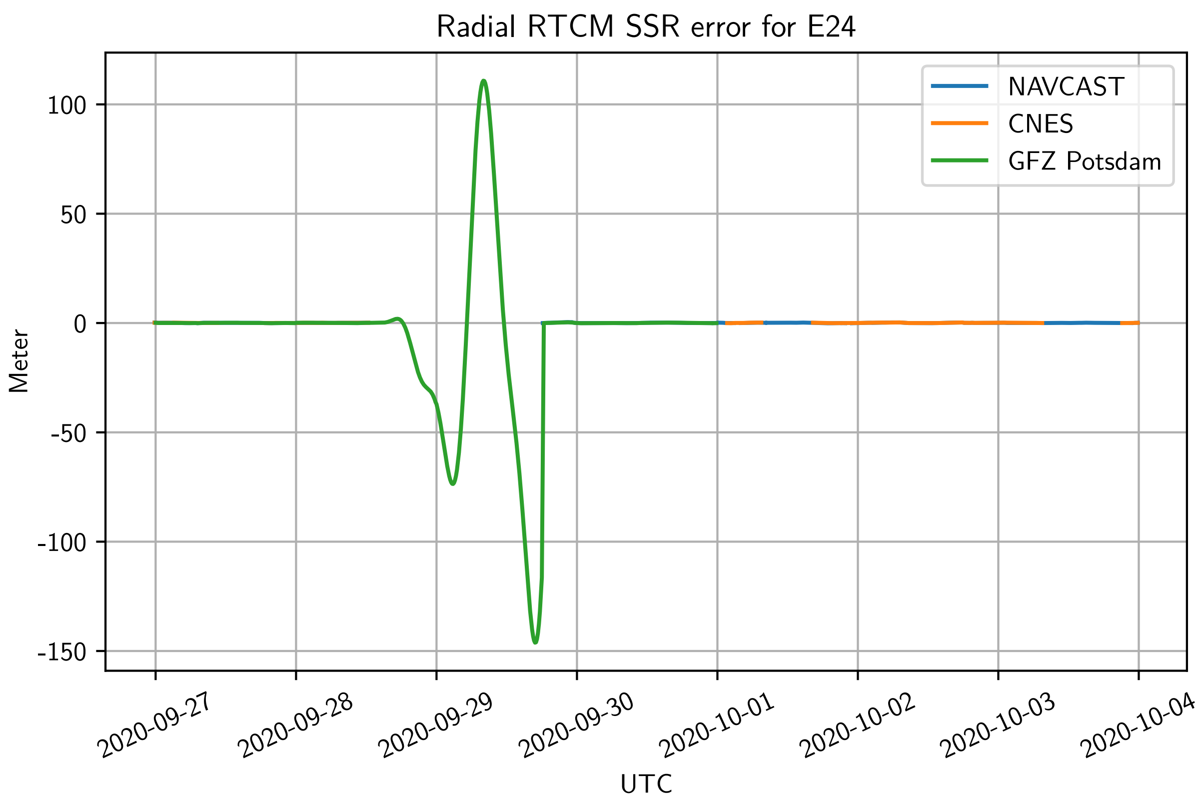
Clock RTCM SSR for E21
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam



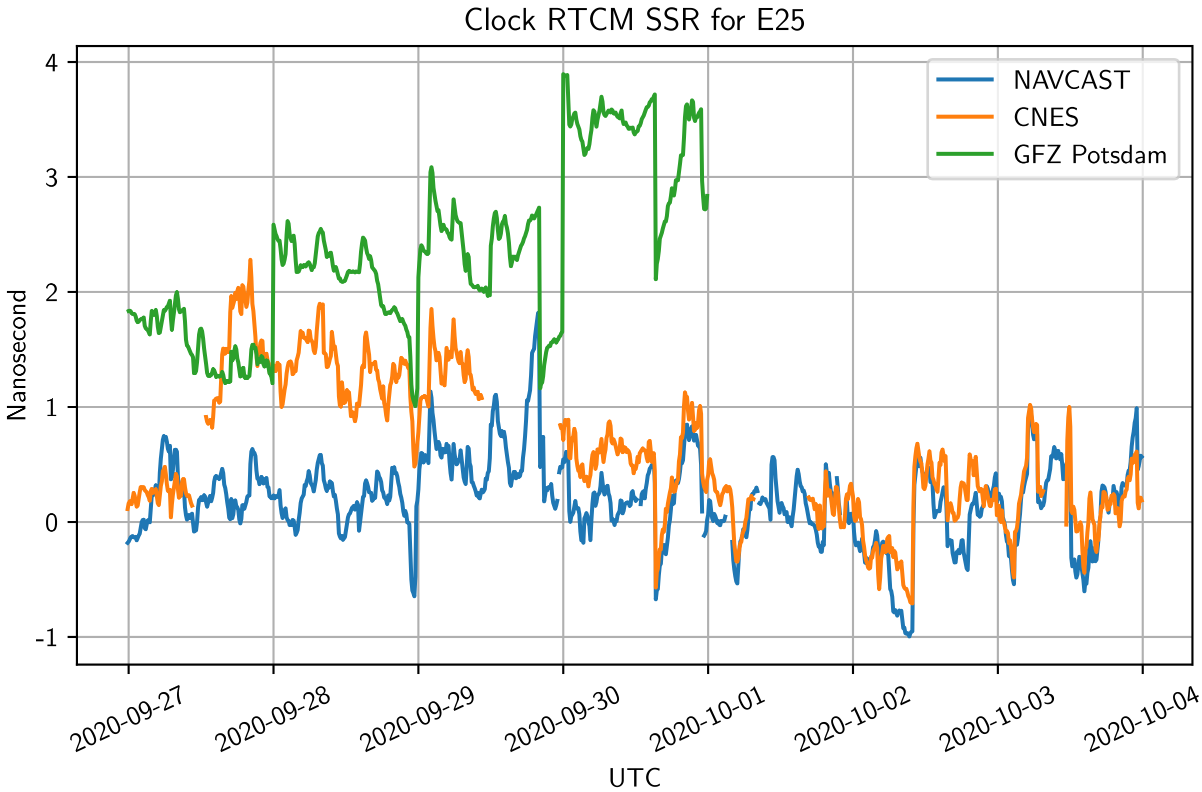
Radial RTCM SSR error for E21
Meter
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

