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

Submitted To

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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 #100, includes data collected from 1 October through 31 December 2017. The next quarterly report will be issued April 30, 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 99.9997%.

NANU summary and evaluation was achieved by reviewing the "Notice: Advisory to Navstar Users" (NANU) reports issued between 1 October and 31 December 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 nine outages were reported in the NANU's this quarter. Eight outages were scheduled ahead of time, while one 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 15.479 meters on Satellite PRN 23. 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 2.209 meters was recorded on satellite PRN 19. 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 4.98 meters at Maspalomas, Spain and 5.36 meters at Bishkek, Kyrgyzstan respectively.

From the analysis performed on data collected between 1 October and 31 December 2017, the GPS performance met all SPS requirements that were evaluated.

TABLE OF CONTENTS

1 Introduction 14
1.1 Objective of GPS SPS Performance Analysis Report 14
1.2 Report Overview 15
1.3 Summary of Performance Requirements and Metrics 15
2 PDOP Availability Standard 20
3 NANU Summary and Evaluation 23
3.1 Satellite Outages from NANU Reports 23
3.2 Service Availability Standard 25
4 Service Reliability Standard 27
5 Accuracy Standard 28
5.1 Position Accuracy 29
5.2 Time Transfer Accuracy 31
5.3 Range Domain Accuracy 32
6 Solar Storms 38
7 IGS Data 41
8 RAIM Performance 44
8.1 Site Performance 44
8.2 RAIM Coverage 45
8.3 RAIM Airport Analysis 48
9 GPS Test NOTAMs Summary 52
9.1 GPS Test NOTAMs Issued 52
9.2 Tracking and Trending of GPS Test NOTAMs 52
9.3 GPS Availability 55
10 Appendices 59
10.1 Appendix A: Performance Summary 59
10.2 Appendix B: Geomagnetic Data 62
10.3 Appendix C: Performance Analysis (PAN) Problem Report 64
10.4 Appendix D: Glossary 65
11 GPS Broadcast Orbit Versus NGA Precise Orbits and URA (IAURA) Bounding Analyses 68

Broadcast Ephemeris vs. NGA Precise Data Availability Plots 72
Current GPS Constellation 72
URA Over-bounding Plots 74
Orbit Error Plots for All Satellites 75
QQ Plots of URA Normalized Error for All Satellites 100
Histogram Plost of H, A, C, and Range Error for All Satellites 106
Timeline of URA Normalized Range Error for All Satellites 129

LIST OF FIGURES

Figure 2-1 World GPS Maximum PDOP 21
Figure 2-2 Satellite Visibility Profile for Worst-Case Point 22
Figure 5-1 Global Vertical Error Histogram 30
Figure 5-2 Global Horizontal Error Histogram 30
Figure 5-3 Time Transfer Error 31
Figure 5-4 Distribution of Daily Max Range Errors 35
Figure 5-5 Distribution of Daily Max Range Rate Errors 35
Figure 5-6 Distribution of Daily max Range Acceleration Errors 36
Figure 5-7 Range Error Histogram 36
Figure 5-8 Maximum Range Error Per Satellite 37
Figure 5-9 Maximum Range Rate Error Per Satellite 37
Figure 5-10 Maximum Range Acceleration Error Per Satellite 37
Figure 6-1 K-Index for 7-9 November 2017 39
Figure 6-2 K-Index for 12-14 October 2017 39
Figure 6-3 K-Index for 4-6 December 2017 39
Figure 7-1 Selected IGS Site Locations 42
Figure 7-2 GPS SPS 95% Horizontal Accuracy Trends at Selected IGS Sites 43
Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites 43
Figure 8-1 RAIM RNP 0.1 Coverage 46
Figure 8-2 RAIM RNP 0.3 Coverage 46
Figure 8-3 RAIM World Wide Coverage Trend 47
Figure 8-4 RAIM RNP Coverage Trend for WAAS NPA Service Area 47
Figure 8-5 RAIM RNP 0.1 Airport Availability 48
Figure 8-6 RAIM RNP 0.3 Airport Availability 49
Figure 8-7 RAIM RNP 0.1 Airport Outages 50
Figure 8-8 RAIM RNP 0.3 Airport Outages 51
Figure 9-1 GPS Test NOTAMs @ FL400 53
Figure 9-2 GPS NOTAMs @ FL250 53
Figure 9-3 GPS NOTAMs @ 10k Feet 54
Figure 9-4 GPS NOTAMs @ 4k Feet 54
Figure 9-5 GPS NOTAMs @ 50 Feet 54
Figure 11-1 GPS Broadcast Orbit Accuracy Standard Deviation Plots 70
Figure 11-1 GPS Broadcast Orbit Accuracy Standard Deviations Using C/A Nav Data 70
Figure 11-2 GPS Broadcast Orbit Accuracy Standard Deviations Using L2C CNAV Data 70
Figure 11-3 GPS Broadcast Orbit Error Means Using C/A Nav Data 71
Figure 11-4 GPS Broadcast Orbit Error Means Using L2C CNAV Data 71
Figure 11-5 Broadcast Ephemeris vs. NGA Precise Data Availability Plots 72
Figure 11-6 Current GPS Constellation 72

Figure 11-7 URA Over-bounding Using C/A Nav Data 74
Figure 11-8 IAURA Over-bounding Using L2C CNAV Data 74
Figure 11-9 Orbit Error PRN-1 (SVN-63) Using C/A Nav Data 75
Figure 11-10 Orbit Error PRN-1 (SVN-63) Using L2C CNAV Data 75
Figure 11-11 Orbit Error PRN-2 (SVN-61) Using C/A Nav Data 76
Figure 11-12 Orbit Error PRN-3 (SVN-69) Using C/A Nav Data 76
Figure 11-13 Orbit Error PRN-3 (SVN-69) Using L2C CNAV Data 77
Figure 11-14 Orbit Error PRN-5 (SVN-50) Using C/A Nav Data 77
Figure 11-15 Orbit Error PRN-5 (SVN-50) Using L2C CNAV Data 78
Figure 11-16 Orbit Error PRN-6 (SVN-67) Using C/A Nav Data 78
Figure 11-17 Orbit Error PRN-6 (SVN-67) Using L2C CNAV Data 79
Figure 11-18 Orbit Error PRN-7 (SVN-48) Using C/A Nav Data 79
Figure 11-19 Orbit Error PRN-7 (SVN-48) Using L2C CNAV Data 80
Figure 11-20 Orbit Error PRN-8 (SVN-72) Using C/A Nav Data 80
Figure 11-21 Orbit Error PRN-8 (SVN-72) Using L2C CNAV Data 81
Figure 11-22 Orbit Error PRN-9 (SVN-68) Using C/A Nav Data 81
Figure 11-23 Orbit Error PRN-9 (SVN-68) Using L2C CNAV Data 82
Figure 11-24 Orbit Error PRN-10 (SVN-73) Using C/A Nav Data 82
Figure 11-25 Orbit Error PRN-10 (SVN-73) Using L2C CNAV Data 83
Figure 11-26 Orbit Error PRN-11 (SVN-46) Using C/A Nav Data 83
Figure 11-27 Orbit Error PRN-12 (SVN-58) Using C/A Nav Data 84
Figure 11-28 Orbit Error PRN-12 (SVN-58) Using L2C CNAV Data 84
Figure 11-29 Orbit Error PRN-13 (SVN-43) Using C/A Nav Data 85
Figure 11-30 Orbit Error PRN-14 (SVN-41) Using C/A Nav Data 85
Figure 11-31 Orbit Error PRN-15 (SVN-55) Using C/A Nav Data 86
Figure 11-32 Orbit Error PRN-15 (SVN-55) Using L2C CNAV Data 86
Figure 11-33 Orbit Error PRN-16 (SVN-56) Using C/A Nav Data 87
Figure 11-34 Orbit Error PRN-17 (SVN-53) Using C/A Nav Data 87
Figure 11-35 Orbit Error PRN-17 (SVN-53) Using L2C CNAV Data 88
Figure 11-36 Orbit Error PRN-18 (SVN-54) Using C/A Nav Data 88
Figure 11-37 Orbit Error PRN-19 (SVN-59) Using C/A Nav Data 89
Figure 11-38 Orbit Error PRN-20 (SVN-51) Using C/A Nav Data 89
Figure 11-39 Orbit Error PRN-21 (SVN-45) Using C/A Nav Data 90
Figure 11-40 Orbit Error PRN-22 (SVN-47) Using C/A Nav Data 90
Figure 11-41 Orbit Error PRN-23 (SVN-60) Using C/A Nav Data 91
Figure 11-42 Orbit Error PRN-24 (SVN-65) Using C/A Nav Data 91
Figure 11-43 Orbit Error PRN-24 (SVN-65) Using L2C CNAV Data 92
Figure 11-44 Orbit Error PRN-25 (SVN-62) Using C/A Nav Data 92
Figure 11-45 Orbit Error PRN-25 (SVN-62) Using L2C CNAV Data 93
Figure 11-46 Orbit Error PRN-26 (SVN-71) Using C/A Nav Data 93

Figure 11-47 Orbit Error PRN-26 (SVN-71) Using L2C CNAV Data 94
Figure 11-48 Orbit Error PRN-27 (SVN-66) Using C/A Nav Data 94
Figure 11-49 Orbit Error PRN-27 (SVN-66) Using L2C CNAV Data 95
Figure 11-50 Orbit Error PRN-28 (SVN-44) Using C/A Nav Data 95
Figure 11-51 Orbit Error PRN-29 (SVN-57) Using C/A Nav Data 96
Figure 11-52 Orbit Error PRN-29 (SVN-57) Using L2C CNAV Data 96
Figure 11-53 Orbit Error PRN-30 (SVN-64) Using C/A Nav Data 97
Figure 11-54 Orbit Error PRN-30 (SVN-64) Using L2C CNAV Data 97
Figure 11-55 Orbit Error PRN-31 (SVN-52) Using C/A Nav Data 98
Figure 11-56 Orbit Error PRN-31 (SVN-52) Using L2C CNAV Data 98
Figure 11-57 Orbit Error PRN-32 (SVN-70) Using C/A Nav Data 99
Figure 11-58 Orbit Error PRN-32 (SVN-70) Using L2C CNAV Data 99
Figure 11-59 QQ Plots of Range Error PRNs 1 to 5 Using C/A Nav Data 100
Figure 11-60 QQ Plots of Range Error PRNs 6 to 9 Using C/A Nav Data 100
Figure 11-61 QQ Plots of Range Error PRNs 10 to 13 Using C/A Nav Data 101
Figure 11-62 QQ Plots of Range Error PRNs 14 to 17 Using C/A Nav Data 101
Figure 11-63 QQ Plots of Range Error PRNs 18 to 21 Using C/A Nav Data 102
Figure 11-64 QQ Plots of Range Error PRNs 22 to 25 Using C/A Nav Data 102
Figure 11-65 QQ Plots of Range Error PRNs 26 to 29 Using C/A Nav Data 103
Figure 11-66 QQ Plots of Range Error PRNs 30 to 32 Using C/A Nav Data 103
Figure 11-67 QQ Plots of Range Error PRNs 1, 3, 5, and 8 Using L2C CNAV Data 104
Figure 11-68 QQ Plots of Range Error PRNs 9, 10, 12, and 15 Using L2C CNAV Data 104
Figure 11-69 QQ Plots of Range Error PRNs 24, 25, 26, and 27 Using L2C CNAV Data 105
Figure 11-70 QQ Plots of Range Error PRNs 29, 31, and 32 Using L2C CNAV Data 105
Figure 11-71 Histograms of H, A, C, and Range Error PRN-1 (SVN-63) Using C/A Nav Data 106
Figure 11-72 Histograms of H, A, C, and Range Error PRN-1 (SVN-63) Using L2C CNAV Data 106
Figure 11-73 Histograms of H, A, C, and Range Error PRN-2 (SVN-61) Using C/A Nav Data 107
Figure 11-74 Histograms of H, A, C, and Range Error PRN-3 (SVN-69) Using C/A Nav Data 107
Figure 11-75 Histograms of H, A, C, and Range Error PRN-3 (SVN-69) Using L2C CNAV Data 108
Figure 11-76 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using C/A Nav Data 108
Figure 11-77 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using L2C CNAV Data 109
Figure 11-78 Histograms of H, A, C, and Range Error PRN-6 (SVN-67) Using C/A Nav Data 109

Figure 11-79 Histograms of H, A, C, and Range Error PRN-7 (SVN-48) Using C/A Nav Data 110
Figure 11-80 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using C/A Nav Data 110
Figure 11-81 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using L2C CNAV Data 111
Figure 11-82 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using C/A Nav Data 111
Figure 11-83 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using L2C CNAV Data 112
Figure 11-84 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using C/A Nav Data 112
Figure 11-85 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using L2C CNAV Data 113
Figure 11-86 Histograms of H, A, C, and Range Error PRN-11 (SVN-46) Using C/A Nav Data 113
Figure 11-87 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using C/A Nav Data 114
Figure 11-88 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using L2C CNAV Data 114
Figure 11-89 Histograms of H, A, C, and Range Error PRN-13 (SVN-43) Using C/A Nav Data 115
Figure 11-90 Histograms of H, A, C, and Range Error PRN-14 (SVN-41) Using C/A Nav Data 115
Figure 11-91 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using C/A Nav Data 116
Figure 11-92 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using L2C CNAV Data 116
Figure 11-93 Histograms of H, A, C, and Range Error PRN-16 (SVN-56) Using C/A Nav Data 117
Figure 11-94 Histograms of H, A, C, and Range Error PRN-17 (SVN-53) Using C/A Nav Data 117
Figure 11-95 Histograms of H, A, C, and Range Error PRN-18 (SVN-54) Using C/A Nav Data 118
Figure 11-96 Histograms of H, A, C, and Range Error PRN-19 (SVN-59) Using C/A Nav Data 118
Figure 11-97 Histograms of H, A, C, and Range Error PRN-20 (SVN-51) Using C/A Nav Data 119
Figure 11-98 Histograms of H, A, C, and Range Error PRN-21 (SVN-45) Using C/A Nav Data 119

Figure 11-99 Histograms of H, A, C, and Range Error PRN-22 (SVN-47) Using C/A Nav Data 120
Figure 11-100 Histograms of H, A, C, and Range Error PRN-23 (SVN-60) Using C/A Nav Data 120
Figure 11-101 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using C/A Nav Data 121
Figure 11-102 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using L2C CNAV Data 121
Figure 11-103 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using C/A Nav Data 122
Figure 11-104 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using L2C CNAV Data 122
Figure 11-105 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using C/A Nav Data 123
Figure 11-106 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using L2C CNAV Data 123
Figure 11-107 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using C/A Nav Data 124
Figure 11-108 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using L2C CNAV Data 124
Figure 11-109 Histograms of H, A, C, and Range Error PRN-28 (SVN-44) Using C/A Nav Data 125
Figure 11-110 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using C/A Nav Data 125
Figure 11-111 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using L2C CNAV Data 126
Figure 11-112 Histograms of H, A, C, and Range Error PRN-30 (SVN-64) Using C/A Nav Data 126
Figure 11-113 Histograms of H, A, C, and Range Error PRN-31 (SVN-52) Using C/A Nav Data 127
Figure 11-114 Histograms of H, A, C, and Range Error PRN-31 (SVN-52) Using L2C CNAV Data 127
Figure 11-115 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using C/A Nav Data 128
Figure 11-116 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using L2C CNAV Data 128
Figure 11-117 Timeline of URA Normalized Range Error PRN-1 (SVN-63) Using C/A Nav Data 129
Figure 11-118 Timeline of IAURA Normalized Range Error PRN-1 (SVN-63) Using L2C CNAV Data 129

Figure 11-119 Timeline of URA Normalized Range Error PRN-2 (SVN-61) Using C/A Nav Data 130
Figure 11-120 Timeline of URA Normalized Range Error PRN-3 (SVN-69) Using C/A Nav Data 130
Figure 11-121 Timeline of IAURA Normalized Range Error PRN-3 (SVN-69) Using L2C CNAV Data 131
Figure 11-122 Timeline of URA Normalized Range Error PRN-5 (SVN-50) Using C/A Nav Data 131
Figure 11-123 Timeline of IAURA Normalized Range Error PRN-5 (SVN-50) Using L2C CNAV Data 132
Figure 11-124 Timeline of URA Normalized Range Error PRN-6 (SVN-67) Using C/A Nav Data 132
Figure 11-125 Timeline of URA Normalized Range Error PRN-7 (SVN-48) Using C/A Nav Data 133
Figure 11-126 Timeline of URA Normalized Range Error PRN-8 (SVN-72) Using C/A Nav Data 133
Figure 11-127 Timeline of IAURA Normalized Range Error PRN-8 (SVN-72) Using L2C CNAV Data 134
Figure 11-128 Timeline of URA Normalized Range Error PRN-9 (SVN-68) Using C/A Nav Data 134
Figure 11-129 Timeline of IAURA Normalized Range Error PRN-9 (SVN-68) Using L2C CNAV Data 135
Figure 11-130 Timeline of URA Normalized Range Error PRN-10 (SVN-73) Using C/A Nav Data 135
Figure 11-131 Timeline of IAURA Normalized Range Error PRN-10 (SVN-73) Using L2C CNAV Data 136
Figure 11-132 Timeline of URA Normalized Range Error PRN-11 (SVN-46) Using C/A Nav Data 136
Figure 11-133 Timeline of URA Normalized Range Error PRN-12 (SVN-58) Using C/A Nav Data 137
Figure 11-134 Timeline of IAURA Normalized Range Error PRN-12 (SVN-58) Using L2C CNAV Data 137
Figure 11-135 Timeline of URA Normalized Range Error PRN-13 (SVN-43) Using C/A Nav Data 138
Figure 11-136 Timeline of URA Normalized Range Error PRN-14 (SVN-41) Using C/A Nav Data 138
Figure 11-137 Timeline of URA Normalized Range Error PRN-15 (SVN-55) Using C/A Nav Data 139
Figure 11-138 Timeline of IAURA Normalized Range Error PRN-15 (SVN-55) Using L2C CNAV Data 139

Figure 11-139 Timeline of URA Normalized Range Error PRN-16 (SVN-56) Using C/A Nav Data 140
Figure 11-140 Timeline of URA Normalized Range Error PRN-17 (SVN-53) Using C/A Nav Data 140
Figure 11-141 Timeline of URA Normalized Range Error PRN-18 (SVN-54) Using C/A Nav Data 141
Figure 11-142 Timeline of URA Normalized Range Error PRN-19 (SVN-59) Using C/A Nav Data 141
Figure 11-143 Timeline of URA Normalized Range Error PRN-20 (SVN-51) Using C/A Nav Data 142
Figure 11-144 Timeline of URA Normalized Range Error PRN-21 (SVN-45) Using C/A Nav Data 142
Figure 11-145 Timeline of URA Normalized Range Error PRN-22 (SVN-47) Using C/A Nav Data 143
Figure 11-146 Timeline of URA Normalized Range Error PRN-23 (SVN-60) Using C/A Nav Data 143
Figure 11-147 Timeline of URA Normalized Range Error PRN-24 (SVN-65) Using C/A Nav Data 144
Figure 11-148 Timeline of IAURA Normalized Range Error PRN-24 (SVN-65) Using L2C CNAV Data 144
Figure 11-149 Timeline of URA Normalized Range Error PRN-25 (SVN-62) Using C/A Nav Data 145
Figure 11-150 Timeline of IAURA Normalized Range Error PRN-25 (SVN-62) Using L2C CNAV Data 145
Figure 11-151 Timeline of URA Normalized Range Error PRN-26 (SVN-71) Using C/A Nav Data 146
Figure 11-152 Timeline of IAURA Normalized Range Error PRN-26 (SVN-71) Using L2C CNAV Data 146
Figure 11-153 Timeline of URA Normalized Range Error PRN-27 (SVN-66) Using C/A Nav Data 147
Figure 11-154 Timeline of IAURA Normalized Range Error PRN-27 (SVN-66) Using L2C CNAV Data 147
Figure 11-155 Timeline of URA Normalized Range Error PRN-28 (SVN-44) Using C/A Nav Data 148
Figure 11-156 Timeline of URA Normalized Range Error PRN-29 (SVN-57) Using C/A Nav Data 148
Figure 11-157 Timeline of IAURA Normalized Range Error PRN-29 (SVN-57) Using L2C CNAV Data 149
Figure 11-158 Timeline of URA Normalized Range Error PRN-30 (SVN-64) Using C/A Nav Data 149

Figure 11-159 Timeline of URA Normalized Range Error PRN-31 (SVN-52) Using C/A Nav Data 150
Figure 11-160 Timeline of IAURA Normalized Range Error PRN-31 (SVN-52) Using L2C CNAV Data..... 150
Figure 11-161 Timeline of URA Normalized Range Error PRN-32 (SVN-70) Using C/A Nav Data 151
Figure 11-162 Timeline of IAURA Normalized Range Error PRN-32 (SVN-70) Using L2C CNAV Data..... 151

LIST OF TABLES

Table 1-1 SPS SIS Performance Requirements Standards 16
Table 2-1 PDOP Availability Statistics 20
Table 3-1 NANUs Affecting Satellite Availability 23
Table 3-2 NANUs Forecasted to Affect Satellite Availability 24
Table 3-3 Cancelled NANUs 24
Table 3-4 GPS Satellite Maintenance Statistics 24
Table 3-5 Accuracies Exceeding Threshold Statistics 26
Table 4-1 User Range Error Accuracy 27
Table 5-1 Horizontal & Vertical Accuracy Statistics for the Quarter 29
Table 5-2 Range Error Statistics 32
Table 5-3 Range Rate Error Statistics 33
Table 5-4 Range Acceleration Error Statistics 34
Table 6-1 Horizontal & Vertical Accuracy Statistics for November 8, 2016 40
Table 7-1 Selected IGS Site Information 41
Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites 42
Table 8-1 RAIM Site Statistics 45
Table 9-1 GPS test NOTAM Durations 52
Table 9-2 GPS Test NOTAM Affected Areas (Square Miles) by Altitude 52
Table 9-3 NOTAM Impact to GPS Availability 55
Table 10-1 Performance Summary 59

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	• 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	✓

slot due to unscheduled interruption		
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 2° 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 2.943 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%)
1 – 7 Oct	2.920	99.9997	99.7222
8 – 14 Oct	2.918	99.9998	99.7519
15 – 21 Oct	2.917	99.9998	99.8015
22 – 28 Oct	2.943	99.9999	99.8611
29 Oct – 4 Nov	2.909	99.9999	99.9107
5 – 11 Nov	2.907	99.9999	99.9404
12 – 18 Nov	2.882	99.9999	99.9801
19 – 25 Nov	2.876	99.9999	99.9702
27 Nov – 2 Dec	2.875	99.9999	99.9801
3 – 9 Dec	2.876	99.9999	99.9603
10 – 16 Dec	2.896	99.9999	99.9503
17 – 23 Dec	2.913	99.9999	99.9702
24 Sep – 30 Dec	2.877	99.9999	99.9900

Figure 2-1 World GPS Maximum PDOP

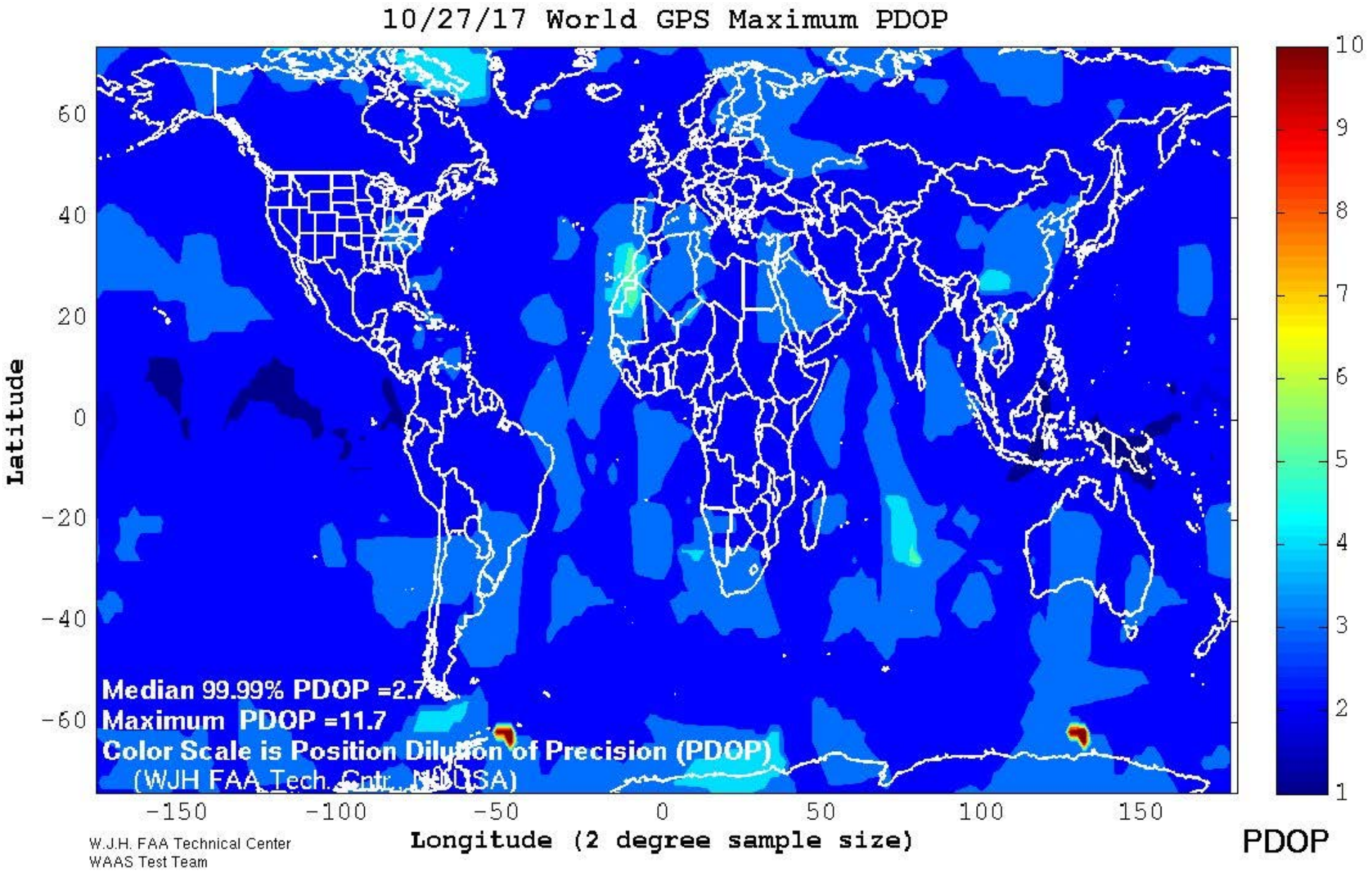
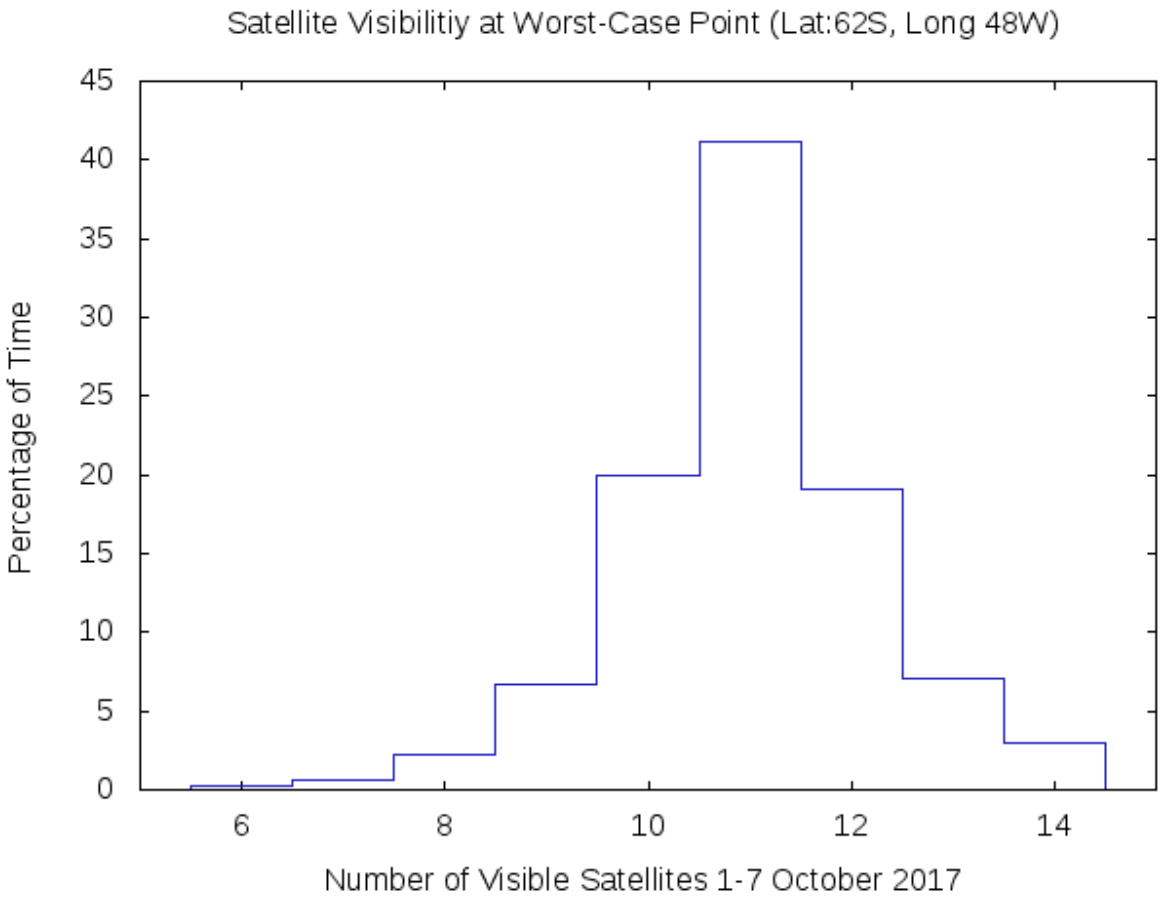


Figure 2-2 Satellite Visibility Profile for Worst-Case Point



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 October through 31 December 2017, there were a total of nine reported outages. Eight outages were maintenance activities and were reported in advance, while one was an unscheduled outage. 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 12.433 hours. The maximum response time following an unscheduled outage was 0.15 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
2017110	1	UNUSABLE	04-Oct-17	09:37	04-Oct-17	12:56	3.32		3.32
2017111	32	FCSTSUMM	04-Oct-17	11:23	04-Oct-17	16:11		4.80	4.80
2017113	29	FCSTSUMM	12-Oct-17	14:21	12-Oct-17	17:28		3.12	3.12
2017115	26	FCSTSUMM	19-Oct-17	16:46	20-Oct-17	00:39		7.88	7.88
2017118	31	FCSTSUMM	27-Oct-17	01:01	27-Oct-17	06:47		5.77	5.77
2017119	29	FCSTSUMM	02-Nov-17	13:41	02-Nov-17	18:57		5.27	5.27
2017121	16	FCSTSUMM	09-Nov-17	16:24	09-Nov-17	21:29		5.08	5.08
2017125	21	FCSTSUMM	14-Dec-17	13:29	14-Dec-17	19:14		5.75	5.75
2017126	6	FCSTSUMM	19-Dec-17	09:24	19-Dec-17	14:27		5.05	5.05
Totals of Unscheduled, Scheduled & Total Downtime							3.32	42.72	46.04

GENERAL NANUs

2017122 – SVN 49 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
2017108	32	FCSTDV	04-Oct	10:00	05-Oct	10:00	24	2017111
2017109	1	UNUSUFN	04-Oct	09:37				2017110
2017112	29	FCSTDV	12-Oct	13:59	13-Oct	01:59	12	2017113
2017114	26	FCSTDV	19-Oct	16:30	20-Oct	04:30	12	2017115
2017116	31	FCSTDV	27-Oct	00:45	27-Oct	12:45	12	2017118
2017117	29	FCSTDV	02-Nov	13:00	03-Nov	01:00	12	2017119
2017120	16	FCSTDV	09-Nov	16:00	10-Nov	04:00	12	2017121
2017123	21	FCSTDV	14-Dec	13:15	15-Dec	01:15	12	2017125
2017124	6	FCSTDV	19-Dec	08:45	19-Dec	20:45	12	2017126
						Total Forecasted Downtime	84	

Table 3-3 Cancelled NANUs

NANU#	PRN	Type	Start Date	Start Time	Comments

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-Oct-17 31-Dec-17	1-Jan-00 31-Dec-17
Total Forecast Downtime (hrs):	84	11902.82
Total Actual Downtime (hrs):	46.04	39195.46
Total Actual Scheduled Downtime (hrs):	42.72	6649.44
Total Actual Unscheduled Downtime (hrs):	3.32	32546.02
Total Satellite Observed MTTR (hrs):	5.12	42.28
Scheduled Satellite Observed MTTR (hrs):	5.34	8.99
Unscheduled Satellite Observed MTTR (hrs):	3.32	174.04
# Total Satellite Outages:	9	927
# Scheduled Satellite Outages:	8	740
# Unscheduled Satellite Outages:	1	187
Percent Operational -- Scheduled Downtime:	99.94	99.86
Percent Operational -- All Downtime:	99.93	99.20

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 October and 31 December 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	7939628	0	100%
Anchorage	7939714	0	100%
Atlanta	7939752	0	100%
Barrow	7939527	0	100%
Bethel	7936369	0	100%
Billings	7939738	0	100%
Boston	7939725	0	100%
Cleveland	7939735	0	100%
Cold Bay	7938174	0	100%
Fairbanks	7931795	0	100%
Gander	7680937	0	100%
Honolulu	7935997	0	100%
Houston	7939749	0	100%
Iqaluit	7939186	0	100%
Juneau	7937831	0	100%
Kansas City	7939644	0	100%
Kotzebue	7937740	0	100%
Los Angeles	7849965	0	100%
Merida	7926682	0	100%
Miami	7245446	0	100%
Minneapolis	7936767	0	100%
Oakland	7939750	0	100%
Salt Lake City	6327535	0	100%
San Jose Del Cabo	7766275	0	100%
San Juan	7569635	0	100%
Seattle	7930723	0	100%
Tapachula	3014158	0	100%
Washington, DC	7935595	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 15.479 meters on satellite PRN 23.

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 Oct – 31 Dec 2017	**Boston**	68,717,506	0	100%
1 Oct – 31 Dec 2017	**Honolulu**	71,583,082	0	100%
1 Oct – 31 Dec 2017	**Los Angeles**	68,495,980	0	100%
1 Oct – 31 Dec 2017	**Miami**	63,530,684	0	100%
1 Oct – 31 Dec 2017	**Merida**	71,546,272	0	100%
1 Oct – 31 Dec 2017	**Juneau**	70,907,391	0	100%
1 Oct – 31 Dec 2017	**Global**	414,780,915	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 October through 31 December 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	3.666	1.610	5.910	3.732
Anchorage	4.069	1.440	7.157	2.857
Atlanta	3.644	1.865	6.450	3.707
Barrow	4.483	1.234	8.488	2.541
Bethel	4.068	1.389	6.564	2.786
Billings	3.504	1.762	5.791	2.782
Boston	3.235	2.052	6.328	3.877
Cleveland	3.527	2.056	6.561	3.641
Cold Bay	3.937	1.516	7.230	2.926
Fairbanks	4.135	1.392	7.169	2.964
Gander	3.353	1.905	6.519	4.087
Honolulu	4.538	3.688	7.611	6.207
Houston	4.145	1.645	6.446	3.403
Iqaluit	4.148	1.621	8.233	3.330
Juneau	3.700	1.529	6.215	3.659
Kansas City	3.610	1.887	5.703	3.721
Kotzebue	4.236	1.364	6.921	2.731
Los Angeles	4.116	1.704	6.056	3.858
Merida	4.238	1.660	7.455	4.670
Miami	3.763	1.593	7.475	3.165
Minneapolis	3.541	1.905	5.733	3.804
Oakland	4.242	1.685	6.492	3.509
Salt Lake City	3.521	1.756	6.187	3.321
San Jose Del Cabo	4.381	1.706	6.941	4.021
San Juan	3.829	2.001	8.548	6.801
Seattle	3.671	1.731	5.951	3.326
Tapachula	4.303	1.954	7.294	5.166
Washington, DC	3.461	2.082	6.104	3.898

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-eight WAAS sites from 1 October to 31 December 2017.

Figure 5-1 Global Vertical Error Histogram

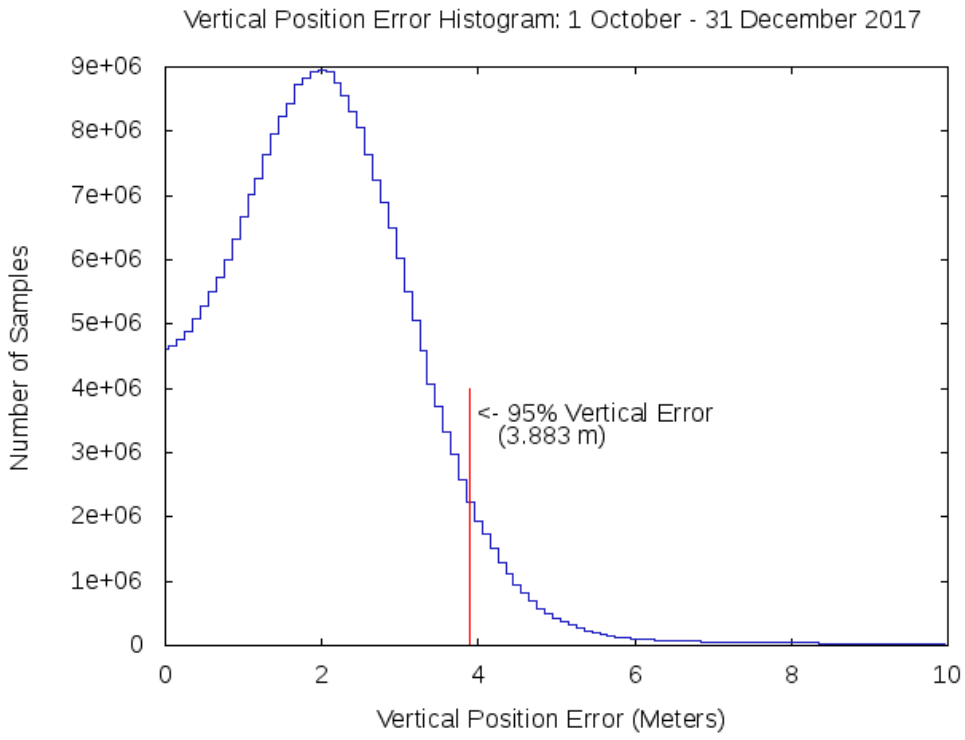
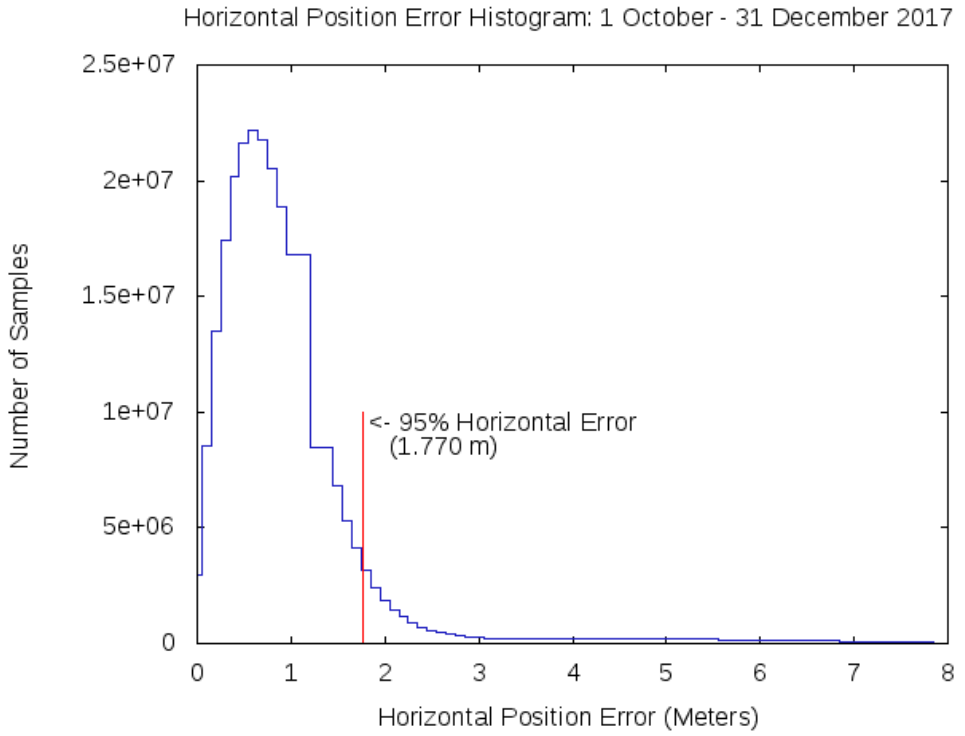


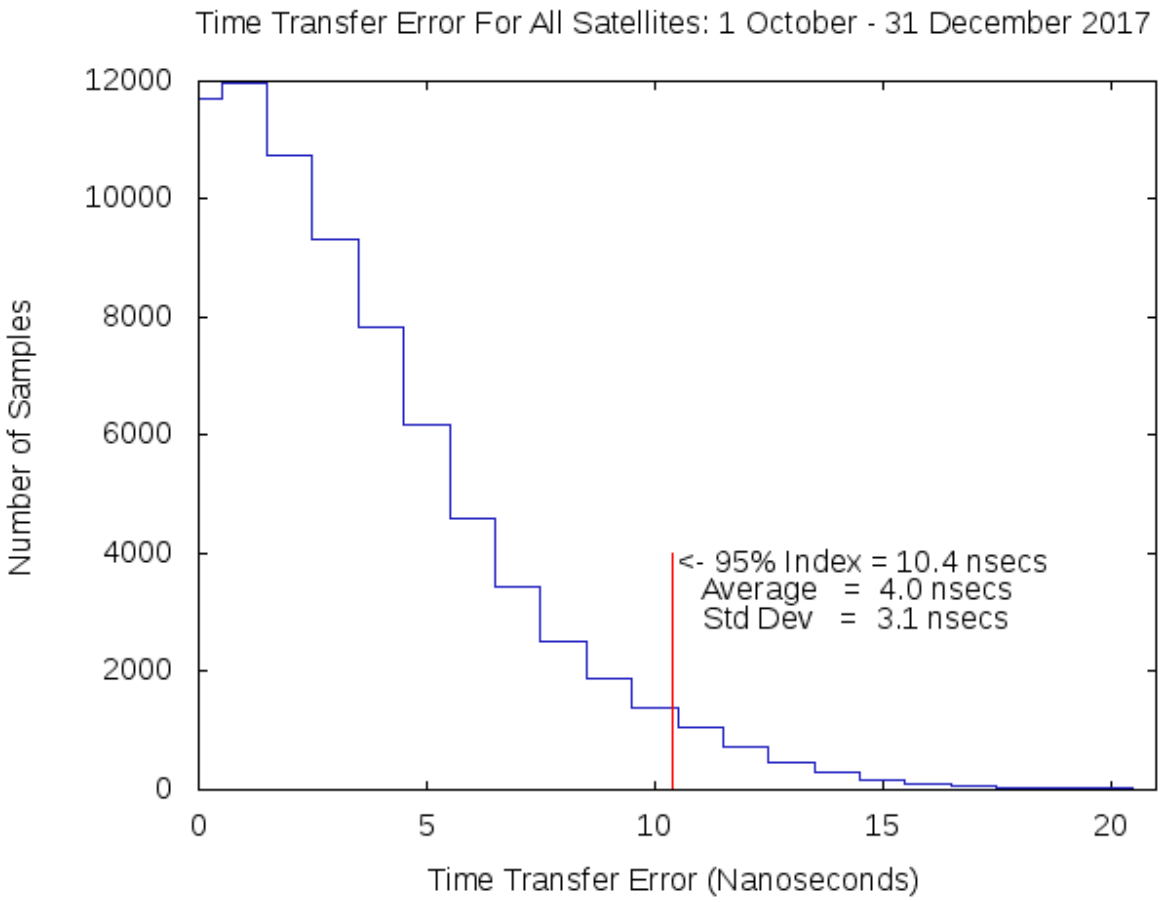
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 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 34.2 nanoseconds. The mean, standard deviation and 95% index of Time Transfer Error, and the maximum UTCOE are all within the requirements of GPS SPS time error.

Figure 5-3 Time Transfer Error



5.3 Range Domain Accuracy

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 October and 31 December 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	1.413	0.671	1.133	2.545	11.756	13834223
2	1.698	1.303	0.926	2.828	7.882	14686765
3	1.123	0.235	0.958	2.089	10.283	14464550
5	1.231	0.476	0.912	2.223	8.989	13645552
6	1.241	0.395	1.003	2.303	8.696	13778520
7	1.669	1.242	1.004	2.945	12.999	12808177
8	1.718	0.955	1.168	3.006	13.071	12672907
9	1.710	1.289	1.010	2.963	15.083	13543985
10	1.485	0.910	0.886	2.472	7.885	13045974
11	1.766	1.246	1.102	3.107	12.406	12369253
12	1.311	0.690	0.969	2.297	9.588	14128446
13	1.238	0.541	0.924	2.187	5.813	13118200
14	1.990	1.640	0.895	3.094	8.802	14191306
15	1.206	0.654	0.870	2.122	5.614	12681283
16	1.907	1.427	1.085	3.179	9.203	13268649
17	1.672	1.160	1.037	2.872	9.381	14653322
18	1.817	1.317	1.061	2.966	6.960	13656453
19	2.209	1.902	1.016	3.438	9.390	14108616
20	1.697	1.316	0.925	2.824	5.515	14198150
21	1.956	1.458	1.135	3.114	6.988	12848261
22	2.188	1.882	0.982	3.408	10.264	13970886
23	1.949	1.582	0.997	3.246	15.479	12996654
24	1.489	0.350	1.163	2.652	8.555	13939373
25	1.472	1.043	0.962	2.591	8.990	14404186
26	1.619	1.239	0.965	2.790	8.027	12665867
27	1.382	0.721	1.035	2.604	14.179	13360274
28	2.159	1.719	1.174	3.547	13.331	13837736
29	1.536	0.910	1.006	2.540	8.549	12816483
30	1.871	1.469	1.062	3.179	12.987	12817448
31	1.490	0.929	0.982	2.564	11.684	13881352
32	1.355	0.740	0.849	2.357	8.389	14320210

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	1.394	2.621	180.810	13834223
2	1.384	2.685	121.790	14686765
3	1.349	2.577	87.340	14464550
5	1.461	2.833	136.630	13645552
6	1.328	2.552	77.120	13778520
7	1.505	2.804	59.750	12808177
8	1.560	2.818	127.670	12672907
9	1.342	2.572	118.770	13543985
10	1.249	2.426	48.600	13045974
11	1.473	2.847	92.940	12369253
12	1.487	2.896	104.870	14128446
13	1.523	2.856	106.210	13118200
14	1.411	2.718	55.040	14191306
15	1.420	2.749	39.700	12681283
16	1.463	2.861	36.500	13268649
17	1.543	2.954	121.500	14653322
18	1.444	2.763	59.920	13656453
19	1.465	2.798	73.280	14108616
20	1.410	2.710	120.020	14198150
21	1.457	2.822	31.070	12848261
22	1.437	2.775	142.560	13970886
23	1.420	2.731	136.300	12996654
24	1.841	3.155	152.190	13939373
25	1.288	2.503	39.880	14404186
26	1.280	2.472	56.750	12665867
27	1.325	2.577	36.210	13360274
28	1.658	2.785	153.820	13837736
29	1.485	2.773	134.280	12816483
30	1.305	2.566	62.080	12817448
31	1.430	2.711	77.740	13881352
32	1.266	2.468	42.970	14320210

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	10.387	19.797	1810	13834223
2	10.169	20.575	1220	14686765
3	10.131	19.660	860	14464550
5	10.160	24.226	1190	13645552
6	10.118	19.628	780	13778520
7	10.698	22.575	600	12808177
8	11.518	21.590	1270	12672907
9	10.302	19.698	1200	13543985
10	10.054	19.650	500	13045974
11	10.257	21.846	930	12369253
12	10.140	25.475	1040	14128446
13	10.916	24.296	1060	13118200
14	10.269	21.519	550	14191306
15	10.038	21.223	390	12681283
16	10.124	23.994	360	13268649
17	10.623	25.232	1210	14653322
18	10.392	23.264	600	13656453
19	10.287	22.357	720	14108616
20	10.125	21.895	1060	14198150
21	10.089	23.708	300	12848261
22	10.178	22.356	1420	13970886
23	10.110	21.558	1350	12996654
24	13.935	27.954	1520	13939373
25	10.015	19.573	410	14404186
26	10.021	19.539	570	12665867
27	10.059	19.711	330	13360274
28	12.805	22.089	1540	13837736
29	11.184	23.535	1350	12816483
30	10.021	19.661	630	12817448
31	10.442	21.422	770	13881352
32	10.048	19.664	430	14320210

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 23 with an error of 15.479 meters. Satellite PRN 20 had the lowest maximum range error of 5.515 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

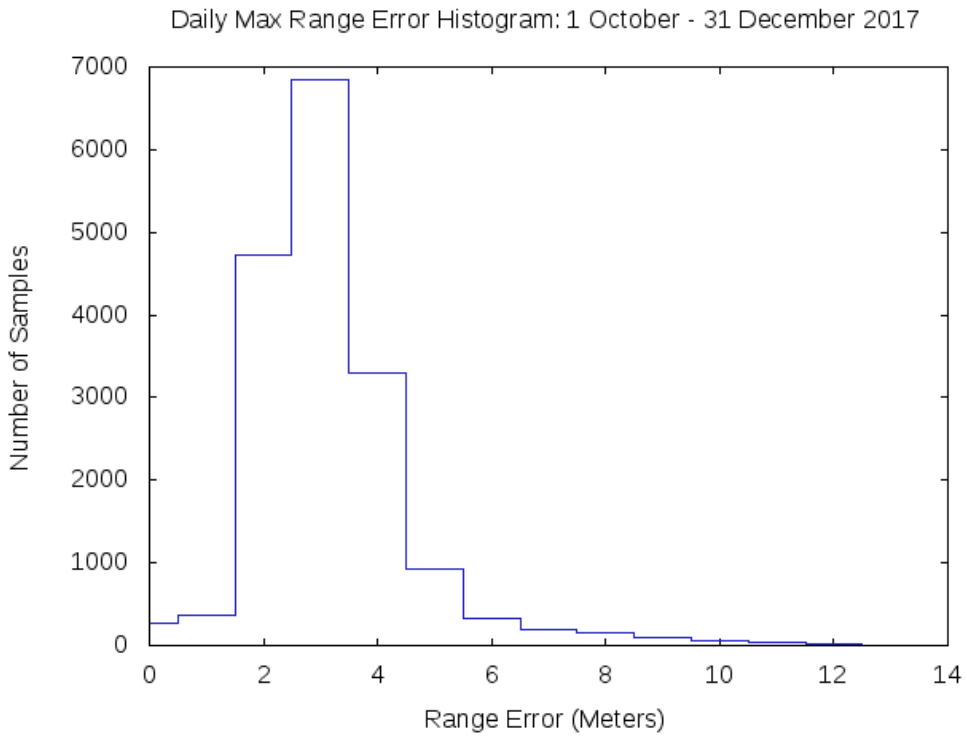


Figure 5-5 Distribution of Daily Max Range Rate Errors

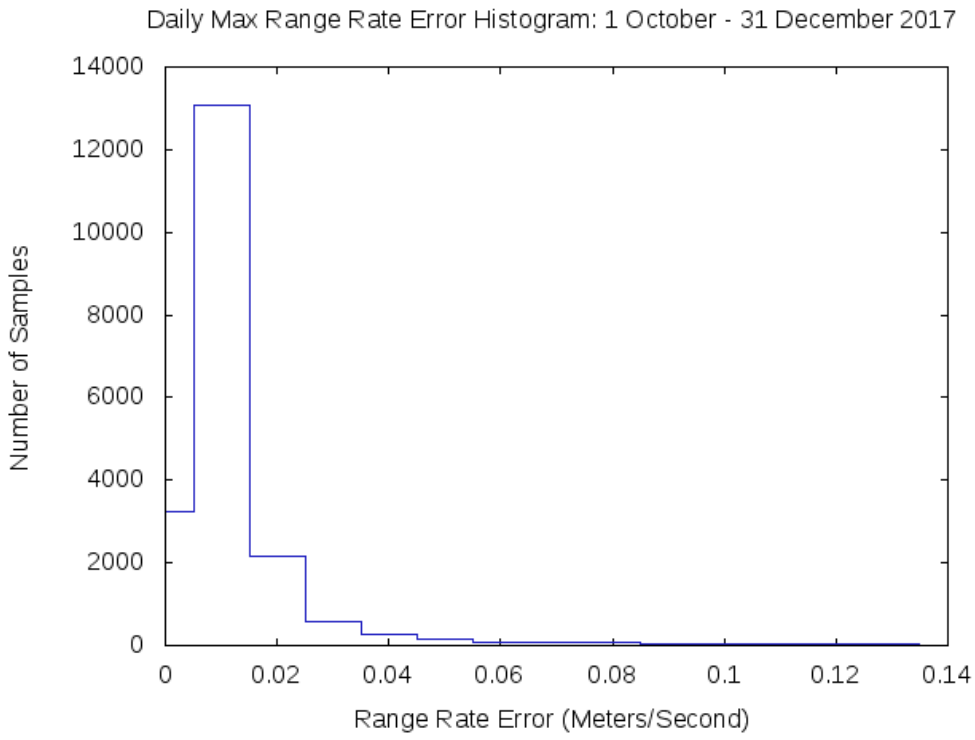


Figure 5-6 Distribution of Daily max Range Acceleration Errors

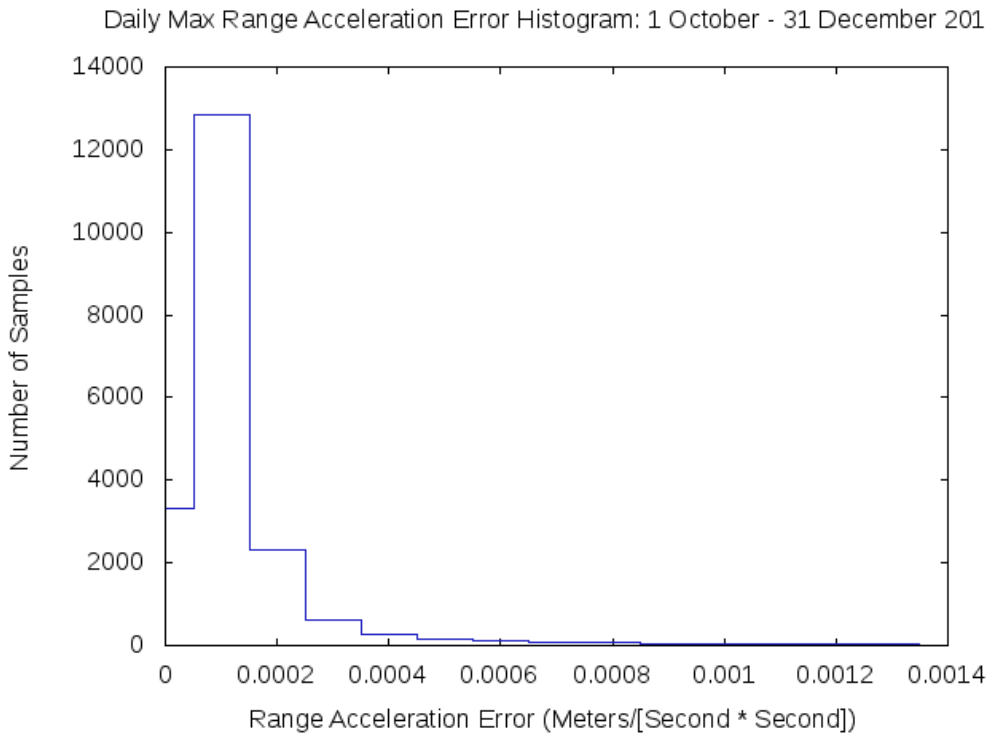


Figure 5-7 Range Error Histogram

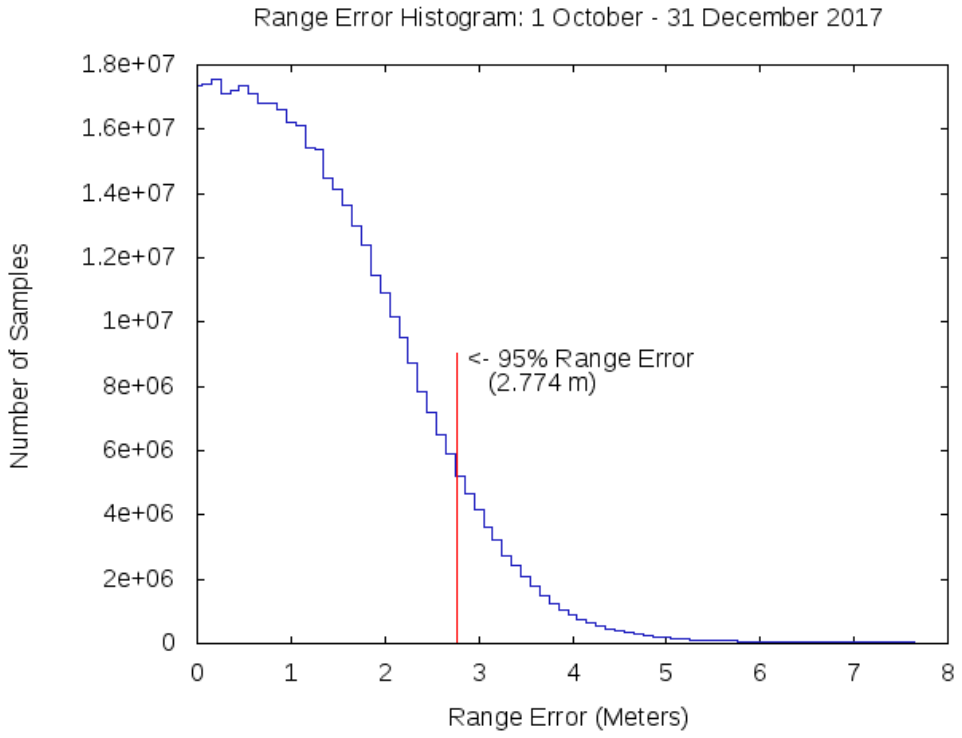


Figure 5-8 Maximum Range Error Per Satellite

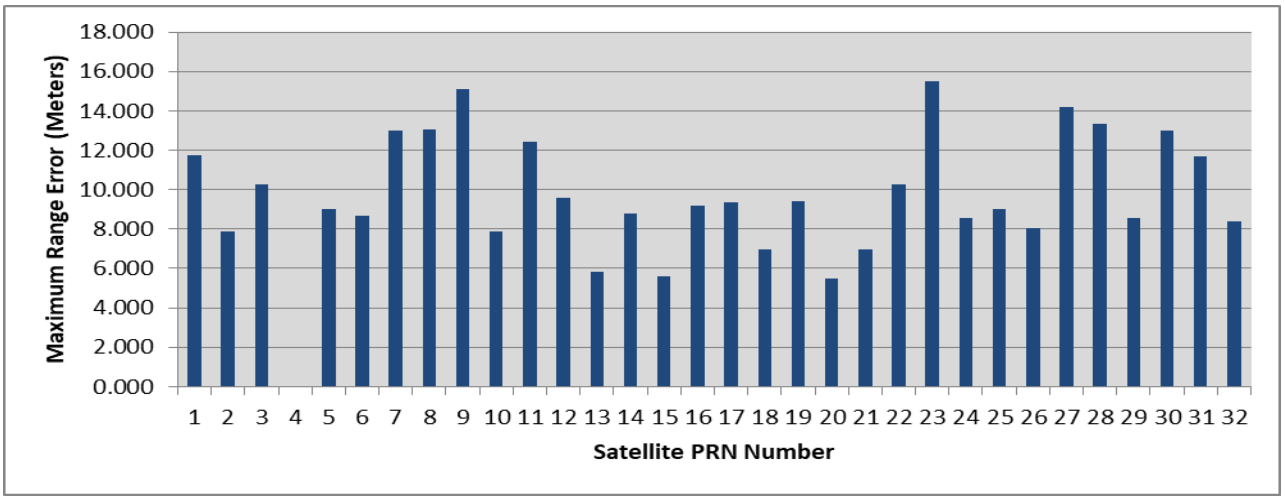


Figure 5-9 Maximum Range Rate Error Per Satellite

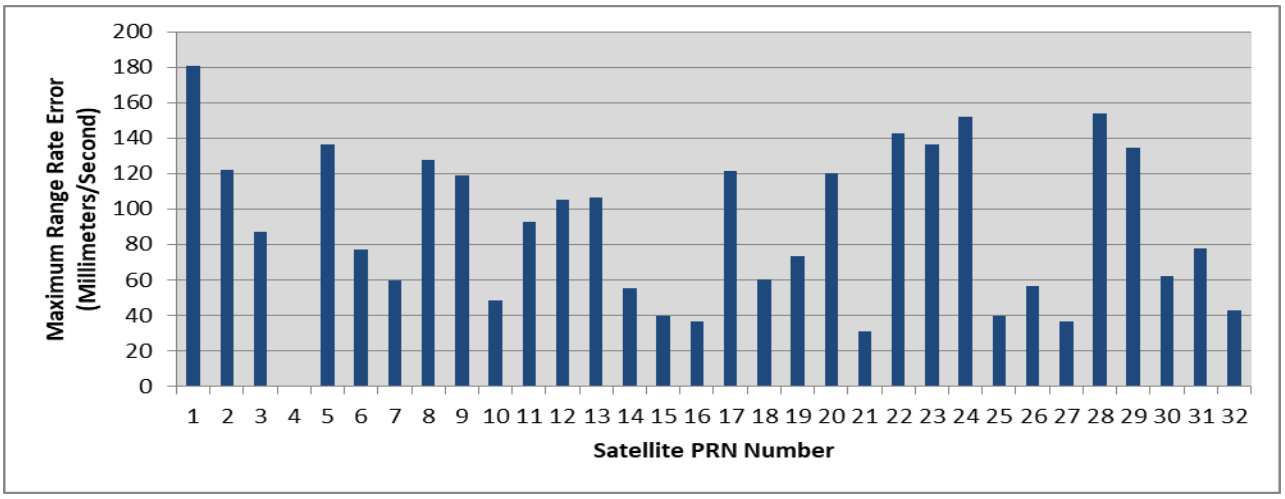
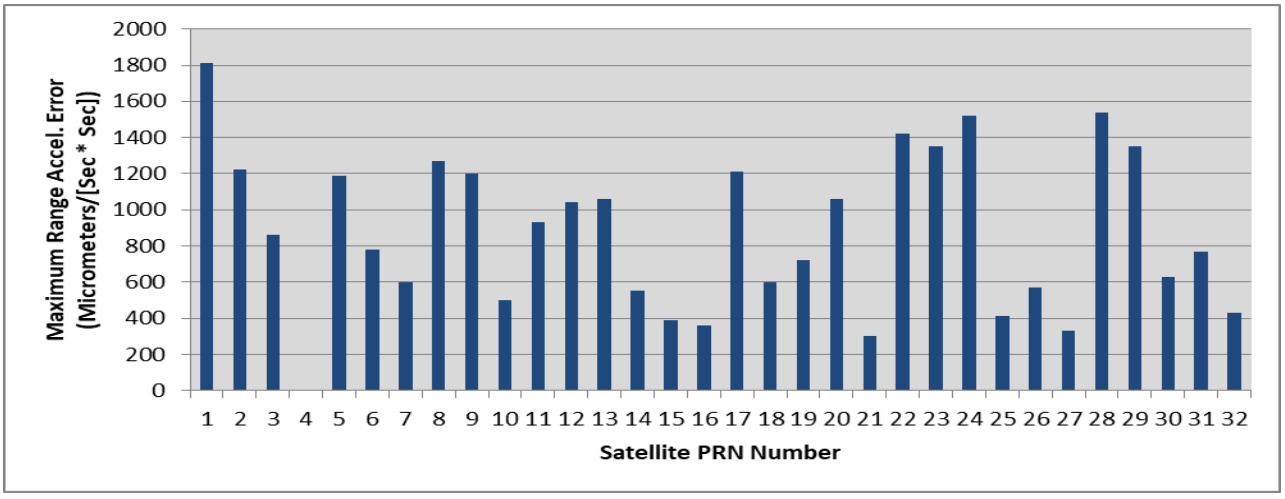


