

Emerging Surveying and Mapping Technologies

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OSBEELS Symposium

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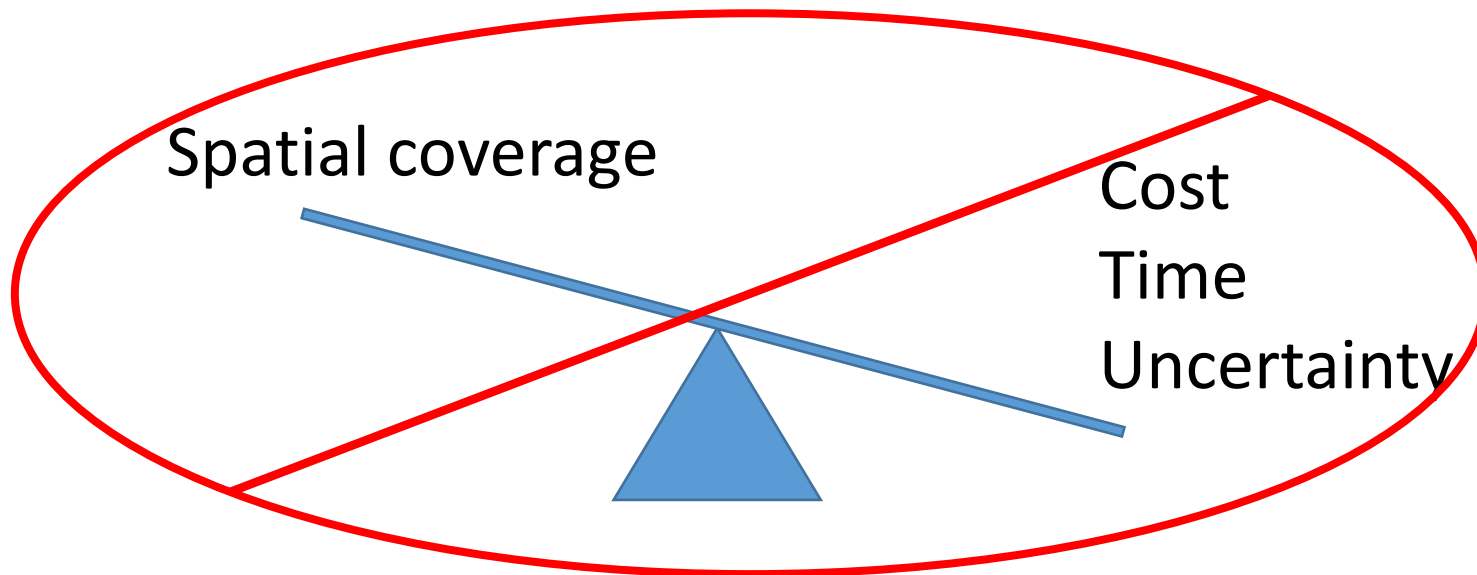
Salem, Oregon

“Boots-on-the-ground” field surveys



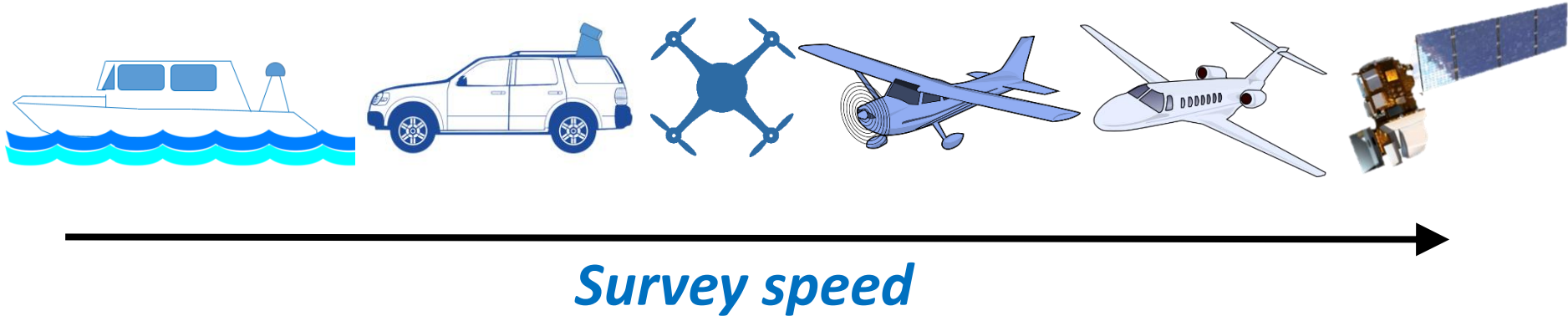
Desired improvements

Spatial coverage (area)	↑
Time	↓
Cost	↓
Spatial uncertainty	↓



Can't be done, due to inherent tradeoffs between these goals!

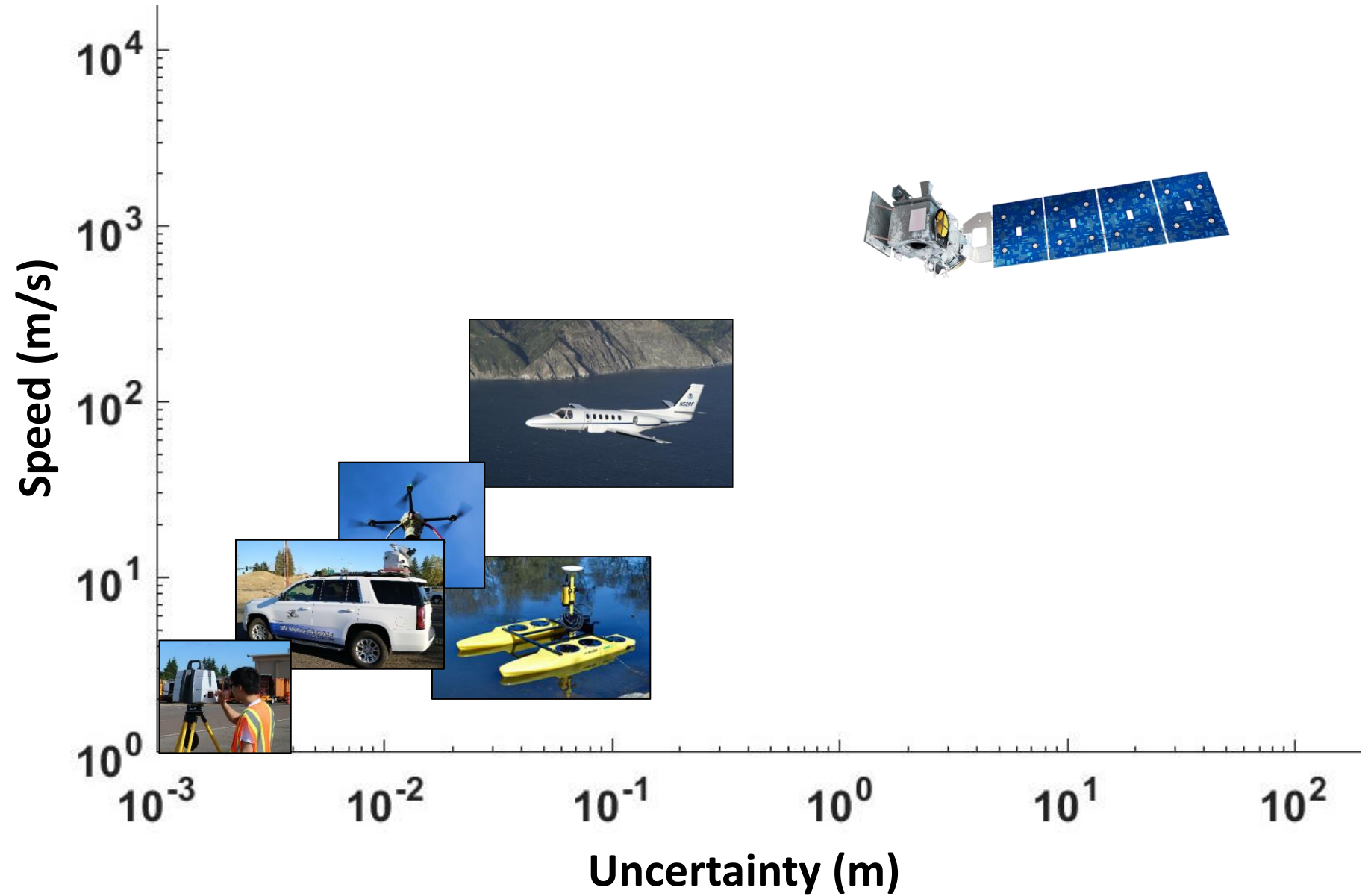
Alternative: moving survey platform



- Nearly certain to cover more ground quickly
- What's the tradeoff? Accuracy
- Objective function:

$$\min\{cost + time\}$$
$$\text{subject to } \{accuracy \leq spec\}$$

Inherent Tradeoffs



Emerging tools & technologies

- Autonomous/unmanned vehicles
 - UAS, ASVs, ROVs
 - UAS-based lidar and Structure from Motion (SfM) photogrammetry
- Direct georeferencing: GNSS-aided INS
 - Smaller, cheaper, lighter carrier-base based GNSS and MEMS INS
- New advances in airborne and mobile lidar
 - Single photon and Geiger mode lidar
 - Topographic-bathymetric lidar
 - Satellite-based lidar
- *How do we quantitatively assess, compare, and optimize for our operational use?*

UAS + SfM Photogrammetry

- SfM
 - Relatively new photogrammetric approach
 - Leverages advanced image matching algorithms from the field of computer vision
 - Can work with a wide range of viewing geometries and consumer-grade cameras
 - *Well suited to UAV imagery!*
 - Highly automated, easy to use software



SfM Workflow

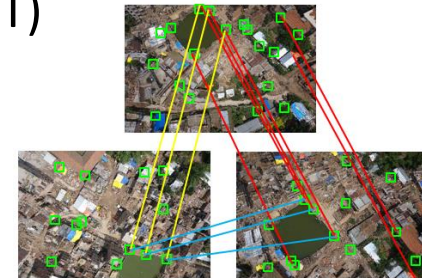
UAS flight(s)



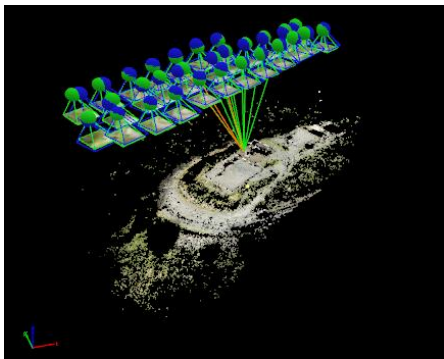
Overlapping imagery
(~80% endlap & sidelap)



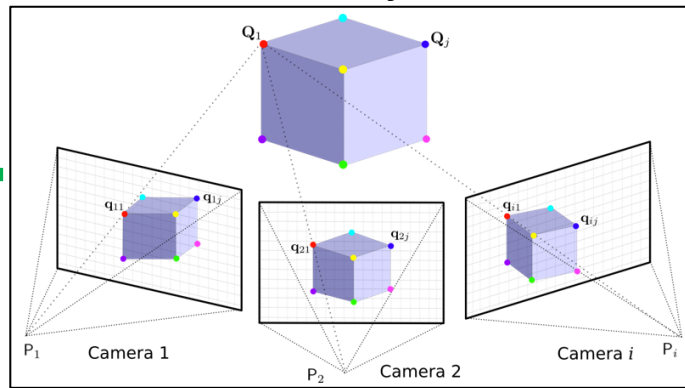
Keypoint computation
& matching (e.g.,
SIFT)



Sparse point cloud



Bundle adjustment

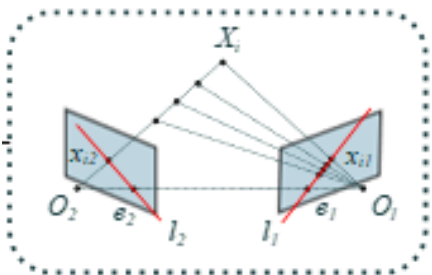


GCPs

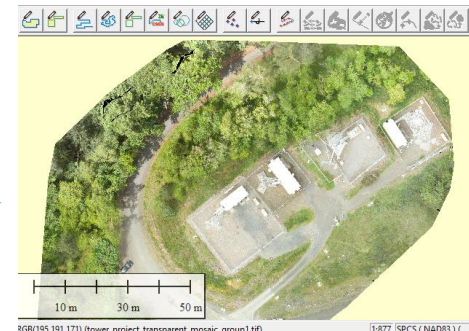


Camera
params (IO)

