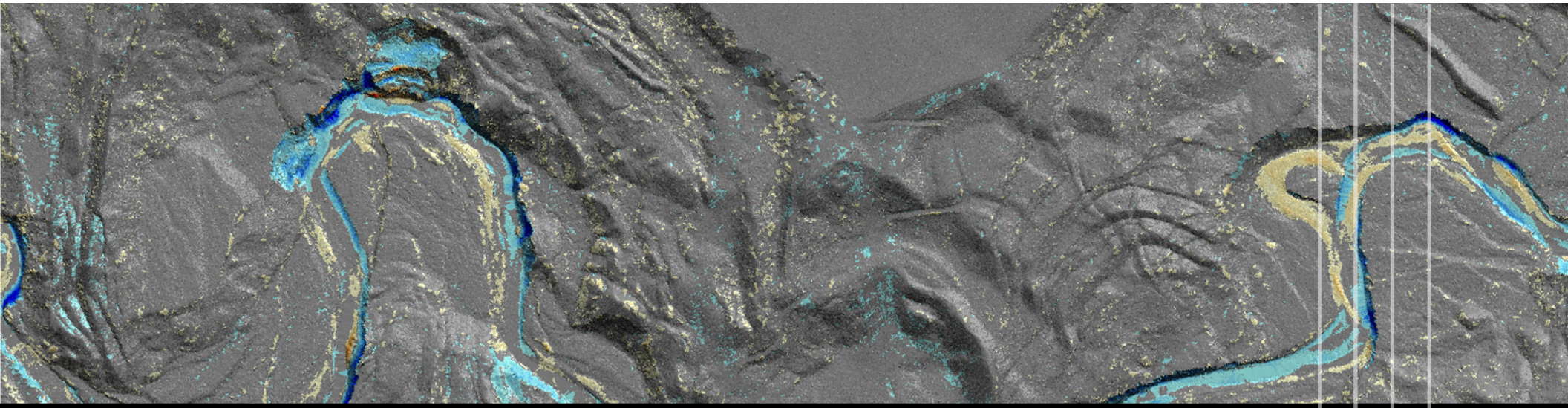


Leveraging three-dimensional remote sensing in geotechnical engineering

Matt Lato

bgcengineering.com

THE CANADIAN GEOTECHNICAL SOCIETY
LA SOCIÉTÉ CANADIENNE DE GÉOTECHNIQUE

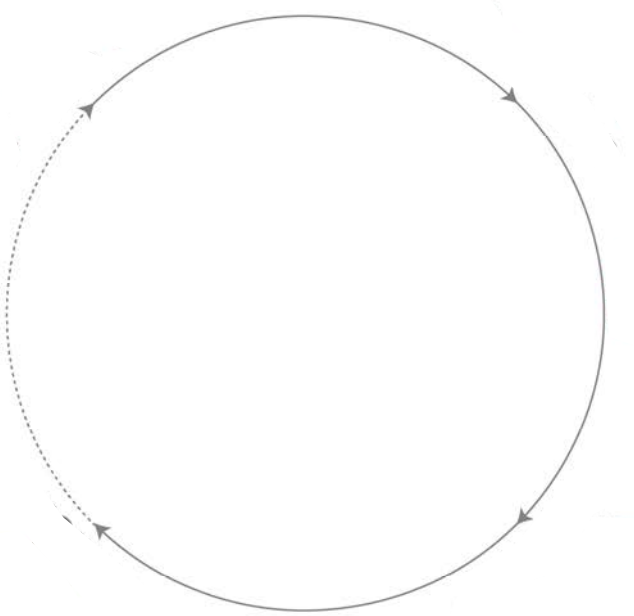
CFG FCG

BGC

Geotechnical engineering

Robust outcomes emerge when designs are based on an understanding of the geology, the environment, and the interaction of these systems over time.

The path to quality engineered outcomes



Geotechnical engineering

Our project sites are often remote, hard to access, and not amenable to spatially distributed and dense data collection and monitoring.

Geotechnical engineering

Often we have a gap between desired and actual data, information and knowledge needed to support design decisions and actions. We accept uncertainty, are challenged to communicate it, and would rather reduce it.

Leveraging 3D remote sensing to fill the gap

The past 15 years have produced significant advances with respect to 3D remote sensing data collection, analysis, and our ability to communicate complex earth science projects.

Changing capabilities

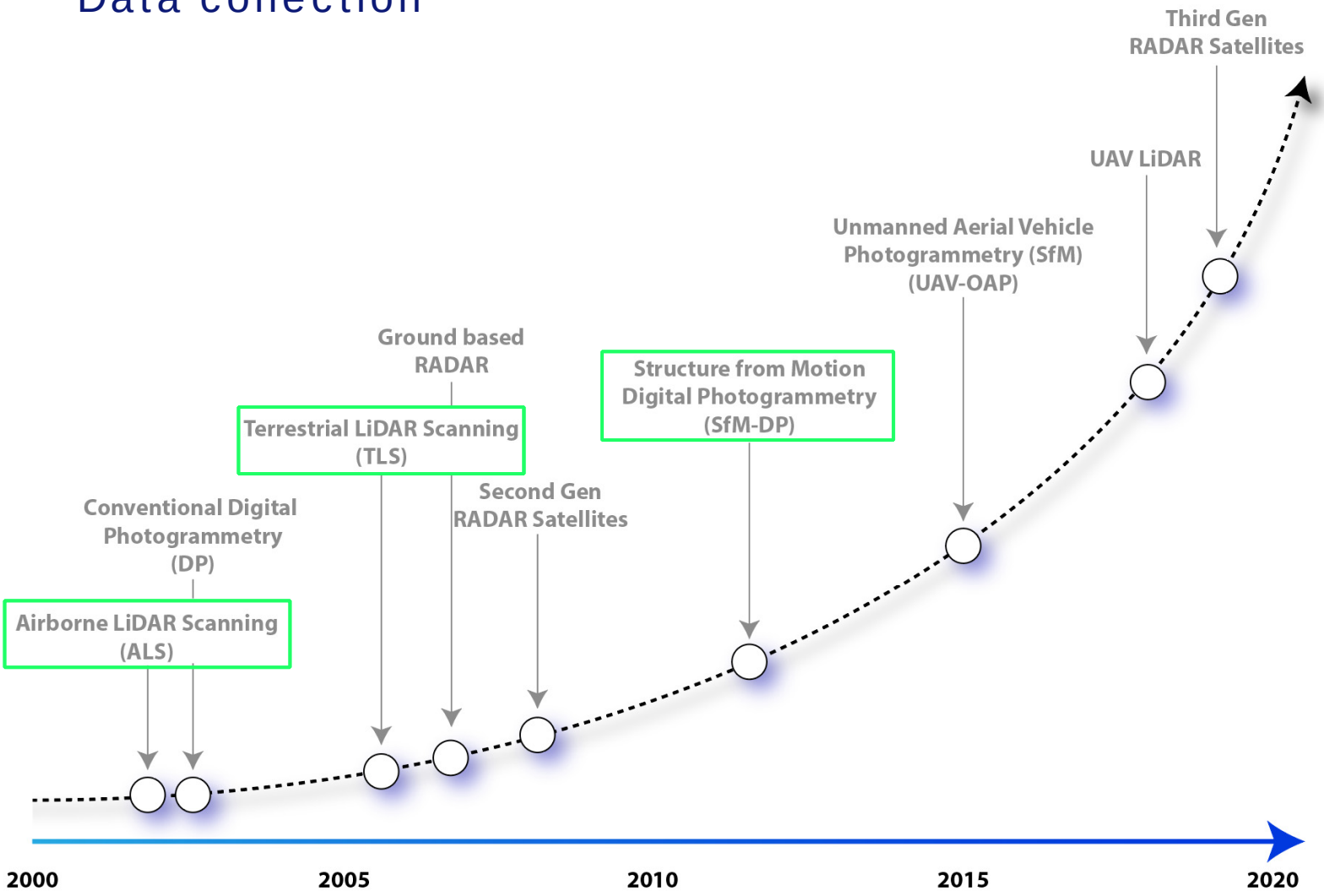
“It should be recognized by all concerned that rock falls will not necessarily occur at suspected locations. In fact no one, no matter how experienced, can predict rock falls of the type that most commonly cause accidents. These involve single rocks or small groups of rocks the stability of which cannot be evaluated in any practical way.”

Peckover and Kerr (Can. Geotch. J., 1977)

“As shown in this study, it is possible to estimate source zone location, volume, and kinematics prior to failure based on the identification of precursor signs of slope failure.”

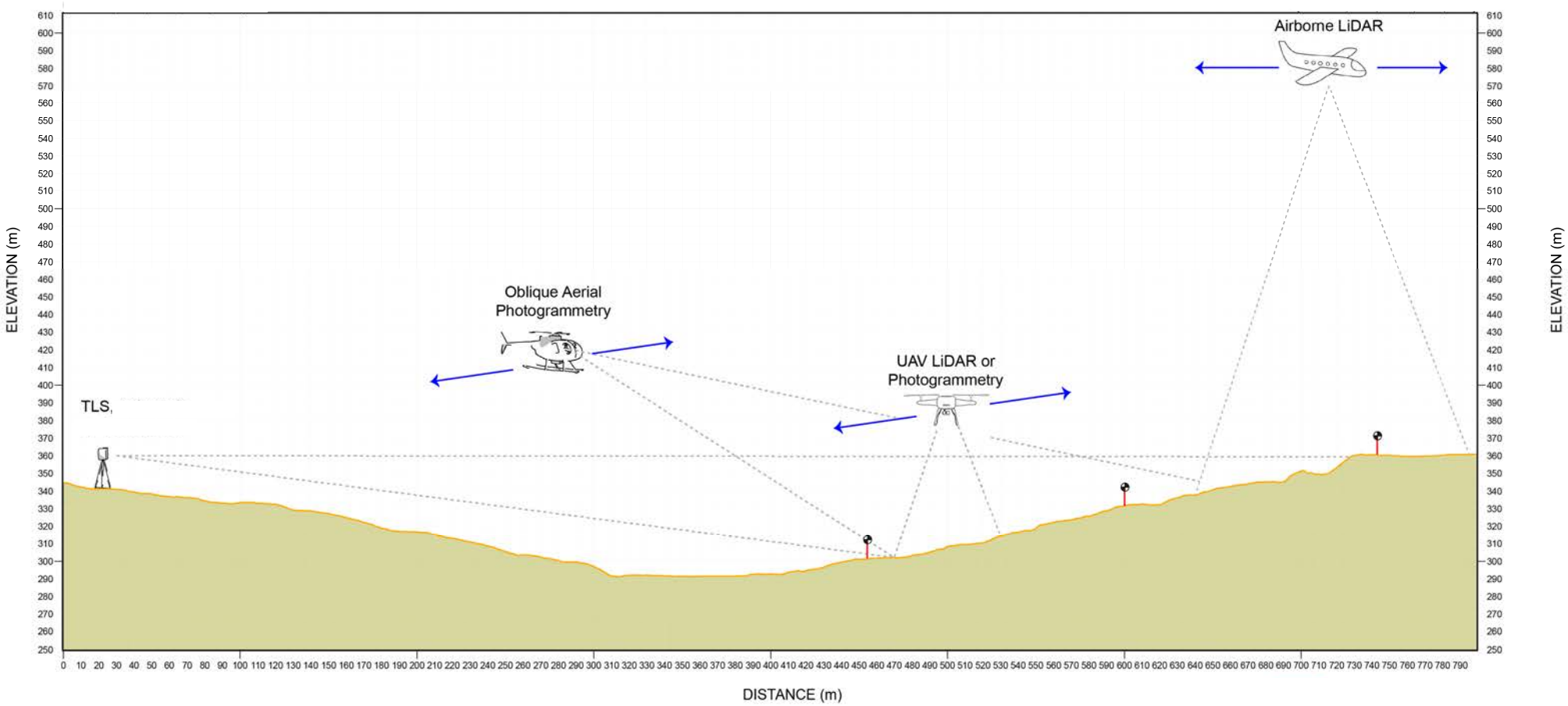
Kromer et al. (Can. Geotch. J., 2017)

Data collection



BGC

3D remote sensing technologies



Information generation

Geometric Analysis (cut/fill volumes)

Manual Discontinuity Mapping (DP)

Manual Discontinuity Mapping (TLS/MLS)

Bare Earth Terrain Analysis

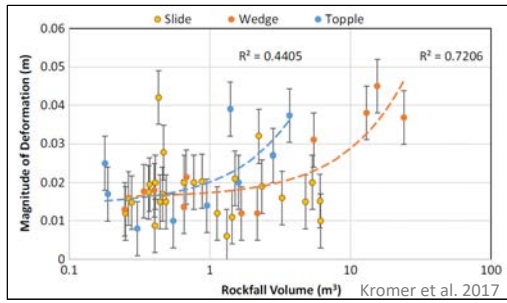
Topographical Change Detection

Automated Discontinuity Mapping (TLS/MLS)

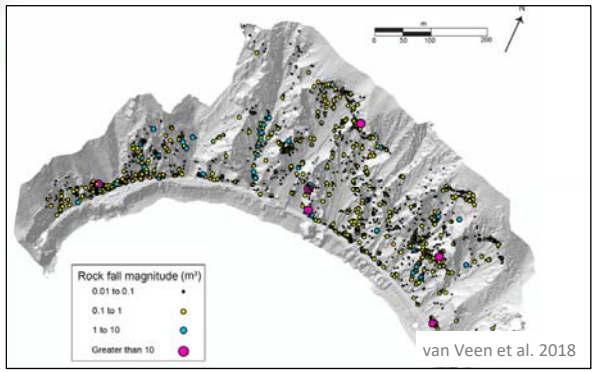
Landslide Velocity Monitoring

Near-Real-Time Slope Failure Warning

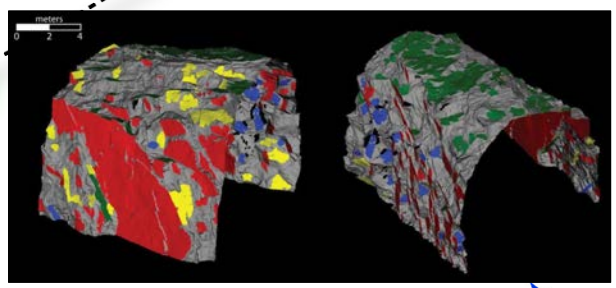
Machine Learning and Forecasting



Kromer et al. 2017

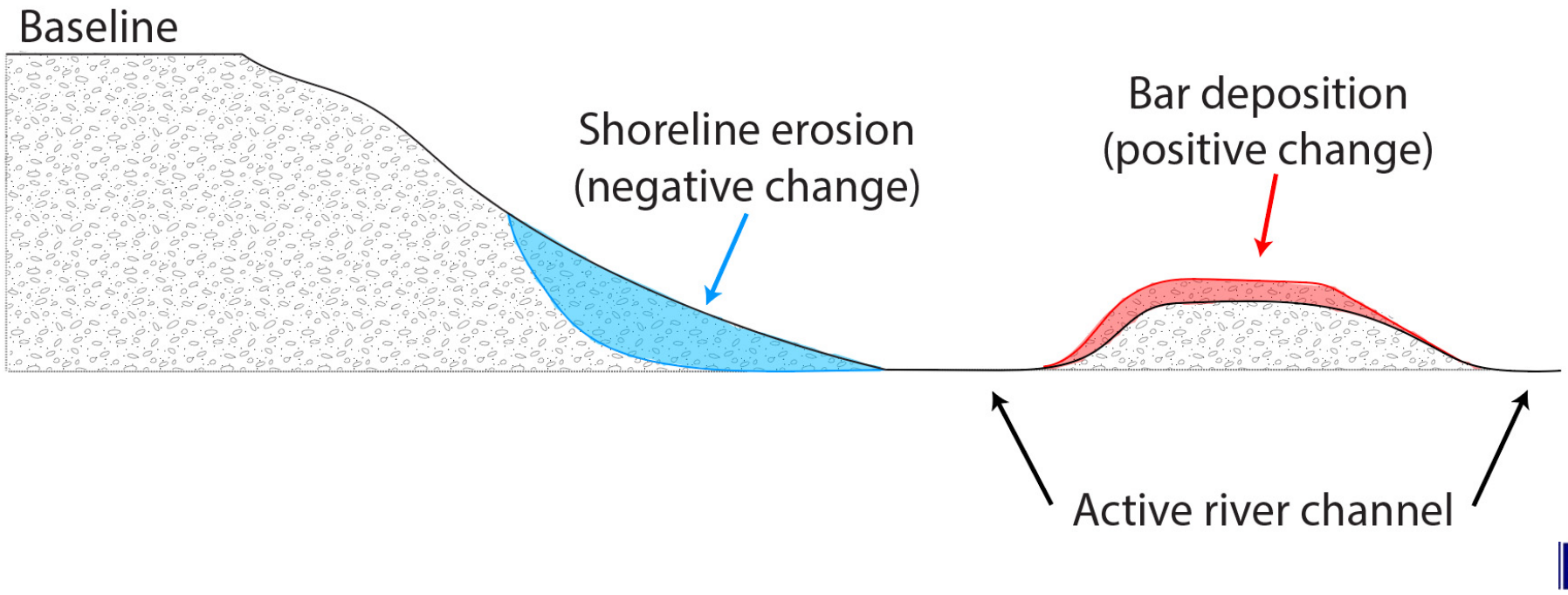


van Veen et al. 2018



2000 2005 2010 2015 2020

Landslide change detection

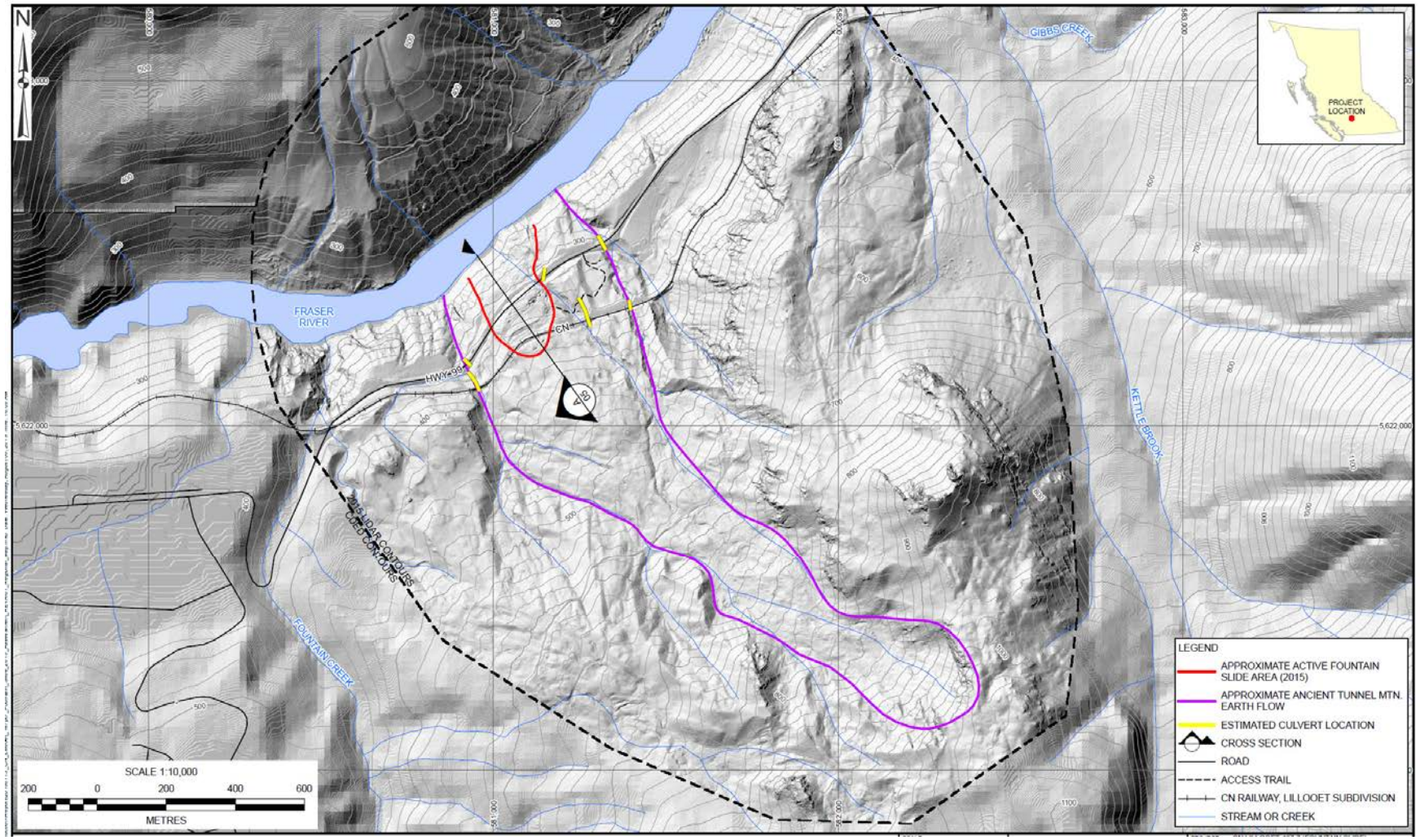


Case studies 1: Highways

BGC: Matthieu Sturzenegger, Andrew Mitchell, Michael Porter, and Rod Kostaschuk
BC Ministry of Transportation and Infrastructure: Sarah Gaib

bgcengineering.com

Ten Mile Slide



Detailed monitoring

Complex landslides with variable movement rates and zones of activity are a perfect opportunity for remote sensing to assist in understanding landslide morphology, anticipated behavior and failures, and design mitigation measures.

