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

Federal Aviation Administration

DR #102
WAAS Reaction to Iono Activity

June 5 2011

Presented to: WAAS Team

By: Bill Wanner

Date: June 7, 2011

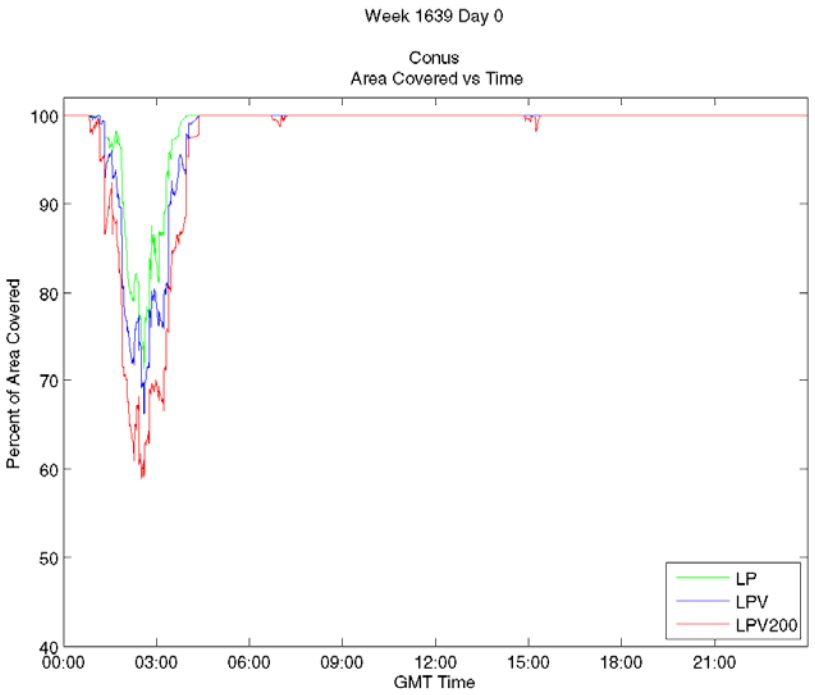
Background

- **This presentation shows the WAAS operational system and WAAS shadow system (Release 3A) reaction to ionospheric activity on June 5, 2011**
  - The activity occurred the evening on June 4 local time in CONUS, but it was past midnight GMT
- **KP reached 6 on this day**
- **WAAS degradation in north central/western CONUS and in southern Florida/Caribbean**
  - Canada also affected
- **WAAS operational system had worse performance than the shadow system**
  - This storm is a good illustration of the improvement Release 3A will have on WAAS performance during ionopheric activity

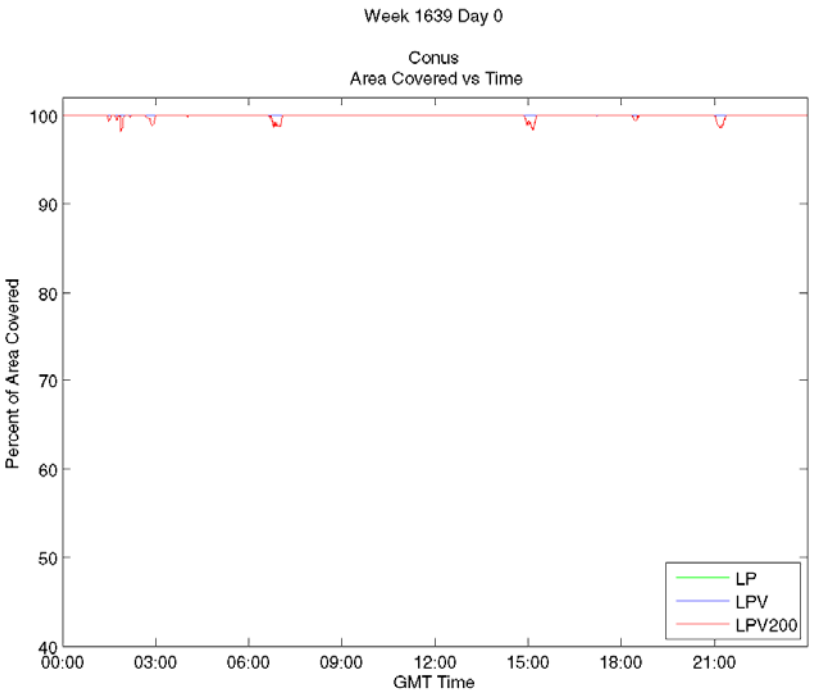
Area Covered vs. Time Plot June 5, 2011

- **The next slide shows the area covered vs. time plot for CONUS**
  - Includes LP, LPV, and LPV 200
- **Operational system and shadow system are shown**
- **Degradation in the operational system occurred from ~1:00 to ~4:30 GMT**
  - Note that the plots state the date as ‘Week 1639 Day 0’ – This is the same day (in GPS nomenclature) as June 5, 2011