MVS



Dense point cloud



End products: orthos,
DEMs, 3D meshes

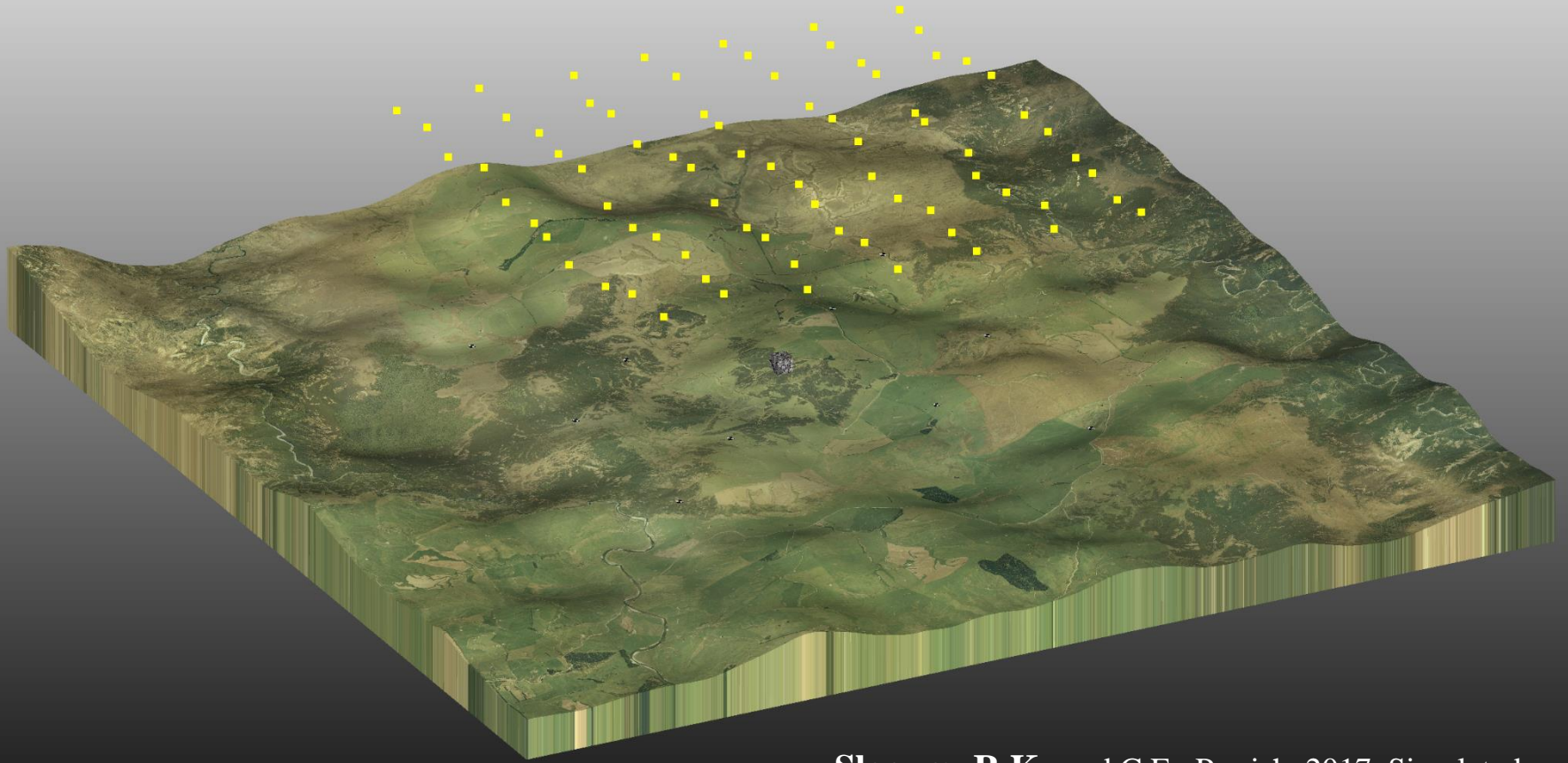
Empirical accuracy assessments, per *ASPRS Positional Accuracy Standards for Digital Geospatial Data & FGDC NSSDA*



$$RMSE_z = \sqrt{\frac{\sum (z_{datai} - z_{checki})^2}{n}}$$

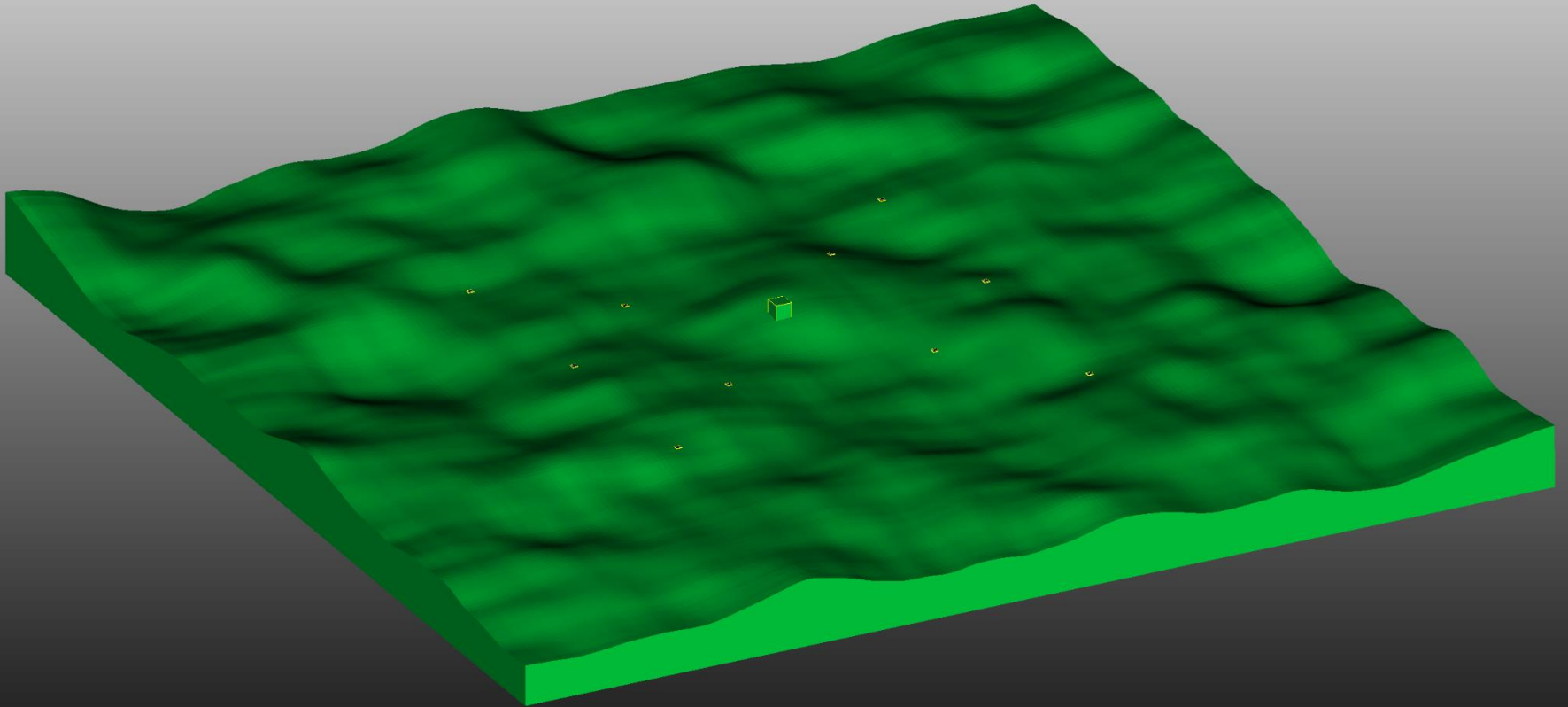
$$Accuracy_z = 1.96(RMSE_z)$$

simUAS

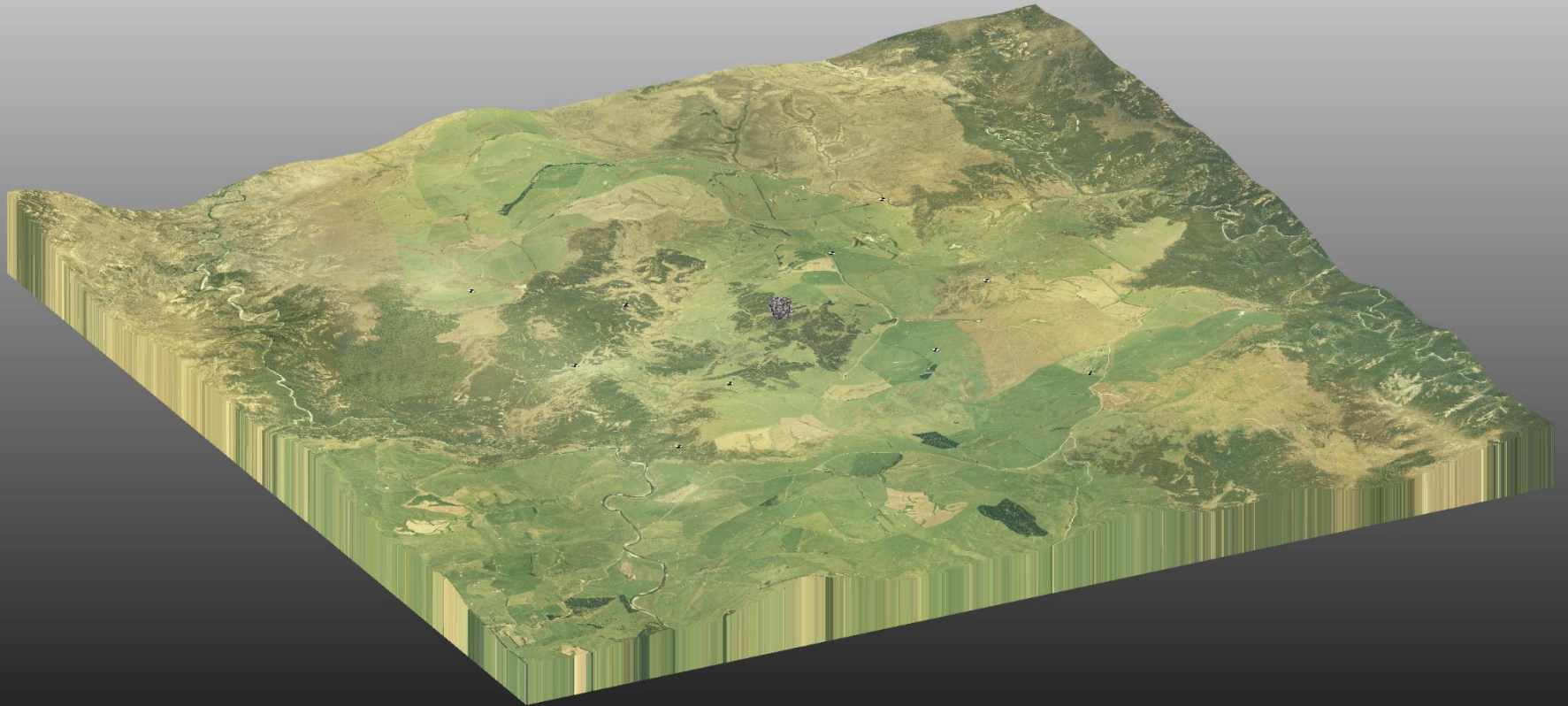


Slocum, R.K., and C.E., Parrish, 2017. Simulated Imagery Rendering Workflow for UAS-Based Photogrammetric 3D Reconstruction Accuracy Assessments. *Remote Sensing*, Vol. 9, No. 4:396.