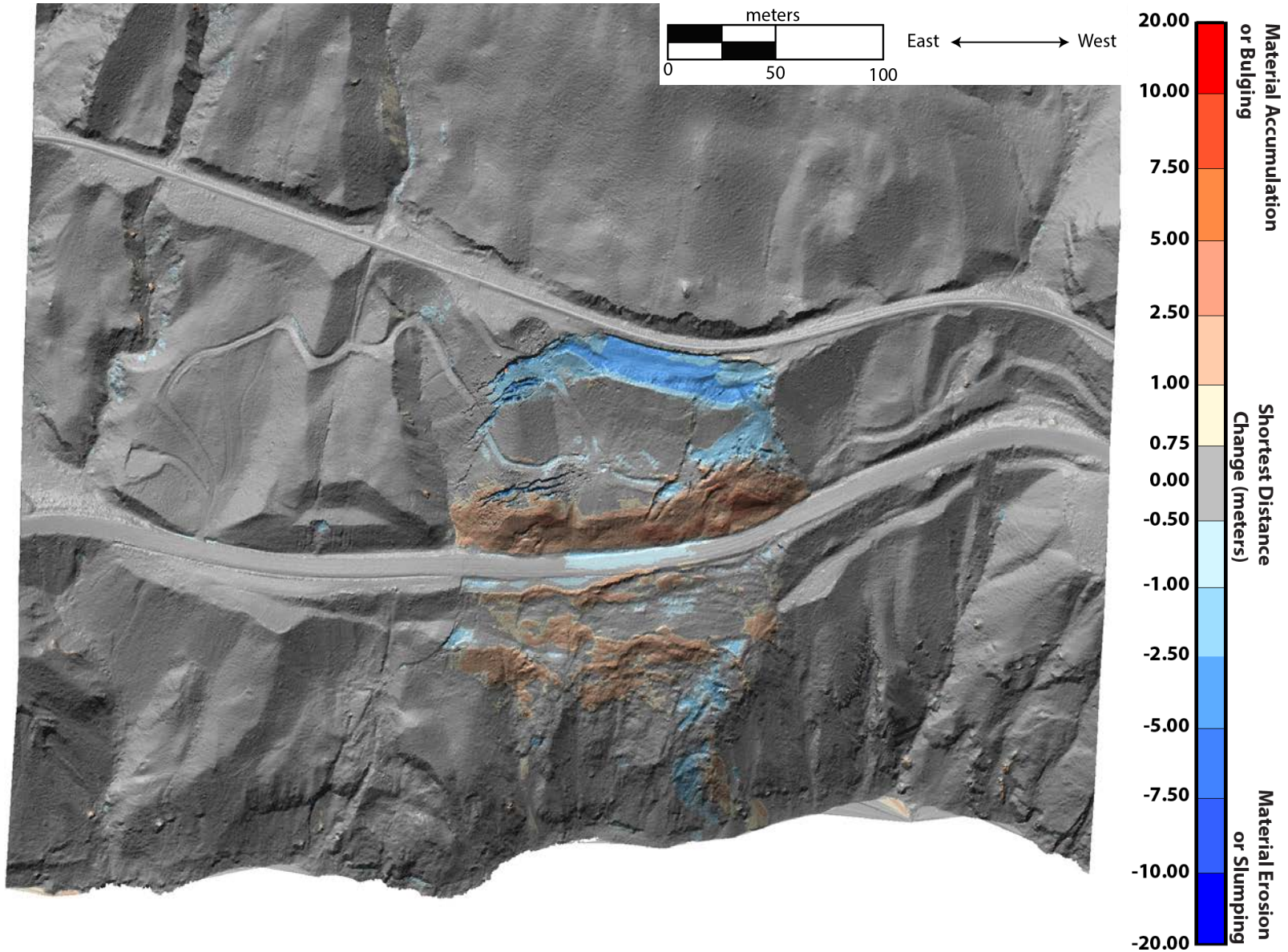
Oblique aerial photogrammetry data

Changes between ALS datasets

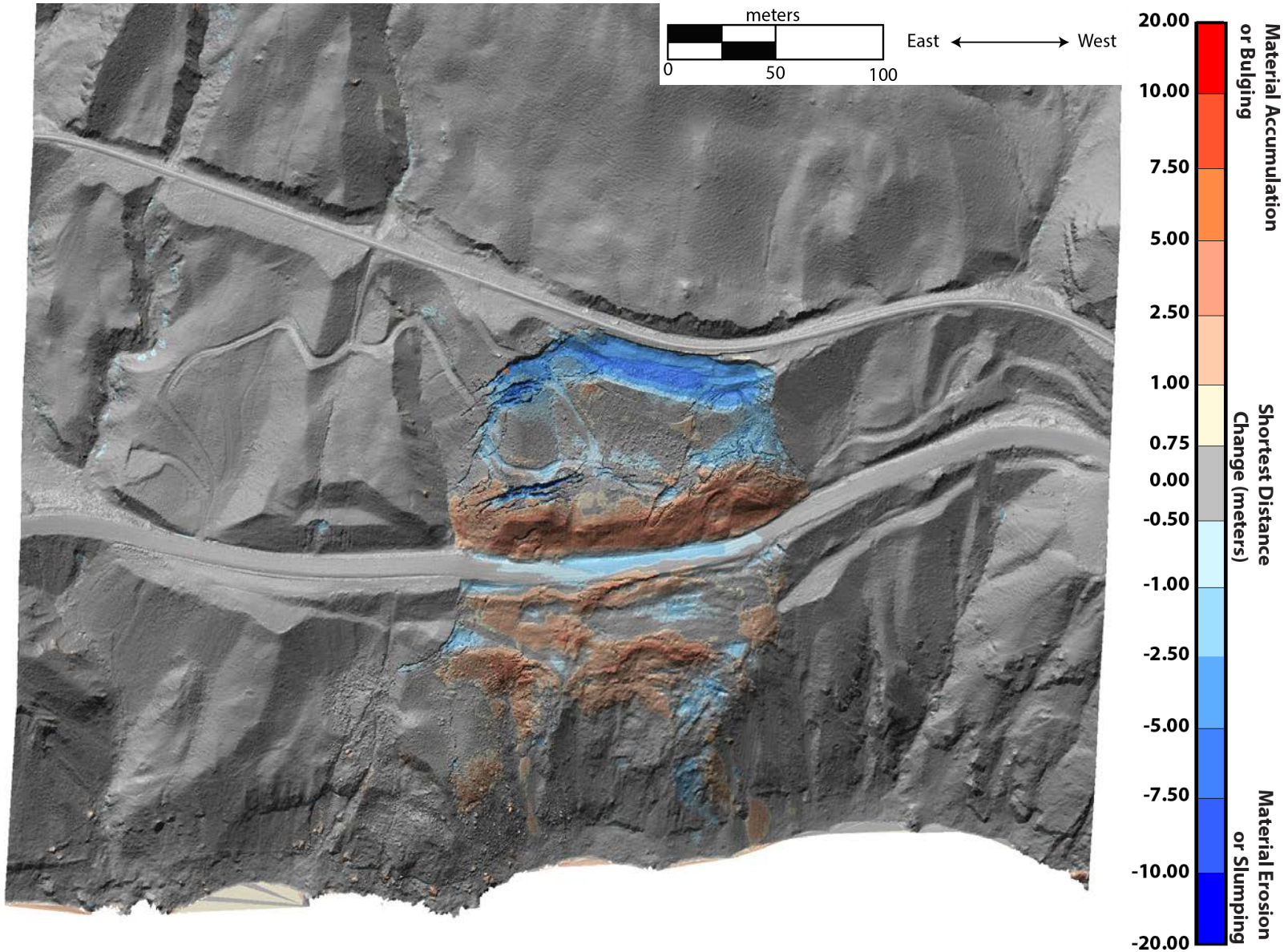
Visualize and understand:

- Impact of the landslide on the highway and railway
- Magnitude, direction and rotation of movement
- Retrogression and zonation of blocks within the landslide
- Linkage between deformation and failure

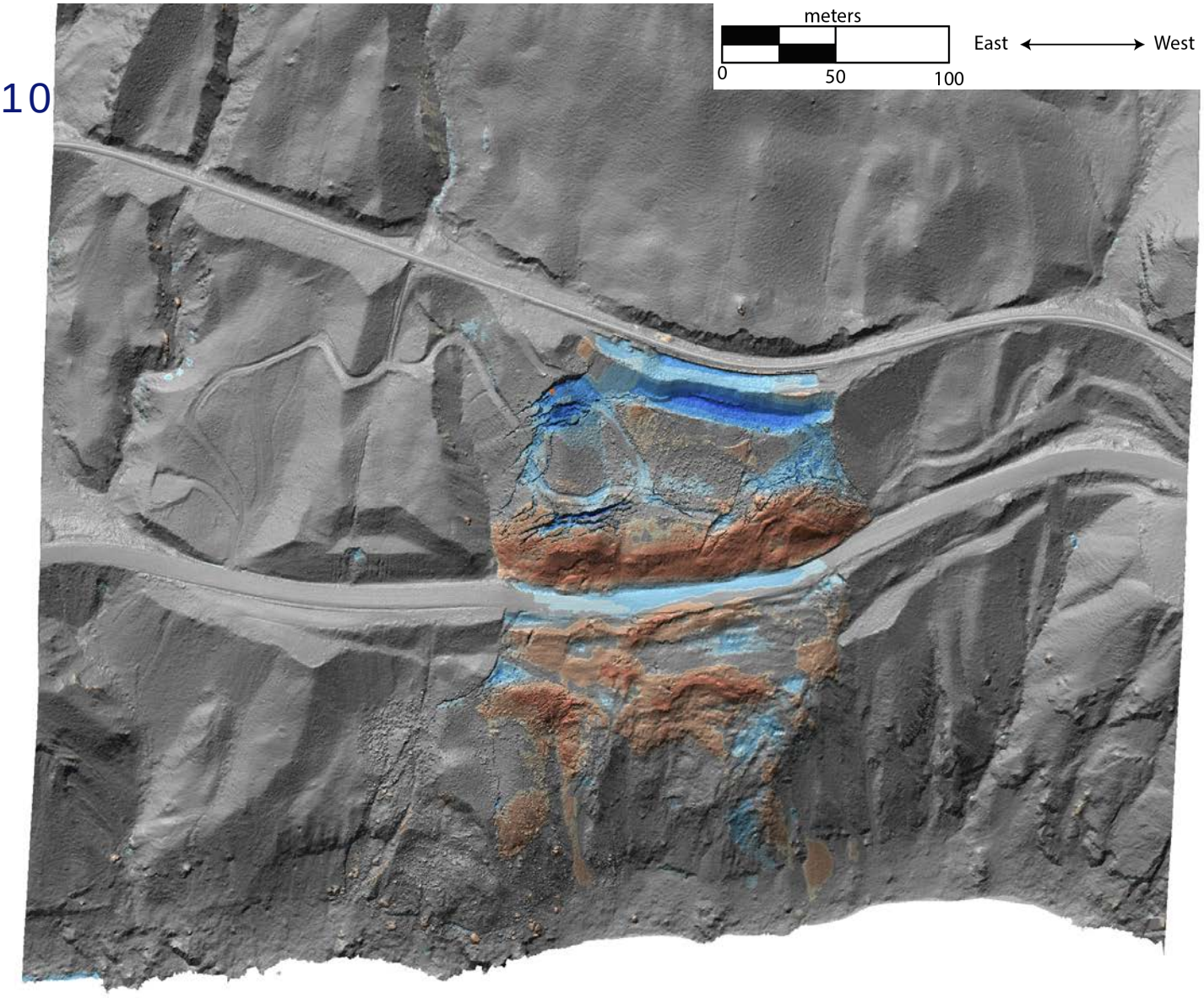
2009 vs 2006


meters
0
50
100
East
West
20.00
10.00
7.50
5.00
2.50
1.00
0.75
0.00
-0.50
-1.00
-2.50
-5.00
-7.50
-10.00
-20.00
Material Accumulation or Bulging
Shortest Distance Change (meters)
Material Erosion or Slumping

