Updates on
Long Term Ionospheric Anomaly Monitor

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IGWG Iono Subgroup Activities

- **The IGWG Iono Subgroup has had 3 major web-ex teleconferences since its formation.**
  - Inception began after 12th International GBAS Working Group Meeting held at the FAA William J. Hughes Technical Center in 2011
  - Cooperation between members has also continued through email discussions

- **The web-ex teleconferences were held on the following dates:**
  - 03 / 08 / 12
  - 06 / 06 / 12
  - 01 / 17 / 13

- **Participating members included the following organizations:**
  - EuroControl, Deutsche Flusicherung (DFS), Federal Aviation Administration (FAA WJHTC), FAA Oklahoma City FSDS (FAA OKC), NAVTAC, Stanford University, Indra, Thales, Electronic Navigation Research Institute (ENRI), and Japan Aerospace Exploration Agency (JAXA)

Major Highlights

- **The main topic of these meetings dealt primary with the Long-term Ionosphere Anomaly Monitor Toolset (LTIAM).**
  - Version 2.1 was made available to participating members. Some functions of MATLAB source code were converted to MEX file using Embedded MATLAB, allows for improvements in runtime and performance.

- **EuroControl continued to work with LTIAM v2.1 to process Iono data from selected GNSS Ground Stations - Canary Island Network.**
  - Initial test runs proved to be unsuccessful and usually ended in a segmentation fault. After the June 6th meeting, EuroControl was able to run the tool against a sample set of Canaries data.

- **ENRI reported that they were developing a separate tool to estimate ionospheric delay differences in the equatorial region.**
  - By this time, the tool was under heavy modification and was suitable for automatic analysis
  - Expressed continued interest in comparing results obtained by the LTIAM and the equatorial region tool against the same data set (January 11, 2012).

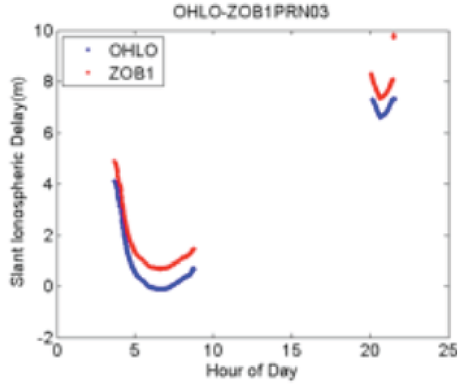
ENRI

Comparison (1)

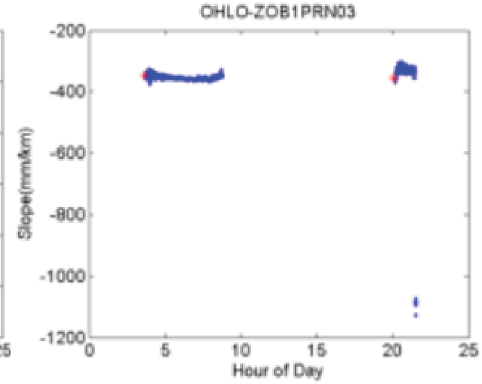
OHLO-ZOB1, PRN03, 11 January 2012

LTIAM (Presented at 03/082012 Meeting)

