Wide Area Augmentation System

Offline Monitoring Quarterly Report #2

1 April 2011 – 30 June 2011

21 October 2011

Prepared for:

Federal Aviation Administration

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Executive Summary

The WAAS Operations Team (AJW-192) was tasked with monitoring the Wide Area Augmentation System (WAAS) to ensure that the integrity requirements defined in Section 3.3 of Algorithm Contribution to 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 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 user's exposure to the failure.

The following assertions are monitored as called for in the Algorithm Contribution to HMI document:

1. Code-noise and Multipath
2. Code-carrier-incoherence (CCC)
3. Signal Quality Monitor (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, GEO CCC, and Space Weather. This report will also include major anomalies that occurred during the time period covered in this report.

Below is a summary of the criteria that were monitored for this report.

Integrity Monitoring	
Code-carrier-coherence (CCC)	5 trips (all on PRN 138)
Code-noise and multipath (CNMP)	All data bounded
Signal-quality monitoring SQM	None
Satellite clock run-off	None
Ionospheric threat model	7 days of interest – April 2, 3, 6, 11, 12, 20 and 30
Continuity Monitoring	
Missed messages	67 on CRW, 27 on CRE and 553 on AMR (unavailable data from 5/27 – 6/6)
External Monitoring	
Antenna Positioning	All sites within 5 cm.
Anomaly Investigations	
Santa Paula AMR SIS outage	~7 min SIS outage on June 16th

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 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 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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1 Introduction

1.1 The definition of offline monitoring

The goal of Offline monitoring 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 user's 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.

1.1.1 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.

1.1.2 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.

1.1.3 Accuracy

Accuracy Monitoring refers to the ability of the WAAS corrections to provide an accurate estimate the user's position.

1.1.4 External Monitoring

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

2 Integrity Monitoring

2.1 Code-noise and multipath (CNMP)

For Figures 2.1-1, 2.1-2 and 2.1-3, 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 2.1-4, if the values go above the marked threshold of 1, that event is a failure. No CNMP failures occurred during the second quarter of 2011.

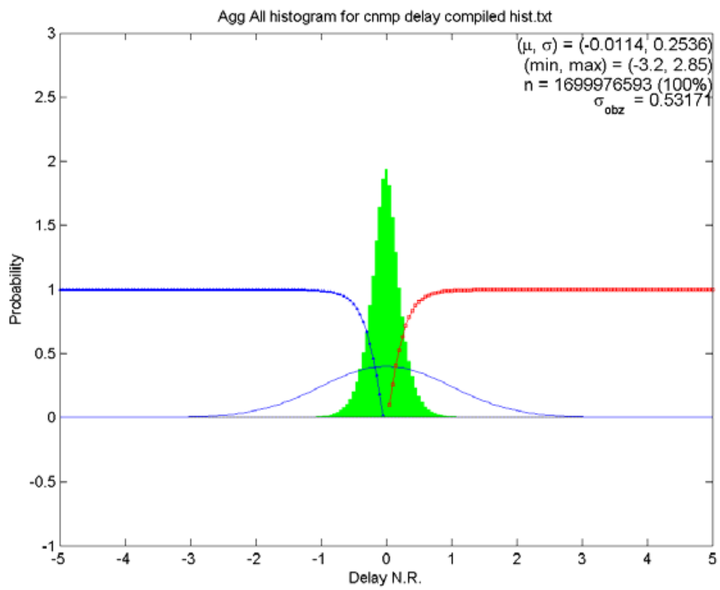


Figure 2.1-1 Aggregate CNMP Delay

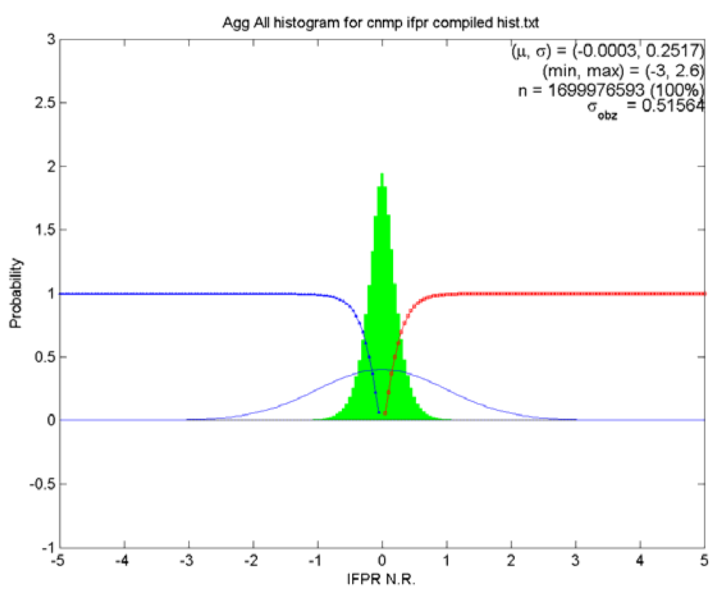


Figure 2.1-2 Aggregate CNMP IFPR

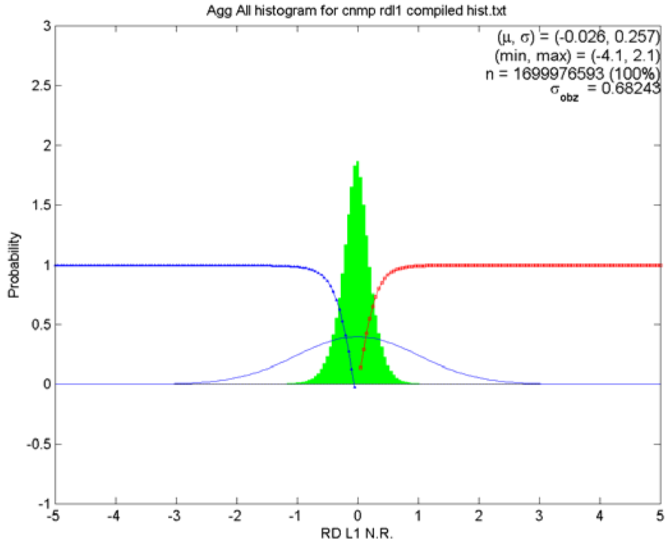


Figure 2.1-3 Aggregate CNMP RDL1

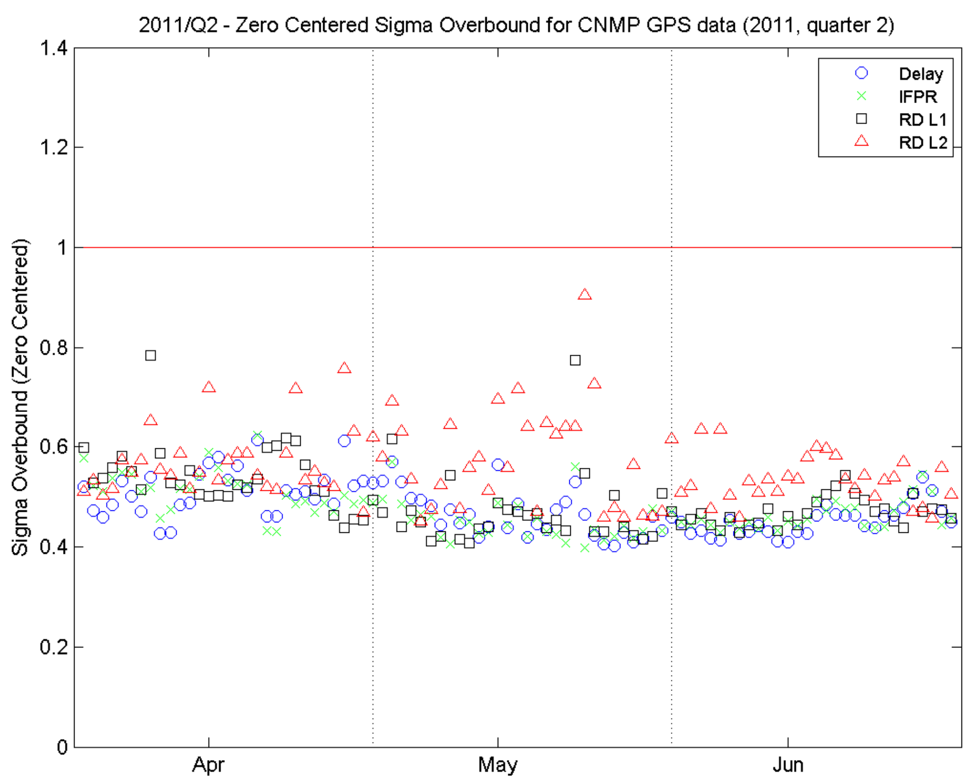


Figure 2.1-4 Daily GPS CNMP Aggregate zero-centered sigma overbound values

2.2 Code-carrier-coherence (CCC)

Anik, Galaxy 15 and all GPS satellites are monitored for CCC trips. All CCC monitor trips are investigated whenever a trip occurs to determine the cause. AMR is not currently monitored since it is not used as ranging source and its UDRE floor is 50m.

Data sources used in correlation and analysis:

- CCC test statistic
- UDRE threshold value
- CMCI measurements from NETS SQA
- WAAS Iono calculation
- L1/L5 Iono GUST calculation
- published planetary K_p and A_p values
- Chi^2 values

Table 1.1.4-2 Reported CCC Trips

CCC Trips for the 2nd quarter 2011				
UTC Time	PRN		C&V	
2011-06-13 10:07:35	138			ZTL
2011-06-13 10:07:57	138	ZDC	ZLA	ZTL
2011-06-13 10:12:46	138	ZDC		
2011-06-18 16:05:34	138	ZDC	ZLA	ZTL
2011-06-18 16:05:53	138	ZDC		ZTL

CCC Trips on CRE/138 are ongoing and under investigation.

2.3 CCC aggregate plots

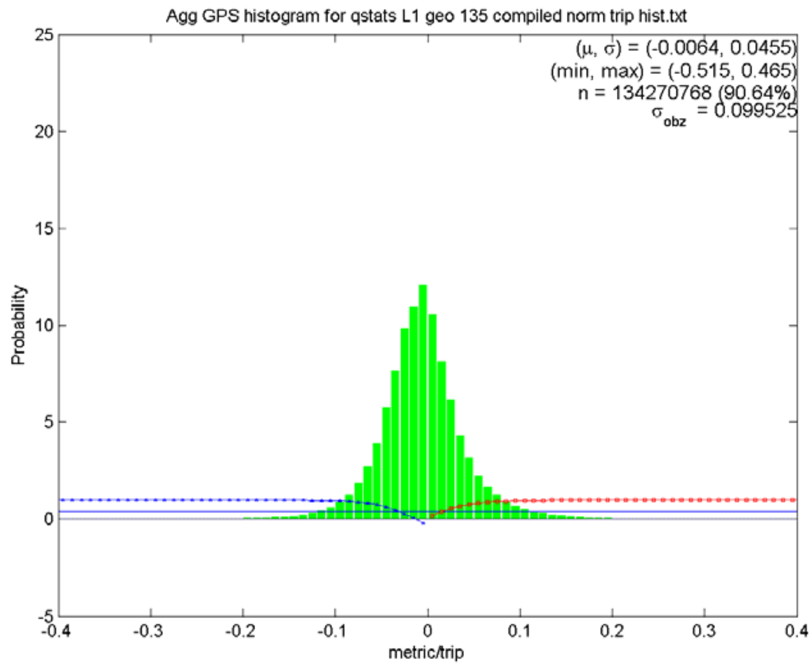


Figure 2.3-1 CCC GPS aggregate for L1

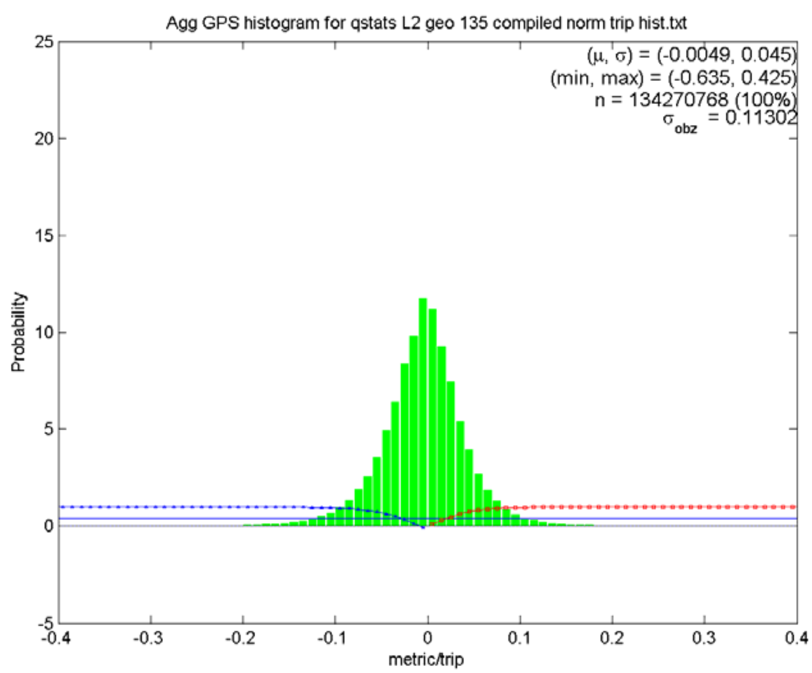


Figure 2.3-2 CCC GPS aggregate for L2

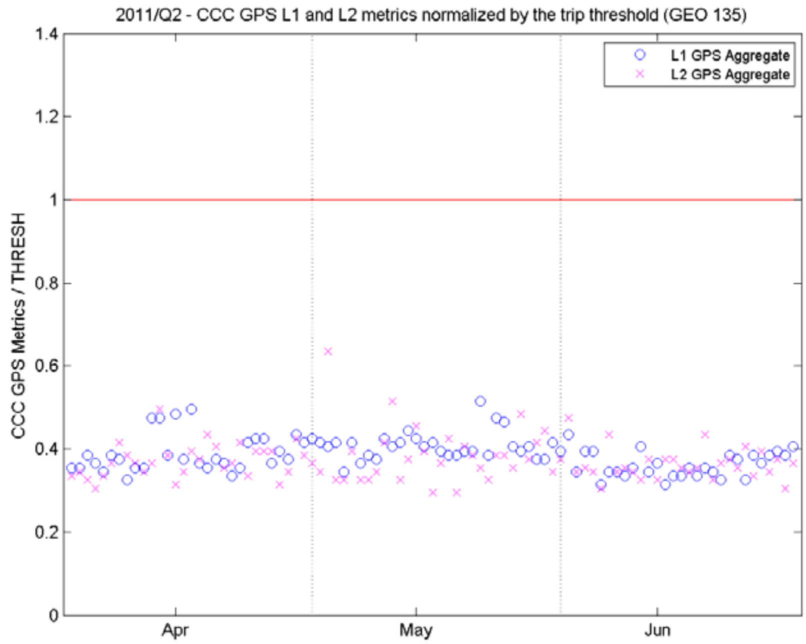


Figure 2.3-3 CCC GPS quarterly plot

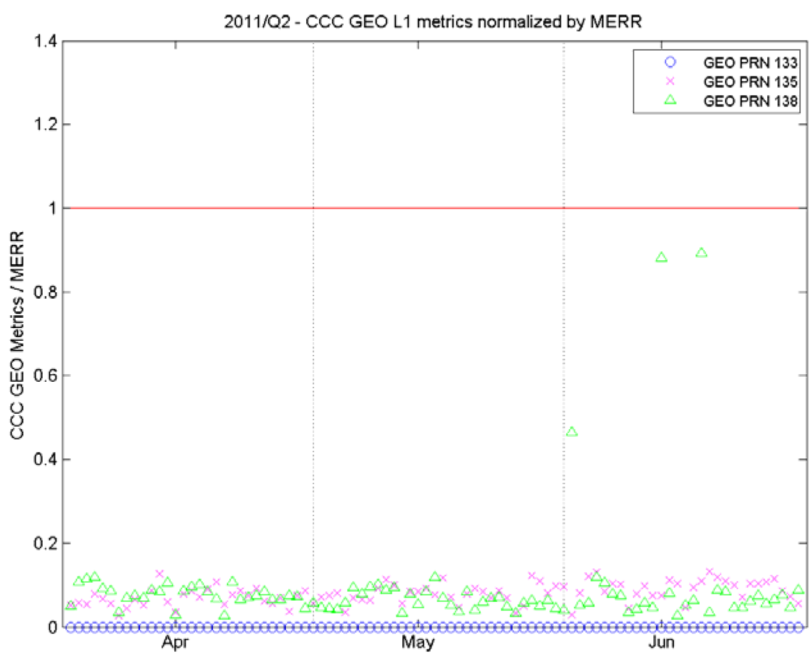


Figure 2.3-4 CCC GEO quarterly plot (integrity)

