SFM mapping of coastal erosion at Point Woronzof

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POINT WORONZOF

Point Woronzof bluff

Point Woronzof bluff

Pt. Woronzof from 1909 to 1954

- From 1909 to 1947 the edge of the bluff moved at 2 ft/year

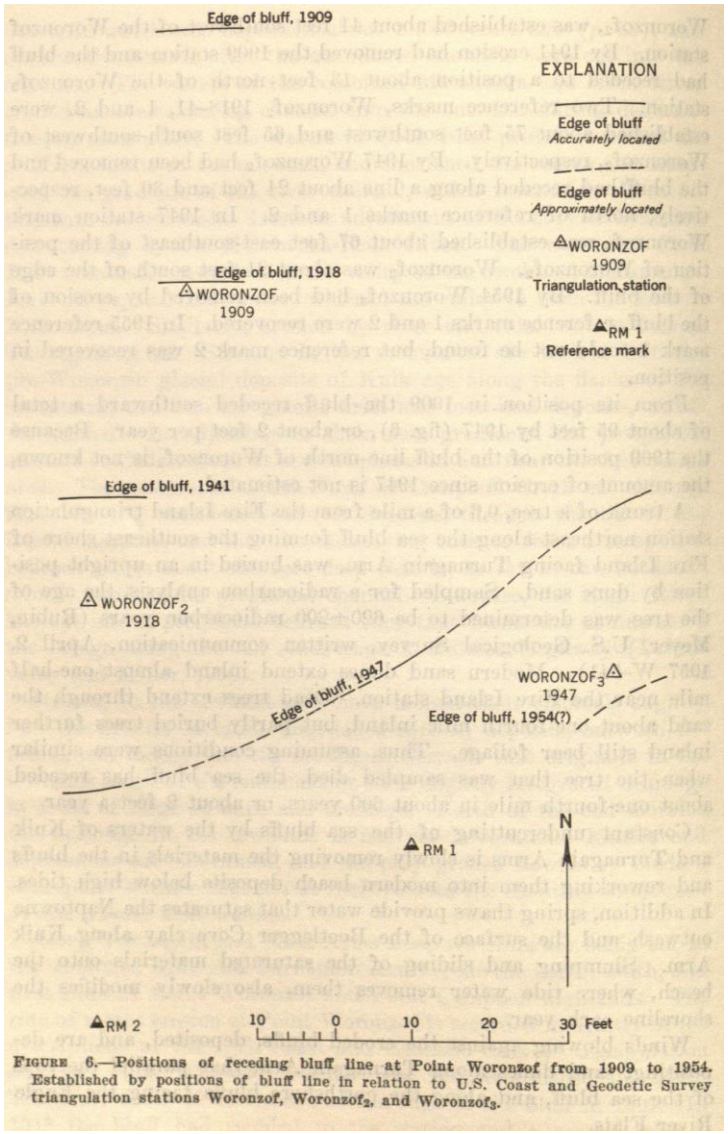
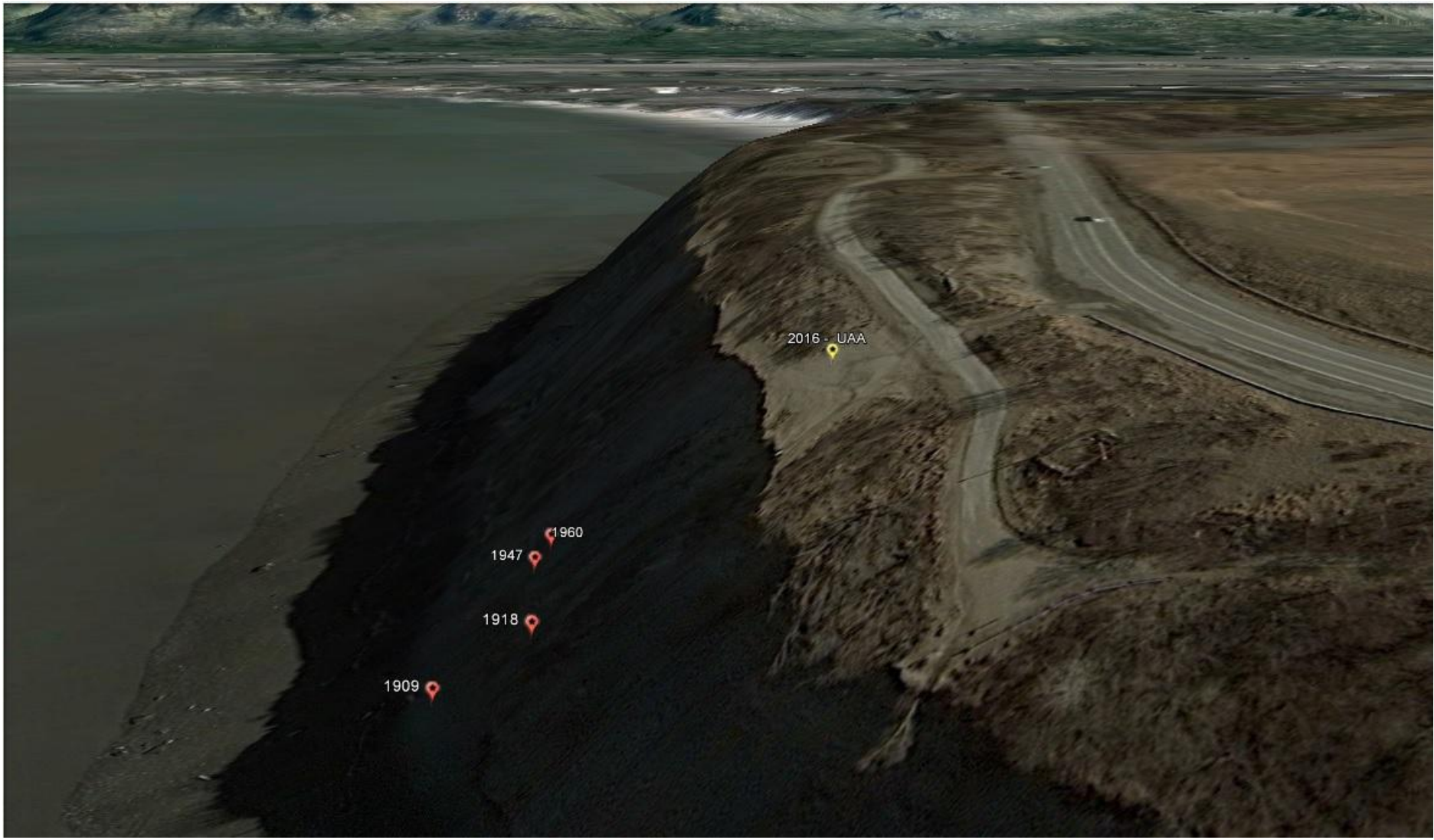


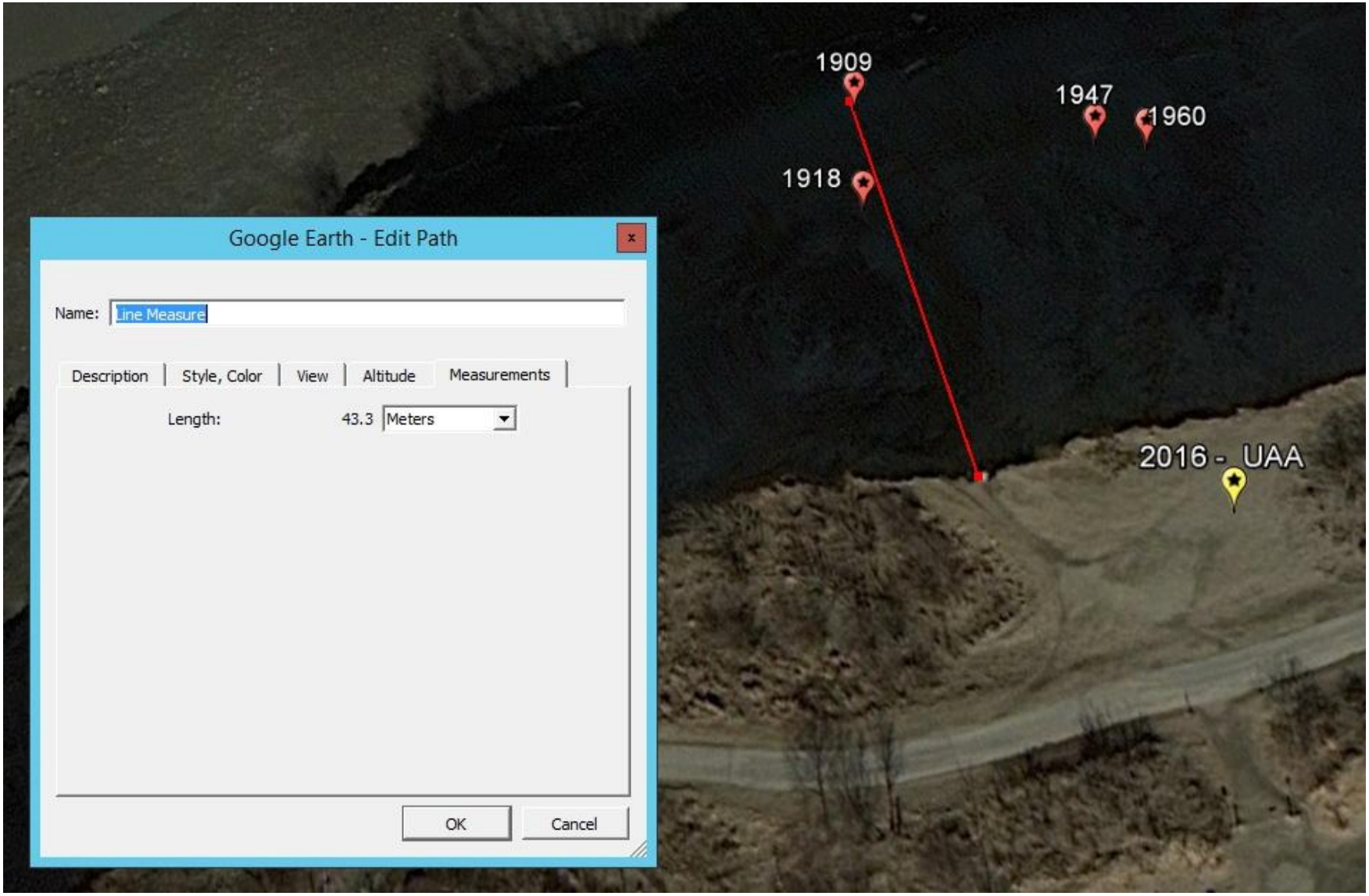
FIGURE 6.—Positions of receding bluff line at Point Woronzof from 1909 to 1954. Established by positions of bluff line in relation to U.S. Coast and Geodetic Survey triangulation stations Woronzof, Woronzof$_2$, and Woronzof$_3$.

Surveying data: 1909-2016



Surveying data: 1909-2016

1909


1909
1947
1960
1918
2016 - UAA
Google Earth - Edit Path
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Meters
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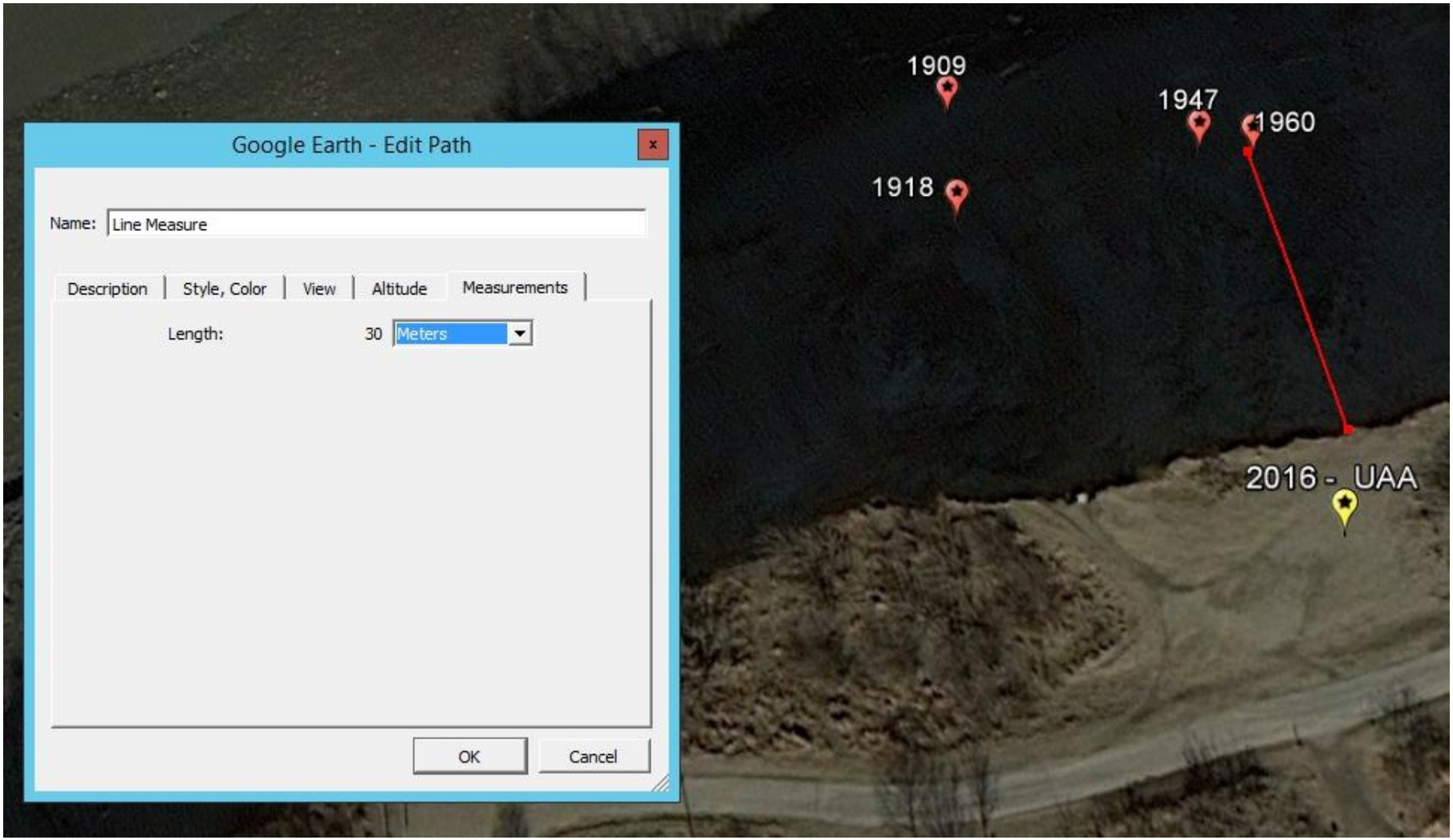
1960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1947
1960
1918
2016 - UAA
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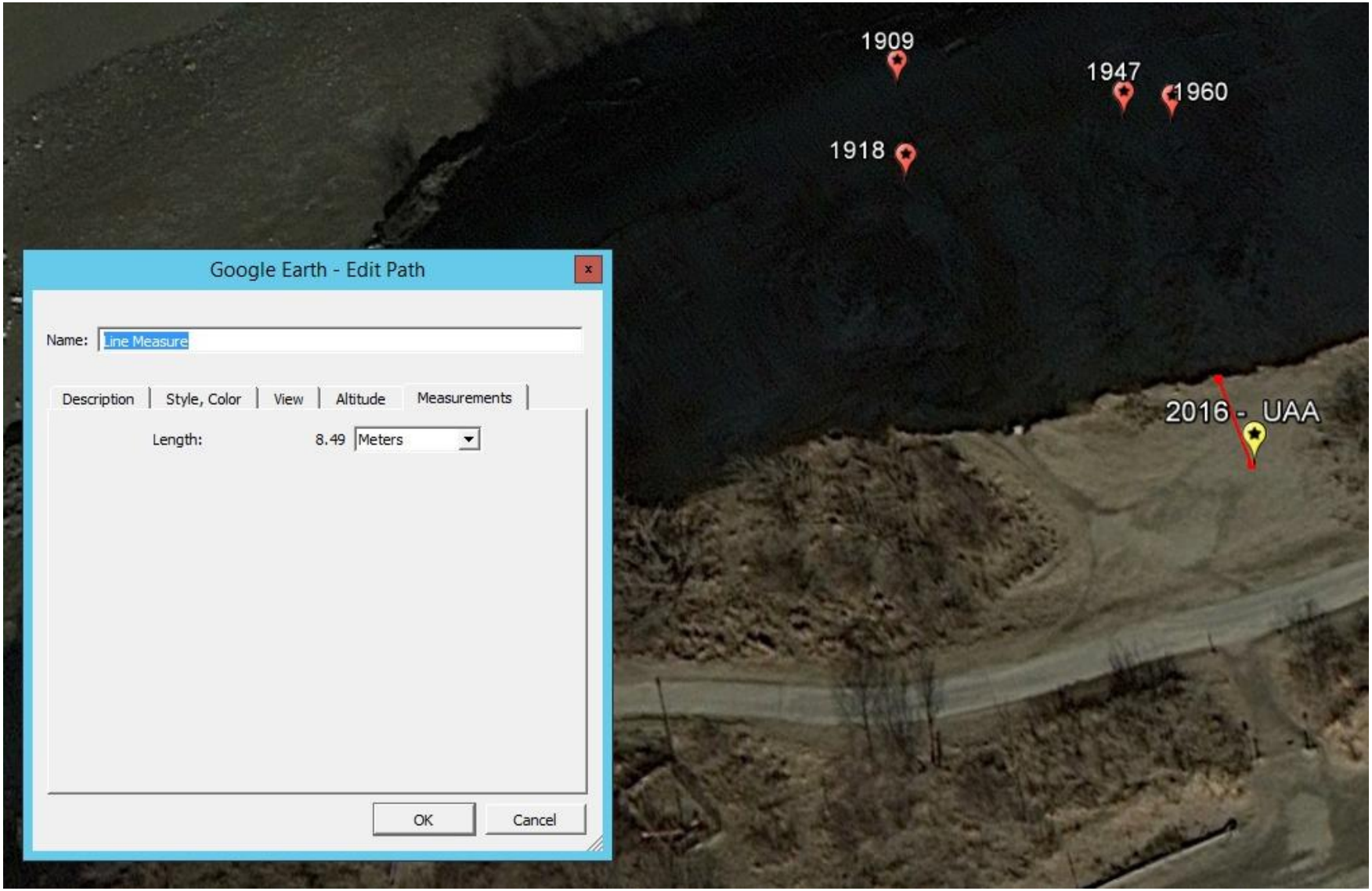
UAA point 2016