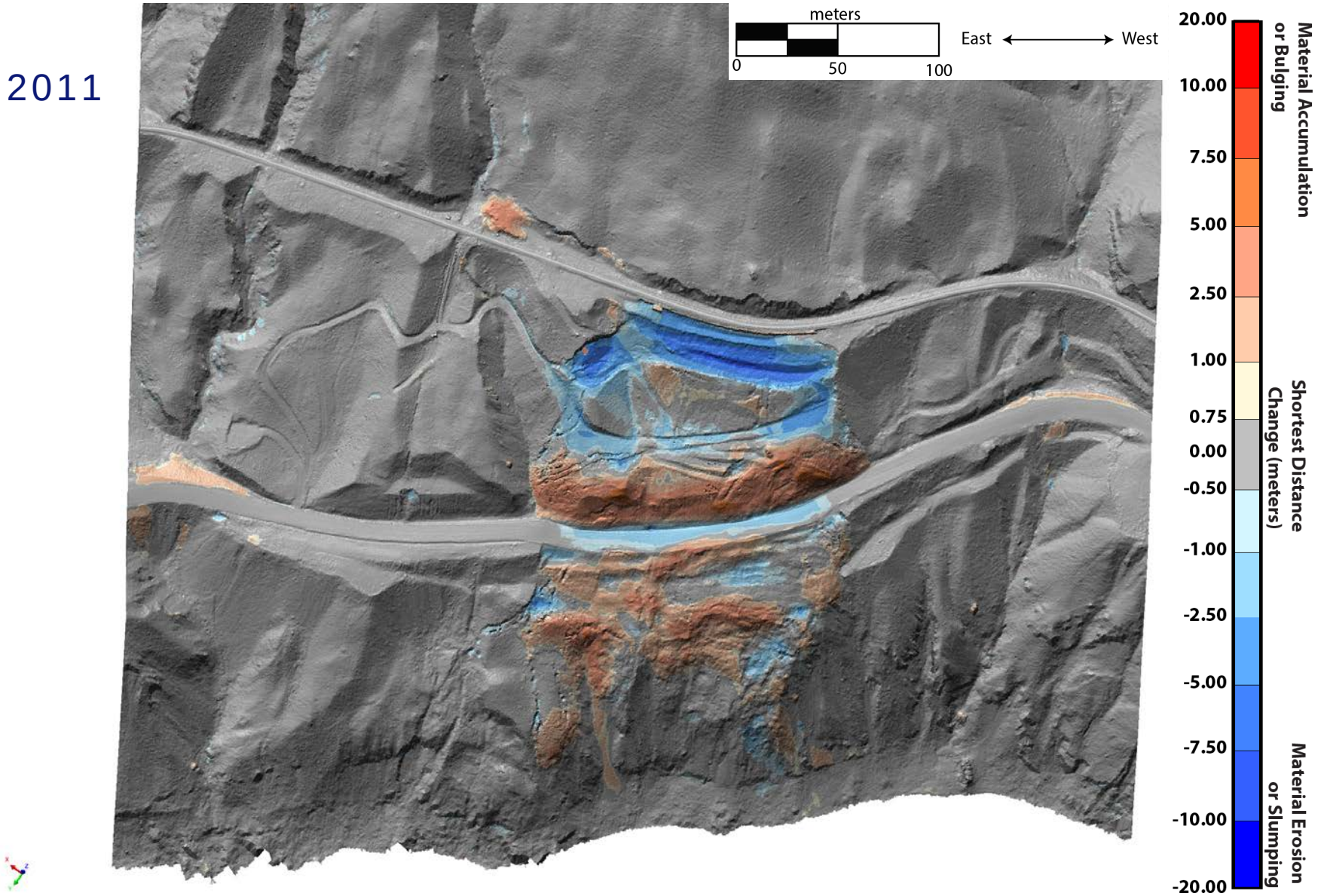
June 2010 vs 2006



September 2010 vs 2006

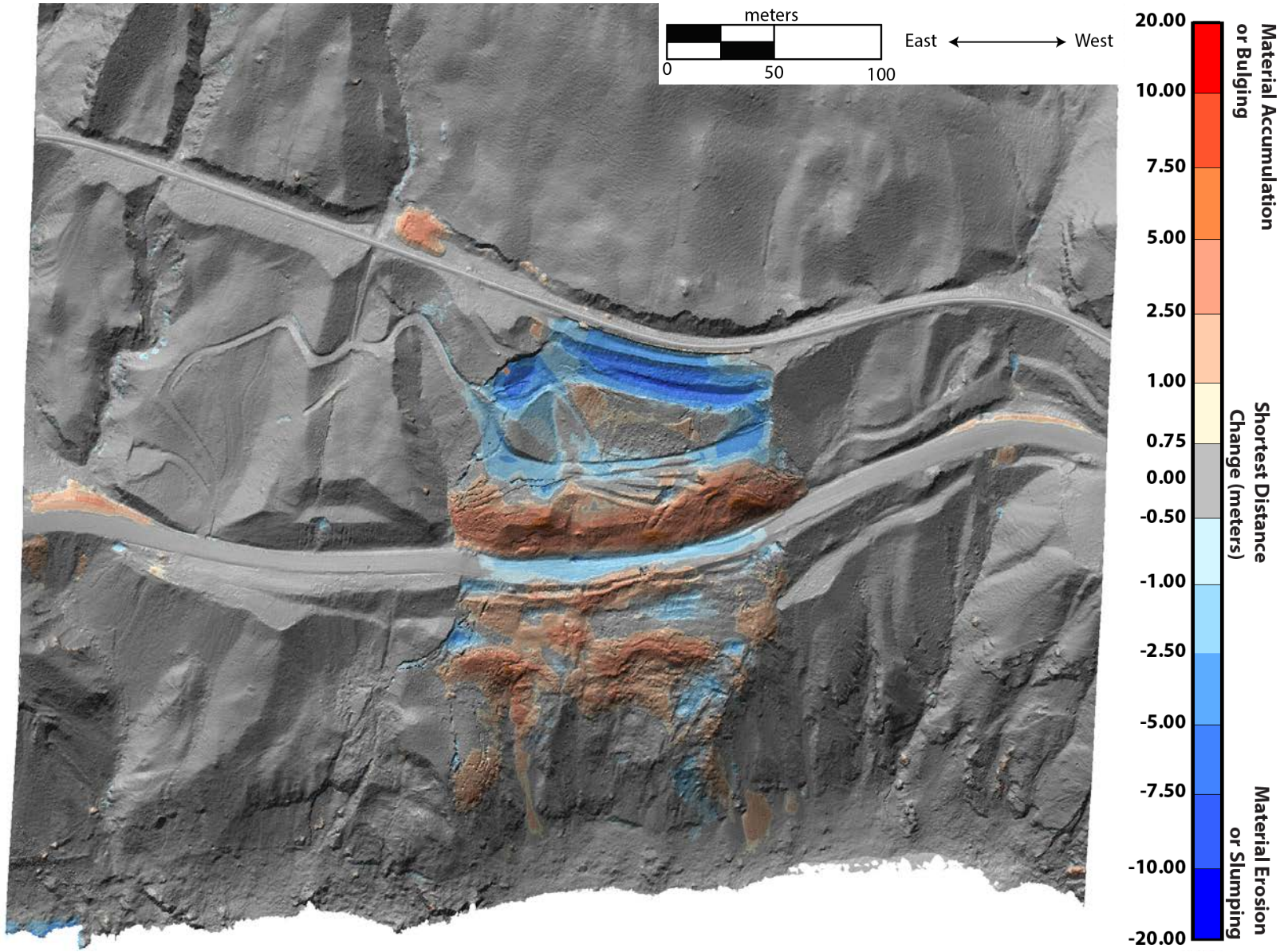


February 2011 vs 2006

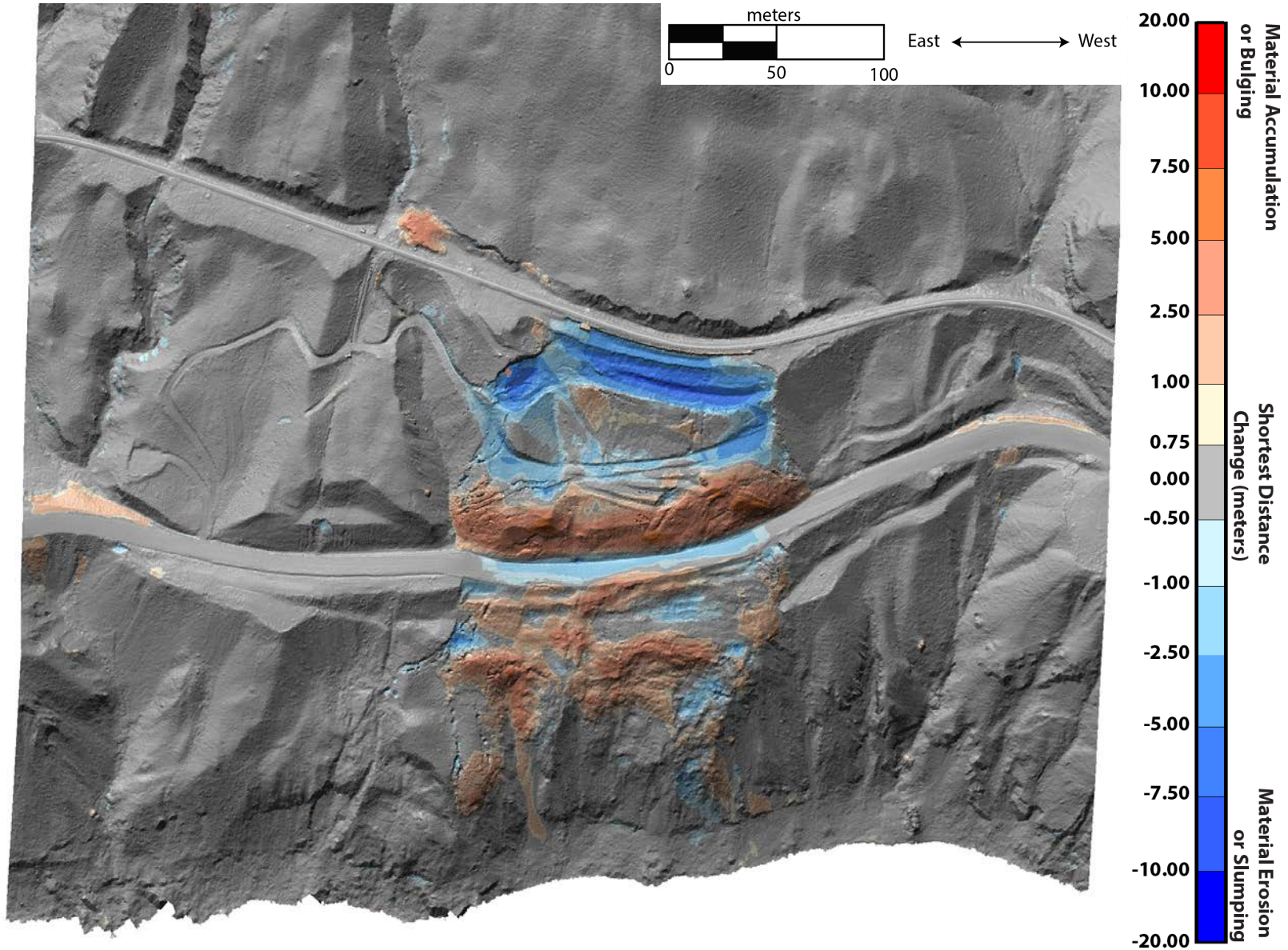


April 2011 vs 2006

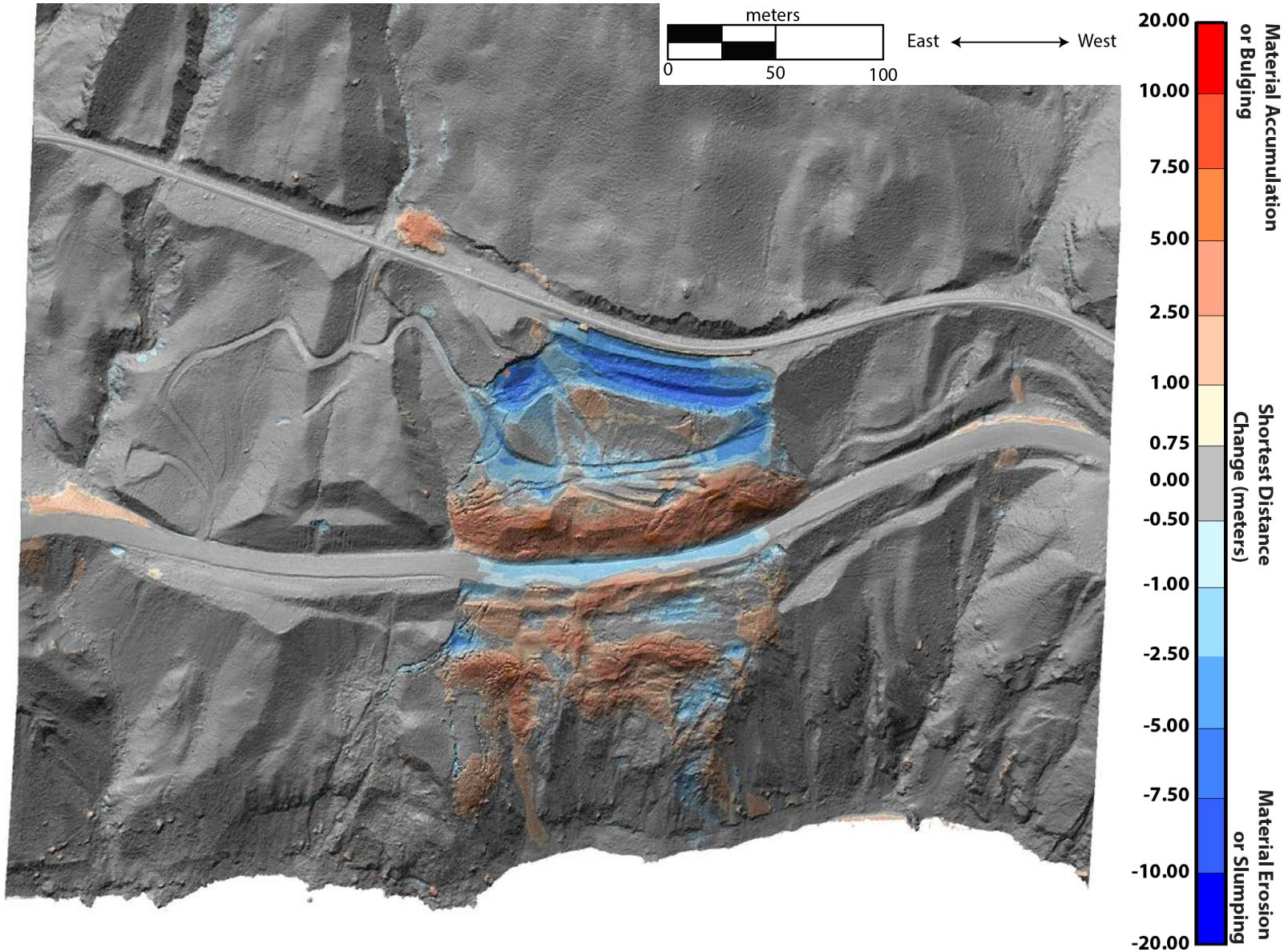
Highway stabilization trial



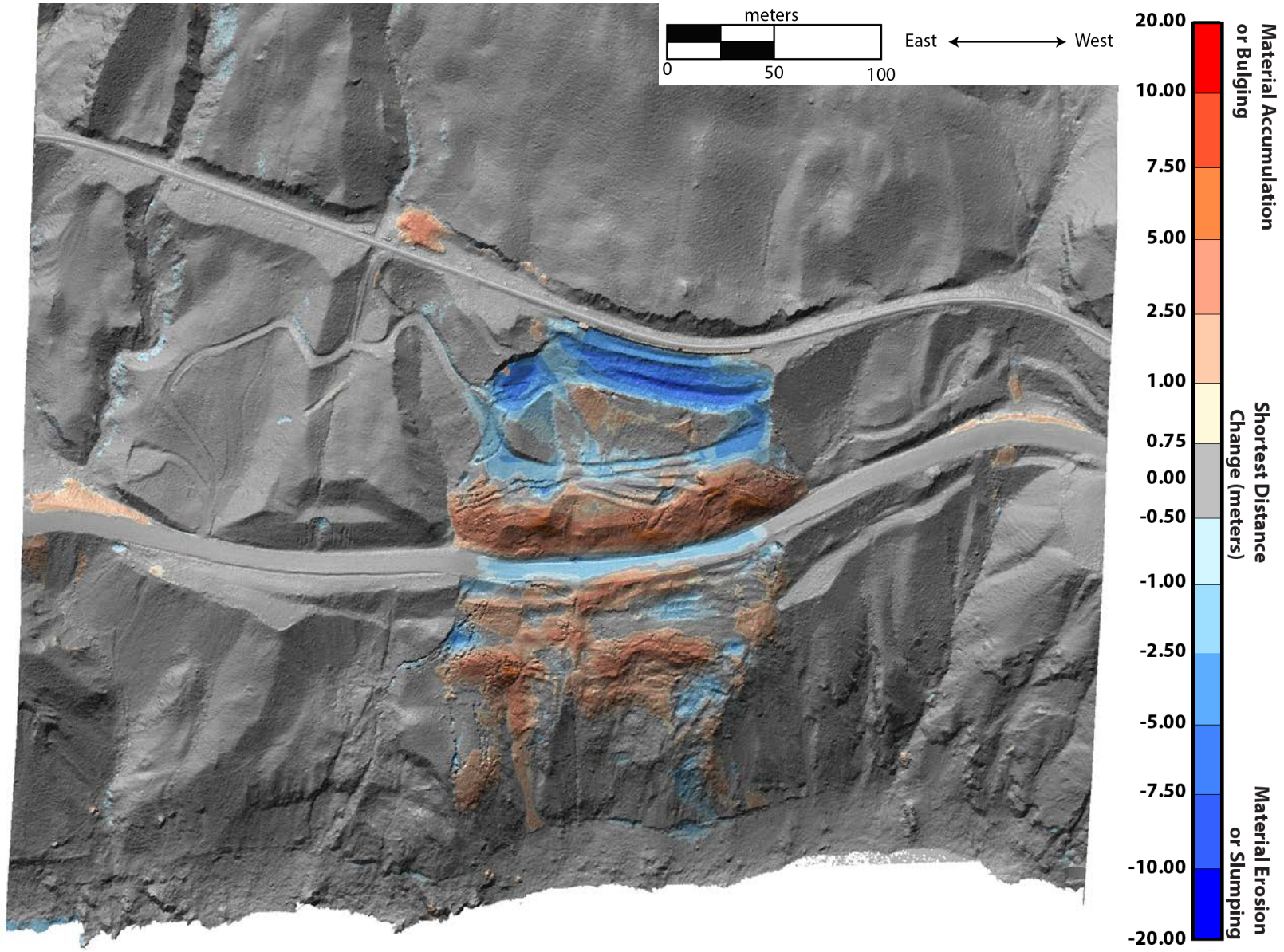
October 2011 vs 2006



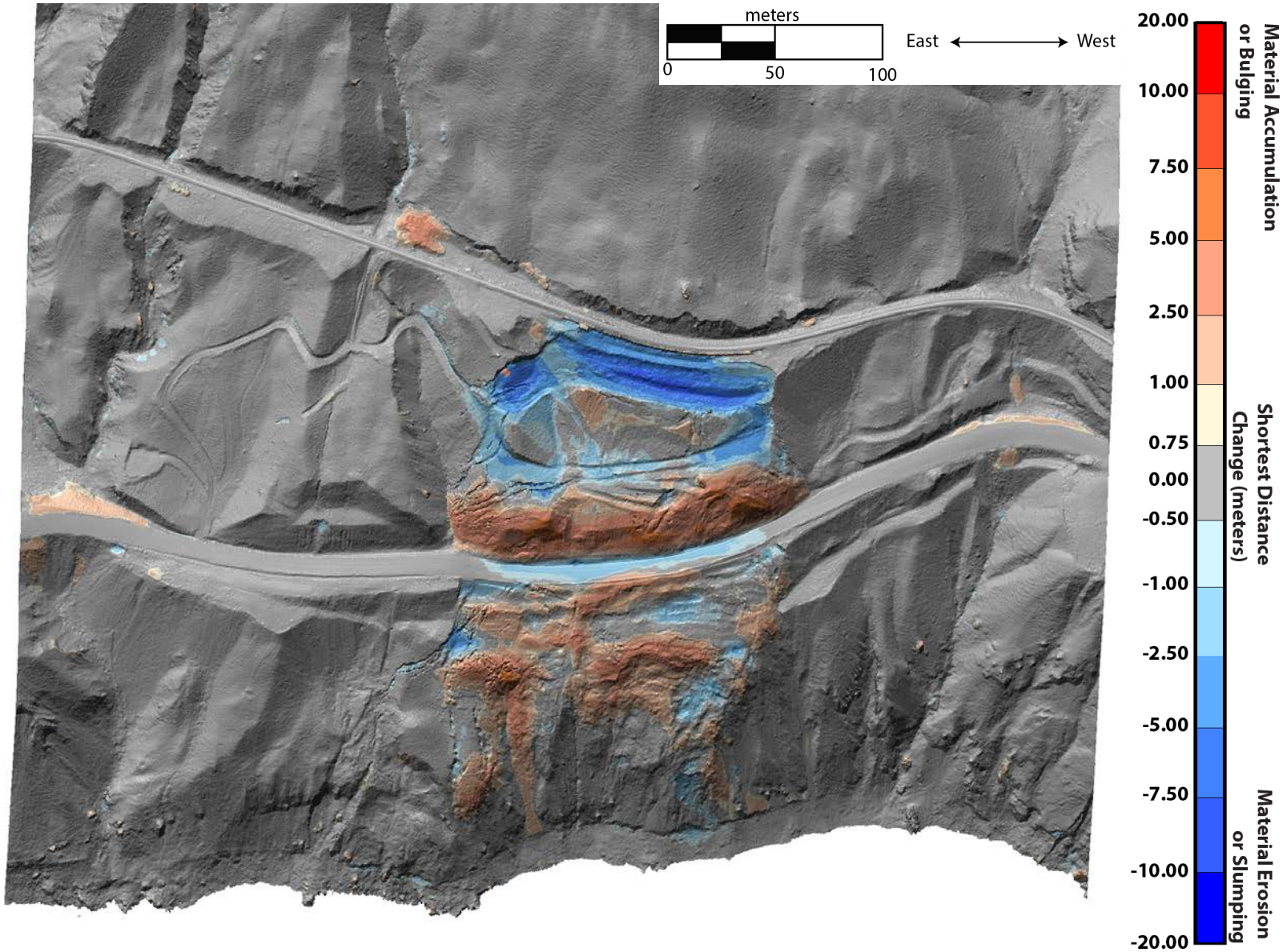
May 2012
vs 2006



October 2012 vs 2006

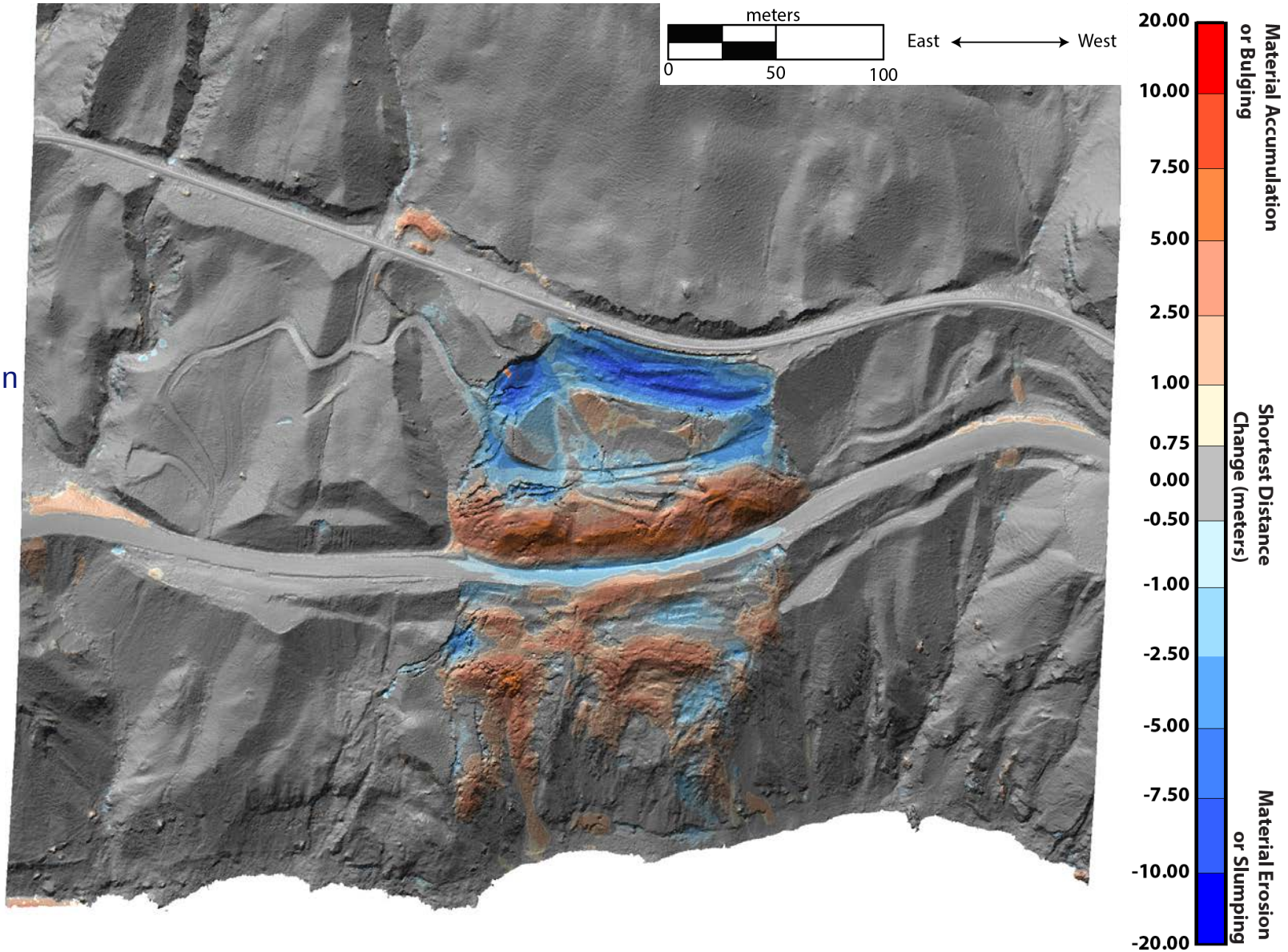


July 2013
vs 2006

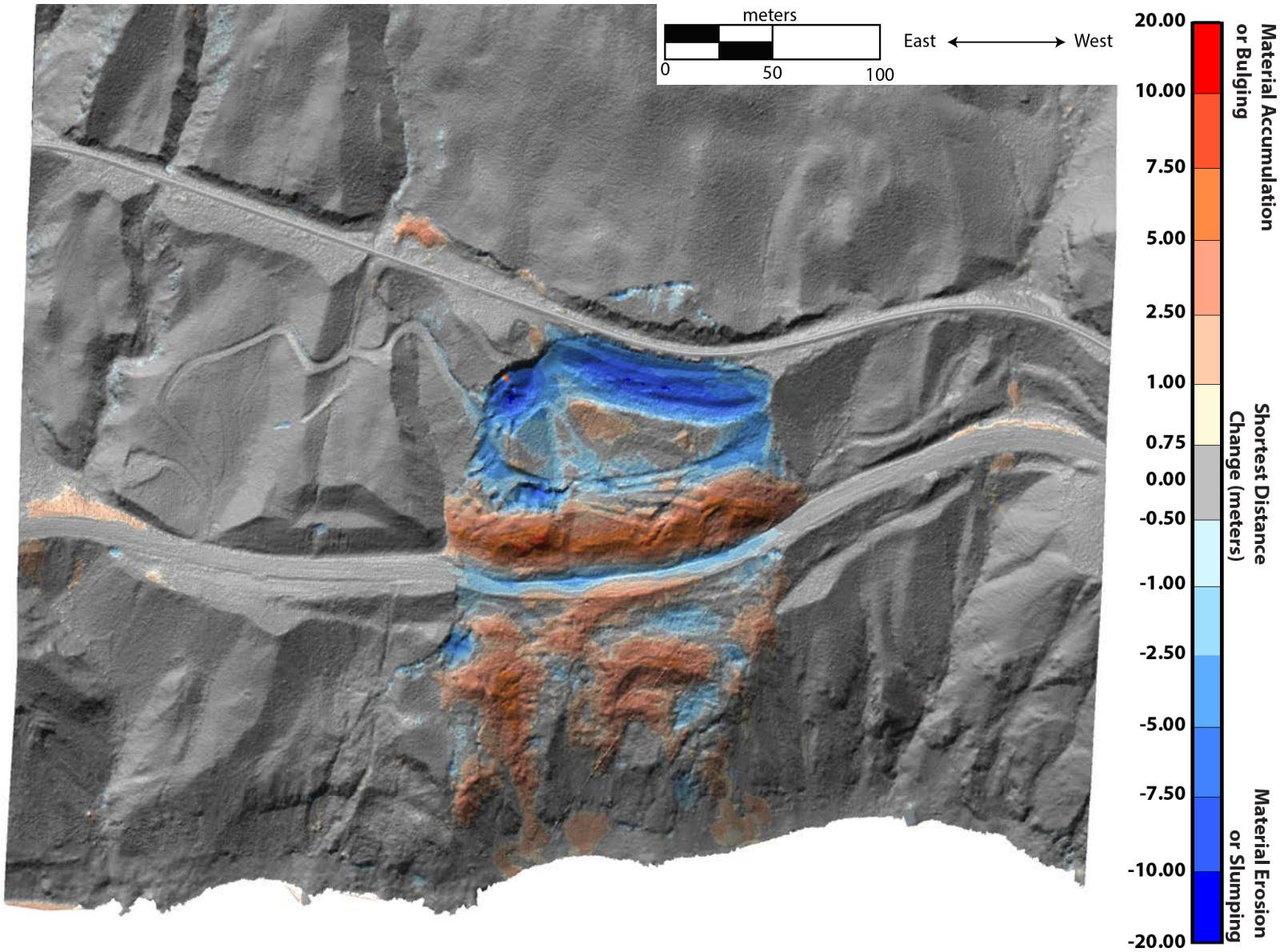


June 2014
vs 2006

Significant reactivation

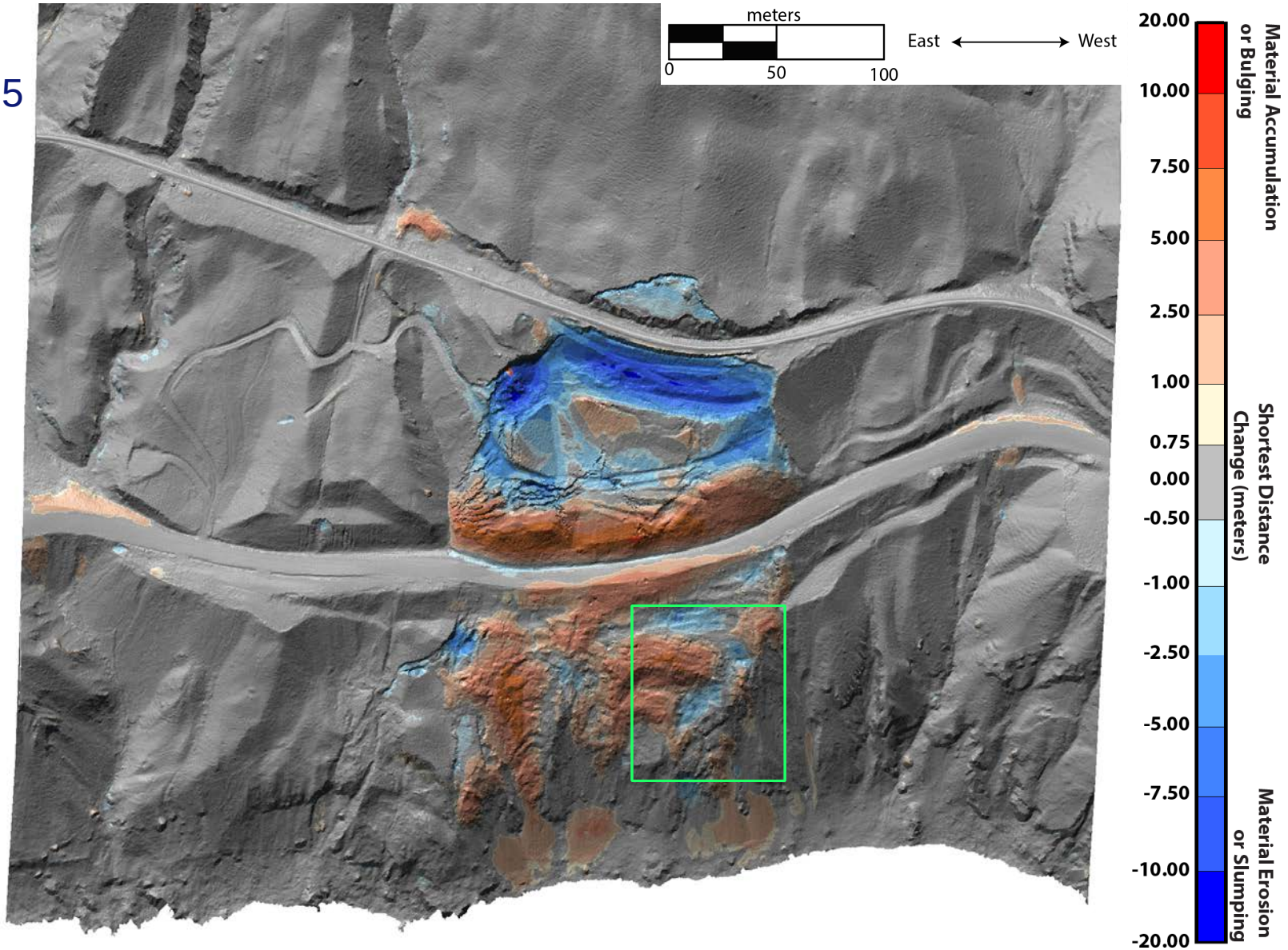


July 2015
vs 2006



