Satellite Navigation Branch, ANG-E66
NSTB/WAAS T&E Team

GLOBAL POSITIONING SYSTEM STANDARD POSITIONING SERVICE PERFORMANCE ANALYSIS REPORT

January 2025

Report #128
Reporting Period: October 1 to December 31, 2024
http://www.nstb.tc.faa.gov/

FAA William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

DOCUMENT VERSION CONTROL

VERSION	DESCRIPTION OF CHANGE	DATE
0.1	Initial Version of Document	01/27/2025
0.2	Technical Edit	01/27/2025
0.3	Peer Review	01/30/2025
1.0	Final Report	01/31/2025

Executive Summary

The Satellite Navigation Office (AJM-32) has tasked the Satellite Navigation Branch (ANG-E66) at the William J. Hughes Technical Center to document the GPS Standard Positioning Service (SPS) performance in quarterly GPS SPS Performance Analysis (PAN) Reports. The reports contain the analysis performed on data collected at 28 Wide Area Augmentation System (WAAS) Reference Stations. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the GPS SPS Performance Standard (5th Edition, dated April 2020).

This GPS SPS Performance Analysis Report #128 includes data collected from the October 1 through December 31, 2024 reporting period. The next quarterly report will be issued April 30, 2025.

Analysis of this data represents the standards specified in the GPS SPS Standard and have been categorized as: Position Dilution of Precision (PDOP) Availability, “Notice Advisory to Navstar Users” (NANU) Summary and Evaluation, Service Availability, Position and Range Accuracy, Solar Storms, International GNSS Service (IGS) Data Performance, Receiver Autonomous Integrity Monitoring (RAIM) Performance, and GPS Test Notices to Airmen (NOTAMs) Summary.

PDOP Availability Standard. This global availability is based on PDOP. Using the weekly almanac posted on the U.S. Coast Guard navigation website, the coverage data for every 2° grid point between 180W to 180E and 74S and 74N was calculated for every minute over a 24-hour period for each of the weeks covered in the reporting period. For this reporting period, the global availability based on PDOP less than six for CONUS was 99.9998%.

NANU Summary and Evaluation. This evaluation was achieved by reviewing the NANU reports issued between October 1 and December 31, 2024. Using this data, a set of statistics were computed that give a relative idea of constellation health for both the current and combined history of past quarters. For this quarter, eight outages were reported in the NANUs. Seven outages were scheduled ahead of time, and one unscheduled NANU occurred.

Service Availability Standard. The quarterly service availability standard was verified using 24-hour position accuracy values computed from data collected at 1-second intervals. All the sites achieved a 100% availability, which exceeds the SPS “average location” value of 99% and the “worst-case location” value of 90%.

Accuracy Standard. Calculating the 24-hour 95% horizontal and vertical position error values verified the accuracy standards. The User Range Error (URE) standard was verified for each satellite from 24-hour accuracy values computed using data collected at the following six sites: Boston, Honolulu, Los Angeles, Miami, Merida, and Juneau. This data was also collected in 1-second samples. All sites achieved 100% reliability, meeting the SPS Standard. The maximum range error recorded was 48.540 meters on PRN4. The SPS Standard states that the range error should never exceed 30 meters for less than 99.79% of the day for a worst-case point and 99.94%

globally. The maximum Root Mean Square (RMS) range error value of 4.050 meters was recorded on satellite PRN19. SPS Standard states that RMS User Range Error (URE) cannot exceed 6 meters in any 24-hour interval.

Solar Storms. Strong geomagnetic storms affected GPS performance this quarter. However, all sites met all GPS SPS Standards on those days with the most significant solar activity.

IGS Data Performance. The IGS is a voluntary federation of many worldwide agencies that pool resources and permanent Global Navigation Satellite System (GNSS) station data to generate precise GNSS products. During the evaluation period, the maximum 95% horizontal and vertical SPS errors were TBD meters at TBD and TBD meters at TBD, respectively.

RAIM Performance. RAIM is a technology developed to assess the integrity of GPS signals in a GPS receiver system. During the evaluation period, the minimum percentage of time in RNP 0.1 mode was 99.944% at Iqaluit. The minimum percent of time spent in RNP 0.3 mode was 100% at all locations evaluated. The maximum 99% HPL value was 127.356 meters at Bethel.

GPS Test NOTAMs Summary. During this evaluation period, GPS Test NOTAMs were not evaluated.

From the analysis performed on data collected between October 1 and December 31, 2024, the GPS performance met all SPS requirements that were evaluated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Objective of GPS SPS Performance Analysis Report

In 1993, the FAA began monitoring and analyzing Global Positioning System (GPS) Standard Positioning Service (SPS) performance data. To ensure the safe and effective use of GPS and its augmentation systems within the NAS, it is critical that characteristics of GPS performance as well as specific causes for service outages be monitored and understood. To accomplish this objective, GPS SPS performance data is documented in a quarterly GPS Analysis report. This report contains data collected at the following 28 WAAS reference station locations:

- Bethel, AK
- Billings, MT
- Fairbanks, AK
- Cold Bay, AK
- Kotzebue, AK
- Juneau, AK
- Albuquerque, NM
- Anchorage, AK
- Boston, MA
- Washington, DC
- Honolulu, HI
- Houston, TX
- Kansas City, KS
- Los Angeles, CA
- Salt Lake City, UT
- Miami, FL
- Minneapolis, MI
- Oakland, CA
- Cleveland, OH
- Seattle, WA
- San Juan, PR
- Atlanta, GA
- Barrow, AK
- Merida, Mexico
- Gander, Canada
- Tapachula, Mexico
- San Jose Del Cabo, Mexico
- Iqaluit, Canada

The analysis of the data is divided to include the performance categories stated in the SPS Performance Standard (5th Edition, April 2020) as well as additional performance categories and are presented as follows:

1. PDOP Availability Standard
2. Service Availability Standard
3. Service Reliability Standard
4. Positioning, Ranging and Timing Accuracy Standard
5. Solar Storms
6. IGS Data
7. RAIM Performance
8. GPS Test NOTAMs Summary
9. GPS Broadcast Orbit vs. NGA Precise Orbits and URA (IAURA) Bounding Analysis

For the performance categories found in the SPS Performance Standard, the results of these analyses have been compared to the performance parameters stated in the SPS Performance Standard. Analyses of events that merit more detailed investigations are documented in the Discrepancy Reports (DRs). The DRs are available at http://www.nstb.tc.faa.gov under "WAAS Technical Reports."

1.2 Report Overview

Section 2 summarizes the results obtained from the coverage calculation program developed by the WAAS Test Team at the William J. Hughes Technical Center. The SPS coverage area program uses the GPS satellite almanacs to compute each satellite position as a function of time for a selected day of the week. This program establishes a 2-degree grid between 180-degrees east and 180-degrees west, and from 74-degrees north and 74-degrees south. The program then computes the PDOP at each grid point (13,500 total grid points) every minute for the entire day and stores the results. After the PDOPs have been saved, the 99.99% index of 1-minute PDOP at each grid point is determined and plotted as contour lines (see Figure 2-1). The program also saves the number of satellites used in PDOP calculation at each grid point for analysis.

Section 3 summarizes the GPS constellation performance by providing the "Notice: Advisory to Navstar Users" (NANU) messages to calculate the total time of forecasted and actual satellite outages. This section also evaluates the Service Availability Standard using 24-hour 95% horizontal and vertical position accuracy values.

Section 4 summarizes service reliability performance. Although the Standard calls for yearly evaluations, this SPS requirement will be reported at quarterly intervals.

Section 5 provides the position accuracies based on data collected on a daily basis at 1-second intervals. This section also provides the statistics on the range error, range error rate, and range acceleration error for each satellite. The overall average, maximum, minimum and standard deviations of the range rates and accelerations are tabulated for each satellite.

Section 6 provides the data collected during solar storms is analyzed to determine the effects, if any, of GPS SPS performance.

Section 7 provides an analysis of GPS-SPS accuracy performance from a selection of high-rate IGS stations around the world.

Section 8 provides a summary of RAIM performance.

Section 9 provides the GPS broadcast orbit versus NGA precise orbits and URA (IAURA) bounding analyses.

Appendix A provides a summary of all the results as compared to the SPS Standard.

Appendix B provides the geomagnetic data used for Section 6.

Appendix C provides a glossary of terms used in this PAN report. This glossary was obtained directly from the GPS SPS Standard document (April 2020).

1.3 Summary of Performance Requirements and Metrics

Table 1-1 lists the performance parameters from the SPS for the L1 (1575.42 MHz) Coarse/Acquisition (C/A) signal and identifies those parameters verified in this report. The L2C (1227.60 MHz) and L5 (1176.45 MHz) signals are pre-operational, and their use is at the users' own risk. No commitment of signal availability for L2C or L5 will be made until the signals are declared fully operational by the DoD and available for users.

Table 1-1 SPS SIS Performance Requirements Standards Evaluated in This Report

Parameter	Conditions and Constraints
Per-Satellite Coverage Terrestrial Service Volume: 100% Coverage Space Service Volume: No Coverage Performance Specified	For any healthy or marginal SPS SIS.
Constellation Coverage Terrestrial Service Volume: 100% Coverage Space Service Volume: No Performance Specified	For any healthy or marginal SPS SIS.

<table>
<tr><th>Parameter</th><th>Conditions and Constraints</th></tr>
<tr><td>User Range Error Accuracy
Single-Frequency C/A-Code
≤7.0 m 95% Global Average URE during normal operations over All Age of Data (AOD)
≤3.8 m 95% Global Average URE during operations at Zero AOD
≤9.7 m 95% Global Average URE during normal operations at Any AOD</td><td>For any healthy or marginal SPS SIS.

Neglecting single-frequency ionospheric delay model errors.

Including group delay time correction (T_{GD}) errors at L1.

Including inter-signal bias (P(Y)-code to C/A-code) errors at L1.

Including Inter-Signal Correction (ISC) errors.</td></tr>
<tr><td>User Range Error Accuracy

Single-Frequency C/A-Code:
≤30 m 99.94% Global Average URE during normal operations
≤30 m 99.79% Worst Case single point average during normal operations</td><td>For any healthy or marginal SPS SIS.

Neglecting single-frequency ionospheric delay model errors.

Including group delay time correction (T_{GD}) errors at L1.

Including inter-signal bias (P(Y)-code to C/A-code) errors at L1.

Including ISC errors.

Standard based on measurement interval of one year; average of daily values within service volume.

Standard based on 3 service failures per year, lasting no more than 6 hours each.</td></tr>
<tr><td>User Range Error Accuracy

Single-Frequency C/A-Code:

≤388 m 95% Global Statistic URE during Extended Operations after 14 Days without Upload</td><td>For any healthy or marginal SPS SIS.</td></tr>
</table>

Parameter	Conditions and Constraints
User Range Error Accuracy Single-Frequency C/A-Code: ≤2.0 m 95% Global Statistic URE during Normal Operations over all AODs for the ensemble of constellation slots	Across all healthy or marginal SPS SIS from satellites occupying constellation slots. Neglecting SF ionospheric delay model errors. Including group delay time correction (T_{GD}) errors at L1. Including inter-signal bias (P(Y)-code to C/A-code) errors at L1. Including ISC errors.
User Range Rate Error Accuracy Single-Frequency C/A Code: ≤6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.
User Range Acceleration Error Accuracy Single-Frequency C/A Code: ≤2 mm/sec^2 95% Global Average URAE over any 3-second interval during normal operations at Any AOD	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.
Coordinated Universal Time Offset Error Accuracy ≤30 nanoseconds 95% Global average UTCOE during normal operations at Any AOD	For any healthy SPS SIS.

Parameter	Conditions and Constraints
Instantaneous URE Integrity Single-Frequency C/A-Code: $\leq 1x10^{-5}$ Probability over any hour of the SPS SIS Instantaneous URE exceeding the NTE tolerance without a timely alert during normal operations	For any healthy SPS SIS. SPS SIS URE NTE tolerance defined to be ±4.42 times the upper bound on the URA value corresponding to the URA index "N" currently broadcast by the satellite. Given that the maximum SPS SIS instantaneous URE did not exceed the NTE tolerance at the start of the hour. UMSI occurs if no timely alert issued after SPS SIS URE NTE tolerance exceeded. Worst case for delayed alert is 6 hour. Neglecting single-frequency ionospheric delay model errors.
Instantaneous UTCOE Integrity Single-Frequency C/A-Code: $\leq 1x10^{-5}$ Probability over any hour of the SPS SIS Instantaneous UTCOE exceeding the NTE tolerance without a timely alert during normal operations.	For any healthy SPS SIS. SPS SIS UTCOE NTE tolerance defined to be ±120 ns. Given that the maximum SPS SIS instantaneous URE did not exceed the NTE tolerance at the start of the hour. Worst case for delayed alert is 6 hours.
Unscheduled Failure Interruption Continuity Unscheduled Failure Interruptions: ≥0.9998 Probability over any hour of not losing the SPS SIS availability from a slot due to unscheduled interruption	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Given that the SPS SIS is available from the slot at the start of the hour.
Status and Problem Reporting Scheduled event affecting service Appropriate NANU issued to the U.S. Coast Guard and the FAA at least 48 hours prior to the event for 95% of the events	For any SPS SIS.

Parameter	Conditions and Constraints
Status and Problem Reporting Unscheduled outage or problem affecting service Appropriate NANU issued to the Coast Guard and the FAA as soon as possible after the event	For any SPS SIS.
Per-Slot Availability ≥0.957 Probability that a slot in the baseline 24-slot configuration will be occupied by a satellite broadcasting a healthy SPS SIS ≥0.957 Probability that a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a healthy SPS SIS	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Applies to satellites broadcasting a healthy SPS SIS that also satisfy the other performance standards in the SPS performance standard.
Constellation Availability ≥0.98 Probability that at least 21 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration ≥0.99999 Probability that at least 20 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Applied to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.

Parameter	Conditions and Constraints
Operational Satellite Count ≥0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	Applies to the total number of operational satellites in the constellation (averaged over any day); where any satellite which appears in the transmitted navigation message almanac is defined to be an operational satellite regardless of whether that satellite is currently broadcasting a healthy SPS SIS or not and regardless of whether the broadcast SPS SIS also satisfies the other performance standards in the SPS performance standard or not.
PDOP Availability ≥98% global PDOP of 6 or less ≥88% worst site PDOP of 6 or less	Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
Service Availability ≥99% Horizontal Service Availability, average location ≥99% Vertical Service Availability, average location	15 m Horizontal (SIS only) 95% threshold. 33 m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
Service Availability ≥90% Horizontal Service Availability, worst-case location ≥90% Vertical Service Availability, worst-case location	15 m Horizontal (SIS only) 95% threshold. 33 m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
Position/Time Accuracy Global Average Position Domain Accuracy: • ≤8 m 95% Horizontal Error • ≤13 m 95 % Vertical Error	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.

Parameter	Conditions and Constraints
Position/Time Accuracy Worst Site Position Domain Accuracy: • ≤15 m 95% Horizontal Error • ≤33 m 95% Vertical Error	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Position/Time Accuracy Time Transfer Domain Accuracy: ≤30 nanoseconds time transfer error 95% of time (SIS only)	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.

2. PDOP AVAILABILITY STANDARD

PDOP Availability is defined as the percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume. Dilution of Precision (DOP) is defined as the magnifying effect on GPS position error induced by mapping GPS range errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

Table 2-1 shows the PDOP Availability Standard parameters.

Table 2-1 PDOP Availability Standard Parameters

PDOP Availability Standard	Conditions and Constraints
≥98% global PDOP of 6 or less ≥88% worst site PDOP of 6 or less	Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.

Almanacs for GPS weeks used for this coverage portion of the report were obtained from the Coast Guard web site (https://www.navcen.uscg.gov/). In addition, real-time broadcast satellite ephemeris and summary NANUs were utilized to incorporate satellite maintenance start and stop times. Using this data, an SPS coverage area program developed by the WAAS Test Team was used to calculate the PDOP at every 2-degree point between longitudes of 180W to 180E and 74S and 74N at 1-minute intervals. This gives 1440 samples for each of the 13,500 grid points in the coverage area. Table 2-2 provides the global averages and worst-case availability over a 24-hour period for each week. Table 2-2 also gives the global 99.9% PDOP value for each of the 13 GPS Weeks. The PDOP was 3.030 or better 99.9% of the time for each of the 24-hour intervals.

Figure 2-1 is a contour plot of PDOP values over the entire globe. Inside each contour area, the PDOP value is greater than or equal to the contour value shown in the legend for that color line. That area's value is also less than the next higher contour value, unless another contour line lies within the current area. A single "DOP hole" where the PDOP value is greater than 6 was evaluated for satellite visibility for one 24-hour interval from the week shaded in Table 2-2. The histogram in Figure 2-2 shows the satellite visibility at the DOP hole position for the 24-hour interval in question. The GPS coverage performance evaluated met the specifications stated in the SPS.

Table 2-2 PDOP Availability Statistics

Date Range of Week	Global 99.9% PDOP Value	Global Average Availability (Spec: ≥98%)	Worst-Case Point Availability (Spec: ≥88%)
09/29/2024 - 10/05/2024	2.8824	100	100
10/06/2024 - 10/12/2024	2.877	100	100
10/13/2024 - 10/19/2024	2.8957	99.9998	99.8412
10/20/2024 - 10/26/2024	2.8804	100	100
10/27/2024 - 11/02/2024	2.8788	100	100
11/03/2024 - 11/09/2024	2.8725	100	100
11/10/2024 - 11/16/2024	2.8801	100	100
11/17/2024 - 11/23/2024	2.8809	100	100
11/24/2024 - 11/30/2024	2.9146	100	100
12/01/2024 - 12/07/2024	2.8843	100	100
12/08/2024 - 12/14/2024	2.9168	100	100

Date Range of Week	Global 99.9% PDOP Value	Global Average Availability (Spec: ≥98%)	Worst-Case Point Availability (Spec: ≥88%)
12/15/2024 - 12/21/2024	2.9968	100	100
12/22/2024 - 12/28/2024	3.0296	100	100
12/29/2024 - 01/04/2025	3.0194	100	100

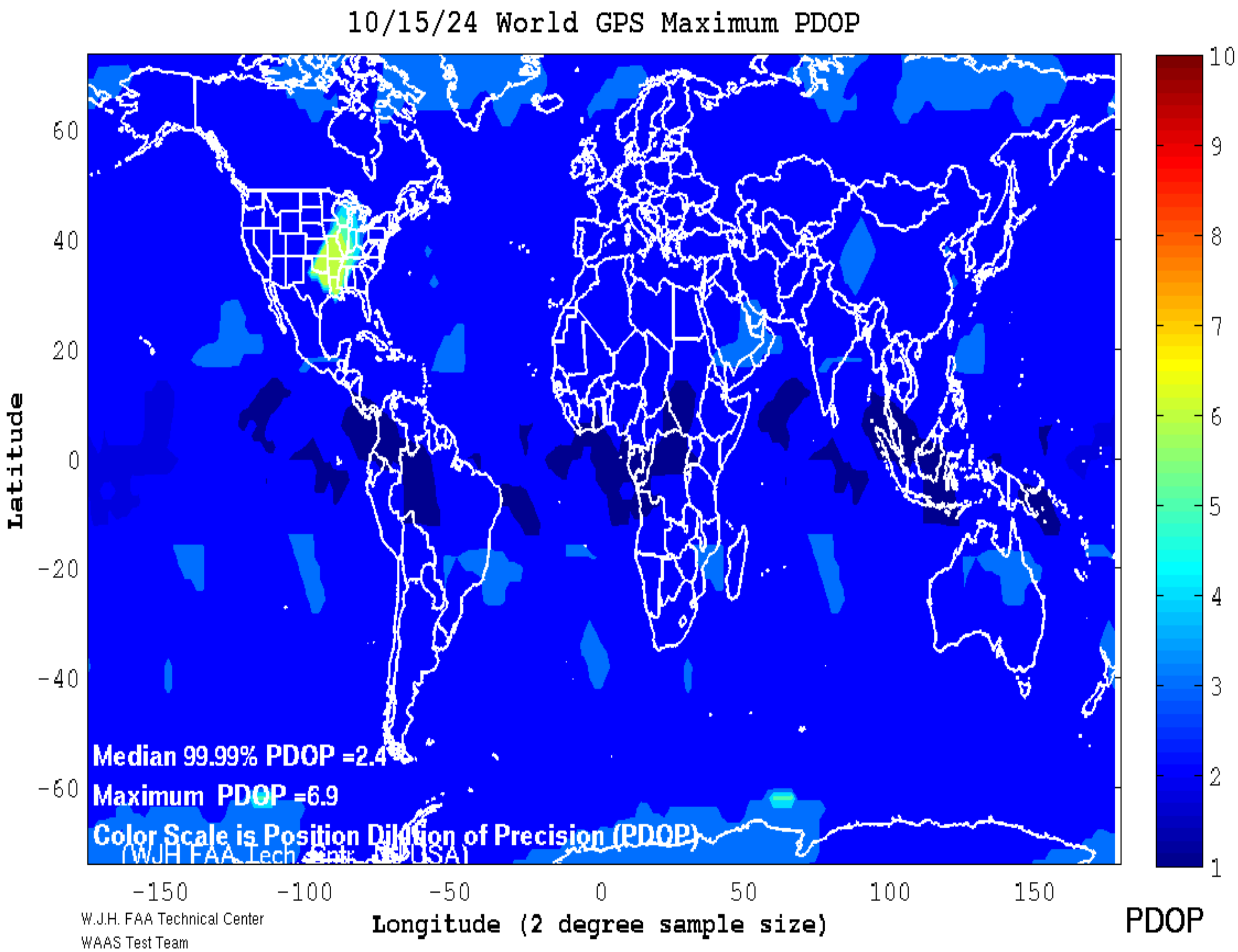


Figure 2-1 World GPS Maximum PDOP

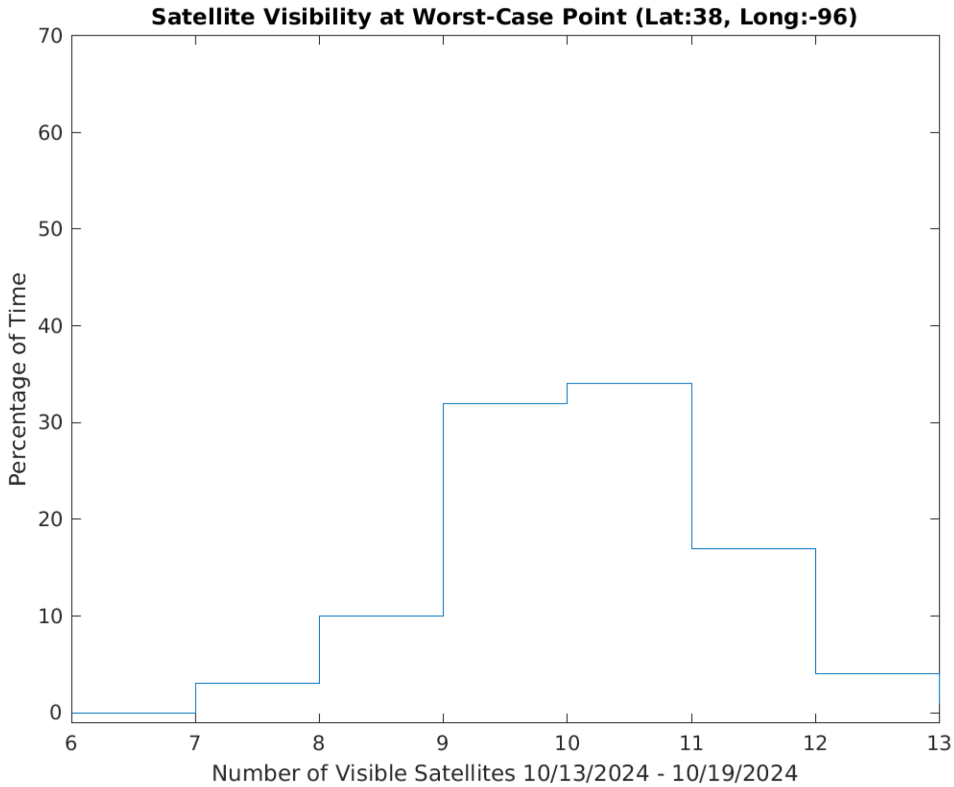


Figure 2-2 Satellite Visibility Profile for Worst-Case Point

3. NANU SUMMARY AND ELEVATION

A Notice Advisory to NAVSTAR Users (NANU) is a periodic bulletin alerting users to changes in the satellite system performance. Table 3-1 shows the parameters for issuing NANUs.

Table 3-1 Parameters for Issuing NANUs

Status and Problem Reporting	Conditions and Constraints
Scheduled event affecting service: Appropriate NANU issued to the U.S. Coast Guard and the FAA at least 48 hours prior to the event	For any SPS SIS.
Unscheduled outage or problem affecting service: Appropriate NANU issued to the U.S. Coast Guard and the FAA as soon as possible after the event	For any SPS SIS.

3.1 Satellite Outages from NANU Reports

Satellite availability performance was analyzed based on published NANUs. During this reporting period, October 1 through December 31, 2024, there were eight reported outages. Seven outages were maintenance activities and were reported in advance, and one was an unscheduled outage. A complete listing of outage NANUs for the reporting period is provided in Table 3-2. A complete listing of the forecasted outage NANUs for the reporting period can be found in Table 3-3. Canceled outage NANUs (if any) are provided in Table 3-4. The minimum duration a scheduled outage was forecasted ahead of time was 53.9 hours. The maximum response time following an unscheduled outage was 0.217 hours. Therefore, the probability of continuity not being affected due to an unscheduled failure interruption was 100%, which met the specification requirement for the 24-slot GPS constellation. A complete listing of the GPS constellation plane and slot designations is provided in Table 9-2. Figure 9-6 shows a graphical representation of the December 31, 2024 GPS constellation.

Table 3-2 NANUs Affecting Satellite Availability

NANU	PRN	TYPE	Start Date	Start Time (UTC)	End Date	End Time (UTC)	Total Unscheduled (hours)	Total Scheduled (hours)	Total (hours)
2024048	11	FCSTSUMM	Oct 03, 2024	23:08	Oct 04, 2024	06:22	0	7.23	7.23
2024051	30	FCSTSUMM	Oct 15, 2024	23:21	Oct 16, 2024	04:32	0	5.18	5.18
2024053	19	FCSTSUMM	Nov 15, 2024	02:32	Nov 15, 2024	08:33	0	6.02	6.02
2024056	12	FCSTSUMM	Nov20, 2024	22:13	Nov 21, 2024	03:31	0	5.3	5.3
2024058	6	UNUSABLE	Nov 26, 2024	16:58	Nov 27, 2024	20:49	27.85	0	27.85
2024061	7	FCSTSUMM	Dec 06, 2024	04:55	Dec 06, 2024	10:20	0	5.42	5.42
2024064	21	FCSTSUMM	Dec 11, 2024	11:01	Dec 13, 2024	19:08	0	56.12	56.12
2024069	9	FCSTSUMM	Dec 23, 2024	15:34	Dec 23, 2024	21:16	0	5.7	5.7
Totals of Unscheduled, Scheduled, and Total Downtime							27.85	90.97	118.82

Table 3-3 NANUs Forecasted to Affect Satellite Availability

NANU	PRN	TYPE	Start Date	Start Time (UTC)	End Date	End Time (UTC)	Total (hours)	Comments
2024047	11	FCSTDV	Oct 03, 2024	23:00	Oct 04, 2024	11:00	12	2024048
2024049	30	FCSTDV	Oct 10, 2024	23:15	Oct 11, 2024	11:15	0	2024050
2024050	30	FCSTRESCD	Oct15, 2024	23:00	Oct 16, 2024	11:00	12	2024051

NANU	PRN	TYPE	Start Date	Start Time (UTC)	End Date	End Time (UTC)	Total (hours)	Comments
2024052	19	FCSTDV	Nov 15, 2024	02:30	Nov 15, 2024	14:30	12	2024053
2024054	12	FCSTDV	Nov 20, 2024	21:45	Nov 21, 2024	09:45	12	2024056
2024057	6	UNUSUFN	Nov 26, 2024	16:59	N/A	N/A	N/A	2024058
2024059	7	FCSTDV	Dec 06, 2024	04:30	Dec 06, 2024	16:30	12	2024061
2024060	21	FCSTMX	Dec 09, 2024	16:00	Dec 19, 2024	16:00	240	2024064
2024063	9	FCSTDV	Dec 18, 2024	15:15	Dec19, 2024	03:15	0	2024065
2024066	9	FCSTDV	Dec 23, 2024	15:15	Dec 24, 2024	03:15	12	2024069
Total Forecasted Downtime							312	

Table 3-4 Canceled NANUs

NANU	PRN	TYPE	Start Date	Start Time (UTC)	Comments
2024065	9	FCSTCANC	Dec 18, 2024	15:15	2024063

Table 3-5 GPS Satellite Maintenance Statistics

Satellite Reliability/Maintainability/Availability (RMA) Parameter	10/01/2024 to 12/31/2024	01/01/2000 to 12/31/2024
Total Forecasted Downtime (hrs)	312	17023.989
Total Actual Downtime (hrs)	118.82	45334.2
Total Actual Scheduled Downtime (hrs)	90.97	9436.58
Total Actual Unscheduled Downtime(hrs)	27.85	35897.62
Total Satellite Observed MTTR (hrs)	14.85	35.67
Scheduled Satellite Observed (hrs)	13.0	9.89
Unscheduled Satellite Observed (hrs)	27.85	113.24
Total Satellite Outages (number)	8	1271
Scheduled Satellite Outages (number)	7	954
Unscheduled Satellite Outages (number)	1	317
Percent Operational—Scheduled Downtime (%)	99.87	99.86
Percent Operational—All Downtime (%)	99.83	99.33

Satellite Reliability, Maintainability, and Availability (RMA) data is being collected based on published NANUs. This data has been summarized in Table 3-5. The Total Satellite Observed MTTR was calculated by taking the average downtime of all satellite outage occurrences. Scheduled downtime was forecasted in advance via NANUs. All other downtime reported via NANU was considered unscheduled. The Percent Operational was calculated based on the ratio of total actual operating hours to total available operating hours for every satellite.

3.2 Service Availability Standard

Service Availability is the percentage of time over any 24-hour interval that the predicted 95% position error is less than the threshold at any given point within the service volume. Horizontal Service Availability and Vertical Service availability are the percentage of time over any 24-hour interval that the predicted 95% horizontal error or vertical error is less than its threshold for any point within the service volume, respectively. Table 3-6 shows the Service Availability Standard.

Table 3-6 Service Availability Standard

Service Availability Standard	Conditions and Constraints
≥99% Horizontal Service Availability, average location	15 m Horizontal (SIS only) 95% threshold. 33 m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and

≥99% Vertical Service Availability, average location	operating within the service volume over any 24-hour interval.
≥90% Horizontal Service Availability, worst-case location ≥90% Vertical Service Availability, worst-case location	15m Horizontal (SIS only) 95% threshold. 33m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.

To verify availability, the data collected from receivers at the 28 WAAS sites was reduced to calculate 24-hour accuracy information and reported in Table 3-7. The data was collected at 1-second intervals between October 1 and December 31, 2024.

Table 3-7 Accuracies Exceeding Threshold Statistics

Site	Total Number of Seconds of SPS Monitoring	Instances of 24-hour Threshold Failures	October 2024—December 2024 Service Availability (%)
Billings	7835258	0	100
Albuquerque	7835719	0	100
Anchorage	7835964	0	100
Boston	7836011	0	100
Washington, DC	7836023	0	100
Honolulu	7835772	0	100
Houston	7835975	0	100
Kansas City	7369690	0	100
Los Angeles	7836006	0	100
Salt Lake City	7835896	0	100
Miami	7835944	0	100
Minneapolis	7836061	0	100
Oakland	7836006	0	100
Cleveland	7835884	0	100
Seattle	7835963	0	100
San Juan	7835299	0	100
Atlanta	7835951	0	100
Juneau	7835862	0	100
Cold Bay	7831854	0	100

Site	Total Number of Seconds of SPS Monitoring	Instances of 24-hour Threshold Failures	October 2024—December 2024 Service Availability (%)
Fairbanks	7834870	0	100
Bethel	7835365	0	100
Kotzebue	7813318	0	100
Barrow	7834844	0	100
Merida	6793660	0	100
Gander	7835172	0	100
Tapachula	6620979	0	100
San Jose Del Cabo	6785334	0	100
Iqaluit	6483185	0	100

4. SERVICE RELIABILITY STANDARD

Service Reliability is the percentage of time over a specific time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites. Table 4-1 shows the User Range Error Accuracy parameters.

Table 4-1 User Range Error Accuracy Parameters

User Range Error Accuracy	Conditions and Constraints
Single Frequency C/A-Code: • ≤30 m 99.94% Global Average URE during normal operations • ≤30 m 99.79% Worst Case single point average during normal operations	For any healthy SPS SIS. Neglecting single-frequency ionospheric delay model errors. Including group delay time correction (T_{GD}) errors at L1. Including inter-signal bias (P(Y)-code to C/A-code) errors at L1. Standard based on measurement interval of 1 year; average of daily values within service volume. Standard based on 3 service failures per year, lasting no more than 6 hours each.

Table 4-2 shows a comparison to the service reliability standard for range data collected at a set of six receivers across North America. Although the specification calls for yearly evaluations, we will be evaluating this SPS requirement at quarterly intervals. Additional range analysis results can be found in Table 5-3. The maximum URE recorded this quarter was 48.540 meters on satellite PRN4.

Table 4-2 User Range Error Accuracy

Date Range of Data Collection	Site	Number of Samples This Quarter	Number of Samples Where SPS URE >30 m NTE	Percentage (%)
October 1–December 31, 2024	Boston	66524845	0	100
October 1–December 31, 2024	Honolulu	67027234	1146109	98.29
October 1–December 31, 2024	Juneau	69845186	0	100
October 1–December 31, 2024	Los Angeles	67884239	0	100
October 1–December 31, 2024	Merida	58714408	483289	99.18
October 1–December 31, 2024	Miami	67833333	0	100
October 1–December 31, 2024	Global	397829245	0	100

5. ACCURACY STANDARD

Positioning Accuracy is the statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval. Horizontal Positioning Accuracy and Vertical Positioning Accuracy are the statistical difference, at a 95% probability, between horizontal or vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval, respectively.

Table 5-1 shows the Accuracy Standard parameters.

Table 5-1 Accuracy Standard Parameters

Position/Time Accuracy	Conditions and Constraints
Position/Time Accuracy Global Average Position Domain Accuracy: • ≤8 m 95% Horizontal Error • ≤13 m 95 % Vertical Error	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Position/Time Accuracy Worst Site Position Domain Accuracy: • ≤15 m 95% Horizontal Error • ≤33 m 95% Vertical Error	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.

Position/Time Accuracy	Conditions and Constraints
Position/Time Accuracy Time Transfer Domain Accuracy: ≤30 nanoseconds time transfer error 95% of time (SIS only)	Defined for a time transfer solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
User Range Error Accuracy Single-Frequency C/A-Code • ≤7.0 m 95% Global Average URE during normal operations over All AODs • ≤3.8 m 95% Global Average URE during operations at Zero AOD • ≤9.7 m 95% Global Average URE during normal operations at Any AOD	For any healthy SPS SIS. Neglecting single-frequency ionospheric delay model errors. Including group delay time correction (T_{GD}) errors at L1. Including inter-signal bias (P(Y)-code to C/A-code) errors at L1. Including Inter-Signal Correction (ISC) errors.
User Range Rate Error Accuracy Single-Frequency C/A Code: ≤6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.
User Range Acceleration Error Accuracy Single-Frequency C/A Code: ≤2 mm/sec^2 95% Global Average URAE over any 3-second interval during normal operations at Any AOD	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.
Coordinated Universal Time Offset Error Accuracy ≤30 nanoseconds 95% Global average UTCOE during normal operations at Any AOD	For any healthy SPS SIS.

5.1 Position Accuracy

The data used for this section was collected for every second from October 1 through December 31, 2024 at the selected WAAS locations. Table 5-2 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter. Every 24-hour analysis period this quarter passed both the worst-case and global average position accuracy requirements set forth by the SPS specification.

Table 5-2 Horizontal and Vertical Accuracy Statistics for the Quarter

Site	95% Vertical (m)	95% Horizontal (m)	99.99% Vertical (m)	99.99% Horizontal (m)
Albuquerque	7.18	2.37	14.91	14.49
Anchorage	9.72	3.5	18.12	7.87
Atlanta	6.75	2.39	12.53	14.93
Barrow	10.89	4.24	23.53	9.23
Bethel	10.53	3.32	17.87	7.88
Billings	6.57	2.73	21.30	12.66
Boston	6.63	2.76	11.91	17.18
Cleveland	6.30	2.42	12.49	19.67
Cold Bay	10.01	2.88	16.21	7.08
Fairbanks	9.51	3.75	19.82	8.46
Gander	6.54	2.94	12.43	11.32
Honolulu	7.72	13.65	16.65	28.11
Houston	6.59	2.5	19.89	13.77
Juneau	8.16	3.39	21.04	9.93
Kansas City	6.18	2.19	18.45	15.74
Kotzebue	10.64	3.71	20.54	8.28
Los Angeles	8.49	2.77	15.73	13.77
Merida	6.78	5.48	29.05	18.25
Miami	6.62	3.49	17.83	13.14
Minneapolis	6.02	2.30	15.61	15.41
Oakland	8.65	2.91	15.96	13.5
Salt Lake City	7.35	2.47	13.38	15.49
San Jose Del Cabo	7.89	5.86	24.97	16.83
San Juan	11.34	11.32	26.23	29.52
Seattle	7.54	2.87	12.44	11.28
Tapachula	8.05	9.19	26.49	28.21
Washington, DC	6.56	2.53	11.15	18.75

Figure 5-1 and Figure 5-2 are the combined histograms of the vertical and horizontal errors for all 28 WAAS sites from October 1 to December 31, 2024.

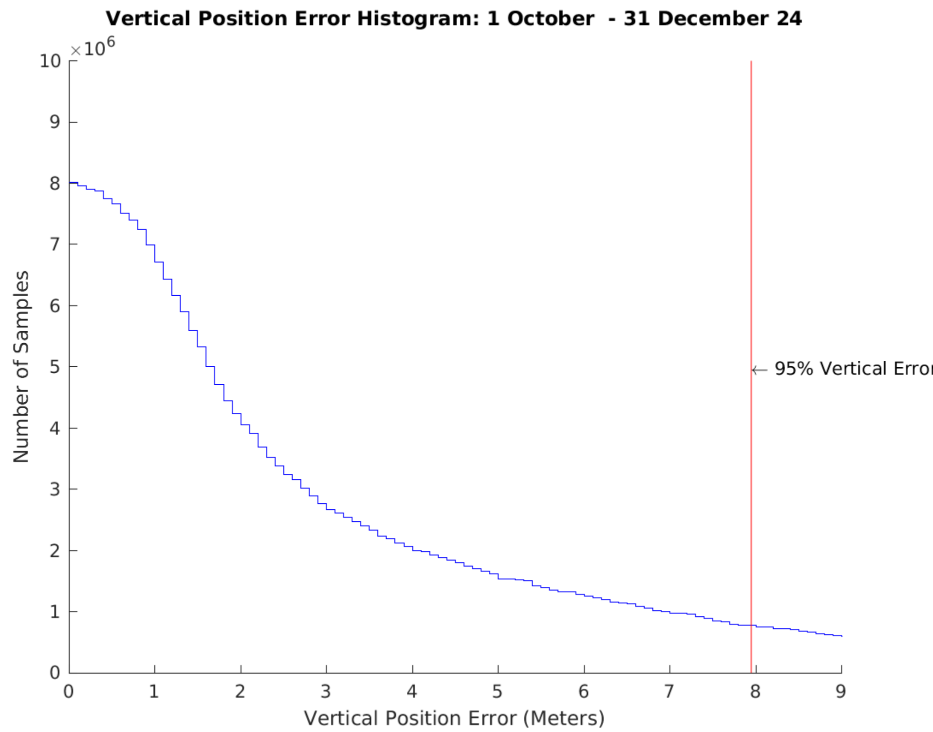


Figure 5-1 Global Vertical Error Histogram

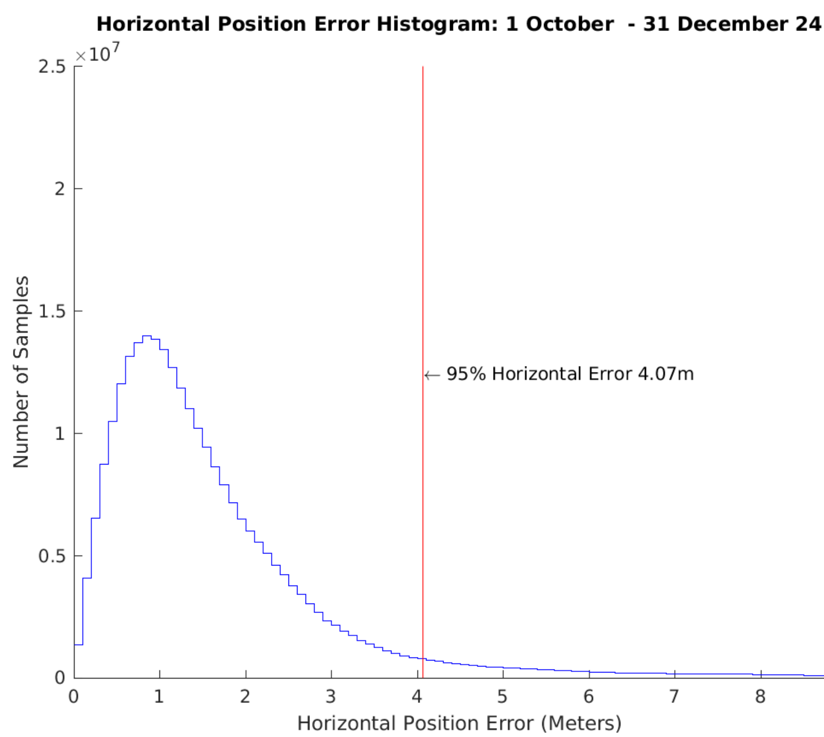


Figure 5-2 Global Horizontal Error Histogram

5.2 Time Transfer Accuracy

The GPS time error data between October 1 and December 31, 2024 was downloaded from the USNO website. The USNO data file contains the time difference between the USNO master clock and GPS system time for each GPS satellites during the time period. Over 10,000 samples of GPS time error are contained in the USNO data file. To evaluate the GPS time transfer error, the data file was used to create a histogram (Figure 5-3) to represent the distribution of GPS time error. The histogram was created by taking the absolute value of time difference between the USNO master clock and GPS system time, then creating data bins with 1 nanosecond precision. The number of samples in each bin was then plotted to form the histogram in Figure 5-3. The maximum instantaneous UTC offset error (UTCOE) for the quarter was 12.2 nanoseconds. The mean, standard deviation, and 95% index of Time Transfer Error, and the maximum UTCOE are all within the requirements of GPS SPS time error.

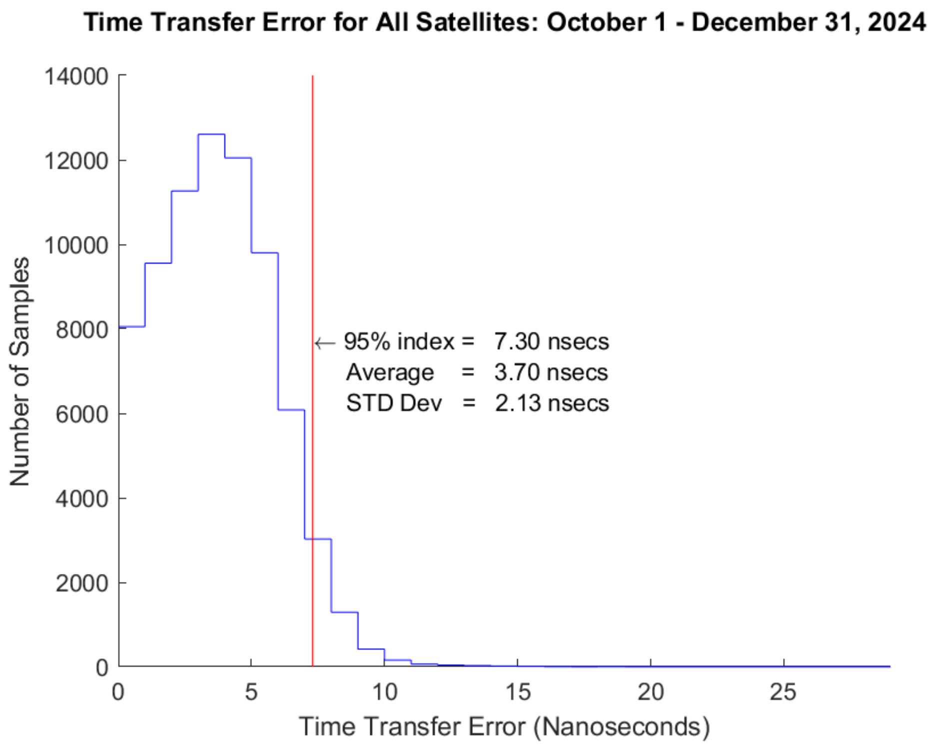


Figure 5-3 Time Transfer Error

5.3 Range Domain Accuracy

Table 5-3 through Table 5-5 provide the statistical data for the range error, range rate error, and the range acceleration error for each satellite. This data was collected between October 1 and December 31, 2024. A weighted average filter was used for the calculation of the range rate error and the range acceleration error. All Range Domain SPS specifications were met.

Table 5-3 Range Error Statistics

PRN	RMS Range Error (<6 m) (m)	Range Error Mean (m)	1σ Range Error (m)	95% Range Error (m)	Max Range Error (SPS Spec. <30 m) (m)	Samples (Number)
1	N/A	N/A	N/A	N/A	N/A	N/A
2	2.97	1.67	2.21	5.25	29.59	13496576
3	2.48	0.68	2.06	4.61	30.47	13804273
4	2.83	0.85	2.15	4.93	48.54	12438574
5	2.53	0.75	2.26	5.05	35.85	13200507
6	3.17	0.54	2.69	6.15	38.81	13183554
7	3.35	1.04	2.31	5.98	20.34	12343927
8	3.01	1.62	2.11	5.13	33.78	12153795
9	2.77	1.02	2.06	5.06	40.87	12855663
10	2.25	0.41	1.81	4.7	26.24	12652816
11	3.0	0.88	2.54	6.18	42.15	13727680
12	2.77	0.7	2.24	5.42	30.86	13038527
13	3.42	0.67	2.98	7.0	37.17	13018494
14	3.48	0.98	2.36	6.0	21.05	12600859
15	2.77	1.1	2.33	5.37	30.69	12057159
16	2.83	1.02	2.1	4.99	35.51	12282067
17	3.58	1.5	2.6	6.61	30.18	13983409
18	2.57	0.52	2.22	5.55	38.3	12280149
19	4.05	2.13	2.8	7.18	33.51	13486848
20	2.84	1.32	2.17	5.46	29.97	12932295
21	2.79	1.51	2.09	5.11	25.58	13448006
22	3.89	1.37	2.59	6.81	25.28	10952202
23	2.1	0.35	1.77	4.64	32.71	12804355
24	3.44	0.57	3.04	7.09	34.78	13208128
25	2.44	0.44	2.11	4.81	25.4	13487440
26	2.55	0.52	1.93	4.57	27.61	12292056
27	2.77	0.81	2.25	4.97	24.99	12935383
28	2.6	0.06	2.1	5.07	23.84	13352858
29	2.59	0.72	2.24	5.54	31.63	12362280

PRN	RMS Range Error (<6 m) (m)	Range Error Mean (m)	1σ Range Error (m)	95% Range Error (m)	Max Range Error (SPS Spec. <30 m) (m)	Samples (Number)
30	3.38	1.04	2.3	5.81	22.92	12295881
31	2.52	0.2	1.96	4.73	26.43	13557280
32	2.55	0.21	2.07	5.17	34.72	13903430

Table 5-4 Range Rate Error Statistics

PRN	Range Rate Error RMS (mm/s)	95% Range Rate Error (mm/s)	Max Range Rate Error (mm/s)	Samples (Number)
1	N/A	N/A	N/A	N/A
2	2.39	4.59	200.48	13496576
3	2.33	4.49	188.99	13804273
4	2.16	4.19	113.14	12438574
5	2.66	5.18	204.21	13200507
6	2.57	4.99	191.24	13183554
7	2.45	4.73	152.17	12343927
8	2.28	4.44	188.08	12153795
9	2.31	4.53	103.32	12855663
10	2.18	4.22	159.73	12652816
11	2.5	4.84	181.65	13727680
12	2.58	4.96	206.59	13038527
13	2.56	5.04	169.07	13018494
14	2.41	4.67	147.68	12600859
15	2.38	4.57	218.82	12057159
16	2.35	4.6	172.32	12282067
17	2.64	5.13	194.66	13983409
18	2.2	4.33	179.9	12280149
19	2.62	5.1	118.3	13486848
20	2.41	4.65	105.67	12932295
21	2.52	4.84	165.67	13448006
22	2.55	4.93	212.43	10952202
23	2.21	4.32	179.94	12804355

PRN	Range Rate Error RMS (mm/s)	95% Range Rate Error (mm/s)	Max Range Rate Error (mm/s)	Samples (Number)
24	2.37	4.54	188.63	13208128
25	2.32	4.52	184.58	13487440
26	2.23	4.21	180.9	12292056
27	2.18	4.25	158.69	12935383
28	2.23	4.31	150.5	13352858
29	2.27	4.43	86.92	12362280
30	2.33	4.48	175.06	12295881
31	2.31	4.46	146.32	13557280
32	2.34	4.61	177.09	13903430

Table 5-5 Range Acceleration Error Statistics

PRN	Rate Acceleration Error RMS (um/s^2)	95% Range Acceleration Error (um/s^2)	Max Range Acceleration Error (um/s^2)	Samples
1	N/A	N/A	N/A	N/A
2	17.64	32.94	2000	13496576
3	16.19	32.22	1870	13804273
4	14.62	30.43	1120	12438574
5	20.6	39.56	2060	13200507
6	17.06	33.24	1890	13183554
7	17.3	33.61	1510	12343927
8	15.93	31.7	1860	12153795
9	15.19	31.03	1000	12855663
10	15.7	31.13	1580	12652816
11	17.33	33.02	1770	13727680
12	19.66	35.29	2030	13038527
13	18.68	34.41	1690	13018494
14	16.58	33.02	1480	12600859
15	18.56	33.92	2230	12057159
16	18.39	34.15	1680	12282067
17	19.38	35.21	1940	13983409

PRN	Rate Acceleration Error RMS (um/s^2)	95% Range Acceleration Error (um/s^2)	Max Range Acceleration Error (um/s^2)	Samples
18	15.49	31.33	1760	12280149
19	18.86	35.04	1180	13486848
20	18.19	34.04	1040	12932295
21	19.29	35.43	1670	13448006
22	17.81	34.31	2100	10952202
23	16.16	31.91	1800	12804355
24	16.58	32.69	1880	13208128
25	16.53	32.86	1920	13487440
26	16.1	31.46	1820	12292056
27	15.26	30.96	1570	12935383
28	16.26	31.72	1510	13352858
29	17.59	32.56	860	12362280
30	15.23	31.0	1760	12295881
31	16.86	33.92	1460	13557280
32	16.22	31.79	1770	13903430

Figure 5-4 through Figure 5-6 are graphical representations of the distributions of the maximum range error, range rate error, and range acceleration error for all satellites. As shown in Table 5-3, the highest maximum range error occurred on PRN4 with an error of 48.540 meters. PRN7 had the lowest maximum range error of 20.340 meters. Figure 5-7 is histogram of satellite range error for all satellites over the entire quarter. Figure 5-8 through Figure 5-10 show the individual maximums per satellite for range error, range rate error, and range acceleration error, respectively.

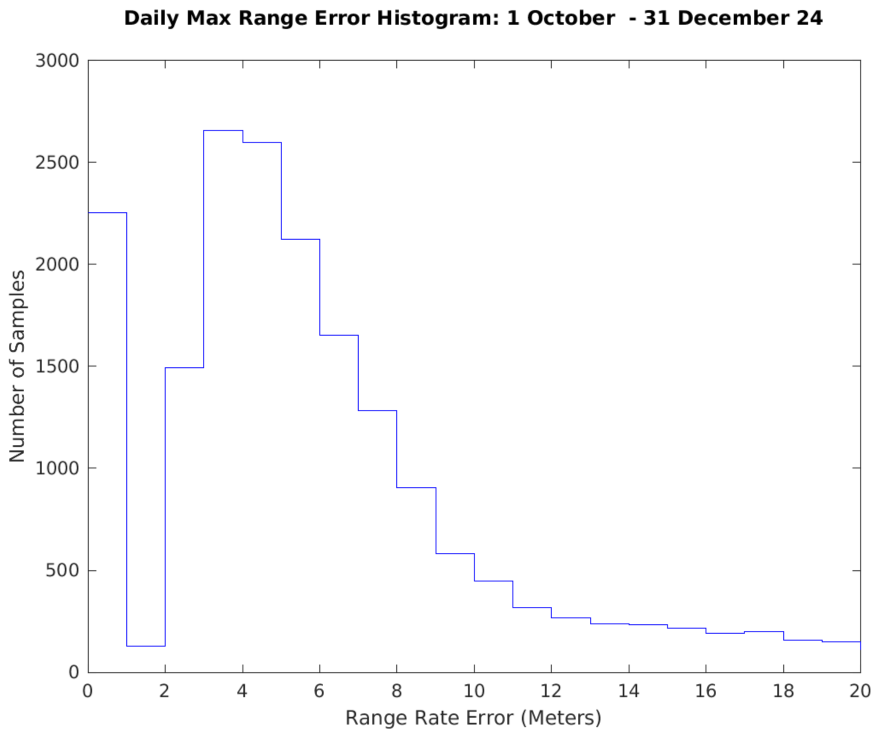


Figure 5-4 Distribution of Daily Max Range Errors

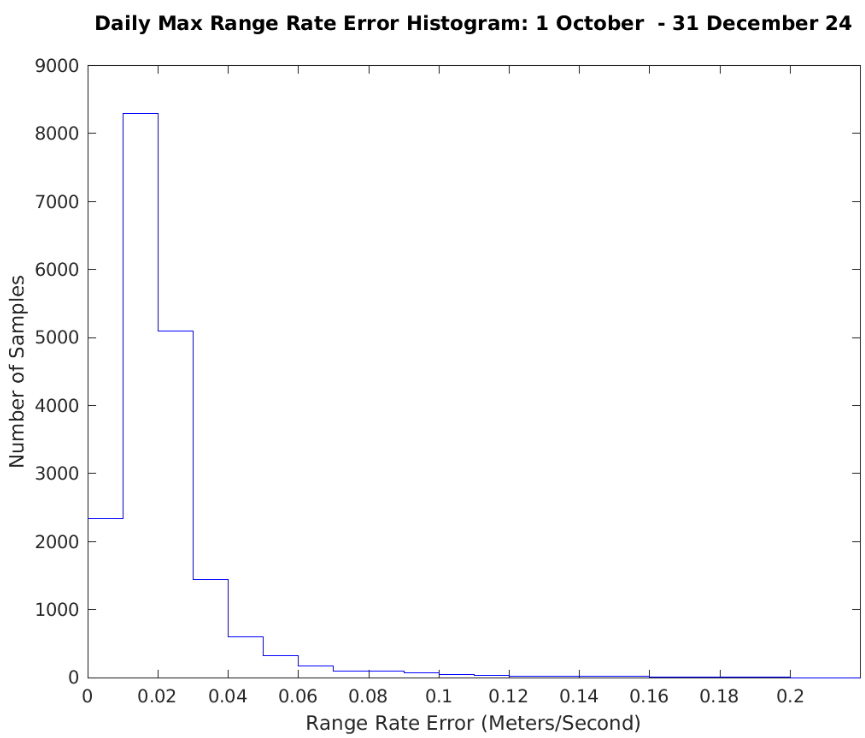


Figure 5-5 Distribution of Daily Max Range Rate Errors

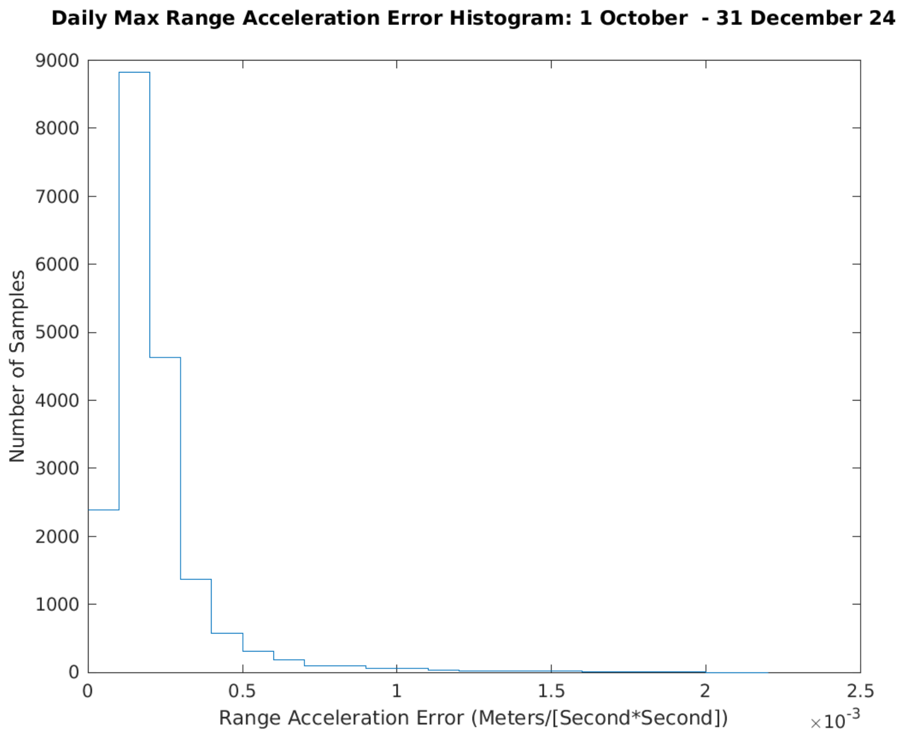


Figure 5-6 Distribution of Daily Max Range Acceleration Errors

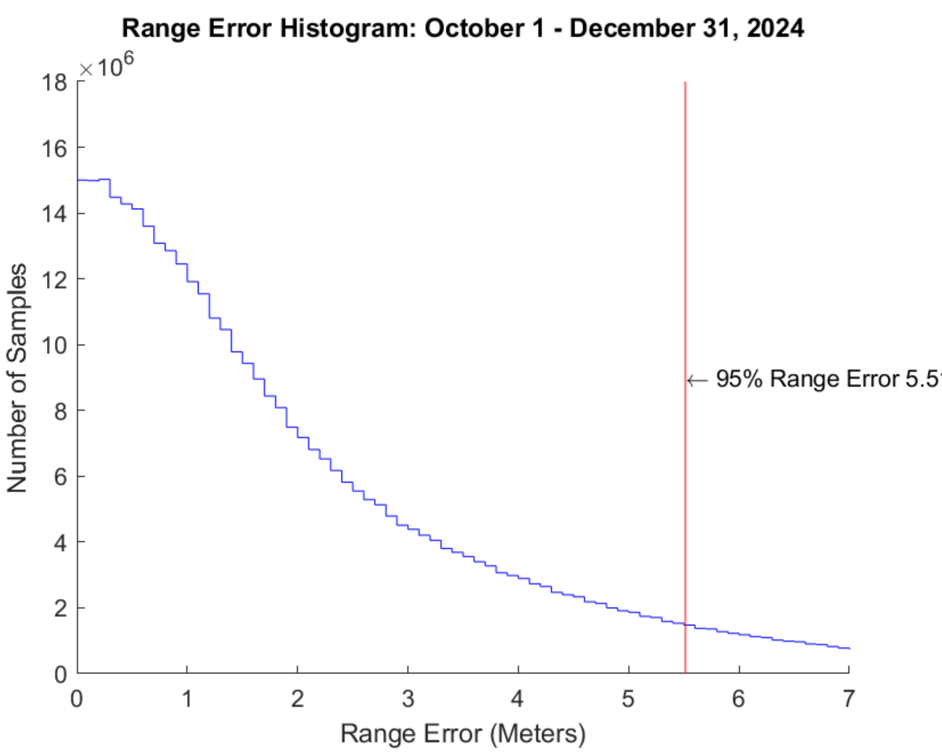


Figure 5-7 Range Error Histogram

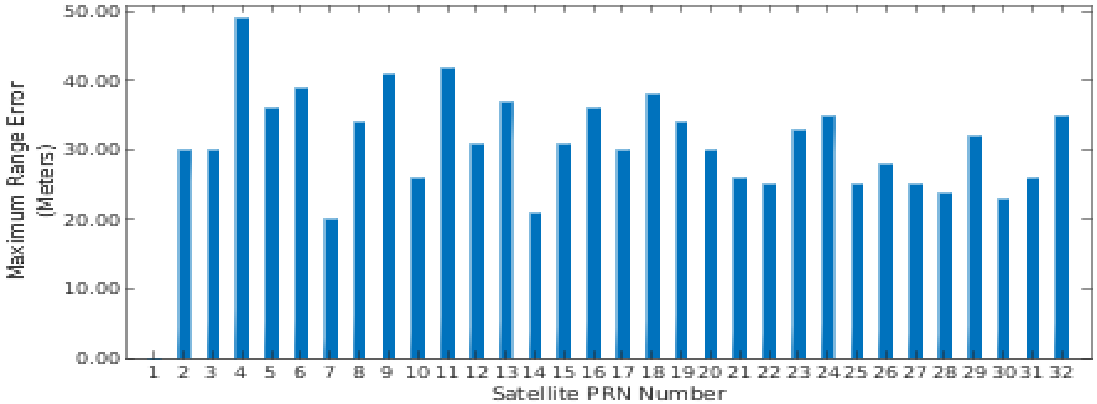


Figure 5-8 Maximum Range Error Per Satellite

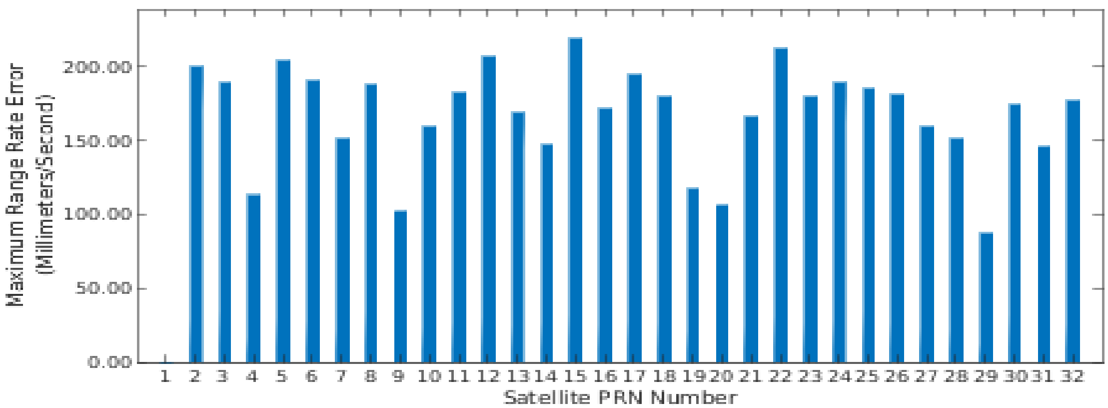


Figure 5-9 Maximum Range Rate Error Per Satellite

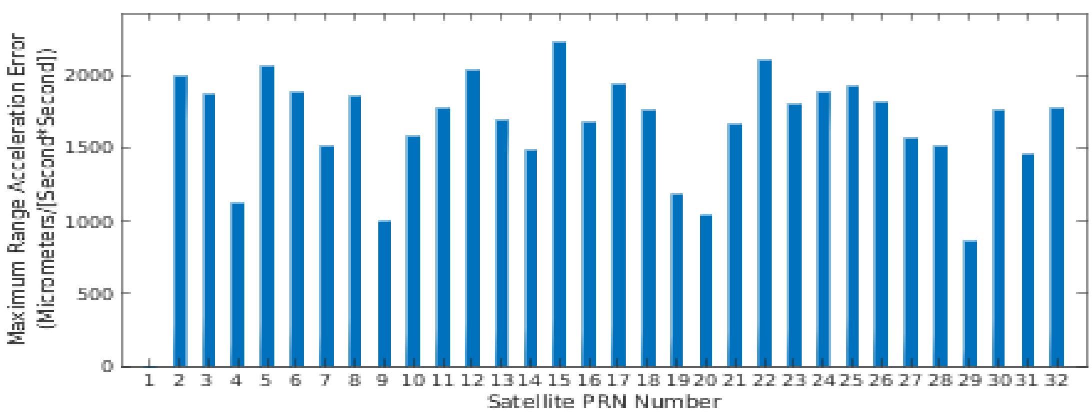


Figure 5-10 Maximum Range Acceleration Error Per Satellite

6. SOLAR STORMS

Solar storm activity is being monitored to assess the possible impact on GPS SPS performance. Solar activity is reported by the Space Weather Prediction Center (SWPC), a division of the National Oceanic and Atmospheric Administration (NOAA). When storm activity is indicated, ionospheric delays of the GPS signal, satellite outages, position accuracy and availability will be analyzed.

The following article was taken from the SEC web site http://swpc.noaa.gov. It briefly explains some of the ideas behind the association of the aurora with geomagnetic activity and a bit about how the 'K-index' or 'K-factor' works.

The aurora is caused by the interaction of high-energy particles (usually electrons) with neutral atoms in the earth's upper atmosphere. These high-energy particles can 'excite' (by collisions) valence electrons that are bound to the neutral atom. The 'excited' electron can then 'de-excite' and return back to its initial, lower energy state, but in the process it releases a photon (a light particle). The combined effect of many photons being released from many atoms results in the aurora display that you see.

The details of how high energy particles are generated during geomagnetic storms constitute an entire discipline of space science in its own right. The basic idea, however, is that the Earth's magnetic field (let us say the 'geomagnetic field') is responding to an outwardly propagating disturbance from the Sun. As the geomagnetic field adjusts to this disturbance, various components of the Earth's field change form, releasing magnetic energy and thereby accelerating charged particles to high energies. These particles, being charged, are forced to stream along the geomagnetic field lines. Some end up in the upper part of the earth's neutral atmosphere and the auroral mechanism begins.

An instrument called a magnetometer may also measure the disturbance of the geomagnetic field. At NOAA's operations center magnetometer data is received from dozens of observatories in one-minute intervals. The data is received at or near to 'real-time' and allows NOAA to keep track of the current state of the geomagnetic conditions. In order to reduce the amount of data NOAA converts the magnetometer data into three-hourly indices, which give a quantitative, but less detailed measure of the level of geomagnetic activity. The K-index scale has a range from 0 to 9 and is directly related to the maximum amount of fluctuation (relative to a quiet day) in the geomagnetic field over a three-hour interval.

The K-index is therefore updated every three hours. The K-index is also necessarily tied to a specific geomagnetic observatory. For locations where there are no observatories, one can only estimate what the local K-index would be by looking at data from the nearest observatory, but this would be subject to some errors from time to time because geomagnetic activity is not always spatially homogenous.

Another item of interest is that the location of the aurora usually changes geomagnetic latitude as the intensity of the geomagnetic storm changes. The location of the aurora often takes on an 'oval-like' shape and is appropriately called the auroral oval.

Figure 6-1 through Figure 6-3 show the K-index for three time periods with significant solar activity. Although there were other days with increased solar activity, these time periods were selected as examples. (See Appendix B for the actual geomagnetic data for this reporting period.)

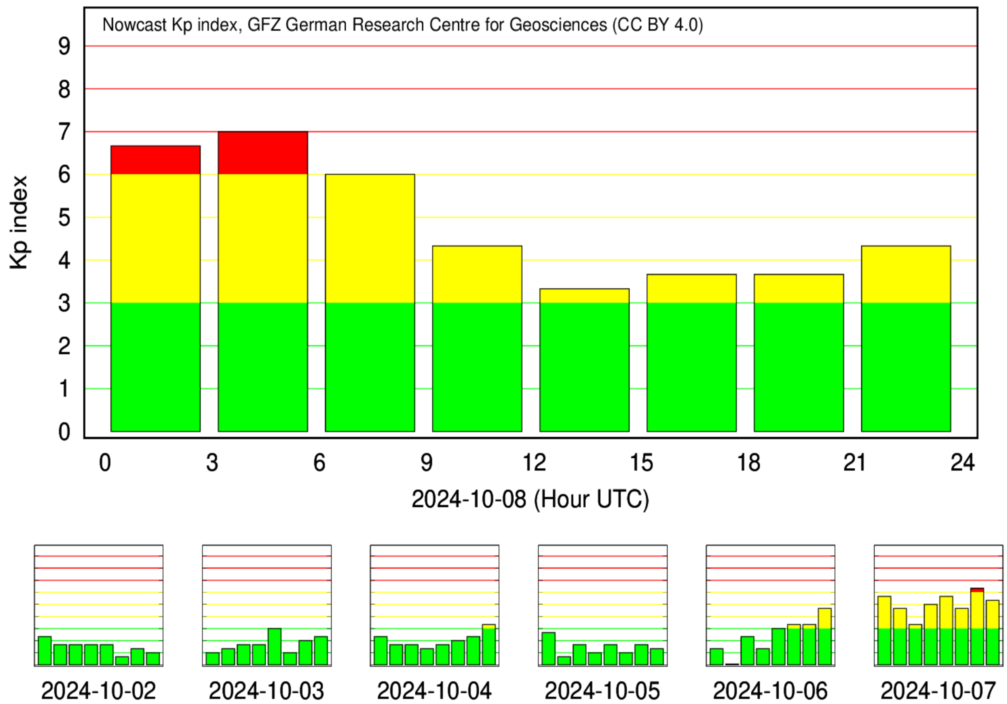


Figure 6-1 K-Index for October 8, 2024

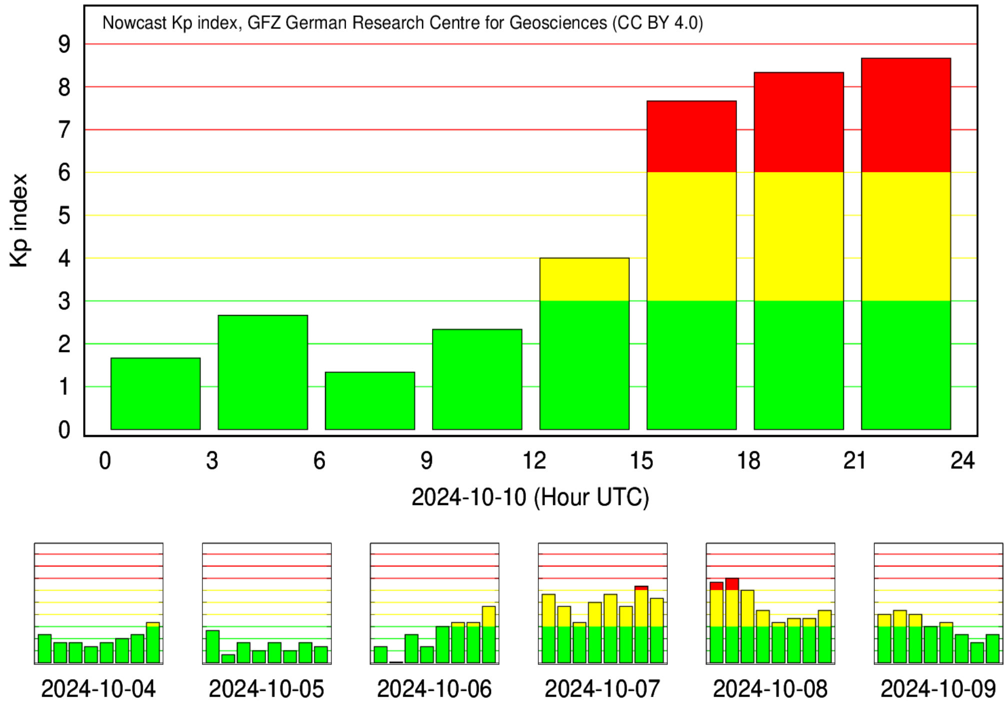


Figure 6-2 K-Index for October 10, 2024

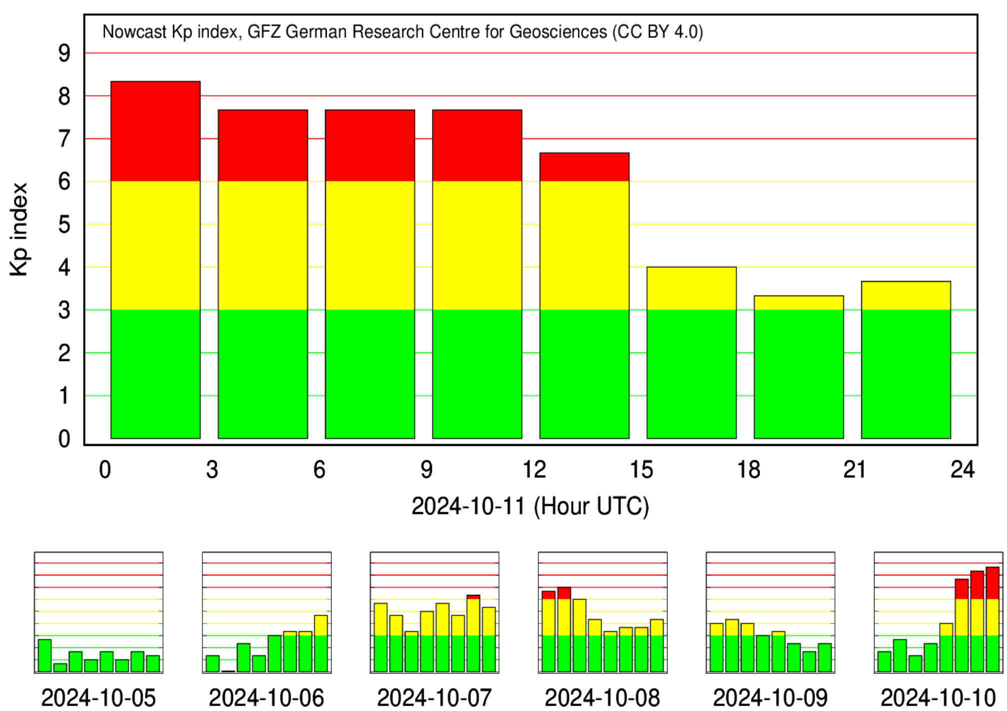


Figure 6-3 K-Index for October 11, 2024

Table 6-1 shows the position accuracy information for the quarter's worst-case storm day, October 10, 2024 (see Figure 6-2). The GPS SPS performance met all requirements during all storms that occurred during this quarter.

Table 6-1 Horizontal and Vertical Accuracy Statistics for October 10, 2024

Site	95% Horizontal (m)	95% Vertical (m)	Max Horizontal (m)	Max Vertical (m)
Albuquerque	9.286	7.488	14.467	14.526
Anchorage	5.971	9.744	7.381	18.896
Atlanta	5.384	8.18	13.388	12.6
Barrow	5.457	9.911	7.315	13.524
Bethel	4.698	10.656	6.388	14.89
Billings	11.112	14.56	14.486	28.333
Boston	12.134	6.137	18.767	11.347
Cleveland	15.756	6.163	21.676	12.803
Cold Bay	3.174	10.274	4.222	11.484
Fairbanks	5.361	10.947	7.941	17.699
Gander	7.885	5.773	9.592	10.057
Honolulu	14.163	6.177	19.372	10.007
Houston	5.981	12.216	13.741	24.343
Iqaluit	4.924	5.328	7.813	17.08
Juneau	6.876	15.568	11.379	25.542
Kansas City	9.435	7.517	16.833	27.825
Kotzebue	4.827	9.417	7.138	18.959
Los Angeles	12.26	8.843	16.249	15.314
Merida	11.375	20.733	17.507	30.797
Miami	5.763	10.329	14.358	15.228
Minneapolis	12.197	8.77	16.688	21.718
Oakland	12.412	9.167	14.418	11.481
Salt Lake City	12.077	7.527	15.012	8.567
San Jose Del Cabo	13.205	16.756	17.414	26.316
San Juan	19.291	19.668	25.014	25.79
Seattle	7.258	8.583	9.996	14.93
Tapachula	18.76	19.042	23.053	26.564
Washington, DC	14.644	5.227	19.521	11.164

7. IGS DATA

GPS SPS accuracy performance was evaluated at a selection of high-rate IGS stations[1]. The IGS is a voluntary federation of many worldwide agencies that pool resources and permanent GNSS station data to generate precise GNSS products.

