Geometric Accuracy Assessment of Data from UKDMC-2, SPOT 4/5 and RapidEye

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Outline

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  - DMC
  - SPOT
  - RapidEye
- **Geometric Assessment**
- **Results**
  - DMC
  - SPOT
  - RapidEye
- **Summary**

DMC-2 Overview

- 5 datasets provided by Steve Mackin of UK DMC-2
- Three bands
  - Green, Red and NIR
- GSD of 22m
- ~650 km swath
- Data for analysis in WGS UTM Zone 13N (Pueblo), and 14N (Sioux Falls)
- Reference Data: GLS2000 and orthoimagery

SPOT Overview

- Data from SPOT-4 and SPOT-5 obtained under North American Data Purchase Agreement
  - SPOT -4 has 4 bands Green, Red, NIR and SWIR at 20 m GSD
  - SPOT -5 has 3 bands Green, Red, NIR at 10 m GSD and SWIR band at 20 m GSD
- 60 x 60 km scene size
- Data for analysis in WGS UTM Zone 13N (Pueblo)
- Reference data: GLS 2000, Orthoimagery

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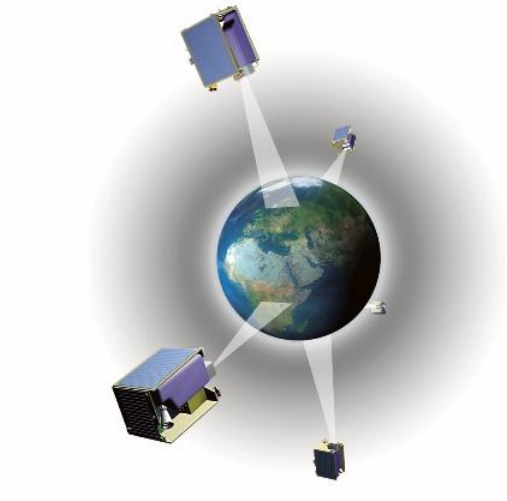
RapidEye Overview



- Data from five-satellite RapidEye (RE) commercial EO constellation were provided by Andreas Brunn
- Five spectral bands
  - Blue, Green, Red, Near Infrared, Red-Edge
- Ground sampling distance: 6.5 m (nadir), Pixel size (orthorectified): 5 m
- Image Size: 25km X 25km
- Data for analysis in WGS UTM Zone 13N (Pueblo) and 14N (Sioux Falls)
- Reference data: Orthoimagery

Geometric Accuracy Assessment

- **Performed using the Landsat Image Assessment System (IAS)**
  - Developed for Radiometric and Geometric Characterization and Calibration for Landsat data.

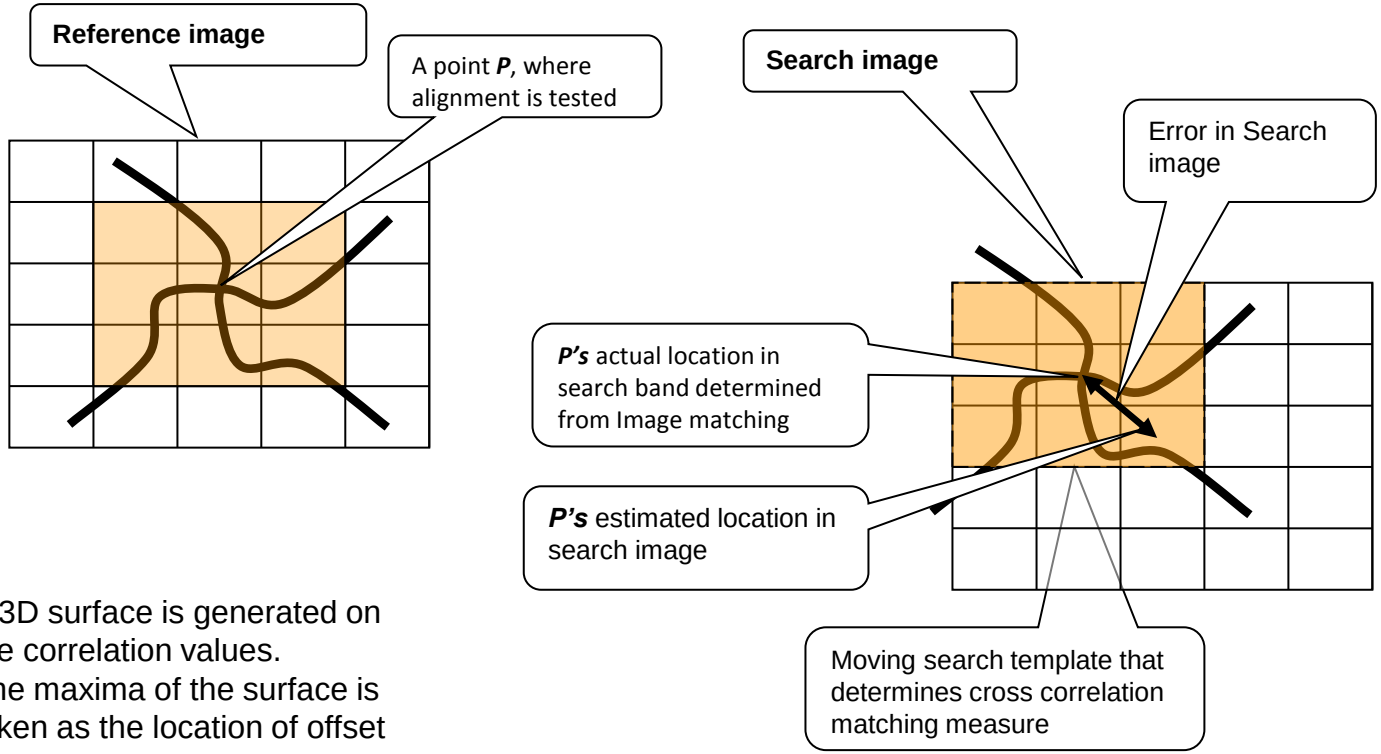
- **Band to Band (B2B) assessment**
  - B2B is performed to test band alignment of the image data
  - It is typically done by registering each band against every other band

- **Image to Image (I2I) registration assessment tool**
  - I2I is usually performed to compare the relative accuracy between two images
  - Performed against an image of higher accuracy (reference data)
  - The results provide an insight to the relative accuracy of the search image with respect to the reference image
  - When the correlated points are plotted in the image, it also helps to detect any systematic bias in the image

Geometric Accuracy Assessment

- Assessed by comparing relative positional of two images
- The input consists of a reference image and a search image
- The reference image and the corresponding pixels in the study image inputs are uniformly sampled (using the image geolocation/header information).
- Image chips (a window of 64 x 64 or 32 x 32 pixels) for reference and study images are selected around these samples.
- Normalized cross-correlation values were generated between the center of the reference image chip, and the pixels in the study image chip.
- $$CC(l,s) = \left(\sum_{i,j} \left(I_R(i,j) - \bar{I}_R\right)\left(I_S(i,j) - \bar{I}_s\right) \right) \Big/ \left(\sqrt{\Sigma\left(I_R - \bar{I}_R\right)^2} \sqrt{\Sigma\left(I_S - \bar{I}_s\right)^2} \right)$$
- CC(*l,s*) is the normalized cross correlation coefficient at location (l,s), and refer to the intensities associated with reference and study image windows, and refer to the mean intensities within the window.

