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Geometric Assessment Summary: Lidar, DEM and Satellite data

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U.S. Department of the Interior
U.S. Geological Survey

Outline

- Data Assessment
  - Geiger and Sigma Space Lidar
  - Vricon DEM
  - RapidEye
  - Deimos-2
- Geometric Assessment Methodologies
- Results
- Summary

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Geiger Mode and Sigma Space Lidar data

- Analysis of data only
  - Sensor independent
  - Perhaps some inferences on the processes
- Geometric Accuracy
  - Accuracy of derived features and not so much individual points
  - Comparison with USGS Lidar data and
- Visual comparisons
- Surface variability analysis

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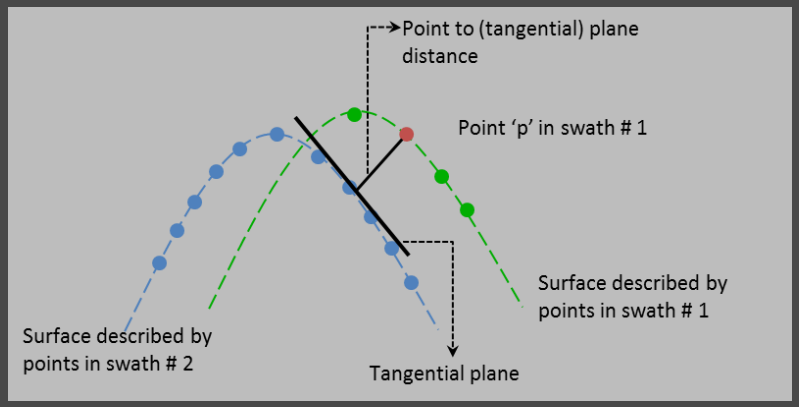
Geometric accuracy analysis

- Analysis with GCPs has been performed by Dewberry and Woolpert
- Comparison with conventional lidar data
- Uniformly select check points in Geiger Mode/Sigma Space data
  - Select single return areas for measurement
  - Check on conventional lidar data
- Select neighboring points in conventional lidar data
- Fit Plane to neighboring points
- Measure Point-to-Plane distance (including sign)
  - Record X,Y,Z, Nx, Ny, Nz and D



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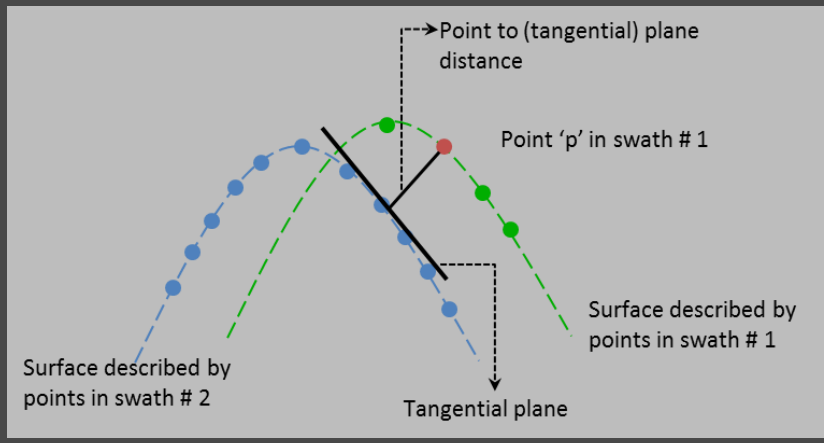
Geometric Analysis

- Vertical Accuracy
  - Use measurements flat areas: Arc cosine of Nz < 5 degrees
  - Compare the elevation values i.e. D
- Horizontal Accuracy
  - Identify measurements from higher slopes
  - Arc cosine of Nz > 10-15 degrees
  - Use least squares solvers to solve
  - $N\Delta X \quad = D$ where N= [Nx Ny Nz]
  - Obtain mean ΔX and standard deviation



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Geometric Analysis

- Geiger-Conventional Lidar
  - dH: Mean -0.07 and RMSD 0.07
  - Mean dX and dY: -0.11 and 0.18 respectively with low standard deviation
- Sigma Space- Conventional
  - dH: Mean -0.10 and RMSD 0.11
  - Mean dX and dY: 0.15 and 0.05 respectively with low standard deviation
- Quite possible that both Geiger and Sigma Space lidar data are more accurate than conventional lidar data
  - Ground based static lidar or perhaps mobile lidar data will be better for such analysis

