WIDE-AREA AUGMENTATION SYSTEM PERFORMANCE ANALYSIS REPORT

Report #5

Reporting Period: April 01 to June 30, 2003

July 31, 2003

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NSTB/WAAS T&E Team
ACB 430
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Executive Summary

Since 1999 the Navigation Branch (ACB-430) 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 this report, the WAAS/NSTB Team is reporting on the performance of the Wide-Area Augmentation System (WAAS). This report is the fifth such WAAS quarterly report. This report covers WAAS performance during the period from April 1, 2003 to June 30, 2003.

The following table shows observations for accuracy and availability made during the reporting period. See the body of the report for results in the continuity, 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. See the body of the report for results when other service levels are available:

Parameter	Site/Maximum	Site/Minimum
95% Horizontal Accuracy	Elko 2.132 meters	Columbus 0.734 meters
95% Vertical Accuracy	Elko 2.594 meters	Chicago 1.126 meters
LPV Instantaneous Availability (HPL < 40 meters & VPL < 50 meters)	Salt Lake City 99.5%	Miami 96.4%
95% HPL	Bangor 34.6 meters	Kansas City 16.5 meters
95% VPL	Bangor 55.6 meters	Kansas City 28.5 meters

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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 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.

The WAAS data transmitted from GEO satellite PRN#122 (AORW) and PRN#134 (POR) were used in the evaluation. Table 1.1 and 1.2 listed 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 between 04/01/2003 and 06/30/2003.

Table 1.1 PA Sites

	Number of Days Evaluated	Number of Samples
NSTB:		
Anderson	90	7750371
Atlantic City	83	7211073
Bangor	82	7101971
Columbus	91	7858741
Dayton	91	7847926
Elko	90	7801445
Grand Forks	89	7710748
Great Falls	89	7694691
Greenwood	89	7673012
Oklahoma City	91	7858494
WAAS:		
Albuquerque	80	6929176
Atlanta	89	7712547
Billings	89	7655489
Boston	87	7534102
Chicago	89	7724394
Cleveland	89	7722676
Dallas	89	7731858
Denver	89	7713235
Houston	89	7659399
Jacksonville	90	7754786
Kansas City	90	7740267
Los Angeles	89	7704825
Memphis	87	7518679
Miami	89	7729127
Minneapolis	90	7732928
New York	89	7692068
Oakland	90	7757300
Salt Lake City	87	7533166
Seattle	85	7319125
Washington DC	90	7748322

Table 1.2 NPA Sites

Location	Number of Days Evaluated	Number of Samples
Bangor	87	7467753
Albuquerque	81	6929760
Anchorage	90	7740206
Atlanta	90	7714049
Billings	89	7655023
Boston	88	7540098
Cleveland	90	7724989
Cold Bay	82	7034639
Honolulu	90	7727927
Houston	89	7658738
Juneau	90	7723265
Kansas City	90	7733513
Los Angeles	90	7706177
Minneapolis	90	7732717
Miami	90	7729595
Oakland	90	7757779
Puerto Rico	90	7736822
Salt Lake City	88	7534697
Seattle	85	7319261
Washington DC	90	7749029

The report is divided to seven performance categories listed below.

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

Table 1.3 lists the performance parameters evaluated for the WAAS in this report.

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 ≤ 500m error 99.999% of the time
Availability GLS*	Not Defined for Current WAAS phase
Availability APV-2*	Not Defined for Current WAAS phase
Availability LPV*	Not Defined for Current WAAS phase
Availability LNAV/VNAV*	Not Defined for Current WAAS phase
Coverage GLS	Not Defined for Current WAAS phase
Coverage APV-2	Not Defined for Current WAAS phase
Coverage LPV	Not Defined for Current WAAS phase
Coverage LNAV/VNAV	≥ 75% of CONUS
NPA Continuity of Navigation	≥ 99.999% of the time
NPA Continuity of Fault Detection	≥ 99.999% of the time
PA Continuity of Function (LNAV/VNAV and LPV)	1-5.5 x 10^{-5} per approach
LPV Availability	≥ 95% of the time
LNAV/VNAV Availability	≥ 95% of the time
Integrity	≤ 4 X 10e-8 HMI's per approach
Accuracy Range Domain	≥ 99.9% of range error bounded by UDRE
Accuracy Ionospheric	≥ 99.9% of ionospheric error bounded by GIVE

* The availability referred is the 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 access the WAAS performance. These events include GPS or WAAS anomalies, relevant receiver malfunctions, and receiver maintenance conducted.

Table 1.4 Test Events

Date	Description
04/01/03 – 06/30/03	NSTB receiver maintenance at Arcata, San Angelo, Prescott and Green Bay
04/26/03	No data for all WAAS sites due to WEI outage
04/30/03	Ionospheric Storm with Kp index of 6
05/09/03	POR GEO SIS outages caused by scheduled testing of GEO.
05/11/03 – 05/15/03	Multiple GEO SIS outages caused by scheduled testing of GEOs.
05/22/03	Ionospheric Storm with Kp index of 5
05/29/03 – 05/30/03	Ionospheric Storm with Kp index of 8
5/30/30 - 0 6/01/03	Poor accuracy and coverage performance caused by installation mistake at Albuquerque where antenna cables of thread A and B were swapped
06/16/03	Ionospheric storm with Kp index of 5

1.2 Report Overview

Section 2.0 provides the vertical and horizontal position accuracies from data collected, on a daily basis, at one-second intervals. The 95% accuracy index for the reporting period is 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 3.0 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.

Section 4.0 provides the percent of coverage provided by WAAS on a daily basis. Monthly roll-up graphs presented indicate the portions of CONUS covered, and the percentage of time that WAAS was available.

Section 5.0 provides the percentage of time continuity requirements were met during the reporting period for each receiver.

Section 6.0 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 AORW and POR.

Section 7.0 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 8.0 provides the GEO ranging performance for AORW and POR.

Section 9.0 summarizes WAAS anomalies and problems identified during the reporting period, which adversely affect WAAS performance described in Table 1.3.

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 four operational service levels: WAAS GLS, WAAS APV-2, WAAS LPV, and WAAS APV-I (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)
GLS	40	12
APV-2	40	20
LPV (LOC/VNAV)	40	50
APV-1 (LNAV/VNAV)	556	50

Table 2.2 shows PA horizontal and vertical position accuracy maintained for 95% of the time at WAAS GLS, APV-2, LPV, and LNAV/VNAV operational service levels for the quarter. Figures 2.1 to 2.4 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 (no ionospheric corrections). Table 2. 3 shows NPA horizontal position accuracy for 95% and 99.999% of the time. Figures 2.5 shows the daily horizontal 95% accuracy for NPA.

During the evaluated period, the 95% horizontal and vertical accuracy at all evaluated sites are less than 7.6 meters for all WAAS operational service levels. The maximum horizontal and vertical LNAV/VNAV errors are 2.150 meters and 2.594 meters, both at Elko. The minimum horizontal and vertical LNAV/VNAV errors are 0.756 meters at Columbus and 1.216 meters at Oklahoma City, respectively. NPA 95% and 99.999% horizontal accuracy at all sites are less than 100 and 500 meters, respectively. The maximum 95% and 99.999% horizontal errors are 6.903 meters and 20.747 meters, both at Honolulu. The minimum 95% and 99.999% horizontal errors are 2.075 meters and 6.337 meters, both at Anchorage.

Figures 2.6 to 2.14 show the distributions of the vertical and horizontal errors in triangle charts and 2-D histogram plots for the quarter at three locations, Oklahoma 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 and the diagonal line shows the point where error equals protection level. Above and to the left in the chart, errors are bounded; below and to the right, errors are not bounded. 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 error 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 GLS (VAL=12m) (Meters)	Vertical APV-2 (VAL=20m) (Meters)	Vertical LPV/ VNAV (VAL=50m) (Meters)	Percentage in PA mode (%)
Anderson	0.905	0.919	*	1.348	1.344	99.991
Atlantic City	0.912	0.940	*	1.279	1.491	99.990
Bangor	1.899	1.952	*	*	2.436	99.966
Columbus	0.734	0.756	*	1.269	1.354	99.989
Dayton	1.956	1.973	*	2.360	2.589	99.990
Elko	2.132	2.150	*	1.882	2.594	99.997
Grand Forks	1.078	1.123	*	1.646	1.770	99.988
Great Falls	1.040	1.060	*	1.328	1.634	99.998
Greenwood	0.853	0.865	*	1.319	1.350	99.990
Oklahoma City	0.769	0.781	*	1.064	1.216	99.989
Albuquerque	0.927	0.939	*	0.998	1.190	99.998
Atlanta	0.842	0.860	*	1.159	1.259	99.983
Billings	0.945	0.961	*	1.315	1.493	99.990
Boston	0.948	0.985	*	0.757	1.539	99.980
Chicago	0.758	0.782	*	1.011	1.126	99.981
Cleveland	0.883	0.909	*	1.151	1.384	99.983
Dallas	0.868	0.882	*	1.152	1.569	99.982
Denver	0.766	0.779	*	1.350	1.432	99.990
Houston	0.852	0.864	*	1.373	1.447	99.982
Jacksonville	0.918	0.935	*	1.209	1.324	99.983
Kansas City	0.763	0.778	*	1.053	1.132	99.982
Los Angeles	1.225	1.263	*	1.295	1.782	99.992
Memphis	0.813	0.831	*	1.076	1.249	99.981
Miami	1.022	1.045	*	0.908	1.542	99.983
Minneapolis	1.083	1.116	*	1.635	1.917	99.981
New York	0.873	0.909	*	1.159	1.336	99.983
Oakland	1.020	1.044	*	1.383	2.003	99.991
Salt Lake City	0.775	0.786	*	1.077	1.330	99.991
Seattle	1.047	1.059	*	1.054	1.628	99.990
Washington DC	0.930	0.953	*	1.187	1.329	99.983

* No data available at this operational service level

Table 2.3 NPA 95% and 99.999% Horizontal Accuracy

Location	95% Horizontal (meters)	99.999% Horizontal (meters)	Percentage in NPA mode (%)
Bangor	2.561	8.682	99.989
Albuquerque	4.540	8.544	99.999
Anchorage	2.075	6.337	99.713
Atlanta	3.268	15.179	99.983
Billings	2.972	12.191	99.992
Boston	2.347	10.738	99.984
Cleveland	3.078	15.871	99.984
Cold Bay	2.386	9.567	99.714
Honolulu	6.903	20.747	99.681
Houston	4.069	8.995	99.983
Juneau	2.076	8.672	99.715
Kansas City	3.112	19.104	99.984
Los Angeles	4.476	10.111	99.992
Miami	3.958	10.954	99.984
Minneapolis	3.116	13.215	99.983
Oakland	3.914	8.840	99.992
Puerto Rico	3.970	15.230	99.982
Salt Lake City	3.204	10.498	99.991
Seattle	2.622	8.7870	99.992
Washington DC	3.094	16.094	99.983

