SSC Geopositional Assessment of the Advanced Wide Field Sensor

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2005 Overview

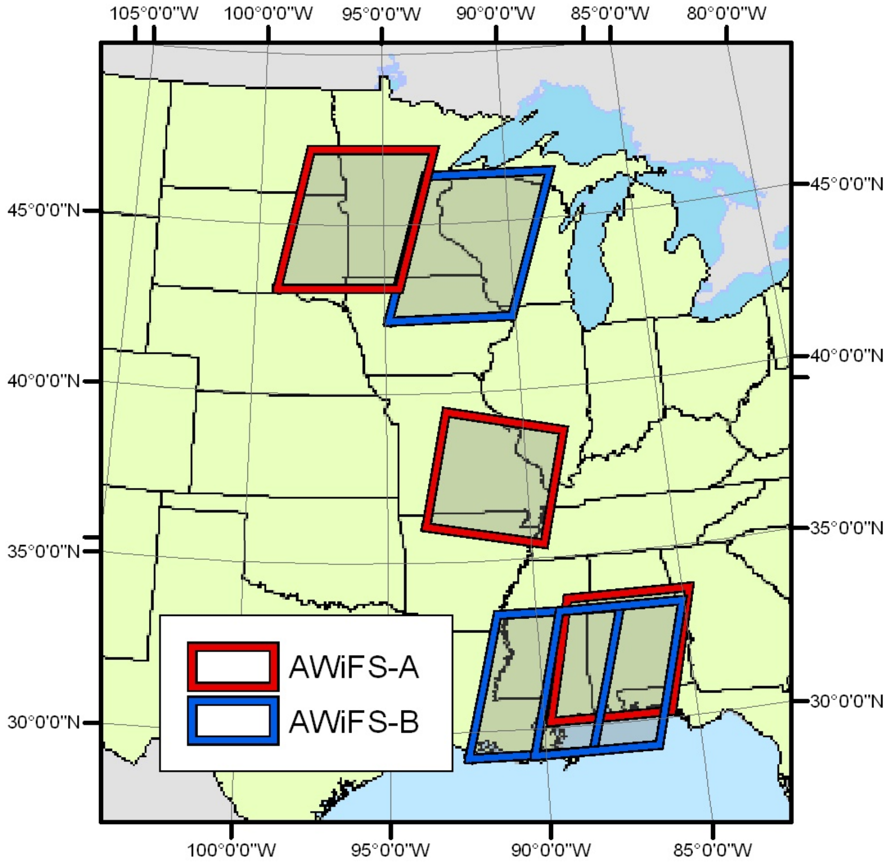
- OBJECTIVE: Provide independent verification of IRS geopositional accuracy claims and of the internal geopositional characterization provided by Lutes (2005)1
- Assessed six sub-scenes (Quads): three from each AWiFS camera
- Manually matched check points to digital orthophoto quarter quadrangle (DOQQ) reference (assumed accuracy ~5 m, RMSE)
- Check points were selected to meet or exceed Federal Geographic Data Committee's guidelines2
- Used ESRI ArcGIS® for data collection and SSC-written MATLAB® scripts for data analysis

[1] Lutes, J., 2005. Resourcesat-1 geometric accuracy assessment. In proceedings of The ASPRS 2005 Annual Conference, Baltimore, MD, March 7–11. Available at http://www.spaceimaging.com/whitepapers_pdfs/2005/Lutes_ASPRS2005_ResourceSat_Accuracy_Assessment.pdf.

[2] Federal Geographic Data Committee, 1998. *Geospatial Positioning Accuracy Standards – Part 3: National Standard for Spatial Data Accuracy.* FGDC-STD-007.3-1998. Subcommittee for Base Cartographic Data. 28 p. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3.

Characterized Scenes

Distribution of Scenes



Acquisition	Camera
270-36-C 14 AUG 2004	AWiFS-A
277-42-C 5 MAR 2005	AWiFS-A
282-50-C 17 JAN 2005	AWiFS-A
270-36-D 14 AUG 2004	AWiFS-B
276-47-D 24 MAR 2005	AWiFS-B
278-47-D 27 APR 2005	AWiFS-B

Methods

Check Point Error

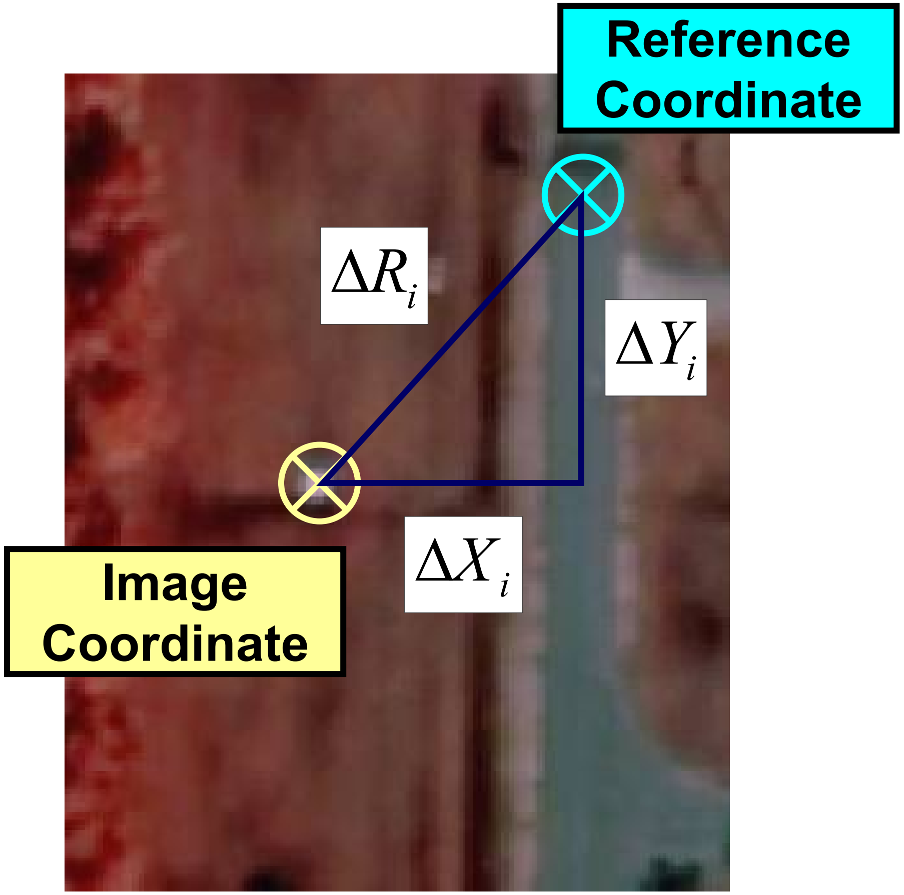
- Check Point Error – differences between image and reference coordinates

$$\Delta X_i = X_{image,i} - X_{reference,i}$$

$$\Delta Y_i = Y_{image,i} - Y_{reference,i}$$

- Check point error radial magnitude calculated by

$$\Delta R_i = \sqrt{\Delta X_i^{\,2} + \Delta Y_i^{\,2}}$$



Sources of Error

- Assessment Error
  - Ground Control Error
    - Pointing
    - Measurement
  - Analyst Error
    - Pointing
- Product Error (potential)
  - Spatial Resolution
  - Pointing (Displacement)
  - Azimuth
  - Scale
  - Orthogonality
  - Other product distortion
  - Terrain effects

"Pointing error" for surveyors & analysts indicates the errors these individuals have in picking their target

random error

"Measurement error" for ground control indicates the error inherent in the measuring instrument or system (in this case, the GPS)

constant systematic error

"Pointing error" for a geoimaging system indicates the constant separation between estimated target coordinates and actual target coordinates

functional systematic error

Error Model: Primary Components

- The error model chosen for generalized assessment

$$X_{image} = X + \varepsilon \quad \text{where} \quad \varepsilon = \varepsilon_{constant} + \varepsilon_{zero-mean}$$

- Horizontal Bias – an estimate of the constant error, designated here as μ_H, is the magnitude of the vector sum of the average error in the *X* and the *Y*

$$\mu_H = \sqrt{\left(\overline{\Delta X}\right)^2 + \left(\overline{\Delta Y}\right)^2}$$

- Circular Standard Error – an estimate of the zero-mean circular equivalent error valid even for elliptical error distributions with minimum to maximum error ratios as low as 0.6

$$\sigma_C \cong \frac{\sigma_{\Delta X} + \sigma_{\Delta Y}}{2} \quad \text{where} \quad \sigma_{\Delta X} = \sqrt{\frac{\sum\left(\Delta X_i - \overline{\Delta X}\right)^2}{n-1}} \quad \& \quad \sigma_{\Delta Y} = \sqrt{\frac{\sum\left(\Delta Y_i - \overline{\Delta Y}\right)^2}{n-1}}$$

Ager (2004)[1] used the horizontal error defined on the right, but Greenwalt and Shultz (1962)[2] found this to be invalid for minimum to maximum error ratios less than 0.8

$$\sigma_H = \sqrt{\frac{\left(\sigma_{\Delta X}{}^2 + \sigma_{\Delta Y}{}^2\right)}{2}}$$

[1] Ager, T.P., 2004. *An Analysis of Metric Accuracy Definitions and Methods of Computation*. NIMA InnoVision white paper.