Figure 5-10 Maximum Range Acceleration Error Per Satellite



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 November 2017

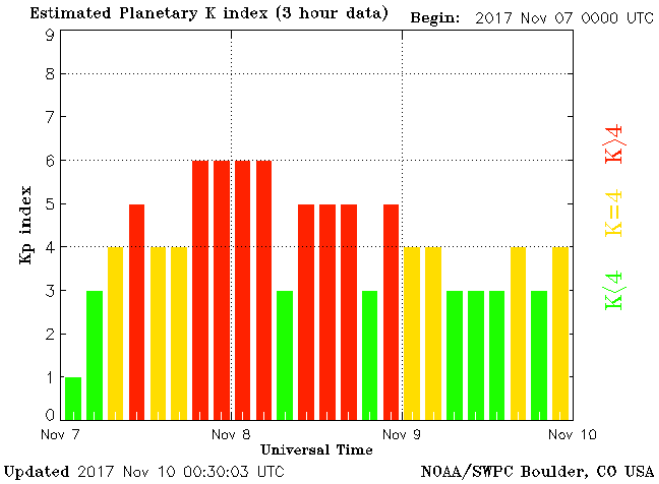


Figure 6-2 K-Index for 12-14 October 2017

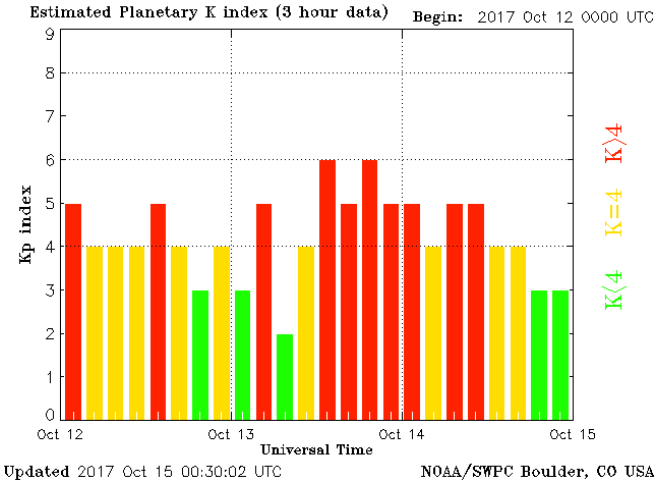


Figure 6-3 K-Index for 4-6 December 2017

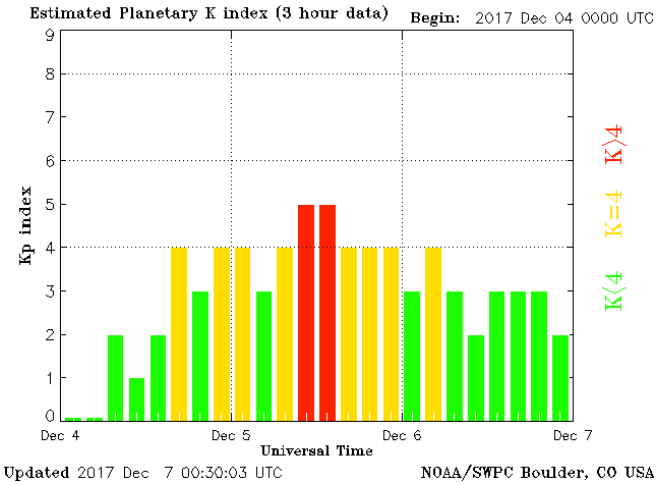


Table 6-1 shows the position accuracy information for the quarter's worst-case storm day, September 8, 2017 (see Figure 6-1). The GPS SPS performance met all requirements during all storms that occurred during this quarter.

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

Site	95% Horizontal (Meters)	95% Vertical (Meters)	Maximum Horizontal (Meters)	Maximum Vertical (Meters)
Albuquerque	2.035	3.206	2.740	4.141
Anchorage	2.016	3.205	2.821	3.996
Atlanta	2.495	3.218	2.974	5.013
Barrow	1.673	4.578	2.625	7.514
Bethel	1.751	3.451	2.626	4.509
Billings	2.244	3.157	2.630	5.855
Boston	2.683	2.707	3.717	3.324
Cleveland	2.843	3.400	3.338	4.732
Cold Bay	2.072	3.368	2.778	4.145
Fairbanks	1.784	3.467	2.546	6.331
Gander	1.622	2.666	2.256	3.338
Honolulu	3.053	4.574	3.418	5.600
Houston	1.883	3.597	2.382	5.152
Iqaluit	1.381	4.158	2.046	6.550
Juneau	1.946	2.684	2.76	4.230
Kansas City	2.637	3.070	3.476	4.344
Kotzebue	1.714	3.896	2.757	5.921
Los Angeles	1.945	3.290	2.365	5.139
Merida	1.793	3.848	2.140	6.009
Miami	1.921	3.179	2.271	3.717
Minneapolis	2.594	2.966	3.285	4.404
Oakland	1.874	3.417	2.171	4.258
Salt Lake City	2.371	3.207	2.897	5.336
San Jose Del Cabo	1.642	3.450	2.401	5.322
San Juan	2.070	3.686	4.379	8.528
Seattle	2.654	2.751	3.451	4.322
Tapachula	-	-	-	-
Washington, DC	3.156	3.203	4.229	3.599

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

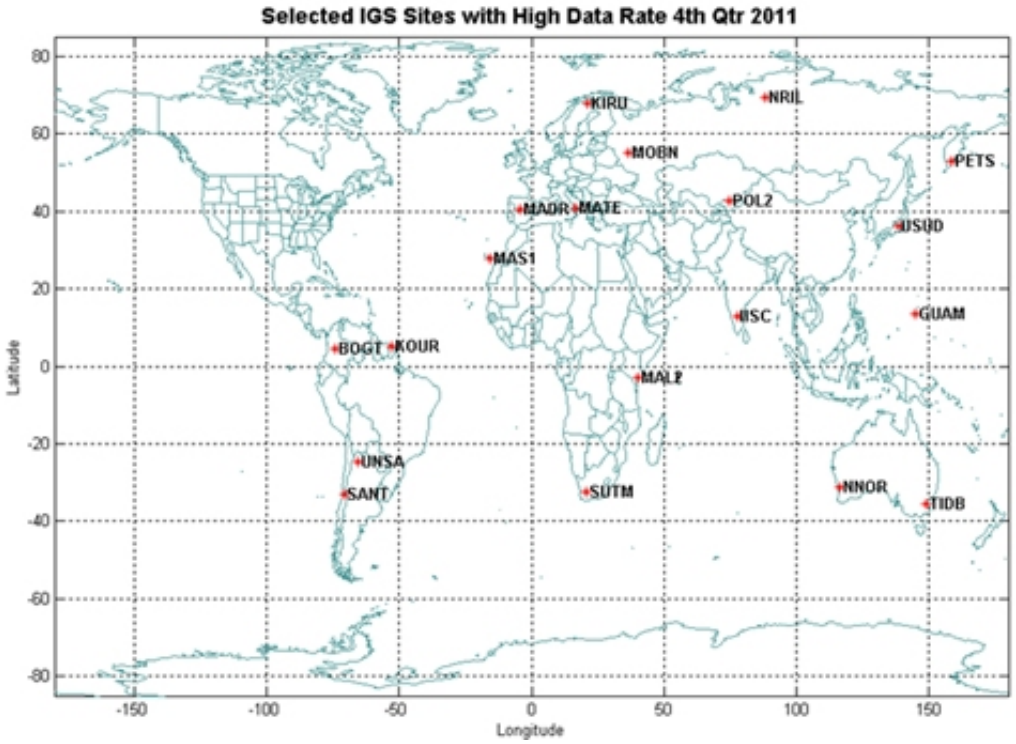


Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Percent Data Available
BOGT	4.30	4.42	7.14	11.81	99.80%
GLPS	2.80	3.83	5.05	9.71	88.85%
GUAM	1.93	3.87	4.80	14.25	99.97%
IISC	1.79	3.99	4.22	9.08	80.30%
KIRU	1.40	3.70	4.12	8.42	100.00%
KOUR	2.45	3.69	4.69	9.52	99.99%
MADR	1.57	3.19	3.66	6.27	100.00%
MAL2	2.10	3.46	4.86	7.96	98.47%
MAS1	4.98	3.69	8.32	11.04	100.00%
MATE	1.59	3.66	6.74	11.03	93.48%
MOBN	0	0	0	0	0.00%
NNOR	1.48	3.90	4.13	7.62	99.97%
NRIL	0	0	0	0	0.00%
PETS	0	0	0	0	0.00%
POL2	2.28	5.36	9.24	20.52	78.39%
SANT	3.37	4.25	9.14	10.82	99.56%
SUTM	1.55	3.74	3.69	7.62	96.44%
TIDB	1.41	3.66	4.09	7.03	99.79%
UNSA	2.82	3.84	5.65	9.58	98.07%
USUD	2.19	4.36	6.06	9.11	99.87%

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

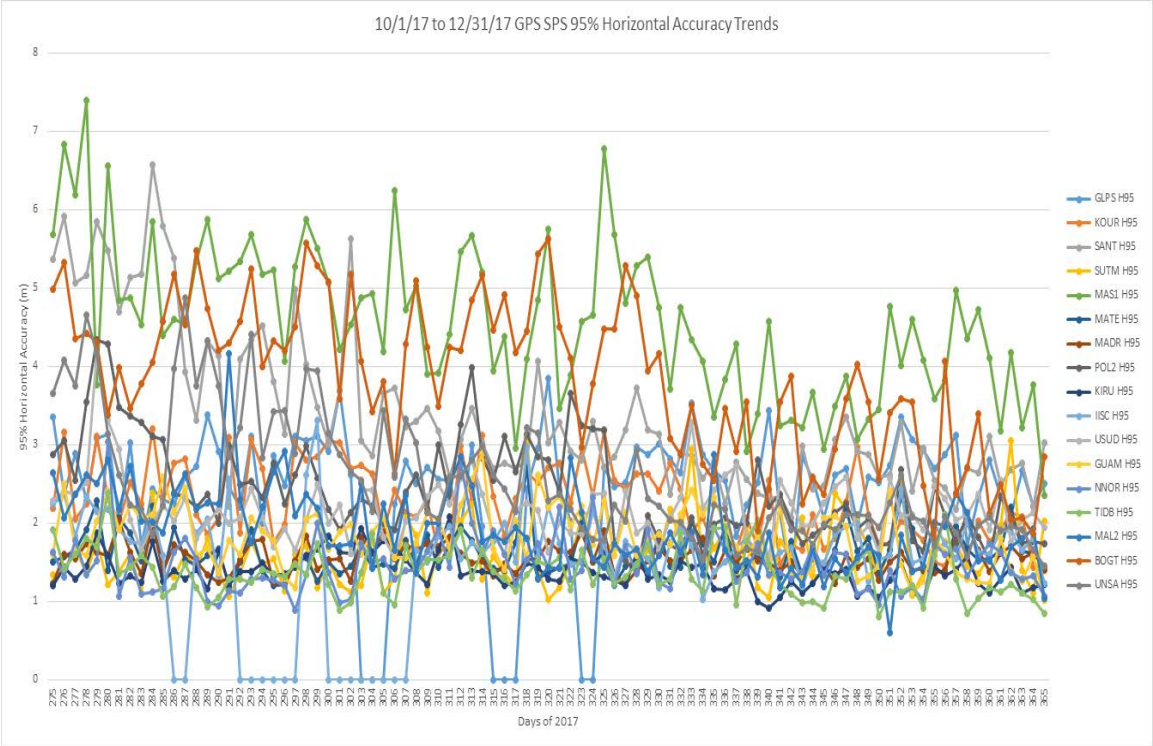
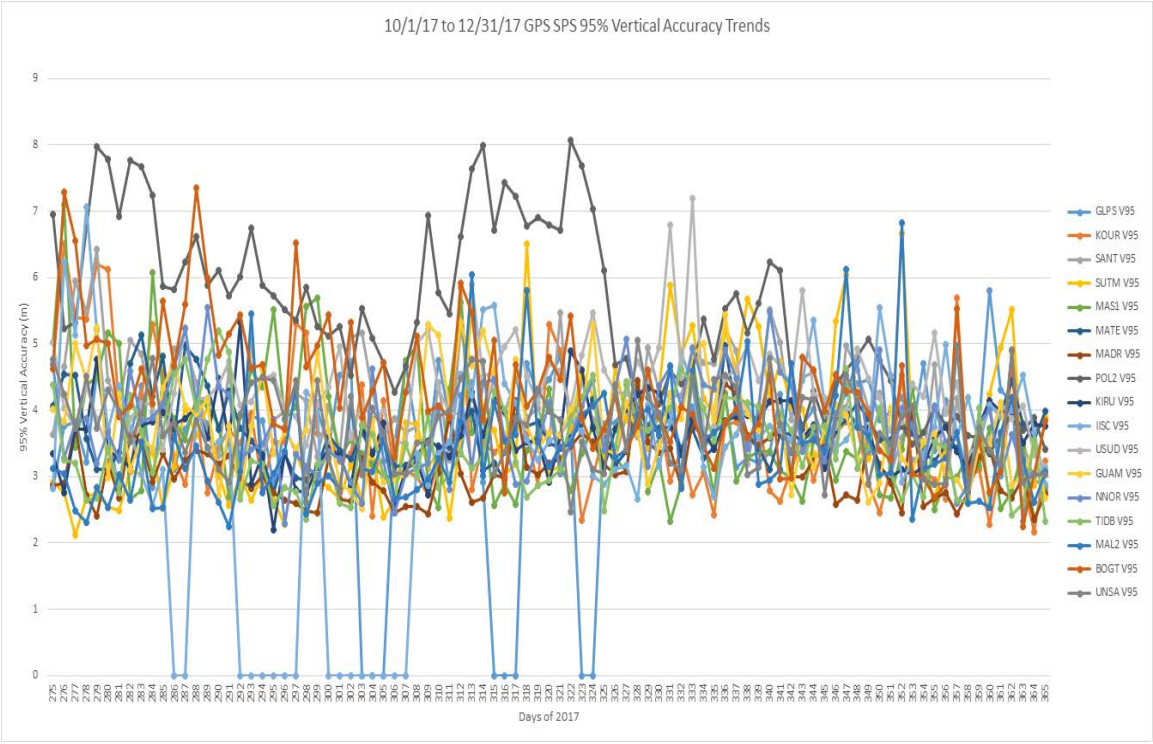


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites



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 99.976% at Iqaluit, Nunavut and Minneapolis, MN. The minimum percent of time spent in RNP 0.3 mode was 100% at all locations evaluated. The maximum 99% HPL value was 131.819 meters at Bethel, AK.

Table 8-1 RAIM Site Statistics

CITY	99% HPL	Percent RNP 0.1	Percent RNP 0.3
Albuquerque	102.993	100	100
Anchorage	125.049	99.992	100
Atlanta	104.161	99.998	100
Barrow	106.193	99.995	100
Bethel	131.819	99.999	100
Billings	117.781	100	100
Boston	112.207	100	100
Cleveland	110.466	99.991	100
Cold Bay	130.032	100	100
Fairbanks	126.134	99.996	100
Gander	124.558	100	100
Honolulu	126.385	100	100
Houston	102.507	100	100
Iqaluit	123.009	99.976	100
Juneau	116.666	99.991	100
Kansas City	101.558	100	100
Kotzebue	109.695	99.998	100
Los Angeles	105.979	99.996	100
Merida	88.600	99.999	100
Miami	121.502	99.983	100
Minneapolis	117.917	99.976	100
Oakland	105.195	100	100
Salt Lake City	109.899	100	100
San Jose Del Cabo	80.087	100	100
San Juan	80.928	100	100
Seattle	105.158	99.993	100
Tapachula	107.891	99.991	100
Washington DC	112.215	100	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 October and 31 December 2017.

Figure 8-1 RAIM RNP 0.1 Coverage

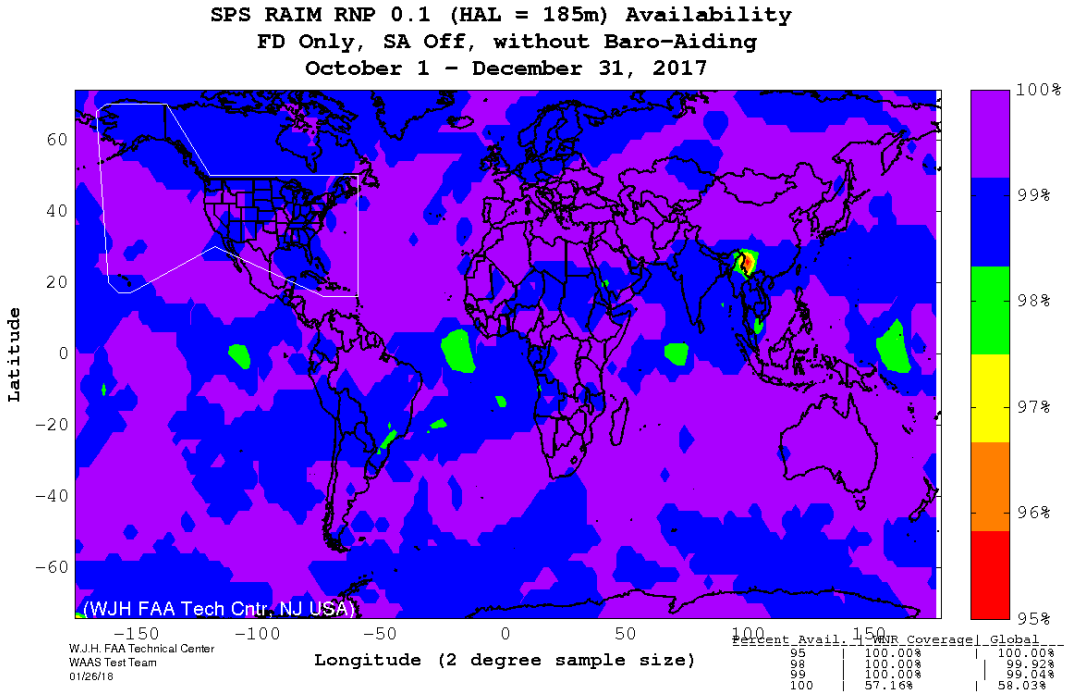


Figure 8-2 RAIM RNP 0.3 Coverage

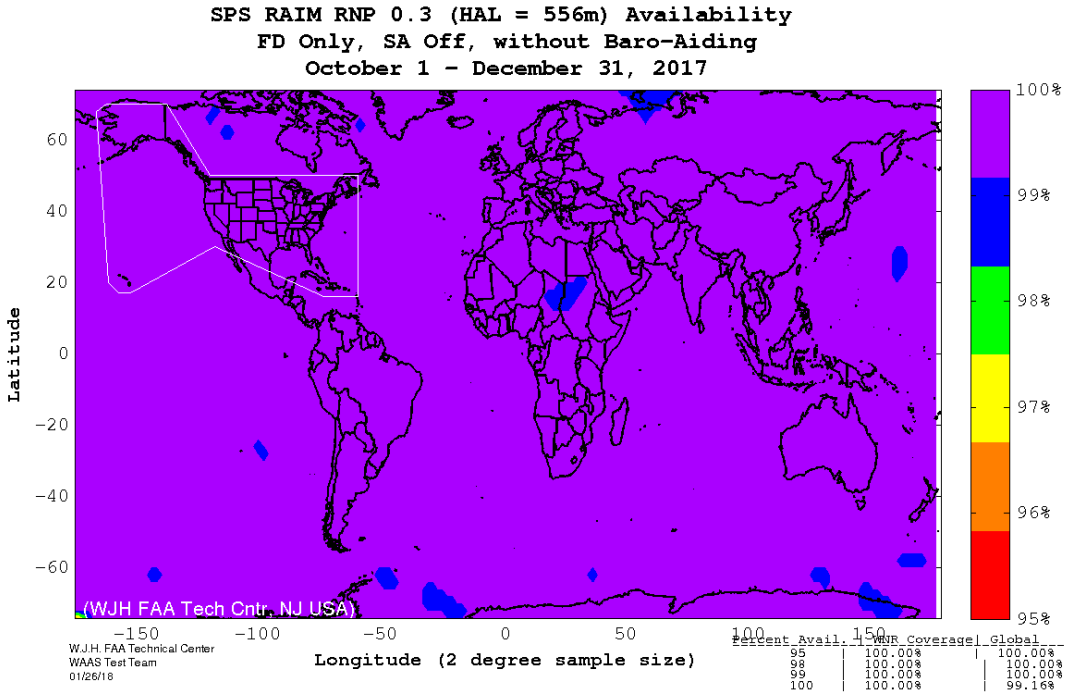


Figure 8-3 RAIM World Wide Coverage Trend

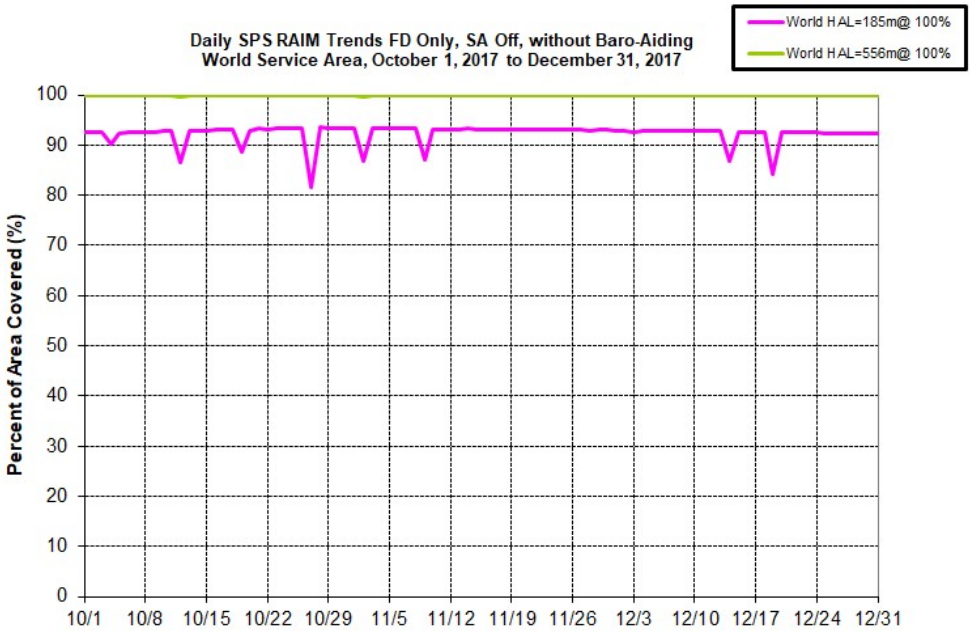
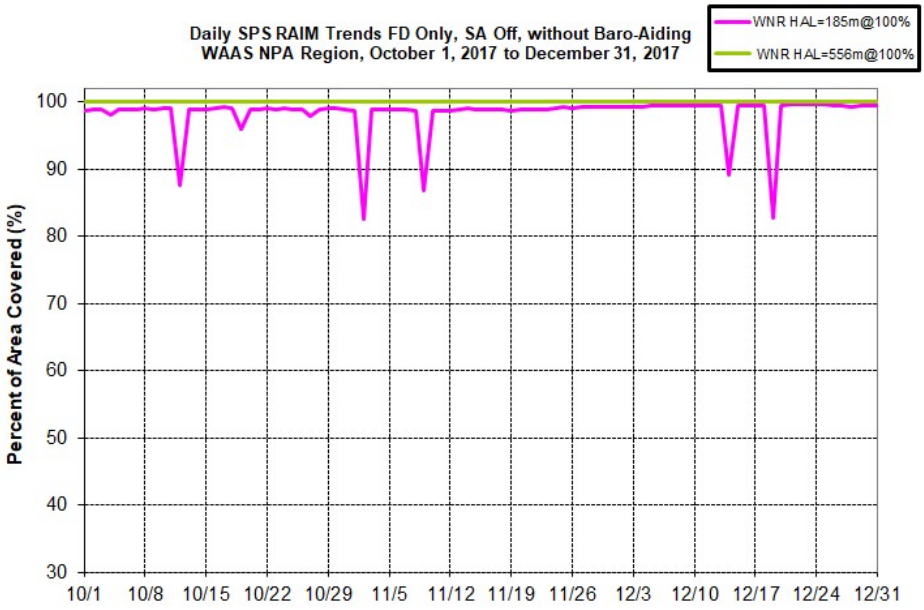


Figure 8-4 RAIM RNP Coverage Trend for WAAS NPA Service Area



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

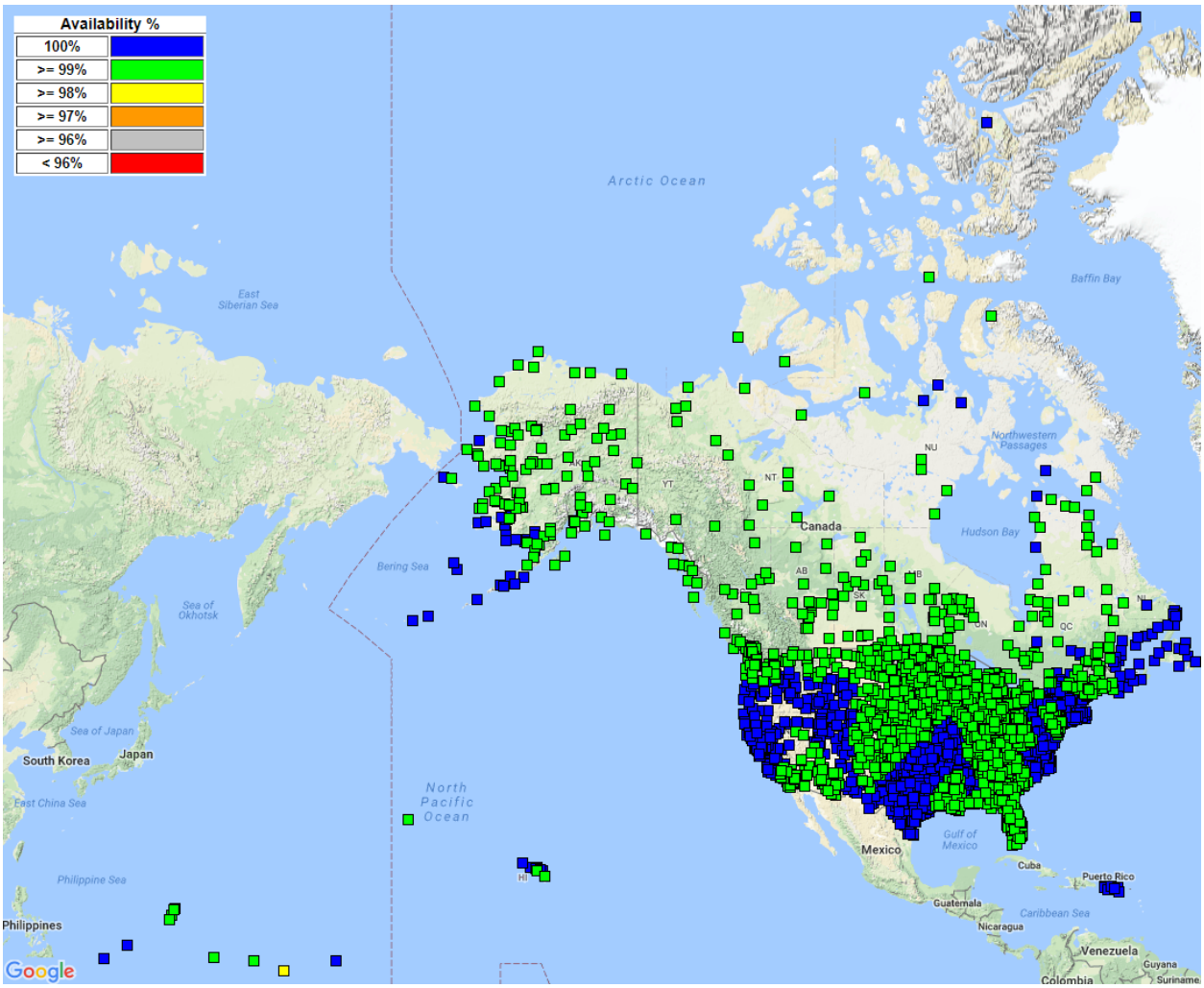
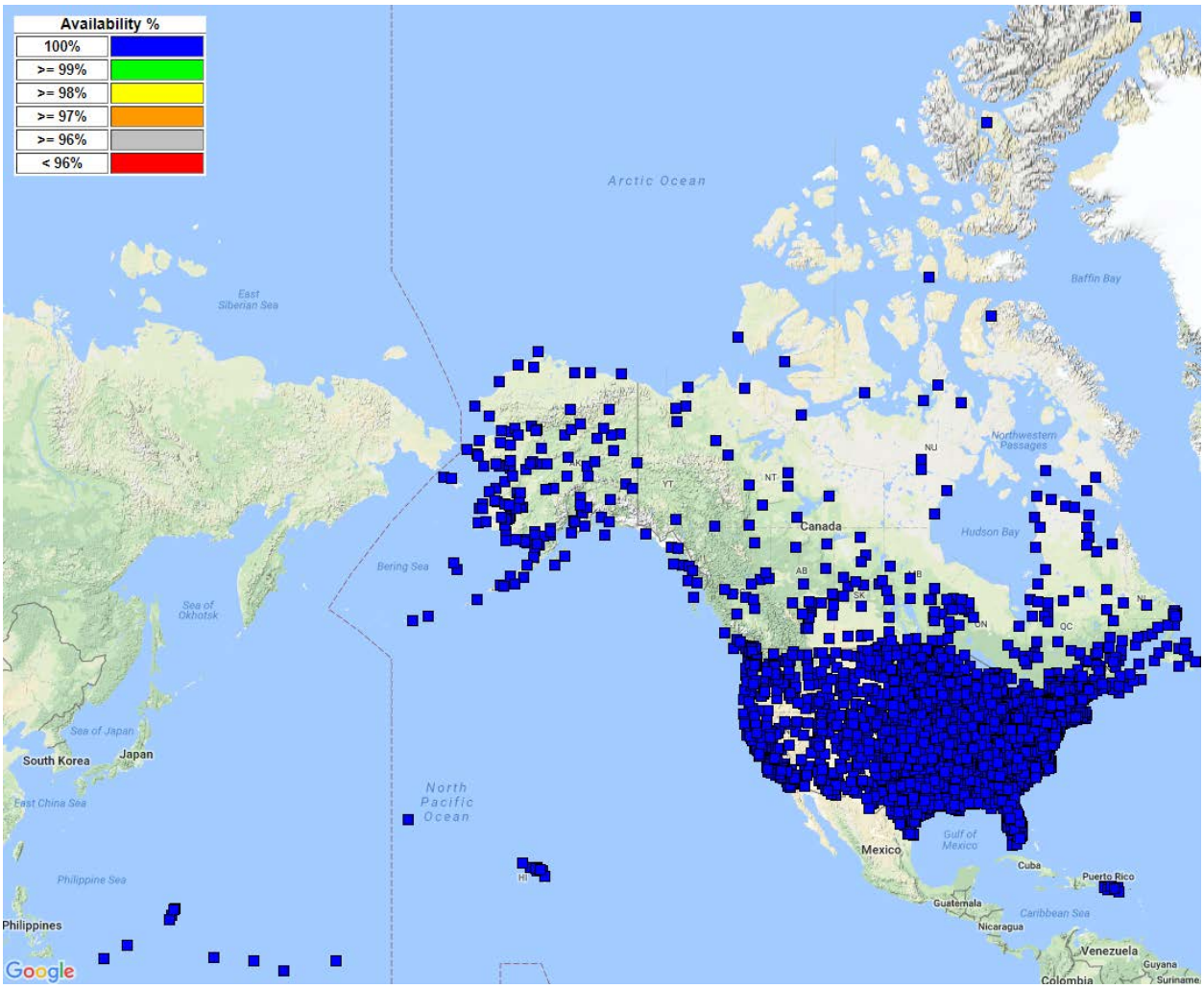


Figure 8-6 RAIM RNP 0.3 Airport Availability



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

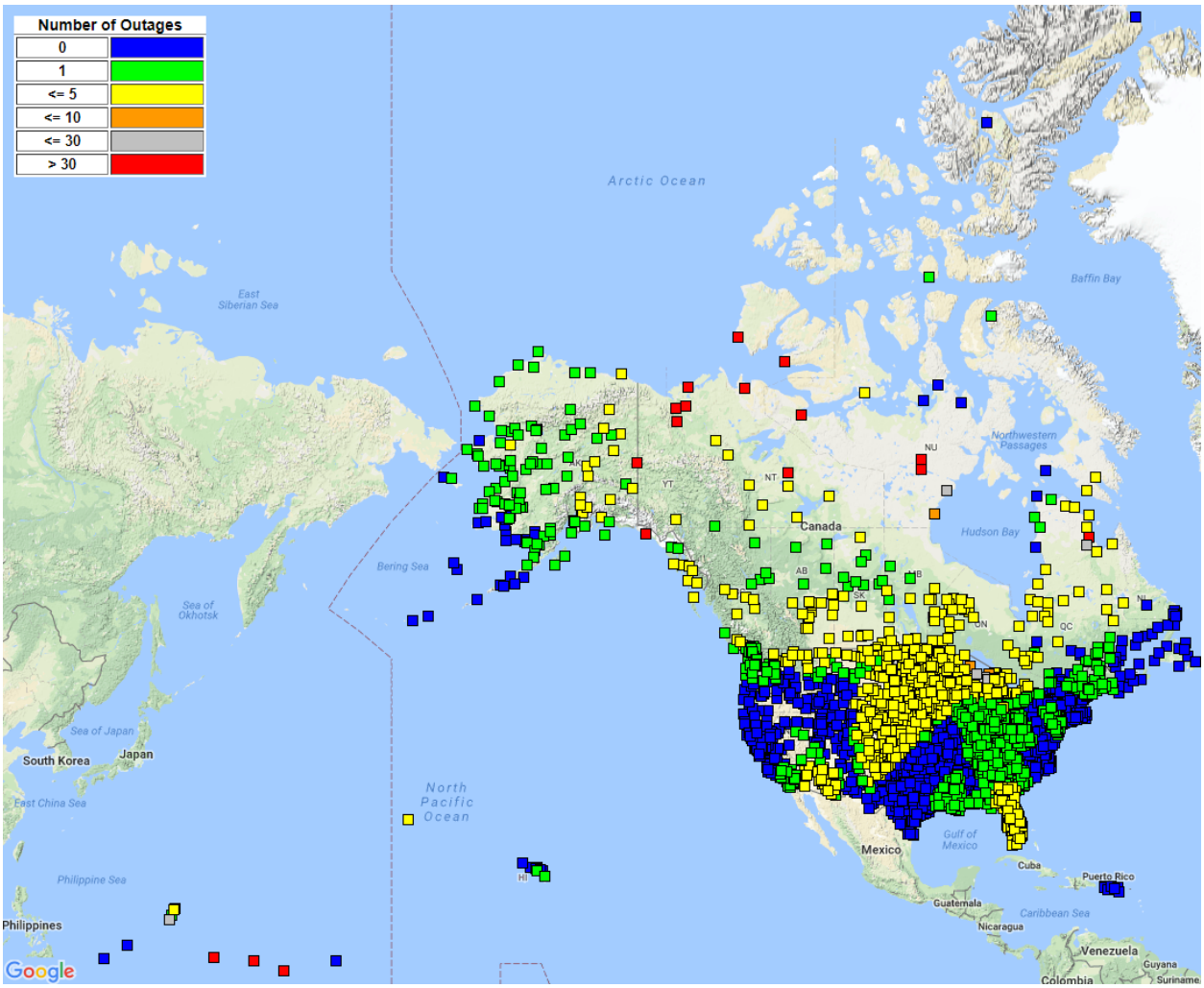
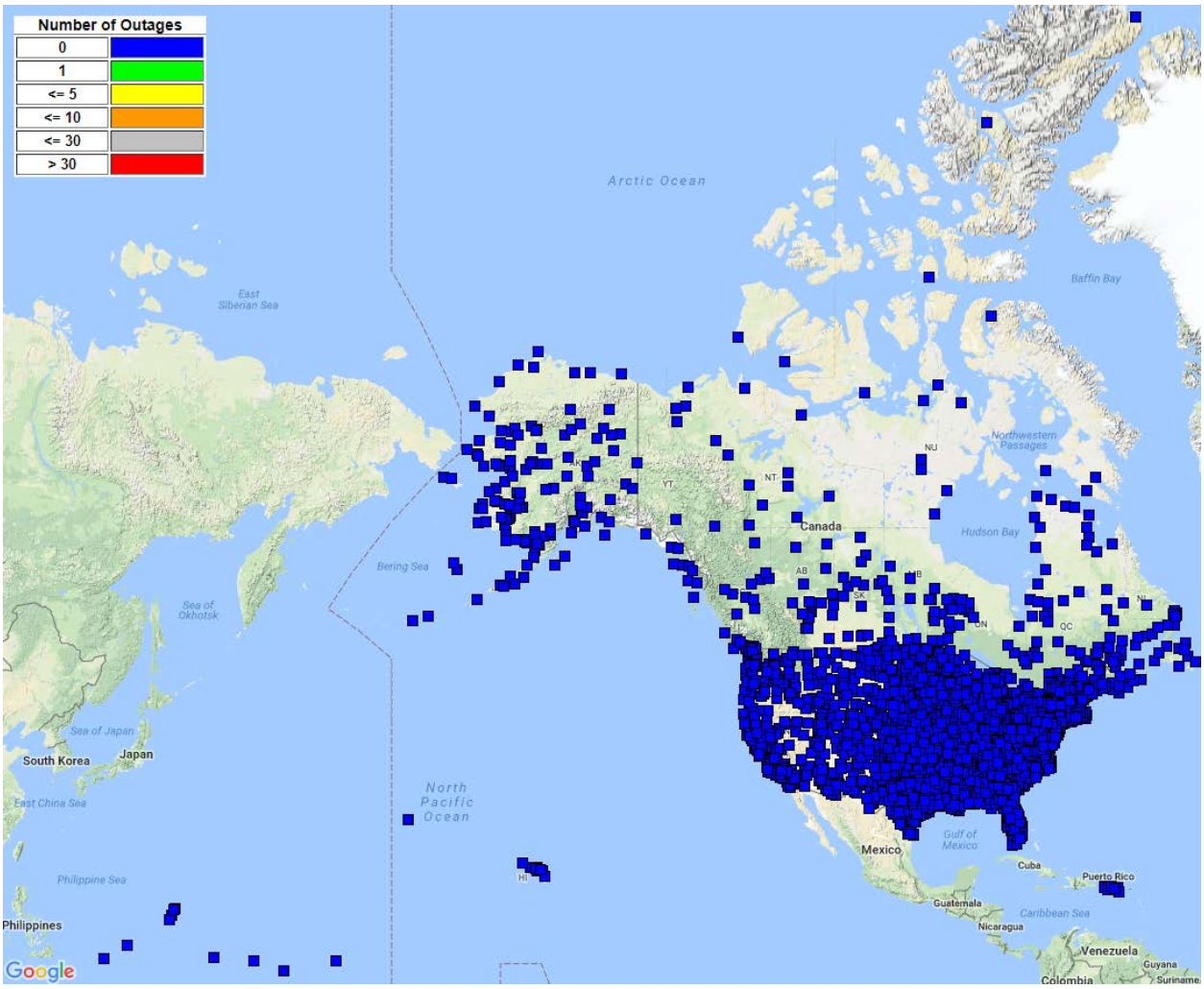


Figure 8-8 RAIM RNP 0.3 Airport Outages



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 October through 31 December 2017, there were a total of 93 GPS test NOTAMs. The total number of days affected in this reporting period is 64. 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	573.3 hours
Minimum Duration	0.50 hours
Media Duration	5.50 hours
Average Duration	6.16 hours
Maximum Duration	23.98 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	10,821	4,809	5,096	5,096	7,338
Average	397,634	291,203	168,384	132,674	85,015
Maximum	1,177,490	1,124,967	783,634	755,011	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

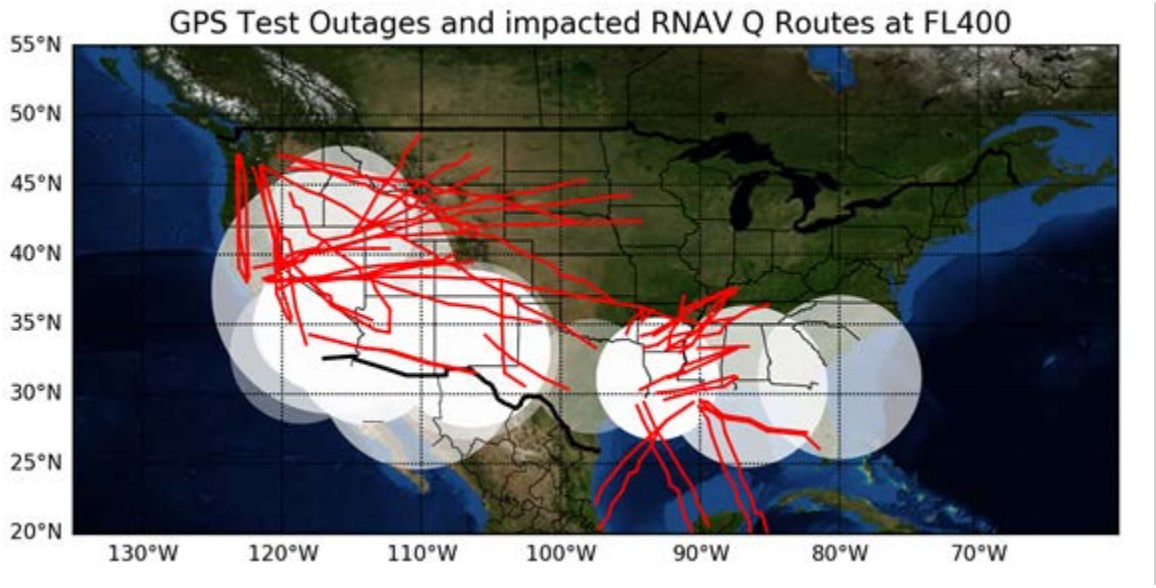


Figure 9-2 GPS NOTAMs @ FL250

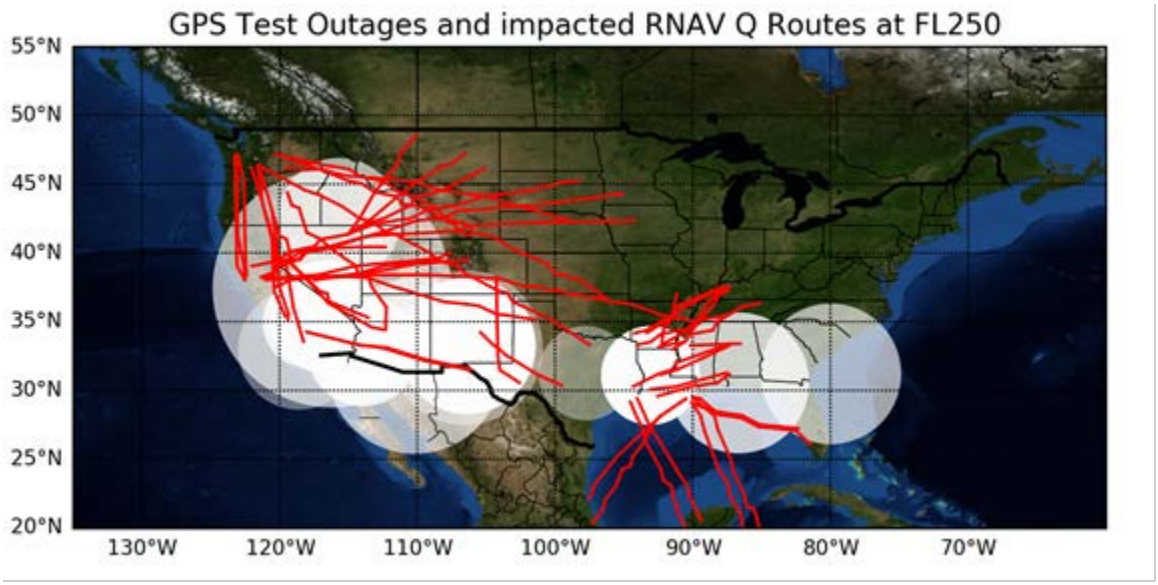


Figure 9-3 GPS NOTAMs @ 10k Feet

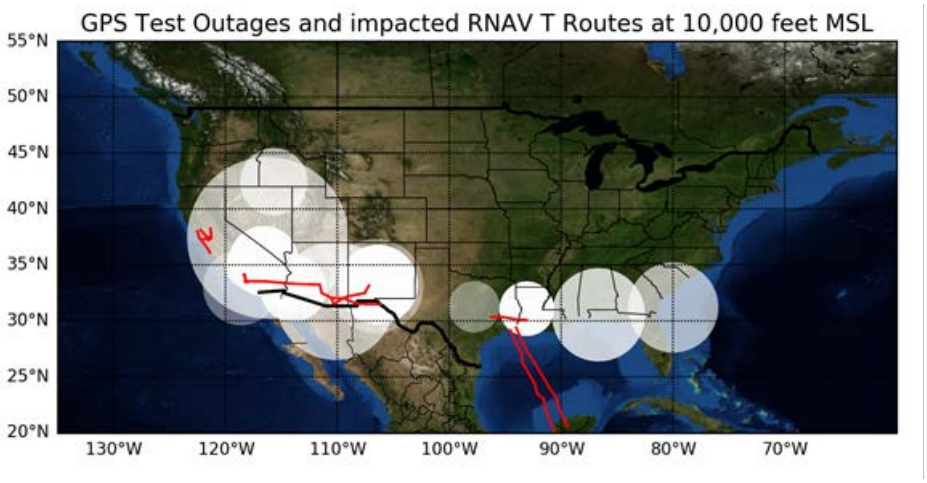


Figure 9-4 GPS NOTAMs @ 4k Feet

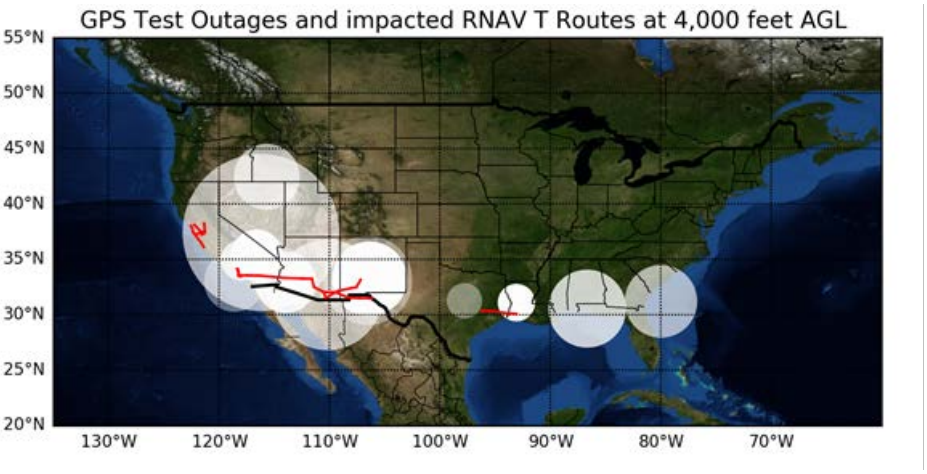
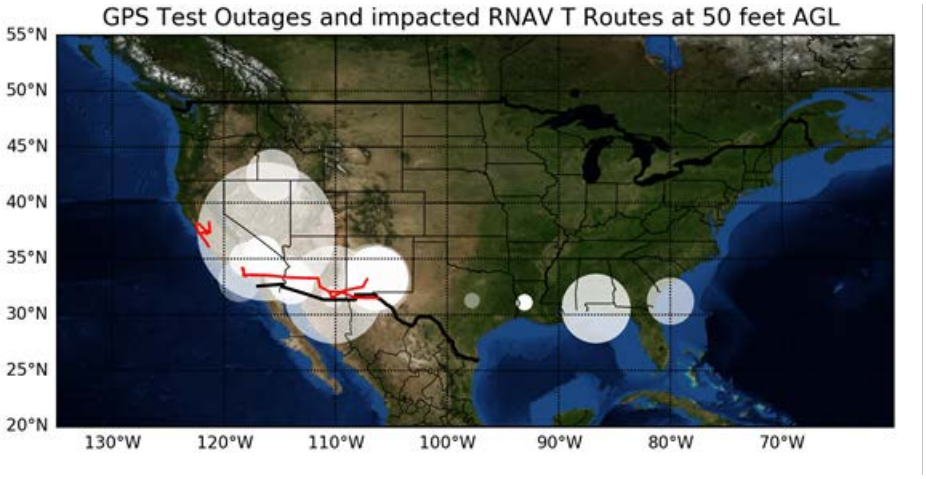


Figure 9-5 GPS NOTAMs @ 50 Feet



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**
2017-10-02 18:30:00	2017-10-05 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-10-03 14:00:00	2017-10-03 20:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-03 20:00:00	2017-10-03 23:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-04 03:00:00	2017-10-05 07:00:00	330647.0000N	1063035.0000W	4.13	5.78	6.40	10.22	12.90
2017-10-04 15:00:00	2017-10-04 19:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-04 19:00:00	2017-10-04 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-05 14:00:00	2017-10-05 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-07 16:00:00	2017-10-07 20:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-07 19:00:00	2017-10-07 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-08 14:30:00	2017-10-08 17:30:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-08 17:30:00	2017-10-08 23:00:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-08 21:00:00	2017-10-08 22:30:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-10-09 16:00:00	2017-10-09 19:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-09 19:00:00	2017-10-09 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-10-09 20:45:00	2017-10-09 23:00:00	372459.0000N	1161137.0000W	14.24	17.23	17.54	22.91	23.74
2017-10-10 08:00:00	2017-10-10 11:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-10-10 18:30:00	2017-10-14 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-10-17 17:00:00	2017-10-17 18:30:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-10-19 18:30:00	2017-10-20 19:00:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-10-21 06:00:00	2017-10-26 13:00:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-10-21 07:00:00	2017-10-23 10:59:00	330057.0000N	1183540.0000W	0.72	1.44	2.27	3.51	4.75
2017-10-22 16:30:00	2017-10-24 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-10-22 18:30:00	2017-10-22 22:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-23 00:00:00	2017-10-26 23:59:00	213728.0000N	1575917.0000W	0.00	0.00	0.00	0.00	0.00
2017-10-23 11:00:00	2017-10-23 13:00:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-23 18:30:00	2017-10-23 22:30:00	325413.0000N	1135609.0000W	1.44	2.48	2.58	4.44	6.71
2017-10-24 18:30:00	2017-10-24 22:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-25 06:00:00	2017-10-26 13:00:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-25 20:30:00	2017-10-26 22:30:00	332511.0000N	1142008.0000W	1.44	2.48	2.48	4.13	5.47
2017-10-26 16:30:00	2017-10-29 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-10-27 00:00:00	2017-10-28 23:59:00	212935.0000N	1580643.0000W	0.00	0.00	0.00	0.00	0.00
2017-10-27 06:00:00	2017-10-28 07:00:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-28 16:30:00	2017-10-29 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-10-29 06:00:00	2017-10-29 13:00:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-29 18:30:00	2017-10-29 22:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-30 06:00:00	2017-10-30 13:00:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-10-30 18:30:00	2017-11-03 22:30:00	313554.0000N	1101640.0000W	0.41	0.10	0.10	0.10	0.41
2017-10-31 11:00:00	2017-10-31 13:00:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-01 18:30:00	2017-11-02 22:30:00	332345.0000N	1142143.0000W	0.52	1.03	1.86	3.51	5.06
2017-11-01 19:00:00	2017-11-01 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-02 06:00:00	2017-11-03 12:00:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-02 19:00:00	2017-11-02 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-03 19:00:00	2017-11-03 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-04 06:00:00	2017-11-04 14:00:00	220250.0000N	1594658.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-04 07:00:00	2017-11-04 12:00:00	314717.0000N	1101117.0000W	4.64	5.99	6.60	9.49	11.66
2017-11-04 14:00:00	2017-11-04 20:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-11-04 20:00:00	2017-11-04 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-05 12:00:00	2017-11-05 18:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-11-05 18:00:00	2017-11-05 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-06 18:30:00	2017-11-10 22:30:00	313554.0000N	1101640.0000W	0.41	0.10	0.10	0.10	0.41
2017-11-07 03:00:00	2017-11-07 09:00:00	310535.0000N	930350.0000W	0.10	1.03	2.17	4.75	6.40
2017-11-07 06:00:00	2017-11-10 14:00:00	220250.0000N	1594658.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-07 07:00:00	2017-11-10 12:00:00	314717.0000N	1101117.0000W	4.64	5.99	6.60	9.49	11.66
2017-11-07 18:30:00	2017-11-08 22:30:00	332345.0000N	1142143.0000W	0.52	1.03	1.86	3.51	5.06
2017-11-07 19:00:00	2017-11-07 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-08 21:00:00	2017-11-08 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-10 19:00:00	2017-11-10 23:59:00	310535.0000N	930350.0000W	0.10	0.10	0.10	0.10	0.10
2017-11-11 07:00:00	2017-11-15 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-12 06:00:00	2017-11-12 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-13 06:00:00	2017-11-13 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-14 06:00:00	2017-11-14 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-15 06:00:00	2017-11-15 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-15 17:00:00	2017-11-17 22:30:00	345545.0000N	1175741.0000W	0.93	1.14	1.65	3.61	4.95
2017-11-16 06:00:00	2017-11-16 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-17 06:00:00	2017-11-17 16:00:00	645447.0000N	1464448.0000W	0.00	0.00	0.00	0.00	0.00
2017-11-17 07:00:00	2017-11-17 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-18 08:00:00	2017-11-18 13:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-11-18 17:30:00	2017-11-18 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-11-19 08:00:00	2017-11-19 13:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-11-19 17:30:00	2017-11-19 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41
2017-11-20 08:00:00	2017-11-20 13:30:00	352112.0000N	1163405.0000W	1.14	2.06	3.72	6.19	8.77
2017-11-20 17:30:00	2017-11-20 23:59:00	352112.0000N	1163405.0000W	0.41	0.21	0.31	0.41	0.41

				Percent Impact at Each Site				
START DATE	**END DATE**	**LAT**	**LONG**	**50**	**4000**	**10000**	**FL250**	**FL400**
2017-11-28 08:00:00	2017-11-28 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-28 17:00:00	2017-11-30 22:30:00	345545.0000N	1175741.0000W	0.93	1.14	1.65	3.61	4.95
2017-11-29 00:01:00	2017-12-02 23:59:00	311546.0000N	974609.0000W	0.10	0.93	2.06	4.44	6.40
2017-11-29 07:00:00	2017-11-29 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-11-30 07:00:00	2017-11-30 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-01 06:00:00	2017-12-04 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-01 17:00:00	2017-12-01 22:30:00	345545.0000N	1175741.0000W	0.93	1.14	1.65	3.61	4.95
2017-12-03 13:00:00	2017-12-03 18:00:00	311230.0000N	795830.0000W	1.03	2.68	3.92	6.40	8.26
2017-12-05 08:00:00	2017-12-05 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-06 06:00:00	2017-12-06 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-07 08:00:00	2017-12-07 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-07 13:00:00	2017-12-07 18:00:00	311230.0000N	795830.0000W	1.03	2.68	3.92	6.40	8.26
2017-12-08 06:00:00	2017-12-08 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-09 17:00:00	2017-12-15 23:59:00	422637.0000N	1154037.0000W	2.27	3.92	4.02	8.67	12.38
2017-12-11 08:00:00	2017-12-11 13:00:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-11 13:00:00	2017-12-15 19:00:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-12-11 17:00:00	2017-12-15 23:59:00	422637.0000N	1154037.0000W	2.27	3.92	4.02	8.67	12.38
2017-12-13 16:00:00	2017-12-13 19:00:00	315437.0000N	1060971.0000W	0.31	0.10	0.10	0.10	0.10
2017-12-14 04:00:00	2017-12-15 10:00:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60
2017-12-14 06:00:00	2017-12-14 14:30:00	331424.0000N	1062147.0000W	3.20	4.23	4.64	8.67	10.53
2017-12-14 13:00:00	2017-12-15 19:00:00	303251.0000N	863904.0000W	3.10	4.02	5.47	7.64	9.60

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	≤ 2.774 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	≤ 2.722 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	≤ 0.022 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	≥ 12.433 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	≤ 0.15 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.	≤ 1.770 m Horizontal ≤ 3.883 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.	≤ 3.688 m Horiz. ≤ 4.538 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.	≤ 10.4 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	≤ 34.2 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 October 01 to December 31, 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 10/04/17, PRN-32 on 10/04/17, PRN-29 on 10/12/17, PRN-26 on 10/19/17, PRN-31 on 10/27/17, PRN-29 on 11/02/17, PRN-16 on 11/09/17, PRN-21 on 12/14/17, and PRN-6 on 12/19/17. Figure 11-2 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. Data for PRN-6, PRN-7, PRN-17 and PRN-30 was missing 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 11-4.1 and 11-4.2 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 11-5.1 thru 11-5.50 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 11-6.1 thru 11-6.13 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 11-7.1 thru 11-7.50 are histograms of the height error, along track error, cross track error, and URA (IAURA) normalized range error.