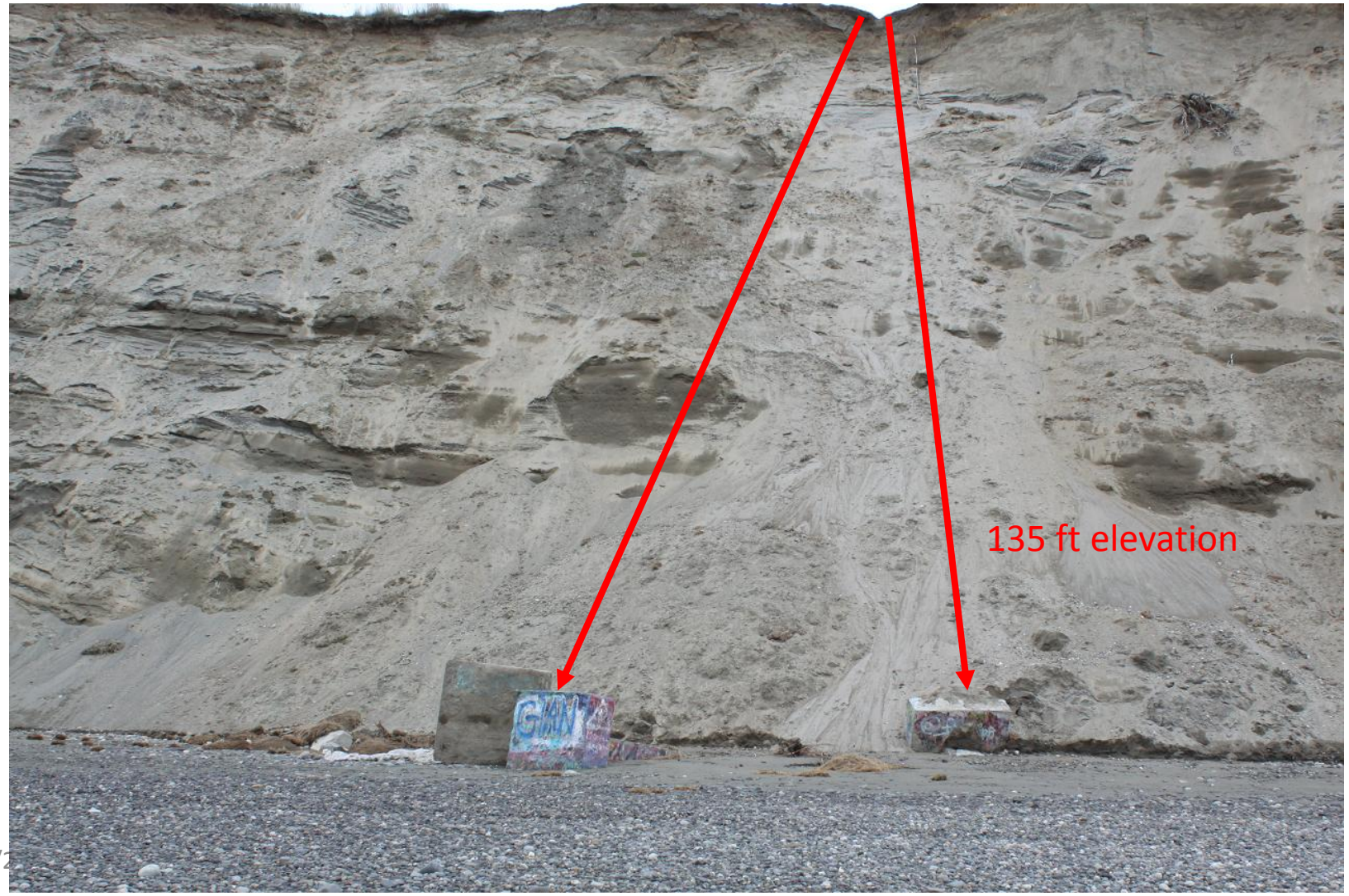


UAA point 2016

From 2011 to 2016

- Distance from UAA point to the edge
  - April 2011: 8.5m
  - October 2016: 3.65m
- Time difference
  - 66 months = 5.5 years
- Erosion rate
  - (8.5-3.65)/5.5 = 0.9m/yr
  - 3ft/yr

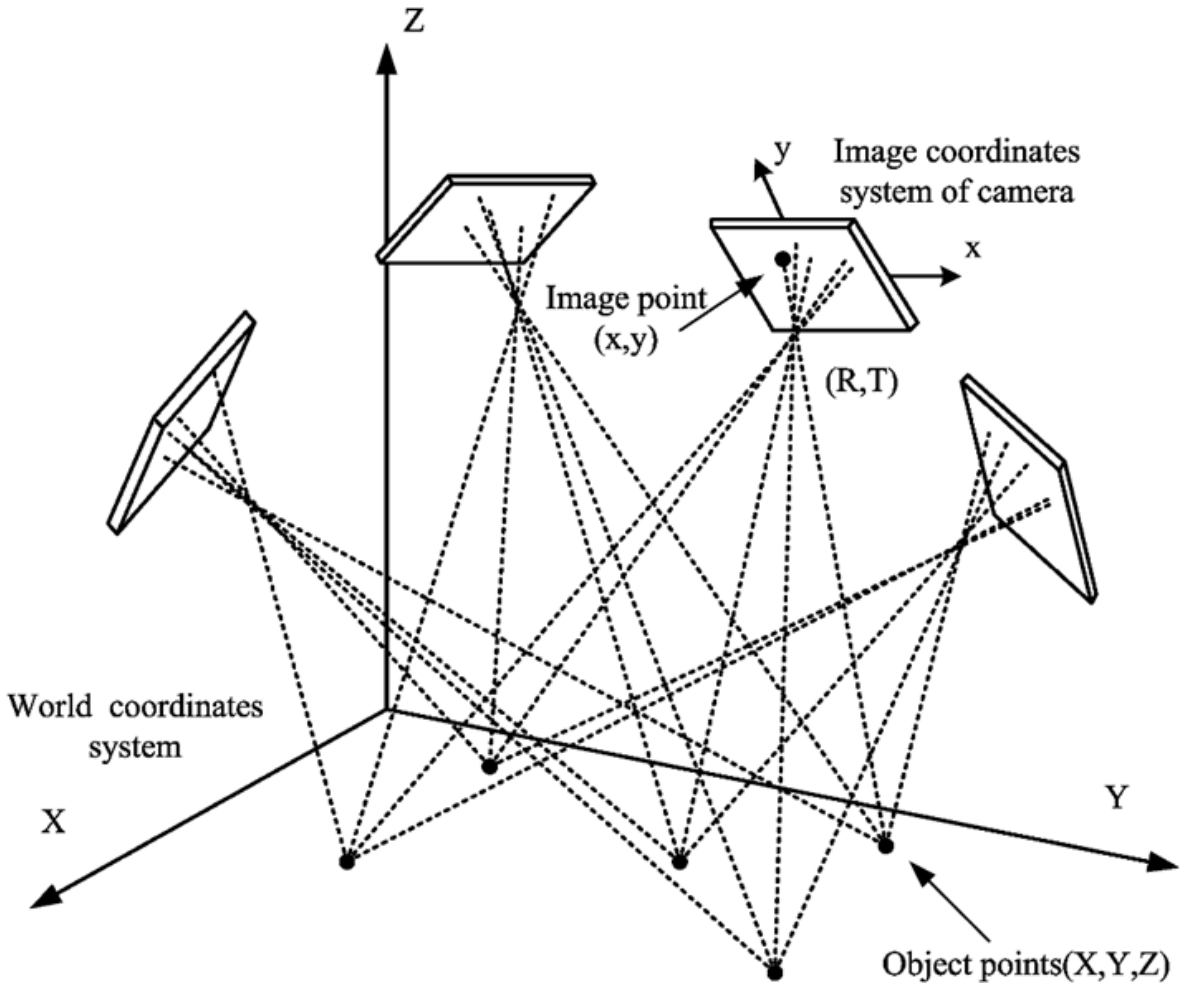
Concrete blocks slide from the top of the bluff



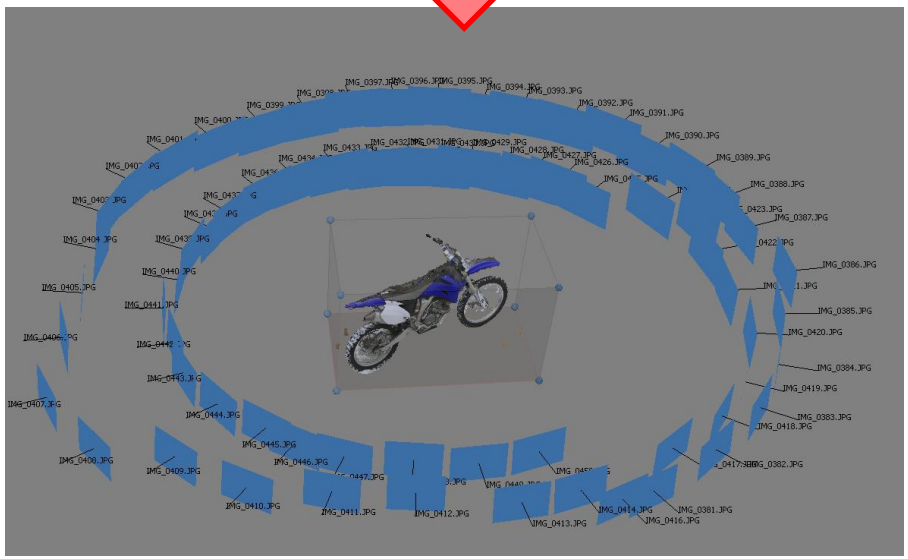
Concrete blocks

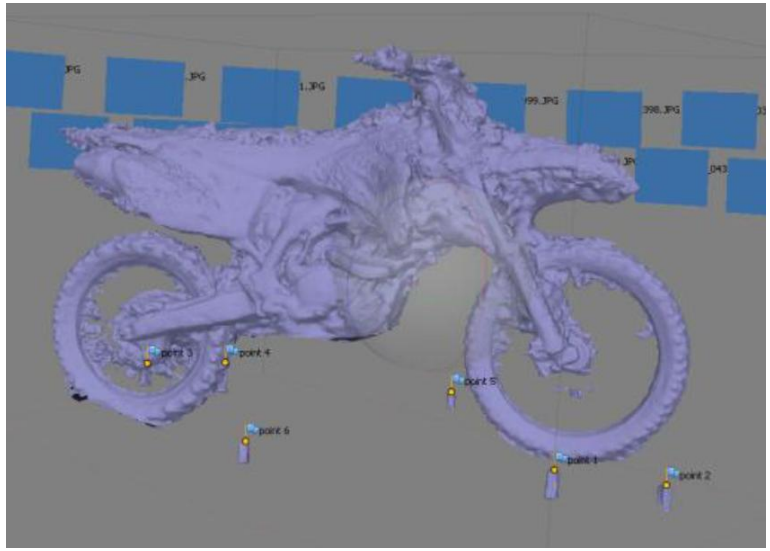
PHOTOGRAMMETRY AND STRUCTURE FROM MOTION (SFM)

An old task: 3D model from multiple pictures



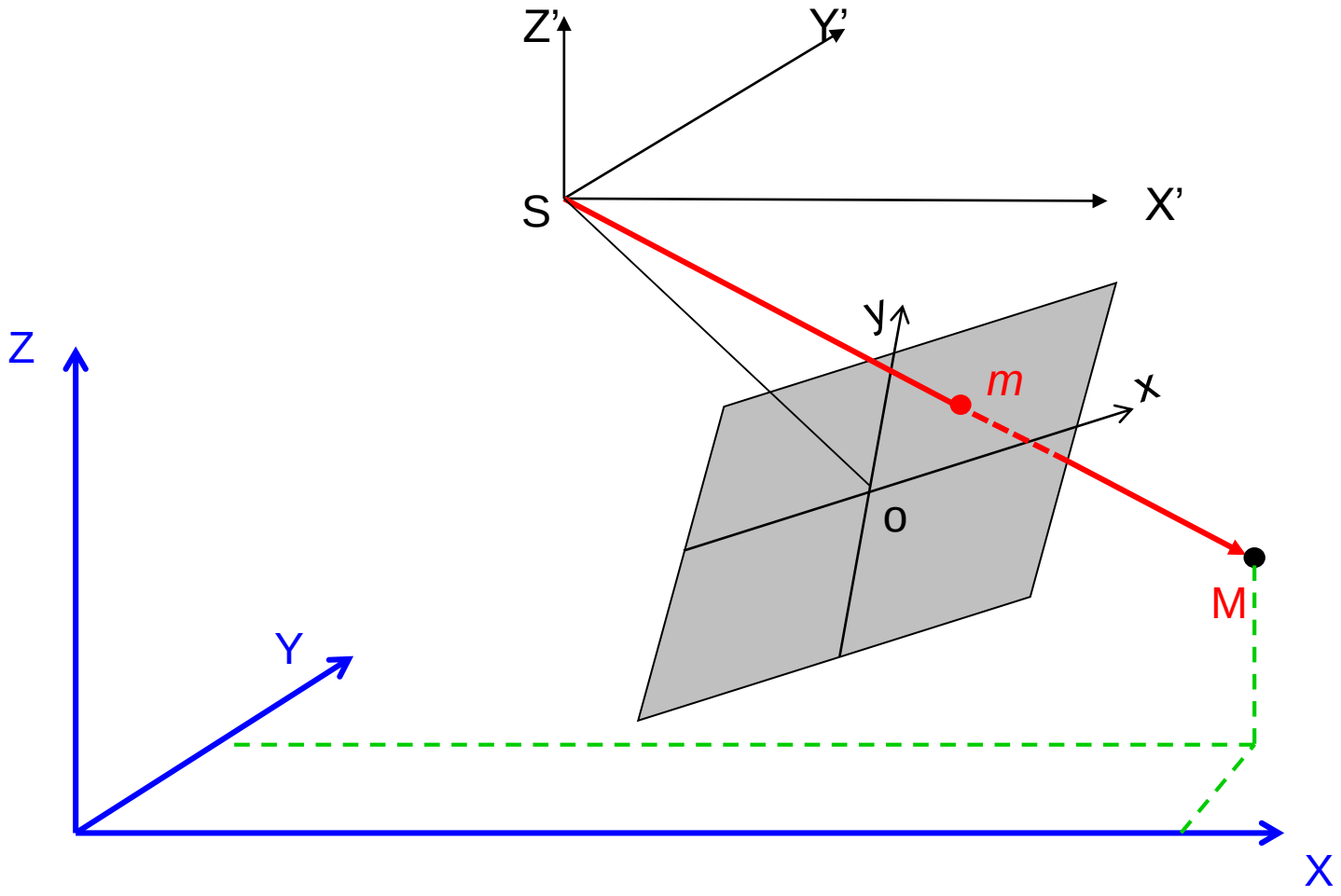
A new tool: Structure from Motion (SFM)



