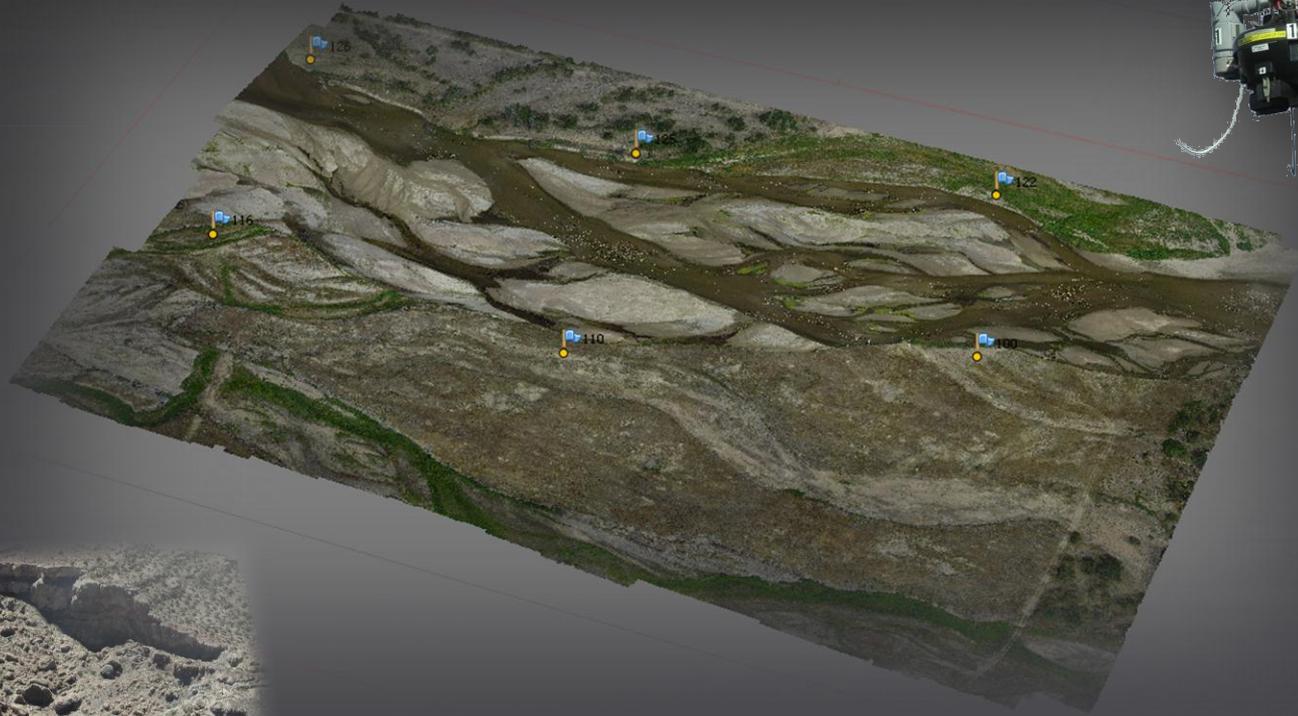


# Structure from Motion

## UAS Point Cloud, Dem, Orthophoto Data Processing



Debeque Landslide, CO

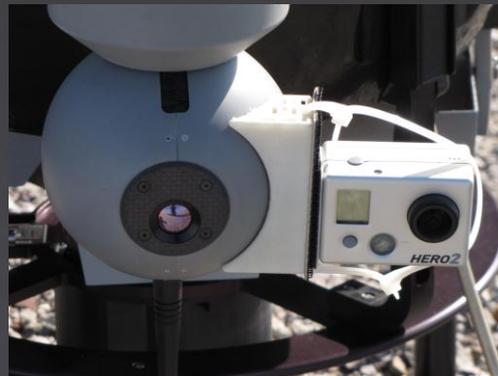
South Platte River, NE

# UAS Point Cloud, Dem, Orthophoto Data Processing



## Canon SX230, GoPro Hero 2/3

- Low Cost Solution
- Higher Resolution (36x more pixels than stock camera)
- Light weight and Size
- HD Video and 11 or 12 megapixel stills to utilize tie point automation tools.
- Canon SX230 is GPS enabled for .exif metadata tagging.
- Canon SX230 is triggered using Canon's CHDK developers kit via a intervalometer.

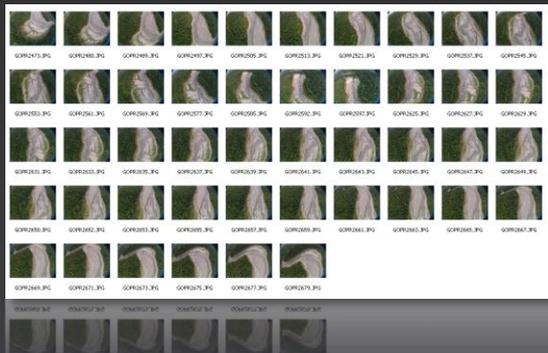


# UAS Point Cloud, Dem, Orthophoto Data Processing

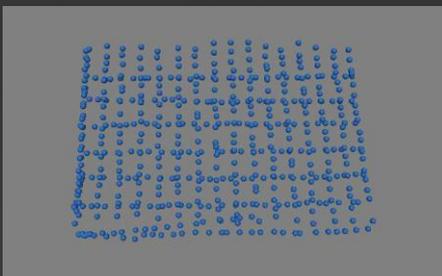
## General Workflow (Photoscan)



