Using Seasonal Monitor Data to Assess Aviation Integrity

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36th Symposium of the International Loran Association
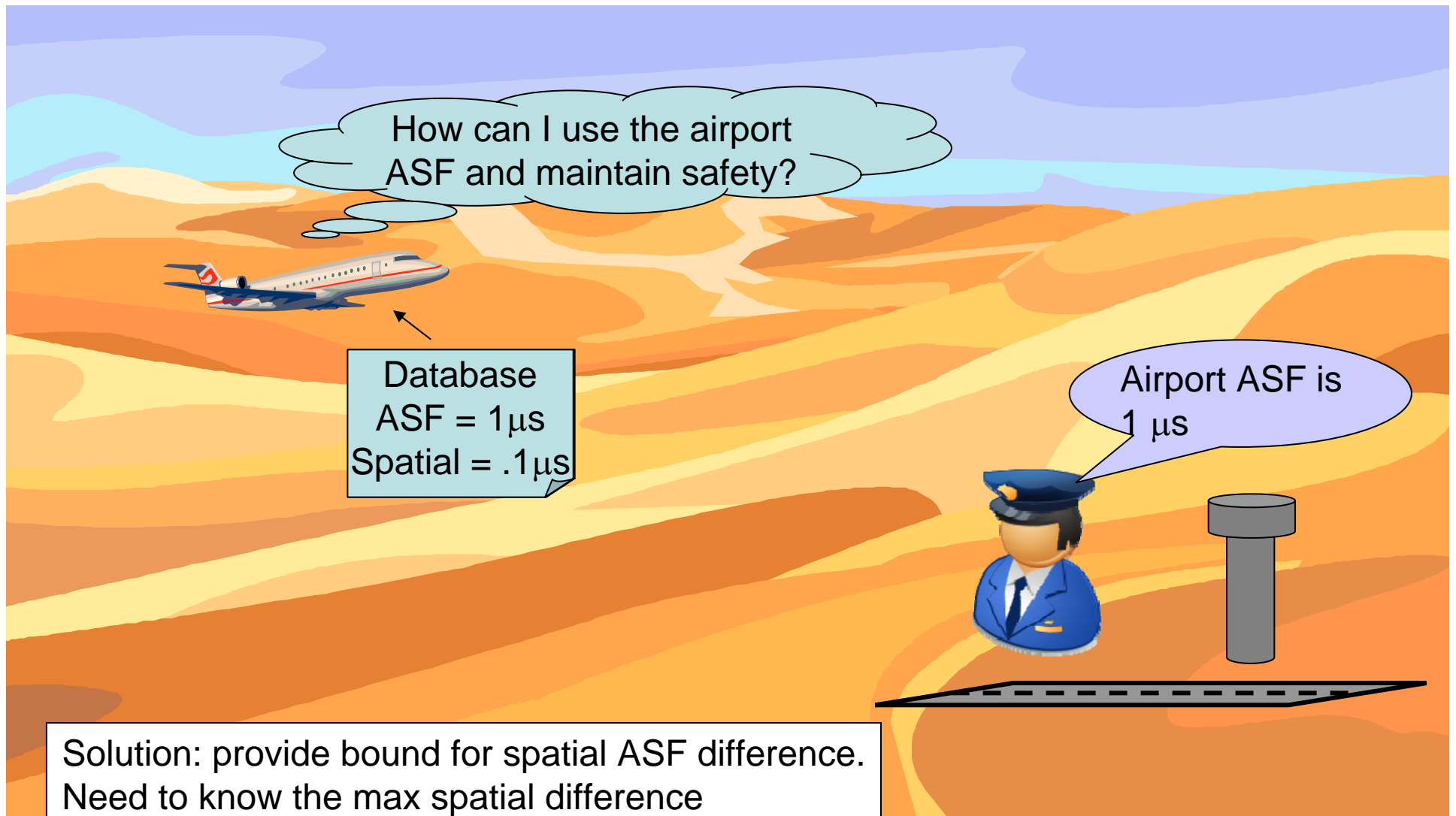
Orlando, FL October 14-17, 2007

Outline

- Bounding for Aviation Integrity
- Seasonal Monitor Sites
- Temporal ASF Variation Bound Analysis
- Midpoint ASF Determination
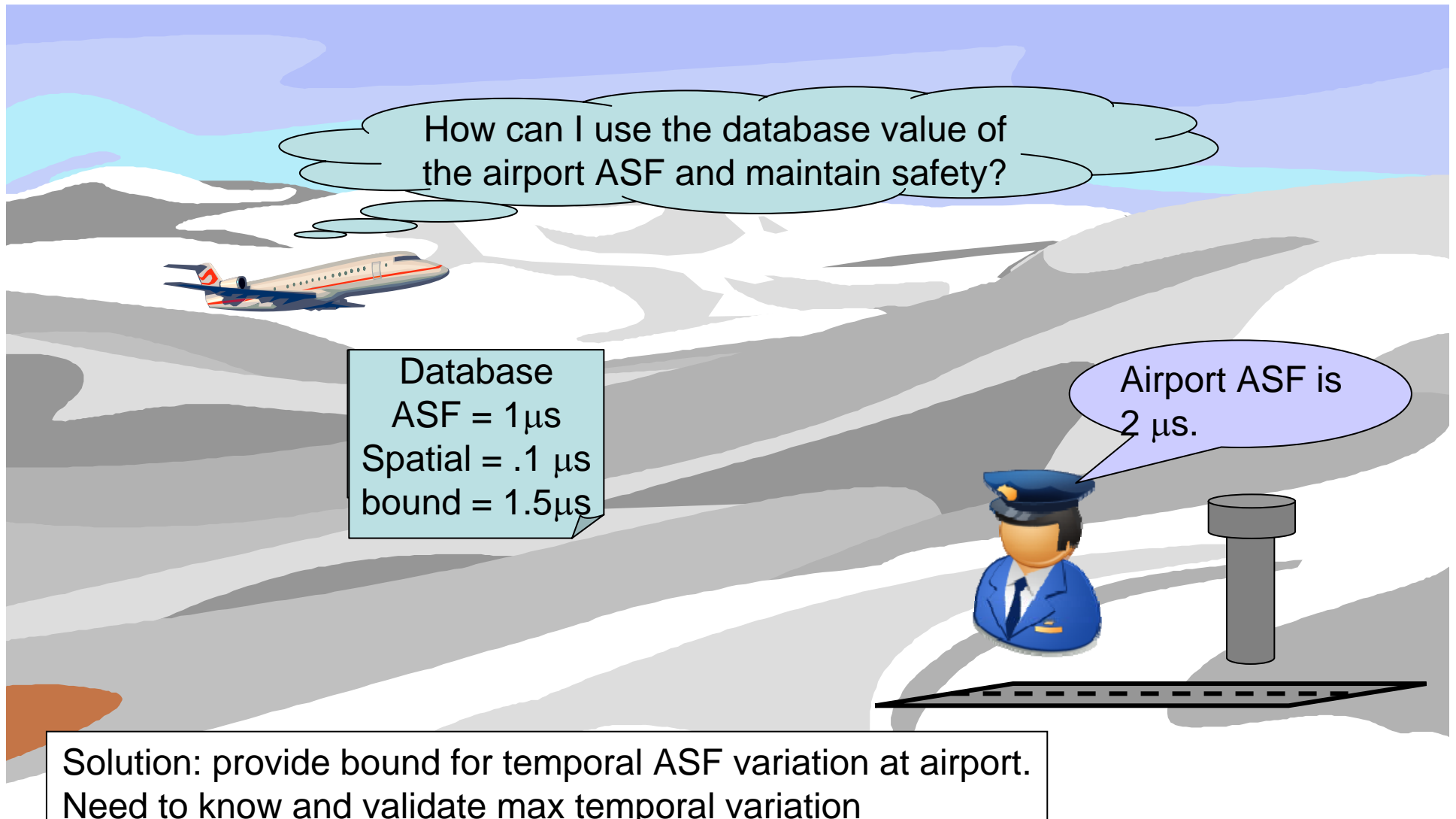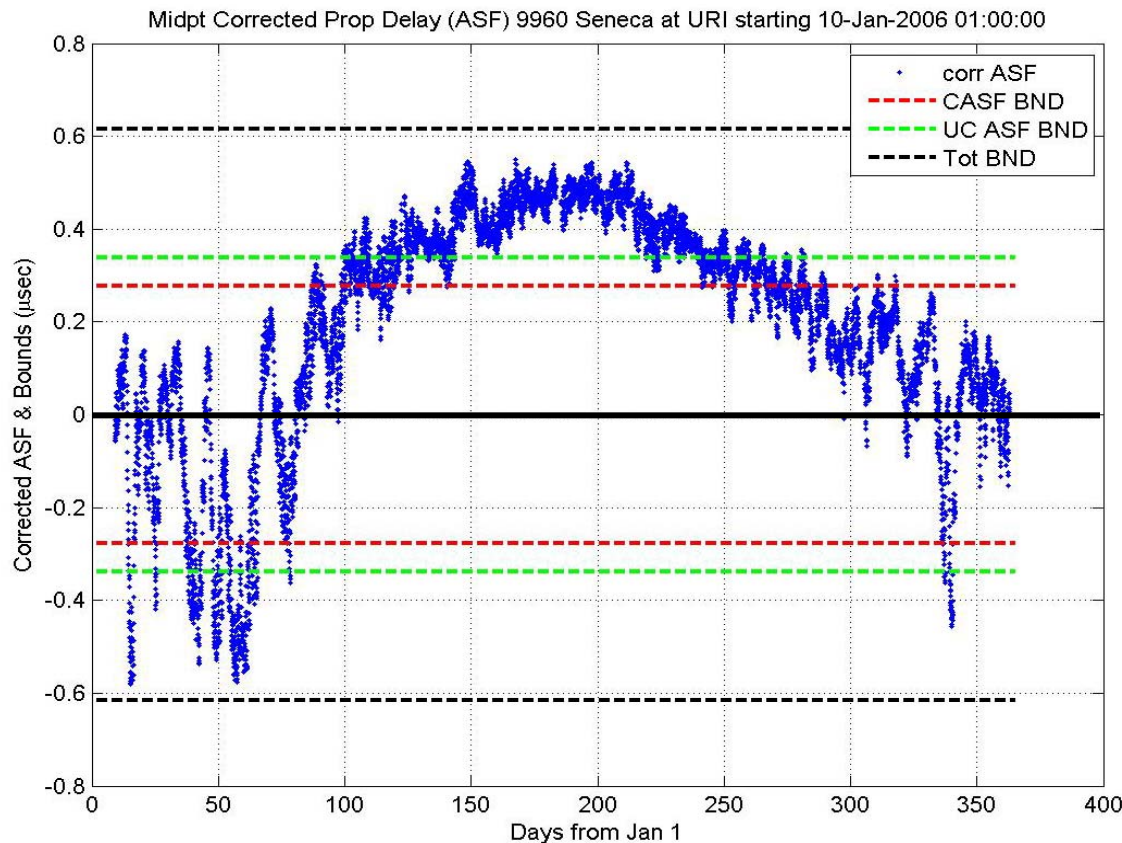- Temporal Variation of Spatial ASF
- Conclusions