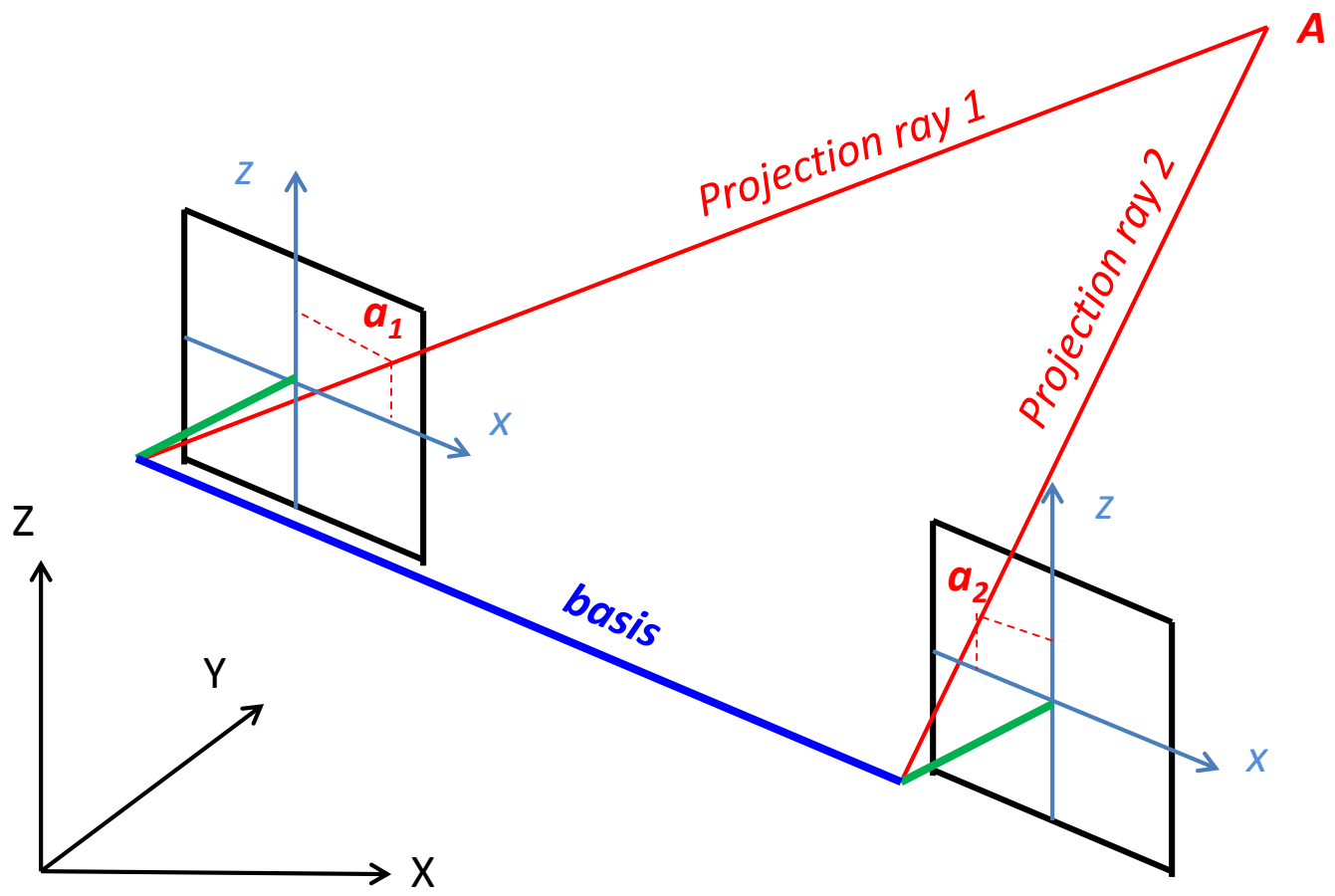


- Automatically generated models
- Measurable in 3D
- Any object, any size

SFM is based on classical photogrammetric concepts: collinearity

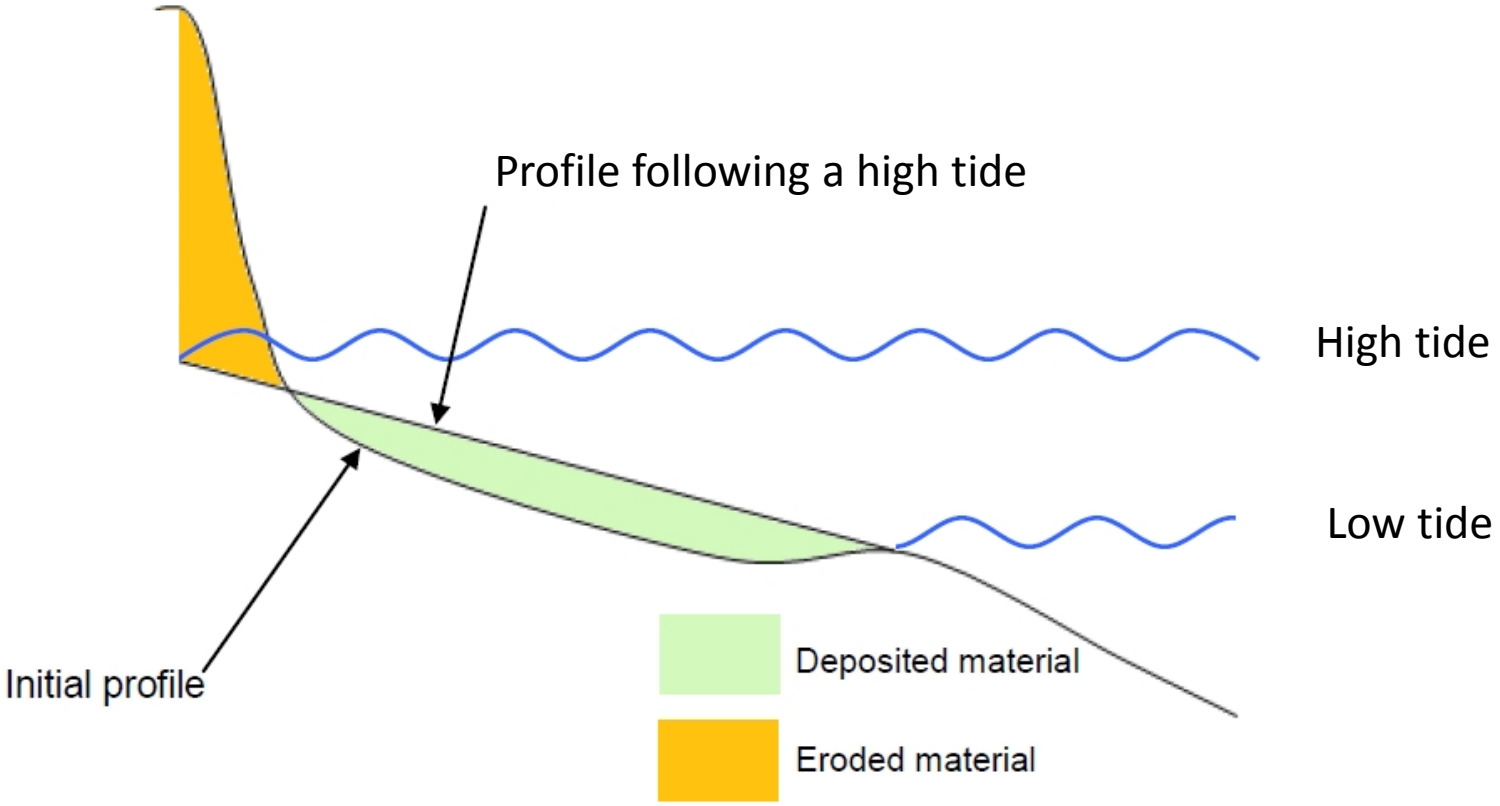


SFM is based on classical photogrammetric concepts: co-planarity



COASTAL BLUFF EROSION

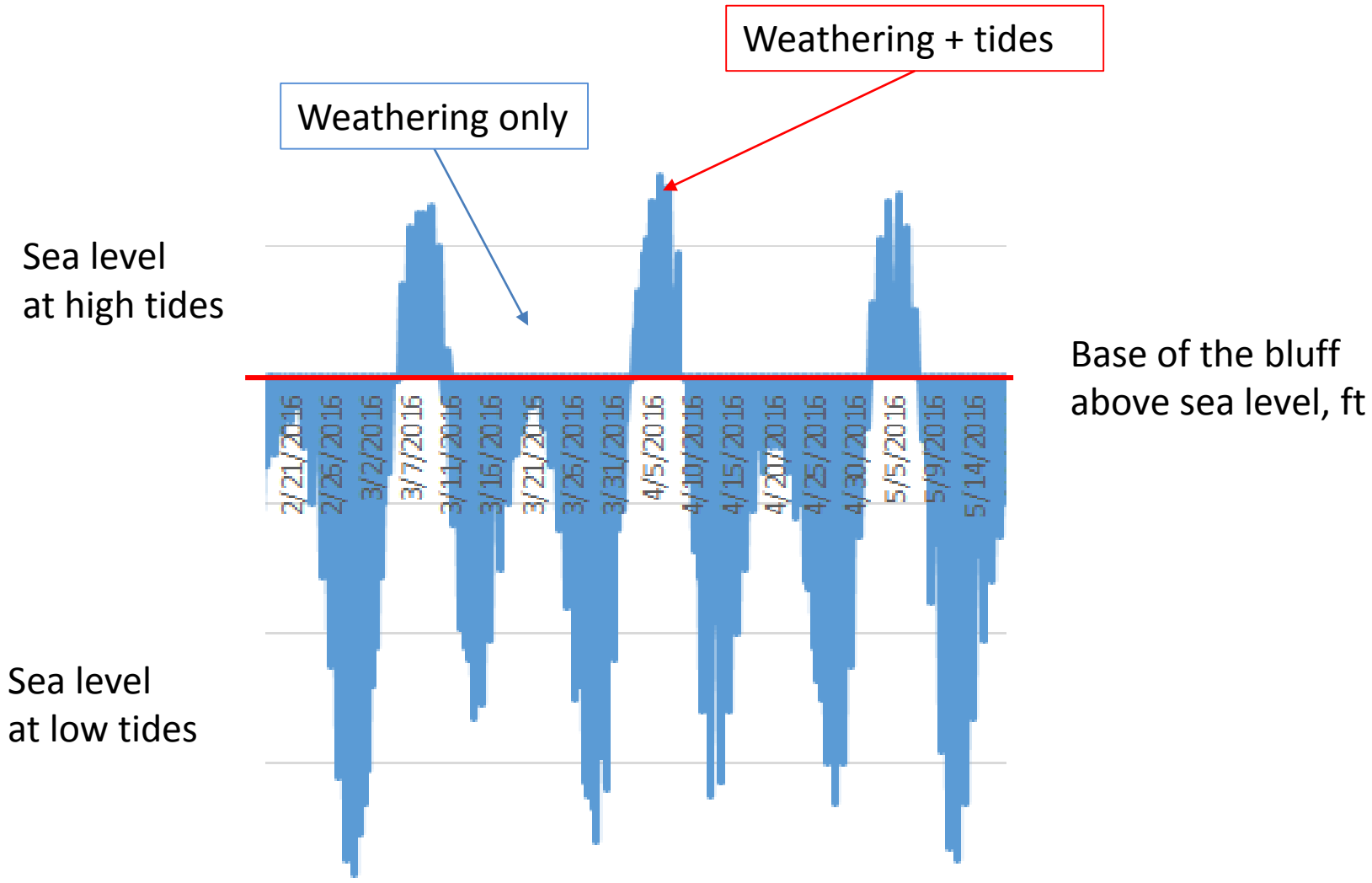
Bluff erosion and tides



Bluff erosion and tides

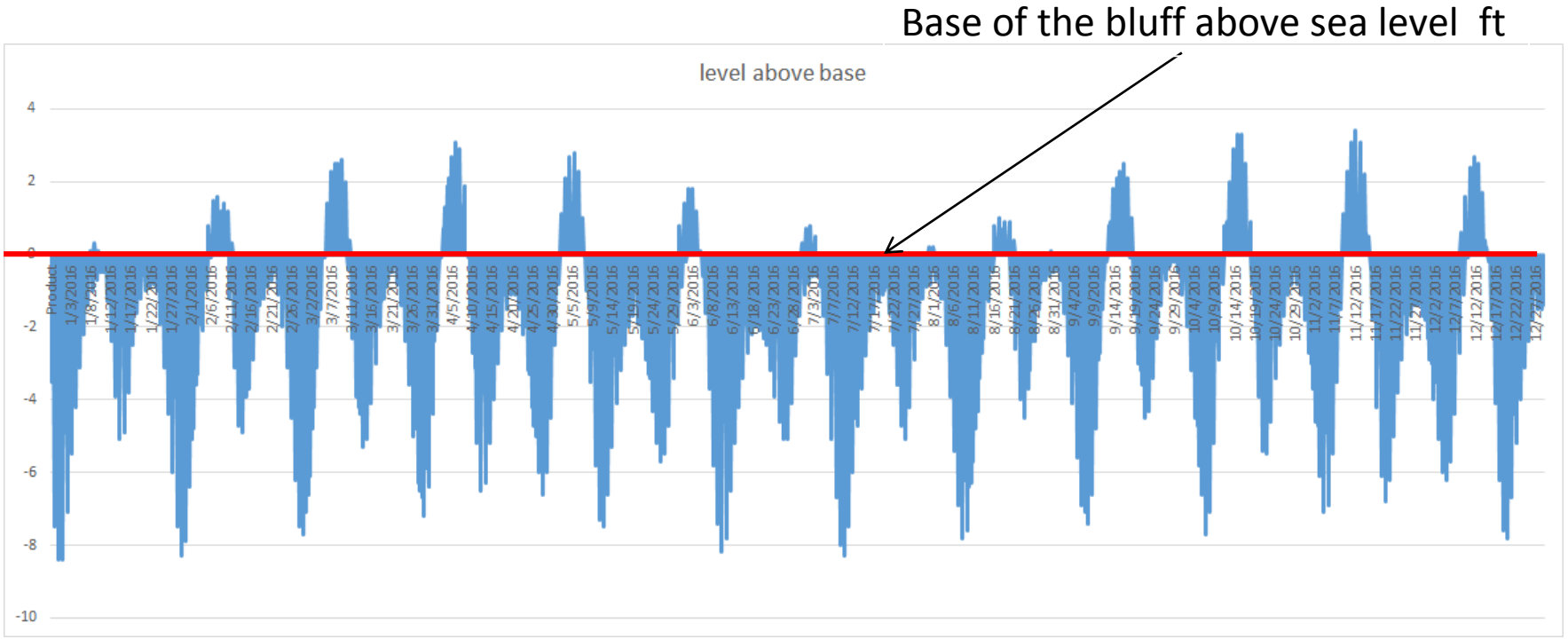
- Water “digs” into the bluff toe at high tides

Bluff erosion: weathering and tides



Combined forces of Moon and Sun: tidal variations

- "Spring" tides: highest high tides
- Neap tides: lowest high tides



Goals

- Create 3D base model for monitoring of bluff erosion
- Evaluate bluff stability at a very high temporal resolution
- Estimate weathering and tidal contribution into bluff erosion

FIELD WORK

Data collection

- Take pictures of the bluff from the beach during the low tide

- Equipment
  - DSLR camera Canon EOS 5D Mark II with Zeiss 50mm lens
  - RTK surveying

Field work specs

- Height of the bluff: 40 m (120 ft)
- Length of the bluff: 830 m (2,750 ft)
- Number of photos (per day): 220
- Photo base: 4 m (12 ft)
- Distance from camera to the bluff toe: 35 m (115 ft)
- Ground resolution: 7.5 mm (1/3“)

Ground control

- Not available on the bluff surface
- Not available on the beach
  - only concrete blocks
- Not available on the edge of the bluff
- Possible on the top (plateau) but not visible from the beach
- Solution: camera location with RTK

DATA PROCESSING

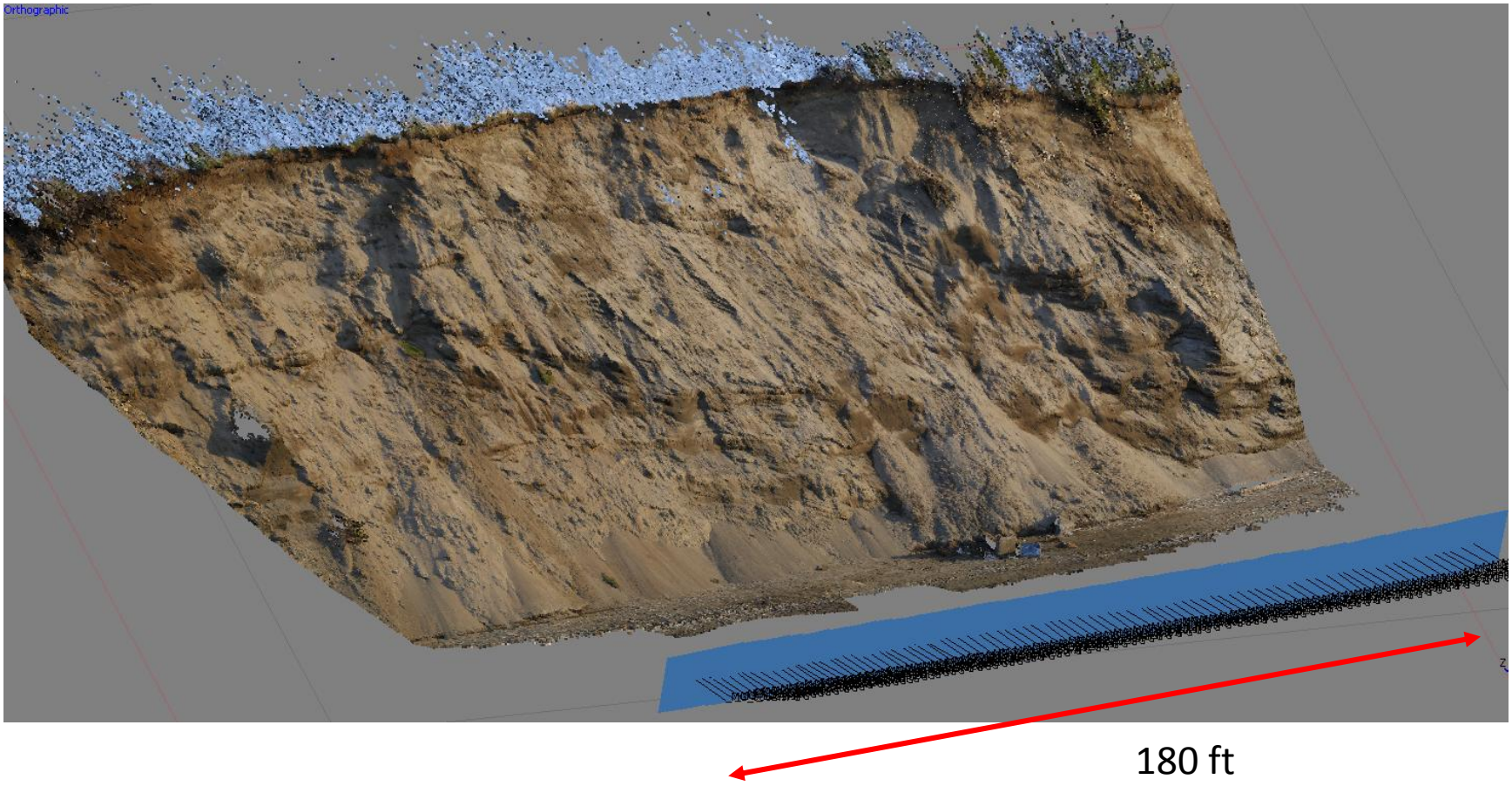
Data processing workflow

- Surveying data adjustment
  - OPUS
- 3D modeling
  - Photoscan (Structure from Motion, SFM)
- Cloud-to-cloud analysis
  - CloudCompare
- Multi-temporal surface analysis
  - Hupercube

