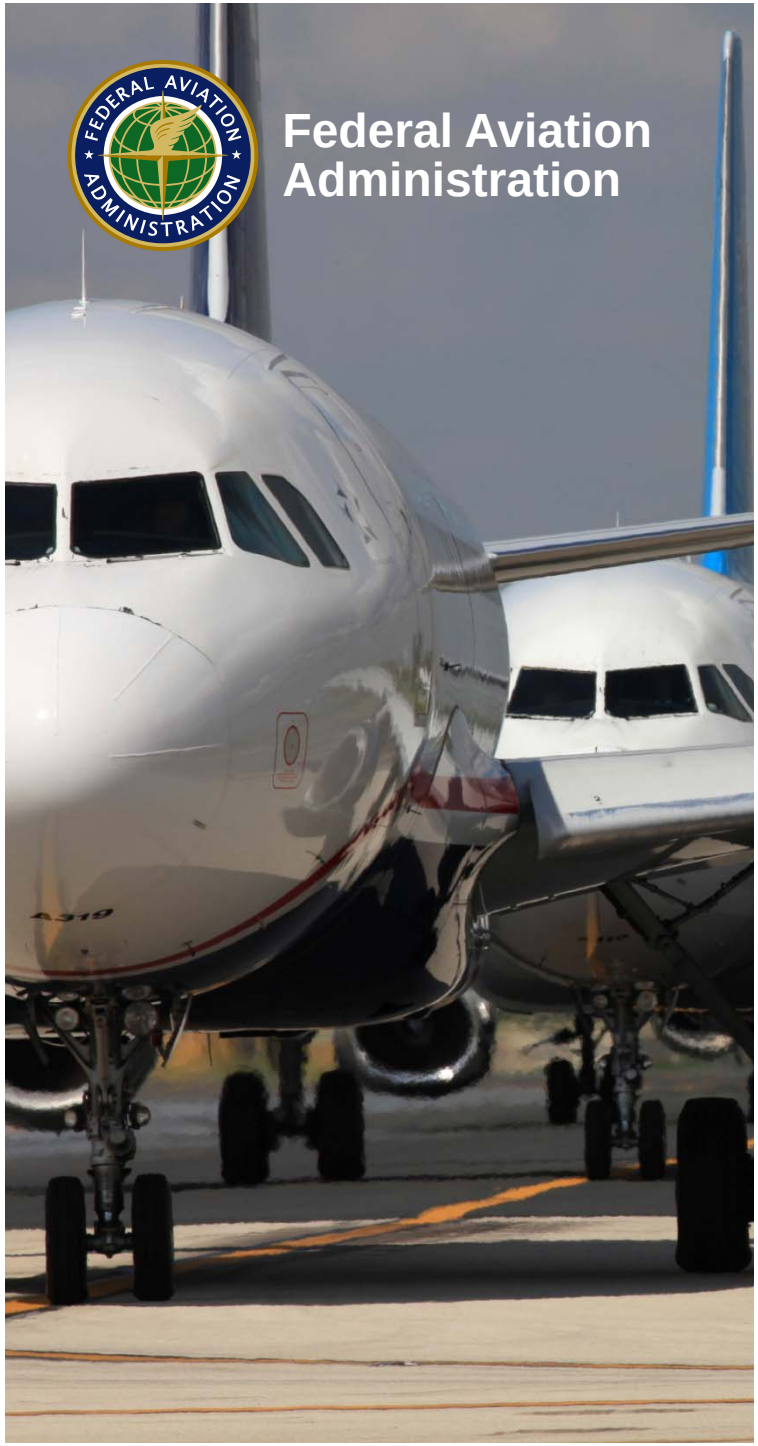
WAAS Technical Report
William J. Hughes Technical Center
Pomona, New Jersey

DR #115
Effect on WAAS from Iono Activity on June 1, 2013

Presented to: Distribution
By: Bill Wanner
Date: June 3, 2013



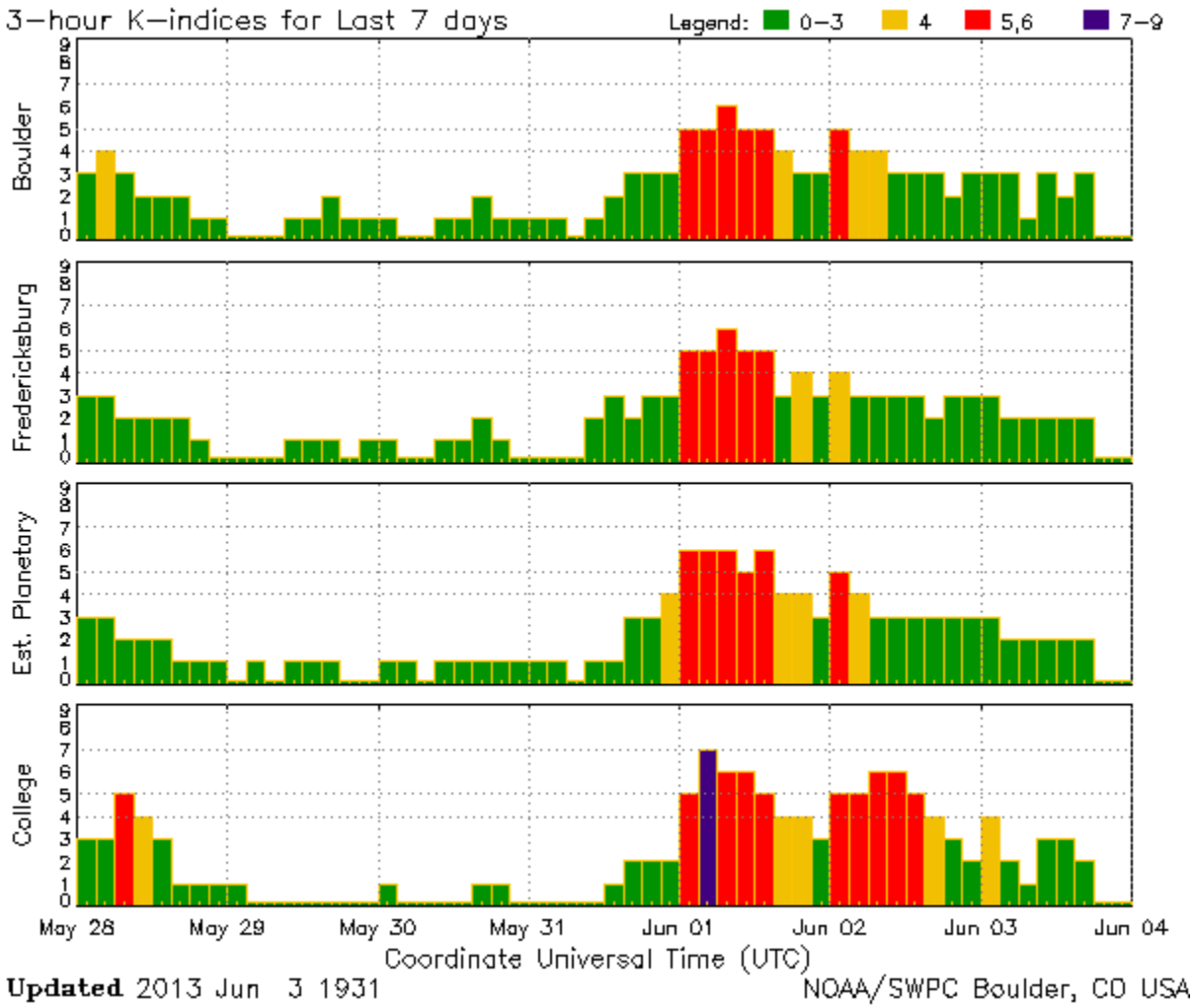
Background

- **From the Spaceweather.com webpage (courtesy of John Lacey June 3 email):**
  - ”[A] lengthy G2-class geomagnetic storm on May 31-June 1 [was] sparked by the arrival of an interplanetary shock wave. The source of the shock is unknown. Current speculation focuses on a co-rotating interaction region (CIR)--that is, a shock-like transition zone between high- and low-speed solar wind streams. Whatever it was, the impact ignited some beautiful auroras. On June 1st, Northern Lights spilled across the Canadian border into more than a dozen US states, turning the sky purple and green as far south as Colorado and Nebraska.”
- **This presentation shows the effects on WAAS aviation users from this solar event**

