



Validation and Evaluation of Geolocation Accuracy of Worldview-1 Imagery

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Overview

- Hey, where's the lidar??
 - Sorry!
- Examine the geometric accuracy of the WorldView-1 Basic Imagery
- Evaluate the geometric accuracy of the WorldView-1 Basic Imagery using RPCs with ground control points

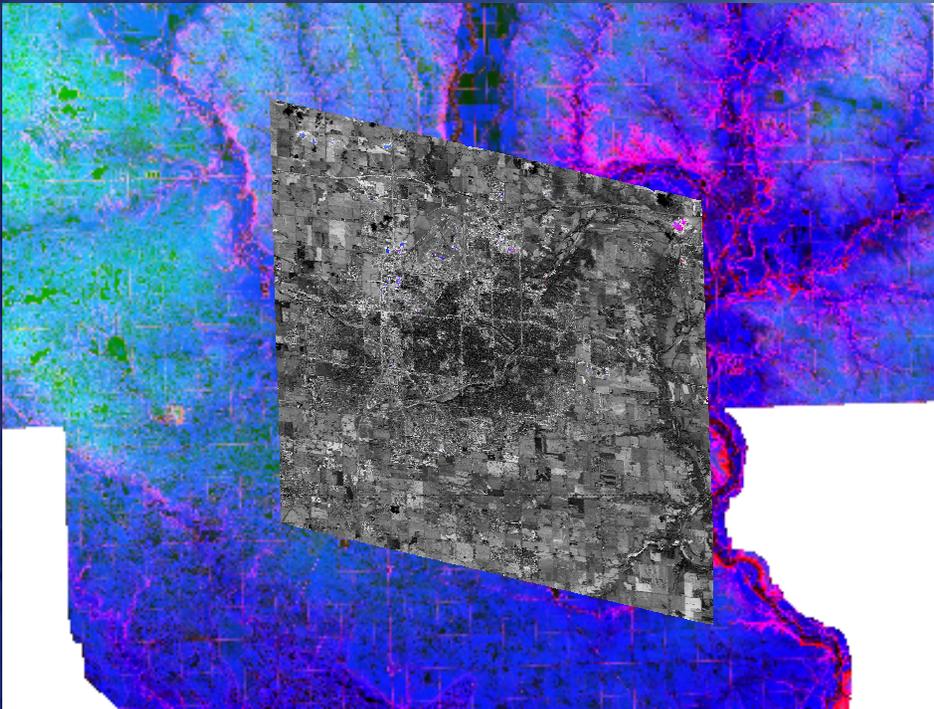
Worldview-1 Satellite

- Resolution: 0.5m panchromatic
- Nominal swath: 17.6km
- Equipped with state-of-art geolocation accuracy. Geolocation accuracy specification of 6.5 m CE90 at nadir, with actual accuracy in the range of 4.0 - 5.5 m CE90 at nadir, excluding terrain and off-nadir effects
- WorldView-2 will be launched in 2009 which provides eight bands of multi-spectral data

Worldview-1 Basic 1B Imagery

- Least processed
- Radiometrically corrected and sensor corrected
- Not projected to a plane using a map projection or datum
- Resulting GSD varies over the entire product
- Basic stereo pairs are supplied as two full scenes with 90% overlap designed for the creation of digital elevation models

Sioux Falls Test Site



- Covering urban and suburban and rural areas
- Basic 1B Stereo Imagery acquired on September 2008
- Elevation Range approx 1200 – 1800 ft
- Relatively flat (3 % slope avg +/- 3 % 2 STD)
- Image size:
 - 38,464 rows
 - 35,180 columns
- ~19.2km X 17.6km on the ground