Tie points from SFM

- Each point has been identified in more than 10 overlapping photos

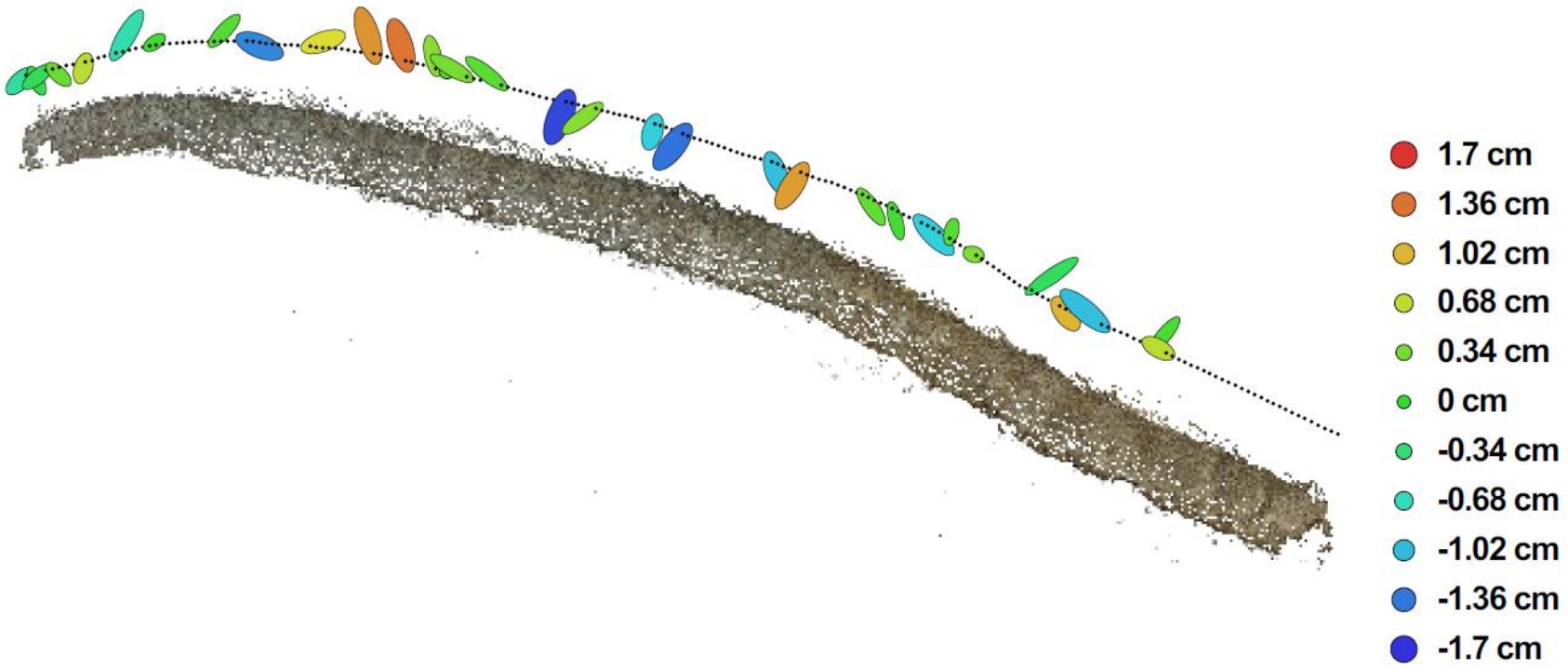
3D model: 97,209,269 points



3D model: 3,050 points per sq.ft

Source image

Camera positional accuracy

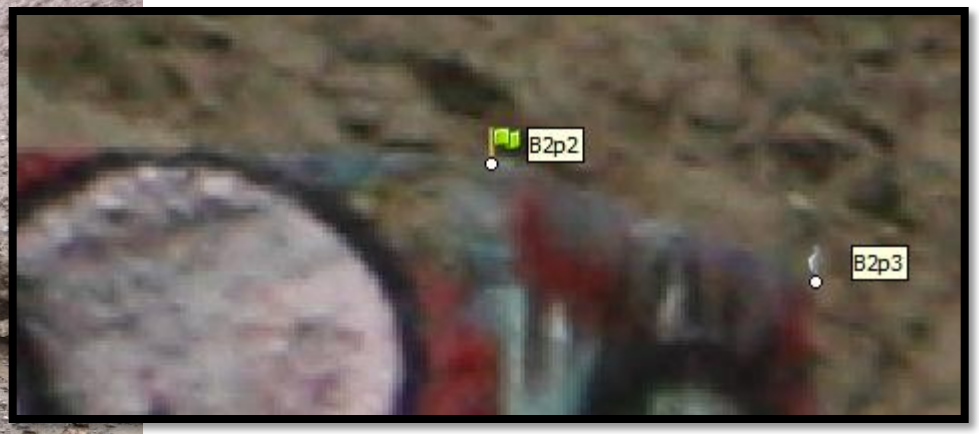


X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
0.8	0.9	0.8	1.2	1.4

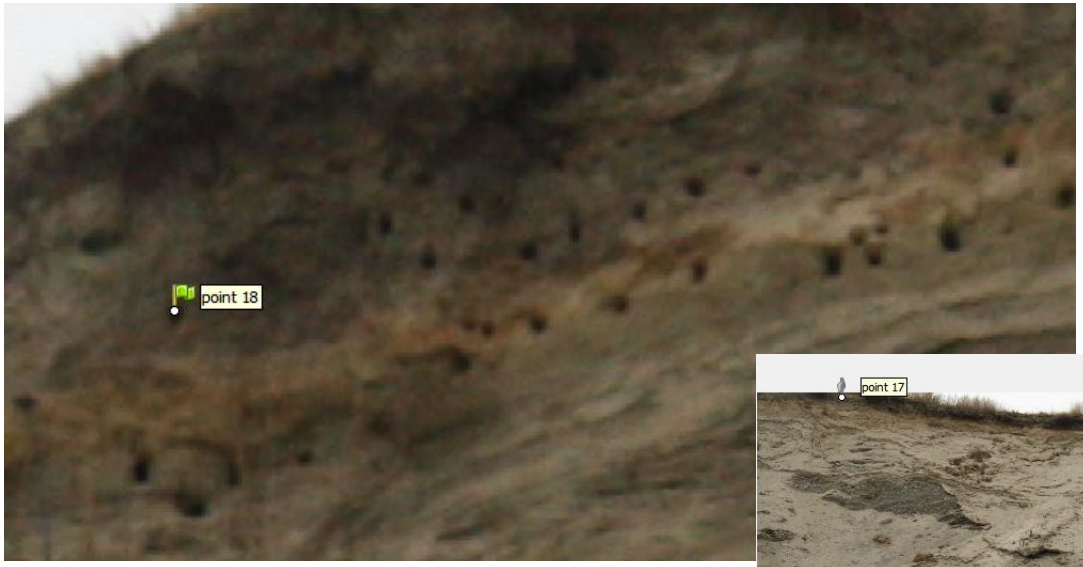
Ground control points accuracy

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
B1p1	-8.07573	-0.376493	-3.56185	8.83436	0.570 (5)
B1p2	-8.43534	-3.23993	-1.01005	9.09243	0.977 (6)
B2p1	-7.34668	-1.61603	-2.62164	7.96607	0.786 (6)
B2p2	-8.51892	2.08473	-4.5291	9.87071	1.369 (6)
B2p4	-9.26168	2.45533	-1.39951	9.68329	1.205 (7)
Total	**8.35101**	**2.17372**	**2.93433**	**9.11453**	**1.040**

