SSC Geopositional Assessment of an AWiFS Image Orthorectified Product

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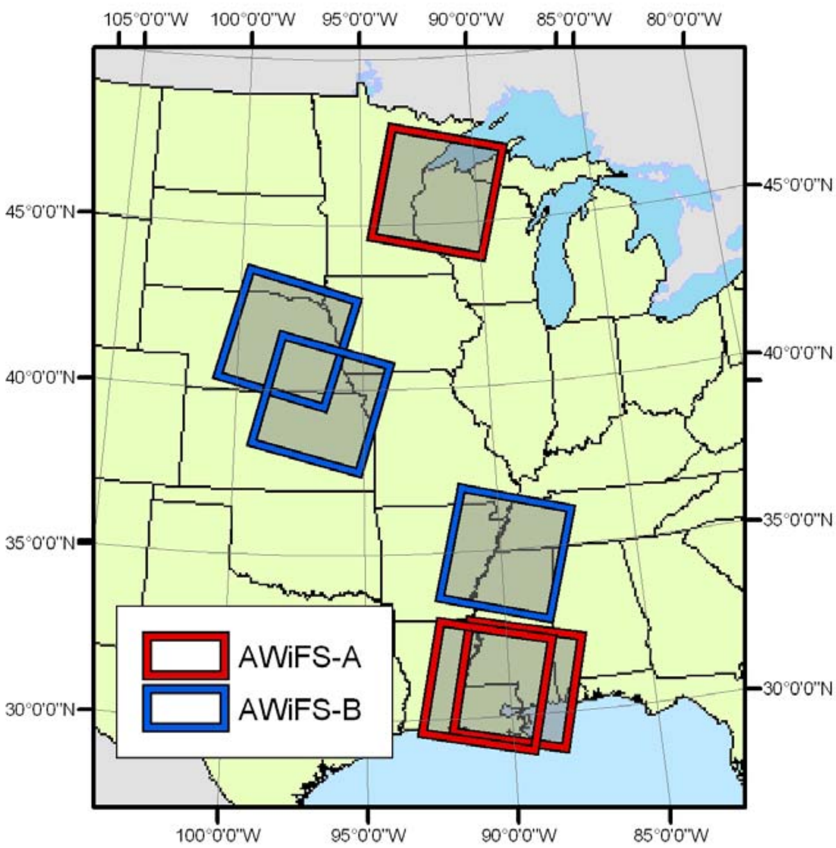
Overview

- OBJECTIVE: Characterize the geopositional accuracy of the AWiFS orthorectified product offered by GeoEye
- Assessed 6 sub-scenes (Quads), 3 from each AWiFS camera
- Manually matched check points to DOQQ reference (assumed accuracy ~12 m, CE_{90})
- Check points were selected to meet or exceed FGDC NSSDA (National Standard for Spatial Data Accuracy) guidelines
- Used ArcGIS for data collection and SSC-written Matlab scripts for data analysis

Characterized Scenes

Distribution of Scenes



Acquisition	Camera
279-48-C 19 JUN 2005	AWiFS-A
274-38-A 05 AUG 2005	AWiFS-A
280-48-C 04 SEP 2005	AWiFS-A
265-41-B 08 AUG 2005	AWiFS-B
267-40-D 18 AUG 2005	AWiFS-B
275-44-D 03 SEP 2005	AWiFS-B

Methods

Check Point Error

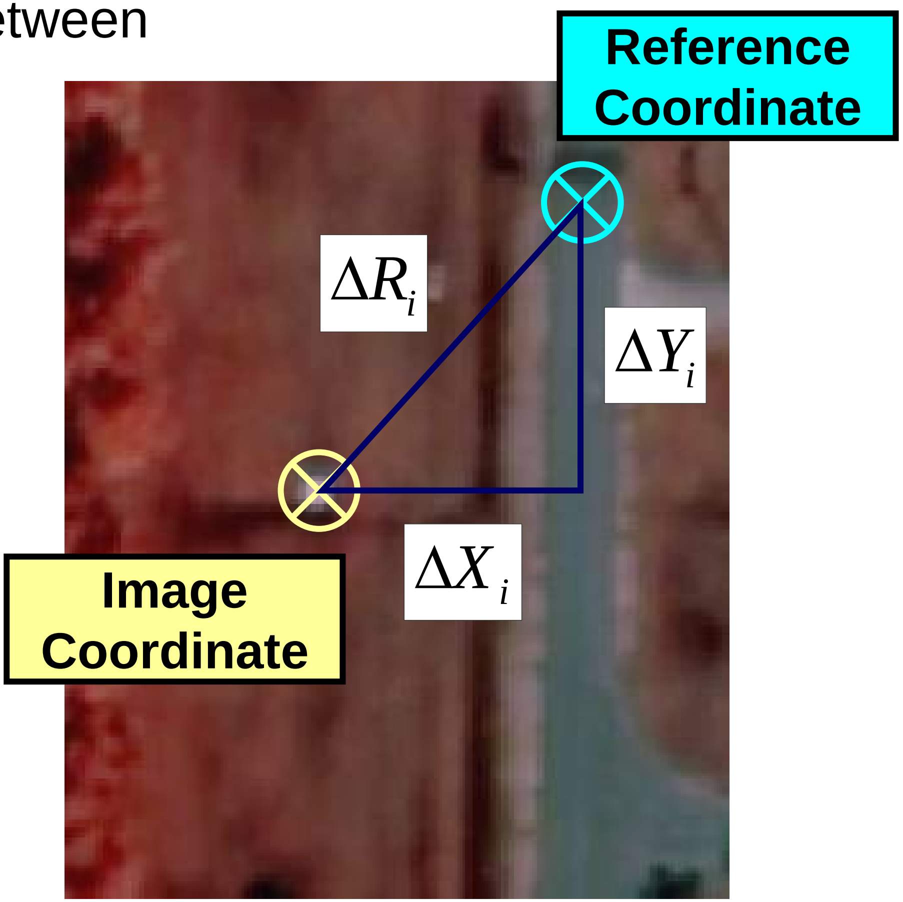
- Check Point Error – differences between image and reference coordinates

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

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

- 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 refers to the errors these individuals have in picking their target.*

- **random error**

- *"Measurement error" for ground control refers to the error inherent in the measuring instrument or system (GPS in this case).*

- **constant systematic error**

- *"Pointing error" for a geo-imaging system refers to 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

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

- *Tom Ager used the horizontal error defined on the right, but Greenwalt and Shultz found this to be invalid for minimum to maximum error ratios less than 0.8.*

