Global Positioning System (GPS)
Standard Positioning Service (SPS)
Performance Analysis Report

Submitted To

Federal Aviation Administration

GPS Product Team

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Submitted by

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Executive Summary

The GPS Product Team has tasked the Navigation Systems Verification and Monitoring Branch at the William J. Hughes Technical Center to document the Global Positioning System (GPS) Standard Positioning Service (SPS) performance in quarterly GPS Performance Analysis (PAN) Reports. The report contains the analysis performed on data collected at twenty-eight Wide Area Augmentation System (WAAS) Reference Stations. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification (September 2008).

This report, Report #99, includes data collected from 1 July through 30 September 2017. The next quarterly report will be issued January 31, 2018.

Analysis of this data includes the following standards and categories: PDOP Availability, NANU Summary and Evaluation, Service Availability, Position and Range Accuracy and Solar Storm Effects on GPS SPS performance.

PDOP availability is based on Position Dilution of Precision (PDOP). Utilizing the weekly almanac posted on the US Coast Guard navigation web site, the coverage for every 5^{o} grid point between 180W to 180E and 80S and 80N 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 99.9993%.

NANU summary and evaluation was achieved by reviewing the "Notice: Advisory to Navstar Users" (NANU) reports issued between 1 July and 30 September 2017. Using this data, we compute a set of statistics that give a relative idea of constellation health for both the current and combined history of past quarters. A total of fifteen outages were reported in the NANU's this quarter. Ten outages were scheduled ahead of time, while five unscheduled NANUs occurred.

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

Calculating the 24-hour 95% horizontal and vertical position error values verified the accuracy standards. The User Range Error 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, San Juan and Juneau. This data was also collected in one-second samples. All sites achieved 100% reliability, meeting the SPS specification. The maximum range error recorded was 20.740 meters on Satellite PRN 15. The SPS specification 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 RMS range error value of 2.162 meters was recorded on satellite PRN 22. The SPS specification states that RMS URE cannot exceed 6 meters in any 24-hour interval.

Geomagnetic storms had little to no effect on GPS performance this quarter. All sites met all GPS Standard Positioning Service (SPS) specifications on those days with the most significant solar activity.

The IGS is a voluntary federation of many worldwide agencies that pool resources and permanent GNSS station data to generate precise GNSS products. During the evaluation period, the maximum 95% horizontal and vertical SPS errors were 3.46 meters at Maspalomas, Spain and 7.59 meters at Kourou, French Guyana respectively.

From the analysis performed on data collected between 1 July and 30 September 2017, the GPS performance met all SPS requirements that were evaluated.

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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. At present, the FAA has approved GPS and WAAS for IFR operations and is further developing WAAS as a GPS augmentation system. In order 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 twenty-eight WAAS reference station locations:

- Bethel, AK
- Billings, MT
- Fairbanks, AK
- Cold Bay, AK
- Kotzebue, AK
- Juneau, AK
- Albuquerque, NM
- Anchorage, AK
- Boston, MA
- Washington, D.C.
- 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 into the four performance categories stated in the Standard Positioning Service Performance Specification (September 2008). These categories are:

- PDOP Availability Standard
- Service Availability Standard
- Service Reliability Standard
- Positioning, Ranging and Timing Accuracy Standard

The results were then compared to the performance parameters stated in the SPS.

1.2 Report Overview

Section 2 of this report 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 5-degree grid between 180 degrees east and 180 degrees west, and from 80 degrees north and 80 degrees south. The program then computes the PDOP at each grid point (1485 total grid points) every minute for the entire day and stores the results. After the PDOP's have been saved the 99.99% index of 1-minute PDOP at each grid point is determined and plotted as contour lines (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 specification 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 one-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.

In Section 6, 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 GPS Test NOTAMs.

Section 9 provides four appendices to summarize the data found in this report and provide further information.

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

Appendix B provides the geomagnetic data used for Section 6.

Appendix C provides a PAN Problem Report.

Appendix D provides a glossary of terms used in this PAN report. This glossary was obtained directly from the GPS SPS specification document (September 2008).

1.3 Summary of Performance Requirements and Metrics

Table 1-1 over the next four pages lists the performance parameters from the SPS and identifies those parameters verified in this report.

Table 1-1 SPS SIS Performance Requirements Standards

Per-Satellite Coverage	**Conditions and Constraints**	**Evaluated in This Report**
Terrestrial Service Volume: 100% Coverage Space Service Volume: No Coverage Performance Specified	• For any health or marginal SPS SIS	✓
Constellation Coverage	**Conditions and Constraints**	
Terrestrial Service Volume: 100% Coverage Space Service Volume: No Coverage Performance Specified	• For any healthy or marginal SPS SIS	✓
User Range Error Accuracy	**Conditions and Constraints**	
Single Frequency C/A-Code • ≤ 7.8m 95% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 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	✓
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 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 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	**Conditions and Constraints**	
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	Conditions and Constraints	Evaluated in This Report
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		
• ≤ 40 nanoseconds 95% Global average UTCOE during normal operations at Any AOD.	• For any healthy SPS SIS	✓
Instantaneous URE Integrity	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 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 • Worst case for delayed alert is 6 hours. • Neglecting singe-frequency ionospheric delay model errors	Please see results in the WAAS PAN report. ✓
Instantaneous UTCOE Integrity	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 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 URE NTE tolerance defined	✓
Unscheduled Failure Interruption Continuity	**Conditions and Constraints**	
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	Conditions and Constraints	Evaluated in This Report
Scheduled event affecting service • Appropriate NANU issued to the 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 Coast Guard and the FAA as soon as possible after the event	• For any SPS SIS	✓
Per-Slot Availability	**Conditions and Constraints**	
• ≥ 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	**Conditions and Constraints**	
• ≥ 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. • Applies to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.	✓
Operational Satellite Count	**Conditions and Constraints**	
• ≥ 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	Conditions and Constraints	Evaluated in This Report
• ≥ 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	**Conditions and Constraints**	
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m 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.	✓
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m 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	**Conditions and Constraints**	
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 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.	✓
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 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.	✓
Time Transfer Domain Accuracy • ≤ 40 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.	✓

2 PDOP Availability Standard

PDOP Availability: 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): 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.

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 (www.navcen.uscg.mil). 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 2º point between longitudes of 180W to 180E and 75S and 75N at one-minute intervals. This gives a total of 1440 samples for each of the 13,500 grid points in the coverage area. Table 2-1 provides the global averages and worst-case availability over a 24-hour period for each week. Table 2-1 also gives the global 99.9% PDOP value for each of the thirteen GPS Weeks. The PDOP was 3.061 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 areas' 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 2-1. 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 2-1 PDOP Availability Statistics

Date Range of Week	Global 99.9% PDOP Value	Global Average Availability (Spec: ≥ 98%)	Worst-Case Point Availability (Spec: ≥ 88%)
2 – 8 Jul	3.044	99.9996	99.5039
9 – 15 Jul	3.015	99.9996	99.4742
16 – 22 Jul	2.997	99.9995	99.4245
23 – 29 Jul	2.964	99.9995	99.3750
30 Jul – 5 Aug	2.989	99.9993	99.3055
6 – 12 Aug	2.962	99.9994	99.3750
13 – 19 Aug	2.942	99.9994	99.4146
20 – 26 Aug	2.959	99.9994	99.4444
27 Aug – 2 Sep	3.047	99.9995	99.4742
3 – 9 Sep	2.942	99.9995	99.4642
10 – 16 Sep	3.061	99.9995	99.5138
17 – 23 Sep	2.922	99.9996	99.5833
24 Sep – 30 Sep	2.910	99.9997	99.6527

Figure 2-1 World GPS Maximum PDOP

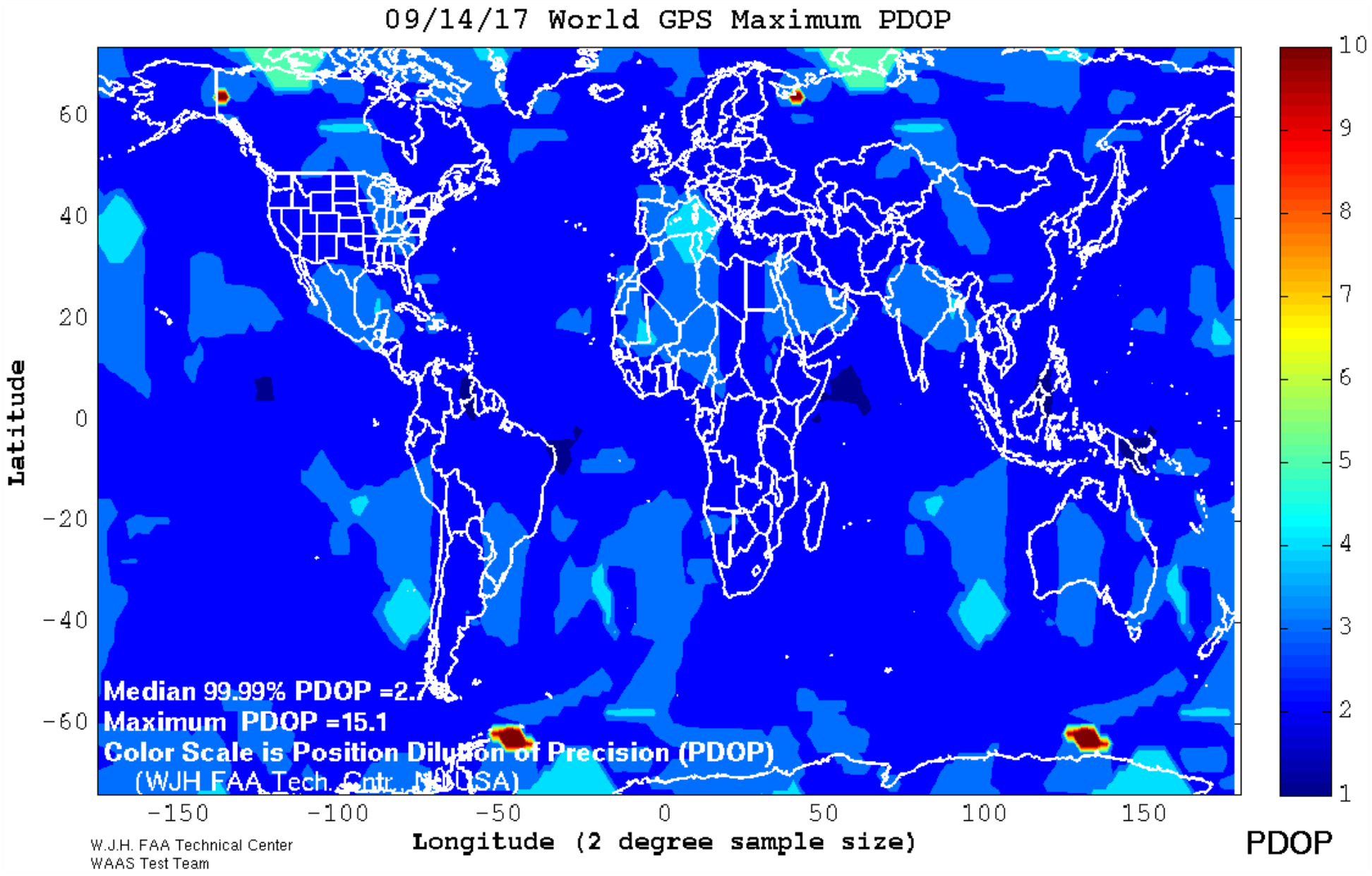
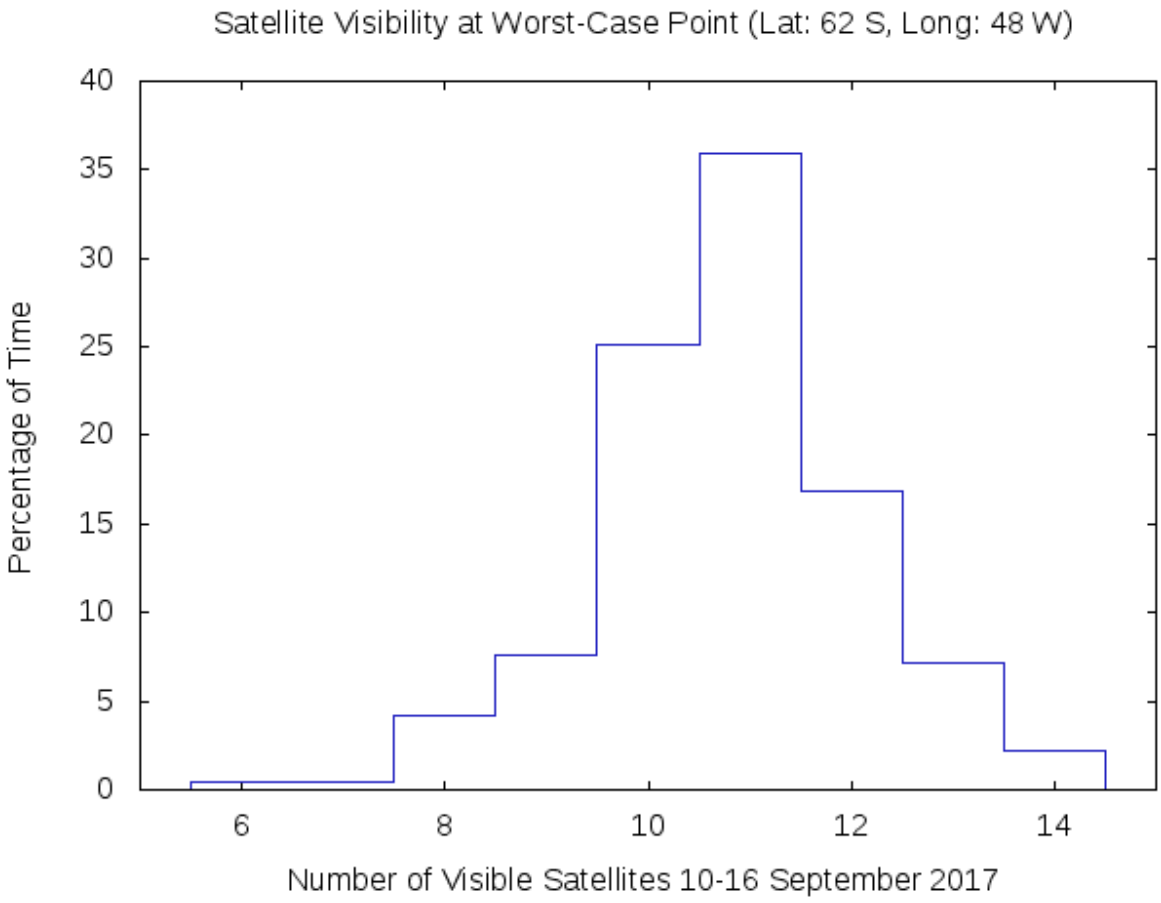


Figure 2-2 Satellite Visibility Profile for Worst-Case Point



3 NANU Summary and Evaluation

NANU: Notice Advisory to NAVSTAR Users – A periodic bulletin alerting users to changes in the satellite system performance.

Status and Problem Reporting	Conditions and Constraints
Scheduled event affecting service • Appropriate NANU issued to the 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 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 "Notice: Advisory to Navstar Users" messages (NANU's). During this reporting period, 1 July through 30 September 2017, there were a total of twenty reported outages. Fifteen outages were maintenance activities and were reported in advance, while five were unscheduled outages. A complete listing of outage NANU's for the reporting period is provided in Table 3-1. A complete listing of the forecasted outage NANU's for the reporting period can be found in Table 3-2. Canceled outage NANU's (if any) are provided in Table 3-3. The minimum duration a scheduled outage was forecasted ahead of time was 125.967 hours. The maximum response time following an unscheduled outage was 0.883 hours. Therefore the probability of continuity not being affected due to an unscheduled failure interruption was 100%, which met the specification requirement.

Table 3-1 NANUs Affecting Satellite Availability

NANU#	PRN	TYPE	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
2017066	2	FCSTSUMM	6-Jul-17	18:41	7-Jul-17	0:09		5.47	5.47
2017067	23	FCSTSUMM	11-Jul-17	23:45	12-Jul-17	2:20		2.58	2.58
2017069	5	FCSTSUMM	13-Jul-17	21:36	14-Jul-17	0:20		2.73	2.73
2017071	7	FCSTSUMM	18-Jul-17	21:27	19-Jul-17	3:27		6.00	6.00
2017075	25	FCSTSUMM	3-Aug-17	16:14	3-Aug-17	21:28		5.23	5.23
2017076	17	FCSTSUMM	8-Aug-17	23:45	9-Aug-17	3:35		3.83	3.83
2017079	15	FCSTSUMM	10-Aug-17	14:39	10-Aug-17	17:52		3.22	3.22
2017081	9	UNUSABLE	11-Aug-17	10:58	11-Aug-17	13:41	2.72		2.72
2017084	31	FCSTSUMM	15-Aug-17	15:02	15-Aug-17	17:20		2.30	2.30
2017088	2	FCSTSUMM	18-Aug-17	3:12	18-Aug-17	5:36		2.40	2.40
2017091	29	FCSTSUMM	22-Aug-17	20:08	22-Aug-17	22:21		2.22	2.22
2017092	12	FCSTSUMM	24-Aug-17	6:13	24-Aug-17	8:35		2.37	2.37
2017093	9	FCSTSUMM	25-Aug-17	8:47	25-Aug-17	13:58		5.18	5.18
2017094	21	FCSTSUMM	29-Aug-17	17:38	29-Aug-17	20:07		2.48	2.48
2017096	5	FCSTSUMM	31-Aug-17	19:56	1-Sep-17	1:13		5.28	5.28
2017097	13	FCSTSUMM	7-Sep-17	10:50	7-Sep-17	17:57		7.12	7.12
2017100	7	UNUSABLE	12-Sep-17	6:25	12-Sep-17	10:07	3.70		3.70
2017103	1	UNUSABLE	14-Sep-17	0:21	14-Sep-17	9:26	9.08		9.08
2017104	7	UNUSABLE	12-Sep-17	13:42	15-Sep-17	20:09	78.45		78.45
2017106	25	UNUSABLE	17-Sep-17	15:00	17-Sep-17	18:13	3.22		3.22
Totals of Unscheduled, Scheduled & Total Downtime							97.17	58.41	155.58

GENERAL NANUs

2017070 – SVN 36 will resume transmitting L-band signal on PRN 4, and will not be included in the almanac.

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2017062	2	FCSTDV	6-Jul	17:55	7-Jul	5:55	12	2017066
2017064	23	FCSTMX	11-Jul	23:00	12-Jul	7:00	8	2017067
2017065	5	FCSTMX	13-Jul	21:00	14-Jul	5:00	8	2017069
2017068	7	FCSTMX	18-Jul	20:30	19-Jul	4:30	8	2017071
2017072	25	FCSTDV	3-Aug	16:05	4-Aug	4:05	12	2017075
2017073	17	FCSTMX	8-Aug	23:00	9-Aug	7:00	8	2017076
2017074	15	FCSTMX	10-Aug	14:00	10-Aug	22:00	8	2017079
2017077	31	FCSTMX	15-Aug	13:00	15-Aug	21:00	8	2017084
2017078	2	FCSTMX	18-Aug	2:30	18-Aug	10:30	8	2017088
2017080	9	UNUSUFN	11-Aug	10:59				2017081
2017082	9	FCSTDV	18-Aug	8:00	18-Aug	20:00	0	2017083
2017085	29	FCSTMX	22-Aug	19:30	23-Aug	3:30	8	2017091
2017086	12	FCSTMX	24-Aug	5:30	24-Aug	13:30	8	2017092
2017087	9	FCSTDV	25-Aug	8:15	25-Aug	20:15	12	2017093
2017089	21	FCSTMX	29-Aug	17:00	30-Aug	1:00	8	2017094
2017090	5	FCSTDV	31-Aug	19:15	1-Sep	7:15	12	2017096
2017095	13	FCSTDV	7-Sep	10:30	7-Sep	22:30	12	2017097
2017098	26	FCSTDV	19-Sep	11:20	19-Sep	23:20	0	2017107
2017099	7	UNUSUFN	12-Sep	6:26				2017100
2017101	7	UNUSUFN	12-Sep	13:42				2017104
2017102	1	UNUSUFN	14-Sep	0:21				2017103
2017105	25	UNUSUFN	17-Sep	15:00				2017106
						Total Forecasted Downtime	140	

Table 3-3 Cancelled NANUs

NANU#	PRN	Type	Start Date	Start Time	Comments
2017107	26	FCSTCANC	19-Sep	11:20	2017098
2017083	9	FCSTCANC	18-Aug	8:00	2017082

Satellite Reliability, Maintainability, and Availability (RMA) data is being collected based on published "Notice: Advisory to Navstar Users" messages (NANU's). This data has been summarized in Table 3-4. The "Total Satellite Observed MTTR" was calculated by taking the average downtime of all satellite outage occurrences. Scheduled downtime was forecasted in advance via NANU's. 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.

Table 3-4 GPS Satellite Maintenance Statistics

Satellite Reliability/Maintainability/Availability (RMA) Parameter	1-Jul-17 30-Sep-17	1-Jan-00 30-Sep-17
Total Forecast Downtime (hrs):	140	11818.82
Total Actual Downtime (hrs):	155.58	39149.42
Total Actual Scheduled Downtime (hrs):	58.41	6606.72
Total Actual Unscheduled Downtime (hrs):	97.17	32542.70
Total Satellite Observed MTTR (hrs):	7.78	42.65
Scheduled Satellite Observed MTTR (hrs):	3.89	9.03
Unscheduled Satellite Observed MTTR (hrs):	19.43	174.96
# Total Satellite Outages:	20	918
# Scheduled Satellite Outages:	15	732
# Unscheduled Satellite Outages:	5	186
Percent Operational -- Scheduled Downtime:	99.91	99.86
Percent Operational -- All Downtime:	99.77	99.19

3.2 Service Availability Standard

Service Availability: 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:** 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:** 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 Availability Standard	Conditions and Constraints
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m 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.
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m 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 twenty-eight WAAS sites was reduced to calculate 24-hour accuracy information and reported in Table 3-5. The data was collected at one-second intervals between 1 July and 30 September 2017.

Table 3-5 Accuracies Exceeding Threshold Statistics

Site	Total Number of Seconds of SPS Monitoring	Instances of 24-hour Threshold Failures	Quarters Service Availability %
Albuquerque	7939198	0	100%
Anchorage	7937803	0	100%
Atlanta	7939196	0	100%
Barrow	7937017	0	100%
Bethel	7938794	0	100%
Billings	7938931	0	100%
Boston	7937750	0	100%
Cleveland	7939149	0	100%
Cold Bay	7940655	0	100%
Fairbanks	7939470	0	100%
Gander	7937451	0	100%
Honolulu	7940675	0	100%
Houston	7938932	0	100%
Iqaluit	7938494	0	100%
Juneau	7939844	0	100%
Kansas City	7939295	0	100%
Kotzebue	7306201	0	100%
Los Angeles	7882786	0	100%
Merida	7840014	0	100%
Miami	7940666	0	100%
Minneapolis	7940671	0	100%
Oakland	7939219	0	100%
Salt Lake City	1606462	0	100%
San Jose Del Cabo	7811055	0	100%
San Juan	7090005	0	100%
Seattle	7757153	0	100%
Tapachula	7929651	0	100%
Washington, DC	7939080	0	100%
Global Average over Reporting Period = 100% (SPS Spec. > 95.87%)			

4 Service Reliability Standard

Service Reliability: 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.

User Range Error Accuracy	Conditions and Constraints
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 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 one year; average of daily values within service volume • Standard based on 3 service failures per year, lasting no more than 6 hours each

Table 4-1 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 5-2. The maximum User Range Error recorded this quarter was 20.740 meters on satellite PRN 15.

Table 4-1 User Range Error Accuracy

Date Range of Data Collection	Site	Number of Samples This Quarter	Number of Samples where SPS URE > 30m NTE	Percentage
1 Jul – 30 Sep 2017	**Boston**	68,538,287	0	100%
1 Jul – 30 Sep 2017	**Honolulu**	71,658,895	0	100%
1 Jul – 30 Sep 2017	**Los Angeles**	68,712,406	0	100%
1 Jul – 30 Sep 2017	**Miami**	69,684,047	0	100%
1 Jul – 30 Sep 2017	**Merida**	70,840,548	0	100%
1 Jul – 30 Sep 2017	**Juneau**	68,803,388	0	100%
1 Jul – 30 Sep 2017	**Global**	418,237,571	0	100%

5 Accuracy Standard

Positioning Accuracy: 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**: 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**: 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/Time Accuracy	Conditions and Constraints
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 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.
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 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.
Time Transfer Domain Accuracy • ≤ 40 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 Accuracy	Conditions and Constraints
Single Frequency C/A-Code • ≤ 7.8m 95% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 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
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
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	**Conditions and Constraints**
• ≤ 40 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 1 July through 30 September 2017 at the selected WAAS locations. Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter. Every twenty-four hour analysis period this quarter passed both the worst-case and global average position accuracy requirements set forth by the SPS specification.

Table 5-1 Horizontal & Vertical Accuracy Statistics for the Quarter

Site	95% Vertical (Meters)	95% Horizontal (Meters)	99.99% Vertical (Meters)	99.99% Horizontal (Meters)
Albuquerque	3.838	1.513	7.566	3.015
Anchorage	3.689	1.675	7.174	3.621
Atlanta	3.973	1.519	7.854	3.744
Barrow	3.673	1.473	7.913	2.897
Bethel	3.975	1.603	7.401	3.857
Billings	3.705	1.513	7.265	2.761
Boston	3.501	1.615	6.870	3.345
Cleveland	3.862	1.608	6.856	3.362
Cold Bay	4.042	1.465	7.757	3.348
Fairbanks	3.467	1.664	6.804	3.293
Gander	3.147	1.651	5.897	3.438
Honolulu	4.419	2.975	9.664	6.155
Houston	4.013	1.708	7.902	3.303
Iqaluit	3.527	1.459	8.505	3.425
Juneau	3.411	1.608	7.260	3.640
Kansas City	3.822	1.475	7.470	3.982
Kotzebue	3.737	1.802	7.517	3.131
Los Angeles	4.488	1.665	8.080	3.546
Merida	3.665	2.619	8.664	8.864
Miami	3.654	1.898	8.080	5.084
Minneapolis	3.618	1.529	6.261	3.509
Oakland	4.719	1.724	7.949	3.430
Salt Lake City	3.574	1.360	5.401	2.309
San Jose Del Cabo	3.790	2.553	8.192	6.365
San Juan	4.064	2.014	8.747	5.824
Seattle	4.026	1.501	6.761	3.161
Tapachula	3.641	3.234	11.628	10.989
Washington, DC	3.855	1.551	7.021	3.417

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-eight WAAS sites from 1 July to 30 September 2017.

Figure 5-1 Global Vertical Error Histogram

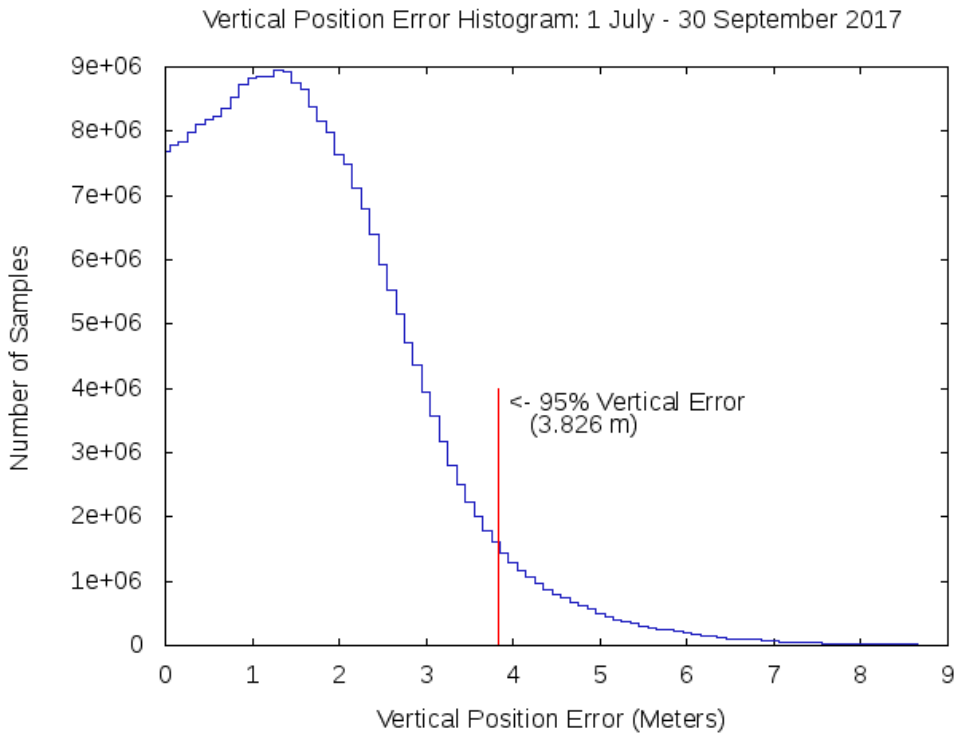
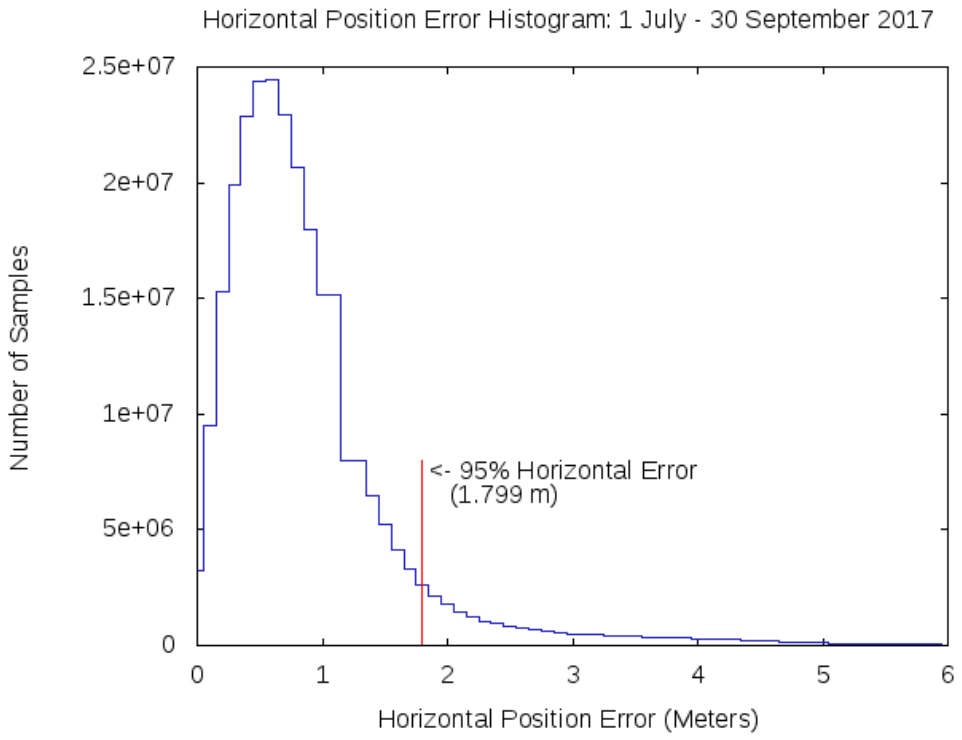


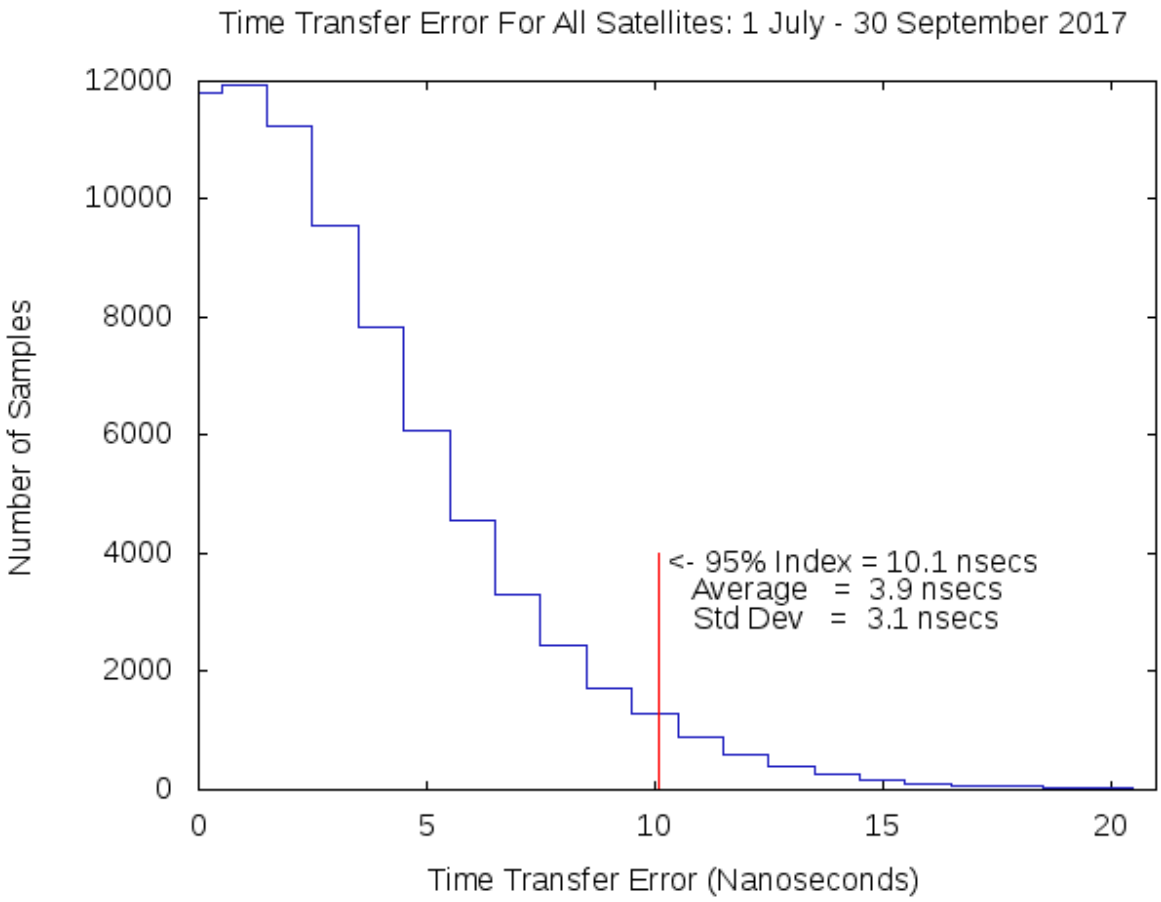
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 July and 30 September 2017 was downloaded from USNO Internet site. 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. In order to evaluate the GPS time transfer error, the data file was used to create a histogram (Fig 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 one nanosecond precision. The number of samples in each bin was then plotted to form the histogram in Fig 5-3. The maximum instantaneous UTC offset error (UTCOE) for the quarter was 28.4 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

Tables 5-3 through 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 1 July and 30 September 2017. 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 5-2 Range Error Statistics

PRN	RMS Range Error (≤ 6 m) (Meters)	Range Error Mean (Meters)	1σ Range Error (Meters)	95% Range Error (Meters)	Max Range Error (SPS Spec. ≤ 30 m) (Meters)	Samples
1	1.202	0.396	0.987	2.160	10.901	13641385
2	1.486	0.906	0.913	2.584	6.782	14552025
3	1.202	0.421	0.994	2.233	12.557	14288846
5	1.310	0.116	1.032	2.403	10.406	13619852
6	1.215	-0.090	0.970	2.304	18.252	13803707
7	1.198	0.787	0.761	2.136	12.890	12084477
8	1.525	0.804	1.038	2.629	13.499	12588765
9	1.317	0.872	0.874	2.385	13.599	13219355
10	1.277	0.550	0.966	2.297	9.660	13110223
11	1.466	0.866	1.007	2.514	16.154	12198652
12	1.224	0.351	1.024	2.329	18.606	13971132
13	1.248	0.351	0.978	2.279	9.019	13091122
14	1.768	1.442	0.872	2.861	12.339	14109081
15	1.320	0.499	1.046	2.428	20.740	12843836
16	1.800	1.425	1.021	2.961	13.752	13103456
17	1.338	0.646	0.956	2.382	18.453	14503072
18	1.751	1.185	1.116	2.939	9.089	13779501
19	1.800	1.346	1.015	3.002	17.900	13997824
20	1.716	1.208	0.999	2.903	7.838	14262628
21	1.778	1.137	1.172	2.996	10.922	13251680
22	2.162	1.870	1.020	3.367	12.162	13625196
23	1.765	1.457	0.909	2.895	15.751	12813670
24	1.462	0.360	1.149	2.652	20.262	13994643
25	1.388	0.807	1.003	2.485	17.157	14044368
26	1.456	1.104	0.869	2.471	10.205	12669932
27	1.376	0.853	0.981	2.460	11.928	13356560
28	1.794	1.137	1.023	3.081	20.248	13716150
29	1.610	0.757	1.120	2.848	14.600	13184682
30	1.201	0.701	0.827	2.150	17.993	12728244
31	1.379	0.887	0.915	2.438	11.769	13775122
32	1.183	0.427	0.934	2.238	11.650	14308385

Table 5-3 Range Rate Error Statistics

PRN	Range Rate Error RMS (mm/s)	95% Range Rate Error (mm/s)	Max Range Rate Error (mm/s)	Samples
1	1.406	2.588	177.070	13641385
2	1.448	2.761	153.900	14552025
3	1.367	2.575	157.550	14288846
5	1.563	2.985	144.810	13619852
6	1.351	2.572	125.980	13803707
7	1.428	2.689	154.750	12084477
8	1.640	2.801	141.830	12588765
9	1.338	2.548	152.130	13219355
10	1.403	2.581	127.810	13110223
11	1.506	2.812	147.760	12198652
12	1.542	2.972	141.650	13971132
13	1.573	2.896	140.600	13091122
14	1.494	2.773	156.220	14109081
15	1.498	2.839	135.570	12843836
16	1.514	2.869	151.460	13103456
17	1.528	2.891	147.290	14503072
18	1.635	2.924	164.220	13779501
19	1.489	2.833	149.180	13997824
20	1.521	2.868	140.820	14262628
21	1.609	3.008	144.450	13251680
22	1.492	2.808	133.260	13625196
23	1.418	2.690	127.310	12813670
24	1.839	3.155	143.210	13994643
25	1.374	2.611	122.850	14044368
26	1.328	2.509	127.950	12669932
27	1.389	2.577	144.190	13356560
28	1.539	2.773	136.940	13716150
29	1.573	2.825	145.120	13184682
30	1.316	2.525	123.800	12728244
31	1.544	2.729	127.250	13775122
32	1.378	2.573	154.540	14308385

Table 5-4 Range Acceleration Error Statistics

PRN	Range Acceleration Error RMS ($\mu m/s^2$)	95% Range Acceleration Error ($\mu m/s^2$)	Max Range Acceleration Error ($\mu m/s^2$)	Samples
1	10.910	20.343	1760	13641385
2	10.566	21.110	1550	14552025
3	10.588	20.339	1560	14288846
5	10.782	25.234	1460	13619852
6	10.431	20.171	1250	13803707
7	10.746	21.277	1540	12084477
8	12.615	21.666	1420	12588765
9	10.394	20.149	1470	13219355
10	10.945	20.431	1270	13110223
11	10.986	21.594	1440	12198652
12	10.547	25.159	1410	13971132
13	11.551	23.866	1380	13091122
14	10.985	21.519	1560	14109081
15	10.828	21.380	1360	12843836
16	10.775	23.875	1520	13103456
17	10.681	23.053	1470	14503072
18	12.144	24.361	1630	13779501
19	10.561	21.457	1500	13997824
20	10.830	22.835	1420	14262628
21	11.410	24.777	1450	13251680
22	10.610	22.624	1330	13625196
23	10.396	21.775	1280	12813670
24	13.847	27.688	1440	13994643
25	10.513	20.286	1230	14044368
26	10.575	20.233	1280	12669932
27	10.983	20.487	1490	13356560
28	11.534	21.552	1370	13716150
29	11.787	23.051	1440	13184682
30	10.306	20.309	1290	12728244
31	11.325	21.364	1270	13775122
32	10.850	20.342	1540	14308385

Figures 5-4, 5-5 and 5-6 are graphical representations of the distributions of the maximum range error, range rate error and range acceleration error for all satellites. The highest maximum range error occurred on satellite PRN 15 with an error of 20.74 meters. Satellite PRN 2 had the lowest maximum range error of 6.782 meters. Figure 5-7 is histogram of satellite range error for all satellites over the entire quarter. Figures 5-8, 5-9, and 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

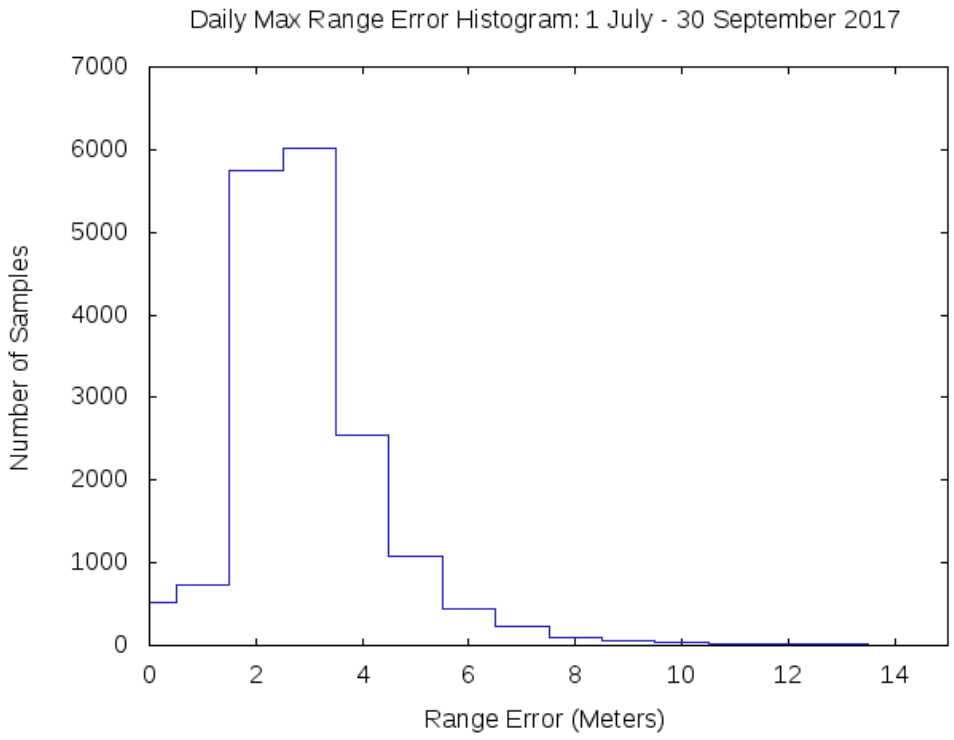


Figure 5-5 Distribution of Daily Max Range Rate Errors

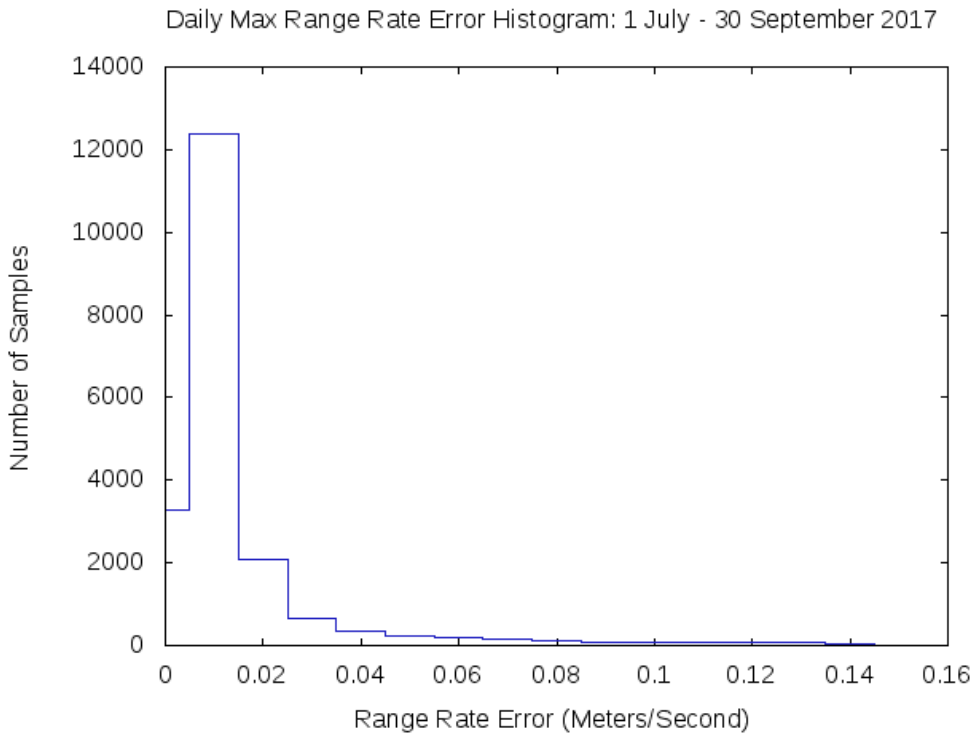


Figure 5-6 Distribution of Daily max Range Acceleration Errors

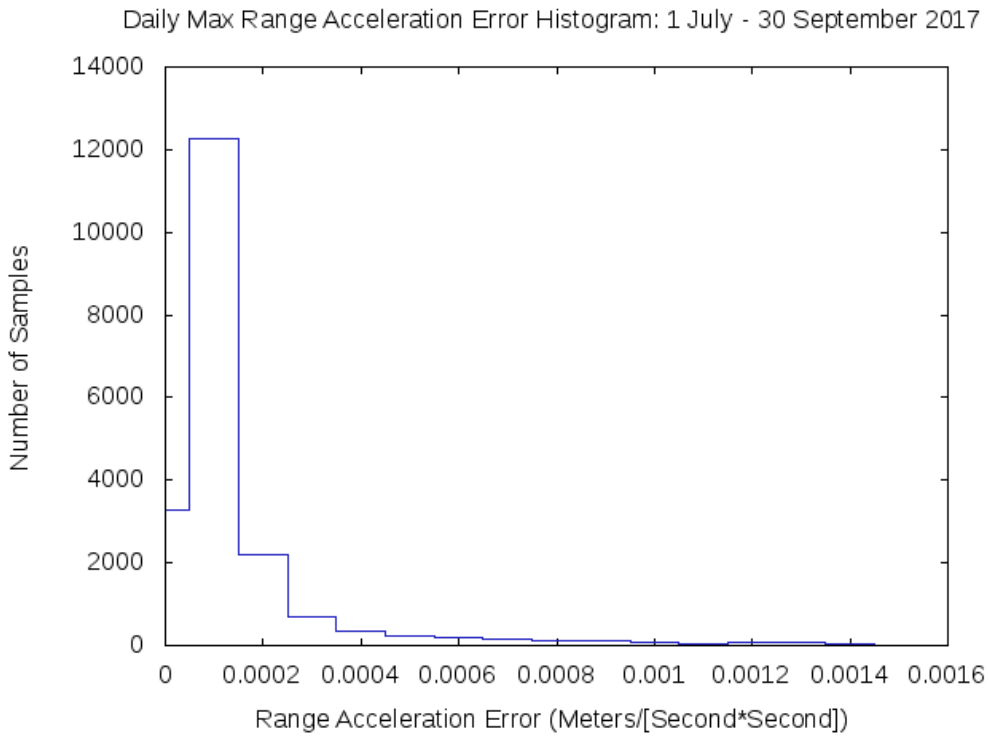


Figure 5-7 Range Error Histogram

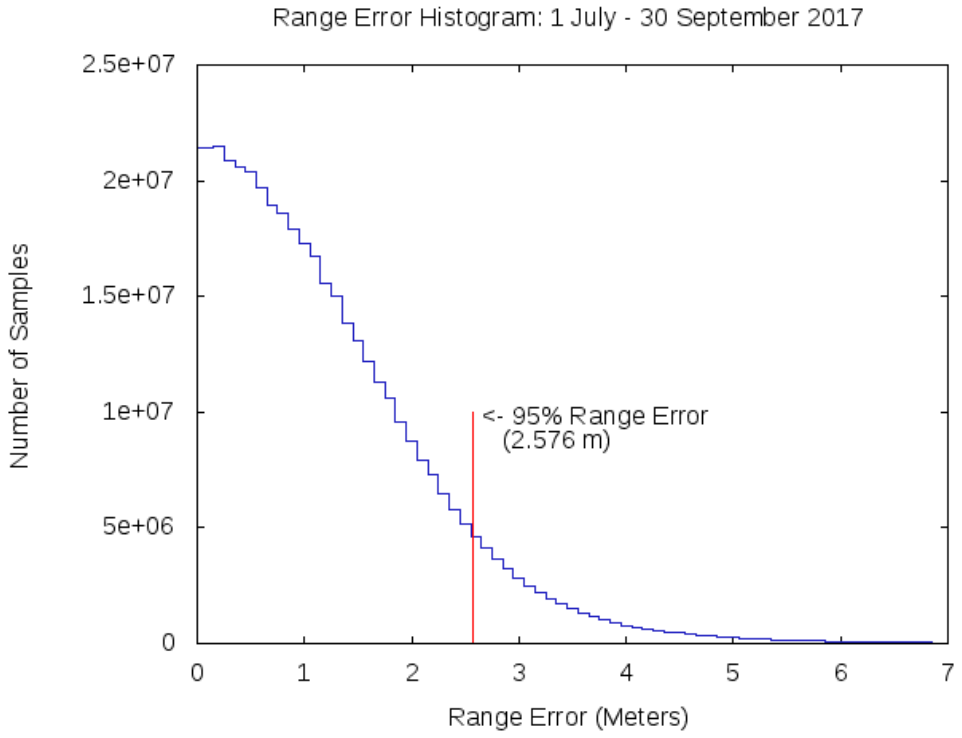


Figure 5-8 Maximum Range Error Per Satellite

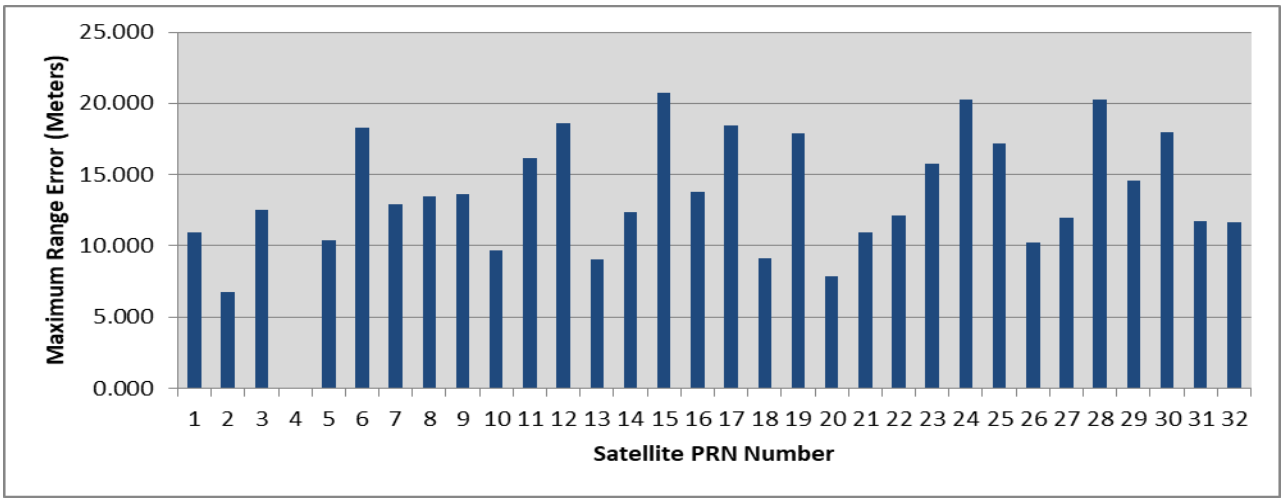


Figure 5-9 Maximum Range Rate Error Per Satellite

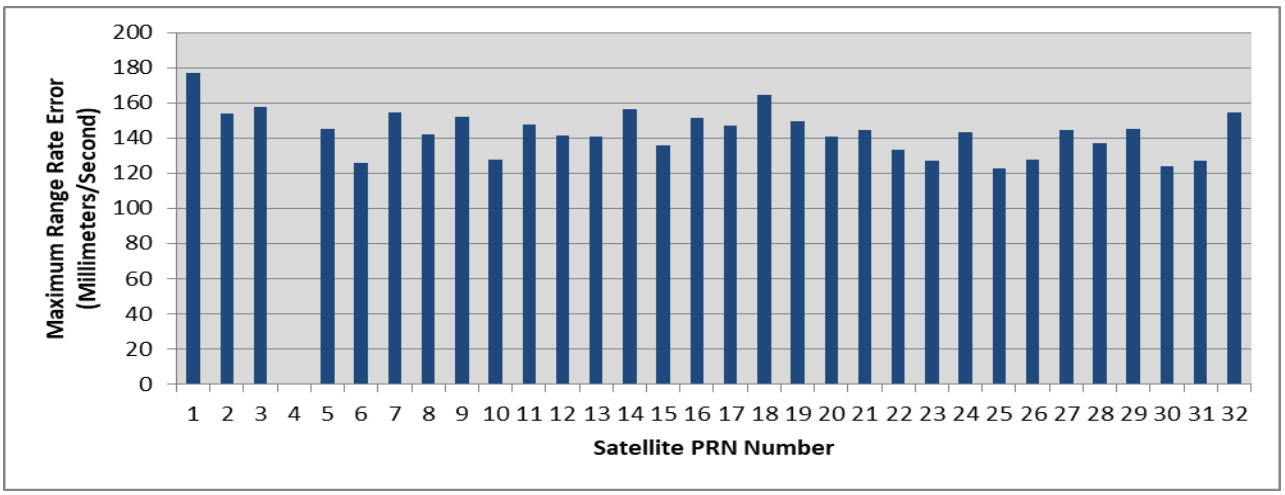
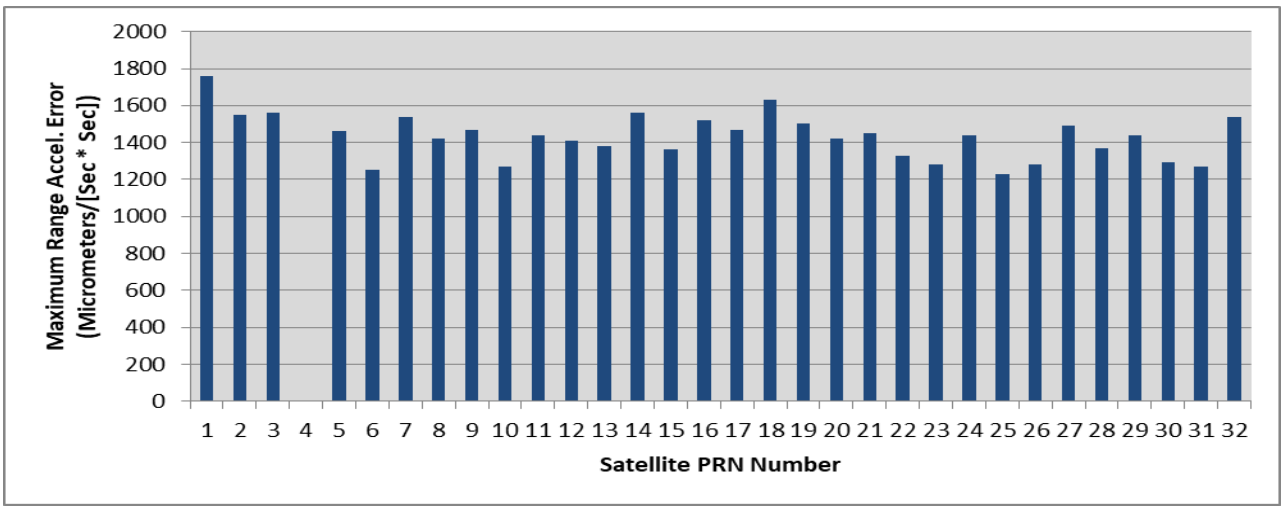


Figure 5-10 Maximum Range Acceleration Error Per Satellite



6 Solar Storms

Solar storm activity is being monitored in order 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.*

Figures 6-1 through 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 7-9 September 2017

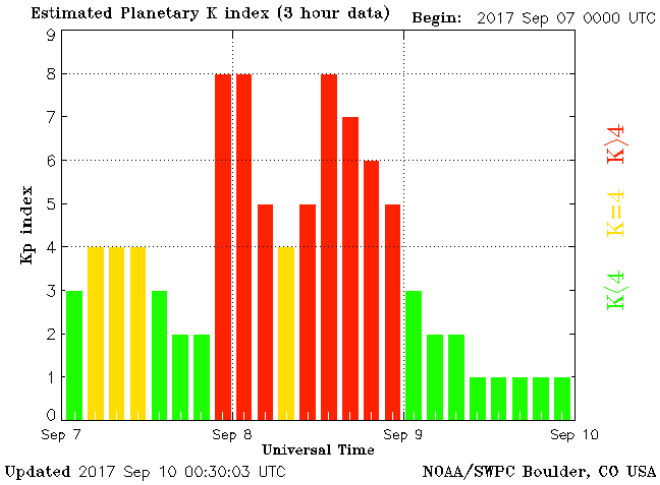


Figure 6-2 K-Index for 27-29 September 2017

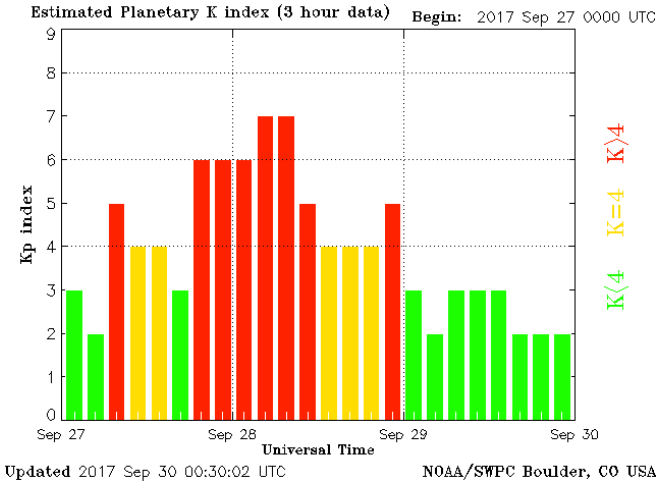


Figure 6-3 K-Index for 15-17 July 2017

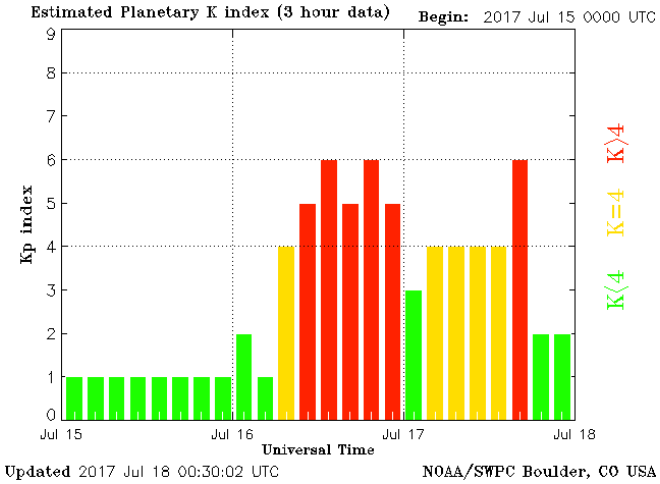


Table 6-1 shows the position accuracy information for the quarter's worst-case storm day, September 8, 2017 (see Figure 6-1). The GPS SPS performance met all requirements during all storms that occurred during this quarter.

