Long-term Ionospheric Anomaly Monitor (LTIAM)
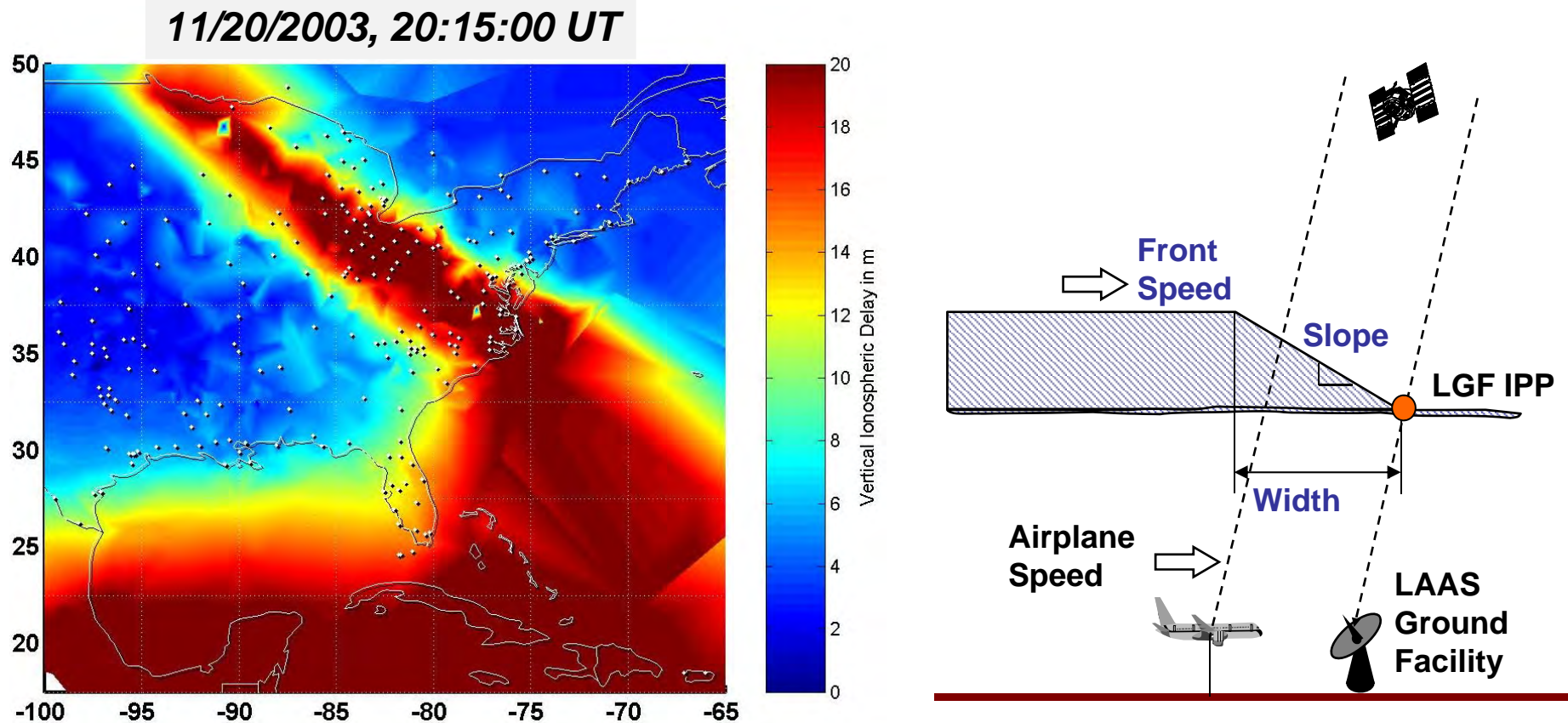# Overview