Basic Scenario
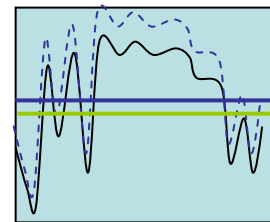
Problem: ASF Changes!

Airport Values in ASF Database

Midpt Corrected Prop Delay (ASF) 9960 Seneca at URI starting 10-Jan-2006 01:00:00

- **Nominal (midpoint) ASF**
  - Zero reference value

- **Bound on temporal variation of ASF beyond nominal value**
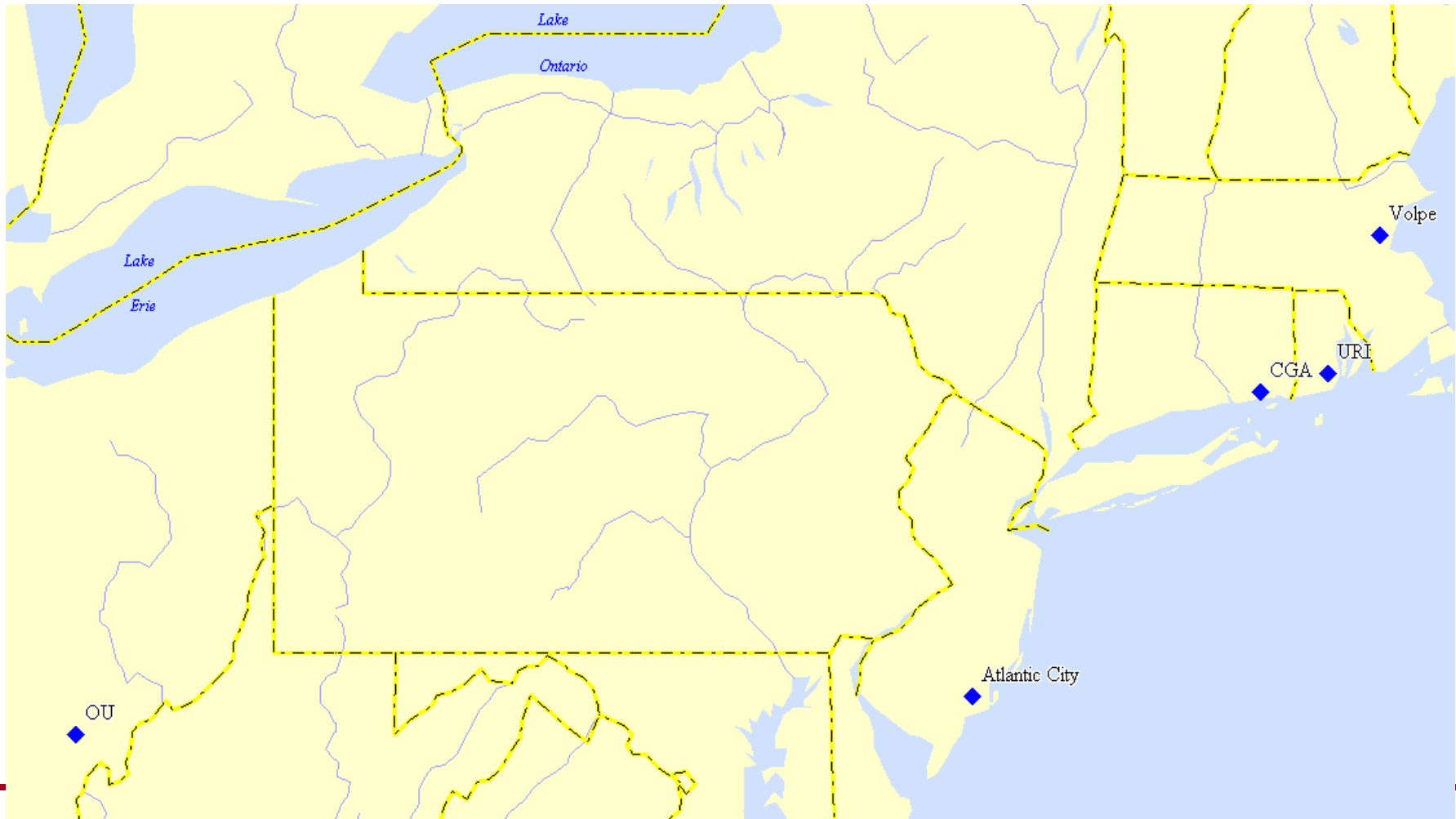 - Correlated with path length
  - Uncorrelated

What Do I Need to Provide?