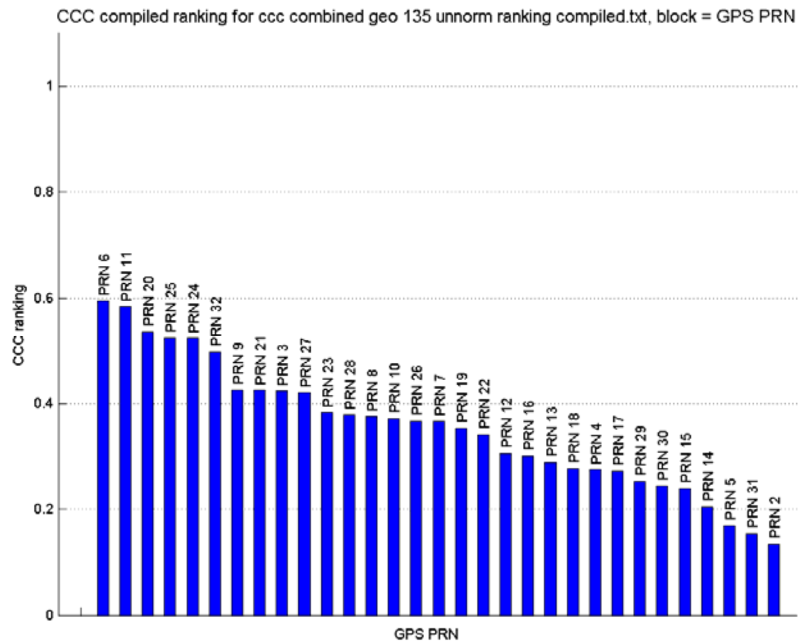


Figure 2.3-5 CCC GPS L1 L2 ranking plot sliced by PRN

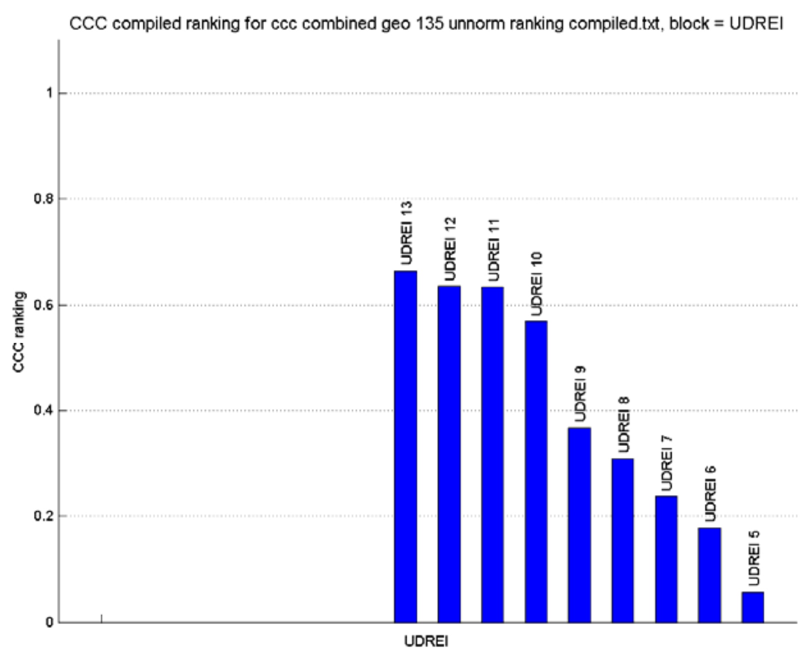


Figure 2.3-6 CCC GPS L1 L2 ranking plot sliced by UDRE

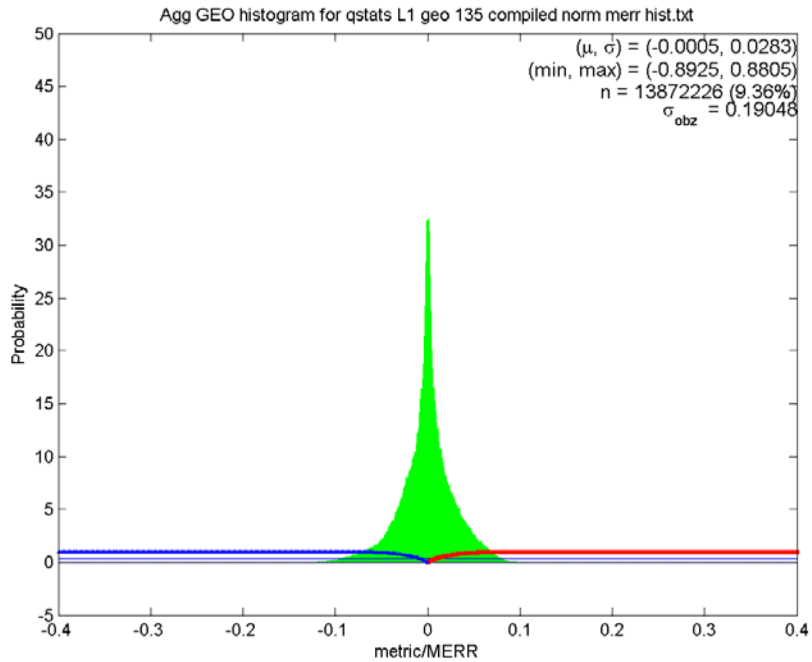


Figure 2.3-7 CCC GEO aggregrate plot for L1

2.4 Signal-quality monitoring (SQM)

SQM data is not available during this quarter due to processing problems. Results will be provided in the next quarterly report.

2.5 Satellite clock run-off analysis

No Satellite clock runoff events occurred during this quarter.

2.6 Ionospheric Threat Model

2.6.1 Daily percentage of GIVE Chi^2 values > 1

Note that data was unavailable between 5/24 through 6/6.

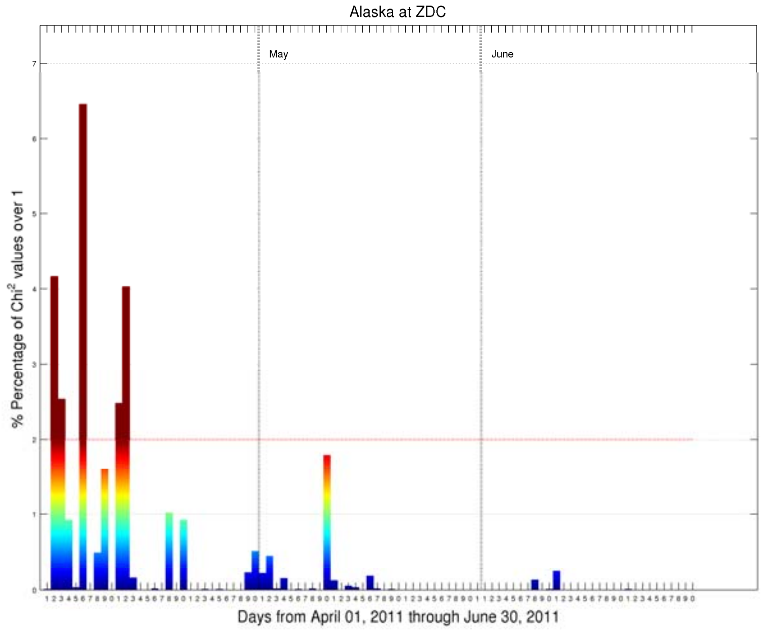


Figure 2.6-1 GIVE Chi^2 trips for Alaska on ZDC

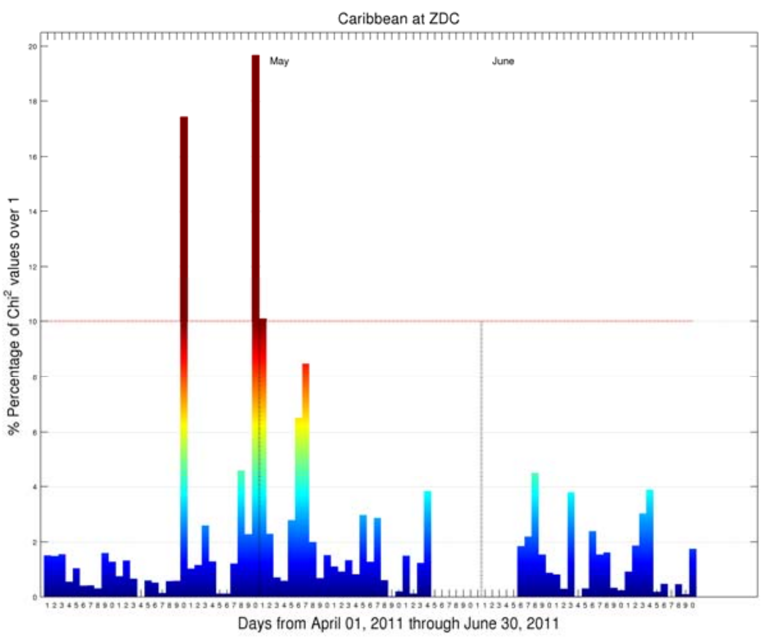


Figure 2.6-2 GIVE Chi^2 trips for the Caribbean on ZDC

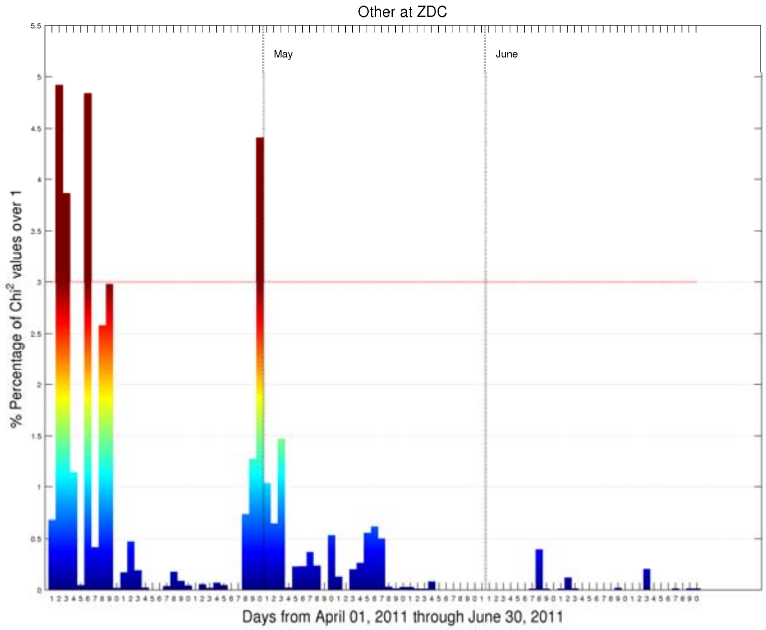


Figure 2.6-3 GIVE Chi^2 trips for Other region on ZDC

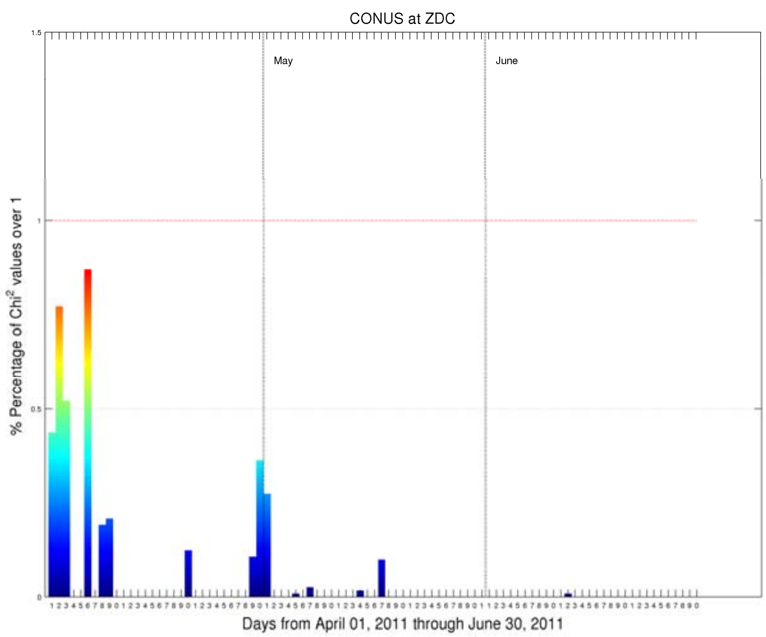


Figure 2.6-4 GIVE Chi^2 trips for CONUS on ZDC

2.6.2 Days of Interest

Table 2.6-1 Threat Model Days of Interest

Date of Trip	Alaska (2%)	Caribbean (10%)	Other (3%)	CONUS (1%)
2011-04-02	4.065		5.0202	
2011-04-03	2.5018		3.8743	
2011-04-06	6.5041		4.8001	
2011-04-11	2.5018			
2011-04-12	4.1097			
2011-04-20		17.4427		
2011-04-30		19.7285	4.4179	

The days listed above require further analysis to determine if there are impacts to the Ionospheric Threat Model.

Days listed indicate regions where the percentage of Chi^2 values > 1 exceed the threshold value.

2.7 L1L2 Bias Levels

See supplemental material section.

3 Availability Monitoring

3.1 Service Volume Model

This analysis is under development.

3.2 System monitoring trips

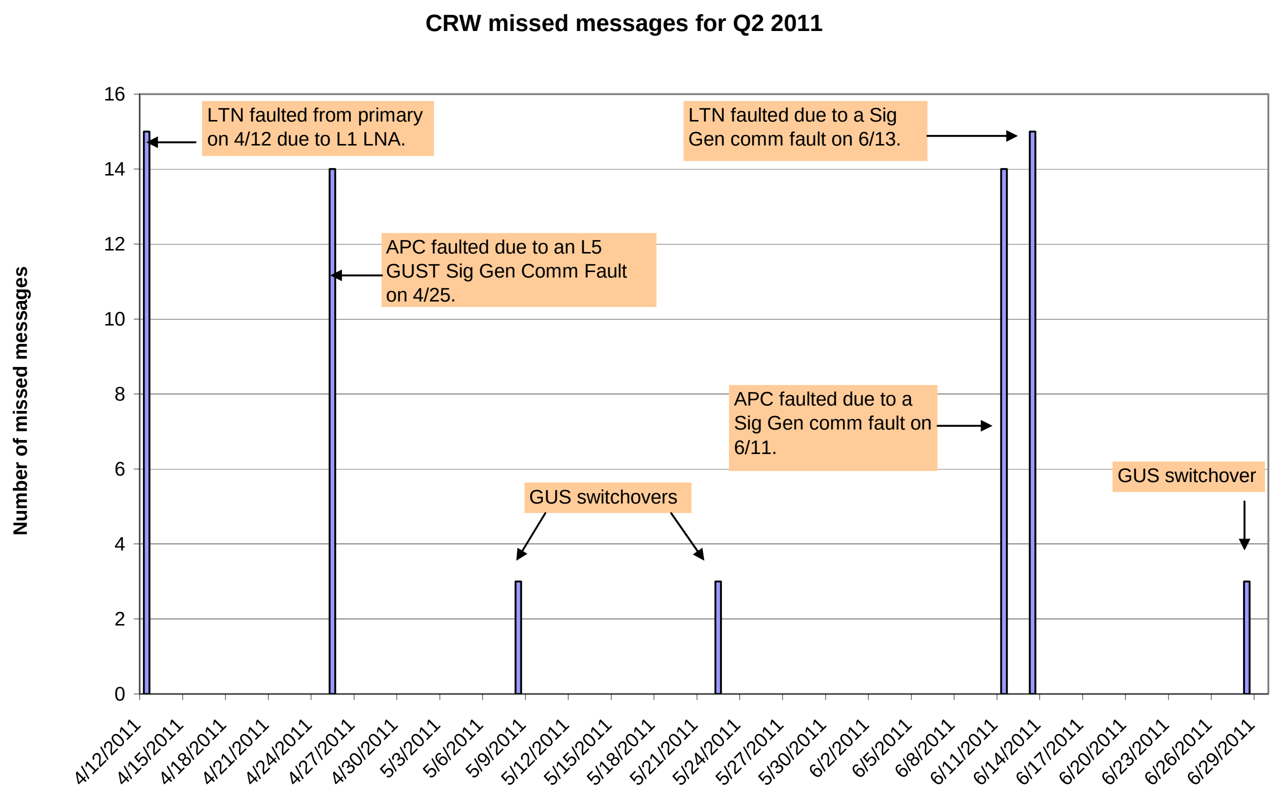
Table 3.2-1 Reported Monitor trips

Monitor Trip	ZDC	ZLA	ZTL
BMV	0	0	0
CCC	12	6	12
L1L2	14	14	14
RDM (Threshold)	0	0	0
SQM	0	0	0
UPM	0	0	0
WNT	0	0	0
WRE BIAS	0	0	0

4 Continuity Monitoring

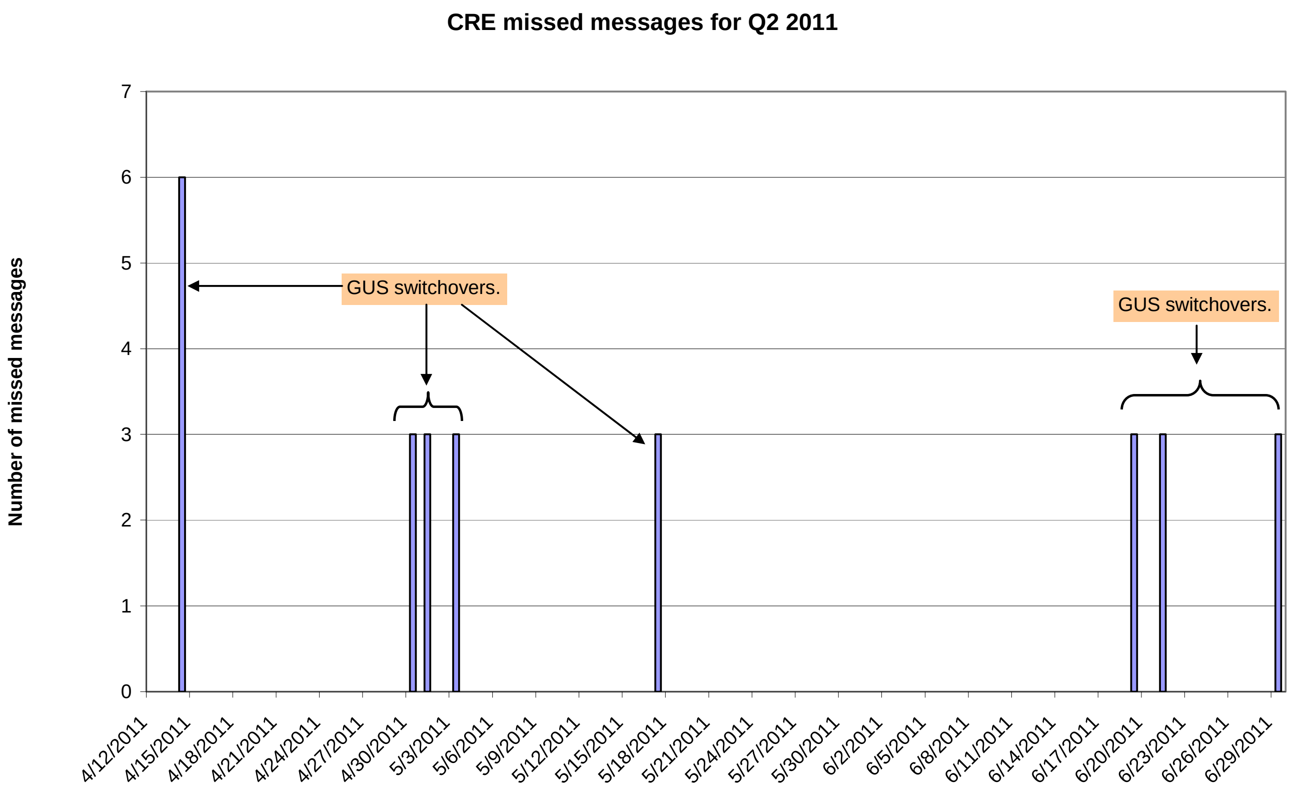
4.1 List of missed messages

The missed messages for the 2nd quarter of 2011 are displayed in the histograms in this section. Each histogram represents one GEO satellite. The histograms are annotated to briefly explain the cause for each instance of missed messages. The totals for missed messages per GEO satellite are as follows: CRW 135 – 67, CRE 138 – 27, AMR 133 – 553. Note that for the dates 5/27 - 6/6 data was unavailable due to power outages.