ICAO ISTF/5

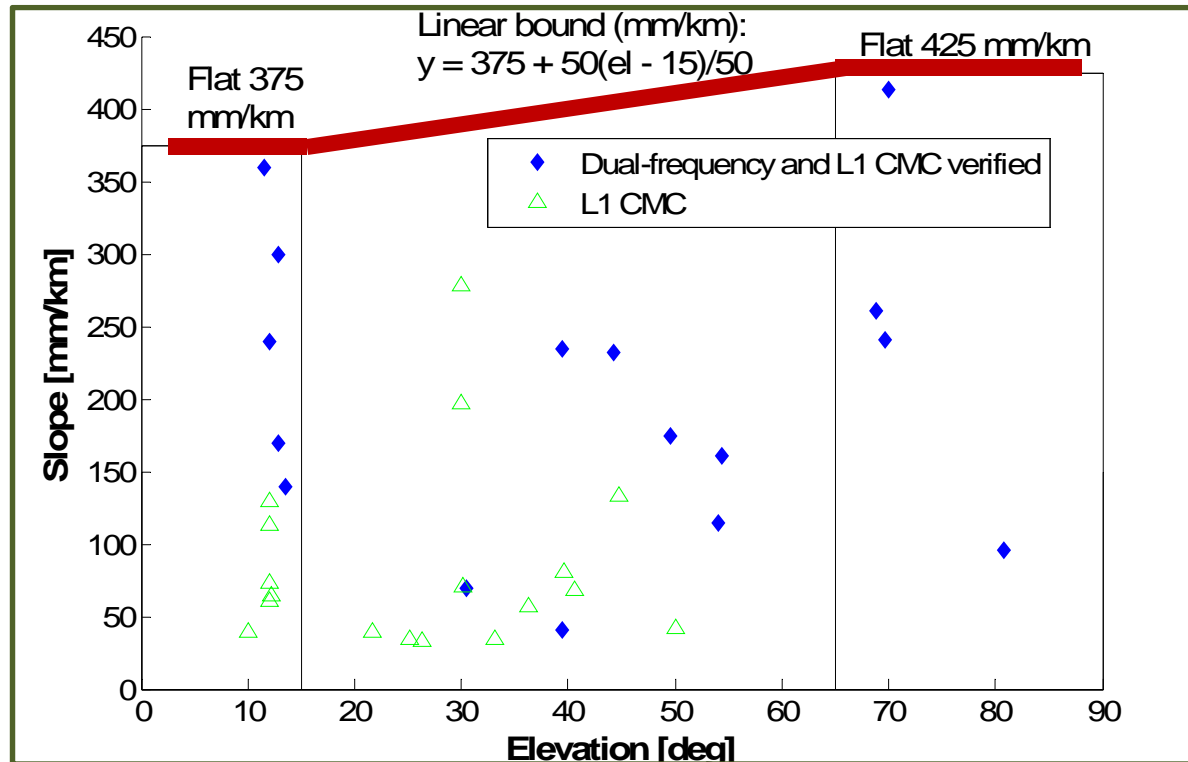### 16 – 18 February, 2015

Threat: Severe Ionosphere Disturbances

11/20/2003, 20:15:00 UT

- **Ionosphere spatial gradients as large as 412 mm/km have been observed in the United States since April 2000.**
- **A worst-case ionospheric threat model was developed for LAAS in CONUS based on study of about 10 severe days.**

Limitations of the CAT I LAAS Ionospheric Anomaly Threat Model

- ## CAT I Ionospheric Anomaly Threat Model

Linear bound (mm/km):
$y = 375 + 50(el - 15)/50$

Flat 375 mm/km

Flat 425 mm/km

- Dual-frequency and L1 CMC verified
- L1 CMC

Slope [mm/km]

Elevation [deg]

S. Datta-Barua, J. Lee, et.al., (2010). Ionospheric Threat Parameterization for Local Area Global-Positioning-System-Based Aircraft Landing Systems . *AIAA, the Journal of Aircraft.*

- ## Limitations:

  – **Constructed based on a small number of ionospheric storm events**

  – **Receiver separations within the CORS network (typically 40 – 100 km) do not reflect the LAAS architecture**