- **Bound on Temporal of ASF**
  - At airport
- **Nominal (Midpoint) ASF**
  - At airport
- **Bound on Temporal Variation of Spatial ASF Difference**
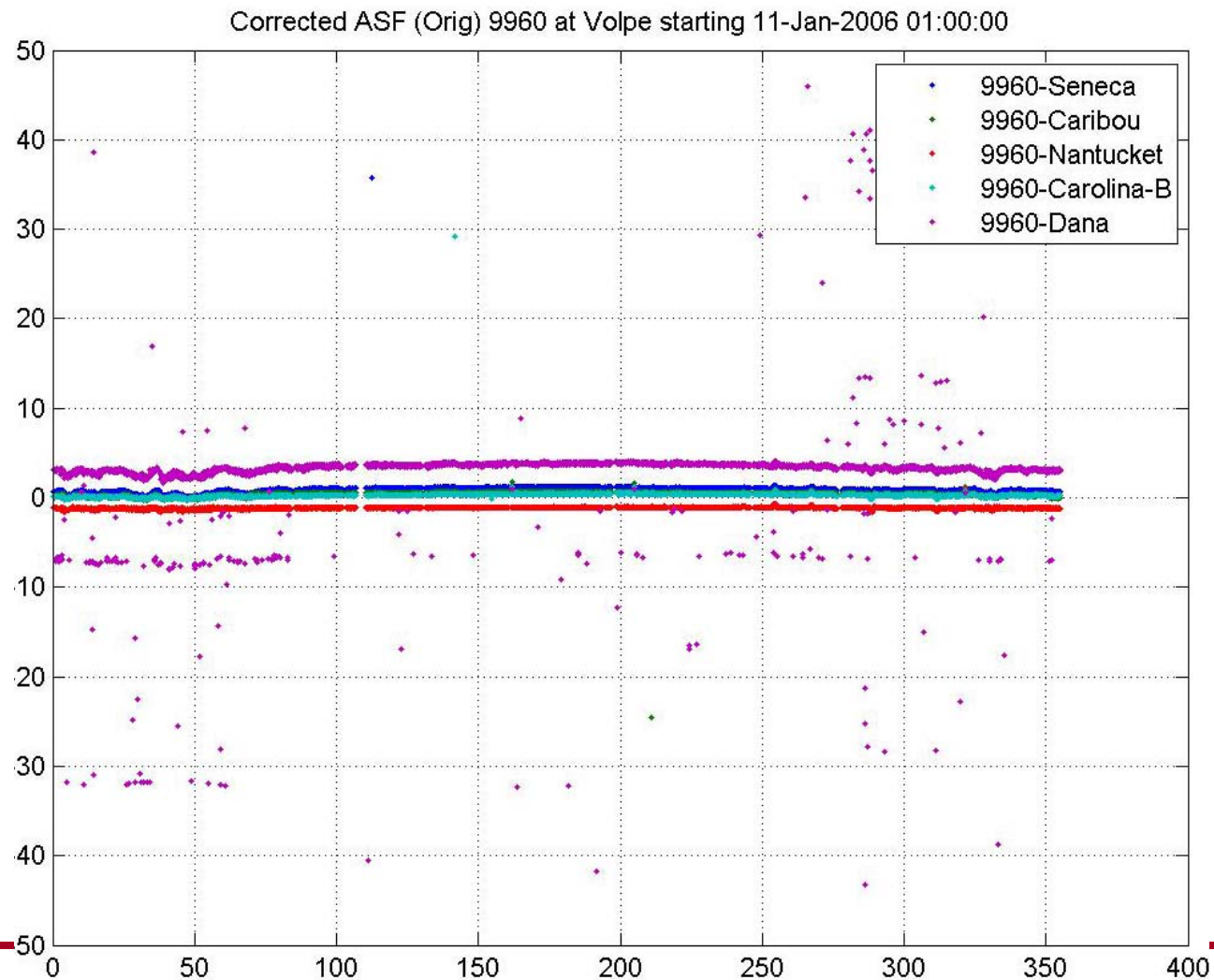 - Already provide bound on spatial ASF difference
  - Is this necessary?

Seasonal Monitor Sites (2006)

Original Data

Corrected ASF (Orig) 9960 at Volpe starting 11-Jan-2006 01:00:00

Legend:
- 9960-Seneca
- 9960-Caribou
- 9960-Nantucket
- 9960-Carolina-B
- 9960-Dana

Filtered Data

Corrected, Mean ASF 9960 at Volpe starting 11-Jan-2006 01:00:00

Legend:
- 9960-Seneca
- 9960-Caribou
- 9960-Nantucket
- 9960-Carolina-B
- 9960-Dana

microsec

Day (from 11-Jan-2006)

Process

Seasonal Monitor Data (1 hour w 1 min exp ave data)

↓

Filter Data (using previous rules)

↓

Calculate midpoint phase & subtract from filtered data

Calculate bounds for corr/uncorr temporal var from model

Calculate Weight, Geometry, & Inversion matrix

Calculate HPL contribution

Calculate position domain error
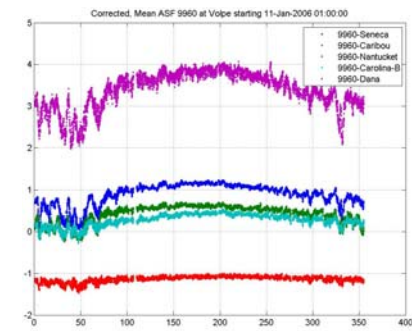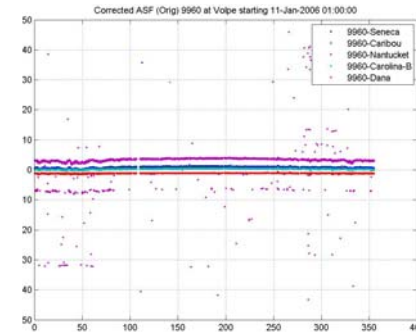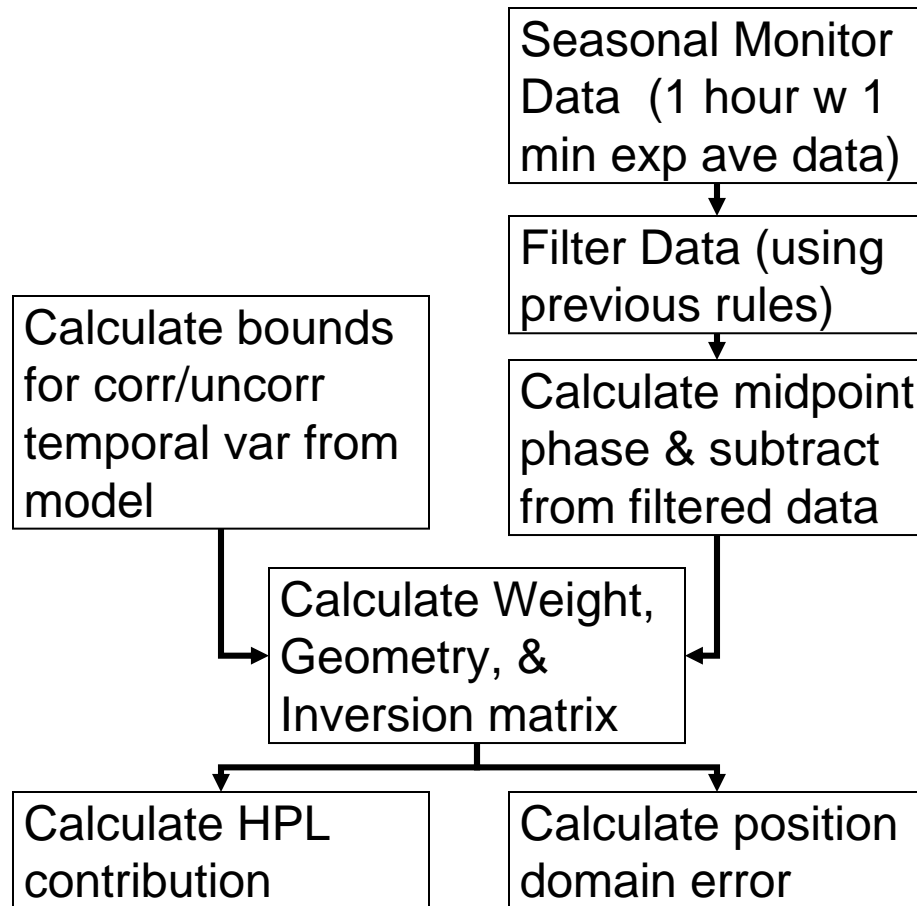
Assessing Performance of Bound on Temporal ASF Variations

- Bob Wenzel discussed 2 models last year
  - 2004 Report Model (Model 1)
  - Weather Regression (Model 3)
- Variation bound composed to 2 components
  - Correlated & Uncorrelated
- Use seasonal monitor data to assess bounds & component
  - Much of past data has been used to develop model
  - The data provides an independent validation
  - Assess range & position domain performance