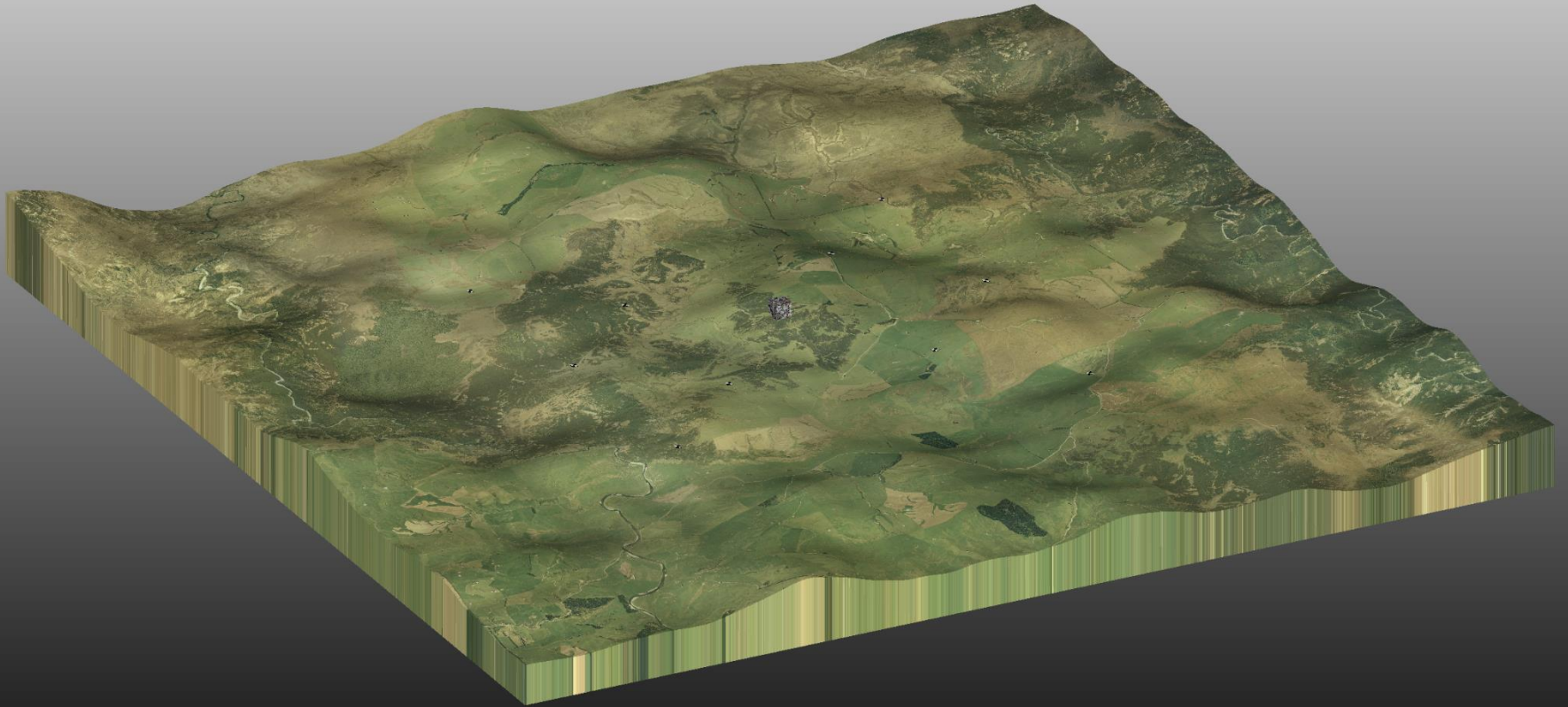
1. Generate Model



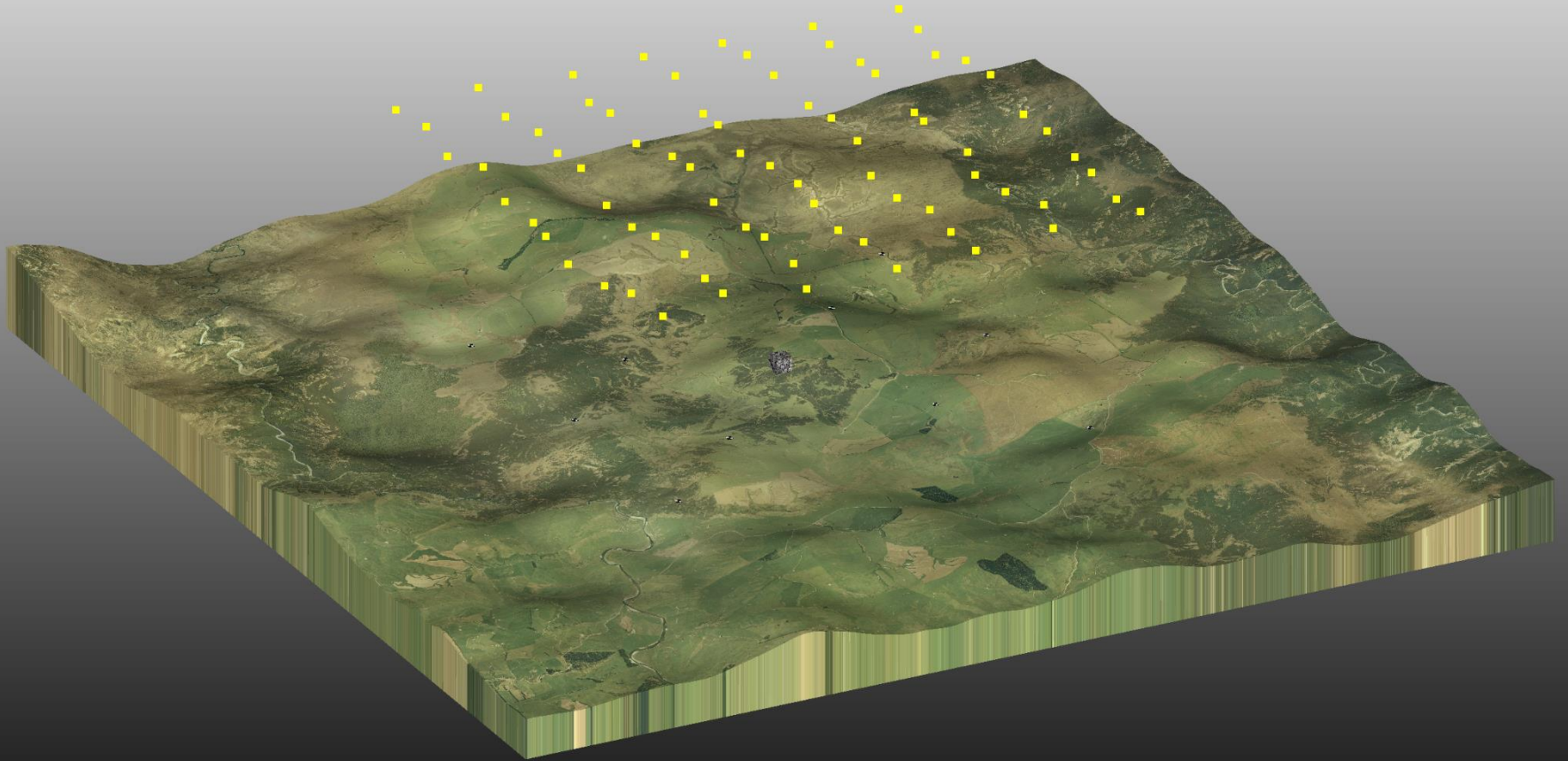
2. Texture Model



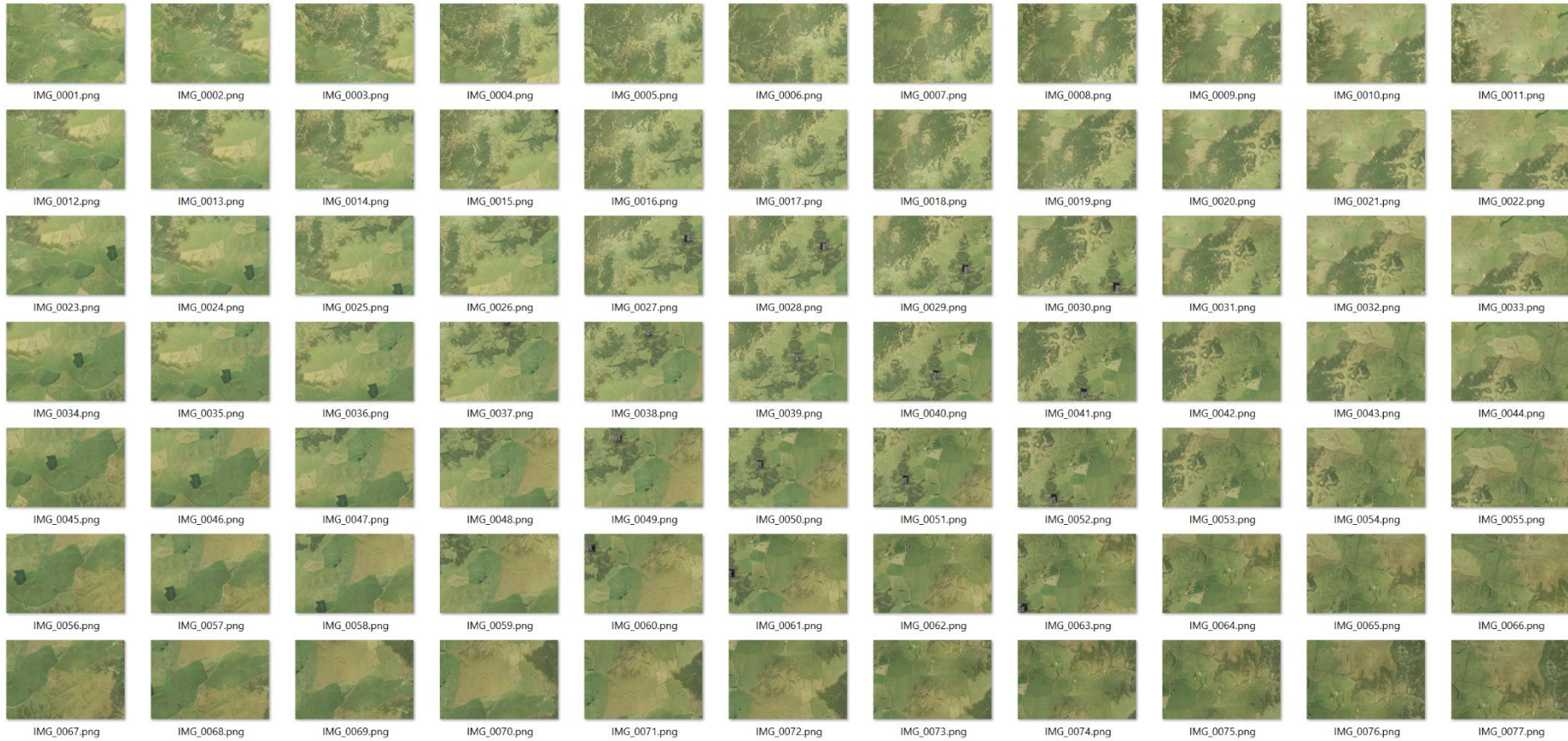
3. Add Lighting to Scene



4. Add Cameras

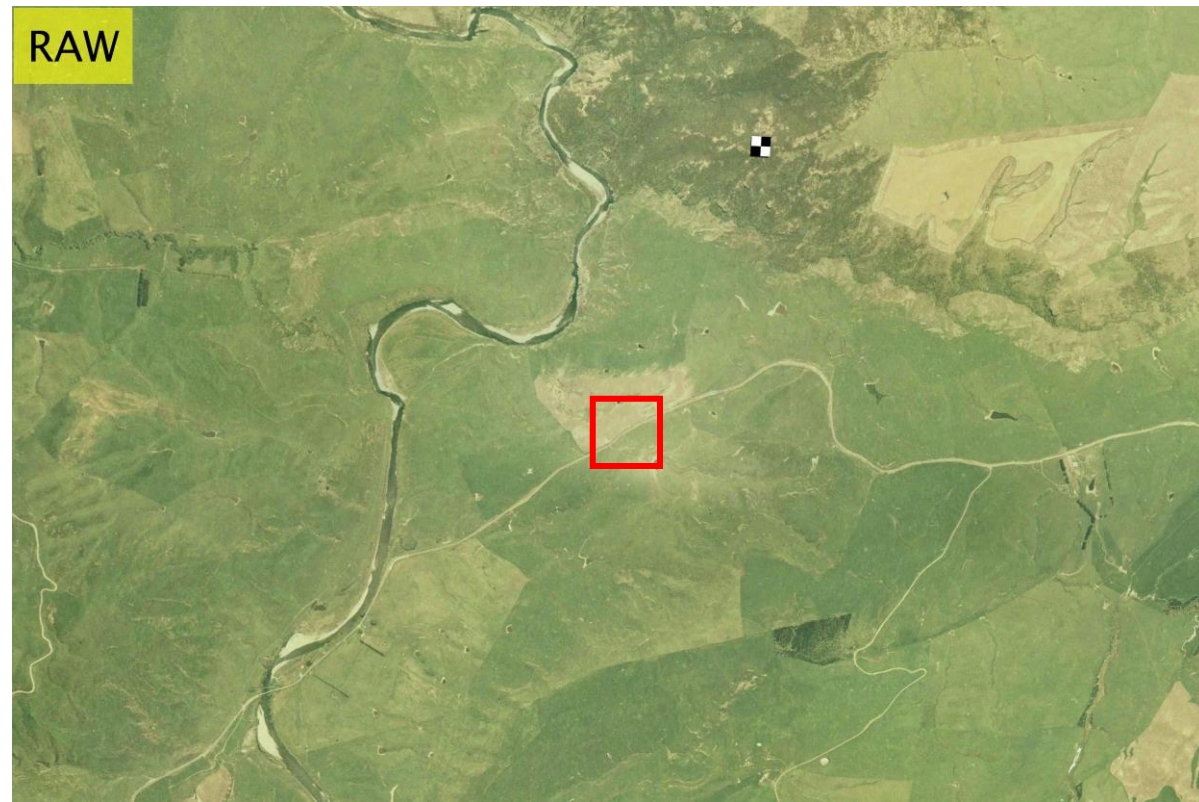


5. Render Imagery



6. Postprocess Imagery

- Lens Distortion
- Vignetting
- Gaussian Noise
- Salt/Pepper Noise
- Gaussian Blur



7. Process Using Commercial SfM

The screenshot displays a commercial Structure from Motion (SfM) software interface. The central 3D view shows a point cloud of a landscape with a grid of ground control points (GCPs) overlaid. The GCPs are labeled with coordinates and names, such as GCP1 through GCP10. The interface includes a 'Reference' table on the left, a 'Markers' table, a 'Scale Bars' section, and a 'Photo' panel on the right showing a grid of image files.