Kp Index

- **The Kp Index is a worldwide weighted average metric that is used to help define the magnitude of a geomagnetic storm**
  - The higher the value the more intense the storm
  - A value of 5 or more generally indicates a storm
- **The following chart shows the Kp index beginning on May 28, 2013**
- **As can be seen, the Kp reached a level of 7 at College and Kp = 6 at other locations on June 1**

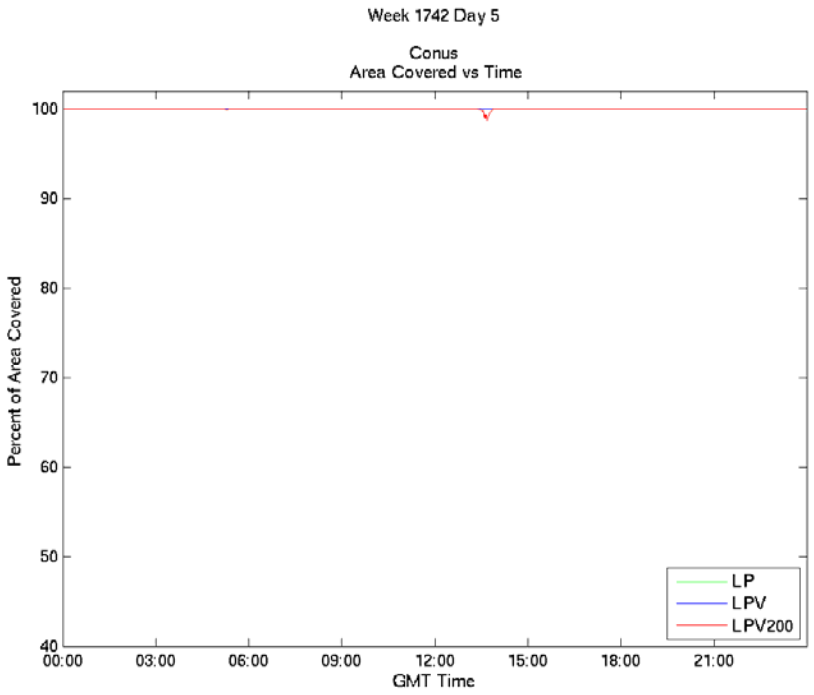
Kp Index Chart

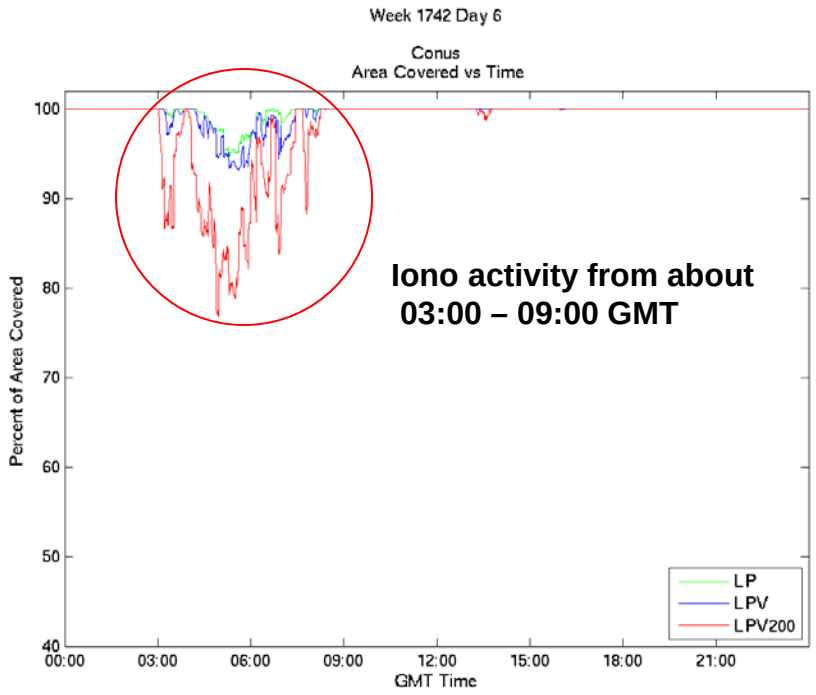


Coverage vs. Time Charts

- **This event affected WAAS early in the day (GMT time) on June 1**
- **For a comparison of a ‘good’ day and the coverage on June 1 the following two slides shows CONUS and Alaska coverage for June 1 and June 2**