Area Covered vs. Time Plot



Operational WAAS

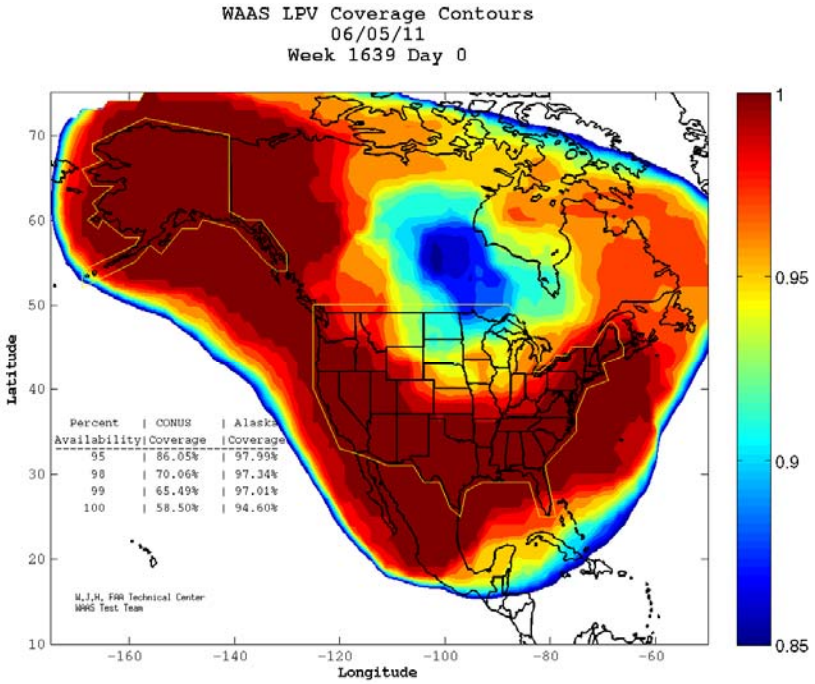


Shadow System Release 3A

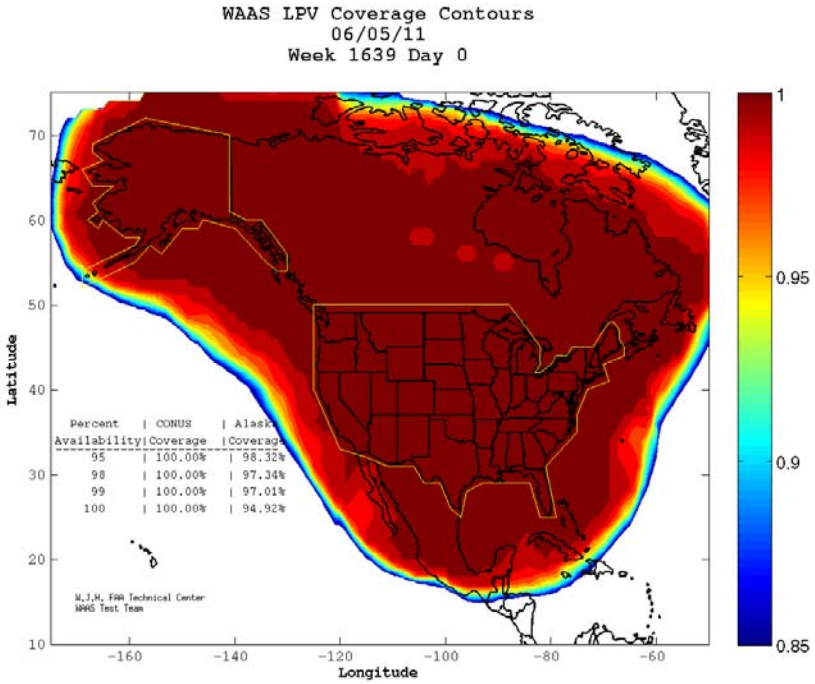
LPV, LPV 200, and LP 24 Hour Plots

- **The next three slides show the North American 24 hour plots for LPV, LPV 200, and LP**
  - Plots for operational and shadow system
  - This plot shows the impact in Canada due to this ionospheric activity
  - Note that Alaska was not affected