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

Error Model: Zero-Mean Components

- The zero-mean error model

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

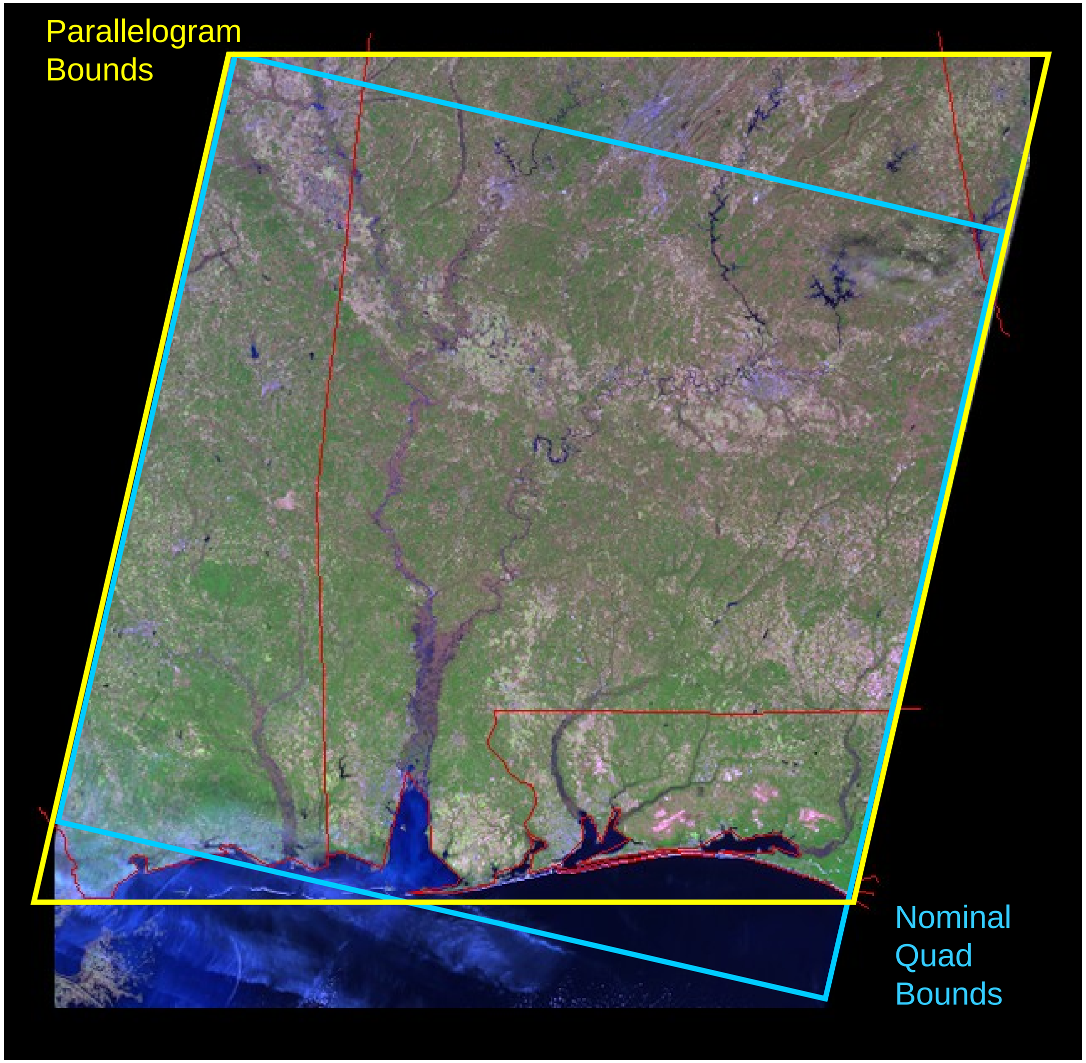
Where u is the across-track position

- *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

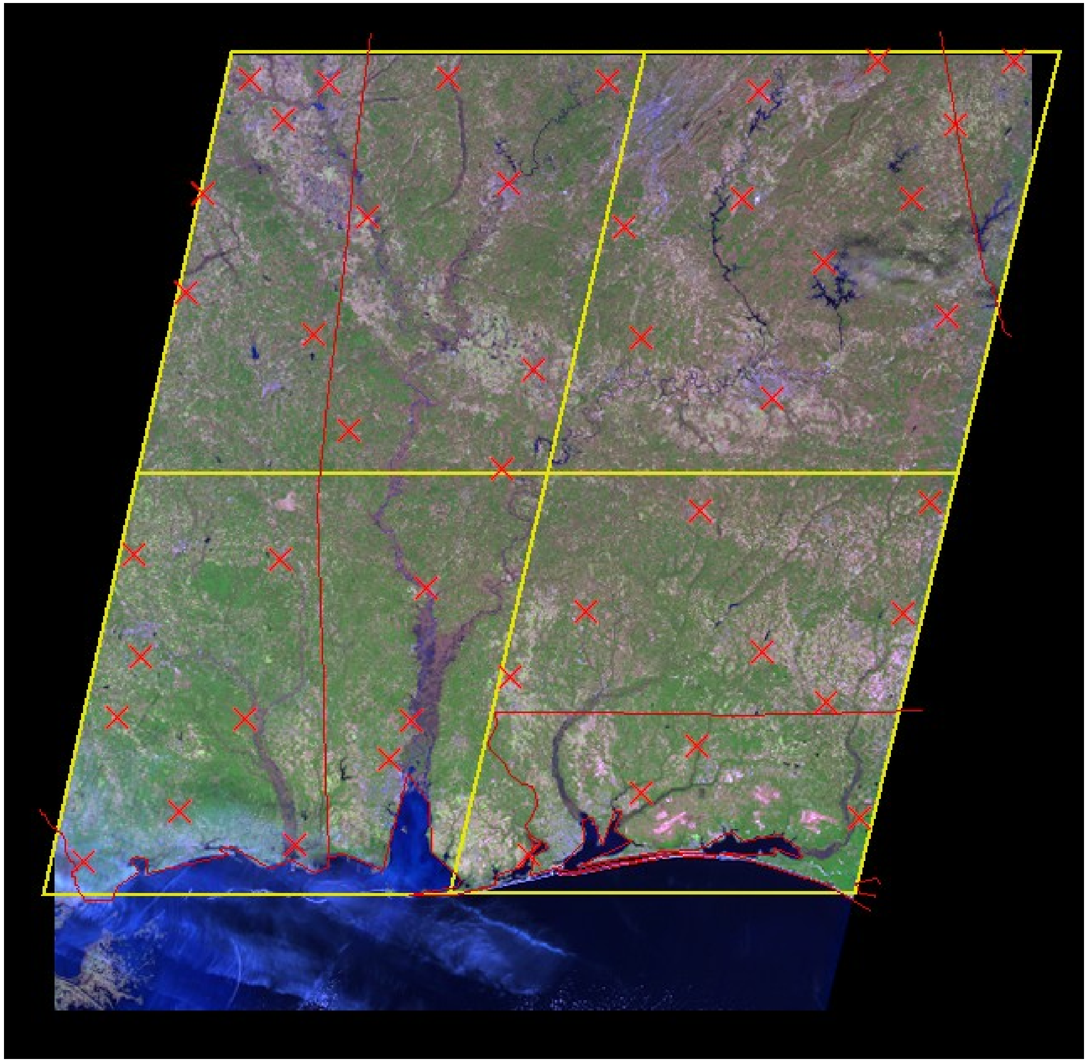
- Area of analysis defined as the “parallelogram”* with the largest area useful for analysis rather than the nominal AWiFS quad boundaries

* East and west bounds are not perfectly parallel.



Methods: Selecting & Distributing Check Points

- Area of analysis divided into quadrants; 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*



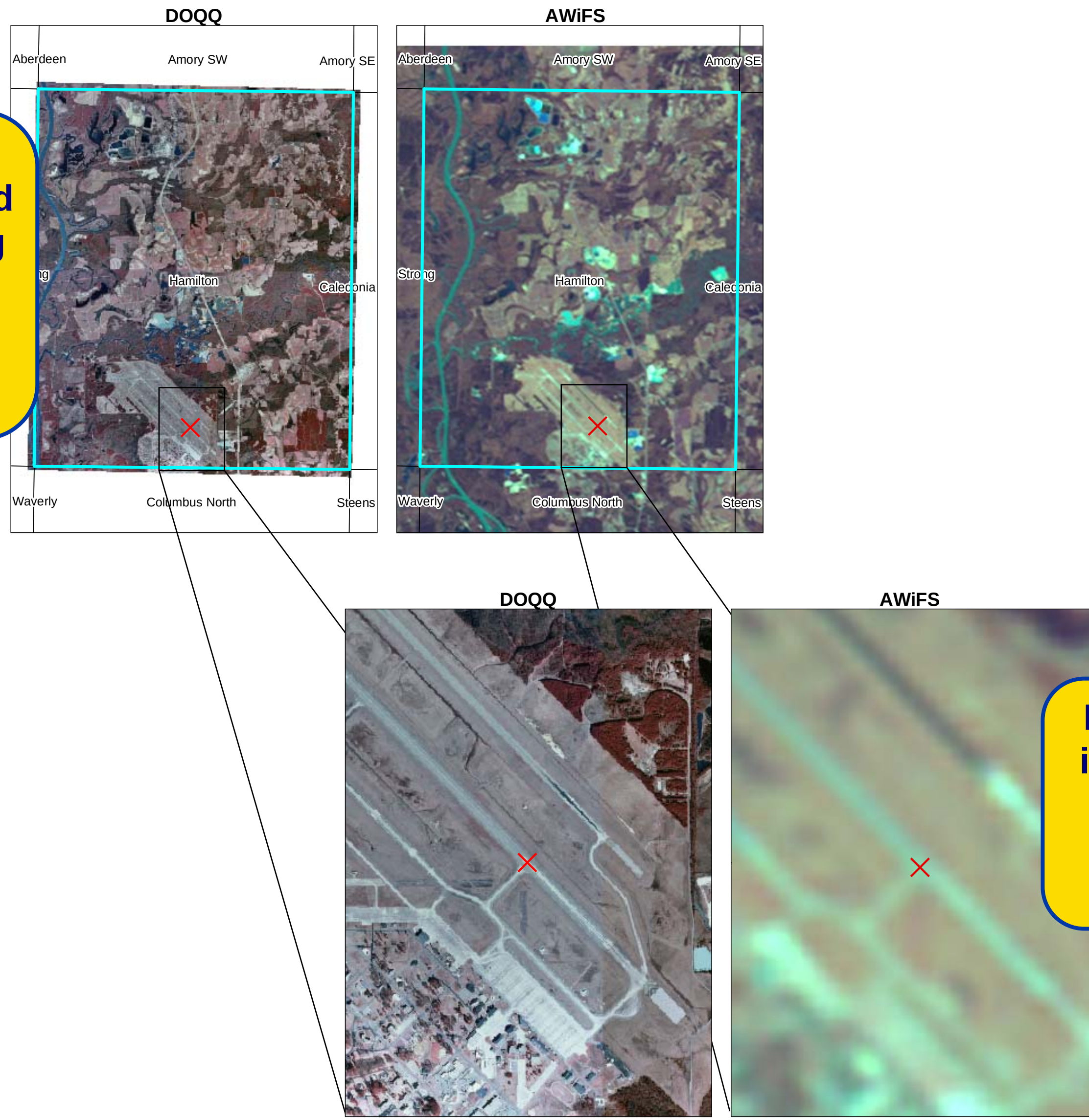
Data Collection Notes

- Tentative check points were collected in ArcMap using heads-up digitizing to a point shapefile overlaying the AWiFS source image.
- All check-point data were collected in AWiFS scene-specific Lambert Conformal Conic projection.
- Reference images (typically DOQQs) were identified and added to the ArcMap project. On-the-fly reprojections 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 1 check point was used per reference image.