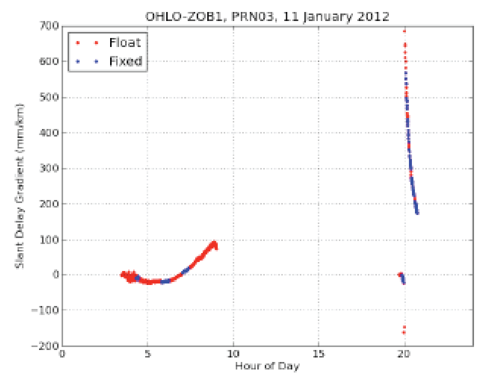
Slant Delay



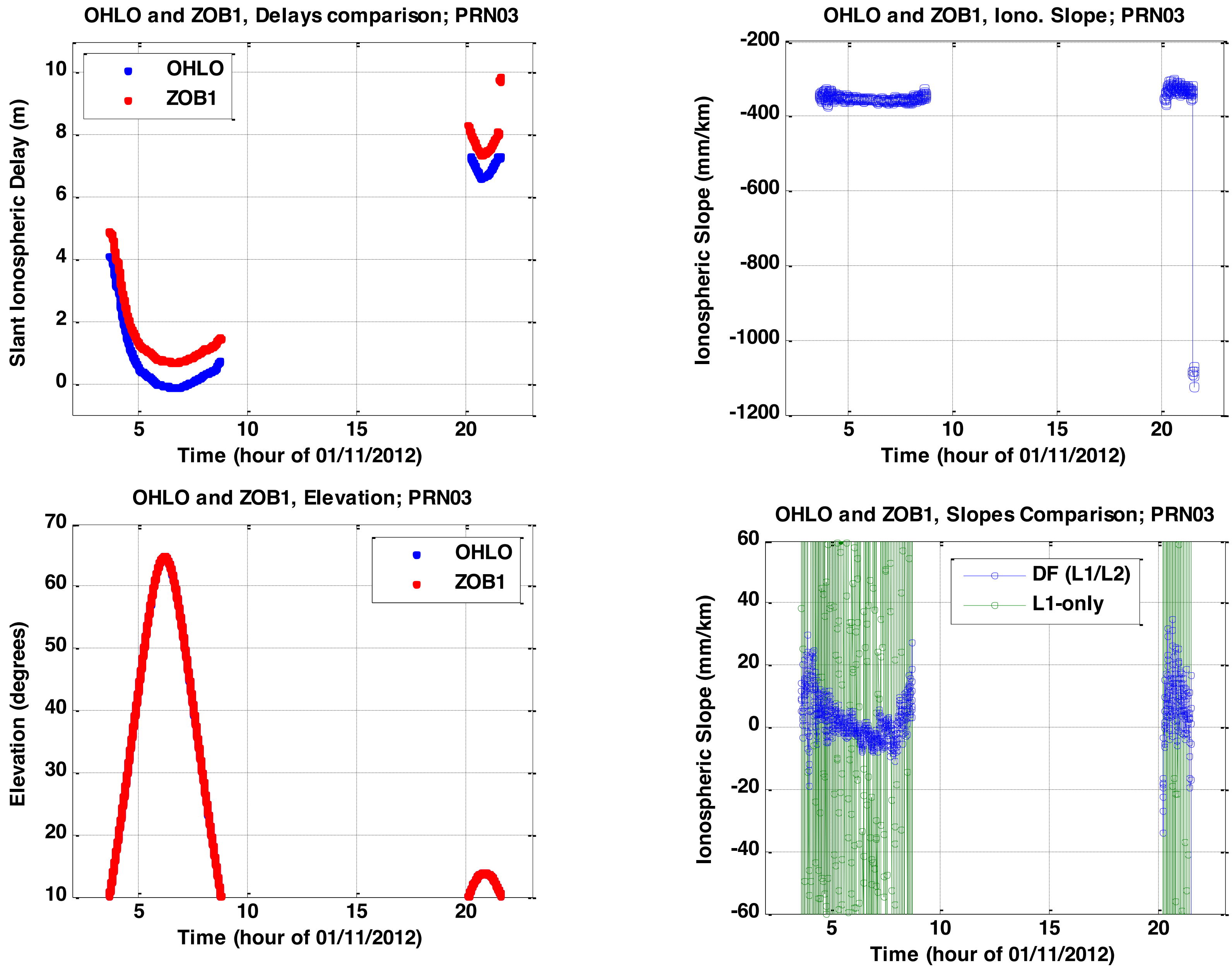
Slant Gradient



ENRI



- Not very good fix-rate, because of lower sampling rate (every 30 sec) and/or parameters needs further optimization
  - 1 Hz data are no more available.
- Large values in the 1st arc in LTIAM results are not seen in ENRI results
- There are extremely large values in the 2nd arc in both => more analysis needed

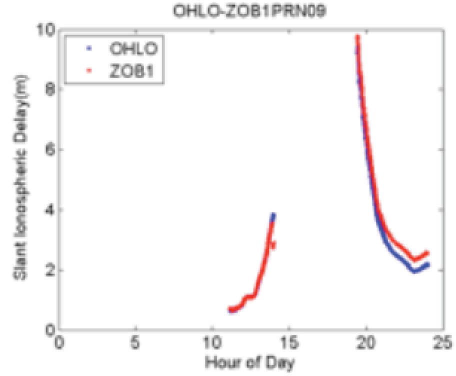

OHLO and ZOB1, Delays comparison; PRN03
OHLO
ZOB1
Slant Ionospheric Delay (m)
Time (hour of 01/11/2012)
OHLO and ZOB1, Iono. Slope; PRN03
Ionospheric Slope (mm/km)
Time (hour of 01/11/2012)
OHLO and ZOB1, Elevation; PRN03
OHLO
ZOB1
Elevation (degrees)
Time (hour of 01/11/2012)
OHLO and ZOB1, Slopes Comparison; PRN03
DF (L1/L2)
L1-only
Ionospheric Slope (mm/km)
Time (hour of 01/11/2012)

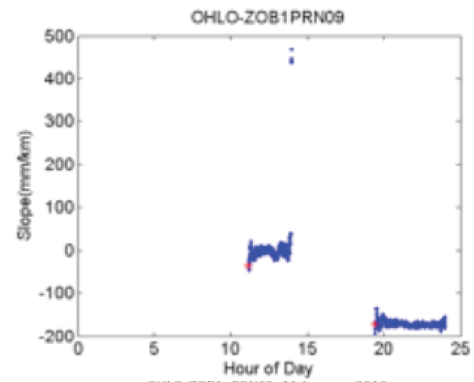
Comparison (2)