Image Collection



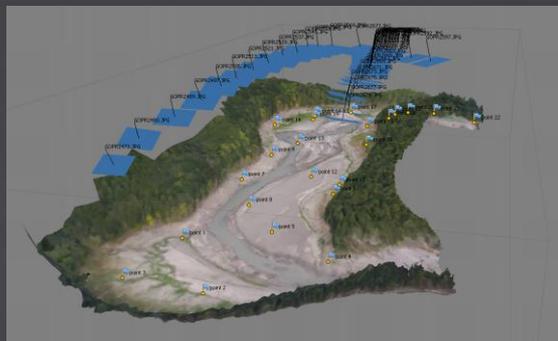
Review Image Tags and Image Alignment



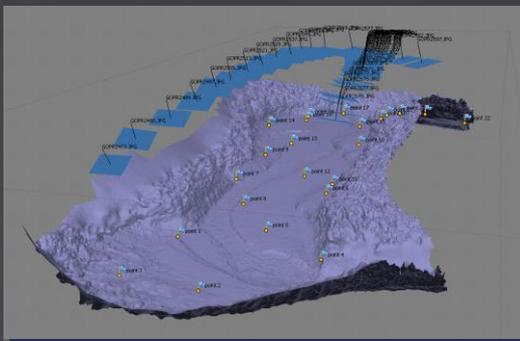
Adding Control

Markers	X/East	Y/North	Z/Altitude	Error (m)	Projections
point 1	-123.568210	48.086959	0.000000	17.144047	22
point 10	-123.562803	48.090145	0.000000	25.312213	28
point 11	-123.564366	48.088317	0.000000	9.612649	28
point 12	-123.564913	48.088904	0.000000	6.895948	27
point 13	-123.564621	48.090891	0.000000	4.743305	27
point 14	-123.564992	48.092181	0.000000	7.886112	24
point 15	-123.561988	48.092058	0.000000	8.820255	21
point 16	-123.563177	48.093653	0.000000	11.291840	17
point 17	-123.561608	48.094250	0.000000	18.108653	12
point 18	-123.560840	48.092864	0.000000	7.182387	17
point 19	-123.563411	48.093172	0.000000	7.471582	17
point 2	-123.567941	48.085551	0.000000	29.852659	10
point 20	-123.559153	48.094806	0.000000	27.087896	9
point 21	-123.560142	48.093762	0.000000	10.065377	13
point 22	-123.556914	48.093873	0.000000	35.939475	4
point 23	-123.557877	48.094949	0.000000	<b>40.091408</b>	8
point 24	0.000000	0.000000	0.000000	0.000000	0
point 3	-123.569360	48.086028	0.000000	28.336538	14
point 4	-123.565498	48.085975	0.000000	14.828336	11
point 5	-123.566355	48.086917	0.000000	10.722515	22
point 6	-123.564695	48.087855	0.000000	11.913958	26
point 7	-123.566647	48.088789	0.000000	5.142936	30
point 8	-123.566677	48.087817	0.000000	3.147138	27
point 9	-123.565667	48.089832	0.000000	15.302667	29
<b>Total Error</b>				<b>18.230015</b>	

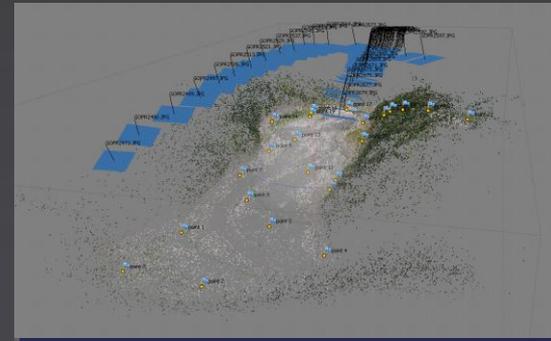
Build Texture and Export Products



Build Geometry



Point Cloud Generation, Camera Calibration and Optimization

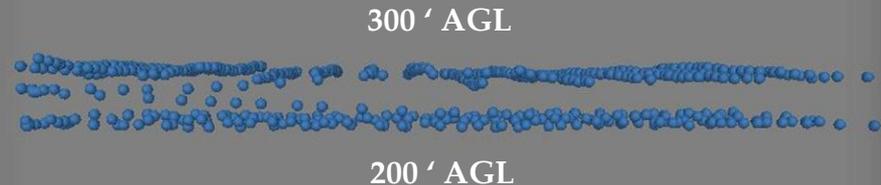
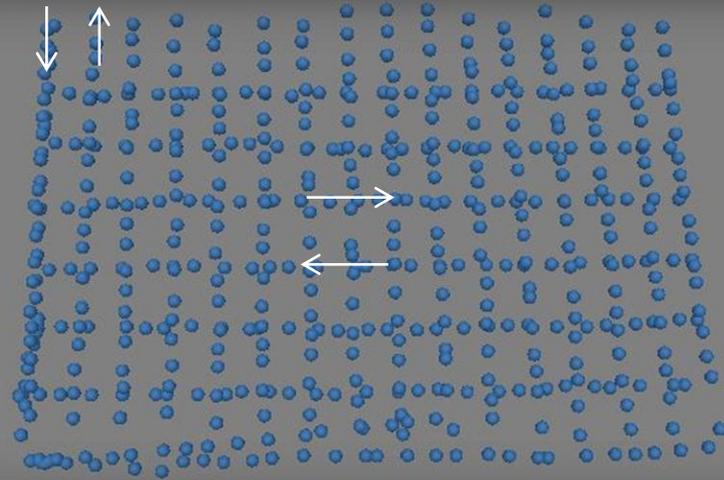


# UAS Point Cloud, Dem, Orthophoto Data Processing



## Image Collection Guidelines

- Focal Length needs to be fixed
  - Photos taken near NADIR
  - Collect 60% in-track overlap
  - Collect 50% side-track overlap
  - Dual Pass Flight Plans preferred
  - A second flight flown perpendicular to the initial flight plan at 1.5 to 2 times the 1<sup>st</sup> GSD helps create geometry in areas with difficult terrain.
  - Shutter speeds should be set to 1/1600 of a second or faster to reduce image blur.
  - Turn off image stabilization on lens
  - Use wide angle lens, avoid fisheye lens.
- 
- $GSD = \text{pixel size} \times \text{flight height (AGL)} / \text{focal length}$
  - Pixel Size = sensor size and format