Need of Long-Term Ionospheric Anomaly (LTIA) Monitor

- **Long-term ionospheric anomaly monitoring is needed to build an Ionospheric threat model, monitor ionospheric anomalies over the system life cycle, verify CAT I threat model, and trigger updates if needed.**
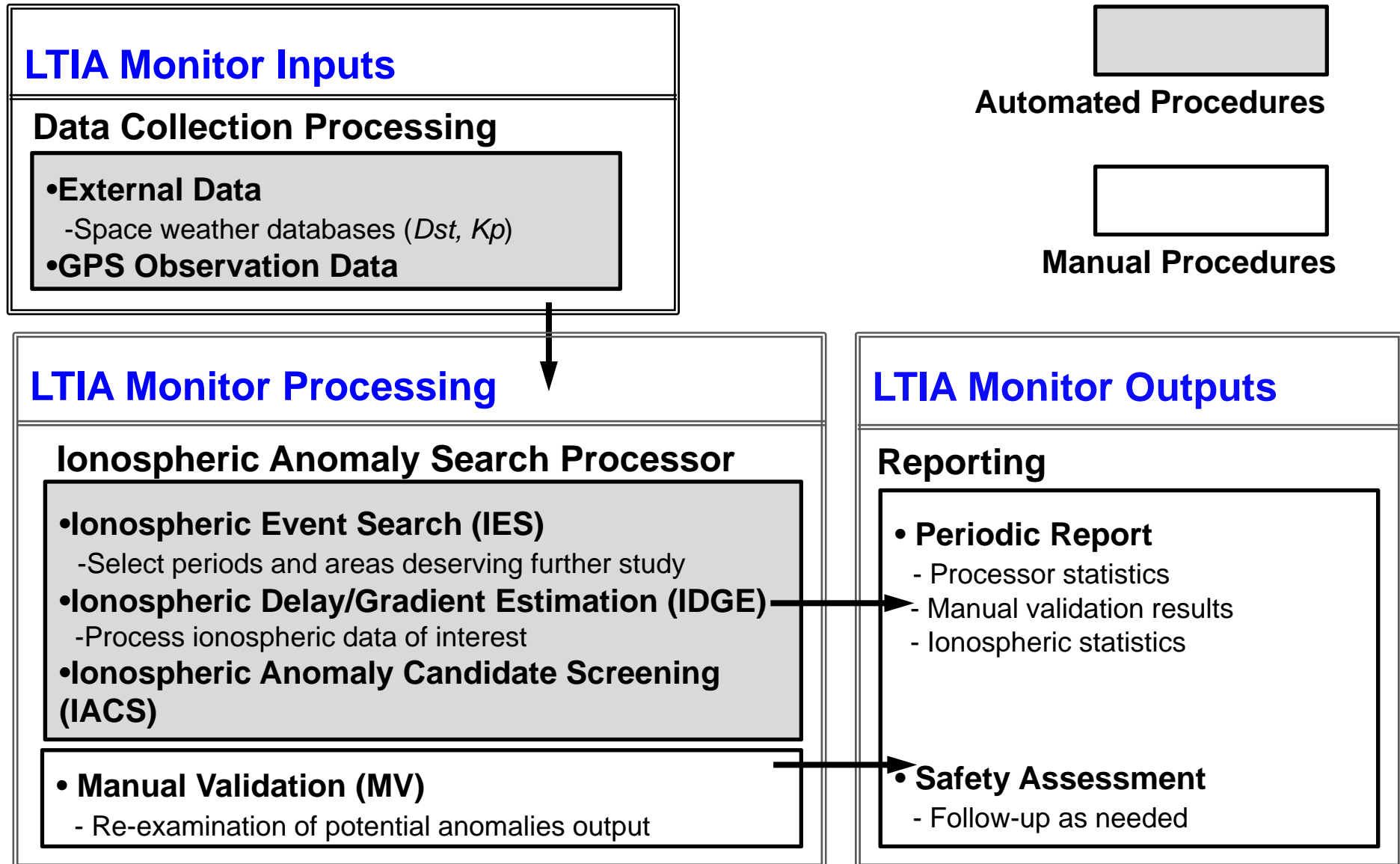
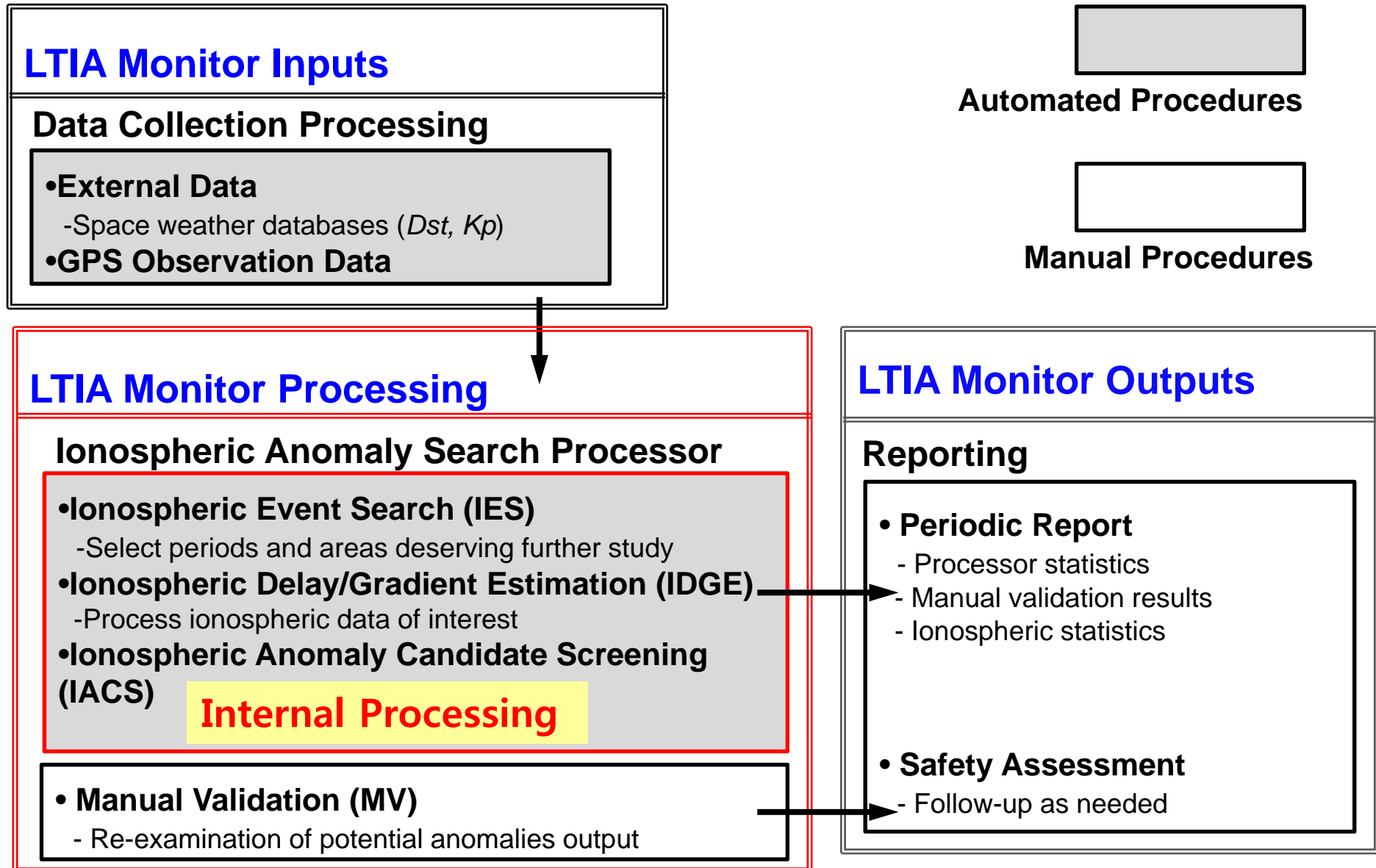# Ionospheric