Figure 2.1 95% Horizontal Accuracy at LNAV/VNAV

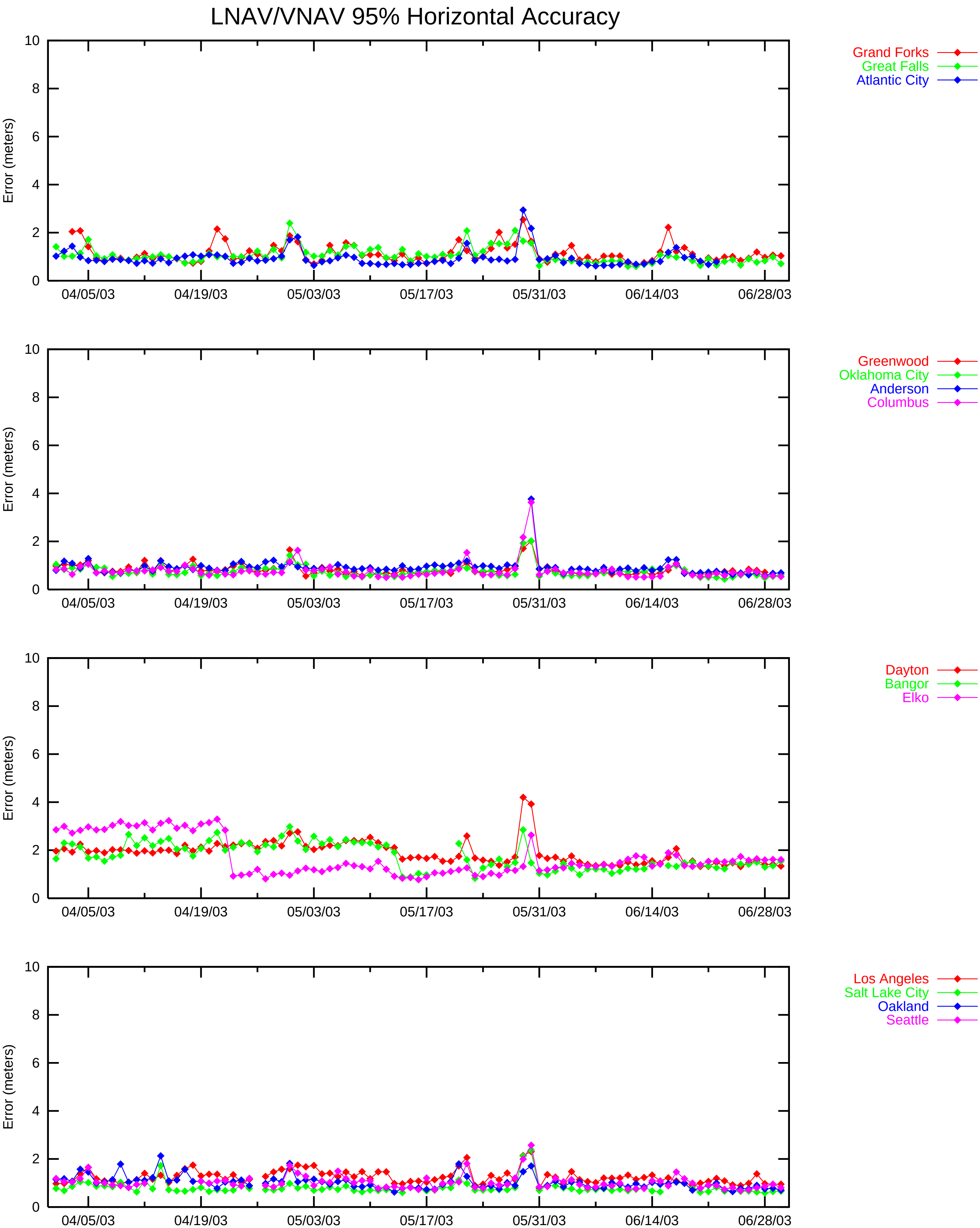


Figure 2.2 95% Horizontal Accuracy at LNAV/VNAV

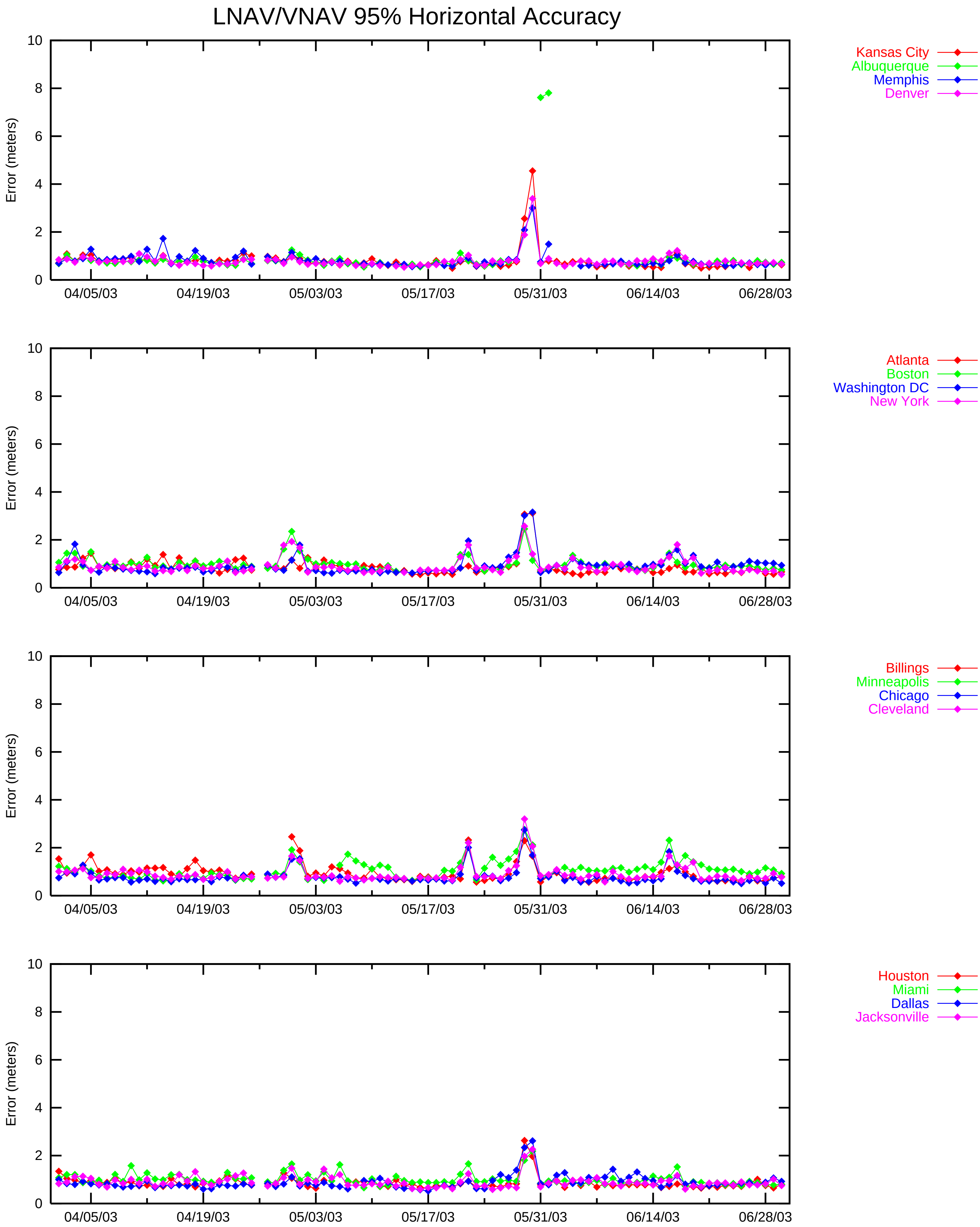


Figure 2.3 95% Vertical Accuracy at LNAV/VNAV

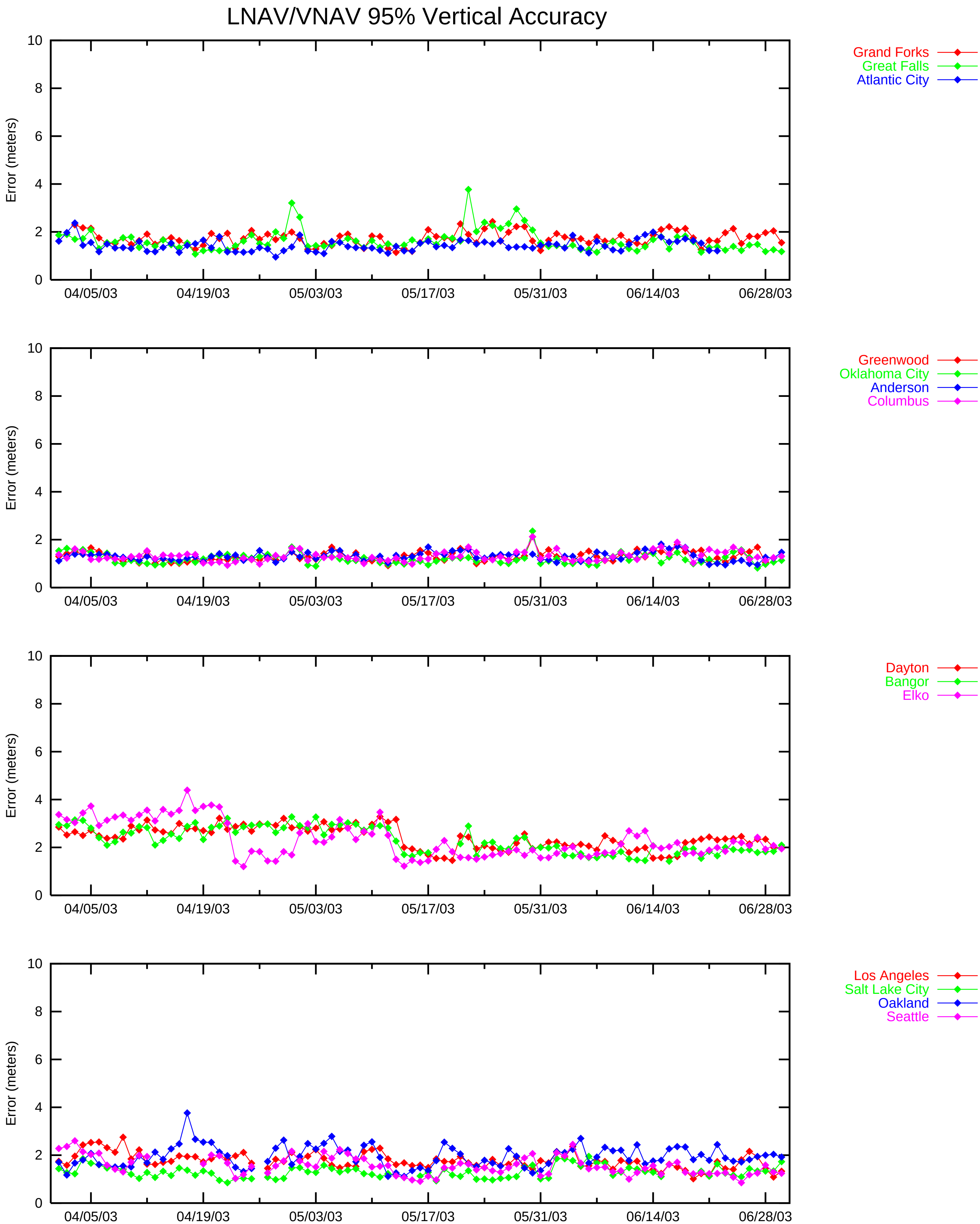


Figure 2.4 95% Vertical Accuracy at LNAV/VNAV

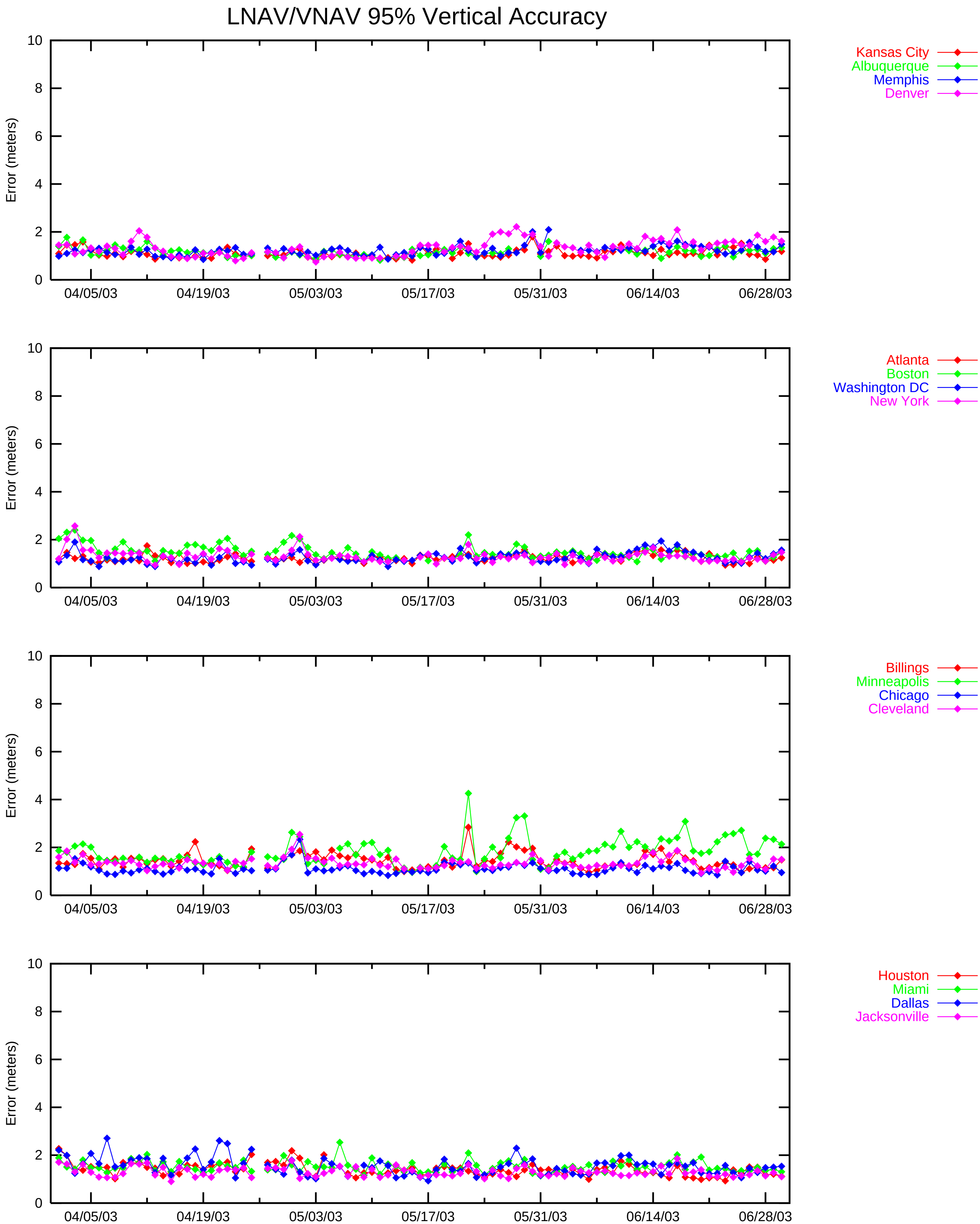


Figure 2.5 NPA 95% Horizontal Accuracy

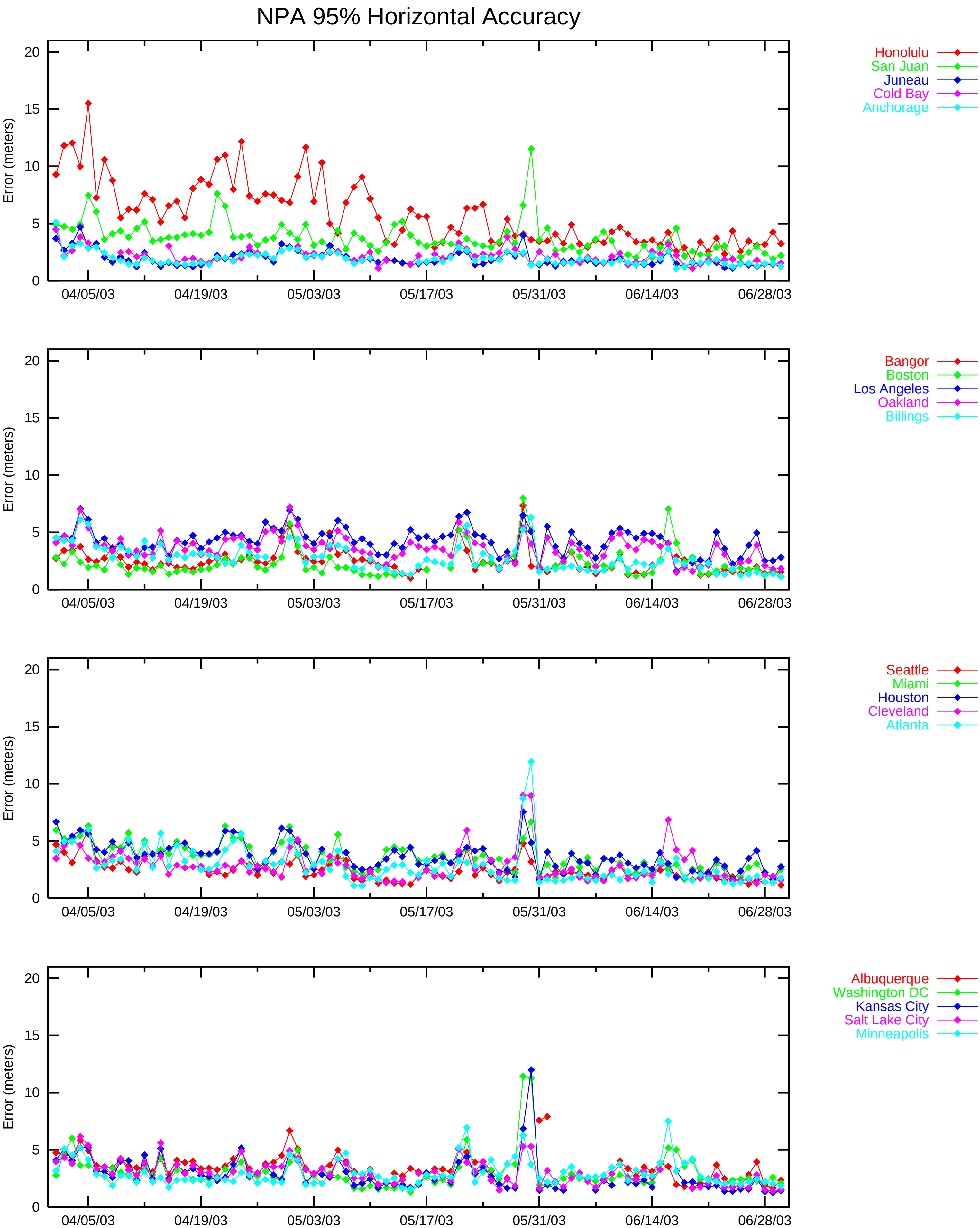
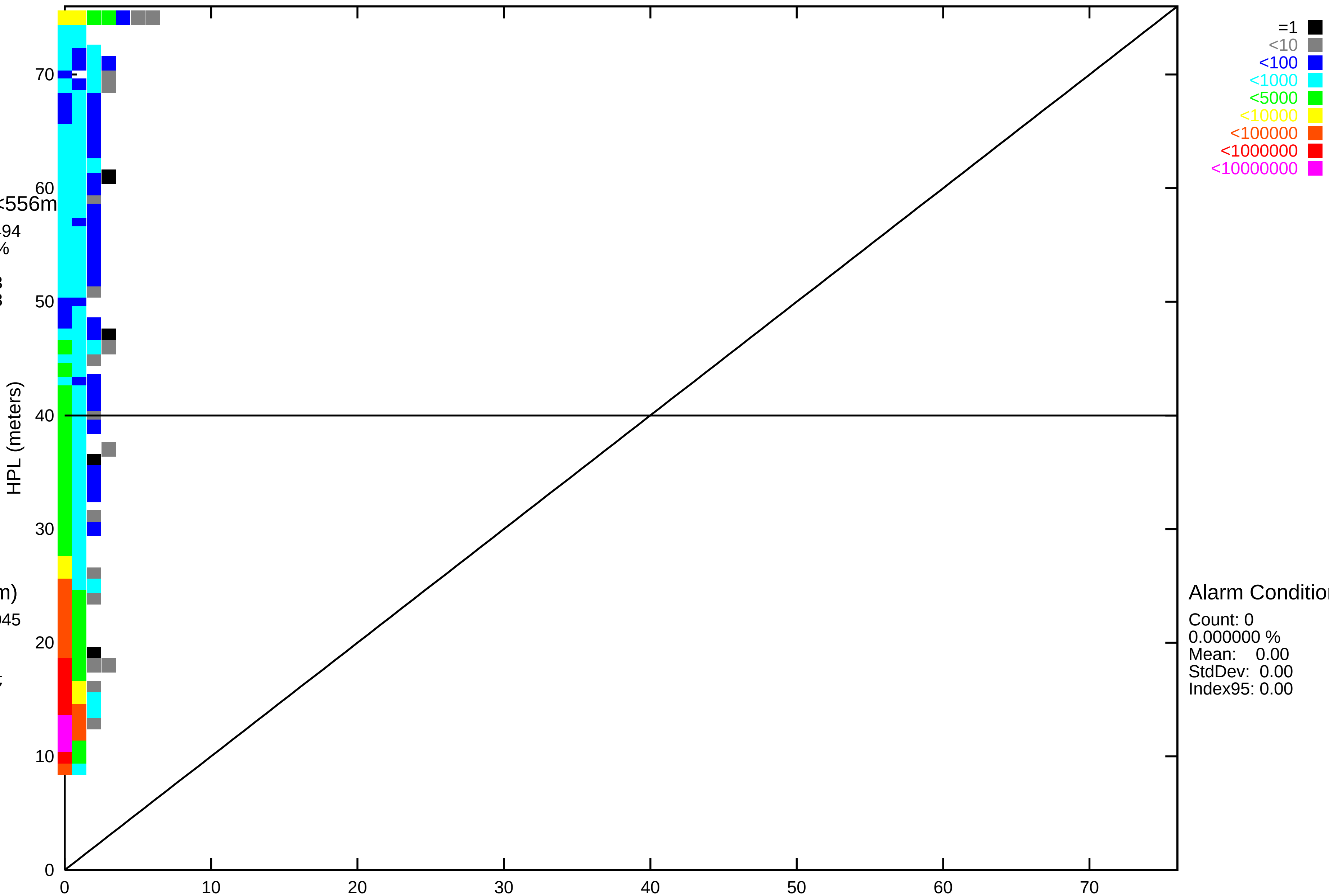


Figure 2.6 Horizontal Triangle Chart for Oklahoma City

Site: Oklahoma_City Date: 04/01/03-06/30/03

PA mode Unavailable(>556m)
Count: 0
0.000000 %
Mean: 0.00
StdDev: 0.00
Index95: 0.00

HPE vs HPL 3D PA Histogram



All Modes
L/VNAV(=<556m)
Count: 7858494
100.000000 %
Mean: 0.38
StdDev: 0.23
Index95: 0.78