# UAS Point Cloud, Dem, Orthophoto Data Processing



Canon sx230 Image

592 Images Aligned for South Platte, NE



# UAS Point Cloud, Dem, Orthophoto Data Processing



## Point Cloud

592 images



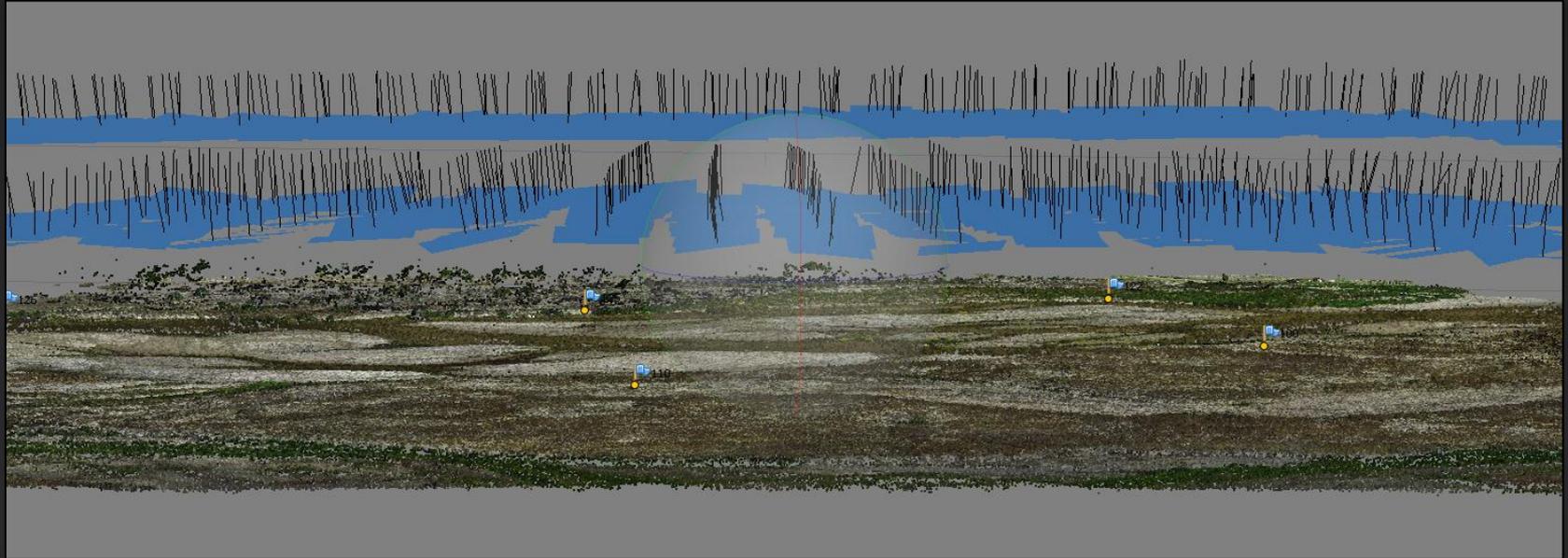
# UAS Point Cloud, Dem, Orthophoto Data Processing



## Point Cloud

200 Ft AGL

300 Ft AGL



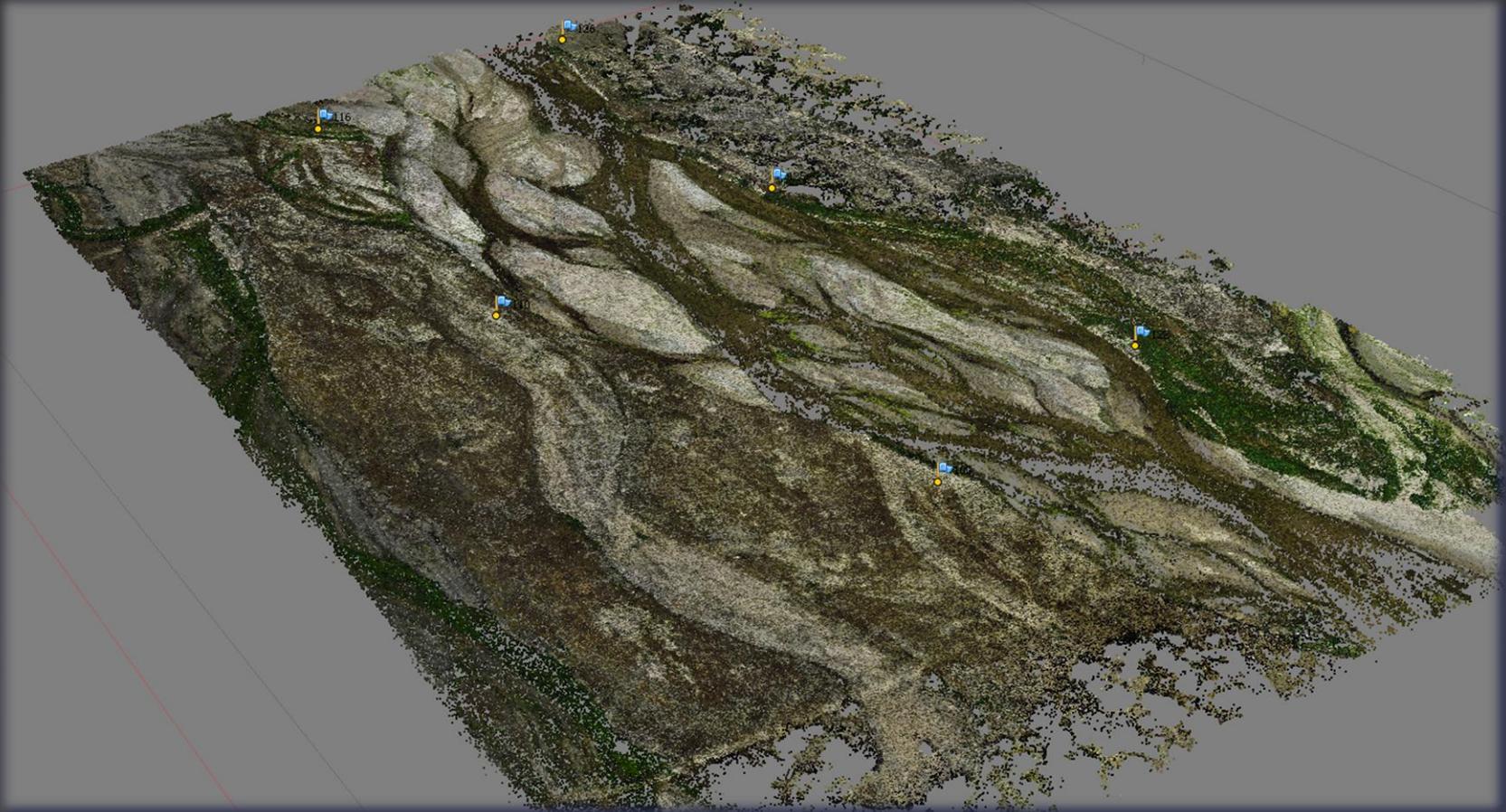
# UAS Point Cloud, Dem, Orthophoto Data Processing



