System & Product Characterization

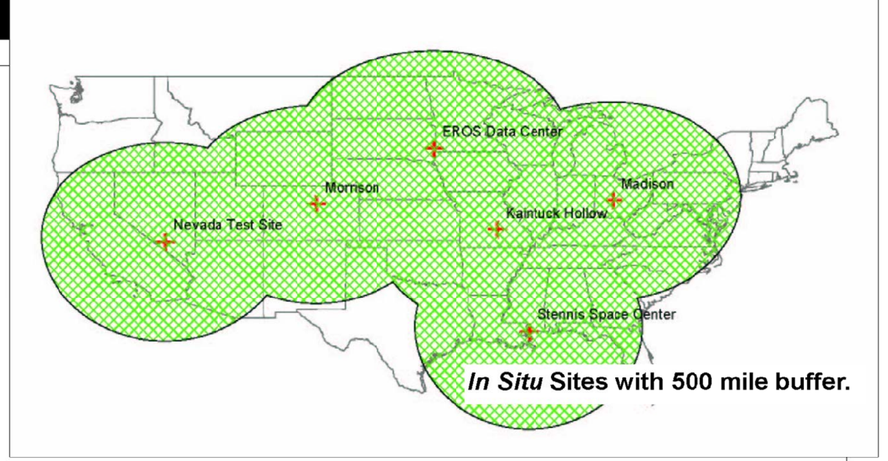
Poster compiled by Phil Rufe, USGS, (prufe@usgs.gov), (573) 308-3540

Issues

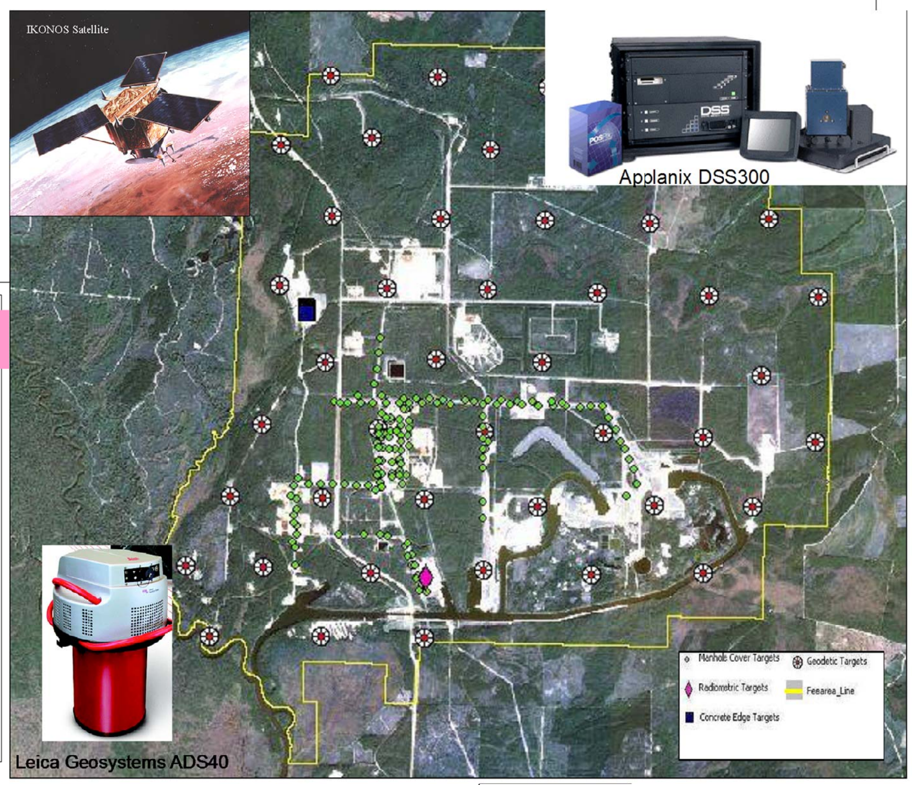
- USGS failure to be prepared for digital cameras resulted from:
  - Lack of experience with digital cameras
  - Lack of instrumentation to continue calibrations
  - Lack of upgrade strategy from analog to digital
  - Lack of standards and policies
- Inability to perform laboratory calibration on small format digital cameras
- Different designs of digital cameras
- Different hardware/software solutions
- Integration of cameras with other systems such as IMU and airborne-GPS equipment

Approach

- Transition from laboratory calibration to identifying and characterizing sources of error in the imaging system. Ensure the integrity of data by verifying and validating the data products produced by the imaging systems. If the product meets the requirements/ specifications, accept it.
- USGS endorses using *in situ* techniques to characterize imaging systems to identify and estimate errors.
- *In situ* techniques to calculate geometric, spatial, and radiometric system characteristics exist.
- Existing *In Situ* Ranges
  - Stennis (Geometric, Spatial, Radiometric)
  - EDC (Geometric, Spatial)
  - Ohio DOT (Geometric)
  - DOE Nevada Test Site (Geometric)
  - Morrison (Geometric)
  - Kaintuck Hollow (Geometric)



In Situ Sites with 500 mile buffer.