Figures 11-8.1 thru 11-8.50 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

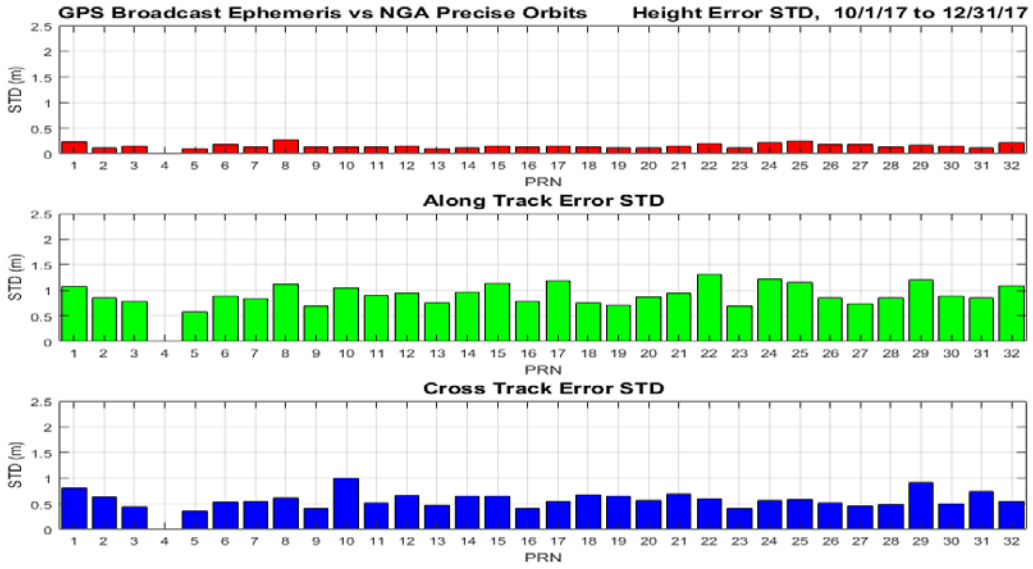


Figure 11-3 GPS Broadcast Orbit Accuracy Standard Deviations Using L2C CNAV Data

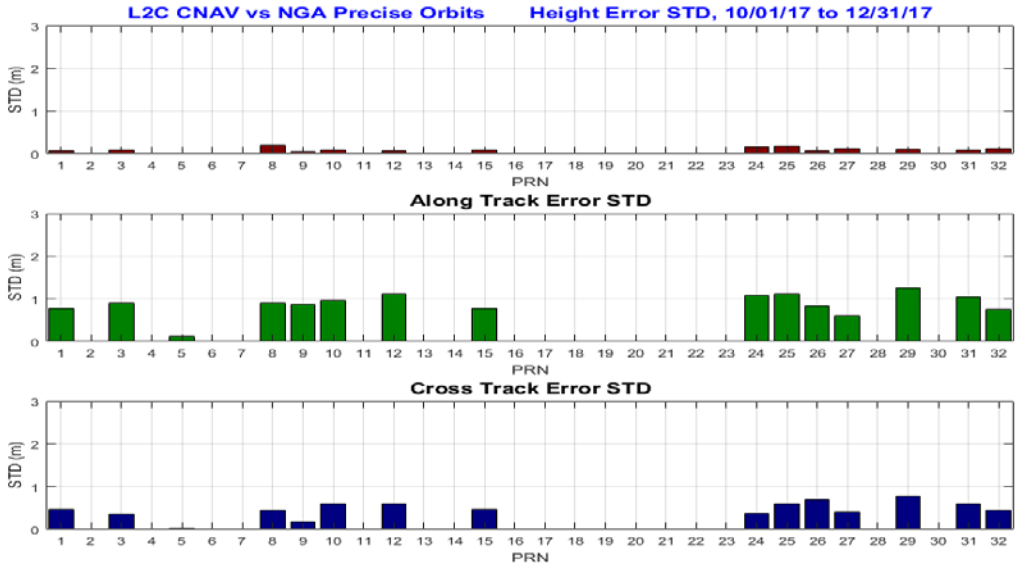


Figure 11-4 GPS Broadcast Orbit Error Means Using C/A Nav Data

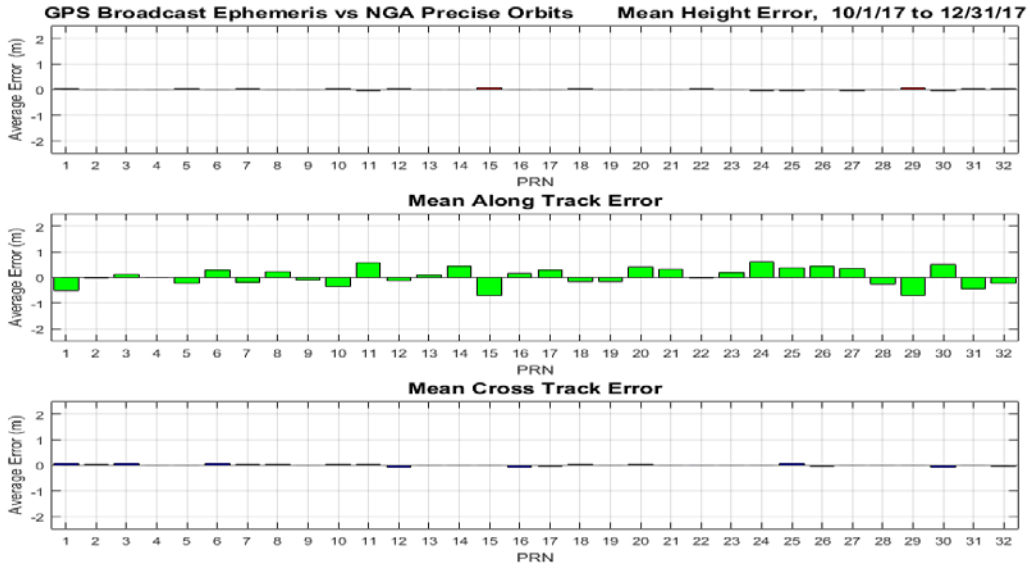
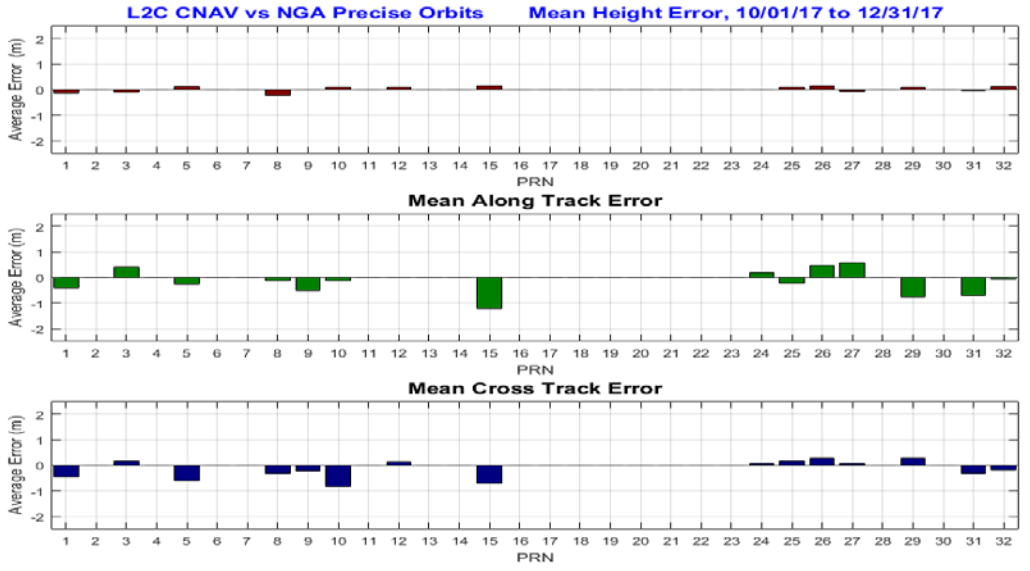
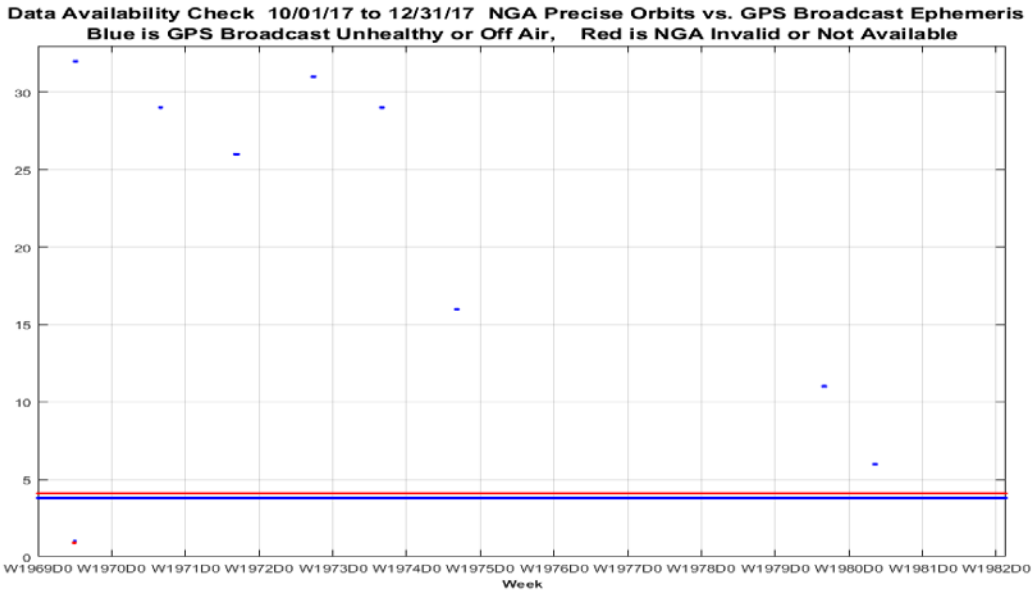


Figure 11-5 GPS Broadcast Orbit Error Means Using L2C CNAV Data



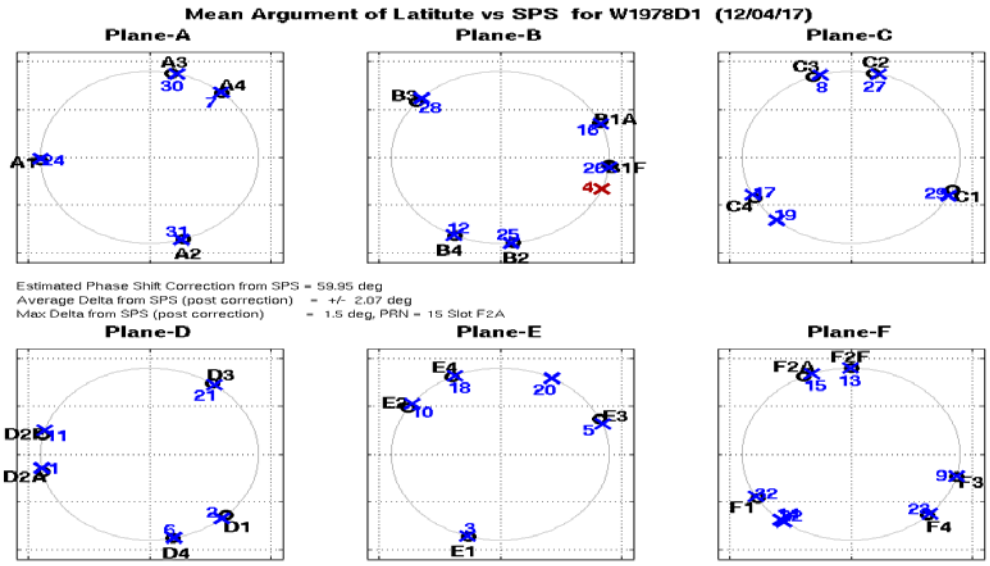
Broadcast Ephemeris vs. NGA Precise Data Availability Plots

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



Current GPS Constellation

Figure 11-7 Current GPS Constellation


Mean Argument of Latitute vs SPS for W1978D1 (12/04/17)
Plane-A
Plane-B
Plane-C
A3
30
A4
A1
24
31
A2
B3
28
B1A
18
26
B1F
4
12
B4
25
B2
C3
8
C2
27
C4
17
19
C1
Estimated Phase Shift Correction from SPS = 59.95 deg
Average Delta from SPS (post correction) = +/- 2.07 deg
Max Delta from SPS (post correction) = 1.5 deg, PRN = 15 Slot F2A
Plane-D
Plane-E
Plane-F
D3
21
D2B
11
D2A
1
6
D4
D1
E4
18
20
E2
10
E3
5
3
E1
F2A
15
F2F
13
9
F3
F1
32
22
F4

URA Over-bounding Plots

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

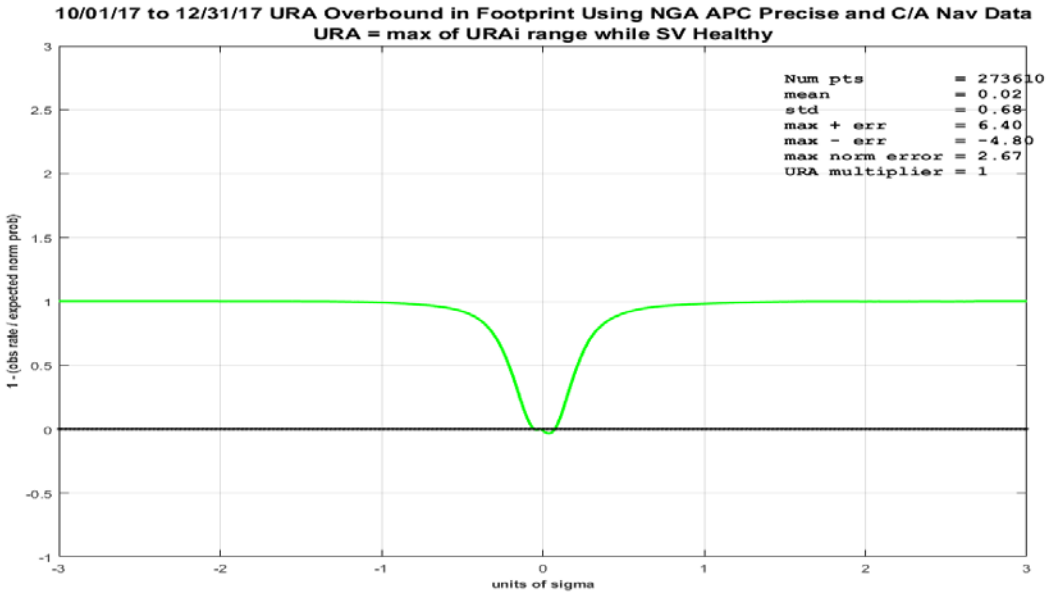
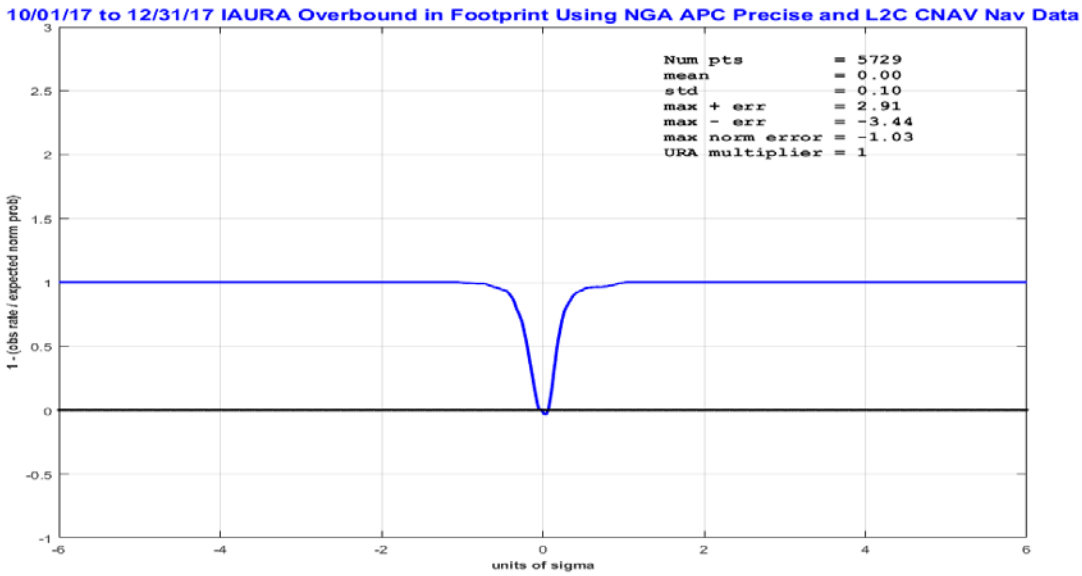