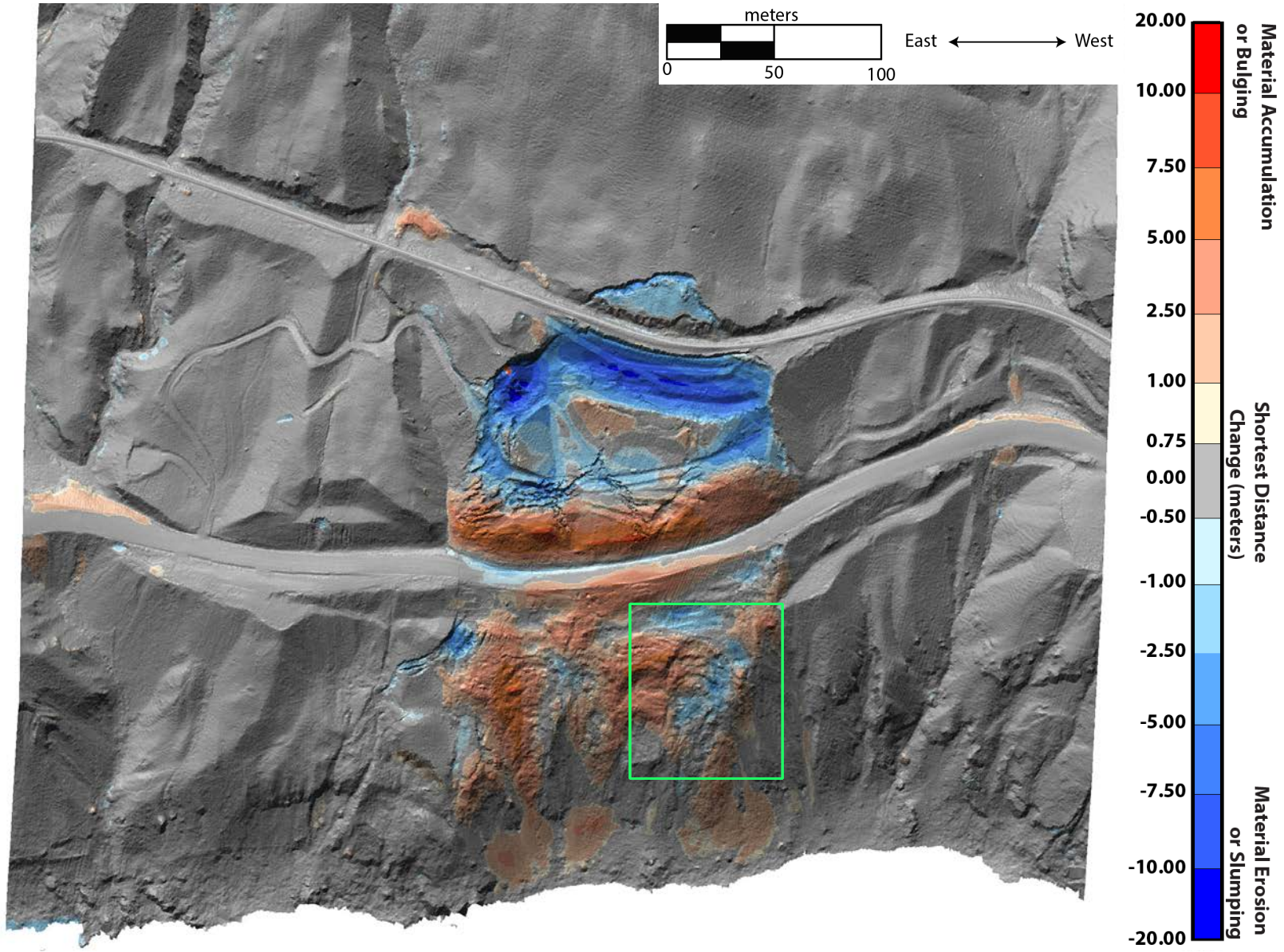
November 2015 vs 2006

Highway grade repair



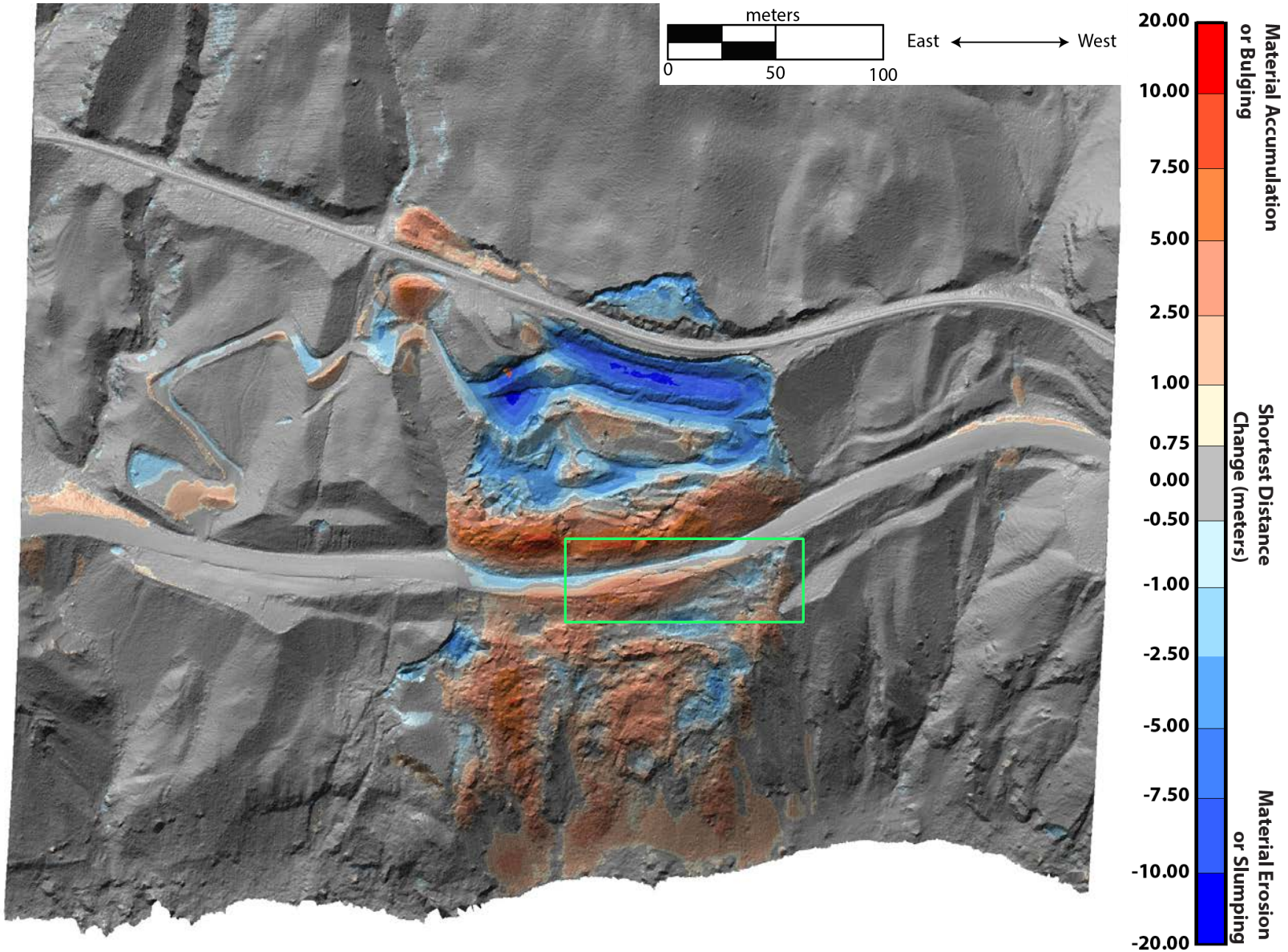
March 2016 vs 2006

Toe failure

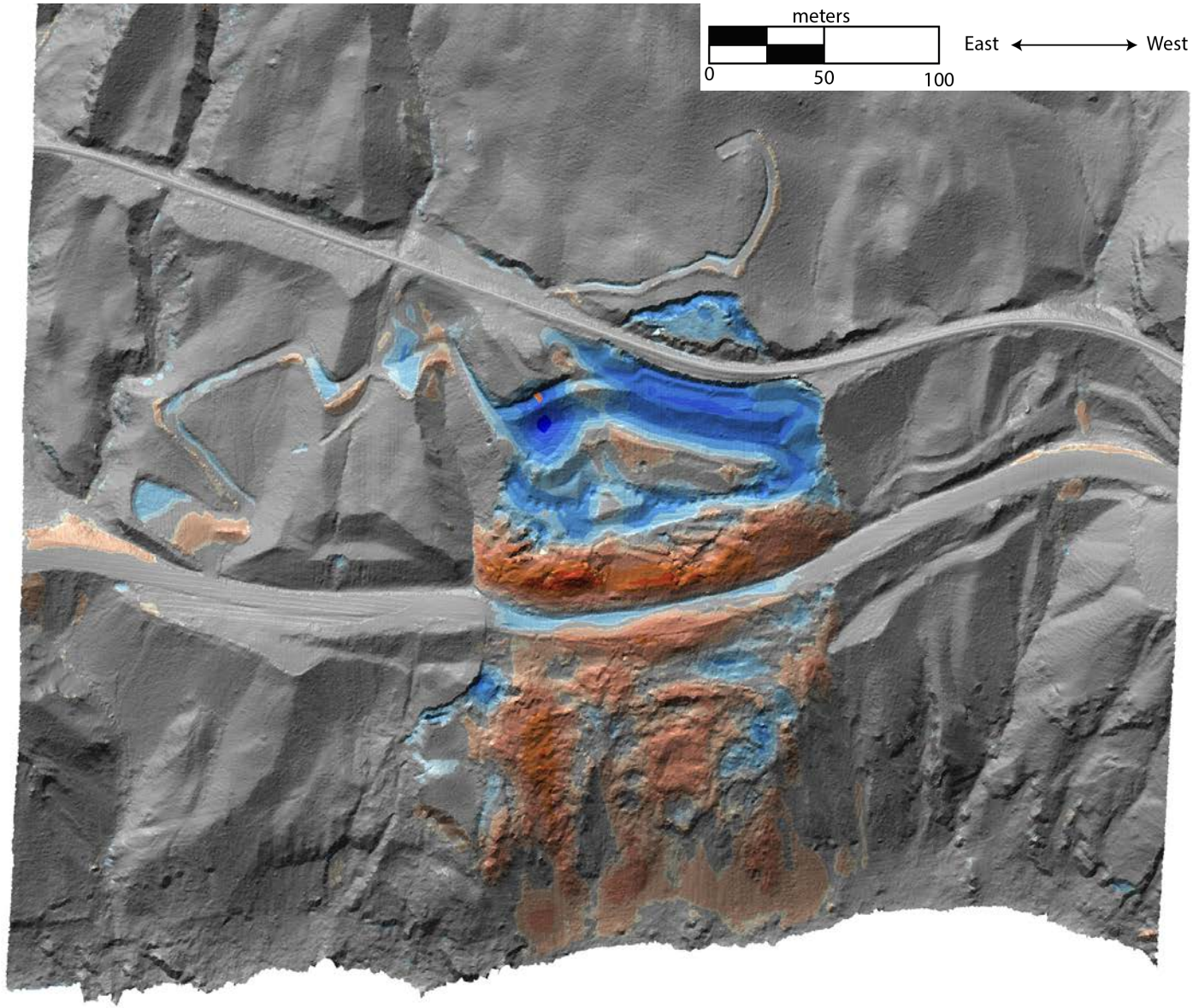


October 2016 vs 2006

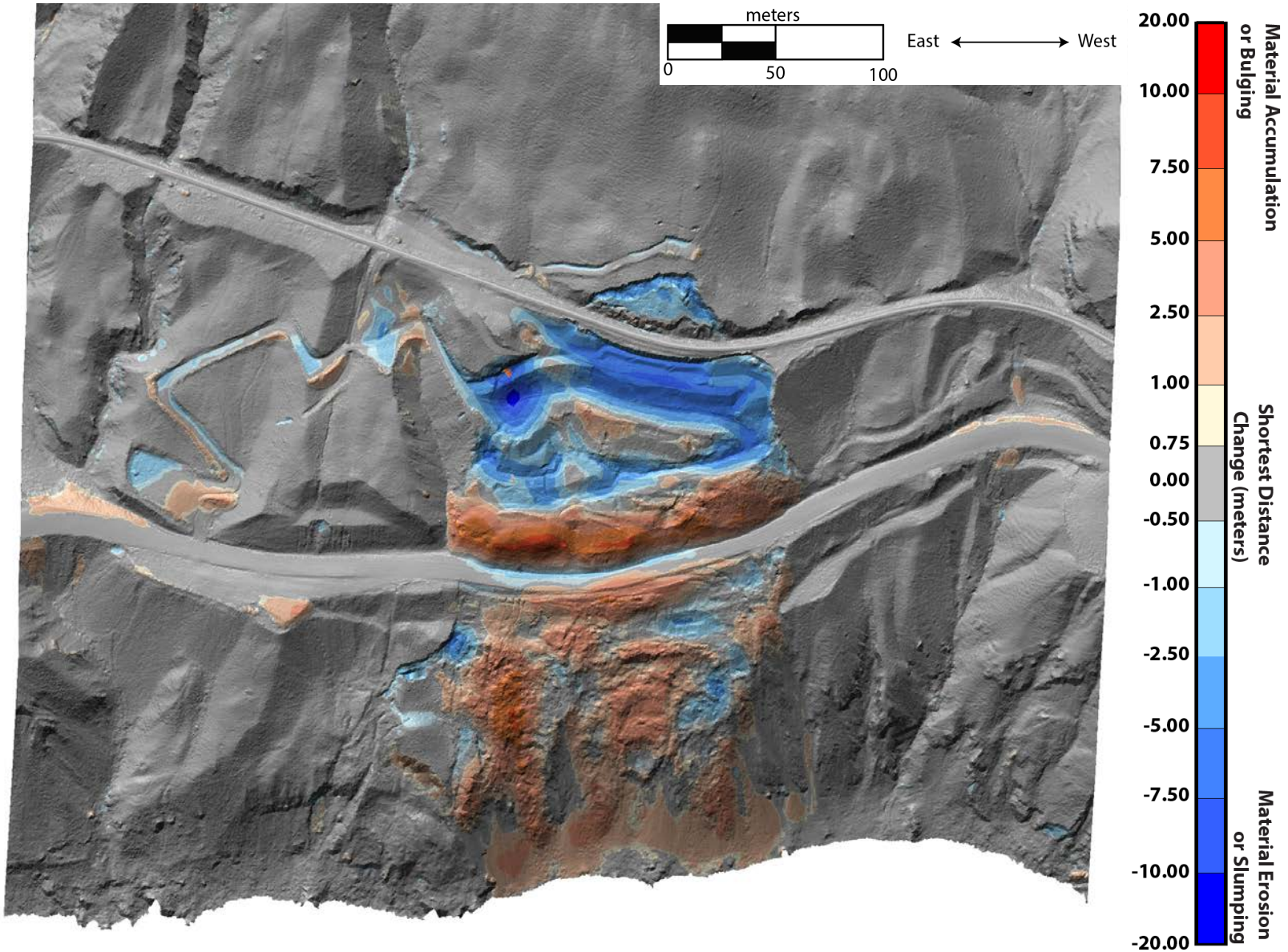
Cracking in the highway



January 2017
vs 2006



April 2017 vs 2006

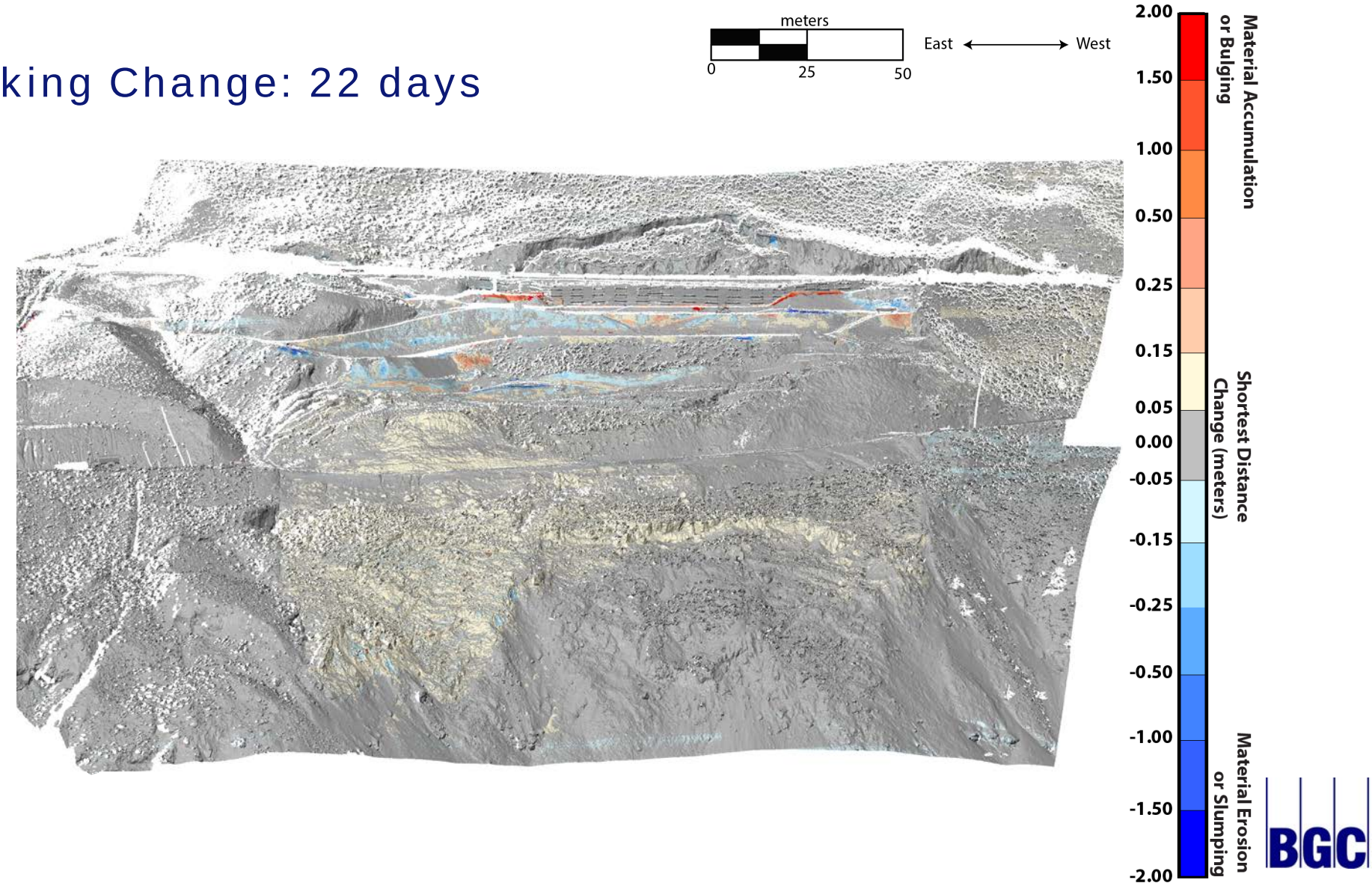


Changes between TLS datasets

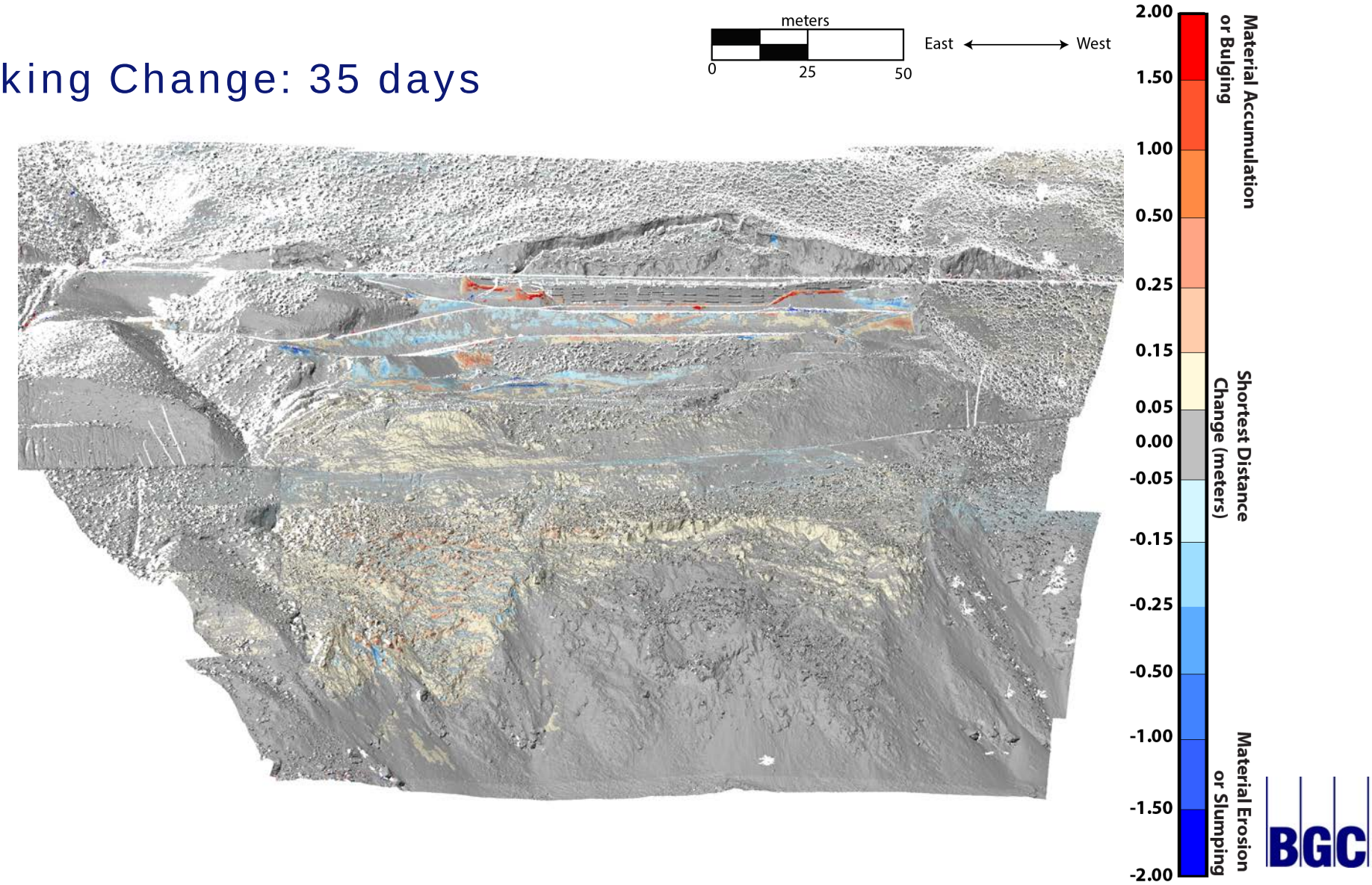
Visualize and understand:

- Small and large magnitude deformation
- Relationship between activity at the toe, mid-slope, and crest
- Identify early stage deformation across the entire slope