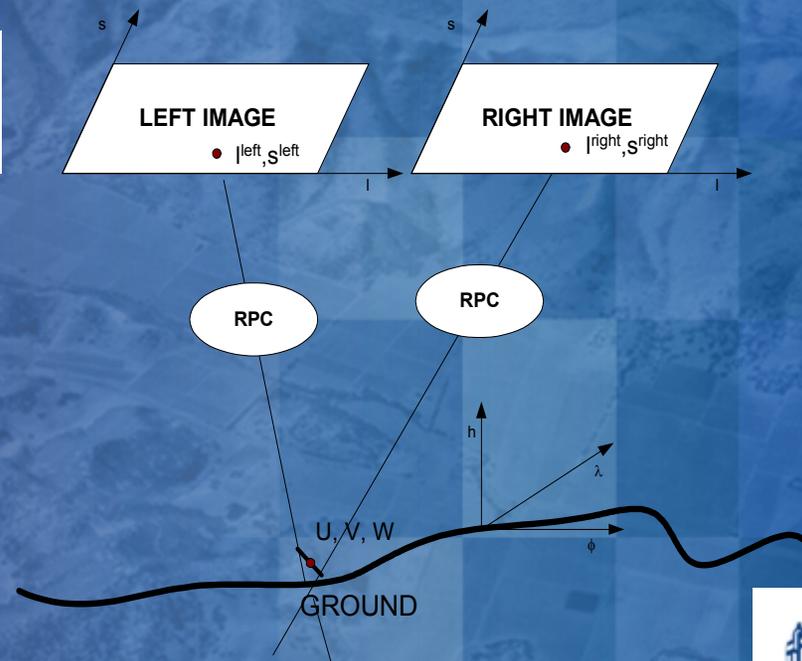
Rational Polynomial Coefficients (RPCs) Model for Transformation between Object and Image Spaces

Object-to-image space RPC transformation is from offset normalised latitude, longitude & height to offset normalized line & sample coordinates

$$l_n = \frac{Num_L(U, V, W)}{Den_L(U, V, W)}, \quad s_n = \frac{Num_S(U, V, W)}{Den_S(U, V, W)}$$

$$Num = \sum_{i=0}^3 \sum_{j=0}^3 \sum_{k=0}^3 a_{ijk} U^i V^j W^k$$

$$Den = \sum_{i=0}^3 \sum_{j=0}^3 \sum_{k=0}^3 b_{ijk} U^i V^j W^k$$



Rational Polynomial Coefficients (RPCs) Model for Transformation between Object and Image Spaces

- An empirical model developed by the satellite vendor, which approximates the 3D physical sensor model of an image.
- It enables a user, having little familiarity with a satellite sensor, to perform geometric correction without GCPs, but with a DEM.
- It is well known that geolocation biases are inherently present because RPCs are derived from orientation data originating from the satellite ephemeris and star tracker observations, without reference to ground control points.