Figure 11-9 IAURA Over-bounding Using L2C CNAV Data



Orbit Error Plots for All Satellites

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

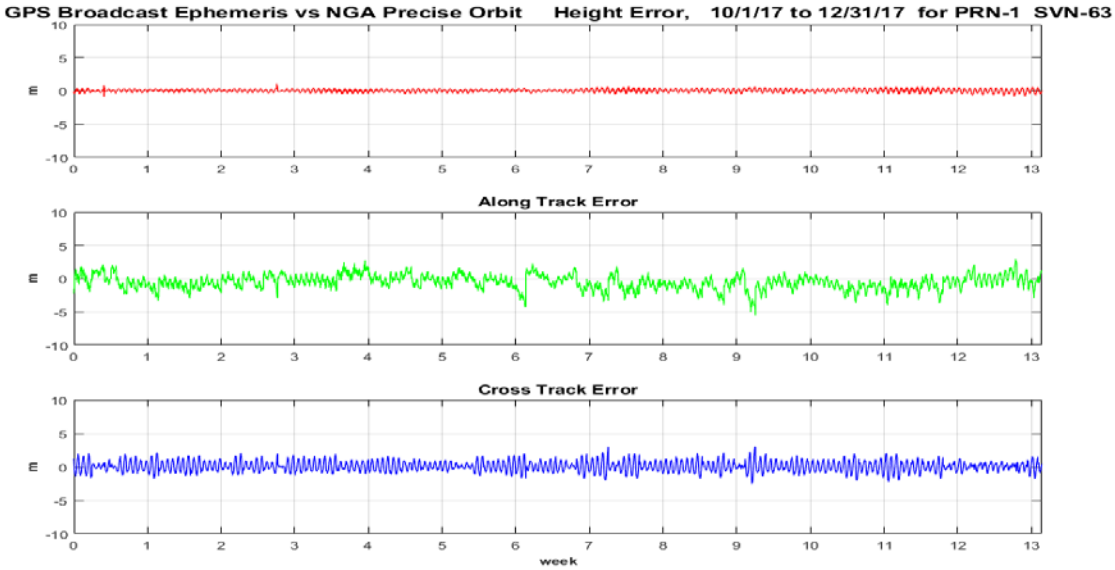


Figure 11-11 Orbit Error PRN-1 (SVN-63) Using L2C CNAV Data

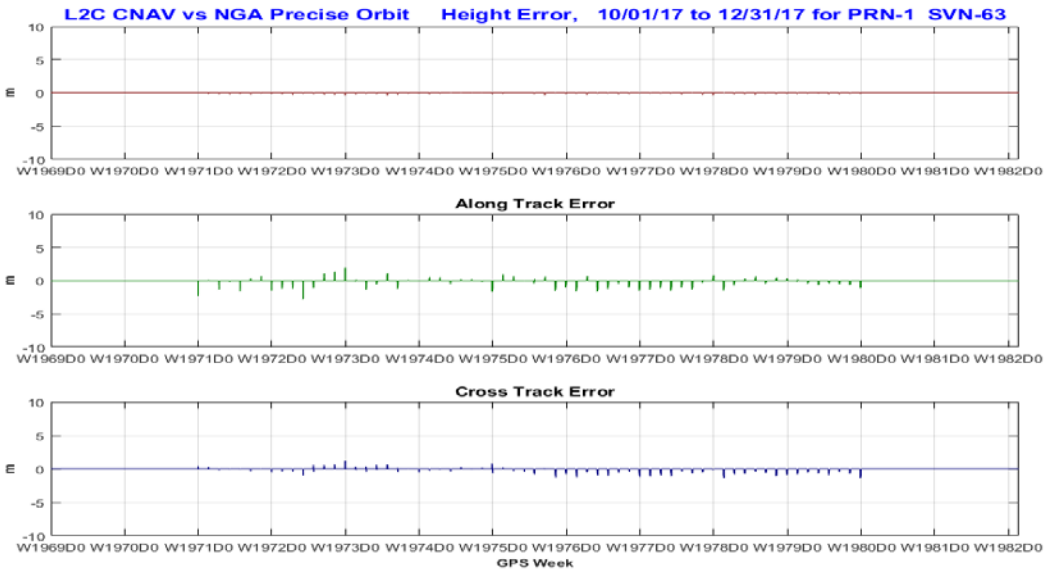


Figure 11-12 Orbit Error PRN-2 (SVN-61) Using C/A Nav Data

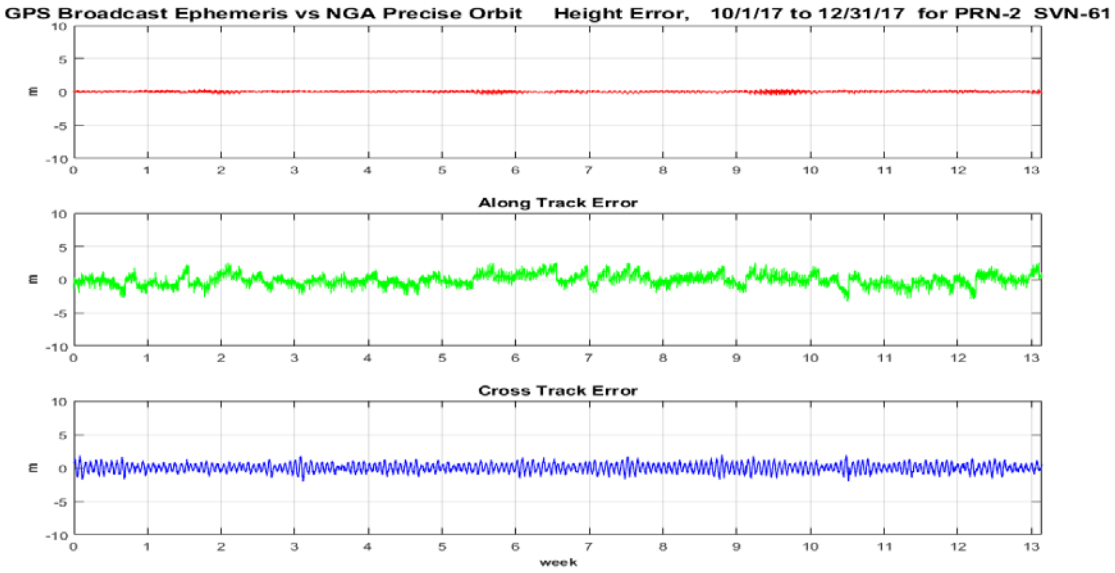


Figure 11-13 Orbit Error PRN-3 (SVN-69) Using C/A Nav Data

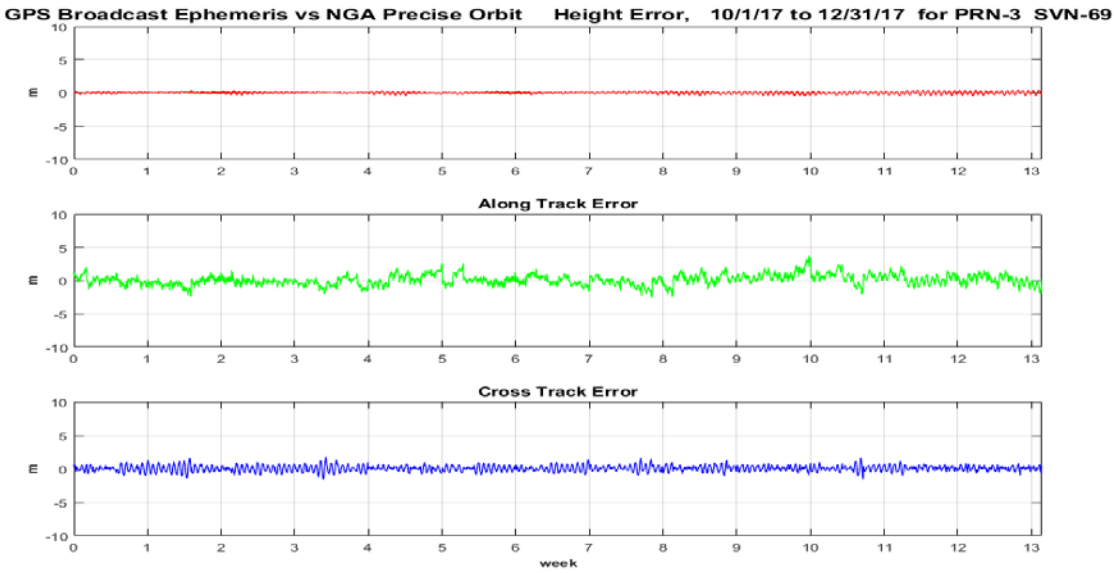


Figure 11-14 Orbit Error PRN-3 (SVN-69) Using L2C CNAV Data

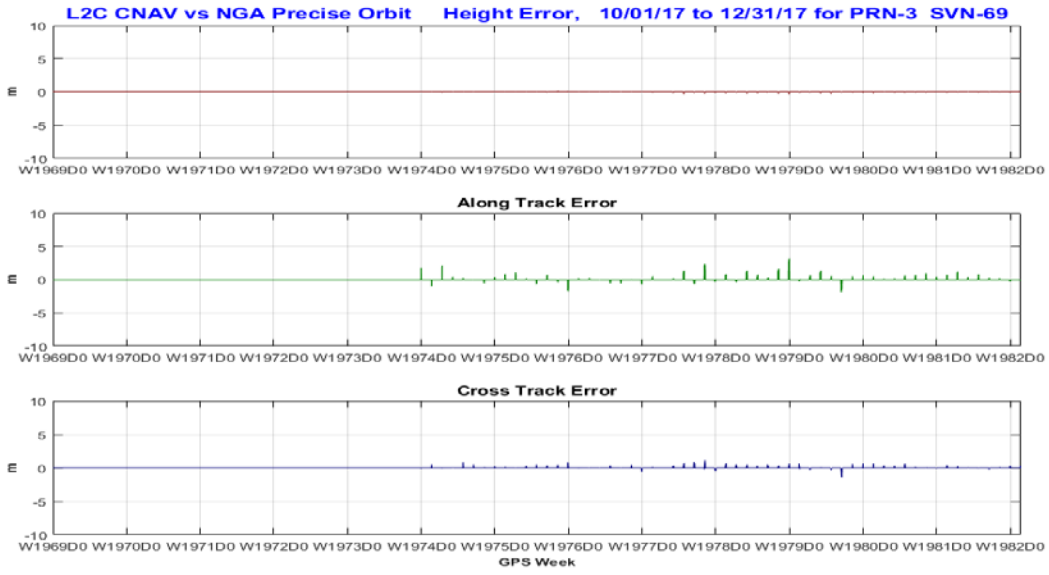


Figure 11-15 Orbit Error PRN-5 (SVN-50) Using C/A Nav Data

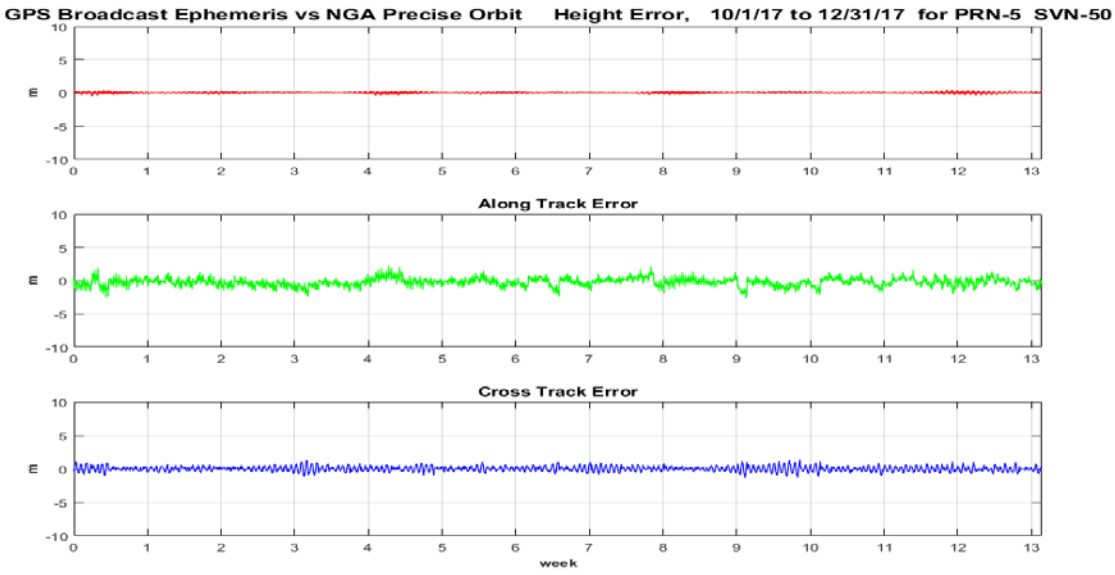


Figure 11-16 Orbit Error PRN-5 (SVN-50) Using L2C CNAV Data

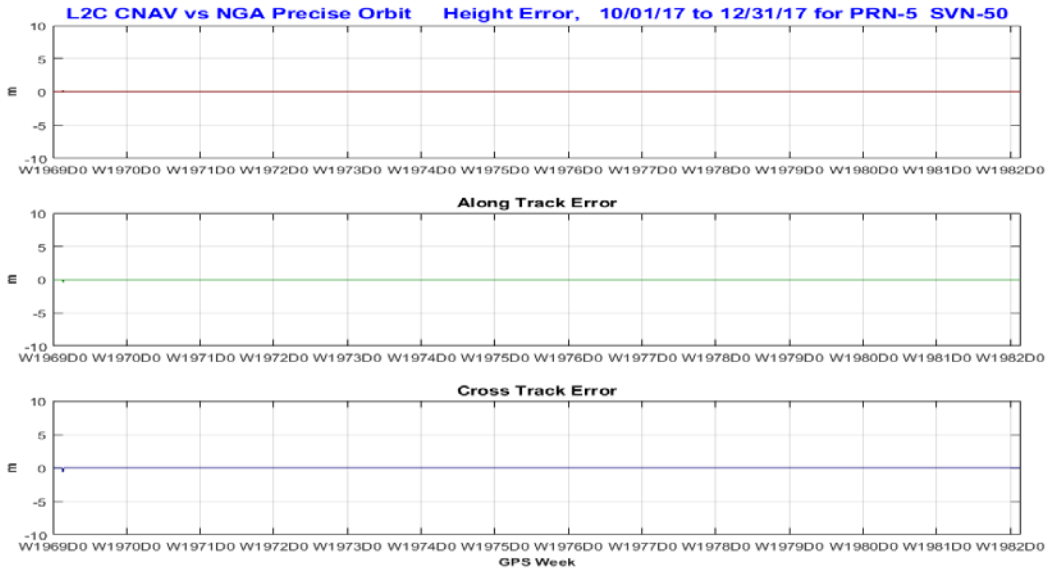


Figure 11-17 Orbit Error PRN-6 (SVN-67) Using C/A Nav Data

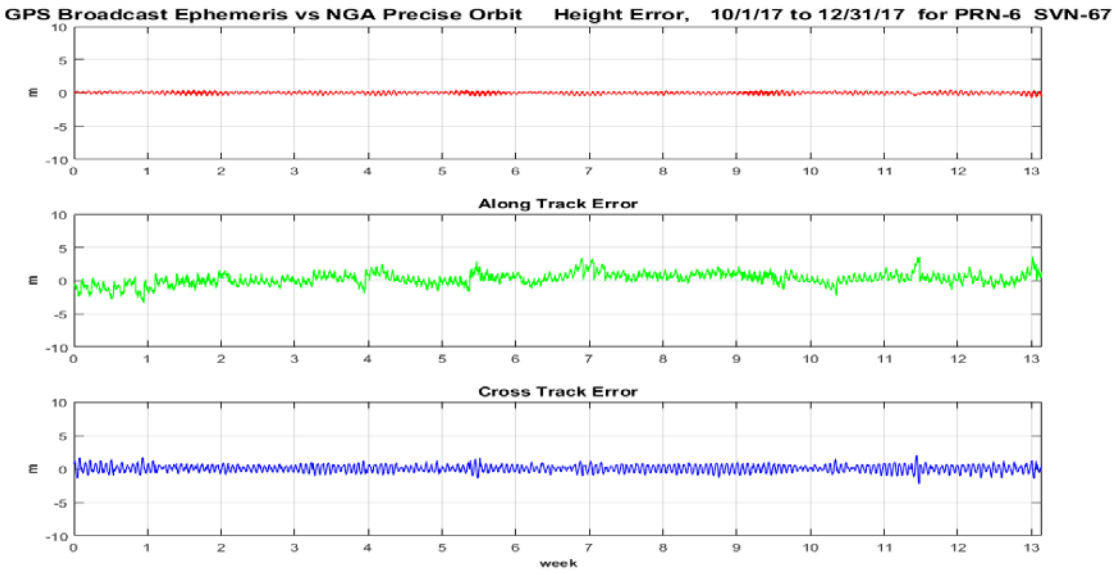


Figure 11-18 Orbit Error PRN-6 (SVN-67) Using L2C CNAV Data

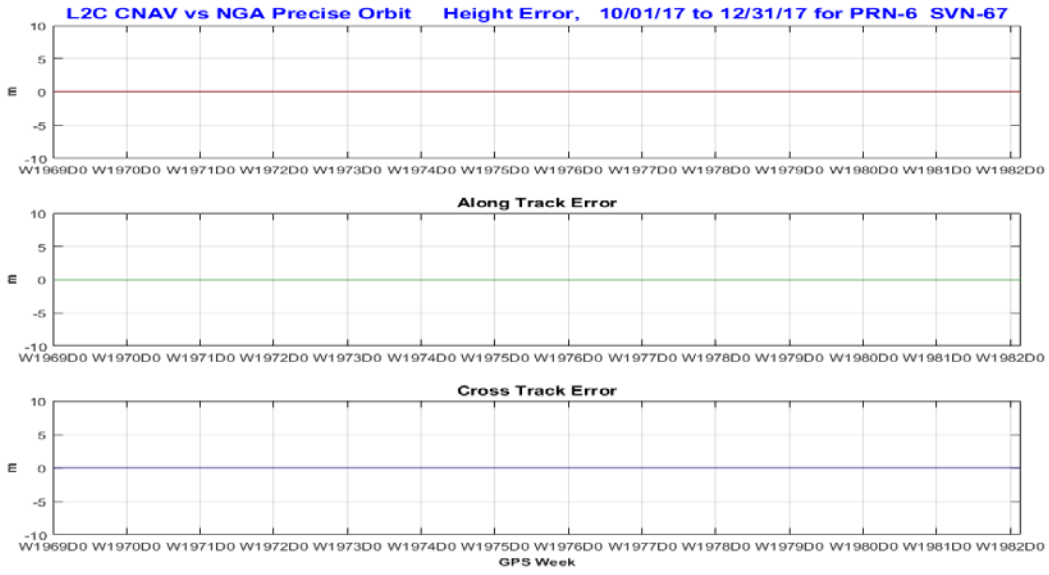


Figure 11-19 Orbit Error PRN-7 (SVN-48) Using C/A Nav Data

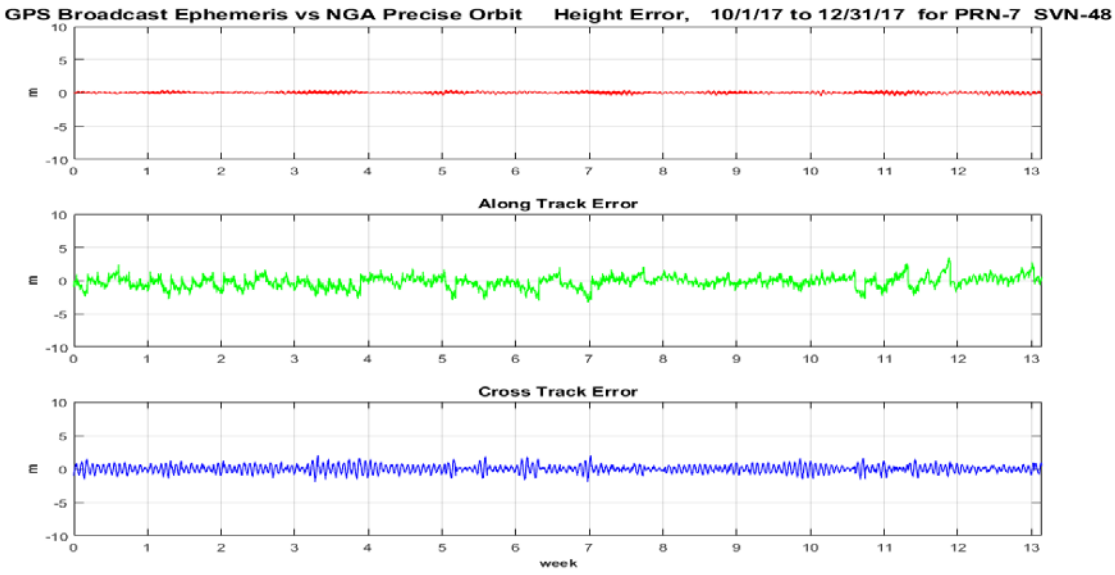


Figure 11-20 Orbit Error PRN-7 (SVN-48) Using L2C CNAV Data

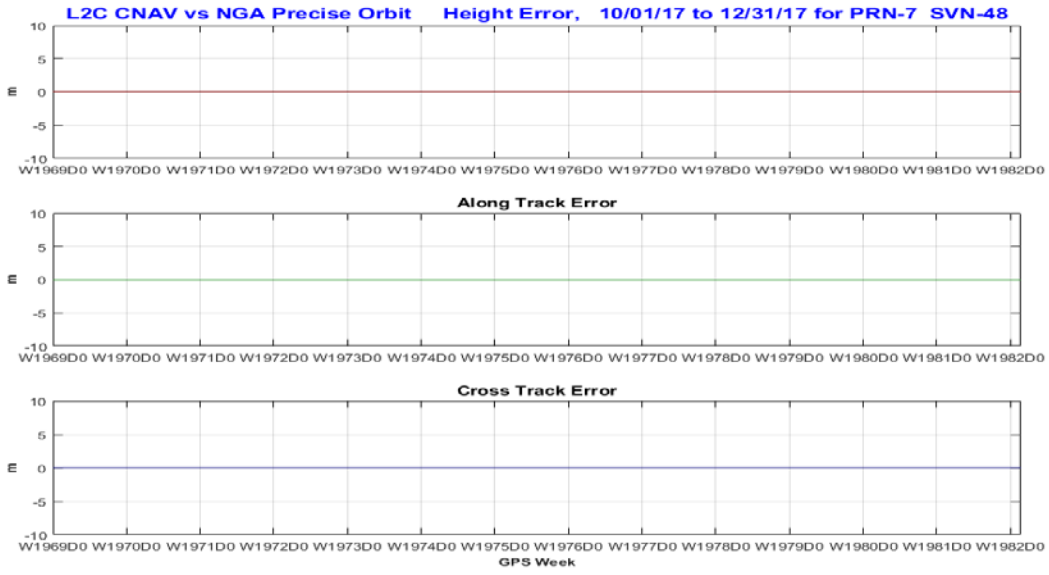


Figure 11-21 Orbit Error PRN-8 (SVN-72) Using C/A Nav Data

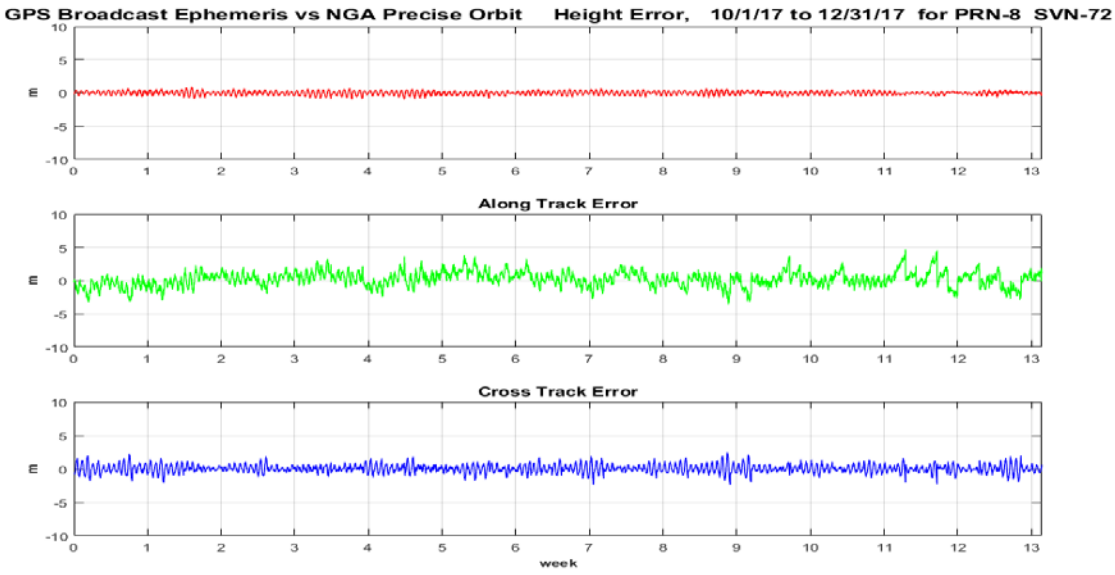


Figure 11-22 Orbit Error PRN-8 (SVN-72) Using L2C CNAV Data

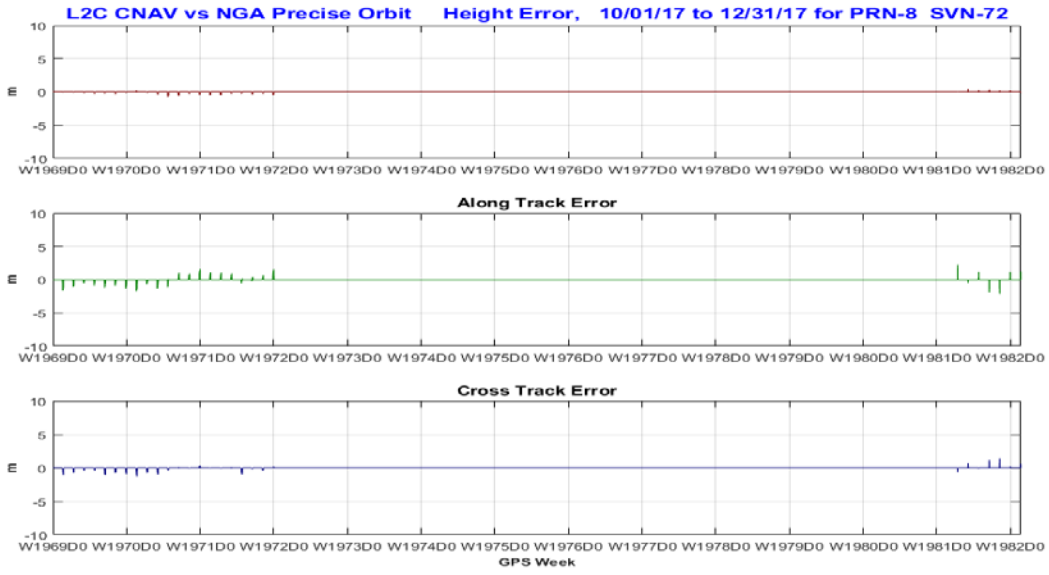


Figure 11-23 Orbit Error PRN-9 (SVN-68) Using C/A Nav Data

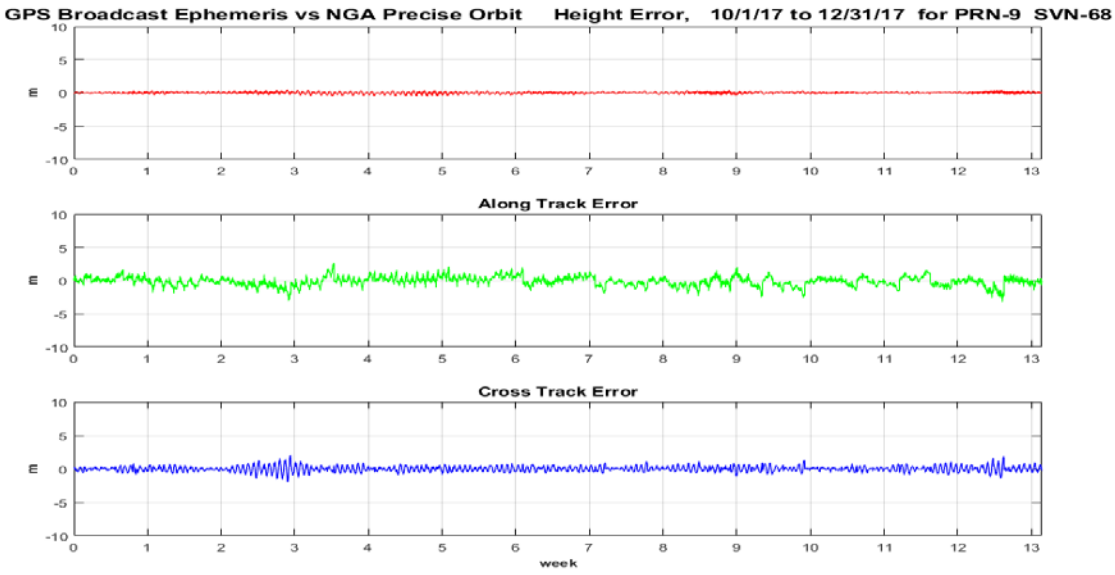


Figure 11-24 Orbit Error PRN-9 (SVN-68) Using L2C CNAV Data

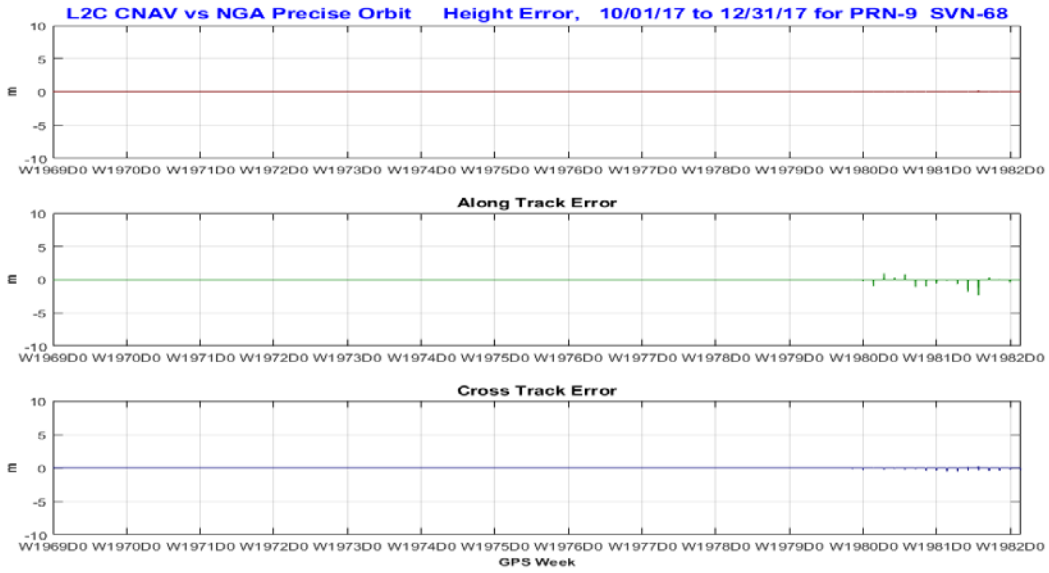


Figure 11-25 Orbit Error PRN-10 (SVN-73) Using C/A Nav Data

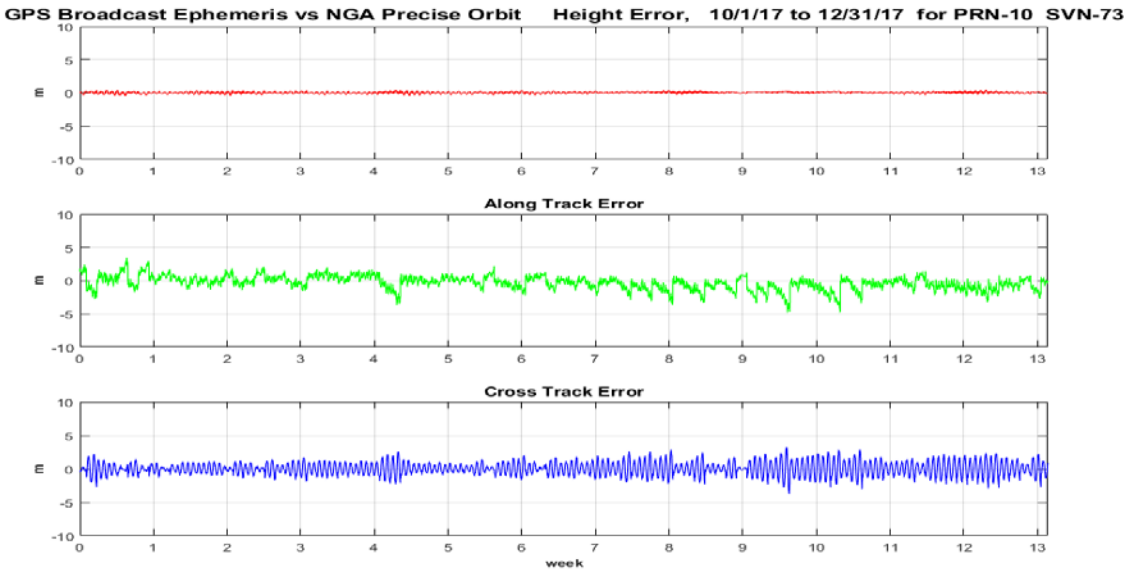


Figure 11-26 Orbit Error PRN-10 (SVN-73) Using L2C CNAV Data

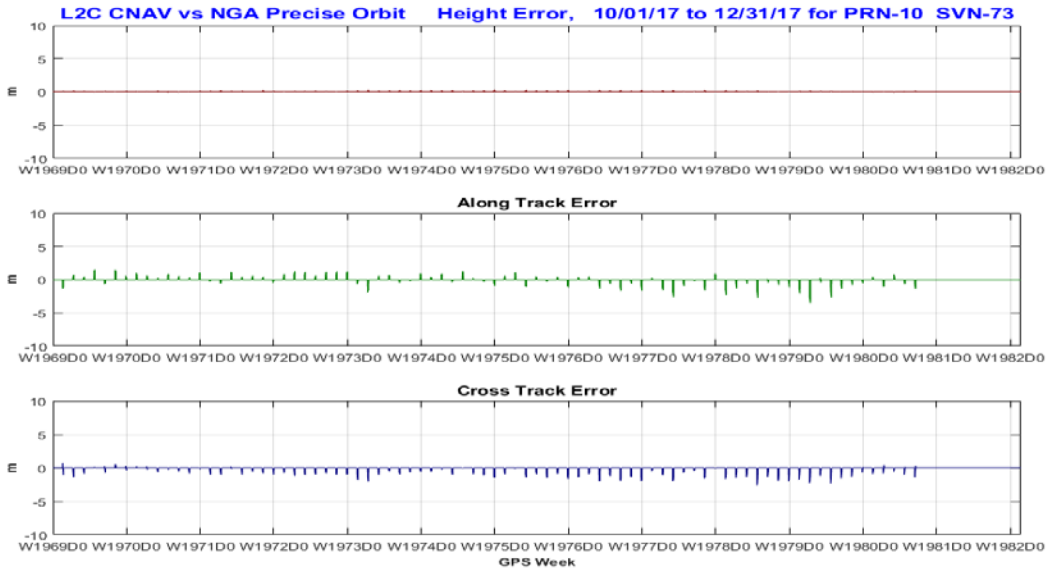


Figure 11-27 Orbit Error PRN-11 (SVN-46) Using C/A Nav Data

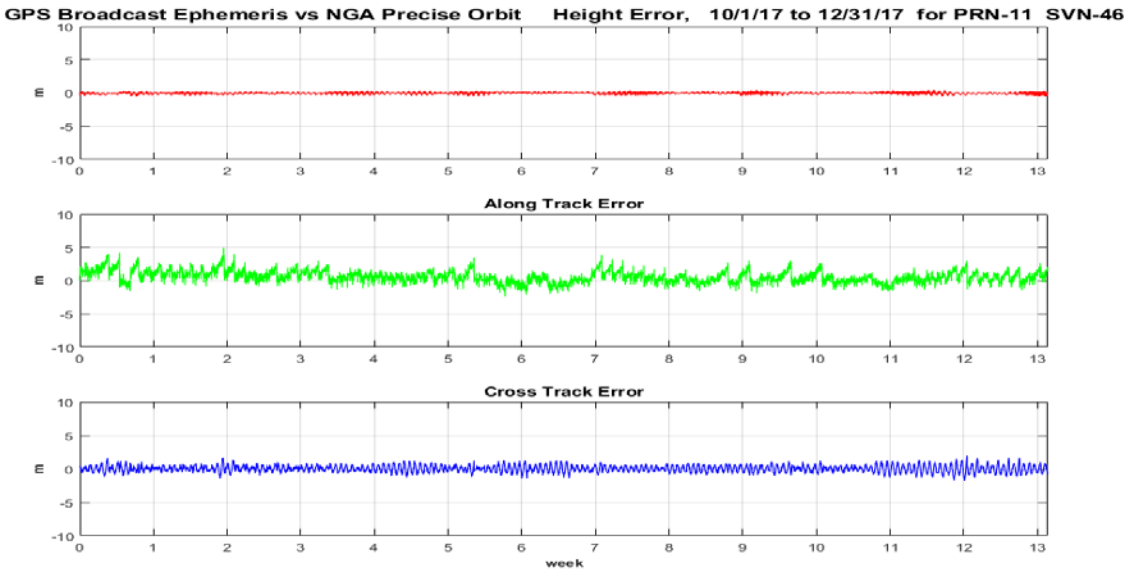


Figure 11-28 Orbit Error PRN-12 (SVN-58) Using C/A Nav Data

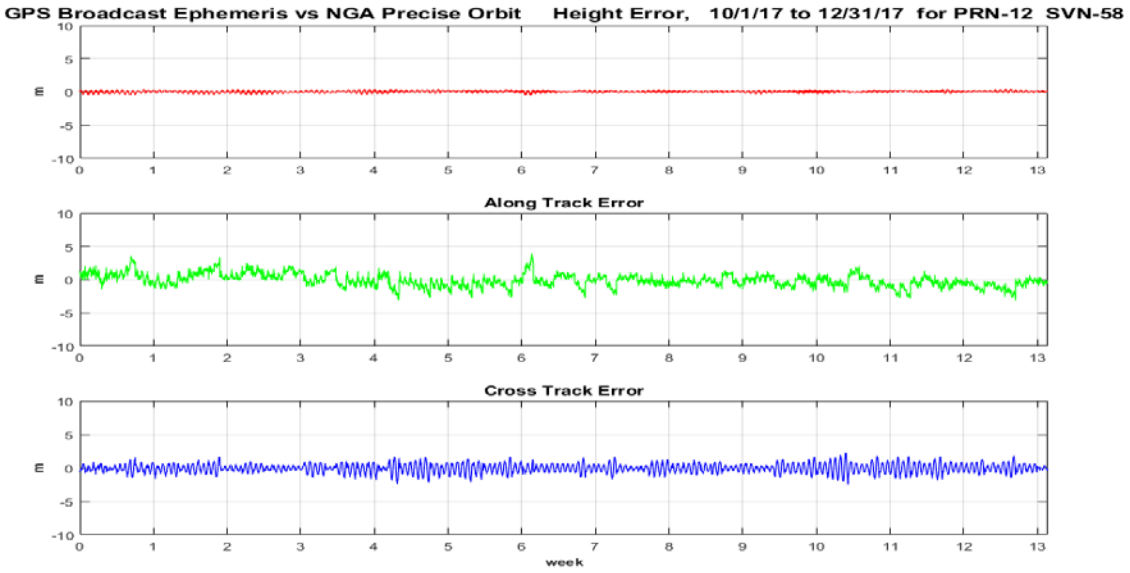


Figure 11-29 Orbit Error PRN-12 (SVN-58) Using L2C CNAV Data

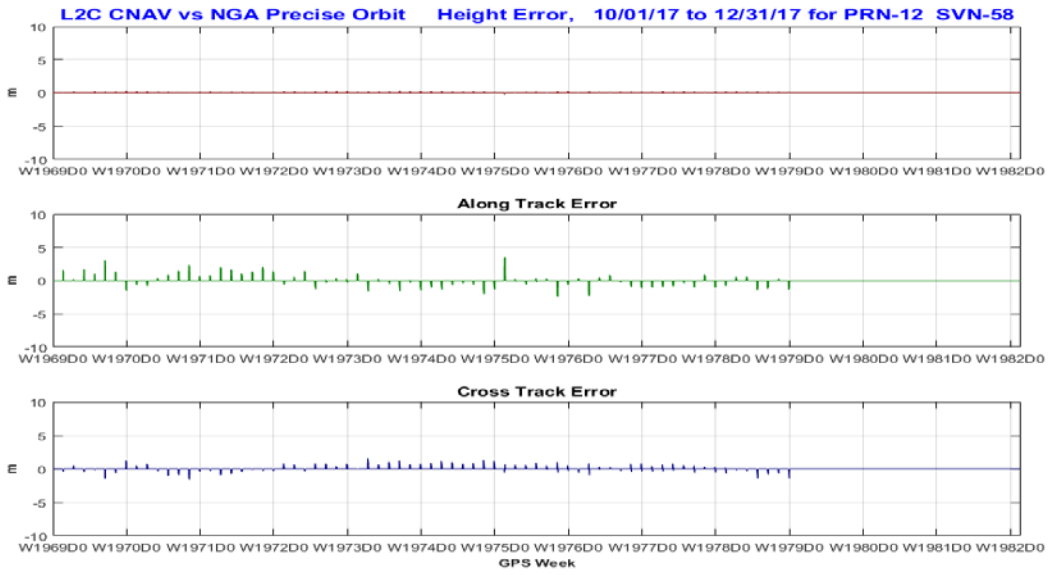


Figure 11-30 Orbit Error PRN-13 (SVN-43) Using C/A Nav Data

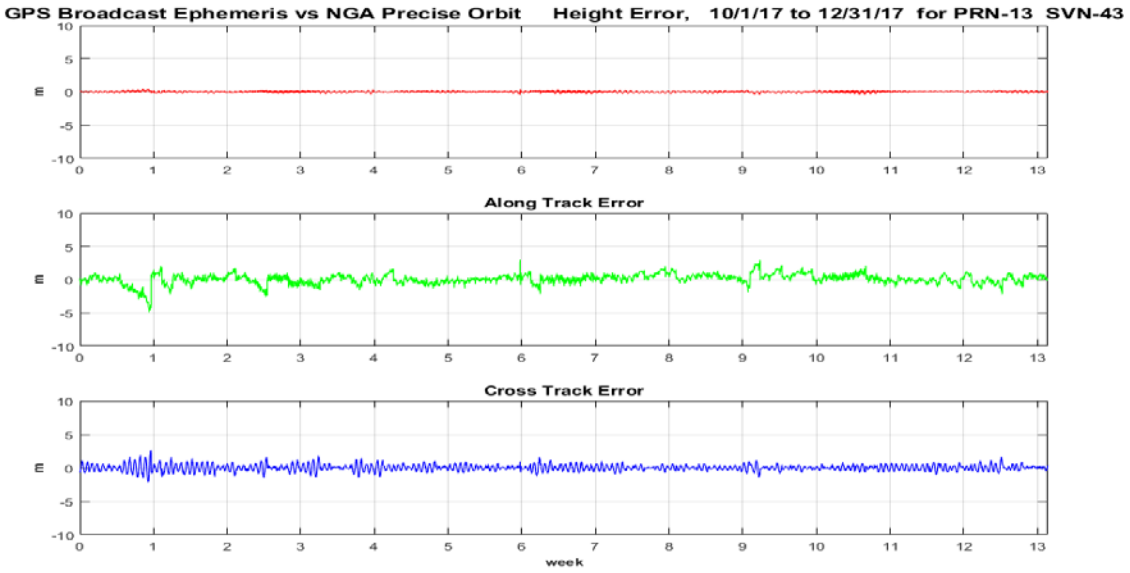


Figure 11-31 Orbit Error PRN-14 (SVN-41) Using C/A Nav Data

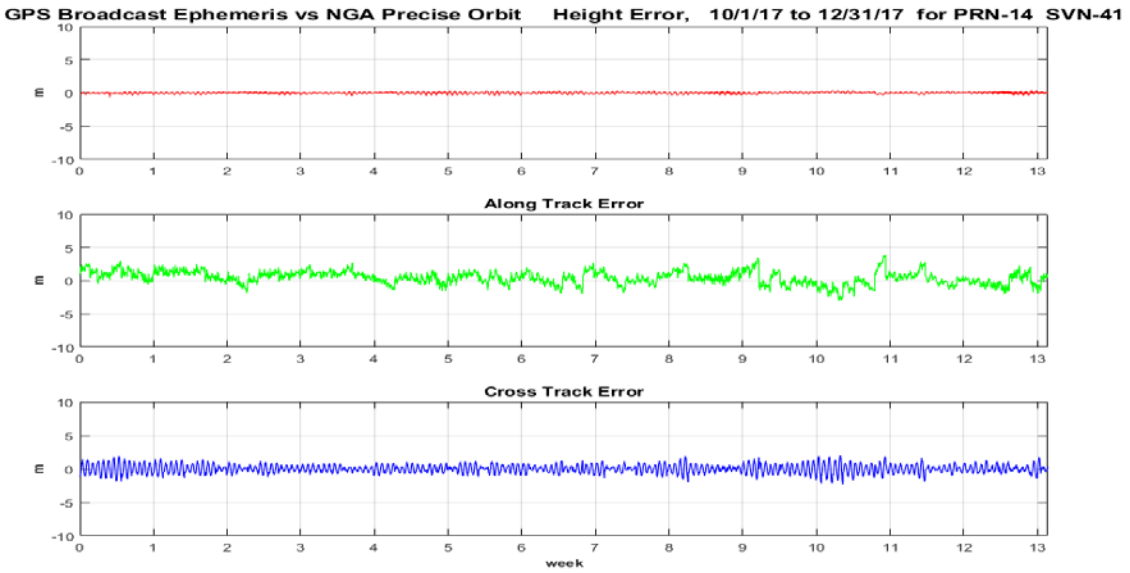


Figure 11-32 Orbit Error PRN-15 (SVN-55) Using C/A Nav Data

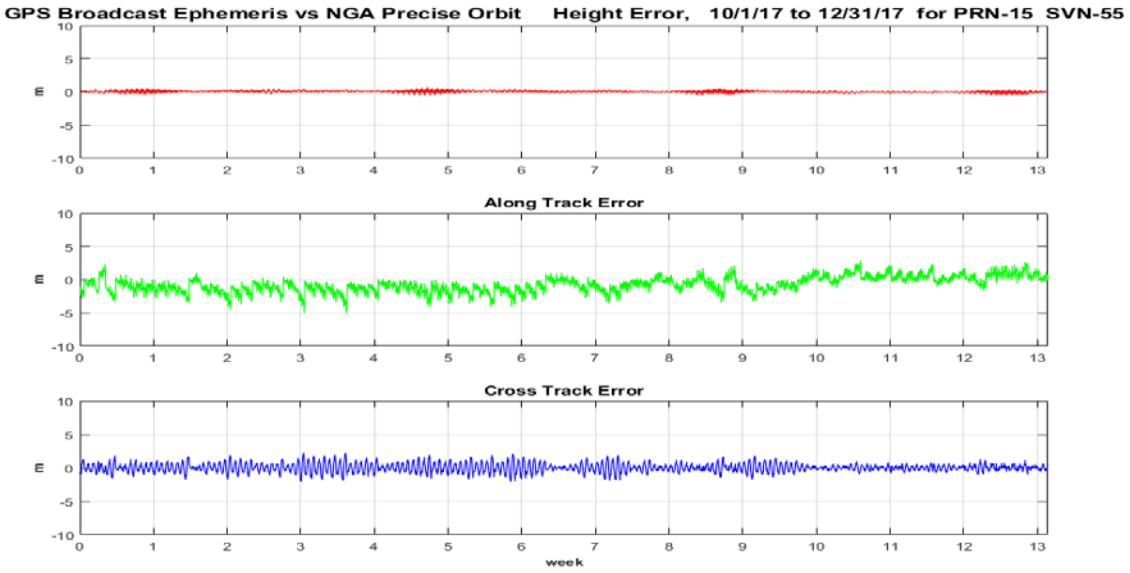


Figure 11-33 Orbit Error PRN-15 (SVN-55) Using L2C CNAV Data

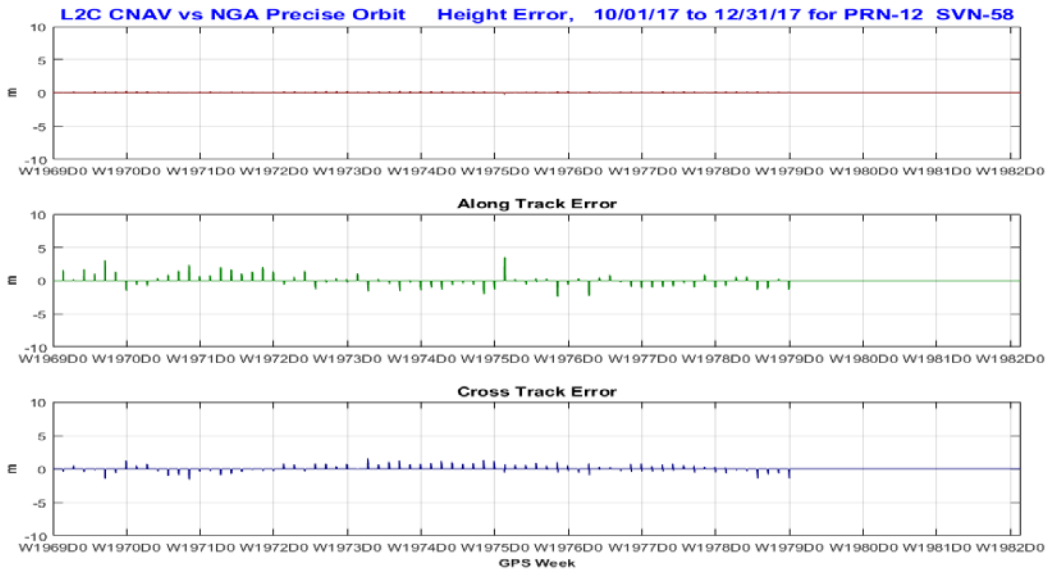


Figure 11-34 Orbit Error PRN-16 (SVN-56) Using C/A Nav Data

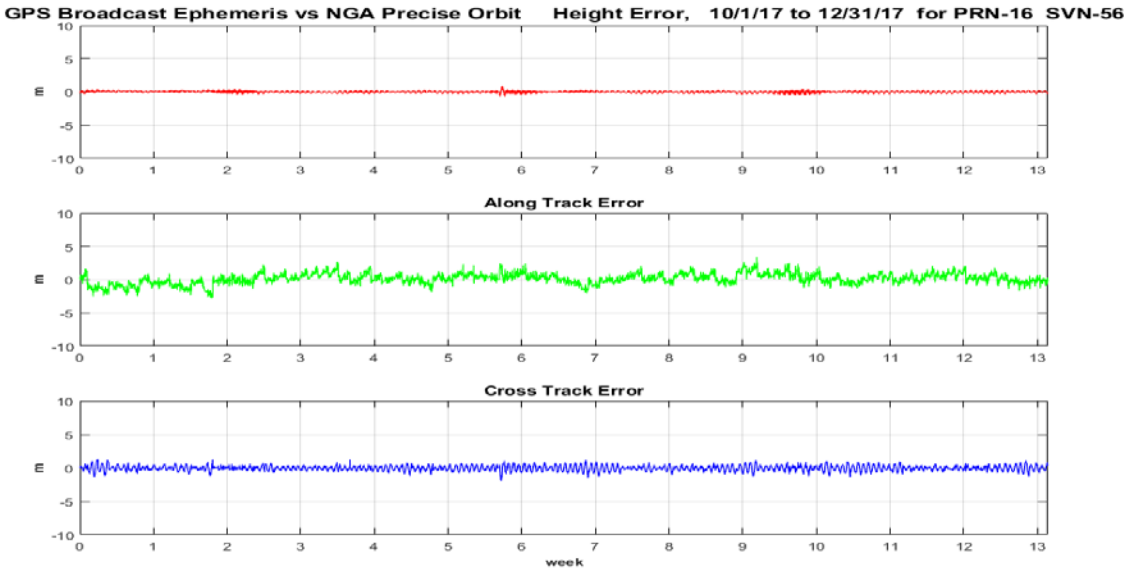


Figure 11-35 Orbit Error PRN-17 (SVN-53) Using C/A Nav Data

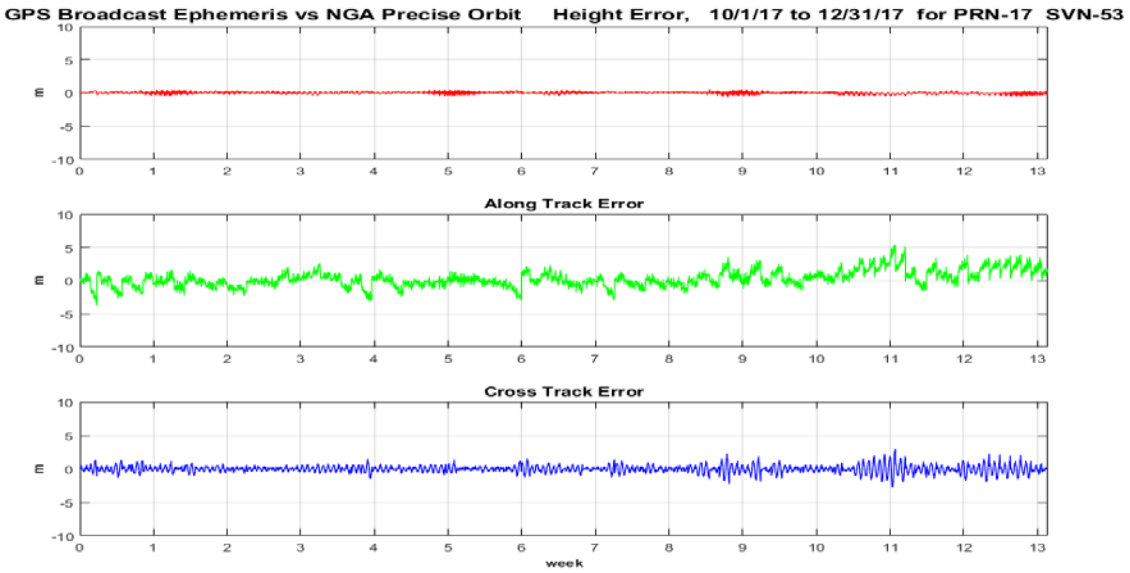


Figure 11-36 Orbit Error PRN-17 (SVN-53) Using L2C CNAV Data

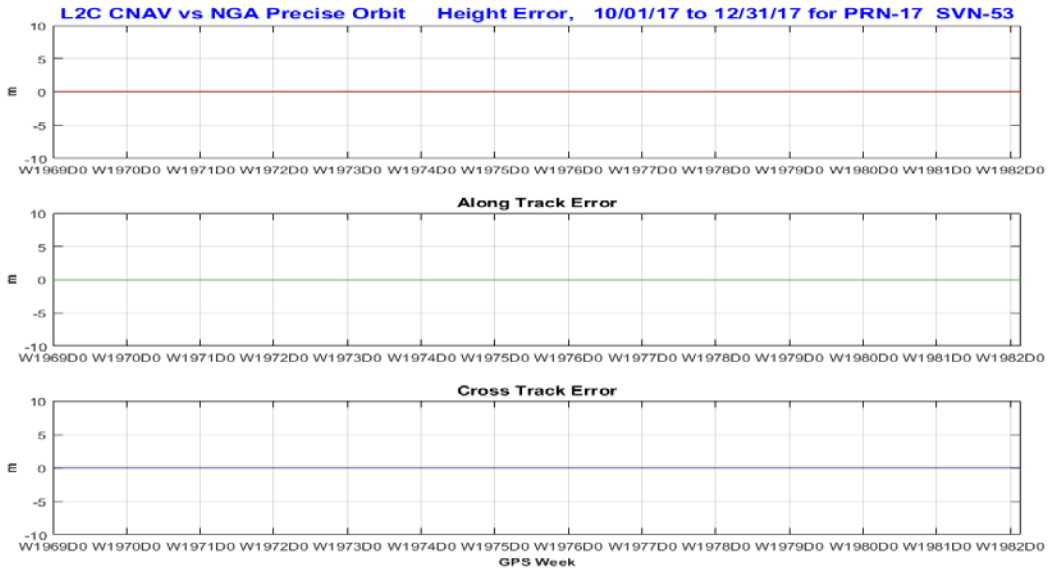


Figure 11-37 Orbit Error PRN-18 (SVN-54) Using C/A Nav Data

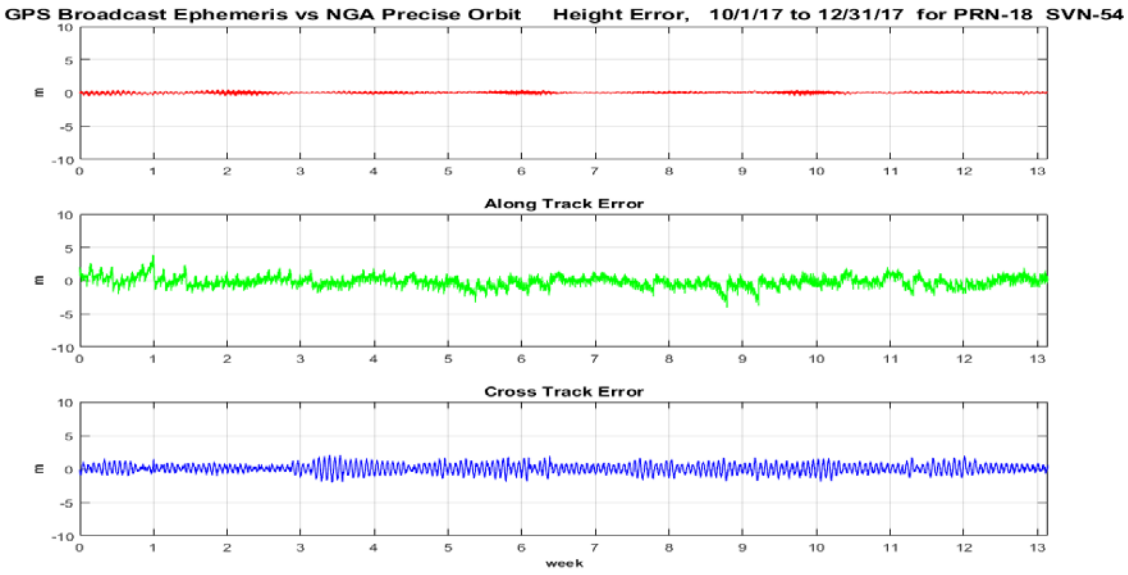


Figure 11-38 Orbit Error PRN-19 (SVN-59) Using C/A Nav Data

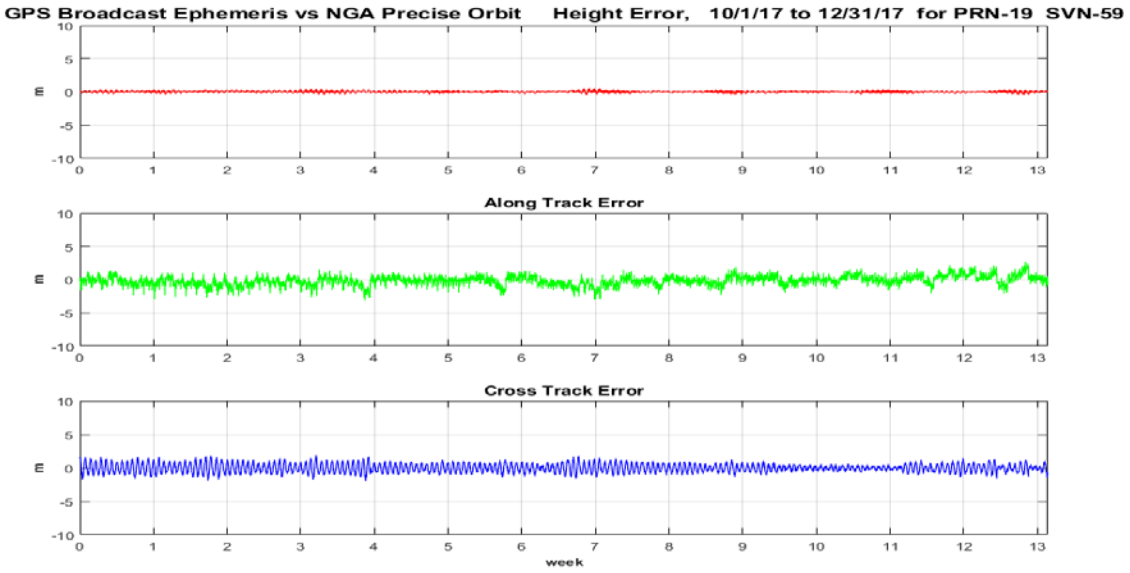


Figure 11-39 Orbit Error PRN-20 (SVN-51) Using C/A Nav Data

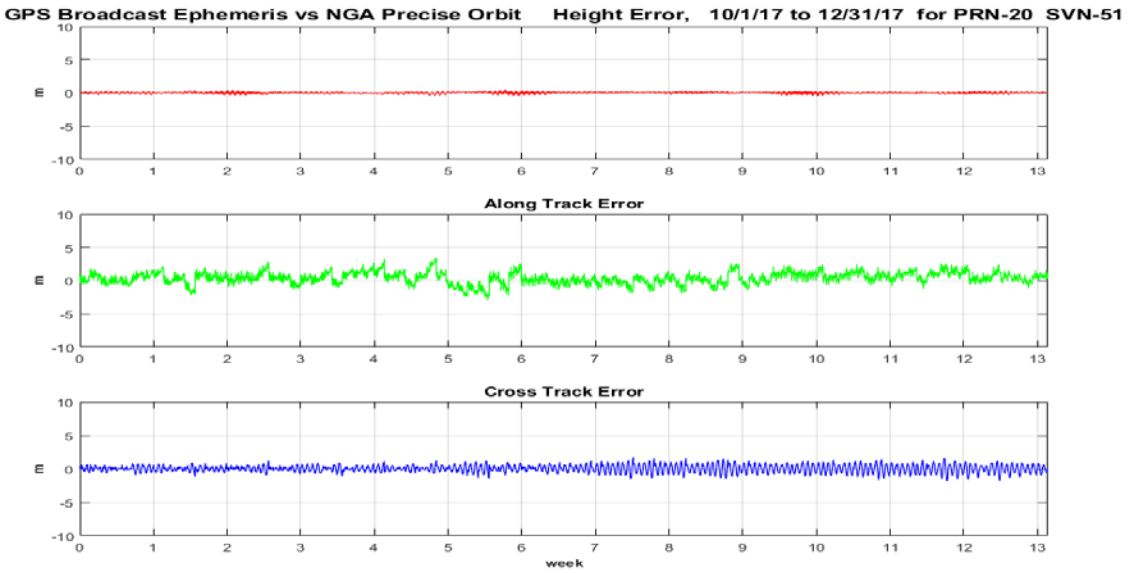


Figure 11-40 Orbit Error PRN-21 (SVN-45) Using C/A Nav Data

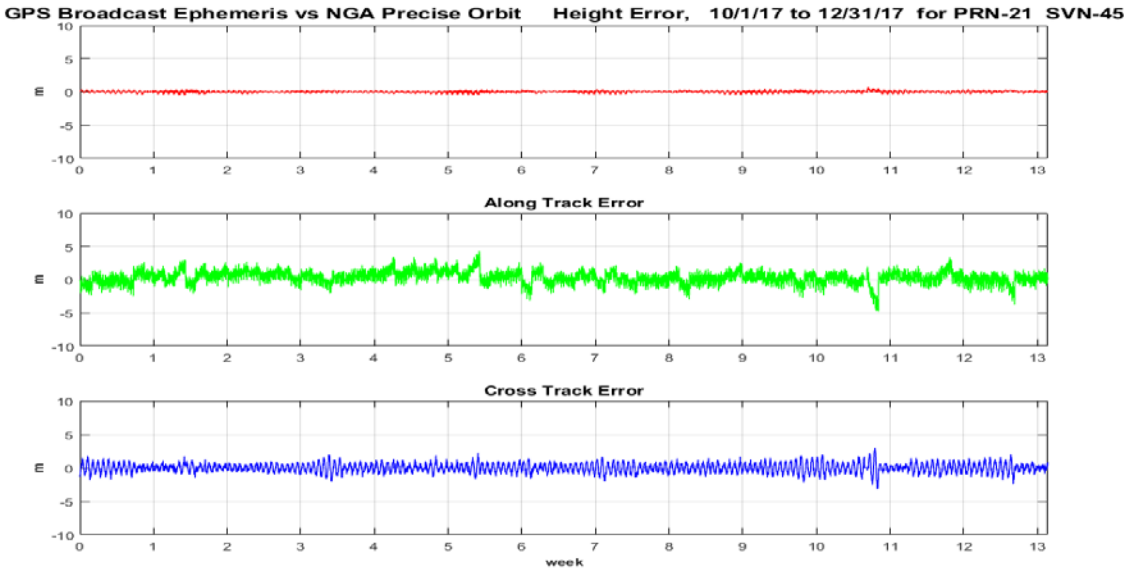


Figure 11-41 Orbit Error PRN-22 (SVN-47) Using C/A Nav Data

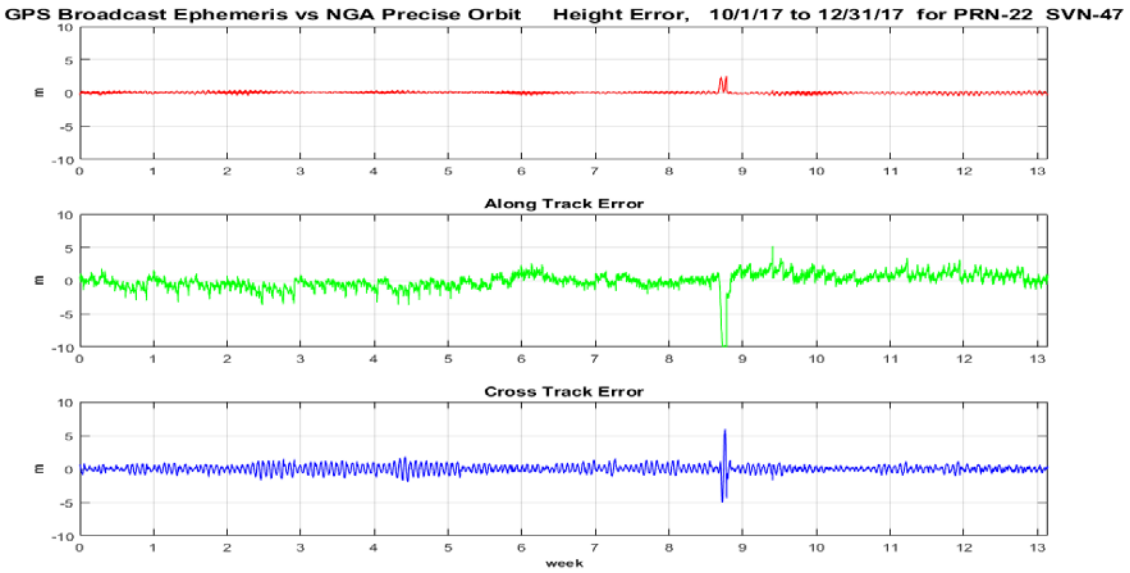


Figure 11-42 Orbit Error PRN-23 (SVN-60) Using C/A Nav Data

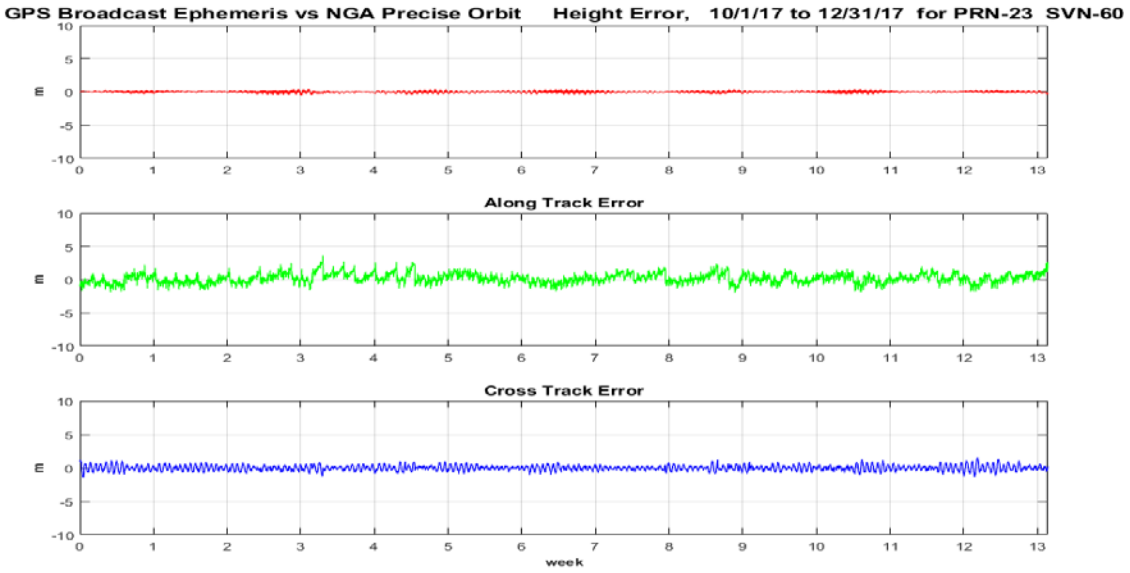


Figure 11-43 Orbit Error PRN-24 (SVN-65) Using C/A Nav Data

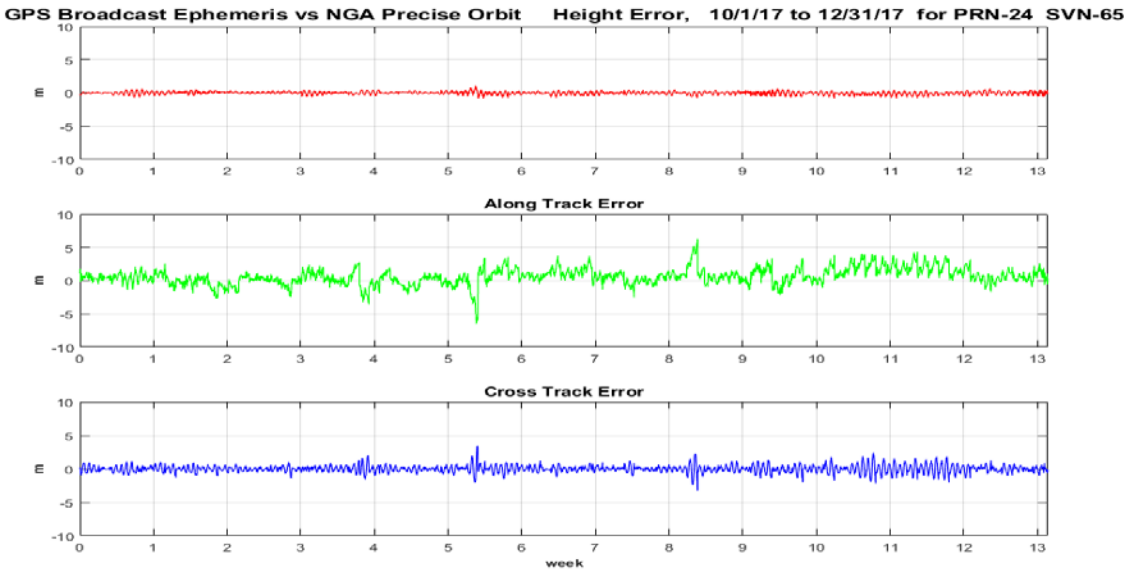


Figure 11-44 Orbit Error PRN-24 (SVN-65) Using L2C CNAV Data

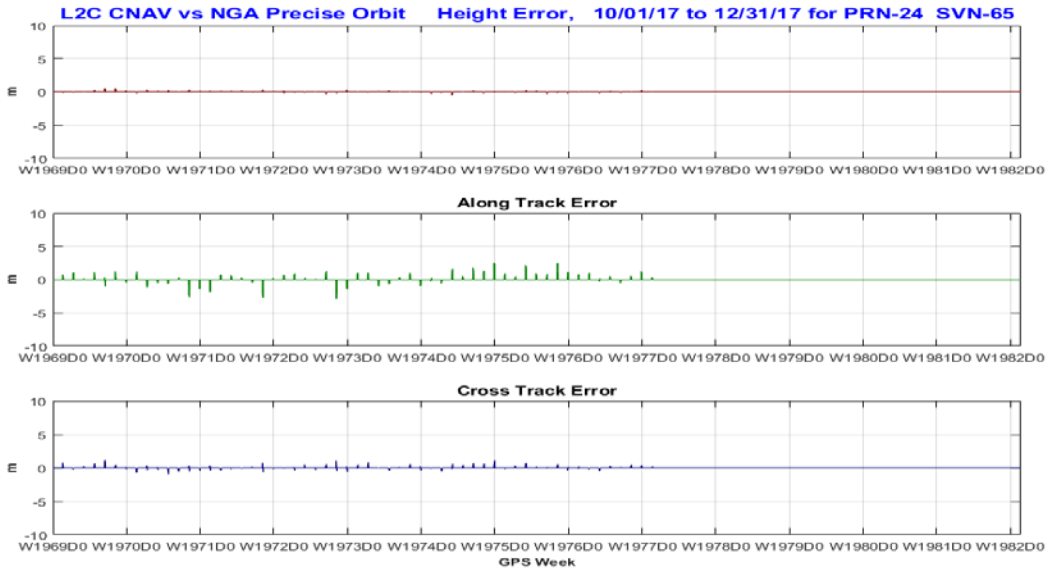


Figure 11-45 Orbit Error PRN-25 (SVN-62) Using C/A Nav Data

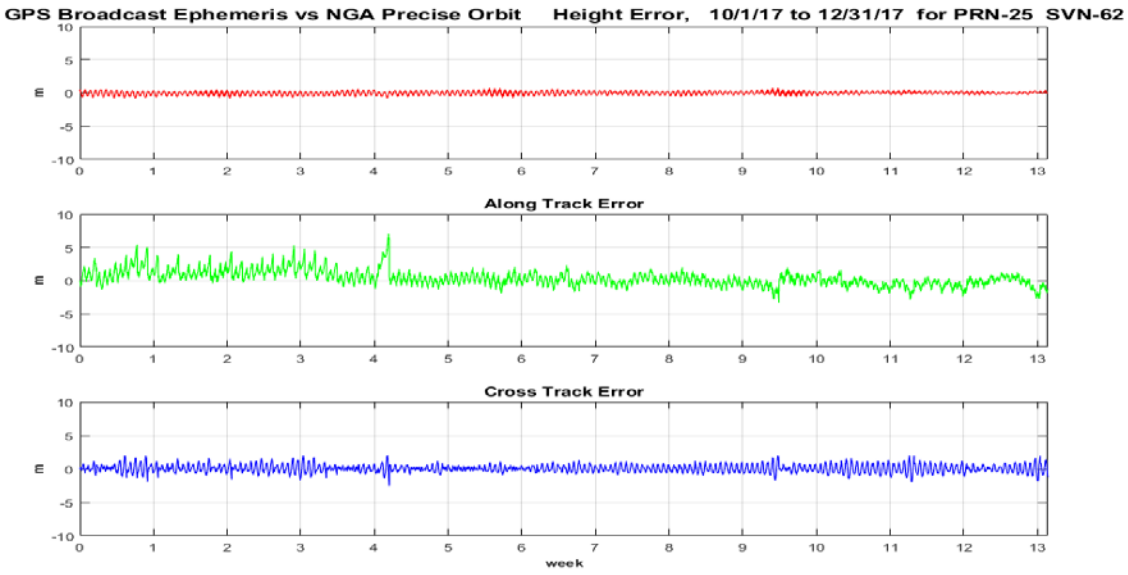


Figure 11-46 Orbit Error PRN-25 (SVN-62) Using L2C CNAV Data

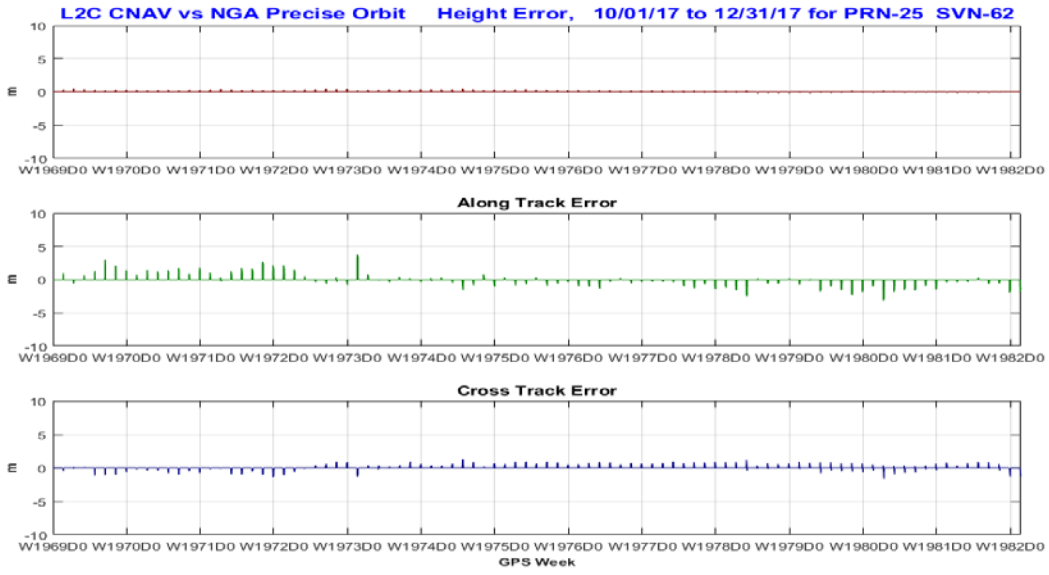