Camera	X (m)	Y (m)	Z (m)	Accuracy (m)
IMG_000...	48.320784	50.454148	43.312332	10.000000
IMG_000...	49.426807	40.505460	43.826699	10.000000
IMG_000...	49.939984	31.310981	41.624821	10.000000
IMG_000...	51.873206	21.113197	41.553313	10.000000
IMG_000...	51.867682	11.096209	42.995930	10.000000
IMG_000...	49.273761	2.661762	41.686266	10.000000
IMG_000...	49.659272	7.604056	41.546622	10.000000
IMG_000...	49.772246	15.790145	44.840250	10.000000
IMG_000...	50.726181	27.610932	42.180960	10.000000
IMG_001...	49.256513	38.779729	42.996879	10.000000
IMG_001...	50.922475	47.172296	43.500416	10.000000
IMG_001...	35.278869	47.199774	43.948151	10.000000
IMG_001...	34.088996	38.617223	42.694633	10.000000
IMG_001...	33.779063	30.050944	43.730736	10.000000
IMG_001...	34.832095	20.356033	43.449179	10.000000
IMG_001...	34.374816	10.911092	41.151220	10.000000
IMG_001...	34.577832	1.672043	41.389633	10.000000
IMG_001...	34.270401	0.824067	44.236221	10.000000
IMG_001...	34.938302	10.214203	43.020803	10.000000
IMG_002...	33.117171	27.875711	43.204299	10.000000
IMG_002...	34.810304	36.935995	42.558574	10.000000

Marker	X (m)	Y (m)	Z (m)	Accuracy (m)
GCP01	40.000000	40.000000	2.000000	0.050000
GCP02	40.000000	0.000000	1.000000	0.050000
GCP03	40.000000	0.000000	1.300000	0.050000
GCP04	20.000000	20.000000	0.100000	0.050000
GCP05	20.000000	20.000000	1.600000	0.050000
GCP06	20.000000	20.000000	1.600000	0.050000
GCP07	20.000000	20.000000	-0.300000	0.050000
GCP08	40.000000	-40.000000	-0.700000	0.050000
GCP09	40.000000	0.000000	0.500000	0.050000
GCP10	40.000000	40.000000	-0.500000	0.050000

Total Error

Distance (m)	Accuracy (m)	Error (m)
0.000000	0.000000	0.000000

Scale Bars

Distance (m)	Accuracy (m)	Error (m)
0.000000	0.000000	0.000000

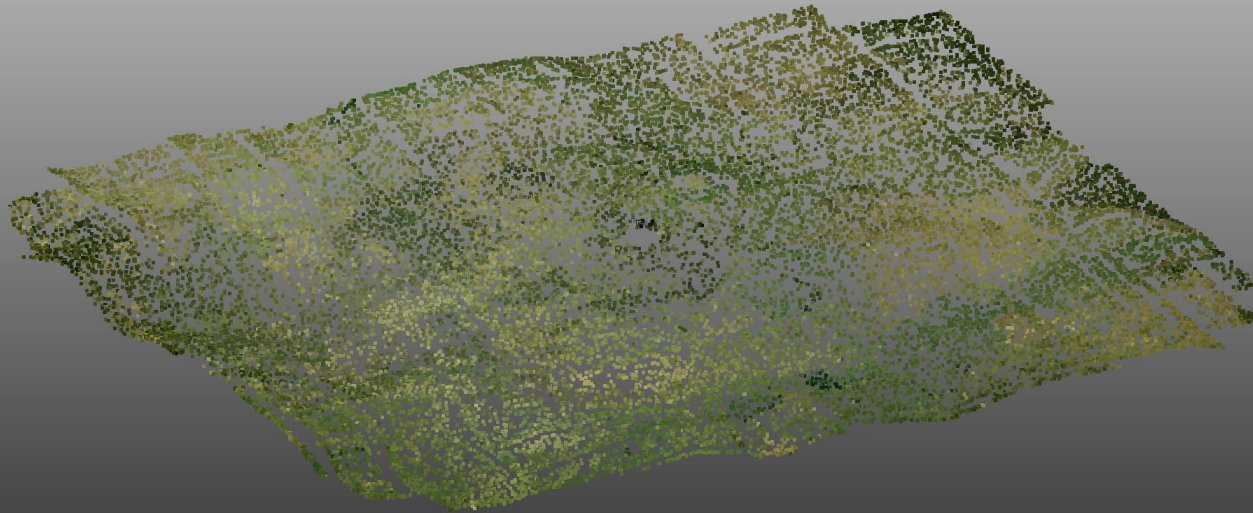
Photo

- IMG_0001.png
- IMG_0002.png
- IMG_0003.png
- IMG_0004.png
- IMG_0005.png
- IMG_0006.png
- IMG_0007.png
- IMG_0008.png
- IMG_0009.png
- IMG_0010.png
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- IMG_0029.png
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- IMG_0042.png
- IMG_0043.png
- IMG_0044.png
- IMG_0045.png
- IMG_0046.png
- IMG_0047.png
- IMG_0048.png
- IMG_0049.png
- IMG_0050.png
- IMG_0051.png
- IMG_0052.png
- IMG_0053.png
- IMG_0054.png
- IMG_0055.png
- IMG_0056.png

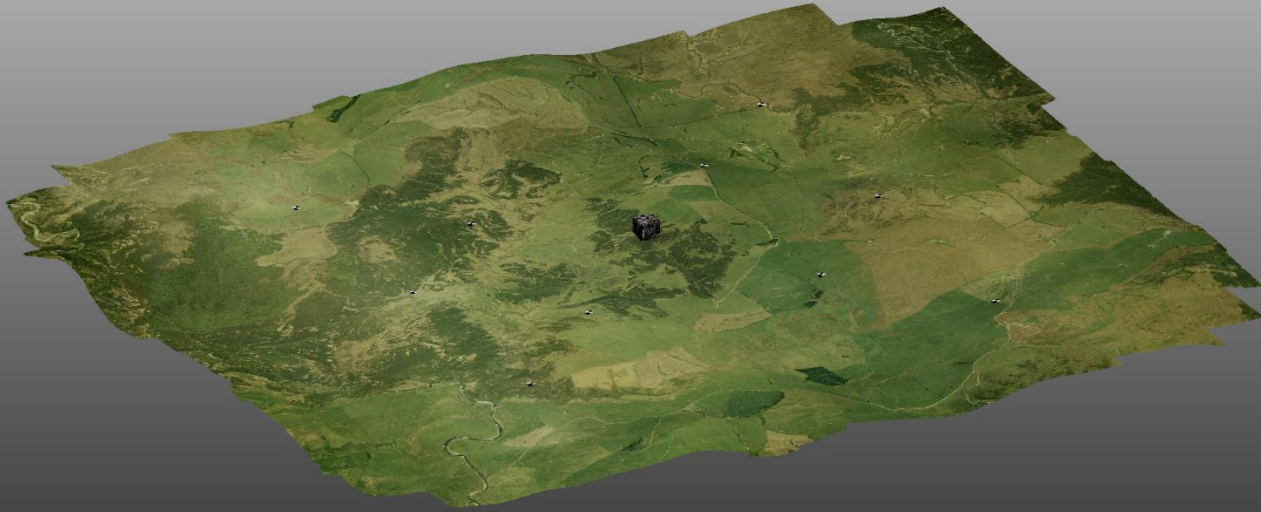
Console

```
2018-02-08 11:17:10 [CPU] estimating 766x766x16 disparity using 766x766x16 tiles
2018-02-08 11:17:11 [GPU] estimating 766x766x16 disparity using 766x766x16 tiles
2018-02-08 11:17:18 [Camera] rectify: 0.129 disparity: 2.013 borders: 0.263 fillres: 0.008 fill: 0
2018-02-08 11:17:18 [GPU] estimating 670x670x16 disparity using 670x670x16 tiles
2018-02-08 11:17:18 [Camera] rectify: 0.129 disparity: 2.048 borders: 0.263 fillres: 0.008 fill: 0
2018-02-08 11:17:18 [GPU] estimating 670x670x16 disparity using 670x670x16 tiles
2018-02-08 11:17:18 [Camera] rectify: 0.129 disparity: 2.083 borders: 0.263 fillres: 0.008 fill: 0
2018-02-08 11:17:18 [GPU] estimating 716x716x16 disparity using 716x716x16 tiles
2018-02-08 11:17:19 [Camera] rectify: 0.119 disparity: 2.011 borders: 0.262 fillres: 0.007 fill: 0
2018-02-08 11:17:19 [GPU] estimating 716x716x16 disparity using 716x716x16 tiles
2018-02-08 11:18:01 [Camera] rectify: 0.105 disparity: 2.071 borders: 0.248 fillres: 0.008 fill: 0
2018-02-08 11:18:01 [GPU] estimating 670x670x16 disparity using 670x670x16 tiles
2018-02-08 11:18:04 [Camera] rectify: 0.090 disparity: 1.982 borders: 0.218 fillres: 0.012 fill: 0
2018-02-08 11:18:04 [CPU] done: reconstruction device performance:
2018-02-08 11:18:04 [CPU] done by CPU
2018-02-08 11:18:04 [CPU] done by GPU
```