Table 6-1 Horizontal & Vertical Accuracy Statistics for September 8, 2016

Site	95% Horizontal (Meters)	95% Vertical (Meters)	Maximum Horizontal (Meters)	Maximum Vertical (Meters)
Albuquerque	2.141	6.879	2.825	7.807
Anchorage	2.538	5.040	3.723	7.973
Atlanta	1.636	6.555	5.109	8.025
Barrow	1.744	4.672	2.847	6.850
Bethel	2.650	5.037	3.965	6.394
Billings	2.085	5.941	2.814	6.924
Boston	2.309	4.526	3.309	7.029
Cleveland	1.862	5.380	4.363	6.680
Cold Bay	2.091	5.166	3.418	6.184
Fairbanks	2.000	4.828	3.037	7.545
Gander	1.734	3.408	2.988	4.418
Honolulu	3.717	5.828	5.940	6.726
Houston	2.277	7.236	3.279	8.186
Iqaluit	1.502	3.721	2.661	8.209
Juneau	2.542	5.046	3.450	7.598
Kansas City	1.926	6.231	5.321	7.462
Kotzebue	2.184	4.801	3.114	7.008
Los Angeles	1.936	7.010	2.367	7.595
Merida	5.752	5.409	9.892	8.247
Miami	3.956	5.338	5.236	8.005
Minneapolis	2.135	5.188	2.939	6.634
Oakland	2.279	7.105	2.933	7.744
Salt Lake City	3.757	5.684	6.658	7.746
San Jose Del Cabo	3.522	4.040	4.787	4.967
San Juan	2.229	5.868	3.114	6.527
Seattle	8.581	6.760	11.499	14.844
Tapachula	1.532	5.724	2.825	7.143
Washington, DC	2.141	6.879	2.825	7.807

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 which are outside of the WAAS service area that also provide a good geographic distribution have been selected. The 3 Russian Federation sites, MOBN, NRIL, and PETS, were not in service. 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. The Russian Federation sites were unavailable for this reporting period. Table 7.2 shows the GPS SPS Accuracy Performance observed at a selection of High Rate IGS sites. Figure 7-3 shows the 95% horizontal accuracy trends at these sites. Figure 7-4 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.

(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

Table 7-1 Selected IGS Site 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
MOBN*	Obninsk	Russian Federation
NNOR	New Norcia	Australia
NRIL*	Norilsk	Russian Federation
PETS*	Petropavlovsk-Kamchatka	Russian Federation
POL2	Bishkek	Kyrgyzstan
SUTM	Sutherland	South Africa
TIDB	Tidbinbilla	Australia
UNSA	Salta	Argentina
USUD	Usuda	Japan

Figure 7-1 Selected IGS Site Locations

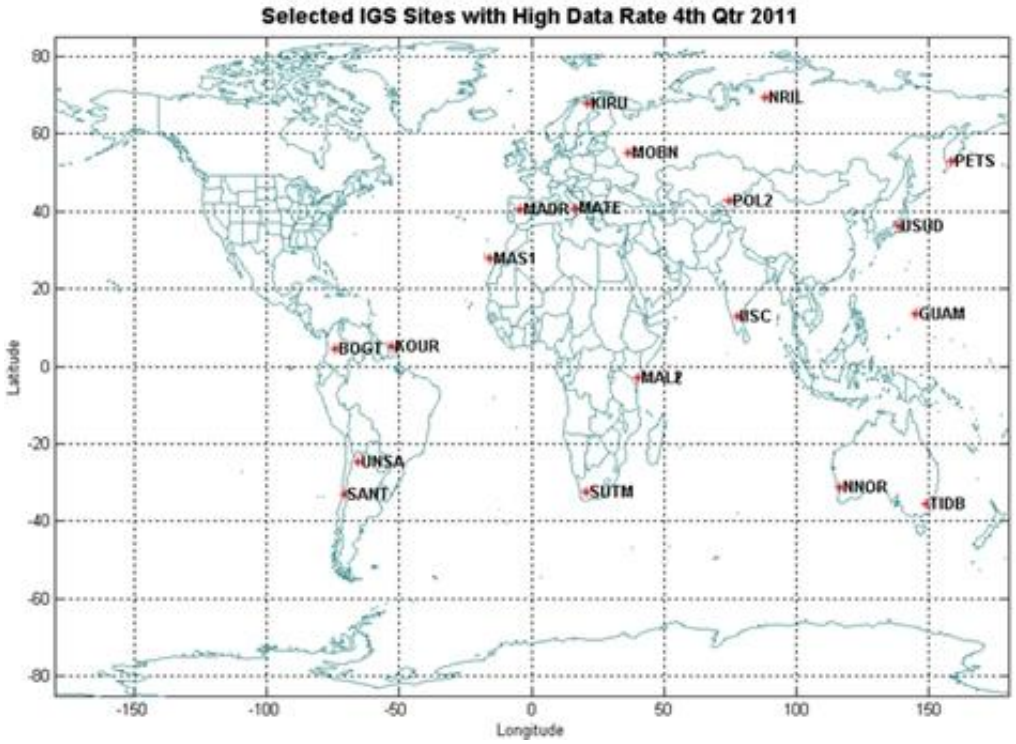


Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Percent Data Available
BOGT	2.68	6.69	7.08	12.95	97.96%
GLPS	2.35	6.47	4.35	11.86	98.85%
GUAM	1.65	7.26	4.14	17.3	98.27%
IISC	1.82	6.61	4.48	12.89	67.15%
KIRU	1.29	2.62	2.54	5.72	98.91%
KOUR	2.23	7.59	4.36	12.92	98.18%
MADR	2.13	3.29	5.48	7.33	98.85%
MAL2	2.9	5.18	11.1	24.33	92.57%
MAS1	3.46	6.03	7.92	13.52	98.88%
MATE	2.9	4.13	10.07	22.12	93.19%
MOBN*	0	0	0	0	0.00%
NNOR	1.52	3.79	5.47	7.02	98.90%
NRIL*	0	0	0	0	0.00%
PETS*	0	0	0	0	0.00%
POL2	2.47	4.26	11.32	19.73	80.72%
SUTM	3.3	4.85	8.16	15.13	96.62%
TIDB	1.87	3.31	3.39	7.49	95.41%
UNSA	1.71	3.11	3.87	6.91	97.83%
USUD	3.43	5.71	6.35	12.42	94.02%
BOGT	2.47	3.84	5.58	10.71	97.92%

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

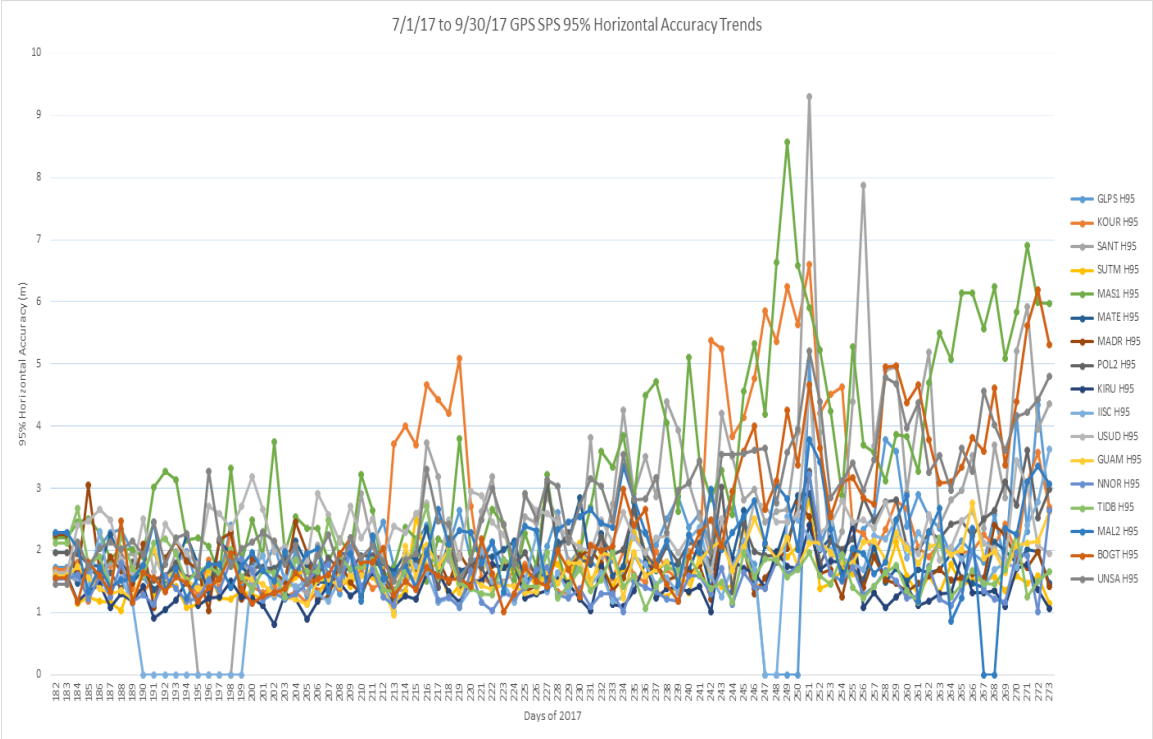
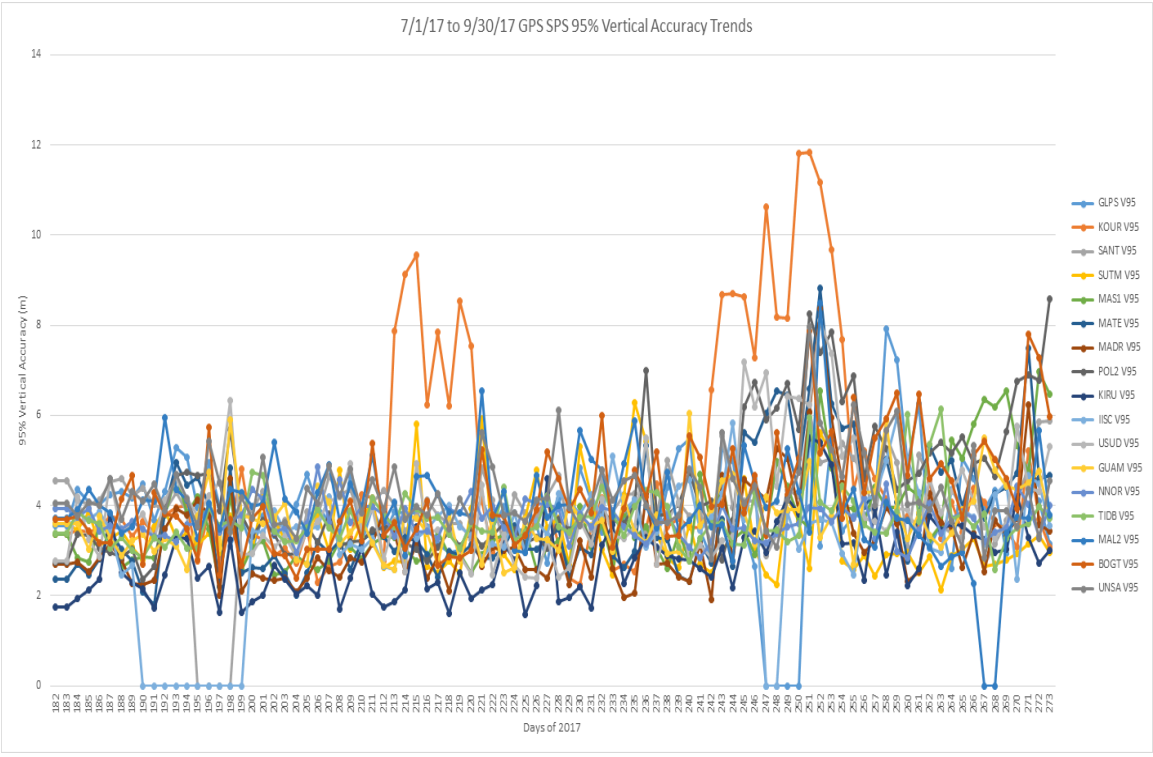


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites



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. In order 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 1/15000.

The horizontal protection limit (HPL) is a figure which 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 twenty-eight sites evaluated. For all sites collected, the minimum percent of time in RNP 0.1 mode was 99.904% at Salt Lake City, Utah. The minimum percent of time spent in RNP 0.3 mode was 100% at all locations evaluated. The maximum 99% HPL value was 146.64 meters at Honolulu, HI.

Table 8-1 RAIM Site Statistics

CITY	99% HPL	Percent RNP 0.1	Percent RNP 0.3
Albuquerque	101.79	99.999	100
Anchorage	125.05	99.986	100
Atlanta	98.77	100	100
Barrow	102.01	100	100
Bethel	127.06	99.998	100
Billings	112.63	99.953	100
Boston	114.78	99.986	100
Cleveland	108.73	99.999	100
Cold Bay	123.19	99.996	100
Fairbanks	123.65	99.992	100
Gander	128.57	99.908	100
Honolulu	146.64	100	100
Houston	94.64	100	100
Iqaluit	124.55	99.988	100
Juneau	124.30	99.968	100
Kansas City	102.02	99.984	100
Kotzebue	112.50	99.993	100
Los Angeles	103.29	99.971	100
Merida	83.05	99.995	100
Miami	115.27	99.992	100
Minneapolis	116.81	99.950	100
Oakland	100.75	99.969	100
Salt Lake City	111.60	99.904	100
San Jose Del Cabo	79.35	100	100
San Juan	82.33	100	100
Seattle	100.58	99.967	100
Tapachula	94.81	99.991	100
Washington DC	106.49	99.993	100

8.2 RAIM Coverage

Figures 8-1 through 8-2 show the world wide RAIM coverage for both RNP 0.1 and RNP 0.3 respectively. Figures 8-3 through 8-4 show the daily RAIM coverage trends between 1 July and 30 September 2017.

Figure 8-1 RAIM RNP 0.1 Coverage

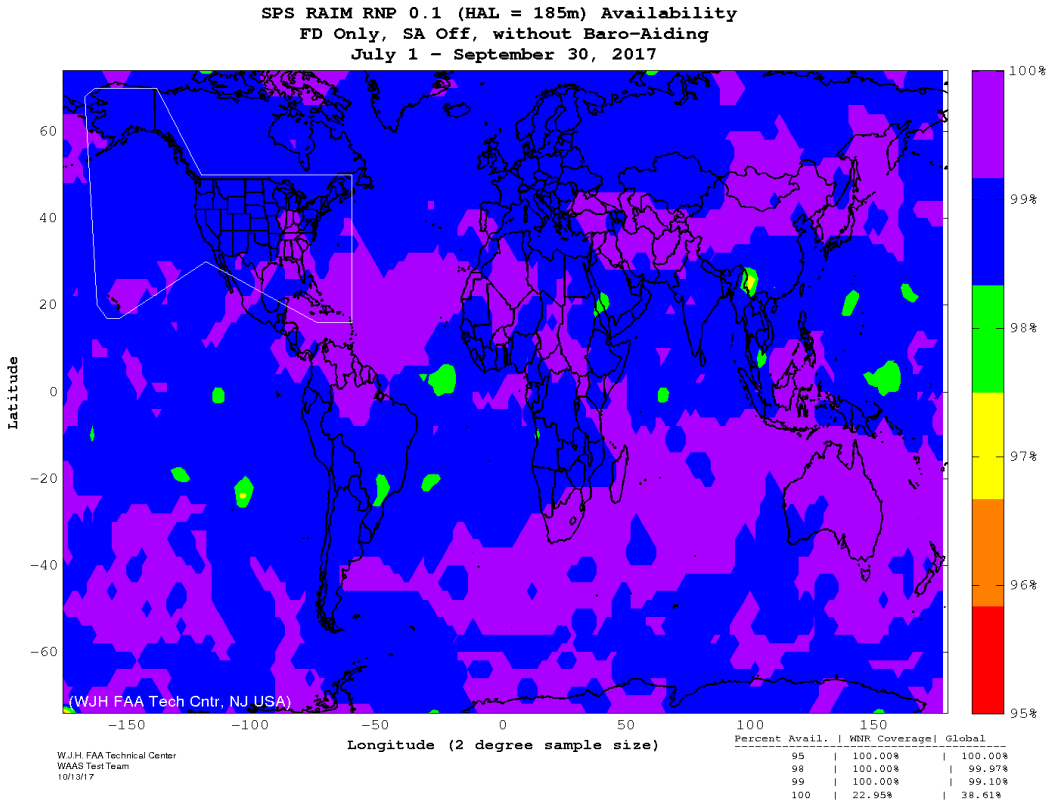


Figure 8-2 RAIM RNP 0.3 Coverage

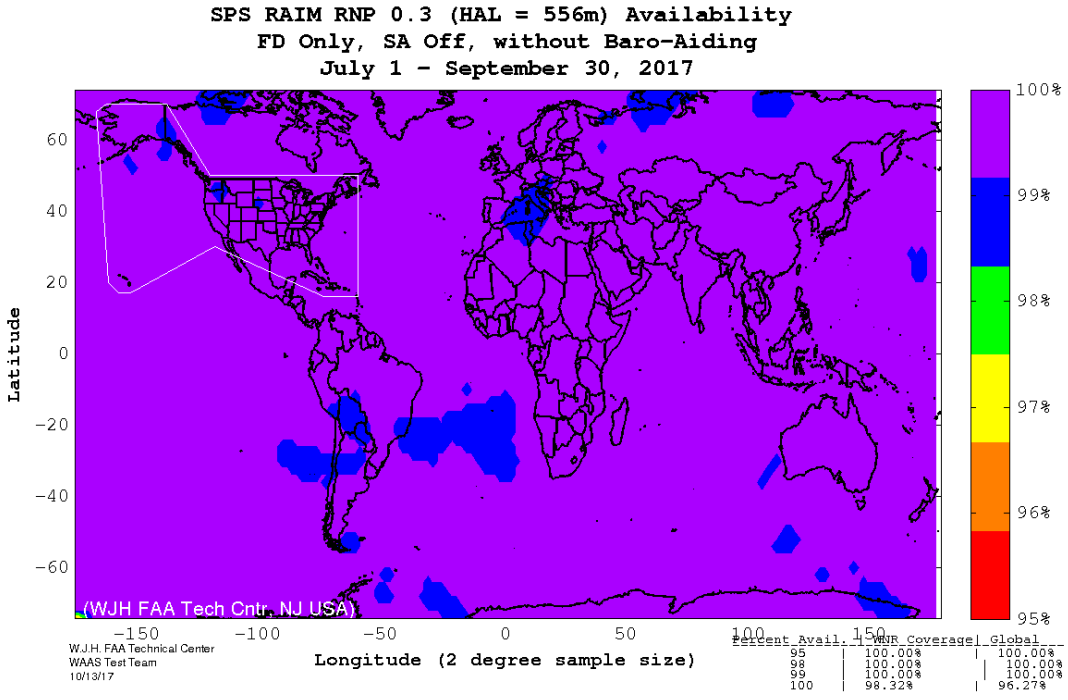


Figure 8-3 RAIM World Wide Coverage Trend

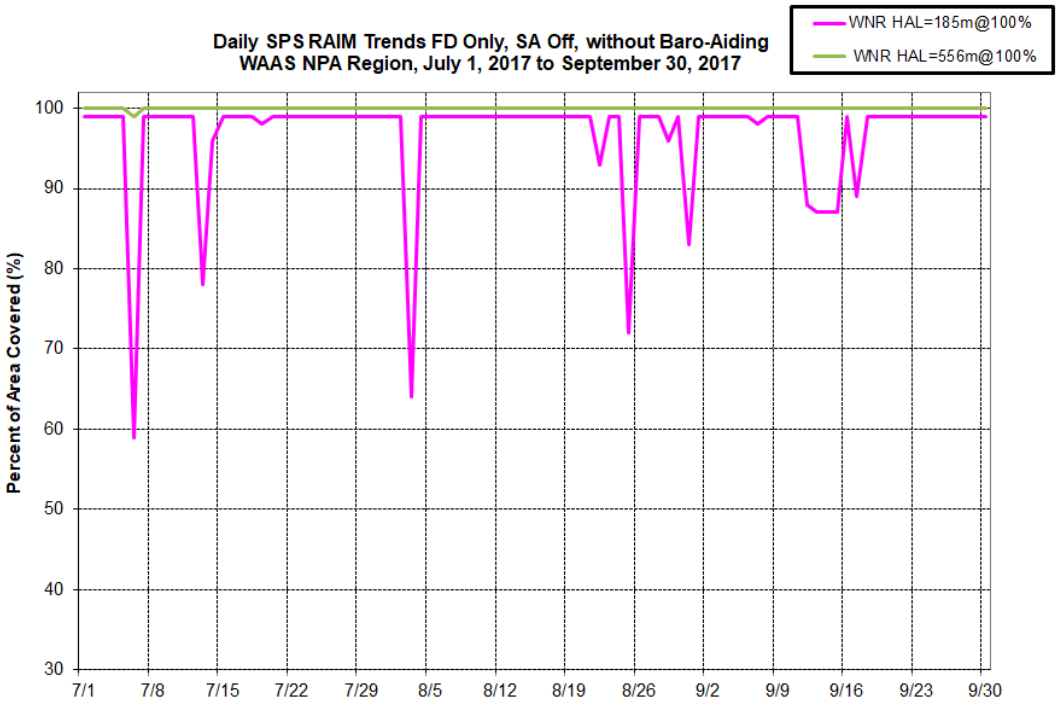
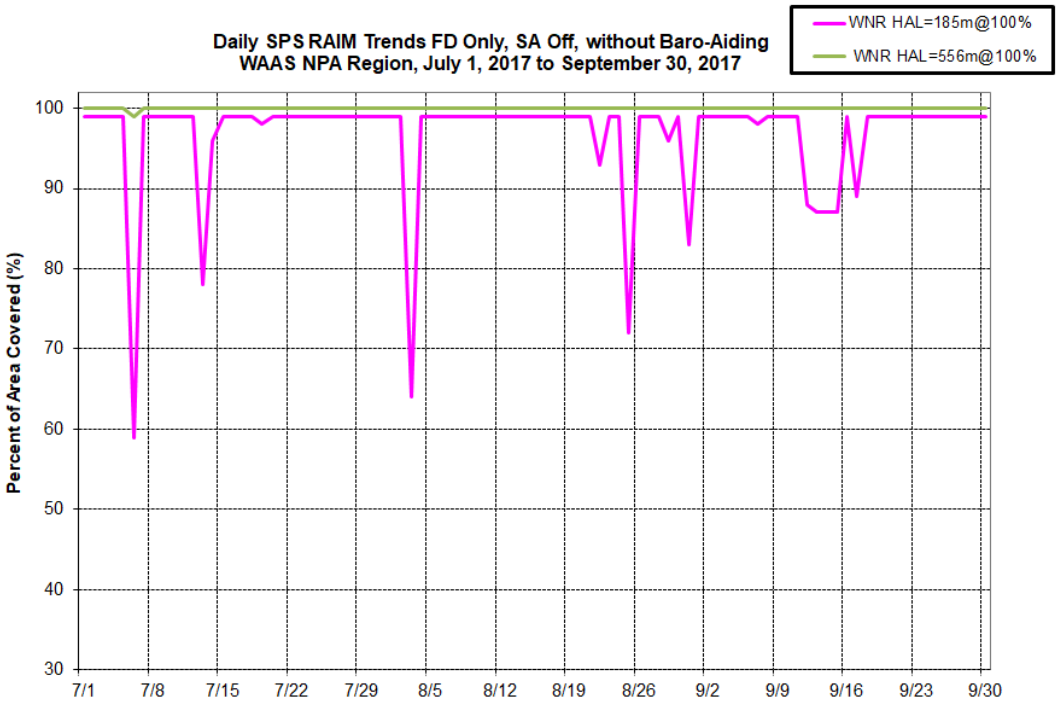


Figure 8-4 RAIM RNP Coverage Trend for WAAS NPA Service Area



8.3 RAIM Airport Analysis

Figures 8-5 and 8-6 shows 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

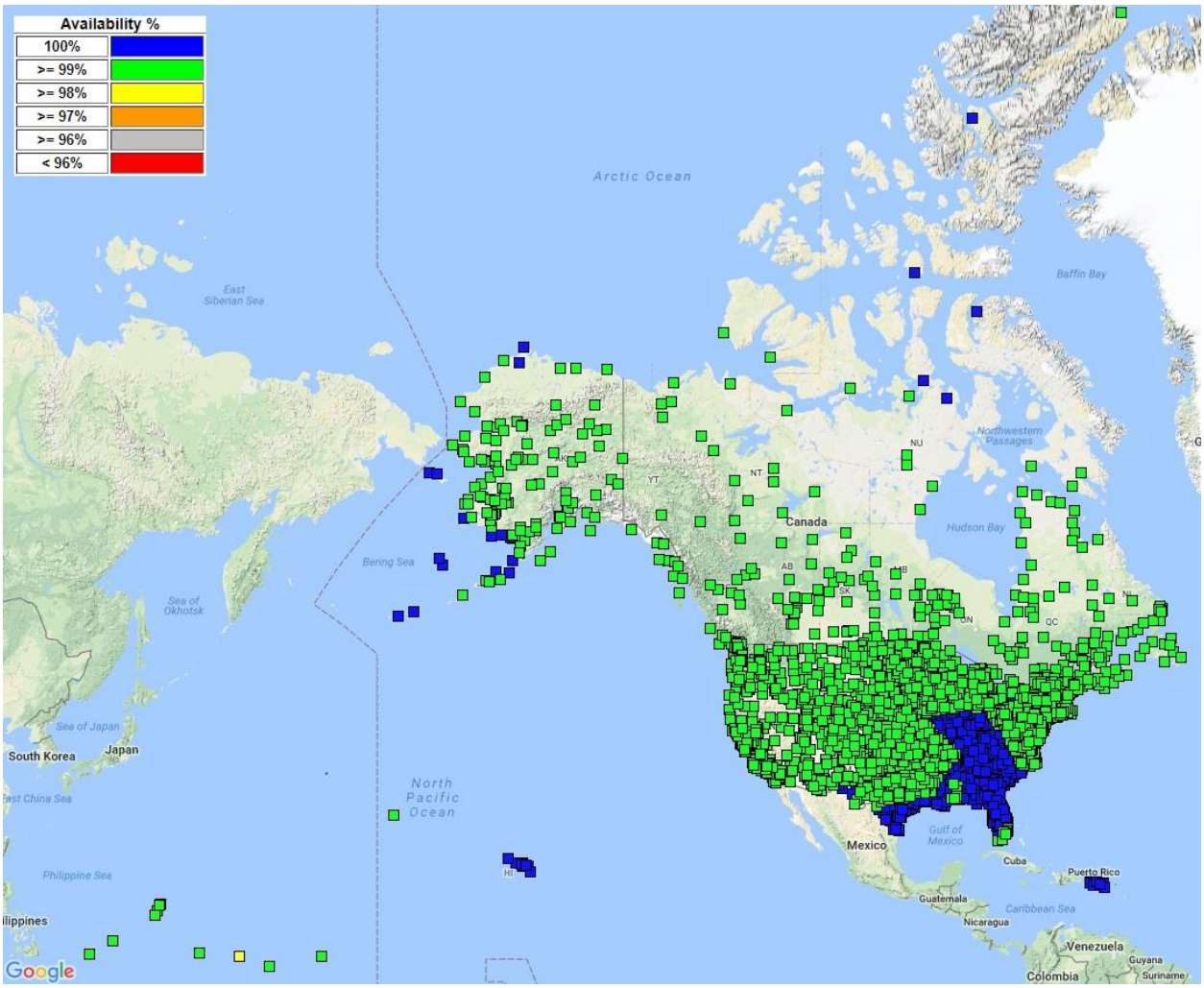
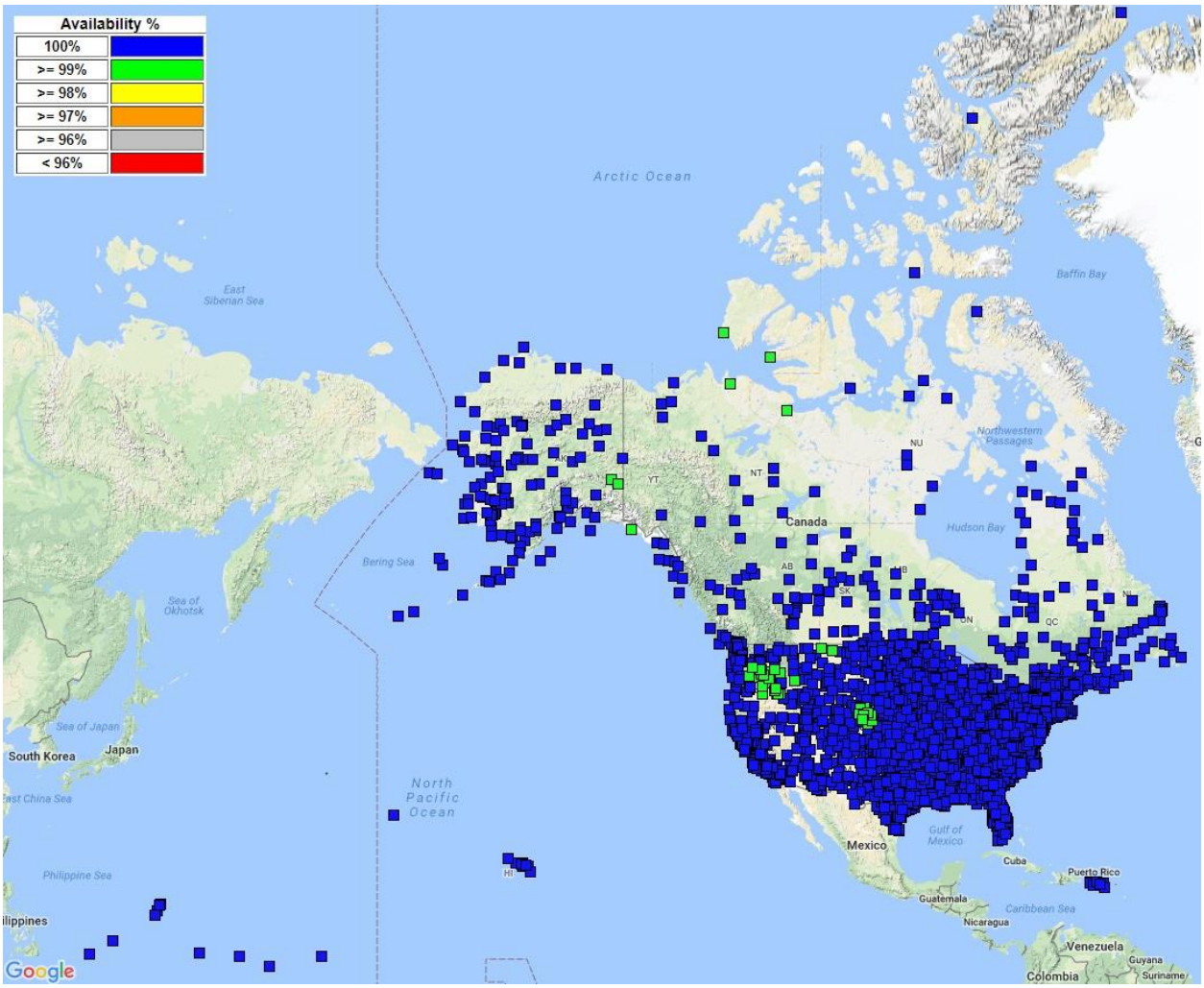


Figure 8-6 RAIM RNP 0.3 Airport Availability



Figures 8-7 and 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

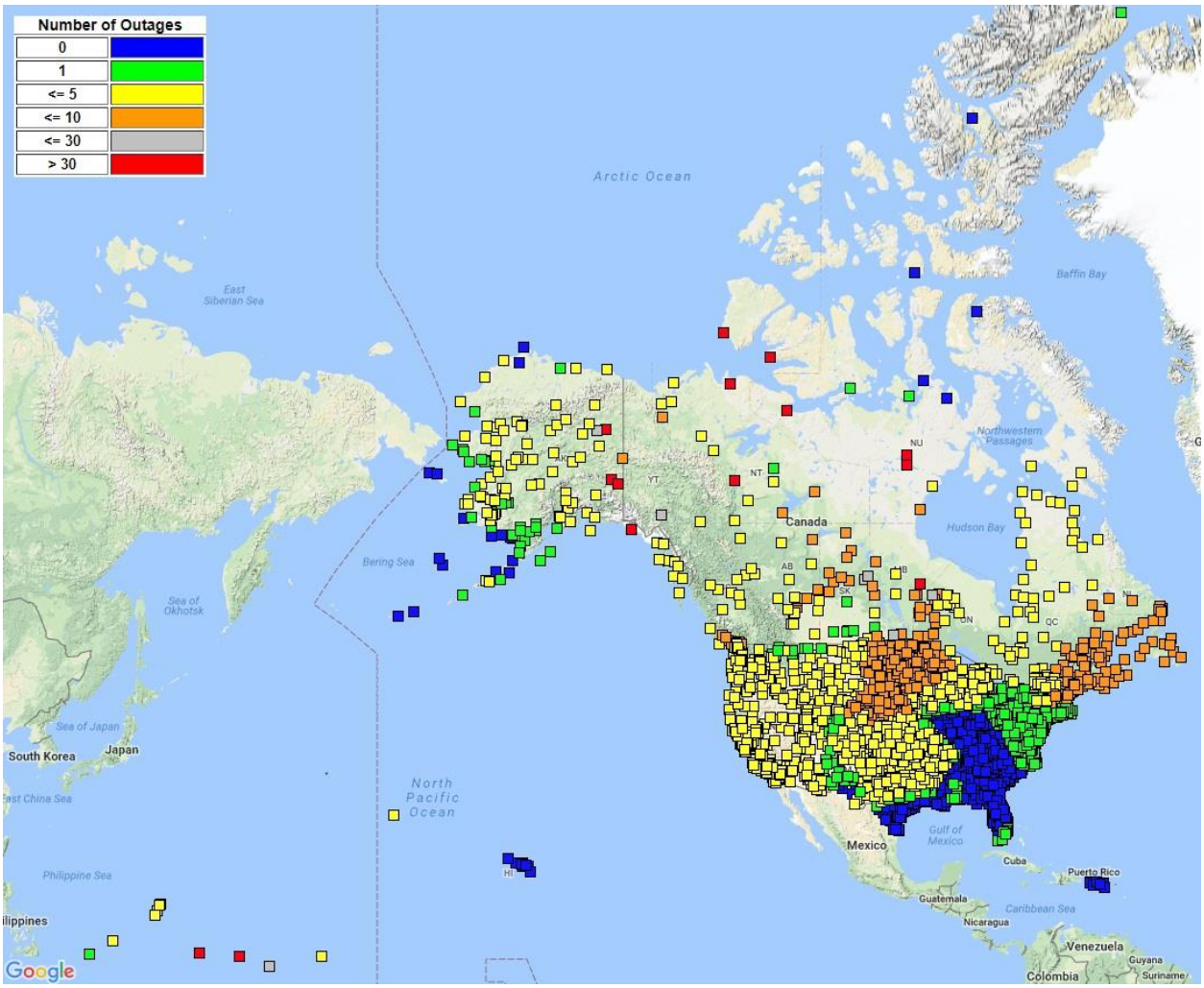
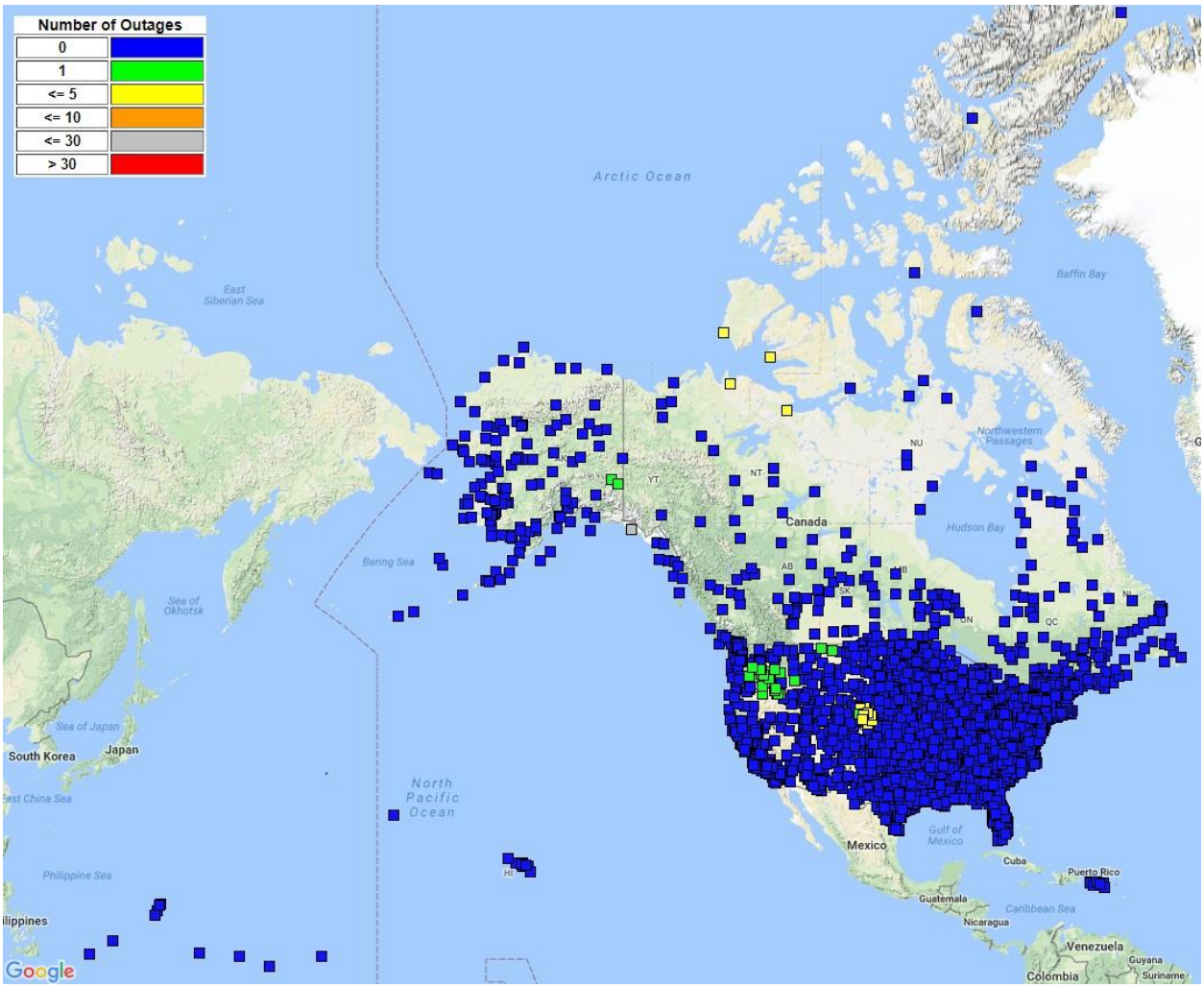


Figure 8-8 RAIM RNP 0.3 Airport Outages



9 GPS Test NOTAMs Summary

GPS test NOTAM: Global Positioning System test Notices to Airmen - GPS test NOTAMs are issued in the event that GPS is predicted to be unreliable and/or unavailable at a defined location for specific times, as indicated in the NOTAM, due to scheduled testing events.

Status and Problem Reporting	Conditions and Constraints
Scheduled event affecting service • Appropriate GPS Test NOTAM issued to the FAA at least 5 hours prior to the event	• For any SPS SIS

9.1 GPS Test NOTAMs Issued

GPS test NOTAMs were tracked and trended from GPS test NOTAMs posted on the FAA Pilot Web website (https://pilotweb.nas.faa.gov/PilotWeb/). During this reporting period, 1 July through 30 September 2017, there were a total of 103 GPS test NOTAMs. The total number of days affected in this reporting period is 79. Tables 8.1 and 8.2 below list the statistics of areas affected and durations. Note that the minimum, average, and maximum durations are on a per GPS test NOTAM basis.

Table 9-1 GPS test NOTAM Durations

Cumulative Duration	601.1 hours
Minimum Duration	1.00 hours
Media Duration	4.50 hours
Average Duration	5.84 hours
Maximum Duration	23.97 hours

Table 9-2 GPS Test NOTAM Affected Areas (Square Miles) by Altitude

	40,000 feet	25,000 feet	10,000 feet	4,000 feet	50 feet
Minimum	10,401	9,989	8,803	8,055	2,812
Average	390,035	297,255	176,656	147,594	101,073
Maximum	1,177,490	1,124,967	783,634	758,560	575,731

9.2 Tracking and Trending of GPS Test NOTAMs

The GPS Test NOTAMs that are tracked and trended for this reporting period were done with a specialized software analysis tool that is designed to not only trend but also archive GPS Test NOTAMs. It is designed to trend archived GPS Test NOTAMs for any specified time frame. In addition to the data provided in this report, this tool will provide all data presented here along with airports with affected procedures via a web interface. The web interface is available at the following URL: http://waas.faa.gov/static/sog/notam/index.html.

The five plots below illustrate a visual depiction of the affected areas at their corresponding altitudes along with the impacted RNAV routes (indicated in red). Note that some GPS Test NOTAMs occupy the same area and position but differ in effective dates and/or durations.

Figure 9-1 GPS Test NOTAMs @ FL400

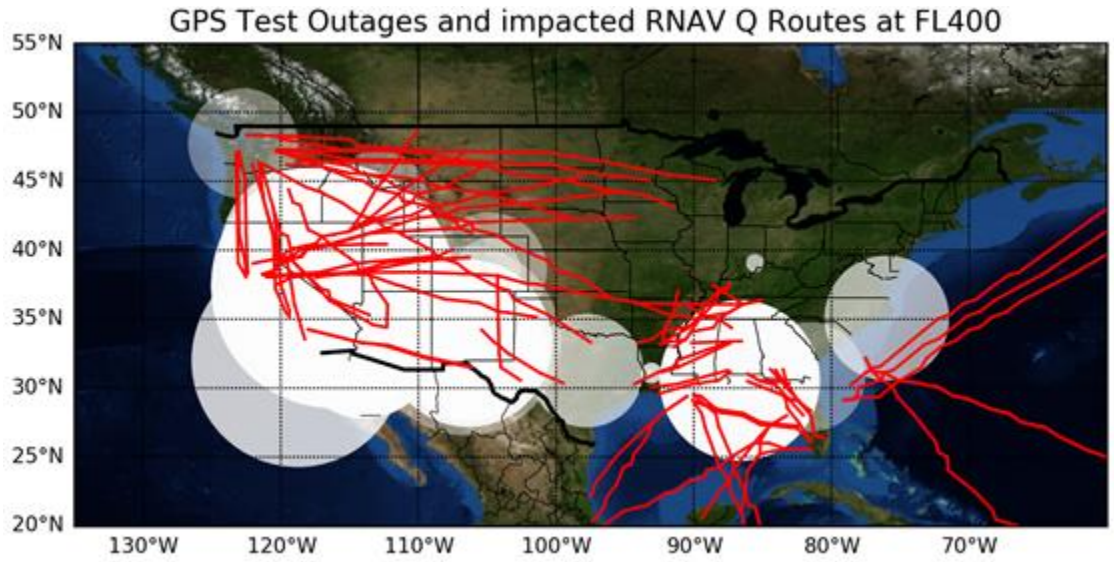


Figure 9-2 GPS NOTAMs @ FL250

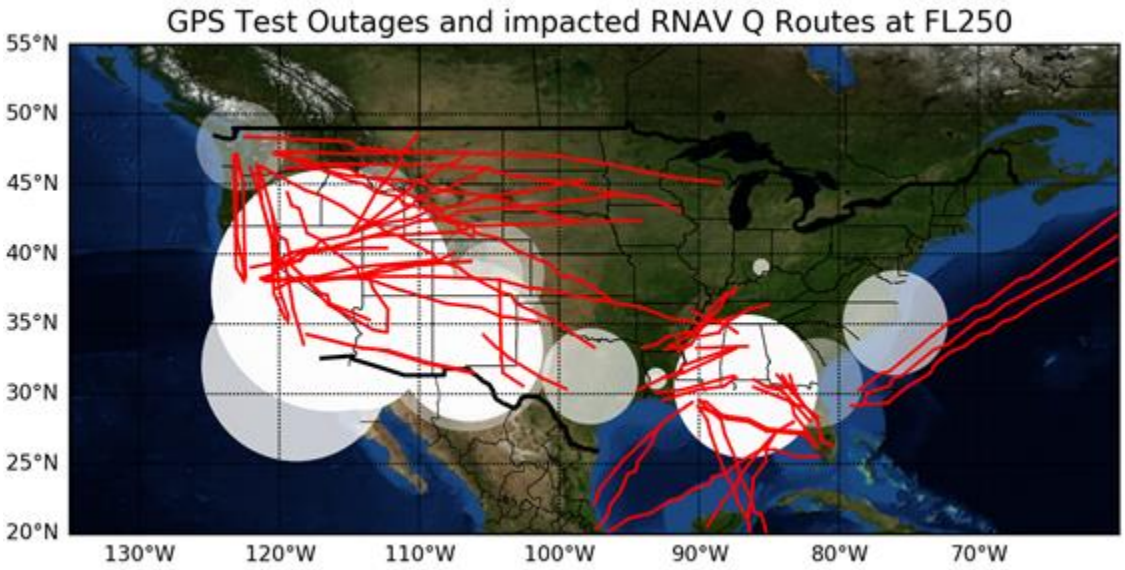


Figure 9-3 GPS NOTAMs @ 10k Feet

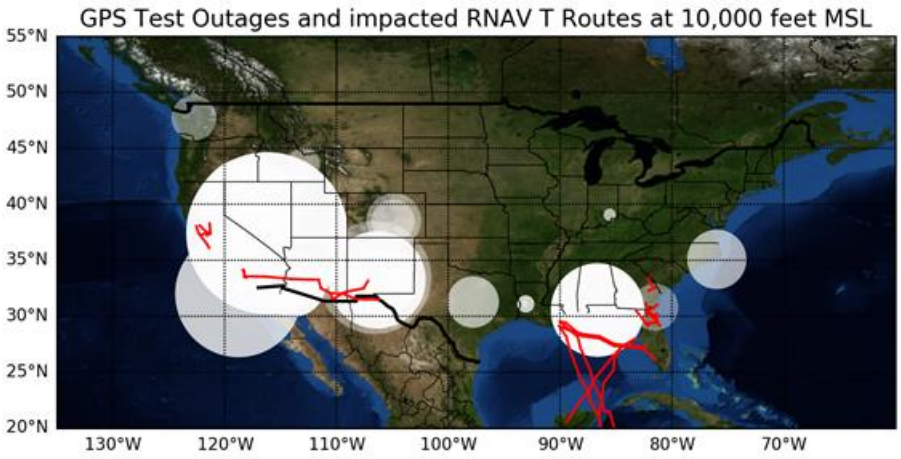


Figure 9-4 GPS NOTAMs @ 4k Feet

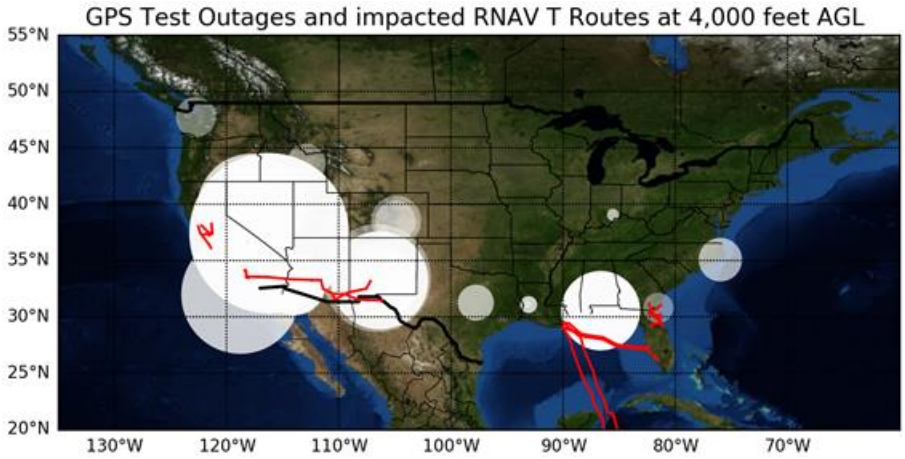
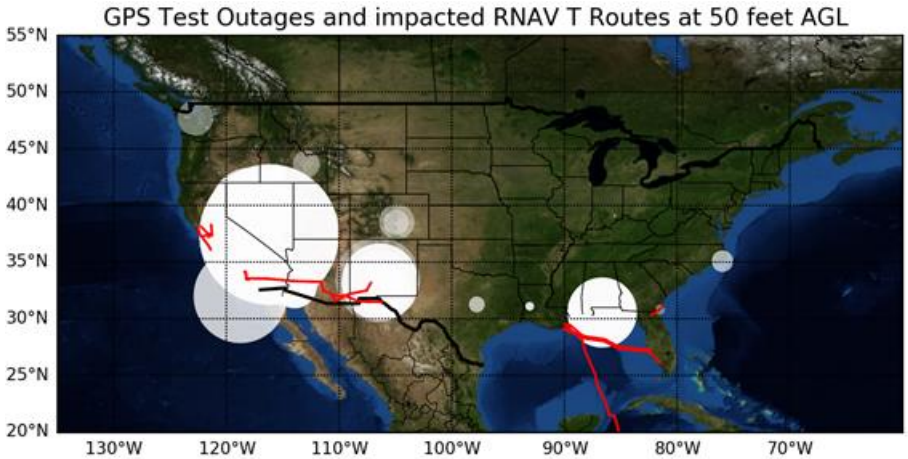


Figure 9-5 GPS NOTAMs @ 50 Feet



9.3 GPS Availability

The impacts to GPS availability are listed below for the corresponding locations and times. The percent impact to GPS availability over CONUS indicates that GPS is impacted for X % of the total area (total area of CONUS), centered at the indicated latitude/longitude. The last five columns in each table represent the impact to GPS availability at the corresponding altitude range. Altitudes 4,000 feet and under are with respect to above ground level (AGL), all remaining altitudes are with respect to MSL (mean sea level). Each row of the following table represents one GPS Test NOTAM. The remaining tables each represent one GPS Test NOTAM.

Table 9-3 NOTAM Impact to GPS Availability

				Percent Impact at Each Site				
START DATE	END DATE	LAT	LONG	50	4000	10000	FL250	FL400
2017-07-01 03:00:00	2017-07-01 10:00:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-02 03:00:00	2017-07-02 22:30:00	352114.0000N	1163329.0000W	2.37	2.37	3.72	6.60	8.26
2017-07-03 03:00:00	2017-07-03 13:30:00	352114.0000N	1163329.0000W	2.37	2.37	3.72	6.60	8.26
2017-07-08 03:00:00	2017-07-08 09:50:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-09 03:00:00	2017-07-12 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-10 03:00:00	2017-07-10 09:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-11 03:00:00	2017-07-11 09:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-12 03:00:00	2017-07-12 09:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-13 03:00:00	2017-07-13 09:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-13 04:30:00	2017-07-15 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-14 03:00:00	2017-07-14 09:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-07-16 03:00:00	2017-07-19 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-16 07:00:00	2017-07-22 13:00:00	433734.0000N	1125400.0000W	0.62	1.44	0.83	3.51	5.57
2017-07-17 18:30:00	2017-07-19 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-07-19 03:00:00	2017-07-19 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-19 14:00:00	2017-07-19 21:00:00	310704.0000N	930913.0000W	0.10	0.10	0.10	0.10	0.10
2017-07-19 21:00:00	2017-07-19 22:30:00	321132.0000N	1060819.0000W	0.83	2.17	1.65	3.82	5.78
2017-07-20 04:30:00	2017-07-20 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-20 11:00:00	2017-07-21 12:59:00	304800.0000N	813100.0000W	0.00	0.72	1.24	3.20	4.64
2017-07-20 18:30:00	2017-07-21 22:30:00	321132.0000N	1060819.0000W	0.83	2.17	1.65	3.82	5.78

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-07-21 04:30:00	2017-07-22 07:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-07-24 13:00:00	2017-07-26 23:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-07-24 19:00:00	2017-07-24 22:59:00	474356.0000N	1224354.0000W	1.14	1.34	1.75	2.99	4.13
2017-07-25 18:30:00	2017-07-26 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-07-26 03:00:00	2017-07-26 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-27 04:30:00	2017-07-28 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-27 13:00:00	2017-07-29 23:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-07-27 18:30:00	2017-07-27 22:30:00	321132.0000N	1060819.0000W	0.83	2.17	1.65	3.82	5.78
2017-07-28 18:00:00	2017-07-29 03:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-07-28 18:30:00	2017-07-28 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-07-28 21:00:00	2017-07-28 22:30:00	321132.0000N	1060819.0000W	0.83	2.17	1.65	3.82	5.78
2017-07-29 04:30:00	2017-07-29 07:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-07-29 18:30:00	2017-07-29 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-07-29 18:30:00	2017-07-30 22:30:00	321132.0000N	1060819.0000W	0.83	2.17	1.65	3.82	5.78
2017-07-30 03:00:00	2017-07-31 07:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-07-30 13:00:00	2017-07-31 23:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-07-31 18:00:00	2017-08-04 03:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-07-31 18:30:00	2017-07-31 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-08-01 00:10:00	2017-08-05 03:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-08-01 03:00:00	2017-08-02 12:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-07-21 04:30:00	2017-07-22 07:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-07-24 13:00:00	2017-07-26 23:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-07-24 19:00:00	2017-07-24 22:59:00	474356.0000N	1224354.0000W	1.14	1.34	1.75	2.99	4.13
2017-07-25 18:30:00	2017-07-26 21:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-07-26 03:00:00	2017-07-26 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-07-27 04:30:00	2017-07-28 07:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-08-01 18:30:00	2017-08-01 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-08-03 04:30:00	2017-08-04 12:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-08-03 18:30:00	2017-08-04 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-08-05 07:00:00	2017-08-06 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-07 18:30:00	2017-08-07 22:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-08-08 00:10:00	2017-08-11 03:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-08-08 03:00:00	2017-08-12 12:00:00	332659.0000N	1063329.0000W	5.16	8.26	8.88	12.18	14.96
2017-08-08 18:00:00	2017-08-08 19:30:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-08-09 08:00:00	2017-08-12 13:00:00	350236.0000N	1174651.0000W	1.34	1.96	2.17	4.13	6.19
2017-08-09 21:00:00	2017-08-09 22:00:00	383010.0000N	1045547.0000W	0.62	1.65	1.65	2.27	2.27
2017-08-09 21:30:00	2017-08-17 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-10 18:00:00	2017-08-10 19:30:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-08-11 16:30:00	2017-08-11 18:30:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-11 18:30:00	2017-08-11 22:30:00	331424.0000N	1062174.0000W	3.20	4.23	4.64	8.67	10.53
2017-08-11 18:30:00	2017-08-13 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-12 18:30:00	2017-08-13 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-13 16:30:00	2017-08-13 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-13 18:30:00	2017-08-13 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-14 08:00:00	2017-08-21 13:00:00	350236.0000N	1174651.0000W	1.34	1.96	2.17	4.13	6.19
2017-08-16 18:30:00	2017-08-17 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-01 18:30:00	2017-08-01 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-08-03 04:30:00	2017-08-04 12:00:00	331424.0000N	1062147.0000W	4.33	6.81	6.81	9.29	11.76
2017-08-03 18:30:00	2017-08-04 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-08-05 07:00:00	2017-08-06 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-07 18:30:00	2017-08-07 22:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-08-08 00:10:00	2017-08-11 03:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-08-17 16:30:00	2017-08-17 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-19 16:30:00	2017-08-20 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-19 18:30:00	2017-08-20 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-22 07:00:00	2017-08-22 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-23 07:00:00	2017-08-23 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-24 08:00:00	2017-08-27 13:00:00	350236.0000N	1174651.0000W	1.34	1.96	2.17	4.13	6.19
2017-08-24 13:00:00	2017-08-25 18:00:00	390335.0000N	853248.0000W	0.00	0.21	0.21	0.21	0.21
2017-08-28 13:00:00	2017-08-29 18:00:00	390335.0000N	853248.0000W	0.00	0.21	0.21	0.21	0.21
2017-09-06 21:30:00	2017-09-06 23:59:00	352112.0000N	1163325.0000W	0.41	0.21	0.31	0.41	0.41
2017-09-07 02:00:00	2017-09-08 14:30:00	424328.0000N	1153544.0000W	0.41	0.21	0.21	0.31	0.41
2017-09-07 18:30:00	2017-09-07 22:30:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-08 13:00:00	2017-09-08 18:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-09-08 17:30:00	2017-09-08 18:30:00	352112.0000N	1163325.0000W	0.41	0.21	0.31	0.41	0.41
2017-09-08 18:30:00	2017-09-08 22:30:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-09 00:01:00	2017-09-11 23:59:00	311546.0000N	974609.0000W	0.10	0.93	2.06	4.44	6.40
2017-09-09 02:00:00	2017-09-09 14:30:00	424328.0000N	1153544.0000W	0.41	0.21	0.21	0.31	0.41
2017-09-09 06:00:00	2017-09-10 22:30:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-09 18:30:00	2017-09-09 20:00:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-10 02:00:00	2017-09-10 14:30:00	424328.0000N	1153544.0000W	0.41	0.21	0.21	0.31	0.41
2017-09-10 18:30:00	2017-09-10 20:00:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-08-17 16:30:00	2017-08-17 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-19 16:30:00	2017-08-20 23:59:00	352114.0000N	1163330.0000W	0.41	0.21	0.31	0.41	0.41
2017-08-19 18:30:00	2017-08-20 22:30:00	352114.0000N	1163330.0000W	2.37	2.37	3.72	6.60	8.36
2017-08-22 07:00:00	2017-08-22 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-23 07:00:00	2017-08-23 13:00:00	320000.0000N	1184500.0000W	2.37	3.82	4.23	6.30	8.36
2017-08-24 08:00:00	2017-08-27 13:00:00	350236.0000N	1174651.0000W	1.34	1.96	2.17	4.13	6.19

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-09-11 02:00:00	2017-09-11 14:30:00	424328.0000N	1153544.0000W	0.41	0.21	0.21	0.31	0.41
2017-09-11 06:00:00	2017-09-11 20:59:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-11 07:00:00	2017-09-12 11:30:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-11 13:00:00	2017-09-15 18:59:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-09-12 00:01:00	2017-09-12 05:00:00	311546.0000N	974609.0000W	0.10	0.93	2.06	4.44	6.40
2017-09-12 02:00:00	2017-09-22 14:30:00	424328.0000N	1153544.0000W	0.41	0.21	0.21	0.31	0.41
2017-09-12 06:00:00	2017-09-14 22:30:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-12 16:30:00	2017-09-14 23:59:00	352112.0000N	1163325.0000W	0.41	0.21	0.31	0.41	0.41
2017-09-12 18:30:00	2017-09-12 20:00:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-13 08:00:00	2017-09-13 11:30:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-14 18:30:00	2017-09-14 20:00:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-14 18:30:00	2017-09-14 22:30:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-15 06:00:00	2017-09-17 22:30:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-15 16:30:00	2017-09-17 23:59:00	352112.0000N	1163325.0000W	0.41	0.21	0.31	0.41	0.41
2017-09-16 07:00:00	2017-09-19 11:30:00	325330.0000N	1060456.0000W	1.44	3.30	3.30	6.60	9.29
2017-09-16 11:00:00	2017-09-23 13:00:00	350432.0000N	755844.0000W	0.41	1.14	1.75	2.89	4.33
2017-09-18 06:00:00	2017-09-18 13:00:00	352112.0000N	1163325.0000W	1.65	2.06	3.92	6.40	8.46
2017-09-18 16:30:00	2017-09-18 18:00:00	393835.0000N	1174702.0000W	5.88	9.91	8.67	14.04	16.20
2017-09-19 19:00:00	2017-09-20 23:59:00	393835.0000N	1174702.0000W	5.88	9.91	8.67	14.04	16.20
2017-09-21 16:30:00	2017-09-21 23:59:00	393835.0000N	1174702.0000W	5.88	9.91	8.67	14.04	16.20
2017-09-22 05:30:00	2017-09-24 12:00:00	383229.0000N	1045209.0000W	1.03	1.96	2.27	5.88	7.33
2017-09-25 11:00:00	2017-09-29 13:00:00	350432.0000N	755844.0000W	0.41	1.14	1.75	2.89	4.33
2017-09-26 16:30:00	2017-09-28 22:30:00	355629.0000N	1173902.0000W	2.68	3.61	5.26	8.67	9.91

10 Appendices

10.1 Appendix A: Performance Summary

Table 10-1 Performance Summary

User Range Error Accuracy	Conditions and Constraints	Measured Performance
Single Frequency C/A-Code • ≤ 7.8m 95% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 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	≤ 2.576 m N/A N/A
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 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 one year; average of daily values within service volume • Standard based on 3 service failures per year, lasting no more than 6 hours each	100% Global 100% WCP
User Range Rate Error Accuracy	**Conditions and Constraints**	
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	≤ 2.760 mm/sec
User Range Acceleration Error Accuracy	**Conditions and Constraints**	
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	≤ 22.074 mm/s^2

Per-Satellite Coverage	**Conditions and Constraints**	**Measured Performance**
Terrestrial Service Volume: • 100% Coverage	• For any health or marginal SPS SIS	100%
Constellation Coverage	**Conditions and Constraints**	
Terrestrial Service Volume: • 100% Coverage	• For any health or marginal SPS SIS	100%
Status and Problem Reporting	**Conditions and Constraints**	
Scheduled event affecting service • Appropriate NANU issued to the Coast Guard and the FAA at least 48 hours prior to the event	• For any SPS SIS	≥ 125.967 hours Prior to event
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	≤ 0.883 hours
Unscheduled Failure Interruption Continuity • ≥ 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.	100%
Operational Satellite Count	**Conditions and Constraints**	
• ≥ 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 operation 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.	100%
PDOP Availability	**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	100 % 100 %
Service Availability	**Conditions and Constraints**	
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m 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.	100% Horizontal 100% Vertical
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m 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.	100% Horizontal 100% Vertical