Bounding over the year
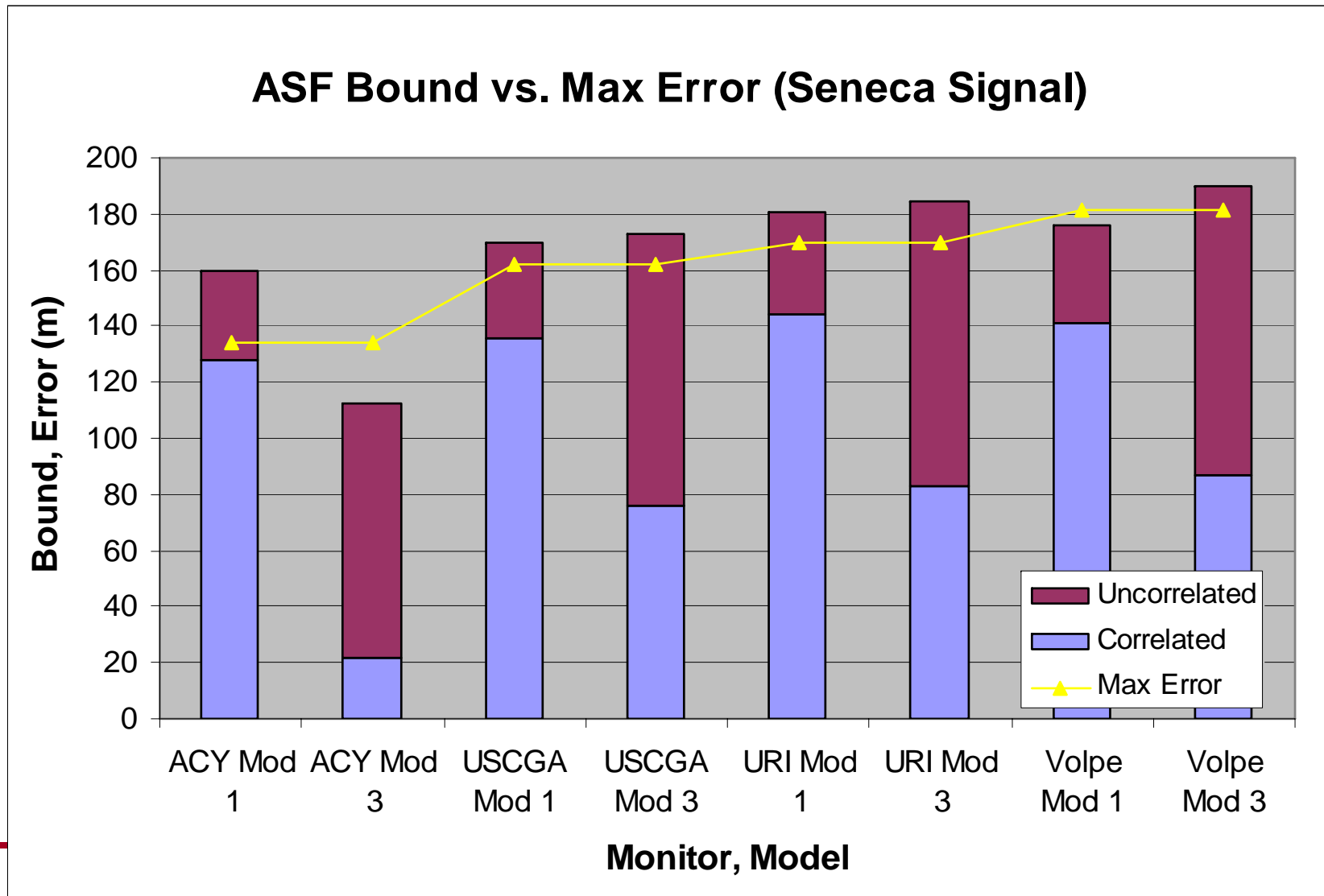

Midpt Corrected Prop Delay (ASF) 9960 Seneca at Volpe starting 11-Jan-2006 01:00:00
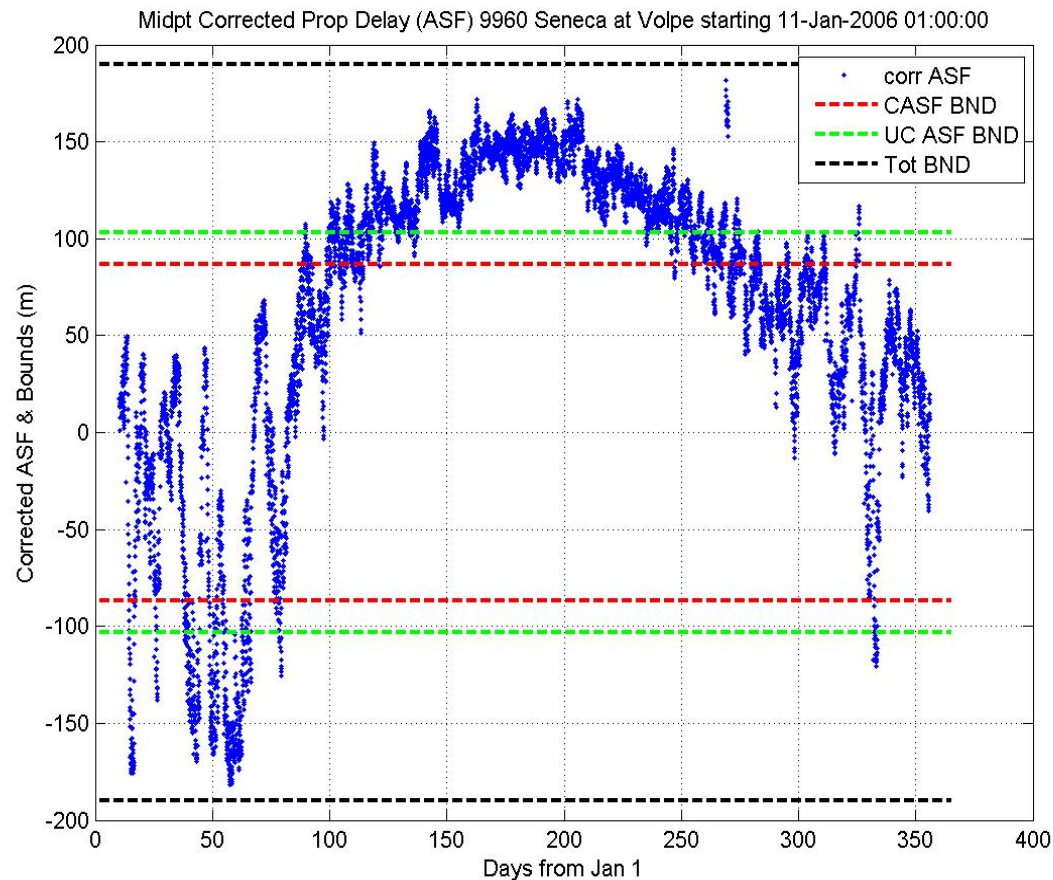
Filtering does not remove all outliers
Want to keep true variations

Histogram of Bound Components for Seneca

ASF Bound vs. Max Error (Seneca Signal)