LPV(=<40m)
Count: 7812045
99.408928 %
Mean: 0.37
StdDev: 0.21
Index95: 0.77

Alarm Condition
Count: 0
0.000000 %
Mean: 0.00
StdDev: 0.00
Index95: 0.00

Samples: 7858494
Mean: 0.38
StdDev: 0.23
Index95: 0.78

PA Samples: 7857628
Mean: 0.38
StdDev: 0.23
Index95: 0.78

Not PA Samples: 866
Mean: 1.96
StdDev: 1.00
Index95: 3.82

Figure 2.7 Vertical Triangle Chart for Oklahoma City

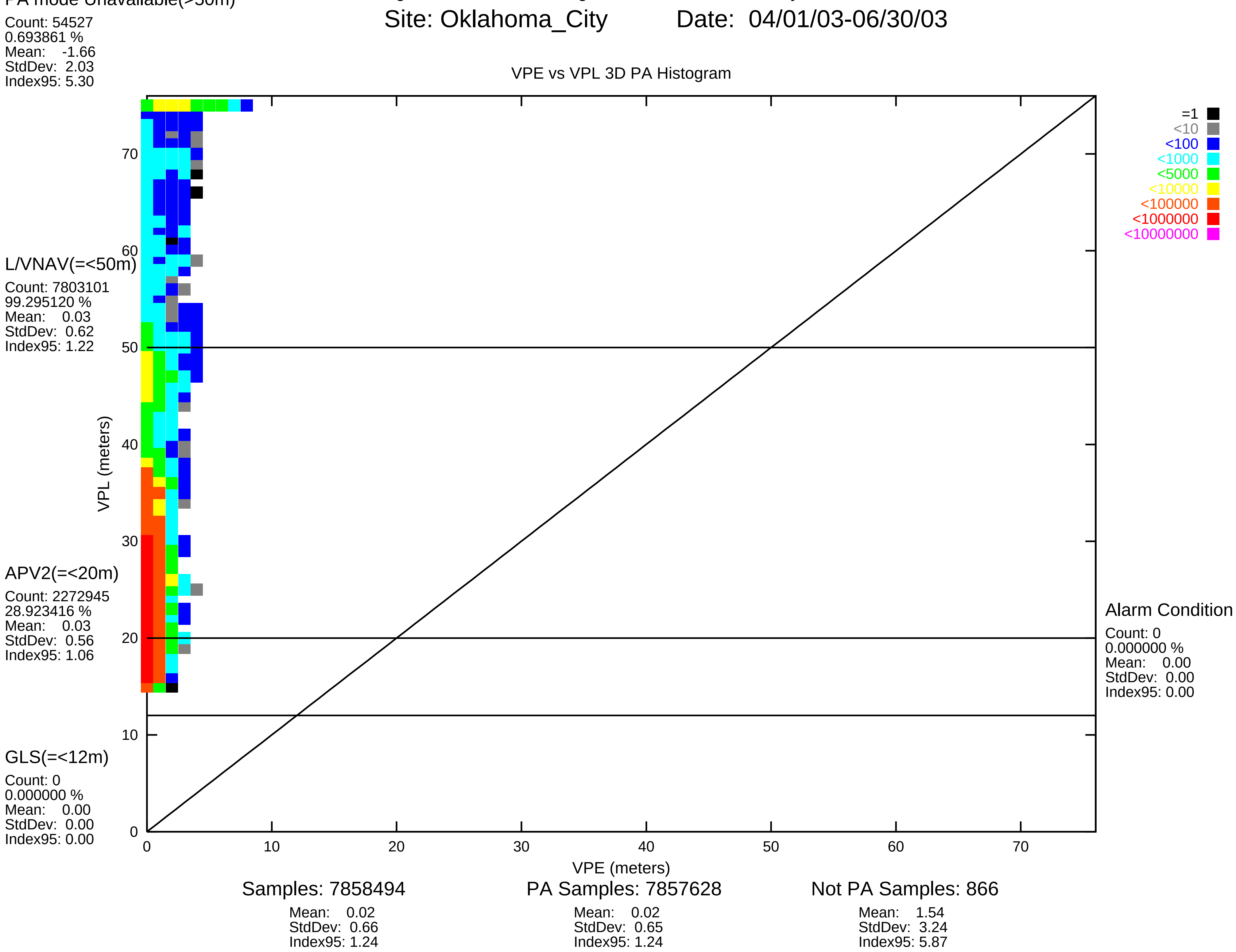


Figure 2.8 2-D Histogram for Oklahoma City

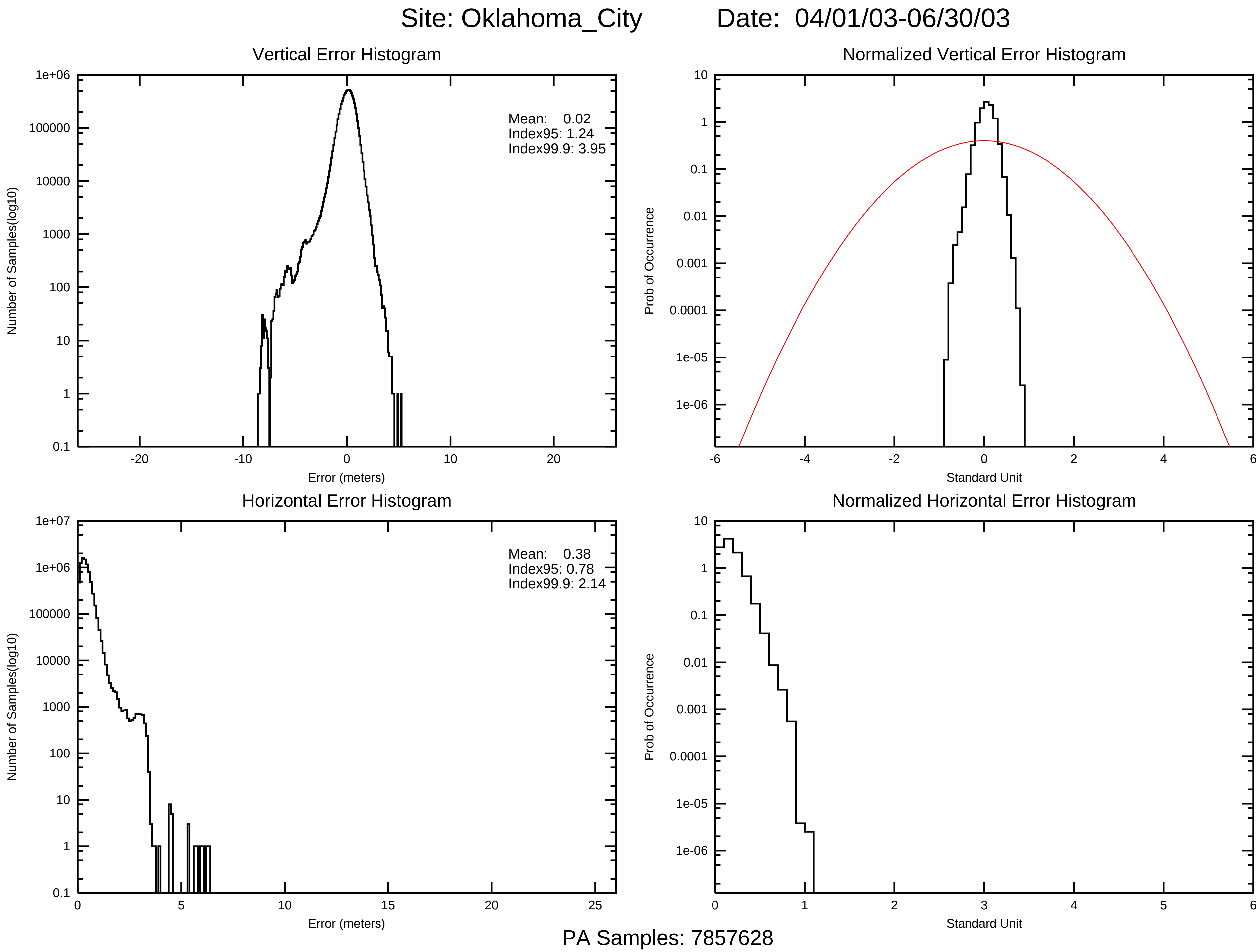


Figure 2.9 Horizontal Triangle Chart for Washington, DC

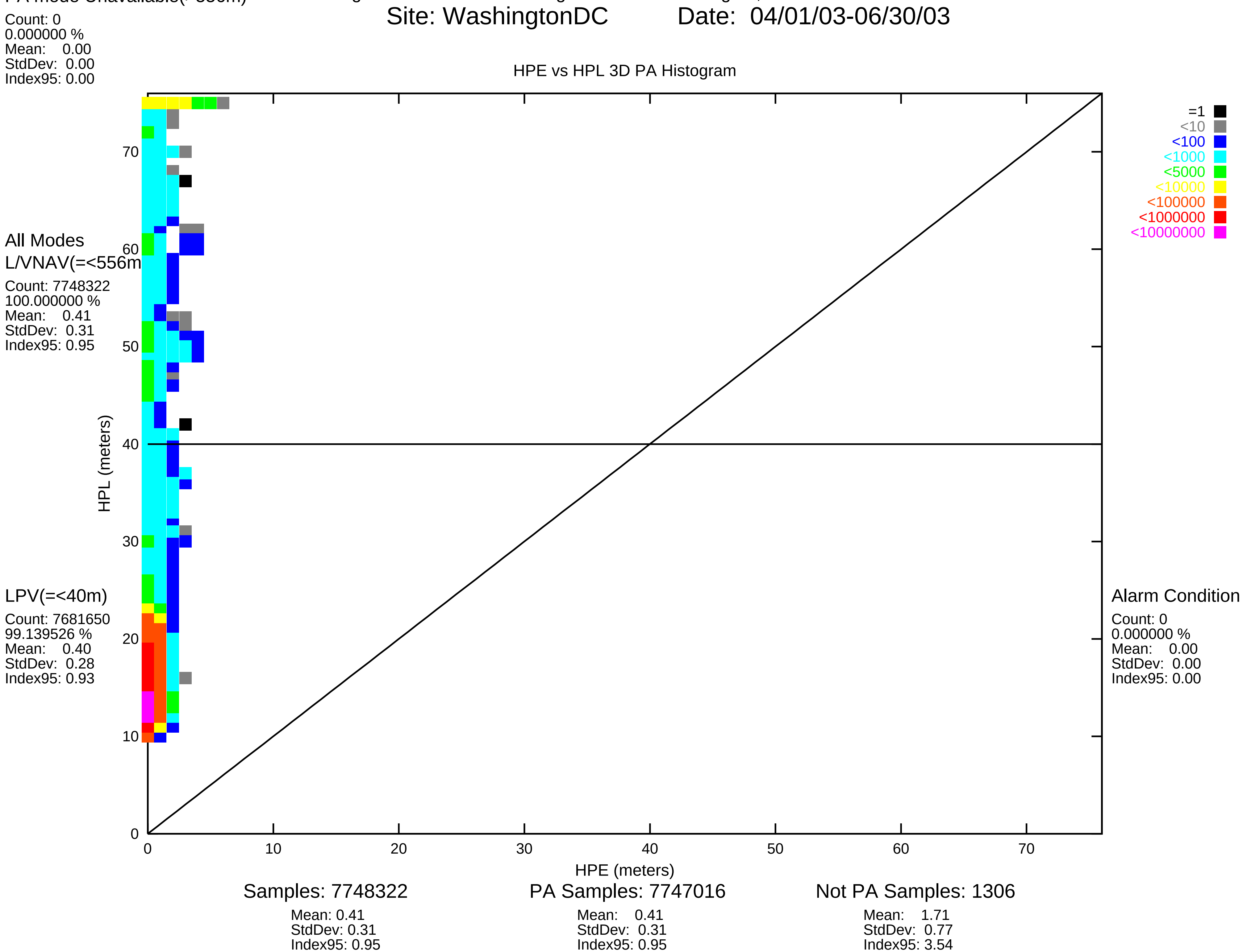


Figure 2.10 Vertical Triangle Chart for Washington, DC

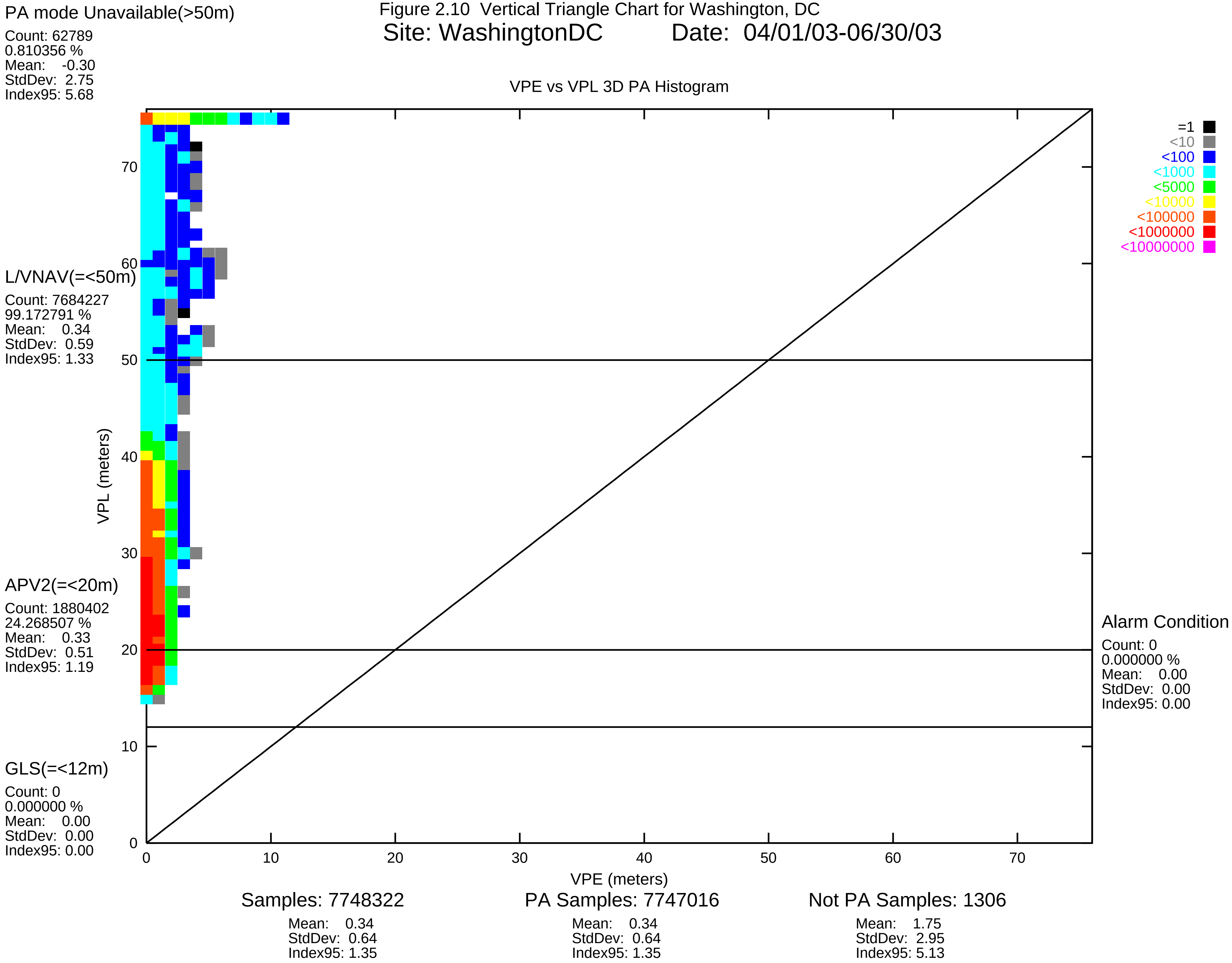
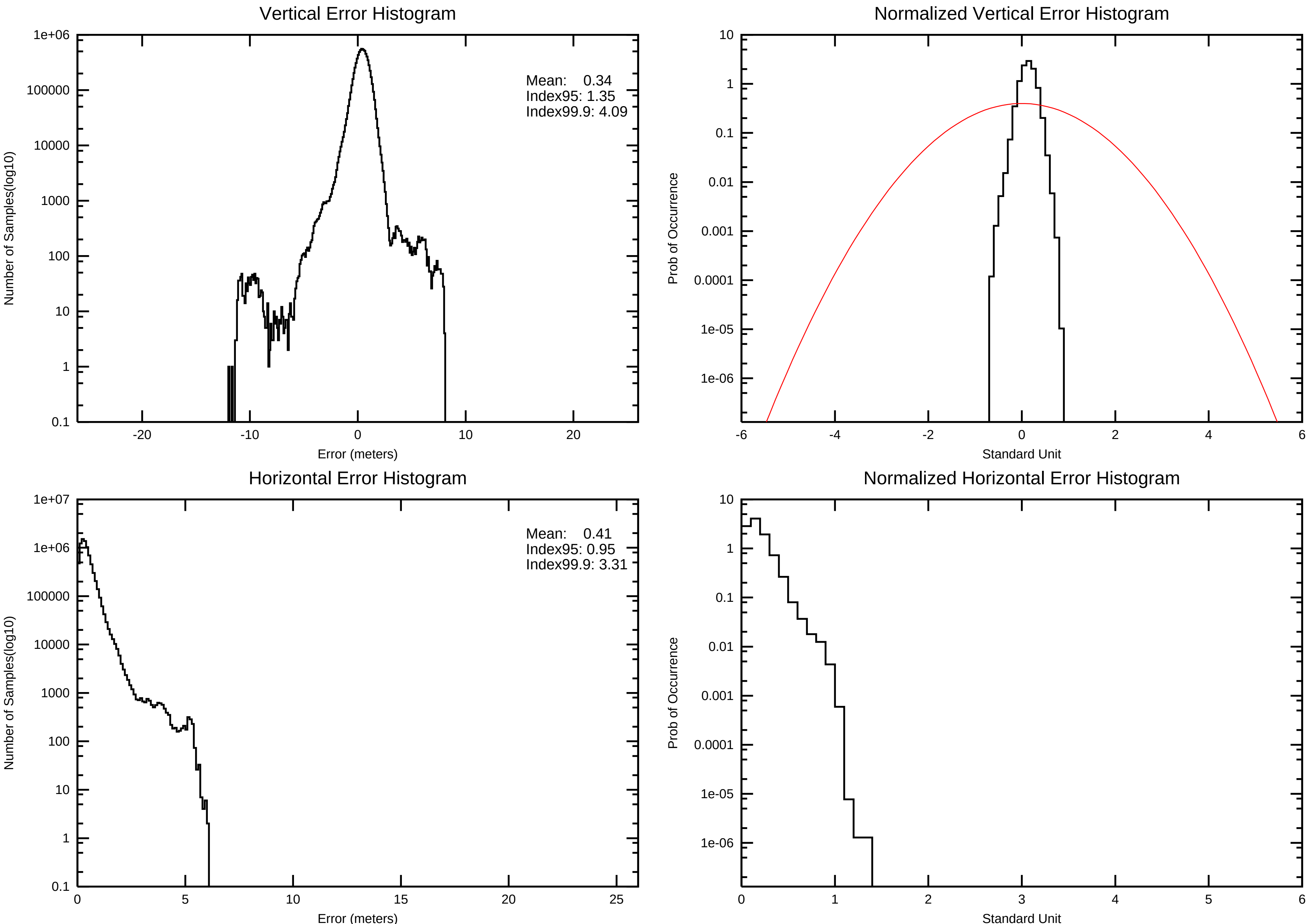


Figure 2.11 2-D Histogram for Washington, DC

Site: WashingtonDC Date: 04/01/03-06/30/03



PA Samples: 7747016

Figure 2.12 Horizontal Triangle Chart for Seattle

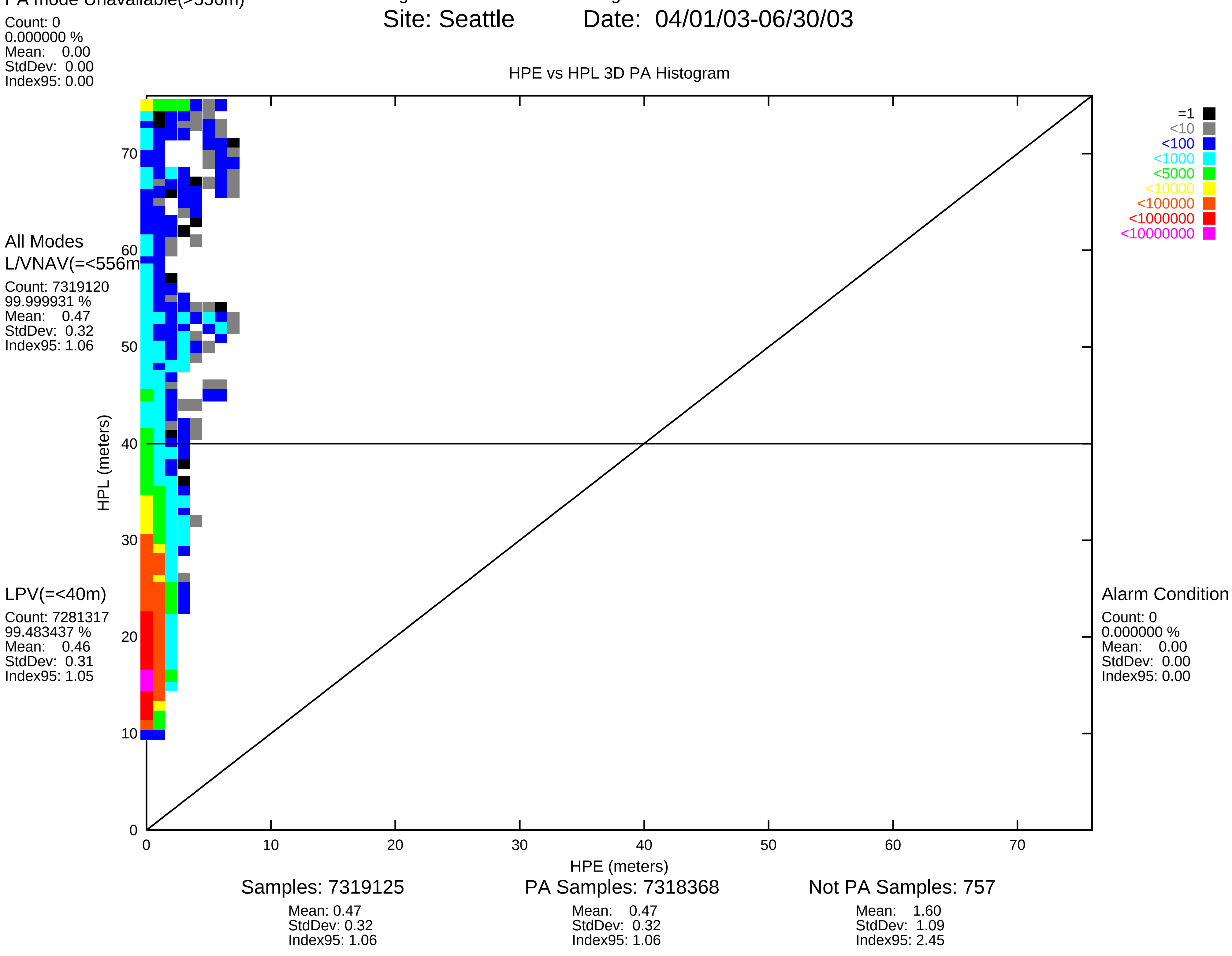


Figure 2.13 Vertical Triangle Chart for Seattle

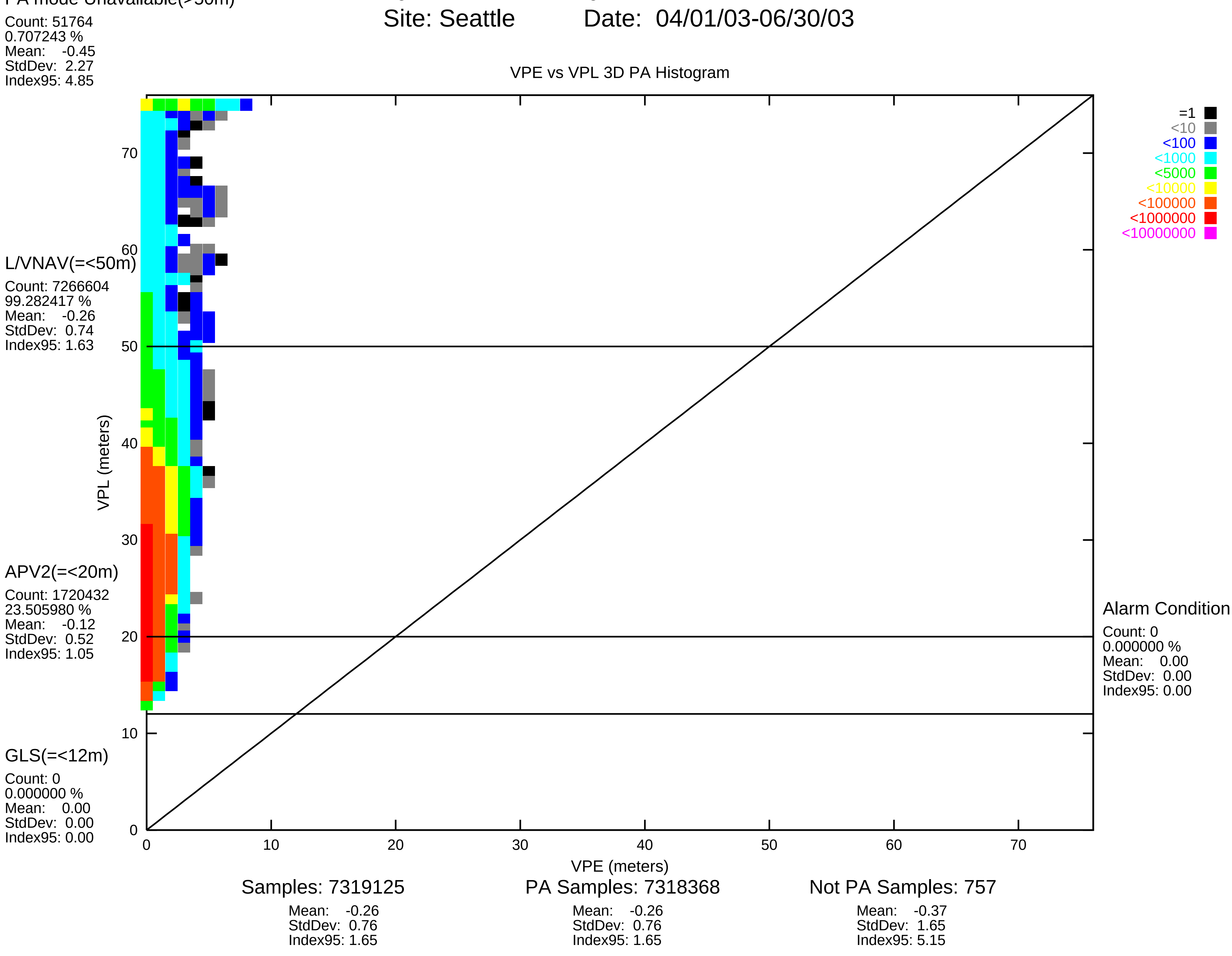
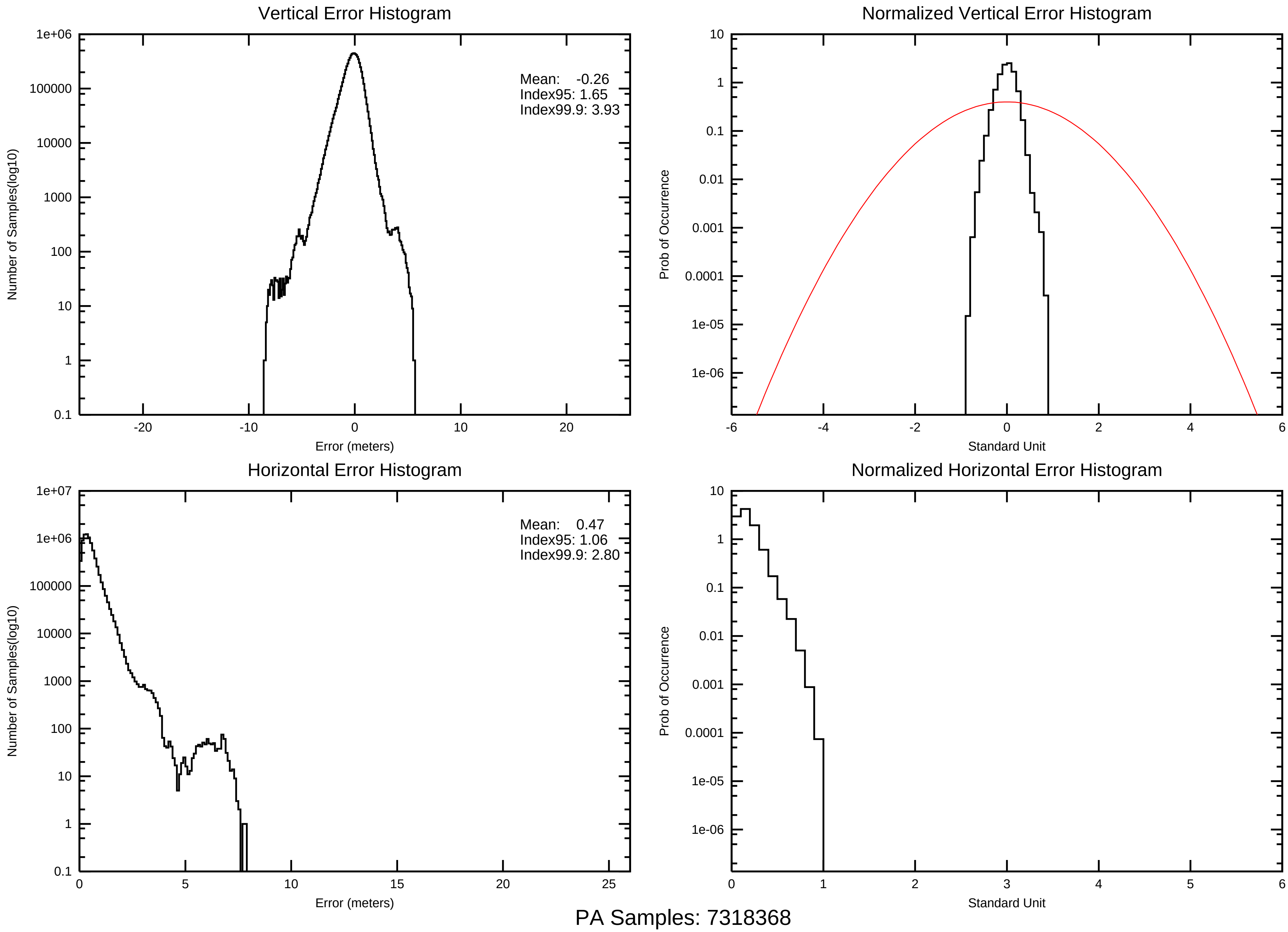


Figure 2.14 2-D Histogram for Seattle

Site: Seattle   Date: 04/01/03-06/30/03



3.0 Availability

WAAS availability evaluation estimates the probability that the WAAS can provide Operational Service Levels (GLS, APV-2, LPV, and APV-1(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 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. Table 3.2 presents the percentage of time that WAAS operational service levels were available at each receiver location. Figure 3.1 and 3.4 show the daily instantaneous availability of LNAV/VNAV and LPV service levels for the evaluated period.

The geographic location of each receiver evaluated is depicted in Figure 3.5 and 3.6, along with the 95% VPL value, the WAAS LPV and APV-1(LNAV/VNAV) instantaneous availability percentage at each location for the quarter.

Table 3.1 95% Protection Level

Location	95% HPL (meters)	95% VPL (meters)	Percentage in PA mode
Anderson	18.105	30.833	99.991
Atlantic City	21.802	36.791	99.990
Bangor	34.566	55.617	99.966
Columbus	18.446	31.166	99.989
Dayton	18.811	31.507	99.990
Elko	23.971	37.378	99.997
Grand Forks	26.918	40.583	99.988
Great Falls	27.905	41.777	99.998
Greenwood	17.233	29.733	99.990
Oklahoma City	19.025	31.997	99.989
Albuquerque	21.587	33.749	99.998
Atlanta	17.369	30.664	99.983
Billings	21.252	30.532	99.990
Boston	26.125	42.669	99.980
Chicago	17.548	28.781	99.981
Cleveland	19.095	31.229	99.983
Dallas	19.085	32.839	99.982
Denver	18.647	29.917	99.990
Houston	22.295	35.378	99.982
Jacksonville	18.112	33.950	99.983
Kansas City	16.512	28.547	99.982
Los Angeles	30.855	45.872	99.992
Memphis	16.658	29.404	99.981
Miami	23.670	44.605	99.983
Minneapolis	19.886	31.609	99.981
New York	22.290	37.700	99.983
Oakland	30.681	45.357	99.991
Salt Lake City	20.288	30.997	99.991
Seattle	24.527	34.207	99.990
Washington DC	18.976	32.600	99.983

Table 3.2 Instantaneous Availability Statistics

Location	GLS (HAL = 40m VAL = 12m) Percentage of time	APV-2 (HAL = 40m VAL = 20m) Percentage of time	LPV (HAL = 40m VAL = 50m) Percentage of time	LNAV/VNAV (HAL= 556m VAL = 50m) Percentage of time
Anderson	*	27.763	99.485	99.510
Atlantic City	*	6.397	98.878	99.031
Bangor	*	*	90.209	90.357
Columbus	*	40.537	98.888	99.248
Dayton	*	23.519	99.316	99.382
Elko	*	16.069	99.037	99.230
Grand Forks	*	9.613	97.343	97.545
Great Falls	*	12.634	98.721	98.810
Greenwood	*	24.714	99.477	99.501
Oklahoma City	*	28.923	99.160	99.295
Albuquerque	*	20.570	99.531	99.654
Atlanta	*	24.672	99.462	99.466
Billings	*	34.397	99.335	99.336
Boston	*	0.016	97.983	98.032
Chicago	*	42.365	99.118	99.202
Cleveland	*	27.892	99.223	99.281
Dallas	*	20.180	99.356	99.381
Denver	*	44.877	99.288	99.431
Houston	*	6.046	99.246	99.254
Jacksonville	*	9.197	99.462	99.483
Kansas City	*	49.179	99.241	99.289
Los Angeles	*	4.011	96.752	97.616
Memphis	*	27.307	99.285	99.370
Miami	*	0.009	97.875	97.961
Minneapolis	*	30.722	98.984	99.135
New York	*	2.607	98.863	98.920
Oakland	*	5.497	96.728	97.155
Salt Lake City	*	36.302	99.532	99.580
Seattle	*	23.491	99.166	99.282
Washington DC	*	24.269	99.062	99.173

* No data is available at this operational service level.

During the evaluated period, the maximum 95% HPL and VPL are 34.566 meters and 55.617 meters, both at Bangor. The minimum 95% HPL and VPL are 16.512 meters and 28.547 meters, both at Kansas City. LNAV/VNAV instantaneous availability ranges between 90.357% and 99.654%. LPV instantaneous availability ranges between 90.209% and 99.532%.