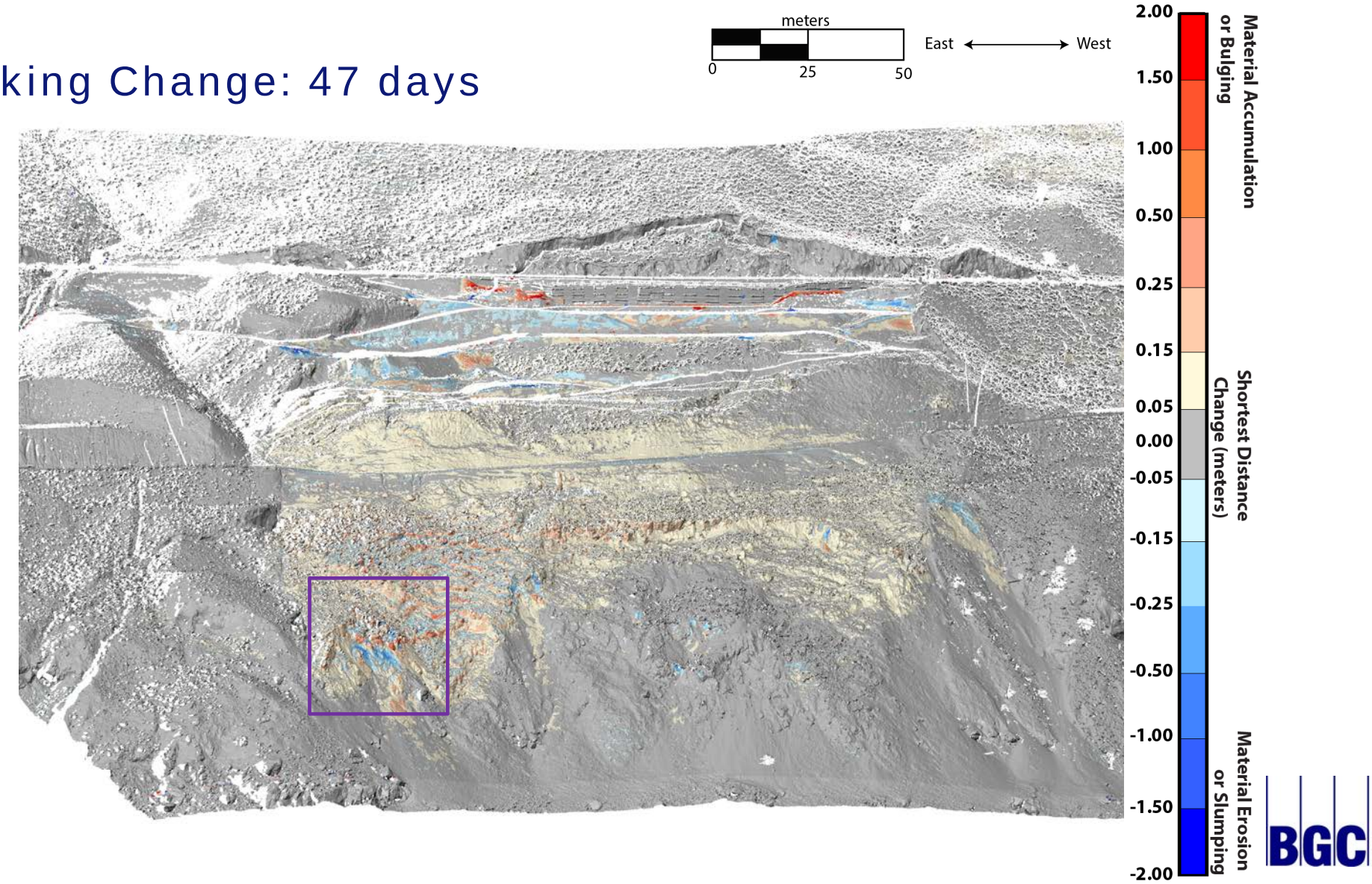
Tracking Change: 22 days



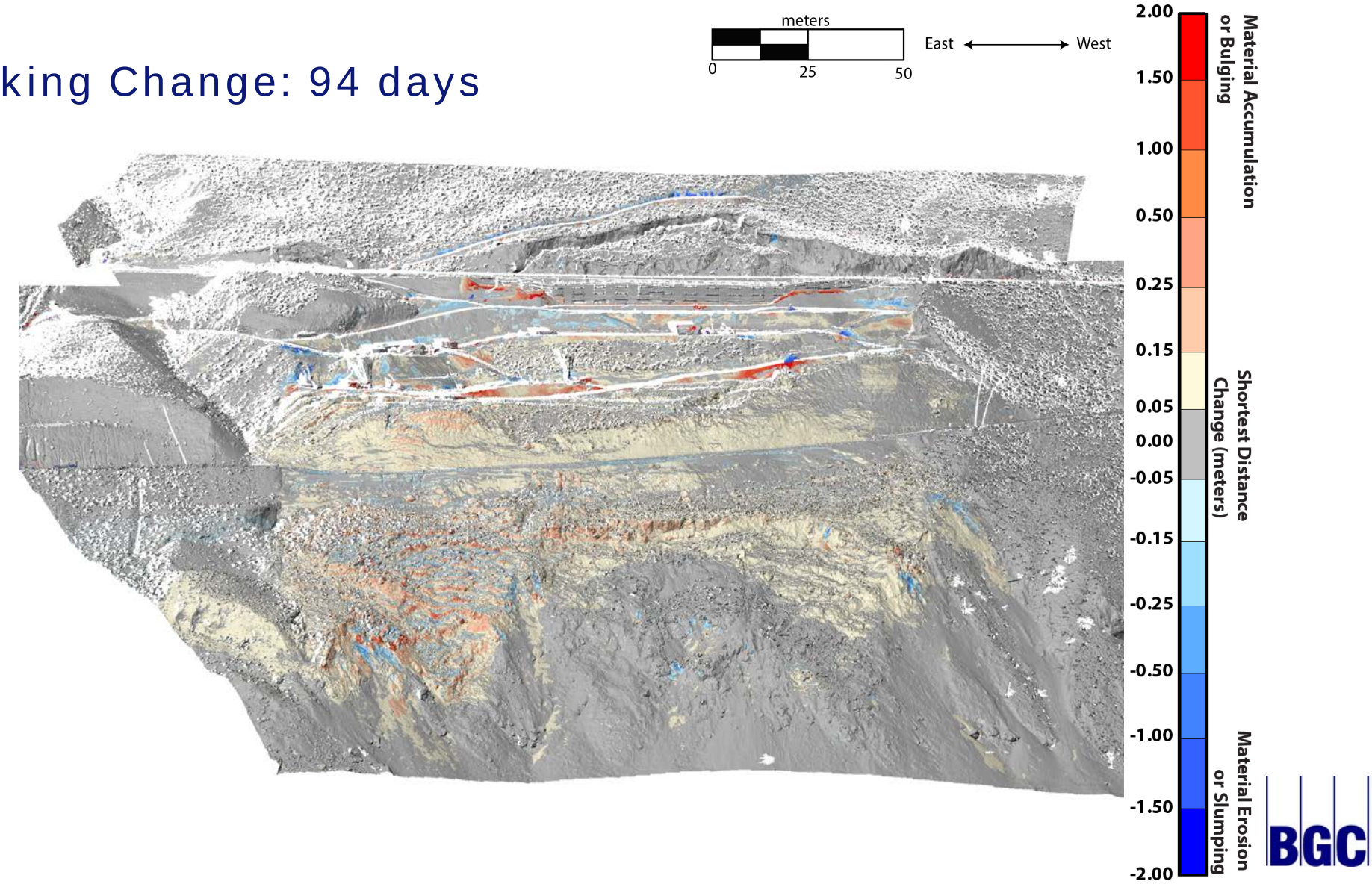
Tracking Change: 35 days



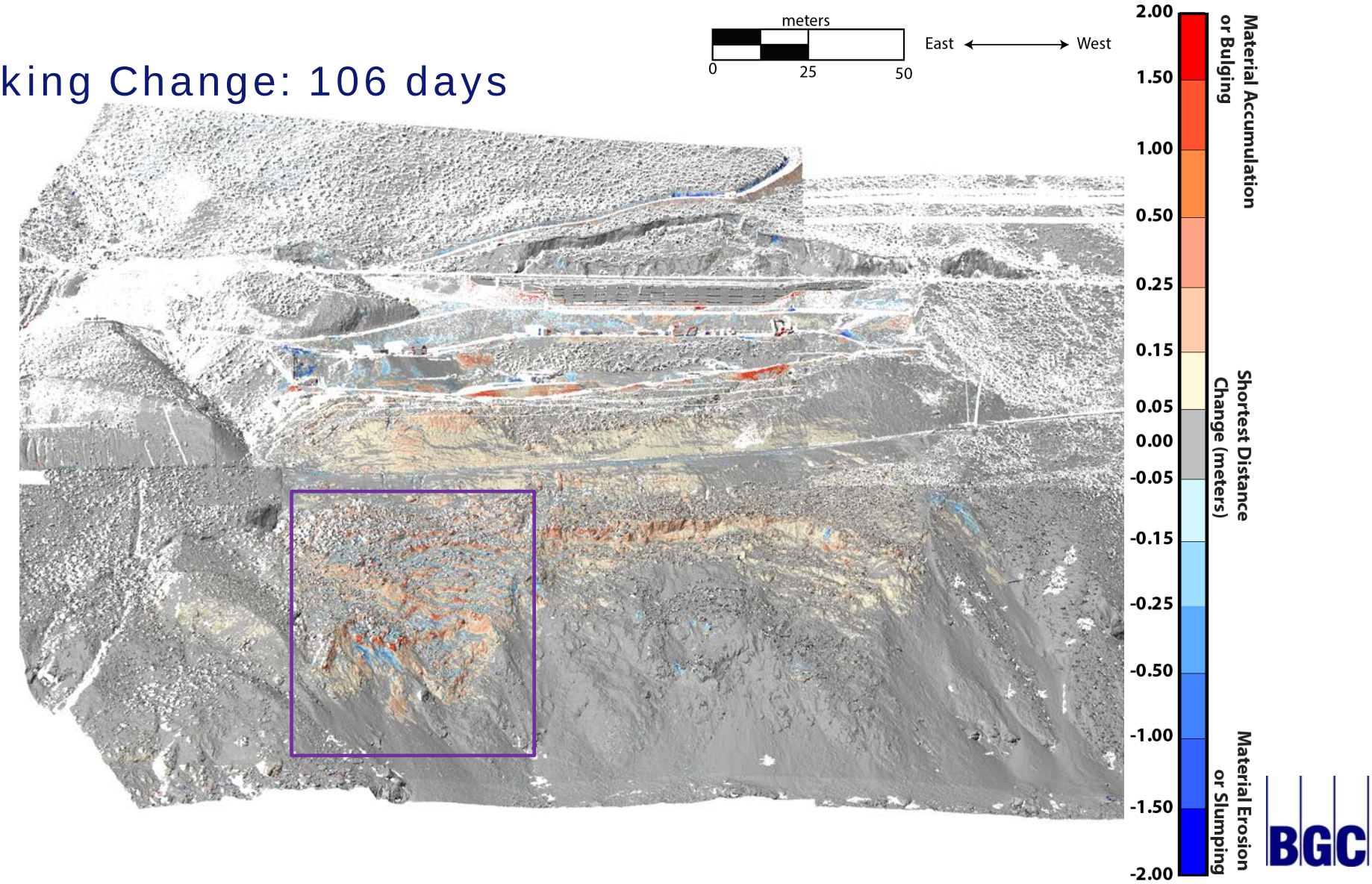
Tracking Change: 47 days



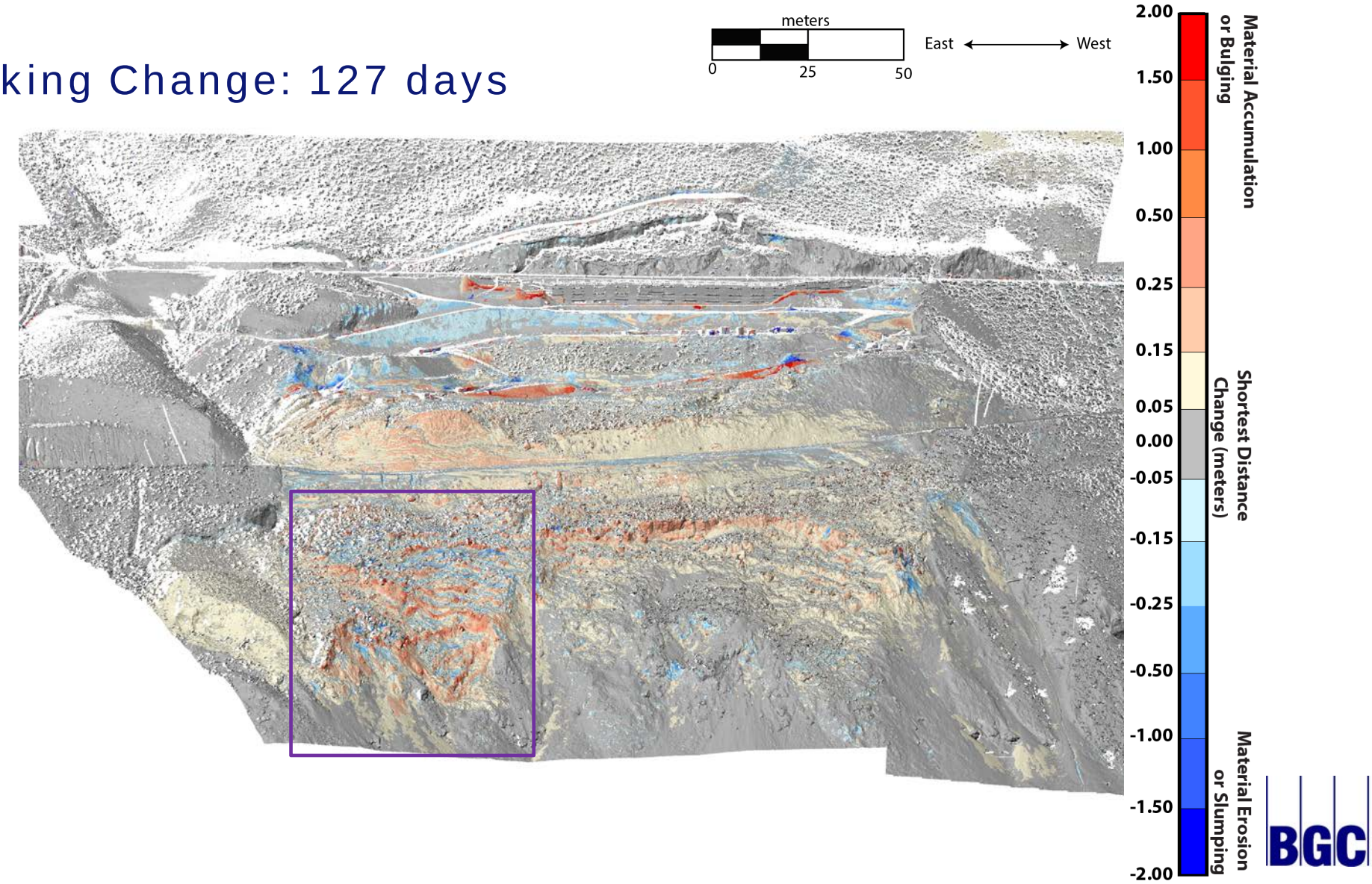
Tracking Change: 94 days



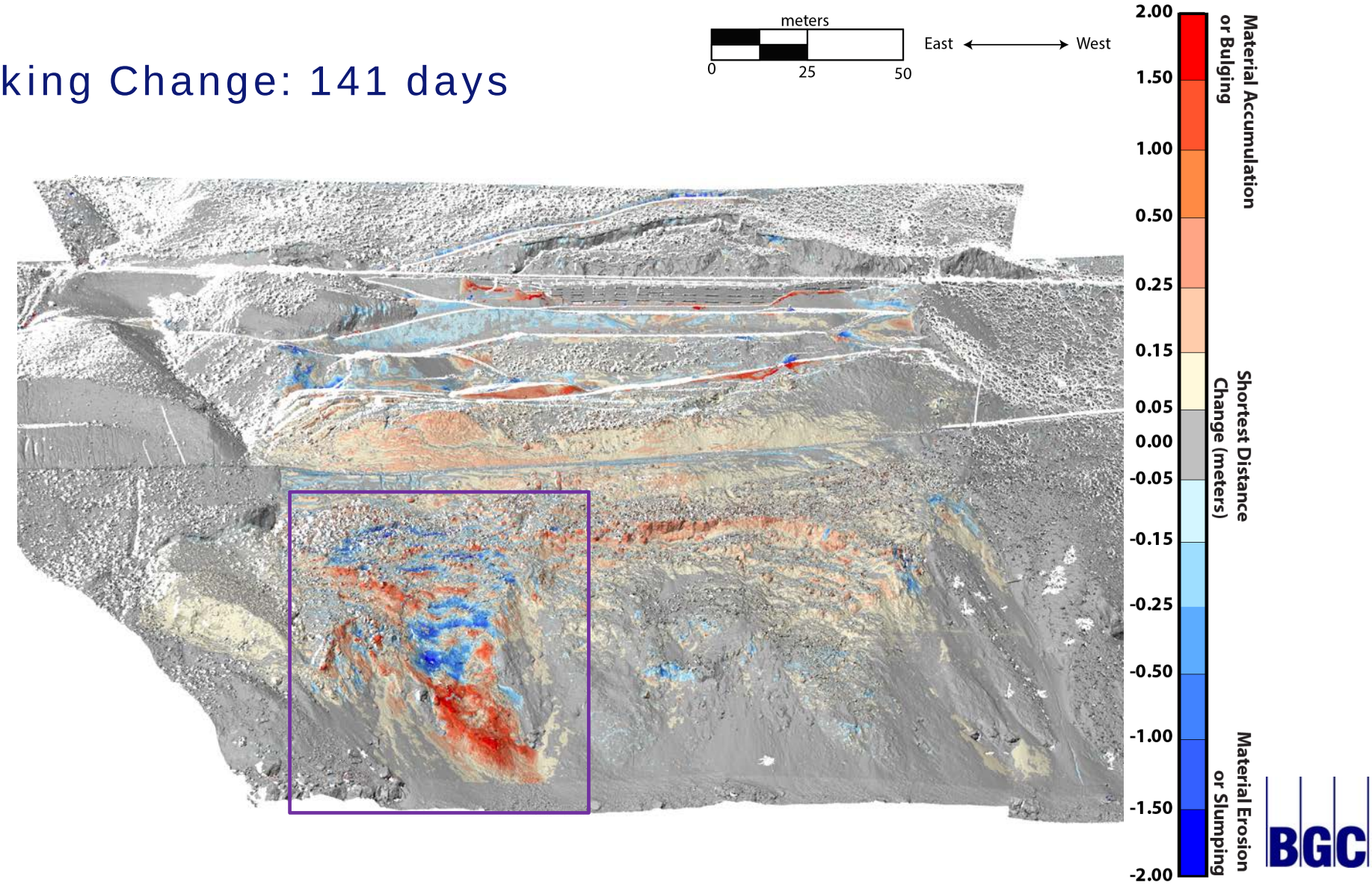
Tracking Change: 106 days



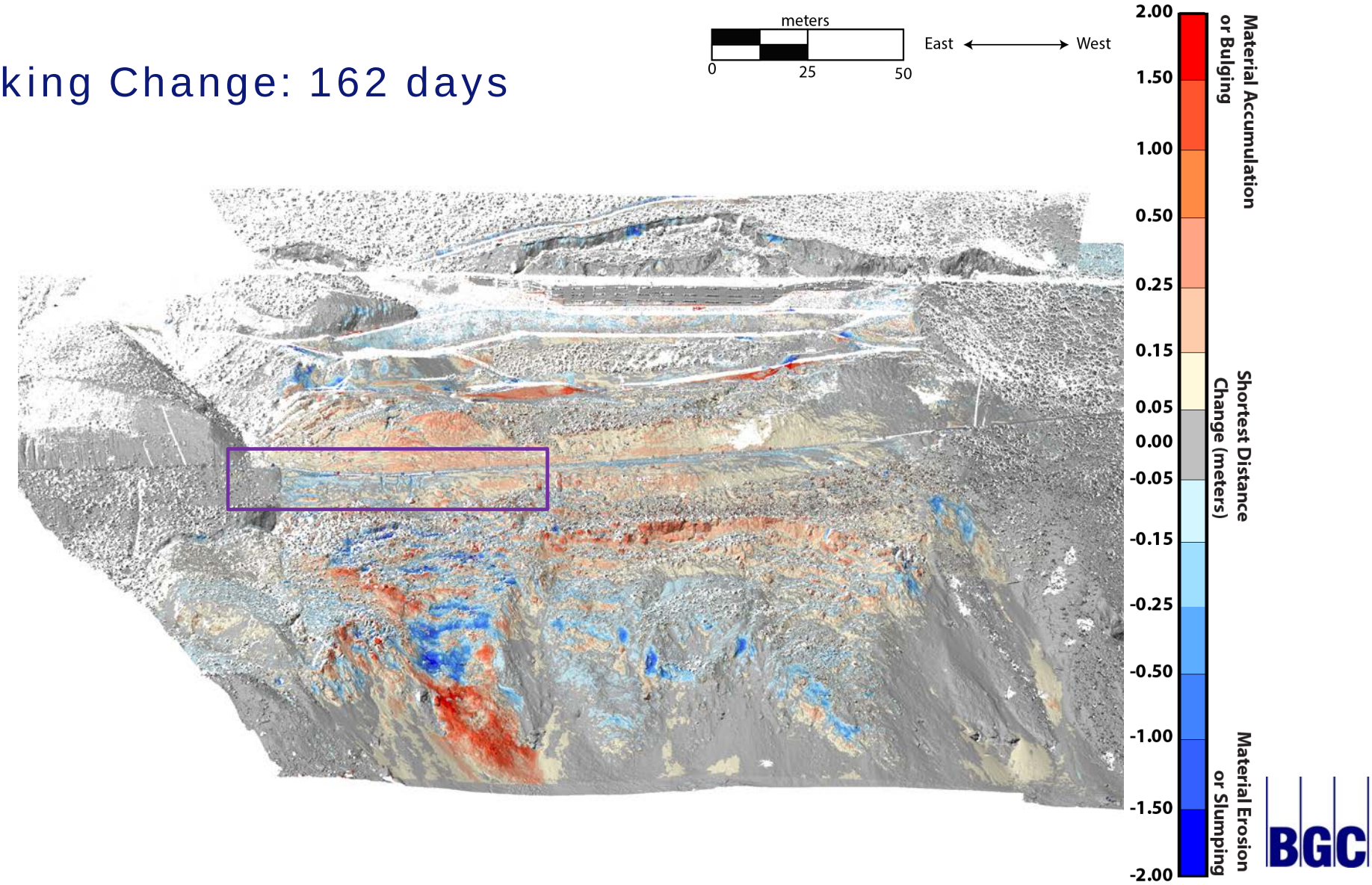
Tracking Change: 127 days



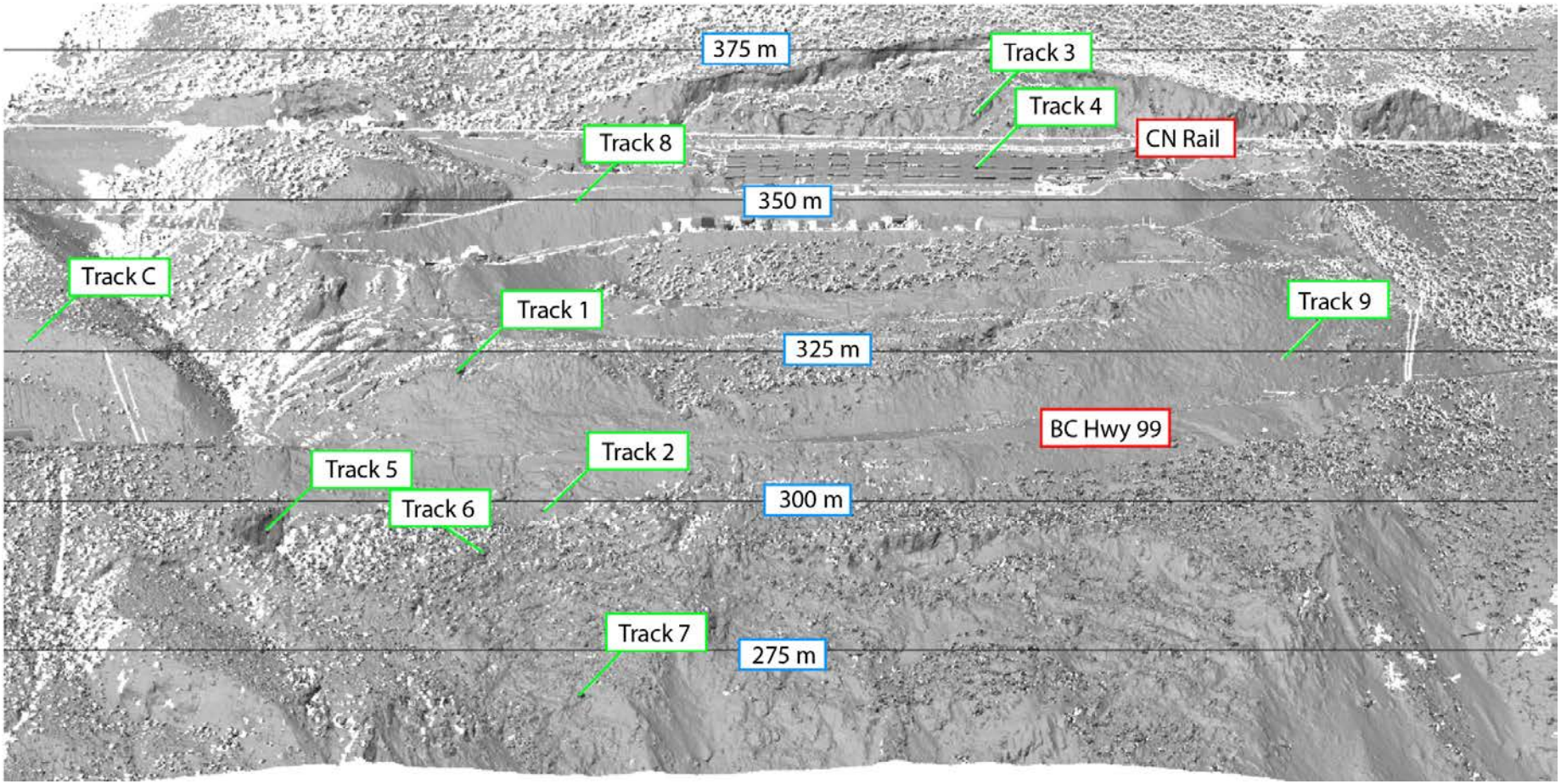
Tracking Change: 141 days



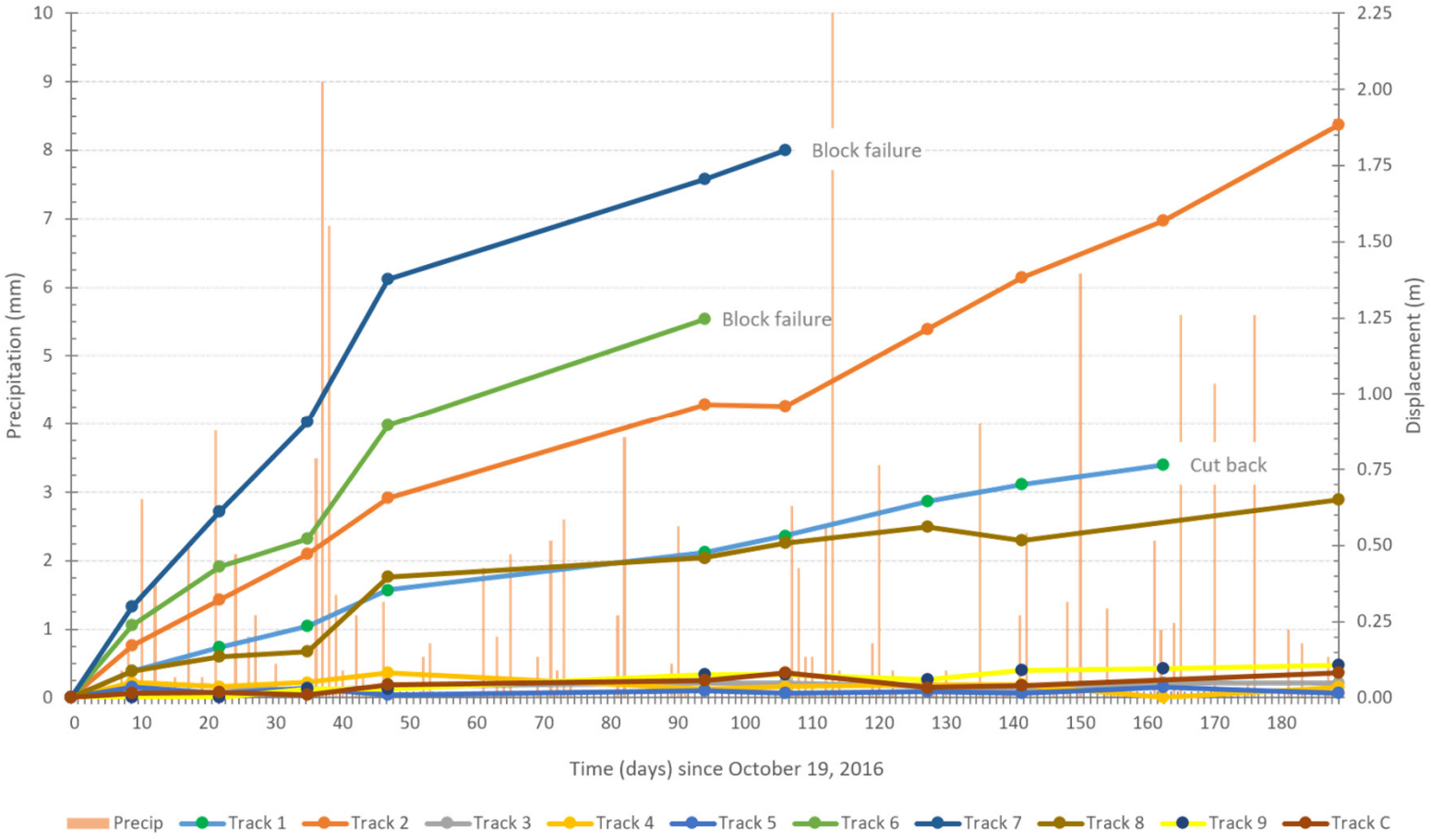
Tracking Change: 162 days



Displacement



Displacement



Key capabilities

Visualize and understand, remotely:

- Analyze deformation across a landslide body