## Point Cloud

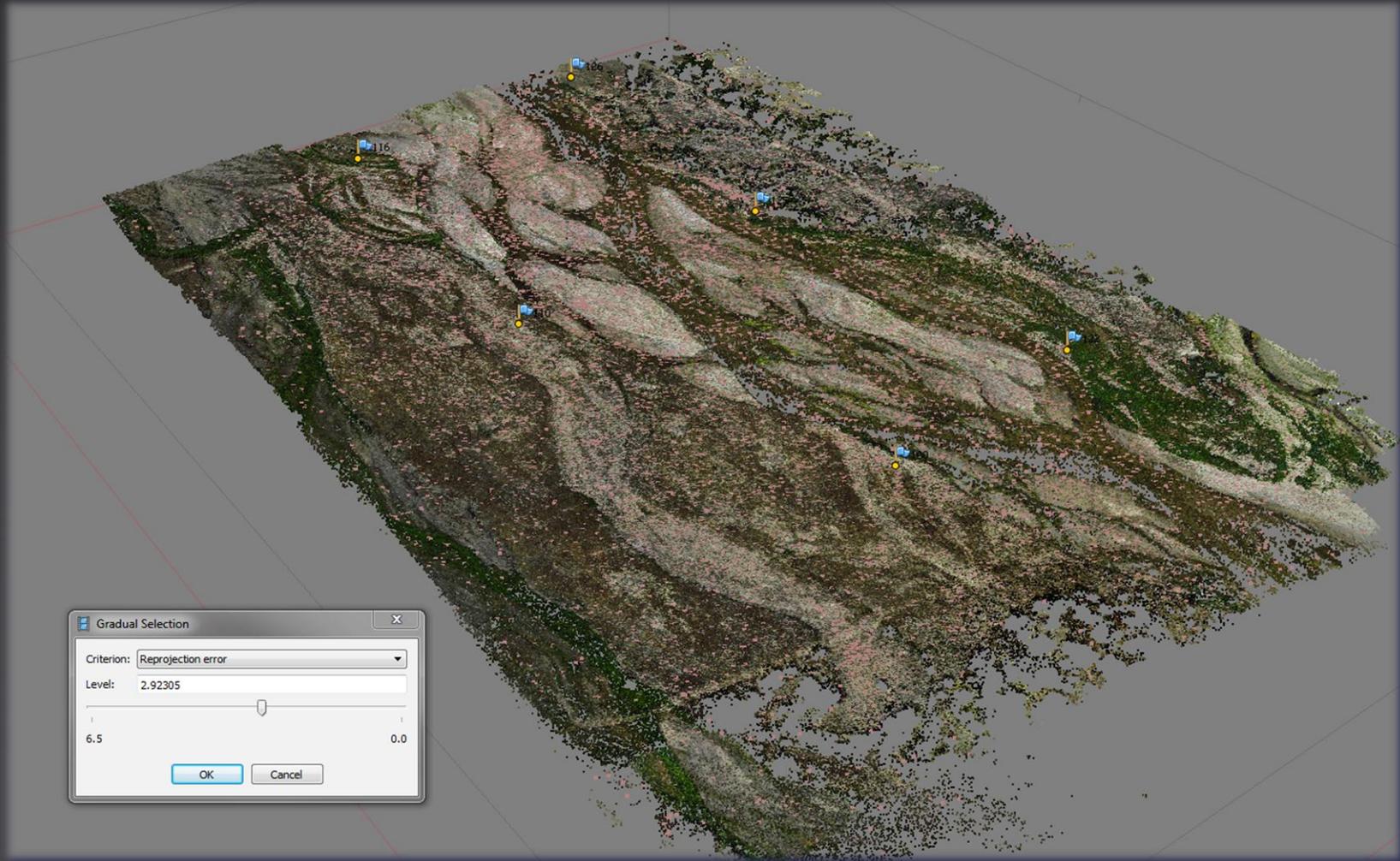
1.8 million points

Area: 0.5 km x 0.4 km



# UAS Point Cloud, Dem, Orthophoto Data Processing

## Gradual Selection



# UAS Point Cloud, Dem, Orthophoto Data Processing



## Setting Ground Control

### Target selection and Optimization (Browns Model)

**Cameras**

Camera	East err (m)	North err (m)	Alt. err (m)	Error (m)	Yaw
IMG_7223.JPG	464111.369587	4124212.029903	1543775.040381	4428065.673212	
IMG_7224.JPG	464124.575960	4124211.891401	1543776.049318	4428067.280160	
IMG_7234.JPG	464251.693947	4124206.954068	1543768.177392	4428073.262814	
IMG_7237.JPG	464265.792220	4124206.243316	1543768.465985	4428074.179573	
IMG_7239.JPG	464262.353761	4124205.239327	1543762.991707	4428070.975467	
IMG_7243.JPG	464239.813237	4124206.201689	1543760.646013	4428068.690797	
IMG_7244.JPG	464221.026535	4124205.685977	1543754.725142	4428064.167616	
IMG_7245.JPG	464210.218788	4124207.906165	1543752.263807	4428064.253431	
IMG_7246.JPG	464200.130378	4124209.198784	1543752.939545	4428064.635338	
IMG_7247.JPG	464185.819930	4124210.908843	1543754.696165	4428065.340301	
IMG_7248.JPG	464173.223000	4124210.303304	1543754.326934	4428063.327094	
IMG_7249.JPG	464161.241962	4124210.823278	1543755.143766	4428062.840259	
IMG_7250.JPG	464149.035183	4124211.701041	1543754.614088	4428062.193600	
IMG_7251.JPG	464135.285116	4124212.108161	1543753.510225	4428060.746684	
IMG_7252.JPG	464122.439426	4124212.751135	1543751.366028	4428059.251582	
IMG_7253.JPG	464108.877993	4124213.390740	1543748.775302	4428057.522689	
IMG_7254.JPG	464096.050143	4124214.170196	1543745.912121	4428055.905993	
IMG_7255.JPG	464083.239230	4124213.967711	1543744.931856	4428054.032984	
IMG_7256.JPG	464070.266037	4124214.004709	1543743.817836	4428052.319425	
IMG_7257.JPG	464057.077717	4124214.370262	1543741.094470	4428050.328306	
IMG_7258.JPG	464043.877205	4124215.967894	1543738.411512	4428049.497576	
IMG_7259.JPG	464031.155573	4124217.540902	1543736.239515	4428048.872270	
IMG_7260.JPG	464018.613477	4124217.749638	1543734.936830	4428047.298220	
IMG_7261.JPG	464005.798461	4124217.813445	1543733.488750	4428045.509933	
IMG_7262.JPG	463993.050176	4124218.044363	1543731.789400	4428043.796719	
IMG_7263.JPG	463980.185206	4124218.171708	1543730.388405	4428042.078865	
