Wide Area Augmentation System Offline Monitoring Quarterly Report #3

1 July 2011 - 30 Sept 2011

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Executive summary

The Wide-Area Augmentation System (WAAS) Operations Team (AJW-192) was tasked with monitoring WAAS to ensure that the integrity requirements defined in Section 3.3 of Algorithm Contribution to Hazardous Misleading Information (HMI) (A014-011). This report contains data collected and analyzed between 4/1/11 and 6/30/11. Data is collected from the WAAS network and stored at the WAAS Support Facility (WSF) at the Mike Monroney Aeronautical Center (MMAC) in Oklahoma City, OK.

The primary evidence that WAAS meets the top level system integrity requirements relies on a mathematical proof supported by a comprehensive analysis of empirical data. The foundation of the proof is built upon a set of carefully constructed assertions. Some assertions require periodic monitoring to ensure that the physical environment has not changed or degraded in a manner that would invalidate the claim. Certain satellite failure modes which have a priori probabilities associated with them must be detected and corrected in a reasonable amount of time to limit the users exposure to the failure. The following assertions are monitored as called for in the Algorithm Contribution to HMI document:

1. Code-Carrier Coherence (CCC)
2. Code-Noise and Multipath (CNMP)
3. Signal Quality Monitoring (SQM)
4. Satellite Clock Runoff
5. Ionospheric Threats
6. Ephemeris Monitoring

Additional monitoring criteria have been added to the original list. These additional monitoring criteria include Wide-area Reference Station (WRS) antenna positions, L1L2 bias levels, missed WAAS user messages, monitor trips, CNMP resets, accuracy, Geosynchronous Earth Orbit (GEO) CCC, and Space Weather. This report will also include major anomalies that occurred during the time period covered in this report. The following table is a summary of the criteria that were monitored for this report.

Integrity monitoring	
CCC	No trips
CNMP	All data bounded
SQM	All metrics below threshold
Satellite clock run-off	No run-off events
Ionospheric threat model	10 days of interest – August 5 & 6, September 9, 10, 14, 17, & 26-29
Continuity monitoring	
Missed messages	CRW (PRN-135) - 81 CRE (PRN-138) - 21 AMR (PRN-133) - 74
External monitoring	
Antenna positioning	All sites within 10 centimeters
Anomaly Investigations	
2011-08-05 Iono Storm	Caused loss of WAAS coverage
2011-09-26 Iono Storm	Caused loss of WAAS coverage

Table 1: Monitor summary

Forward

The scope of this document is limited to analysis performed on data extracted from the WAAS system, or on data that would directly affect the WAAS system. Moreover, the target audience is the Federal Aviation Administration (FAA) WAAS management as well as the engineers that support the WAAS program. This includes (but is not necessarily limited to) federally employed personnel, contractors, sub-contractors, and other FAA WAAS Integrity Performance Panel (WIPP) support.

The data and information contained in this document is not for general use, as it may contain unexplained anomalies and/or data which may lead to unsupported conclusions. Any dissemination of this data should be coordinated with the appropriate management.

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Chapter 1

Introduction

1.1 The definition of offline monitoring

The goal of Offline Monitoring (OLM) is to track the performance of WAAS, establish baseline performance and characterize anomalous behavior to determine if further investigation is necessary.

1.2 Elements of system monitoring

Monitoring addressed in this document can be categorized into five types, namely Integrity, Availability, Continuity, Accuracy and External Monitoring. Each category represents a class of performance that the system exhibits. The intent of this document is to provide a summary of results for several checks of each of the above types in conjunction with condensed plots that show at a glance quarterly performance. Each monitoring subsection contains a brief description of the relevant figures and tables along with a pointer to a section in Appendix A which contains more detailed (and more numerous) figures and tables.

1.2.1 Integrity

Integrity monitoring is viewed by many to be the most important type since as a breach of this class of performance represents a potentially hazardous situation. Loss of Integrity happens when an error in a users position exceeds the protection limits that he computes. There are monitors in WAAS which internally ensure that these error bounds represent an over-bound of the generated errors. Each monitor has a slightly different method for ensuring integrity, and the individual monitor integrity methodology is described in their respective monitor subsections.

1.2.2 Availability

Availability Monitoring is straightforward, evaluates the coverage of WAAS over the time period in question. There are specifics to be defined for this type, namely the Alarm Limits (Vertical and Horizontal) as well as the coverage contour.

1.2.3 Continuity

Continuity monitoring refers to events which can cause a loss of availability but not a breach of integrity. Typically, this assessment looks at monitor trips, setting satellites unusable or any issue which would cause a loss of service.

1.2.4 Accuracy

Accuracy Monitoring refers to the ability of the WAAS corrections to provide an accurate estimate the users position.

1.2.5 External monitoring

External monitoring entails events external to the WAAS, including broadcast ephemerides, plate-tectonic movement (antenna positions), space weather, etc., that can result in anomalous WAAS performance.

Chapter 2

Integrity monitoring

2.1 Code-noise and multipath

No failures were found when monitoring the HMI assertion (Appendix A.2) for the third quarter of 2011. There were no failure for the sigma overbound or any of the aggregate or sliced distribution plots.

For Figures 2.1, 2.2, and 2.3, CNMP passes if the tails (red and blue lines) do not dip below zero on the vertical axis. If a dip below zero occurs inside of plus or minus 0.25 that event is not considered a failure. For Figure 2.4, if the values go above the marked threshold of 1, that event is a failure. No CNMP failures occurred during the third quarter of 2011.

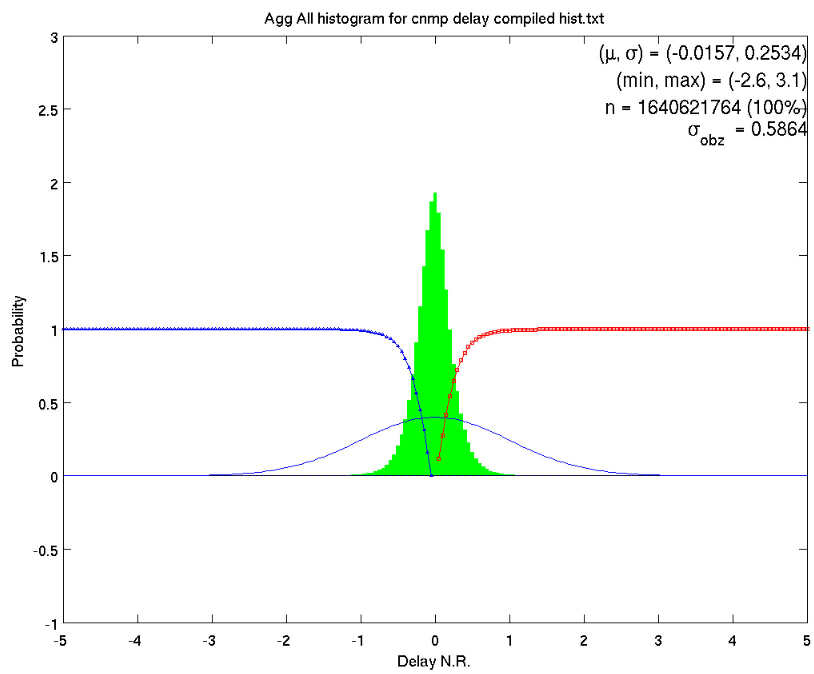


Figure 2.1: Aggregate CNMP Delay

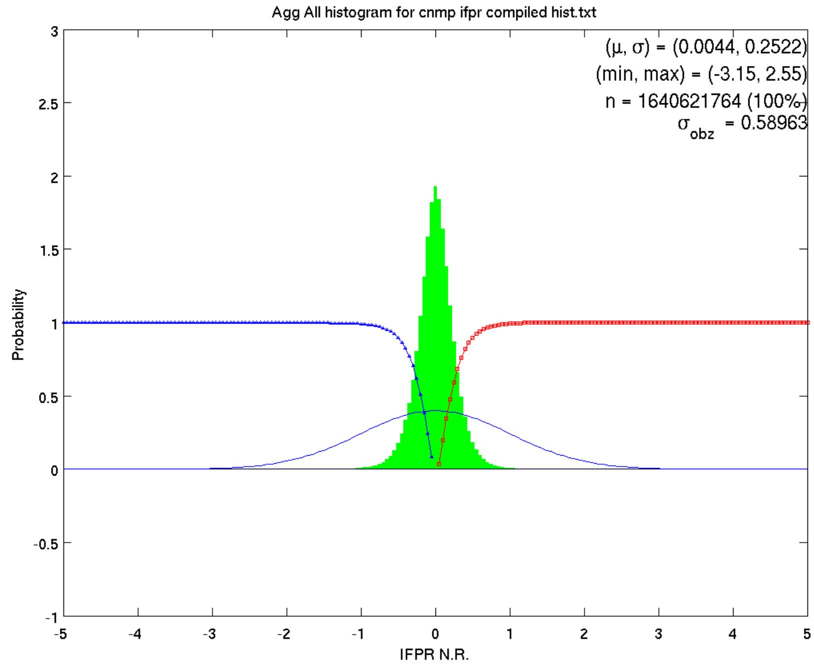


Figure 2.2: Aggregate CNMP IFPR

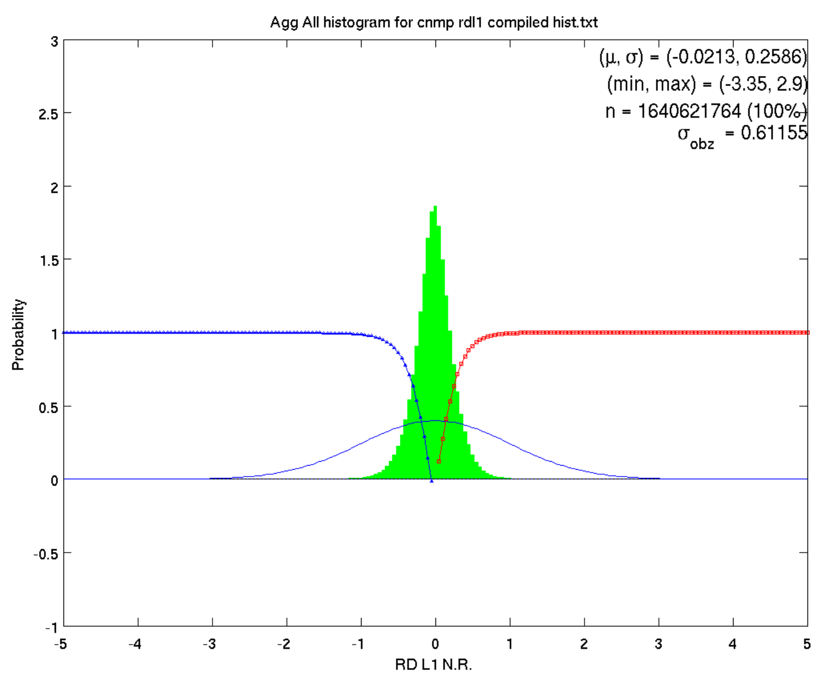


Figure 2.3: Aggregate CNMP RDL1

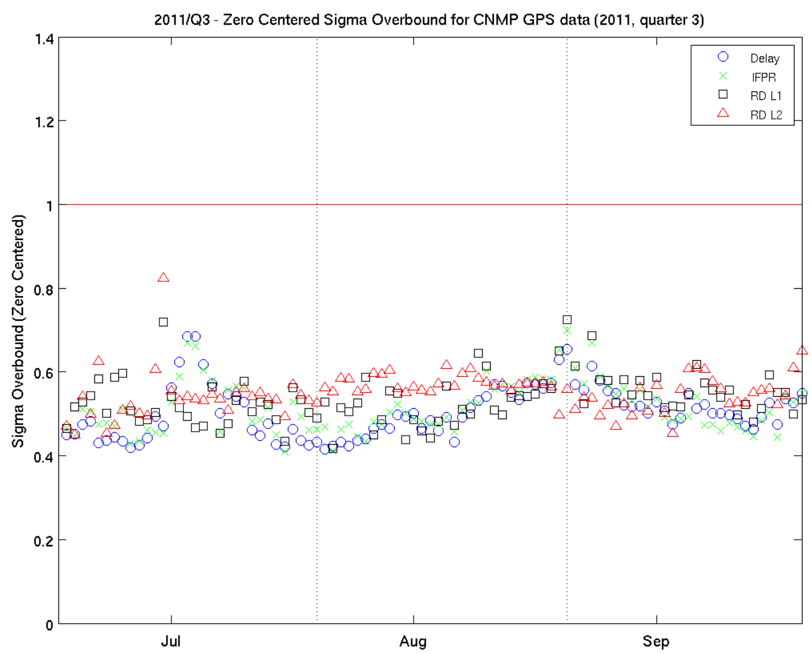


Figure 2.4: Daily GPS CNMP Aggregate zero-centered sigma overbound values

2.2 Code-carrier-coherence

2.2.1 GEO CCC integrity

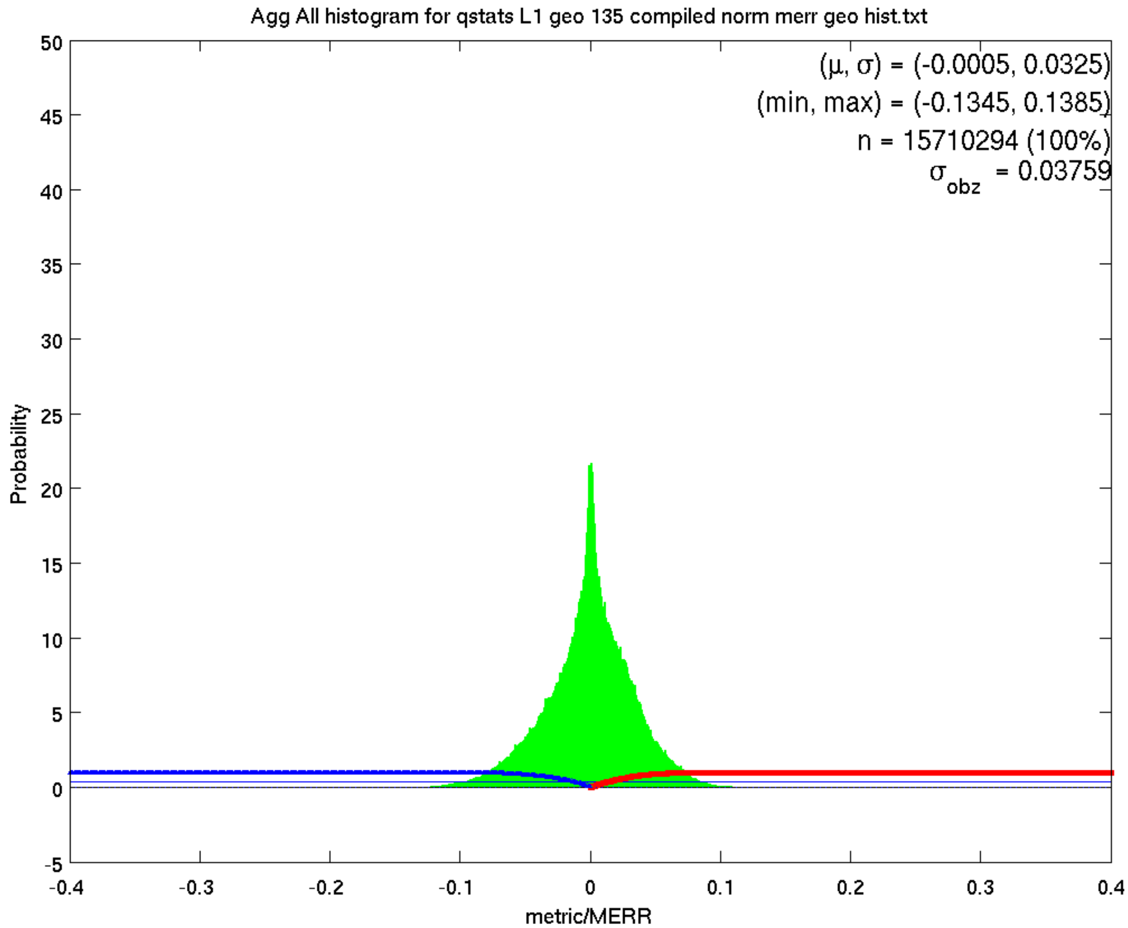


Figure 2.5: Pooled histrogram of CCC GEO metric/MERR

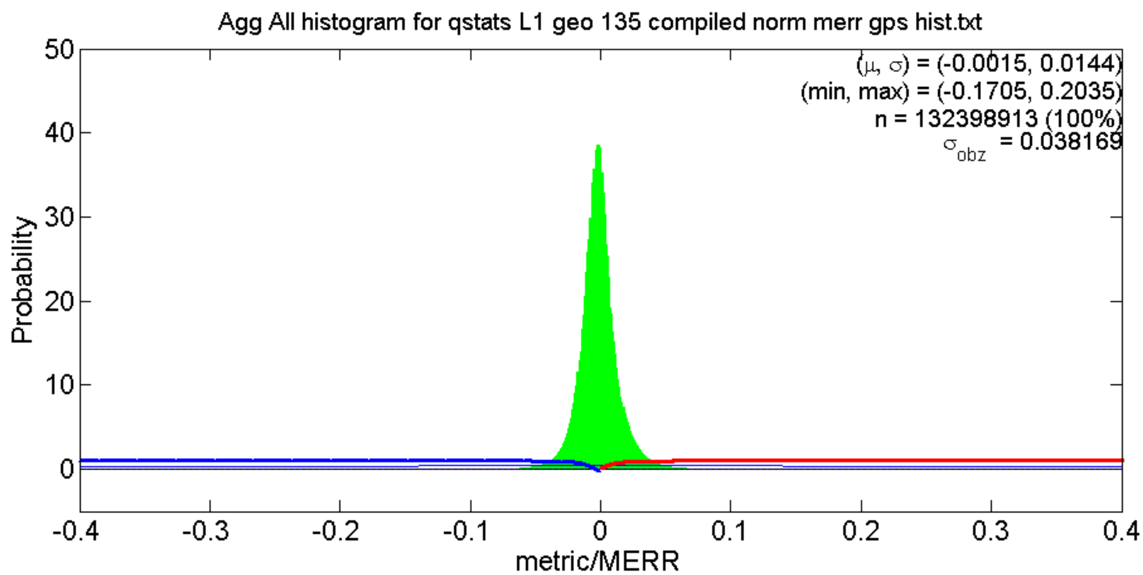


Figure 2.6: Pooled histrogram of CCC GPS metric/MERR

2.3 Signal Quality Monitoring

All four metrics for GEO and GPS satellites below threshold for the quarter.