Sites with high data rate (1 Hz) with good availability that are outside of the WAAS service area and that also provide a good geographic distribution have been selected. To facilitate differentiating between GPS accuracy issues and receiver tracking problems, an automatic data screening function excluded errors greater than 500 meters and or times when VDOP or HDOP were greater than 10. The remaining receiver tracking issues are still included in the processing and are forced into the 50.1-meter histogram bin. These issues cause the outliers seen in the 99.99% statistics and are visible in the 95% accuracy trend plots.

High-quality broadcast navigation data and Klobuchar model data is created by voting across all available IGS high-rate RINEX navigation data. Some manual review may be necessary to recover missing navigation data where the number of IGS sites reporting navigation data was below the voting threshold (i.e., 4).

Table 7-1 and Figure 7-1 show the IGS site information and locations. Table 7-2 shows the GPS SPS accuracy performance observed at a selection of high-rate IGS sites. Figure 7-2 shows the 95% horizontal accuracy trends at these sites. Figure 7-3 shows the 95% vertical accuracy trends at these sites. A value of zero indicates no data. The ramping error in the trend plots for the equatorial sites is due to seasonal variations in the ionosphere that cannot be corrected by the Klobuchar thin shell model of the ionosphere utilized by single-frequency GPS SPS receivers.

Table 7-1 Selected IGS Sites Information

ID	City	Country
BOGT	Bogota	Colombia
GLPS	Puerto Ayora	Ecuador
GUAM	Dededo	Guam
IISC	Bangalore	India
KIRU	Kiruna	Sweden
KOUR	Kourou	French Guyana
MADR	Robledo	Spain
MAL2	Malindi	Kenya
MAS1	Maspalomas	Spain
MATE	Matera	Italy

[1] J.M. Dow, R.E. Neilan, G. Gendt, "The International GPS Service (IGS): Celebrating the 10th Anniversary and Looking to the Next Decade," Adv. Space Res. 36 vol. 36, no. 3, pp. 320-326, 2005. doi: 10.1016/j.asr.2005.05.125

ID	City	Country
NNOR	New Norcia	Australia
POL2	Bishkek	Kyrgyzstan
SUTM	Sutherland	South Africa
TIDB	Tidbinbilla	Australia
UNSA	Salta	Argentina
USUD	Usuda	Japan

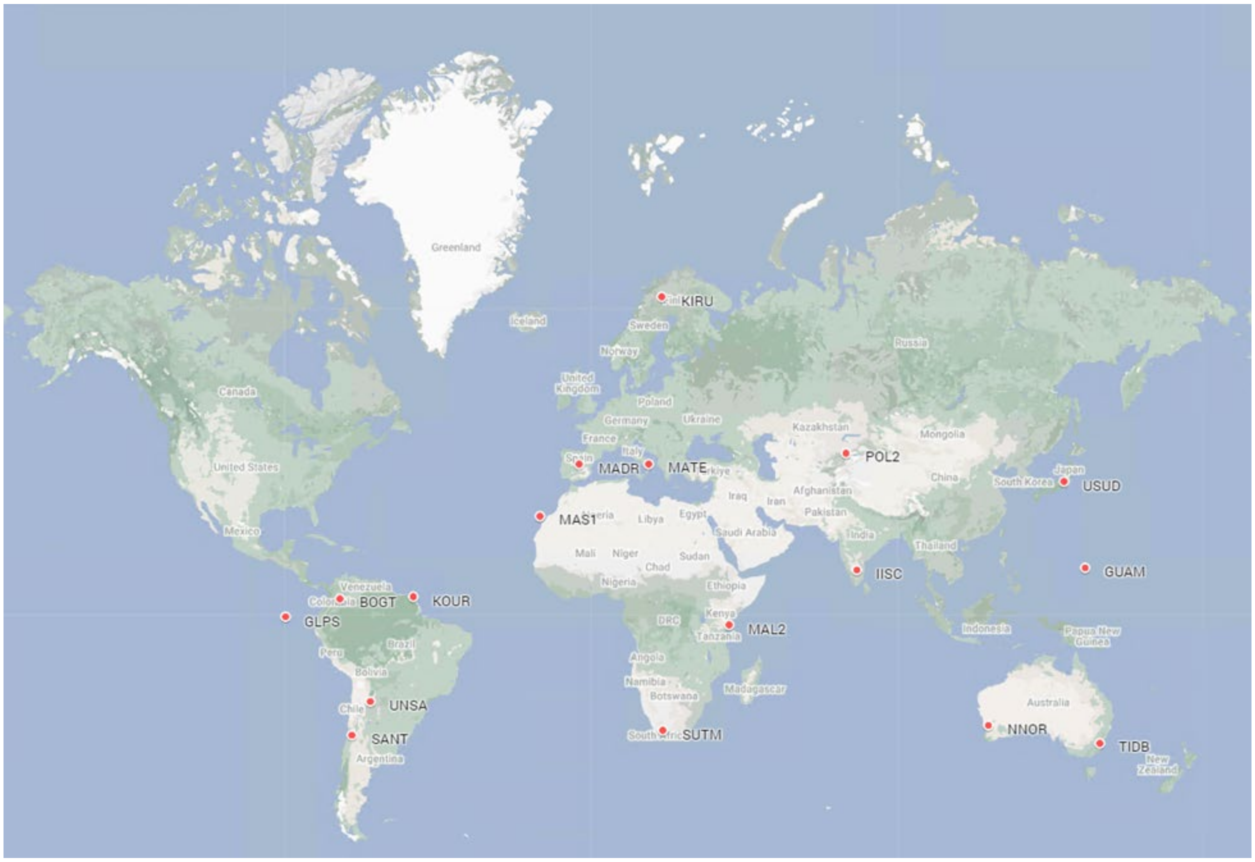


Figure 7-1 Selected IGS Site Locations

Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Data Available (%)
GLPS	N/A	N/A	N/A	N/A	N/A
GUAM	N/A	N/A	N/A	N/A	N/A
IISC	N/A	N/A	N/A	N/A	N/A
KIRU	N/A	N/A	N/A	N/A	N/A
KOUR	N/A	N/A	N/A	N/A	N/A
MADR	8.8	20.98	25.63	36.58	49.71
MAL2	N/A	N/A	N/A	N/A	N/A
MALI	N/A	N/A	N/A	N/A	N/A
MAS1	N/A	N/A	N/A	N/A	N/A
MATE	N/A	N/A	N/A	N/A	N/A
MOBN	N/A	N/A	N/A	N/A	N/A
NNOR	N/A	N/A	N/A	N/A	N/A
NRIL	N/A	N/A	N/A	N/A	N/A
PETS	N/A	N/A	N/A	N/A	N/A
POL2	4.4	19.12	14.23	29.83	49.69
SANT	N/A	N/A	N/A	N/A	N/A
SUTM	N/A	N/A	N/A	N/A	N/A
TIDB	9.58	19.03	50.01	50.01	93.99
USUD	N/A	N/A	N/A	N/A	N/A

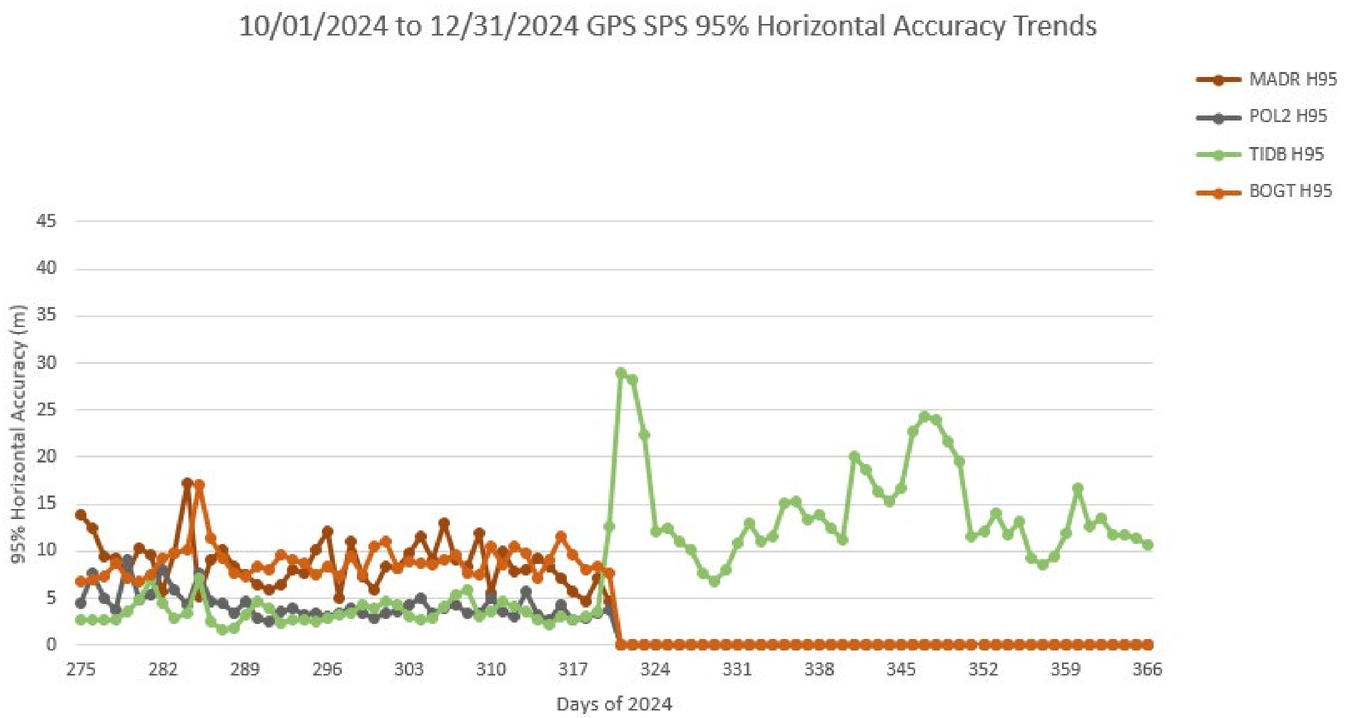


Figure 7-2 GPS SPS 95% Horizontal Accuracy Trends at Selected IGS Sites

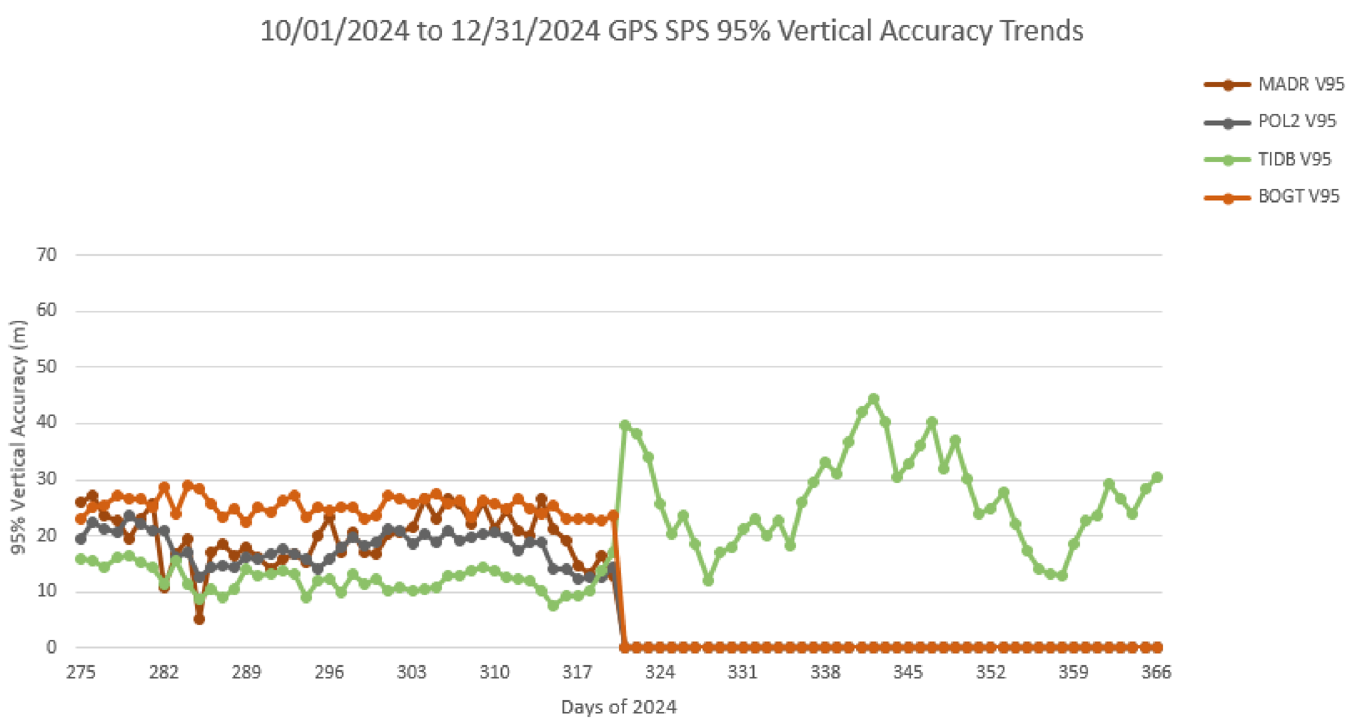


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites

8. RAIM PERFORMANCE

Receiver autonomous integrity monitoring (RAIM) is a technology developed to assess the integrity of GPS signals in a GPS receiver system. It is especially important in safety critical GPS applications, such as aviation. For a GPS receiver to perform RAIM or fault detection (FD) function, a minimum of five visible satellites with satisfactory geometry must be visible. RAIM has various kinds of implementations; one of them performs consistency checks between all position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if the consistency checks fail.

Availability is a performance indicator of the RAIM algorithm. Availability is a function of the geometry of the constellation in view and of other environmental conditions. All the analysis performed here is utilizing the "Fault-Detection with no baro-aiding and SA off" RAIM implementation. Additional modes will be assessed at a future date. The test statistic used is a function of the pseudorange measurement residual (the difference between the expected measurement and the observed measurement) and the amount of redundancy. The test statistic is compared with a threshold value and is determined based on the requirements for the probability of false alarm (Pfa), the probability of missed detection (Pmd), and the expected measurement noise. In aviation systems, the Pfa is fixed at 1/15,000.

The horizontal protection limit (HPL) is a figure that represents the radius of a circle in the horizontal plane, centered on the GPS position solution, and is guaranteed to contain the true position of the receiver to within the specifications of the RAIM scheme (i.e., meets the Pfa and Pmd). The HPL is calculated as a function of the RAIM threshold and the satellite geometry at the time of the measurement. The HPL is compared with the horizontal alarm limit (HAL) to determine if RAIM is available. The RNP values shown here are measured in nautical miles. The computed HPL must be less than the RNP value for the service to be available.

8.1 Site Performance

Table 8-1 shows the RAIM performance for the 28 sites evaluated. For all sites collected, the minimum percent of time in RNP 0.1 mode was 99.944% at Iqaluit. The minimum percent of time spent in RNP 0.3 mode was 100 at all locations evaluated. The maximum 99% HPL value was 127.356 meters at Bethel.

Table 8-1 RAIM Site Statistics

City	99% HPL (m)	RNP 0.1 (%)	RNP 0.3 (%)
Atlantic City	96.277	100	100
Albuquerque	87.186	100	100
Anchorage	122.134	100	100
Atlanta	86.862	100	100
Barrow	114.927	100	100

City	99% HPL (m)	RNP 0.1 (%)	RNP 0.3 (%)
Bethel	127.356	100	100
Billings	108.824	100	100
Boston	109.799	100	100
Cleveland	105.432	100	100
Cold Bay	101.453	100	100
Fairbanks	119.931	100	100
Gander	126.522	100	100
Honolulu	94.383	99.98093	100
Houston	76.551	100	100
Iqaluit	121.28	99.94435	100
Juneau	124.458	100	100
Kansas City	119.855	99.99372	100
Kotzebue	113.778	99.96945	100
Los Angeles	84.734	99.98979	100
Merida	70.919	100	100
Miami	88.049	100	100
Minneapolis	120.218	100	100
Oakland	84.076	99.99502	100
Salt Lake City	96.098	99.99778	100
San Jose Del Cabo	69.604	99.99101	100
San Juan	88.435	100	100
Seattle	105.537	100	100
Tapachula	76.41	100	100
Washington, DC	96.713	100	100

8.2 RAIM Coverage

Figure 8-1 and Figure 8-2 show the worldwide RAIM coverage for both RNP 0.1 and RNP 0.3, respectively. Figure 8-3 and Figure 8-4 show the daily RAIM coverage trends between October 1 and December 31, 2024.

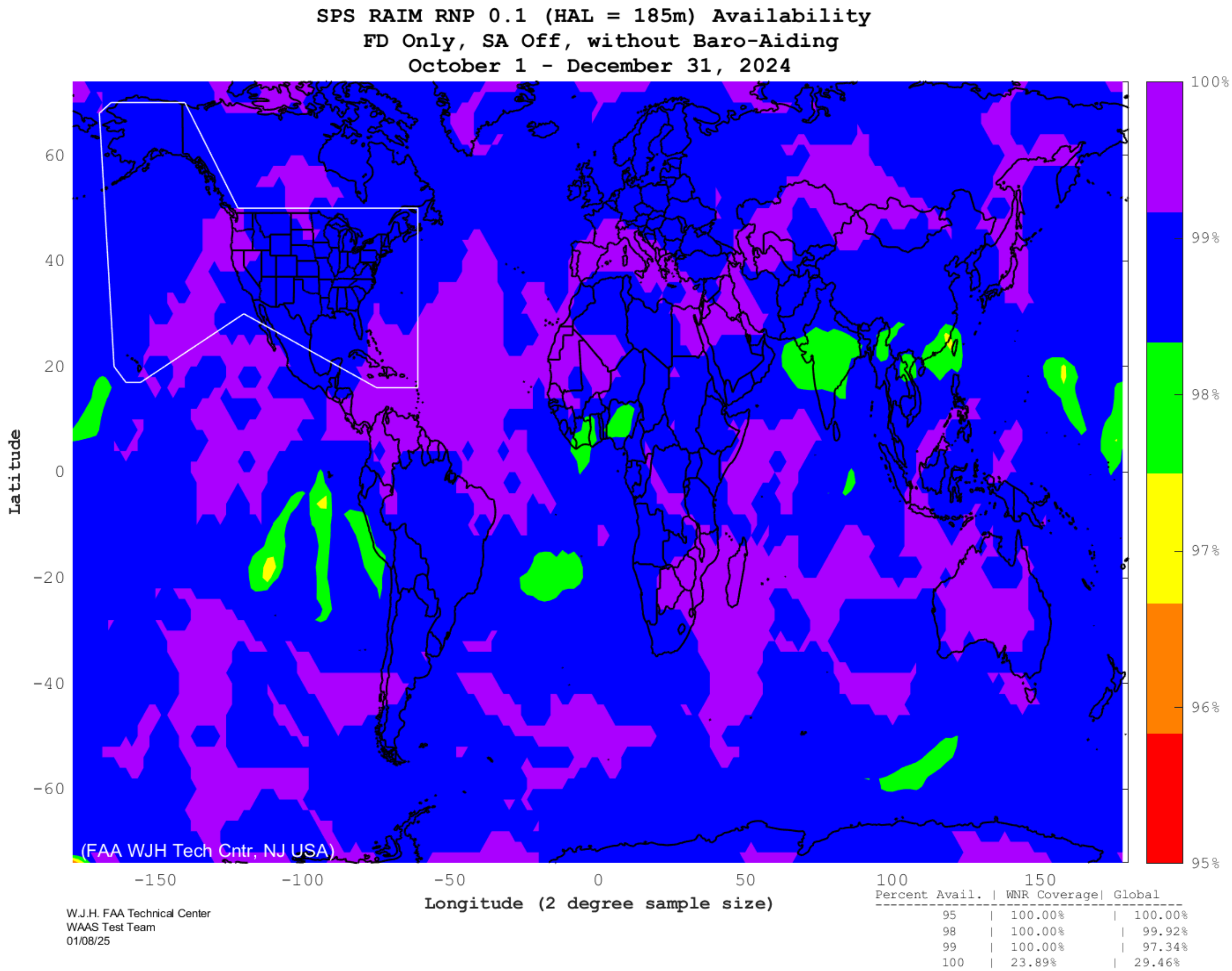
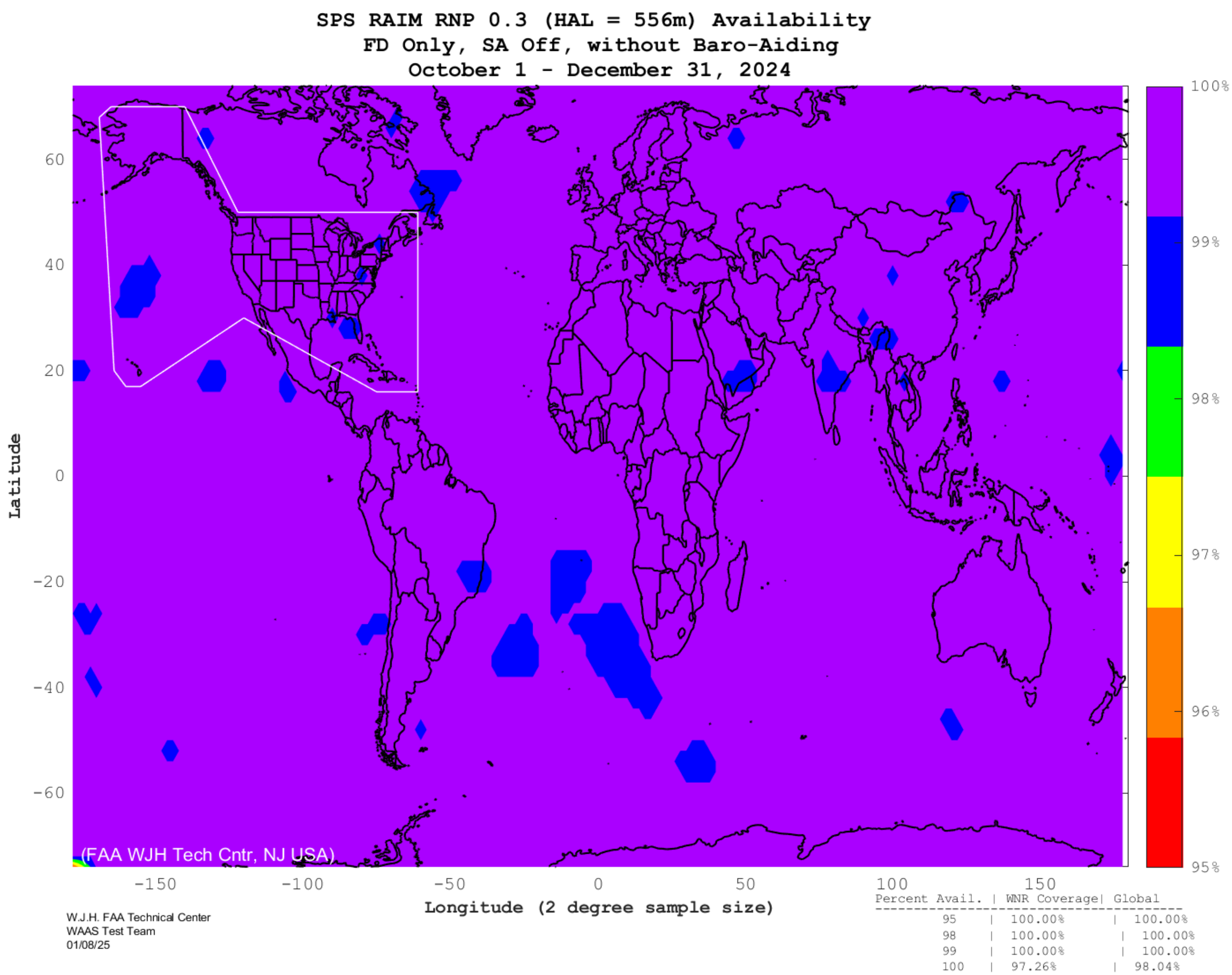


Figure 8-1 RAIM RNP 0.1 Coverage



Percent Avail.	WNR Coverage	Global
95	100.00%	100.00%
98	100.00%	100.00%
99	100.00%	100.00%
100	97.26%	98.04%

Figure 8-2 RAIM RNP 0.3 Coverage

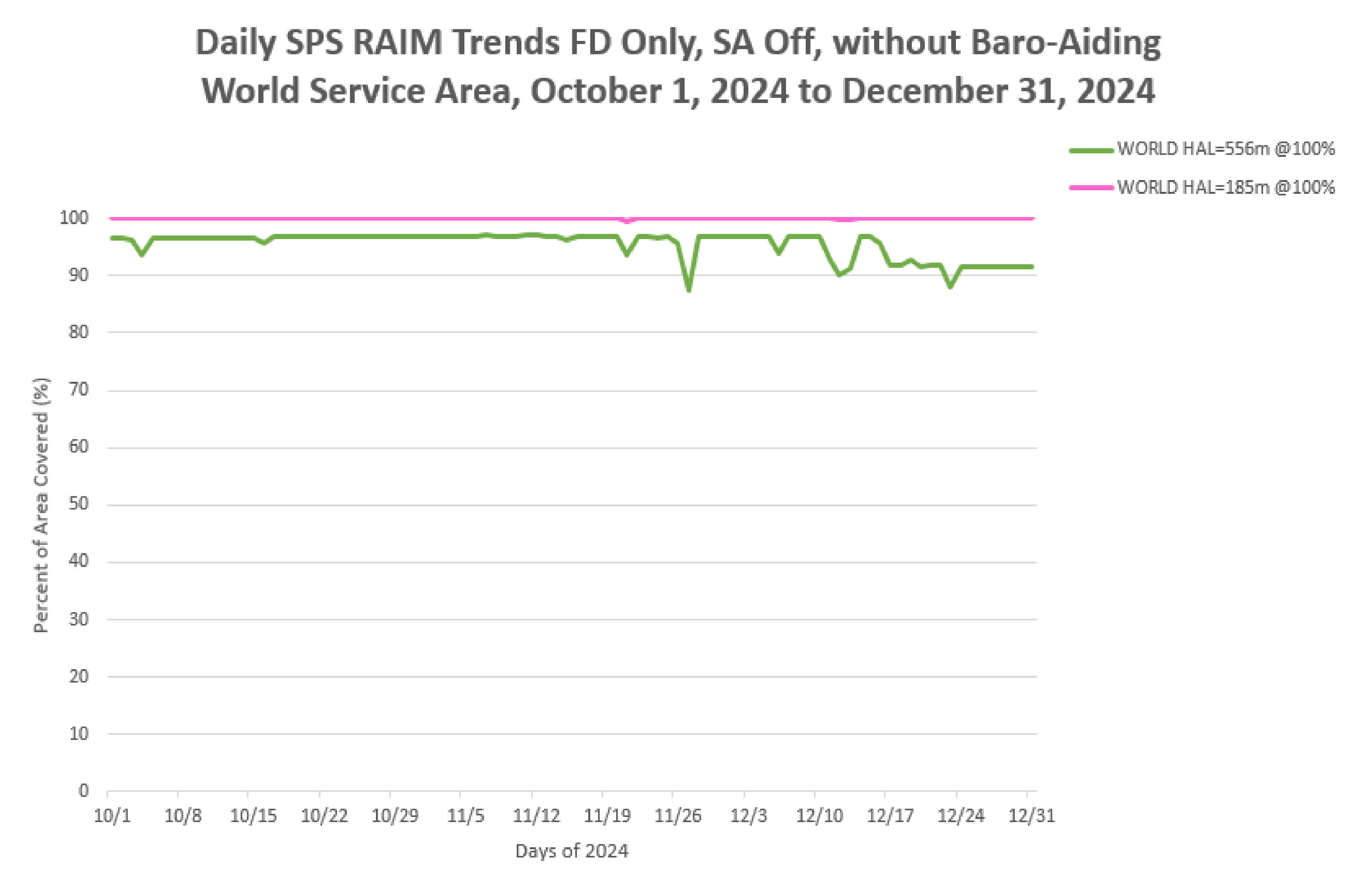


Figure 8-3 RAIM Worldwide Coverage Trend

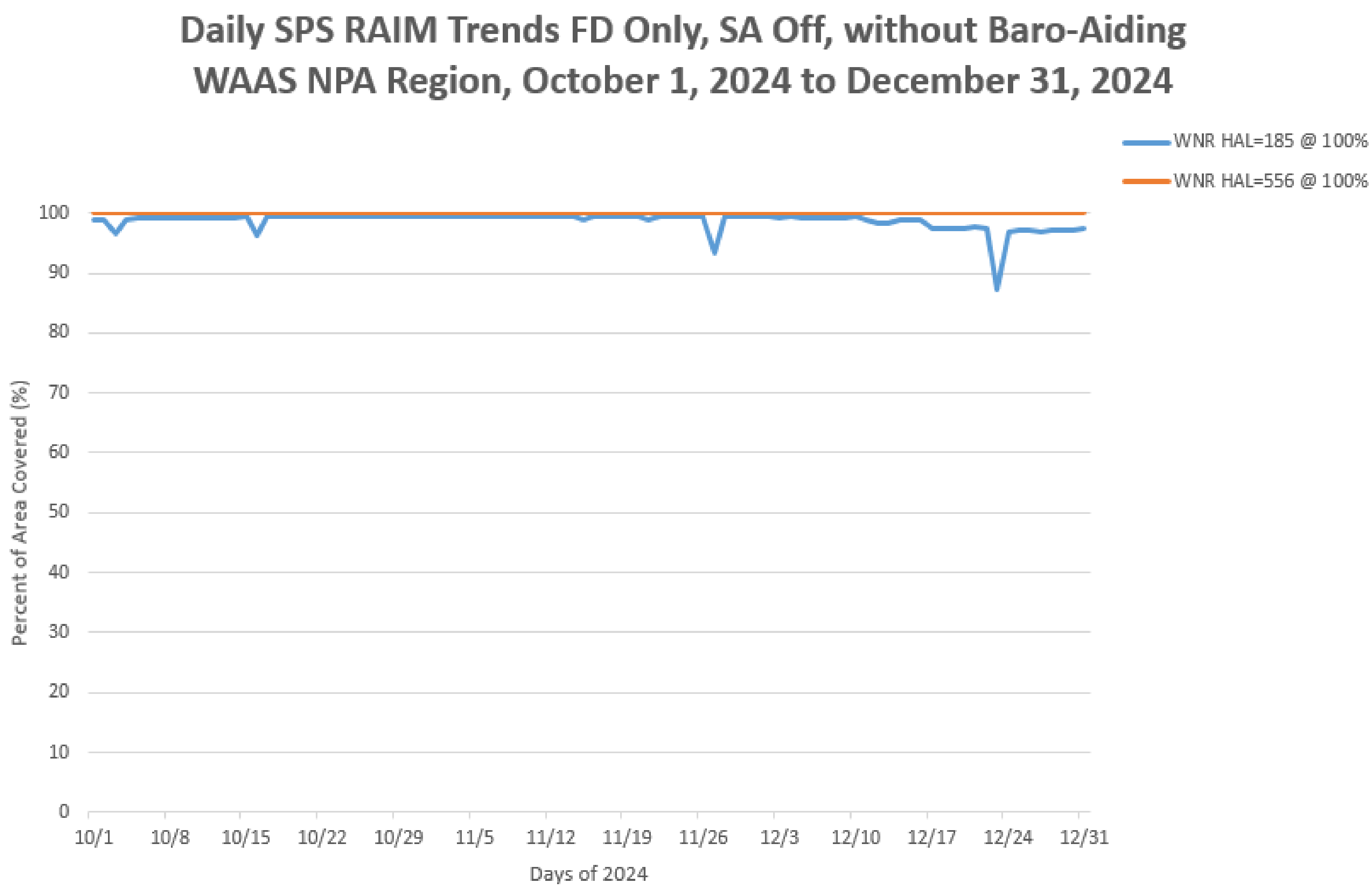


Figure 8-4 RAIM RNP Coverage Trend for WAAS NPA Service Area

8.3 RAIM Airport Analysis

Figure 8-5 and Figure 8-6 show RAIM RNP 0.1 and RNP 0.3 availability at all U.S. and Canadian airports that have an RNAV (GPS) published approach or better.

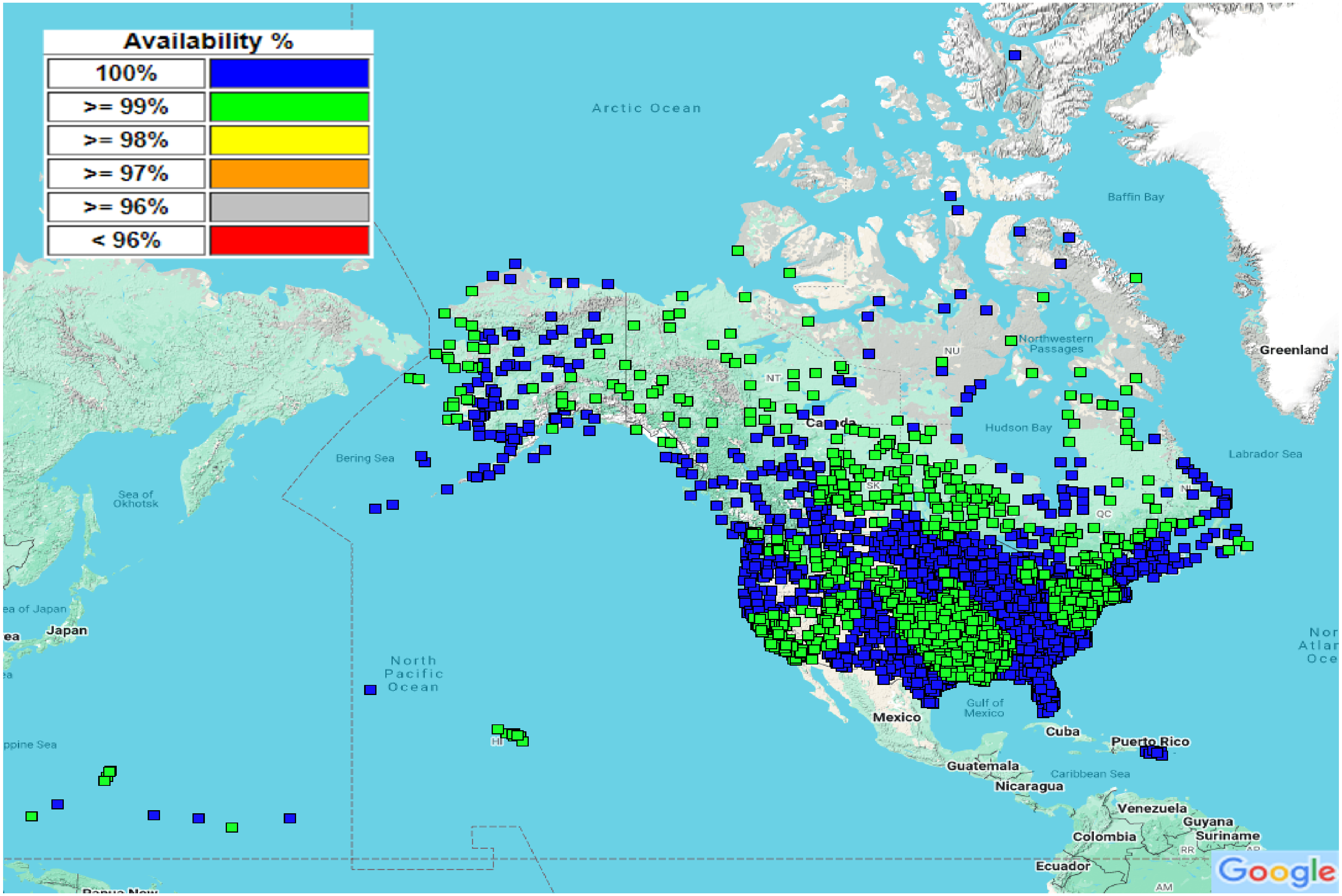


Figure 8-5 RAIM RNP 0.1 Airport Availability

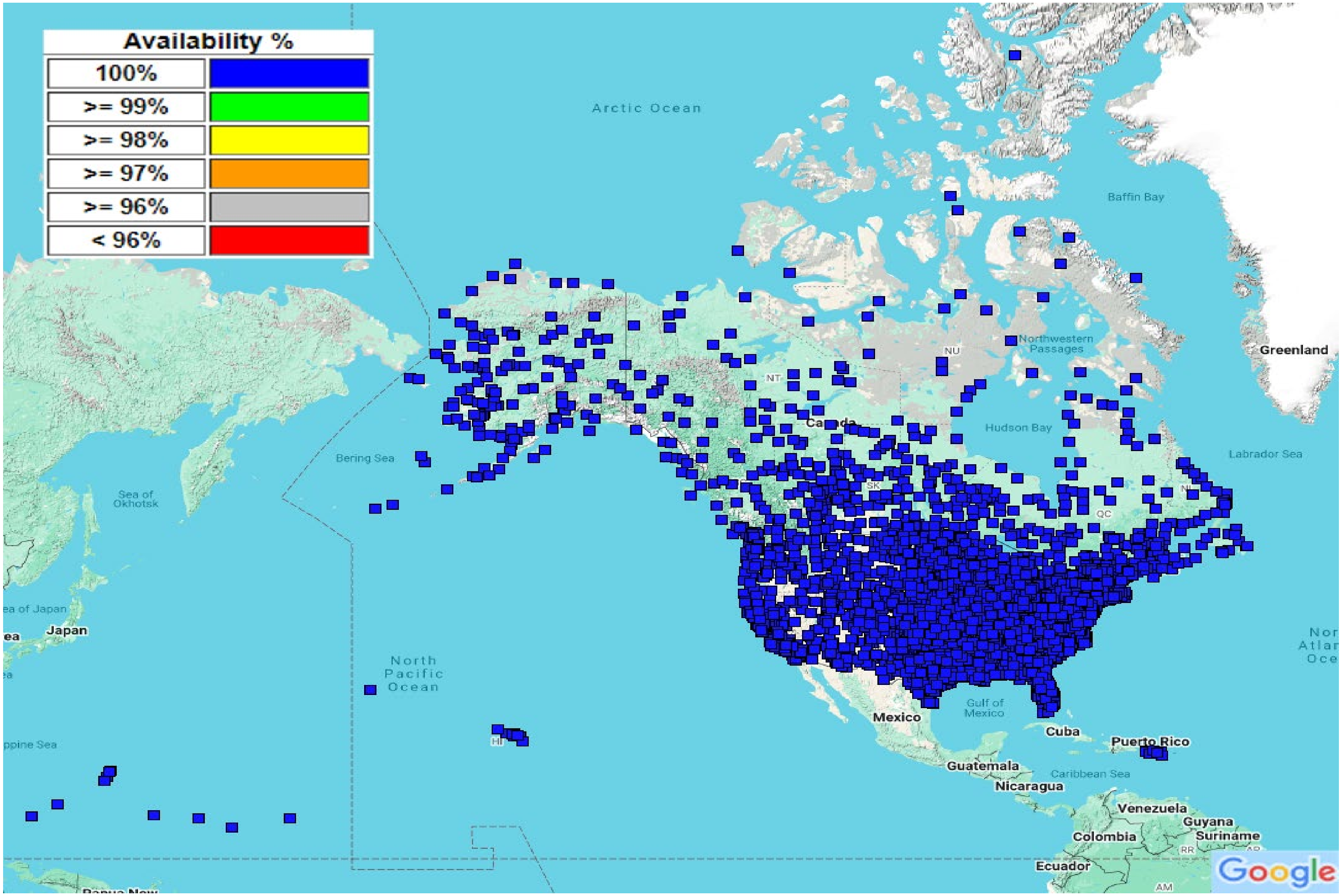


Figure 8-6 RAIM RNP 0.3 Airport Availability

Figure 8-7 and Figure 8-8 respectively show the number of RAIM RNP 0.1 and RAIM RNP 0.3 outages for every airport in the U.S. and Canada that have a RNAV (GPS) published approach or better.

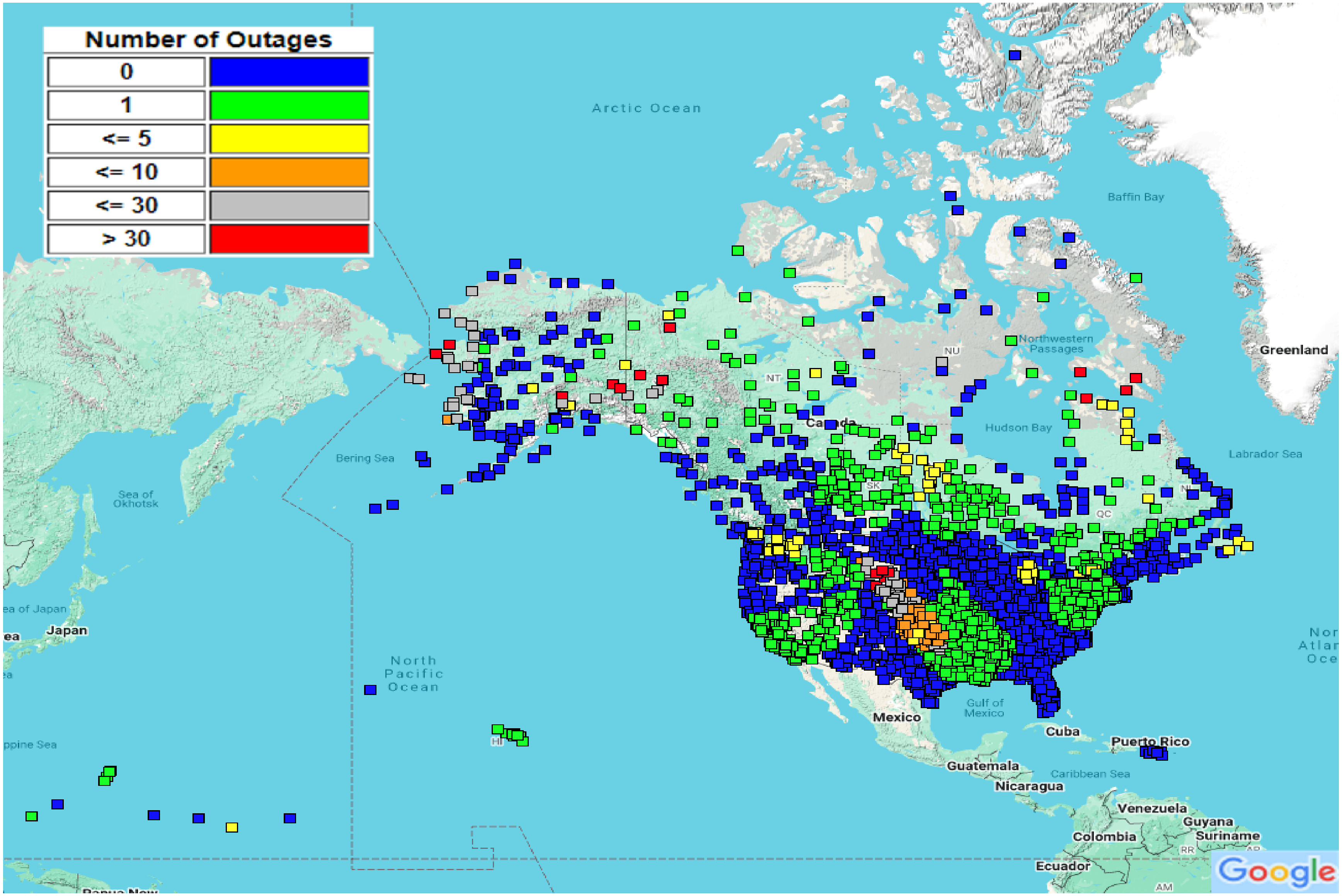


Figure 8-7 RAIM RNP 0.1 Airport Outages

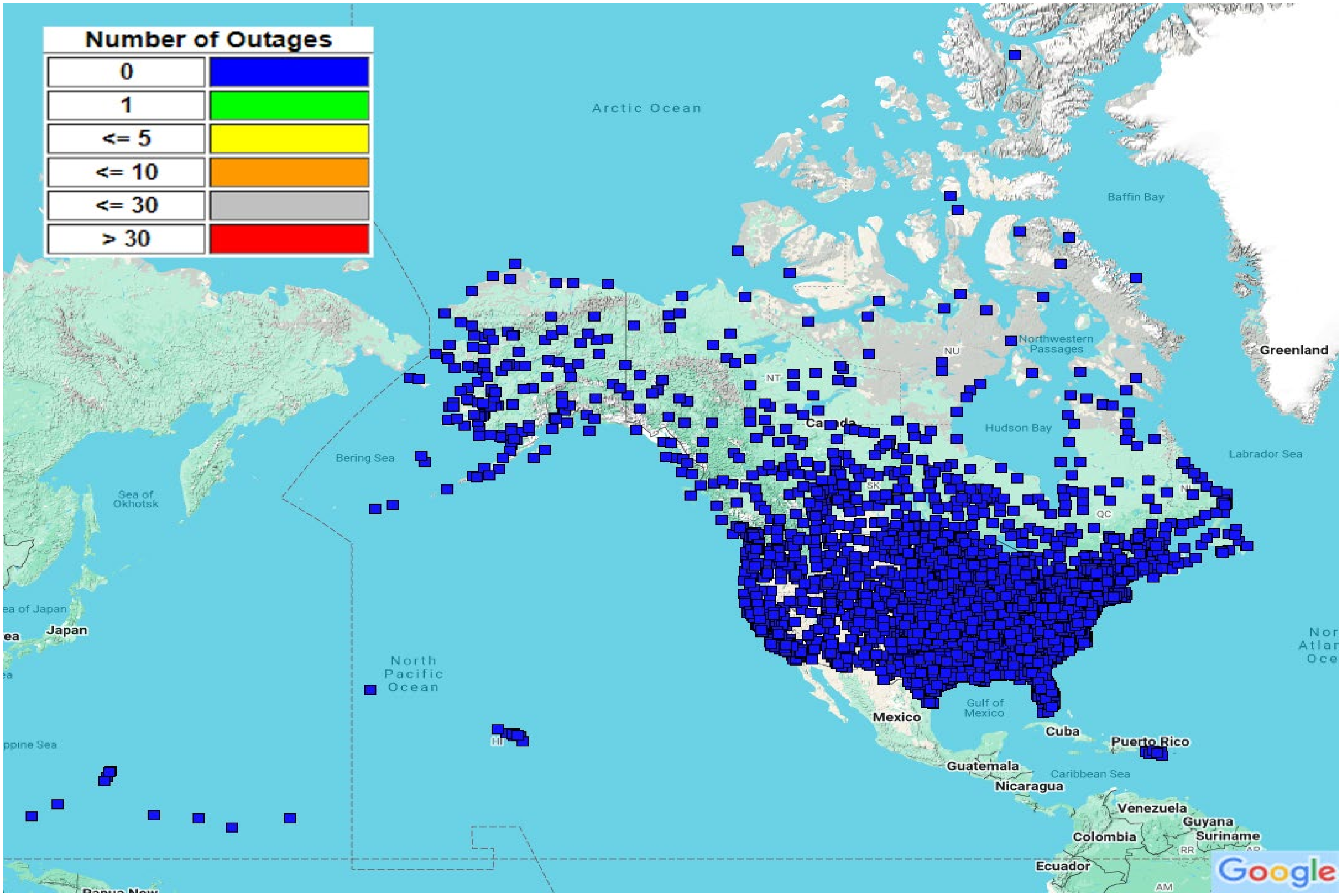


Figure 8-8 RAIM RNP 0.3 Airport Outages

9. GPS BROADCAST ORBIT VS. NGA PRECISE ORBITS AND URA (IAURA) BOUNDING ANALYSIS

As part of the WAAS off-line monitoring process, the accuracy of the GPS broadcast ephemeris is periodically compared to the NGA precise orbit information to monitor the validity of an a priori assumption concerning the accuracy of the GPS broadcast ephemeris information. That a priori assumption is part of a brute force computer simulation analysis utilized as part of the safety proof of the WAAS MT-28 functionality. That brute force analysis searches a simulated error sphere around a GPS satellite for a worst-case projection of post-correction ephemeris error to any user. A pessimistic extrapolation of historical data was used as an a priori to limit the radius of the searched sphere to a finite distance. This periodic offline monitoring verifies that the original logic of the a priori assumption remains sound.

The assumptions being validated are:

- Height Error: +/-15 meters (standard deviation <2.8 m)
- Along Track Error: +/-65 meters (standard deviation <12.2 m)
- Cross Track Error: +/-30 meters (standard deviation <5.6 m)

C/A Nav data URA bounding and L2C CNAV IAURA bounding performance are also evaluated.

For C/A Nav data, all IGS high-rate 15-minute broadcast navigation data RINEX format files are downloaded and merged into 24-hour broadcast navigation data files, which are then added to RINEX nav data files from all WAAS peripheral reference stations. A majority voting algorithm is used to screen the navigation data after a LSB recovery algorithm is applied. NGA APC precise ephemeris referenced to the GPS satellite antenna phase center is downloaded from the NGA site. GPS satellite positions are computed every 15 minutes and differenced with the precise orbits. The resulting error information is then segregated into the Height, Along Track, and Cross Track (HAC) error data. The standard deviation of those errors is then computed for each dimension for each satellite. Figure 9-1 and Figure 9-2 show the standard deviation results.

The assumption is valid if a 5.33 scaling of the standard deviation across all satellites is within the a priori. Three months of data from October 1 to December 31, 2024 are presented. Only data points in which GPS is healthy and valid precise data is available are considered. There was maintenance on PRN11 from 10/03/24 to 10/04/24; PRN30 from 10/15/24 to 10/16/2024; PRN19 on 11/15/24; PRN12 from 11/20/24 to 11/21/24; PRN6 from 11/26/24 to 11/27/24; PRN7 on 12/06/24; PRN21 from 12/11/24 to 12/13/24; and PRN9 on 12/23/24. Figure 9-5 shows the availability of C/A Nav data. There were no points where GPS was healthy, and the NGA data was missing.

For L2C CNAV data, raw 300-bit L2C and L5 CNAV message data is obtained from the WAAS G3 test receivers located at the NSTB ACY reference station. Those receivers are located at the William J. Hughes Technical Center in Atlantic City, NJ. CNAV data was only available while the satellites were in view of ACY G3 test receivers. This is the reason for the sparseness in the CNAV data. Because of the sparseness of the data, CNAV data from rising and setting satellites was used for the entire 3-hour fit interval, even though on rising and setting satellites there would have normally been an ephemeris set update at the 2-hour points. Those missing updates may or may not have provided improvement to the accuracy. L2C is used because there are more L2C capable satellites than L5 capable satellites. Table 9-1 shows the satellites that are capable of broadcasting L2C, L5 and L1C. In the December 31, 2024 GPS constellation, PRN1 is not in use as SVN63 was set to Unusable and decommissioned on July 10, 2023. SVN44 (PRN22) is the most recent satellite, which was added to the constellation on August 18, 2023.

Table 9-1 Signal Capability per Satellite Vehicle

PRN	SVN	Block Type	L2C	L5	L1C
1	63	IIF	Yes	Yes	N/A
2	61	IIR	N/A	N/A	N/A
3	69	IIF	Yes	Yes	N/A
4	74	III	Yes	Yes	Yes
5	50	IIR-M	Yes	N/A	N/A
6	67	IIF	Yes	Yes	N/A
7	48	IIR-M	Yes	N/A	N/A
8	72	IIF	Yes	Yes	N/A
9	68	IIF	Yes	Yes	N/A
10	73	IIF	Yes	Yes	N/A
11	78	III	Yes	Yes	Yes
12	58	IIR-M	Yes	N/A	N/A
13	43	IIR	N/A	N/A	N/A
14	77	III	Yes	Yes	Yes
15	55	IIR-M	Yes	N/A	N/A
16	56	IIR	N/A	N/A	N/A
17	53	IIR-M	Yes	N/A	N/A
18	75	III	Yes	Yes	Yes
19	59	IIR	N/A	N/A	N/A
20	51	IIR	N/A	N/A	N/A
21	45	IIR	N/A	N/A	N/A
22	44	IIR	N/A	N/A	N/A
23	76	III	Yes	Yes	Yes
24	65	IIF	Yes	Yes	N/A
25	62	IIF	Yes	Yes	N/A
26	71	IIF	Yes	Yes	N/A
27	66	IIF	Yes	Yes	N/A
28	79	III	Yes	Yes	Yes

PRN	SVN	Block Type	L2C	L5	L1C
29	57	IIR-M	Yes	N/A	N/A
30	64	IIF	Yes	Yes	N/A
31	52	IIR-M	Yes	N/A	N/A
32	70	IIF	Yes	Yes	N/A

The sign convention for this analysis is error = broadcast ECEF - precise ECEF. Along track is positive in the direction of the velocity vector. Cross track completes a right-hand system with height and along track.

Figure 9-7 through Figure 9-10 are URA (IAURA) overbounding plots. URA bounding using C/A Nav data used the maximum of the range indicated by the broadcast URA index. IAURA bounding using CNAV data used the algorithm from IS-GPS-200/IS-GPS-705. The error used in the analysis is at the location of maximum error in the footprint (usually edge of coverage). Review of the bounding plots, the QQ plots, and the histograms indicates that CNAV data is not as conservative as using the max URA from the C/A Nav data. The CNAV over bounding plot does not pass. Sparseness of data may have contributed to the failure to over bound. (i.e., using the full 3-hour fit interval at the beginning and end of tracks).

Figure 9-10 through Figure 9-65 are plots of the height, along track, and cross track error relative to NGA precise orbits by PRN number. These plots do not include clock error.

Figure 9-66 through Figure 9-79 are QQ plots of the URA (IAURA) normalized total range error (height, along track, cross track, and clock) projected onto the surface of the earth. The surface of the Earth is approximated using +/-13.9-degrees from the bore sight of the satellite. The max URA of the broadcast URA index range is used for the C/A Nav data, and IAURA is used for the CNAV data. The range of the QQ plot axis has been fixed at +/-5. Annotations are provided for any instances beyond that range.

Errors larger than 3 times URA (IAURA) for C/A and 4 times URA (IURA) for CNAV were investigated.

Figure 9-80 through Figure 9-134 are histograms of the height error, along track error, cross track error, and URA (IAURA) normalized range error.

Figure 9-135 through Figure 9-190 are the timelines of the URA (IAURA) normalized range error. Missing data points are in red and are NANUs for the C/A data. The large number of red points in the CNAV data are the points where the satellites are out of view of ACY.

9.1 GPS Broadcast Orbit Accuracy Standard Deviation Plots

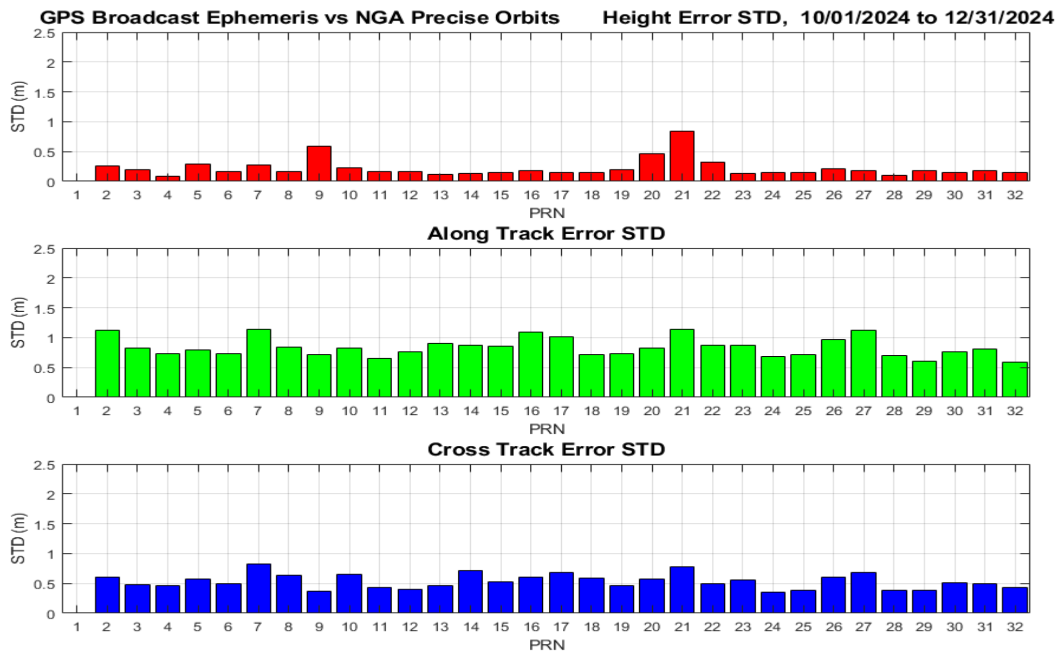


Figure 9-1 GPS Broadcast Orbit Accuracy Standard Deviations Using C/A Nav Data

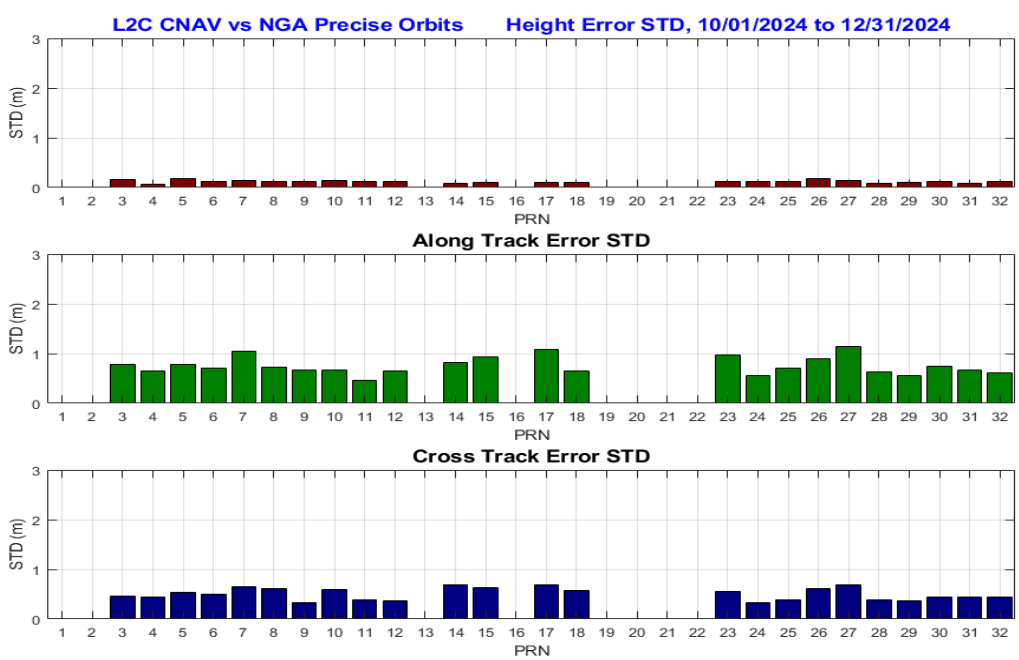


Figure 9-2 GPS Broadcast Orbit Accuracy Standard Deviations Using L2C CNAV Data

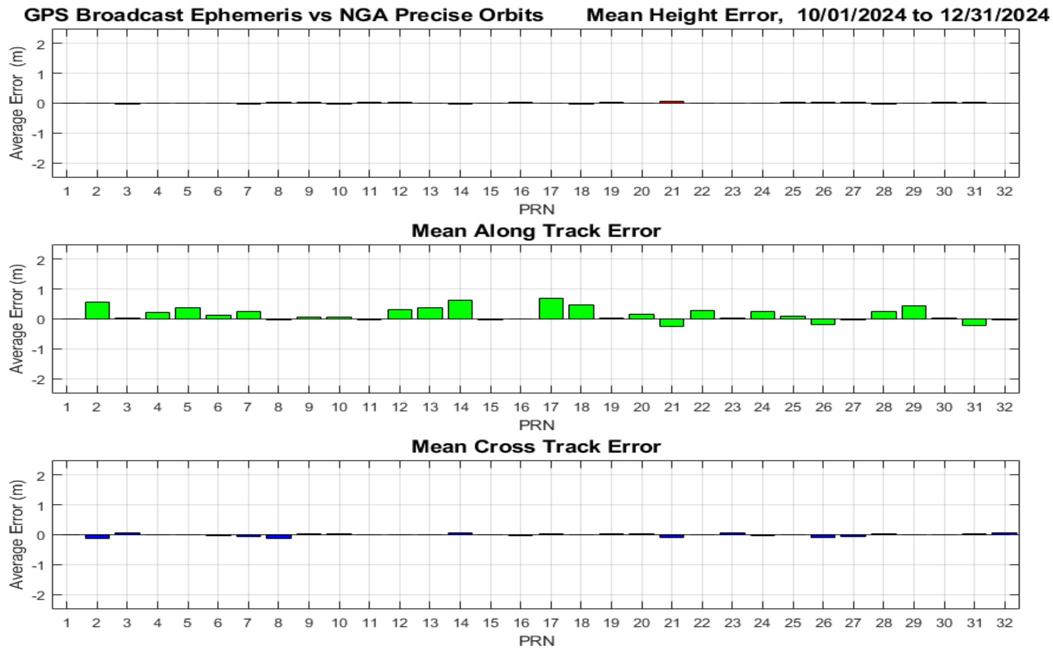


Figure 9-3 GPS Broadcast Orbit Error Means Using C/A Nav Data

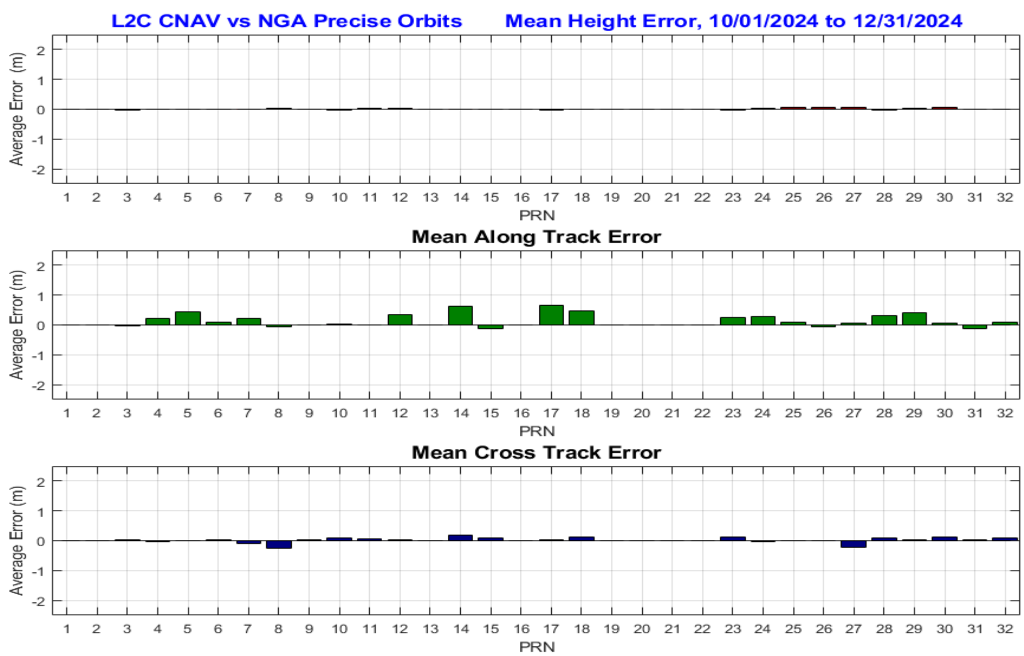


Figure 9-4 GPS Broadcast Orbit Error Means Using L2C CNAV Data

9.2 Broadcast Ephemeris vs. NGA Precise Data Availability Plots

Figure 9-5 Broadcast Ephemeris vs. NGA Precise Data Availability Plots

9.3 Current GPS Constellation

Table 9-2 is a listing of the current GPS constellation plane and slot designations provided by the United States Coast Guard (USCG) Navigation Center (NavCen) as depicted by their GPS Satellite Locations Slant Chart. Table 9-2 reflects actual orbital configuration and may not match the current GPS constellation Operational Advisory (AO) status published by the USCG NavCen, which depicts the control station configuration. GPS constellation slots designated with an asterisk refer to the expandable slots. Expandable slots are divided into a fore (F) and an aft (A) slot. Figure 9-6 is a graphical representation of the current GPS constellation during the reporting period.

Table 9-2 GPS Constellation Plane/Slot per SVN

Plane	Slot	SVN	PRN	Block Type
A	1	65	24	IIF
A	2			
A	2F	79	28	III
A	2A	52	31	IIR-M
A	3	64	30	IIF
A	4	48	7	IIR-M

Plane	Slot	SVN	PRN	Block Type
B	1			
B	1F	71	26	IIF
B	1A	56	16	IIR
B	2	62	25	IIF
B	3	44	22	IIR
B	4	58	12	IIR-M
B		77	14	III
C	1	57	29	IIR-M
C	2	66	27	IIF
C	3	72	8	IIF
C	4			
C	4F	53	17	IIR-M
C	4A	59	19	IIR
D	1	78	11	IIR
D	2			
D	2F	45	21	III
D	2A	61	2	III
D	3	75	18	IIR
D	4	67	6	IIF
E	1	69	3	IIF
E	2	73	10	IIF
E	3			
E	3F	51	20	IIR
E	3A	50	5	IIR-M
E	4	76	23	III
F	1	70	32	IIF
F	2			
F	2F	43	13	IIR
F	2A	55	15	IIR-M
F	3	68	9	IIF
F	4	74	4	III