Position/Time Accuracy	Conditions and Constraints	
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 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.	≤ 1.799 m Horizontal ≤ 3.826 m Vertical
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 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.	≤ 3.234 m Horiz. ≤ 4.719 m Vert.
Time Transfer Domain Accuracy • ≤ 40 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.	≤ 10.1 nanoseconds
Instantaneous UTCOE Integrity • NTE ±120 nanoseconds 99.999% of time without a timely alert (SIS only)	• For any healthy SPS SIS • Worst case for delayed alert is 6 hours	≤ 28.4 nanoseconds
Per-Slot Availability	**Conditions and Constraints**	
• ≥ 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.	100% 100%
Constellation Availability	**Conditions and Constraints**	
• ≥ 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. • Applies to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.	100% 100%

10.2 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							
2017 07 01	14	2	4	3	2	3	3	3	2	15	2	4	3	1	4	4	2	1	11	2	3	3	2	3	3	3	2
2017 07 02	20	3	3	4	4	3	3	3	4	22	2	3	6	4	4	1	2	2	18	3	2	5	4	3	2	3	4
2017 07 03	7	2	3	2	2	2	1	1	1	6	1	3	1	3	1	1	1	0	5	2	2	1	2	1	1	1	1
2017 07 04	5	1	1	1	2	2	1	2	2	2	1	2	1	0	0	0	0	1	4	1	1	1	1	1	1	1	2
2017 07 05	2	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	3	1	1	1	1	1	0	0	1
2017 07 06	8	0	1	2	2	2	3	2	3	3	0	1	1	0	1	2	1	2	7	1	1	2	2	2	2	2	3
2017 07 07	5	2	2	1	1	2	1	1	2	3	2	2	0	0	1	0	1	1	5	2	2	1	1	1	1	1	2
2017 07 08	3	1	0	1	1	2	1	1	1	0	0	1	0	0	0	0	0	0	3	1	1	1	1	1	0	1	1
2017 07 09	26	5	3	3	5	3	3	4	4	28	4	4	3	6	3	4	3	3	28	5	4	2	5	2	3	4	4
2017 07 10	11	3	4	1	1	2	2	3	2	12	4	4	2	2	1	2	2	2	9	3	4	2	1	1	2	1	2
2017 07 11	9	2	3	3	2	2	2	1	2	13	2	4	4	2	3	2	2	1	8	2	3	3	2	1	2	1	2
2017 07 12	5	1	1	1	2	2	2	1	1	4	1	2	1	1	2	2	1	0	4	1	1	1	1	1	1	0	1
2017 07 13	5	1	1	1	1	2	2	2	2	4	1	1	0	1	3	1	1	0	4	1	1	1	1	1	1	1	2
2017 07 14	3	1	1	0	1	2	1	1	1	3	1	1	0	0	0	0	3	0	4	1	1	1	1	1	1	0	1
2017 07 15	4	1	1	1	1	2	1	1	1	1	0	1	1	0	0	0	0	0	4	1	1	1	1	1	1	1	1
2017 07 16	29	2	1	4	5	4	4	5	5	91	1	1	5	7	9	6	4	4	41	2	1	4	5	6	5	6	5
2017 07 17	23	3	4	4	4	4	5	2	2	54	3	4	6	6	6	7	1	2	27	3	4	4	4	4	6	2	2
2017 07 18	7	3	3	1	1	2	1	1	1	13	3	4	3	1	2	1	4	1	7	3	3	2	1	2	1	0	1
2017 07 19	5	1	1	1	2	2	2	1	1	2	1	1	0	2	0	0	0	1	4	1	1	0	1	1	1	1	1
2017 07 20	6	0	2	1	1	2	2	2	3	6	1	2	1	1	1	1	3	2	7	1	2	1	1	1	2	3	3
2017 07 21	13	3	4	2	1	3	3	1	3	19	3	4	3	2	4	5	2	2	14	4	3	3	1	2	3	1	3
2017 07 22	18	3	2	4	5	2	2	3	3	31	3	3	6	6	3	3	3	3	16	3	2	4	5	2	2	2	3
2017 07 23	16	3	3	4	3	3	2	2	4	35	2	3	6	6	6	2	2	2	14	3	3	3	3	3	2	2	4
2017 07 24	13	3	3	4	3	2	1	2	3	21	2	3	5	4	5	3	1	2	12	3	3	3	2	2	2	2	4
2017 07 25	9	3	2	2	2	2	2	2	3	18	3	2	4	4	5	2	2	2	9	2	2	2	2	3	2	2	3
2017 07 26	15	4	3	5	2	2	2	1	1	19	3	2	5	5	4	2	1	0	11	3	2	4	2	2	2	1	1
2017 07 27	8	1	2	2	1	3	2	1	3	12	0	1	1	1	2	4	1	5	6	1	1	2	1	2	2	1	3
2017 07 28	7	2	1	1	2	3	2	2	1	11	2	2	0	3	2	5	1	1	7	2	1	1	2	2	3	3	2
2017 07 29	4	1	1	2	2	2	1	0	1	4	1	1	1	2	1	2	1	0	4	1	1	2	1	1	1	0	1
2017 07 30	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	4	1	2	1	1	1	0	1	0
2017 07 31	2	-1	-1	-1	-1	-1	0	-1	1	8	-1	-1	-1	-1	-1	-1	0	-1	3	3	0	1	0	1	1	0	0	1
2017 08 01	10	1	1	2	2	4	3	2	2	2	1	1	1	-1	0	1	0	1	6	1	1	2	2	3	1	1	1
2017 08 02	8	1	1	1	2	4	2	2	1	5	1	1	0	0	3	3	0	0	5	1	1	1	1	2	2	1	1
2017 08 03	11	1	1	1	2	3	3	3	4	6	0	0	0	0	1	4	2	2	12	1	1	1	1	2	4	4	4
2017 08 04	19	2	4	4	3	4	3	3	3	39	1	3	6	5	6	5	4	2	23	3	4	4	4	4	4	3	3
2017 08 05	17	3	4	3	2	4	3	3	3	35	3	4	6	4	5	5	4	2	16	3	4	3	2	3	3	3	3
2017 08 06	13	3	3	2	4	3	1	3	2	23	3	3	4	6	4	2	2	2	13	3	3	3	4	2	1	2	2
2017 08 07	6	1	2	2	3	2	1	1	1	7	1	1	2	4	3	1	0	0	5	1	2	2	2	2	1	0	1
2017 08 08	5	0	1	0	2	3	2	2	1	5	1	0	1	1	1	2	1	3	5	1	1	1	1	1	2	2	1
2017 08 09	5	0	1	2	1	2	1	2	2	4	1	0	1	2	3	1	1	0	5	1	1	2	1	1	1	1	2
2017 08 10	7	0	1	1	2	4	2	2	1	4	0	2	1	3	1	1	0	0	5	1	1	2	2	2	1	0	2
2017 08 11	7	1	2	2	1	2	2	3	2	5	1	2	1	2	1	2	2	1	7	2	2	1	1	1	2	3	2
2017 08 12	12	3	3	2	2	3	1	3	3	9	3	3	3	1	2	1	2	2	11	3	3	2	2	2	1	3	3
2017 08 13	9	2	3	2	2	2	3	2	1	7	2	2	3	2	2	1	1	1	7	2	2	2	2	2	2	2	2
2017 08 14	5	2	1	0	2	2	1	1	2	4	2	1	0	1	2	0	1	2	5	2	1	1	1	2	1	1	2
2017 08 15	3	1	1	0	1	2	1	1	1	2	1	1	0	0	0	0	1	1	4	1	1	1	1	1	0	1	1
2017 08 16	5	2	1	1	2	2	1	1	2	5	1	1	2	1	2	1	1	2	6	2	1	1	2	1	1	1	2
2017 08 17	20	2	2	5	4	4	3	3	3	59	3	2	6	7	7	5	4	3	29	3	2	5	5	5	3	4	4
2017 08 18	20	5	3	2	3	4	3	4	2	40	3	3	4	5	6	5	6	2	21	4	3	2	3	4	3	5	3
2017 08 19	23	4	4	4	3	3	4	3	4	57	5	4	7	6	6	5	3	3	31	5	4	5	4	4	5	3	4
2017 08 20	21	4	5	3	4	3	3	2	3	32	4	5	6	5	4	3	2	2	22	5	5	3	3	2	3	3	3

2017	08	21	13	2	3	3	4	3	1	2	3	16	3	2	5	4	3	1	2	2	11	3	2	3	3	2	1	2	3
2017	08	22	16	5	4	3	2	3	1	2	2	37	6	5	5	5	5	3	1	2	23	6	5	3	2	3	2	2	3
2017	08	23	17	3	4	3	3	4	3	3	2	72	3	4	5	5	7	8	5	2	25	3	4	4	3	5	4	5	3
2017	08	24	16	4	4	4	3	3	2	1	1	38	2	5	6	6	6	2	0	0	11	3	3	3	3	3	2	1	1
2017	08	25	7	1	2	2	2	3	2	1	1	6	1	1	1	3	3	1	1	1	5	1	1	2	2	2	1	1	2
2017	08	26	5	1	1	2	1	2	2	2	1	2	0	1	1	0	1	2	1	0	5	1	1	2	1	1	2	1	1
2017	08	27	6	2	1	0	2	2	2	2	2	14	2	1	0	4	2	5	3	2	10	3	1	1	3	2	3	3	3
2017	08	28	3	1	1	0	2	1	1	1	0	6	2	1	1	3	3	1	0	0	4	1	1	1	1	1	1	0	1
2017	08	29	10	1	2	2	1	2	2	4	3	6	1	1	2	0	3	1	3	1	10	1	2	2	1	1	2	4	3
2017	08	30	5	2	2	2	2	2	0	1	0	4	1	1	3	2	1	0	0	0	5	2	2	2	1	1	0	0	0
2017	08	31	20	2	3	4	5	4	3	3	2	42	2	2	5	6	6	6	3	3	31	2	3	5	5	5	4	4	3
2017	09	01	17	4	3	2	4	4	2	2	3	29	3	3	3	6	6	3	2	2	19	4	3	2	4	4	2	2	4
2017	09	02	25	4	5	5	3	3	3	3	3	32	4	5	5	6	3	4	2	2	26	4	5	5	3	2	3	3	3
2017	09	03	10	3	3	1	2	3	2	2	2	17	3	2	1	5	4	4	1	1	9	3	3	1	2	3	2	2	2
2017	09	04	16	4	3	2	2	2	2	4	4	16	2	1	2	5	4	3	2	3	18	4	3	2	2	2	2	4	5
2017	09	05	11	3	3	3	2	2	3	2	2	14	3	3	3	4	4	1	1	1	12	4	3	3	2	2	3	2	2
2017	09	06	18	2	2	2	4	5	3	1	4	9	1	1	2	4	2	2	0	3	11	2	2	2	3	3	2	0	4
2017	09	07	23	2	3	3	3	4	3	2	6	60	3	5	7	7	4	3	3	6	38	3	4	4	4	3	2	2	8
2017	09	08	50	6	4	4	4	7	5	4	4	110	6	6	4	5	9	7	6	4	96	8	5	4	5	8	7	6	5
2017	09	09	6	3	2	2	1	1	1	1	1	3	3	1	1	1	1	0	0	0	6	3	2	2	1	1	1	1	1
2017	09	10	12	1	1	1	1	2	5	3	3	3	0	0	0	0	0	1	1	3	7	1	0	1	1	1	3	2	4
2017	09	11	8	3	2	2	1	3	1	2	2	19	4	3	4	4	4	3	2	2	11	3	3	2	2	3	2	3	3
2017	09	12	16	3	2	3	3	2	2	3	5	25	4	2	3	5	5	4	3	3	18	3	2	3	2	3	2	4	5
2017	09	13	13	5	3	3	2	2	2	1	1	30	4	4	7	4	3	1	0	0	15	5	3	4	2	2	2	1	0
2017	09	14	19	2	2	1	2	3	5	5	3	38	2	1	2	5	6	6	4	5	25	2	2	1	2	4	6	5	4
2017	09	15	30	6	4	4	3	4	2	4	4	51	3	5	5	6	6	6	4	4	36	6	4	5	3	4	3	5	5
2017	09	16	23	5	5	2	3	3	3	2	4	52	5	6	5	6	6	5	3	3	30	5	6	3	3	4	4	3	4
2017	09	17	13	4	3	2	2	3	3	2	2	39	4	3	2	6	6	6	3	2	17	3	4	2	3	4	4	2	2
2017	09	18	21	4	4	5	3	3	3	2	3	51	4	3	7	7	5	4	2	2	22	4	4	5	4	3	3	2	3
2017	09	19	6	2	1	1	2	2	1	2	2	11	1	1	0	4	3	2	2	4	8	3	2	1	2	2	2	3	3
2017	09	20	8	3	3	2	2	2	1	2	1	19	3	3	3	5	5	2	1	0	10	3	3	2	2	2	1	2	1
2017	09	21	7	1	2	3	2	2	1	1	2	9	1	1	4	3	4	0	0	0	7	1	2	3	2	2	0	1	2
2017	09	22	5	1	1	1	1	1	2	2	2	6	1	1	3	1	2	2	2	1	5	1	1	1	1	1	1	2	2
2017	09	23	4	1	1	1	1	1	2	2	1	5	1	1	3	2	2	0	1	1	5	1	2	1	1	1	1	2	2
2017	09	24	5	1	2	0	1	1	2	2	2	7	0	1	0	3	3	3	1	2	6	1	2	1	1	1	1	2	3
2017	09	25	5	3	2	1	1	1	1	1	0	2	3	1	0	0	0	0	0	0	5	3	2	1	1	0	1	0	1
2017	09	26	3	0	0	2	1	1	1	1	2	2	0	1	1	0	0	0	0	2	4	1	1	2	1	1	0	0	2
2017	09	27	24	3	2	4	4	3	2	5	5	47	2	1	5	6	6	6	4	5	37	3	2	5	4	4	3	6	6
2017	09	28	41	5	6	6	4	3	3	3	5	72	5	6	8	5	5	6	3	3	55	6	7	7	5	4	4	4	5
2017	09	29	8	3	2	3	2	2	1	1	2	29	3	2	4	6	6	3	1	2	12	3	2	3	3	3	2	2	2
2017	09	30	11	2	3	3	2	2	3	2	3	36	2	3	5	4	6	6	3	3	5	2	3	4	2	3	4	2	3

10.3 Appendix C: Performance Analysis (PAN) Problem Report

In 1993, the FAA began monitoring and analyzing Global Positioning System (GPS) Standard Positioning Service (SPS) performance data. At present, the FAA has approved GPS for IFR and is developing WAAS as a GPS augmentation system. In order 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 Performance Analysis (PAN) report. The PAN report contains data collected at various National Satellite Test Bed (NSTB) and Wide Area Augmentation System (WAAS) reference station locations. This PAN Problem Report will be issued only when the performance data fails to meet the GPS Standard Positioning Service (SPS) Signal Specification.

Problem Description:

There were no problems this quarter.

10.4 Appendix D: Glossary

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (September 2008). An understanding of these terms and definitions is a necessary prerequisite to full understanding of the Signal Specification.

General Terms and Definitions

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.

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 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 – 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 which 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 3.0.

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. Also known as the *pseudo range*.

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 a 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.

11 GPS Broadcast Orbit Versus NGA Precise Orbits and URA (IAURA) Bounding Analyses

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 off-line monitoring verifies that the original logic of the a priori assumption remains sound.

The assumption being validated is:

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. Figures 11-1.1 through 11-1.4 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 July 01 to September 30, 2017 is presented. Only data points where GPS is healthy and valid precise data is available are considered. There was maintenance on PRN-1 on 09/14/17, PRN-2 on 07/06/17 and 08/18/17, PRN-5 on 07/13/17 and 08/31/17, PRN-7 on 07/18/17 to 07/19/17 and 09/12/17, PRN-9 on 08/11/17 and 08/25/17, PRN-12 on 08/24/17, PRN-13 on 09/07/17, PRN-15 on 08/10/17, PRN-17 on 08/08/17, PRN-21 on 08/29/17, PRN-23 on 07/11/17, PRN-25 on 08/03/17 and 09/17/17, PRN-26 on 09/19/17, PRN-29 on 08/22/17, and PRN-31 on 08/15/17. Figure 11-5 shows the availability of C/A Nav data. There were no points where GPS was healthy and the NGA data was missing. There are no points where GPS C/A GPS Nav data is unavailable other than during NANUs.

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. 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. There was no missing data for the quarter.

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.

Figures 11-7 and 11-8 are URA (IAURA) over bounding 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)

Figures 11-9 thru 11-58 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.

Figures 11-59 thru 11-70 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. +/- 13.9° from the bore sight of the satellite is used to approximate the surface of the earth. The max URA of the broadcast URA index range is used for the C/A Nav data, 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.

Figures 11-71 thru 11-117 are histograms of the height error, along track error, cross track error, and URA (IAURA) normalized range error.

Figures 11-118 thru 11-164 are the timelines of the URA (IAURA) normalized range error. Missing data point are in red and are NANUs for the C/A data. The large number of red points in the CNAV data is the points where the satellites are out of view of ACY.

Figure 11-1 GPS Broadcast Orbit Accuracy Standard Deviation Plots

Figure 11-2 GPS Broadcast Orbit Accuracy Standard Deviations Using C/A Nav Data

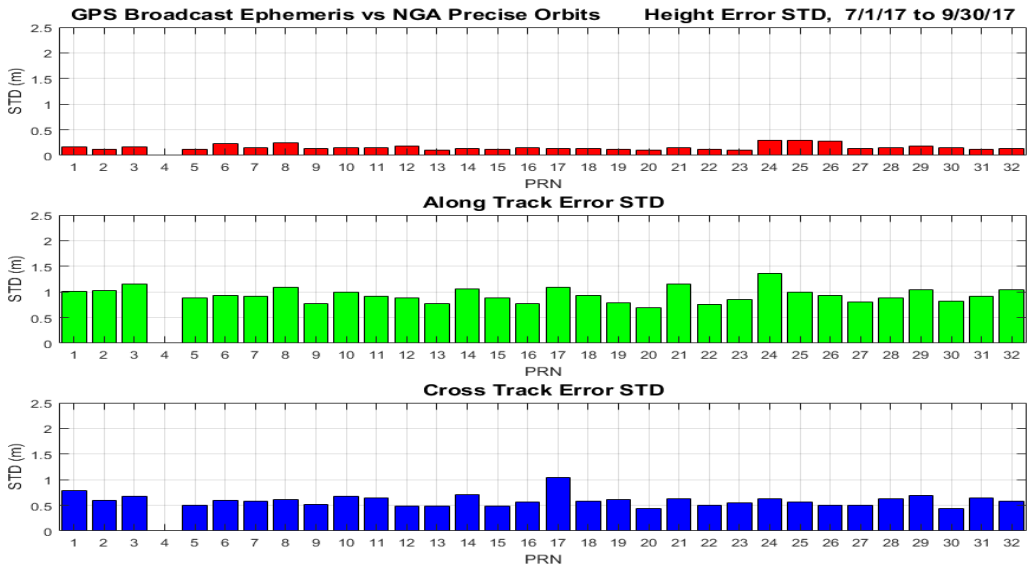


Figure 11-3 GPS Broadcast Orbit Accuracy Standard Deviations Using L2C CNAV Data

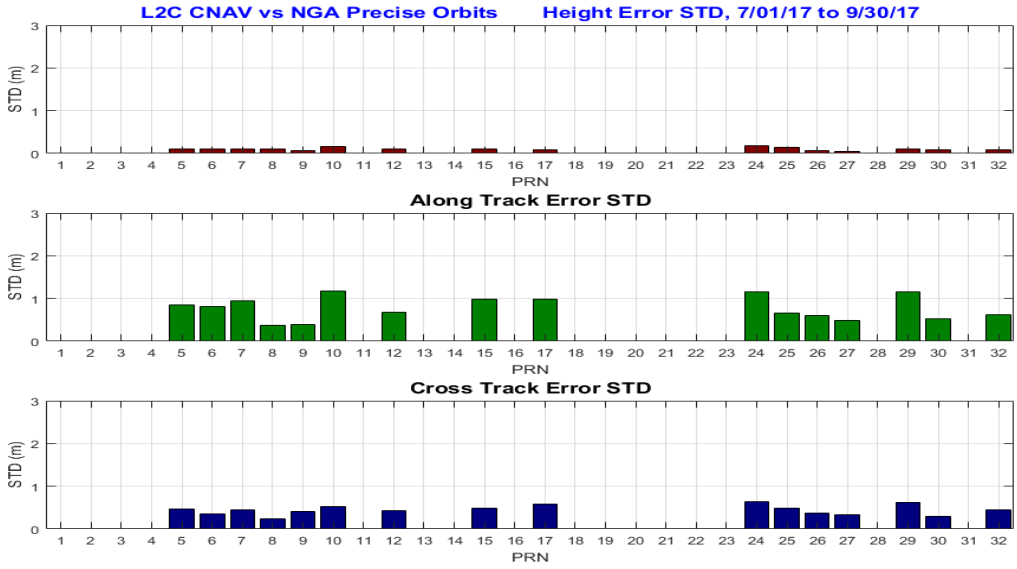


Figure 11-4 GPS Broadcast Orbit Error Means Using C/A Nav Data

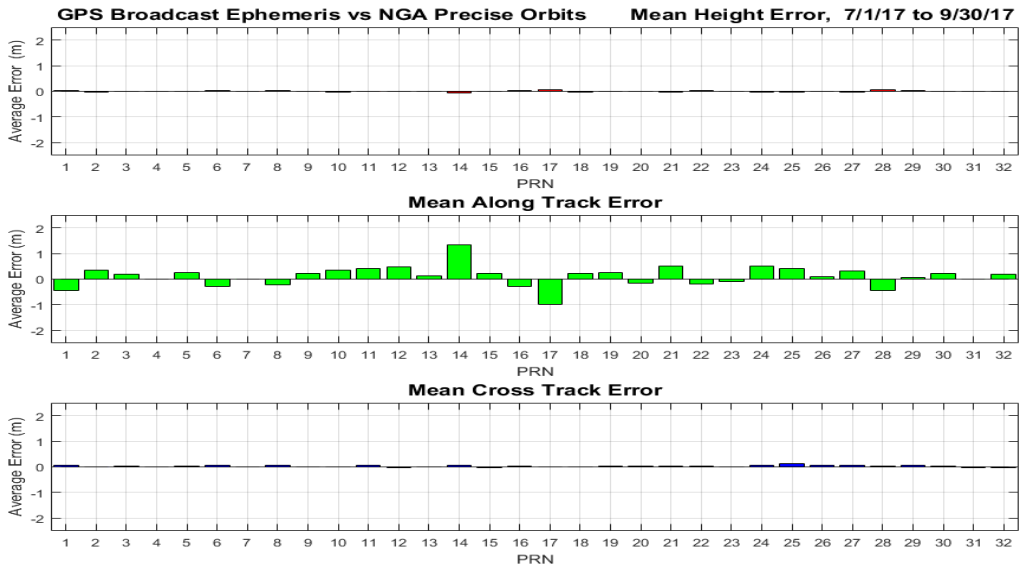
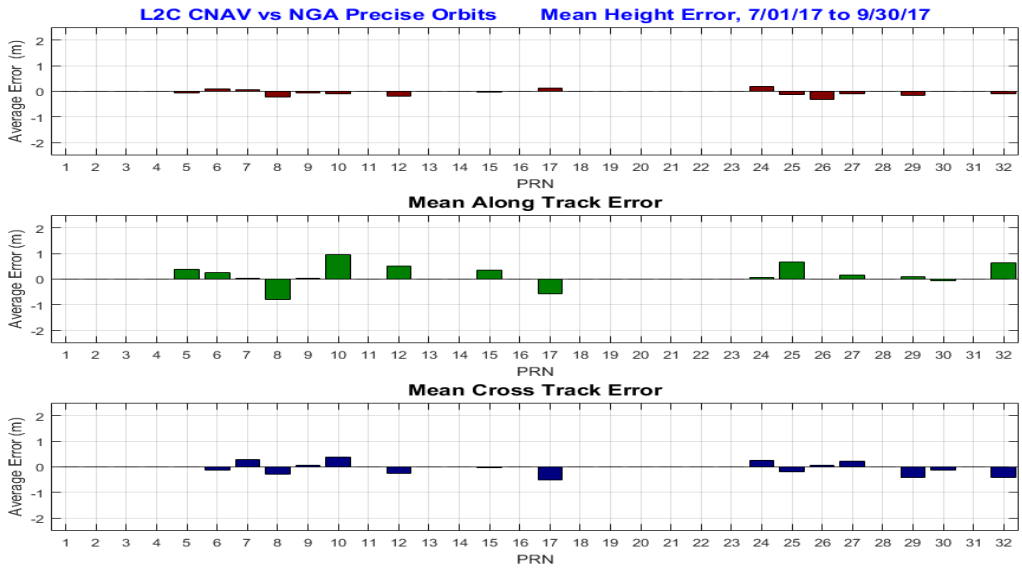
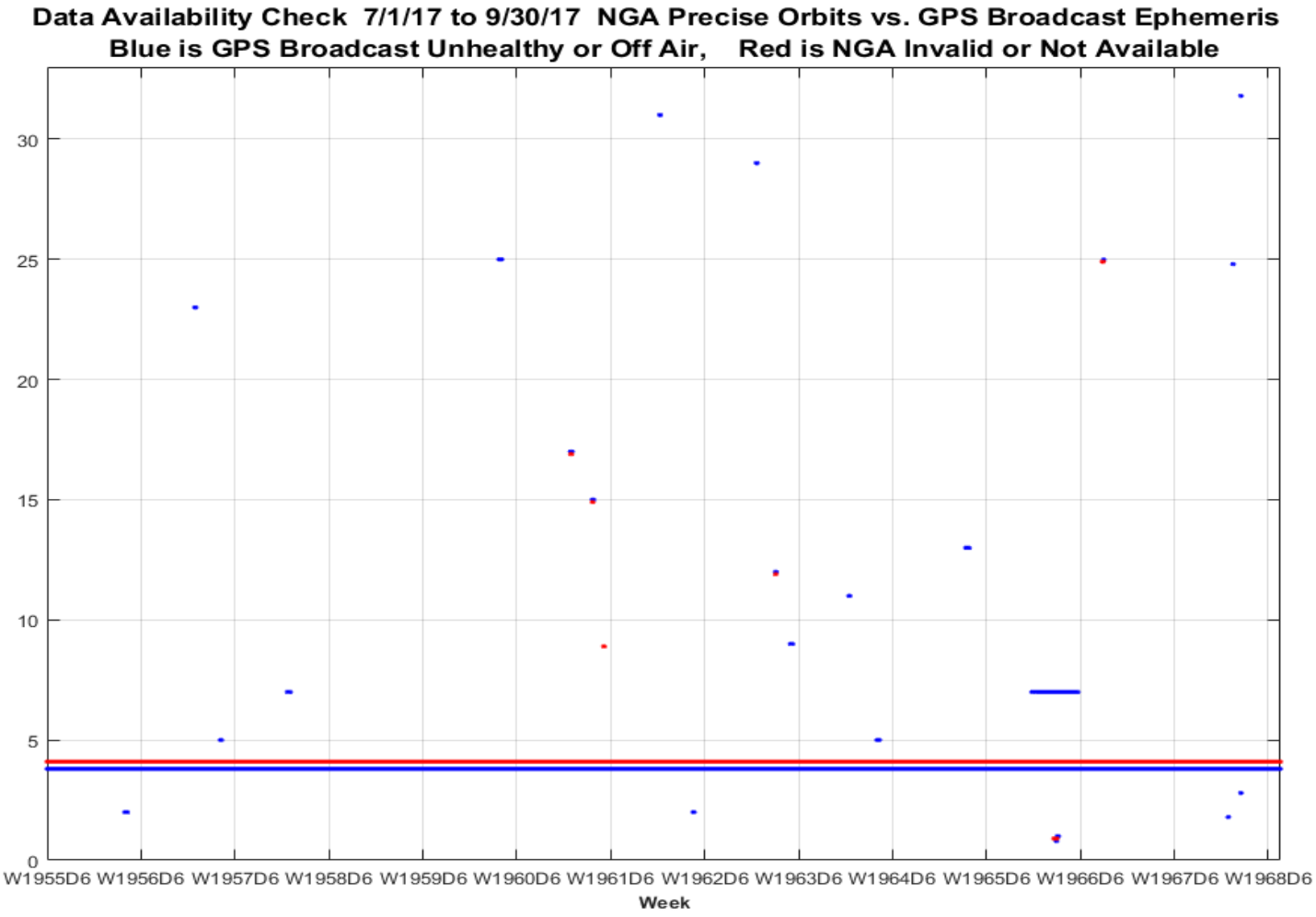


Figure 11-5 GPS Broadcast Orbit Error Means Using L2C CNAV Data



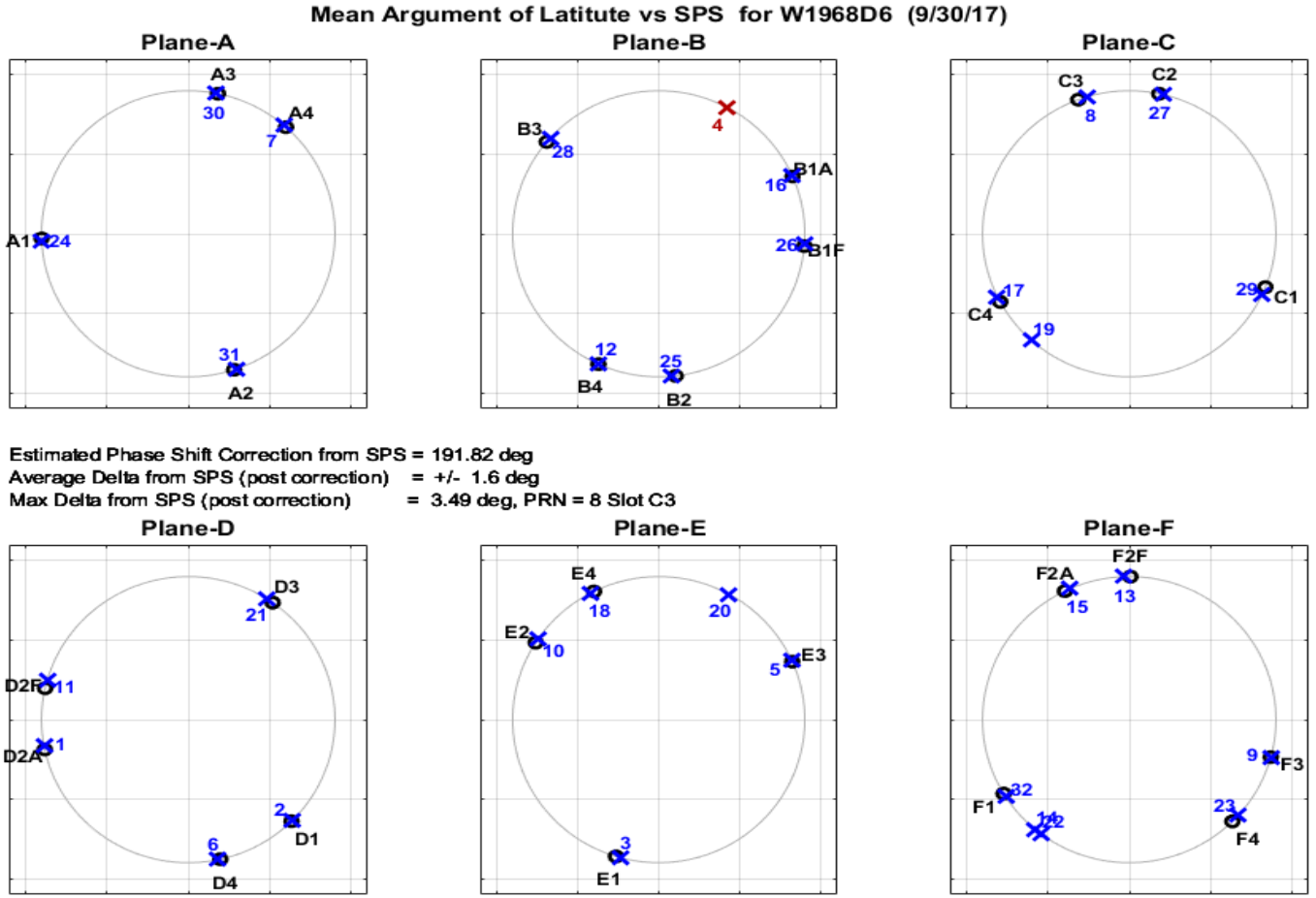
Broadcast Ephemeris vs. NGA Precise Data Availability Plots

Figure 11-6 Broadcast Ephemeris vs. NGA Precise Data Availability Plots



Current GPS Constellation

Figure 11-7 Current GPS Constellation



URA Over-bounding Plots

Figure 11-8 URA Over-bounding Using C/A Nav Data

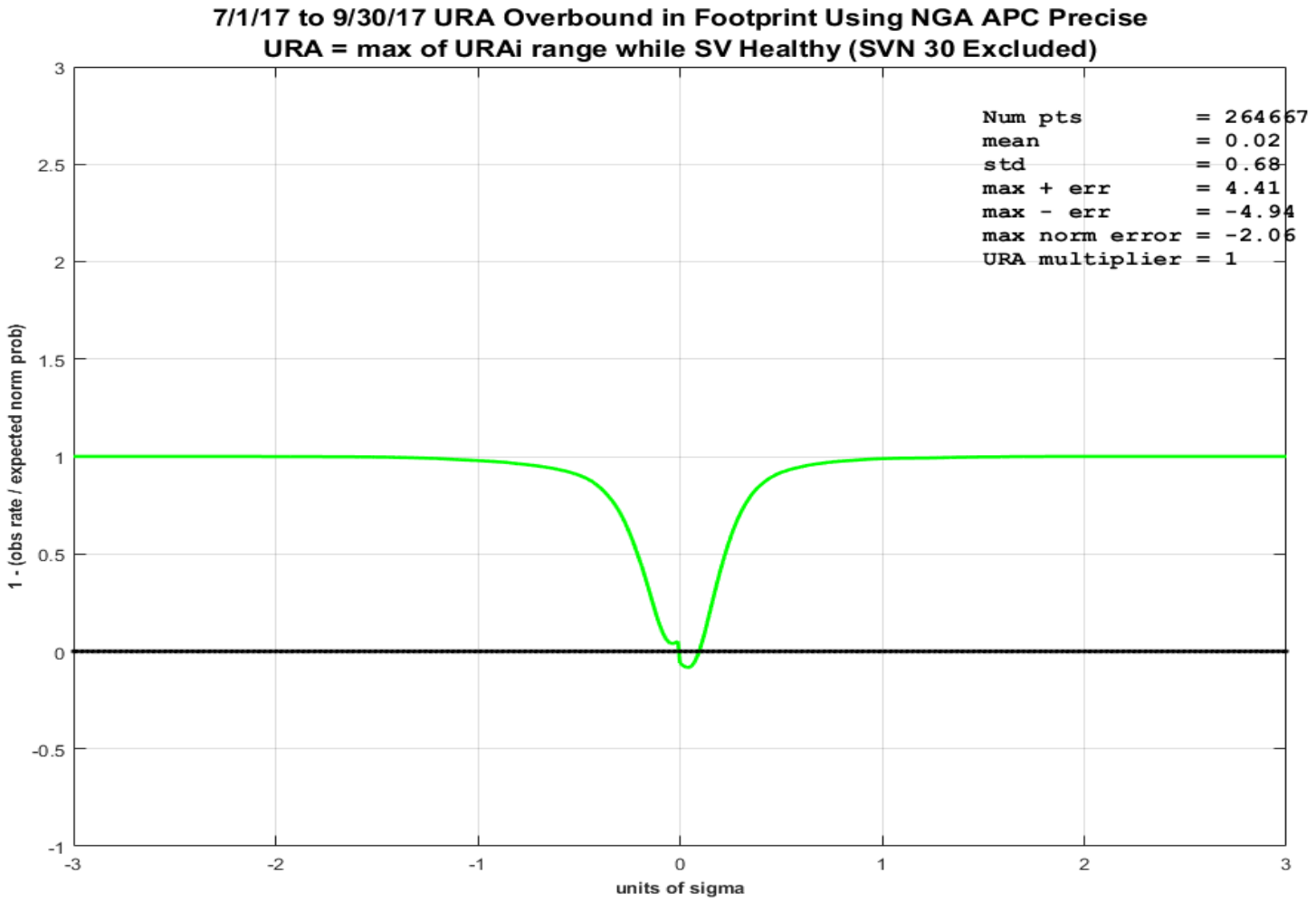
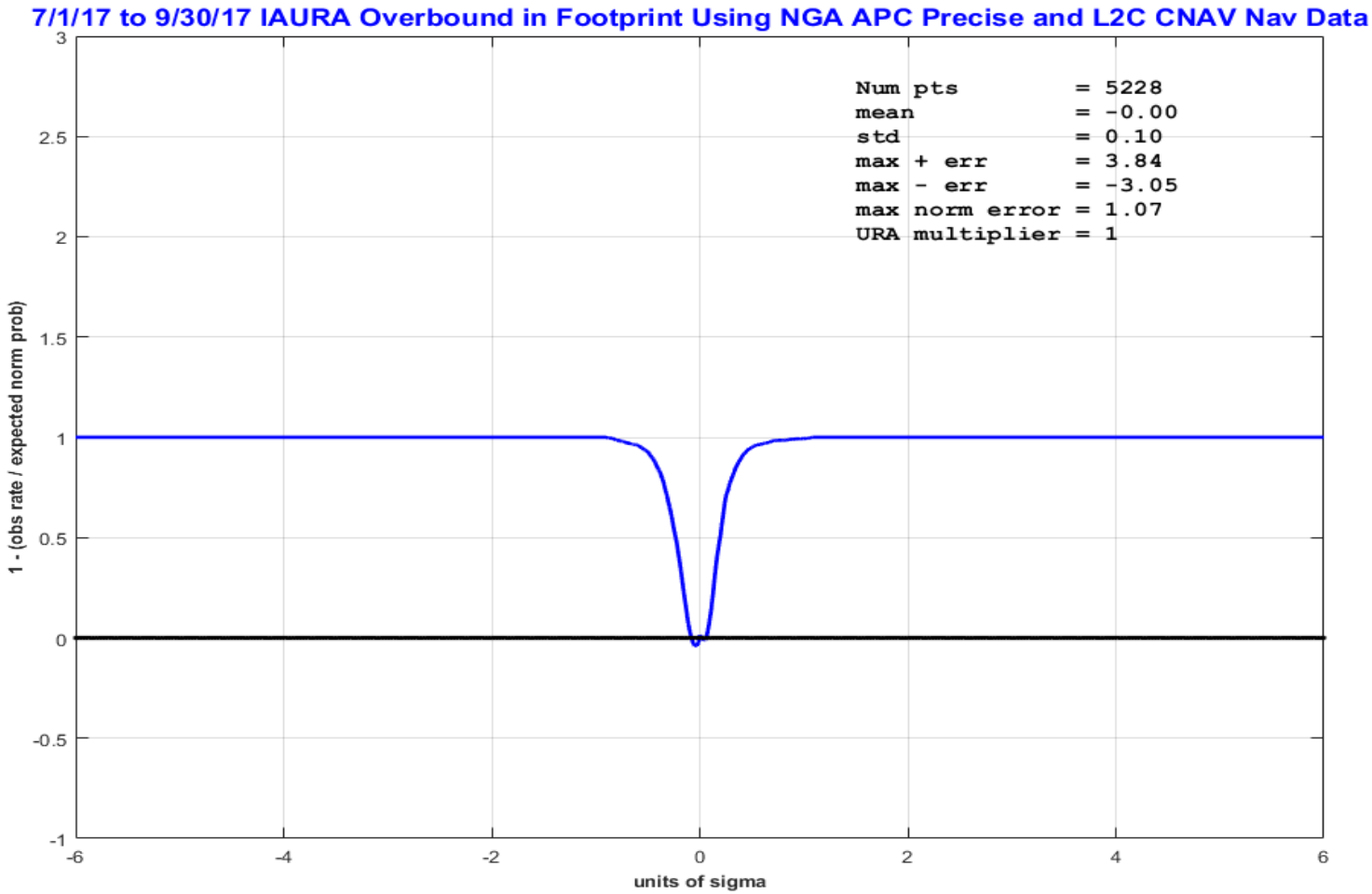