Ground Control Points

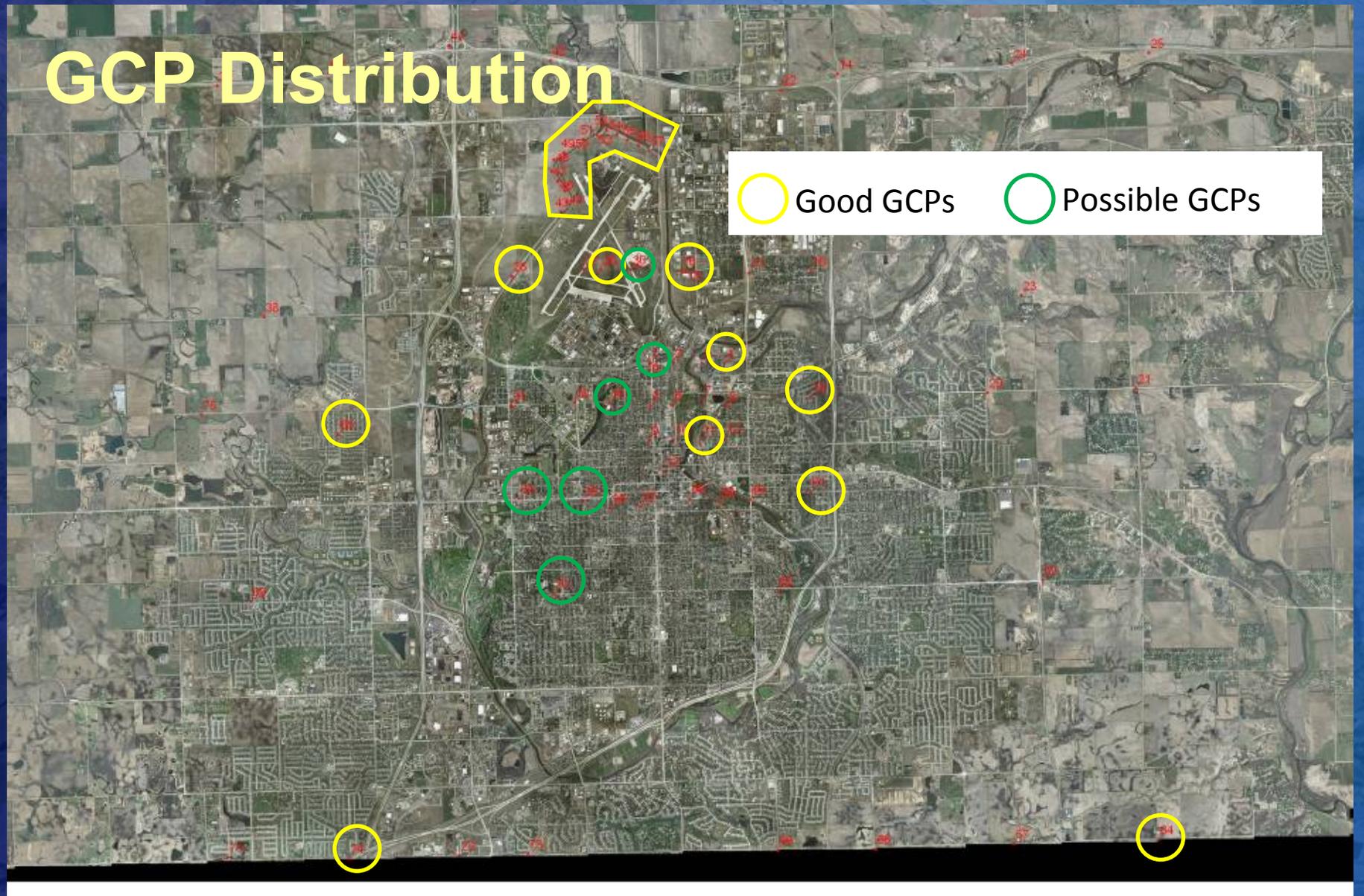
- Total of 76 GCPs available
- Surveyed for previous city/county ortho control
- Measured by differential GPS survey
- Accuracy:
 - Horizontal: 2 cm @ 1-sigma
 - Vertical: 2 cm @ 1-sigma
- Some GCPs invisible on Worldview-1 image
- Unidentifiable on Worldview-1 image
 - Occluded
 - Under trees