Figure 3.1 LNAV/VNAV Instantaneous Availability

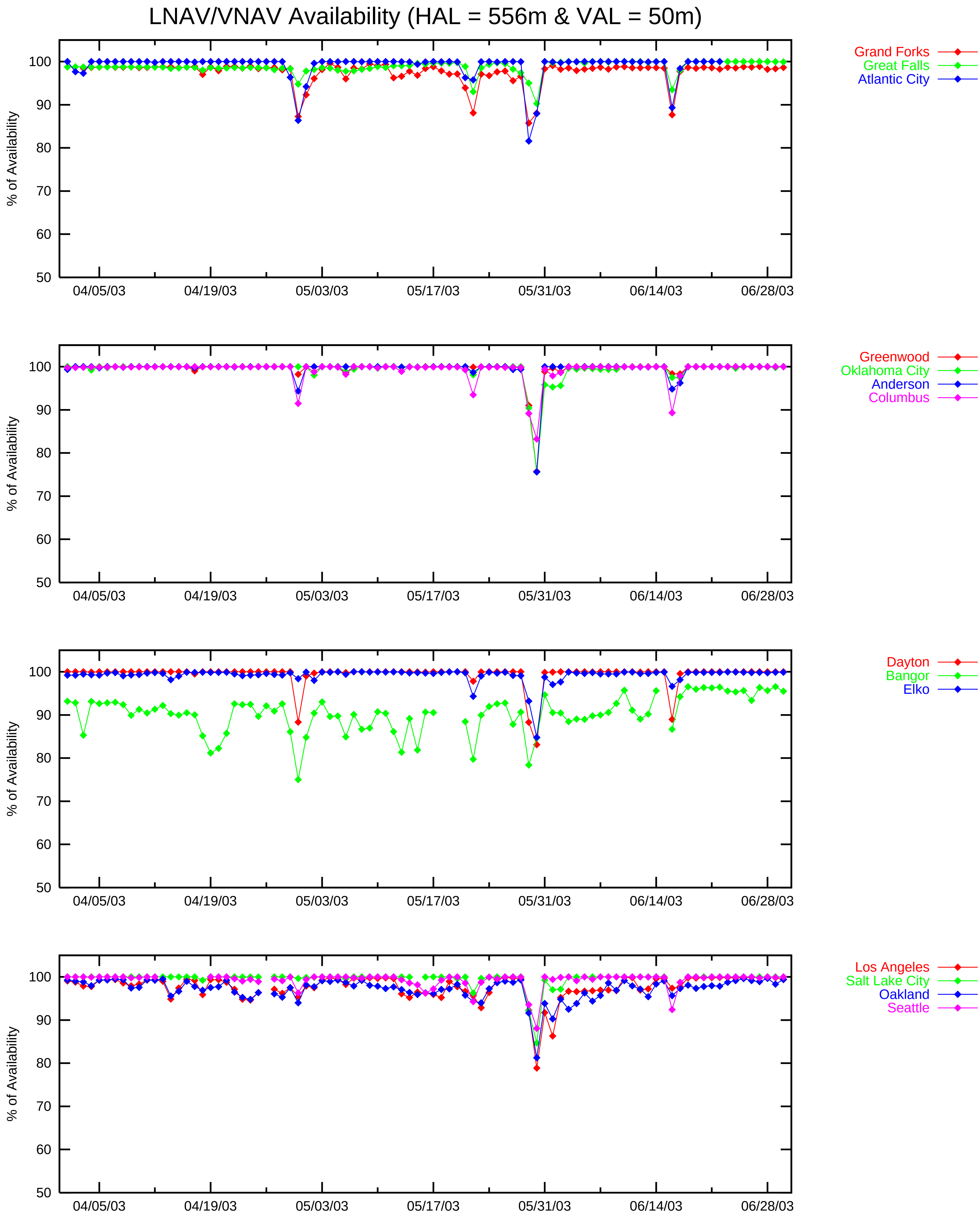


Figure 3.2 LNAV/VNAV Instantaneous Availability

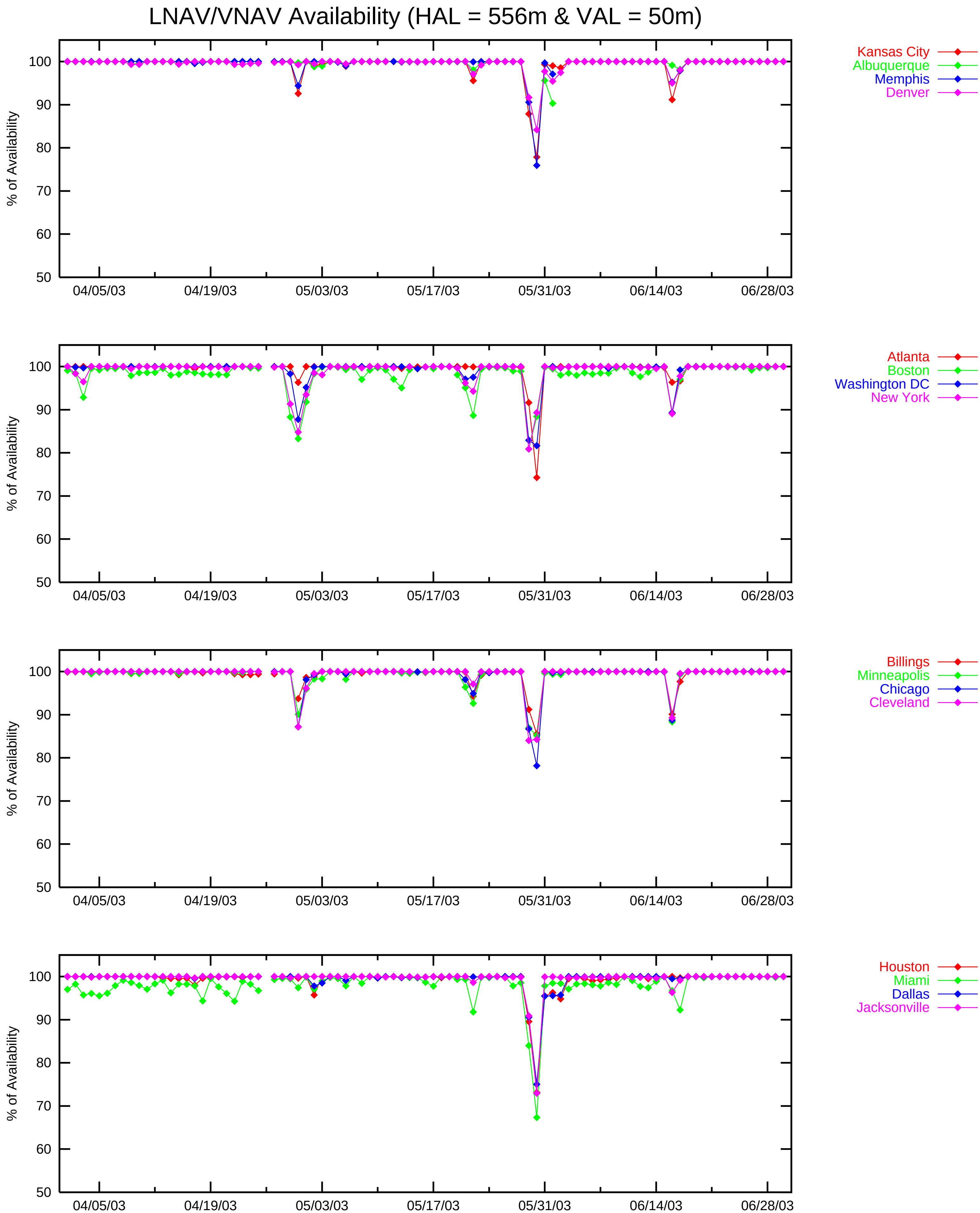
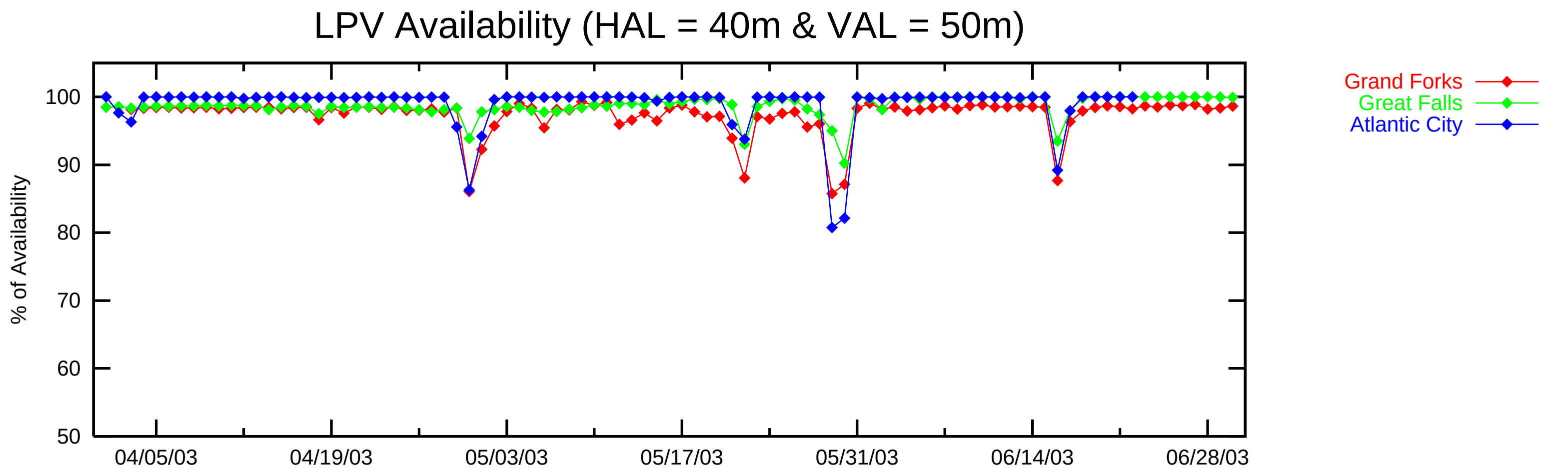
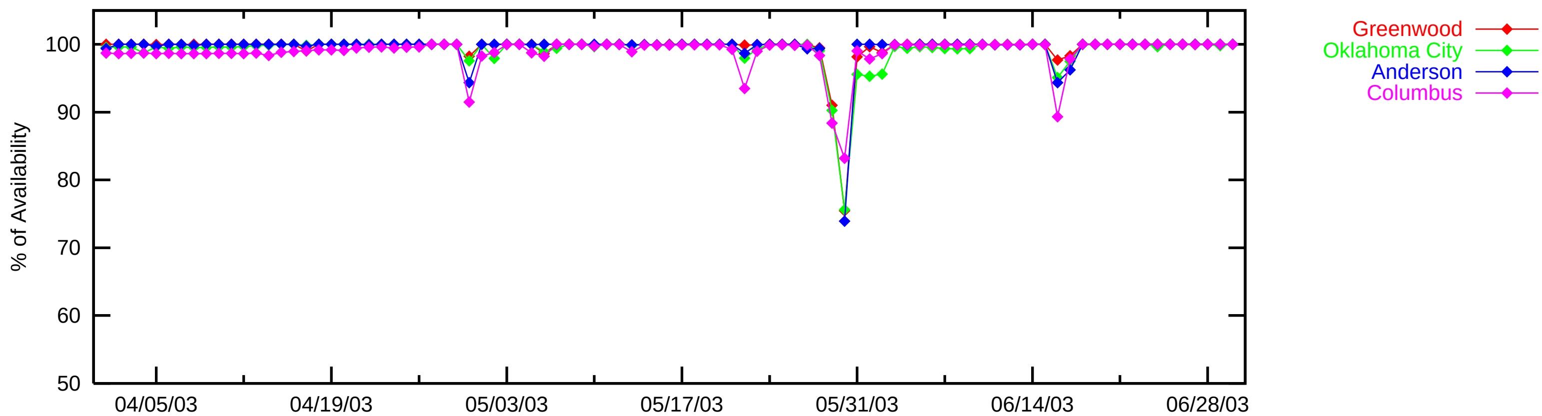
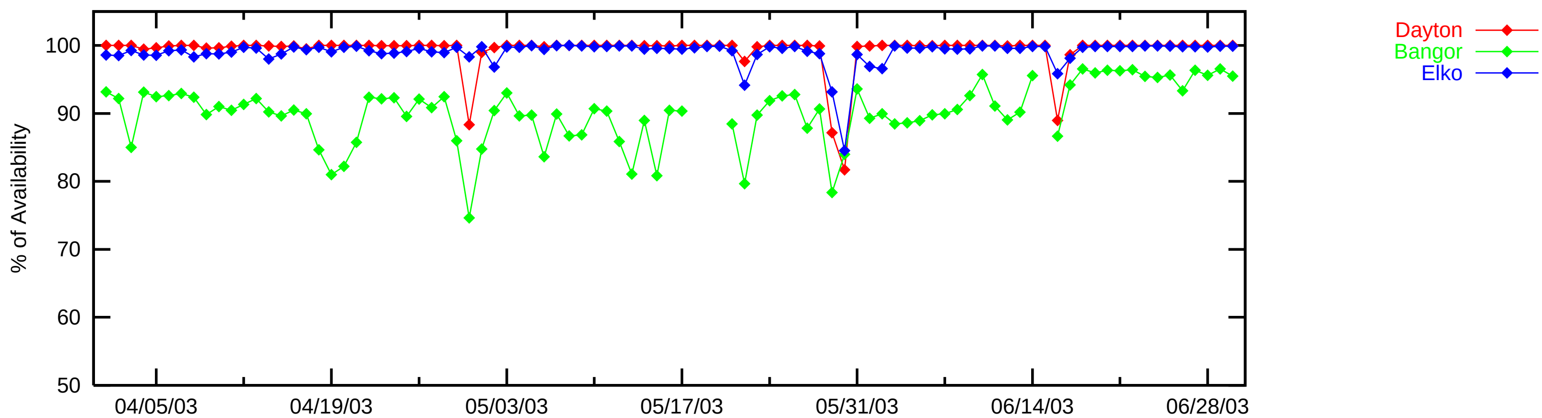


Figure 3.3 LPV Instantaneous Availability







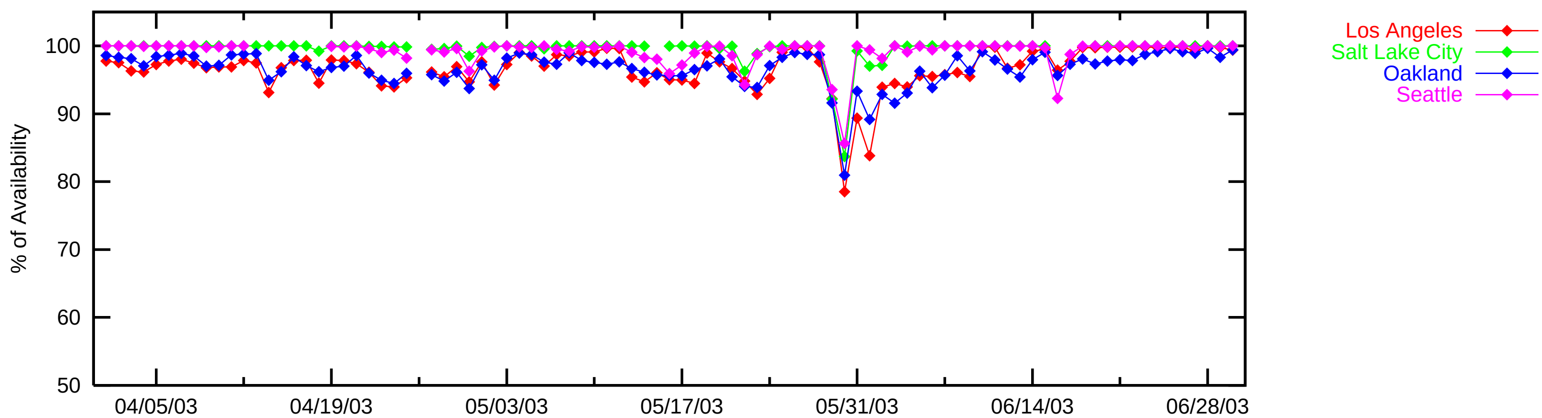


Figure 3.4 LPV Instantaneous Availability

LPV Availability (HAL = 40m & VAL = 50m)

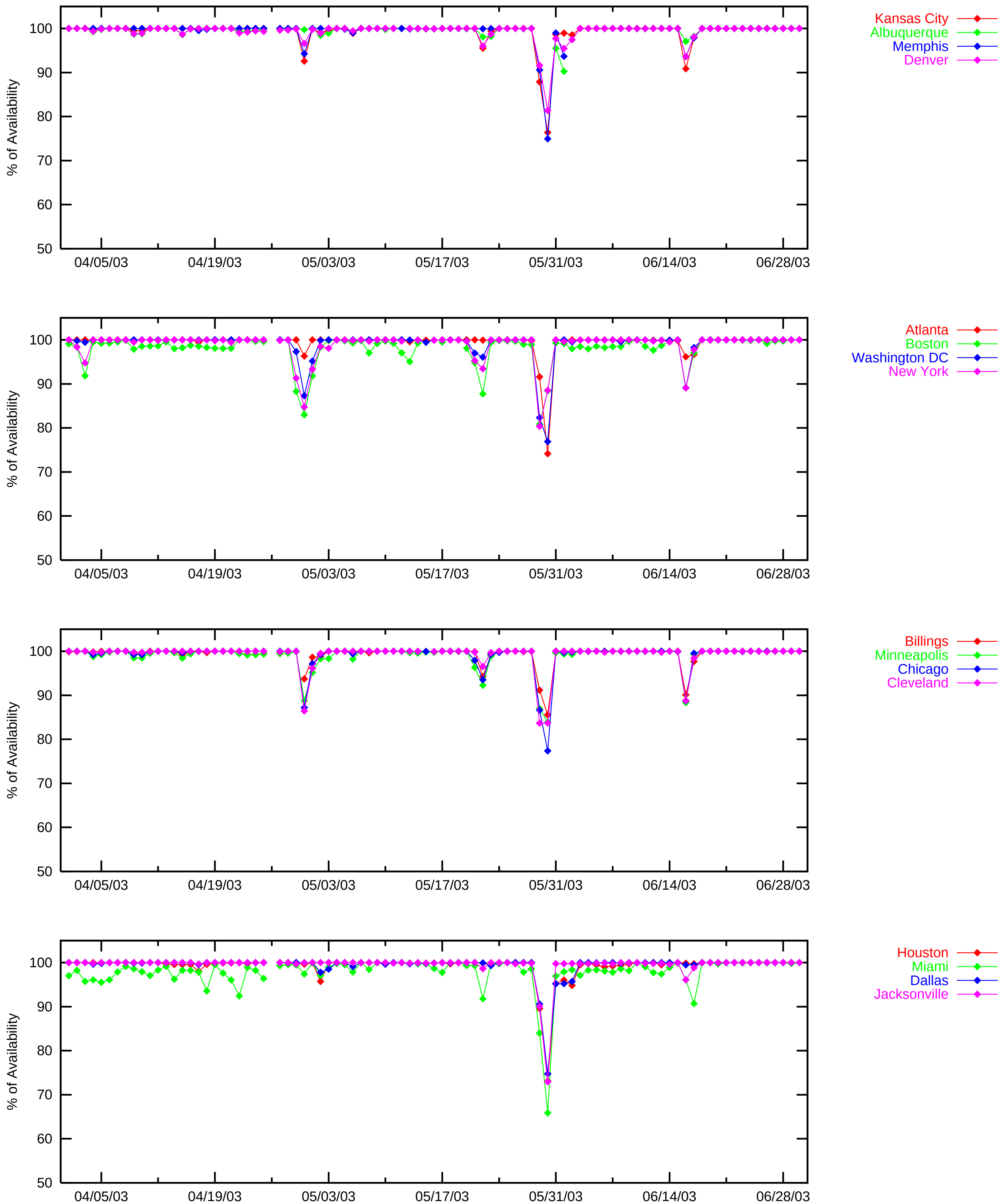


Figure 3.5 95% VPL , LPV and LNAV/VNAV Availability – NSTB sites

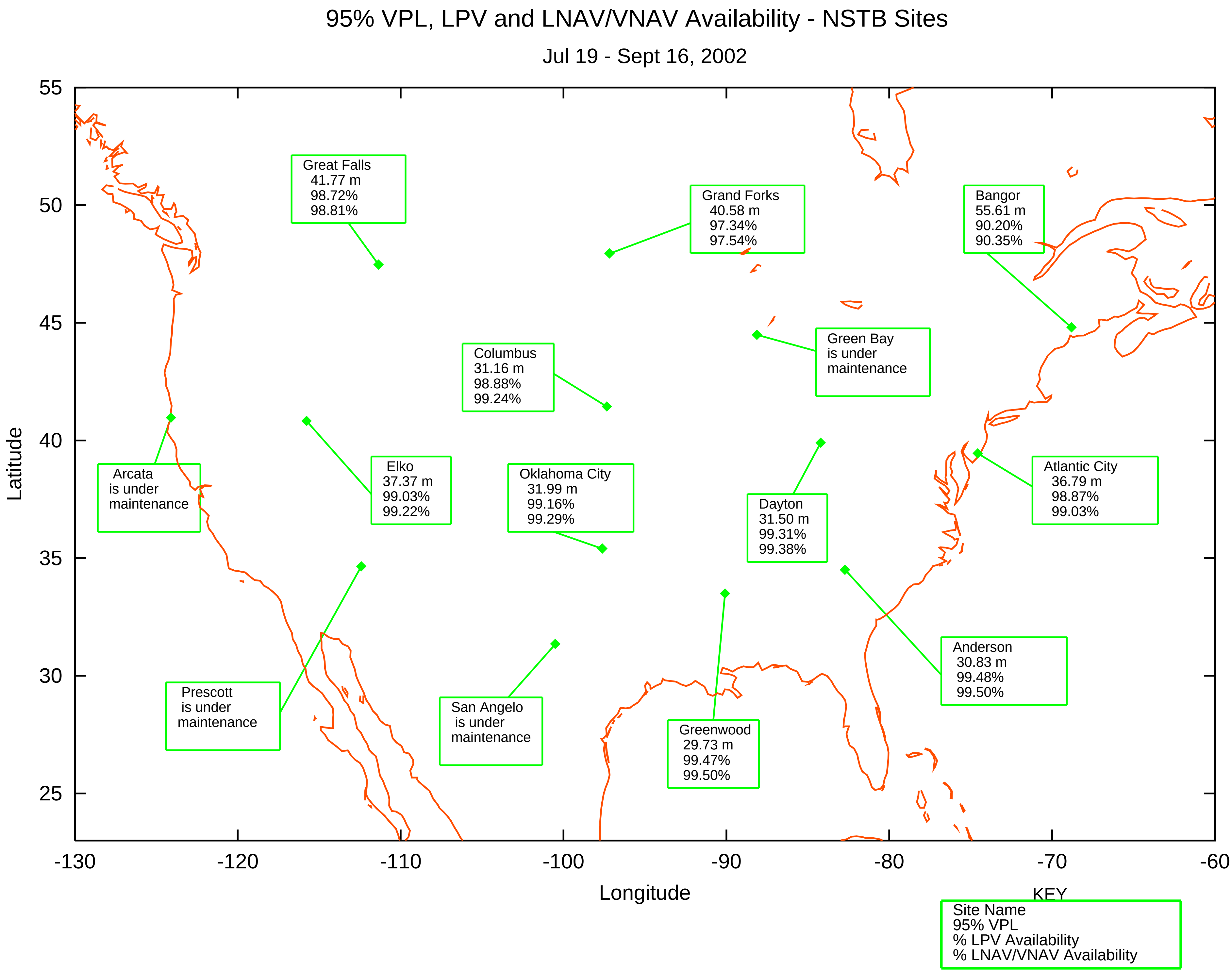
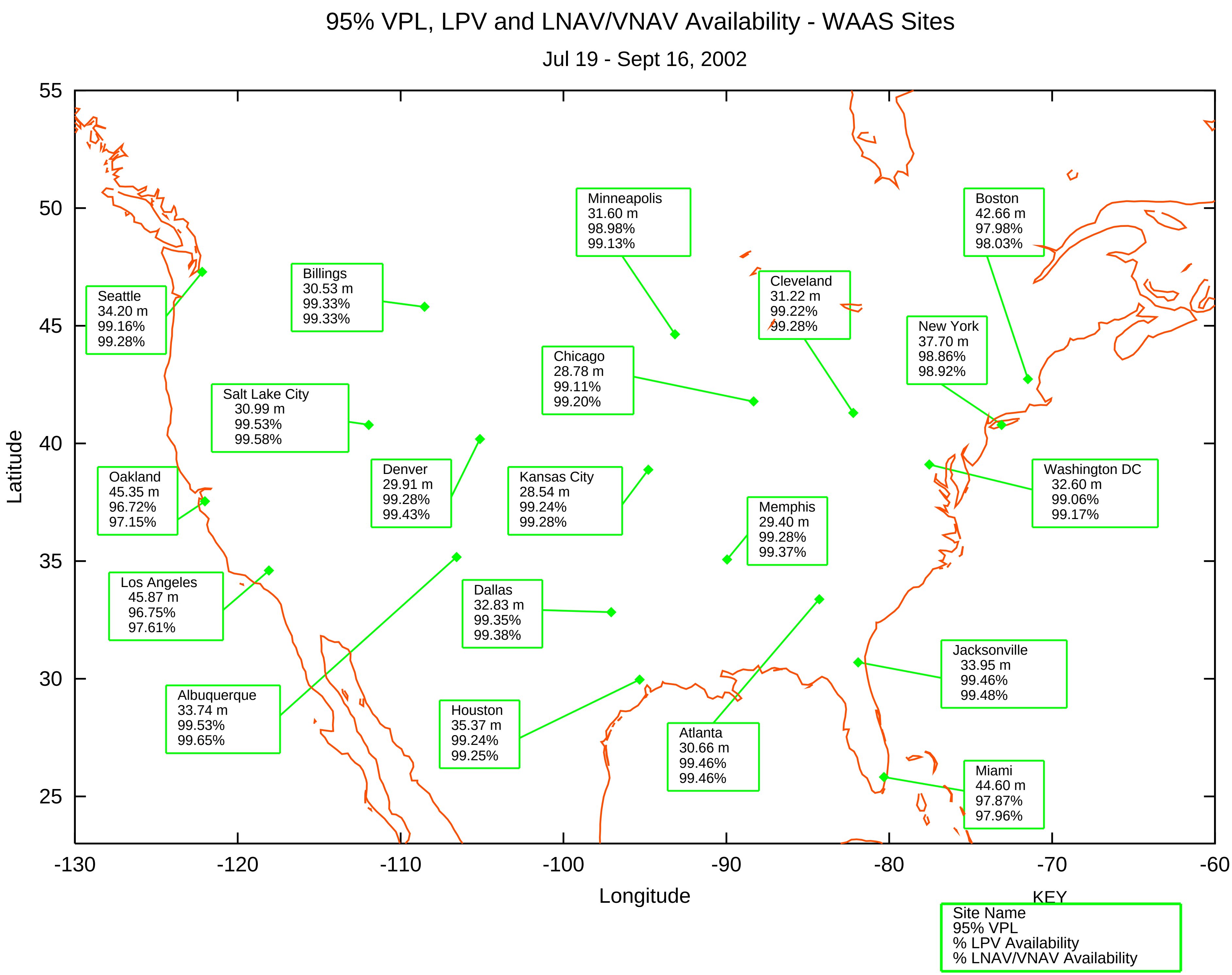