- Connect between activity at the toe, mid-slope, and crest
- Monitor performance of mitigation efforts
- Ability to identify locations of concern across the entire slope

Case Study 2: Communities and highways

Matthew Lato, Michael Porter, and Scott Anderson
Accepted: ASCE Journal of Geotechnical and Geoenvironmental Engineering

bgcengineering.com

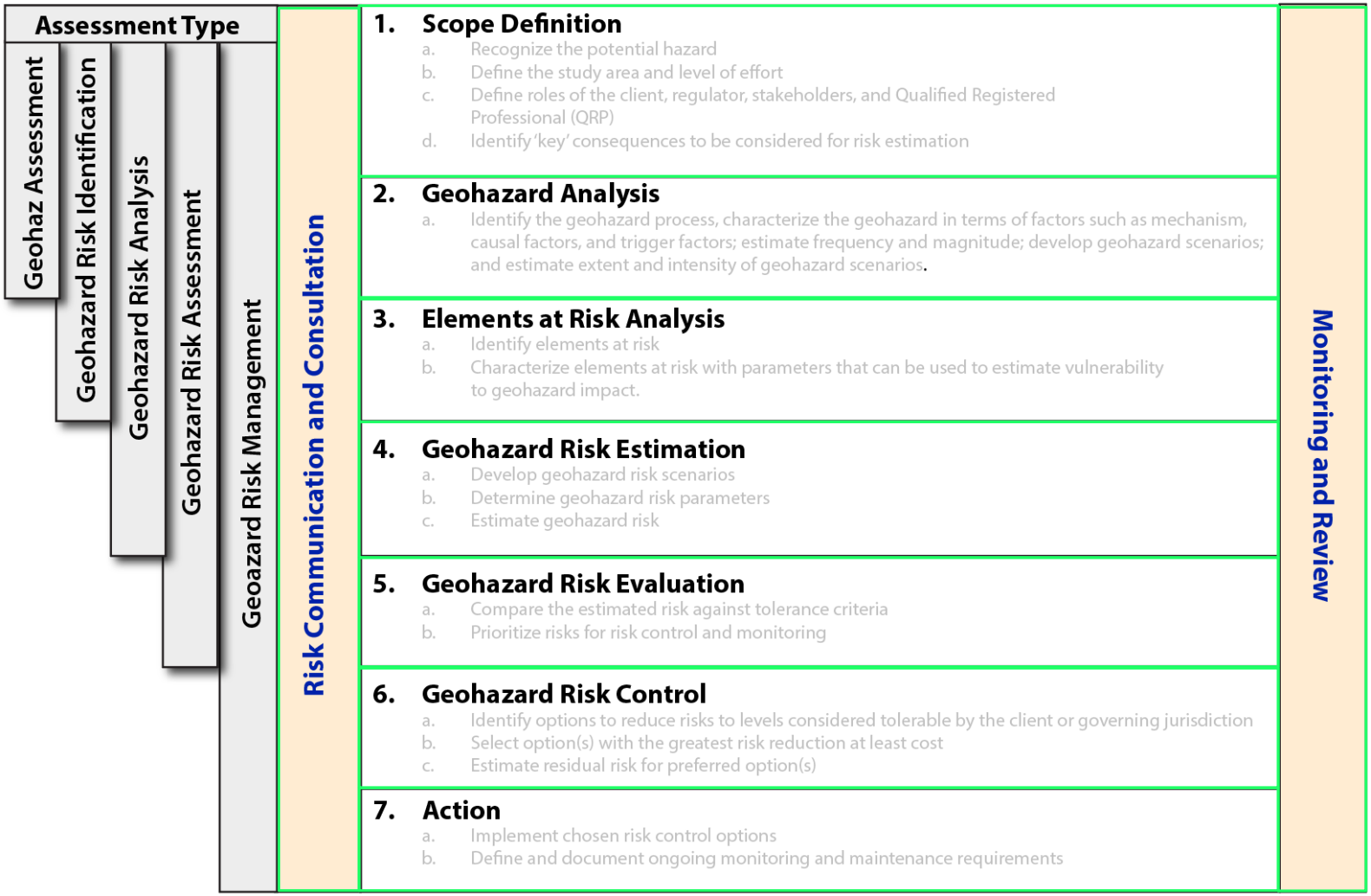
BGC

Regional geohazard identification and risk management

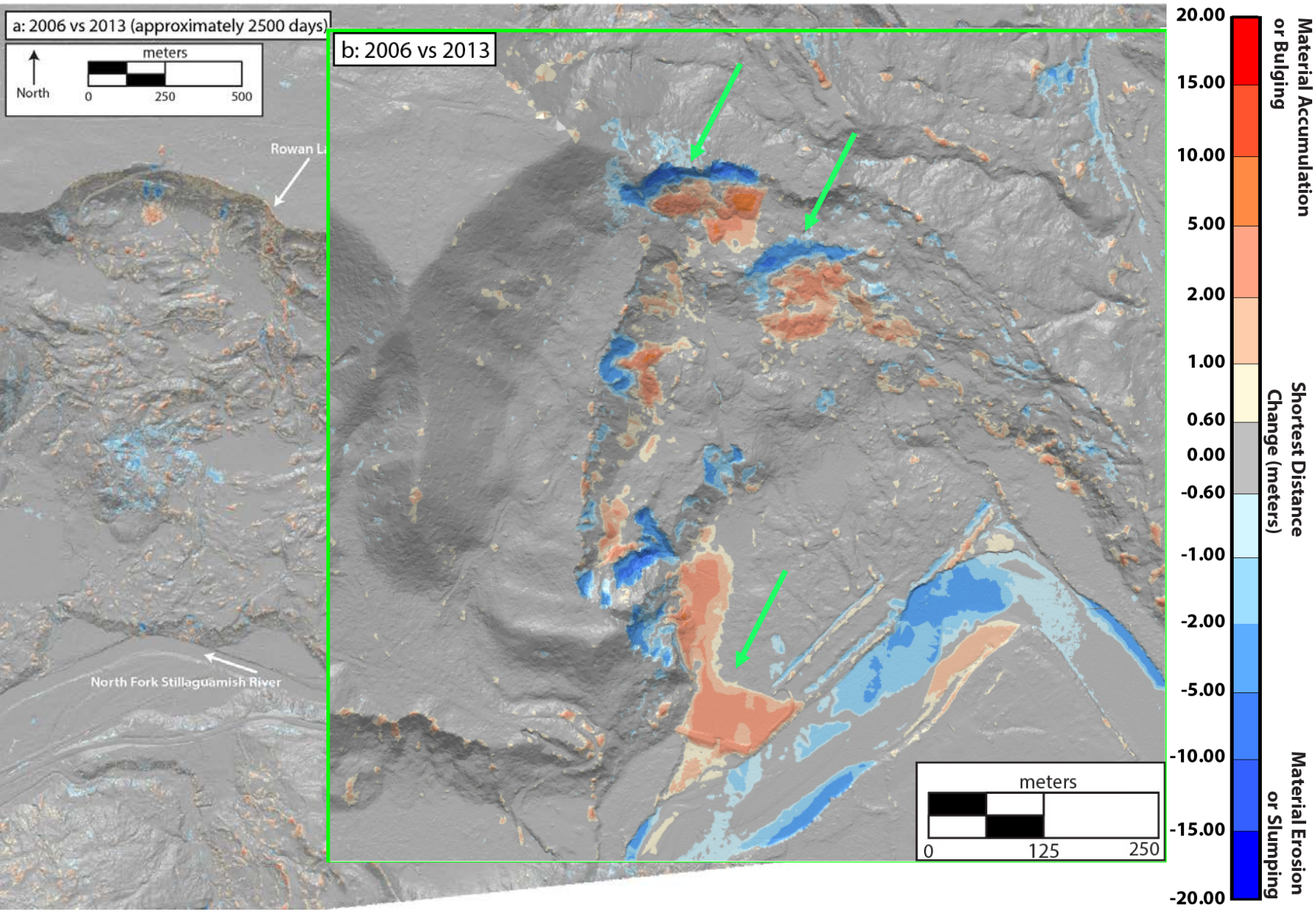
We have the ability to collect, process and interpret spatially extensive ALS data for the purpose of change detection mapping for geohazard identification and landslide characterization.