E24

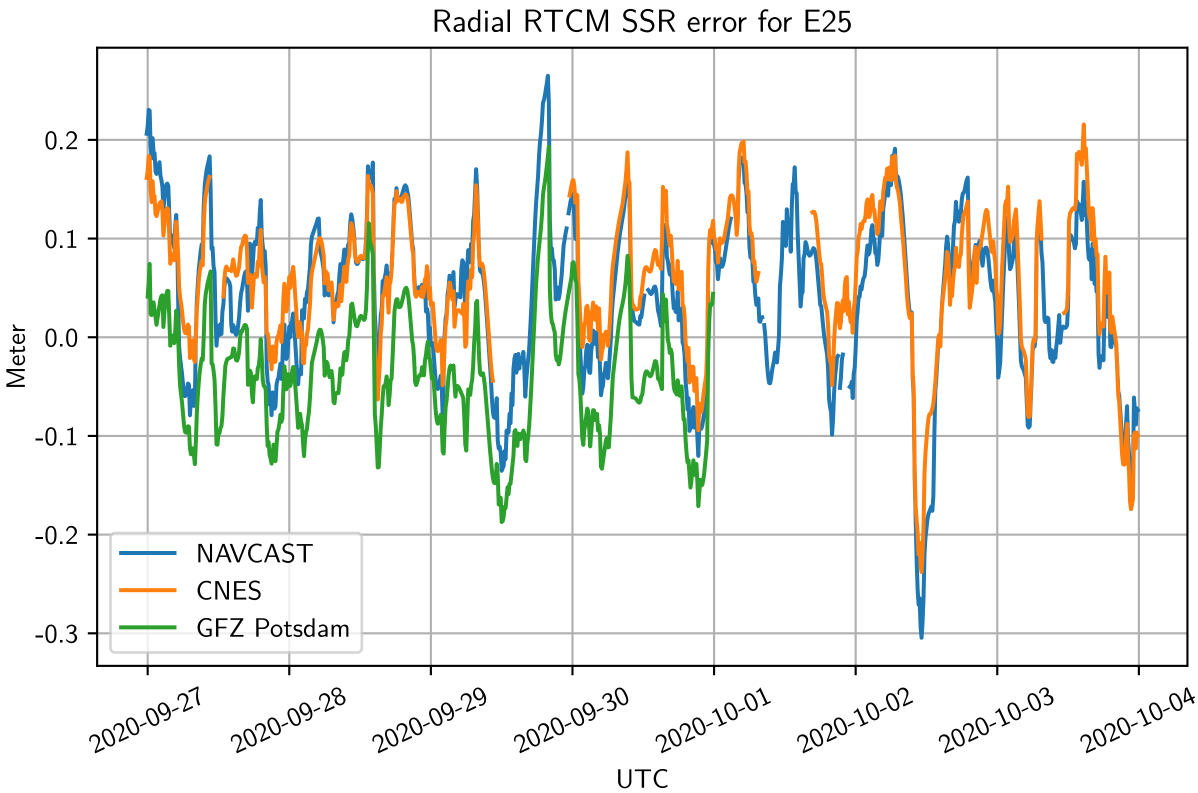

Clock RTCM SSR for E24
1e9
1.0
0.8
0.6
0.4
0.2
0.0
Nanosecond
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam


Radial RTCM SSR error for E24
100
50
0
-50
-100
-150
Meter
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC
NAVCAST
CNES
GFZ Potsdam