Figure 3.6 95% VPL , LPV and LNAV/VNAV Availability – WAAS sites



4.0 Coverage

WAAS Coverage area evaluation estimates the percent of CONUS where WAAS is providing LPV, 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 PA service volume, while NPA coverage was calculated at two-minute intervals and five degree spacing over NPA service volume.

Figures 4.1 to 4.3 show the WAAS LNAV/VNAV coverage area of each month for this quarter. Figures 4.4 to 4.6 show the WAAS LPV coverage area of each month for this quarter. Figures 4.7 to 4.9 show the NPA coverage area of each month for this quarter. Daily analysis for PA was based on both LPV and LNAV/VNAV service level requirements and on a 95% requirement. This means that the percentage of the service volume wherein the service levels were maintained for at least 95% of each day was reported as the coverage statistic for each of these service levels. The coverage plots included in this section also provide 99, 95, 75 and 50% contours to illustrate how much of the service volume was available for these percentages of the day. Figure 4.10 shows the daily WAAS LNAV/VNAV and LPV coverage and Ionospheric Storm Kp index values for this quarter. Drops in LPV and LNAV/VNAV coverage on April 30, May 22, May 29, May 30 and June 16 are caused by ionospheric activity. Figure 4.11 shows the daily NPA coverage and Ionospheric Storm Kp index values for this quarter. Drops in NPA coverage on May 9 and May 12-15 are caused by POR SIS outages.

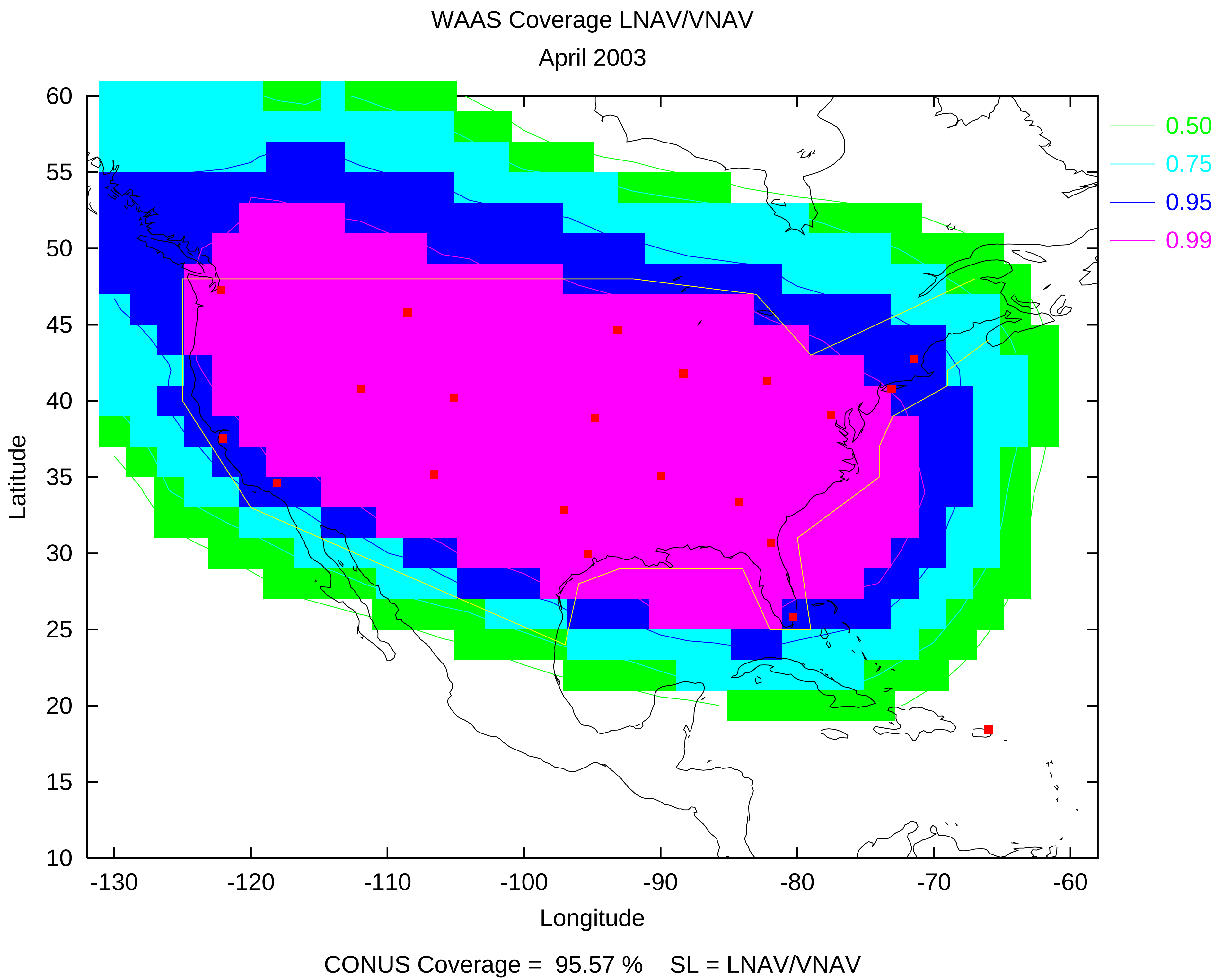


Figure 4.1 WAAS LNAV/VNAV Coverage - April

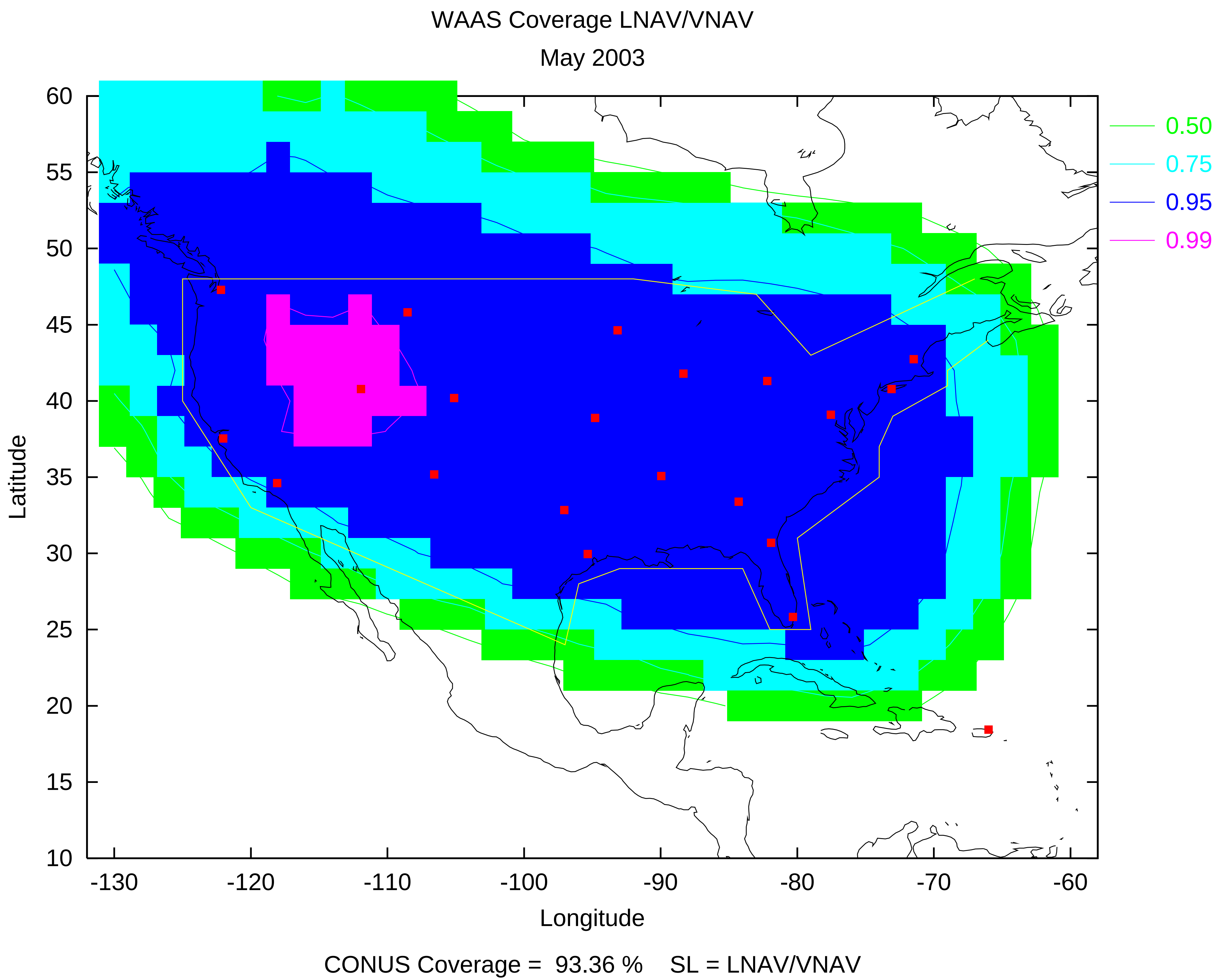


Figure 4.2 WAAS LNAV/VNAV Coverage - May

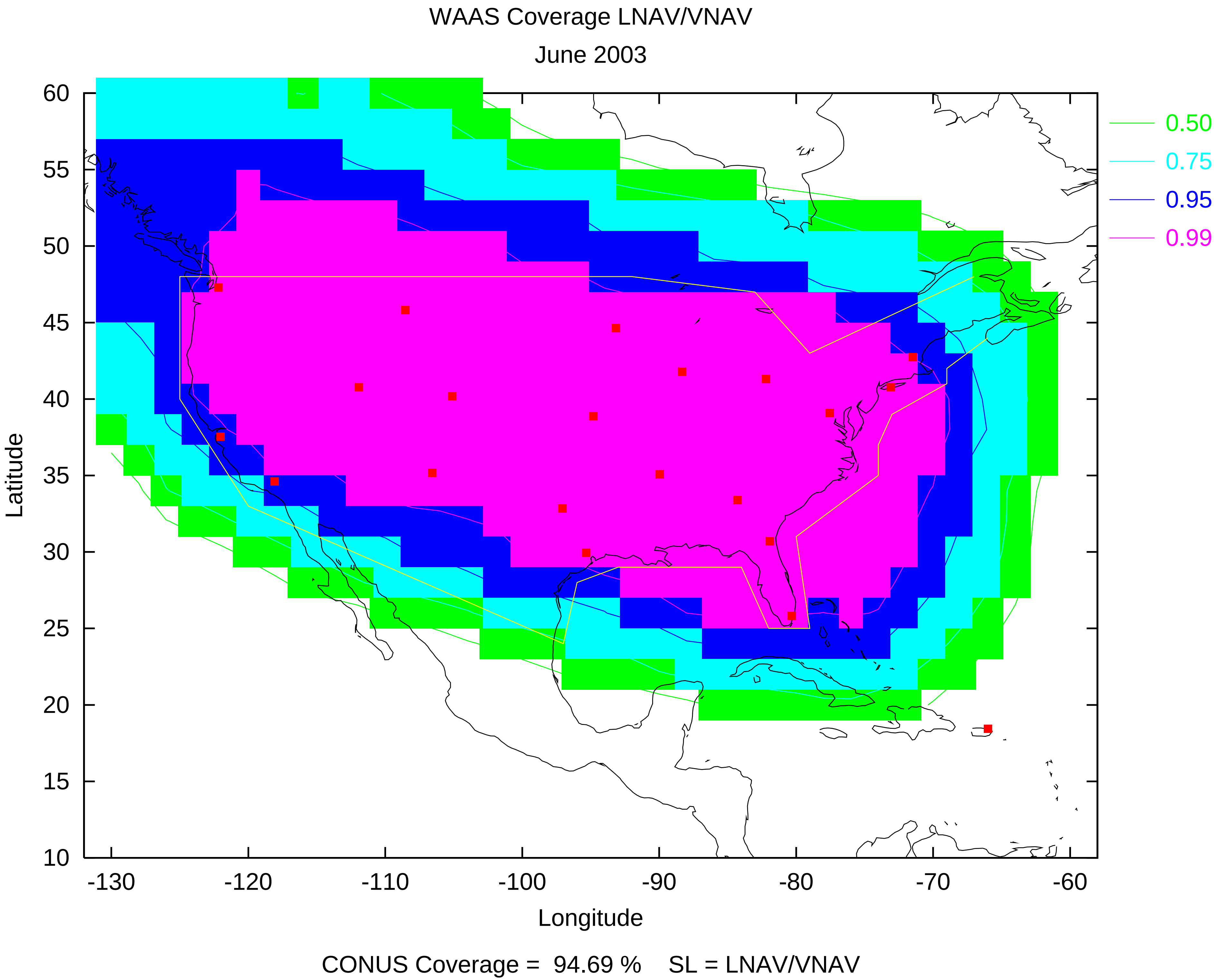
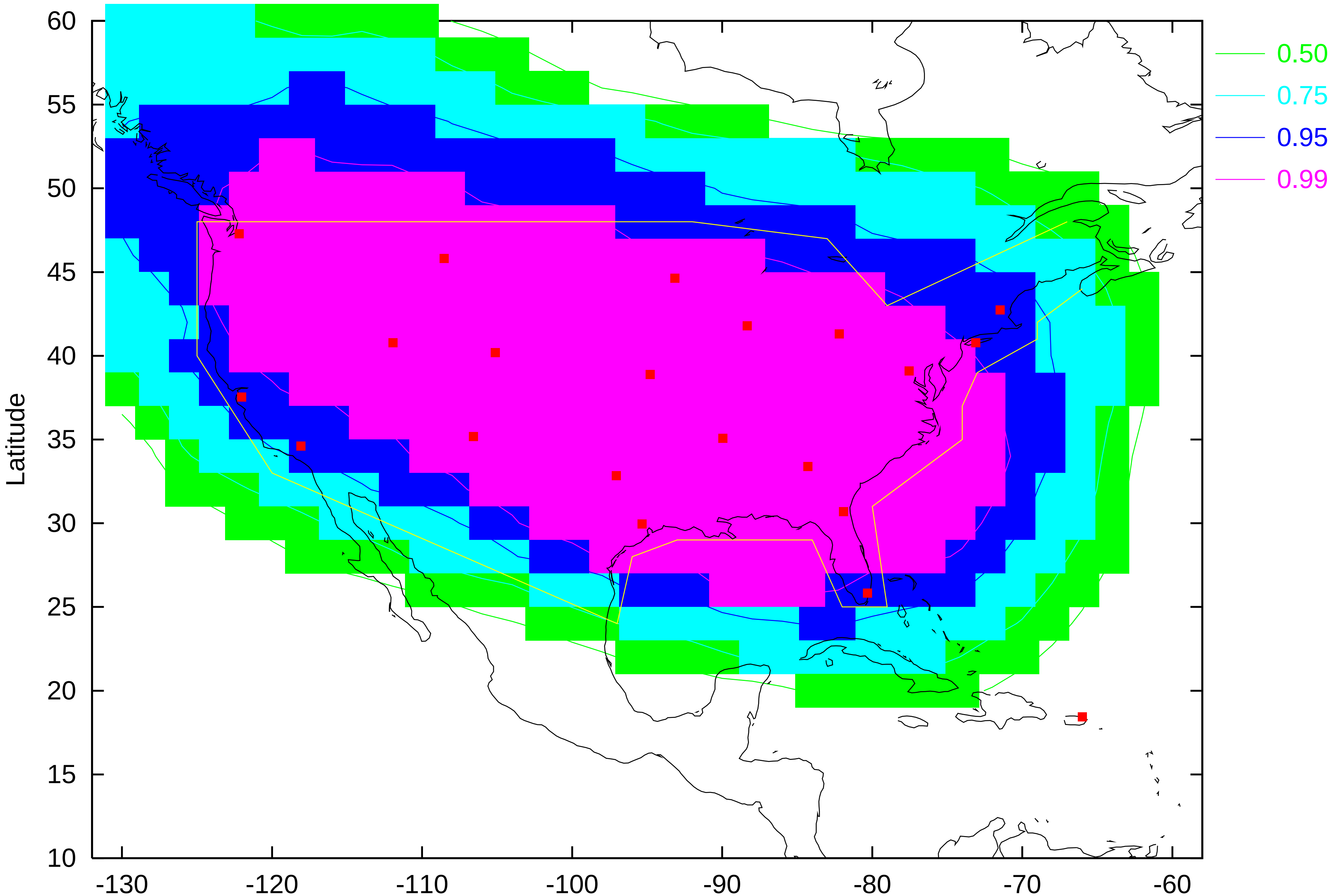