OHLO-ZOB1, PRN09, 11 January 2012

Slant Delay **Slant Gradient**

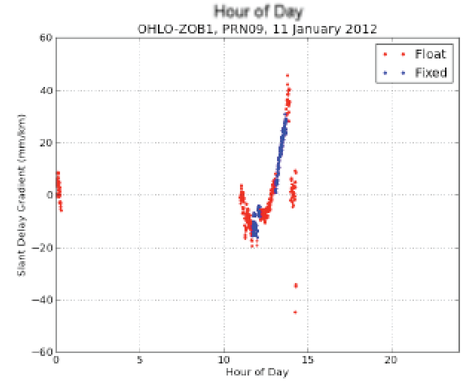
LTIAM (Presented at 03/082012 Meeting)



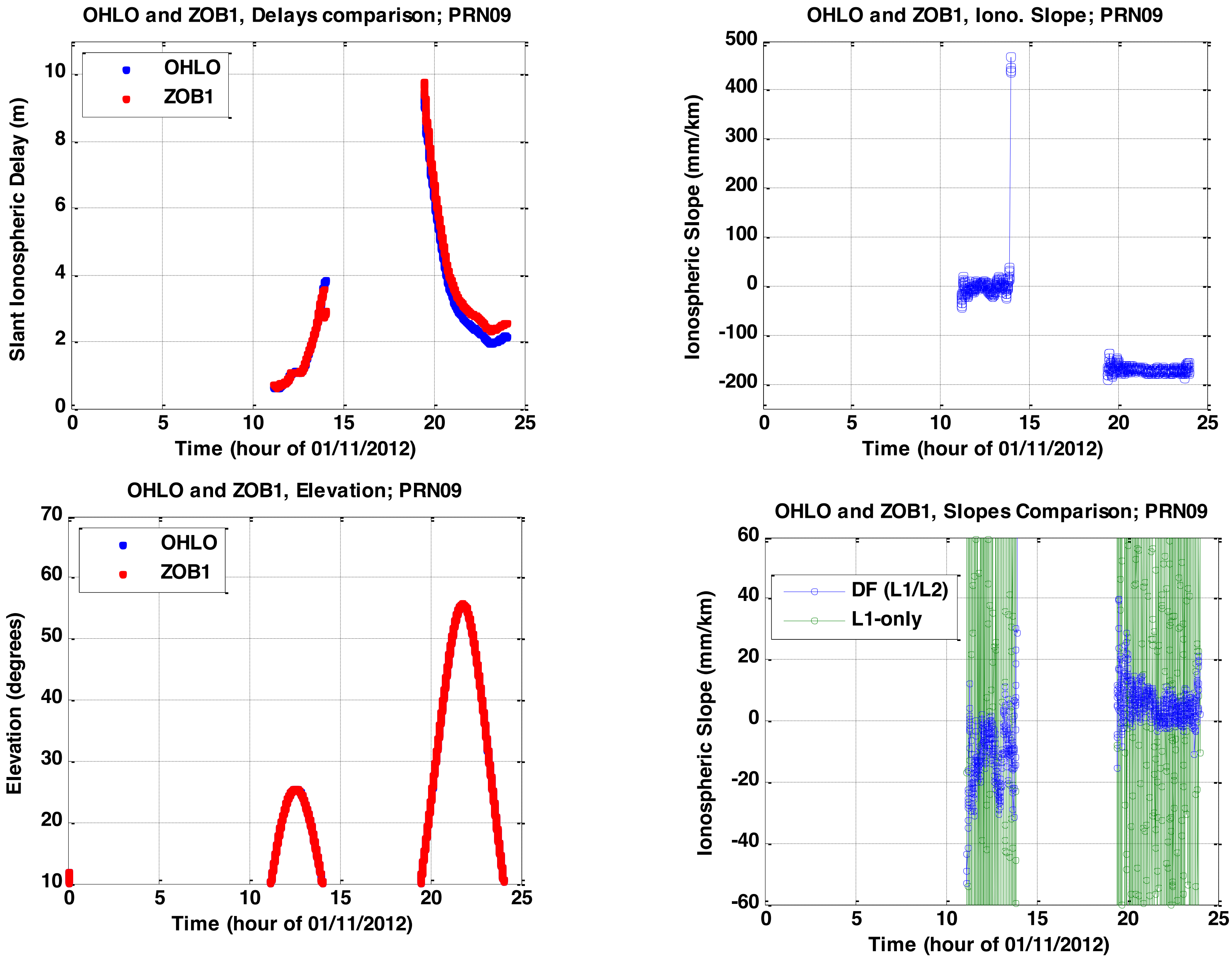


OHLO

ENRI



- Values in the 1st arc in LTIAM results are in a similar range as ENRI results
- The reason why the 2nd arc is missing in ENRI results are under investigation