E25

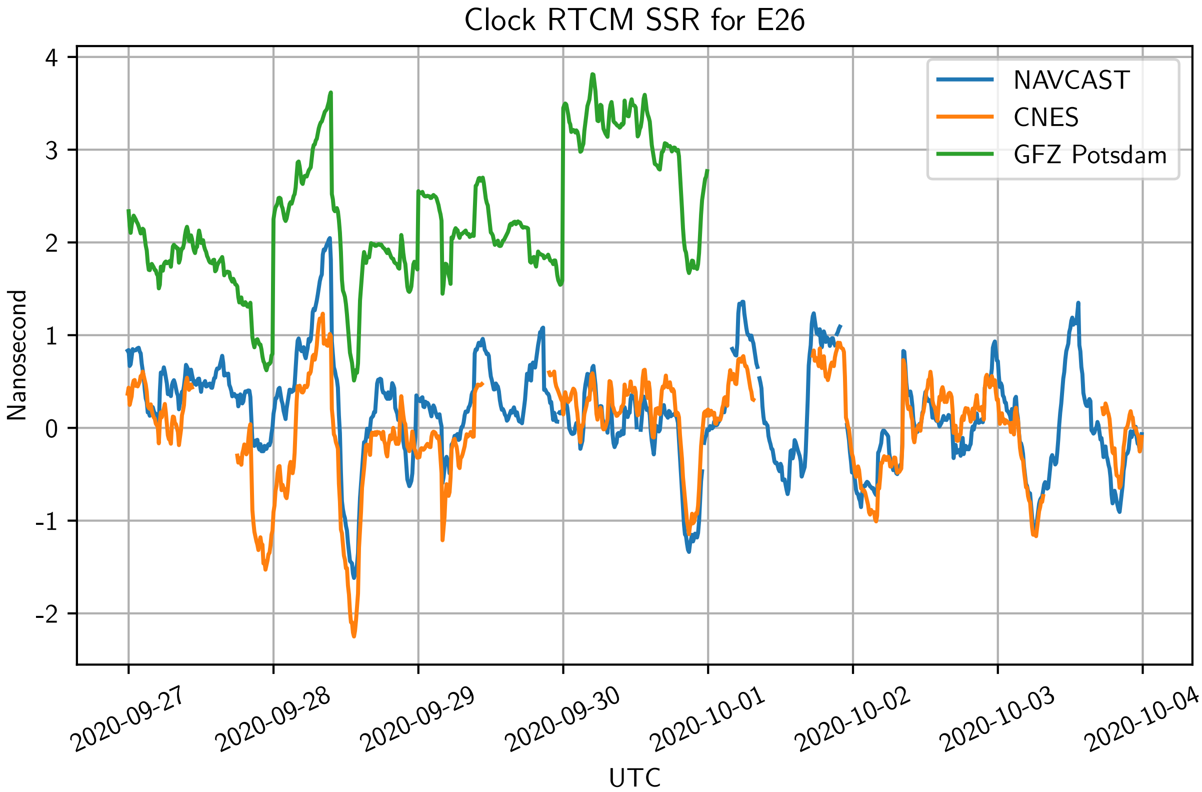


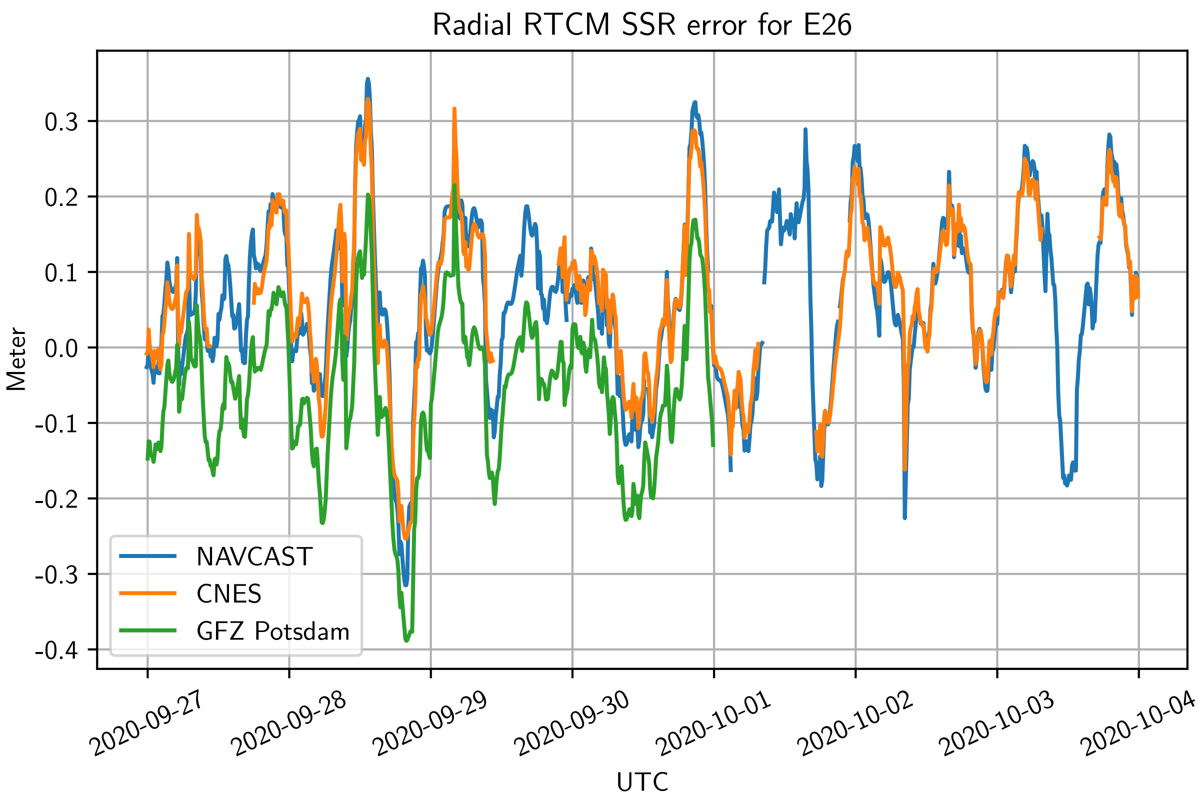
Clock RTCM SSR for E25
Nanosecond
UTC
NAVCAST
CNES
GFZ Potsdam
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04



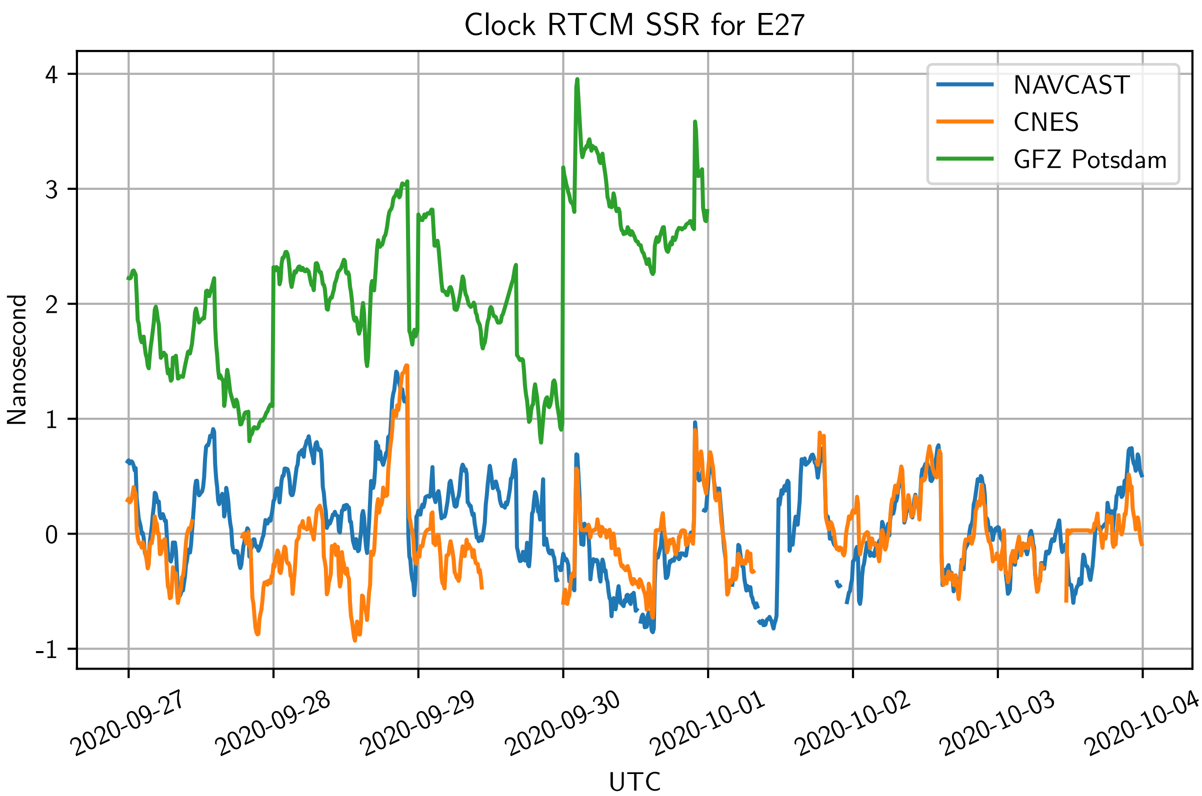
Radial RTCM SSR error for E25
Meter
UTC
NAVCAST
CNES
GFZ Potsdam
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04