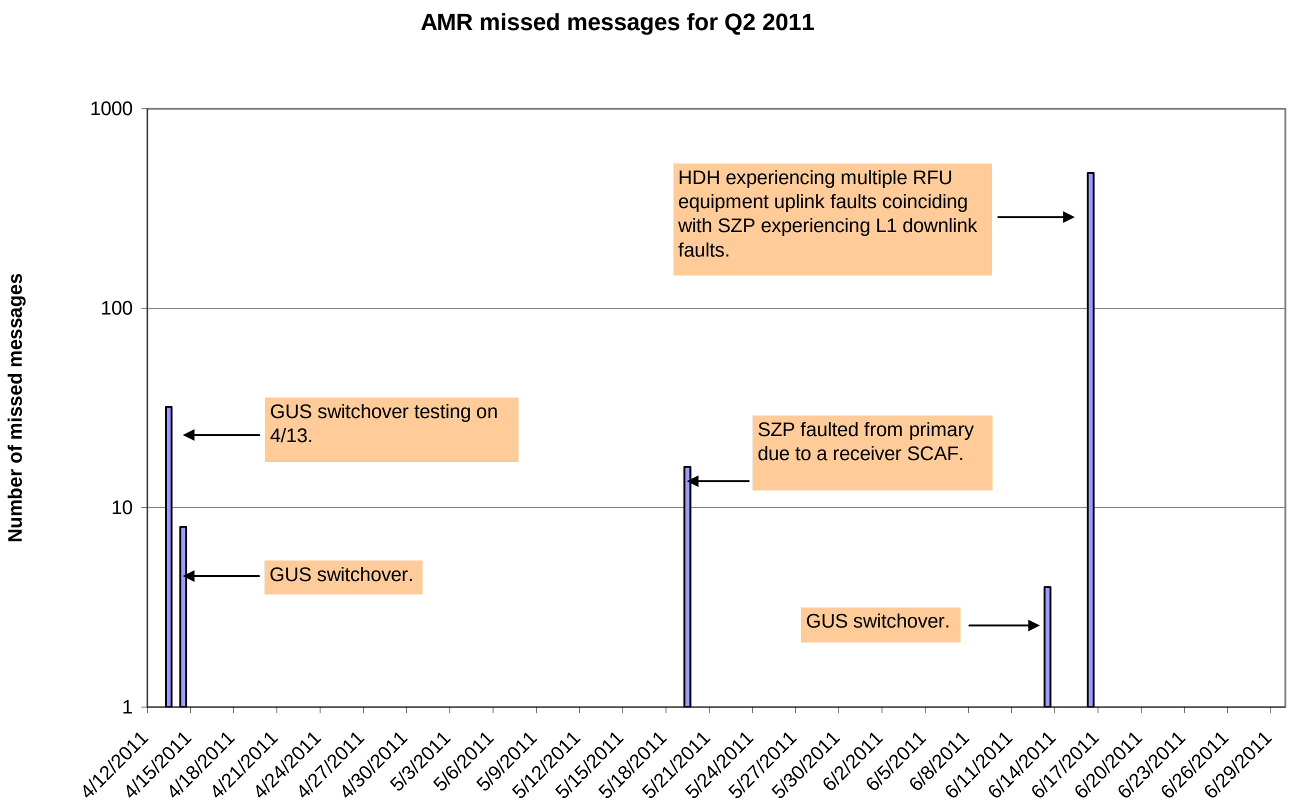
	4/12/11	4/13/11	4/14/11	4/25/11	4/30/11	5/1/11	5/3/11	5/8/11	5/19/11	5/17/11	5/19/11	5/20/11	5/21/11	5/22/11	5/23/11	5/24/11	6/3/11	6/11/11	6/13/11	6/16/11	6/19/11	6/21/11	6/28/11	6/29/11
CRW	15	0	0	14	0	0	0	3	0	0	0	0	0	3	0	0	0	14	15	0	0	0	3	0

Figure 4.1-1 CRW missed messages Q2 2011



	4/12/11	4/13/11	4/14/11	4/25/11	4/30/11	5/1/11	5/3/11	5/8/11	5/19/11	5/17/11	5/19/11	5/20/11	5/21/11	5/22/11	5/23/11	5/24/11	6/3/11	6/11/11	6/13/11	6/16/11	6/19/11	6/21/11	6/28/11	6/29/11
CRE	0	0	6	0	3	3	3	0	0	3	0	0	0	0	0	0	0	0	0	0	3	3	0	3

Figure 4.1-2 CRE missed messages Q2 2011



	4/12/11	4/13/11	4/14/11	4/25/11	4/30/11	5/1/11	5/3/11	5/8/11	5/19/11	5/17/11	5/19/11	5/20/11	5/21/11	5/22/11	5/23/11	5/24/11	6/3/11	6/11/11	6/13/11	6/16/11	6/19/11	6/21/11	6/28/11	6/29/11
AMR	0	32	8	0	0	0	0	0	16	0	16	0	0	0	0	0	1	0	4	476	0	0	0	0

Figure 4.1-3 AMR missed messages Q2 2011

4.2 CNMP resets

This section will be added in a future revision.

5 Accuracy Monitoring

This section will be added in a future revision.

6 External Monitoring

6.1 Antenna phase center positions

- Results against CSRS-PPP indicate that rms position errors for all sites are less than 5 cm.
- Results against WFO-R2 indicate that rms position errors for all 107 sites are less than 5 cm.
  - The 7 WREs with rms position errors greater than 5 cm are all less than 8.5 cm
  - HNL exhibited the largest error, 8.5 cm

6.2 Ephemerides monitoring

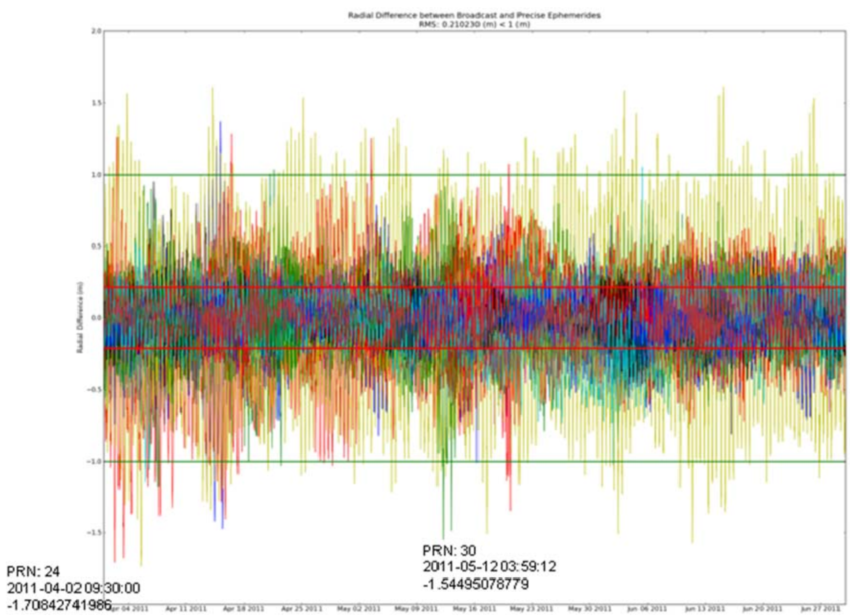


Figure 6.2-1Radial ephemeris

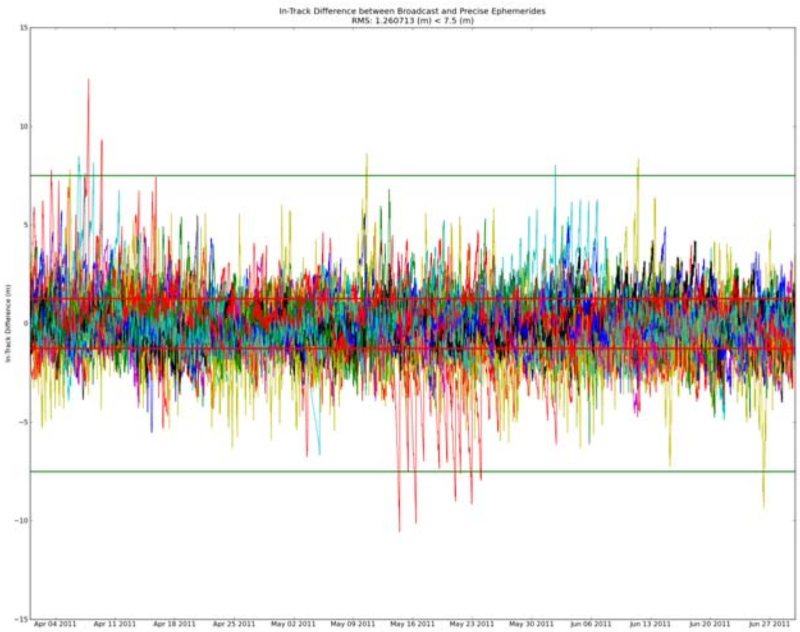


Figure 6.2-2 In-track ephemeris

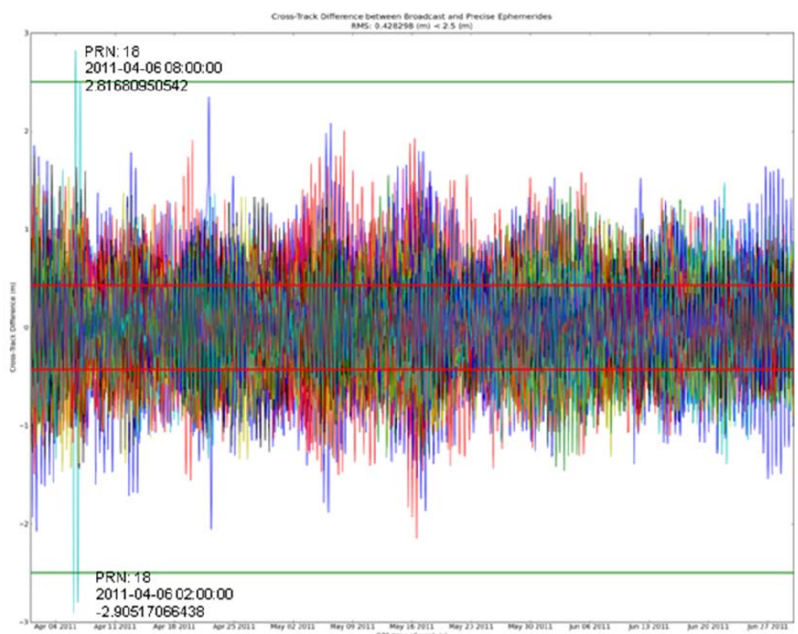


Figure 6.2-3 Cross-track ephemeris

Table 6.2-1 RIC outliers

PRN	R	I	C	PRN	R	I	C
1	0	0	0	17	0	77	0
2	0	0	0	18	14	19	23
3	0	0	0	19	0	0	0
4	0	6	0	20	0	0	0
5	0	0	0	21	0	0	0
6	0	0	0	22	1	0	0
7	0	0	0	23	0	0	0
8	52	0	0	24	174	37	0
9	14	0	0	25	1	0	0
10	19	0	0	26	0	0	0
11	0	0	0	27	715	31	0
12	0	0	0	28	0	0	0
13	0	0	0	29	0	0	0
14	0	0	0	30	20	0	0
15	0	0	0	31	0	0	0
16	0	0	0	32	1	2	0

6.3 Space Weather Monitoring

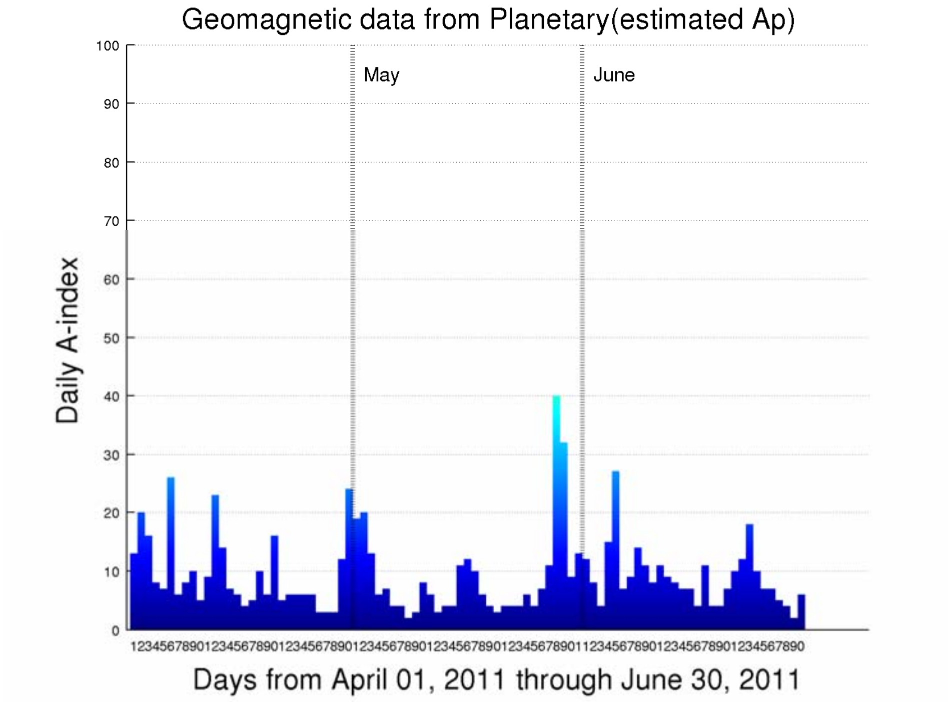


Figure 6.3-1 Daily estimated Planetary A-index

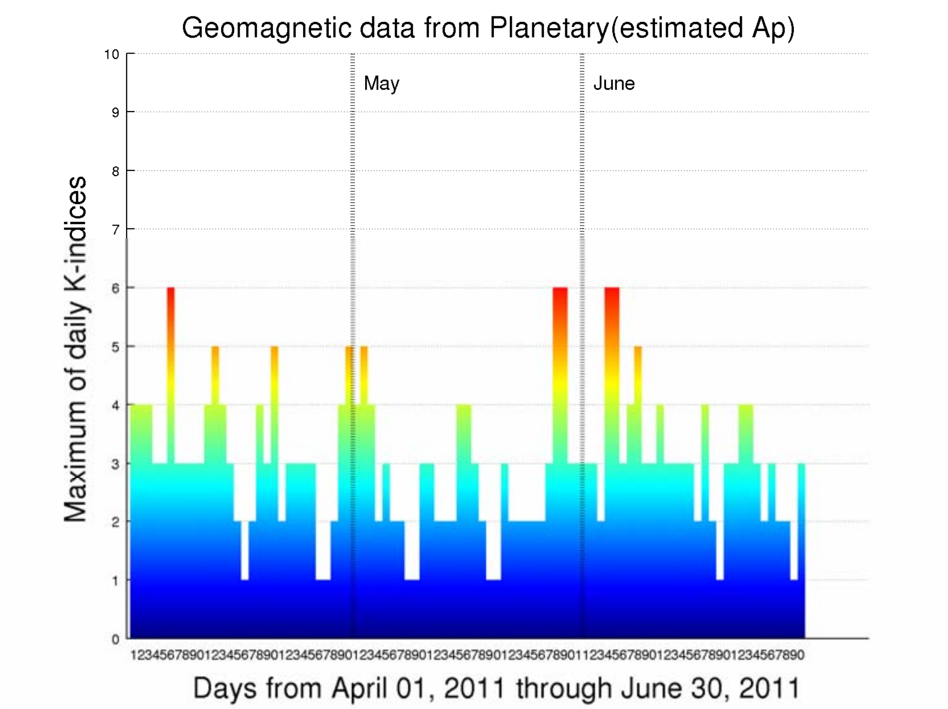


Figure 6.3-2 Maximum daily K-index from estimated Planetary

6.4 GEO CCC Signal Quality Analysis (SQA)

Two unique events caused degraded CCC on CRE during Q2. In early April, the Doppler change was excessively near 0 Hz each day. CCC performance improved after the Doppler magnitude increased over the same time period. Notably, PR oscillation correction would likely prevent this type of degradation; and hardware tests would be needed to verify software simulation.

In mid-June, the BRE GUST receiver experienced anomalous several-meter L5 PR jumps. The data and problem was analyzed by J. Lacey of Lockheed Martin and briefed at the weekly system monitoring teleconferences. The GUST receiver was replaced and since then the CCC statistic has exhibited nominal performance.

Figure 6.4-1 Doppler shift comparison for April 6th and nominal day

Figure 6.4-2 PRN 138 long-term CCC metric indicating effects of Doppler and BRE L5 PR spikes

7 Anomaly Investigation

7.1 AMR SIS outage in June

There was an AMR SIS outage that lasted approximately 7 minutes on June 16, 2011 beginning at 20:40:00 UTC. Paumalu (HDH) faulted first at 19:37:04 UTC and was in Maintenance mode at the time of a Santa Paula (SZP) GUST fault at 20:40:00. SIS was restored when Paumalu was put into Primary mode at 20:46:41 UTC. The GUST Significant Events related to the faults are listed in Table 7.1-1. Table 7.1-2 details the missing WUMs as there were displayed on the WAAS performance webpage.