Example AWiFS Check Point

Obtained Digital Ortho Quarter-Quad (DOQQ) containing point

(DOQQ CE_{90} assumed 7-10 m)



Extracted AWiFS image coordinate and DOQQ reference coordinate

Check Point Collection Flow

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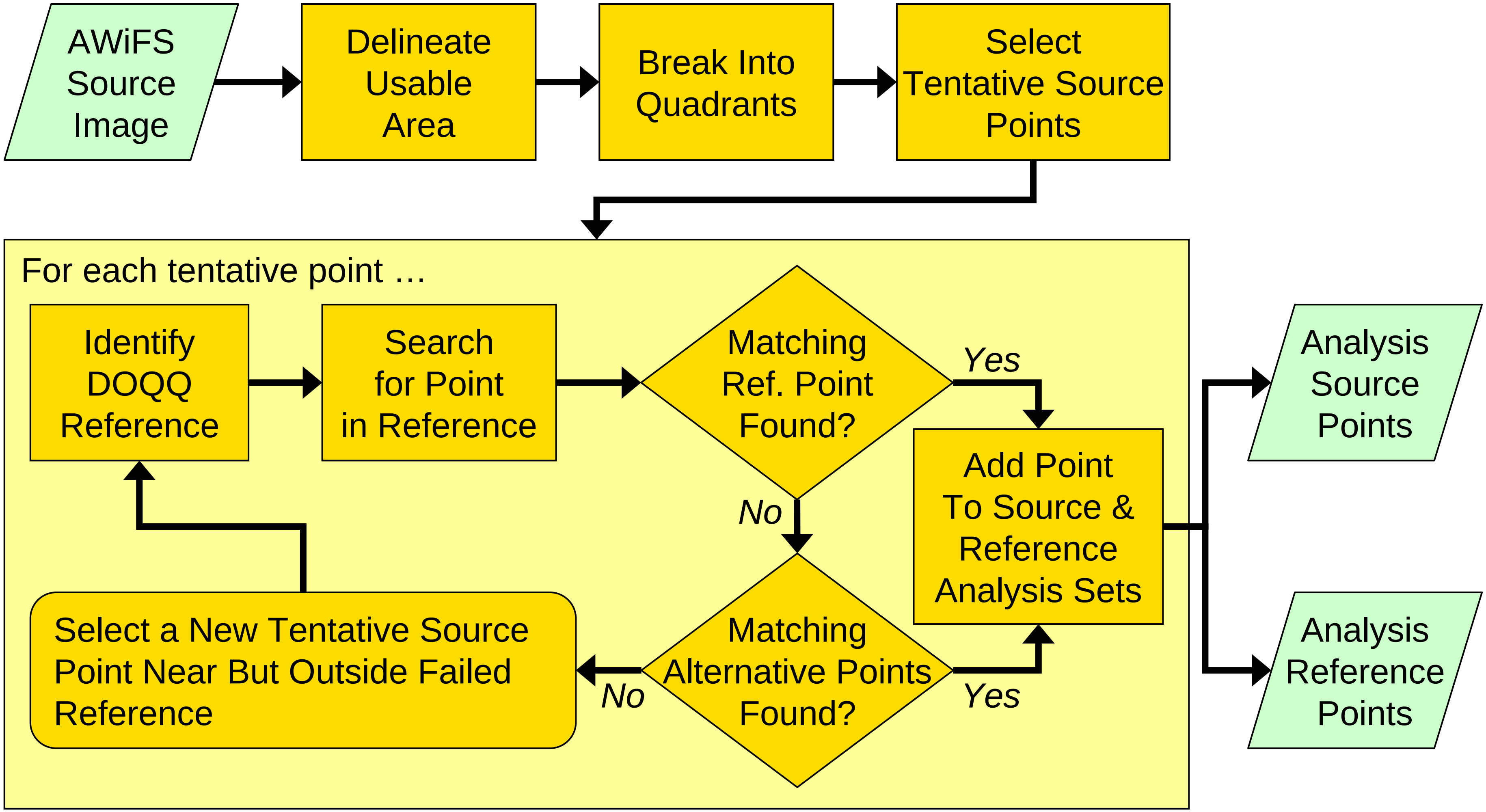
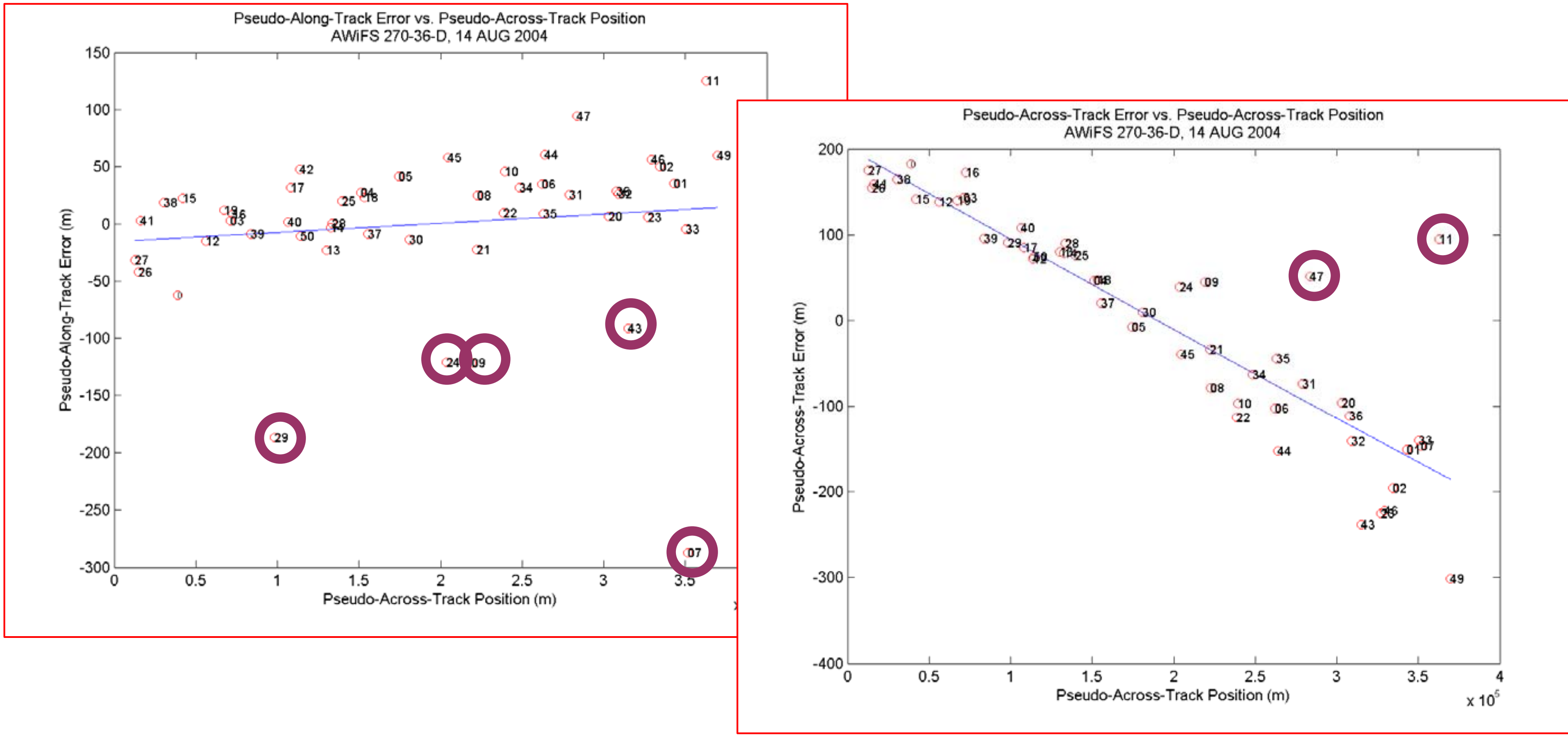