E26

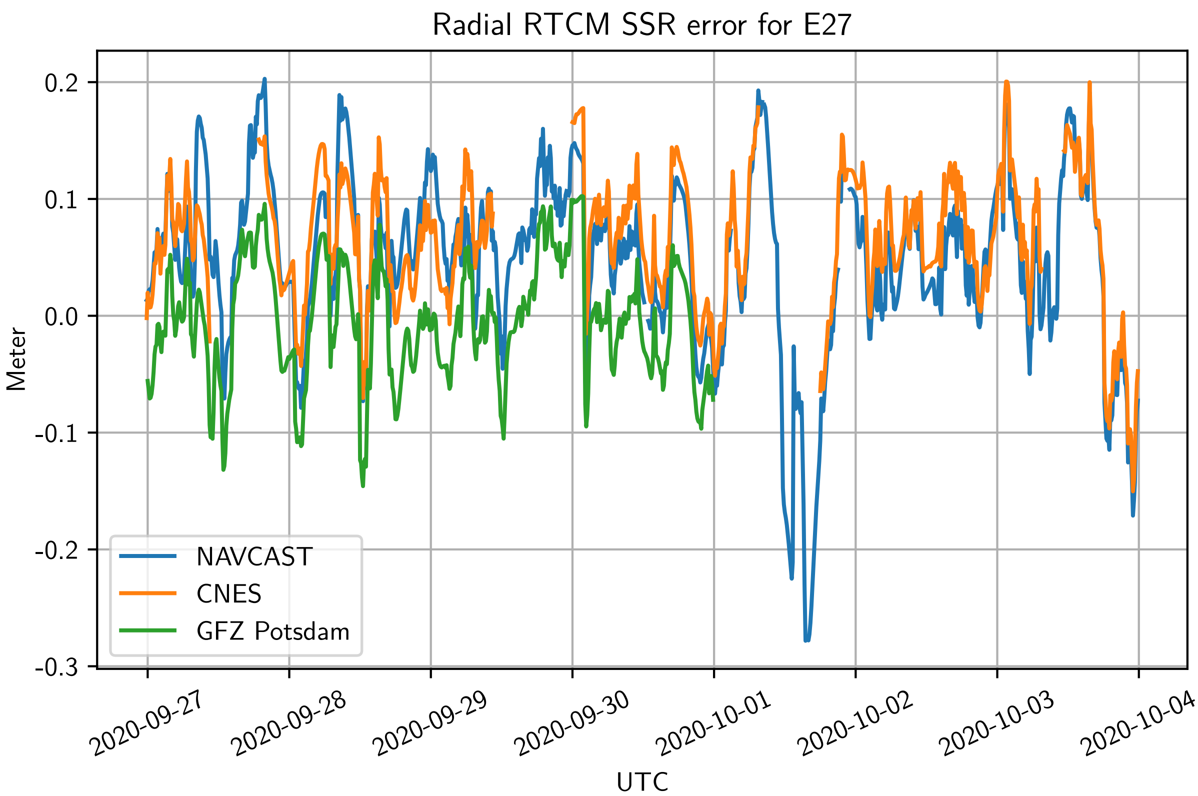

Clock RTCM SSR for E26
Nanosecond
UTC
NAVCAST
CNES
GFZ Potsdam
4
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04


Radial RTCM SSR error for E26
Meter
UTC
NAVCAST
CNES
GFZ Potsdam
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04