LPV 24 Hour Plot

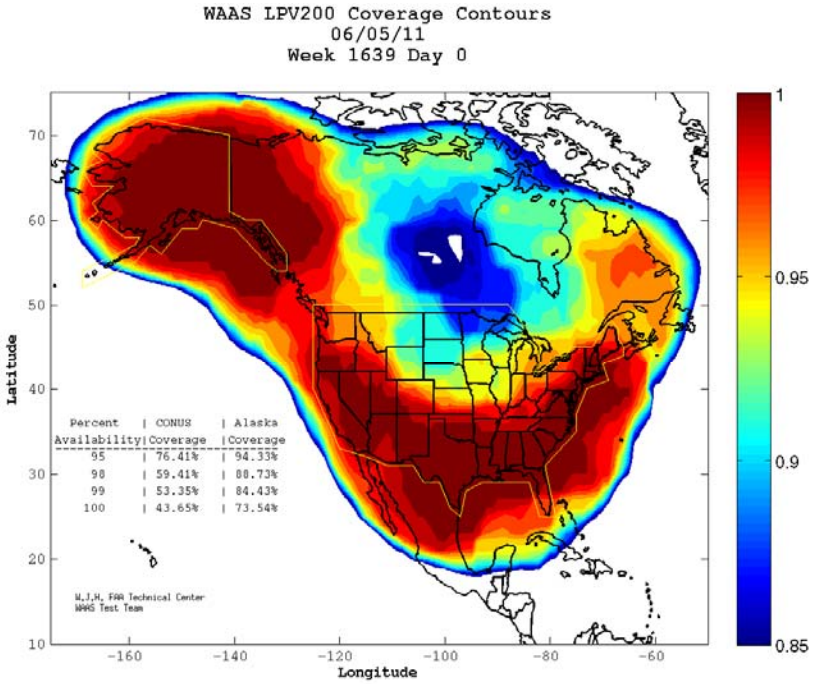


Operational WAAS

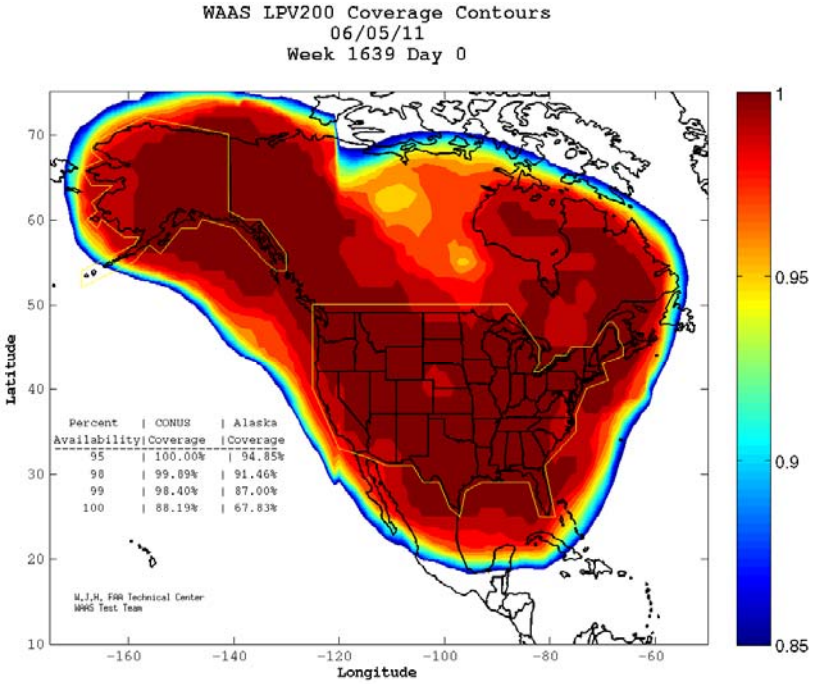


Shadow System Release 3A

LPV 200 24 Hour Plot

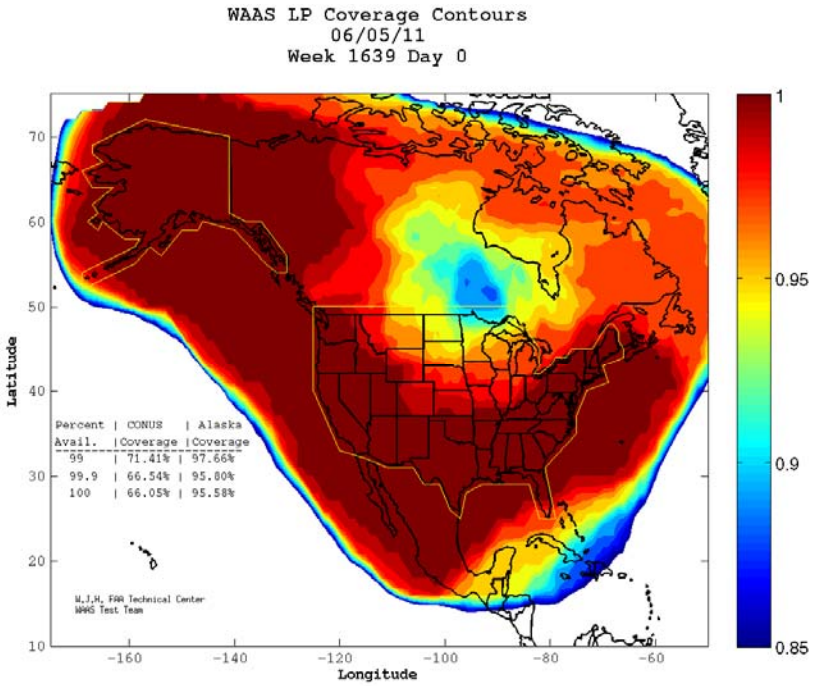


Operational WAAS

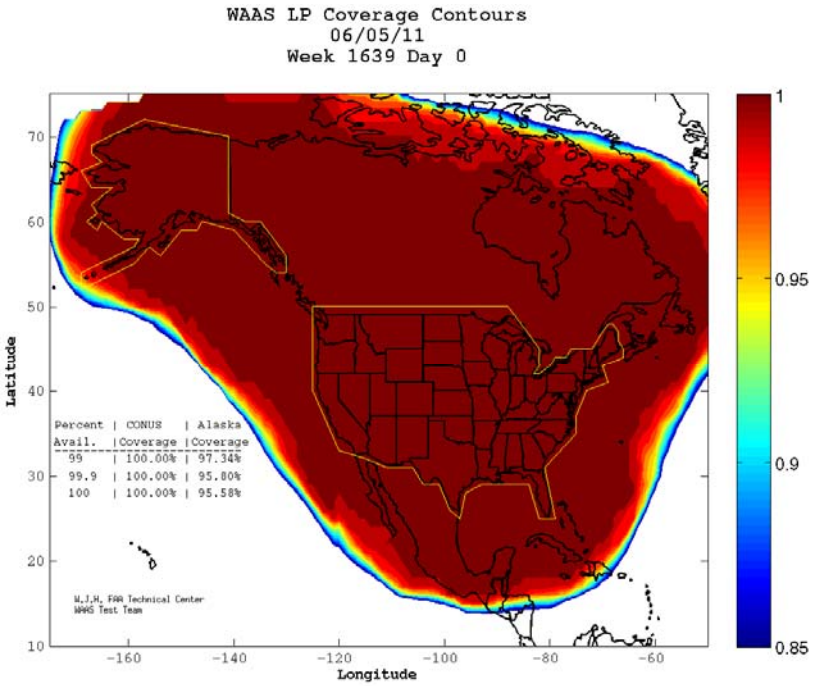


Shadow System Release 3A

LP 24 Hour Plot



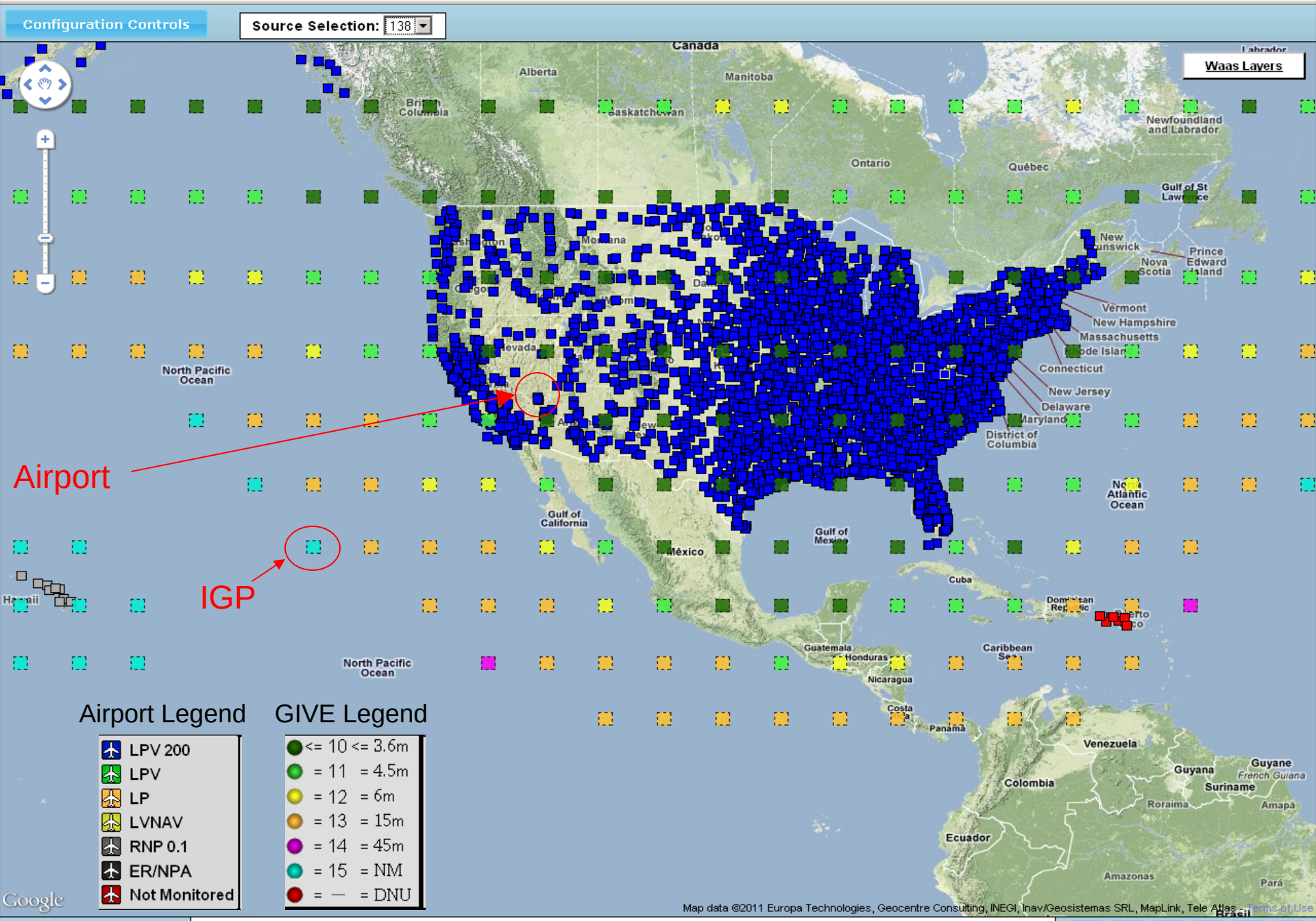
Operational WAAS



Shadow System Release 3A

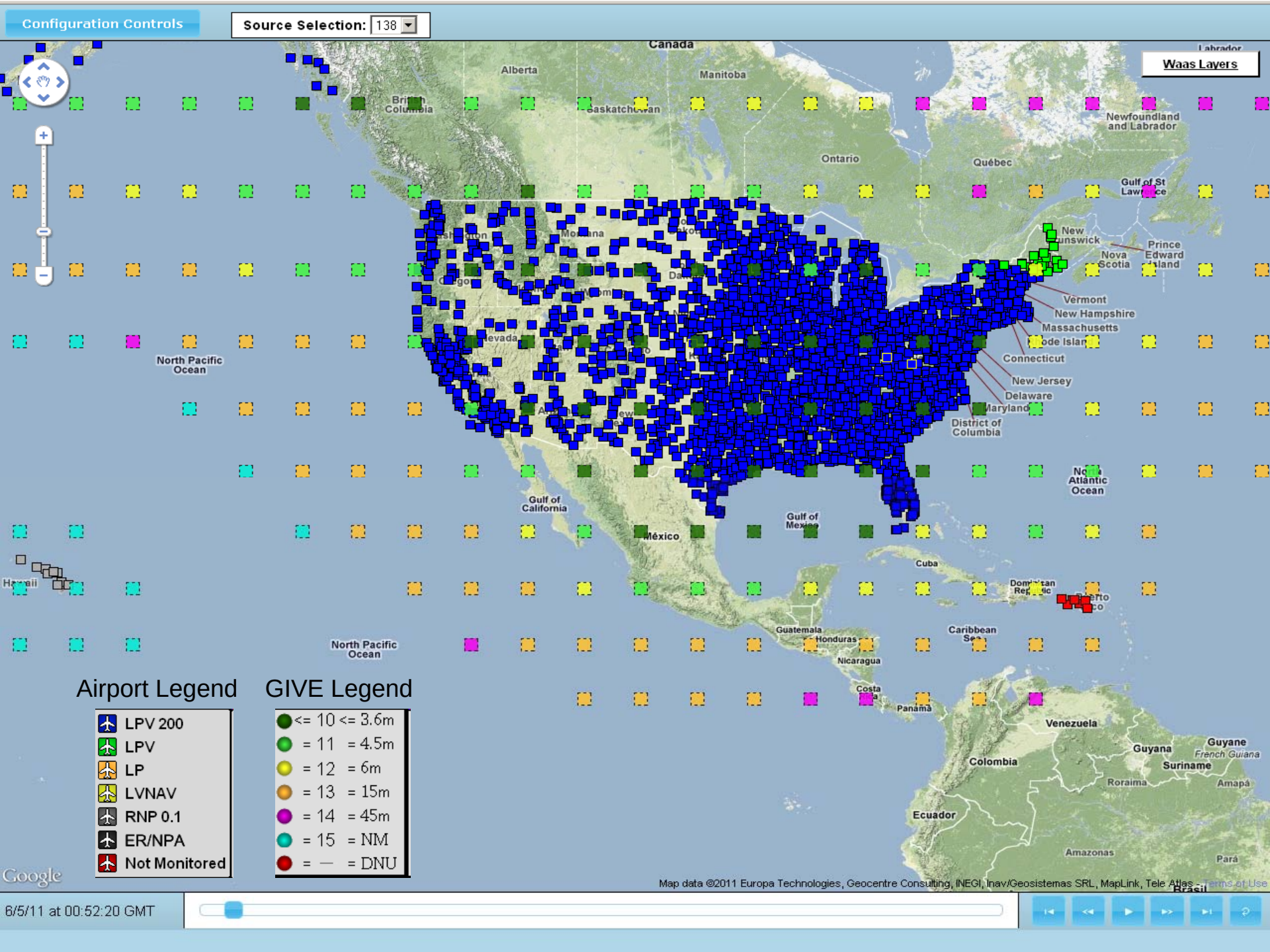
Snapshot Plots

- **The following few slides show the airports in CONUS affected by ionospheric activity in the operational WAAS**
  - Plots also include IGP GIVEs at the time the snapshot is taken
  - Each small square is an airport that has at least a GPS published procedure
  - Each larger square is an IGP
- **The first plot is at the beginning of the day (00:10:36 GMT)**
  - No ionospheric activity that affects WAAS at this time
- **Airport Legend notes**
  - The legend refers to what service is supported at that airport based on the calculated VPL and HPL
    - This does not necessarily mean that there is a published approach for that service