Check points: concrete blocks

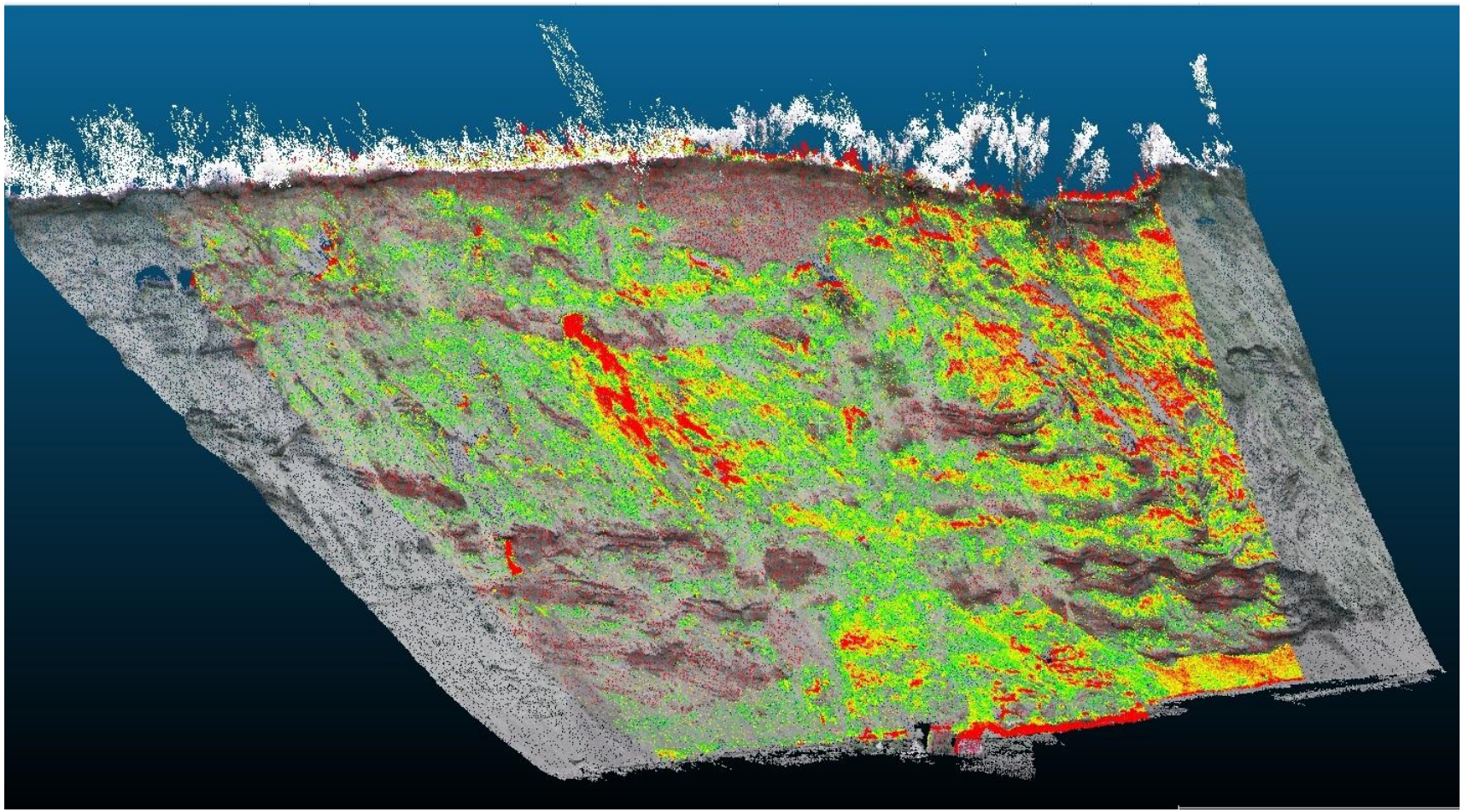


Check points: bluff features

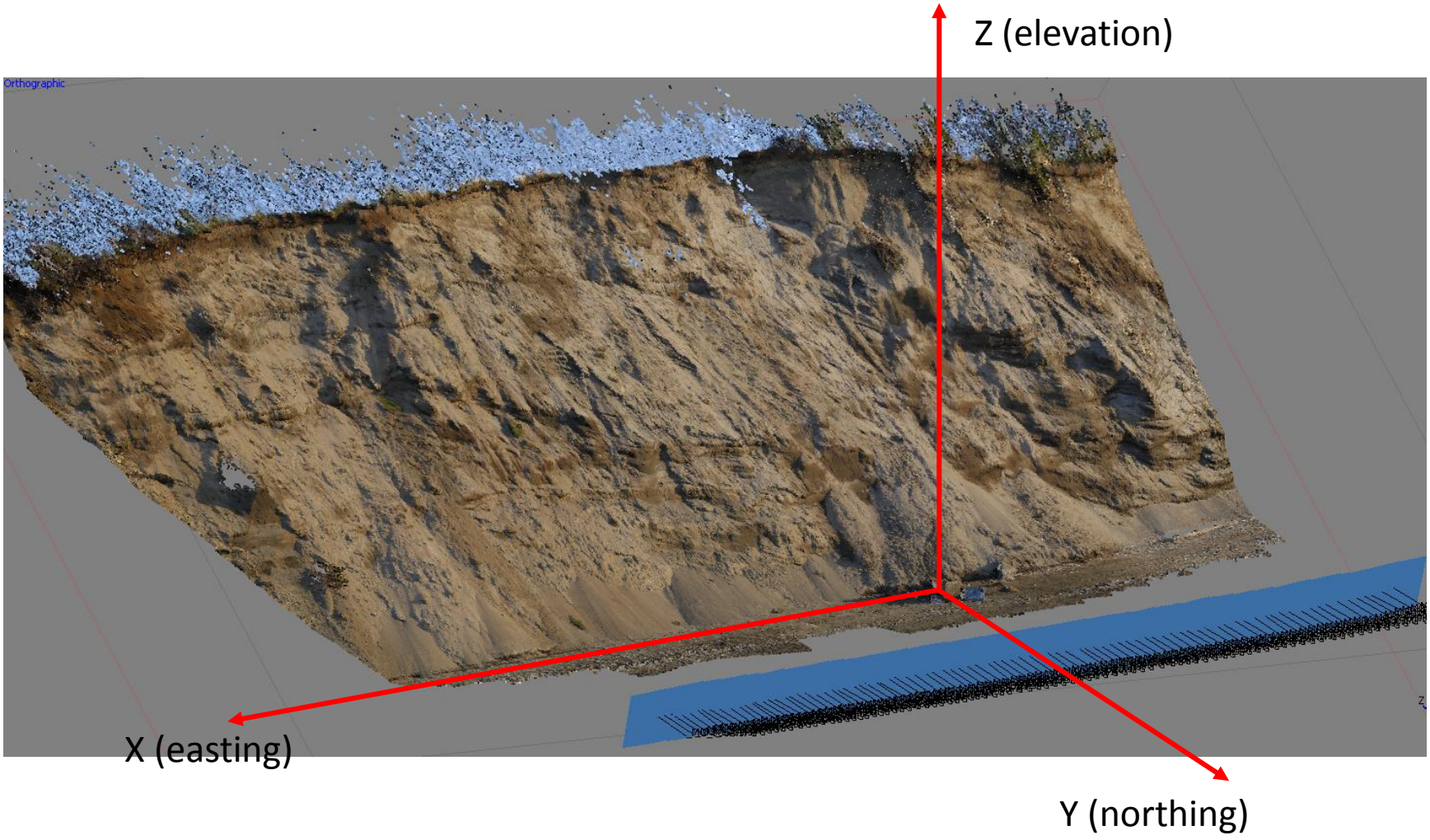


CLOUD-TO-CLOUD

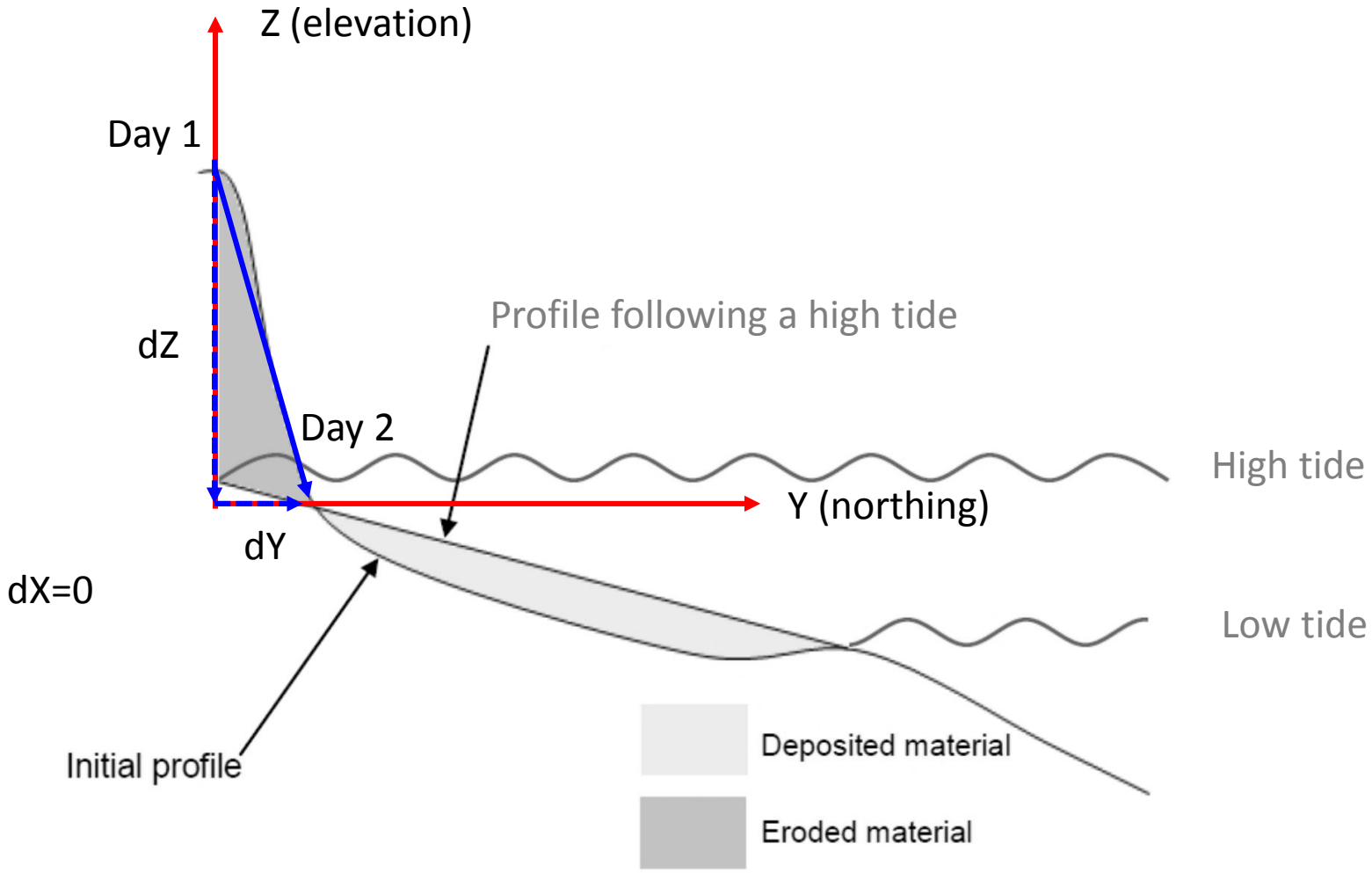
Cloud-to-cloud registration



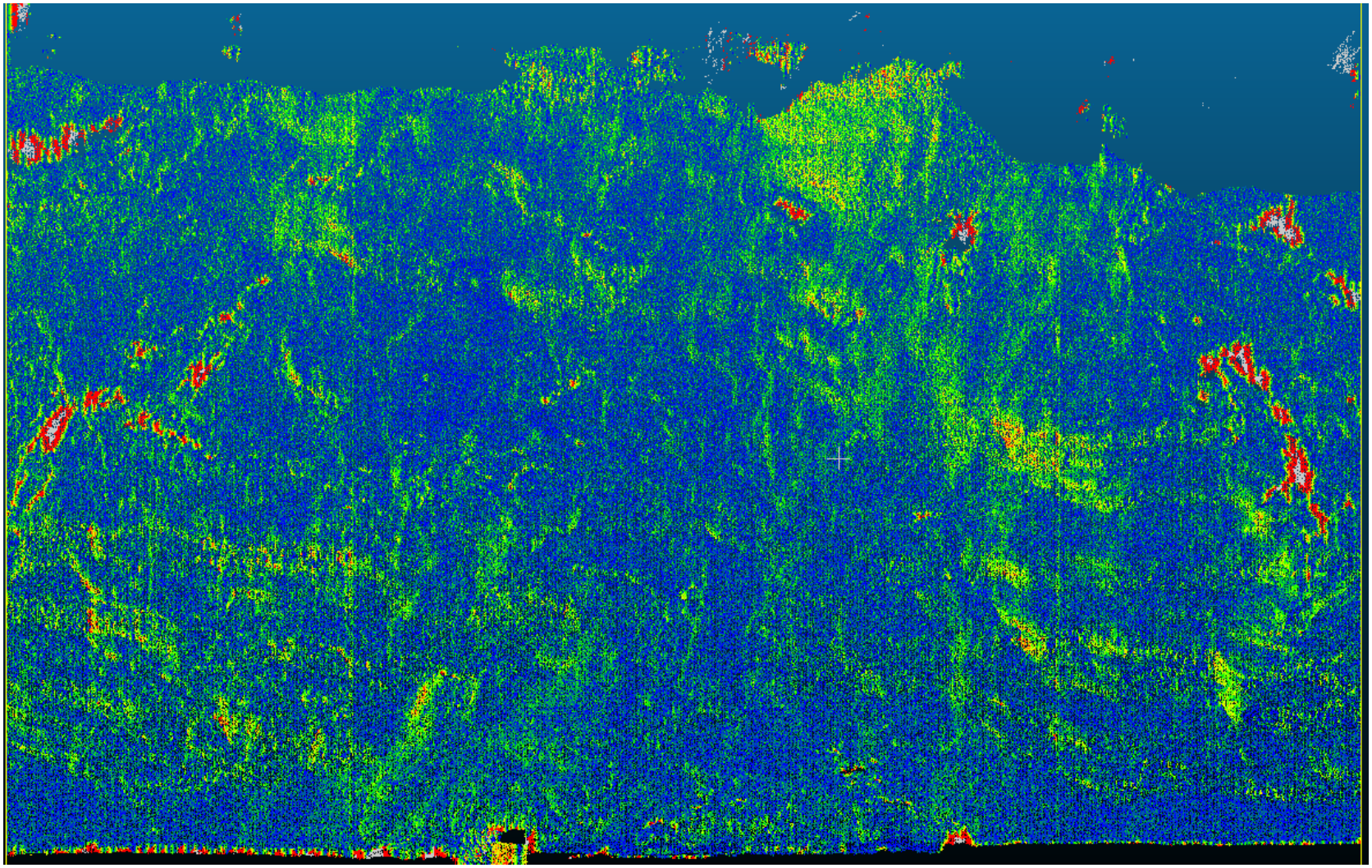
3D movement components



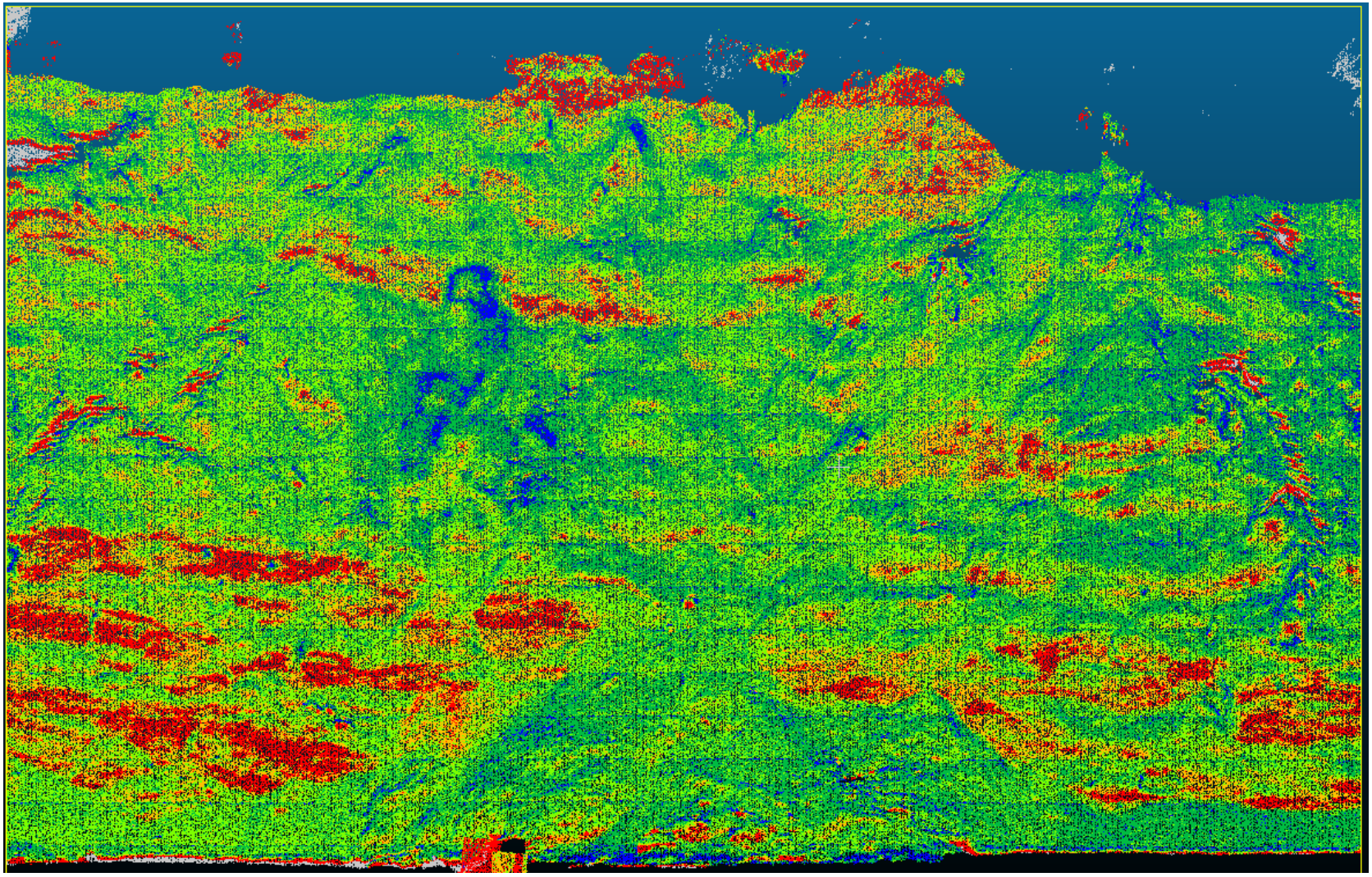
Surface movement: 3D components



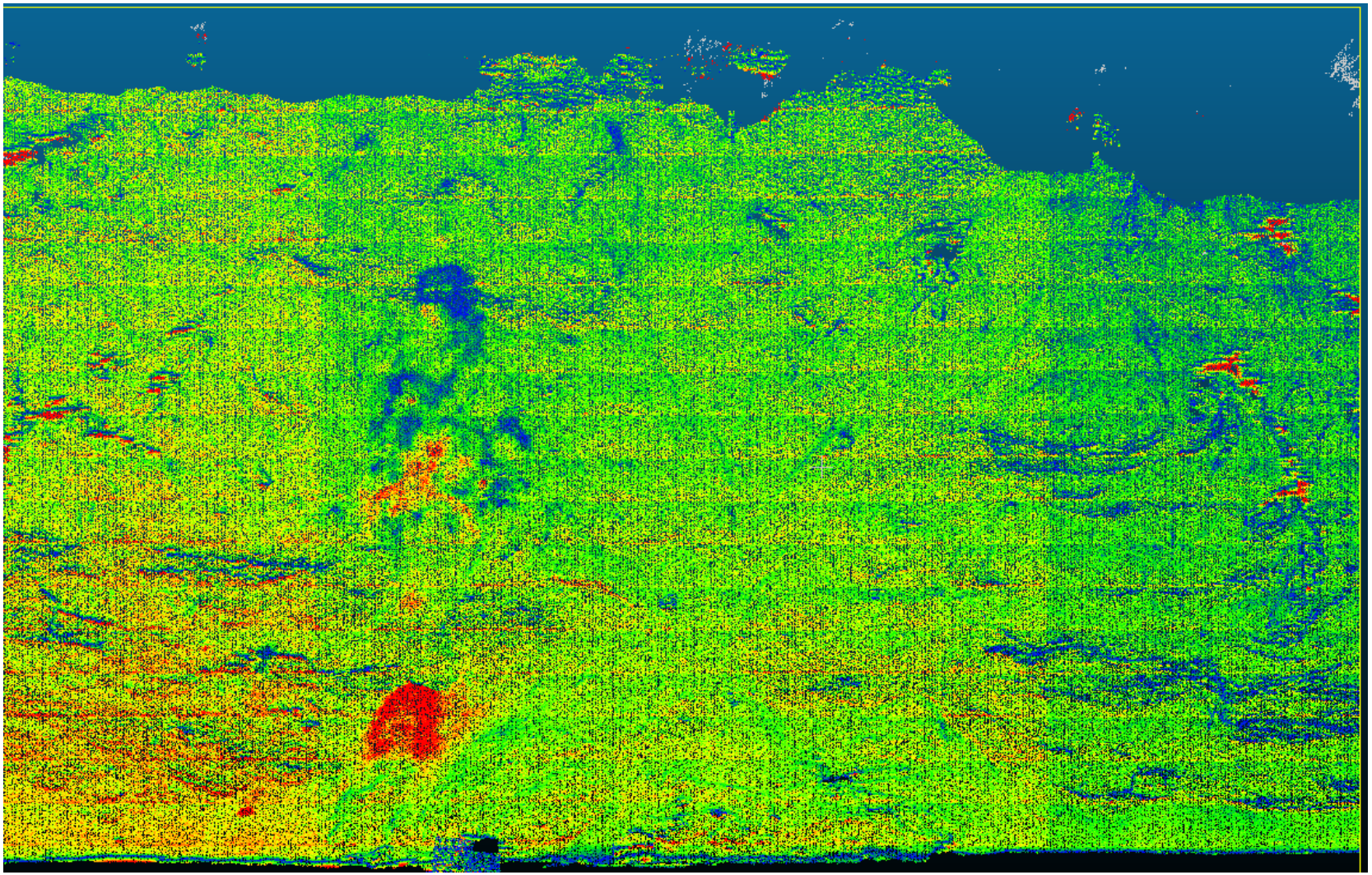
Surface movement: dX



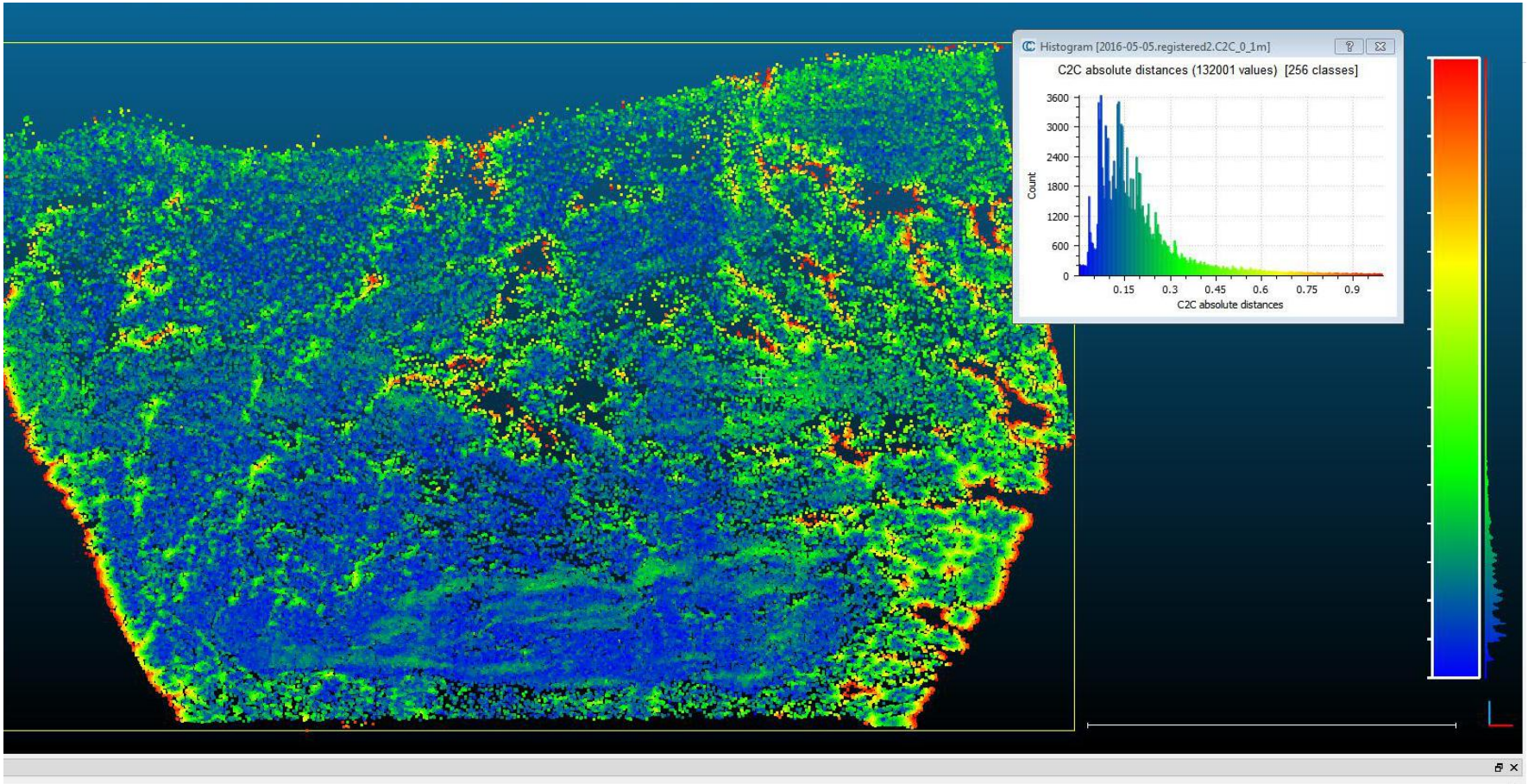
Surface movement: dY



Surface movement: dZ



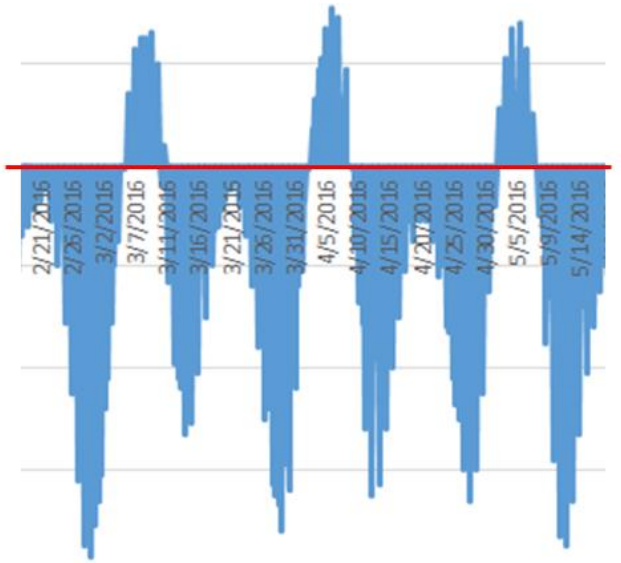
Surface movement: dX+dY+dZ



BLUFF DYNAMICS

High tides above the base of bluff in 2016

- May: 7 days
- June-August: tides are below the base of the bluff
- September: tides were not high as predicted
- October: 8 days
- November: 7 days