E27

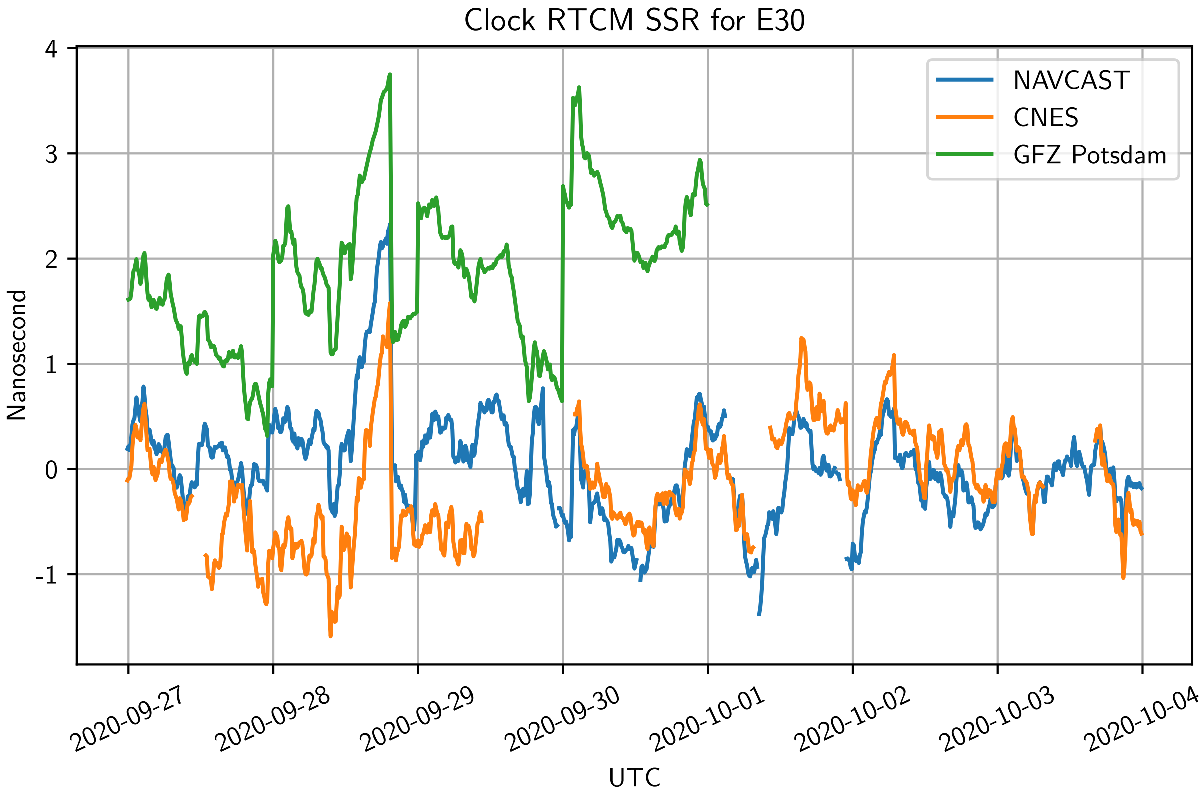


Clock RTCM SSR for E27
Nanosecond
4
3
2
1
0
-1
NAVCAST
CNES
GFZ Potsdam
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

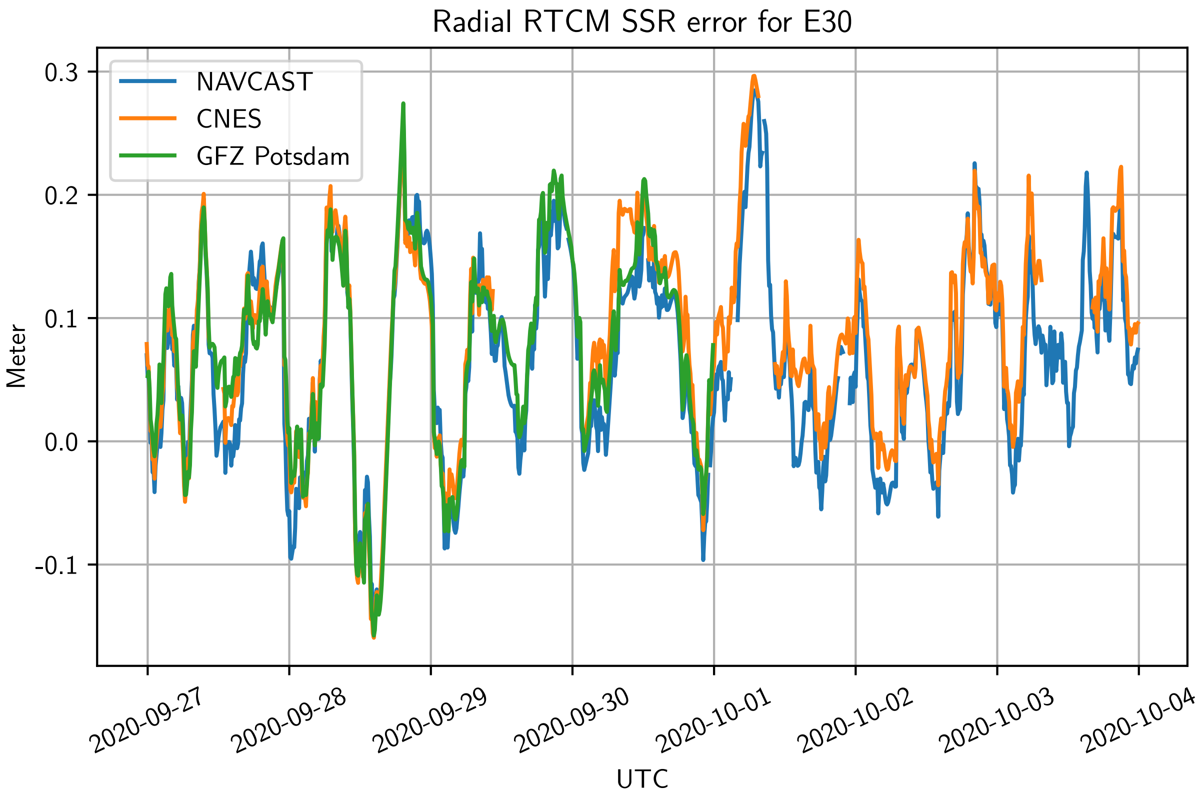


Radial RTCM SSR error for E27
Meter
0.2
0.1
0.0
-0.1
-0.2
-0.3
NAVCAST
CNES
GFZ Potsdam
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E30