IMG_7264.JPG	463967.155140	4124218.080371	1543729.059758	4428040.165293	
IMG_7265.JPG	463953.853733	4124217.880766	1543727.676063	4428038.051076	

**Markers**

Marker	East err (m)	North err (m)	Alt. err (m)	Error (m)	Projections
100	0.049478	0.068653	-0.323064	0.333963	19
110	0.055109	-0.096919	0.379504	0.395542	21
116	-0.048355	-0.007056	-0.192669	0.198769	8
118					
120					
122	-0.107144	-0.040719	0.134316	0.176575	17
125	0.040916	-0.077893	1.069424	1.073038	24
126	0.050884	0.076103	0.001799	0.091564	4
129					
130					
132					
134					
137					
138					
140					
142					
144					
146					
<b>Total Error</b>	<b>0.066170</b>	<b>0.065736</b>	<b>0.246398</b>	<b>0.263460</b>	

**Ground Control Settings**

Coordinate System: WGS 84 / UTM zone 14N (EPSG::32614)

Measurement accuracy: Camera accuracy (m): 10, Marker accuracy (m): 0.04, Scale bar accuracy (m): 0.001, Projection accuracy (pix): 0.1, Tie point accuracy (pix): 3

Camera correction:  Enable correction

X: 0, Yaw: 0, Y: 0, Pitch: 180, Z: 0, Roll: 0

OK Cancel

**Photos**

IMG_9266.JPG	IMG_9267.JPG	IMG_9268.JPG	IMG_9269.JPG	IMG_9270.JPG	IMG_9271.JPG	IMG_9272.JPG
IMG_9273.JPG	IMG_9274.JPG	IMG_9275.JPG	IMG_9276.JPG	IMG_9296.JPG	IMG_9297.JPG	IMG_9298.JPG

**Console**

```
OpenGL Vendor: ATI Technologies Inc.
OpenGL Renderer: AMD Radeon HD 7570
OpenGL Version: 4.2.11320 Compatibility Profile Context
Maximum Texture Size: 16384
Quad Buffered Stereo: not enabled
ARB_vertex_buffer_object: supported
ARB_texture_non_power_of_two: supported
Loading project...
Loaded project in 88.224 sec
Finished processing in 88.225 sec (exit code 1)
Finished processing in 0 sec (exit code 1)
>>>
```

# UAS Point Cloud, Dem, Orthophoto Data Processing



## Setting Ground Control Targets



At 200' AGL flight height target has about 17 pixels



Coordinate collection using  
Real Time Kinematic (RTK)  
system.



# UAS Point Cloud, Dem, Orthophoto Data Processing



## Setting Ground Control

Target selection, Camera Calibration, Optimization (Browns Model)

Initial calibration data is calculated during the align photos processing step.

During georeferencing the model is linearly transformed, the nonlinear component (lens distortion) is not removed.