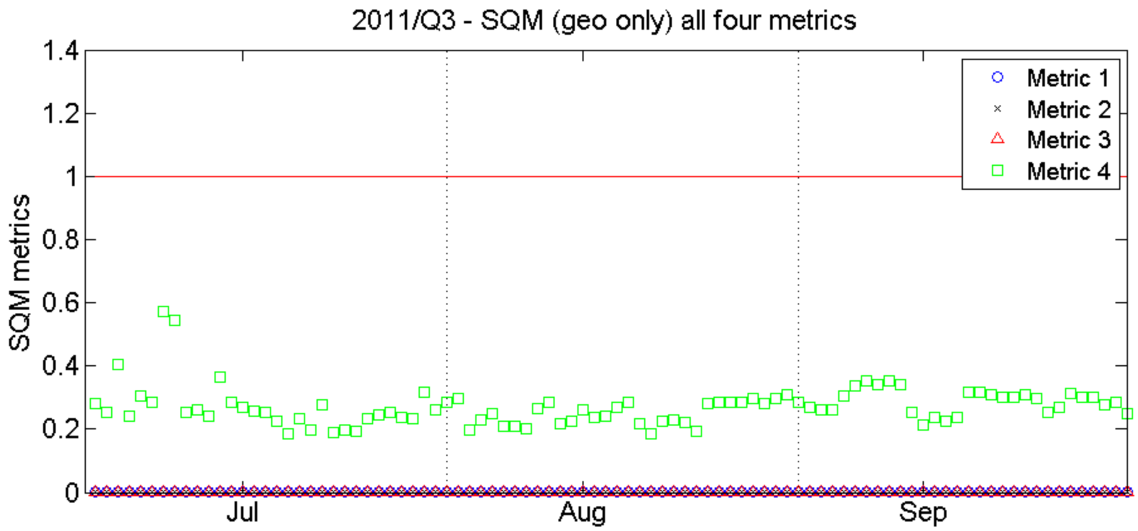


Figure 2.7: Time-series graph of GEO SQM max metrics 1-4

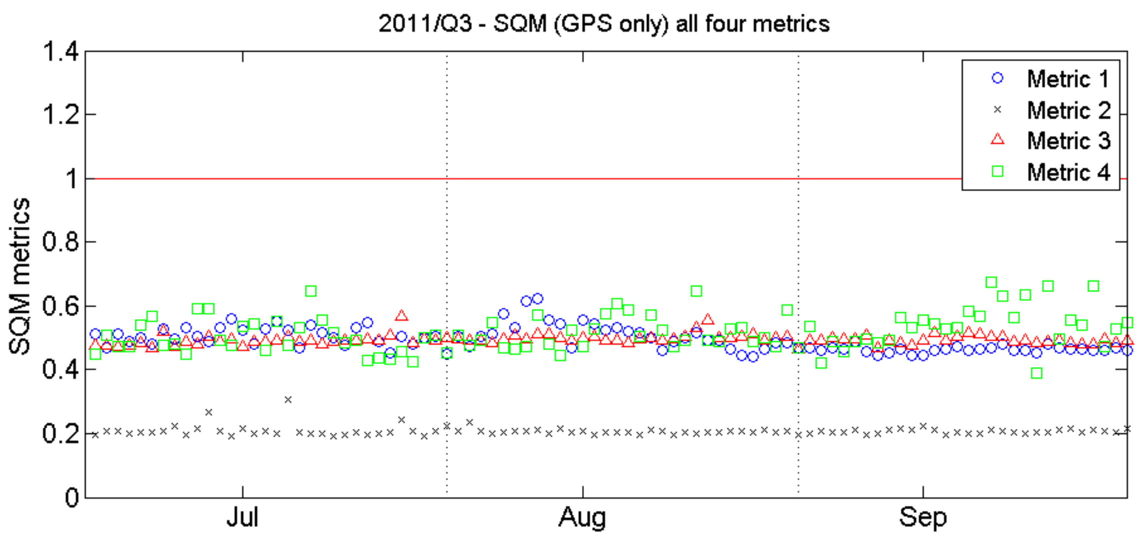


Figure 2.8: Time-series graph of GPS SQM max metrics 1-4

2.4 Ionospheric threat model

2.4.1 Daily percentage of Chi^2 values > 1

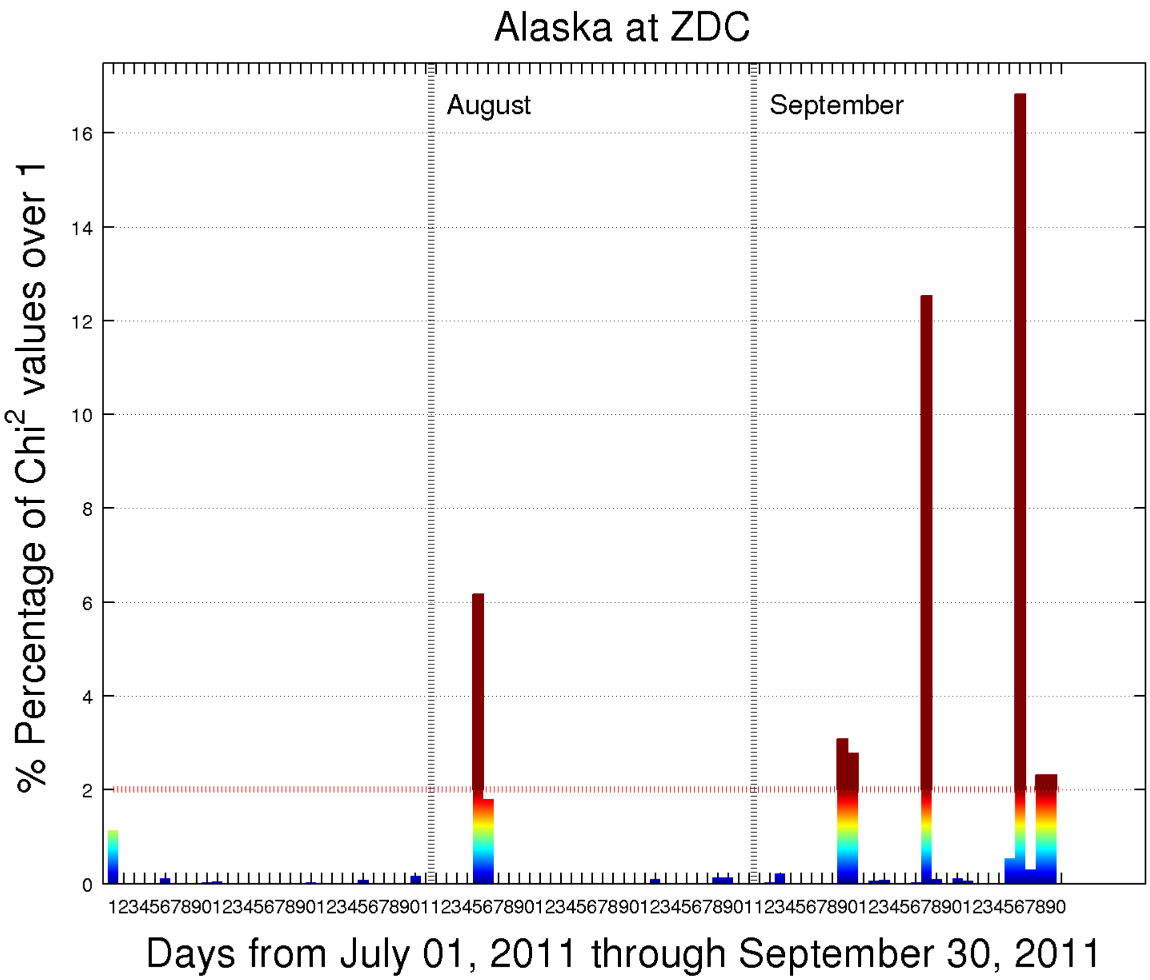


Figure 2.9: Alaska region daily % Chi^2 values >1 taken from ZDC

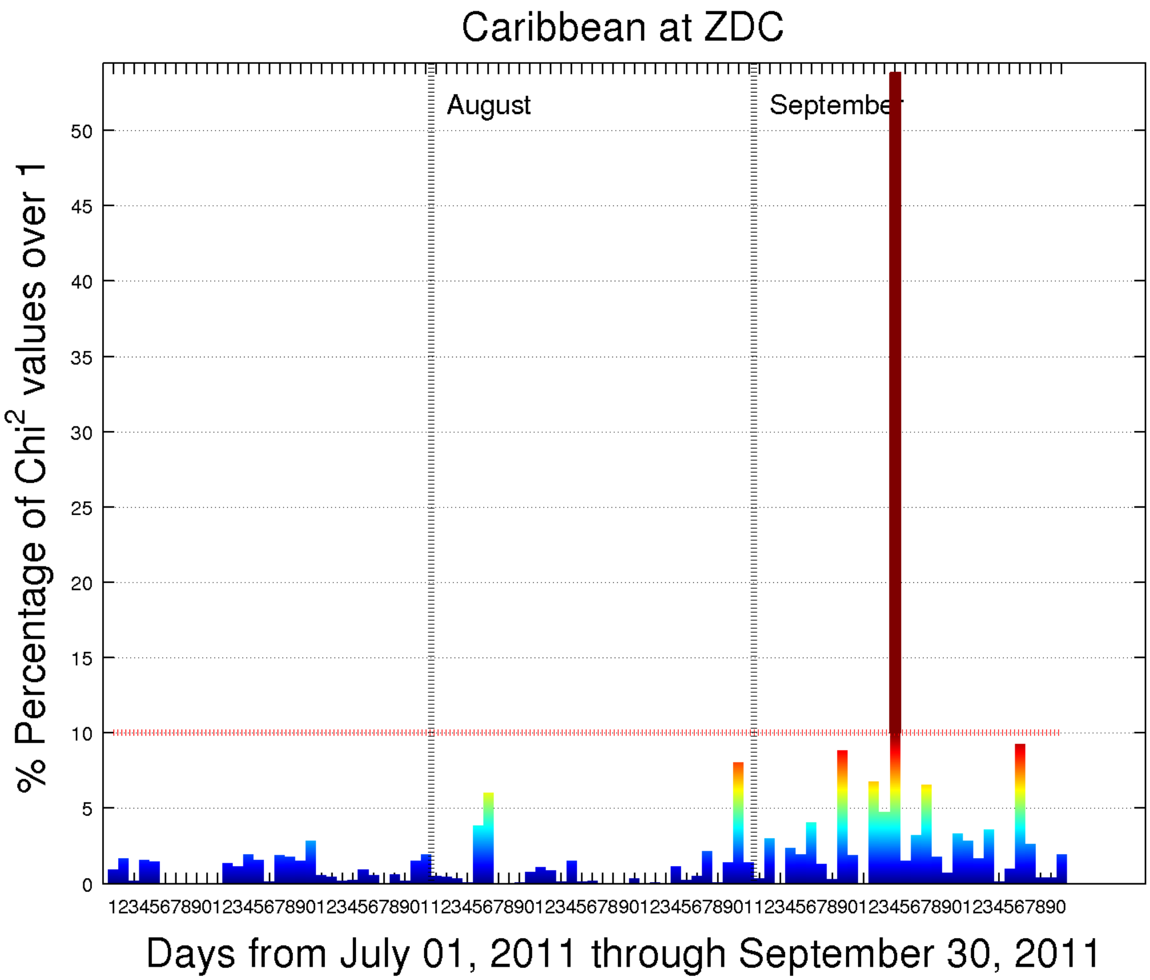


Figure 2.10: Caribbean region daily % Chi^2 values > 1 taken from ZDC

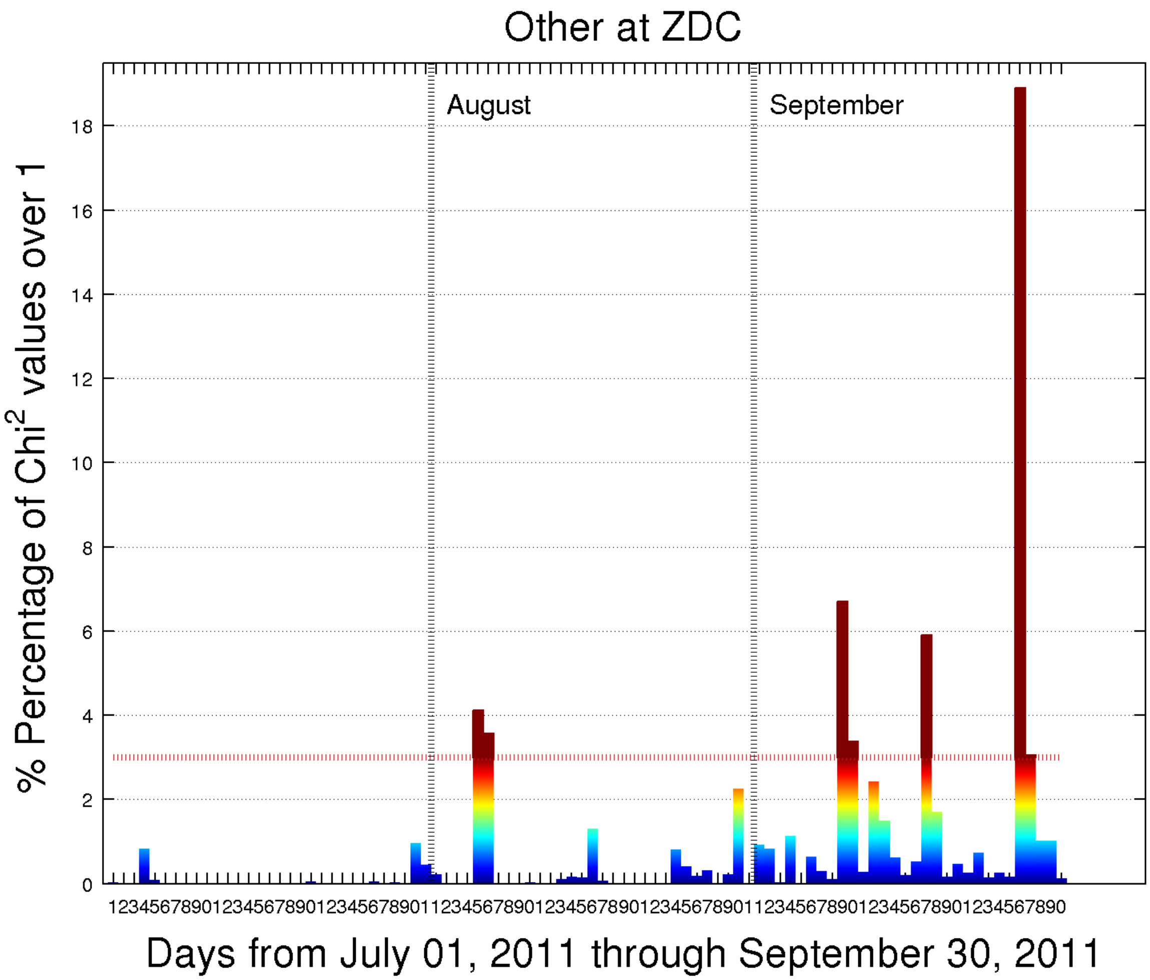


Figure 2.11: Other region daily % Chi^2 values > 1 taken from ZDC

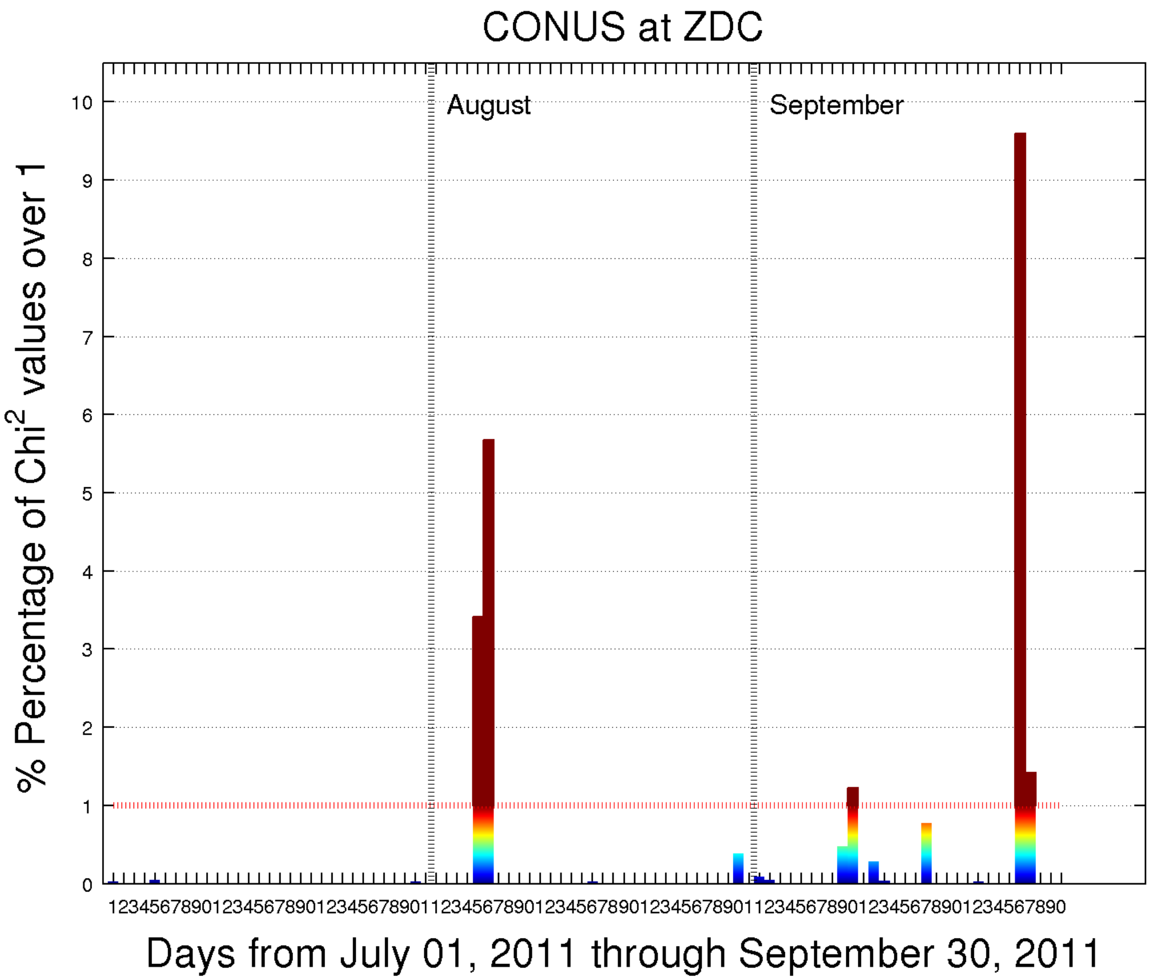


Figure 2.12: CONUS region daily % Chi^2 values > 1 taken from ZDC

2.4.2 Days of interest

These days require further analysis to determine if there are impacts to the ionospheric threat model.

Date of trip	Alaska (2%)	Caribbean (10%)	Other (3%)	CONUS (1%)
2011-08-05	6.2	0	4.1	3.4
2011-08-06	6.2	0	3.6	5.7
2011-09-09	3.1	0	6.7	0
2011-09-10	2.8	0	3.4	1.2
2011-09-14	6.2	53.8	0	0
2011-09-17	12.5	0	5.9	0
2011-09-26	16.8	0	18.9	9.6
2011-09-27	6.2	0	3.0	1.4
2011-09-28	2.3	0	0	0
2011-09-29	2.3	0	0	0

Table 2.1: Days when the % of $\text{Chi}^2 > 1$ exceed the threshold value

Chapter 3

Availability monitoring

3.1 Service volume model

This analysis is under development.

3.2 System monitoring trips

Component	**ZDC**	**ZLA**	**ZTL**
BMV	0	0	0
CCC	0	0	0
L1L2	12	12	12
$RDM_{threshold}$	0	0	0
SQM	0	0	0
UPM	0	0	0
WNT	0	0	0
WRE_{bias}	0	0	0

Table 3.1: System monitoring trips

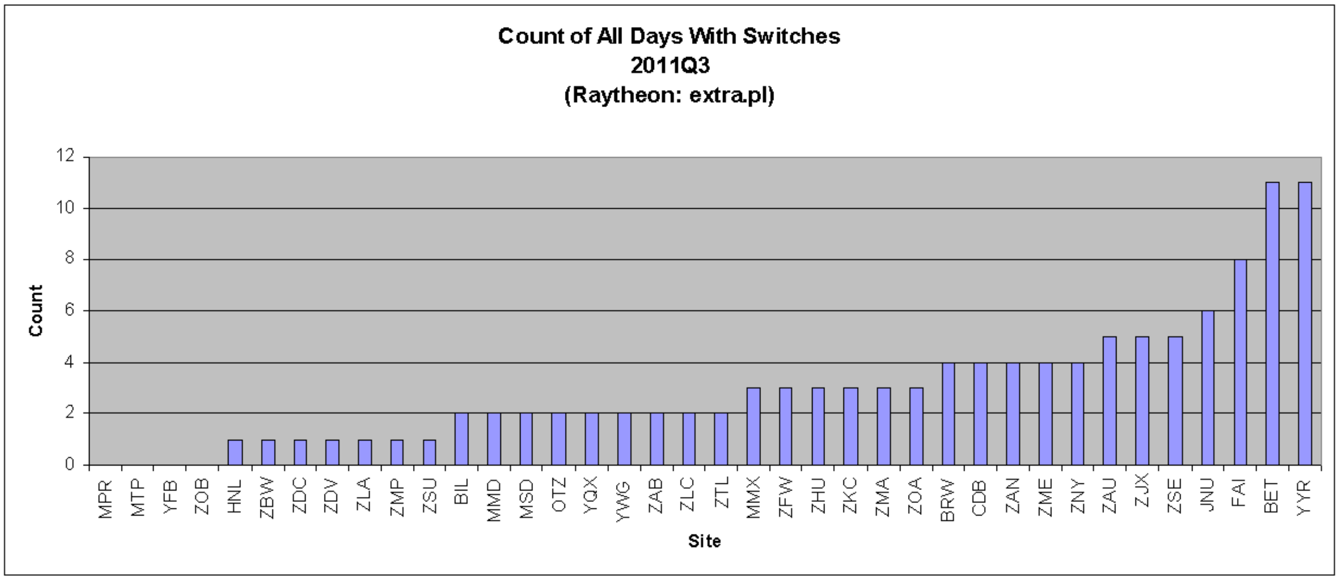


Figure 3.1: Count of all days with switches

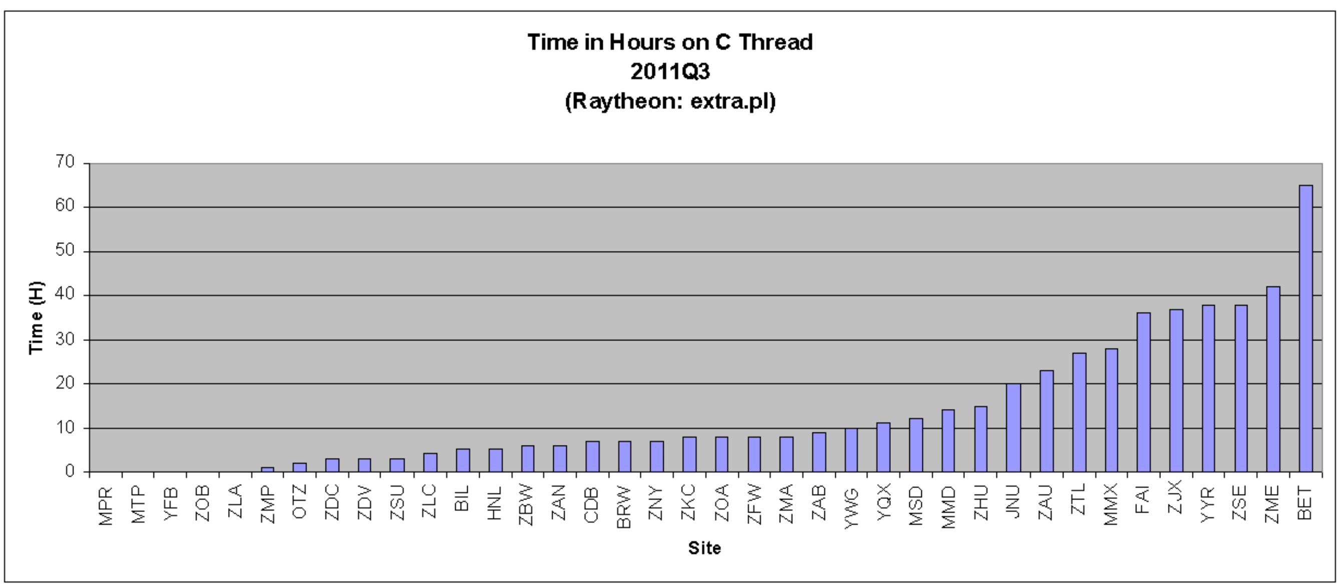


Figure 3.2: Time on C thread

Chapter 4

Continuity monitoring

4.1 CCC monitor trips

There were no trips for this period.

UTC time	PRN	ZDC	ZLA	ZTL
No trips				

Table 4.1: Reported CCC trips

4.2 Histograms of CCC GEO metric/trip threshold

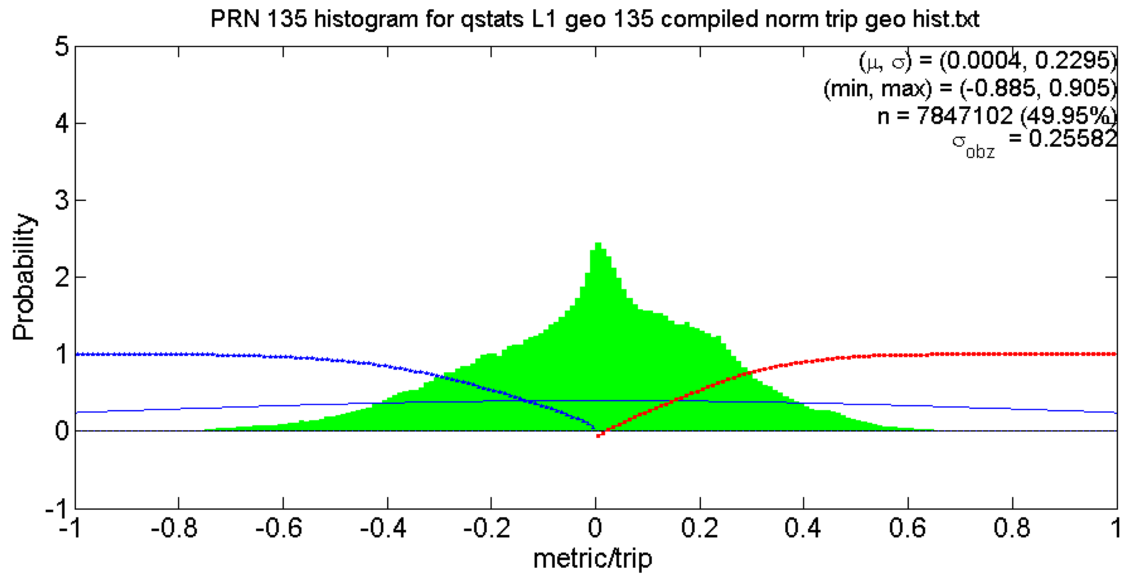


Figure 4.1: Histrogram of PRN 135 metric/trip threshold

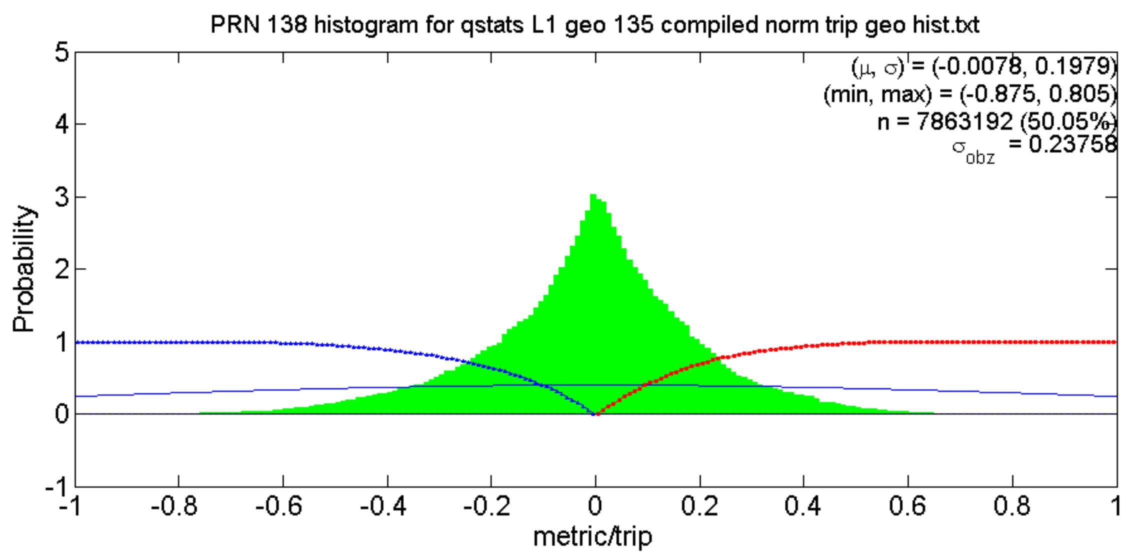


Figure 4.2: Histrogram of PRN 138 metric/trip threshold

4.3 Histograms of CCC GPS metric/trip threshold

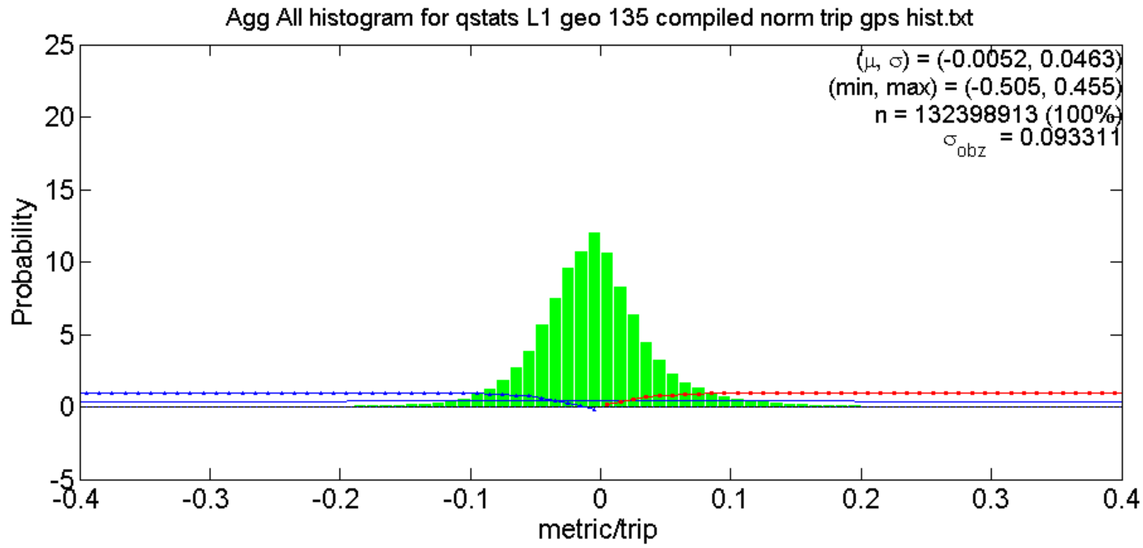


Figure 4.3: Pooled histrogram of GPS L1 metric/trip threshold

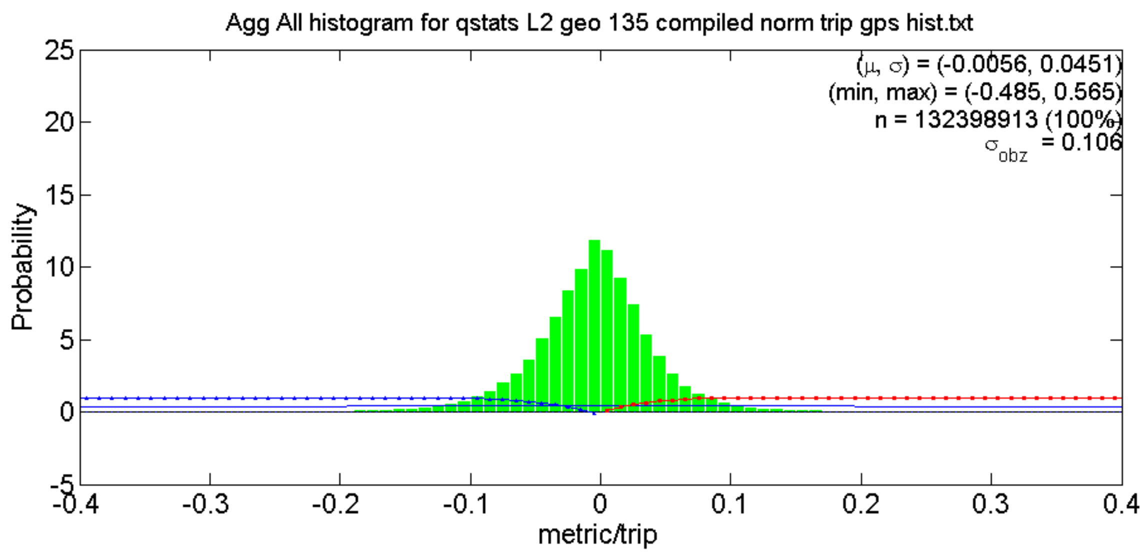


Figure 4.4: Pooled histrogram of GPS L2 metric/trip threshold

4.4 Time series of CCC GPS metric/trip threshold

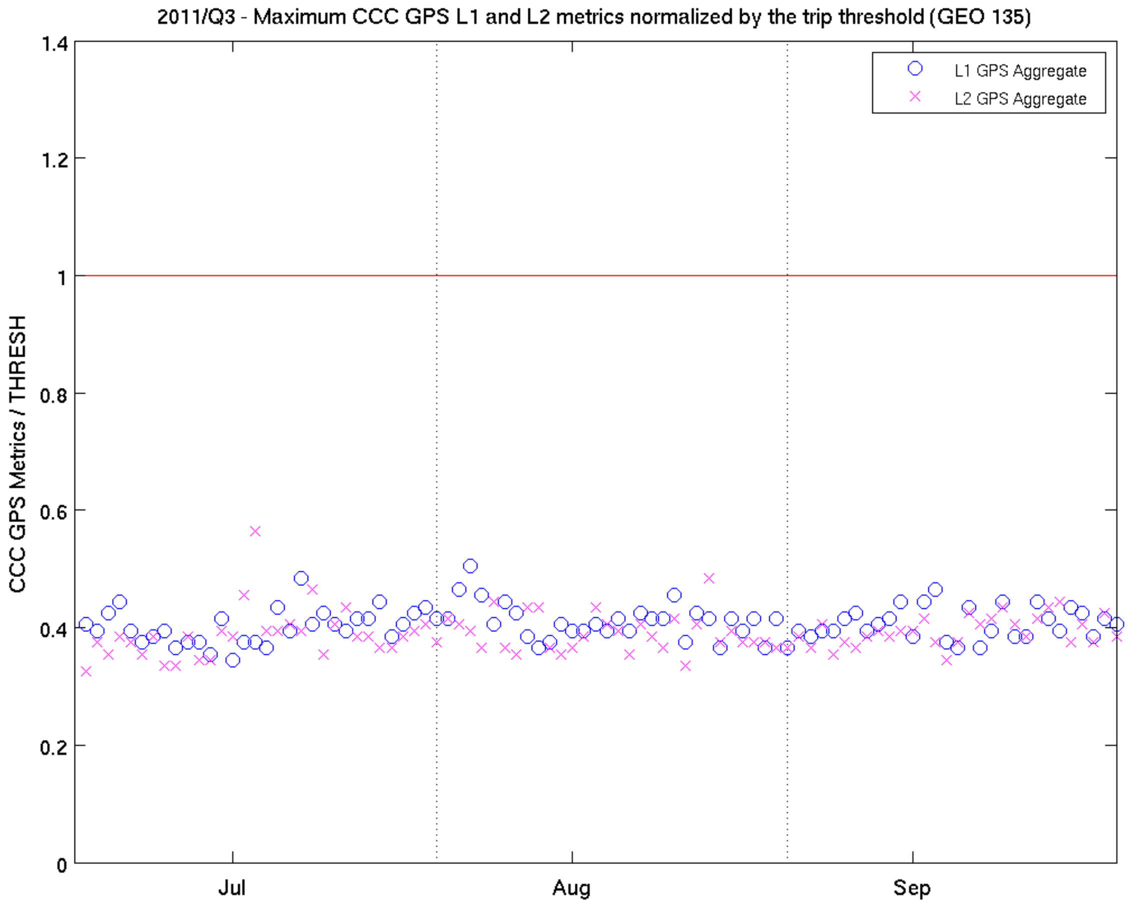


Figure 4.5: Time series graph of GPS L1 L2 max metric/trip threshold

4.5 List of missed messages

The missed messages for the 3rd quarter of 2011 are displayed in the histograms in this section. Each histogram represents one GEO satellite. Brief explanations for the cause of each instance of missed messages are provided below. The totals for missed messages per GEO satellite are as follows:

- CRW (PRN-135) - 81
- CRE (PRN-138) - 21
- AMR (PRN-133) - 74

4.5.1 CRW (PRN-135) Events

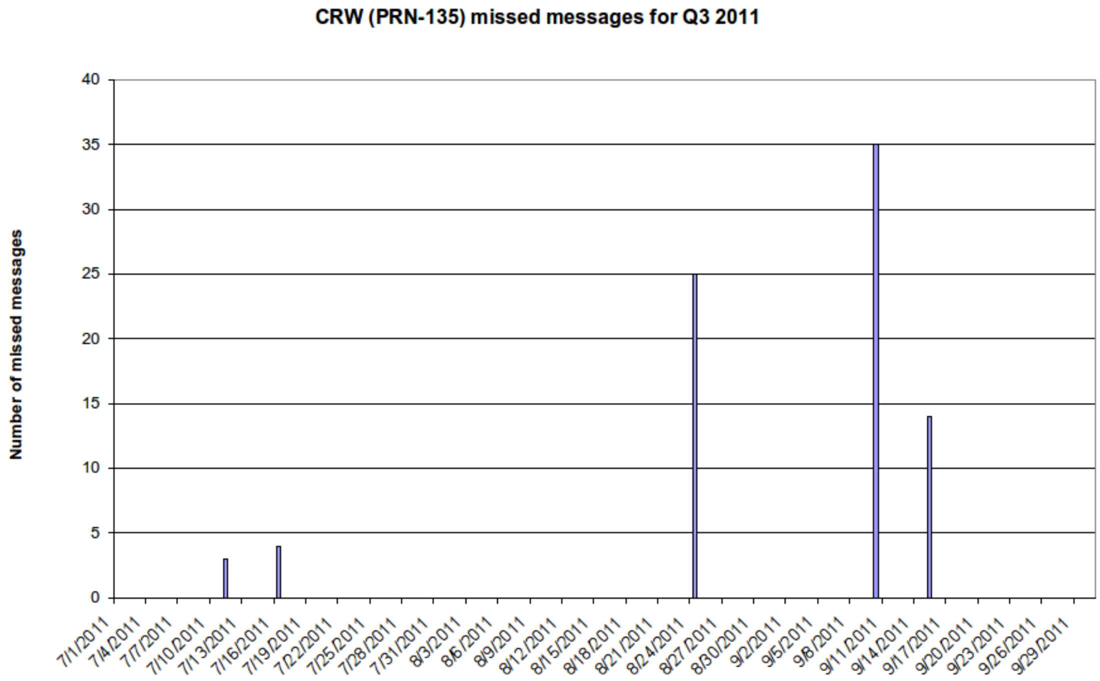
- 7/11 and 7/16: Scheduled GUST switchovers for software upgrades.
- 8/24 and 9/10: Carrier phase/frequency noise at APC due to the SGS clock.
- 9/15: LTN faulted due to a waveguide component arc fault on the C5 KPA.

4.5.2 CRE (PRN-138) Events

- 7/16: Scheduled GUST switchover for software upgrade at WBN.
- 8/25: BRE faulted at 11:58:45 due to an RFU KPA airflow fault.
- 8/27: GUST switchover, BRE to primary mode.

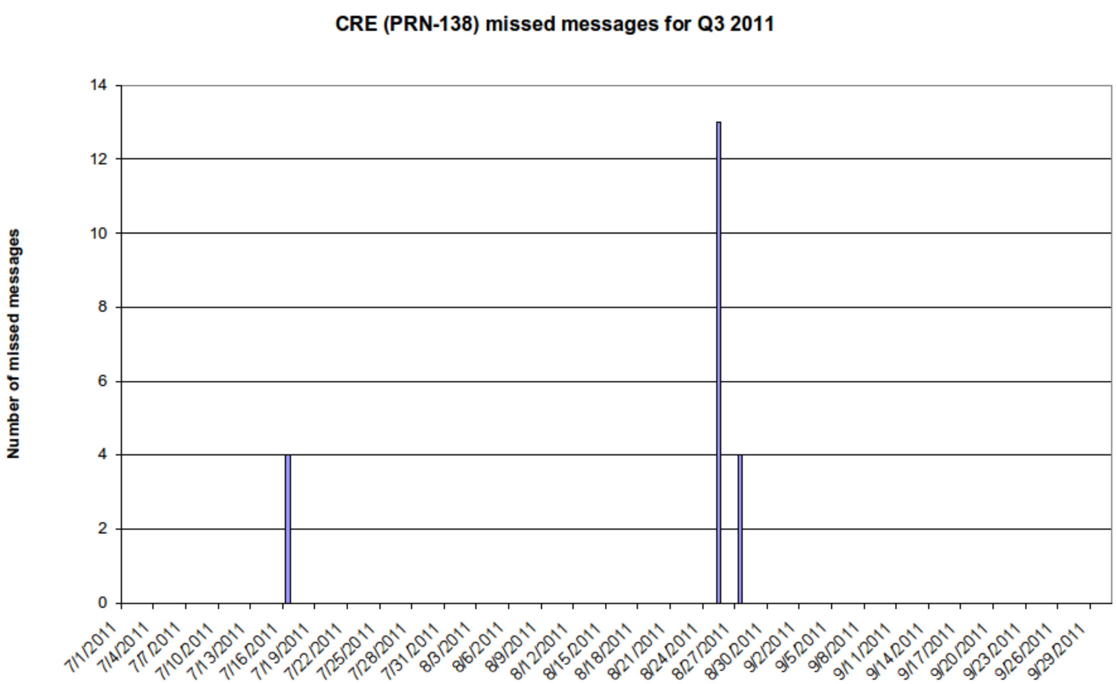
4.5.3 AMR (PRN-133) Events

- 7/14 and 7/16: Scheduled GUST switchover for software upgrades to both GUST sites.
- 7/26: SZP mode changed to faulted due to an RFU equipment uplink fault at 23:32:20.
- 7/29: Scheduled GUST switchover for scheduled maintenance at HDH.
- 9/12: Multiple L5 test translator message faults at HDH due to delayed acquisition of L5 signal on the TLT loopback section.
- 9/13: Scheduled GUST switchover for RFU M&C server upgrade.
- 9/14: HDH mode changed to faulted due to a receiver SCAF.
- 9/19: Scheduled GUST switchover for scheduled maintenance at SZP.



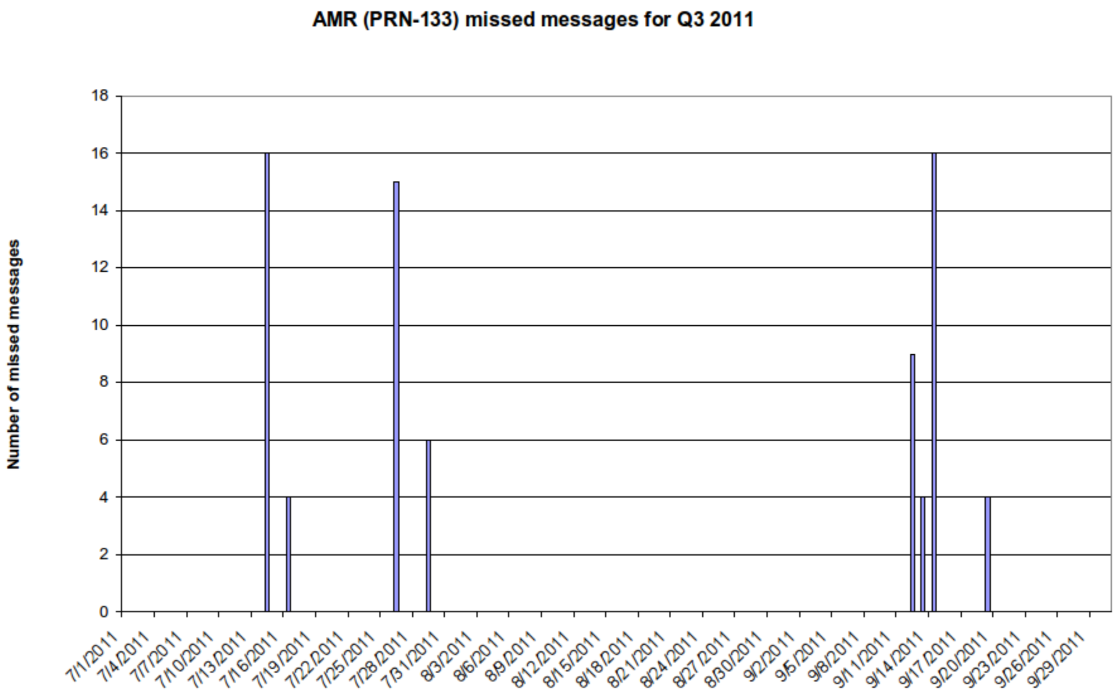
	7/1/2011	7/11/11	7/14/11	7/16/11	7/26/11	7/29/11	8/24/11	8/25/11	8/27/11	9/10/11	9/12/11	9/13/11	9/14/11	9/15/11	9/19/11	9/30/11
CRW	0	3	0	4	0	0	25	0	0	35	0	0	0	14	0	0

Figure 4.6: CRW missed messages



	7/1/2011	7/11/11	7/14/11	7/16/11	7/26/11	7/29/11	8/24/11	8/25/11	8/27/11	9/10/11	9/12/11	9/13/11	9/14/11	9/15/11	9/19/11	9/30/11
CRE	0	0	0	4	0	0	0	13	4	0	0	0	0	0	0	0

Figure 4.7: CRE missed messages



	7/1/2011	7/11/11	7/14/11	7/16/11	7/26/11	7/29/11	8/24/11	8/25/11	8/27/11	9/10/11	9/12/11	9/13/11	9/14/11	9/15/11	9/19/11	9/30/11
AMR	0	0	16	4	15	6	0	0	0	0	9	4	16	0	4	0

Figure 4.8: AMR missed messages

4.6 CNMP resets

This section will be added in a future report.

Chapter 5

Accuracy monitoring

This chapter can be added in a future report.

Chapter 6

External monitoring

6.1 Antenna phase center positions

Data from 2011-07-17 was used in this survey. The results were compared against Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP). In this comparison Root Mean Square (RMS) position errors for all sites are less than five centimeters. There was no observation data available for MTP, so it was not included.

The survey results were also compared to the coordinates in the fielded WAAS Follow On contract (WFO) release three software. The surveyed sites were within ten centimeters of the fielded coordinates.

6.2 Ephemerides monitoring

Figures 6.1, 6.2, and 6.3 show the cross-track, in-track, and radial ephemeris deltas betweens National Geodetic Survey (NGS) precise ephemeris and WAAS Continuously Operating Reference Station (CORS) Receiver INdependent EXchange Format (RINEX) epheremis.Table 6.1 contains the GPS PRN numbers for outliers.

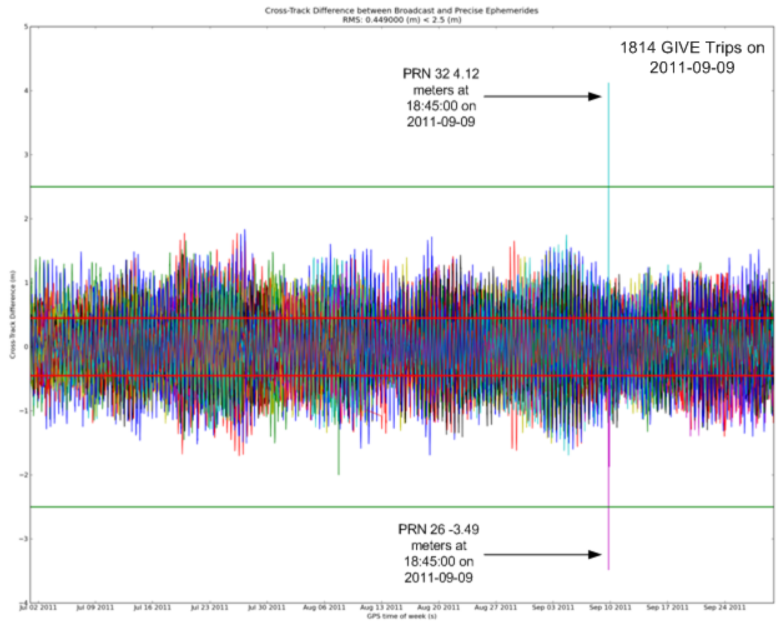


Figure 6.1: Q3 2011 Plot of Cross-Track Ephemeris Deltas between NGS and CORS Ephemeris

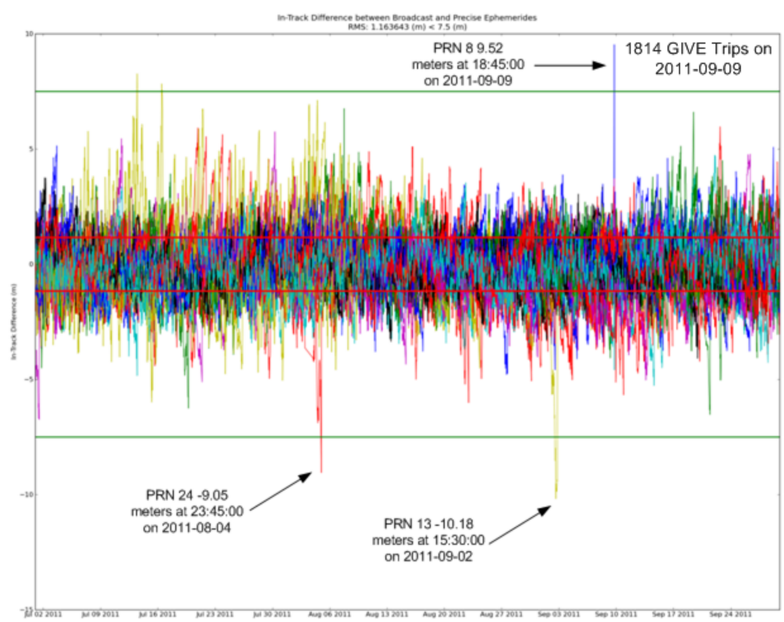


Figure 6.2: Q3 2011 Plot of In-Track Ephemeris Deltas between NGS and CORS Ephemeris

GPS PRN	Radial	In-Track	Cross-Track
1	0	0	0
2	0	0	0
3	10	0	0
4	0	0	0
5	0	0	0
6	7	0	0
7	0	0	0
8	2	1	0
9	5	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	4	29	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	1	0	0
21	0	0	0
22	0	0	0
23	2	0	0
24	53	6	0
25	0	0	0
26	3	0	1
27	717	8	0
28	0	0	0
29	0	0	0
30	52	0	0
31	0	0	0
32	2	0	1

Table 6.1: Q3 2011 Number of Outliers for each GPS PRN

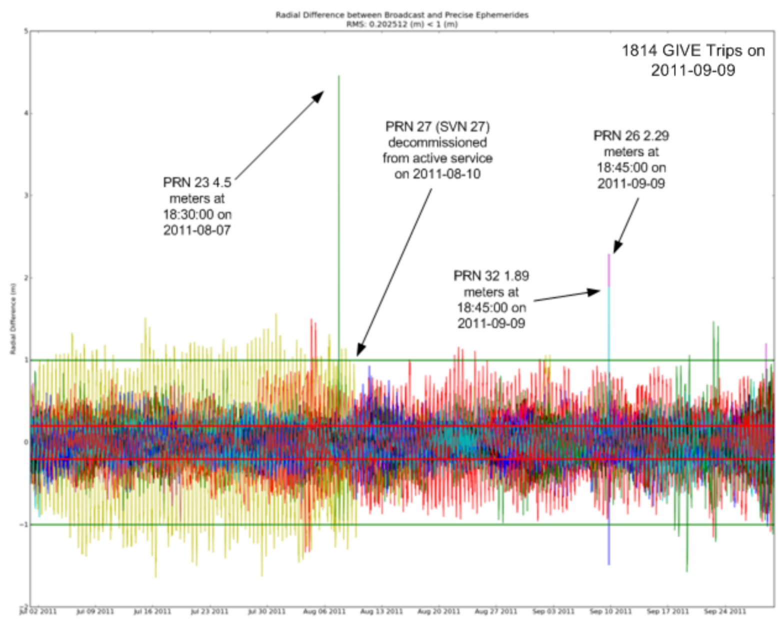


Figure 6.3: Q3 2011 Plot of Radial Ephemeris Deltas between NGS and CORS Ephemeris

6.3 Space weather monitoring

6.3.1 Planetary A-K indices

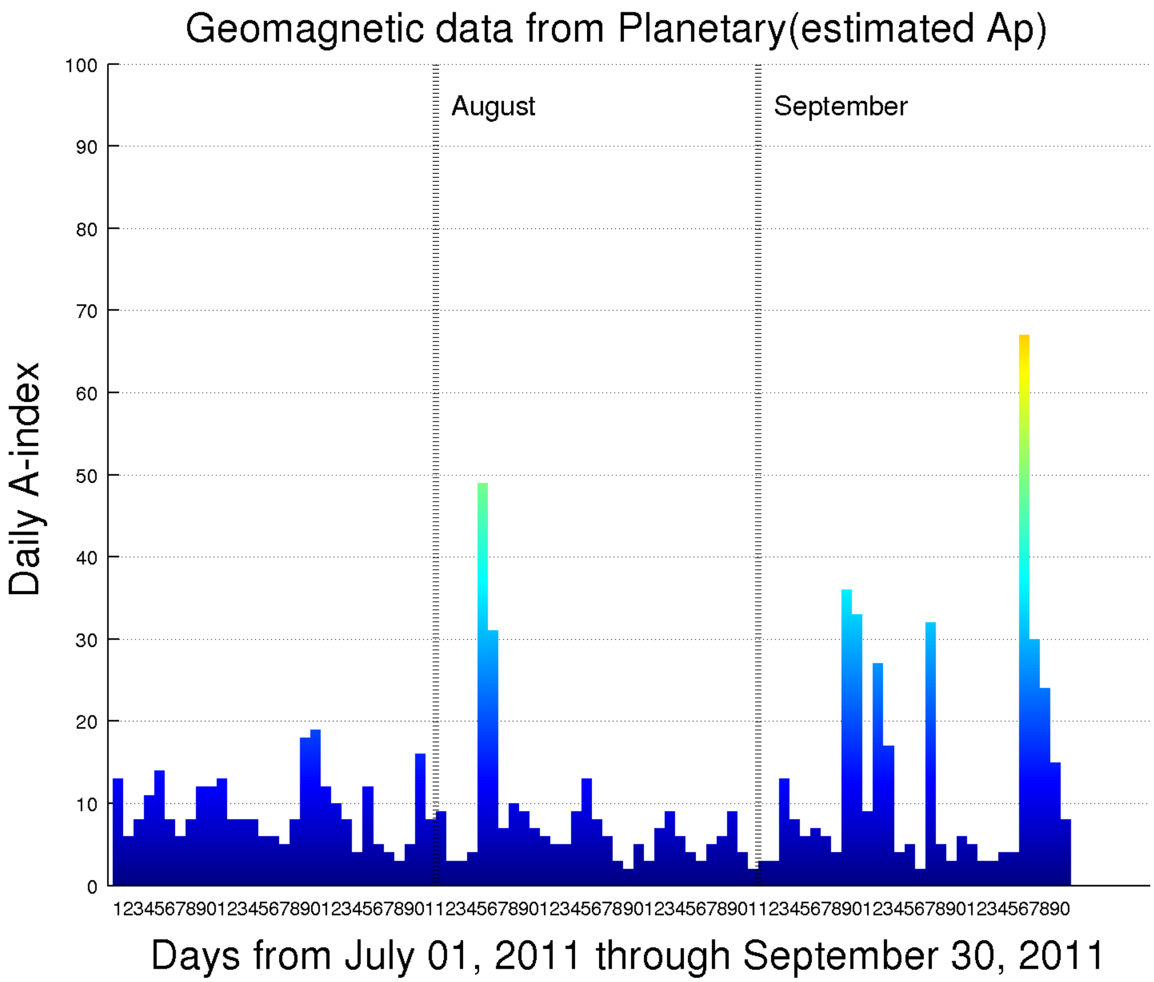


Figure 6.4: Planetary A_p values

6.4 GEO CCC signal quality analysis (GSQA)

- Three ionospheric peaks (on or near 8/6, 9/9 and 9/26) caused degraded and skewed long-term CCC metrics on CRE and CRW. All WAAS GEOs were affected. Planetary K_p indices peaked on these days 6.5. Note that it cannot be determined whether or not the peak activity contributed to the code-carrier coherence at the satellite without iono supertruth measurements. Also, the raw and carrier-smoothed pseudorange is considerably greater with the 100-second smoothing time constant (long-term CCC) than with 10-second smoothing time constant (short-term CCC).