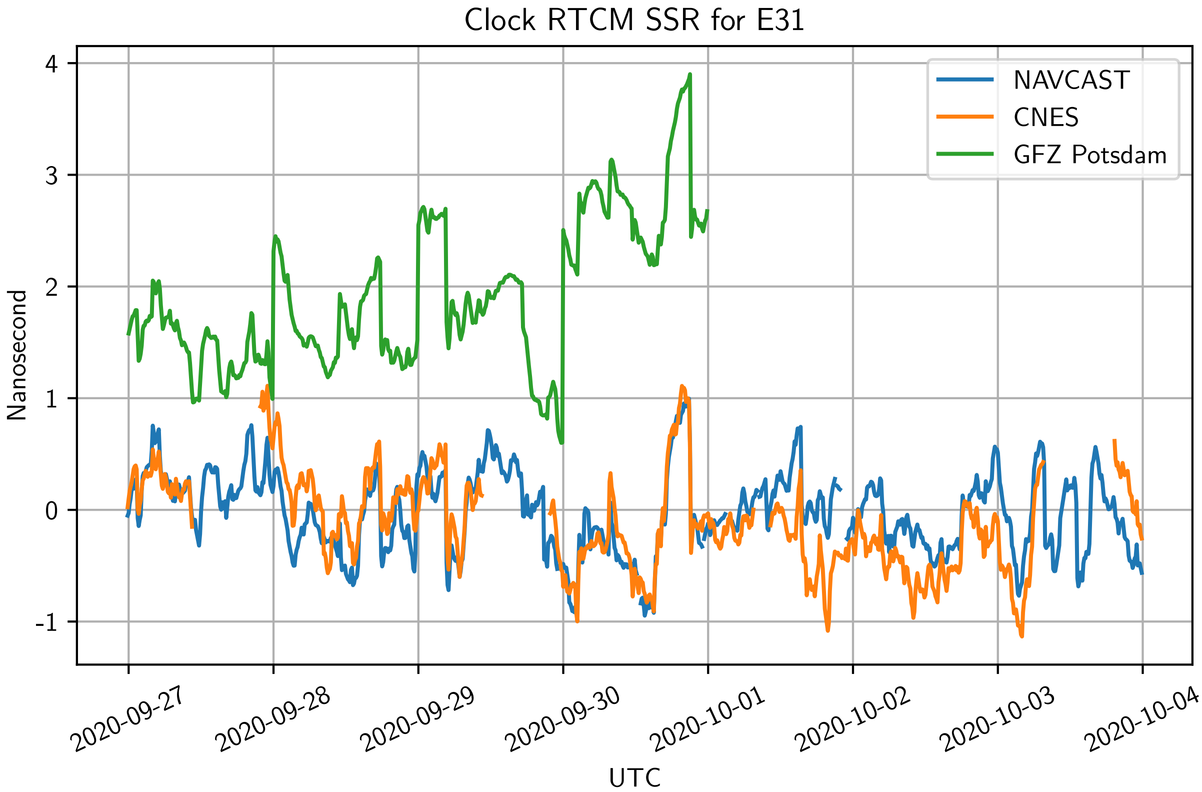


Clock RTCM SSR for E30
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

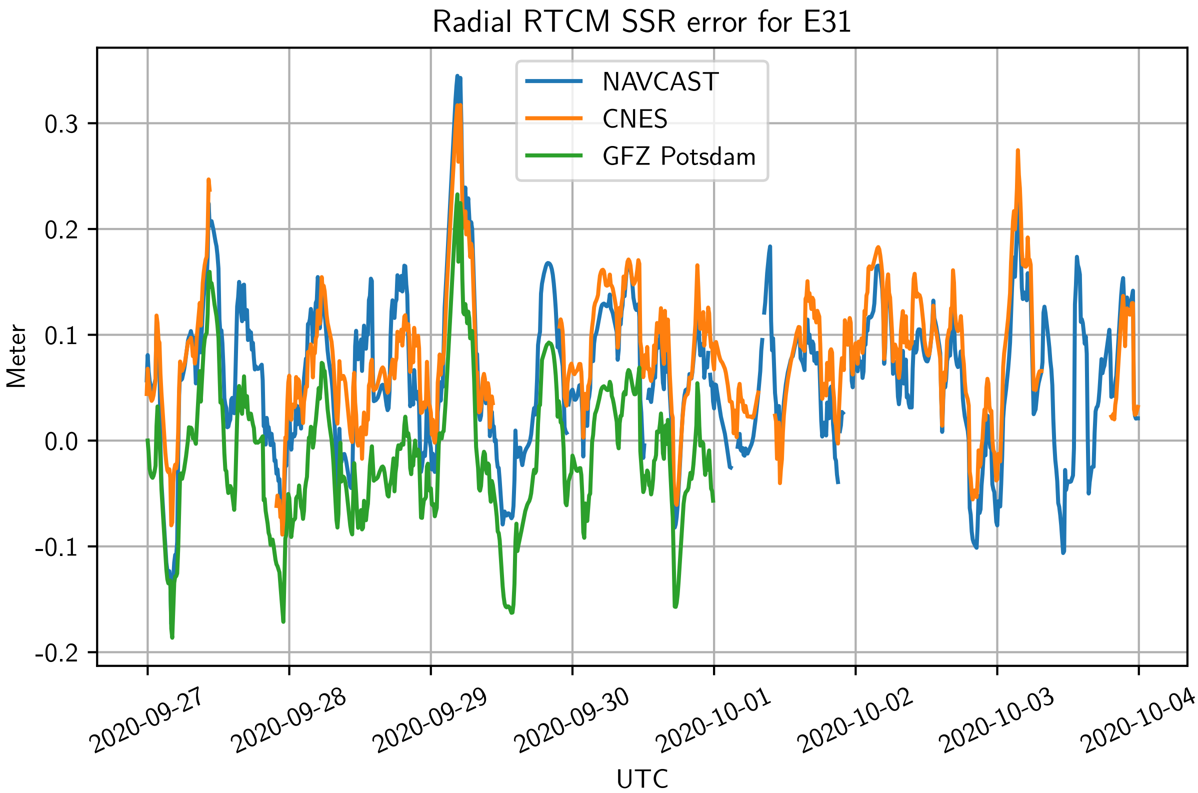


Radial RTCM SSR error for E30
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E31