[2] Greenwalt, C.R., and M.E. Shultz, 1962. Principles *of Error Theory and Cartographic Applications.* ACIC Technical Report No. 96, United States Air Force, Aeronautical Chart and Information Center, St. Louis, Missouri, 98 pp.

Error Model: Zero-Mean Components

- The zero-mean error model

$$\varepsilon_{zero-mean} = \varepsilon_{along\text{-}track}(u) + \varepsilon_{across-track}(u) + \varepsilon_{non-systematic}$$

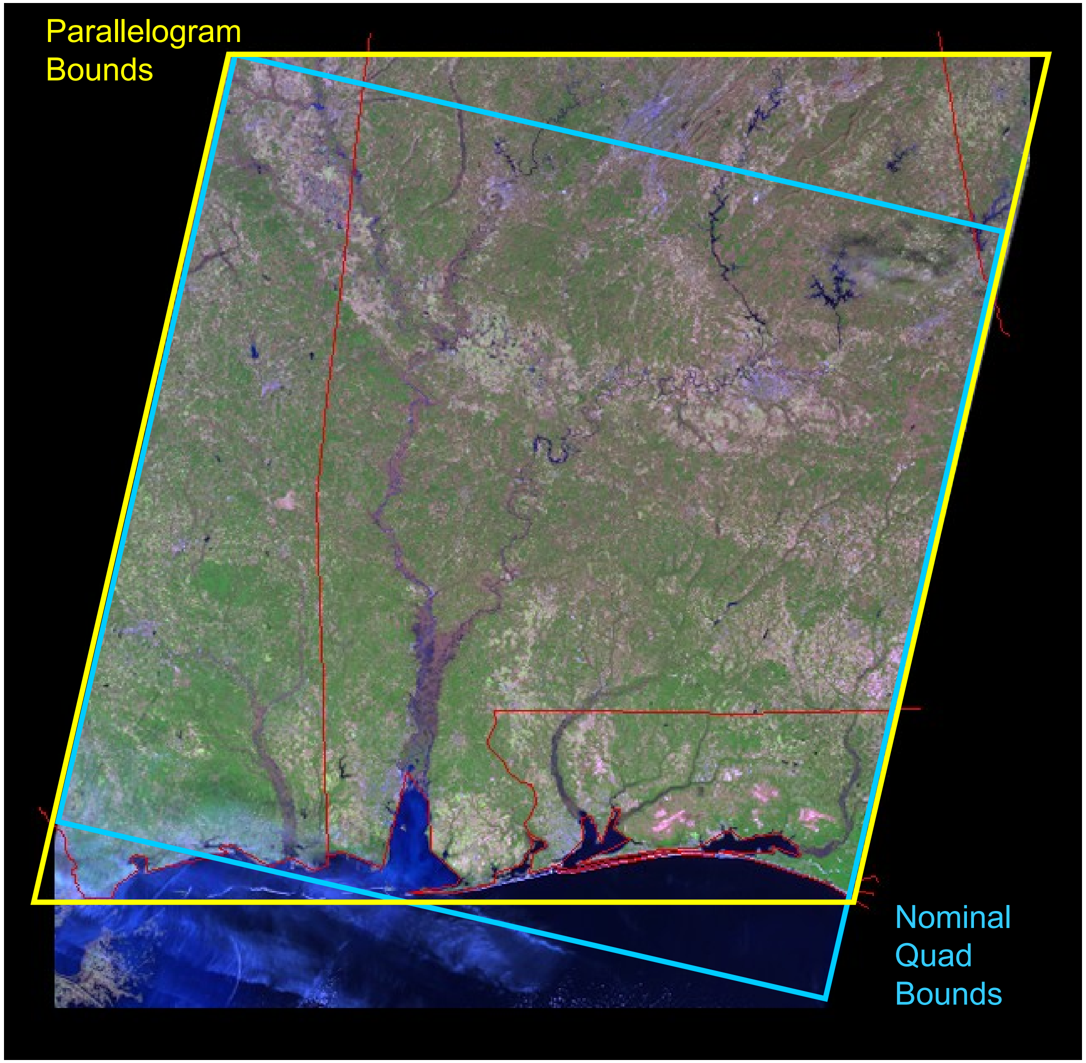
Where u is the across-track position

- It is important to examine the zero-mean error more closely in the case of AWiFS because the error distribution clearly departs from a simple circular error distribution with a horizontal bias
- The along and across track errors, while functionally more complex than horizontal bias, are still systematic errors that are largely correctable
- The non-systematic error represents random error and harder to model errors such as terrain distortion; this error is the most difficult (costliest) to correct

Defining Area of Analysis

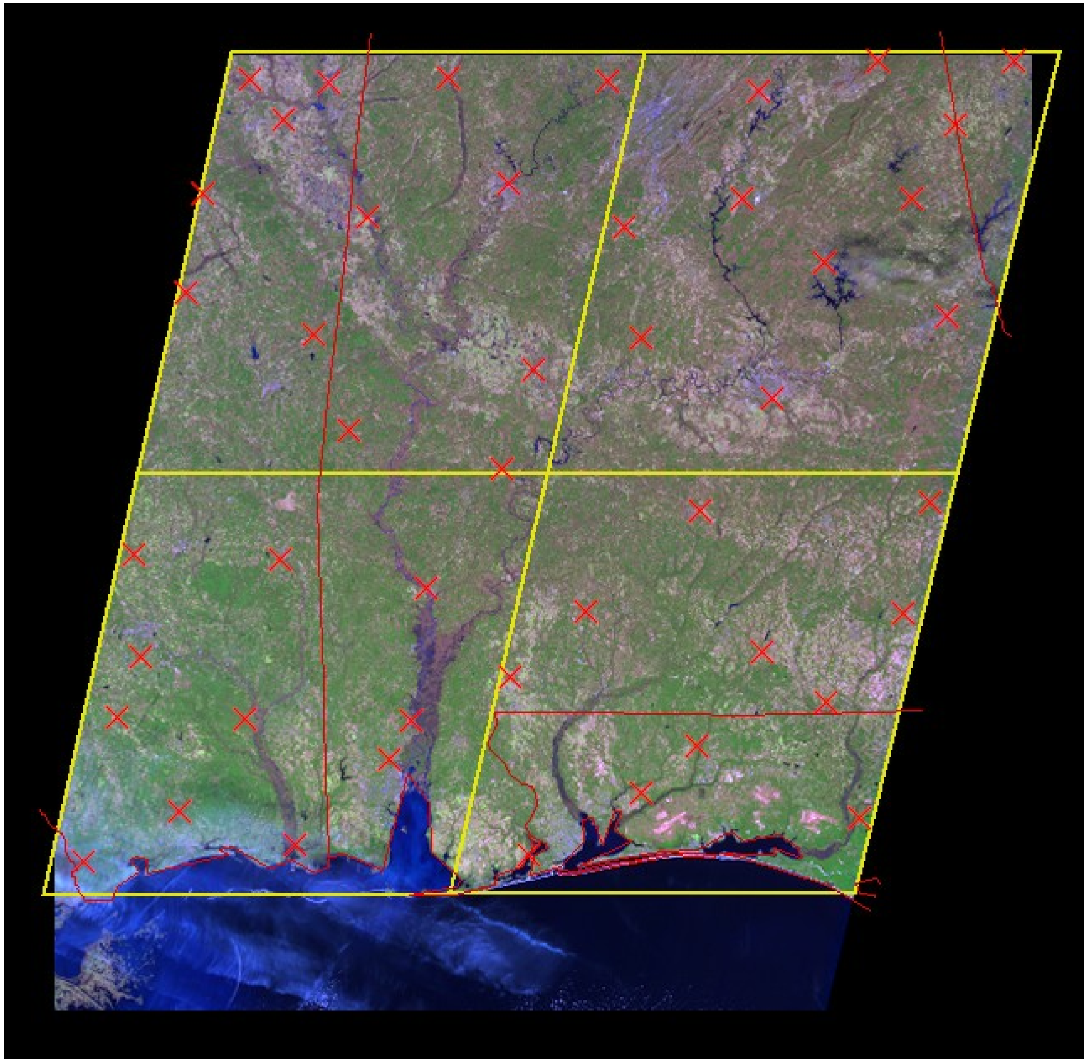
- Area of analysis defined as the “parallelogram”* with the largest area useful for analysis rather than the nominal AWiFS quad boundaries

* East and west bounds are not perfectly parallel.