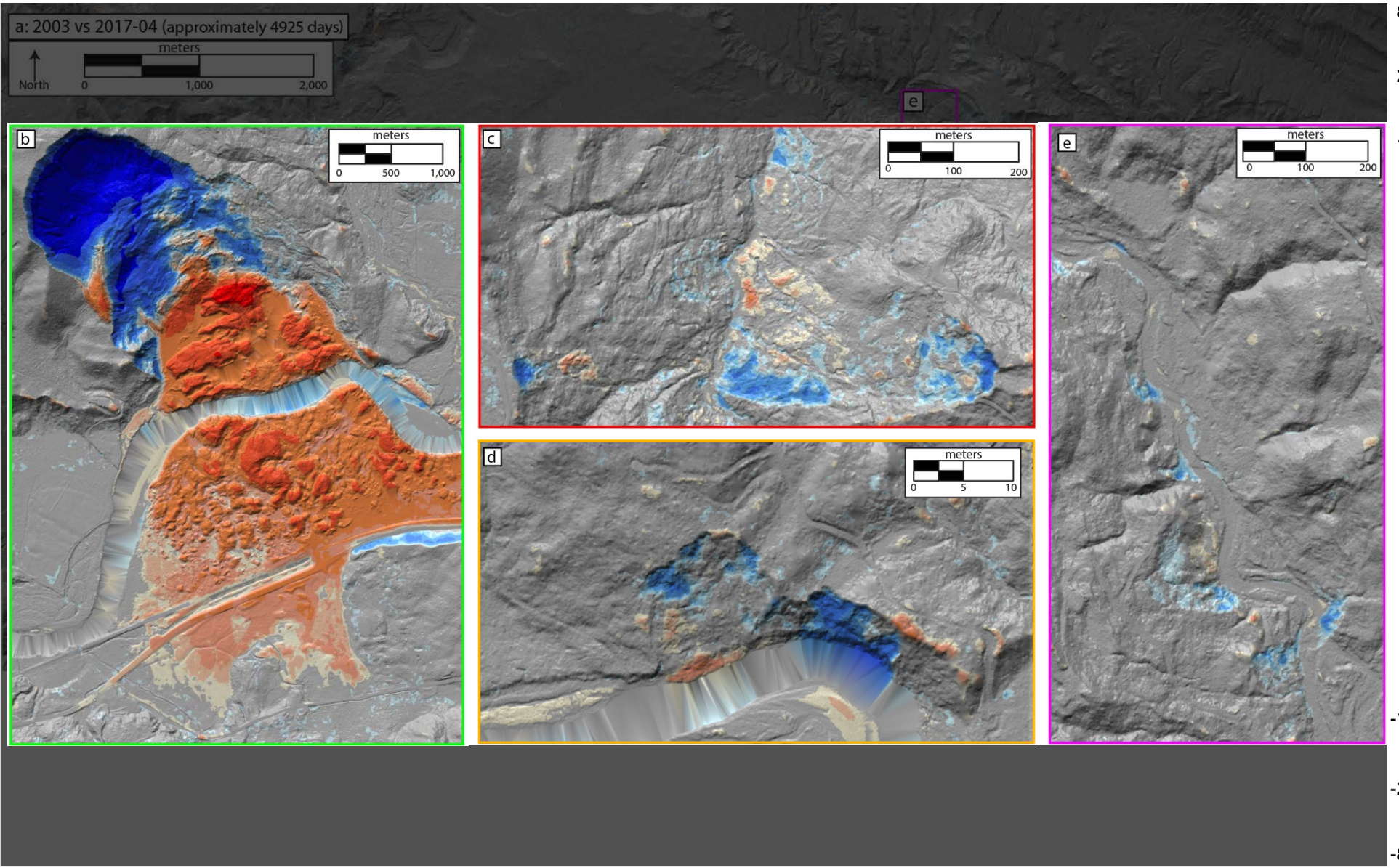
If such analyses are conducted at regular intervals the information generated can be used to inform regional landslide risk assessments, aid in risk communication, and reduce risk from landslides due to better decision making.

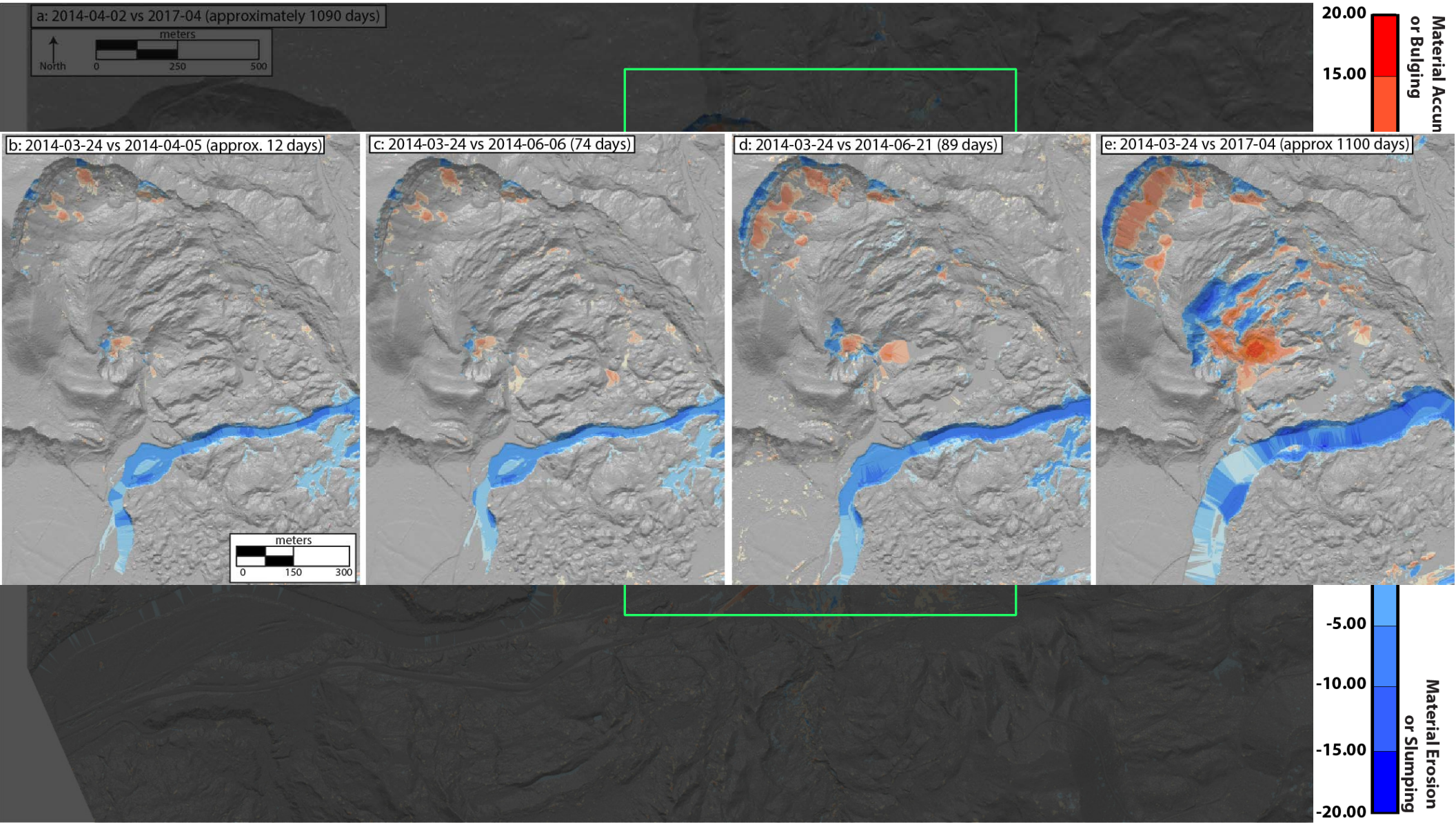
Risk Informed Decision Making



Modified after: CSA, ISO


a: 2006 vs 2013 (approximately 2500 days)
meters
North
0
250
500
Rowan L
North Fork Stillaguamish River
b: 2006 vs 2013
meters
0
125
250
20.00
15.00
10.00
5.00
2.00
1.00
0.60
0.00
-0.60
-1.00
-2.00
-5.00
-10.00
-15.00
-20.00
Material Accumulation or Bulging
Shortest Distance Change (meters)
Material Erosion or Slumping


a: 2003 vs 2017-04 (approximately 4925 days)
meters
North
0
1,000
2,000
b
meters
0
500
1,000
c
meters
0
100
200
d
meters
0
5
10
e
e
meters
0
100
200
80.00
20.00
10.00
5.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-5.00
-10.00
-20.00
-80.00
Material Accumulation or Bulging
Shortest Distance Change (meters)
Material Erosion or Slumping


a: 2014-04-02 vs 2017-04 (approximately 1090 days)
meters
North
0
250
500
20.00
15.00
Material Accumulation or Bulging
b: 2014-03-24 vs 2014-04-05 (approx. 12 days)
c: 2014-03-24 vs 2014-06-06 (74 days)
d: 2014-03-24 vs 2014-06-21 (89 days)
e: 2014-03-24 vs 2017-04 (approx 1100 days)
meters
0
150
300
-5.00
-10.00
-15.00
-20.00
Material Erosion or Slumping

Key capabilities

Identify and assess:

- Landslide and bank erosion activity across spatially extensive networks
- Discrete behavior of blocks within landslides
- Rates of movement and potential impacts on corridor operations

Assist in planning and prioritization of detailed investigations and risk mitigation

Our ability to do better

“One of government’s key roles is to promote public safety, it is critical for the public to understand the risks posed by potential natural disasters and to mitigate or minimize their impact.”

SR 530 Landslide Commission (2014)