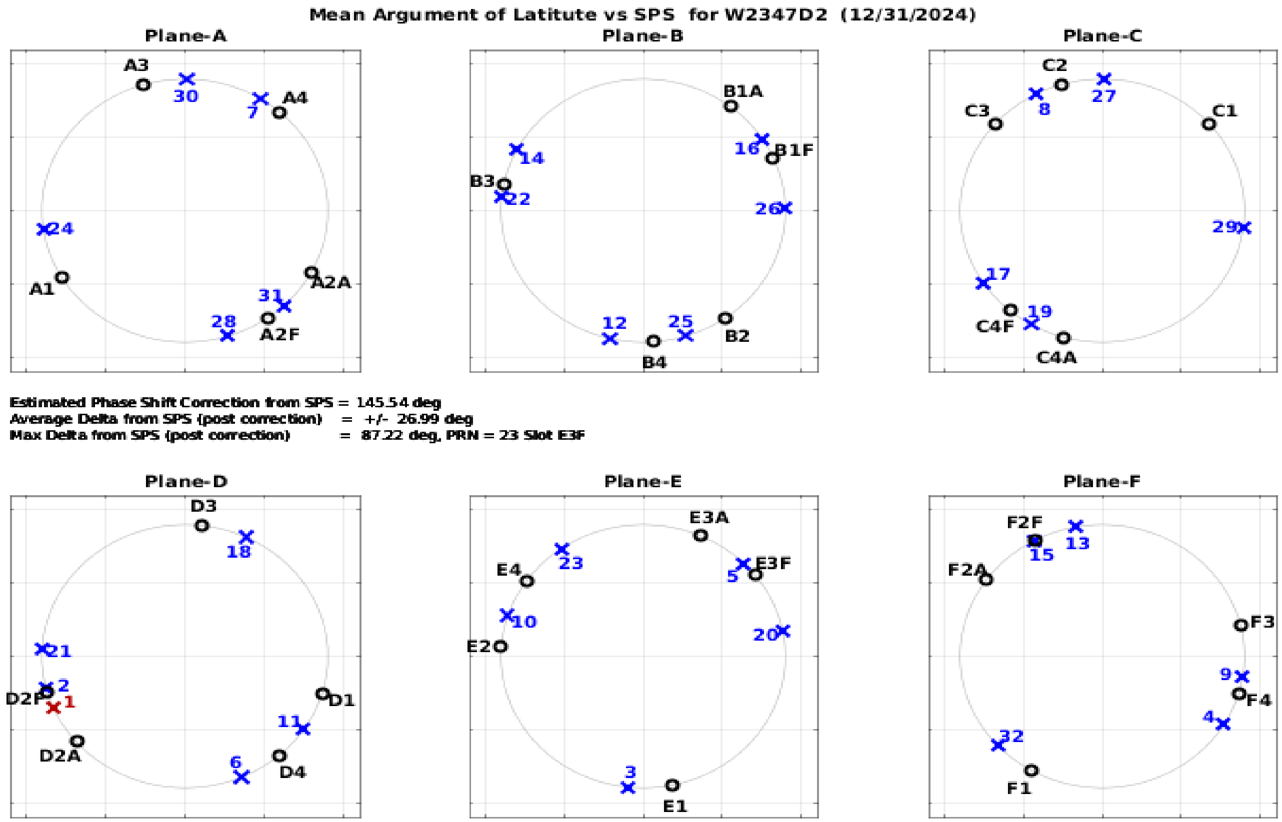


Figure 9-6 December 31, 2024 GPS Constellation

9.4 URA Overbounding Plots

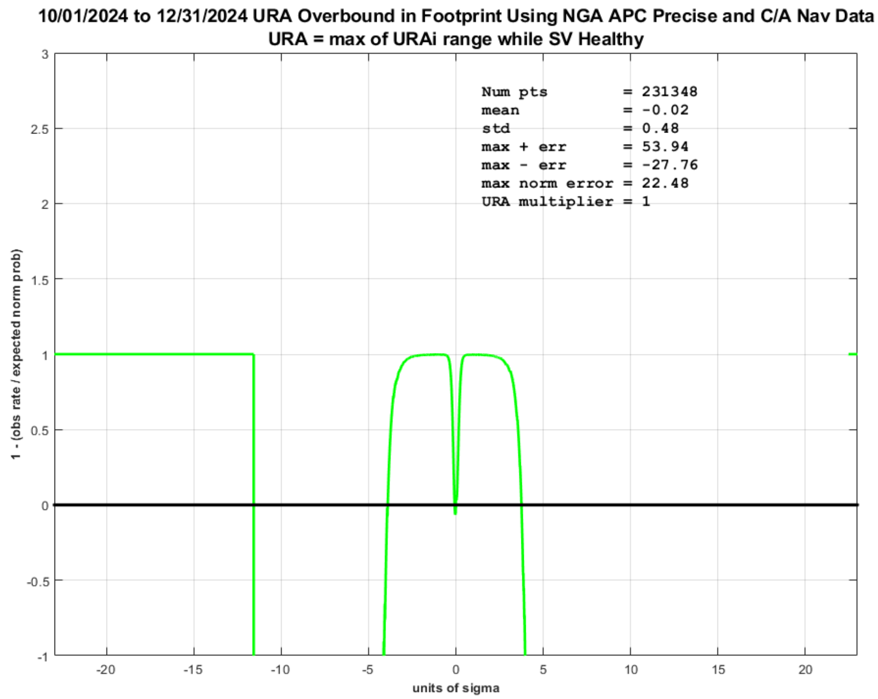


Figure 9-7 URA Overbounding Using C/A Nav Data

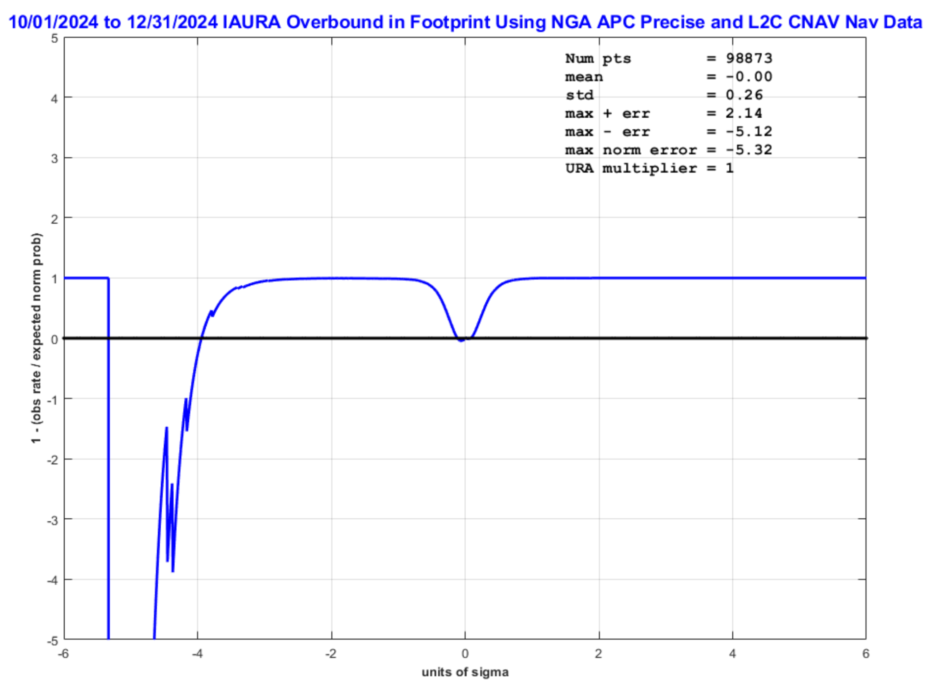


Figure 9-8 IAURA Overbounding Using L2C CNAV Data

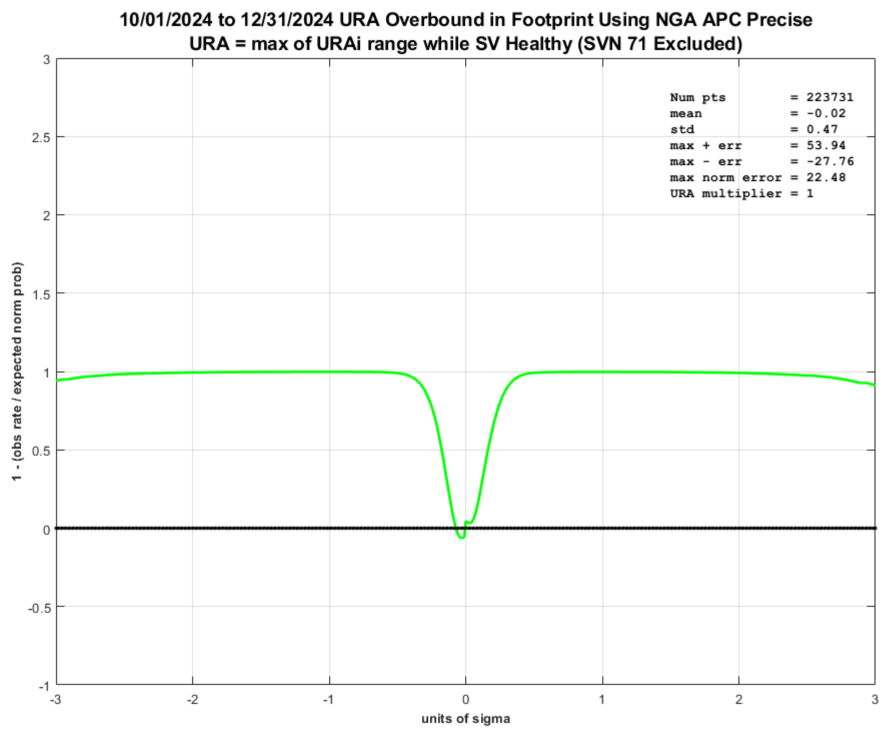


Figure 9-9 URA Overbounding Using L2C CNAV Data

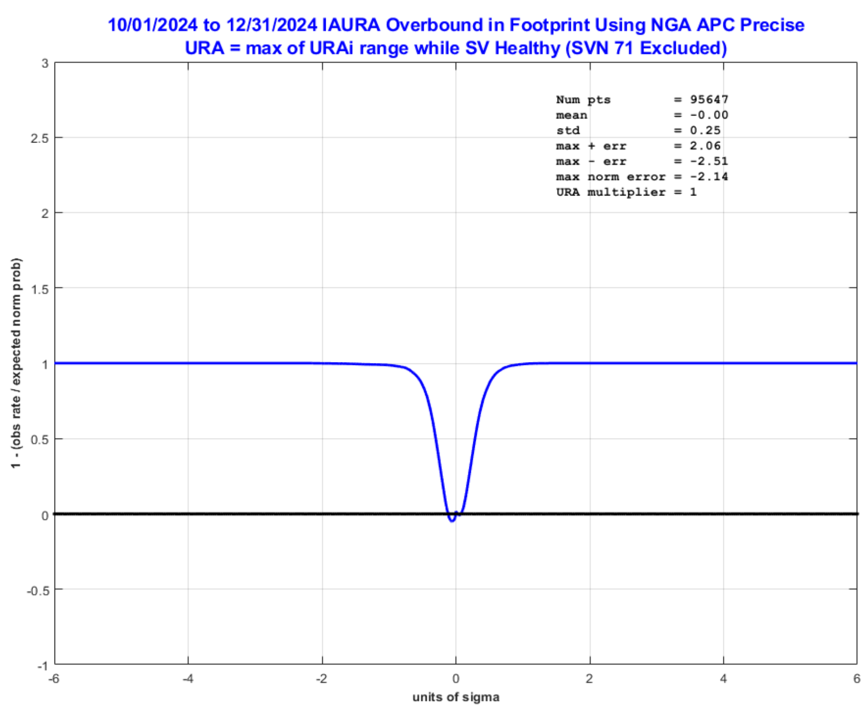


Figure 9-10 IAURA Overbounding SVN 71 Excluded Using L2C CNAV Data

9.5 Orbit Error Plots for All Satellites

Figure 9-11 Orbit Error PRN2 (SVN61) Using C/A Nav Data

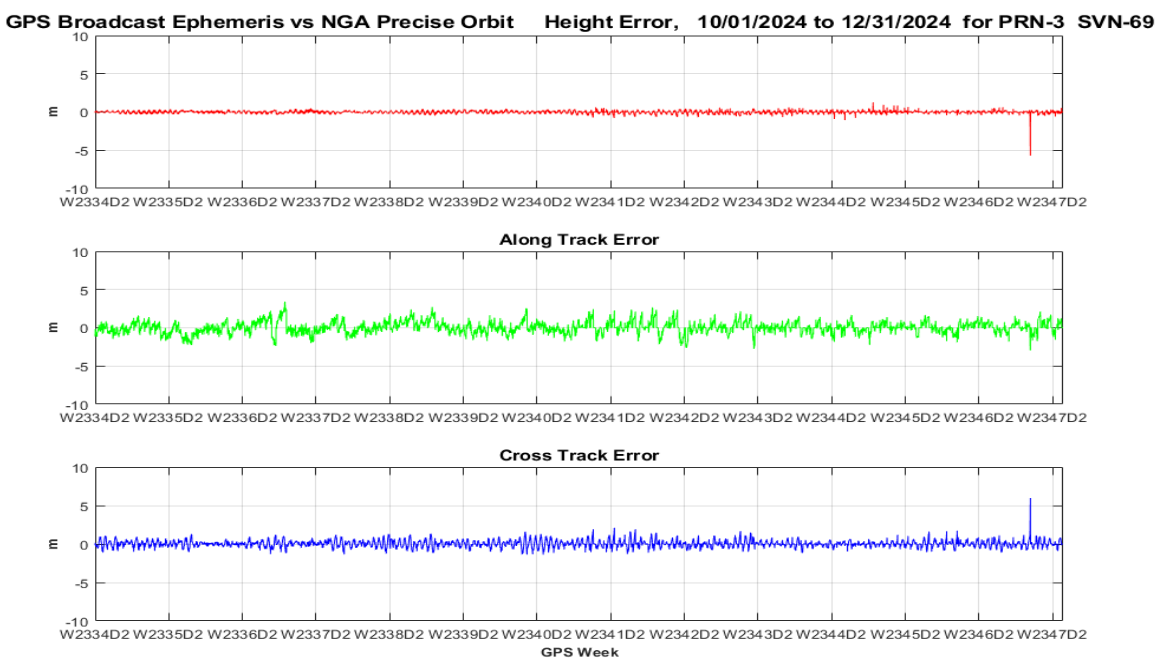


Figure 9-12 Orbit Error PRN3 (SVN69) Using C/A Nav Data

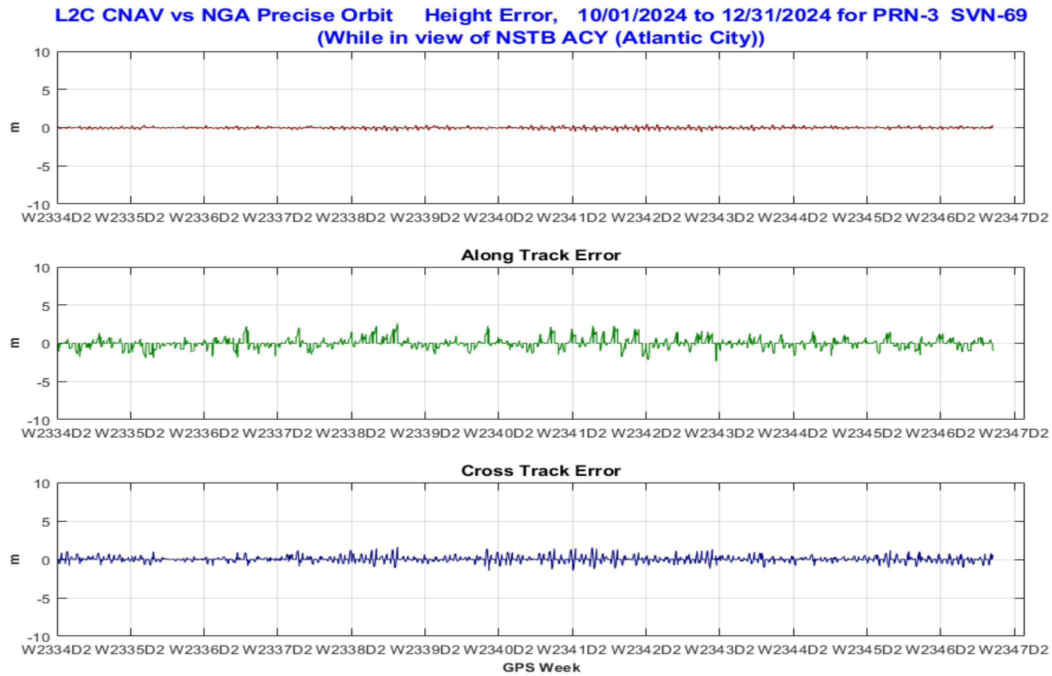


Figure 9-13 Orbit Error PRN3 (SVN69) Using L2C CNAV Data

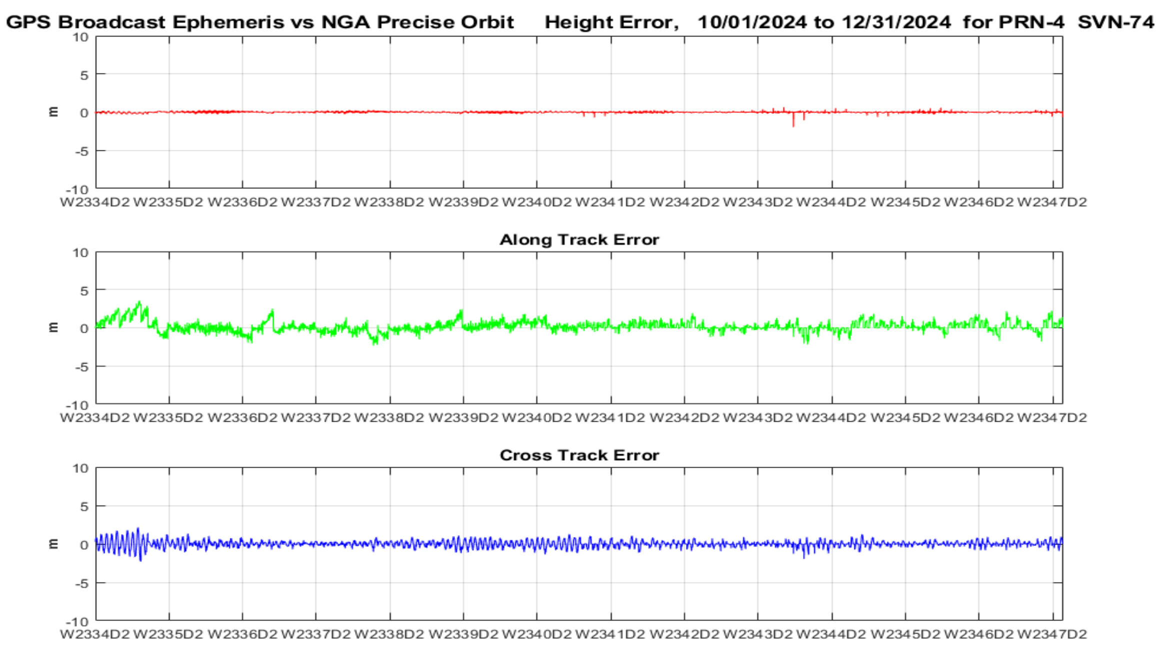


Figure 9-14 Orbit Error PRN4 (SVN74) Using C/A Nav Data

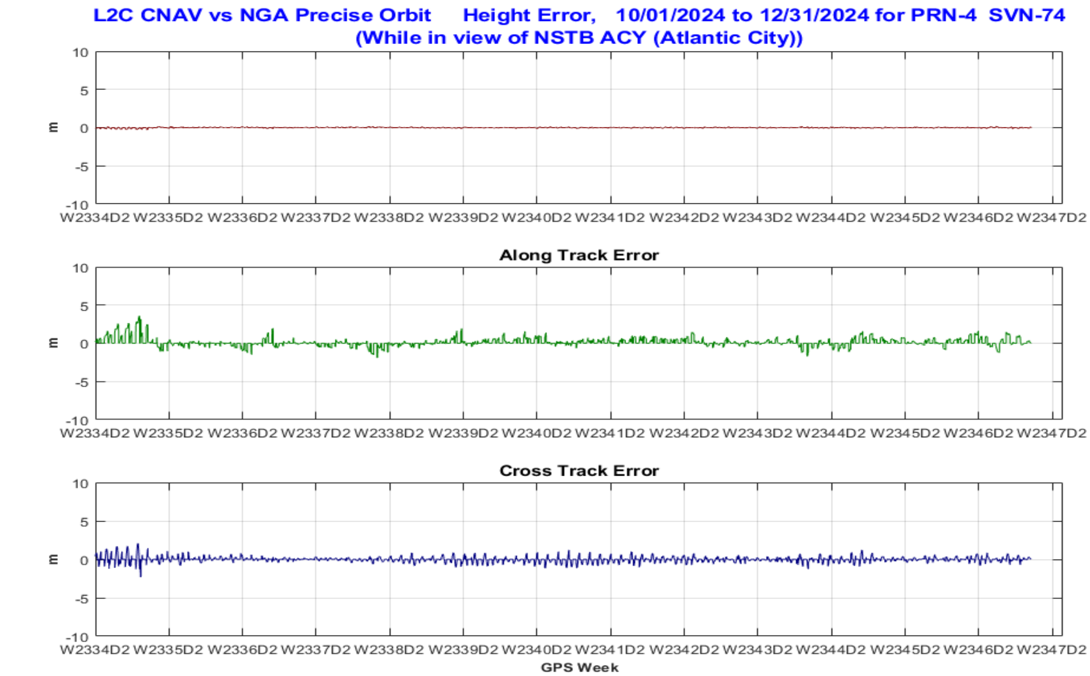


Figure 9-15 Orbit Error PRN4 (SVN74) Using L2C CNAV Data

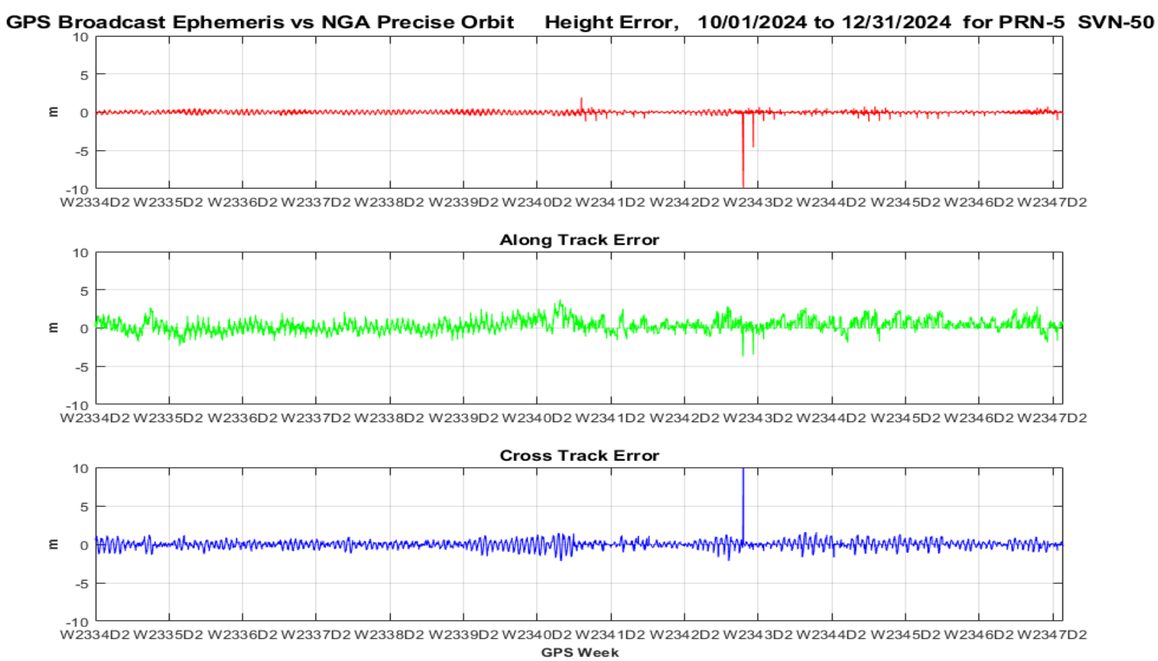


Figure 9-16 Orbit Error PRN5 (SVN50) Using C/A Nav Data

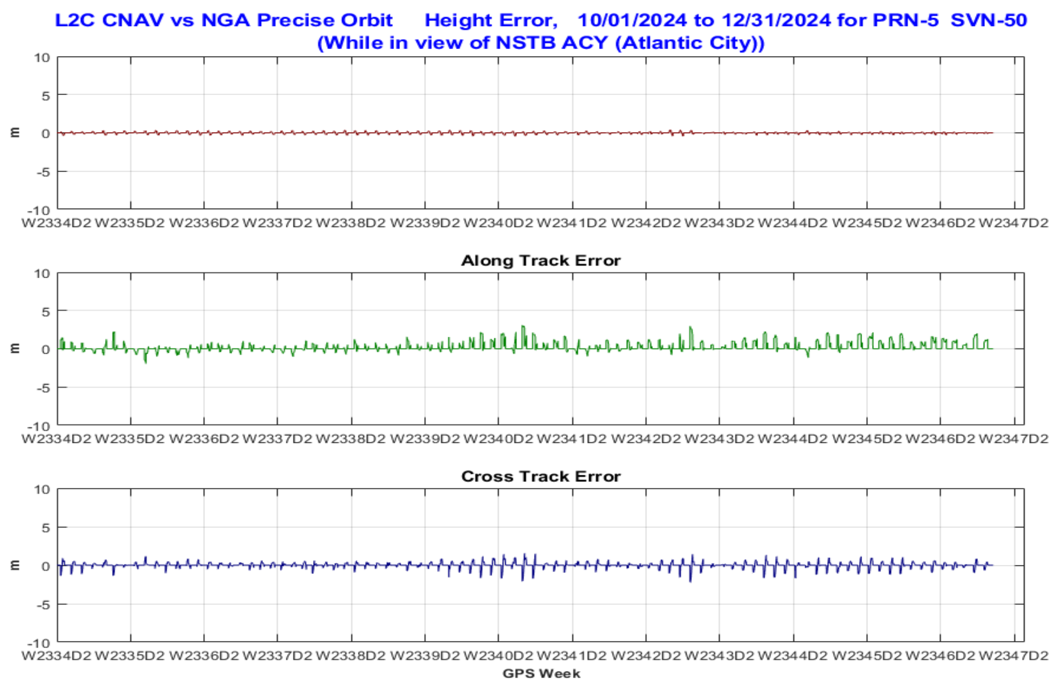


Figure 9-17 Orbit Error PRN5 (SVN50) Using L2C CNAV Data

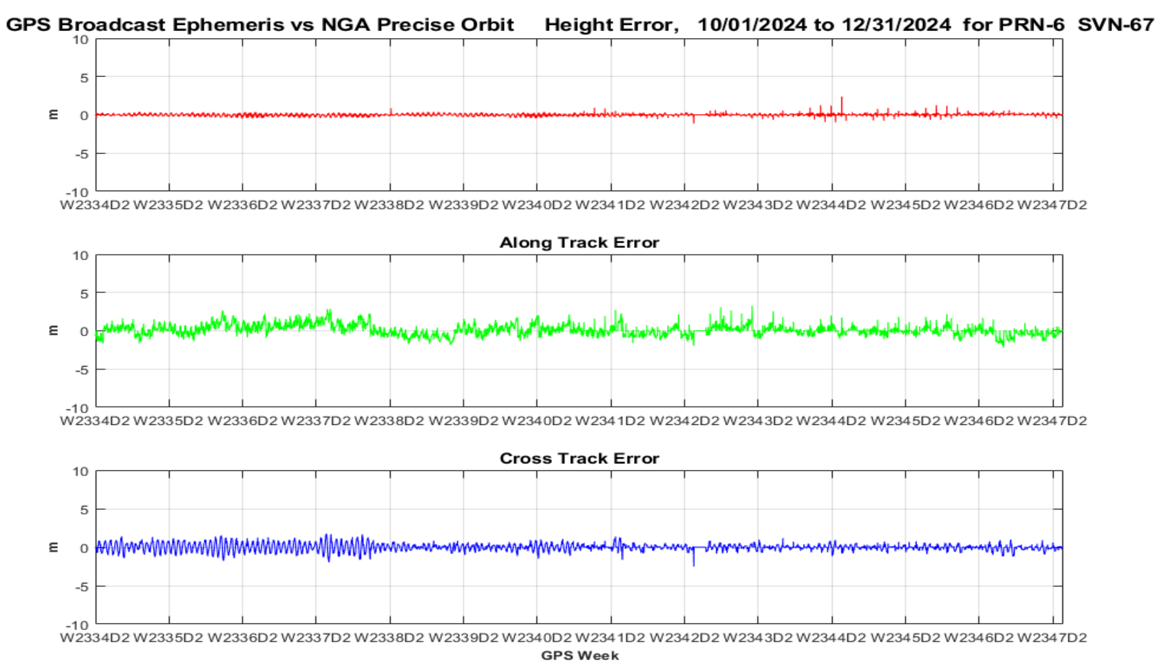


Figure 9-18 Orbit Error PRN6 (SVN67) Using C/A Nav Data

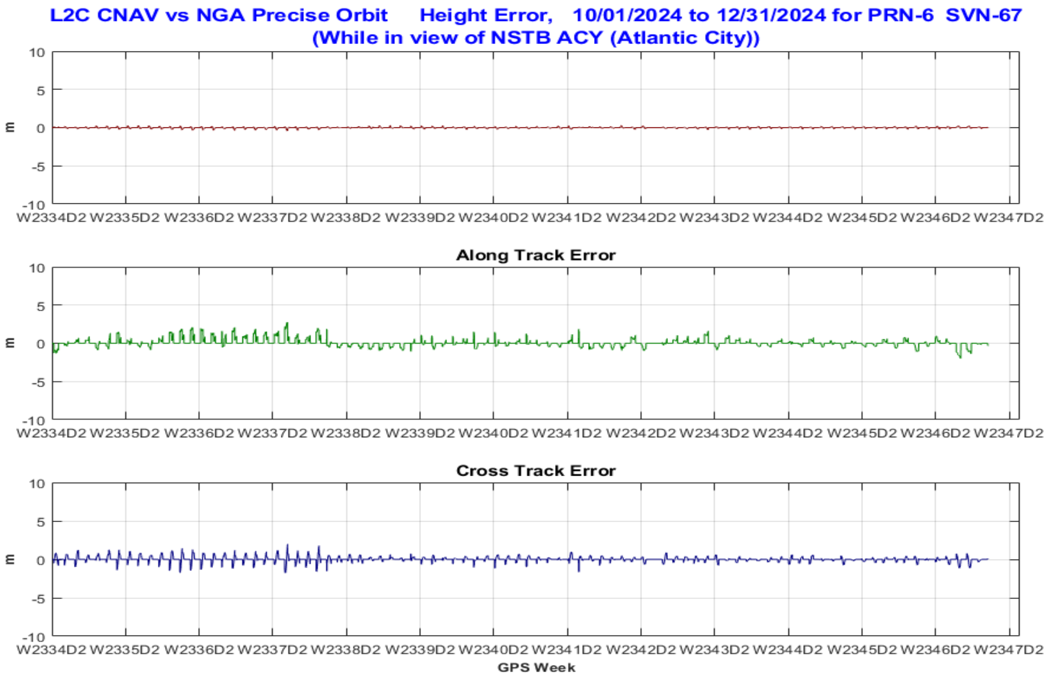


Figure 9-19 Orbit Error PRN6 (SVN67) Using L2C CNAV Data

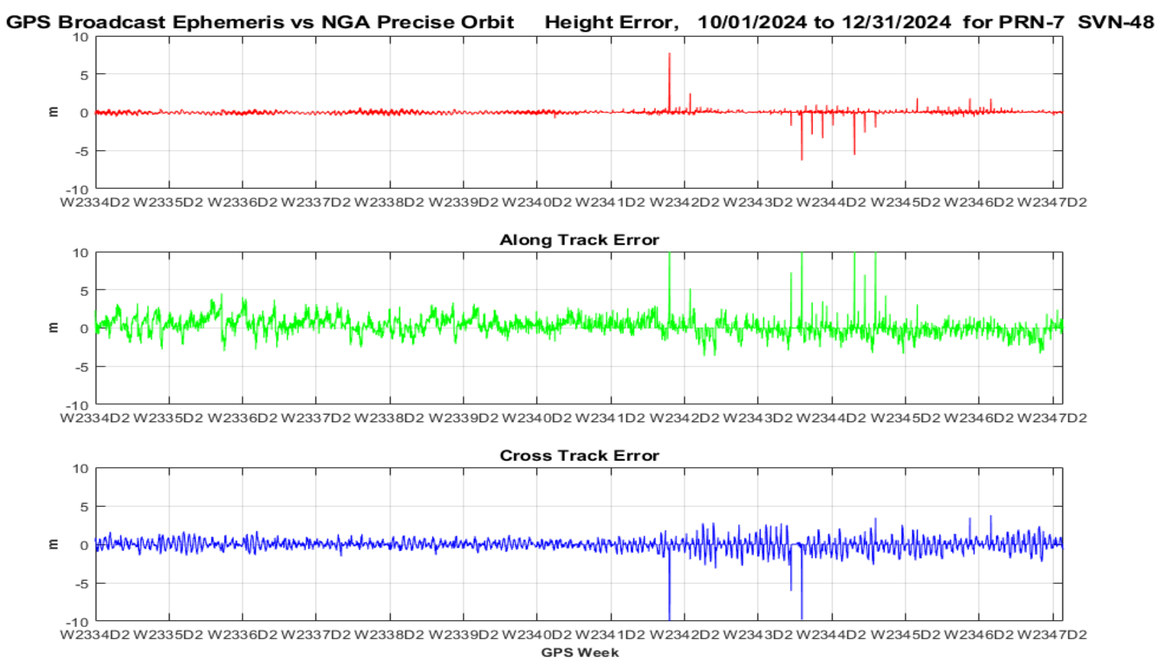


Figure 9-20 Orbit Error PRN7 (SVN48) Using C/A Nav Data

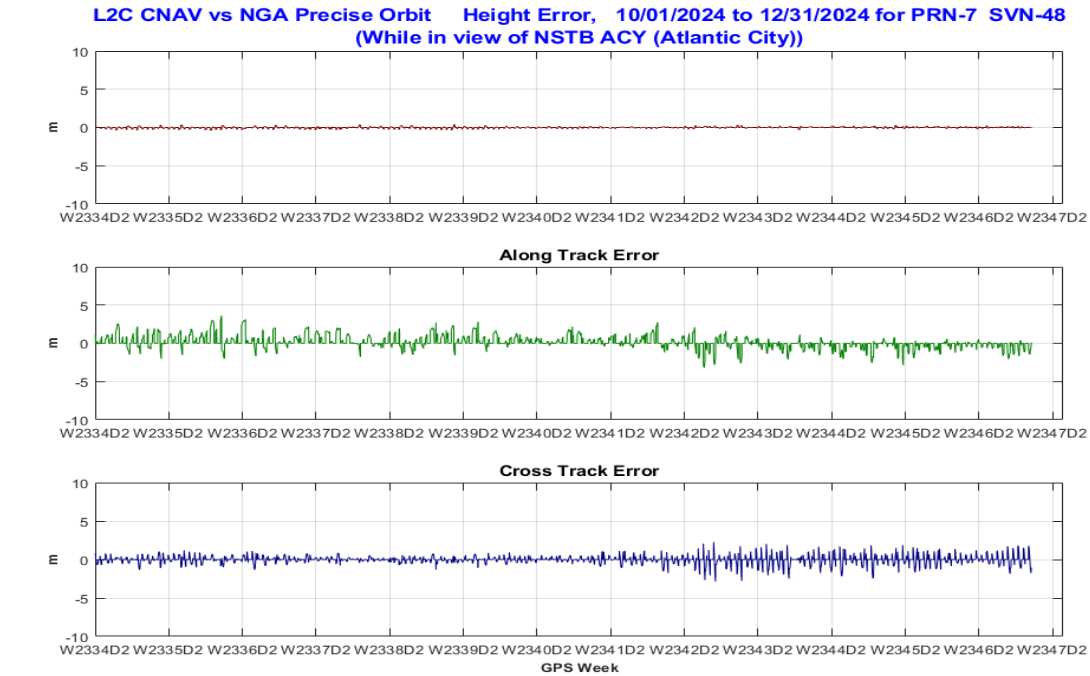


Figure 9-21 Orbit Error PRN7 (SVN48) Using L2C CNAV Data

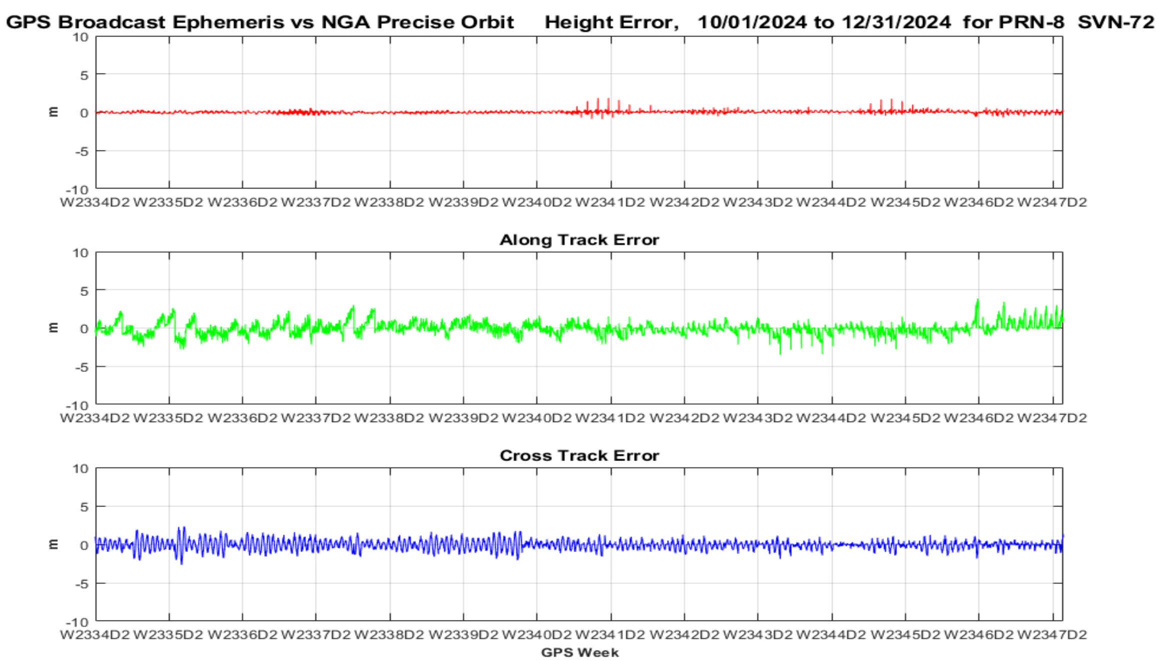


Figure 9-22 Orbit Error PRN8 (SVN72) Using C/A Nav Data

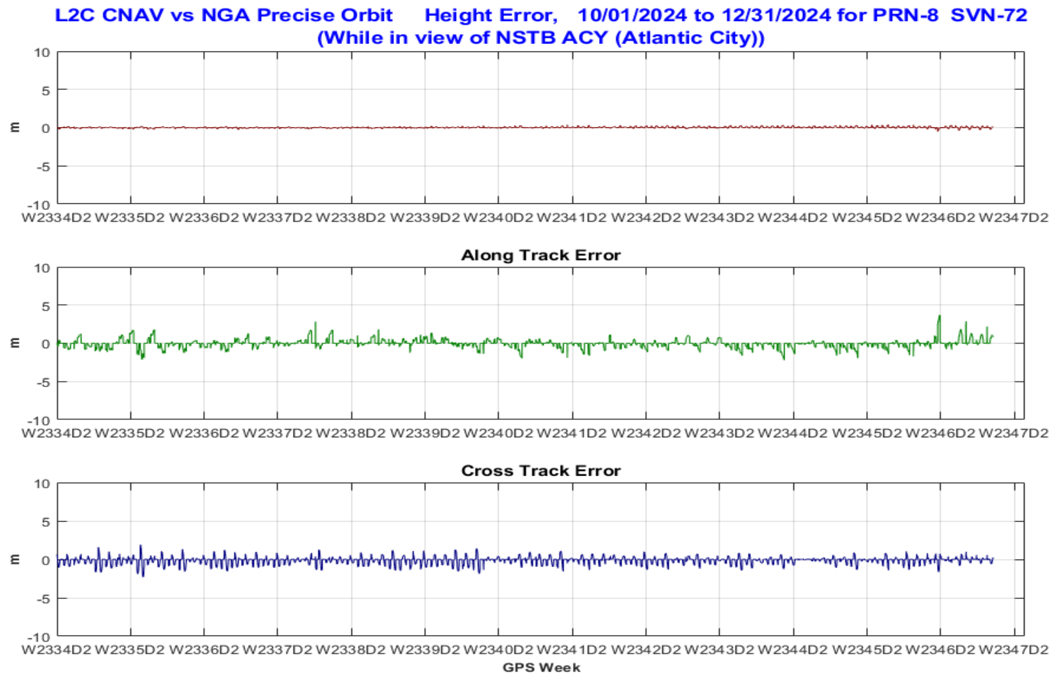


Figure 9-23 Orbit Error PRN8 (SVN72) Using L2C CNAV Data

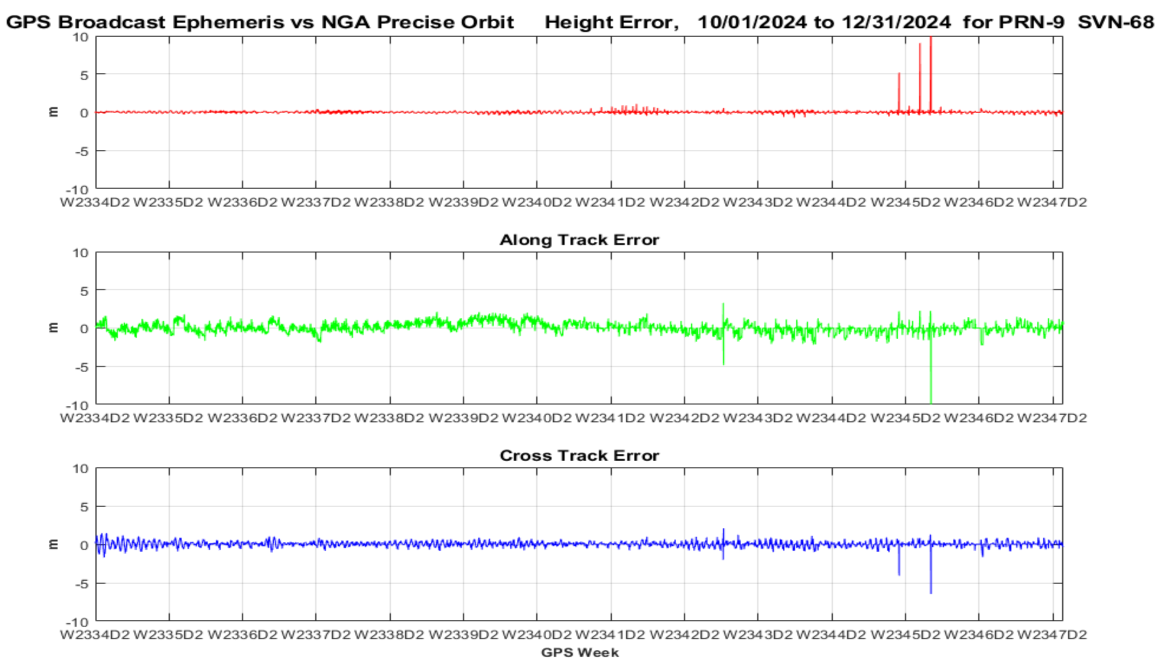


Figure 9-24 Orbit Error PRN9 (SVN68) Using C/A Nav Data

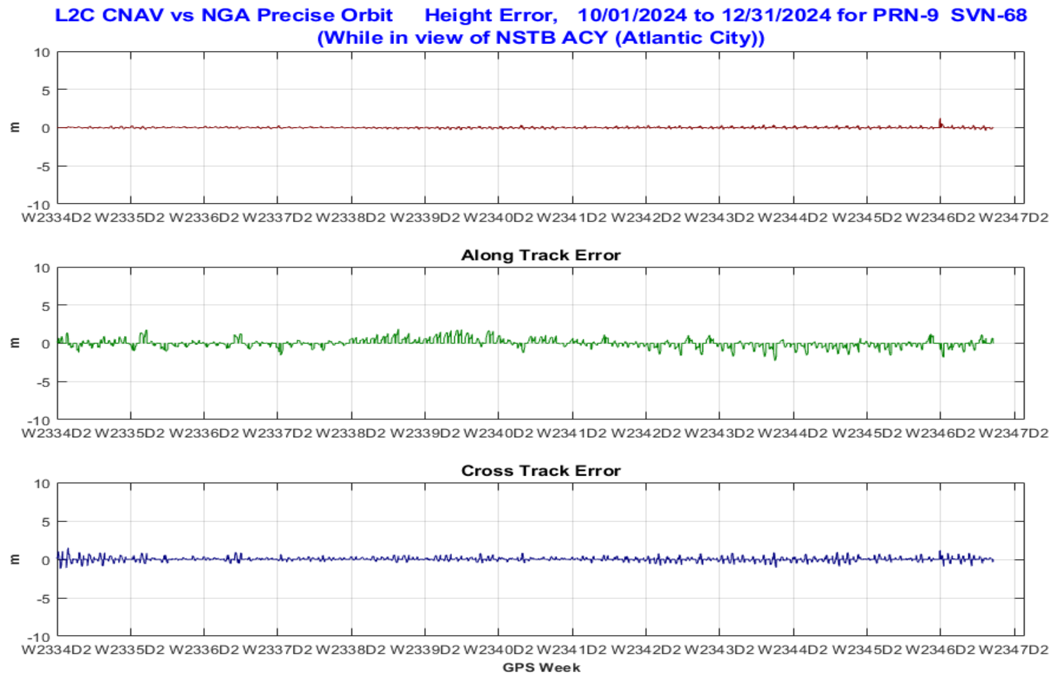


Figure 9-25 Orbit Error PRN9 (SVN68) Using L2C CNAV Data

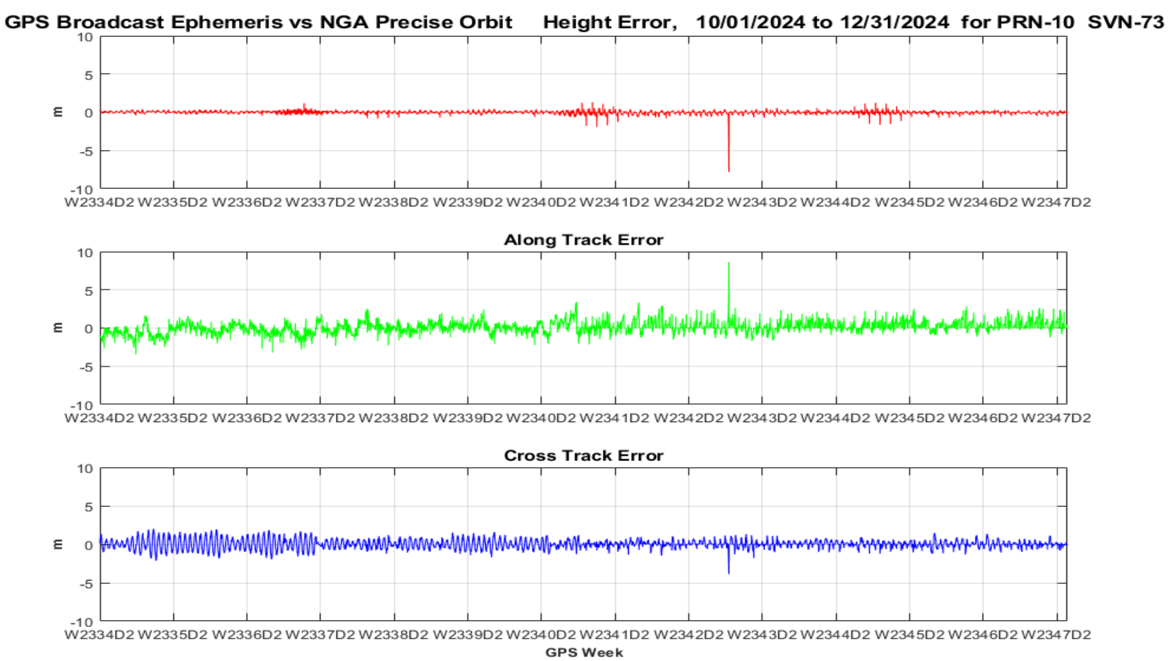


Figure 9-26 Orbit Error PRN10 (SVN73) Using C/A Nav Data

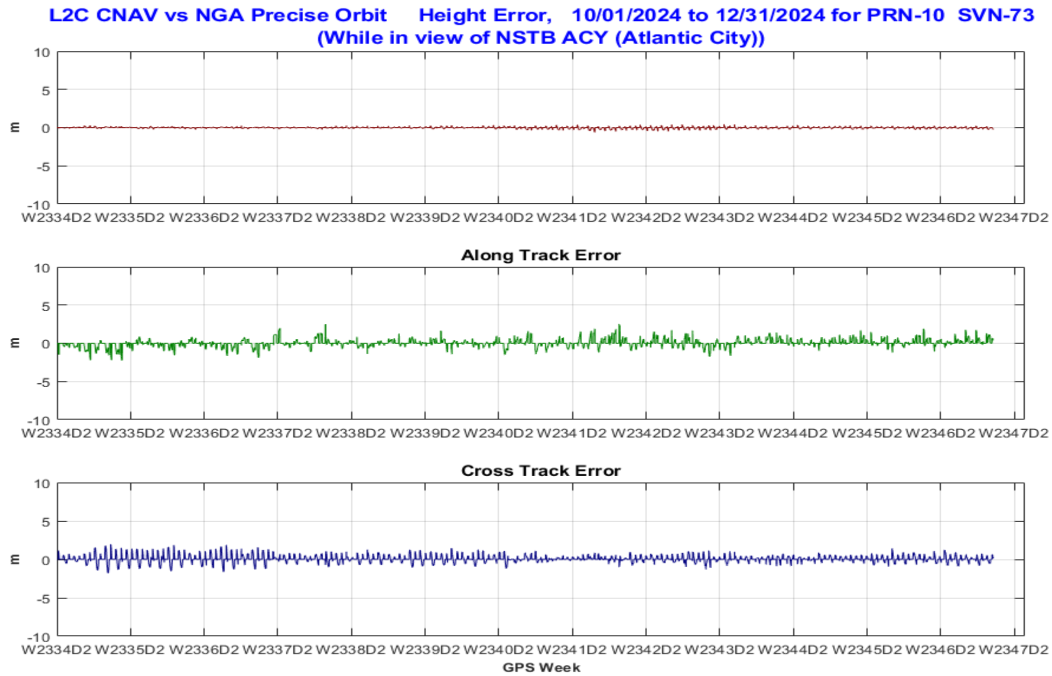


Figure 9-27 Orbit Error PRN10 (SVN73) Using L2C CNAV Data

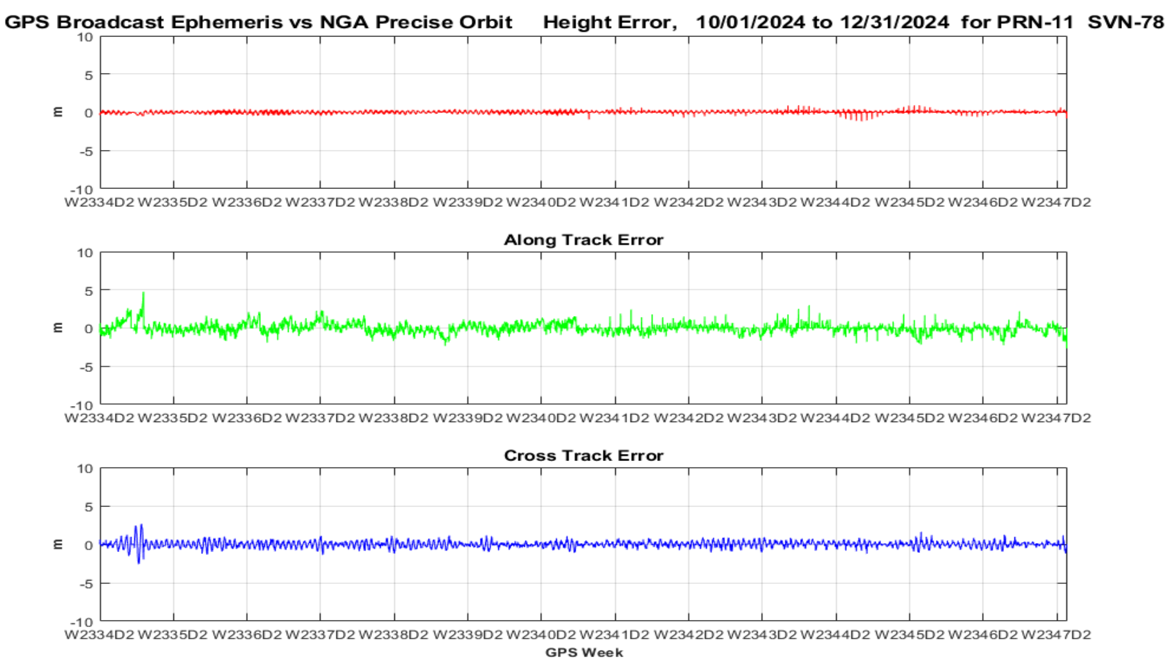


Figure 9-28 Orbit Error PRN11 (SVN78) Using C/A Nav Data

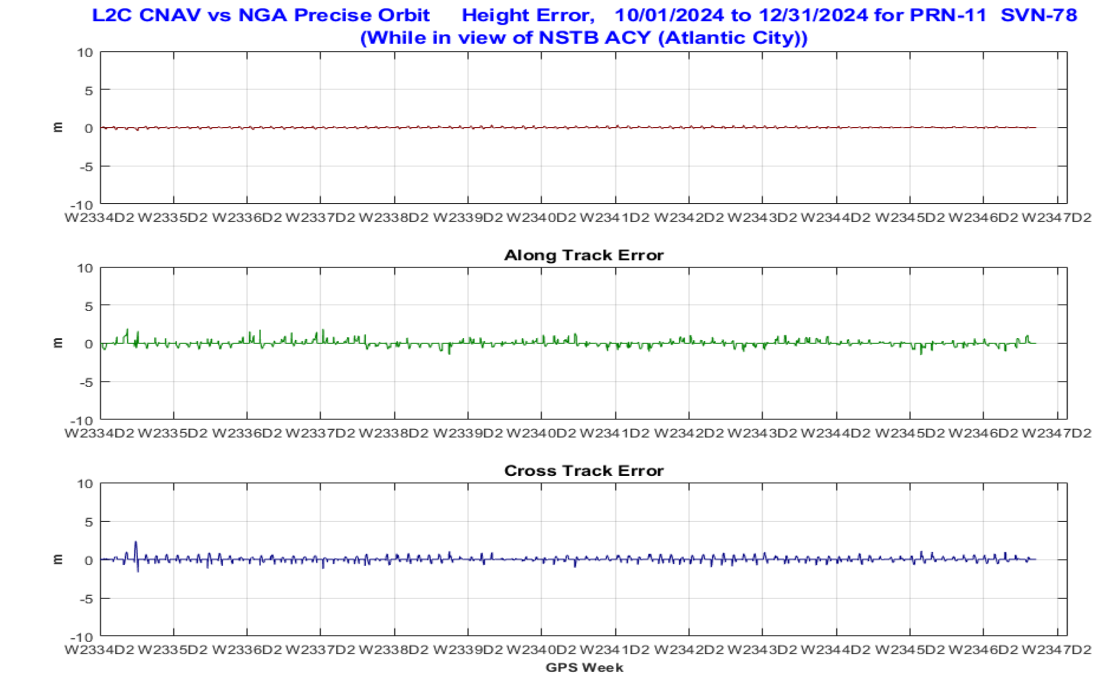


Figure 9-29 Orbit Error PRN11 (SVN78) Using L2C CNAV Data

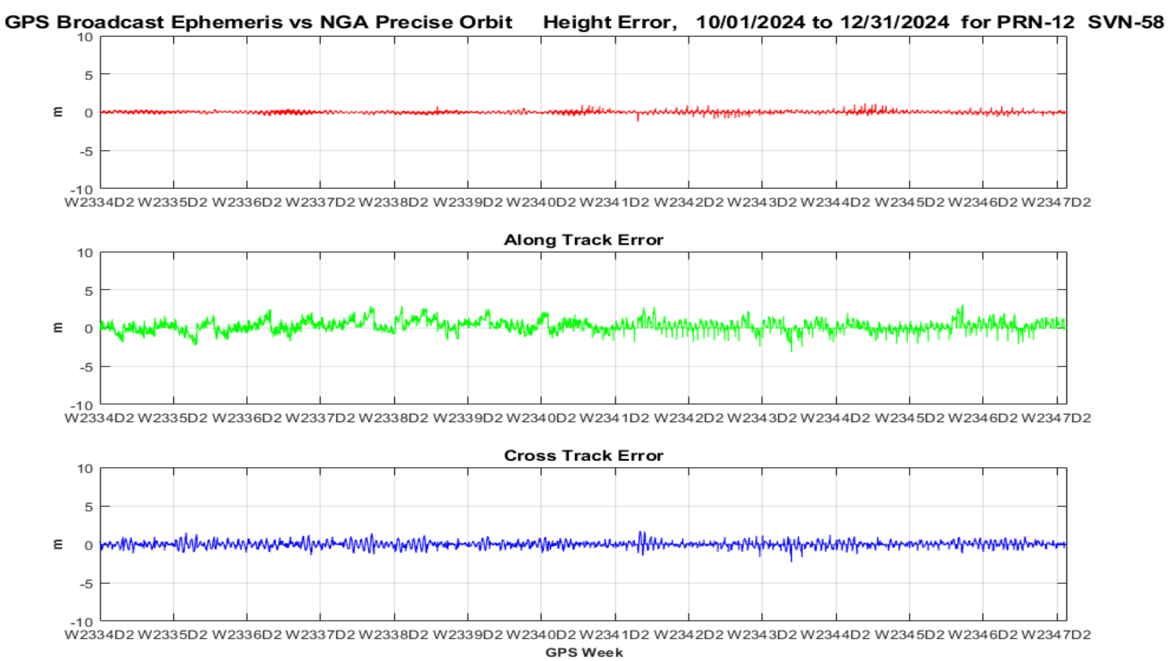


Figure 9-30 Orbit Error PRN12 (SVN58) Using C/A Nav Data

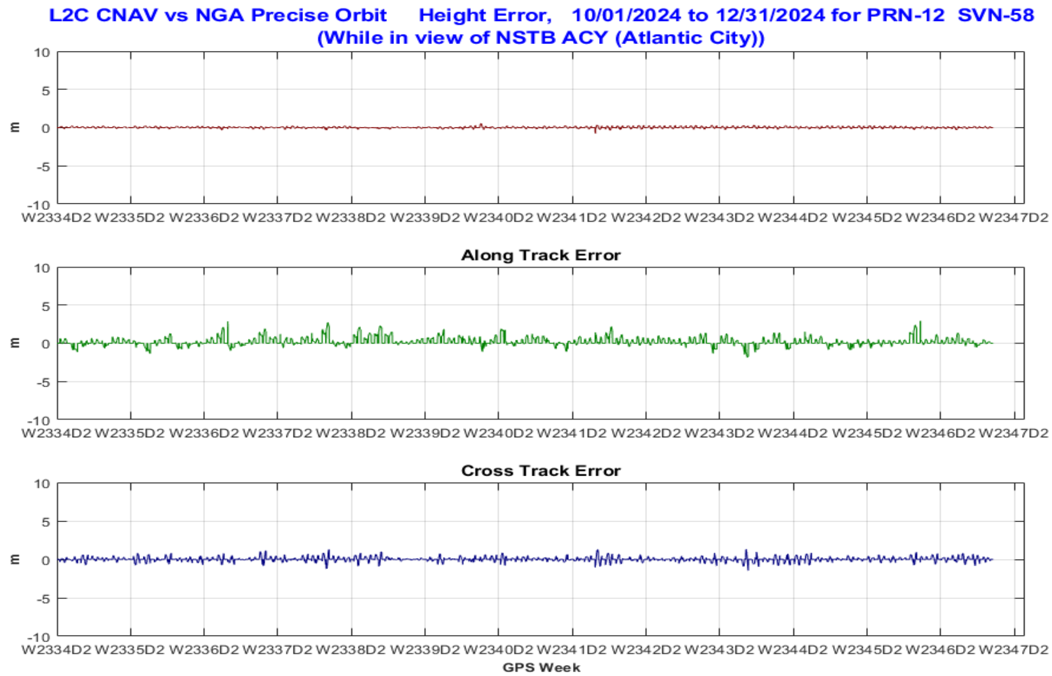


Figure 9-31 Orbit Error PRN12 (SVN58) Using L2C CNAV Data

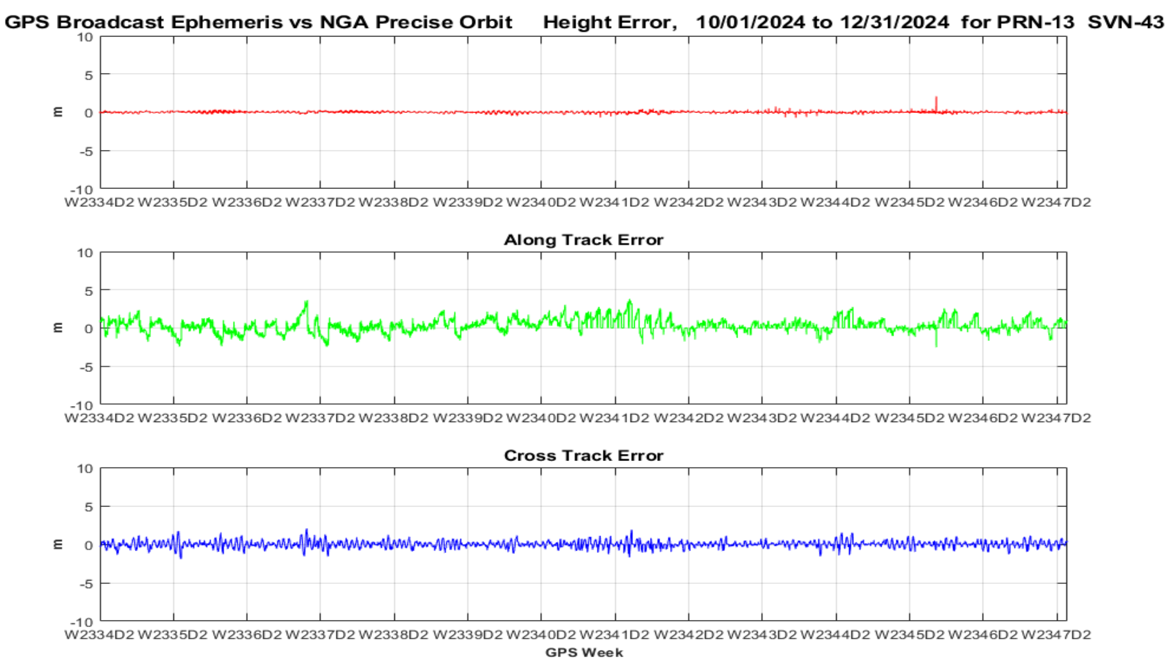


Figure 9-32 Orbit Error PRN13 (SVN43) Using C/A Nav Data

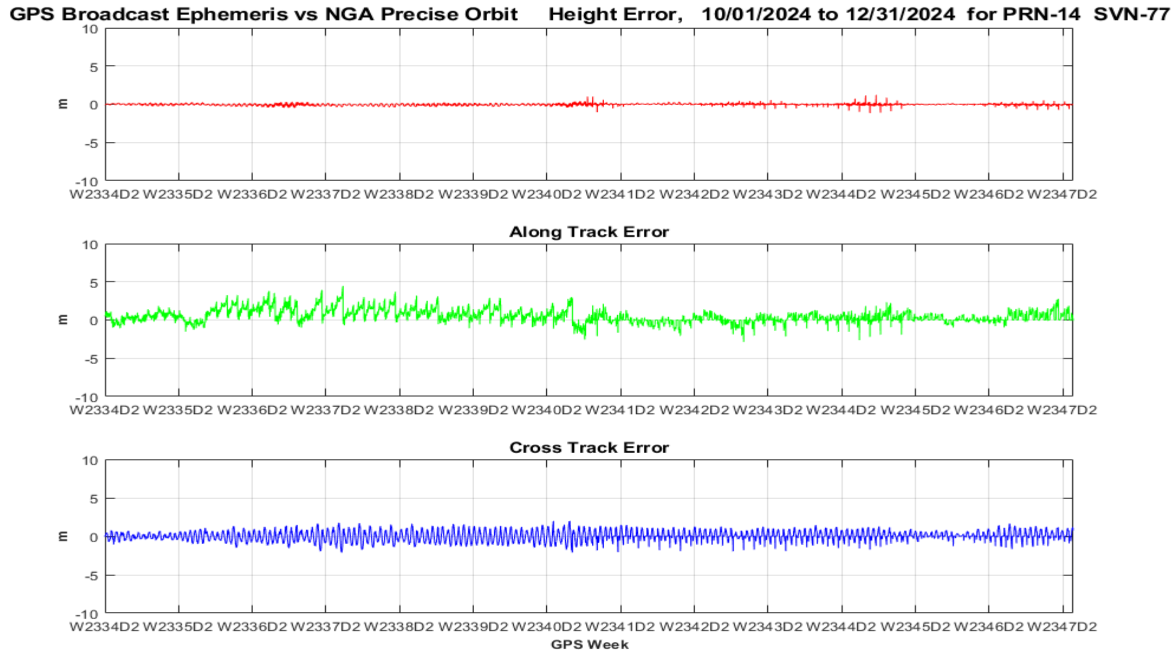


Figure 9-33 Orbit Error PRN14 (SVN77) Using C/A Nav Data

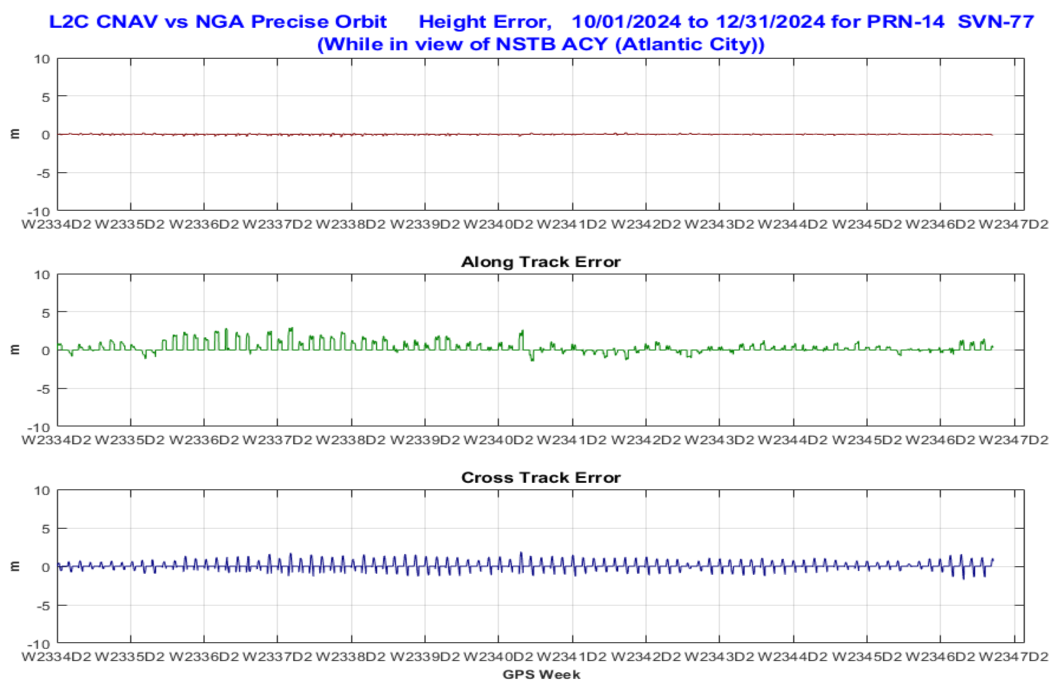


Figure 9-34 Orbit Error PRN14 (SVN77) Using L2C CNAV Data

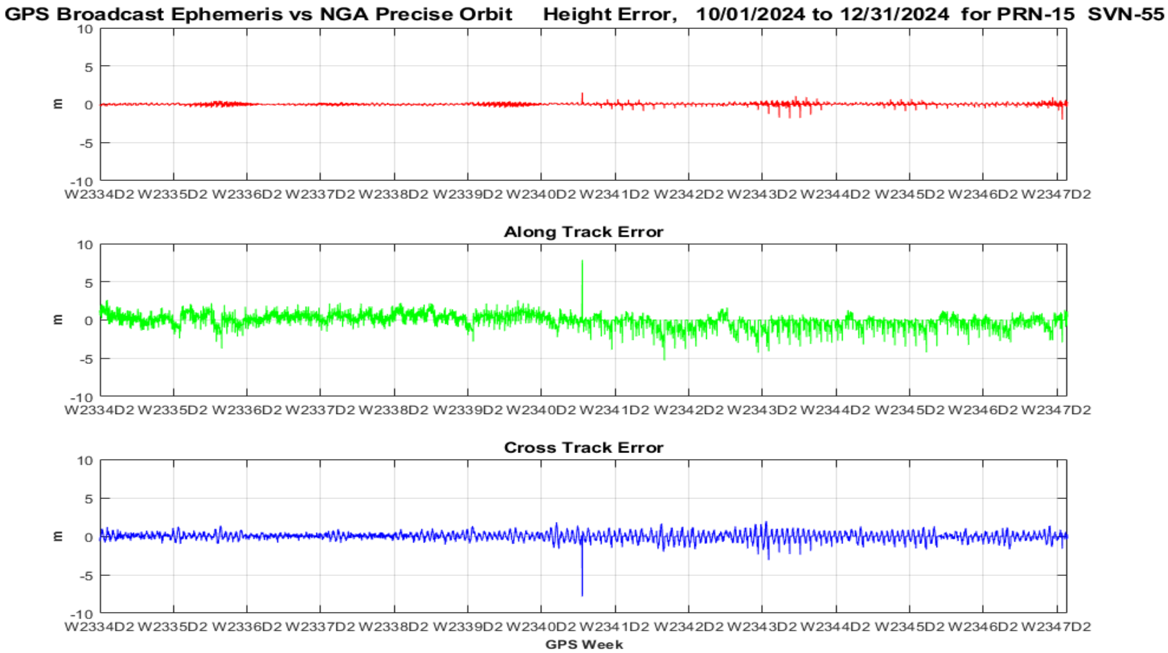


Figure 9-35 Orbit Error PRN15 (SVN55) Using C/A Nav Data

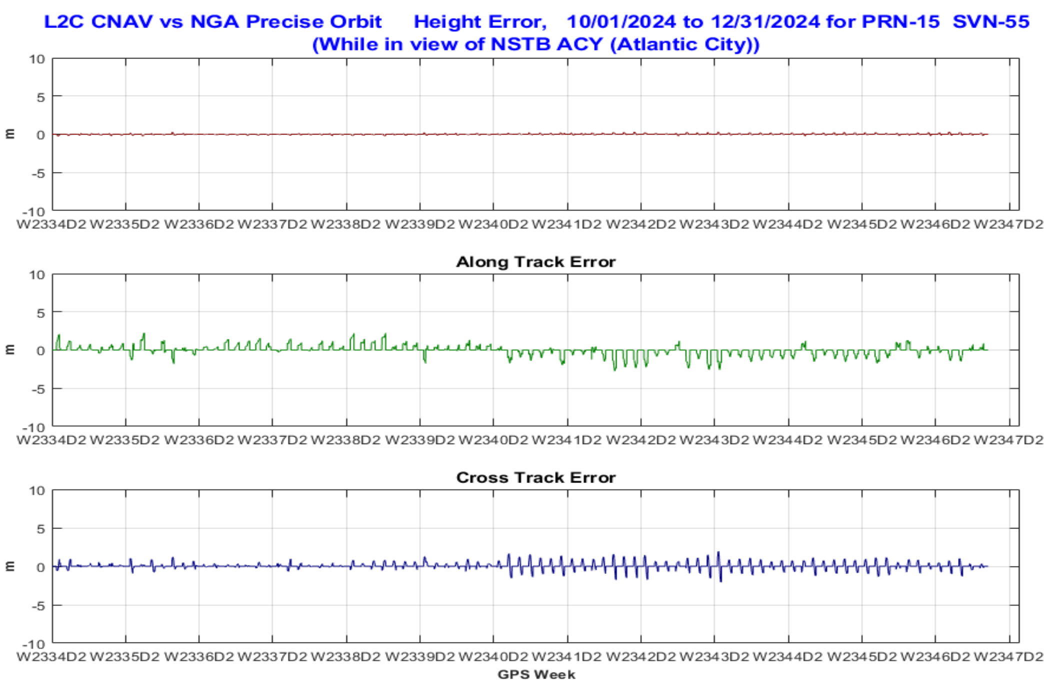


Figure 9-36 Orbit Error PRN15 (SVN55) Using L2C CNAV Data

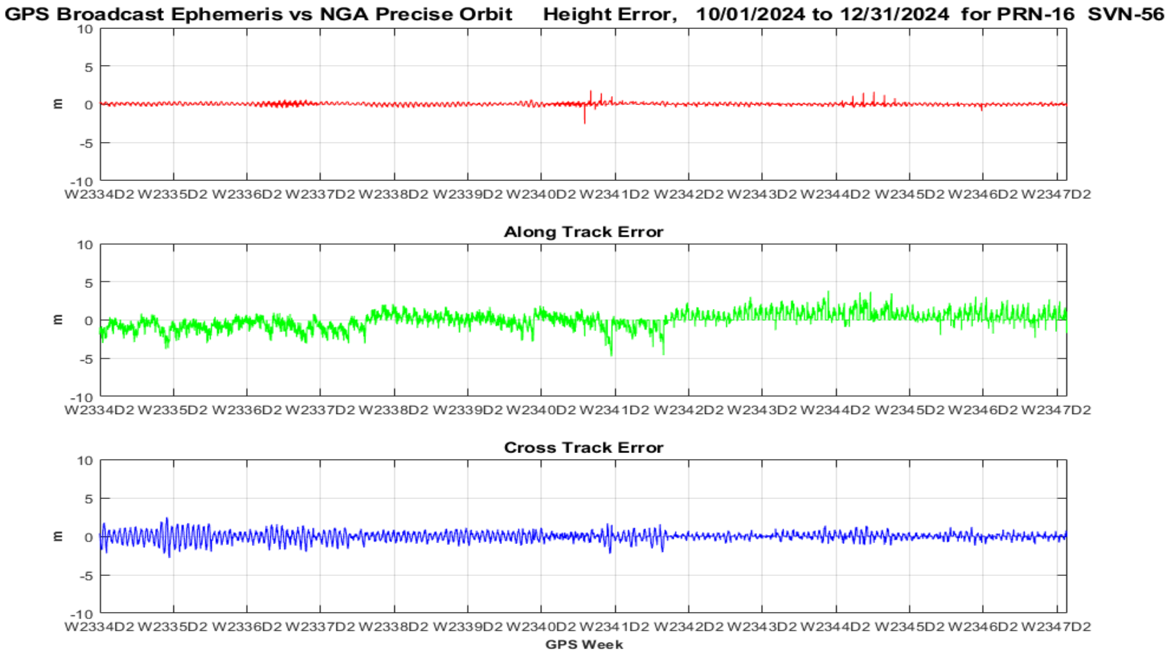


Figure 9-37 Orbit Error PRN16 (SVN56) Using C/A Nav Data

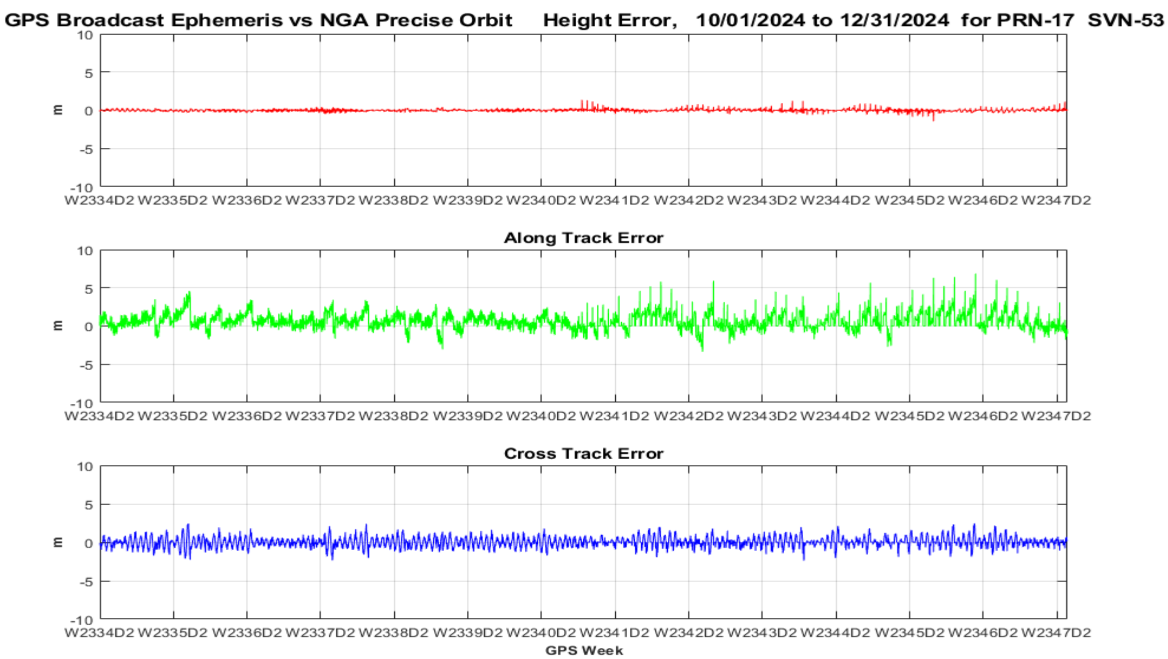


Figure 9-38 Orbit Error PRN17 (SVN53) Using C/A Nav Data

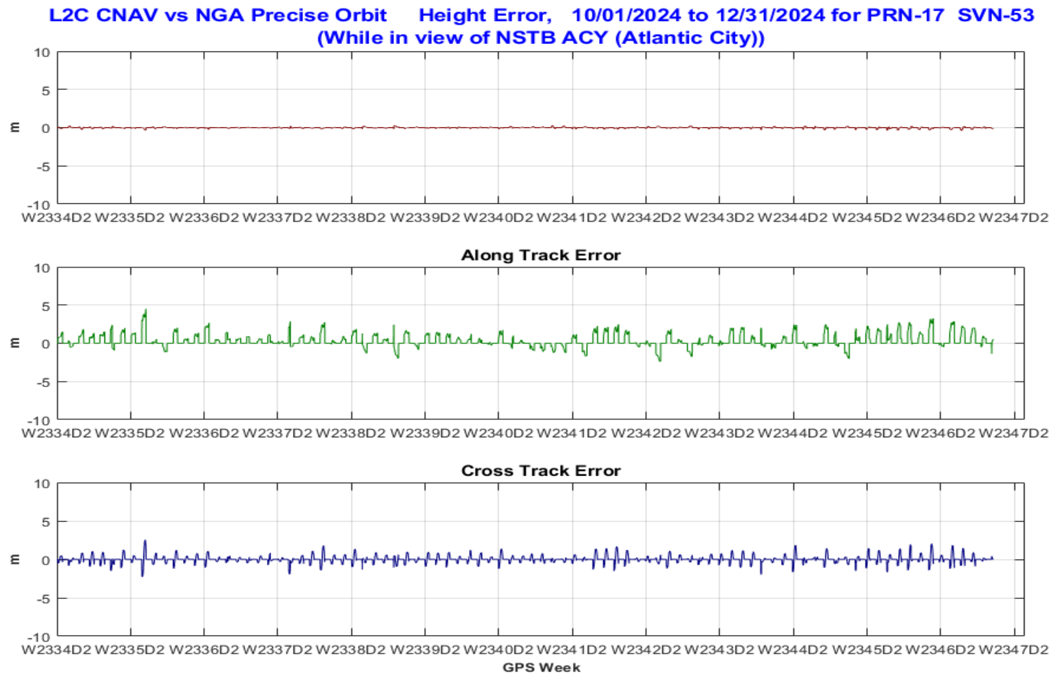


Figure 9-39 Orbit Error PRN17 (SVN53) Using L2C CNAV Data

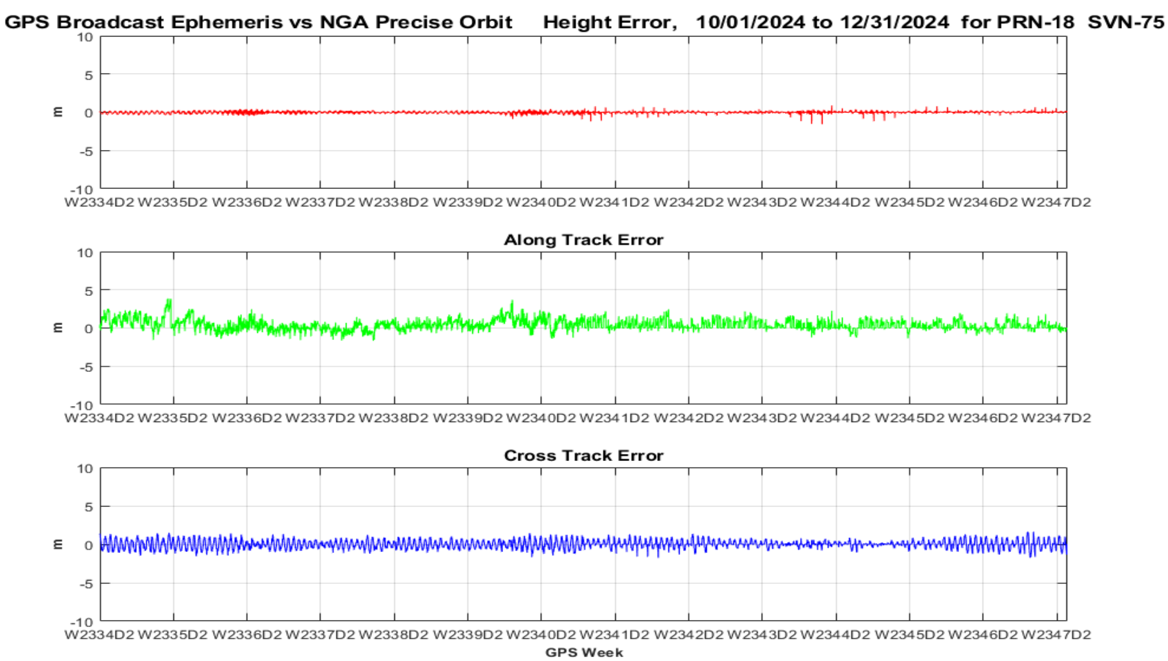


Figure 9-40 Orbit Error PRN18 (SVN75) Using C/A Nav Data

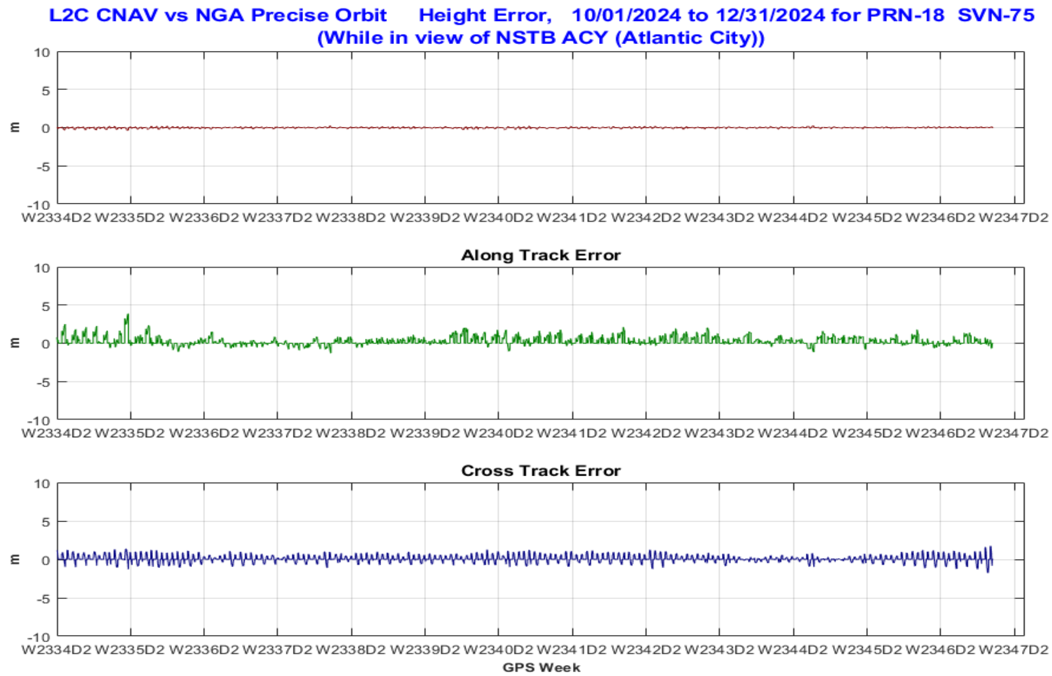


Figure 9-41 Orbit Error PRN18 (SVN75) Using L2C CNAV Data

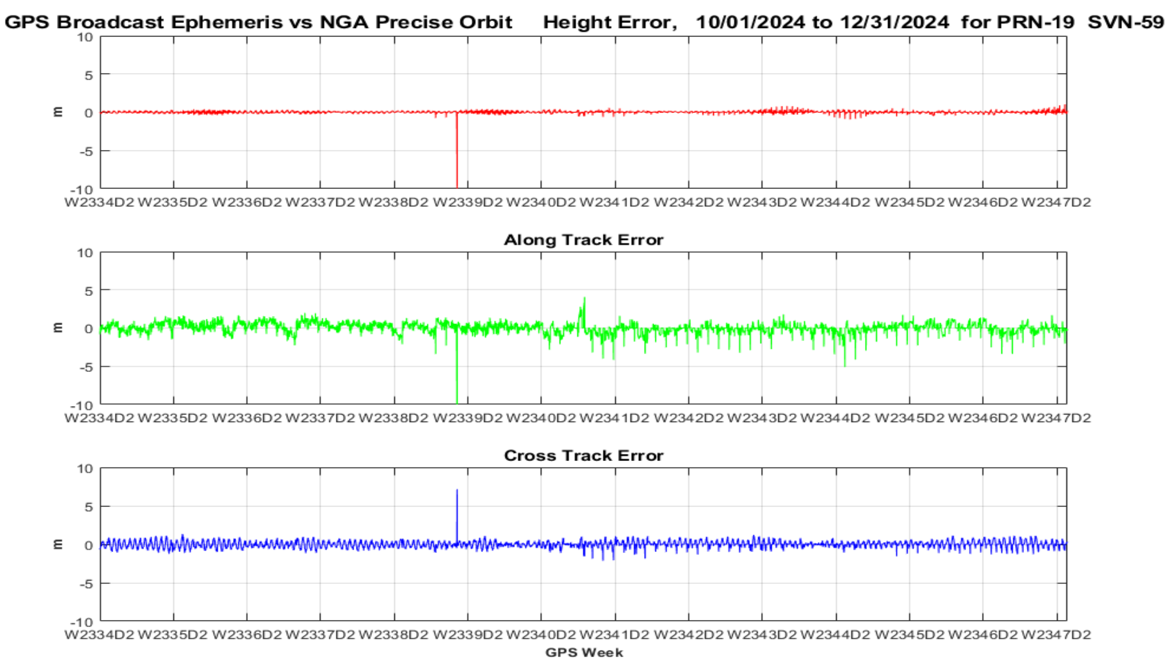


Figure 9-42 Orbit Error PRN19 (SVN59) Using C/A Nav Data

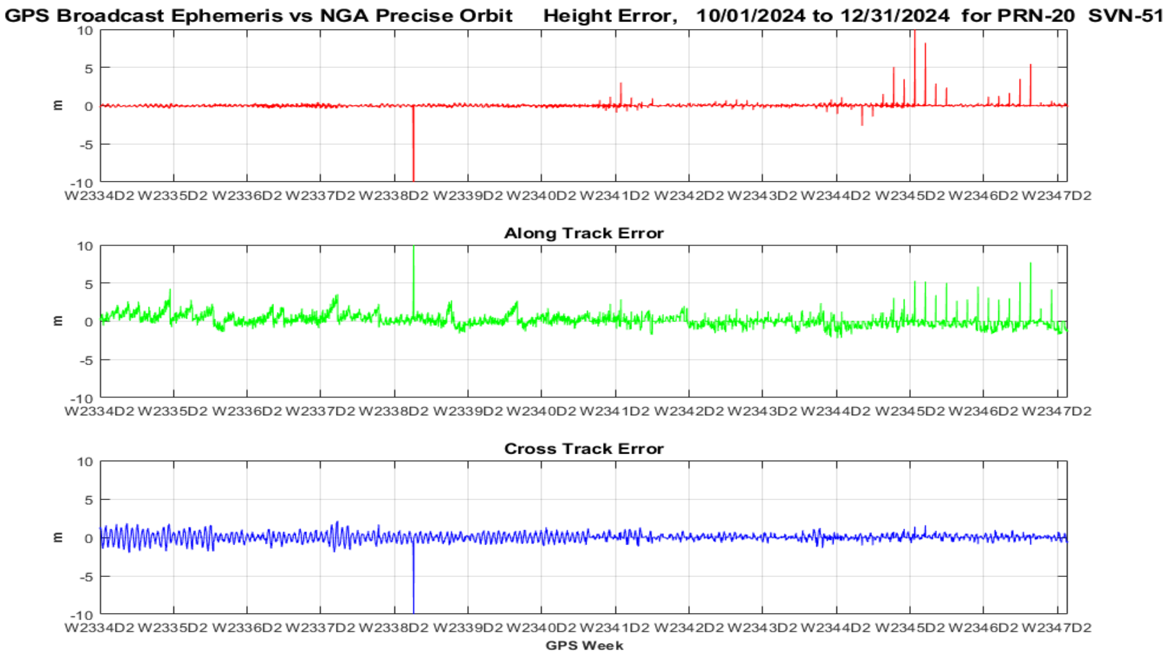