Methods: Selecting & Distributing Check Points

- Area of analysis divided into quadrants and check points selected in each
  - Selected 45 to 50 points (NSSDA minimum = 20)
  - At least 20% in each quadrant
  - *Did not strictly maintain point separation of 10% of diagonal*



Data Collection Notes

- Tentative check points were collected in ESRI ArcMap using heads-up digitizing to a point shapefile overlaying the AWiFS source image
- All check point data were collected in the AWiFS scene-specific Lambert Conformal Conic projection
- Reference images (typically DOQQs) were identified and added to the ArcMap project; on-the-fly re-projections by ArcMap were found to be sufficient
- Reference images were searched for tentative check points identified in the AWiFS source image
  - If a tentative point was missing or indistinct in the reference image, both images were searched for an alternative
  - No more than one check point was used per reference image

Example AWiFS Check Point

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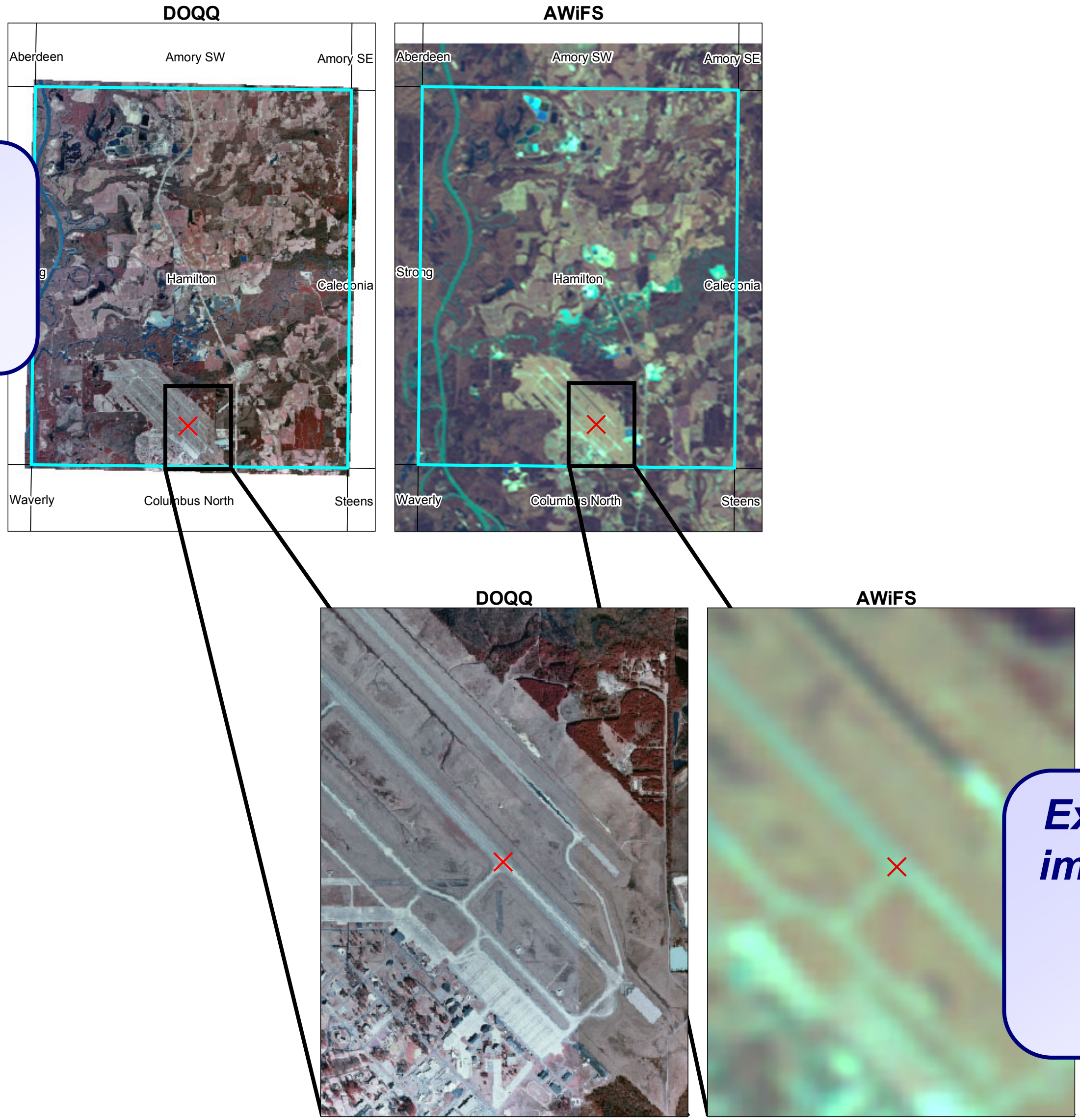
Obtained DOQQ containing point (DOQQ RMSE assumed ~5 m)



Extracted AWiFS image coordinate and DOQQ reference coordinate

Check Point Collection Flow

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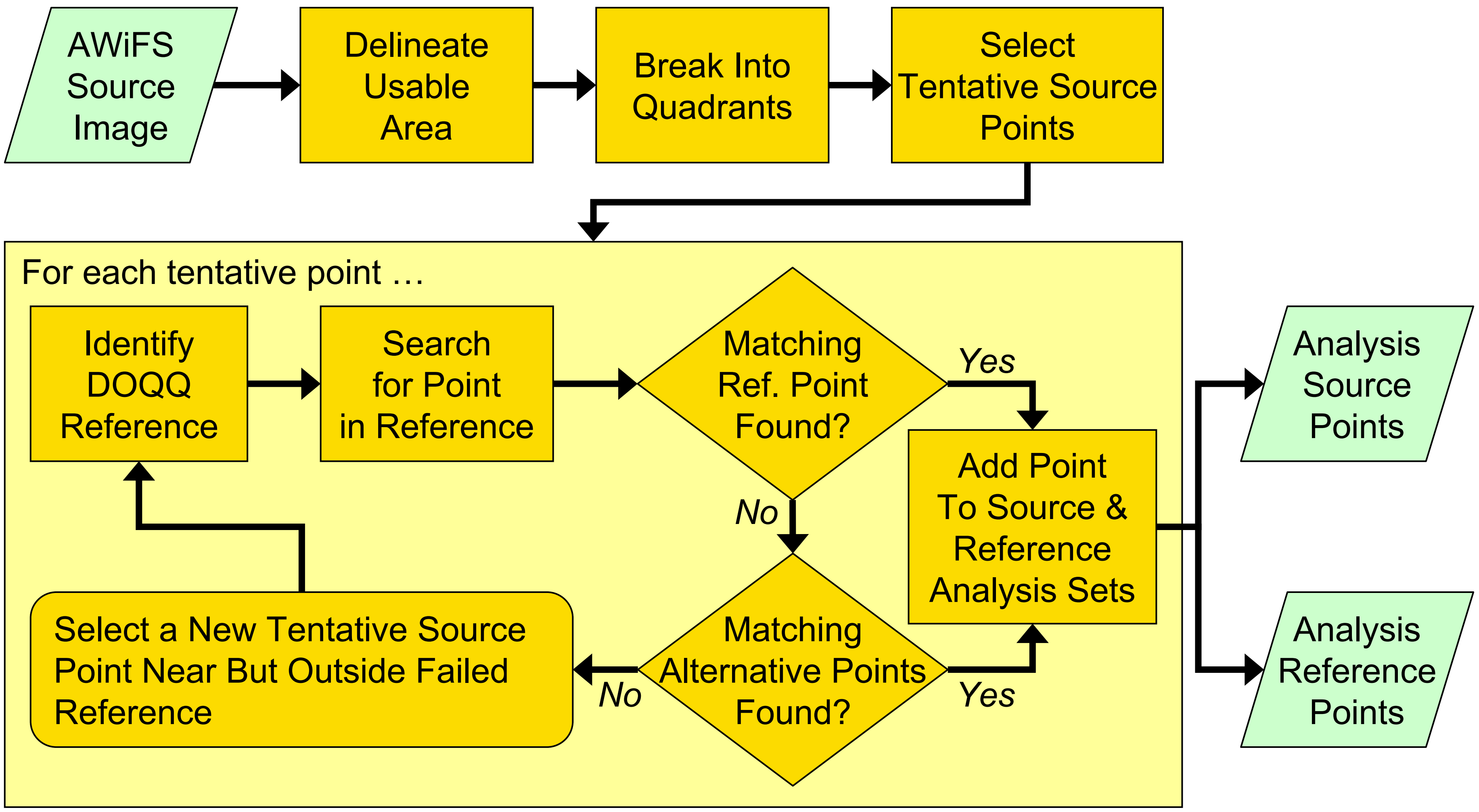
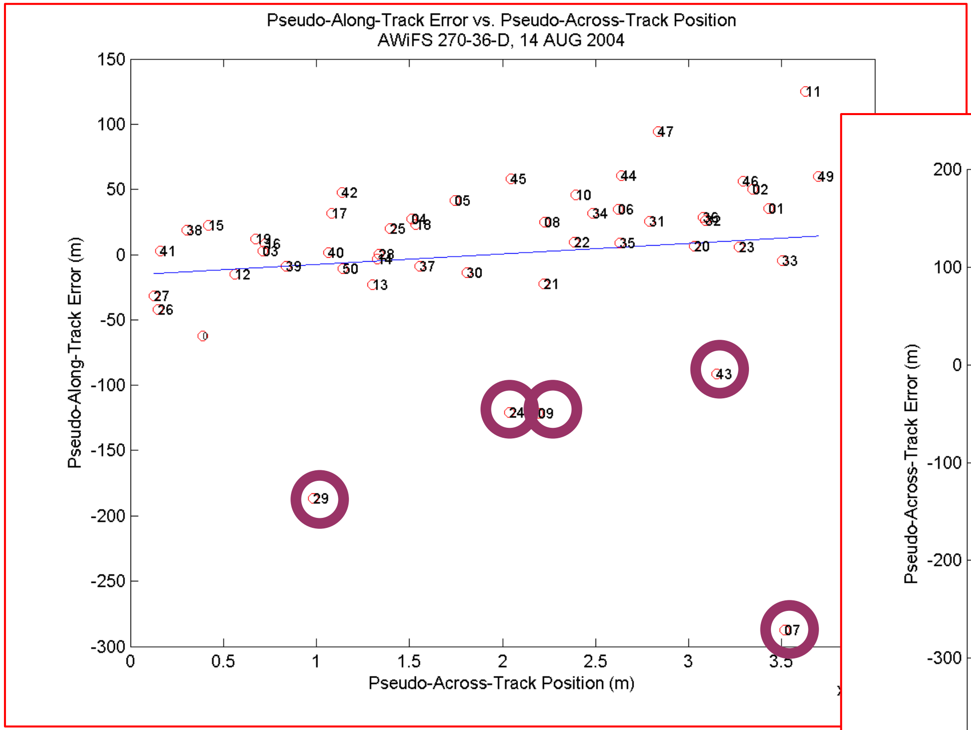
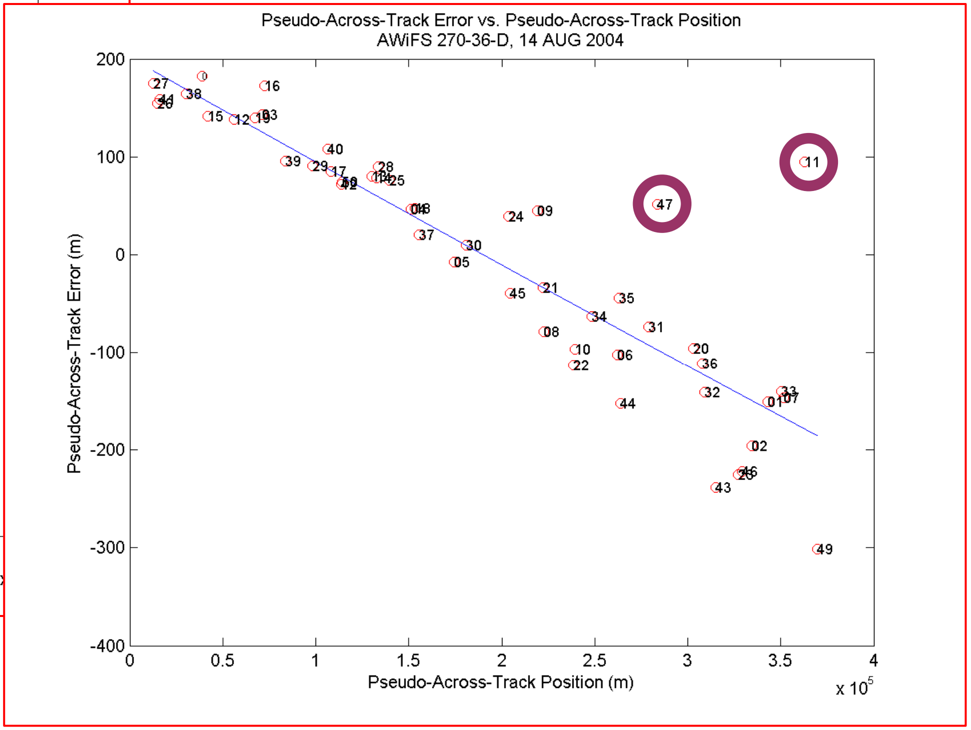