Histogram of Bound Components for Caribou

ASF Bound vs. Max Error (Caribou Signal)
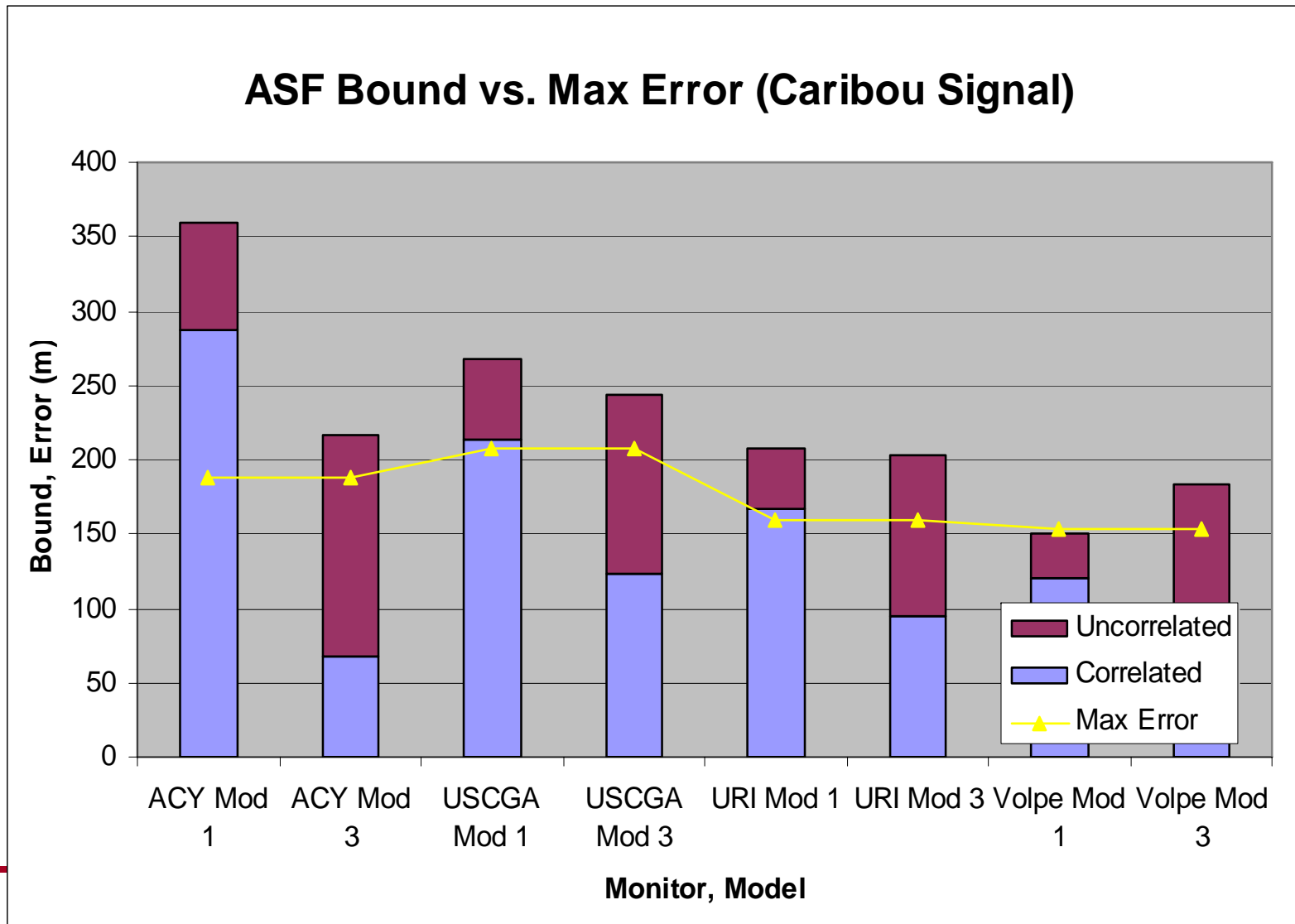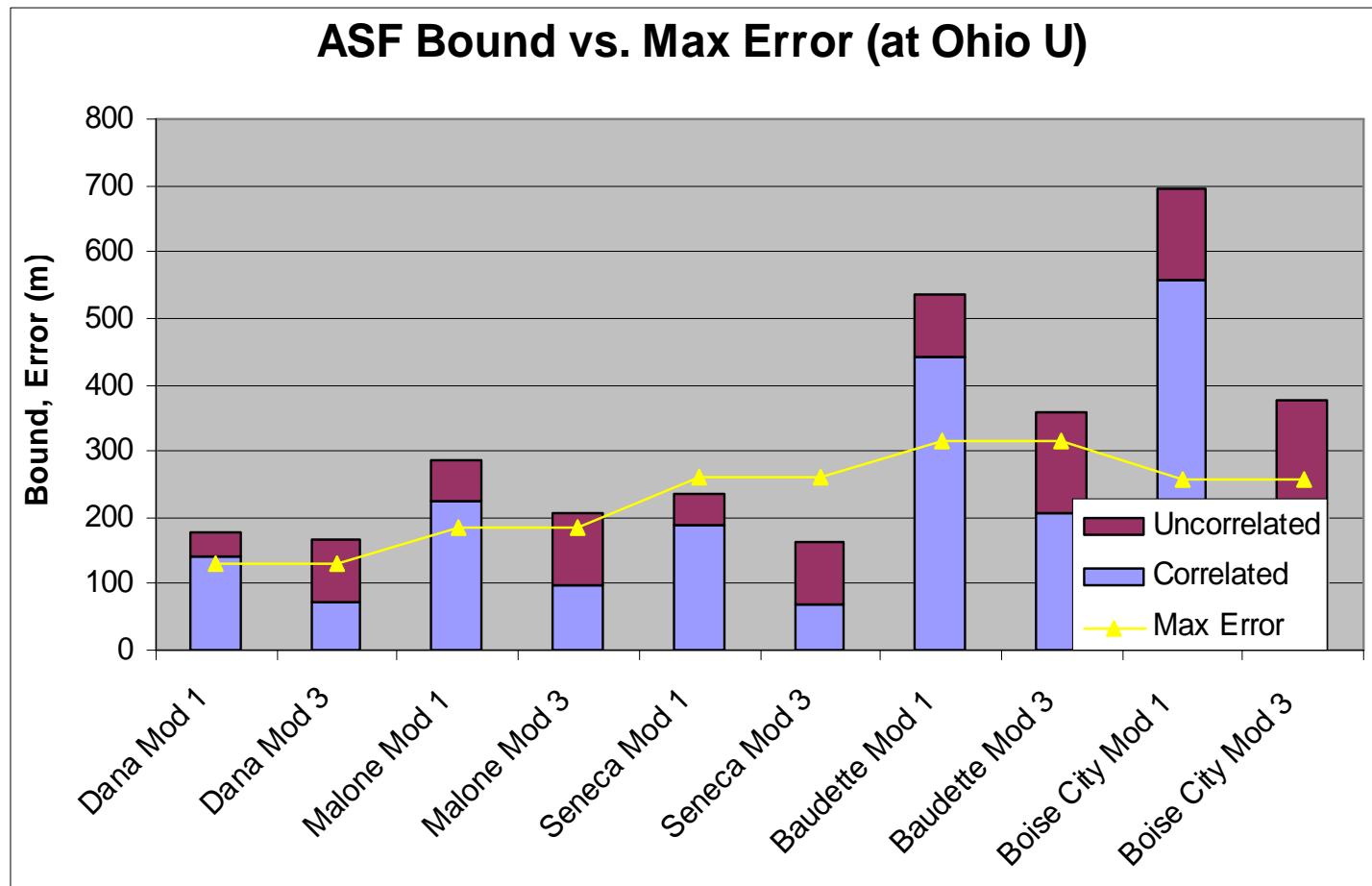
Histogram of Bound Components for Nantucket

ASF Bound vs. Max Error (Nantucket Signal)
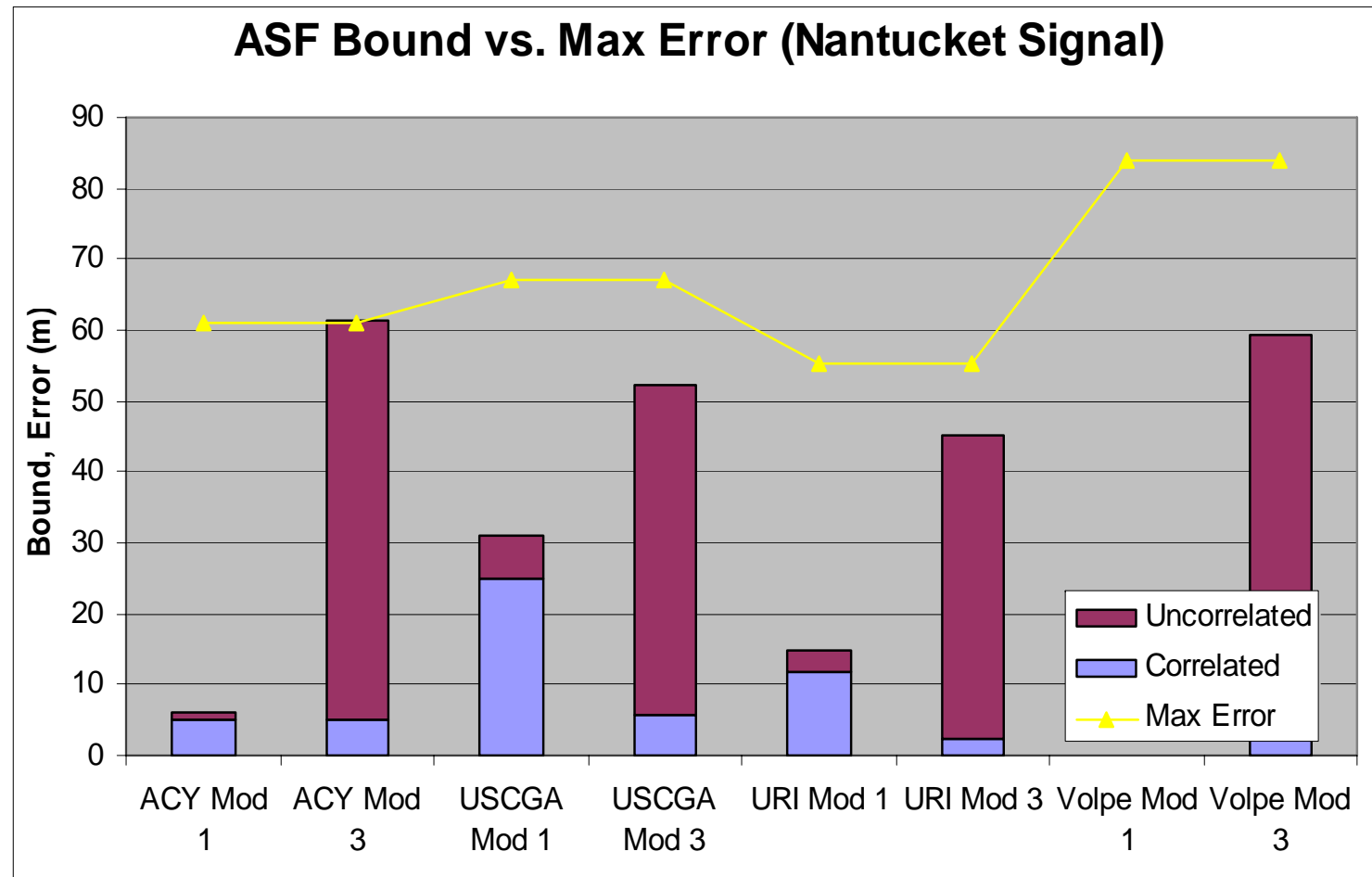
- Model 1 bounds poorly due to coarseness of grid
- Model 3 is better but also does not bound
  - Grid may also be issue

Histogram of Bound Components at Ohio U

ASF Bound vs. Max Error (at Ohio U)

- Model 1 overall bounds are larger
- Model 3 has larger uncorrelated

Bounding in the Position Domain

Location	Volpe	URI	USCGA	Atlantic City	Ohio U
Model 1 (HPL)	104.2	151.8	180.1	122.5	132.4
Model 3 (HPL)	148.4	195.0	222.1	137.9	191.5
Max Err (Nom)	84.5	101.0	142.0	82.6	100.3
Max Err (10%)	100.0	119.0	166.2	97.7	129.8

Using to Data to Assess Prediction of Seasonal Midpoint ASF

- Goal: take airport ASF measurement and determine where the seasonal midpoint
  - Where in seasonal cycle is measured ASF?