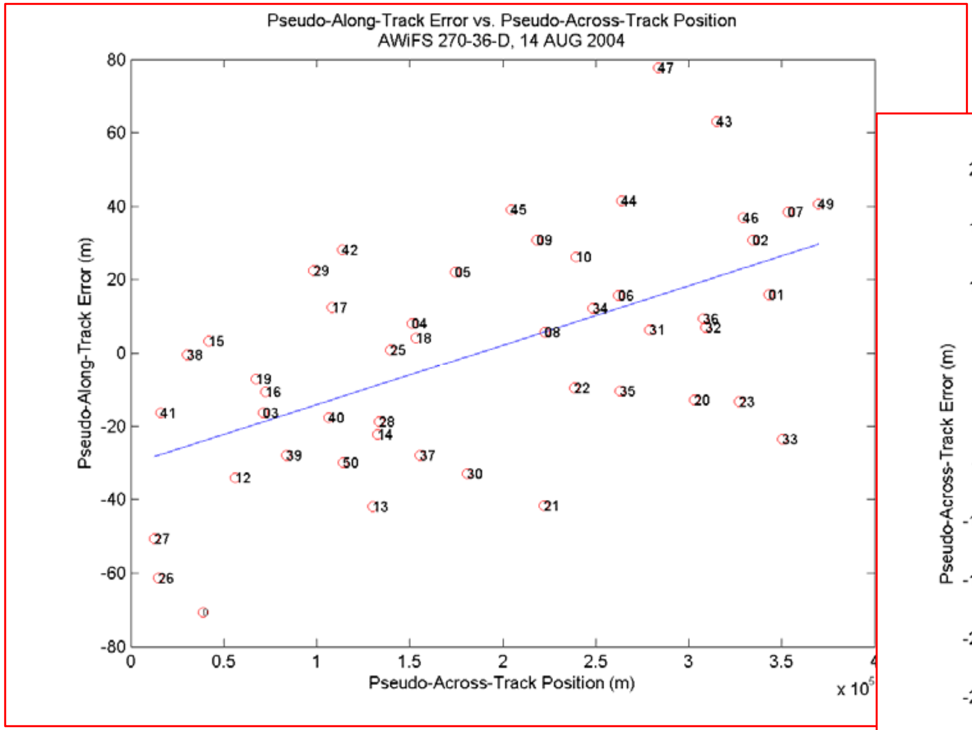
Check Point Blunder Detection

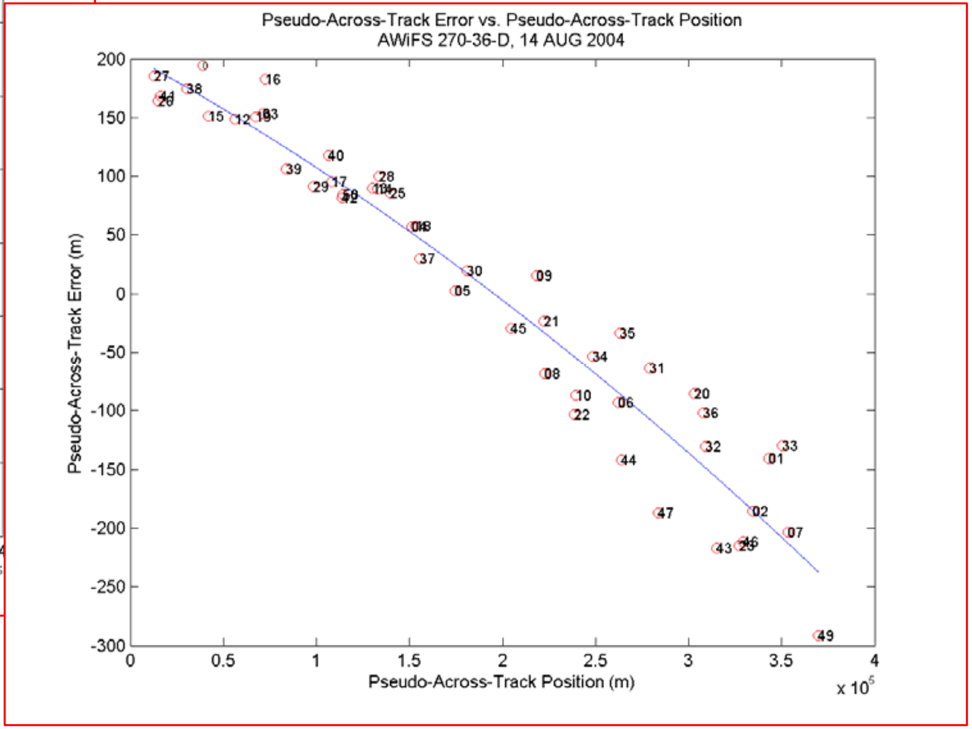
- Transform the frame of reference for the check points from the AWiFS image projection to a quasi-satellite-path frame (approximate along-track position: positive Y; approximate across-track position: positive X).
  - Shift frame origin to minimum X, minimum Y of analysis area.
  - Rotate frame so that 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 there is a systematic relationship between position and error.
- If there is a systematic relationship, determine if some of the check points depart from a clear trend (this is a somewhat subjective choice).
- Re-submit any out-of-step points to be re-evaluated as check points.
- Repeat check point blunder detection.