OHLO and ZOB1, Delays comparison; PRN09
Slant Ionospheric Delay (m)
Time (hour of 01/11/2012)
OHLO
ZOB1
OHLO and ZOB1, Iono. Slope; PRN09
Ionospheric Slope (mm/km)
Time (hour of 01/11/2012)
OHLO and ZOB1, Elevation; PRN09
Elevation (degrees)
Time (hour of 01/11/2012)
OHLO
ZOB1
OHLO and ZOB1, Slopes Comparison; PRN09
Ionospheric Slope (mm/km)
Time (hour of 01/11/2012)
DF (L1/L2)
L1-only

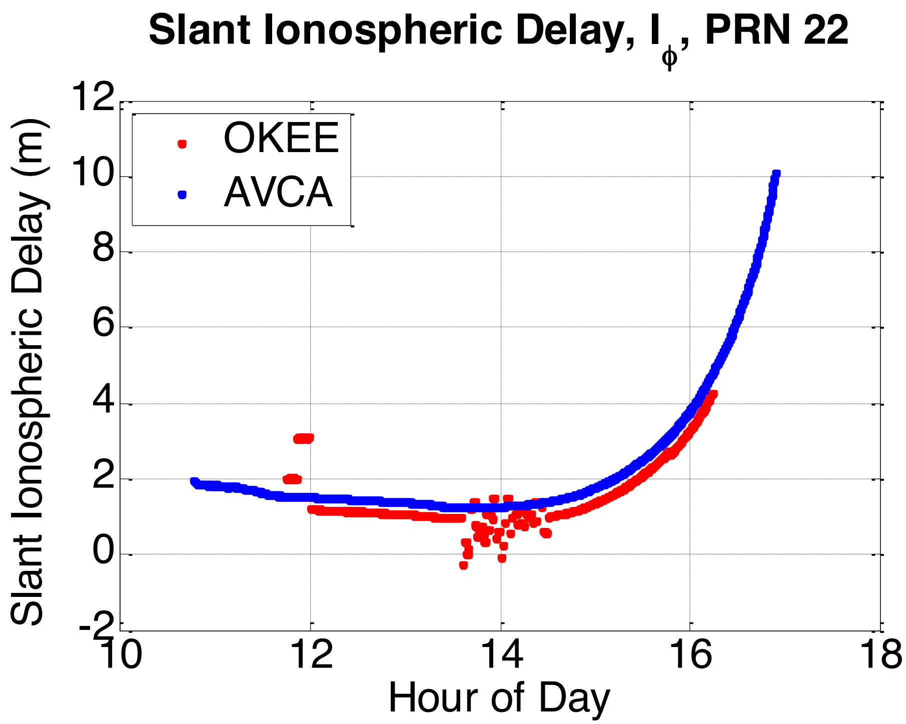
Optimized GNSS Network Station Selection

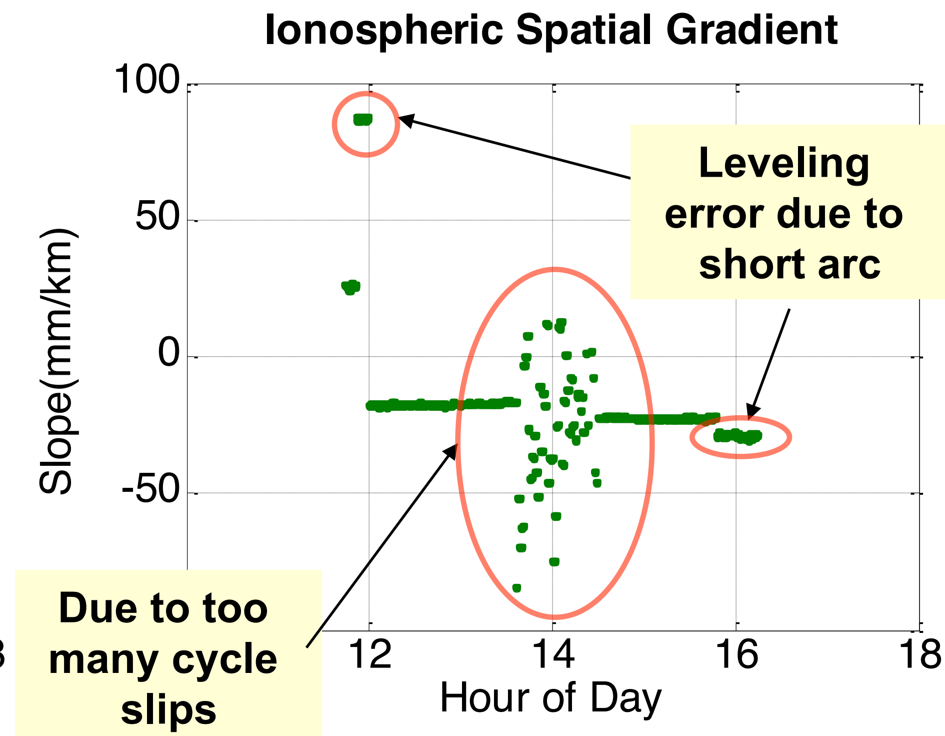
- **Use of the Long-Term Ionosphere Anomaly Monitor (LTIAM) continues**
  - Software enables the post-processing of data continuously collected by GPS reference station networks
  - The number of stations with poor GPS data quality also increases, as the total number of processed stations increases
- **A selection criteria needs to be defined to reduce processing time in both the automated procedure and the manual analysis/validation**
  - The use of poor-quality GPS data degrades the accuracy of ionospheric delay estimates and produces too many faulty candidates
- **An optimized method to select well-distributed, high-quality stations for GNSS network is proposed**
  - Too many geographically redundant stations brings an excessive computational load