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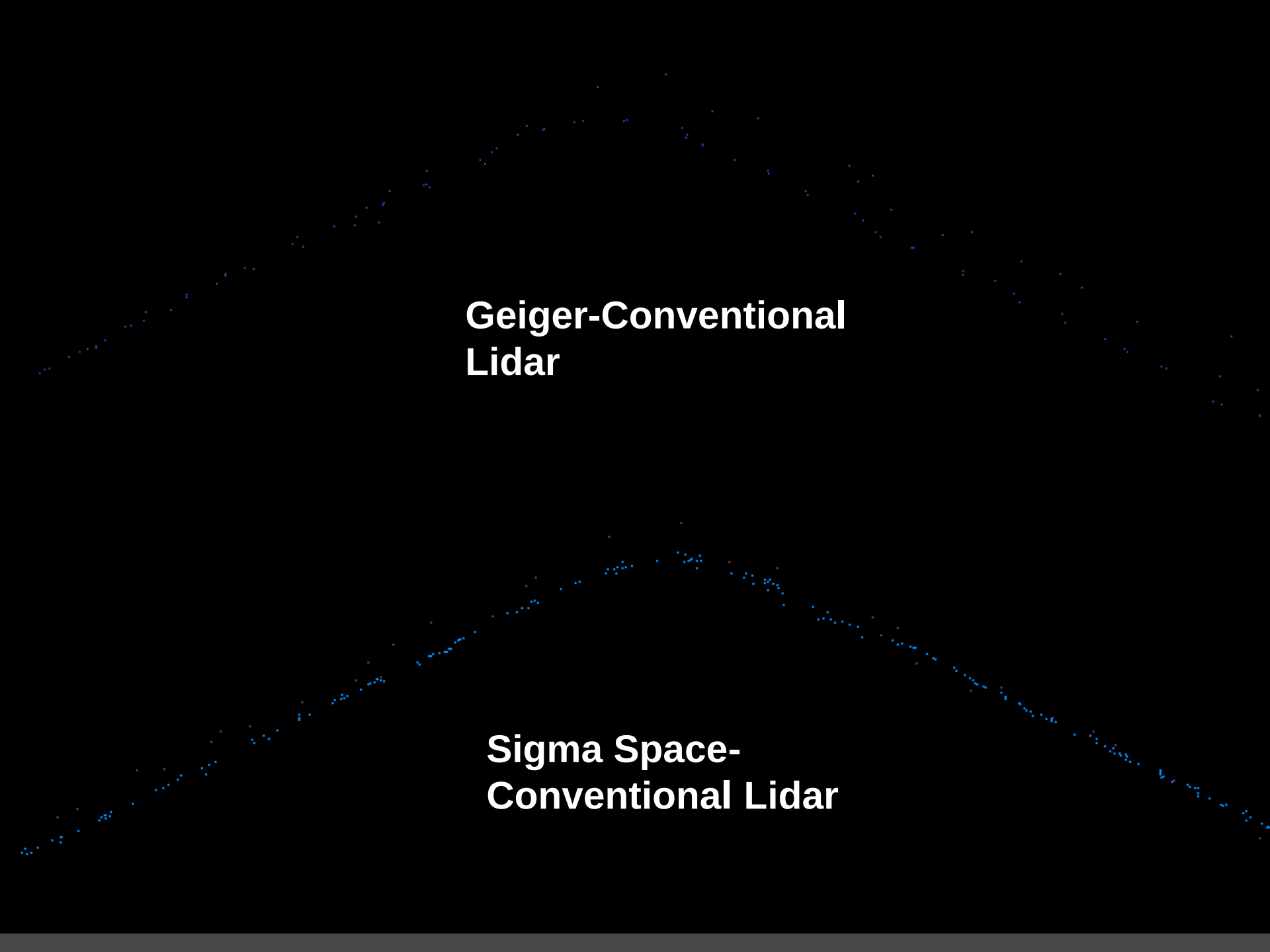
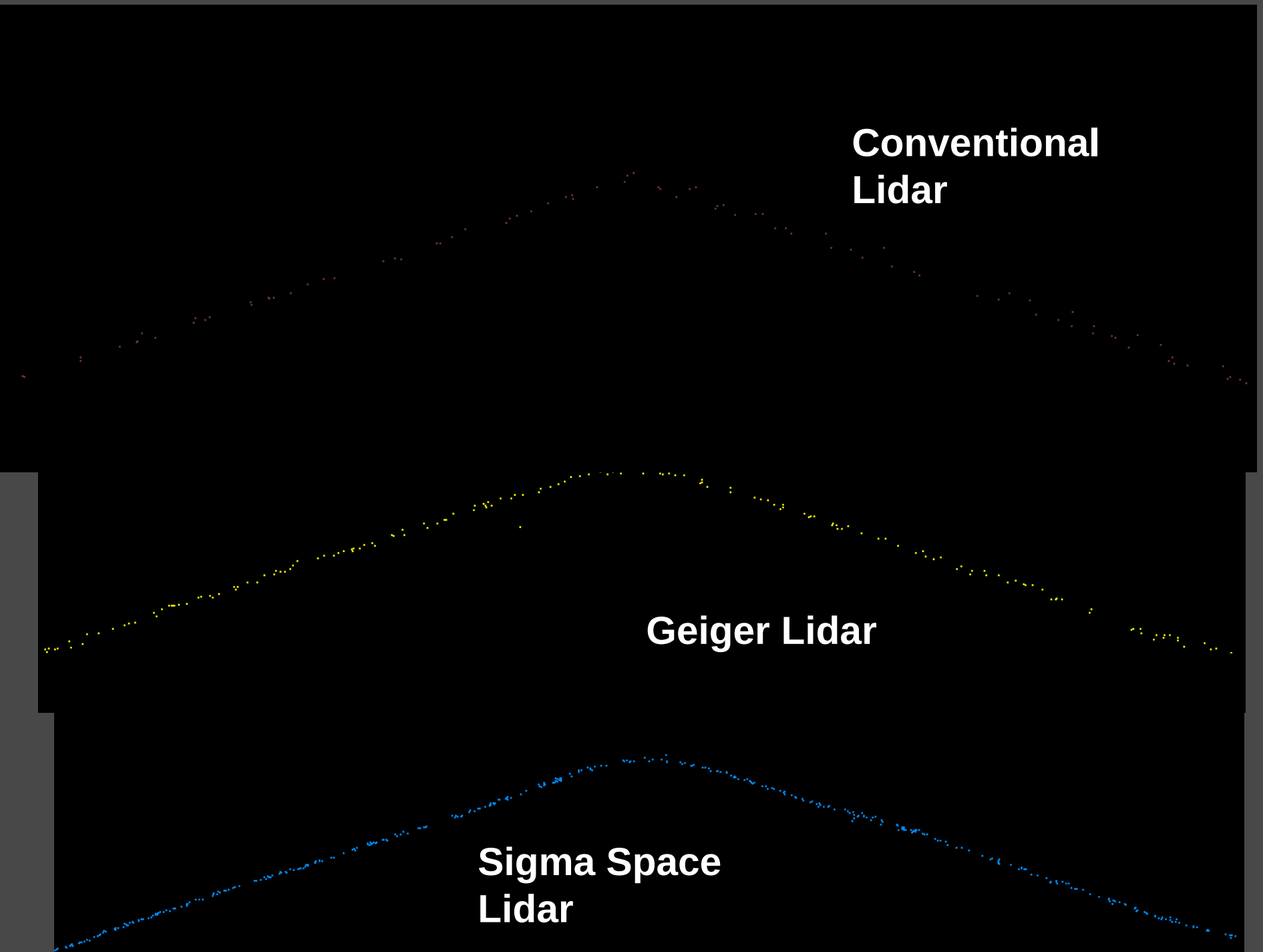