Figure 9-43 Orbit Error PRN20 (SVN51) Using C/A Nav Data

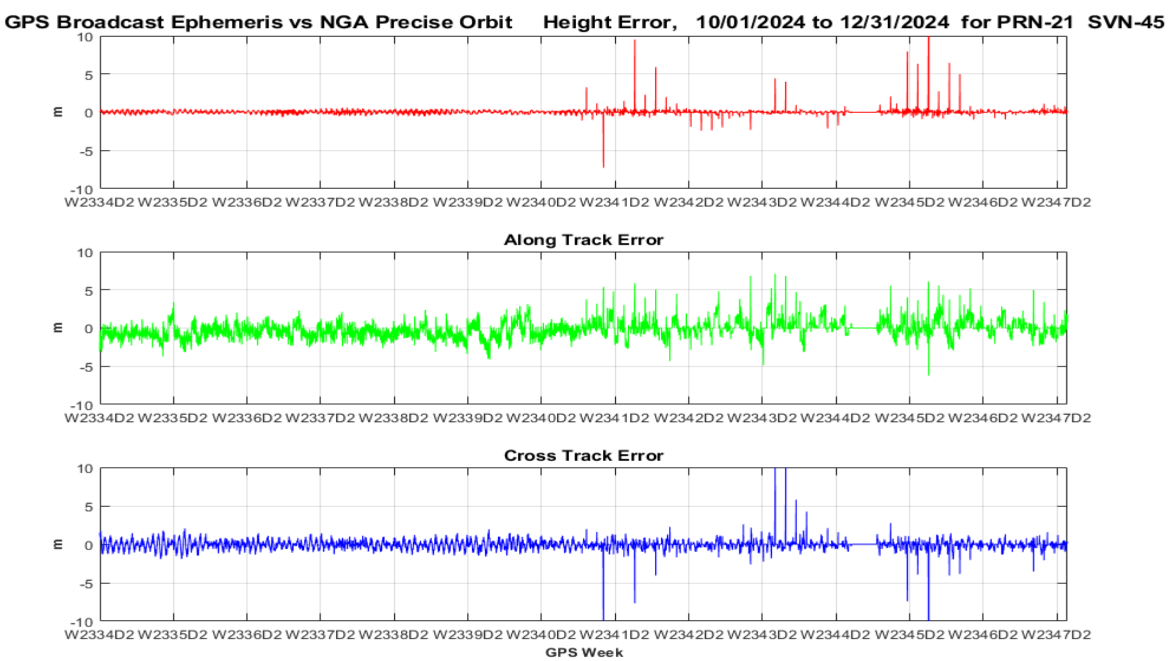


Figure 9-44 Orbit Error PRN21 (SVN45) Using C/A Nav Data

Figure 9-45 Orbit Error PRN22 (SVN44) Using C/A Nav Data

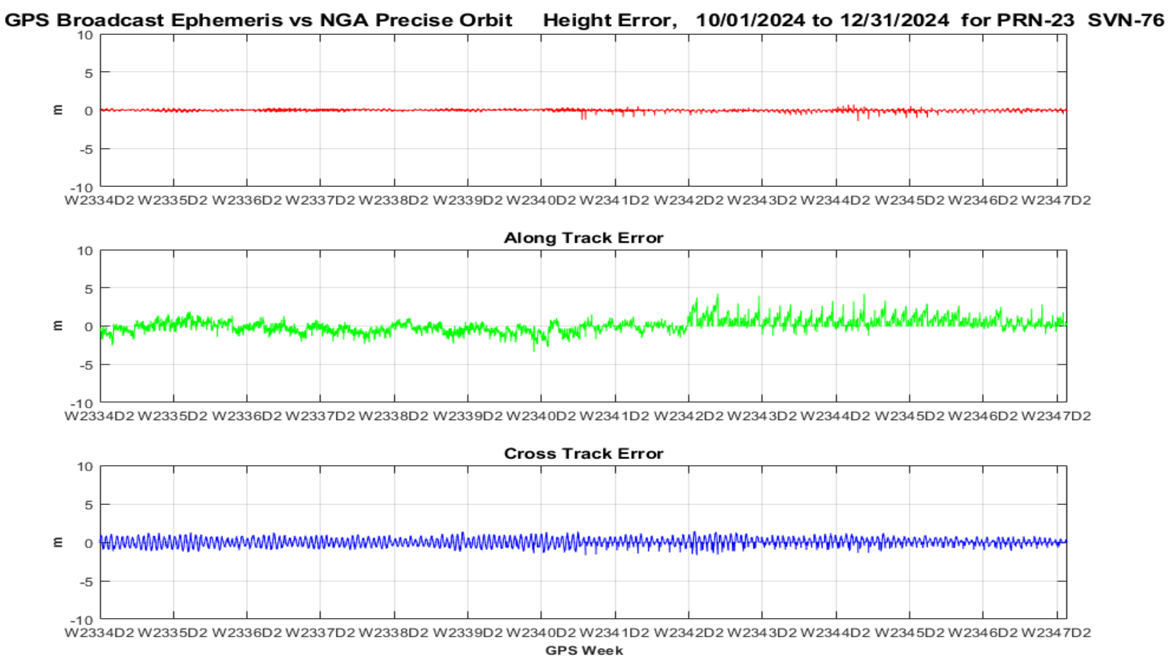


Figure 9-46 Orbit Error PRN23 (SVN76) Using C/A Nav Data

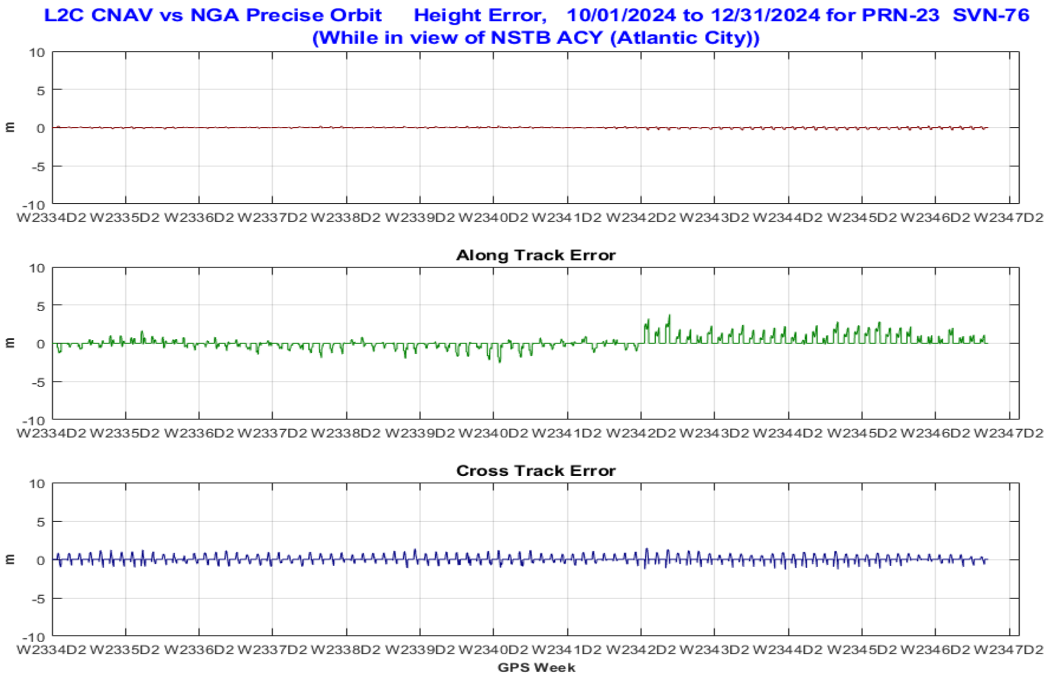


Figure 9-47 Orbit Error PRN23 (SVN76) Using L2C CNAV Data

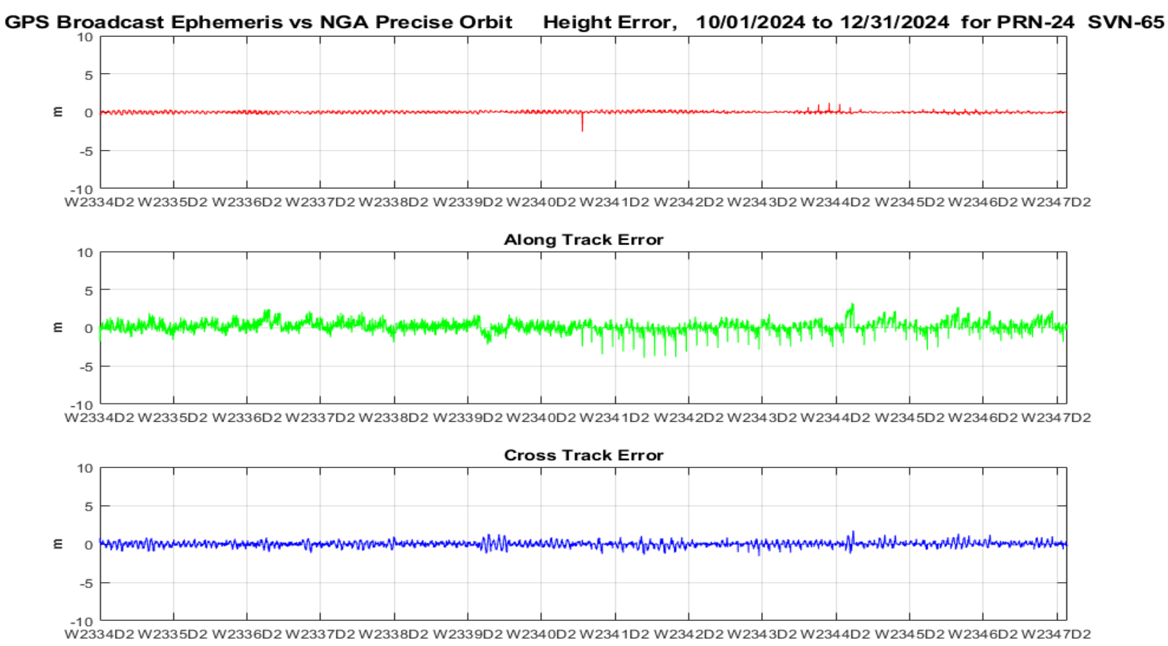


Figure 9-48 Orbit Error PRN24 (SVN65) Using C/A Nav Data

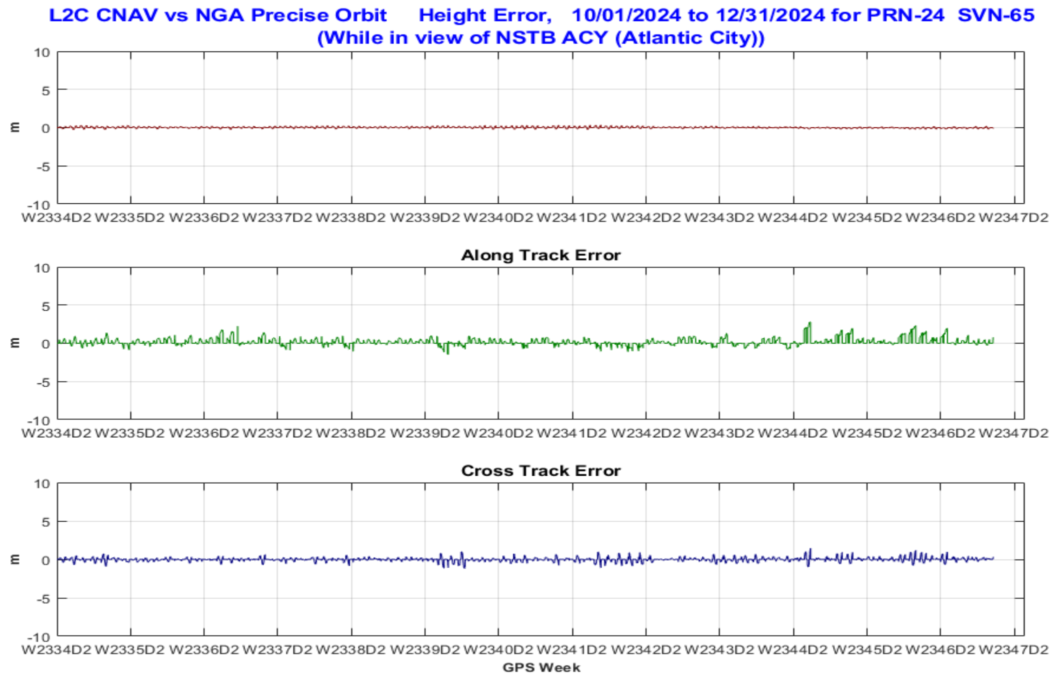


Figure 9-49 Orbit Error PRN24 (SVN65) Using L2C CNAV Data

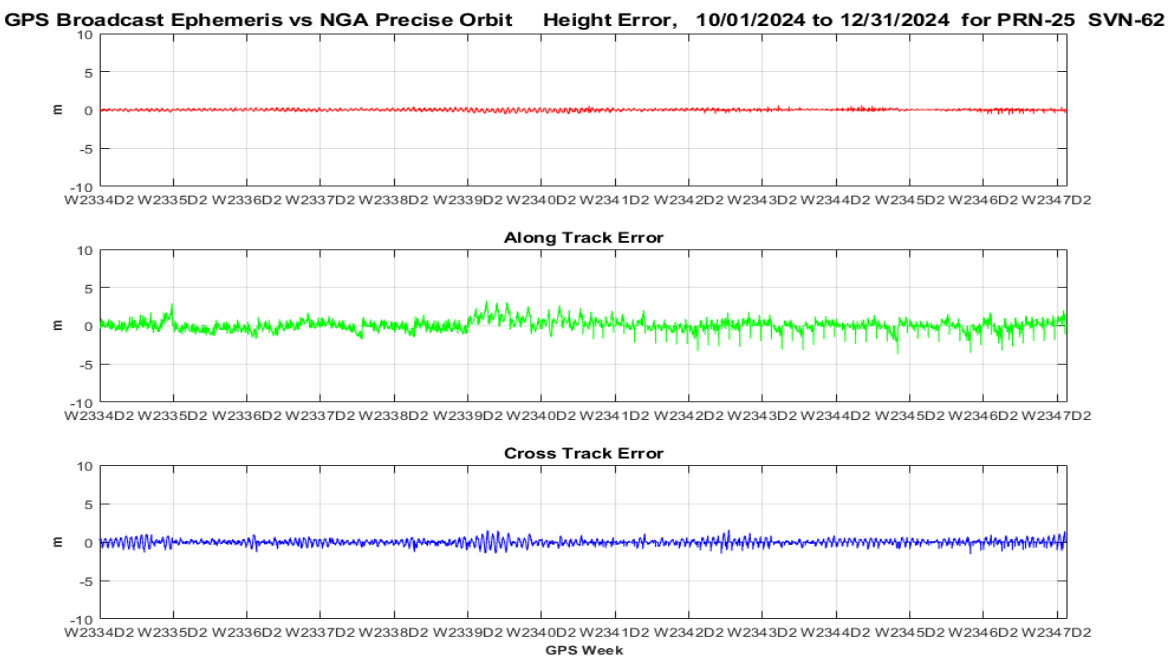


Figure 9-50 Orbit Error PRN25 (SVN62) Using C/A Nav Data

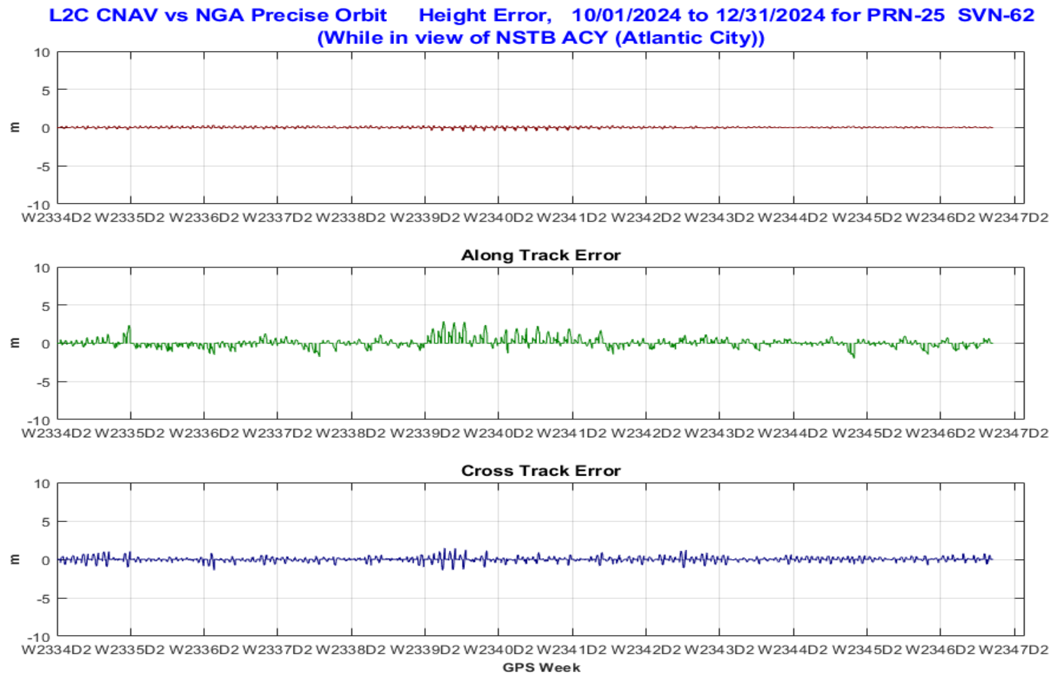


Figure 9-51 Orbit Error PRN25 (SVN62) Using L2C CNAV Data

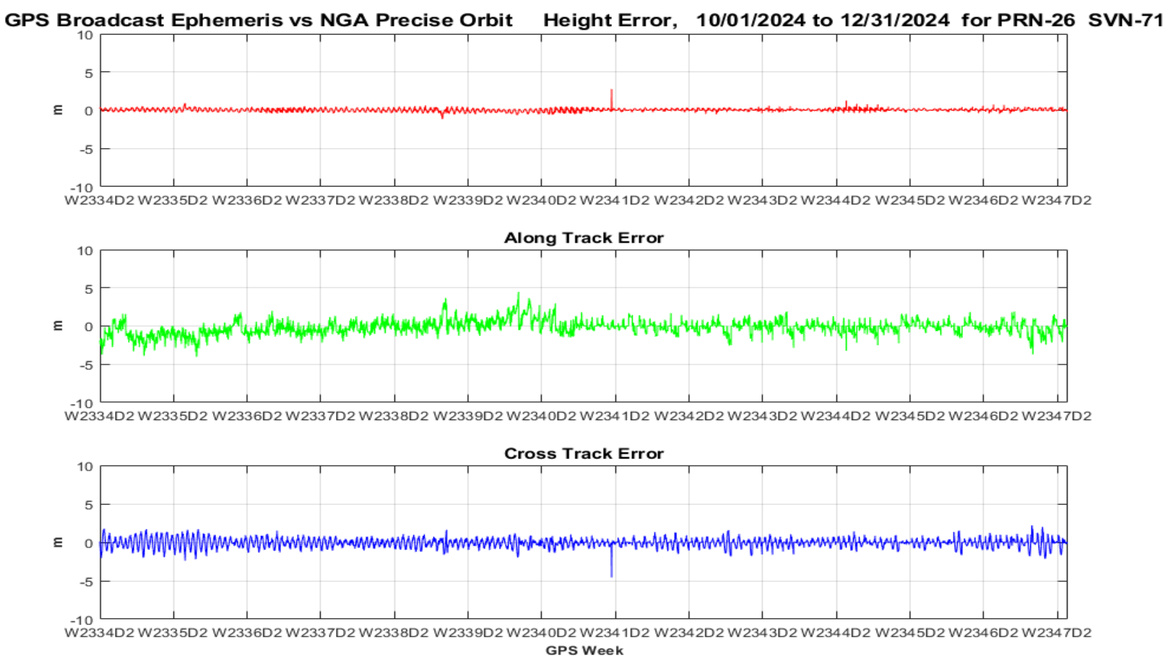


Figure 9-52 Orbit Error PRN26 (SVN71) Using C/A Nav Data

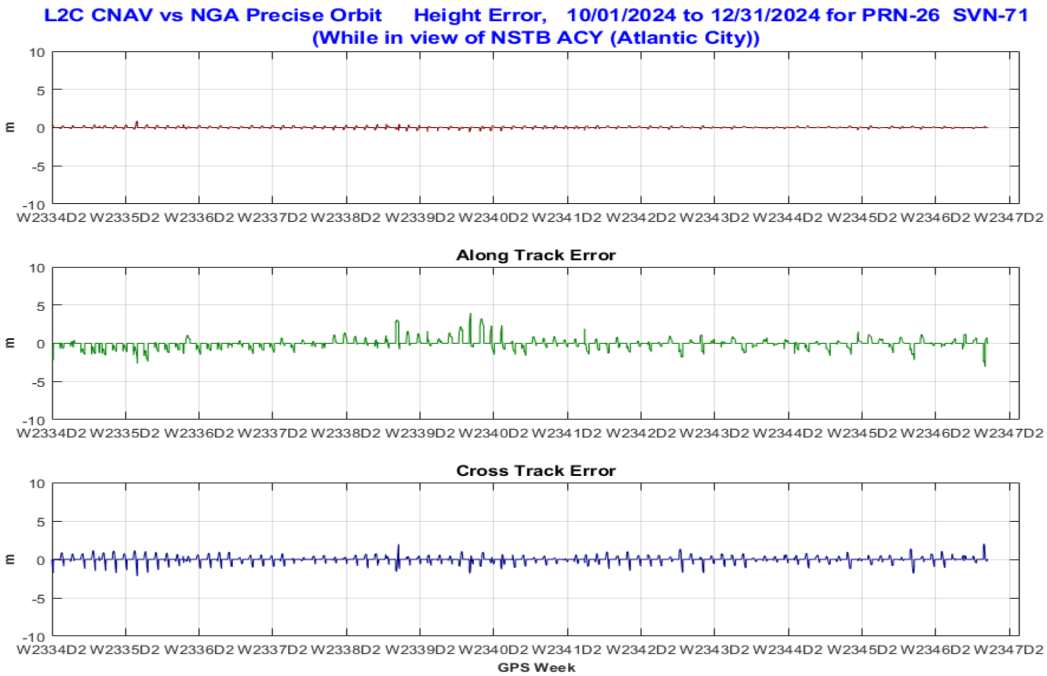


Figure 9-53 Orbit Error PRN26 (SVN71) Using L2C CNAV Data

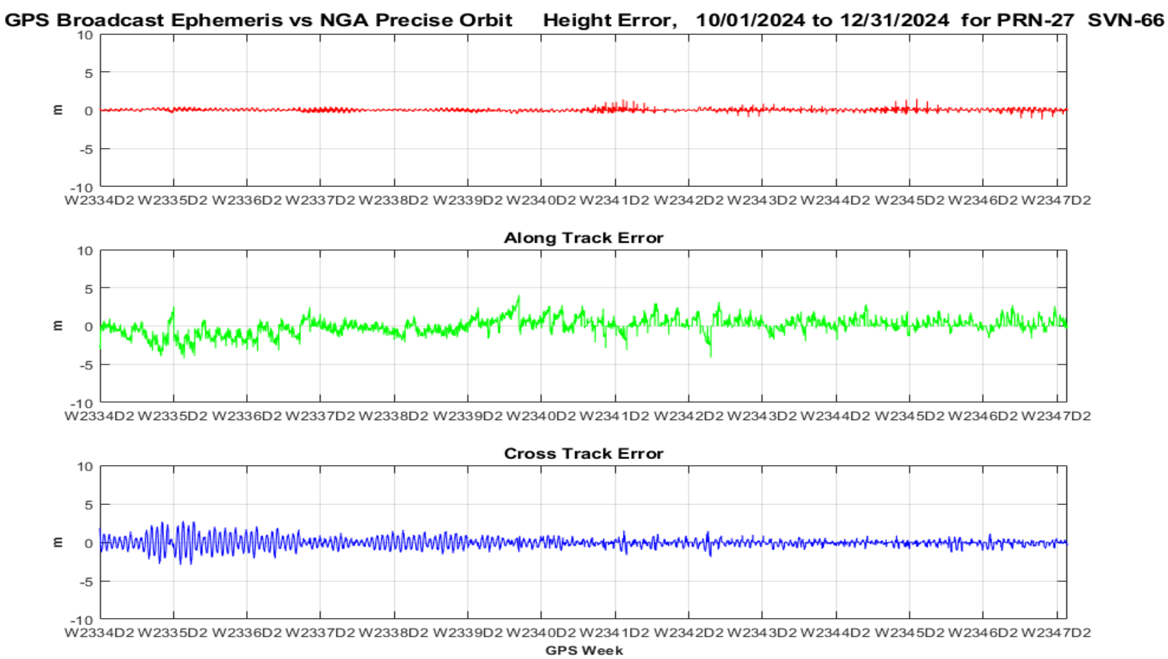


Figure 9-54 Orbit Error PRN27 (SVN66) Using C/A Nav Data

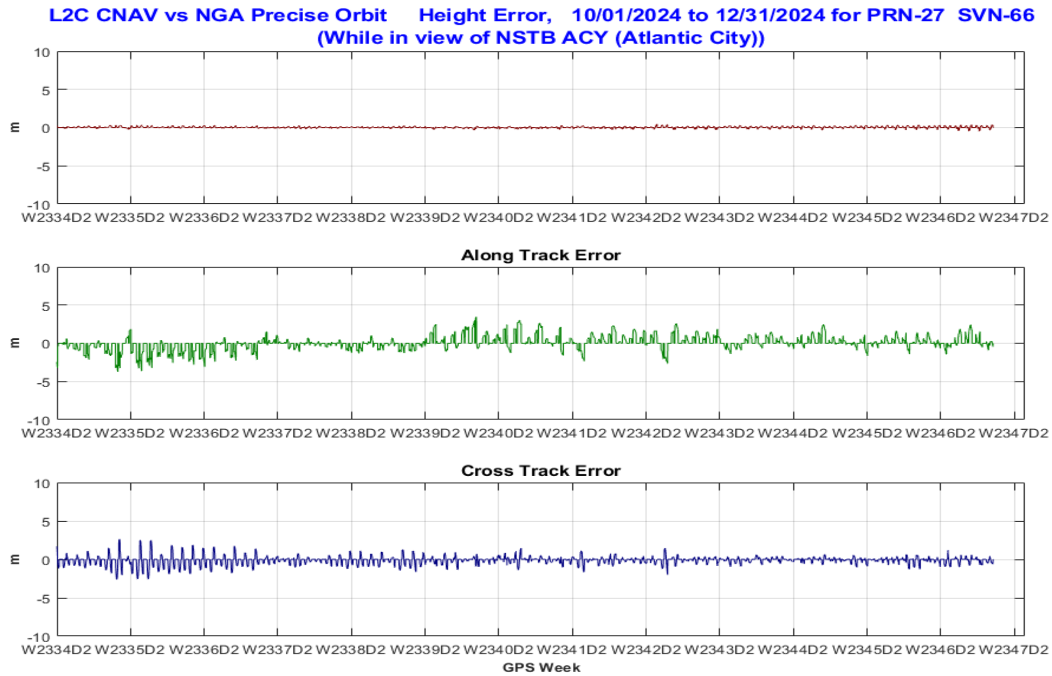


Figure 9-55 Orbit Error PRN27 (SVN66) Using L2C CNAV Data

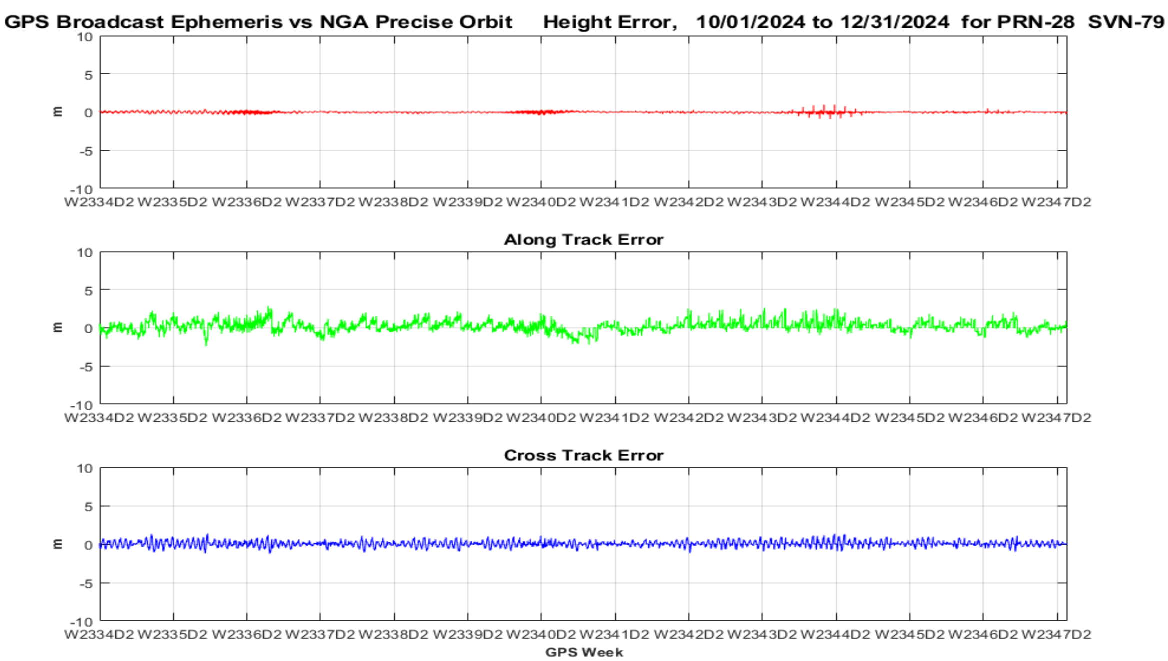


Figure 9-56 Orbit Error PRN28 (SVN79) Using C/A Nav Data

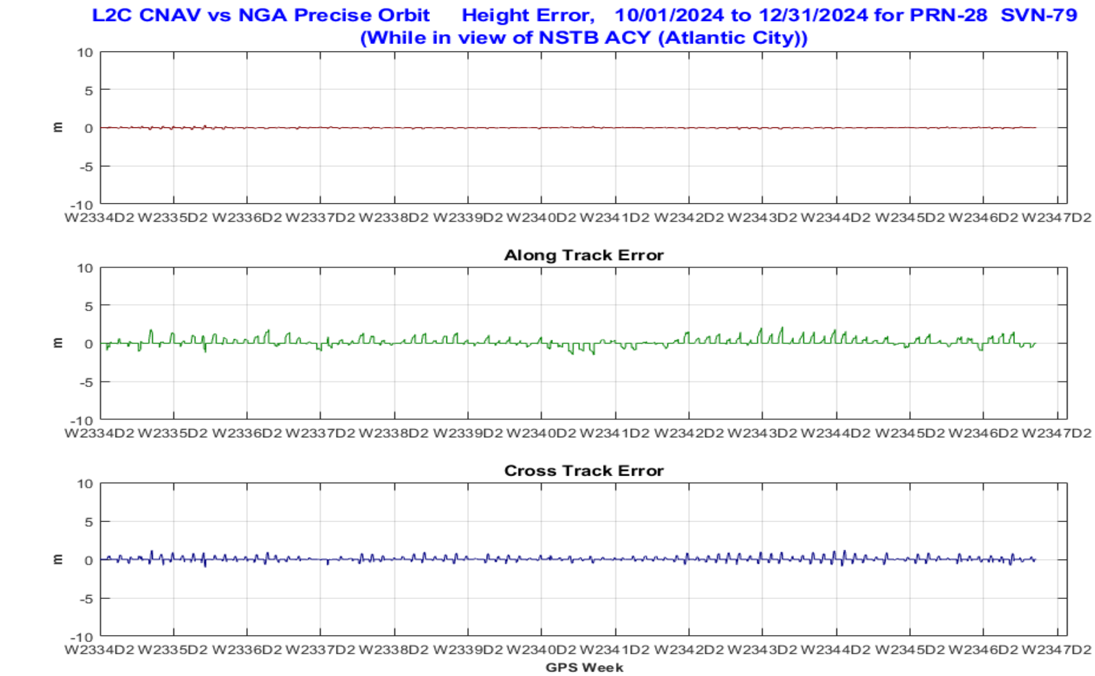


Figure 9-57 Orbit Error PRN28 (SVN79) Using L2C CNAV Data

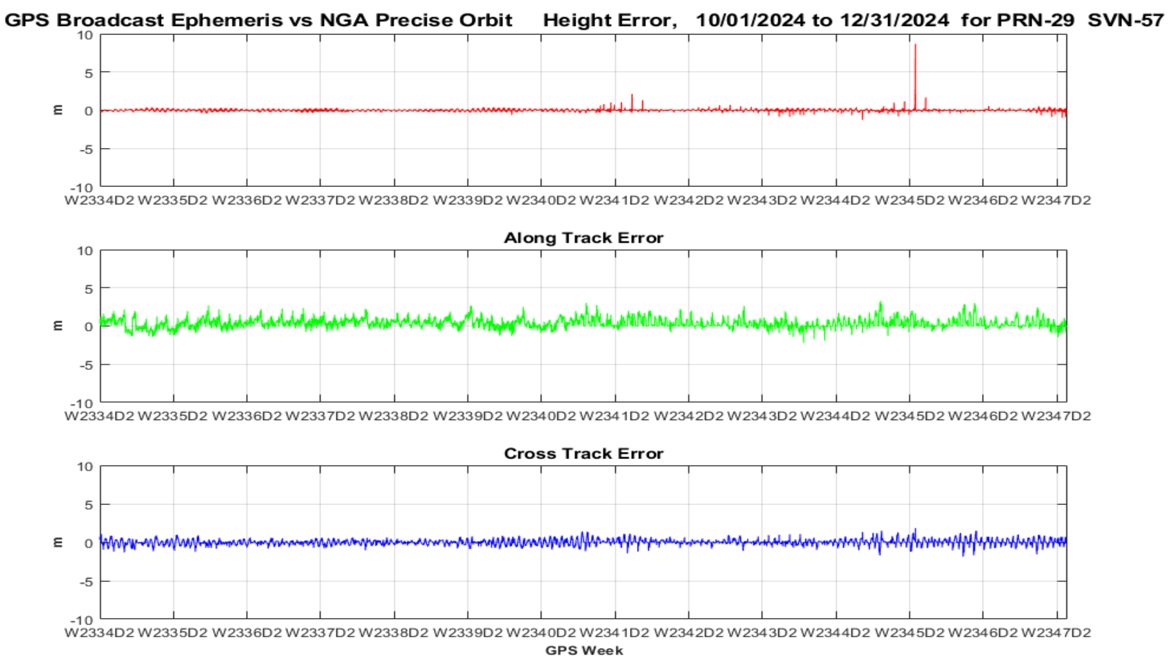


Figure 9-58 Orbit Error PRN29 (SVN57) Using C/A Nav Data

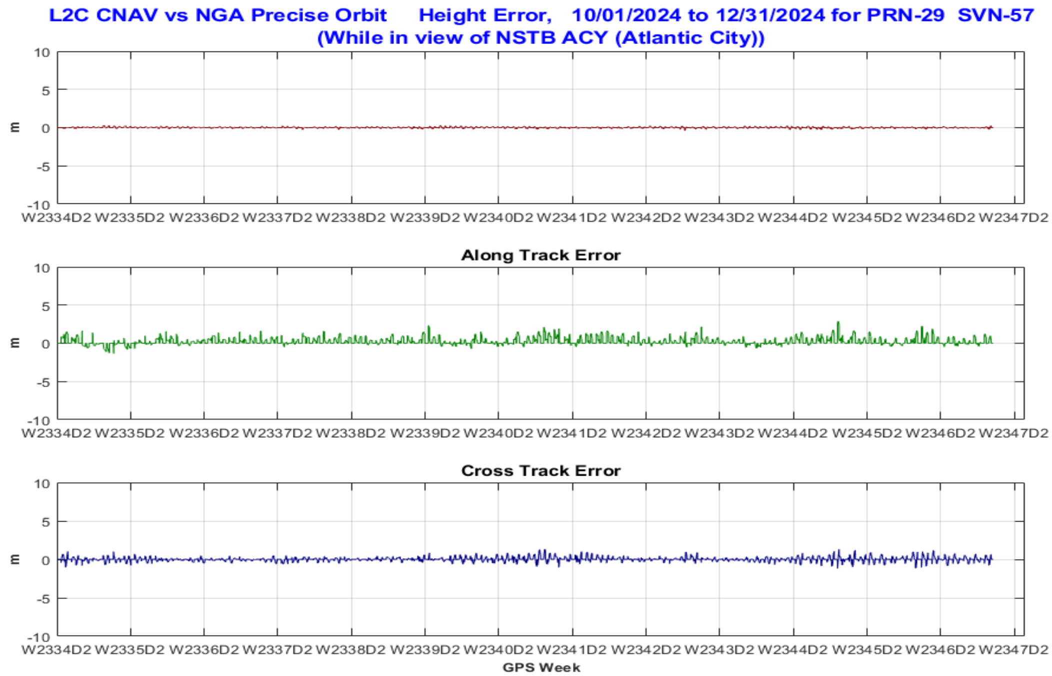


Figure 9-59 Orbit Error PRN29 (SVN57) Using L2C CNAV Data

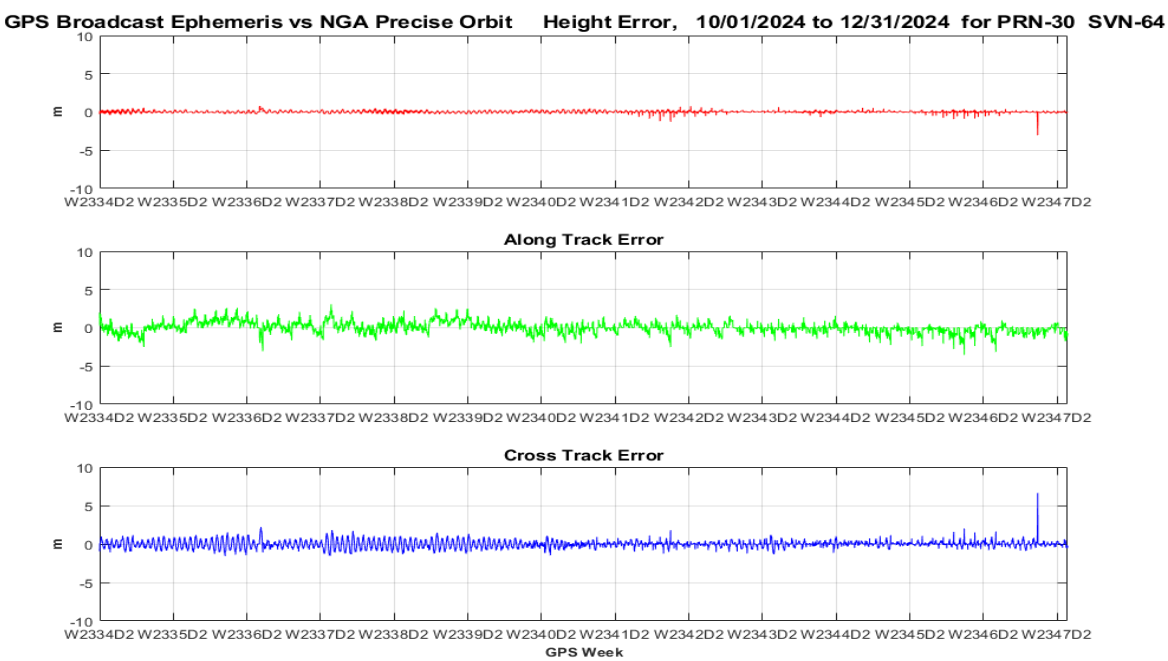


Figure 9-60 Orbit Error PRN30 (SVN64) Using C/A Nav Data

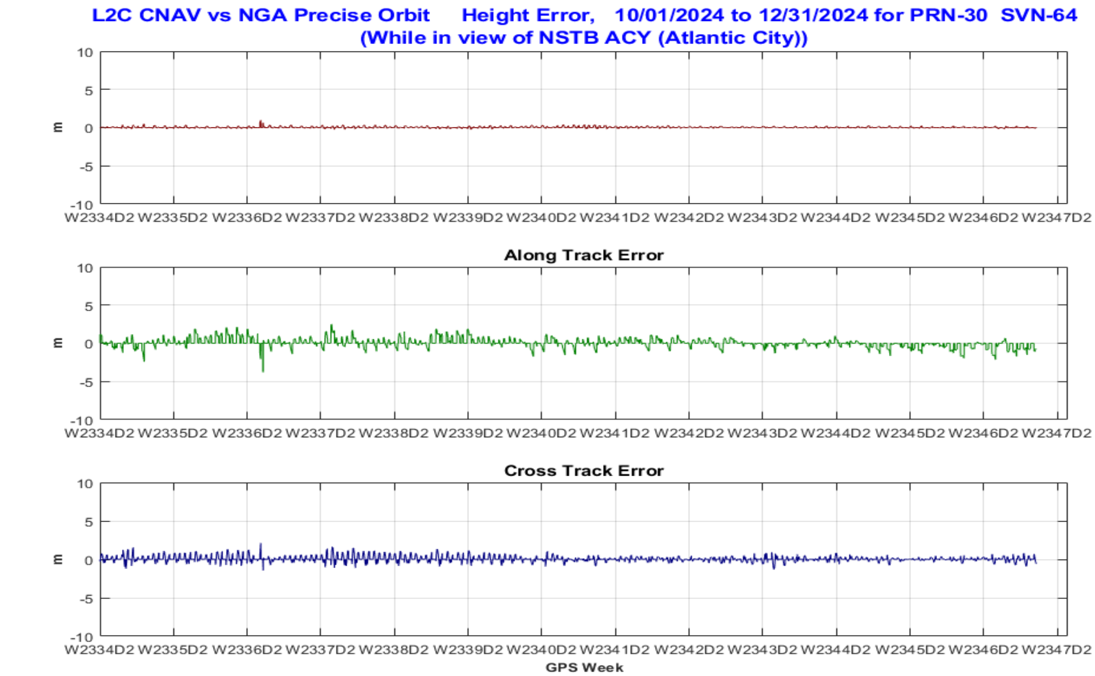


Figure 9-61 Orbit Error PRN30 (SVN64) Using L2C CNAV Data

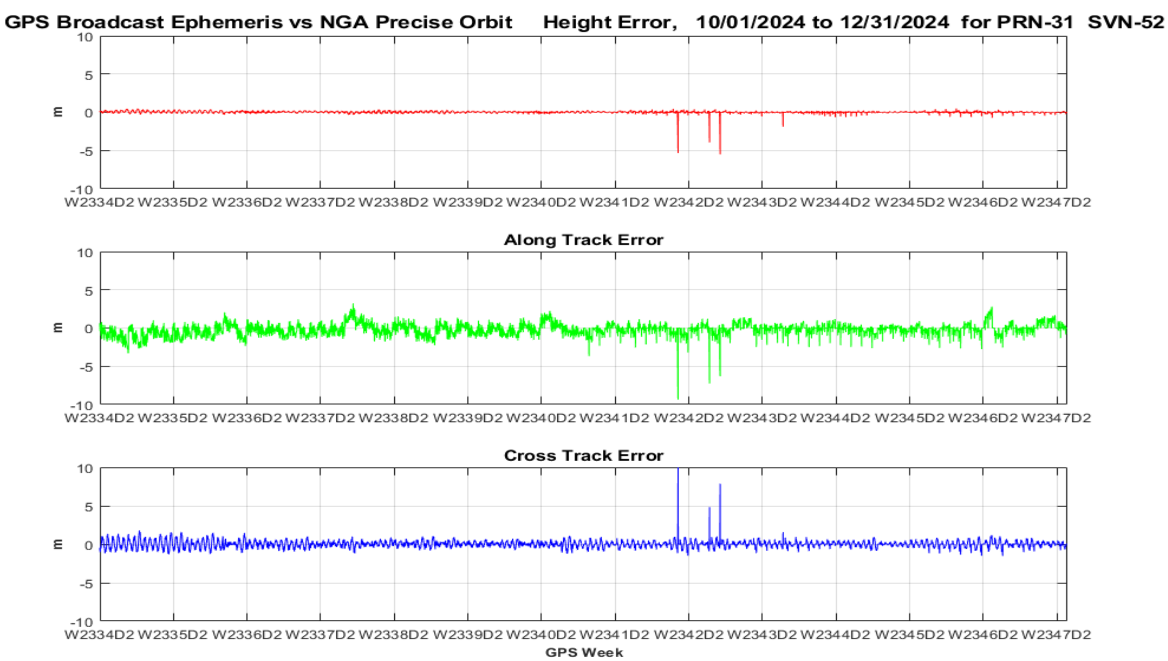


Figure 9-62 Orbit Error PRN31 (SVN52) Using C/A Nav Data

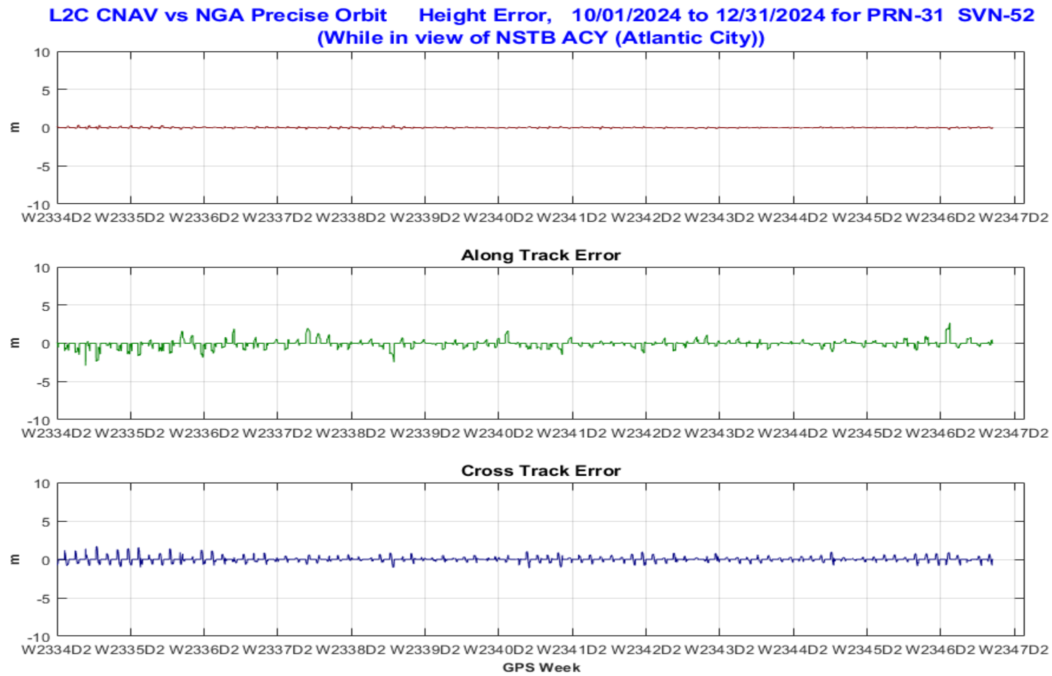


Figure 9-63 Orbit Error PRN31 (SVN52) Using L2C CNAV Data

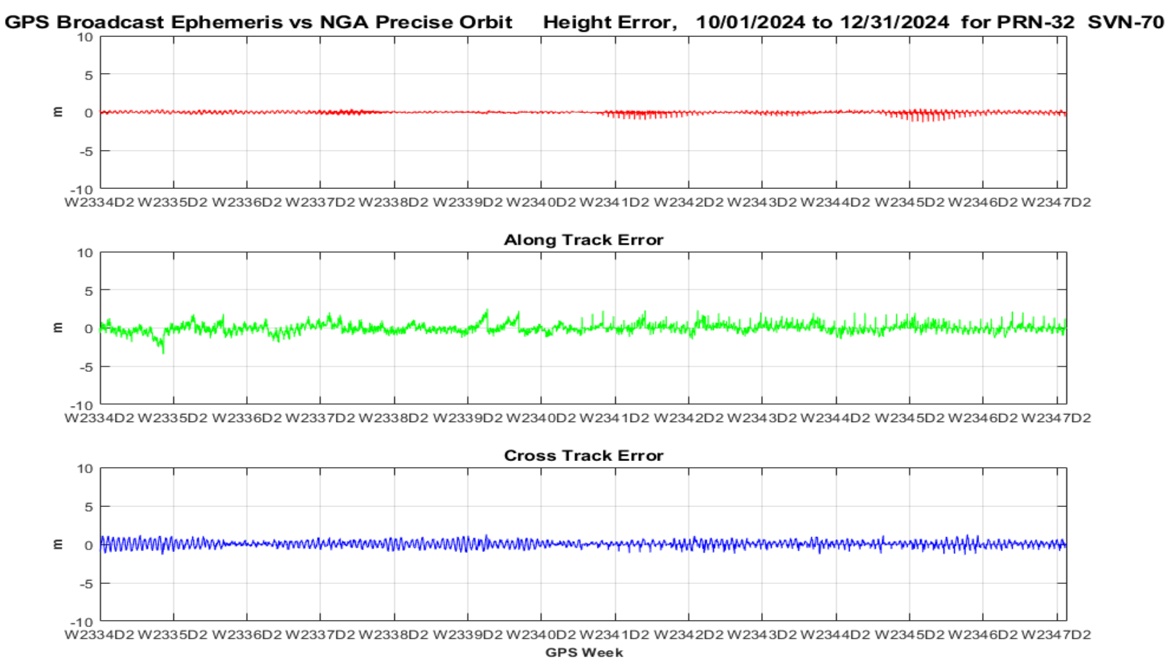


Figure 9-64 Orbit Error PRN32 (SVN70) Using C/A Nav Data

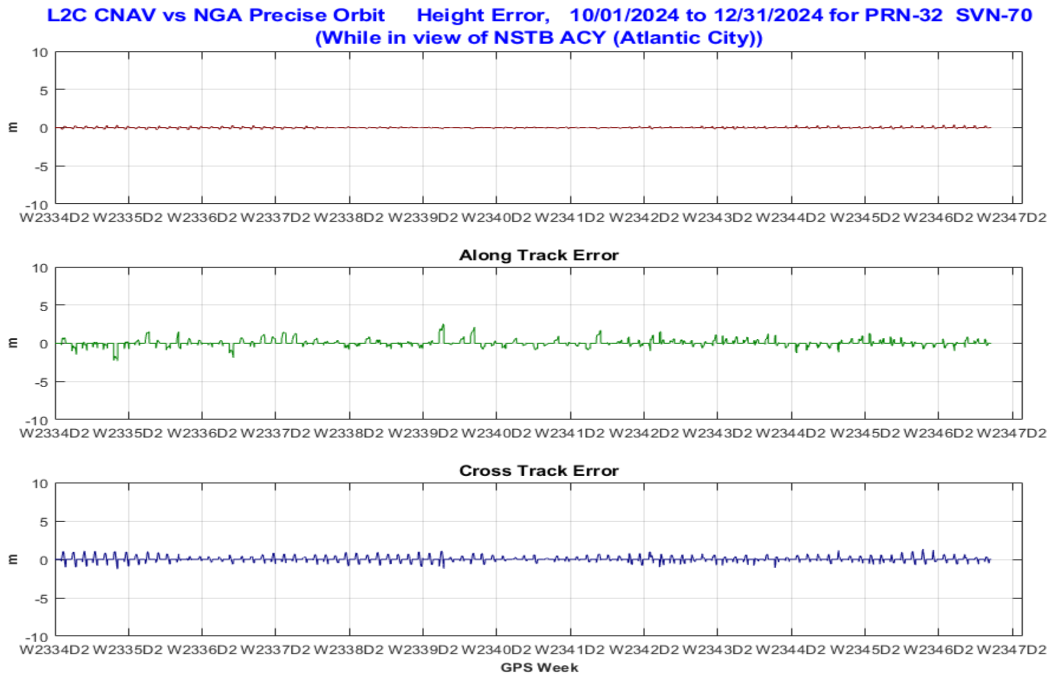


Figure 9-65 Orbit Error PRN32 (SVN70) Using L2C CNAV Data

9.6 QQ Plots of URA Normalized Error for All Satellites

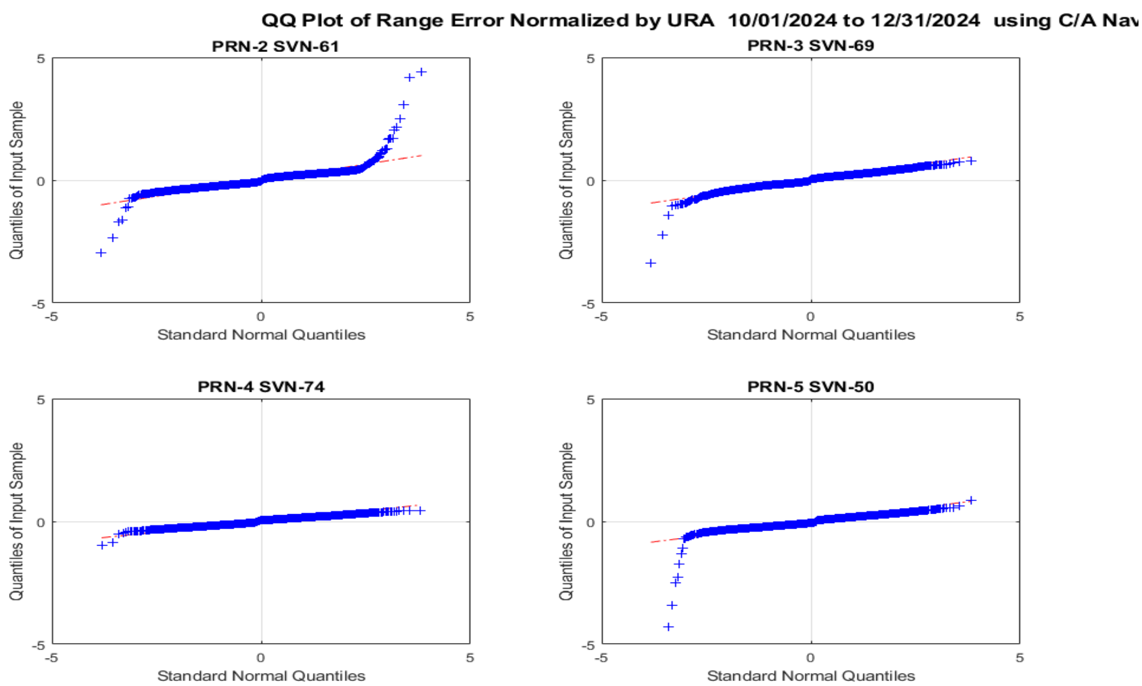


Figure 9-66 QQ Plots of Range Error PRNs 2 to 5 Using C/A Nav Data

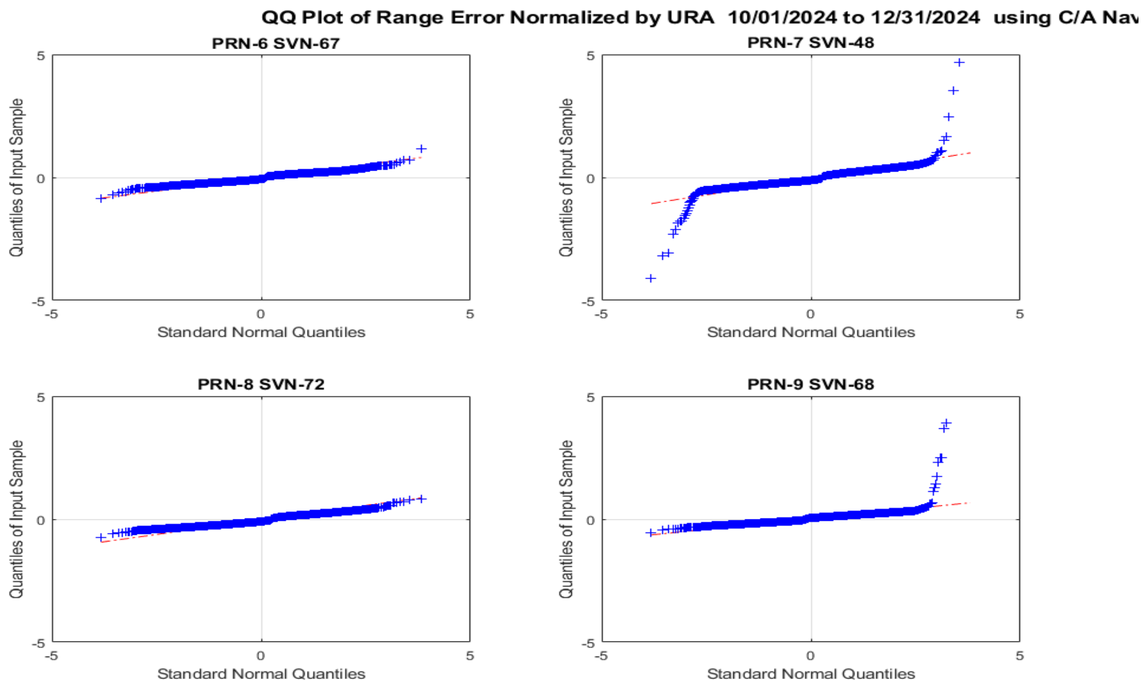


Figure 9-67 QQ Plots of Range Error PRNs 6 to 9 Using C/A Nav Data

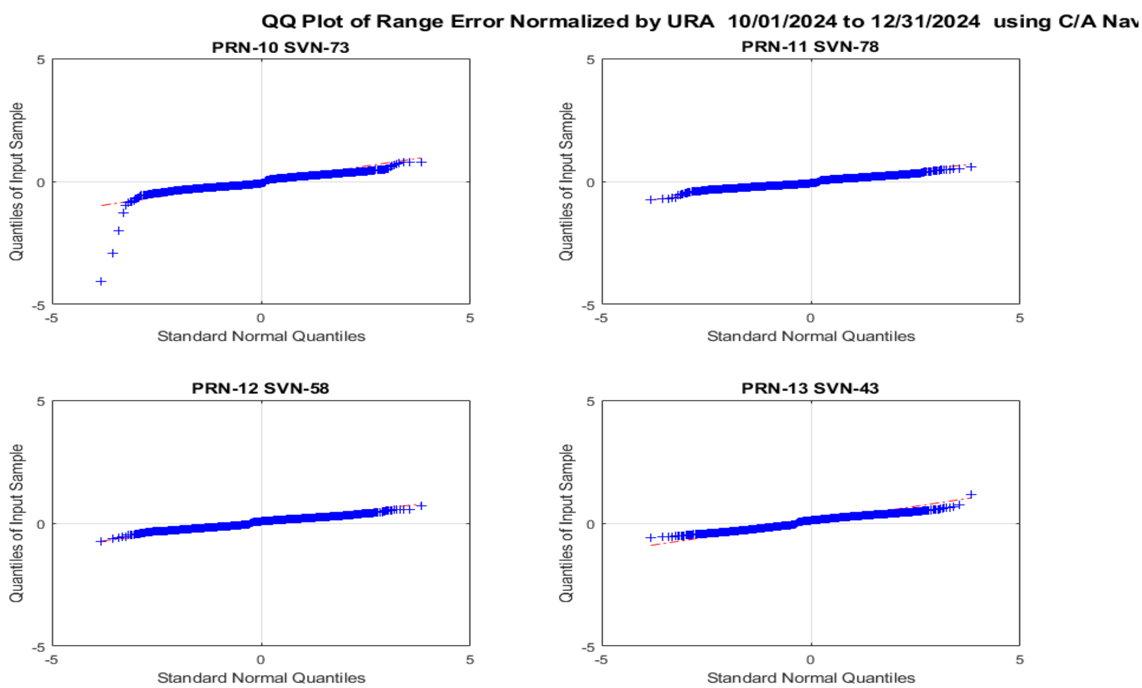


Figure 9-68 QQ Plots of Range Error PRNs 10 to 13 Using C/A Nav Data

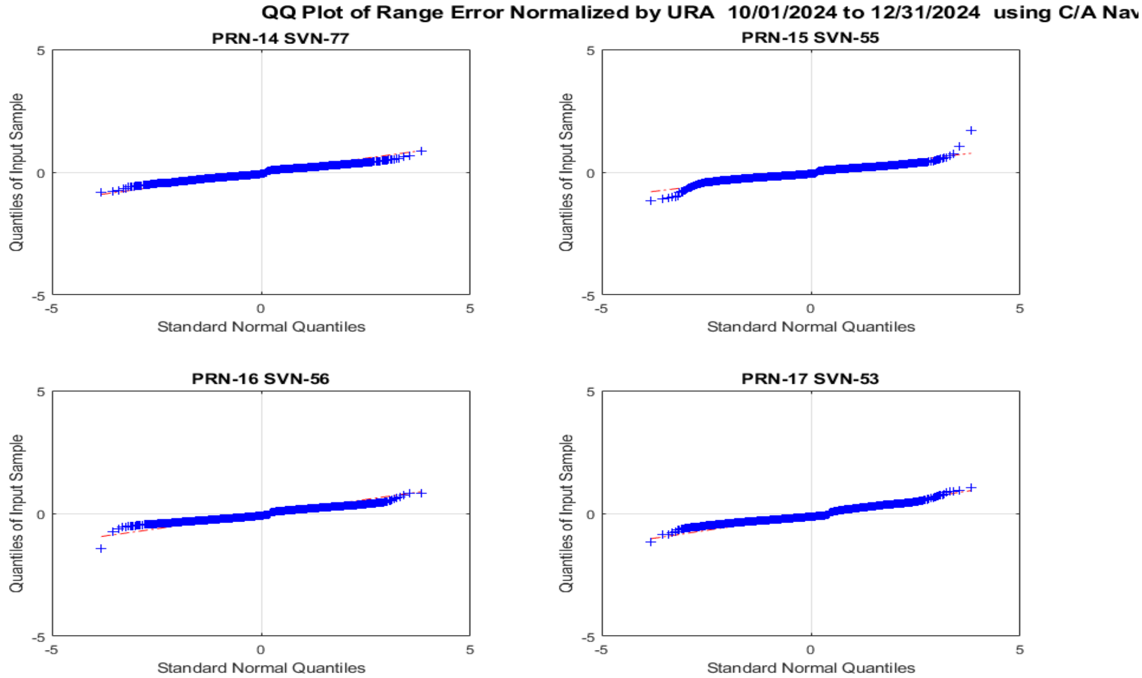


Figure 9-69 QQ Plots of Range Error PRNs 14 to 17 Using C/A Nav Data

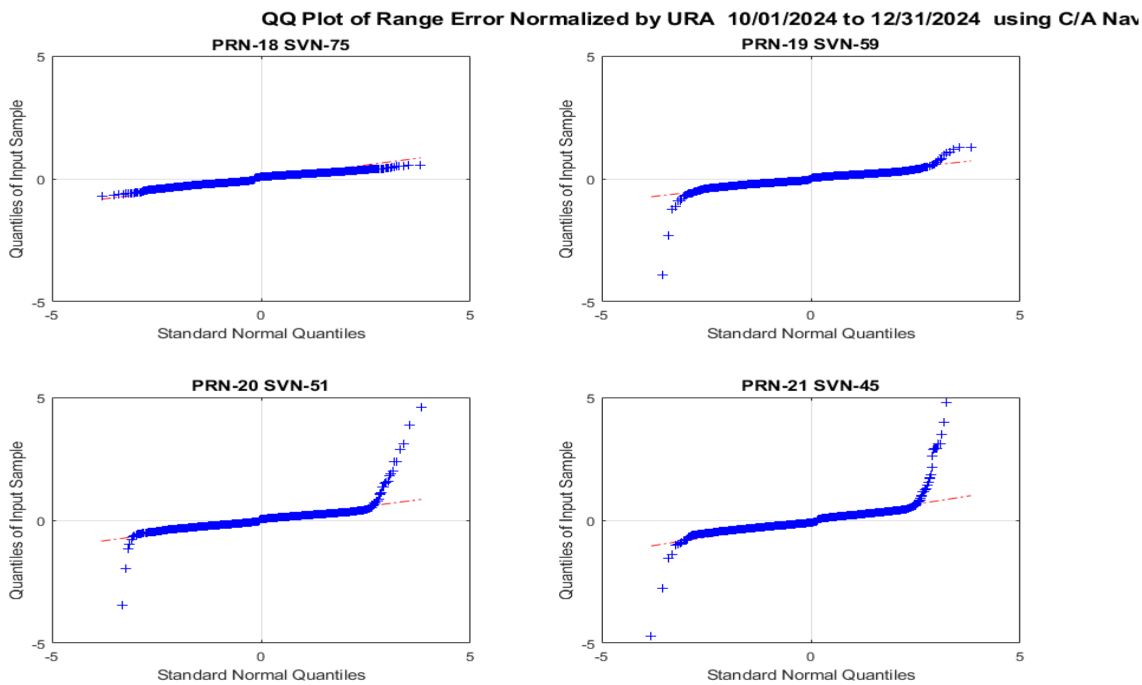


Figure 9-70 QQ Plots of Range Error PRNs 18 to 21 Using C/A Nav Data

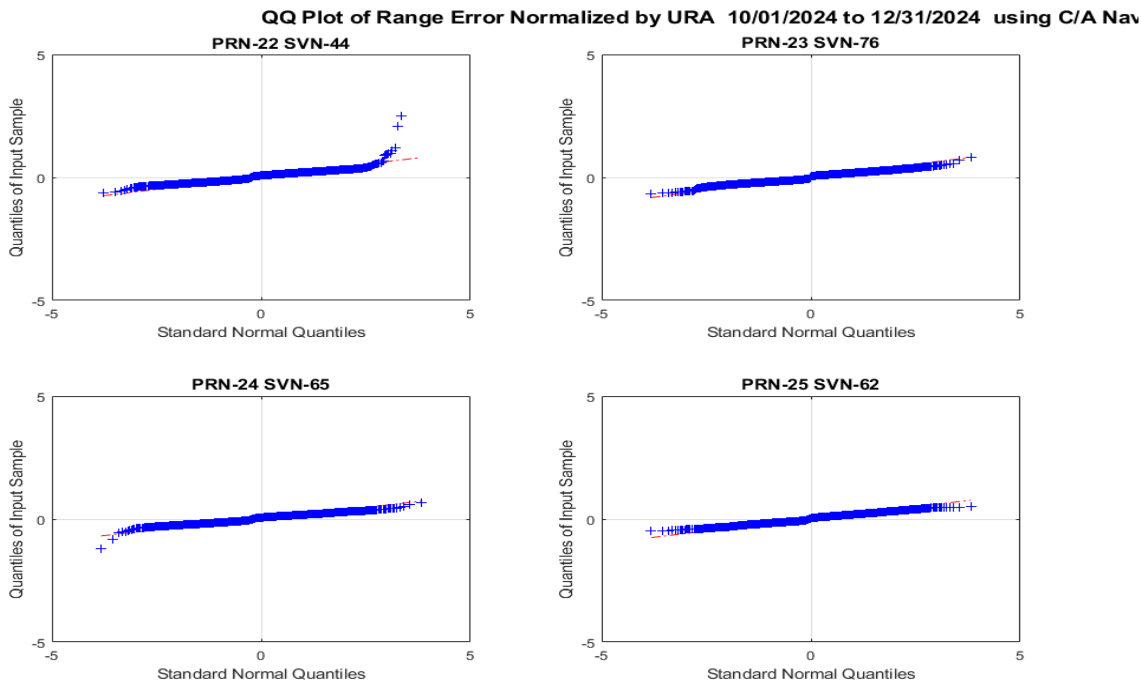


Figure 9-71 QQ Plots of Range Error PRNs 22 to 25 Using C/A Nav Data

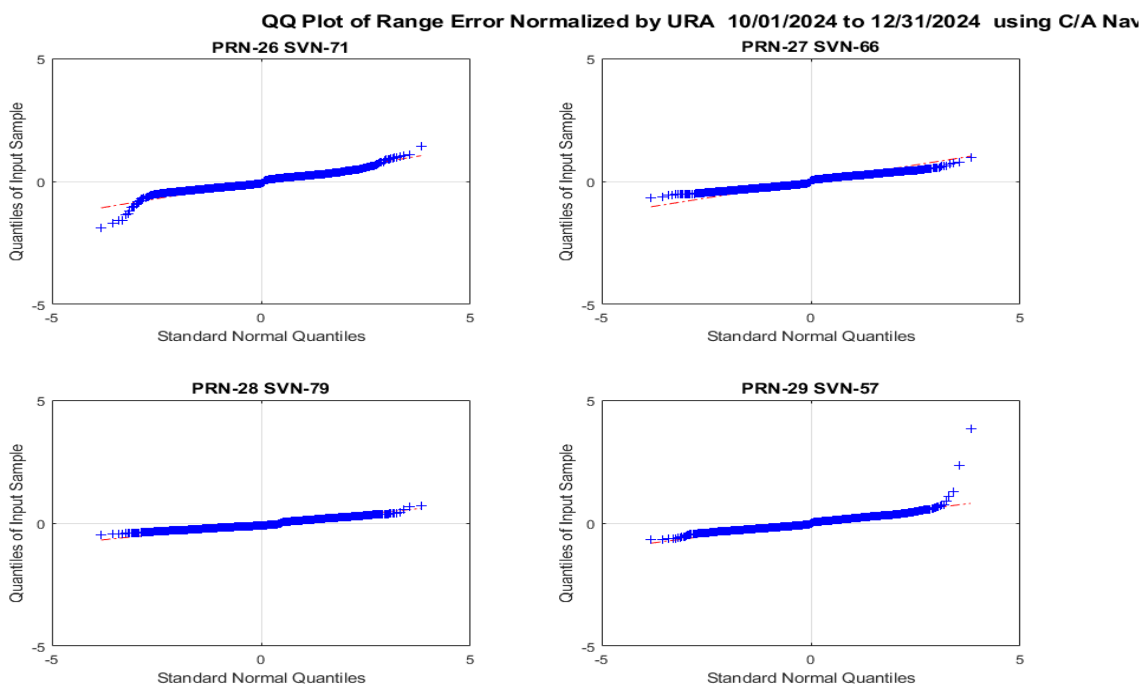


Figure 9-72 QQ Plots of Range Error PRNs 26 to 29 Using C/A Nav Data

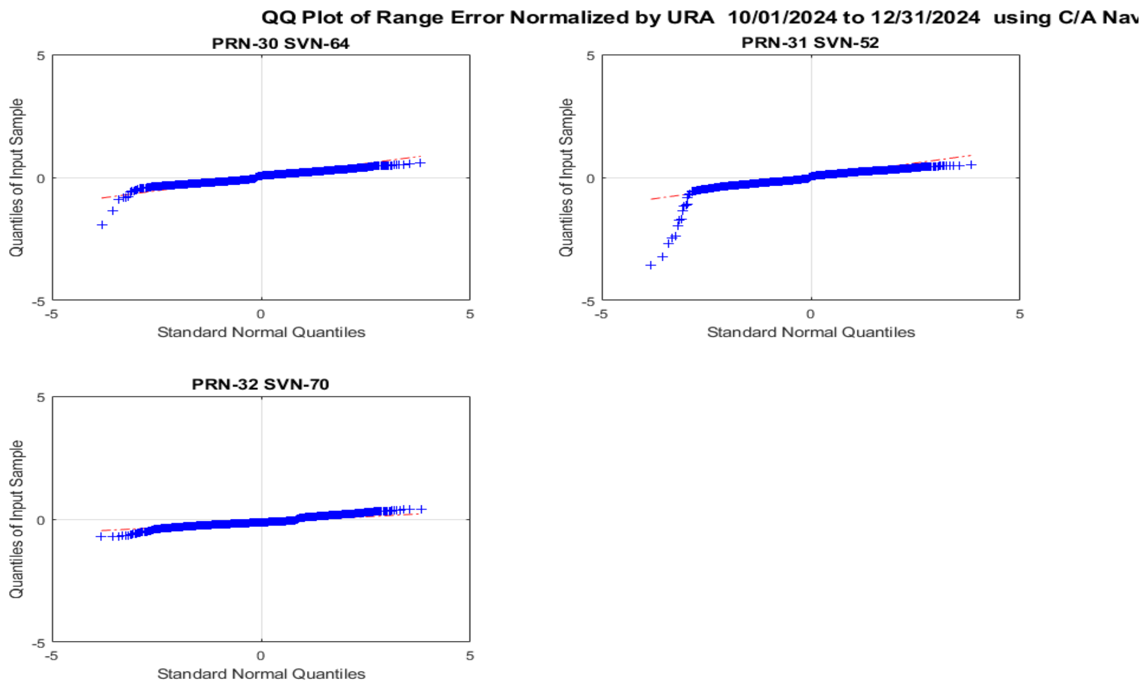


Figure 9-73 QQ Plots of Range Error PRNs 30 to 32 Using C/A Nav Data

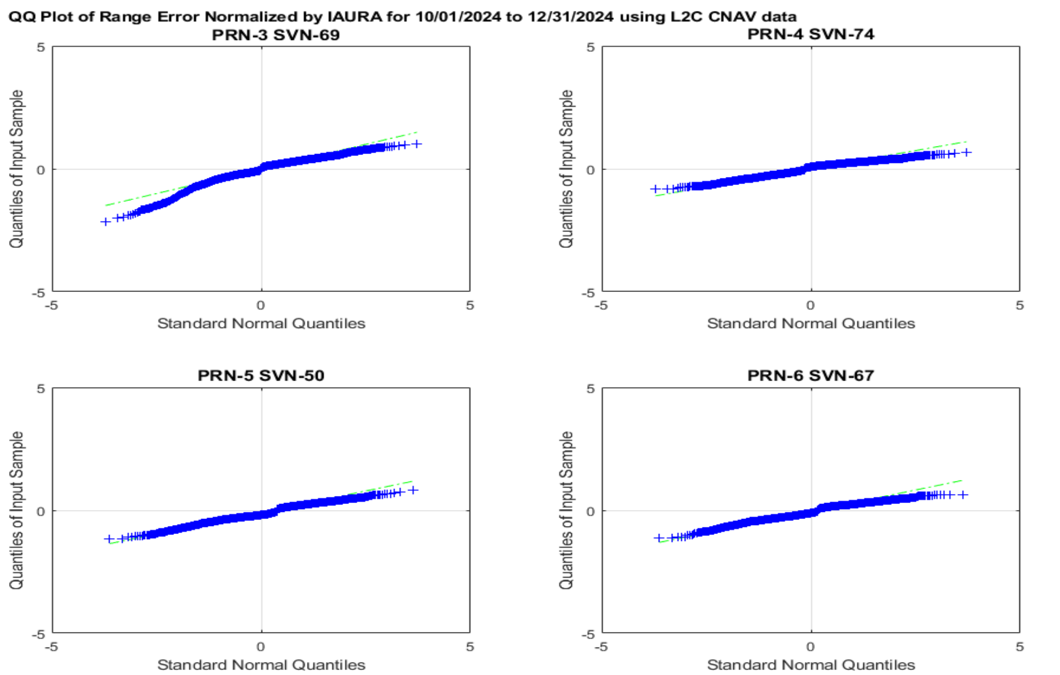


Figure 9-74 QQ Plots of Range Error PRNs 3, 4, 5, and 6 Using L2C CNAV Data

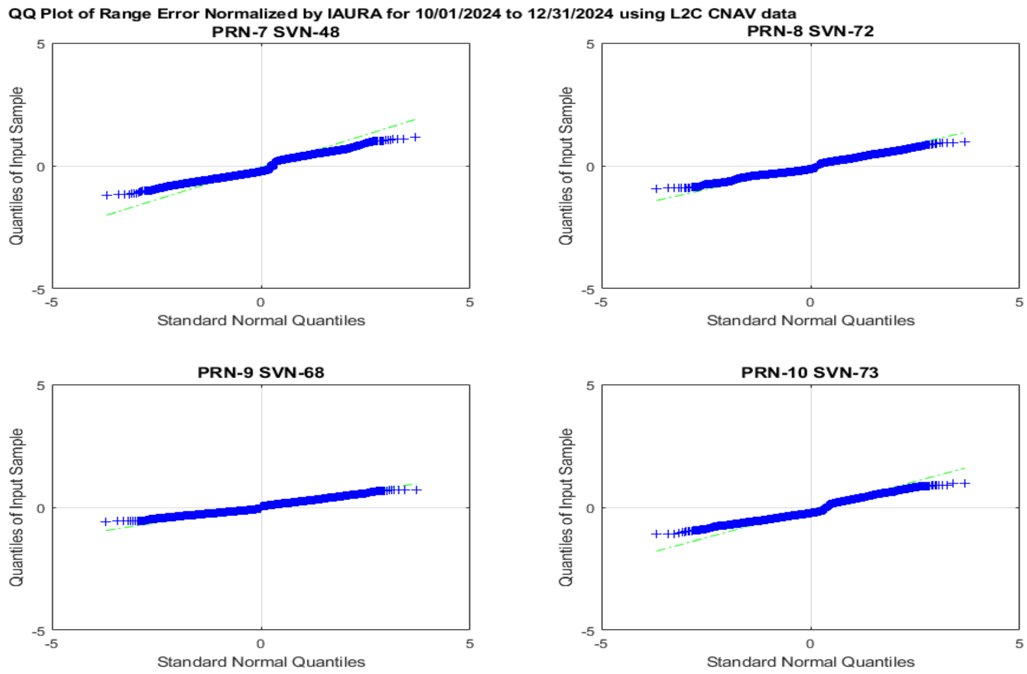


Figure 9-75 QQ Plots of Range Error PRNs 7, 8, 9, and 10 Using L2C CNAV Data

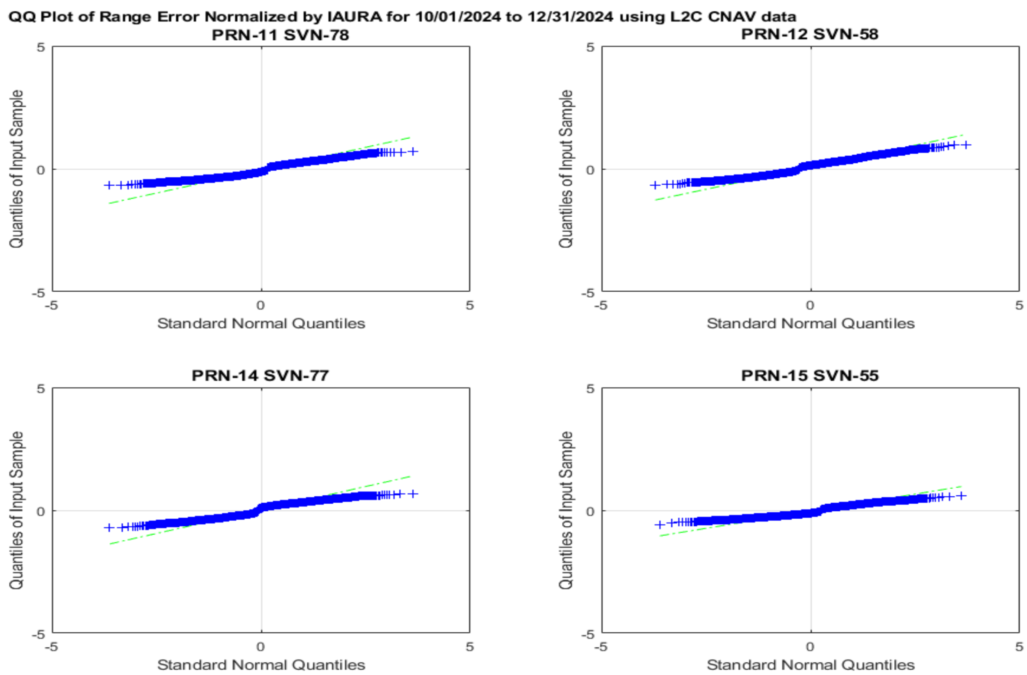


Figure 9-76 QQ Plots of Range Error PRNs 11, 12, 14, and 15 Using L2C CNAV Data

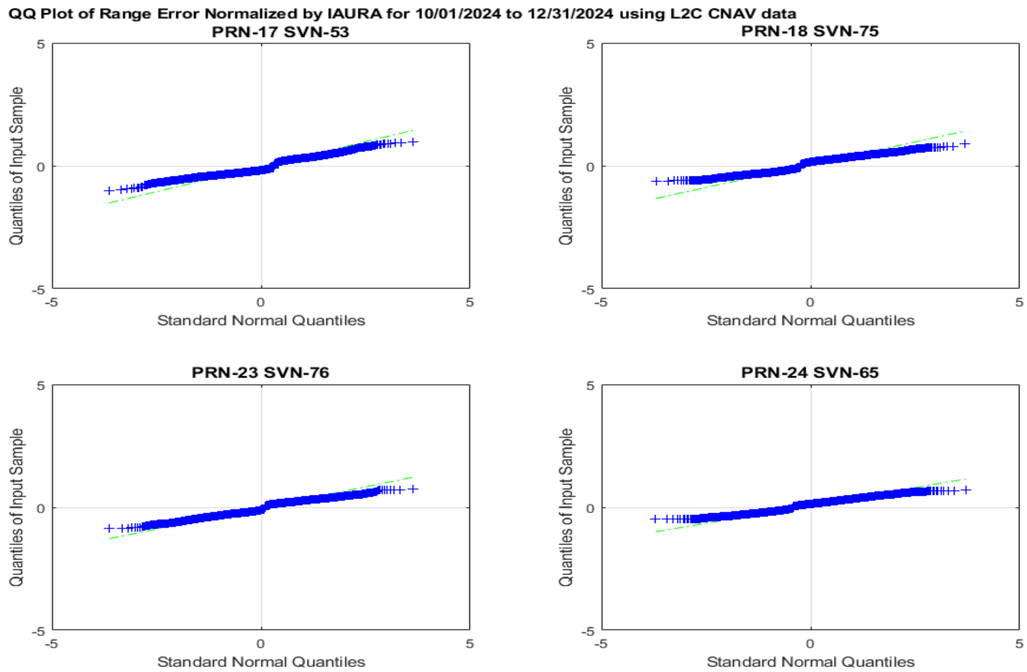


Figure 9-77 QQ Plots of Range Error PRNs 17, 18, 23, and 24 Using L2C CNAV Data

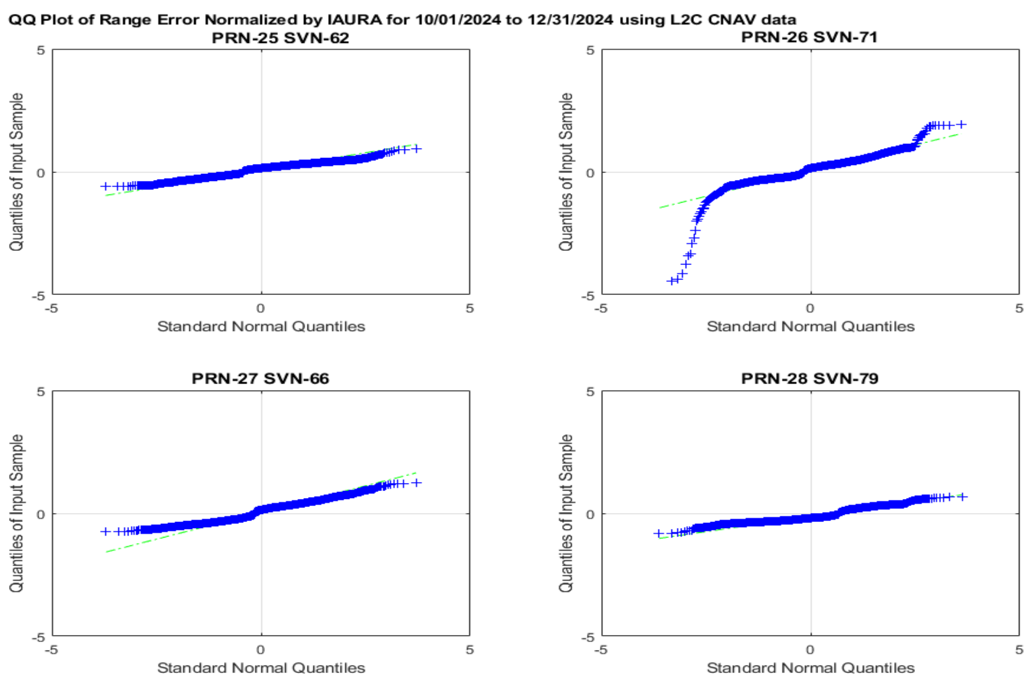


Figure 9-78 QQ Plots of Range Error PRNs 25, 26, 27, and 28 Using L2C CNAV Data