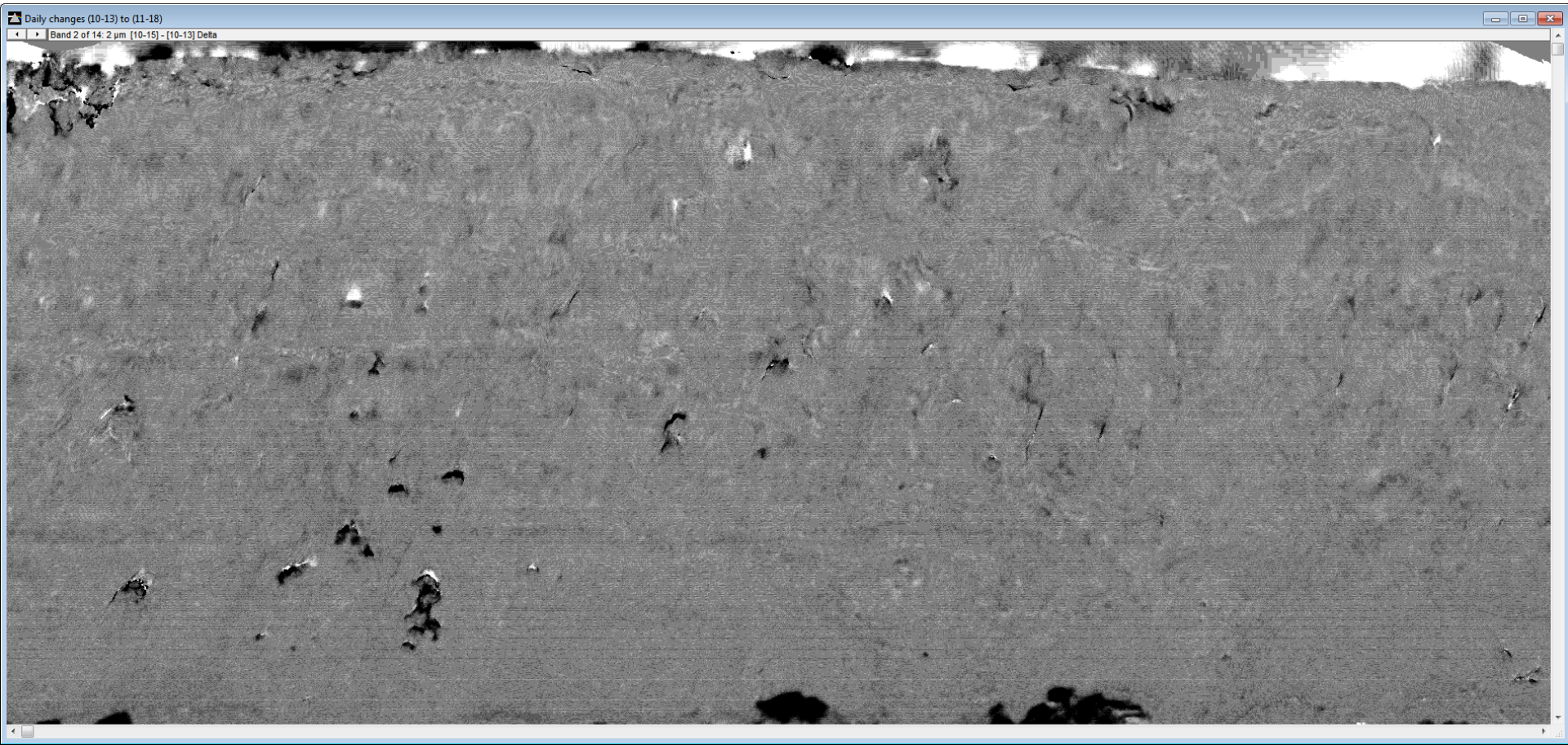


Mapping the bluff dynamics

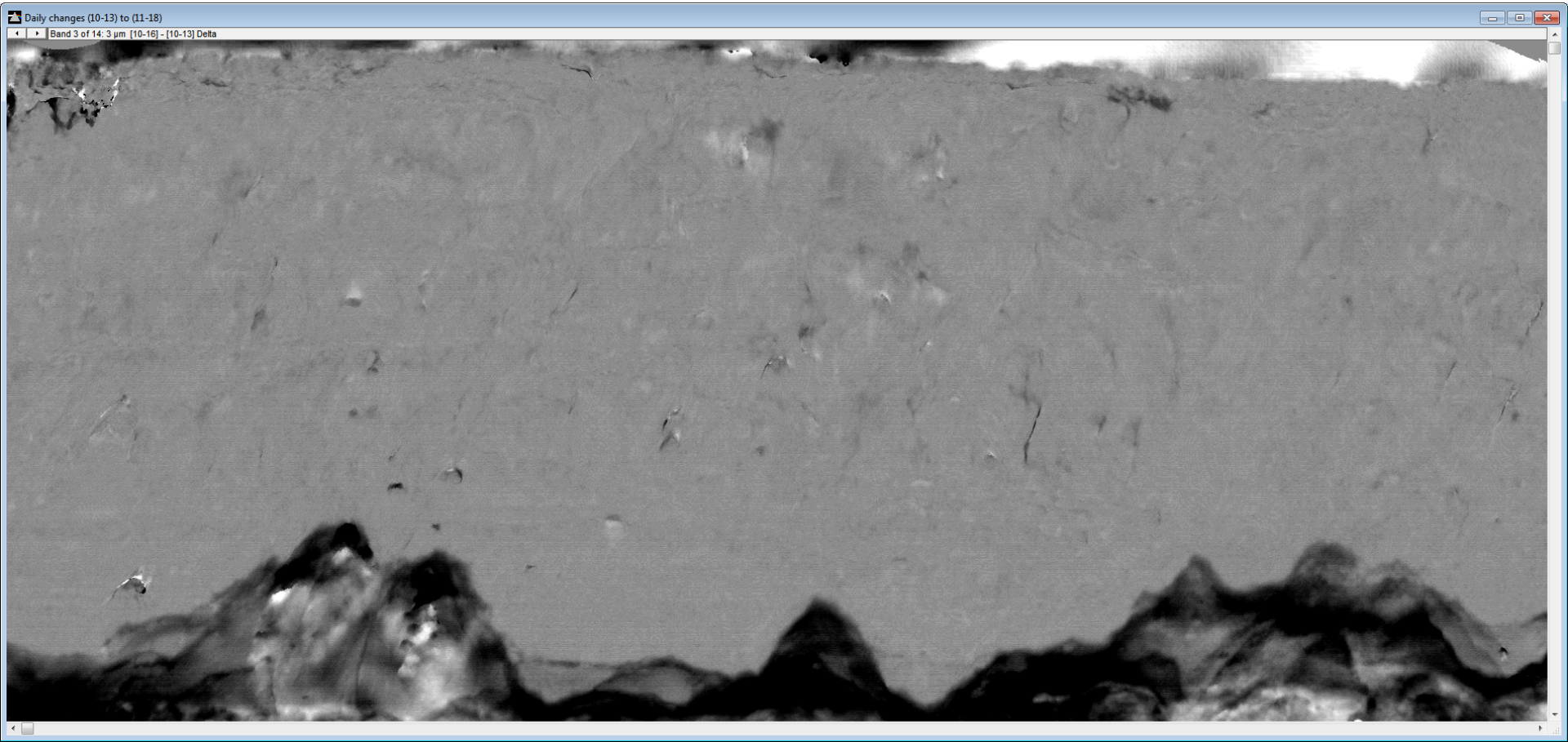
- Reconstruct 3D surface for each day of observations
- Align surfaces
- Chose first surface as a base
- Sequentially subtract surfaces
- Visualize differences
- Calculate gain and loss in volume

Illustration: bluff segment 200m

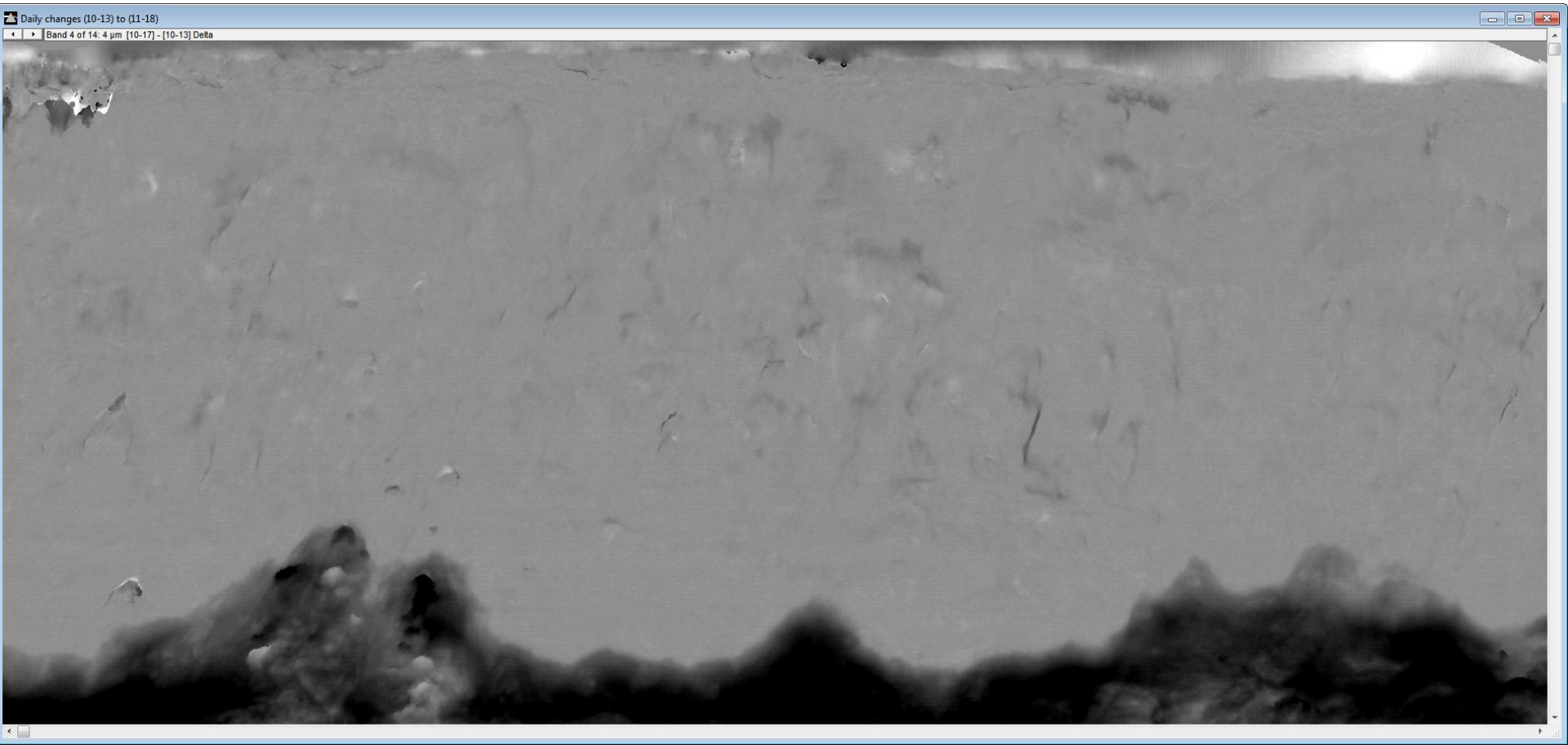
October 15 vs October 13: 2 days
No high tide yet