Check Point Blunder Detection

- Transform the frame of reference for the check points from the AWiFS image projection to a quasi-satellite-path frame (approximate along track position: positive Y, approximate across track position: positive X)
  - Shift frame origin to minimum X, minimum Y of analysis area
  - Rotate frame so that satellite-path direction (approximated by average azimuth of east and west bounds of analysis area) is up
- Compute residuals from difference in source and reference coordinates of check points
- Compute zero-mean residuals by subtracting overall means from residuals
- Plot both components of zero-mean residuals vs. across track check point positions
  - Along track zero-mean residuals vs. across track position
  - Across track zero-mean residuals vs. across track position
- Observe the plots to determine if systematic relationship between position and error exists
- If systematic relationship exists, determine if some of the check points depart from a clear trend (this is a subjective choice in the 2005 analysis)
- Re-submit any out-of-step points to be re-evaluated as check points
- Repeat check point blunder detection

Before Blunder Detection





After Blunder Detection

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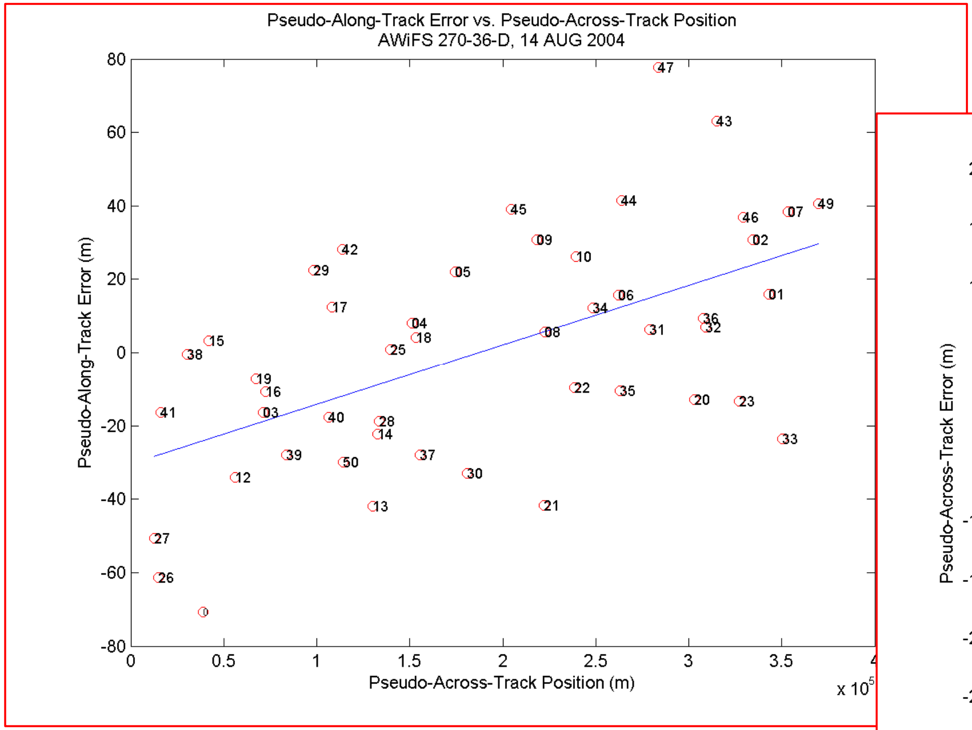
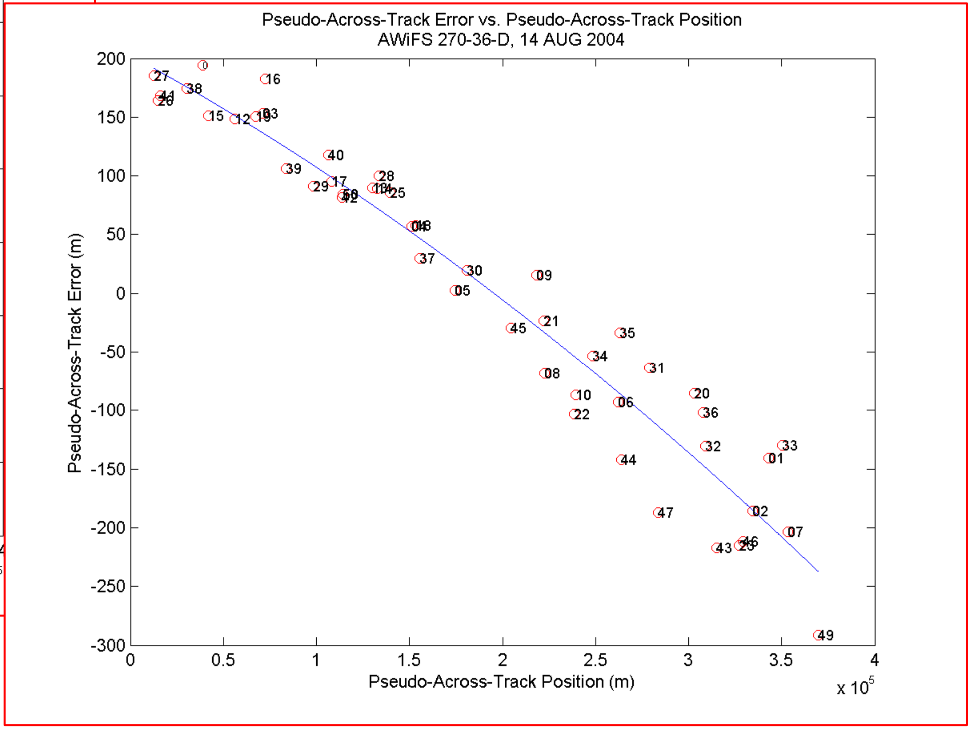
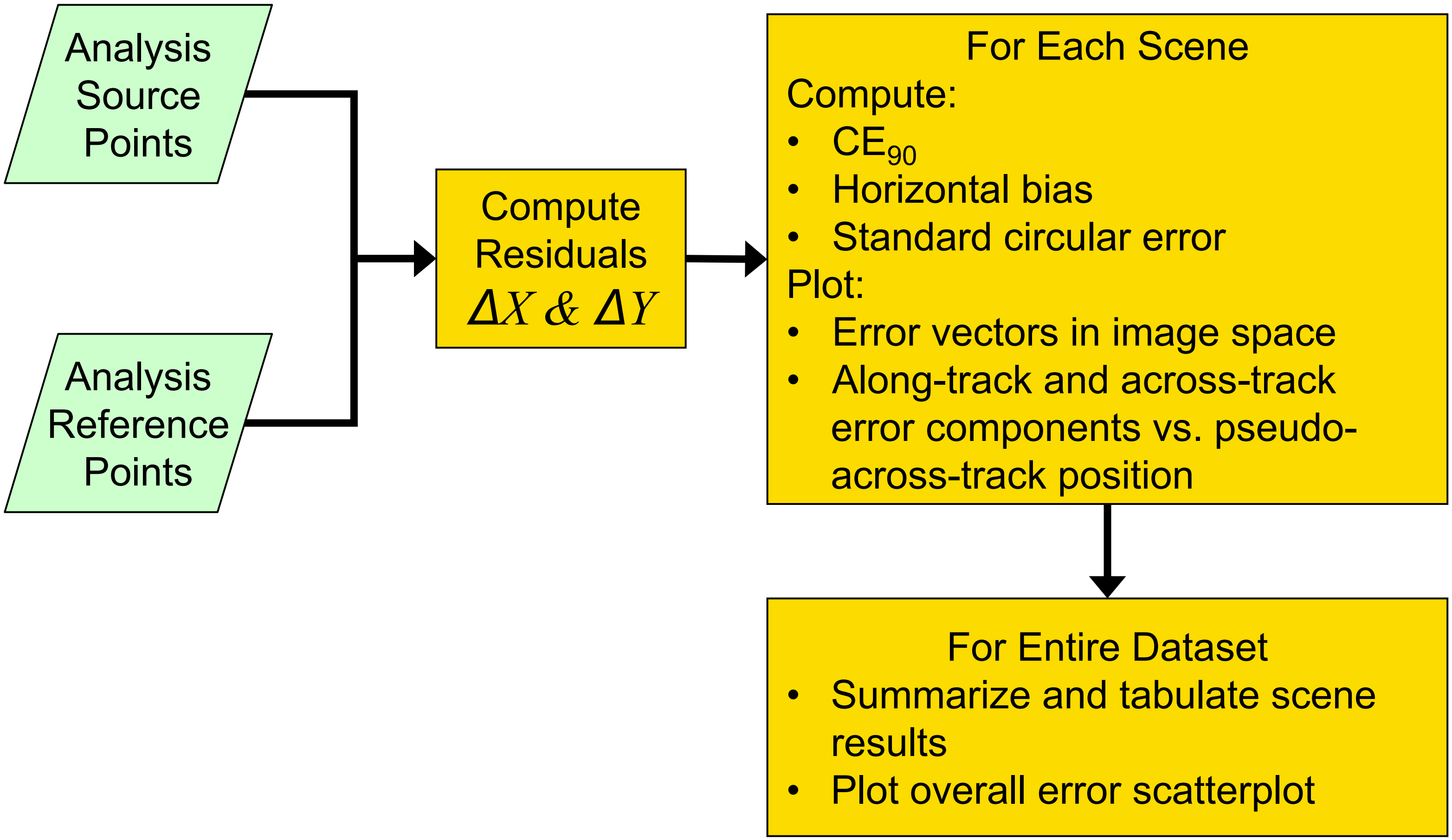