- Develop model for predicting ASF
  - ASF data: seasonal monitor
 - Model data: weather & conductivity data

Assessing Magnitude of Temporal Variation of Spatial ASF

- Break down of the components of ASF suggests a term for temporal variation of spatial ASF
  - Assumption is that ASF differences on approach path does not change
  - Maximum distance is ~ 20 nm
- Test temporal variation of spatial ASF using seasonal monitor data
- URI-Volpe is 64 miles, USCGA-URI is 30 miles
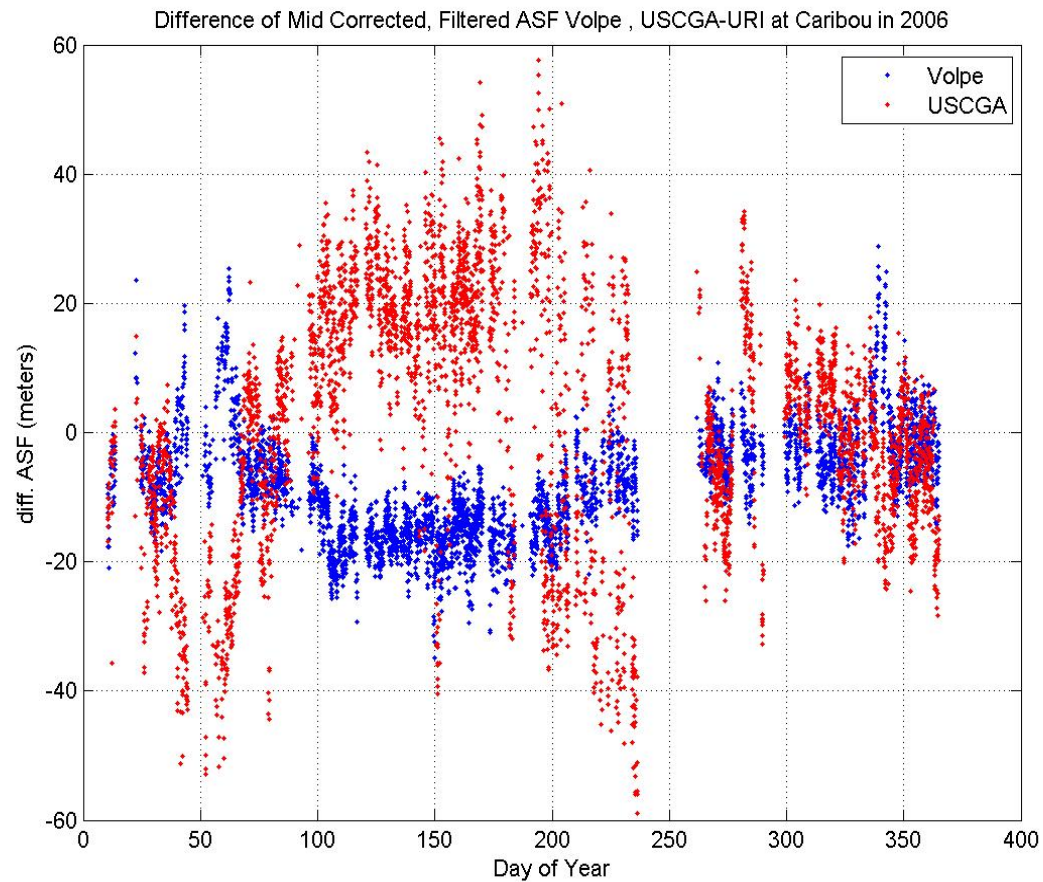
Seneca ASF Difference at Volpe & USCGA from URI

Difference of Mid Corrected, Filtered ASF Volpe , USCGA-URI at Seneca in 2006
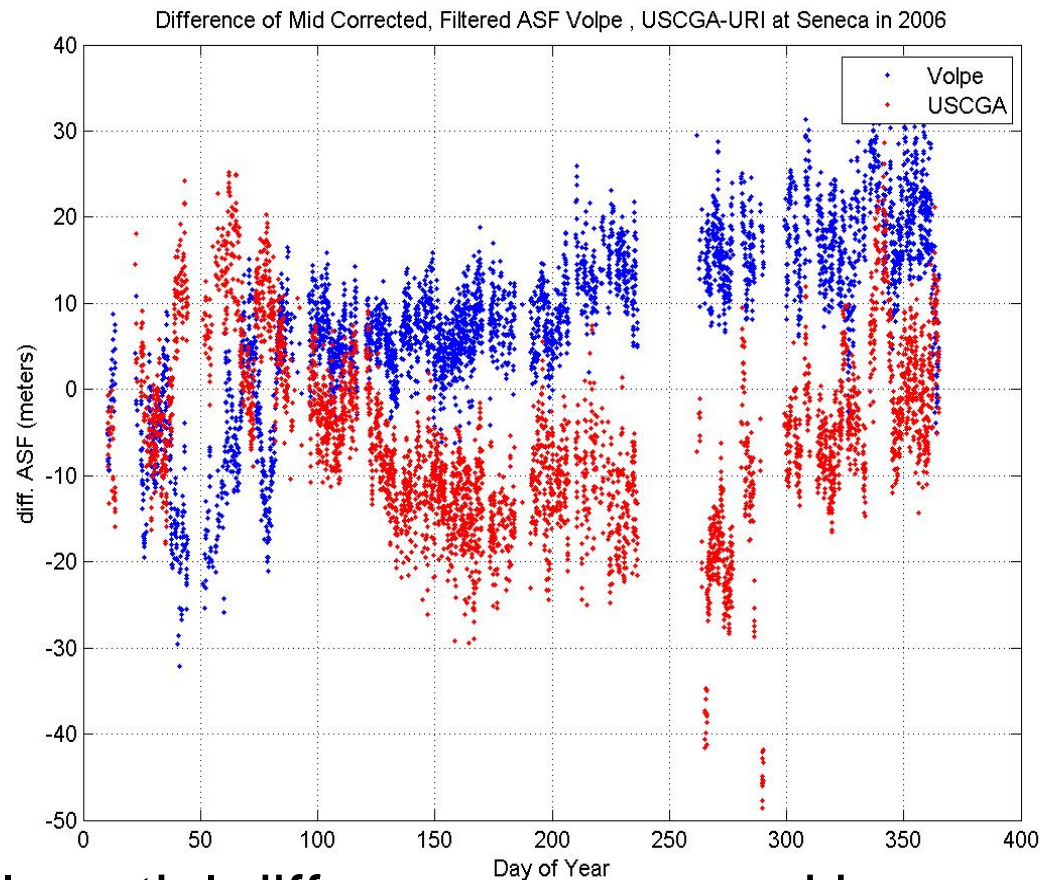
Nominal spatial differences removed by removing midpoint values at both locations

