WIDE-AREA AUGMENTATION SYSTEM PERFORMANCE ANALYSIS REPORT

Report #23

Reporting Period: October 1 to December 31, 2007

January 2008

FAA/William J. Hughes Technical Center
NSTB/WAAS T&E Team
Atlantic City International Airport, NJ 08405

Executive Summary

Since 1999 the WAAS Group at the William J. Hughes Technical Center has reported GPS performance as measured against the GPS Standard Positioning Service (SPS) Signal Specification. These quarterly reports are known as the PAN (Performance Analysis Network) Report. In addition to that report, the WAAS/NSTB Team reports on the performance of the Wide-Area Augmentation System (WAAS). This report is the twenty-first such WAAS quarterly report. This report covers WAAS performance during the period from October 1, 2007 to December 31 2007.

The following table shows observations for accuracy and availability made during the reporting period. See the body of the report for additional results in accuracy, availability, safety index, range accuracy, WAAS broadcast message rates and GEO ranging availability. Please note that the results in the below table are valid when the Localizer Approach with Vertical Guidance (LPV) service is available. LPV service is available when the calculated Horizontal Protection Level (HPL) is less than 40 meters and the Vertical Protection Level (VPL) is less than 50 meters.

Parameter	CONUS Site/Maximum	CONUS Site/Minimum	All Sites Site/Maximum	All Sites Site/Minimum
95% Horizontal Accuracy	Arcata 1.195 meters	Albuquerque 0.615 meters	Arcata 1.195 meters	Fairbanks 0.477 meters
95% Vertical Accuracy	Miami 1.282 meters	Salt Lake City 0.849 meters	Barrow 1.949 meters	Salt Lake City 0.849 meters
LPV Availability (HPL < 40 meters & VPL < 50 meters)	Salt Lake City 99.998%	Chicago 92.72%	Salt Lake City 99.998%	Tapachula 43.93%
95% HPL	Arcata 21.609 meters	Kansas City 13.356 meters	Tapachula 58.454 meters	Kansas City 13.356 meters
95% VPL	Oakland 33.741 meters	Kansas City 21.628 meters	Tapachula 78.035 meters	Kansas City 21.628 meters

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX

1.0 INTRODUCTION

The FAA began monitoring GPS SPS performance in order to ensure the safe and effective use of the satellite navigation system in the National Airspace System (NAS). The Wide Area Augmentation System (WAAS) adds more timely integrity monitoring of GPS and improves position accuracy and availability of GPS within the WAAS coverage area.

Objectives of this report are:

a. To evaluate and monitor the ability of WAAS to augment GPS by characterizing important performance parameters.
b. To analyze the effects of GPS satellite operation and maintenance, and ionospheric activity on the WAAS performance.
c. To investigate any GPS and WAAS anomalies and determine their impact on potential users.
d. To archive performance of GPS and WAAS for future evaluations.

The WAAS data transmitted from GEO satellite PRN#135 (CRW) and PRN#138 (CRE) were used in the evaluation. Currently both CRW and CRE GEO satellites provide a ranging capability for enroute through NPA service, but not for PA service.

Table 1.1 and Table 1.2 list NSTB and WAAS reference station receivers used in Precision Approach (PA) and Non-Precision Approach (NPA) evaluation process, respectively. This report presents results from three months of data, collected from October 1, 2007 to December 31, 2007

Table 1-1 PA Sites

	Number of Days Evaluated	Number of Samples
NSTB:		
Arcata	87	7514349
Atlantic City	89	7653136
Oklahoma City	86	7459289
WAAS:		
Albuquerque	92	7940097
Anchorage	92	7941345
Atlanta	92	7940504
Barrow	91	7895262
Bethel	91	7903296
Billings	92	7941332
Boston	92	7933265
Chicago	92	7941609
Cleveland	92	7935722
Cold Bay	89	7719618
Dallas	92	7941901
Denver	92	7935131
Fairbanks	92	7914851
Gander	92	7942881
Goose Bay	76	6600355
Houston	92	7934024
Iqaluit	79	6832907
Jacksonville	92	7939651
Juneau	92	7912101
Kansas City	92	7940343
Kotzebue	91	7886629
Los Angeles	92	7940933
Memphis	92	7937134
Merida	82	7056466
Mexico City	82	7072712
Miami	92	7940512
Minneapolis	92	7940876
New York	87	7529376
Oakland	92	7935492
Puerto Vallarta	82	7064527
Salt Lake City	92	7942372
San Jose Del Cabo	82	7064260
Seattle	91	7852985
Tapachula	74	6401440
Washington DC	92	7941558
Winnipeg	91	7858717

Table 1-2 NPA Sites

Location	Number of Days Evaluated	Number of Samples
Albuquerque	89.42	7725496
Anchorage	90.42	7812300
Atlanta	88.57	7652318
Barrow	86.43	7468175
Bethel	88.97	7686890
Billings	89.42	7725698
Boston	89.29	7714241
Cleveland	88.45	7641712
Cold Bay	89.46	7728972
Fairbanks	88.95	7685462
Gander	90.07	7781678
Honolulu	88.38	7635931
Houston	90.34	7805045
Iqaluit	46.54	4021105
Juneau	90.63	7830104
Kansas City	89.53	7735293
Kotzebue	88.09	7610964
Los Angeles	88.80	7672661
Merida	81.27	7021380
Miami	89.59	7740242
Minneapolis	89.33	7717960
Oakland	88.36	7633880
Salt Lake City	89.45	7728541
San Jose Del Cabo	80.16	6925910
San Juan	89.93	7770050
Seattle	87.07	7523260
Tapachula	73.75	6372142
Washington DC	88.26	7625990

The report is divided in the performance categories listed below. This report also includes WAAS LPV Service Availability at Selected Airports, and WAAS Deterministic Code Noise and Multipath (CNMP) Bounding Analysis.

1. WAAS Position Accuracy
2. WAAS Operational Service Availability
3. Coverage
4. Integrity
5. WAAS Range Domain Accuracy
6. GEO Ranging Performance

Table 1.3 lists the performance parameters evaluated for the WAAS in this report. Please note that these are the performance parameters associated with the WAAS IOC system. These requirements are extracted from the FAA Specification FAA-E-2892B Change 1and FAA Specification FAA-E-2976, as applicable.

Table 1-3 WAAS Performance Parameters

Performance Parameter	Expected WAAS Performance
PA Accuracy Horizontal	≤ 7.6m error 95% of the time
PA Accuracy Vertical	≤ 7.6m error 95% of the time
NPA Accuracy Horizontal	≤ 100m error 95% of the time ≤ 556m error 99.999% of the time
Availability LPV*	Not Defined for Current WAAS phase
Availability LNAV/VNAV*	Not Defined for Current WAAS phase
LPV and LNAV/VNAV Outages and outage rate	Not Defined for Current WAAS phase
LNAV Outages and outage rates	Not Defined for Current WAAS phase
Coverage LPV	Not Defined for Current WAAS phase For this report - 95% availability of 75% of CONUS
Coverage LNAV/VNAV	95% availability of 75% of CONUS
Coverage NPA	99.9% availability of 75% of service volume
LPV Availability	≥ 95% of the time within the service volume
LNAV/VNAV Availability	≥ 95% of the time within the service volume
Integrity	≤ 4 X 10e-8 HMI's per approach

* Instantaneous availability (i.e. Availability is calculated every second.)

1.1 Event Summary

Table 1.4 lists test events that occurred during the reporting period that affected WAAS performance or the ability to determine the WAAS performance. These events include GPS or WAAS anomalies, relevant receiver malfunctions, and receiver maintenance conducted. Detailed analyses of particular events are documented in the Discrepancy Reports (DR). The DRs are posted on the website http://www.nstb.tc.faa.gov under 'WAAS Technical Reports' and can also be accessed via hyperlink from Table 1.4 below.

Table 1-4 Test Events

GPS Week	Date	Sites	Events
1447 day 1	10/1/07	Oklahoma City	Oklahoma City outage.
1447 day 1	10/1/07	Winnipeg	Winnipeg outage.
1447 day 3	10/3/07	Several International Sites	Better IGP availability enhanced PA coverage in Mexico and Canada.
1447 day 5 to 1448 day 2	10/5/07 to 10/9/07	Arcata	Arcata outage.
1447 day 6 to 1448 day 2	10/6/07 to 10/9/07	Atlantic City	Atlantic City outage.

GPS Week	Date	Sites	Events
1448 day 1	10/8/07	CRW-only sites	C&V selected source switch on CRW GUST's preceded CRW Geo initialization.
1448 day 1	10/8/07	Multiple Sites	See DR# 65, "Three Unforecasted GPS Satellite Outages Caused Reduced Ranging Availability."
1448 day 1 to 1448 day 3	10/8/07 to 10/10/07	Multiple Sites	Upgraded GPS ground system experienced issues uploading to IIR & IIR-M SV's, causing unexpected SV outages. See NANU's 2007120, 2007121, 2007124, 2007126, 2007128, 2007135.
1450 day 3	10/24/07	Seattle	L2 interference at Seattle.
1450 day 4 to 1455 day 5	10/25/07 to 11/30/07	Iqaluit	Iqaluit outage.
1451 day 0 to 1451 day 1	10/28/07 to 10/29/07	Oklahoma City	Oklahoma City outage.
1451 day 2	10/30/07	All WAAS sites	WEI outage.
1451 day 3	10/31/07	All sites	PRN 15 usable as of 2246 Zulu, per NANU 2007146.
1451 day 3	10/31/07	Arcata	Arcata outage.
1451 day 4 to 1452 day 3	11/1/07 to 11/7/07	Tapachula	Tapachula outage.
1451 day 5	11/2/07	All WAAS sites	WEI outages.
1452 day 3 to 1455 day 5	11/7/07 to 11/30/07	Goose Bay	Goose Bay outage.
1453 day 0 to 1453 day 3	11/11/07 to 11/14/07	Oklahoma City	Oklahoma City outage.
1454 day 6 to 1455 day 3	11/24/07 to 11/28/07	NY	NY outage.
1456 day 2	12/4/07	All WAAS sites	WEI outage.
1456 day 5 to 1457 day 0	12/7/07 to 12/9/07	Cold Bay	Cold Bay outages.
1456 day 5	12/7/07	Seattle	Seattle outage.
1457 day 3	12/12/07	All sites	Geo initialization following C&V fault.
1457 day 2 to 1458 day 4	12/11/07 to 12/20/07	All Mexico Sites	No Mexico data. Tech Center Ring 1 WEI was down, and Mexico's link to Ring 2 was broken (repaired on 12/21/07).
1458 day 2	12/18/07	All WAAS Sites	WEI outage.
1458 day 3	12/19/07	None	See DR# 64, "SV PRN 27 Unexpectedly Set to Not Monitored."
1458 day 4	12/20/07	All sites	SV PRN 7 decommissioned. See NANU 2007169.
1460 day 1 to 1460 day 3	12/31/07 to 1/2/08	Tapachula	Tapachula outage.

1.2 Report Overview

Section 2 provides the vertical and horizontal position accuracies from data collected, on a daily basis, at one-second intervals. The 95% accuracy index and the maximum accuracy for the reporting period are tabulated. The daily 95% accuracy index is plotted graphically for each receiver. Histograms of the vertical and horizontal error distribution are provided for three receivers within the WAAS service area.

Section 3 summarizes the WAAS instantaneous availability performance, at each receiver, for three operational service levels during the reporting period. Daily availability is also plotted for each receiver evaluated. The number of outages and outage rate for each site is reported.

Section 4 provides the percent of coverage provided by WAAS on a daily basis. Monthly roll-up graphs presented indicate the portions of service volume covered, and the percentage of time that WAAS was available.

Section 5 summarizes the number of HMI's detected during the reporting period and presents a safety margin index for each receiver. The safety index reflects the amount of over bounding of position error by WAAS protection levels. This section also includes update rates of WAAS messages transmitted from CRE and CRW.

Section 6 provides the UDRE and GIVE bounding percentage and the 95% index of the range and ionospheric accuracy for each satellite tracked by the WAAS receiver in Houston.

Section 7 provides the GEO ranging performance for CRE and CRW.

Section 8 summarizes WAAS anomalies and problems identified during the reporting period, which adversely affect WAAS performance described in Table 1.3.

Section 9 provides WAAS LPV availability and outages at selected airports.

Section 10 provides the assessment of WAAS CNMP bounding for 114 WAAS receivers.

Section 11 compares GPS broadcast orbits versus the IGS precise orbits

Section 12 provides the difference between the WRS locations in the current software and the latest survey.

2.0 WAAS POSITION ACCURACY

Navigation error data, collected from WAAS and NSTB reference stations, was processed to determine position accuracy at each location. This was accomplished by utilizing the GPS/WAAS position solution tool to compute a MOPS-weighted least squares user navigation solution, and WAAS horizontal and vertical protection levels (HPL & VPL), once every second. The user position calculated for each receiver was compared to the surveyed position of the antenna to assess position error associated with the WAAS SIS over time. The position errors were analyzed and statistics were generated for three operational service levels: WAAS LPV, WAAS LPV200, and WAAS LNAV/VNAV, as shown in Table 2.1. For this evaluation, the WAAS operational service level is considered available at a given time and location, if the computed WAAS HPL and VPL are within the horizontal and vertical alarm limits (HAL & VAL) specified in Table 2.1.

Table 2-1 Operational Service Levels

WAAS Operational Service Levels	Horizontal Alert Limit HAL (meters)	Vertical Alert Limit VAL (meters)
LPV (LOC/VNAV)	40	50
LNAV/VNAV	556	50
LPV200	40	35

Table 2.2 shows PA horizontal and vertical position accuracy maintained for 95% of the time at LPV and LNAV/VNAV operational service levels for the quarter. The table also includes 95% SPS accuracy for certain locations. Figures 2.1 to 2.6 show the daily horizontal and vertical 95% accuracy for LNAV/VNAV operational service level for the period. Note that WAAS accuracy statistics presented are compiled only when all WAAS corrections (fast, long term, and ionospheric) for at least 4 satellites are available. This is referred to as PA navigation mode. The percentage of time that PA navigation mode was supported by WAAS at each receiver is also shown in Table 2.2. A user is considered to be in NPA navigation mode if only WAAS fast and long term corrections are available to a user (i.e. no ionospheric corrections). Table 2.3 shows NPA horizontal position

accuracy for 95% and 99.999% of the time. This table also shows the maximum NPA horizontal position error for the quarter. Figures 2.7 to 2.8 show the daily horizontal 95% accuracy for NPA.

During the evaluated period, the 95% horizontal and vertical accuracy at all evaluated sites were less than 2 meters for both WAAS operational service levels. The maximum 95% horizontal and vertical LPV errors are 1.195 meters at Arcata and 1.949 at Barrow, respectively. The minimum 95% horizontal and vertical LPV errors are 0.477 meters at Albuquerque and 0.754 meters at Seattle, respectively. The maximum 95% and 99.999% NPA horizontal errors are 2.461 meters and 5.942 meters at Honolulu, respectively. The minimum 95% and 99.999% horizontal errors are .822 meters at Barrow and 1.907 meters at Bethel.

Currently, both CRE and CRW GEO satellites provide a ranging capability for enroute through NPA service, but not for PA service.

Table 2.4 shows the maximum horizontal and vertical position errors while the calculated HPL and VPL met the LPV service levels. The column marked 'Horizontal (or Vertical) Error/HPL (or VPL)' is the ratio of position error to protection level at the time the maximum error occurred. The column marked 'Horizontal (or Vertical) Maximum Ratio' is the maximum position error to protection level ratio for the quarter.

Figures 2.9 to 2.17 show the distributions of the vertical and horizontal errors in triangle charts and 2-D histogram plots for the quarter at three locations, Kansas City, Washington DC and Seattle. The triangle charts show the distributions of vertical position errors (VPE) versus vertical protection levels (VPL) and horizontal position errors (HPE) versus horizontal protection levels (HPL). The horizontal axis is the position error and the vertical axis is the WAAS protection levels. Lower protection levels equate to better availability. The diagonal line shows the point where error equals protection level. Above and to the left of the diagonal line in the chart, errors are bounded (WAAS is providing integrity in the position domain); below and to the right, errors are not bounded (HMI could be present). The horizontal lines at various protection levels represent the various operational service levels as defined in Table 2.1. The 2-D histogram plots contain four histograms showing the distributions of vertical and horizontal position errors and normalized position errors. The left top and bottom histograms show the distributions of the actual vertical and horizontal errors. The horizontal axis is the position errors and the vertical axis is the total count of data samples (log scale) in each 0.1-meter bin. The right top and bottom histograms show the distributions of the actual vertical and horizontal errors normalized by one-sigma value of the protection level; vertical - (VPL/5.33) and horizontal - (HPL/6.0). The horizontal axis is the standard units and vertical axis is the observed distribution of normalized errors data samples in each 0.1-sigma bin. Narrowness of the normalized error distributions shows very good observed safety performance.

Table 2-2 PA 95% Horizontal and Vertical Accuracy

Location	Horizontal GLS/APV2/LPV (HAL=40m) (Meters)	Horizontal APV-1(LNAV) (HAL=556m) (Meters)	Vertical LPV/VNAV (VAL=50m) (Meters)	Percentage in PA mode (%)	SPS Accuracy	
					95% Horizontal (Meters)	95% Vertical (Meters)
Atlantic City	0.808	0.808	1.064	99.99767	*	*
Arcata	1.195	1.195	1.176	100	*	*
Oklahoma City	0.634	0.634	0.993	99.99813	*	*
Albuquerque	0.615	0.615	0.870	99.99896	2.318	4.289
Anchorage	0.519	0.519	0.908	99.99835	*	*
Atlanta	0.702	0.702	0.997	99.99822	2.648	4.846
Barrow	0.562	0.563	1.949	99.96550	*	*
Bethel	0.520	0.520	0.875	99.99863	2.111	5.111
Billings	0.703	0.703	0.959	99.99896	2.391	4.384
Boston	0.715	0.715	1.002	99.99774	3.319	4.76
Chicago	0.753	0.753	0.999	99.99822	*	*
Cleveland	0.738	0.738	1.023	99.99776	2.738	4.782
Cold Bay	0.774	0.776	0.962	99.99861	*	*
Dallas	0.655	0.655	1.094	99.99829	*	*
Denver	0.643	0.643	0.993	99.99896	*	*
Fairbanks	0.477	0.477	0.967	99.99842	1.901	5.102
Gander	0.848	0.851	1.020	99.98216	*	*
Goose Bay	0.727	0.730	1.153	99.97799	*	*
Houston	0.664	0.664	1.192	99.99828	2.406	4.733
Iqaluit	0.868	0.952	1.391	99.10851	*	*
Jacksonville	0.682	0.682	1.132	99.99776	*	*
Juneau	0.544	0.544	1.131	99.99780	*	*
Kansas City	0.715	0.715	0.945	99.99829	2.594	4.649
Kotzebue	0.575	0.575	1.160	99.96711	1.881	5.264
Los Angeles	0.698	0.698	0.924	99.99897	2.302	5.083
Memphis	0.656	0.656	0.987	99.99829	*	*
Merida	0.768	0.768	1.214	100	*	*
Mexico City	0.874	0.876	1.439	100	*	*
Miami	0.814	0.814	1.282	99.99776	2.515	5.504
Minneapolis	0.689	0.689	1.067	99.99829	2.55	4.586
New York	0.755	0.755	1.006	99.99762	*	*
Oakland	0.689	0.689	0.920	99.99904	2.282	5.007
Puerto Vallarta	0.831	0.840	1.466	100	*	*
Salt Lake City	0.652	0.652	0.849	99.99897	2.356	4.395
San Jose Del Cabo	0.789	0.790	1.620	100	*	*
Seattle	0.891	0.891	0.930	99.99903	2.391	4.518
Tapachula	1.088	1.163	1.591	98.83089	*	*
Washington DC	0.685	0.685	0.972	99.99776	2.75	5.042
Winnipeg	0.730	0.730	0.979	99.99827	*	*

* SPS accuracy not computed for this location.

Table 2-3 NPA 95% and 99.999% Horizontal Accuracy

Location	95% Horizontal (meters)	99.999% Horizontal (meters)	Percentage in NPA mode (%)	Maximum Horizontal Error
Albuquerque	0.958	2.344	99.998	3.175
Anchorage	0.939	2.258	99.998	2.907
Atlanta	1.233	3.032	99.998	3.153
Barrow	0.822	1.938	99.987	6.094
Bethel	1.147	1.907	99.998	7.590
Billings	1.389	2.408	99.998	2.523
Boston	1.456	4.286	99.998	6.714
Cleveland	1.423	2.917	99.998	3.177
Cold Bay	1.315	2.46	99.998	3.227
Fairbanks	0.831	2.179	99.998	6.674
Gander	1.446	3.013	99.994	3.143
Honolulu	2.461	5.942	97.564	6.278
Houston	0.991	2.633	99.998	2.743
Iqaluit	1.020	2.810	99.994	8.354
Juneau	1.009	2.364	99.998	8.180
Kansas City	1.27	2.444	99.998	2.567
Kotzebue	0.892	2.243	99.984	3.073
Los Angeles	0.968	2.627	99.998	4.048
Merida	0.956	4.113	100	4.401
Miami	1.071	2.605	99.998	4.549
Minneapolis	1.481	3.558	99.998	5.719
Oakland	1.016	2.256	99.998	3.007
Salt Lake City	1.175	2.114	99.998	2.252
San Jose Del Cabo	0.922	5.008	99.999	5.136
San Juan	1.113	2.603	99.998	2.760
Seattle	1.413	2.689	99.998	5.033
Tapachula	1.414	4.719	100	4.857
Washington DC	1.373	2.972	99.998	3.202

Table 2-4 Maximum Position Errors and Position Error/Protection Level Ratio

Location	Horizontal Error (m)	Horizontal Error/HPL	Horizontal Maximum Ratio	Vertical Error (m)	Vertical Error/VPL	Vertical Maximum Ratio
Atlantic City	1.993	0.151	0.151	3.627	0.095	0.149
Arcata	2.938	0.112	0.149	4.689	0.157	0.158
Oklahoma City	2.067	0.197	0.197	3.884	0.216	0.216
Albuquerque	2.817	0.162	0.176	2.332	0.109	0.129
Anchorage	2.260	0.135	0.135	3.141	0.107	0.131
Atlanta	1.619	0.083	0.160	2.842	0.112	0.112
Chicago	1.685	0.080	0.144	2.995	0.206	0.206
Barrow	4.963	0.171	0.174	3.643	0.154	0.163
Bethel	1.436	0.081	0.087	2.530	0.088	0.140
Billings	1.723	0.072	0.129	3.930	0.173	0.173
Boston	2.507	0.172	0.175	3.151	0.130	0.161
Cleveland	1.961	0.059	0.142	2.888	0.121	0.164
Cold Bay	2.271	0.077	0.094	3.426	0.136	0.159
Dallas	1.596	0.087	0.167	2.647	0.132	0.176
Denver	1.757	0.115	0.125	3.762	0.093	0.133
Fairbanks	3.615	0.245	0.245	2.592	0.110	0.120
Gander	2.481	0.062	0.129	3.633	0.141	0.183
Goose Bay	3.219	0.105	0.144	2.928	0.131	0.135
Houston	1.783	0.098	0.155	2.535	0.095	0.144
Iqaluit	5.084	0.167	0.167	2.827	0.074	0.123
Jacksonville	1.875	0.147	0.147	3.037	0.117	0.117
Juneau	1.569	0.131	0.131	3.369	0.068	0.136
Kansas City	1.628	0.151	0.154	5.016	0.207	0.207
Kotzebue	2.250	0.134	0.134	3.245	0.140	0.147
Los Angeles	1.887	0.110	0.144	4.253	0.210	0.210
Memphis	1.629	0.135	0.146	3.718	0.075	0.098
Merida	1.614	0.090	0.107	3.604	0.093	0.115
Mexico City	3.166	0.132	0.161	3.260	0.067	0.098
Miami	2.457	0.075	0.135	4.221	0.142	0.142
Minneapolis	2.404	0.181	0.181	5.029	0.155	0.171
New York	1.612	0.075	0.139	3.368	0.090	0.114
Oakland	2.187	0.147	0.149	4.266	0.160	0.160
Puerto Vallarta	4.216	0.154	0.200	5.854	0.143	0.157
Salt Lake City	1.588	0.125	0.125	2.686	0.080	0.105

San Jose Del Cabo	2.858	0.115	0.135	3.473	0.109	0.109
Seattle	2.409	0.159	0.161	2.525	0.086	0.119
Tapachula	4.238	0.146	0.146	5.734	0.118	0.118
Washington DC	1.689	0.117	0.130	4.111	0.083	0.130
Winnipeg	1.651	0.112	0.112	5.656	0.135	0.151

Figure 2-1 95% Horizontal Accuracy at LNAV/VNAV

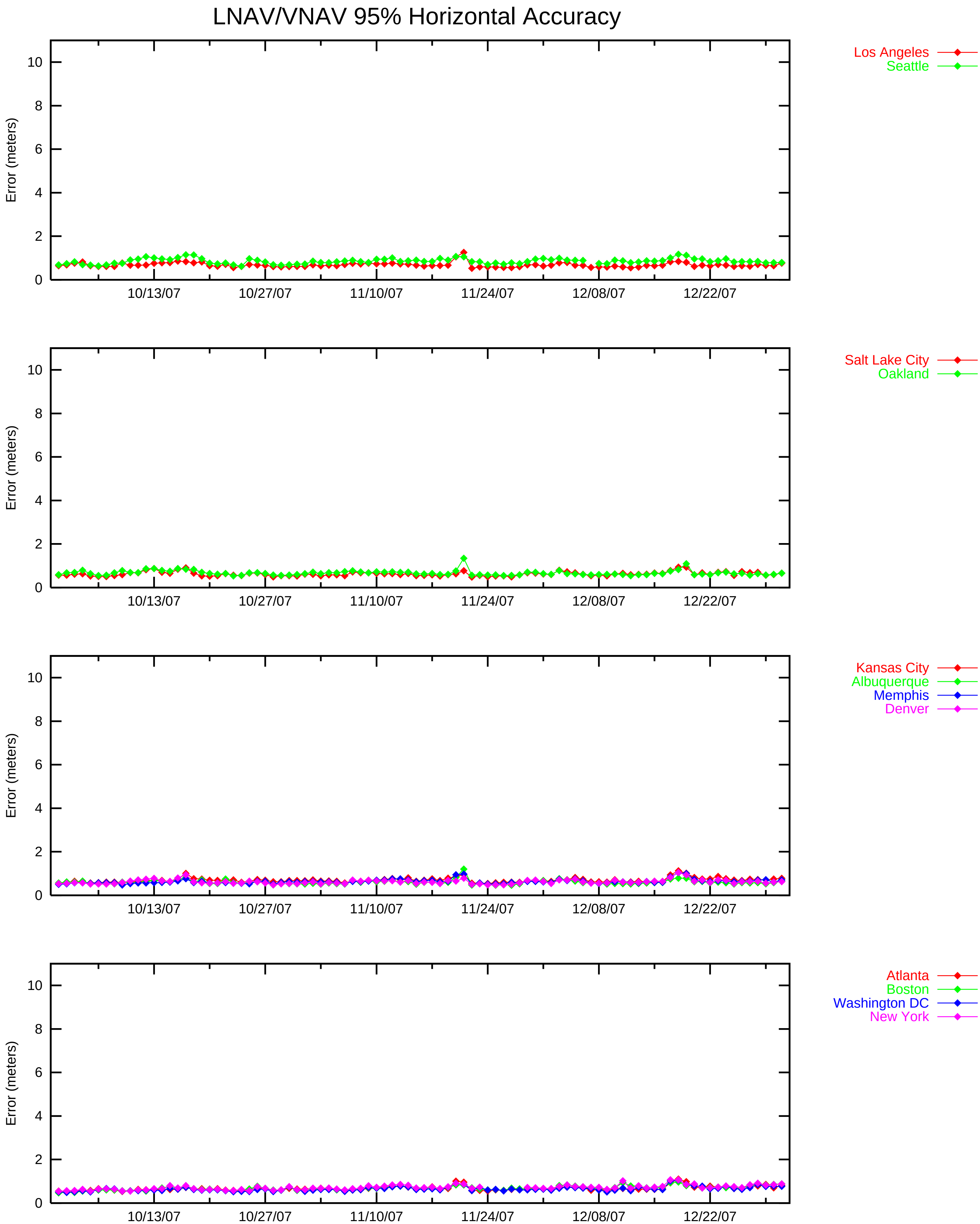


Figure 2-2 95% Horizontal Accuracy at LNAV/VNAV

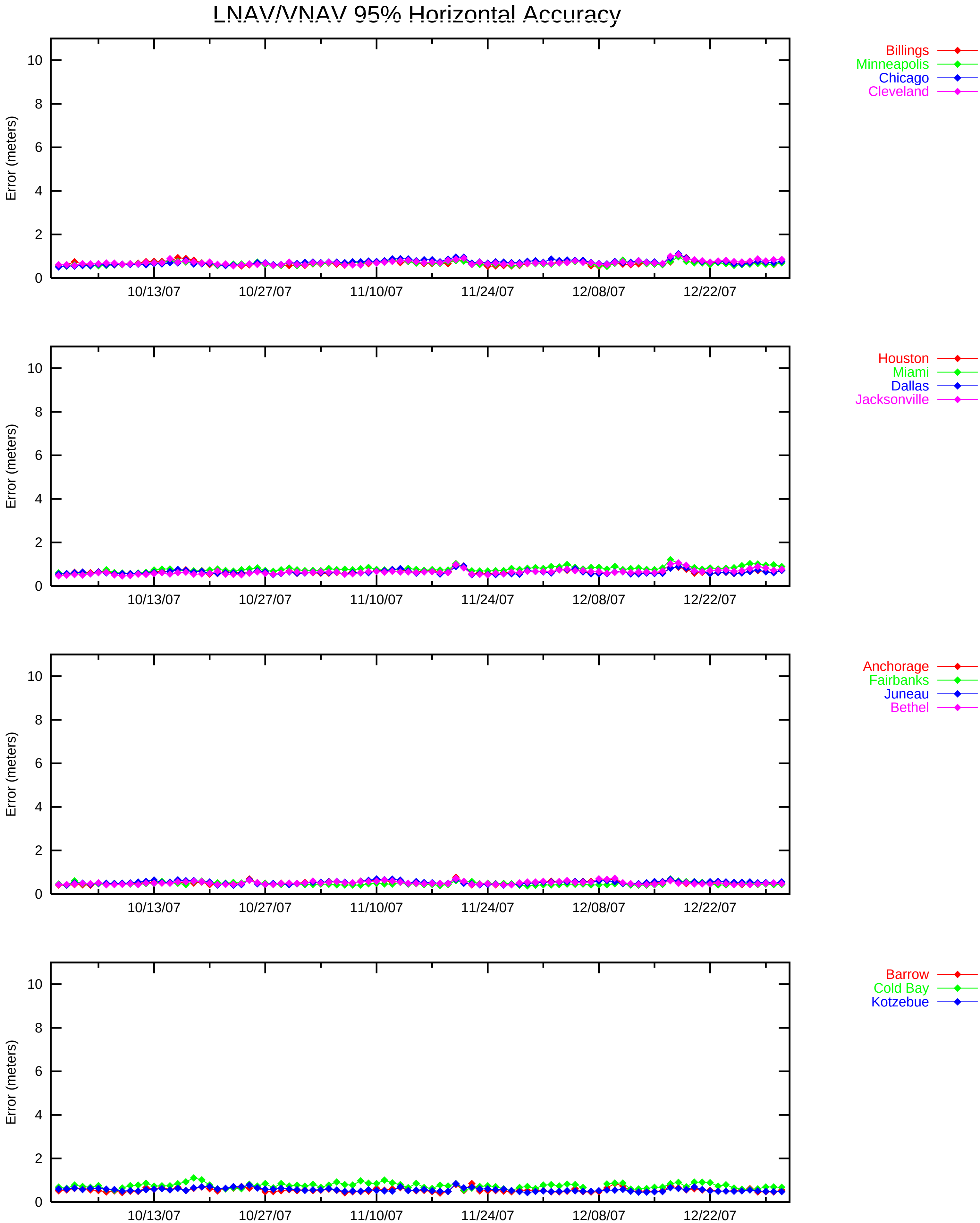


Figure 2-3 95% Horizontal Accuracy at LNAV/VNAV

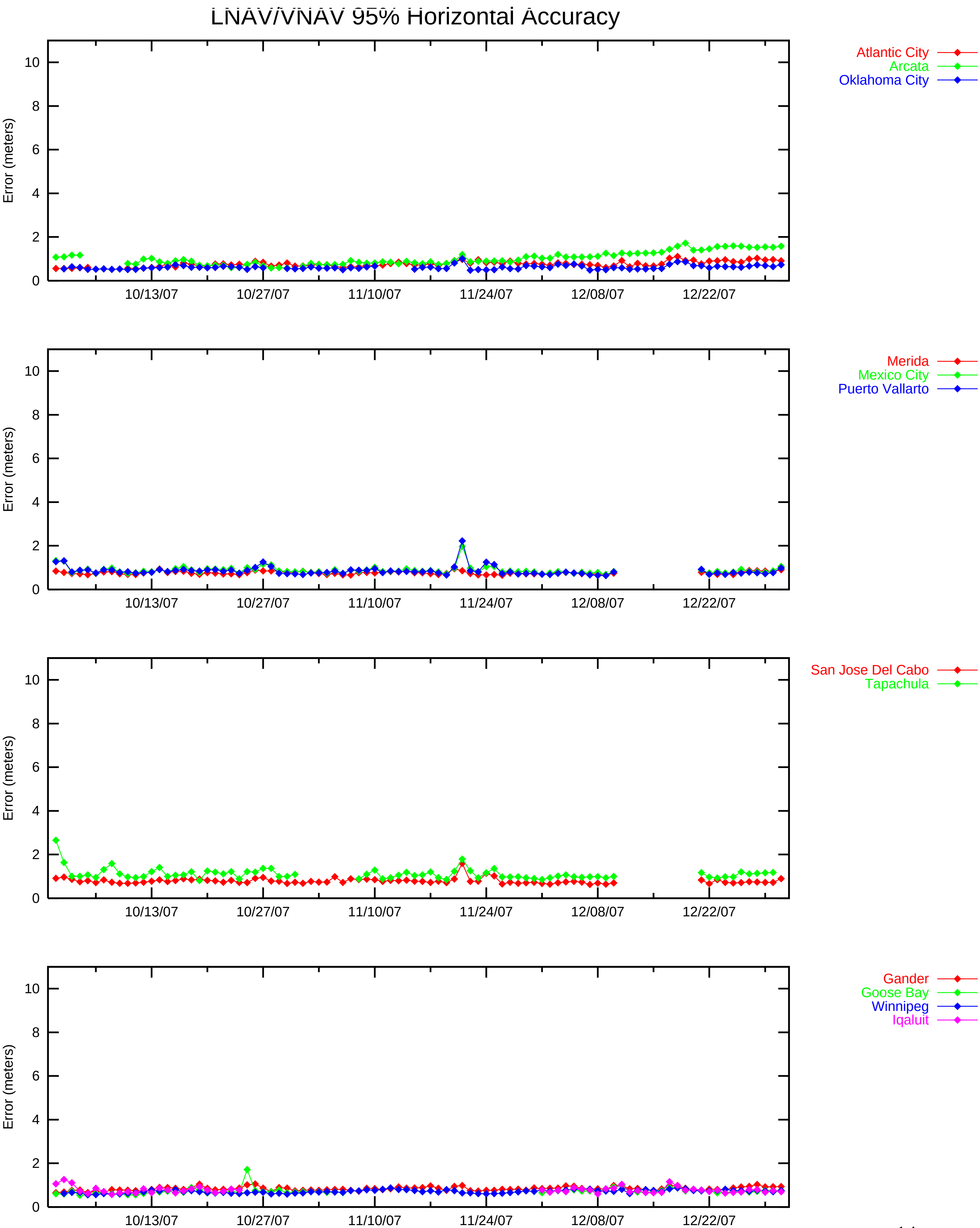


Figure 2-4 95% Vertical Accuracy at LNAV/VNAV

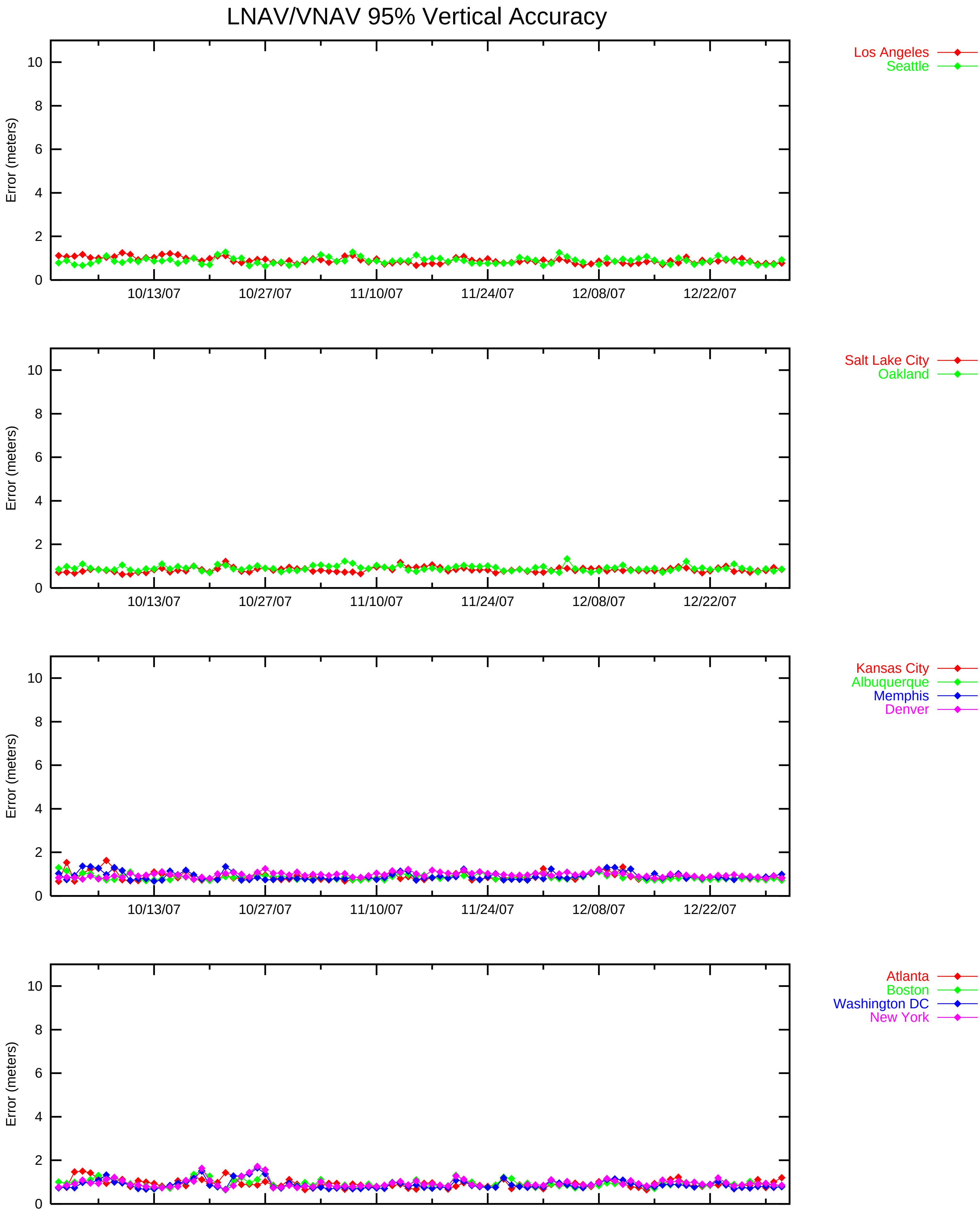


Figure 2-5 95% Vertical Accuracy at LNAV/VNAV

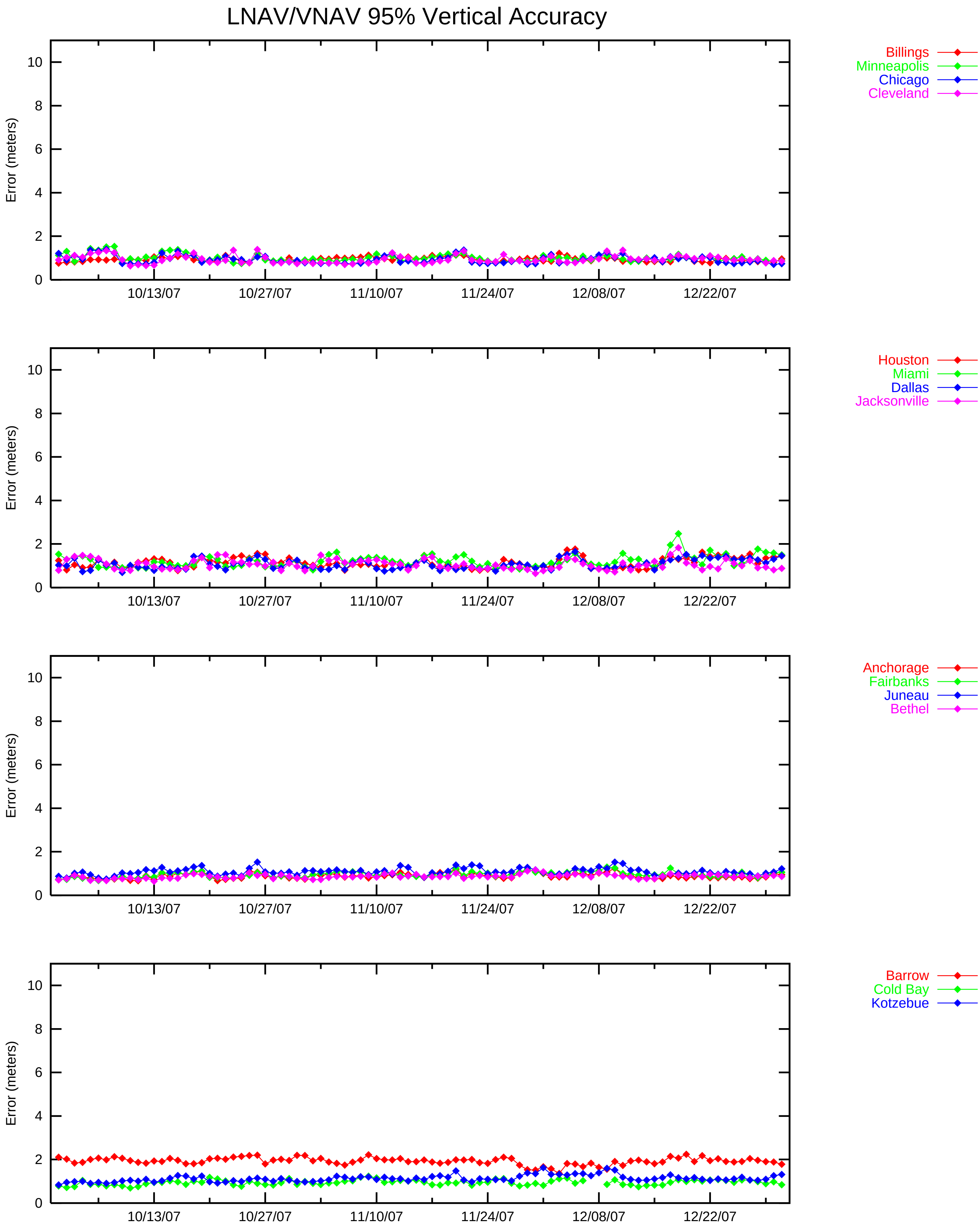


Figure 2-6 95% Vertical Accuracy at LNAV/VNAV

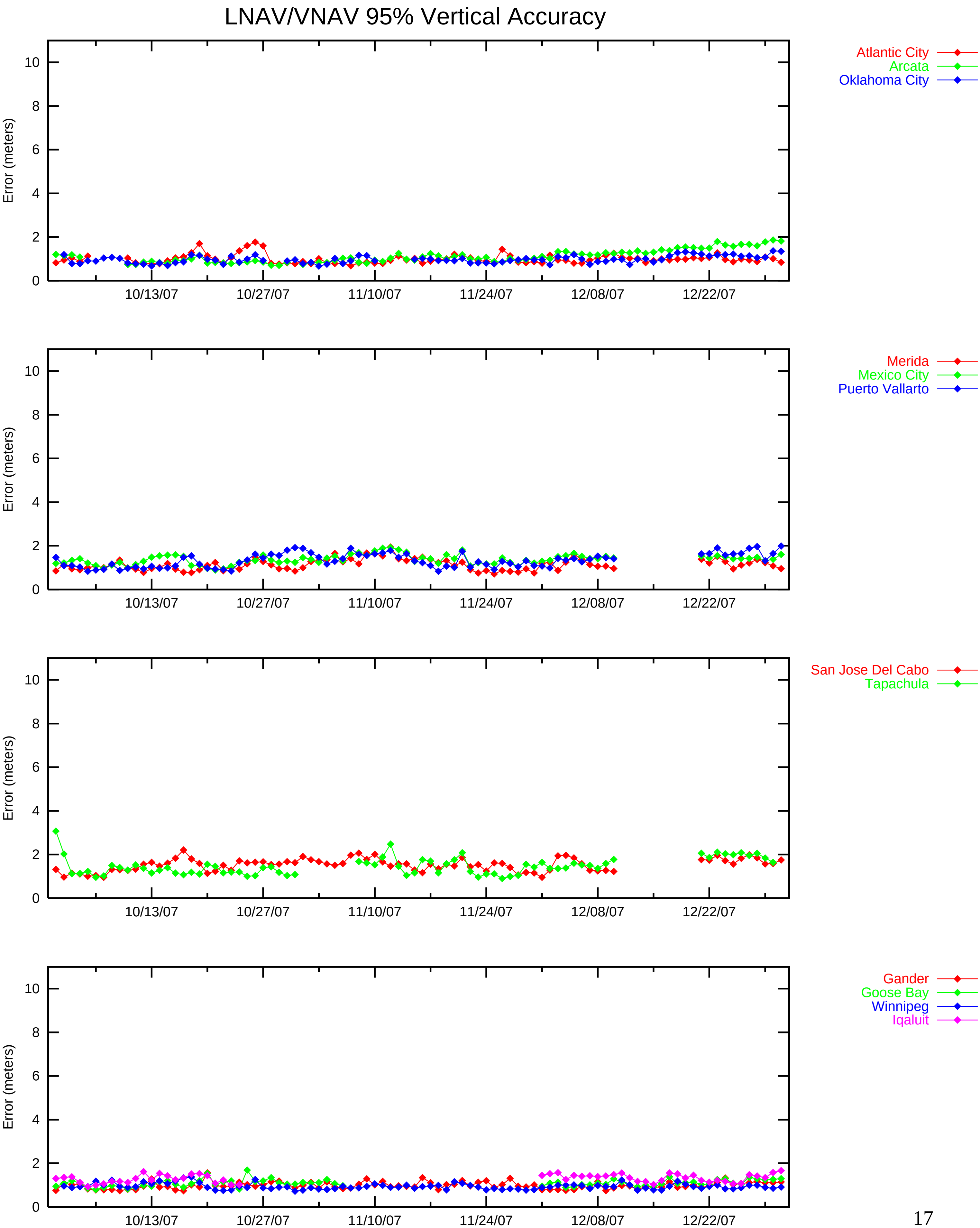
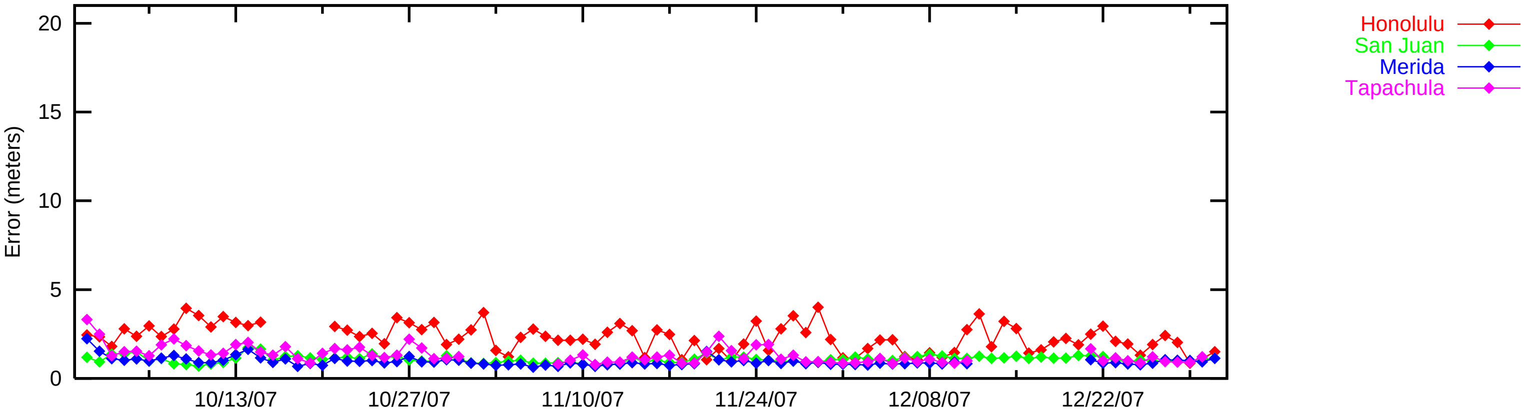
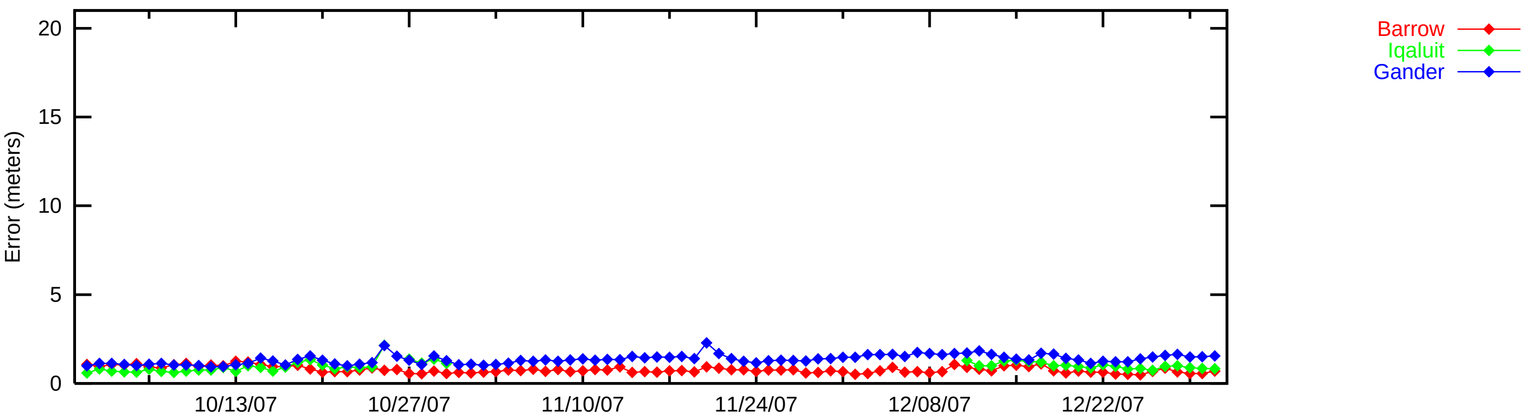
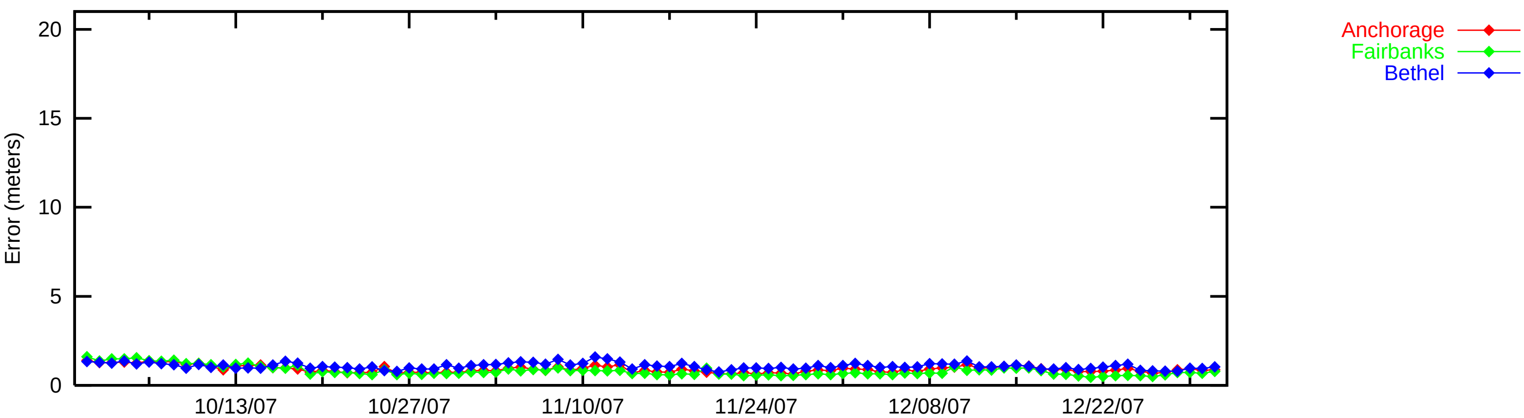