Geometric Accuracy Assessment : Image Registration



- A 3D surface is generated on the correlation values.
- The maxima of the surface is taken as the location of offset

DMC-2 Data Analysis

DMC-2 Data Analysis

- **Data acquired over Sioux Falls, SD and Pueblo, CO**

DMC2 Study Target Region	Acquisition Date	Assessment	
		I2I	B2B
Pueblo, CO	2011-06-23	Yes	Yes
Pueblo, CO	2011-08-16	Yes	No
Pueblo, CO	2011-09-04	Yes	No
Sioux Falls, SD	2010-07-27	Yes	Yes
Sioux Falls, SD	2011-09-19	Yes	No

- **Datasets were Geometrically corrected to L1T products**
- **Coordinate System: WGS84 UTM Zones 13 and 14N**
- **Reference data used: GLS2000 15 m GSD PAN data were resampled to 22 m to match DMC-2 data**

DMC-2 I2I Results: Sioux Falls

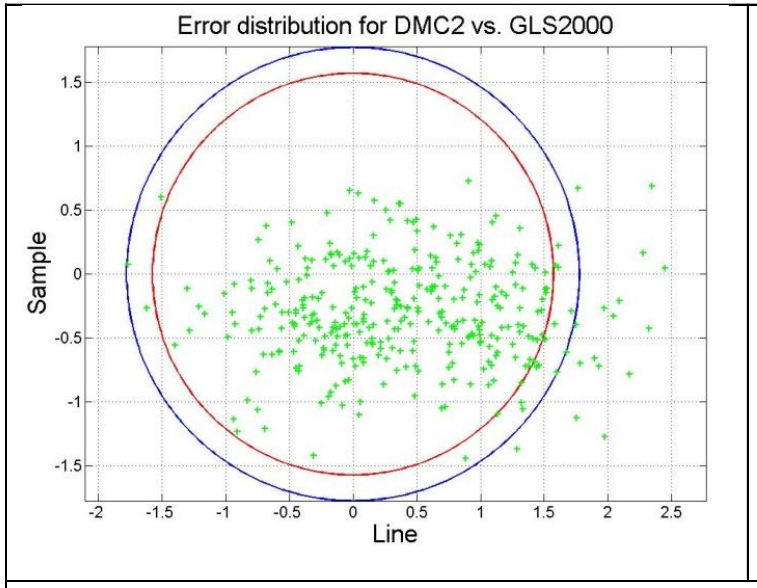
Summary statistics for DMC-2 I2I analysis for imagery over Sioux Falls

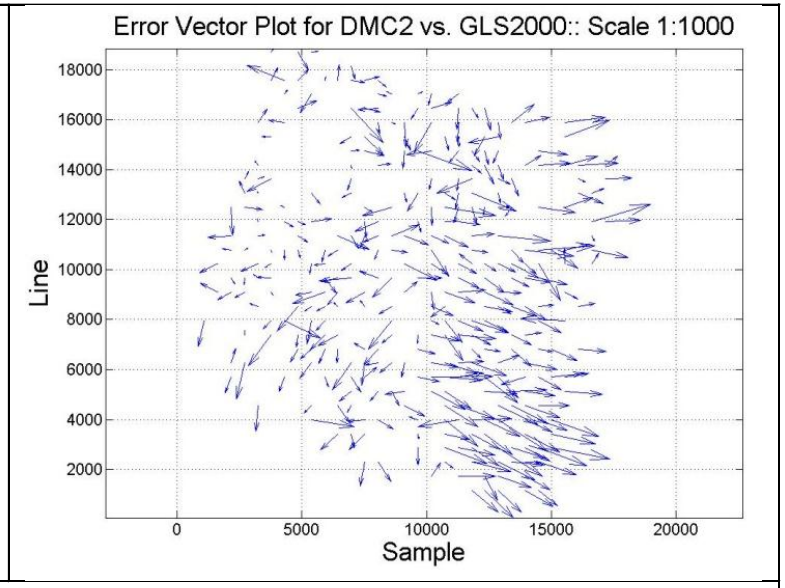
		Line	Sample	Line	Sample
Sioux Falls Dataset 1 277 points		Pixels		Meters	
	Mean	-0.314	0.408	-6.91	8.97
	Std Dev	0.286	0.654	6.30	14.40
	RMSE	0.425	0.770	9.34	16.94
	Total RMSE	0.879		19.35	
Sioux Falls Dataset 2 125 points					
	Mean	0.673	1.113	14.80	24.50
	Std Dev	0.339	0.334	7.46	7.36
	RMSE	0.753	1.162	16.56	25.57
		1.38*		30.46*	

** Part of the image had haze/clouds*

DMC-2 I2I Results: Sioux Falls

- **Dataset 1**

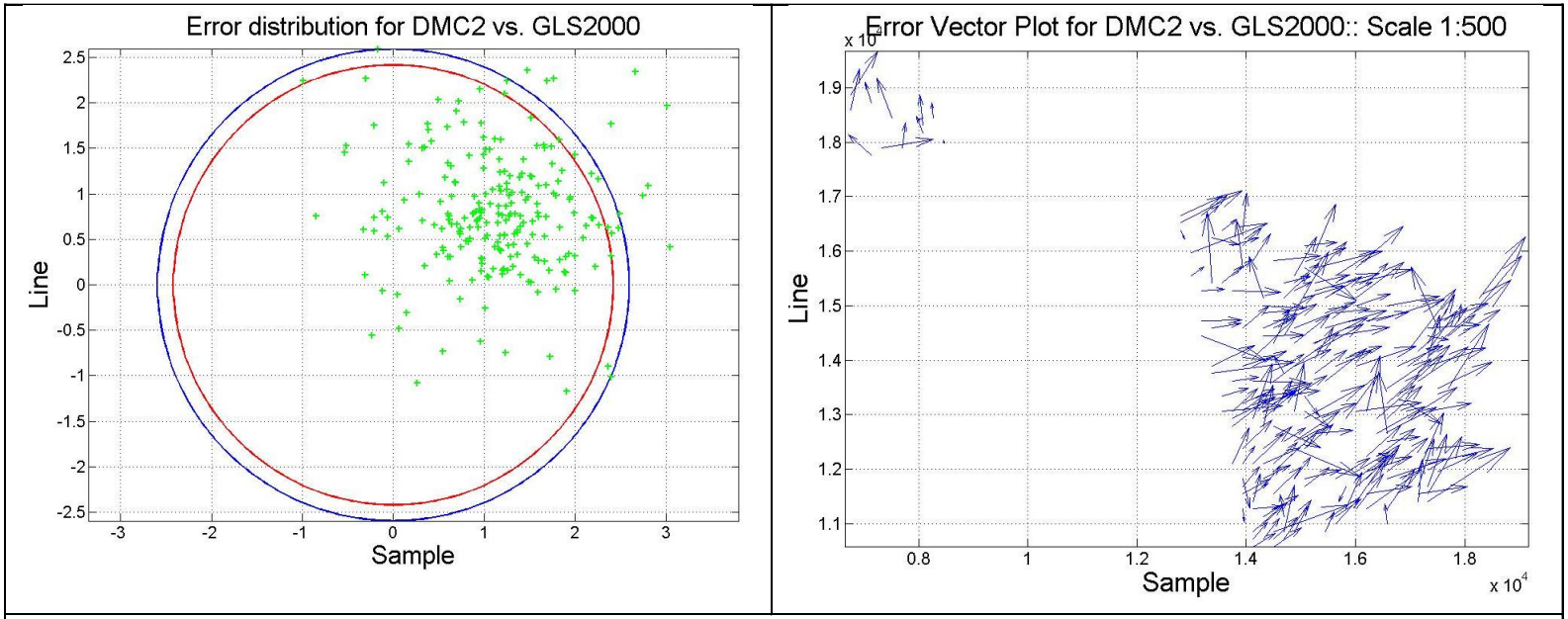




DMC 2 data over Sioux Falls
RMSE of 0.87 pixels or 19.34 m
The Red and Blue circles indicate the 90th and 95th percentile values of error