October 16 vs October 13: 3 days
High tide in

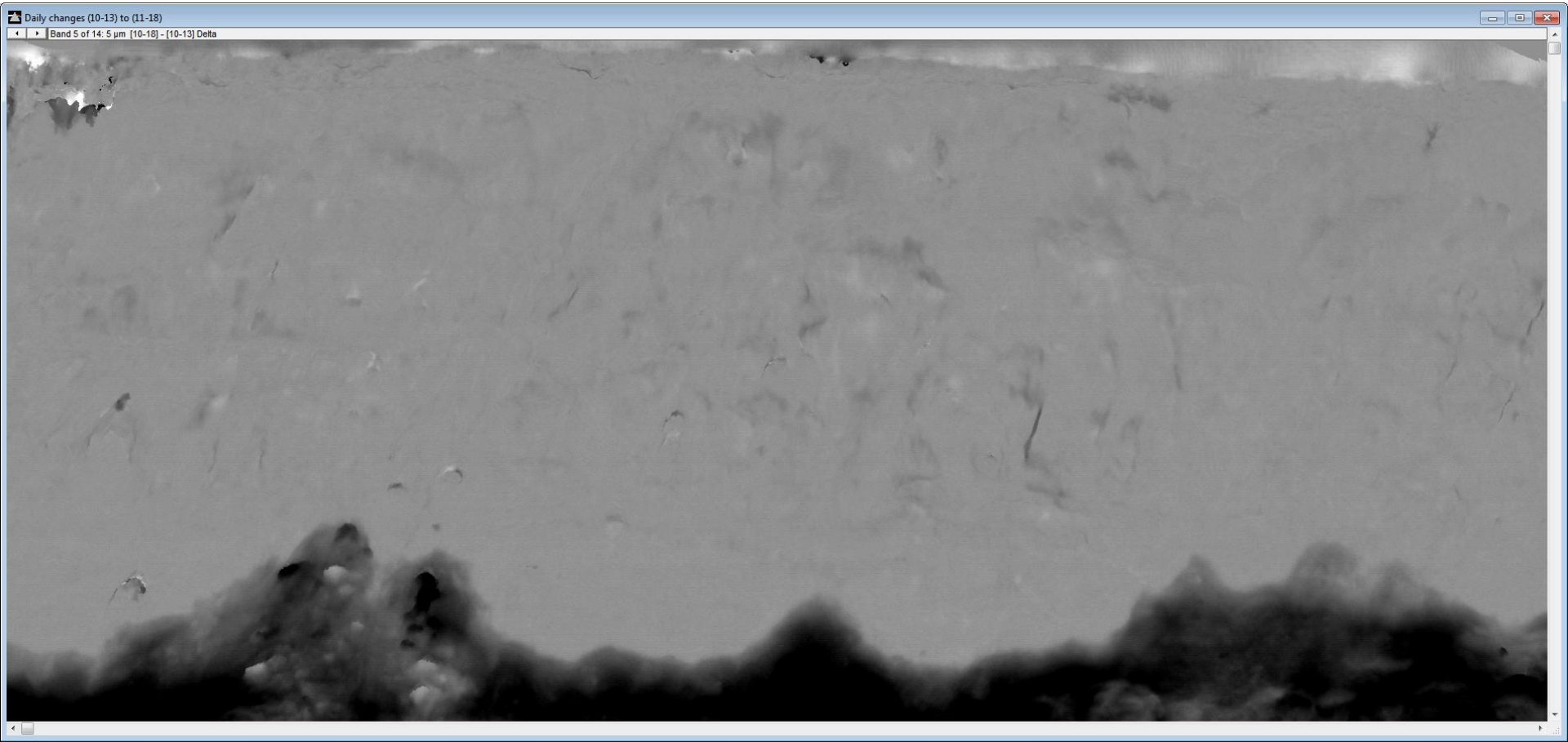


October 17 vs October 13: 4 days
High tide in

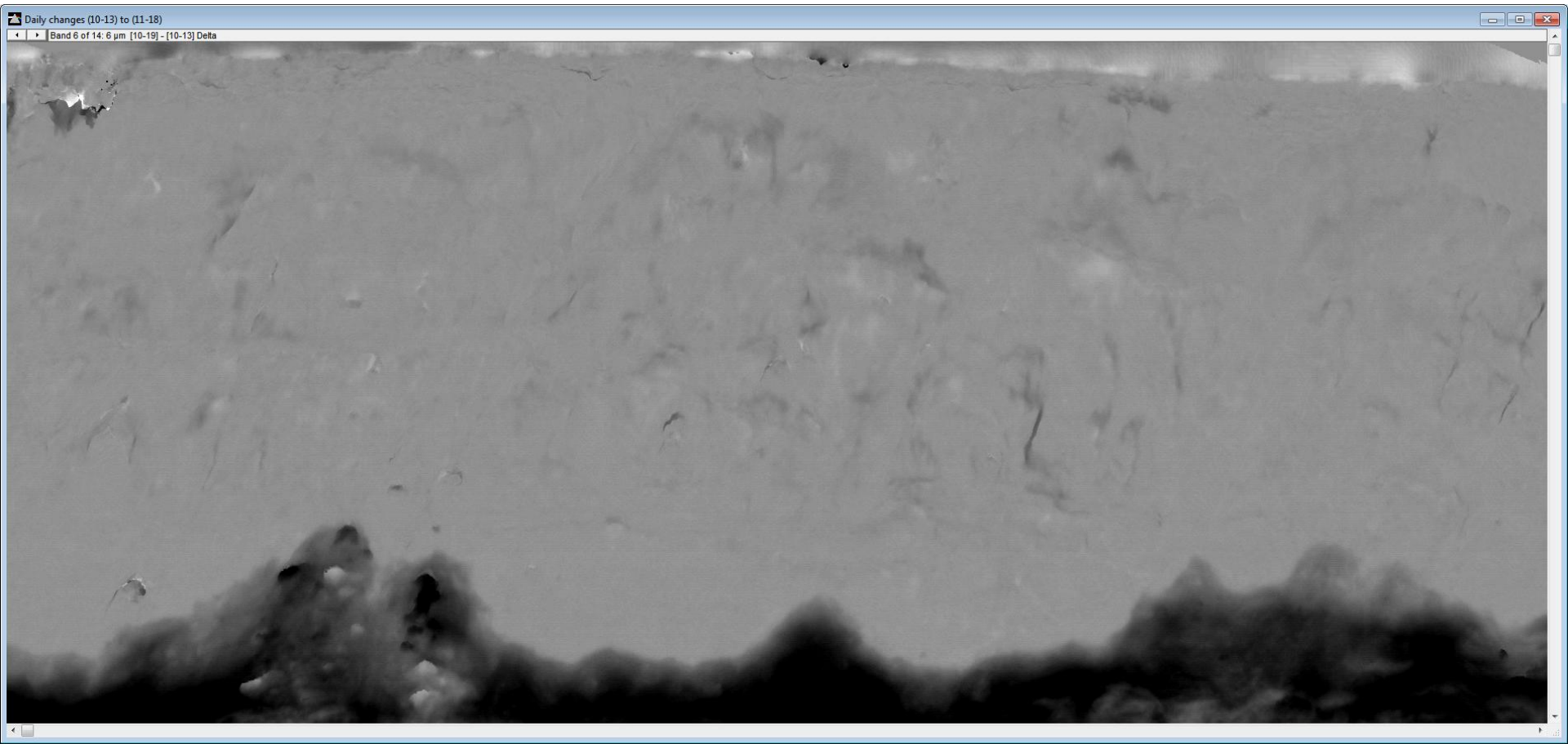


October 18 vs October 13: 5 days

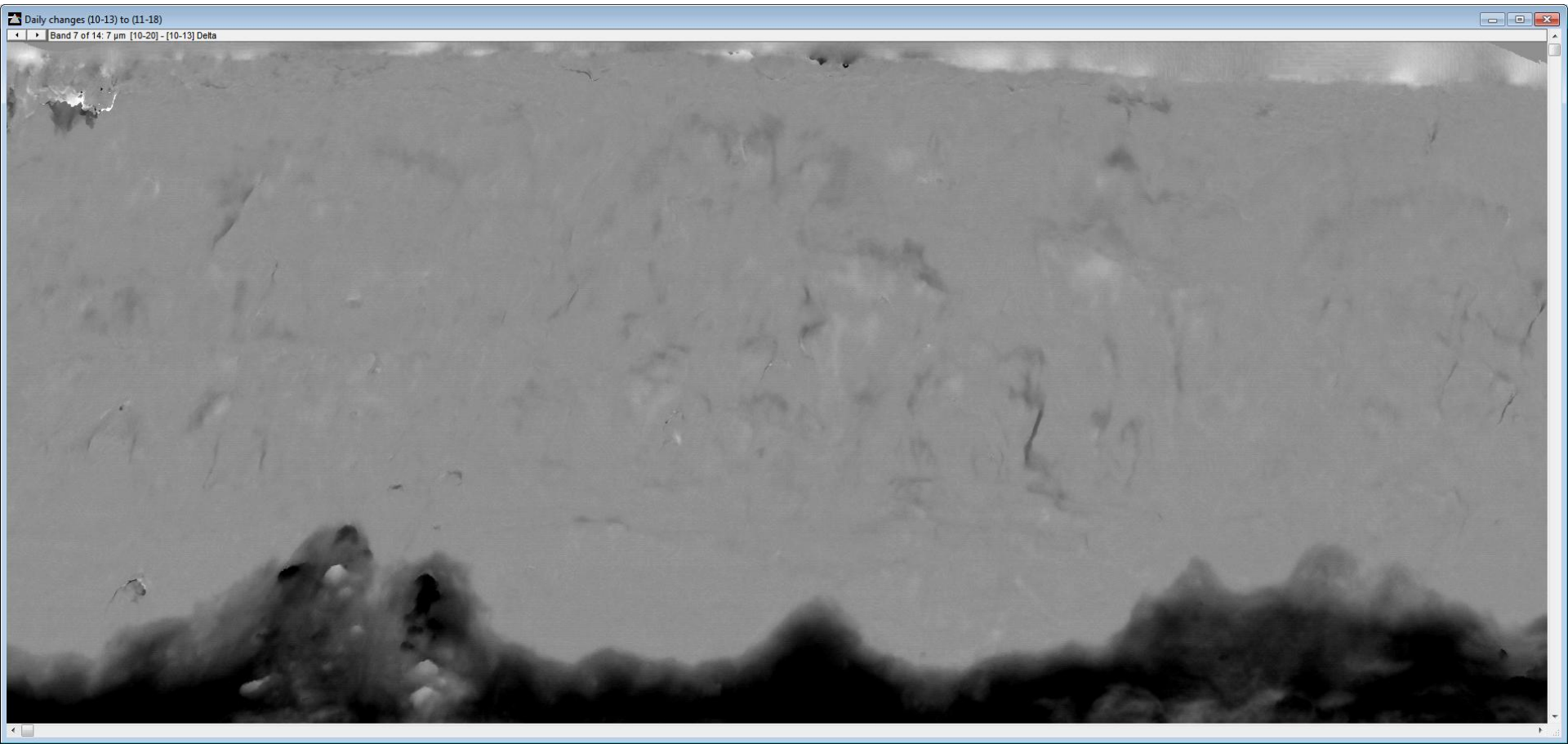
High tide in



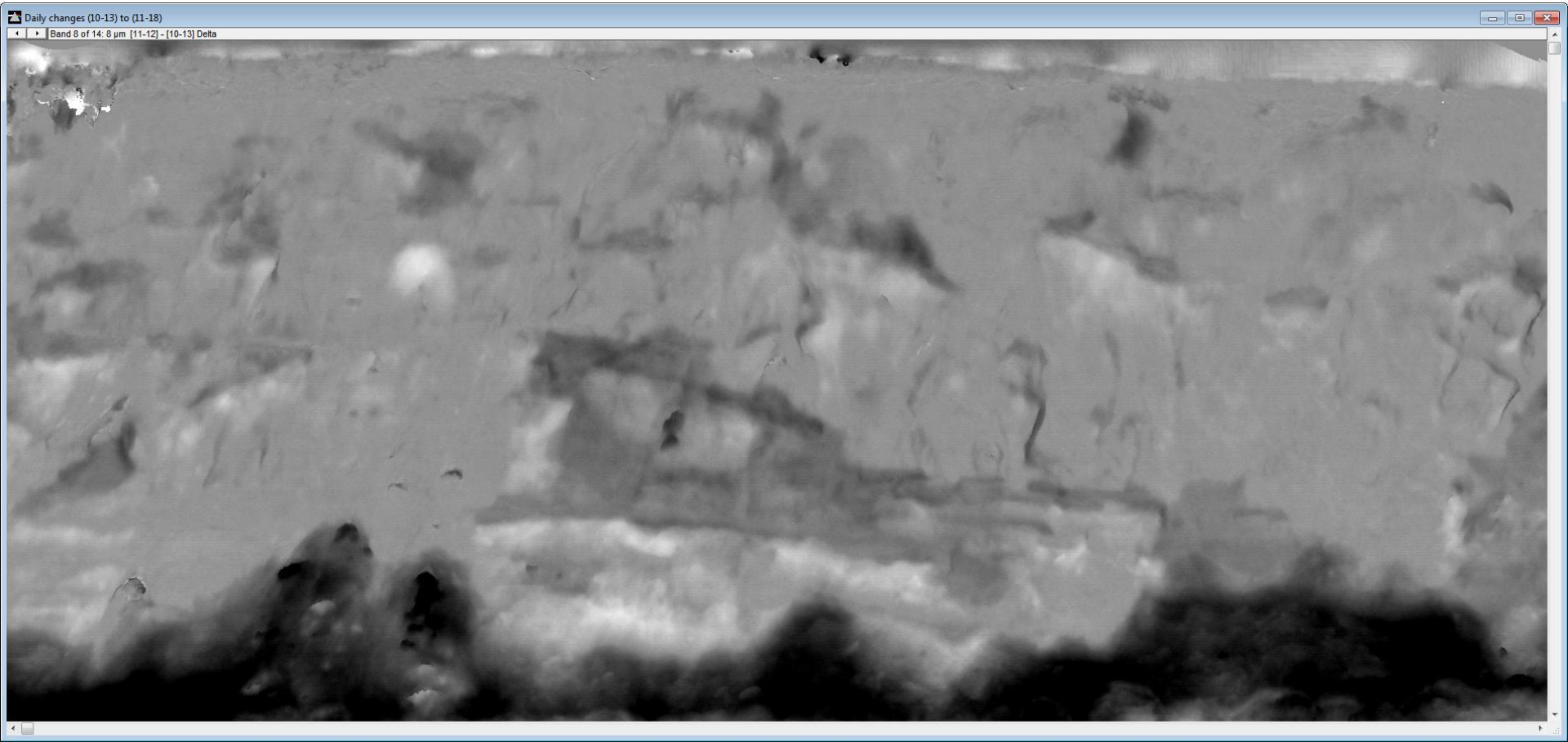
October 19 vs October 13: 6 days
High tide is getting lower



October 20 vs October 13: 7 days
High tide is even lower

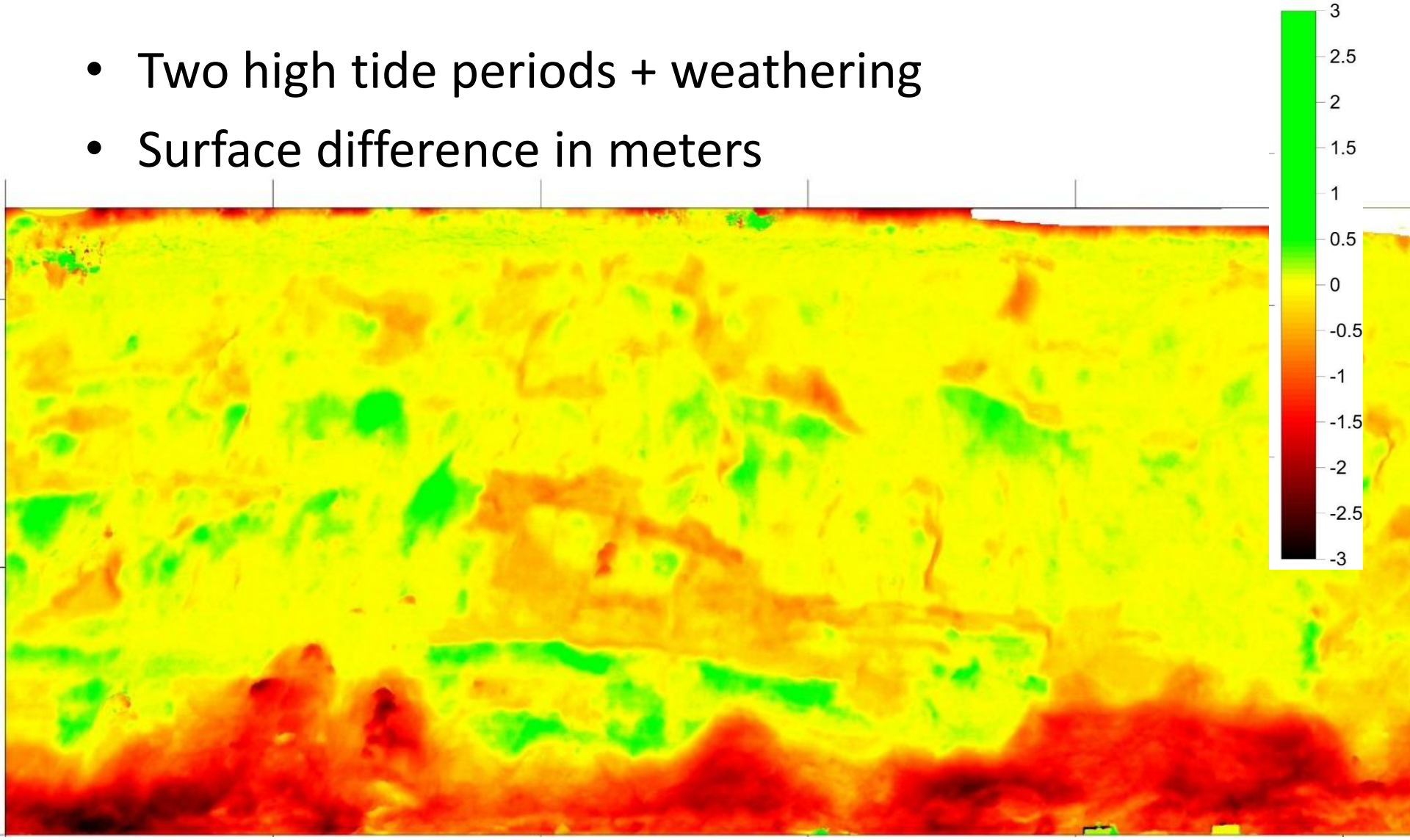


Three weeks later: November 12
No tides, just weathering



November 18 vs October 13: 35 days

- Two high tide periods + weathering
- Surface difference in meters



Volume balance

	10/20 minus 10/13	11/12 minus 10/20	11/18 minus 11/12	11/18 minus 10/13
	high tides in October	weathering between high tides	high tides in November	two high tides and weathering
Loss, m^3	-1144.8	-372.9	-419.0	-1682.4
Gain, m^3	107.6	583.7	108.3	249.7
Net, m^3	-1037.2	210.8	-310.7	-1432.7
Net, yd^3	-1356.3	275.8	-406.4	-1873.9
Trucks	136	28	41	187

- Bluff segment
  - Length 502 ft
  - Height 138 ft
- Surface area
  - 69,498 sq.ft
  - 6,456 sq.m

FURTHER STUDY

Terrestrial SFM Spring 2017

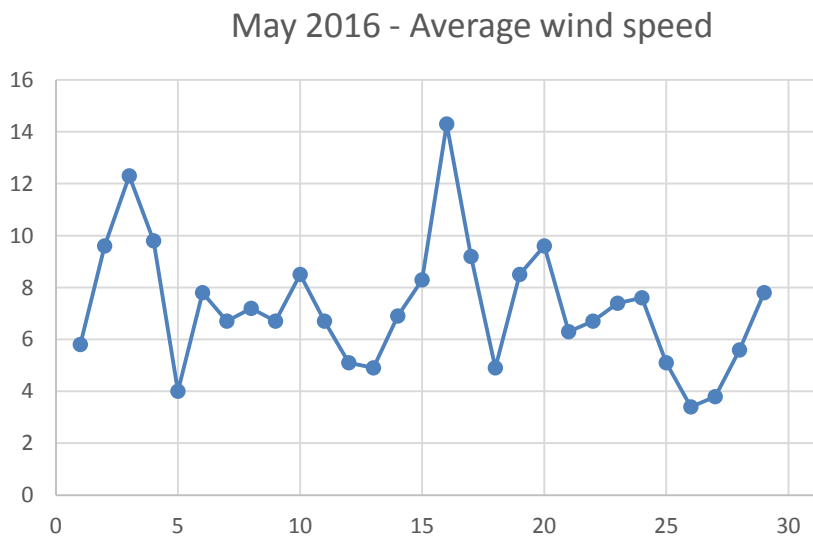
- Complete one year cycle
- Build an annual dynamic 3D model
- Explore seasonal phases of erosion
- Define slop stability areas

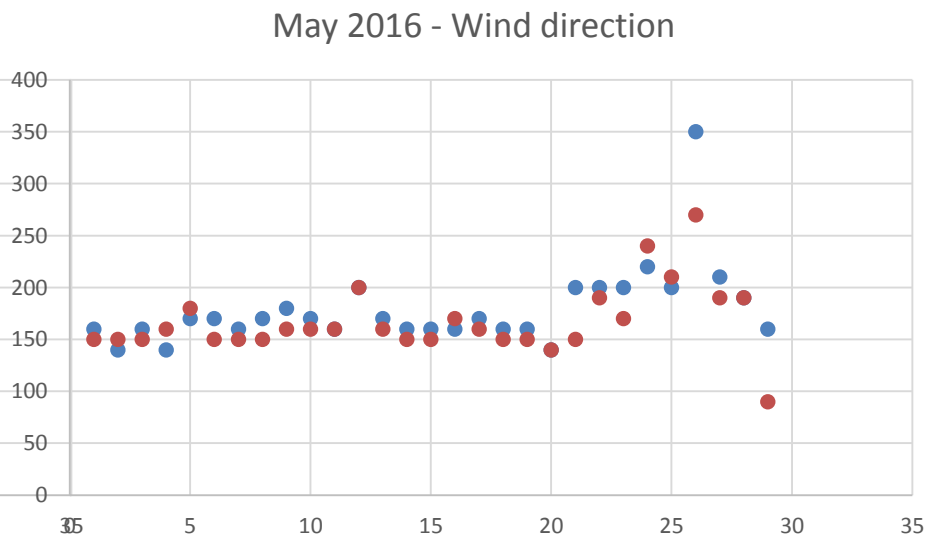
Weather data analysis

- Correlate bluff dynamics with
  - air temperature
  - precipitation
  - wind speed
  - wind direction
- Evaluate wave height and possibly shallow water wave power/energy