Figure 11-47 Orbit Error PRN-26 (SVN-71) Using C/A Nav Data

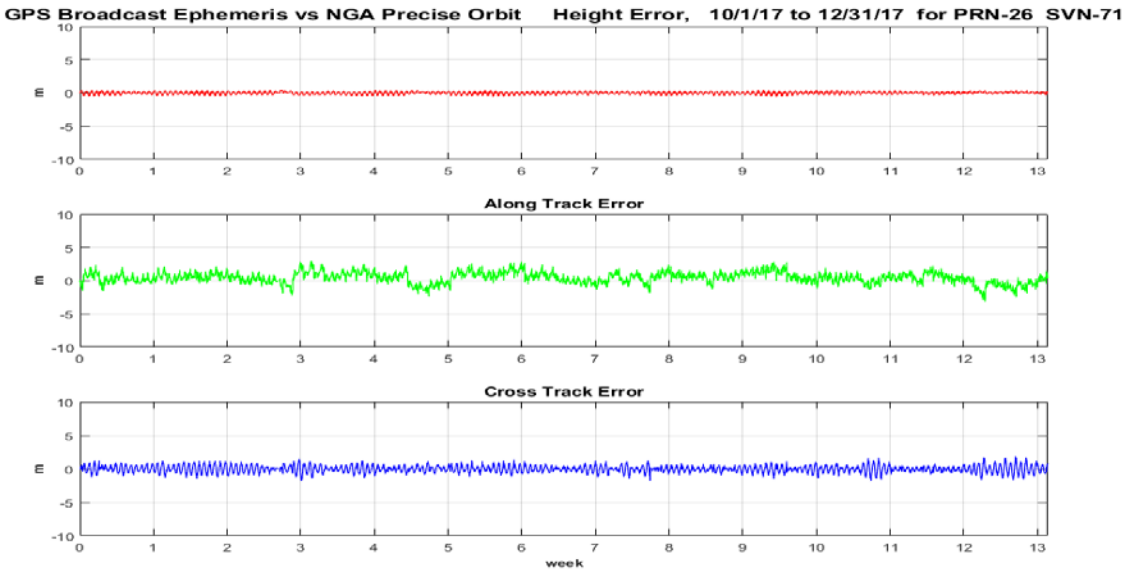


Figure 11-48 Orbit Error PRN-26 (SVN-71) Using L2C CNAV Data

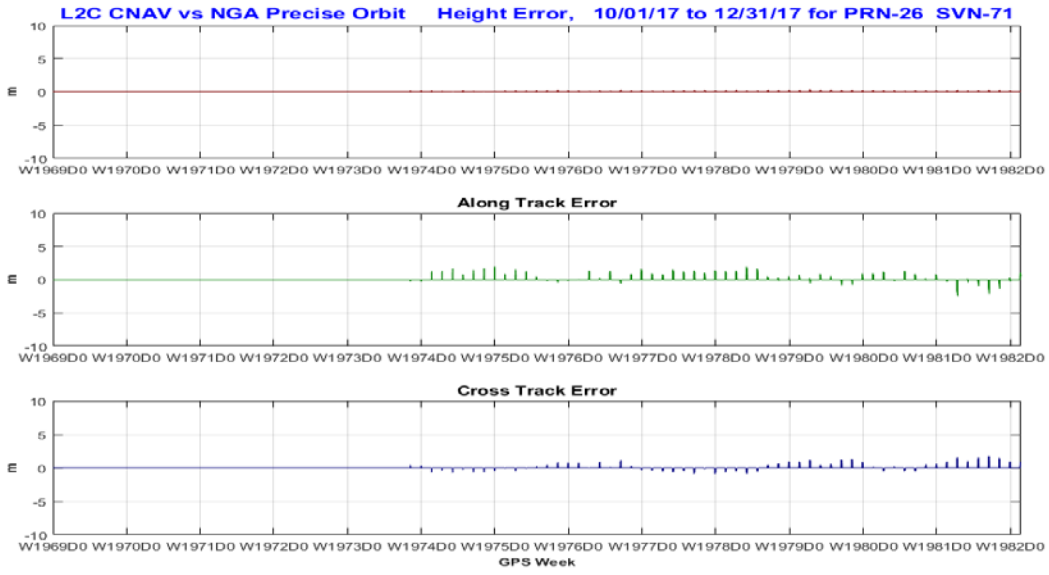


Figure 11-49 Orbit Error PRN-27 (SVN-66) Using C/A Nav Data

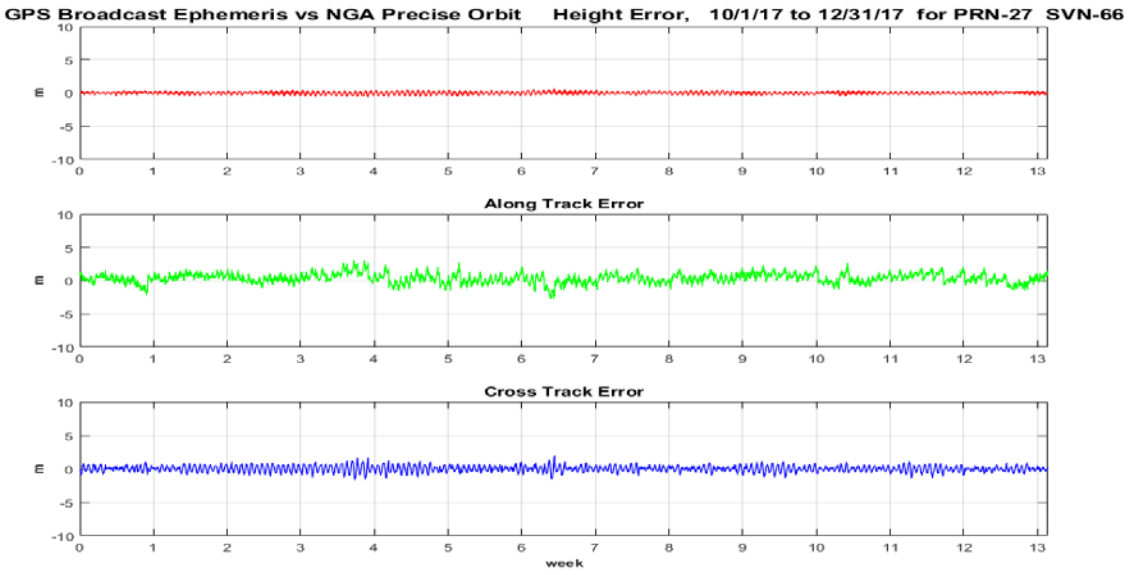


Figure 11-50 Orbit Error PRN-27 (SVN-66) Using L2C CNAV Data

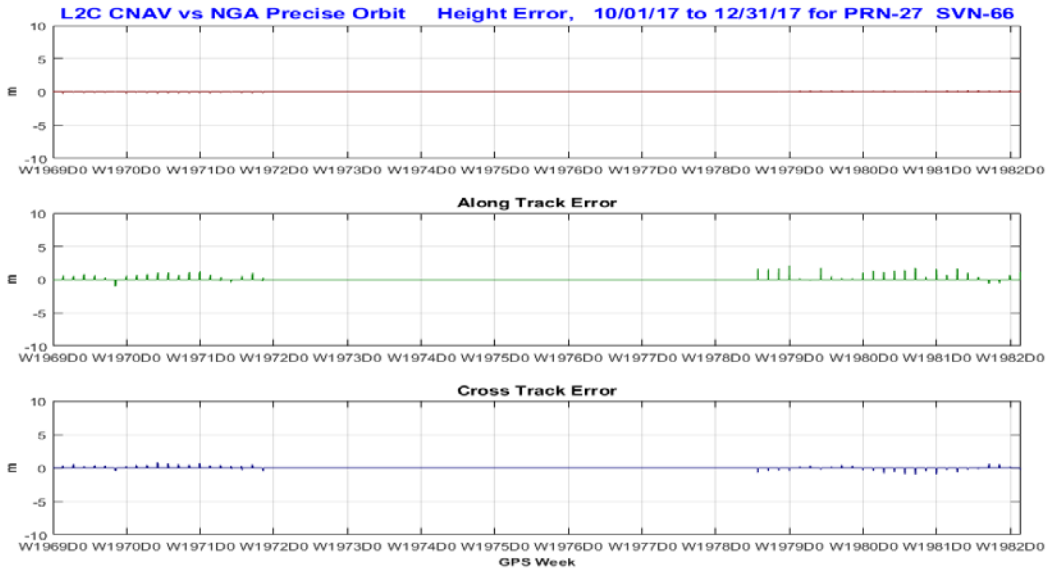


Figure 11-51 Orbit Error PRN-28 (SVN-44) Using C/A Nav Data

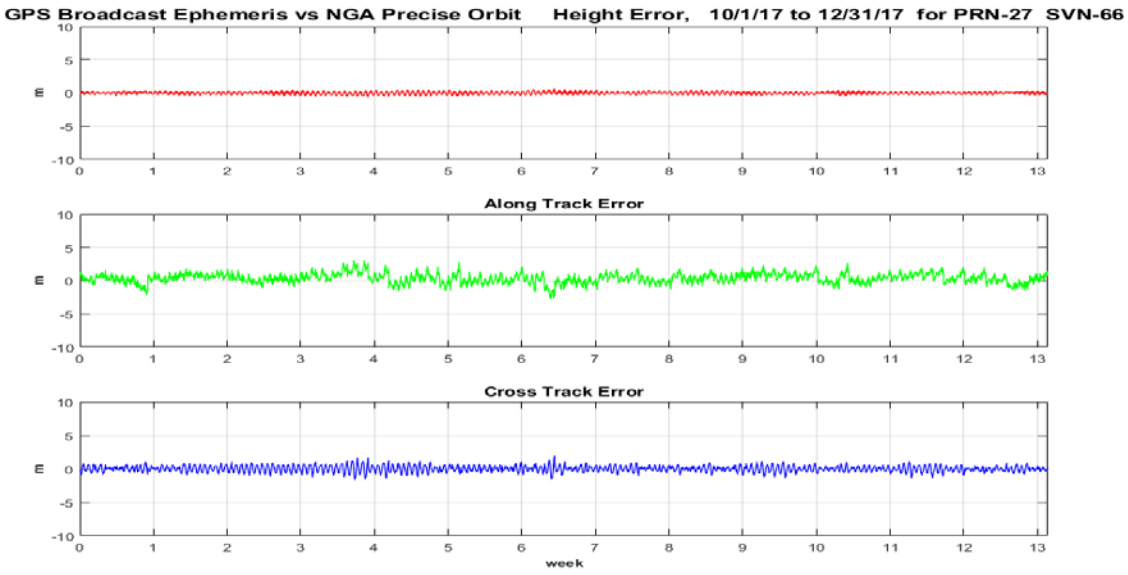


Figure 11-52 Orbit Error PRN-29 (SVN-57) Using C/A Nav Data

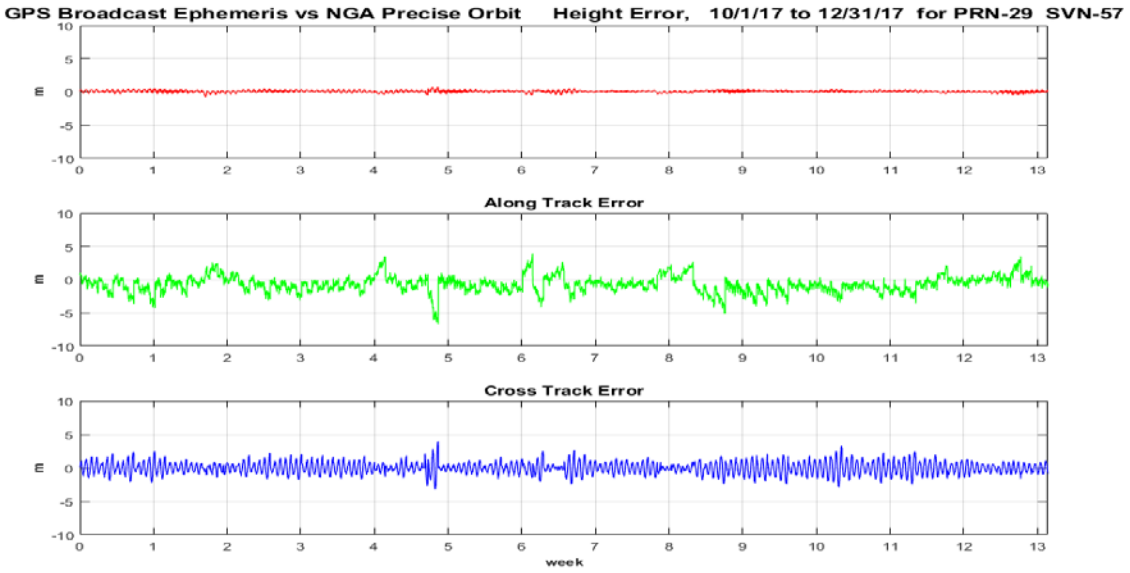


Figure 11-53 Orbit Error PRN-29 (SVN-57) Using L2C CNAV Data

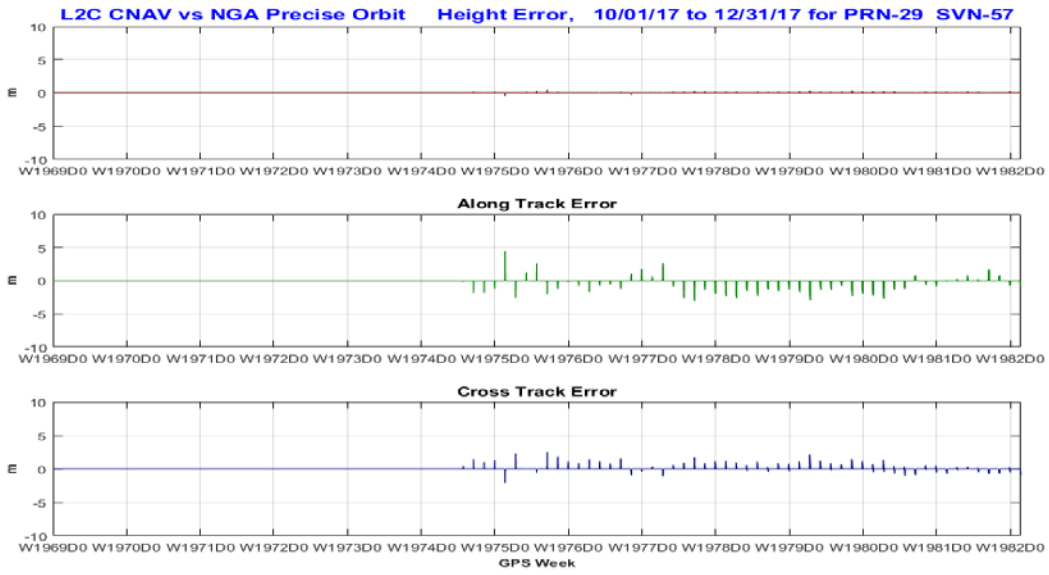


Figure 11-54 Orbit Error PRN-30 (SVN-64) Using C/A Nav Data

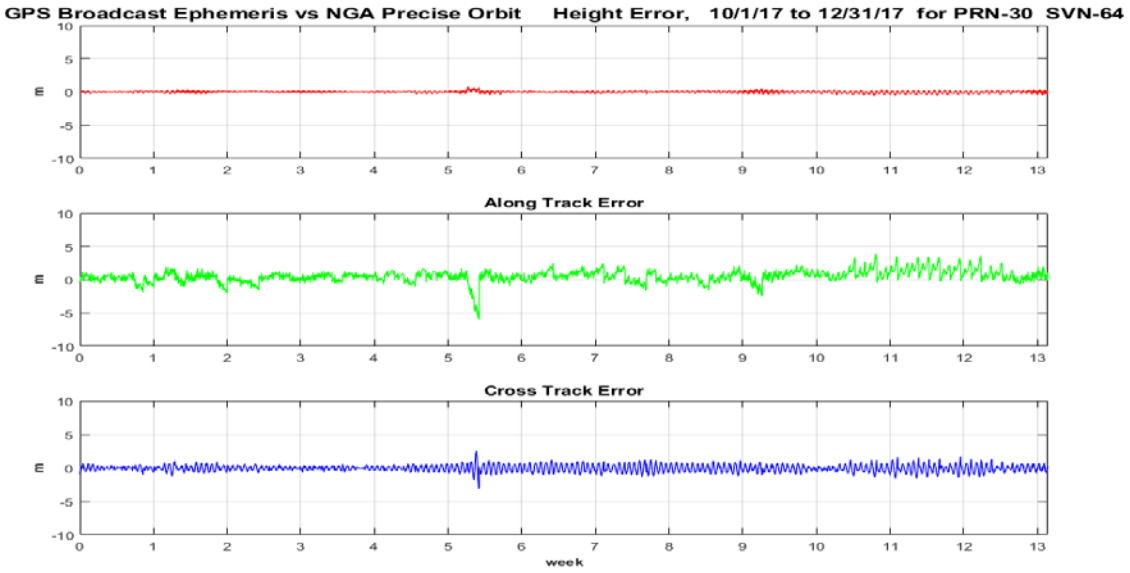


Figure 11-55 Orbit Error PRN-30 (SVN-64) Using L2C CNAV Data

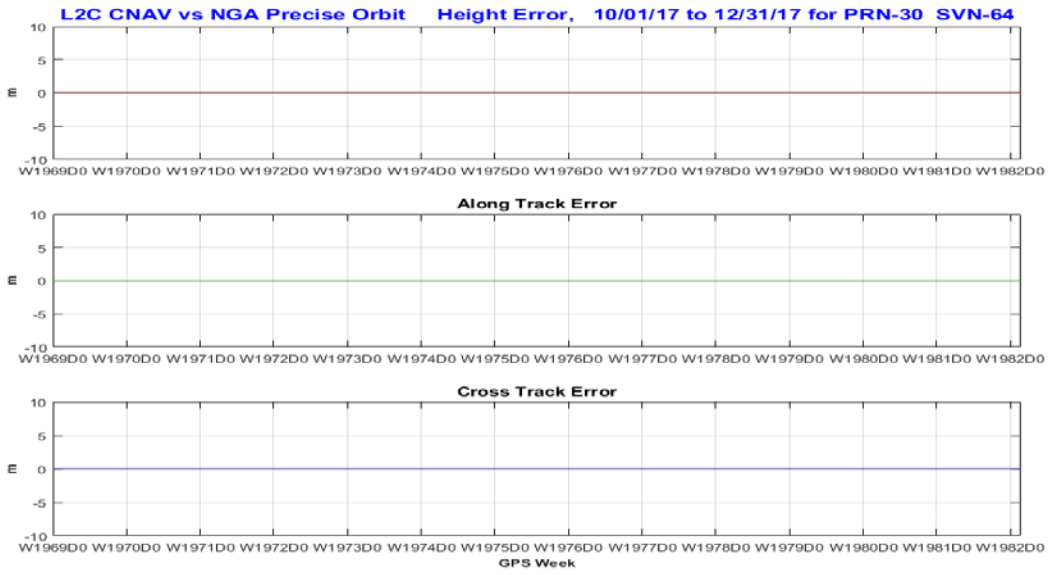


Figure 11-56 Orbit Error PRN-31 (SVN-52) Using C/A Nav Data

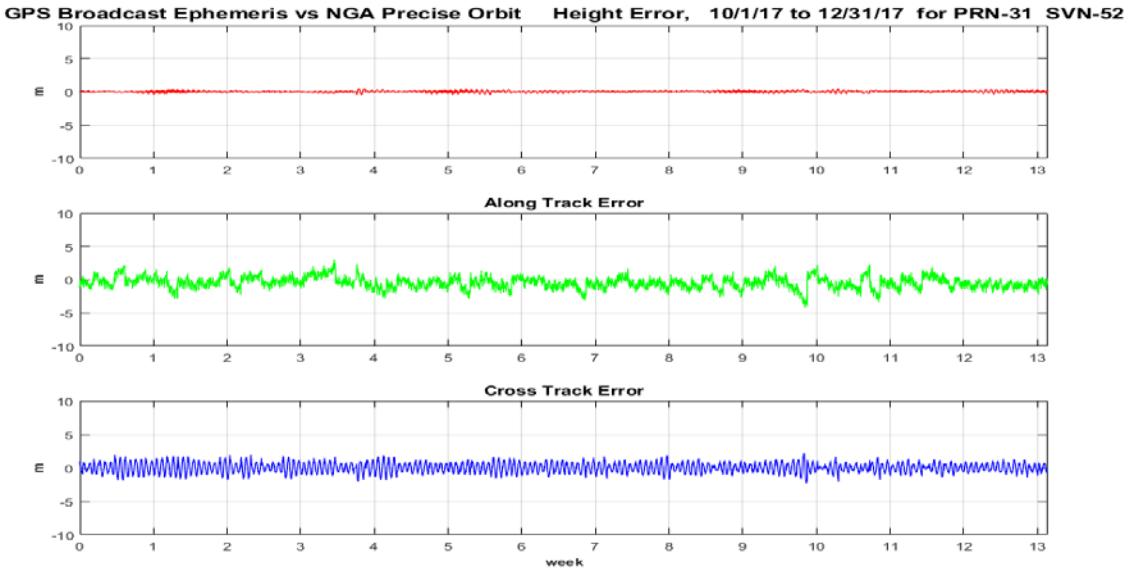


Figure 11-57 Orbit Error PRN-31 (SVN-52) Using L2C CNAV Data

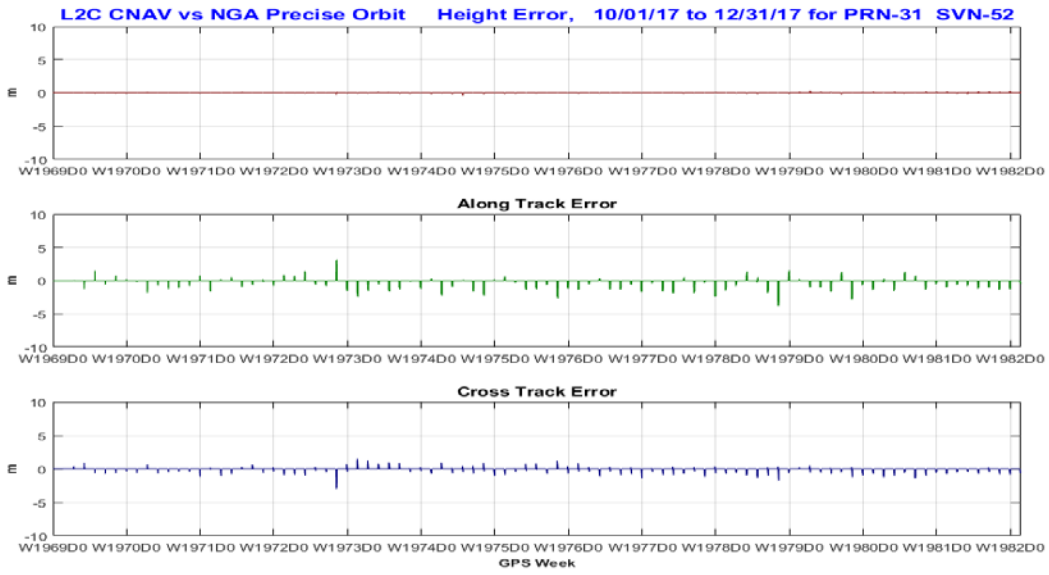


Figure 11-58 Orbit Error PRN-32 (SVN-70) Using C/A Nav Data

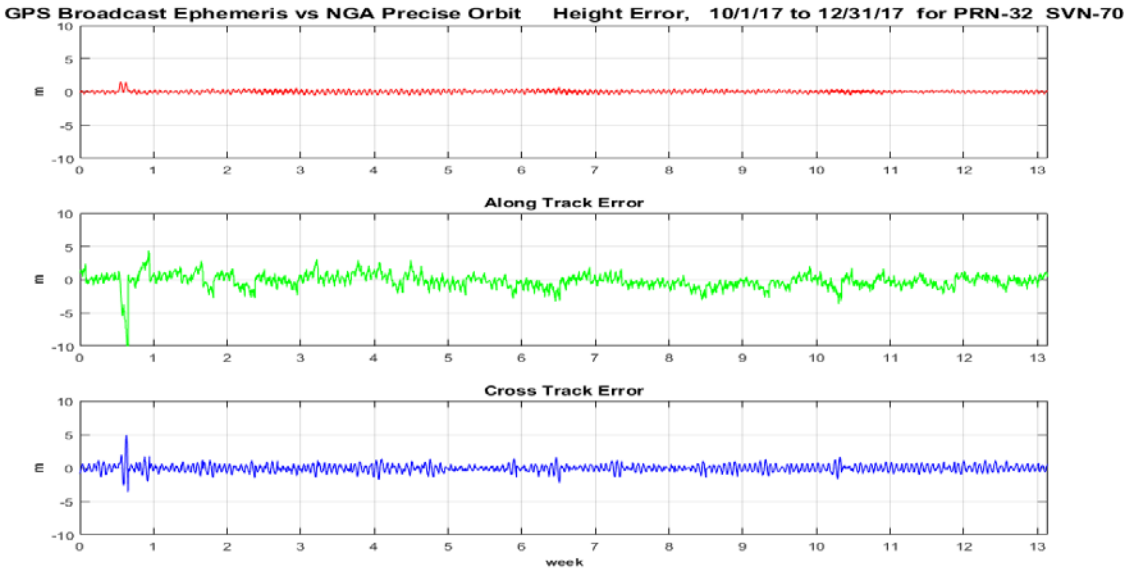
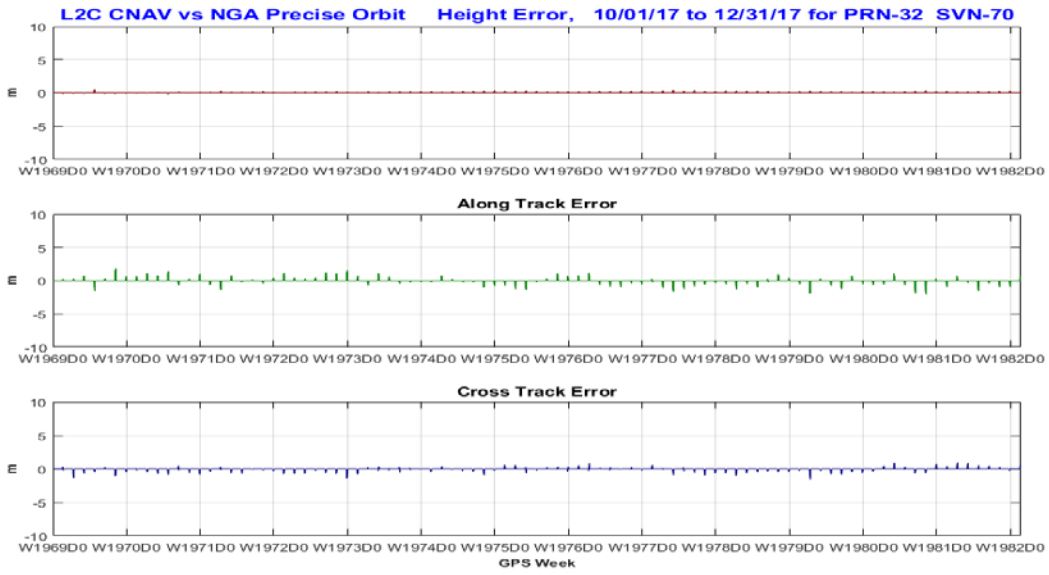


Figure 11-59 Orbit Error PRN-32 (SVN-70) Using L2C CNAV Data



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

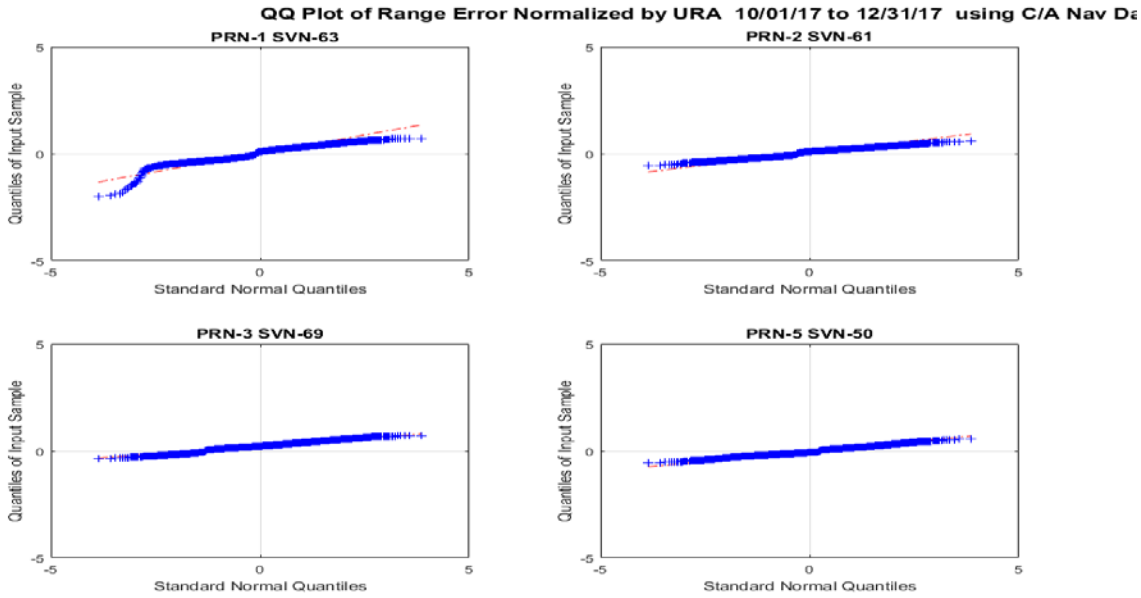


Figure 11-61 QQ Plots of Range Error PRNs 6 to 9 Using C/A Nav Data

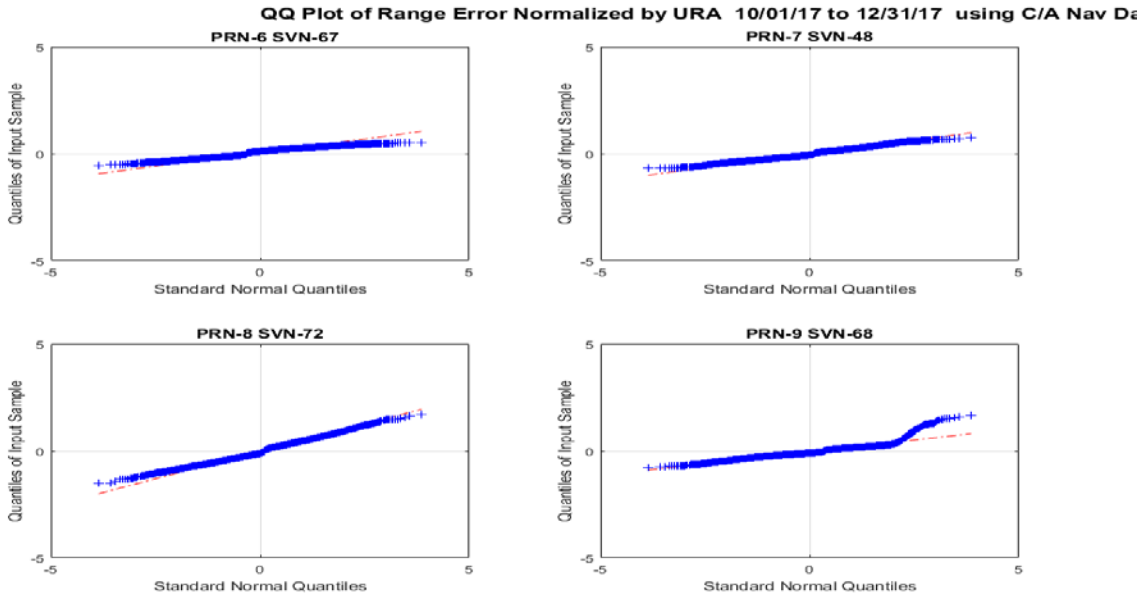


Figure 11-62 QQ Plots of Range Error PRNs 10 to 13 Using C/A Nav Data

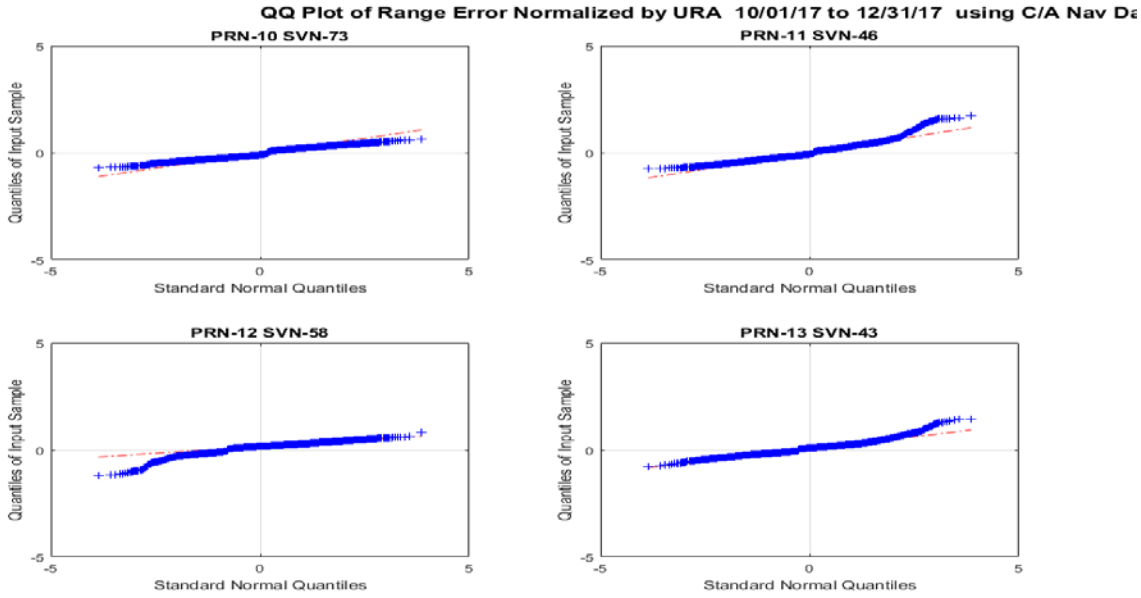


Figure 11-63 QQ Plots of Range Error PRNs 14 to 17 Using C/A Nav Data

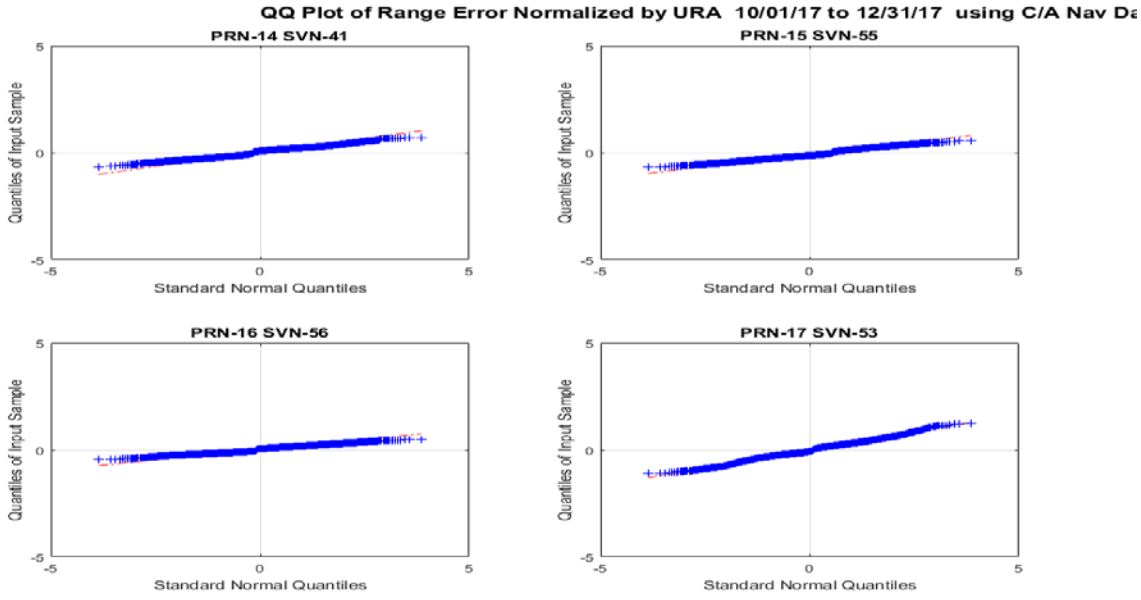


Figure 11-64 QQ Plots of Range Error PRNs 18 to 21 Using C/A Nav Data

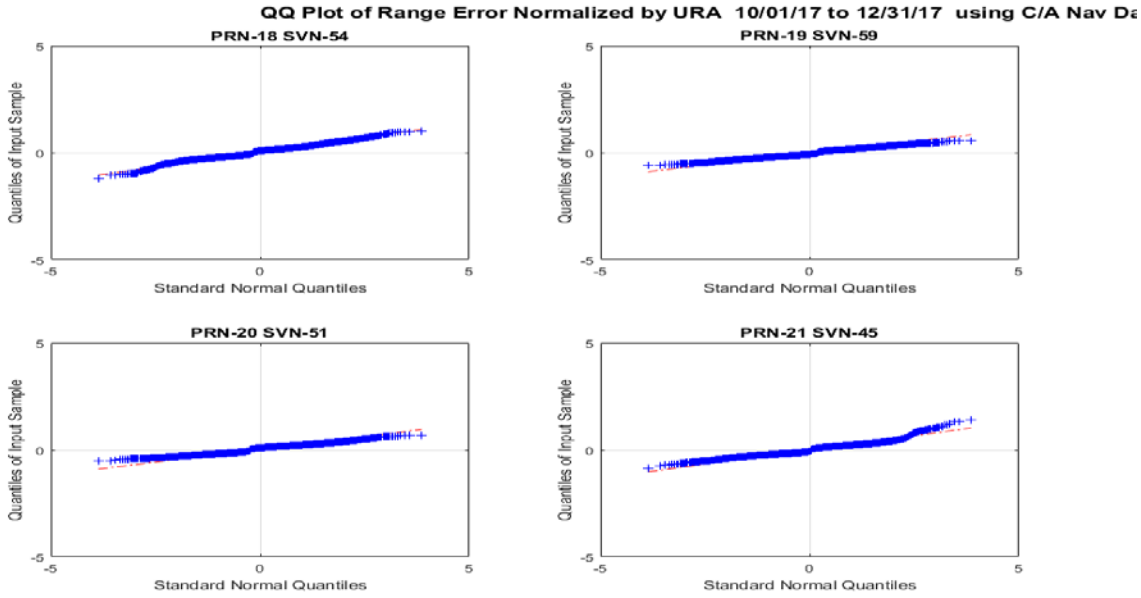


Figure 11-65 QQ Plots of Range Error PRNs 22 to 25 Using C/A Nav Data

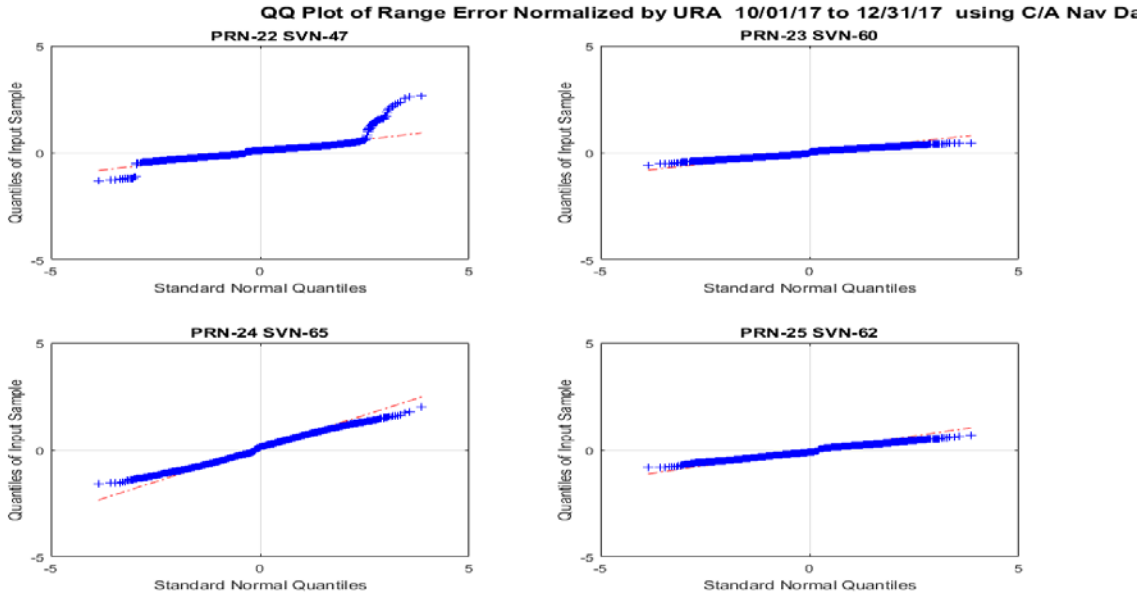


Figure 11-66 QQ Plots of Range Error PRNs 26 to 29 Using C/A Nav Data

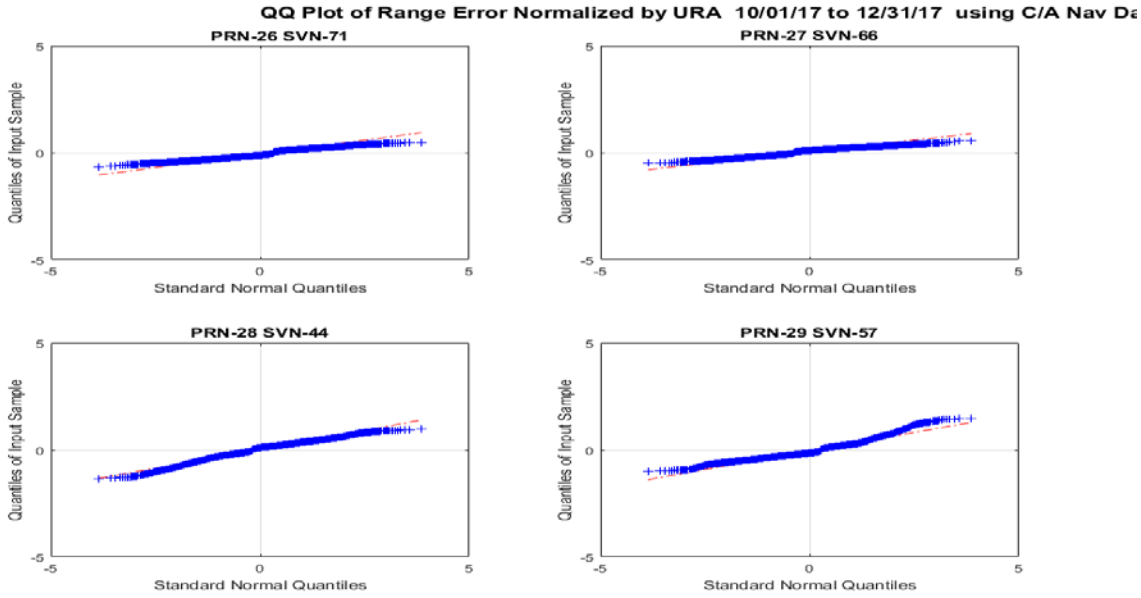


Figure 11-67 QQ Plots of Range Error PRNs 30 to 32 Using C/A Nav Data

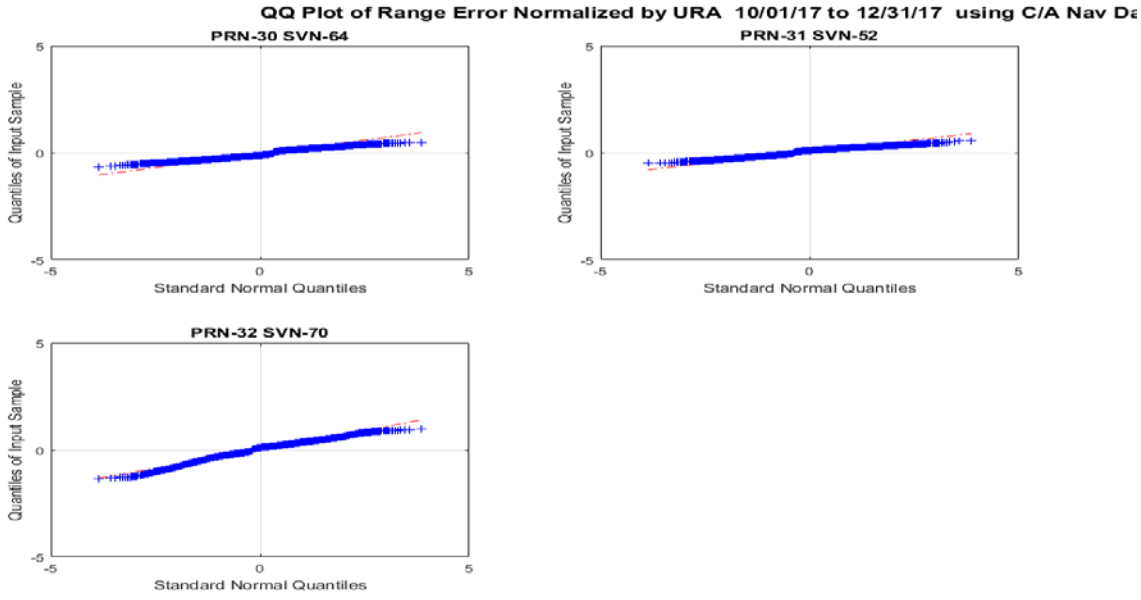


Figure 11-68 QQ Plots of Range Error PRNs 1, 3, 5, and 8 Using L2C CNAV Data

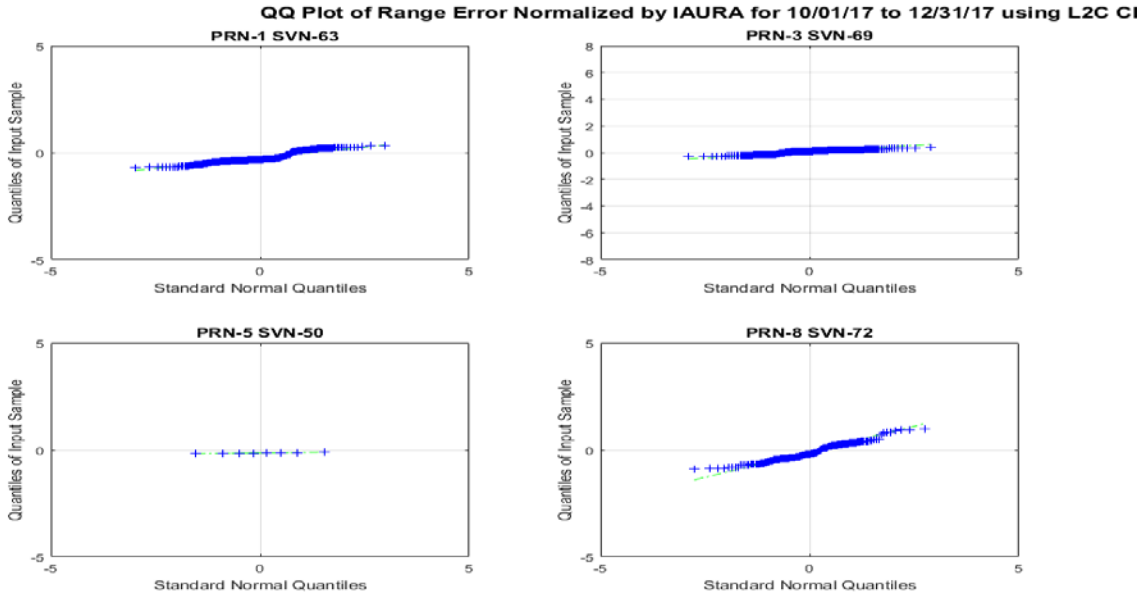


Figure 11-69 QQ Plots of Range Error PRNs 9, 10, 12, and 15 Using L2C CNAV Data

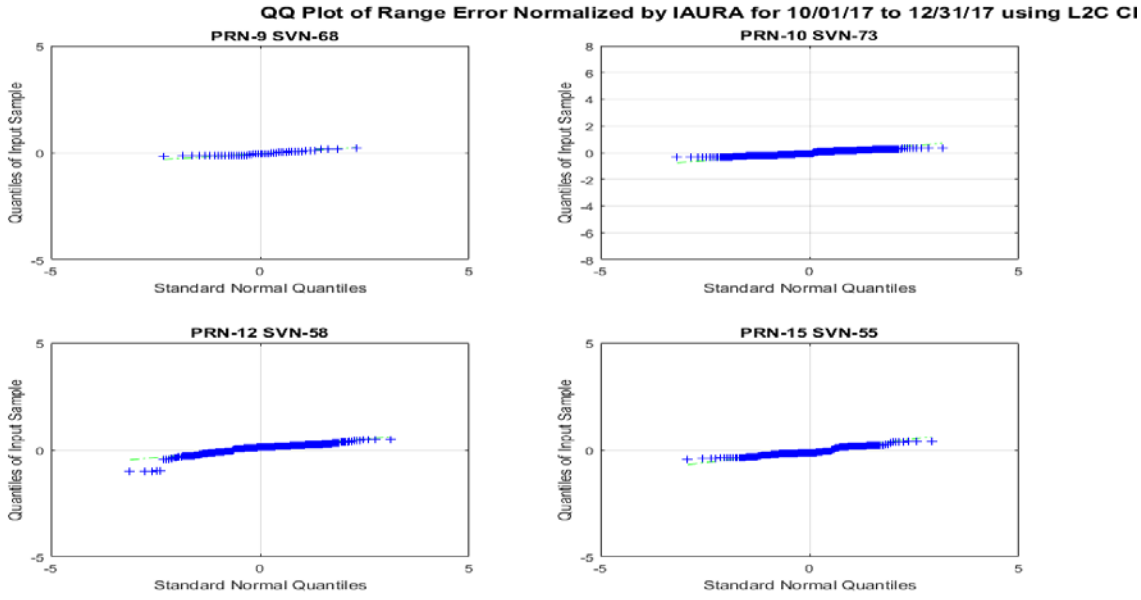


Figure 11-70 QQ Plots of Range Error PRNs 24, 25, 26, and 27 Using L2C CNAV Data

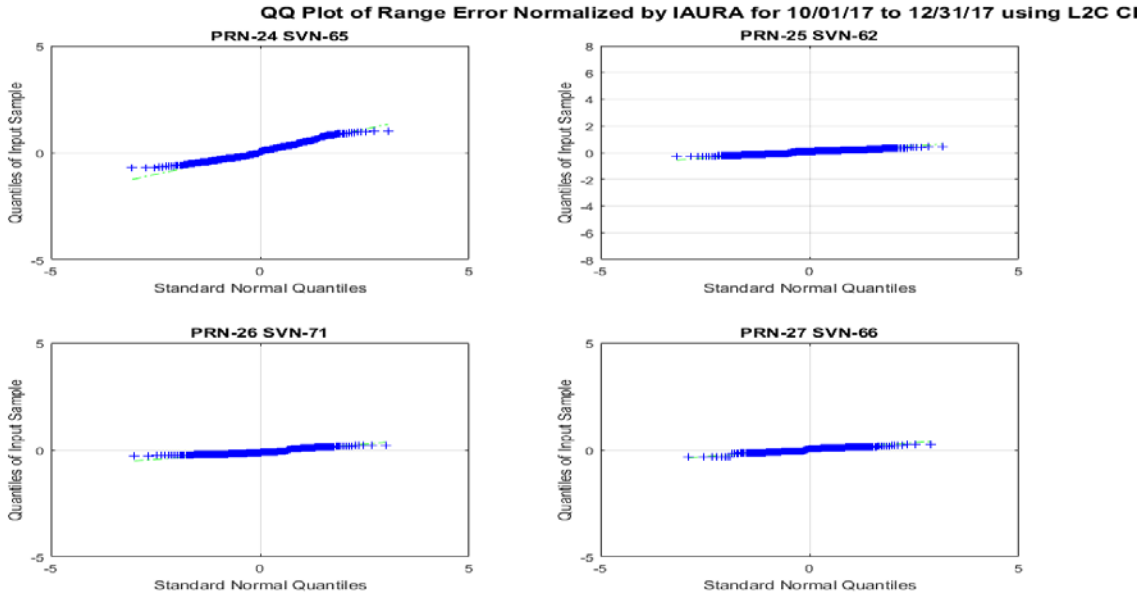
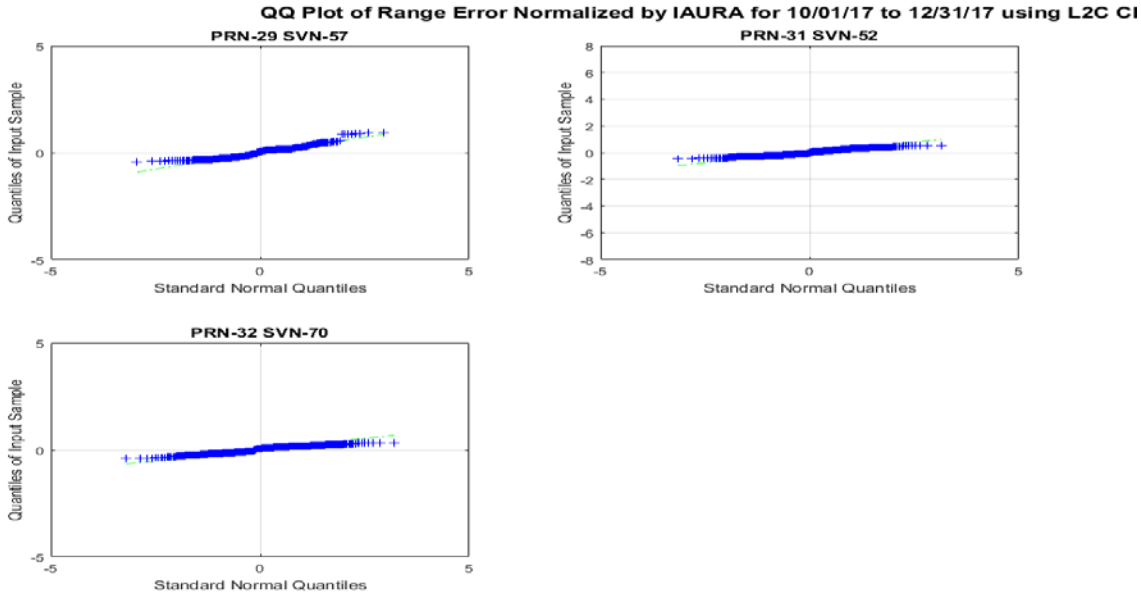


Figure 11-71 QQ Plots of Range Error PRNs 29, 31, and 32 Using L2C CNAV Data



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

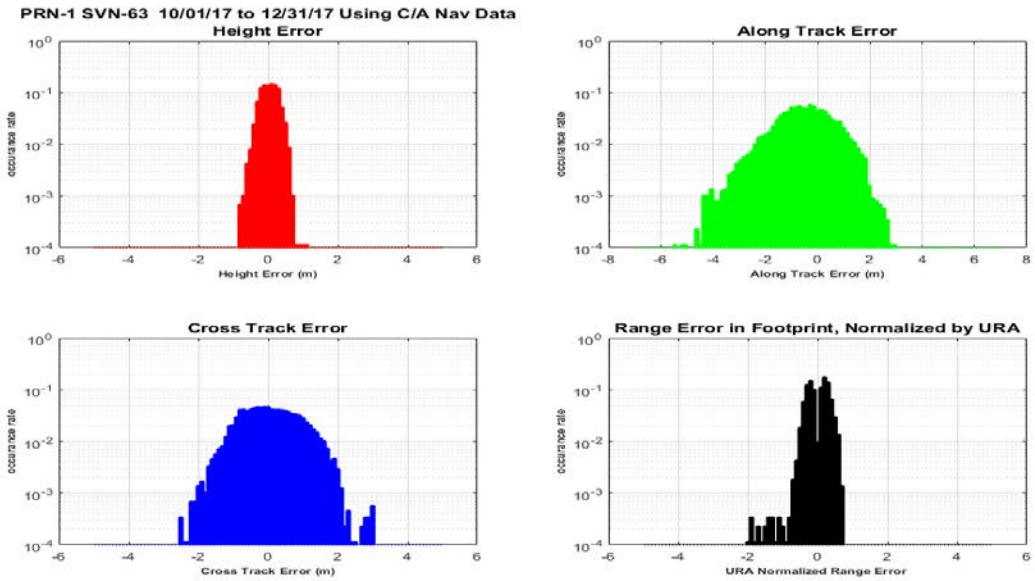


Figure 11-73 Histograms of H, A, C, and Range Error PRN-1 (SVN-63) Using L2C CNAV Data

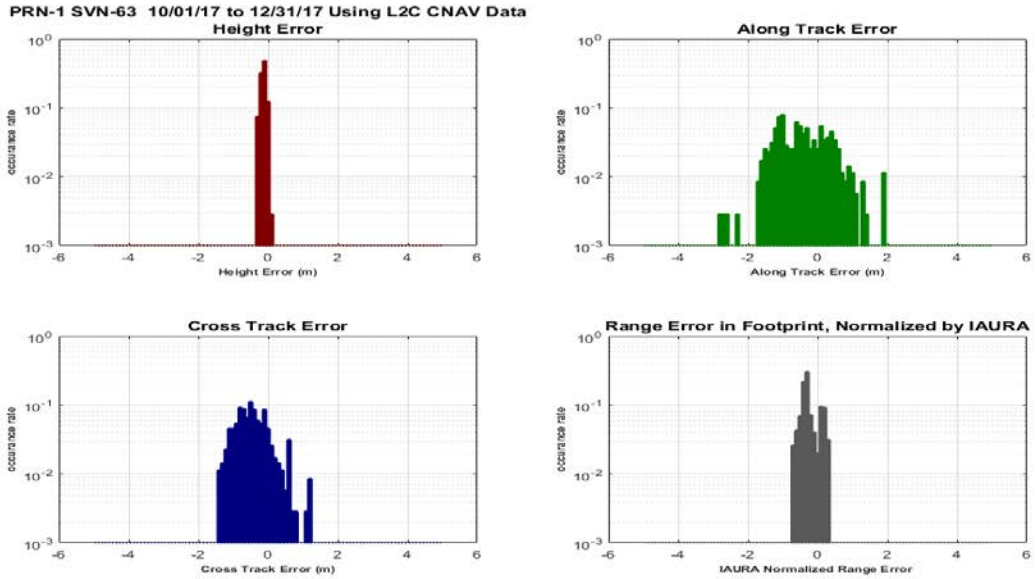


Figure 11-74 Histograms of H, A, C, and Range Error PRN-2 (SVN-61) Using C/A Nav Data

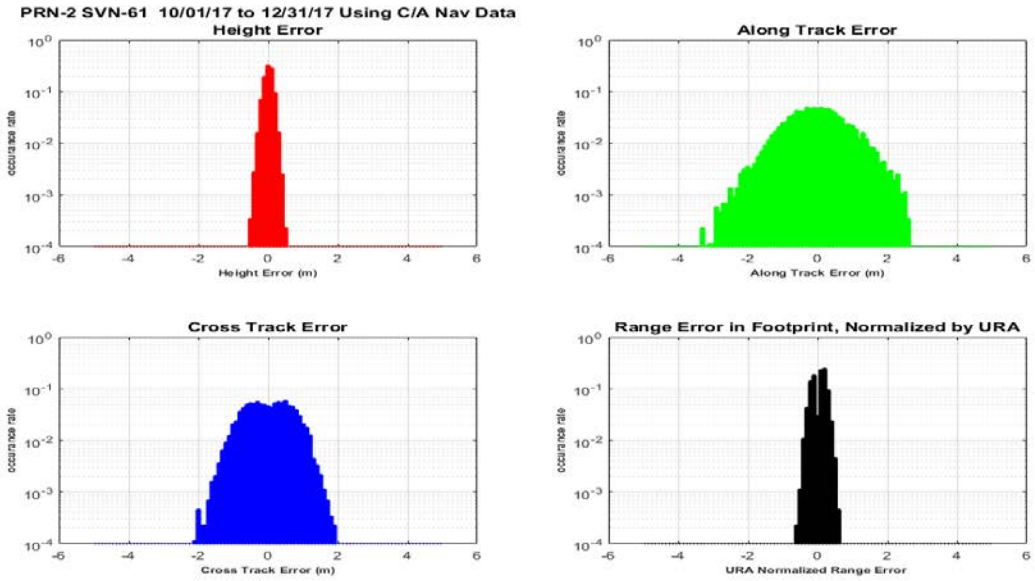


Figure 11-75 Histograms of H, A, C, and Range Error PRN-3 (SVN-69) Using C/A Nav Data

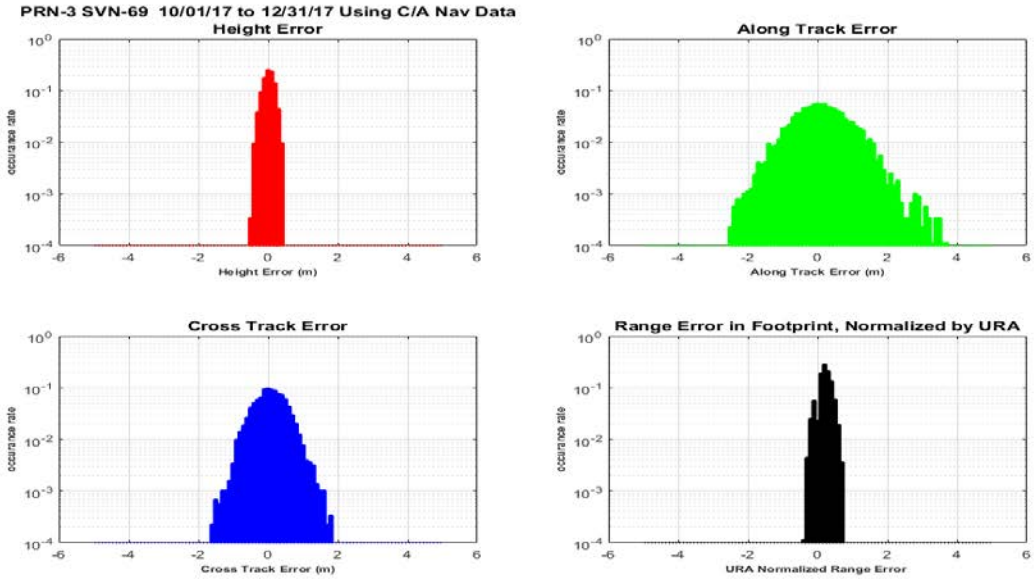


Figure 11-76 Histograms of H, A, C, and Range Error PRN-3 (SVN-69) Using L2C CNAV Data

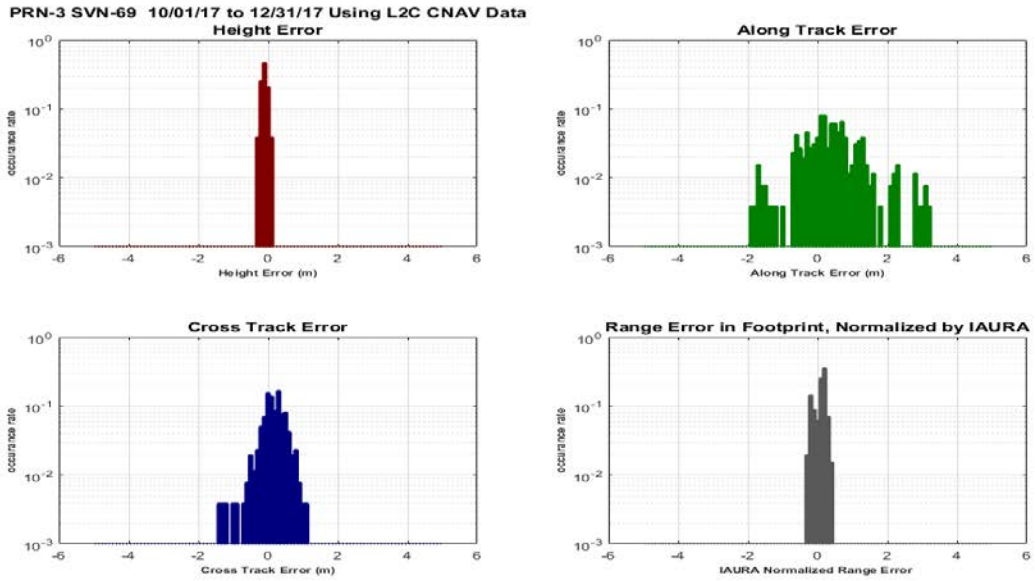


Figure 11-77 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using C/A Nav Data

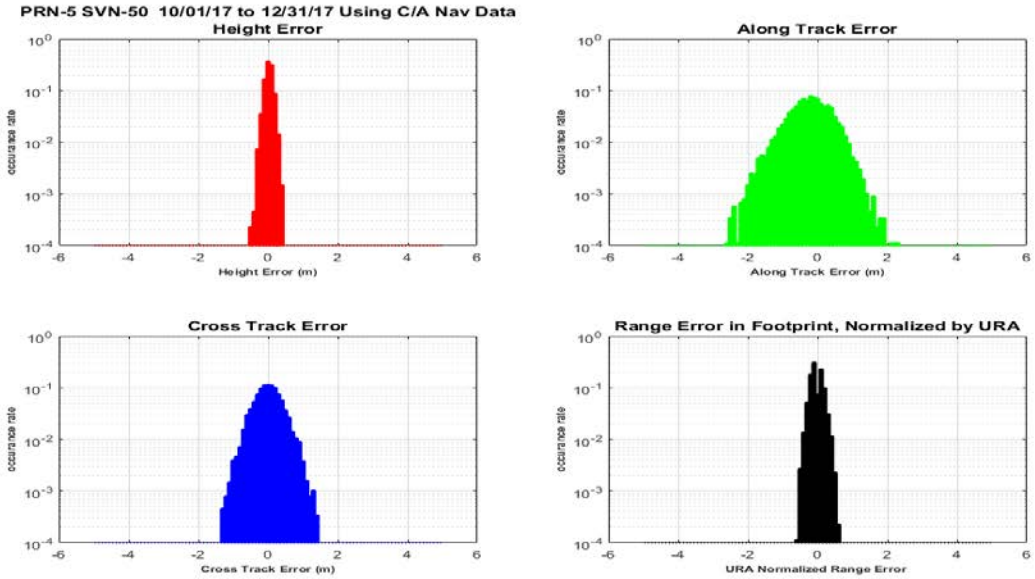


Figure 11-78 Histograms of H, A, C, and Range Error PRN-5 (SVN-50) Using L2C CNAV Data

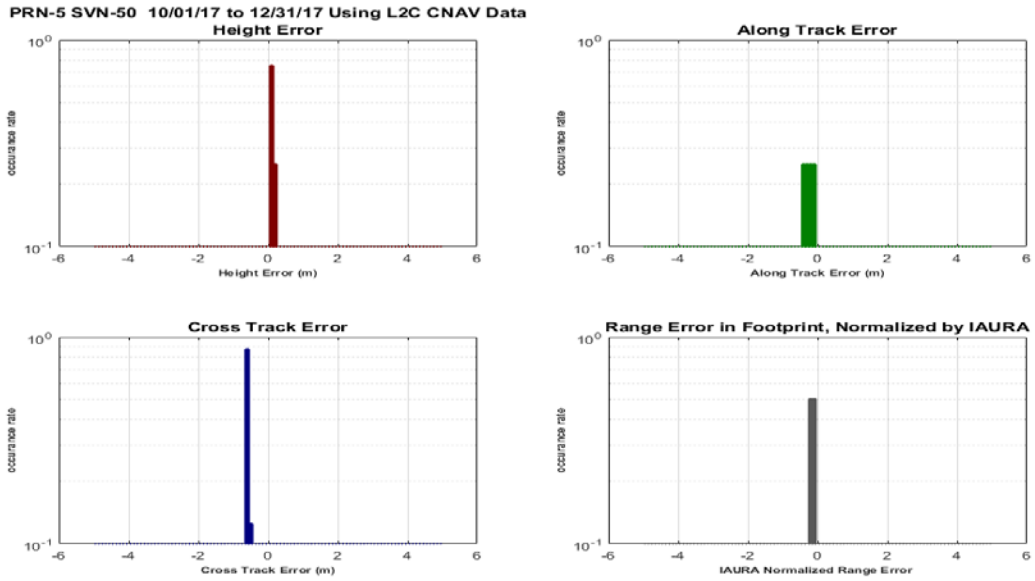


Figure 11-79 Histograms of H, A, C, and Range Error PRN-6 (SVN-67) Using C/A Nav Data

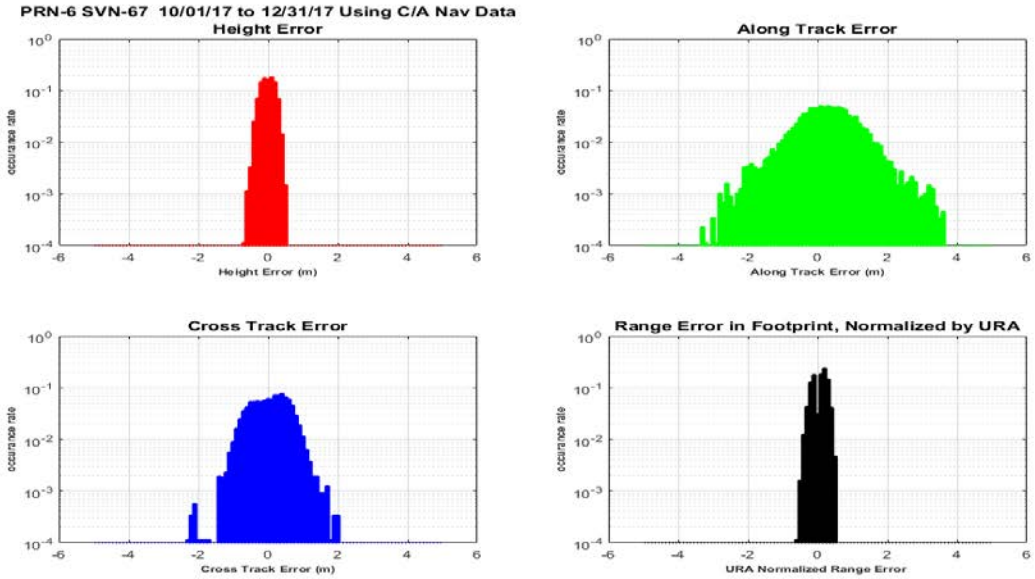


Figure 11-80 Histograms of H, A, C, and Range Error PRN-7 (SVN-48) Using C/A Nav Data

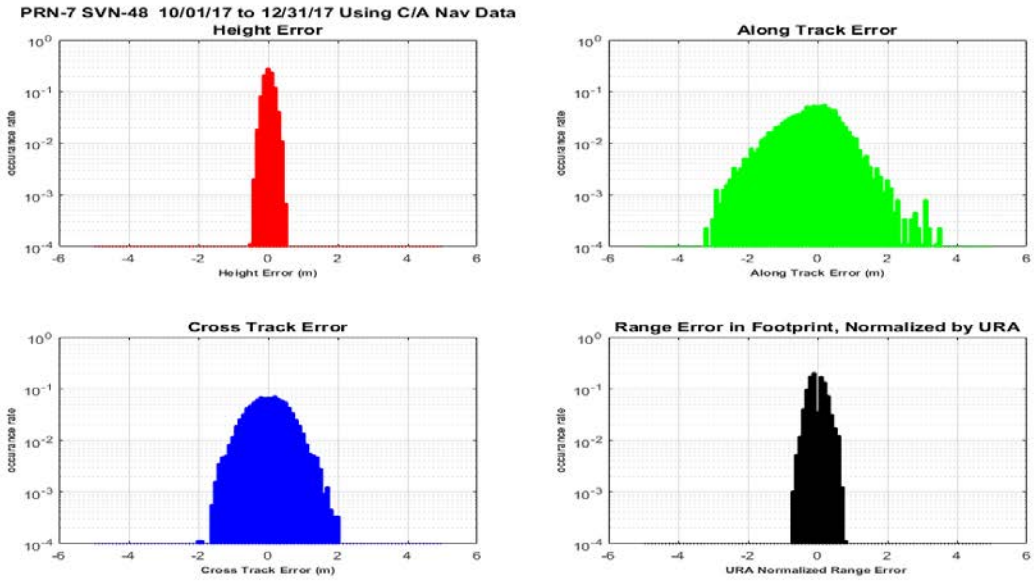


Figure 11-81 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using C/A Nav Data