The optimization process is used to correct nonlinear deformations.

### Camera Calibration Parameters

**F<sub>x</sub> F<sub>y</sub>** – Focal Length in x and y dimensions measured in pixels.

**C<sub>x</sub>, C<sub>y</sub>** Principal point coordinate – Coordinates of lens optical axis interception with sensor plane

**Skew** – Skew transformation coefficient

**K<sub>1</sub>, k<sub>2</sub>, k<sub>3</sub>, k<sub>4</sub>** – Radial Distortion coefficients

**P<sub>1</sub>, p<sub>2</sub>** – Tangential Distortion coefficients

Camera Calibration

Canon PowerShot SX230 HS (5 mm)  
592 images, 4000x3000 pix

Camera type: Frame

Pixel size (mm): 0.0015494 x 0.0015494

Focal length (mm): 5

Initial Adjusted

fx: 3326.47 k1: -0.0342763  
fy: 3325.37 k2: 0.00943593  
cx: 2027.8 k3: 0.0129316  
cy: 1508.46 k4: 0  
skew: 0.619443 p1: 0.00190104  
p2: 0.00258602

Image	Resolution	Camera model	Focal length	Date & time
IMG_7223.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:48:14
IMG_7224.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:48:16
IMG_7234.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:48:41
IMG_7237.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:48:49
IMG_7239.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:48:54
IMG_7243.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:04
IMG_7244.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:07
IMG_7245.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:09
IMG_7246.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:12
IMG_7247.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:15
IMG_7248.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:17
IMG_7249.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:20
IMG_7250.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:22
IMG_7251.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:25
IMG_7252.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:27
IMG_7253.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:30
IMG_7254.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:33
IMG_7255.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:35
IMG_7256.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:38
IMG_7257.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:40
IMG_7258.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:43
IMG_7259.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:45
IMG_7260.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:48
IMG_7261.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:50
IMG_7262.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:53
IMG_7263.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:55
IMG_7264.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:49:58
IMG_7265.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:50:00
IMG_7266.J...	4000x3000	Canon PowerSh...	5	2013:07:24 08:50:03