Table 7.1-1 Sig Events detailing 2011-06-16 GUST Faults

06/16/2011	19:37:04	NEW	NO	NO	WRN	GES	HDH	GUS-A	501	Mode change to Faulted
06/16/2011	19:37:20	NEW	NO	NO	WRN	GES	HDH	GUS-A	501	Mode change to Maintenance
06/16/2011	20:40:00	NEW	NO	NO	WRN	GES	SZP	GUS-A	501	Mode change to Faulted
06/16/2011	20:41:51	NEW	NO	NO	INF	GES	HDH	GUS-A	501	Mode change to Verification
06/16/2011	20:46:34	NEW	NO	NO	INF	GES	HDH	GUS-A	501	Mode change to Backup
06/16/2011	20:46:41	NEW	NO	NO	INF	GES	HDH	GUS-A	501	Mode change to Primary
06/16/2011	20:48:33	NEW	NO	NO	WRN	GES	SZP	GUS-A	501	Mode change to Maintenance

Table 7.1-2 Missing WUMs during 2011-06-16 AMR SIS Outage

Missing message [06/16/2011 20:39:34 (992291989) - 06/16/2011 20:39:35 (992291990)]
Missing message [06/16/2011 20:39:36 (992291991) - 06/16/2011 20:39:41 (992291996)]
Missing message [06/16/2011 20:39:43 (992291998) - 06/16/2011 20:39:46 (992292001)]
Missing message [06/16/2011 20:39:47 (992292002) - 06/16/2011 20:39:48 (992292003)]
Missing message [06/16/2011 20:39:49 (992292004) - 06/16/2011 20:39:53 (992292008)]
Missing message [06/16/2011 20:39:56 (992292011) - 06/16/2011 20:39:58 (992292013)]
Missing message [06/16/2011 20:40:02 (992292017) - 06/16/2011 20:46:51 (992292426)]

The SZP GUST fault at 20:40:00 UTC on this day was due to an SE 44 L1 GEO Downlink Message Check Fault. This significant event was caused by low C/No which in turn caused the GUST receiver at SZP to lose lock on the L1 GEO downlink signal. After 60 seconds of missed WUMs on its downlink signal, SZP faulted from Primary mode. The root cause of the low C/No was commercial power problems at SZP which caused the antenna to stop tracking.

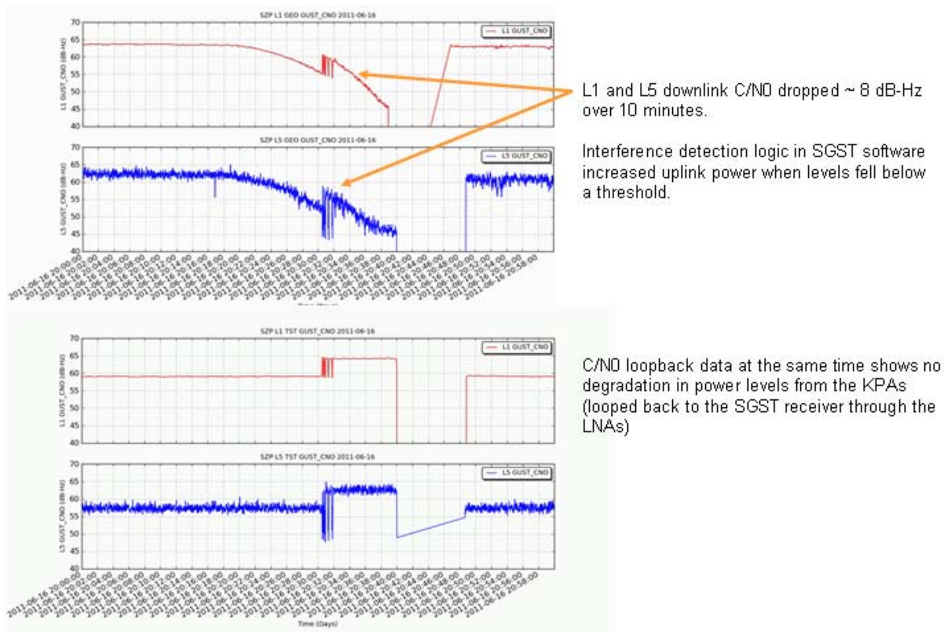


Figure 7.1-1 SZP Downlink C/No Degradation prior to fault on 2011-06-16

Paumalu faulted 8 times during the day prior to the fault at 19:37:04 and was kept in Maintenance to accommodate the replacement of a faulty Radio Frequency Uplink (RFU) Frequency Distribution Amplifier (FDA) by site technicians. In each case the HDH Maintenance and Control Computer (M&C) reported FDA faults and replacement of the RFU FDA did not resolve the issue.

Later investigation of the HDH FDA showed that the faults were characterized by the M&C loss of Ethernet communication with the FDA. When this happened, a fault was raised and a 30 second recover timer began. After 30 seconds, the M&C attempted to re-establish the communication socket. Each communication failure was brief and had been observed to last less than 12 seconds. After each failure, communication was re-established in less than 12 seconds. The FDA communication failures did not adversely affect the fundamental operation of the FDA frequency distribution as it continued to pass the proper frequency references to the up-converters and test loop translators in the RFU. The failures caused the RFU to pass a communication fault alert to the HDH Signal Generator Subsystem (SGS) which then declared a GUST Fault. This type of FDA fault was experienced previously in 2009 on the Paumalu Broadband Global Area Network (BGAN) RF Subsystem. At that time, the site worked with the FDA manufacturer but was unable to develop a fix and instead a change was made to the M&C application's alarming criteria. An M&C workaround was implemented to designate the FDA communication faults as a warning rather than a major alarm. The alarm was made visible to maintainers but was no longer reported to the SGS. This M&C update was deployed to both AMR GUSTs as an emergency mod in September 2011. HDH was upgraded on 2011-09-01 and SZP was upgraded on 2011-09-13 and the issue is now being closely monitored.

8 Materials and Methods

This section describes which tool was run, flags set, build number, data files used, any pre-processing done, etc.

8.1 Antenna Positioning

- Sites were surveyed on 2011-04-20 and cross compared against the following:
    - CSRS-PPP
    - WFO-R2
    - Coordinates projected to six months beyond WFO WFO Release 3, that is, 2012-05-01
    - used latest page-NT version (k)
        - NGS updated to IGS05 coordinates

- Accurate antenna positions needed to support DGPS applications
- Correct for Time Dependent Process
    - Tectonic Plate Movement
    - Subsidence
- Correct for Shift Events
    - Seismic
    - Maintenance
- WIPP Review for integrity issues
    - Greater than 10 cm WIPP should review
    - Greater than 25 cm WIPP must review
    - Special case for Mexico City (25 cm for review)
- Project the need for a WAAS Antenna Coordinate Update

8.2 Clock Runoff

8.2.1 Monitoring approach

- Events typically result in a fast correction that exceeds 256 meters
- When this occurs, the satellite is set Do Not Use until the correction reaches a reasonable size
- Events where the satellite is set Do Not Use from excessively large fast corrections while the satellite is healthy are recorded

8.3 Ionospheric Threat Model

8.3.1 Monitoring approach

- Monitor for Chi^2 values greater than 1 in the four regions, including:
    - CONUS > 1%
    - Alaska > 2%
    - Caribbean > 10%
    - Other > 3%

8.4 Ephemeris

Compared broadcast vs precise in HCL to ensure sigmas are less than 1m, 2.5m, 7.5m for Radial, Cross Track, and In Track.

8.5 GEO Signal Quality Analysis

8.5.1 Data

The analysis uses MATLAB to compile data from the GEO monitoring equipment in OKC.

8.5.2 Tools

The MATLAB analysis and plotting code is run on machine provided by Zeta.

9 Supplemental Material

9.1 Ionospheric Threat Model

9.1.1 Monitoring regions

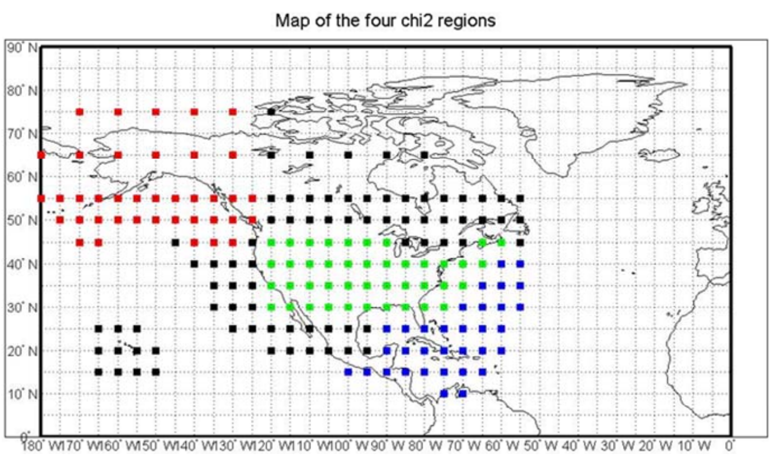


Figure 9.1-1 Map of the four Chi^2 regions

9.2 CNMP

The assertion in the HMI documents 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.

To monitor this assertion, 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 the equations appendix. 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. For the second quarter of 2011, there were no failures for the sigma overbound or any of the aggregate or sliced distribution plots.

9.2.1 Analysis on poor performing sites

For the second quarter of 2011, there was one high point on the daily aggregate sigma overbound plot (Fig 2.1-4). This point was high due to MPR-A, RDL2. The distribution plot sliced for this WRE can be seen below.

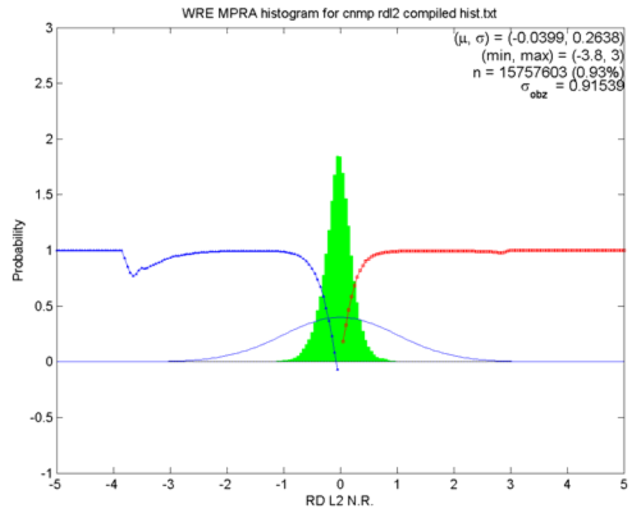


Figure 9.2.1-1 MPR-A Poor CNMP Performance

There is no known reason for the poor performance at this site. The performance of this site for the third quarter of 2011 will analyzed to determine whether this was just an isolated event or is part of a long term trend.

MSD-A has had issues in the past that were believed to be due to bad cabling at the site. The analysis from this quarter confirms that the cabling was the issue. The performance at this site with the new cable was nominal for the entire quarter. This is illustrated in Figure 9.2.1-2.

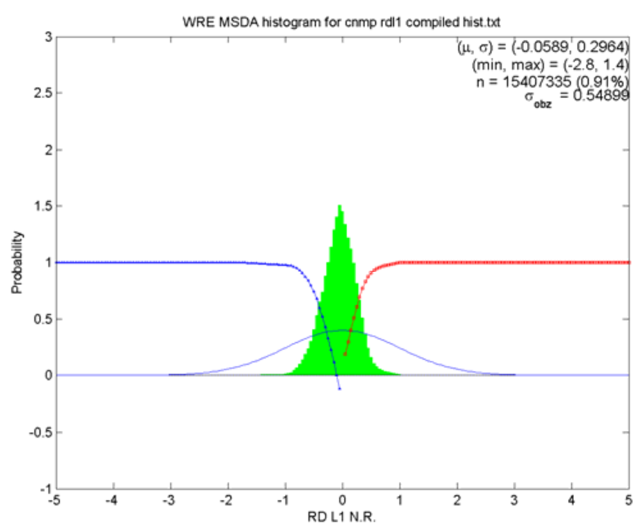


Figure 9.2.1-2 MSD-A Nominal CNMP Performance

The following Table contains more detailed information on the worst performing sites of the quarter. This Table is generated by ranking the worst threads for each of the three statistics. The worst thread in a category was given 5 points, while the second worst was given 4 points, and so on. The points were totaled across all three metrics to give the table below. Only one thread per WRS appears below, so that 5 WRS are on the table (i.e. all three Houston threads might otherwise appear in the table).

Sliced by WRE Legend: - = passed X = did not pass WRE #, WRE Name	L1				IFPR				Delay			
	μ	σ	|max|	pass/fail	μ	σ	|max|	pass/fail	μ	σ	|max|	pass/fail
106, Tapachula_B	**-0.058**	**0.35**	**4.05**	**-**	**-0.032**	**0.31**	**2.65**	**-**	**0.017**	**0.32**	**3.20**	**-**
29, Houston_C	**-0.072**	**0.44**	**2.65**	**-**	**0.105**	**0.41**	**2.80**	**-**	**-0.110**	**0.40**	**2.80**	**-**
6, Anchorage_A	**-0.050**	**0.28**	**1.90**	**-**	**-0.012**	**0.28**	**2.60**	**-**	**-0.006**	**0.29**	**2.65**	**-**
64, Seattle_B	**0.004**	**0.26**	**3.45**	**-**	**-0.004**	**0.24**	**2.50**	**-**	**0.073**	**0.24**	**1.85**	**-**
57, Oakland_A	**-0.021**	**0.22**	**1.45**	**-**	**0.010**	**0.21**	**1.50**	**-**	**-0.023**	**0.21**	**1.60**	**-**

Table 9.2-1 CNMP results from poor performing WRE slices

9.3 GEO Signal Quality Analysis

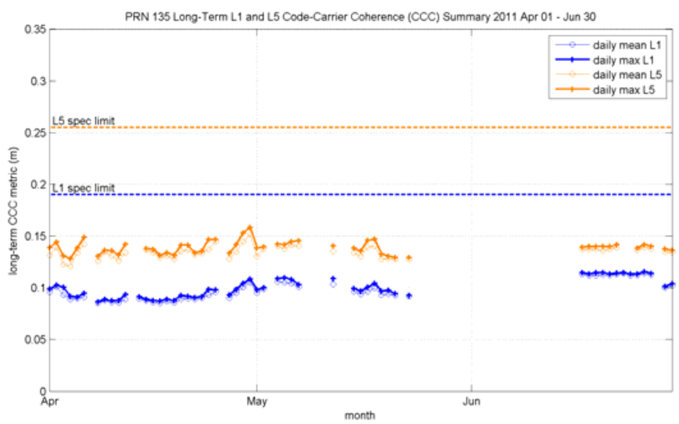


Figure 9.3-1 long-term CCC PRN135

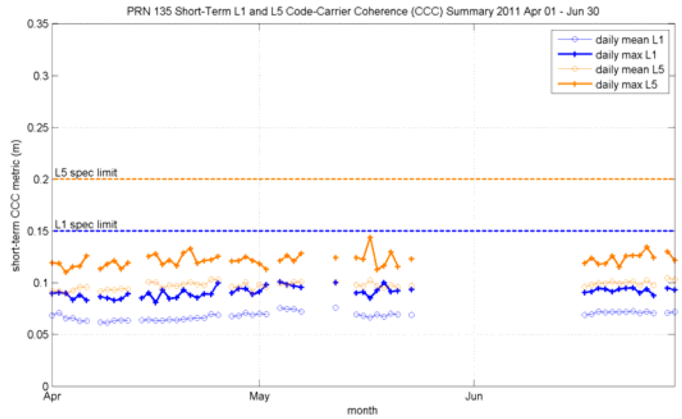


Figure 9.3-2 short term CCC PRN 135

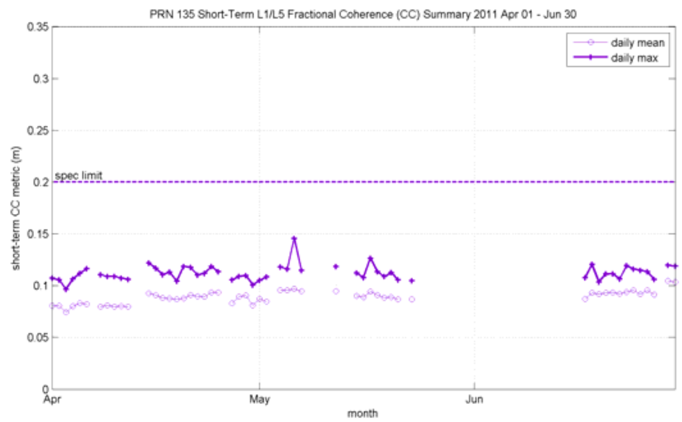


Figure 9.3-3 PRN 135 short-term CC

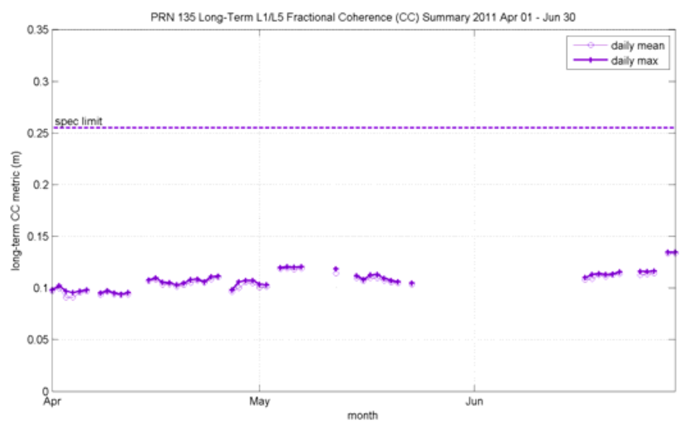


Figure 9.3-4 PRN 135 long-term CC

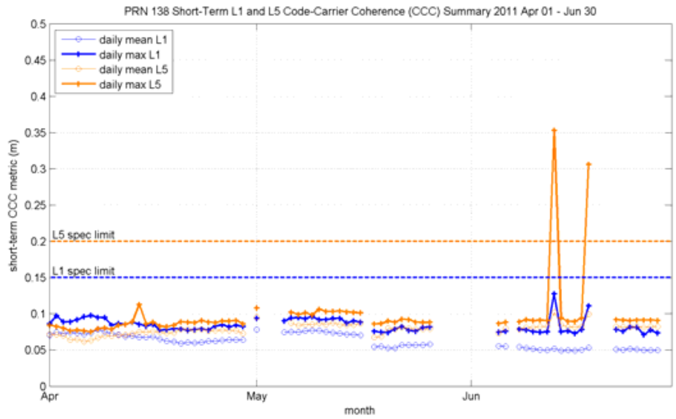
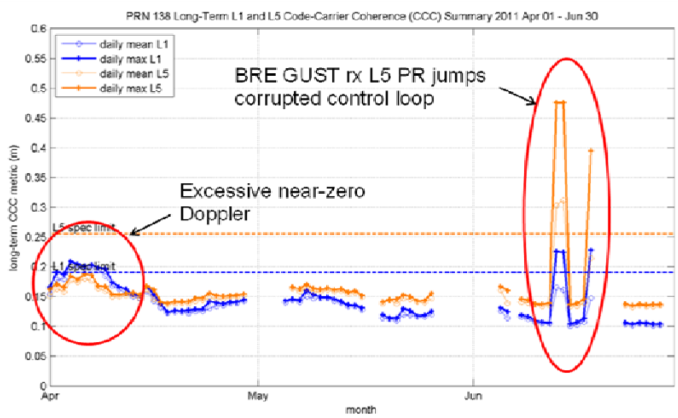