Ground Control Points

Examples of GCPs invisible on Worldview-1 image



GCP Distribution



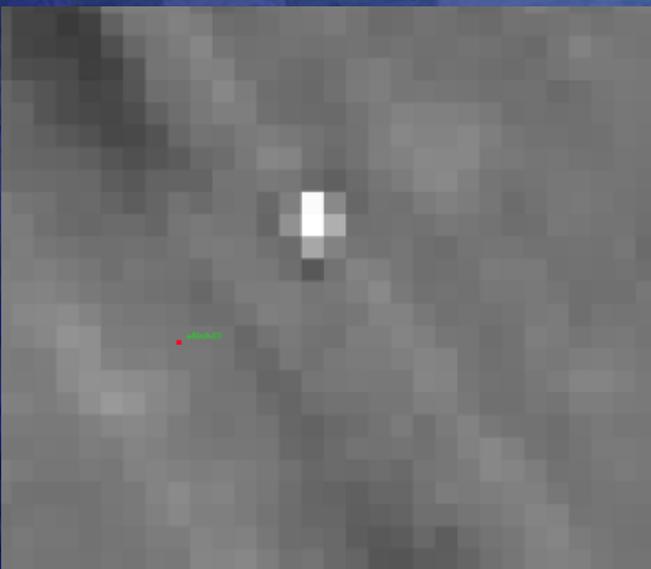


Imagery Dates: Mar 17, 2005 - Jul 8, 2007

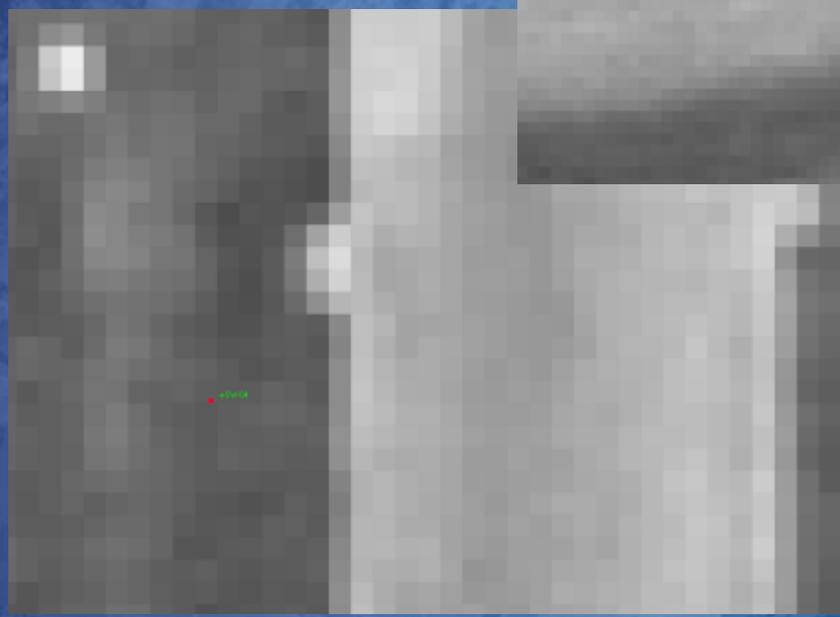
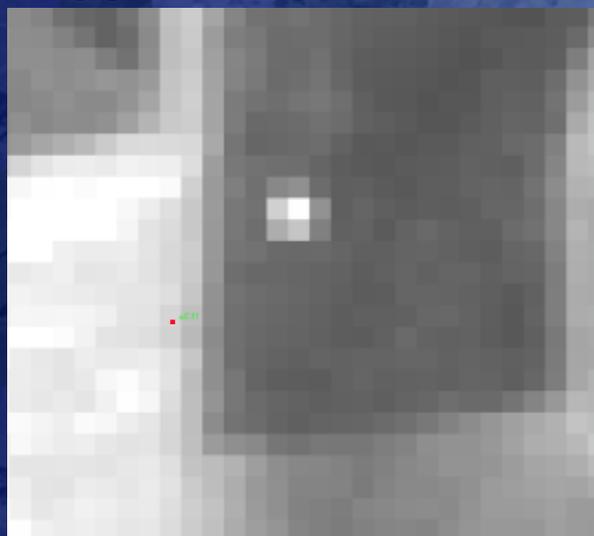
43°32'54.43" N 98°43'31.18" W elev 1400 ft

Eye alt 12.98 mi





Projection of GCPs to image space using supplied-RPCs



Geolocation Accuracy using Supplied-RPCs

Differences between computed planimetric coordinates using supplied-RPCs and GPS-survey coordinates

Mean X	3.045856
Mean Y	2.666523
Absolute Maximum X	3.574630
Absolute Maximum Y	3.662483
Absolute Minimum X	2.281949
Absolute Minimum Y	0.768556
RMSE X	3.071854
RMSE Y	2.751465

Unit: Meter

Bias-Corrected RPCs

$$l + F(l, s) = \frac{Num_L(U, V, W)}{Den_L(U, V, W)} L_S + L_0$$
$$s + G(l, s) = \frac{Num_S(U, V, W)}{Den_S(U, V, W)} S_S + S_0$$