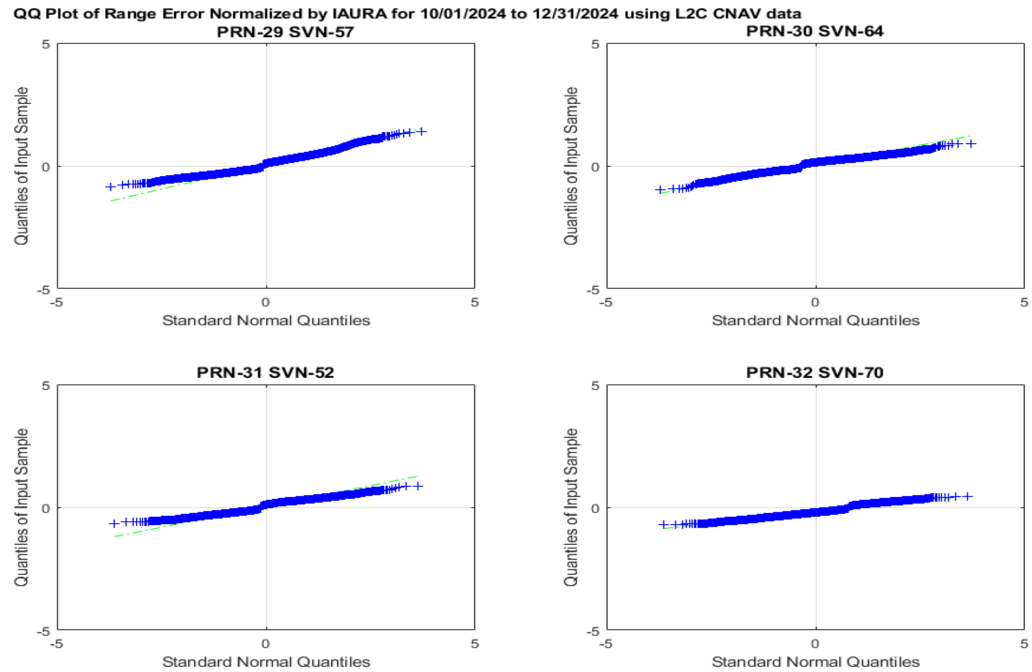


Figure 9-79 QQ Plots of Range Error PRNs 29, 30, 31, and 32 Using L2C CNAV Data

9.7 Histogram Plots of H, A, C, and Range Error for All Satellites

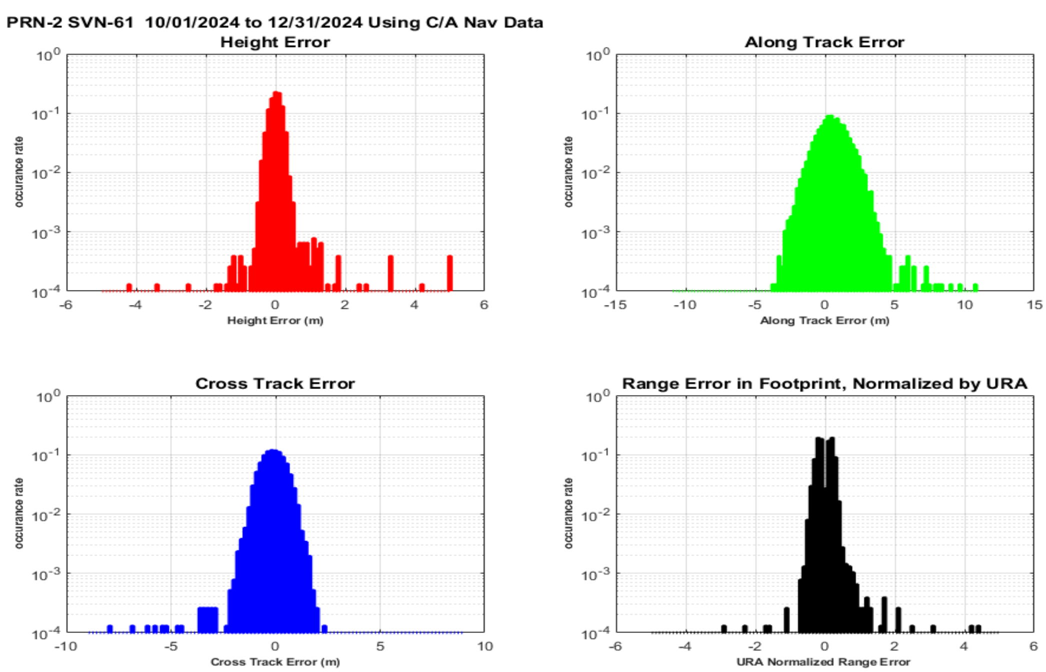


Figure 9-80 Histograms of H, A, C, and Range Error PRN2 (SVN61) Using C/A Nav Data

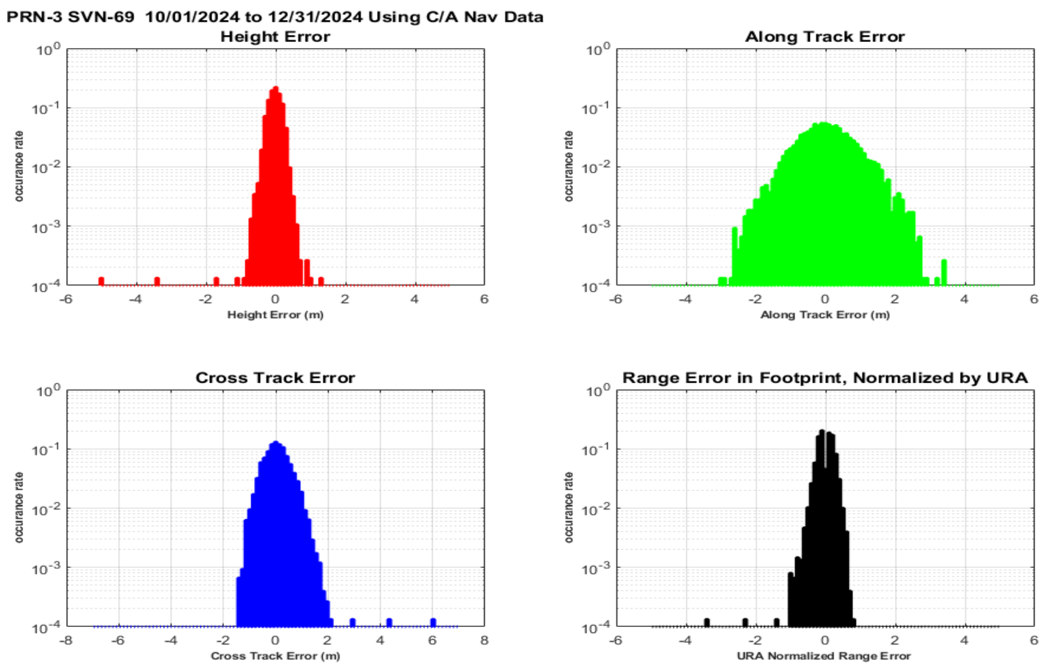


Figure 9-81 Histograms of H, A, C, and Range Error PRN3 (SVN69) Using C/A Nav Data

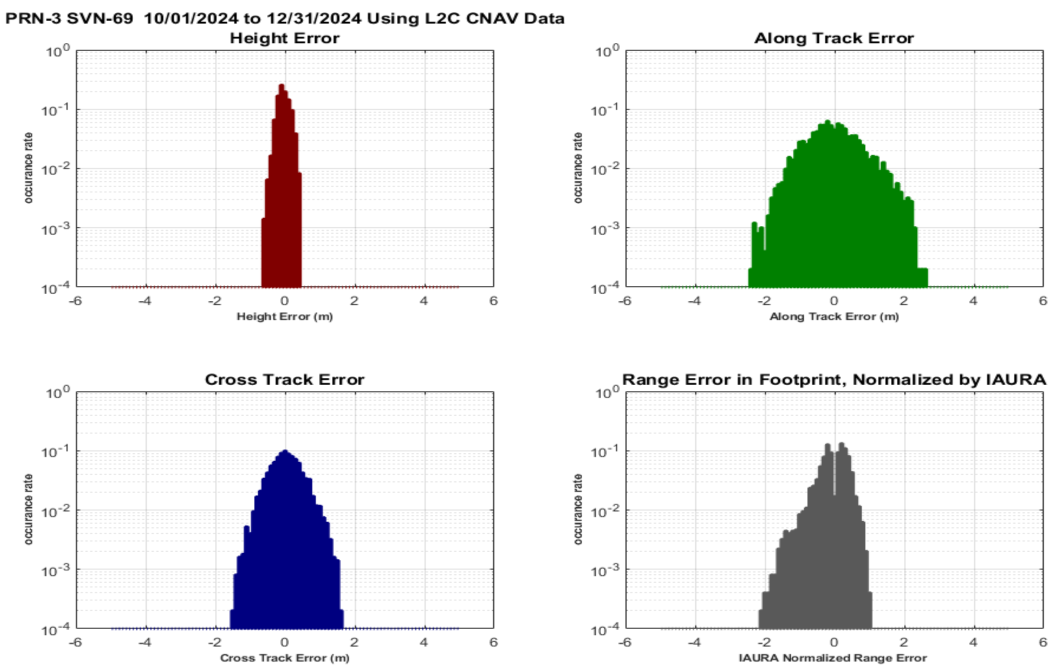


Figure 9-82 Histograms of H, A, C, and Range Error PRN3 (SVN69) Using L2C CNAV Data

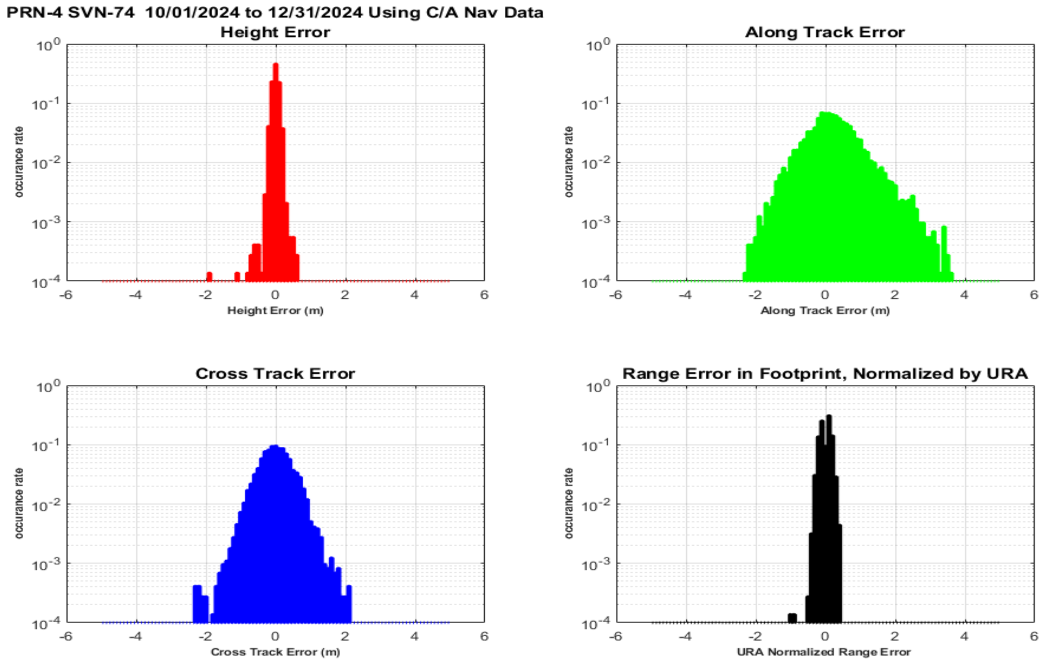


Figure 9-83 Histograms of H, A, C, and Range Error PRN4 (SVN74) Using C/A Nav Data

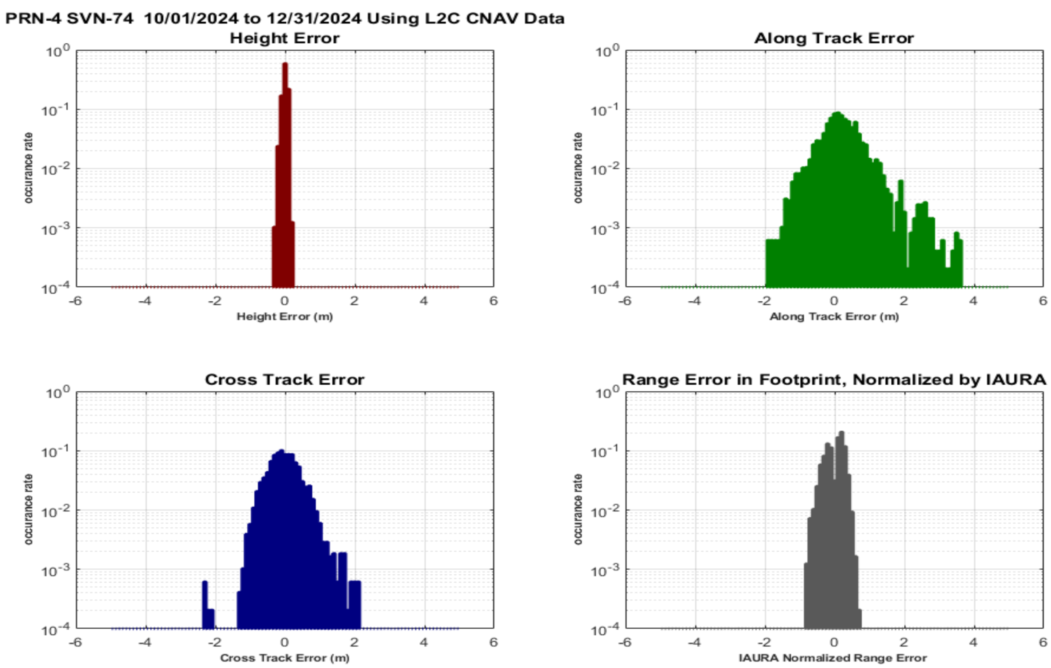


Figure 9-84 Histograms of H, A, C, and Range Error PRN4 (SVN74) Using L2C CNAV Data

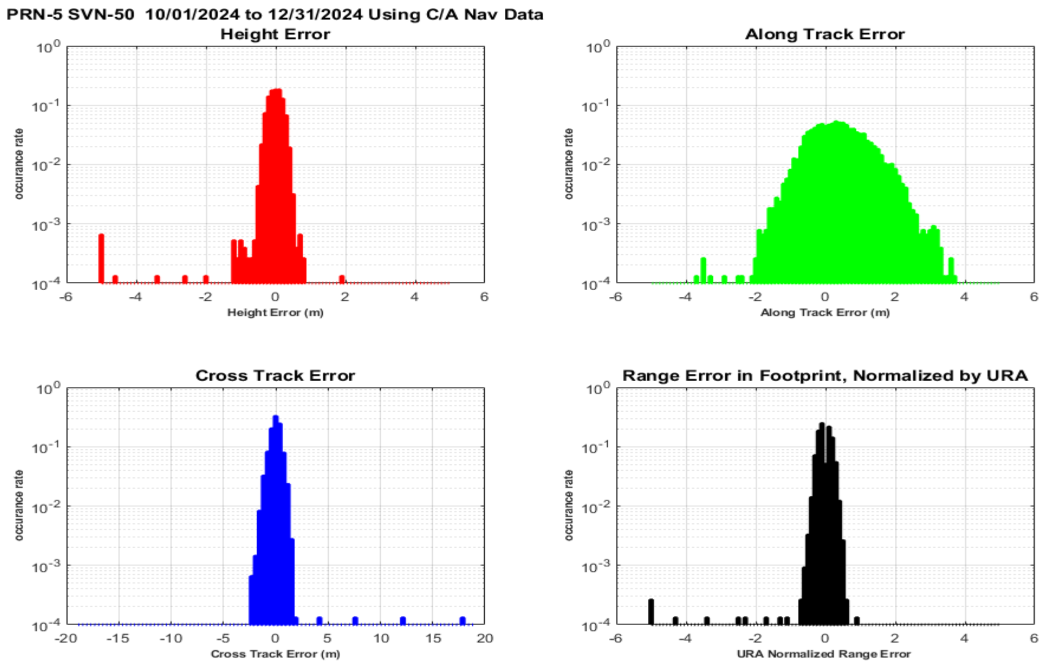


Figure 9-85 Histograms of H, A, C, and Range Error PRN5 (SVN50) Using C/A Nav Data

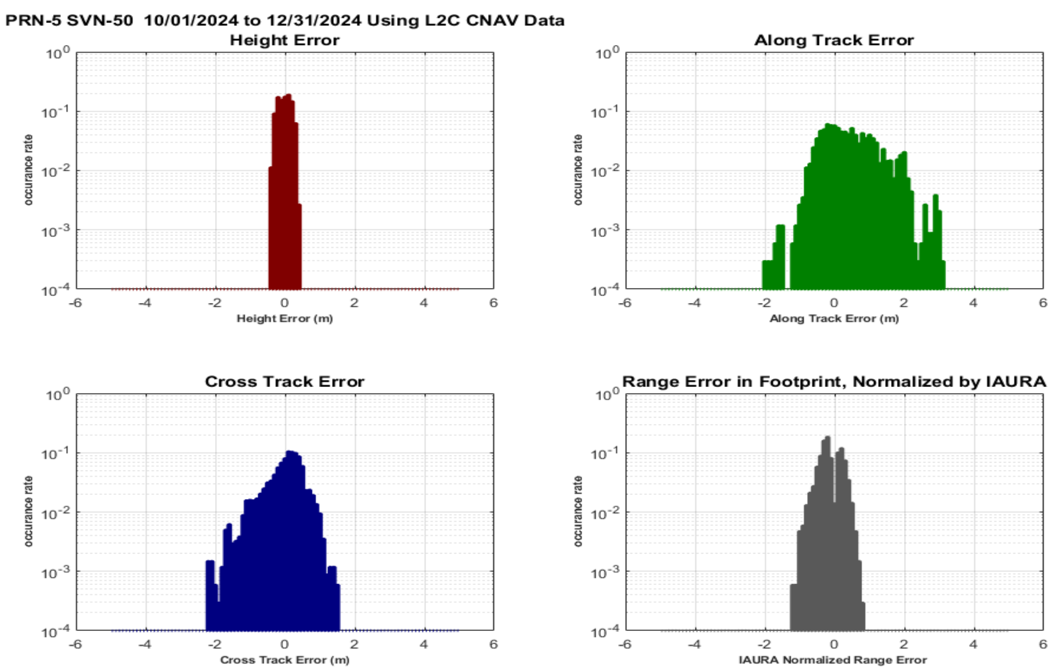


Figure 9-86 Histograms of H, A, C, and Range Error PRN5 (SVN50) Using L2C CNAV Data

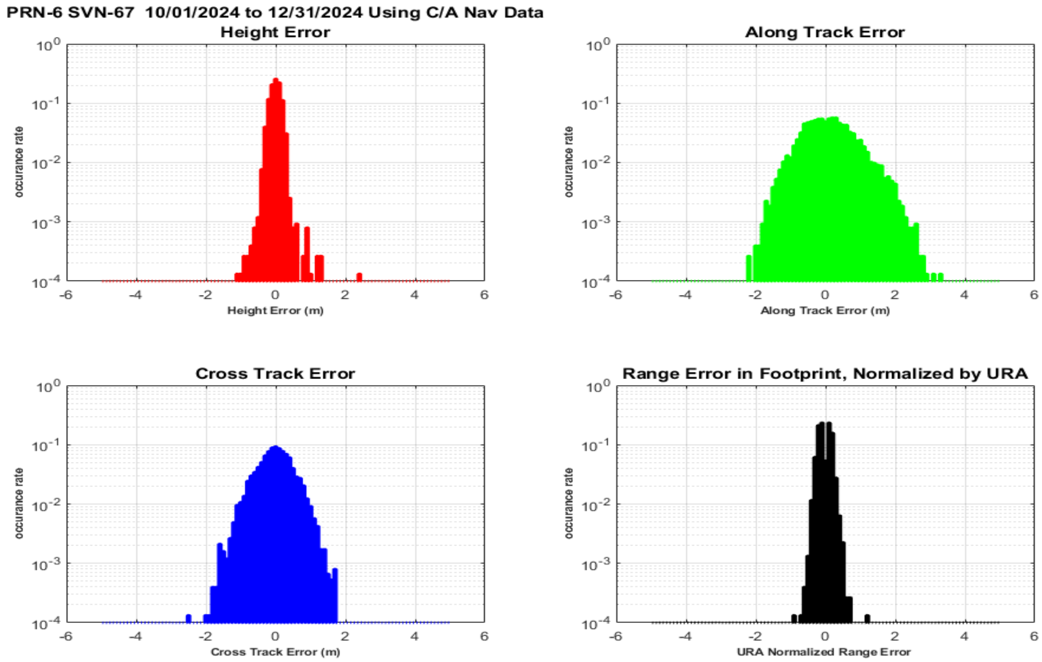


Figure 9-87 Histograms of H, A, C, and Range Error PRN6 (SVN67) Using C/A Nav Data

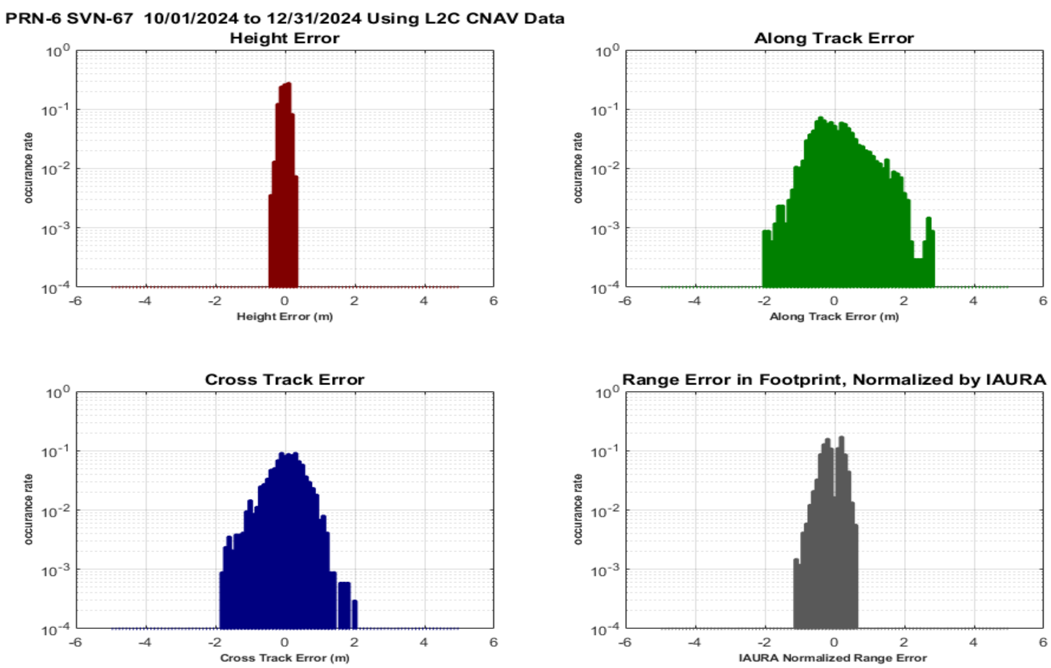


Figure 9-88 Histograms of H, A, C, and Range Error PRN6 (SVN67) Using L2C CNAV Data

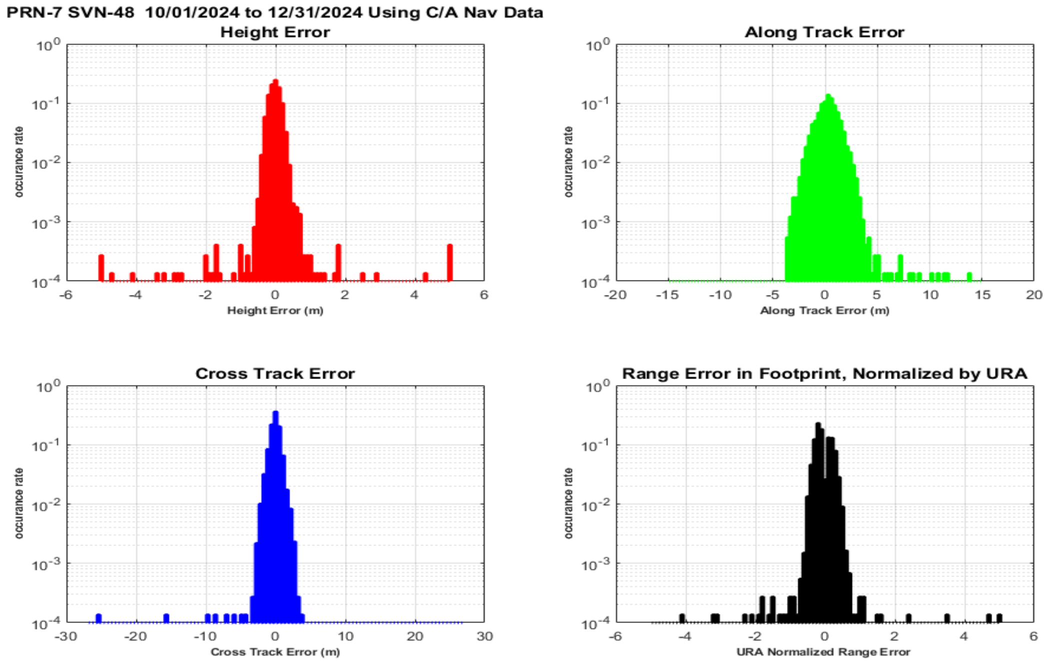


Figure 9-89 Histograms of H, A, C, and Range Error PRN7 (SVN48) Using C/A Nav Data

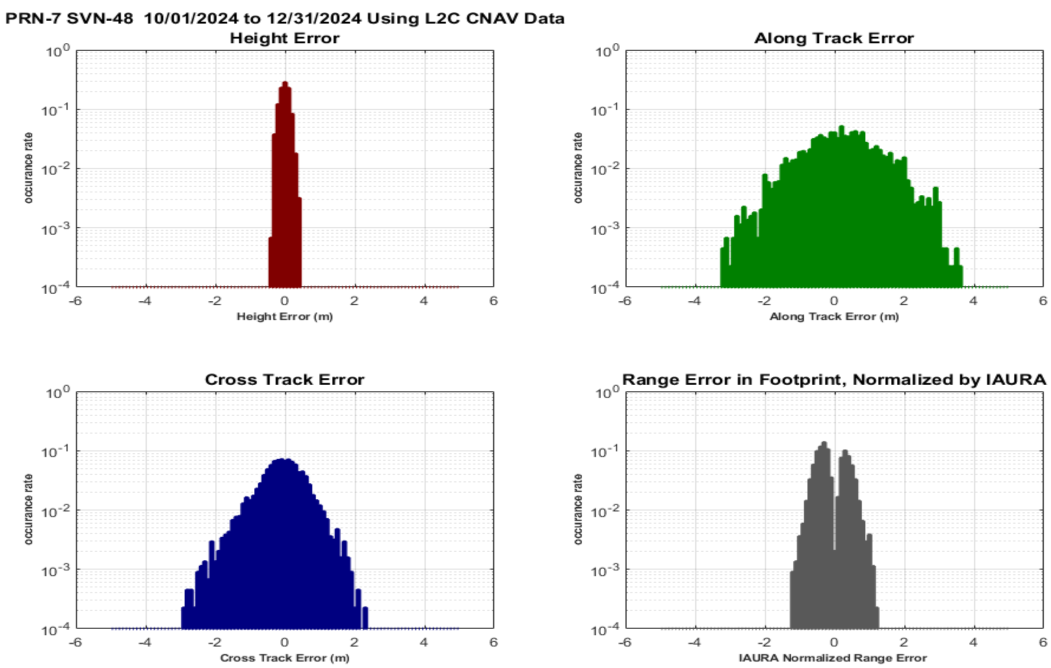


Figure 9-90 Histograms of H, A, C, and Range Error PRN7 (SVN48) Using L2C CNAV Data

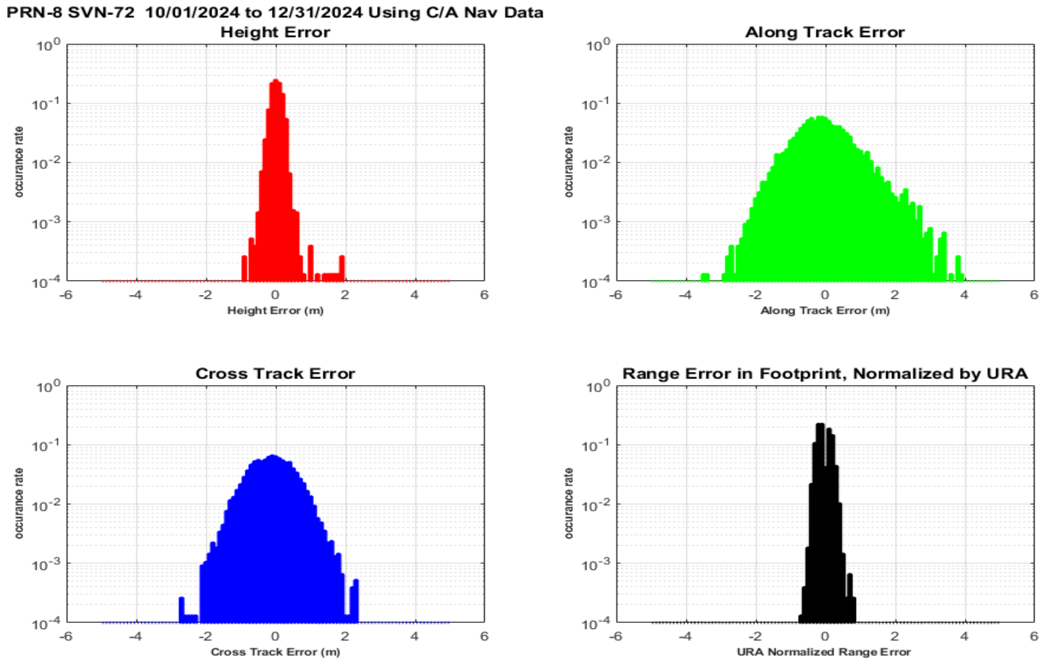


Figure 9-91 Histograms of H, A, C, and Range Error PRN8 (SVN72) Using C/A Nav Data

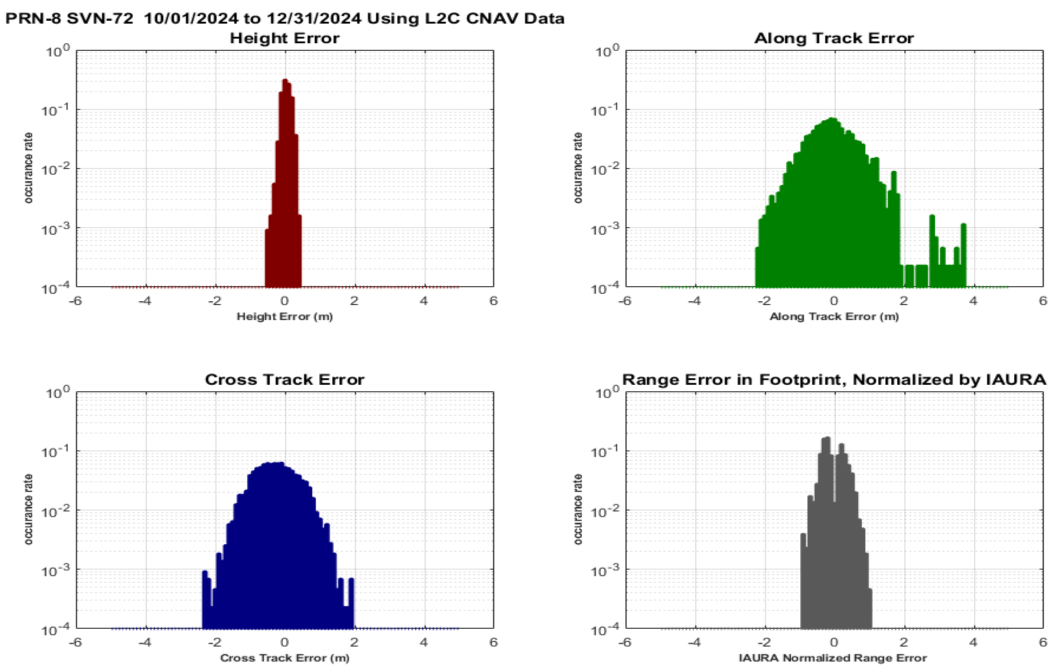


Figure 9-92 Histograms of H, A, C, and Range Error PRN8 (SVN72) Using L2C CNAV Data

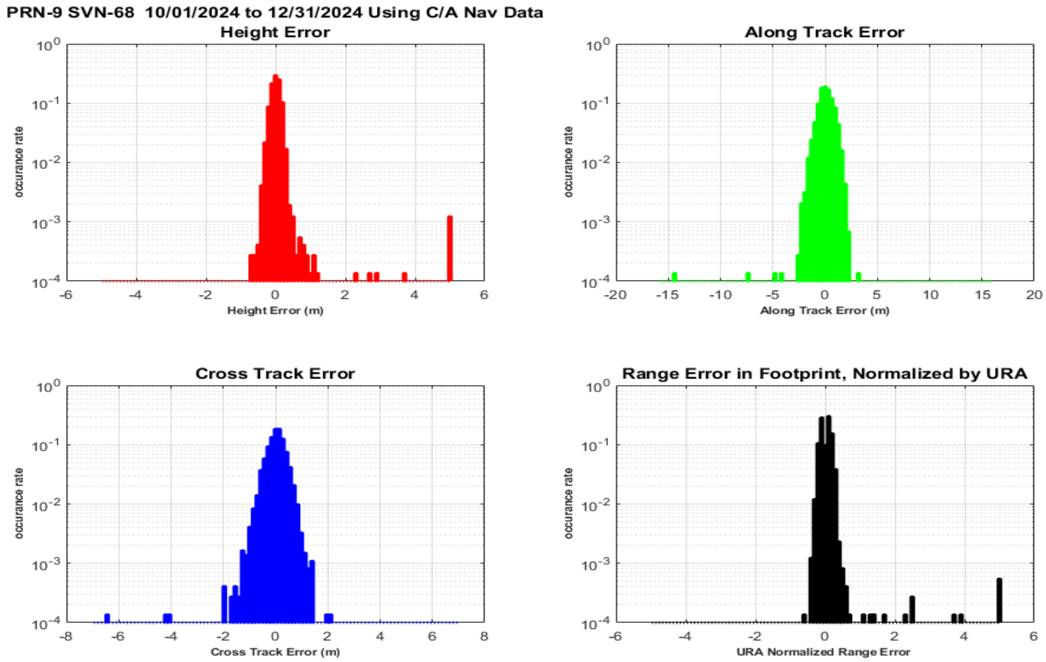


Figure 9-93 Histograms of H, A, C, and Range Error PRN9 (SVN68) Using C/A Nav Data

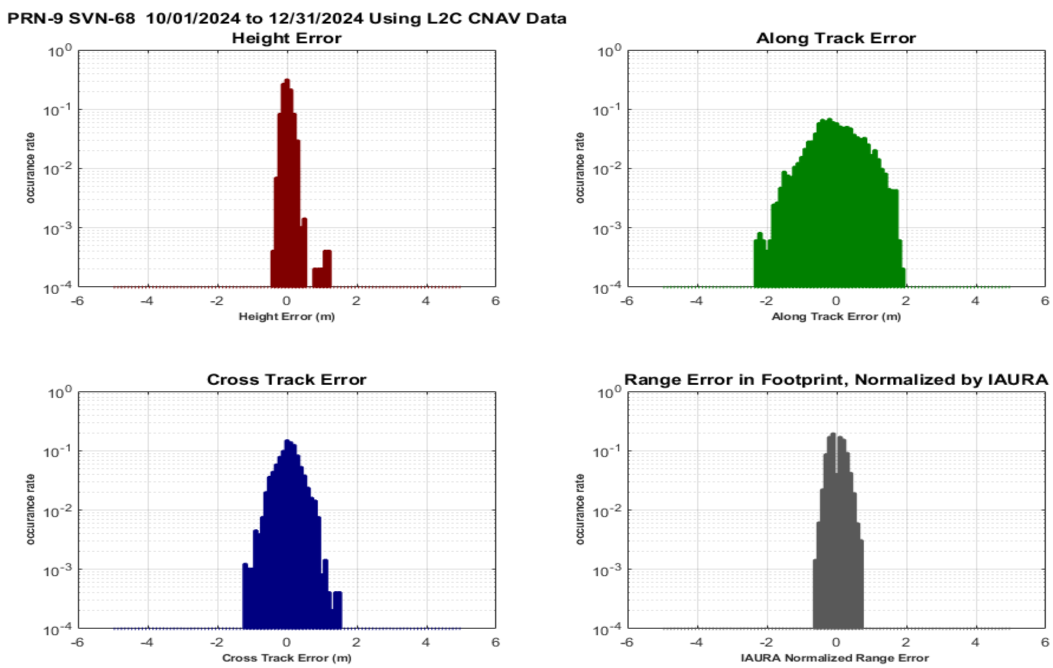


Figure 9-94 Histograms of H, A, C, and Range Error PRN9 (SVN68) Using L2C CNAV Data

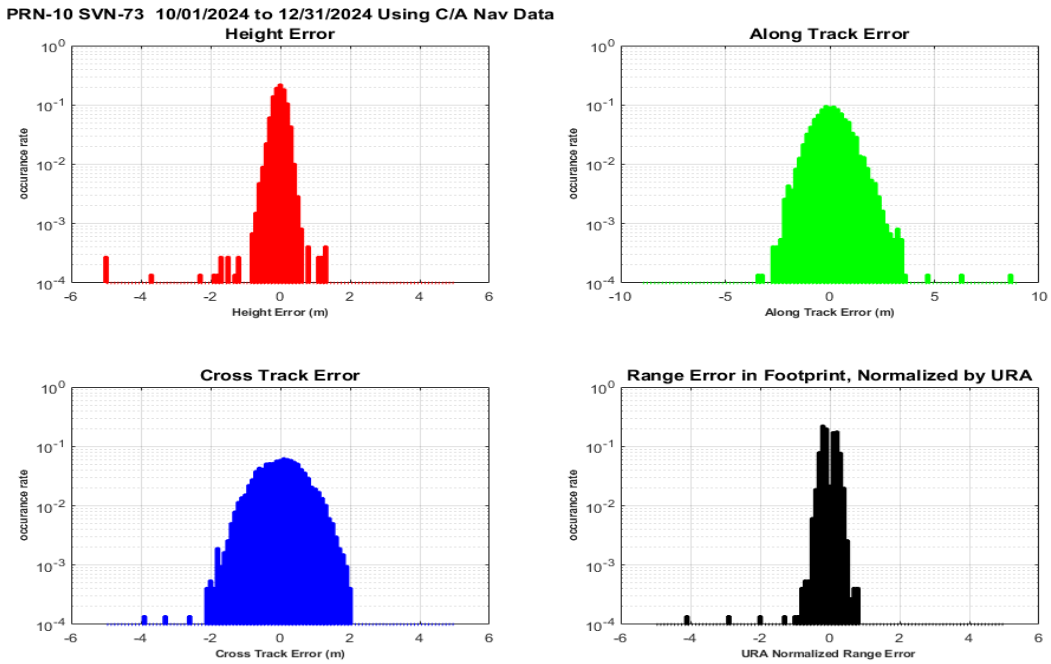


Figure 9-95 Histograms of H, A, C, and Range Error PRN10 (SVN73) Using C/A Nav Data

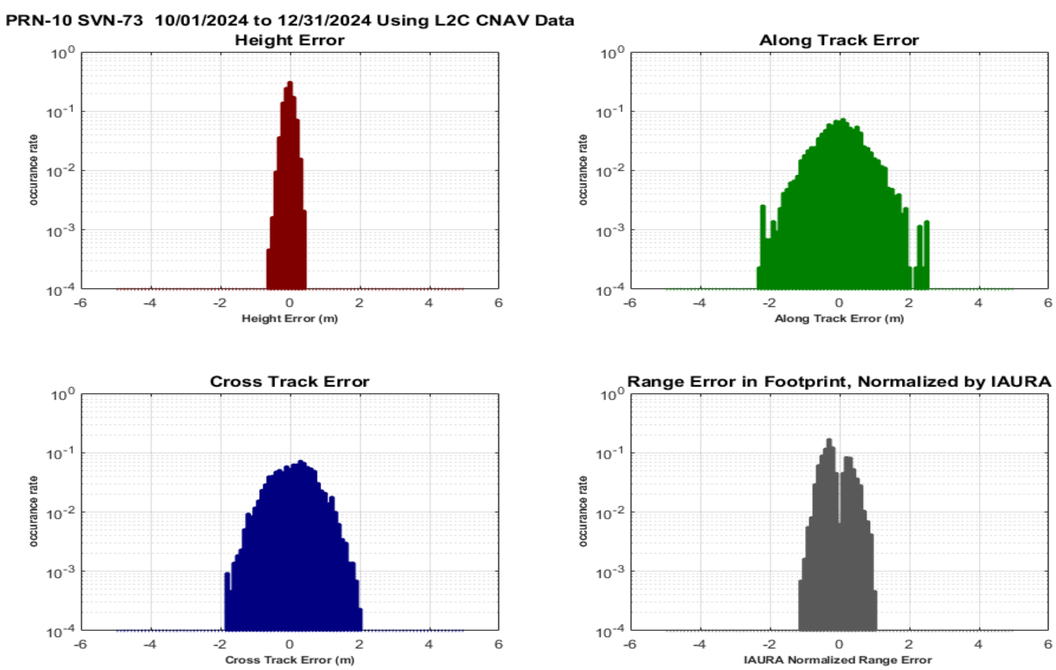


Figure 9-96 Histograms of H, A, C, and Range Error PRN10 (SVN73) Using L2C CNAV Data

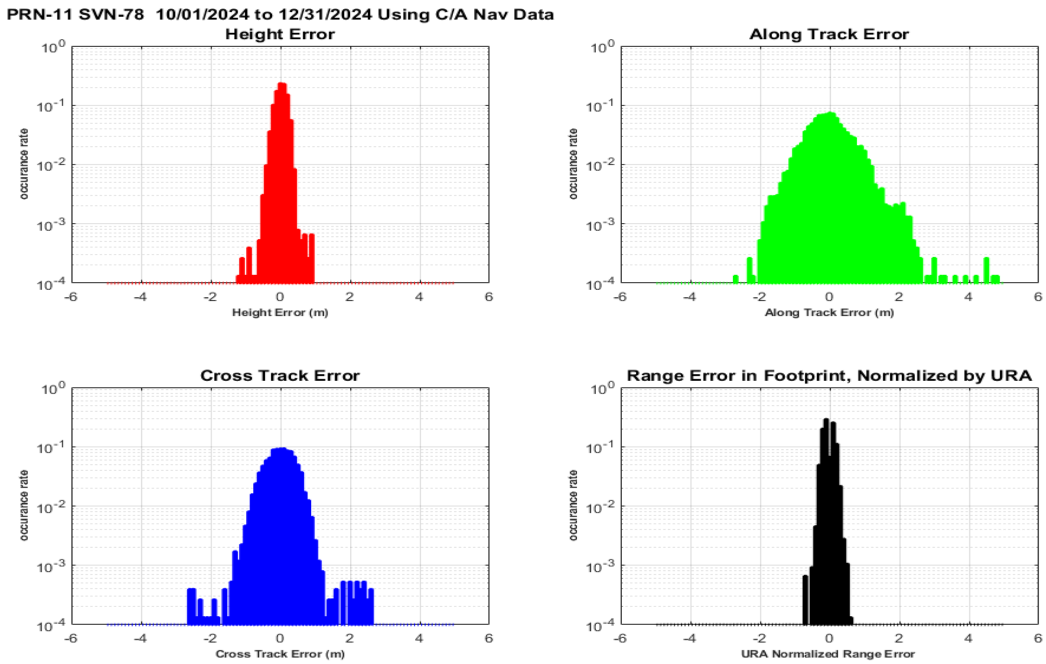


Figure 9-97 Histograms of H, A, C, and Range Error PRN11 (SVN78) Using C/A Nav Data

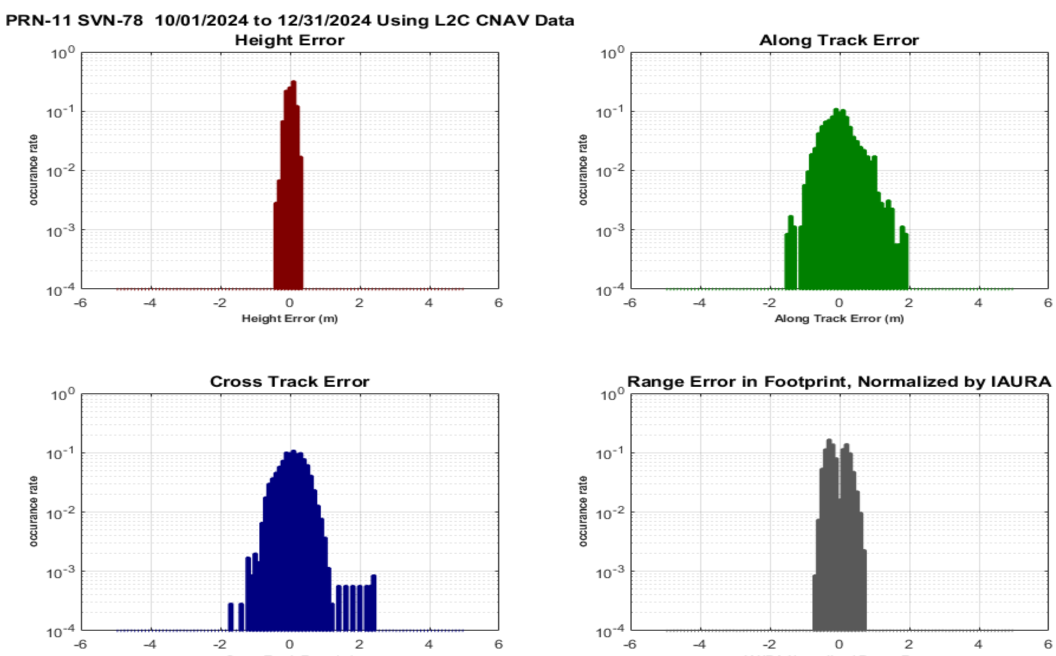


Figure 9-98 Histograms of H, A, C, and Range Error PRN11 (SVN78) Using L2C CNAV Data

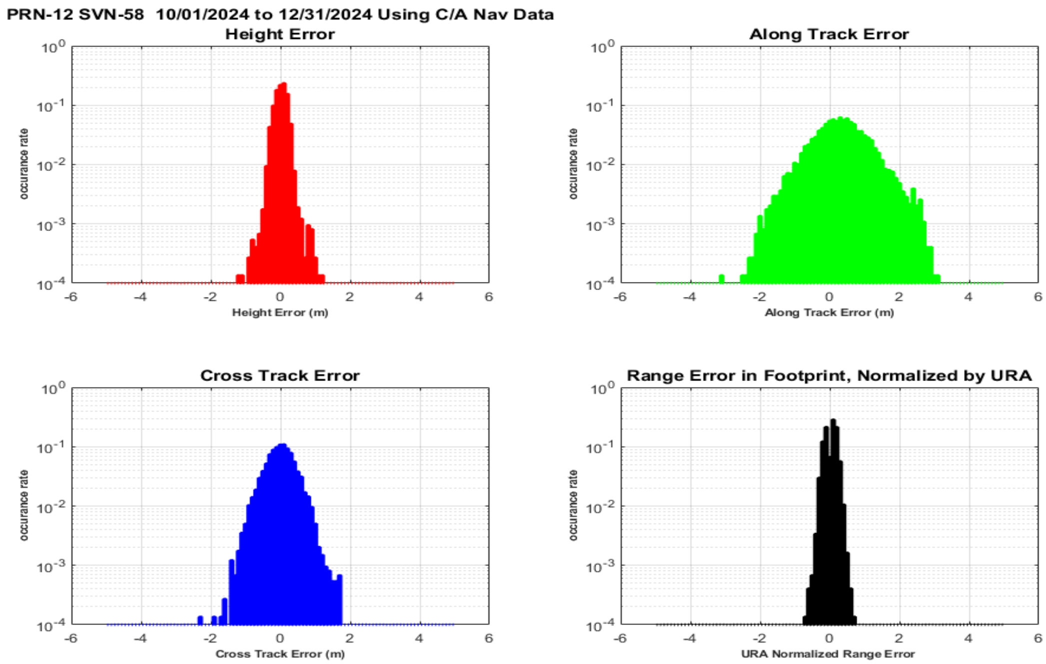


Figure 9-99 Histograms of H, A, C, and Range Error PRN12 (SVN58) Using C/A Nav Data

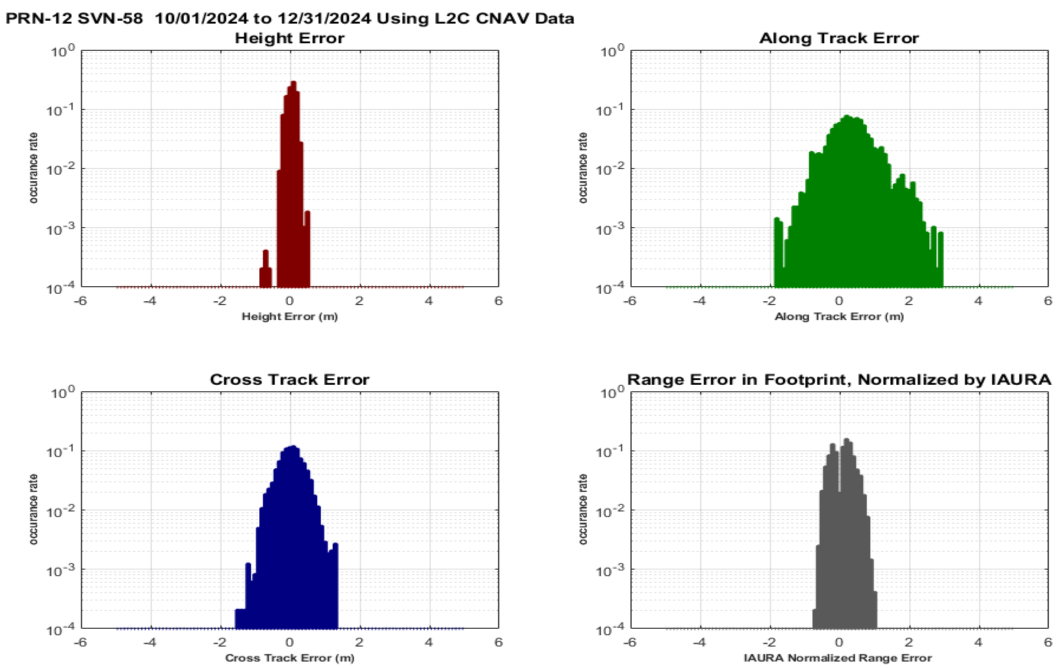


Figure 9-100 Histograms of H, A, C, and Range Error PRN12 (SVN58) Using L2C CNAV Data

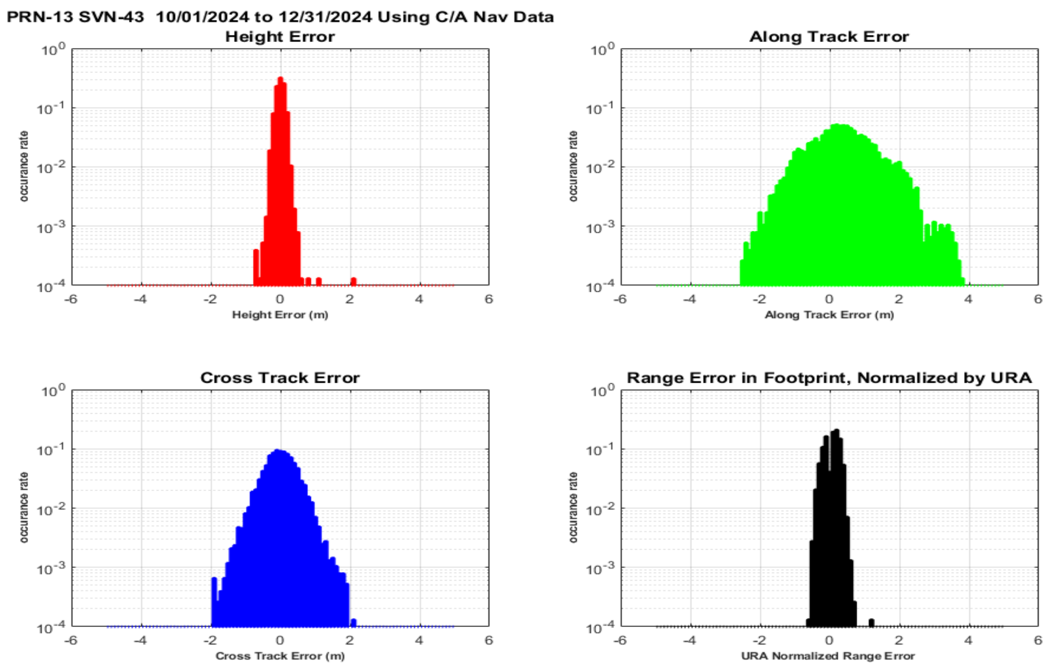


Figure 9-101 Histograms of H, A, C, and Range Error PRN13 (SVN43) Using C/A Nav Data

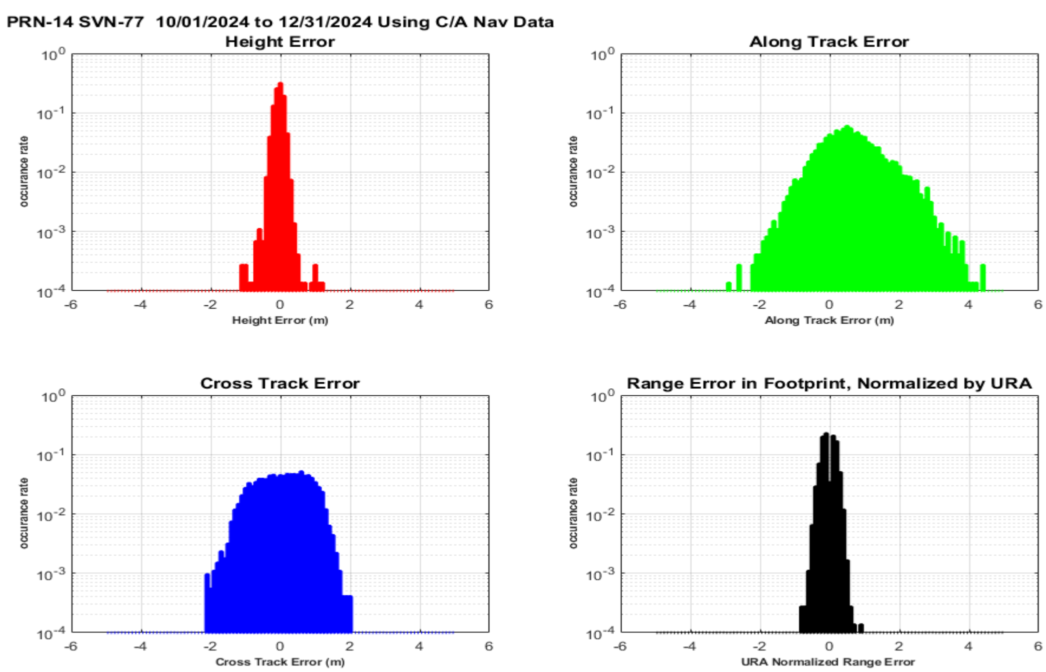


Figure 9-102 Histograms of H, A, C, and Range Error PRN14 (SVN77) Using C/A Nav Data

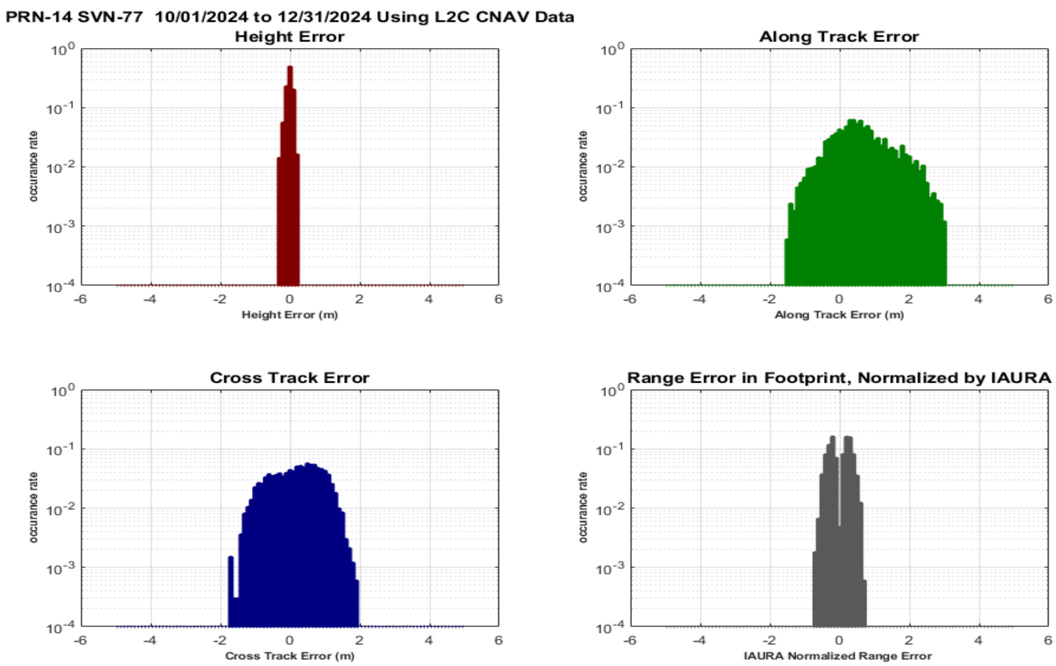


Figure 9-103 Histograms of H, A, C, and Range Error PRN14 (SVN77) Using L2C CNAV Data

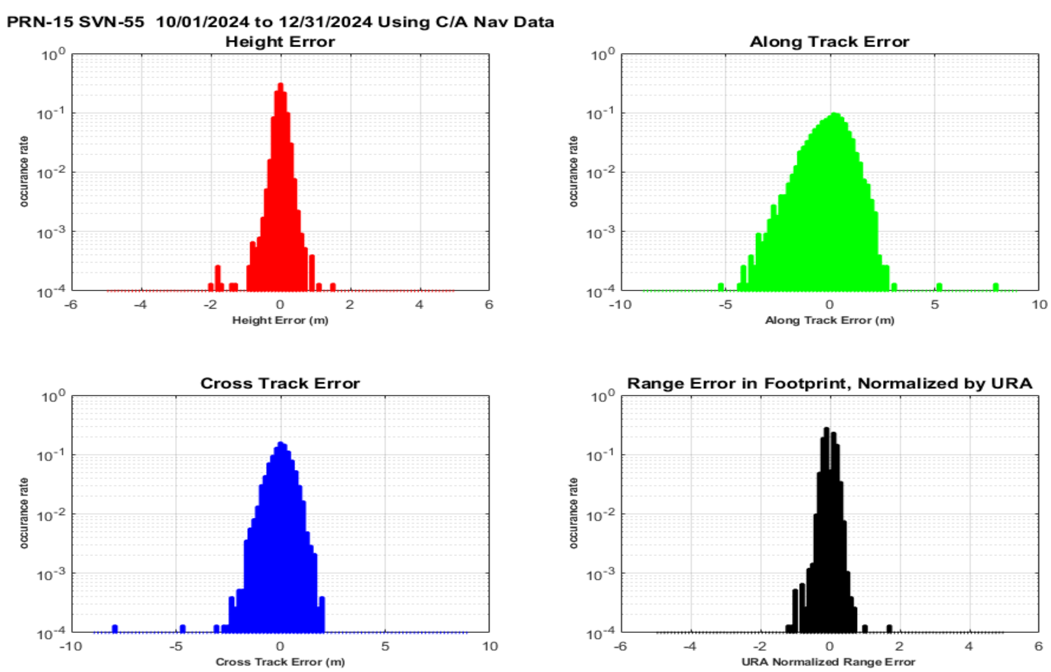


Figure 9-104 Histograms of H, A, C, and Range Error PRN15 (SVN55) Using C/A Nav Data

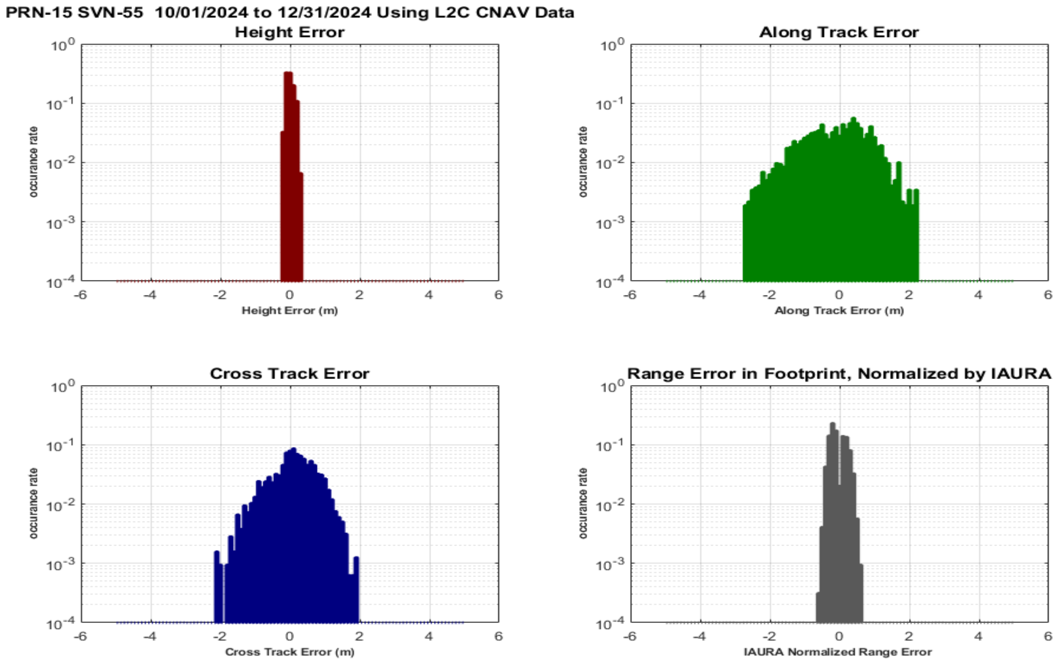


Figure 9-105 Histograms of H, A, C, and Range Error PRN15 (SVN55) Using L2C CNAV Data

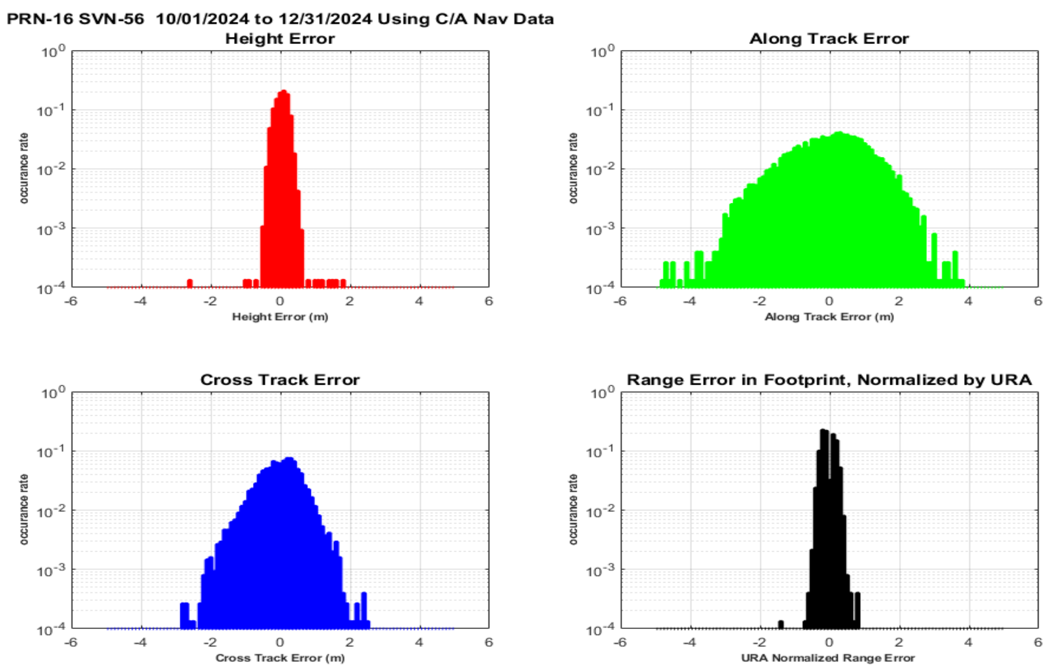


Figure 9-106 Histograms of H, A, C, and Range Error PRN16 (SVN56) Using C/A Nav Data

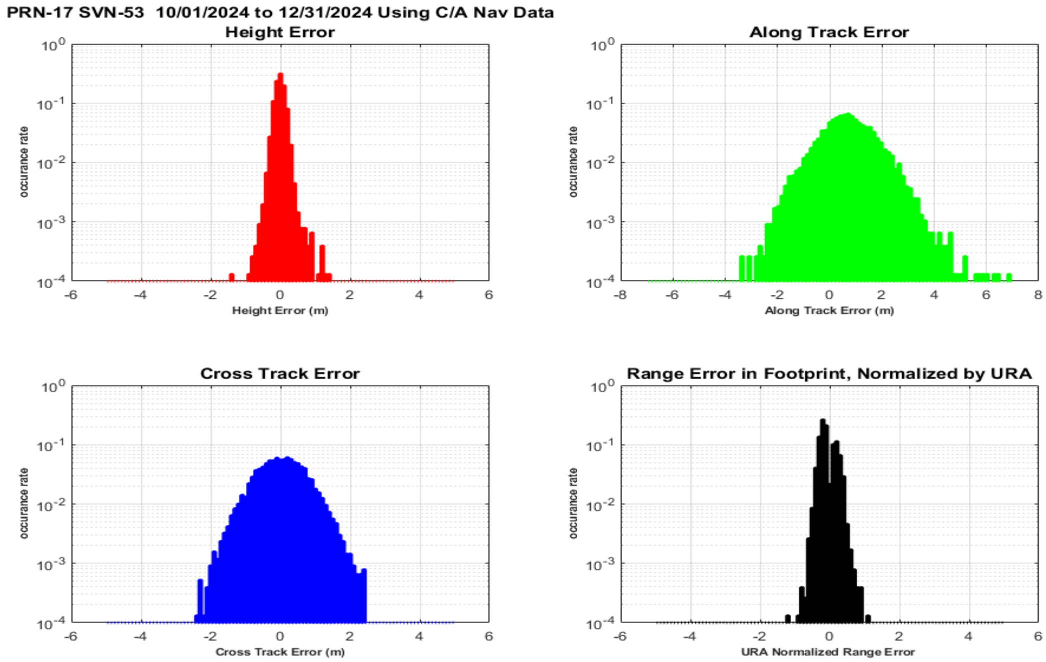


Figure 9-107 Histograms of H, A, C, and Range Error PRN17 (SVN53) Using C/A Nav Data