Caribou ASF Difference at Volpe & USCGA from URI

Difference of Mid Corrected, Filtered ASF Volpe , USCGA-URI at Caribou in 2006

Dana ASF Difference at Volpe & USCGA from URI

Difference of Mid Corrected, Filtered ASF Volpe , USCGA-URI at Dana in 2006
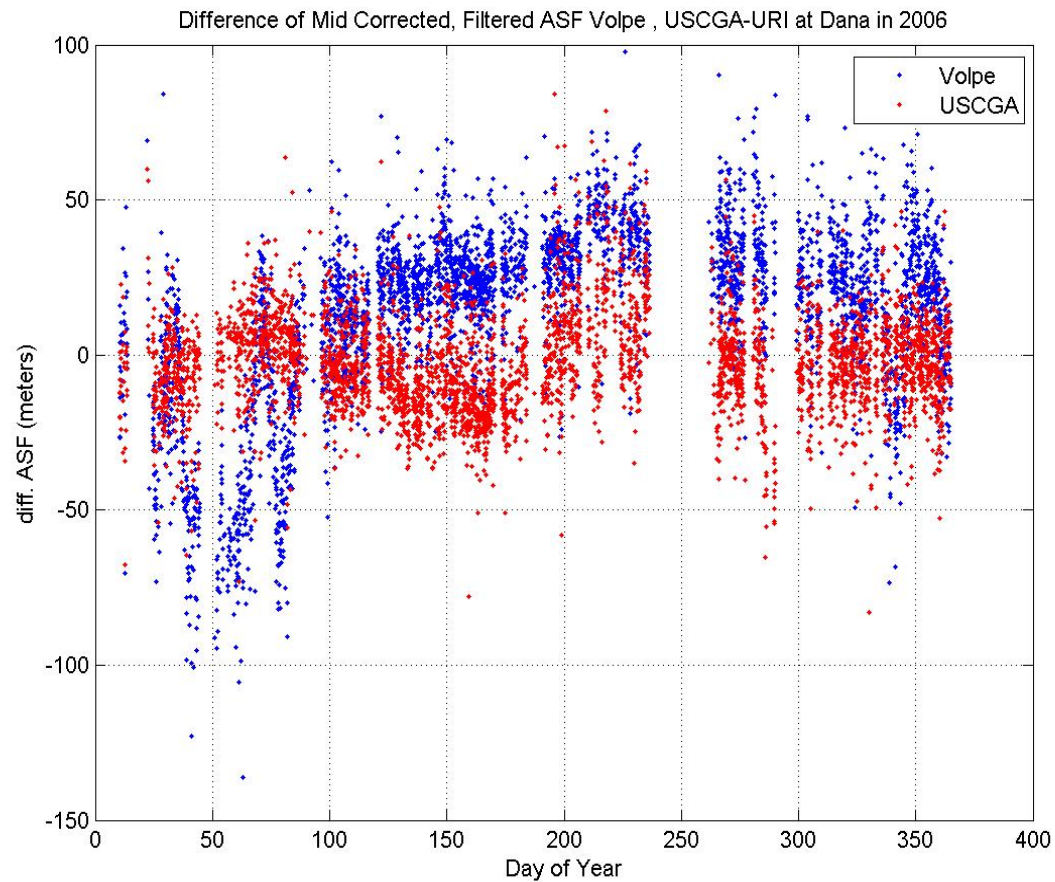
Carolina Beach ASF Difference at Volpe & USCGA from URI
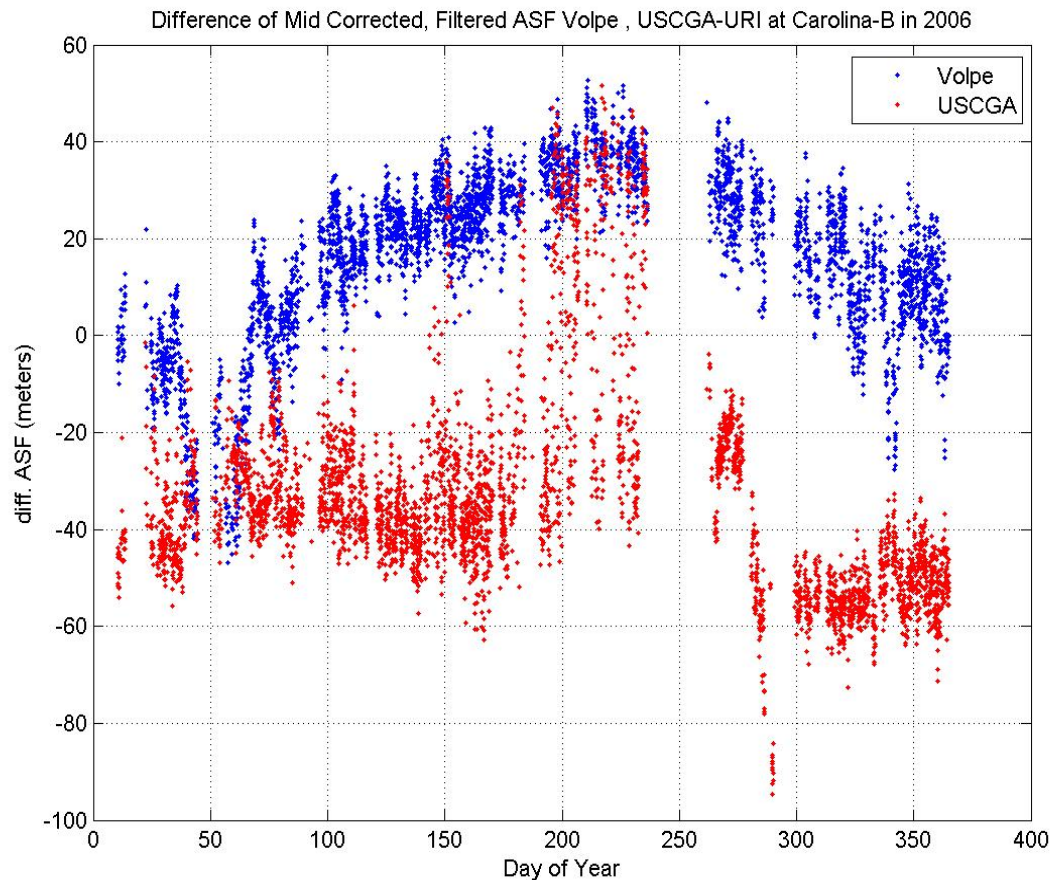
Difference of Mid Corrected, Filtered ASF Volpe , USCGA-URI at Carolina-B in 2006