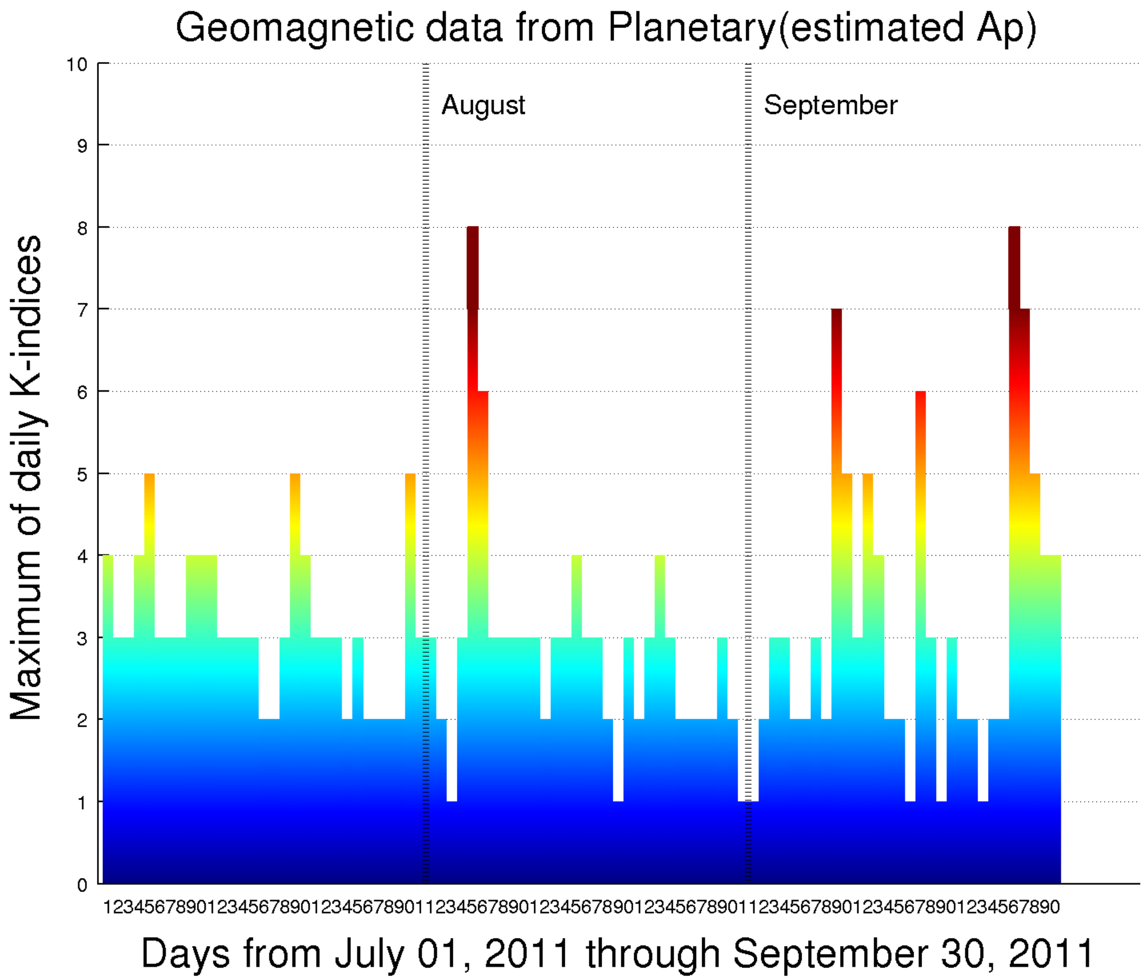


Figure 6.5: Planetary K_p values

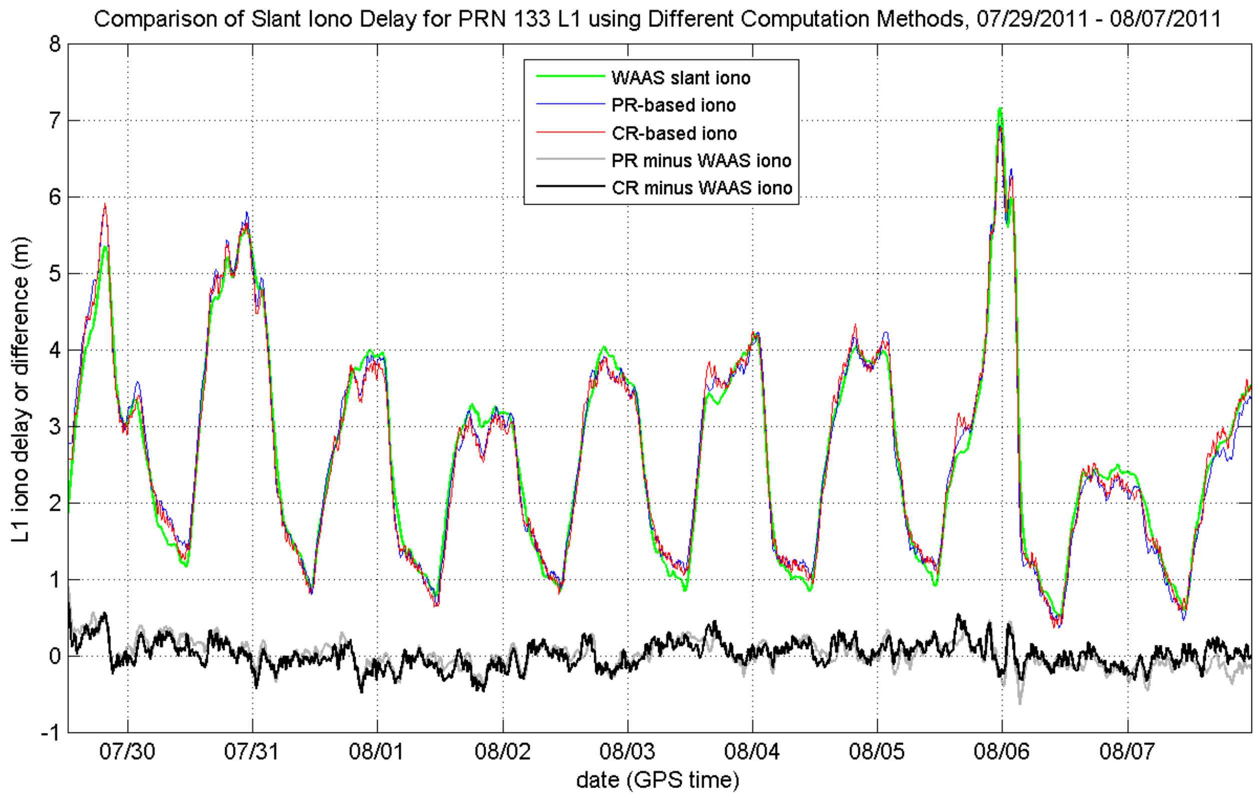


Figure 6.6: Slant iono delay for PRN 133 L1 for 7/29 to 8/7

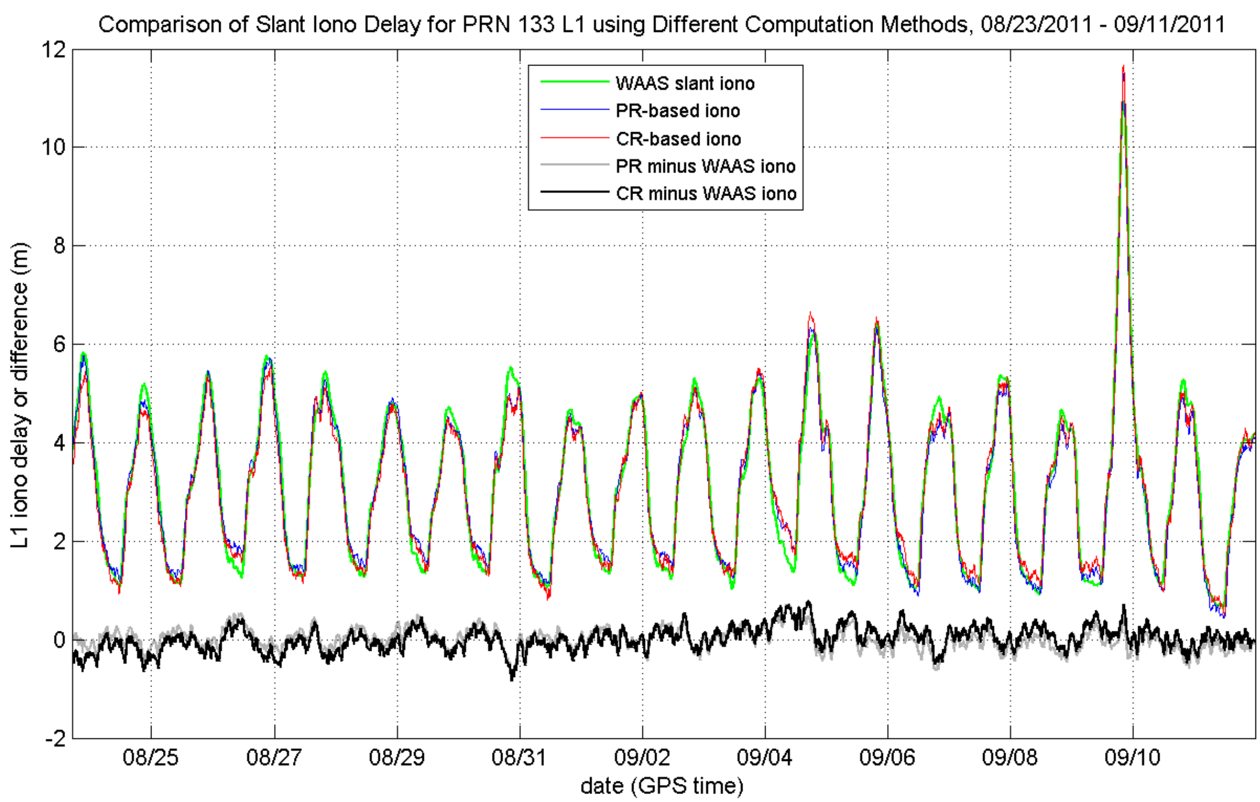


Figure 6.7: Slant iono delay for PRN 133 L1 for 8/23 to 9/11

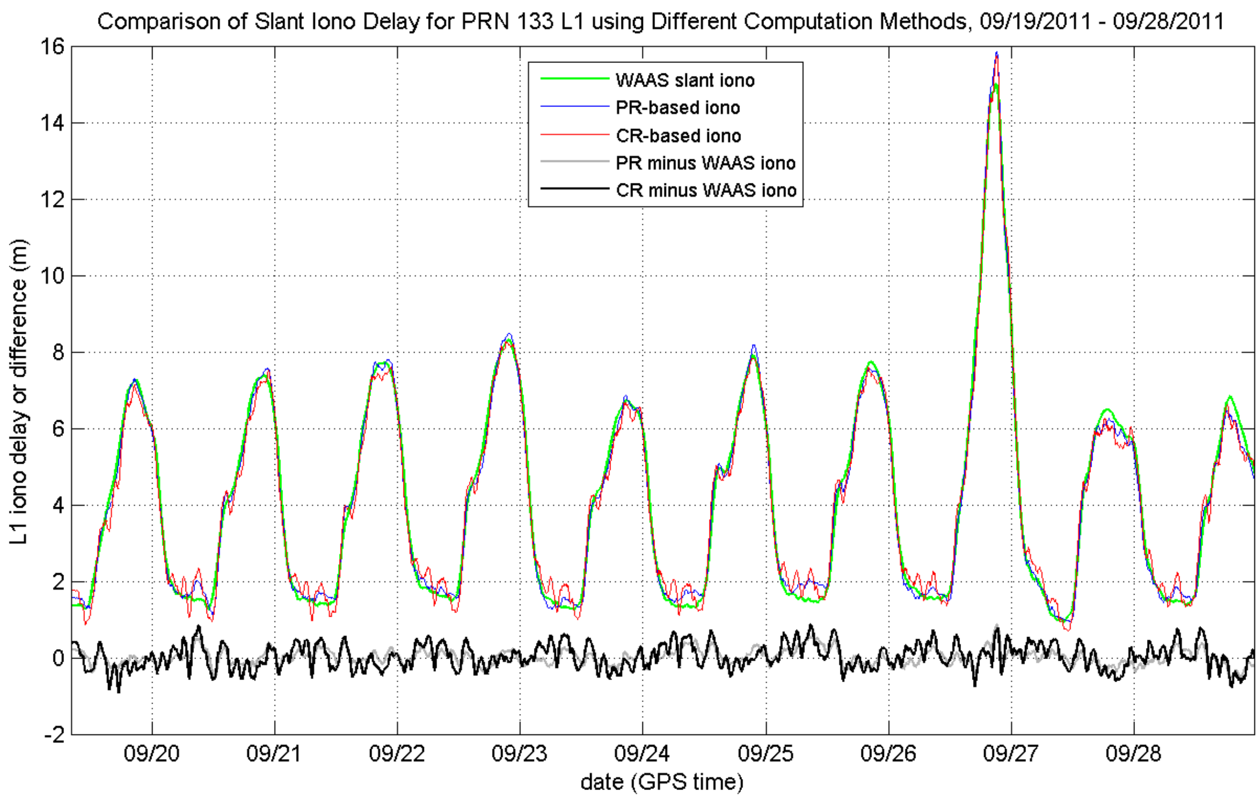


Figure 6.8: Slant iono delay for PRN 133 L1 for 9/19 to 9/28

- Woodbine (Backup) feed cracked on or near 9/7, causing CCC/CC metric peaking (not on signal-in-space)
- Napa (Primary) SGS clock instability in early September caused elevated CRW CCC/CC metrics (but still remained under the 0.2-m and 0.15-m threshold values for L5 and L1 respectively)

Note that the remaining GSQA figures can be found in the supplemental material section.

		L1 CCC		**L5 CCC**		**CC**	
		short-term	long-term	short-term	long-term	short-term	long-term
PRN 135 CRW	max	OK	OK	OK	OK	OK	OK
	mean	OK	OK	OK	OK	OK	OK
PRN 138 CRE	max	OK	OK	OK	OK	OK	OK
	mean	OK	OK	OK	OK	OK	OK

Table 6.2: GSQA performance summary

OK = always below spec limit

Chapter 7

Anomaly investigation

7.1 Major Anomalies

The GUST site at Paumalu, Hawaii (HDH) has not experienced Carrier Phase Standard Deviation noise, low C/N0, or parity issues to the level that it did in Quarter 2 (Q2) 2011. There are ongoing efforts to ensure stability and continually monitor performance. There were no HDH GUST faults during Q3 caused by this type of noise.

An Ionospheric storm occurred on 2011-08-05. The planetary K_p index provided by the NOAA reached a value of 8 on this day. The storm caused SVM coverage failures throughout CONUS and Alaska. SVM reported the coverage values shown in Table 7.1 and plots of the LPV 99% coverage are shown in Table 7.1.

SVM Report Type	LPV 99% Contour
Composite CRW / CRE CONUS	48.16
Composite CRE / AMR CONUS	48.16
CRW CONUS	48.16
CRE CONUS	48.16
AMR CONUS	47.94
Composite CRW / CRE Alaska	70.73
Composite CRE / AMR Alaska	70.73
CRW Alaska	70.73
CRE Alaska	70.73
AMR Alaska	52.07

Table 7.1: SVM Coverage during 2011-08-05 Iono Storm

A plot of the Chi^2 values for the worst point in the storm is shown in Figure 7.2, a plot of the average Chi^2 values throughout the day is shown in Figure 7.3, and a plot of all GIVE Trips reported on 08/05 is shown in Figure 7.4.

Another large Ionospheric storm occurred on 2011-09-26. Once again LPV Service was degraded over the northern and western sections of CONUS as well as all of Alaska. Plots of SVM Coverage for CONUS and Alaska are shown in Figure 7.4. The planetary K_p index reached a value of 8. The operators issued a NOTAM at 19:24 Zulu.

Table 7.2 shows the SVM Coverage for both CONUS and Alaska on this day. Figures 7.6 7.7 show the Chi^2 values for the day.

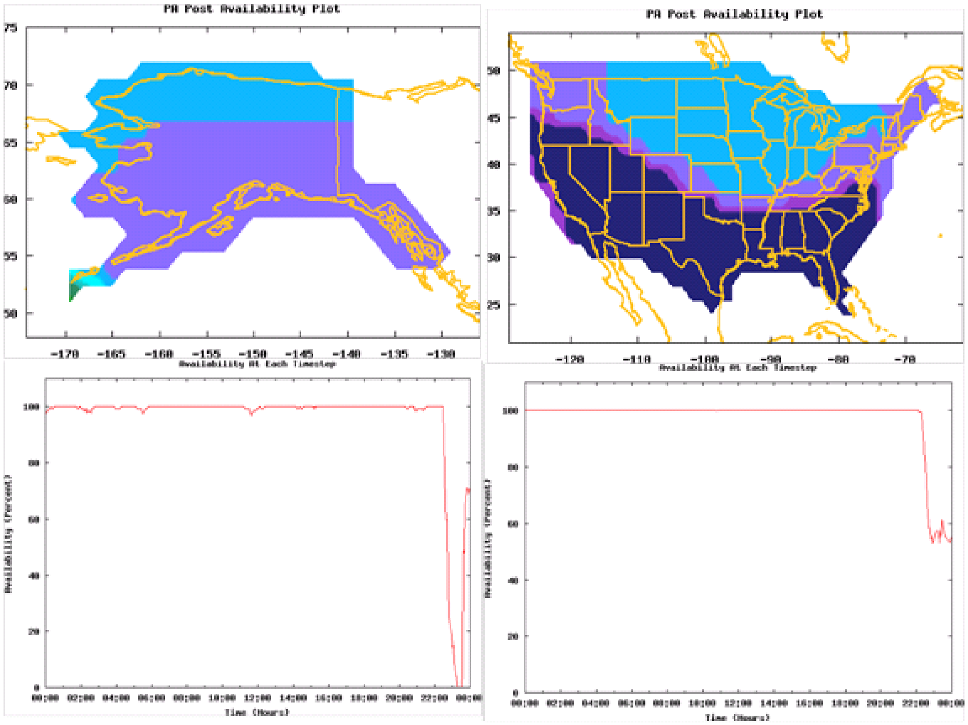


Figure 7.1: LPV 99% Coverage during 2011-08-05 Iono Storm

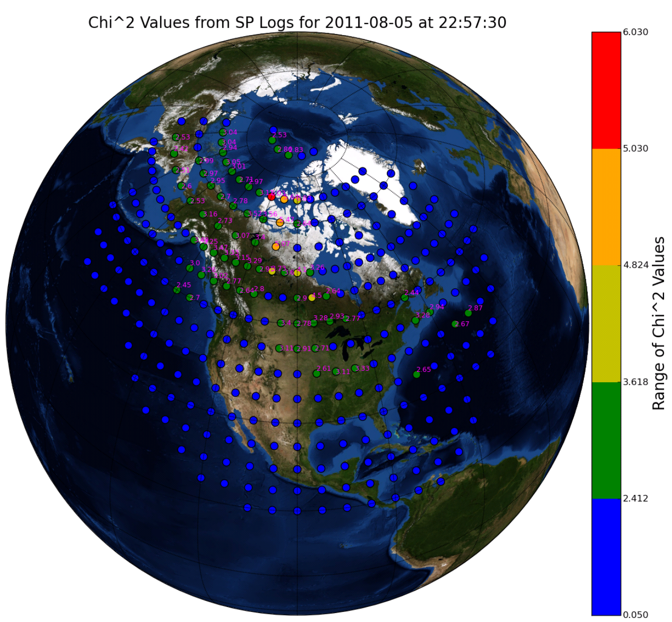


Figure 7.2: Chi^2 Values at Worst Point during 2011-08-05 Iono Storm

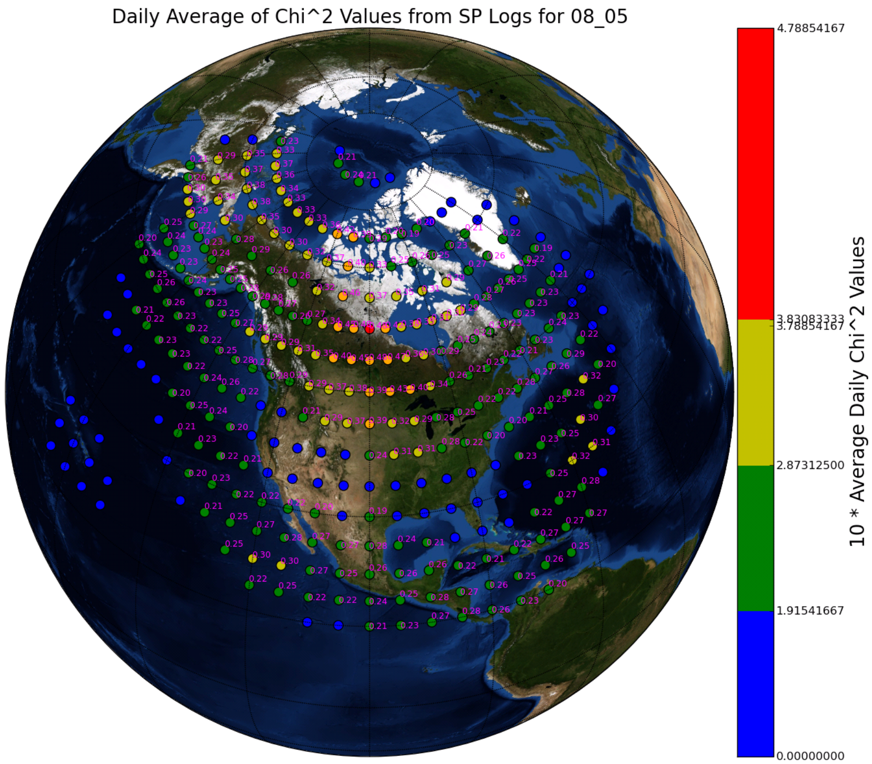


Figure 7.3: Daily Average of Chi^2 Values during 2011-08-05 Iono Storm

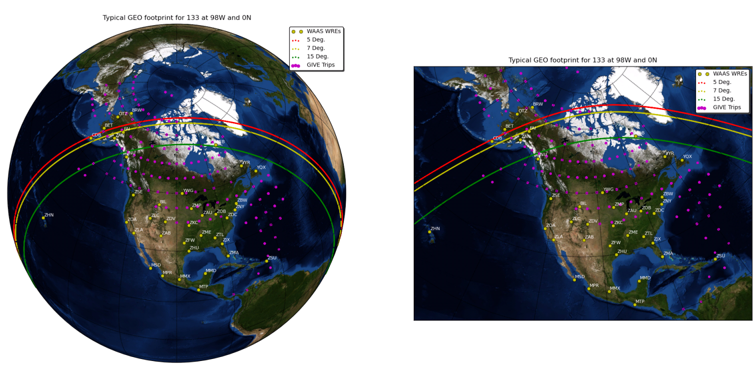


Figure 7.4: GIVE Trips during 2011-08-05 Iono Storm

SVM Report Type	LPV 99% Contour
Composite CRW / CRE CONUS	39.04
Composite CRE / AMR CONUS	39.29
CRW CONUS	38.80
CRE CONUS	39.04
AMR CONUS	39.29
Composite CRW / CRE Alaska	80.04
Composite CRE / AMR Alaska	68.12
CRW Alaska	78.10
CRE Alaska	64.78
AMR Alaska	37.82

Table 7.2: SVM Coverage during 2011-09-26 Iono Storm

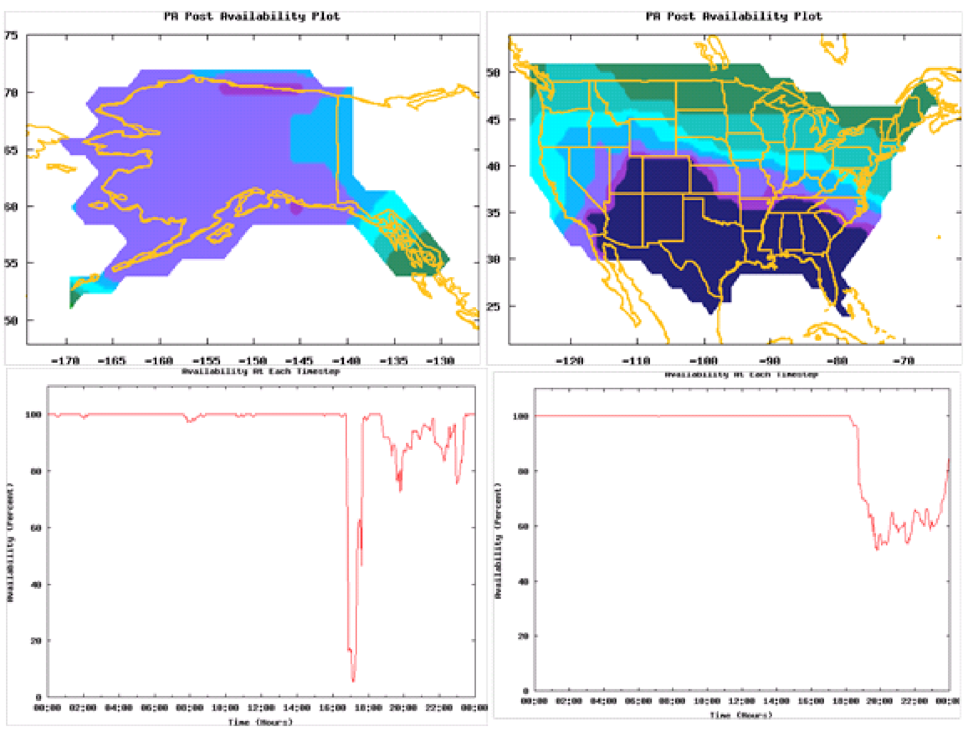


Figure 7.5: LPV 99% Coverage during 2011-09-26 Iono Storm

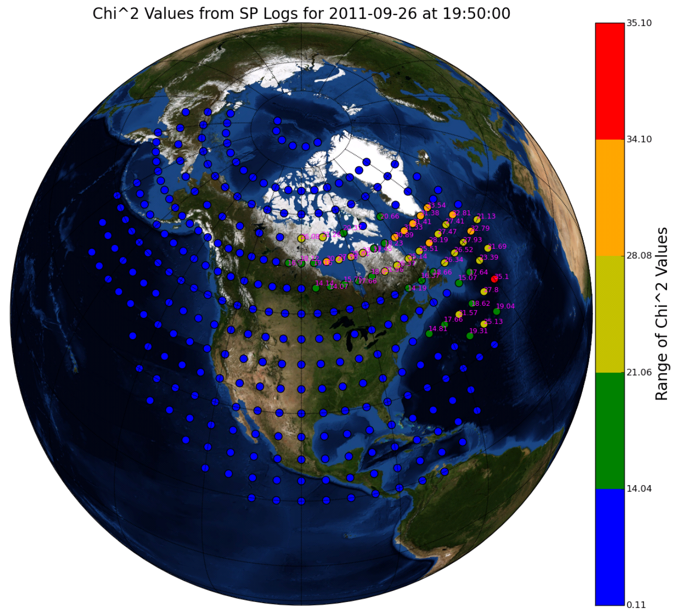


Figure 7.6: Chi^2 Values at Worst Point during 2011-09-26 Iono Storm

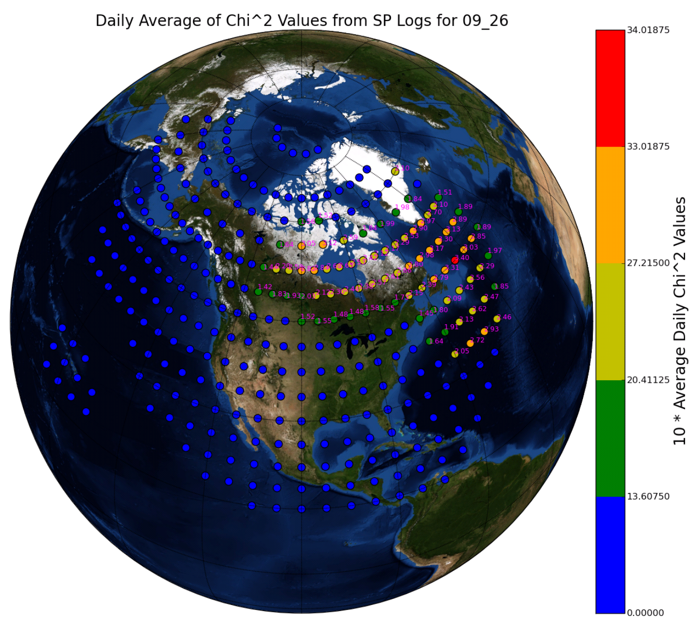


Figure 7.7: Daily Average of Chi^2 Values during 2011-09-26 Iono Storm

Chapter 8

Materials and methods

8.1 Code-carrier-coherence

Anik, Galaxy 15, AMR and all GPS satellites are monitored for CCC trips. All CCC monitor trips are investigated whenever a trip occurs to determine the cause. Data sources used in correlation and analysis include:

- CCC test statistic
- UDRE threshold value
- Code Minus Carrier corrected for Iono (CMCI) measurements from NETS SQA
- WAAS Iono calculation
- L1/L5 Iono GEO Uplink Subsystem Type 1 (GUST) calculation
- published planetary K_p and A_p values
- Chi^2 values

8.2 Antenna positioning

Accurate antenna positions are needed for WAAS or any Differential Global Positioning System (DGPS) application. The positions must be updated to correct for time dependent processes like tectonic plate movement and subsidence. They also need to be updated for events which shift the position of the antennas. These might include seismic events or maintenance. Antenna position results from OLM will be used to determine if the WAAS antenna coordinates require an update.