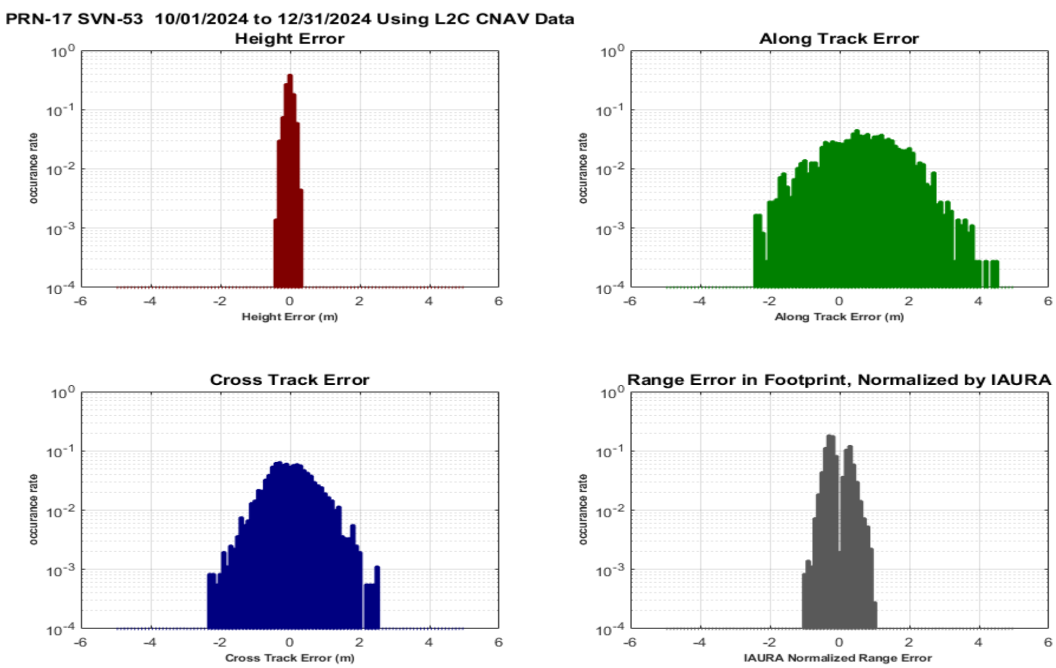


Figure 9-108 Histograms of H, A, C, and Range Error PRN17 (SVN53) Using L2C CNAV Data

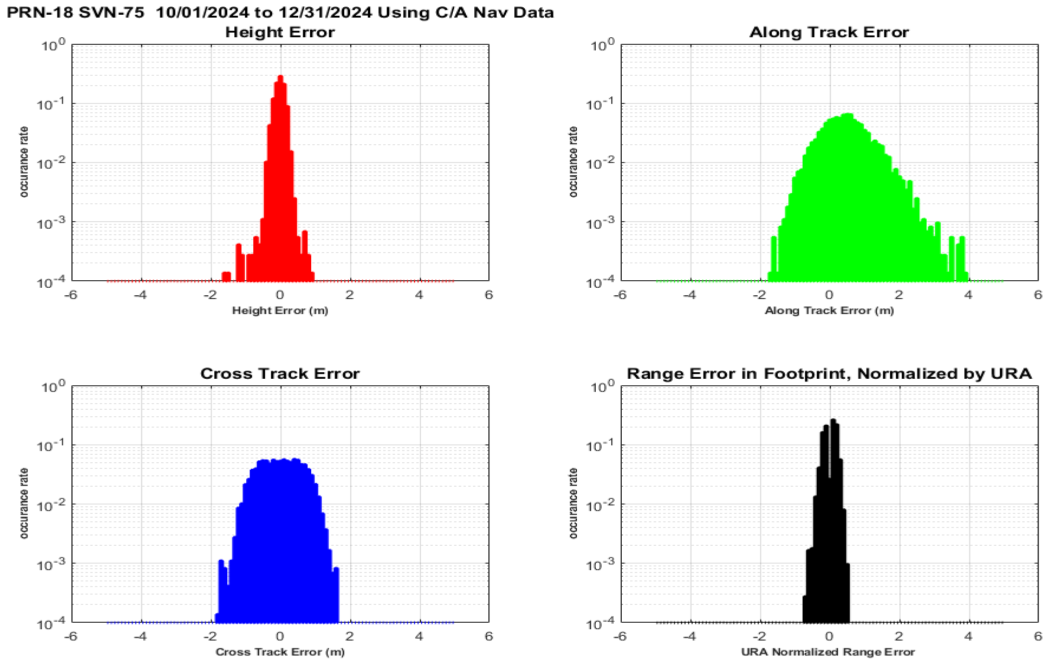


Figure 9-109 Histograms of H, A, C, and Range Error PRN18 (SVN75) Using C/A Nav Data

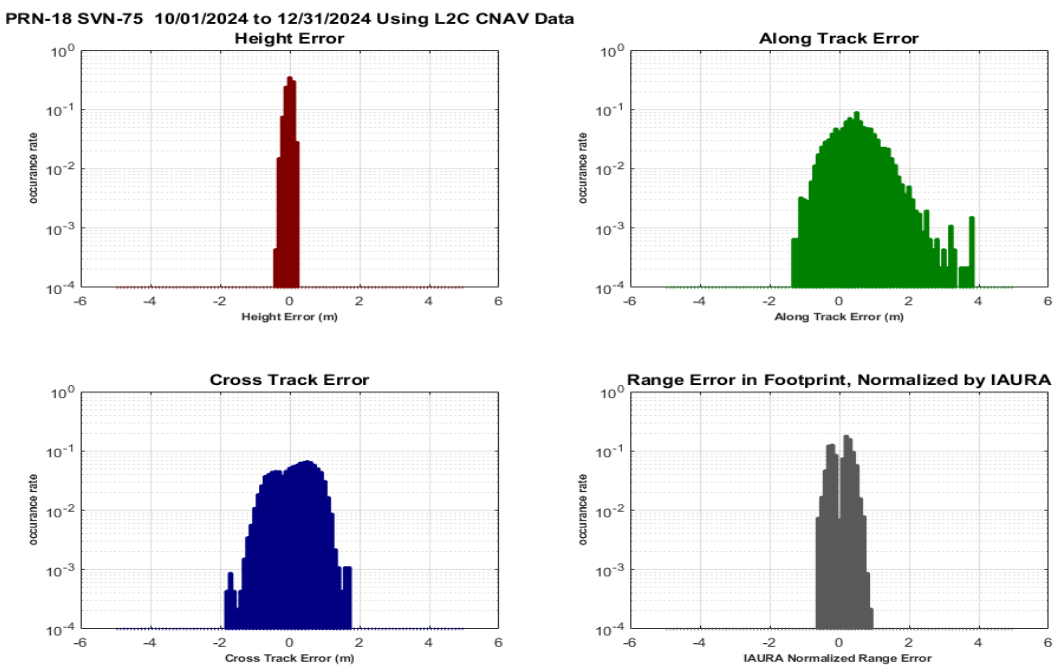


Figure 9-110 Histograms of H, A, C, and Range Error PRN18 (SVN75) Using L2C CNAV Data

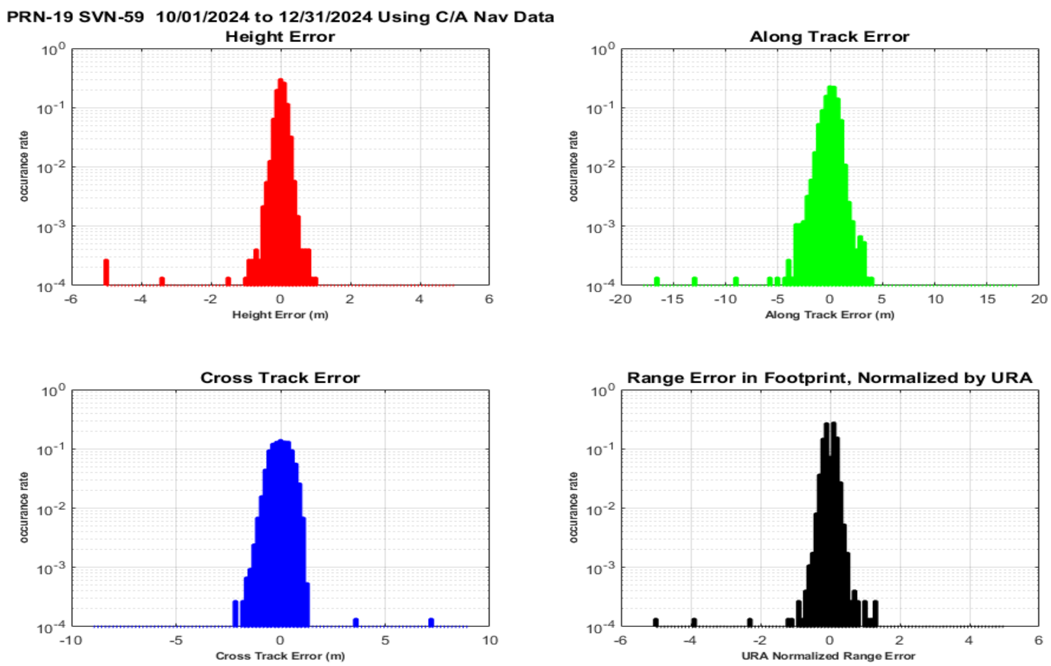


Figure 9-111 Histograms of H, A, C, and Range Error PRN19 (SVN59) Using C/A Nav Data

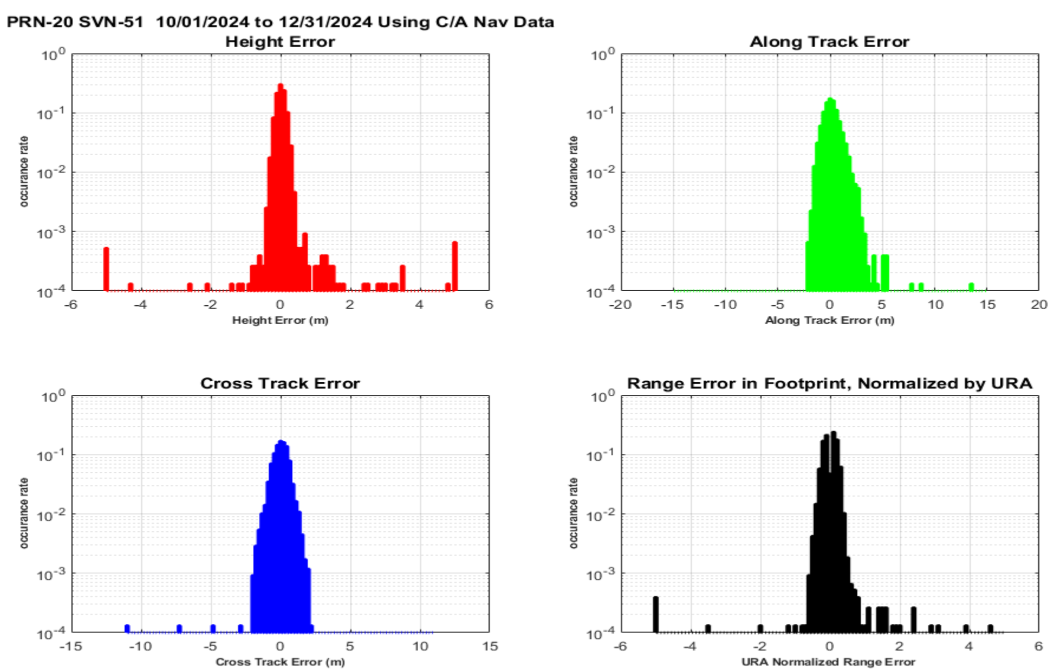


Figure 9-112 Histograms of H, A, C, and Range Error PRN20 (SVN51) Using C/A Nav Data

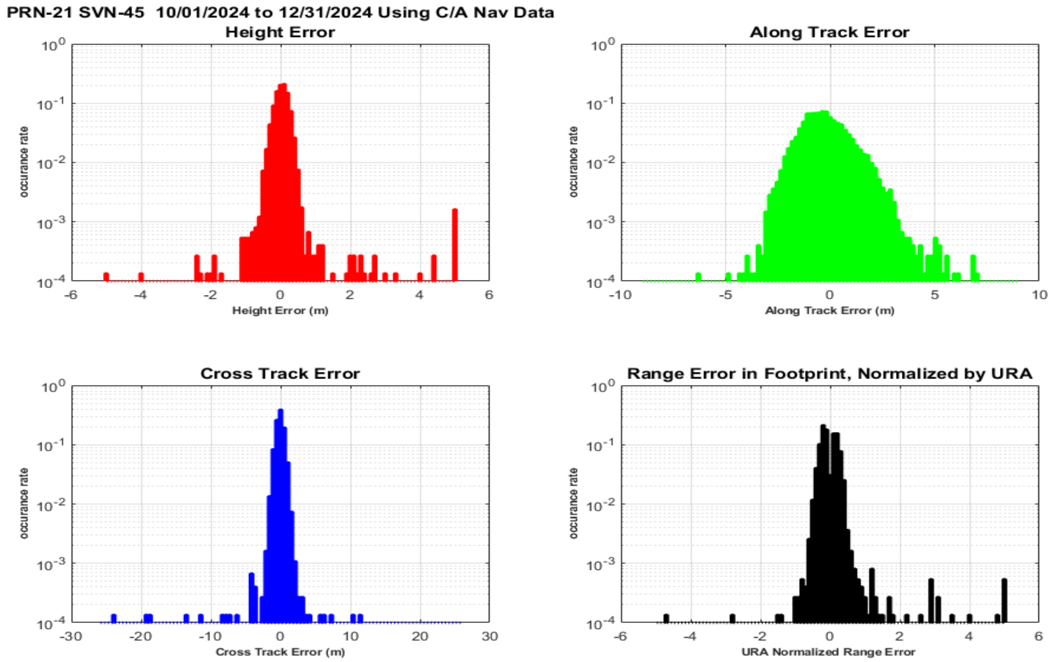


Figure 9-113 Histograms of H, A, C, and Range Error PRN21 (SVN45) Using C/A Nav Data

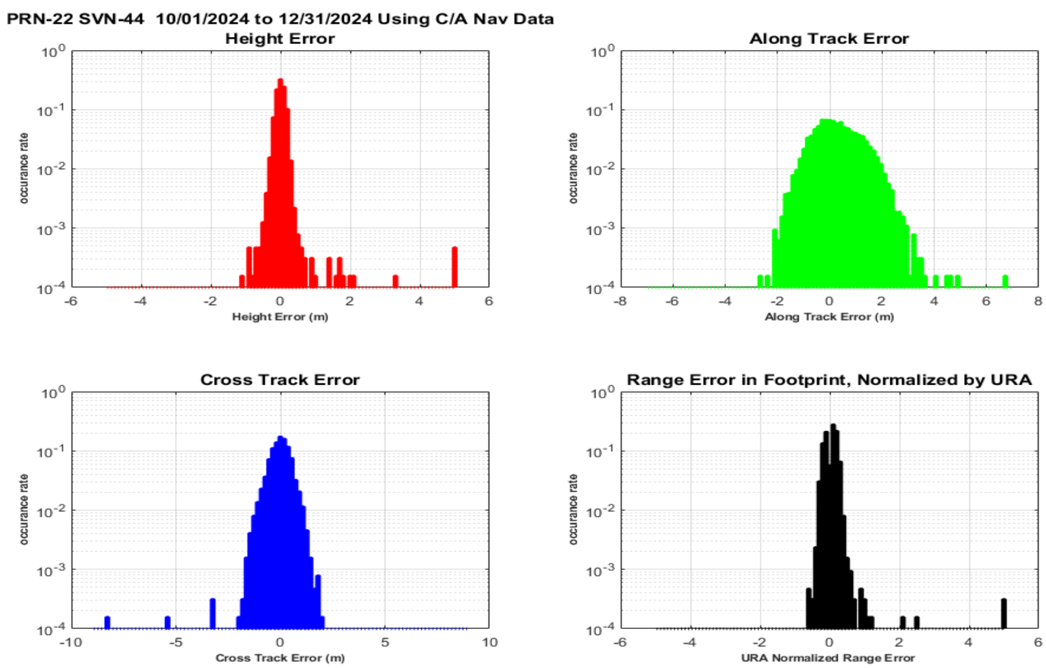


Figure 9-114 Histograms of H, A, C, and Range Error PRN22 (SVN44) Using C/A Nav Data

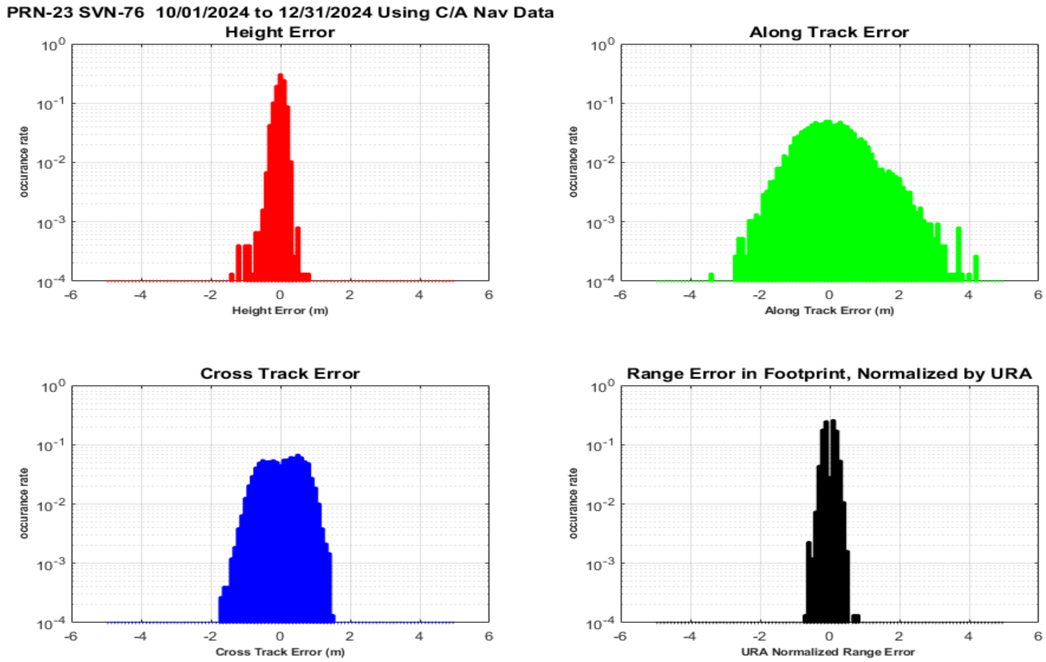


Figure 9-115 Histograms of H, A, C, and Range Error PRN23 (SVN76) Using C/A Nav Data

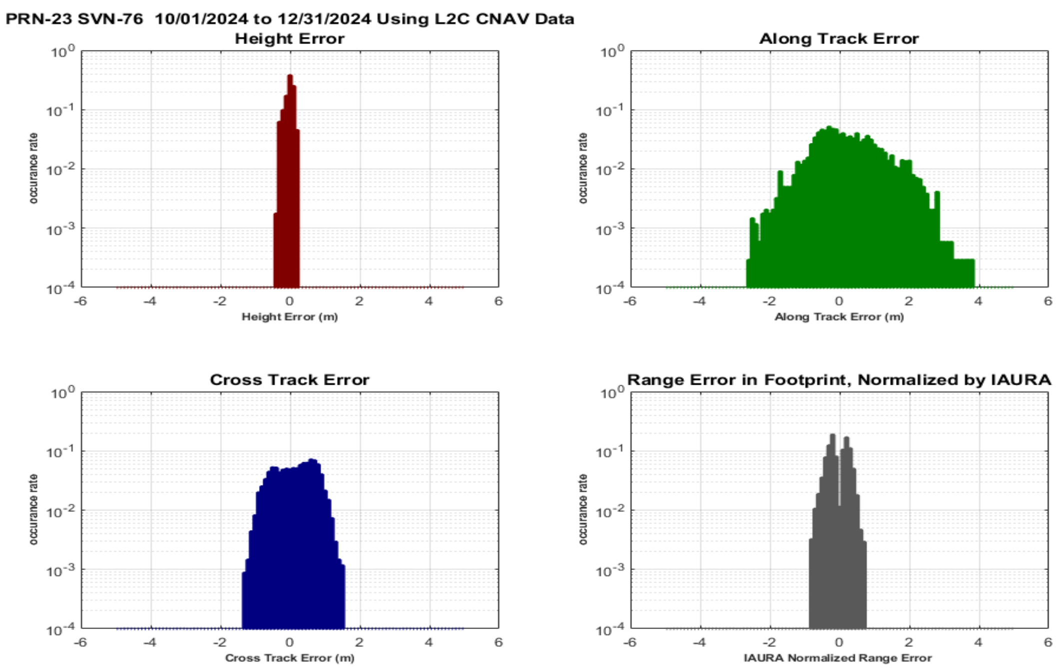


Figure 9-116 Histograms of H, A, C, and Range Error PRN23 (SVN76) Using L2C CNAV Data

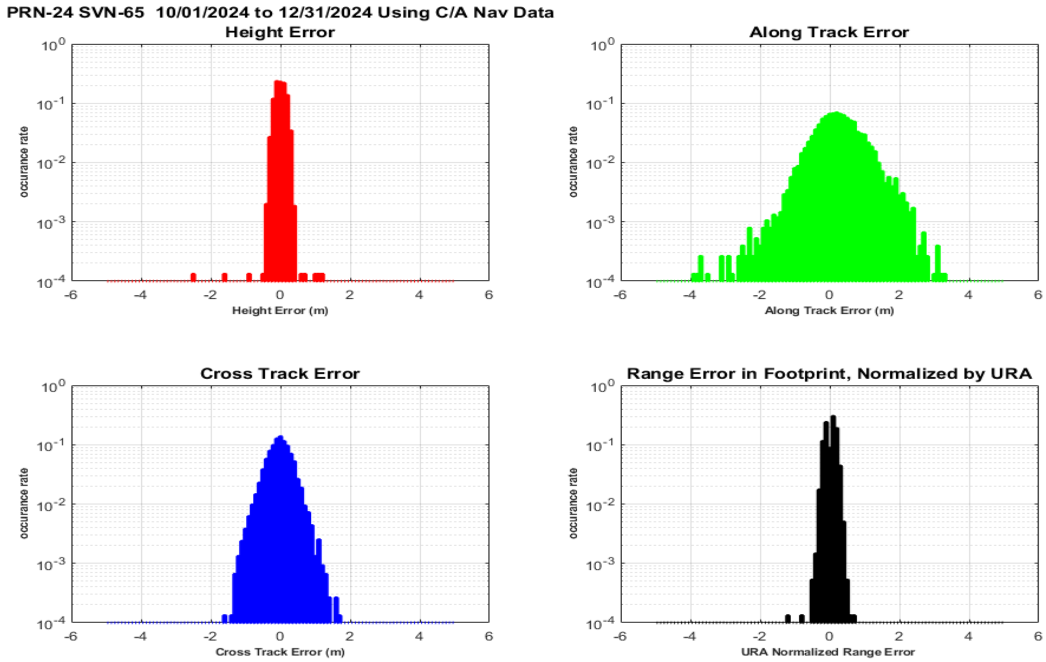


Figure 9-117 Histograms of H, A, C, and Range Error PRN24 (SVN65) Using C/A Nav Data

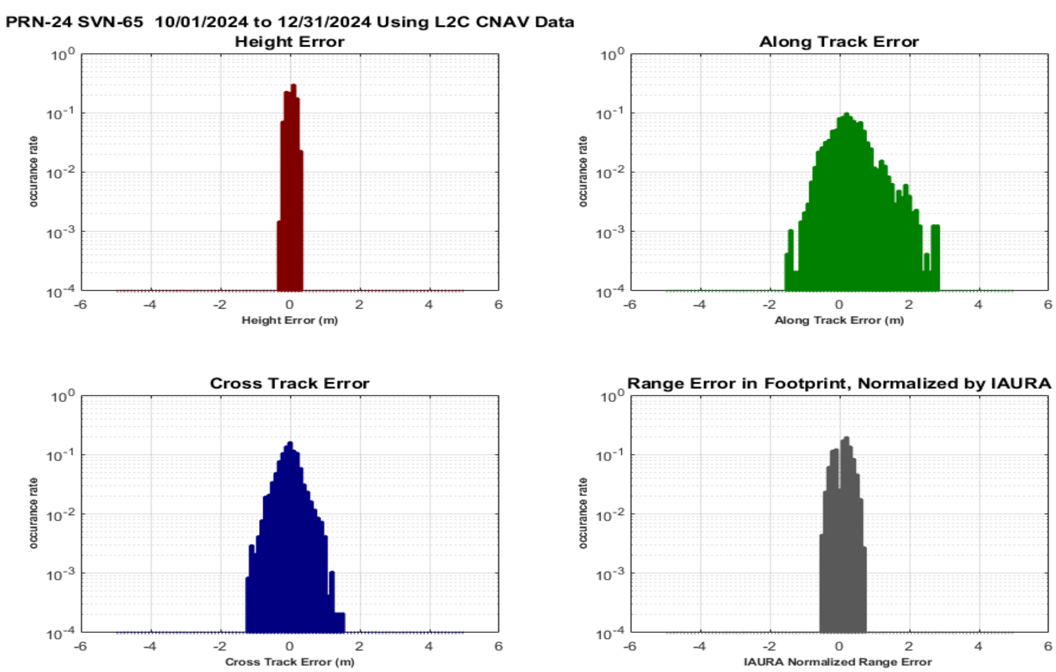


Figure 9-118 Histograms of H, A, C, and Range Error PRN24 (SVN65) Using L2C CNAV Data

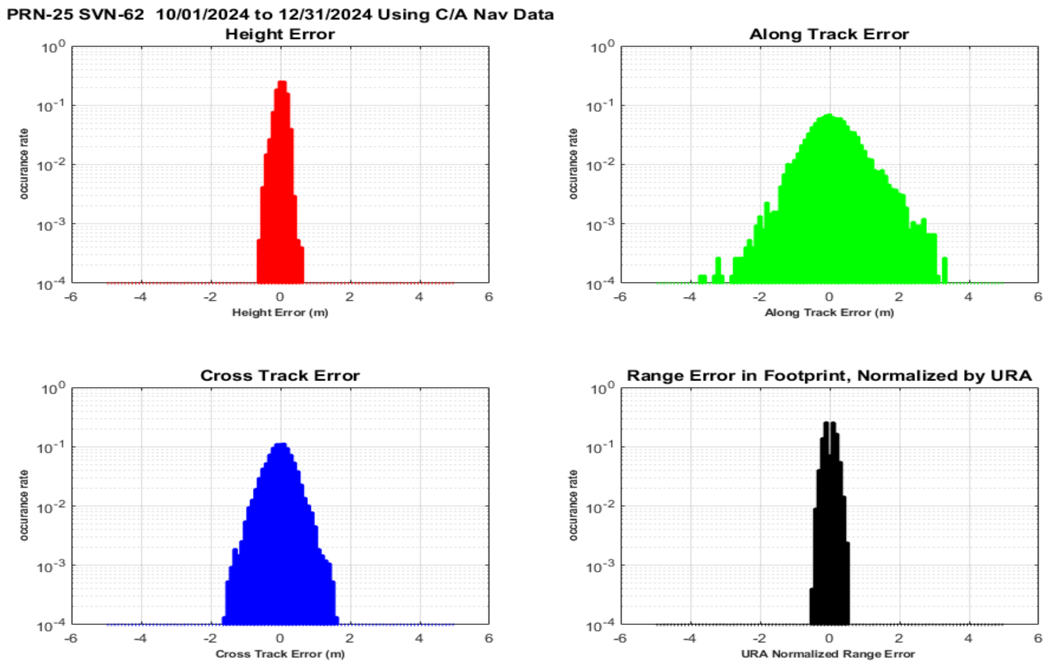


Figure 9-119 Histograms of H, A, C, and Range Error PRN25 (SVN62) Using C/A Nav Data

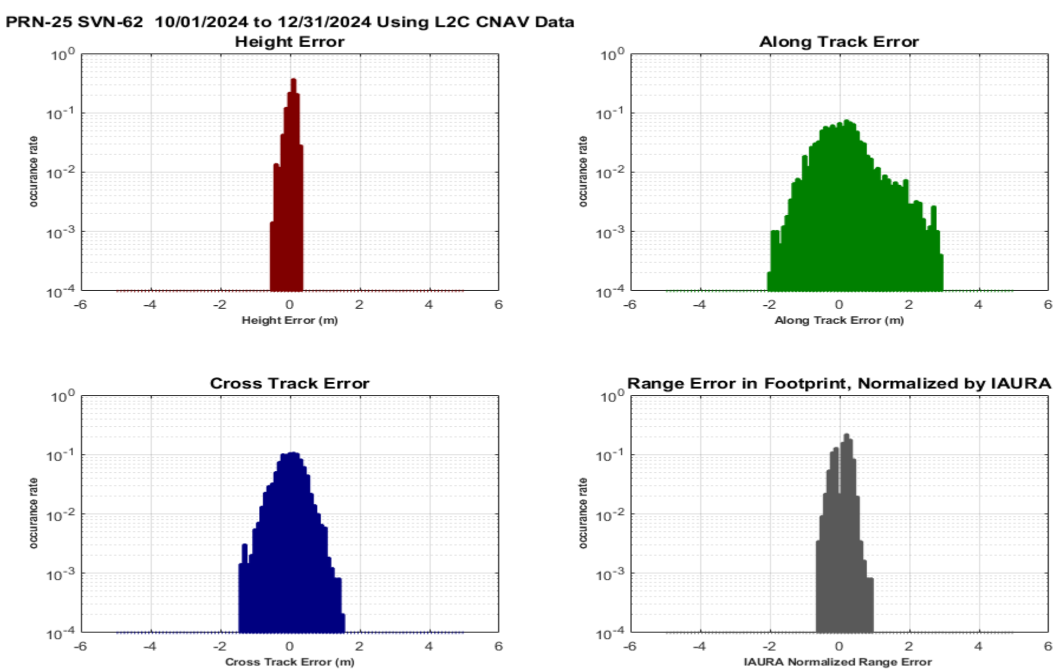


Figure 9-120 Histograms of H, A, C, and Range Error PRN25 (SVN62) Using L2C CNAV Data

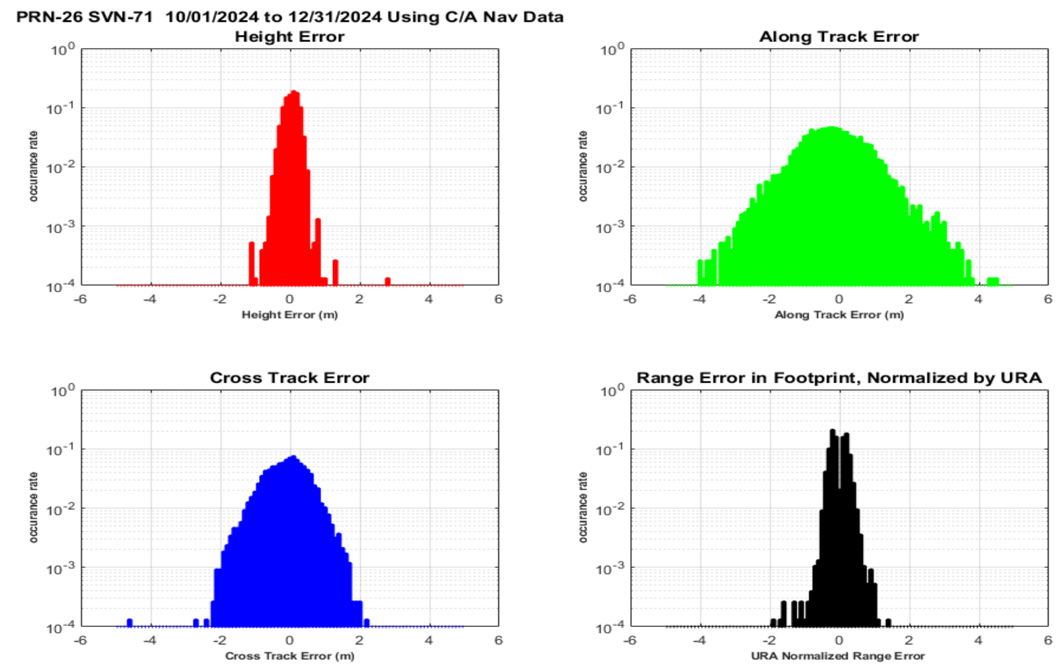


Figure 9-121 Histograms of H, A, C, and Range Error PRN26 (SVN71) Using C/A Nav Data

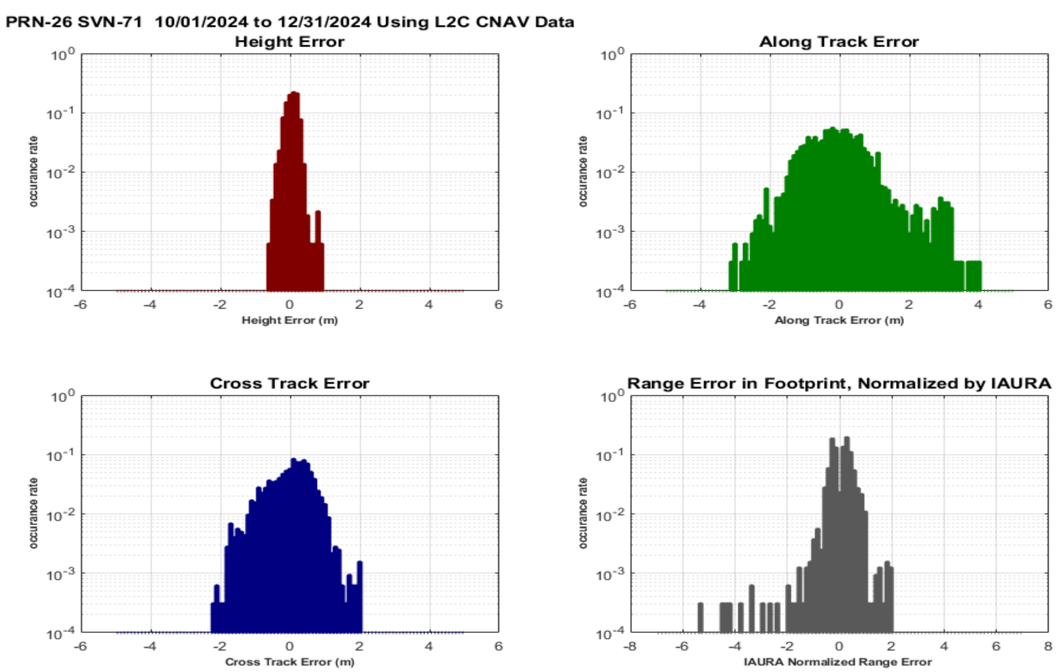


Figure 9-122 Histograms of H, A, C, and Range Error PRN26 (SVN71) Using L2C CNAV Data

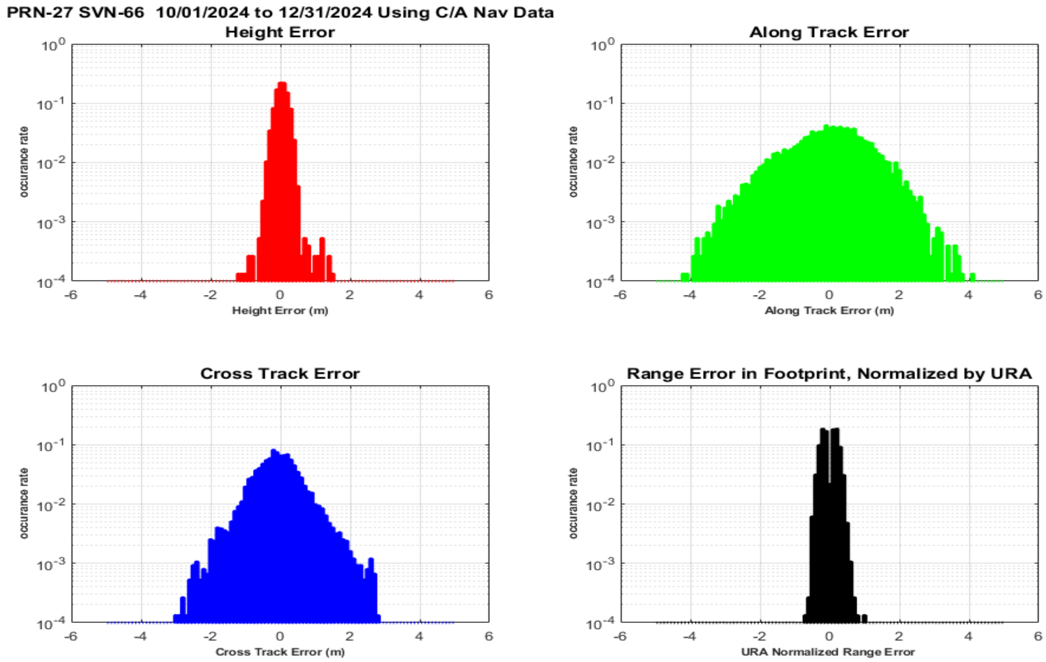


Figure 9-123 Histograms of H, A, C, and Range Error PRN27 (SVN66) Using C/A Nav Data

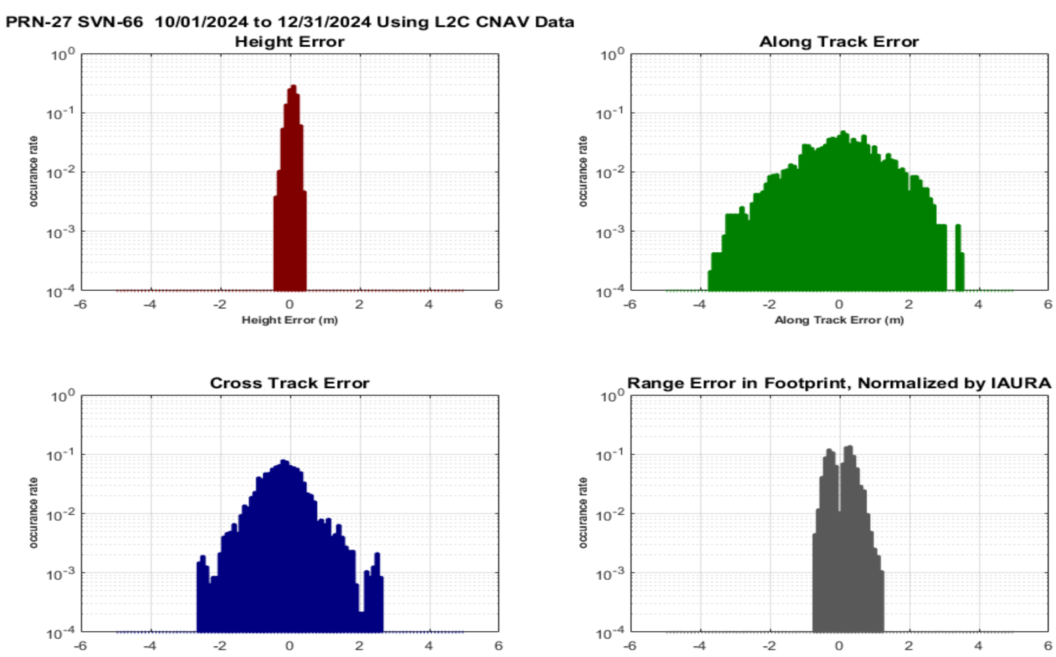


Figure 9-124 Histograms of H, A, C, and Range Error PRN27 (SVN66) Using L2C CNAV Data

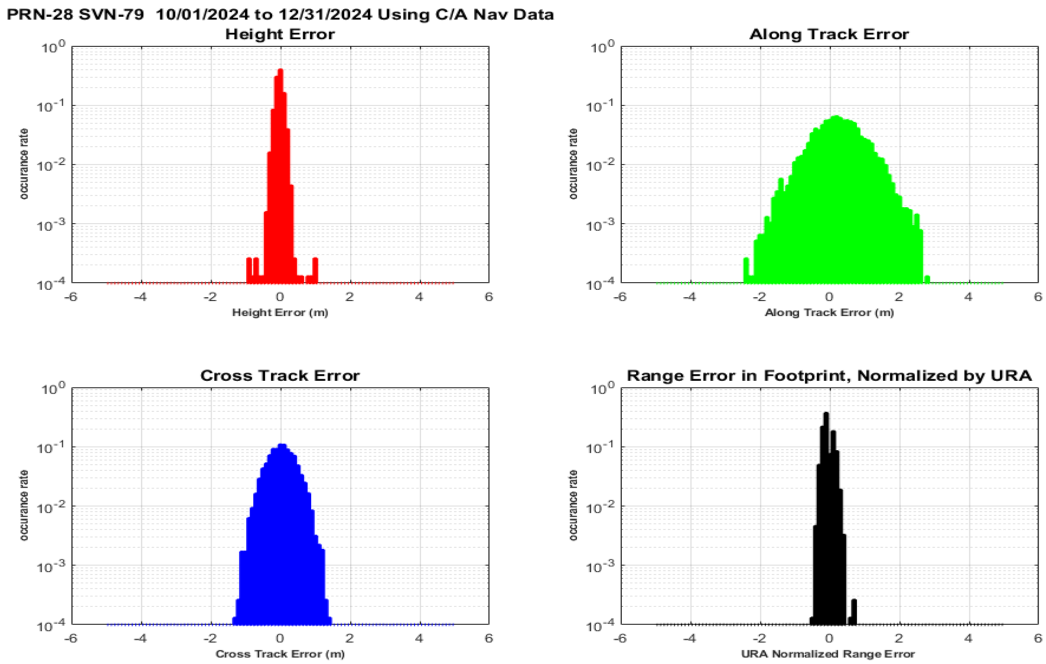


Figure 9-125 Histograms of H, A, C, and Range Error PRN28 (SVN79) Using C/A Nav Data

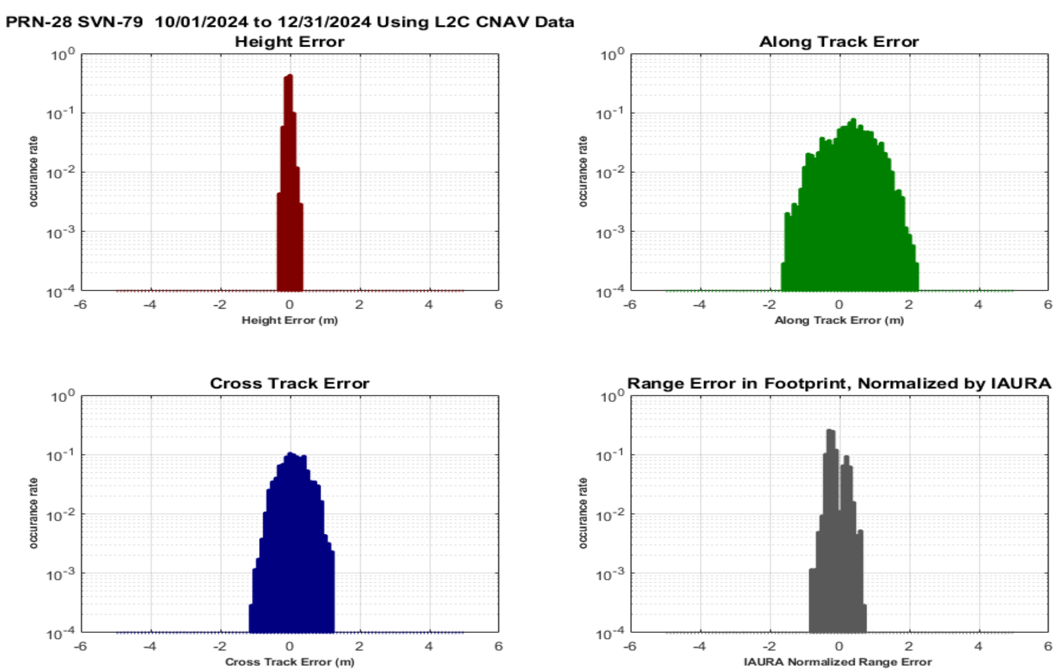


Figure 9-126 Histograms of H, A, C, and Range Error PRN28 (SVN79) Using L2C CNAV Data

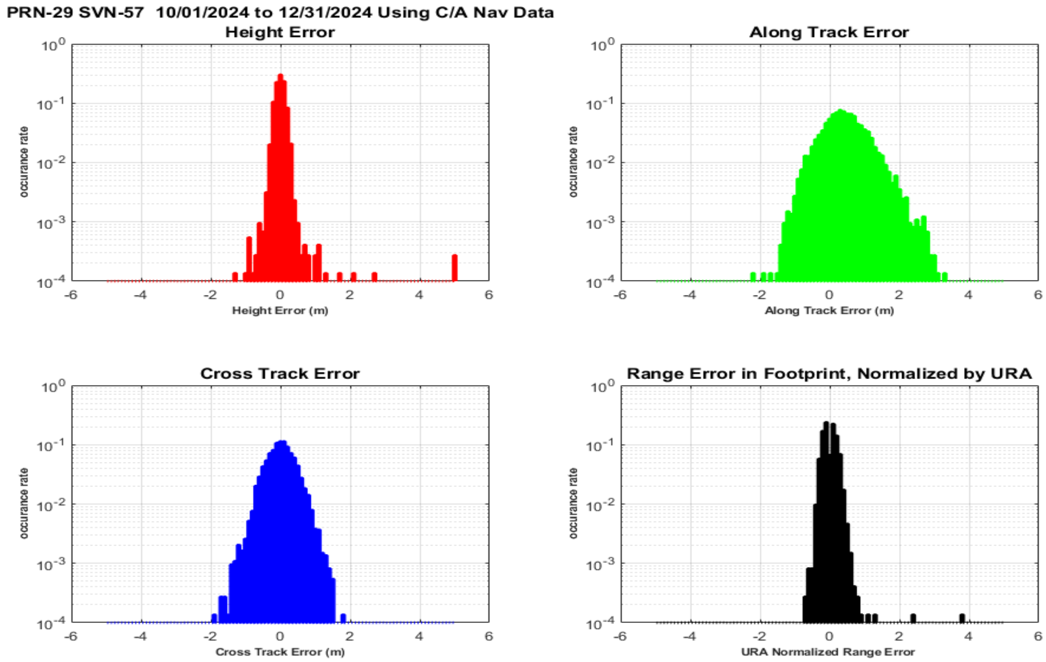


Figure 9-127 Histograms of H, A, C, and Range Error PRN29 (SVN57) Using C/A Nav Data

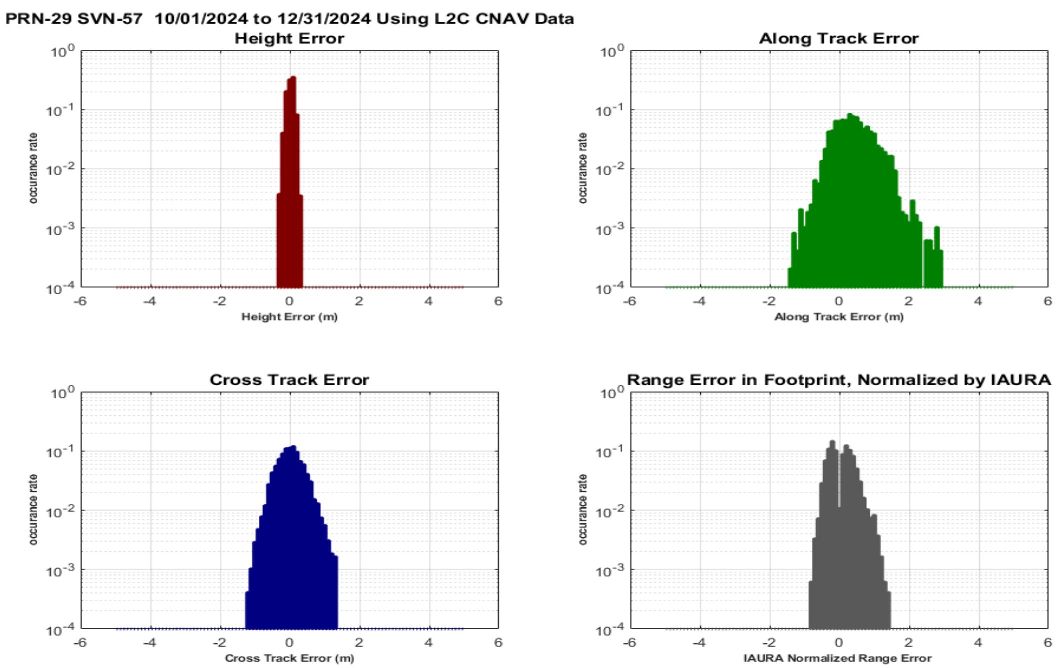


Figure 9-128 Histograms of H, A, C, and Range Error PRN29 (SVN57) Using L2C CNAV Data

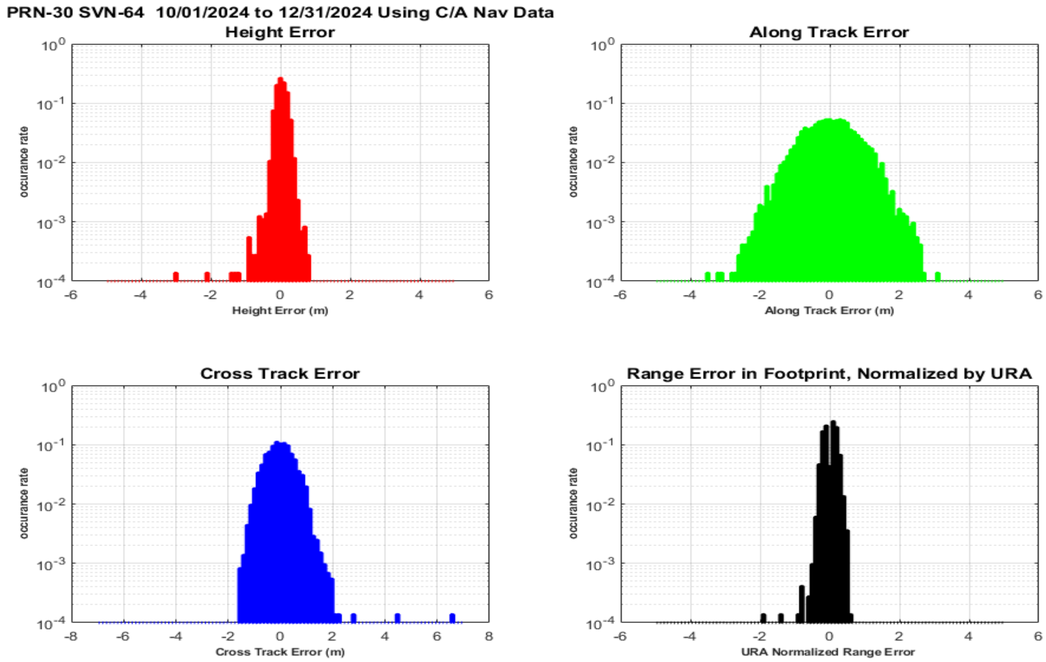


Figure 9-129 Histograms of H, A, C, and Range Error PRN30 (SVN64) Using C/A Nav Data

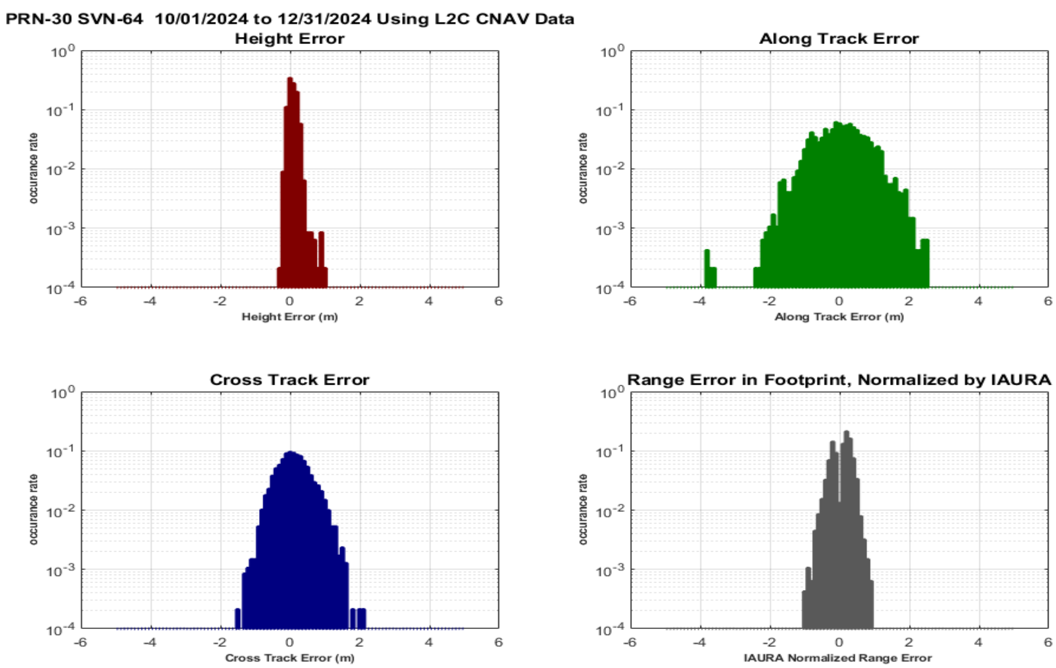


Figure 9-130 Histograms of H, A, C, and Range Error PRN30 (SVN64) Using L2C CNAV Data

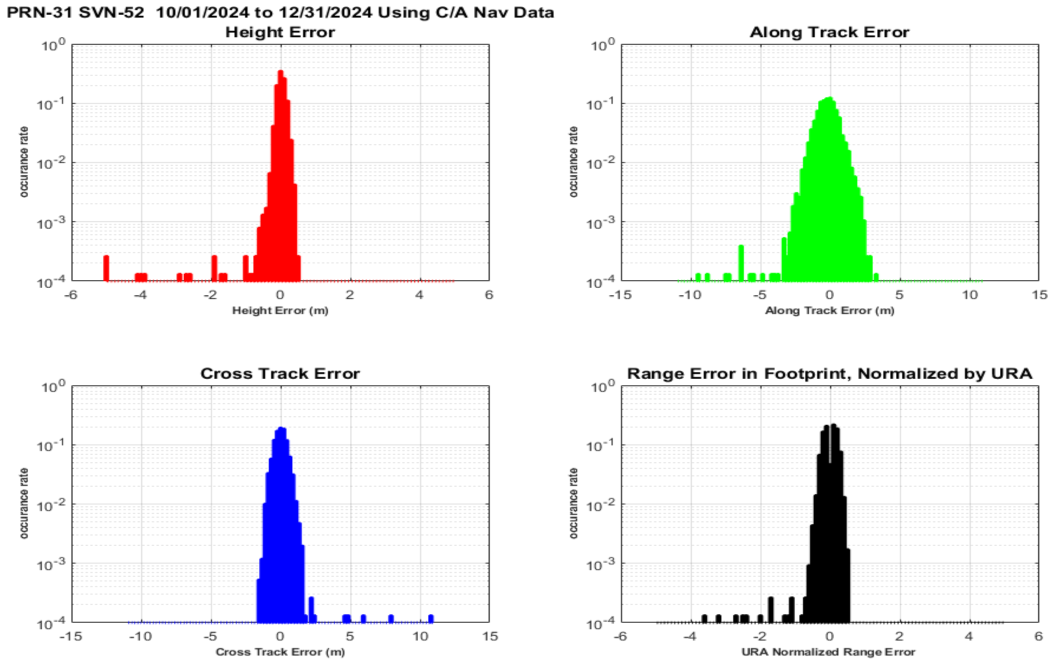


Figure 9-131 Histograms of H, A, C, and Range Error PRN31 (SVN52) Using C/A Nav Data

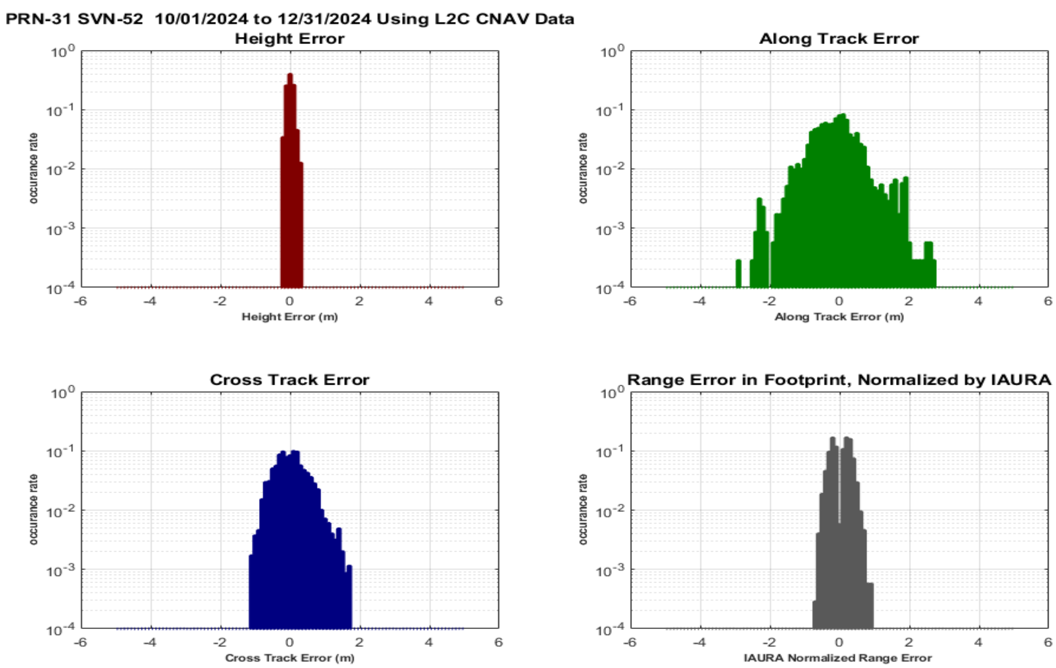


Figure 9-132 Histograms of H, A, C, and Range Error PRN31 (SVN52) Using L2C CNAV Data

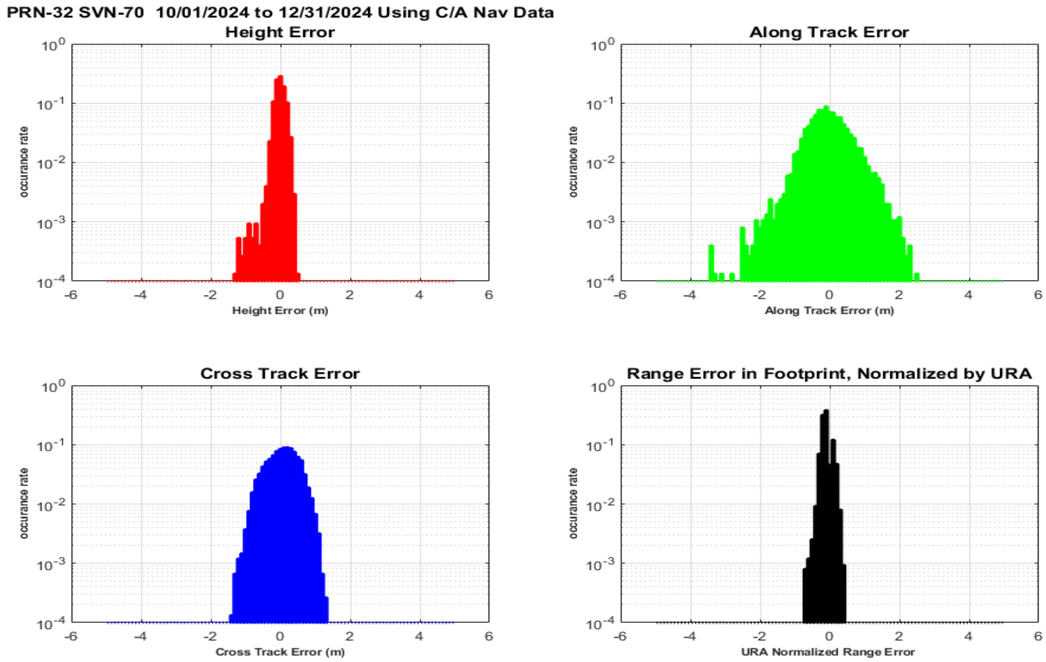


Figure 9-133 Histograms of H, A, C, and Range Error PRN32 (SVN70) Using C/A Nav Data

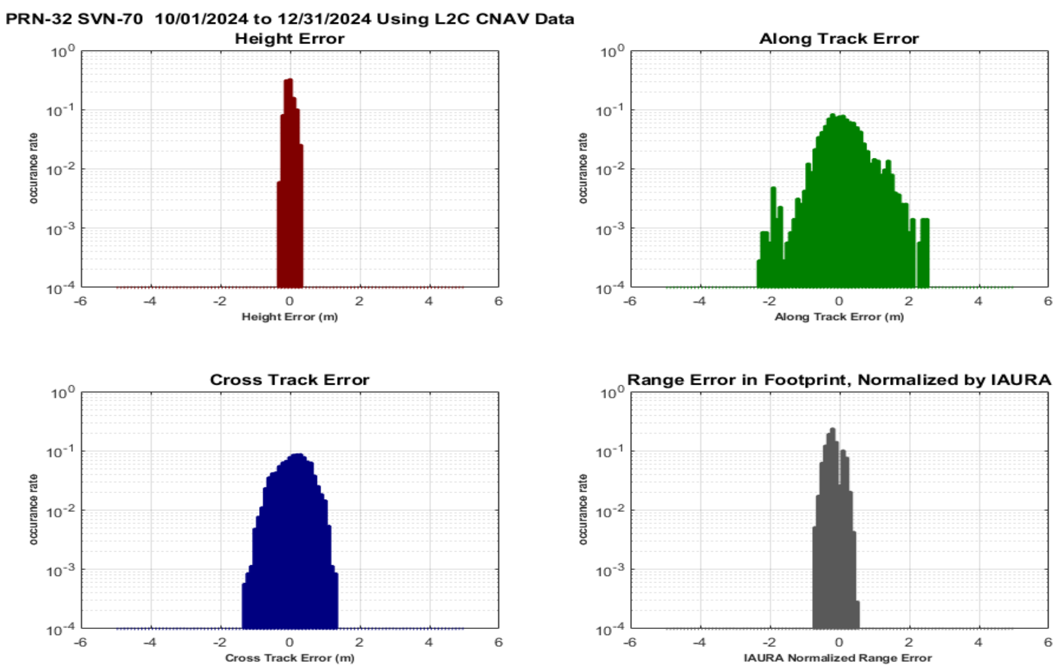


Figure 9-134 Histograms of H, A, C, and Range Error PRN32 (SVN70) Using L2C CNAV Data

9.8 Timeline of URA Normalized Range Error for All Satellites

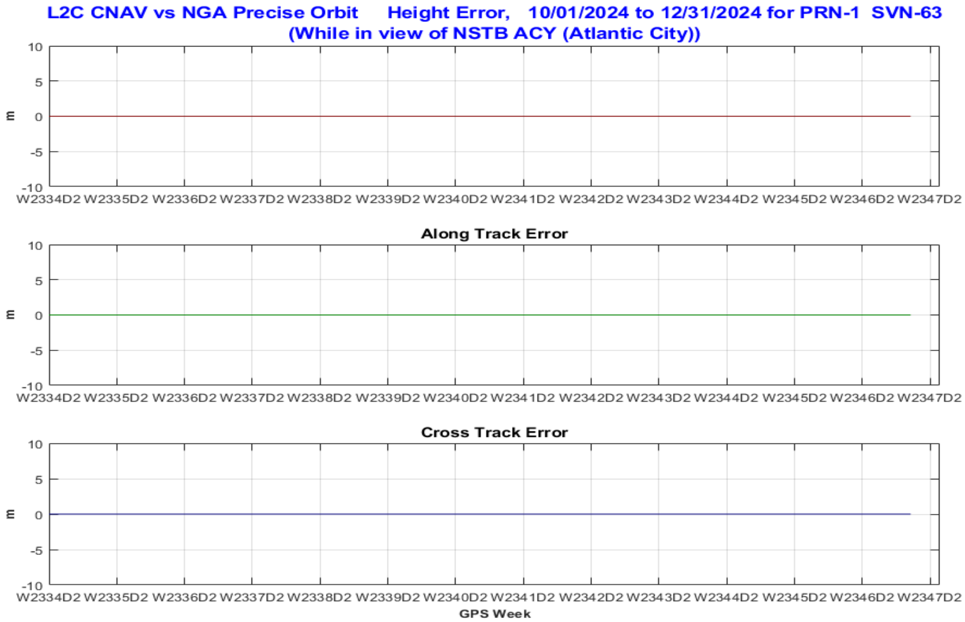


Figure 9-135 Timeline of IAURA Normalized Range Error PRN1 (SVN63) Using L2C CNAV Data

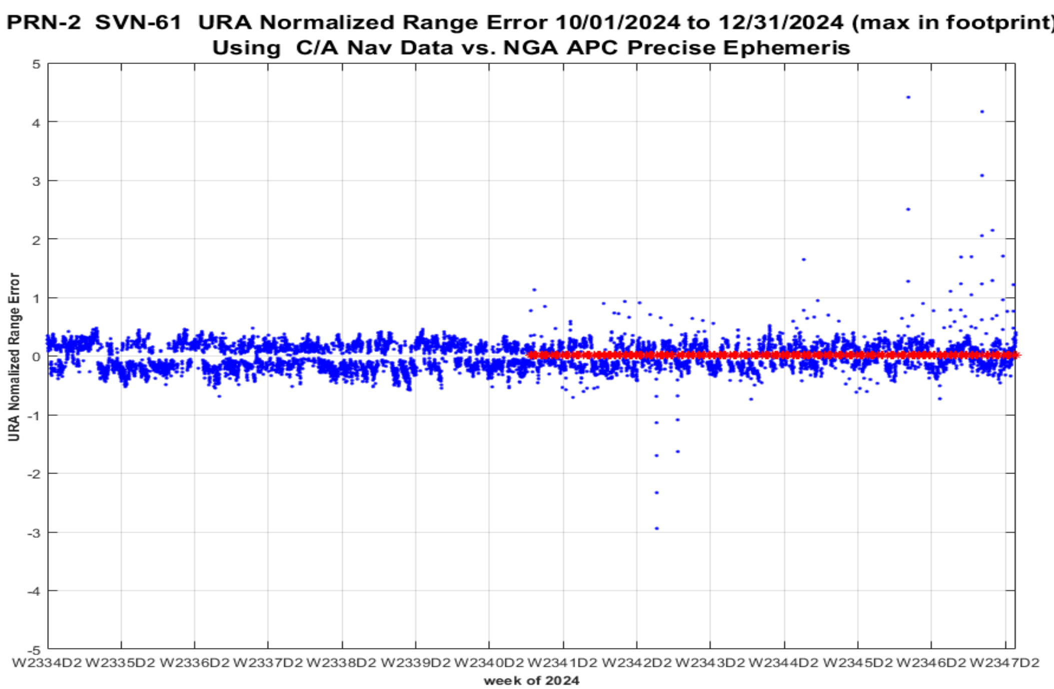


Figure 9-136 Timeline of URA Normalized Range Error PRN2 (SVN61) Using C/A Nav Data

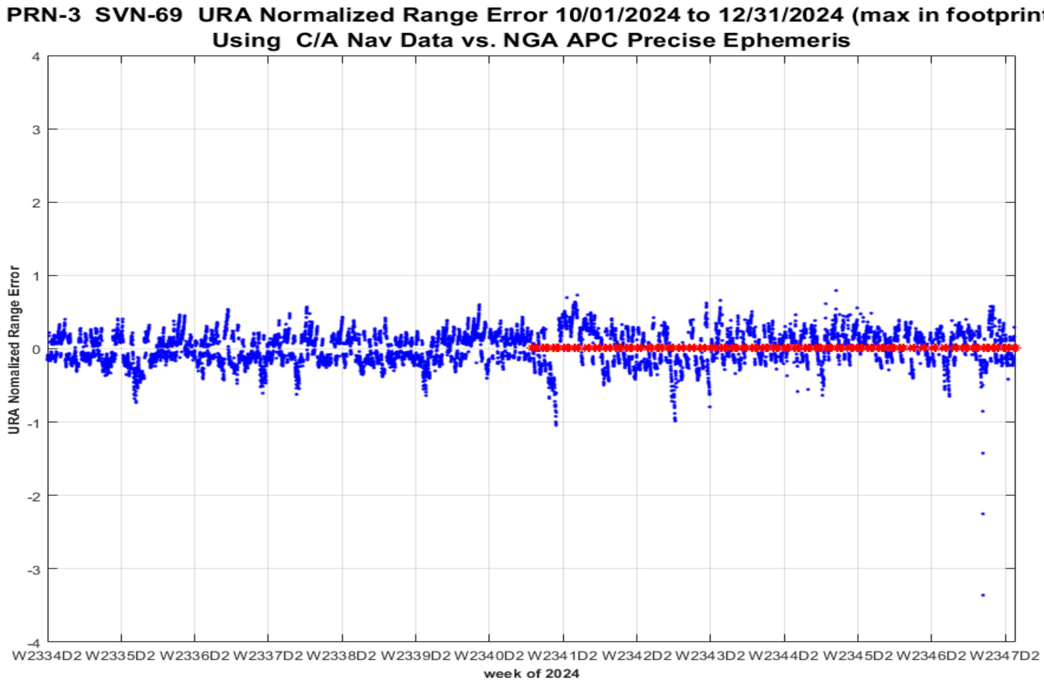


Figure 9-137 Timeline of URA Normalized Range Error PRN3 (SVN69) Using C/A Nav Data

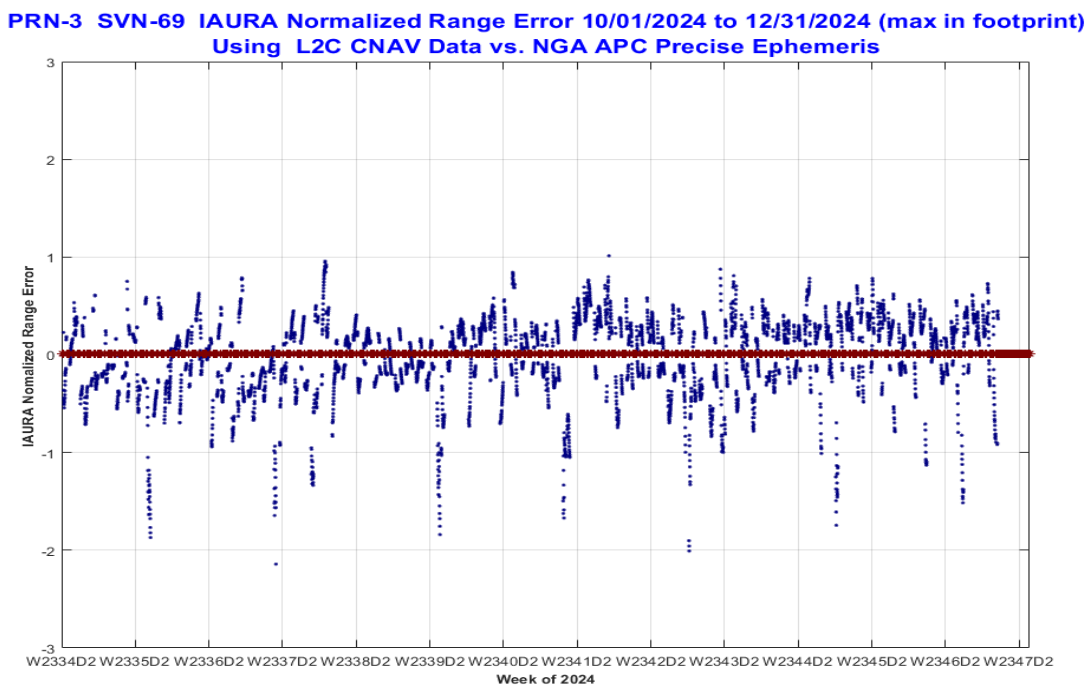


Figure 9-138 Timeline of IAURA Normalized Range Error PRN3 (SVN69) Using L2C CNAV Data

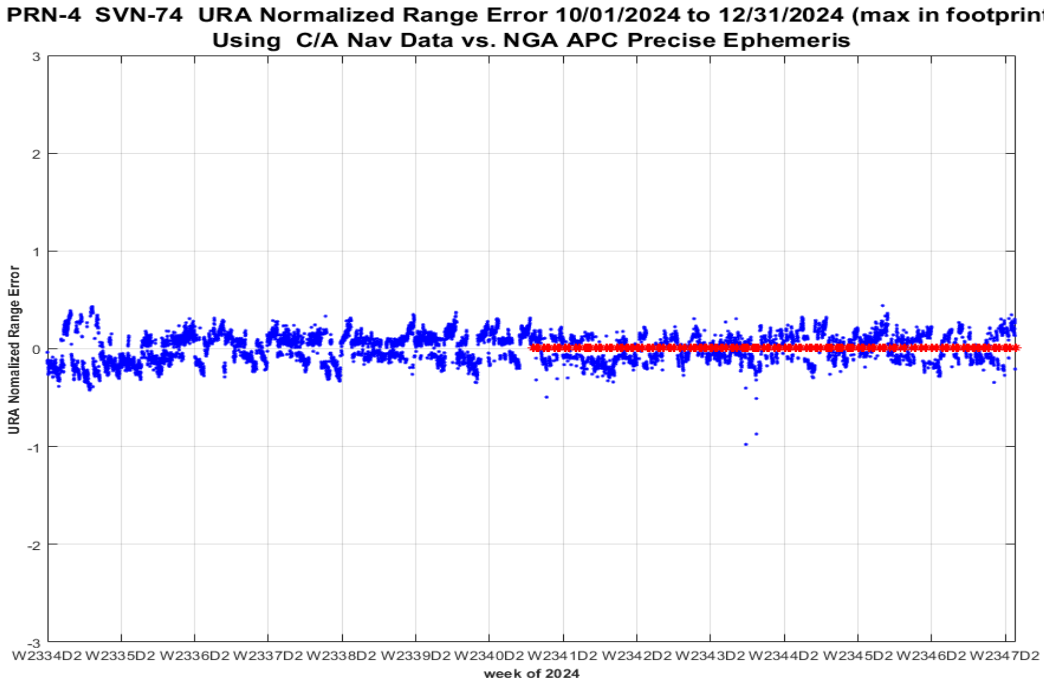


Figure 9-139 Timeline of URA Normalized Range Error PRN4 (SVN74) Using C/A Nav Data

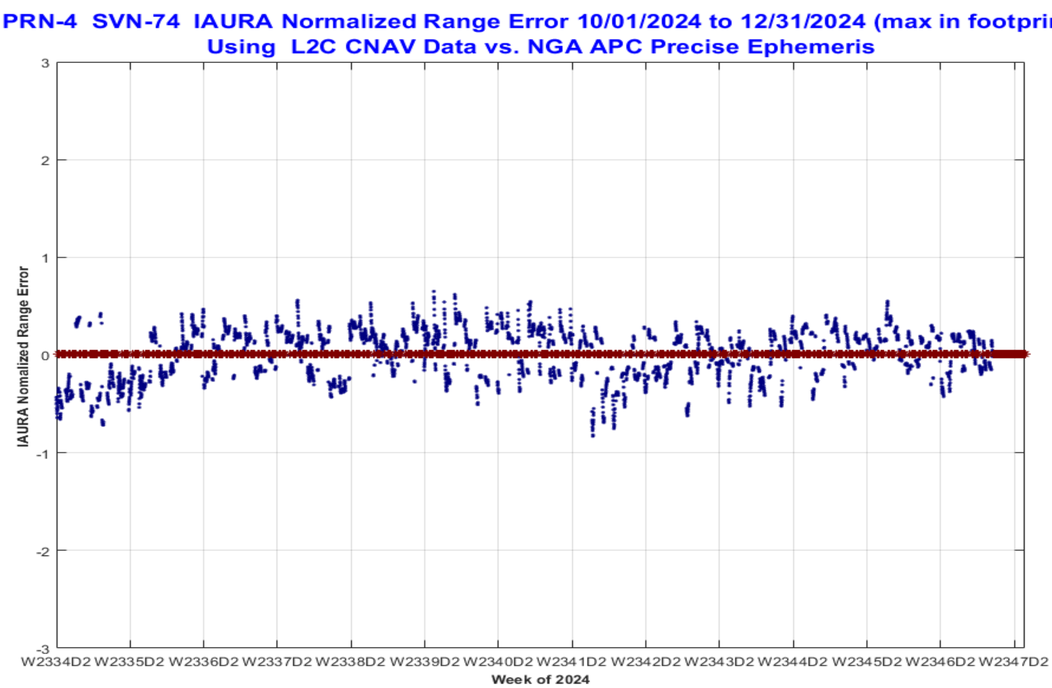


Figure 9-140 Timeline of IAURA Normalized Range Error PRN4 (SVN74) Using L2C CNAV Data