    - For example, not all the airports in the next slide have published LPV 200 approaches
  - 'LPV 200' = **VPL is less than 35 m** and **HPL is less than 40 m**
  - 'LPV' = **VPL is between 35 m and 50 m** and **HPL is less than 40 m**
  - 'LP' = **VPL is greater than 50 m** and **HPL is less than 40 m**
  - 'LVNAV' = **VPL is less than 50 m** and **HPL is between 40 m and 556 m**
  - 'Not Monitored' = **VPL is greater than 50 m** and **HPL is greater than 40 m**
  - 'RNP 0.1' and 'ER/NPA' not of interest in these plots


Configuration Controls
Source Selection: 138
Waas Layers
Airport
IGP
Airport Legend
LPV 200
LPV
LP
LVNAV
RNP 0.1
ER/NPA
Not Monitored
GIVE Legend
<= 10 <= 3.6m
= 11 = 4.5m
= 12 = 6m
= 13 = 15m
= 14 = 45m
= 15 = NM
= — = DNU
Canada
Alberta
Manitoba
Ontario
Québec
Newfoundland and Labrador
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Pacific Ocean
Gulf of California
Gulf of Mexico
México
Cuba
Guatemala
Honduras
Nicaragua
Panamá
Caribbean Sea
Venezuela
Colombia
Guyana
Suriname
Ecuador
Amazonas
Pará
Roraima
Amapá
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas - Terms of Use
6/5/11 at 00:10:36 GMT