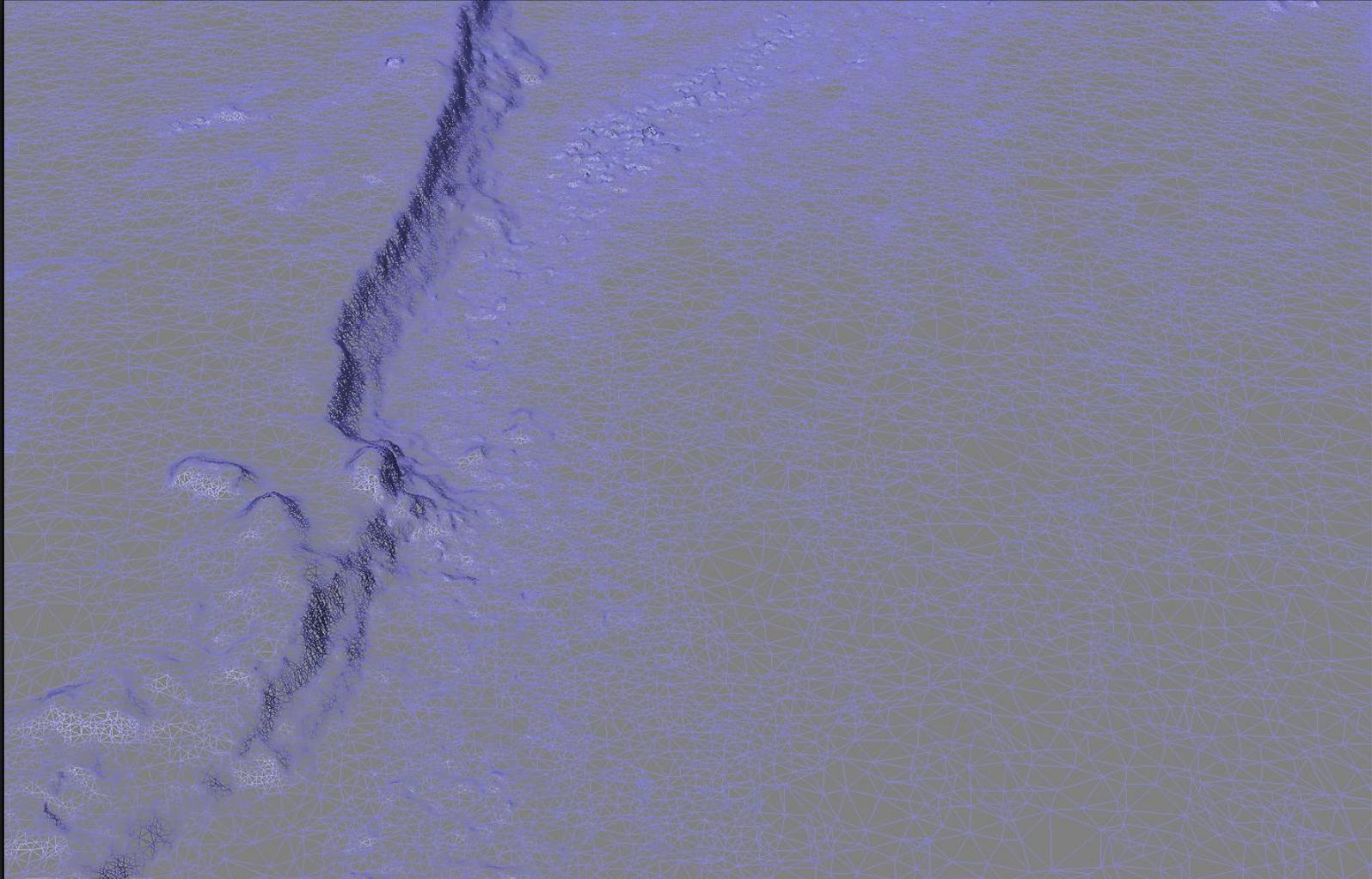
OK Cancel

# UAS Point Cloud, Dem, Orthophoto Data Processing



## DSM Example

Wire Frame - 10 million faces

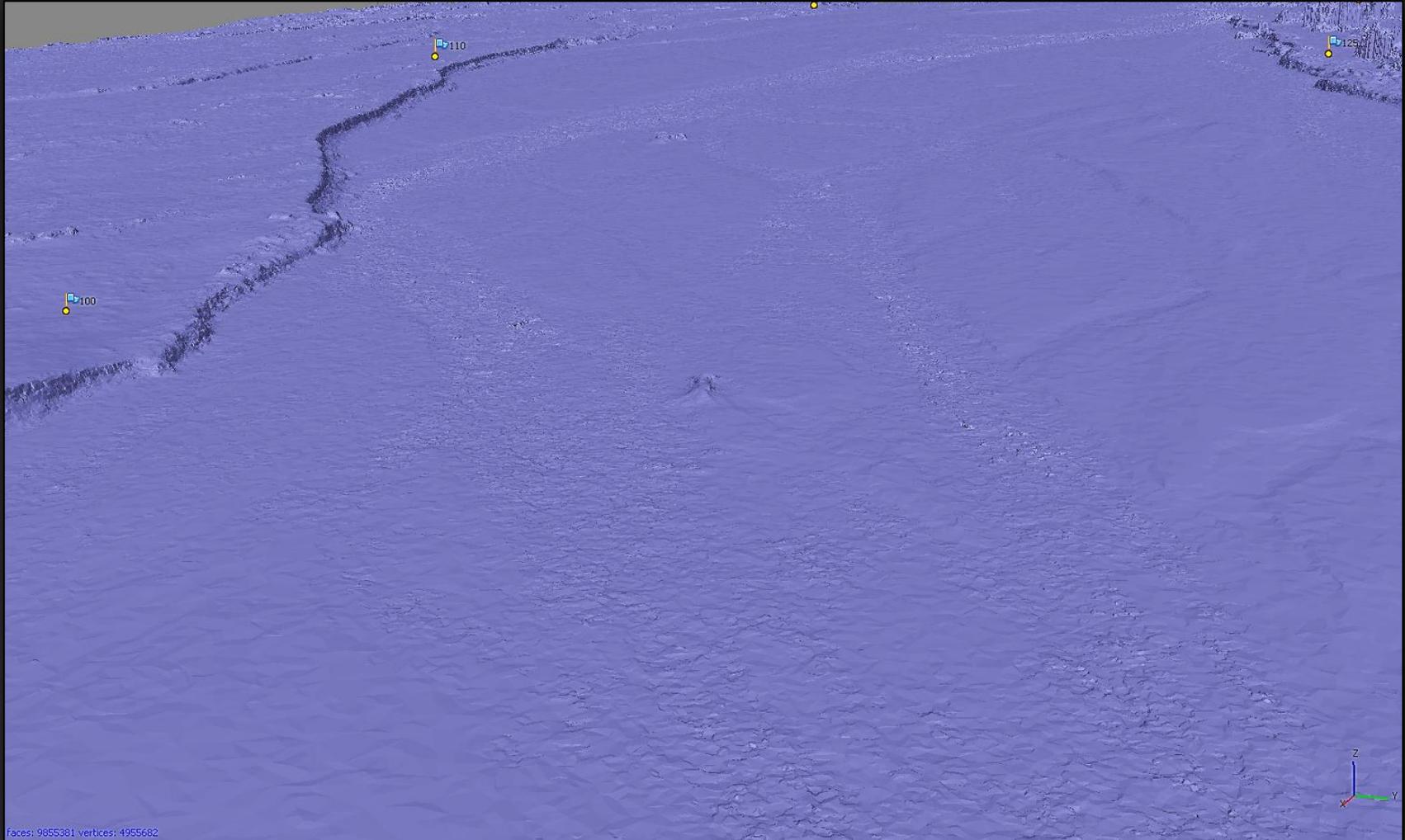


# UAS Point Cloud, Dem, Orthophoto Data Processing



DSM Example

10 million faces



# UAS Point Cloud, Dem, Orthophoto Data Processing



DSM

GSD 0.091 m = 3.5112"



# UAS Point Cloud, Dem, Orthophoto Data Processing

## Orthophoto

GSD = 0.0222 m or 0.8778"