Poorly Sited GPS Stations

http://xenon.colorado.edu/reflections/GPS_reflections/BadGPSSites.html

Impact of Poor GPS Data Quality on Ionospheric Delay/Gradient Estimation





- **Station Selection is needed to reduce processing time in both the automated procedure and the manual analysis/validation**
  - The use of poor-quality GPS data degrades the accuracy of ionospheric delay estimates and produces too many faulty anomaly candidates

Optimized GNSS Network Station Selection

GPS Data-Quality-Measurement Algorithms

•LTIAM pre-processing
-IOD Cycle Slip Detection
-Outlier Detection

•TEQC algorithm
-Cycle Slip Detection using Multipath Estimates
-Percentage of Observations
-RMS of Multipath on Code

•Adaptive Filter algorithm
-Receiver Noise Estimation on Code

High-quality Station Selection

• Optimal Threshold Determination
- 2-D Iterative Max. Sensitivity Ratio Search
- Determining Thresholds of Data Quality Parameters

Well-distributed Sub-network Selection

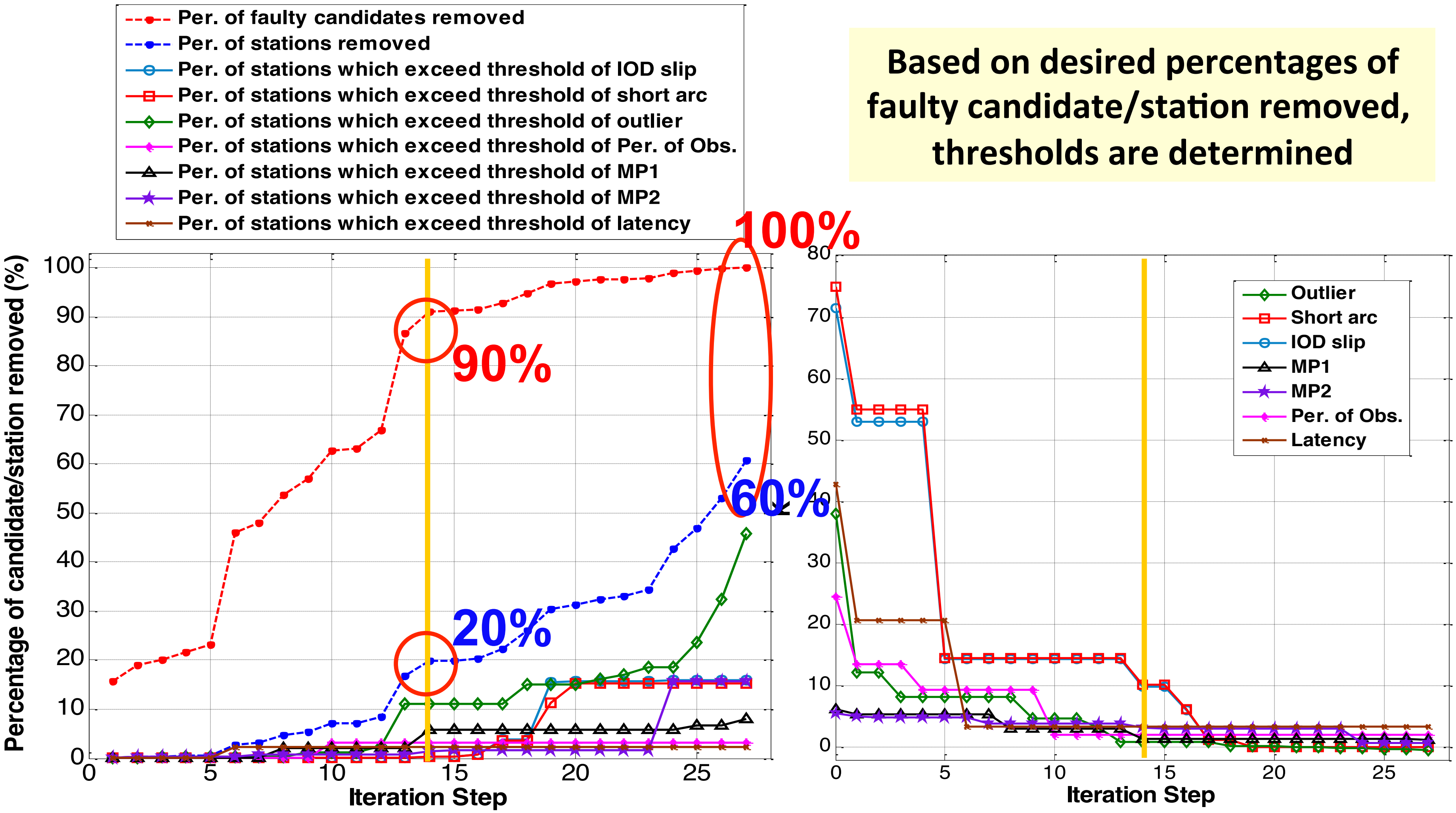
• Station Recovery Processing
- Loss of Coverage Check
- Considering geographical distribution