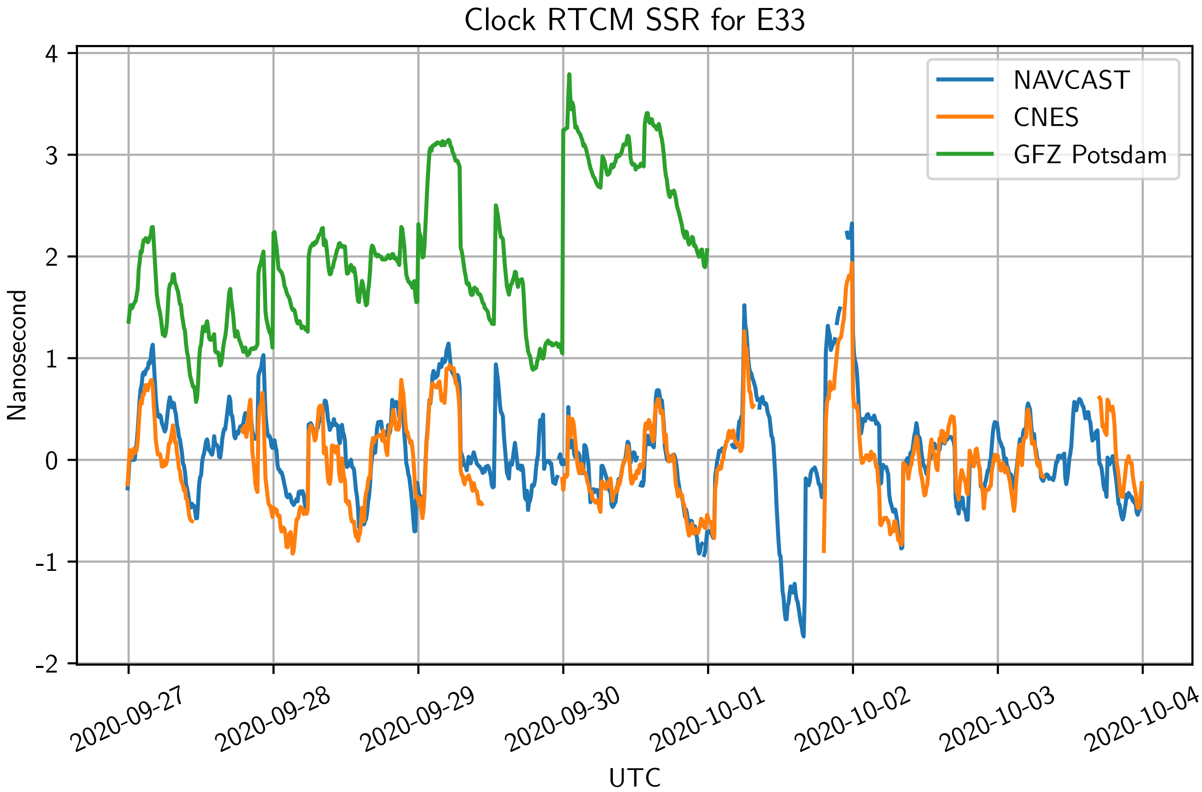


Clock RTCM SSR for E31
NAVCAST
CNES
GFZ Potsdam
Nanosecond
4
3
2
1
0
-1
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

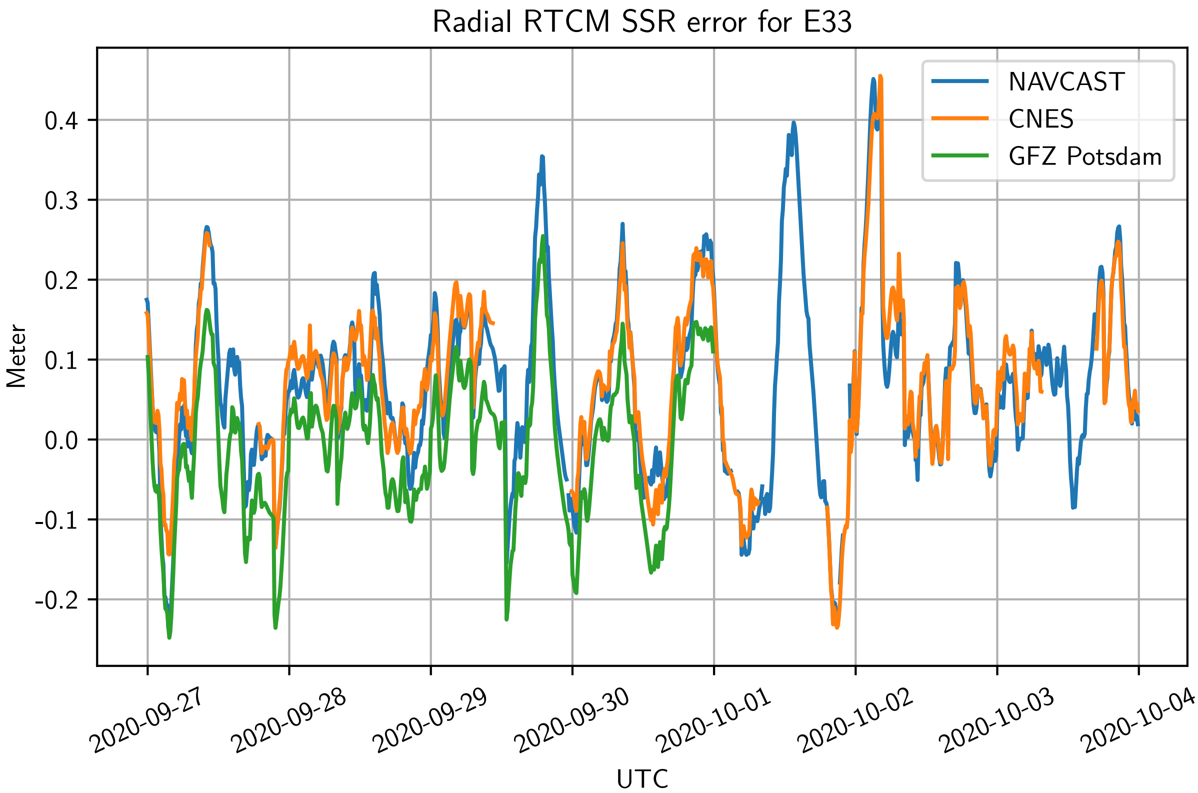


Radial RTCM SSR error for E31
NAVCAST
CNES
GFZ Potsdam
Meter
0.3
0.2
0.1
0.0
-0.1
-0.2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E33