Area: 0.5 km x 0.4 km

=



# UAS Point Cloud, Dem, Orthophoto Data Processing

## Orthophoto



# UAS Point Cloud, Dem, Orthophoto Data Processing

NAIP Orthophoto at similar scale



# UAS Point Cloud, Dem, Orthophoto Data Processing

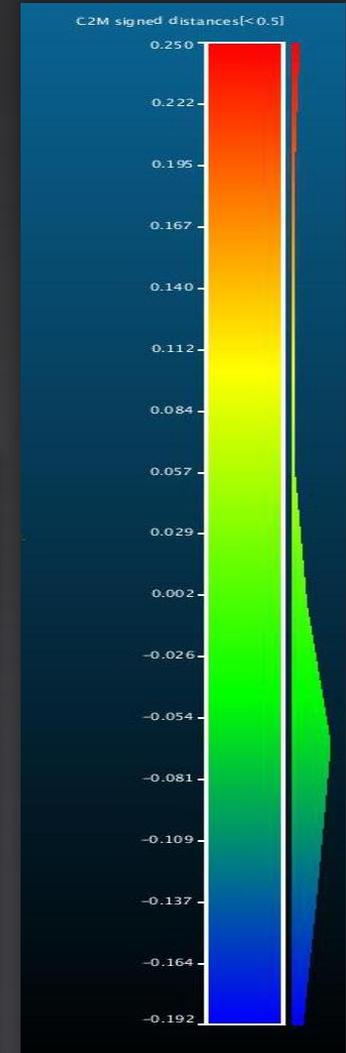
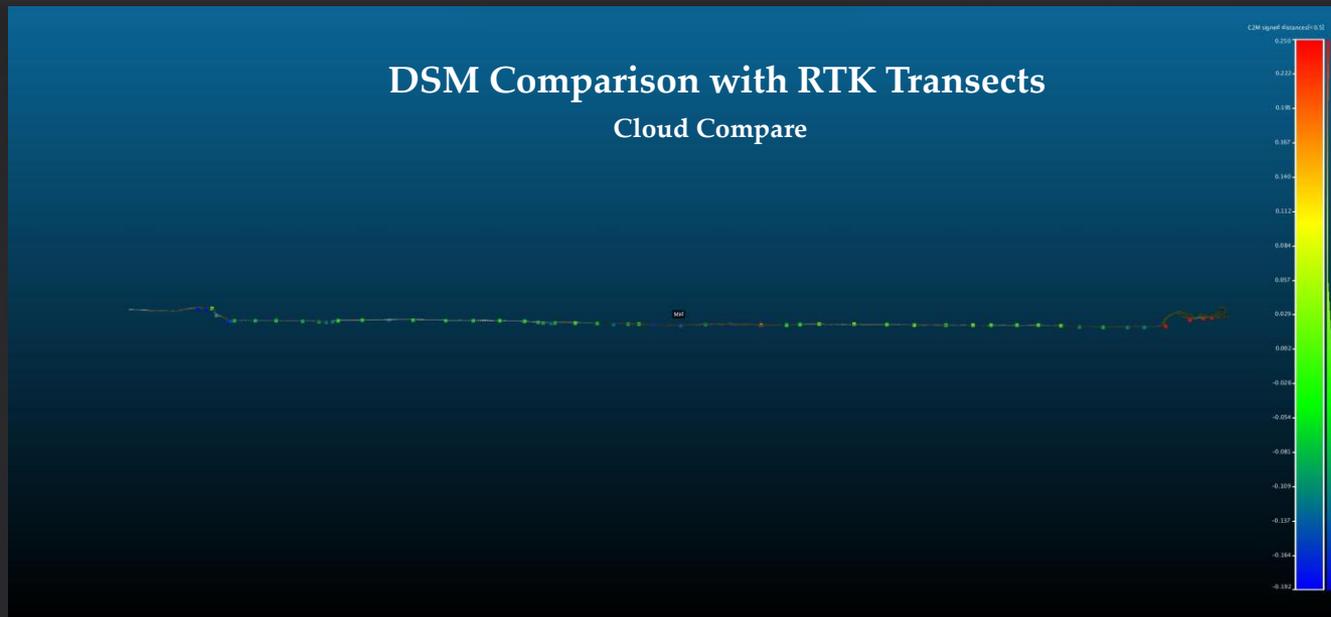
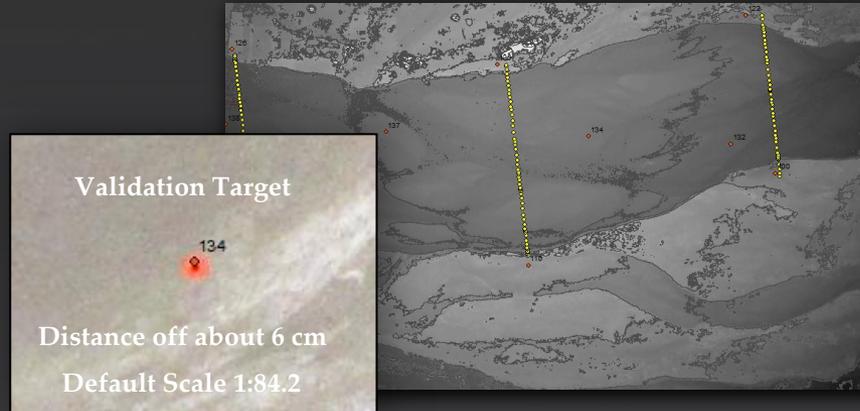


## Ground Sampled Distance

DSM GSD = 5.28 cm, 2.08 in  
Ortho GSD = 2.22 cm, 0.87 in

## Initial Accuracy

East X - RMS = 6.2 cm  
North Y - RMS = 6.7 cm  
Alt Z - RMS = 24 cm  
Error (Pixel) = 1.265 pix



# UAS Point Cloud, Dem, Orthophoto Data Processing

## Limitations



# UAS Point Cloud, Dem, Orthophoto Data Processing



## Limitations



# UAS Point Cloud, Dem, Orthophoto Data Processing



## Camera Selection Tips

Source: Photo Modeler and Photoscan

- High resolution: most high quality cameras support resolutions of 5-8 mega pixels or better.
- Used high quality fixed lens and try to avoid digital zoom. Digital zoom settings manipulates the photo without actually adjusting the focal length.
- Do not use vibration reduction or image stabilization lenses.
- Use a wide angle lens. Wide angle lenses suit better for reconstructing spatial relations between objects than telephoto. However wide angle lens typically have more lens distortions.

## Shooting Tips

- Avoid shiny and transparent objects. Shoot under a cloudy sky if need be.
- Avoid unwanted foregrounds and moving objects.
- Avoid not textured and flat objects.
- Shoot pictures with a lot of overlap.
- Do not crop or geometrically transform the images.
- More photos are better than not enough.
- Collect images from different directions.

# Questions?

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