Figure 4.3 WAAS LNAV/VNAV Coverage - June

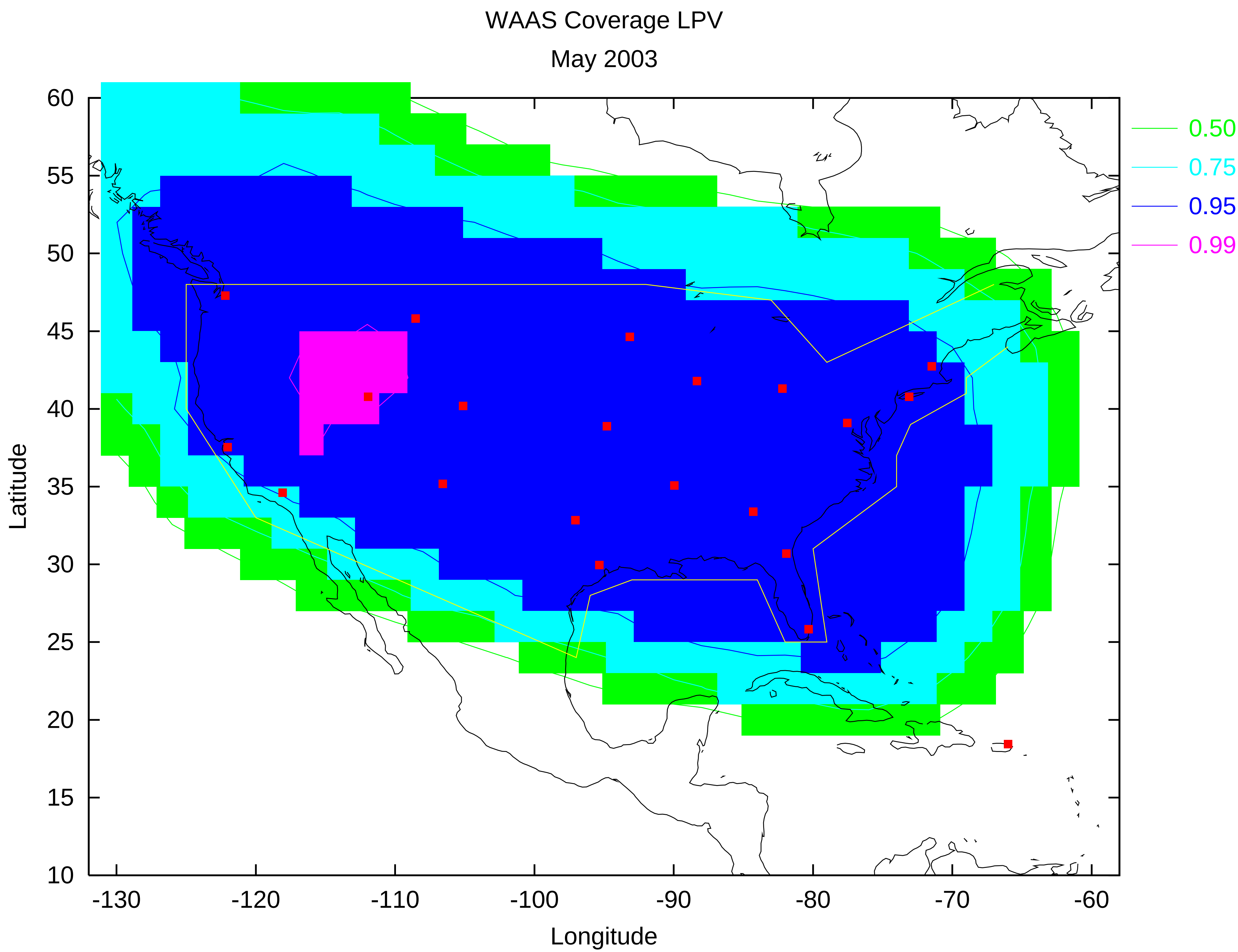
WAAS Coverage LPV

April 2003



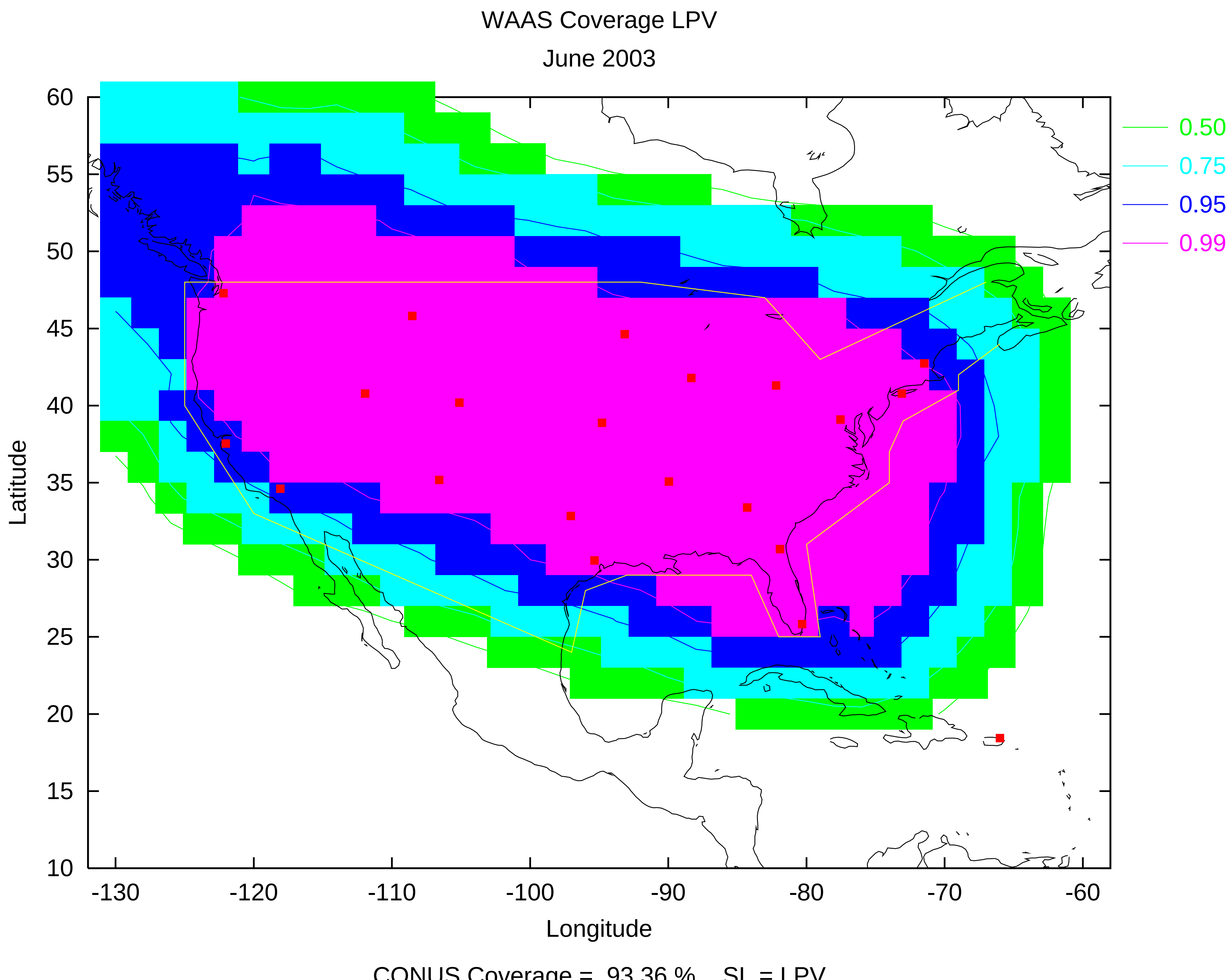
CONUS Coverage = 93.8 % SL = LPV

Figure 4.4 WAAS LPV Coverage - April



CONUS Coverage = 92.03 % SL = LPV

Figure 4.5 WAAS LPV Coverage - May



CONUS Coverage = 93.36 % SL = LPV

Figure 4.6 WAAS LPV Coverage - June

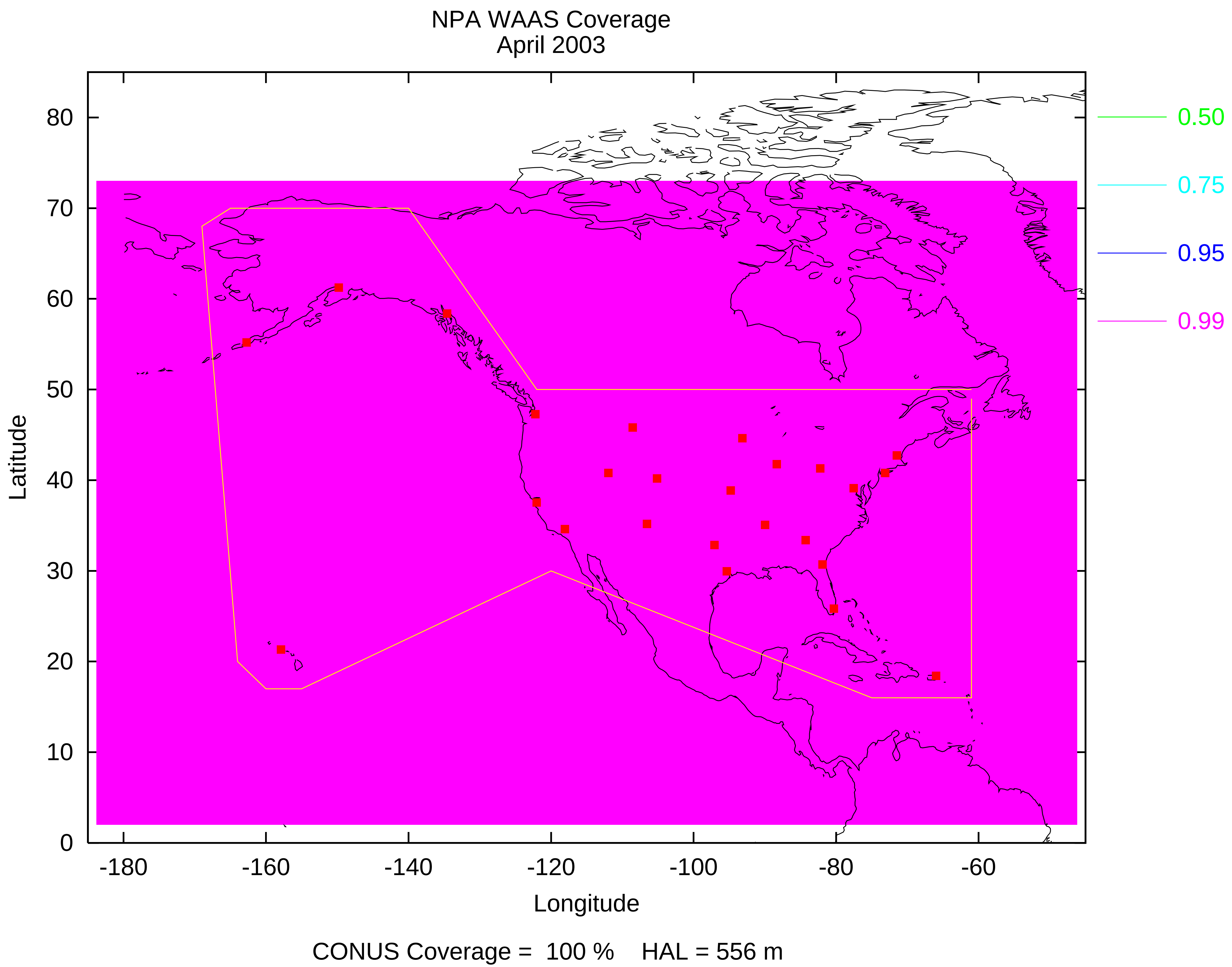


Figure 4.7 WAAS NPA Coverage - April

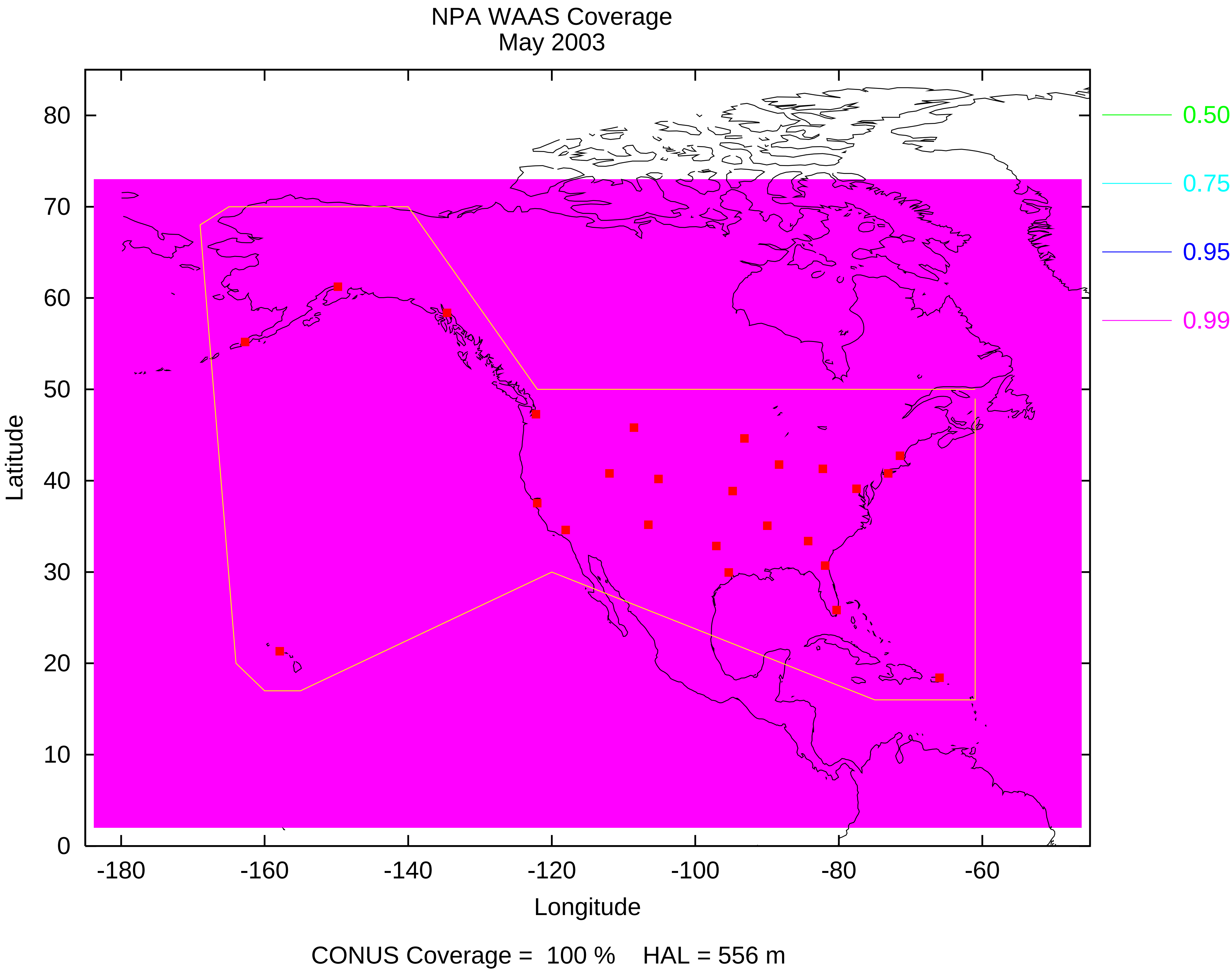


Figure 4.8 WAAS NPA Coverage - May

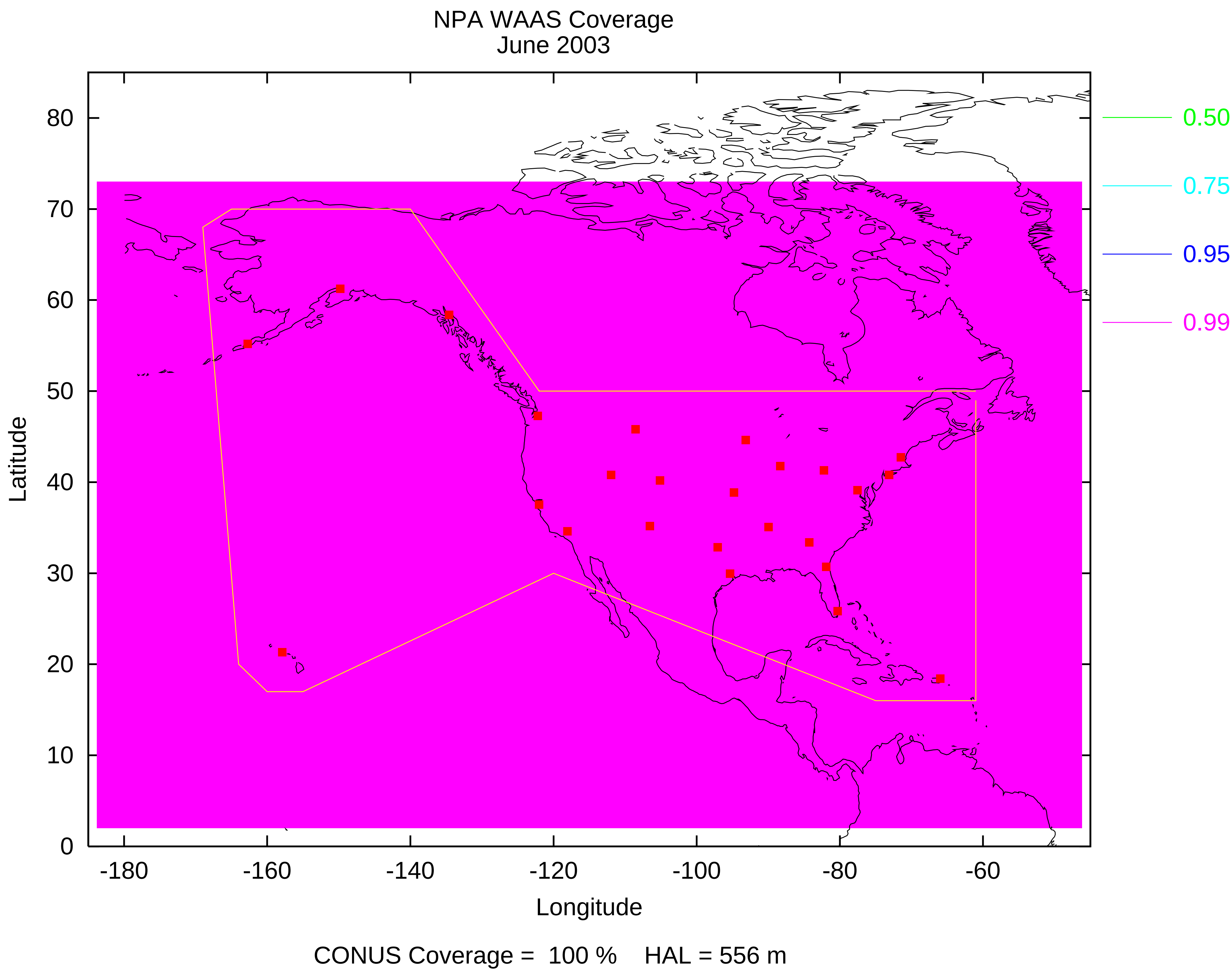


Figure 4.9 WAAS NPA Coverage - June

Figure 4.10 Daily WAAS LNAV/VNAV and LPV Coverage

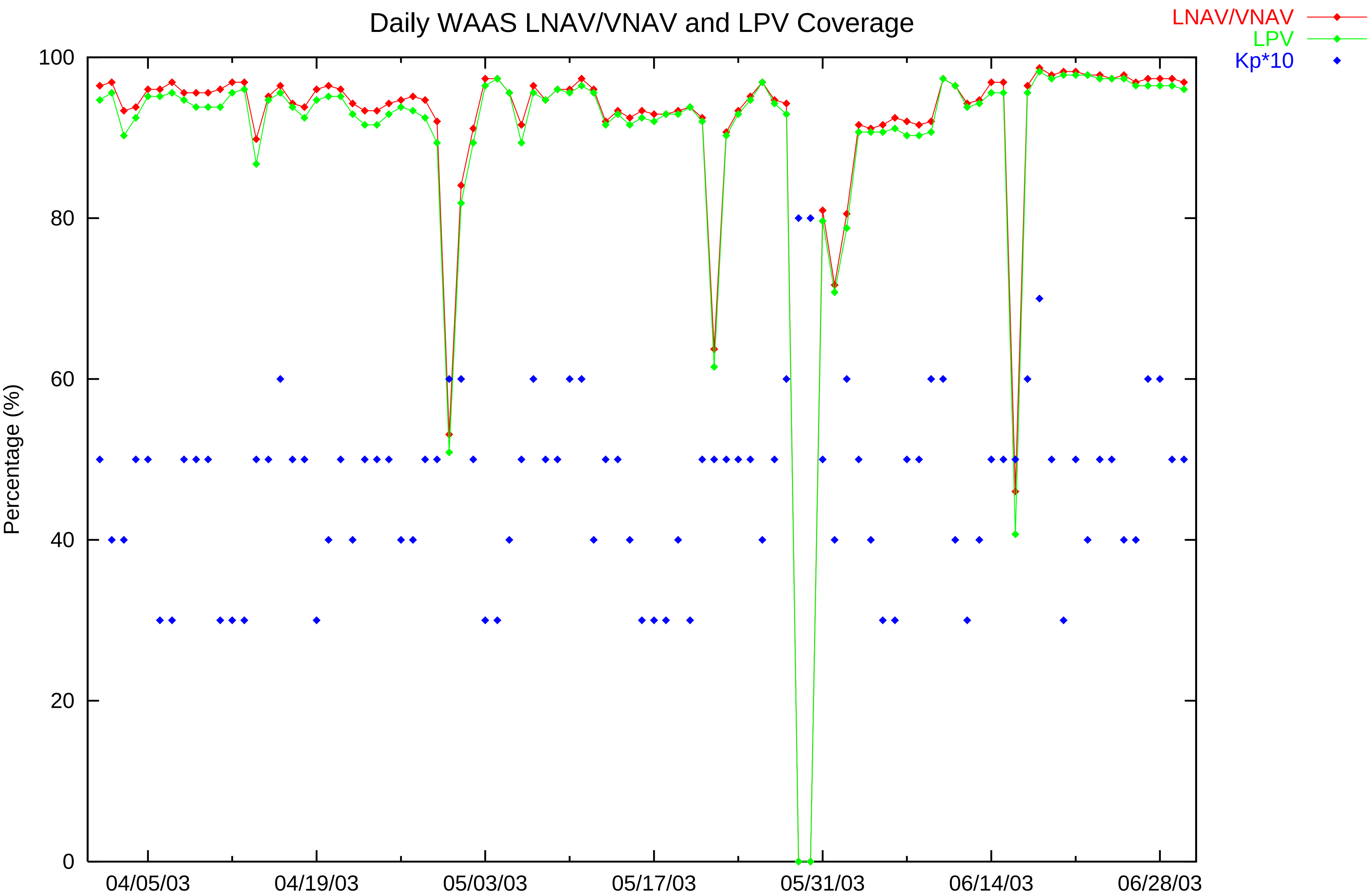
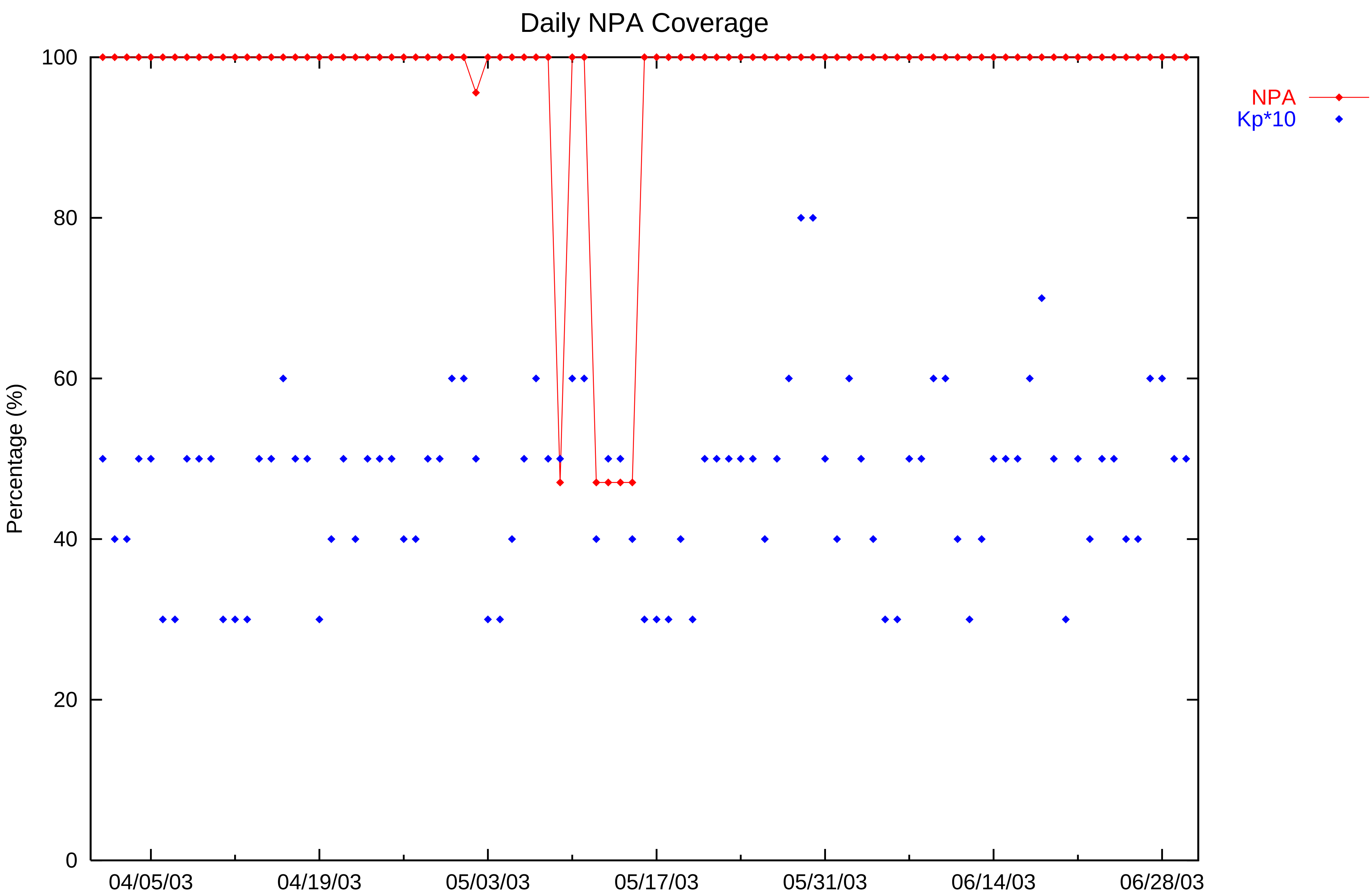


Figure 4.11 Daily NPA Coverage



5.0 Continuity

5.1 PA Continuity of Function

PA continuity of function was evaluated by monitoring the WAAS accuracy and integrity performance. Navigation error data for each reference site was divided into multiple bins consisting of 150 data samples. The position accuracy and integrity performance data for each bin was analyzed and statistics were generated to evaluate the data as follows:

- The horizontal and vertical position errors are less than 7.6 meter 95% of the time for each bin.
- No HMIs have occurred in the horizontal or vertical dimensions.