Coverage vs. Time Charts – CONUS – May 31 vs June 1

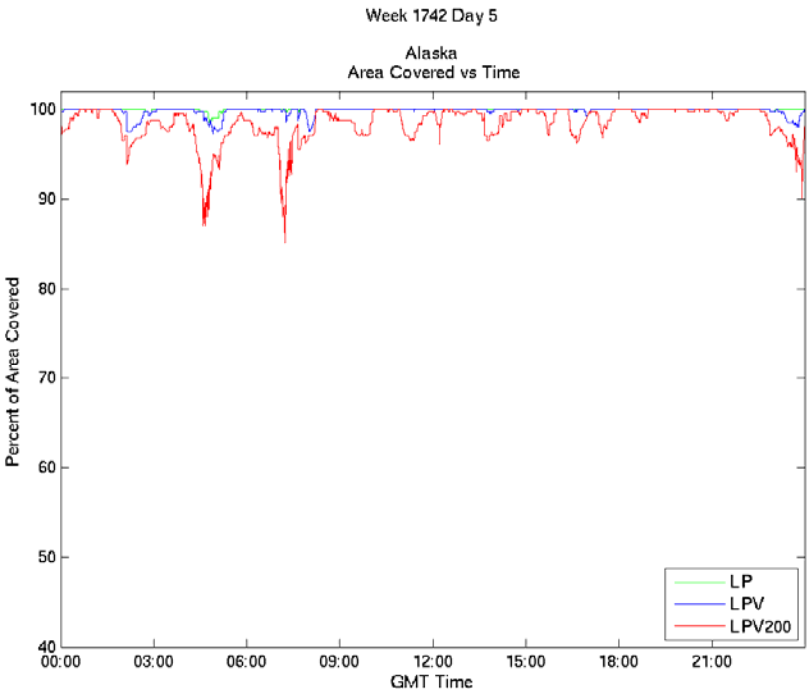


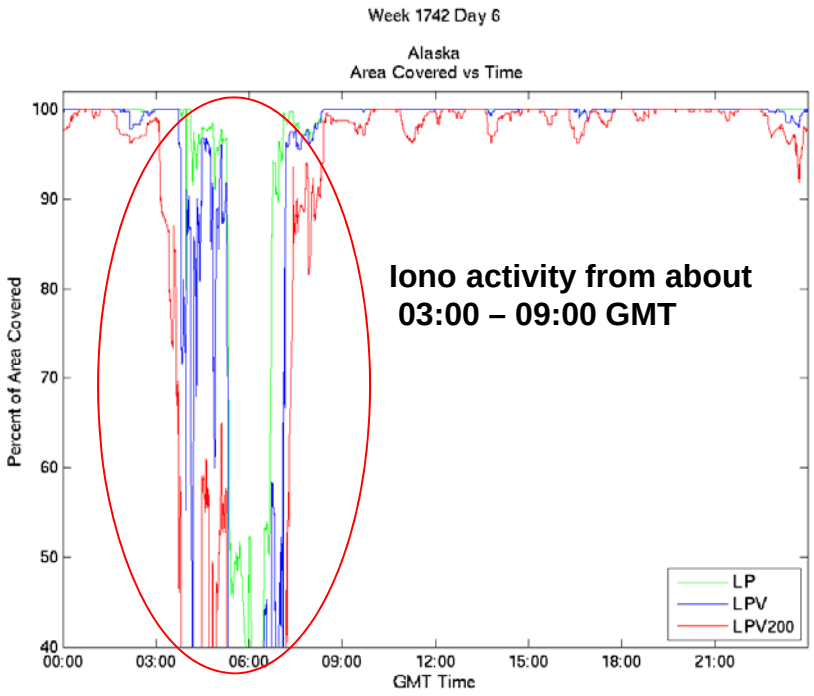


May 31, 2013

June 1, 2013

Coverage vs. Time Charts – Alaska – May 31 vs June 1





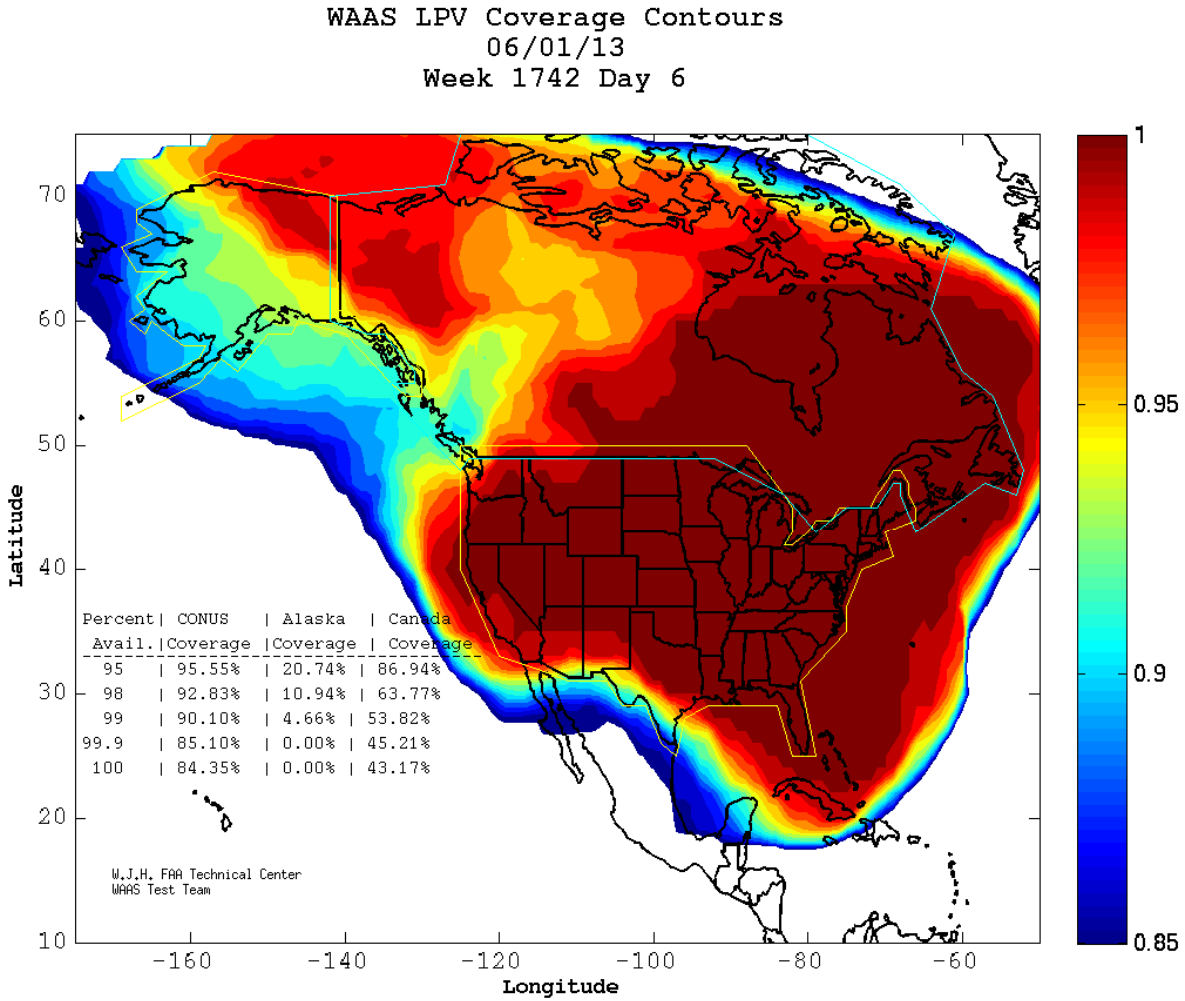
May 31, 2013

June 1, 2013

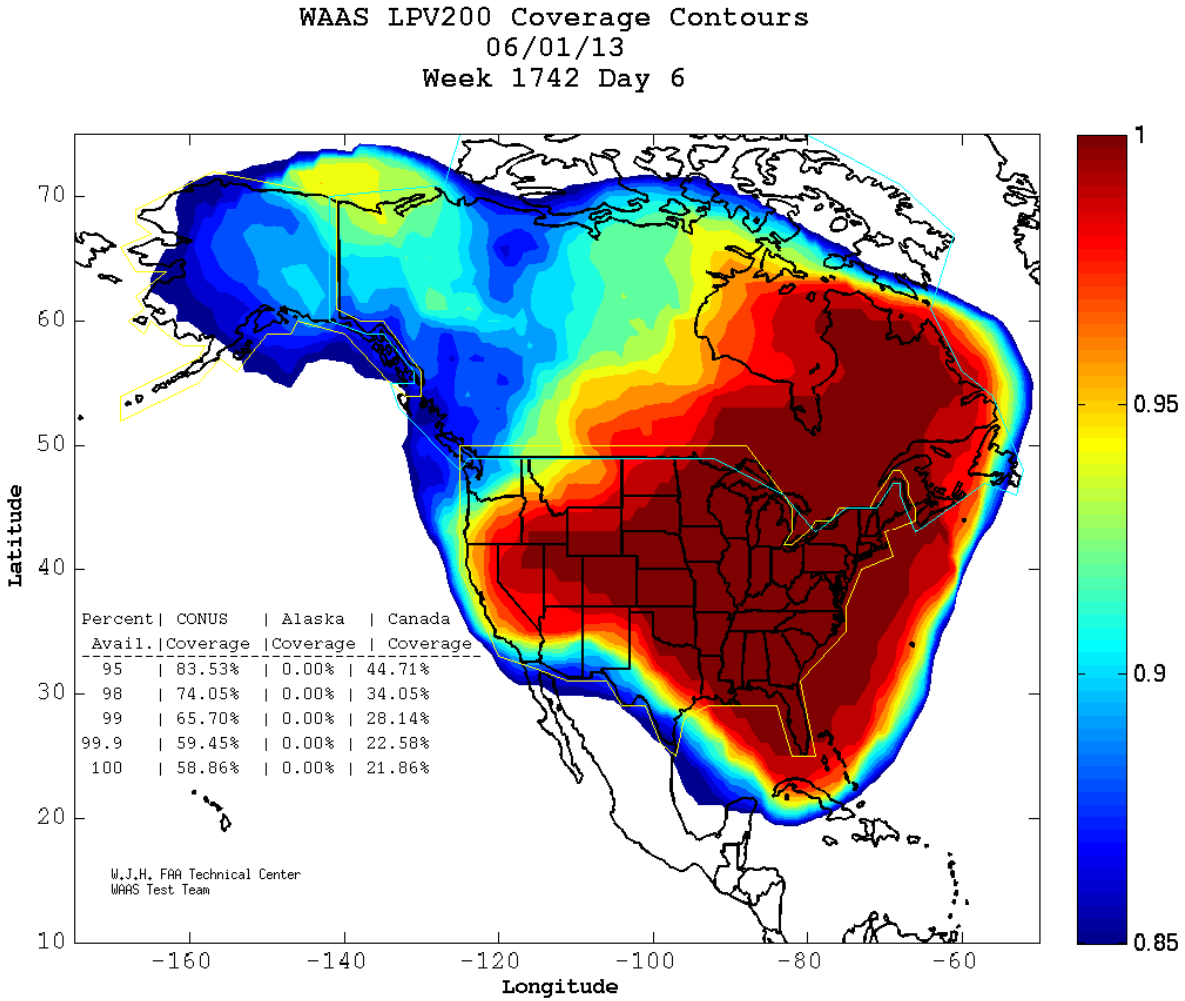
Coverage Charts

- **The next two slides show the LPV and LPV-200 coverage for June 1, respectively**
- **For this event, coverage was lost in Alaska, northwestern US, west coast, and the southwest**
- **After the LPV and LPV-200 charts is the LP and RNP- 0.1 coverage charts**
  - LP coverage is normally 100%
    - Coverage lost in Alaska, Canada, and Southwest CONUS
  - RNP- 0.1 is also normally 100%
    - Stayed at 100% for this event