Figure 2-7 NPA 95% Horizontal Accuracy







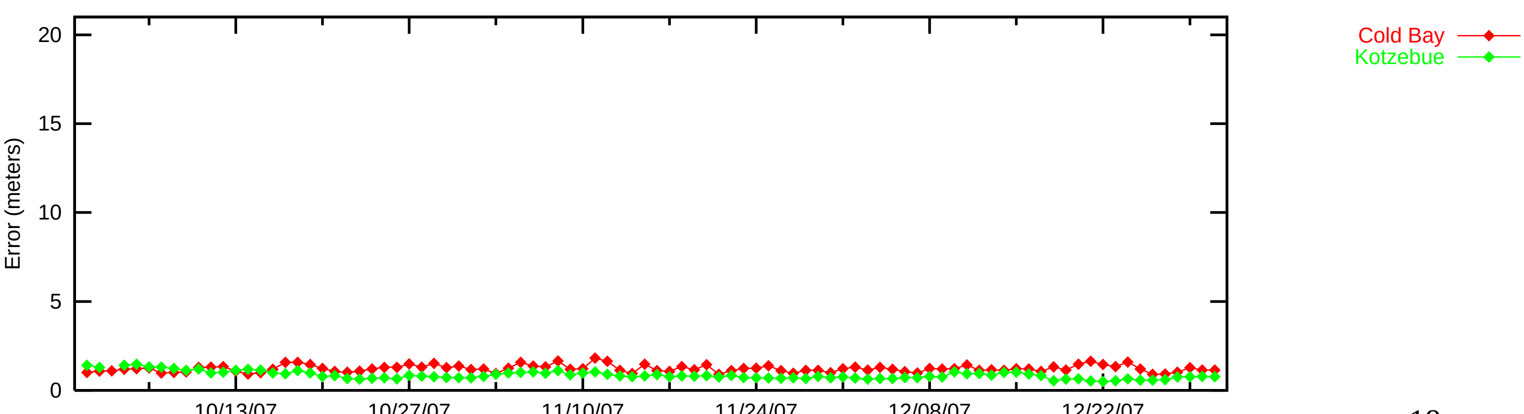


Figure 2-8 NPA 95% Horizontal Accuracy

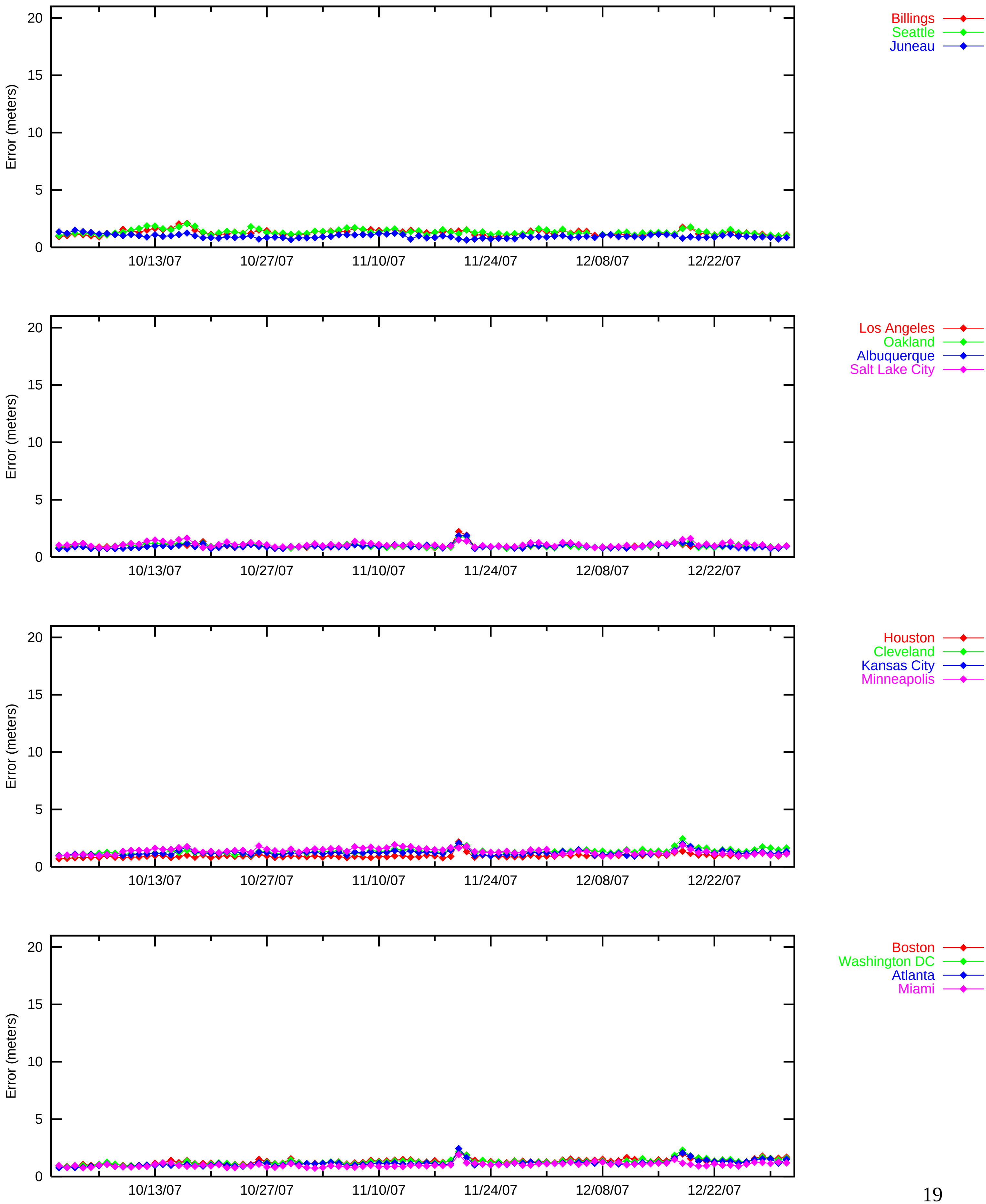


Figure 2-9 Horizontal Triangle Chart for Kansas City

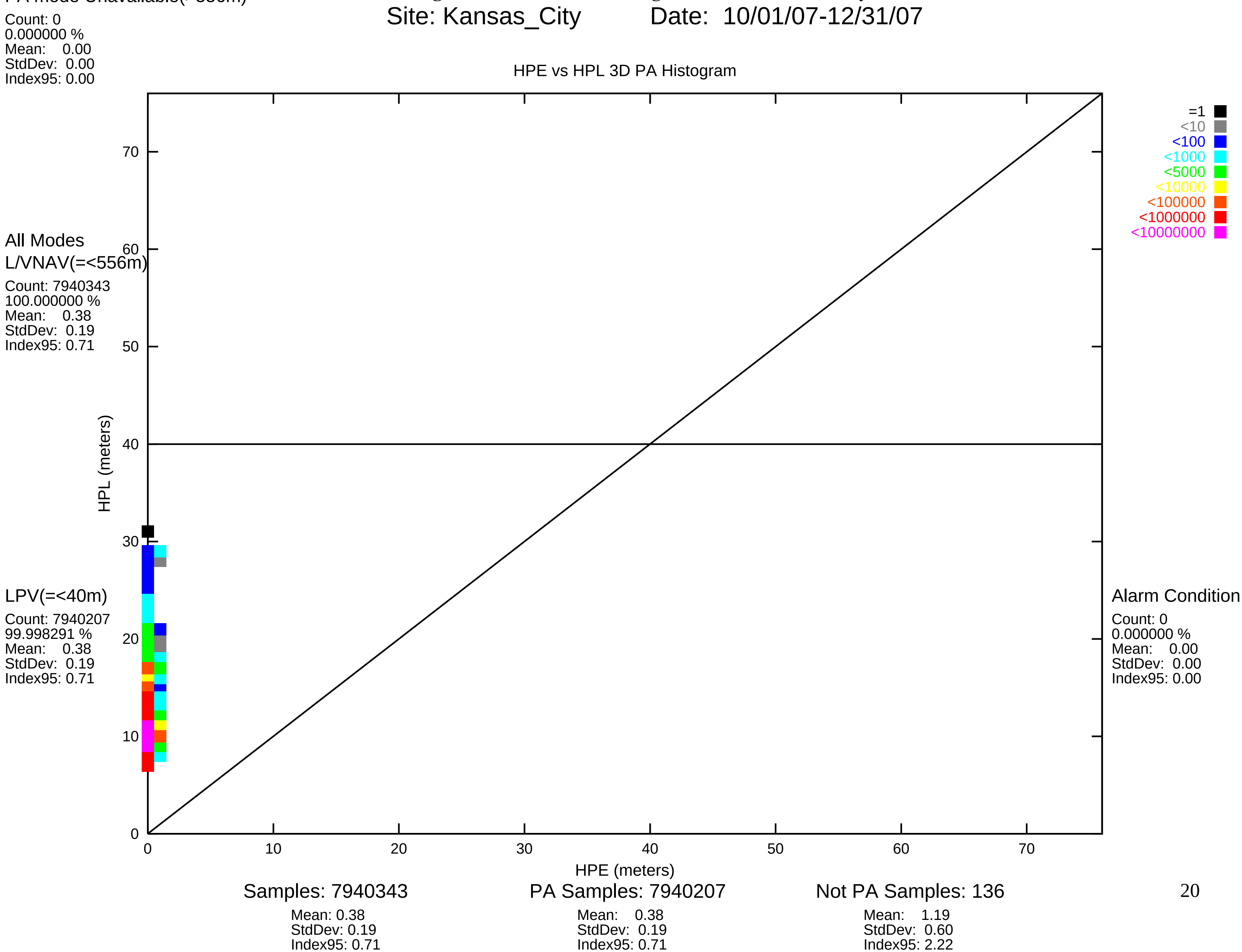


Figure 2-10 Vertical Triangle Chart for Kansas City

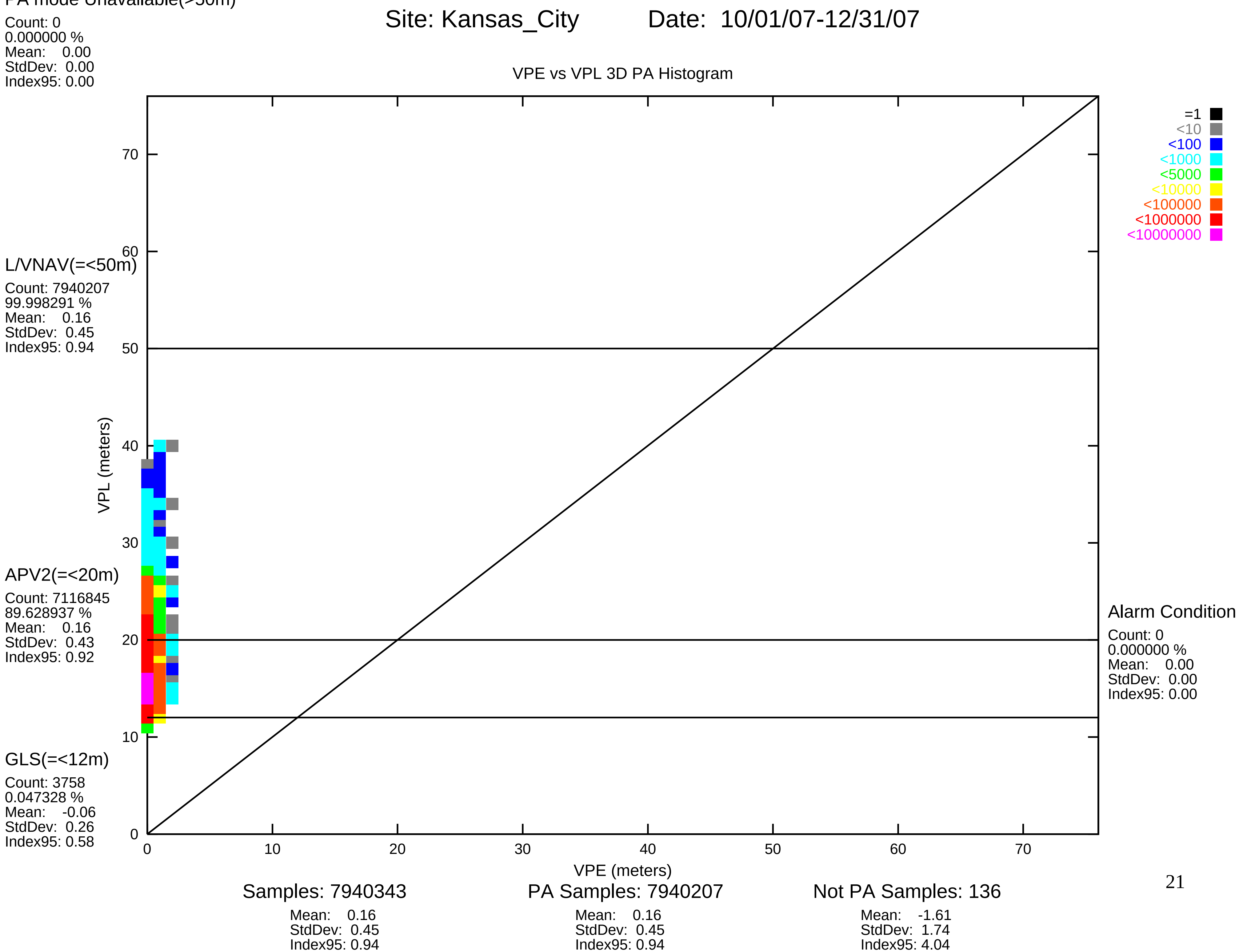


Figure 2-11 2-D Histogram for Kansas City

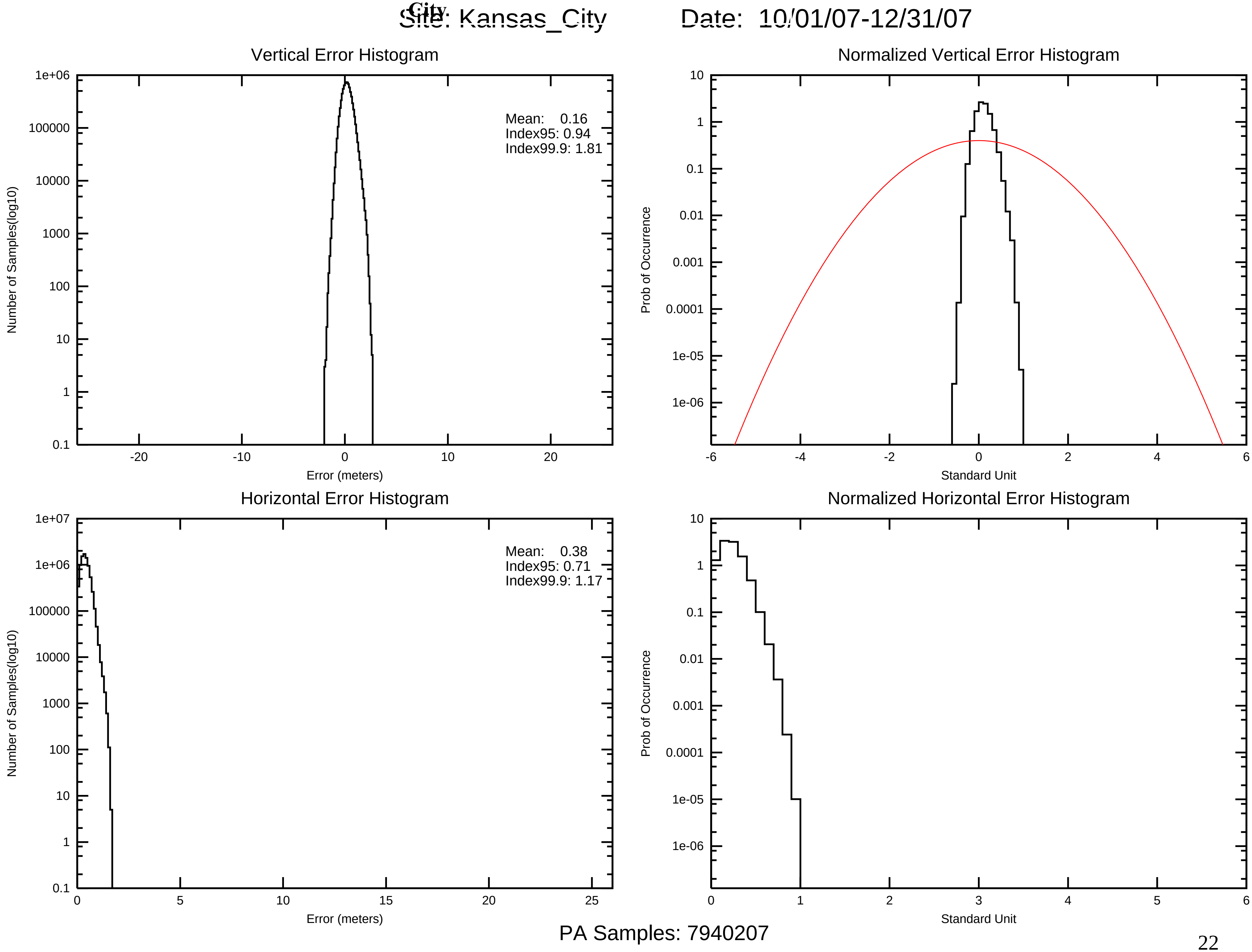


Figure 2-12 Horizontal Triangle Chart for Washington, DC

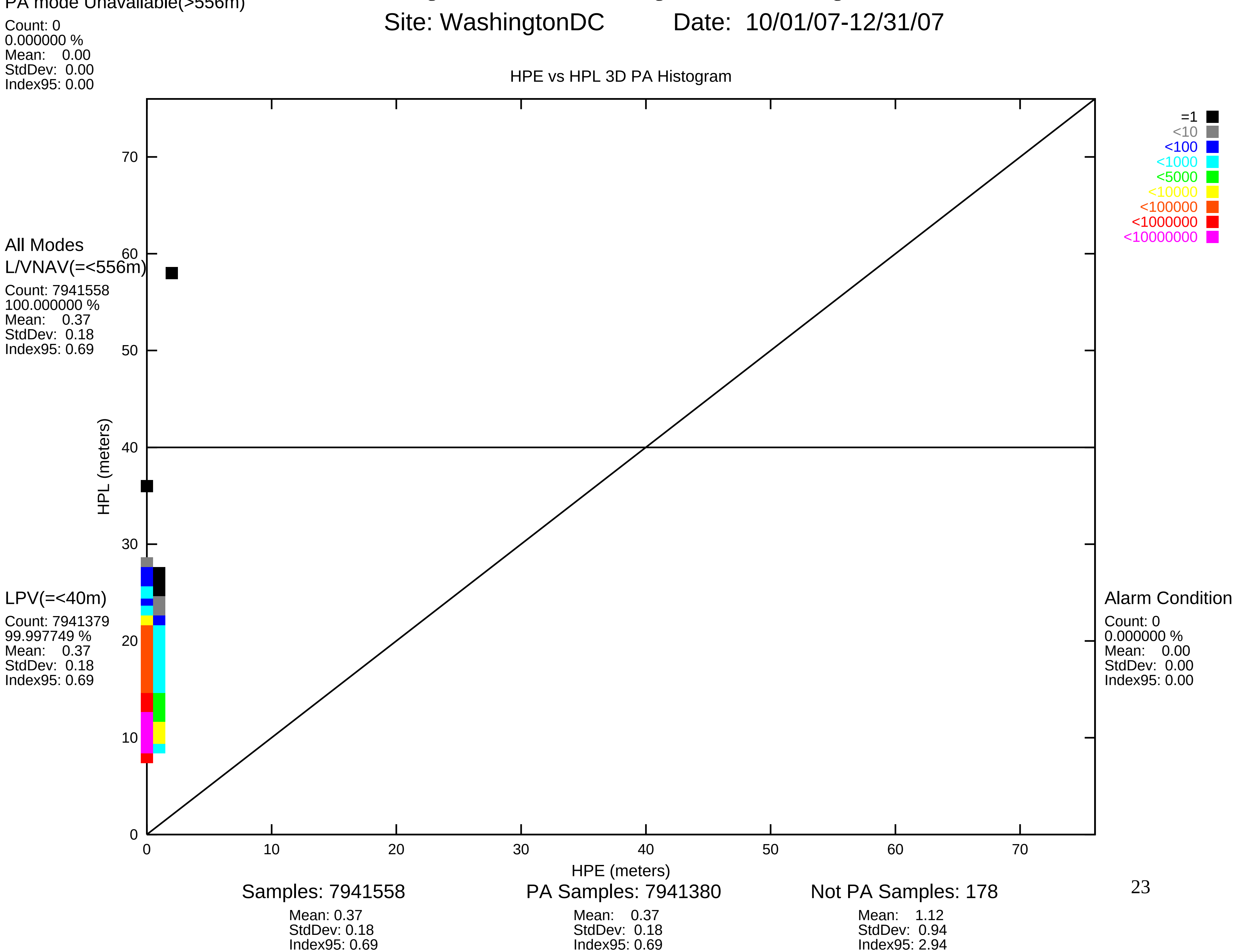


Figure 2-13 Vertical Triangle Chart for Washington, DC

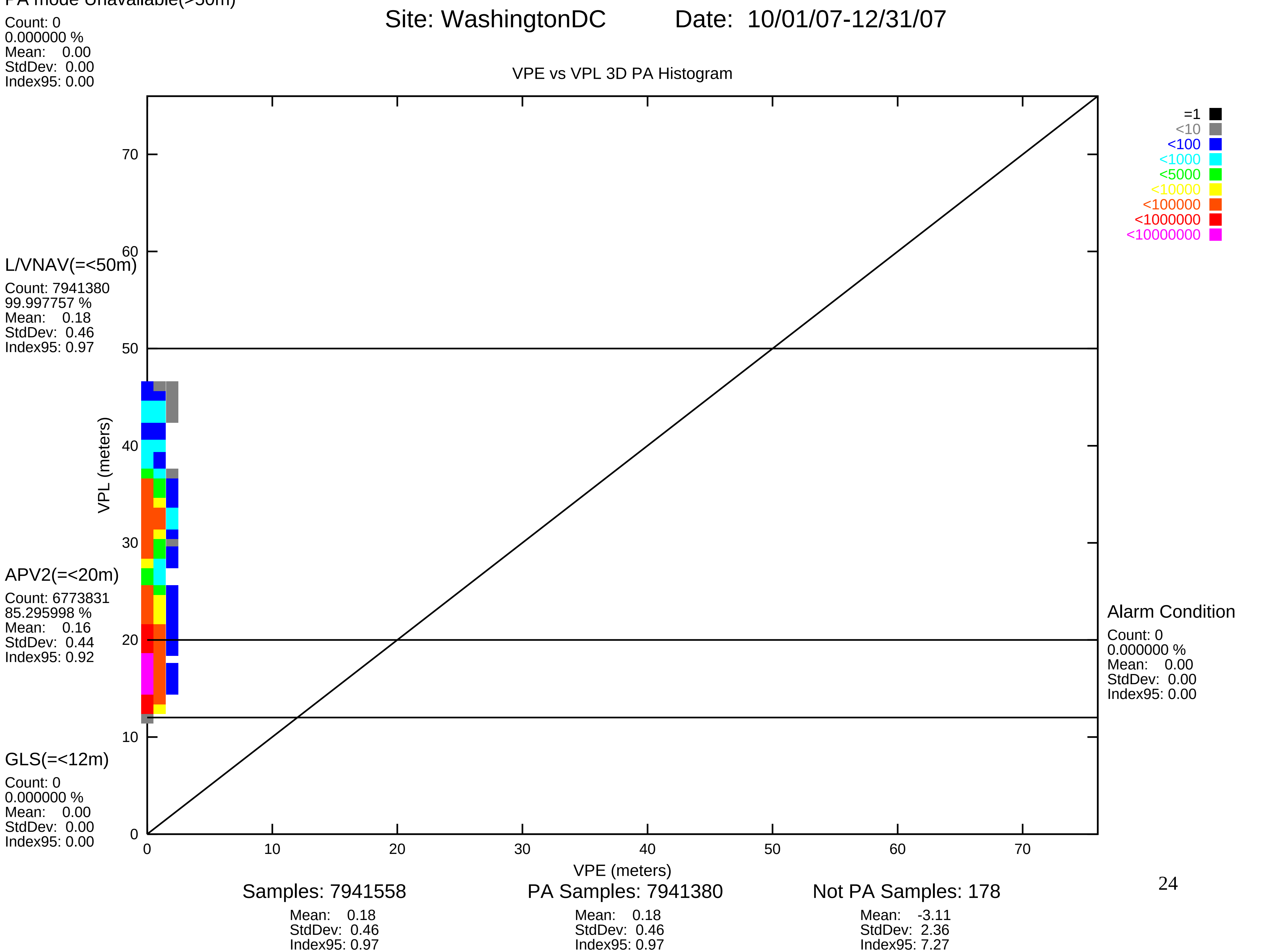


Figure 2-14 2-D Histogram for Washington, DC

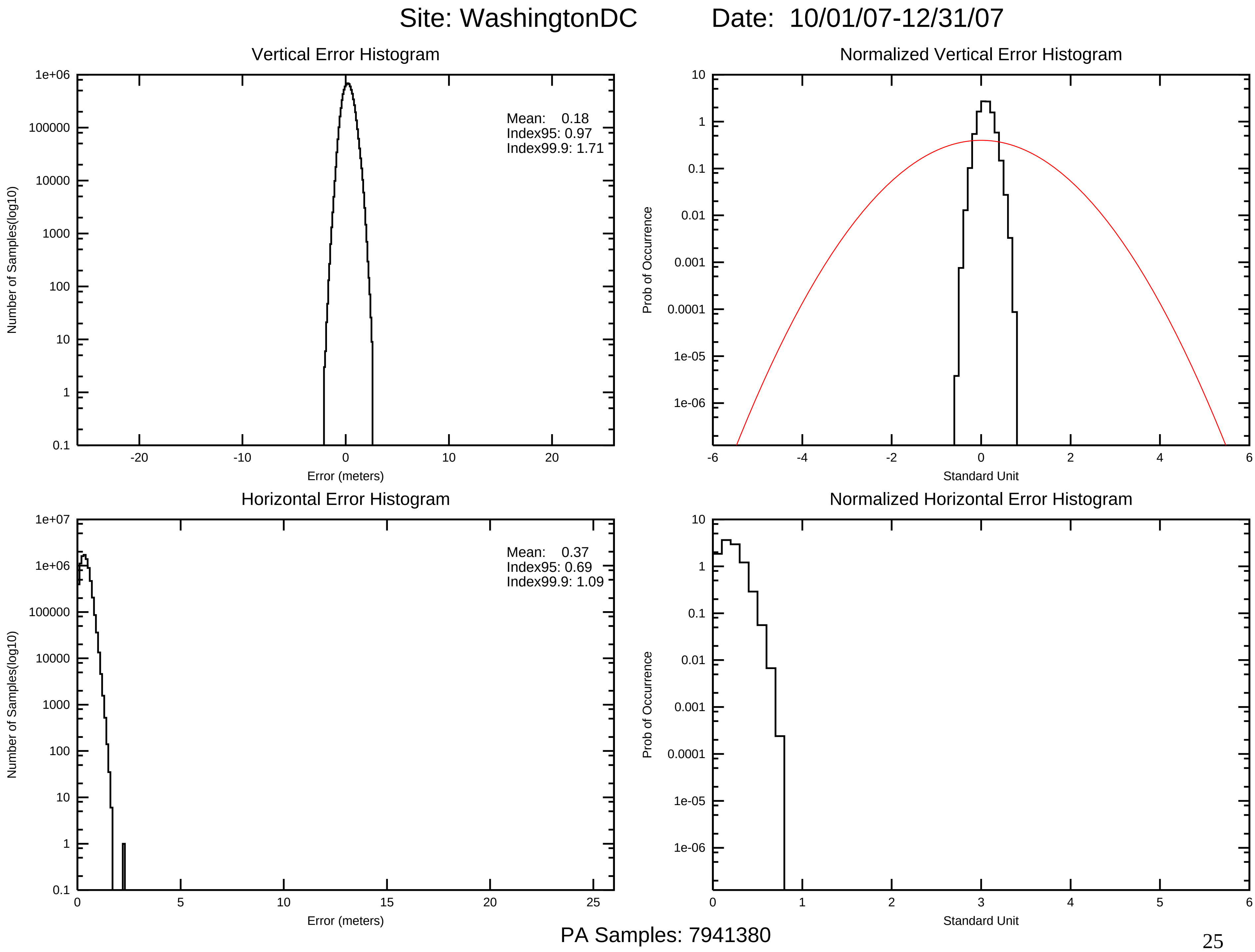


Figure 2-15 Horizontal Triangle Chart for Seattle

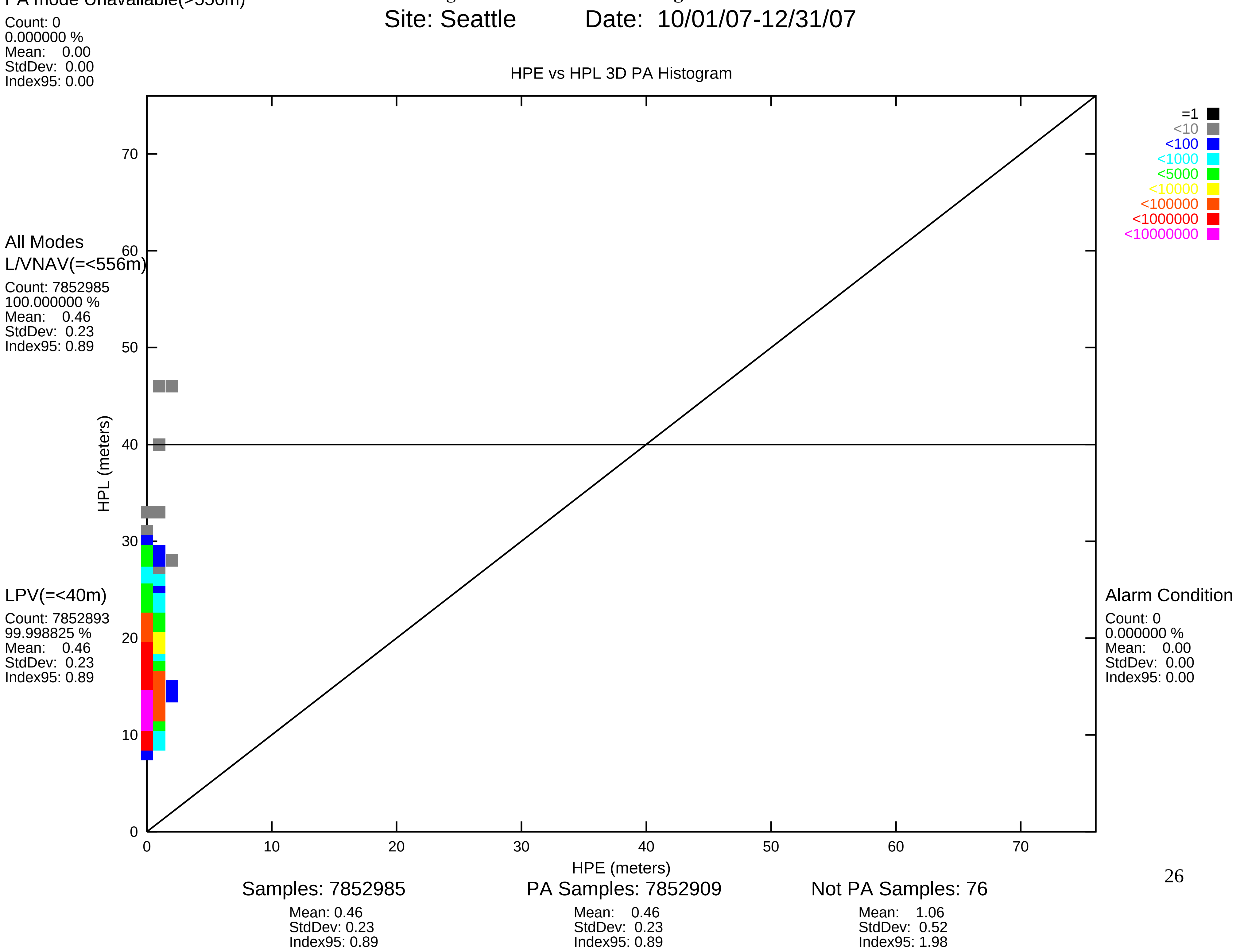


Figure 2-16 Vertical Triangle Chart for Seattle

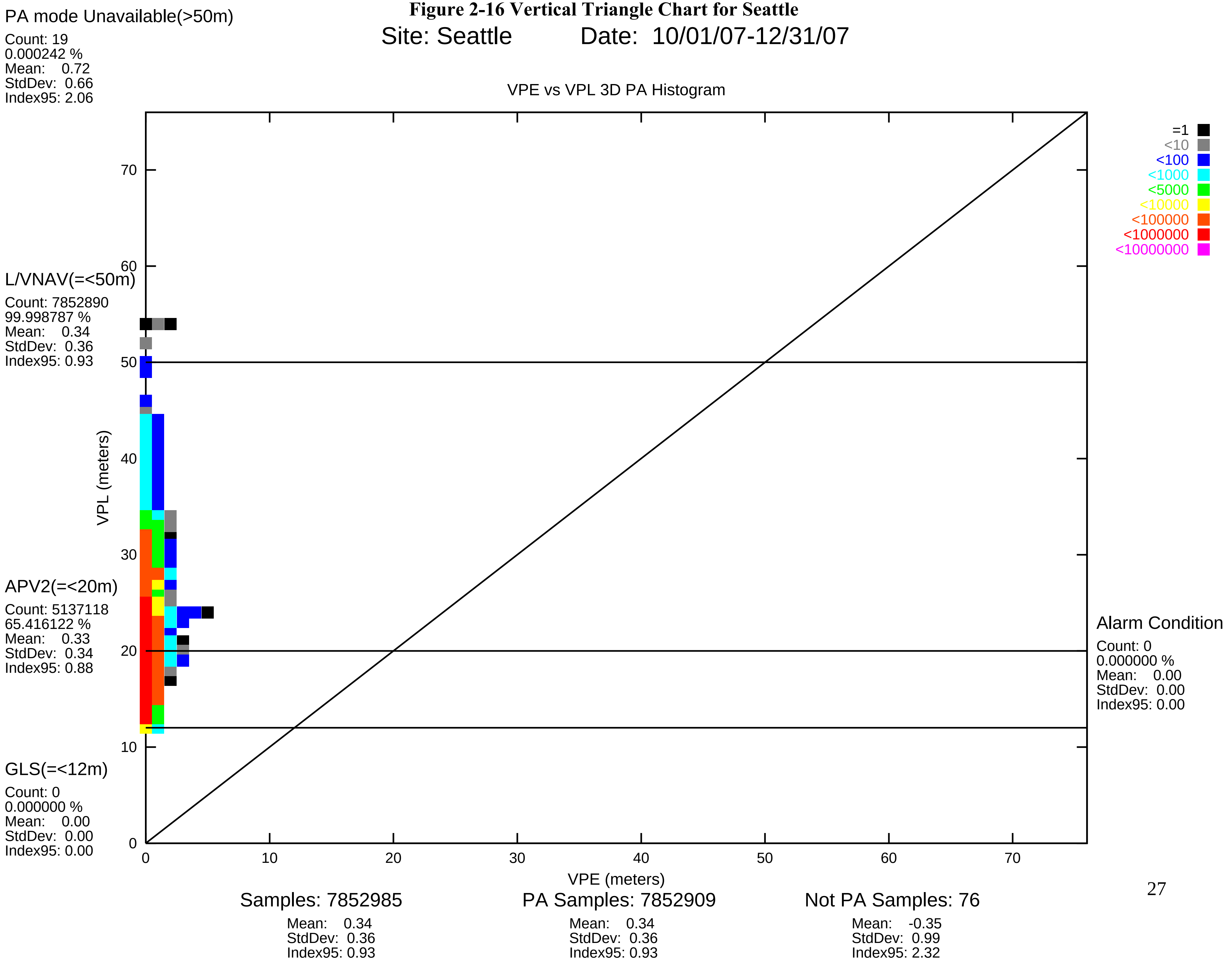
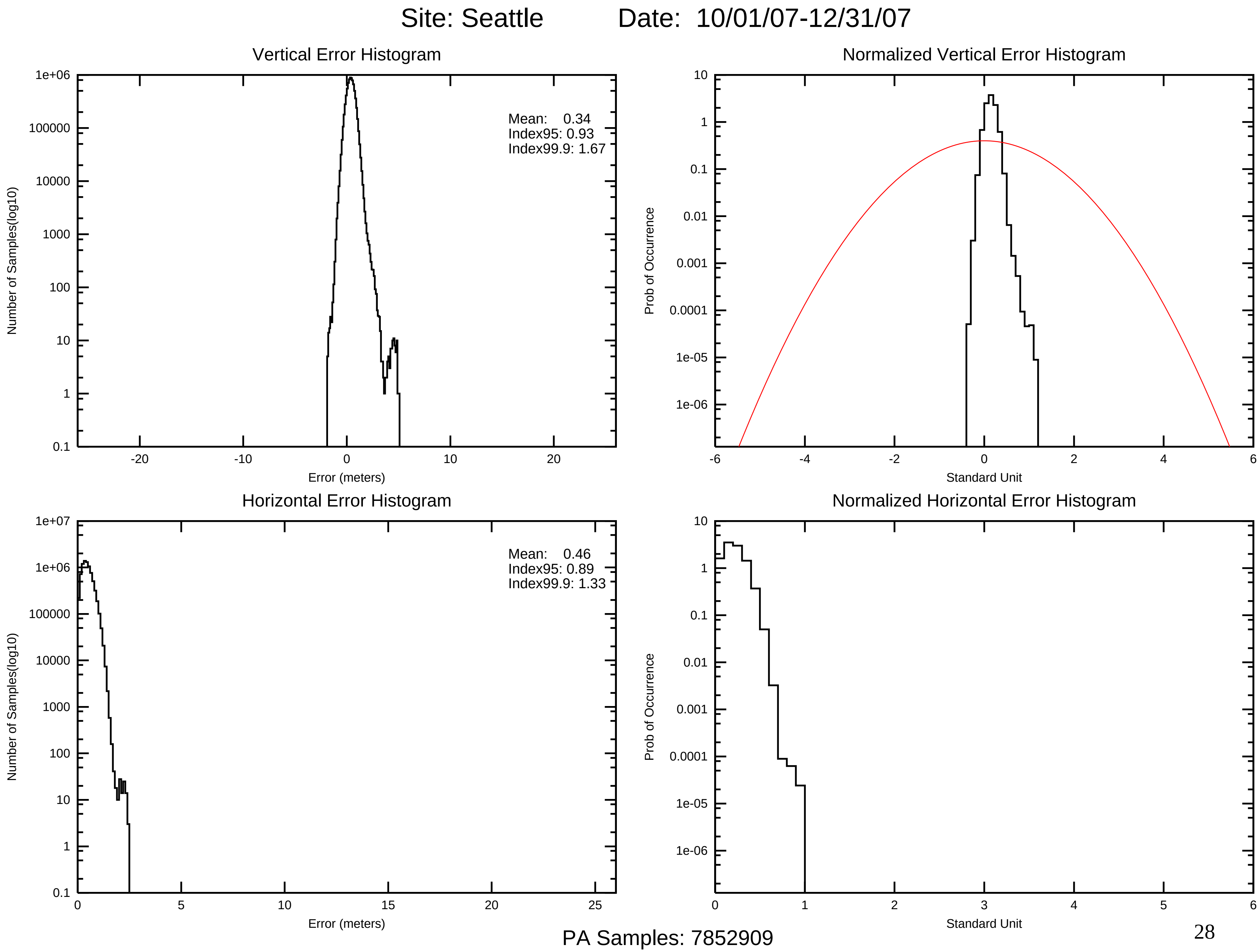


Figure 2-17 2-D Histogram for Seattle



3.0 AVAILABILITY

WAAS availability evaluation estimates the probability that the WAAS can provide service for the operational service levels (LPV and LNAV/VNAV) defined in Table 2.1. At each receiver, the WAAS message, along with the GPS/GEO satellites tracked, were used to produce WAAS protection levels in accordance with the WAAS MOPS. Table 3.1 shows the protection levels that were maintained for 95% of the time for each receiver location for the quarter. The table also included the percentage in PA mode as described in section 2.0. The first two columns of Table 3.2 presents the average portion of time that WAAS operational service levels are available at each receiver location.

Availability of LPV and LNVA/VNAV service is evaluated by monitoring the WAAS protection levels at receiver locations throughout the test period. If both the vertical and horizontal protection levels are not greater than their respective alert limits (VAL and HAL) then the service is available. If either of the protection levels exceeds the required alert level then the operational service at that location is considered unavailable and an outage in service is recorded with its duration. The operational service is not considered available again until the protection levels are both within the alert limits for at least 15 minutes. Although this will reduce operational service availability minimally, it substantially reduces the number of service outages and prevents excessive switching in and out of service availability. The percent of time that LPV and LNVA/VNAV service is available using the fifteen-minute window criteria is presented in the last two columns in Table 3.2. The LPV and LNVA/VNAV service outages and associated outage rate for the test period is presented in Table 3.4. The outage rate is the percent of approaches that theoretically would be interrupted by a loss of operational service once the approach had started. Figures 3.1 through 3.6 show the daily availability of LNAV/VNAV and LPV service levels for the evaluated period. Figures 3.7 through 3.12 show the daily interruptions of LNAV/VNAV and LPV service levels for the evaluated period.

The following table shows the maximum and minimum 95% HPL and VPL observed for this evaluated period.