User position tool maintains PA mode of operation as defined in Section 2.0. If the above conditions are met, then the continuity flag is set to "1" to indicate the continuity of function is met for that particular flight segment. The continuity of function percentile statistic was computed for each site by summing the continuity flags of "1" together and dividing by the total number of test segments (bins) accumulated. Table 5.1 shows the PA Continuity of Function probability ranges from 0.994242 (Albuquerque) to 0.999900 (Salt Lake City).

Table 5.1 PA Continuity of Function

Location	PA Continuity of Function
Anderson	0.999806
Atlantic City	0.999605
Bangor	0.998606
Columbus	0.999236
Dayton	0.999541
Elko	0.998250
Grand Forks	0.999630
Great Falls	0.999747
Greenwood	0.999355
Oklahoma City	0.999771
Albuquerque	0.994242
Atlanta	0.999475
Billings	0.999784
Boston	0.999124
Chicago	0.999514
Cleveland	0.999534
Dallas	0.999709
Denver	0.999864
Houston	0.999745
Jacksonville	0.999420
Kansas City	0.999438
Los Angeles	0.999805
Memphis	0.999302
Miami	0.999204
Minneapolis	0.999534
New York	0.999376
Oakland	0.999671
Salt Lake City	0.999900
Seattle	0.999816
Washington DC	0.999497

5.2 NPA Continuity of Navigation

NPA continuity of navigation was evaluated by monitoring the accuracy performance throughout each flight hour. Navigation error data for each site was divided into multiple bins consisting of 3600 data samples. The position accuracy data for each bin was analyzed and statistics were generated to evaluate the data. If the horizontal position error is less than 100 meters 95% of the time, then the continuity of navigation flag is set to "1" to indicate the continuity of navigation is met for that particular flight hour. The continuity of navigation percentile statistic was computed for each reference site by summing the continuity of navigation flags of "1" together and dividing by the total number of test hours (bins) accumulated. The NPA Continuity of Navigation column of Table 5.2 shows all evaluated sites passed the requirements with the maximum probability of 1.

5.3 NPA Continuity of Fault Detection

NPA continuity of fault detection was evaluated by monitoring the integrity performance throughout each flight hour. Navigation error data for each reference site was divided into multiple bins consisting of 3600 data samples. The horizontal and vertical position error data for each bin was analyzed and statistics were generated to evaluate the data as follows:

- No HMIs have occurred in the horizontal dimension.
- User maintains NPA navigation mode of operation as defined in Section 2.0.

If the above conditions are met, then the continuity of fault detection flag is set to "1" to indicate the continuity of fault detection is met for that particular flight hour. The continuity of fault detection percentile statistic was computed for each reference site by summing the continuity of fault detection flags of "1" together and dividing by the total number of test hours (bins) accumulated. The NPA Continuity of Fault Detection column of Table 5.2 shows the probability ranges from 0.970093 (Honolulu) to 0.998961 (Albuquerque).

Table 5.2 NPA Continuity

Location	Continuity of Navigation	Continuity of Fault Detection
Bangor	1	0.994214
Albuquerque	1	0.998961
Anchorage	1	0.980410
Atlanta	1	0.995800
Billings	1	0.997648
Boston	1	0.996176
Cleveland	1	0.994408
Cold Bay	1	0.970694
Honolulu	1	0.970093
Houston	1	0.993891
Juneau	1	0.979888
Kansas City	1	0.993467
Los Angeles	1	0.997198
Miami	1	0.995345
Minneapolis	1	0.995806
Oakland	1	0.997216
Puerto Rico	1	0.994419
Salt Lake City	1	0.996654
Seattle	1	0.997541
Washington DC	1	0.995355

5.4 LPV Availability

LPV availability was evaluated by monitoring the accuracy, integrity and availability performance throughout each flight segment. Navigation error data for each reference site was divided into multiple bins consisting of 150 data samples. The position accuracy, integrity and availability performance data for each bin was analyzed and statistics were generated to evaluate the data as follows:

- The horizontal and vertical position errors are less than 7.6 meter 95% of the time for each bin.
- No HMIs have occurred in the horizontal or vertical dimensions.
- User maintains PA mode of operation as defined in section 2.0.
- VPL is less than or equal to 50m and HPL is less than or equal to 40 m.

If the above conditions are met, then the continuity of function flag is set to “1” to indicate the LPV availability is met for that particular flight segment. The availability percentile statistic was computed for each reference site by summing the continuity of function flags of “1” together and dividing by the total number of test segments (bins) accumulated. LPV Availability column of Table 5.3 shows the probability for availability ranges from 0.8433 (Bangor) to 0.9941 (Anderson).

5.5 LNAV/VNAV Availability

LNAV/VNAV availability was evaluated by monitoring the accuracy, integrity and availability performance throughout each flight segment. Navigation error data for each reference site was divided into multiple bins consisting of 150 data samples. The position accuracy, integrity and availability performance data for each bin was analyzed and statistics were generated to evaluate the data as follows:

- The horizontal and vertical position errors are less than 7.6 meter 95% of the time for each bin.
- No HMIs have occurred in the horizontal or vertical dimensions.
- User maintains PA mode of operation as defined in section 2.0.
- VPL is less than or equal to 50m and HPL is less than or equal to 556 m.

If the above conditions are met, then the continuity of function flag is set to “1” to indicate the LNAV/VNAV availability is met for that particular flight segment. The availability percentile statistic was computed for each reference site by summing the continuity of function flags of “1” together and dividing by the total number of test segments (bins) accumulated. LNAV/VNAV Availability column of Table 5.3 shows the availability ranges from 0.8481 (Bangor) to 0.9946 (Salt Lake City).

5.6 NPA Availability

NPA availability was evaluated by monitoring the accuracy, integrity and availability performance throughout each flight hour. Navigation error data for each reference site was divided into multiple bins consisting of 3600 data samples. The horizontal and vertical position error data for each bin was analyzed and statistics were generated to evaluate the data as follows:

- The horizontal position errors are less than 100 meters 95% of time for each bin
- No HMIs have occurred in the horizontal dimension.
- User maintains NPA navigation mode of operation as defined in Section 2.0.
- HPL is less than or equal to 556 meters.

If the above conditions are met, then the availability flag is set to “1” to indicate NPA availability is met for that particular flight hour. The NPA availability percentile statistic was computed for each reference site by summing the availability flags of “1” together and dividing by the total number of test hours (bins) accumulated.

The NPA Availability column of Table 5.4 shows the availability ranges from 0.964486 (Honolulu) to 0.998961 (Albuquerque).

Table 5.3 LPV and LNAV/VNAV Availability

Location	LPV Availability	LNAV/VNAV Availability
Anderson	0.9941	0.9943
Atlantic City	0.9861	0.9886
Bangor	0.8433	0.8481
Columbus	0.9864	0.9902
Dayton	0.9913	0.9927
Elko	0.9781	0.9835
Grand Forks	0.9666	0.9692
Great Falls	0.9832	0.9851
Greenwood	0.9937	0.9942
Oklahoma City	0.9889	0.9907
Albuquerque	0.9882	0.9898
Atlanta	0.9936	0.9937
Billings	0.9918	0.9919
Boston	0.9727	0.9733
Chicago	0.9899	0.9911
Cleveland	0.9911	0.9919
Dallas	0.9915	0.9918
Denver	0.9915	0.9931
Houston	0.9901	0.9903
Jacksonville	0.993	0.9933
Kansas City	0.9916	0.9923
Los Angeles	0.9551	0.9649
Memphis	0.9878	0.9913
Miami	0.9673	0.9683
Minneapolis	0.9882	0.9901
New York	0.9865	0.9871
Oakland	0.9546	0.9602
Salt Lake City	0.9937	0.9946
Seattle	0.9869	0.9898
Washington DC	0.9895	0.9906

Table 5.4 NPA Availability

Location	NPA Availability
Bangor	0.994214
Albuquerque	0.998961
Anchorage	0.980410
Atlanta	0.995800
Billings	0.997648
Boston	0.996176
Cleveland	0.994408
Cold Bay	0.969666
Honolulu	0.964486
Houston	0.993891
Juneau	0.979888
Kansas City	0.993467
Los Angeles	0.997198
Miami	0.995345
Minneapolis	0.995806
Oakland	0.997216
Puerto Rico	0.994419
Salt Lake City	0.996654
Seattle	0.997541
Washington DC	0.995355

6.0 Integrity

6.1 HMI Analysis

Analysis of integrity includes the identification and evaluation of HMIs (hazardously misleading information), as well as the generation of a safety index to illustrate the margin of safety that WAAS protection levels are maintaining. The safety margin index (shown in Table 6.1) 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 6.1 Safety Margin Index and HMI Statistics

Location	Safety Index		Number of HMIs
	Horizontal	Vertical	
Anderson	5.45	5.92	0
Atlantic City	2.86	3.33	0
Bangor	3.33	2.96	0
Columbus	4.62	3.14	0
Dayton	3.33	3.81	0
Elko	3.33	2.42	0
Grand Forks	2.31	1.44	0
Great Falls	5.45	4.44	0
Greenwood	3.75	4.44	0
Oklahoma City	6.00	5.92	0
Albuquerque	1.40	6.66	0
Atlanta	5.00	5.92	0
Billings	5.00	3.81	0
Boston	4.00	4.44	0
Chicago	5.00	5.92	0
Cleveland	3.33	2.42	0
Dallas	2.40	4.10	0
Denver	5.45	3.81	0
Houston	4.29	4.44	0
Jacksonville	5.00	4.44	0
Kansas City	5.00	5.92	0
Los Angeles	6.67	6.66	0
Memphis	5.00	5.33	0
Miami	3.75	5.92	0
Minneapolis	3.75	3.81	0
New York	5.00	5.92	0
Oakland	4.00	2.54	0
Salt Lake City	5.00	3.81	0
Seattle	6.67	5.92	0
Washington DC	4.62	6.66	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. As evidenced by the statistics in the above table, the safety margin index never drops below 1.4 at any site. Also, Table 6.1 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 or more seconds pass before this event is corrected by WAAS.

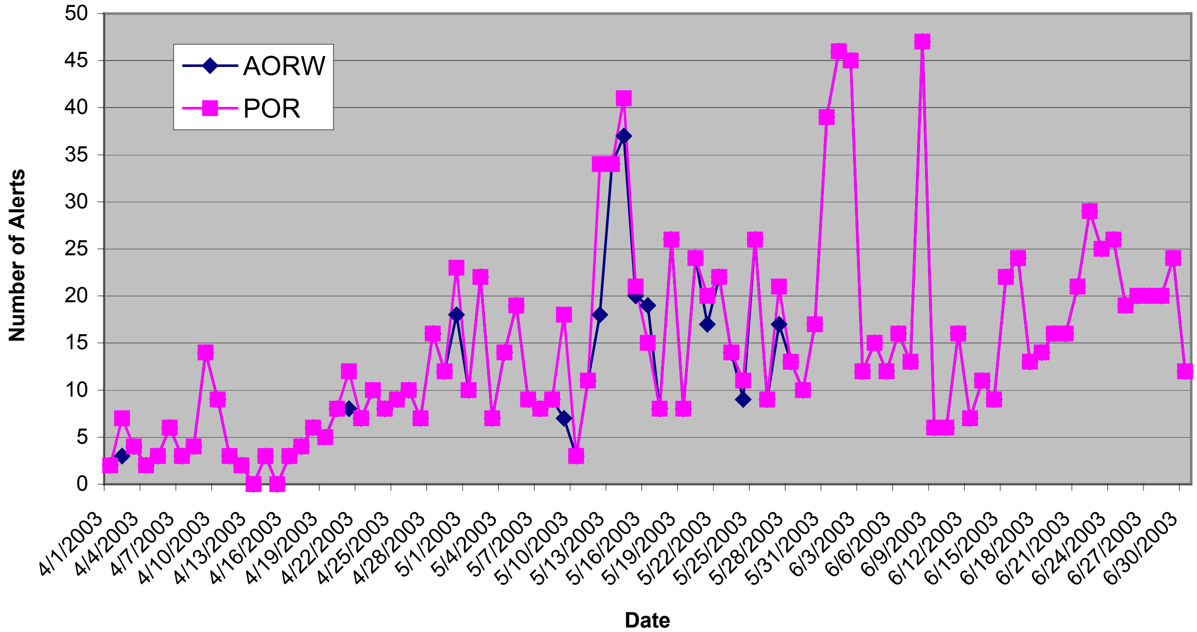
6.2 Broadcast Alerts

The WAAS produces 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. Ionospheric Grid Point (IGP) alerts increase the Grid Ionospheric Vertical Error (GIVE) of IGP's, which can affect the usage of satellites whose pierce points are in the vicinity of the IGP. An increase in either UDRE's or GIVE'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 continuity of fault detection to not be met for that flight segment. Table 6.2 shows the total number of alerts and Figure 6.1 shows the number of SV alerts that occurred daily during the reporting period. Note there are no IGP alerts since the installation of the new GIVE Monitor in November 2001.

Table 6.2 WAAS SV Alert

	Number of Alert	
Message Type	**AORW**	**POR**
0	111	193
3	98	102
6	1	1
24	26	31
26	0	0
Total Alerts	236	327

Figure 6.1 SV Daily Alert Trends



6.3 Availability of WAAS Messages (AORW & POR)

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 6.3 lists the maximum intervals at which each message must broadcast to meet system requirements.

GUS switchovers or satellite vehicle alerts can interrupt the normal broadcast message stream. If these things happen to 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. Table 6.4 to 6.8 show fast correction, long correction, ephemeris covariance, ionosphere correction, and ionospheric mask message rates statistics broadcasted on AORW. The message rates statistics for POR are shown in table 6.9 to 6.13.

Table 6.3 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 6.4 WAAS Fast Correction and Degradation Message Rates - AORW

Message Type	**On Time**	**Late**	**Max Late Length (seconds)**
0	1311049	477	366
1	139493	2	529
3	1310796	507	372
7	74471	130	632
9	92129	3	442
10	74465	139	432
17	29657	9	767
24	1309850	684	372

Table 6.5 WAAS Long Correction Message Rates(Type 24 and 25) - AORW

SV	On Time	Late	Max Late Length (seconds)
1	49984	1	171
2	59110	1	510
3	53029	1	333
4	58177	1	182
5	45010	1	425
6	51113	3	593
7	54201	3	346
8	49495	1	591
9	51555	1	171
10	57650	3	433
11	52691	2	178
13	50090	2	168
14	54854	0	0
15	49050	2	422
16	56532	3	597
17	44518	5	597
18	48999	2	601
20	49652	1	166
21	16700	5	590
23	47766	1	177
24	57200	4	512
25	59131	1	189
26	53237	2	600
27	45996	1	176
28	46522	0	0
29	53236	4	598
30	50526	2	422
31	50594	0	0

Table 6.6 WAAS Ephemeris Covariance Message Rates (Type 28) - AORW

SV	On Time	Late	Max Late Length (seconds)
1	42310	1	130
2	44356	4	437
3	43732	4	233
4	43858	4	192
5	40009	6	592
6	42321	5	589
7	43629	4	192
8	41350	1	594
9	44897	2	158
10	43177	9	528
11	45814	1	288
13	41726	3	193
14	43060	3	192
15	41411	5	547
16	43325	4	600
17	35307	5	565
18	41470	5	577
20	42445	1	164
21	12801	1	163
23	37993	3	191
24	41846	5	575
25	42103	4	193
26	41033	3	563
27	34404	1	192
28	36998	4	192
29	42085	6	576
30	42638	5	564
31	39722	1	149
122	83545	9	576
134	83248	4	480

Table 6.7 WAAS Ionospheric Correction Message Rates (Type 26) - AORW

Band	Block	On Time	Late	Max Late Length (seconds)
0	0	27292	15	577
1	0	27278	20	864
1	1	27317	11	864
1	2	27281	16	576
1	3	27290	20	864
1	4	27280	18	864
2	0	27290	16	864
2	1	27283	15	864
2	2	27272	17	864
2	3	27286	18	576
2	4	27272	21	576
2	5	27287	20	576
3	0	27306	24	576

Table 6.8 WAAS Ionospheric Mask Message Rates (Type 18) - AORW

Band	On Time	Late	Max Late Length (seconds)
0	67470	1	479
1	67480	1	599
2	67436	1	593
3	67506	1	581

Table 6.9 WAAS Fast Correction and Degradation Message Rates - POR

Message Type	On Time	Late	Max Late Length (seconds)
0	1307999	508	3824
1	137844	11	3871
3	1307660	540	3818
7	73574	168	3973
9	91894	17	3925
10	73578	139	3854
17	29478	21	4287
24	1306660	721	3821

Table 6.10 WAAS Long Correction Message Rates (Type 24 and 25) - POR

SV	On Time	Late	Max Late Length (seconds)
1	49954	0	0
2	58898	2	597
3	52853	2	333
4	58122	2	171
5	44812	6	3922
6	50941	3	593
7	54174	1	339
8	49442	1	591
9	51364	6	2653
10	57552	3	433
11	52558	1	2716
13	50034	2	157
14	54676	3	2560
15	48849	3	422
16	56328	3	597
17	44300	7	3160
18	48796	3	601
20	49627	1	178
21	16700	5	590
23	47593	1	177
24	57113	7	3068
25	59002	3	183
26	53025	3	600
27	45958	1	162
28	46381	0	0
29	53109	4	598
30	50376	4	1033
31	50446	0	0

Table 6.11 WAAS Ephemeris Covariance Message Rates (Type 28) – POR

SV	On Time	Late	Max Late Length (seconds)
1	41825	3	1102
2	43803	3	437
3	43110	8	2448
4	43329	2	191
5	39333	5	592
6	41771	7	589
7	43129	2	176
8	40858	4	1120
9	44213	6	2472
10	42612	7	528
11	45168	4	2784
13	41226	4	193
14	42421	2	192
15	40754	6	2727
16	42760	6	600
17	34716	8	565
18	40828	5	577
20	41952	2	151
21	12406	0	0
23	37405	5	2420
24	41320	8	3016
25	41522	4	384
26	40395	9	1120
27	33960	0	0
28	36451	2	2472
29	41528	5	576
30	42029	8	2696
31	39162	1	192
122	82430	19	3937
134	82310	3	480

Table 6.12 WAAS Ionospheric Correction Message Rates (Type 26) – POR

Band	Block	On Time	Late	Max Late Length (seconds)
0	0	27219	27	4038
0	1	27226	22	4034
0	2	27231	21	4034
1	0	27225	23	4032
1	1	27222	24	4323
1	2	27196	24	4320
1	3	27232	24	4322
1	4	27201	25	4032
2	0	27202	28	4034
2	1	27214	32	4032
2	2	27233	26	4034
2	3	27241	31	4032

Table 6.13 WAAS Ionospheric Mask Message Rates (Type 18) - POR

Band	On Time	Late	Max Late Length (seconds)
0	66929	10	3967
1	66941	10	3841
2	67018	10	3889

7.0 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 is required to bound 99.9% of the residual error on a pseudorange after application of fast and long-term corrections. 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 the WAAS receivers in Billings, Houston, and Washington DC during the quarter. Table 7.1 shows the range error 95% index and 3.29σ bounding statistics for each SV at the selected locations. During the evaluated period, all GPS satellite residual errors were less than 3.062 meters 95% of the time and all satellites range errors were bounded 99.9% of the time by the UDRE.

A GIVE is broadcast by the WAAS for each IGP that is monitored by the system and is required to bound 99.9% of the ionospheric error. The WAAS broadcast the ionospheric model using IGP's at predefine 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 ionospheric delay interpolated from the IGP's and GPS dual frequency measurement at that GPS satellite.

GPS satellite ionospheric errors were calculated for the WAAS receivers in Billings, Houston and Washington DC during the quarter. Table 7.2 shows the ionospheric error 95% index and 3.29σ bounding statistics for each SV at the selected locations. All GPS satellite ionospheric errors were less than 2.046 meters 95% of the time and all satellites were bounded at least 99.9% of the time. Figure 7.1 to 7.4 show the daily trend of the 95% Range and Ionospheric Errors for Houston.