Weather data analysis

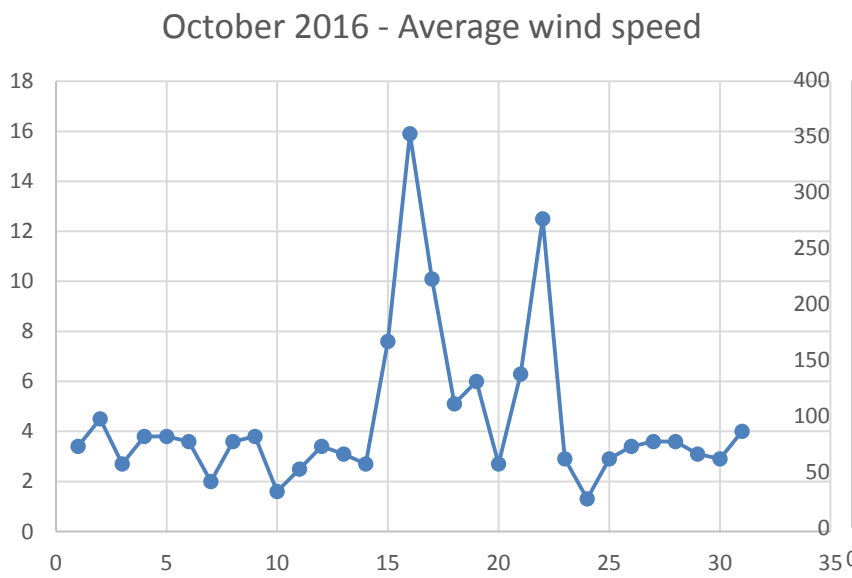
- Wind speed and direction: May 2016

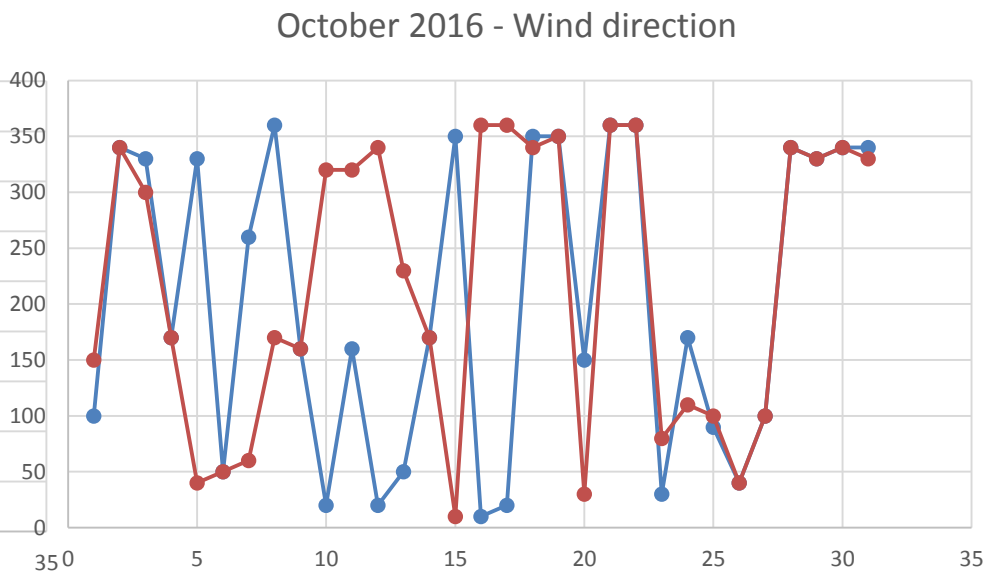




Weather data analysis

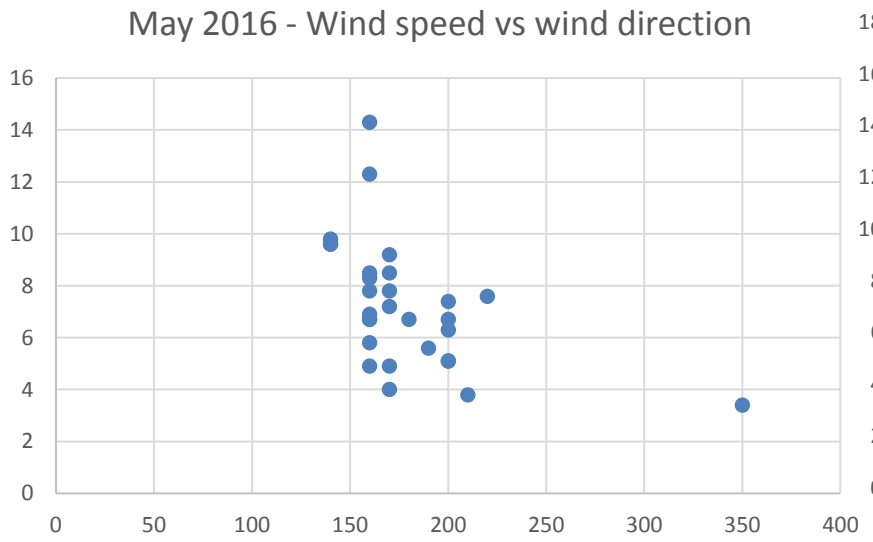
- Wind speed and direction: October 2016

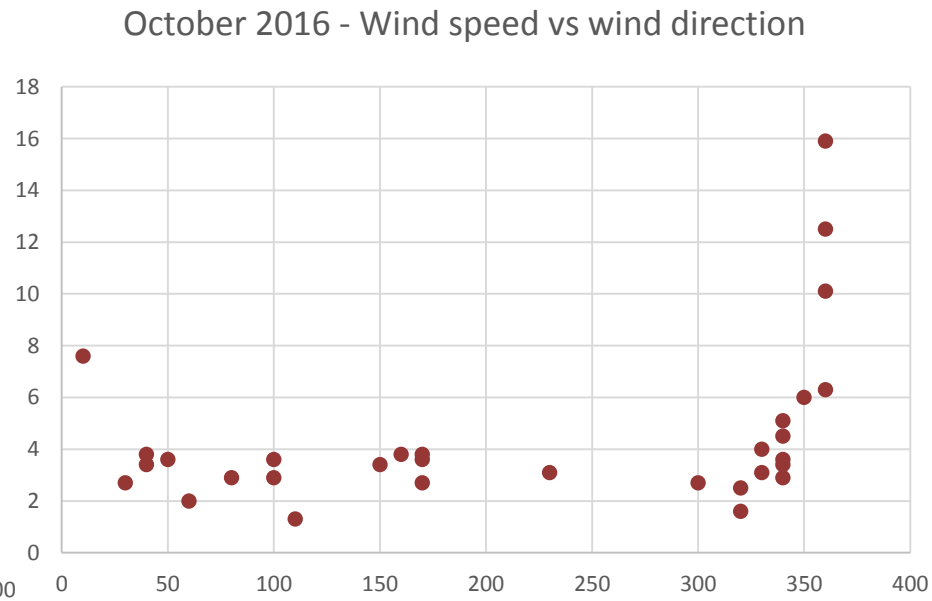




Weather data analysis

- Wind speed vs wind direction

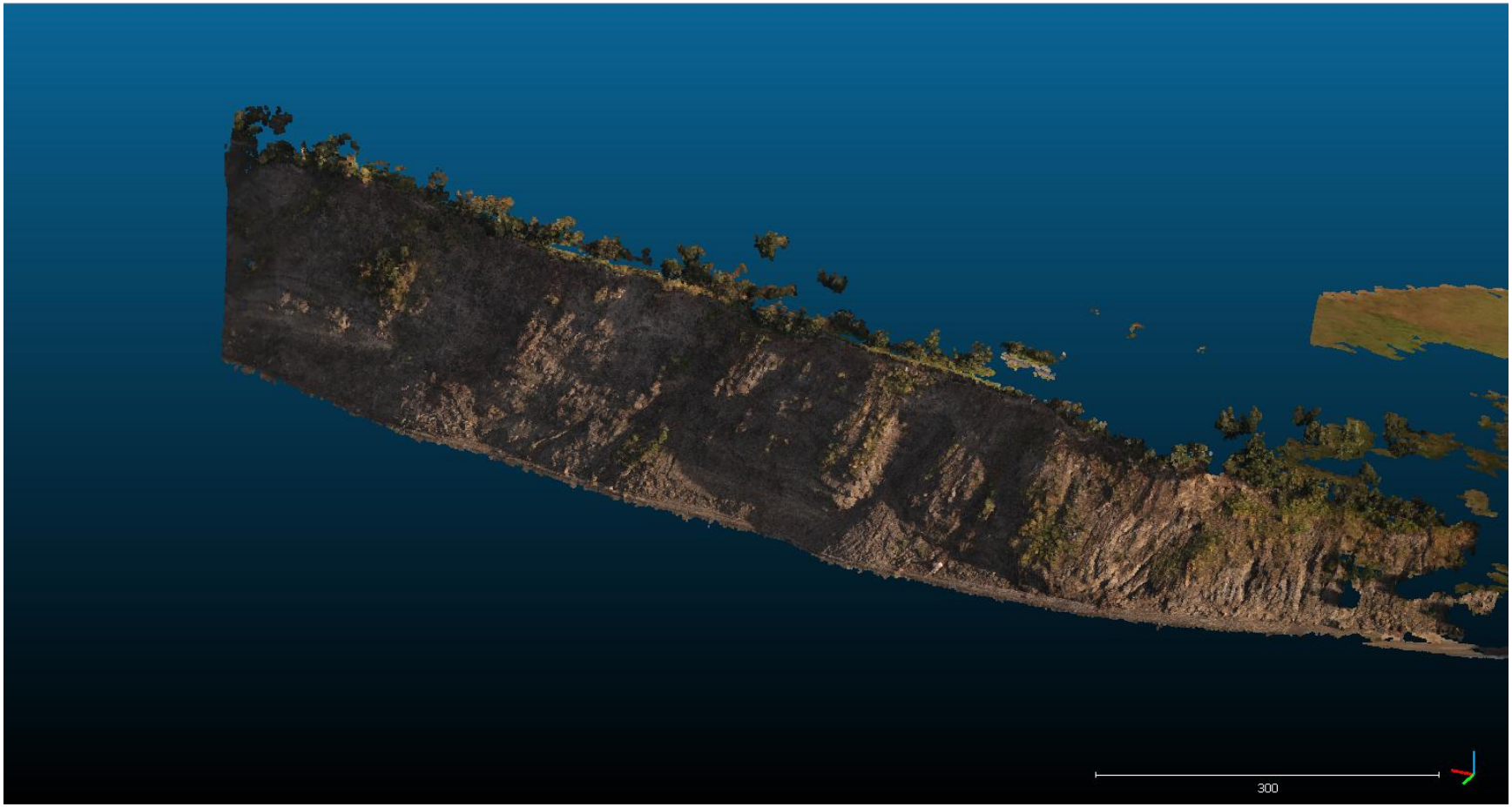




Geological analysis

- Map the geology of the bluff (transect)
- Correlate bluff stability zones with geology

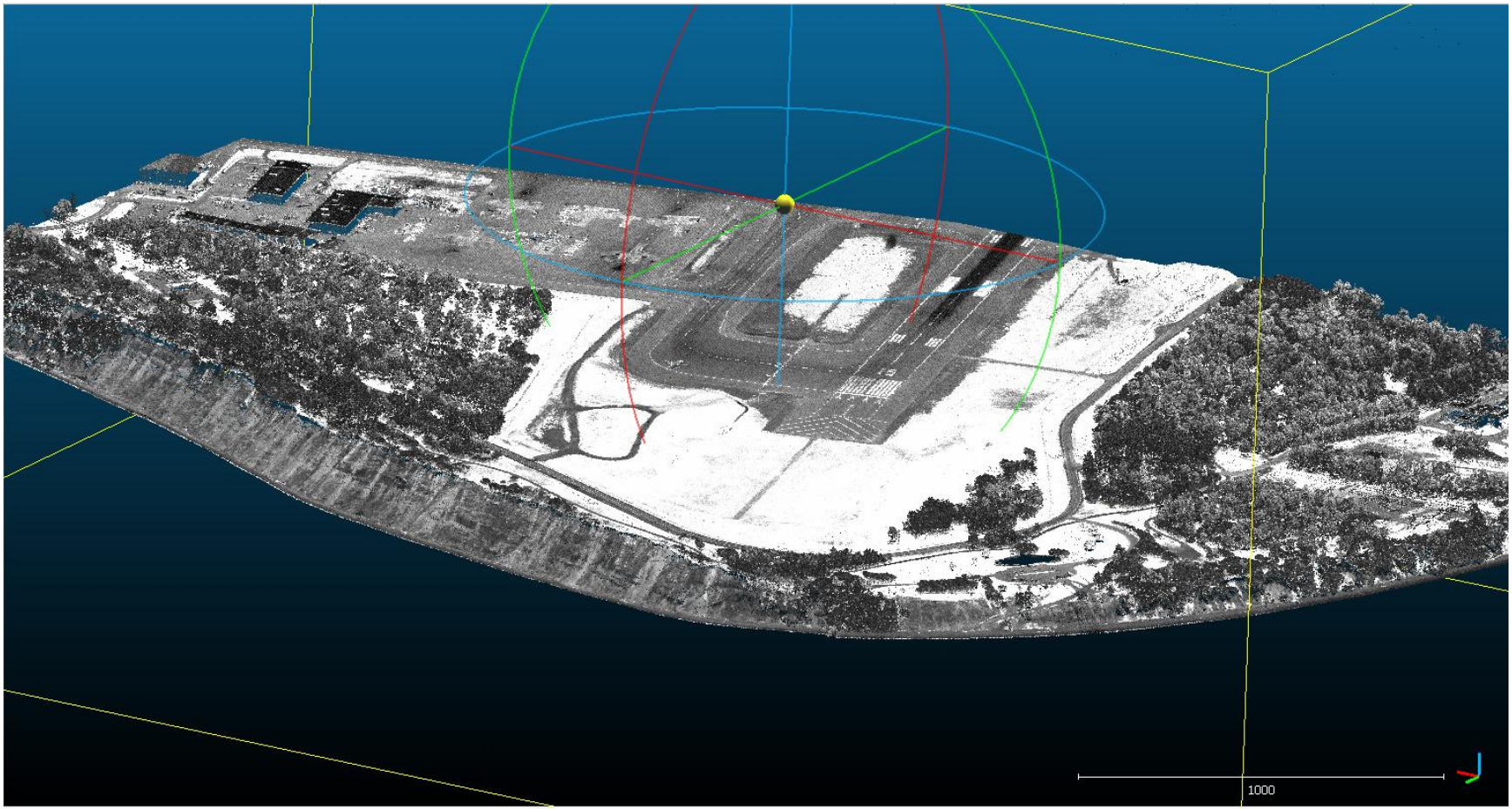
Historical 3D data: aerial photography (2010)



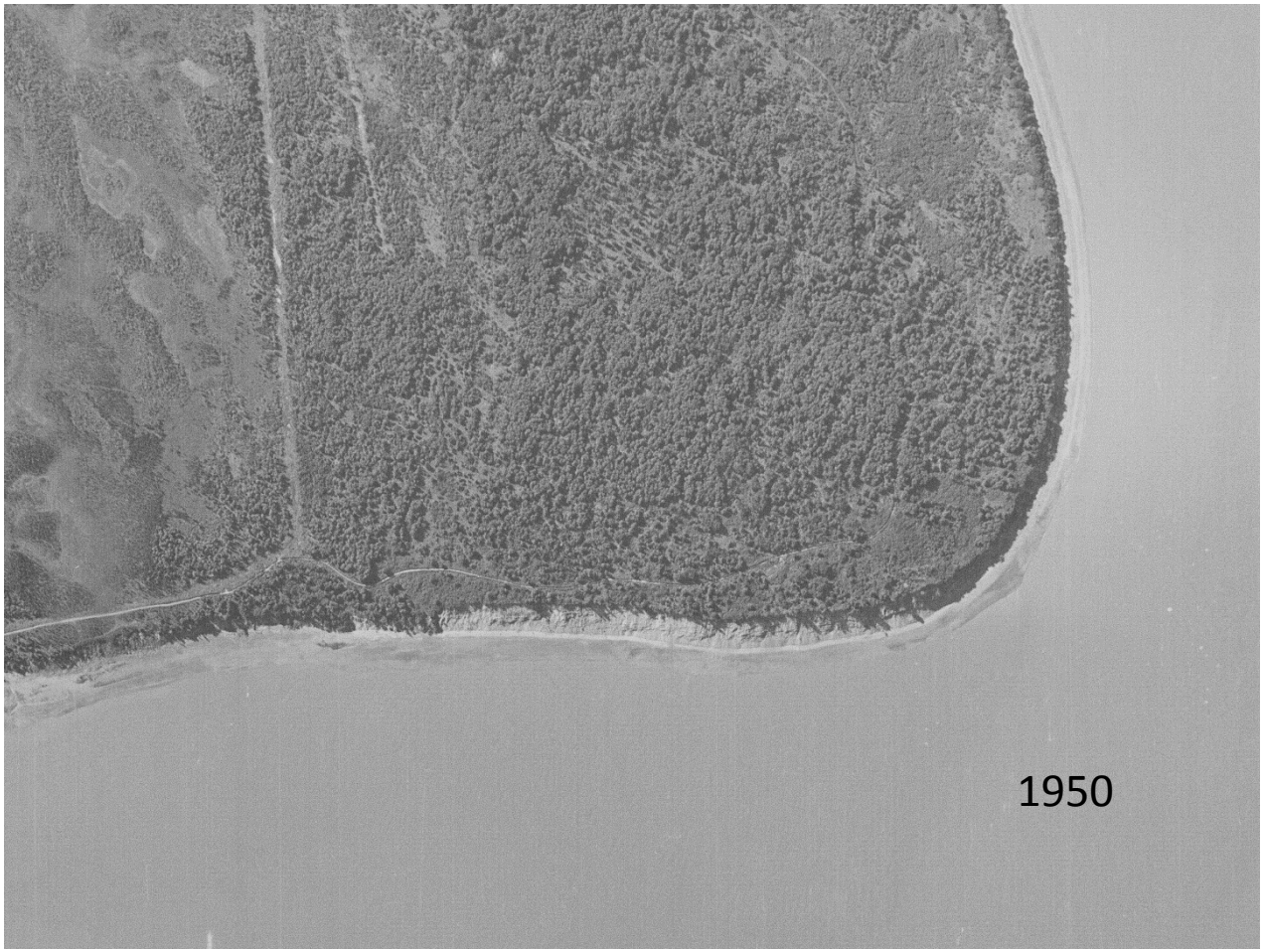
Oblique aerial photography (2010)

- Height of the bluff: 40 m (120 ft)
- Length of the bluff : ~600 m (fragment)
- Number of photos: 5
- Photo base: 230 - 430 m
- Distance from camera to the bluff: 390 m
- Ground resolution: 5 cm (2”)

LiDAR 2015



Historical aerial photographs 1950-2010



Summary

- The bluff moves!
- Hi-precision 3D base model has been created to monitor bluff erosion
- A map of bluff stability zones has been created at a very high spatial resolution
- Weathering and tidal contribution into bluff erosion have been evaluated and mapped

Acknowledgements

- Prof. Tom Ravens, UAA
- Dr. Jon Zufelt, HDR
- Prof. Jeff Hollingsworth, UAA
- Aleksey Voloshin, UAA Geomatics student