• Subset Selection Processing
- Voronoi Method
- Baseline Distance Check

High-quality Station Selection

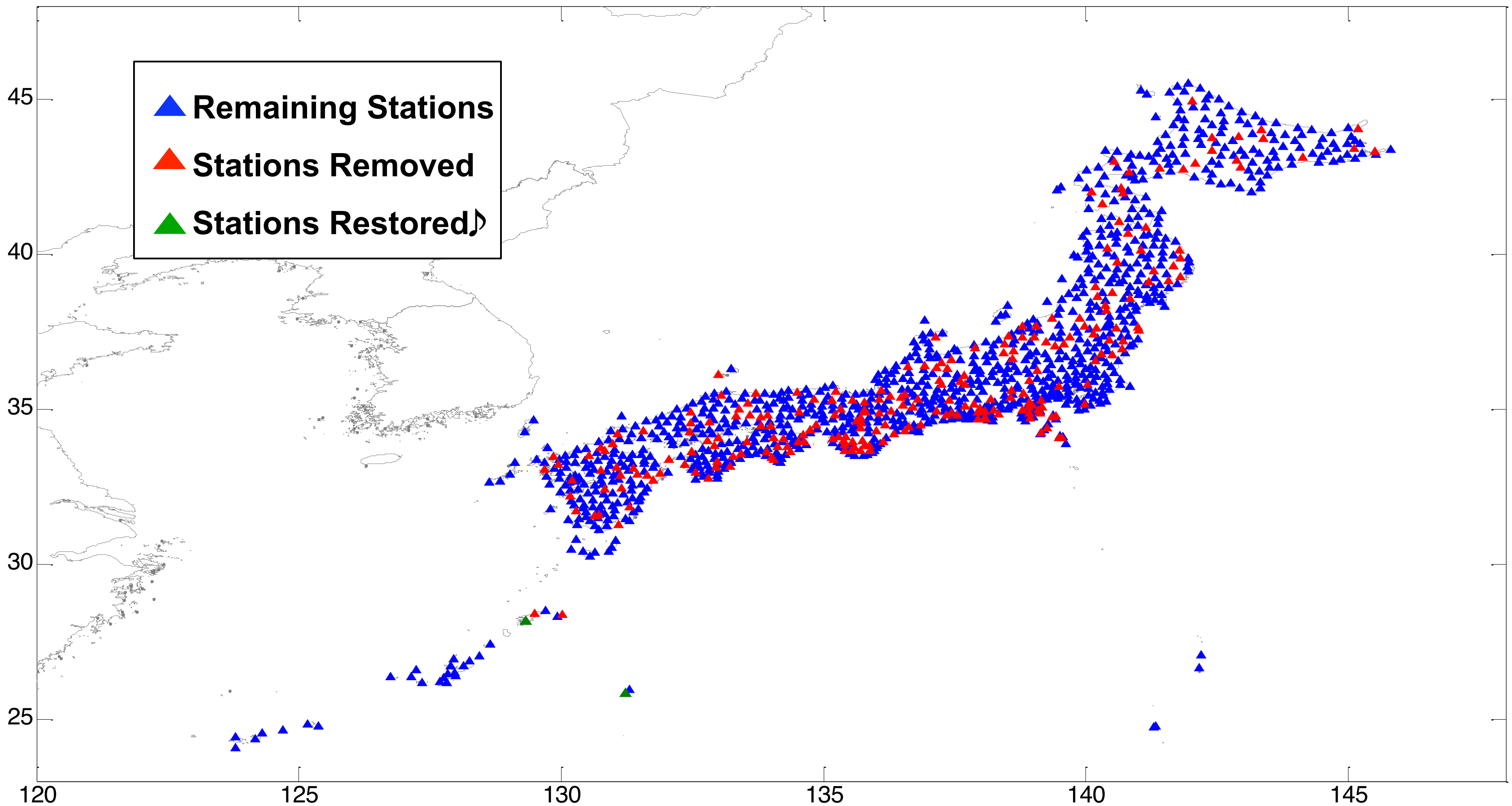
Determining Thresholds of Data Quality Parameters