Parameter	CONUS Site/Maximum	CONUS Site/Minimum	All Sites Site/Maximum	All Sites Site/Minimum
95% HPL	Arcata 21.609 meters	Kansas City 13.356 meters	Tapachula 58.454 meters	Kansas City 13.356 meters
95% VPL	Oakland 33.741 meters	Kansas City 21.628 meters	Tapachula 78.035 meters	Kansas City 21.628 meters

Availability of NPA service is evaluated by monitoring the WAAS horizontal protection level at receiver locations throughout the test period. If the horizontal protection level is not greater than the horizontal alert limit (HAL = 556m) then the service is available. If the horizontal protection level exceeds the required alert level or if WAAS navigation message is not received then the NPA service at that location is considered unavailable and an outage in service is recorded with its duration. The NPA service is not considered available again until the horizontal protection level is within the alert limit for at least 15 minutes. The percent of time that NPA service is available using the fifteen-minute window criteria is presented in Table 3.3. The NPA service outages and associated outage rate for this period is presented in Table 3.5. The outage rate is the percent of NPA approaches that theoretically would be interrupted by a loss of operational service once the approach had started.

During this evaluated period, the higher NPA outages at Barrow and Kotzebue are due to CRW GUS switchovers, higher NPA outages at Iqaluit are due to CRE GUS switchovers.

Table 3-1 95% Protection Level

Location	95% HPL (meters)	95% VPL (meters)	Percentage in PA mode
Atlantic City	17.410	29.310	99.997665
Arcata	21.609	32.068	100
Oklahoma City	13.559	23.001	99.998131
Albuquerque	14.330	23.689	99.998955
Anchorage	17.282	30.110	99.998352
Atlanta	13.522	22.594	99.998222
Barrow	21.739	57.239	99.965500
Bethel	20.428	35.974	99.998634
Billings	15.014	22.153	99.998955
Boston	18.234	26.421	99.997742
Chicago	14.163	22.001	99.998222
Cleveland	15.463	24.321	99.997757
Cold Bay	31.445	46.162	99.998611
Dallas	13.533	23.745	99.998291
Denver	13.717	22.011	99.998955
Fairbanks	16.870	31.938	99.998421
Gander	27.366	38.125	99.982162
Goose Bay	26.598	37.574	99.977989
Houston	14.348	24.020	99.998283
Iqaluit	52.039	63.838	99.108505
Jacksonville	15.059	25.667	99.997757
Juneau	16.577	27.004	99.997803
Kansas City	13.356	21.628	99.998291
Kotzebue	20.618	42.213	99.967110
Los Angeles	18.120	32.005	99.998970
Memphis	13.549	22.090	99.998291
Merida	22.126	34.724	100
Mexico City	30.893	45.605	100
Miami	16.182	31.418	99.997757
Minneapolis	14.971	21.769	99.998291
New York	17.477	26.334	99.997620
Oakland	21.227	33.741	99.999039
Puerto Vallarta	37.353	51.282	100
Salt Lake City	14.048	22.697	99.998970
San Jose Del Cabo	33.090	48.176	100
Seattle	18.070	24.975	99.999031
Tapachula	58.454	78.035	98.830887
Washington DC	15.712	24.753	99.997757
Winnipeg	18.153	23.556	99.998268

Table 3-2 Quarterly Availability Statistics

Location	LPV *Average Availability Percentage of time*	LNAV/VNAV *Average Availability Percentage of time*	LPV 200 WAAS *With 15 minute window*	LPV WAAS *With 15 minute window*	LNAV/VNAV *With 15 minute window*
Atlantic City	0.99997663	0.99997663	0.97252988	0.99997658	0.99997658
Arcata	0.99907231	0.99907231	0.97581324	0.99869264	0.99869264
Oklahoma City	0.99998122	0.99998134	0.99968472	0.99998121	0.99998134
Albuquerque	0.99998665	0.99998665	0.99963424	0.99998664	0.99998664
Anchorage	0.99992621	0.99992621	0.99148297	0.99992575	0.99992575
Atlanta	0.99997759	0.99997759	0.99966186	0.99997756	0.99997756
Chicago	0.92725044	0.92748249	0.99970830	0.99998223	0.99998223
Barrow	0.99480736	0.99480736	0.71491333	0.92090899	0.92114526
Bethel	0.99998957	0.99998957	0.90879108	0.99443669	0.99443669
Billings	0.99997628	0.99997628	0.99996193	0.99998954	0.99998954
Boston	0.99998224	0.99998224	0.98835314	0.99997703	0.99997703
Cleveland	0.99997759	0.99997759	0.99675835	0.99997755	0.99997755
Cold Bay	0.97873884	0.97928888	0.70325557	0.96723175	0.96795529
Dallas	0.99998289	0.99998289	0.99977373	0.99998286	0.99998286
Denver	0.99998665	0.99998665	0.99989831	0.99998663	0.99998663
Fairbanks	0.99706906	0.99706906	0.96233040	0.99692315	0.99692315
Gander	0.99130124	0.99264187	0.83266167	0.98914077	0.99063838
Goose Bay	0.99276280	0.99557585	0.97947220	0.99544633	0.99761240
Houston	0.99998212	0.99998283	0.99980341	0.99998208	0.99998284
Iqaluit	0.82549506	0.86126769	0.86615236	0.93268540	0.94895133
Jacksonville	0.99997759	0.99997759	0.99859862	0.99997756	0.99997756
Juneau	0.99988472	0.99988472	0.99605401	0.99988372	0.99988372
Kansas City	0.99998289	0.99998289	0.99991162	0.99998285	0.99998285
Kotzebue	0.97878635	0.97887820	0.86091597	0.97778362	0.97787718
Los Angeles	0.99960458	0.99964023	0.96789701	0.99947391	0.99950265
Memphis	0.99998224	0.99998224	0.99988358	0.99998222	0.99998222
Merida	0.99922639	0.99939203	0.94473123	0.99920585	0.99937171
Mexico City	0.97181588	0.97745049	0.66503187	0.95749593	0.96915689
Miami	0.99996728	0.99996728	0.97214919	0.99995991	0.99995991
Minneapolis	0.99998289	0.99998289	0.99986926	0.99998285	0.99998285
New York	0.99997622	0.99997622	0.98733232	0.99997700	0.99997700
Oakland	0.99556059	0.99561894	0.95638722	0.99499924	0.99512023
Puerto Vallarta	0.92664504	0.94054252	0.45065330	0.91777005	0.93417036
Salt Lake City	0.99998957	0.99998957	0.99985694	0.99998954	0.99998954
San Jose Del Cabo	0.95596355	0.96497709	0.59297358	0.94430357	0.95369008
Seattle	0.99998587	0.99998790	0.99931745	0.99997527	0.99997731
Tapachula	0.43932021	0.49094343	0.04207093	0.36081814	0.41835924
Washington DC	0.99997747	0.99997759	0.98822262	0.99997744	0.99997756
Winnipeg	0.99998271	0.99998271	0.99979490	0.99998268	0.99998268

Table 3-3 NPA Availability

Location	NPA Availability (Excluding RAIM/FDE)
Albuquerque	0.99999533
Anchorage	0.99998719
Atlanta	0.99999411
Barrow	0.99986975
Bethel	0.99998698
Billings	0.99999534
Boston	0.99999183
Cleveland	0.99999175
Cold Bay	0.99998716
Fairbanks	0.99998697
Gander	0.99993007
Honolulu	0.99999175
Houston	0.99999423
Iqaluit	0.99992626
Juneau	0.99999578
Kansas City	0.99999534
Kotzebue	0.99986592
Los Angeles	0.99999530
Merida	100
Miami	0.99999418
Minneapolis	0.99999533
Oakland	0.99999528
Puerto Rico	0.99999420
Salt Lake City	0.99999534
Seattle	0.99999521
Tapachula	100
Washington DC	0.99999409

Table 3-4 LPV and LNAV/VNAV Outage Rate

Location	LPV 200 Outages	LPV 200 Outage Rates	LPV Outages	LPV Outage Rates	LNAV/VNAV Outages	LNAV/VNAV Outage Rates
Atlantic City	231	0.004661	1	0.000020	1	0.000020
Arcata	305	0.006246	76	0.001521	76	0.001521
Oklahoma City	16	0.000322	2	0.000040	1	0.000020
Albuquerque	9	0.000170	1	0.000019	1	0.000019
Anchorage	259	0.004940	3	0.000057	3	0.000057
Atlanta	7	0.000132	1	0.000019	1	0.000019
Chicago	4	0.000076	1	0.000019	1	0.000019
Barrow	1165	0.031016	598	0.012359	594	0.012273
Bethel	662	0.013841	100	0.001911	100	0.001911
Billings	2	0.000038	1	0.000019	1	0.000019
Boston	162	0.003103	2	0.000038	2	0.000038
Cleveland	78	0.001481	1	0.000019	1	0.000019
Cold Bay	1005	0.027800	372	0.007482	348	0.006994
Dallas	5	0.000095	1	0.000019	1	0.000019
Denver	7	0.000130	1	0.000019	1	0.000019
Fairbanks	443	0.008734	100	0.001903	100	0.001903
Gander	991	0.022501	140	0.002676	120	0.002290
Goose Bay	127	0.003322	40	0.001030	24	0.000616
Houston	8	0.000151	2	0.000038	1	0.000019
Iqaluit	362	0.013285	206	0.007021	134	0.004488
Jacksonville	27	0.000511	1	0.000019	1	0.000019
Juneau	120	0.002287	4	0.000076	4	0.000076
Kansas City	5	0.000095	1	0.000019	1	0.000019
Kotzebue	949	0.020990	398	0.007751	397	0.007731
Los Angeles	371	0.007249	45	0.000851	44	0.000832
Memphis	4	0.000076	1	0.000019	1	0.000019
Merida	363	0.008178	6	0.000128	4	0.000085
Mexico City	1190	0.038025	303	0.006725	252	0.005525
Miami	116	0.002257	3	0.000057	3	0.000057
Minneapolis	4	0.000076	1	0.000019	1	0.000019
New York	110	0.002222	1	0.000020	1	0.000020
Oakland	498	0.009854	94	0.001788	94	0.001788
Puerto Vallarta	1003	0.047379	465	0.010786	470	0.010704
Salt Lake City	6	0.000113	1	0.000019	1	0.000019
San Jose Del Cabo	957	0.034337	360	0.008111	357	0.007964
Seattle	19	0.000364	3	0.000057	3	0.000057
Tapachula	194	0.109893	1164	0.076880	1216	0.069075
Washington DC	115	0.002200	1	0.000019	1	0.000019
Winnipeg	4	0.000076	1	0.000019	1	0.000019

Table 3-5 NPA Outage Rates

Location	NPA Outages	NPA Outage Rate
Albuquerque	1	0.00001944
Anchorage	1	0.00001922
Atlanta	1	0.00001962
Barrow	11	0.00021689
Bethel	1	0.00001954
Billings	1	0.00001944
Boston	1	0.00001946
Cleveland	1	0.00001964
Cold Bay	1	0.00001945
Fairbanks	1	0.00001954
Gander	6	0.00011341
Honolulu	1	0.00000825
Houston	1	0.00001923
Iqaluit	4	0.00014138
Juneau	1	0.00001917
Kansas City	1	0.00001940
Kotzebue	11	0.00021714
Los Angeles	1	0.00001957
Merida	0	0
Miami	1	0.00001940
Minneapolis	1	0.00001945
Oakland	1	0.00001967
Puerto Rico	1	0.00001932
Salt Lake City	1	0.00001942
Seattle	1	0.00001996
Tapachula	0	0
Washington DC	1	0.00001969

Figure 3-1 LPV Instantaneous Availability

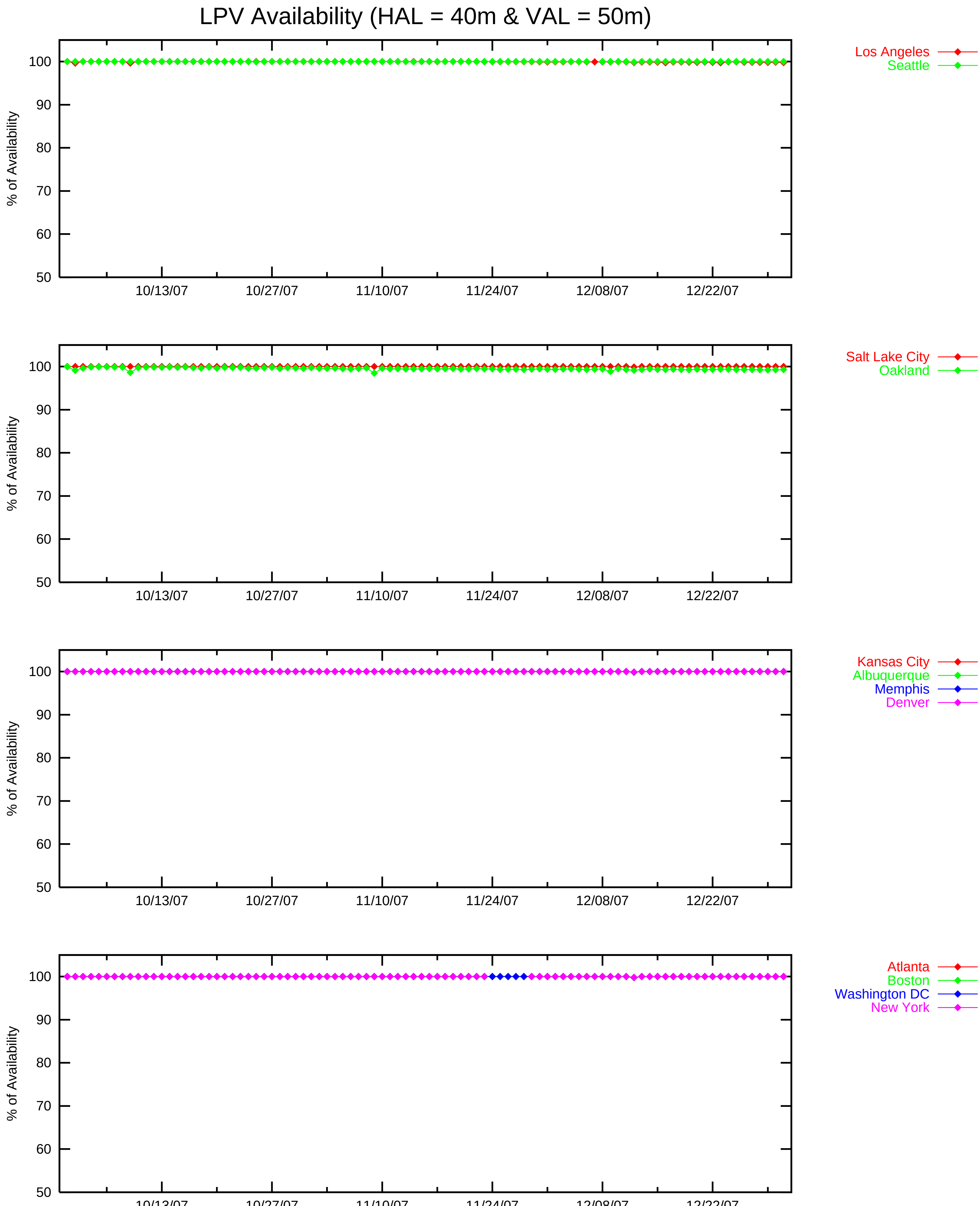


Figure 3-2 LPV Instantaneous Availability

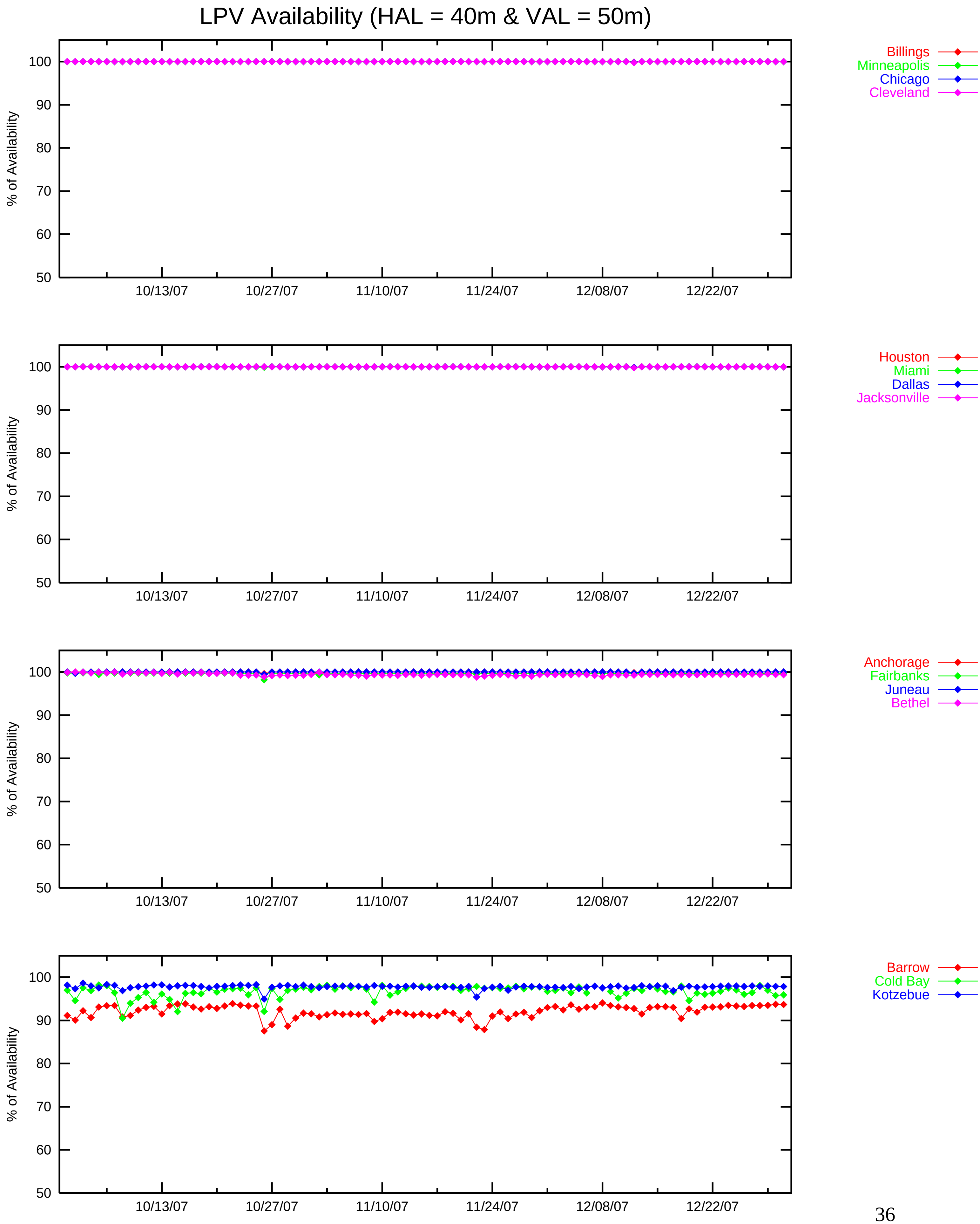


Figure 3-3 LPV Instantaneous Availability

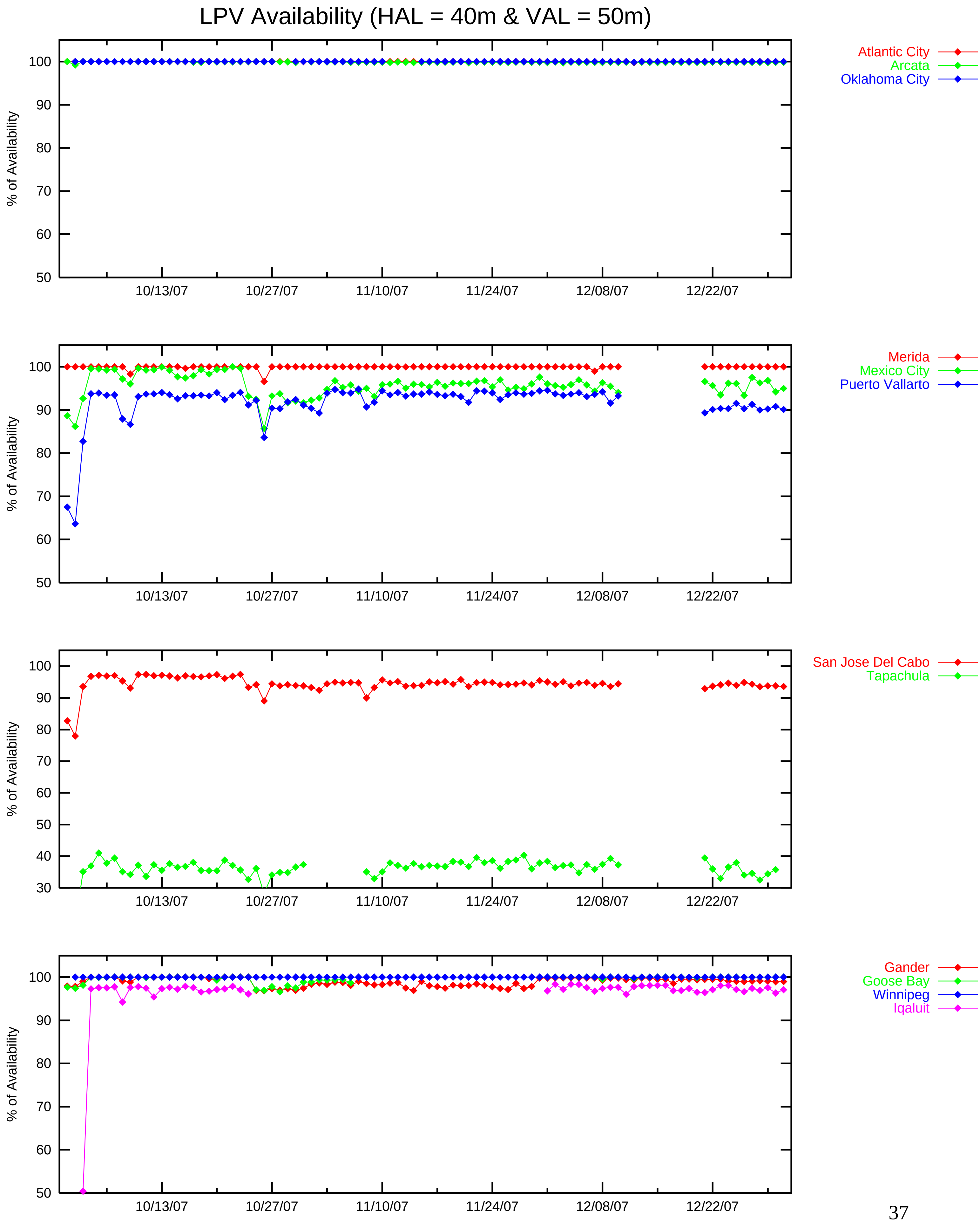


Figure 3-4 LNAV/VNAV Instantaneous Availability

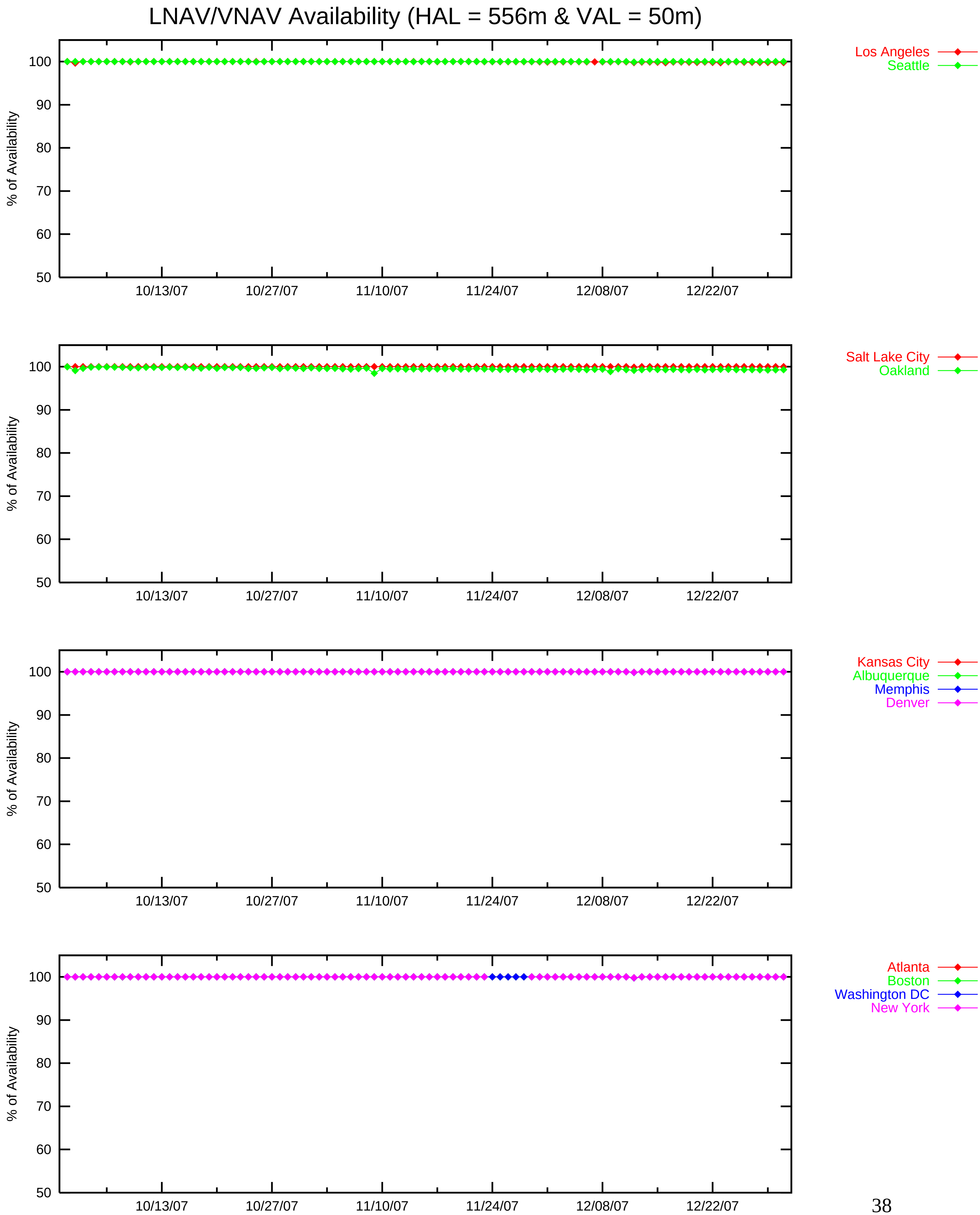


Figure 3-5 LNAV/VNAV Instantaneous Availability

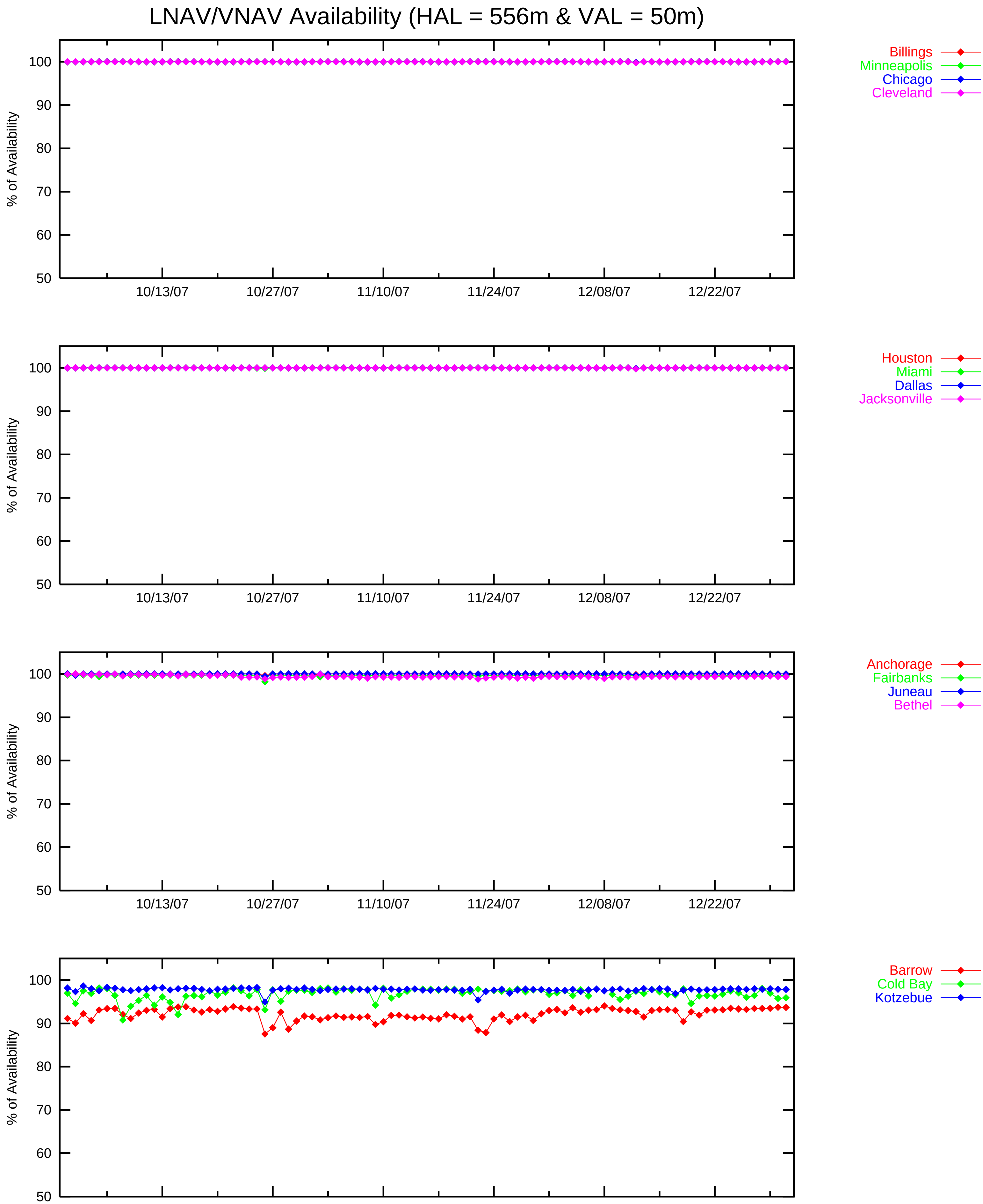
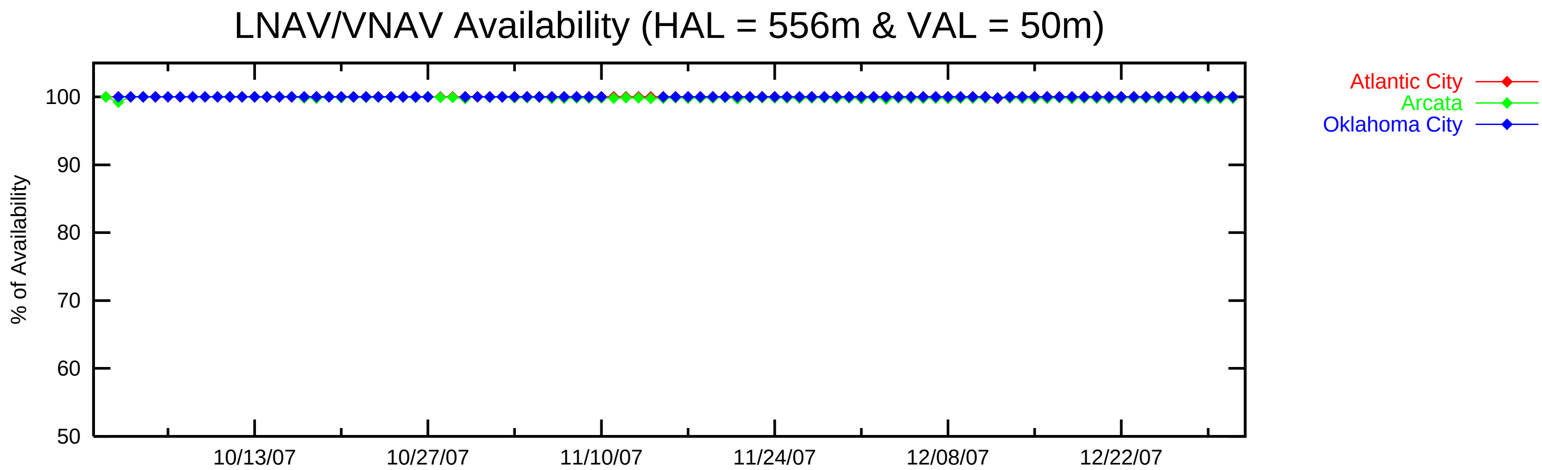
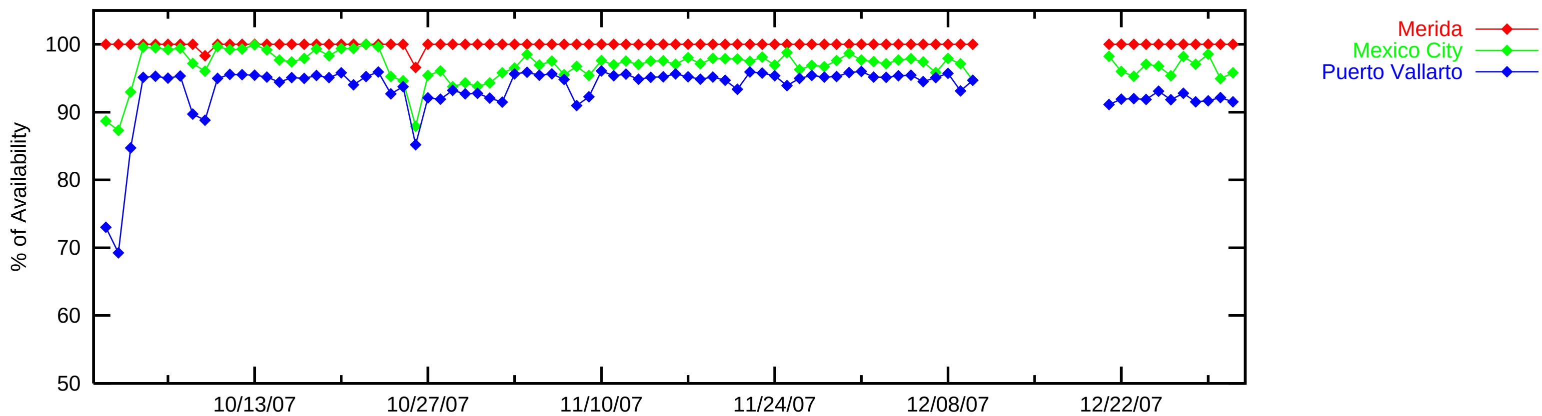
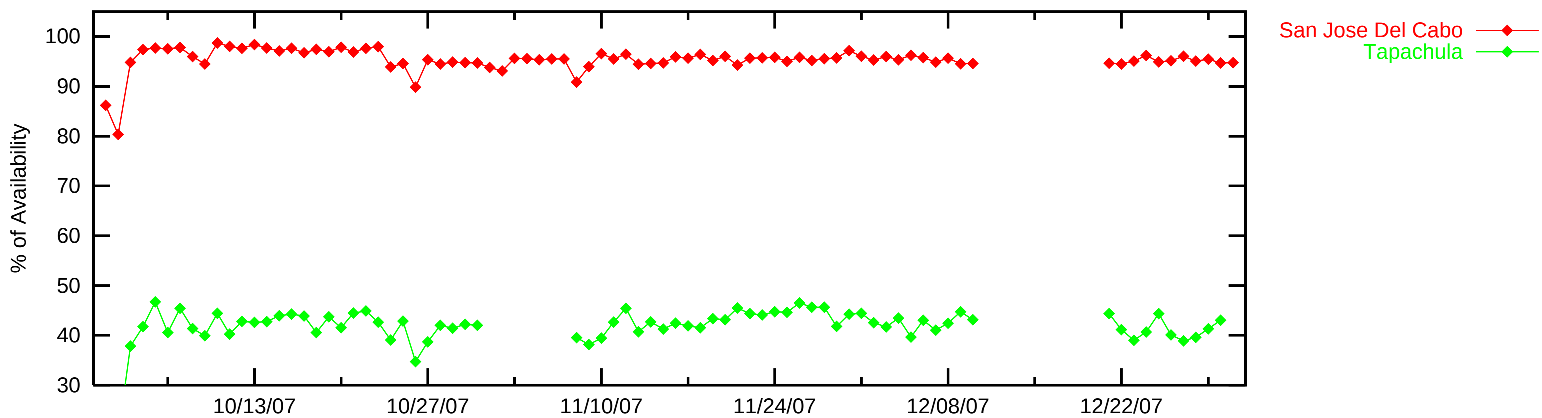