Overall Effect in Position

N-E Error using 9960 at Volpe using URI for corrections 2006

Overall Effect in Position

Pos & Time Error using 9960 ASF from Volpe w URI corrections 2006

Overall Effect in Position

Pos & Time Error using 9960 ASF from USCGA w URI corrections 2006
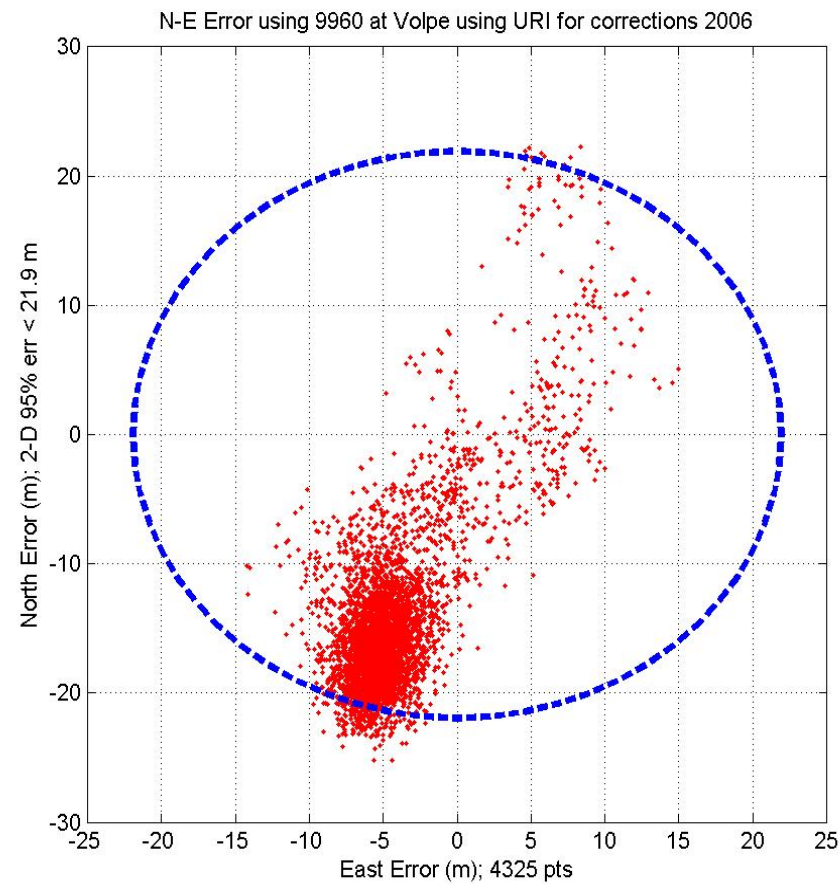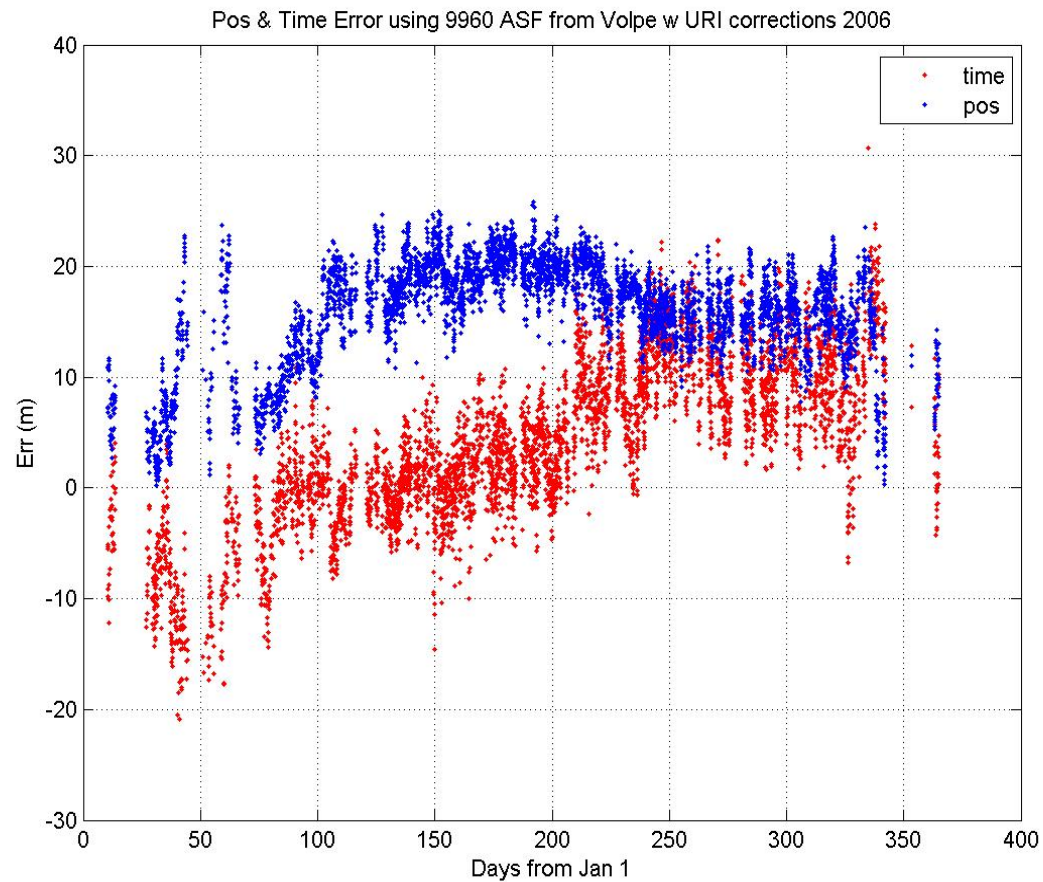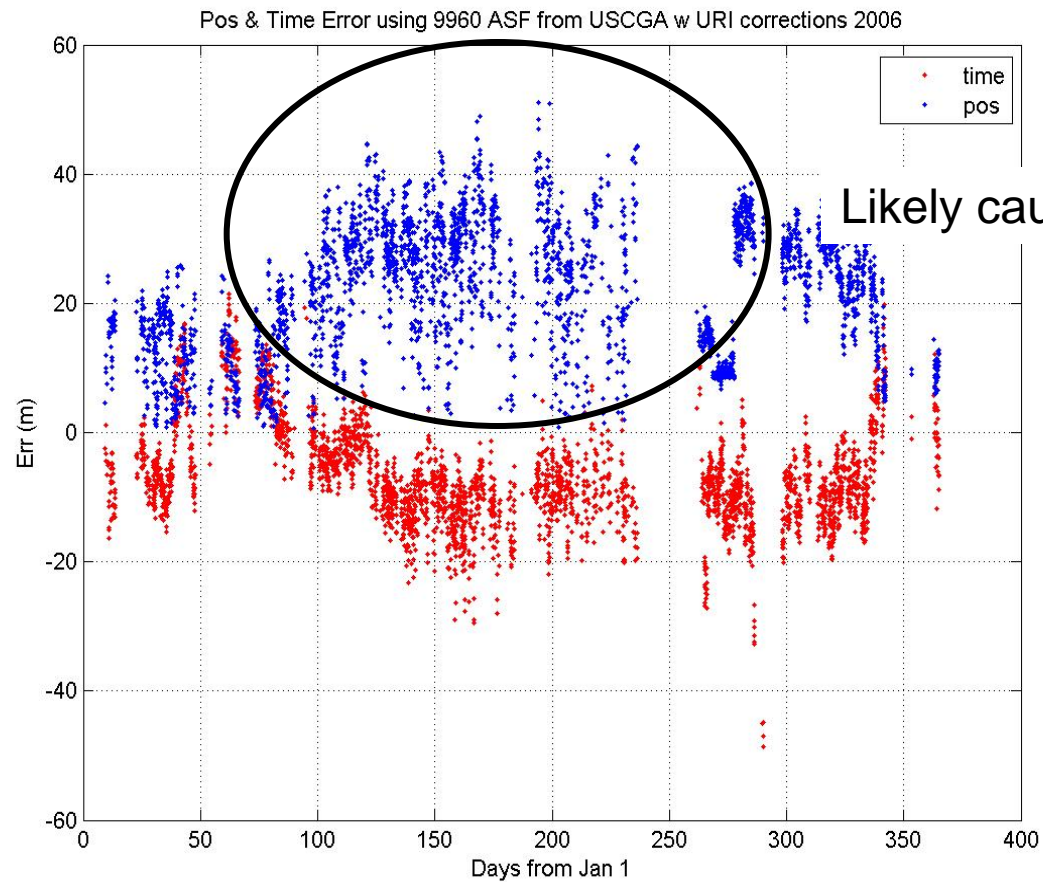
Likely caused by noise

Carolina Beach ASF (Volpe is baseline)

Differential Corrected ASF from CarolinaB with baseline monitor Volpe
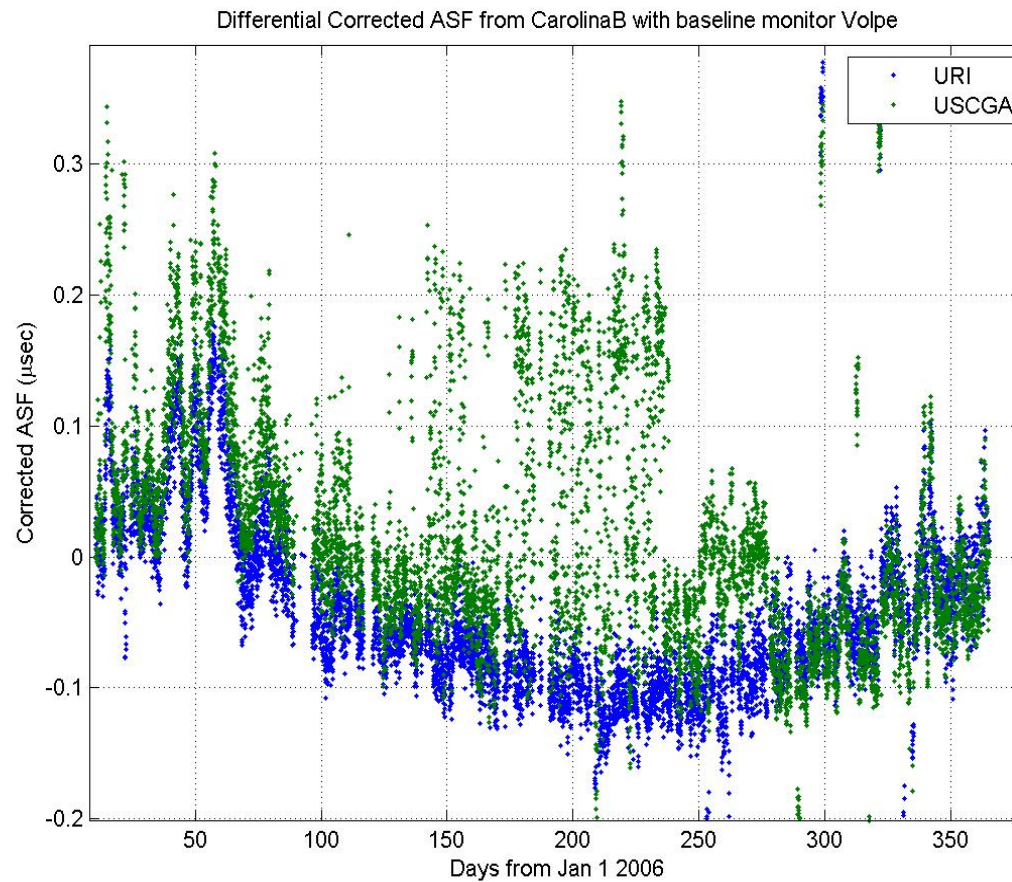
Thoughts

- There is some temporal variation of the spatial error
  - For example, URI minus Volpe data is not flat
  - Seems most significant over the winter with range domain errors up to 30 m or more
- This does not seem to be due solely to noise
  - Noise may contribute 5-20 m
- Question: What does this mean for the aviation approach model?

Reflections

- There is temporal variation of the spatial ASF, approach path distances
- The variation may be ~ 5-15 m in the position domain
  - Nominal spatial differences taken out by removing midpoint values at both locations
- Can account for this in the error budget by
  - Increasing position bound on spatial ASF
  - Adding an additional term
- dLoran accuracy of 10-20 m still seems reasonable

Closing Thoughts & Future Work

- Still need to work on ASF issues for aviation integrity
- Temporal variation bounds seems reasonable
  - Position domain always bounded
  - Work out signals that are not bounded
- Midpoint estimation still being developed
- Temporal of Spatial may need to be incorporated into hazards
- Collecting data from more seasonal monitor sites in 2007 & 2008

Acknowledgments & Disclaimer

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- The views expressed herein are those of the authors and are not to be construed as official or reflecting the views of the U.S. Coast Guard, Federal Aviation Administration, Department of Transportation or Department of Homeland Security or any other person or organization.