Threat Space with Newly Validated Ionospheric Anomalies
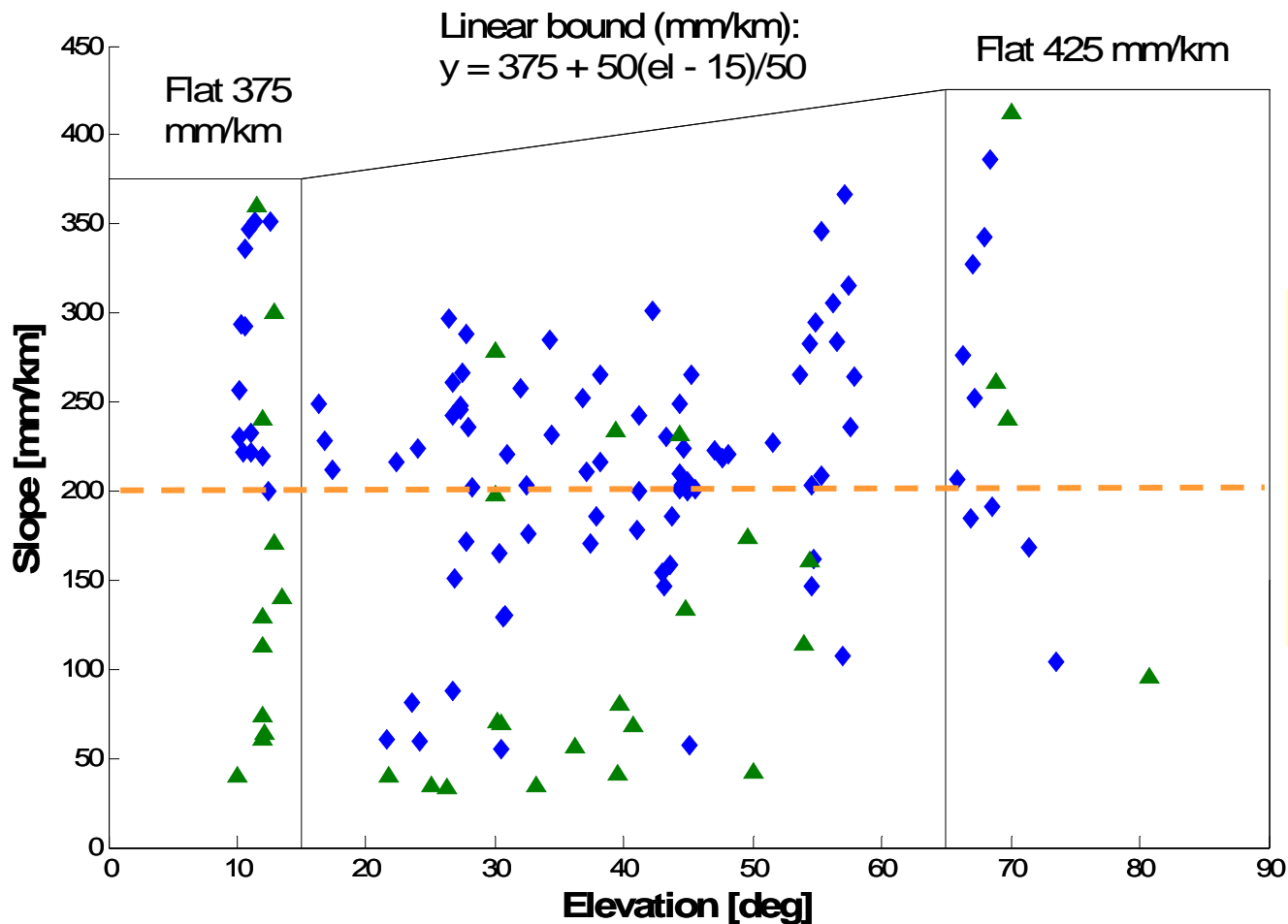
All 10 severe days of data from the CONUS ionospheric storm archive were processed