Figure 11-9 IAURA Over-bounding Using L2C CNAV Data



Orbit Error Plots for All Satellites

Figure 11-10 Orbit Error PRN-1 (SVN-63) Using C/A Nav Data

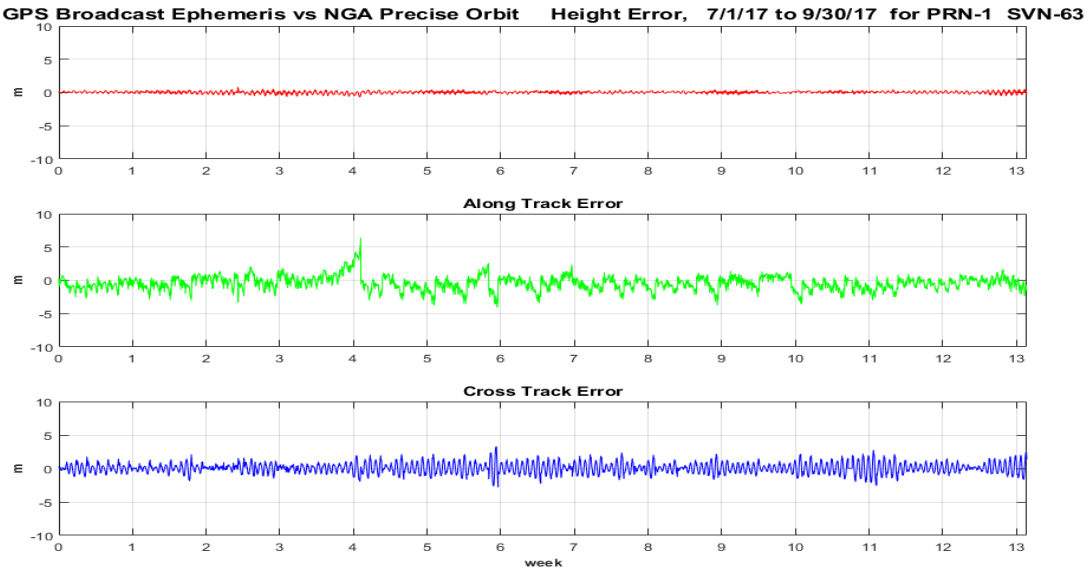


Figure 11-11 Orbit Error PRN-1 (SVN-63) Using L2C CNAV Data

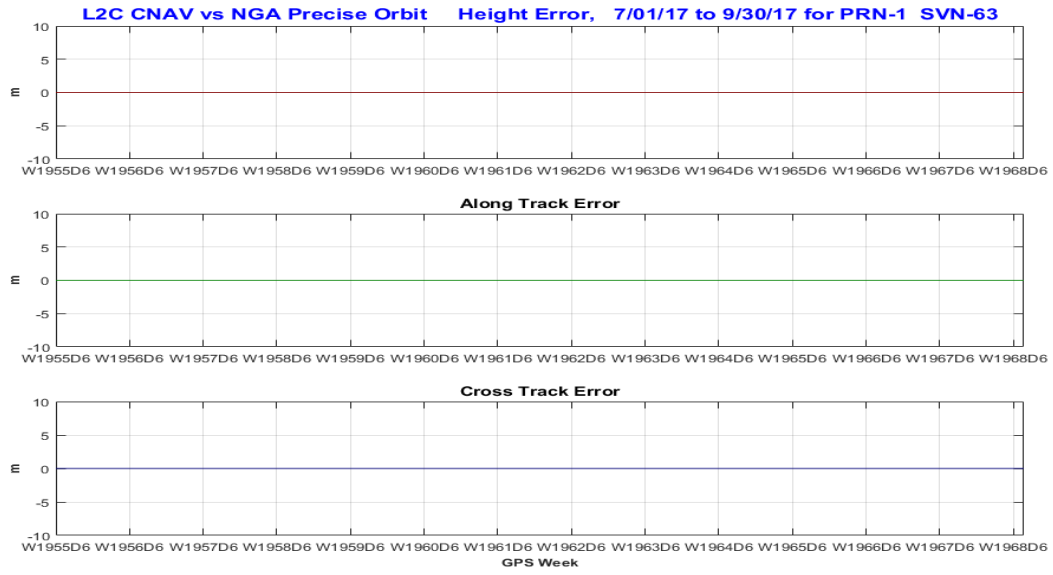


Figure 11-12 Orbit Error PRN-2 (SVN-61) Using C/A Nav Data

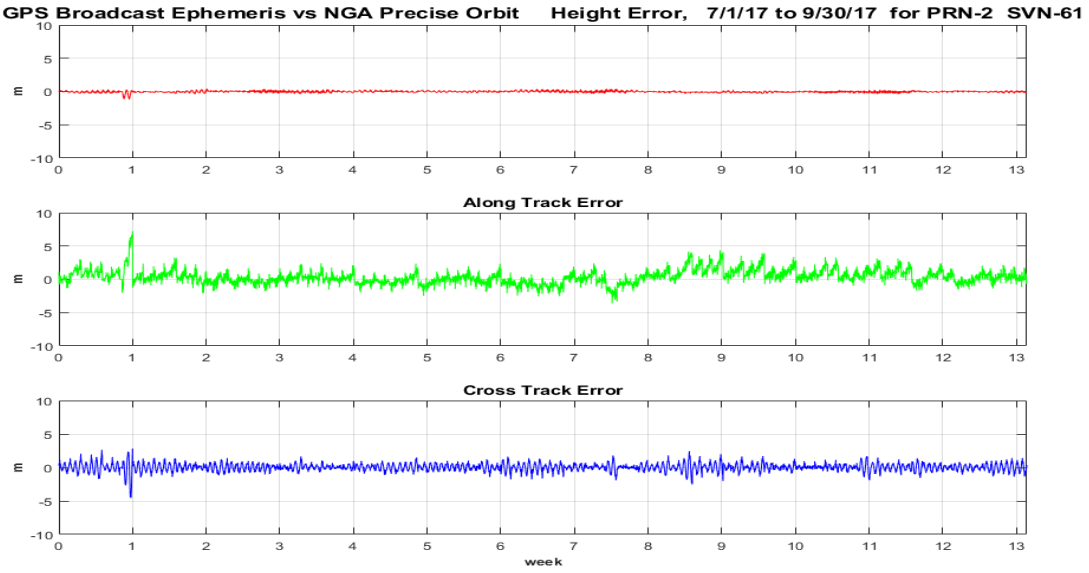


Figure 11-13 Orbit Error PRN-3 (SVN-69) Using C/A Nav Data

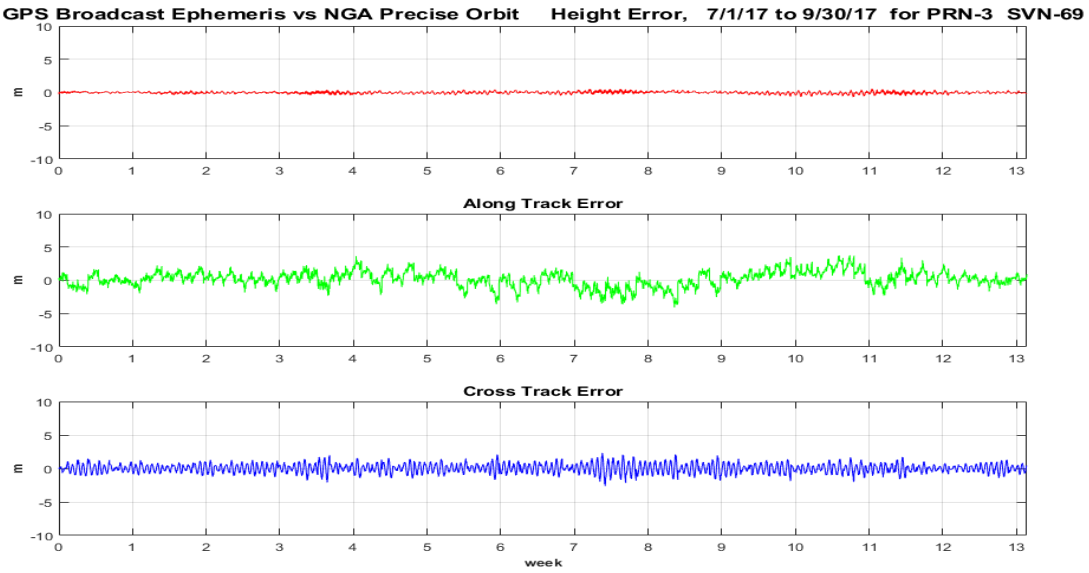


Figure 11-14 Orbit Error PRN-3 (SVN-69) Using L2C CNAV Data

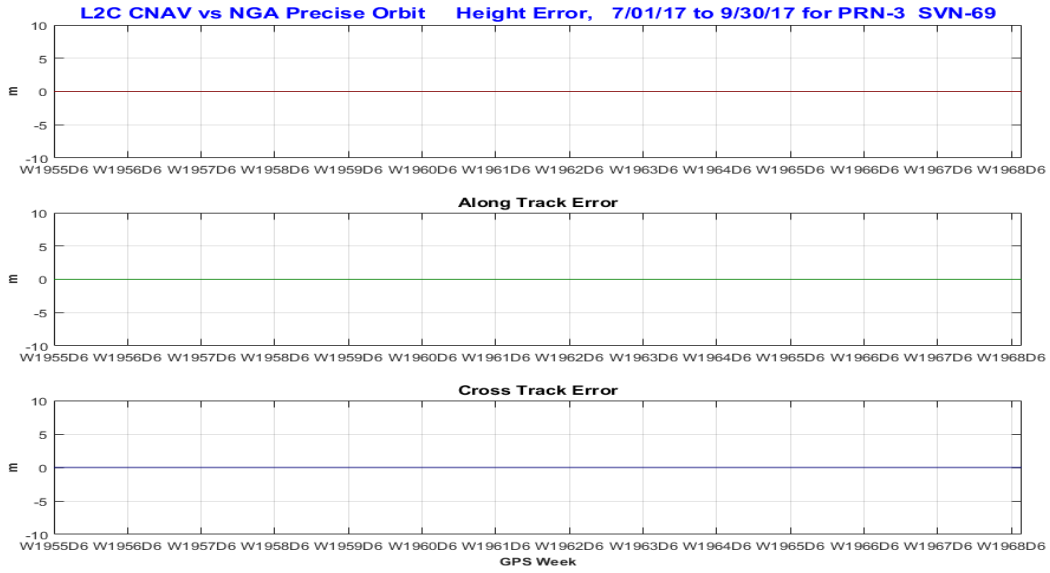


Figure 11-15 Orbit Error PRN-5 (SVN-50) Using C/A Nav Data

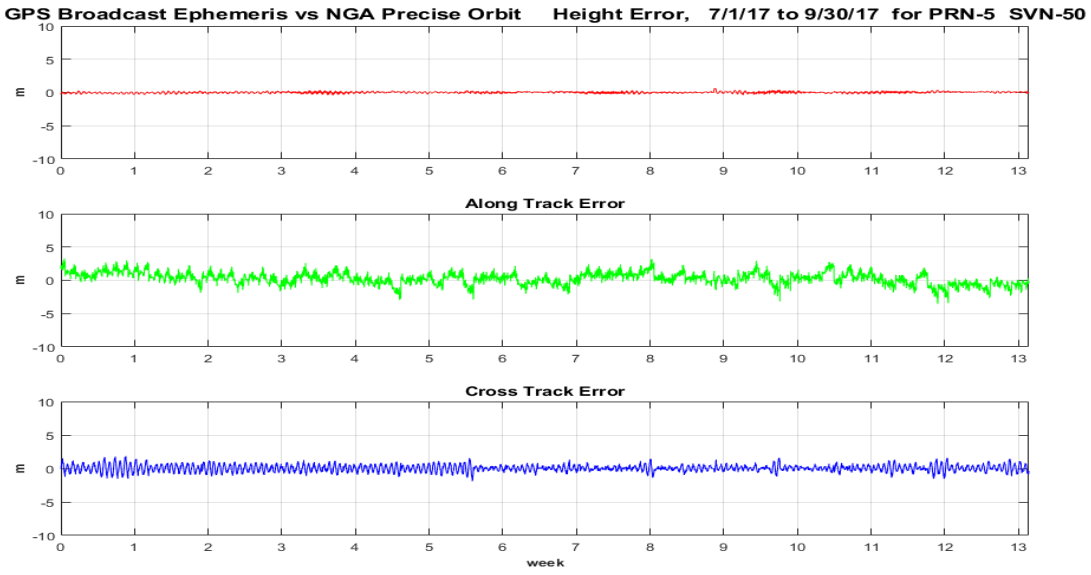


Figure 11-16 Orbit Error PRN-5 (SVN-50) Using L2C CNAV Data

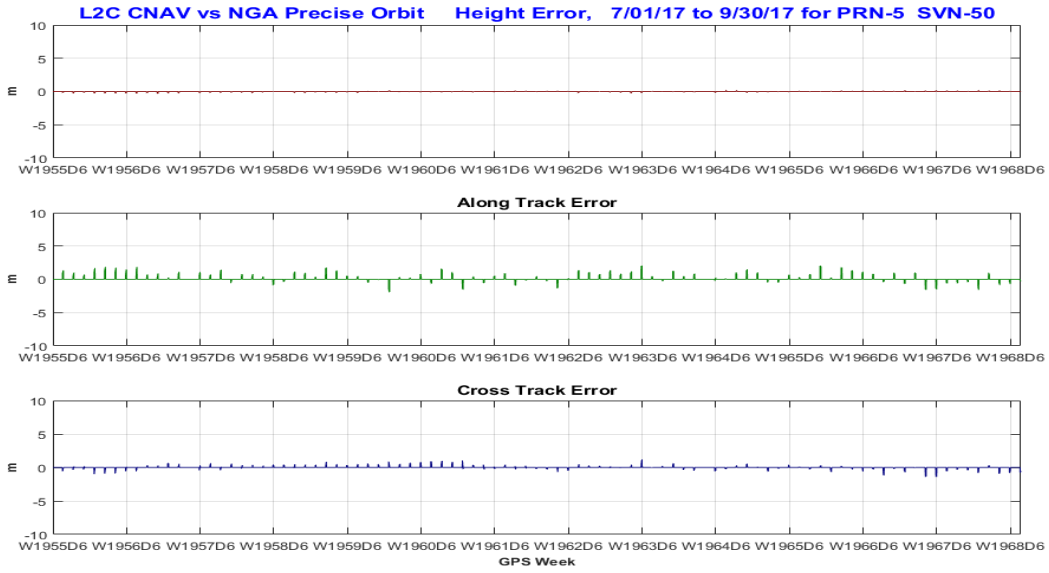


Figure 11-17 Orbit Error PRN-6 (SVN-67) Using C/A Nav Data

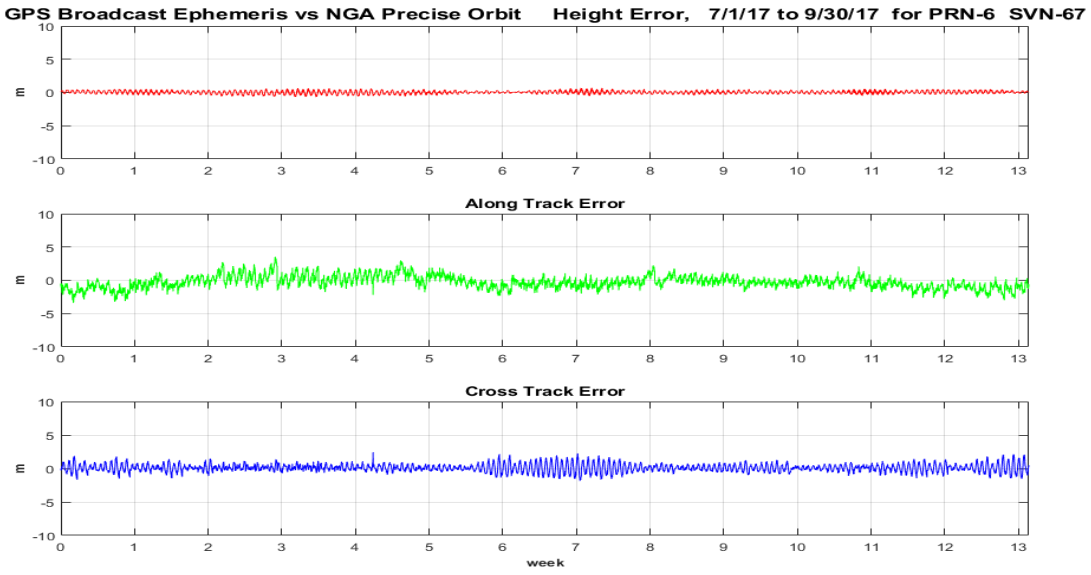


Figure 11-18 Orbit Error PRN-6 (SVN-67) Using L2C CNAV Data

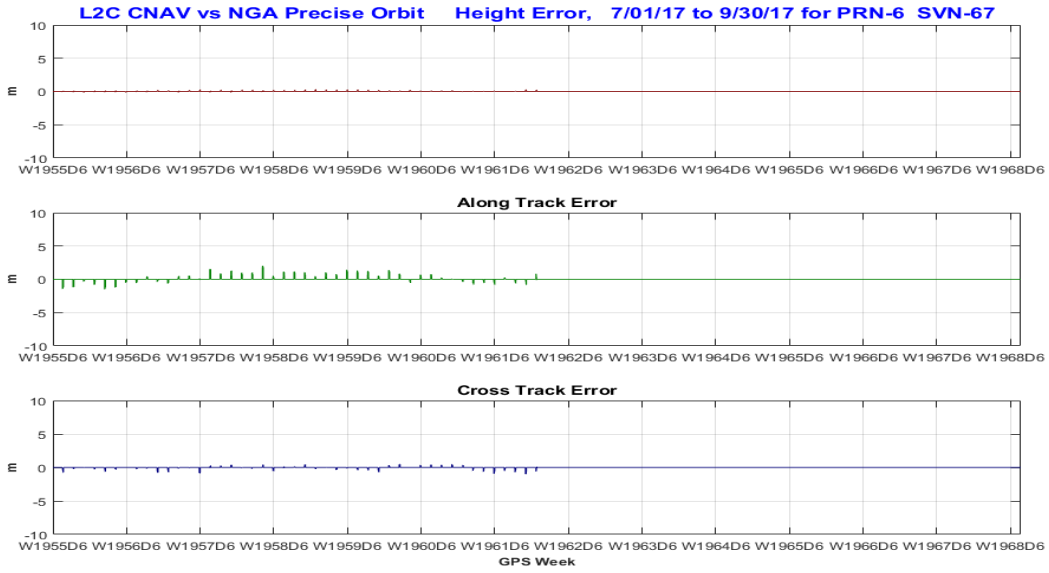


Figure 11-19 Orbit Error PRN-7 (SVN-48) Using C/A Nav Data

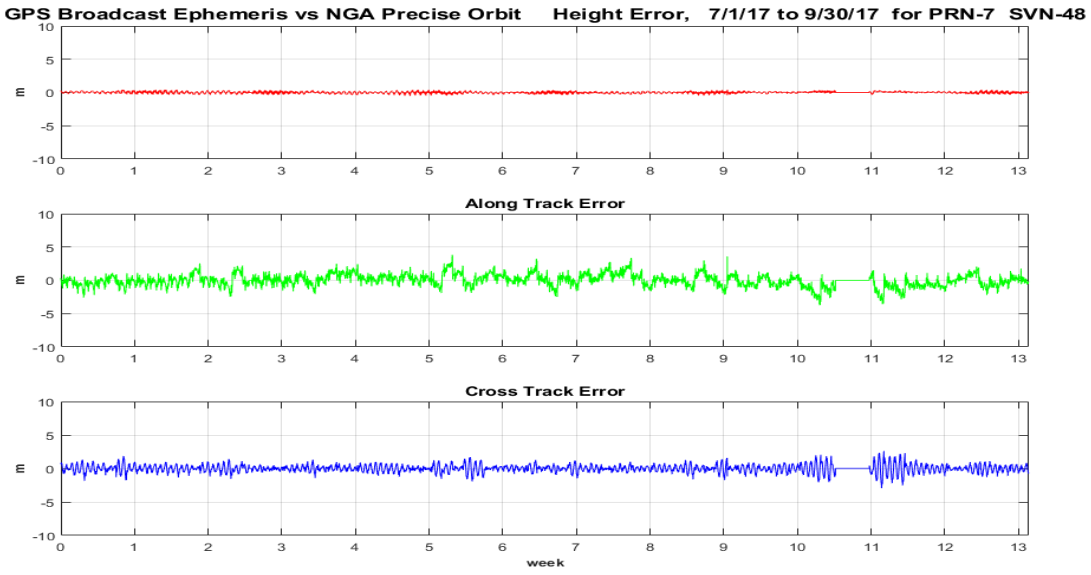


Figure 11-20 Orbit Error PRN-7 (SVN-48) Using L2C CNAV Data

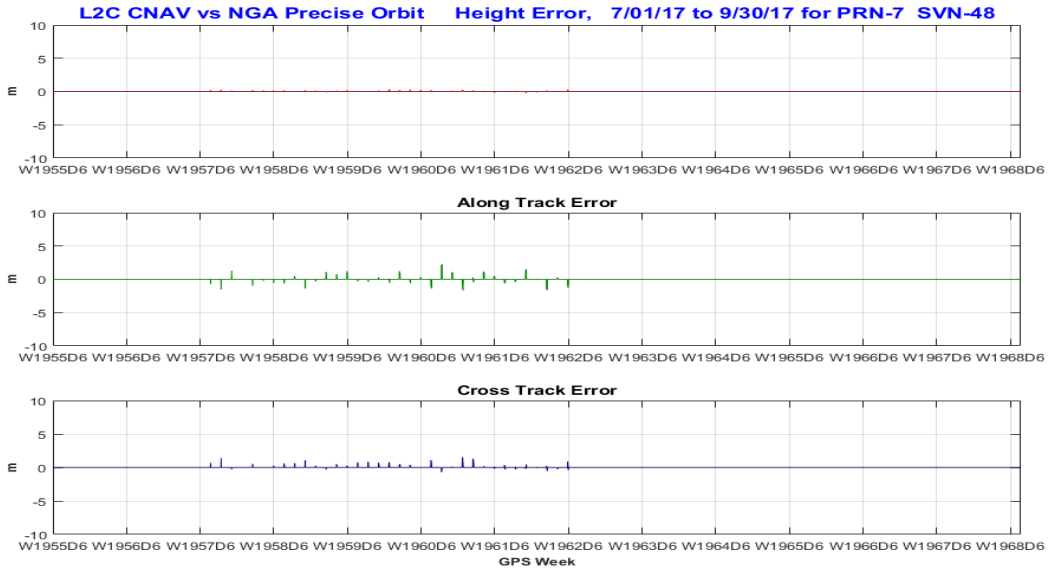


Figure 11-21 Orbit Error PRN-8 (SVN-72) Using C/A Nav Data

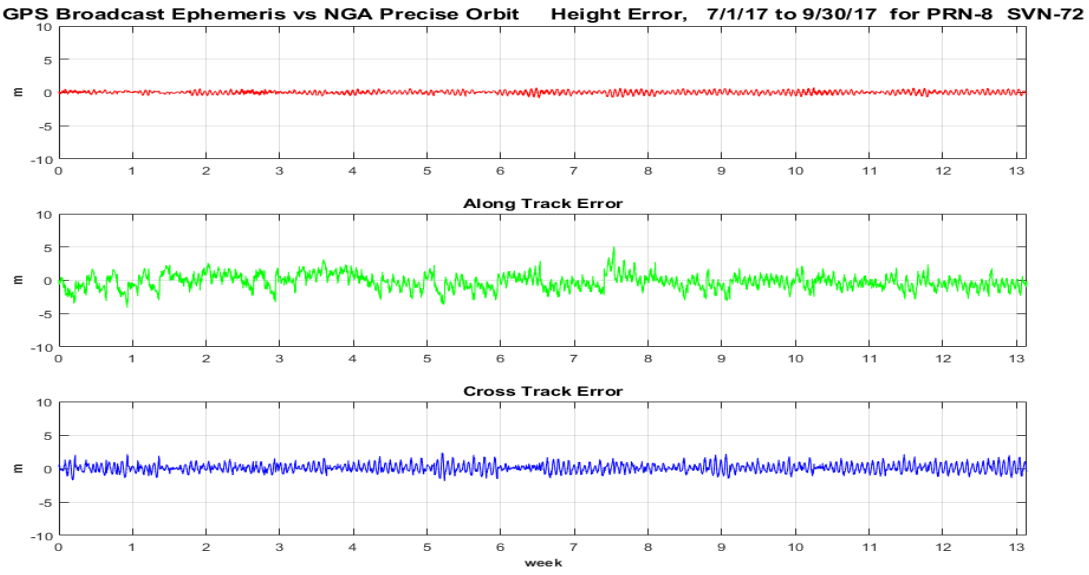


Figure 11-22 Orbit Error PRN-8 (SVN-72) Using L2C CNAV Data

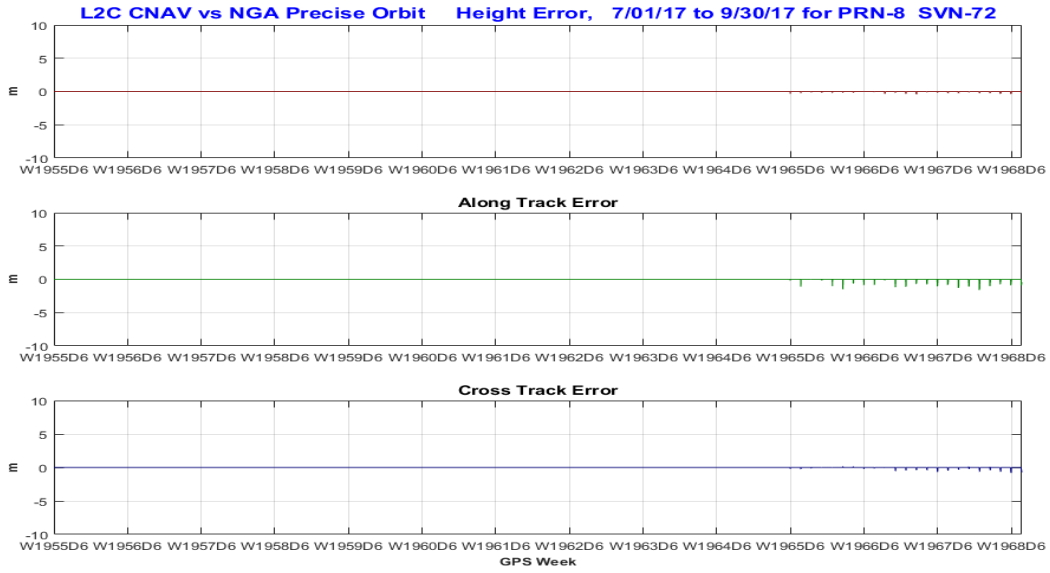


Figure 11-23 Orbit Error PRN-9 (SVN-68) Using C/A Nav Data

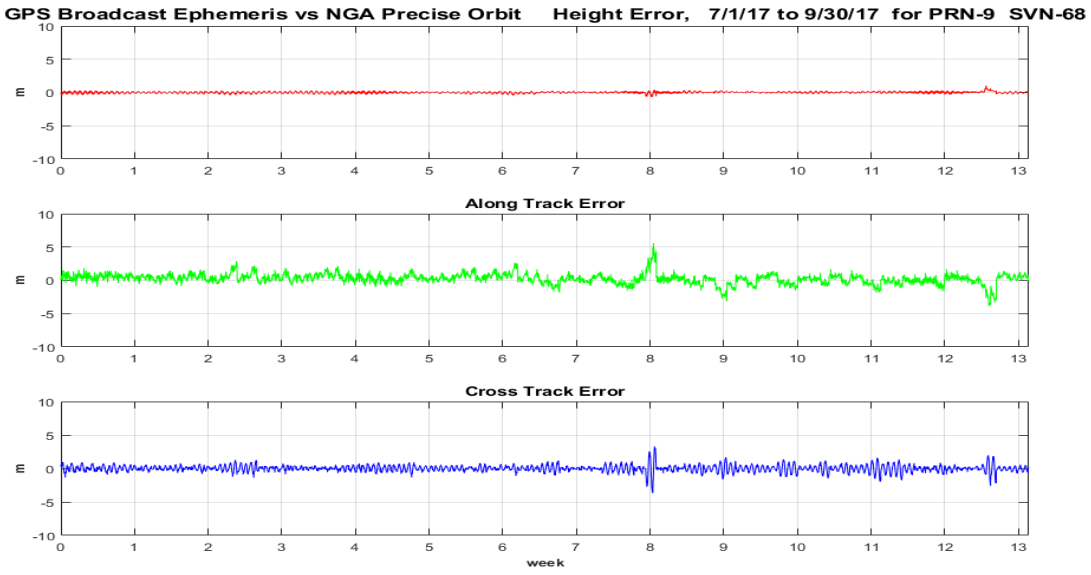


Figure 11-24 Orbit Error PRN-9 (SVN-68) Using L2C CNAV Data

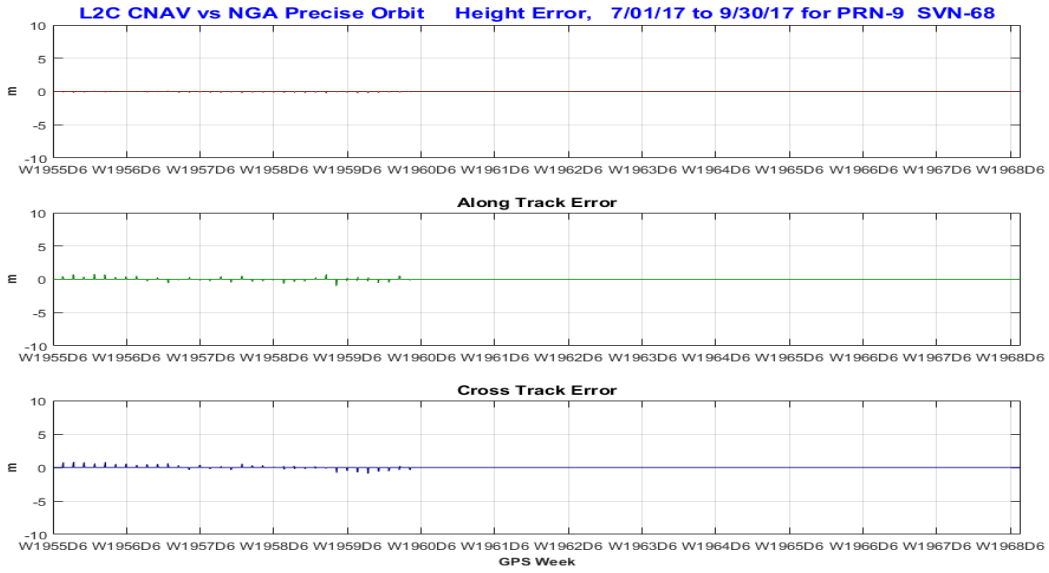


Figure 11-25 Orbit Error PRN-10 (SVN-73) Using C/A Nav Data

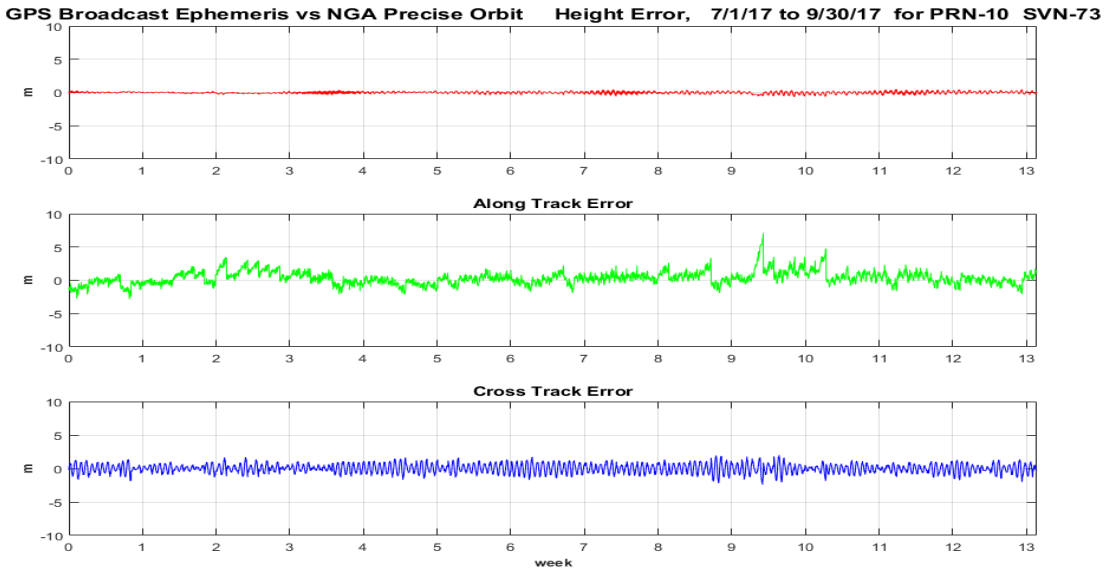


Figure 11-26 Orbit Error PRN-10 (SVN-73) Using L2C CNAV Data

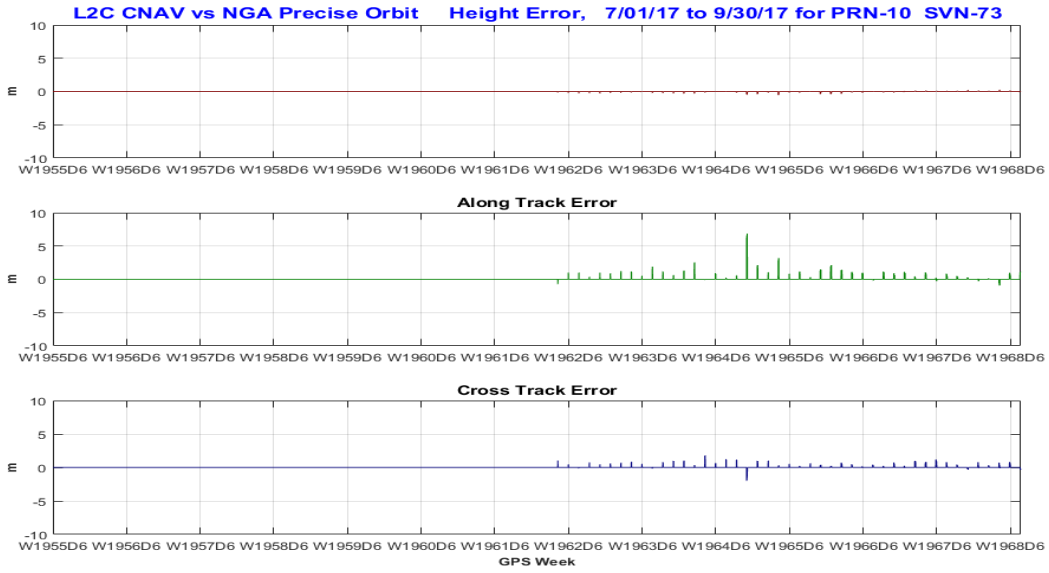


Figure 11-27 Orbit Error PRN-11 (SVN-46) Using C/A Nav Data

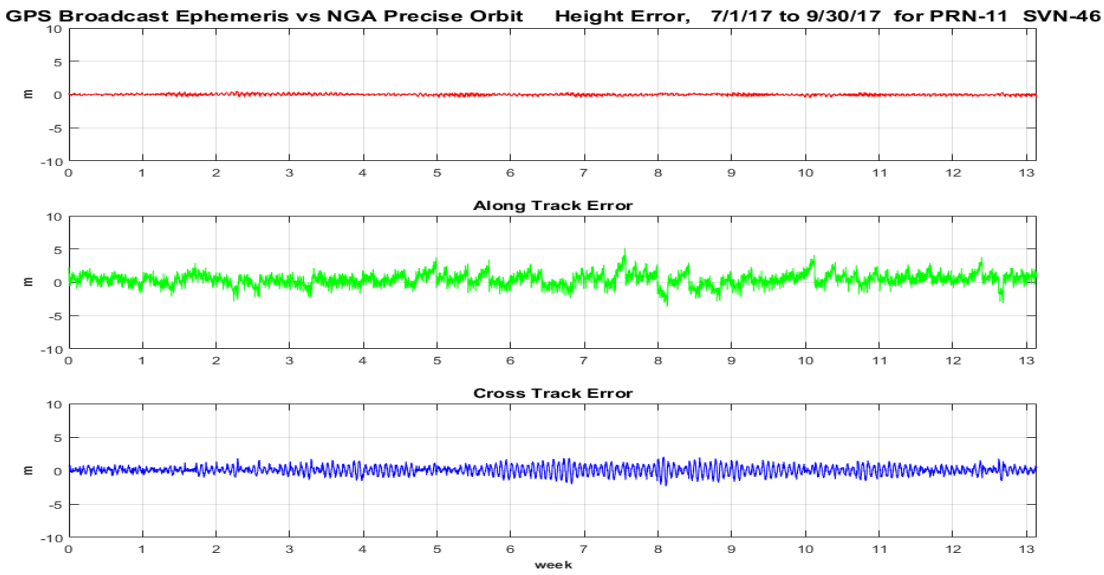


Figure 11-28 Orbit Error PRN-12 (SVN-58) Using C/A Nav Data

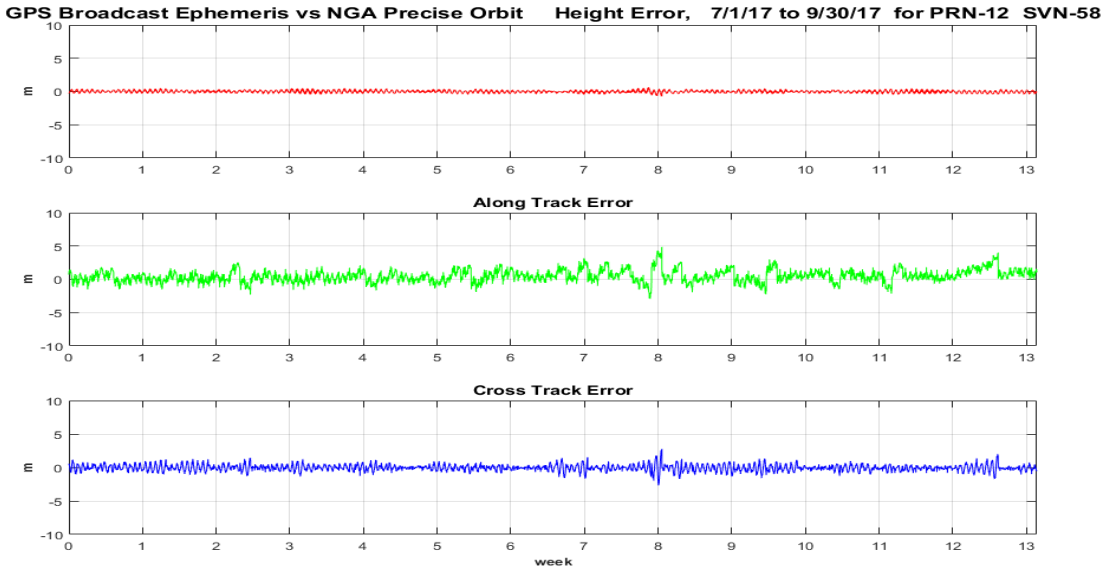


Figure 11-29 Orbit Error PRN-12 (SVN-58) Using L2C CNAV Data

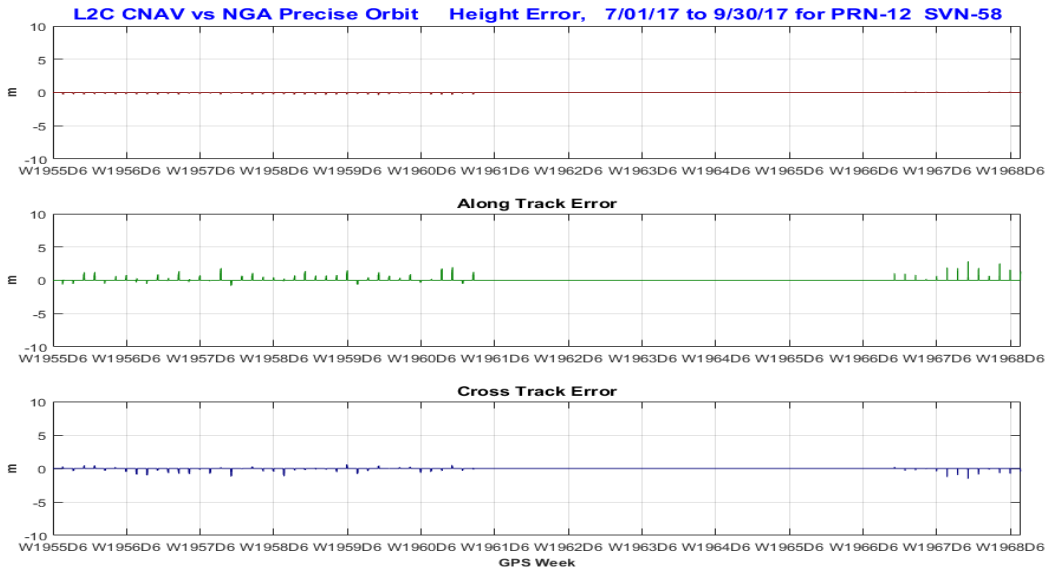


Figure 11-30 Orbit Error PRN-13 (SVN-43) Using C/A Nav Data

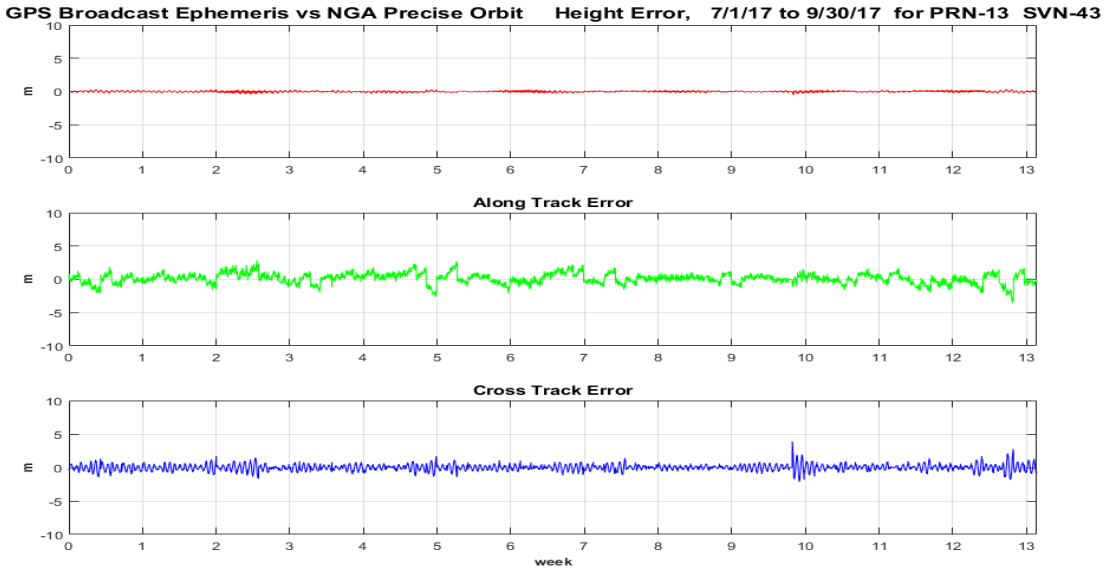


Figure 11-31 Orbit Error PRN-14 (SVN-41) Using C/A Nav Data

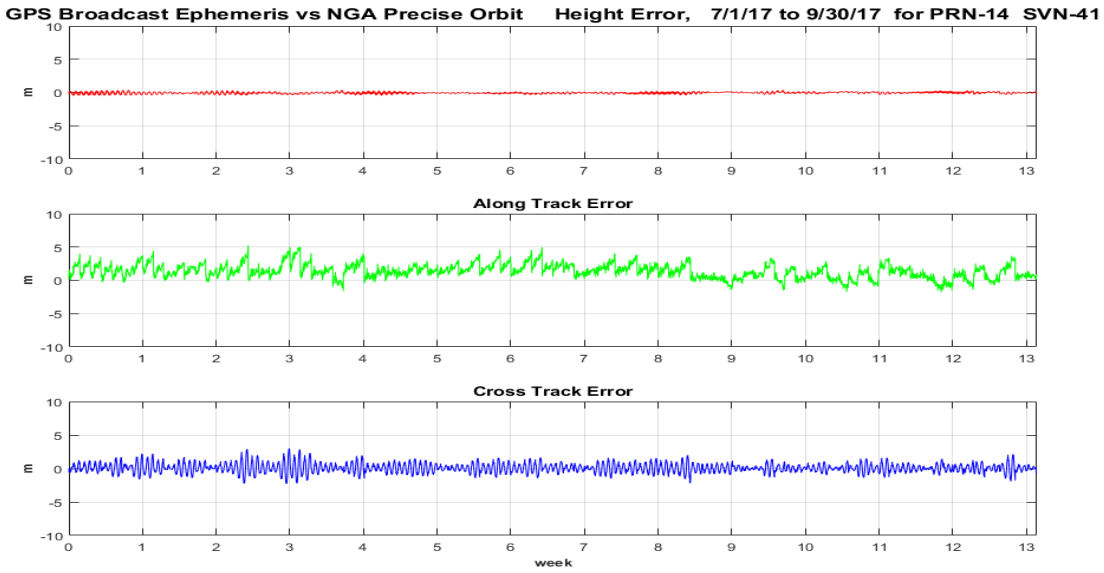


Figure 11-32 Orbit Error PRN-15 (SVN-55) Using C/A Nav Data

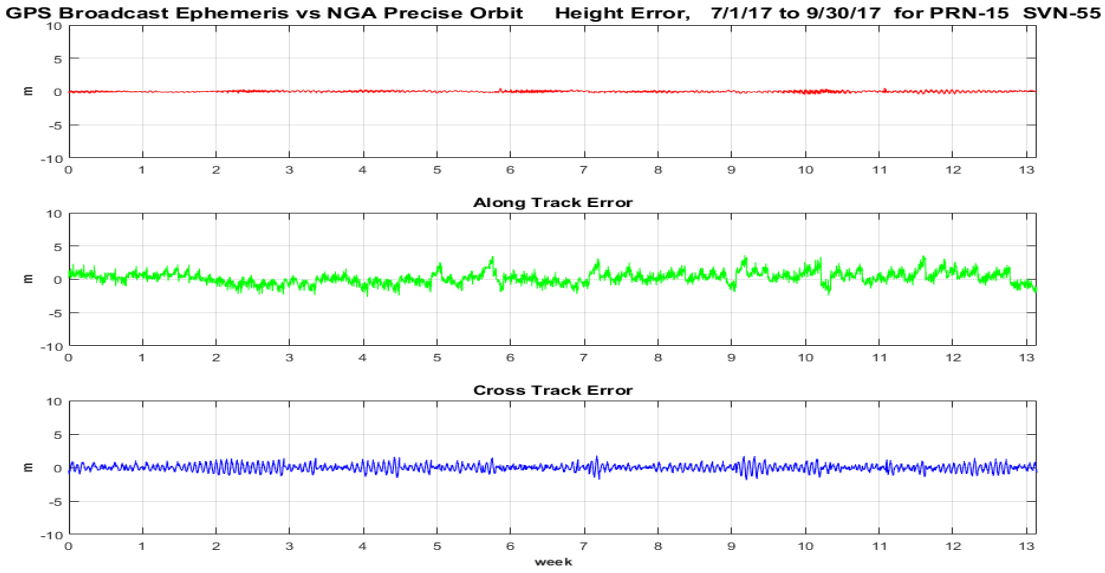


Figure 11-33 Orbit Error PRN-15 (SVN-55) Using L2C CNAV Data

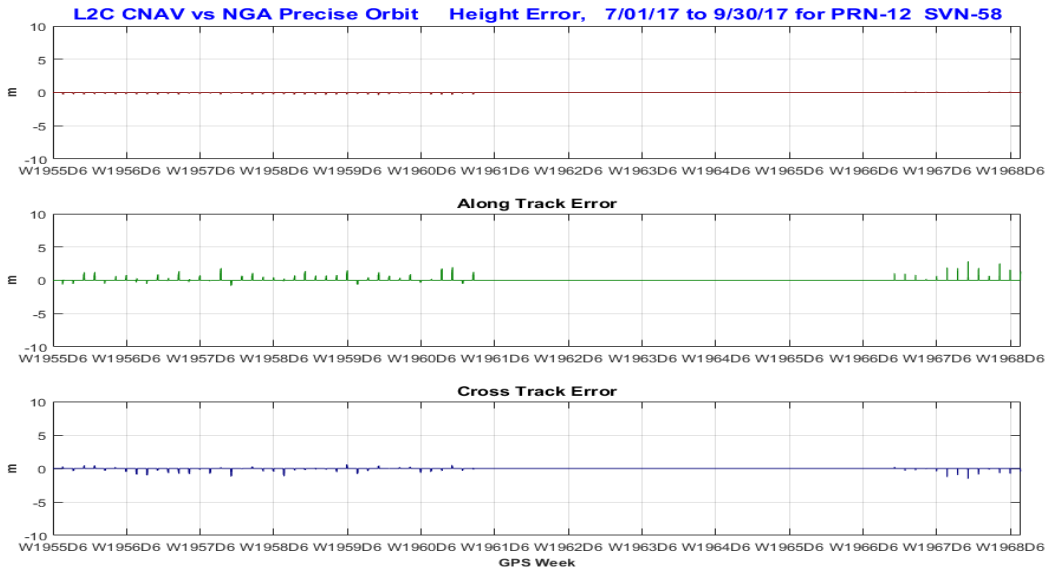


Figure 11-34 Orbit Error PRN-16 (SVN-56) Using C/A Nav Data

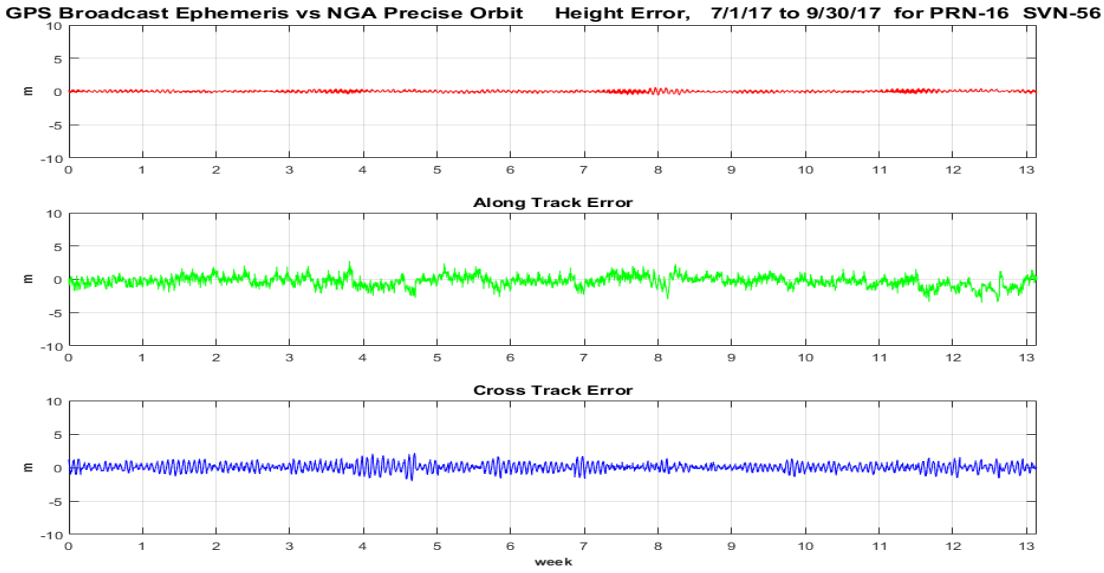


Figure 11-35 Orbit Error PRN-17 (SVN-53) Using C/A Nav Data

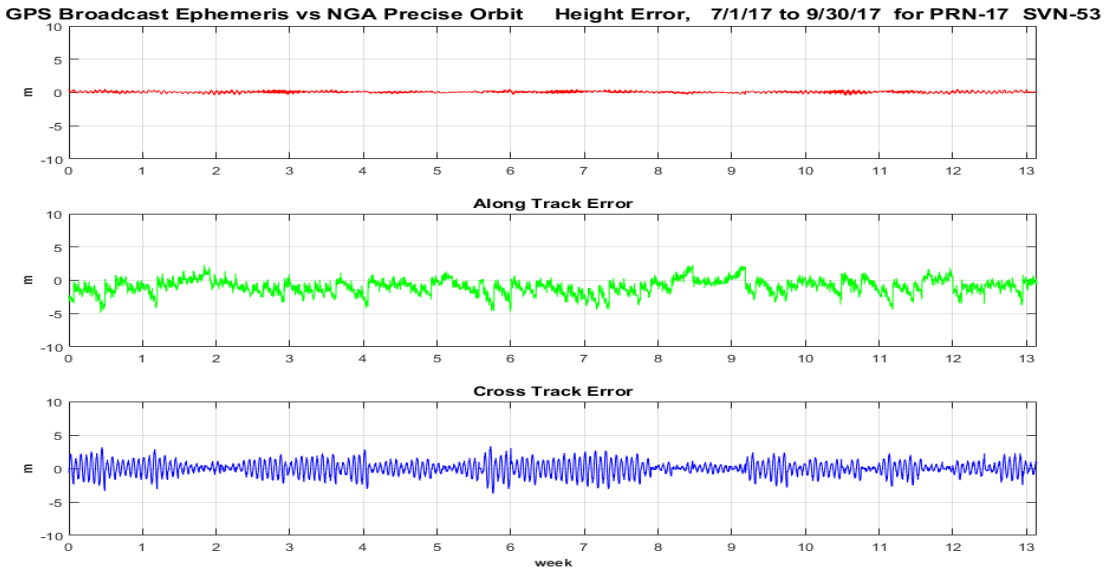


Figure 11-36 Orbit Error PRN-17 (SVN-53) Using L2C CNAV Data

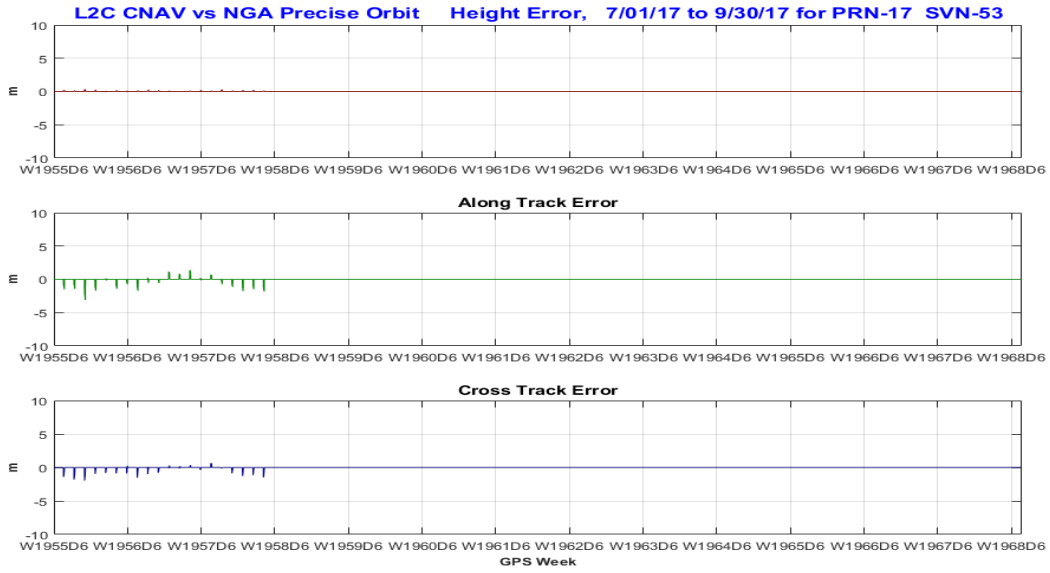


Figure 11-37 Orbit Error PRN-18 (SVN-54) Using C/A Nav Data

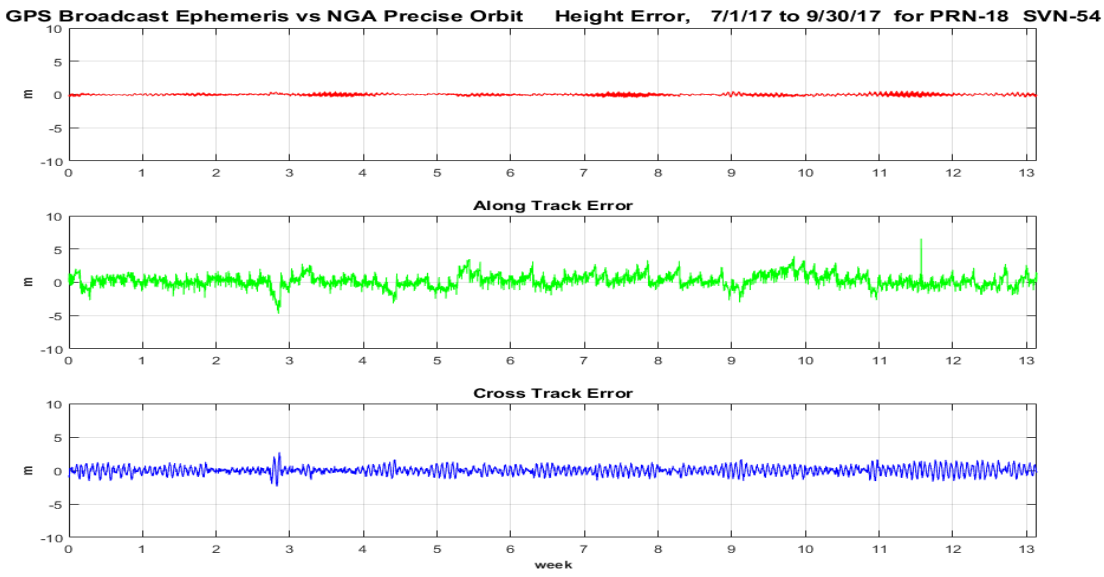


Figure 11-38 Orbit Error PRN-19 (SVN-59) Using C/A Nav Data

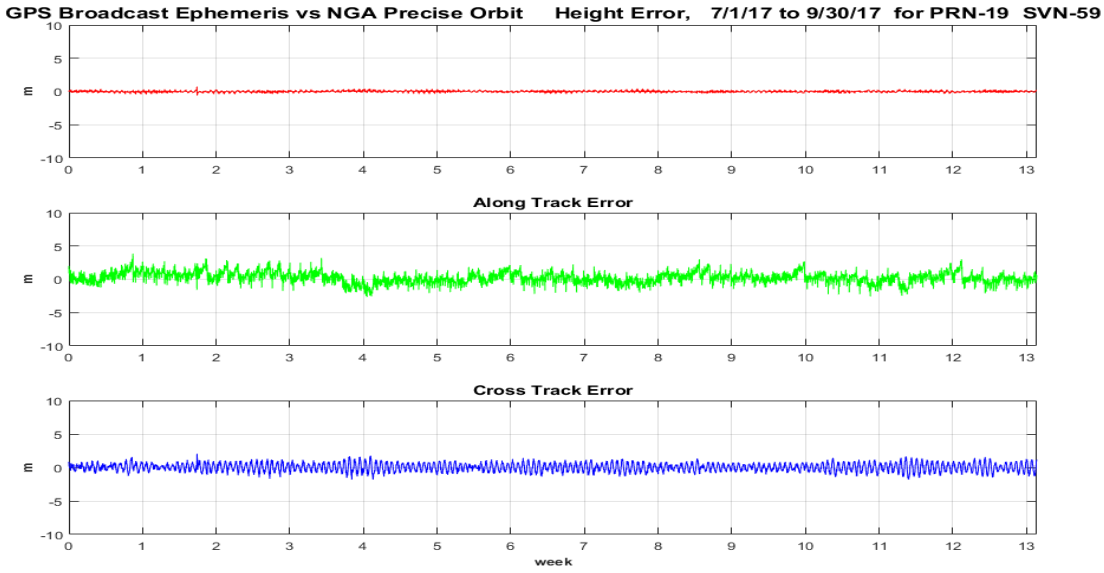


Figure 11-39 Orbit Error PRN-20 (SVN-51) Using C/A Nav Data

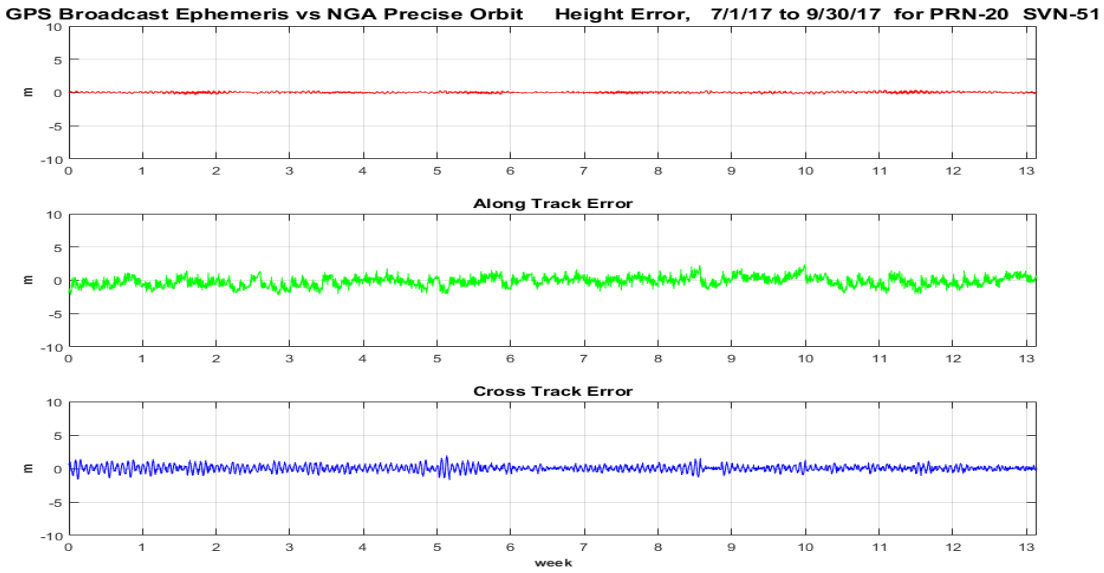


Figure 11-40 Orbit Error PRN-21 (SVN-45) Using C/A Nav Data

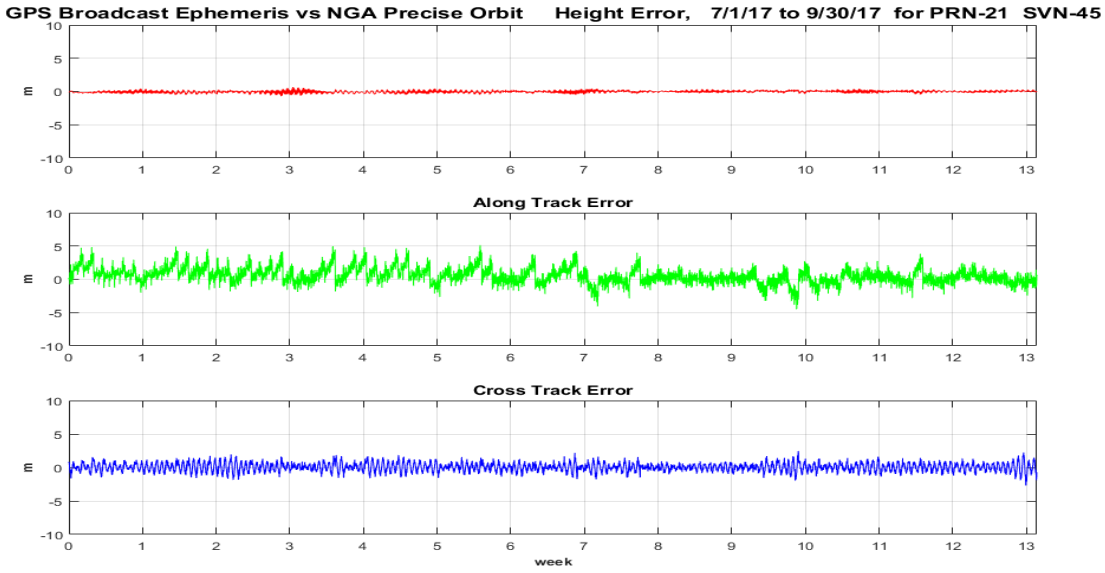


Figure 11-41 Orbit Error PRN-22 (SVN-47) Using C/A Nav Data

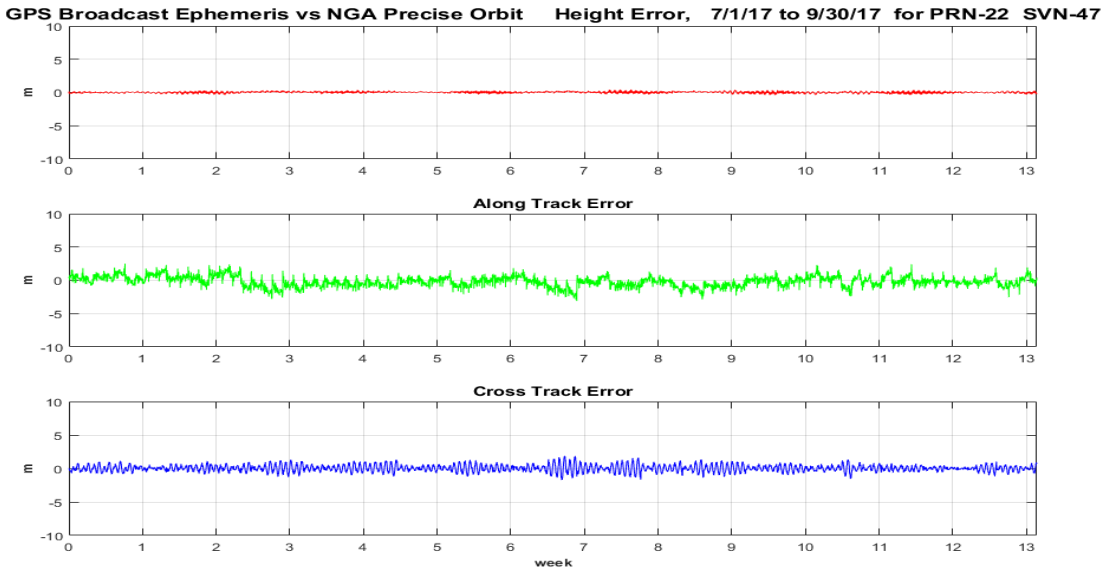


Figure 11-42 Orbit Error PRN-23 (SVN-60) Using C/A Nav Data

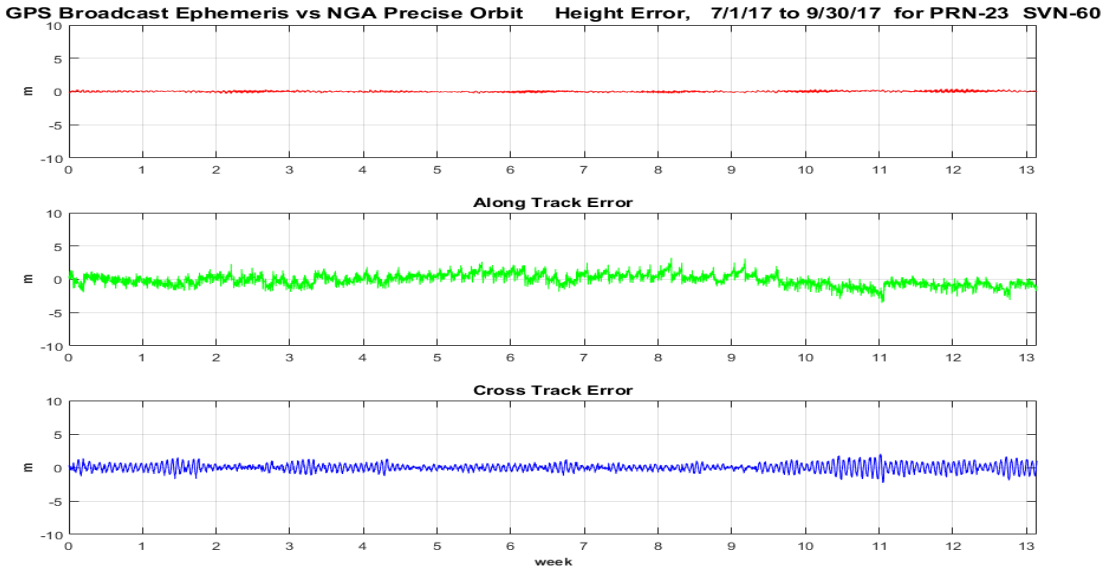


Figure 11-43 Orbit Error PRN-24 (SVN-65) Using C/A Nav Data

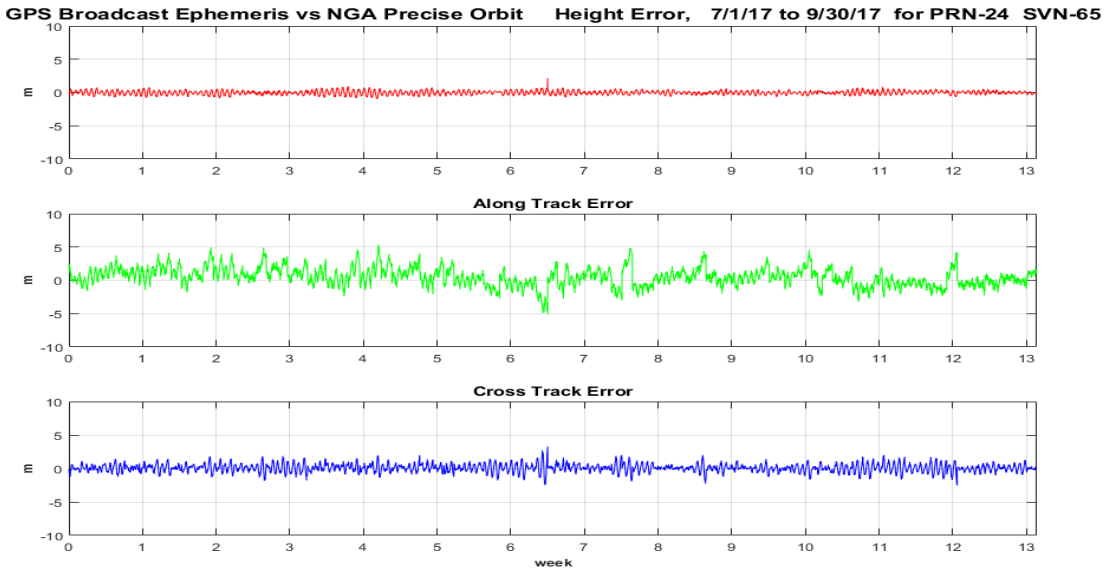


Figure 11-44 Orbit Error PRN-24 (SVN-65) Using L2C CNAV Data

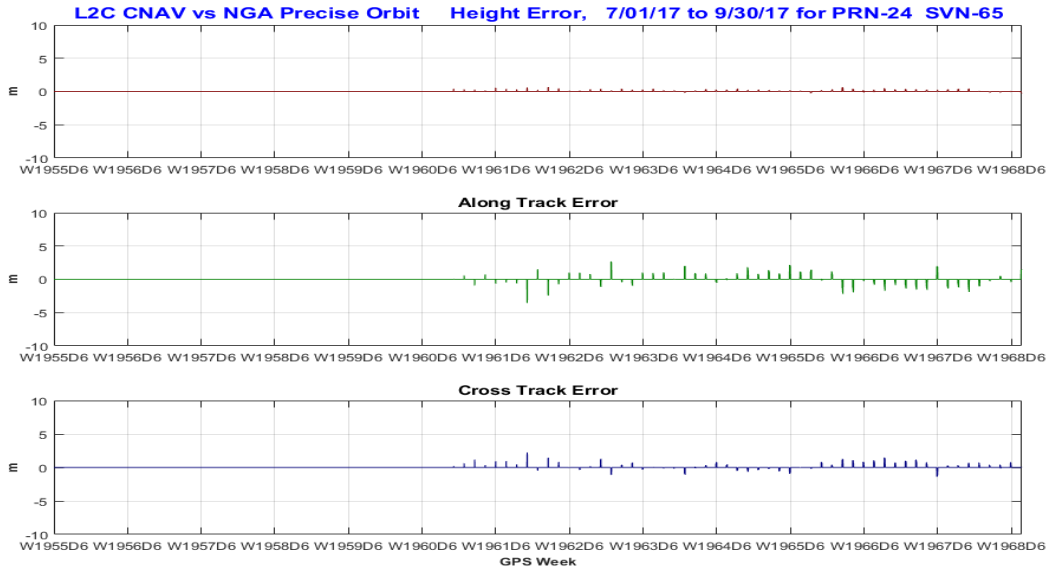


Figure 11-45 Orbit Error PRN-25 (SVN-62) Using C/A Nav Data