Figure 3-6 LNAV/VNAV Instantaneous Availability







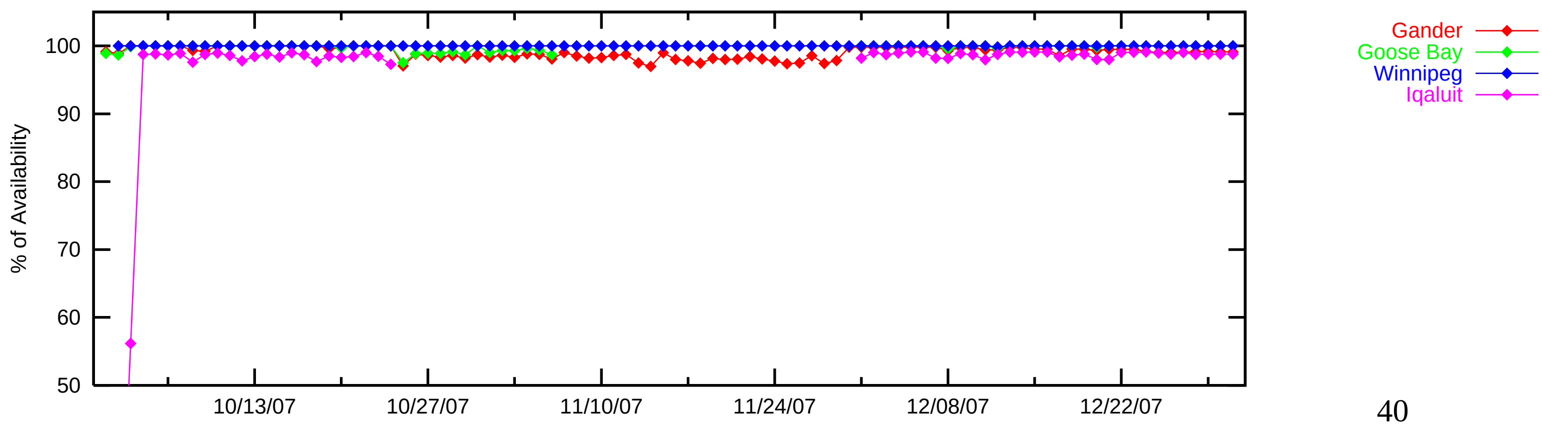


Figure 3-7 LPV Outages

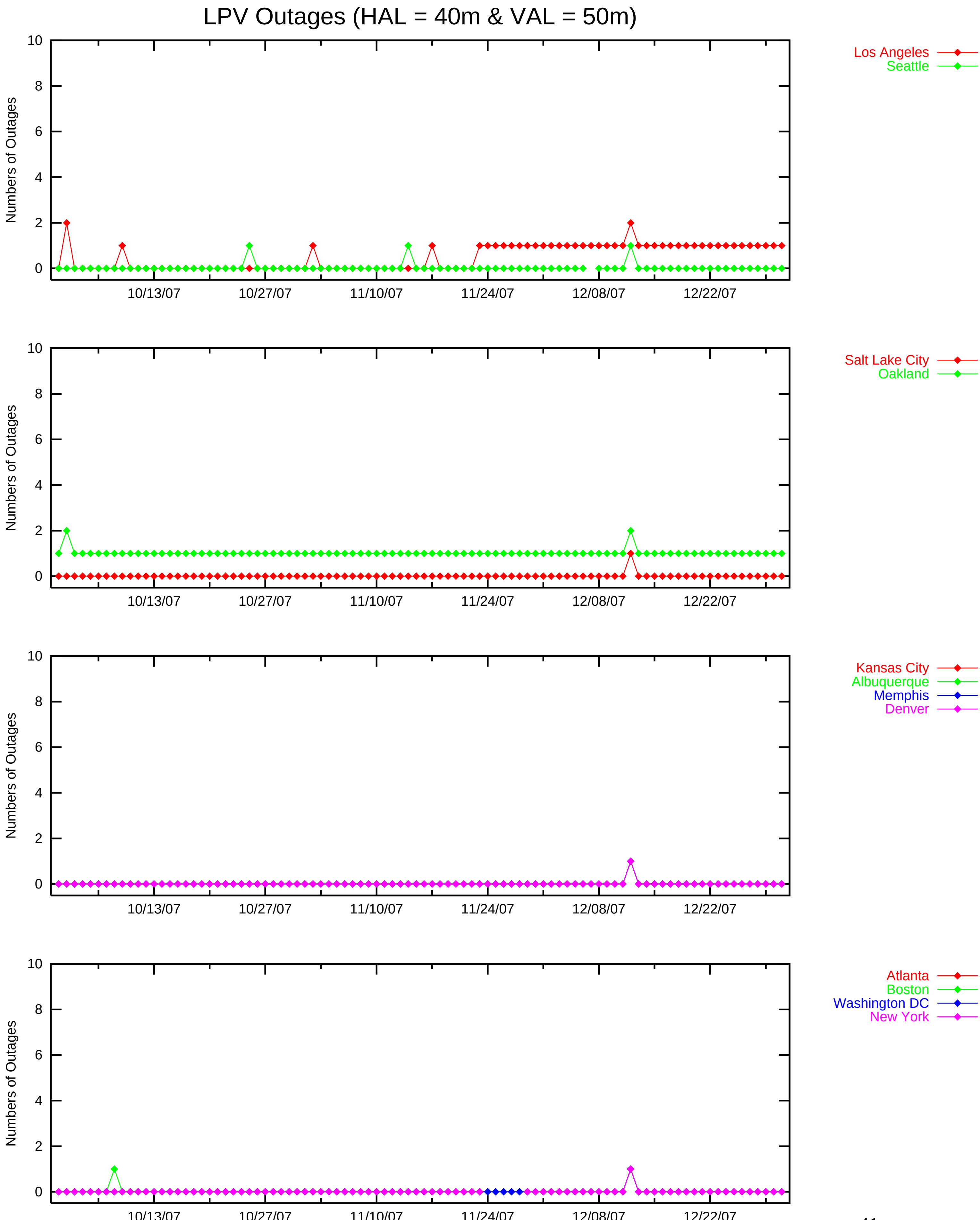


Figure 3-8 LPV Outages

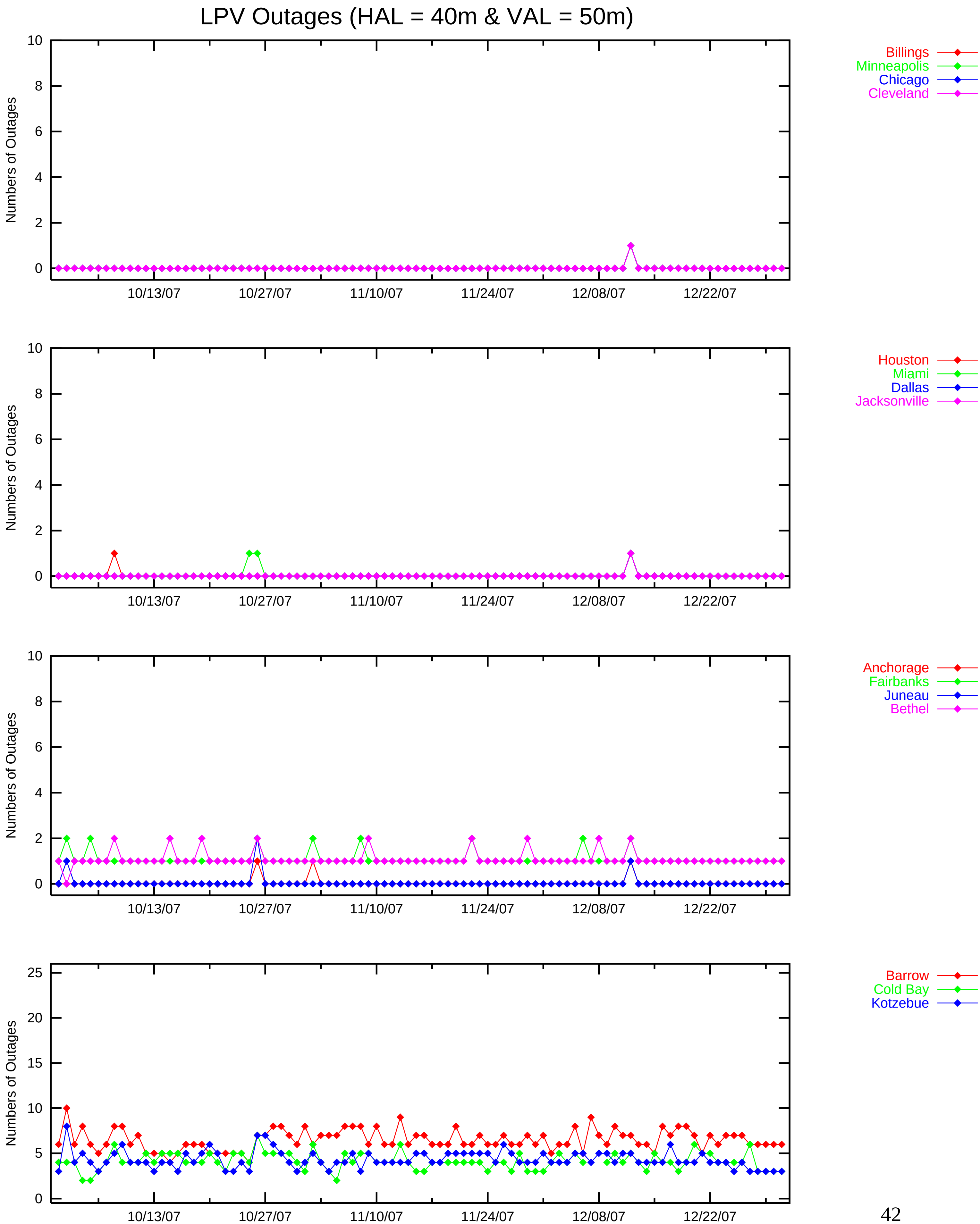


Figure 3-9 LPV Outages

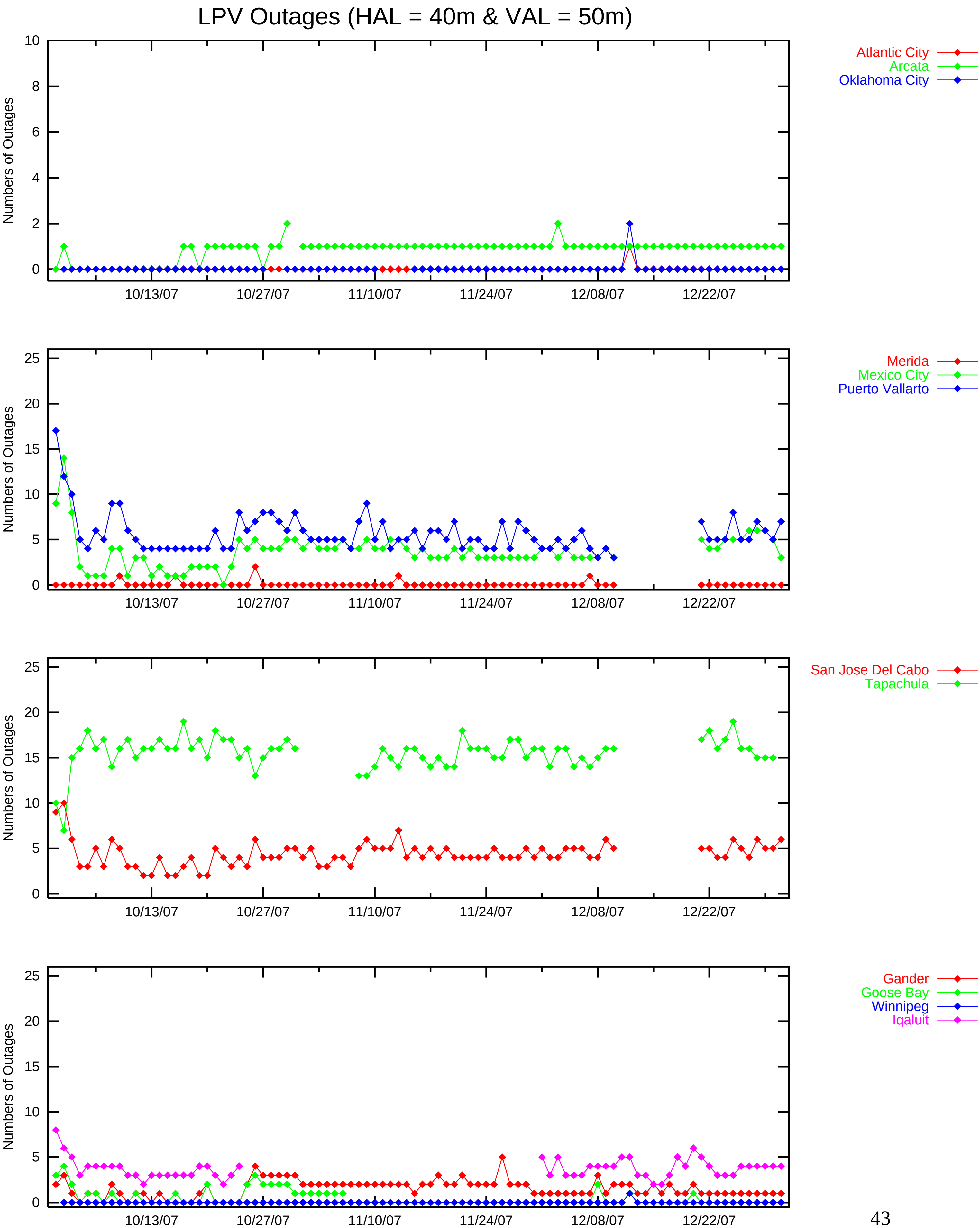


Figure 3-10 LNAV/VNAV Outages

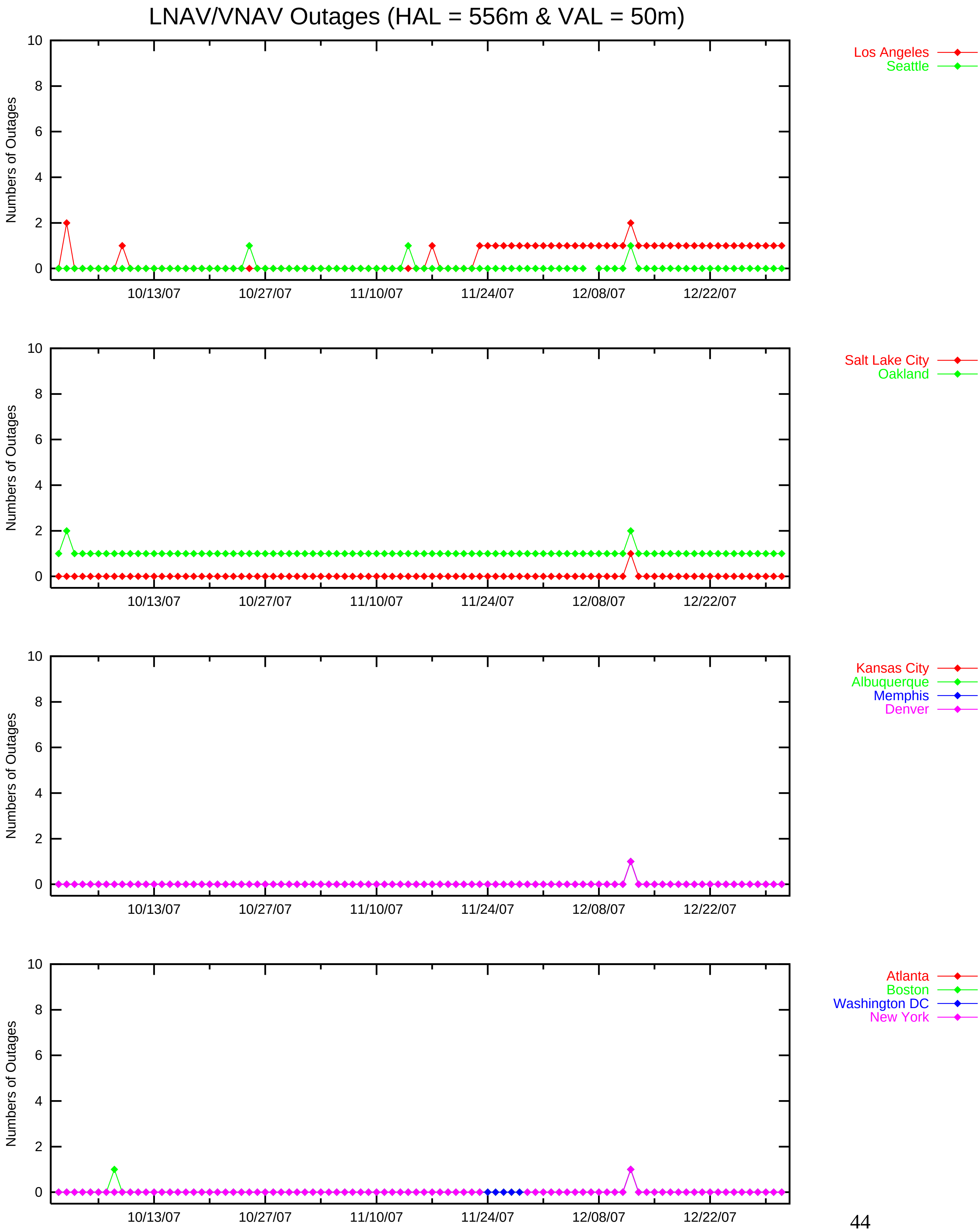


Figure 3-11 LNAV/VNAV Outages

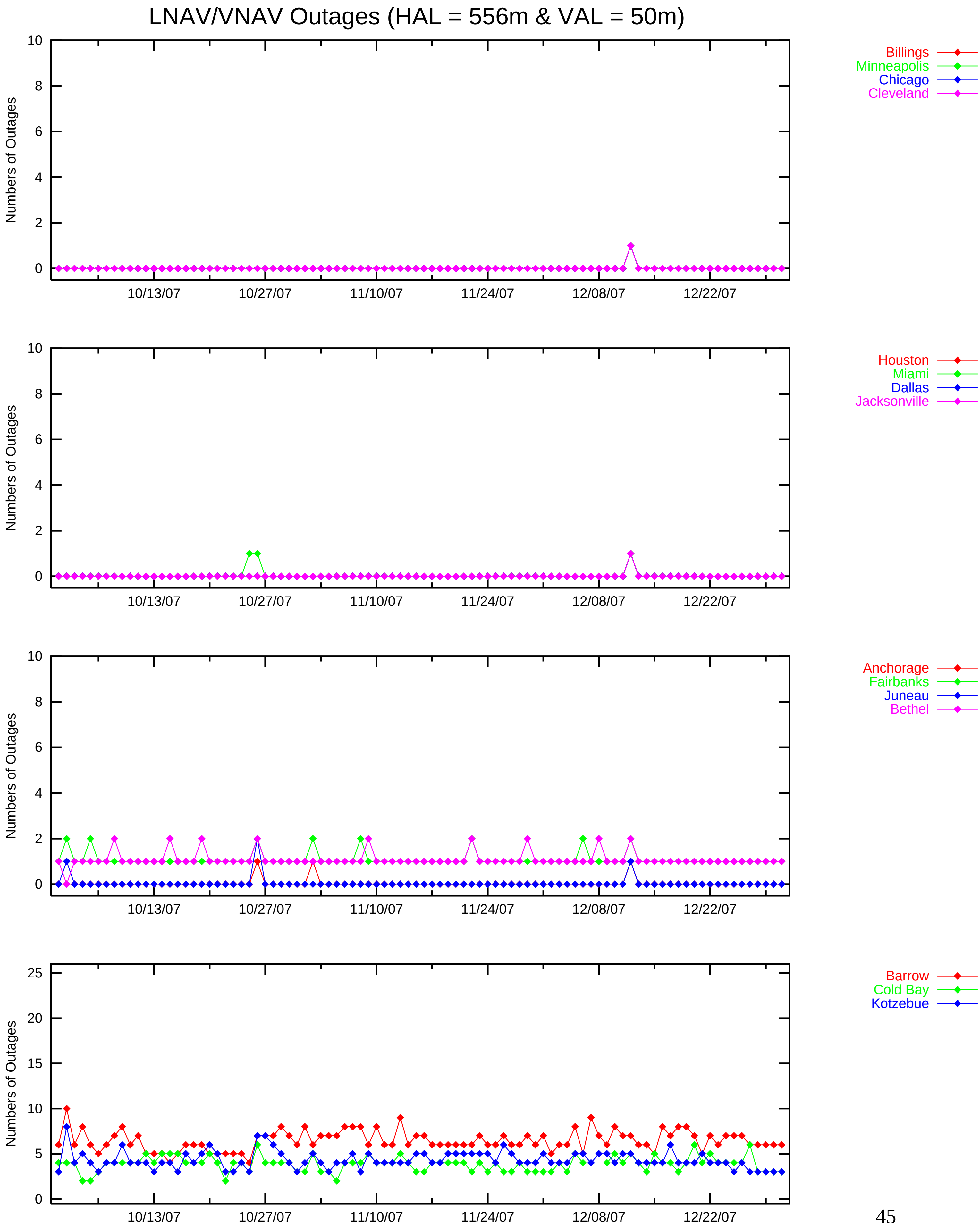
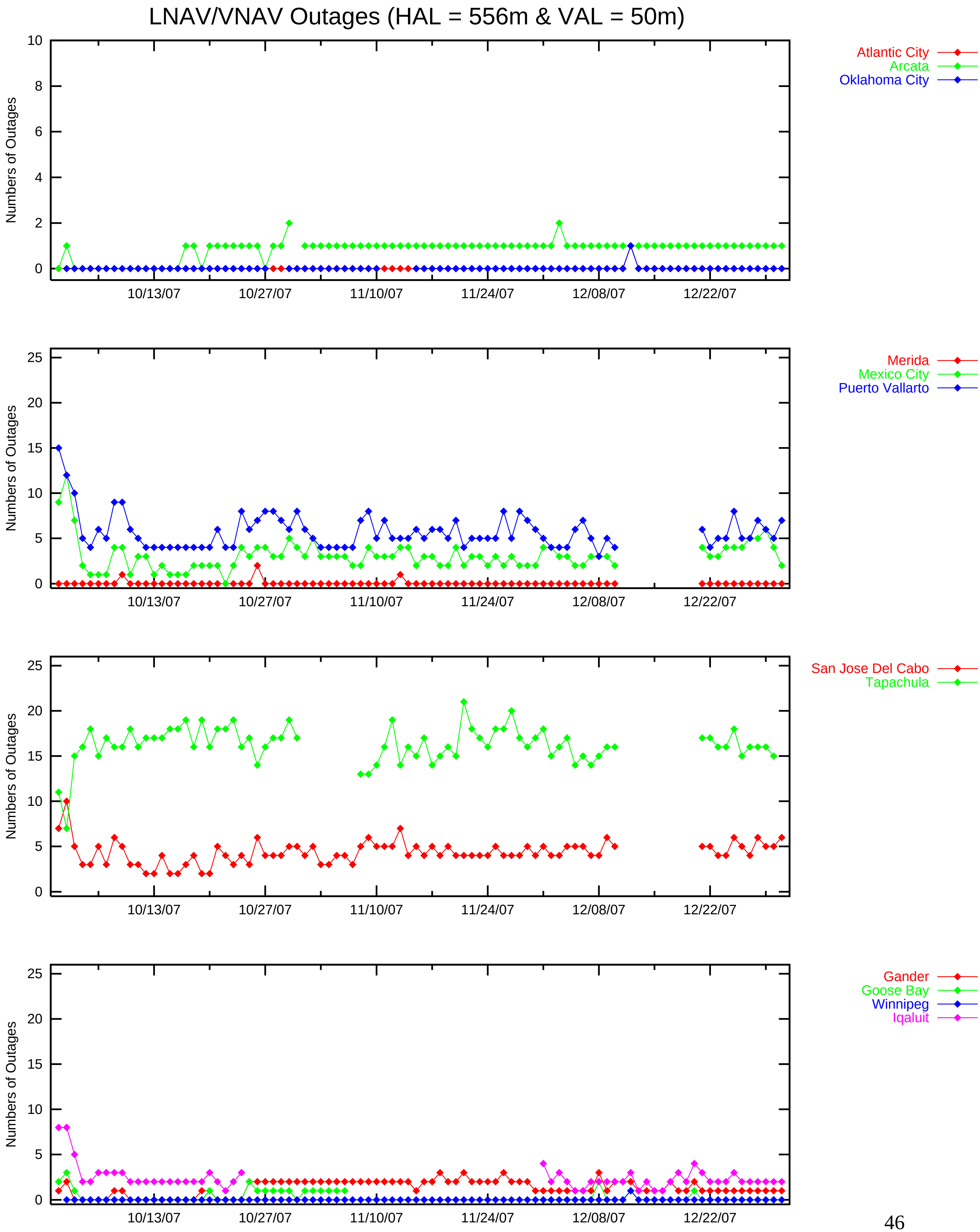


Figure 3-12 LNAV/VNAV Outages



4.0 COVERAGE

WAAS coverage area evaluation estimates the percent of service volume where WAAS is providing LPV, LPV200, LNAV/VNAV and NPA services. The WAAS message and the GPS/GEO satellite status are used to determine WAAS availability across North America. For PA coverage, protection levels were calculated at two-minute intervals and at two degree spacing over the PA service volume, while NPA coverage was calculated at two-minute intervals and five degree spacing over the NPA service volume.

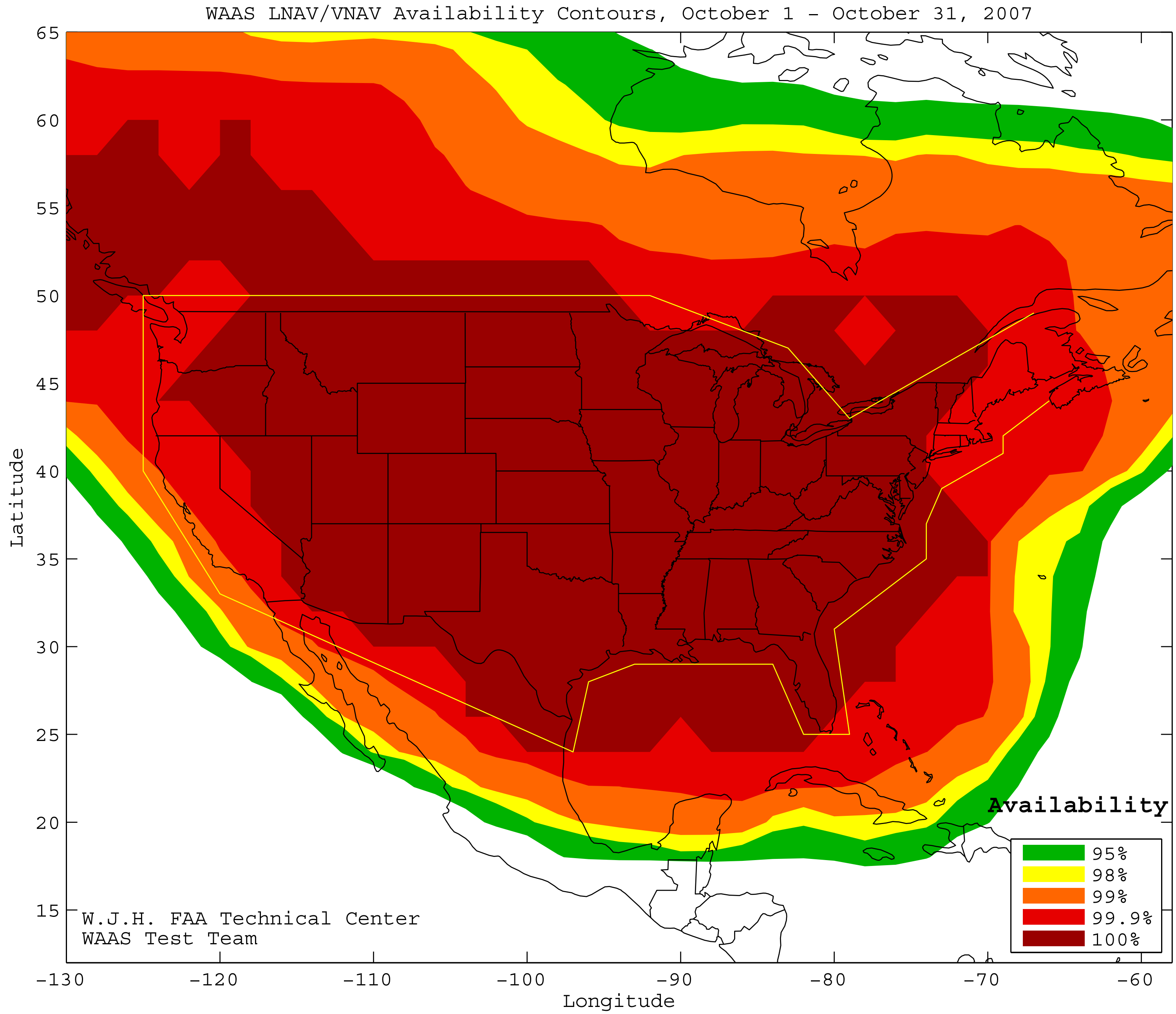
Daily analysis for PA was conducted for LPV, LPV200, and LNAV/VNAV service levels. The coverage plots provide 100, 99, 95, 90 and 80% availability contours. Figures 4.1 to 4.3 show the LNAV/VNAV CONUS coverage, Figures 4.5 to 4.7 show the LPV CONUS coverage, Figures 4.9 to 4.11 show the LPV200 CONUS coverage, and Figures 4.19 to 4.21 show the LPV Alaska coverage for each month for this quarter. Figure 4.4, 4.8, 4.12, and 4.22 show the rollup LNAV/VNAV, LPV, and LPV200 for the quarter. Figure 4.17 shows the daily LNAV/VNAV and LPV CONUS coverage, and Figure 4.23 shows the daily LPV Alaska coverage at 99% availability and ionosphere KP index values for this quarter.

Daily analysis for NPA was based on a 99.9% availability requirement. The NPA coverage plots provide 100, 99.9 and 99% availability contours. Figure 4.13 to 4.15 show the NPA coverage area of each month and Figure 4.16 shows the rollup NPA coverage for the quarter. Figure 4.18 shows the daily NPA coverage at 99.9% availability and ionosphere Kp index values for this quarter.

During this evaluated period, the lower than normal LPV Alaska coverage on 10/26/2007 is due to a couple of satellites out for service.

Please note that this quarter does not include rollup CONUS coverage plots since WAAS commissioning (July 2003) and rollup Alaska coverage plots since added to WAAS (Oct 2006). Five Mexico sites and four Canada sites were added to the WAAS system this quarter. The additional sites change the coverage and combining the data will reflect inaccurate averaging.

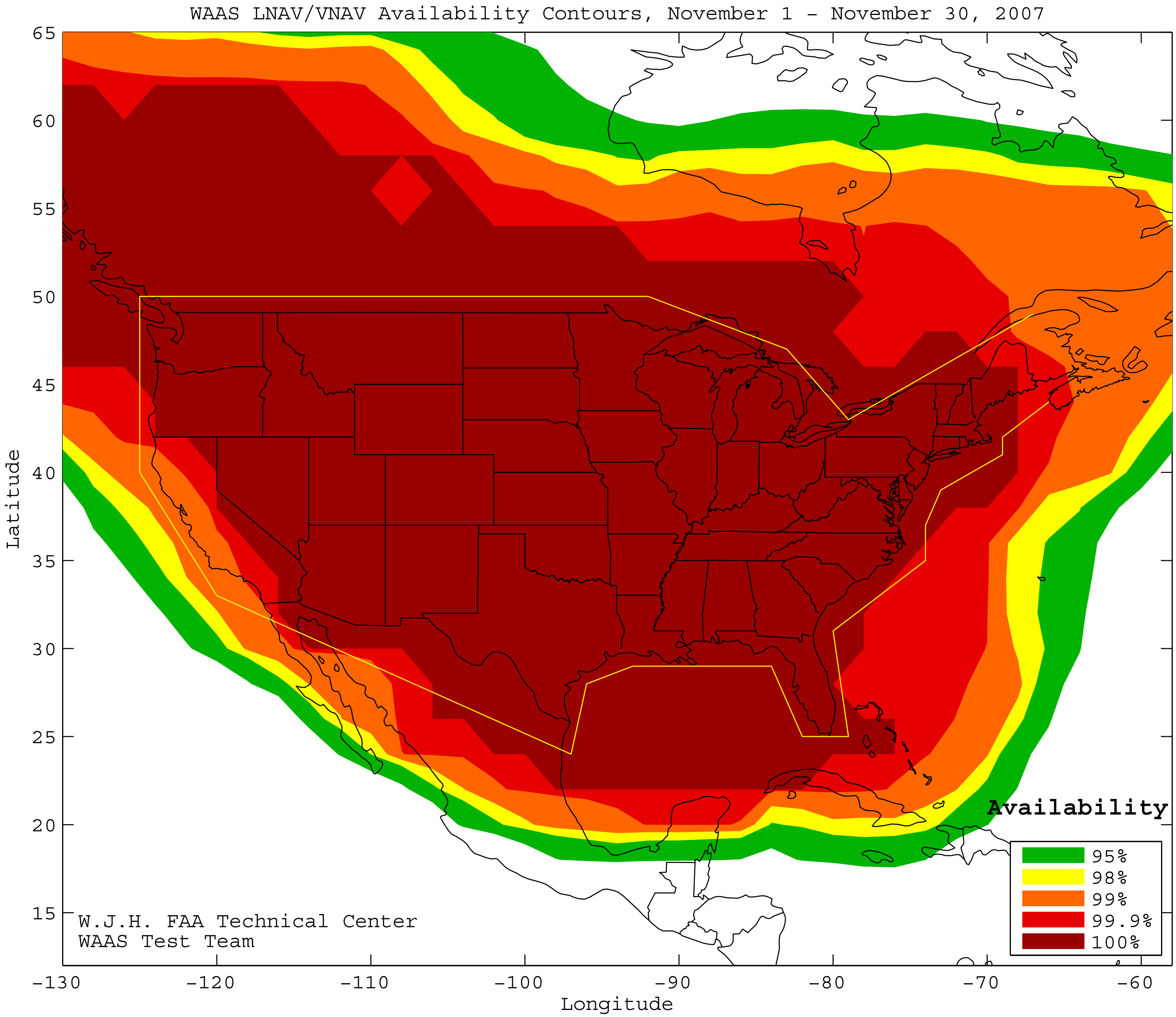
Figure 4-1 WAAS LNAV/VNAV Coverage - October



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 89.88%

SL = LNAV/VNAV

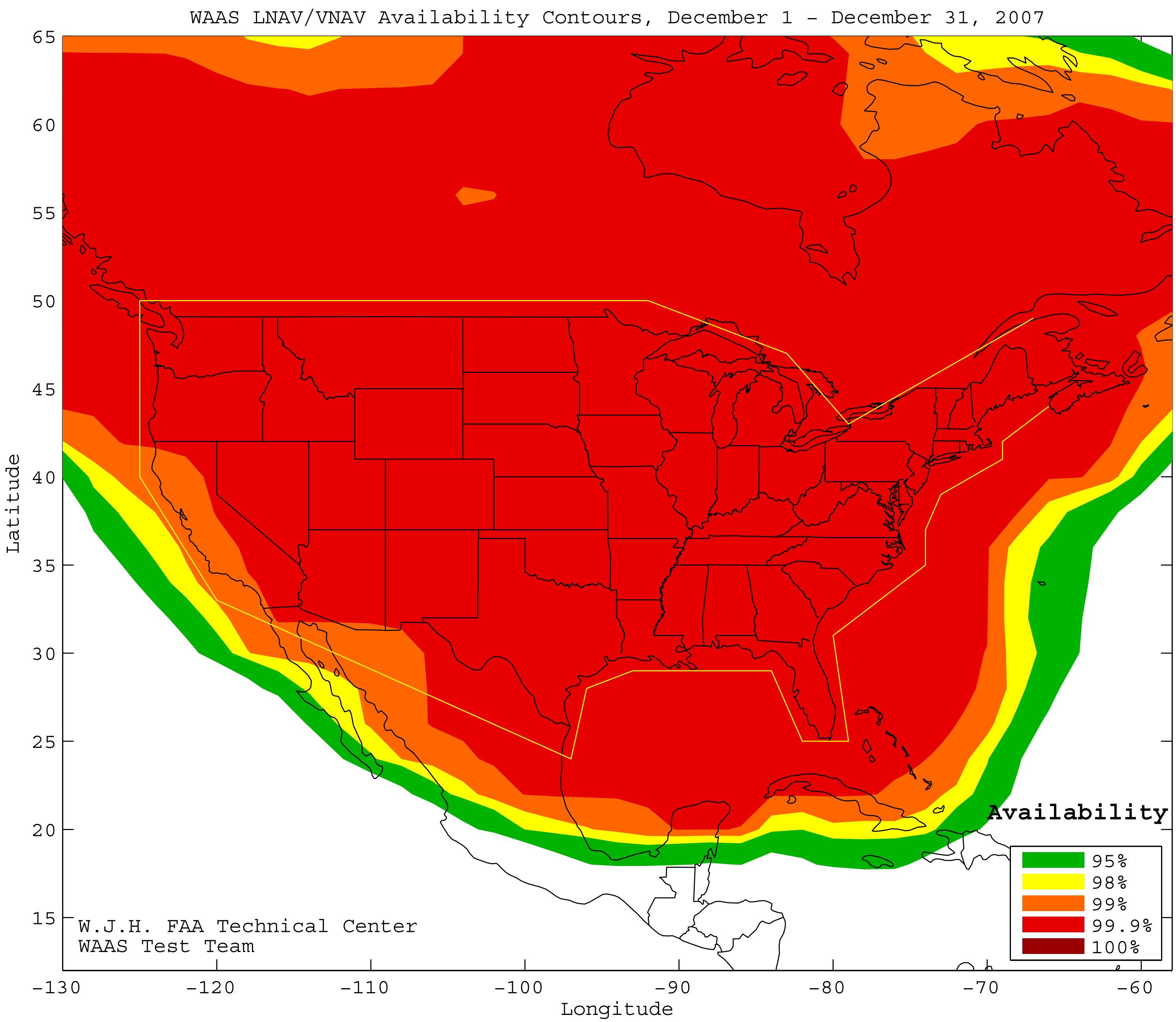
Figure 4-2 WAAS LNAV/VNAV Coverage - November



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 96.76%

SL = LNAV/VNAV

Figure 4-3 WAAS LNAV/VNAV Coverage - December



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 0%

SL = LNAV/VNAV

Figure 4-4 WAAS LNAV/VNAV Coverage for the Quarter

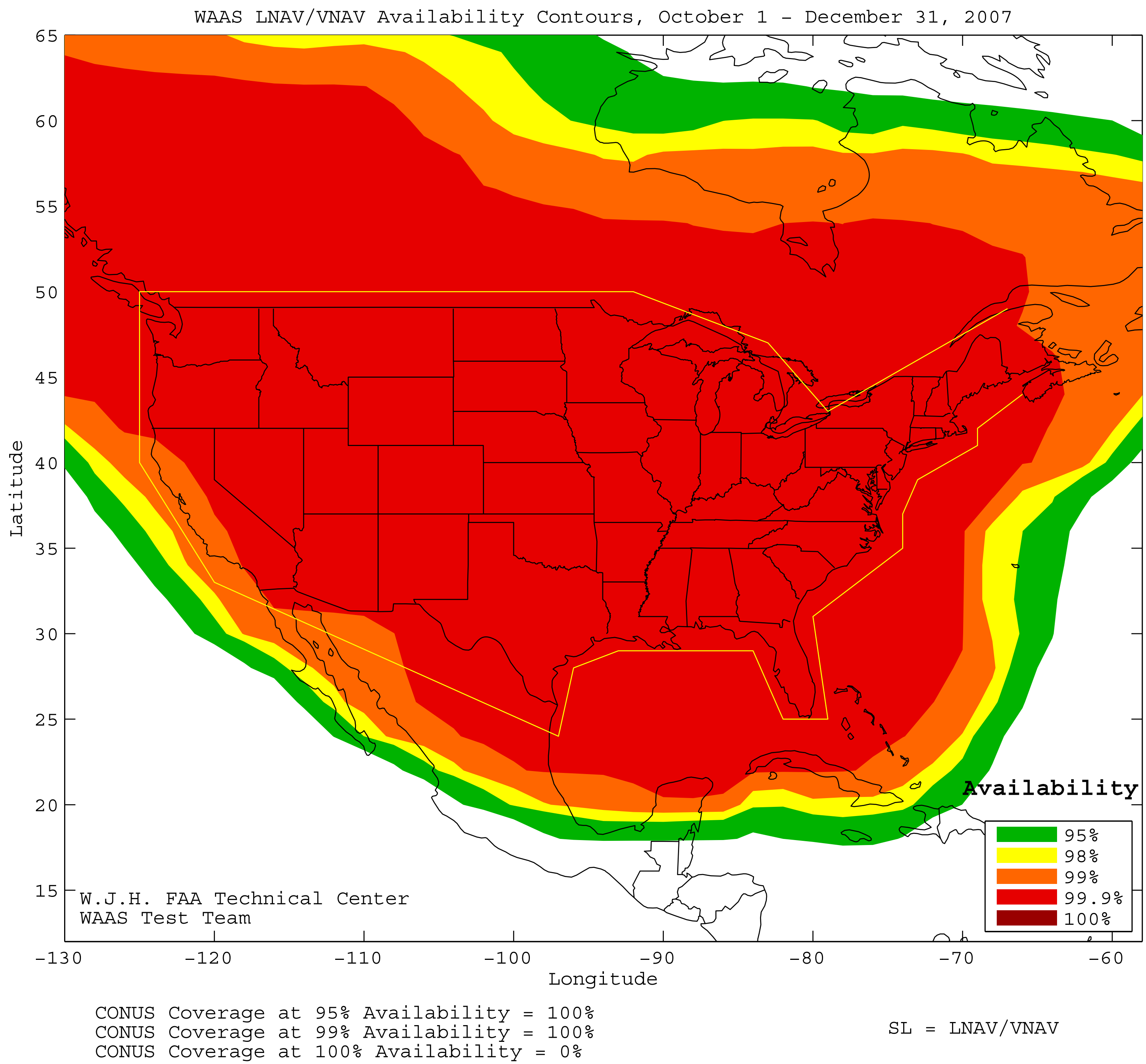
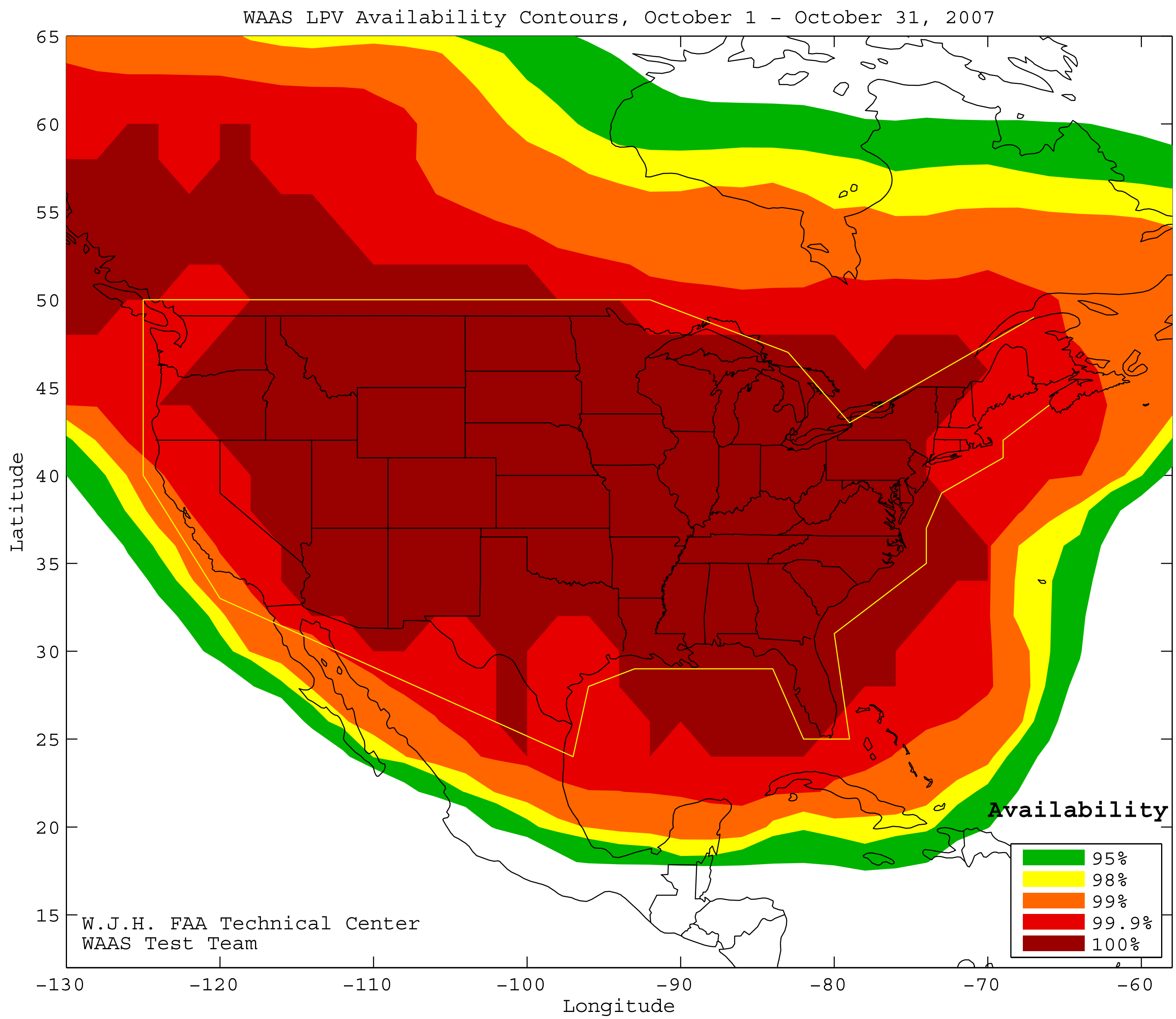


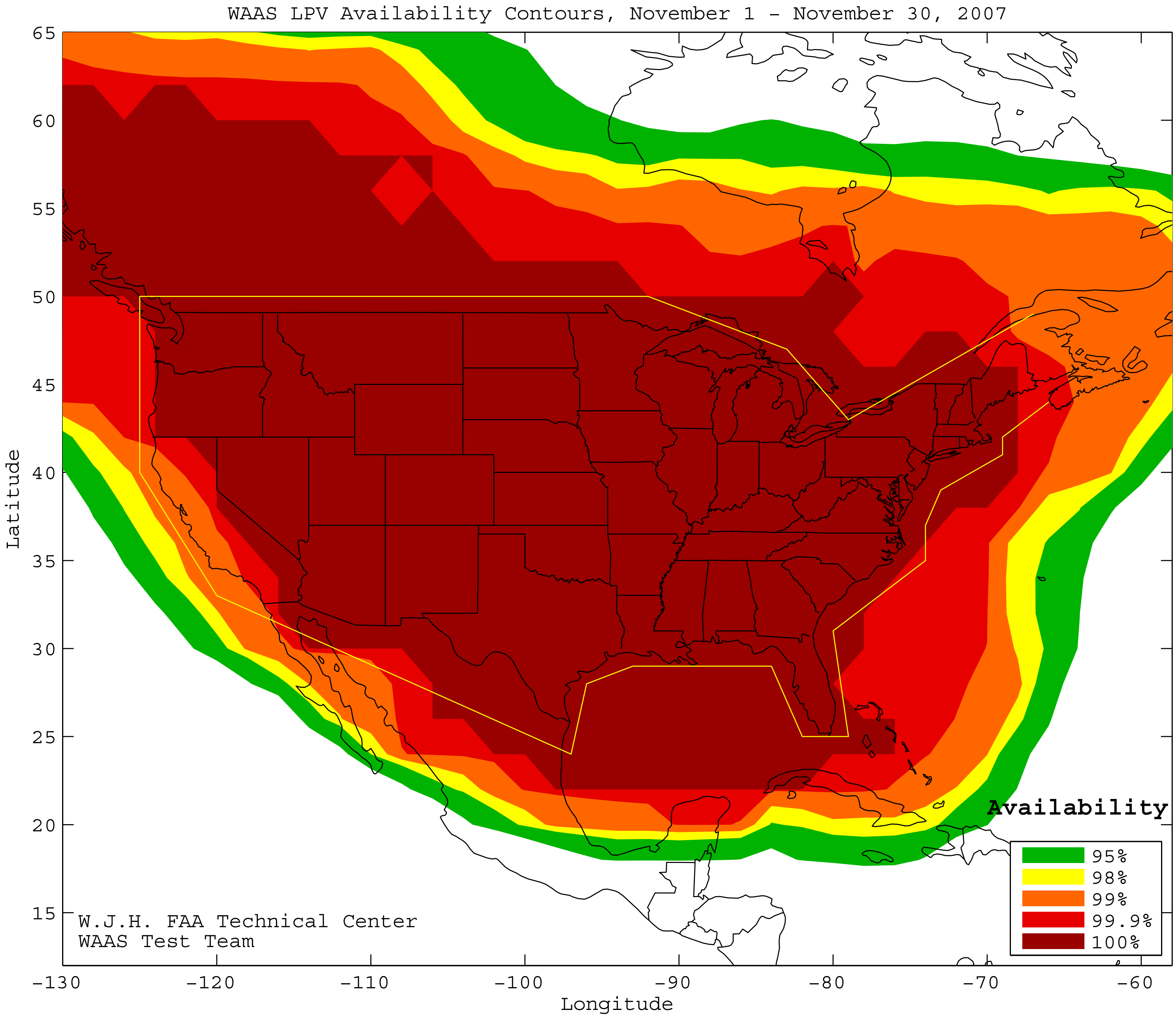
Figure 4-5 WAAS LPV Coverage - October



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 86.64%

SL = LPV

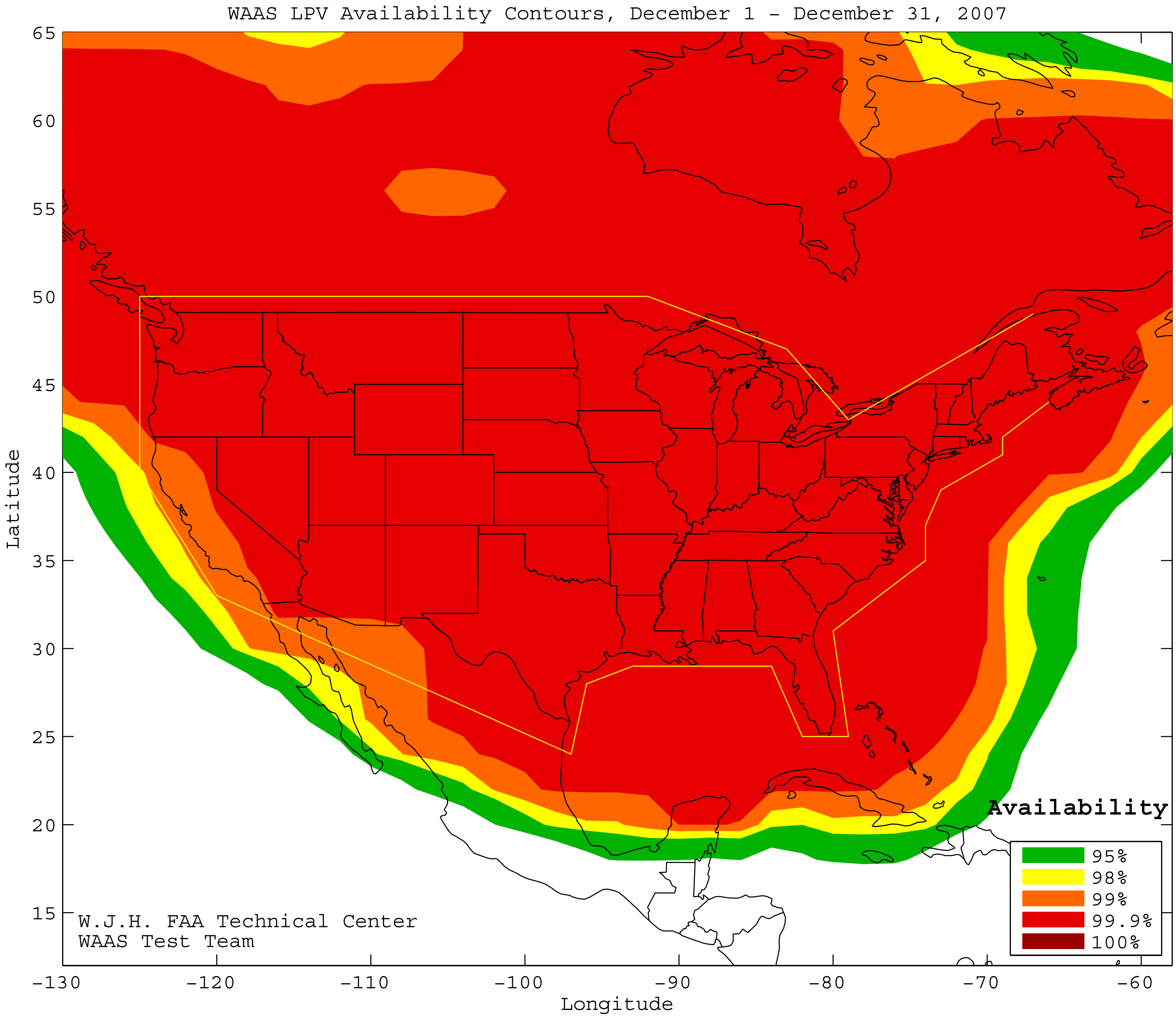
Figure 4-6 WAAS LPV Coverage - November



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 96.76%

SL = LPV

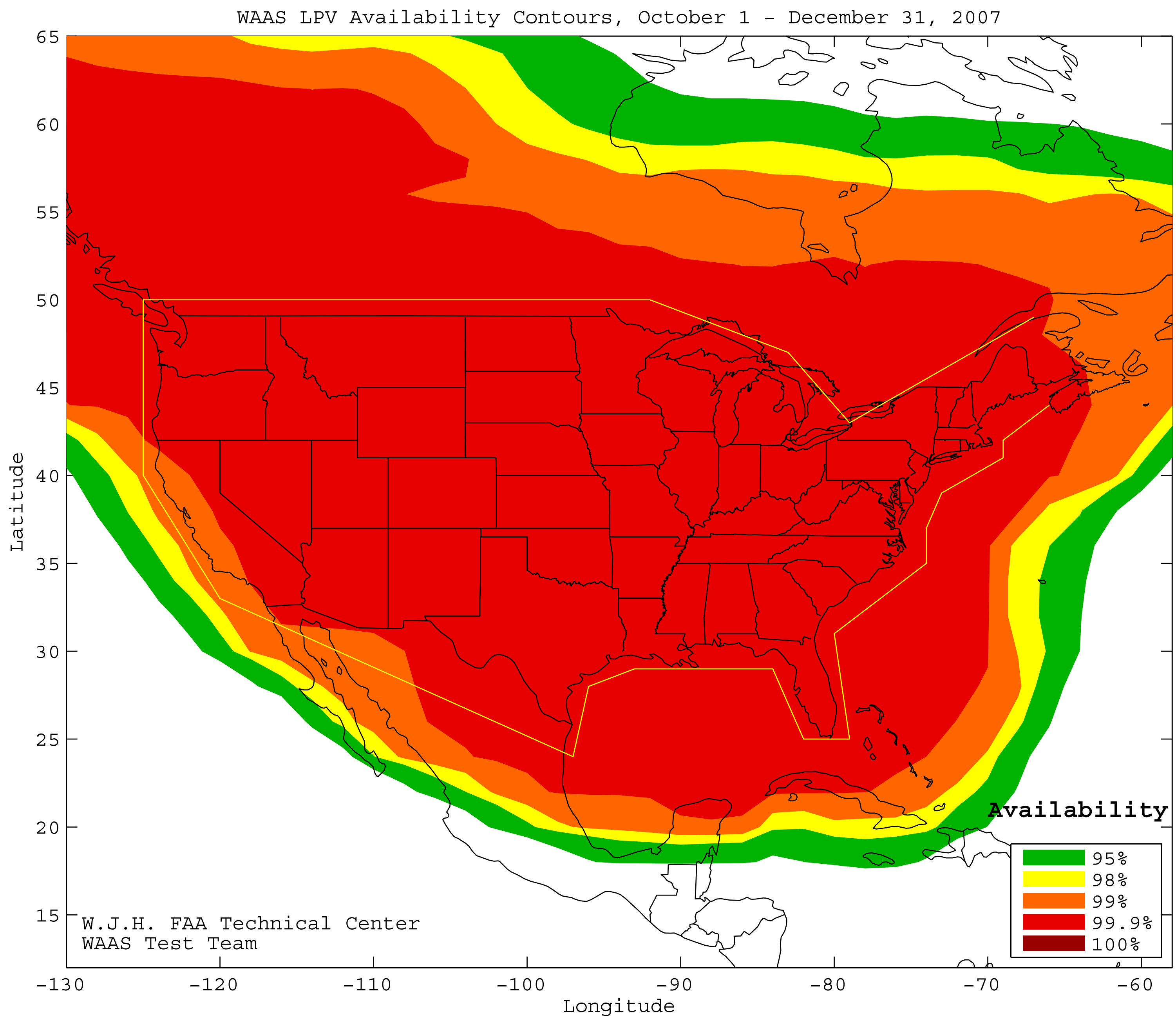
Figure 4-7 WAAS LPV Coverage - December



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 0%

SL = LPV

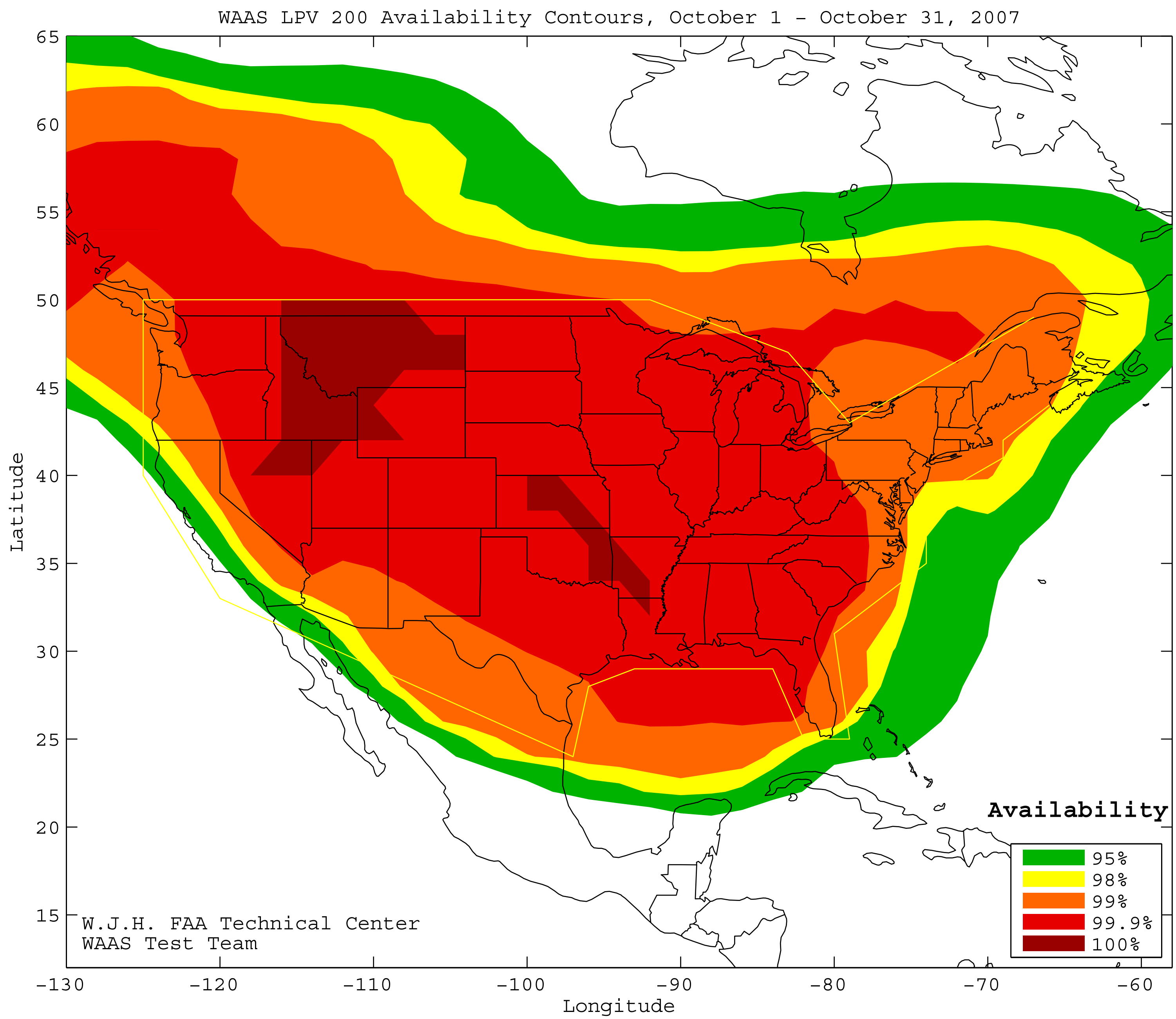
Figure 4-8 WAAS LPV Coverage for the Quarter



CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 0%

SL = LPV

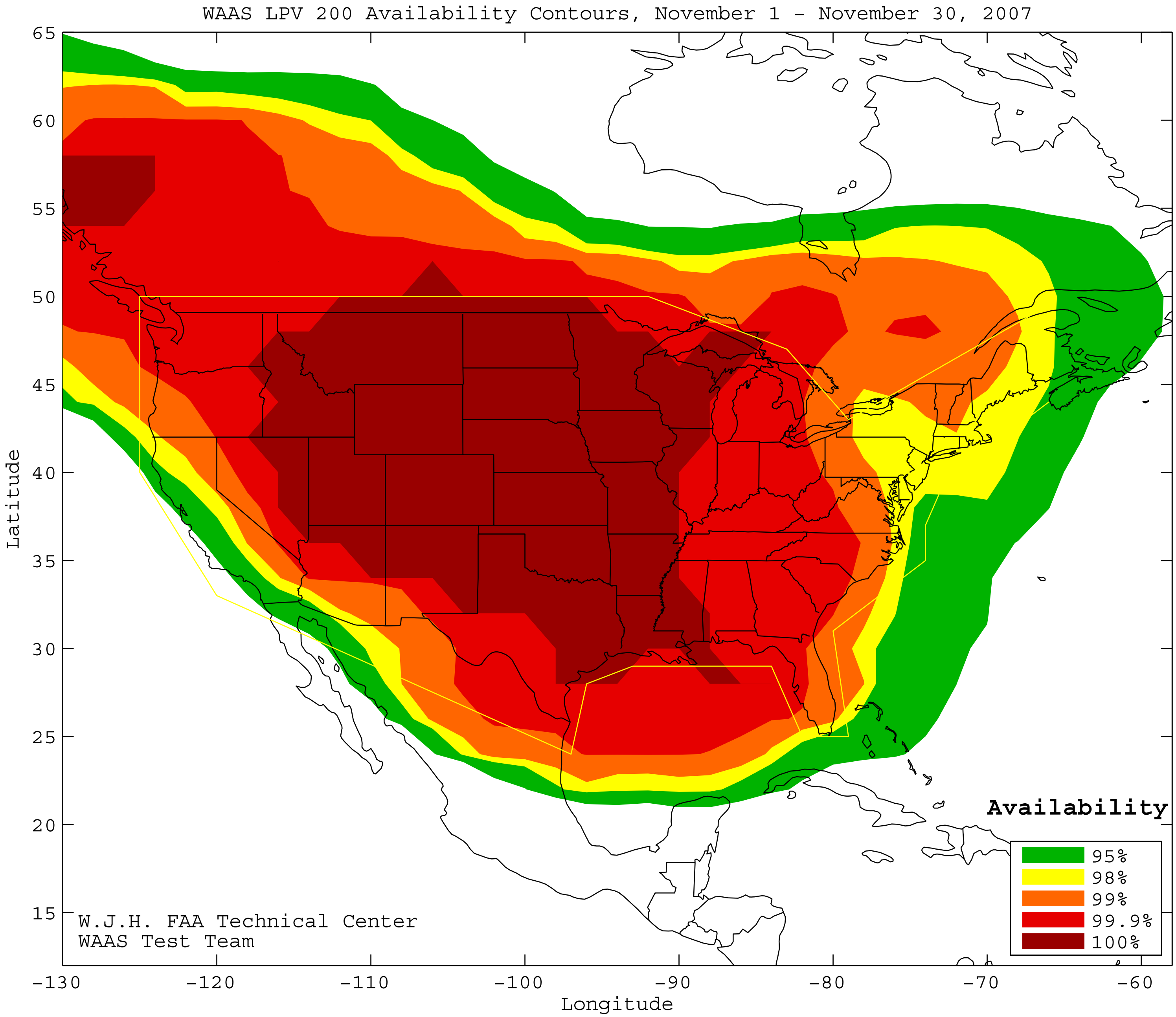
Figure 4-9 WAAS LPV 200 CONUS Coverage - October



CONUS Coverage at 95% Availability = 99.19%
CONUS Coverage at 99% Availability = 94.33%
CONUS Coverage at 100% Availability = 14.98%

SL = LPV 200

Figure 4-10 WAAS LPV 200 CONUS Coverage - November



CONUS Coverage at 95% Availability = 99.19%
CONUS Coverage at 99% Availability = 87.45%
CONUS Coverage at 100% Availability = 53.04%

SL = LPV 200

Figure 4-11 WAAS LPV 200 CONUS Coverage - December

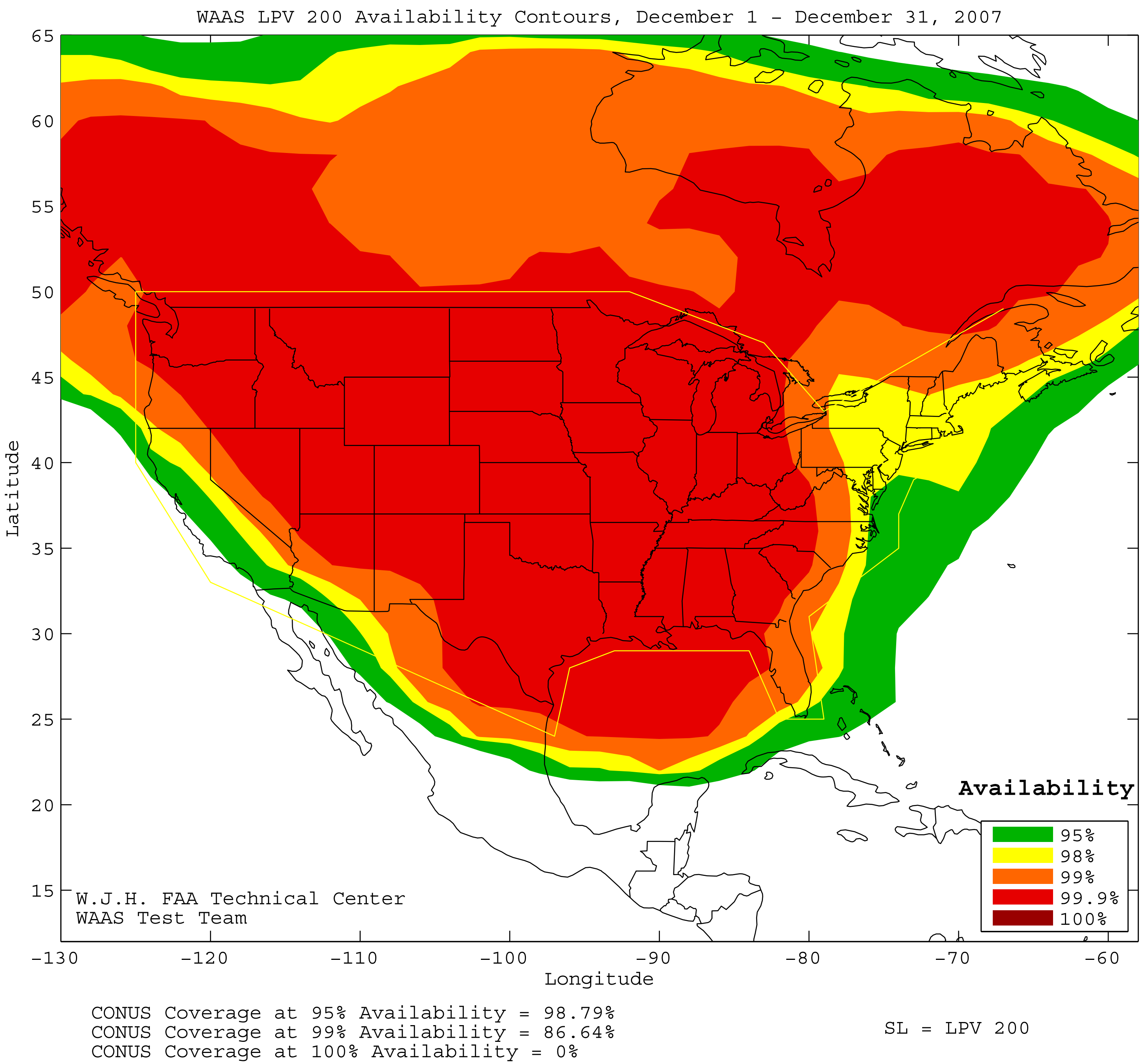


Figure 4-12 WAAS LPV 200 CONUS Coverage - Quarter

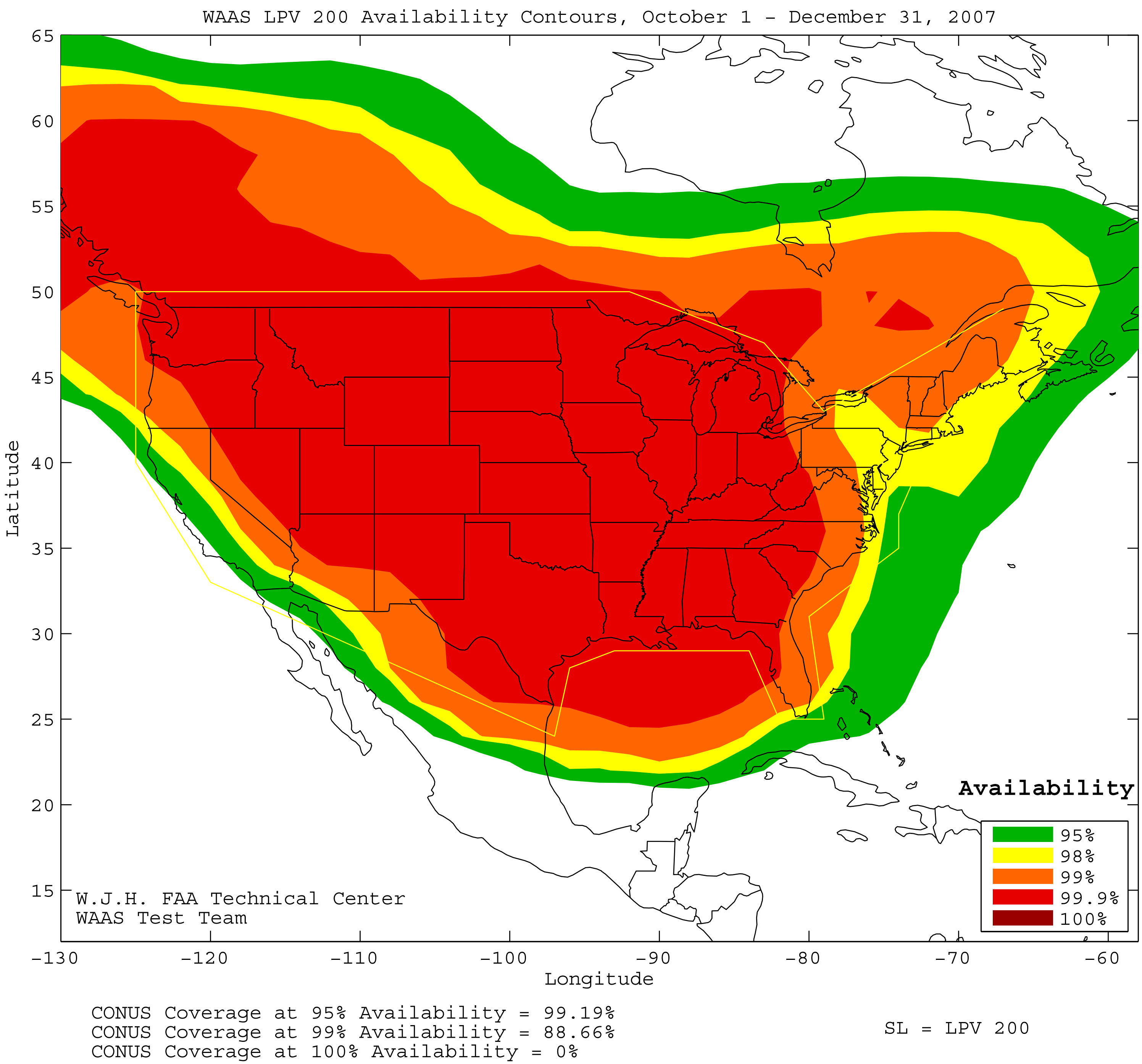
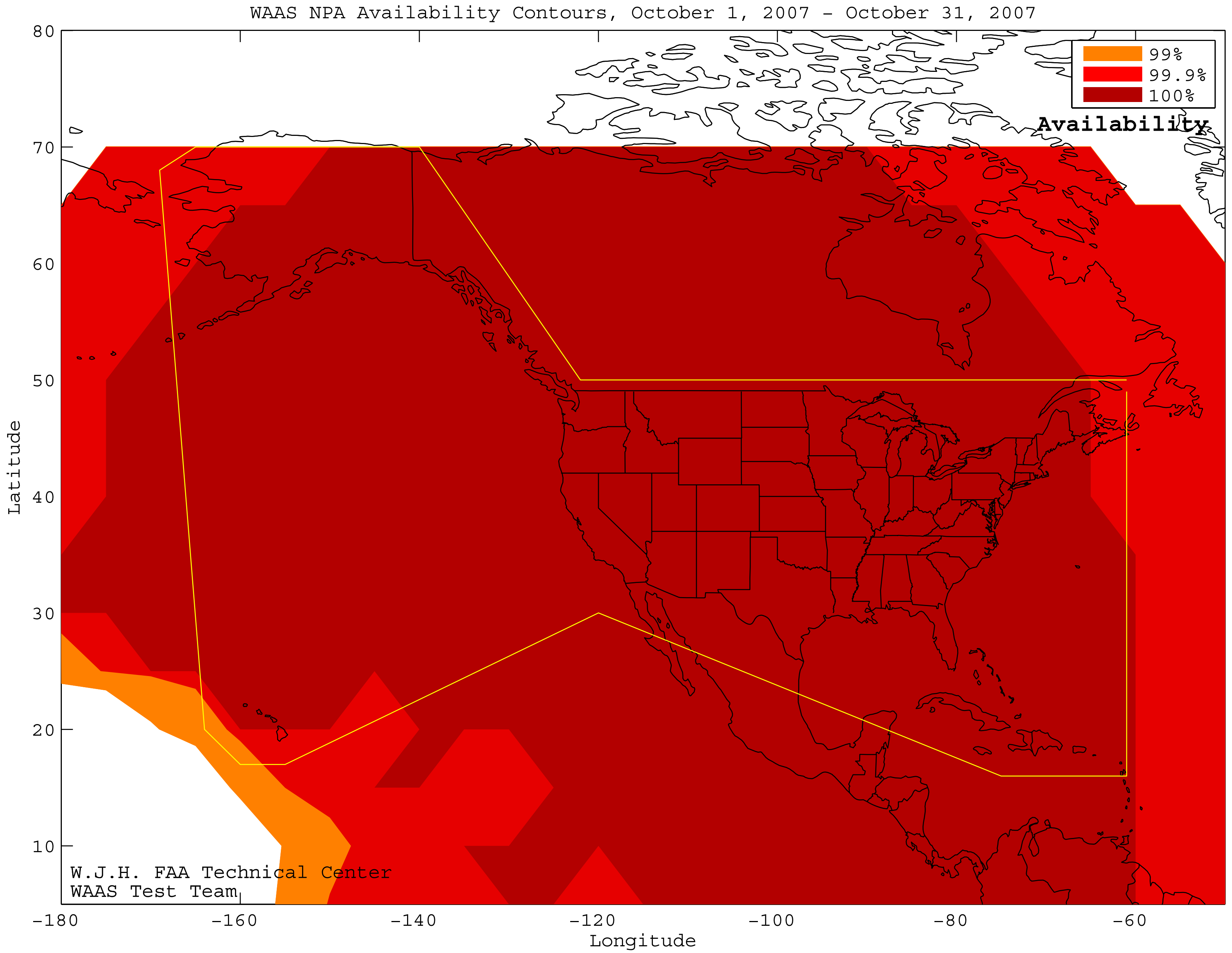


Figure 4-13 WAAS NPA Coverage - October



WAAS Coverage at 99% Availability = 100%
WAAS Coverage at 99.9% Availability = 100%
WAAS Coverage at 100% Availability = 99.26%

SL = NPA

Figure 4-14 WAAS NPA Coverage - November

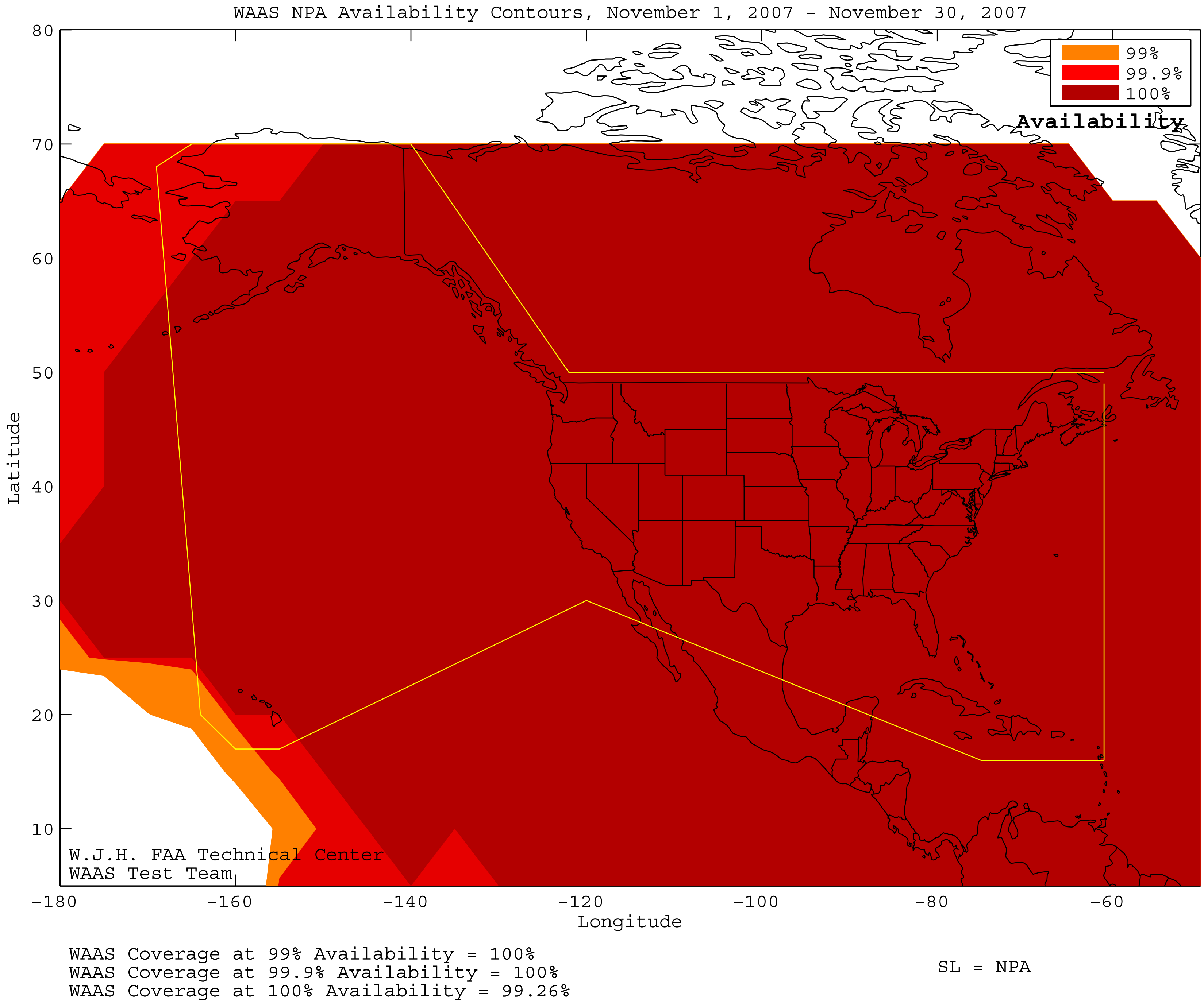
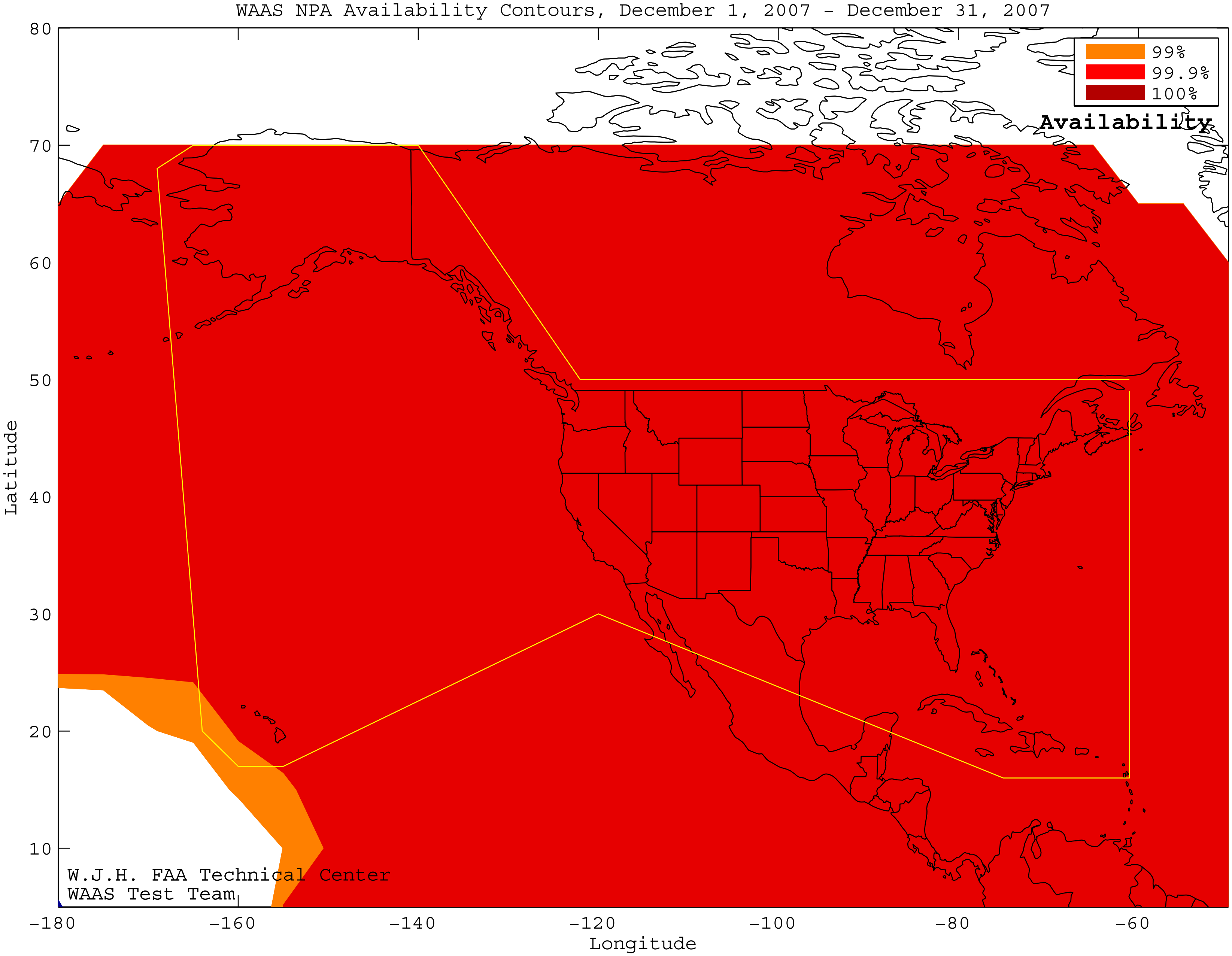


Figure 4-15 WAAS NPA Coverage - December



WAAS Coverage at 99% Availability = 100%
WAAS Coverage at 99.9% Availability = 100%
WAAS Coverage at 100% Availability = 0%

SL = NPA

Figure 4-16 WAAS NPA Coverage for the Quarter

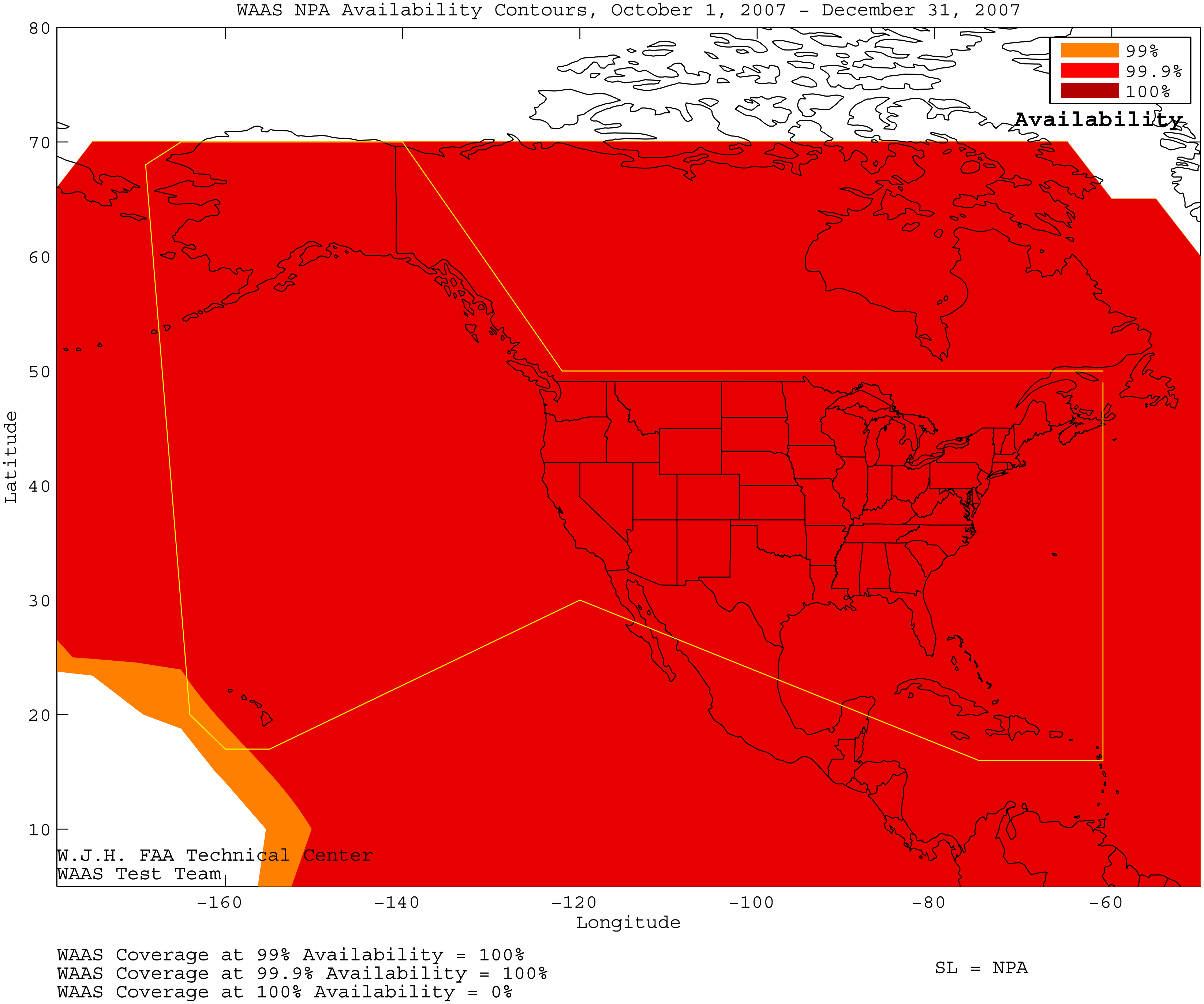


Figure 4-17 Daily LNAV/VNAV and LPV Coverage

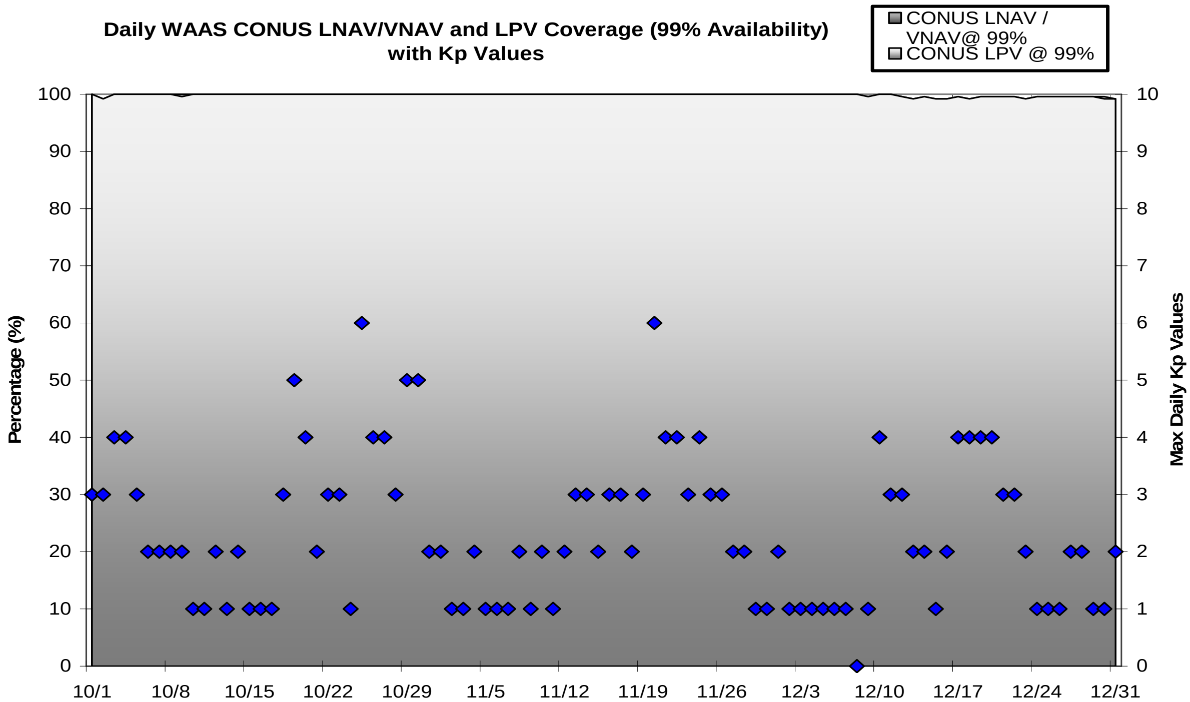


Figure 4-18 Daily NPA Coverage

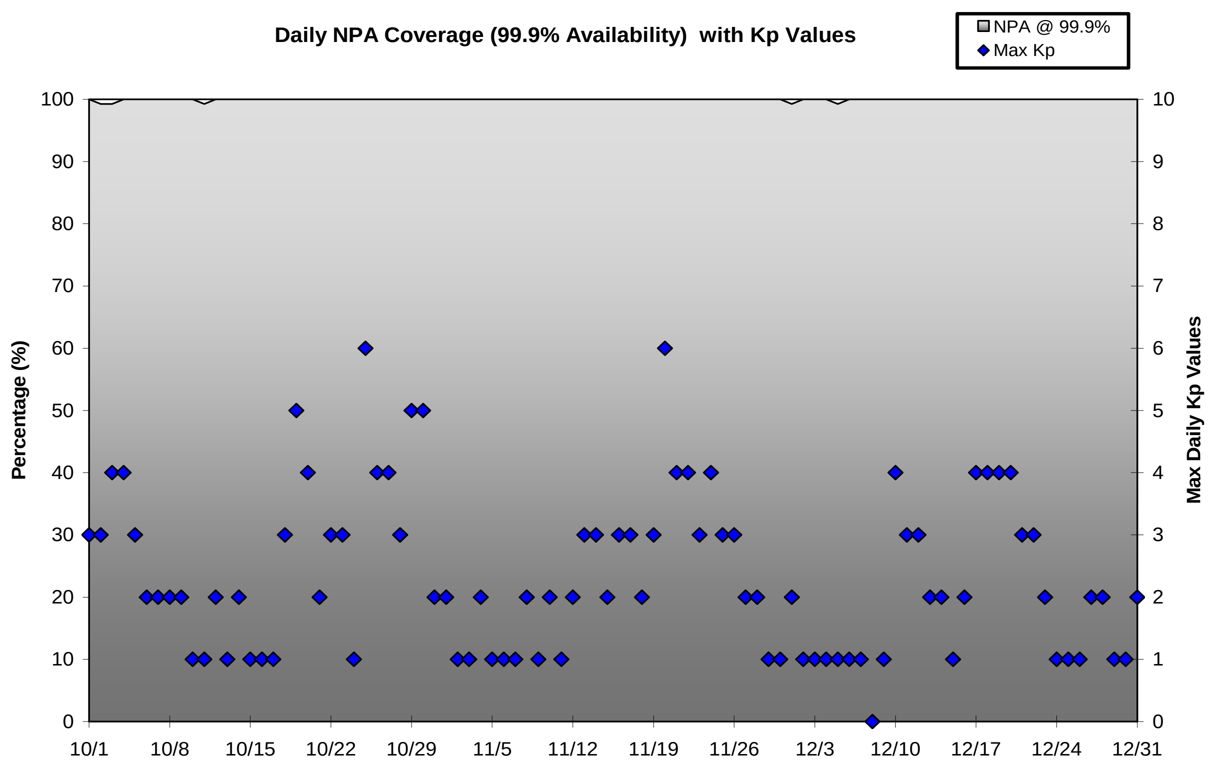
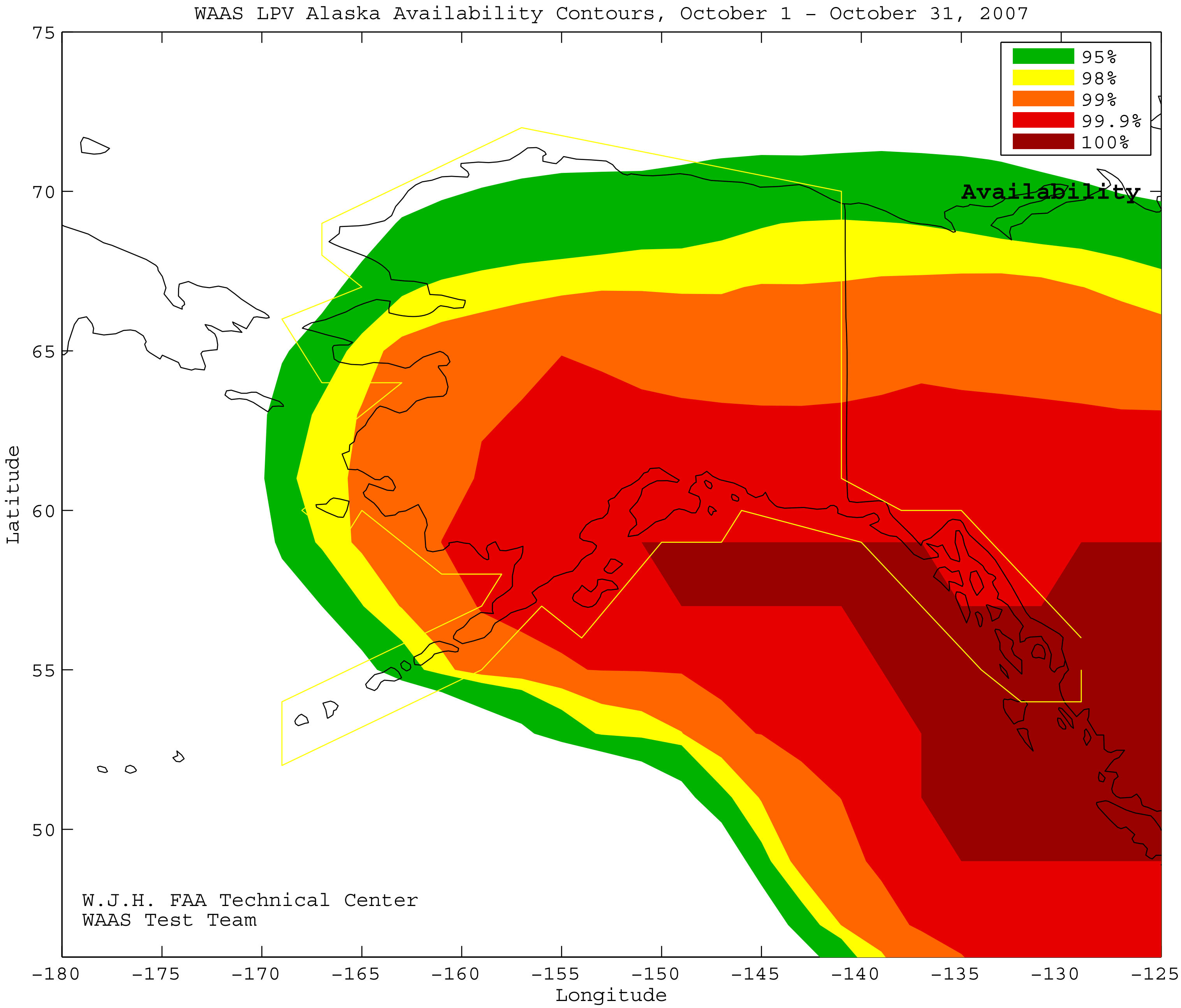


Figure 4-19 LPV Alaska Coverage - October



Alaska Coverage at 95% Availability = 90.22%
Alaska Coverage at 99% Availability = 63.04%
Alaska Coverage at 100% Availability = 15.22%

Figure 4-20 LPV Alaska Coverage - November

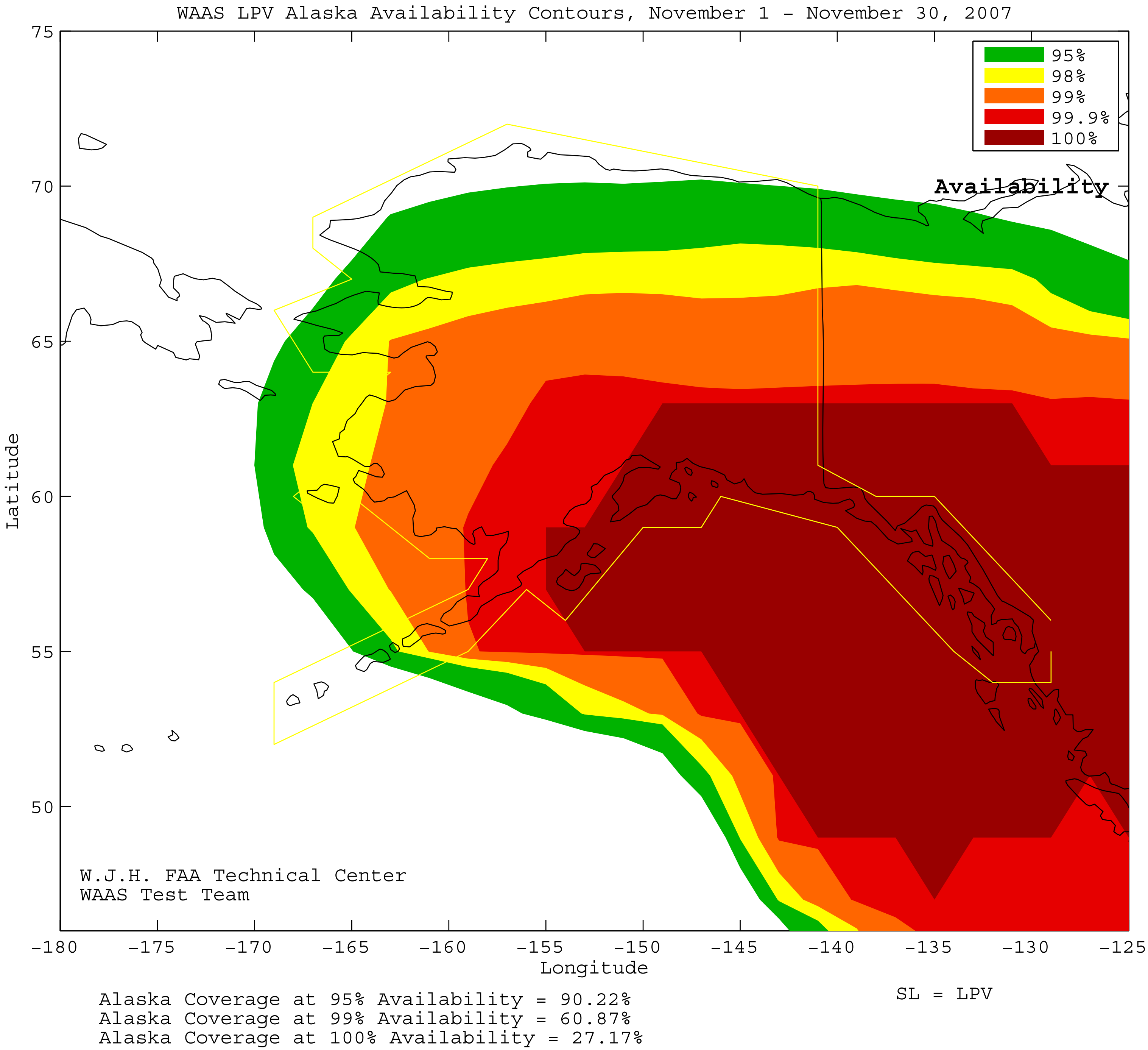


Figure 4-21 LPV Alaska Coverage - December

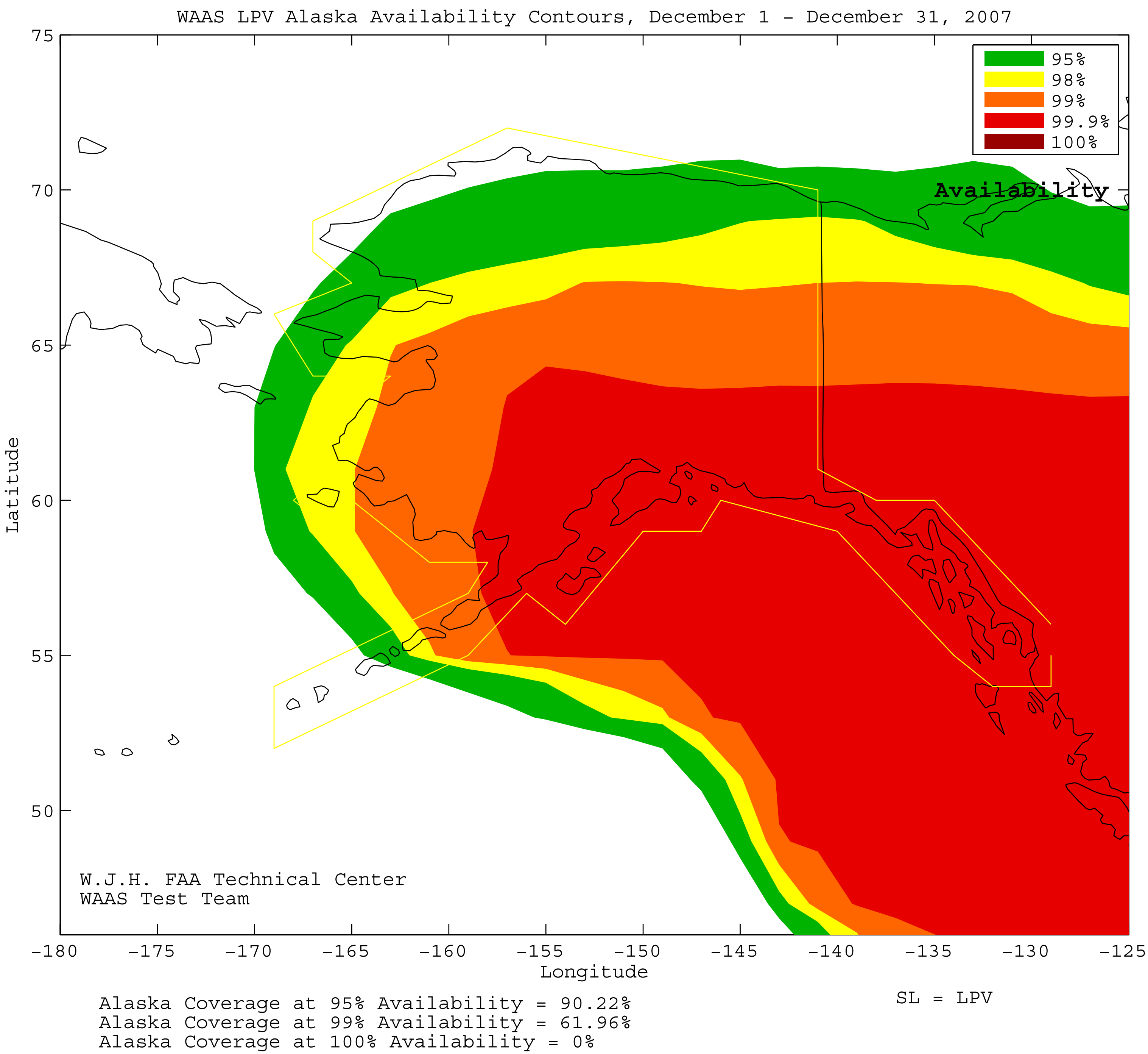
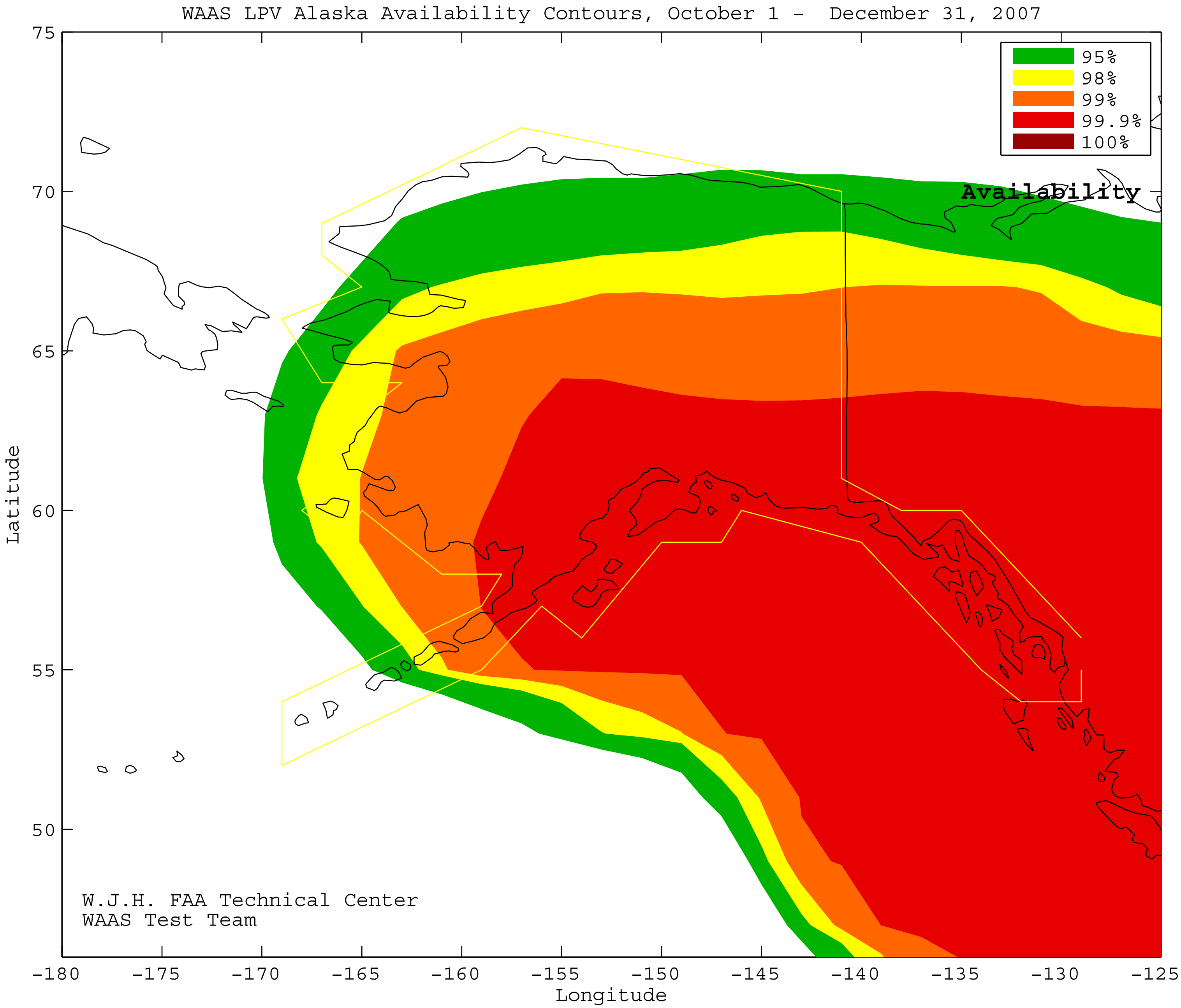