Legend:
◆ Newly Verified Anomalies
▲ Threat points in the current threat model

Overview of LTIA Monitor

LTIA Monitor Inputs

Data Collection Processing

- **External Data**
  - Space weather databases (*Dst, Kp*)
- **GPS Observation Data**

Automated Procedures

Manual Procedures

LTIA Monitor Processing

Ionospheric Anomaly Search Processor

- **Ionospheric Event Search (IES)**
  - Select periods and areas deserving further study
- **Ionospheric Delay/Gradient Estimation (IDGE)**
  - Process ionospheric data of interest
- **Ionospheric Anomaly Candidate Screening (IACS)**

- **Manual Validation (MV)**
  - Re-examination of potential anomalies output

LTIA Monitor Outputs

Reporting

- **Periodic Report**
  - Processor statistics
  - Manual validation results
  - Ionospheric statistics

- **Safety Assessment**
  - Follow-up as needed

Overview of LTIA Monitor

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Internal Processing

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LTIA Monitor Outputs

Reporting

- • Periodic Report
  - - Processor statistics
  - - Manual validation results
  - - Ionospheric statistics

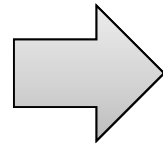- • Safety Assessment
  - - Follow-up as needed

Internal Processing

Iono. Event Search

- Search for periods/areas of interest

- Automated daily processing

- Event selection criteria

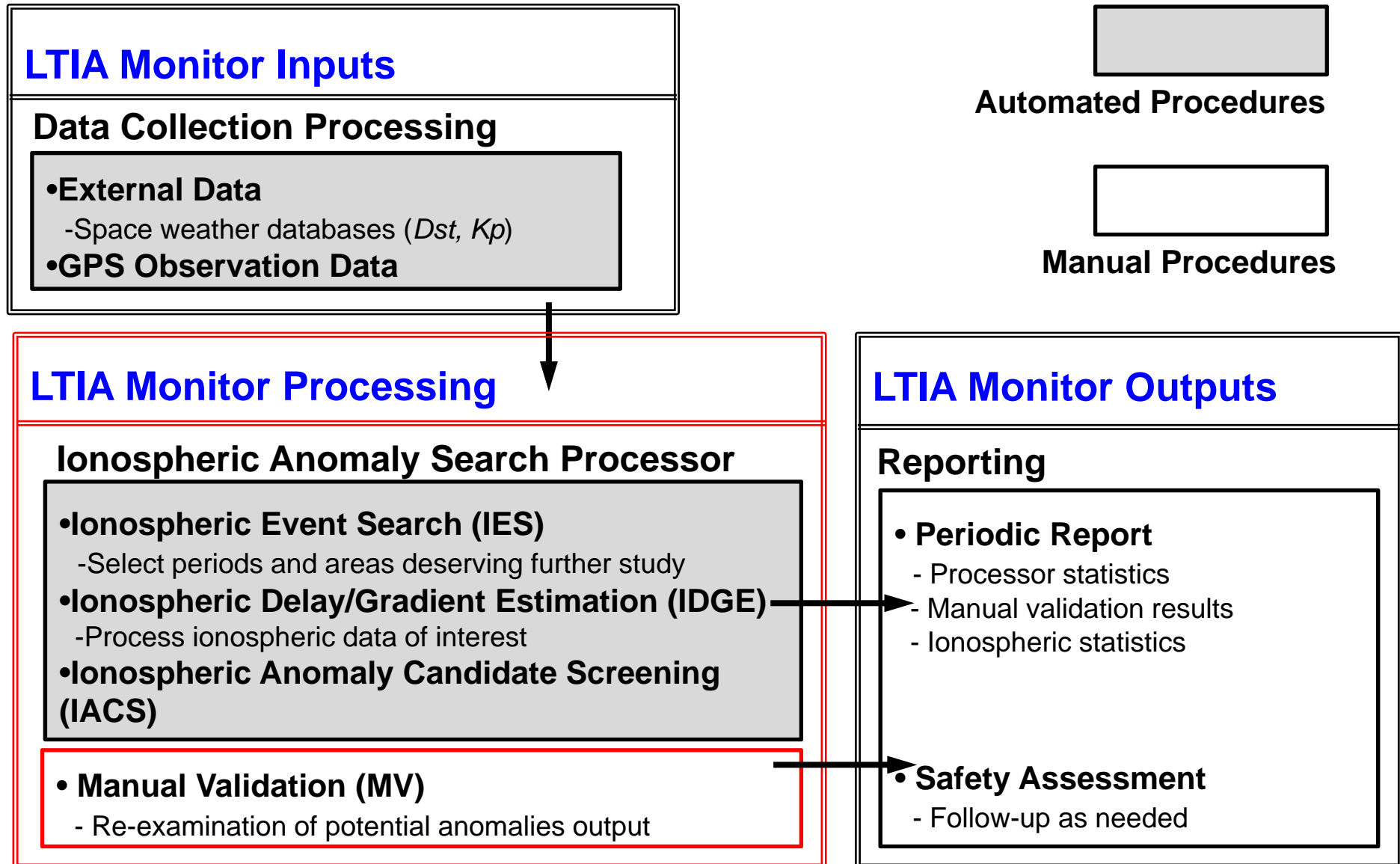| Kp	$>Kp\_th$
Dst	$<Dst\_th$

Iono. Delay & Gradient Estimation

- Create "simple truth" data using dual-frequency data

- Estimate iono. gradients using station-pair method
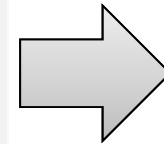
Iono. Anomaly Candidate Screening

- Search for unusually large gradients (e.g., > 300 mm/km)

- Automated screening to remove receiver faults, data errors

Overview of LTIA Monitor

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LTIA Monitor Processing

Ionospheric Anomaly Search Processor

- **Ionospheric Event Search (IES)**
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LTIA Monitor Outputs