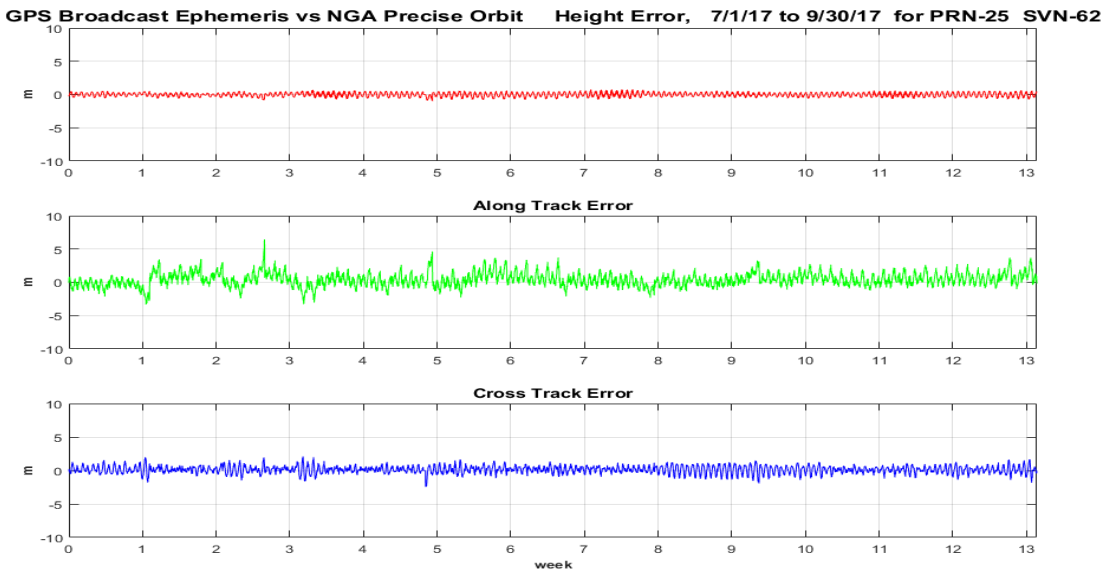


Figure 11-46 Orbit Error PRN-25 (SVN-62) Using L2C CNAV Data

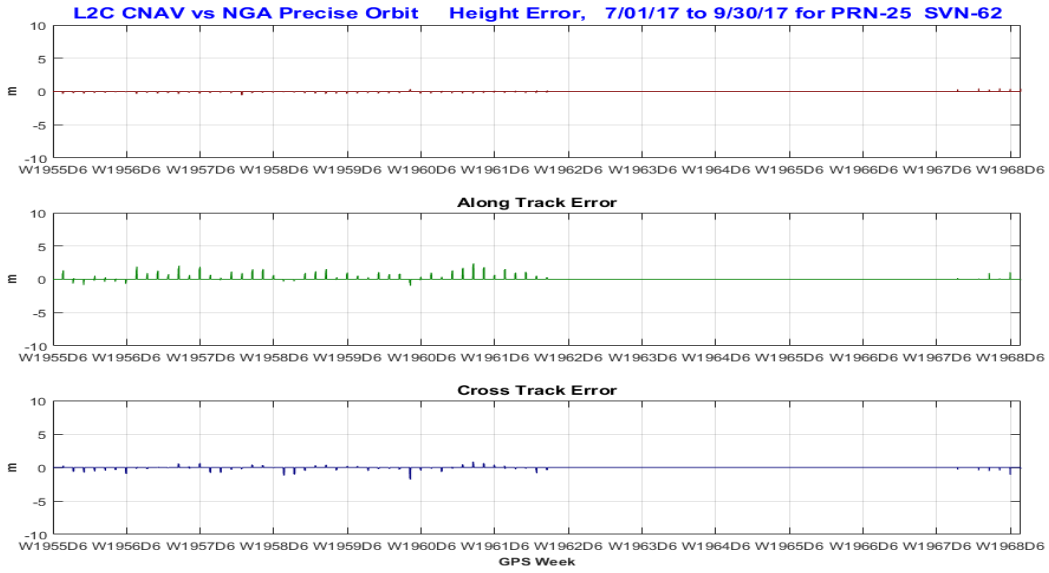


Figure 11-47 Orbit Error PRN-26 (SVN-71) Using C/A Nav Data

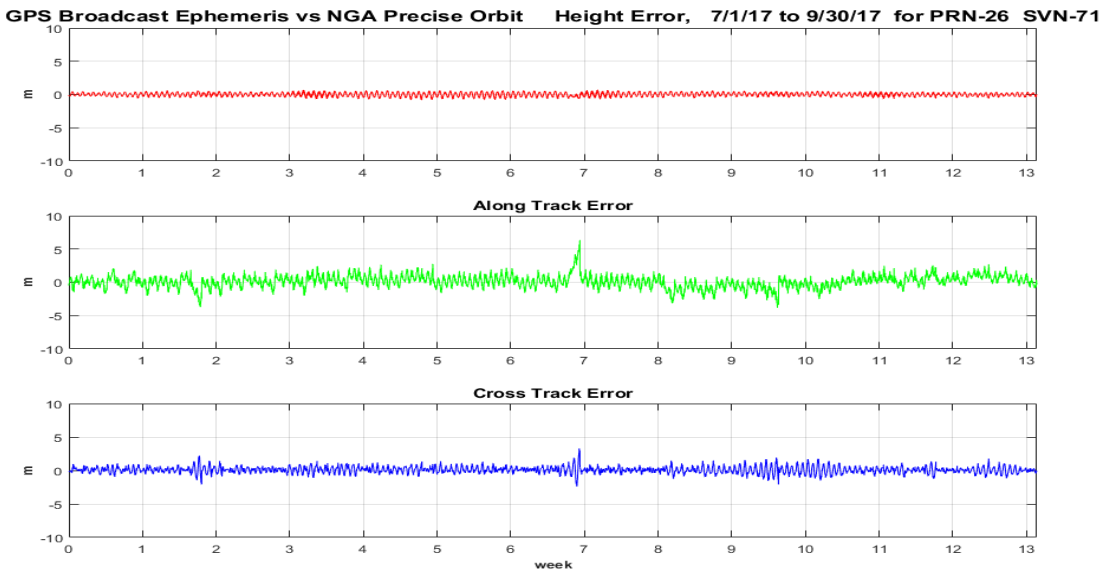


Figure 11-48 Orbit Error PRN-26 (SVN-71) Using L2C CNAV Data

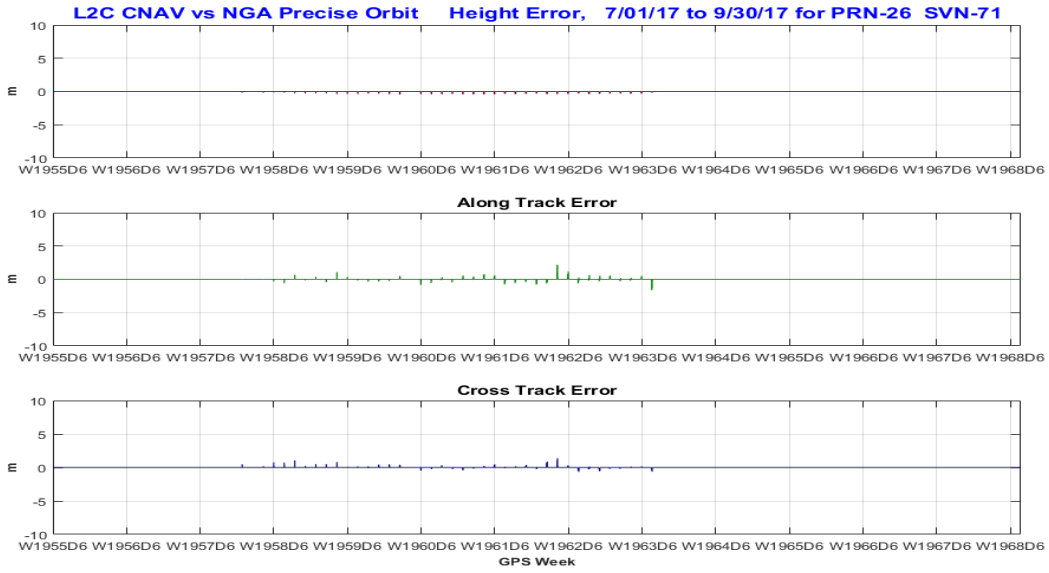


Figure 11-49 Orbit Error PRN-27 (SVN-66) Using C/A Nav Data

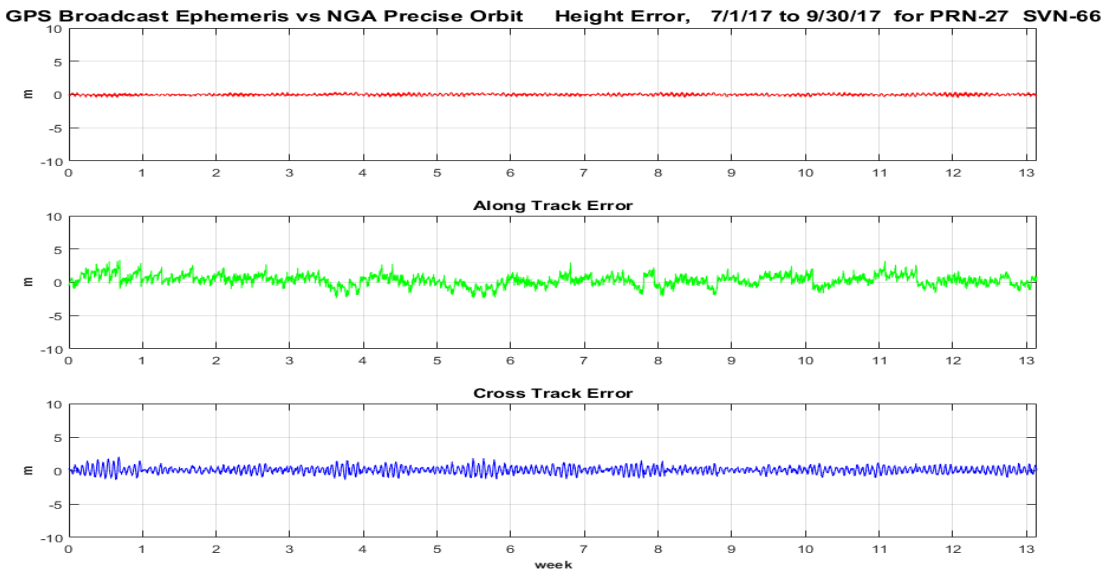


Figure 11-50 Orbit Error PRN-27 (SVN-66) Using L2C CNAV Data

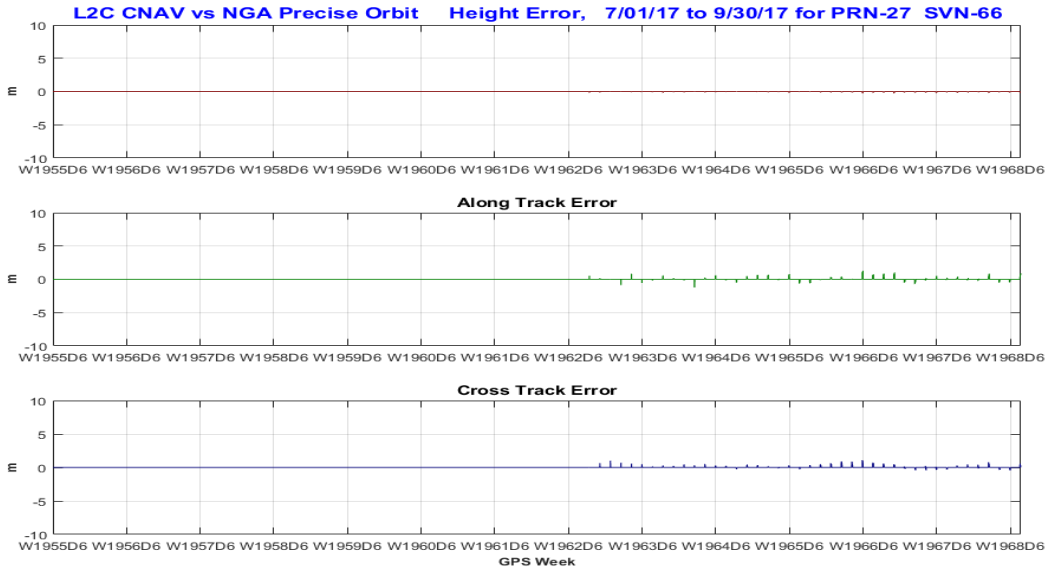


Figure 11-51 Orbit Error PRN-28 (SVN-44) Using C/A Nav Data

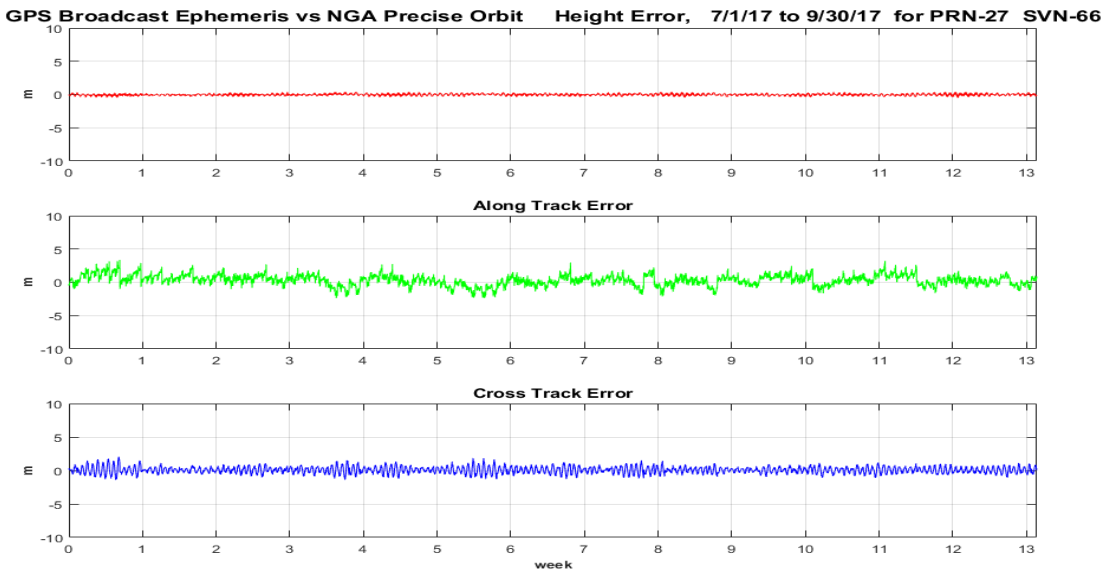


Figure 11-52 Orbit Error PRN-29 (SVN-57) Using C/A Nav Data

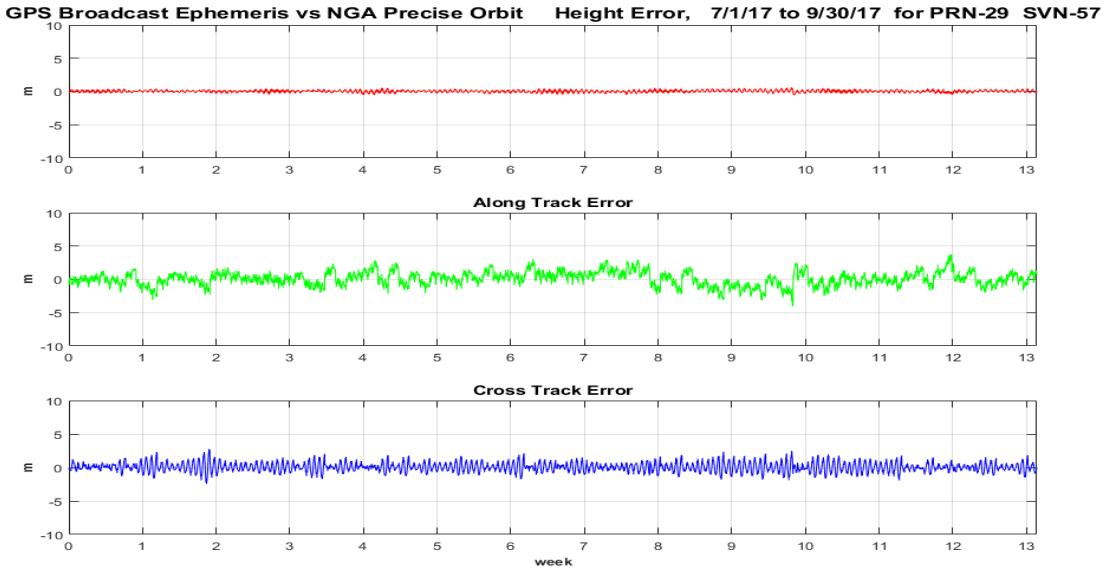


Figure 11-53 Orbit Error PRN-29 (SVN-57) Using L2C CNAV Data

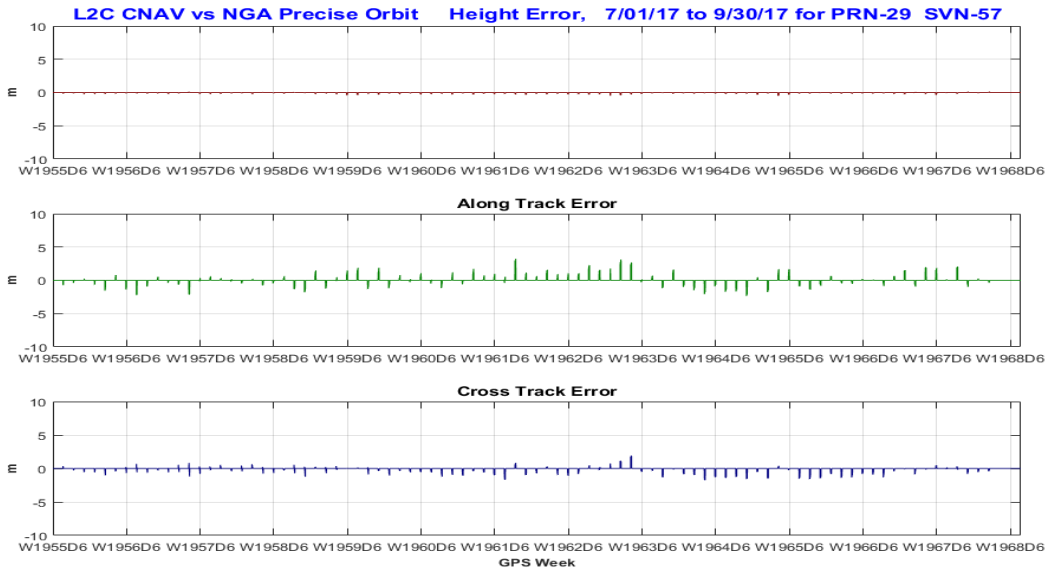


Figure 11-54 Orbit Error PRN-30 (SVN-64) Using C/A Nav Data

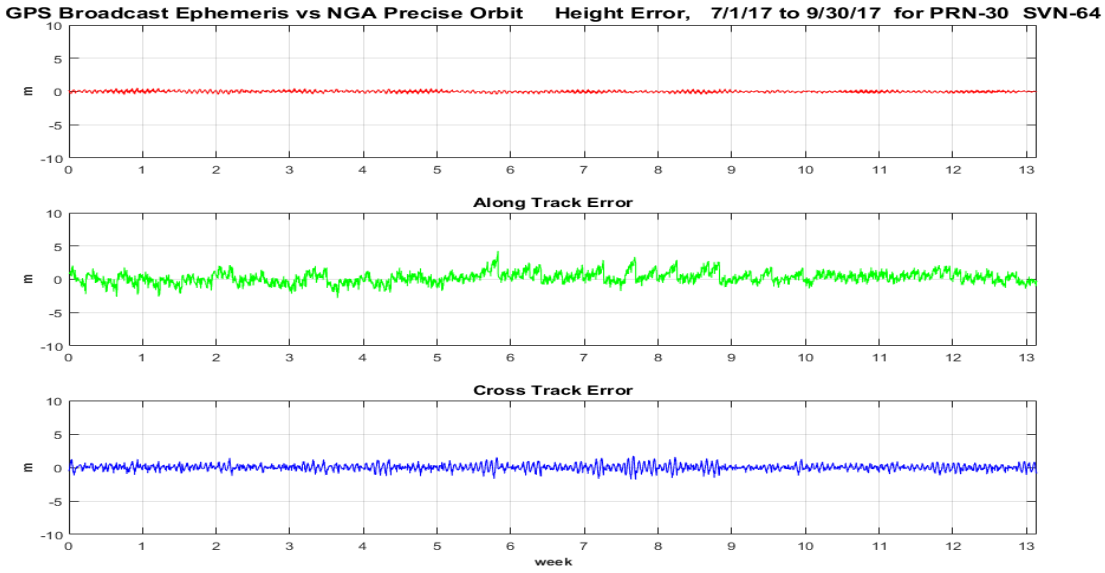


Figure 11-55 Orbit Error PRN-30 (SVN-64) Using L2C CNAV Data

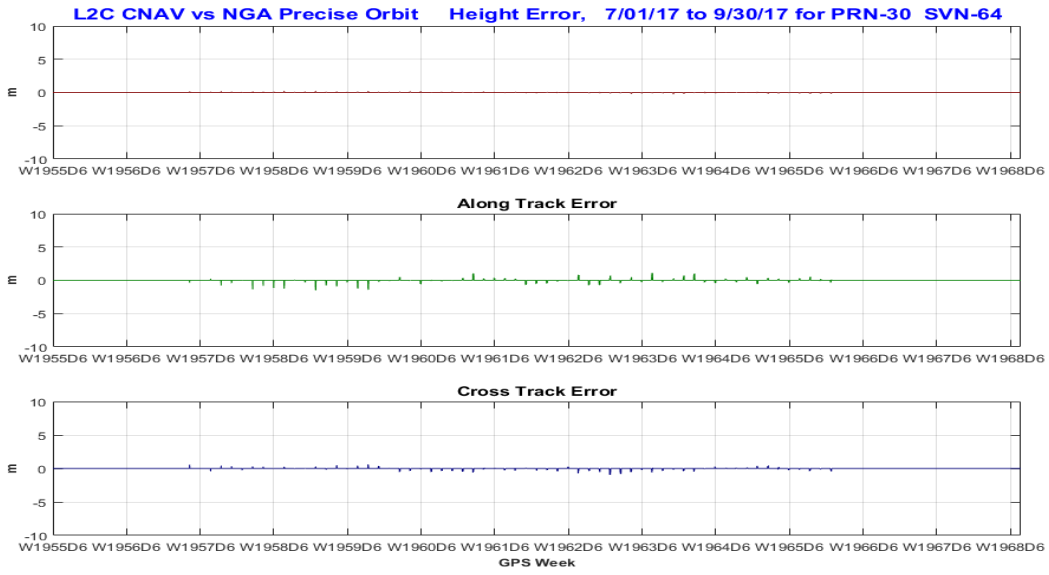


Figure 11-56 Orbit Error PRN-31 (SVN-52) Using C/A Nav Data

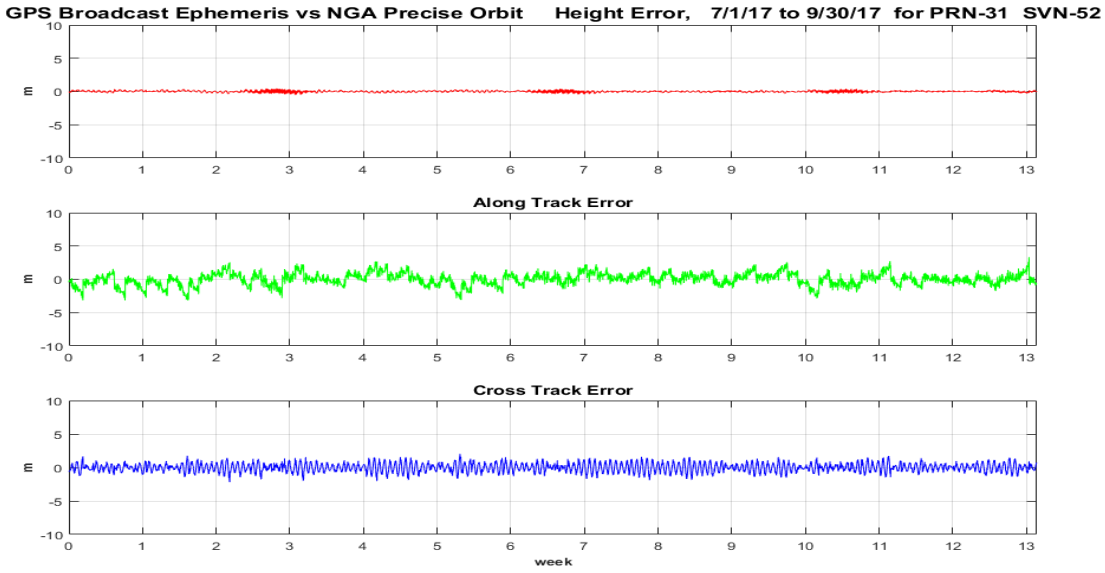


Figure 11-57 Orbit Error PRN-31 (SVN-52) Using L2C CNAV Data

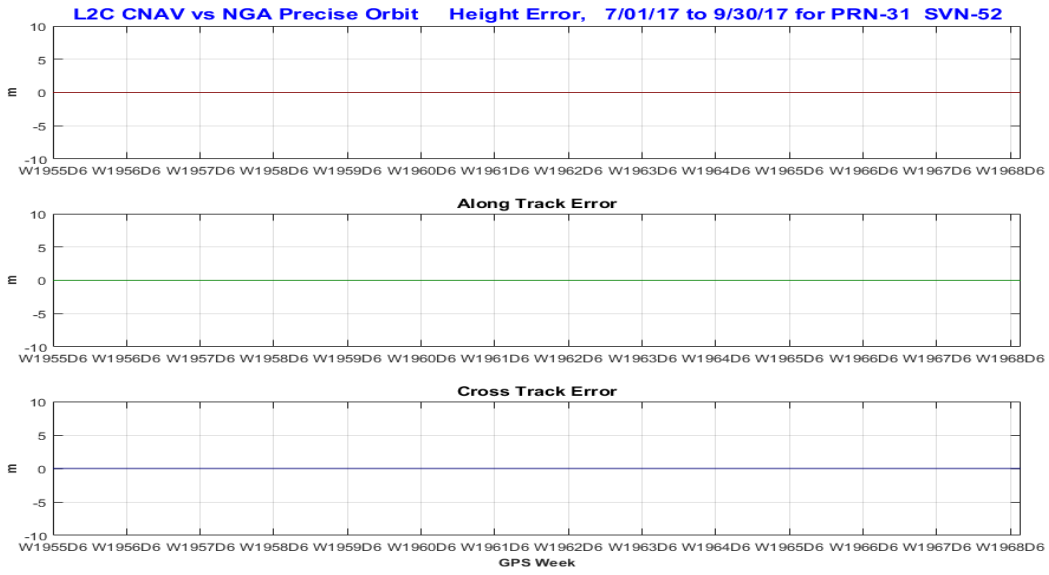


Figure 11-58 Orbit Error PRN-32 (SVN-70) Using C/A Nav Data

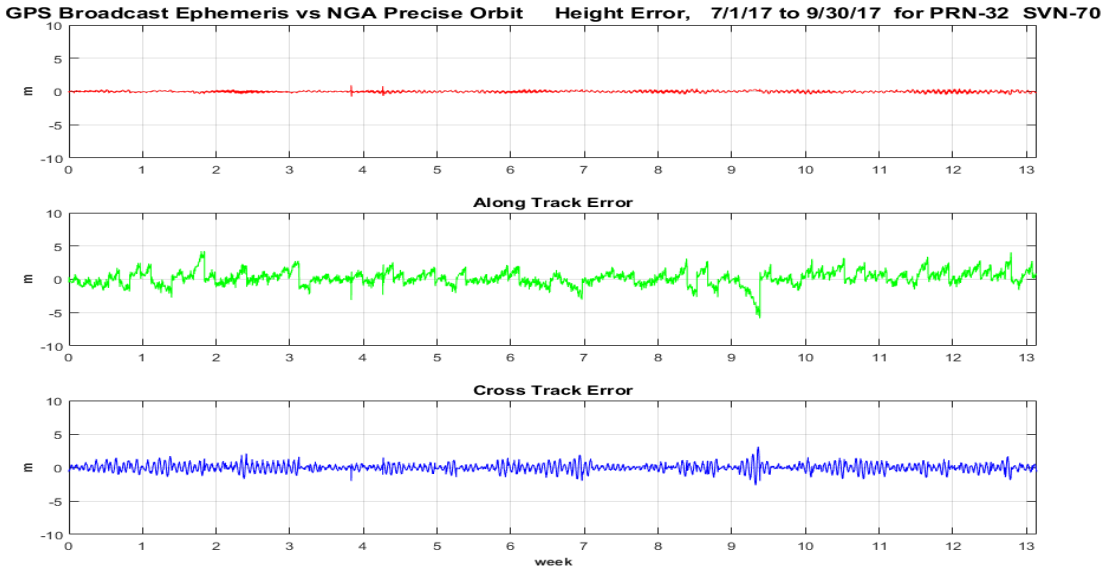
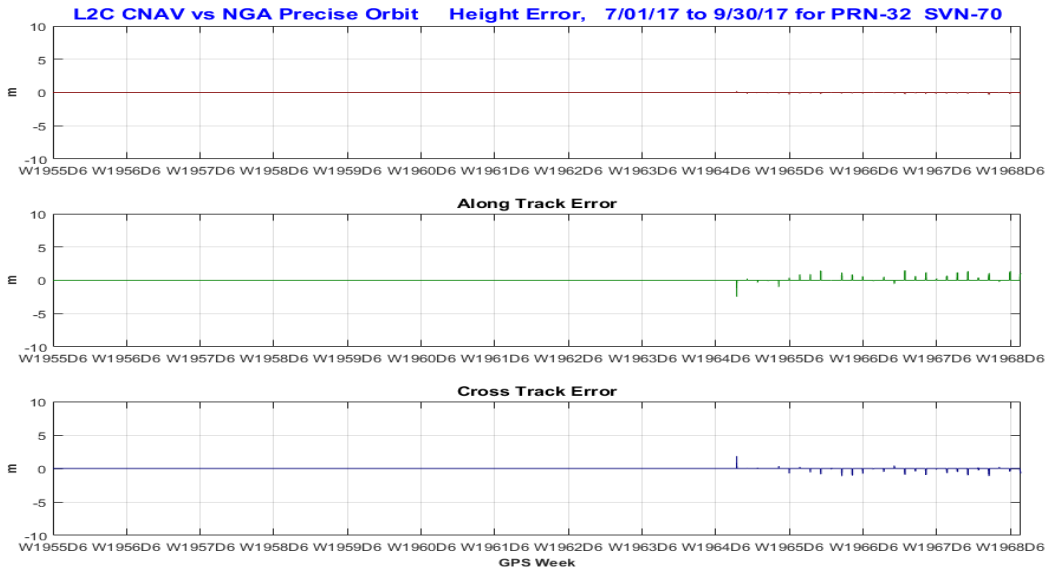


Figure 11-59 Orbit Error PRN-32 (SVN-70) Using L2C CNAV Data



QQ Plots of URA Normalized Error for All Satellites

Figure 11-60 QQ Plots of Range Error PRNs 1 to 5 Using C/A Nav Data

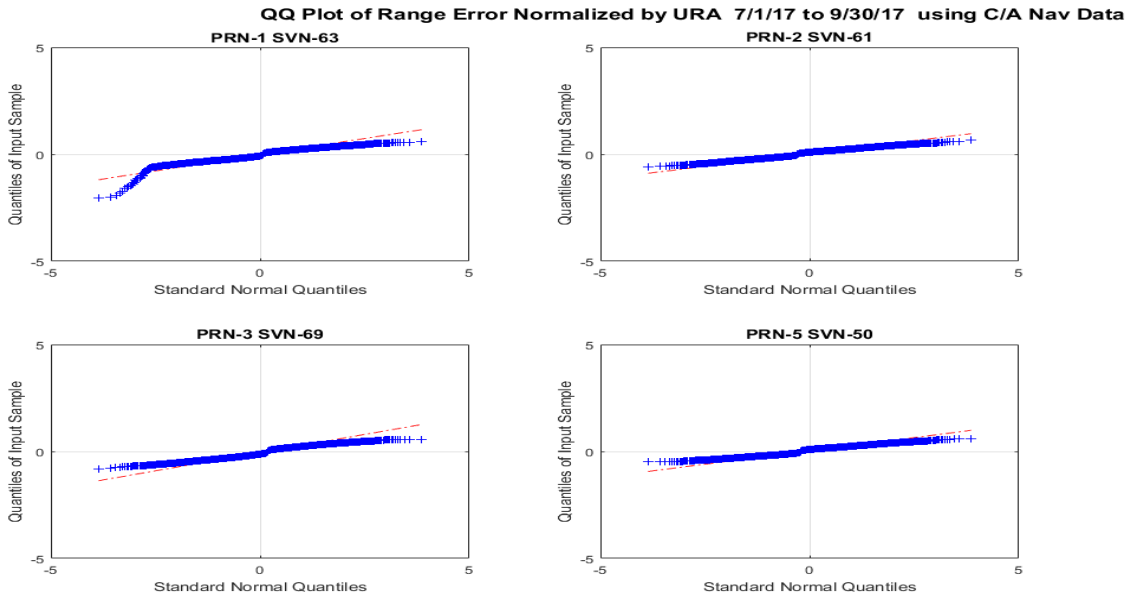


Figure 11-61 QQ Plots of Range Error PRNs 6 to 9 Using C/A Nav Data

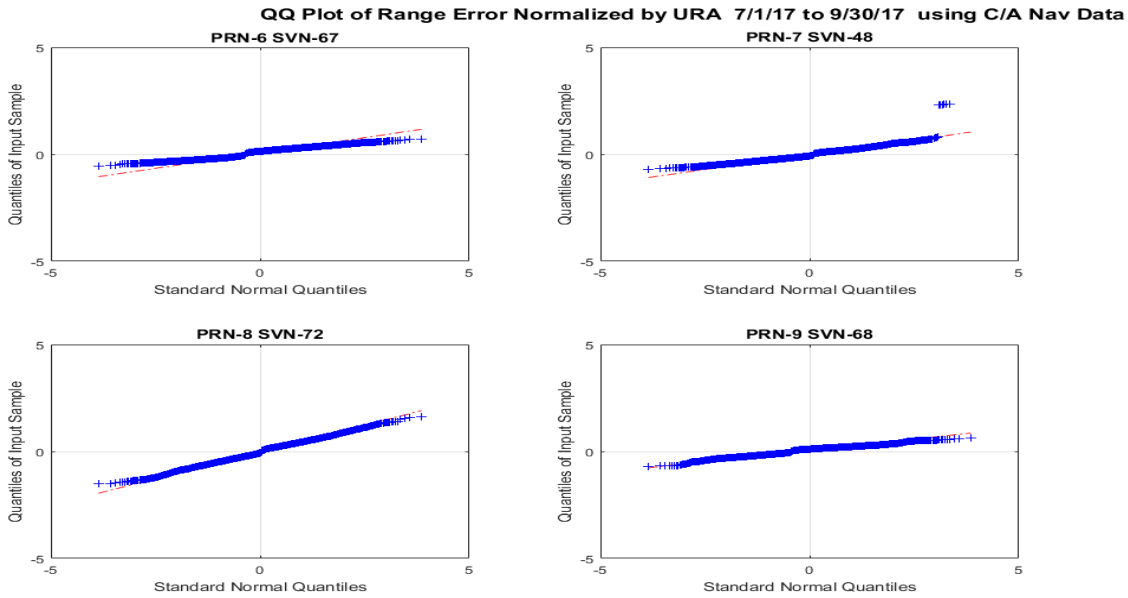


Figure 11-62 QQ Plots of Range Error PRNs 10 to 13 Using C/A Nav Data

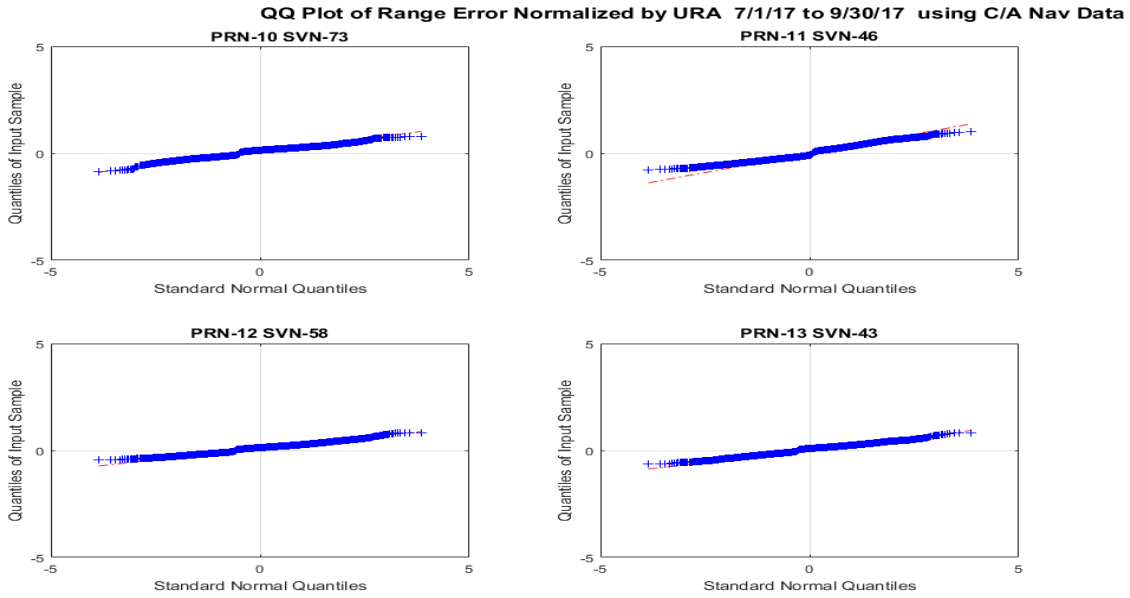


Figure 11-63 QQ Plots of Range Error PRNs 14 to 17 Using C/A Nav Data

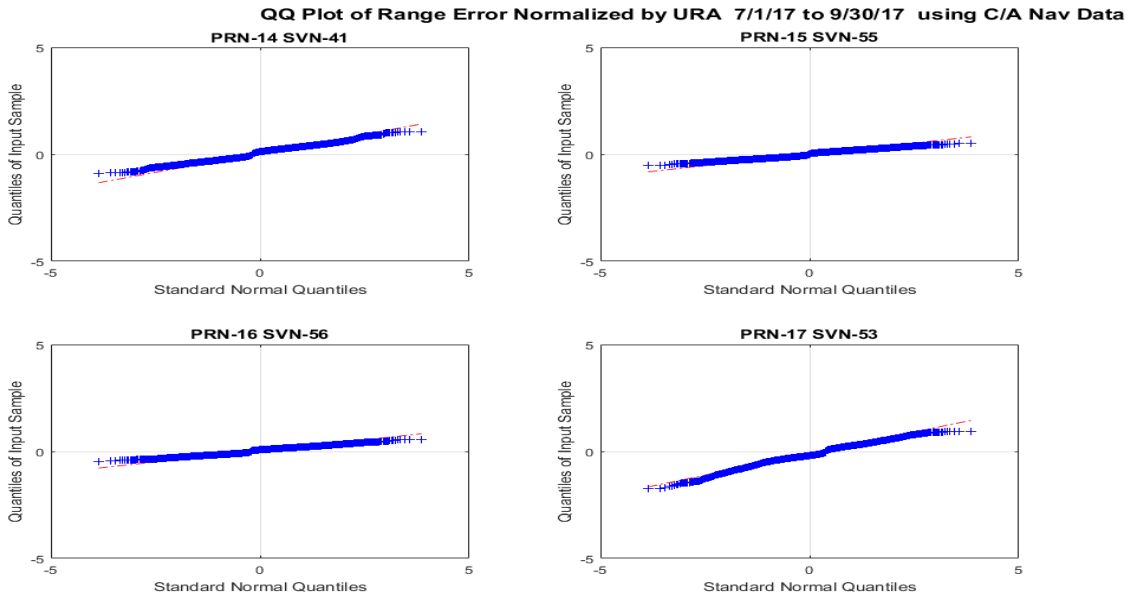


Figure 11-64 QQ Plots of Range Error PRNs 18 to 21 Using C/A Nav Data

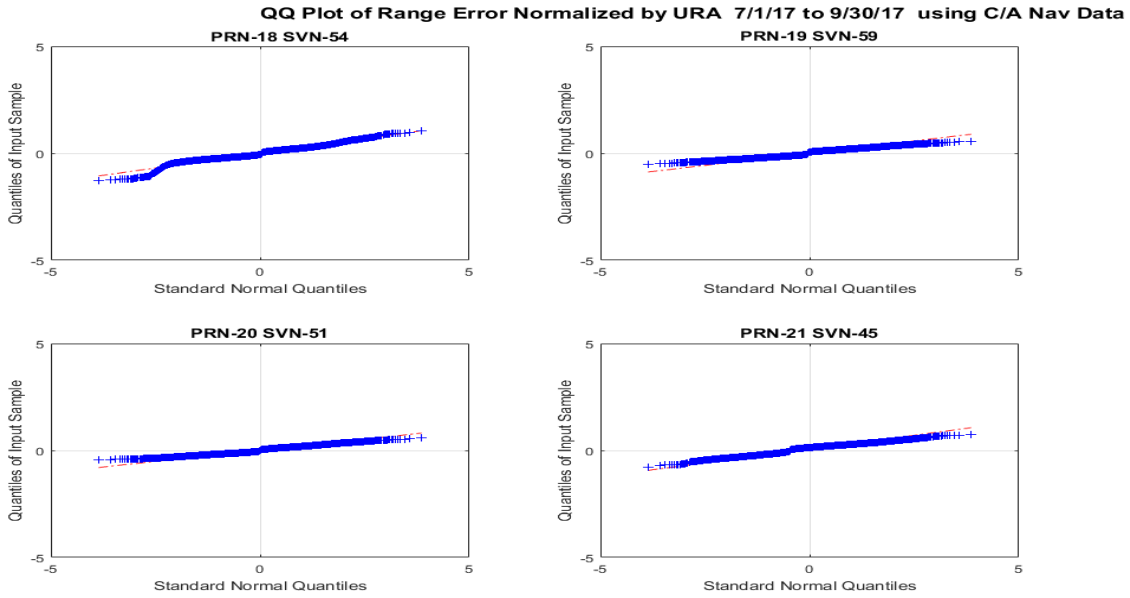


Figure 11-65 QQ Plots of Range Error PRNs 22 to 25 Using C/A Nav Data

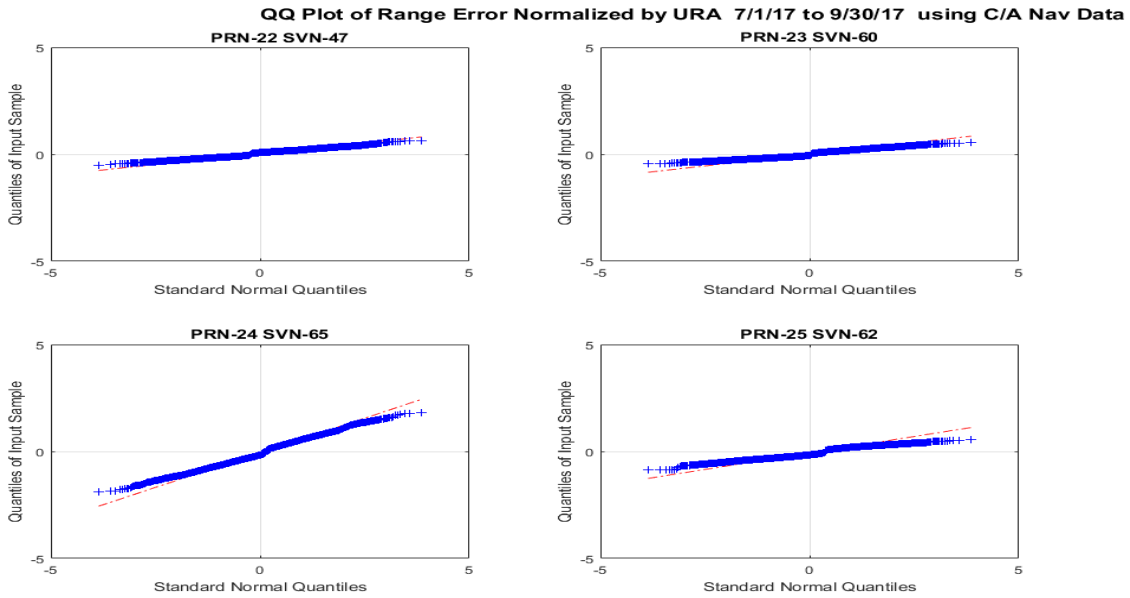


Figure 11-66 QQ Plots of Range Error PRNs 26 to 29 Using C/A Nav Data

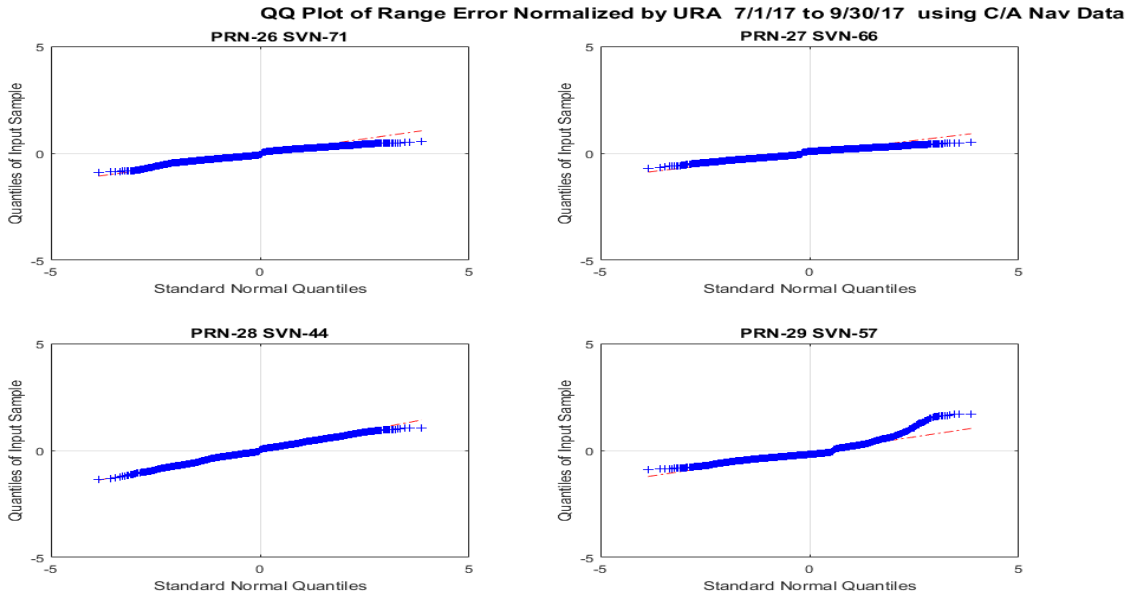


Figure 11-67 QQ Plots of Range Error PRNs 30 to 32 Using C/A Nav Data

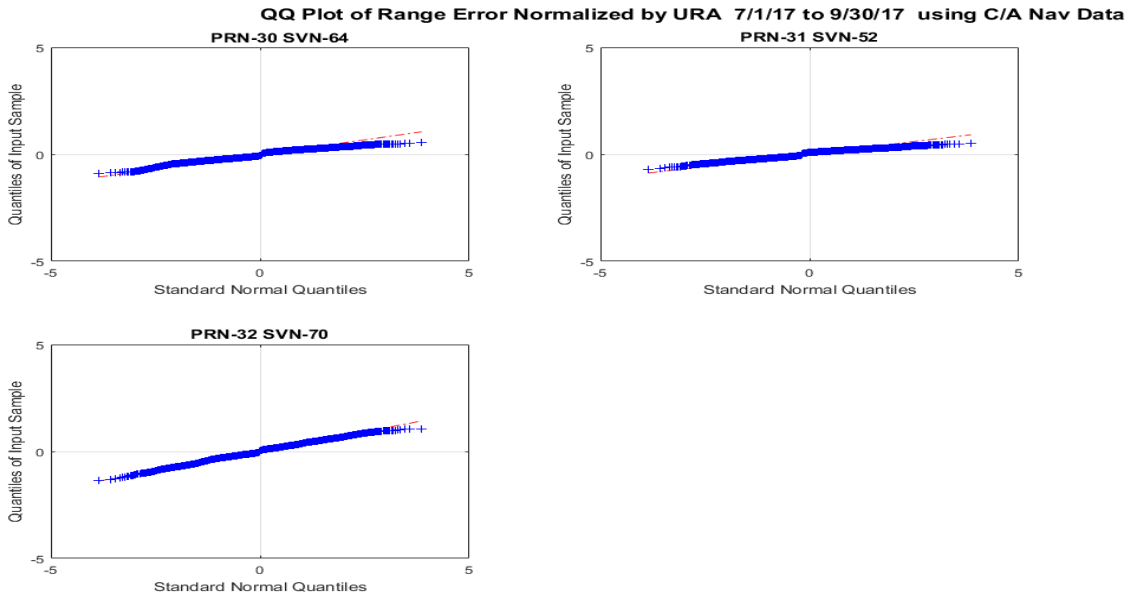


Figure 11-68 QQ Plots of Range Error PRNs 5, 6, 7, and 8 Using L2C CNAV Data

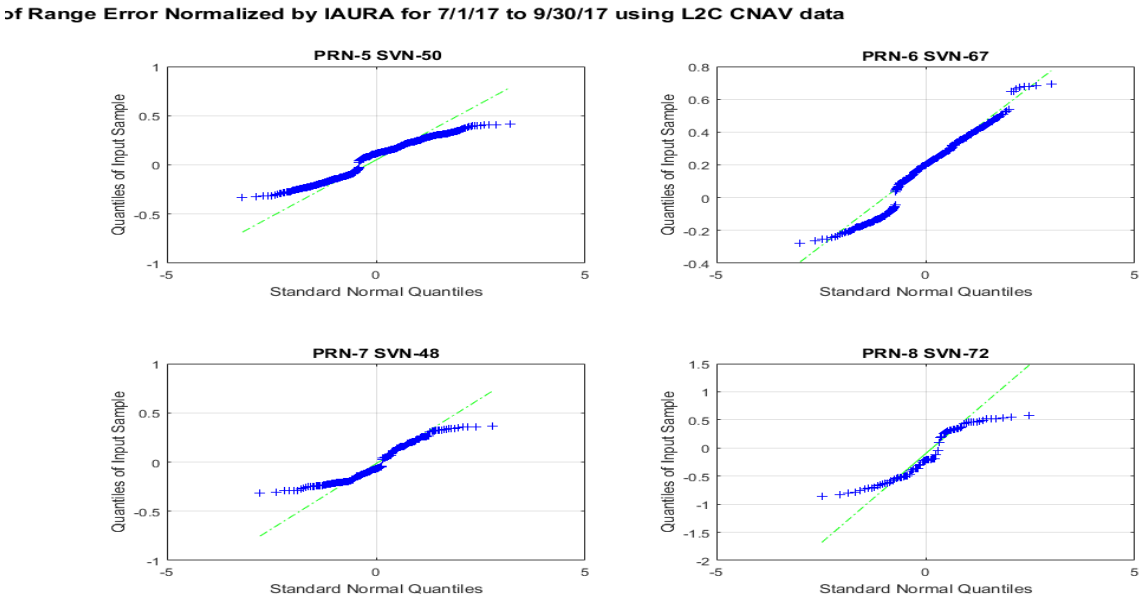


Figure 11-69 QQ Plots of Range Error PRNs 9, 10, 12, and 15 Using L2C CNAV Data

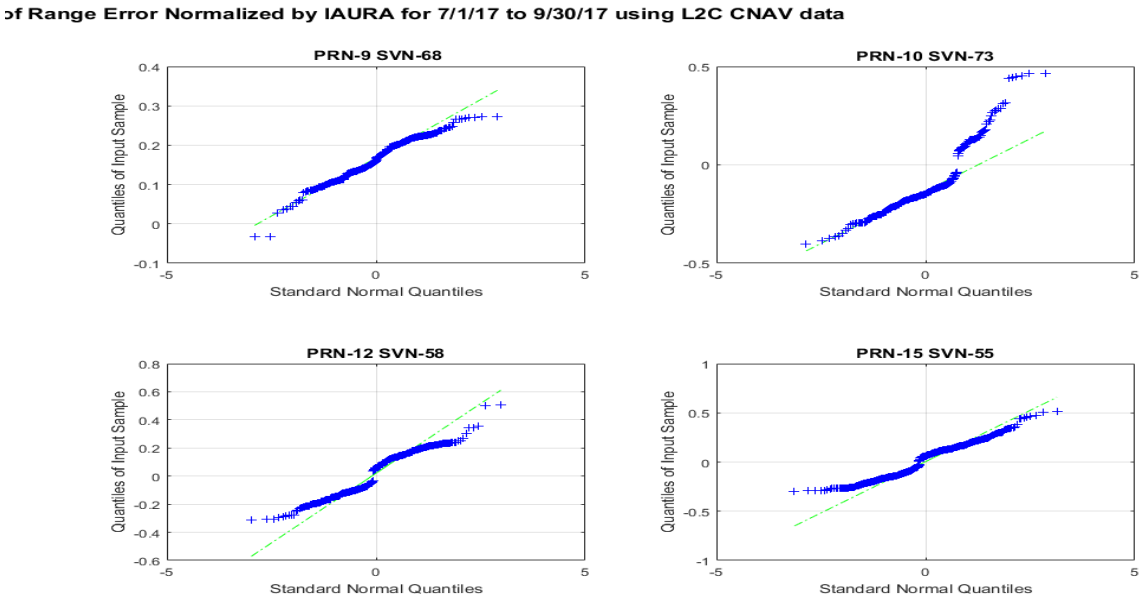


Figure 11-70 QQ Plots of Range Error PRNs 17, 24, 25, and 26 Using L2C CNAV Data

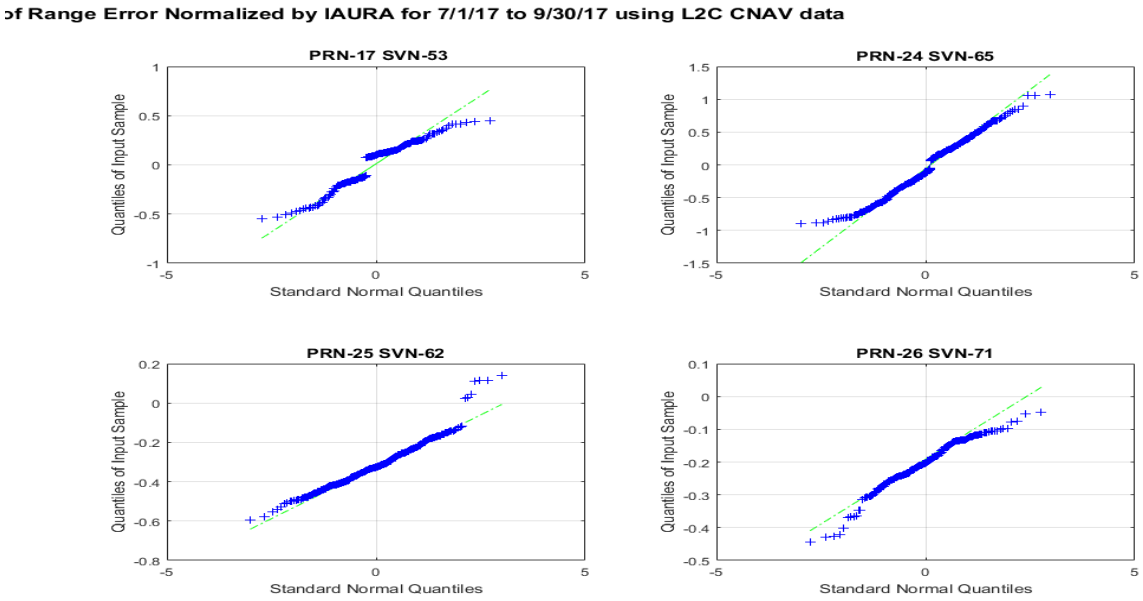
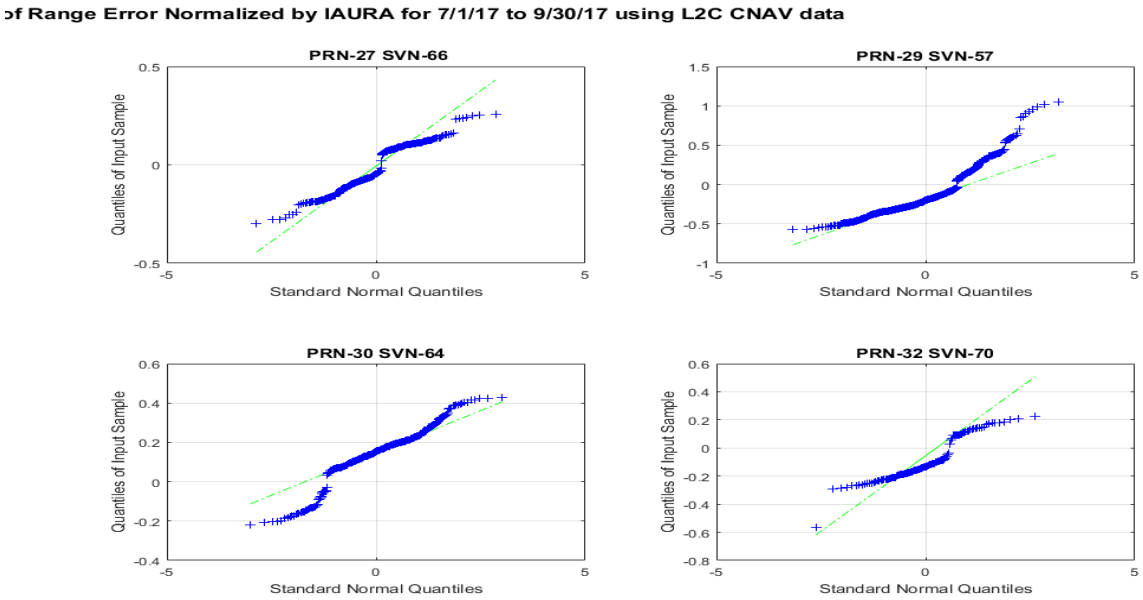


Figure 11-71 QQ Plots of Range Error PRNs 27, 29, 30, and 32 Using L2C CNAV Data



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

Figure 11-72 Histograms of H, A, C, and Range Error PRN-1 (SVN-63) Using C/A Nav Data

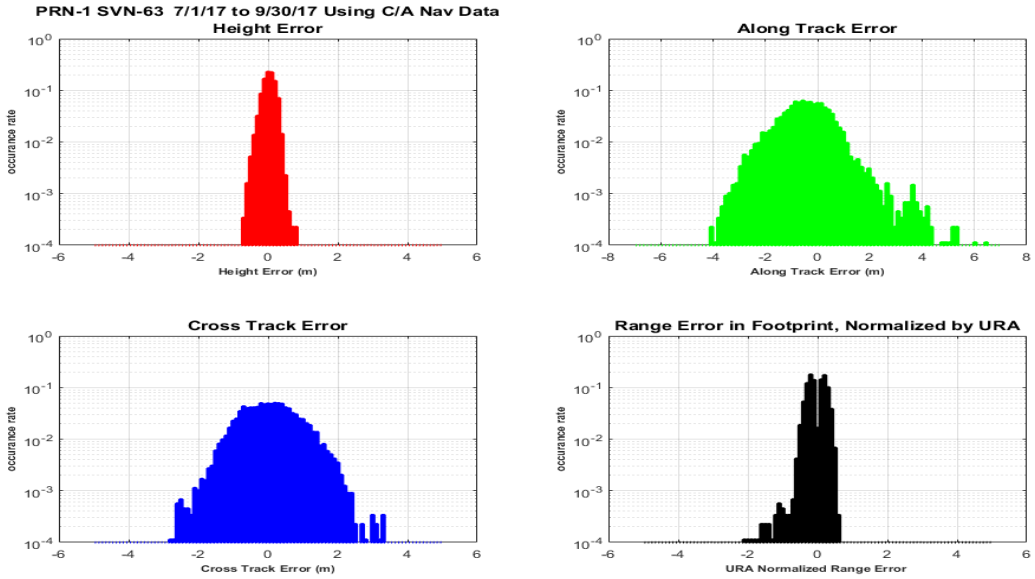


Figure 11-73 Histograms of H, A, C, and Range Error PRN-2 (SVN-61) Using C/A Nav Data

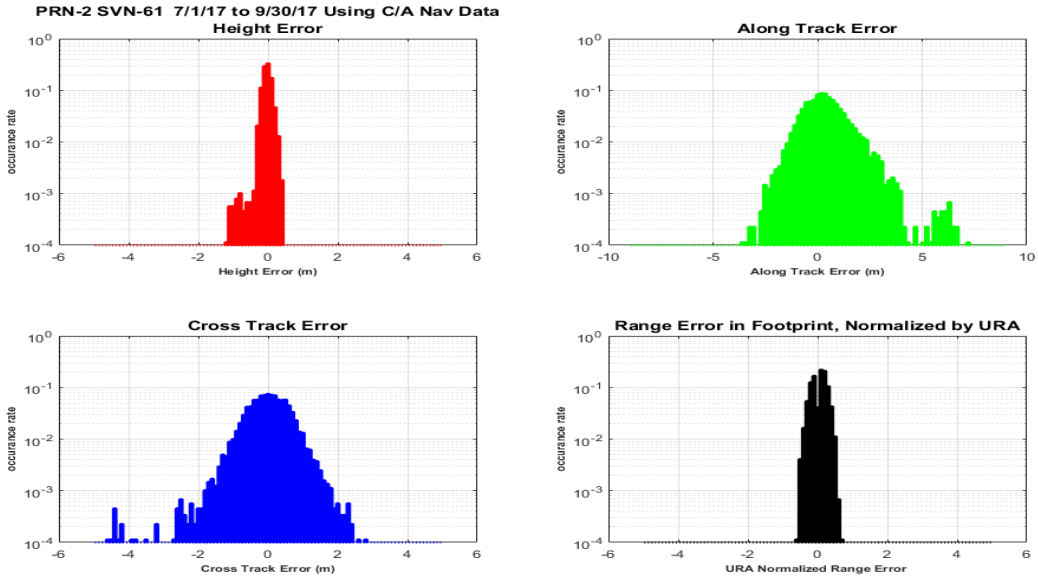


Figure 11-74 Histograms of H, A, C, and Range Error PRN-3 (SVN-69) Using C/A Nav Data

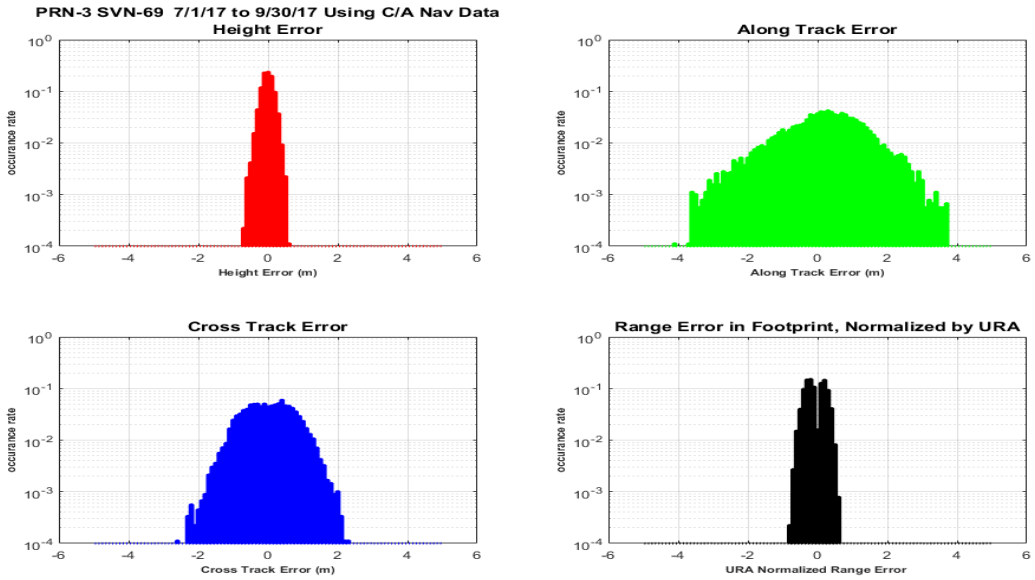


Figure 11-75 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using C/A Nav Data

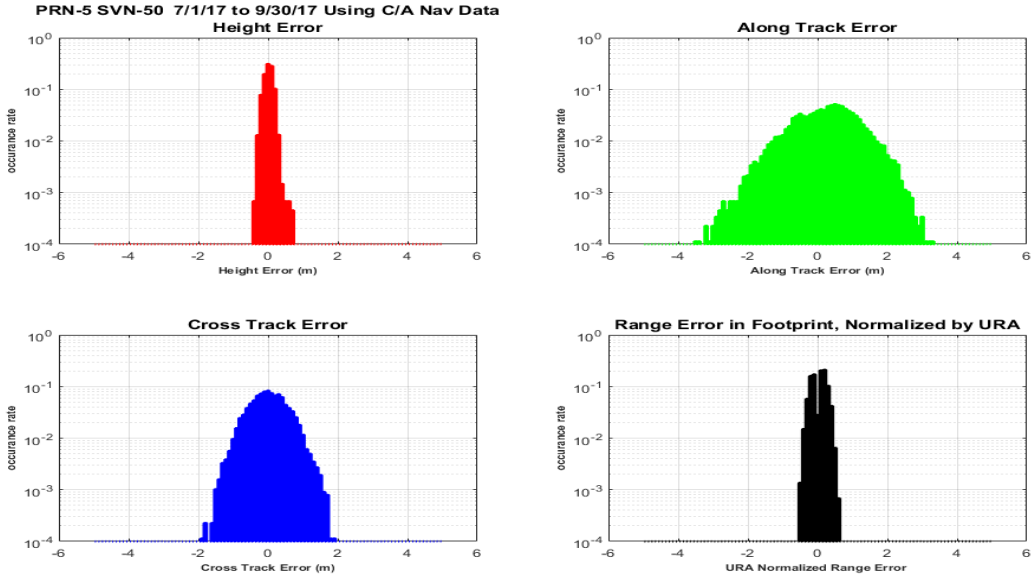


Figure 11-76 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using L2C CNAV Data

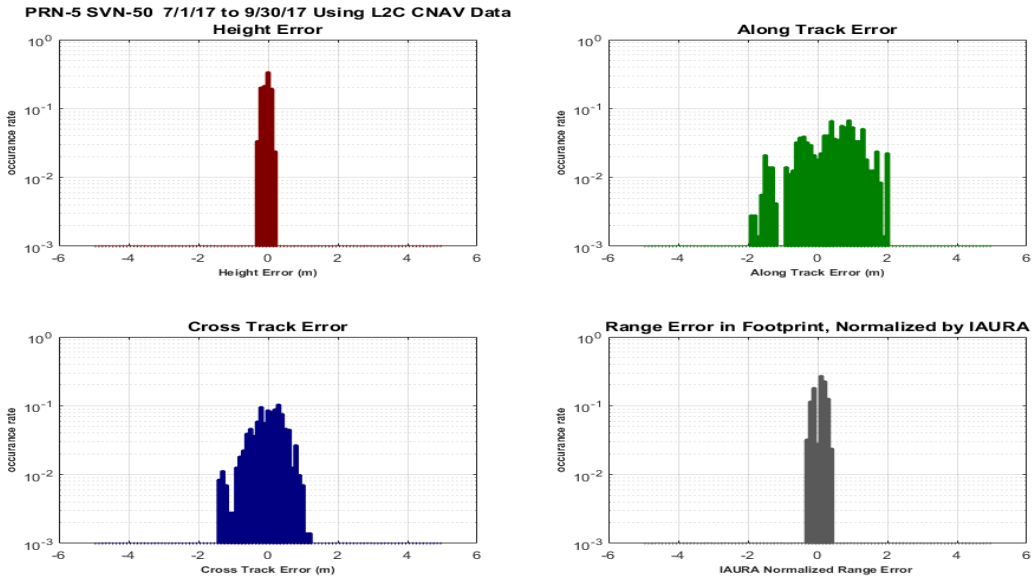


Figure 11-77 Histograms of H, A, C, and Range Error PRN-6 (SVN-67) Using C/A Nav Data