Before Blunder Detection

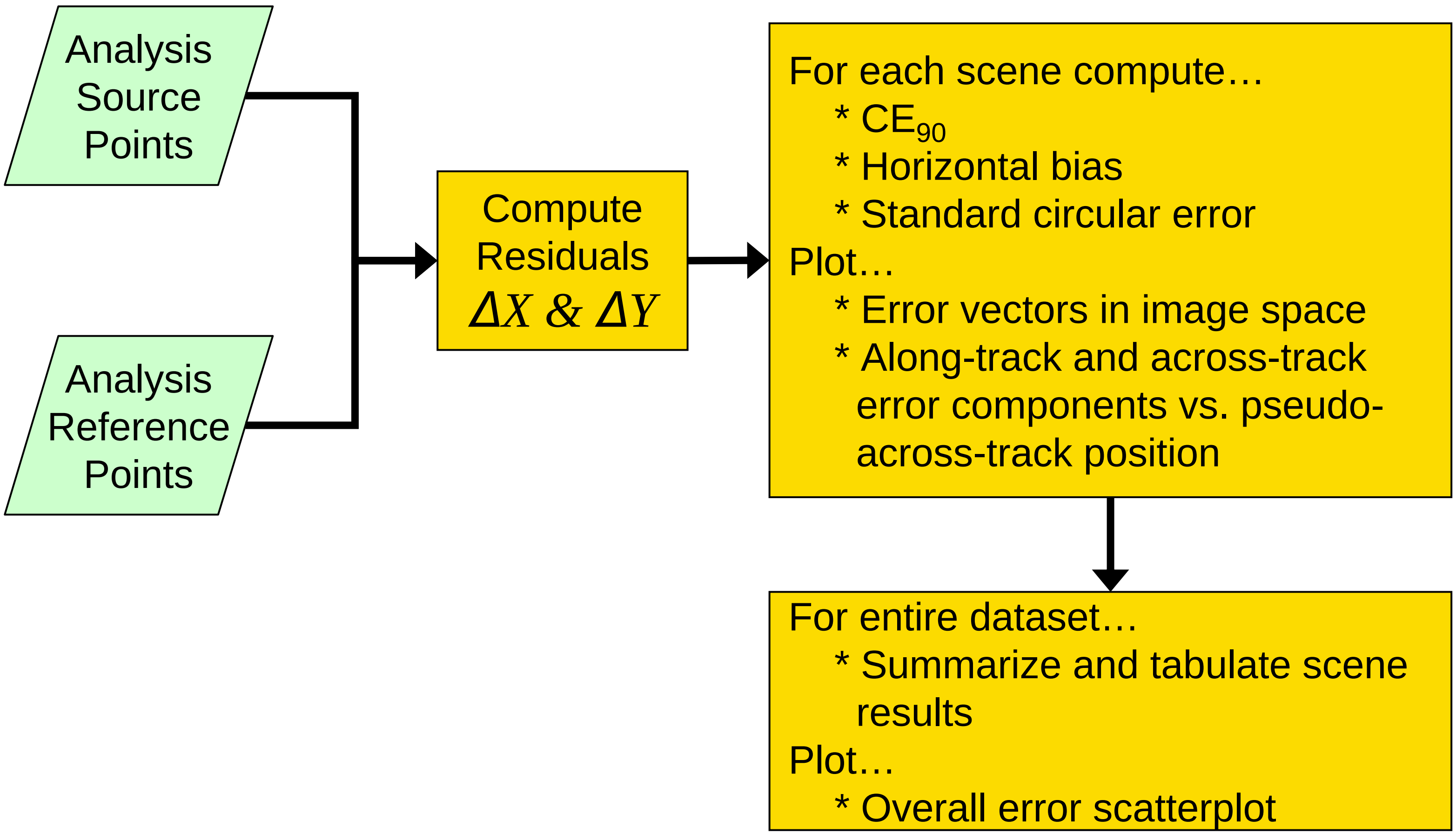


After Blunder Detection



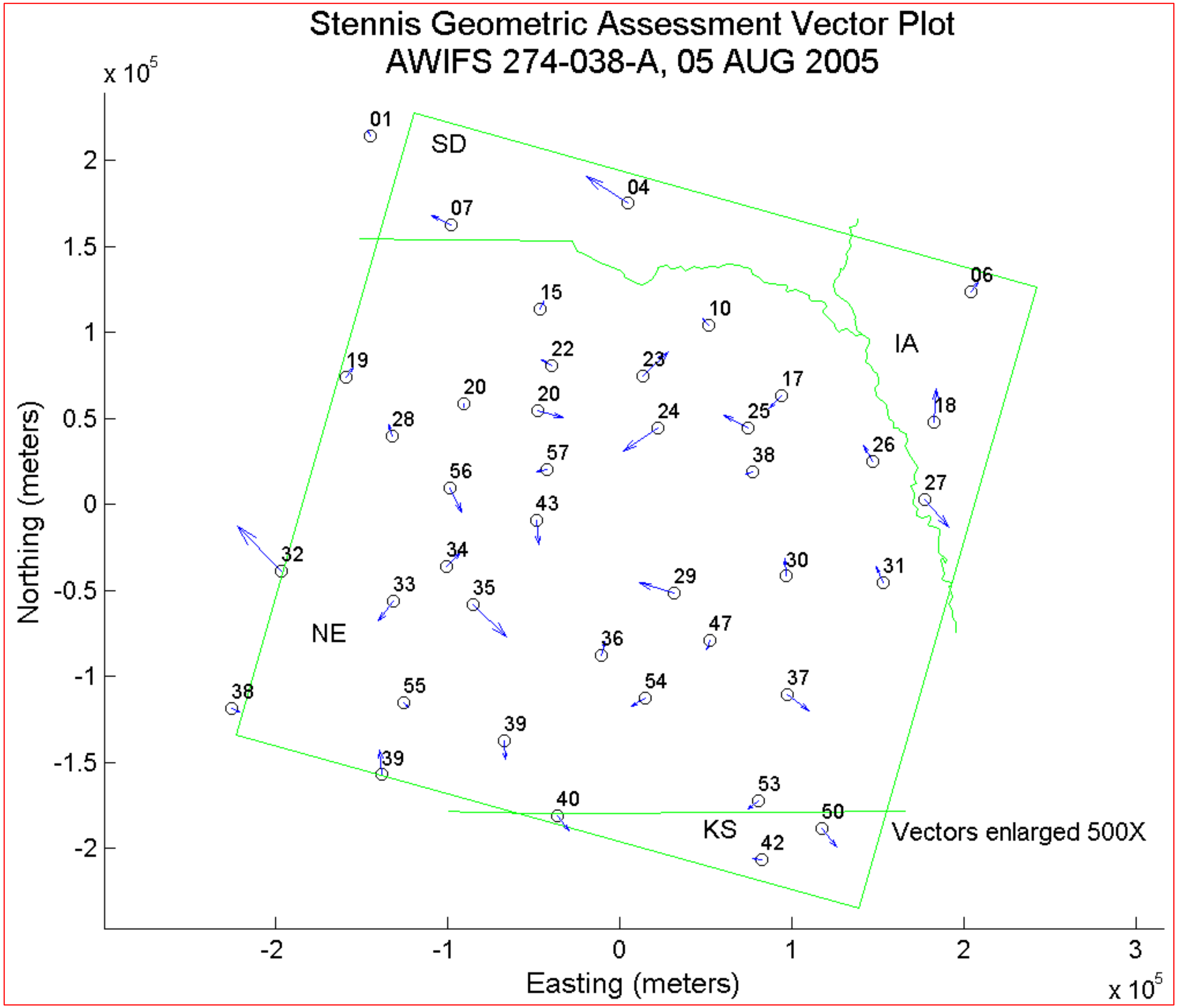


Analyses Flow