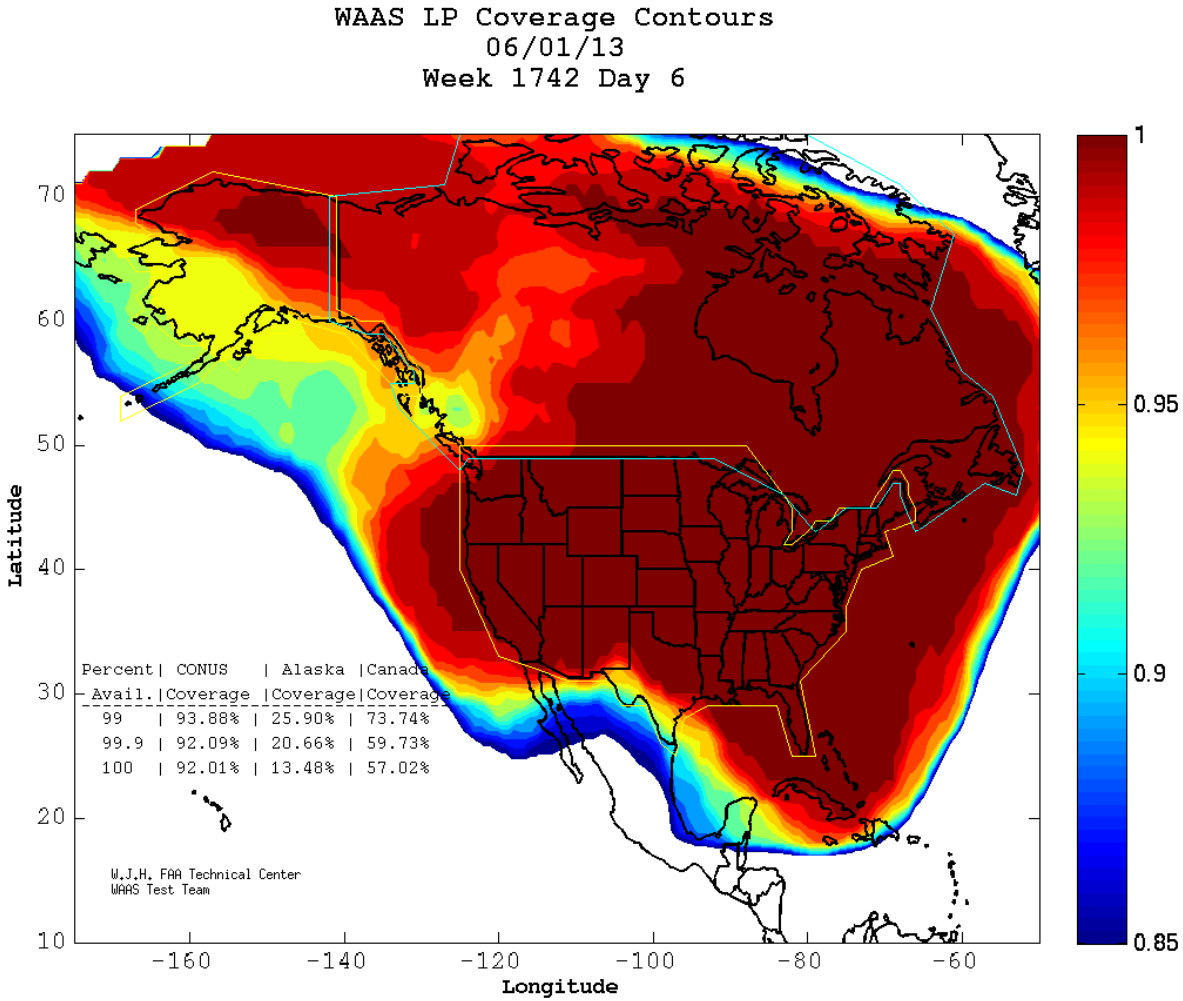
LPV Coverage – June 1, 2013



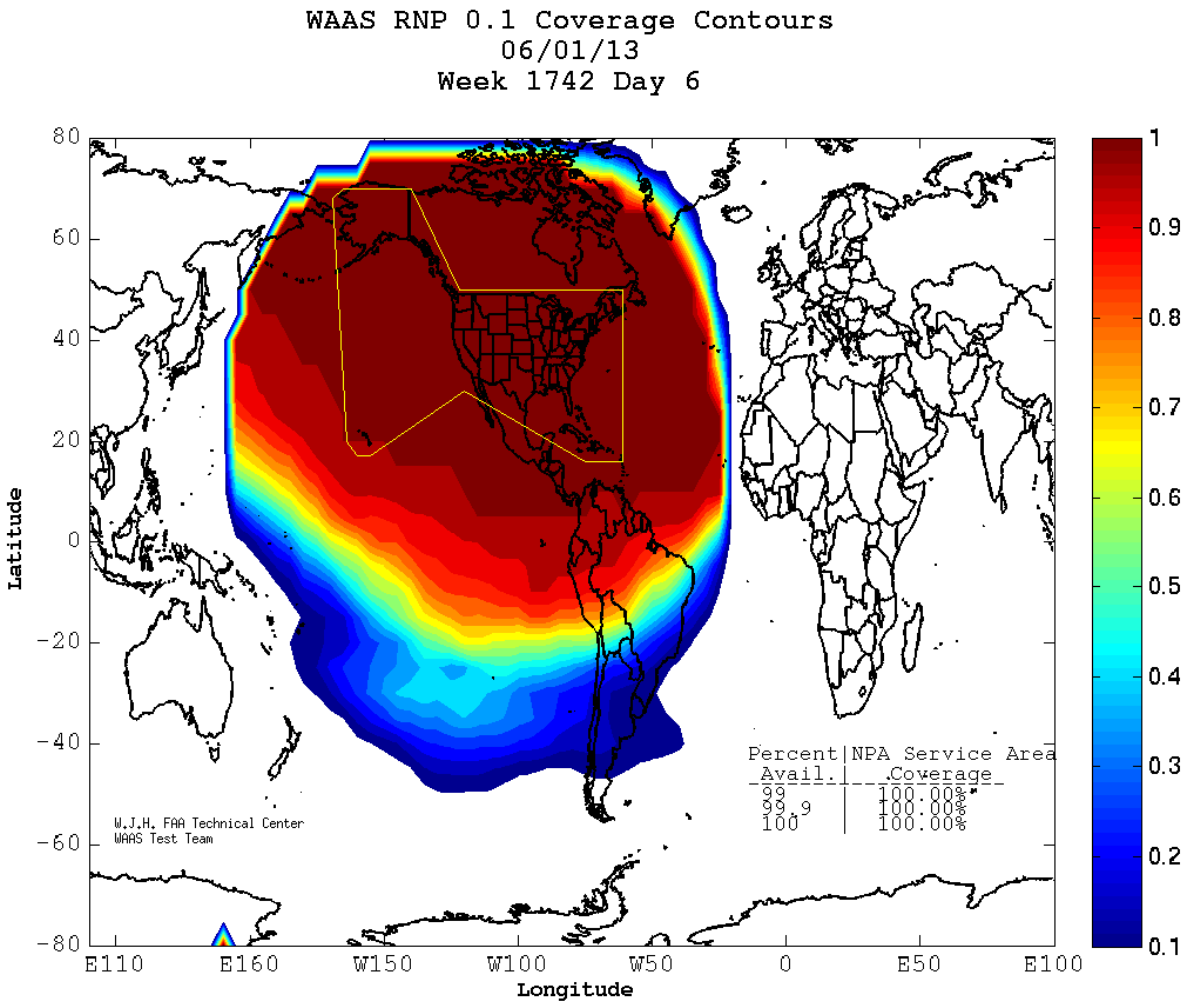
LPV-200 Coverage – June 1, 2013



LP Coverage – June 1, 2013



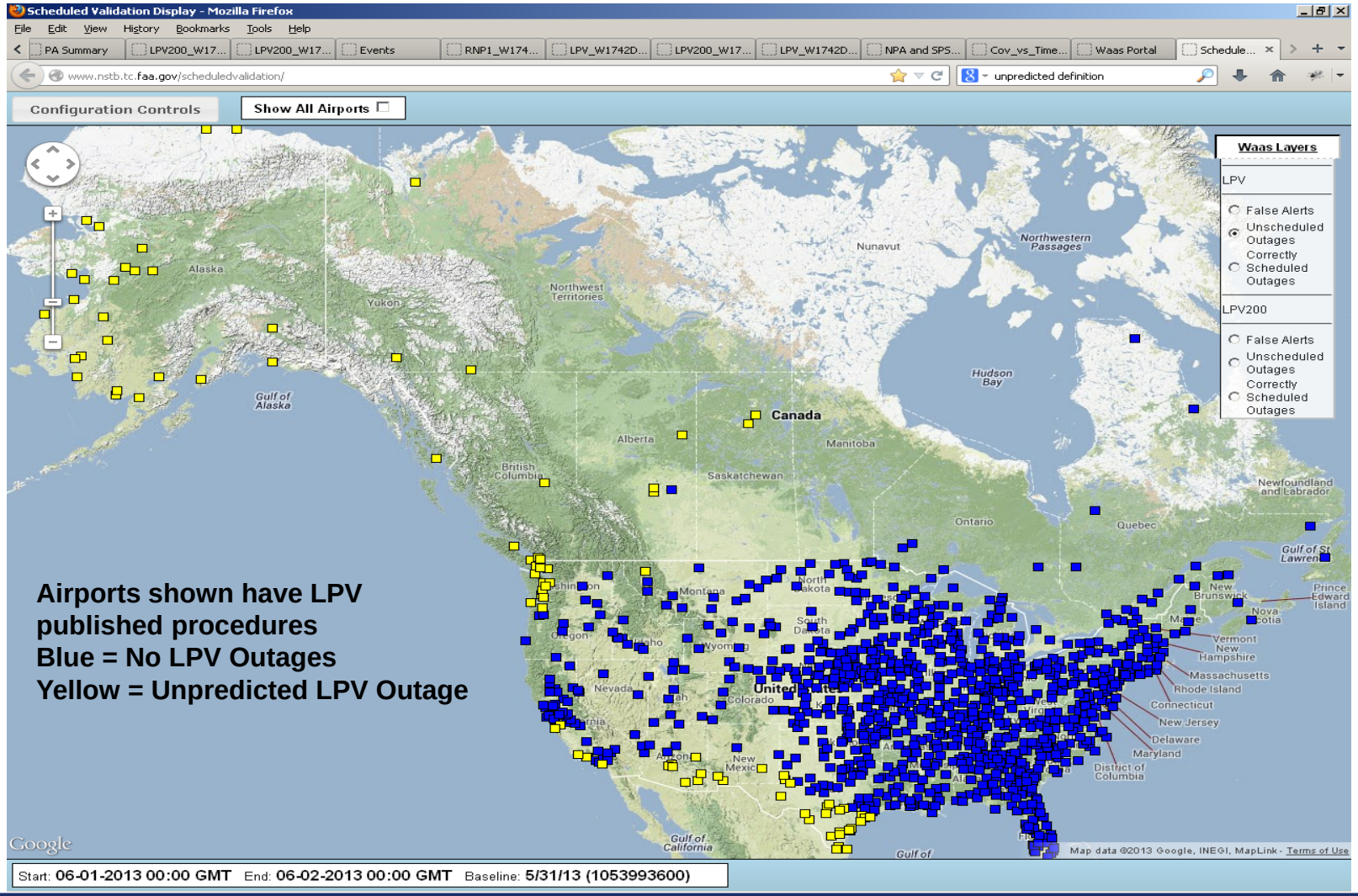
RNP 0.1 Coverage – June 1, 2013



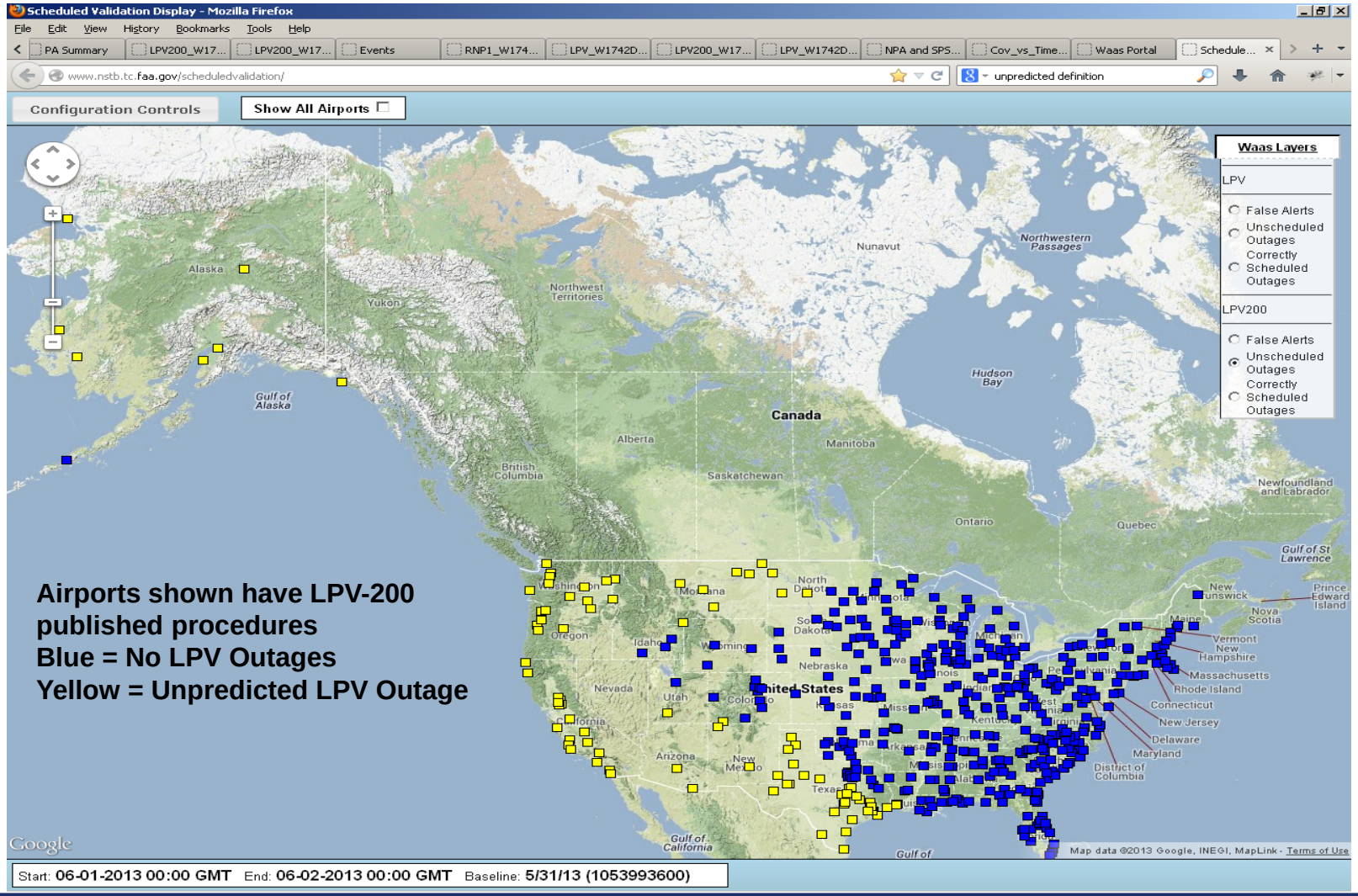
Airport Scheduling

- **The following 2 charts show the airports with LPV and LPV-200, respectively, service that was predicted to be available on June 1 but was not available due to the iono activity**
  - Only airports with LPV or LPV-200 published procedures are shown
  - Blue means there were no outages at that airport
  - Yellow means there was an unpredicted outage at that airport