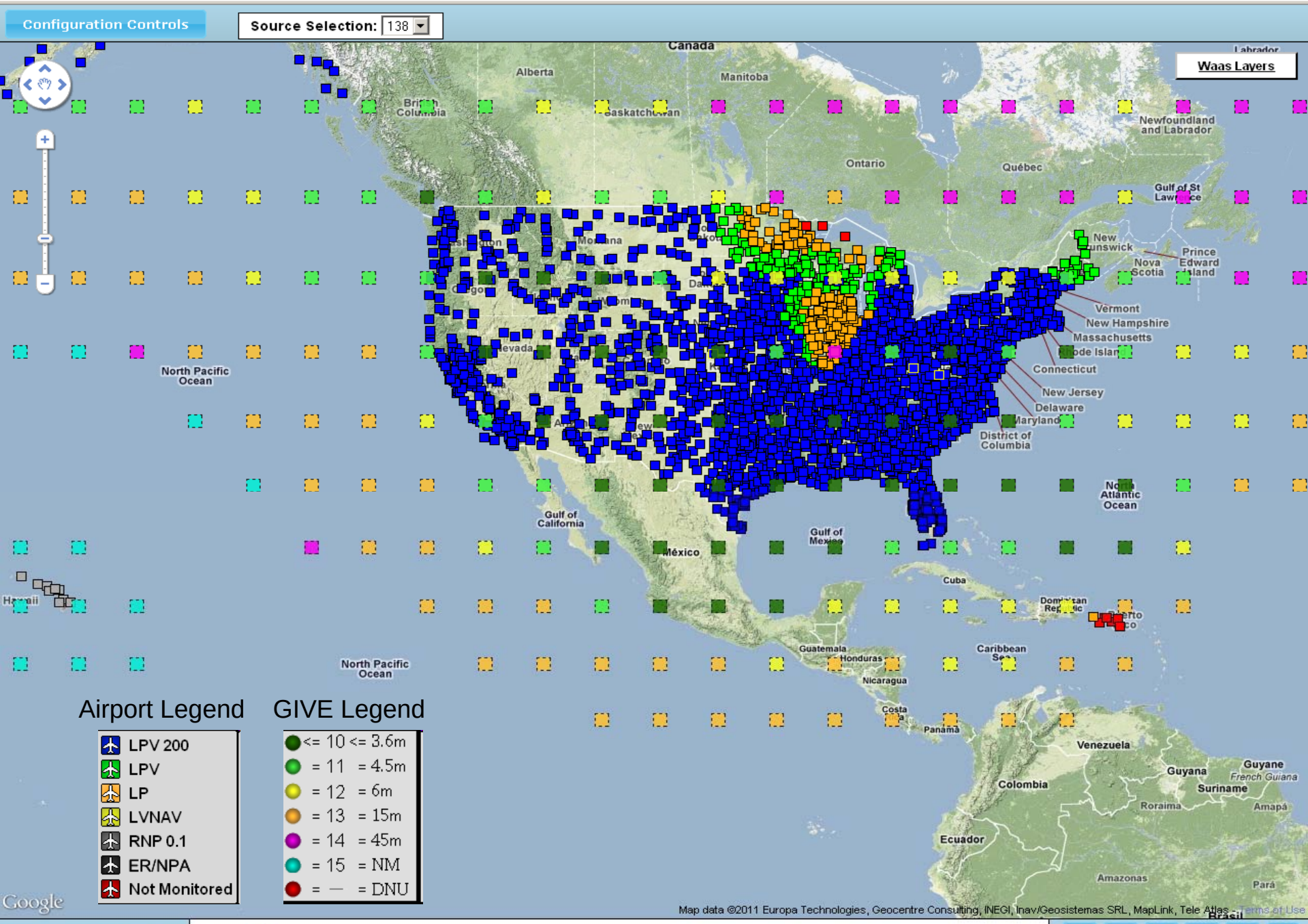
Onset of Iono Activity

- **The next slide shows that iono activity is first seen at 00:52:20 GMT**
- **The HPLs and VPLs calculated at airports in Northeast CONUS no longer support LPV 200 service, though they normally do**
  - Color of those airports is now ‘Green’ and not ‘Blue’
  - GIVEs for IGPs in that region are higher than on a normal day at this time
  - GIVEs are elevated on this day since the vertical delays for IGPs in the Northeast are low, but vertical delays further south are higher than normal


Configuration Controls
Source Selection: 138
Waas Layers
Canada
Alberta
Manitoba
Ontario
Québec
Newfoundland and Labrador
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Pacific Ocean
Gulf of California
Gulf of Mexico
México
Cuba
Guatemala
Honduras
Nicaragua
Costa Rica
Panama
Caribbean Sea
Venezuela
Colombia
Ecuador
Guyana
Suriname
Guyane
French Guiana
Roraima
Amapá
Amazonas
Pará
Airport Legend
LPV 200
LPV
LP
LVNAV
RNP 0.1
ER/NPA
Not Monitored
GIVE Legend
<= 10 <= 3.6m
= 11 = 4.5m
= 12 = 6m
= 13 = 15m
= 14 = 45m
= 15 = NM
= — = DNU
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas
6/5/11 at 00:52:20 GMT