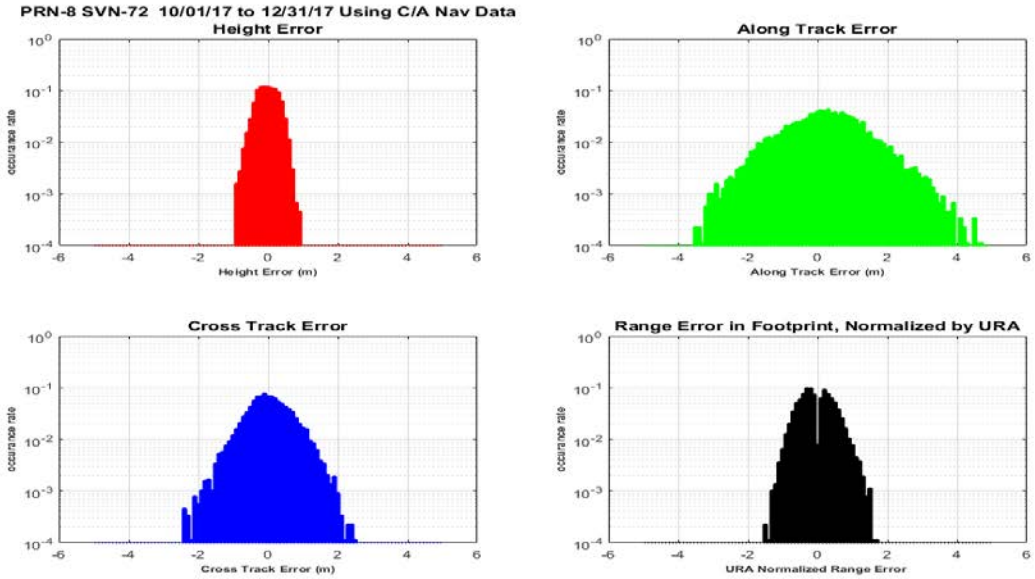


Figure 11-82 Histograms of H, A, C, and Range Error PRN-8 (SVN-72) Using L2C CNAV Data

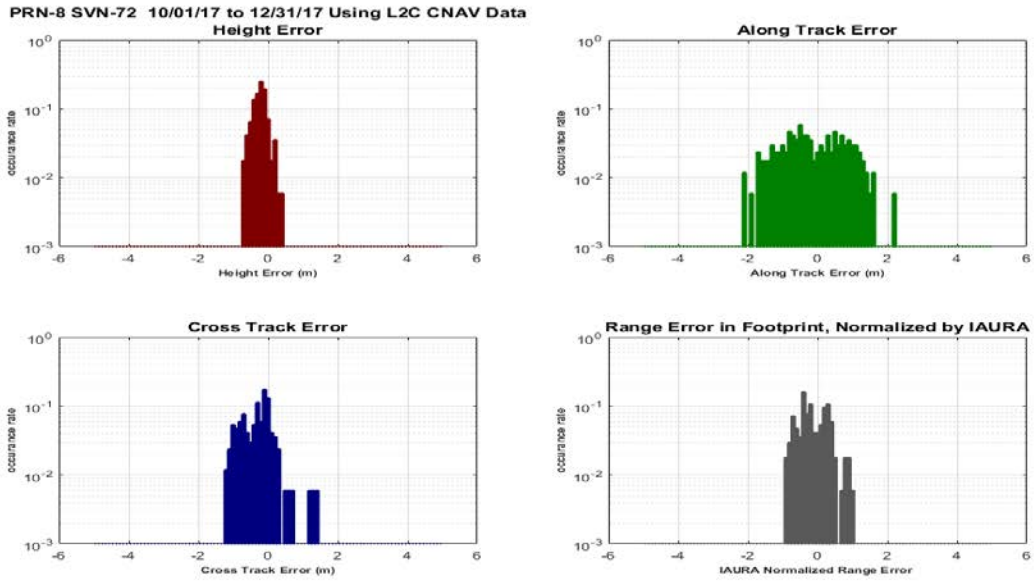


Figure 11-83 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using C/A Nav Data

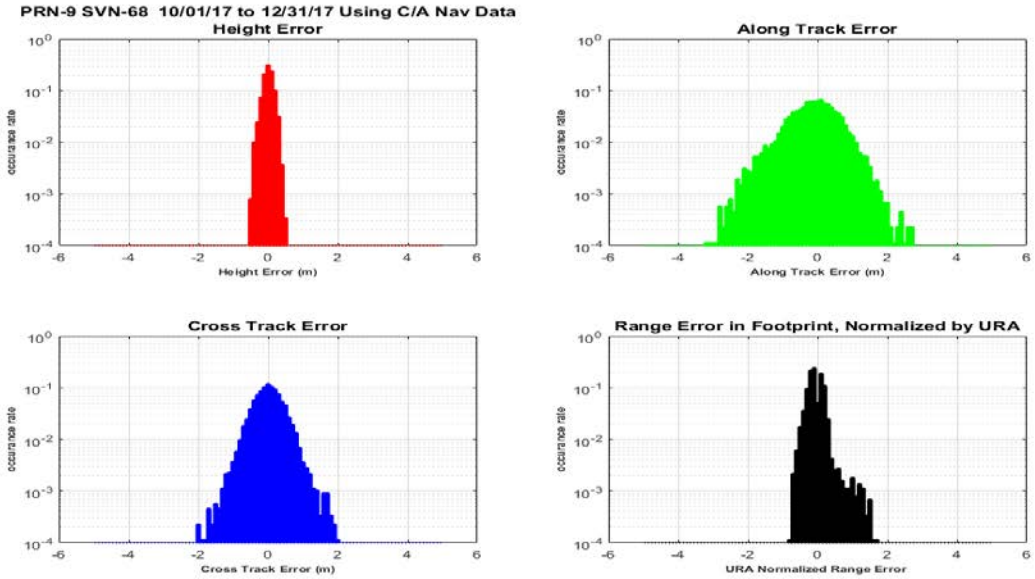


Figure 11-84 Histograms of H, A, C, and Range Error PRN-9 (SVN-68) Using L2C CNAV Data

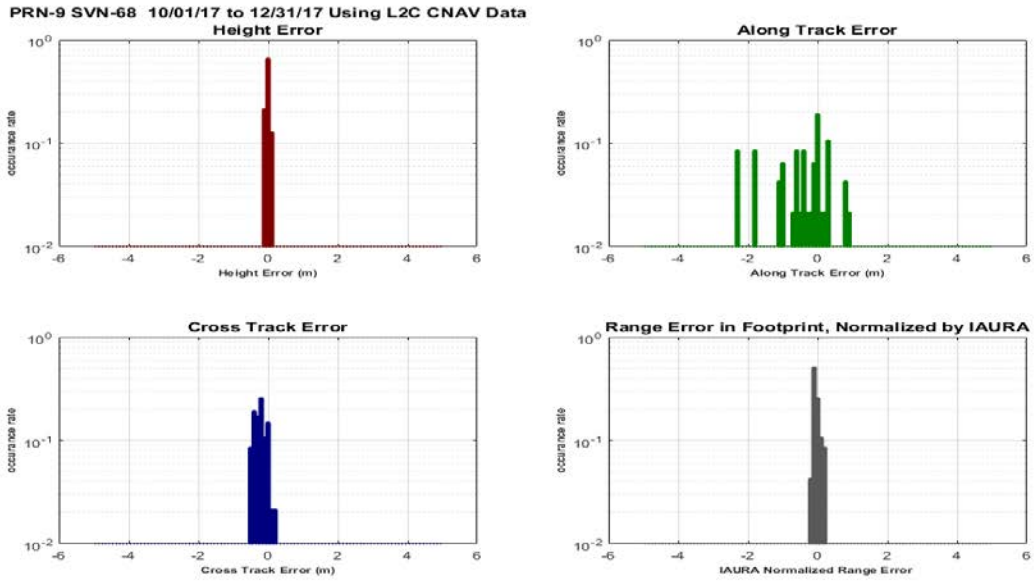


Figure 11-85 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using C/A Nav Data

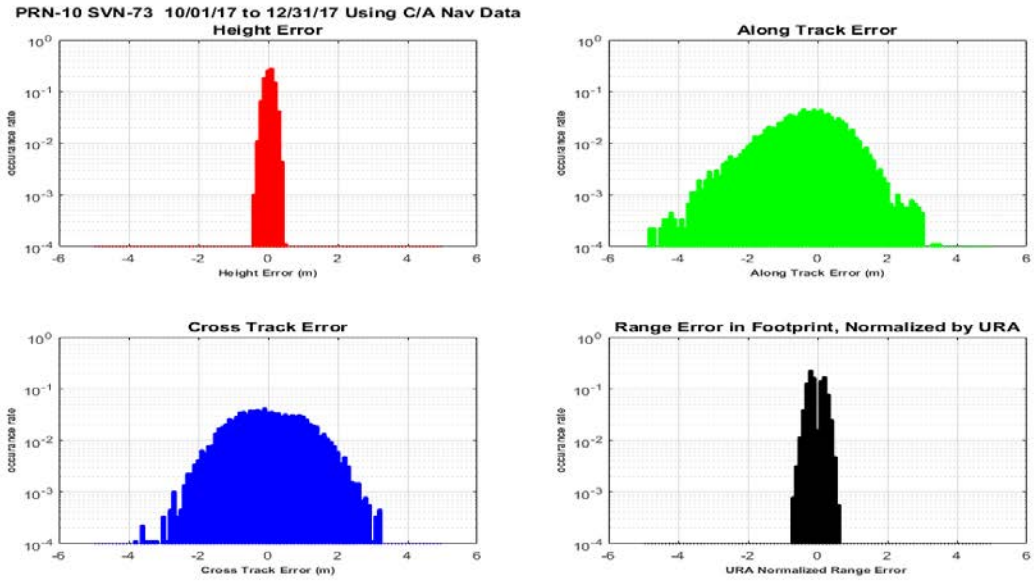


Figure 11-86 Histograms of H, A, C, and Range Error PRN-10 (SVN-73) Using L2C CNAV Data

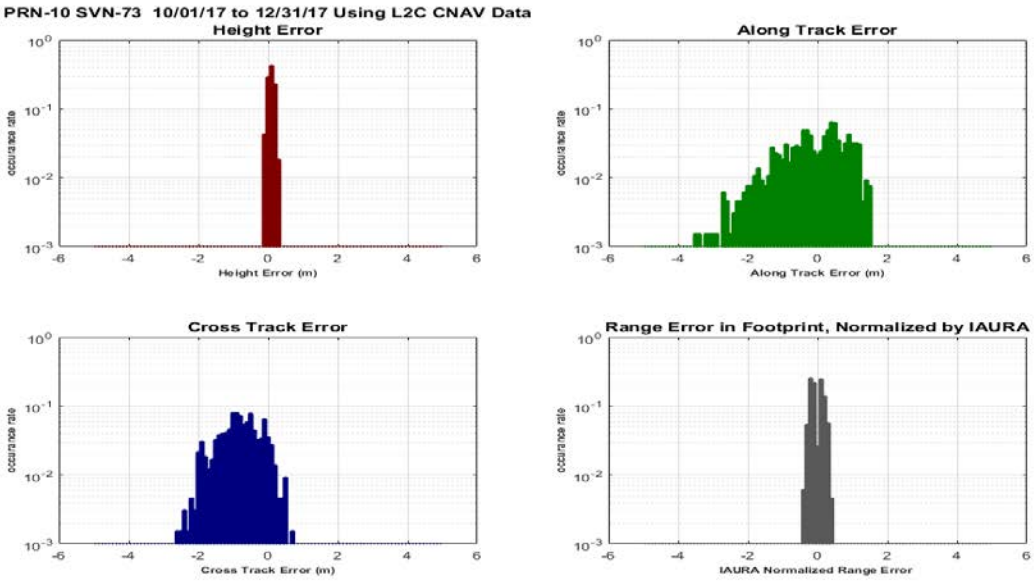


Figure 11-87 Histograms of H, A, C, and Range Error PRN-11 (SVN-46) Using C/A Nav Data

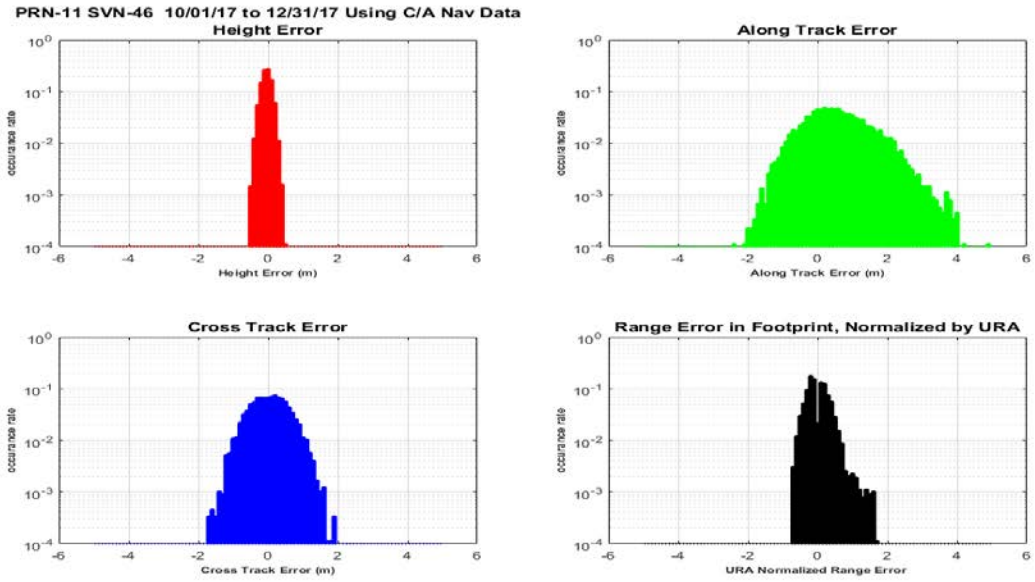


Figure 11-88 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using C/A Nav Data

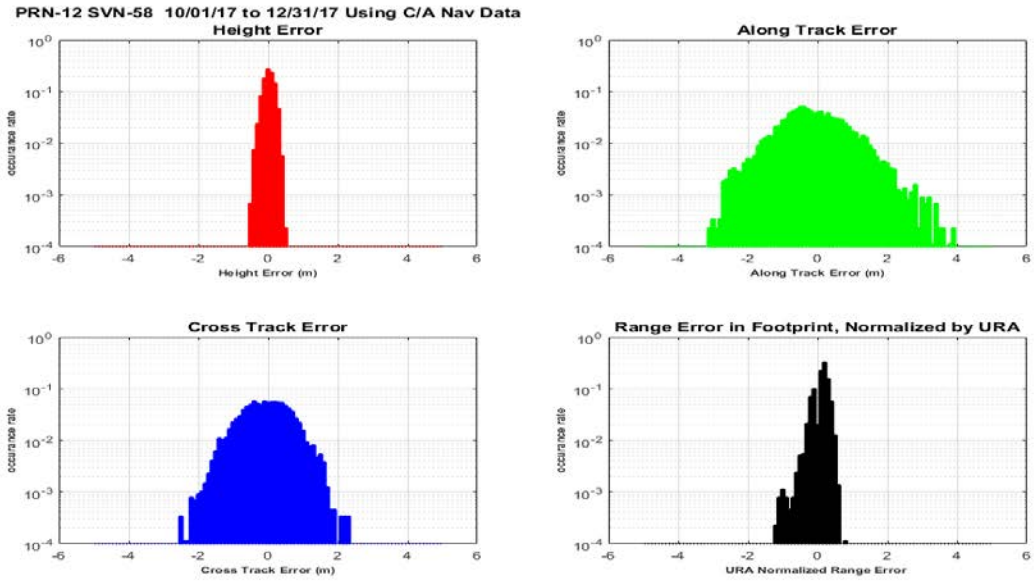


Figure 11-89 Histograms of H, A, C, and Range Error PRN-12 (SVN-58) Using L2C CNAV Data

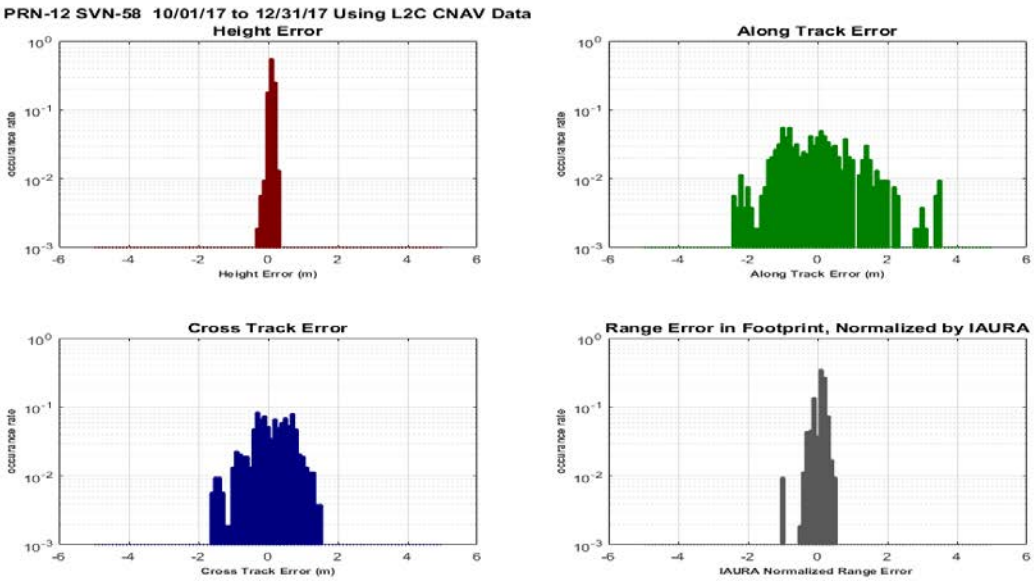


Figure 11-90 Histograms of H, A, C, and Range Error PRN-13 (SVN-43) Using C/A Nav Data

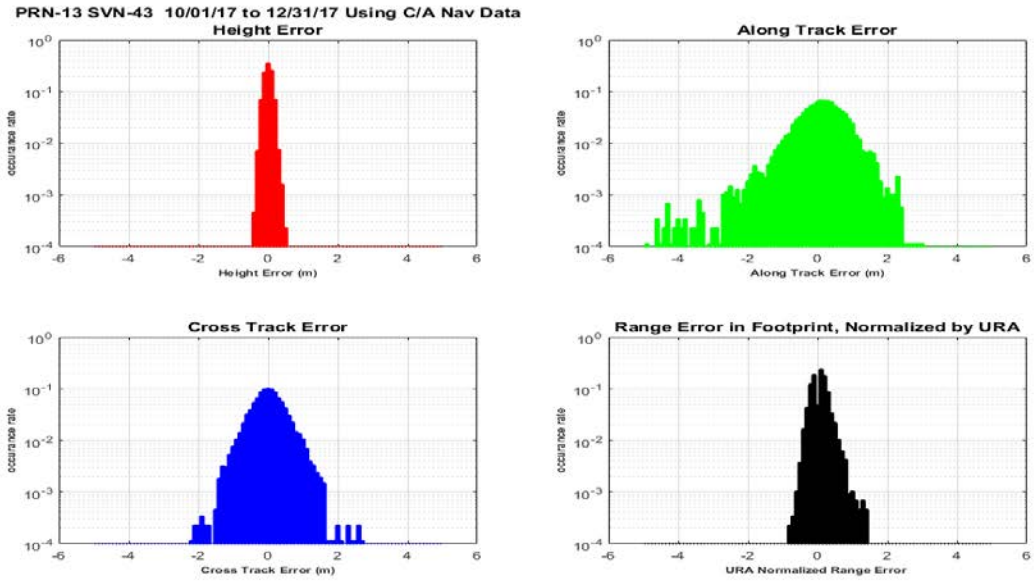


Figure 11-91 Histograms of H, A, C, and Range Error PRN-14 (SVN-41) Using C/A Nav Data

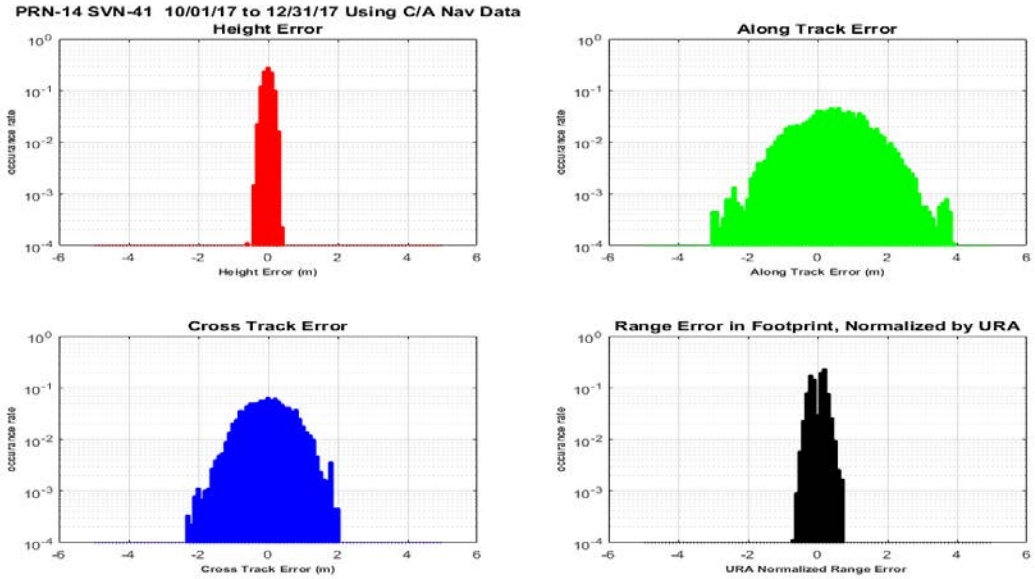


Figure 11-92 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using C/A Nav Data

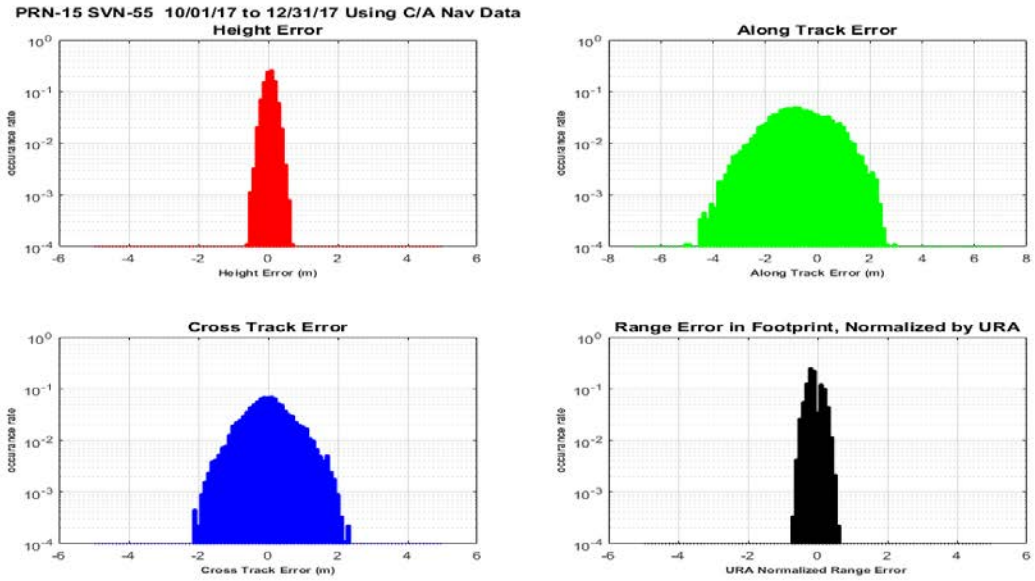


Figure 11-93 Histograms of H, A, C, and Range Error PRN-15 (SVN-55) Using L2C CNAV Data

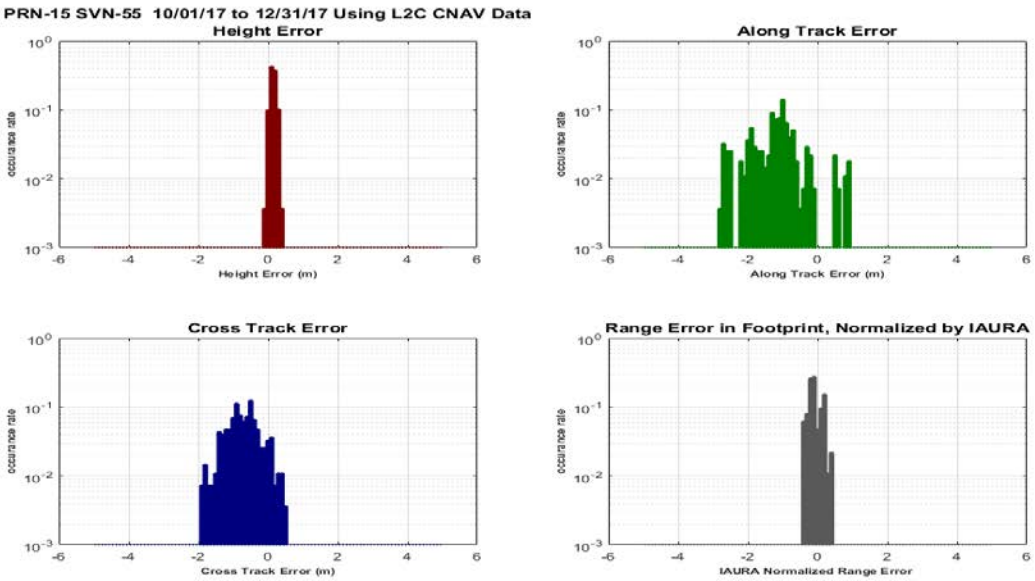


Figure 11-94 Histograms of H, A, C, and Range Error PRN-16 (SVN-56) Using C/A Nav Data

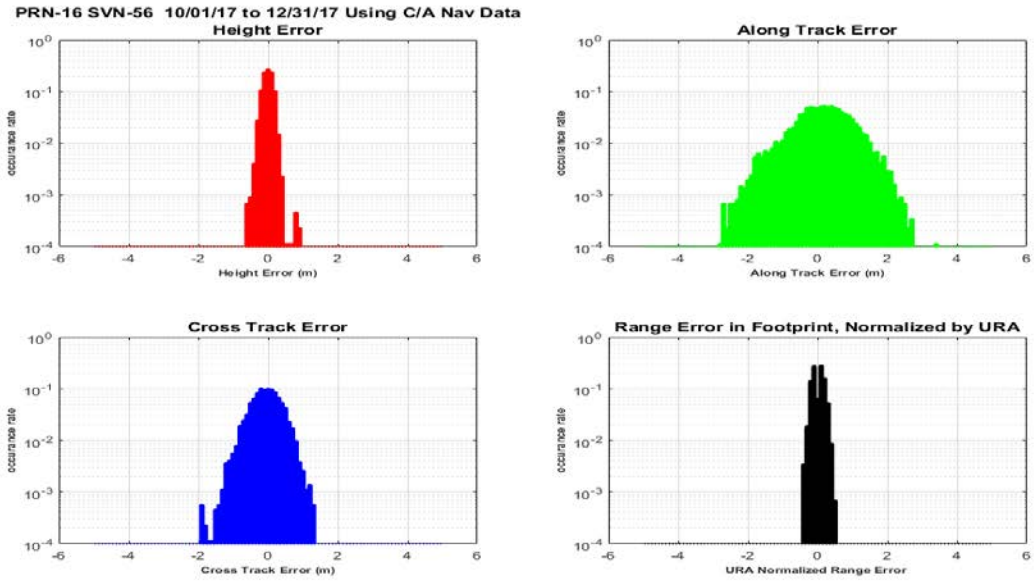


Figure 11-95 Histograms of H, A, C, and Range Error PRN-17 (SVN-53) Using C/A Nav Data

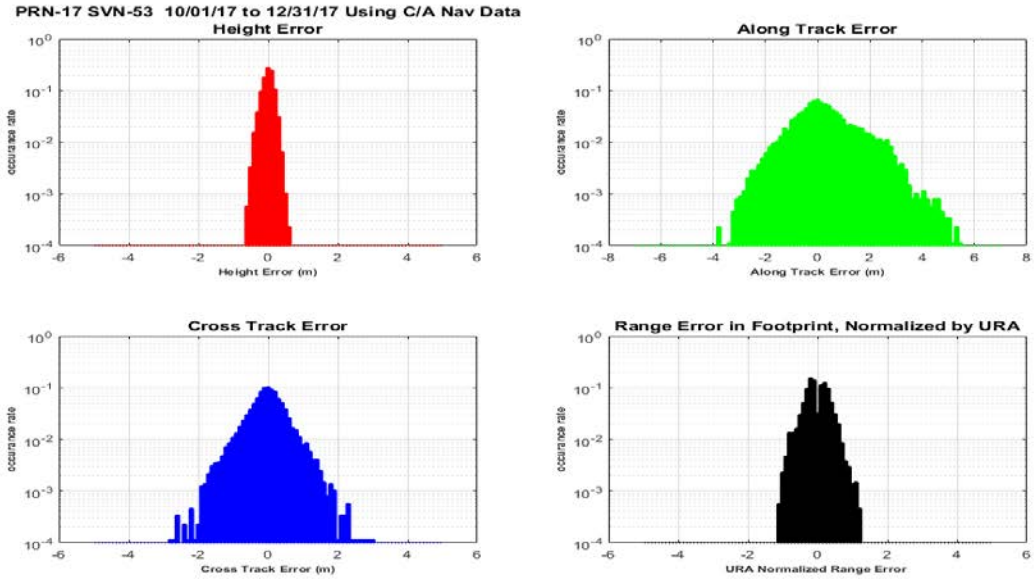


Figure 11-96 Histograms of H, A, C, and Range Error PRN-18 (SVN-54) Using C/A Nav Data

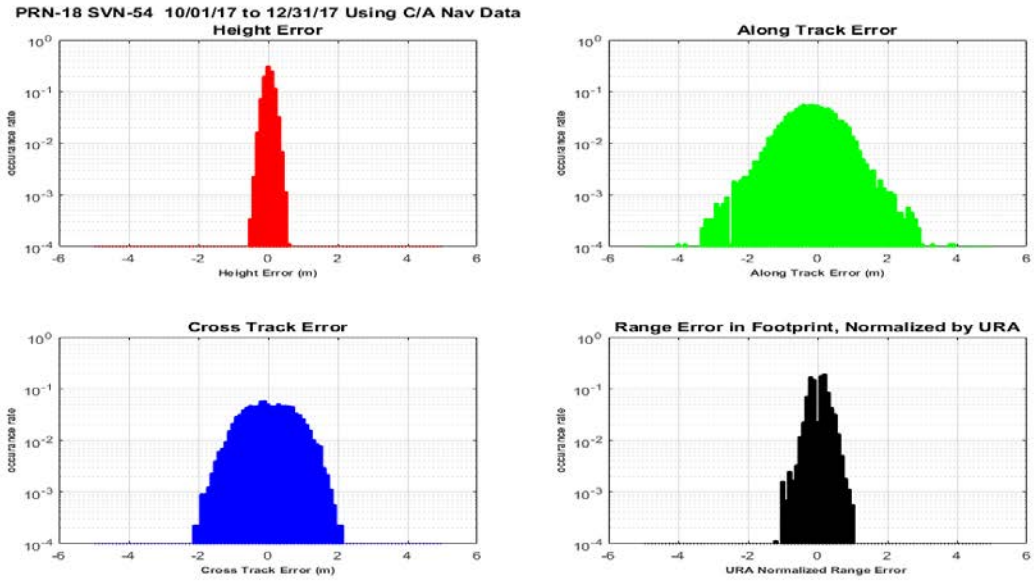


Figure 11-97 Histograms of H, A, C, and Range Error PRN-19 (SVN-59) Using C/A Nav Data

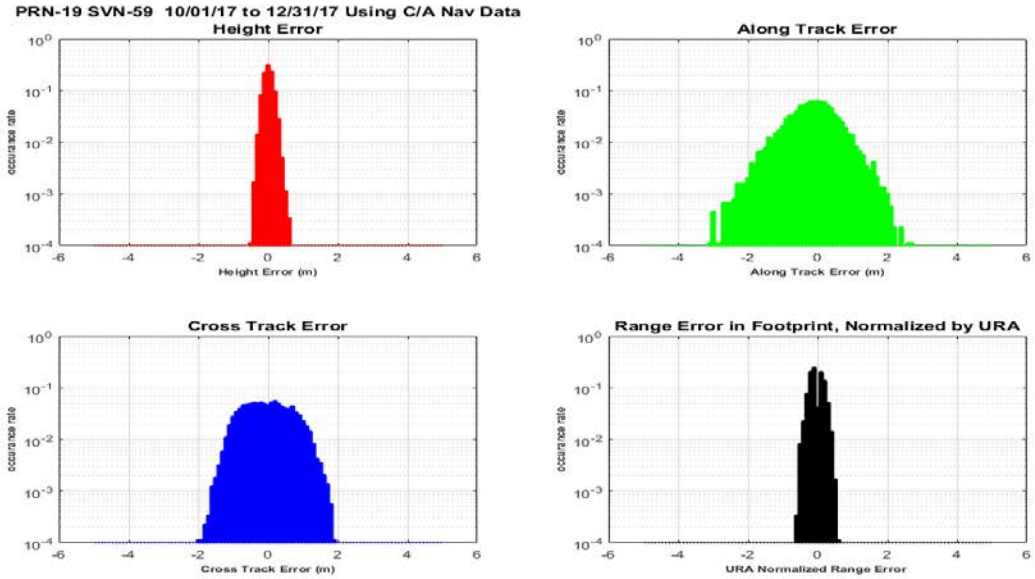


Figure 11-98 Histograms of H, A, C, and Range Error PRN-20 (SVN-51) Using C/A Nav Data

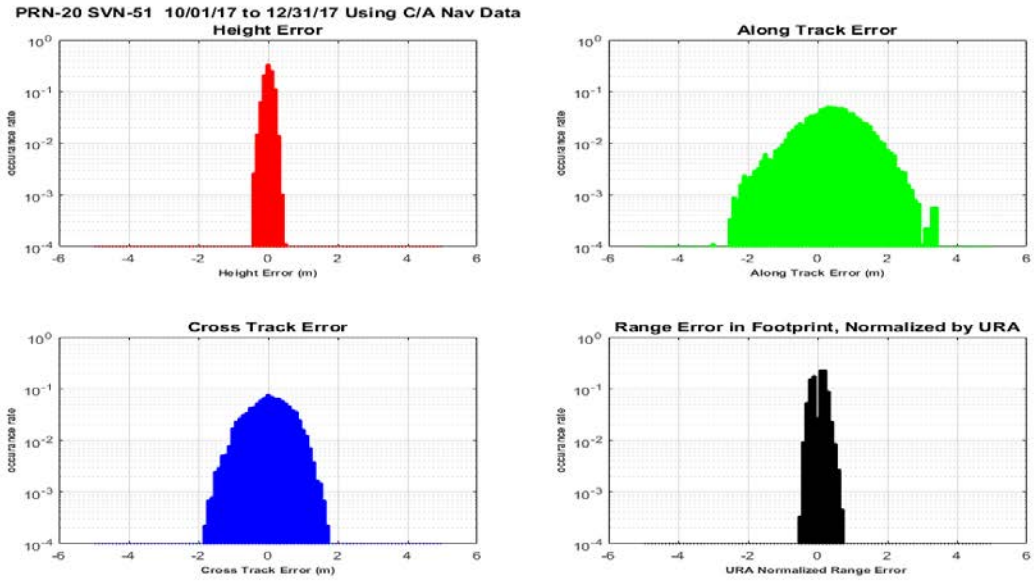


Figure 11-99 Histograms of H, A, C, and Range Error PRN-21 (SVN-45) Using C/A Nav Data

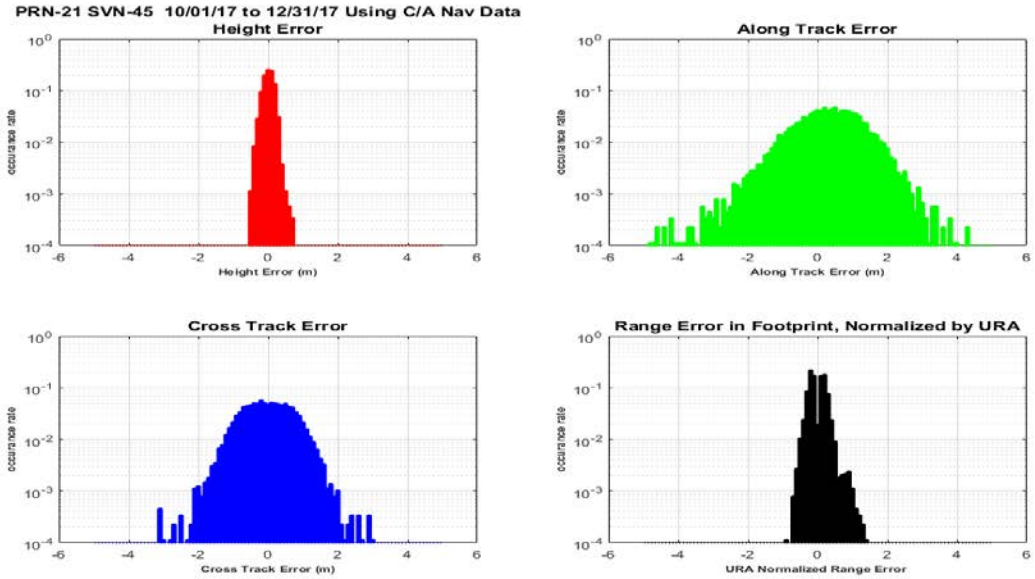


Figure 11-100 Histograms of H, A, C, and Range Error PRN-22 (SVN-47) Using C/A Nav Data

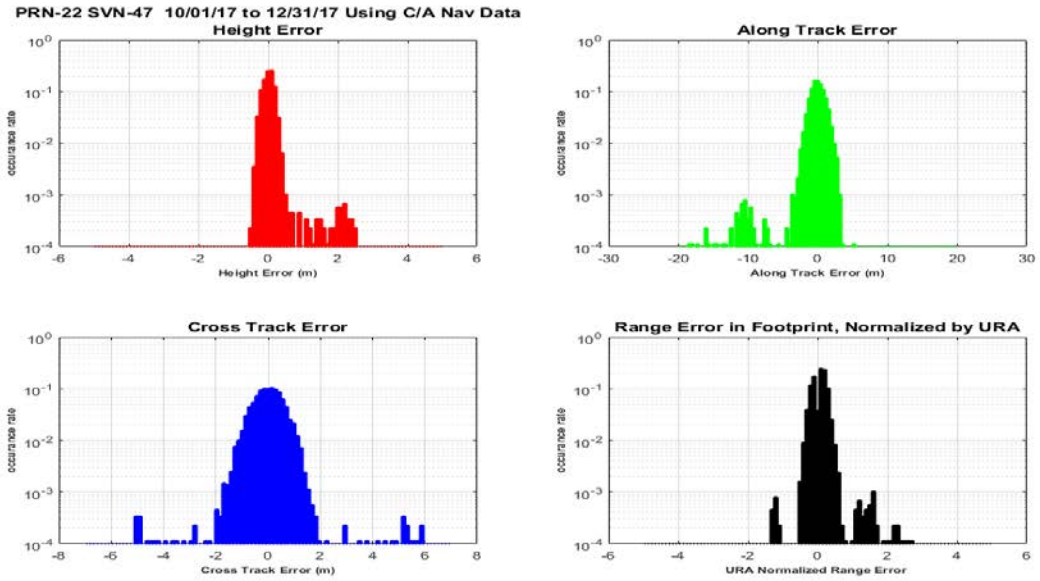


Figure 11-101 Histograms of H, A, C, and Range Error PRN-23 (SVN-60) Using C/A Nav Data

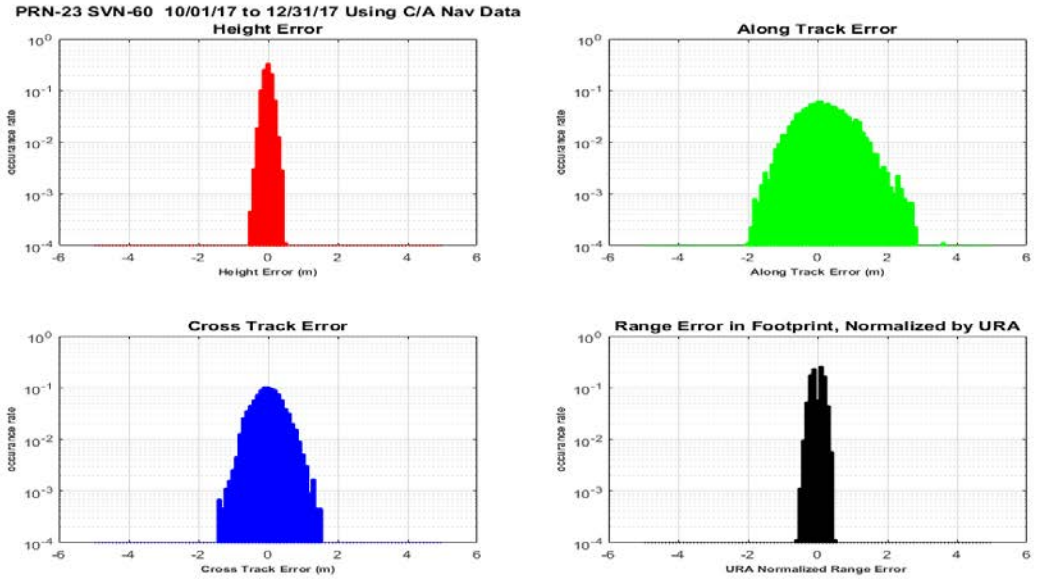


Figure 11-102 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using C/A Nav Data

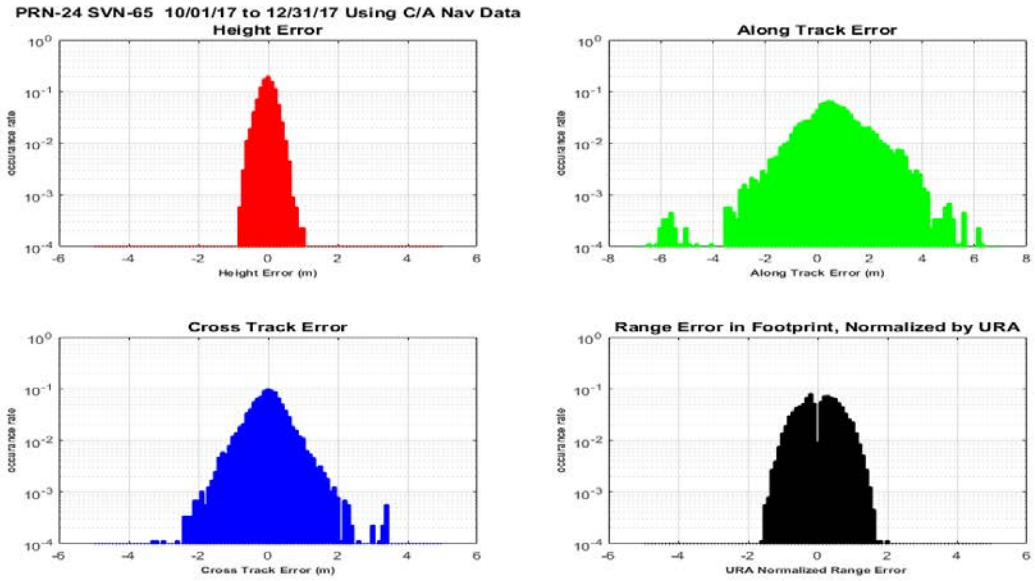


Figure 11-103 Histograms of H, A, C, and Range Error PRN-24 (SVN-65) Using L2C CNAV Data

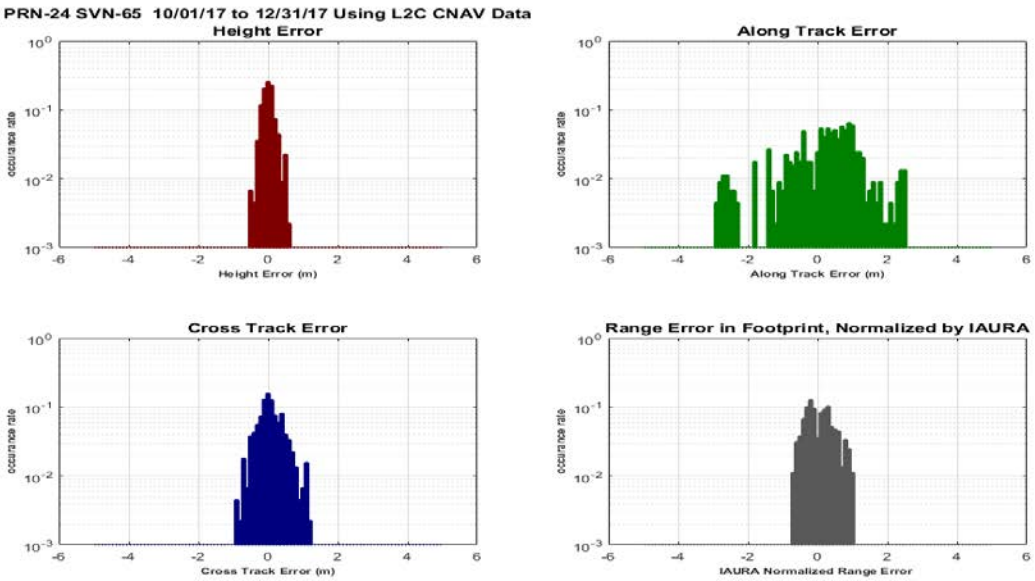


Figure 11-104 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using C/A Nav Data

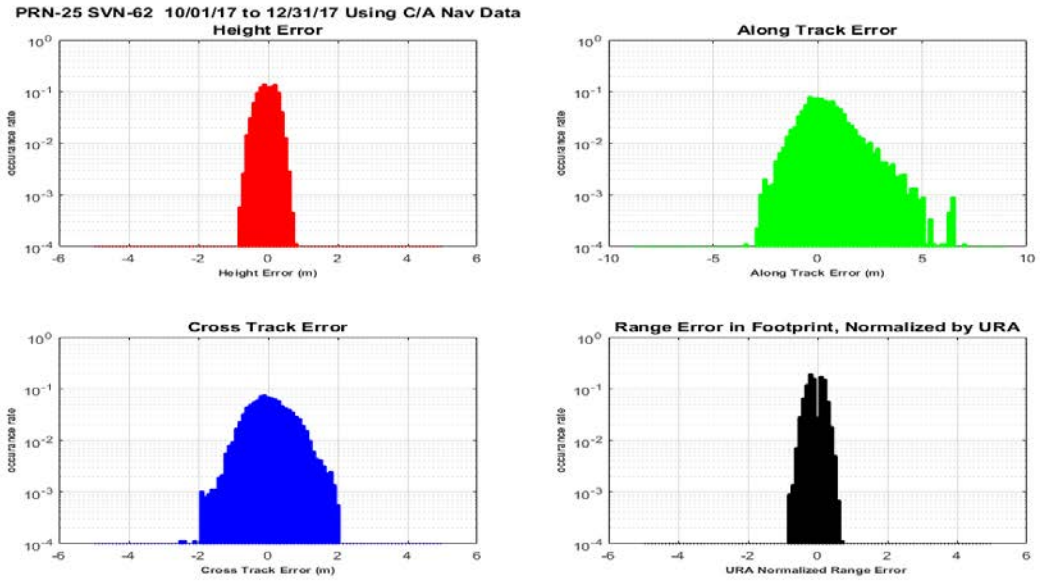


Figure 11-105 Histograms of H, A, C, and Range Error PRN-25 (SVN-62) Using L2C CNAV Data

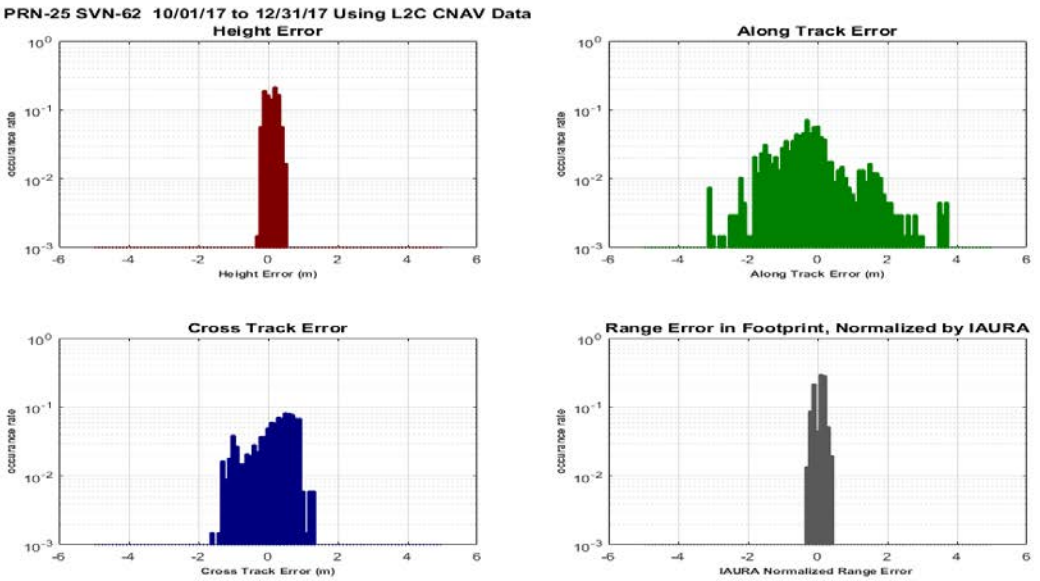


Figure 11-106 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using C/A Nav Data

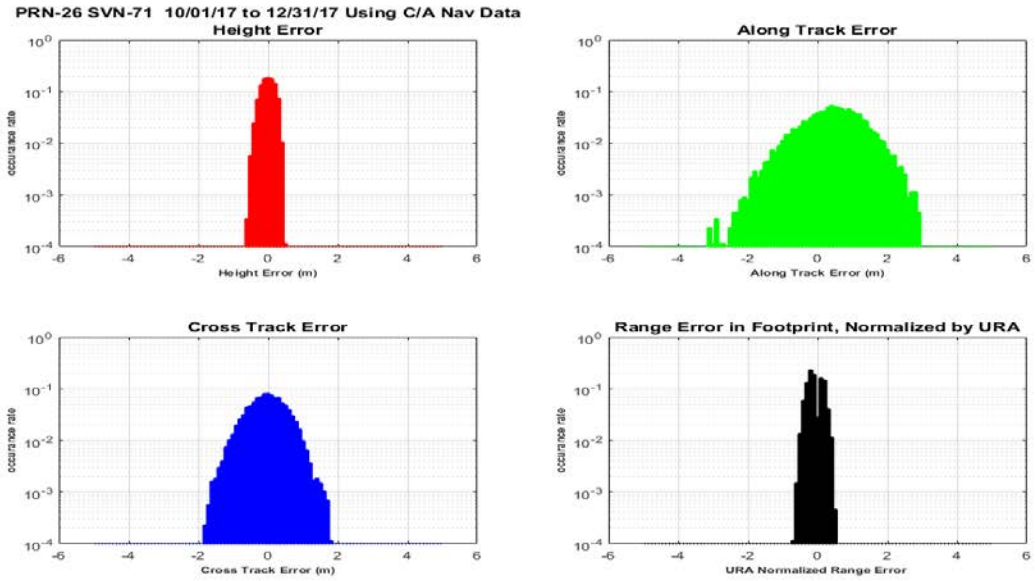


Figure 11-107 Histograms of H, A, C, and Range Error PRN-26 (SVN-71) Using L2C CNAV Data

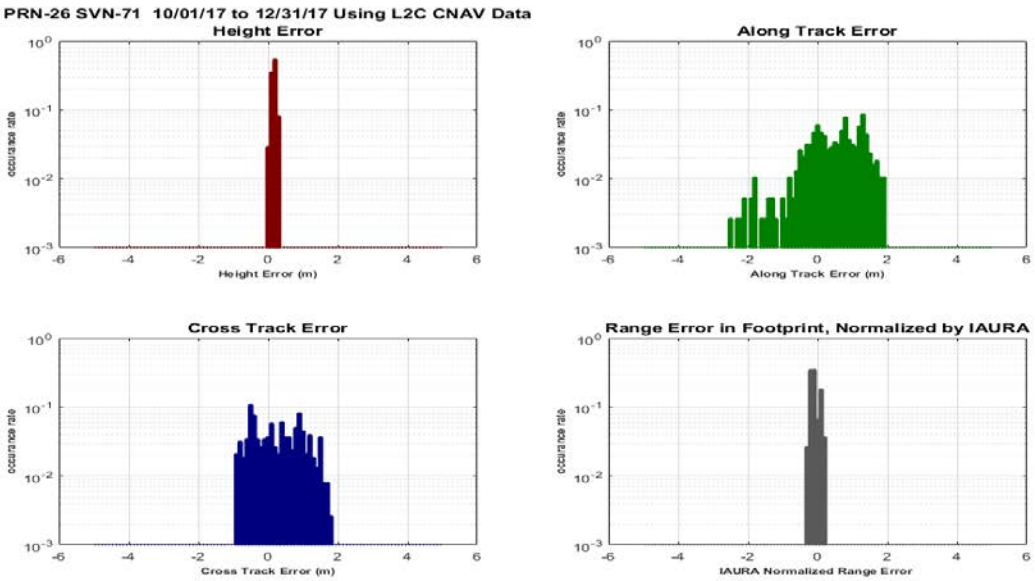


Figure 11-108 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using C/A Nav Data

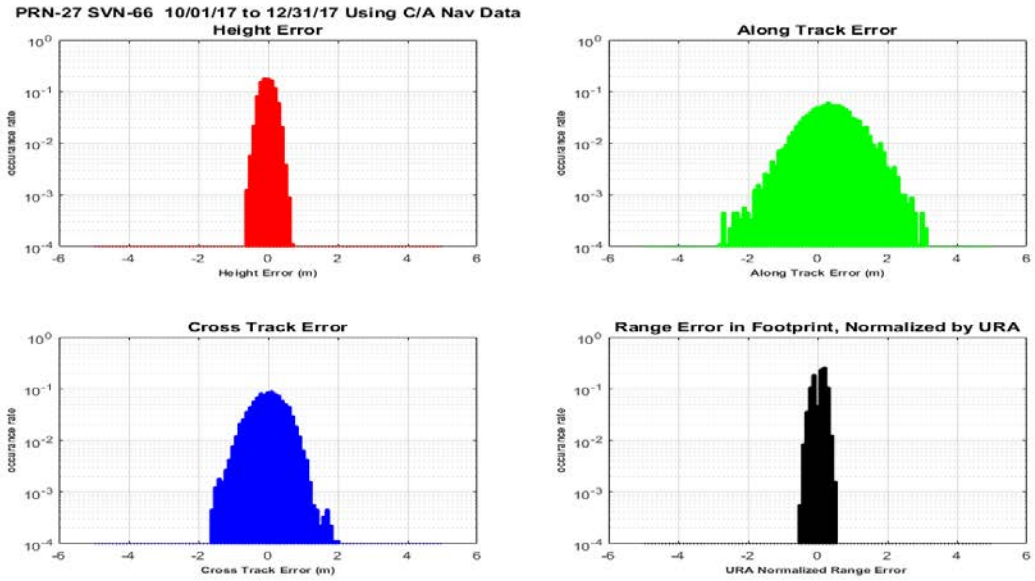


Figure 11-109 Histograms of H, A, C, and Range Error PRN-27 (SVN-66) Using L2C CNAV Data

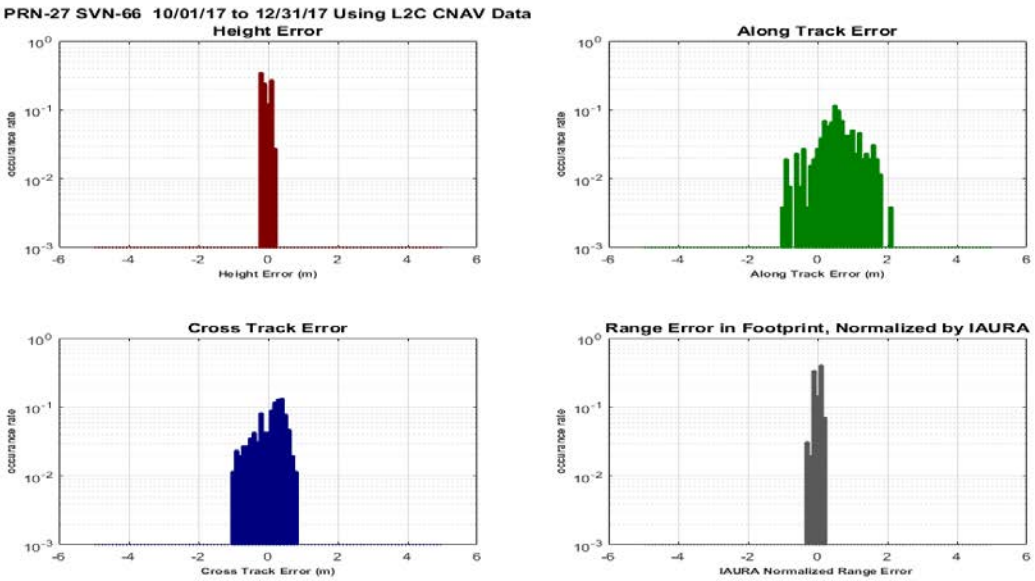


Figure 11-110 Histograms of H, A, C, and Range Error PRN-28 (SVN-44) Using C/A Nav Data