DMC-2 I2I Results: Sioux Falls

- **Dataset 2**



DMC 2 data over Sioux Falls
RMSE of 1.34 pixels or 29.56 m
The Red and Blue circles indicate the 90th and 95th percentile values of error

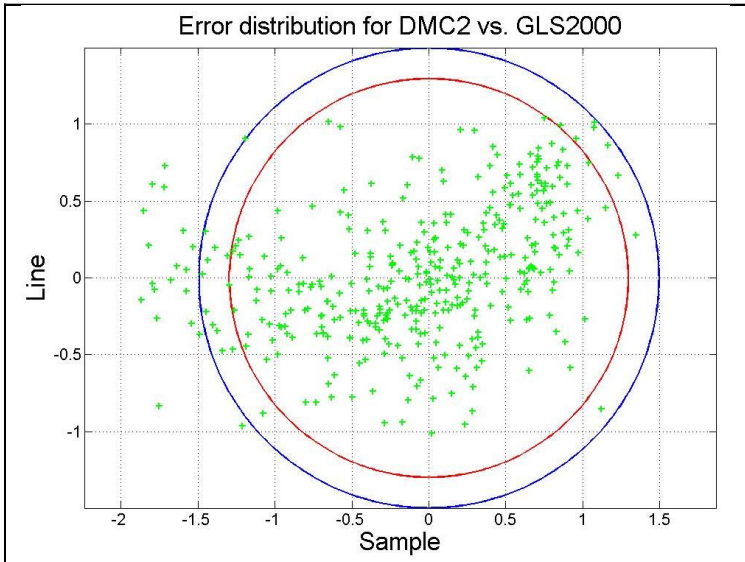
DMC-2 I2I Results: Pueblo

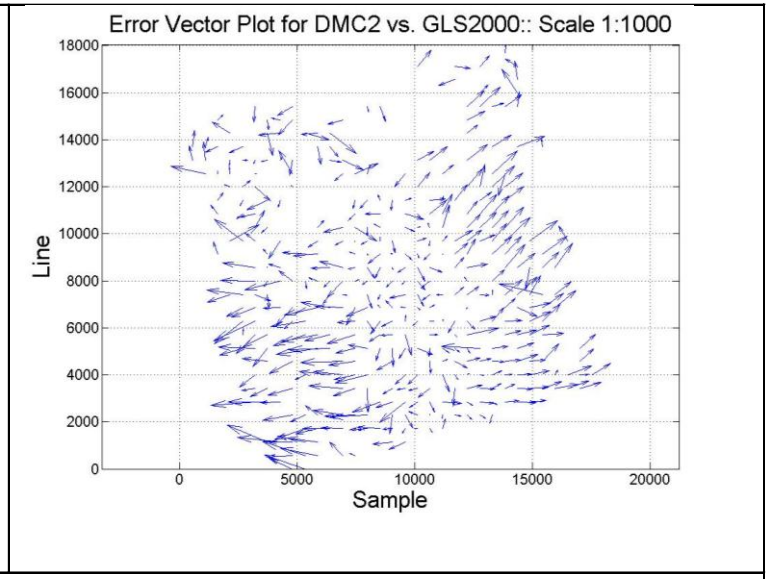
Summary statistics for DMC-2 I2I analysis for imagery over Pueblo

		Line	Sample	Line	Sample
		Pixels		Meters	
Pueblo Dataset 1 191 points	Mean	-0.256	-0.139	-5.63	-3.06
	Std Dev	0.183	0.255	4.03	5.61
	RMSE	0.314	0.290	6.91	6.38
	Total RMSE	0.428		9.40	
Pueblo Dataset 2 218 points	Mean	-0.203	-0.279	-4.48	-6.14
	Std Dev	0.175	0.178	3.85	3.91
	RMSE	0.268	0.330	5.90	7.27
	Total RMSE	0.426		9.37	
Pueblo Dataset 3 235 Points	Mean	-0.062	-0.019	-1.36	-0.43
	Std Dev	0.226	0.490	4.97	10.79
	RMSE	0.234	0.490	5.15	10.78
	Total RMSE	0.543		11.94	

DMC-2 I2I Results: Pueblo

- **Dataset 1**

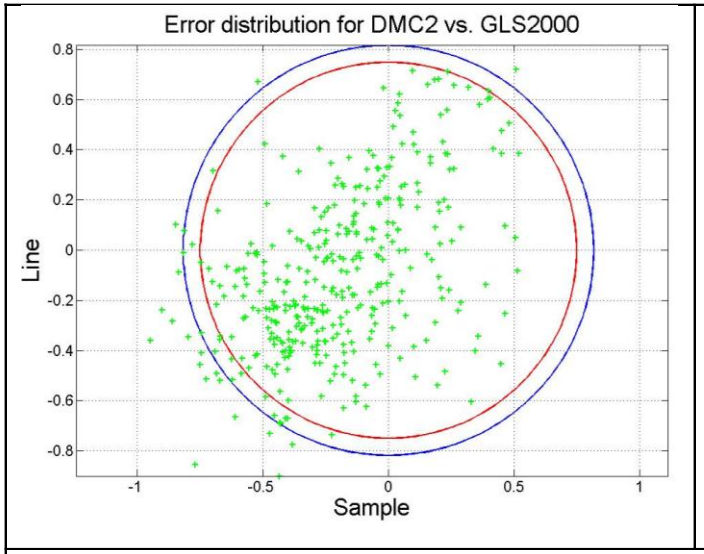


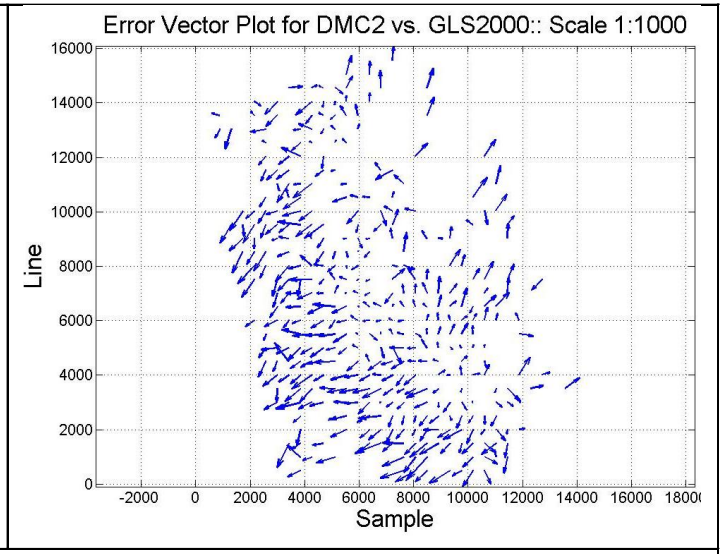


DMC 2 data over Pueblo
RMSE of 0.427 pixels or 9.40m
The Red and Blue circles indicate the 90th and 95th percentile values of error