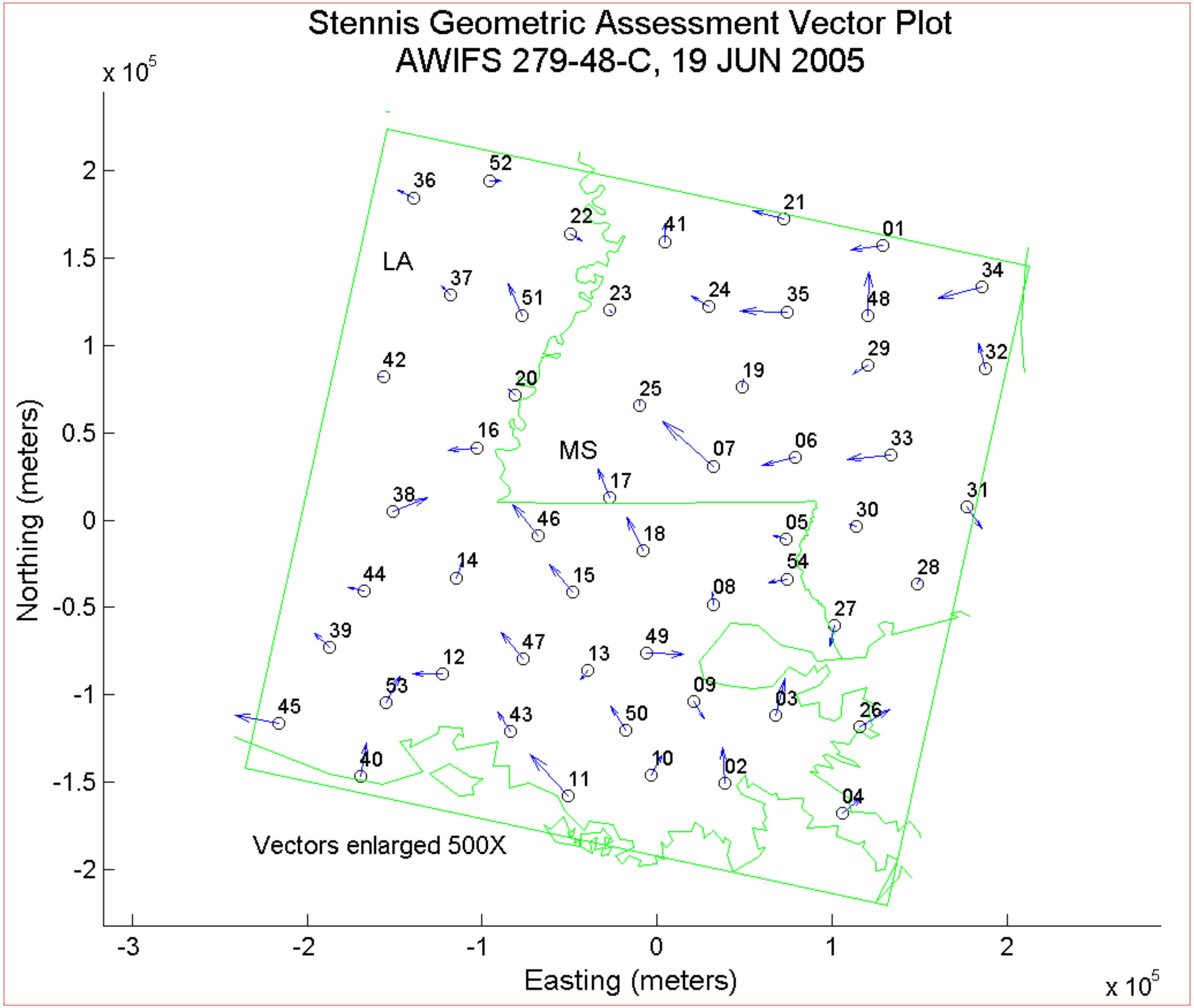


Results

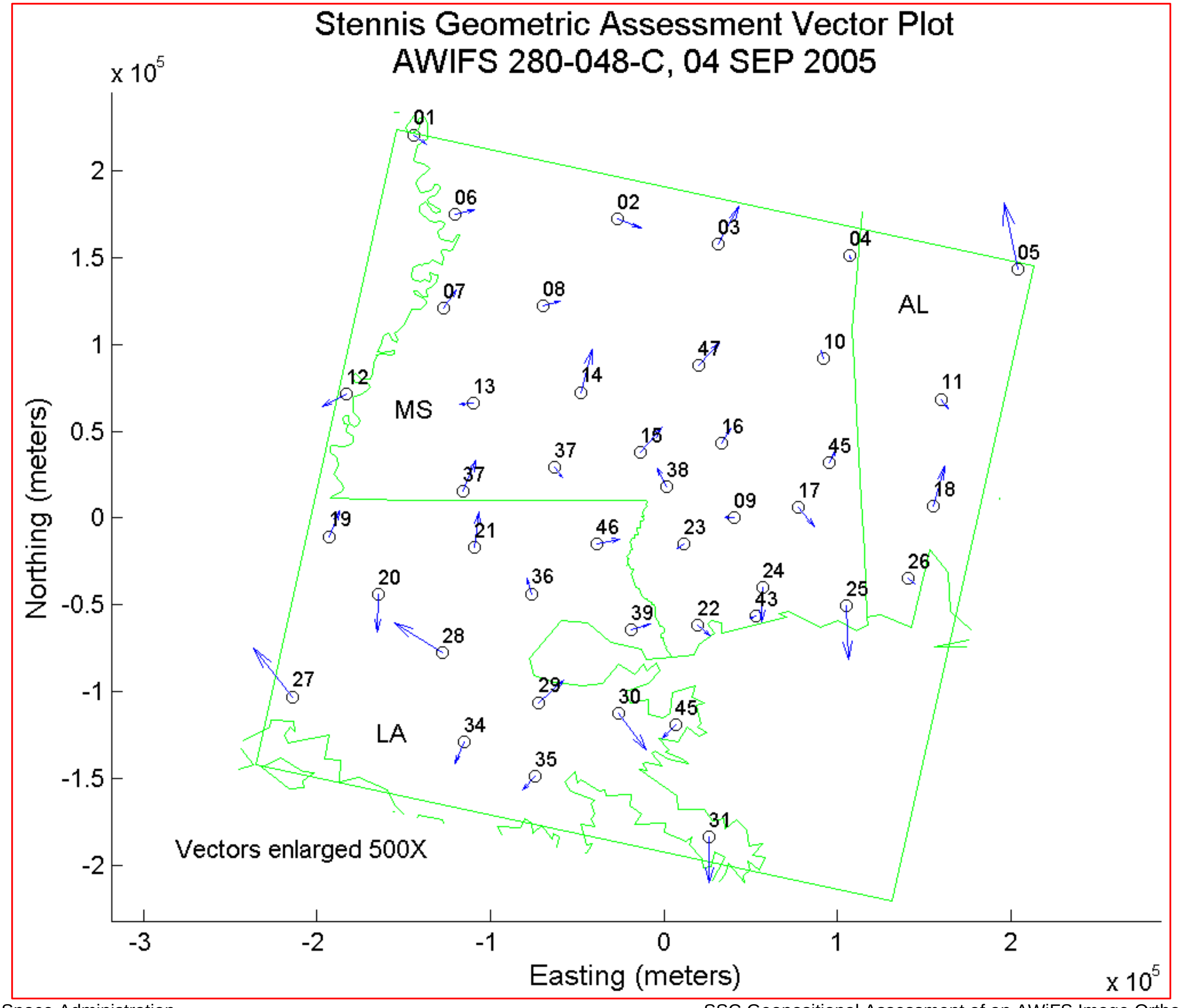
Scene Results: AWiFS A(1)



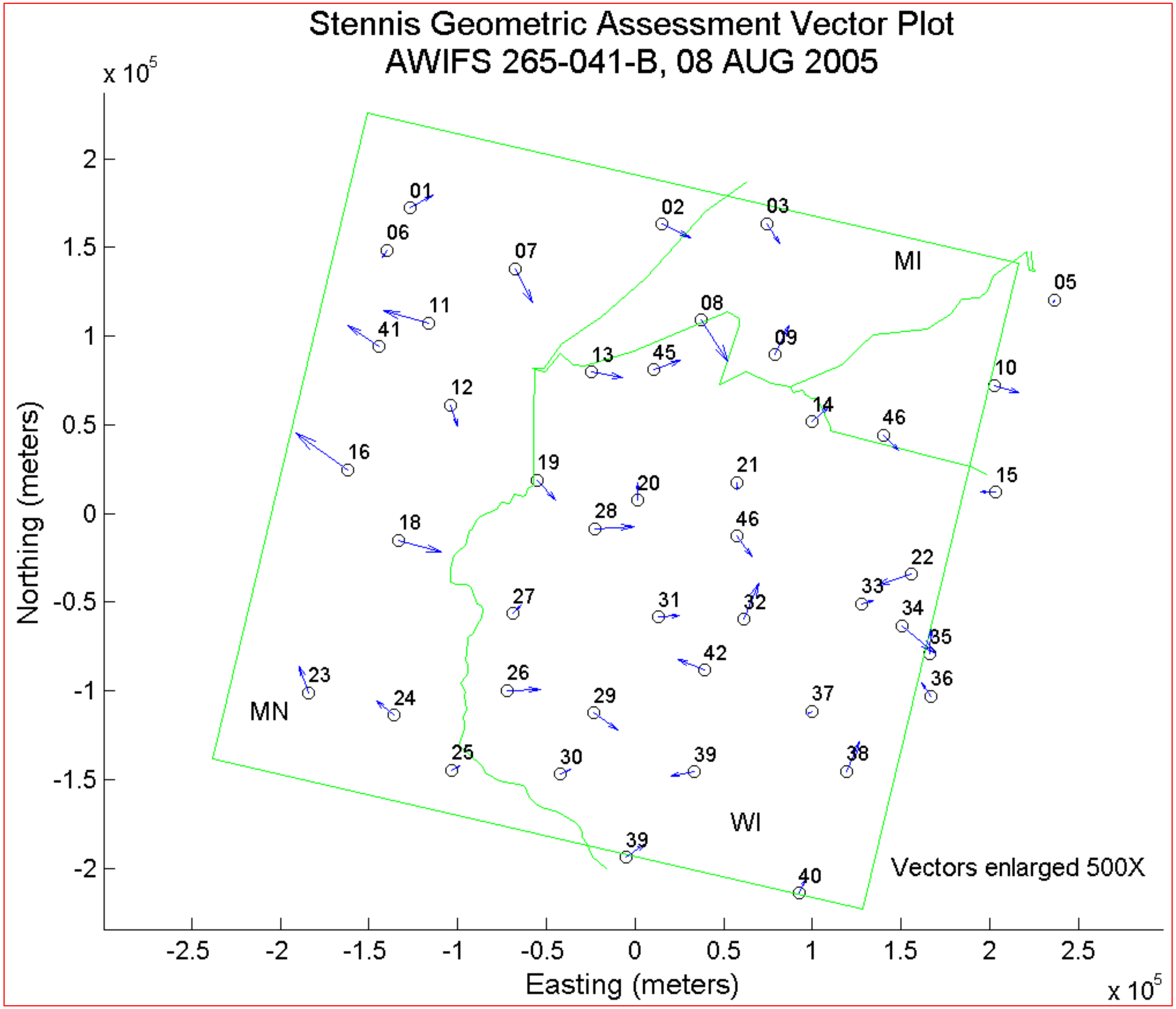
Scene Results: AWiFS A(2)