Table 7.1 Range Error 95% index and 3.29 Sigma Bounding

Site →	Billings		Washington DC		Houston	
SV ↓	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding	95% Range Error	3.29 Sigma Bounding
1	1.684	99.98	1.667	99.99	2.143	100.00
2	1.754	100.00	3.062	100.00	2.363	100.00
3	1.666	100.00	1.268	100.00	2.267	100.00
4	1.872	100.00	2.741	100.00	2.015	100.00
5	1.749	100.00	1.406	99.97	2.789	100.00
6	1.769	99.99	1.571	100.00	1.772	100.00
7	1.300	100.00	1.593	100.00	2.365	100.00
8	1.619	100.00	1.812	100.00	2.447	100.00
9	1.706	100.00	1.483	99.94	2.088	100.00
10	1.665	100.00	1.545	100.00	2.810	100.00
11	1.775	99.99	2.240	100.00	2.913	100.00
12	-	-	-	-	-	-
13	2.072	100.00	1.468	100.00	2.120	100.00
14	1.339	100.00	1.517	99.94	2.808	99.98
15	1.782	100.00	1.837	99.95	2.281	100.00
16	1.547	100.00	2.089	100.00	2.777	100.00
17	1.708	100.00	1.373	100.00	1.782	100.00
18	1.373	100.00	1.852	99.93	2.987	100.00
19	-	-	-	-	-	-
20	1.670	100.00	1.849	100.00	2.832	100.00
21	1.378	100.00	2.355	99.94	2.563	99.97
22	-	-	-	-	-	-
23	1.588	100.00	1.363	99.94	2.129	99.99
24	2.220	100.00	1.929	100.00	2.331	100.00
25	1.821	99.98	1.660	100.00	2.225	100.00
26	1.867	100.00	2.099	100.00	1.981	100.00
27	1.846	100.00	1.618	100.00	2.063	100.00
28	1.595	100.00	1.469	100.00	2.803	100.00
29	1.731	100.00	1.331	100.00	2.029	100.00
30	2.212	100.00	1.504	100.00	2.275	100.00
31	1.420	100.00	1.603	100.00	2.447	100.00
122	3.606	99.99	2.883	99.99	2.200	99.99

Table 7.2 Ionospheric Error 95% index and 3.29 Sigma Bounding

Site →	Billings		Washington DC		Houston	
SV ↓	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding	95% Iono Error	3.29 Sigma Bounding
1	0.760	100.00	0.899	100.00	1.307	100.00
2	0.878	100.00	1.528	100.00	1.544	100.00
3	0.699	100.00	0.627	100.00	1.225	100.00
4	1.174	100.00	1.527	100.00	1.257	100.00
5	0.812	100.00	0.760	100.00	1.441	100.00
6	0.750	100.00	0.886	100.00	0.988	100.00
7	0.717	100.00	0.853	100.00	1.616	100.00
8	0.814	100.00	0.948	100.00	1.689	100.00
9	0.737	100.00	0.552	100.00	1.030	100.00
10	0.973	100.00	1.242	100.00	1.973	100.00
11	0.789	100.00	1.078	100.00	1.657	100.00
12	-	-	-	-	-	-
13	0.852	100.00	0.801	100.00	1.212	100.00
14	0.818	100.00	1.133	100.00	1.909	100.00
15	0.710	100.00	1.045	100.00	1.532	100.00
16	0.788	100.00	1.161	100.00	1.627	100.00
17	0.855	100.00	0.740	100.00	1.164	100.00
18	0.787	100.00	1.277	100.00	2.046	100.00
19	-	-	-	-	-	-
20	0.797	100.00	1.064	100.00	1.707	100.00
21	1.110	100.00	1.771	100.00	2.007	100.00
22	-	-	-	-	-	-
23	0.727	100.00	0.763	100.00	1.374	100.00
24	1.309	100.00	1.067	100.00	1.439	100.00
25	0.999	100.00	0.950	100.00	1.415	100.00
26	0.858	100.00	0.987	100.00	1.004	100.00
27	1.117	100.00	0.596	100.00	1.285	100.00
28	0.938	100.00	1.106	100.00	1.995	100.00
29	0.707	100.00	0.691	100.00	1.097	100.00
30	0.864	100.00	0.725	100.00	0.985	100.00
31	0.755	100.00	0.889	100.00	1.522	100.00

Figure 7.1   95% Range Error (SV 1—SV 16) - Houston

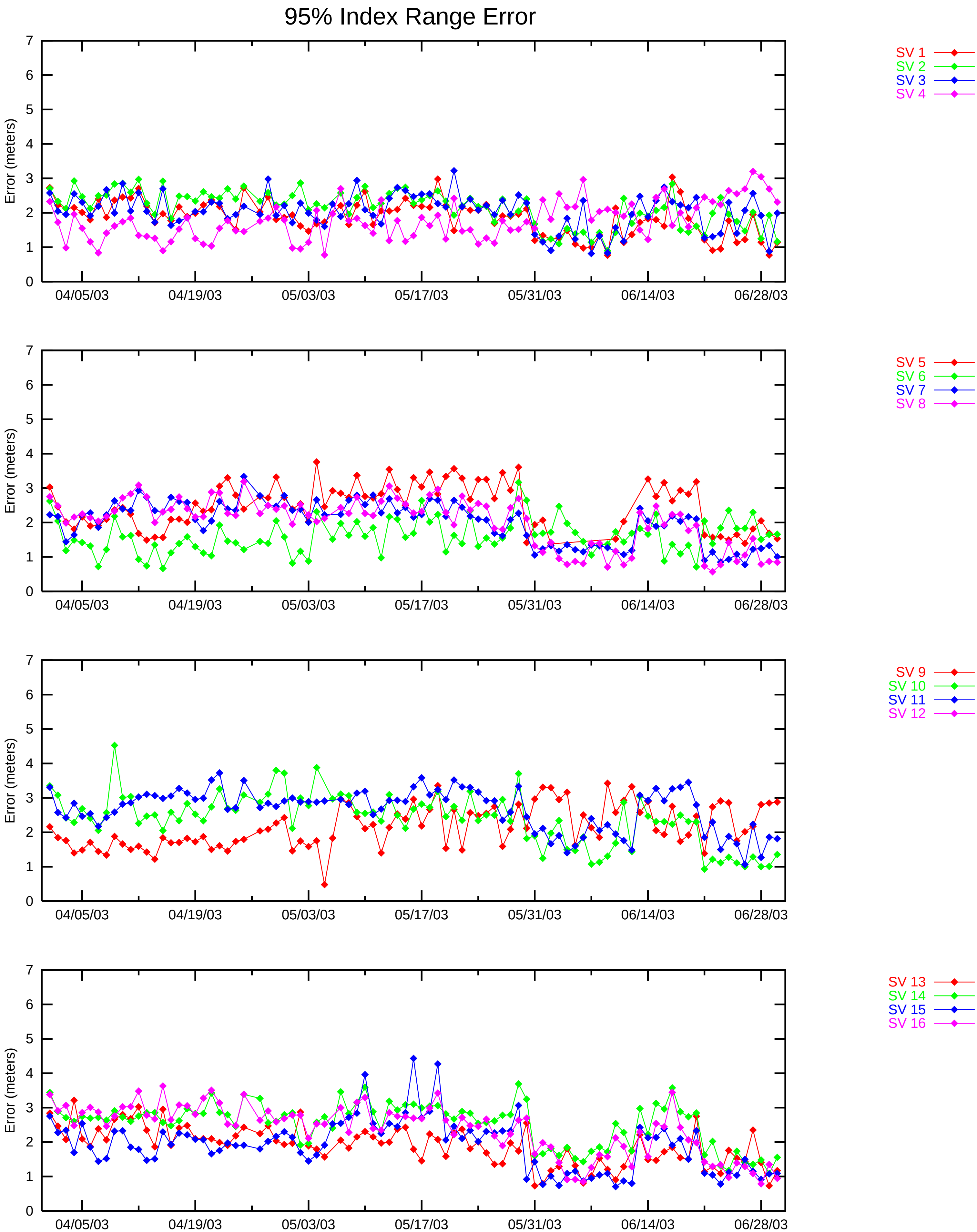


Figure 7.2 95% Range Error (SV 17—SV 31 and SV 122) - Houston

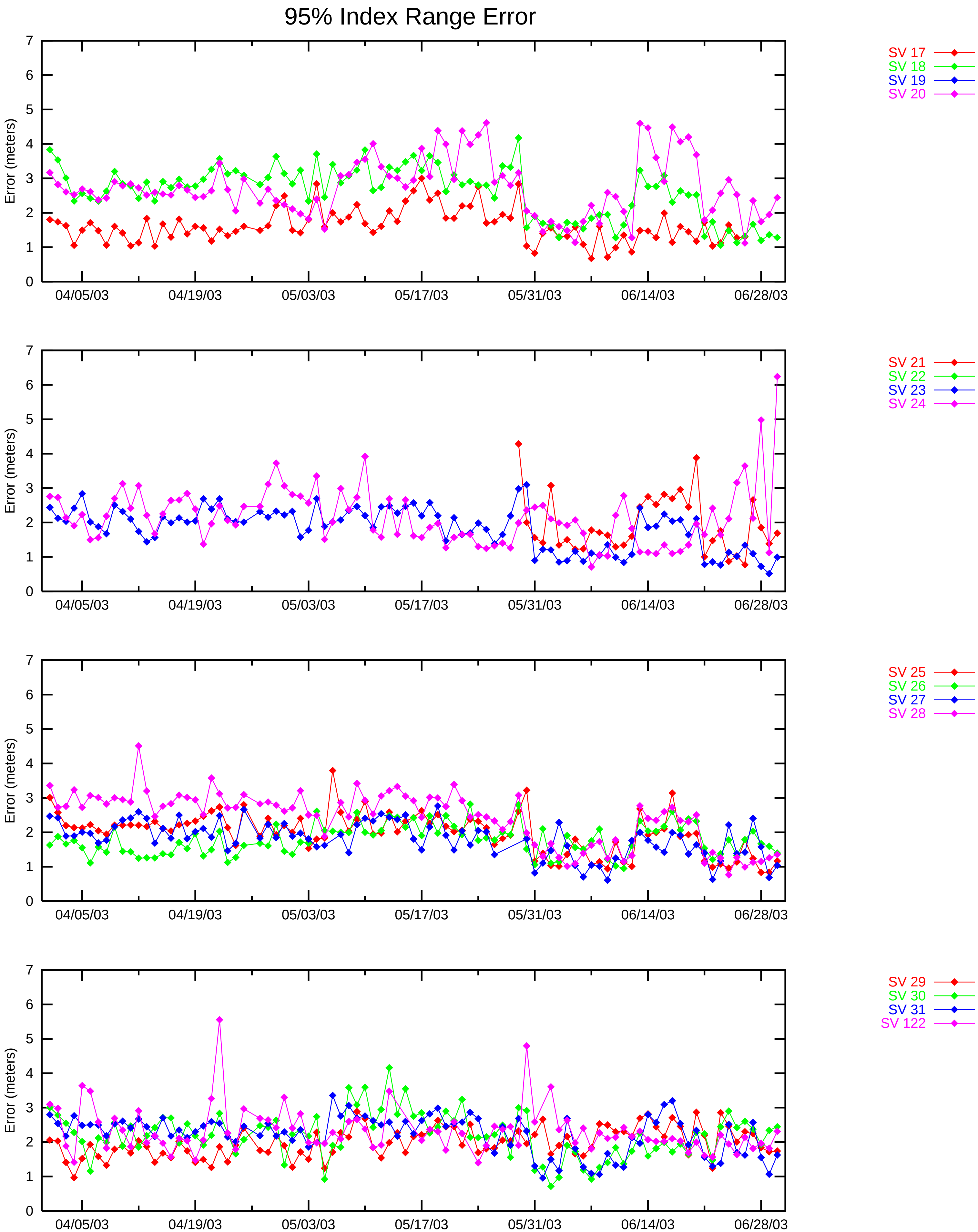


Figure 7.3   95% Ionospheric Error (SV 1—SV 16) – Houston

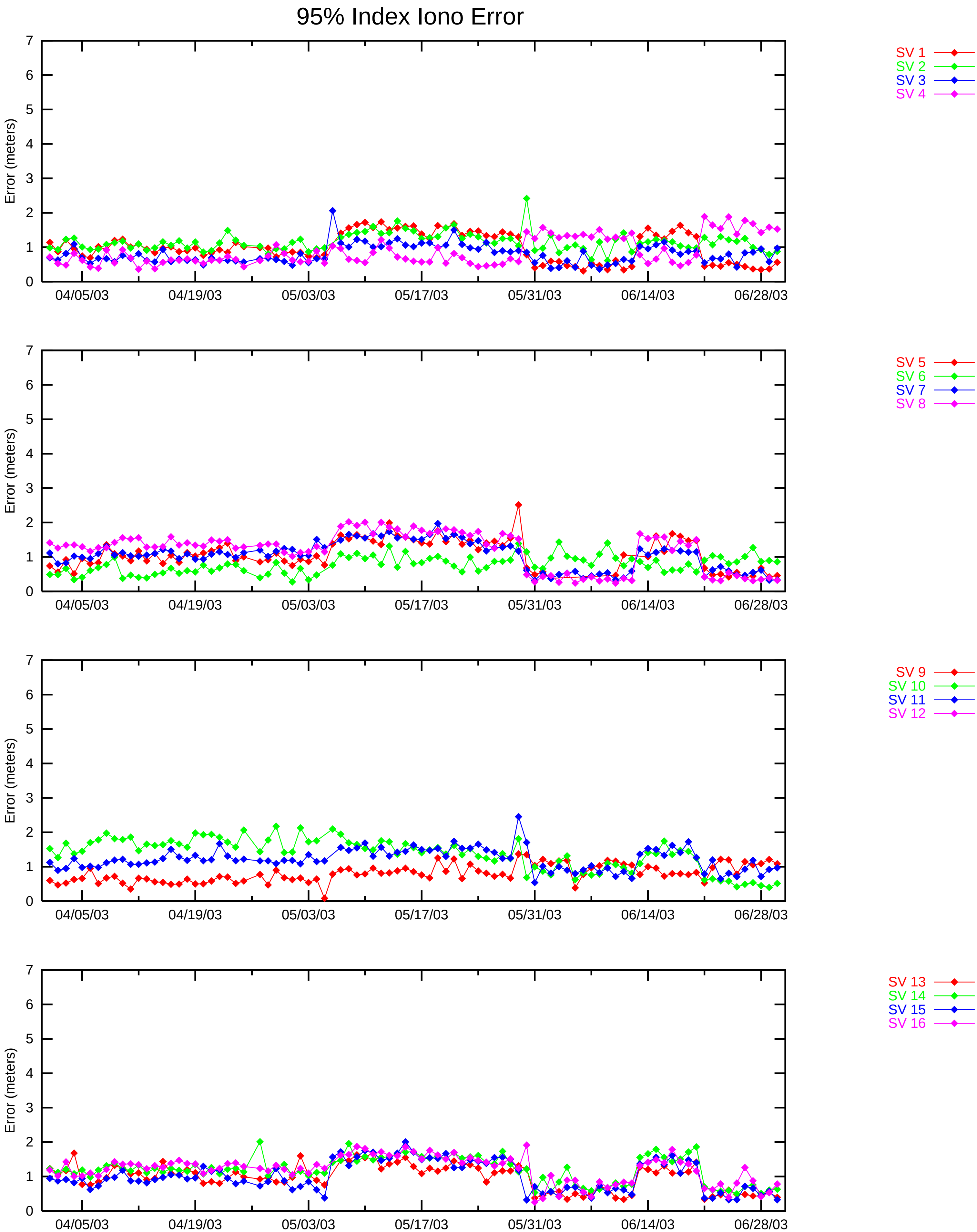
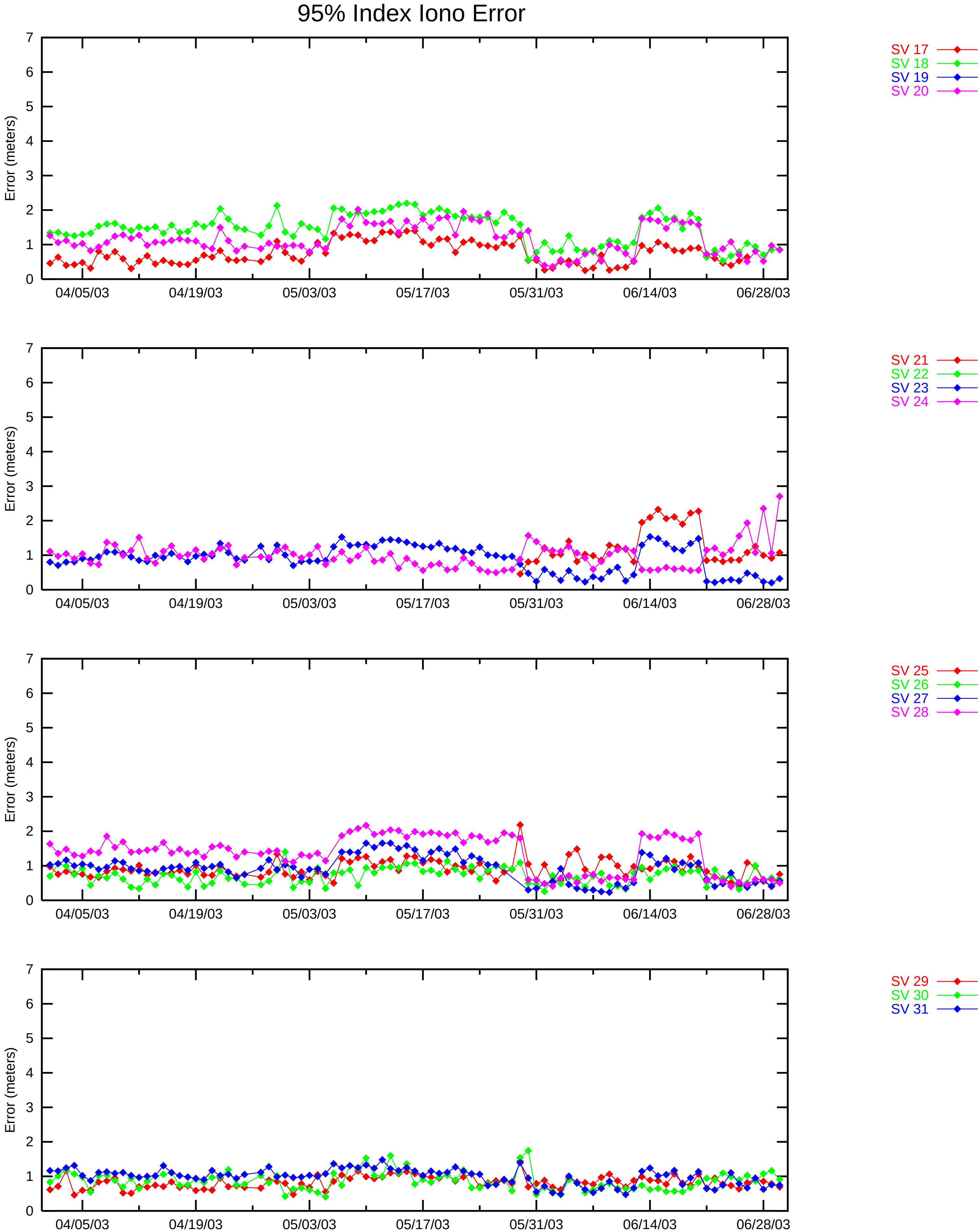


Figure 7.4 95% Ionospheric Error (SV 17—SV 31) – Houston



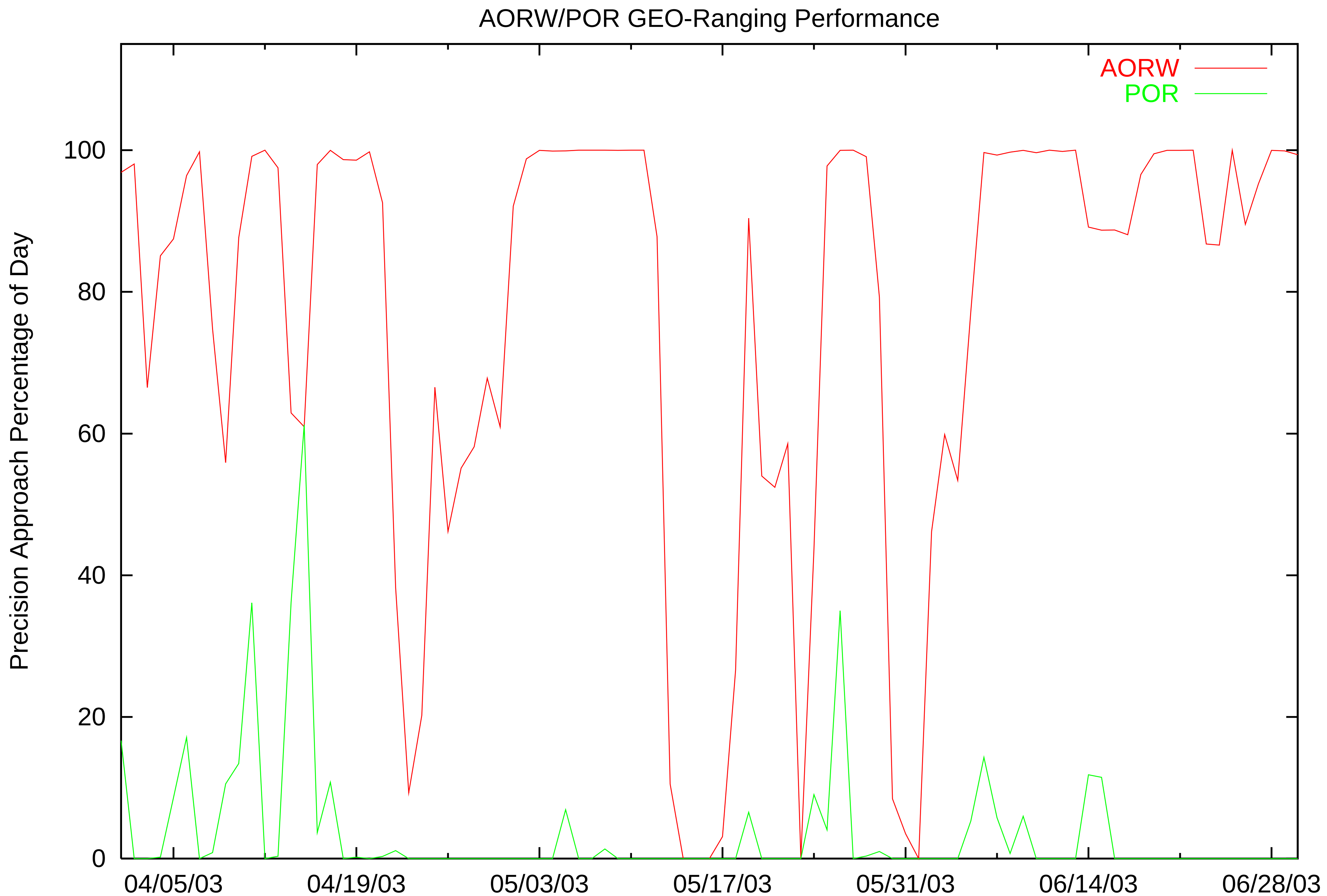
8.0 GEO Ranging Performance

Table 8.1 shows the GEO-Ranging performance for AORW and POR satellites throughout the evaluated period. The percentage of PA ranging availability for the AORW and POR is 76.14% and 3.70% , respectively. Figure 8.1 shows the trend of PA Ranging Availability for the AORW and POR satellite. The AORW and POR daily performance was somewhat sporadic throughout the quarter. These events include, but are not limited to GUS switchovers and Ionospheric storms. The effects of each one of these events can be clearly seen in the performance trend of the AORW satellite. Drops in PA ranging availability below 60 percent of the day are not uncommon during these types of events. Of course, the longer the event, the greater the effect on performance.

Table 8.1 GEO Ranging Availability

GEO	PA (%)	NPA (%)	Not Monitored (%)	Do Not Use (%)
AORW	76.14	19.92	2.77	1.17
POR	3.70	80.86	13.80	1.63

Figure 8.1 Daily PA GEO Ranging Availability Trend



9.0 WAAS Problem Summary

During the ongoing WAAS evaluation process any problems or anomalies discovered will be documented in this section. Many WAAS performance parameters are evaluated at each reference receiver on a daily basis. If WAAS performance fails to meet requirements then a problem description and detailed analysis will be included in this section.

PRN 27 Clock Error Observations, May 26, 2003 (Week 1220 Day1)

PRN 27 experienced what appeared to be a ramp clock error starting approximately second-of-week 144000 and extending thru 149000, growing to a magnitude of about 38 meters by that time. The satellite was visible to the northeast United States and eastern Canada. The DoD switched the satellite to unhealthy at time 149669. The magnitude of the anomaly was less than SA had been in the past. WAAS detected the clock error and provided appropriate corrections, until the satellite was switched to Unhealthy, at which time the WAAS declared PRN 27 "Do Not Use". WAAS performed as designed during this anomaly. See GPS PAN report 42 for further details.

PRN 5 Clock Anomaly Observations, June 11, 2003 (Week 1223 Day3)

PRN 5 experienced what appeared to be a ramp clock error starting approximately second-of-week 329500 and extending thru 332390, growing to a maximum magnitude of about 30 meters. The satellite was visible to the Southeast United States and Caribbean. (The DoD switched the satellite to unhealthy at time 332390). The PRN5 anomaly appeared to be a clock ramp (with a change in direction) from about 329500 until 332390. The magnitude of the anomaly was less than SA had been in the past. WAAS detected the clock error and provided appropriate corrections, until the satellite was switched to Unhealthy (time 332390), at which time the WAAS declared PRN 5 "Do Not Use" with an alert (beginning at 332399). WAAS performed as designed during this anomaly. See GPS PAN report 42 for further details.

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.

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.