DMC-2 I2I Results: Pueblo

- **Dataset 2**

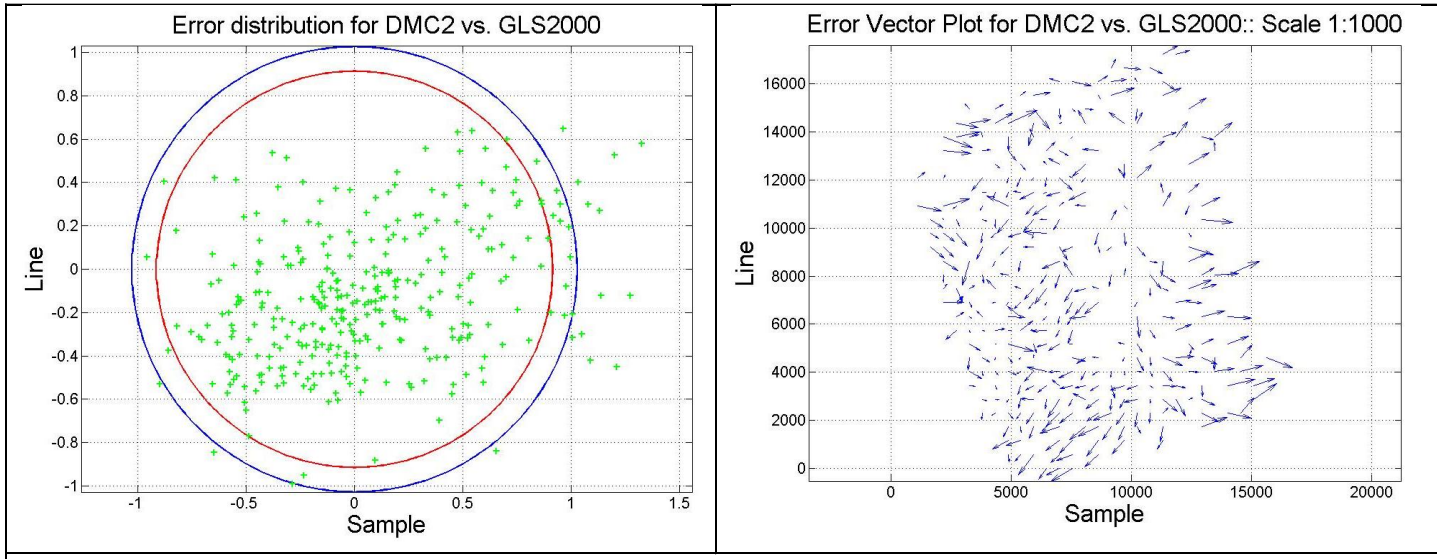




DMC 2 data over Sioux Falls
RMSE of 0.425 pixels or 9.37 m
The Red and Blue circles indicate the 90th and 95th percentile values of error

DMC-2 I2I Results: Pueblo

- **Dataset 3**



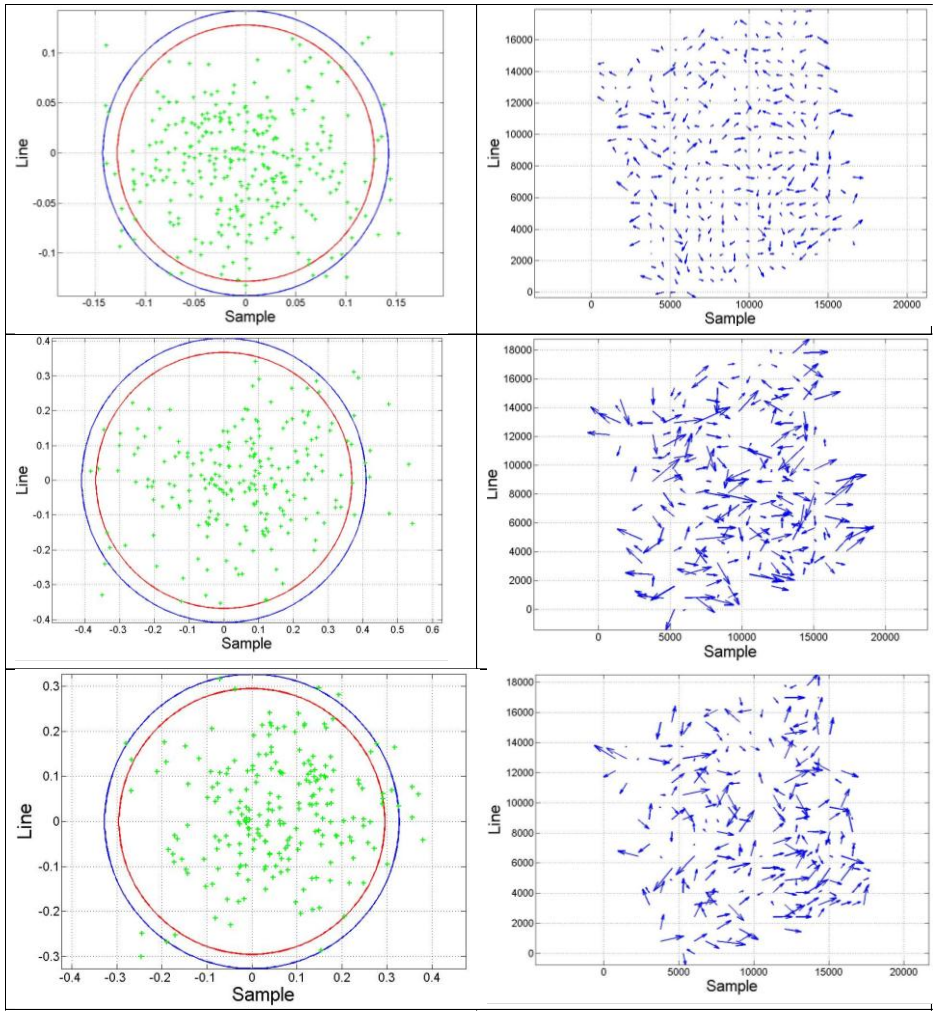
DMC 2 data over Sioux Falls
RMSE of 0.543 pixels or 11.94 m
The Red and Blue circles indicate the 90th and 95th percentile values of error

DMC-2 B2B Results

Band 1- Band 2
RMSE: .05 pixels

Band 1- Band 3
RMSE: 0.11 pixels

Band 2- Band 3
RMSE: 0.15 pixels



SPOT Data Analysis

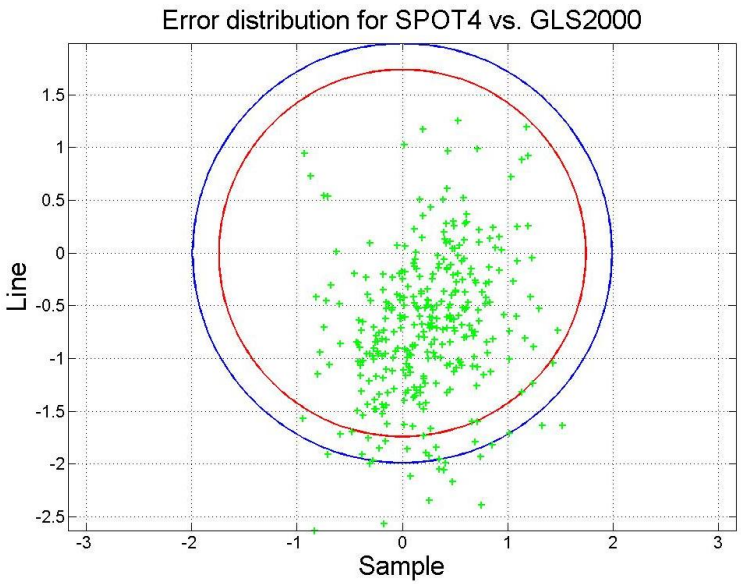
SPOT Data Analysis

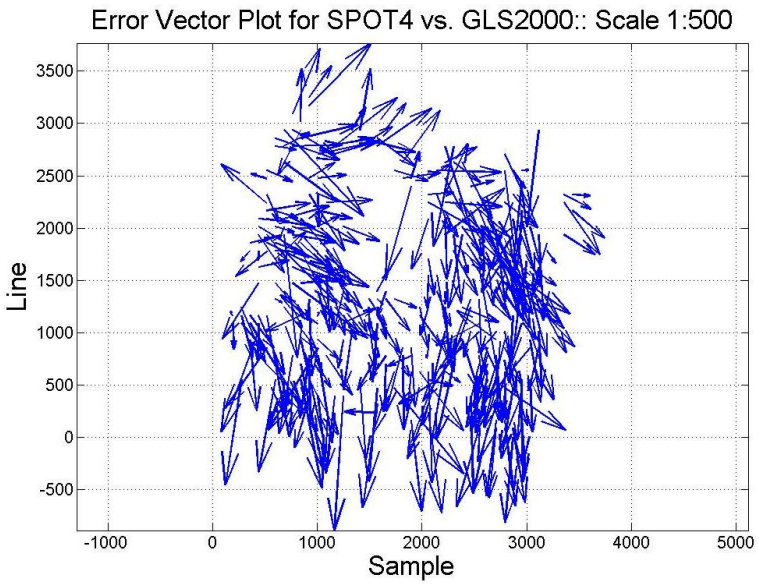
- **Band registration for both SPOT 4 and SPOT 5 validated**
  - Each of the 4 bands were tested against the other
- **Relative accuracy of SPOT data tested against GLS2000 and Orthoimagery**
  - 15 m GSD PAN GLS2000 imagery was resampled to 20 m for testing SPOT 4 data
  - 4 inch GSD orthoimagery was mosaicked and resampled to 10m for testing SPOT 5 images
  - Coordinate System: WGS 84 UTM Zone 13N