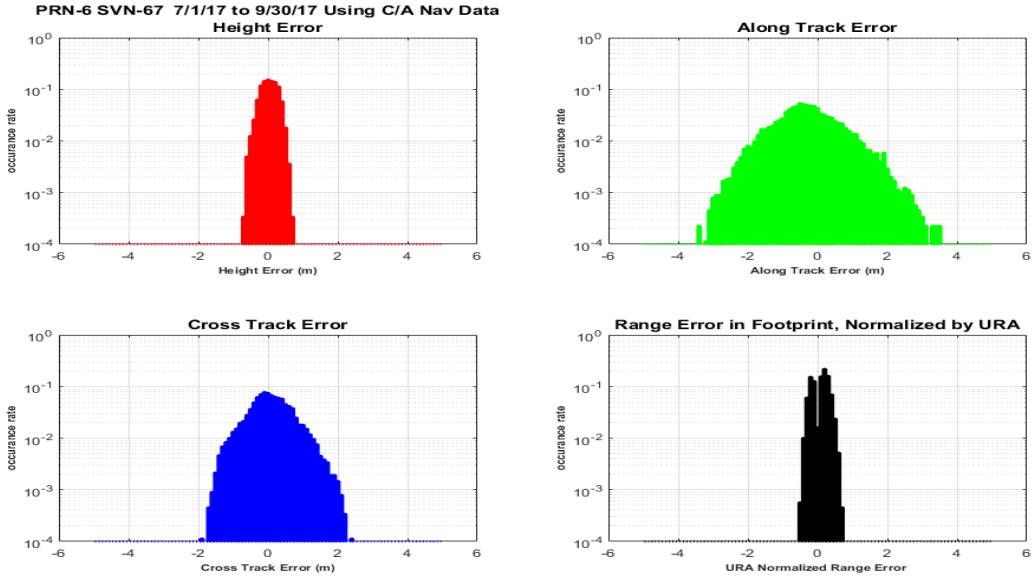


Figure 11-78 Histograms of H, A, C, and Range Error PRN-6 (SVN-67) Using L2C CNAV Data

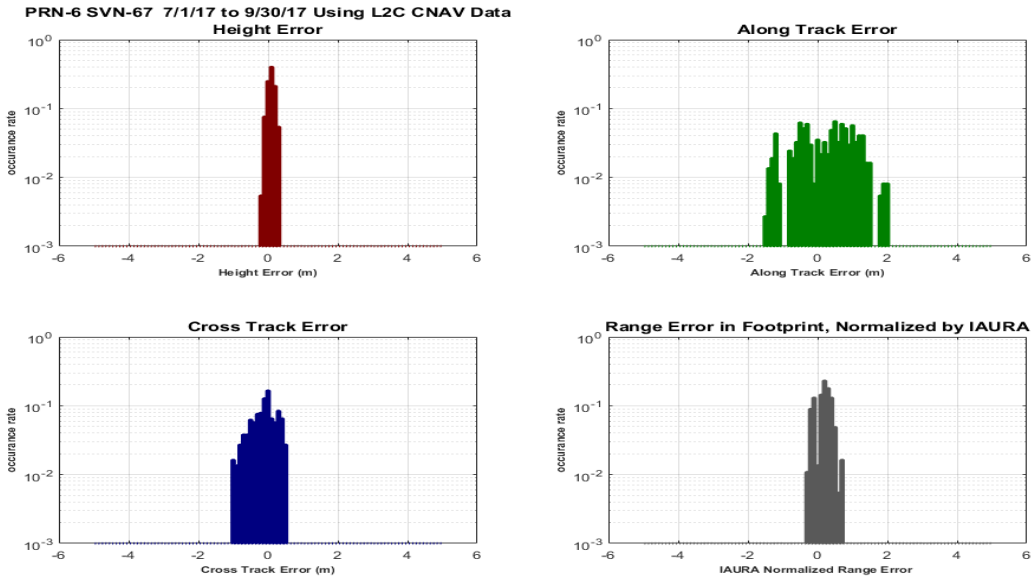


Figure 11-79 Histograms of H, A, C, and Range Error PRN-7 (SVN-48) Using C/A Nav Data

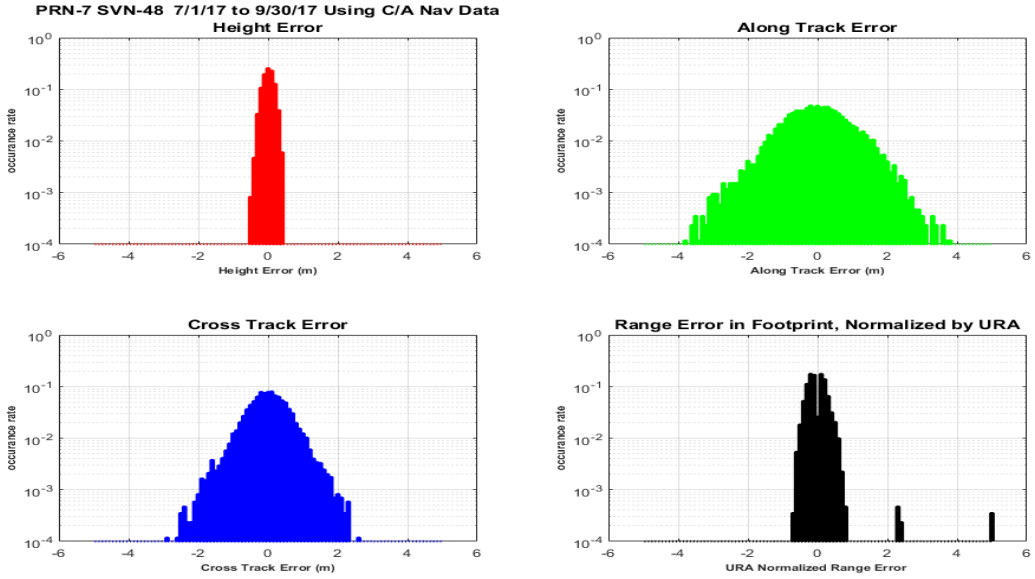


Figure 11-80 Histograms of H, A, C, and Range Error PRN-7 (SVN-48) Using L2C CNAV Data

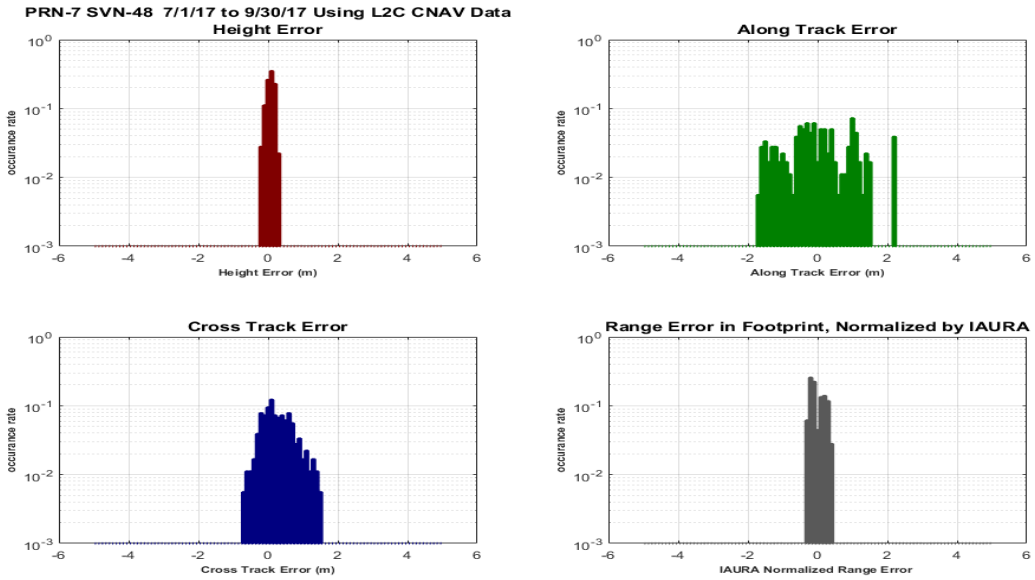


Figure 11-81 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using C/A Nav Data

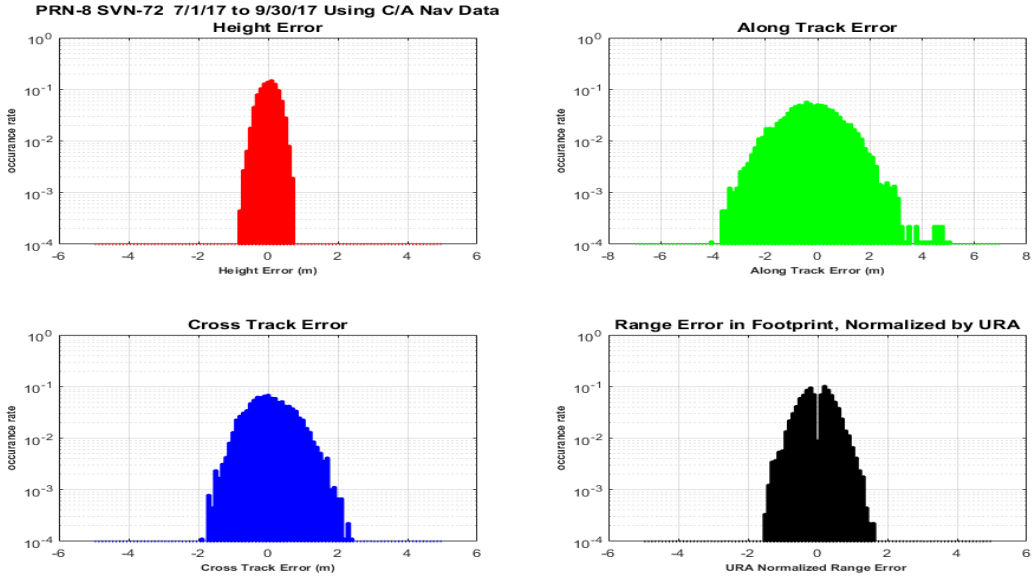


Figure 11-82 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using L2C CNAV Data

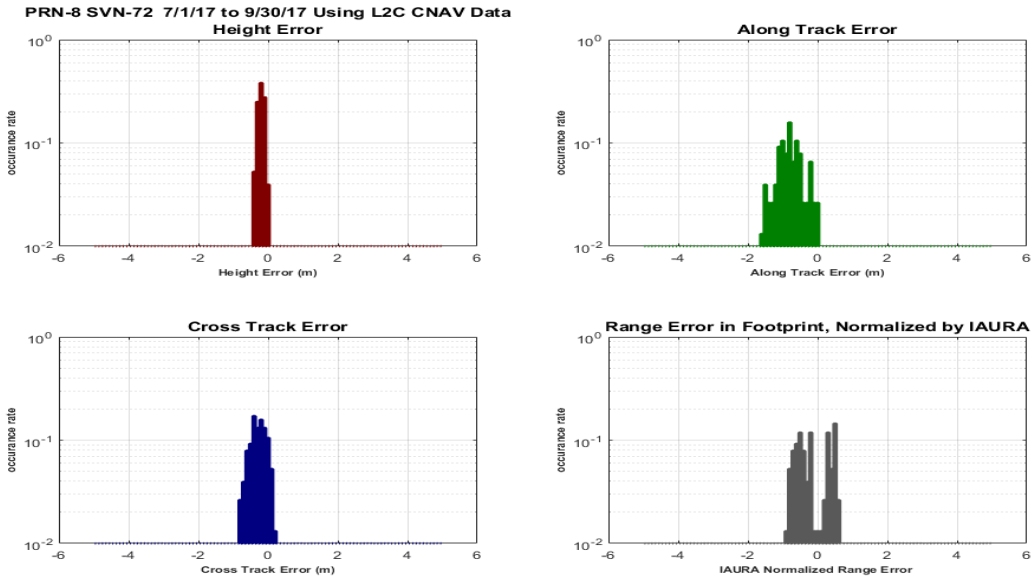


Figure 11-83 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using C/A Nav Data

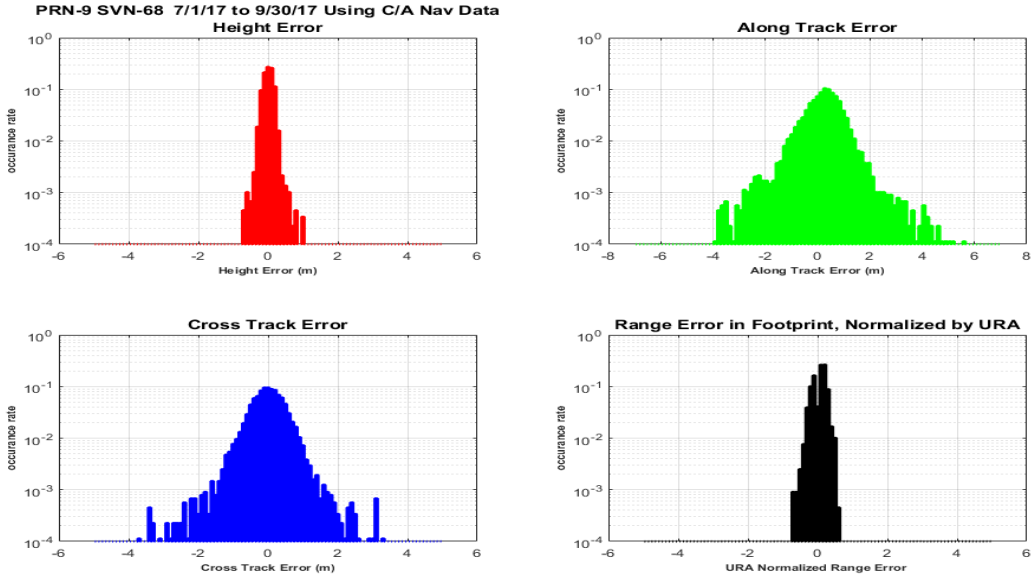


Figure 11-84 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using L2C CNAV Data

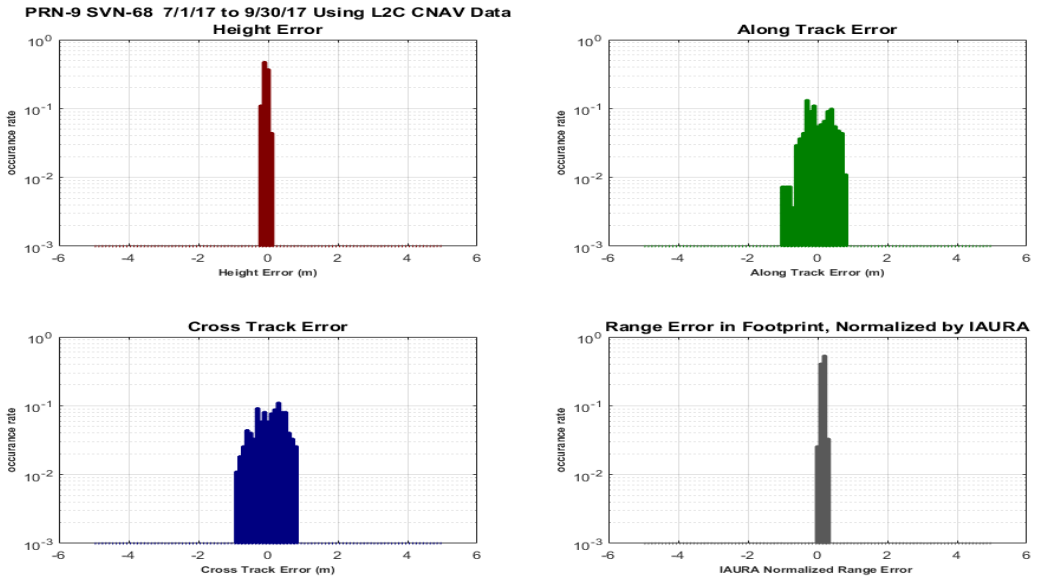


Figure 11-85 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using C/A Nav Data

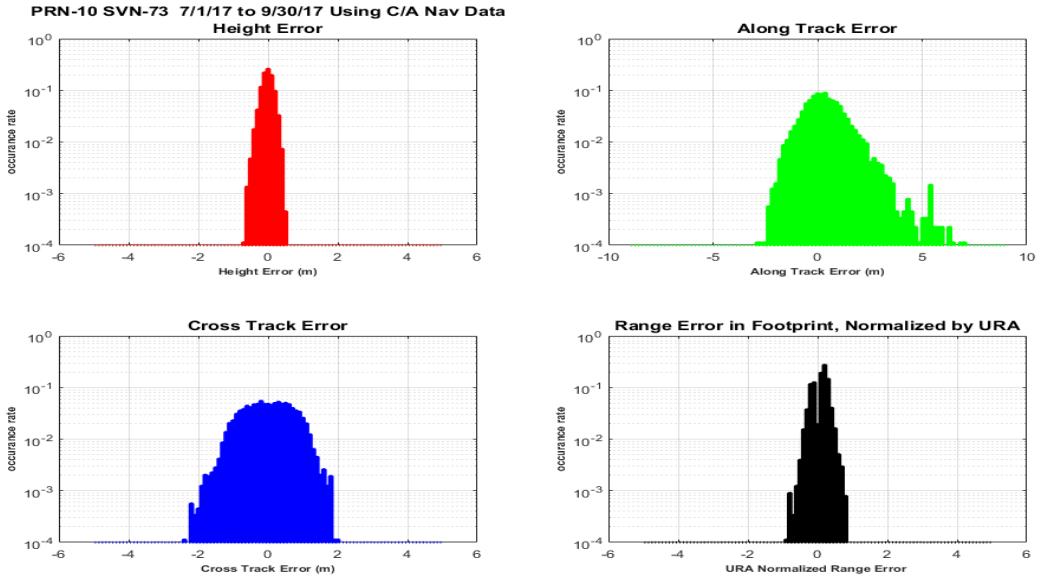


Figure 11-86 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using L2C CNAV Data

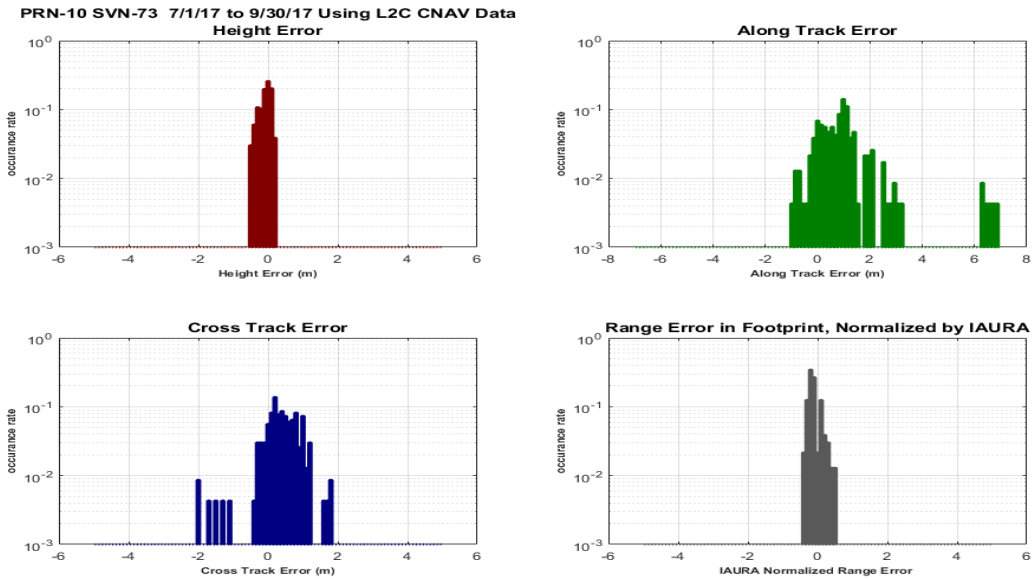


Figure 11-87 Histograms of H, A, C, and Range Error PRN-11 (SVN-46) Using C/A Nav Data

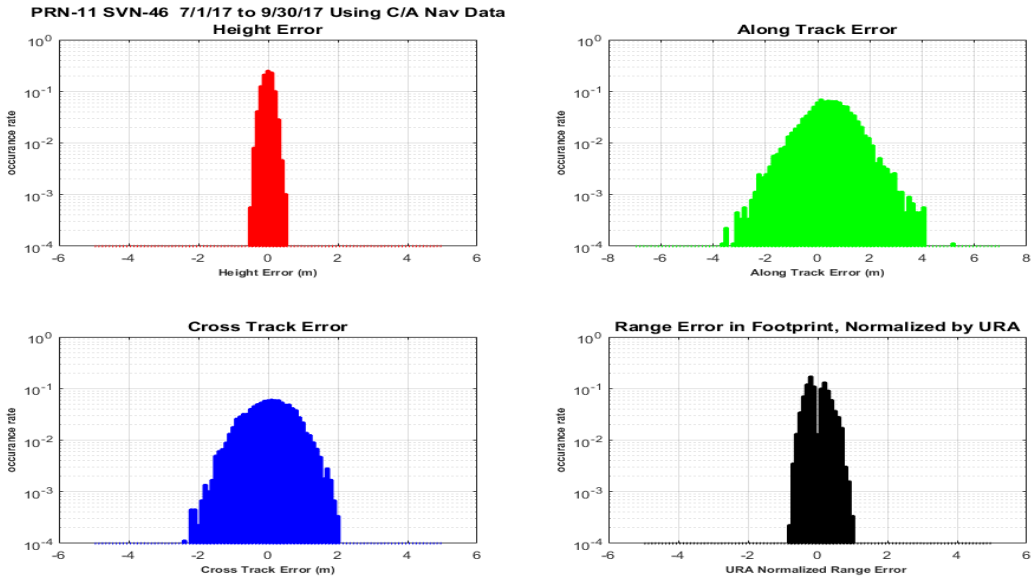


Figure 11-88 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using C/A Nav Data

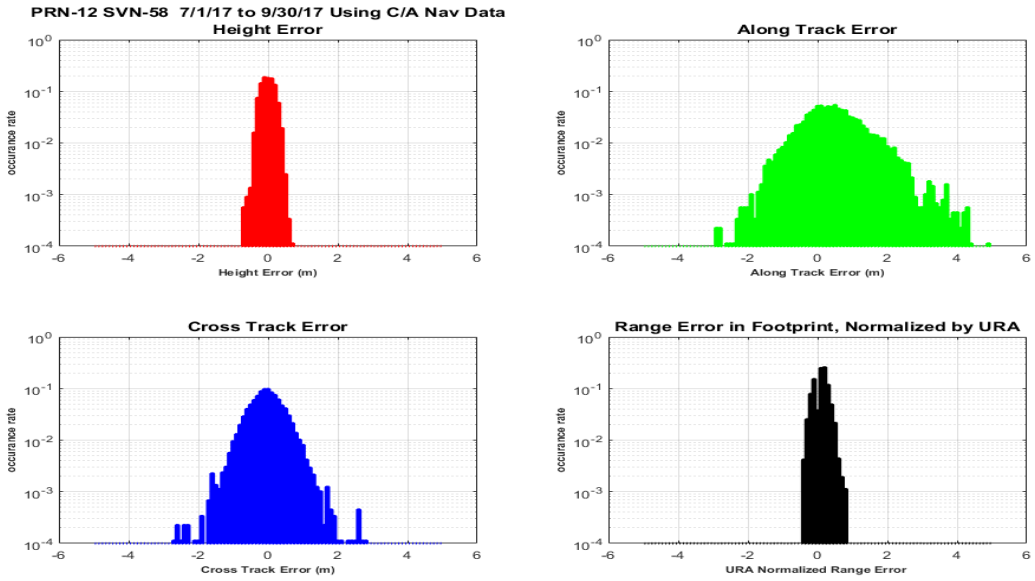


Figure 11-89 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using L2C CNAV Data

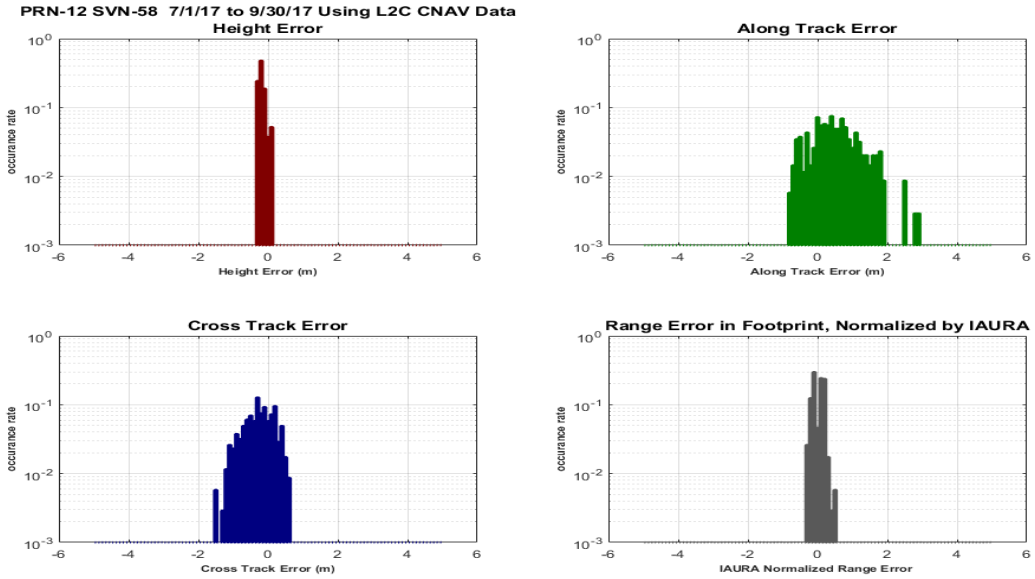


Figure 11-90 Histograms of H, A, C, and Range Error PRN-13 (SVN-43) Using C/A Nav Data

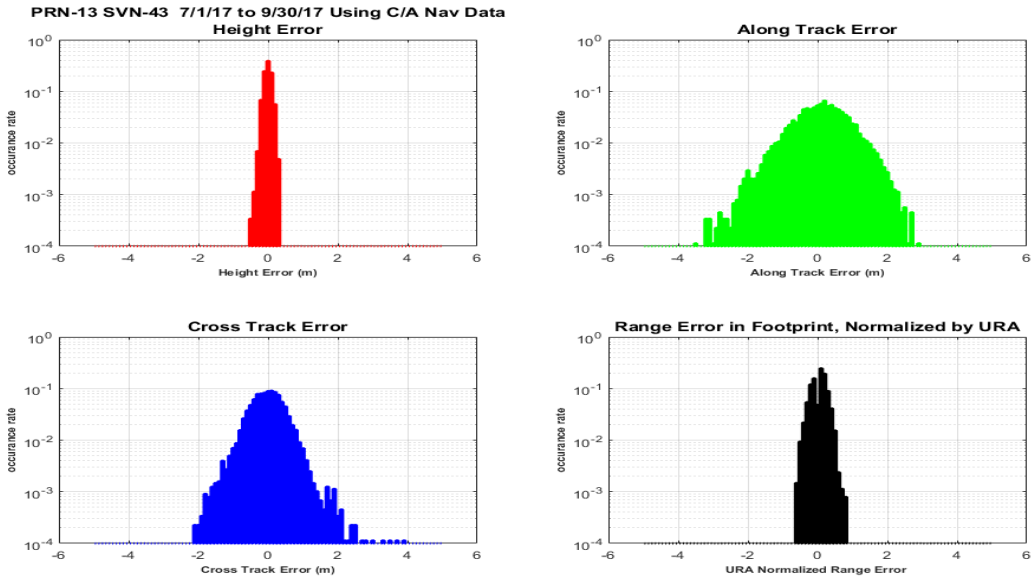


Figure 11-91 Histograms of H, A, C, and Range Error PRN-14 (SVN-41) Using C/A Nav Data

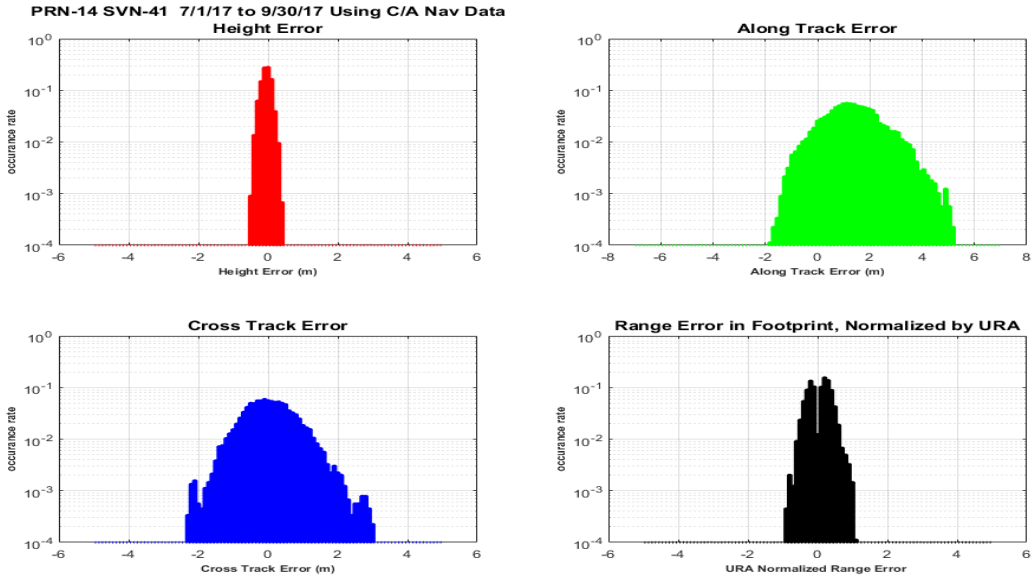


Figure 11-92 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using C/A Nav Data

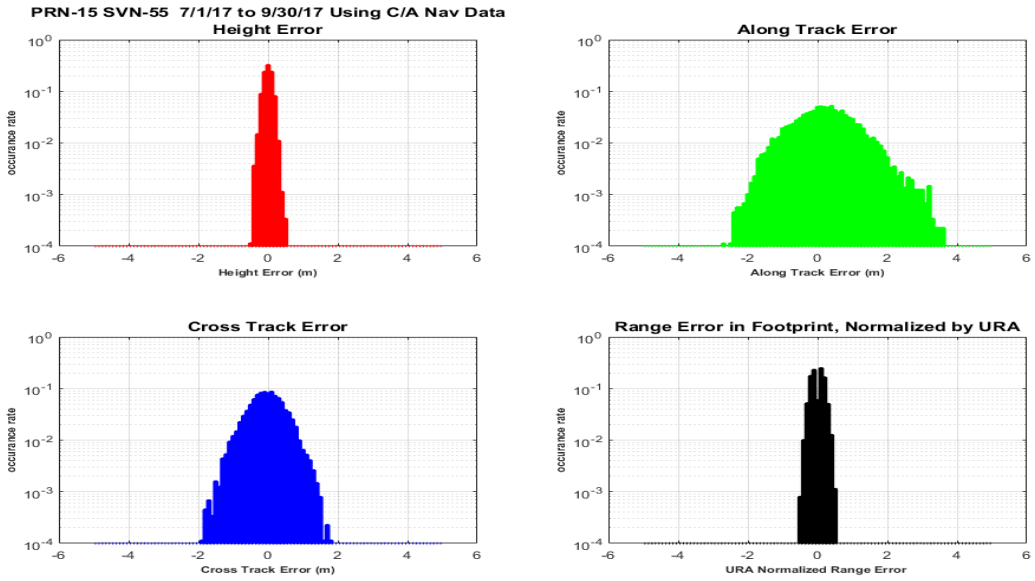


Figure 11-93 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using L2C CNAV Data

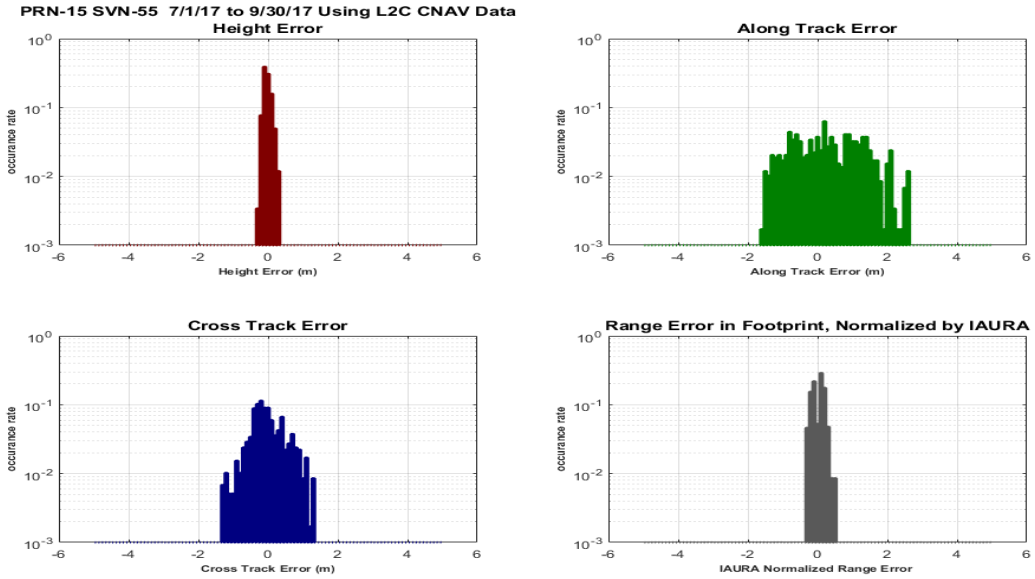


Figure 11-94 Histograms of H, A, C, and Range Error PRN-16 (SVN-56) Using C/A Nav Data

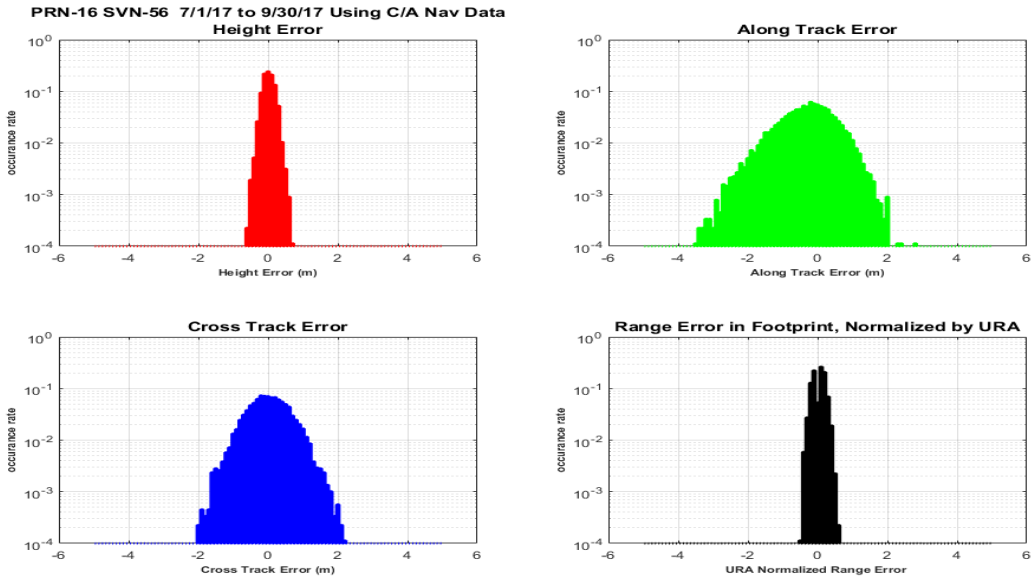


Figure 11-95 Histograms of H, A, C, and Range Error PRN-17 (SVN-53) Using C/A Nav Data

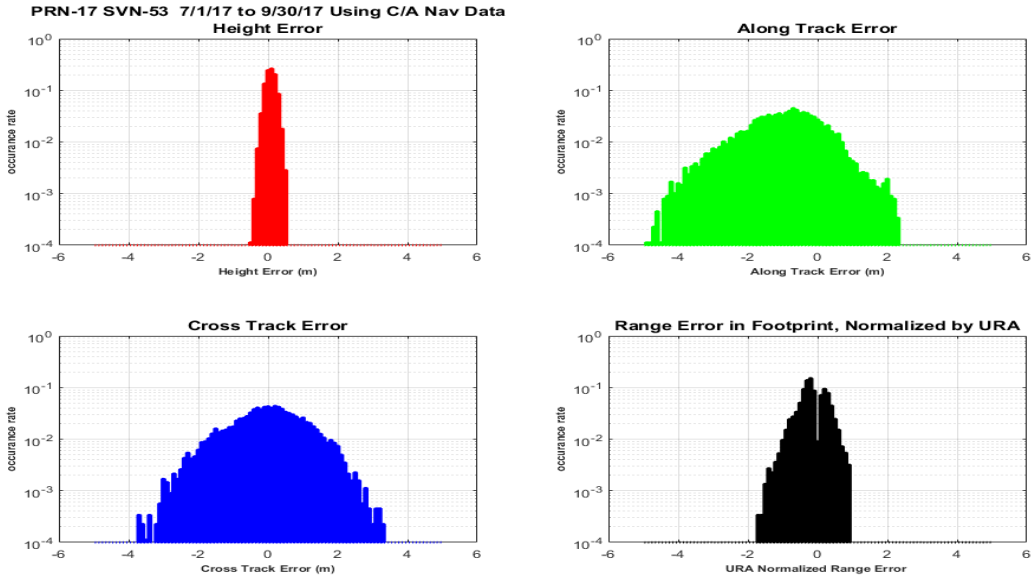


Figure 11-96 Histograms of H, A, C, and Range Error PRN-17 (SVN-53) Using L2C CNAV Data

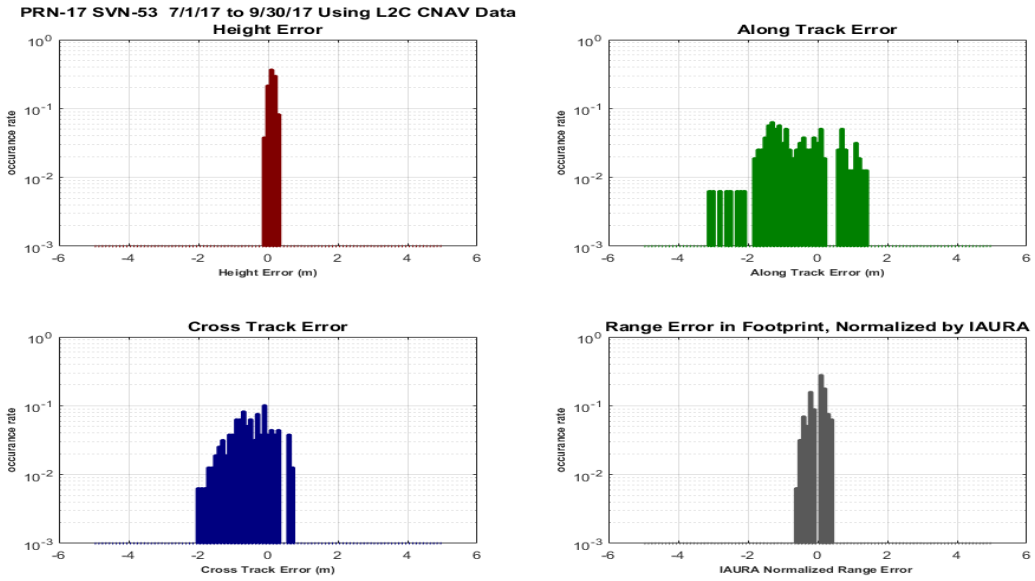


Figure 11-97 Histograms of H, A, C, and Range Error PRN-18 (SVN-54) Using C/A Nav Data

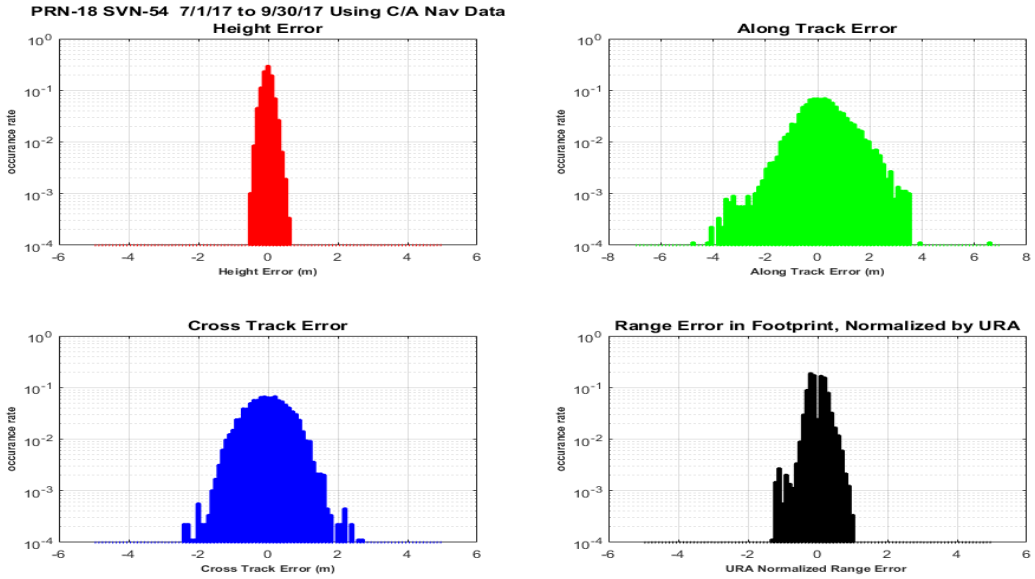


Figure 11-98 Histograms of H, A, C, and Range Error PRN-19 (SVN-59) Using C/A Nav Data

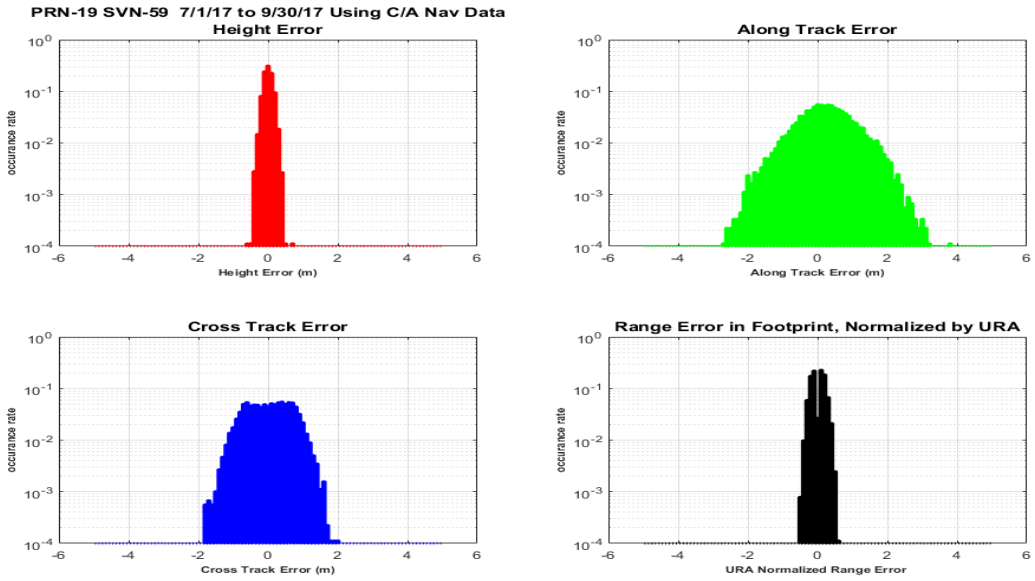


Figure 11-99 Histograms of H, A, C, and Range Error PRN-20 (SVN-51) Using C/A Nav Data

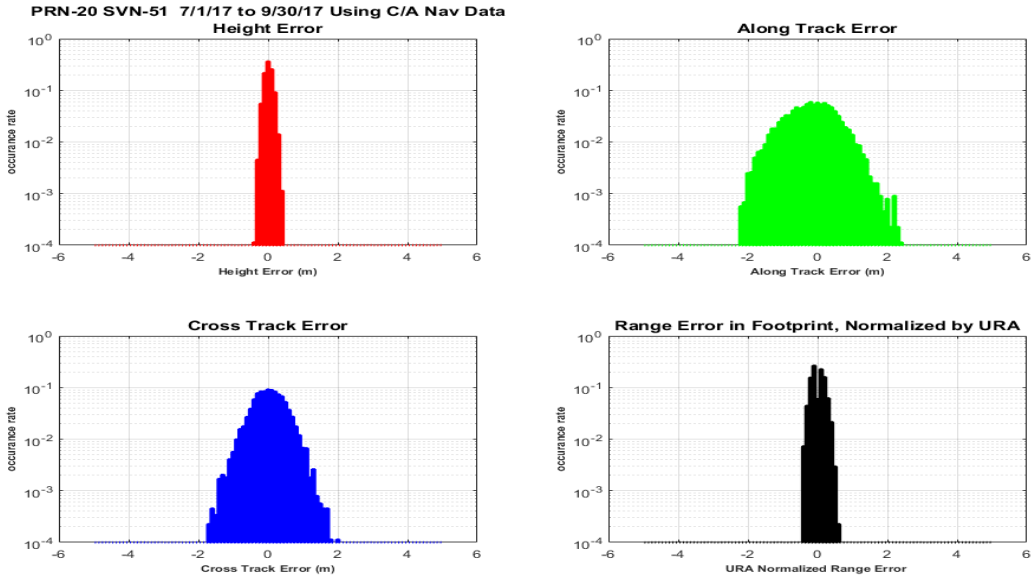


Figure 11-100 Histograms of H, A, C, and Range Error PRN-21 (SVN-45) Using C/A Nav Data

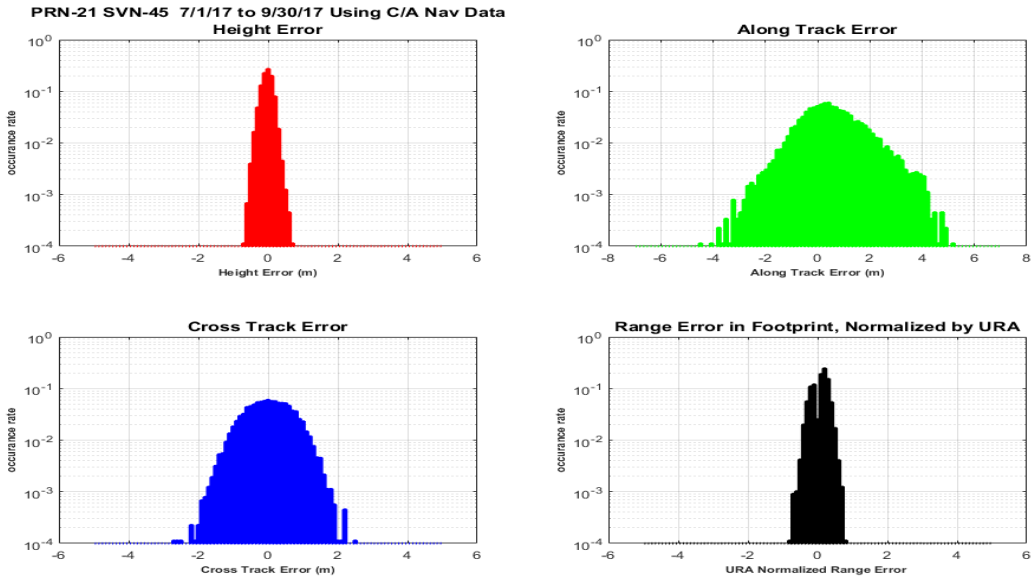


Figure 11-101 Histograms of H, A, C, and Range Error PRN-22 (SVN-47) Using C/A Nav Data

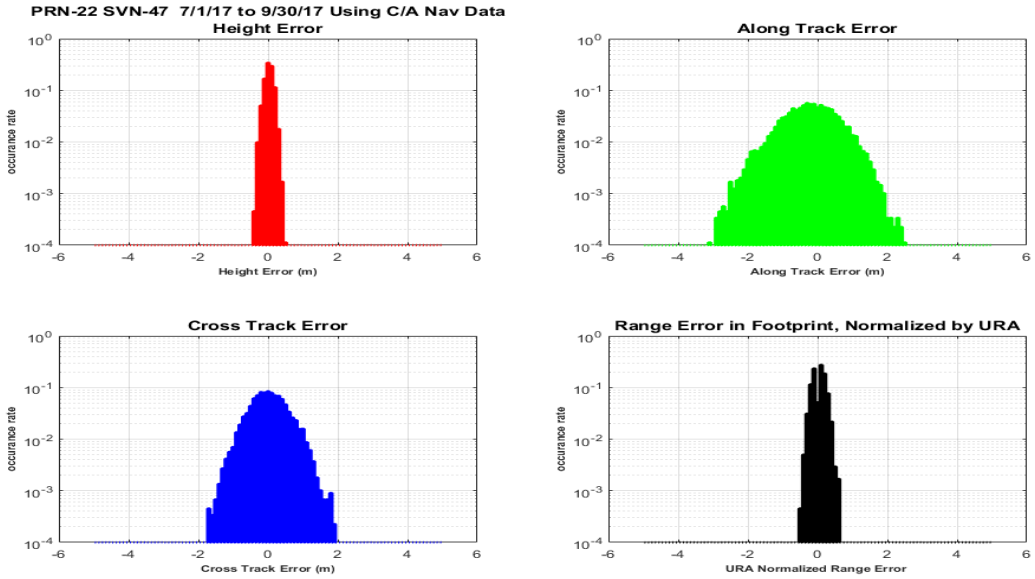


Figure 11-102 Histograms of H, A, C, and Range Error PRN-23 (SVN-60) Using C/A Nav Data

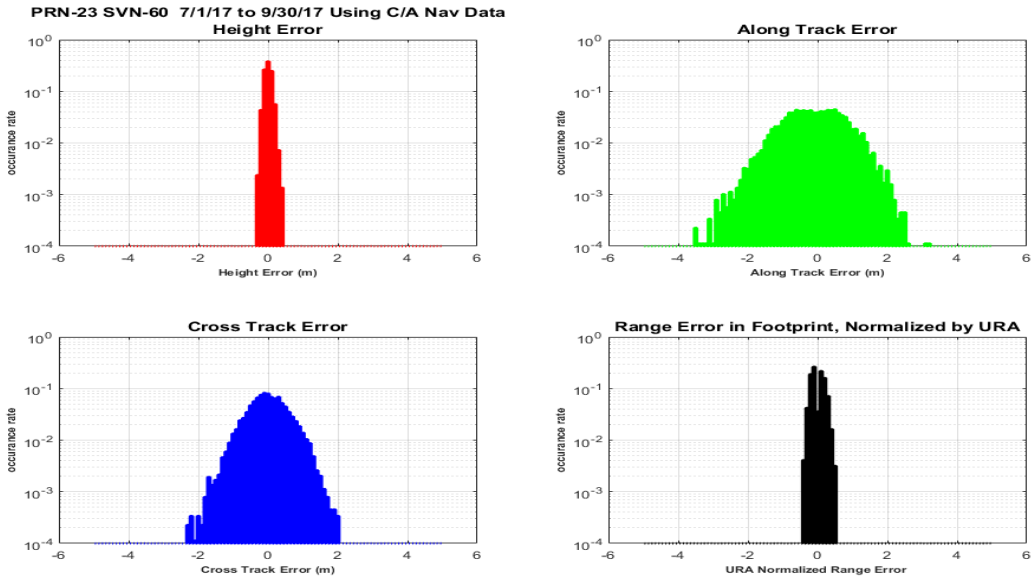


Figure 11-103 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using C/A Nav Data

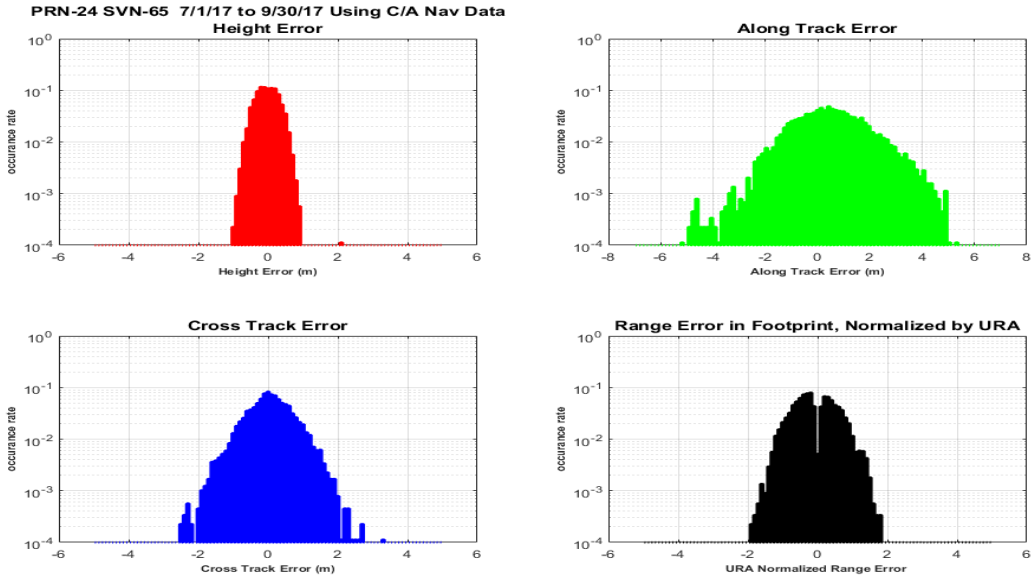


Figure 11-104 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using L2C CNAV Data

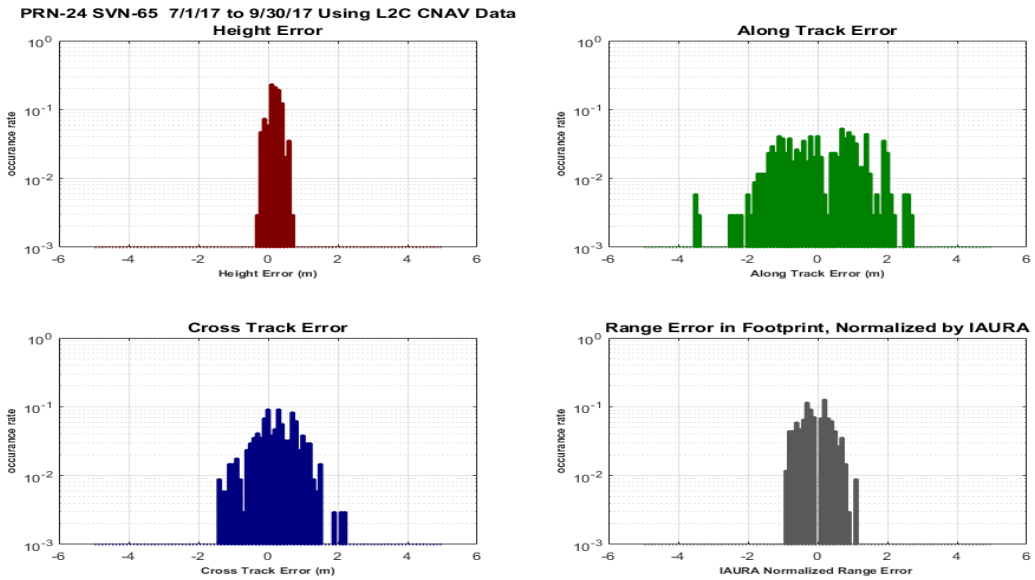


Figure 11-105 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using C/A Nav Data

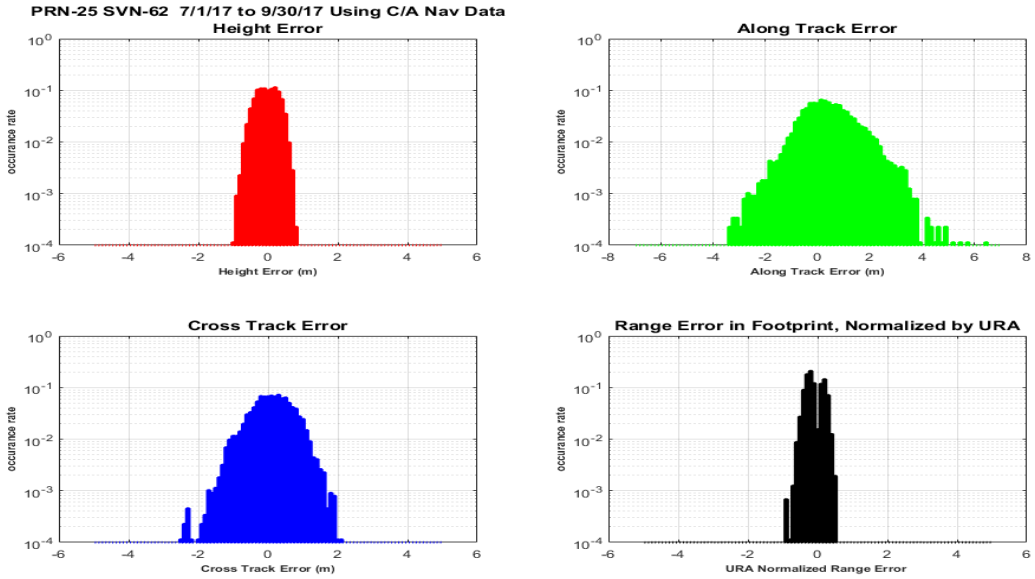


Figure 11-106 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using L2C CNAV Data

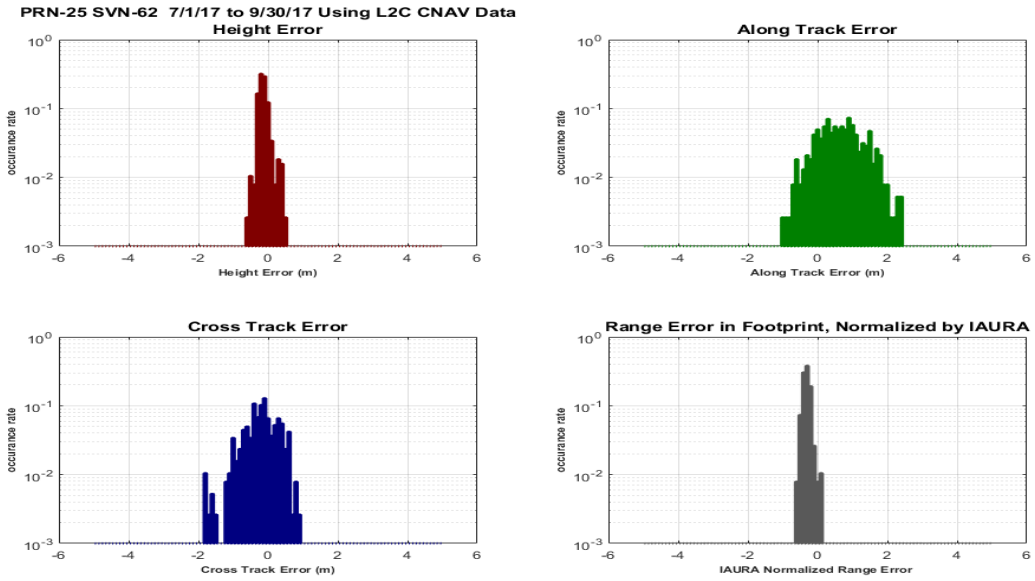


Figure 11-107 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using C/A Nav Data

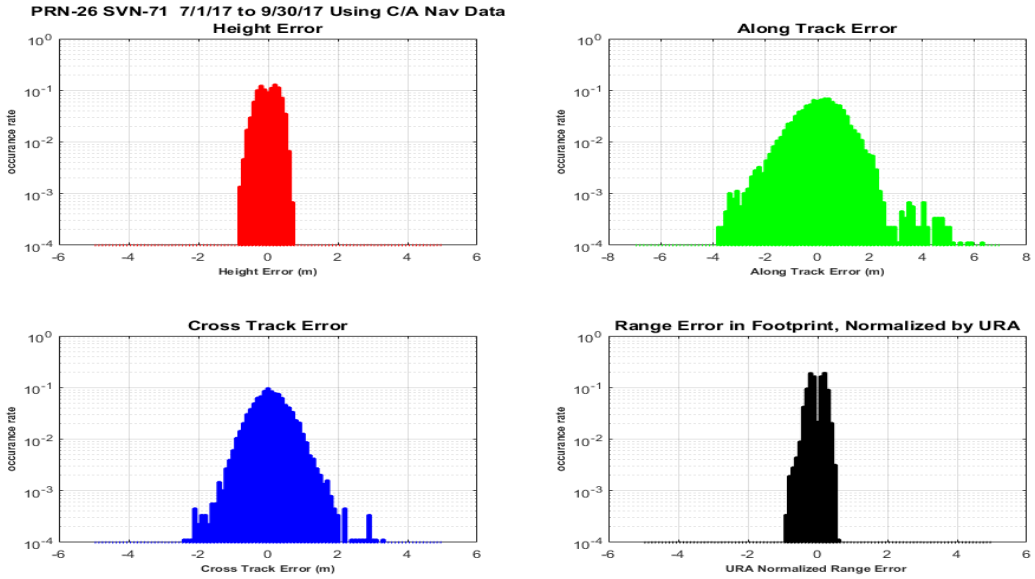


Figure 11-108 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using L2C CNAV Data