The WIPP reviews antenna position changes based on how much the antenna moves. If the antenna moves more than ten centimeters, the WIPP should review. If an antenna moves more than 25 centimeters, the WIPP must review. Mexico city is a special case due to the rapid subsidence at that site. It is allowed 25 centimeters before review.

The NGS's suite of survey software (PAGE-NT) (pnt6k version 2011.09.28) was used to conduct a survey with WAAS site data from 2011-07-17. These results were compared against CSRS-PPP using the same input data. In this comparison RMS position errors for all sites are less than five centimeters. There was no observation data available for MTP, so it was not included.

The survey results were also compared to the fielded WFO release three. The coordinates for the release are projected to 2012-05-01. In order to make the comparison, the surveyed sites positions were projected to the same date.

8.3 Satellite Clock Run-off Monitoring Approach

A GPS clock run-off event is typically correlated with a WAAS fast correction that exceeds 256 meters. When this occurs, the satellite is set to Do Not Use until the correction reaches a reasonable size. A real clock-runoff would be considered when these events happend at times that the GPS satellite is in a healthy status and there is no Notice Advisory to NAVigation System with Time And Range (NAVSTAR) Users (NANU) in effect for the specific GPS SV.

The approach to monitor for GPS clock run-off events is to collect and database quarterly data for SV health from CORS RINEX files, NANUs from the US Coast Guard, and Fast Correction and User Domain Range Error Index (UDREI) data from WAAS User Message (WUM)s. Once databased, the data is extracted for the entire quarter and plotted for each GPS PRN. Any days of interest are then re-plotted with more detail for that specific day. There were three days of interest in Q3 2011 for PRNs 26 and 32, but no clock runoff events. Table 8.1 shows the days of interest in Q3 2011.

GPS PRN	Date
PRN 26	2011-09-10
PRN 26	2011-09-14
PRN 32	2011-09-25

Table 8.1: Days of Interest for Clock Run-off Events

Figures 8.1 and 8.2 show plots of these metrics used to identify clock runoffs for PRNs 26 and 32, respectively.

Figures 8.3, 8.4, and 8.5 show a few hours of data surrounding each event in the preceeding quarterly plots where the UDREI reached 15, or Do Not Use, and there were no NANUs issued for the SV at the time. None of these 3 events were instance of real clock runoff events as explained below.

Figures 8.6, 8.7, and 8.8 on page 53 show GPS PRN 32 coverage footprints on 2011-09-14 at 12:30:00, 14:30:00, and 15:30:00 UTC. At the time of the brief UDREI spike to 15 for PRN 32 on this day, there were only a few WAAS WREs tracking PRN 32. One hour after the spike, no WAAS WREs could view PRN 32. Approximately 16 minutes after the spike to 15, the Fast Corrections reached a value of 256 meters and the WAAS UDREI had been steady at a value of 14, or Not Monitored, since GPS 32 was no longer tracked by any WAAS WREs.

In the same manner as the example of PRN 32, each of the 3 days of interest during Q3 2011 happened during times of a GPS PRN transitioning from being monitored by a few WAAS WREs to none or vice versa. Even though there were no NANUs or unhealthy states for these satellites during these brief bumps to a UDREI of 15, they occurred during a transition of the GPS SV either just coming into view of a few WAAS WREs or dropping out of view of the last few remaining WREs that could track the SV. Such transitions can cause the UDREI values to reach 15 without a NANU and are not considered real clock run-off events.

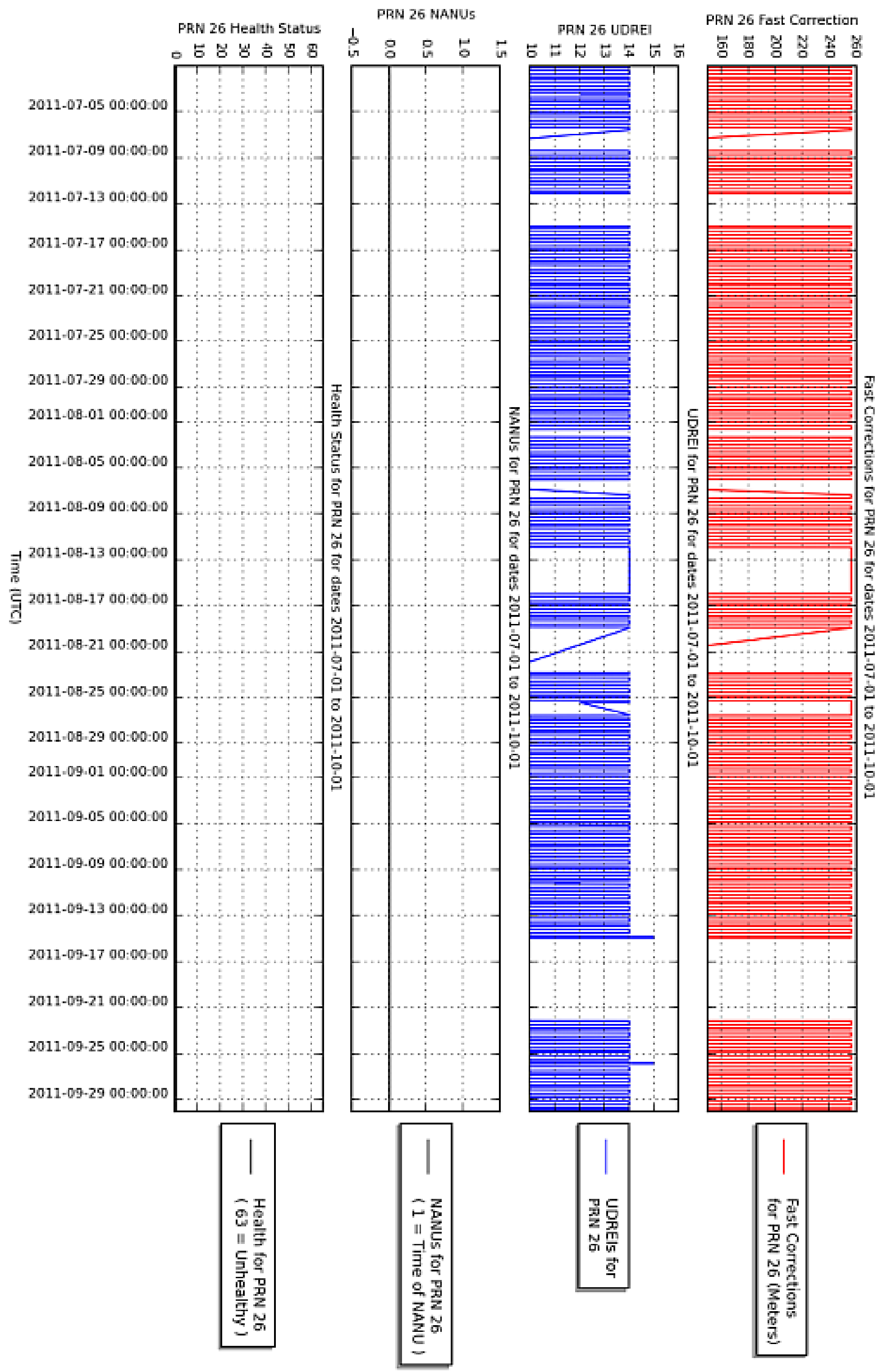


Figure 8.1: Q3 2011 Plot of GPS SV Fast Corrections, UDREI, NANUs, and Health for PRN 26

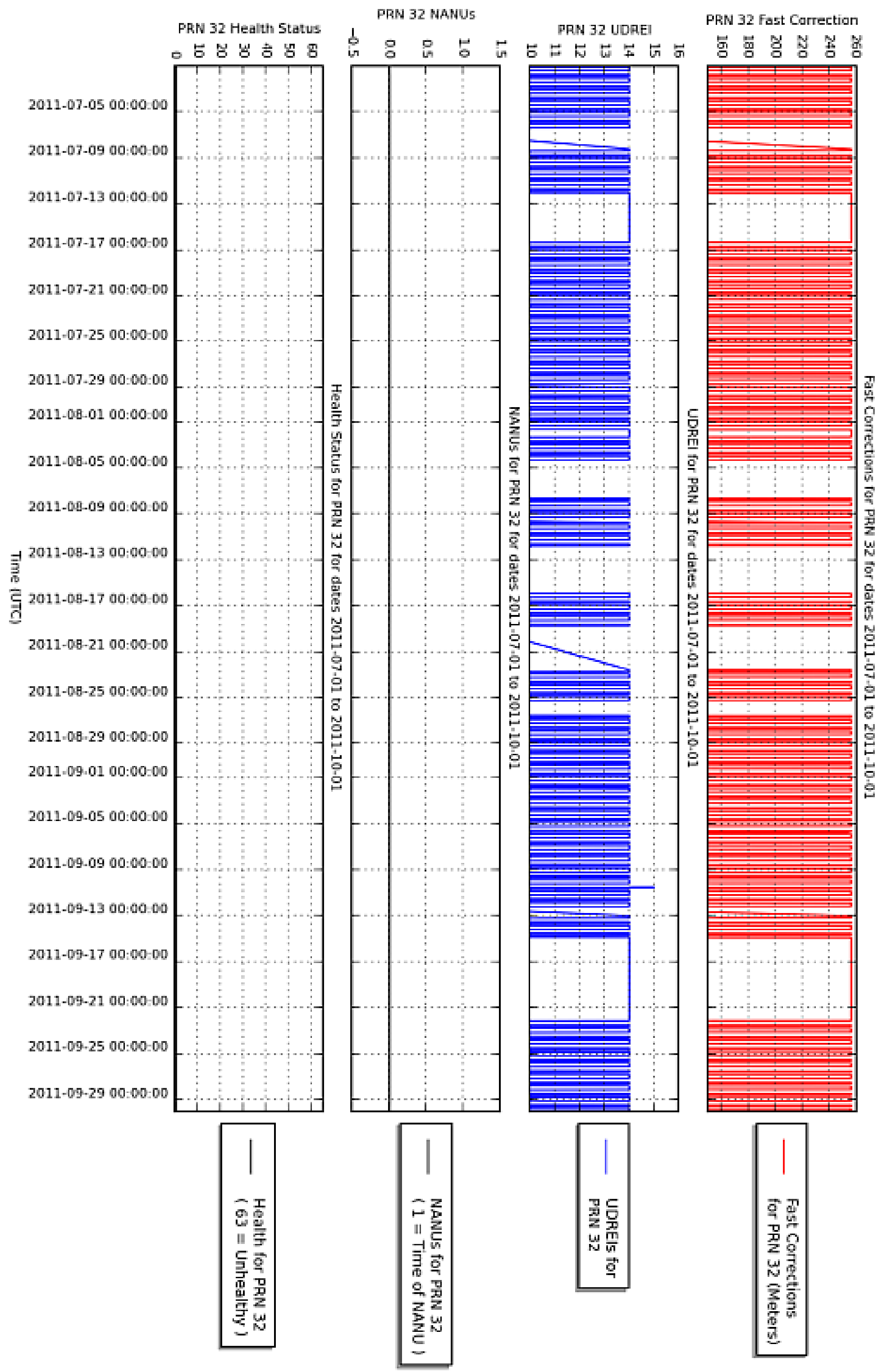


Figure 8.2: Q3 2011 Plot of GPS SV Fast Corrections, UDREI, NANUs, and Health for PRN 32

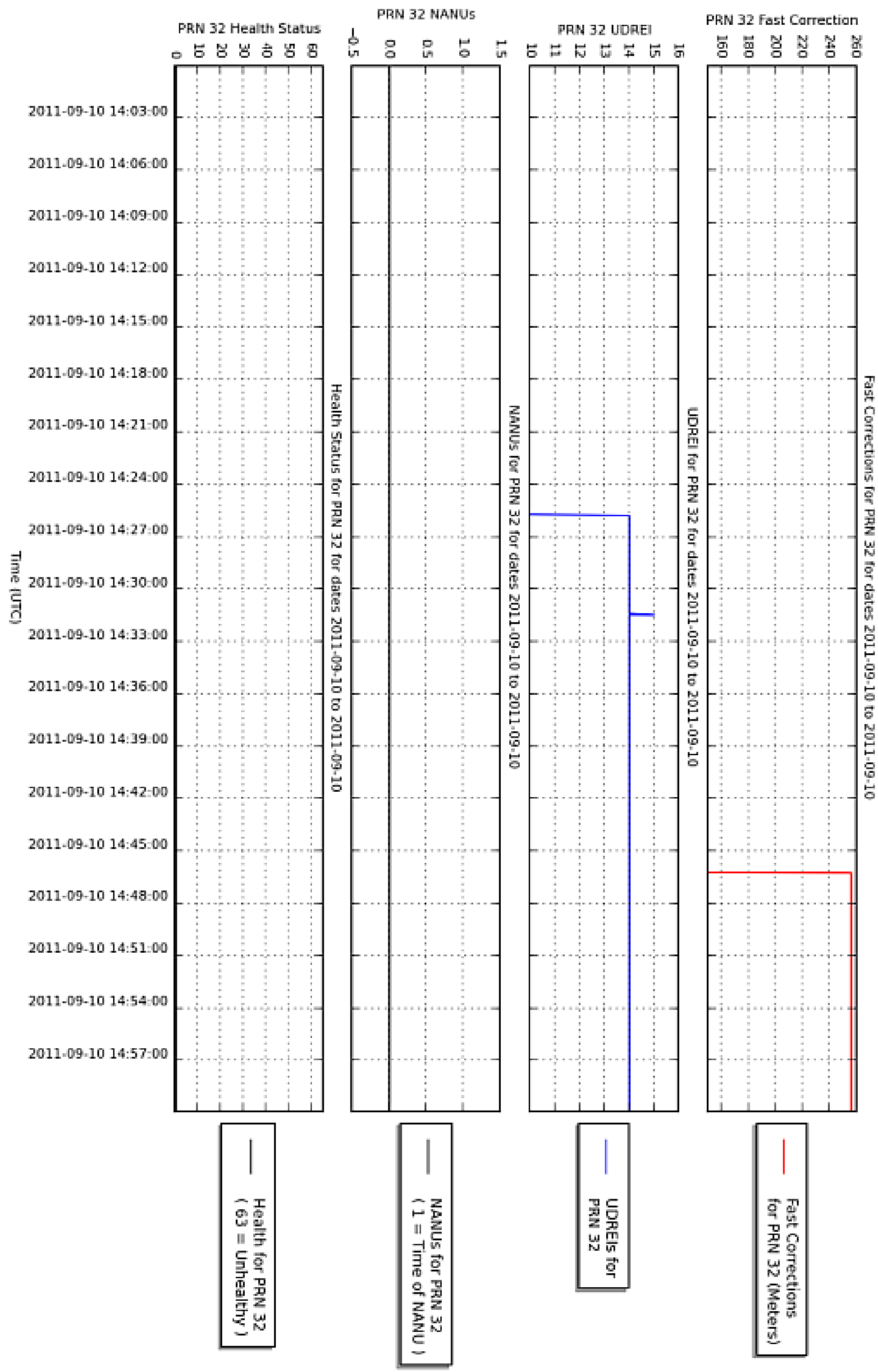


Figure 8.3: 2011-09-10 Plot of GPS SV Fast Corrections, UDREI, NANUs, and Health for PRN 32

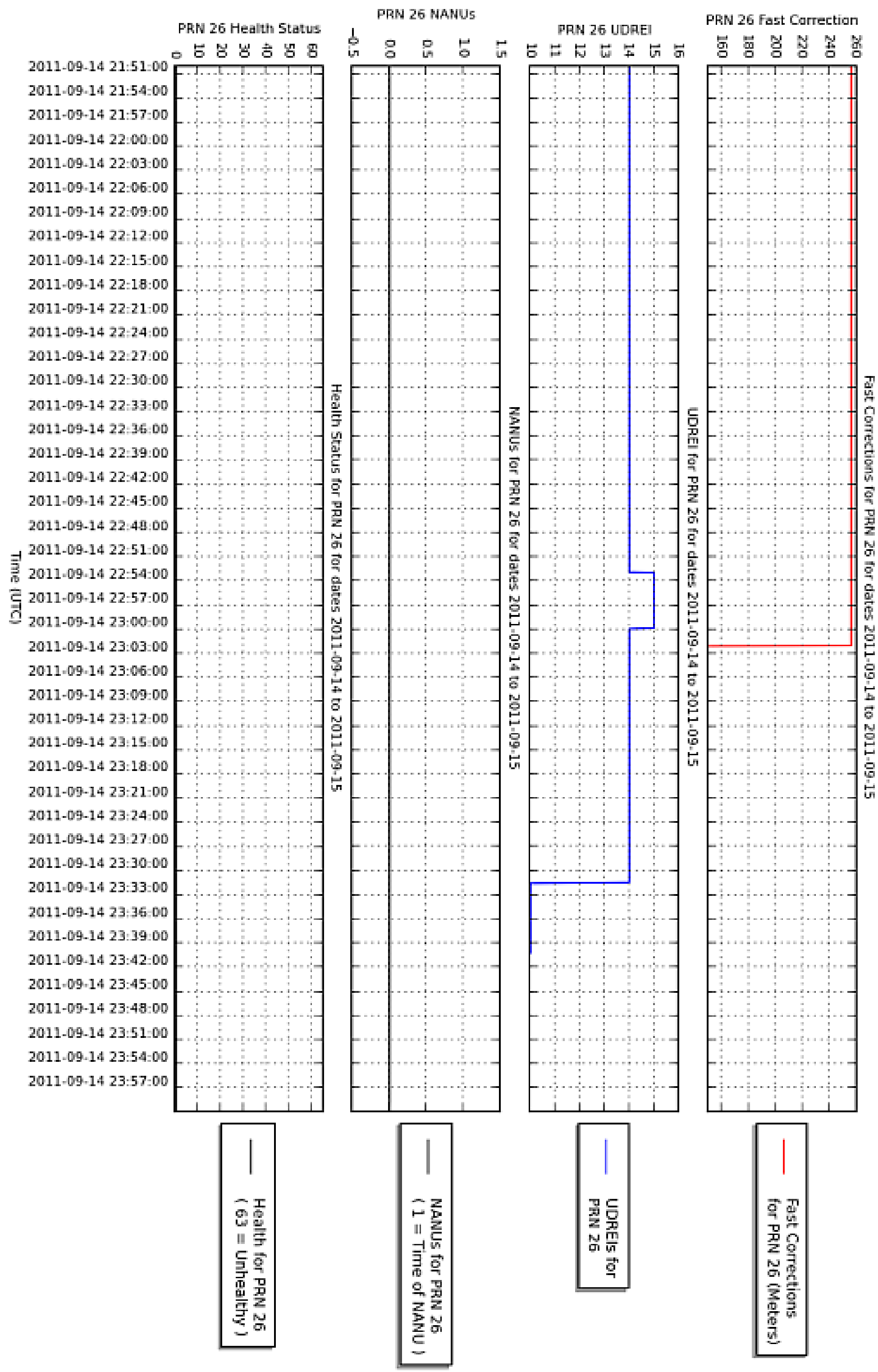


Figure 8.4: 2011-09-14 Plot of GPS SV Fast Corrections, UDREI, NANUs, and Health for PRN 26

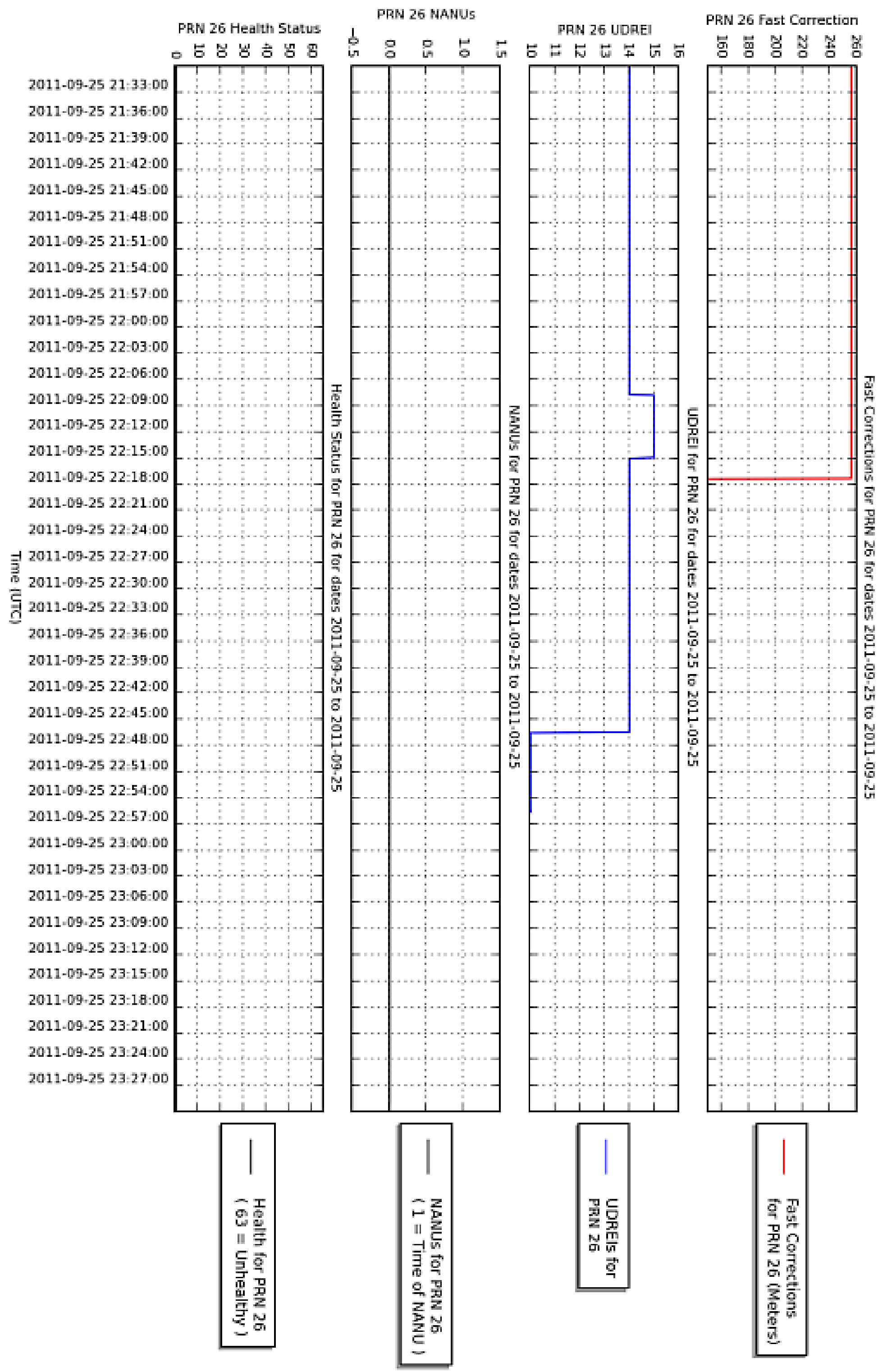


Figure 8.5: 2011-09-25 Plot of GPS SV Fast Corrections, UDREI, NANUs, and Health for PRN 26