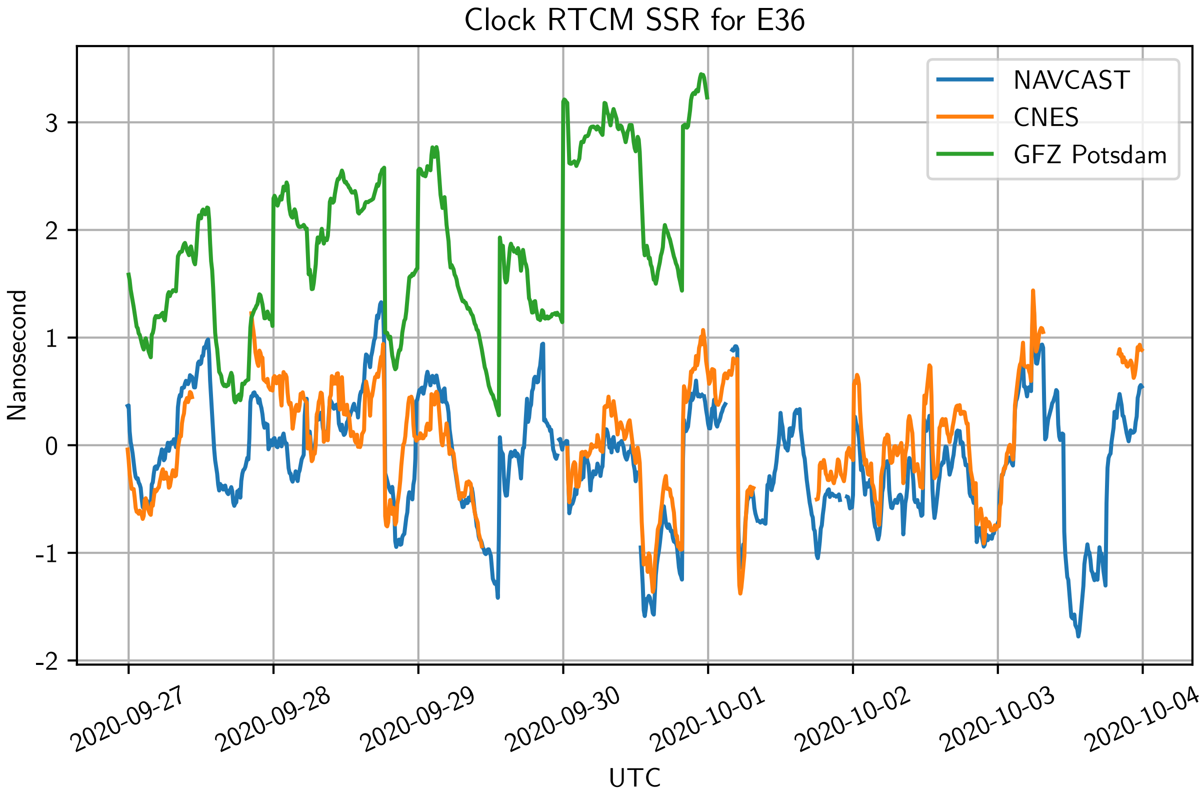


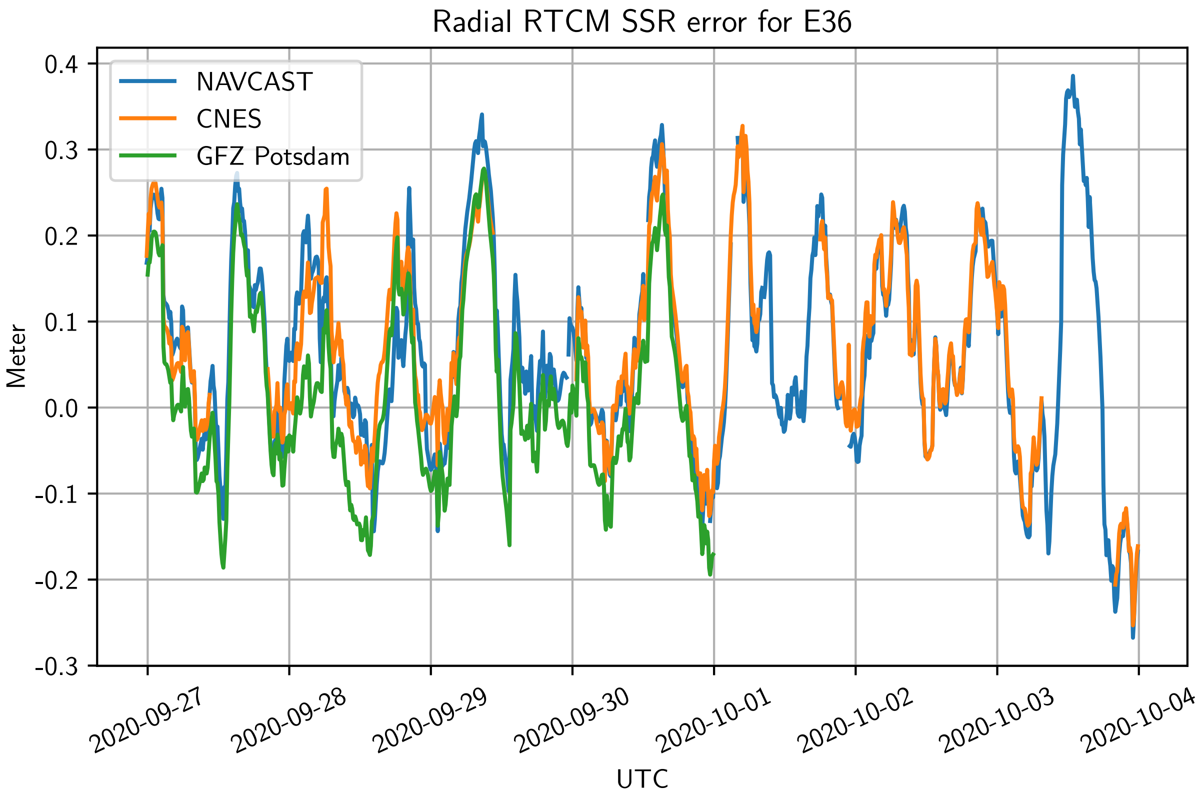
Clock RTCM SSR for E33
Nanosecond
4
3
2
1
0
-1
-2
NAVCAST
CNES
GFZ Potsdam
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC



Radial RTCM SSR error for E33
Meter
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
NAVCAST
CNES
GFZ Potsdam
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC

E36


Clock RTCM SSR for E36
NAVCAST
CNES
GFZ Potsdam
Nanosecond
3
2
1
0
-1
-2
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC


Radial RTCM SSR error for E36
NAVCAST
CNES
GFZ Potsdam
Meter
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
2020-09-27
2020-09-28
2020-09-29
2020-09-30
2020-10-01
2020-10-02
2020-10-03
2020-10-04
UTC