SPOT-4 I2I Results

Summary statistics for SPOT-4 I2I analysis for imagery over Pueblo

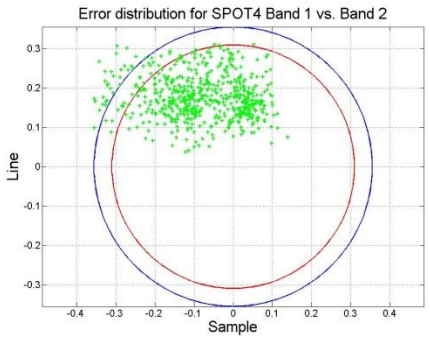
Pueblo Data 506 Points	Line	Sample	Line	Sample
	Pixels		Meters	
Mean	-0.734	0.183	-14.65	3.66
StDev	0.383	0.338	7.66	6.77
RMSE	0.826	0.384	16.52	7.68
Total RMSE	0.911		18.22	

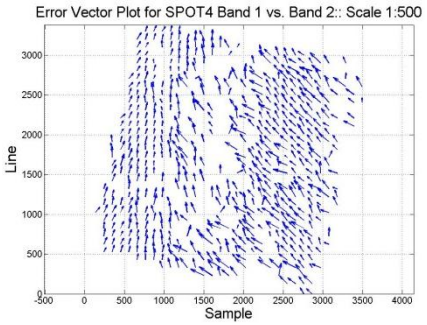




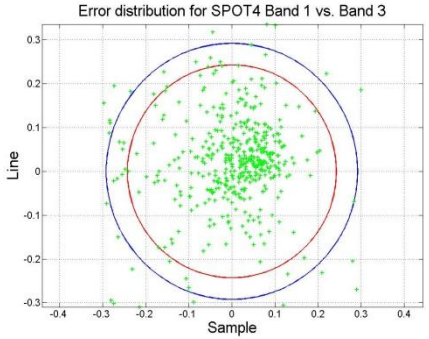
SPOT-4 B2B Results

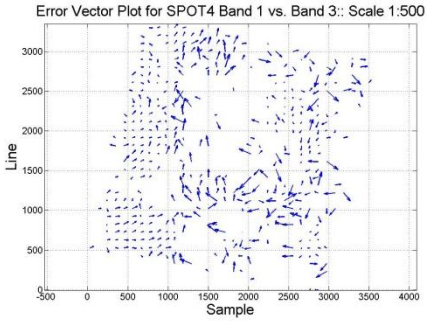
Band 1 vs. Band 2:
RMSE 0.193 pixels



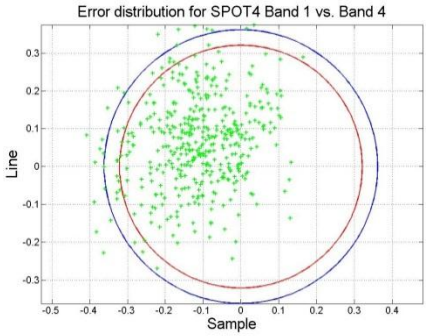


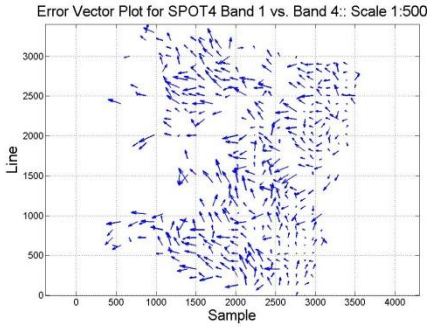
Band 1 vs. Band 3:
RMSE 0.253 pixels





Band 1 vs. Band 4:
RMSE 0.147 pixels





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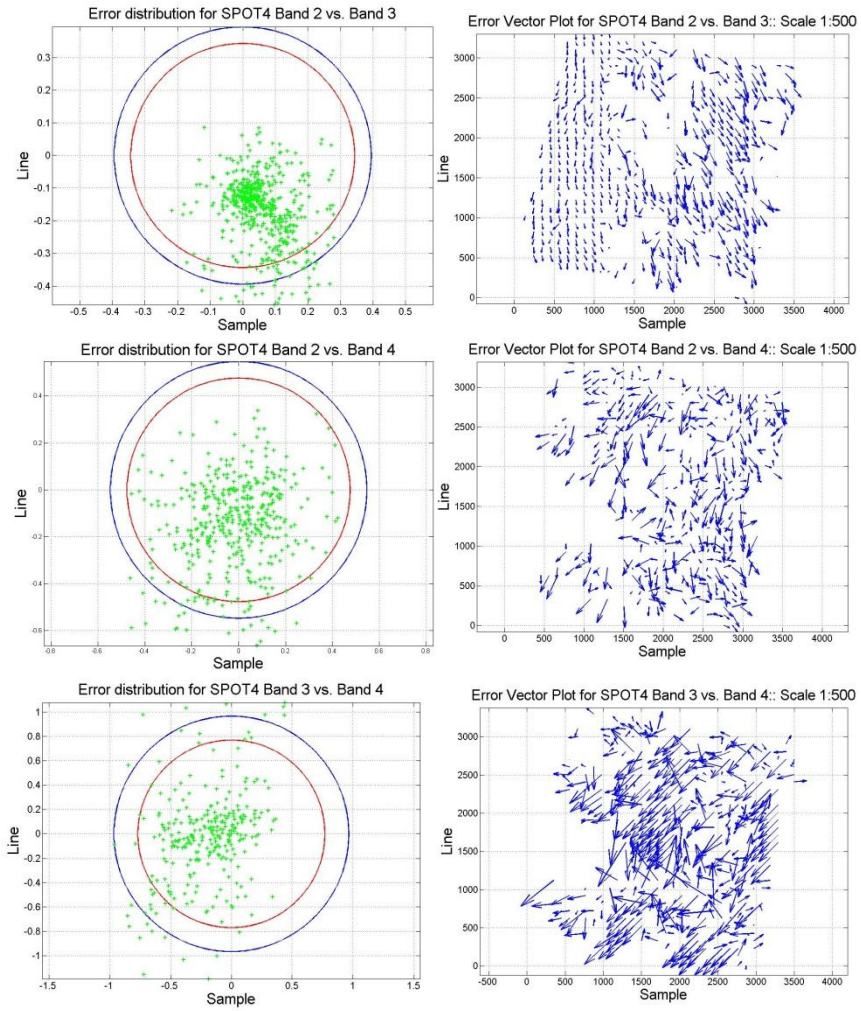
SPOT-4 B2B Results