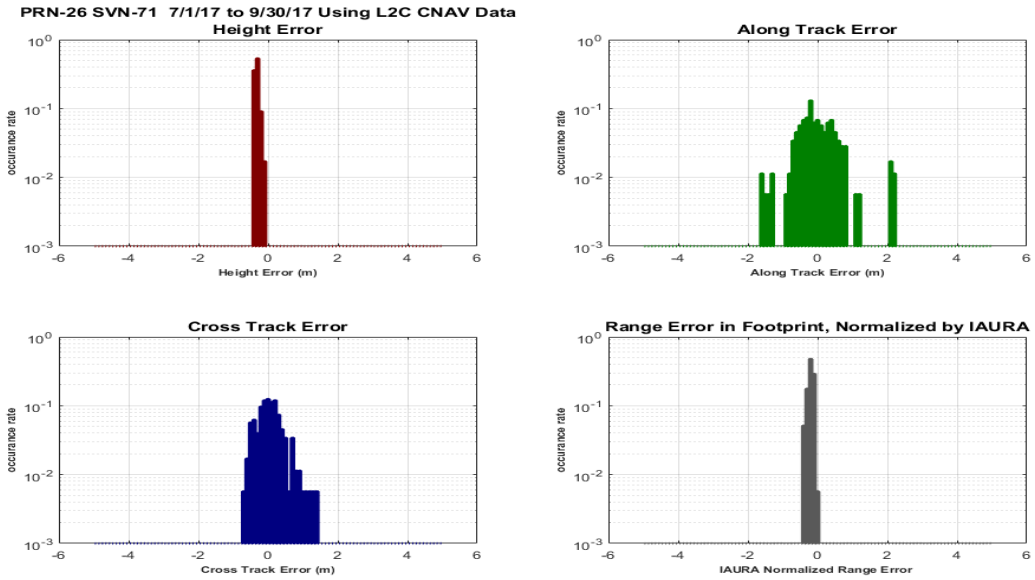


Figure 11-109 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using C/A Nav Data

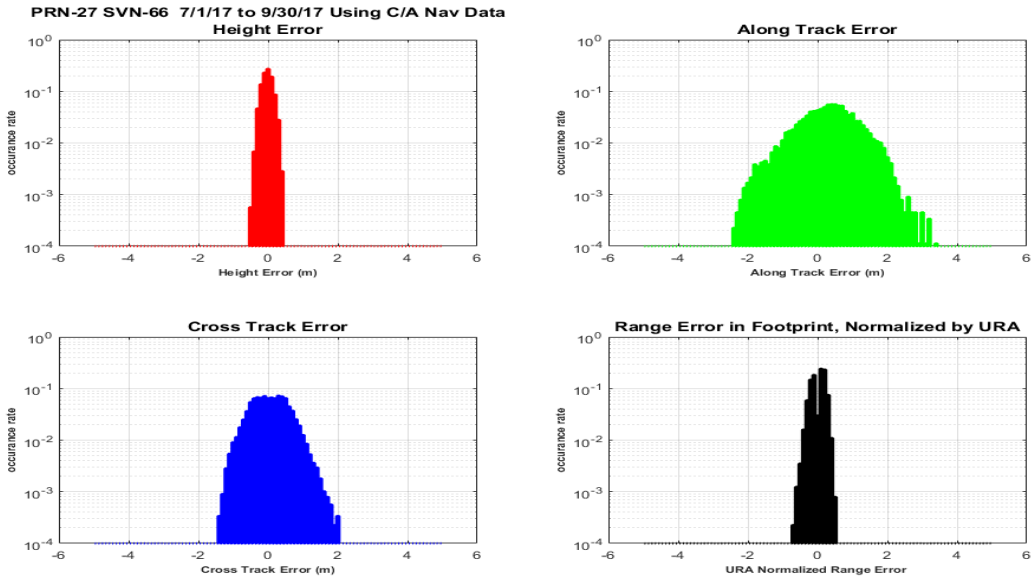


Figure 11-110 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using L2C CNAV Data

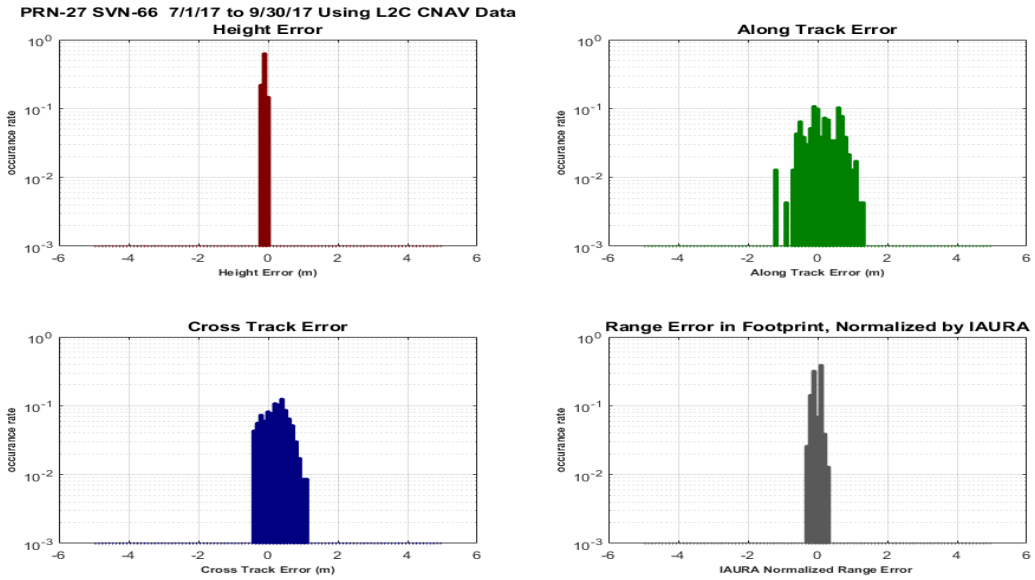


Figure 11-111 Histograms of H, A, C, and Range Error PRN-28 (SVN-44) Using C/A Nav Data

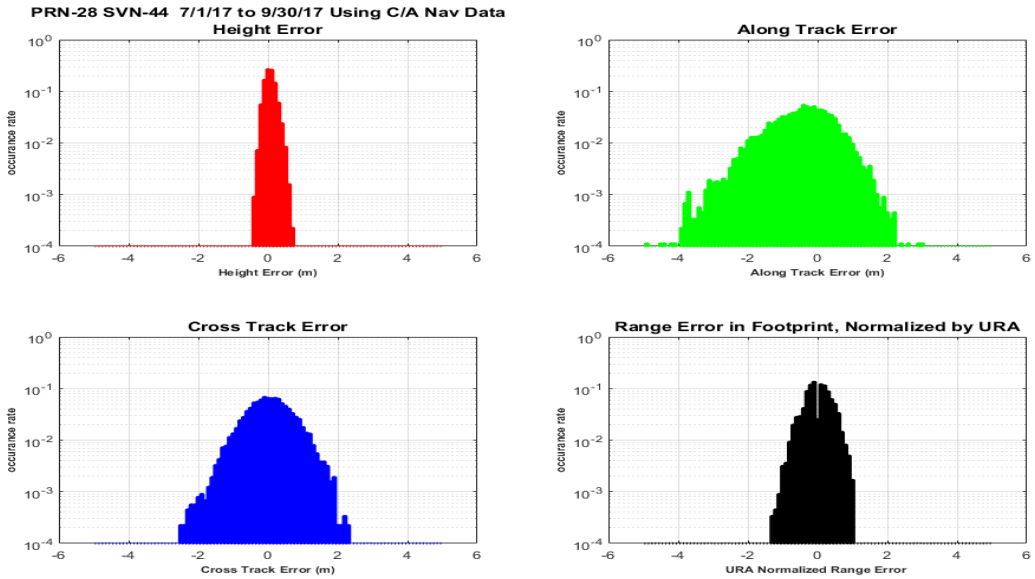


Figure 11-112 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using C/A Nav Data

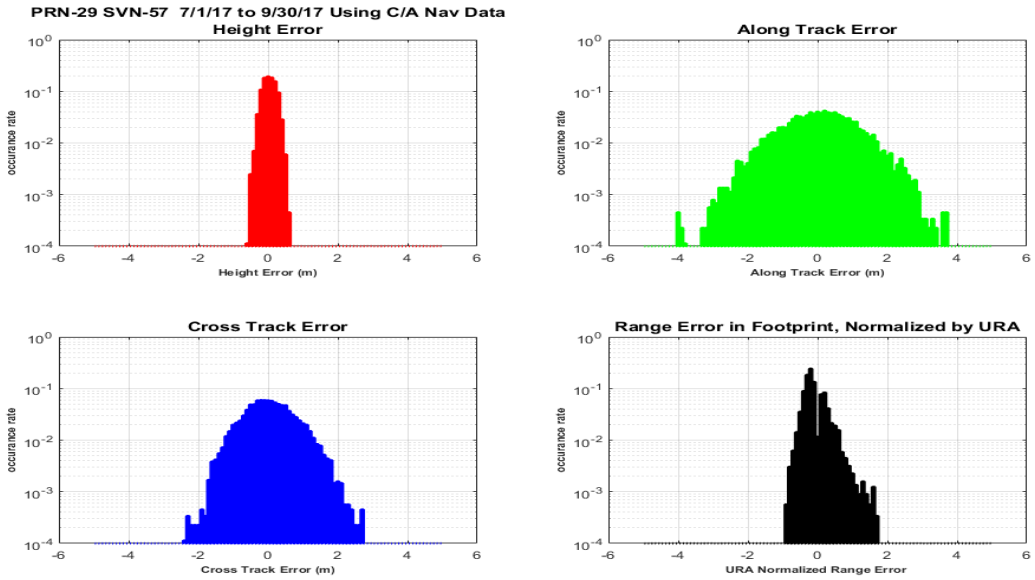


Figure 11-113 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using L2C CNAV Data

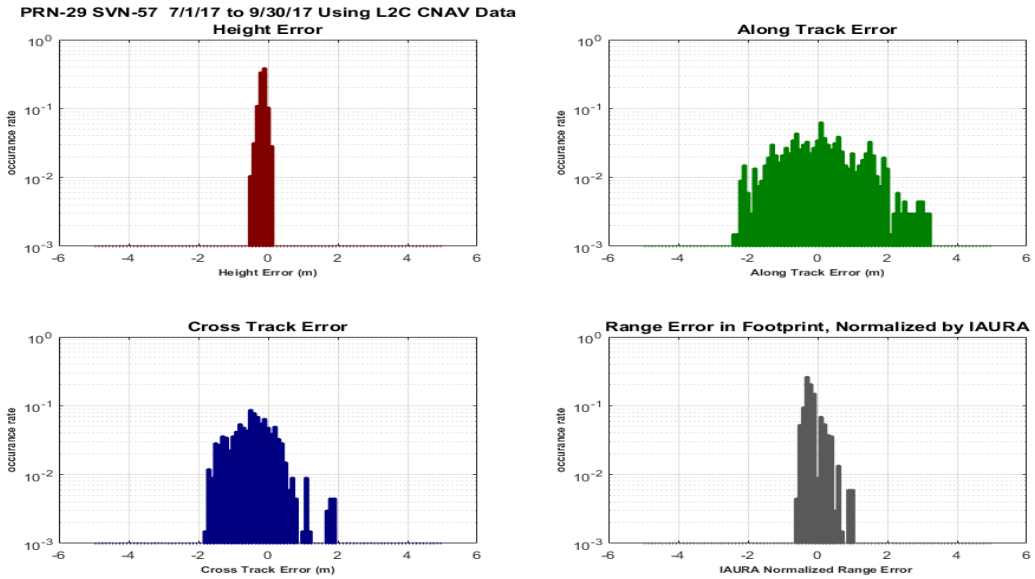


Figure 11-114 Histograms of H, A, C, and Range Error PRN-30 (SVN-64) Using C/A Nav Data

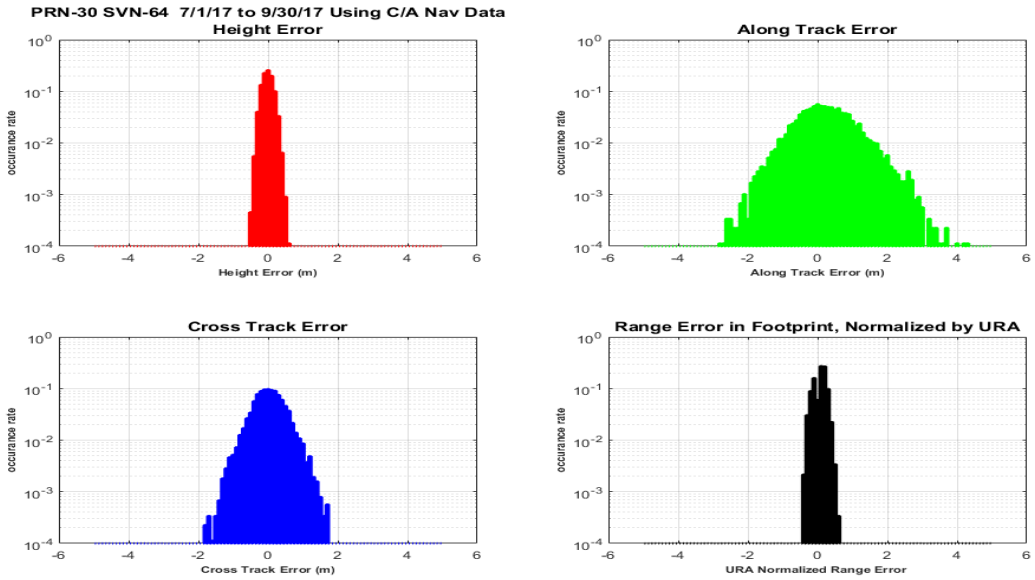


Figure 11-115 Histograms of H, A, C, and Range Error PRN-30 (SVN-64) Using L2C CNAV Data

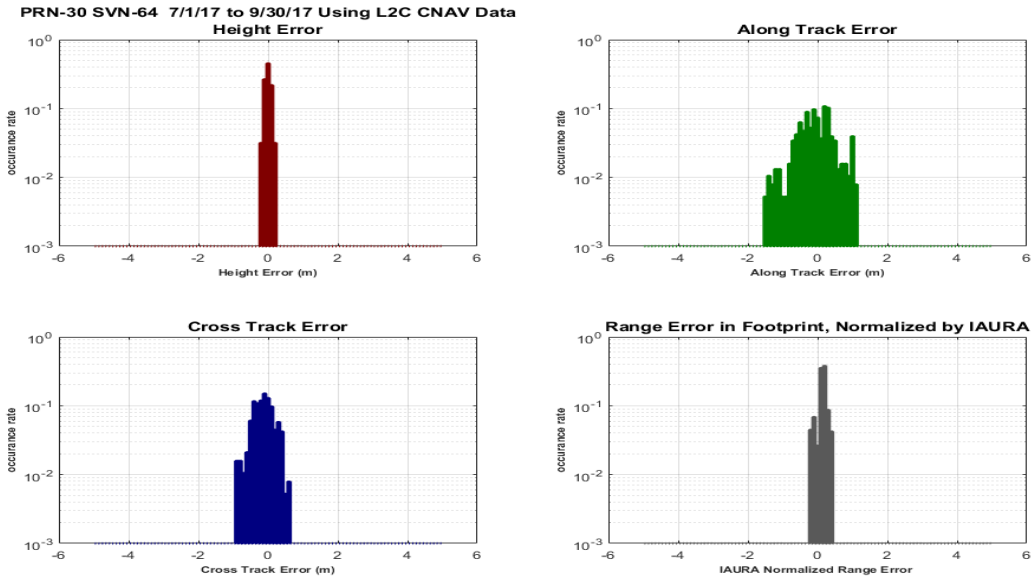


Figure 11-116 Histograms of H, A, C, and Range Error PRN-31 (SVN-52) Using C/A Nav Data

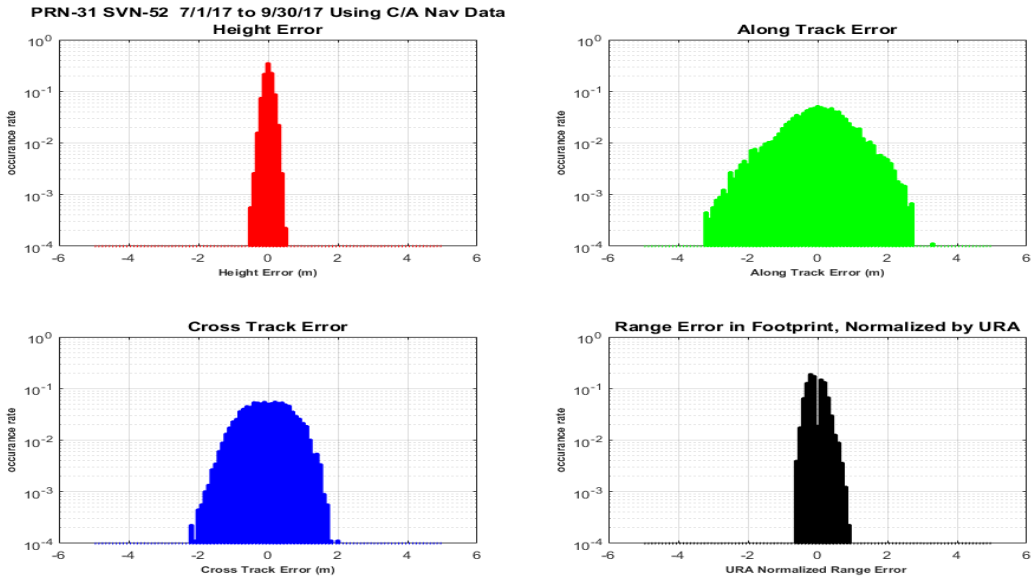


Figure 11-117 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using C/A Nav Data

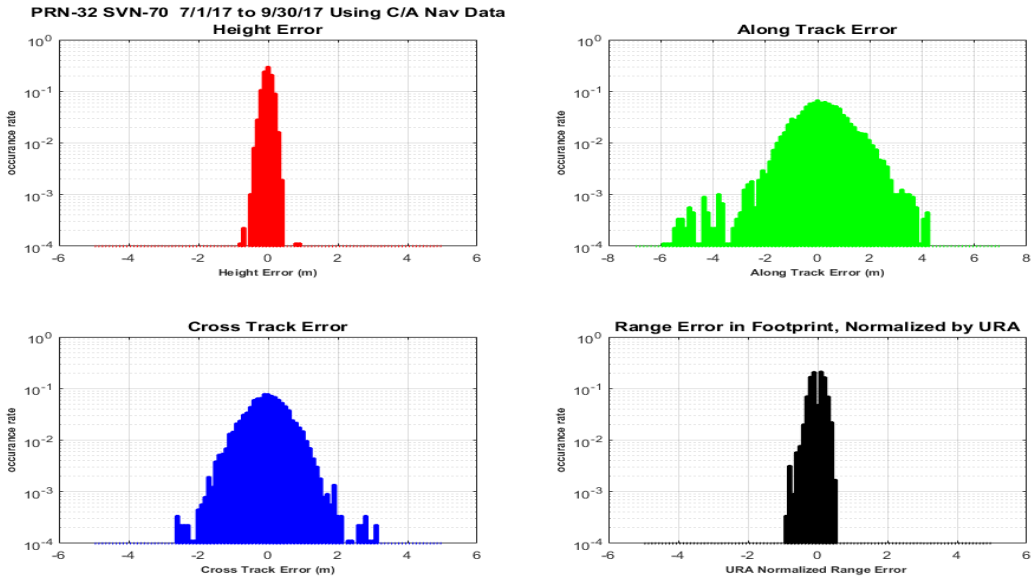
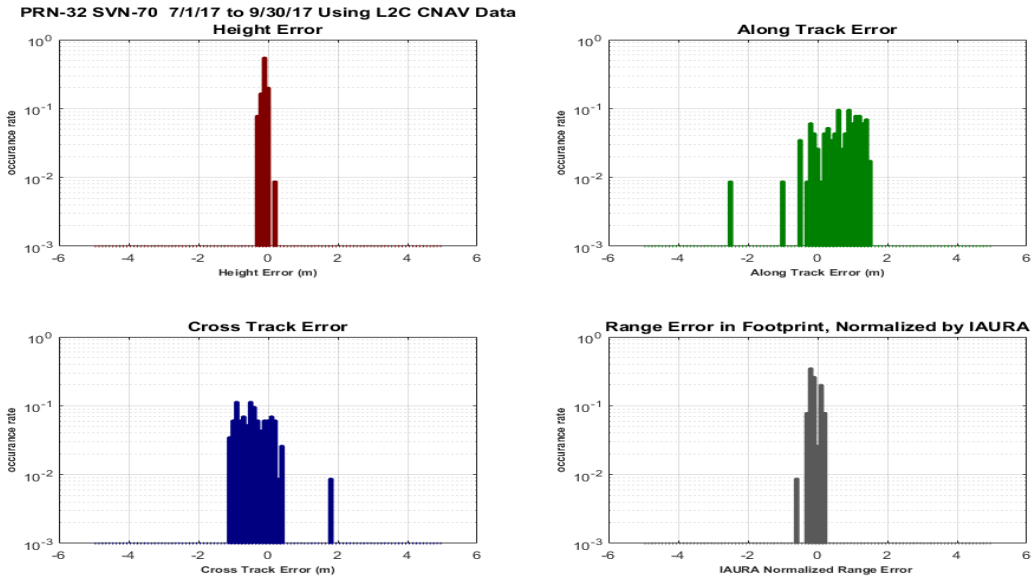


Figure 11-118 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using L2C CNAV Data



Timeline of URA Normalized Range Error for All Satellites

Figure 11-119 Timeline of URA Normalized Range Error PRN-1 (SVN-63) Using C/A Nav Data

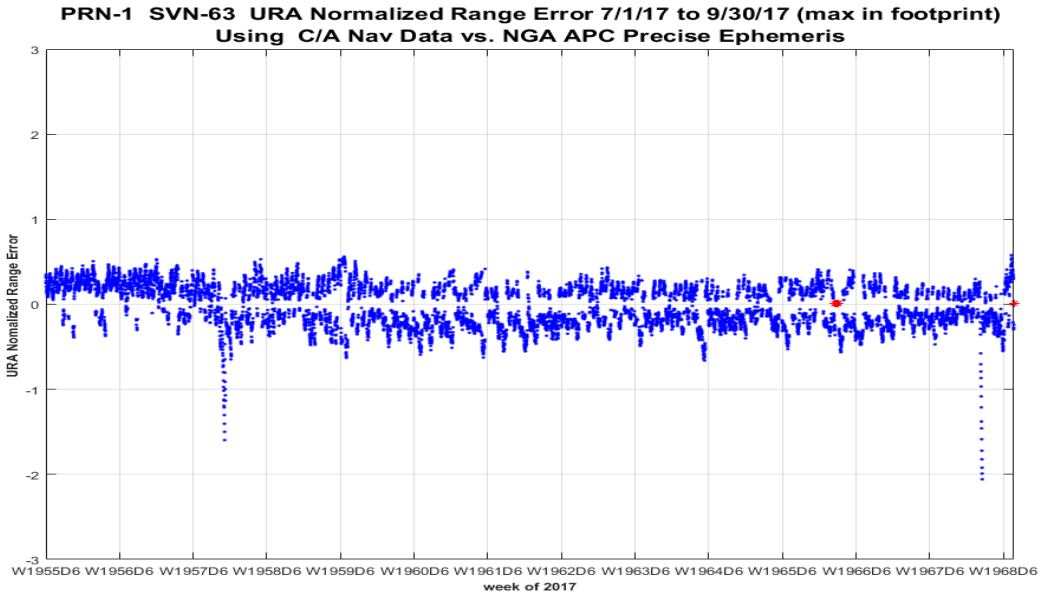


Figure 11-120 Timeline of URA Normalized Range Error PRN-2 (SVN-61) Using C/A Nav Data

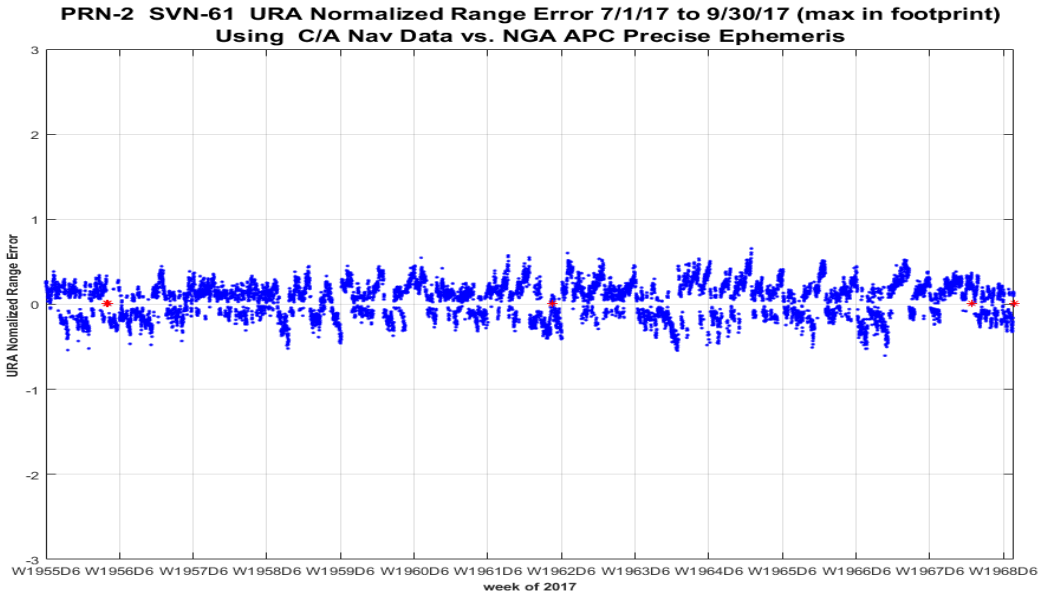


Figure 11-121 Timeline of URA Normalized Range Error PRN-3 (SVN-69) Using C/A Nav Data

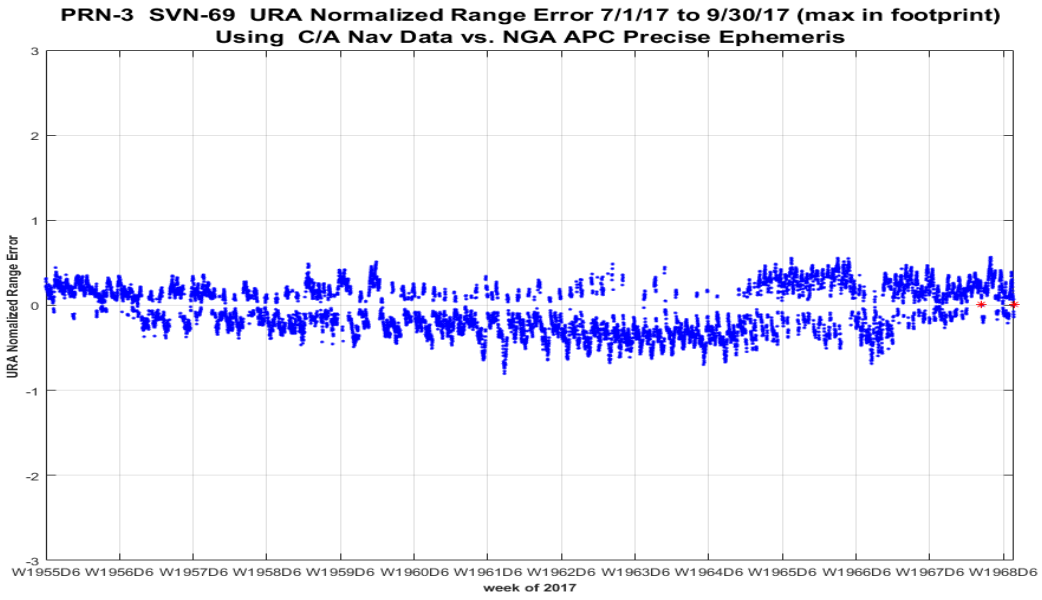


Figure 11-122 Timeline of URA Normalized Range Error PRN-5 (SVN-50) Using C/A Nav Data

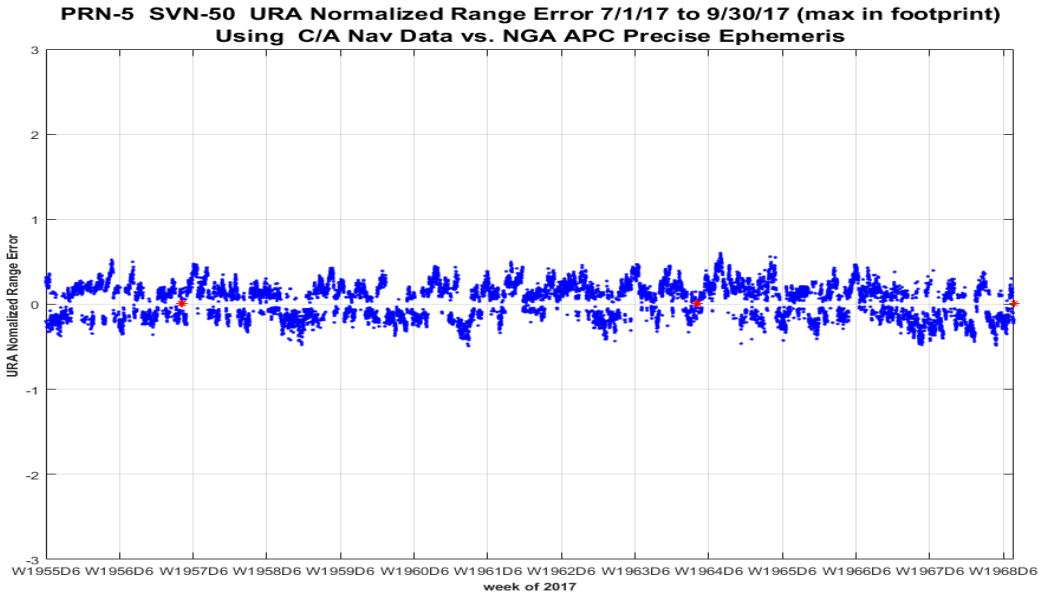


Figure 11-123 Timeline of IAURA Normalized Range Error PRN-5 (SVN-50) Using L2C CNAV Data

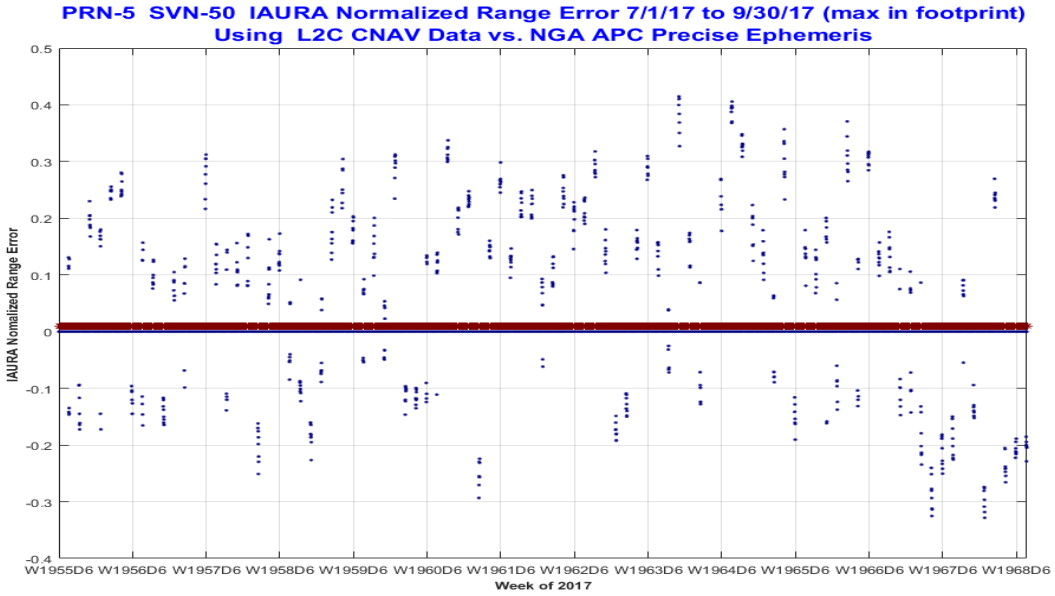


Figure 11-124 Timeline of URA Normalized Range Error PRN-6 (SVN-67) Using C/A Nav Data

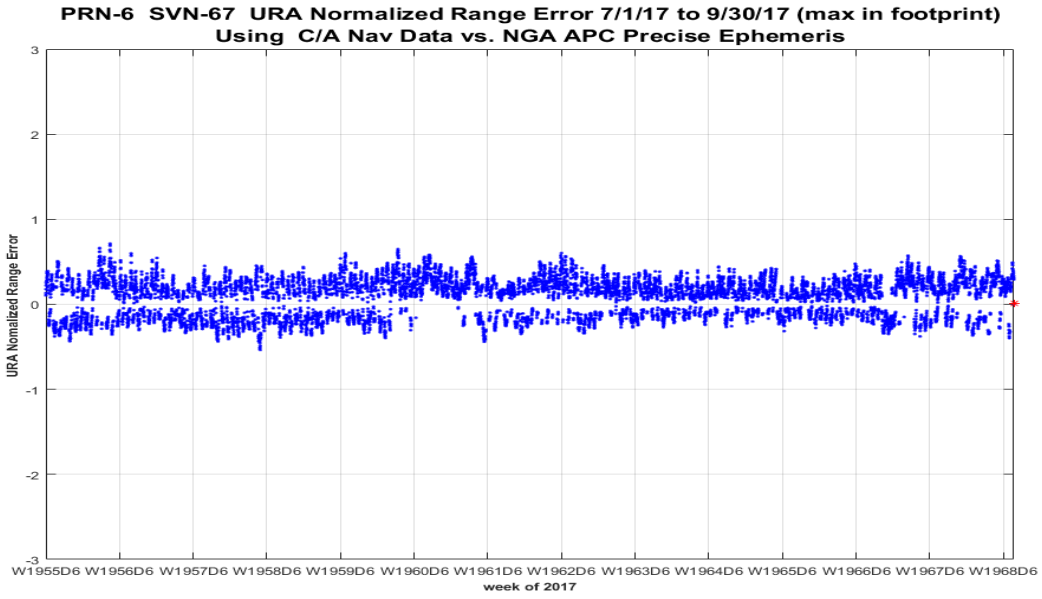


Figure 11-125 Timeline of IAURA Normalized Range Error PRN-6 (SVN-67) Using L2C CNAV Data

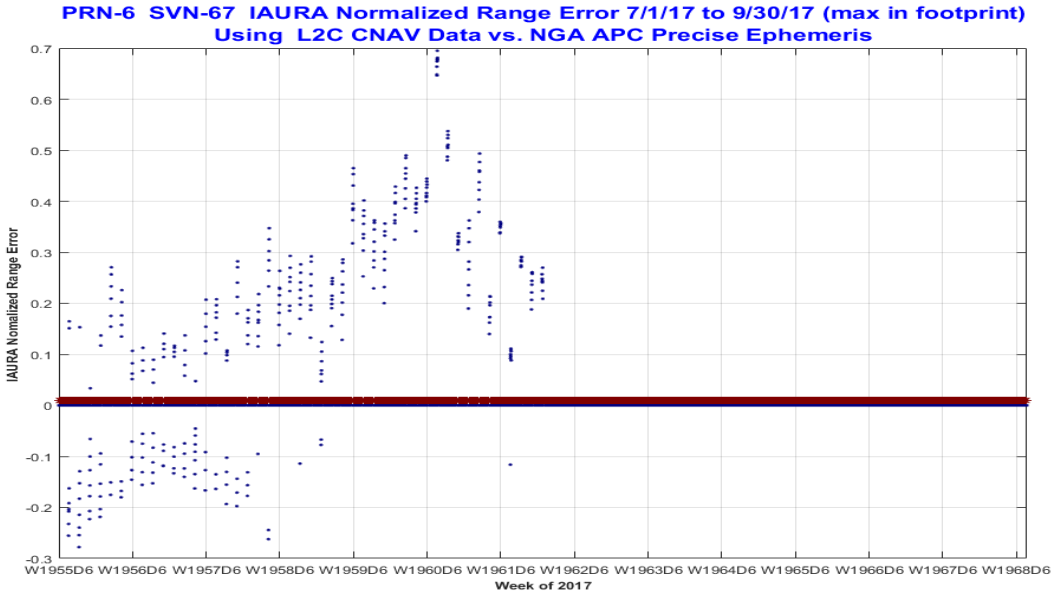


Figure 11-126 Timeline of URA Normalized Range Error PRN-7 (SVN-48) Using C/A Nav Data

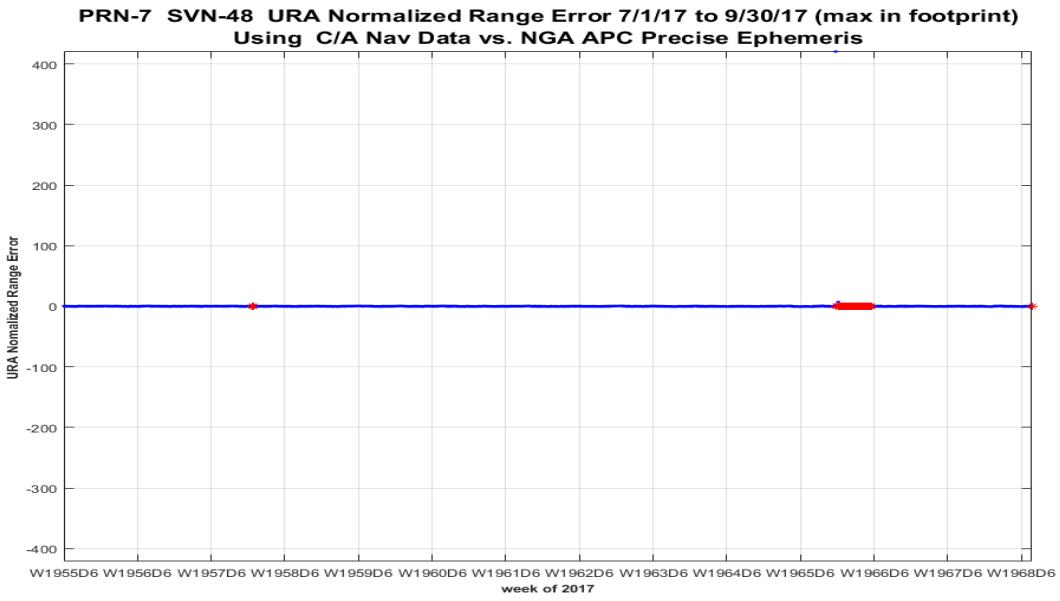


Figure 11-127 Timeline of IAURA Normalized Range Error PRN-7 (SVN-48) Using L2C CNAV Data

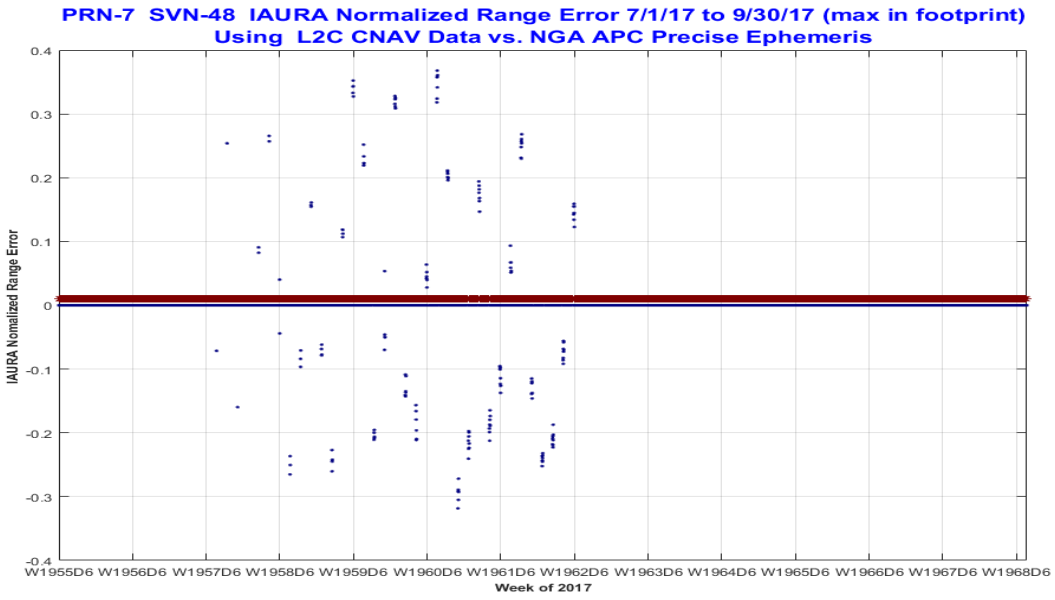


Figure 11-128 Timeline of URA Normalized Range Error PRN-8 (SVN-72) Using C/A Nav Data

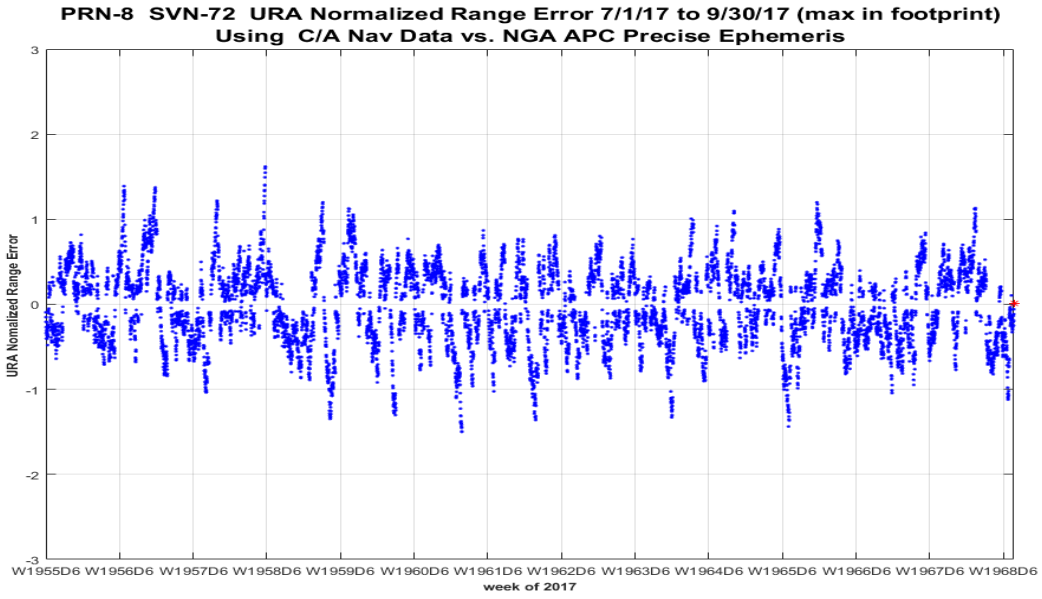


Figure 11-129 Timeline of IAURA Normalized Range Error PRN-8 (SVN-72) Using L2C CNAV Data

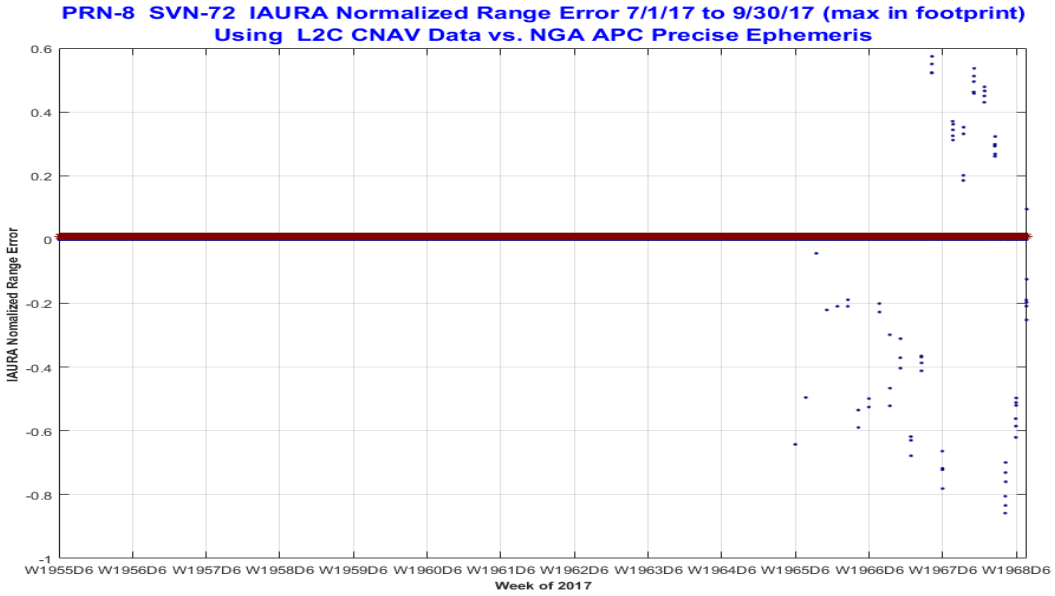


Figure 11-130 Timeline of URA Normalized Range Error PRN-9 (SVN-68) Using C/A Nav Data

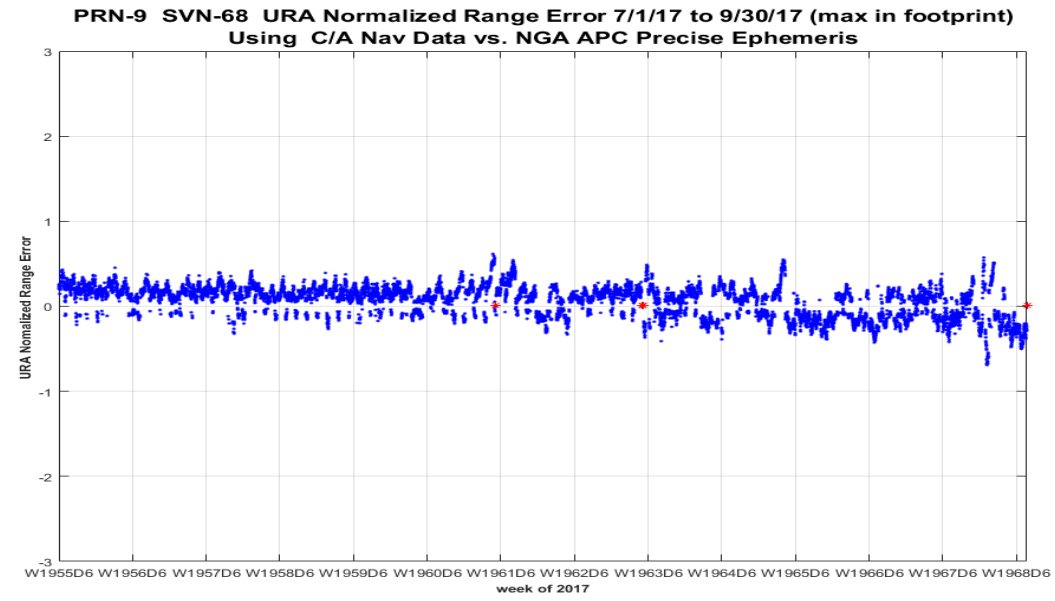


Figure 11-131 Timeline of IAURA Normalized Range Error PRN-9 (SVN-68) Using L2C CNAV Data

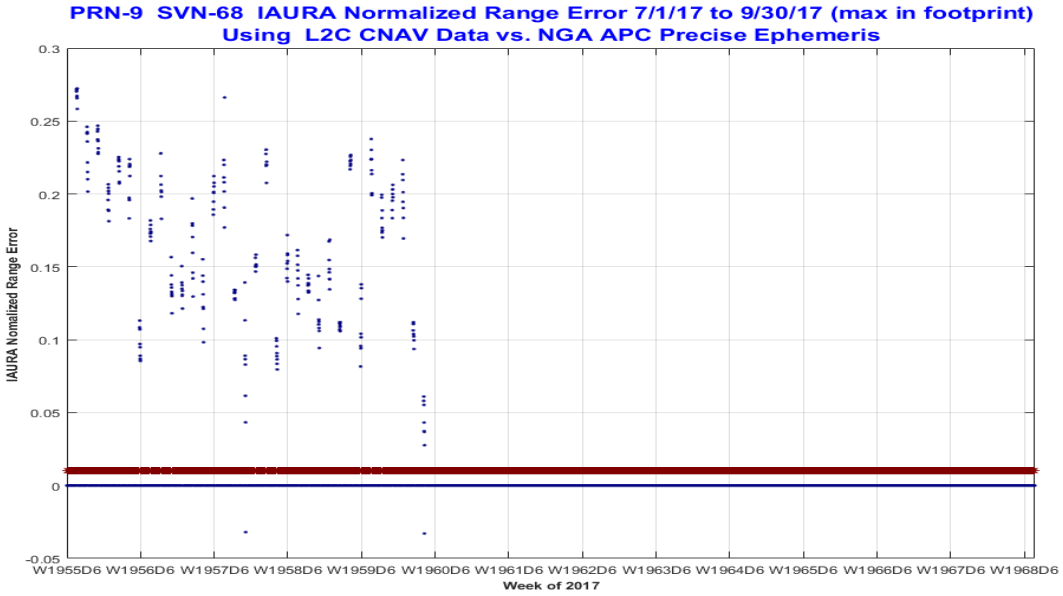


Figure 11-132 Timeline of URA Normalized Range Error PRN-10 (SVN-73) Using C/A Nav Data

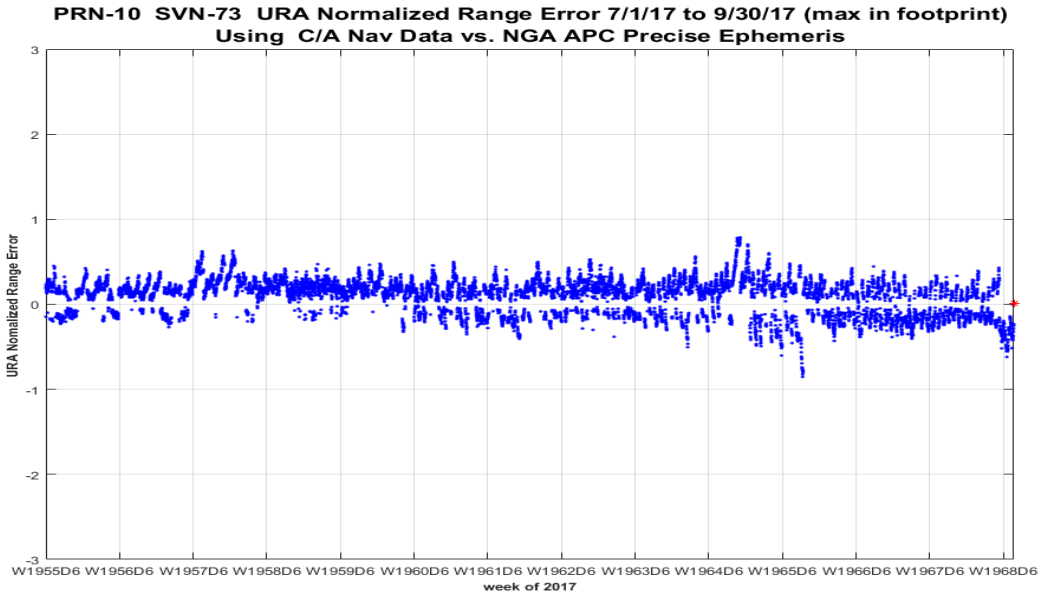


Figure 11-133 Timeline of IAURA Normalized Range Error PRN-10 (SVN-73) Using L2C CNAV Data

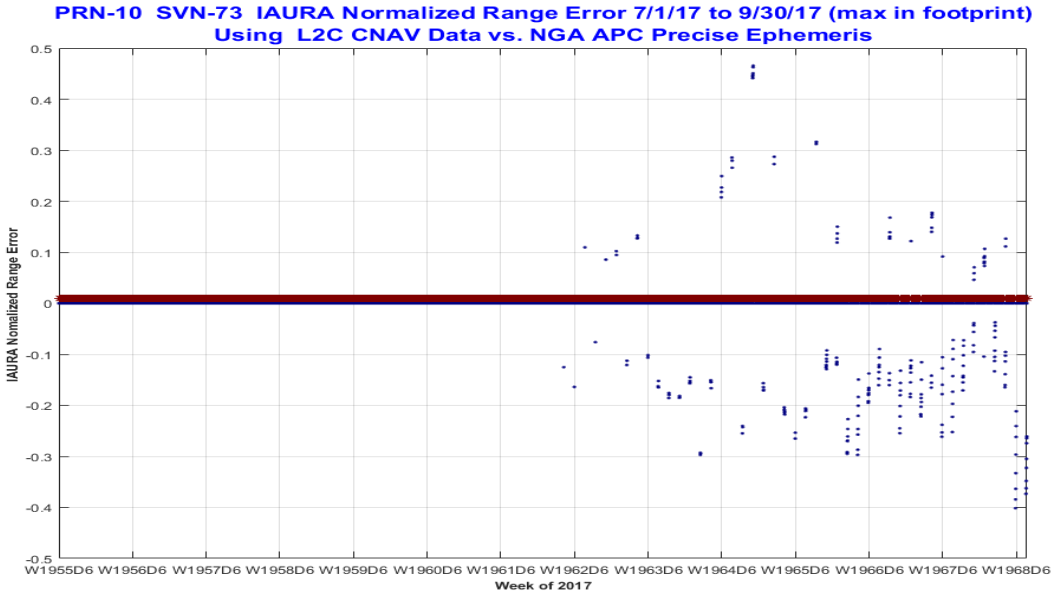


Figure 11-134 Timeline of URA Normalized Range Error PRN-11 (SVN-46) Using C/A Nav Data

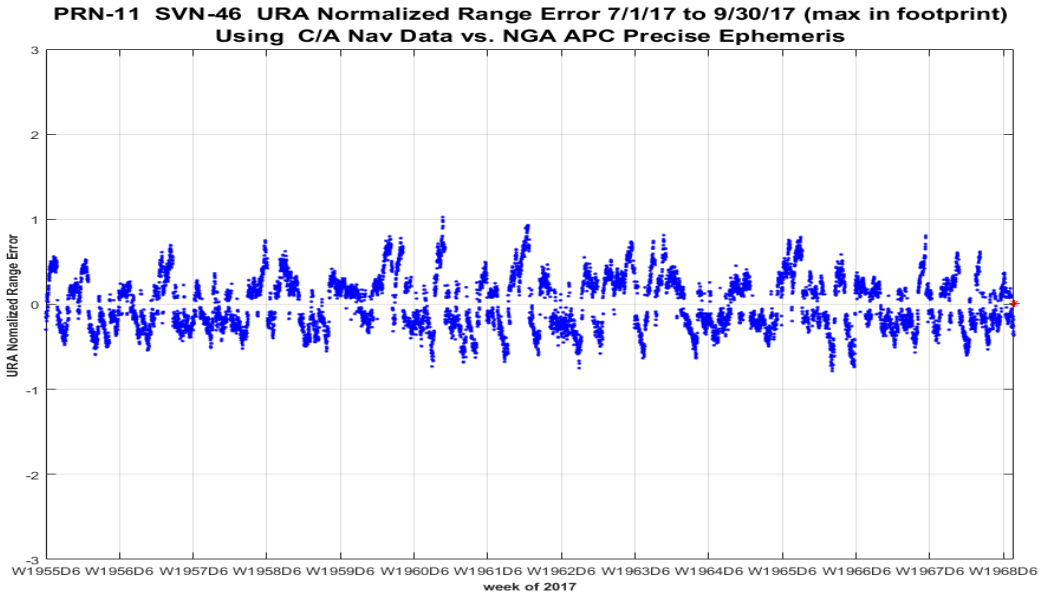


Figure 11-135 Timeline of URA Normalized Range Error PRN-12 (SVN-58) Using C/A Nav Data

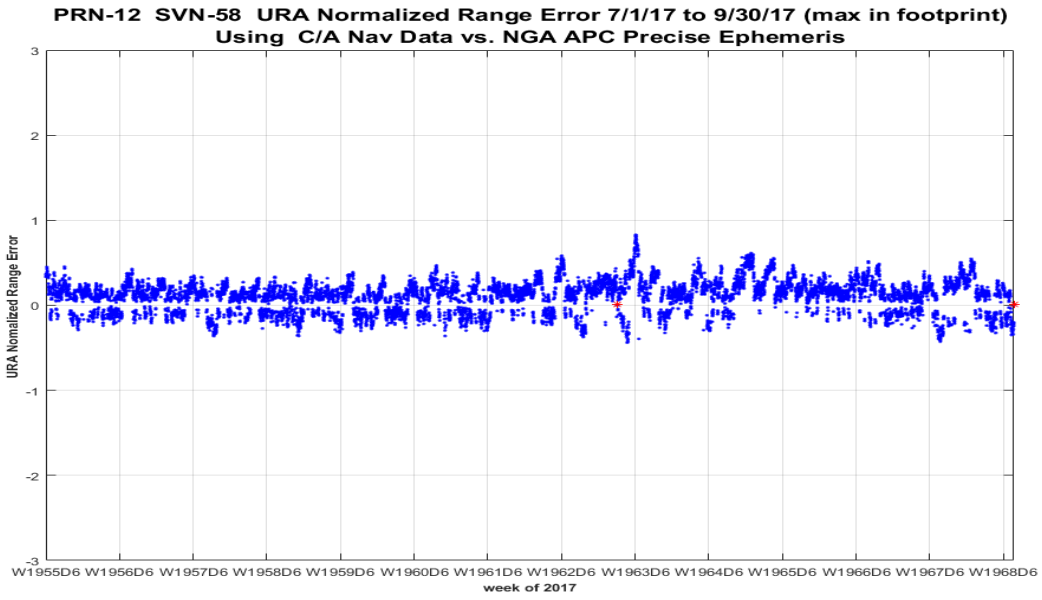


Figure 11-136 Timeline of IAURA Normalized Range Error PRN-12 (SVN-58) Using L2C CNAV Data

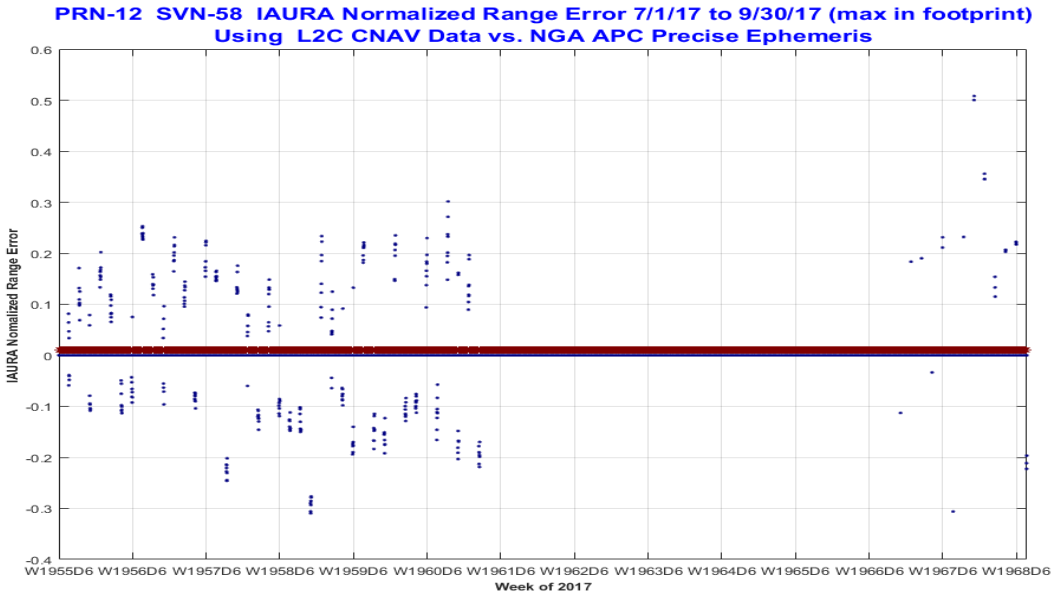


Figure 11-137 Timeline of URA Normalized Range Error PRN-13 (SVN-43) Using C/A Nav Data

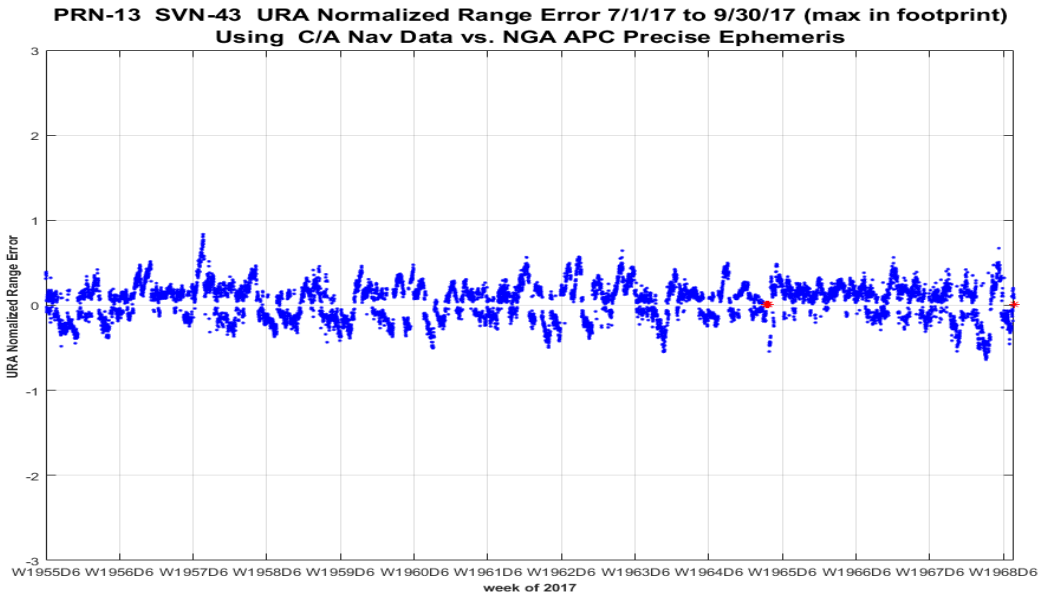


Figure 11-138 Timeline of URA Normalized Range Error PRN-14 (SVN-41) Using C/A Nav Data