Analyses Flow



Results

Individual Scene Results

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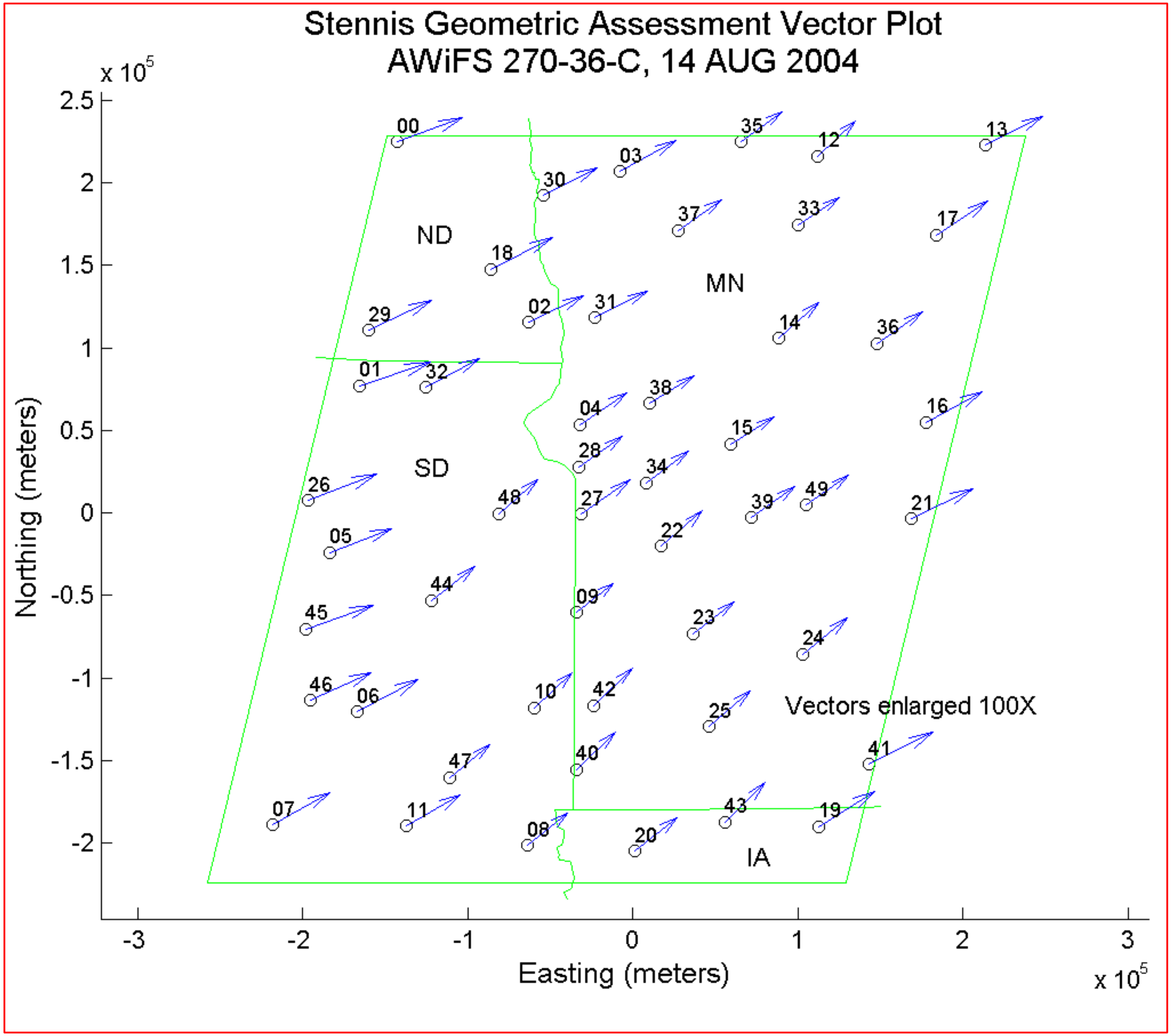
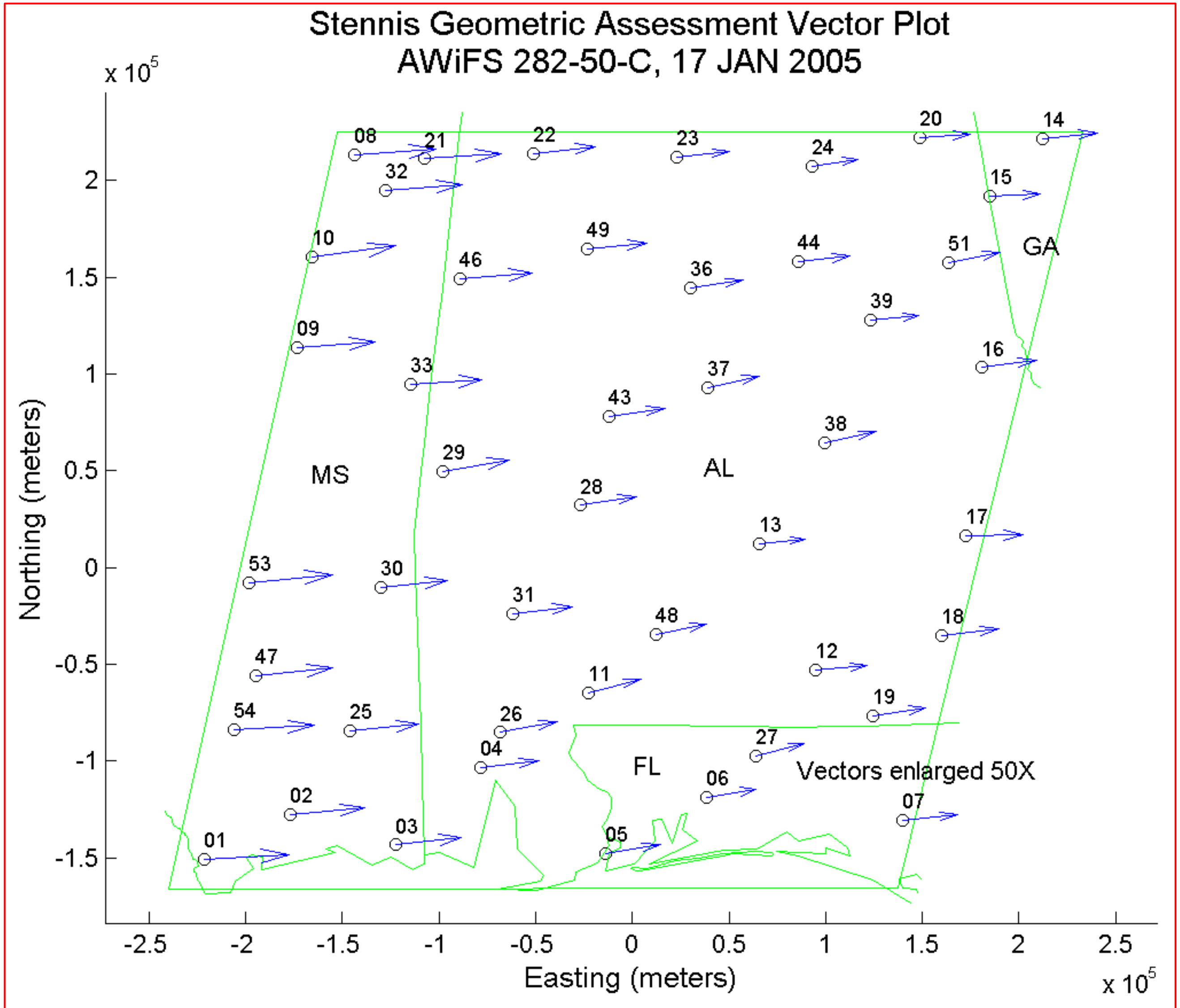
AWiFS A (1)