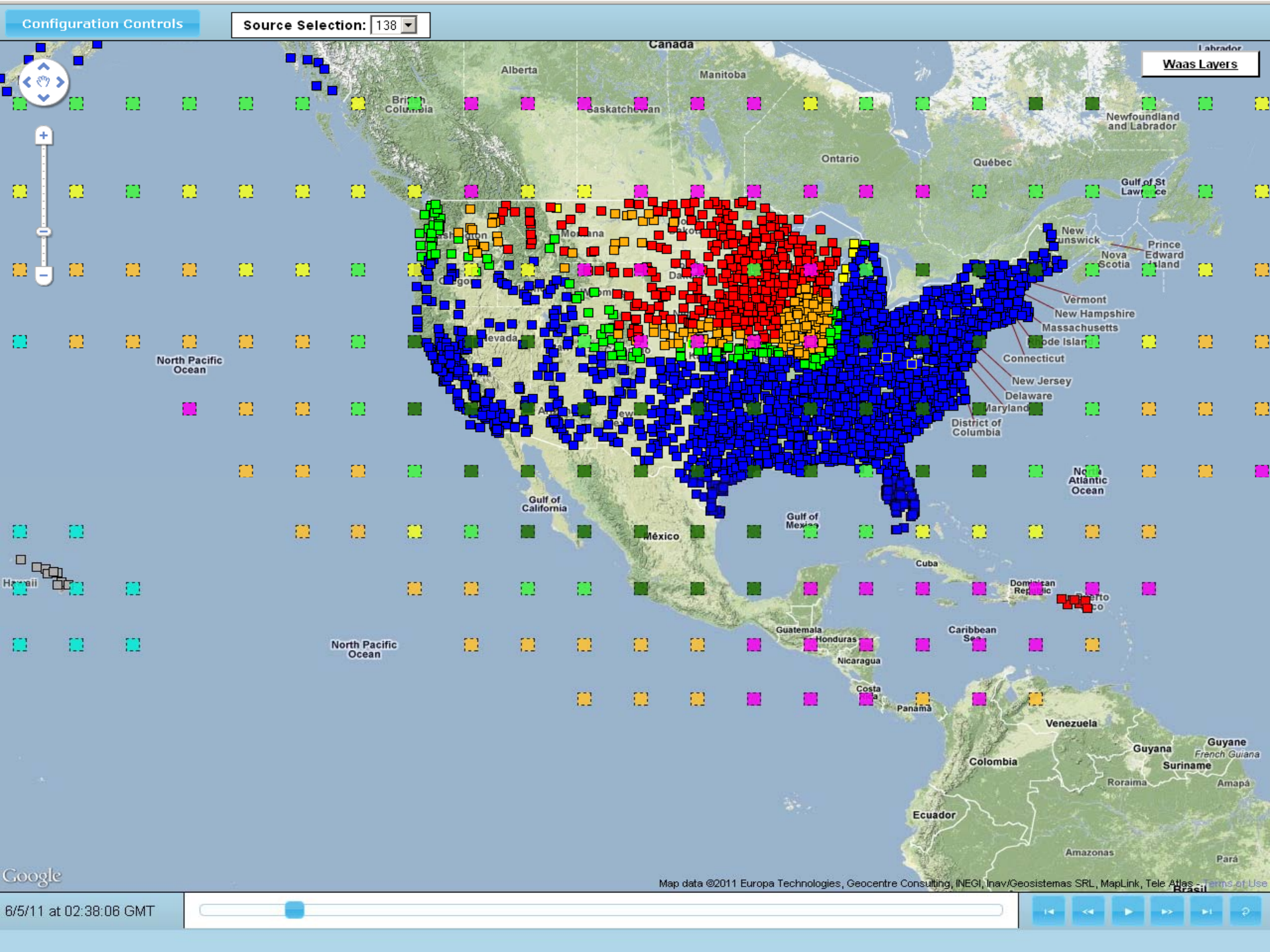
North Central CONUS Affected

- **GIVEs continue to increase across the northern part of CONUS and in Canada**
- **As shown in the next slide, at 01:19:48 GMT the HPLs and VPLs calculated at many airports in north/central CONUS no longer support LPV 200 service**


Configuration Controls
Source Selection: 138
Waas Layers
Canada
Alberta
Manitoba
Ontario
Québec
Newfoundland and Labrador
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Pacific Ocean
Gulf of California
Gulf of Mexico
México
Cuba
Guatemala
Honduras
Nicaragua
Costa Rica
Panama
Caribbean Sea
Venezuela
Colombia
Ecuador
Guyana
Suriname
Amazonas
Roraima
Amapá
Pará
Airport Legend
LPV 200
LPV
LP
LVNAV
RNP 0.1
ER/NPA
Not Monitored
GIVE Legend
<= 10 <= 3.6m
= 11 = 4.5m
= 12 = 6m
= 13 = 15m
= 14 = 45m
= 15 = NM
= — = DNU
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas
6/5/11 at 01:19:48 GMT