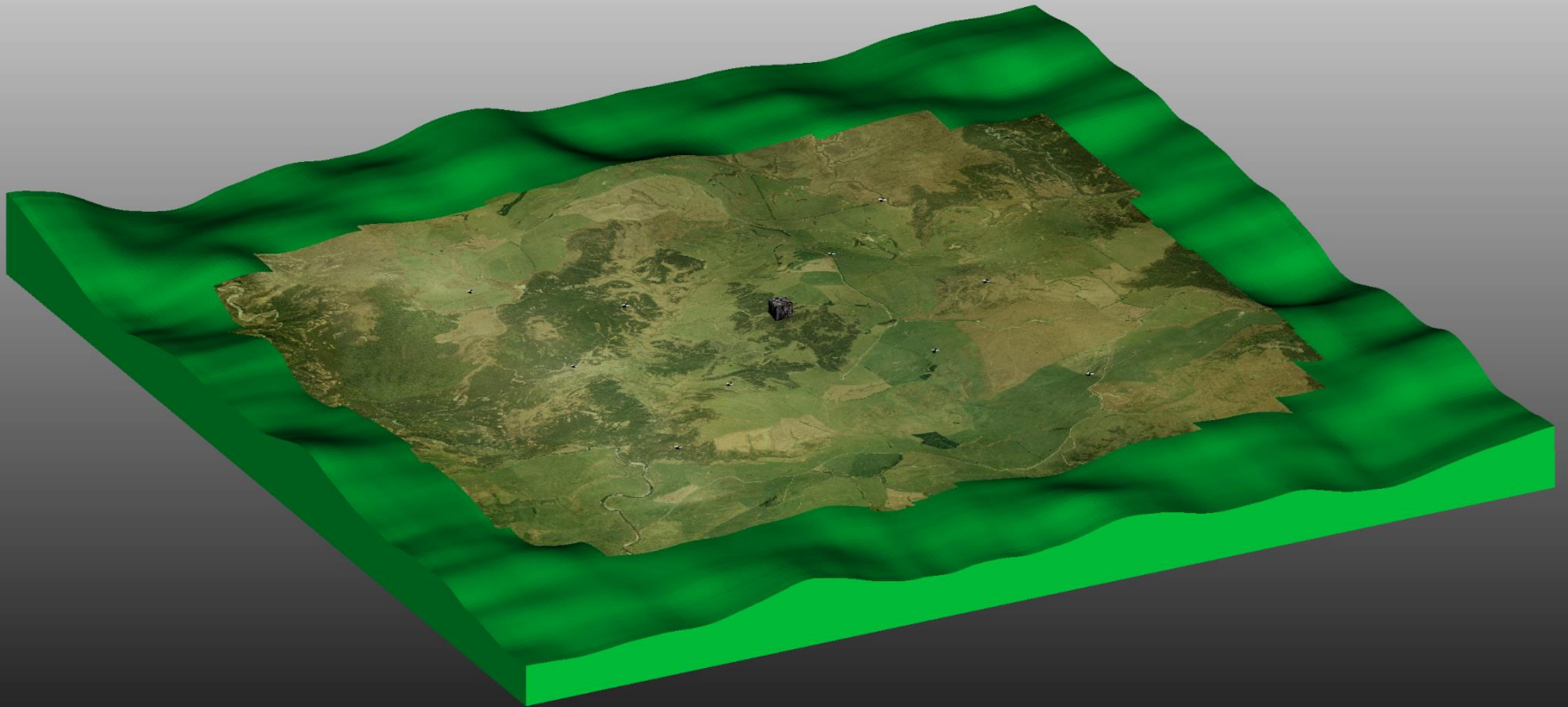
8. Generate Sparse Pointcloud



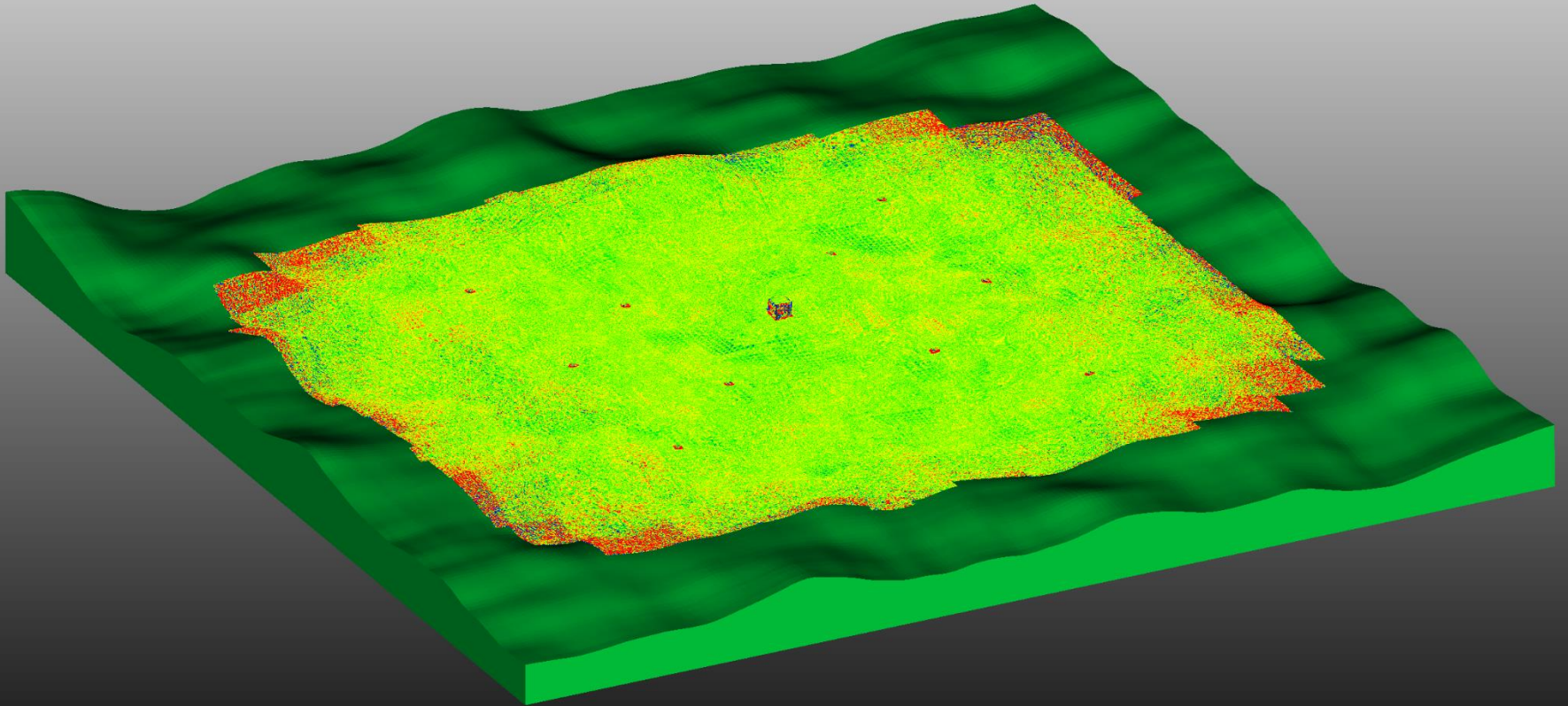
9. Generate Dense Pointcloud



10. Compare Dense Pointcloud to Mesh



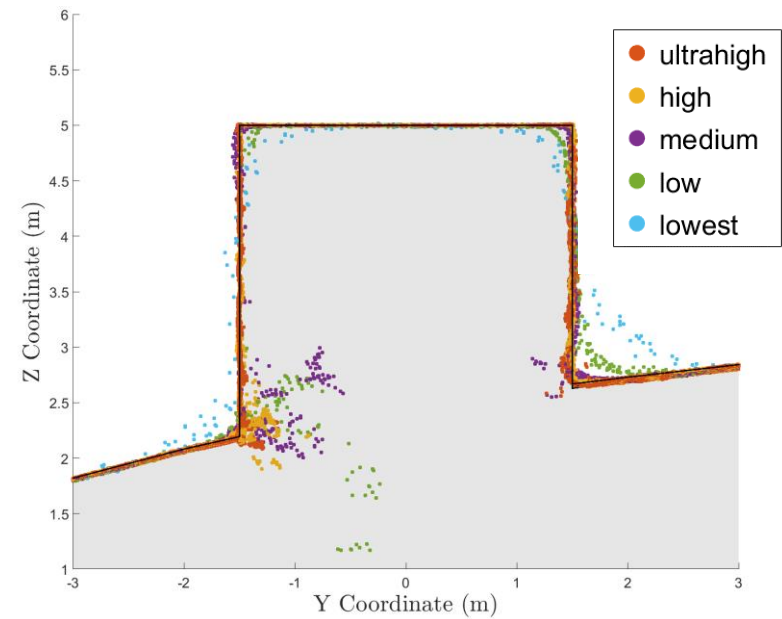
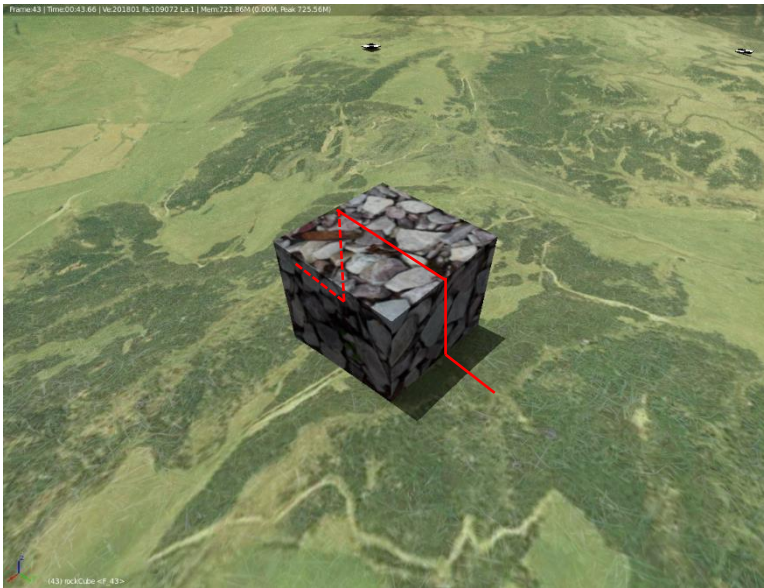
11. Compute Cloud to Mesh Distances



CloudCompare

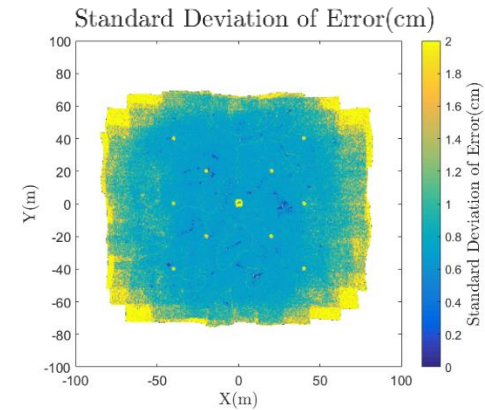
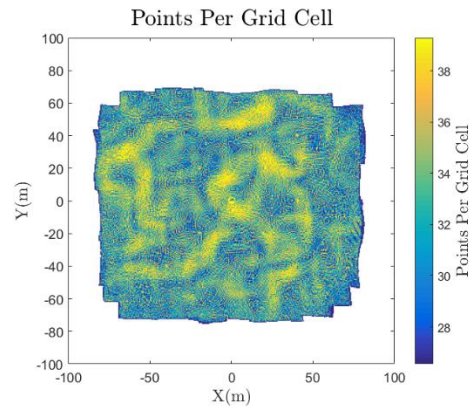
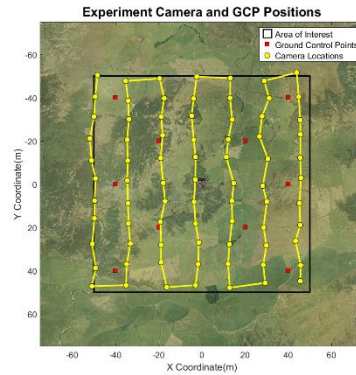
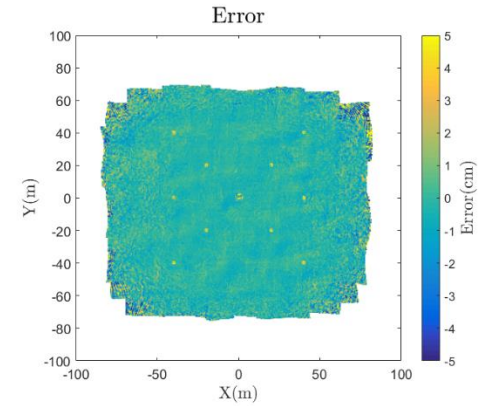
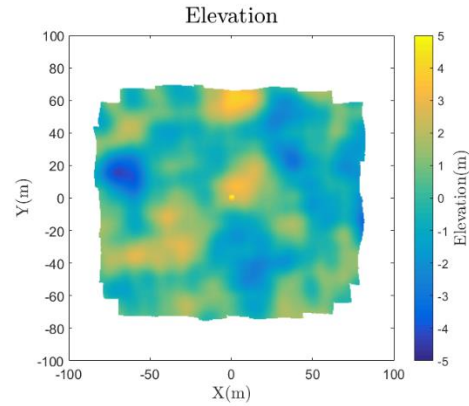
Qualitative Results