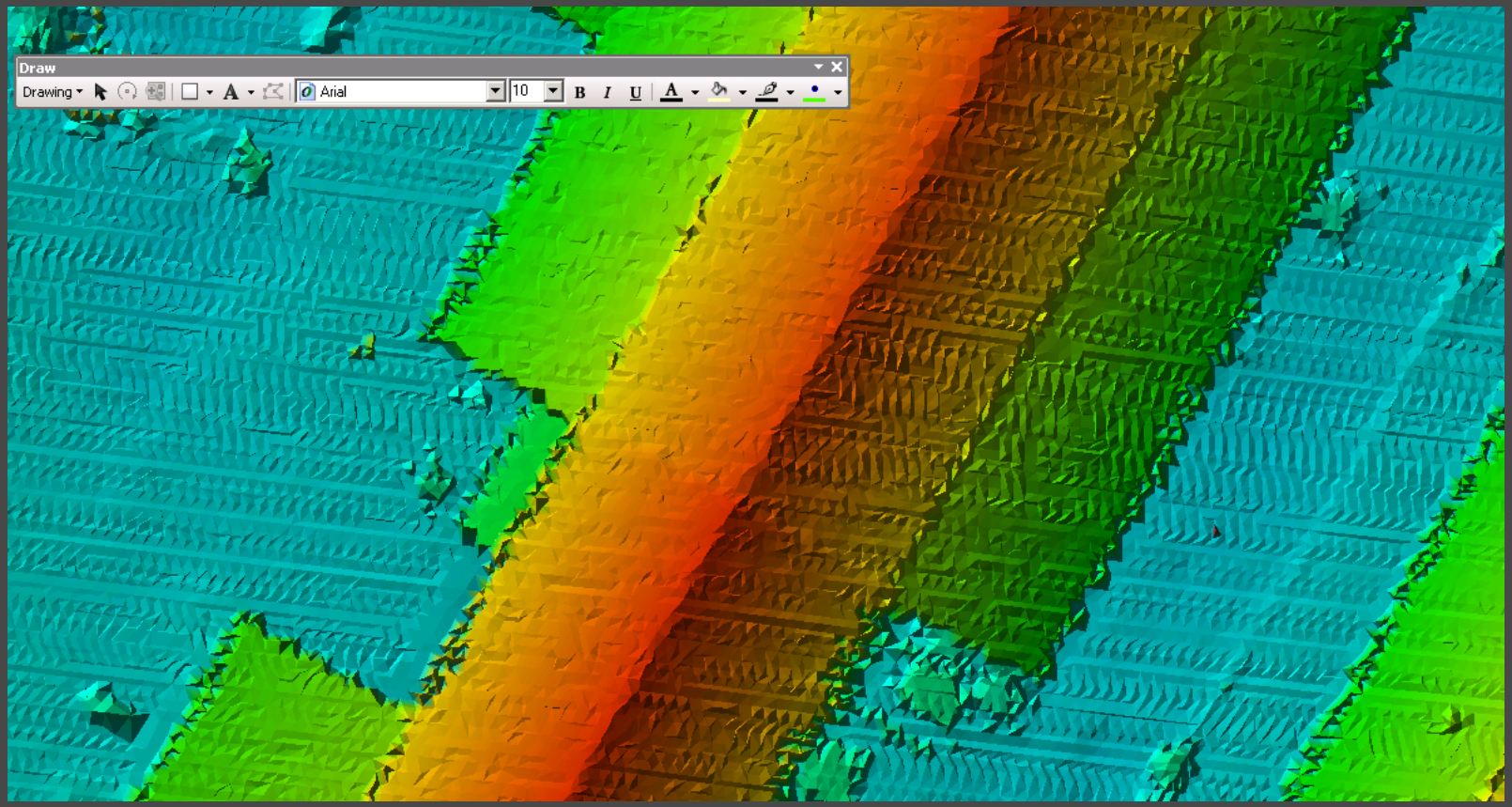