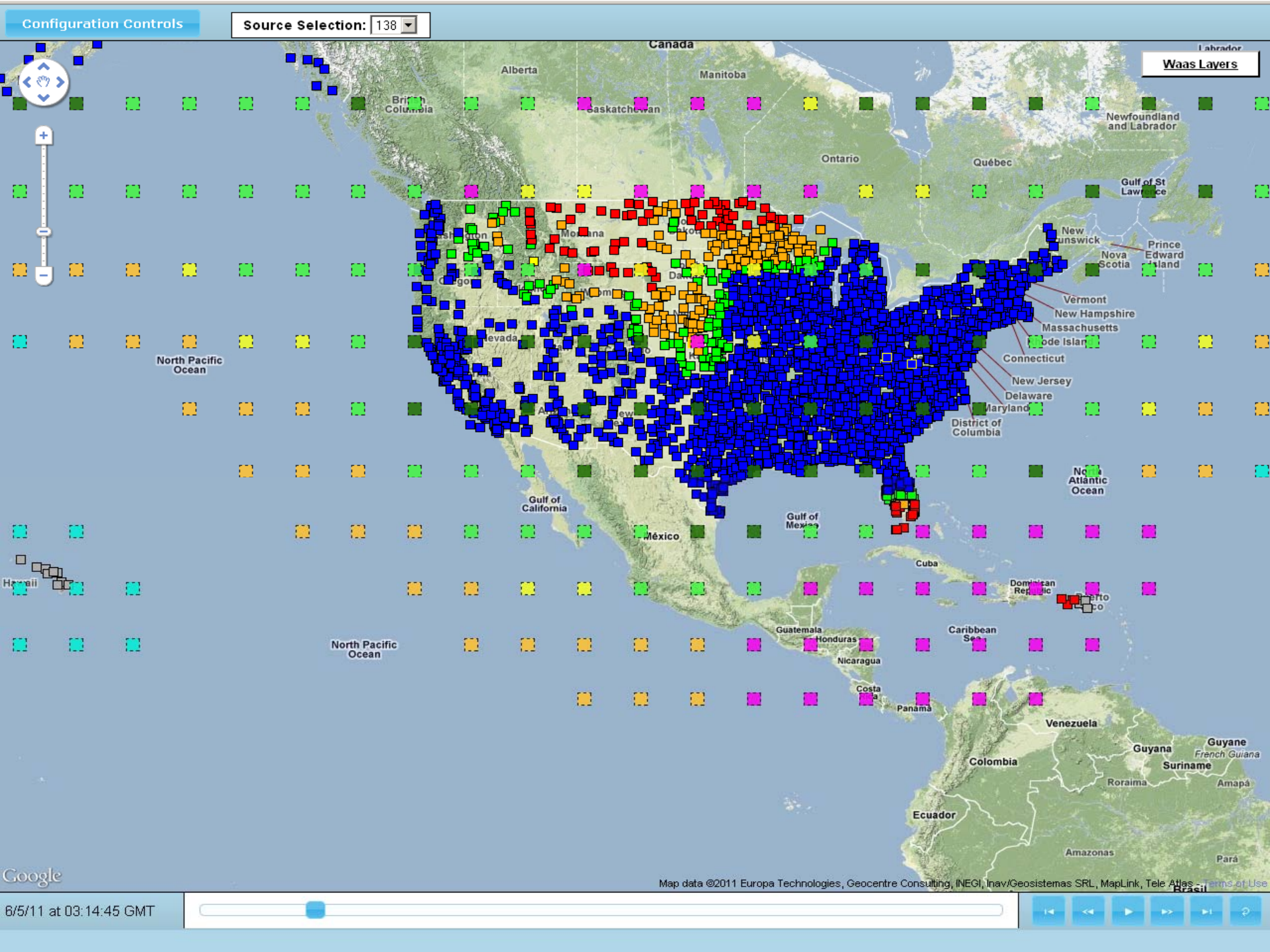
Iono Activity Continues

- **The GIVEs, moving westward, continue to increase**
  - GIVEs in CONUS have reached storm state (GIVE = 45 meters)
  - As shown in the next slide, at 02:38:06 GMT the HPLs and VPLs calculated at even more airports in CONUS no longer support LPV 200 service
    - Many airports no longer have a precision approach capability (i.e. the airports in red)
    - This time was about when the height of the storm occurred
      - From a WAAS perspective
    - Note the GIVEs for IGPs in the southeast also have been set to 45 meters
      - The GIVE values for these IGPs are usually much less
        - » For example, 3.6 m or 4.5 m for many of the IGPs in that region


Configuration Controls
Source Selection: 138
Waas Layers
Canada
Alberta
Manitoba
Saskatchewan
Ontario
Québec
Newfoundland and Labrador
Gulf of St Lawrence
Prince Edward Island
Nova Scotia
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Atlantic Ocean
North Pacific Ocean
Gulf of California
Gulf of Mexico
México
Cuba
Guatemala
Honduras
Nicaragua
Caribbean Sea
Panama
Venezuela
Colombia
Guyana
Suriname
Guyane
French Guiana
Roraima
Amapá
Ecuador
Amazonas
Pará
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas - Terms of Use
6/5/11 at 02:38:06 GMT

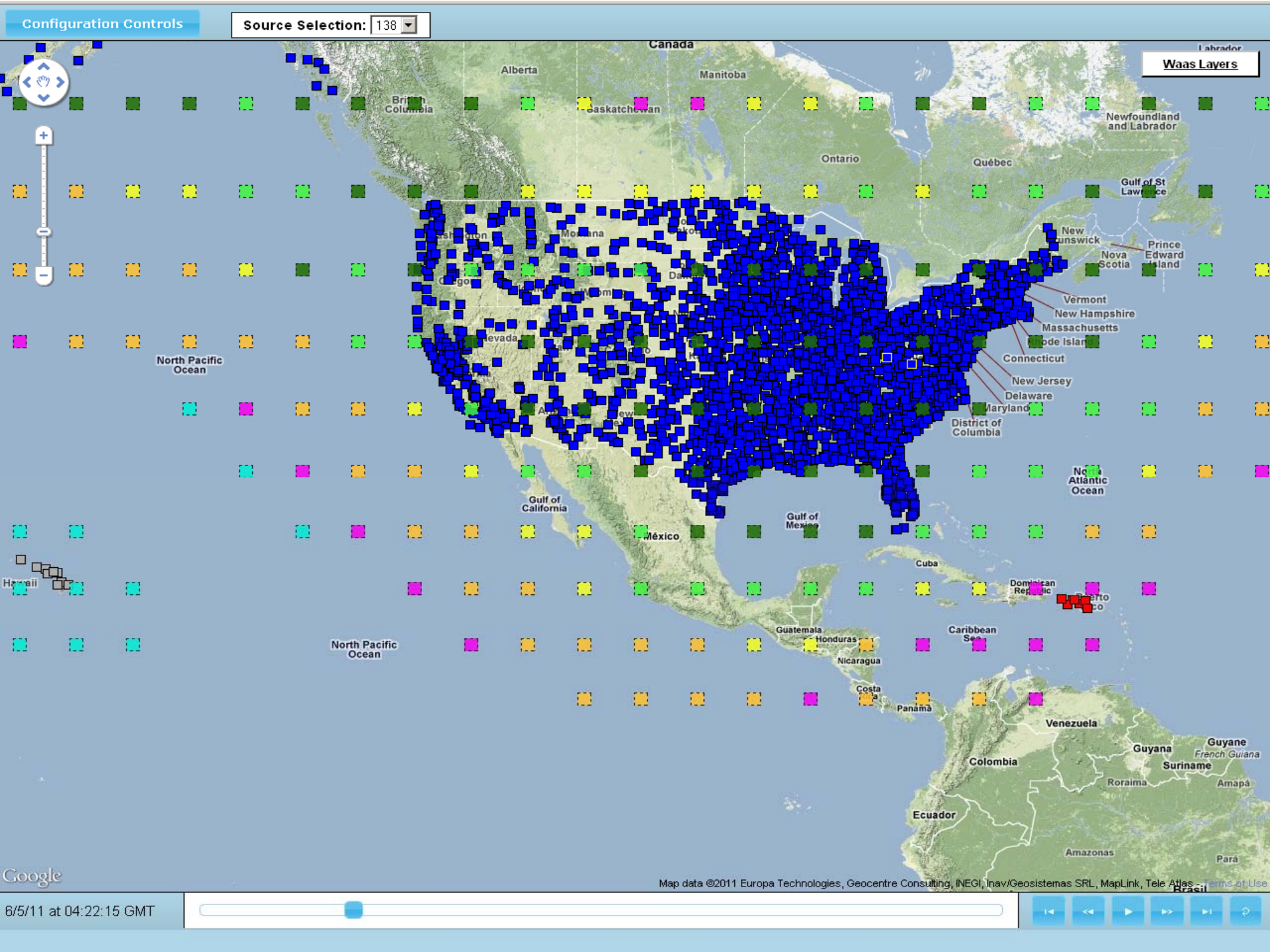
South Florida Effect

- **At 03:14:44 the IGP at 25 degrees latitude, - 80 degrees longitude went to 45 meters**
- **This triggered HPLs and VPLs to rise in South Florida so LPV 200 service was no longer supported**
- **The next slide shows the airports affected at 03:14:45**
- **Also note that the ionospheric activity is still affecting WAAS service elsewhere in CONUS**