Figure 9.3-5 PRN 138 short-term CCC



Note: missing values indicate days with switchovers or incomplete data

Figure 9.3-6 PRN 138 long-term CCC

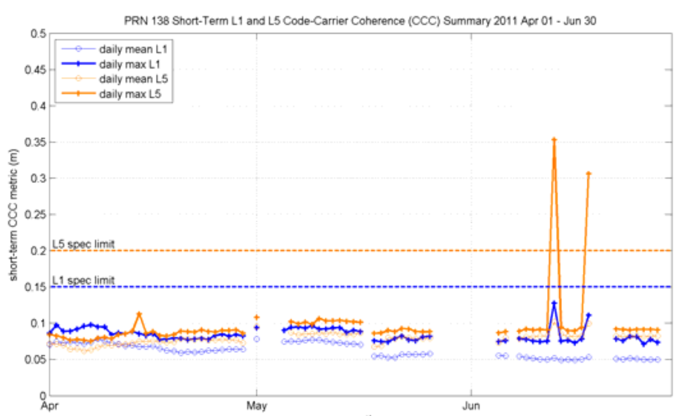


Figure 9.3-7 PRN 138 short-term CCC

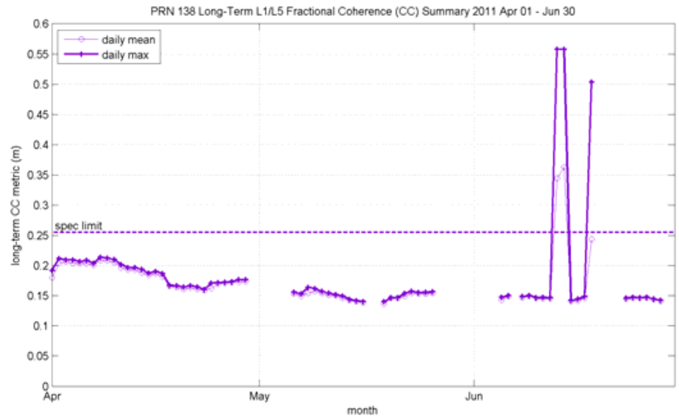


Figure 9.3-8 PRN 138 long-term CC

9.4 L1L2 Bias Levels

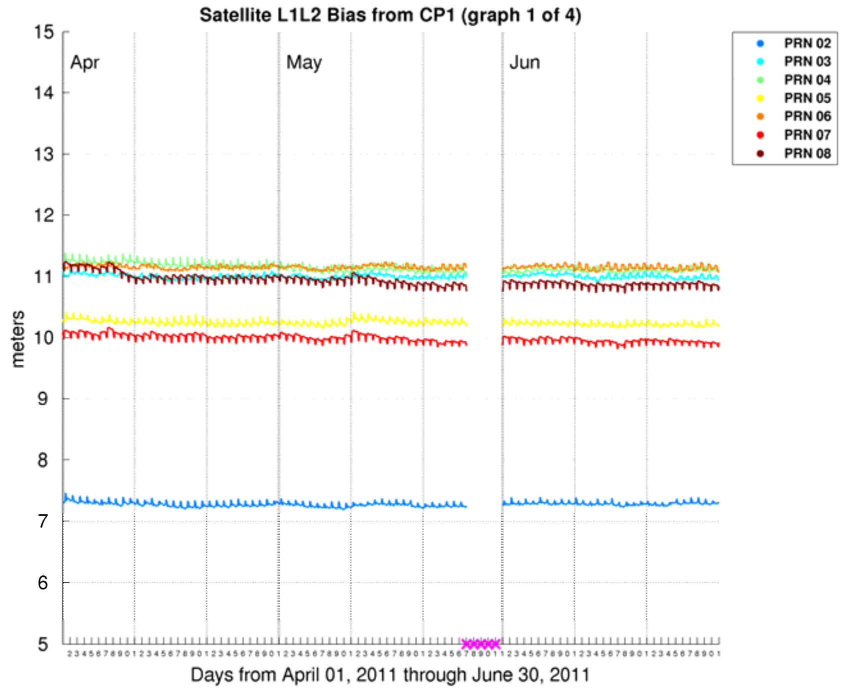


Figure 9.4-1 PRN2-8 L1L2 bias from CP1

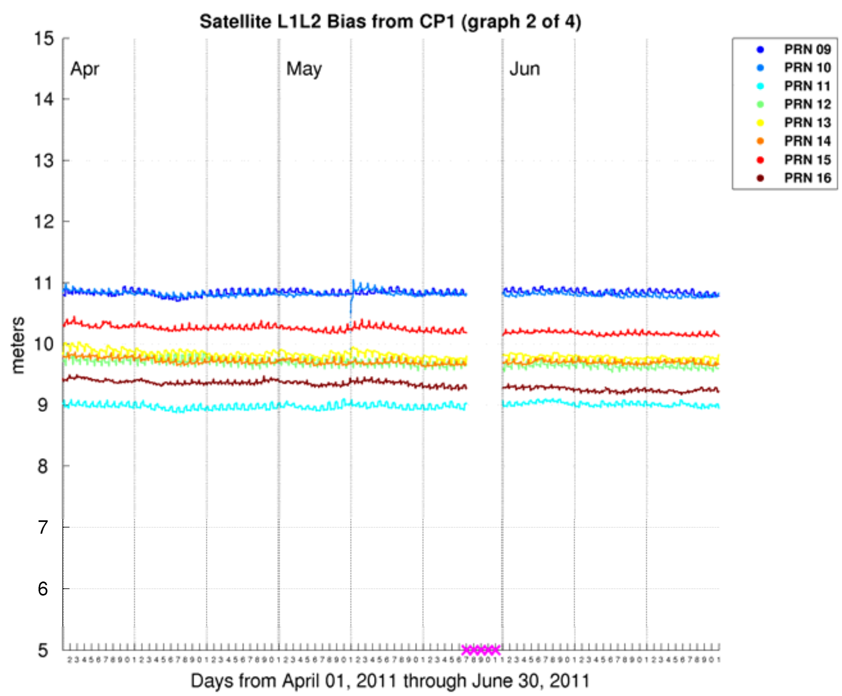


Figure 9.4-2 PRN9-16 L1L2 Bias from CP1

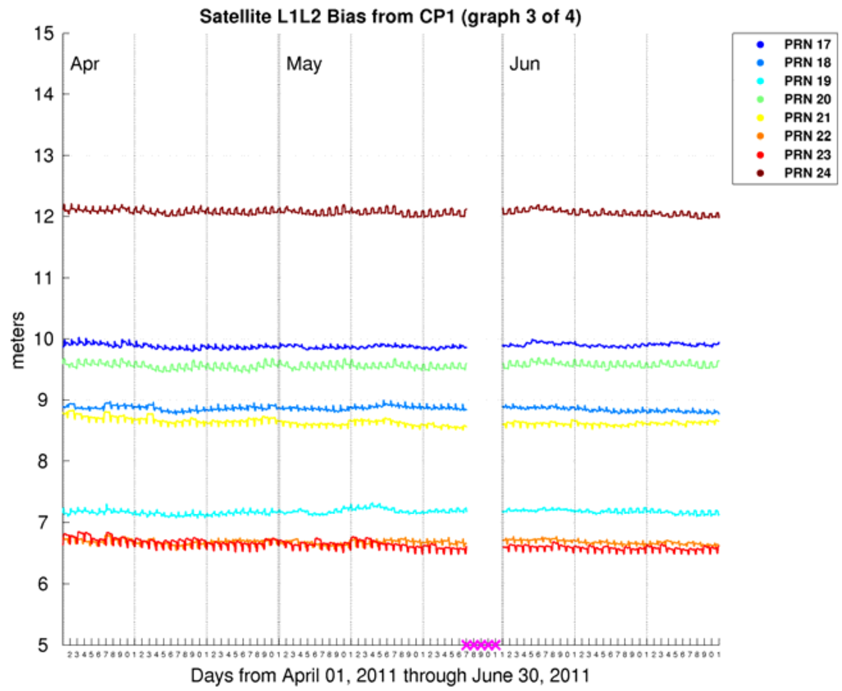


Figure 9.4-3 PRN17-24 L1L2 Bias from CP1

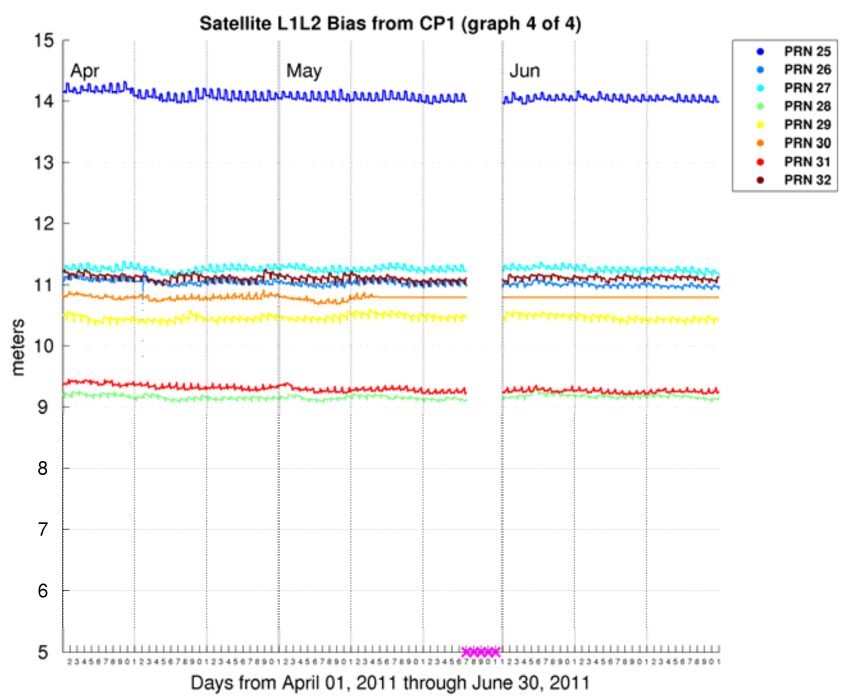


Figure 9.4-4 PRN25-32 L1L2 Bias from CP1

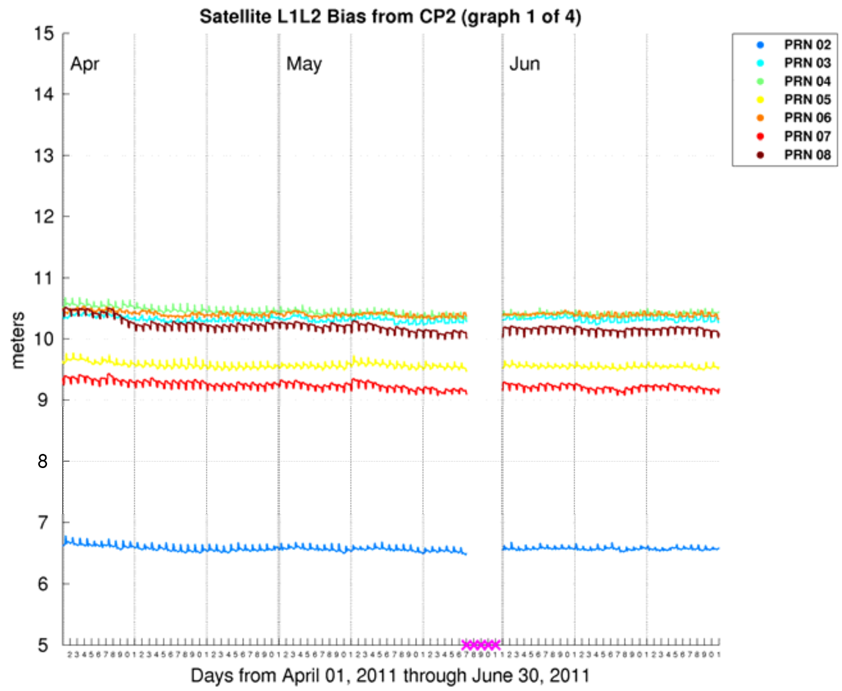


Figure 9.4-5 PRN2-8 L1L2 Bias from CP2

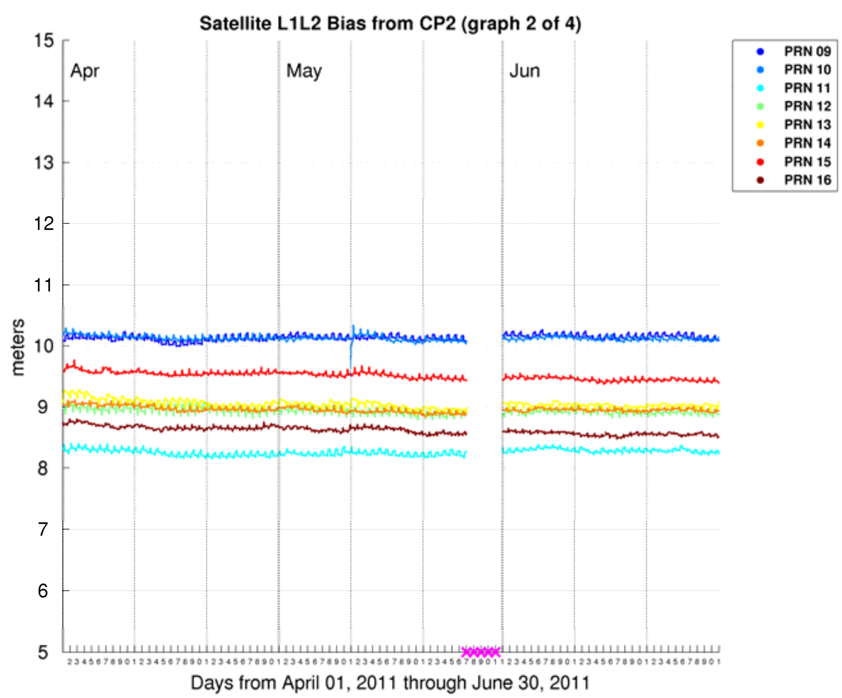


Figure 9.4-6 PRN9-16 L1L2 Bias from CP2

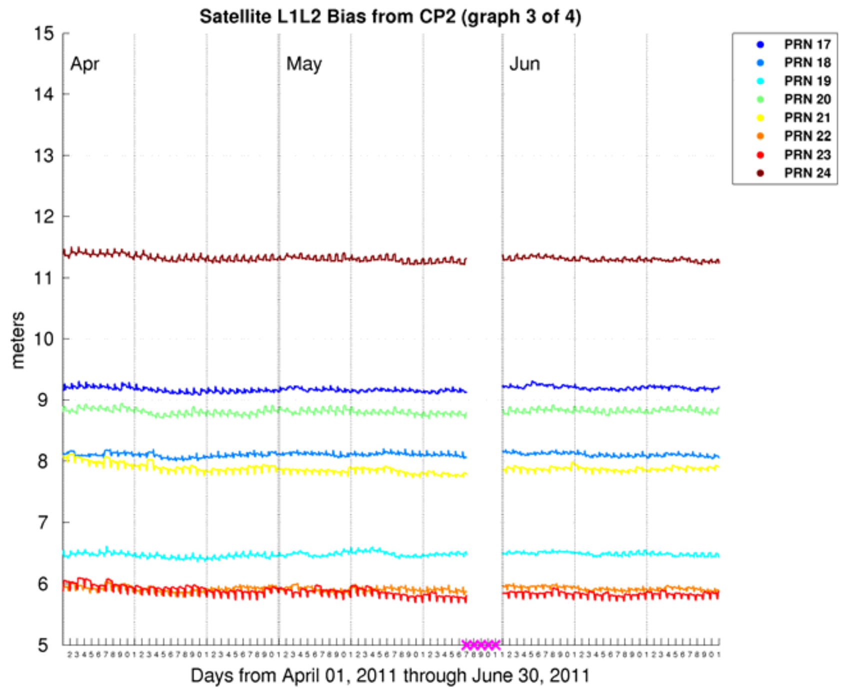


Figure 9.4-7 PRN17-24 L1L2 Bias from CP2

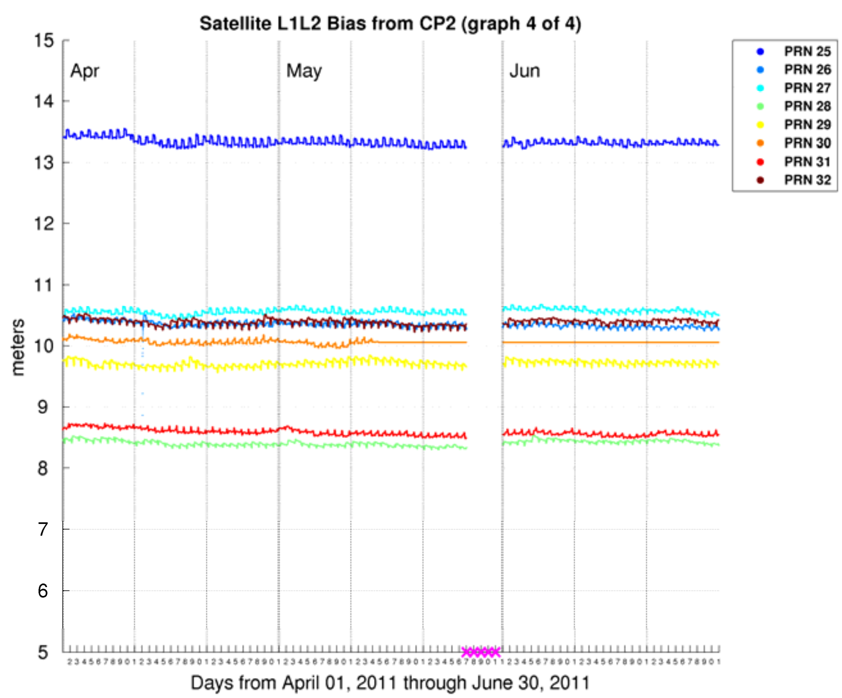


Figure 9.4-8 PRN25-32 L1L2 Bias for CP2

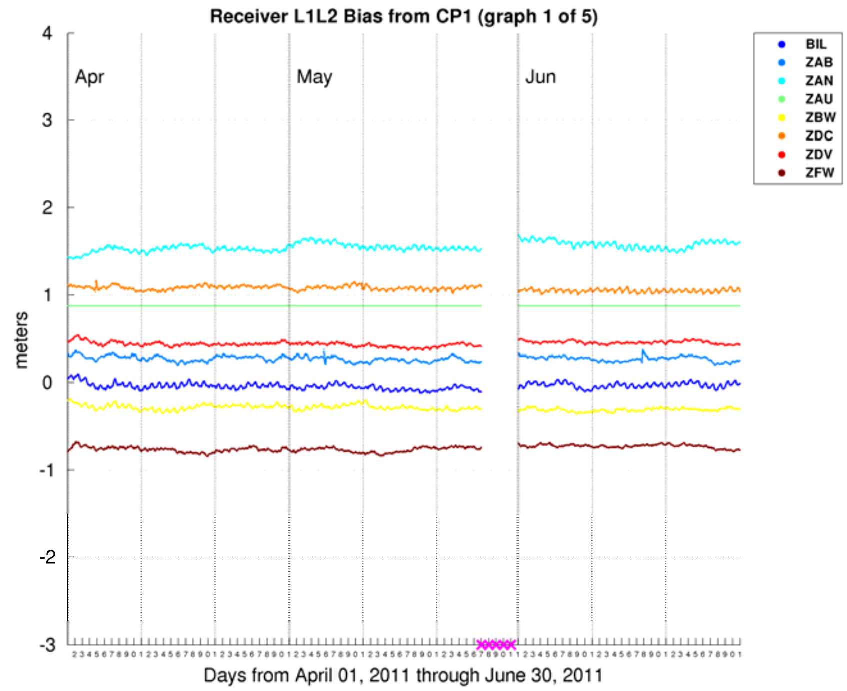


Figure 9.4-9 Receiver L1L2 Bias from CP1 (1 of 5)

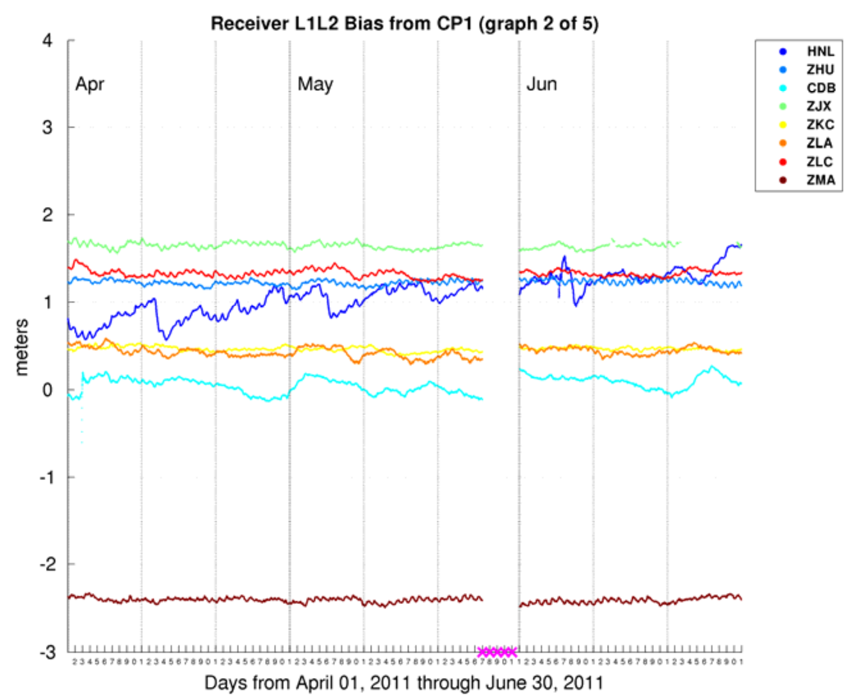