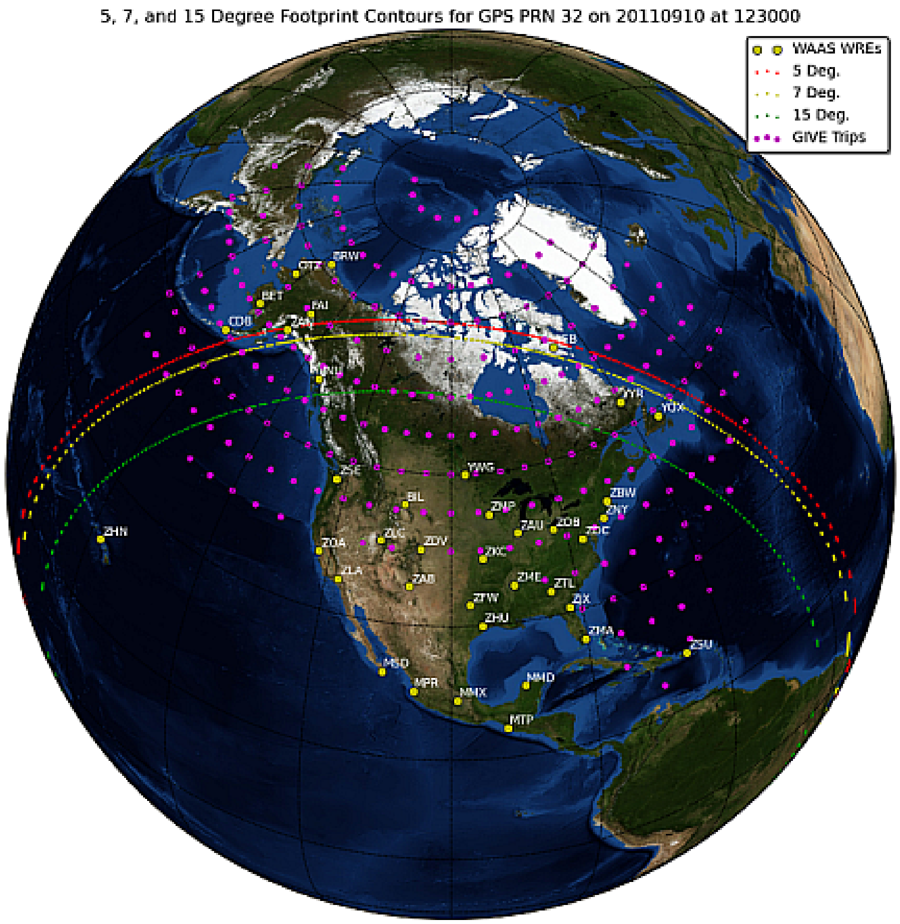


Figure 8.6: PRN 32 Coverage Footprint at 12:30:00 UTC on 2011-09-10

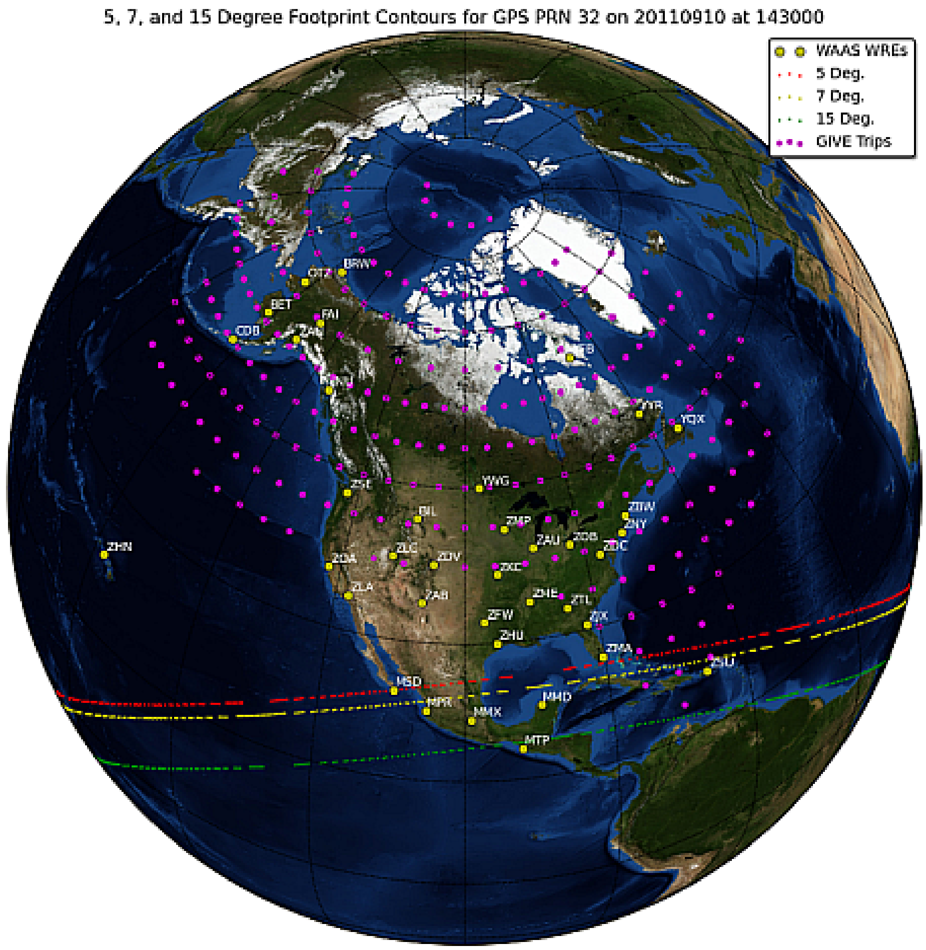


Figure 8.7: PRN 32 Coverage Footprint at 14:30:00 UTC on 2011-09-10

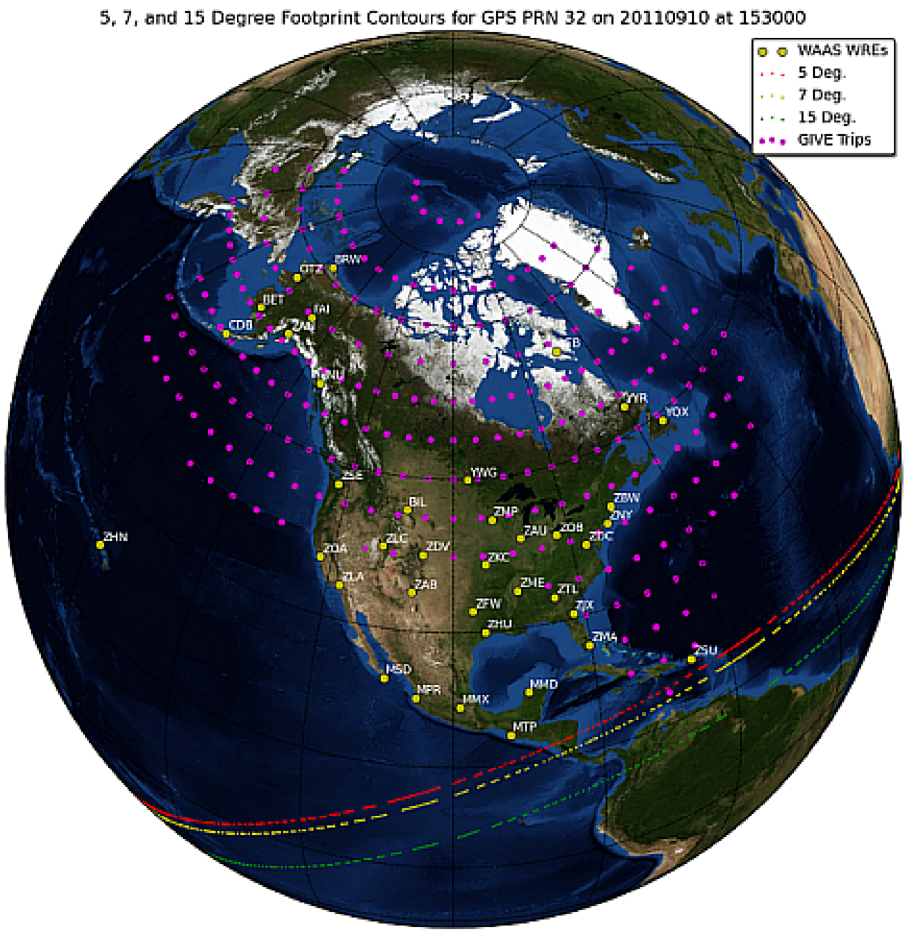


Figure 8.8: PRN 32 Coverage Footprint at 15:30:00 UTC on 2011-09-10

8.4 Ephemerides Monitoring Approach

The difference between the precise GPS ephemeris provided by the NGS and the ephemeris derived from the CORS RINEXfiles for all available sites is computed and analyzed. A voting algorithm is employed to select the best set of ephemerides from the CORs data. Outliers are analyzed and tabulated.

8.5 Ionospheric threat model monitoring approach

Monitor the percentage of Chi^2 values > than 1 each day for the four regions and determine whether the threshold has been reached. The regions and thresholds are:

Region	**Threshold (%)**
CONUS	1
Alaska	2
Caribbean	10
Other	3

Table 8.2: Threat model regions and threshold settings

8.6 Code-noise and multipath

To monitor the CNMP HMI assertion (appendix A.2), we check the bounding for three statistics, L1, IFPR, and Delay. The equations used to determine a passing or failing grade for the distribution plots are in Appendix 9.3.2. The sigma zero centered sigma overbound plots are considered to be passing if the value is less than one, which is marked in the plots.

8.7 GEO signal quality analysis (GSQA)

8.7.1 Data

- Backup GUST receiver data from Lockheed Martin used for the analysis

8.7.2 Methods

- Graphs of data were generated using MATLAB

Chapter 9

Supplemental material

9.1 Ionospheric threat model defined regions

The plot of the regions will be updated in the next report to reflect the additional IGP point that was recently added.

9.2 Code-noise and multi path

9.2.1 Analysis of poor performing sites

For the second quarter of 2011, MPR-A was found to have poor CNMP performance. To follow up the results for the third quarter of 2011 for MPR-A are included here in Figure 9.1. There is no ongoing CNMP issue with MPR-A, so the issue will be considered resolved.

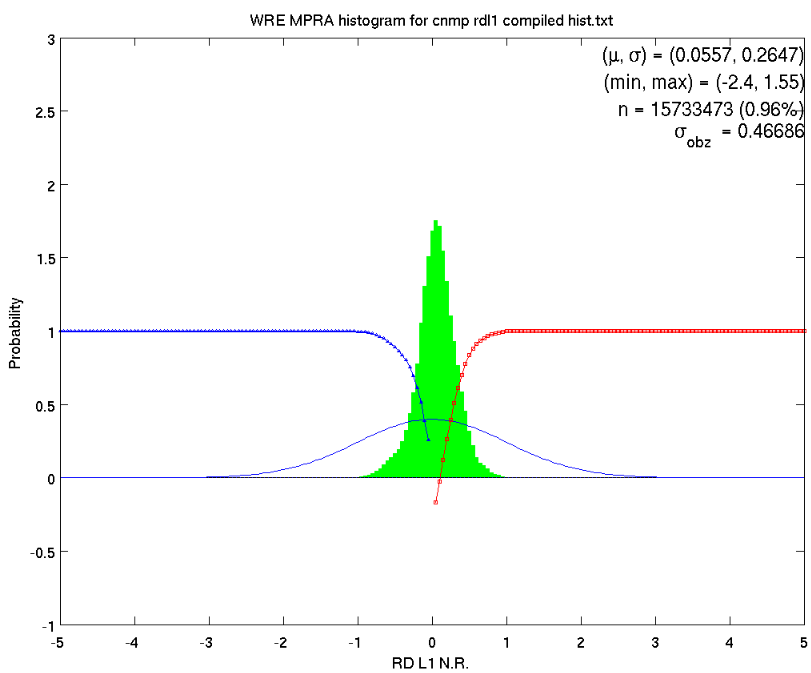


Figure 9.1: MPR-A RDL1

Table 9.1: Poor performing WREs for CNMP

WRE	L1				IFPR				Delay			
	μ	σ	$\lvert max \rvert$	pass?	μ	σ	$\lvert max \rvert$	pass?	μ	σ	$\lvert max \rvert$	pass?
29, Houston_C	0.069	0.45	3.35	yes	0.109	0.42	3.15	yes	-0.117	0.41	2.75	yes
6, Anchorage_A	-0.040	0.28	2.35	yes	0.002	0.29	2.90	yes	-0.022	0.30	2.90	yes
56, New_York_C	-0.042	0.33	2.65	yes	-0.007	0.32	2.55	yes	-0.010	0.31	2.30	yes
20, Denver_C	-0.057	0.34	2.70	yes	-0.009	0.35	2.45	yes	-0.014	0.35	2.20	yes
82, Fairbanks_B	-0.032	0.20	3.20	yes	-0.015	0.19	1.60	yes	0.006	0.20	1.50	yes

Table 9.1 contains information on the worst performing sites of the quarter. Table 9.1 is generated by ranking the worst threads for each of the three statistics (worst meaning largest zero-centered sigma overbound). The worst thread in a category was given 10 points, while the second worst was given 9 points, and so on. The points were totaled across all three metrics to give table 9.1. Only one WRE per WRS appears, so that 5 different WRS are on the table (i.e. the three Houston threads would otherwise take up 3 of the 5 spots).

9.3 Equations

9.3.1 Code-carrier-coherence

$$ccc_y^j = \frac{\sum_i \left[\frac{\mu^j_{y,cnmp,i}}{(\sigma^j_{y,cnmp,i})^2} \right]}{\sum_i \left[(\sigma^j_{y,cnmp,i})^{-2} \right]}$$

where:
$\mu^j_{y,cnmp,i}$ is the instantaneous difference of the code measurements vs. the adjusted carrier phase for SV j as measured by WRE i for each $y \in L1, L2$,
$\sigma^j_{y,cnmp,i}$ is the standard deviation of the CNMP measurements for SV j as measured by WRE i for each $y \in L1, L2$,
$|ccc^j_y|$ is the carrier-smoothed, CCC monitor output statistic generated by a first-order smoothing filter with $\tau_c = 25$ seconds.
The probability of the CCC metric exceeding the Maximum Error Range Residual (MERR) is:

$$P_{HMI} = \Phi^R \left(\frac{\text{MERR} - \text{MDE}_{\text{monitor}}}{\sqrt{\sigma^2_{udre,nominal} + F^2_{PP}\sigma^2_{uive,nominal}}} \right)$$

$$\text{MERR} = 5.33\sqrt{\sigma^2_{udre} + (F_{pp}\sigma_{uive})^2}$$

$$\text{MDE} = T_{ccc} + k_{ma}\sigma_{test}$$

$$(\Phi^R)^{-1}(P_{md}) = k_{md}$$

9.3.2 Code-noise and multipath

The Cumulative Density Function (CDF) is defined as:

$$\Phi^R(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{\frac{-t^2}{2}} dt$$

$$\Delta(x) = \begin{cases} \frac{\Phi^R_{theory}(x) - \Phi^R_{data}(x)}{\Phi^R_{theory}(x)} & \text{if } x \geq 0 \\ \frac{[1-\Phi^R_{theory}(x)] - [1-\Phi^R_{data}(x)]}{1-\Phi^R_{theory}(x)} & \text{if } x < 0 \end{cases}$$

CNMP passes when the following condition is met:

$$\Delta(x) > 0 \text{ for all } |x| > 0.25$$

9.4 Tables

9.4.1 Code-carrier-coherence

UDREI	$\tau_{ccc,gps}$	$\tau_{ccc,geo}$
5	1.94	0
6	1.99	0
7	3.00	0
8	3.88	0
9	4.00	0
10	6.00	2.5
11	12.0	3.0
12	40.0	7.1
13	100	20

Table 9.2: CCC trip thresholds per UDRE index

9.4.2 WRE listing

Location	**Symbol**
Bethel, Alaska	BET
Billings, Montana	BIL
Barrow, Alaska	BRW
Cold Bay, Alaska	CDB
Fairbanks, Alaska	FAI
Honolulu, Hawaii	HNL
Juneau, Alaska	JNU
Mrida, Yucatn	MMD/Q9C
Mexico City	MMX/Q9A
Puerto Vallarta, Jalisco	MPR/Q9B
San Jos del Cabo, Baja California Sur	MSD/Q9E
Tapachula, Chiapas	MTP/Q9D
Kotzebue, Alaska	OTZ
Iqaluit, Nunavut	YFB
Gander, Newfoundland and Labrador	YQX
Winnipeg, Manitoba	YWG
Goose Bay, Newfoundland and Labrador	YYR
Albuquerque, New Mexico	ZAB
Anchorage, Alaska	ZAN
Aurora, Illinois	ZAU
Nashua, New Hampshire	ZBW
Leesburg, Virginia	ZDC
Longmont, Colorado	ZDV
Fort Worth, Texas	ZFW
Houston, Texas	ZHU
Hilliard, Florida	ZJX
Olathe, Kansas	ZKC
Palmdale, California	ZLA
Salt Lake City, Utah	ZLC
Miami, Florida	ZMA
Memphis, Tennessee	ZME
Farmington, Minnesota	ZMP
Ronkonkoma, New York	ZNY
Fremont, California	ZOA
Oberlin, Ohio	ZOB
Auburn, Washington	ZSE
San Juan, Puerto Rico	ZSU
Hampton, Georgia	ZTL

Table 9.3: WRE listing

9.4.3 Space vehicle designators

SV	Common name	Int. designator	Owner	Launch date
CRE	Anik F1-R	2005-036A	Inmarsat	2005-09-08
CRW	Galaxy 15 or PanAm	2005-041A	Intelsat	2005-10-13
AMR	Inmarsat 4-F3 or AMR	2008-039A	Inmarsat	2008-08-18

Table 9.4: GEO satellite information I

SV	PRN	GUST sites	Position	Period	Apogee	Perigee	RCS
CRE	PRN 138	WBN BRE	$107.3 \pm 0.01°$W	1436.09min	35796m	35777m	$5.0139m^2$
CRW	PRN 135	LTN APC	$133.0 \pm 0.01°$W	1436.08min	35798m	35974m	$3.9811m^2$
AMR	PRN 133	SZP HDH	$98.0 \pm 3.01°$W	1436.11min	35776m	35776m	$2.1948m^2$