Airports with Unpredicted LPV Outages – June 1, 2013



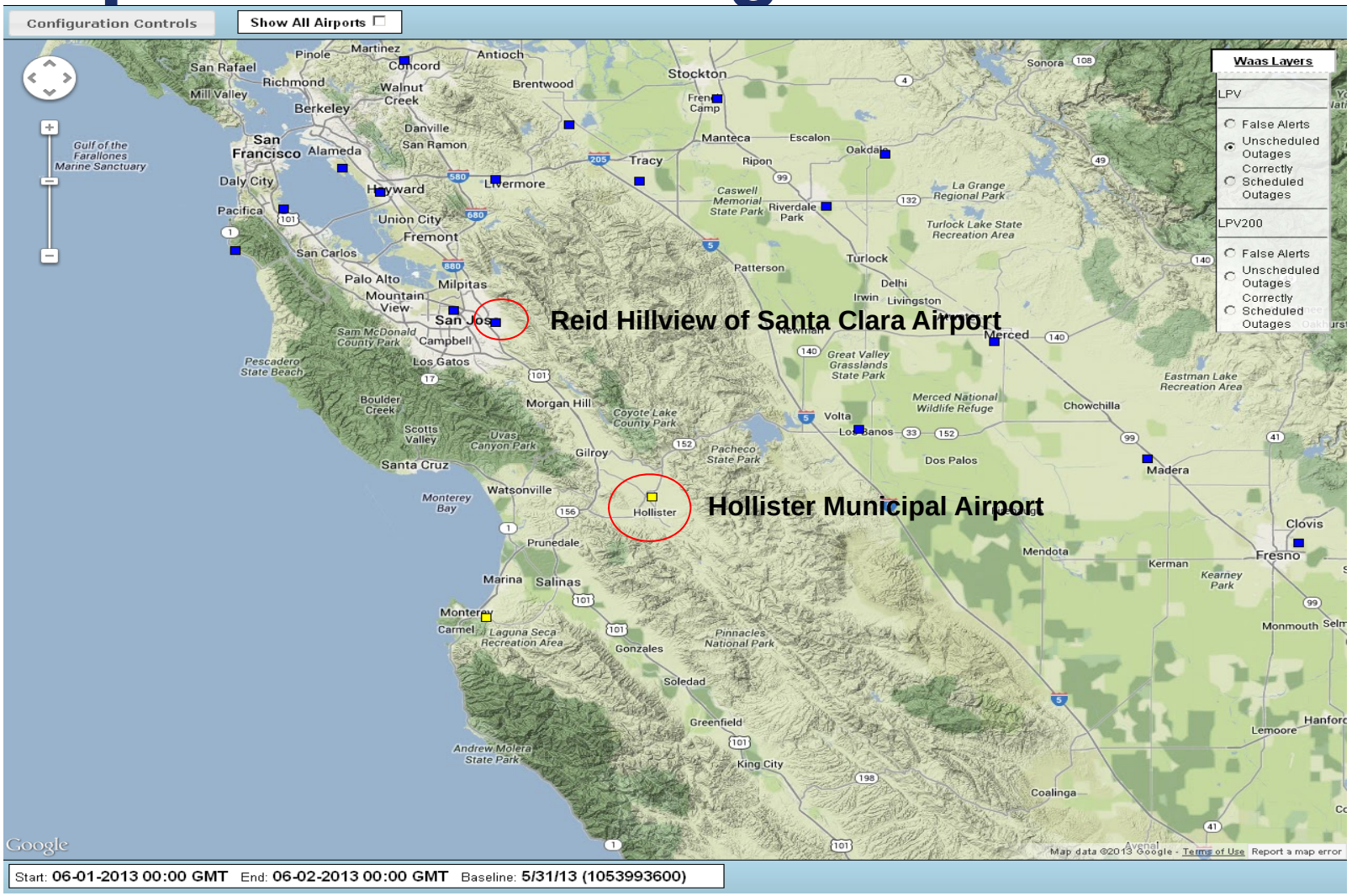
Airports with Unpredicted LPV-200 Outages – June 1, 2013



Airport Scheduling

- **In the previous "Airports with Unpredicted LPV Outages" chart some airports on the west coast do not have outages even though adjacent airports do have outages**
- **The next slide shows an example in California**
  - The Reid Hillview of Santa Clara Airport (RHV) has no outage while Hollister Municipal Airport (CVH) does
    - The airports are about 40 miles apart
    - The LPV outage at CVH occurred at 06:51 GMT and lasted for about 4 minutes