Band 2 vs. Band 3:
RMSE 0.15 pixels

Band 2 vs. Band 4:
RMSE 0.175 pixels

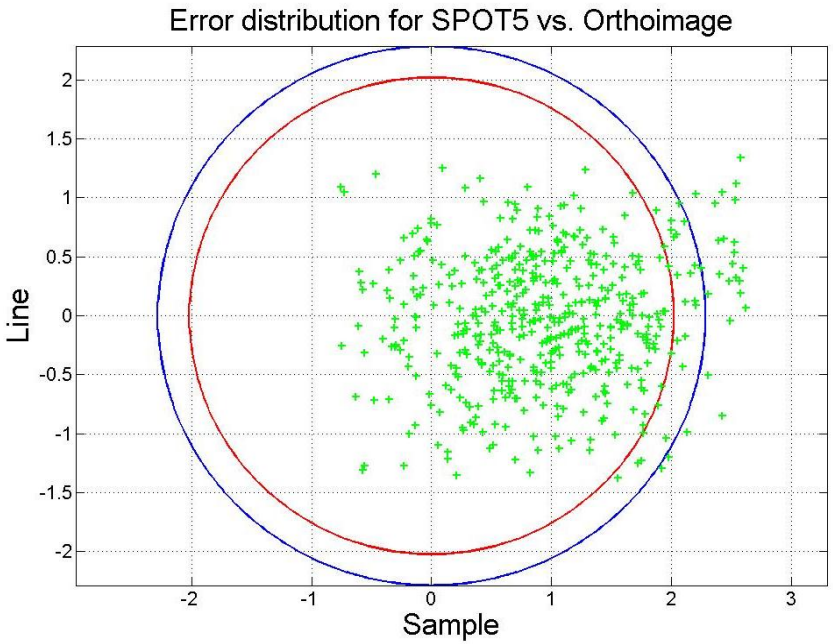
Band 3 vs. Band 4:
RMSE 0.45 pixels

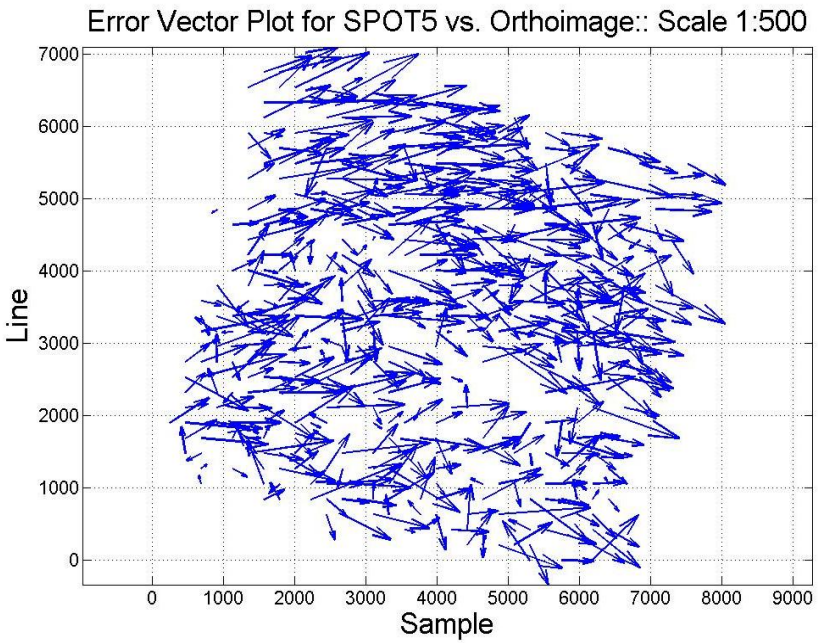


SPOT-5 I2I Results

Summary statistics for SPOT-5 I2I analysis for imagery over Pueblo

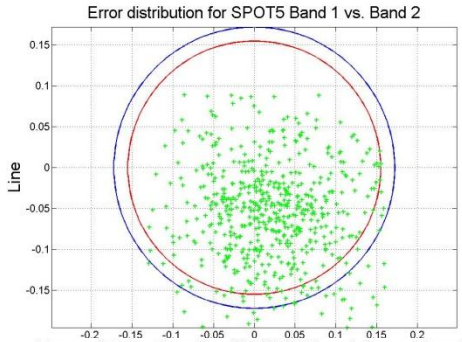
Pueblo Data 506 Points	Line	Sample	Line	Sample
	Pixels		Meters	
Mean	-0.033	0.983	9.83	0.98
StDev	0.394	0.981	9.81	1.06
RMSE	0.394	1.079	10.79	1.15
Total RMSE	1.149		11.49	