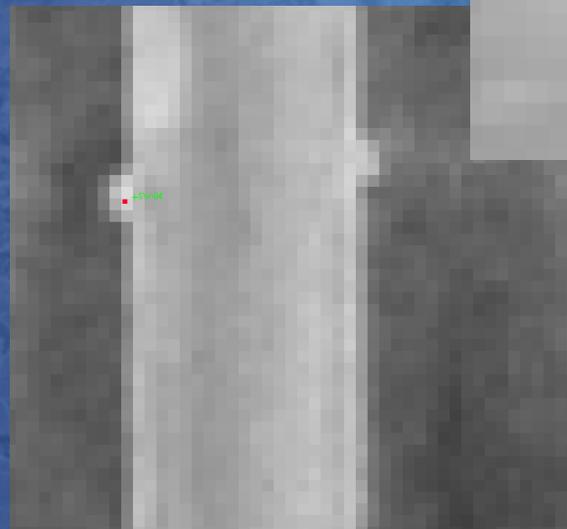
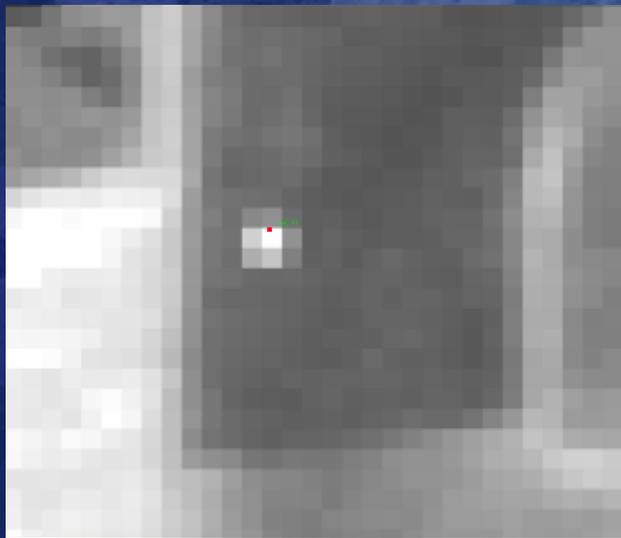
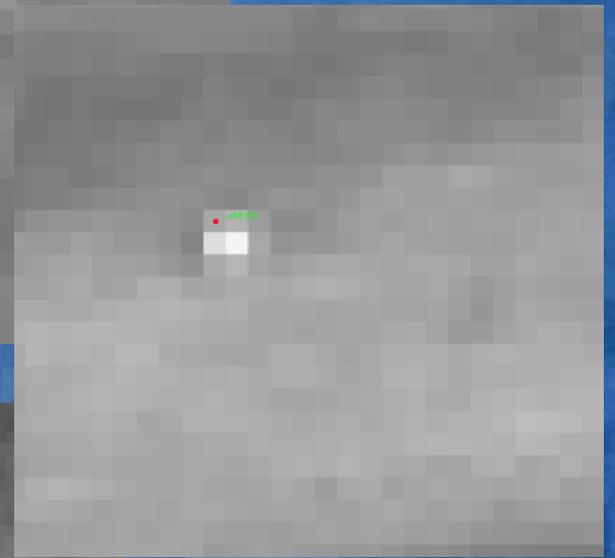
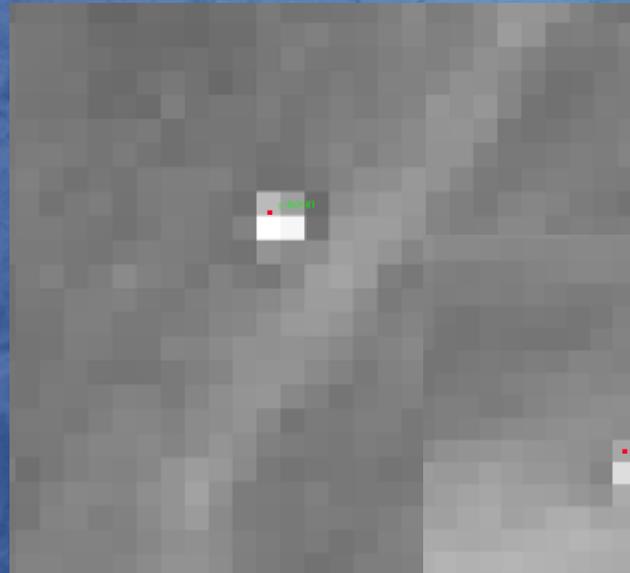
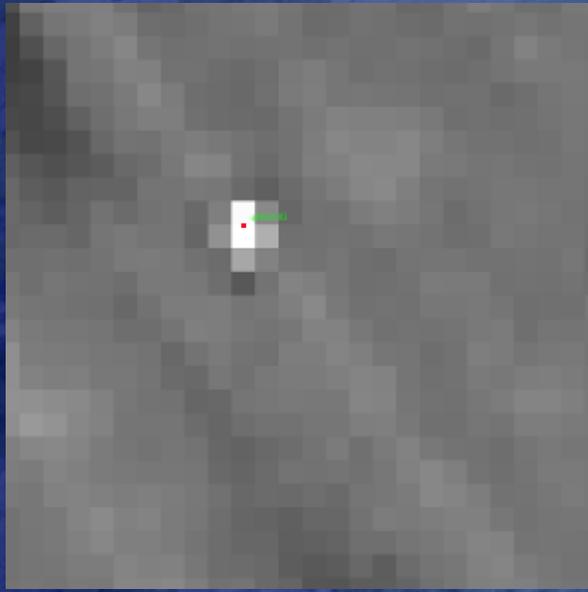
RPCs
(vendor supplied)