Table 9.5: GEO satellite information II

9.5 References

WAAS CDRL A014-011 *Algorithm Contribution to HMI for WAAS*

9.6 GEO signal quality analysis (GSQA)

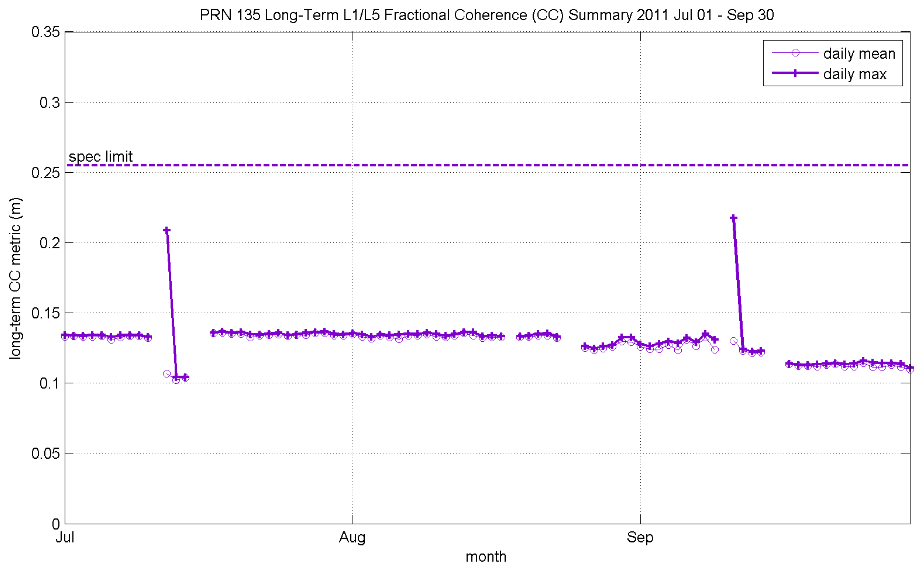


Figure 9.2: Long-term fractional coherence (CC) for PRN 135

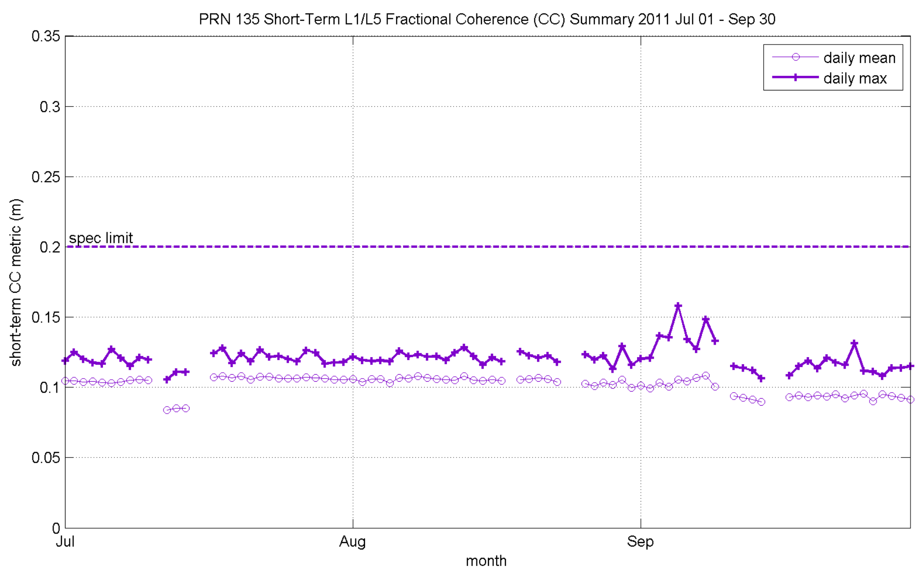


Figure 9.3: Short-term fractional coherence (CC) for PRN 135

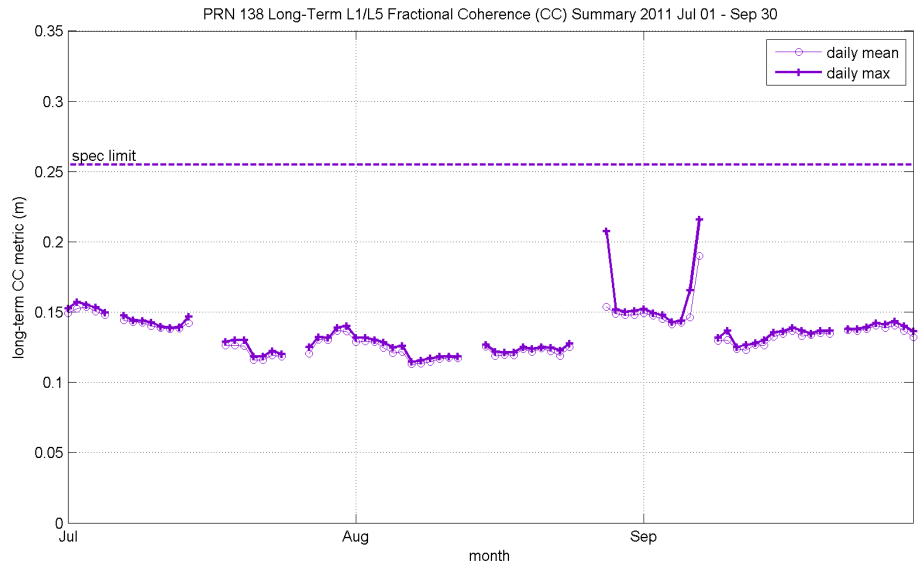


Figure 9.4: Long-term fractional coherence (CC) for PRN 138

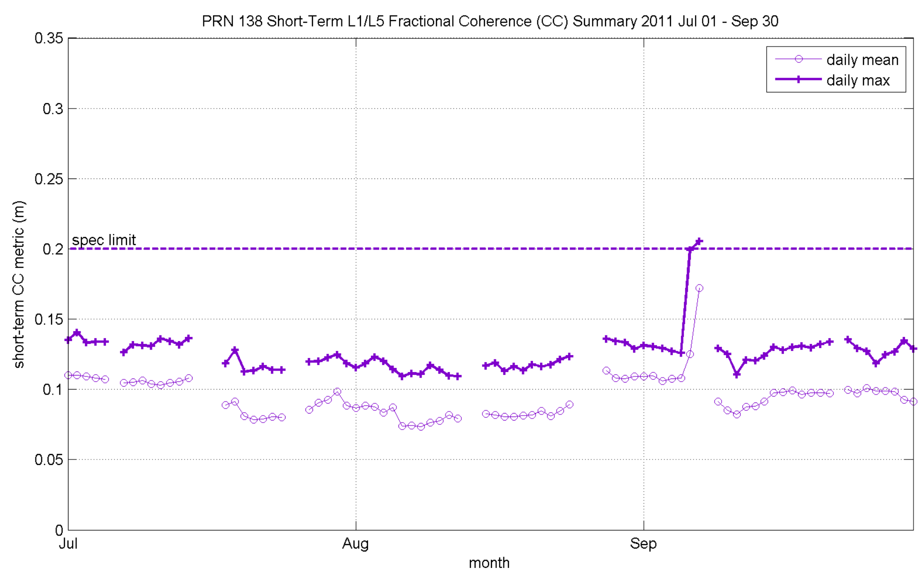


Figure 9.5: Short-term fractional coherence (CC) for PRN 138

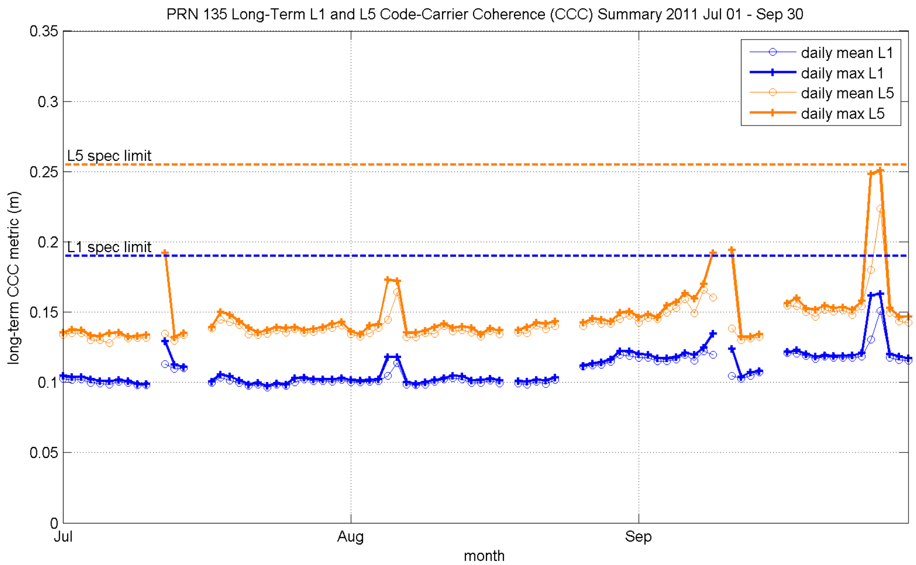


Figure 9.6: Long-term code-carrier coherence (CCC) for PRN 135

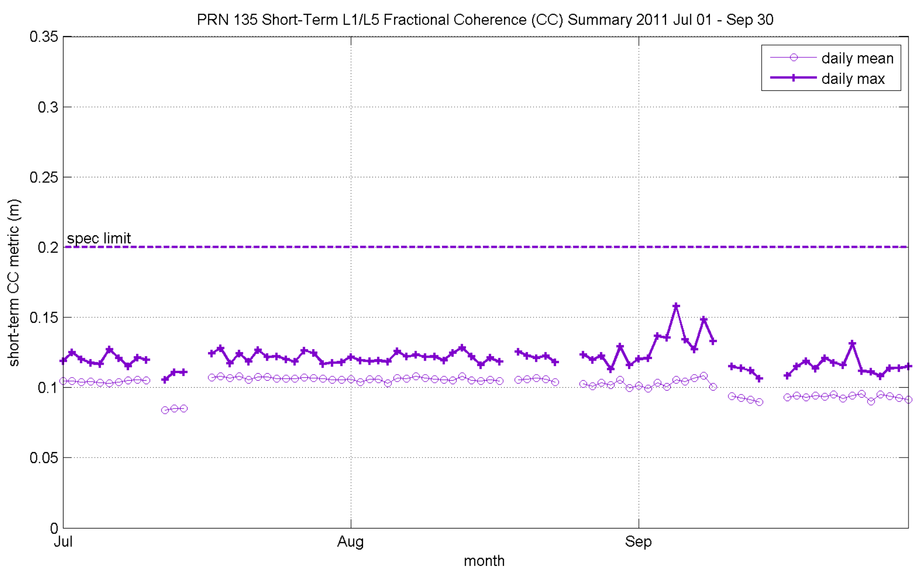


Figure 9.7: Short-term fractional coherence (CC) for PRN 135

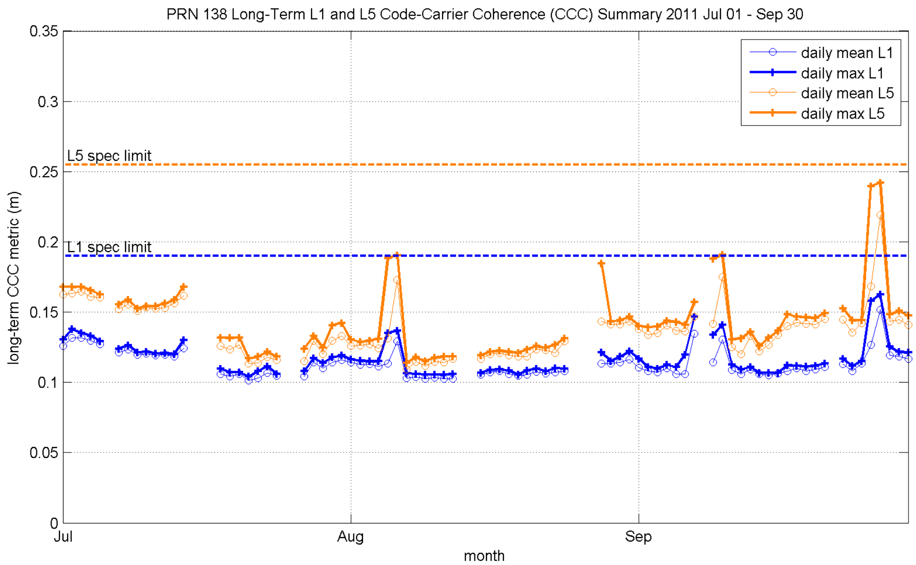


Figure 9.8: Long-term code-carrier coherence (CCC) for PRN 138

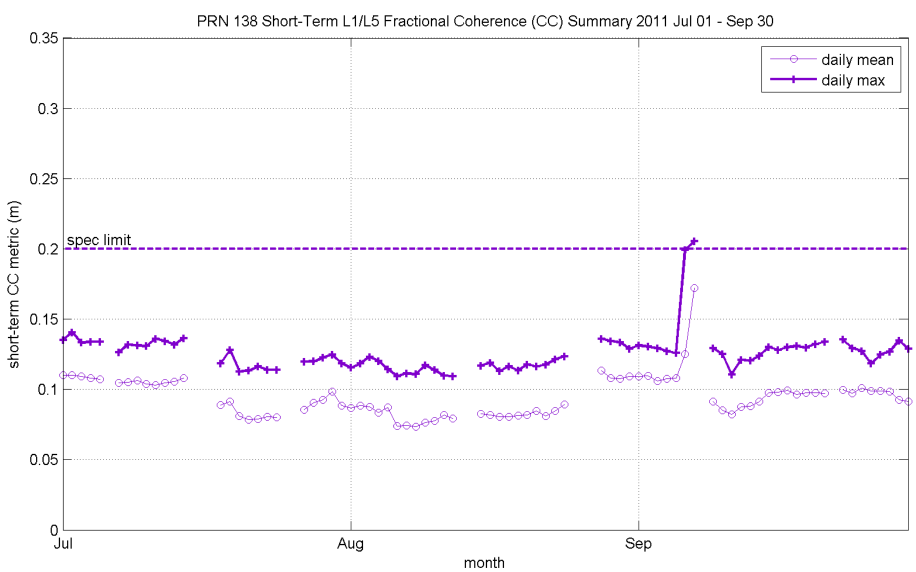


Figure 9.9: Short-term fractional coherence (CC) for PRN 138

9.7 L1L2 bias levels

9.7.1 Satellites from CP1

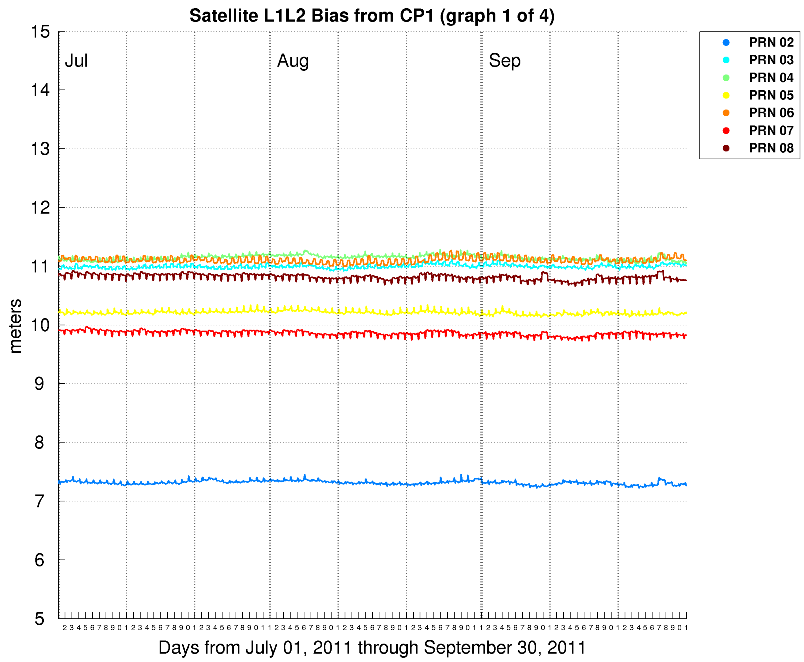


Figure 9.10: L1l2 bias for PRNs 2 through 8 from CP1

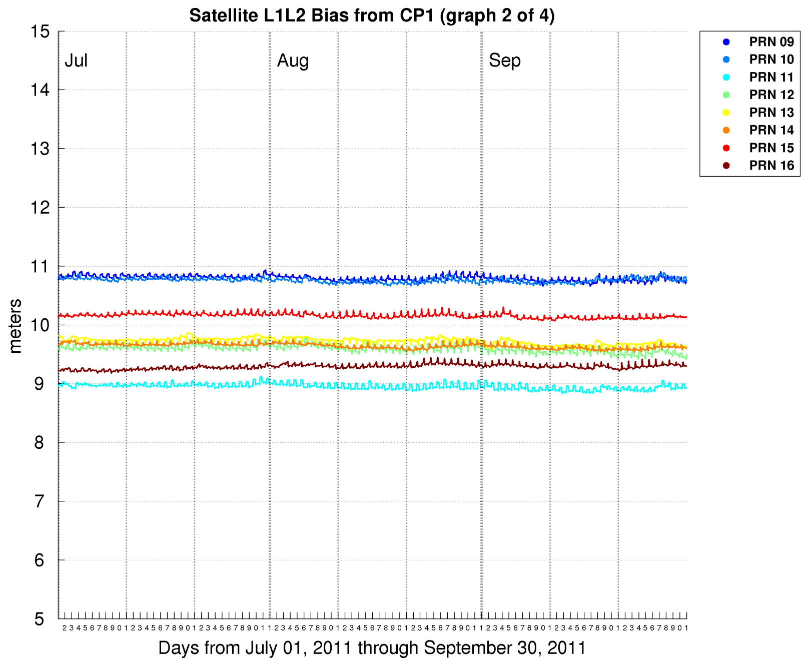


Figure 9.11: L1l2 bias for PRNs 9 through 16 from CP1

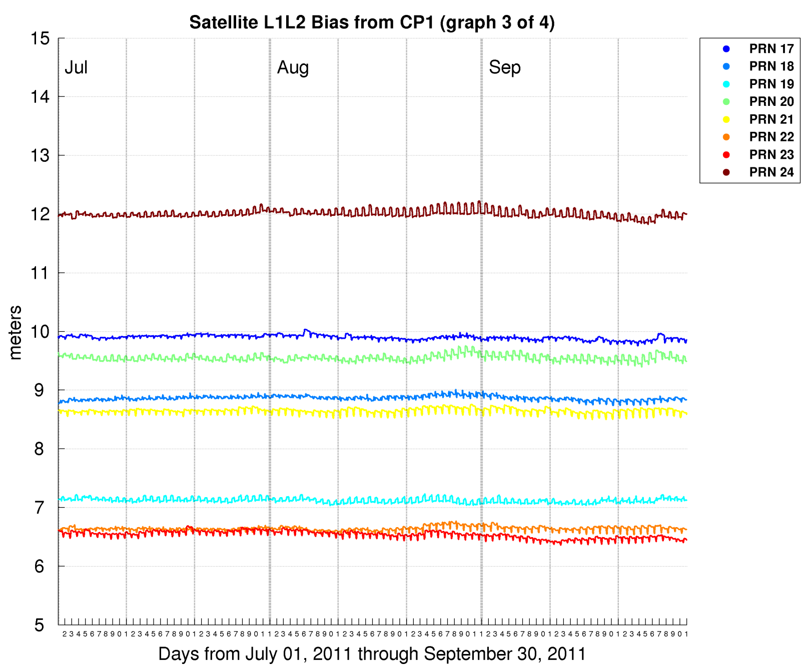


Figure 9.12: L1l2 bias for PRNs 17 through 24 from CP1

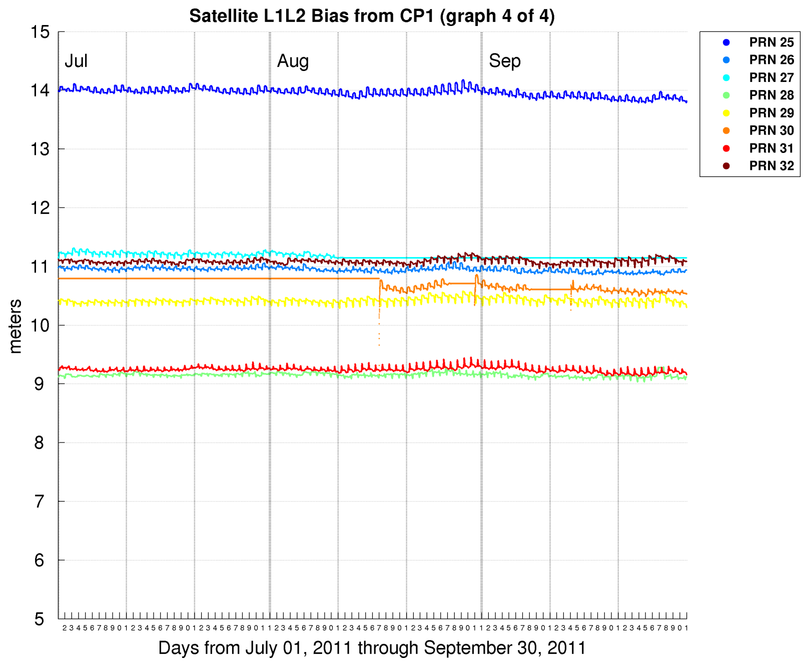


Figure 9.13: L1l2 bias for PRNs 25 through 32 from CP1

9.7.2 Satellites from CP2

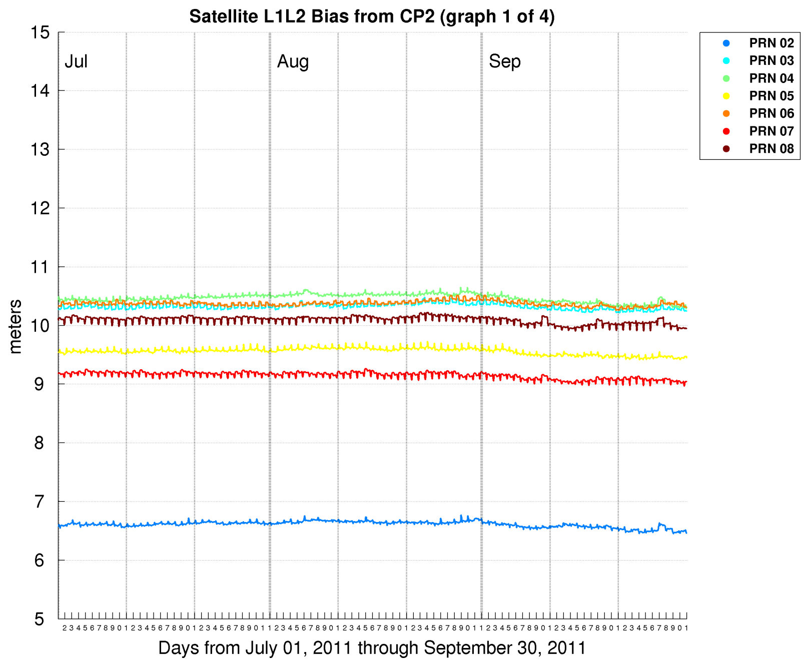


Figure 9.14: L1l2 bias for PRNs 2 through 8 from CP2

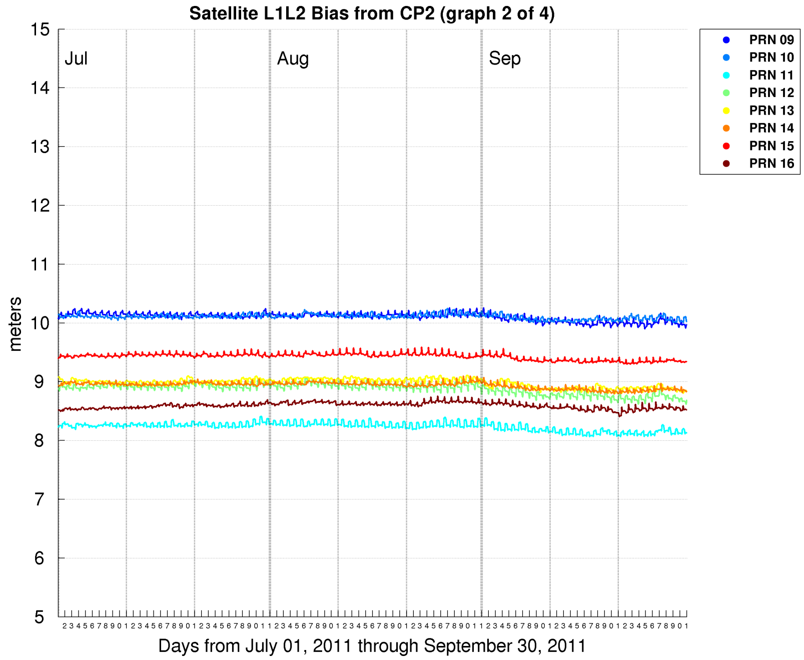


Figure 9.15: L1l2 bias for PRNs 9 through 16 from CP2

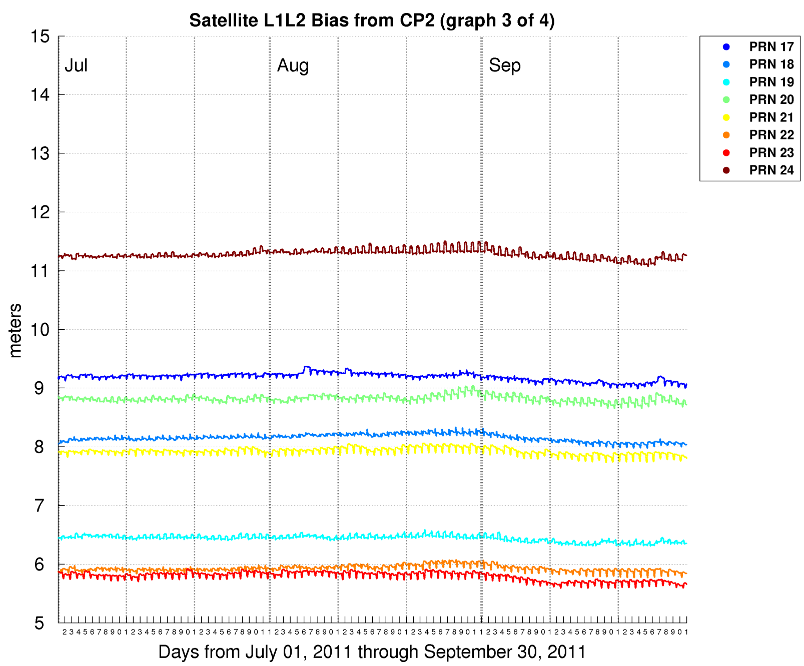


Figure 9.16: L1l2 bias for PRNs 17 through 24 from CP2

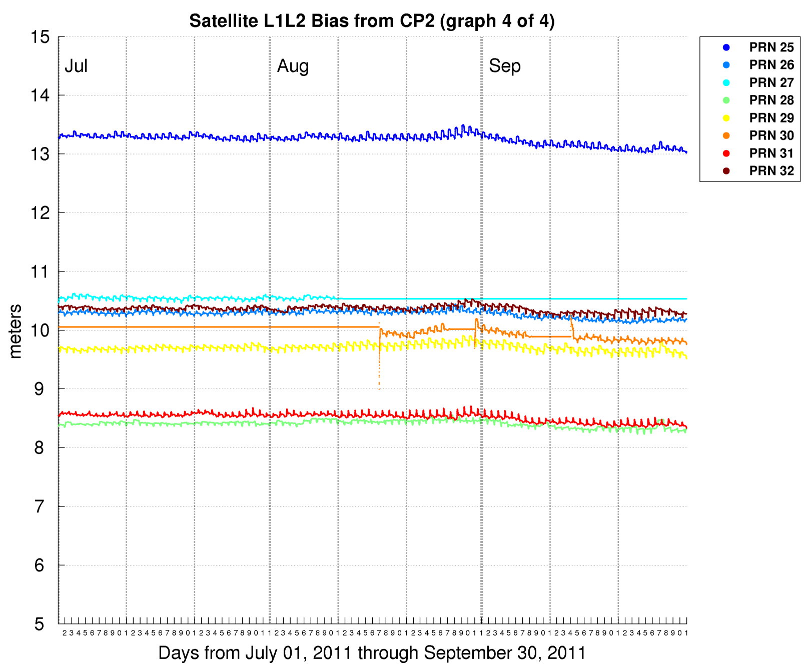


Figure 9.17: L1l2 bias for PRNs 25 through 32 from CP2

9.7.3 WREs from CP1

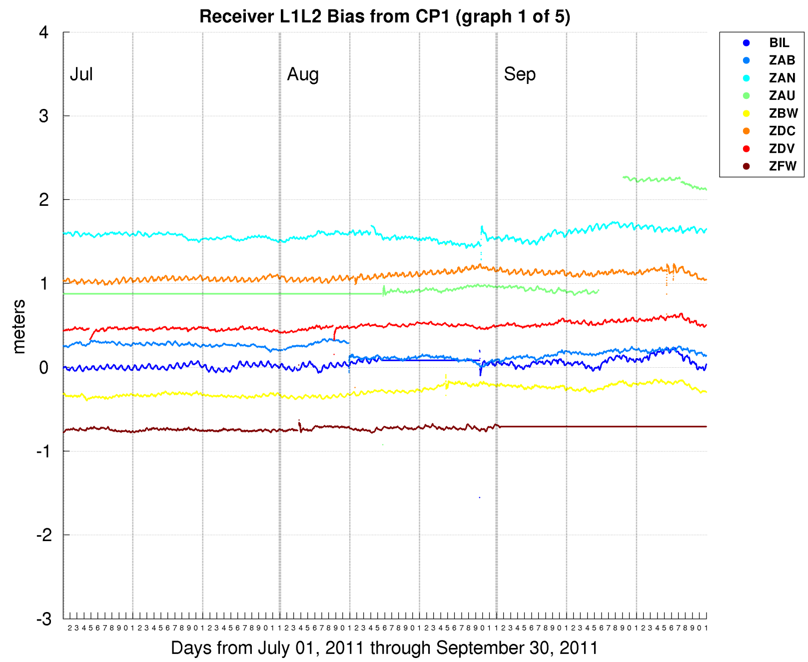


Figure 9.18: L1l2 bias for BIL ZAB ZAN ZAU ZBW ZDC ZDV ZFW from CP1

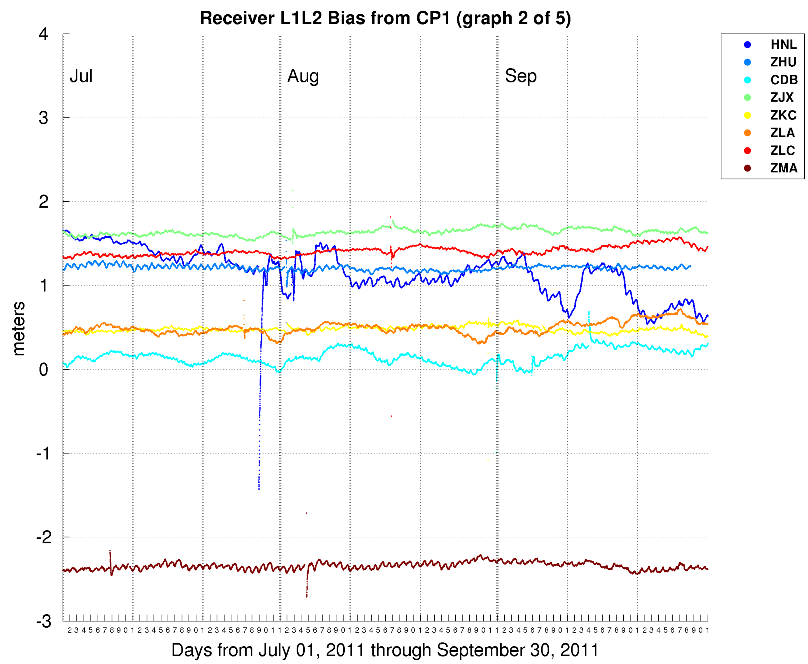


Figure 9.19: L1l2 bias for HNL ZHU CDB ZJX ZKC ZLA ZLC ZMA from CP1

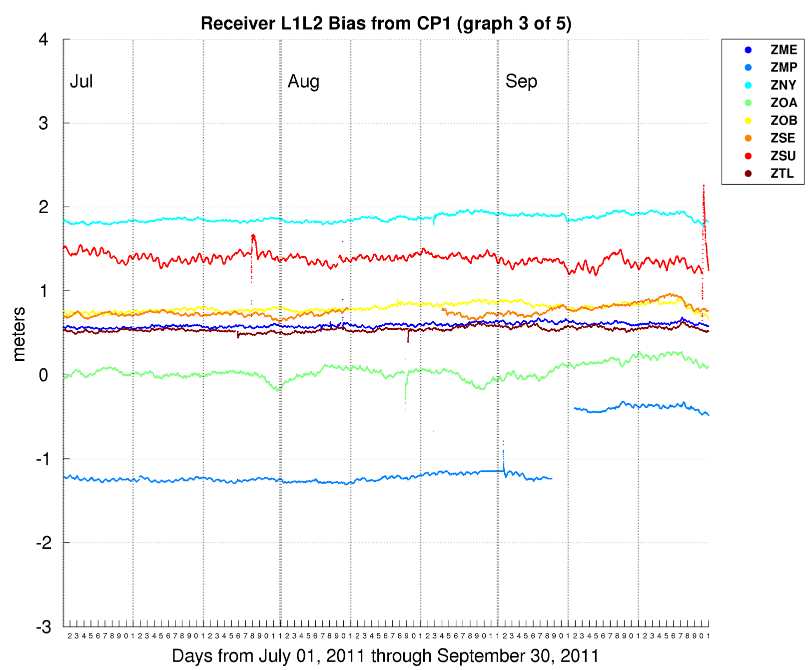


Figure 9.20: L1l2 bias for ZME ZMP ZNY ZOA ZOB ZSE ZSU ZTL from CP1

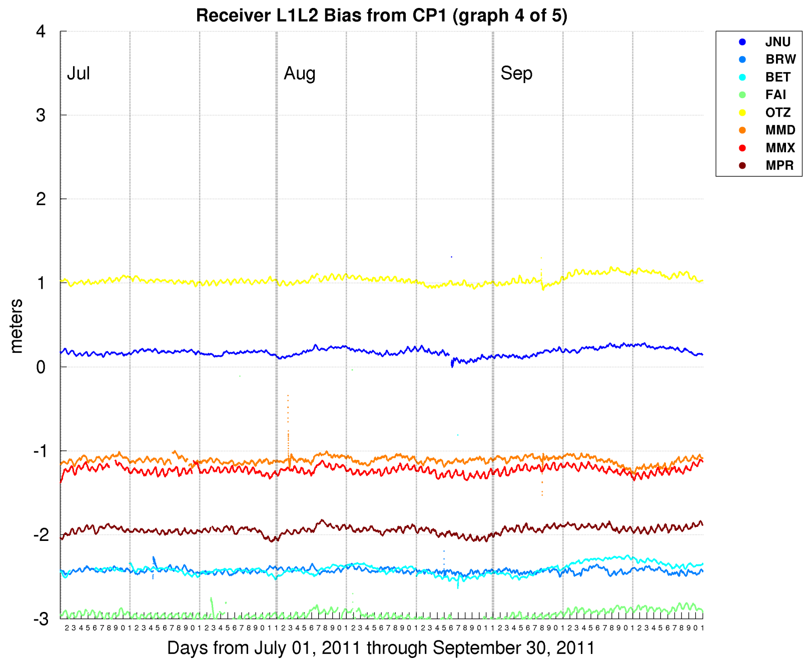


Figure 9.21: L1l2 bias for JNU BRW BET FAI OTZ MMD MMX MPR from CP1

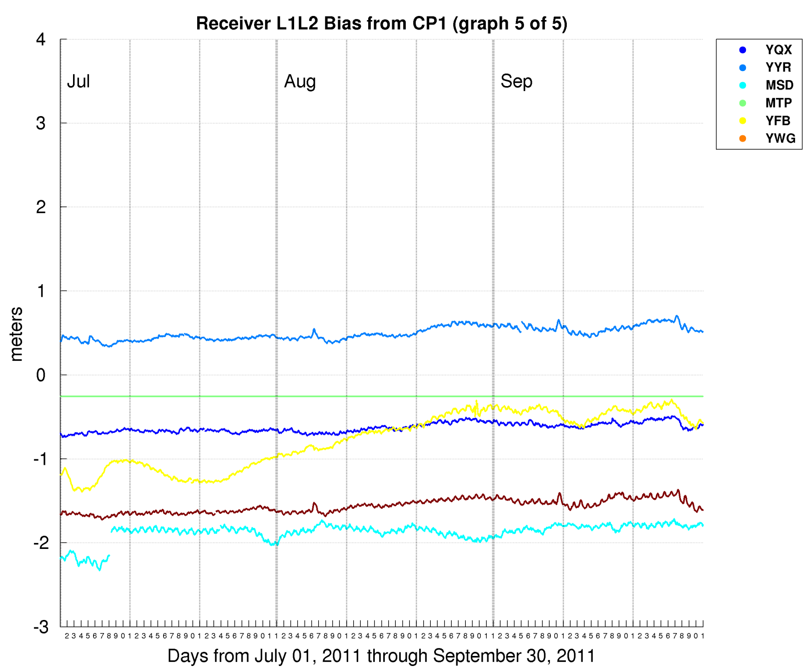


Figure 9.22: L1l2 bias for YQX YYR MSD MTP YFB YWG from CP1

9.7.4 WREs from CP2

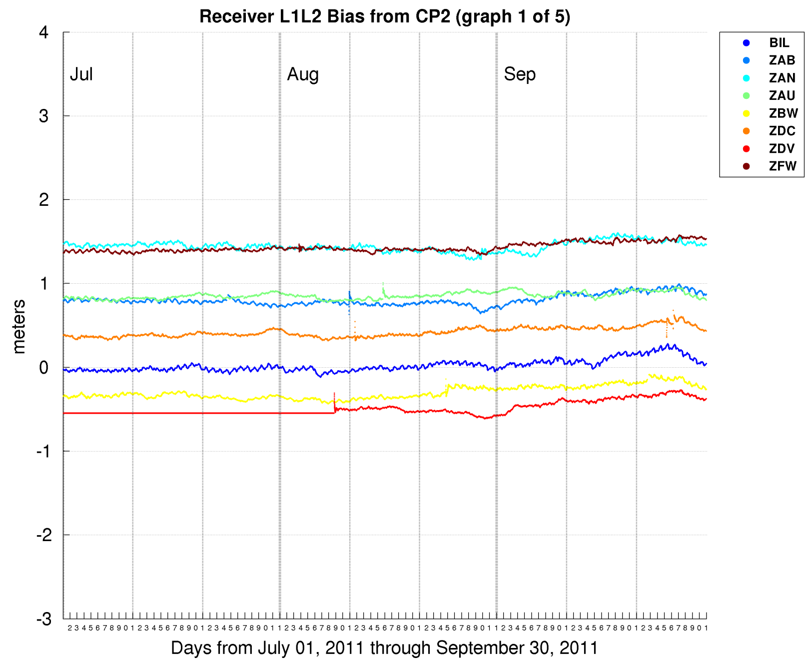


Figure 9.23: L1l2 bias for BIL ZAB ZAN ZAU ZBW ZDC ZDV ZFW from CP2

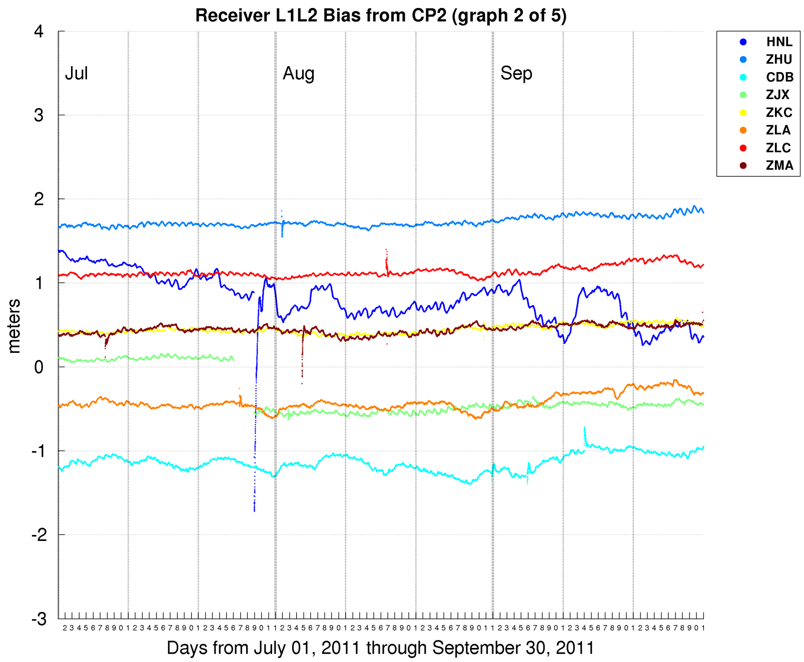


Figure 9.24: L1l2 bias for HNL ZHU CDB ZJX ZKC ZLA ZLC ZMA from CP2

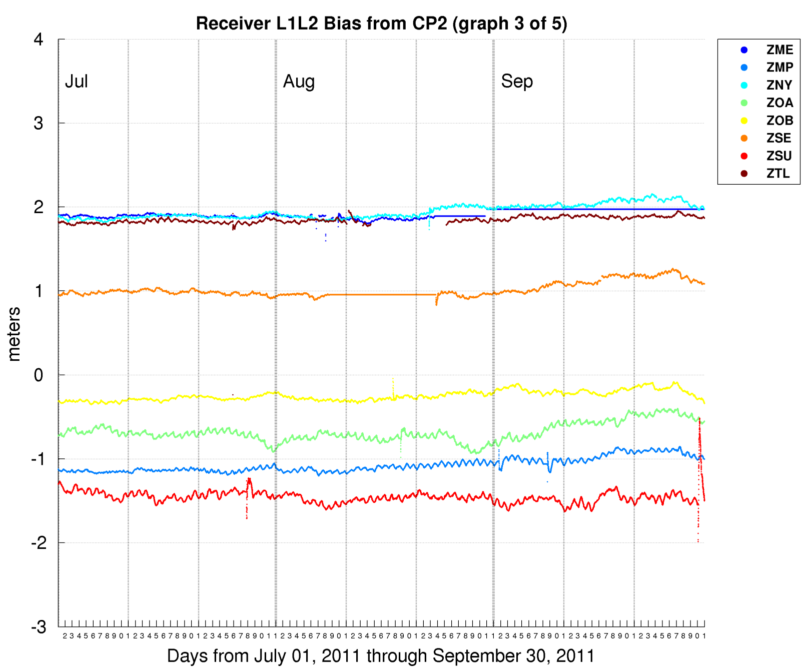


Figure 9.25: L1l2 bias for ZME ZMP ZNY ZOA ZOB ZSE ZSU ZTL from CP2

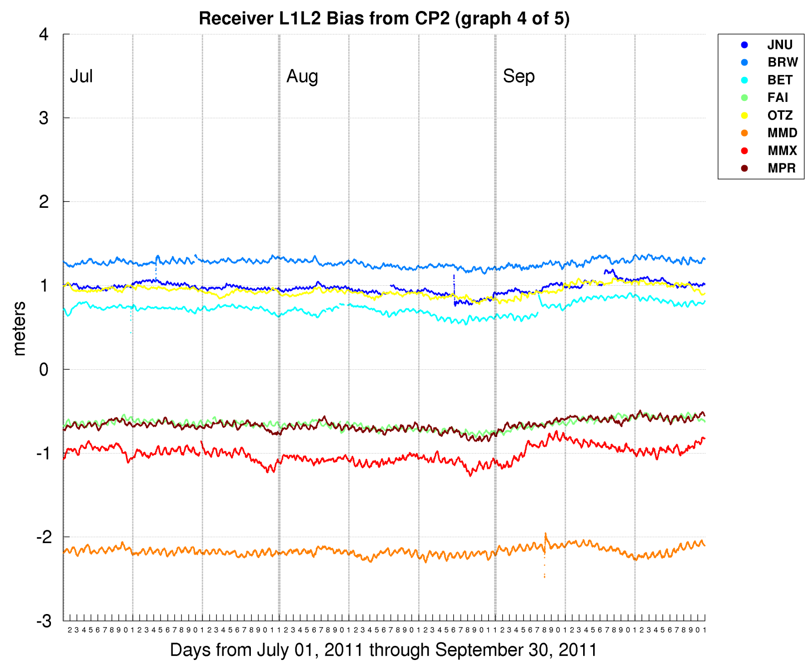


Figure 9.26: L1l2 bias for JNU BRW BET FAI OTZ MMD MMX MPR from CP2

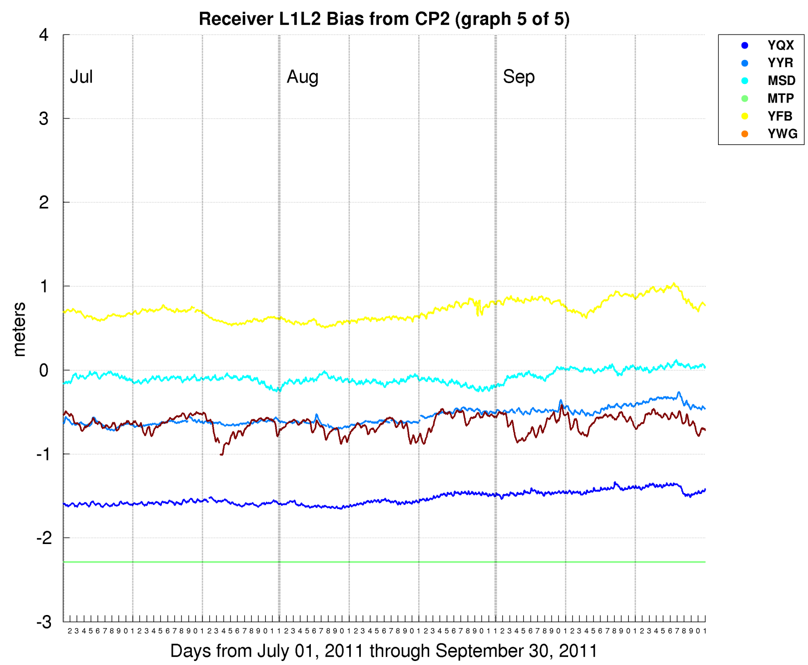


Figure 9.27: L1l2 bias for YQX YYR MSD MTP YFB YWG from CP2

Appendix A

Assertions

A.1 Code-carrier-coherence

The *a priori* probability of a CCC failure is less than $1e^{-4}$ per set of satellites in view per hour for GPS satellites and $1.14e^{-4}$ for GEO satellites.

A.2 Code-noise and multipath

The HMI document for CNMP states:

> The Code Noise and Multipath (CNMP) error bound is sufficiently conservative such that the error in linear combinations of L1 and L2 measurements is overbounded by a Gaussian distribution with a sigma described by the Root Sum Square (RSS) of L1 and L2 CNMP error bounds except for biases, which are handled separately.

A.3 Antenna positioning

The Root Sum Square (RSS) position error for each WAAS reference station antenna is 10 centimeters or less when measured relative to the International Terrestrial Reference Frame (ITRF) datum for any given epoch (Mexico City is allowed 25 centimeters). The ITRF datum version (realization) is the one consistent with the World Geodetic System's latest reference coordinate system (WGS-84) and also used for positions of the Global Positioning System (GPS) Operational Control Segment monitoring stations.

A.4 Ionospheric threat model

The values of $\sigma_{\text{decorr\_undersampeled}}$ and ϵ_{iono} adequately protect against worst case undersampled ionosphere over the life of any ionospheric correction message, when the storm detectors have not tripped.

A.5 Satellite Clock Runoff

The *a priori* probability of a GPS satellite failure resutling in a rapid chagne in the GPS clock correction is less than $1.0\text{x}10^{-4}$ per satellite.

Appendix B

Coding standards and guidelines

B.1 Introduction

The standards and guidelines for the Offline Monitoring effort are recorded here."Standards represent a "rule" that is assumed to be "enforceable", that is, it has been agreed to by the stakeholders and recorded as official. PCRs can (but not necessarily will) be blocked due to lack of upholding a standard. Furthermore, standards can certainly have exceptions, but these are dealt with on a case-by-case basis and recorded as such. "Guidelines", on the other-hand, are not enforceable. Guidelines represent good ideas and common engineering practices across the group. Program Change Request (PCR)s cannot be blocked as a result of not following a guideline.

Transitioning from a guideline to a standard is a done on a case-by-case basis. While there is no hard and fast rule for how this is done, the steps for this usually contain an initial agreement by the stakeholders (which included management and engineers) that a standard ought to be adopted, a resource (with associated level of effort) assigned, and an initial assessment as to how much work is involved (estimated end date, etc). The process of transitioning from a guideline to a standard is known as refactoring, and the practice is encouraged as long as stakeholder buy in is considered at each step.

The standards and guidelines are differentiated by the words "shall" and "should".

B.2 Integrity standards for MATLAB

The integrity standards for MatLab were developed during the WAAS FLP Release 6/7 time frame. These standards represent rules that, if broken, could lead to incorrect or erroneous results (not necessarily a tool crash but actual incorrect output). These are documented in the WAAS HMI document (in section 4.3.3 of that document) and are repeated here in their condensed form. More detail can be found in the WAAS HMI document. Note that these standards are enforced by use of the CD_STD_CHK tool which parses the files/scripts line by line checking for breaches.

- MATLAB Calling Ambiguity:
  - Ensure that no MATLAB keywords are used as function names.
  - Use functions, not scripts.
  - Function name and filename being the same is required.
  - One function per file required.
  - Functions should not be influenced by anything other than inputs:

  - No **global** variables.
  - No **persistent** variables.

- MATLAB Functionality Ambiguity:
  - The **squeeze** function shall not be used.

- Windows Ambiguity:
  - The **exist** function shall not be used.

- Coding Clarity:
  - The **eval** command shall not be used.

- Consistency Check:
  - OSP consistency must be addressed.
  - Critical parameters need to not be hardcoded in the tools

- Repeatability:
  - The actual scripts that were used to generate the data, tables and plots need to be captured along with the outputs, as well as a mapping to the actual data set used.

B.3 HMI/OLM coding standards

Along with the Integrity standards described in section 9.4.1, there exist several "Offline Monitoring" coding standards. These are coding standards which are attached to the running of the Offline Monitoring code and which have been identified as required for the processing of the offline monitoring data. Currently, there are five standards:

- All open files shall be closed
  - This requirement should be applied over all tools for all Offline Monitoring scripts. This requirement is simple, as it just requires that any file which is opened be appropriately closed in the same script that opens it.

- In MatLab, the **figure** command needs to always have a file ID associated with the open figure
  - The MatLab coding language allows the user to create figures without assigning a file id variable. Closing the specific figure is then impossible in general, and the figure must be closed either by keeping track of the current figure ID, or by applying the /textbfclose all command. Neither of these is desired, and as such, each figure must have a unique file ID in memory.

- In MatLab, the close all command shall not be used.
  - The **close all** command is issued to close all figures with or without a file ID. As standards are in place to assign a file ID for all figures, this line of code is unnecessary and should not be used.

- All open figures should have the option to be closed
  - The MatLab tools should not leave open figures after the analysis is run (by default). For particular tools, it may be desirable to keep the plots up on the screen, but the option to close them should be implemented
- Use **cs_saveplot** or **cs_saveexact_plot** for saving plots in MatLab
  - The **cs_saveplot** function is a common script which saves figures to results directories. There are several options when saving a plot, as using this function allows one place to modify the saving requirements.

B.4 File naming conventions

While no complete convention exists, there are standard "pieces" which shall be enforced for the OLM effort. These refer to the labels inside the actual name of the tool which refer to information in the data file. The requirements are listed below:

- Filenames shall be named using a prefix, followed by an "_", then the ISO8601 date in the form of YYYY-MM-DD, followed by a "." and the extension.
- Filenames shall use lowercase letters, integers, underscores and dashes.
- There shall be no more than one "." in a file name
- Text files shall end with the suffix ".txt"
- Binary files shall end with the suffix ".bin"
- Files which contain data for a particular PRN shall have a six-character label of the form "prnDDD" where DDD are the three digits referring to the PRN number. PRNs less than 100 shall have a leading zero, and PRNs less than 10 shall have two leading zeros.
- Files which contain data for a particular WRE shall have a six-character label of the form "wreDDD" where DDD are the three digits referring to the WRE number. WREs less than 100 shall have a leading zero, and WREs less than 10 shall have two leading zeros. Also note that WREs start counting at 0, so for a 38-station system, the WRE number range from 0 to 113.
- Files which contain data for a particular UDREI shall have a seven-character label of the form "udreiDD" where DD are the two digits referring to the UDREI. UDREIs less than 10 shall have a leading zero. Also note that UDREIs start counting at 0, so UDREIs range from 0 to 15.
- Files which contain data for a particular GIVEI shall have a seven-character label of the form "giveiDD" where DD are the two digits referring to the GIVE index. GIVEIs less than 10 shall have a leading zero. Also note that GIVEIs start counting at 0, so GIVEIs range from 0 to 15.

B.5 OLM file formats

Standard file formats have been defined for four types of files, listed below. These represent standards, and are enforceable requirements.

B.5.1 Histogram files