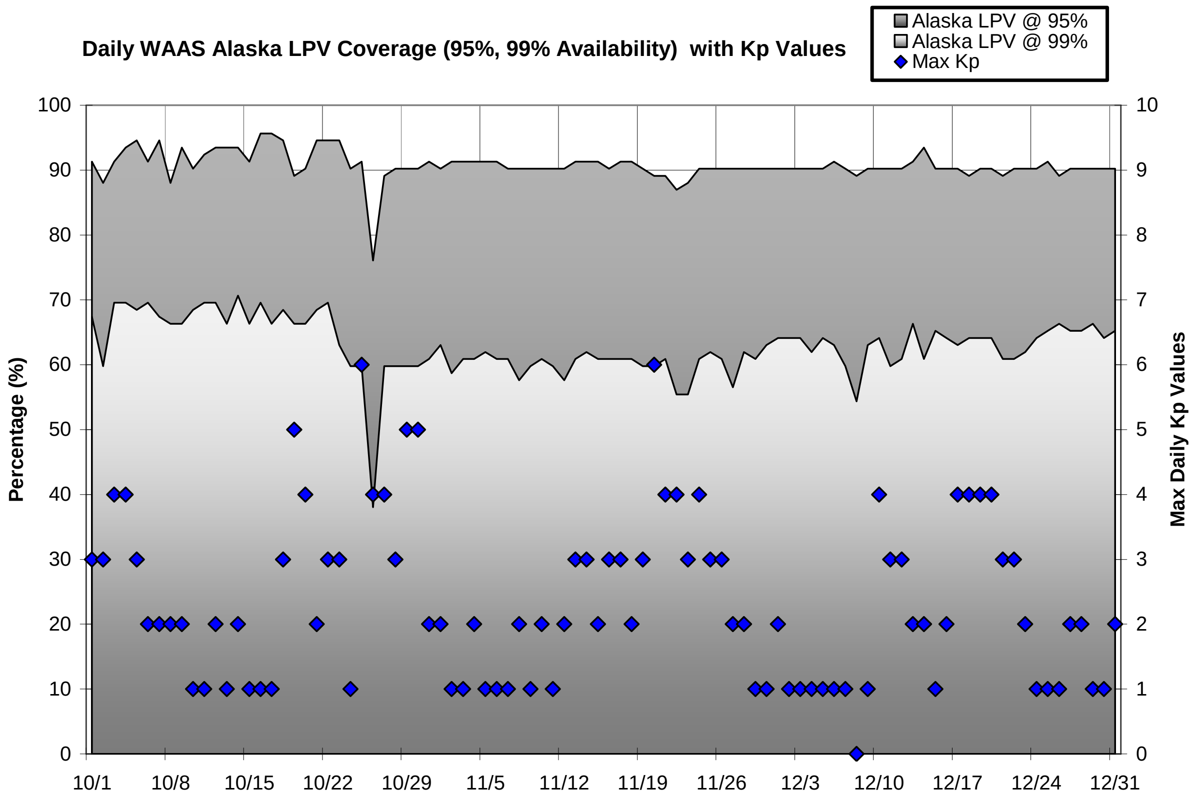
Figure 4-22 LPV Alaska Coverage - Quarter



Alaska Coverage at 95% Availability = 90.22%
Alaska Coverage at 99% Availability = 60.87%
Alaska Coverage at 100% Availability = 0%

SL = LPV

Figure 4-23 Daily LPV Alaska Coverage



5.0 INTEGRITY

5.1 HMI Analysis

Analysis of integrity includes the identification and evaluation of HMI (hazardously misleading information), as well as the generation of a safety index to illustrate the margin of safety that WAAS protection levels are providing. The safety margin index (shown in Table 5.1) is a metric that shows how well the protection levels are bounding the maximum observed error. The process for determining this index involves normalizing the largest error observed at a site. This is accomplished by dividing this maximum observed error by the WAAS estimated standard deviation of the error. The safety margin requirement, 5.33 standard units for vertical and 6 standard units for horizontal, is then divided by this maximum normalized error.

Table 5-1 Safety Margin Index and HMI Statistics

Location	Safety Index		Number of HMIs
	Horizontal	Vertical	
Atlantic City	6.67	6.66	0
Arcata	7.50	6.66	0
Oklahoma City	5.45	4.85	0
Albuquerque	6.00	7.61	0
Anchorage	7.50	8.88	0
Atlanta	6.67	6.66	0
Barrow	6.00	5.92	0
Bethel	12.00	10.66	0
Billings	8.57	7.61	0
Boston	6.00	5.92	0
Chicago	7.50	4.85	0
Cleveland	7.50	7.61	0
Cold Bay	12.00	8.88	0
Dallas	6.00	5.92	0
Denver	8.57	5.92	0
Fairbanks	4.29	8.88	0
Gander	8.57	8.88	0
Goose Bay	7.50	8.88	0
Houston	6.67	5.92	0
Iqaluit	3.53	5.33	0
Jacksonville	7.50	6.66	0
Juneau	8.57	4.85	0
Kansas City	6.67	5.92	0
Kotzebue	7.50	6.66	0
Los Angeles	7.50	7.61	0
Memphis	7.50	7.61	0
Merida	10.00	8.88	0
Mexico City	6.67	5.92	0
Miami	7.50	5.33	0
Minneapolis	6.00	6.66	0
New York	7.50	7.61	0
Oakland	7.50	8.88	0

Puerto Vallarta	5.00	6.66	0
Salt Lake City	8.57	8.88	0
San Jose Del Cabo	7.50	7.61	0
Seattle	6.67	4.85	0
Tapachula	7.50	8.88	0
Washington DC	8.57	7.61	0
Winnipeg	10.00	8.88	0

An observed safety margin index of greater than one indicates safe bounding of the greatest observed error, less than one indicates that the maximum error was not bounded, and a result equal to one means that the error was equal to the protection level. The lowest safety margin index is 3.53 at Iqaluit. Table 5.1 also shows the number of HMIs that occurred during the quarter, of which there were none. An HMI occurs if the position error exceeds the protection level in the vertical or horizontal dimensions at any time and 6.2 seconds or more passes before this event is corrected by WAAS. Since WAAS was made available to the public in August 2000 there has not been an HMI event. Note that the FAA commissioned WAAS for safety of life services in July 2003.

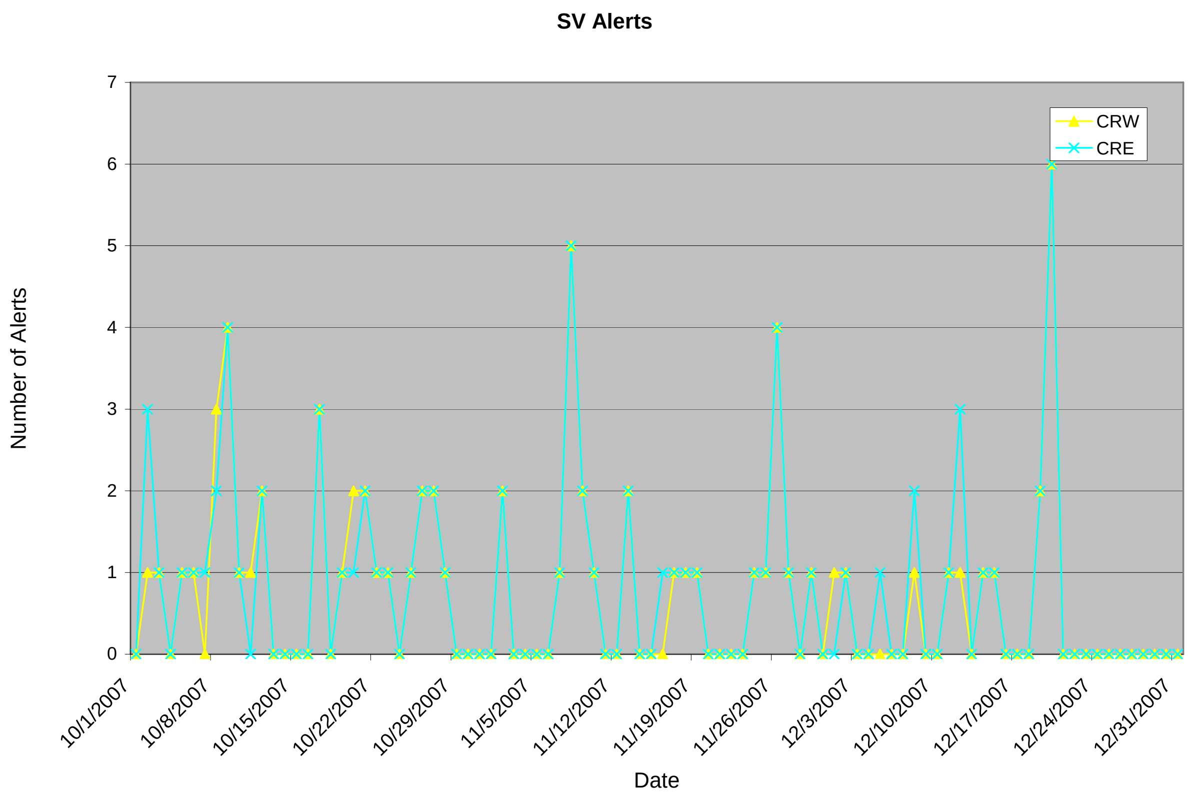
5.2 Broadcast Alerts

The WAAS transmits alert messages to protect the users from satellite degradation or severe ionospheric activity, both of which can cause unsafe conditions for a user. Space Vehicle (SV) alerts increase the User Differential Range Error (UDRE) of satellites, which can reduce the weighting of the satellite in the navigation solution, or completely exclude it from the navigation solution. An increase in UDRE's after an alert effectively increases the user protection levels (HPL and VPL), which affect the availability. Additionally, if an alert message sequence lasts for more than 12 seconds, WAAS fast corrections can time out, causing a loss of continuity. Table 5.2 shows the total number of alerts and the average number of alerts per day. Figure 5.1 shows the number of SV alerts that occurred daily during the reporting period. Often the number of alerts on one GEO is the same as the number of alerts on the other GEO. Therefore, lines tend to overlap in most points on this plot.

Table 5-2 WAAS SV Alert

	Number of Alerts		Average Alerts Per Day	
Message Type	**CRW**	**CRE**	**CRW**	**CRE**
2	14	16	0.1522	0.1739
3	33	32	0.3587	0.3478
4	23	26	0.2500	0.2826
5	0	0	0	0
6	0	0	0	0
24	0	0	0	0
26	0	0	0	0
Total Alerts	70	74	0.7609	0.8043

Figure 5-1 SV Daily Alert Trends



5.3 Availability of WAAS Messages (CRE and CRW)

For an accurate and current user position to be calculated, the content of the WAAS message must be broadcast and received within precise time specifications. This aspect of the WAAS is critical to maintaining integrity requirements. Each message type in the WAAS SIS has a specific amount of time for which it must be received anew. Although the content of every message is relevant to the functionality of the system, the importance of different messages varies along with the frequency with which they must be received. Table 5.3 lists the maximum intervals at which each message must broadcast to meet system requirements.

GUS switchovers or broadcast WAAS alerts can interrupt the normal broadcast message stream. If these events occur at a time when the maximum interval of a specific message is approaching, that message may be delayed, resulting in its late transmittal.

All late messages statistics reported during the quarter were caused by GEO SIS outages, GUS switchovers and SV alerts except message type 7 and 10. Occasionally, message type 7 and 10 were late and they were not caused by GEO SIS outages, GUS switchovers or SV alerts. The lateness of type 7 and type 10 messages has little or no impact on user performance and safety.

Tables 5.4 to 5.8 show fast correction, long correction, ephemeris covariance, ionosphere correction, and ionospheric mask message rates statistics broadcasted on CRW. Table 5.9 to 5.13 show message rates statistics broadcasted on CRE.

Table 5-3 Update Rates for WAAS Messages

Data	Associated Message Types	Maximum Update Interval (seconds)	En Route, Terminal, NPA Timeout (seconds)	Precision Approach Timeout (seconds)
WAAS in Test Mode	0	6	N/A	N/A
PRN Mask	1	60	None	None
UDREI	2-6, 24	6	18	12
Fast Corrections	2-5, 24	See Table A-8 in RTCA DO-229C	See Table A-8 in RTCA DO-229C	See Table A-8 in RTCA DO-229C
Long Term Corrections	24, 25	120	360	240
GEO Nav. Data	9	120	360	240
Fast Correction Degradation	7	120	360	240
Weighting Factors	8	120	240	240
Degradation Parameters	10	120	360	240
Ionospheric Grid Mask	18	300	None	None
Ionospheric Corrections	26	300	600	600
UTC Timing Data	12	300	None	None
Almanac Data	17	300	None	None

Table 5-4 WAAS Fast Correction and Degradation Message Rates – CRW

Message Type	On Time	Late	Max Late Length (seconds)
0	61	12	526775
1	117283	21	162
2	1324749	53	26
3	1324825	39	25
4	1324790	43	27
7	105911	72	164
9	93142	2	345
10	106040	81	148
17	32289	10	443

Table 5-5 WAAS Long Correction Message Rates (Type 24 and 25) - CRW

SV	On Time	Late	Max Late Length (seconds)
1	51100	0	0
2	50493	0	0
3	55739	0	0
4	51343	0	0
5	56036	0	0
6	51507	0	0
7	41519	0	0
8	50230	0	0
9	55278	0	0
10	51738	0	0
11	58722	0	0
12	52232	0	0
13	50548	1	170
14	51012	0	0
15	34892	0	0
16	52573	0	0
17	50834	1	156
18	50821	0	0
19	53020	0	0
20	54516	0	0
21	48964	0	0
22	50372	0	0
23	50400	0	0
24	50808	0	0
25	50084	0	0
26	52136	0	0
27	50054	1	166
28	50858	1	170
29	13479	0	0
30	56690	0	0
31	51466	1	156

Table 5-6 WAAS Ephemeris Covariance Message Rates (Type 28) – CRW

SV	On Time	Late	Max Late Length (seconds)
1	47692	1	136
2	47307	0	0
3	52160	0	0
4	47838	0	0
5	52361	0	0
6	48091	0	0
7	38677	0	0
8	47023	0	0
9	51801	2	210
10	48307	0	0
11	54899	1	169
12	48670	1	160
13	46829	0	0
14	47125	0	0
15	32421	1	203
16	48379	1	130
17	46400	0	0
18	46328	2	155
19	48091	0	0
20	49070	2	183
21	44116	1	170
22	45503	0	0
23	45346	0	0
24	45729	0	0
25	45105	1	134
26	46951	0	0
27	45033	1	121
28	45766	0	0
29	12068	0	0
30	50906	0	0
31	46345	0	0
135	83304	0	0
138	83249	1	193

Table 5-7 WAAS Ionospheric Correction Message Rates (Type 26) - CRW

Band	Block	On Time	Late	Max Late Length (seconds)
0	0	27547	35	517
0	1	27535	35	454
0	2	27545	37	464
0	3	27540	37	566
1	0	27550	36	442
1	1	27542	36	436
1	2	27551	40	479
1	3	27537	46	478
1	4	27538	44	551
2	0	27535	46	560
2	1	27542	45	549
2	2	27543	40	544

2	3	27542	50	318
2	4	27543	49	317
2	5	27519	49	323
3	0	27546	34	312
3	1	27545	38	364
3	2	27544	35	359
9	0	27541	33	549
9	1	27547	39	530
9	2	27546	36	525
9	3	27550	40	538
9	4	27554	33	406

Table 5-8 WAAS Ionospheric Mask Message Rates (Type 18) - CRW

Band	On Time	Late	Max Late Length (seconds)
0	82682	0	0
1	82640	0	0
2	82690	0	0
3	82755	0	0
9	82633	0	0

Table 5-9 WAAS Fast Correction and Degradation Message Rates – CRE

Message Type	On Time	Late	Max Late Length (seconds)
0	37	6	488733
1	117364	24	167
2	1324764	53	21
3	1324831	38	21
4	1324825	35	17
7	105858	68	160
9	93150	0	0
10	105924	67	157
17	32306	12	375

Table 5-10 WAAS Long Correction Message Rates (Type 24 and 25) - CRE

SV	On Time	Late	Max Late Length (seconds)
1	51093	0	0
2	50495	0	0
3	55754	1	167
4	51343	1	166
5	56045	1	166
6	51509	1	189
7	41523	0	0
8	50233	1	161
9	55279	0	0
10	51742	0	0
11	58718	0	0
12	52229	0	0
13	50543	1	187
14	51010	0	0
15	34891	0	0
16	52581	0	0
17	50841	0	0
18	50801	1	167
19	53028	0	0
20	54515	0	0
21	48970	1	189
22	50357	0	0
23	50388	1	161
24	50806	0	0
25	50070	0	0
26	52139	0	0
27	50052	0	0
28	50875	1	187
29	13477	0	0
30	56698	0	0
31	51454	0	0

Table 5-11 WAAS Ephemeris Covariance Message Rates (Type 28) – CRE

SV	On Time	Late	Max Late Length (seconds)
1	47691	1	137
2	47306	0	0
3	52158	0	0
4	47837	1	127
5	52363	0	0
6	48085	0	0
7	38677	1	144
8	47023	1	152
9	51799	1	210
10	48306	0	0
11	54906	0	0
12	48672	1	163
13	46836	0	0
14	47119	0	0
15	32419	2	203
16	48376	0	0
17	46402	1	181
18	46335	0	0
19	48087	0	0
20	49074	0	0
21	44125	2	171
22	45502	0	0
23	45349	0	0
24	45730	0	0
25	45114	1	132
26	46950	0	0
27	45036	1	121
28	45764	0	0
29	12071	0	0
30	50900	0	0
31	46340	0	0
135	83313	0	0
138	83239	0	0

Table 5-12 WAAS Ionospheric Correction Message Rates (Type 26) – CRE

Band	Block	On Time	Late	Max Late Length (seconds)
0	0	27539	49	432
0	1	27534	47	432
0	2	27545	40	432
0	3	27548	34	400
1	0	27532	46	430
1	1	27540	38	424
1	2	27530	44	432
1	3	27550	41	425
1	4	27542	41	430
2	0	27545	38	411
2	1	27551	36	416

2	2	27545	34	435
2	3	27554	34	436
2	4	27560	31	448
2	5	27547	29	436
3	0	27540	44	432
3	1	27541	31	452
3	2	27550	42	457
9	0	27528	40	456
9	1	27564	28	439
9	2	27545	35	438
9	3	27550	41	427
9	4	27536	45	412

Table 5-13 WAAS Ionospheric Mask Message Rates (Type 18) - CRE

Band	On Time	Late	Max Late Length (seconds)
0	82520	0	0
1	82698	0	0
2	82660	0	0
3	82614	0	0
9	82532	0	0

6.0 SV RANGE ACCURACY

Range accuracy evaluation computes the probability that the WAAS User Differential Range Error (UDRE) and Grid Ionospheric Vertical Error (GIVE) statistically bound 99.9% of the range residuals for each satellite tracked by the receiver. A UDRE is broadcast by the WAAS for each satellite that is monitored by the system and the 99.9% bound (3.29 sigma) of the residual error on a pseudorange after application of fast and long-term corrections is checked. The pseudorange residual error is determined by taking the difference between the raw pseudorange and a calculated reference range. The reference range is equal to the true range between the corrected satellite position and surveyed user antenna plus all corrections (WAAS Fast Clock, WAAS Long-Term Clock, WAAS Ionospheric delay, Tropospheric delay, Receiver Clock Bias, and Multipath). Since the true ionospheric delay and multipath error are not precisely known, the estimated variance in these error sources are added to the UDRE before the comparing it to the residual error.

GPS satellite range residual errors were calculated for twelve WAAS receivers during the quarter. Table 6.1 and 6.2 show the range error 95% index and 99.9% (3.29 sigma) bounding statistics for each SV at the selected locations. Figures 6.1 and 6.2 show the range error for each SV as measured by the WAAS receivers at the Washington DC reference station.

A GIVE is broadcast by the WAAS for each IGP that is monitored by the system and the 99.9% (3.29 sigma) bound of the ionospheric error is checked. The WAAS broadcasts the ionospheric model using IGP's at predefined geographic locations. Each IGP contains the vertical ionospheric delay and the error in that delay in the form of the GIVE. The ionospheric error is determined by taking the difference between the WAAS vertical ionospheric delay interpolated from the IGP's and GPS dual frequency measurement at that GPS satellite.

GPS satellite ionospheric errors were calculated for twelve WAAS receivers during the quarter. Table 6.3 and 6.4 show the ionospheric error 95% index and 99.9% (3.29 sigma) bounding statistics for each SV at the selected locations. Figures 6.3 and 6.4 show the ionospheric error for each SV as measured by the WAAS receiver at the Washington DC reference station.

Table 6-1 Range Error 95% index and 3.29 Sigma Bounding

Site →	Billings		Albuquerque		Boston		Washington DC		Houston		Kansas City	
SV ↓	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding
1	1.618	100.00	1.527	100.00	1.243	100.00	0.838	100.00	1.085	100.00	1.075	100.00
2	0.886	100.00	1.462	100.00	1.163	100.00	1.424	100.00	2.354	100.00	1.464	100.00
3	1.690	100.00	1.213	100.00	1.556	100.00	1.195	100.00	1.324	100.00	1.227	100.00
4	1.903	100.00	1.709	100.00	1.773	100.00	1.046	100.00	1.619	100.00	1.329	100.00
5	1.462	100.00	0.933	100.00	0.929	100.00	0.738	100.00	1.131	100.00	0.921	100.00
6	2.652	100.00	1.491	100.00	1.793	100.00	1.002	100.00	1.067	100.00	1.564	100.00
7	1.392	100.00	1.019	100.00	1.118	100.00	1.127	100.00	1.165	100.00	1.219	100.00
8	1.534	100.00	1.088	100.00	1.380	100.00	1.099	100.00	0.983	100.00	1.212	100.00
9	1.548	100.00	1.569	100.00	1.375	100.00	1.083	100.00	1.174	100.00	1.177	100.00
10	0.810	100.00	1.201	100.00	0.810	100.00	1.048	100.00	1.295	100.00	1.399	100.00
11	0.903	100.00	1.086	100.00	1.074	100.00	1.164	100.00	1.177	100.00	1.037	100.00
12	1.450	100.00	1.449	100.00	1.396	100.00	0.963	100.00	0.899	100.00	1.613	100.00
13	1.603	100.00	1.289	100.00	1.299	100.00	0.897	100.00	1.181	100.00	1.310	100.00
14	1.965	100.00	1.128	100.00	0.971	100.00	0.846	100.00	1.169	100.00	2.064	100.00
15	2.012	100.00	1.678	100.00	1.749	100.00	1.192	100.00	1.340	100.00	1.630	100.00
16	1.026	100.00	1.044	100.00	0.894	100.00	0.926	100.00	1.354	100.00	0.842	100.00
17	2.903	100.00	1.225	100.00	1.702	100.00	1.063	100.00	1.774	100.00	1.322	100.00
18	0.680	100.00	0.740	100.00	0.957	100.00	1.447	100.00	1.571	100.00	1.170	100.00
19	2.346	100.00	2.015	100.00	2.043	100.00	1.834	100.00	2.321	100.00	2.467	100.00
20	1.095	100.00	0.912	100.00	1.332	100.00	1.031	100.00	1.569	100.00	1.153	100.00
21	0.647	100.00	1.064	100.00	0.954	100.00	1.233	100.00	1.858	100.00	1.077	100.00
22	0.855	100.00	0.809	100.00	1.406	100.00	1.483	100.00	1.307	100.00	1.105	100.00
23	1.030	100.00	1.535	100.00	1.732	100.00	1.903	100.00	2.194	100.00	1.560	100.00
24	1.793	100.00	1.991	100.00	2.214	100.00	1.454	100.00	1.141	100.00	1.333	100.00
25	1.856	100.00	1.323	100.00	2.072	100.00	1.118	100.00	1.054	100.00	1.588	100.00
26	1.662	100.00	1.593	100.00	1.688	100.00	1.296	100.00	1.106	100.00	1.428	100.00
27	1.394	100.00	1.204	100.00	1.562	100.00	1.026	100.00	0.966	100.00	1.497	100.00
28	0.689	100.00	0.891	100.00	1.073	100.00	0.921	100.00	1.371	100.00	0.914	100.00
29	1.785	100.00	1.193	100.00	1.175	100.00	1.002	100.00	1.338	100.00	1.420	100.00
30	2.171	100.00	1.571	100.00	1.857	100.00	1.306	100.00	1.375	100.00	1.317	100.00
31	2.415	100.00	1.407	100.00	1.007	100.00	0.978	100.00	1.218	100.00	1.422	100.00
122	-	-	-	-	-	-	-	-	-	-	-	-
134	-	-	-	-	-	-	-	-	-	-	-	-

Table 6-2 Range Error 95% index and 3.29 Sigma Bounding

Site →	Los Angeles		Salt Lake City		Miami		Minneapolis		Atlanta		Juneau	
SV ↓	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding
1	0.763	100.00	0.968	100.00	1.193	100.00	1.416	100.00	1.271	100.00	1.508	100.00
2	1.863	100.00	1.629	100.00	1.495	100.00	1.167	100.00	1.389	100.00	0.962	100.00
3	0.906	100.00	1.017	100.00	1.315	100.00	1.588	100.00	1.264	100.00	1.366	100.00
4	1.172	100.00	1.808	100.00	2.911	100.00	1.381	100.00	1.450	100.00	1.965	100.00
5	1.476	100.00	0.919	100.00	1.303	100.00	1.271	100.00	1.007	100.00	1.342	100.00
6	0.860	100.00	1.285	100.00	1.955	100.00	1.621	100.00	1.484	100.00	2.045	100.00
7	0.868	100.00	0.736	100.00	1.201	100.00	1.126	100.00	0.935	100.00	1.356	100.00
8	0.853	100.00	0.950	100.00	1.005	100.00	1.138	100.00	1.169	100.00	1.484	100.00
9	1.536	100.00	1.573	100.00	1.001	100.00	1.156	100.00	1.006	100.00	1.683	100.00
10	1.110	100.00	0.893	100.00	1.219	100.00	0.961	100.00	0.828	100.00	1.077	100.00
11	1.392	100.00	1.013	100.00	1.154	100.00	1.061	100.00	0.893	100.00	1.085	100.00
12	0.888	100.00	1.074	100.00	1.404	100.00	1.467	100.00	1.187	100.00	1.526	100.00
13	0.784	100.00	0.948	100.00	1.507	100.00	1.446	100.00	1.502	100.00	1.538	100.00
14	1.116	100.00	0.726	100.00	1.276	100.00	0.982	100.00	1.058	100.00	1.018	100.00
15	0.958	100.00	1.331	100.00	1.319	100.00	1.837	100.00	1.353	100.00	2.208	100.00
16	1.358	100.00	0.817	100.00	1.271	100.00	0.844	100.00	0.878	100.00	0.915	100.00
17	1.296	100.00	1.069	100.00	1.215	100.00	0.924	100.00	1.096	100.00	1.552	100.00
18	1.656	100.00	1.372	100.00	1.609	100.00	0.879	100.00	1.037	100.00	0.808	100.00
19	3.282	100.00	1.996	100.00	2.136	100.00	1.670	100.00	1.996	100.00	1.496	100.00
20	1.172	100.00	1.043	100.00	1.370	100.00	1.027	100.00	0.826	100.00	0.832	100.00
21	1.526	100.00	1.062	100.00	3.059	100.00	0.899	100.00	1.142	100.00	0.727	100.00
22	1.344	100.00	1.150	100.00	1.868	100.00	0.698	100.00	1.183	100.00	0.818	100.00
23	1.997	100.00	1.491	100.00	1.950	100.00	1.342	100.00	1.556	100.00	0.920	100.00
24	1.571	100.00	1.614	100.00	1.287	100.00	1.841	100.00	1.436	100.00	2.124	100.00
25	0.817	100.00	1.132	100.00	1.632	100.00	1.617	100.00	1.396	100.00	1.983	100.00
26	1.270	100.00	1.660	100.00	1.747	100.00	1.589	100.00	1.747	100.00	1.897	100.00
27	0.724	100.00	1.191	100.00	1.309	100.00	1.549	100.00	1.340	100.00	1.758	100.00
28	1.094	100.00	0.675	100.00	1.781	100.00	0.790	100.00	0.873	100.00	0.936	100.00
29	1.047	100.00	0.946	100.00	1.670	100.00	1.449	100.00	1.361	100.00	1.383	100.00
30	0.976	100.00	1.267	100.00	1.747	100.00	1.749	100.00	1.389	100.00	1.965	100.00
31	1.098	100.00	1.234	100.00	1.954	100.00	1.201	100.00	1.178	100.00	1.462	100.00
122	-	-	-	-	-	-	-	-	-	-	-	-
134	-	-	-	-	-	-	-	-	-	-	-	-

Table 6-3 Ionospheric Error 95% index and 3.29 Sigma Bounding

Site →	Billings		Albuquerque		Boston		Washington DC		Houston		Kansas City	
SV ↓	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding
1	0.967	100.00	0.907	100.00	0.794	100.00	0.486	100.00	0.645	100.00	0.504	100.00
2	0.794	100.00	1.077	100.00	0.796	100.00	1.048	100.00	1.304	100.00	1.011	100.00
3	0.834	100.00	0.529	100.00	0.686	100.00	0.365	100.00	0.690	100.00	0.464	100.00
4	1.220	100.00	0.973	100.00	1.241	100.00	0.649	100.00	1.111	100.00	0.940	100.00
5	0.567	100.00	0.576	100.00	0.406	100.00	0.302	100.00	0.514	100.00	0.260	100.00
6	1.329	100.00	0.877	100.00	0.889	100.00	0.451	100.00	0.678	100.00	0.813	100.00
7	0.788	100.00	0.505	100.00	0.553	100.00	0.539	100.00	0.430	100.00	0.455	100.00
8	0.901	100.00	0.464	100.00	0.554	100.00	0.695	100.00	0.415	100.00	0.487	100.00
9	0.740	100.00	0.700	100.00	0.694	100.00	0.482	100.00	0.505	100.00	0.569	100.00
10	0.478	100.00	0.552	100.00	0.460	100.00	0.589	100.00	0.682	100.00	0.538	100.00
11	0.407	100.00	0.441	100.00	0.459	100.00	0.584	100.00	0.613	100.00	0.547	100.00
12	0.672	100.00	0.703	100.00	0.642	100.00	0.327	100.00	0.380	100.00	0.672	100.00
13	0.877	100.00	0.649	100.00	0.586	100.00	0.336	100.00	0.591	100.00	0.421	100.00
14	1.472	100.00	0.565	100.00	0.570	100.00	0.430	100.00	0.491	100.00	0.852	100.00
15	1.259	100.00	1.046	100.00	1.020	100.00	0.703	100.00	0.996	100.00	0.983	100.00
16	0.513	100.00	0.621	100.00	0.440	100.00	0.559	100.00	0.725	100.00	0.457	100.00
17	2.014	100.00	0.605	100.00	1.050	100.00	0.487	100.00	0.935	100.00	0.706	100.00
18	0.370	100.00	0.475	100.00	0.618	100.00	0.955	100.00	0.716	100.00	0.672	100.00
19	1.345	100.00	1.415	100.00	1.413	100.00	1.535	100.00	1.622	100.00	1.519	100.00
20	0.393	100.00	0.577	100.00	0.859	100.00	0.570	100.00	0.676	100.00	0.437	100.00
21	0.518	100.00	0.837	100.00	0.805	100.00	0.937	100.00	1.235	100.00	0.673	100.00
22	0.400	100.00	0.568	100.00	1.069	100.00	1.107	100.00	0.800	100.00	0.741	100.00
23	0.875	100.00	1.229	100.00	1.383	100.00	1.582	100.00	1.456	100.00	1.250	100.00
24	1.300	100.00	1.192	100.00	1.386	100.00	0.924	100.00	1.000	100.00	0.970	100.00
25	1.228	100.00	0.676	100.00	1.044	100.00	0.517	100.00	0.525	100.00	0.646	100.00
26	0.975	100.00	0.890	100.00	0.763	100.00	0.668	100.00	0.743	100.00	0.750	100.00
27	0.632	100.00	0.572	100.00	0.572	100.00	0.453	100.00	0.454	100.00	0.586	100.00
28	0.415	100.00	0.497	100.00	0.513	100.00	0.684	100.00	0.906	100.00	0.632	100.00
29	0.904	100.00	0.503	100.00	0.370	100.00	0.379	100.00	0.785	100.00	0.575	100.00
30	1.072	100.00	0.834	100.00	0.936	100.00	0.603	100.00	0.647	100.00	0.596	100.00
31	1.662	100.00	0.713	100.00	0.548	100.00	0.591	100.00	0.784	100.00	0.677	100.00

Table 6-4 Ionospheric Error 95% index and 3.29 Sigma Bounding

Site →	Los Angeles		Salt Lake City		Miami		Minneapolis		Atlanta		Juneau	
SV ↓	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding
1	0.437	100.00	0.403	100.00	0.745	100.00	0.813	100.00	0.622	100.00	0.841	100.00
2	1.173	100.00	1.169	100.00	0.907	100.00	0.878	100.00	0.846	100.00	0.716	100.00
3	0.463	100.00	0.469	100.00	0.552	100.00	0.658	100.00	0.498	100.00	0.640	100.00
4	0.657	100.00	1.010	100.00	1.740	100.00	0.790	100.00	0.938	100.00	1.226	100.00
5	0.579	100.00	0.554	100.00	0.456	100.00	0.388	100.00	0.401	100.00	0.565	100.00
6	0.702	100.00	0.735	100.00	0.940	100.00	0.807	100.00	0.791	100.00	1.184	100.00
7	0.393	100.00	0.350	100.00	0.530	100.00	0.490	100.00	0.425	100.00	0.775	100.00
8	0.455	100.00	0.439	100.00	0.568	100.00	0.437	100.00	0.456	100.00	0.717	100.00
9	0.566	100.00	0.576	100.00	0.605	100.00	0.495	100.00	0.597	100.00	0.814	100.00
10	0.648	100.00	0.392	100.00	0.513	100.00	0.346	100.00	0.360	100.00	0.556	100.00
11	0.806	100.00	0.532	100.00	0.540	100.00	0.405	100.00	0.411	100.00	0.418	100.00
12	0.385	100.00	0.404	100.00	0.692	100.00	0.643	100.00	0.596	100.00	0.796	100.00
13	0.490	100.00	0.467	100.00	0.683	100.00	0.599	100.00	0.576	100.00	0.739	100.00
14	0.662	100.00	0.509	100.00	0.666	100.00	0.484	100.00	0.373	100.00	0.399	100.00
15	0.594	100.00	0.690	100.00	0.986	100.00	1.057	100.00	0.980	100.00	1.256	100.00
16	0.775	100.00	0.400	100.00	0.580	100.00	0.390	100.00	0.401	100.00	0.339	100.00
17	0.601	100.00	0.505	100.00	0.659	100.00	0.576	100.00	0.570	100.00	0.856	100.00
18	0.921	100.00	0.882	100.00	0.925	100.00	0.578	100.00	0.520	100.00	0.511	100.00
19	1.922	100.00	1.445	100.00	1.397	100.00	1.196	100.00	1.376	100.00	1.163	100.00
20	0.515	100.00	0.437	100.00	0.811	100.00	0.681	100.00	0.426	100.00	0.358	100.00
21	0.917	100.00	0.746	100.00	1.864	100.00	0.712	100.00	0.735	100.00	0.407	100.00
22	0.830	100.00	0.821	100.00	1.196	100.00	0.609	100.00	0.796	100.00	0.508	100.00
23	1.354	100.00	1.199	100.00	1.533	100.00	1.226	100.00	1.275	100.00	0.878	100.00
24	1.058	100.00	1.034	100.00	1.062	100.00	1.176	100.00	1.069	100.00	1.455	100.00
25	0.513	100.00	0.641	100.00	0.884	100.00	0.680	100.00	0.660	100.00	1.085	100.00
26	0.706	100.00	0.851	100.00	0.982	100.00	0.898	100.00	0.992	100.00	1.021	100.00
27	0.389	100.00	0.575	100.00	0.597	100.00	0.592	100.00	0.565	100.00	0.898	100.00
28	0.675	100.00	0.481	100.00	1.195	100.00	0.529	100.00	0.558	100.00	0.379	100.00
29	0.734	100.00	0.329	100.00	0.589	100.00	0.633	100.00	0.665	100.00	0.694	100.00
30	0.564	100.00	0.666	100.00	0.868	100.00	0.916	100.00	0.713	100.00	1.038	100.00
31	0.619	100.00	0.598	100.00	0.951	100.00	0.685	100.00	0.600	100.00	0.759	100.00