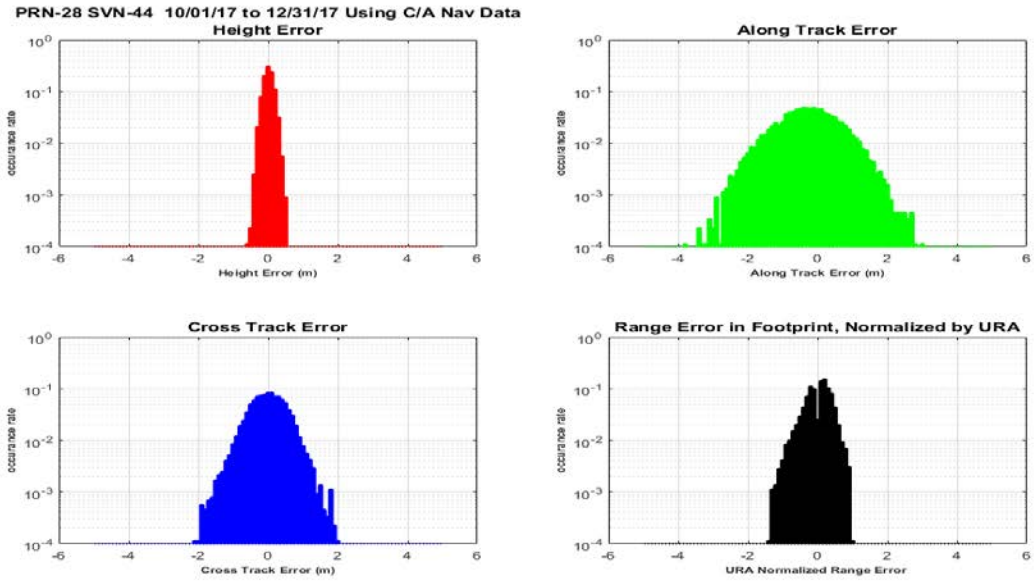


Figure 11-111 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using C/A Nav Data

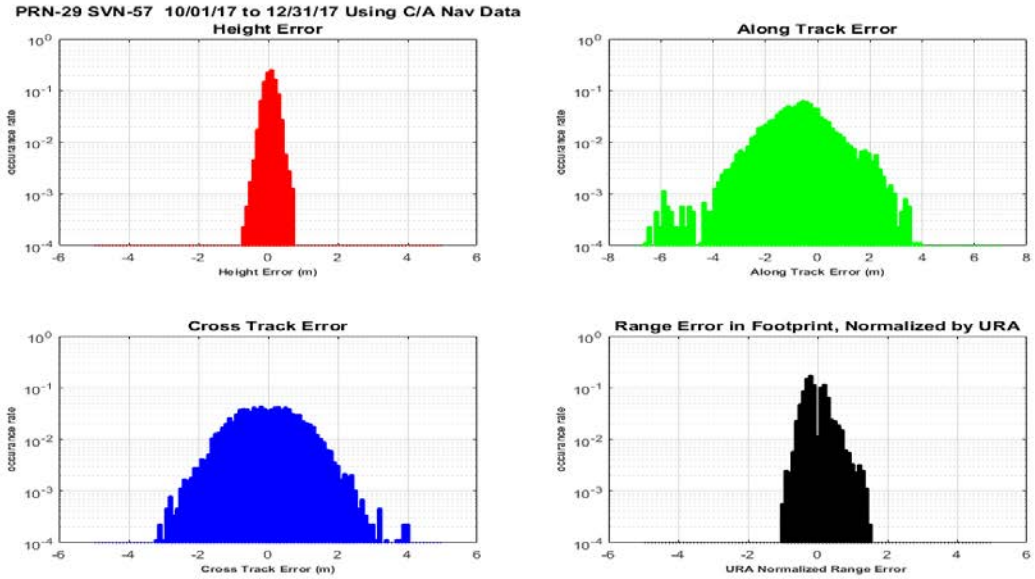


Figure 11-112 Histograms of H, A, C, and Range Error PRN-29 (SVN-57) Using L2C CNAV Data

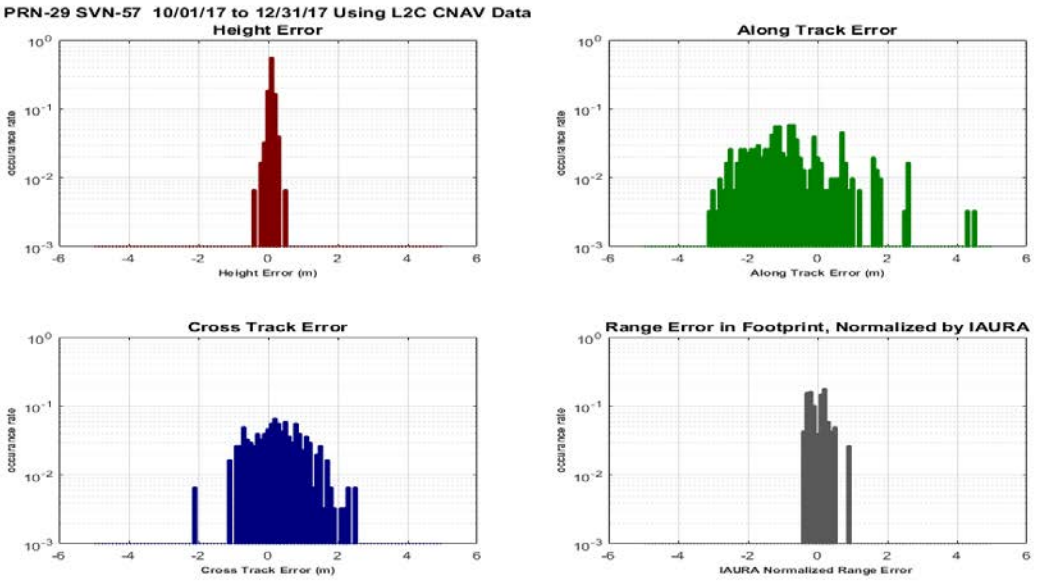


Figure 11-113 Histograms of H, A, C, and Range Error PRN-30 (SVN-64) Using C/A Nav Data

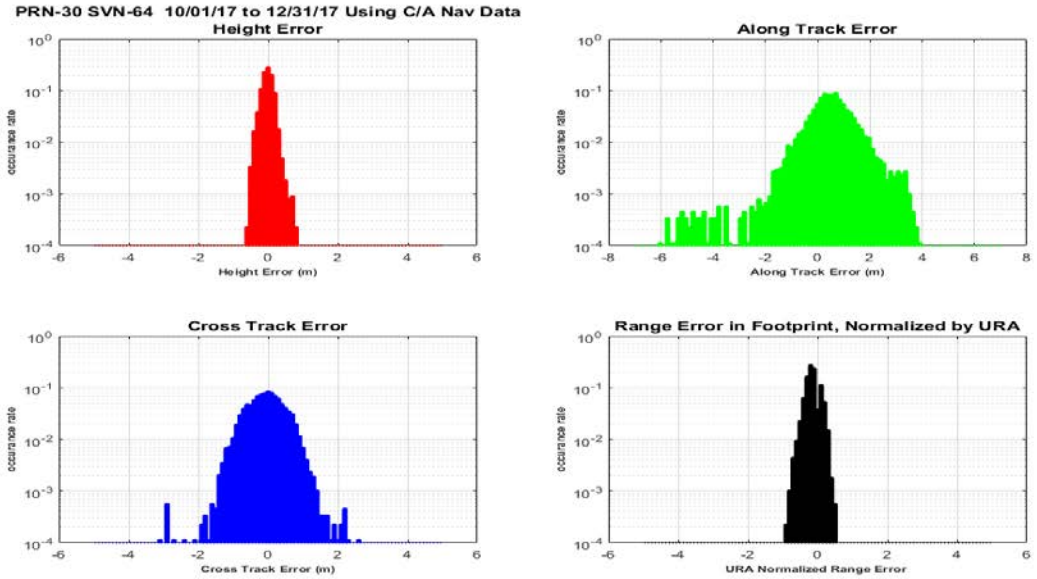


Figure 11-114 Histograms of H, A, C, and Range Error PRN-31 (SVN-52) Using C/A Nav Data

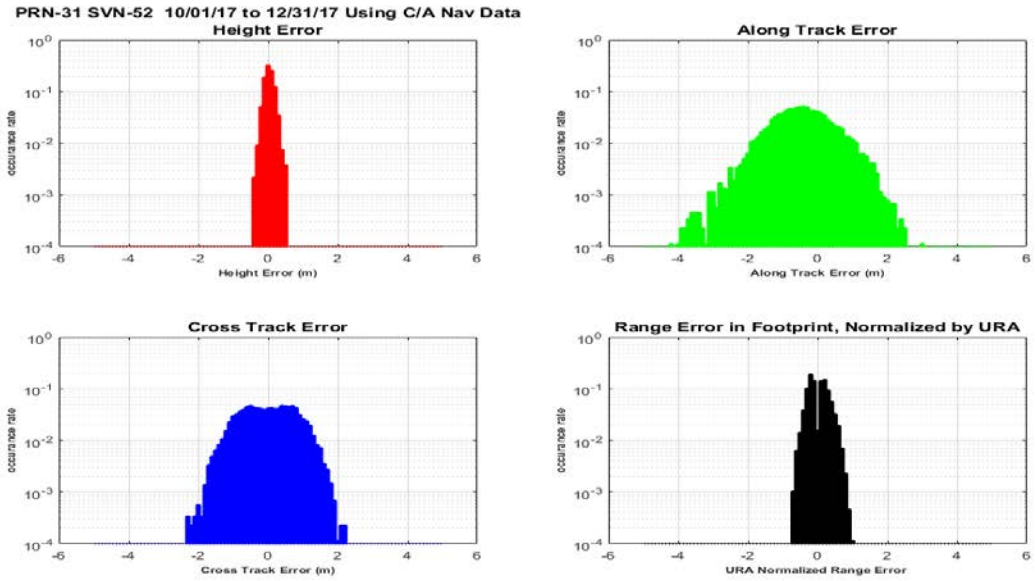


Figure 11-115 Histograms of H, A, C, and Range Error PRN-31 (SVN-52) Using L2C CNAV Data

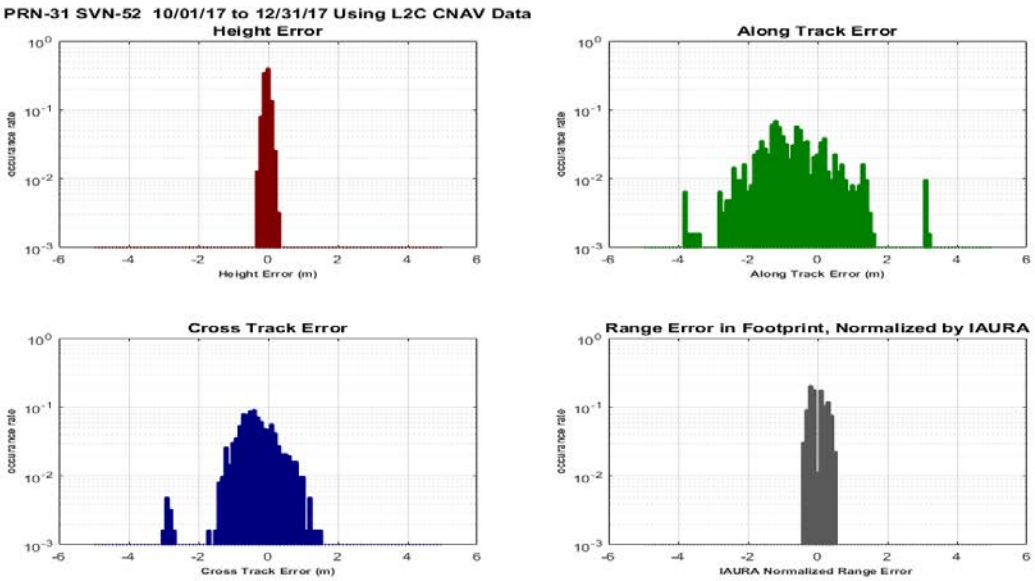


Figure 11-116 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using C/A Nav Data

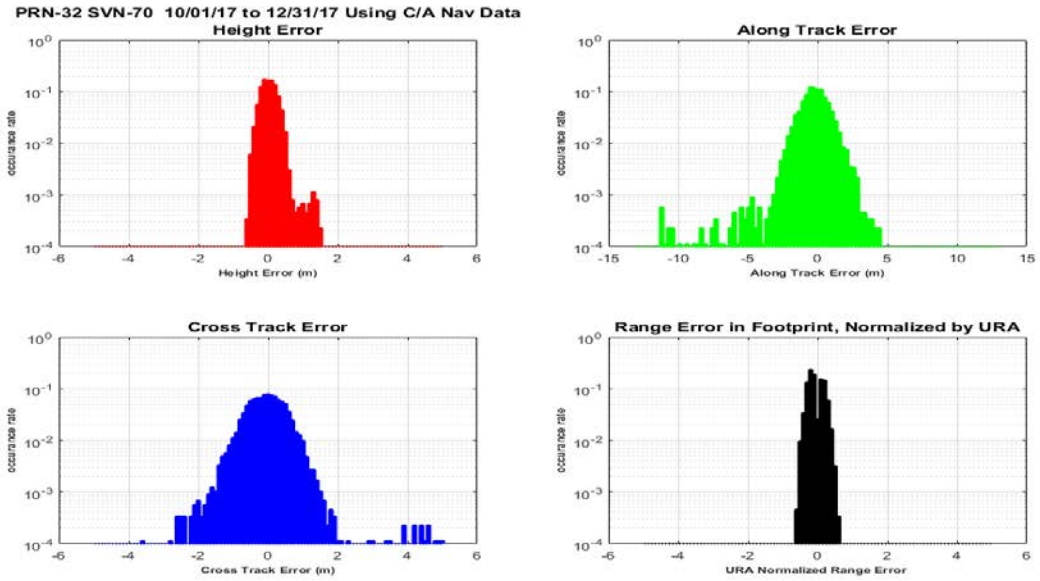
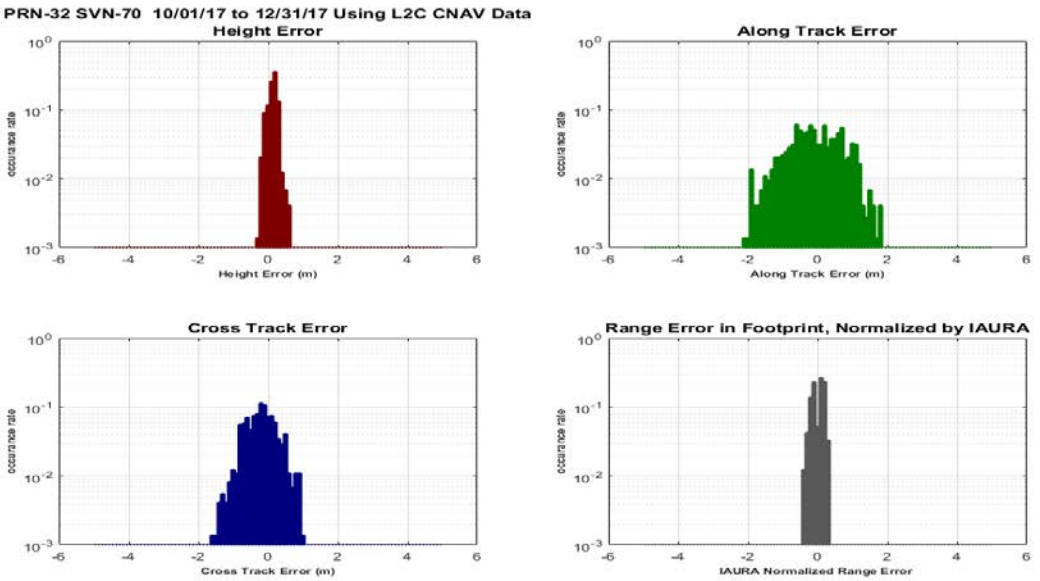


Figure 11-117 Histograms of H, A, C, and Range Error PRN-32 (SVN-70) Using L2C CNAV Data



Timeline of URA Normalized Range Error for All Satellites

Figure 11-118 Timeline of URA Normalized Range Error PRN-1 (SVN-63) Using C/A Nav Data

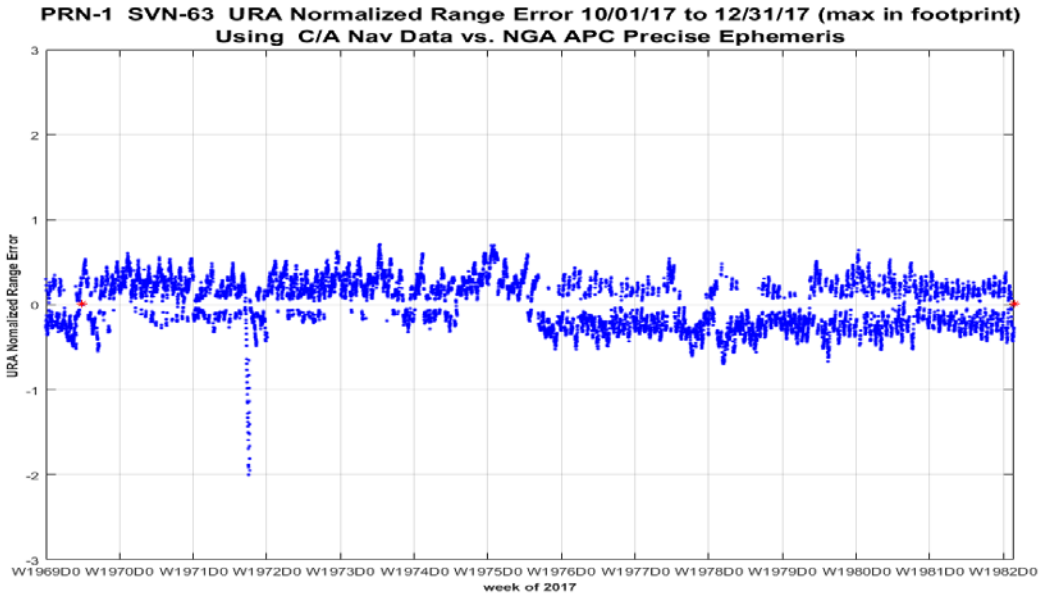


Figure 11-119 Timeline of IAURA Normalized Range Error PRN-1 (SVN-63) Using L2C CNAV Data

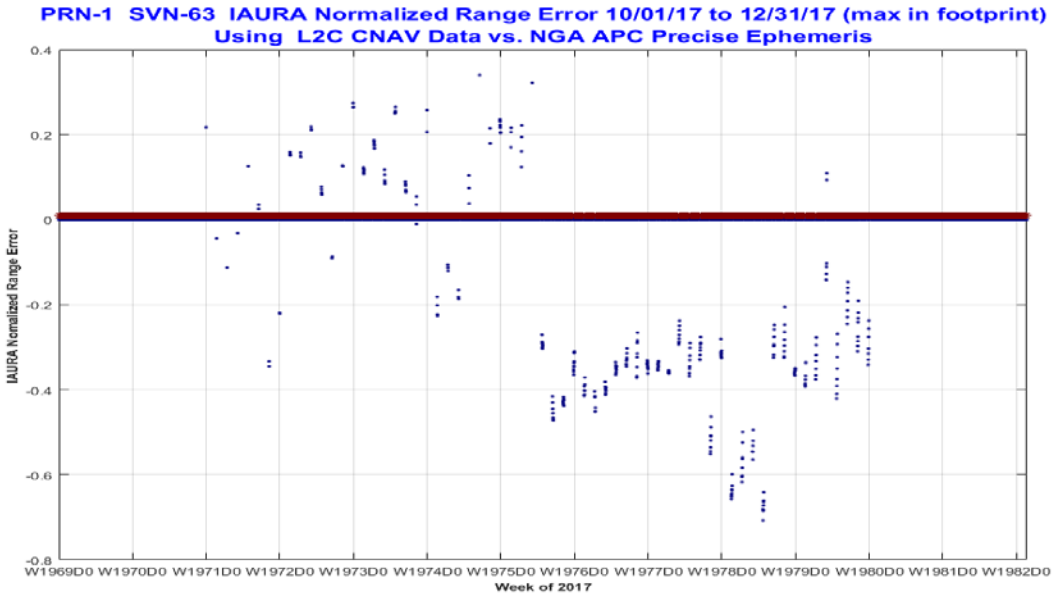


Figure 11-120 Timeline of URA Normalized Range Error PRN-2 (SVN-61) Using C/A Nav Data

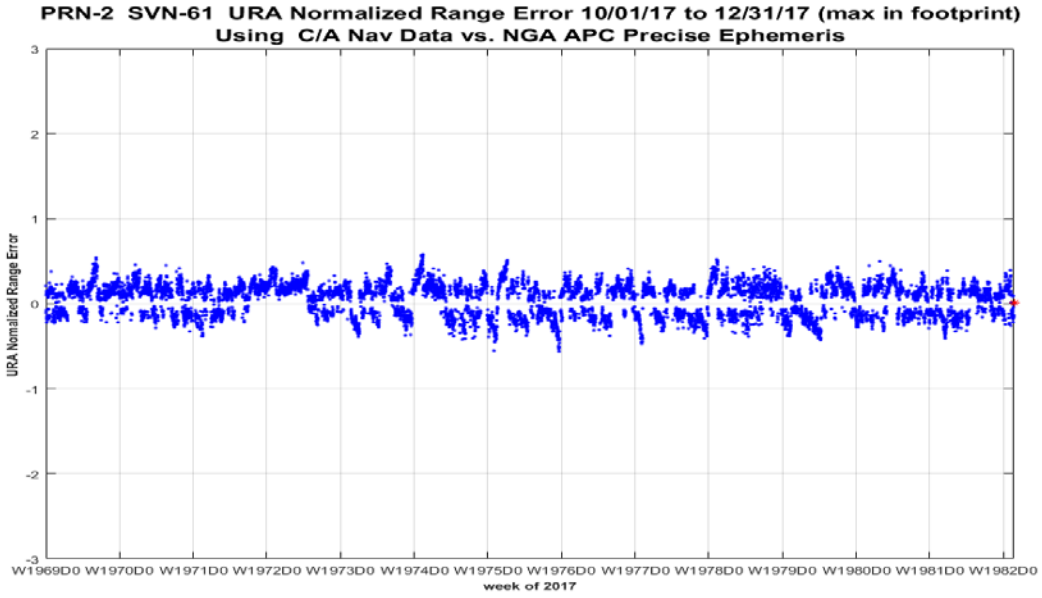


Figure 11-121 Timeline of URA Normalized Range Error PRN-3 (SVN-69) Using C/A Nav Data

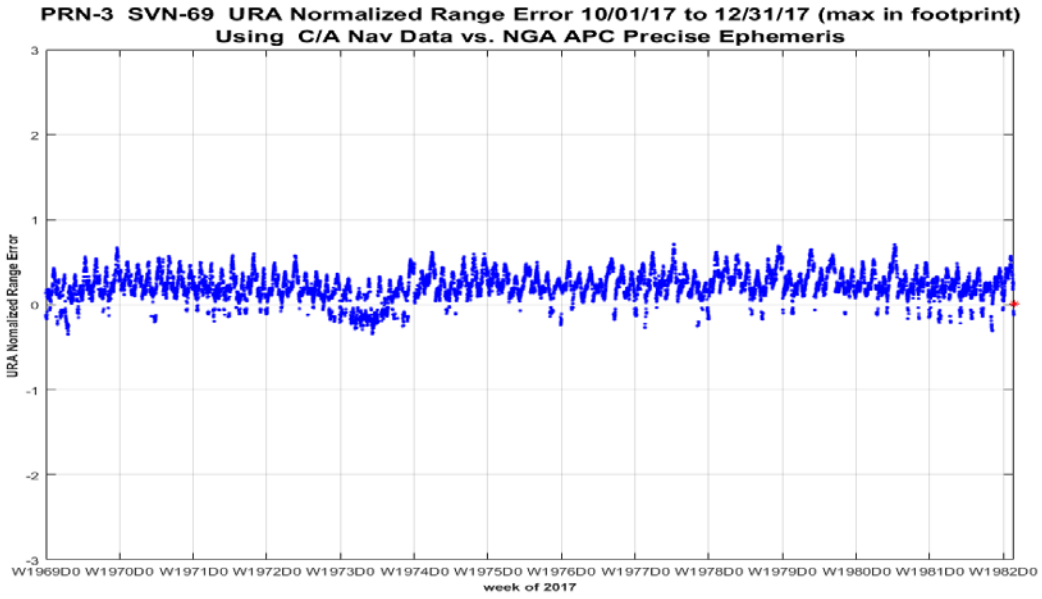


Figure 11-122 Timeline of IAURA Normalized Range Error PRN-3 (SVN-69) Using L2C CNAV Data

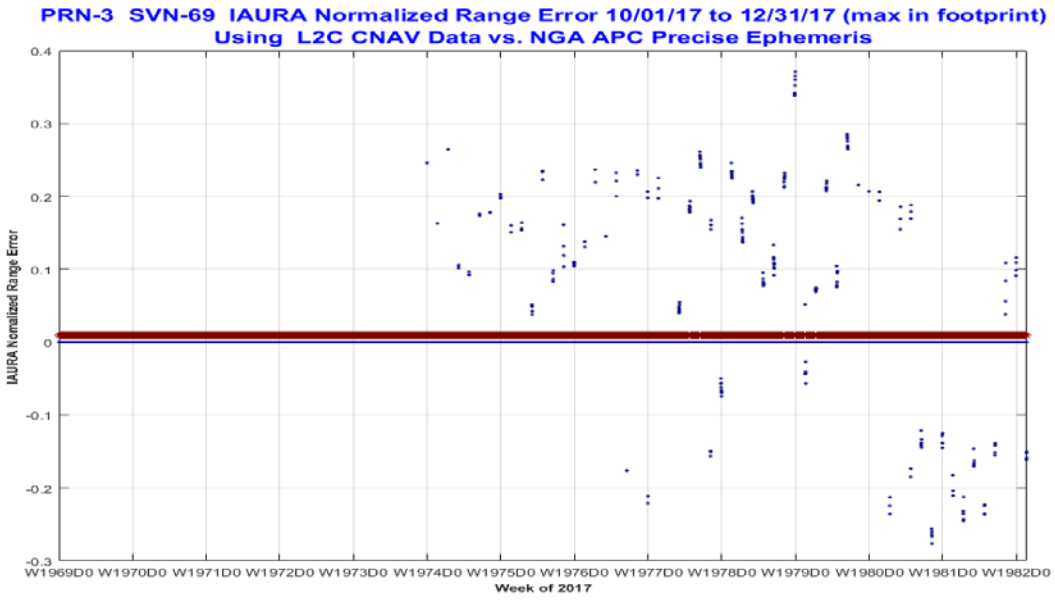


Figure 11-123 Timeline of URA Normalized Range Error PRN-5 (SVN-50) Using C/A Nav Data

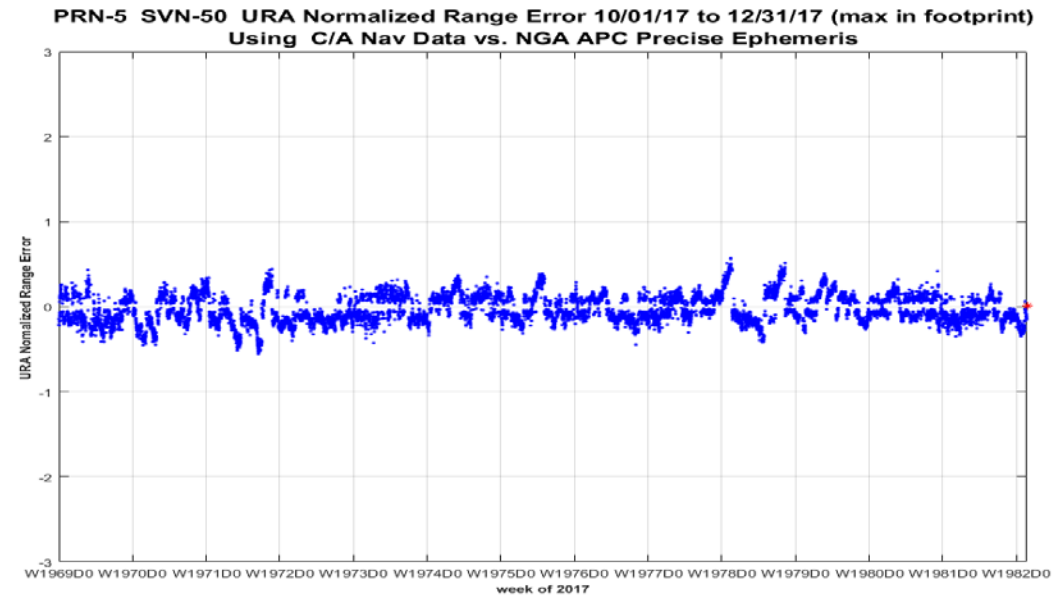


Figure 11-124 Timeline of IAURA Normalized Range Error PRN-5 (SVN-50) Using L2C CNAV Data

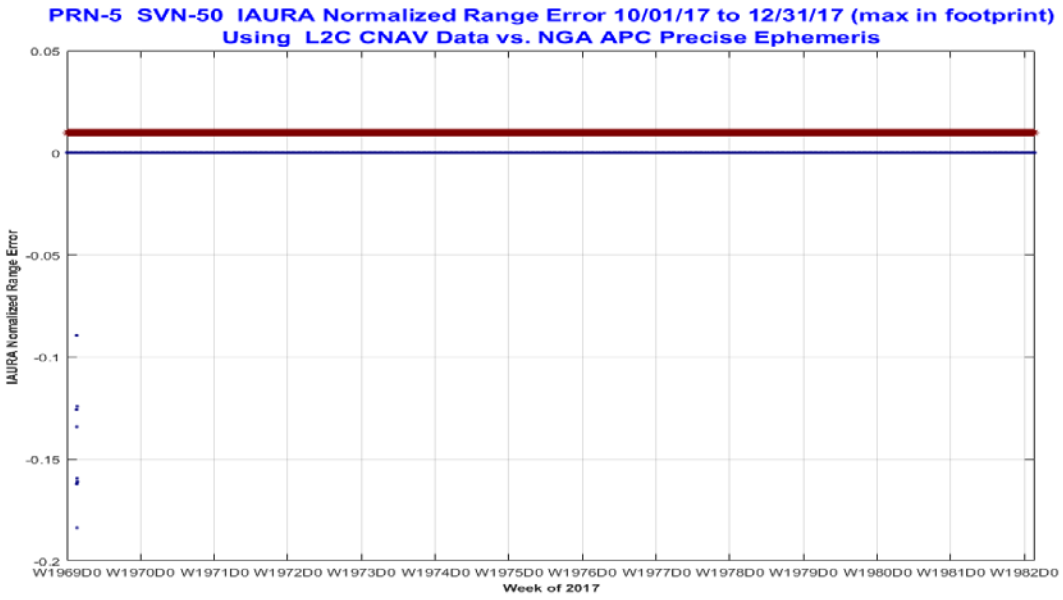


Figure 11-125 Timeline of URA Normalized Range Error PRN-6 (SVN-67) Using C/A Nav Data

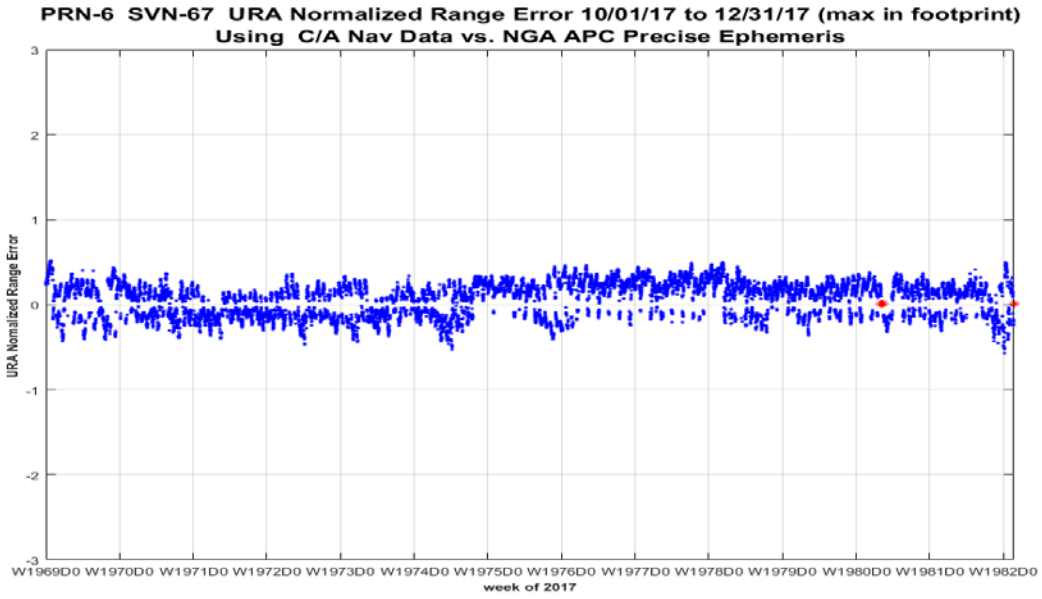


Figure 11-126 Timeline of URA Normalized Range Error PRN-7 (SVN-48) Using C/A Nav Data

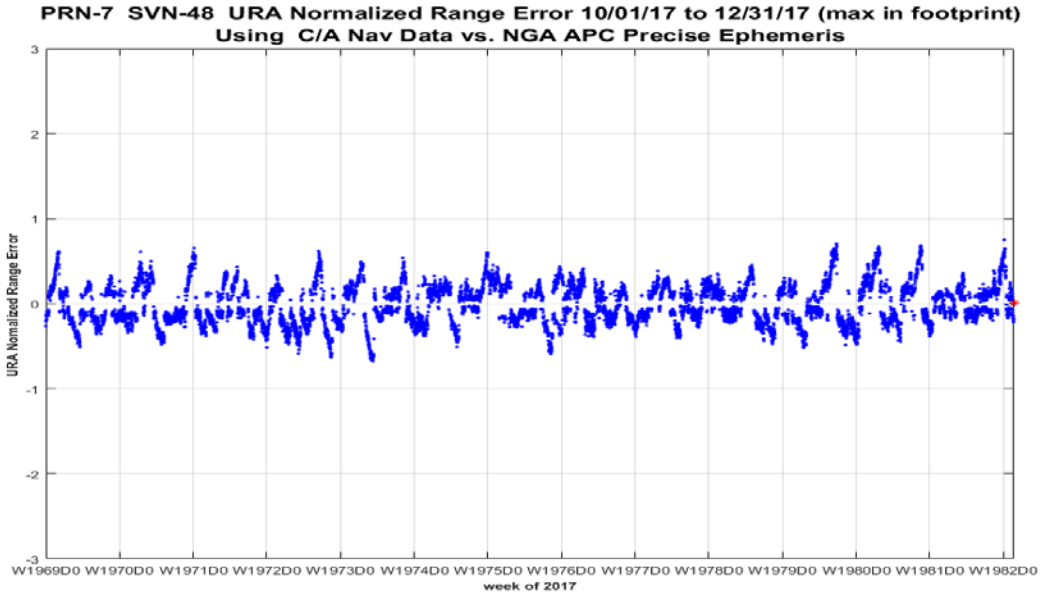


Figure 11-127 Timeline of URA Normalized Range Error PRN-8 (SVN-72) Using C/A Nav Data

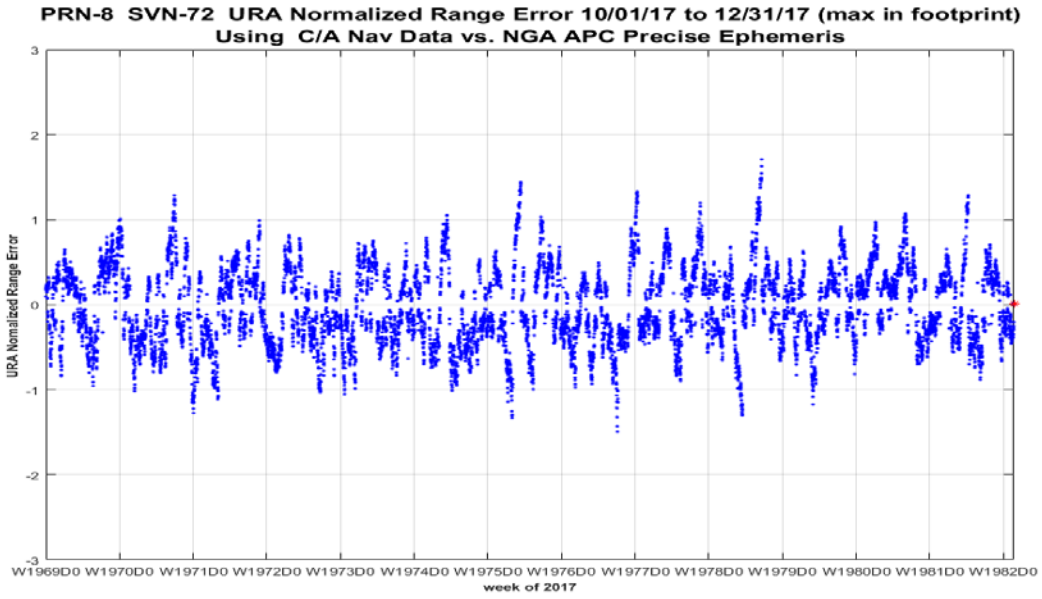


Figure 11-128 Timeline of IAURA Normalized Range Error PRN-8 (SVN-72) Using L2C CNAV Data

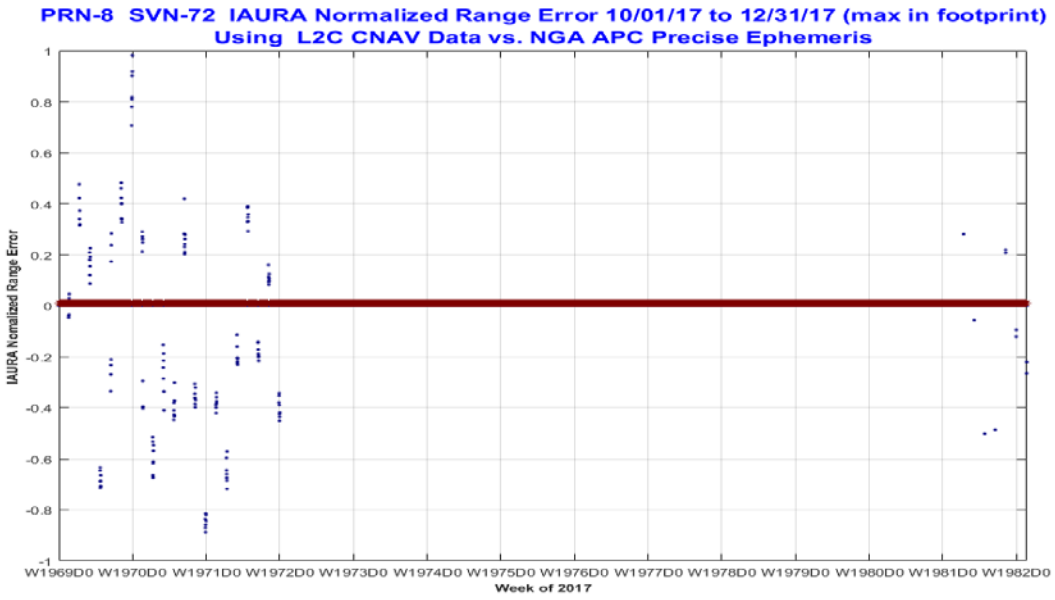


Figure 11-129 Timeline of URA Normalized Range Error PRN-9 (SVN-68) Using C/A Nav Data

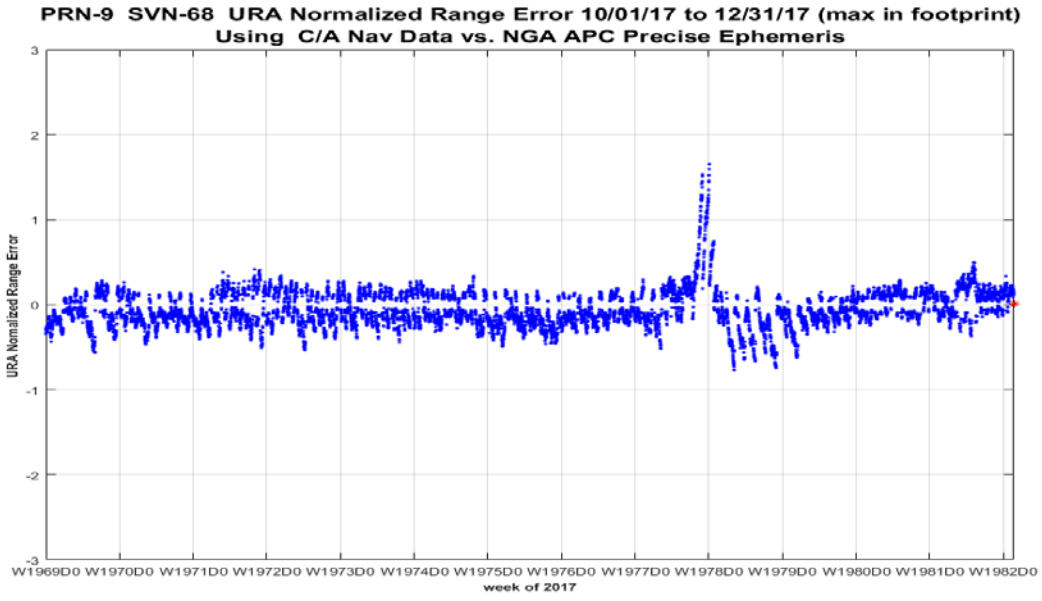


Figure 11-130 Timeline of IAURA Normalized Range Error PRN-9 (SVN-68) Using L2C CNAV Data

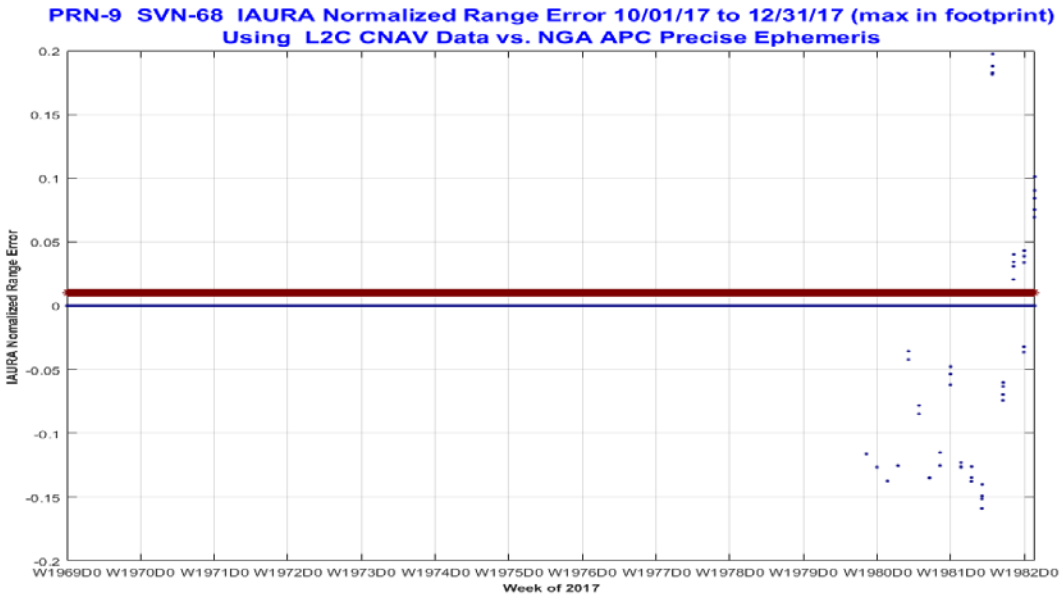


Figure 11-131 Timeline of URA Normalized Range Error PRN-10 (SVN-73) Using C/A Nav Data

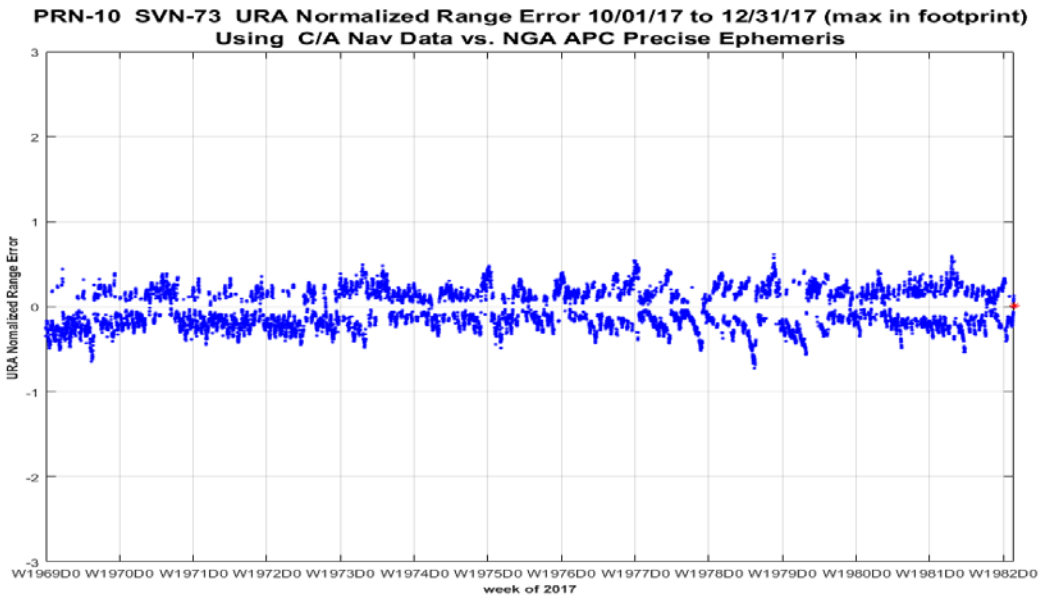


Figure 11-132 Timeline of IAURA Normalized Range Error PRN-10 (SVN-73) Using L2C CNAV Data

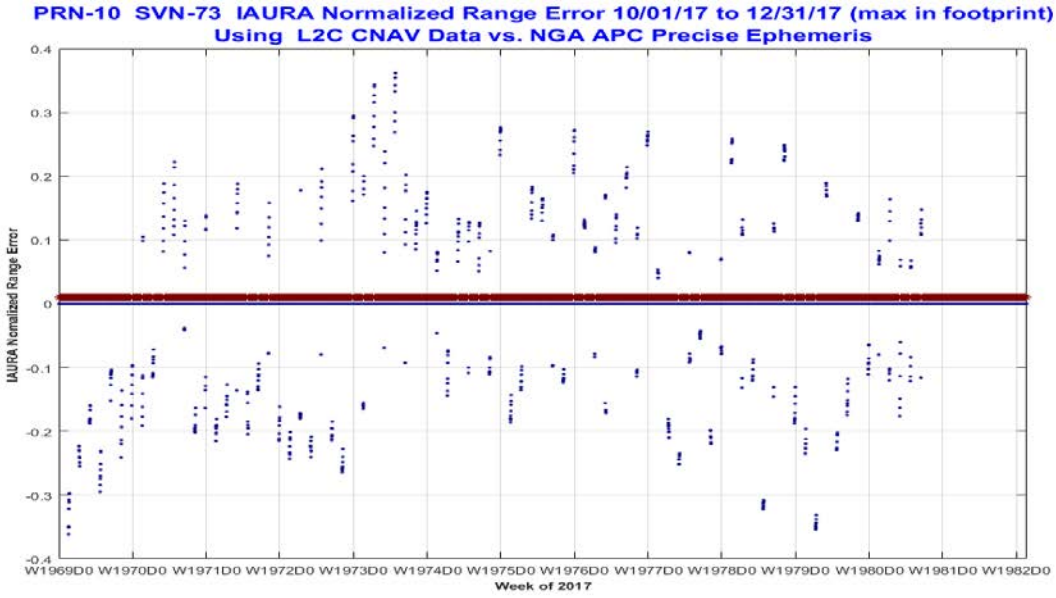


Figure 11-133 Timeline of URA Normalized Range Error PRN-11 (SVN-46) Using C/A Nav Data

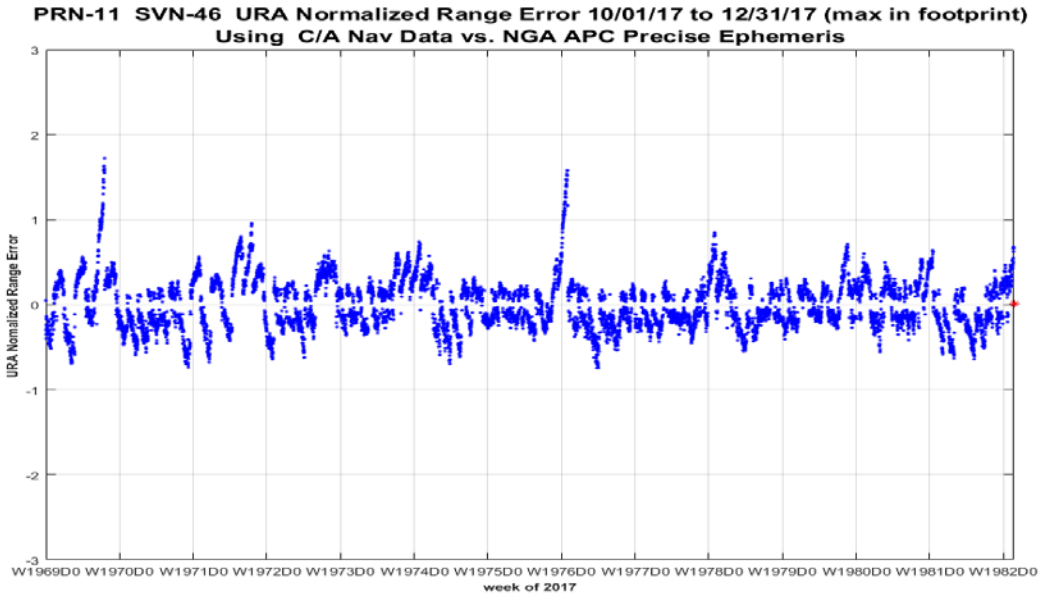


Figure 11-134 Timeline of URA Normalized Range Error PRN-12 (SVN-58) Using C/A Nav Data

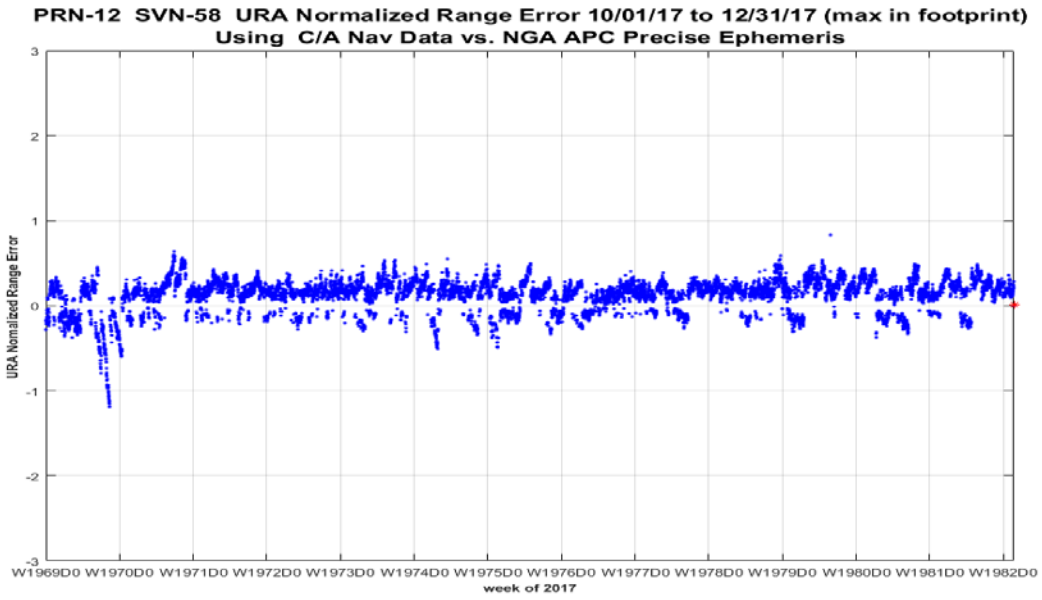


Figure 11-135 Timeline of IAURA Normalized Range Error PRN-12 (SVN-58) Using L2C CNAV Data

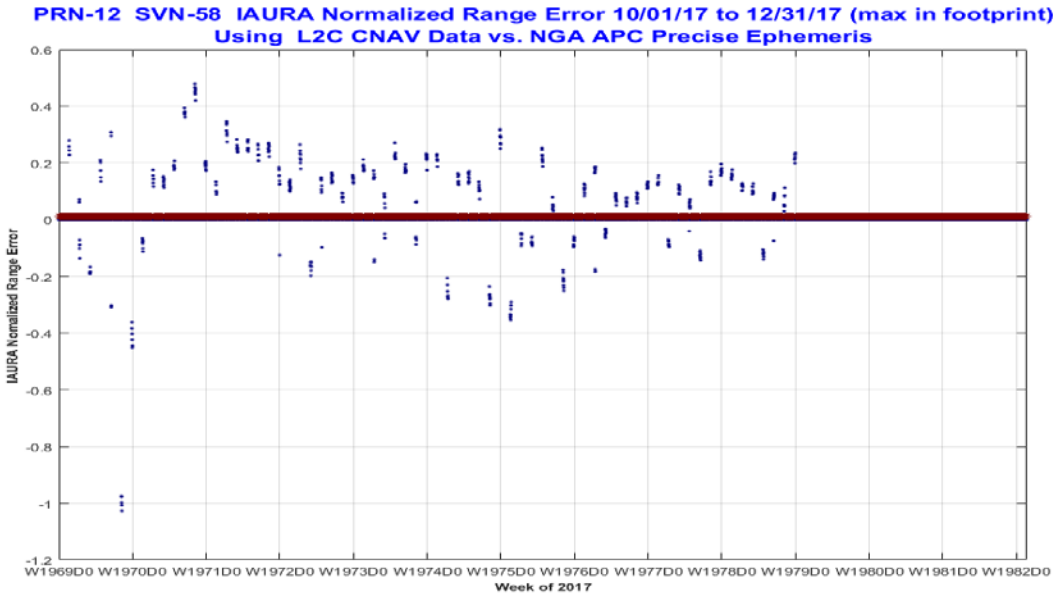


Figure 11-136 Timeline of URA Normalized Range Error PRN-13 (SVN-43) Using C/A Nav Data

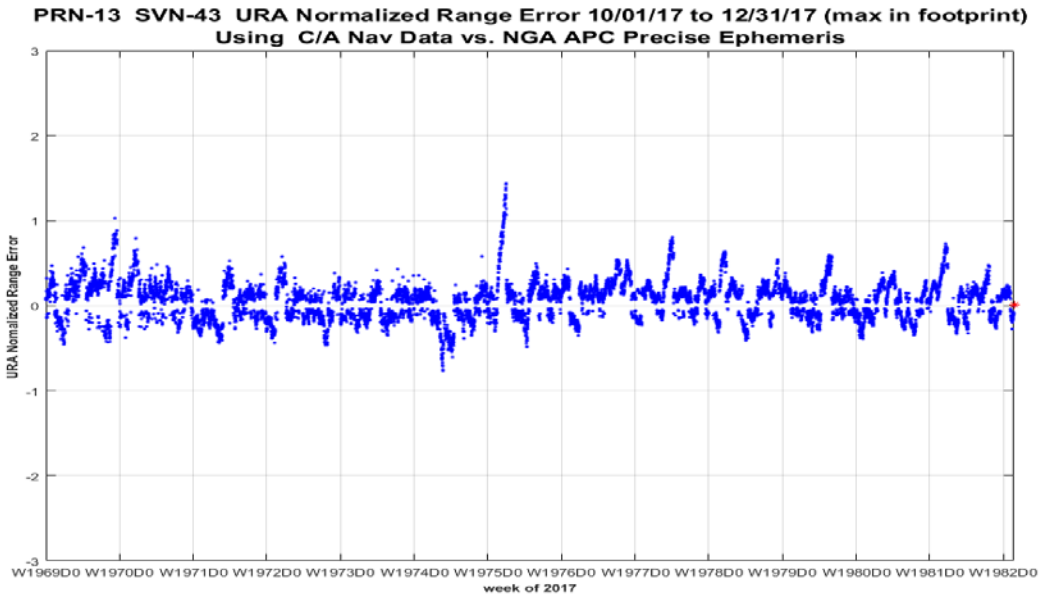


Figure 11-137 Timeline of URA Normalized Range Error PRN-14 (SVN-41) Using C/A Nav Data