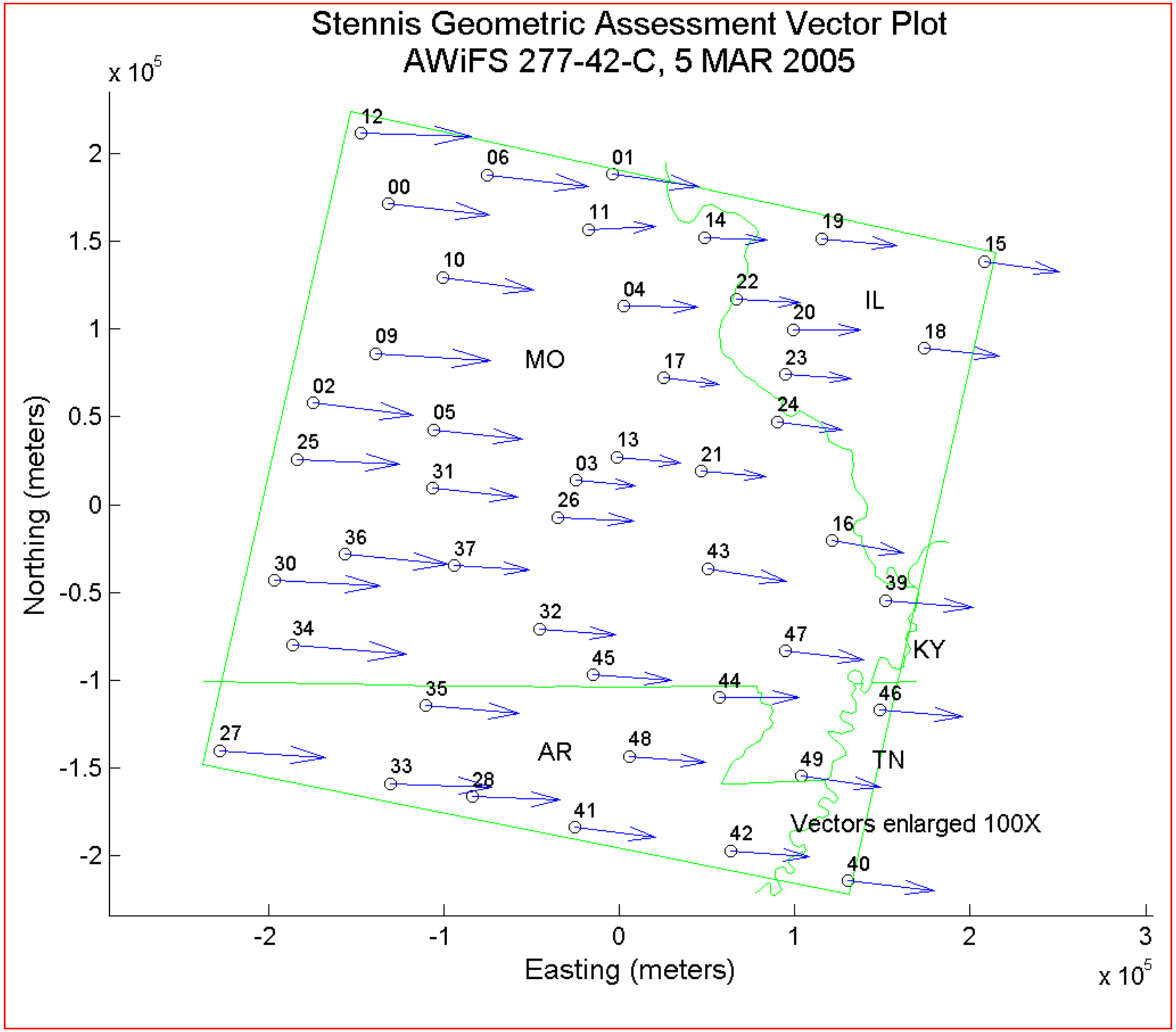


Individual Scene Results

AWiFS A (2)

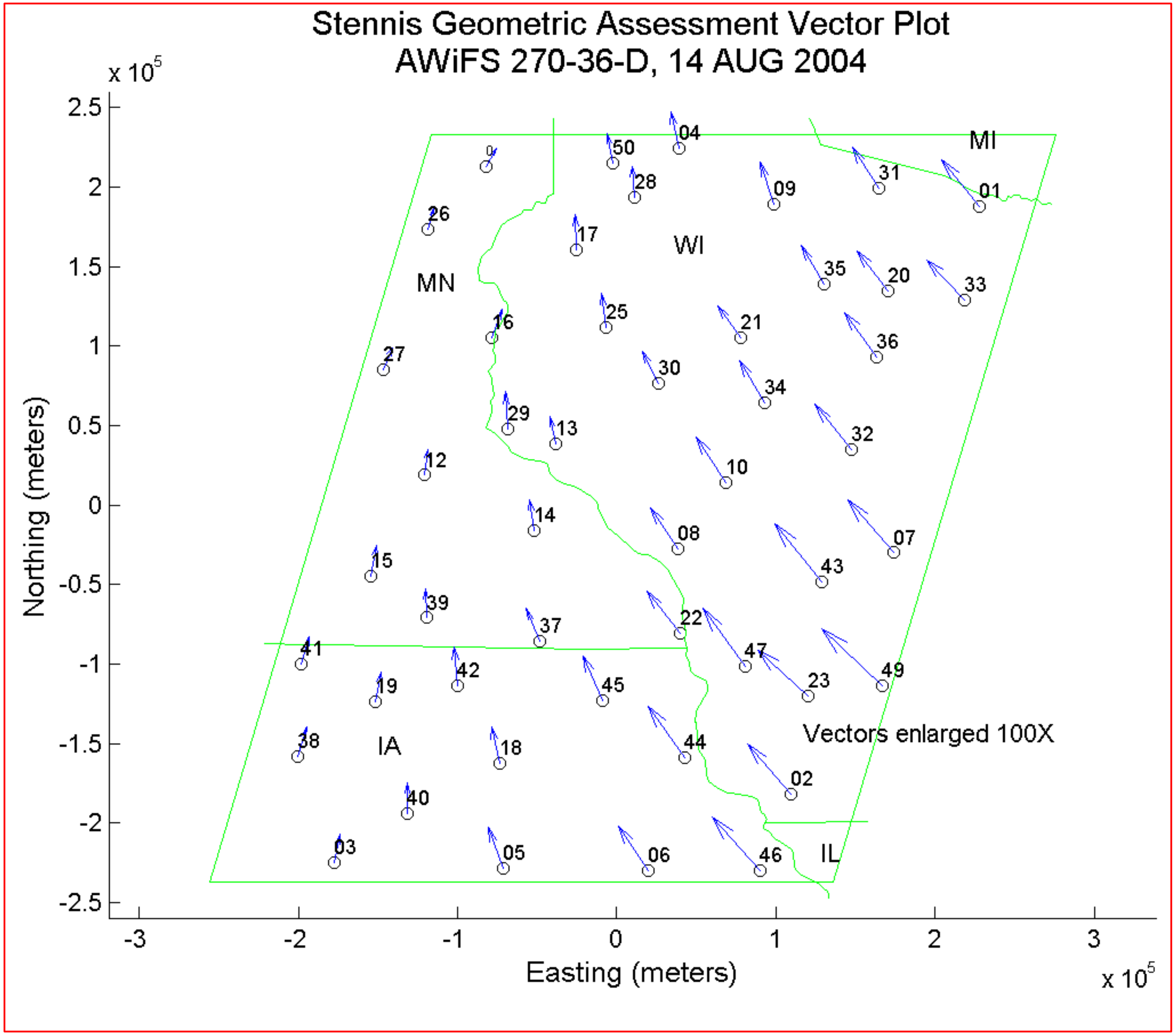


Individual Scene Results
AWiFS A (3)