Reporting

- **Periodic Report**
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Automated Procedures
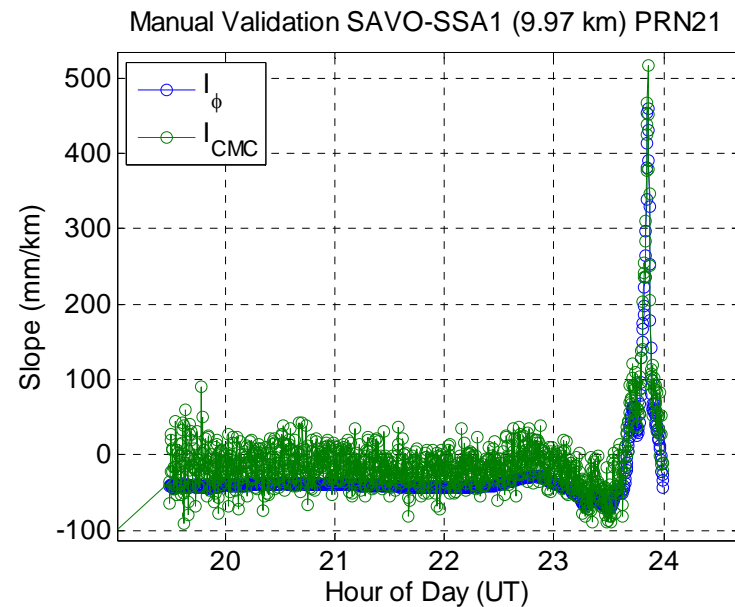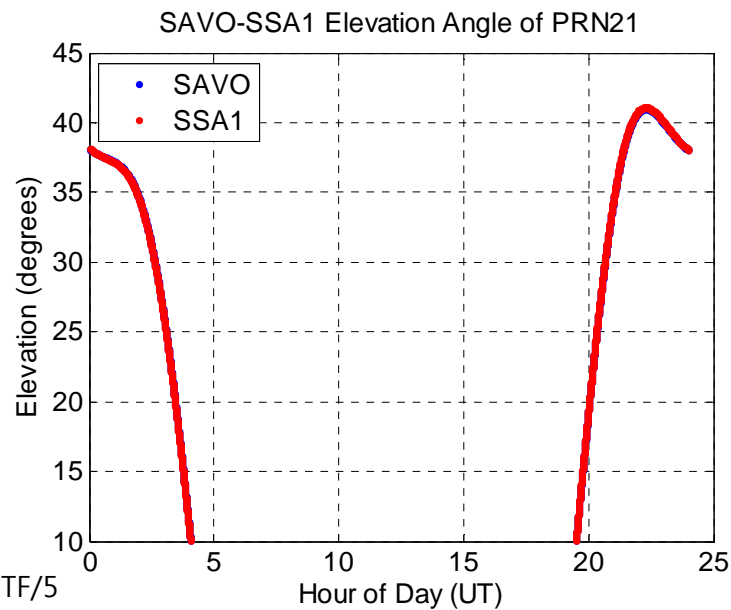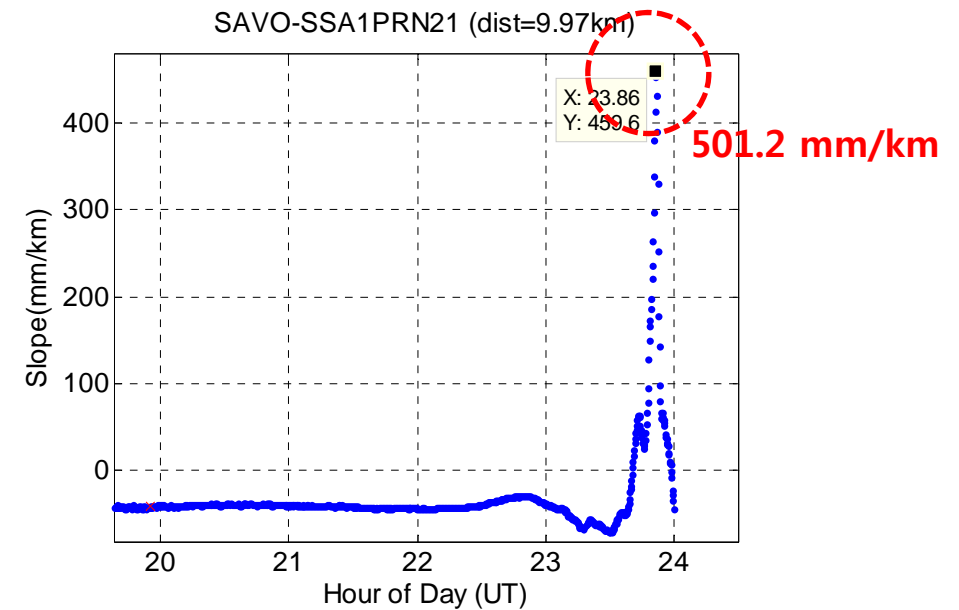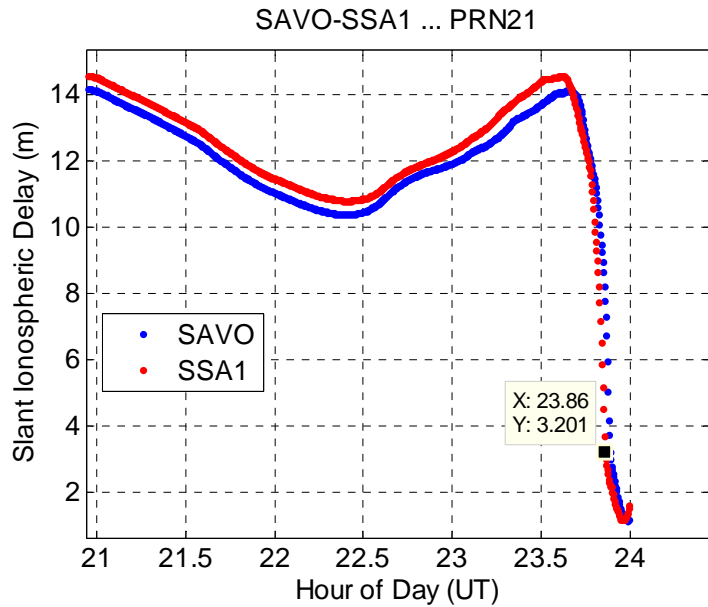
Manual Procedures

Manual Validation

- **Validate that the observed events are actually due to the ionosphere and not receiver faults or data errors using L1-only measurement**