Geiger-Conventional Lidar
Sigma Space-Conventional Lidar


Conventional Lidar
Geiger Lidar
Sigma Space Lidar

Conventional Lidar DEM



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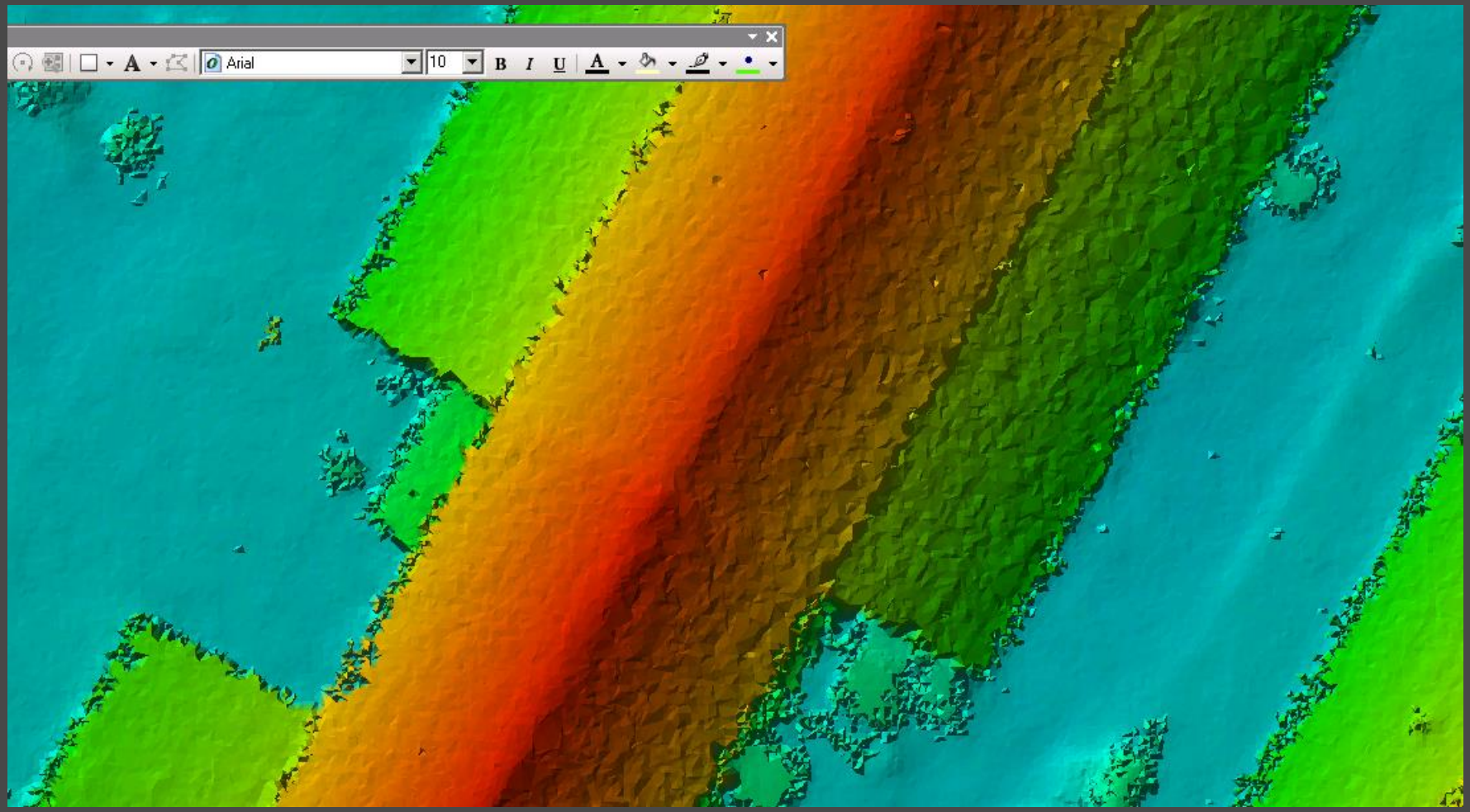
Geiger Mode DEM