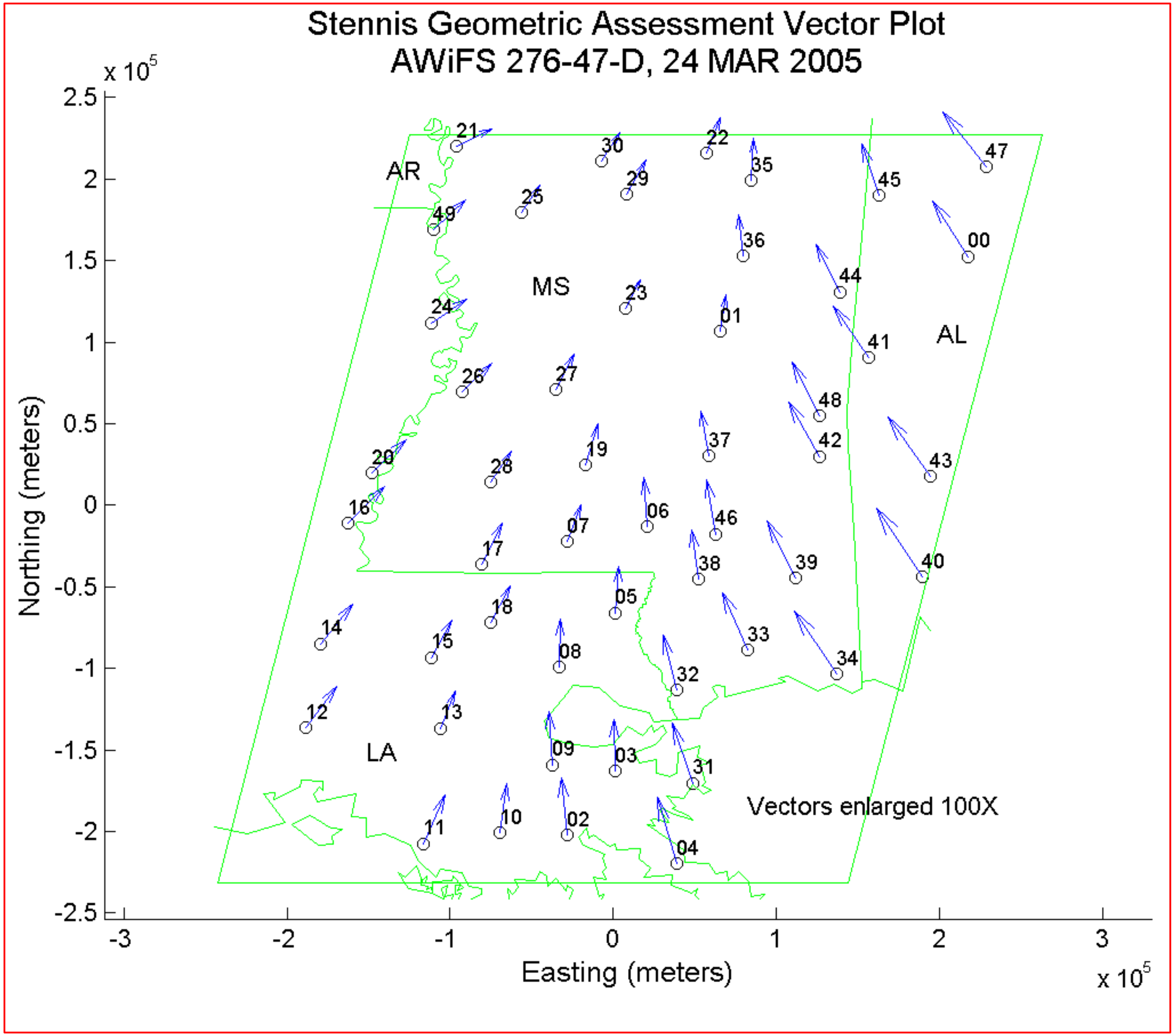


Individual Scene Results

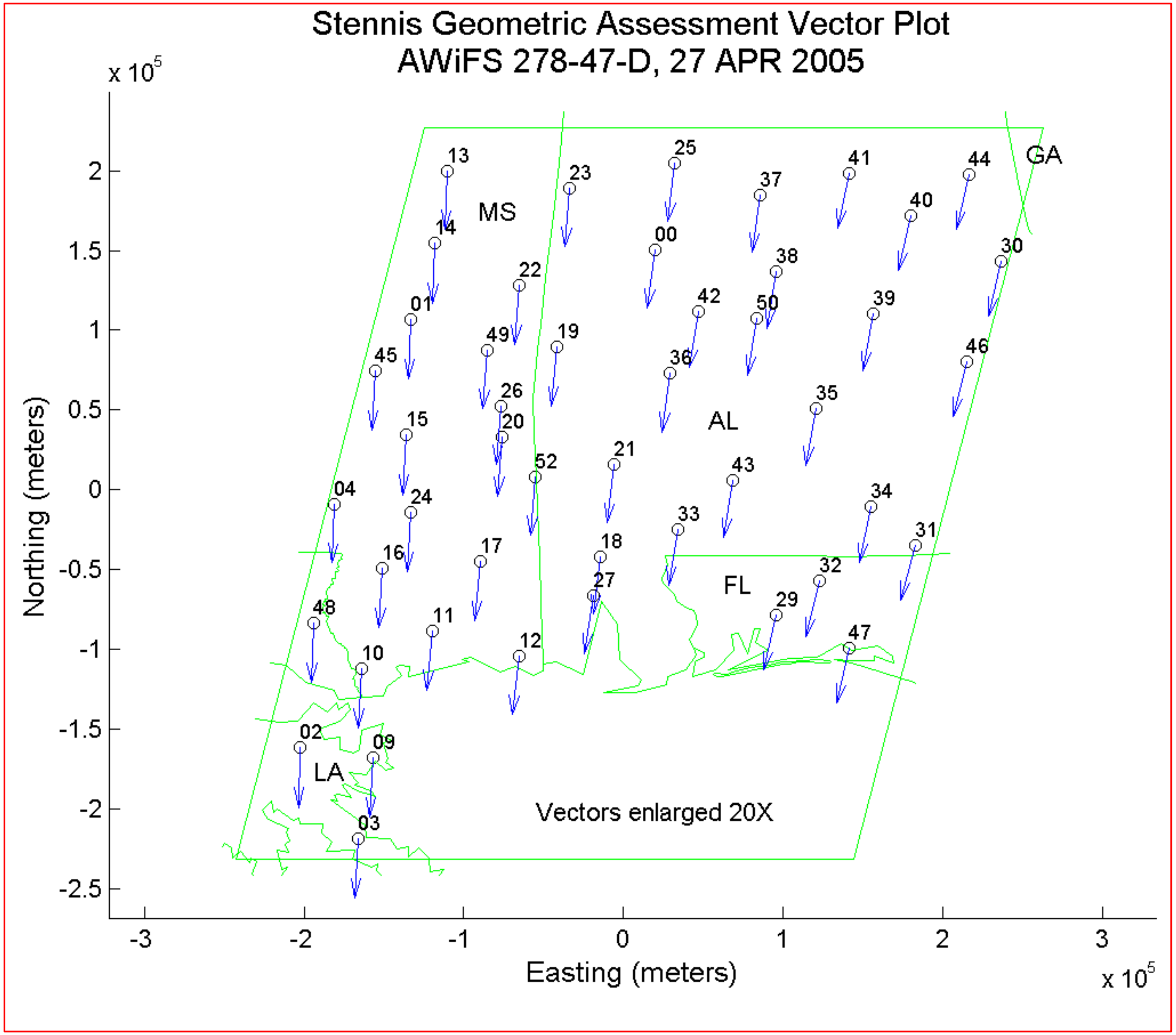
AWiFS B (1)