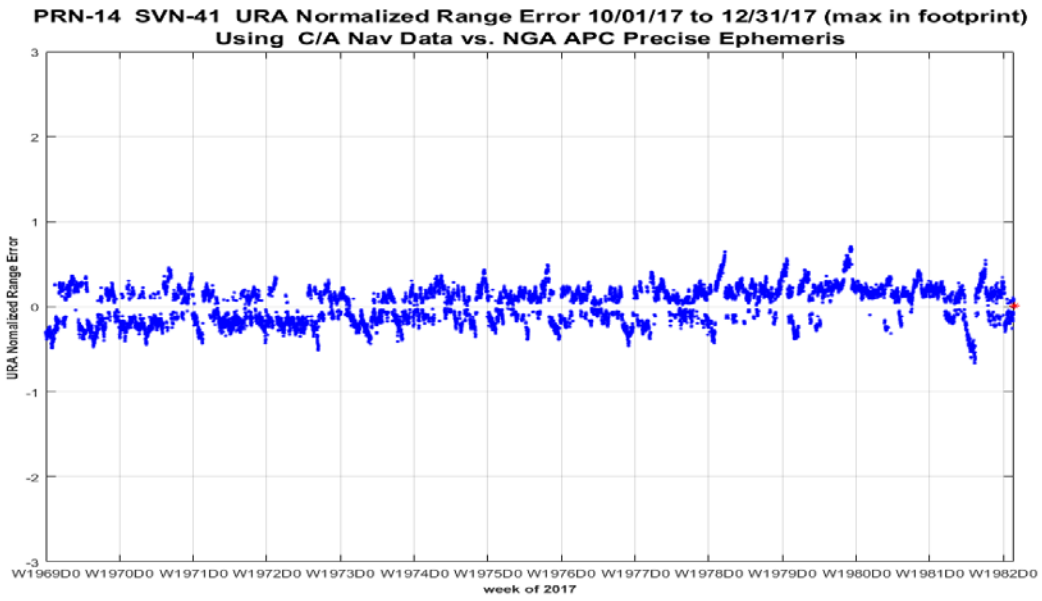


Figure 11-138 Timeline of URA Normalized Range Error PRN-15 (SVN-55) Using C/A Nav Data

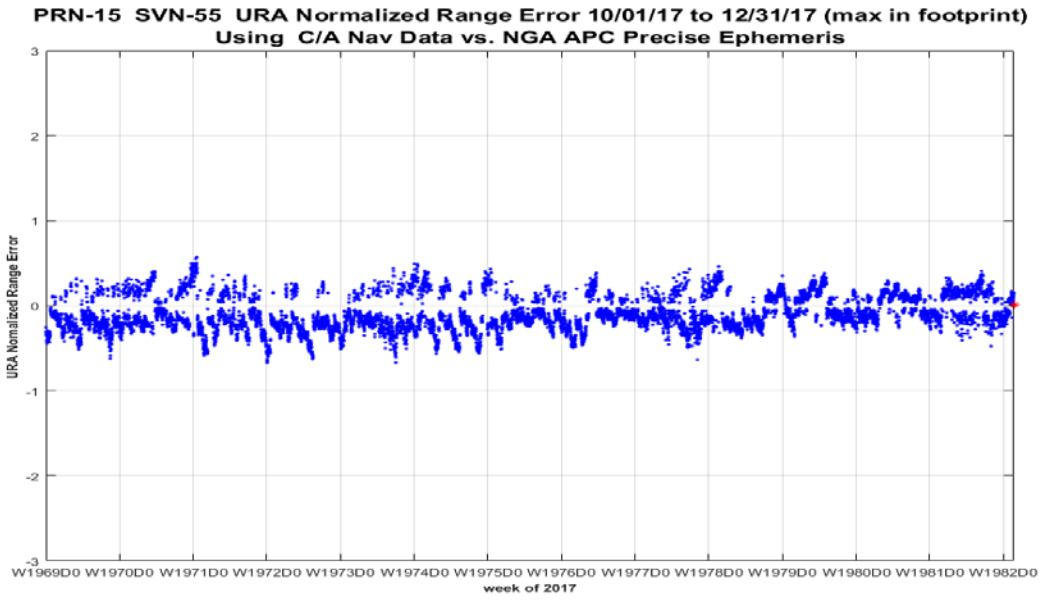


Figure 11-139 Timeline of IAURA Normalized Range Error PRN-15 (SVN-55) Using L2C CNAV Data

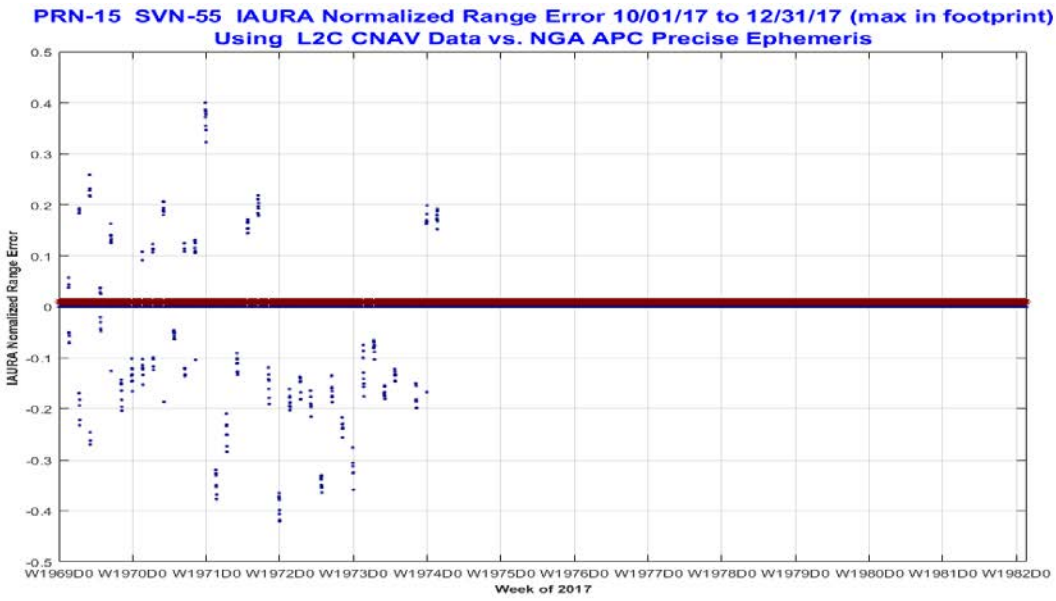


Figure 11-140 Timeline of URA Normalized Range Error PRN-16 (SVN-56) Using C/A Nav Data

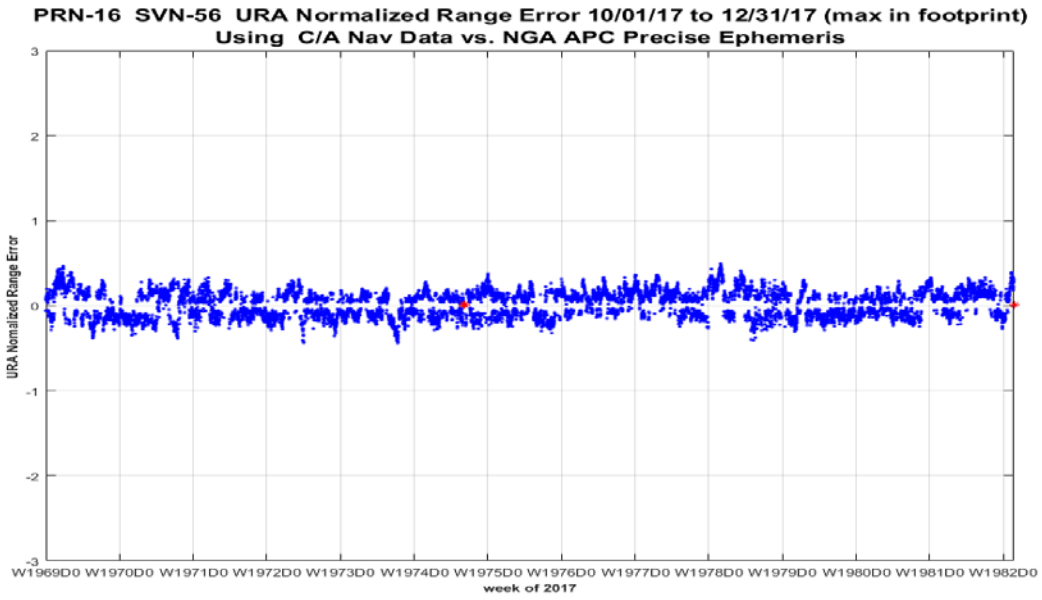


Figure 11-141 Timeline of URA Normalized Range Error PRN-17 (SVN-53) Using C/A Nav Data

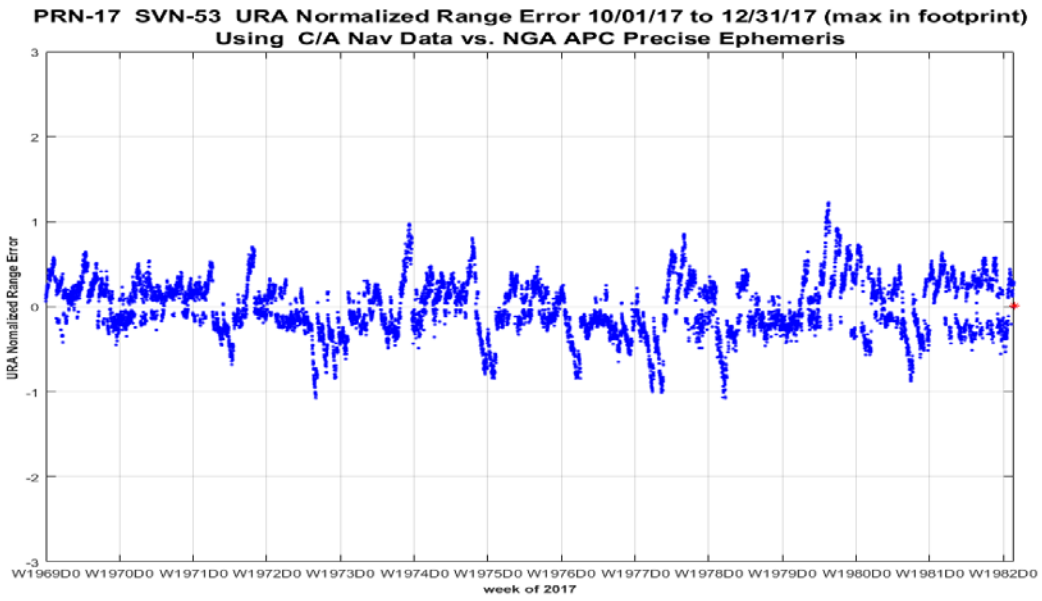


Figure 11-142 Timeline of URA Normalized Range Error PRN-18 (SVN-54) Using C/A Nav Data

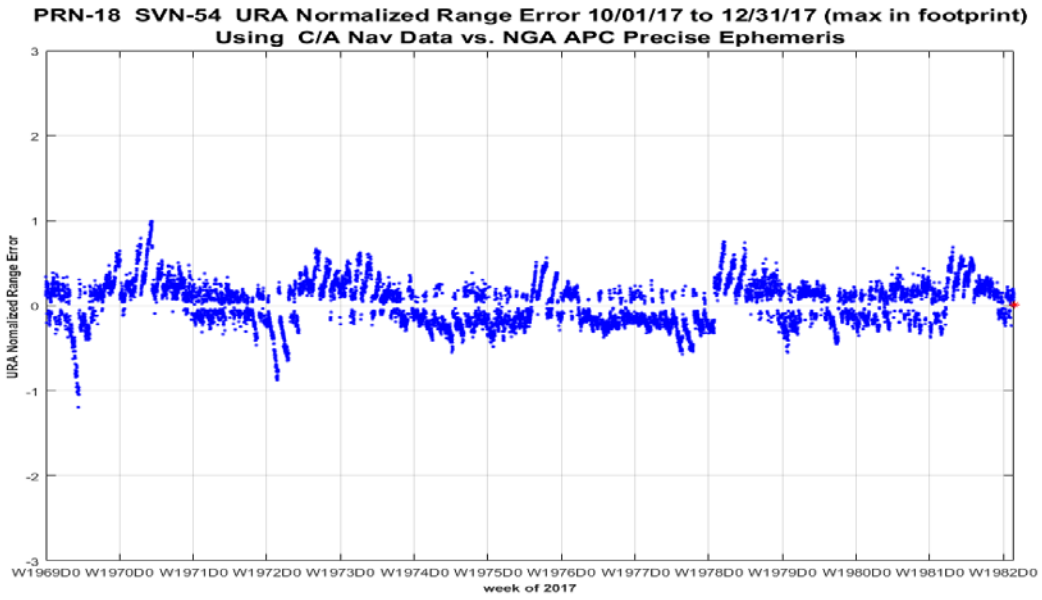


Figure 11-143 Timeline of URA Normalized Range Error PRN-19 (SVN-59) Using C/A Nav Data

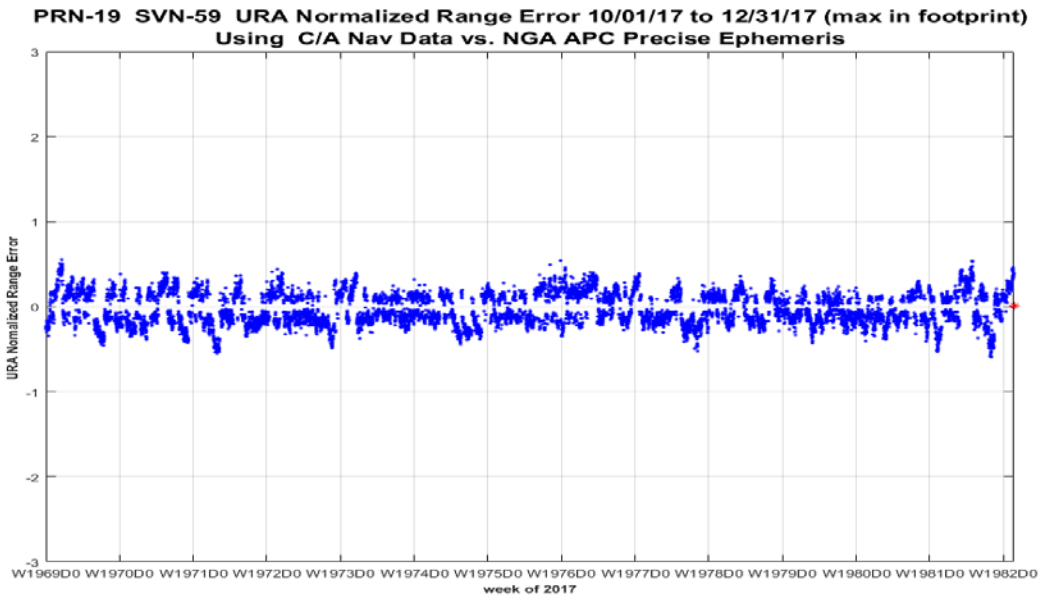


Figure 11-144 Timeline of URA Normalized Range Error PRN-20 (SVN-51) Using C/A Nav Data

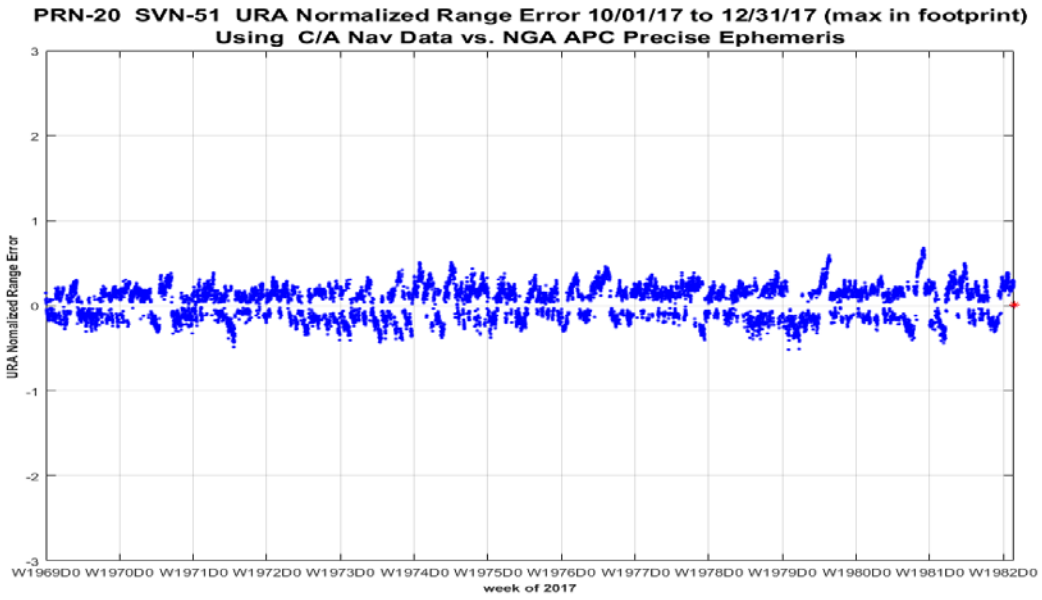


Figure 11-145 Timeline of URA Normalized Range Error PRN-21 (SVN-45) Using C/A Nav Data

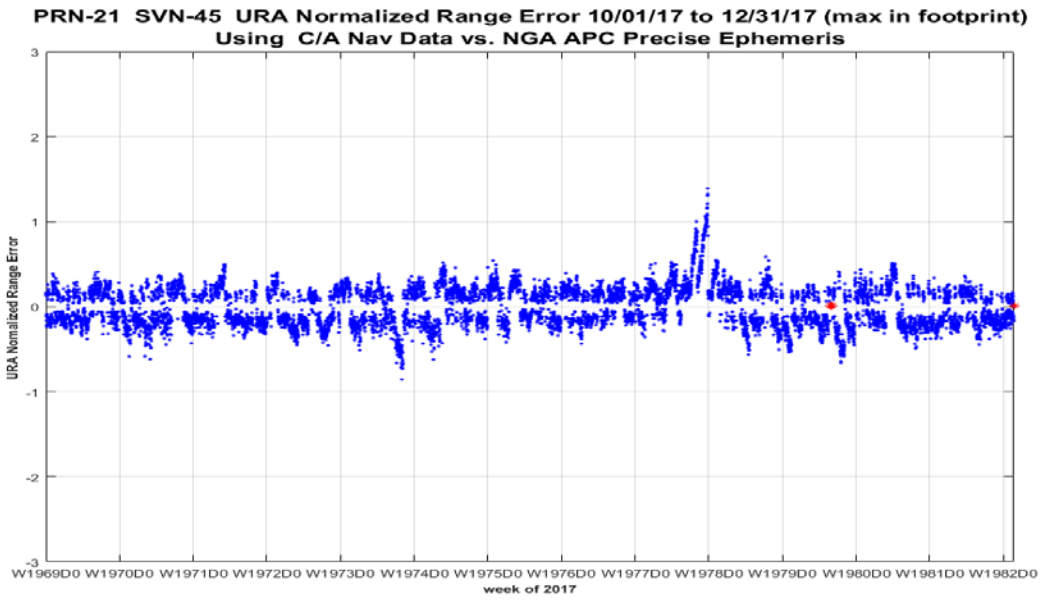


Figure 11-146 Timeline of URA Normalized Range Error PRN-22 (SVN-47) Using C/A Nav Data

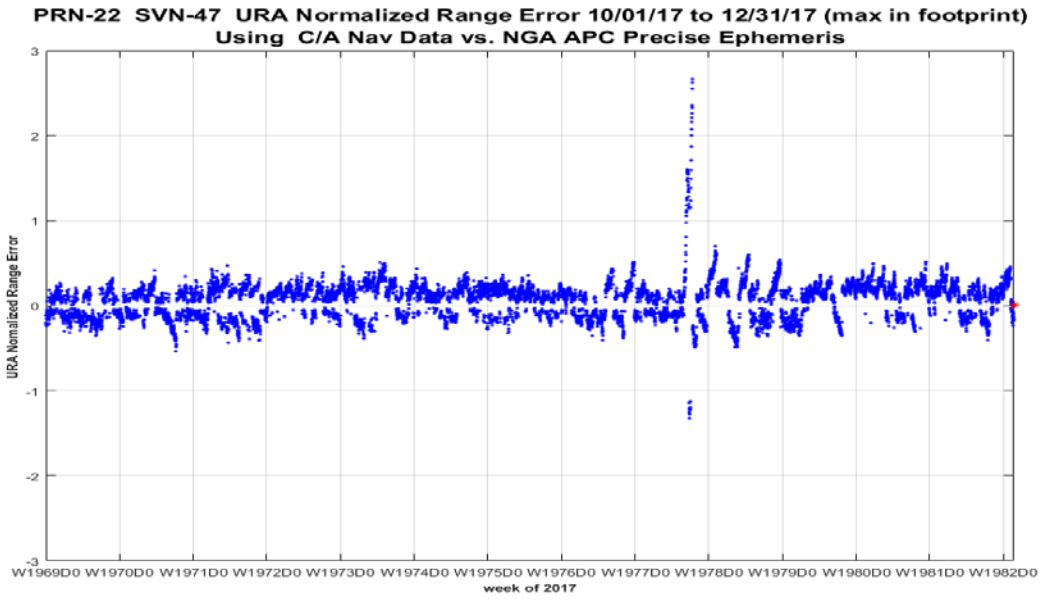


Figure 11-147 Timeline of URA Normalized Range Error PRN-23 (SVN-60) Using C/A Nav Data

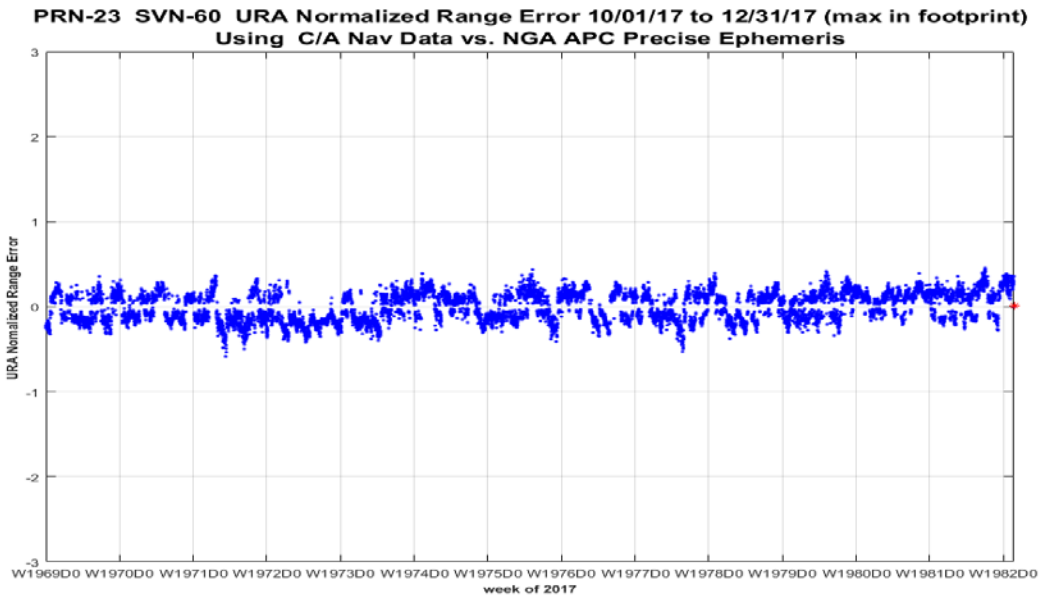


Figure 11-148 Timeline of URA Normalized Range Error PRN-24 (SVN-65) Using C/A Nav Data

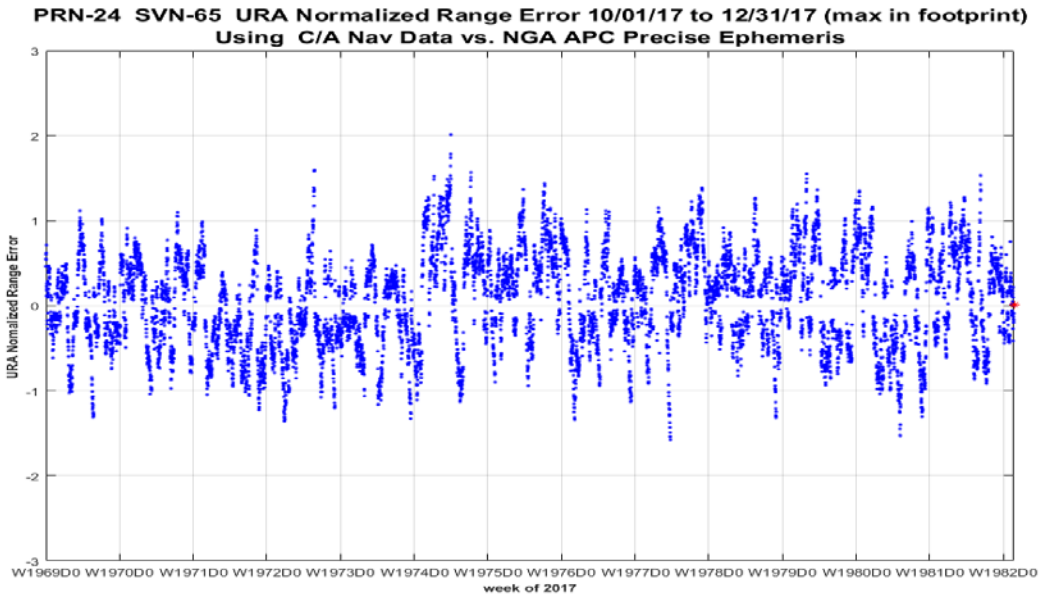


Figure 11-149 Timeline of IAURA Normalized Range Error PRN-24 (SVN-65) Using L2C CNAV Data

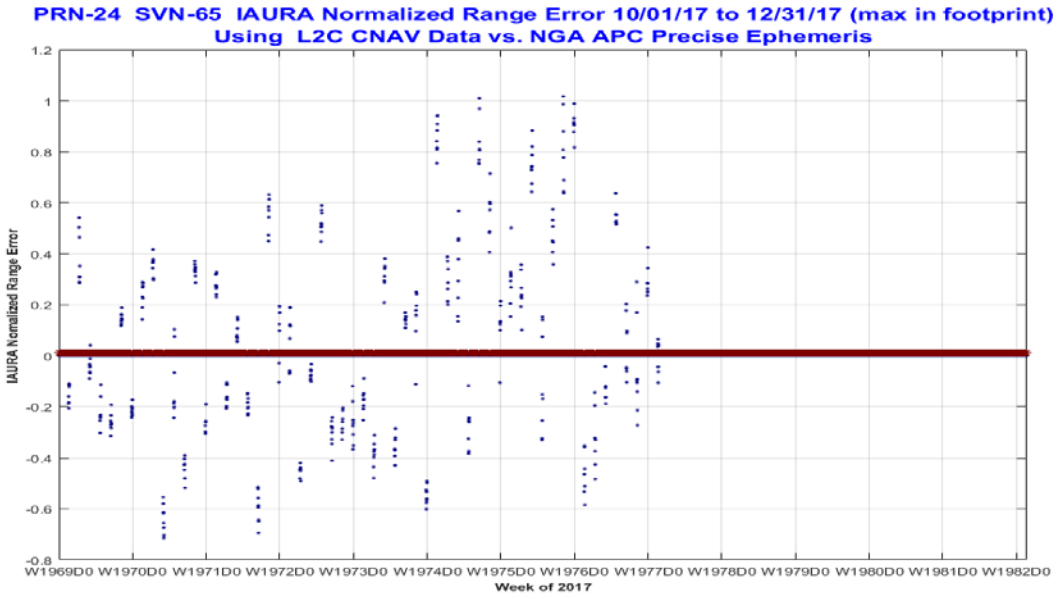


Figure 11-150 Timeline of URA Normalized Range Error PRN-25 (SVN-62) Using C/A Nav Data

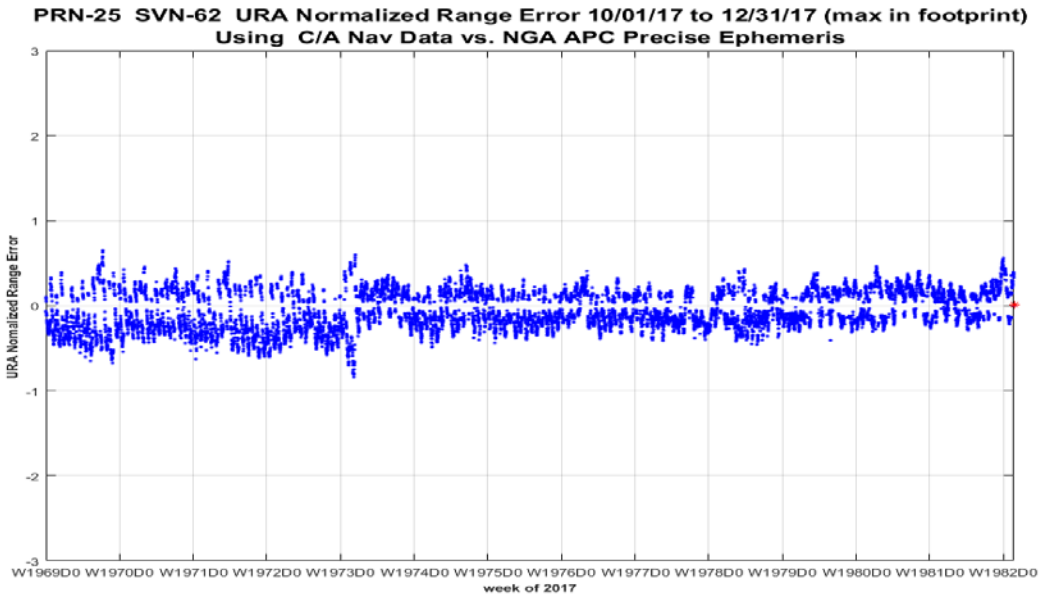


Figure 11-151 Timeline of IAURA Normalized Range Error PRN-25 (SVN-62) Using L2C CNAV Data

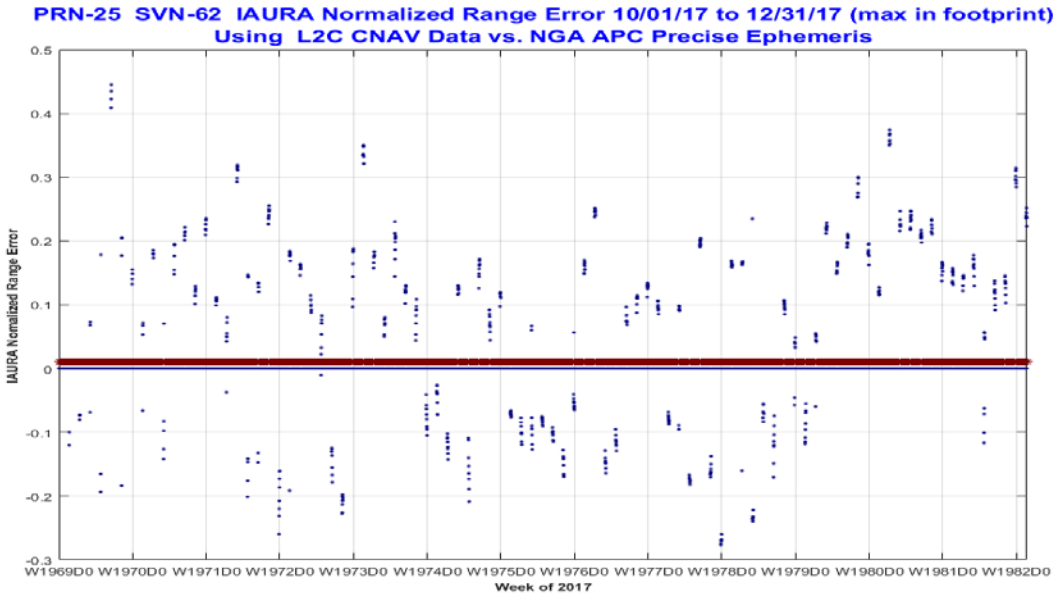


Figure 11-152 Timeline of URA Normalized Range Error PRN-26 (SVN-71) Using C/A Nav Data

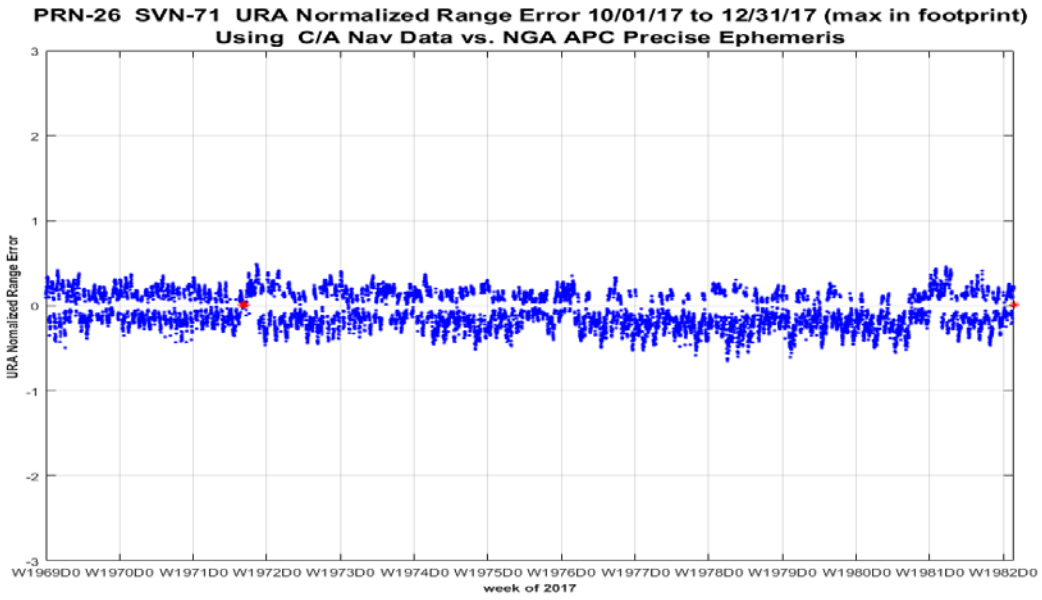


Figure 11-153 Timeline of IAURA Normalized Range Error PRN-26 (SVN-71) Using L2C CNAV Data

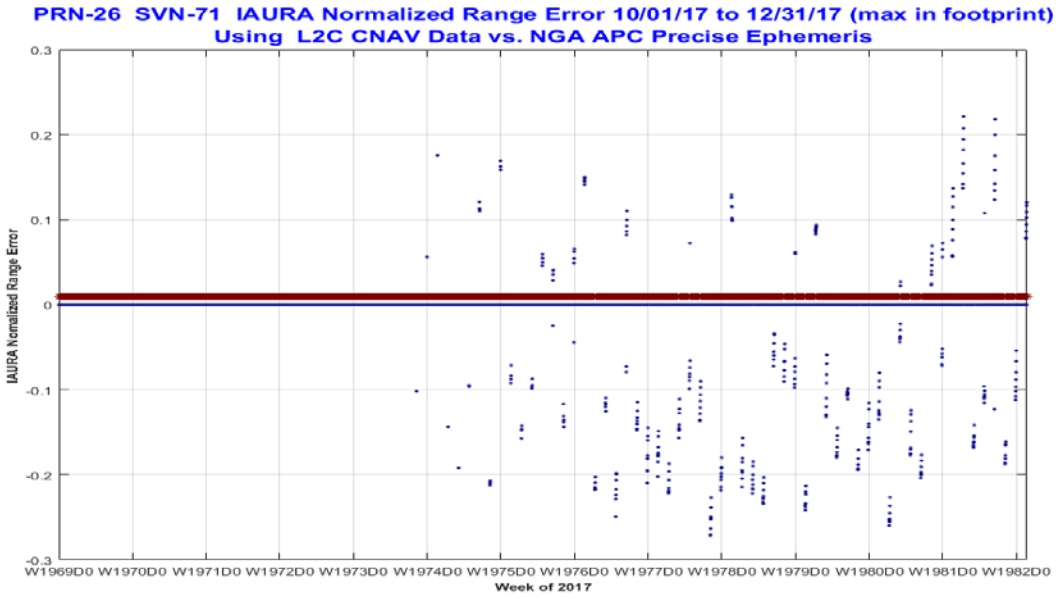


Figure 11-154 Timeline of URA Normalized Range Error PRN-27 (SVN-66) Using C/A Nav Data

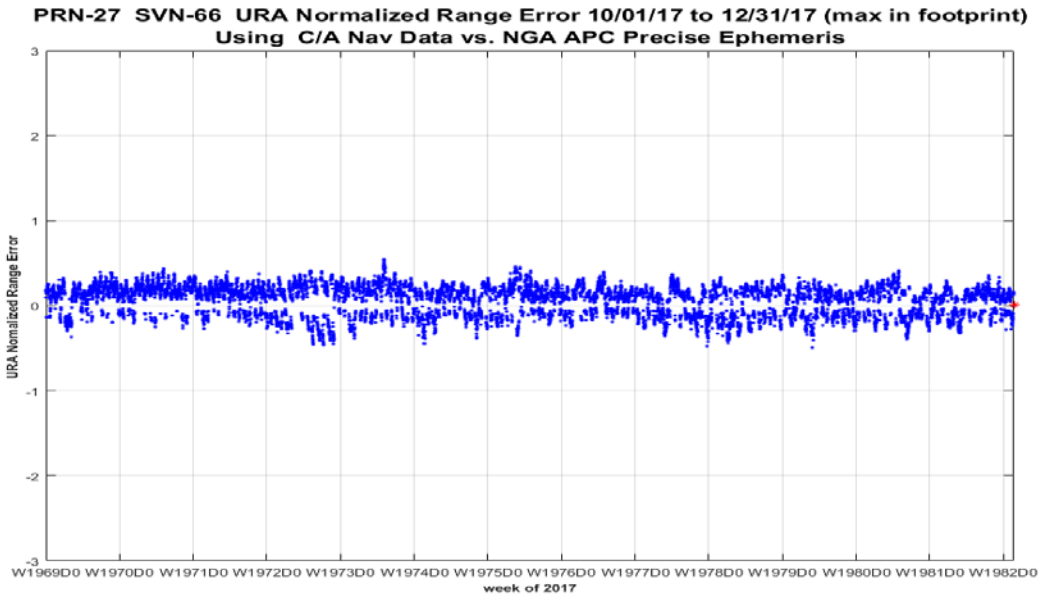


Figure 11-155 Timeline of IAURA Normalized Range Error PRN-27 (SVN-66) Using L2C CNAV Data

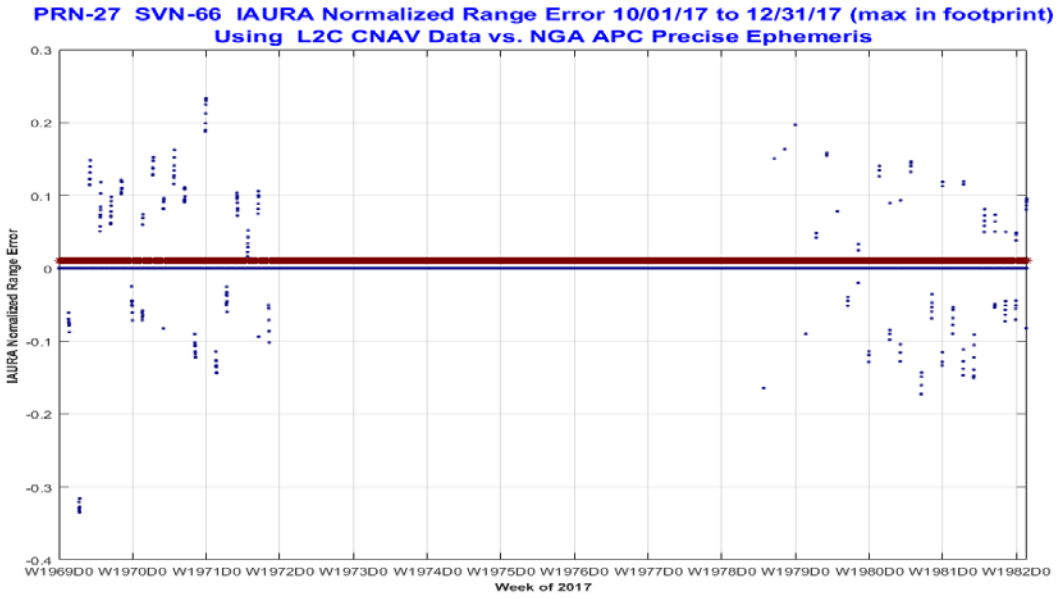


Figure 11-156 Timeline of URA Normalized Range Error PRN-28 (SVN-44) Using C/A Nav Data

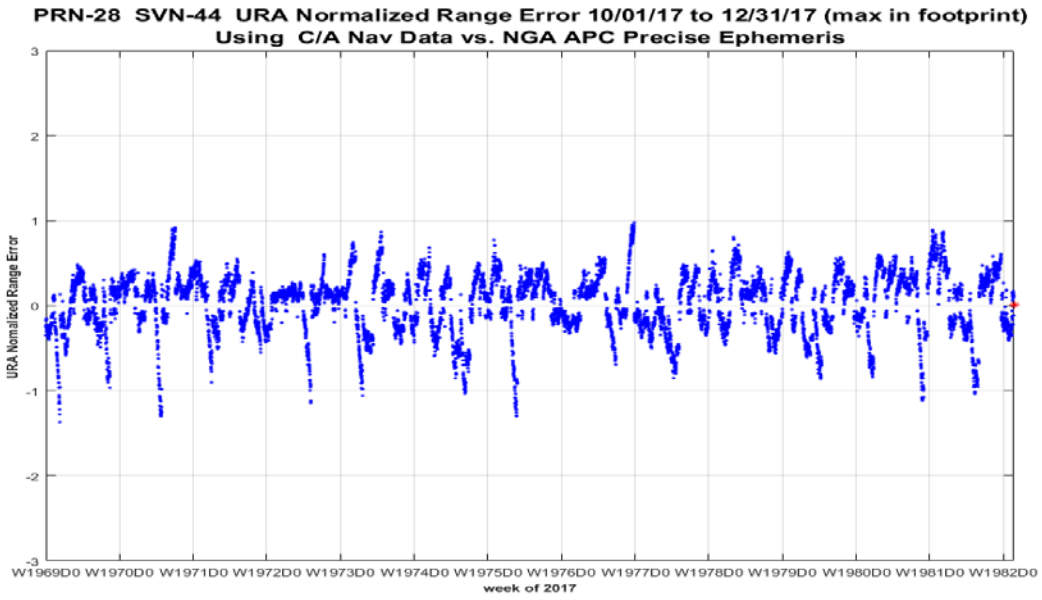


Figure 11-157 Timeline of URA Normalized Range Error PRN-29 (SVN-57) Using C/A Nav Data

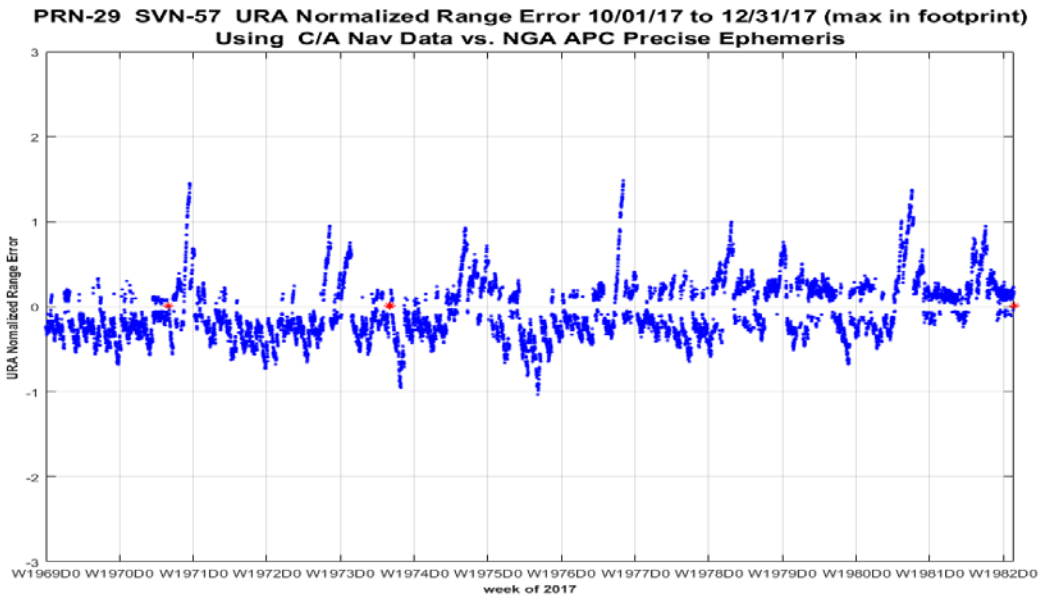


Figure 11-158 Timeline of IAURA Normalized Range Error PRN-29 (SVN-57) Using L2C CNAV Data

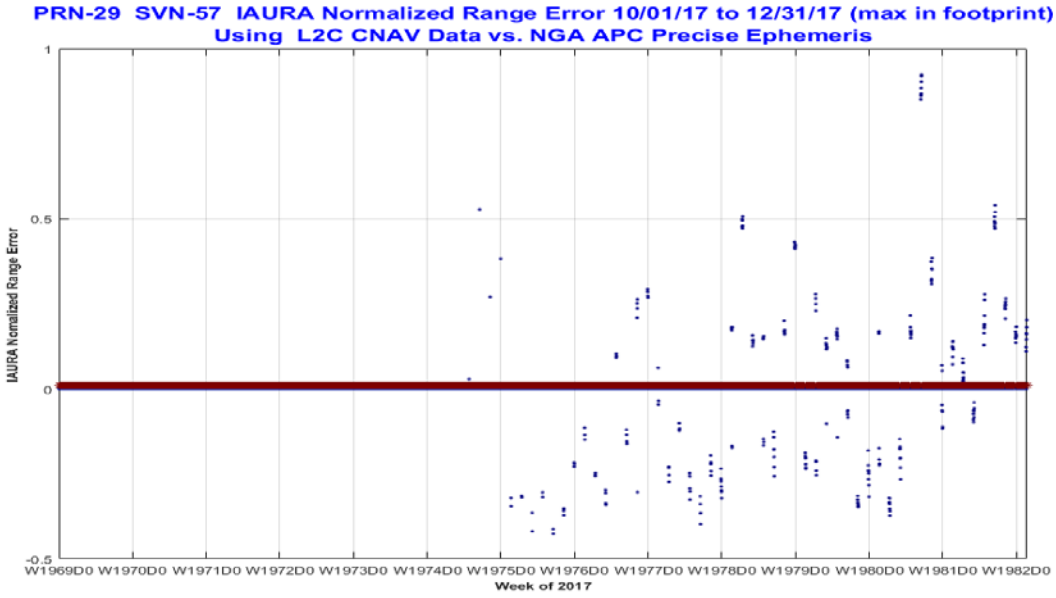


Figure 11-159 Timeline of URA Normalized Range Error PRN-30 (SVN-64) Using C/A Nav Data

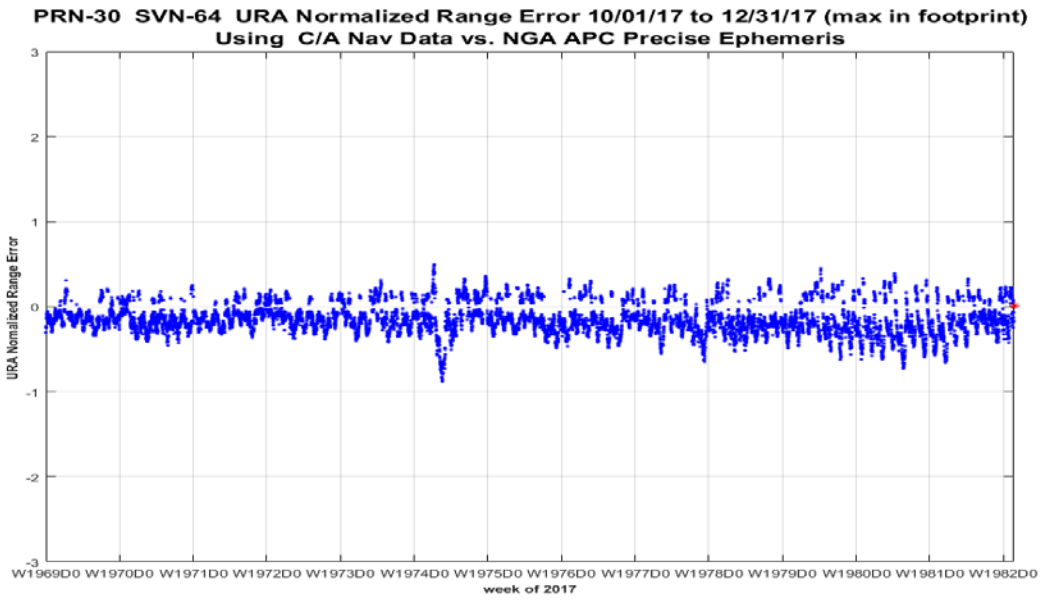


Figure 11-160 Timeline of URA Normalized Range Error PRN-31 (SVN-52) Using C/A Nav Data

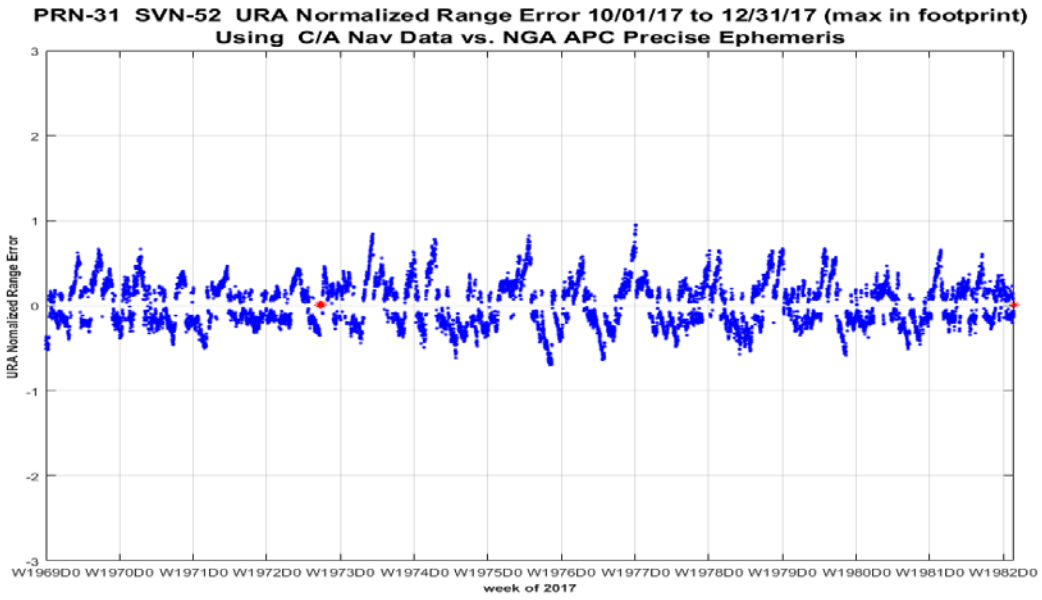


Figure 11-161 Timeline of IAURA Normalized Range Error PRN-31 (SVN-52) Using L2C CNAV Data

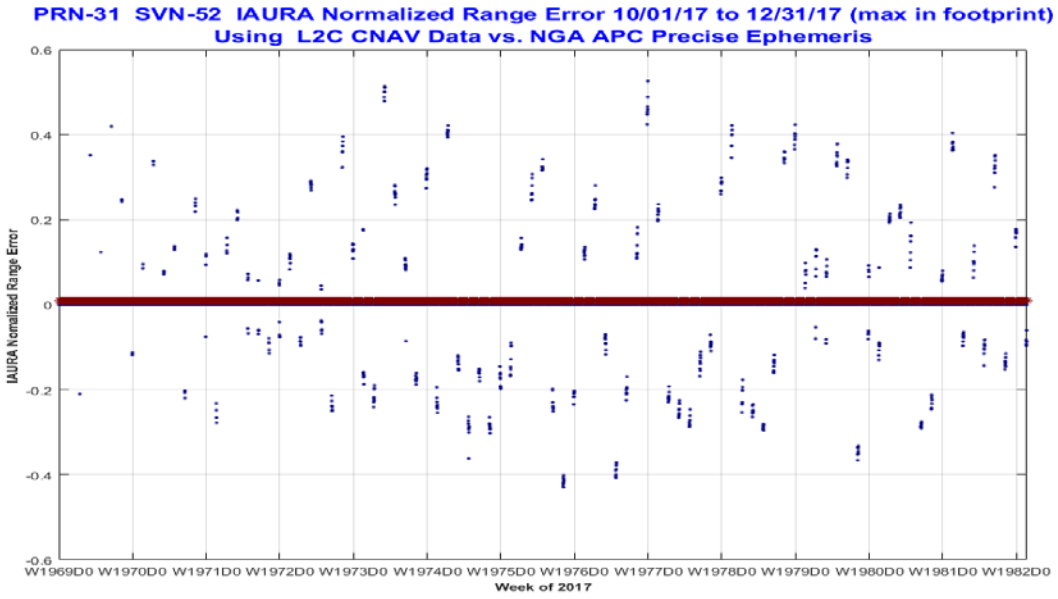


Figure 11-162 Timeline of URA Normalized Range Error PRN-32 (SVN-70) Using C/A Nav Data

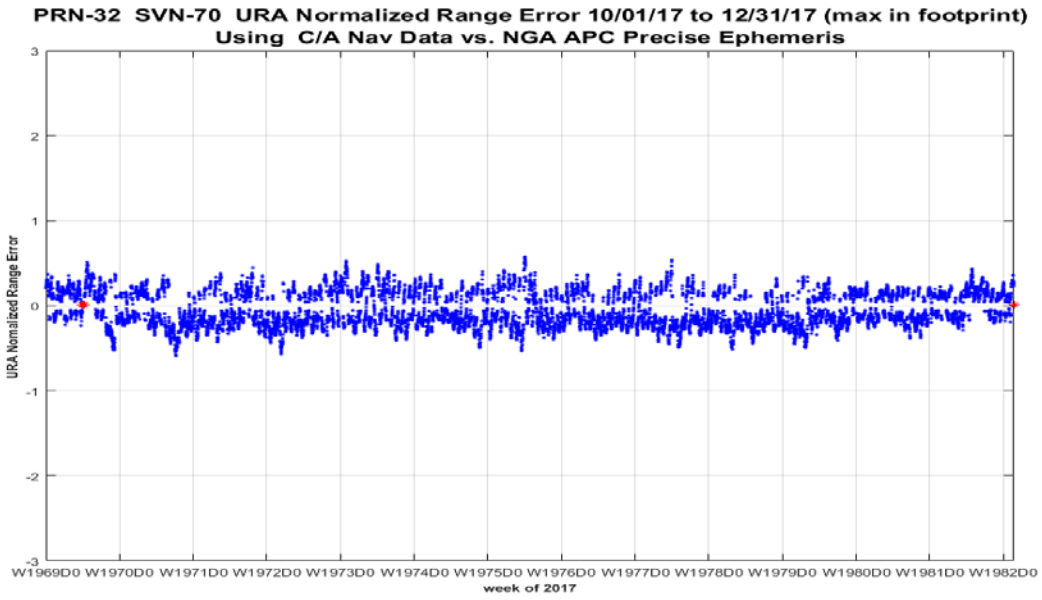
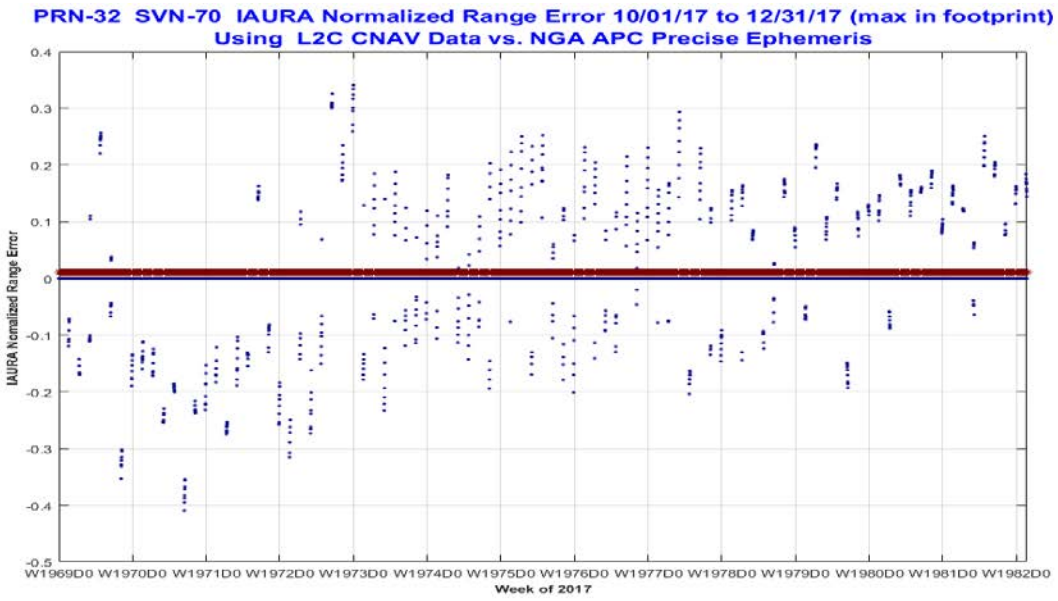



Figure 11-163 Timeline of IAURA Normalized Range Error PRN-32 (SVN-70) Using L2C CNAV Data