Configuration Controls
Source Selection: 138
Waas Layers
Canada
Alberta
Manitoba
Ontario
Québec
Newfoundland and Labrador
Gulf of St Lawrence
Prince Edward Island
Nova Scotia
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Atlantic Ocean
North Pacific Ocean
Gulf of California
México
Gulf of Mexico
Cuba
Guatemala
Honduras
Nicaragua
Caribbean Sea
Panamá
Venezuela
Colombia
Guyana
Suriname
Guyane
Roraima
Amapá
Ecuador
Amazonas
Pará
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas - Terms of Use
6/5/11 at 03:14:45 GMT

End of Event for WAAS

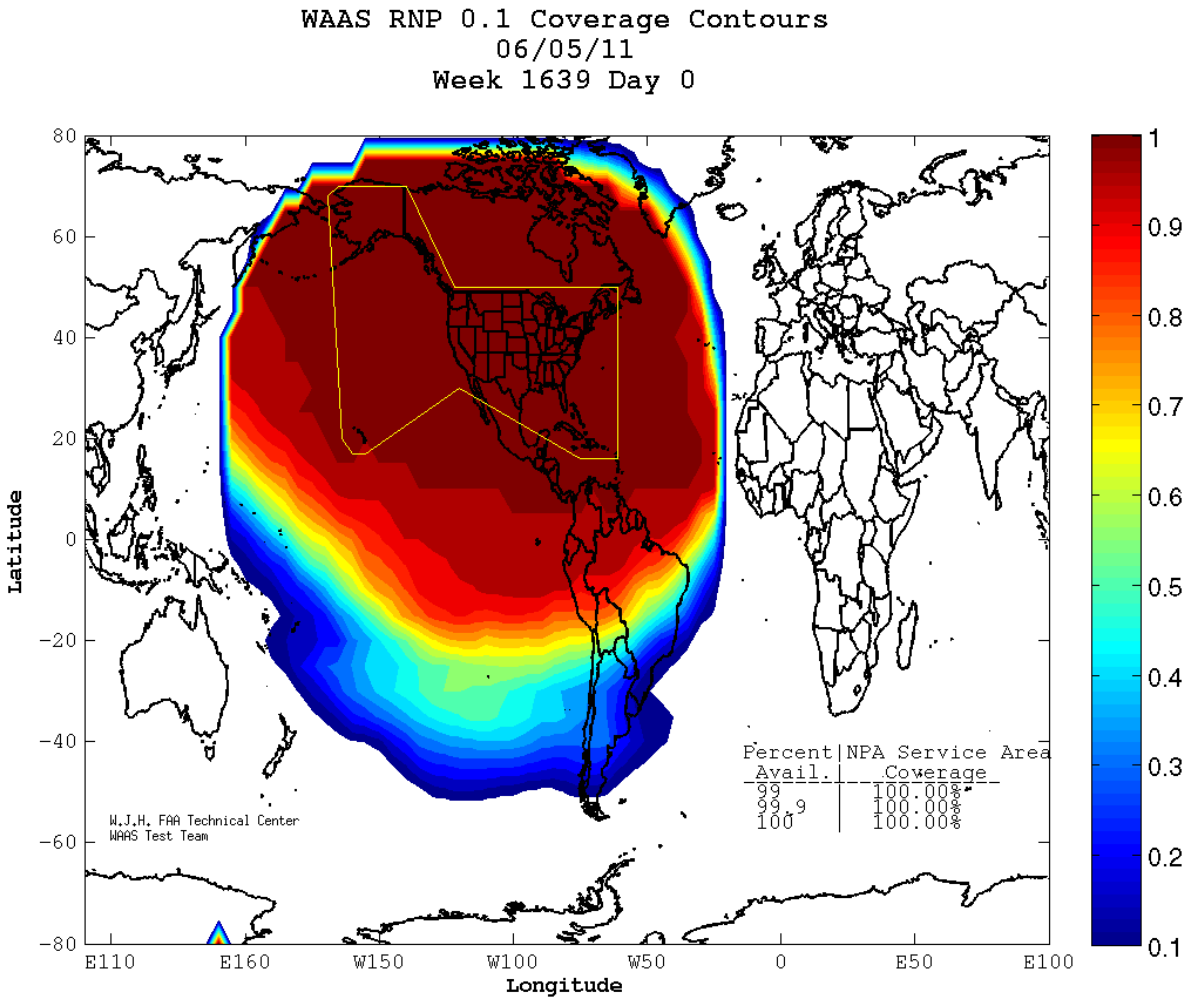
- **As shown on the next slide, all was back to normal in CONUS at 04:22:15**
  - All airports in CONUS are colored ‘blue’
- **Total time for the event was about 3.5 hours**
  - 00:52:20 – 04:22:15 GMT


Configuration Controls
Source Selection: 138
Waas Layers
Canada
Alberta
Manitoba
Ontario
Québec
Newfoundland and Labrador
Vermont
New Hampshire
Massachusetts
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
North Pacific Ocean
Gulf of California
Gulf of Mexico
México
Cuba
Guatemala
Honduras
Nicaragua
Caribbean Sea
Panamá
Venezuela
Colombia
Guyana
Suriname
Ecuador
Amazonas
Roraima
Amapá
Pará
Google
Map data ©2011 Europa Technologies, Geocentre Consulting, INEGI, Inav/Geosistemas SRL, MapLink, Tele Atlas - Terms of Use
6/5/11 at 04:22:15 GMT

24 hour RNP 0.1 WAAS Coverage

- **The next slide shows the 24 hour RNP 0.1 plot in North America for the operational WAAS and the shadow (Release 3A)**
  - Note that only WAAS monitored satellites are used to produce this plot, so it is more conservative than if both WAAS monitored and not monitored satellites were used
- **As expected, there was no affect from the iono activity on RNP 0.1 coverage**
- **RNP 0.1 = HPL is less than 186 meters**

24 hour RNP 0.1 WAAS Coverage



Accuracy

- **There was only a little effect on position accuracy due to this ionospheric activity**
- **At Minneapolis:**
  - Maximum horizontal position error: 3.89 meters
  - Maximum vertical position error: 5.15 meters
- **For an NPA position solution (i.e. no WAAS ionosphere correction used) at Minneapolis:**
  - Maximum horizontal position error: 5.71 meters
- **For an SPS postion solution at Minneapolis:**
  - Maximum horizontal position error: 6.29 meters
  - Maximum vertical position error: 4.87 meters

Conclusion

- **Ionospheric activity on June 5, 2011 caused a negative impact on the WAAS operational system**
  - The activity affected WAAS for approximately 3.5 hours early in the day (GMT time)
- **Based on data analyzed from the shadow system, WAAS Release 3A would mitigate most of the effects of this storm**
  - LPV 200 service would still have been negatively affected
- **RNP 0.1 and SPS coverage and accuracy was not affected**