Lower Photoscan Dense Quality = round corners

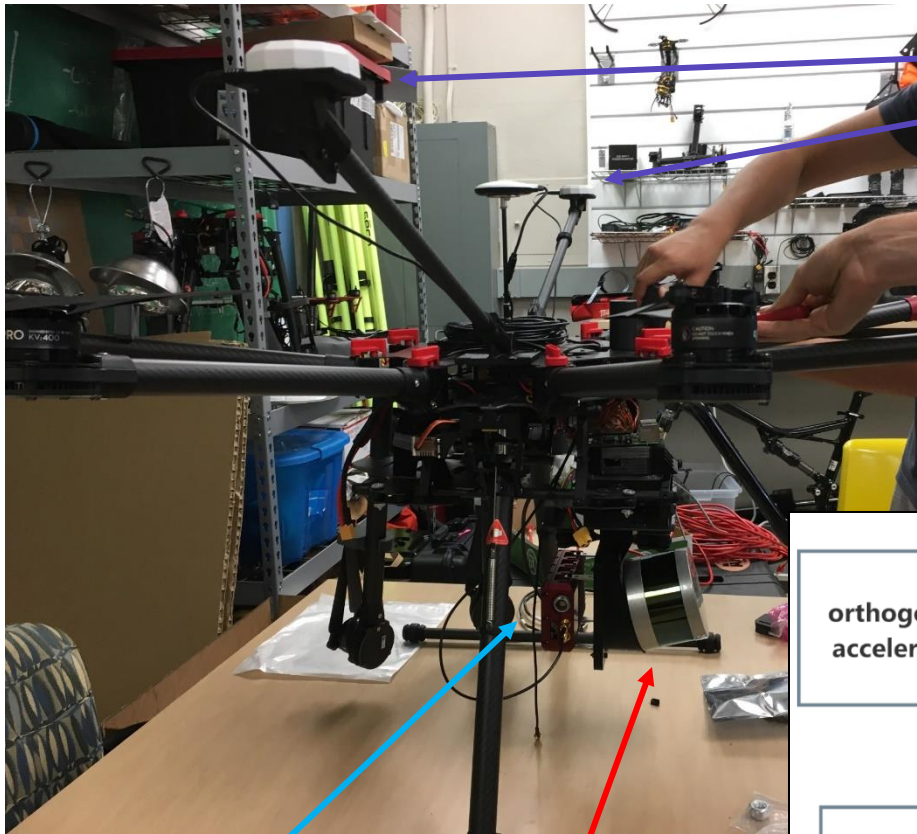


Quantitative Results

Compute error by comparing to groundtruth mesh



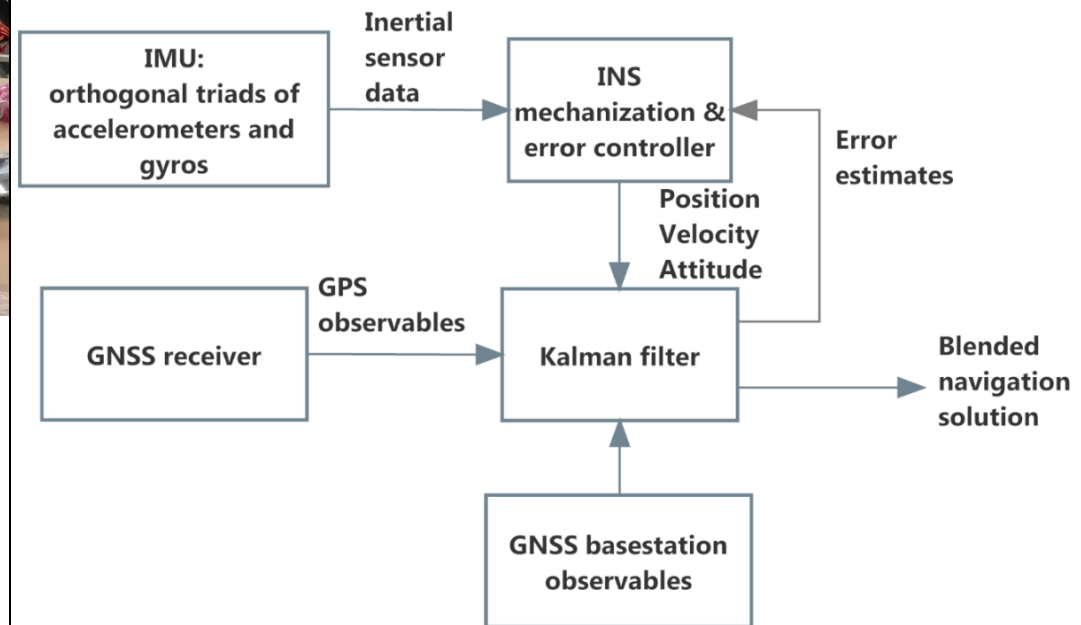
Another option: Direct Georeferencing



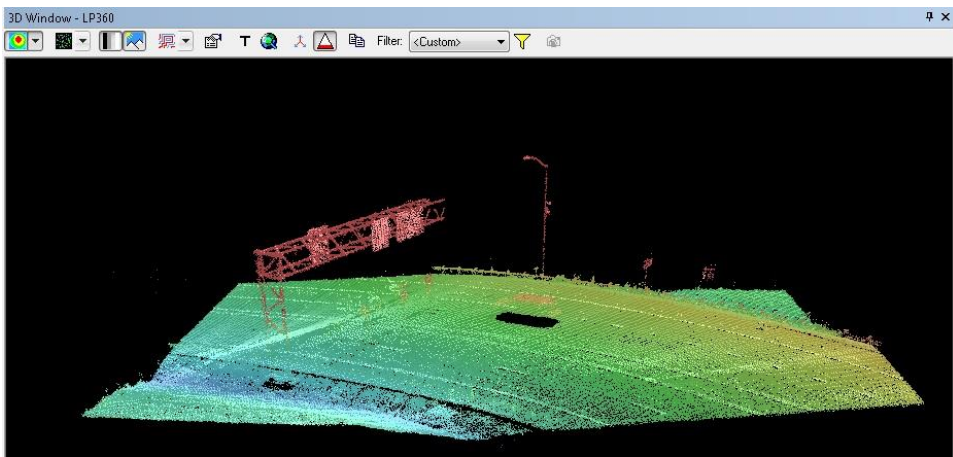
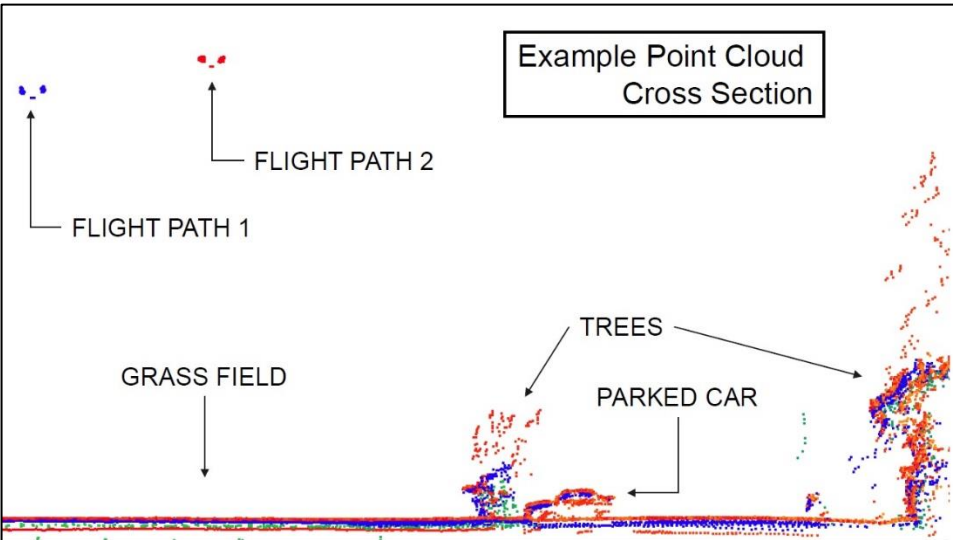
GNSS antennas

GNSS-aided
INS

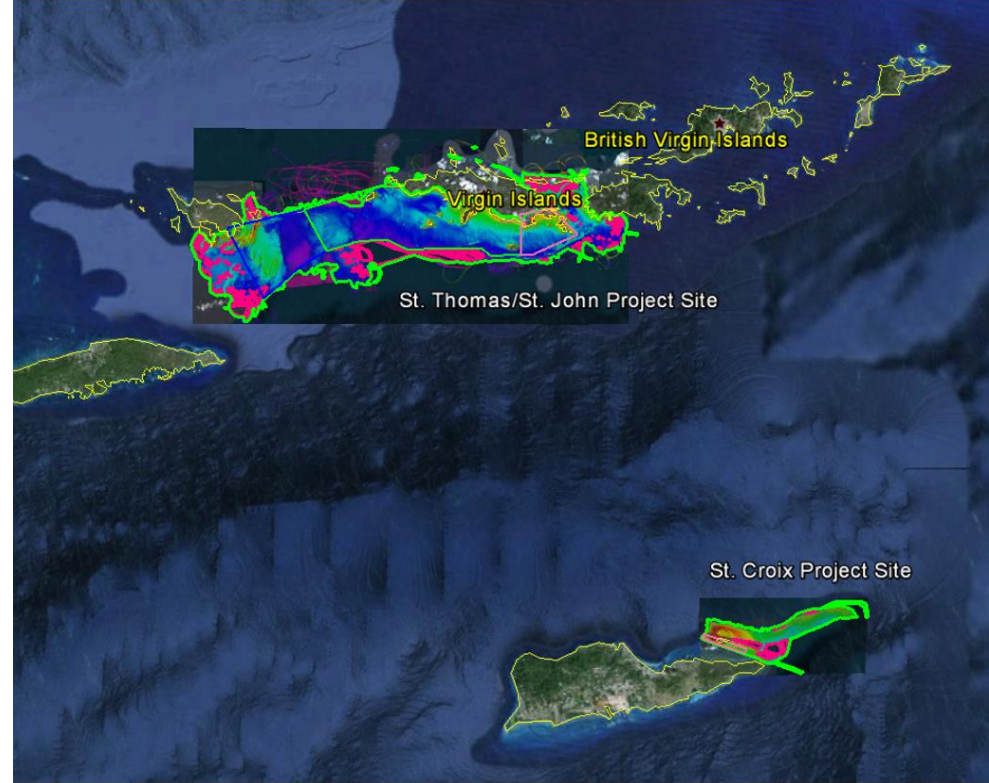
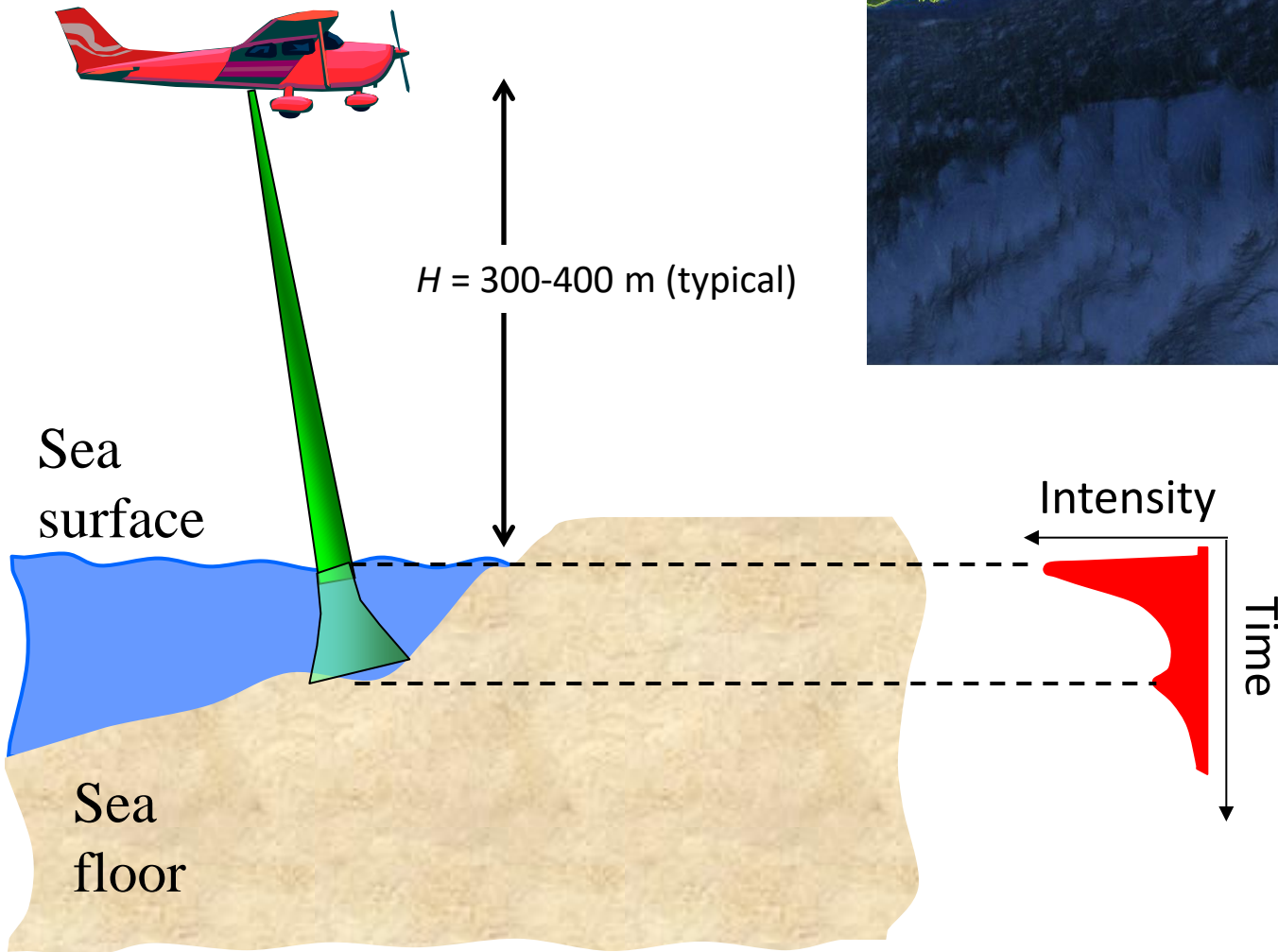
Velodyne Puck
Lidar