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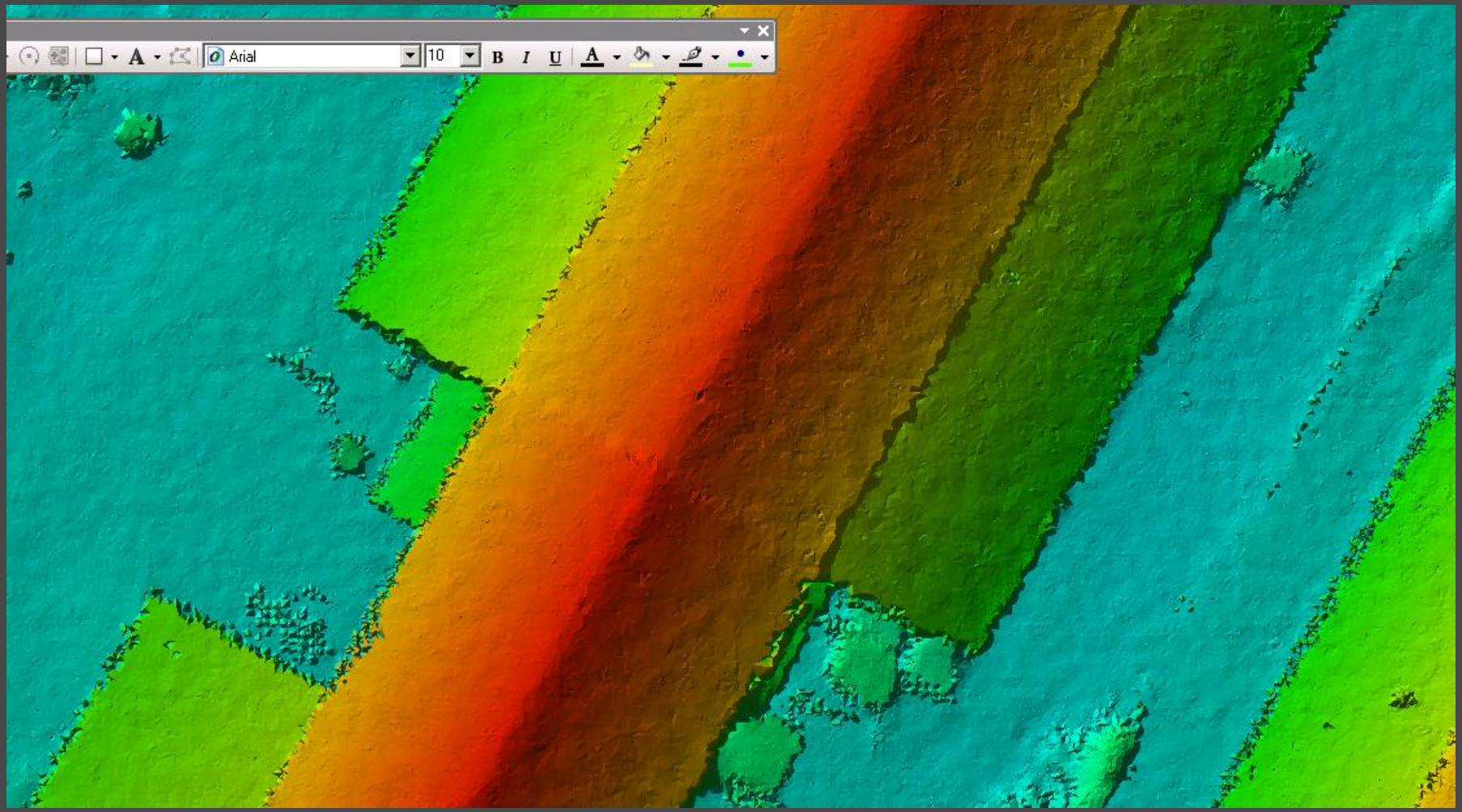
Sigma Space DEM



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Variability analysis

- Analysis similar to PCA
  - Select locations uniformly
  - Gather points in neighborhood
  - Generate covariance matrix and determine eigen values $\lambda_1, \lambda_2, \lambda_3$ $where$ $\lambda_1 > \lambda_2 > \lambda_3$
  - Calculate λ_3 as measure of variability

	Mean	SD
Geiger Mode	9.40E-04	0.28
Sigma Space	5.01E-04	0.37
Conventional Lidar	0.0014	0.53

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Vricon DEM Analysis

- Digital Surface Model over Palmer, Alaska provided by Digital Globe
- Data in UTM and heights are ellipsoidal
- Generated from multi-image nominally 50 cm resolution satellite imagery
- Reference Data
  - **Lidar data in state plane and elevation were orthometric**
  - **Reference data were converted to match Vricon DSM**