Figure 6-1 95% Range Error (SV 1 -- SV 16) - Washington, DC

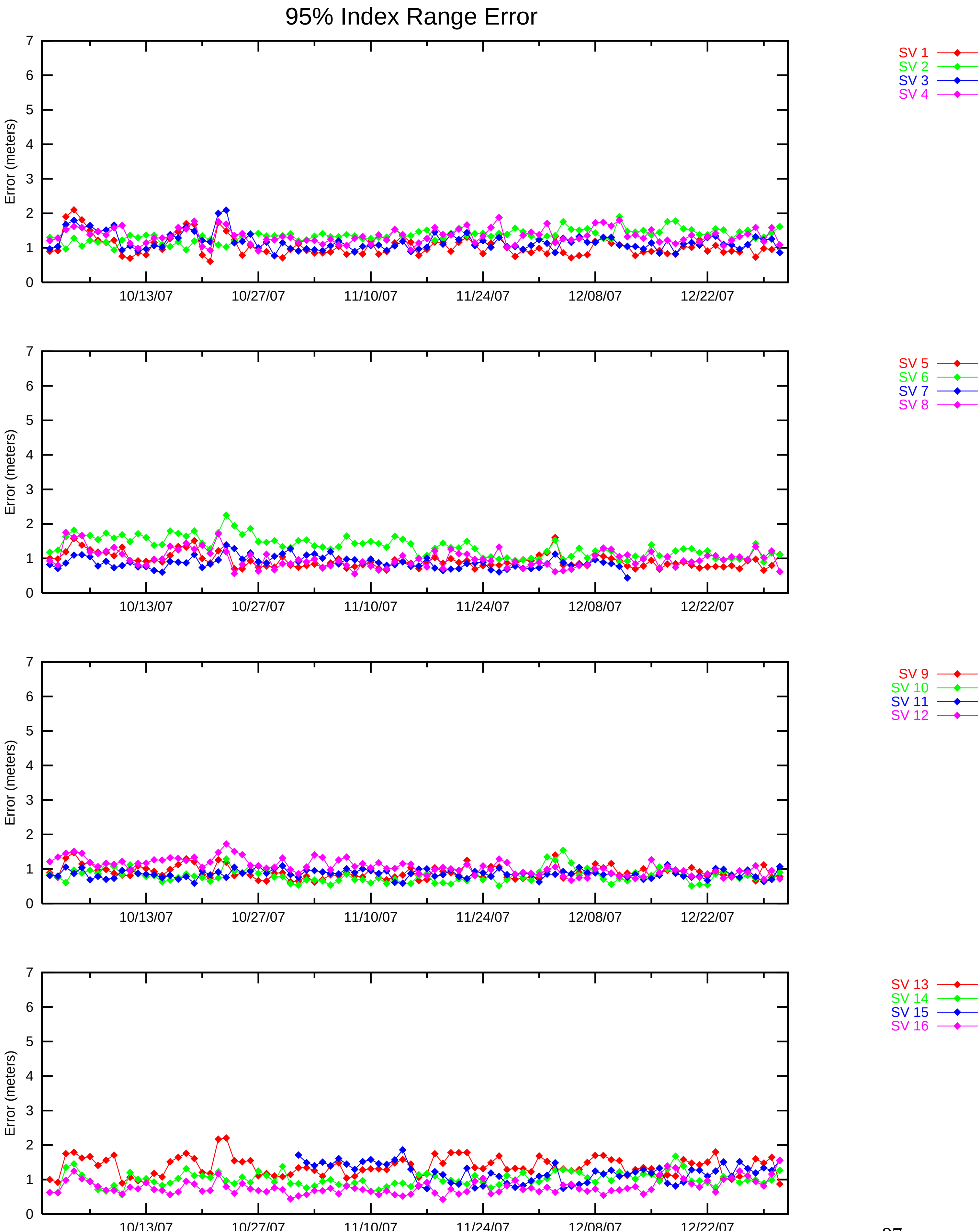


Figure 6-2 95% Range Error (SV 17 -- SV 31) - Washington, DC

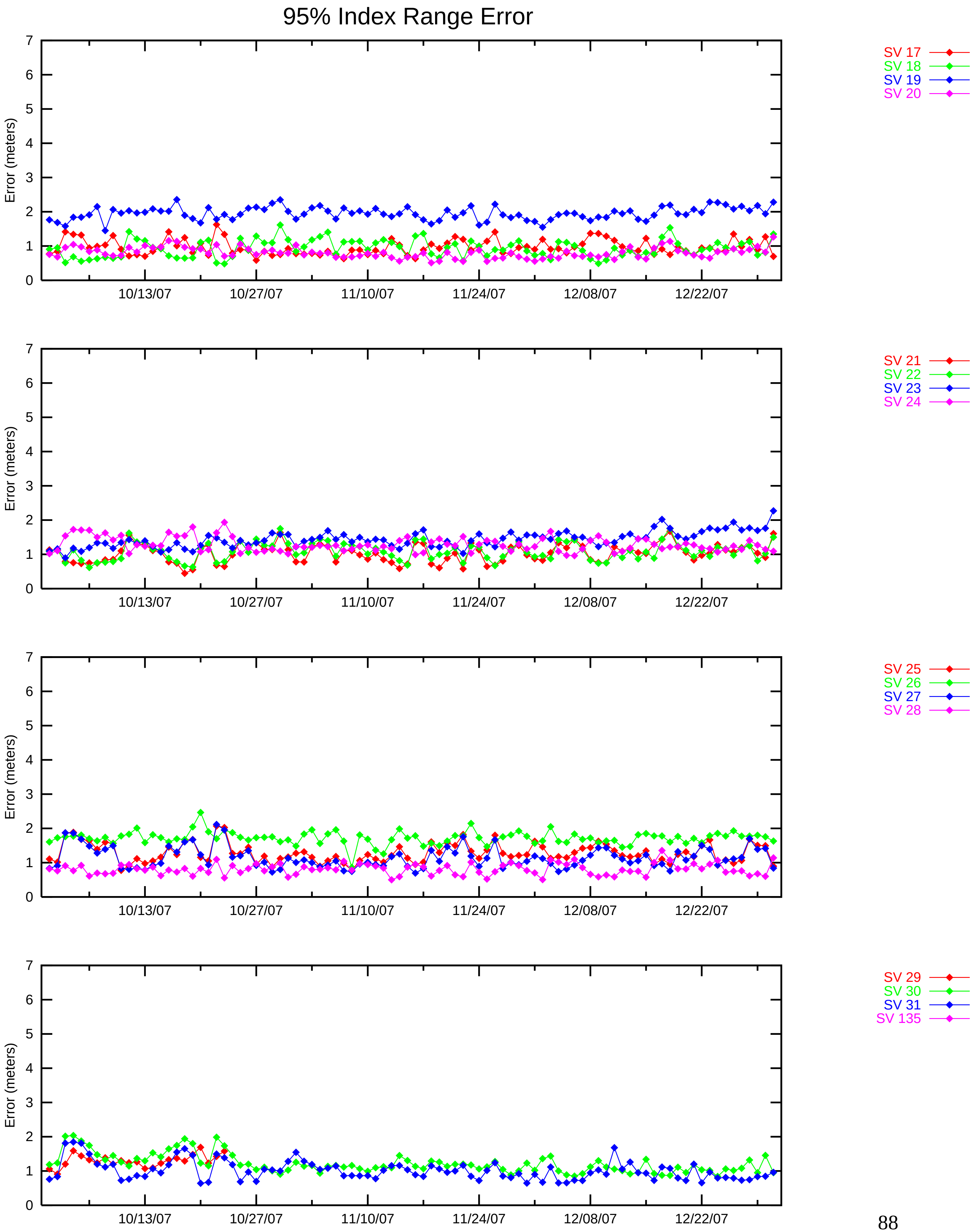


Figure 6-3 95% Ionospheric Error (SV 1 -- SV 16) - Washington, DC

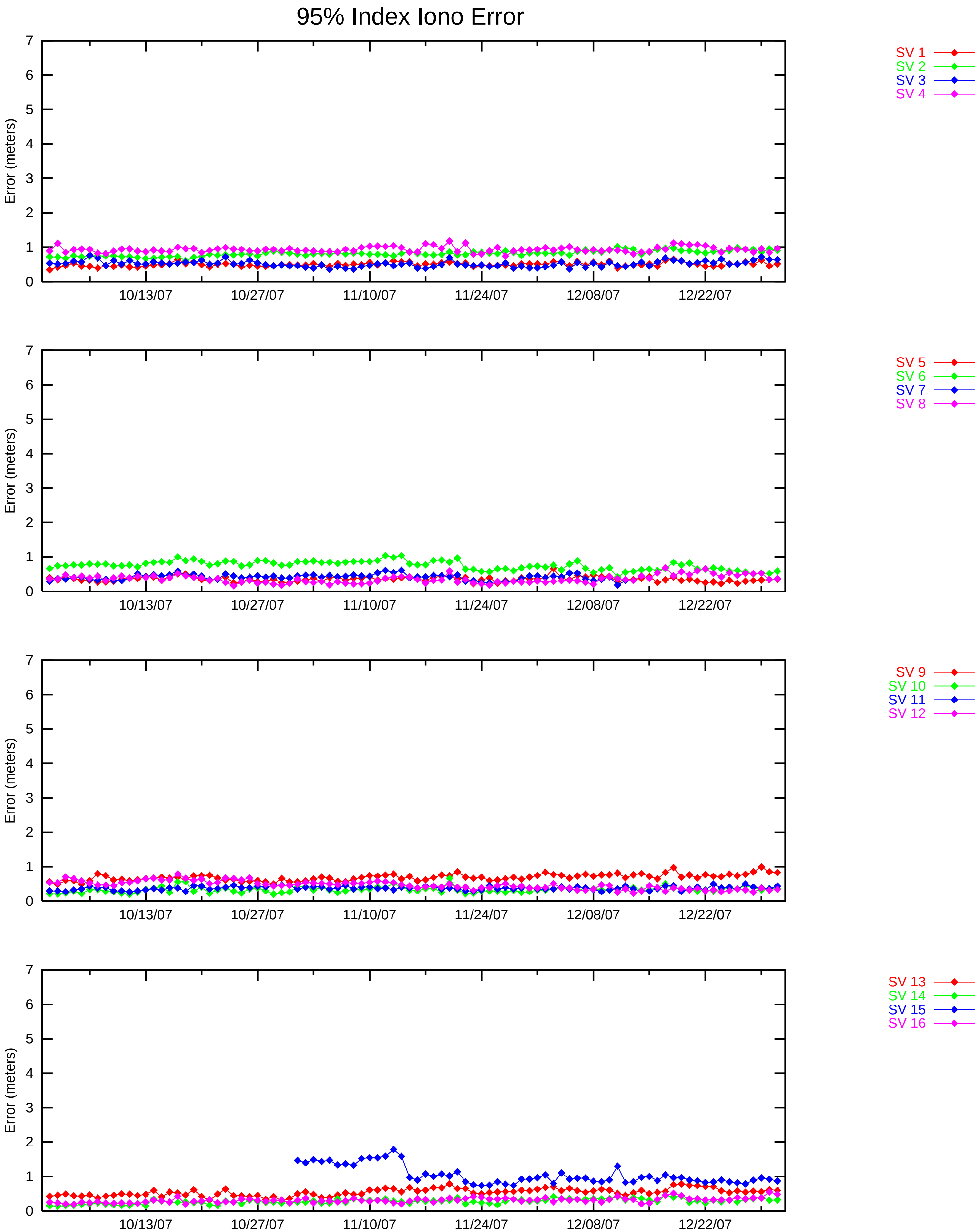
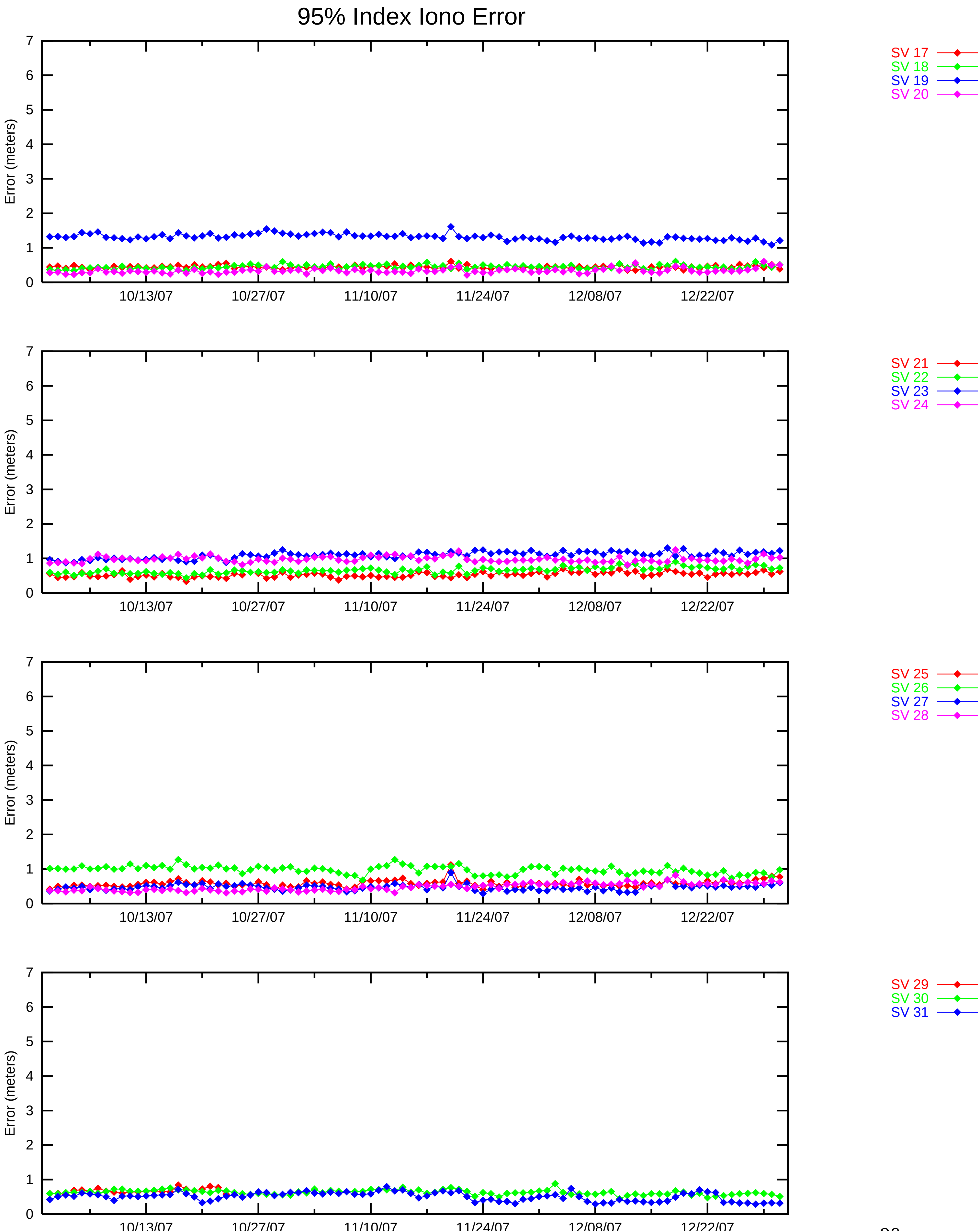


Figure 6-4 95% Ionospheric Error (SV 17 -- SV 31) - Washington, DC



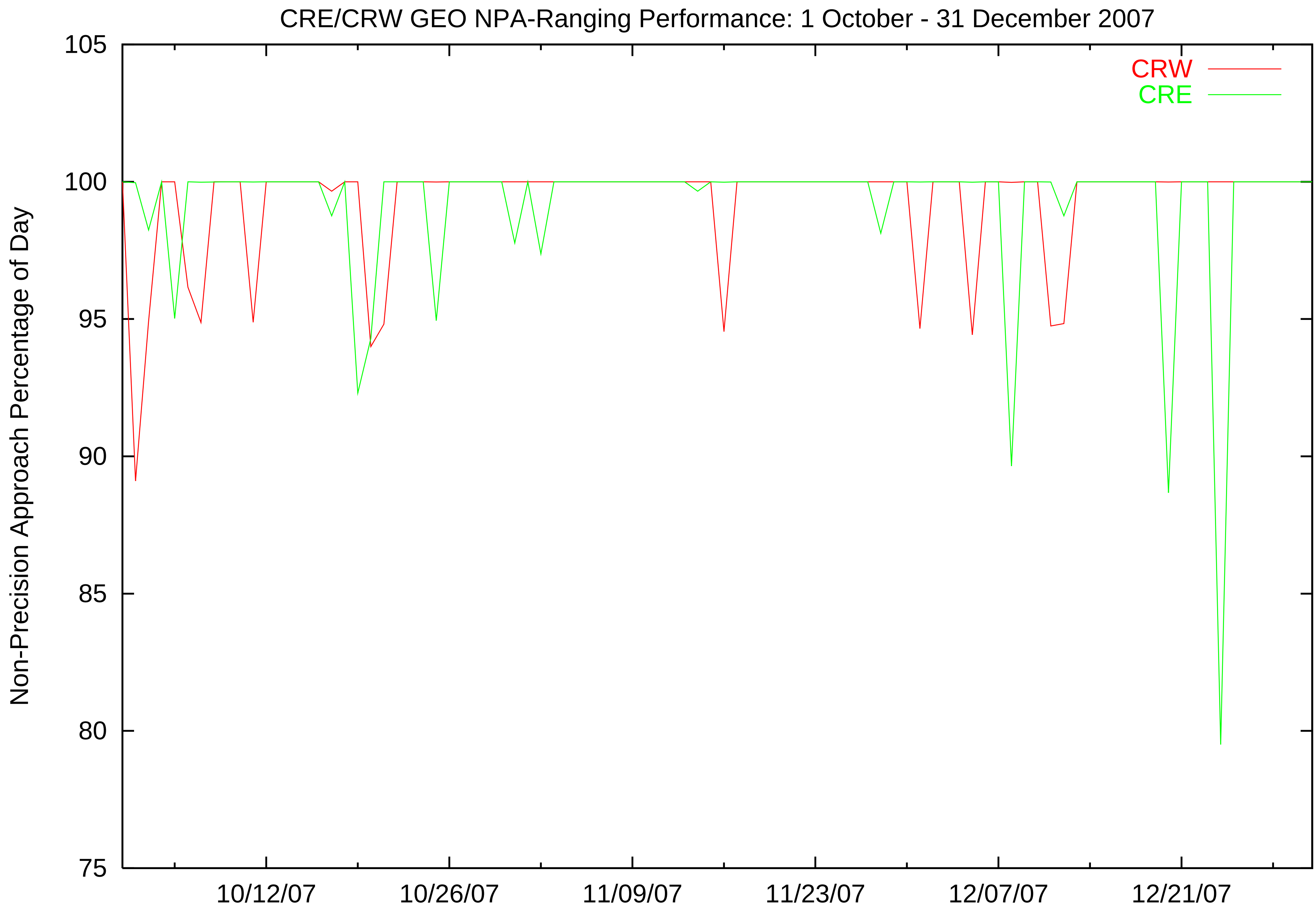
7.0 GEO RANGING PERFORMANCE

For the evaluated period, both CRW and CRE GEO satellites provide ranging capability for enroute through NPA service, but not for PA service. Table 7.1 shows the GEO-Ranging performance for CRE and CRW GEO satellites throughout the evaluated period. Figure 7.1 shows the trend of NPA Ranging Availability for the CRE and CRW GEO satellite.

Table 7-1 GEO Ranging Availability

GEO	PA (%)	NPA (%)	Not Monitored (%)	Do Not Use (%)
CRW	0	99.256	0.623	0.120
CRE	0	99.163	0.680	0.156

Figure 7-1 Daily NPA GEO Ranging Availability Trend



8.0 WAAS PROBLEM SUMMARY

Events that adversely affected the WAAS service for this evaluated period are listed in Table 8.1. These events include any WAAS anomalies and problems that affected the WAAS performance. Details of each of the events are documented in the WAAS Discrepancy Report (DR). The DRs are available on the website http://www.nstb.tc.faa.gov under 'WAAS Technical Reports', and can also be accessed via hyperlink below.

Table 8-1 WAAS Problem Summary

Date	Events
10/8/07	See DR# 65, "Three Unforecasted GPS Satellite Outages Caused Reduced Ranging Availability."
12/19/07	See DR# 64, "SV PRN 27 Unexpectedly Set to Not Monitored."

9.0 WAAS AIRPORT AVAILABILITY

The WAAS airport availability evaluation determines the number and length LVP service outages at selected airports from the transmitted WAAS navigation message. The navigation messages transmitted from all GEO satellites are processed simultaneously, and WAAS protection levels (VPL and HPL) are computed at each airport once a second in accordance with the WAAS MOPS. Once the protection levels have been produced at each airport an LPV service evaluation is conducted to identify outages in service (i.e. when protection levels exceed alert limits). WAAS LPV service is available for a user when the vertical protection level (VPL) is less than or equal to vertical alert limit (VAL) of 50 meters and the horizontal protection level (HPL) is less than or equal to horizontal alert limit (HAL) of 40 meters. If both conditions are met at a specified airport location then WAAS LPV service is available at that airport. If either one of the conditions are not met at a specified airport location then WAAS LPV service at that airport is unavailable and an outage in LPV service is recorded with its duration. When the LPV service becomes unavailable it is not considered available again until protection levels are below or equal to alert limits for at least 15 minutes. Although this will reduce LPV service availability minimally, it substantially reduces the number of service outages and prevents excessive switching in and out of service availability. When computing LPV service availability, an extra two minutes of outage time was prefixed to each outage. The number of WAAS LPV service outages and the availability at selected airports for this evaluated period of WAAS operation is presented in Table 9.1. Figures 9.1 and 9.2 provide a graphical representation of WAAS LPV service availability and outage counts for the same period, respectively.

Table 9-1 WAAS LPV Outages and Availability

Airport Id	Airport Name	State	Outages	Availability
ANC	TED STEVENS ANCHORAGE INTL	AK	2	0.999911
79J	ANDALUSIA-OPP	AL	1	0.999967
EKY	BESSEMER	AL	1	0.999967
BHM	BIRMINGHAM INTL	AL	1	0.999967
DHN	DOTHAN RGNL	AL	1	0.999967
HSV	HUNTSVILLE INTL-CARL T JONES F	AL	1	0.999967
JKA	JACK EDWARDS	AL	1	0.999967
MDQ	MADISON COUNTY EXECUTIVE/TOM S	AL	1	0.999967
BFM	MOBILE DOWNTOWN	AL	1	0.999967
MOB	MOBILE RGNL	AL	1	0.999967
MGM	MONTGOMERY RGNL (DANNELLY FIELD)	AL	1	0.999967
MSL	NORTHWEST ALABAMA RGNL	AL	1	0.999967
DCU	PRYOR FIELD RGNL	AL	1	0.999967
LIT	ADAMS FIELD	AR	1	0.999967
M73	ALMYRA MUNICIPAL	AR	1	0.999967
BYH	ARKANSAS INTL	AR	1	0.999967
VBT	BENTONVILLE MUNICIPAL/LOUISE M THAD	AR	1	0.999967
HRO	BOONE COUNTY	AR	1	0.999967
FSM	FORT SMITH RGNL	AR	1	0.999967
PBF	GRIDER FIELD	AR	1	0.999967
XNA	NORTHWEST ARKANSAS RGNL	AR	1	0.999967
BPK	OZARK RGNL	AR	1	0.999967
ROG	ROGERS MUNICIPAL-CARTER FIELD	AR	1	0.999967
SRC	SEARCY MUNICIPAL	AR	1	0.999967
ELD	SOUTH ARKANSAS RGNL AT GOODWIN	AR	1	0.999967
ASG	SPRINGDALE MUNICIPAL	AR	1	0.999967
SGT	STUTTGART MUNICIPAL	AR	1	0.999967
ARG	WALNUT RIDGE RGNL	AR	1	0.999967
PRC	ERNEST A. LOVE FIELD	AZ	1	0.999974

GCN	GRAND CANYON NATIONAL PARK	AZ	1	0.999974
IFP	LAUGHLIN/BULLHEAD INTL	AZ	1	0.999974
DVT	PHOENIX DEER VALLEY	AZ	1	0.999974
PHX	PHOENIX SKY HARBOR INTL	AZ	1	0.999974
SJN	ST JOHNS INDUSTRIAL AIR PARK	AZ	1	0.999974
TUS	TUCSON INTL	AZ	1	0.999974
IWA	WILLIAMS GATEWAY	AZ	1	0.999974
APV	APPLE VALLEY	CA	2	0.999922
ACV	ARCATA	CA	73	0.997841
DAG	BARSTOW-DAGGETT	CA	2	0.999923
C83	BYRON	CA	82	0.995577
CMA	CAMARILLO	CA	86	0.996117
CNO	CHINO	CA	33	0.999174
FAT	FRESNO YOSEMITE INTL	CA	52	0.998454
WJF	GENERAL WM J FOX AIRFIELD	CA	43	0.998877
HAF	HALF MOON BAY	CA	94	0.992769
SNA	JOHN WAYNE AIRPORT-ORANGE COUNTY	CA	58	0.998286
LGB	LONG BEACH /DAUGHERTY FIELD	CA	66	0.997841
LAX	LOS ANGELES INTL	CA	71	0.997467
CRQ	MC CLELLAN-PALOMAR	CA	50	0.998729
BFL	MEADOWS FIELD	CA	57	0.998118
OAK	METROPOLITAN OAKLAND INTL	CA	91	0.99384
MRY	MONTEREY PENINSULA	CA	94	0.99263
APC	NAPA COUNTY	CA	85	0.994647
O02	NERVINO	CA	6	0.999873
SJC	NORMAN Y. MINETA SAN JOSE INTL	CA	93	0.993853
VCB	NUT TREE	CA	76	0.995765
ONT	ONTARIO INTL	CA	30	0.999281
OXR	OXNARD	CA	92	0.995741
PMD	PALMDALE RGNL/USAF PLANT 42	CA	39	0.999002
RDD	REDDING MUNICIPAL	CA	56	0.998231
RAL	RIVERSIDE MUNICIPAL	CA	23	0.999461
SMF	SACRAMENTO INTL	CA	66	0.997099
MHR	SACRAMENTO MATHER	CA	64	0.997455
SFO	SAN FRANCISCO INTL	CA	94	0.993255
TCY	TRACY MUNICIPAL	CA	81	0.995807
COS	CITY OF COLORADO SPRINGS MUNICIPAL	CO	1	0.999971
AKO	COLORADO PLAINS RGNL	CO	1	0.999971
CEZ	CORTEZ MUNICIPAL	CO	1	0.999974
DEN	DENVER INTL	CO	1	0.999971
GXY	GREELEY-WELD COUNTY	CO	1	0.999971
ITR	KIT CARSON COUNTY	CO	1	0.999971
LAA	LAMAR MUNICIPAL	CO	1	0.999971
PUB	PUEBLO MEMORIAL	CO	1	0.999971
ALS	SAN LUIS VALLEY RGNL/BERGMAN	CO	1	0.999971
HDN	YAMPA VALLEY	CO	1	0.999974
BDL	BRADLEY INTL	CT	1	0.999962
GON	GROTON-NEW LONDON	CT	2	0.999925
HVN	TWEED-NEW HAVEN	CT	1	0.999962
OXC	WATERBURY-OXFORD	CT	1	0.999962
DCA	RONALD REAGAN WASHINGTON NATIONAL	DC	1	0.999962
EVY	SUMMIT	DE	1	0.999962
GED	SUSSEX COUNTY	DE	1	0.999962

CEW	BOB SIKES	FL	1	0.999967
BCT	BOCA RATON	FL	1	0.999962
DAB	DAYTONA BEACH INTL	FL	1	0.999962
DED	DELAND MUNICIPAL-SIDNEY H TAYLOR FIELD	FL	1	0.999962
FXE	FORT LAUDERDALE EXECUTIVE	FL	1	0.999962
FLL	FORT LAUDERDALE/HOLLYWOOD INTL	FL	1	0.999962
GNV	GAINESVILLE RGNL	FL	1	0.999962
BKV	HERNANDO COUNTY	FL	1	0.999962
JAX	JACKSONVILLE INTL	FL	1	0.999962
TMB	KENDALL-TAMIAMI EXECUTIVE	FL	2	0.99994
EYW	KEY WEST INTL	FL	1	0.999962
ISM	KISSIMMEE GATEWAY	FL	1	0.999962
LEE	LEESBURG INTL	FL	1	0.999962
MLB	MELBOURNE INTL	FL	1	0.999962
COI	MERRITT ISLAND	FL	1	0.999962
MIA	MIAMI INTL	FL	2	0.999946
APF	NAPLES MUNICIPAL	FL	1	0.999962
EVB	NEW SMYRNA BEACH MUNICIPAL	FL	1	0.999962
OCF	OCALA INTL-JIM TAYLOR FIELD	FL	1	0.999962
MCO	ORLANDO INTL	FL	1	0.999962
PBI	PALM BEACH INTL	FL	1	0.999962
PFN	PANAMA CITY-BAY CO INTL	FL	1	0.999967
PNS	PENSACOLA RGNL	FL	1	0.999967
PMP	POMPANO BEACH AIRPARK	FL	1	0.999962
SRQ	SARASOTA/BRADENTON INTL	FL	1	0.999962
RSW	SOUTHWEST FLORIDA INTL	FL	1	0.999962
PIE	ST PETERSBURG-CLEARWATER INTL	FL	1	0.999962
TLH	TALLAHASSEE RGNL	FL	1	0.999962
TPA	TAMPA INTL	FL	1	0.999962
VDF	VANDENBERG	FL	1	0.999962
GIF	WINTER HAVEN'S GILBERT	FL	1	0.999962
AGS	AUGUSTA RGNL AT BUSH FIELD	GA	1	0.999962
BQK	BRUNSWICK GOLDEN ISLES	GA	1	0.999962
CSG	COLUMBUS METROPOLITAN	GA	1	0.999967
DNN	DALTON MUNICIPAL	GA	1	0.999967
ATL	HARTSFIELD - JACKSON ATLANTA	GA	1	0.999962
MCN	MIDDLE GEORGIA RGNL	GA	1	0.999962
MGR	MOULTRIE MUNICIPAL	GA	1	0.999962
CCO	NEWNAN COWETA COUNTY	GA	1	0.999967
SAV	SAVANNAH/HILTON HEAD INTL	GA	1	0.999962
ACJ	SOUTHER FIELD	GA	1	0.999962
ABY	SOUTHWEST GEORGIA RGNL	GA	1	0.999962
TBR	STATESBORO-BULLOCH COUNTY	GA	1	0.999962
VLD	VALDOSTA RGNL	GA	1	0.999962
AYS	WAYCROSS-WARE COUNTY	GA	1	0.999962
CTJ	WEST GEORGIA RGNL - O V GRAY	GA	1	0.999967
IKV	ANKENY RGNL	IA	1	0.999967
DVN	DAVENPORT MUNICIPAL	IA	1	0.999967
DSM	DES MOINES INTL	IA	1	0.999967
DBQ	DUBUQUE RGNL	IA	1	0.999967
FFL	FAIRFIELD MUNICIPAL	IA	1	0.999967
EOK	KEOKUK MUNICIPAL	IA	1	0.999967
MCW	MASON CITY MUNICIPAL	IA	1	0.999967

MXO	MONTICELLO RGNL	IA	1	0.999967
MUT	MUSCATINE MUNICIPAL	IA	1	0.999967
TNU	NEWTON MUNICIPAL	IA	1	0.999967
OTM	OTTUMWA INDUSTRIAL	IA	1	0.999967
SDA	SHENANDOAH MUNICIPAL	IA	1	0.999967
SLB	STORM LAKE MUNICIPAL	IA	1	0.999967
CID	THE EASTERN IOWA	IA	1	0.999967
ALO	WATERLOO RGNL	IA	1	0.999967
BOI	BOISE AIR TERMINAL/GOWEN FIELD	ID	1	0.999974
IDA	IDAHO FALLS RGNL	ID	1	0.999974
LWS	LEWISTON-NEZ PERCE COUNTY	ID	1	0.999974
S67	NAMPA MUNICIPAL	ID	1	0.999974
PIH	POCATELLO RGNL	ID	1	0.999974
SPI	ABRAHAM LINCOLN CAPITAL	IL	1	0.999967
FEP	ALBERTUS	IL	1	0.999967
ARR	AURORA MUNICIPAL	IL	1	0.999967
BMI	CENTRAL IL REGL ARPT AT BLOOMI	IL	1	0.999967
ENL	CENTRALIA MUNICIPAL	IL	1	0.999967
MDW	CHICAGO MIDWAY INTL	IL	1	0.999967
ORD	CHICAGO O'HARE INTL	IL	1	0.999967
RFD	CHICAGO/ROCKFORD INTL	IL	1	0.999967
DEC	DECATUR	IL	1	0.999967
FOA	FLORA MUNICIPAL	IL	1	0.999967
IKK	GREATER KANKAKEE	IL	1	0.999967
PIA	GREATER PEORIA RGNL	IL	1	0.999967
3LF	LITCHFIELD MUNICIPAL	IL	1	0.999967
PPQ	PITTSFIELD PENSTONE MUNICIPAL	IL	1	0.999967
MLI	QUAD CITY INTL	IL	1	0.999967
TIP	RANTOUL NATL AVN CNTR-FRANK EL	IL	1	0.999967
SLO	SALEM-LECKRONE	IL	1	0.999967
ALN	ST LOUIS RGNL	IL	1	0.999967
UGN	WAUKEGAN RGNL	IL	1	0.999967
BAK	COLUMBUS MUNICIPAL	IN	1	0.999967
GWB	DE KALB COUNTY	IN	1	0.999967
MIE	DELAWARE COUNTY - JOHNSON FIELD	IN	1	0.999967
EKM	ELKHART MUNICIPAL	IN	1	0.999967
FWA	FORT WAYNE INTL	IN	1	0.999967
SER	FREEMAN MUNICIPAL	IN	1	0.999967
IND	INDIANAPOLIS INTL	IN	1	0.999967
MZZ	MARION MUNICIPAL	IN	1	0.999967
CEV	METTEL FIELD	IN	1	0.999967
BMG	MONROE COUNTY	IN	1	0.999967
LAF	PURDUE UNIVERSITY	IN	1	0.999967
GEZ	SHELBYVILLE MUNICIPAL	IN	1	0.999967
SBN	SOUTH BEND RGNL	IN	1	0.999967
ANQ	TRI-STATE STEUBEN COUNTY	IN	1	0.999967
PTS	ATKINSON MUNICIPAL	KS	1	0.999967
AAO	COLONEL JAMES JABARA	KS	1	0.999967
DDC	DODGE CITY RGNL	KS	1	0.999967
FOE	FORBES FIELD	KS	1	0.999967
HYS	HAYS RGNL	KS	1	0.999967
OJC	JOHNSON COUNTY EXECUTIVE	KS	1	0.999967
LWC	LAWRENCE MUNICIPAL	KS	1	0.999967

MHK	MANHATTAN RGNL	KS	1	0.999967
IXD	NEW CENTURY AIRCENTER	KS	1	0.999967
EWK	NEWTON-CITY-COUNTY	KS	1	0.999967
OEL	OAKLEY MUNICIPAL	KS	1	0.999967
TOP	PHILIP BILLARD MUNICIPAL	KS	1	0.999967
GLD	RENNER FIELD /GOODLAND MUNICIPAL	KS	1	0.999967
SLN	SALINA MUNICIPAL	KS	1	0.999967
TQK	SCOTT CITY MUNICIPAL	KS	1	0.999967
CBK	SHALZ FIELD	KS	1	0.999967
WLD	STROTHER FIELD	KS	1	0.999967
ULS	ULYSSES	KS	1	0.999967
ICT	WICHITA MID-CONTINENT	KS	1	0.999967
EKX	ADDINGTON FIELD	KY	1	0.999967
PAH	BARKLEY RGNL	KY	1	0.999967
K22	BIG SANDY RGNL	KY	1	0.999962
LEX	BLUE GRASS	KY	1	0.999967
LOU	BOWMAN FIELD	KY	1	0.999967
CVG	CINCINNATI/NORTHERN KENTUCKY	KY	1	0.999967
LOZ	LONDON-CORBIN ARPT-MAGEE FIELD	KY	1	0.999962
SDF	LOUISVILLE INTL-STANDIFORD FIELD	KY	1	0.999967
OWB	OWENSBORO-DAVIESS COUNTY	KY	1	0.999967
W38	WILLIAMSBURG-WHITLEY COUNTY	KY	1	0.999962
ARA	ACADIANA RGNL	LA	1	0.999967
AEX	ALEXANDRIA INTL	LA	1	0.999967
BTR	BATON ROUGE METROPOLITAN RYAN	LA	1	0.999967
DRI	BEAUREGARD RGNL	LA	1	0.999967
CWF	CHENNAULT INTL	LA	1	0.999967
ESF	ESLER RGNL	LA	1	0.999967
PTN	HARRY P WILLIAMS MEMORIAL	LA	1	0.999967
LFT	LAFAYETTE RGNL	LA	1	0.999967
LCH	LAKE CHARLES RGNL	LA	1	0.999967
NEW	LAKEFRONT	LA	1	0.999967
MSY	LOUIS ARMSTRONG NEW ORLEANS IN	LA	1	0.999967
DTN	SHREVEPORT DOWNTOWN	LA	1	0.999967
SHV	SHREVEPORT RGNL	LA	1	0.999967
TVR	VICKSBURG TALLULAH RGNL	LA	1	0.999967
HYA	BARNSTABLE MUNICIPAL - BOARDMAN/POLAN	MA	3	0.999904
BOS	GENERAL EDWARD LAWRENCE LOGAN	MA	2	0.999922
BED	LAURENCE G HANSCOM FIELD	MA	2	0.999924
MVY	MARTHAS VINEYARD	MA	2	0.99992
OWD	NORWOOD MEMORIAL	MA	2	0.999922
PVC	PROVINCETOWN MUNICIPAL	MA	3	0.999903
ORH	WORCESTER RGNL	MA	1	0.999962
BWI	BALTIMORE/WASHINGTON INTL	MD	1	0.999962
DMW	CARROLL COUNTY RGNL/JACK B POA	MD	1	0.999962
FDK	FREDERICK MUNICIPAL	MD	1	0.999962
GAI	MONTGOMERY COUNTY AIRPARK	MD	1	0.999962
2W6	ST. MARY'S COUNTY RGNL	MD	1	0.999962
LEW	AUBURN/LEWISTON MUNICIPAL	ME	2	0.999936
AUG	AUGUSTA STATE	ME	2	0.999916
BHB	HANCOCK COUNTY-BAR HARBOR	ME	2	0.999906
PQI	NORTHERN MAINE RGNL ARPT AT PR	ME	5	0.999866
PWM	PORTLAND INTL JETPORT	ME	2	0.999921

ARB	ANN ARBOR MUNICIPAL	MI	1	0.999962
ACB	ANTRIM COUNTY	MI	1	0.999967
FNT	BISHOP INTL	MI	1	0.999962
CIU	CHIPPEWA COUNTY INTL	MI	1	0.999967
DTW	DETROIT METROPOLITAN WAYNE COUNTY	MI	1	0.999962
GRR	GERALD R. FORD INTL	MI	1	0.999967
CMX	HOUGHTON COUNTY MEMORIAL	MI	1	0.999967
ADG	LENAWEE COUNTY	MI	1	0.999962
OZW	LIVINGSTON COUNTY SPENCER J. H	MI	1	0.999962
MBS	MBS INTL	MI	1	0.999962
MKG	MUSKEGON COUNTY	MI	1	0.999967
HYX	SAGINAW COUNTY H.W. BROWNE	MI	1	0.999962
BIV	TULIP CITY	MI	1	0.999967
YIP	WILLOW RUN	MI	1	0.999962
ANE	ANOKA COUNTY-BLAINE ARPT	MN	1	0.999967
BDE	BAUDETTE INTL	MN	1	0.999967
BRD	BRAINERD LAKES RGNL	MN	1	0.999967
AXN	CHANDLER FIELD	MN	1	0.999967
HIB	CHISHOLM-HIBBING	MN	1	0.999967
DLH	DULUTH INTL	MN	1	0.999967
MSP	MINNEAPOLIS-ST PAUL INTL/WOLD-	MN	1	0.999967
RGK	RED WING RGNL	MN	1	0.999967
RST	ROCHESTER INTL	MN	1	0.999967
STC	ST CLOUD RGNL	MN	1	0.999967
JYG	ST JAMES MUNICIPAL	MN	1	0.999967
STP	ST PAUL DOWNTOWN HOLMAN FIELD	MN	1	0.999967
BDH	WILLMAR MUNICIPAL	MN	1	0.999967
CGI	CAPE GIRARDEAU RGNL	MO	1	0.999967
MKC	CHARLES B. WHEELER DOWNTOWN	MO	1	0.999967
GPH	CLAY COUNTY RGNL	MO	1	0.999967
COU	COLUMBIA RGNL	MO	1	0.999967
LBO	FLOYD W. JONES LEBANON	MO	1	0.999967
HIG	HIGGINSVILLE INDUSTRIAL MUNICIPAL	MO	1	0.999967
VER	JESSE VIERTEL MEMORIAL	MO	1	0.999967
JLN	JOPLIN RGNL	MO	1	0.999967
MCI	KANSAS CITY INTL	MO	1	0.999967
TKX	KENNETT MEMORIAL	MO	1	0.999967
IRK	KIRKSVILLE RGNL	MO	1	0.999967
STL	LAMBERT-ST LOUIS INTL	MO	1	0.999967
AIZ	LEE C FINE MEMORIAL	MO	1	0.999967
6M6	LEWIS COUNTY RGNL	MO	1	0.999967
MYJ	MEXICO MEMORIAL	MO	1	0.999967
M58	MONETT MUNICIPAL	MO	1	0.999967
EOS	NEOSHO HUGH ROBINSON	MO	1	0.999967
STJ	ROSECRANS MEMORIAL	MO	1	0.999967
DMO	SEDALIA MEMORIAL	MO	1	0.999967
SIK	SIKESTON MEMORIAL MUNICIPAL	MO	1	0.999967
9K4	SKYHAVEN	MO	1	0.999967
SGF	SPRINGFIELD-BRANSON NATIONAL	MO	1	0.999967
TBN	WAYNESVILLE RGNL ARPT AT FORNE	MO	1	0.999967
UNO	WEST PLAINS MUNICIPAL	MO	1	0.999967
GTR	GOLDEN TRIANGLE RGNL	MS	1	0.999967
GWO	GREENWOOD-LEFLORE	MS	1	0.999967

GNF	GRENADA MUNICIPAL	MS	1	0.999967
GPT	GULFPORT-BILOXI INTL	MS	1	0.999967
HBG	HATTIESBURG BOBBY L CHAIN MUNICIPAL	MS	1	0.999967
PIB	HATTIESBURG-LAUREL RGNL	MS	1	0.999967
JAN	JACKSON-EVERS INTL	MS	1	0.999967
MEI	KEY FIELD	MS	1	0.999967
OLV	OLIVE BRANCH	MS	1	0.999967
CRX	ROSCOE TURNER	MS	1	0.999967
UTA	TUNICA MUNICIPAL	MS	1	0.999967
UOX	UNIVERSITY-OXFORD	MS	1	0.999967
BTM	BERT MOONEY	MT	1	0.999974
BIL	BILLINGS LOGAN INTL	MT	1	0.999974
MLS	FRANK WILEY FIELD	MT	1	0.999974
GPI	GLACIER PARK INTL	MT	1	0.999974
HLN	HELENA RGNL	MT	1	0.999974
LWT	LEWISTOWN MUNICIPAL	MT	1	0.999974
HBI	ASHEBORO RGNL	NC	1	0.999962
AVL	ASHEVILLE RGNL	NC	1	0.999962
CLT	CHARLOTTE/DOUGLAS INTL	NC	1	0.999962
JQF	CONCORD RGNL	NC	1	0.999962
EWN	CRAVEN COUNTY RGNL	NC	1	0.999962
ECG	ELIZABETH CITY CG AIR STATION	NC	1	0.999962
FAY	FAYETTEVILLE RGNL/GRANNIS FIELD	NC	1	0.999962
LHZ	FRANKLIN COUNTY	NC	1	0.999962
AKH	GASTONIA MUNICIPAL	NC	1	0.999962
GWW	GOLDSBORO-WAYNE MUNICIPAL	NC	1	0.999962
ISO	KINSTON RGNL JETPORT	NC	1	0.999962
EQY	MONROE RGNL	NC	1	0.999962
EDE	NORTHEASTERN RGNL	NC	1	0.999962
GSO	PIEDMONT TRIAD INTL	NC	1	0.999962
PGV	PITT-GREENVILLE	NC	1	0.999962
RDU	RALEIGH-DURHAM INTL	NC	1	0.999962
RWI	ROCKY MOUNT-WILSON RGNL	NC	1	0.999962
RUQ	ROWAN COUNTY	NC	1	0.999962
TTA	SANFORD-LEE COUNTY RGNL	NC	1	0.999962
SVH	STATESVILLE RGNL	NC	1	0.999962
ILM	WILMINGTON INTL	NC	1	0.999962
BIS	BISMARCK MUNICIPAL	ND	1	0.999967
DIK	DICKINSON - THEODORE ROOSEVELT	ND	1	0.999967
GFK	GRAND FORKS INTL	ND	1	0.999967
FAR	HECTOR INTL	ND	1	0.999967
MOT	MINOT INTL	ND	1	0.999967
ANW	AINSWORTH MUNICIPAL	NE	1	0.999967
AIA	ALLIANCE MUNICIPAL	NE	1	0.999971
BIE	BEATRICE MUNICIPAL	NE	1	0.999967
FNB	BRENNER FIELD	NE	1	0.999967
HDE	BREWSTER FIELD	NE	1	0.999967
GRI	CENTRAL NEBRASKA RGNL	NE	1	0.999967
CDR	CHADRON MUNICIPAL	NE	1	0.999971
OLU	COLUMBUS MUNICIPAL	NE	1	0.999967
OMA	EPPLEY AIRFIELD	NE	1	0.999967
FET	FREMONT MUNICIPAL	NE	1	0.999967
HSI	HASTINGS MUNICIPAL	NE	1	0.999967

LXN	JIM KELLY FIELD	NE	1	0.999967
OFK	KARL STEFAN MEMORIAL	NE	1	0.999967
EAR	KEARNEY RGNL	NE	1	0.999967
IBM	KIMBALL MUNICIPAL/ROBERT E ARRAJ FIELD	NE	1	0.999971
LNK	LINCOLN	NE	1	0.999967
MCK	MC COOK RGNL	NE	1	0.999967
MLE	MILLARD	NE	1	0.999967
VTN	MILLER FIELD	NE	1	0.999967
LBF	NORTH PLATTE RGNL AIRPORT LEE	NE	1	0.999967
PMV	PLATTSMOUTH MUNICIPAL	NE	1	0.999967
SCB	SCRIBNER STATE	NE	1	0.999967
OGA	SEARLE FIELD	NE	1	0.999968
SNY	SIDNEY MUNICIPAL/LLOYD W. CARR FIELD	NE	1	0.999971
ONL	THE O'NEILL MUNICIPAL - JOHN L BAKER	NE	1	0.999967
LCG	WAYNE MUNICIPAL	NE	1	0.999967
BFF	WESTERN NEB. RGNL/WILLIAM B. H	NE	1	0.999971
JYR	YORK MUNICIPAL	NE	1	0.999967
ASH	BOIRE FIELD	NH	1	0.999962
CON	CONCORD MUNICIPAL	NH	1	0.999962
PSM	PORTSMOUTH INTL AT PEASE	NH	2	0.999924
ACY	ATLANTIC CITY INTL	NJ	1	0.999962
WWD	CAPE MAY COUNTY	NJ	1	0.999962
MIV	MILLVILLE MUNICIPAL	NJ	1	0.999962
EWR	NEWARK LIBERTY INTL	NJ	1	0.999962
ABQ	ALBUQUERQUE INTL SUNPORT	NM	1	0.999971
CVN	CLOVIS MUNICIPAL	NM	1	0.999971
AEG	DOUBLE EAGLE II	NM	1	0.999971
FMN	FOUR CORNERS RGNL	NM	1	0.999974
SVC	GRANT COUNTY	NM	1	0.999974
LRU	LAS CRUCES INTL	NM	1	0.999971
ROW	ROSWELL INTL AIR CENTER	NM	1	0.999971
LAS	MC CARRAN INTL	NV	1	0.999974
4SD	RENO/STEAD	NV	2	0.999946
WMC	WINNEMUCCA MUNICIPAL	NV	1	0.999974
9G3	AKRON	NY	1	0.999962
ALB	ALBANY INTL	NY	1	0.999962
HWV	BROOKHAVEN	NY	1	0.999962
BUF	BUFFALO NIAGARA INTL	NY	1	0.999962
OLE	CATTARAUGUS COUNTY-OLEAN	NY	1	0.999962
JHW	CHAUTAUQUA COUNTY/JAMESTOWN	NY	1	0.999962
ELM	ELMIRA/CORNING RGNL	NY	1	0.999962
FOK	FRANCIS S GABRESKI	NY	2	0.999934
BGM	GREATER BINGHAMTON	NY	1	0.999962
ROC	GREATER ROCHESTER INTL	NY	1	0.999962
JFK	JOHN F KENNEDY INTL	NY	1	0.999962
LGA	LA GUARDIA	NY	1	0.999962
MSS	MASSENA INTL-RICHARDS FIELD	NY	1	0.999962
PBG	PLATTSBURGH INTL	NY	1	0.999962
SWF	STEWART INTL	NY	1	0.999962
SYR	SYRACUSE HANCOCK INTL	NY	1	0.999962
ELZ	WELLSVILLE MUNICIPA ARPT TARANTINE	NY	1	0.999962
HPN	WESTCHESTER COUNTY	NY	1	0.999962
CXY	CAPITAL CITY	OH	1	0.999962

LUK	CINCINNATI MUNICIPAL AIRPORT LUNKEN	OH	1	0.999962
CLE	CLEVELAND-HOPKINS INTL	OH	1	0.999962
MGY	DAYTON-WRIGHT BROTHERS	OH	1	0.999962
FDY	FINDLAY	OH	1	0.999962
I19	GREENE COUNTY-LEWIS A. JACKSON	OH	1	0.999962
DAY	JAMES M COX DAYTON INTL	OH	1	0.999962
1G3	KENT STATE UNIVERSITY	OH	1	0.999962
I68	LEBANON-WARREN COUNTY	OH	1	0.999962
OSU	OHIO STATE UNIVERSITY	OH	1	0.999962
UNI	OHIO UNIVERSITY SNYDER FIELD	OH	1	0.999962
CMH	PORT COLUMBUS INTL	OH	1	0.999962
RZT	ROSS COUNTY	OH	1	0.999962
TOL	TOLEDO EXPRESS	OH	1	0.999962
1G0	WOOD COUNTY	OH	1	0.999962
AVK	ALVA RGNL	OK	1	0.999967
CQB	CHANDLER RGNL	OK	1	0.999967
CHK	CHICKASHA MUNICIPAL	OK	1	0.999967
GCM	CLAREMORE RGNL	OK	1	0.999967
F29	CLARENCE E PAGE MUNICIPAL	OK	1	0.999967
1K4	DAVID JAY PERRY	OK	1	0.999967
MKO	DAVIS FIELD	OK	1	0.999967
DUA	EAKER FIELD	OK	1	0.999967
2O8	HINTON MUNICIPAL	OK	1	0.999967
HBR	HOBART MUNICIPAL	OK	1	0.999967
MLC	MC ALESTER RGNL	OK	1	0.999967
MIO	MIAMI MUNICIPAL	OK	1	0.999967
MDF	MOORELAND MUNICIPAL	OK	1	0.999967
OKM	OKMULGEE RGNL	OK	1	0.999967
PVJ	PAULS VALLEY MUNICIPAL	OK	1	0.999967
PNC	PONCA CITY RGNL	OK	1	0.999967
RVS	RICHARD LLOYD JONES JR	OK	1	0.999967
2K4	SCOTT FIELD	OK	1	0.999967
SNL	SHAWNEE RGNL	OK	1	0.999967
SWO	STILLWATER RGNL	OK	1	0.999967
TQH	TAHLEQUAH MUNICIPAL	OK	1	0.999967
TUL	TULSA INTL	OK	1	0.999967
OKC	WILL ROGERS WORLD	OK	1	0.999967
UAO	AURORA STATE	OR	1	0.999975
LMT	KLAMATH FALLS	OR	2	0.999956
LGD	LA GRANDE/UNION COUNTY	OR	1	0.999974
EUG	MAHLON SWEET FIELD	OR	1	0.999974
SLE	MCNARY FIELD	OR	1	0.999974
ONP	NEWPORT MUNICIPAL	OR	3	0.999897
PDX	PORTLAND INTL	OR	1	0.999975
AGC	ALLEGHENY COUNTY	PA	1	0.999962
AOO	ALTOONA-BLAIR COUNTY	PA	1	0.999962
BFD	BRADFORD RGNL	PA	1	0.999962
BTP	BUTLER COUNTY/K W SCHOLTER FIELD	PA	1	0.999962
9D4	DECK	PA	1	0.999962
HZL	HAZLETON MUNICIPAL	PA	1	0.999962
JST	JOHN MURTHA JOHNSTOWN-CAMBRIA	PA	1	0.999962
LNS	LANCASTER	PA	1	0.999962
ABE	LEHIGH VALLEY INTL	PA	1	0.999962