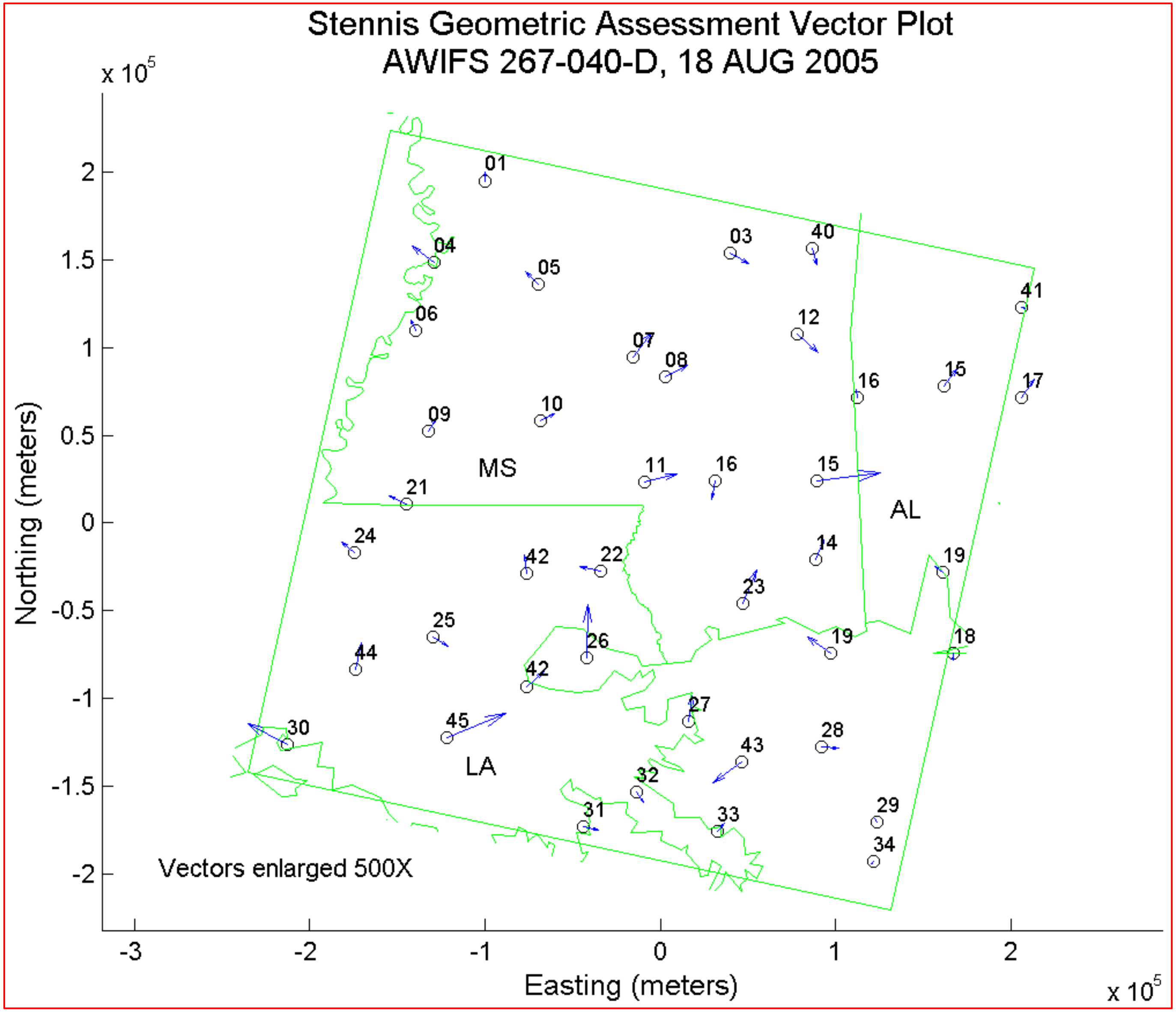
Scene Results: AWiFS A(3)



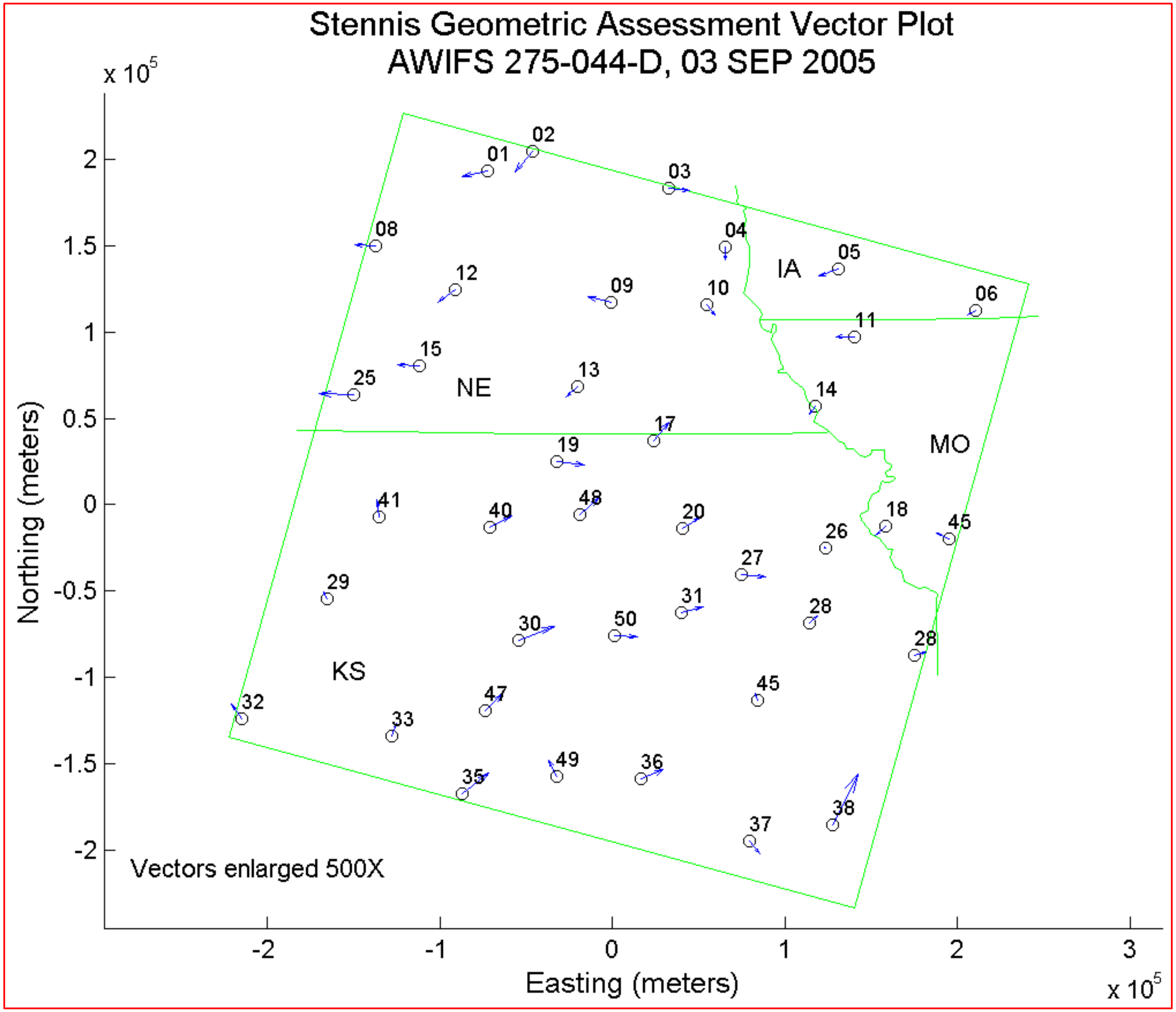
Scene Results: AWiFS B(1)



Scene Results: AWiFS B(2)