Figure 9.4-10 Receiver L1L2 Bias from CP1 (2 of 5)

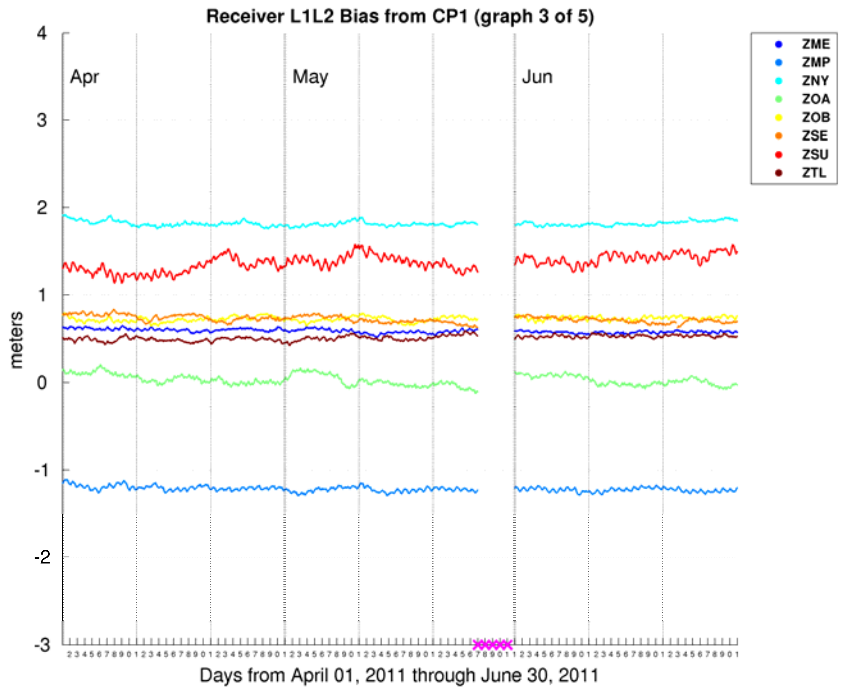


Figure 9.4-11 Receiver L1L2 Bias from CP1 (3 of 5)

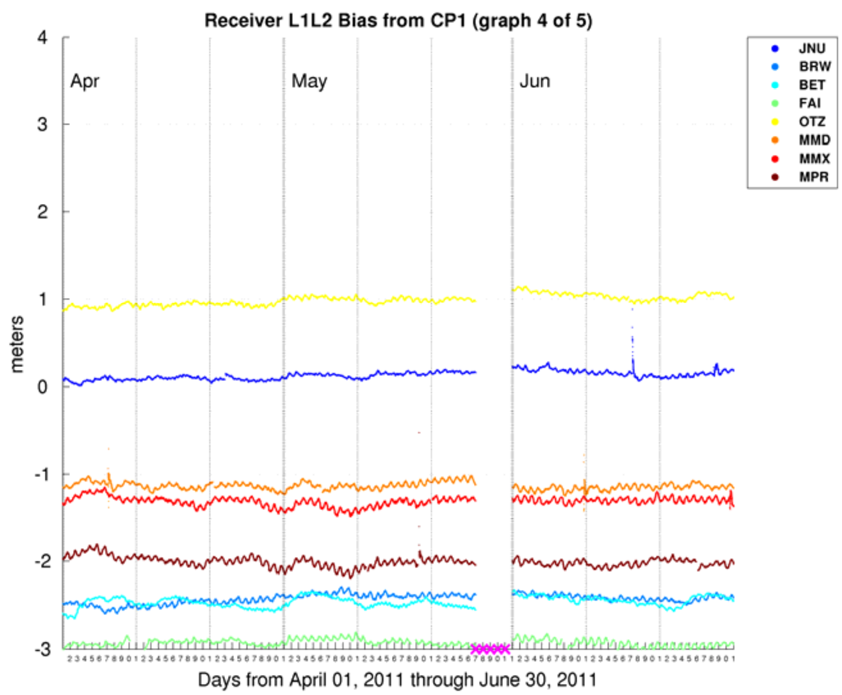


Figure 9.4-12 Receiver L1L2 Bias from CP1 (4 of 5)

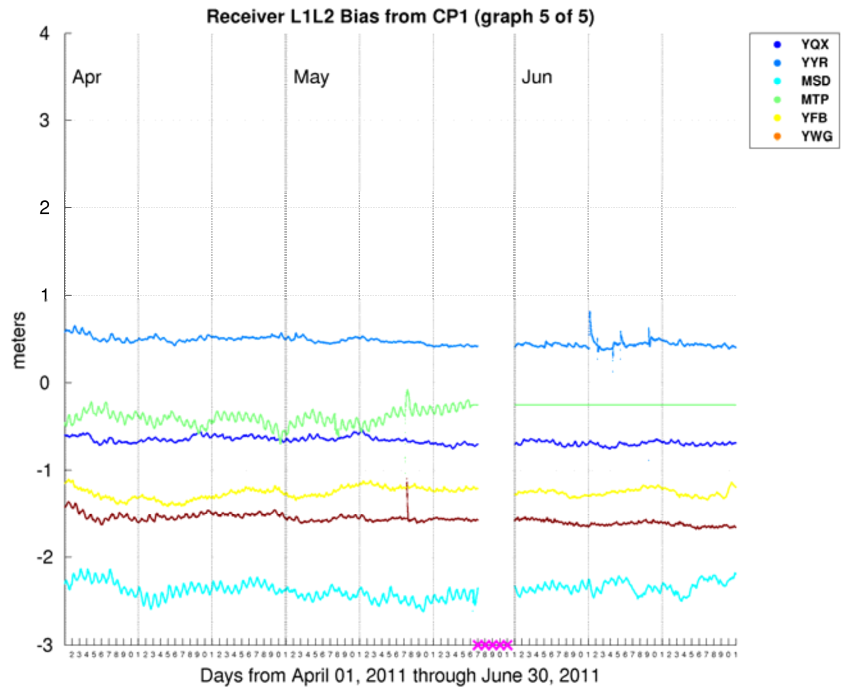


Figure 9.4-13 Receiver L1L2 Bias from CP1 (5 of 5)

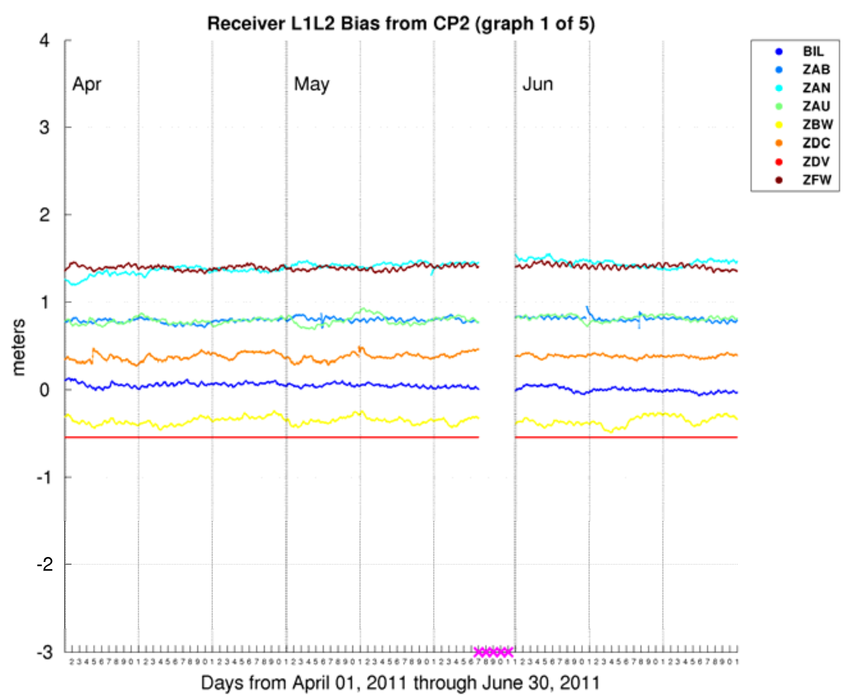


Figure 9.4-14 Receiver L1L2 bias from CP2 (1 of 5)

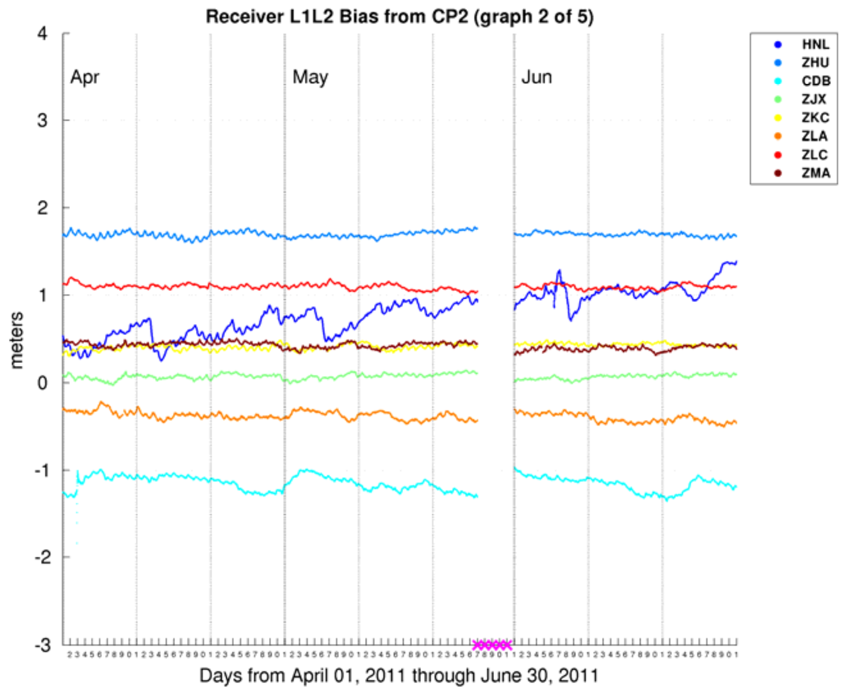


Figure 9.4-15 Receiver L1L2 bias from CP2 (2 of 5)

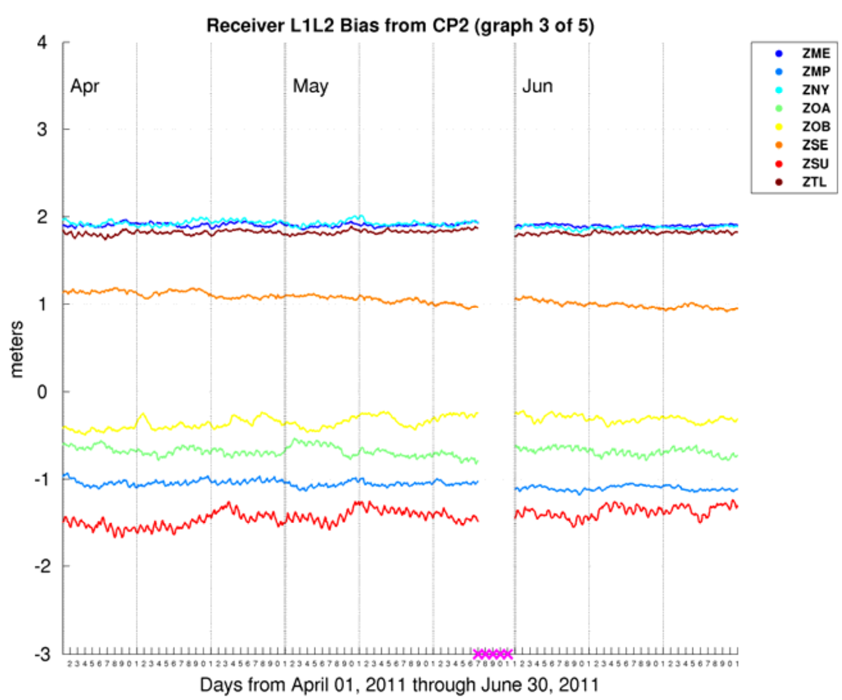


Figure 9.4-16 Receiver L1L2 bias from CP2 (3 of 5)

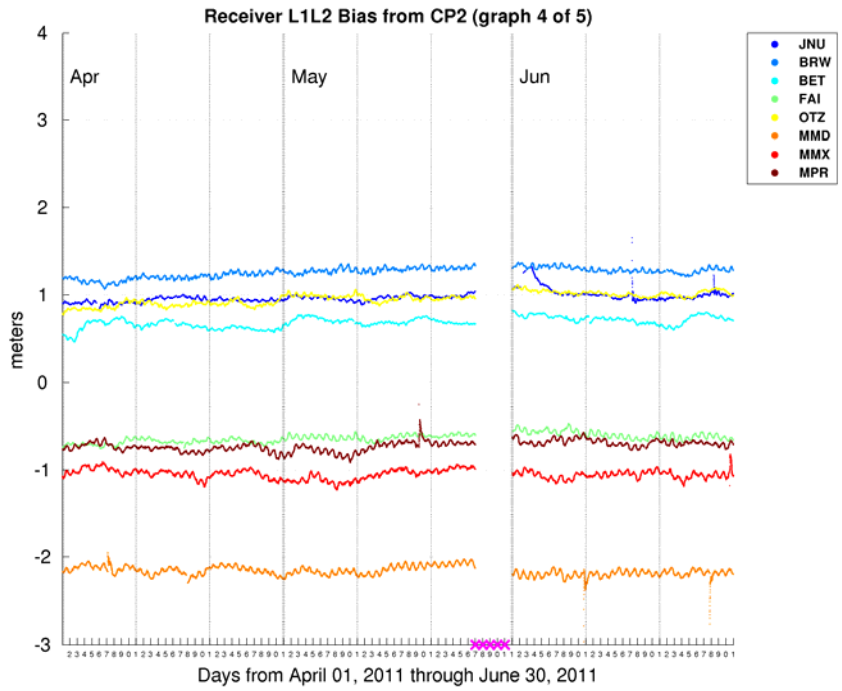


Figure 9.4-17 Receiver L1L2 bias from CP2 (4 of 5)

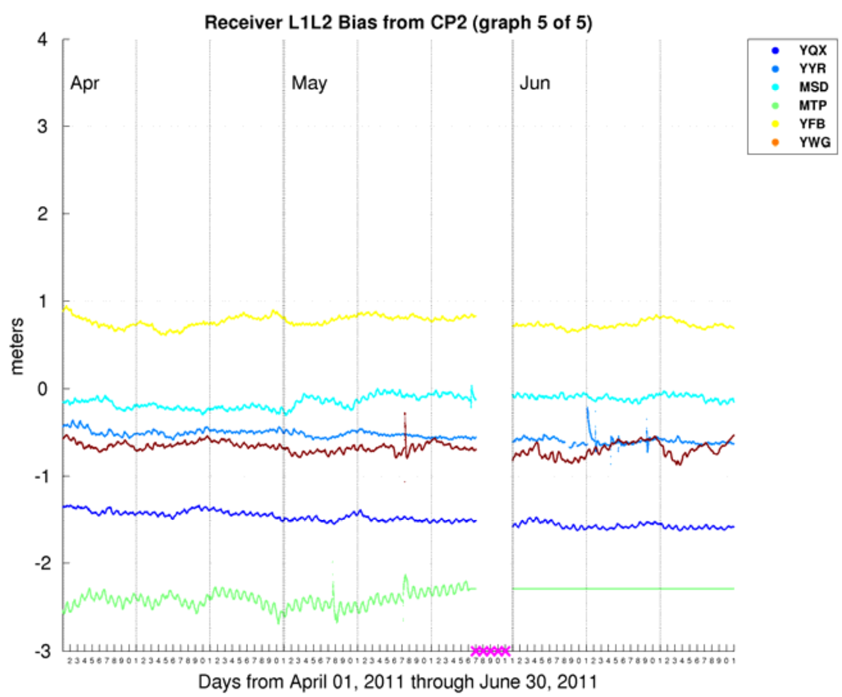


Figure 9.4-18 Receiver L1L2 bias from CP2 (5 of 5)

10 Appendix

10.1 Equations

10.1.1 CNMP

The cumulative density function (CDF) is defined as:

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

Equation 10.1-1 : Cumulative Density Function (CDF)

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

Equation 10.1-2

CNMP passes for $\Delta x > 0$ for all $|x| > 0.25$.