Comparison of Slopes, ZOB1 and GARF, SVN 38
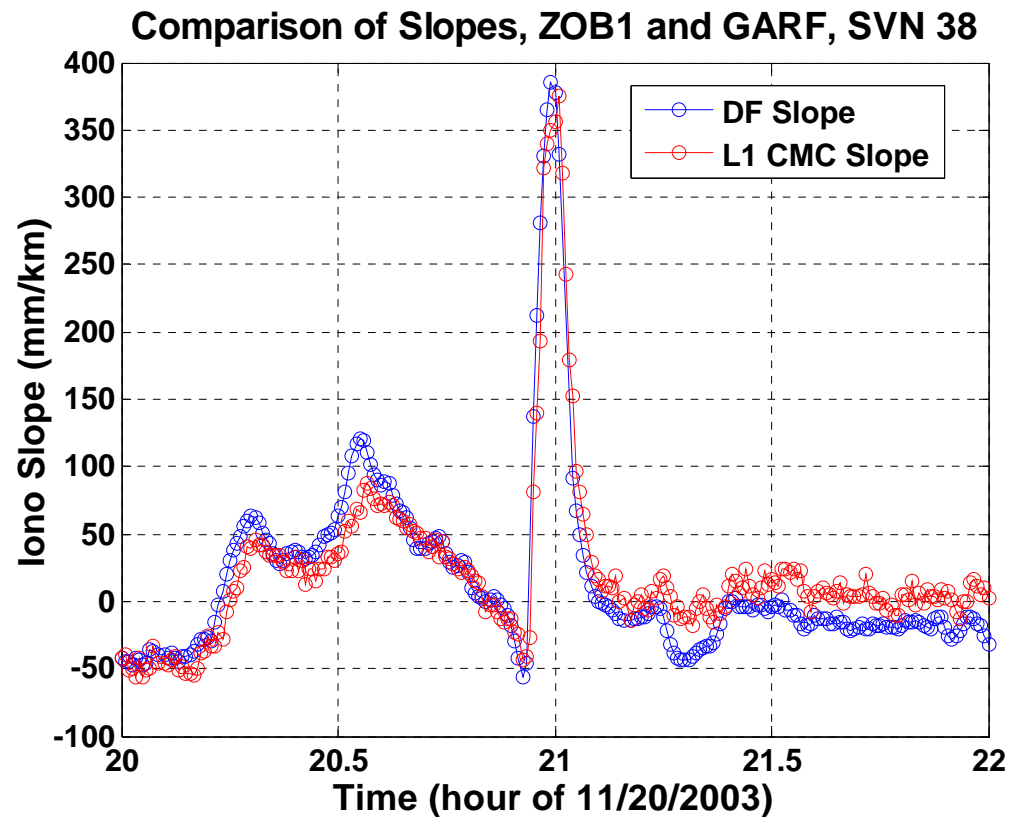
Example of LTIAM Plots for Anomaly Candidate
(Brazilian TM Study: SAVO-SSA1 PRN 21)

SAVO-SSA1 ... PRN21

SAVO-SSA1PRN21 (dist=9.97km)

SAVO-SSA1 Elevation Angle of PRN21

Manual Validation SAVO-SSA1 (9.97 km) PRN21

501.2 mm/km

Distribution of LTIAM software tool

- **Version 2.1 was made available to IGWG participating members (2012)**

- **The same version of the tool and supporting documents are available to the ISTF group members (an approval from FAA is obtained)**

    - **LTIAM-2.1 (zip file)**

    - **LTIAM Algorithm Description Doc v2.1**

    - **LTIAM User Manual v2.0**

- **Application form for LTIAM software package**

References

- **"User Manual for the Long-Term Ionospheric Anomaly (LTIA) Monitoring of the Ground-Based Augmentation System,"** *KAIST*, **Version 2.0, June 20, 2012**

- **"Algorithm Description Document and User Manual for Long-Term Ionospheric Anomaly Monitor (LTIAM) of the Local Area Augmentation System,"** *Tetra Tech AMT, Inc., Stanford University, KAIST*, **Version 2.1, August 13, 2012.**

- S. Jung and J. Lee, "Long Term Ionospheric Anomaly Monitoring for Ground Based Augmentation Systems." *Radio Sci.*, 47, RS4006, July 2012, doi:10.1029/2012RS005016.

- J. Lee, S. Jung, M. Kim, J. Seo, S. Pullen, and S. Close, "Results from Automated Ionospheric Data Analysis for Ground-Based Augmentation Systems," *Proceedings of the Institute of Navigation International Technical Meeting* (ION ITM 2012), Newport Beach CA, January, 2012

- J. Lee, S. Jung, and S. Pullen, "Enhancements of Long Term Ionospheric Anomalies Monitoring for the Ground-Based Augmentation System," *Proceedings of the Institute of Navigation International Technical Meeting* (ION ITM 2011), San Diego, CA, January 24-26, 2011

- J. Lee, S. Jung, E. Bang, S. Pullen, and P. Enge, "Long Term Monitoring of Ionospheric Anomalies to Support the Local Area Augmentation System," *Proceedings of the 23rd International Technical Meeting of the Satellite Division of the Institute of Navigation* (ION-GNSS 2010), Portland, OR, September 2010.