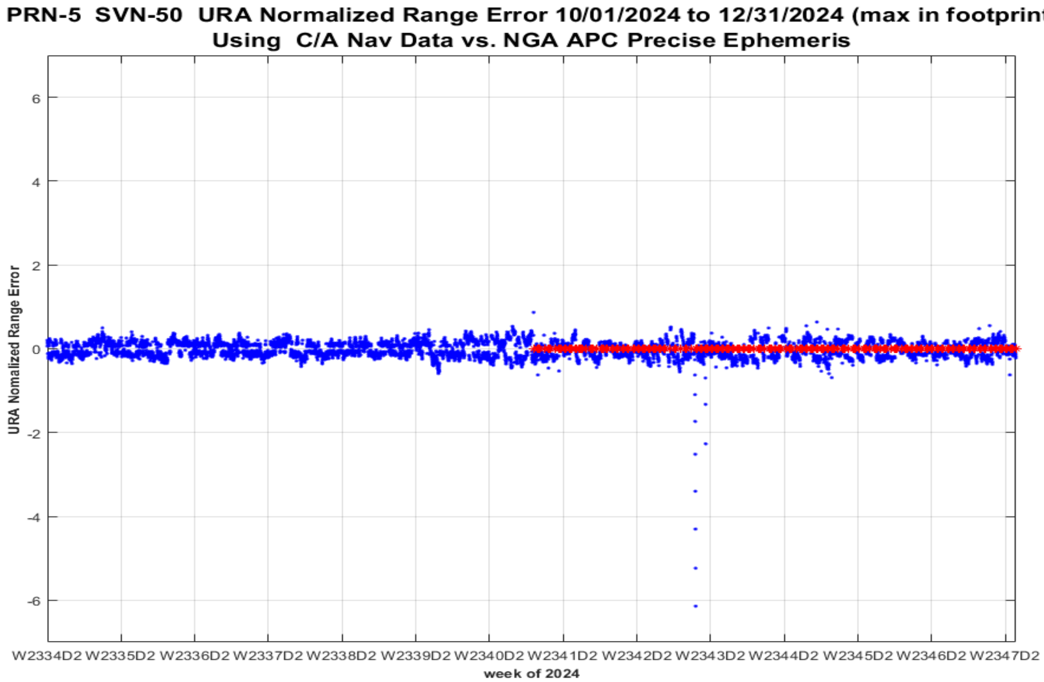


Figure 9-141 Timeline of URA Normalized Range Error PRN5 (SVN50) Using C/A Nav Data

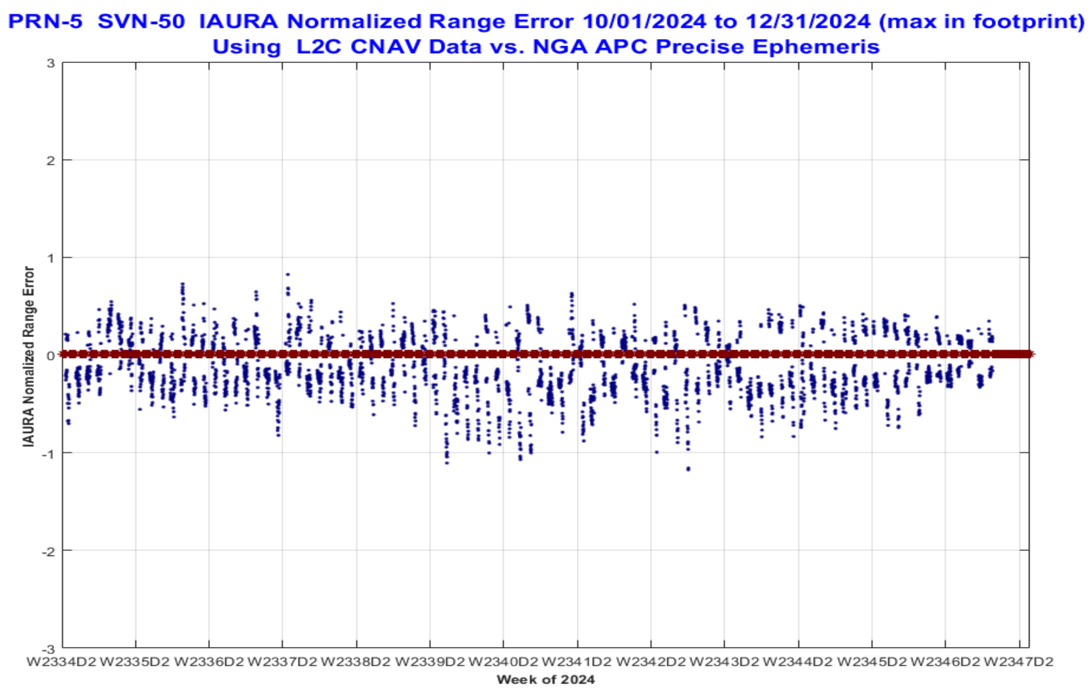


Figure 9-142 Timeline of IAURA Normalized Range Error PRN5 (SVN50) Using L2C CNAV Data

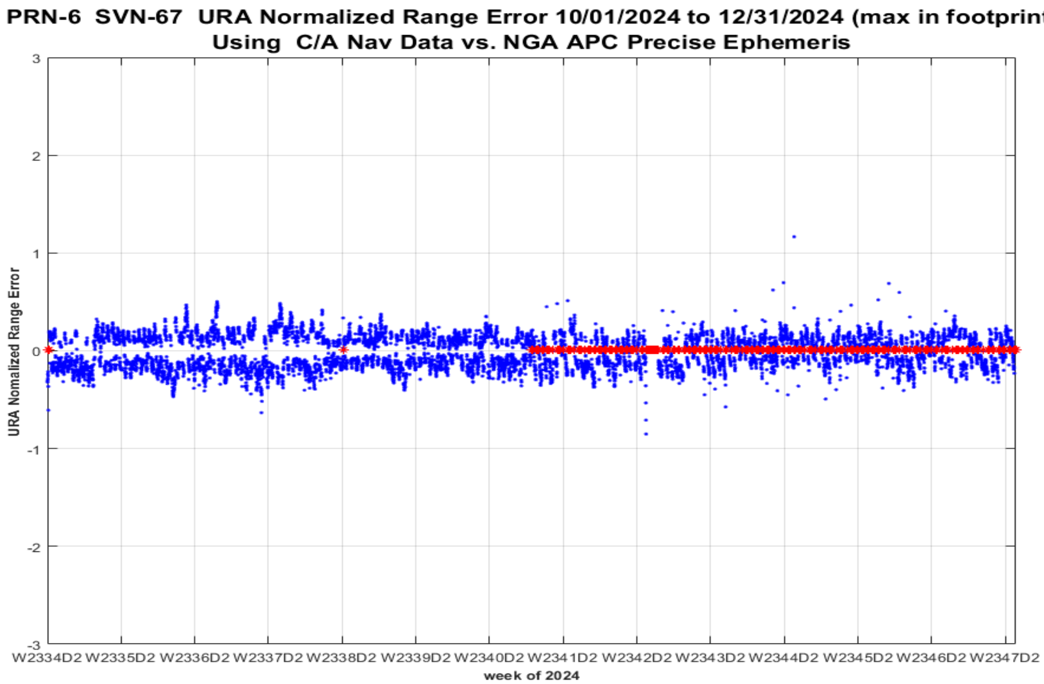


Figure 9-143 Timeline of URA Normalized Range Error PRN6 (SVN67) Using C/A Nav Data

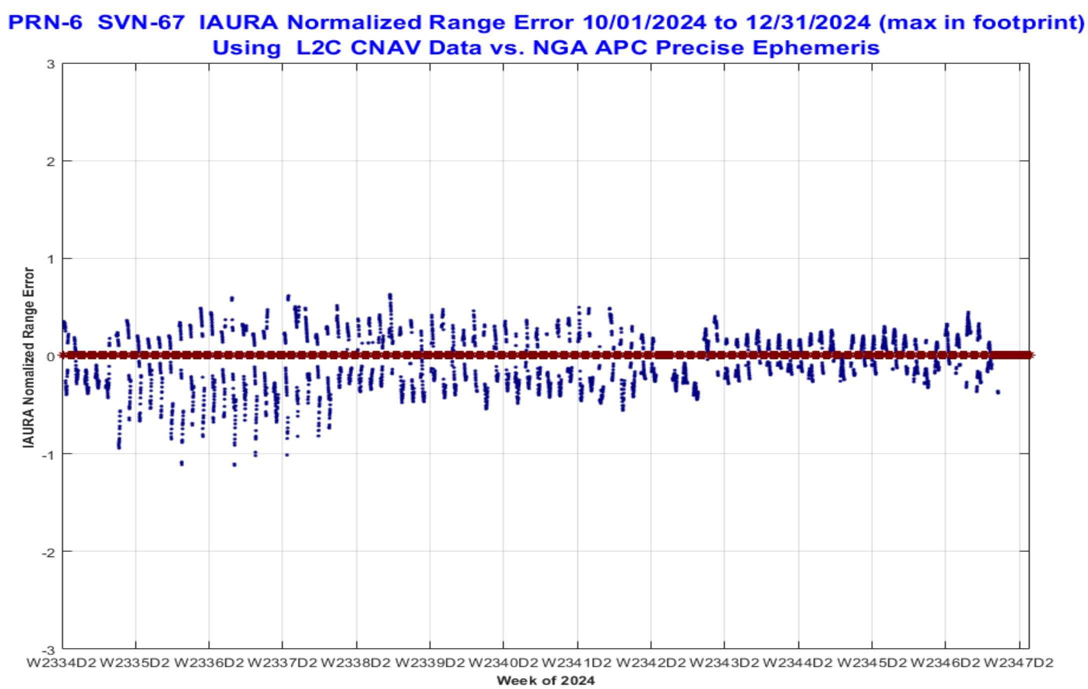


Figure 9-144 Timeline of IAURA Normalized Range Error PRN6 (SVN67) Using L2C CNAV Data

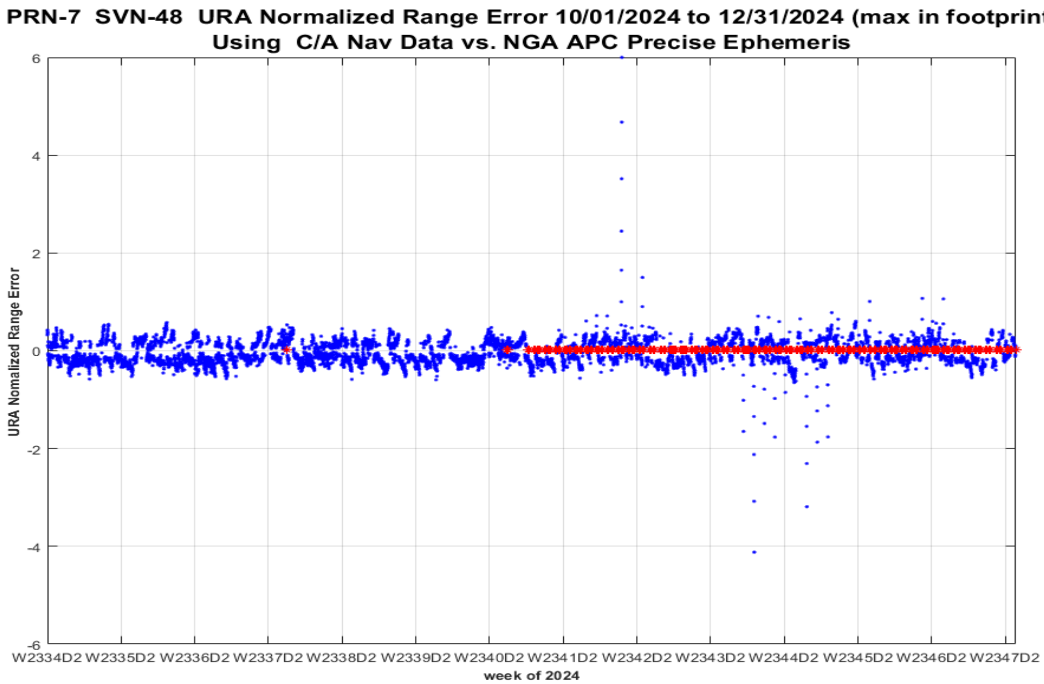


Figure 9-145 Timeline of URA Normalized Range Error PRN7 (SVN48) Using C/A Nav Data

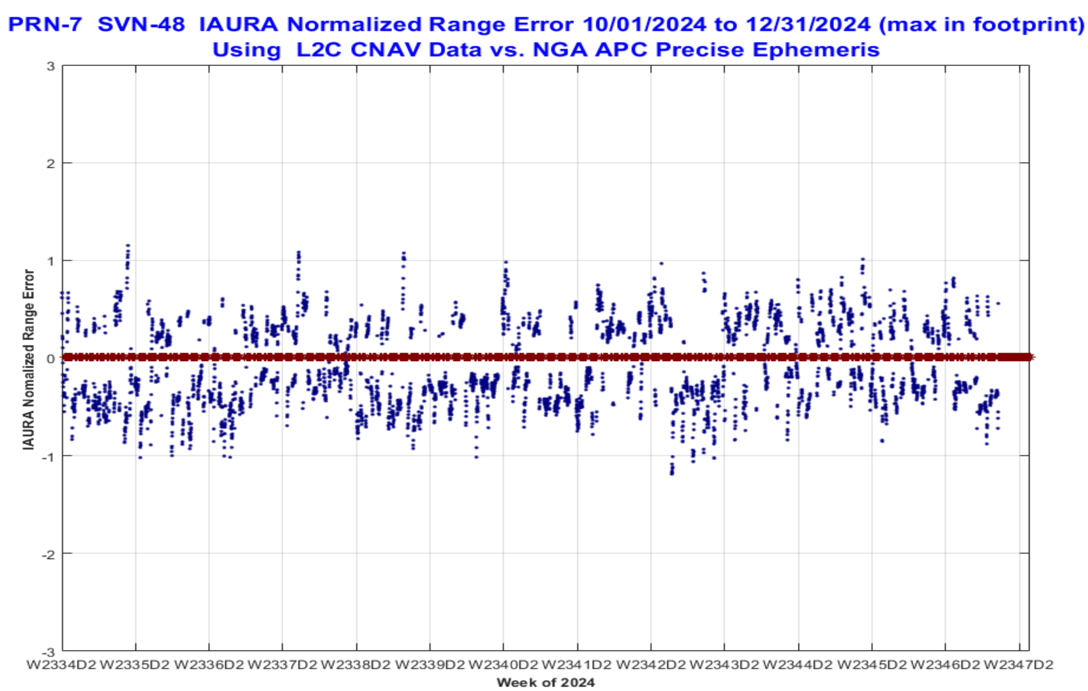


Figure 9-146 Timeline of IAURA Normalized Range Error PRN7 (SVN48) Using L2C CNAV Data

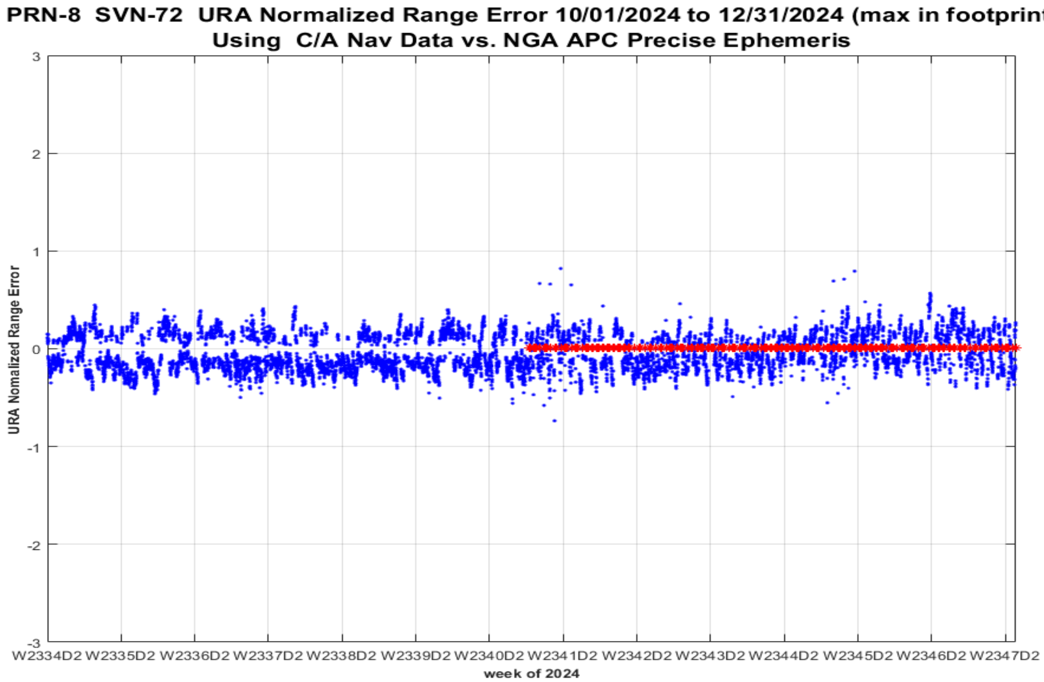


Figure 9-147 Timeline of URA Normalized Range Error PRN8 (SVN72) Using C/A Nav Data

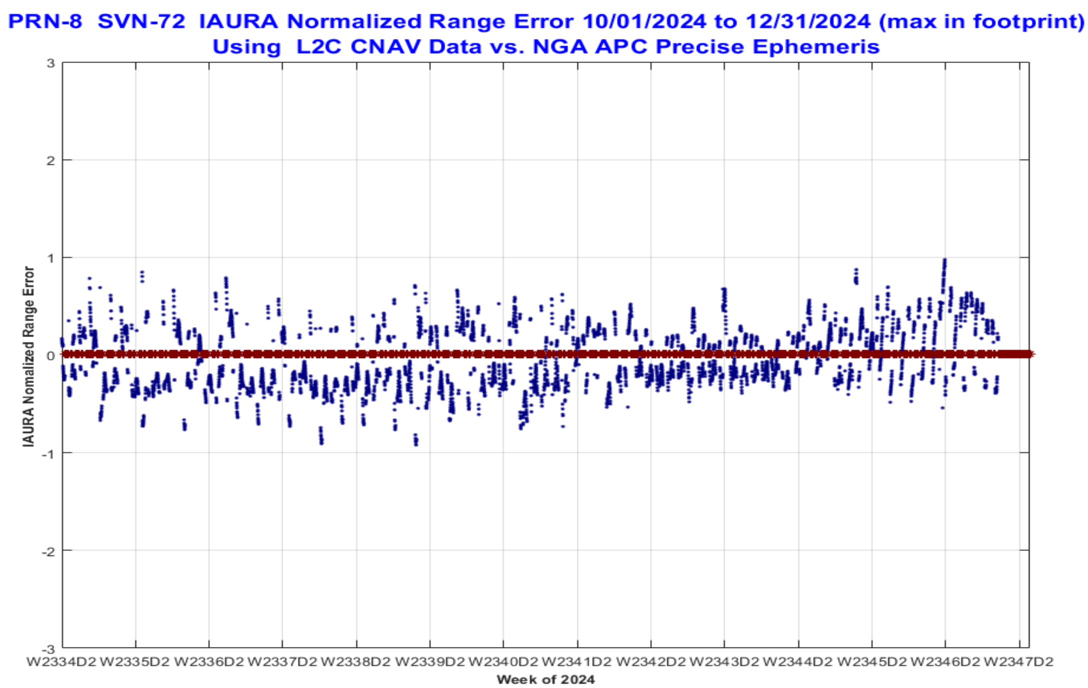


Figure 9-148 Timeline of IAURA Normalized Range Error PRN8 (SVN72) Using L2C CNAV Data

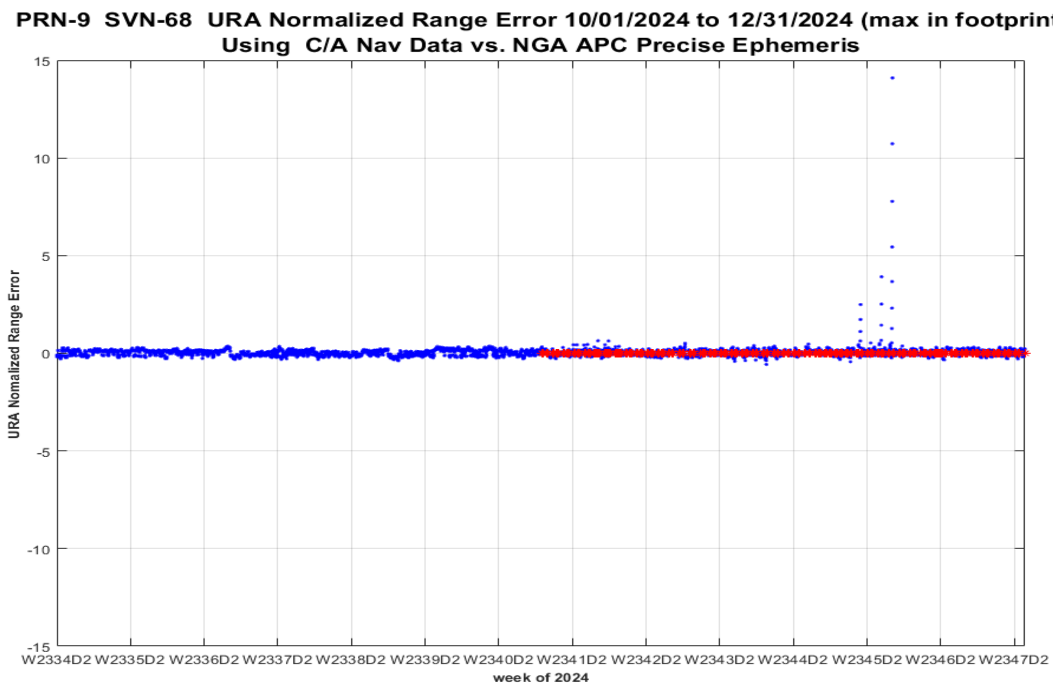


Figure 9-149 Timeline of URA Normalized Range Error PRN9 (SVN68) Using C/A Nav Data

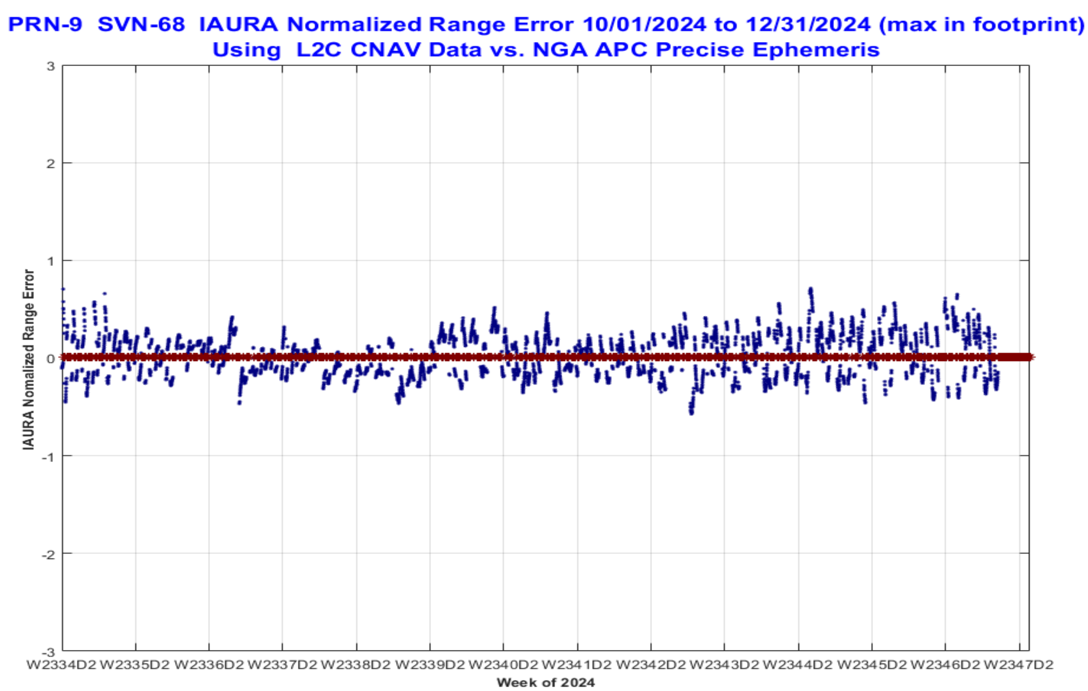


Figure 9-150 Timeline of IAURA Normalized Range Error PRN9 (SVN68) Using L2C CNAV Data

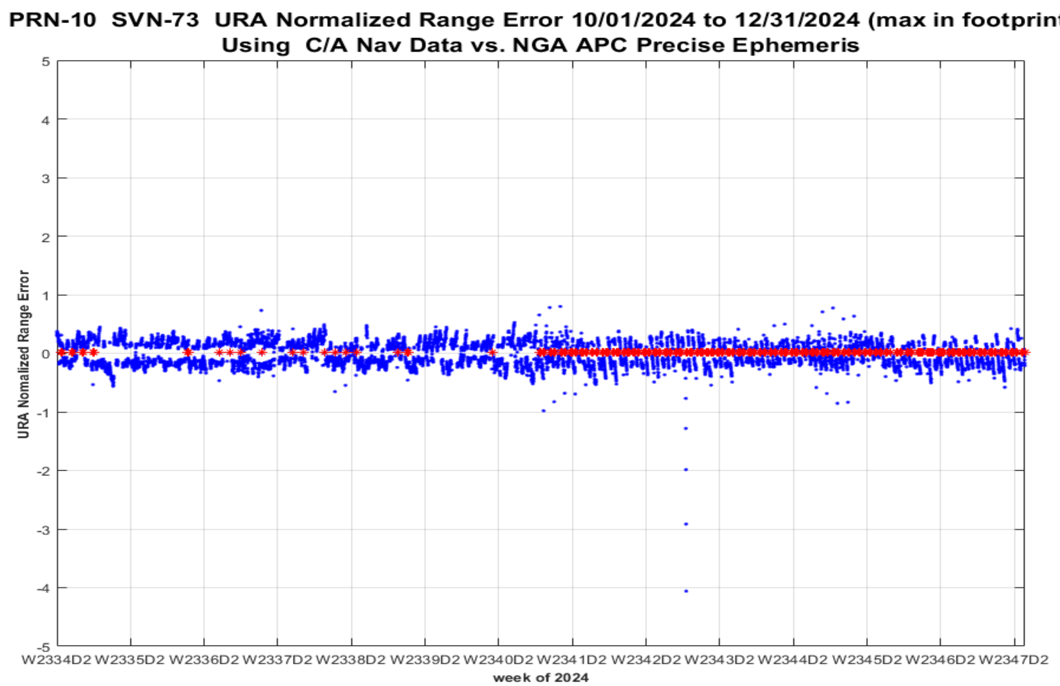


Figure 9-151 Timeline of URA Normalized Range Error PRN10 (SVN73) Using C/A Nav Data

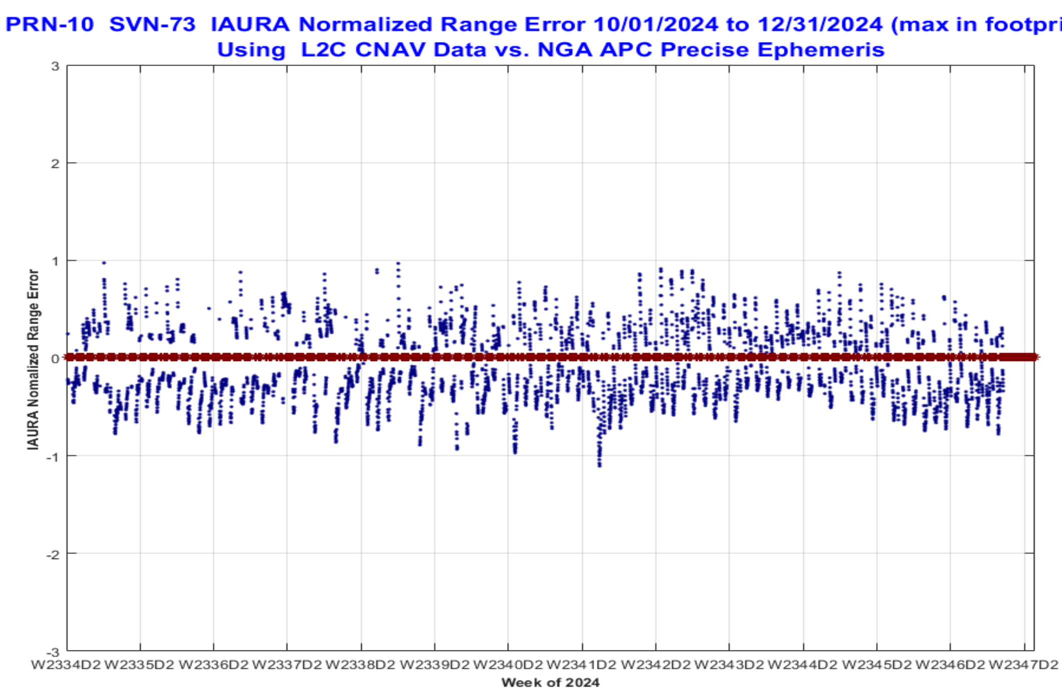


Figure 9-152 Timeline of IAURA Normalized Range Error PRN10 (SVN73) Using L2C CNAV Data

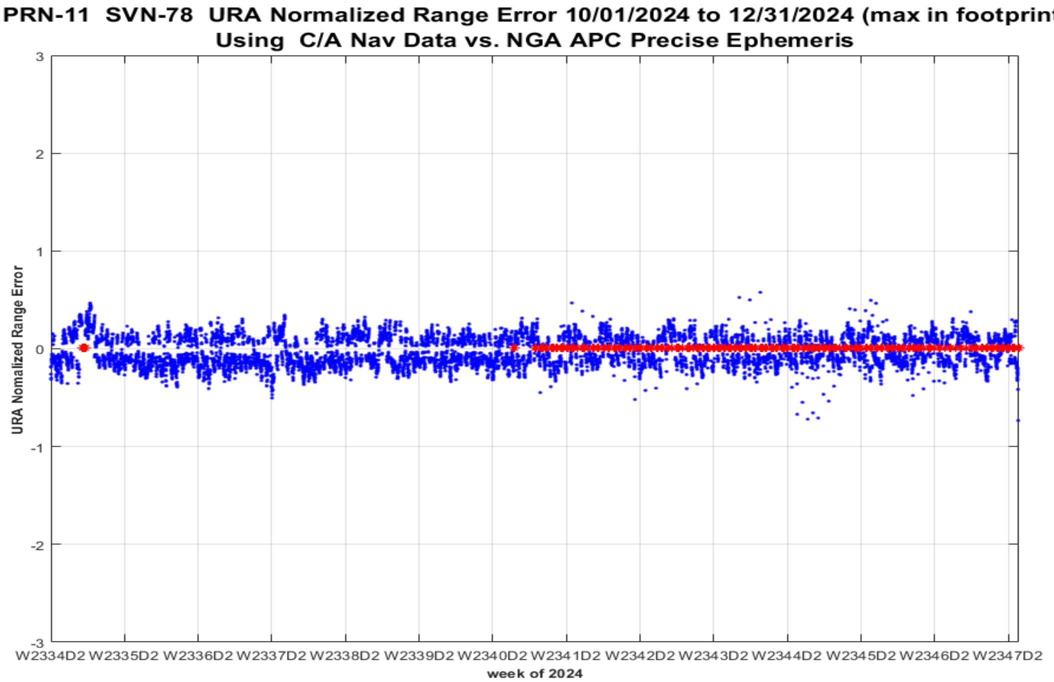


Figure 9-153 Timeline of URA Normalized Range Error PRN11 (SVN78) Using C/A Nav Data

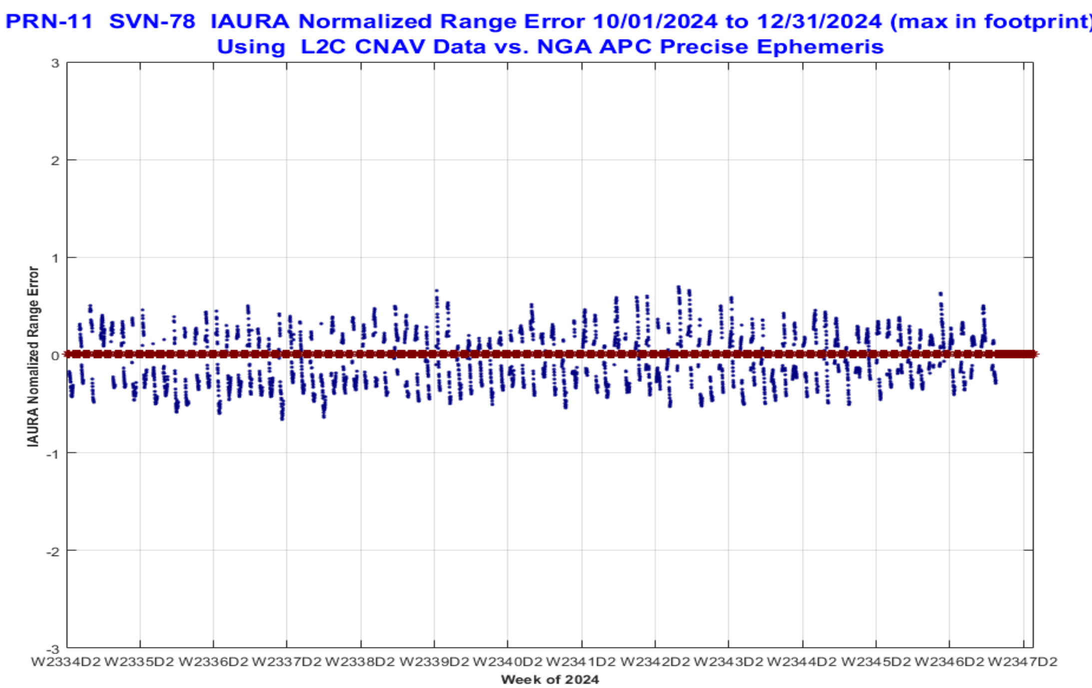


Figure 9-154 Timeline of IAURA Normalized Range Error PRN11 (SVN78) Using L2C CNAV Data

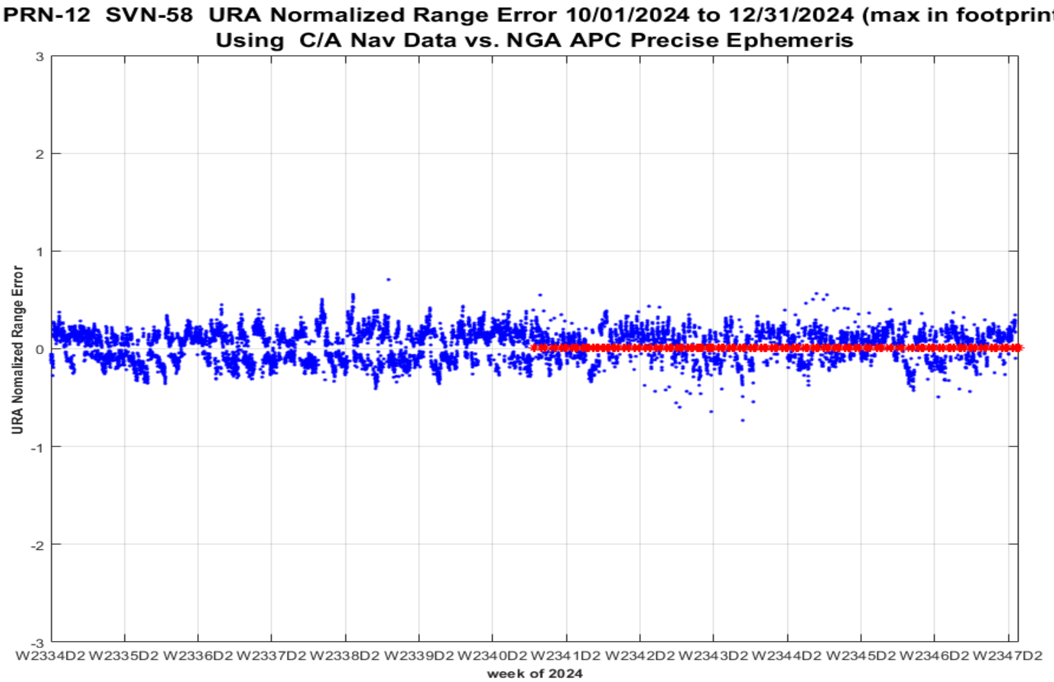


Figure 9-155 Timeline of URA Normalized Range Error PRN12 (SVN58) Using C/A Nav Data

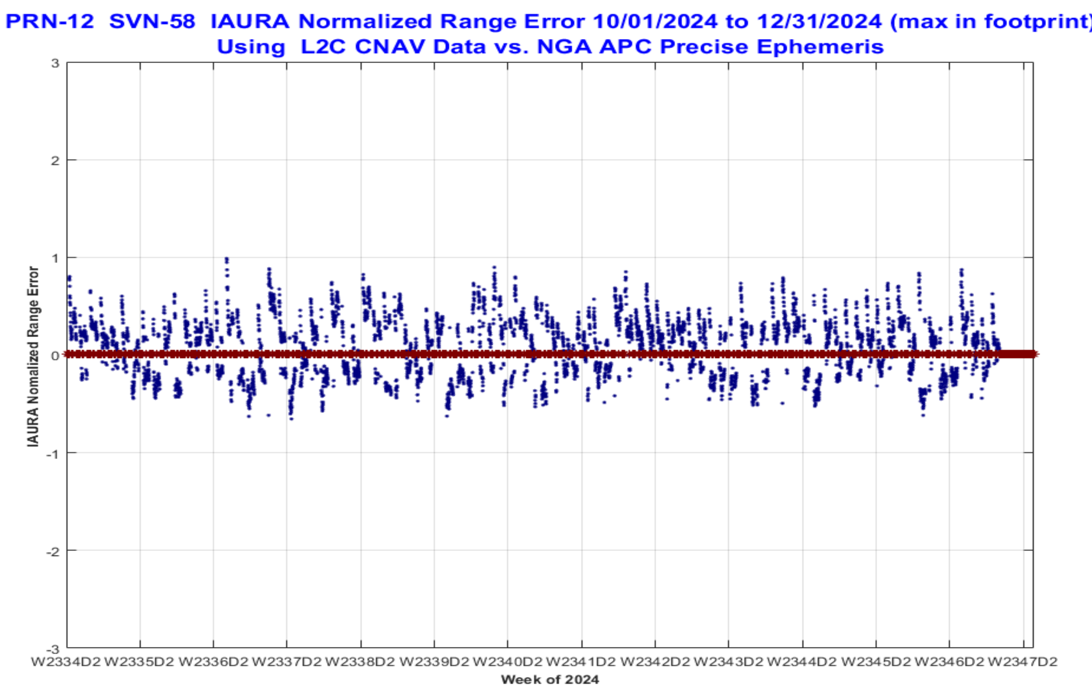


Figure 9-156 Timeline of IAURA Normalized Range Error PRN12 (SVN58) Using L2C CNAV Data

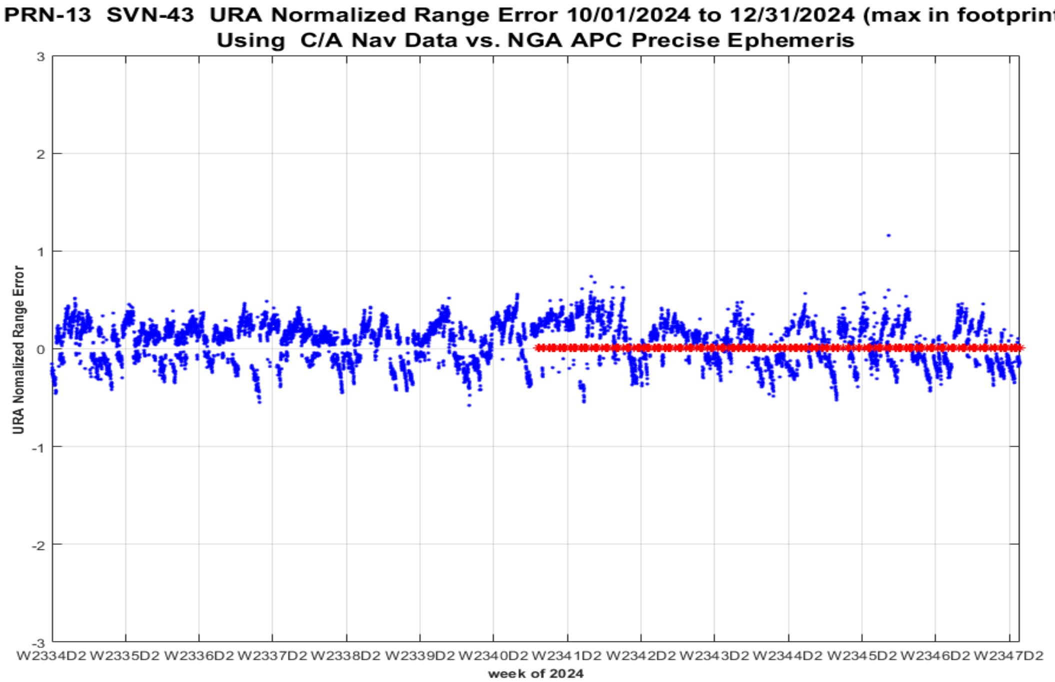


Figure 9-157 Timeline of URA Normalized Range Error PRN13 (SVN43) Using C/A Nav Data

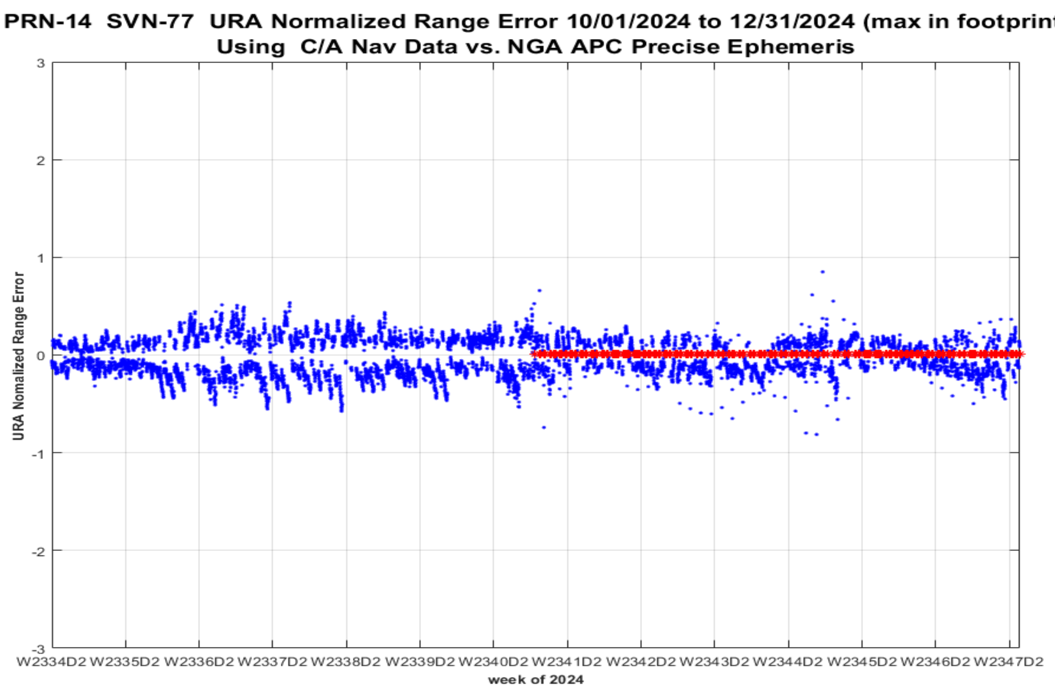


Figure 9-158 Timeline of URA Normalized Range Error PRN14 (SVN77) Using C/A Nav Data

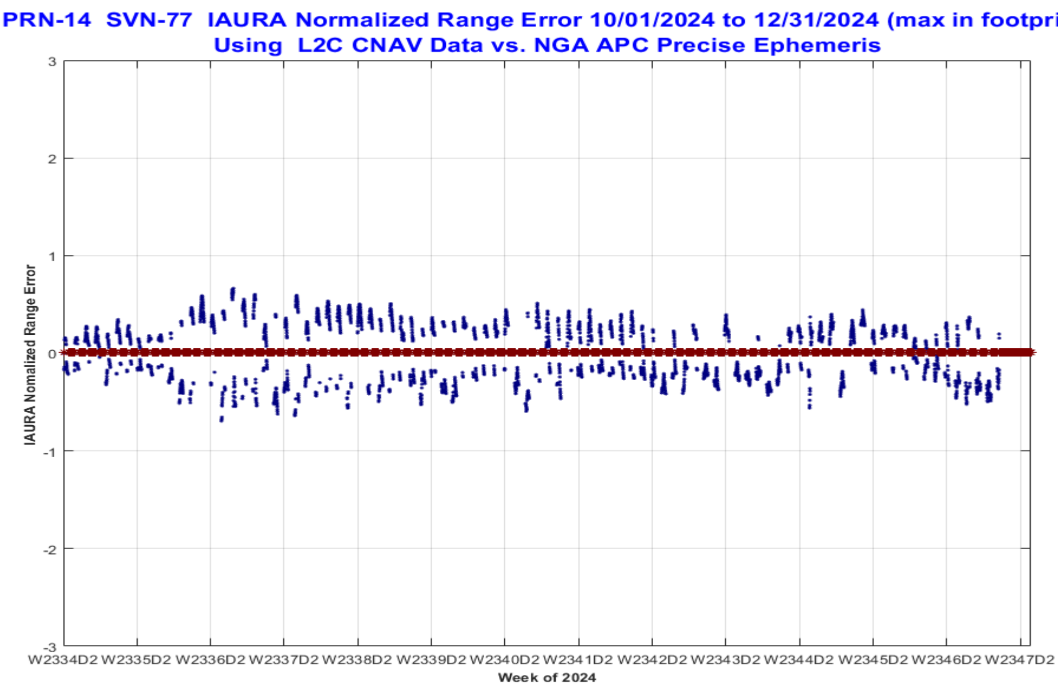


Figure 9-159 Timeline of IAURA Normalized Range Error PRN14 (SVN77) Using L2C CNAV Data

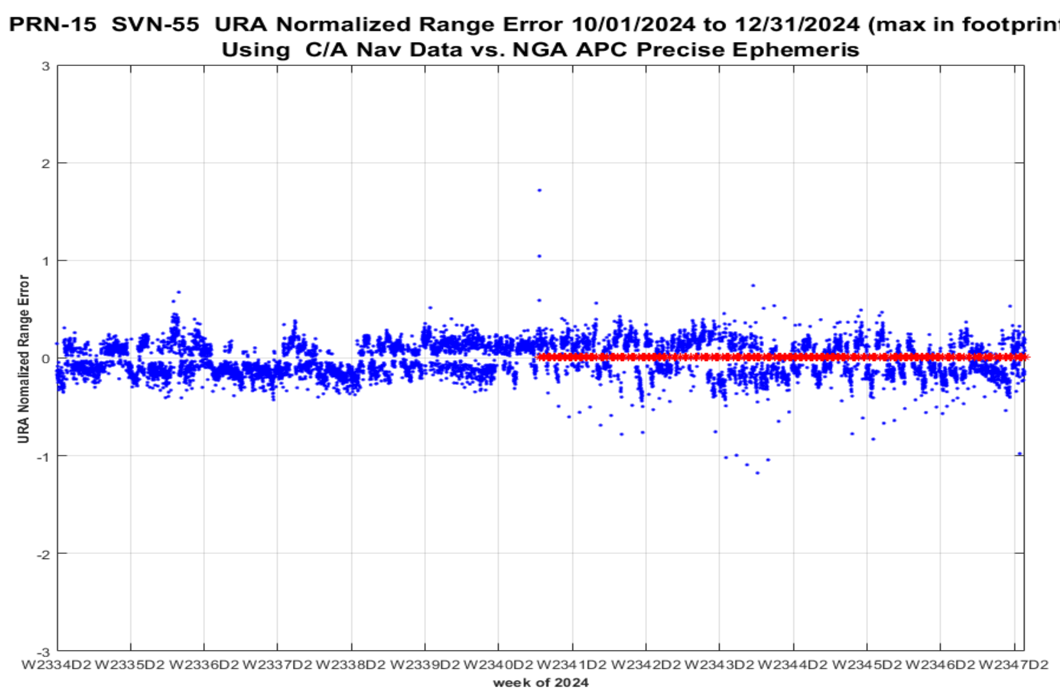


Figure 9-160 Timeline of URA Normalized Range Error PRN15 (SVN55) Using C/A Nav Data

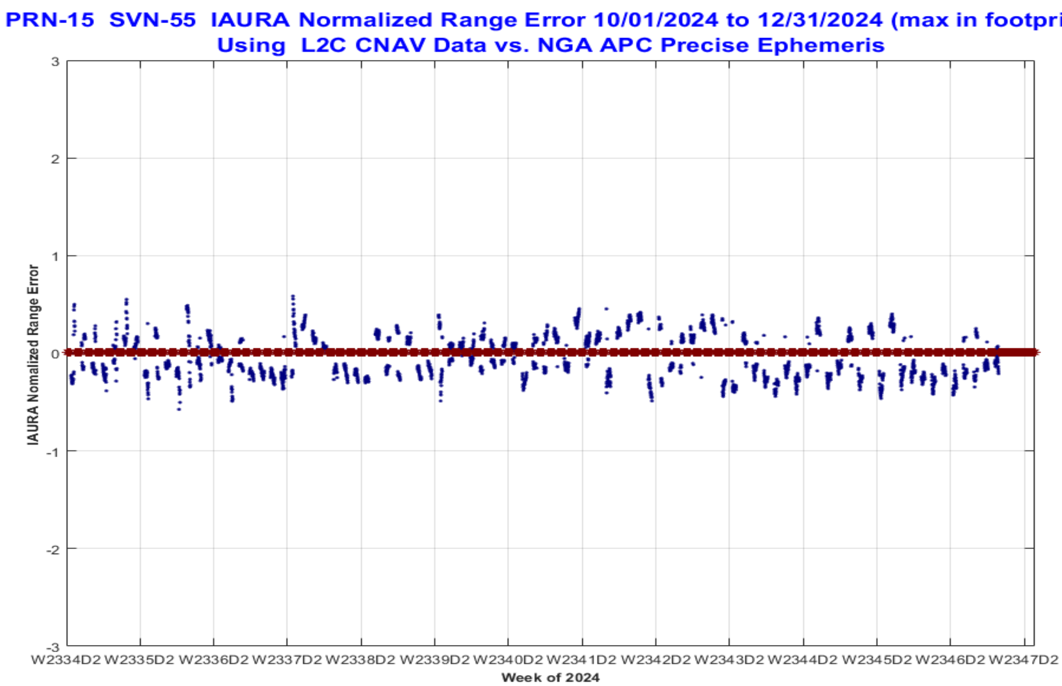


Figure 9-161 Timeline of IAURA Normalized Range Error PRN15 (SVN55) Using L2C CNAV Data

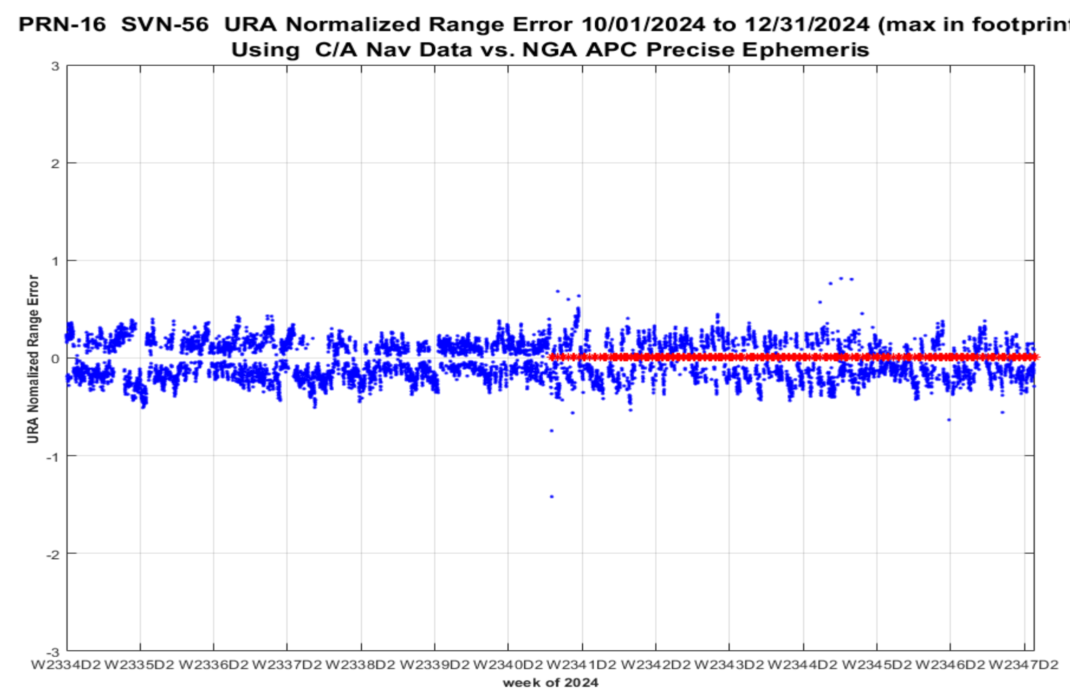


Figure 9-162 Timeline of URA Normalized Range Error PRN16 (SVN56) Using C/A Nav Data

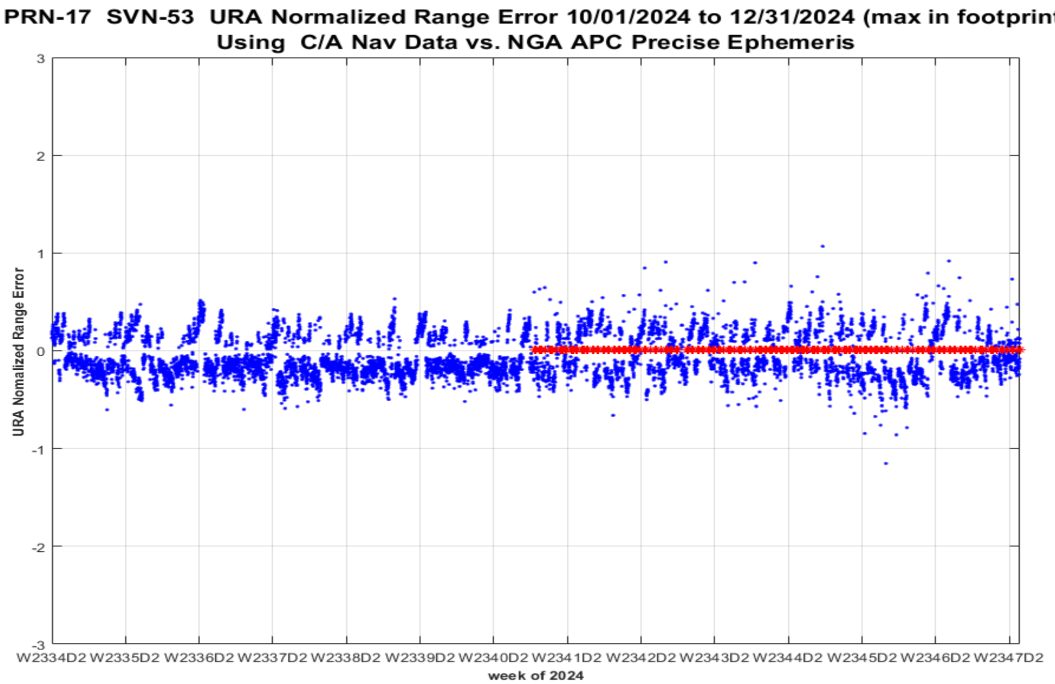


Figure 9-163 Timeline of URA Normalized Range Error PRN17 (SVN53) Using C/A Nav Data

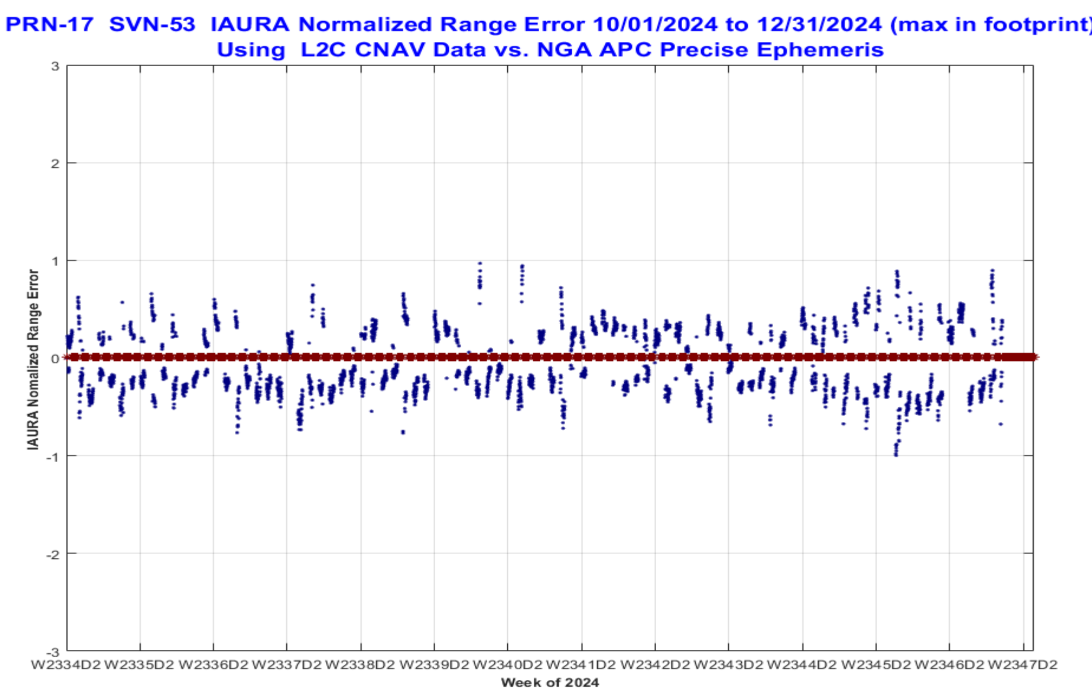


Figure 9-164 Timeline of IAURA Normalized Range Error PRN17 (SVN53) Using L2C CNAV Data

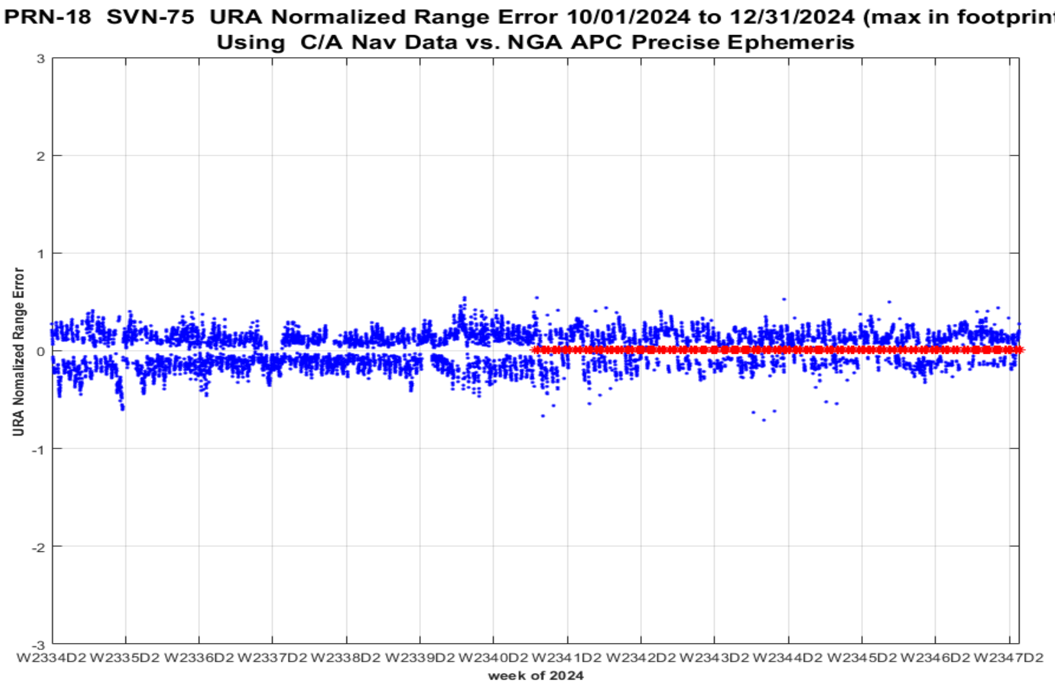


Figure 9-165 Timeline of URA Normalized Range Error PRN18 (SVN75) Using C/A Nav Data

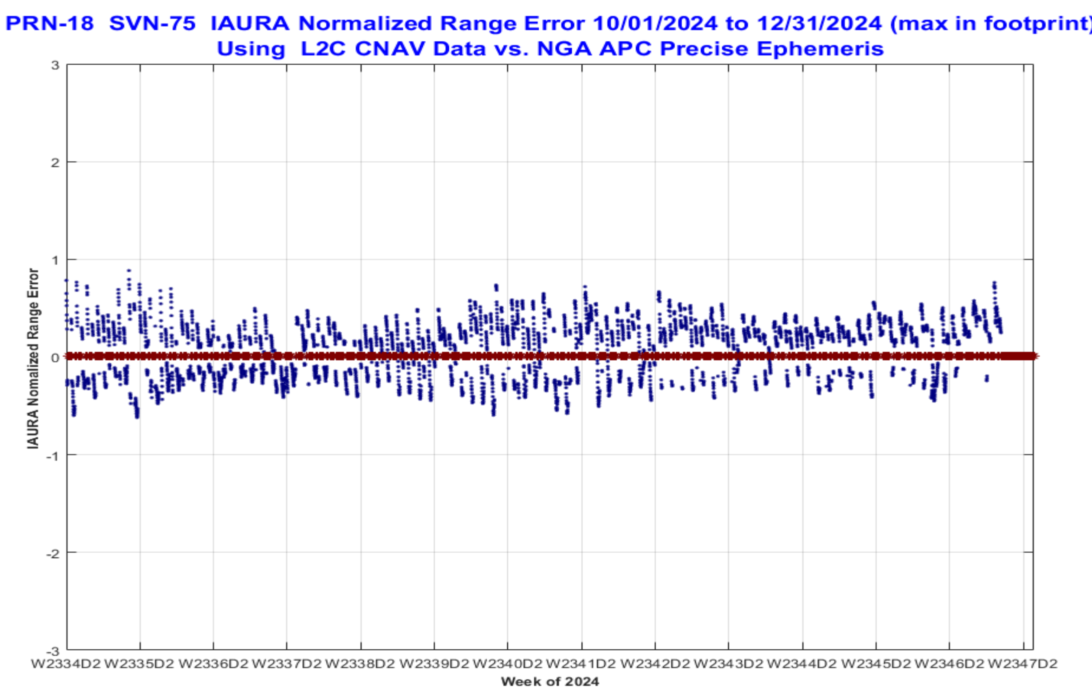


Figure 9-166 Timeline of IAURA Normalized Range Error PRN18 (SVN75) Using L2C CNAV Data

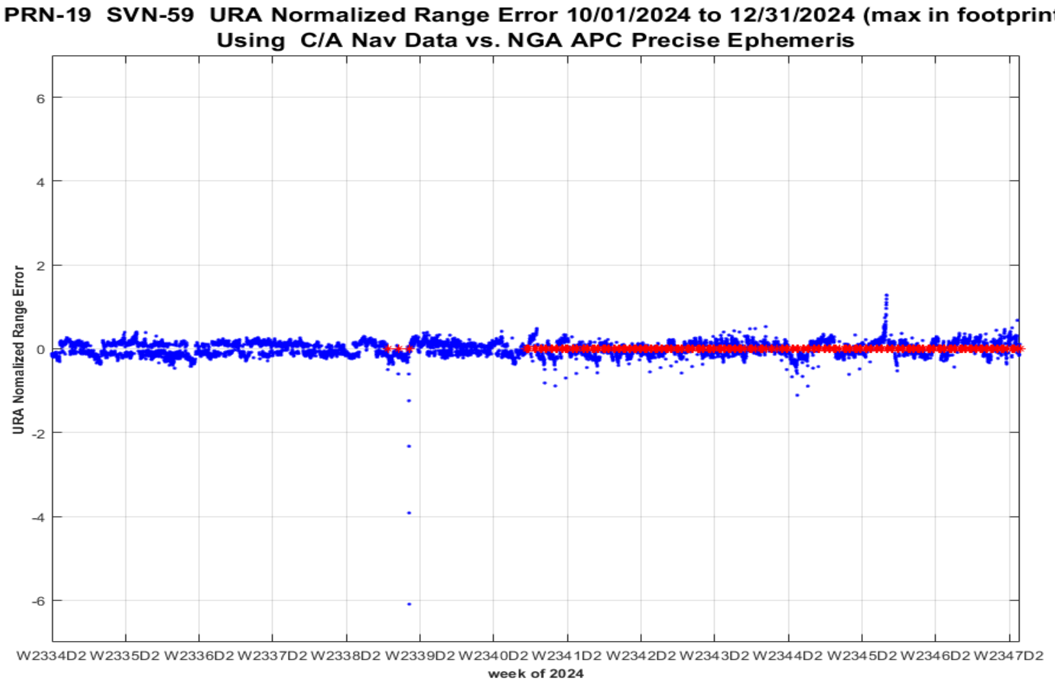


Figure 9-167 Timeline of URA Normalized Range Error PRN19 (SVN59) Using C/A Nav Data

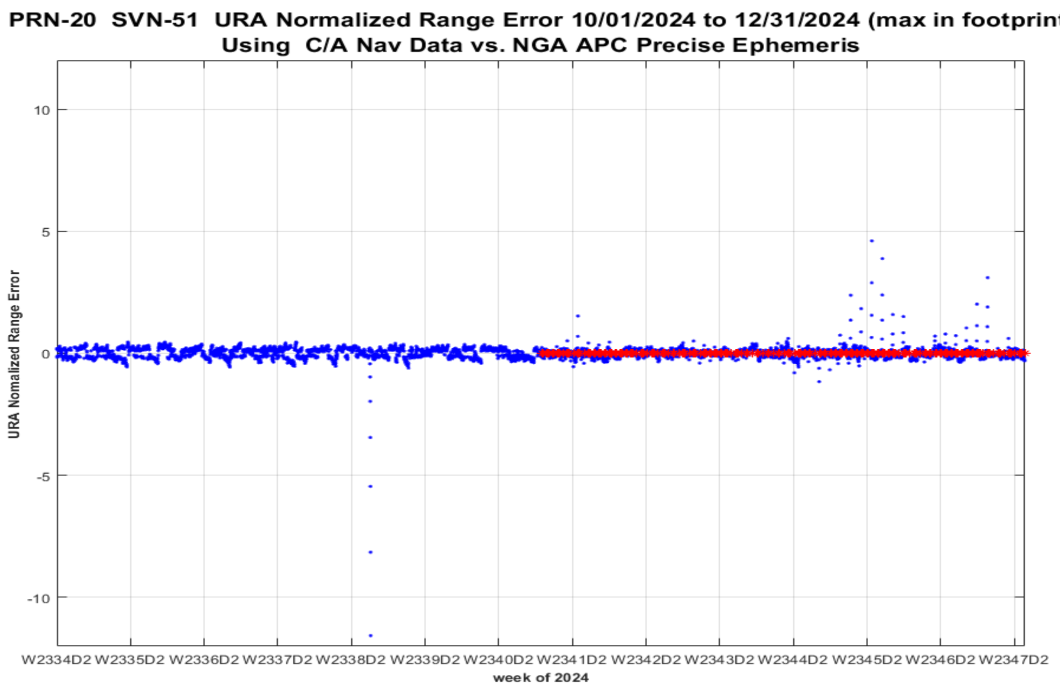


Figure 9-168 Timeline of URA Normalized Range Error PRN20 (SVN51) Using C/A Nav Data

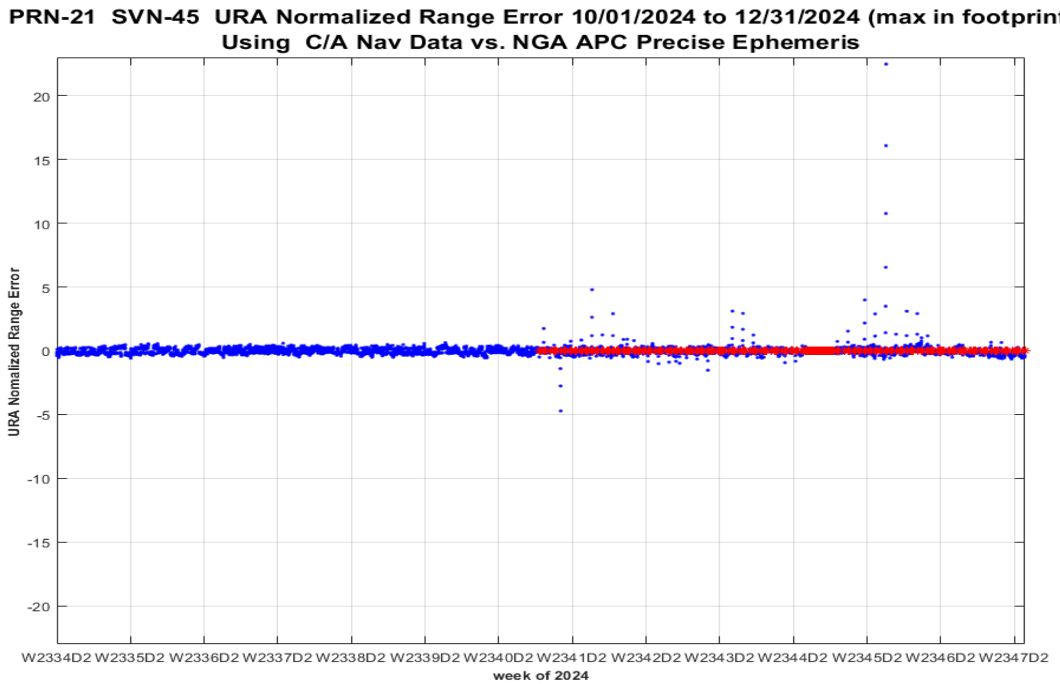


Figure 9-169 Timeline of URA Normalized Range Error PRN21 (SVN45) Using C/A Nav Data

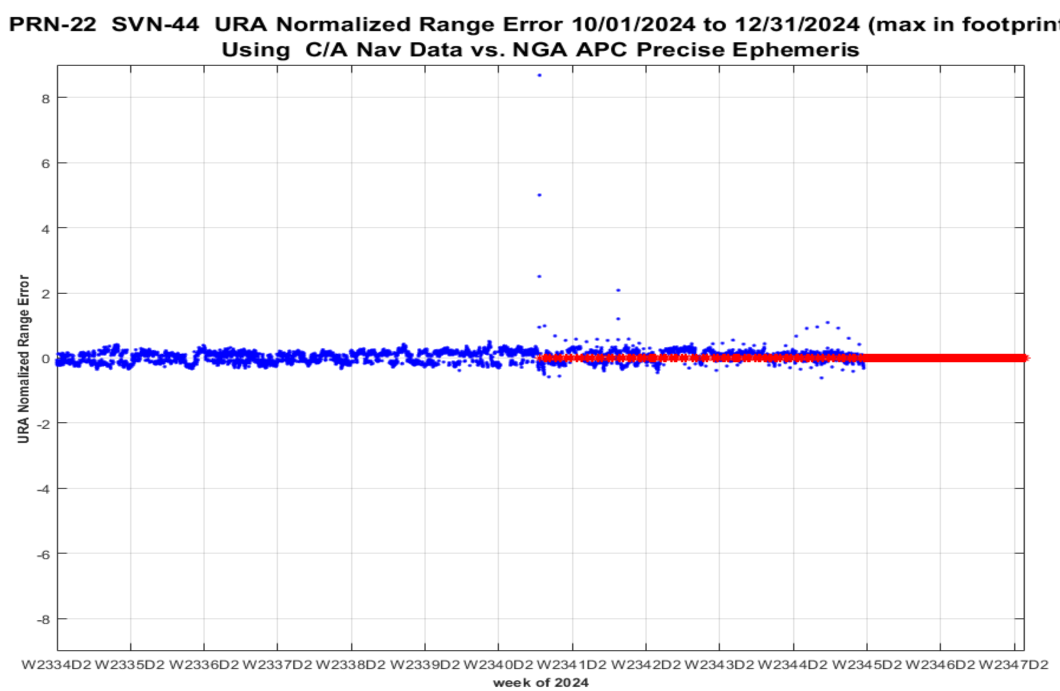


Figure 9-170 Timeline of URA Normalized Range Error PRN22 (SVN44) Using C/A Nav Data

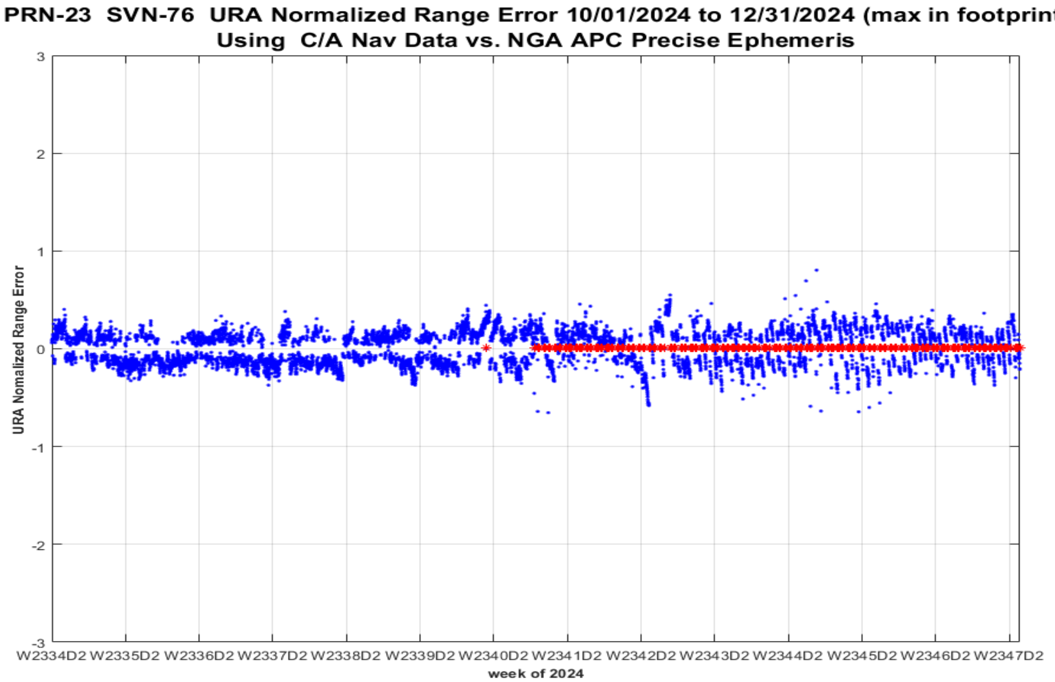


Figure 9-171 Timeline of URA Normalized Range Error PRN23 (SVN76) Using C/A Nav Data