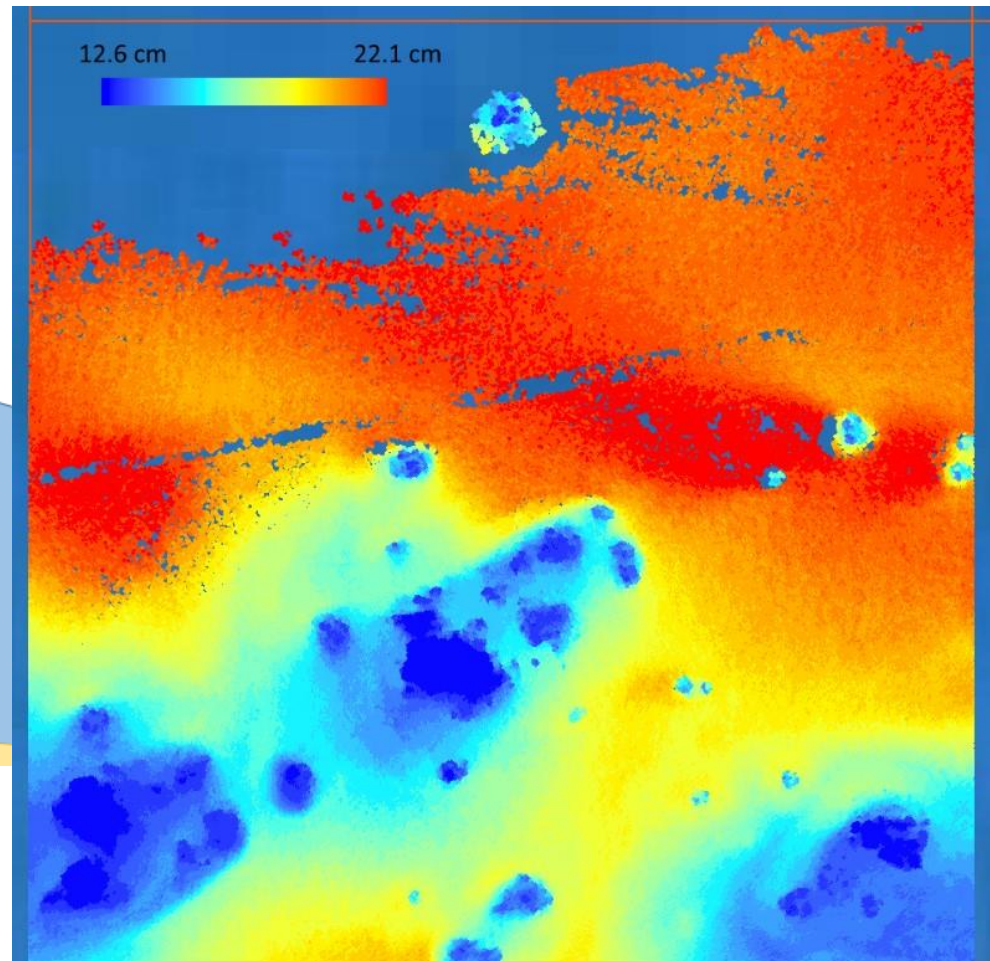
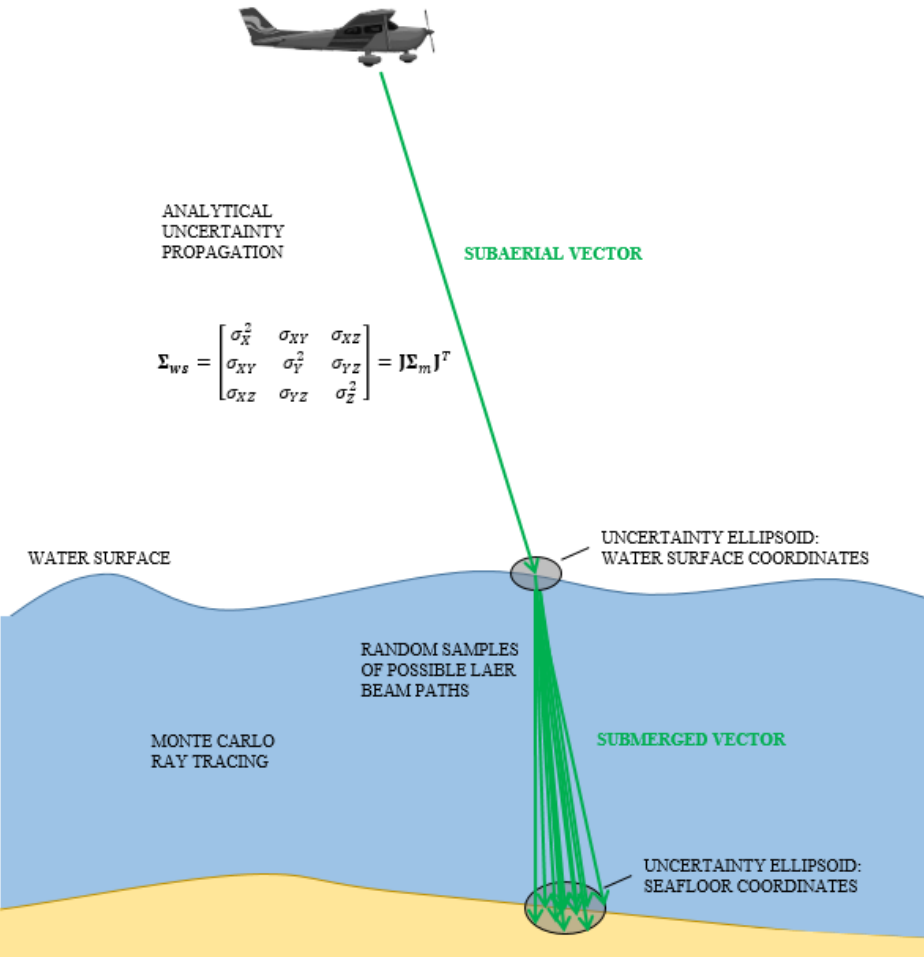
DG for UAS-lidar



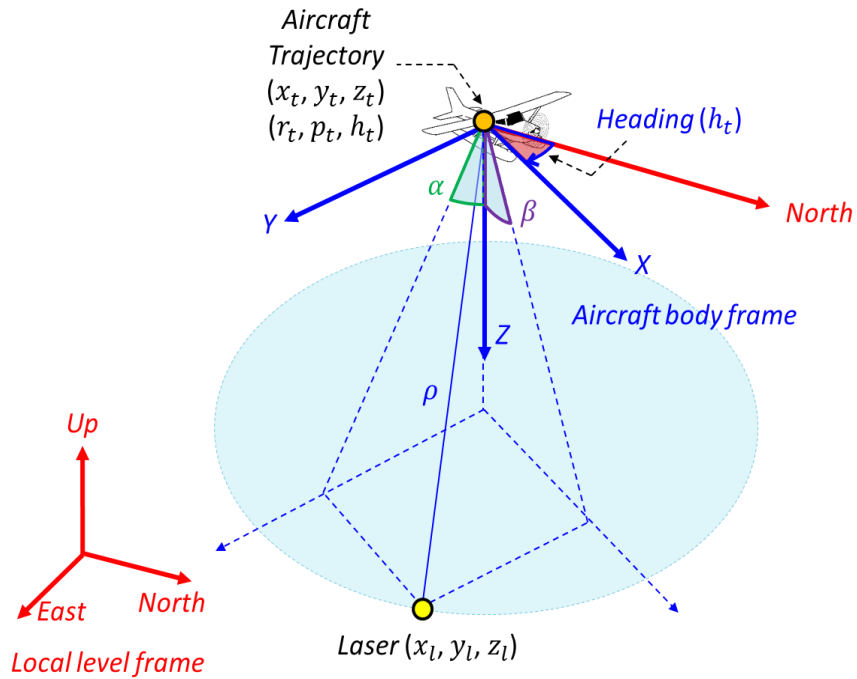
Topographic-Bathymetric Lidar



Topo-Bathy Lidar Uncertainty Modeling



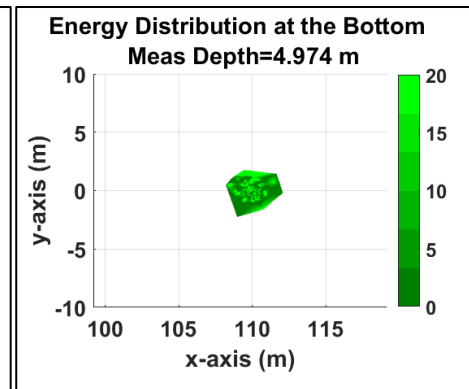
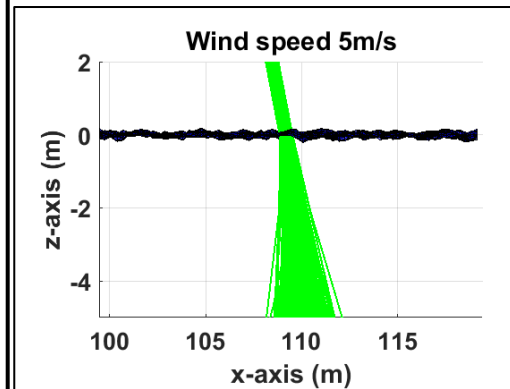
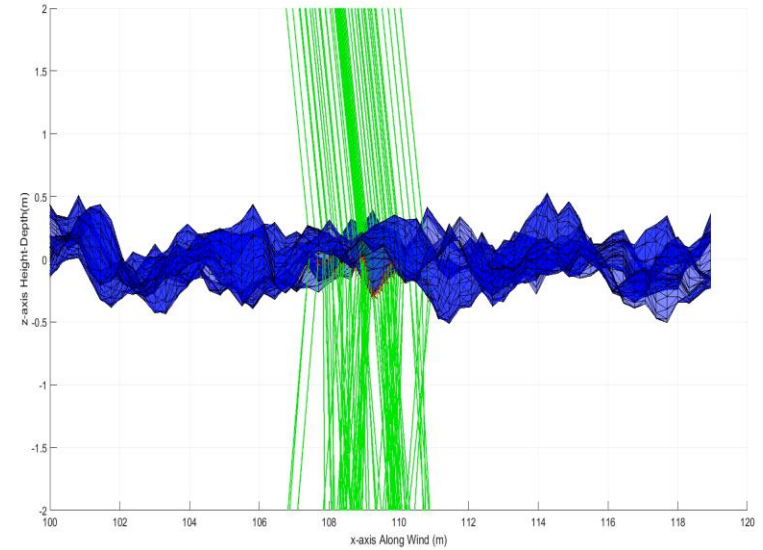
Subaerial Uncertainty



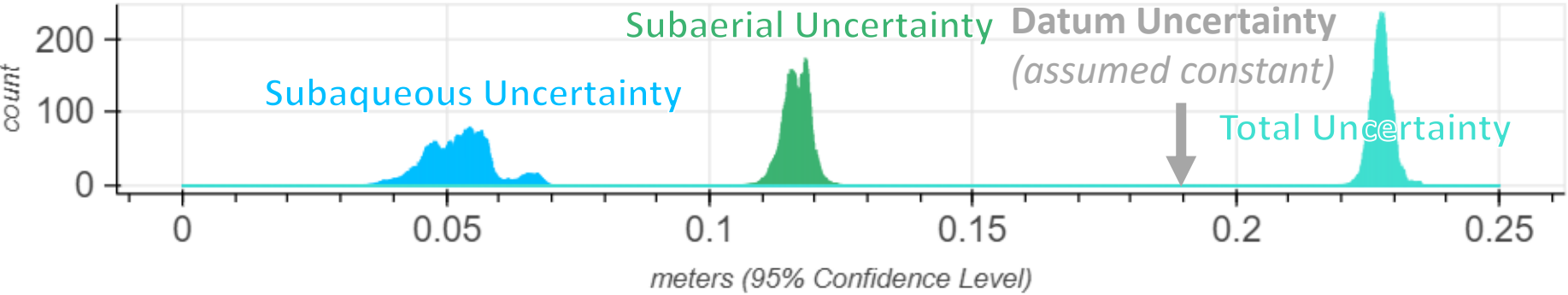
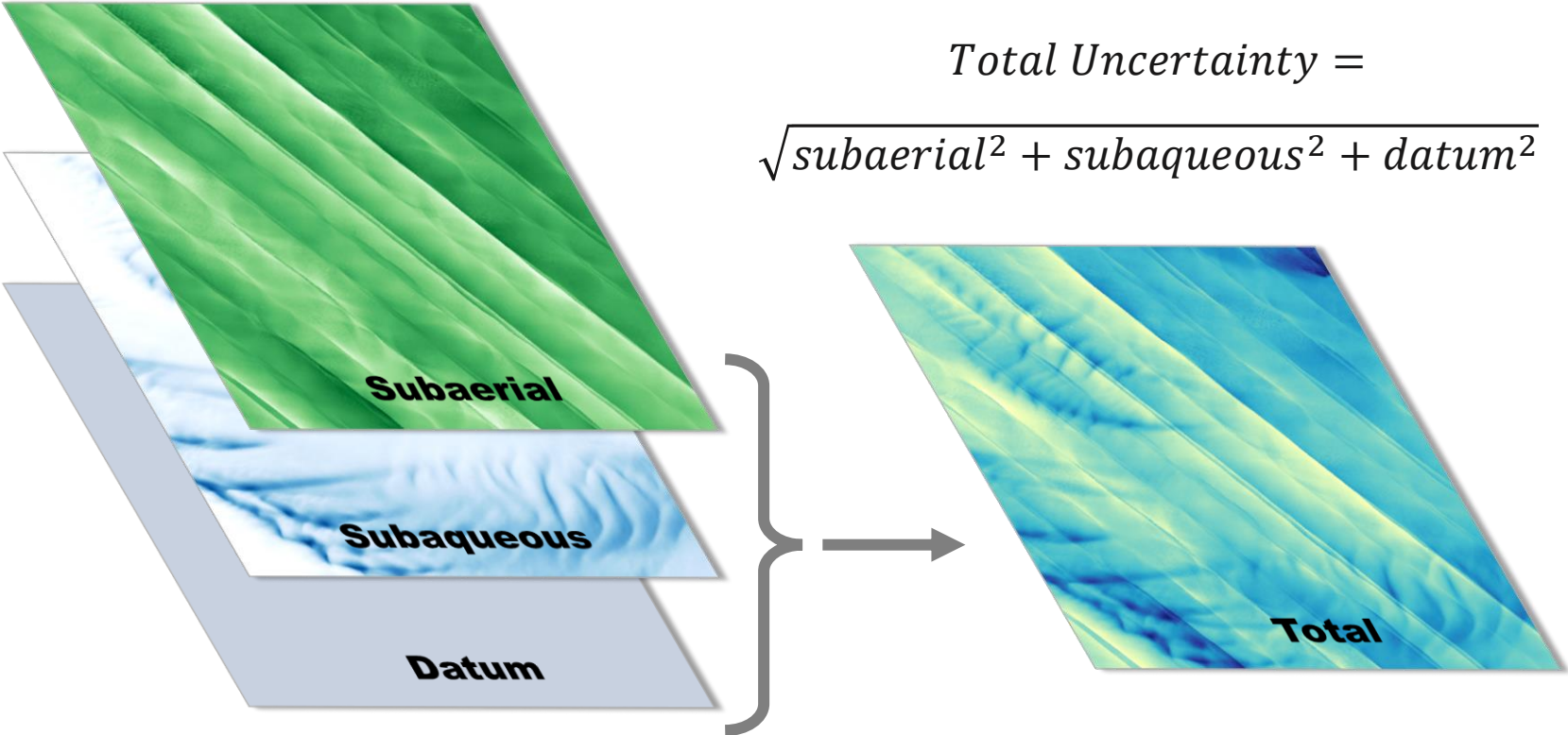
$$\begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} = \begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} + R_b^l R_{ls}^b \begin{bmatrix} 0 \\ 0 \\ -\rho \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}_M$$

$$\Sigma = \begin{bmatrix} \sigma_X^2 & \sigma_{XY} & \sigma_{XZ} \\ \sigma_{XY} & \sigma_Y^2 & \sigma_{YZ} \\ \sigma_{XZ} & \sigma_{YZ} & \sigma_Z^2 \end{bmatrix} = J \begin{bmatrix} \sigma_\alpha & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \sigma_\rho \end{bmatrix} J^T$$