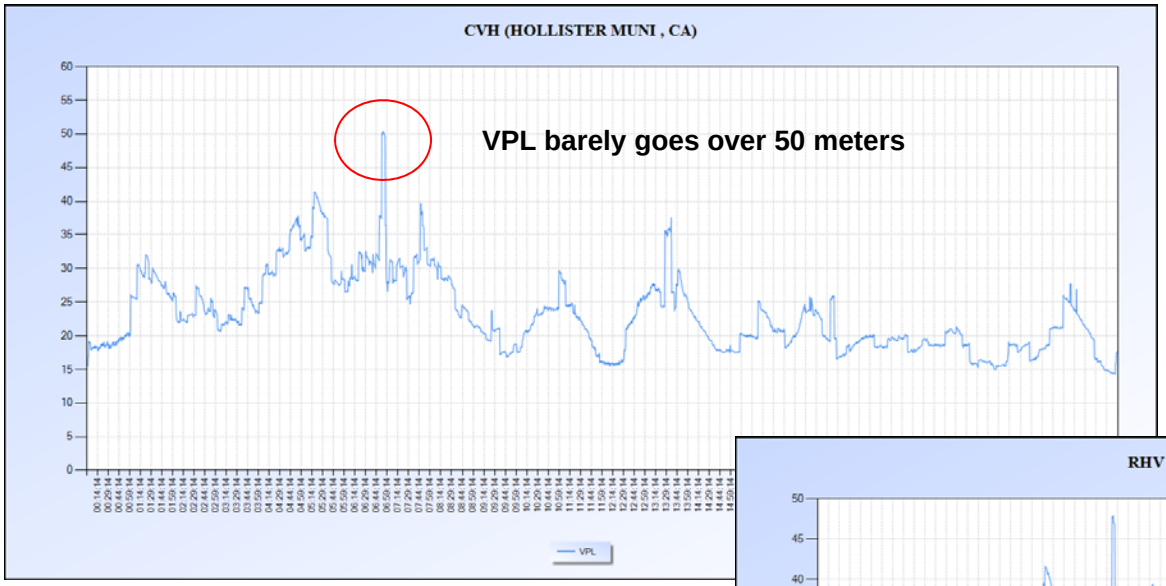
Airport Scheduling

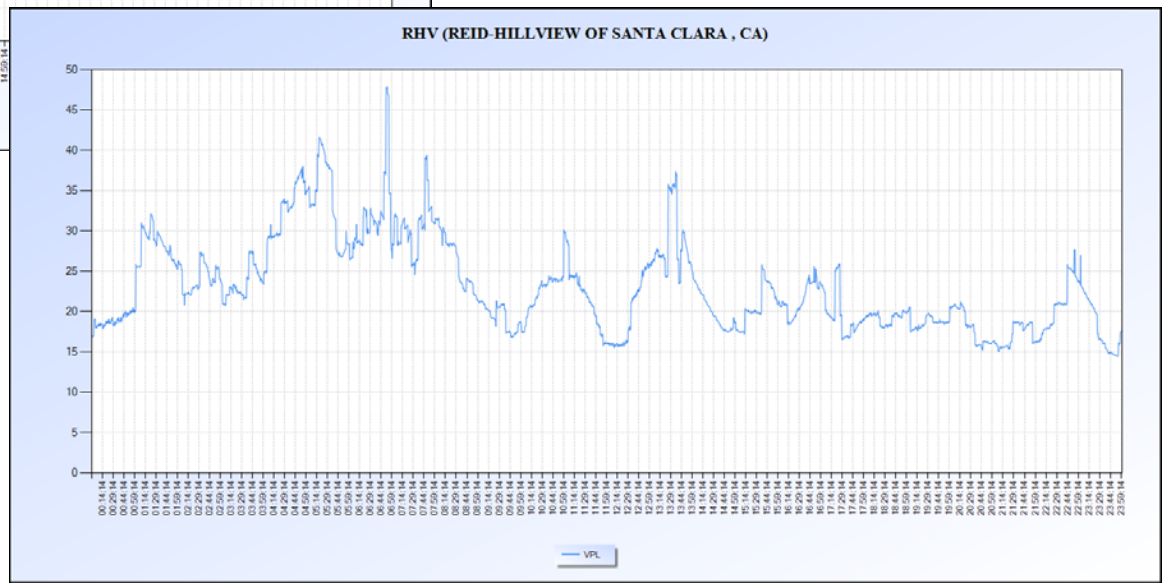


Airport Scheduling

- The next slide shows the VPL for the Reid Hillview of Santa Clara Airport (RHV) and Hollister Municipal Airport (CVH) Airport
  - The high VPL for the day at Hollister Municipal Airport was 50.4 meters at about 06:51 GMT
  - The high VPL for the day at Reid Hillview of Santa Clara Airport was 47.8 meters at about 06:51 GMT