10.2 References

WAAS CDRL A014-011 "Algorithm Contribution to HMI for the WAAS"

10.3 Assertions

10.3.1 Code Carrier Coherence

The *a priori* probability of a CCC failure is less than 1x10-4 per set of satellites in view per hour for GPS satellites and 1.14x10-4 for GEO satellites.

10.3.2 CNMP

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.

10.3.3 Antenna Monitoring

The position error (RSS) for each WAAS reference station antenna is 10 cm or less when measured relative to the ITRF datum for any given epoch. (Mexico City is allowed 25cm). The ITRF datum version (realization) is the one consistent with WGS-84 and also used for positions of the GPS Operational Control Segment monitoring stations.

10.3.4 Ephemeris

The CDF of GPS ephemeris errors in a Height, Cross-track, and Along-track (HCL) coordinate system is bounded by the CDF of a zero-mean Gaussian distribution along each axis whose standard deviations are σosp-ephh, ospephc, and ?osp-ephl. The probability that a satellite's position error is not characterized by this a priori ephemeris model is less than 10-4 per hour.

10.3.5 Ionospheric Threat Model

The values of $\sigma_{decorr\_undersampeled}$ 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.

10.4 Coding standards and guidelines

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. PCRs 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".

10.4.1 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.

10.4.2 Offline Monitoring 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 "close 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 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.

10.4.3 File naming conventions

While no complete convention exists, there are standard "pieces" which shall be enforced for the Offline Monitoring 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 UDRE index. 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.

10.4.4 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.

Table 10.4-1 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 edges defined in table 10.4-1.

Table 10.4-1 Data histogram bin requirements

Data Description	Data file	Data min	Bin width	Data max	Units
Raw CCC metric (L1 and L2)	Qstats*	-8.0	0.01	8.0	meters
CCC metrics normalized by trip threshold	Qstats*	-3.0	0.01	3.0	None
CCC metrics normalized by MERR	Qstats*	-2.0	0.001	2.0	None
Max SQM metric	SQM_reduced	0	0.001	2.0	None

Table 10.4-2 below shows the slicing requirements, i.e., the number of columns (and their designations) for each type of slice.

Table 10.4-2 Slicing requirements

Slice Description	# 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 through 14 represent the data associated with a UDREI of one less than the column, i.e., UDREIs of 0 through 13. The last two columns represent satellites which are NM and DU 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 data ns the aggregate of the GEO data respectively. This order is maintained.

10.4.5 OLM file formats

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

10.4.5.1 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.

10.4.5.2 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.

10.4.5.3Time 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 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).

10.4.5.4Quantity 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.

10.4.5.5Quarterly 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.

10.5 Offline Monitoring Process and Procedures

10.5.1 Schedule and Meetings
The offline monitoring 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 offline monitoring 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

10.5.2 Data Processing
The data processing strategy for the Offline Monitoring 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.

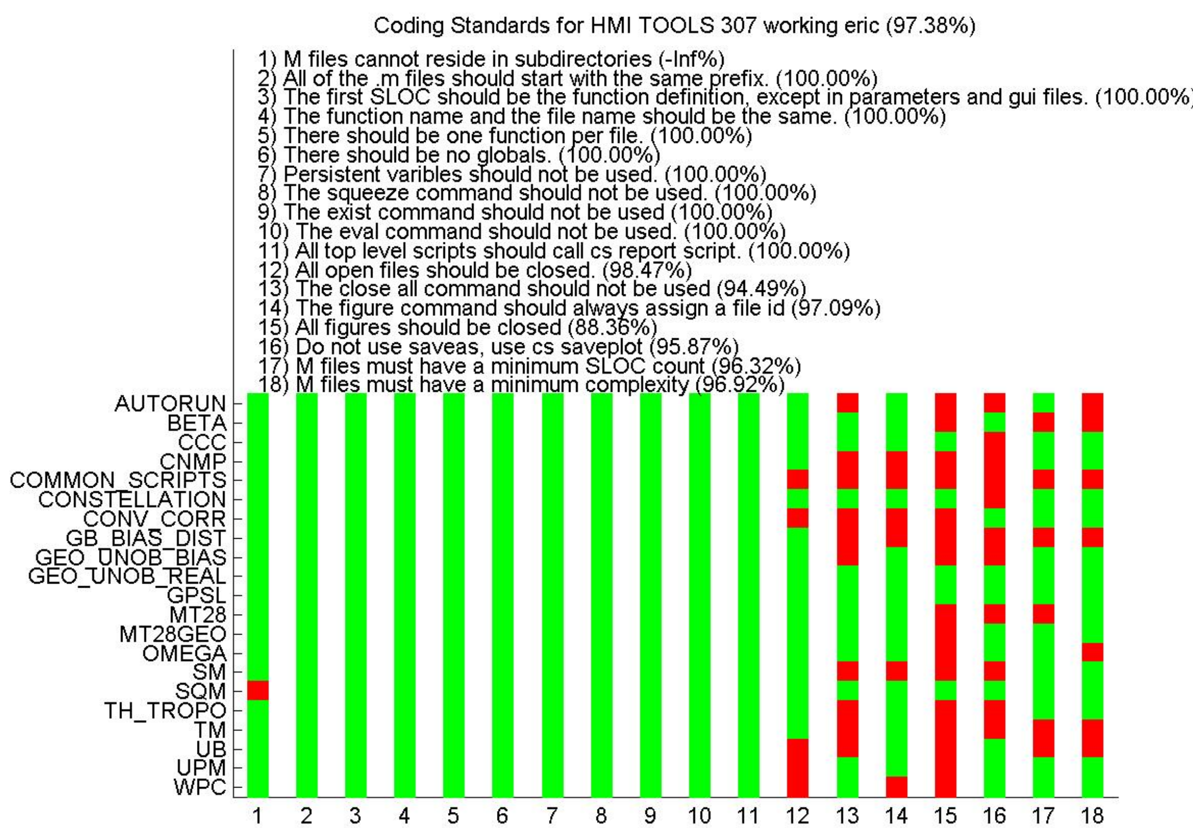
Once the daily analyses have been run, the results are compiled into a “report” directory. This includes the accumulation of histogram data, and the plotting of statistics across the quarter.

10.5.3 Tool Strategy
Tool builds created at both SOS and 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.

An example of the current coding standards plot is shown below. As can be seen, 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 SLOC count and complexity) are also listed. The plot below just serves as an example.



10.6 Acronym and Abbreviations

==Numbers==
1PPS One Pulse per Second
==A==
AAC Aeronautical Administrative Communication
A-S Anti-spoofing
A/D Analog-to-digital (conversion)
AC Alternating Current
ACEPS ARTCC Critical and Essential Power System
ACS Access Router
ADC Analog-to-digital converter
ADD Algorithm Description Document
ADR Accumulated delta range
ADS Automatic dependent surveillance
ADS_B Aircraft–automatic Dependent Surveillance-Broadcast
AF Airway Facilities (Airway Facilities name has been changed to Technical Operation)
AGC Automatic gain control
AGL Above Ground Level
AHRS Attitude and heading reference system
AIC Akaike information-theoretic criterion
AIRS Advanced inertial reference sphere
AIS Aeronautical Information System
AIT Automatic Integrity Test
AIX Advance Interactive eXecutive
ALF Atmospheric loss factor
ALS Autonomous landing system
altBOC Alternate binary offset carrier
ANH Access Node Hub
AODE Age of data word, ephemeris
AOR-E Atlantic Ocean Region East (WAAS)
AOR-W Atlantic Ocean Region West (WAAS)
AOS Operational Support Navigation and Landing Branch (PNB.1.2.2.2 p.35)
APV- I Approach with Vertical Guidance (For APV- I , VAL = 50m, HAL = 40m in HMI)
AR Autoregressive
ARMA Autoregressive moving average
ARNS Aeronautical Radio Navigation Services
ARP Antenna Reference Point
ARTCC Air Route Traffic Control Center
ASD Amplitude spectral density
ASIC Application-specific integrated circuit
ASL Above Sea Level
ASQF Application-Specific Qualification Facility (EGNOS)
ATC Air Traffic Control
ATCT Air Traffic Control Towers
ATCU Air Traffic Control Unit
ATM Air Traffic Management
AWACS Airborne Warning and Control System

==B==
BCN Backbone Concentrator Node
BDUMP Binary Data Utilities and Manipulation Program
BEI Bias Error Injection (HMI)
BIPM International Bureau of Weight and Measures
BIT Built-in Test
BMV Broadcast Message Validation
BOC Binary offset carrier

BOE Basis of Estimate
Bps Bits per Second
BPSK Binary phase-shift keying
BQT Build Qualification Test
BRASS Bilingual Request and Security Subsystem
BUTS
BW Bandwidth

==C==
C&V Correction and verification (WAAS)
C/A Coarse acquisition (channel or code)
C/No Carrier to Noise
CASE Computer Aided Software Engineering (it is a Software Engineering System tool)
CAT Collection & Analysis Tools
CCB Configuration Control Board (hardware only - see SCCB for Software [PNB.1.2.2.4, p4]
CCC Code Carrier Coherence
CCD Configuration Control Decision
CCS Configuration Control System
CDCV
CDF Cumulative Distribution Function
CDM Code-division multiplexing
CDMA Code-division multiple access
CDTI Cockpit Display of Traffic Information
CDRL Contract Data Requirements List
CEP Circle error probable
CHIA Change Impact Assessment aka Change Impact Analysis
CID Commercial Item Drawing
CIDS Critical Item Development Specification
CLIN Contract Line Item Number
cm centimeters
CMCI Code Minus Carrier Minus Iono Delay
CME coronal mass ejection (when the sun emitted a C-class solar flare in space that effect on WAAS)
CMP Comparator (Fault Tree)
CMTP Contractors Master Test Plan
CNMP Code Noise and Multipath (CNMP) | Code Noise and Multipath
CNS Communication Navigation Surveillance
COB Close of Business
CONUS Conterminous United States
Contiguous United States
Continental United States
CORS Continuously Operating Reference Station
COSPAS Acronym from transliterated Russian title "Cosmicheskaya Sistyema Poiska Avariynich Sudov," meaning "Space System for the Search of Vessels in Distress"
COTS Commercial Off-The-Shelf
CP Corrections Processor
CPDLC Controller Pilot Datalink Communications
CPR Cost Performance Report
CPS Chips per second
CPSD Carrier Phase Standard Deviation
CPU Central Processor Unit
CRC Cyclic Redundancy Check
CRE Central Region East (geo satellite East)
CRL Communications Research Laboratory
CRW Central Region West (geo satellite West)
CSC Computer Software Component
CSCI Computer Software Configuration Item
CSU Computer Software Unit
CV Correction & Verification
CW Continuous Wave
CWAAS Canadian WAAS

==D==
dB Decibel
dBi Decibel relative to isotropically radiated power
dBW Decibel relative to 1 Watt
DC Direct Current
DCAF
DCP Data Collection Processor (WRS)
DD Double Delta (in SQM tool)
DDD Database Driven Development
DFC Dole Frequency Contract
DGNSS Differential GNSS
DGPS Differential Global Positioning System
DH Decision Height
DLL Delay Loop-Lock (in HMI analysis)
DM Detection Metrics (in SQM ADD)
DME Distance measurement equipment
DNS Domain Name System
DNU Do Not Use (a SV setting indicating its data should not be used)
DOD Department of Defense (USA)
DOP Dilution of Precision
DQT Design Qualification Test
DRMS Distance Root Mean Square
DRS Data Reduction Software
DRT Deployment Readiness Test
D/T Detection Metric / Threshold
DT&E Development Test and Evaluation

==E==
EBC Event Based Certification
ECEF Earth-centered, earth-fixed (coordinates)
ECI Earth-centered inertial (coordinates)
ECR Engineering Change Request
EGNOS European (also Geostationary) Navigation Overlay System
EIRP Effective isotropic radiated power
EIRP Equivalent Isotropically Radiated Power
EMA Electromagnetic accelerator or accelerometer
EML Early Minus Late (in SQM tool)
ENU East-north-up (coordinates)
EOP Earth Orbit Parameters
ESA European Space Agency
ESD Electro Static Discharge
Extreme Storm Detector
ESGN Electrically Supported Gyro Navigation (System USA)
ESS ESSMain Page | Enhanced Shadow System
EU European Union
EVM Earned Value Management
EWAN EGNOS Wide-Area (communication) Network (EGNOS)

==F==
FAA Federal Aviation Administration (USA)
FAR Federal Aviation Regulation - Part 171
FAS Final Approach Segment
FCS Frame Check Sequence (O&M access Router)
FCR File Change Report
FDI F D I (we need to find out)
FDP Field Deployment Plan
FEC Forward Error Correction
FF Fault Free (Fault Tree)

FLL Frequency-lock loop
FLP Full LPV Lateral Precision with Vertical guidance
FM Frequency modulation
FMEA Failure Modes and Effects Analysis
FOB Freight-On-Board
FOC Full Operational Capability
FOG Fiberoptic gyroscope
FPE Final prediction error (Akaike's)
FRDF Facility Reference Data File
FRP Federal Radionavigation Plan
FSCK It is a Unix utility for checking and repairing file system
FSLF Free-space loss factor
FT Feet
FTA Fault Tree Analysis
FTD Fails To Detect (Fault Tree)
FVS Functional Verification System

==G==
GA General Aviation
GAD Ground Accuracy Designator
GAGAN GPS & GEO Augmented Navigation (India)
GBAS Ground-based augmentation system
GCCC Geo Code Carrier Coherence
GCCS Geostationary Communication and Control Segment
GCS Geostationary Communications Subsystem
GCST Geostationary Communications Subsystem Type 1
GDOP Geometric dilution of precision
GEO Geostationary Earth Orbit
Geosynchronous Satellite
GES GPS Earth Station COMSAT
Ground Earth Station
GFE Government-Furnished Equipment
GIC GPS Integrity Channel
GIM Global Ionospheric Model
GIP Government Industry Partnership
GIPSY GPS Infrared Positioning System
GIS Geographic information system(s)
GISE Grid Ionospheric Slant Error
GIVE Grid Ionospheric Vertical Error
GIVEI Grid Ionospheric Vertical Error Indicator
GLONASS Global Orbiting Navigation Satellite System
GLS Global Positioning System Landing System
GNSS Global Navigation Satellite System
GNSSP Global Navigation Satellite System Panel
GOA GIPSY/OASIS analysis
GP GUS Processor
GPS Global Positioning System
GPSL GPS Leveling (GPSL) Tool|GSP Leveling HMI tool
GPT GUS Processor Type 1
GSP GEO Satellite Payload
GSQA GEO Signal Quality Analysis
GST GEO Satellite Transponder
GUI Graphical User Interface
GUS Geostationary Satellite Up-link Station
GUSP GUS Processor
GUST GEO Uplink Subsystem Type 1

==H==
HAC Height, Along, Cross

HAL Horizontal Alert Limit
HCL Height, Cross-track, and Along-track
hcp HMI Critical Parameters (HCP) | HMI Critical Parameters
HDOP Horizontal Dilution of Precision
HFWG Human Factors Work Group
HMI Hazardously Misleading Information (HMI)|Hazardously Misleading Information
HNL Honolulu, WRS Site
HOW Handover word
HRB Hazard Review Board
HRG Hemispheric resonator gyroscope
HTEM HMI Tool Execution Manual (HTEM) | HMI Tool Execution Manual
HWCI Hardware Configuration Item
Hz Hertz