Geometric Approach

$$\text{Easting Delta} = \Delta X = X_{input} - X_{control}$$

$$\text{Northing Delta} = \Delta Y = Y_{input} - Y_{control}$$

$$\text{Number of Input Targets Used for Image Characterization} = n$$

These equations may be found in FGDC-STD-007.3-1998

- Locations of geodetic targets and manhole covers identified in the imagery are compared to "true" locations of the targets
- Positional differences are calculated from the ground truth data to the same points in the image being evaluated
- From these differences statistics are calculated
- The following equations should be used if there is negligible bias present in the dataset.

$$RMSE_x = \sqrt{\sum \frac{(\Delta X)^2}{n}} \qquad CE_{90} = \frac{2.1460}{2}(RMSE_x + RMSE_y)$$

$$RMSE_y = \sqrt{\sum \frac{(\Delta Y)^2}{n}} \qquad CE_{95} = \frac{2.4477}{2}(RMSE_x + RMSE_y)$$

$$RMSE_{net} = \sqrt{RMSE_x^2 + RMSE_y^2}$$

The BIAS Zone

Determining if bias is negligible requires calculating bias and standard deviation, and then diving the bias by the standard deviation: μ_x/σ_c

To calculate standard deviation (random error):

$$\text{Easting Standard Deviation} = \sigma_X = \sqrt{\frac{\sum(\Delta X - \mu_X)^2}{(n-1)}}$$

$$\text{Northing Standard Deviation} = \sigma_Y = \sqrt{\frac{\sum(\Delta Y - \mu_Y)^2}{(n-1)}}$$

$$\text{Standard Deviation Min/Max Ratio} = \frac{\min(\sigma_X, \sigma_Y)}{\max(\sigma_X, \sigma_Y)}$$

$$\text{Total Standard Deviation} = \sigma_C = \frac{\sigma_X + \sigma_Y}{2}$$

To calculate bias:

$$\text{EastingBias} = \mu_x = \frac{\sum \Delta X}{n}$$

$$\text{NorthingBias} = \mu_Y = \frac{\sum \Delta Y}{n}$$

$$\text{TotalBias} = \mu_H = \sqrt{(\mu_X)^2 + (\mu_Y)^2}$$

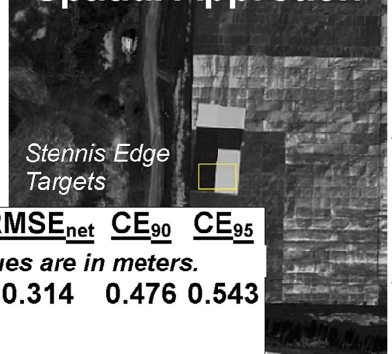
If $\mu_x/\sigma_c > 0.1$, then bias is not negligible and these empirical equations should be used

$$\text{Total Delta} = \Delta R = \sqrt{(\Delta X)^2 + (\Delta Y)^2}$$

$$\text{Empirical } CE_{90} = 90\%\{\Delta R\}$$

$$\text{Empirical } CE_{95} = 95\%\{\Delta R\}$$

Spatial Approach



- Spatial parameters measure the resolving power of an imaging system. They are influenced by the quality of the lens, the size of the individual CCD detector, and processing of the imagery.
- Spatial Quality is described by parameters like Modulation Transfer Function (MTF), Ground Sample Distance (GSD), Instantaneous Field of View, Ground Sample Interval
- MTF can be determined through Point Spread Function, Line Spread Function, or Relative Edge Response

Geometric Results

Sensor	Operator	Product Ground Sample Distance	μ_H/σ_c	$RMSE_x$	$RMSE_y$	$RMSE_{net}$	CE_{90}	CE_{95}
DSS 300	Emerge	0.3m	0.27	0.23	0.214	0.314	0.476	0.543
DAIS	Space Imaging	0.5m	0.22	0.35	0.33	0.048	0.73	0.83
ADS40	EarthData Int'l	0.25m	1.36	0.2	0.02	0.29	0.43	0.49
IKONOS	Space Imaging	1.0m	2.60	1.24	1.09	1.65	2.28	2.53

*RMSE and CE values are in meters.

Spatial Results

Sensor	Band	RER Easting	RER Northing	RER Average
DAIS	Blue	0.89	0.8	0.8
	Green	0.88	0.63	0.8
	Red	0.49	0.44	0.5
	Near-Infrared	0.64	0.83	0.7
IKONOS	Panchromatic	0.85	0.65	0.8
ADS40	Blue	0.37	0.41	0.4
	Green	0.53	0.57	0.6
	Red	0.60	0.48	0.5
	Near-Infrared	0.58	0.65	0.6
	Panchromatic	0.47	0.51	0.5
DSS 300	RER not calculated due to image saturation.			

Relative Edge Response (RER) is a geometric mean of normalized edge response differences measured in two directions of image pixels (X and Y) at points distanced from the edge by -0.5 and 0.5 GSD:

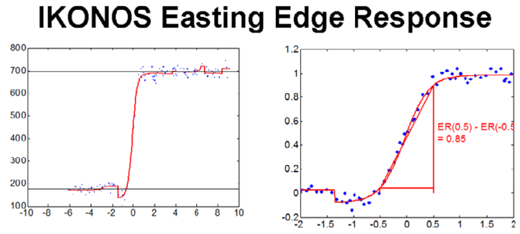
$$RER = \sqrt{[ER_X(0.5) - ER_X(-0.5)][ER_Y(0.5) - ER_Y(-0.5)]}$$

RER Notes

RER is a parameter utilized in the General Image Quality Equation (GIQE). GIQE uses RER and other parameters to calculate a National Image Interpretability Rating System value for an image.

RER is sensitive to resampling of the image and to non-linear radiometric responses in the sensor.

IKONOS Easting Edge Response



IKONOS Northing Edge Response