PNE	NORTHEAST PHILADELPHIA	PA	1	0.999962
PHL	PHILADELPHIA INTL	PA	1	0.999962
PIT	PITTSBURGH INTL	PA	1	0.999962
FWQ	ROSTRAVER	PA	1	0.999962
OYM	ST MARYS MUNICIPAL	PA	1	0.999962
UNV	UNIVERSITY PARK	PA	1	0.999962
FKL	VENANGO RGNL	PA	1	0.999962
BID	BLOCK ISLAND STATE	RI	2	0.999924
PVD	THEODORE FRANCIS GREEN STATE	RI	2	0.999923
AIK	AIKEN MUNICIPAL	SC	1	0.999962
AND	ANDERSON RGNL	SC	1	0.999962
CHS	CHARLESTON AFB/INTL	SC	1	0.999962
JZI	CHARLESTON EXECUTIVE	SC	1	0.999962
CAE	COLUMBIA METROPOLITAN	SC	1	0.999962
GYH	DONALDSON CENTER	SC	1	0.999962
GSP	GREENVILLE SPARTANBURG INTL	SC	1	0.999962
MYR	MYRTLE BEACH INTL	SC	1	0.999962
ABR	ABERDEEN RGNL	SD	1	0.999967
BKX	BROOKINGS RGNL	SD	1	0.999967
YKN	CHAN GURNEY MUNICIPAL	SD	1	0.999967
HON	HURON RGNL	SD	1	0.999967
FSD	JOE FOSS FIELD	SD	1	0.999967
MHE	MITCHELL MUNICIPAL	SD	1	0.999967
PIR	PIERRE RGNL	SD	1	0.999967
RAP	RAPID CITY RGNL	SD	1	0.999971
PVE	BEECH RIVER RGNL	TN	1	0.999967
UCY	EVERETT-STEWART	TN	1	0.999967
CHA	LOVELL FIELD	TN	1	0.999967
TYS	MC GHEE TYSON	TN	1	0.999962
MEM	MEMPHIS INTL	TN	1	0.999967
NQA	MILLINGTON RGNL JETPORT	TN	1	0.999967
BNA	NASHVILLE INTL	TN	1	0.999967
TRI	TRI-CITIES RGNL TN/VA	TN	1	0.999962
ABI	ABILENE RGNL	TX	1	0.999967
ADS	ADDISON	TX	1	0.999967
ALI	ALICE INTL	TX	2	0.999951
LFK	ANGELINA COUNTY	TX	1	0.999967
GKY	ARLINGTON MUNICIPAL	TX	1	0.999967
AUS	AUSTIN-BERGSTROM INTL	TX	2	0.999951
LBX	BRAZORIA COUNTY	TX	2	0.999951
BWD	BROWNWOOD RGNL	TX	1	0.999967
E30	BRUCE FIELD	TX	1	0.999967
TKI	COLLIN COUNTY RGNL AT MC KINNEY	TX	1	0.999967
CRP	CORPUS CHRISTI INTL	TX	2	0.999951
PRX	COX FIELD	TX	1	0.999967
RBD	DALLAS EXECUTIVE	TX	1	0.999967
DAL	DALLAS LOVE FIELD	TX	1	0.999967
DFW	DALLAS/FORT WORTH INTL	TX	1	0.999967
DWH	DAVID WAYNE HOOKS MEMORIAL	TX	1	0.999967
DRT	DEL RIO INTL	TX	1	0.999971
TPL	DRAUGHON-MILLER CENTRAL TEXAS	TX	1	0.999967
CLL	EASTERWOOD FIELD	TX	2	0.999951
EBG	EDINBURG INTL	TX	2	0.999951

ELP	EL PASO INTL	TX	1	0.999971
AFW	FORT WORTH ALLIANCE	TX	1	0.999967
FWS	FORT WORTH SPINKS	TX	1	0.999967
IAH	GEORGE BUSH INTERCONTINENTAL	TX	1	0.999967
PVW	HALE COUNTY	TX	1	0.999971
AXH	HOUSTON-SOUTHWEST	TX	2	0.999951
ERV	KERRVILLE MUNI/LOUIS SCHREINER	TX	1	0.999967
LNC	LANCASTER	TX	1	0.999967
LRD	LAREDO INTL	TX	1	0.999967
CXO	LONE STAR EXECUTIVE	TX	1	0.999967
LBB	LUBBOCK PRESTON SMITH INTL	TX	1	0.999971
GVT	MAJORS	TX	1	0.999967
MFE	MC ALLEN MILLER INTL	TX	2	0.999951
HQZ	MESQUITE METRO	TX	1	0.999967
MAF	MIDLAND INTL	TX	1	0.999971
OSA	MOUNT PLEASANT RGNL	TX	1	0.999967
RAS	MUSTANG BEACH	TX	2	0.999951
BAZ	NEW BRAUNFELS MUNICIPAL	TX	2	0.999951
AMA	RICK HUSBAND AMARILLO INTL	TX	1	0.999967
GRK	ROBERT GRAY AAF	TX	1	0.999967
SJT	SAN ANGELO RGNL/MATHIS FIELD	TX	1	0.999967
SAT	SAN ANTONIO INTL	TX	2	0.999951
HYI	SAN MARCOS MUNICIPAL	TX	2	0.999951
GLS	SCHOLES INTL AT GALVESTON	TX	1	0.999967
SPS	SHEPPARD AFB/WICHITA FALLS MUNICIPAL	TX	1	0.999967
SGR	SUGAR LAND RGNL	TX	2	0.999951
T43	T P MC CAMPBELL	TX	2	0.999951
TRL	TERRELL MUNICIPAL	TX	1	0.999967
TYR	TYLER POUNDS RGNL	TX	1	0.999967
HRL	VALLEY INTL	TX	2	0.999951
IWS	WEST HOUSTON	TX	2	0.999951
HOU	WILLIAM P HOBBY	TX	1	0.999967
CDC	CEDAR CITY RGNL	UT	1	0.999974
KNB	KANAB MUNICIPAL	UT	1	0.999974
LGU	LOGAN-CACHE	UT	1	0.999974
OGD	OGDEN-HINCKLEY	UT	1	0.999974
PVU	PROVO MUNICIPAL	UT	1	0.999974
SLC	SALT LAKE CITY INTL	UT	1	0.999974
SGU	ST GEORGE MUNICIPAL	UT	1	0.999974
MTV	BLUE RIDGE	VA	1	0.999962
CHO	CHARLOTTESVILLE-ALBEMARLE	VA	1	0.999962
FCI	CHESTERFIELD COUNTY	VA	1	0.999962
JYO	LEESBURG EXECUTIVE	VA	1	0.999962
LNP	LONESOME PINE	VA	1	0.999962
HEF	MANASSAS RGNL/HARRY P. DAVIS	VA	1	0.999962
MKJ	MOUNTAIN EMPIRE	VA	1	0.999962
PSK	NEW RIVER VALLEY	VA	1	0.999962
PHF	NEWPORT NEWS/WILLIAMSBURG INTL	VA	1	0.999962
ORF	NORFOLK INTL	VA	1	0.999962
RIC	RICHMOND INTL	VA	1	0.999962
RMN	STAFFORD RGNL	VA	1	0.999962
BCB	VIRGINIA TECH/MONTGOMERY EXECUTIVE	VA	1	0.999962
IAD	WASHINGTON DULLES INTL	VA	1	0.999962

BTV	BURLINGTON INTL	VT	1	0.999962
FSO	FRANKLIN COUNTY STATE	VT	1	0.999962
BLI	BELLINGHAM INTL	WA	2	0.999927
FHR	FRIDAY HARBOR	WA	2	0.999925
MWH	GRANT CO INTL	WA	1	0.999974
OLM	OLYMPIA	WA	1	0.999975
PUW	PULLMAN/MOSCOW RGNL	WA	1	0.999974
RLD	RICHLAND	WA	1	0.999974
SEA	SEATTLE-TACOMA INTL	WA	2	0.999947
BVS	SKAGIT RGNL	WA	2	0.999932
PAE	SNOHOMISH COUNTY (PAINE FIELD)	WA	2	0.999941
GEG	SPOKANE INTL	WA	1	0.999974
ALW	WALLA WALLA RGNL	WA	1	0.999974
GRB	AUSTIN STRAUBEL INTL	WI	1	0.999967
CWA	CENTRAL WISCONSIN	WI	1	0.999967
MSN	DANE COUNTY RGNL-TRUAX FIELD	WI	1	0.999967
EGV	EAGLE RIVER UNION	WI	1	0.999967
FLD	FOND DU LAC COUNTY	WI	1	0.999967
MKE	GENERAL MITCHELL INTL	WI	1	0.999967
MTW	MANITOWOC COUNTY	WI	1	0.999967
MFI	MARSHFIELD MUNICIPAL	WI	1	0.999967
ATW	OUTAGAMIE COUNTY RGNL	WI	1	0.999967
RHI	RHINELANDER-ONEIDA COUNTY	WI	1	0.999967
RPD	RICE LAKE RGNL - CARL'S FIELD	WI	1	0.999967
HYR	SAWYER COUNTY	WI	1	0.999967
SBM	SHEBOYGAN COUNTY MEMORIAL	WI	1	0.999967
JVL	SOUTHERN WISCONSIN RGNL	WI	1	0.999967
OSH	WITTMAN RGNL	WI	1	0.999967
PKB	MID-OHIO VALLEY RGNL	WV	1	0.999962
HTS	TRI-STATE/MILTON J. FERGUSON	WV	1	0.999962
CYS	CHEYENNE RGNL/JERRY OLSON FIELD	WY	1	0.999971
EVW	EVANSTON-UINTA COUNTY BURNS FIELD	WY	1	0.999974
GCC	GILLETTE-CAMPBELL COUNTY	WY	1	0.999974
JAC	JACKSON HOLE	WY	1	0.999974
JAC	JACKSON HOLE	WY	1	0.999974
LAR	LARAMIE RGNL	WY	1	0.999974
CPR	NATRONA COUNTY INTL	WY	1	0.999974
RIW	RIVERTON RGNL	WY	1	0.999974
RKS	ROCK SPRINGS-SWEETWATER COUNTY	WY	1	0.999974
SHR	SHERIDAN COUNTY	WY	1	0.999974
COD	YELLOWSTONE RGNL	WY	1	0.999974

Figure 9-1 WAAS LPV Availability

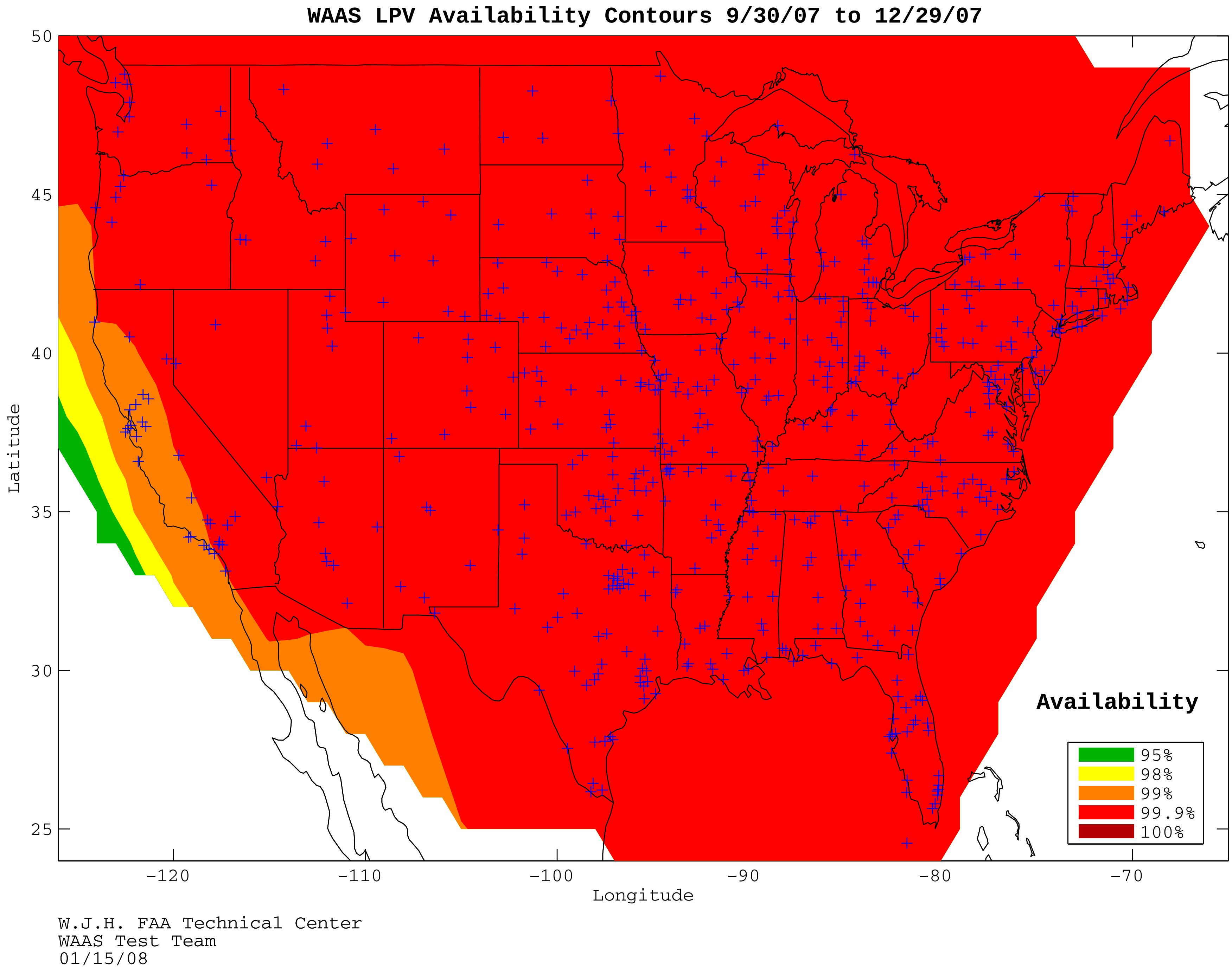
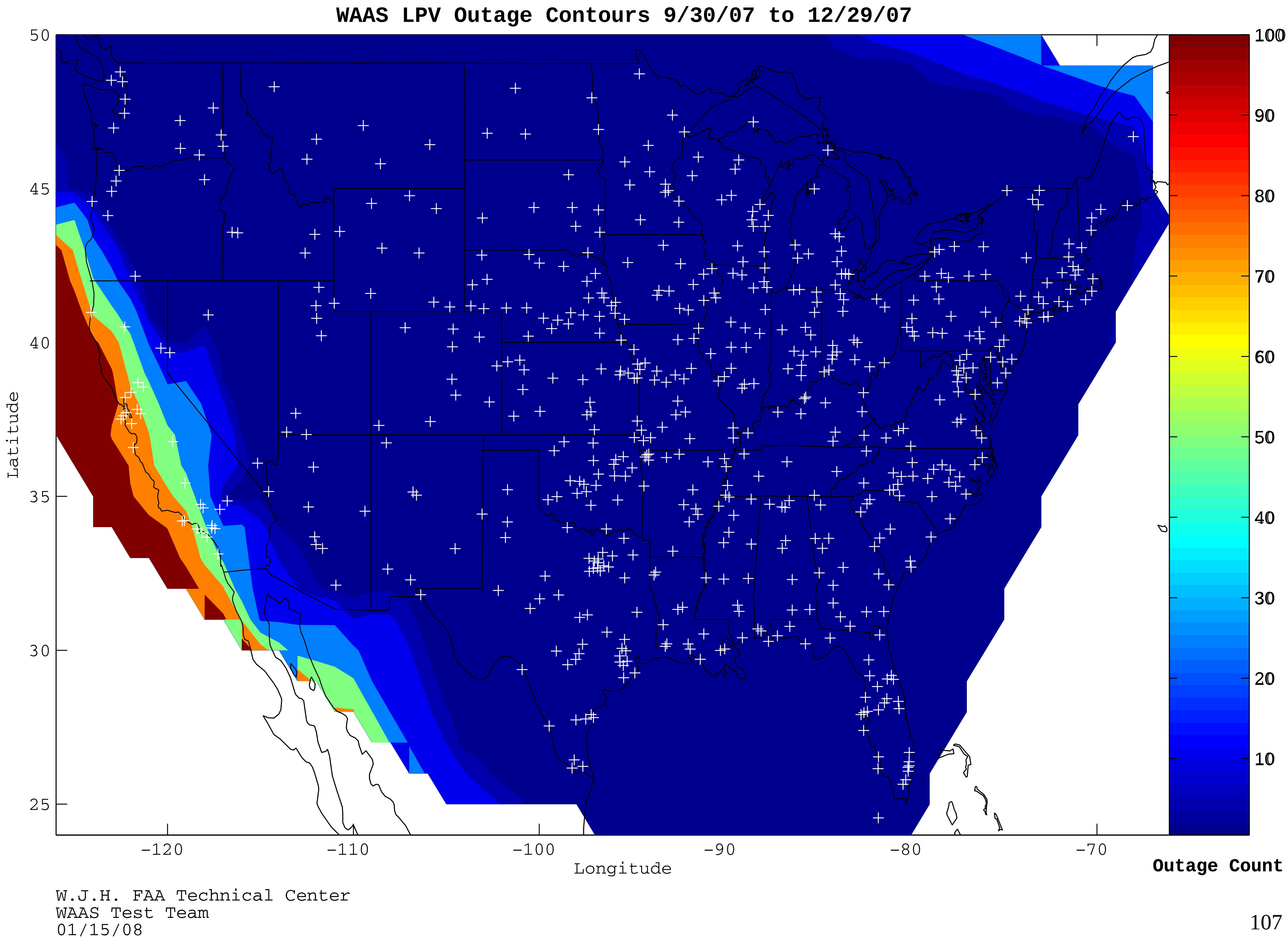


Figure 9-2 WAAS LPV Outage



10.0 WAAS DETERMINISTIC CODE NOISE AND MULTIPATH BOUNDING ANALYSIS

WAAS utilizes a deterministic model to estimate the residual CNMP noise after the application of standard dual frequency carrier smoothing techniques to minimize the effects of multipath and code noise. This analysis performs an assessment of how well that deterministic model bounds the actual errors. This analysis is periodically performed as part of the WAAS Test Team's off-line monitoring to ensure that there are no drastic detrimental changes to the multipath environment at the WAAS Reference Stations (WRSs). This analysis also ensures that WAAS system is not indefinitely exposed to conspiring receiver failure symptoms that would invalidate the CNMP bounding estimate in a manner that would exceed the assumption that no more than one receiver is conspiring to deceive the WAAS monitors at any time by underestimating the residual measurement noise the safety monitors. Although some failures mechanisms that cause CNMP bounding issues are occasionally seen, no "conspiring" errors have ever been detected. That is, data has caused the safety monitors to trip unnecessarily versus missing a necessary trip.

The analysis post processes measurement data to estimate the pseudorange code to carrier ambiguity for each entire arc of measurements for each satellite pass. The ambiguity estimate is then used to level the carrier measurement. The leveled carrier is then used as a multipath free truth estimate. The WAAS real time deterministic CNMP smoothing algorithm is then applied to the original measurements. The difference between the smoothed measurements and the leveled truth measurements is compared to the deterministic noise estimates. Only arcs with continuous carrier phase greater in length than 7200 seconds are utilized for this analysis to minimize the impacts of non-zero mean multipath biasing the truth estimates. The WAAS dual frequency cycle slip detector algorithm is used to detect any discontinuities in the carrier phase.

Statistics are calculated on how well the 0.1 multiples of the deterministically estimated standard deviation bounds the difference between the leveled truth and the real time smoothed measurements. Those statistics are then compared to a theoretical gaussian distribution and an extensive set of plots are generated and manually reviewed. Table 10.1 recaps the results of that manual analysis.

Table 10-1 CNMP Bounding Statistics

WAAS Site	WRE	Jan 07	Feb 07	Mar 07	Apr 07	May 07	Jun 07	Jul 07	Aug 07	Sep 07	Oct 07	Nov 07	Dec 07
Albuquerque	A	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Yellow
	B	Blue	Green	Blue	Blue	Yellow	Blue	Green	Yellow	Blue	Blue	Blue	Blue
	C	Blue	Yellow	Blue	Blue	Blue	Yellow	Blue	Blue	Blue	Blue	Green	Blue
Anchorage	A	Red	Green	Yellow	Red	Green	Green	Green	Blue	Blue	Yellow	–	–
	B	Green	Green	Red	Red	Yellow	Yellow	Green	Blue	Green	Green	–	Blue
	C	Red	Red	Red	Green	Green	Green	Yellow	Blue	Yellow	Yellow	–	–
Atlanta	A	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	B	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	C	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Barrow	A										Blue	Blue	Yellow
	B	*	*	*	*	*	*	*	*	*	Green	Blue	Blue
	C										Blue	Blue	Blue
Bethel	A										Blue	Blue	Blue
	B	*	*	*	*	*	*	*	*	*	Blue	Blue	Blue
	C										Blue	Blue	Blue
Billings	A	Green	Blue	Green	Blue	Yellow	Blue	Green	Green	Blue	Yellow	Blue	Blue
	B	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green	Yellow	Green	Blue
	C	Green	Blue	Green	Blue	Blue	Yellow	Blue	Green	Green	Blue	Blue	Green
Boston	A	Blue	Blue	Blue	Blue	Green	Blue	Yellow	Blue	Blue	Blue	Blue	Blue
	B	Blue	Yellow	Yellow	Yellow	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	C	Blue	Blue	Blue	Blue	Yellow	Yellow	Blue	Blue	Blue	Blue	Blue	Blue
Chicago	A	Green	Blue	Green	Blue	Blue	Blue	Blue	Blue	Blue	Green	Blue	Green
	B	Green	Blue	Blue	Blue	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue
	C	Blue	Yellow	Blue	Blue	Yellow	Yellow	Blue	Blue	Blue	Red	Blue	Blue
Cleveland	A	Green	Green	Yellow	Green	Yellow	Blue	Green	Blue	Yellow	Yellow	Blue	Blue
	B	Blue	Green	Red	Yellow	Green	Blue	Blue	Blue	Green	Blue	Blue	Yellow
	C	Green	Blue	Yellow	Green	Yellow	Blue	Yellow	Green	Blue	Yellow	Green	Blue
Cold Bay	A	Green	Yellow	Red	Yellow	Yellow	Red	Yellow	Blue	Green	Yellow	Green	Blue
	B	Red	Red	Red	Yellow	Red	Red	Red	Green	Yellow	Blue	Yellow	Blue
	C	Red	Yellow	Green	Blue	Green	Red	Green	Blue	Blue	Blue	Blue	Green
Dallas	A	Red	Red	Red	Green	Red	Red	Yellow	Yellow	Blue	Yellow	Blue	Green
	B	Yellow	Red	Red	Red	Yellow	Red	Yellow	Blue	Blue	Green	Blue	Blue
	C	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Denver	A	Blue	Yellow	Yellow	Yellow	Blue	Blue	Blue	Blue	Blue	Blue	Yellow	Blue
	B	Blue	Blue	Yellow	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	C	Blue	Blue	Green	Green	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue
Fairbanks	A										Blue	Blue	–
	B	*	*	*	*	*	*	*	*	*	Blue	Blue	Blue
	C										Blue	Blue	–
Gander	A										Blue	Blue	Blue
	B	*	*	*	*	*	*	*	*	*	Blue	Blue	Blue
	C										Blue	Blue	Blue
Goose Bay	A										Blue	Blue	Blue
	B	*	*	*	*	*	*	*	*	*	Yellow	Blue	Blue
	C										Blue	Blue	Blue
Honolulu	A	Yellow	Green	Green	Green	Green	Yellow	Yellow	Blue	Blue	Red	Yellow	Blue
	B	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	C	Yellow	Green	Green	Blue	Red	Green	Blue	Blue	Blue	Blue	Blue	Blue
Houston	A	Green	Yellow	Yellow	Yellow	Green	Green	Yellow	Green	Blue	Blue	Blue	Yellow
	B	Red	Green	Yellow	Blue	Green	Red	Green	Yellow	Blue	Blue	Blue	Green
	C	Green	Red	Red	Yellow	Yellow	Green	Green	Yellow	Green	Green	Green	Green
Iqaluit	A										Blue	–	–
	B	*	*	*	*	*	*	*	*	*	Blue	Green	Green
	C										Blue	Blue	Blue
Jacksonville	A	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	B	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	C	Green	Blue	Blue	Blue	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue

- (Blue) **Excellent** - 3.29s bounded 100%
- (Green) **Good** - 4s bounded 100%
- (Yellow) **Fair** - 4s bounded 100% with one worst satellite excluded (Requires manual review if symptoms repeat from month to month)
- (Red) **Poor** – Requires manual review

Shaded receivers represent legacy receivers (non-G2). These receivers are predominantly the trouble receivers, with over 95% of their failures occurring on the L2 frequency.
* International sites' data is not shown prior to their addition into the WAAS system.
- Thread was not evaluated due to receiver or network issues.

WAAS Site	WRE	Jan 07	Feb 07	Mar 07	Apr 07	May 07	Jun 07	Jul 07	Aug 07	Sep 07	Oct 07	Nov 07	Dec 07
Juneau	A	yellow	yellow	red	red	green	green	green	blue	yellow	green	blue	blue
	B	blue	blue	yellow	red	blue	blue	blue	blue	blue	blue	blue	blue
	C	blue	blue	yellow	yellow	blue	blue	green	blue	green	blue	blue	blue
Kansas City	A	red	red	red	red	red	yellow	yellow	blue	yellow	yellow	blue	blue
	B	yellow	red	red	blue	blue	yellow	blue	yellow	blue	blue	blue	green
	C	green	blue	yellow	blue	blue	blue	blue	blue	blue	blue	blue	green
Kotzebue	A										blue	blue	–
	B	*	*	*	*	*	*	*	*	*	blue	blue	–
	C										green	blue	–
Los Angeles	A	blue	blue	yellow	blue	yellow	red	blue	yellow	blue	blue	blue	yellow
	B	blue	blue	blue	blue	blue	yellow	blue	green	blue	blue	yellow	yellow
	C	blue	blue	green	blue	blue	blue	blue	blue	blue	blue	blue	blue
Memphis	A	blue	blue	blue	blue	yellow	blue	blue	green	blue	green	blue	blue
	B	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
	C	blue	green	blue	blue	blue	blue	blue	blue	yellow	yellow	blue	blue
Merida	A										blue	blue	blue
	B	*	*	*	*	*	*	*	*	*	blue	blue	blue
	C										blue	blue	blue
Mexico City	A										red	blue	blue
	B	*	*	*	*	*	*	*	*	*	yellow	red	green
	C										red	yellow	yellow
Miami	A	yellow	yellow	yellow	red	blue	green	yellow	yellow	yellow	green	green	green
	B	green	green	blue	blue	blue	green	blue	blue	blue	blue	blue	blue
	C	yellow	blue	blue	red	blue	yellow	green	blue	green	green	yellow	green
Minneapolis	A	green	yellow	red	red	red	red	blue	yellow	blue	blue	blue	blue
	B	yellow	red	green	red	red	yellow	yellow	yellow	blue	blue	green	blue
	C	red	red	yellow	green	red	red	yellow	blue	blue	yellow	yellow	blue
New York	A	blue	blue	blue	green	blue	blue	yellow	blue	blue	blue	blue	blue
	B	yellow	green	blue	yellow	blue	blue	blue	blue	blue	blue	blue	blue
	C	red	red	red	red	green	green	green	green	green	blue	green	green
Oakland	A	yellow	red	red	yellow	yellow	blue	red	blue	blue	green	blue	green
	B	red	red	red	blue	green	blue	yellow	yellow	yellow	blue	red	yellow
	C	red	green	red	yellow	red	red	red	red	red	red	red	red
Puerto Vallarta	A										blue	green	blue
	B	*	*	*	*	*	*	*	*	*	blue	yellow	green
	C										blue	yellow	red
Salt Lake City	A	red	red	red	red	blue	blue	blue	yellow	blue	blue	blue	blue
	B	green	yellow	yellow	green	red	yellow	yellow	red	blue	yellow	blue	yellow
	C	red	yellow	green	yellow	blue	yellow	blue	yellow	blue	yellow	blue	blue
San Jose Del Cabo	A										red	red	red
	B	*	*	*	*	*	*	*	*	*	red	yellow	red
	C										green	red	red
San Juan	A	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
	B	blue	blue	blue	blue	yellow	blue	blue	blue	blue	green	green	blue
	C	blue	green	blue	blue	blue	blue	blue	green	blue	blue	green	blue
Seattle	A	green	green	red	yellow	blue	blue	yellow	blue	blue	blue	blue	blue
	B	red	red	blue	red	blue	green	green	blue	blue	blue	blue	blue
	C	blue	red	green	yellow	yellow	blue	red	yellow	blue	blue	blue	blue
Tapachula	A										red	blue	yellow
	B	*	*	*	*	*	*	*	*	*	red	yellow	yellow
	C										red	red	red
Washington, DC	A	blue	green	yellow	yellow	blue	yellow	green	yellow	blue	blue	blue	blue
	B	yellow	yellow	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
	C	green	green	yellow	blue	blue	blue	blue	blue	blue	blue	blue	blue
Winnipeg	A										blue	blue	blue
	B	*	*	*	*	*	*	*	*	*	blue	blue	blue
	C										blue	blue	blue

- (blue) **Excellent** - 3.29s bounded 100%
- (green) **Good** - 4s bounded 100%
- (yellow) **Fair** - 4s bounded 100% with one worst satellite excluded (Requires manual review if symptoms repeat from month to month)
- (red) **Poor** – Requires manual review

Shaded receivers represent legacy receivers (non-G2). These receivers are predominantly the trouble receivers, with over 95% of their failures occurring on the L2 frequency.
* International sites' data is not shown prior to their addition into the WAAS system.
- Thread was not evaluated due to receiver or network issues.

11.0 GPS BROADCAST ORBIT VS. IGS PRECISE ORBITS ANALYSIS

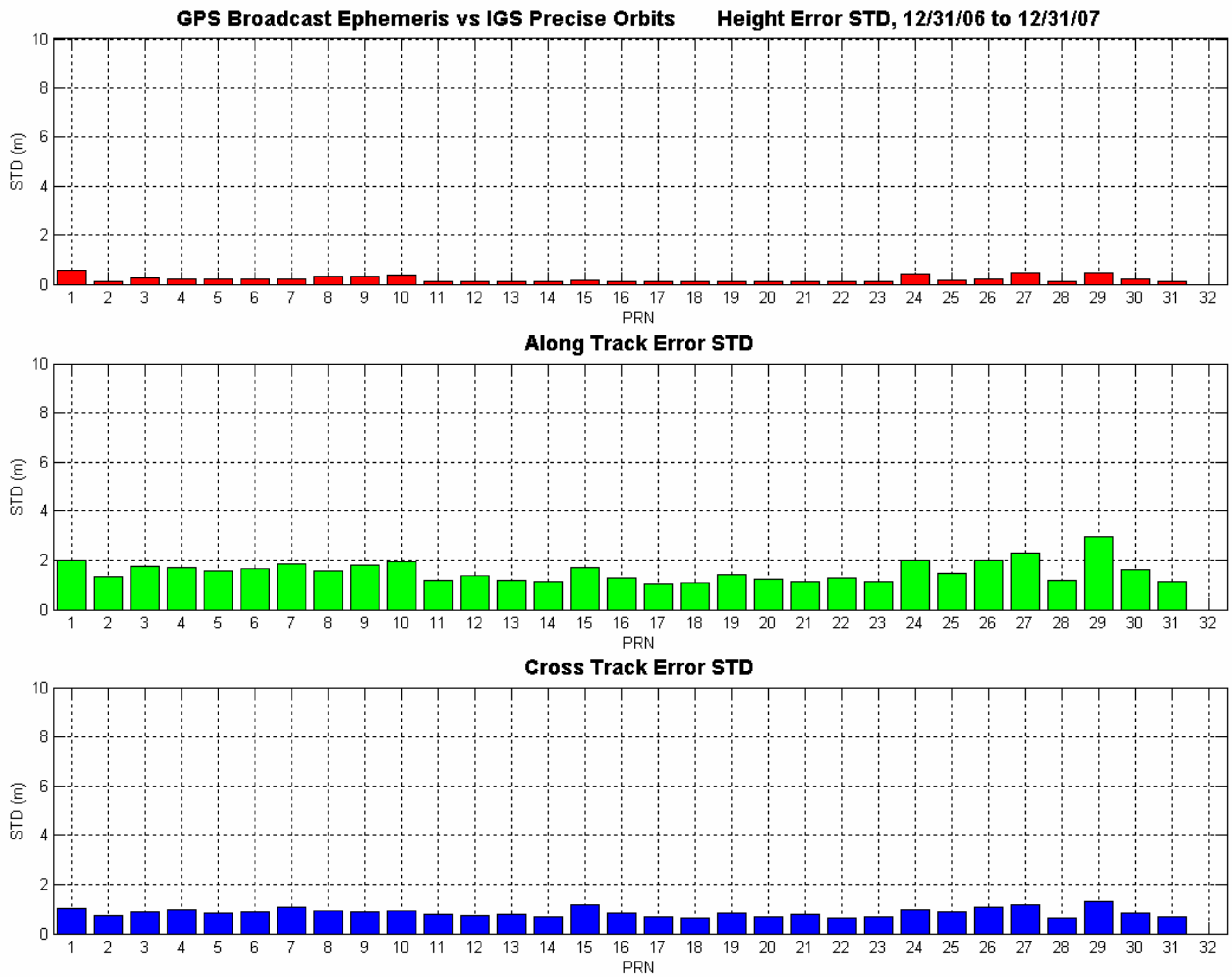
As part of the WAAS off-line monitoring process, the accuracy of the GPS broadcast ephemeris is periodically compared to the IGS precise orbit information to monitor the validity of an a priori assumption concerning the accuracy of the GPS broadcast ephemeris information that is part of a brute force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

Height Error:	+/- 15 meters,
Along Track Error:	+/- 65 meters,
Cross Track Error:	+/- 30 meters,

24 hour global GPB broadcast ephemeris information files and IGS precise orbit files are downloaded from the National Geodetic Survey (NGS). GPS satellite positions are computed every 15 minutes and differenced with the precise orbits. The resulting error information is then segregated into the Height, Along Track, Cross Track (HAC) error data. The standard deviation of the error is then computed for each dimension for each satellite. The assumption if valid if a 5.33 scaling of the standard deviation across all satellites is within the a priori. Only data points where GPS is healthy and valid IGS data is available are considered.

One year of data from 1/1/07 to 12/31/07 is presented. Figure 11-1 is a plot of the standard deviations. The worst case standard deviation meet the criteria (PRN 1 Height, PRN 29 Along Track, PRN 29 Cross Track), therefore the assumption is validated.

Figure 11-1 Standard Deviation for Height, Along Track, and Cross Track



12.0 WAAS REFERENCE STATION SURVEY VALIDATION

The precisely surveyed location of each WAAS WRS is updated occasionally. This update requires a change to the WAAS software. To ensure there is no large (> 10cm RSS) change in the WAAS reference station position between software updates, a new survey is calculated each quarter. The RSS difference between the current survey location and the newly calculated survey location is shown in this section.

The surveys calculate the L1 phase center positions (ECEF X, Y, and Z) of each WRS antenna in IRTF-2000. The latitude, longitude, and height are in WGS-84 computed from the IRTF ECEF using a GraftNet utility after interpolation. The results are cross-checked against OPUS (USA and Mexico) or CSRS (Canada) using 24 hours worth of data. The current survey date is October 21, 2007 for all sites except for Jacksonville (ZJX). The date for ZJX was October 27, 2007.

Figure 12-1 and Figure 12-2 show the difference between the WRS locations in the current software and the latest survey. Two figures are used so all reference stations could be identified in the chart. Also, note the y-axis scale change between the two figures. Each reference station has three independent strings of equipment, and a surveyed location is required for each string. All three strings of a reference station are shown in the two figures. For example, BET1 identifies the RSS delta for the Bethel WRS string 1. The next two bars in the chart are Bethel string 2 and Bethel string 3.

The survey from the current software is from the 'Release 6/7' version of the WAAS operational software. Most of the surveys are well below the 10 cm threshold. However, two reference stations are noteworthy. First, the RSS delta for each string at the Mexico City (MMX) WRS is slightly less than 50 cm. The majority of this difference is in height (reflected in the y-axis due to the location of the MMX reference station), as shown in Table 12-1. This difference is the limited amount of data available for the original MMX survey. The quality of this survey for MMX is much improved over the previous survey. The other reference station of note is Barrow (BRW) WRS. The majority of this difference is in the z-axis (height), as shown in Table 12-2. 24-hour OPUS surveys were performed every 12 weeks for Barrow between the old survey date and the current survey date. Those surveys were all consistent with the current surveys indicating the error was in the original Barrow survey.

The current surveys conducted for this analysis will be used in the next update of WAAS software, scheduled for deployment in September 2008.

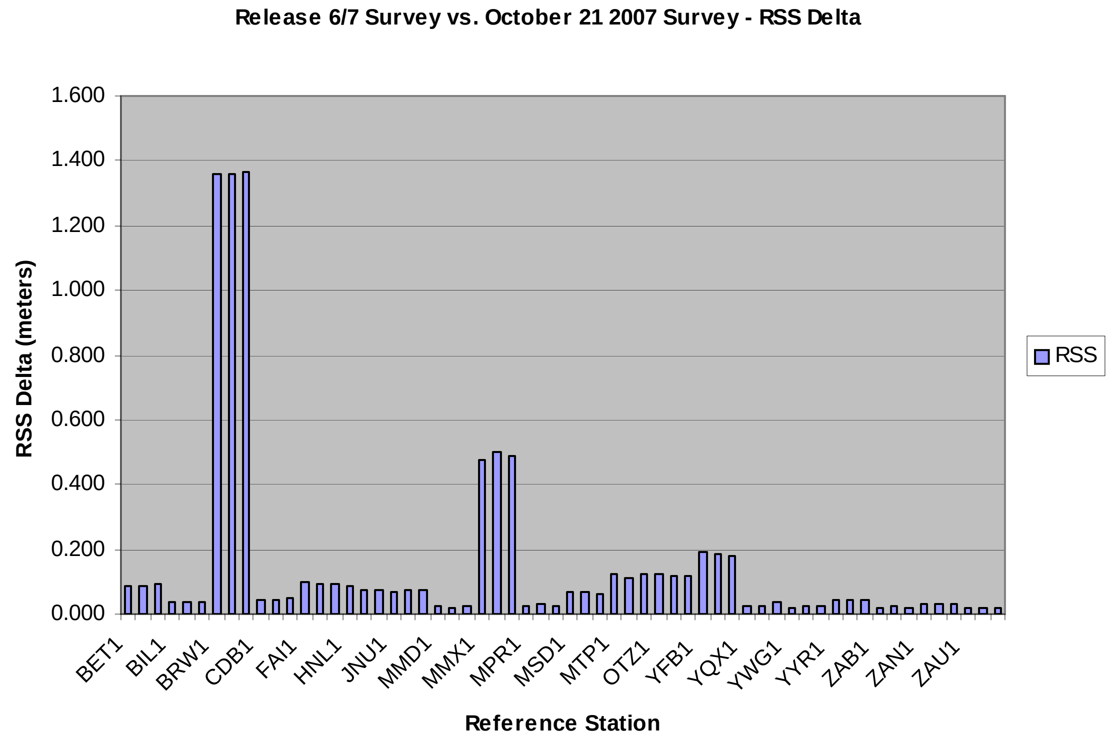


Figure 12-1 Survey Delta for 20 WRSs

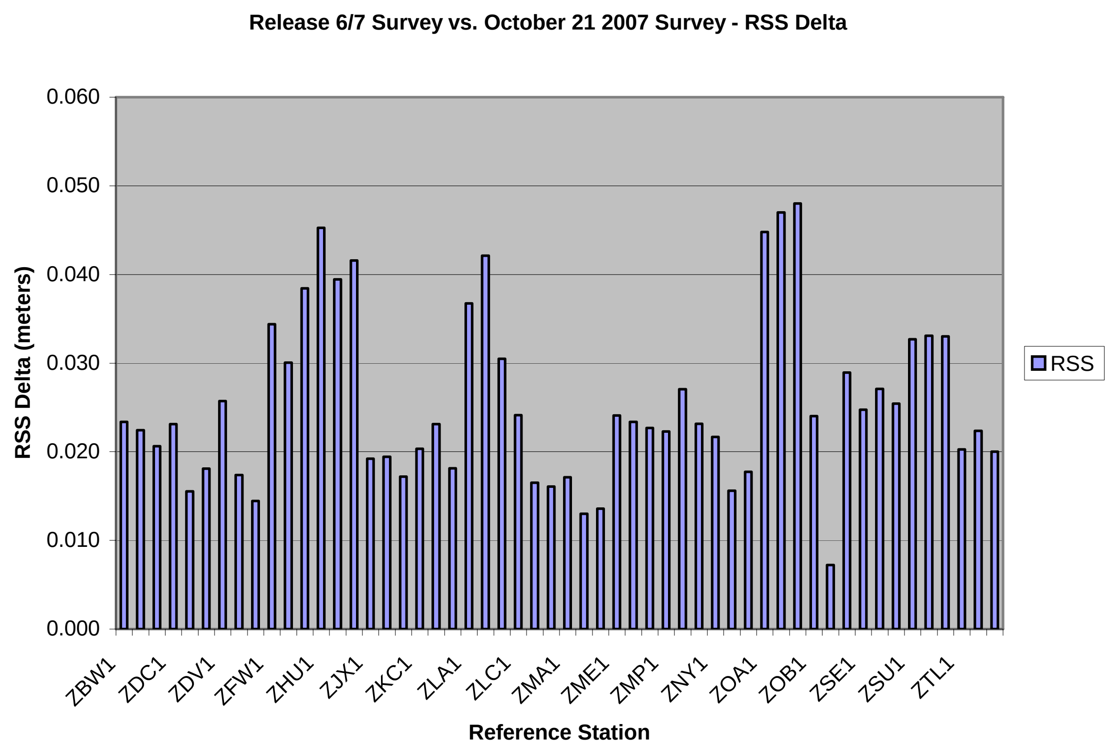


Figure 12-2 Survey Delta for 18 WRSs

WRS	Delta X (m)	Delta Y (m)	Delta Z (m)
MMX1	0.086	0.4453	-0.1531
MMX2	0.0891	0.4623	-0.1604
MMX3	0.086	0.4514	-0.156

Table 12-1 Mexico City WRS Delta Survey Position

WRS	Delta X (m)	Delta Y (m)	Delta Z (m)
BRW1	0.2776	0.1558	-1.3186
BRW2	0.2816	0.1616	-1.3168
BRW3	0.2784	0.1576	-1.3254

Table 12-2 Barrow WRS Delta Survey Position

Appendix A: Glossary

General Terms and Definitions

Alert. An alert is an indication provided by the GPS/WAAS equipment to inform the user when the positioning performance achieved by the equipment does not meet the integrity requirements.

APV-ILNAV/VNAV. APV-I is a WAAS operational service level with an HAL equal to 556 meters and a VAL equal to 50 meters.

Availability. The availability of a navigation system is the ability of the system to provide the required function and performance at the initiation of the intended operation. Availability is an indication of the ability of the system to provide usable service within the specified coverage area.

AVP-II. APV-II is a WAAS operational service level with an HAL equal to 40 meters and a VAL equal to 20 meters.

CONUS. Continental United States.

Continuity. The continuity of a system is the ability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation.

Coverage. The coverage provided by a radio navigation system is that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy. Coverage is influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, and other factors that affect signal availability.

Dilution of Precision (DOP). The magnifying effect on GPS position error induced by mapping GPS ranging errors into position through the position solution. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

DR. Discrepancy Report

Fault Detection and Exclusion (FDE). Fault detection and exclusion is a receiver processing scheme that autonomously provides integrity monitoring for the position solution, using redundant range measurements. The FDE consists of two distinct parts: fault detection and fault exclusion. The fault detection part detects the presence of an unacceptably large position error for a given mode of flight. Upon the detection, fault exclusion follows and excludes the source of the unacceptably large position error, thereby allowing navigation to return to normal performance without an interruption in service.

GEO. Geostationary Satellite.

Global Positioning System (GPS). A space-based positioning, velocity, and time system composed of space, control, and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment consists of five monitor stations, three ground antennas, and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

GLS. GLS is a WAAS operational service level with HAL equal to 40 meters and VAL equal to 12 meters.

Grid Ionospheric Vertical Error (GIVE). GIVEs indicate the accuracy of ionospheric vertical delay correction at a geographically defined ionospheric grid point (IGP). WAAS transmits one GIVE for each IGP in the mask.

Hazardous Misleading Information (HMI). Hazardous misleading information is any position data, that is output, that has an error larger than the current protection level (HPL/VPL), without any indication of the error (e.g., alert message sequence).

Horizontal Alert Limit (HAL). The Horizontal Alert Limit (HAL) is the radius of a circle in the horizontal plane (the local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, which describes the region that is required to contain the indicated horizontal position with a probability of $1\text{-}10^{-7}$ per flight hour, for a particular navigation mode, assuming the probability of a GPS satellite integrity failure being included in the position solution is less than or equal to 10^{-4} per hour.

Horizontal Protection Level (HPL). The Horizontal Protection Level is the radius of a circle in the horizontal plane (the plane tangent to the WGS-84 ellipsoid), with its center being at the true position, which describes the region that is assured to contain the indicated horizontal position. It is based upon the error estimates provided by WAAS.

Ionospheric Grid Point (IGP). IGP is a geographically defined point for which the WAAS provides the vertical ionospheric delay.

LNAV. Lateral Navigation.

MOPS. Minimum Operational Performance Standards.

Navigation Message. Message structure designed to carry navigation data.

Non-Precision Approach (NPA) Navigation Mode. The Non-Precision Approach navigation mode refers to the navigation solution operating with a minimum of four satellites with fast and long term WAAS corrections (no WAAS ionospheric corrections) available.

Position Solution. The use of ranging signal measurements and navigation data from at least four satellites to solve for three position coordinates and a time offset.

Precision Approach (PA) Navigation Mode. The Precision Approach navigation mode refers to the navigation solution operating with a minimum of four satellites with all WAAS corrections (fast, long term, and ionospheric) available.

Selective Availability. Protection technique employed by the DOD to deny full system accuracy to unauthorized users.

Standard Positioning Service (SPS). Three-dimensional position and time determination capability provided to a user equipped with a minimum capability GPS SPS receiver in accordance with GPS national policy and the performance specifications.

SV. Satellite Vehicle.

User Differential Range Error (UDRE). UDRE's indicate the accuracy of combined fast and slow error corrections. WAAS transmits one UDRE for each satellite in the mask.

Vertical Alert Limit (VAL). The Vertical Alert Limit is half the length of a segment on the vertical axis (perpendicular to the horizontal plane of WGS-84 ellipsoid), with its center being at the true position, which describes the region that is required to contain the indicated vertical position with a probability of $1\text{-}10^{-7}$ per flight hour, for a particular navigation mode, assuming the probability of a GPS satellite integrity failure being included in the position solution is less than or equal to 10^{-4} per hour.

Vertical Protection Level (VPL). The Vertical Protection Level is half the length of a segment on the vertical axis (perpendicular to the horizontal plane of WGS-84 ellipsoid), with its center being at the true position, which describes the region that is assured to contain the indicated vertical position. It is based upon the error estimates provided by WAAS.

VNAV. Vertical Navigation.

Wide Area Augmentation System (WAAS). The WAAS is made up of an integrity reference monitoring network, processing facilities, geostationary satellites, and control facilities. Wide area reference stations and integrity monitors are widely dispersed data collection sites that contain GPS/WAAS ranging receivers that monitor all signals from the GPS, as well as the WAAS geostationary satellites. The reference stations collect measurements from the GPS and WAAS satellites so that differential corrections, ionospheric delay information, GPS/WAAS accuracy, WAAS network time, GPS time, and UTC can be determined. The wide area reference station and integrity monitor data are forwarded to the central data processing sites. These sites process the data in order to determine differential corrections, ionospheric delay information, and GPS/WAAS accuracy, as well as verify residual error bounds for each monitored satellite. The central data processing sites also generate navigation messages for the geostationary satellites and WAAS messages. This information is modulated on the GPS-like signal and broadcast to the users from geostationary satellites.