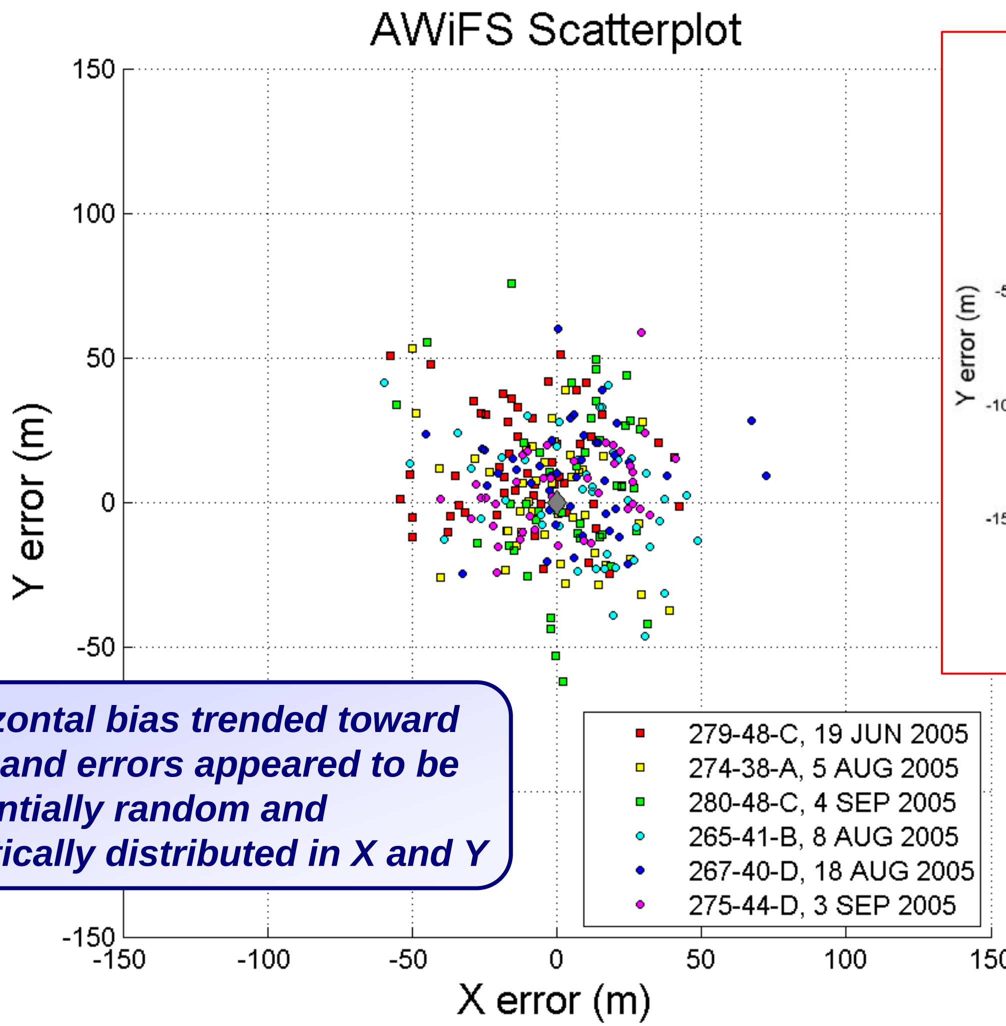


Scene Results: AWiFS B(3)

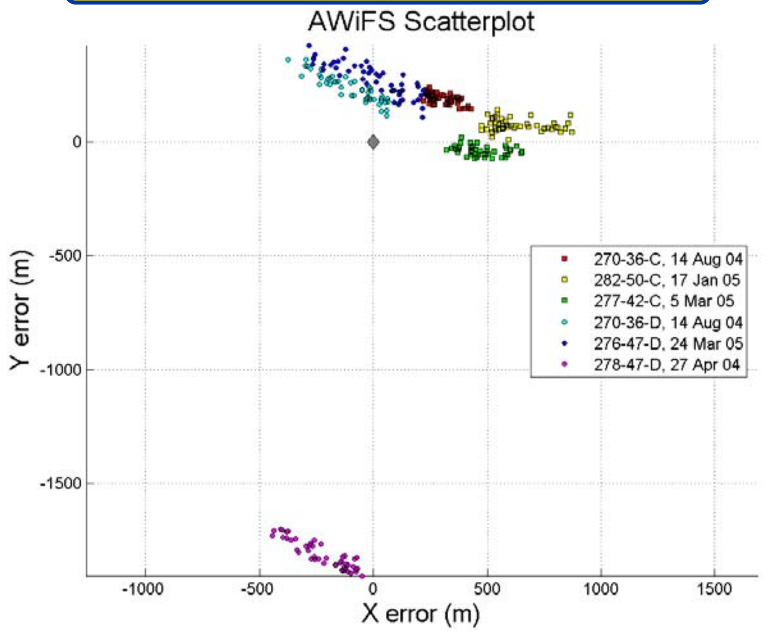


Overall Scatter

AWiFS Ortho (JACIE 2007)



AWiFS Geo (JACIE 2006)

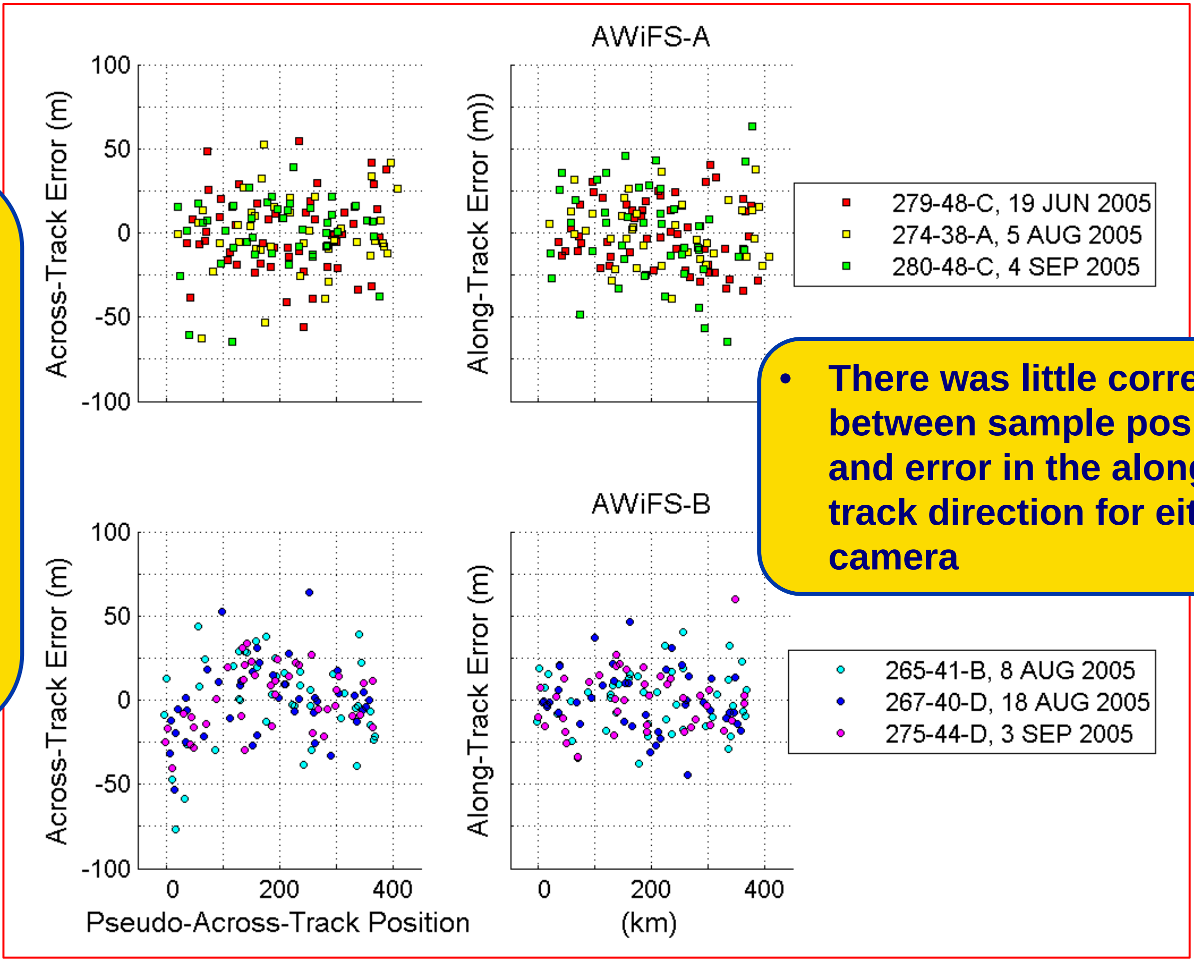


Horizontal bias trended toward zero and errors appeared to be essentially random and identically distributed in X and Y

Contrasted with the AWiFS Geo product (characterized for JACIE 2006), which showed biases greater than 200 m and greater spread of errors in the across-track (X) direction

Zero-Mean Errors by Sample

- **In general, there was little correlation between sample position and error in across-track direction**
- **Western edge of B Camera scenes may show a slight westward error trend (up to ~half pixel)**



- **There was little correlation between sample position and error in the along-track direction for either camera**

Summary of Results

AWiFS Product	Acquisition Date	Sub-scene	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE_{90} (m)
AWiFS-A *Ortho*	19 JUN 2005	279-48-A	16	21	51
	5 AUG 2005	274-38-A	3	21	45
	4 SEP 2005	280-48-C	6	25	55
AWiFS-B *Ortho*	8 AUG 2005	265-41-B	8	23	49
	18 AUG 2005	267-40-D	11	20	46
	3 SEP2005	275-44-D	5	18	36

- The mean CE_{90} of AWiFS *Geo* images characterized was 47 m and ranged from 36 m to 55 m
- All scenes showed consistent sub-pixel geopositional accuracy

References

Ager, T.P., 2004. An Analysis of Metric Accuracy Definitions and Methods of Computation, an internal report of InnoVision in support of the National Geospatial-Intelligence Agency. 13 pp.

Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy (FGDC-STD-007.3-1998, 1998).

Greenwalt, C.R. and M.E. Shultz, 1962. Principles of Error Theory and Cartographic Applications (ACIC Technical Report No. 96, 1962).

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