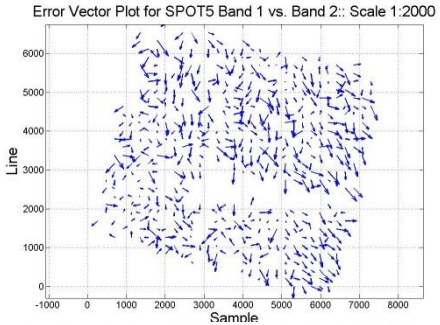




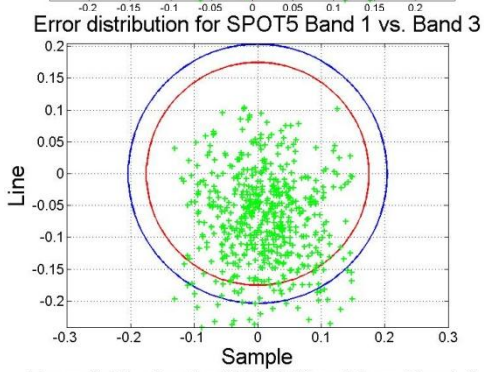
SPOT-5 B2B Results

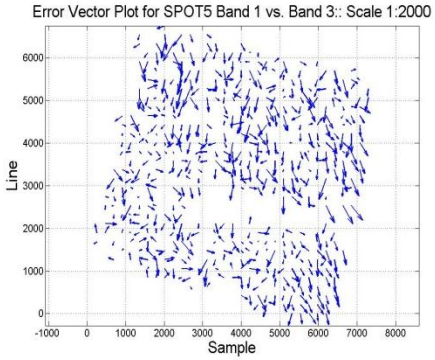
Band 1 vs. Band 2:
RMSE 0.11 pixels



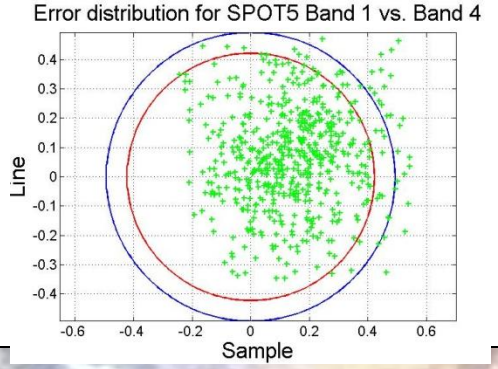


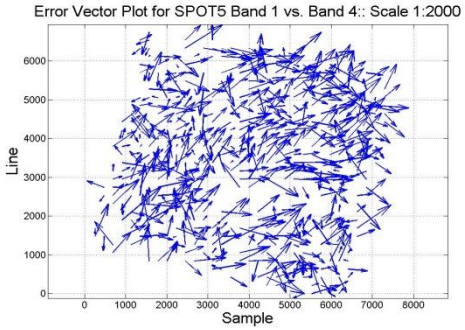
Band 1 vs. Band 3:
RMSE 0.12 pixels





Band 1 vs. Band 4:
RMSE 0.21 pixels





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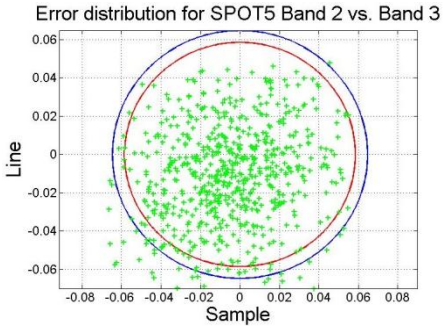
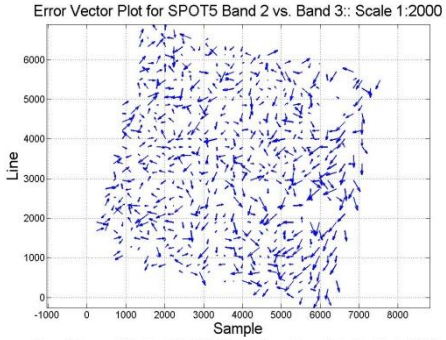
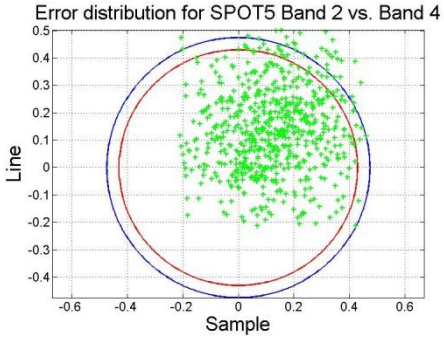
SPOT-5 B2B Results

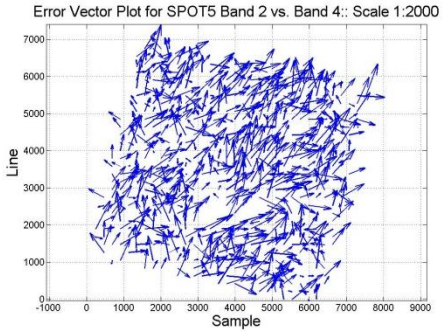
Band 2 vs. Band 3:
RMSE 0.04 pixels



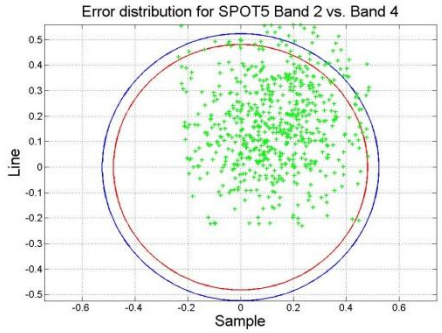


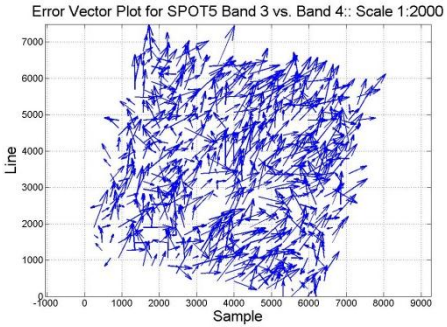
Band 2 vs. Band 4:
RMSE 0.23 pixels





Band 3 vs. Band 4:
RMSE 0.27 pixels





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RapidEye Data Analysis

RapidEye Data Analysis

- **Data acquired over Sioux Falls, SD and Pueblo, CO**

Rapideye Study Target Region	Rapideye satellite number	Acquisition Date	Assessment
			I2I
Pueblo, CO	2	2011-10-10	Yes
Pueblo, CO	3	2011-08-25	Yes
Sioux Falls, SD	1	2011-05-28	Yes
Sioux Falls, SD	4	2010-07-17	Yes
Sioux Falls, SD	5	2011-09-28	Yes

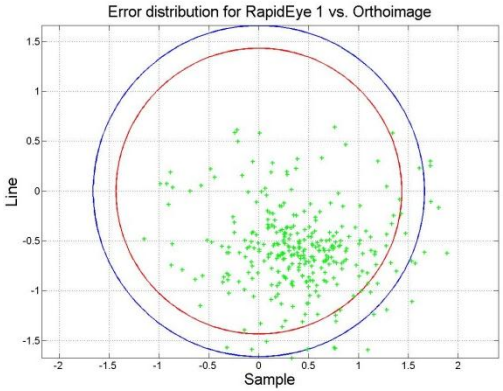
- **All datasets were Radiometrically and geometrically corrected Level 3A products rectified using SRTM DEM**
- **Coordinate System: WGS84 UTM Zones 13 and 14N**
- **Reference data used: Orthorectified aerial image data resampled to 5m pixel size.**

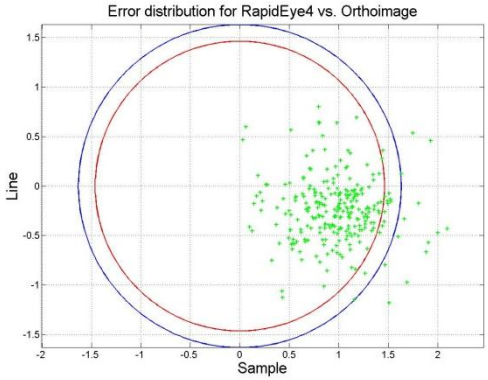
RapidEye I2I Results: Sioux Falls

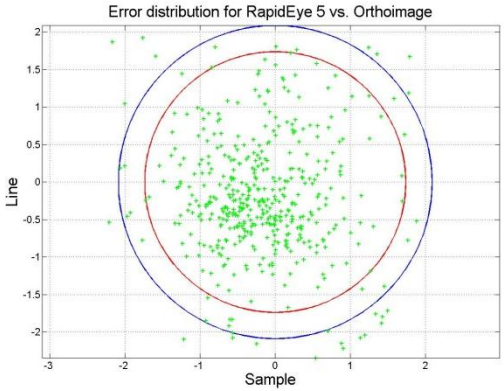
Summary statistics for RapidEye I2I analysis for imagery over Sioux Falls

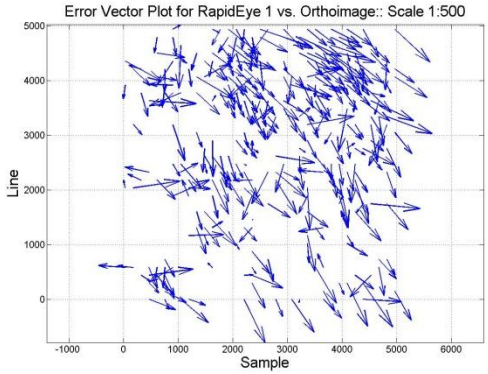
		Line	Sample	Line	Sample
		Pixels		Meters	
Sioux Falls RE 1 142 points	Mean	-0.580	0.416	-2.90	2.08
	Std Dev	0.126	0.255	0.63	1.27
	RMSE	0.594	0.487	2.97	2.44
	Total RMSE	0.768		3.84	
Sioux Falls RE 4 176 points	Mean	-0.274	0.996	-1.37	4.98
	Std Dev	0.168	0.254	0.84	1.27
	RMSE	0.321	1.028	1.60	5.12
	Total RMSE	1.076		5.38	
Sioux Falls RE 5 223 Points	Mean	-0.385	-0.258	-1.92	-1.29
	Std Dev	0.294	0.390	1.47	1.95
	RMSE	0.484	0.466	2.42	2.33
	Total RMSE	0.672		3.36	