Technology Summary

bgcengineering.com

3D change detection techniques

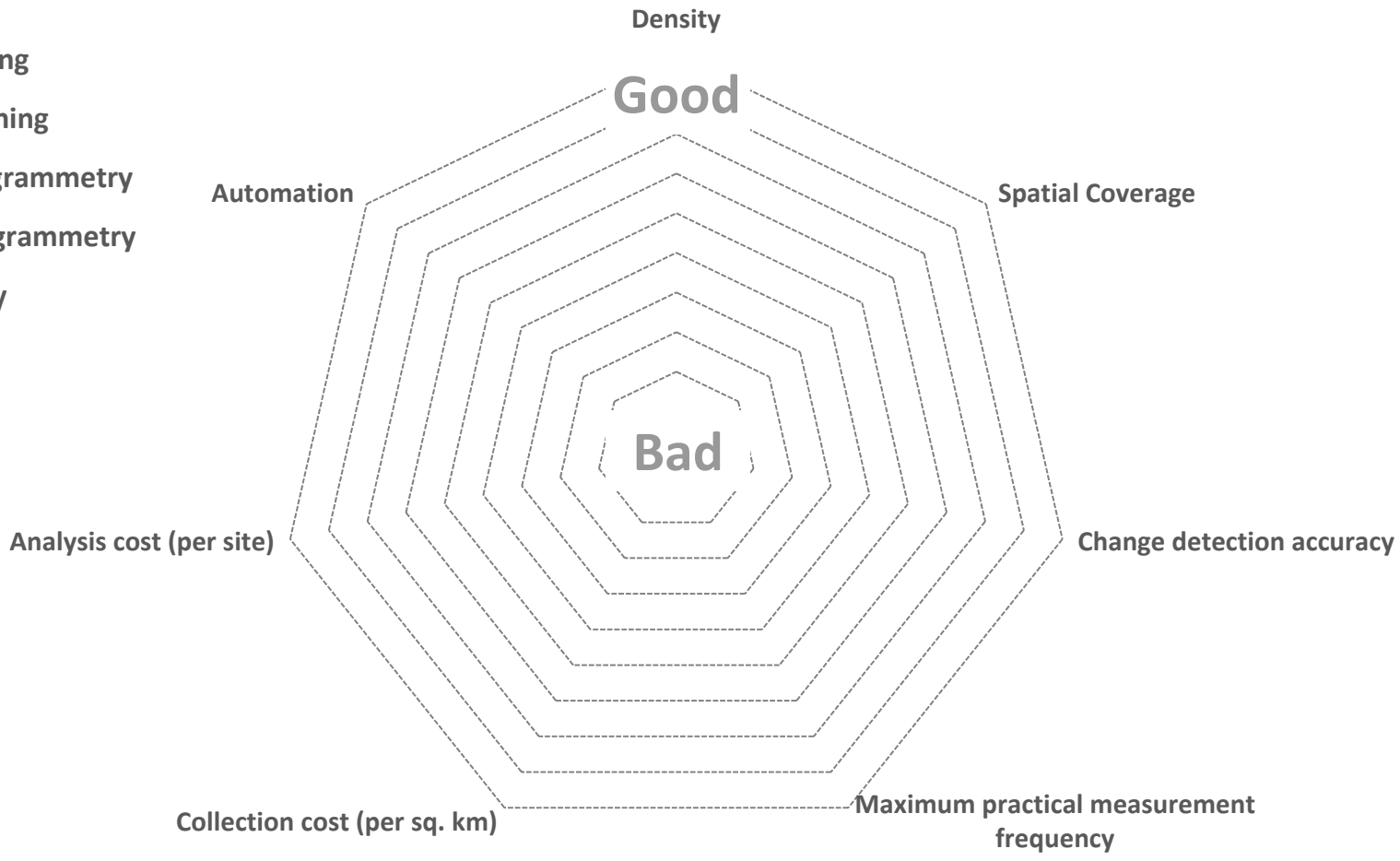
Airborne Lidar Scanning

Terrestrial Lidar Scanning

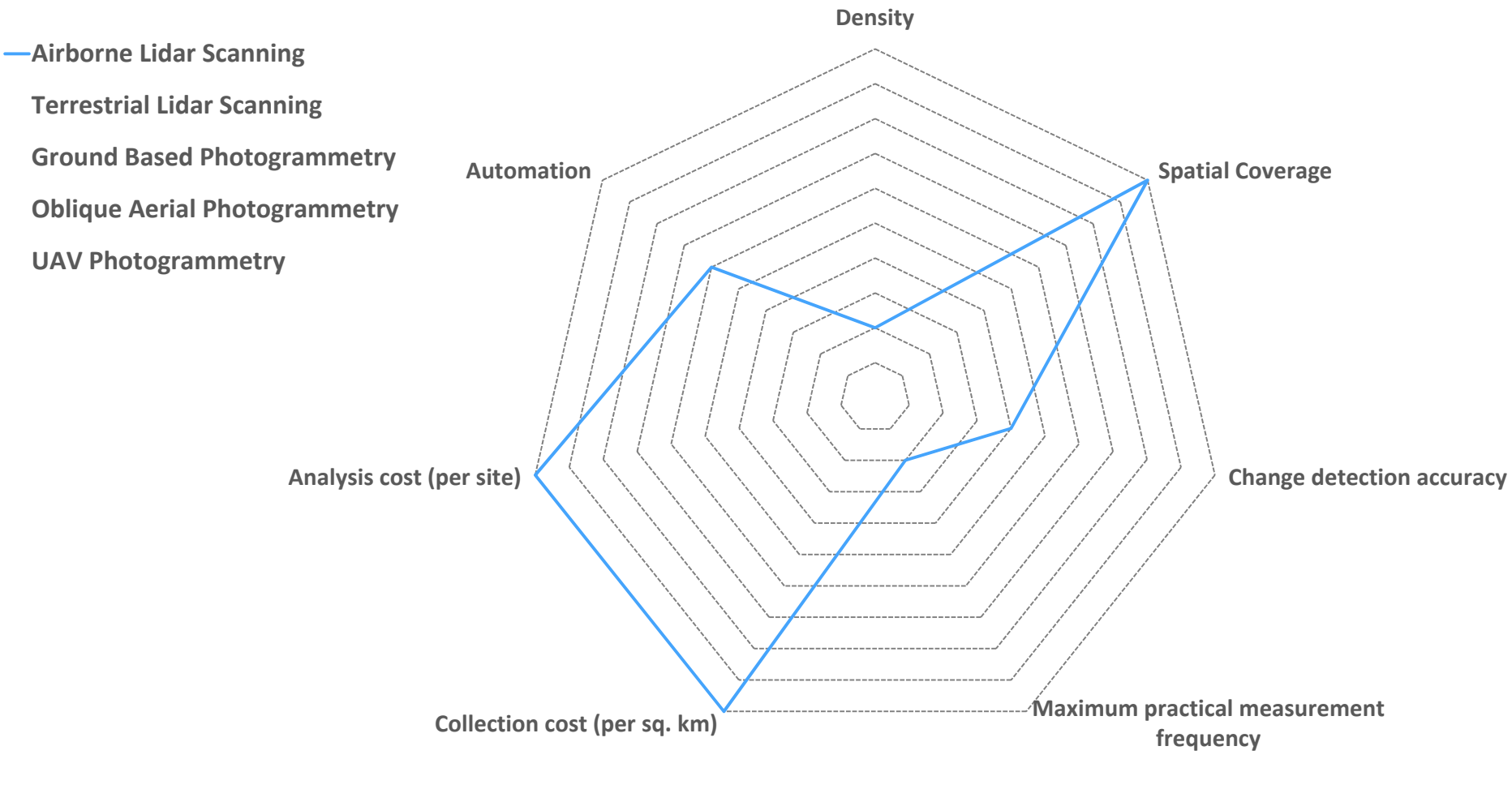
Ground Based Photogrammetry

Oblique Aerial Photogrammetry

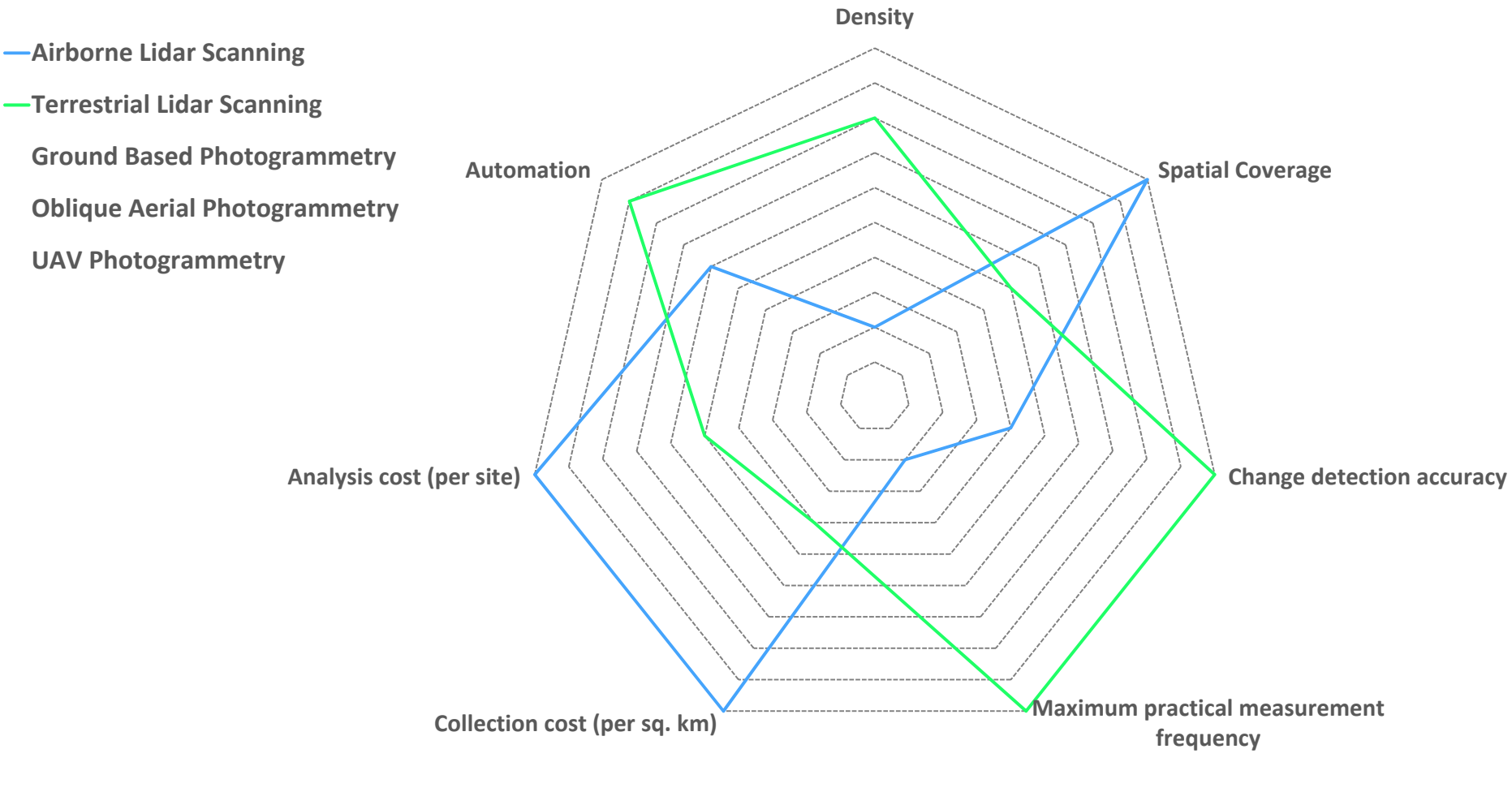
UAV Photogrammetry



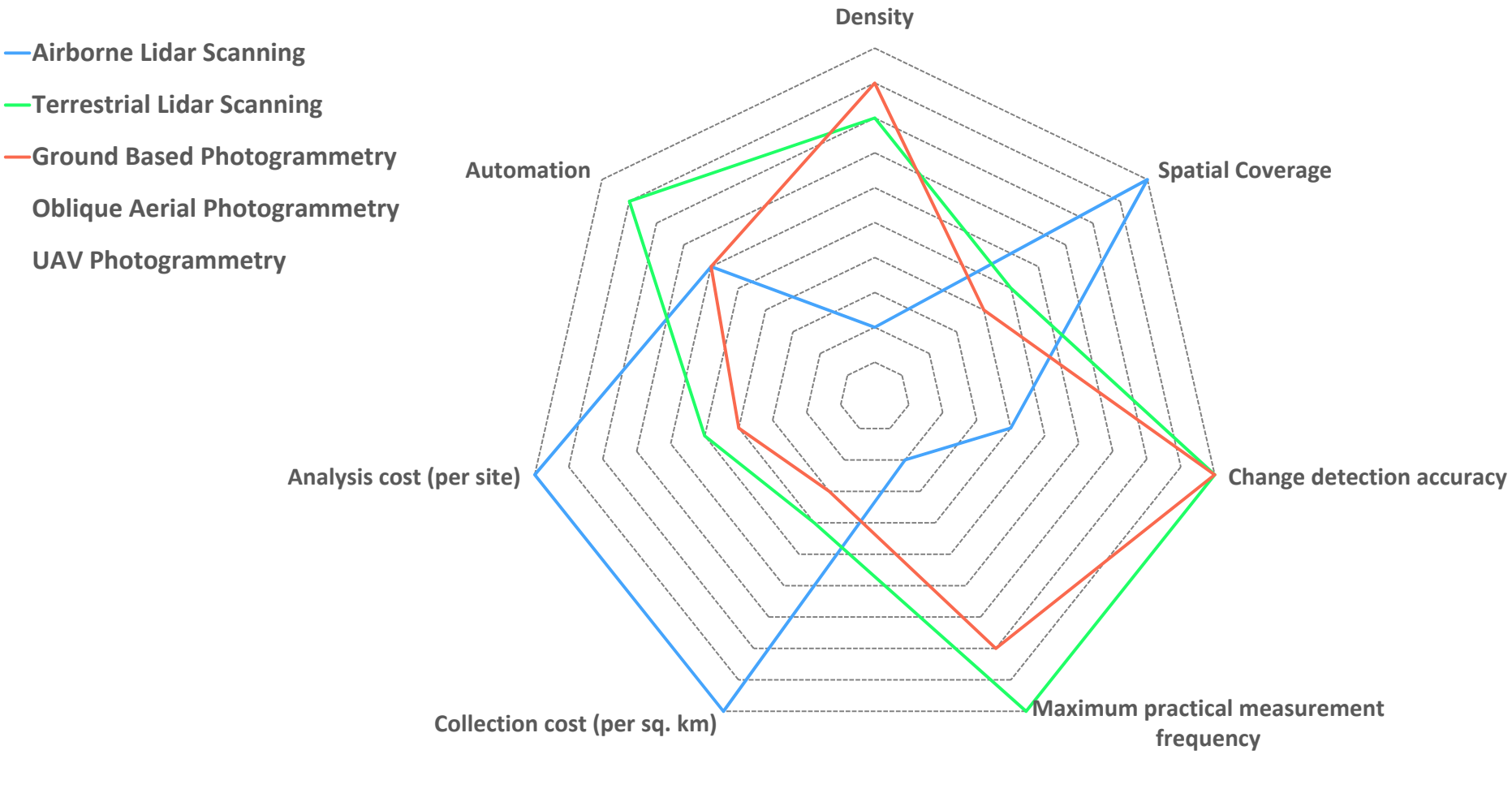
3D change detection techniques



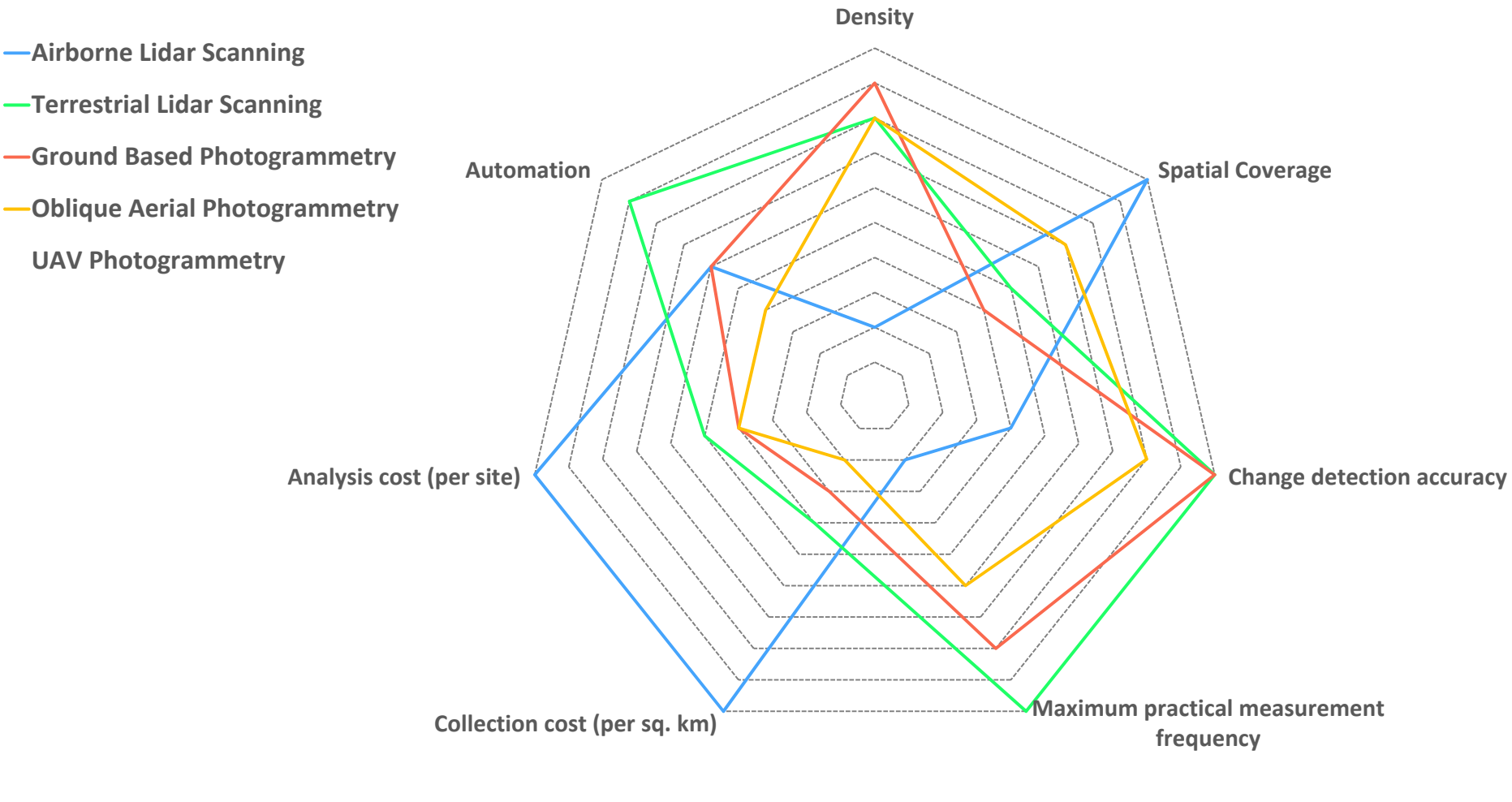
3D change detection techniques



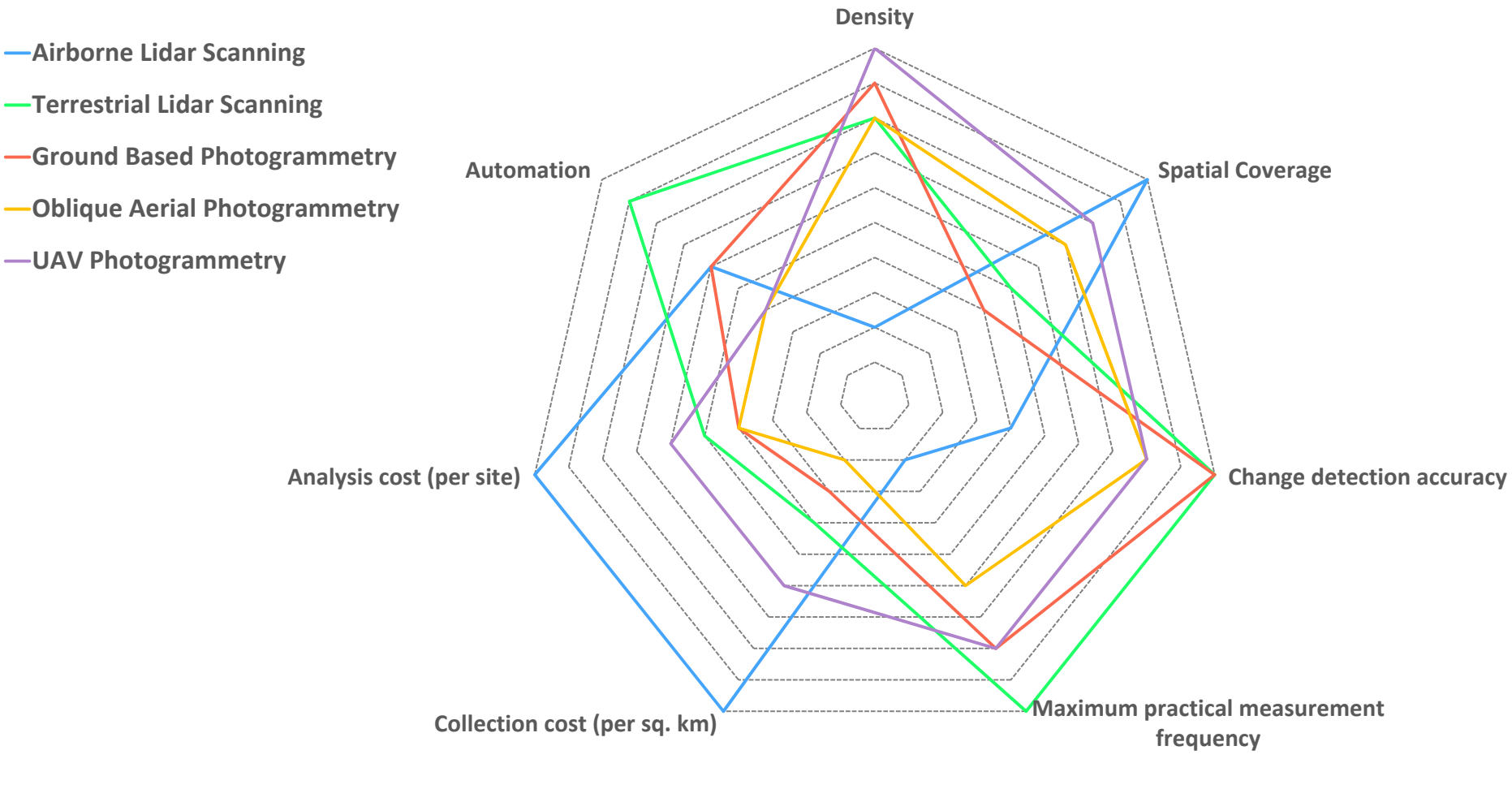
3D change detection techniques



3D change detection techniques



3D change detection techniques



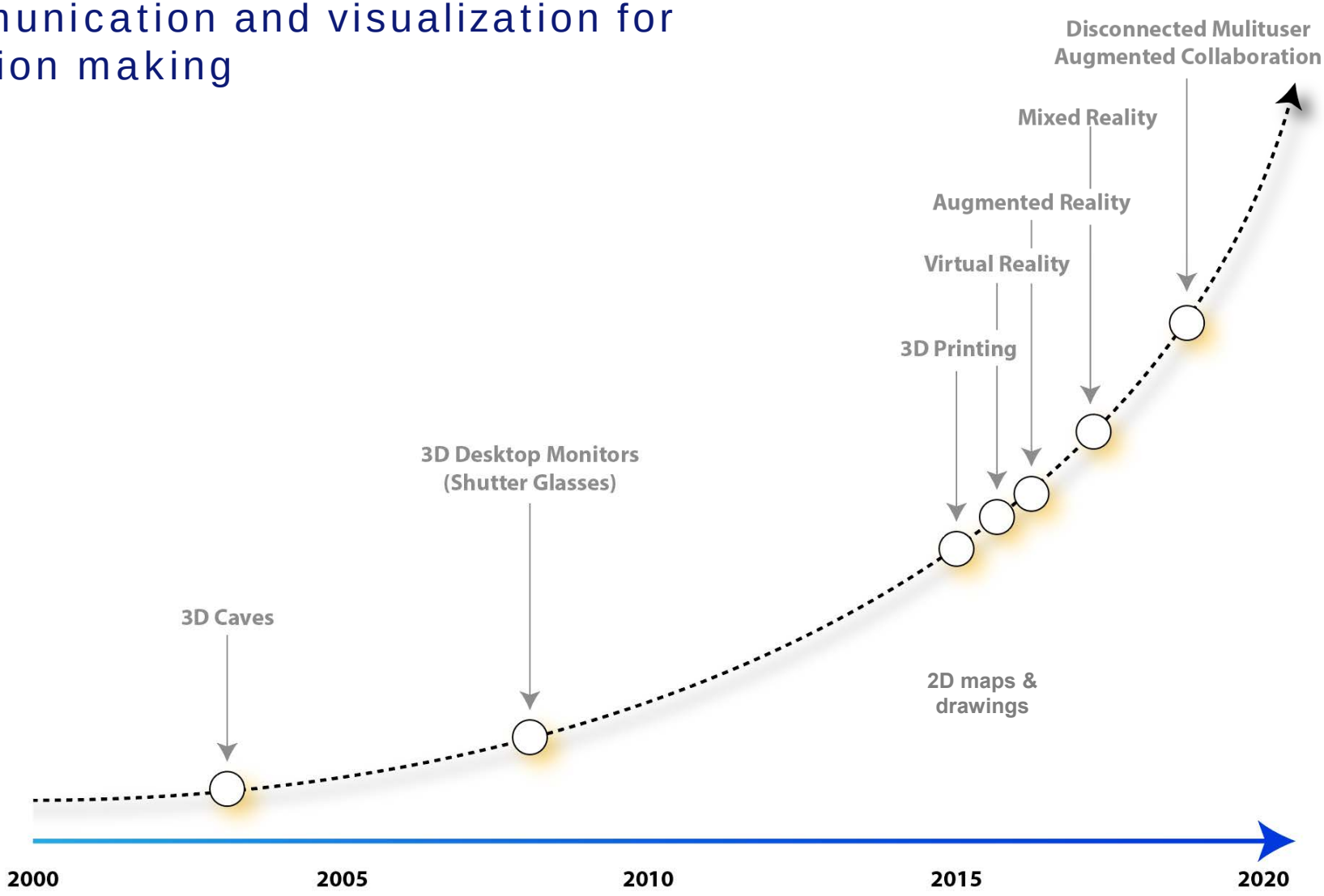
Data Visualization & Communication

BGC: Bill Burton, Gerald Magnusson, Brent Mooder, Tim Thibault, Jordan Wischmann

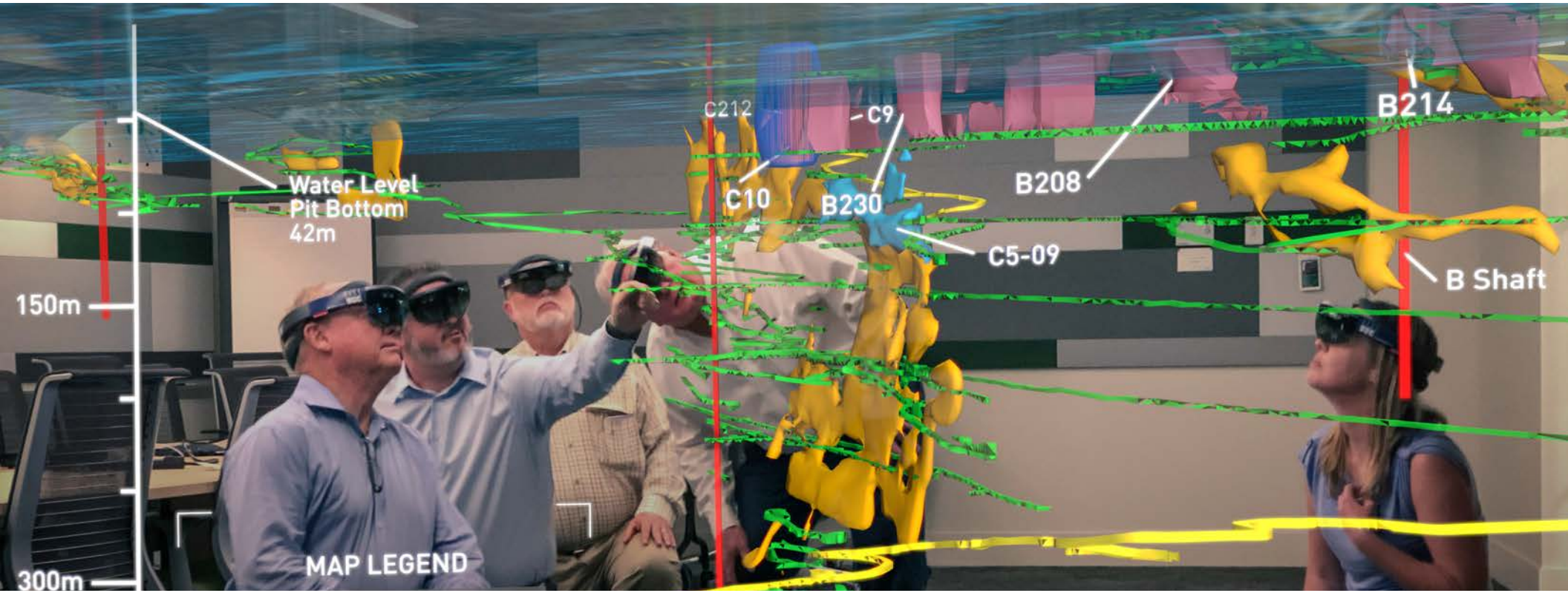
bgcengineering.com

BGC

Communication and visualization for decision making



“There is a fundamental disconnect between the wealth of digital data available to us and the physical world in which we apply it. While reality is three-dimensional, the rich data we now have to inform our decisions and actions remains trapped on two-dimensional pages and screens” Harvard Business Review



Independent Technical Review Board

“During the meetings the IPRP was provided a preview of the 3-D virtual images of the underground workings that have been prepared. The Panel considers these to be a very effective communication tool both to the site workers, regulators and the public and encourages their further development and use.”

Conclusions

3D remote sensing allows us to view and understand the physical environment over time unlike any other technology. Leveraging available capabilities, and developing future applications, will create the opportunity for better geotechnical decisions. The technology is ready today, the analytical methods are proven.

“The future is already here — it's just not very evenly distributed”

William Gibson, 1993

Acknowledgements

Jean Hutchinson, Mark Diederichs, Rob Harrap
Scott McDougall, Pete Quinn, Mike Porter, Scott Anderson
Bill Burton, Steve Hedberg, Andrew Mitchell, Elin Morgan
Ryan Kromer, Megan van Veen, Dave Gauthier, Emily Rowe
Malte Voege, Regula Frauenfelder, Andi Pfaffhuber
Tom Edwards, Trevor Evan, Mario Ruel, Melissa Ruel, Suzanne Lacasse
BGC, NGI, Rio Tinto, CN, BC MoTI, CIRNAC