RPCs
(corrected)



Projection of GCP to Image Space using Corrected-RPCs

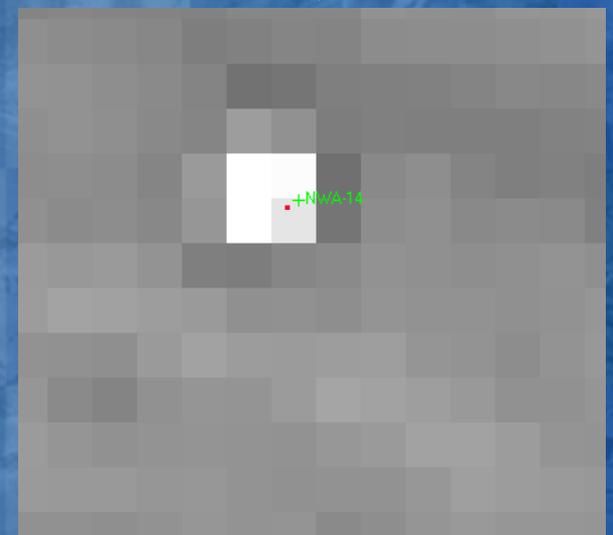
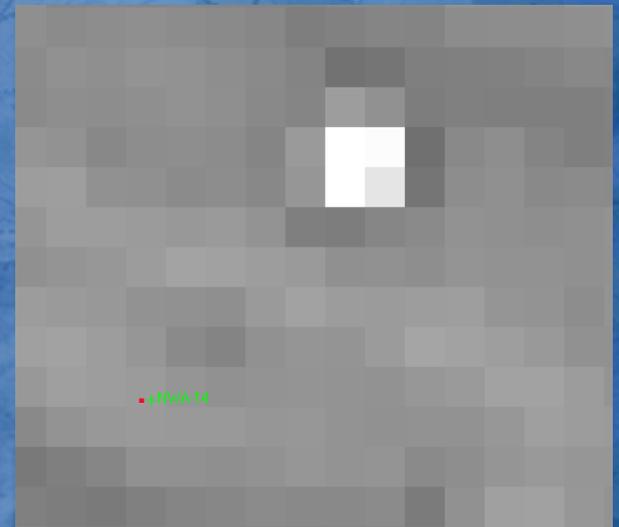