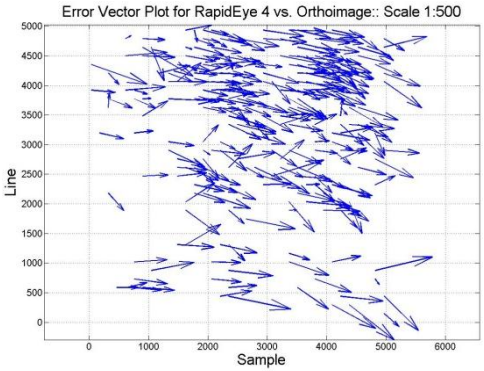
RapidEye I2I Results: Sioux Falls

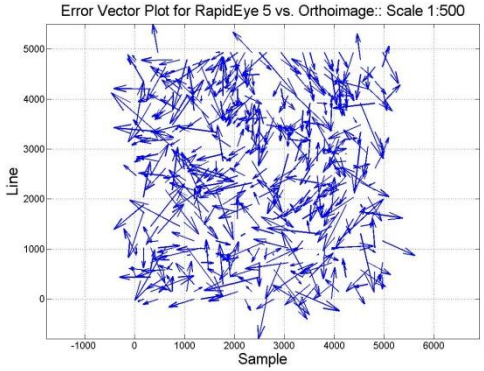










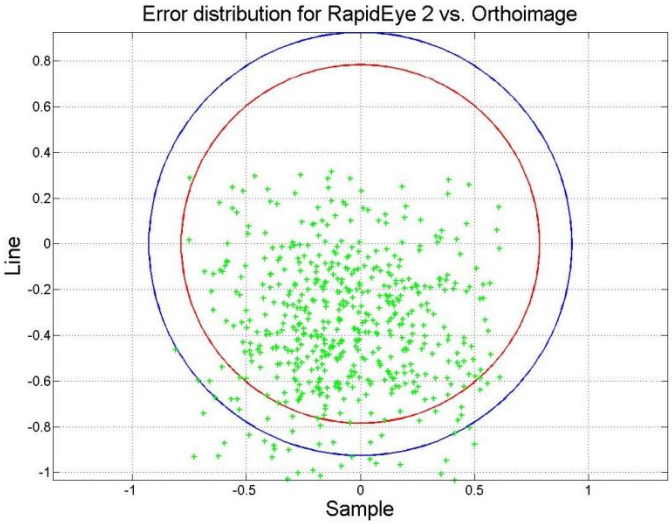


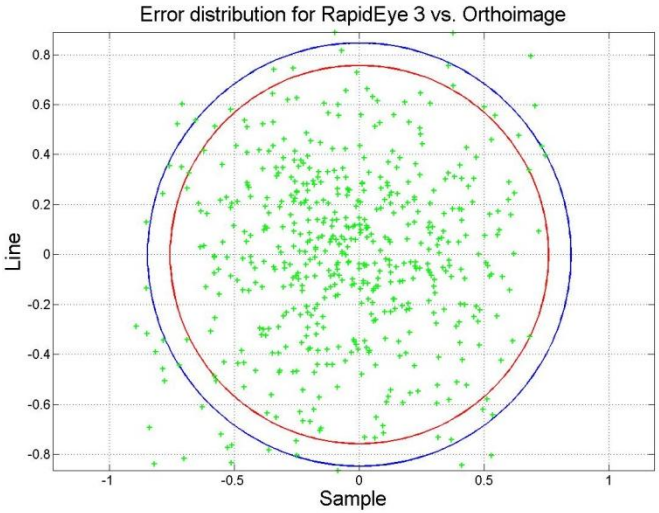
RapidEye I2I Results: Pueblo

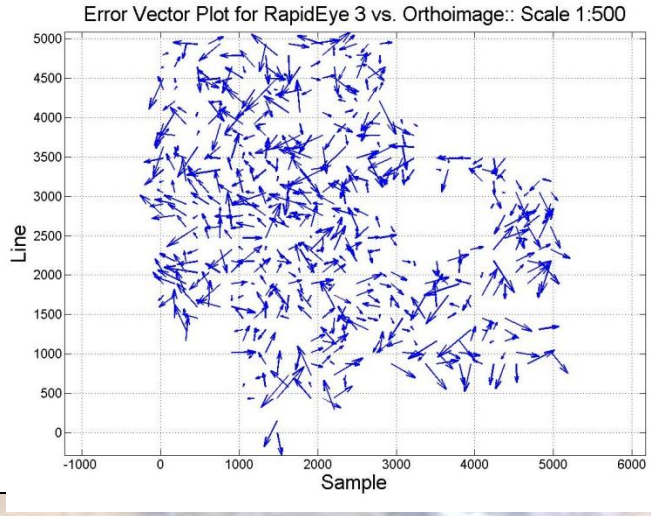
Summary statistics for RapidEye I2I analysis for imagery over Pueblo

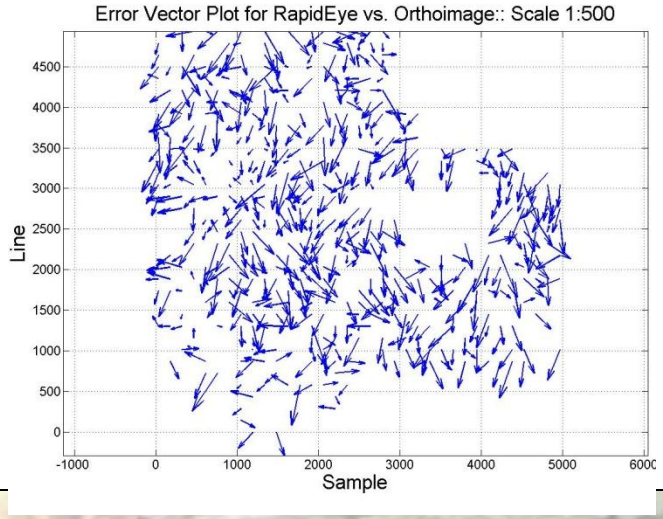
		Line	Sample	Line	Sample
		Pixels		Meters	
Pueblo RE 2 347 points	Mean	-0.354	-0.076	-1.77	-0.38
	Std Dev	0.194	0.196	0.97	0.98
	RMSE	0.403	0.209	2.02	1.05
	Total RMSE	0.454		2.27	
Pueblo RE 3 332 points	Mean	0.030	-0.070	0.15	-0.35
	Std Dev	0.39	0.417	1.09	1.04
	RMSE	0.401	0.420	1.10	1.10
	Total RMSE	0.49		2.46	

RapidEye I2I Results: Pueblo









Data Analysis: Non Parametric vs. Parametric

- **Tdist outlier detection-parametric method, built into Landsat IAS.**
  - used as the default method
  - Threshold of 0.95
- **Median Absolute Deviation method**
  - If $X_1, X_2, \ldots X_n$, are data
  - $MAD_X =$ Median $(|X_i - X_{median}|)$ where X_{median} is the median value of $X_1, X_2, \ldots X_n$
  - $Z_{Xi} = \frac{|X_i - Median(X_i)|}{MAD_{Xi}}$ is determined
  - All values of $X_1, X_2, \ldots X_n$ for which the corresponding $Z_{Xi=1,..n}$ is greater than $\in = 3$ is considered outlier

USGS

Non Parametric vs. Parametric

- **Median Absolute Deviation is easier to understand**
- **Provides accurate results as long as outliers are less than 50% of the data**
- **At $\in = 3$, the MAD outlier detection retains more points than tdist at 0.95 value**
- **Comparing results from > 50 comparisons at $\in = 3$ and tdist at 0.95,**
  - MAD based thresholding shows slightly higher RMSE
  - Other tests have shown in areas covered with clouds etc. where I2I results are unpredictable, MAD based outlier removal provides better results
  - Extension to multivariate robust covariance measure also straightforward (Gnadesikan-Kettenring)

Summary

- **Remote Sensing Technologies (RST) team has completed the data characterizations for DMC-2, SPOT4-5, and RapidEye**
- **Future Analysis:**
  - Continued data assessments for Medium resolution datasets ..
  - Elevation data characterizations
  - More data are welcome
  - More collaborations welcome

Questions?