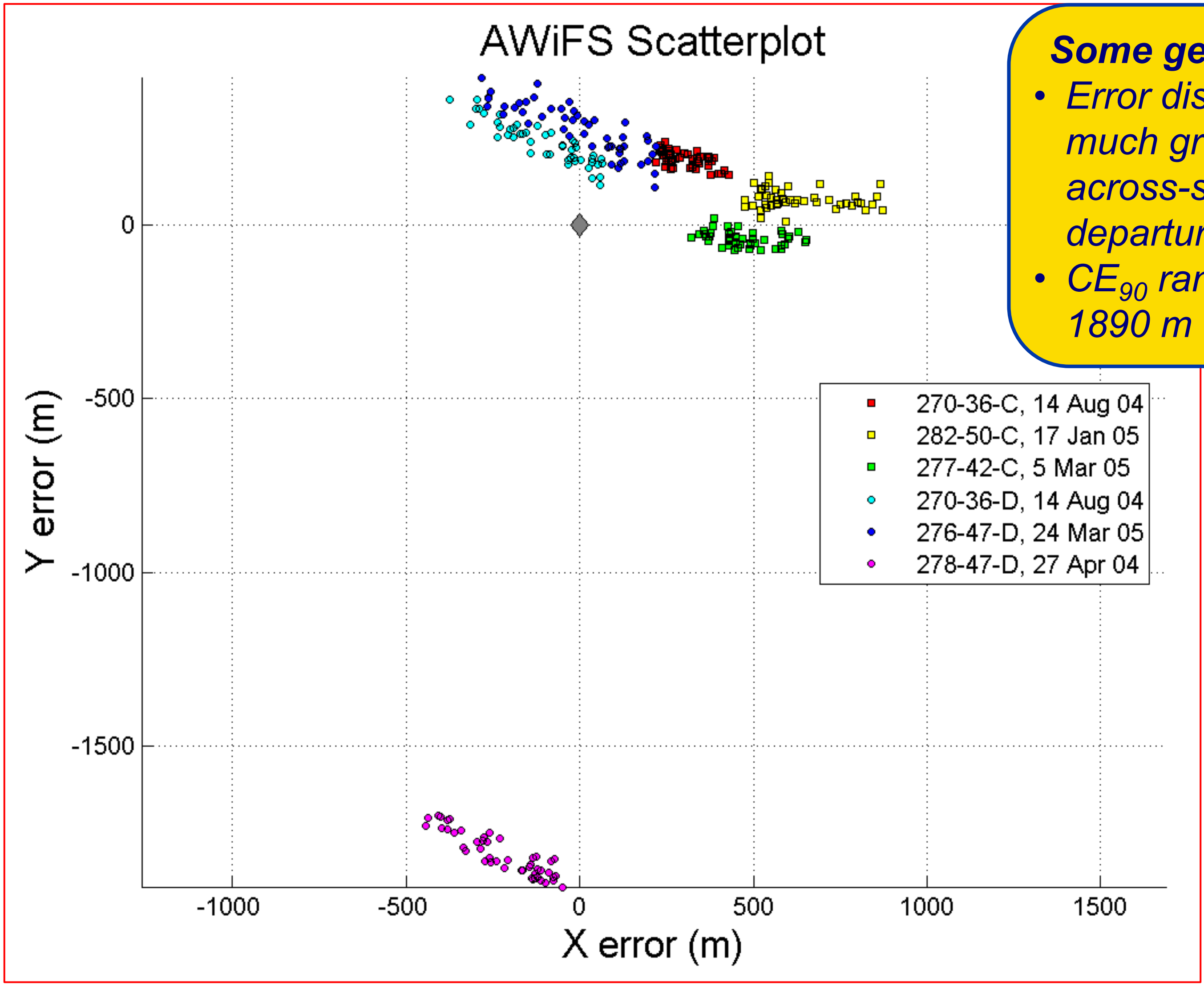
Individual Scene Results
AWiFS B (2)



Individual Scene Results
AWiFS B (3)



Overall Scatter



Some general characteristics:

- *Error distributions showed much greater spread in the across-scan direction (large departure from circularity)*
- *CE_{90} ranged from 410 m to 1890 m*

Zero-Mean Errors by Sample

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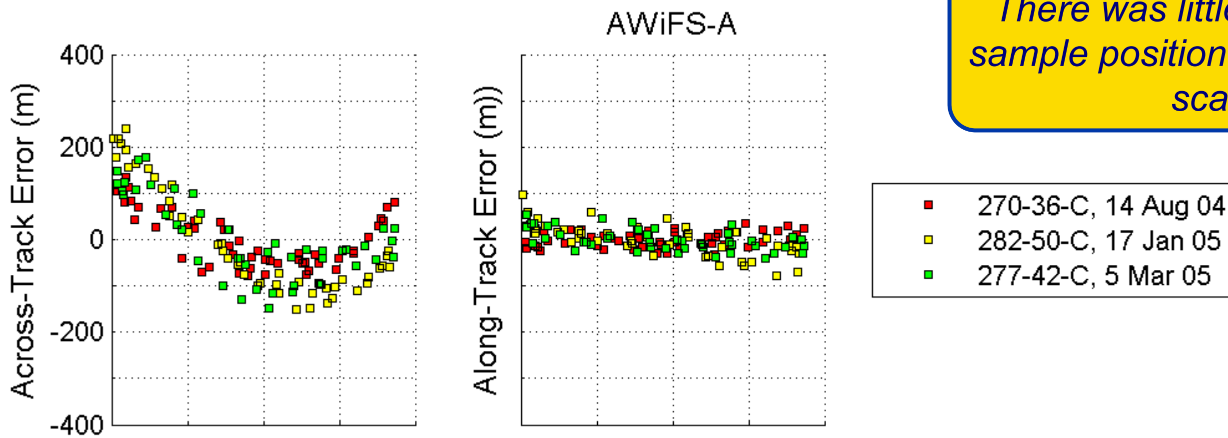
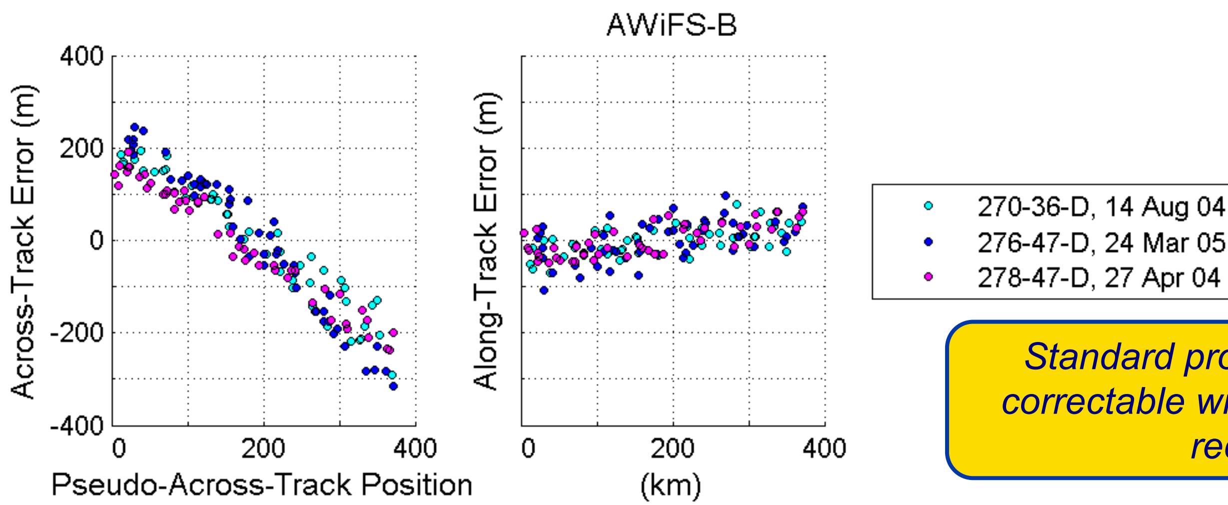
There was little correlation between sample position and error in the along-scan direction



Across-scan errors for AWiFS-A have a 2nd order relationship with sample position



Standard products appear to be correctable with simple polynomial rectification

Across-scan errors for AWiFS-B have a linear relationship with sample position

Summary of Results

AWiFS Product	Acquisition Date	Sub-scene	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE_{90} (m)
AWiFS-A *Geo*	14-Aug-2004	270-36-C	354	41	423
	17-Jan-2005	282-50-C	636	74	823
	5-Mar-2005	277-42-C	475	54	599
AWiFS-B *Geo*	14-Aug-2004	270-36-D	262	92	438
	24-Mar-2005	276-47-D	274	110	413
	27-Apr-2005	278-47-D	1826	89	1887

- The mean CE_{90} of AWiFS *Geo* images characterized was 760 m
  - Ranged from 423 m to 1887 m
- Lutes (2005) analyzed 8 AWiFS scenes and found a mean CE_{90} of 610 m
  - Ranged from 294 m to 756 m
- Both analyses are in general agreement with the exception of the 27 APR 2005 results in the SSC study
- Both analyses show generally grosser error than the estimate of 320 m stated in the *IRS-P6 Data User's Manual* (2003)[1]

[1] National Remote Sensing Agency, 2003. *IRS-P6 Data User's Manual.* Edition No. 1. IRS-P6/NRSA/NDC/HB-10/03, Department of Space, Govt. of India. October, 142 p. http://www.euromap.de/download/P6_data_user_handbook.pdf (accessed February 6, 2006).

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14. ABSTRACT
The geopositional accuracy of the standard geocorrected product from the Advanced Wide Field Sensor (AWiFS) was evaluated using digital orthophoto quarter quadrangles and other reference sources of similar accuracy. Images were analyzed from summer 2004 through spring 2005. Forty to fifty check points were collected manually per scene and analyzed to determine overall circular error, estimates of horizontal bias, and other systematic errors. Measured errors were somewhat higher than the specifications for the data, but they were consistent with the analysis of the distributing vendor.

15. SUBJECT TERMS
AWiFS, geopositional accuracy, DOQQ

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