The number of columns in a histogram file shall be one more than the sum of the number of slices. For example, is a histogram file contained an aggregate histogram, slices by UDREI and slices by PRN (both GEO and GPS), there would be 1+1+16+44 = 62 columns. The first column is the bins, the second column is the aggregate, columns 3 through 18 are the 16 UDRE slices (with columns 17 and 18 being NM and DU), columns 19 through 50 are the 32 GPS PRNs, columns 51 through 60 are the GEO PRNS (which the last five being held in reserve), column 61 is the aggregate GPS histogram and column 62 is the aggregate GEO histogram.

- Histogram files are stored as raw counts, not probabilities and the bins are recorded as bin centers.
- Histogram files can be daily or compiled into a report.
- The histogram file shall have a header which has column headings lined up with the columns of the data.

B.5.2 Statistics files

Each statistic in the statistics file shall be defined to be able to be computed using bins (either centers or edges) and the raw counts, and each column in the histogram file shall have all statistics computed for it. Thus, the dimensions of a statistics file shall be as such.

- The number of rows is the same as the number of statistics
- The number of columns shall be the same as the number of slices

In order to account for the column of bins, a statistic index is placed there, so that each column in a histogram file corresponds to the same column in the statistic file. There are currently fifteen descriptive statistics computed for each histogram file:

1. Counts
2. Mean
3. Standard Deviation
4. Minimum
5. Maximum
6. Absolute Maximum
7. Sigma Over-bound (Zero-centered)
8. Sigma Over-bound (Mean-centered)
9. 1st Quartile
10. Median (2nd Quartile)
11. 3rd Quartile

12. Mean of Absolute Value

13. Standard Deviation of Absolute Value

14. RMS

15. Variance

The statistics file shall have a header which has column headings lined up with the columns of the data, as well as the list of statistics represented in the file. Statistics files can be daily or compiled into a report.

B.5.3 Time-series files

Time series files represent a quantity which evolves over time. These can be any quantity, but currently only satellite quantities are created. Thus, the file naming convention for PRN (described in 4.4.2) are utilized.

The time series files have as the first three columns three different representation of time. The first is WAAS time, the second is Universal Time, Coordinated (UTC) in ISO-8601 format (HHMMSS) and the third is seconds in the day. After the first three columns, more columns can be added. The intent of the time series file is to have all of the data which a plot would require in the subsequent columns. Time series files are only attached to daily quantities, but several time series files could be concatenated together to create a multi-day files (and plot).

B.5.4 Quantity files

Quantity files contain two dimensional slices of a particular quantity. For example, creating a UDREI/ GPS PRN slice for the absolute maximum of the CCC metric would allow a user to see which satellite have issues at which UDREIs. As both dimensions are used, only one statistic per file can be represented. Quantity files are currently only daily files, but they could be created for a compiled data for some statistics.

B.5.5 Quarterly files

Quarterly files are the files which are plotted over the period of the quarter. Thus, the first column is the number of the day in the quarter and the second (and subsequent) columns are data to be plotted. The data set can be customized for the particular plot.

B.6 Histogram slicing and bin requirements

For many of the analyses, histograms are used to show compliance to particular requirements. As there is inherent averaging in the creating an aggregate histogram, the concept of slicing was introduced early in the WAAS analysis process. This requires that data from (potentially) different error sources are not averaged into a single histogram, but are examined separately. In order to compile results across multiple days (and data sets), both the bin centers and the number of columns for each type of slice needs to be fixed. Modifying these requirements at a later date would make long term trending difficult, if not impossible.

The table below shows the bin requirements for the data files which are to be histogrammed by one or more of the Offline Monitoring analyses. Note that the minimum and maximum data cutoffs are defined to be the bin EDGES, not the bin centers. Thus, the bin centers are in between the defined edges. The

Data description	Filename	Data min	Bin width	Data max	Units
Raw CCC metric (L1 and L2)	qstats*	-8.0	0.01	8.0	meters
CCC metrics / trip threshold	qstats*	-3.0	0.01	3.0	none
CCC metrics / MERR value	qstats*	-2.0	0.001	2	none
Max SQM metric	sqm_reduced*	0	0.001	2.0	none

Table B.1: Data histogram bin requirements

table below shows the slicing requirements. These include the number of columns and designations for each type of slice.

Slice description	# of columns	Column description
Aggregate	1	This is the histogram of the entire metric. There is always one column, no more.
UDRE index	16	Columns 1-14 represent the data associated with a UDREI of one less than the column, i.e., UDREIs of 0-13. The last two columns represent satellites which are NM (not monitored) and DU (don't use) respectively.
PRN	44	The PRN slices come in a few sets. The first set is the first 32 PRNs. The second set is 10 columns devoted to past, current and future GEOs. The first five GEO columns are the GEO PRNS of 122, 133, 134, 135, and 138. The next five columns are reserved for future GEO PRNS. Finally, the last two columns are the aggregate of the GPS and GEO data respectively.

Table B.2: Data slicing requirements

B.7 OLM process and procedures

B.7.1 Schedule and meetings

The OLM group will meet approximately twice a quarter. One set of meetings is to be set for the first week of the new quarter to go over plans for that quarter. The second set of meetings is to be set for shortly before the WIPP. For both meetings, the general purpose is to plan for the next WIPP or the next OLM report, as the case may be. At the meetings, task lists with priorities and resources are created, to be reviewed at the next set of meetings. The OLM document is release once a quarter. The analyses should be running during the quarter, and should be being reviewed on a periodic basis. Once the quarter ends, three dates are pertinent.

- Two weeks after the quarter ends All analyses complete

- Four weeks after the quarter ends Draft document released
- Six weeks after the quarter ends Final document completed

B.7.2 Data processing

The data processing strategy for the OLM document is to currently run the safety processor prototype on blocks of snoop files, approximately one week long. The blocks are then run in succession to create a quarters worth of data, which spans the three months of the quarter in question. The blocks of data are usually a week long, but due to data issues, as well as week VS month cutoff issues, the lengths of the individual blocks may vary.

Standard processing is applied across the analyses for the individual days. This includes the creation of histogram files, histogram statistics files, time series files, and two dimensional quantity files. There are associated plots as well for each of the above mentioned plots. In addition to the standard processing, analyses specific to the tool are also run for each day. In this way, analysis specific data reduction and results are generated on a daily basis.

Once the daily analyses have been run, the results are compiled into a report directory. This includes the accumulation of histogram data, and the plotting of statistics across the quarter.

B.7.3 Tool strategy

Tool builds created at both Safety and Operations Support (SOS) and Sequoia Research Corporation (SRC) are valid, and need to have proper versioning attached to them. All of the results from a single quarter should come from one version of a tool, and this version should be recorded in the OLM document.

Both regression testing and coding standards checking are as automated as possible, and both have tools associated with them. For the regression testing, the "reg" MatLab tool has been created. This tool is stored in the OLM repository, and runs the regression tests for the MatLab tools in an automated way (from reg_go). The coding standards are checked via the CODE_STD_CHK tool. There is one standard which checks that all of the scripts are in the top-level directory, followed by the ten integrity standards, followed again by the five OLM coding standards.

As is often the case, tools (old and new) do not comply with the coding standard at the outset. As such, a "refactoring" approach is adopted. By "refactoring", it is mean that some way to assess the level of non-compliance is required (either by manual review or via automation) before work commences on fixing the issue across the tool set. Once this is assessed, the work commences as is best seen fit by the group, and the standard is enforced for future tools.

The SQM tool is the only tool which does not have all of its scripts in the top level folder. Thus, it is not possible to assess any other issues until that first issue has been worked. For the other tools, the ten integrity standards are all met, and then several of the OLM standards are in a state of non-compliance. As of the writing of this document, PCRs are in place to fix the issues. Note that two other standards (which have to do with Single Line of Code (SLOC) count and complexity) are also listed.

Appendix C

Acronym and abbreviations

CCC Code-Carrier Coherence . . . 1

CDF Cumulative Density Function . . . 60

CMCI Code Minus Carrier corrected for Iono . . . 46

CNMP Code-Noise and Multipath . . . 1

CORS WAAS Continuously Operating Reference Station . . . 32

CSRS-PPP Canadian Spatial Reference System Precise Point Positioning . . . 32

DGPS Differential Global Positioning System . . . 46

FAA Federal Aviation Administration . . . 2

GEO Geosynchronous Earth Orbit . . . 1

GPS Global Positioning System . . . 81

GUST GEO Uplink Subsystem Type 1 . . . 46

HMI Hazardous Misleading Information . . . 1

IFPR Ionospheric Free PseudoRange

ITRF International Terrestrial Reference Frame . . . 81

MERR Maximum Error Range Residual . . . 59

MMAC Mike Monroney Aeronautical Center . . . 1

NANU Notice Advisory to NAVSTAR Users . . . 47

NAVSTAR NAVigation System with Time And Range . . . 47

NGS National Geodetic Survey . . . 32

OLM Offline Monitoring . . . 8

PAGE-NT The NGS's suite of survey software . . . 46

PCR Program Change Request . . . 82

RDL1 Range Domain for the L1 frequency

RINEX Receiver INdependent EXchange Format . . . 32

RMS Root Mean Square . . . 32

RSS Root Sum Square . . . 81

SLOC Single Line of Code . . . 88
SOS Safety and Operations Support . . . 88
SQM Signal Quality Monitoring . . . 1
SRC Sequoia Research Corporation . . . 88
UDREI User Domain Range Error Index . . . 47
UTC Universal Time, Coordinated . . . 86
WAAS Wide-Area Augmentation System . . . 1
WFO WAAS Follow On contract . . . 32
WGS-84 World Geodetic System's latest reference coordinate system . . . 81
WIPP WAAS Integrity Performance Panel . . . 2
WRS Wide-area Reference Station . . . 1
WSF WAAS Support Facility . . . 1
WUM WAAS User Message . . . 47