Subaqueous Uncertainty



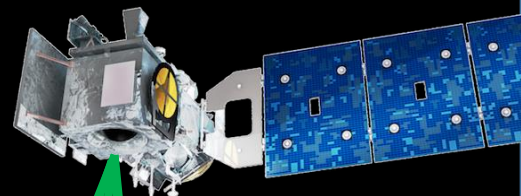
Combining component uncertainties



Space-based Lidar



ICESat-2 ATLAS



~500 km

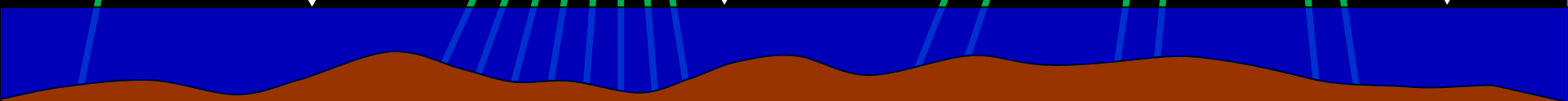
ER-2 MABEL



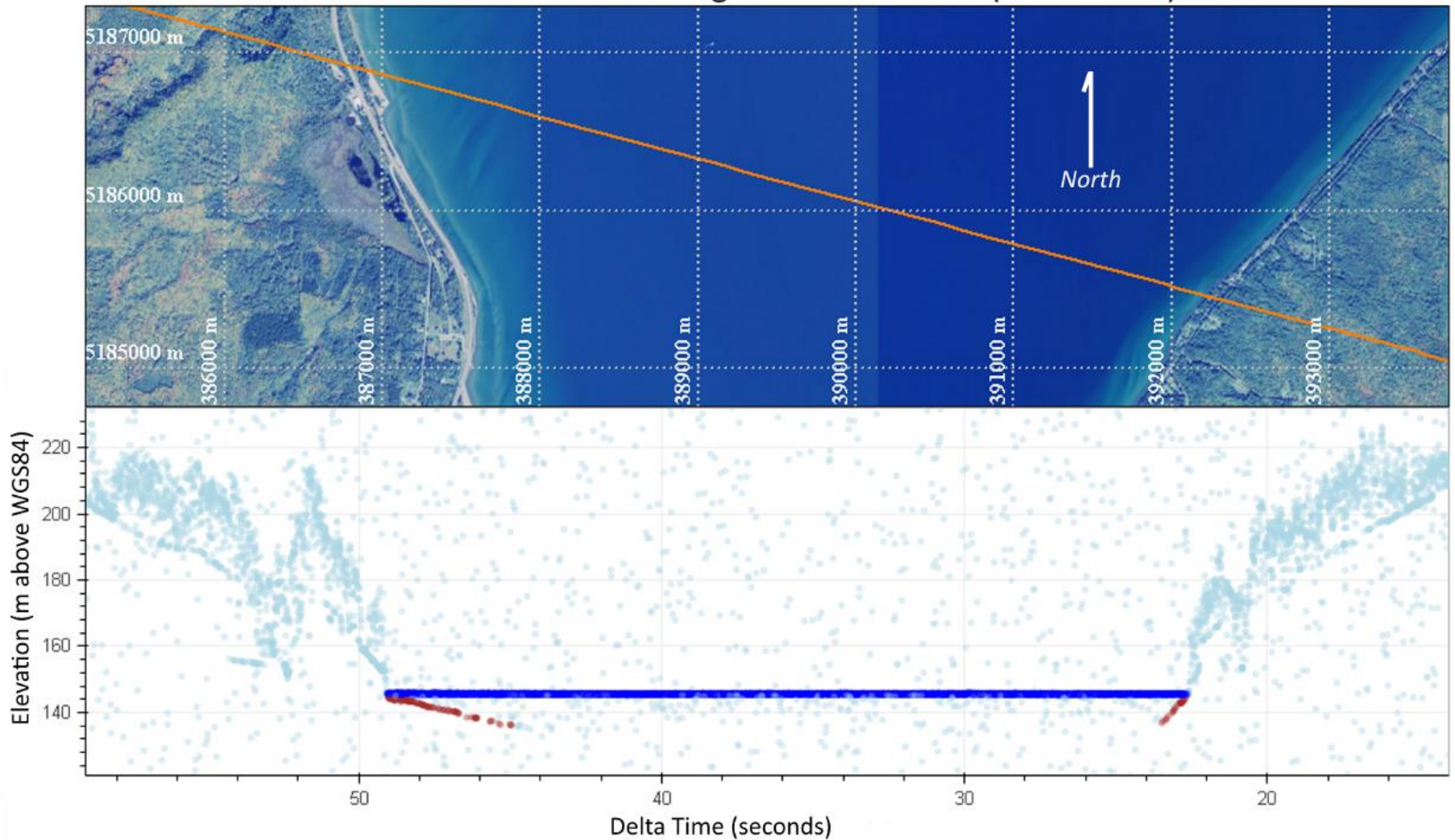
20 km

JALBTCX agency aircraft

<1 km



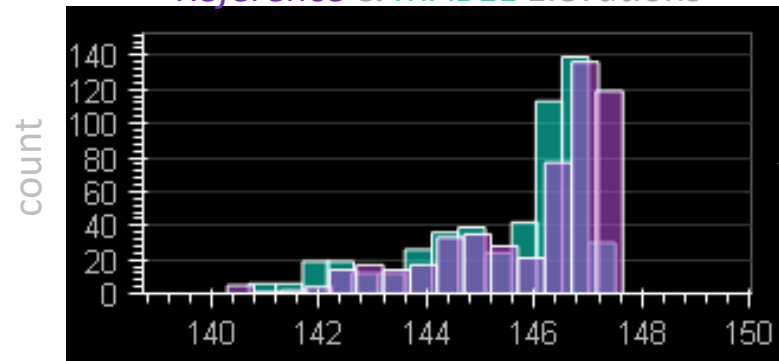
Photon Elevations along MABEL Trackline (Channel 11)



Forfinski-Sarkozi, N.A., and C.E. Parrish, 2016. Analysis of MABEL Bathymetry in Keweenaw Bay and Implications for ICESat-2 ATLAS. *Remote Sensing*, Vol. 8, No. 9.

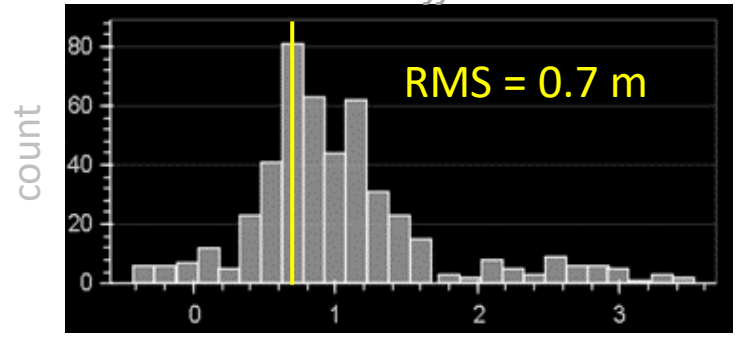
Comparison with Reference Bathymetry

Reference & MABEL Elevations



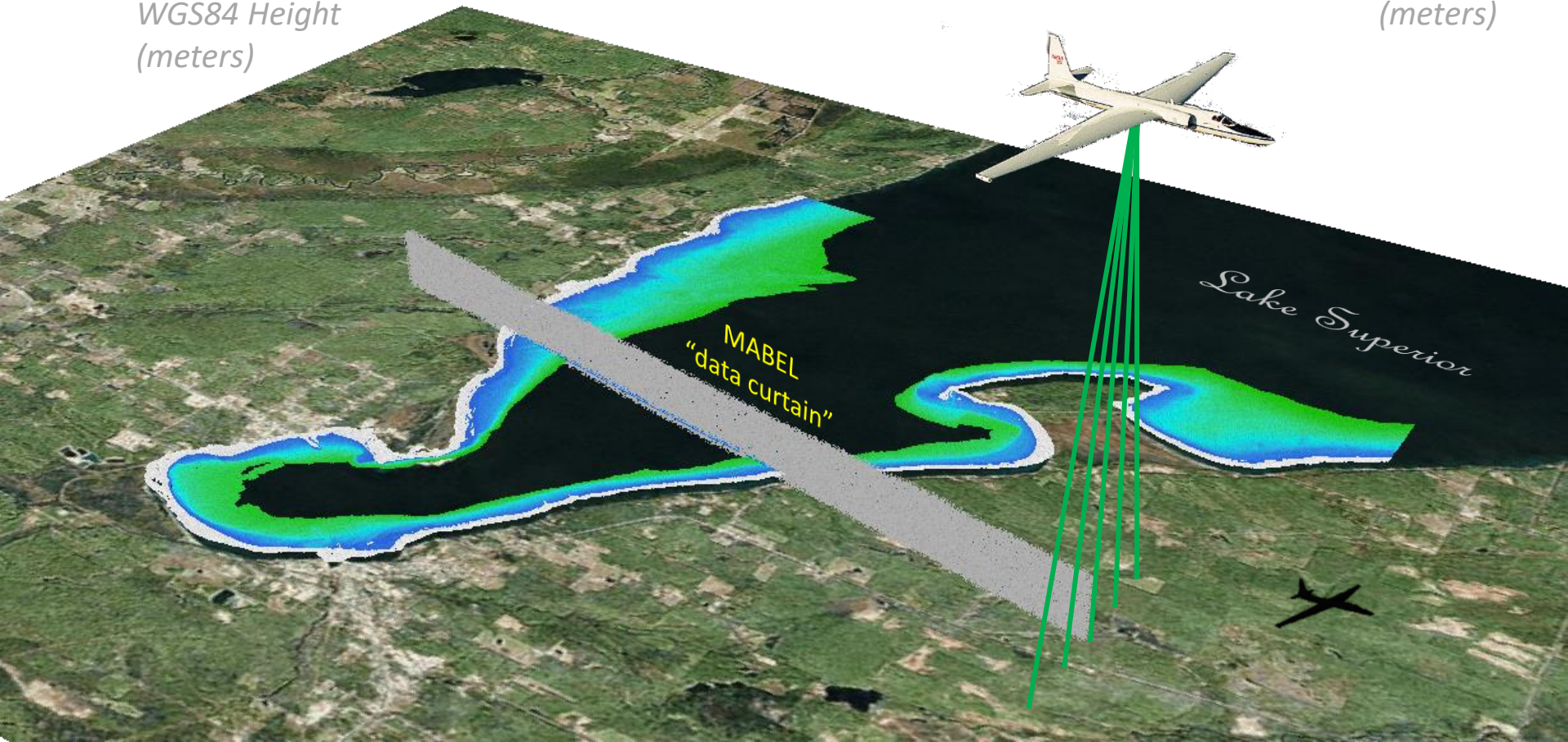
difference the histograms →

Elevation Differences



WGS84 Height (meters)

(meters)



Unsolved Challenges

- When more data becomes too much data
 - Big data, AI/machine learning, cloud processing
 - Data -> information -> insight
- Linking empirical accuracy assessments and modeled uncertainties
- Sensor/technology-neutral assessment methods
- Standards, guidelines, and best practices!!
 - In an era of accelerating growth in new mobile/airborne surveying and mapping technologies, need ways of dismissing hype and ensuring appropriate technology use to ensure specs of job are met

Acknowledgements

- Grad Students

- Richie Slocum
- Chase Simpson
- Nick Forfiniski-Sarkozi
- Matt Gillins

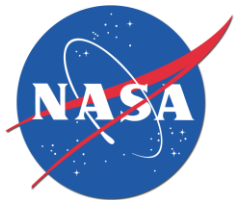
- Postdocs

- Jaehoon Jung
- Firat Eren (UNH)



Acknowledgements

- This work was supported by the following grants:
 - NASA Research Opportunities in Space and Earth Sciences (ROSES): Grant # NNX15AQ22G: “ICESat-2 Algorithm Development for the Coastal Zone”
 - Department of the Interior, USGS: AmericaView Grant # G14AP00002: “OregonView”
 - NOAA CIMRS Grant # NA11OAR4320091A:
 - “Seafloor Reflectance Mapping from EAARL-B Topobathymetric Lidar Data in the U.S. Virgin Islands” (2015)
 - “Enhanced EAARL-B Lidar Processing and Waveform Analysis for the U.S. Virgin Islands” (2016)
 - Optimizing UAS Imagery Acquisition and Processing for Shallow Bathymetric Mapping (2017-2018)
 - ODOT, Agreement 30530, WO 16-05: “Eyes in the Sky: Bridge Inspections with Unmanned Aerial Vehicles”
 - PacTrans UTC Region 10: 69A3551747110-UWSC10003: “An Airborne Lidar Scanning and Deep Learning System for Real-time Event Extraction and Control Policies in Urban Transportation Networks “



Questions



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College of Engineering

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