==I==
I-3 INMARSAT-3
I/S Interference-to-Signal ratio
IAD Incremental Asynchronous Data
ICAO International Civil Aviation Organization
ICAT
ICC Ionospheric correction computation
Inter-code comparison
Interface Control Contractor
ICD Interface Control Document
ICDLS Interim Contractor Depot Logistics Support
ICG International Committee on GNSS (United Nation)
ID Identifier
IDV Independent Data Verification (of WAAS)
IF Intermediate frequency
IFOG Integrating or interferometric Fiberoptic gyroscope
IFPR Ionospheric Free PseudoRange (HMI)
IGD Ionospheric grid Delay (HMI)
IGP Ionospheric grid point (for WAAS)
IGS International GNSS Service
ILS Instrument Landing System
ILS Integrated Logistic Support
IMC Instrument Meteorologic Condition
IM Integrity Monitor
IMS I M S
IMUT Utility Function (inside the Integrity Monitor)
IMVM Broadcast Message Validation
IMU Inertial measurement unit
Inmarsat International Mobil (originally "Maritime") Satellite Organization
INS Inertial navigation system
IOC Initial Operating Capability
IOD Issue of Data
IODC Issue of data, clock
IODE Issue of data, ephemeris
IODF Issue of Data Fast Correction
IODI Issue of Data Ionosphere
IODP Ionosphere Issue of Data PRN
ION Institute of Navigation
IONO Ionosphere, Ionospheric
IOT In-orbit test
IPP Ionospheric Pierce Point
IR Implementation Report
IRB Inter-receiver Bias (in SQM, defined as the component of the detection metric measurements that are caused by receiver filter distortion)

IRD Interface Requirements Documents
IRS Interface Requirements Specification
IRU Inertial reference unit
ISA Inertial sensor assembly
ISP Integrated Software Prototype
ITRF International Terrestrial Reference Frame
IUA Item Under Analysis

==J==
JAA Joint Aviation Authorities (regulatory authorities of a number of European States, similar to FAA)
JFS Journaled File System (is a 64-bit file system created by IBM)
JPALS Joint precision approach and landing system for air force (similar to LAAS)
JPL Jet Propulsion Laboratory
JRC Joint Resource Council
JTIDS Joint Tactical Information Distribution System

==K==
Kbps Kilobits per second
kHz Kilohertz
km Kilometer
KP KP is a index used to indicate the severity of the global magnetic disturbances in near Earth space.
KPA Klystron Power Amplifier
KTP Knowledge Transfer Plan
KVM Keyboard Video Mouse

==L==
L1 Radio Frequency L1 (GPS)
L2 Radio Frequency L2 (GPS)
LAAS Local Area Augmentation System
LADGPS Local-area differential GPS
LD Location determination
LEM Lunar Excursion module
LEO Low-Earth Orbiter
LGF Local Area Augmentation System Ground Facility
LHCP Left-hand circularly polarized
LNA Low Noise Amplifier
LNAV Lateral NAVigation (also referred to as NPA - Non-Precision Approach)
LNAV/VNAVLateral Navigation/Vertical Navigation (LNAV/VNAV)
LORAN Long-range navigation
LOF Loss of Function (HMI)
LOS Line of sight (measurement in HMI)
LPV Localizer Performance with Vertical Guidance (preferred), '''OR''' Lateral Precision with Vertical Guidance '''OR''' Lateral positioning with vertical guidance
LRU Line Replaceable Units
LSB Least Significant Bit
LSP Local Status Panel
LTC Linear Time Code
LTC Longitudinal Time Code
LTI Linear Time-Invariant (in Kalman Filter)
LTN Littleton, CO
LTP Local Area Augmentation System Test Prototype
LTP Local tangent plane

==M==
M Meter
MASPS Minimum Aviation System Performance Standard
MBOC Modified BOC
Mbps Million bits per second

M&C Monitor & Control
MCC Mission/Master Control Center (EGNOS)
Mchips Megachips
MCP Message Control Processor
MCPS Million Chips Per Second
MCS Master Control Station
MDE Minimum Detectable Error (in CCC tool)
MDT Maintenance Data Terminal
MEDLL Multipath-estimating delay-lock loop
MEMS Microelectromechanical system(s)
MEO Medium Earth Orbit
MERR Maximum Error Range Residual
MHz Megahertz
MI Misleading Information (Fault Tree)
MIL-STD Military Standard
MIPS Master Integrated Program Schedule
ML Maximum likelihood
MLA Multipath Limiting Antenna
MLE Maximum likelihood estimate (or estimator)
MMSE Minimum mean-squared error (estimator)
MMT Multipath mitigation technology
MOPS Minimum Operational Performance Standards
MPR Porta Vallarta Reference Station in Mexico
MPS Maintenance Processor System
ms millisecond
MSAS MTSAT Satellite-based Augmentation System (Japan)
MSB Most Significant Bit
MSL Mean Sea Level
MTBF Mean Time Between Failure
MTL Multi-Tool Launcher
MTSAT Multifunction Transport Satellite (Japan)
MTTR Mean Time to Repair
MVUE Minimum-variance unbiased estimator
mW-hr/cm2Milliwatt-hours per centimeter squared
mW/cm2 Milliwatts per centimeter squared
MWG Momentum wheel gyroscope

==N==
NA Not Applicable
NANU Notice Advisory to NAVSTAR Users
NAS National Airspace System
NAVSTAR Navigation system with time and range
NAWC Naval Air Warfare Center
NCO Numerically controlled oscillator
NCP NAS Change Proposal
NDI Non-Developmental Item
NDU Navigation Data Unit
NED North-east-down (coordinates)
NFF Non Fault Free (Fault Tree)
NGS National Geodetic Survey (USA)
NICS NAS Interfacility Communications System
NIST National Institute of Standards and Technology
NLES Navigation Land Earth Station(s) (EGNOS)
ns nanosecond
NOTAM Notice to Airmen
NPA Nonprecision Approach (see also LNAV - Lateral Navigation)
NSE Navigation Sensor Error
NSRS National Spatial Reference System

NSTB National Satellite Test Bed
NTP Network Time Protocol

==O==
.odiff Formatted Orbit Differential File
O&M Operations and Maintenance Station
OAC O & M Access Router
OASIS Orbit analysis simulation software
OBAD Old but active data
OCC Operational Control Center
OCXO Oven Controlled Crystal Oscillator
OD Orbit determination
OEI O & M External Interface
OLM Off Line Monitoring
OPUS Online Positioning User Service (of NGS)
OS Open service (of Galileo)
OSP Operational System Parameter

==P==
P-Code Precise or Protected Code
P3I Pre-Planned Product Improvement
PA Precision Approach
PACF Performance Assessment and Checkout Facility (EGNOS)
PAN Performance Analysis Network (part of WAAS Performance Analysis Report)
PAT&E Production Acceptance Test and Evaluation
PBF Position Bias Filter
PBLI Product Baseline Listing Index
PBN performance Based Navigation
PCR Problem/Change Report (PNB.1.2.2.2, p.35) '''or''' Problem Change Request (PNB.1.2.2.2, p.12) [Note multiple definitions, even in the same document. Probably all mean the same thing]
PCRB Program Change Review Board
PCS
PDF Portable Document Format
Probability Distribution Function
PDOP Position dilution of precision
PDL Program Design Language
PEP Program Execution Plan
PHMI Probability Hazardously Misleading Information
PI Proportional and integral (controller)
PID Process Input Data (of WAAS)
PID Proportional, integral, and differential (control)
PIGA Pulse integrating gyroscopic accelerometer
PLL Phase-lock loop
PLCI unknown. see PNB.1.2.2.4, p.6
PLRS Position Location and Reporting System (U.S. Army)
PN PRN Number
PNB (Raytheon) Program Notebook
PNE Phase Noise Enhancer
PNT Positioning Navigation and Timing
POM Program Overview Meeting
POR Pacific Ocean Region
PPD Personal Privacy Devices
PPE Personal Protective Equipment
PPFL Pierce Point Filter Line
PPS Precise Positioning Service
PPS Pulse(s) per second
PR Pseudorange
PRCf Pseudorange Correction fast
PROTCV Prototype Correction and Verification

PRN Pseudorandom noise (see also PN and SVN)
PRS Public Regulated service (of Galileo)
PRSD Pseudo Range Standard Deviation
PSD Power spectral density
PUID Project Unique Identifier
PVR Performance Validation Record (HMI)

==Q==
QA Quality Assurance
==R==
RAG Receiver antenna gain (relative to isotropic)
RAIM Receiver Autonomous Integrity Monitoring (see RAIM in Wikipediahttp//en.wikipedia.org/wiki/Receiver_Autonomous_Integrity_Monitoring)
RAM Random-Access Memory
RCM Reliability Centered Maintenance
RDM Range Domain Monitor
RDT Relative Detection Time (in SQM ADD)
REA Raytheon Engineering Authority '''aka''' Lead Engineer (PNB.1.2.2.2, p.6) '''OR''' Responsible Engineering Activity (PNB.1.2.2.4, p.1)
RF Radiofrequency
RFU Radio Frequency Uplink
RG Rate Group
RGC Range Group Converter
RHCP Right-hand circularly polarized
RIMS Ranging and Integrity Monitoring Stations(s) (EGNOS)
RINEX Receiver Independent Exchange format (for GPS data)
RLG Ring laser gyroscope
RMA Reliability, maintainability, availability
RMMS Remote Maintenance Monitoring System
RMS/rms root mean square
RMS Reference monitoring station
RMS Remote Monitoring Subsystem
RNP Required Navigation Performance
ROT Residual Over Threshold
Rate Of TEC (TEC Total Electron Content)
ROUS Rodents Of Unusual Size
RPY Roll-pitch-yaw (coordinates)
RR Reference Receiver
RS Reference Station
RSP Remote Status Panel
RSS Root Sum Square
RTC Real Time Control
RTCA Radio Technical Commission for Aeronautics, Inc., Washington, DC
RTCM Real Time Correction Messages
RTCM Radio Technical Commission for Maritime Service
RTOS Real-time operating system
RVCG Rotational vibratory coriolis gyroscope
RVR Runway Visual Range

==S==
s second
SA Selective availability (also abbreviated "S/A")
SACIL Safety Assurance Configuration Index List
SAR Search and rescue (service of Galileo) '''OR''' Safety Assessment Report
SARP Standards and Recommended Practices (Japan)
SARPS Standards and Recommended Practices
SARSAT Search and rescue satellite-aided tracking
SAS Software Accomplishment Summary
SATCOM or Satcom which stands for Satellite Communication
SAW Surface acoustic wave

SBAS Space-based augmentation system
SBIA Safety Baseline Impact Assessment
SBIRLEO Space-based infrared low earth orbit
SC Special Committee
SCAF A Receiver Error (Scale Cross Ambiguity Function)
SCC Satellite Control Center
SCCB Software Change Control Board '''OR''' Software Configuration Control Board
SCM Software Configuration Management
SCN
SCOUT Scripps coordinate update tools
SCP Satellite Correction Processing (of WAAS)
SCR Specification Change Request (PNB.1.2.2.2, p.36) '''or''' (aka Specification Change Report but probably not official) '''or''' Software Change Request (PNB.1.2.2.4, p.2 PNB.1.2.2.2, p.12) [Probably incorrect]
SD Signal Deformation
SDF Software Development Folder
SDR Software Design Review
System Design Review
SEWG Systems Engineering Working Group
SF Scale Factor
SGS Signal Generator Subsystem
SGST Signal Generator Subsystem Type 1
SIS Signal in space
SIT System Integration Test
SLB Short Loop Back (Fault Tree)
SLES Second Level Engineering Support
SLOC Single Line of Code (term often used for budgeting purposes in level B code)
SM Solar magnetic
Sigma Manager (SM) in HMI Tool | Sigma Manager in HMI tool
Safety Monitor(SM) in C&V | Safety Monitor in C&V
SMS Safety Management System
SMS Service Monitoring Subsystem
SNAS Satellite Navigation Augmentation System (China)
SNMP Simple Network Management Protocol
SNR Signal-to-noise ratio
SOL Safety of Life Service (of Galileo) OR S*** Out Of Luck
SOS Safety and Operation Support
SOW Statement of Work
SP Safety Processor
SPS Software Product Specification (C&V)
Standard Positioning Service (GPS)
SQM Signal Quality Monitor/Signal Quality Monitoring
SRM Safety Risk Management
SRR Software Release Record
SRS Software Requirements Specification
SSD System Support Documentation
SSM System Support Modification
SSP Site Specific Parameters
SSWG System Safety Working Group
STD Software Test Descriptions
STF Signal Task Force (of Galileo) OR Software Test Facility
STP Software Test Plans
SV Space Vehicle
SVM Service Volume Model
SVN Space Vehicle Number (=PRN for GPS)

==T==
TACAS Traffic Alert and Collision Avoidance System
TBB To Be Broadcast (In HMI GIVE section GIVE_TBB)

TBD To Be Determined
TCAS Traffic Collision Avoidance System
TCN Terrestrial Communications Network
TCS Terrestrial Communications Subsystem (for WAAS)
TCXO Temperature-compensated Xtal (crystal) oscillator
TDMA Time Duplex Multiple Access
TDOA Time difference of arrival
TDOP Time dilution of precision
TDS Time Distribution System
TEC Total Electron Content
TECU Total Electron Content Units
TIB WAAS Technical Instruction Book|Technical Instruction Book
TLM Telemetry word
TLT Test Loop Translator
TM Threat Model Tool
TO Technical Operation
TOA Time of Applicability
TOA Time of arrival
TOD Time of Day
TOF Time of Applicability (is this correct? see TOA above)
TOW Time of Week
TRACON Terminal Radar Approach Control
TSO Technical Standard Order
TSS Test Support Software
TSWM Time Stamped WAAS Message (Fault Tree)
TTA Time to Alarm or Time to Alert
TTFF Time to first fix
TTT Time-to-Transmit (in SQM ADD)
TWG Transition Working Group

==U==
U.S. United States
UB UIVE Bounding Tool
UDRE User Differential Range Error
UDREI User Differential Range Error Indicator (SRS, p.C-612) '''OR''' UDRE Index (see HMI Doc A014_011 p220) where indices range from 3 to 13. Each UDREI represents a specific UDRE.
UE User Equipment (i.e. the WAAS-enabled GPS reciever a typical user would be operating to obtain WAAS corrections. See MOPS DO-229D)
UERE User-equivalent range error
UGP User Grid Points
UIVE User Ionospheric Vertical Error
UL Underwriter Laboratories
UPM User Position Monitor (in Safety Processor) or User Position Monitor Tool
URA User Range Accuracy
URE User range error
USAF United States Air Force
USN United States Navy
USNO US Naval Observatory
USTS
UTC Universal Time, Coordinated (or Coordinated Universal Time)
UTM Universal Transverse Mercator

==V==
VAG Visitor Access Gateway
VAL Vertical alert limit
VCG Vibratory coriolis gyroscope
VDB Very High Frequency Data Broadcast
VDD Version Description Document

VDOP Vertical Dilution of Precision
VHF Very high frequency (30-300 MHz)
VME Versa Module Eurocard
VNAV Vertical Navigation
VOR VHF Omnirange (radionavigation aid)
VPE Vertical Position Error
VPL Vertical Protection Levels
VRTM Verification Requirements Traceability Matrix <OR> Verification Requirements Test Matrix
VRW Velocity Random Walk

==W==
W3P WAAS 3rd Generation Prototype
W3CP WAAS 3rd Generation Correction Processor Prototype
W3SP WAAS 3rd Generation Safety Processor Prototype
WAAS Wide Area Augmentation System
WADGPS Wide-area differential GPS
WBN Woodbine, Maryland
WCCB WAAS Change Control Board
WCN WAAS Communications Node
WCR WAAS Change Request
WEI WAAS External Interface
WFO WAAS Follow On {contract}
WG Working Group
WGS World Geodetic System
WIPP WAAS Integrity & Performance Panel
WIRP Wide Area Augmentation System Integrigy & Performance Panel Integrity Resolution Process
WISP WAAS Integrated Software Prototype (equivalent to PROT_SP) (check on this definition) OR WAAS Integrity Simulated Safety Processor
WJHTC William J. Hughes Technical Center - Atlantic City, NJ
WLF WAAS Lab Facility
WMP WAAS Message Processor
WMS Wide Area Master Station | Wide-area Master Station
WN Week Number
WNT WAAS Network Time
WOS WAAS Operations Specialist
WPR WAAS Problem Report
WRE Wide-area Reference Equipment (WRE) | Wide-area Reference Equipment
WRS Wide Area Reference Station | Wide-area Reference Station
WRT With Respect To
WTMS WAAS Training and Maintenance System
WUM WAAS Users Message OR WAAS User Message
WUPS WAAS Users Position Solution OR WAAS User Position Software

==X==
==Y==
==Z==
ZAB Albuquerque Air Route Traffic Control Center (ARTCC)
ZAU Chicago Air Route Traffic Control Center (ARTCC)
ZBW Boston Air Route Traffic Control Center (ARTCC)
ZDC Washington Air Route Traffic Control Center (ARTCC)
ZFTZ Zero Filled Type Zero
ZFW Dallas-Ft Worth Air Route Traffic Control Center (ARTCC)
ZHU Houston Air Route Traffic Control Center (ARTCC)
ZID Indianapolis Air Route Traffic Control Center (ARTCC)
ZJX Jacksonville Air Route Traffic Control Center (ARTCC)
ZKC Kansas City Air Route Traffic Control Center (ARTCC)
ZLA Los Angeles Air Route Traffic Control Center (ARTCC)
ZLC Salt Lake City Air Route Traffic Control Center (ARTCC)

ZLG Zero-Lock Gyroscope ("Zero Lock Gyro" and "ZLG" are trademarks of Northrop Grumman Corp.)
ZMA Miami Air Route Traffic Control Center (ARTCC)
ZME Memphis Air Route Traffic Control Center (ARTCC)
ZMP Minneapolis Air Route Traffic Control Center (ARTCC)
ZNY New York Air Route Traffic Control Center (ARTCC)
ZOA Oakland Air Route Traffic Control Center (ARTCC)
ZOB Cleveland Air Route Traffic Control Center (ARTCC)
ZSE Seattle Air Route Traffic Control Center (ARTCC)
ZSU San Juan Air Route Traffic Control Center (ARTCC)
ZTL Atlanta Air Route Traffic Control Center (ARTCC)