Comparison of Supplied-RPCs and Corrected-RPCs in Object-to-Image Projection

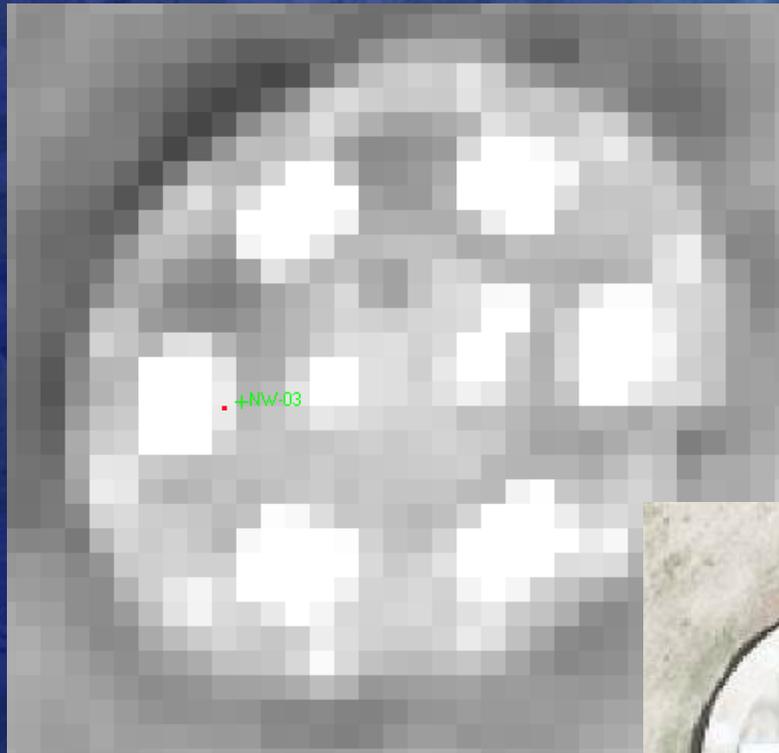


supplied-RPCs

corrected-RPCs



Comparison of Supplied-RPCs and Corrected-RPCs in Object-to-Image Projection



supplied-RPCs

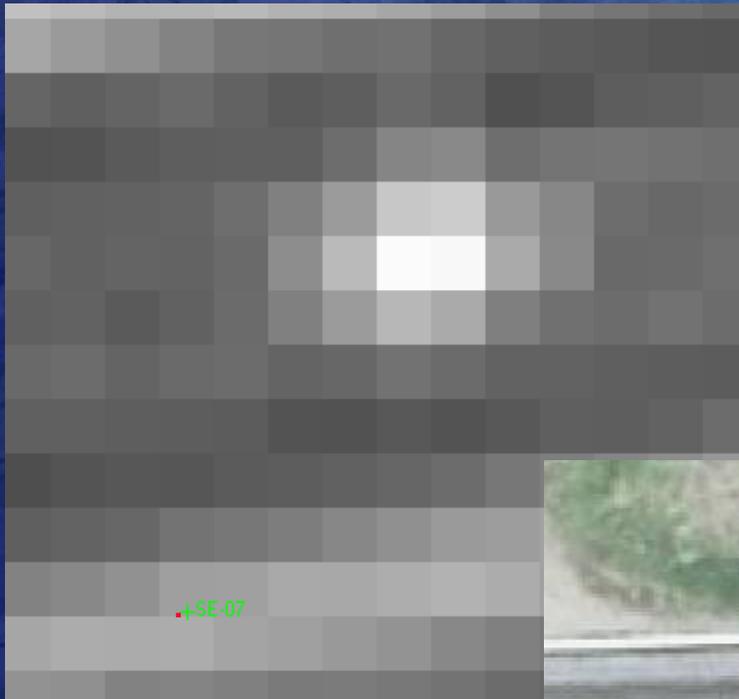


corrected-RPCs

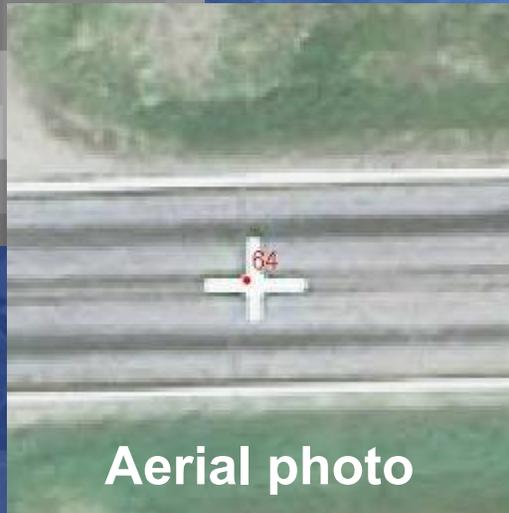


Aerial photo

Comparison of Supplied-RPCs and Corrected-RPCs in Object-to-Image Projection



supplied-RPCs



Aerial photo



corrected-RPCs



Geolocation Accuracy using Corrected RPCs

Differences between computed planimetric coordinates using corrected RPCs and GPS-survey coordinates

Mean X	0.433670
Mean Y	0.411203
Absolute Maximum X	1.247171
Absolute Maximum Y	2.401483
Absolute Minimum X	0.024330
Absolute Minimum Y	0.004213
RMSE X	0.548703
RMSE Y	0.630789

Unit: Meter

Conclusions

- The geolocation errors using supplied RPCs is around 3m in both X and Y directions, well within the product geolocation accuracy specification
- It is possible to use GCPs to correct the errors in the supplied RPCs, and thus improving the geolocation accuracy
- With 6 GCPs, 0.5m and 0.6m geolocation accuracy in X and Y have been achieved in Sioux Falls test site
- Measurement of some GCP image coordinates may not be very precise. Higher geolocation accuracy can be expected with better quality image measurement
 - Worldview-friendly GCPs are needed
- Tests should be conducted in wider areas with large terrain variations

Next Steps

- Incorporate these adjustments into the stereo pair and create 3-D DTM
- Compare data derived from stereo to multiple overlapping lidar flights & range data
- Compare features using extraction algorithms derived from Worldview-1 stereo to features derived airborne and terrestrial lidar derivations
- Assess feasibility of using Worldview-1 stereo data to provide objective source for airborne lidar calibration/validation