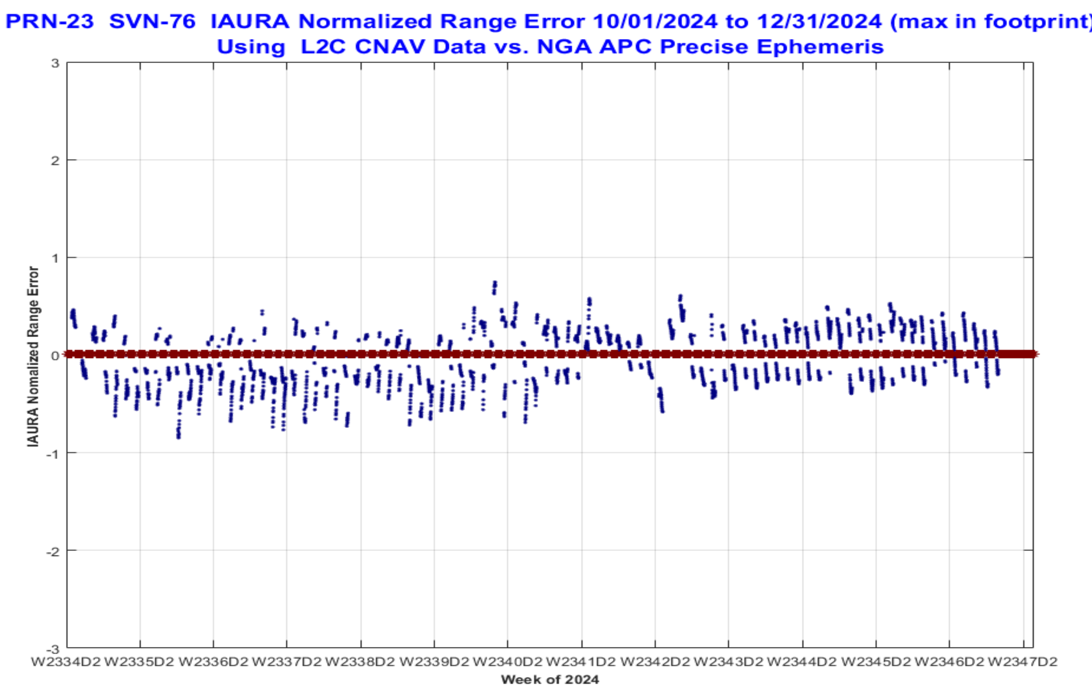


Figure 9-172 Timeline of IAURA Normalized Range Error PRN23 (SVN76) Using L2C CNAV Data

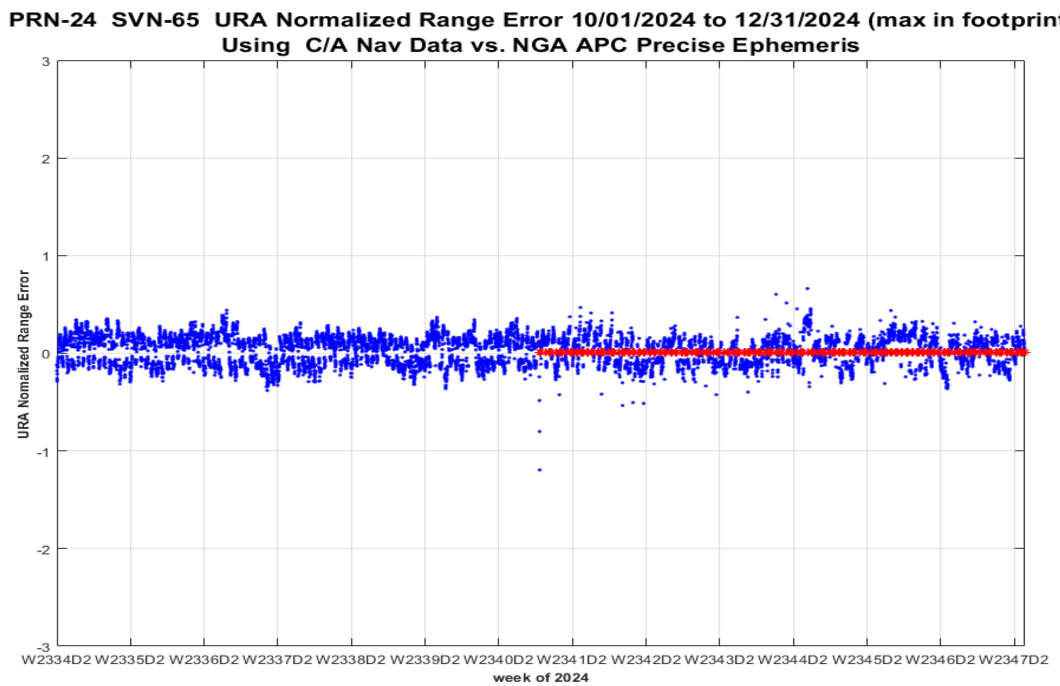


Figure 9-173 Timeline of URA Normalized Range Error PRN24 (SVN65) Using C/A Nav Data

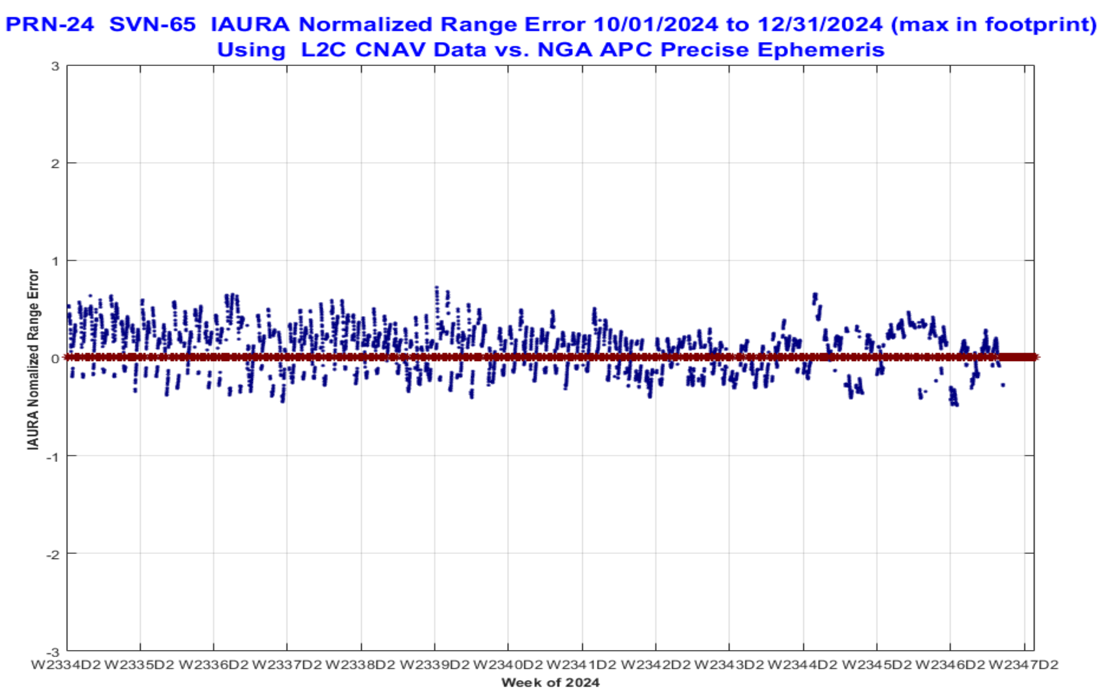


Figure 9-174 Timeline of IAURA Normalized Range Error PRN24 (SVN65) Using L2C CNAV Data

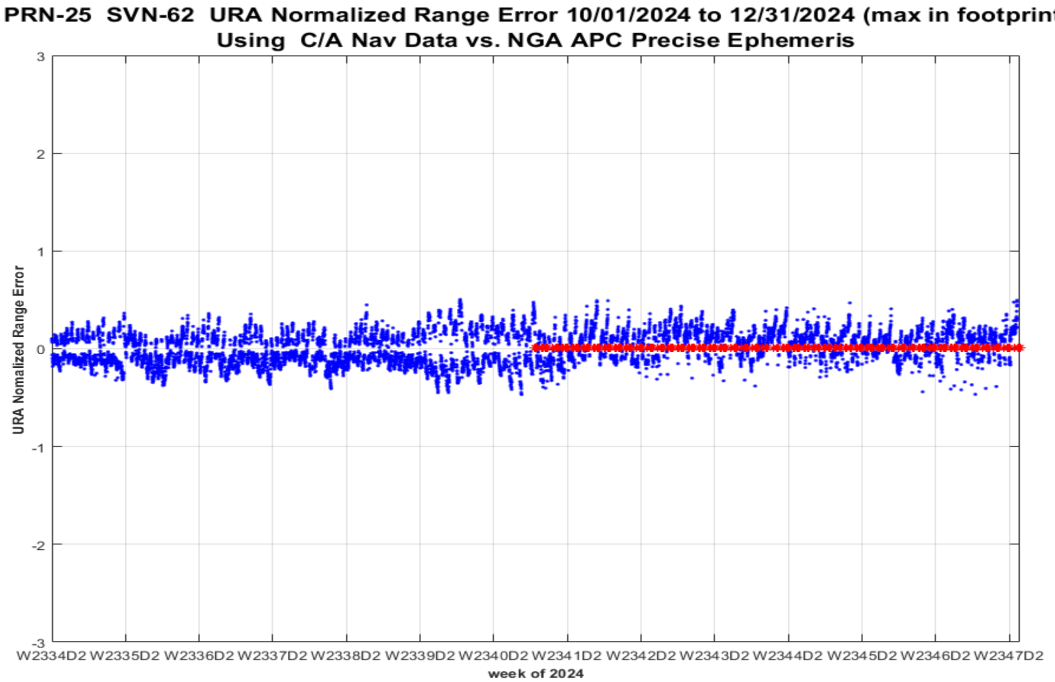


Figure 9-175 Timeline of URA Normalized Range Error PRN25 (SVN62) Using C/A Nav Data

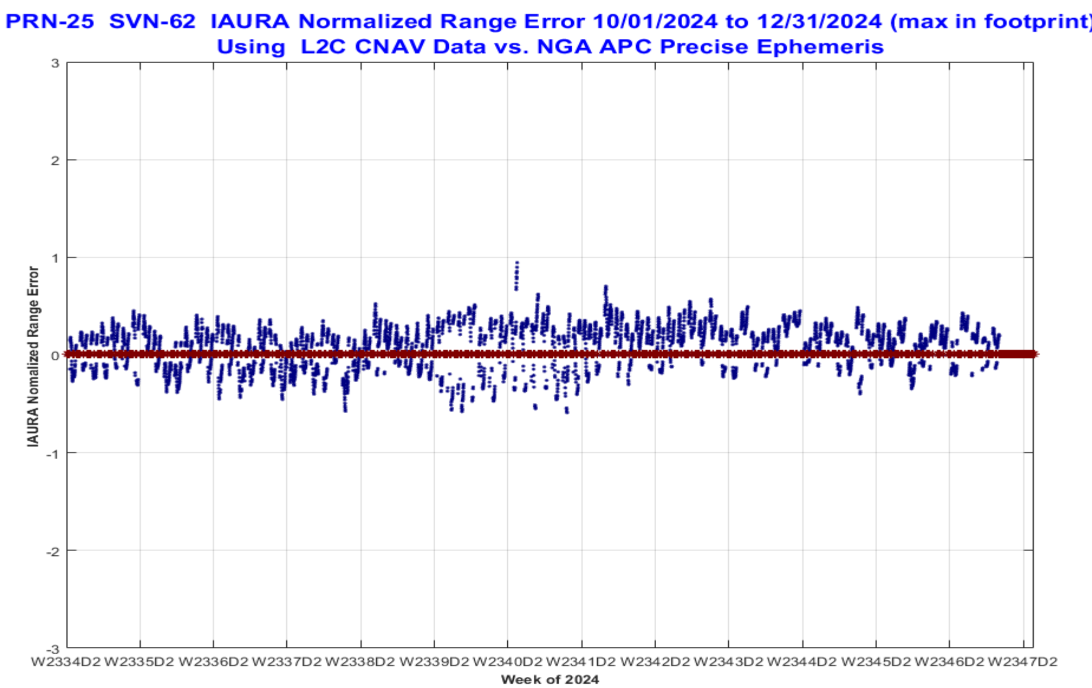


Figure 9-176 Timeline of IAURA Normalized Range Error PRN25 (SVN62) Using L2C CNAV Data

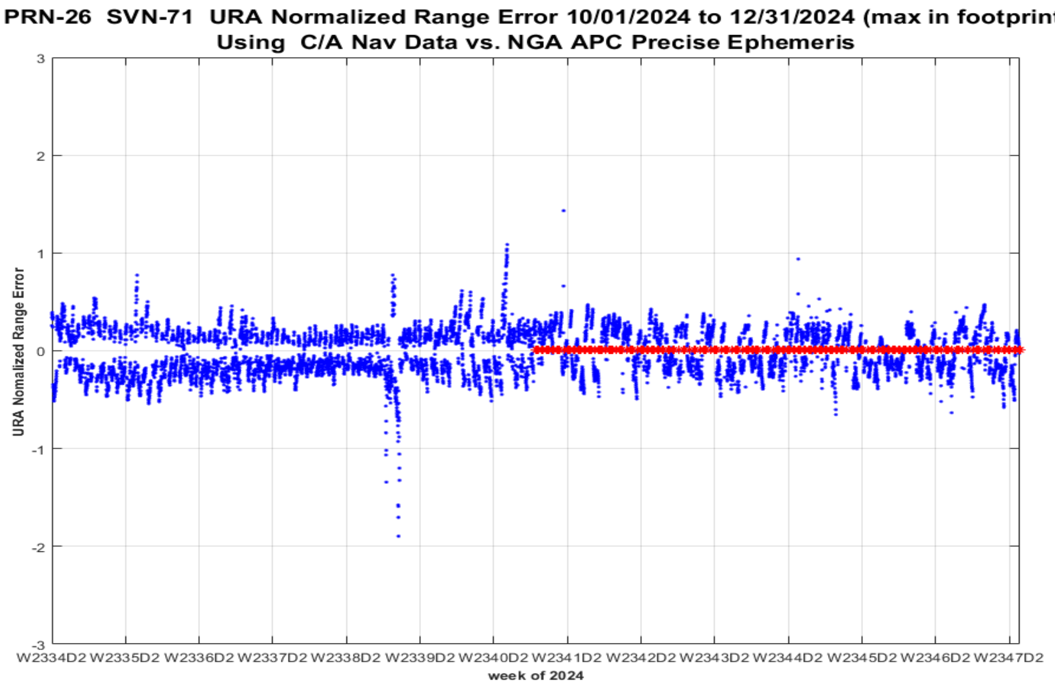


Figure 9-177 Timeline of URA Normalized Range Error PRN26 (SVN71) Using C/A Nav Data

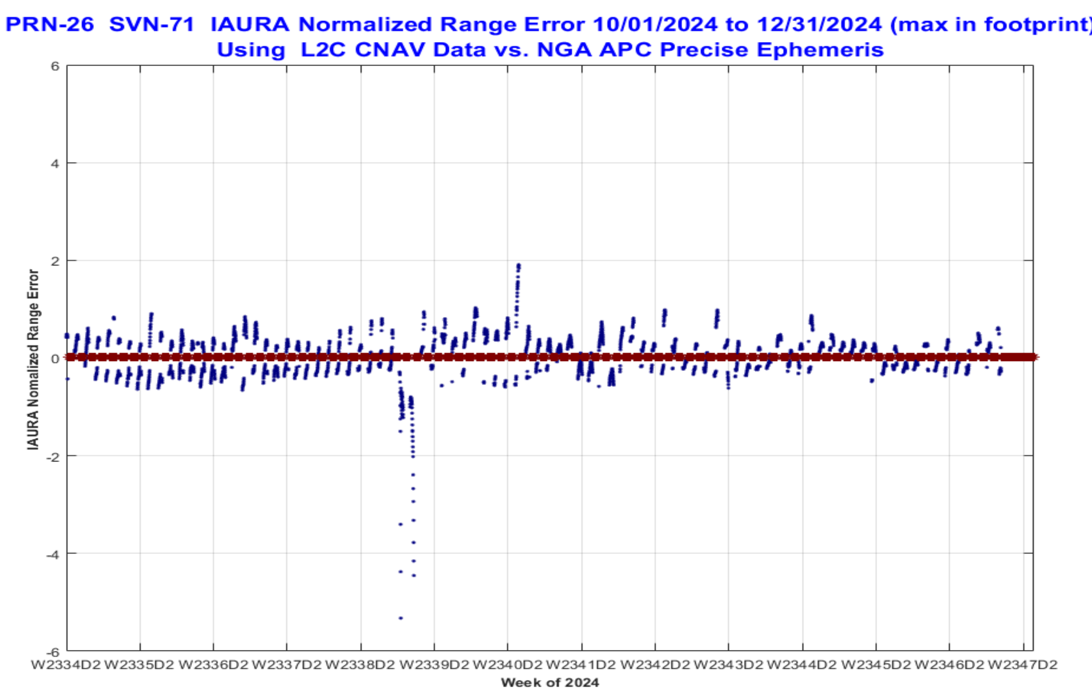


Figure 9-178 Timeline of IAURA Normalized Range Error PRN26 (SVN71) Using L2C CNAV Data

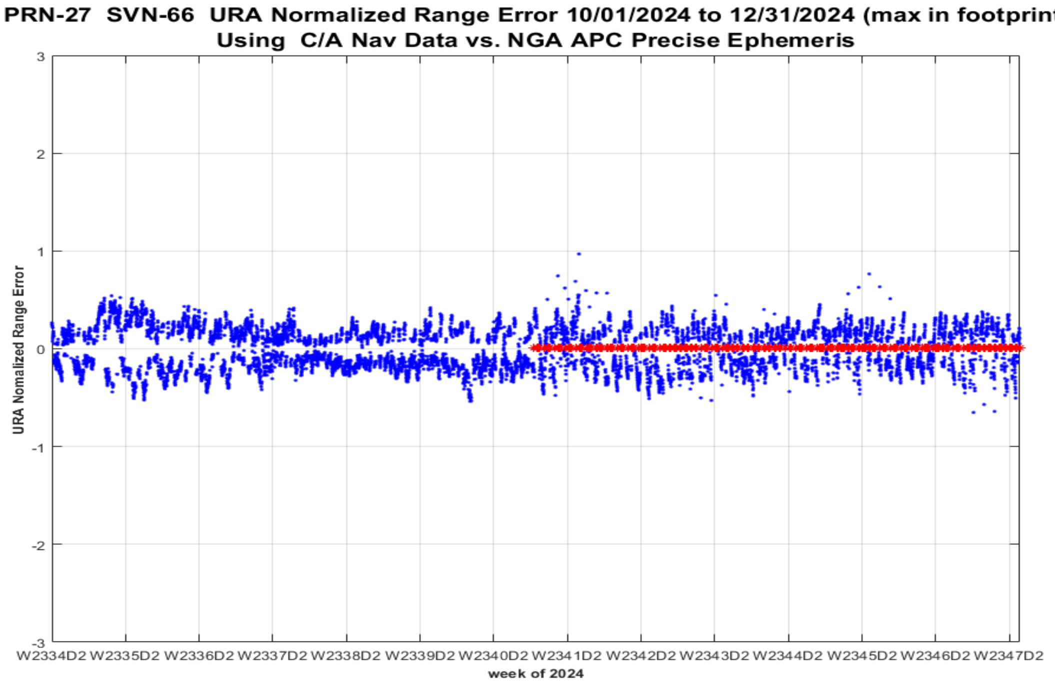


Figure 9-179 Timeline of URA Normalized Range Error PRN27 (SVN66) Using C/A Nav Data

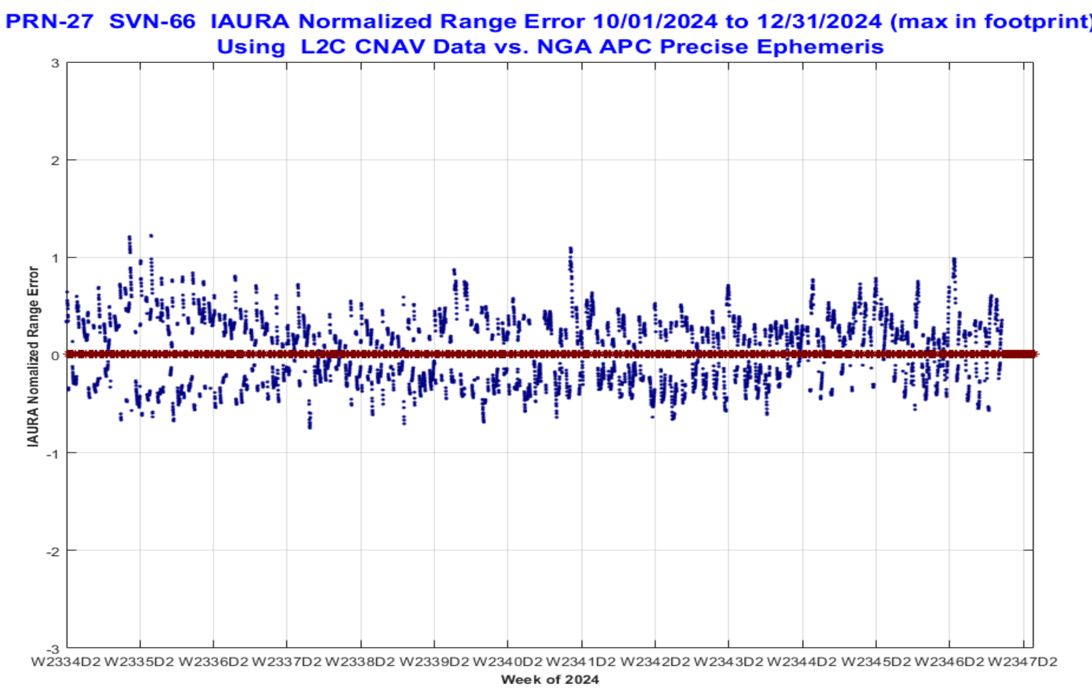


Figure 9-180 Timeline of IAURA Normalized Range Error PRN27 (SVN66) Using L2C CNAV Data

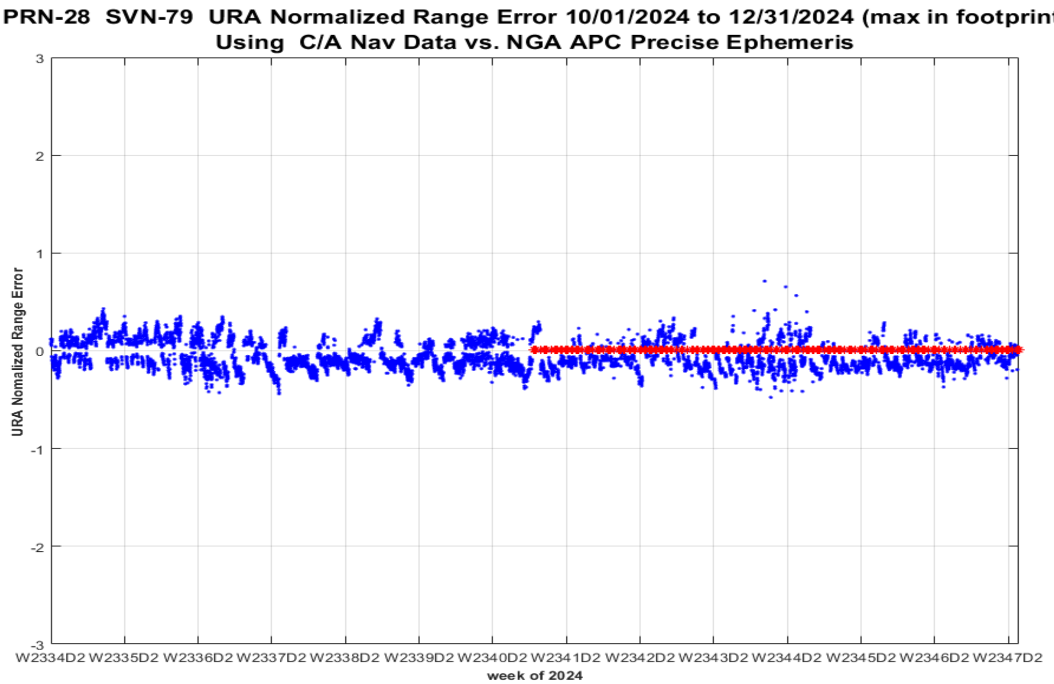


Figure 9-181 Timeline of URA Normalized Range Error PRN28 (SVN79) Using C/A Nav Data

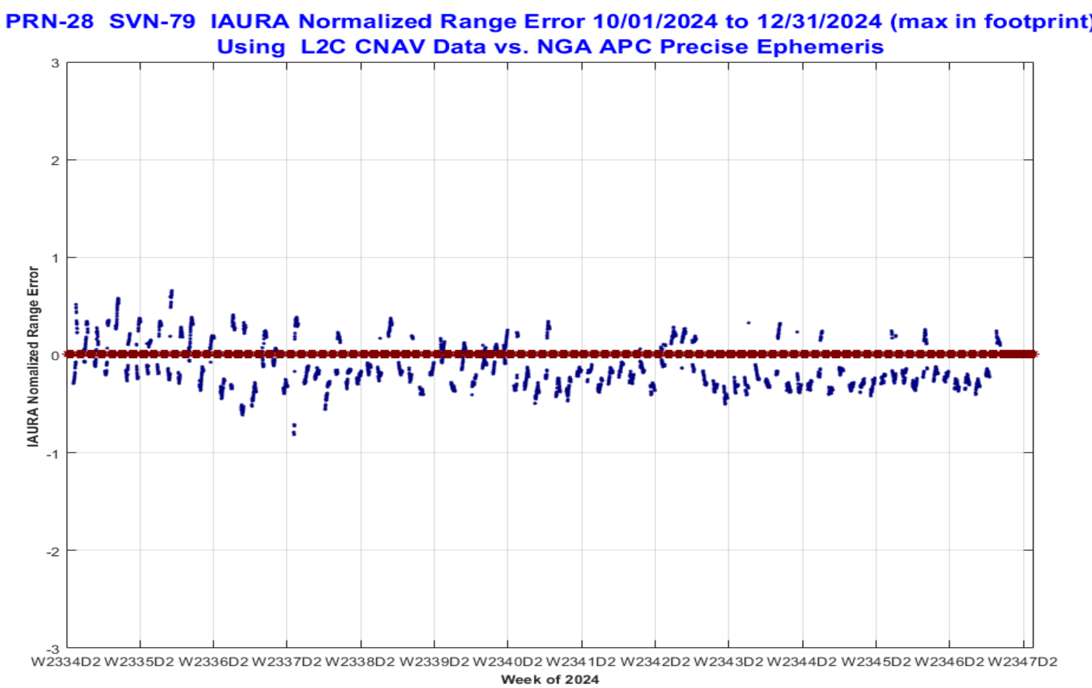


Figure 9-182 Timeline of IAURA Normalized Range Error PRN28 (SVN79) Using L2C CNAV Data

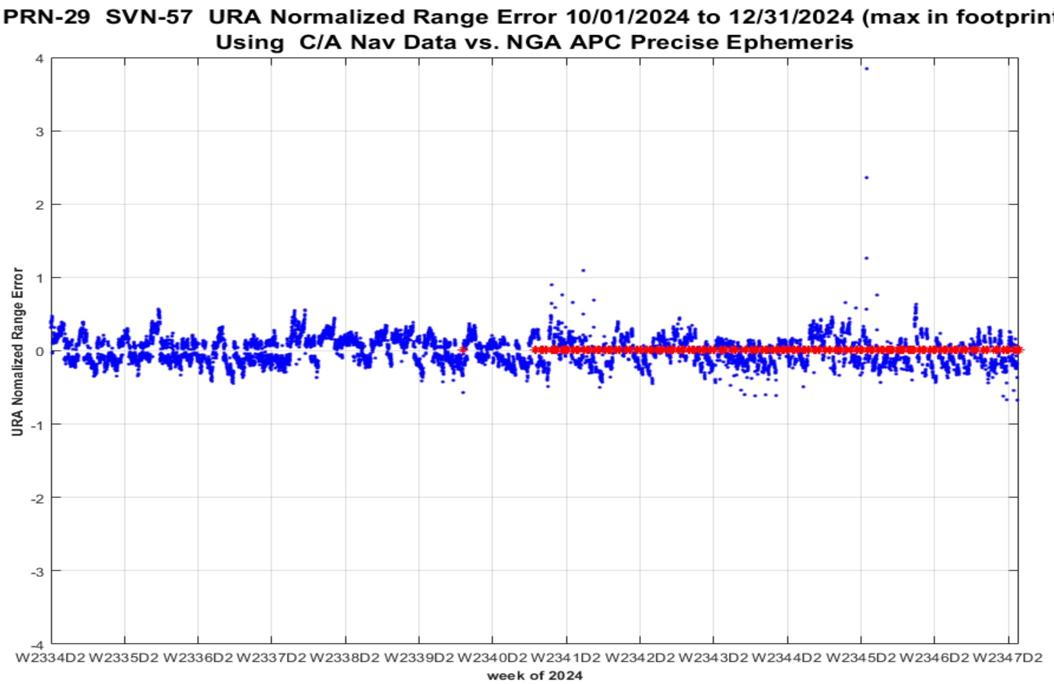


Figure 9-183 Timeline of URA Normalized Range Error PRN29 (SVN57) Using C/A Nav Data

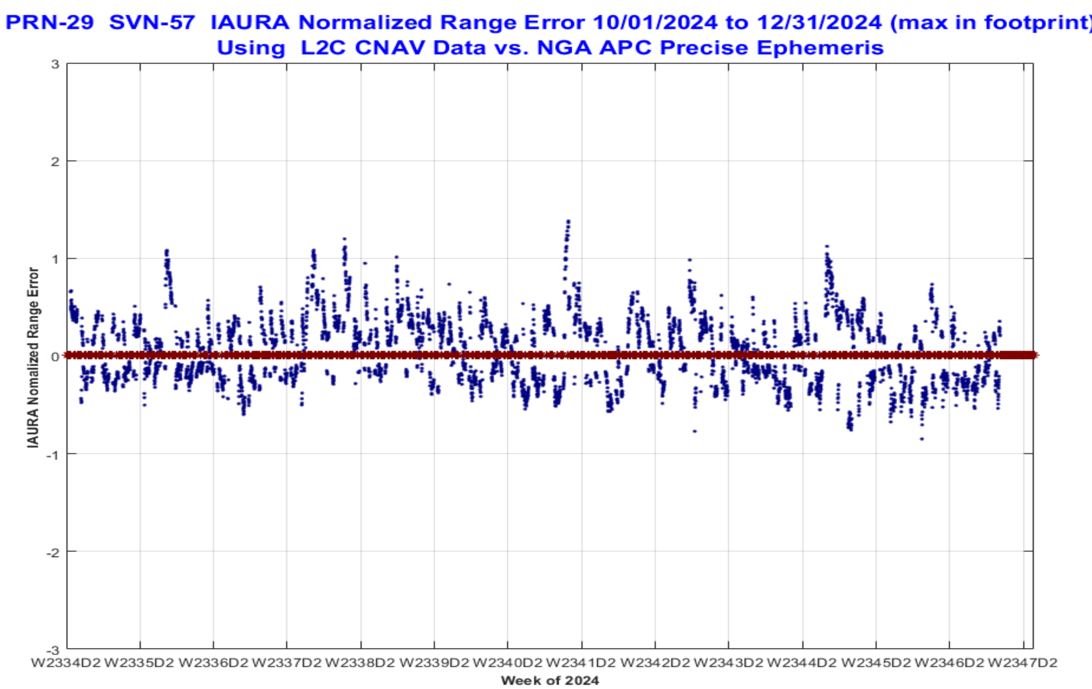


Figure 9-184 Timeline of IAURA Normalized Range Error PRN29 (SVN57) Using L2C CNAV Data

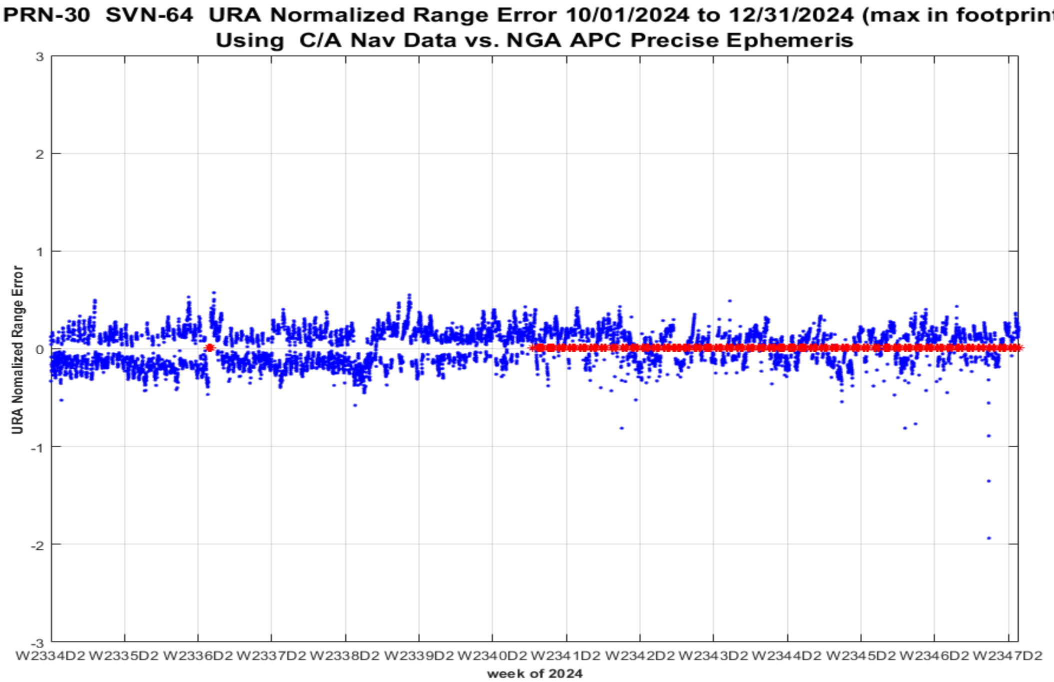


Figure 9-185 Timeline of URA Normalized Range Error PRN30 (SVN64) Using C/A Nav Data

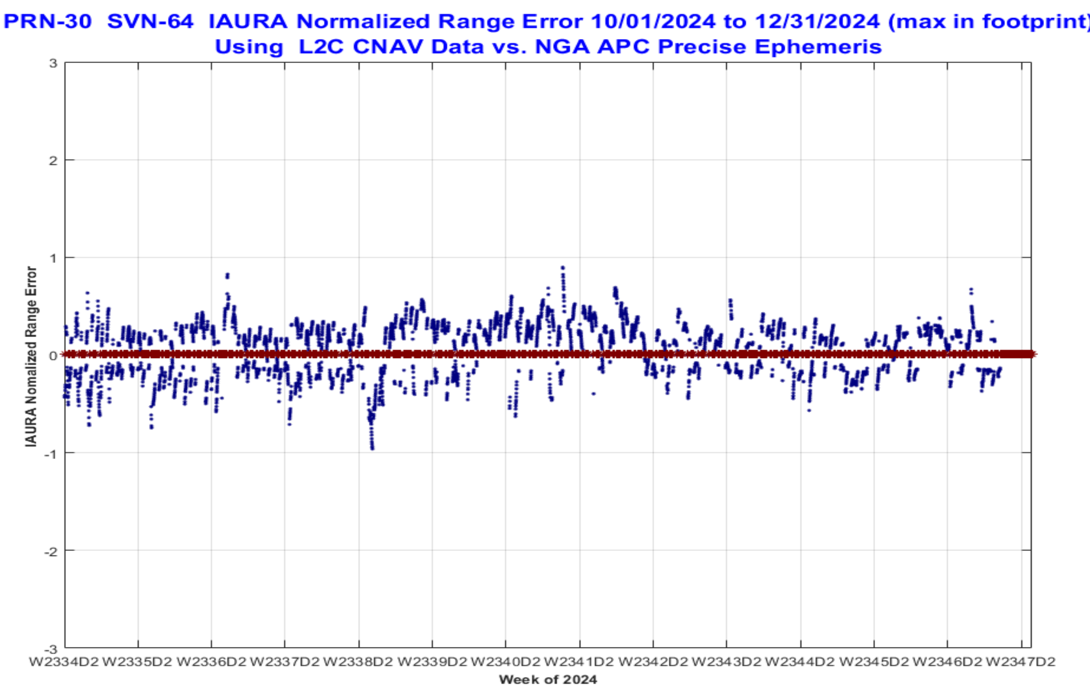


Figure 9-186 Timeline of IAURA Normalized Range Error PRN30 (SVN64) Using L2C CNAV Data

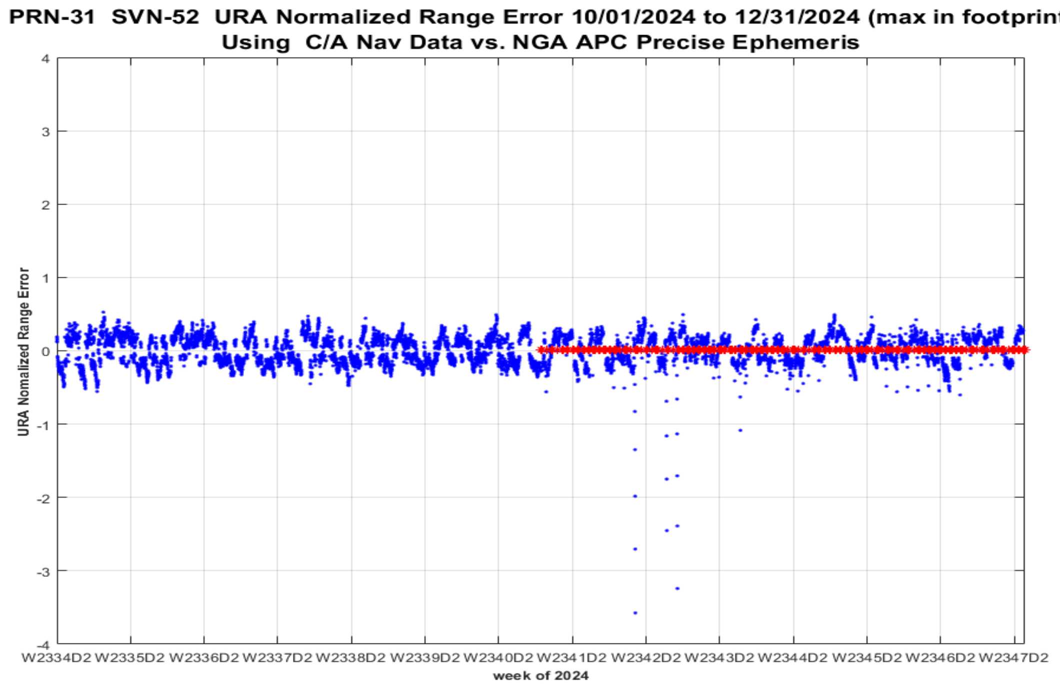


Figure 9-187 Timeline of URA Normalized Range Error PRN31 (SVN52) Using C/A Nav Data

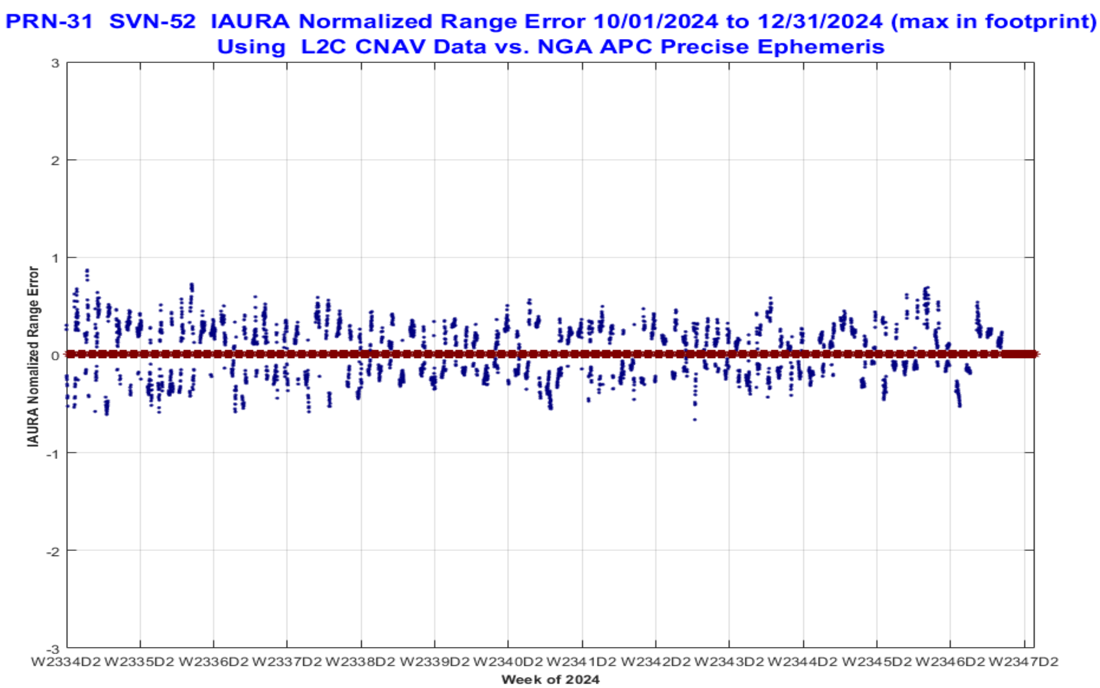


Figure 9-188 Timeline of IAURA Normalized Range Error PRN31 (SVN52) Using L2C CNAV Data

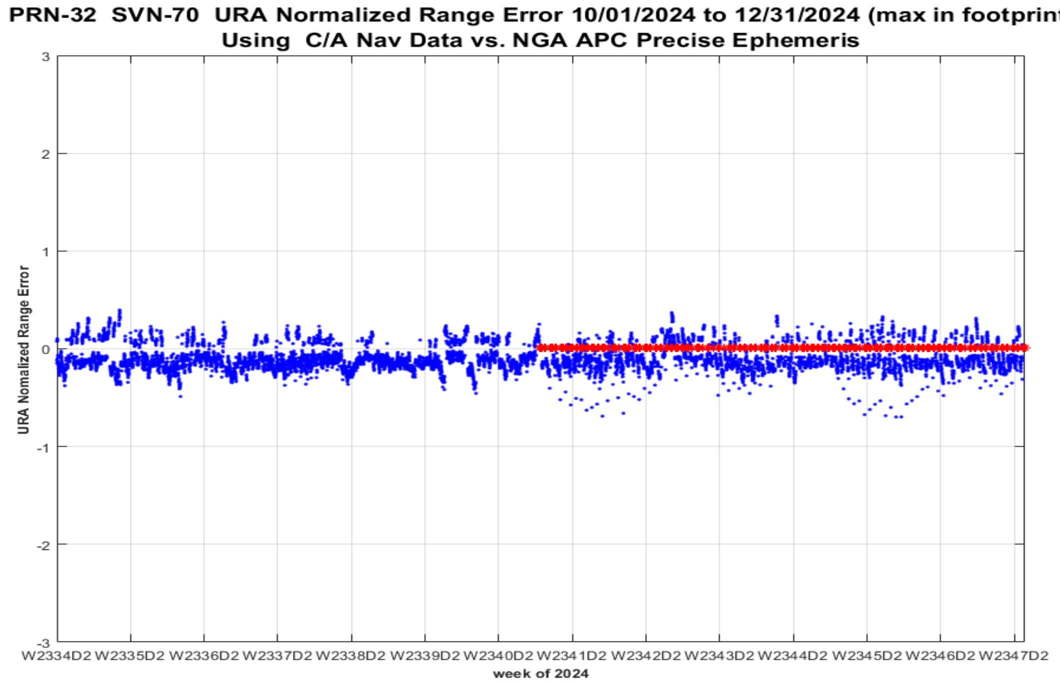


Figure 9-189 Timeline of URA Normalized Range Error PRN32 (SVN70) Using C/A Nav Data

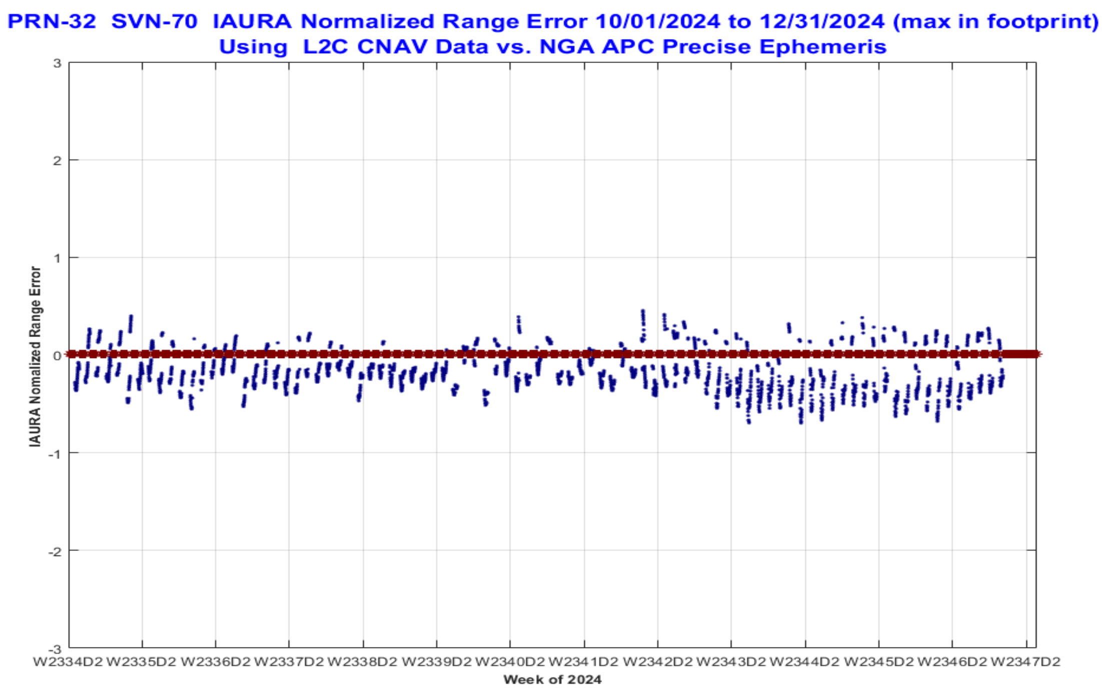


Figure 9-190 Timeline of IAURA Normalized Range Error PRN32 (SVN70) Using L2C CNAV Data

APPENDIX A: PERFORMANCE SUMMARY

Table A-0-1 Performance Summary

Parameter	Measured Performance	Conditions and Constraints
User Range Error Accuracy Single-Frequency C/A-Code 1. ≤7.8 m 95% Global Average URE during normal operations over All AODs 2. ≤6.0 m 95% Global Average URE during operations at Zero AOD 3. ≤12.8 m 95% Global Average URE during normal operations at Any AOD	1. ≤5.514 m 2. N/A 3. N/A	For any healthy SPS SIS. Neglecting single-frequency ionospheric delay model errors. Including group delay time correction (T_{GD}) errors at L1. Including inter-signal bias (P(Y)-code to C/A-code) errors at L1.
User Range Error Accuracy Single-Frequency C/A-Code 1. ≤0.03 mm 99.94% Global Average URE during normal operations 2. ≤0.03 mm 99.79% Worst Case single point average during normal operations	1. 100% Global 2. 100% WCP	For any healthy SPS SIS. Neglecting single-frequency ionospheric delay model errors. Including group delay time correction (T_{GD}) errors at L1. Standard based on measurement interval of one year; average of daily values within service volume Standard based on 3 service failures per year, lasting no more than 6 hours each
User Range Rate Error Accuracy Single-Frequency C/A Code: ≤6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	≤4.618 mm/sec	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.

Parameter	Measured Performance	Conditions and Constraints
User Range Acceleration Error Accuracy Single-Frequency C/A Code: ≤2 mm/sec^2 95% Global Average URAE over any 3-second interval during normal operations at Any AOD	≤33.094 mm/s^2	For any healthy SPS SIS. Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers. Neglecting single-frequency ionospheric delay model errors.
Per-Satellite Coverage Terrestrial Service Volume: 100% Coverage	100%	For any healthy or marginal SPS SIS.
Constellation Coverage Terrestrial Service Volume: 100% Coverage	100%	For any healthy or marginal SPS SIS.
Status and Problem Reporting Scheduled event affecting service Appropriate NANU issued to the U.S. Coast Guard and the FAA at least 48 hours prior to the event	≥53.9 hours Prior to event	For any SPS SIS.
Status and Problem Reporting Unscheduled outage or problem affecting service Appropriate NANU issued to the U.S. Coast Guard and the FAA as soon as possible after the event	≤0.217 hours	For any SPS SIS.

Parameter	Measured Performance	Conditions and Constraints
Status and Problem Reporting Unscheduled Failure Interruption Continuity: ≥0.9998 Probability over any hour of not losing the SPS SIS availability from a slot due to unscheduled interruption	100%	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Given that the SPS SIS is available from the slot at the start of the hour.
Operational Satellite Count ≥0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	100%	Applies to the total number of operational satellites in the constellation (averaged over any day); where any satellite which appears in the transmitted navigation message almanac is defined to be an operational satellite regardless of whether that satellite is currently broadcasting a healthy SPS SIS or not and regardless of whether the broadcast SPS SIS also satisfies the other performance standards in the SPS performance standard or not.
PDOP Availability 1. ≥98% global PDOP of 6 or less 2. ≥88% worst site PDOP of 6 or less	1. 100% 2. 100%	Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
Service Availability 1. ≥99% Horizontal Service Availability, average location 2. ≥99% Vertical Service Availability, average location	1. 100% Horizontal 2. 100% Vertical	15m Horizontal (SIS only) 95% threshold. 33m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.

Parameter	Measured Performance	Conditions and Constraints
Service Availability 1. ≥90% Horizontal Service Availability, worst-case location 2. ≥90% Vertical Service Availability, worst-case location	1. 100% Horizontal 2. 100% Vertical	15m Horizontal (SIS only) 95% threshold. 33 m Vertical (SIS only) 95% threshold. Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
Position/Time Accuracy Global Average Position Domain Accuracy: 1. ≤8 m 95% Horizontal Error 2. ≤13 m 95 % Vertical Error	1. ≤4.442 m Horizontal 2. ≤7.925 m Vertical	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Position/Time Accuracy Worst Site Position Domain Accuracy: 1. ≤15 m 95% Horizontal Error 2. ≤33 m 95% Vertical Error	1. ≤13.650 m Horizontal 2. ≤11.340 m Vertical	Defined for a position/time solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Position/Time Accuracy Time Transfer Domain Accuracy: ≤30 nanoseconds time transfer error 95% of time (SIS only)	≤7.3 .2 nanoseconds	Defined for a time transfer solution meeting the representative user conditions. Standard based on a measurement interval of 24 hours averaged over all points in the service volume.

Parameter	Measured Performance	Conditions and Constraints
Position/Time Accuracy Instantaneous UTCOE Integrity: NTE ±120 nanoseconds 99.999% of time without a timely alert. (SIS only)	≤12.2 nanoseconds	For any healthy SPS SIS. Worst case for delayed alert is 6 hours.
Per-Slot Availability 1. ≥0.957 Probability that a slot in the baseline 24-slot configuration will be occupied by a satellite broadcasting a healthy SPS SIS 2. ≥0.957 Probability that a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a healthy SPS SIS	1. 100% 2. 100%	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Applies to satellites broadcasting a healthy SPS SIS that also satisfy the other performance standards in the SPS performance standard.

Parameter	Measured Performance	Conditions and Constraints
Constellation Availability 1. ≥0.98 Probability that at least 21 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration 2. ≥0.99999 Probability that at least 20 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration	1. 100% 2. 100%	Calculated as an average over all slots in the 24-slot constellation, normalized annually. Applied to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.

APPENDIX B: GEOMAGNETIC DATA

\# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center

\# Current Quarter Daily Geomagnetic Data

#	Middle Latitude - Fredericksburg -									High Latitude ---- College ----									Estimated --- Planetary ---								
# Date	A	K-indices								A	K-indices								A	K-indices							
2024 10 01	5	1	2	2	1	2	1	2	1	3	1	2	1	0	0	2	1	1	6	2.33	2.33	1.67	1.00	1.33	2.00	1.67	1.33
2024 10 02	6	2	2	1	2	2	1	2	1	-1	2	1	2	5	5	0	1	-1	7	2.67	2.33	1.67	2.33	2.00	0.67	1.67	1.33
2024 10 03	8	0	1	1	2	4	2	2	2	7	0	1	1	3	3	2	2	1	8	1.33	1.67	2.00	2.00	3.00	1.67	2.33	2.00
2024 10 04	6	1	1	1	1	2	2	2	3	3	1	1	1	0	1	1	1	2	8	2.33	1.67	1.67	1.33	1.33	2.33	2.33	3.33
2024 10 05	8	1	1	2	2	3	2	3	2	4	2	0	2	1	1	1	1	1	7	2.67	1.33	2.00	1.67	2.33	1.00	2.00	1.67
2024 10 06	13	1	1	3	2	3	3	3	4	7	1	0	2	2	2	2	2	3	16	1.67	1.00	2.33	1.67	3.00	3.33	3.67	5.00
2024 10 07	33	4	4	3	5	5	4	5	4	67	4	4	4	7	7	5	6	5	55	5.33	4.67	3.33	5.33	6.33	4.00	6.33	5.33
2024 10 08	29	5	5	5	3	3	3	3	4	73	5	6	8	6	5	5	4	3	58	6.67	7.33	5.67	4.33	3.67	4.00	3.67	4.33
2024 10 09	15	3	4	4	3	3	2	2	2	34	3	4	6	5	4	5	3	3	19	4.00	4.67	4.00	3.00	3.67	2.33	2.00	2.33
2024 10 10	50	2	2	1	2	3	7	6	7	116	3	3	2	4	6	9	8	7	96	2.00	2.67	1.67	2.00	3.33	7.67	8.33	8.67
2024 10 11	68	6	7	7	5	6	4	3	3	123	5	7	9	6	8	5	3	3	116	8.00	7.67	8.00	7.33	6.67	4.33	3.33	3.33
2024 10 12	16	3	1	3	4	4	2	4	2	33	4	2	2	7	5	3	3	2	20	3.67	2.00	2.67	5.00	4.00	2.67	3.67	2.67
2024 10 13	3	1	1	0	2	2	1	2	0	4	1	0	0	2	3	1	1	1	5	1.67	1.33	1.00	2.00	1.67	1.00	2.00	1.00
2024 10 14	6	1	1	1	1	2	1	2	3	6	1	0	3	2	2	1	1	2	8	1.00	1.00	2.00	1.33	1.33	1.00	2.33	3.67
2024 10 15	9	2	2	2	2	4	2	2	1	27	2	2	6	4	5	4	3	2	15	3.33	2.67	4.00	2.67	3.33	3.00	2.33	2.33
2024 10 16	11	2	2	3	2	3	3	3	2	31	1	2	6	5	5	5	2	2	15	2.33	3.00	3.33	3.00	3.00	3.33	3.33	3.00
2024 10 17	7	3	2	2	2	2	1	1	1	10	2	4	4	1	1	2	1	1	9	3.33	3.00	2.00	1.67	1.00	1.33	1.67	2.00
2024 10 18	10	2	3	1	2	3	2	2	3	19	2	2	1	4	5	4	3	3	14	3.33	2.67	1.33	2.00	3.00	3.00	3.00	4.00
2024 10 19	15	3	3	3	3	4	2	2	3	36	5	4	6	5	5	3	3	2	23	4.67	4.33	3.67	3.00	3.33	2.33	3.67	4.00
2024 10 20	6	2	2	2	1	2	2	1	2	6	2	2	2	3	2	1	0	0	7	3.00	2.33	2.00	1.33	1.33	1.00	1.00	1.67
2024 10 21	3	0	0	1	1	2	1	1	1	3	0	0	2	2	0	2	1	0	5	0.67	0.33	1.67	2.00	1.00	1.67	1.33	2.00
2024 10 22	7	2	2	2	2	2	2	1	2	25	1	2	5	5	4	5	3	2	8	1.67	2.33	2.33	2.67	2.00	2.33	1.67	2.00
2024 10 23	7	1	2	1	2	3	2	2	1	15	1	1	1	5	5	1	2	1	9	1.67	2.67	1.67	3.00	2.67	1.33	2.00	1.67
2024 10 24	10	2	4	3	1	2	2	2	1	11	1	4	3	3	3	2	1	0	13	3.00	4.33	3.67	2.00	1.00	2.00	2.00	1.67
2024 10 25	2	1	0	0	0	1	2	1	0	1	1	0	0	0	0	0	0	1	3	1.67	0.67	0.67	0.67	0.33	0.67	0.67	1.00

2024 10 26	11	1	1	1	2	3	3	3	4	9	0	0	0	2	4	3	3	2	14	1.67	1.00	1.67	1.67	2.67	3.33	4.00	4.33
2024 10 27	8	3	1	1	2	2	3	2	2	14	1	2	2	4	3	4	3	2	10	3.00	2.00	1.00	2.67	2.00	2.67	2.67	2.67
2024 10 28	11	2	4	3	2	3	2	1	2	30	2	3	5	4	6	5	2	2	17	3.00	4.67	4.00	2.67	3.00	2.67	2.00	2.33
2024 10 29	10	2	1	2	2	3	3	3	2	14	3	2	4	3	3	2	3	2	12	3.33	2.00	2.33	2.00	2.00	2.67	3.67	2.67
2024 10 30	10	3	2	3	3	3	2	1	1	18	3	3	3	4	5	3	2	1	15	4.00	3.00	3.33	4.00	3.00	2.33	1.67	1.33
2024 10 31	8	1	1	1	1	3	2	3	3	4	1	0	1	1	1	1	2	2	9	1.33	1.00	1.33	1.67	1.67	2.00	3.33	3.67
2024 11 01	6	2	1	1	1	3	2	2	0	14	2	1	1	5	5	0	1	0	7	3.00	1.33	1.33	2.33	2.67	0.67	1.33	0.33
2024 11 02	9	0	1	1	3	3	3	3	2	22	0	0	2	5	5	5	2	3	13	0.67	1.00	1.67	4.00	3.67	2.67	3.00	3.33
2024 11 03	8	2	0	1	1	2	3	3	3	6	2	1	0	0	0	2	3	3	11	2.67	1.00	1.00	1.33	0.67	3.33	3.33	4.00
2024 11 04	11	3	4	2	2	3	1	1	2	20	3	3	5	5	3	3	1	1	14	4.00	4.33	2.67	2.33	2.33	1.67	1.00	2.67
2024 11 05	10	2	1	3	2	3	3	2	2	19	1	0	4	5	5	3	2	2	11	2.67	1.67	3.00	2.67	2.67	2.67	2.33	2.67
2024 11 06	9	3	3	2	2	3	2	1	1	24	3	2	6	5	4	2	1	1	10	3.33	3.33	2.33	2.00	2.33	2.00	2.00	1.67
2024 11 07	7	1	1	2	2	1	3	2	2	11	1	1	3	5	2	2	1	1	9	1.33	1.00	2.00	2.33	0.67	3.00	2.67	3.00
2024 11 08	7	1	0	2	1	2	1	3	3	7	1	1	1	3	2	0	3	2	11	2.33	1.00	1.33	1.67	2.00	1.33	4.00	3.67
2024 11 09	24	4	3	3	5	4	4	3	3	48	2	3	4	6	6	6	6	3	32	4.00	4.00	3.67	5.00	5.00	4.33	4.33	3.67
2024 11 10	15	4	3	2	1	4	3	3	2	35	4	2	3	5	6	5	5	2	25	4.00	4.00	2.33	2.33	4.33	4.00	5.33	3.00
2024 11 11	7	2	1	3	2	2	2	1	1	23	1	1	6	5	4	3	2	1	10	2.33	2.00	3.67	2.67	2.00	2.67	1.67	1.33
2024 11 12	4	2	1	2	1	2	1	1	0	5	0	1	3	1	1	3	1	0	5	2.00	1.33	2.00	1.00	1.33	1.67	1.00	0.67
2024 11 13	5	2	2	0	0	3	1	1	1	13	1	1	0	4	5	3	2	1	7	3.00	2.33	0.33	1.33	2.67	1.33	1.67	1.00
2024 11 14	10	0	3	2	1	3	2	2	4	14	0	2	1	3	4	4	3	3	11	1.00	3.33	1.33	1.33	2.00	2.67	3.33	3.67
2024 11 15	10	3	3	3	2	2	2	2	2	22	2	3	4	4	4	5	3	2	13	3.00	3.67	2.67	2.33	2.67	2.67	2.67	2.33
2024 11 16	8	3	3	3	2	2	1	0	1	9	3	2	4	3	2	1	0	0	8	3.67	2.67	2.67	2.00	1.67	0.67	0.33	0.67
2024 11 17	6	0	3	2	2	2	1	1	1	14	0	1	2	5	5	1	1	0	8	1.00	3.00	2.00	2.33	2.67	1.00	1.33	1.33
2024 11 18	3	1	2	0	0	2	2	0	1	2	0	1	0	1	1	2	0	0	4	1.00	2.00	0.33	0.67	1.00	1.33	1.00	1.33
2024 11 19	6	0	1	2	2	3	2	2	1	21	0	0	2	3	6	5	3	1	9	1.00	1.00	1.67	2.00	3.00	3.00	2.67	1.33
2024 11 20	8	0	3	3	2	2	2	1	2	11	0	2	4	4	3	2	1	0	9	1.00	3.00	3.00	2.67	1.67	1.67	1.00	1.67
2024 11 21	5	0	-1	-1	-1	-1	-1	2	2	7	0	1	3	3	1	1	1	3	8	0.67	1.33	1.67	1.67	1.00	1.67	3.00	3.00
2024 11 22	10	1	1	1	2	3	4	2	3	19	2	1	0	3	5	5	3	3	12	2.33	2.00	0.67	1.67	3.00	3.67	2.67	3.33
2024 11 23	7	2	1	1	1	3	2	3	1	11	1	1	2	4	4	2	2	1	8	2.00	1.67	1.67	1.67	3.00	1.67	2.33	1.67
2024 11 24	7	1	1	2	1	2	2	2	3	3	0	1	0	0	0	1	2	2	7	1.67	1.67	1.67	1.00	0.67	1.67	1.67	3.67
2024 11 25	9	2	2	2	2	3	3	1	2	17	3	2	1	5	4	4	1	1	11	3.33	2.33	2.00	2.33	2.67	3.00	2.33	2.33
2024 11 26	6	3	2	0	1	2	2	1	2	2	1	1	0	1	2	1	0	0	7	3.33	2.33	1.00	1.33	1.00	0.67	1.00	2.00
2024 11 27	3	0	0	1	1	1	2	1	1	2	0	0	0	2	1	0	0	1	5	1.00	0.67	1.67	2.00	0.67	1.00	1.00	2.33
2024 11 28	3	1	1	0	1	1	2	1	0	1	1	1	0	0	0	0	1	0	4	2.00	1.00	0.67	1.00	0.67	0.67	1.00	0.33
2024 11 29	6	1	2	1	2	2	2	2	2	-1	0	1	0	4	1	1	-1	-1	8	1.67	2.33	1.67	2.33	2.00	1.33	2.67	2.67

2024 11 30	9	4	2	2	1	2	2	1	2	5	3	3	2	0	1	0	0	1	11	4.67	3.33	2.33	0.67	1.00	0.67	1.00	2.33
2024 12 01	6	1	1	2	2	2	2	2	2	5	0	0	2	4	0	0	1	1	7	1.33	1.00	2.33	1.33	1.00	1.67	2.33	3.00
2024 12 02	6	2	2	1	0	2	2	2	2	2	0	0	0	0	2	0	1	1	6	2.33	2.00	1.00	0.67	1.33	0.67	1.67	2.00
2024 12 03	10	3	2	3	2	2	3	2	2	21	2	2	5	5	3	3	4	1	13	3.67	3.00	2.33	2.00	2.00	3.00	3.33	2.00
2024 12 04	5	1	1	1	1	2	2	2	2	8	1	0	1	4	3	1	1	2	7	1.67	1.33	1.33	2.00	2.00	1.67	2.33	2.00
2024 12 05	5	2	2	1	1	1	2	1	1	3	1	1	0	3	1	0	0	0	5	2.33	2.33	1.33	1.33	0.67	1.00	1.00	1.00
2024 12 06	4	1	2	1	1	1	2	1	1	2	0	1	2	1	0	1	1	0	5	1.67	2.67	1.33	1.00	0.67	1.33	1.00	1.00
2024 12 07	5	1	1	1	1	2	2	2	2	7	0	1	1	4	3	0	1	1	6	1.33	1.67	1.00	2.00	1.33	1.33	2.00	1.67
2024 12 08	4	0	1	1	0	3	2	2	0	14	0	0	3	3	5	4	2	0	7	0.67	1.67	1.33	1.67	2.67	2.00	2.33	1.33
2024 12 09	12	3	2	2	2	3	3	3	3	39	2	2	4	5	5	7	4	2	16	4.00	3.00	2.33	2.67	2.67	3.33	3.00	3.67
2024 12 10	7	2	2	2	2	2	2	1	2	13	2	2	3	5	3	2	2	0	8	3.00	2.33	2.33	2.33	1.33	1.67	1.67	2.00
2024 12 11	4	1	1	2	1	1	2	1	0	15	1	1	5	4	4	2	0	1	6	2.00	2.33	2.00	1.00	1.00	1.33	1.00	1.33
2024 12 12	4	2	1	0	1	1	2	2	1	2	0	1	1	1	1	1	0	0	6	2.67	2.00	1.00	1.00	0.67	1.33	1.67	0.67
2024 12 13	2	0	0	1	1	1	2	0	1	5	0	0	1	3	2	3	0	0	4	0.33	0.33	1.67	1.67	1.00	1.67	0.67	0.67
2024 12 14	8	1	1	1	3	2	3	2	2	23	0	0	2	5	4	5	5	1	10	1.00	1.33	1.33	2.67	1.33	3.33	3.00	3.33
2024 12 15	9	2	2	1	3	3	2	2	2	19	0	2	2	5	5	4	2	2	12	3.00	3.00	2.00	2.67	3.33	2.00	2.67	2.33
2024 12 16	11	1	3	3	3	1	2	3	3	30	0	2	6	6	4	3	4	2	14	1.33	3.00	3.00	3.00	1.67	2.67	3.67	3.67
2024 12 17	20	3	4	4	4	3	4	2	3	31	3	6	5	4	4	4	3	2	29	4.00	5.33	4.67	4.00	3.67	4.33	2.33	3.33
2024 12 18	12	3	1	2	3	2	4	3	1	18	3	1	2	4	4	4	4	2	15	3.67	2.00	2.67	3.33	2.67	3.33	4.00	1.33
2024 12 19	9	4	2	1	1	2	3	1	2	8	3	2	1	2	3	2	1	2	11	4.00	3.00	1.67	1.33	2.00	2.00	2.00	2.67
2024 12 20	10	3	2	1	1	3	2	3	3	12	3	2	0	2	4	3	3	2	13	3.67	3.00	1.33	1.67	3.00	3.00	3.33	2.33
2024 12 21	13	3	3	1	3	3	2	3	3	11	2	2	2	3	3	3	3	2	16	3.33	3.33	2.00	3.00	2.67	3.00	3.67	3.33
2024 12 22	15	2	1	2	3	4	4	3	3	23	2	1	2	5	5	4	4	3	14	2.33	2.33	2.33	3.00	3.33	3.00	3.00	3.33
2024 12 23	11	3	1	2	1	2	4	2	3	13	3	1	1	1	4	4	2	3	12	3.67	2.00	2.00	1.00	2.33	3.33	2.67	3.33
2024 12 24	9	2	2	1	1	3	3	2	3	16	2	2	1	0	5	5	2	2	12	2.67	2.67	2.00	1.00	2.67	3.00	2.33	3.67
2024 12 25	5	2	1	1	2	2	2	1	0	3	1	2	2	2	1	0	0	0	5	2.33	2.00	1.67	2.00	1.33	0.67	1.00	0.33
2024 12 26	3	0	0	1	0	2	2	1	1	0	0	0	0	0	0	0	0	0	3	0.33	0.33	0.67	0.67	0.67	0.67	0.67	0.67
2024 12 27	3	1	0	0	0	2	2	1	0	1	0	0	0	2	1	0	0	0	4	1.00	0.33	0.67	0.67	1.00	1.33	1.33	0.67
2024 12 28	4	0	0	1	1	2	3	2	0	2	0	0	1	2	0	0	1	0	4	0.67	0.67	1.33	1.67	0.67	1.33	1.67	0.67
2024 12 29	5	1	0	1	2	2	2	2	1	5	0	0	3	3	1	0	0	1	5	1.33	0.67	1.33	2.00	1.67	1.33	1.00	1.33
2024 12 30	7	1	1	2	1	2	3	2	2	9	0	0	4	2	4	1	1	1	7	1.00	2.00	2.67	1.67	1.67	1.67	2.00	2.33
2024 12 31	10	0	1	2	1	2	4	3	3	15	0	0	5	3	1	4	3	3	12	0.33	0.67	2.33	1.33	1.00	4.33	4.00	4.00

APPENDIX C: KEY TERMS

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (April 2020). Understanding these terms and definitions is necessary to fully understand the Signal Specification.

General Terms and Definitions

Alarm: An indication requiring an immediate response (e.g., to preserve integrity).

Alert: Generic term encompassing both alarm and warning.

Alerted Misleading Signal-in-Space Information (AMSI): The pseudorange data set (e.g., pseudorange measurement and NAV data) provided by a SPS SIS provides alerted MSI (AMSI) when the instantaneous URE exceeds the SIS URE NTE tolerance, but a timely alert (alarm or warning) is provided.

Almanac Longitude of the Ascending Node (.o): Equatorial angle from the Prime Meridian (Greenwich) at the weekly epoch to the ascending node at the ephemeris reference epoch.

AOD: Age of Data.

Auxiliary Satellite: An operational satellite that is not occupying a defined orbital slot in the baseline 24-slot constellation or the expandable 24-slot constellation. Auxiliary satellites are typically either newly launched satellites waiting to take their place in the baseline/expandable 24-slot constellation, or they are older satellites that are nearing the end of their useful lives and have been shifted out of the baseline/expandable 24-slot constellation. The SPS SIS broadcast by an auxiliary satellite is not required to meet all the standards in Section 3.

Coarse/Acquisition (C/A) Code: A PRN code sequence used to modulate the GPS L1 carrier.

Corrected Longitude of Ascending Node (Ωk) and Geographic Longitude of the Ascending Node (GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the ascending node, both at arbitrary time T_k.

Dilution of Precision (DOP): The magnifying effect on GPS position error induced by mapping GPS ranging errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

Equatorial Angle: An angle along the equator in the direction of Earth's rotation.

Geometric Range: The difference between the estimated locations of a GPS satellite and an SPS receiver.

Ground Track Equatorial Crossing (GEC, λ, 2 SOPS GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the

Southern to the Northern hemisphere. GEC is equal to Ωk when the argument of latitude (Φ) is zero.

Instantaneous User Range Error (URE): The difference between the pseudo range measured at a given location and the expected pseudo range, as derived from the navigation message and the true user position, neglecting the bias in receiver clock relative to GPS time. A signal-in-space (SIS) URE includes residual orbit, satellite clock, and group delay errors. A system URE (sometimes known as a User Equivalent Range Error, or UERE) contains all line-of-sight error sources, to include SIS, single-frequency ionosphere model error, troposphere model error, multipath and receiver noise.

Longitude of Ascending Node (LAN): A general term for the location of the ascending node, which is the point that an orbit intersects the equator when crossing from the Southern to the Northern hemisphere.

Longitude of the Ground track Equatorial Crossing (GEC, λ, 2 SOPS GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the Southern to the Northern hemisphere. GEC is equal to Ωk when the argument of latitude (Φ) is zero.

Mean Down Time (MDT): A measure of time required to restore function after any downing event.

Mean Time Between Downing Events (MTBDE): A measure of time between any downing events.

Mean Time Between Failures (MTBF): A measure of time between unscheduled downing events.

Mean Time to Restore (MTTR): A measure of time required to restore function after an unscheduled downing event.

Navigation Message: Data contained in each satellite's ranging signal and consisting of the ranging signal time-of-transmission, the transmitting satellite's orbital elements, an almanac containing abbreviated orbital element information to support satellite selection, ranging measurement correction information, and status flags. The message structure is described in Section 2.1.2 of the SPS Performance Standard.

Operational Satellite: A GPS satellite that is capable of, but is not necessarily, transmitting a usable ranging signal.

PDOP Availability: Defined to be the percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume.

Positioning Accuracy: Defined to be the statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

• **Horizontal Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between horizontal position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

• **Vertical Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

Position Solution: An estimate of a user's location derived from ranging signal measurements and navigation data from GPS.

Position Solution Geometry: The set of direction cosines that define the instantaneous relationship of each satellite's ranging signal vector to each of the position solution coordinate axes.

Pseudo Random Noise (PRN): A binary sequence that appears to be random over a specified time interval unless the shift register configuration and initial conditions for generating the sequence are known. Each satellite generates a unique PRN sequence that is effectively uncorrelated (orthogonal) to any other satellite's code over the integration time constant of a receiver's code tracking loop.

Representative SPS Receiver: The minimum signal reception and processing assumptions employed by the U.S. Government to characterize SPS performance in accordance with performance standards defined in Section 3 of the SPS Performance Standard. Representative SPS receiver capability assumptions are identified in Section 2.2 of the SPS Performance Standard.

Right Ascension of Ascending Node (RAAN): Equatorial angle from the celestial principal direction to the ascending node.

Root Mean Square (RMS) SIS URE: A statistic that represents instantaneous SIS URE performance in an RMS sense over some sample interval. The statistic can be for an individual satellite or for the entire constellation. The sample interval for URE assessment used in the SPS Performance Standard is 24 hours.

Selective Availability: Protection technique formerly employed to deny full system accuracy to unauthorized users. SA was discontinued effective midnight May 1, 2000.

Service Availability: Defined to be the percentage of time over any 24-hour interval that the predicted 95% positioning error is less than its threshold for any given point within the service volume.

• **Horizontal Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% horizontal error is less than its threshold for any point within the service volume.

• **Vertical Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% vertical error is less than its threshold for any point within the service volume.

Service Degradation: A condition over a time interval during which one or more SPS performance standards are not supported.

Service Failure: A condition over a time interval during which a healthy GPS satellite's ranging signal exceeds the Not-to-Exceed (NTE) SPS SIS URE tolerance.

Service Reliability: The percentage of time over a specified time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites.

Service Volume: The spatial volume supported by SPS performance standards. Specifically, the SPS Performance Standard supports the terrestrial service volume. The terrestrial service volume covers from the surface of the Earth up to an altitude of 3,000 kilometers.

SPS Performance Envelope: The range of nominal variation in specified aspects of SPS performance.

SPS Performance Standard: A quantifiable minimum level for a specified aspect of GPS SPS performance. SPS performance standards are defined in Section 3.

SPS Ranging Signal: An electromagnetic signal originating from an operational satellite. The SPS ranging signal consists of a Pseudo Random Noise (PRN) C/A code, a timing reference, and sufficient data to support the position solution generation process. A description of the GPS SPS signal is provided in Section 2. The formal definition of the SPS ranging signal is provided in ICD IS-GPS-200G.

SPS Ranging Signal Measurement: The difference between the ranging signal time of reception (as determined by the receiver's clock) and the time of transmission derived from the navigation signal (as defined by the satellite's clock) multiplied by the speed of light. This is also known as the *pseudorange*.

SPS SIS User Range Error (URE) Statistic:

• A satellite SPS SIS URE statistic is defined to be the Root Mean Square (RMS) difference between SPS ranging signal measurements (neglecting user clock bias and errors due to propagation environment and receiver), and "true" ranges between the satellite and an SPS user at any point within the service volume over a specified time interval.

• A constellation SPS SIS URE statistic is defined to be the average of all satellite SPS SIS URE statistics over a specified time interval.

Time Transfer Accuracy Relative to UTC (USNO): The difference at a 95% probability between user UTC time estimates and UTC (USNO) at any point within the service volume over any 24-hour interval.

Transient Behavior: Short-term behavior not consistent with steady-state expectations.

Usable SPS Ranging Signal: An SPS ranging signal that can be received, processed, and used in a position solution by a receiver with representative SPS receiver capabilities.

User Navigation Error (UNE): Given a sufficiently stationary and ergodic satellite constellation ranging error behavior over a minimum sample interval, multiplication of the DOP and a constellation ranging error standard deviation value will yield an approximation of the RMS position error. This RMS approximation is known as the UNE (UHNE for horizontal, UVNE for vertical, and so on). The user is cautioned that any divergence away from the stationary and ergodic assumptions will cause the UNE to diverge from an RMS value based on actual measurements.

User Range Accuracy (URA): A conservative representation of each satellite's expected (1σ) SIS URE performance (excluding residual group delay) based on historical data. A URA value is provided that is representative over the curve fit interval of the navigation data from which the URA is read. The URA is a coarse representation of the URE statistic in that it is quantized to levels represented in ICD IS-GPS-200G.