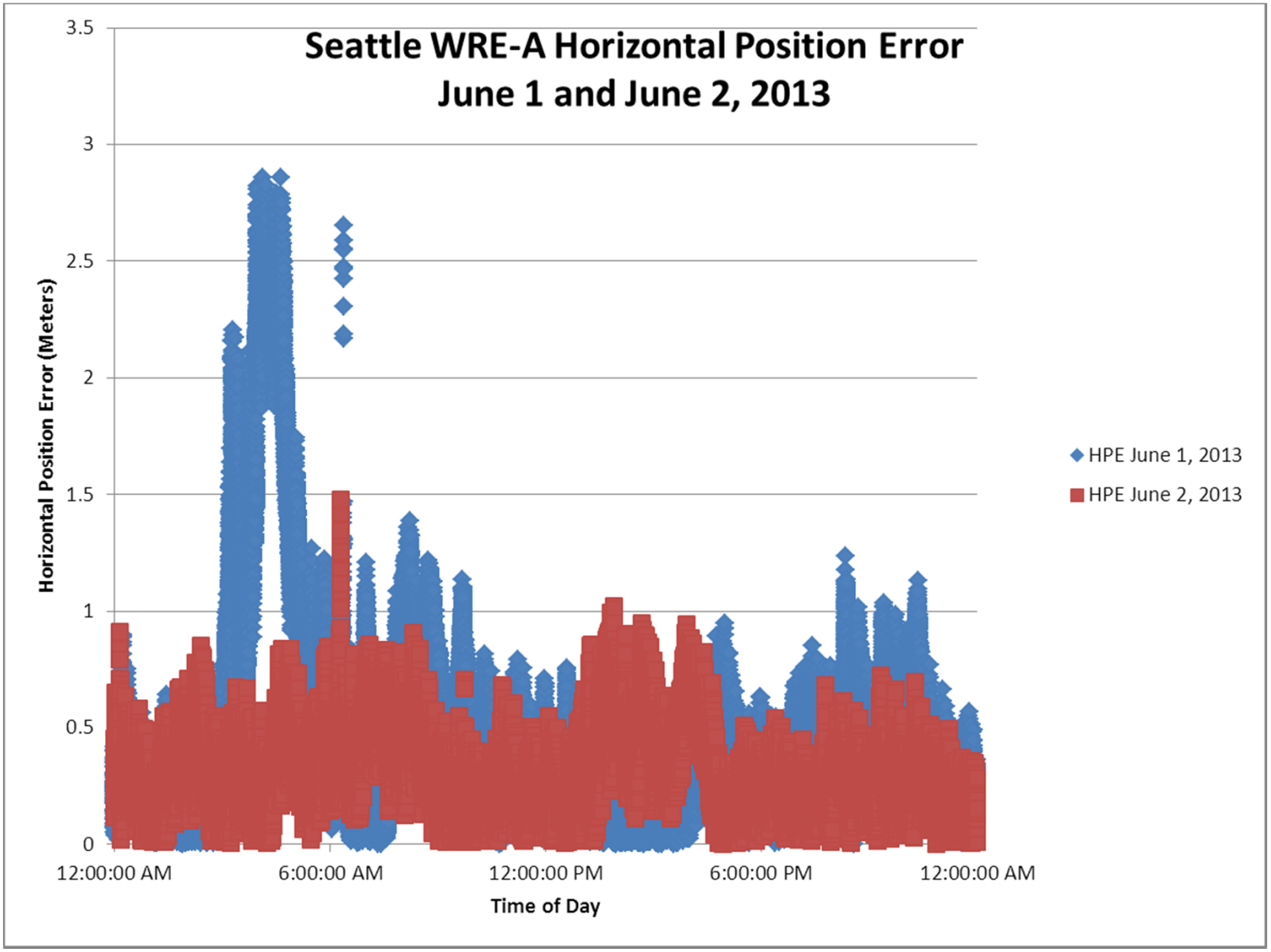
Airport Scheduling

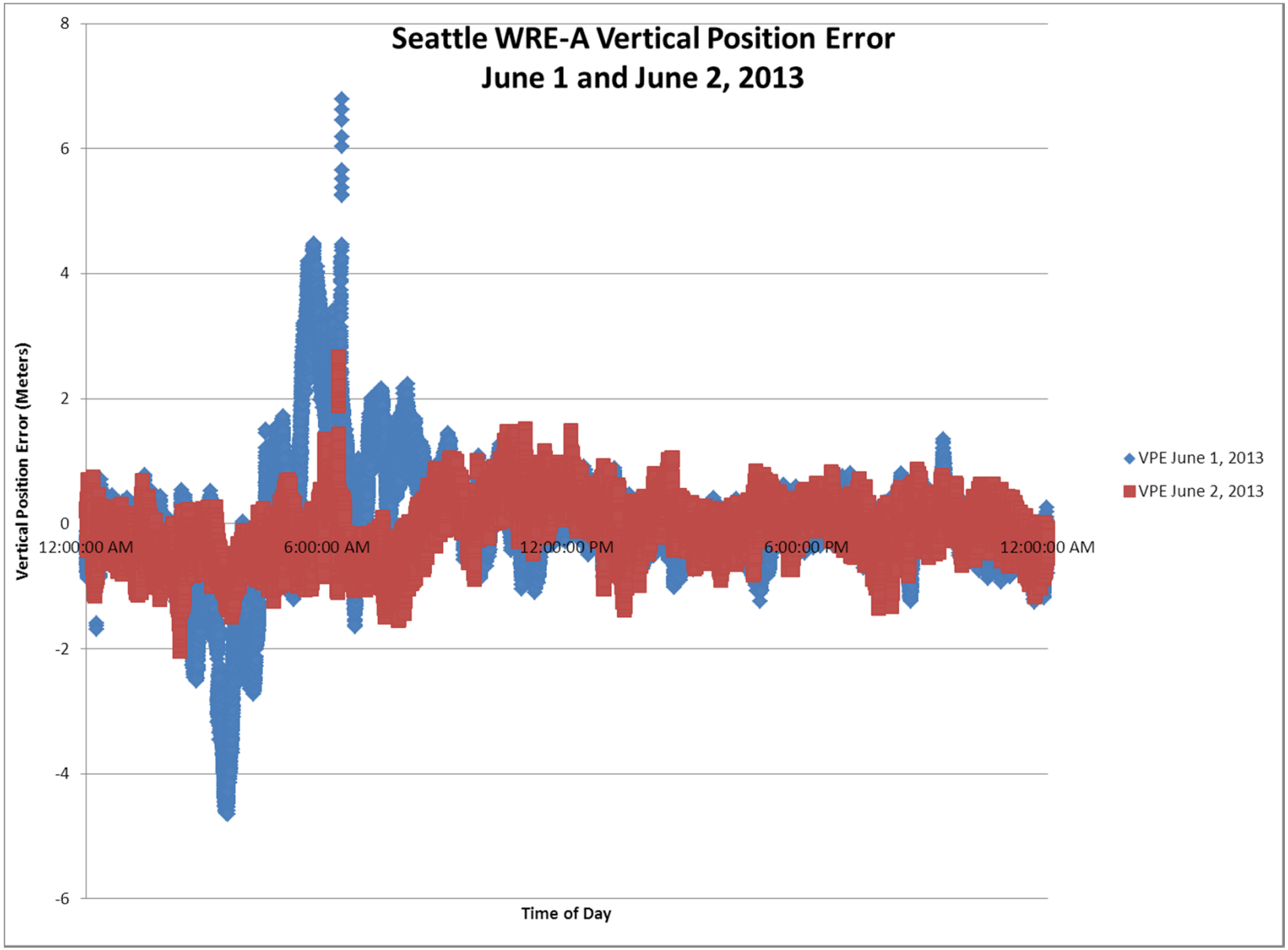




Accuracy – WAAS User

- **Accuracy was higher on June 1 than other days**
  - Both horizontal and vertical position errors were higher
- **Next two charts show the HPE and VPE, respectively, at the Seattle WAAS reference station on June 1 and June 2**
  - Seattle is used as an example
- **The maximum HPE at Seattle is normally less than 1.5 meters**
  - The maximum HPE was about 2.9 meters on June 1
  - HPL was 22.5 meters at the time of the maximum error
    - HPE/HPL ratio = .13
- **The maximum VPE at Seattle is normally less than 3 meters**
  - The maximum VPE was about 6.8 meters on June 1
  - VPL was 25.3 meters at the time of the maximum error
    - VPE/VPL ratio = .27, the highest of all WAAS sites on June 1 but VPE was still very well bounded by VPL


Seattle WRE-A Horizontal Position Error
June 1 and June 2, 2013
Horizontal Position Error (Meters)
3.5
3
2.5
2
1.5
1
0.5
0
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
Time of Day
HPE June 1, 2013
HPE June 2, 2013


Seattle WRE-A Vertical Position Error
June 1 and June 2, 2013
Vertical Position Error (Meters)
8
6
4
2
0
-2
-4
-6
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
Time of Day
VPE June 1, 2013
VPE June 2, 2013

Accuracy – GPS User

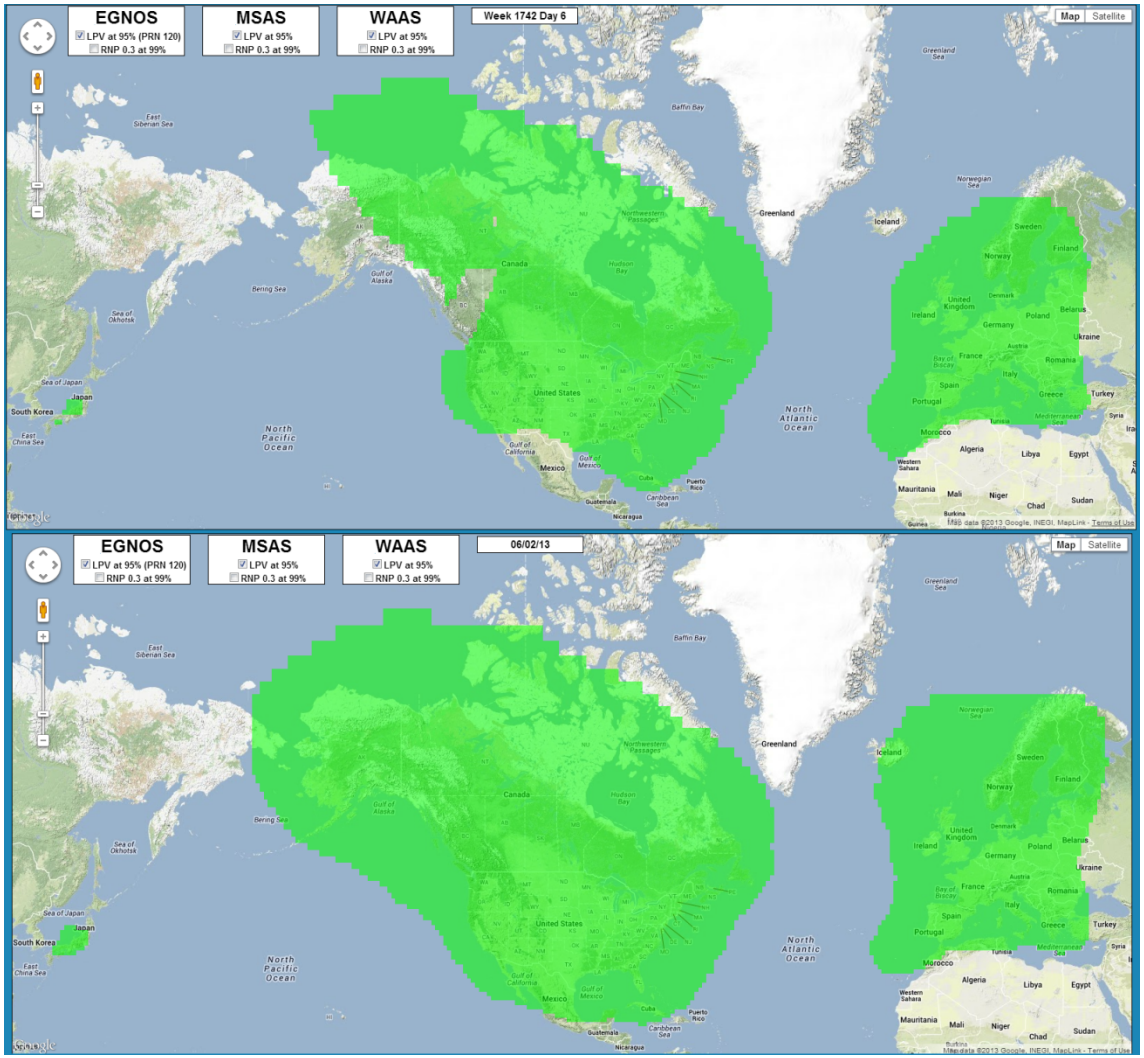
- **The following table shows a comparison of the calculated accuracy for a single frequency L1 SPS user and a position solution using dual frequency (L1 and L2) for several sites:**

Site Name	Dual Frequency Horizontal Position Error (m)	Dual Frequency Vertical Position Error (m)	SPS Horizontal Position Error (m)	SPS Vertical Position Error (m)
Cold Bay	3.239	3.991	6.857	9.308
San Jose del Cabo	3.035	3.974	5.576	15.317
Los Angeles	2.903	5.079	4.786	11.373
Oakland	3.069	6.473	5.961	10.235

EGNOS Coverage

- **Since EGNOS is publishing LPV procedures we took a look at the 24 hour coverage plot**
- **The plot is based on data collected from the Atlantic City and Bangor NSTB reference receivers**
  - Data from ENGOS GEO PRN 120
- **On the next slide the top plot is WAAS and EGNOS LPV coverage on June 1 and the bottom plot is June 2**
  - Little impact to EGNOS LPV coverage due to the iono activity on June 1 when compared to June 2
- **MSAS is included in the plot but there is no LPV approved procedures that use MSAS**

WAAS/EGNOS Coverage June 1-2



Conclusion

- **Iono activity on June 1 caused a loss of LP, LPV, and LPV-200 coverage in the WAAS service volume**
- **Accuracy for a WAAS and single frequency GPS user was increased on June 1 compared to June 2**
- **EGNOS coverage was minimally impacted due to this iono event**