Based on desired percentages of faulty candidate/station removed, thresholds are determined



Results from Japanese GPS Networks

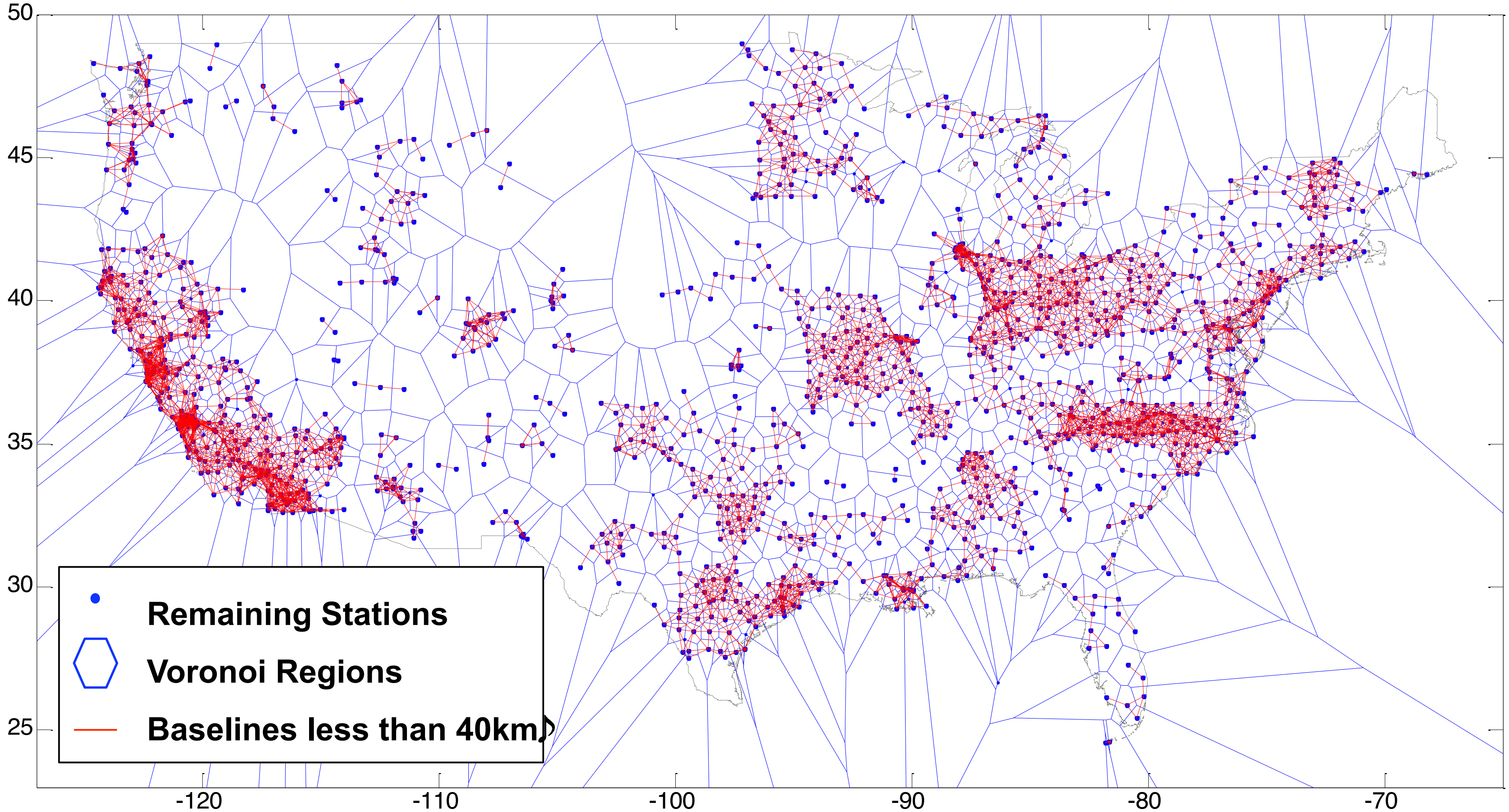
	After high-quality station selection♪	After station recovery♪
# of stations removed in GEONET (Out of 1229)♪	238 (19.4%)♪	236 (19.2%)♪
# of faulty ionospheric anomaly candidates remov ed on seven days (Out of 530)♪	479 (90.4%)♪	477 (90.0%)♪