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Vricon DEM Analysis

- Spot Heights over
  - Clear and open areas
  - Sloping surfaces (building roof)
  - Linear surfaces like roads
- Mean of -0.27 m and SD of 1.69 m
- Some points to ponder:
  - Matches very well in clear and open areas (< 40 cm)
  - Sloping areas have higher differences
  - Discrepancy appears near trees etc.
    - Probably due to satellite look angles
  - Horizontal errors need to be checked further
    - Appears to be within the 1.5 m of Lidar
    - Lidar may not be horizontally accurate

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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**

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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.
-

$$CC(l,s) = \left(\sum_{i,j} (I_R(i,j) - \bar{I}_R)(I_S(i,j) - \bar{I}_S) \right) \Big/ \left(\sqrt{\sum (I_R - \bar{I}_R)^2} \sqrt{\sum (I_S - \bar{I}_S)^2} \right)$$

- 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.

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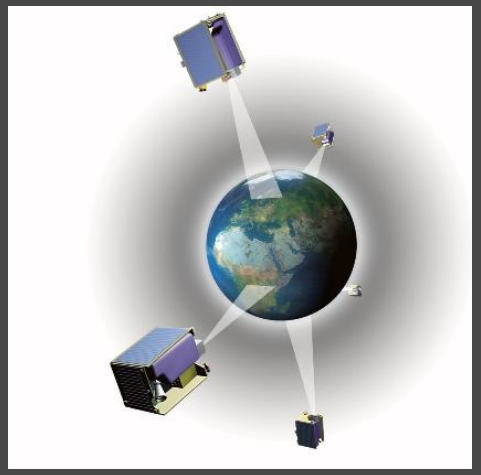
RapidEye Overview



- Over 60 datasets 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) and rail Road Valley
- Reference data: Orthoimagery

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Rapid Eye Analysis

- Analysis of 45 data sets over Sioux Falls, Pueblo and Rail Road Valley
- Band registration and absolute accuracy analysis
- Pueblo: 15 images

	Line	Sample	RMSE L	RMSE S
Average	-0.39	-0.59	0.50	0.64
StdDev	0.37	0.20	0.30	0.17
Range	-1.23	-0.78	-0.91	-0.68

- Sioux Falls:35 images

	Line	Sample	RMSE L	RMSE S
Average	-0.65	0.34	0.68	0.49
StdDev	0.42	0.34	0.41	0.22
Range	-1.79	-1.26	-1.72	-0.76

- RVPN: Band registration checks only
  - All bands registered to less than 0.1 pixels except band 5, which was 0.15 pixels

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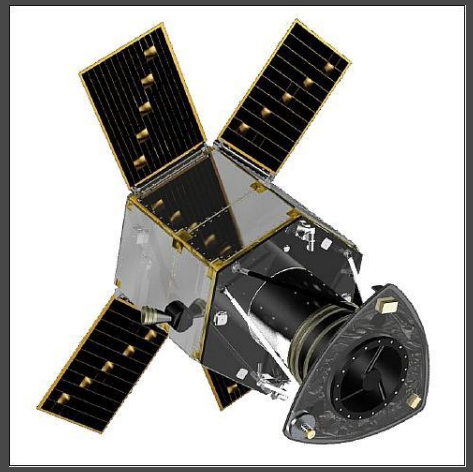
Deimos-2

- Three datasets from Urthecast
  - **DC, Alaska and Sioux Falls**
  - Sioux Falls data set analyzed for accuracy
- Reference data: Orthoimagery and Ground Control Points over Sioux Falls only
- Over 60 Check points and GCPs used for the analysis



	Line	Sample
Mean	0.79	0.81
Standard Deviation	1.83	1.08
RMSE	1.98	1.35

	Line	Sample
Mean	1.07	0.35
Standard Deviation	1.76	1.25
RMSE	2.05	1.29

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Continuing Analysis

- Deimos-2
  - MTF and Spatial Resolution analysis
- Planet Labs
  - Geometric, Radiometric and Spatial Resolution analysis
- Vricon DEM
  - Further Analysis of “what to expect?”
  - Spatial resolution tests
- More Collaboration!
  - Please contact me at asampath@usgs.gov
  - Or Greg Stensaas at stensaas@usgs.gov

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