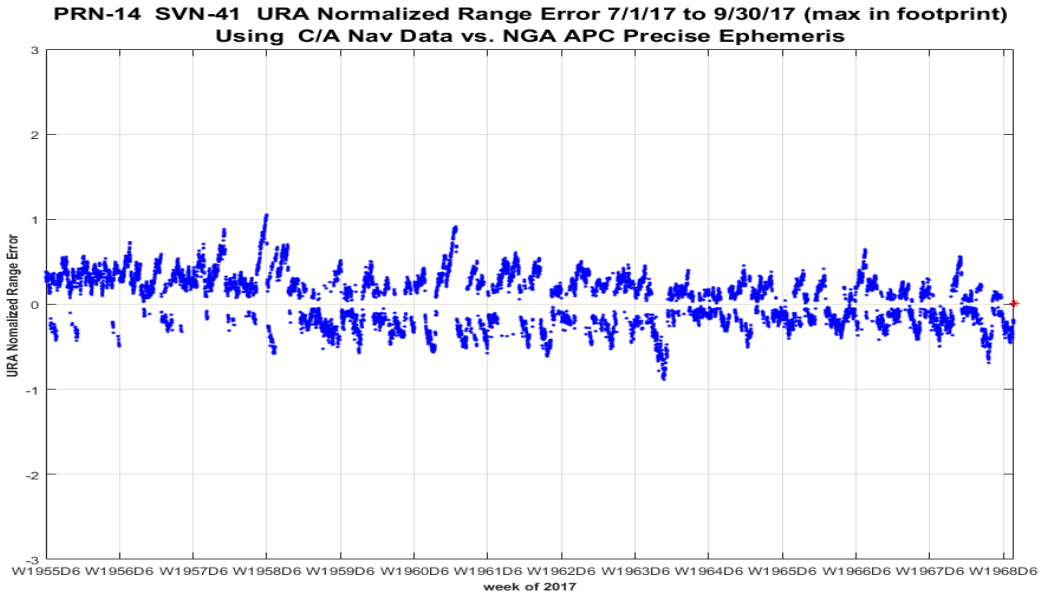


Figure 11-139 Timeline of URA Normalized Range Error PRN-15 (SVN-55) Using C/A Nav Data

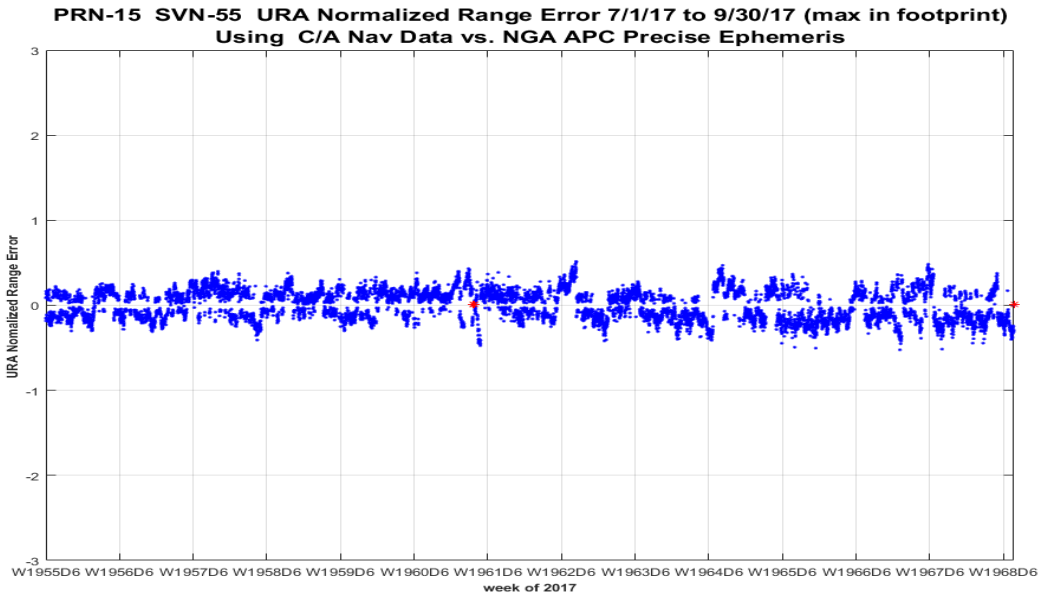


Figure 11-140 Timeline of IAURA Normalized Range Error PRN-15 (SVN-55) Using L2C CNAV Data

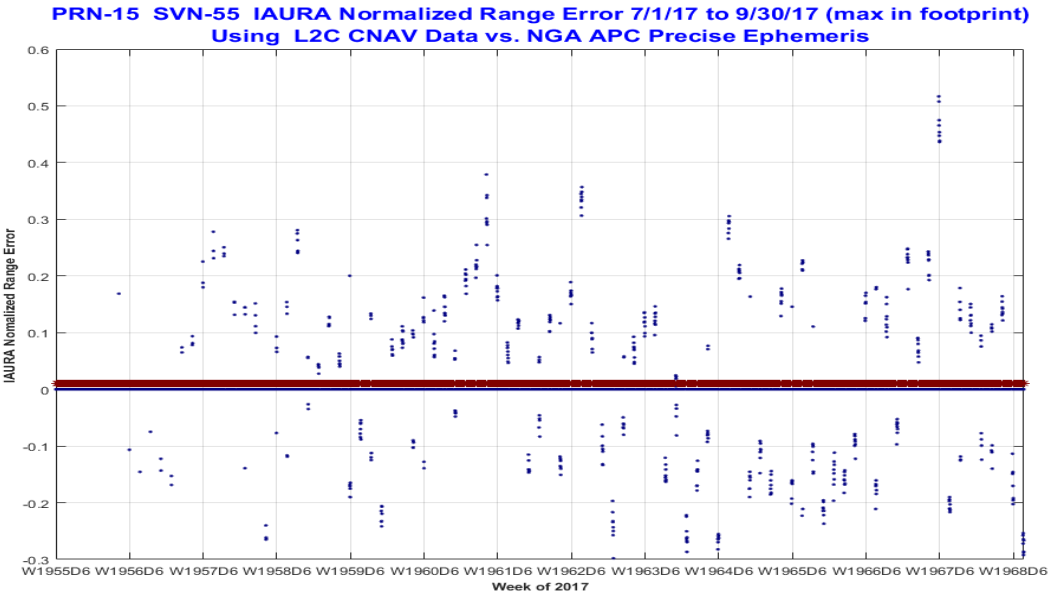


Figure 11-141 Timeline of URA Normalized Range Error PRN-16 (SVN-56) Using C/A Nav Data

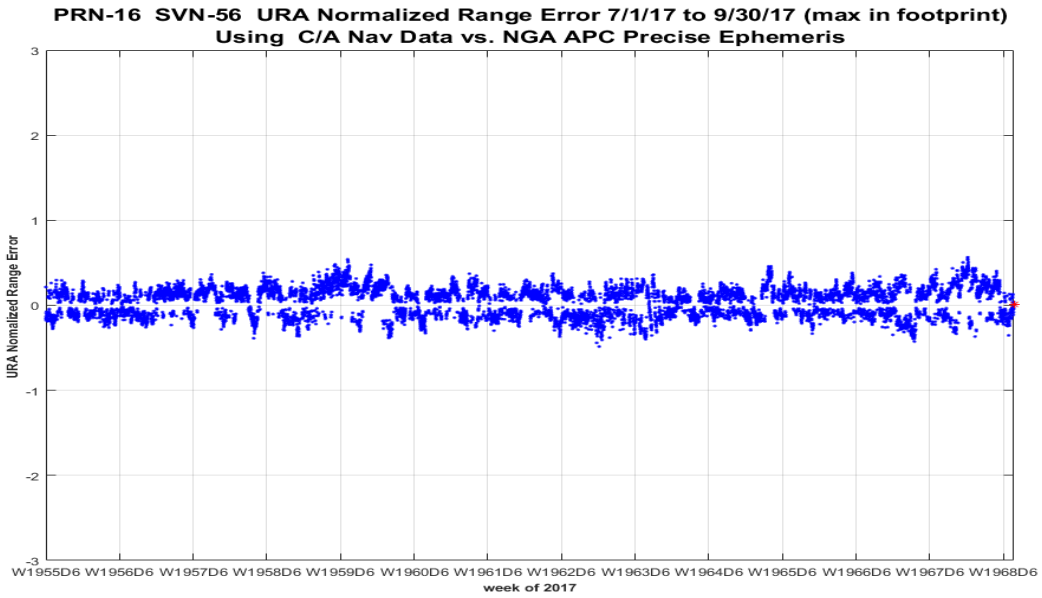


Figure 11-142 Timeline of URA Normalized Range Error PRN-17 (SVN-53) Using C/A Nav Data

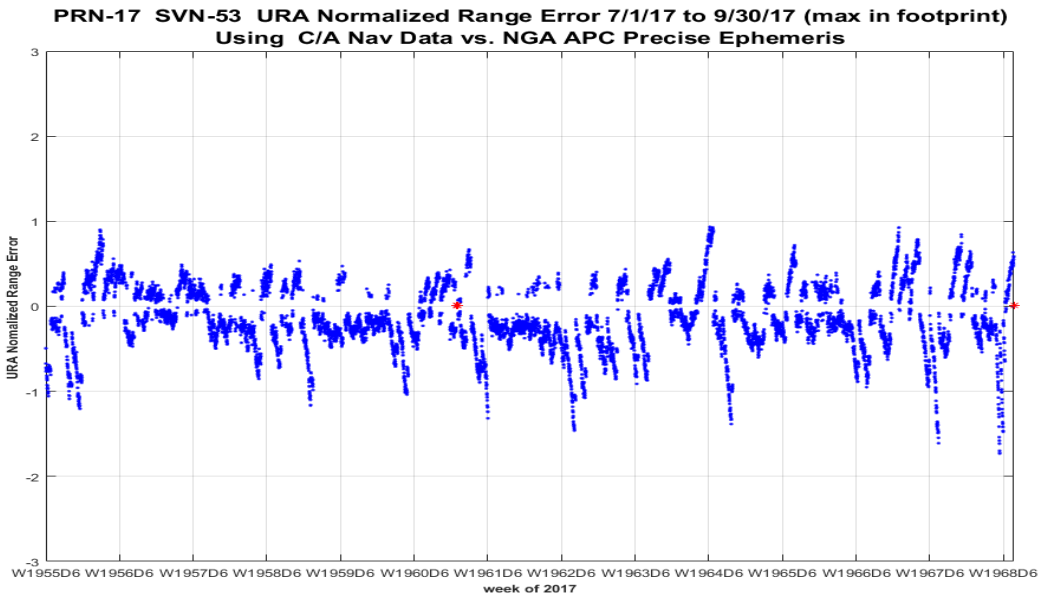


Figure 11-143 Timeline of IAURA Normalized Range Error PRN-17 (SVN-53) Using L2C CNAV Data

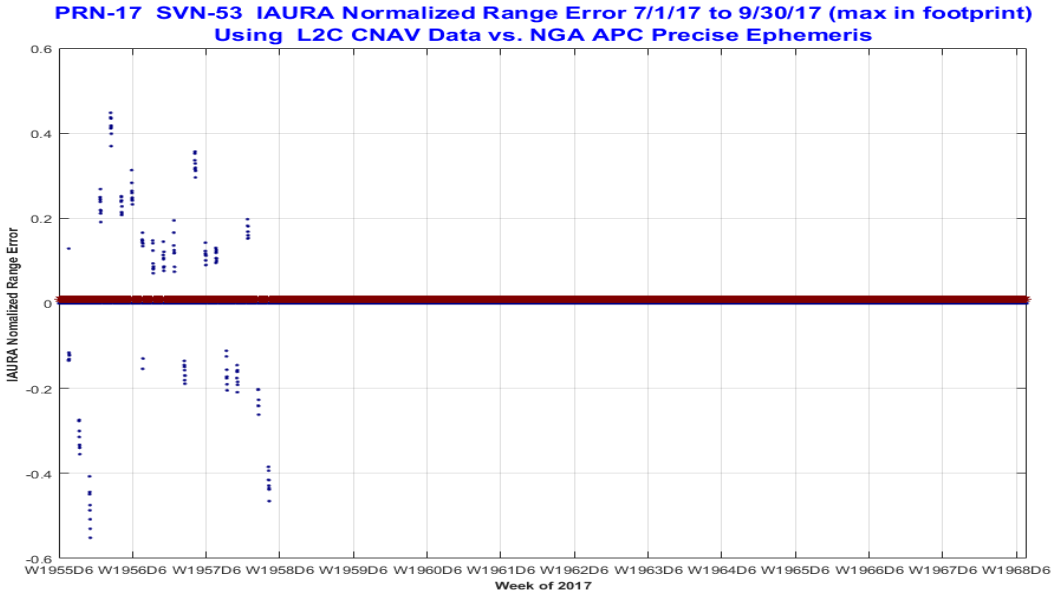


Figure 11-144 Timeline of URA Normalized Range Error PRN-18 (SVN-54) Using C/A Nav Data

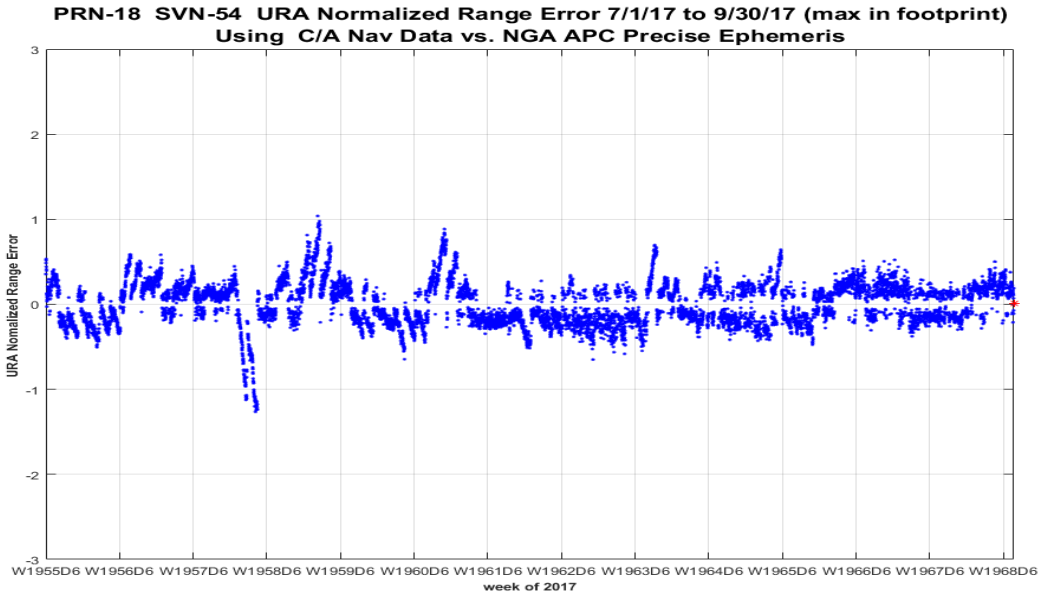


Figure 11-145 Timeline of URA Normalized Range Error PRN-19 (SVN-59) Using C/A Nav Data

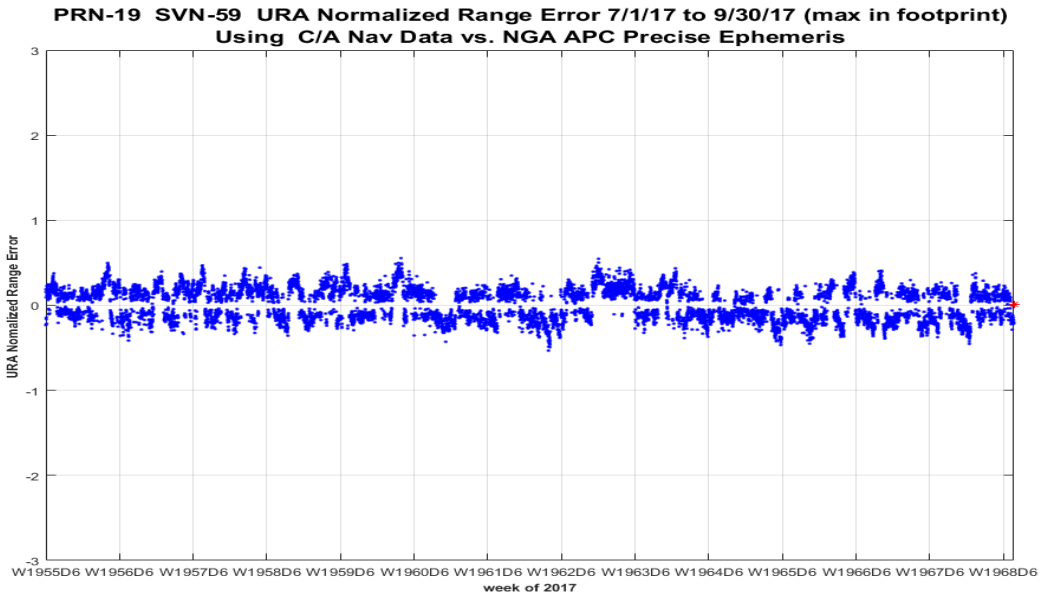


Figure 11-146 Timeline of URA Normalized Range Error PRN-20 (SVN-51) Using C/A Nav Data

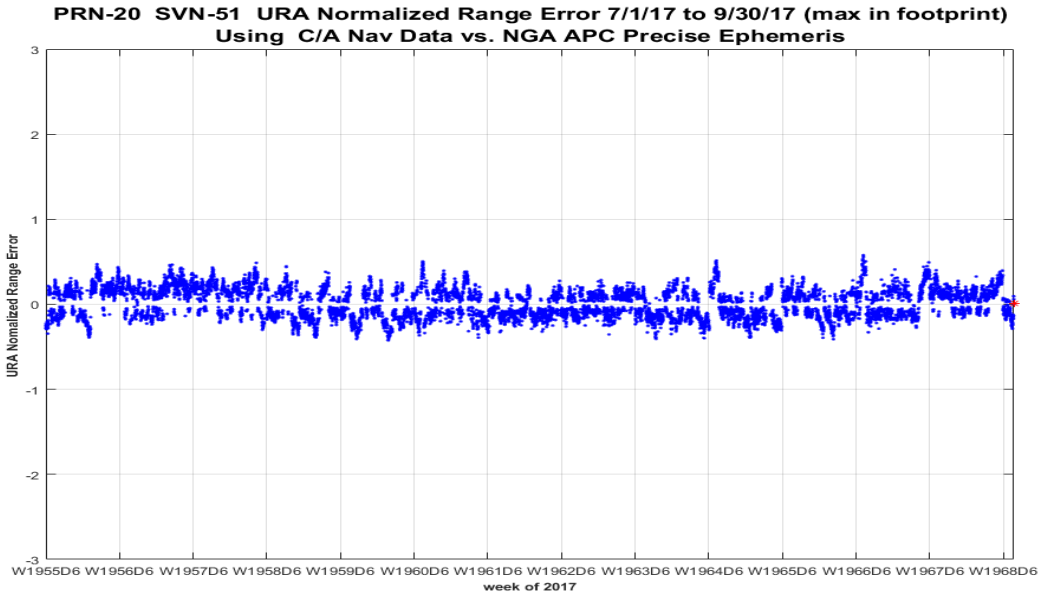


Figure 11-147 Timeline of URA Normalized Range Error PRN-21 (SVN-45) Using C/A Nav Data

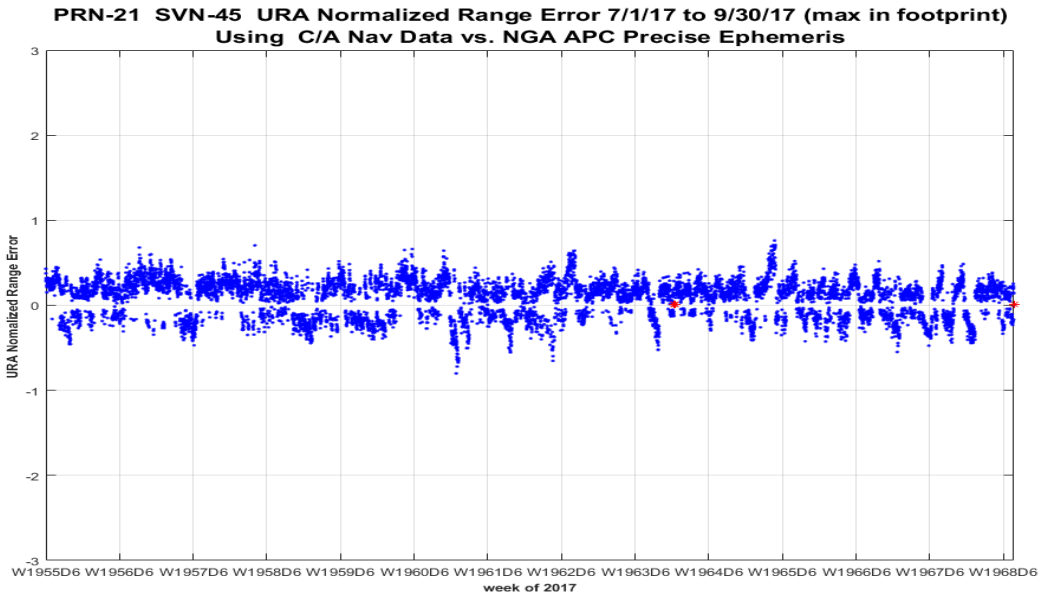


Figure 11-148 Timeline of URA Normalized Range Error PRN-22 (SVN-47) Using C/A Nav Data

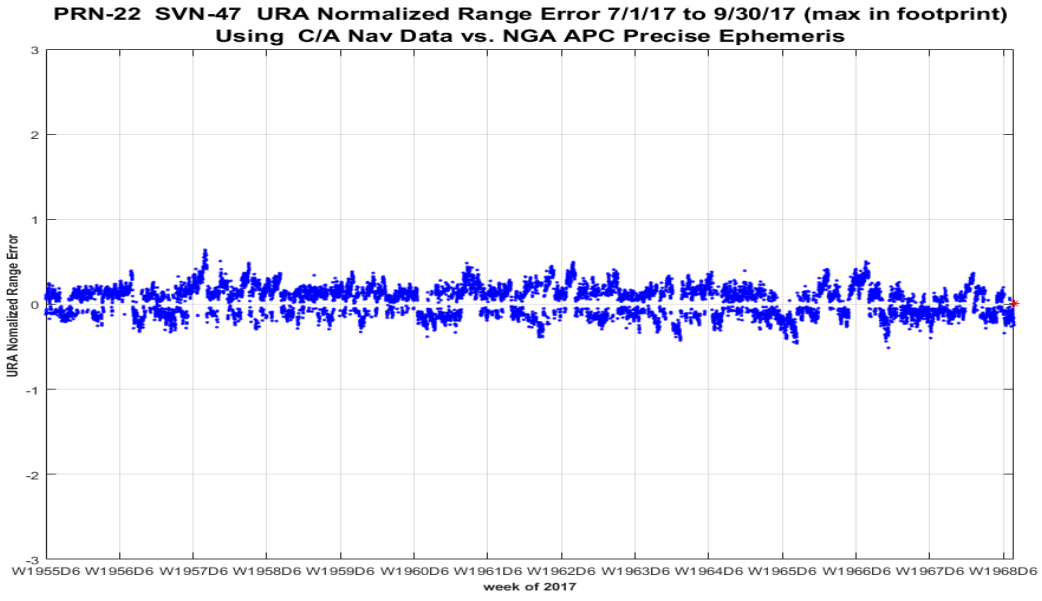


Figure 11-149 Timeline of URA Normalized Range Error PRN-23 (SVN-60) Using C/A Nav Data

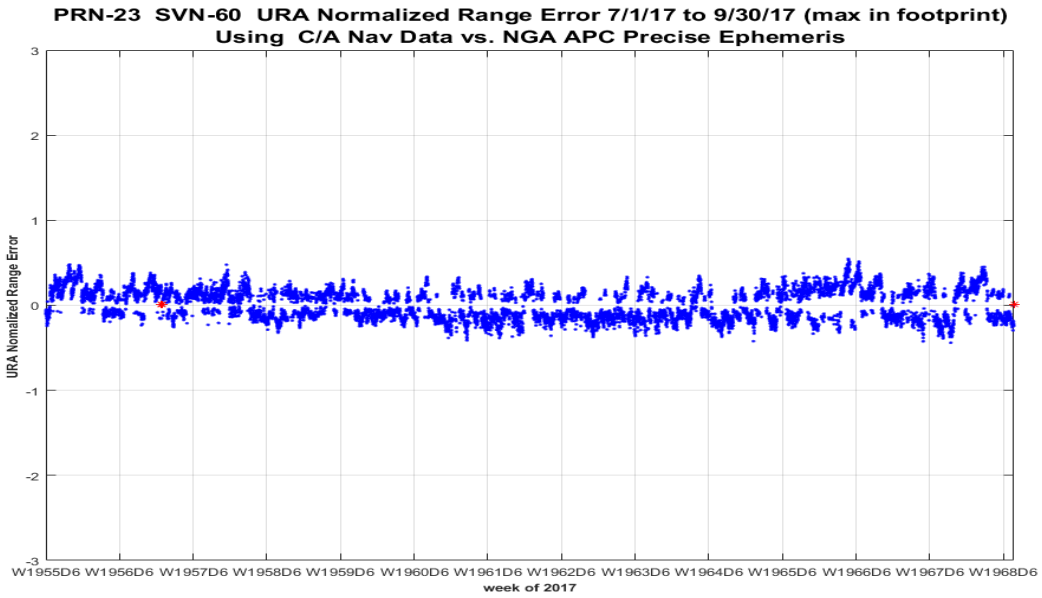


Figure 11-150 Timeline of URA Normalized Range Error PRN-24 (SVN-65) Using C/A Nav Data

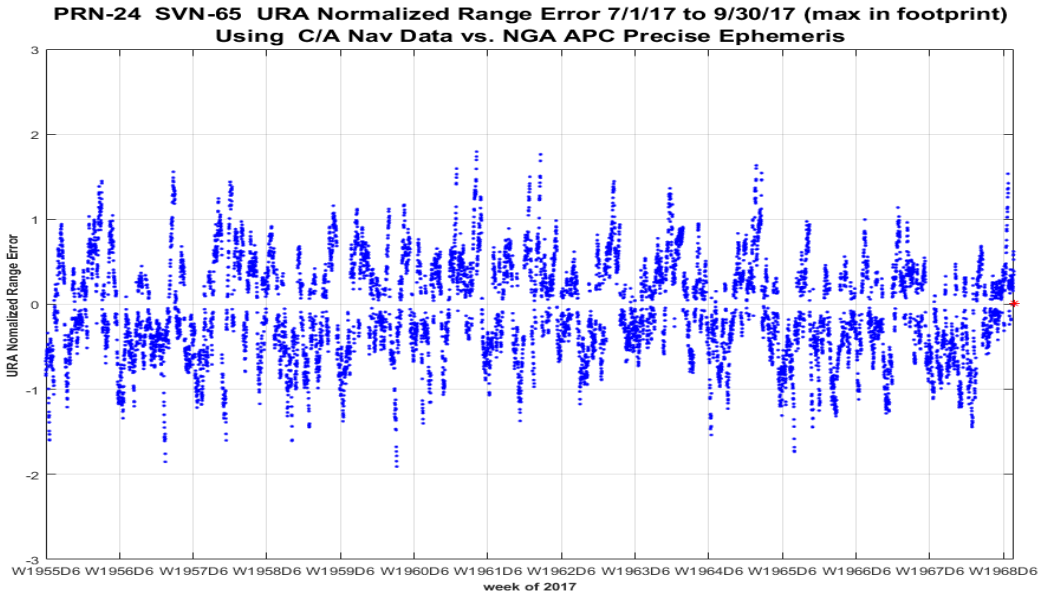


Figure 11-151 Timeline of IAURA Normalized Range Error PRN-24 (SVN-65) Using L2C CNAV Data

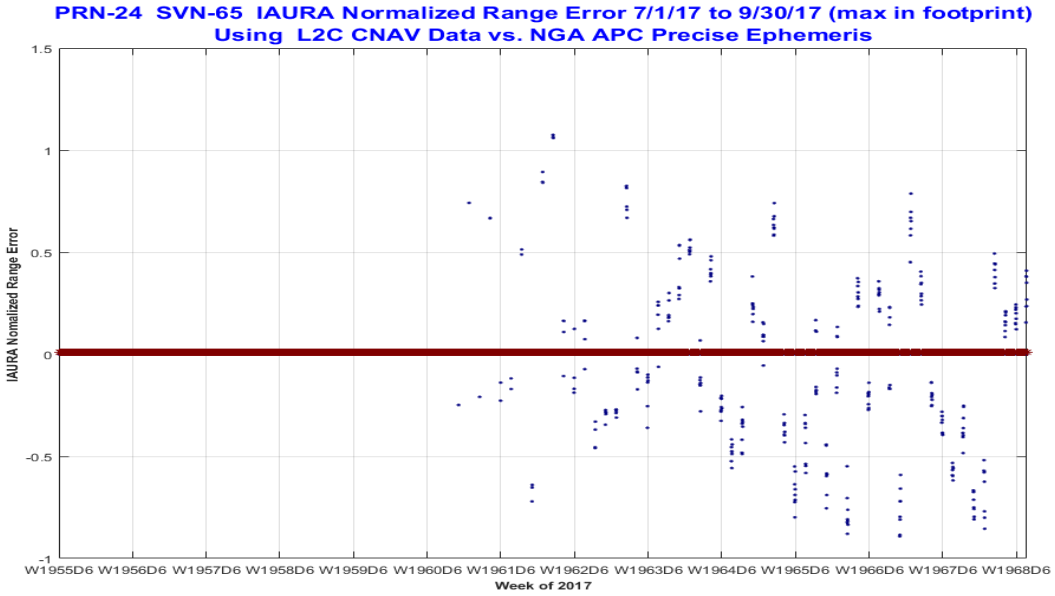


Figure 11-152 Timeline of URA Normalized Range Error PRN-25 (SVN-62) Using C/A Nav Data

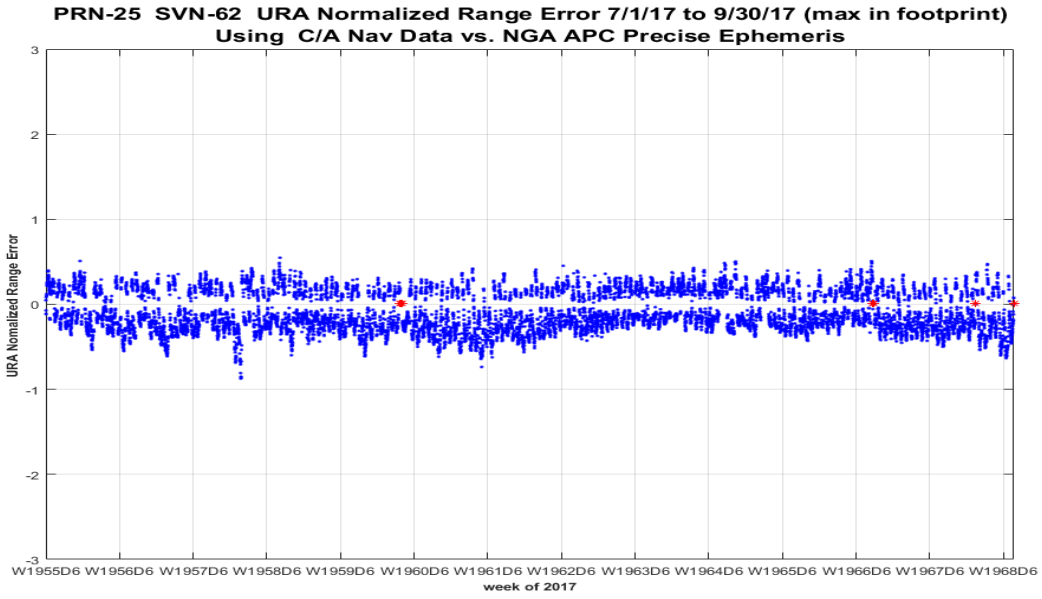


Figure 11-153 Timeline of IAURA Normalized Range Error PRN-25 (SVN-62) Using L2C CNAV Data

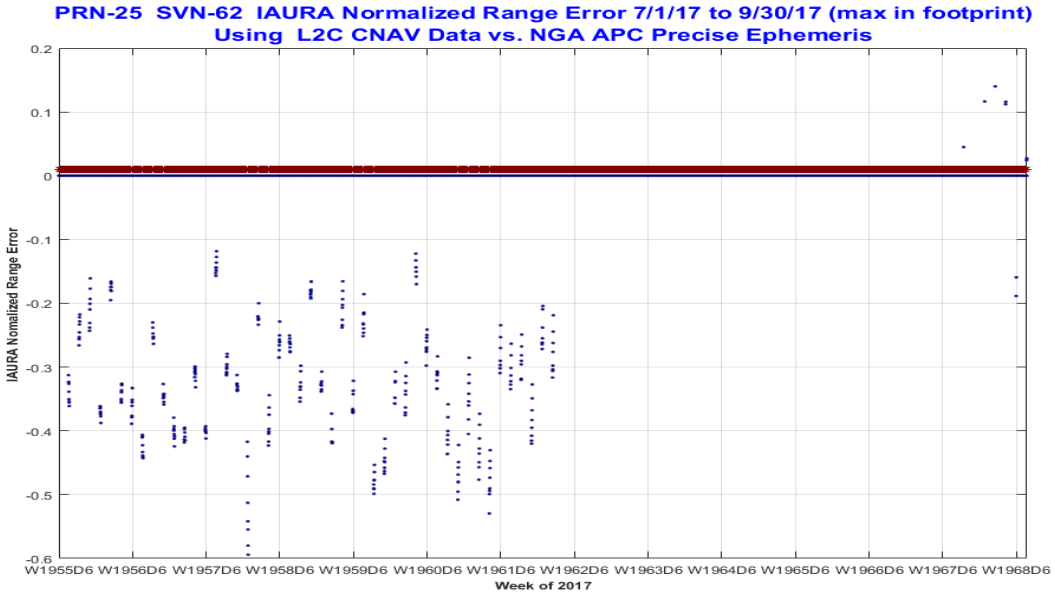


Figure 11-154 Timeline of URA Normalized Range Error PRN-26 (SVN-71) Using C/A Nav Data

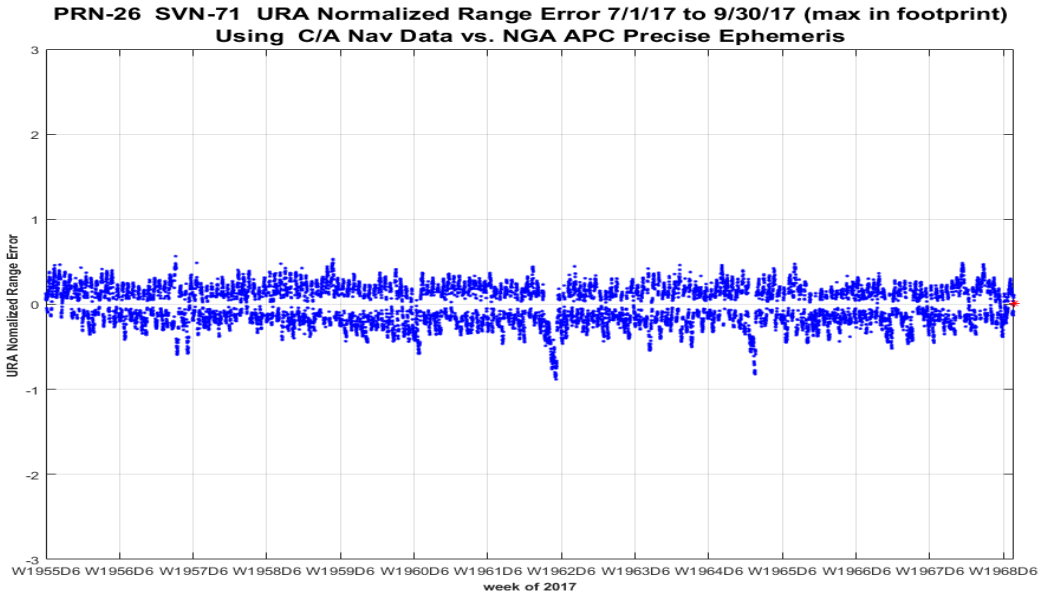


Figure 11-155 Timeline of IAURA Normalized Range Error PRN-26 (SVN-71) Using L2C CNAV Data

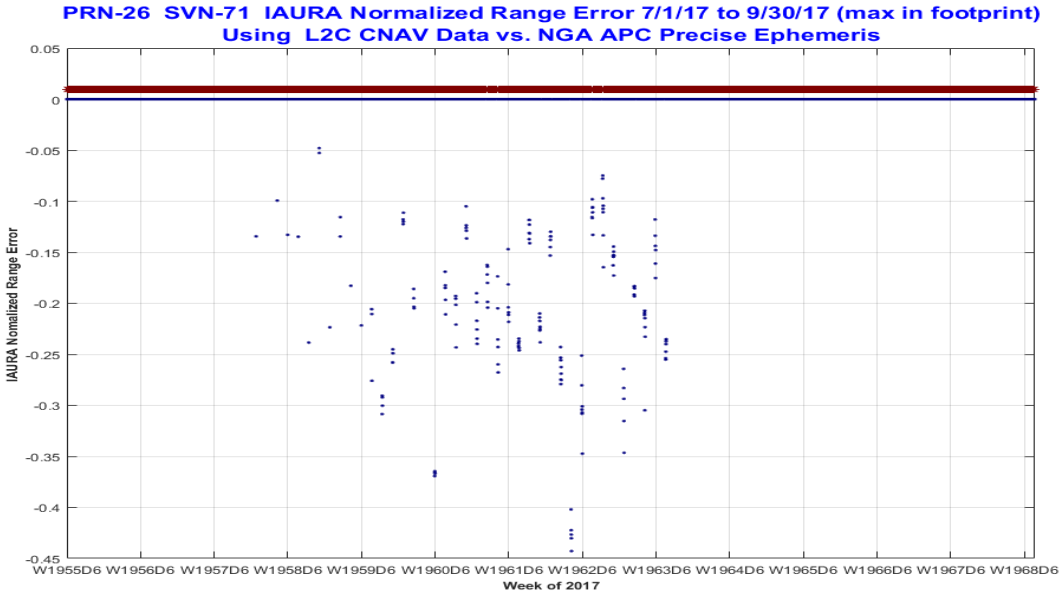


Figure 11-156 Timeline of URA Normalized Range Error PRN-27 (SVN-66) Using C/A Nav Data

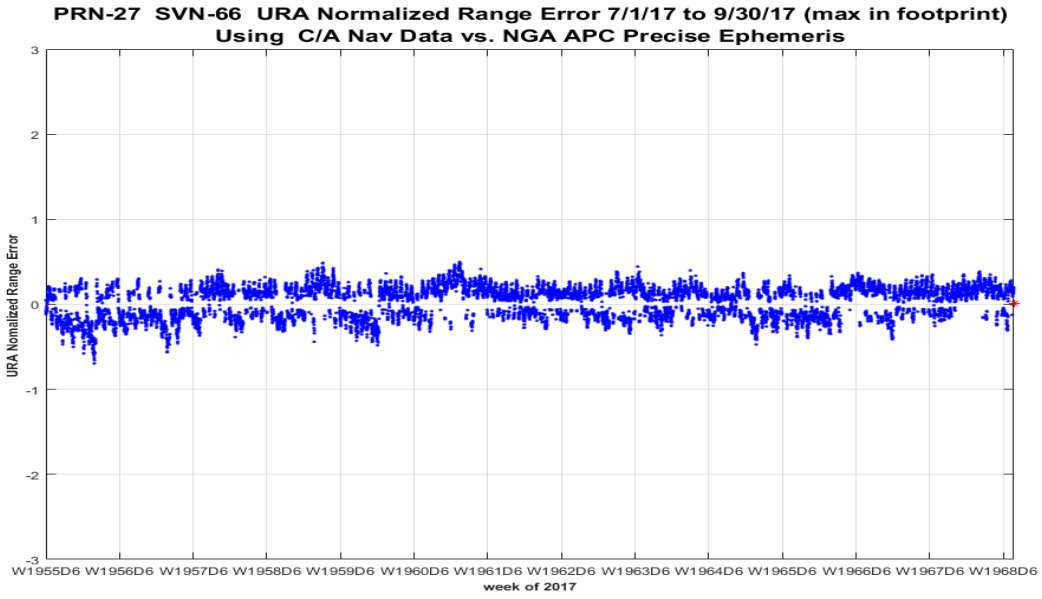


Figure 11-157 Timeline of IAURA Normalized Range Error PRN-27 (SVN-66) Using L2C CNAV Data

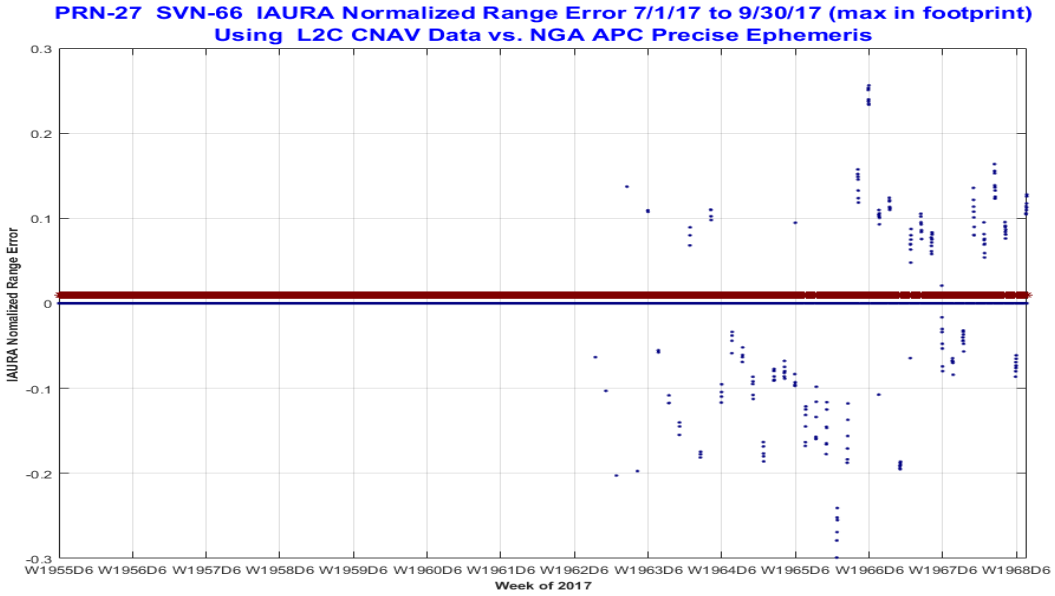


Figure 11-158 Timeline of URA Normalized Range Error PRN-28 (SVN-44) Using C/A Nav Data

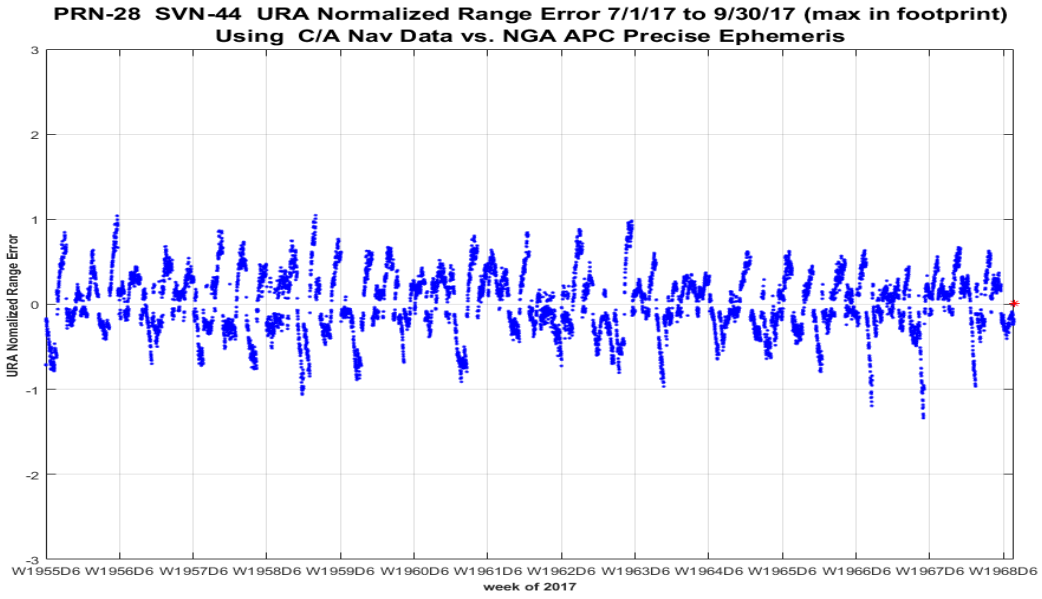


Figure 11-159 Timeline of URA Normalized Range Error PRN-29 (SVN-57) Using C/A Nav Data

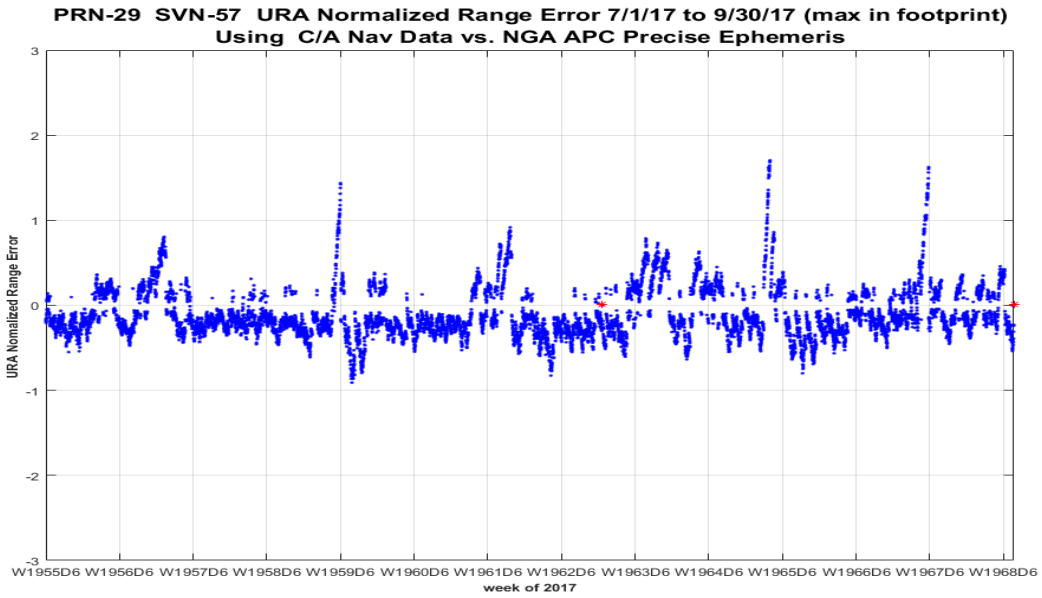


Figure 11-160 Timeline of IAURA Normalized Range Error PRN-29 (SVN-57) Using L2C CNAV Data

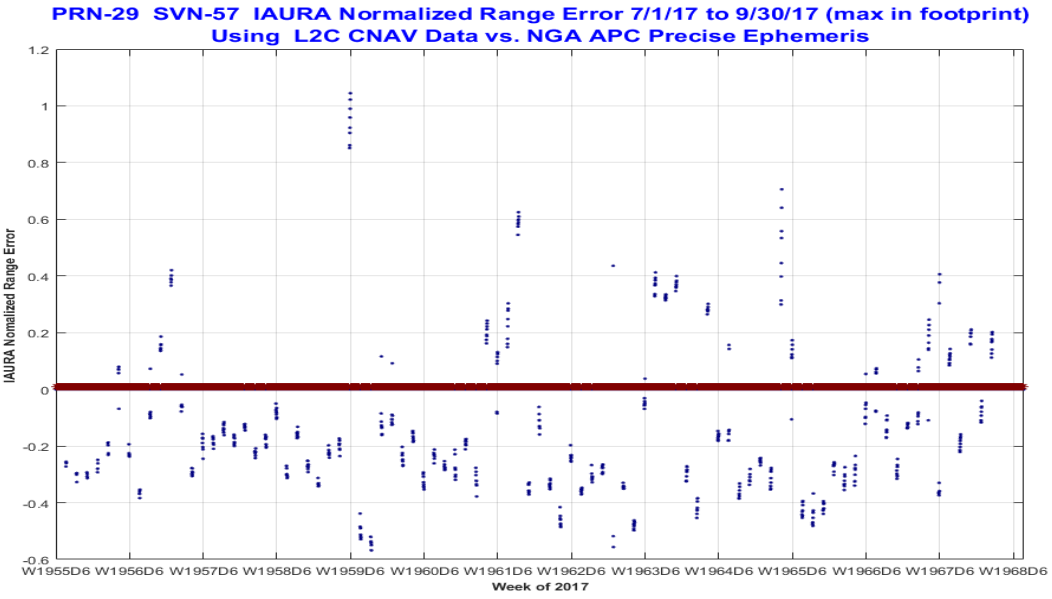


Figure 11-161 Timeline of URA Normalized Range Error PRN-30 (SVN-64) Using C/A Nav Data

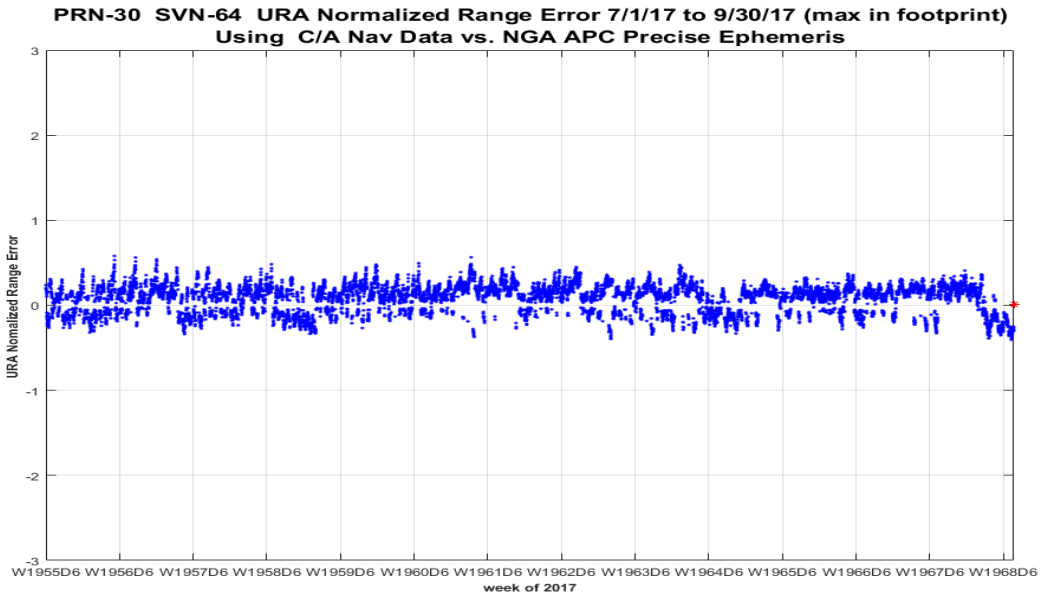


Figure 11-162 Timeline of IAURA Normalized Range Error PRN-30 (SVN-64) Using L2C CNAV Data

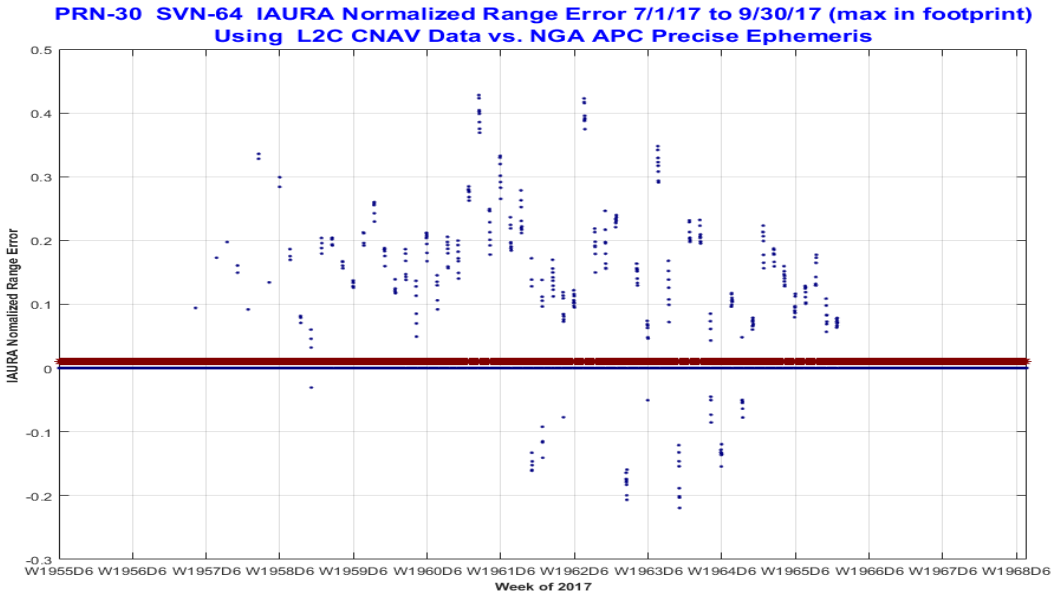


Figure 11-163 Timeline of URA Normalized Range Error PRN-31 (SVN-52) Using C/A Nav Data

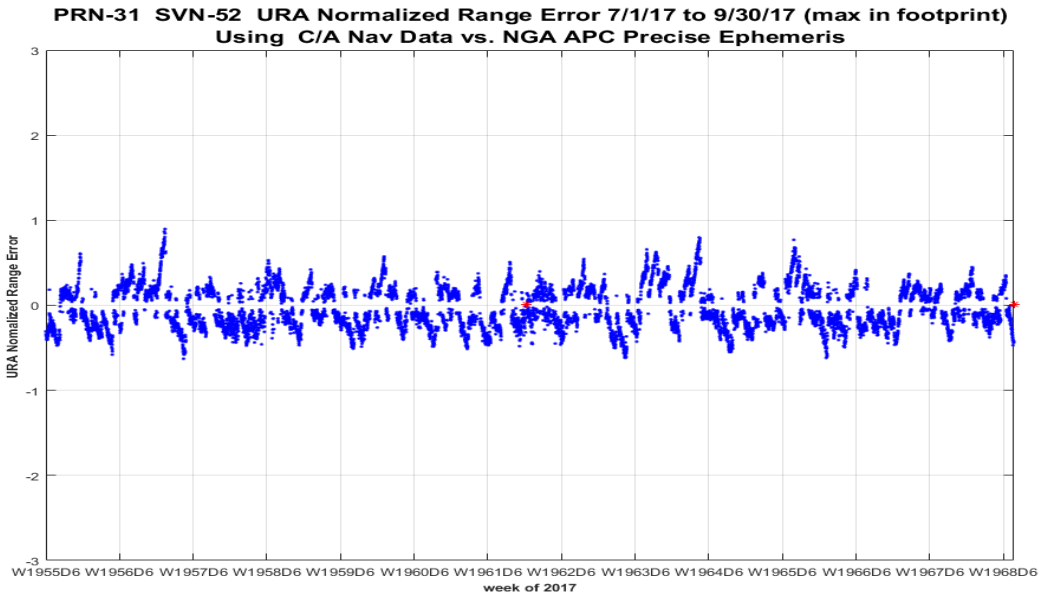


Figure 11-164 Timeline of URA Normalized Range Error PRN-32 (SVN-70) Using C/A Nav Data

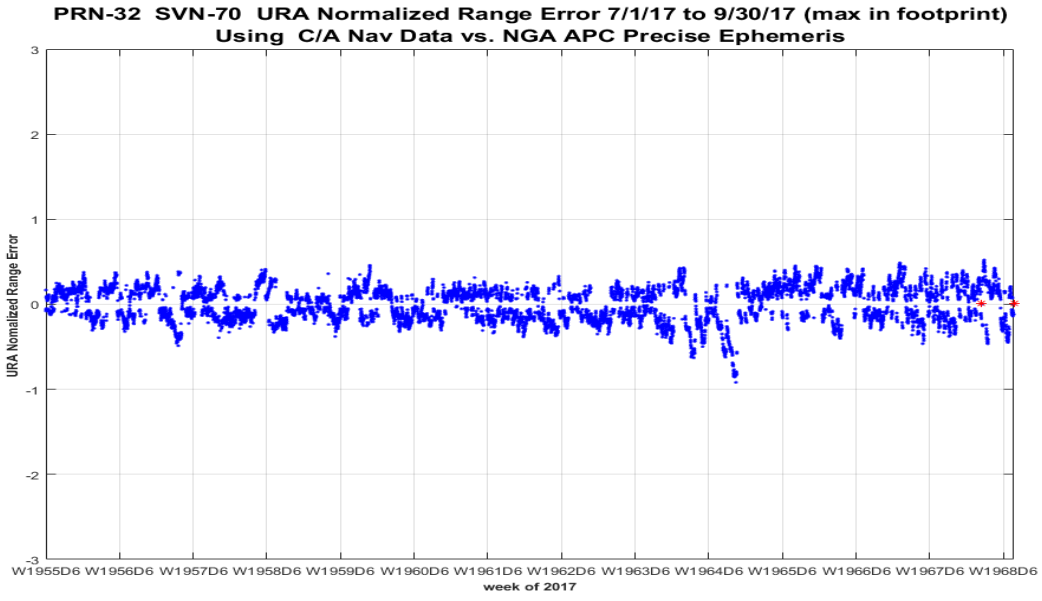
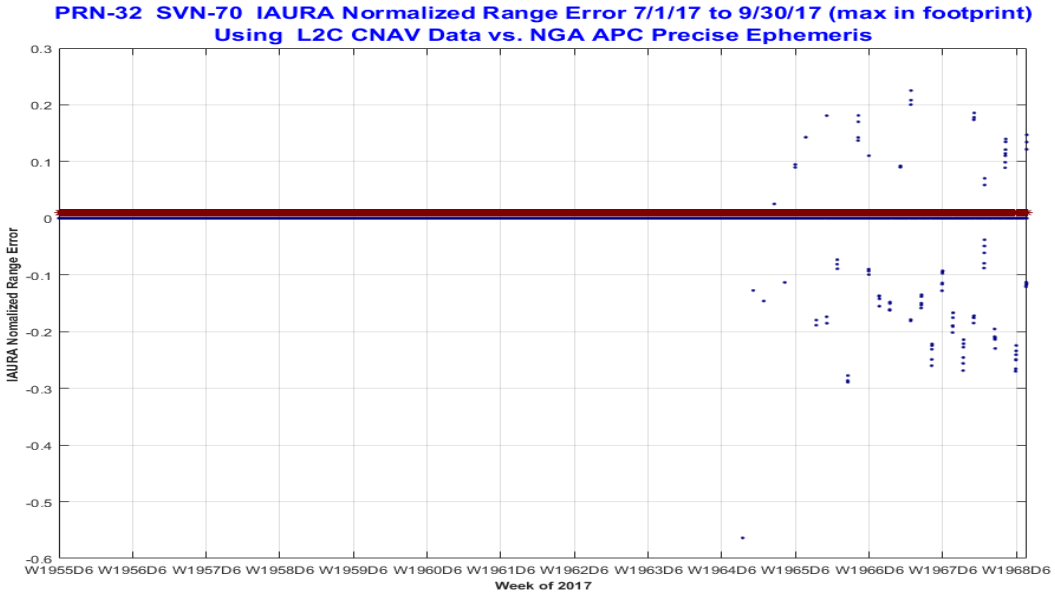



Figure 11-165 Timeline of IAURA Normalized Range Error PRN-32 (SVN-70) Using L2C CNAV Data