Results from Well-distributed Sub-network Selection

Subset Selection with a Baseline Constraint of 100km

	After station recovery processin g♪	After subset selection process ing♪
# of stations (Out of 1587)♪	1328 (83.7%)♪	734 (46.3%)♪



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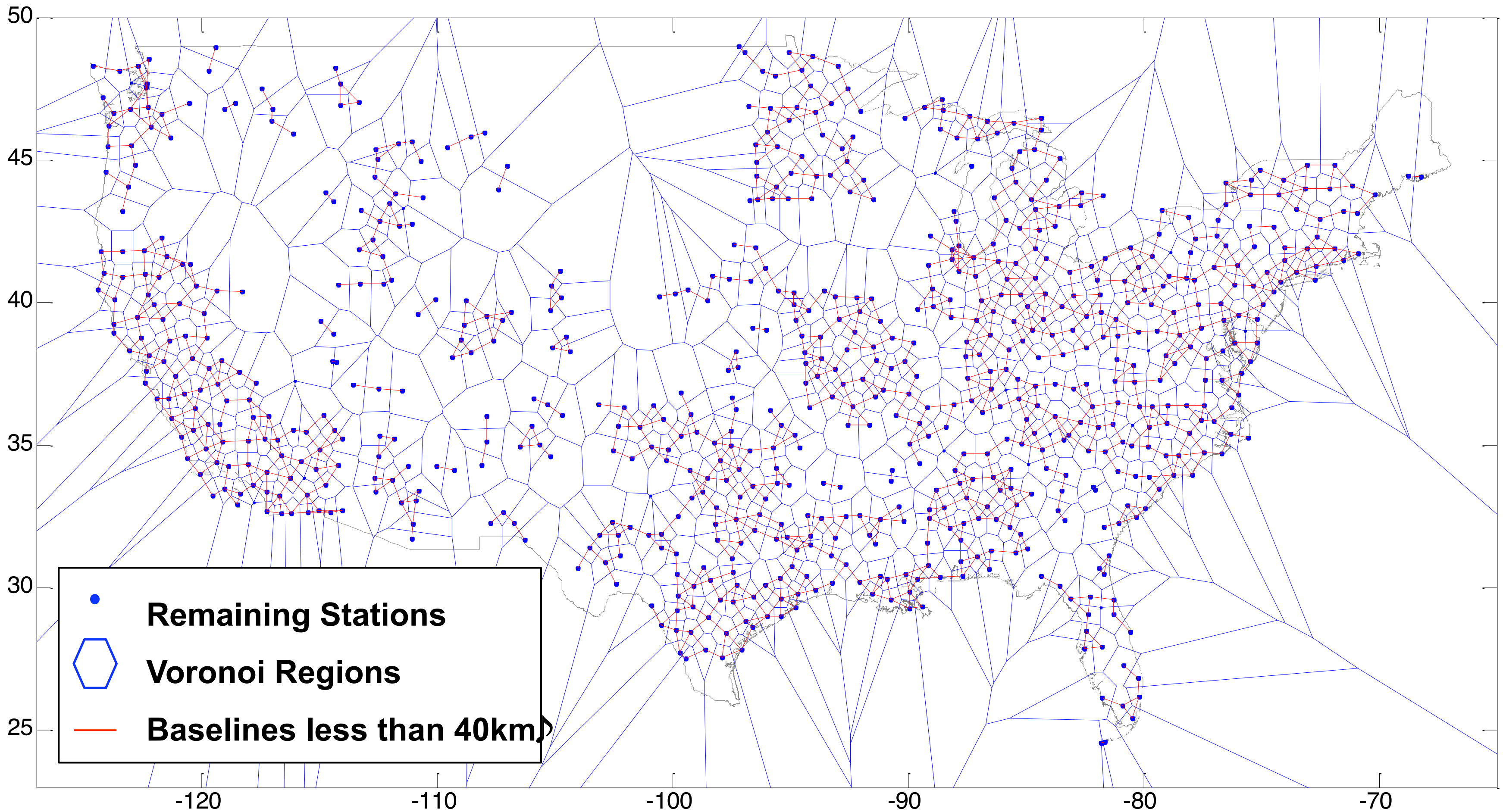

Summary

- Reported IGWG Iono Subgroup activities
  - Use of the Long-Term Ionosphere Anomaly Monitor (LTIAM) continues (by FAA, EuroControl, ENRI)
  - Request to IGWG to provide LTIAM for ISTF
- An Optimized method to select GNSS network stations with well-distributed, high-quality data
  - To reduce processing time in both the automated procedure and the manual analysis/validation
  - 89% reduction on faulty anomaly candidates was achieved while discarding only 16% of CORS stations
  - Standardized station-selection criteria for regional threat-model can be defined.
- Lists of GNSS network stations ranked by data quality are available.

  Rank_of_CORS_stations_CONUS_May2012.xlsx

Thank you for your attention

Comments?