UAS for Rockfall Site Monitoring

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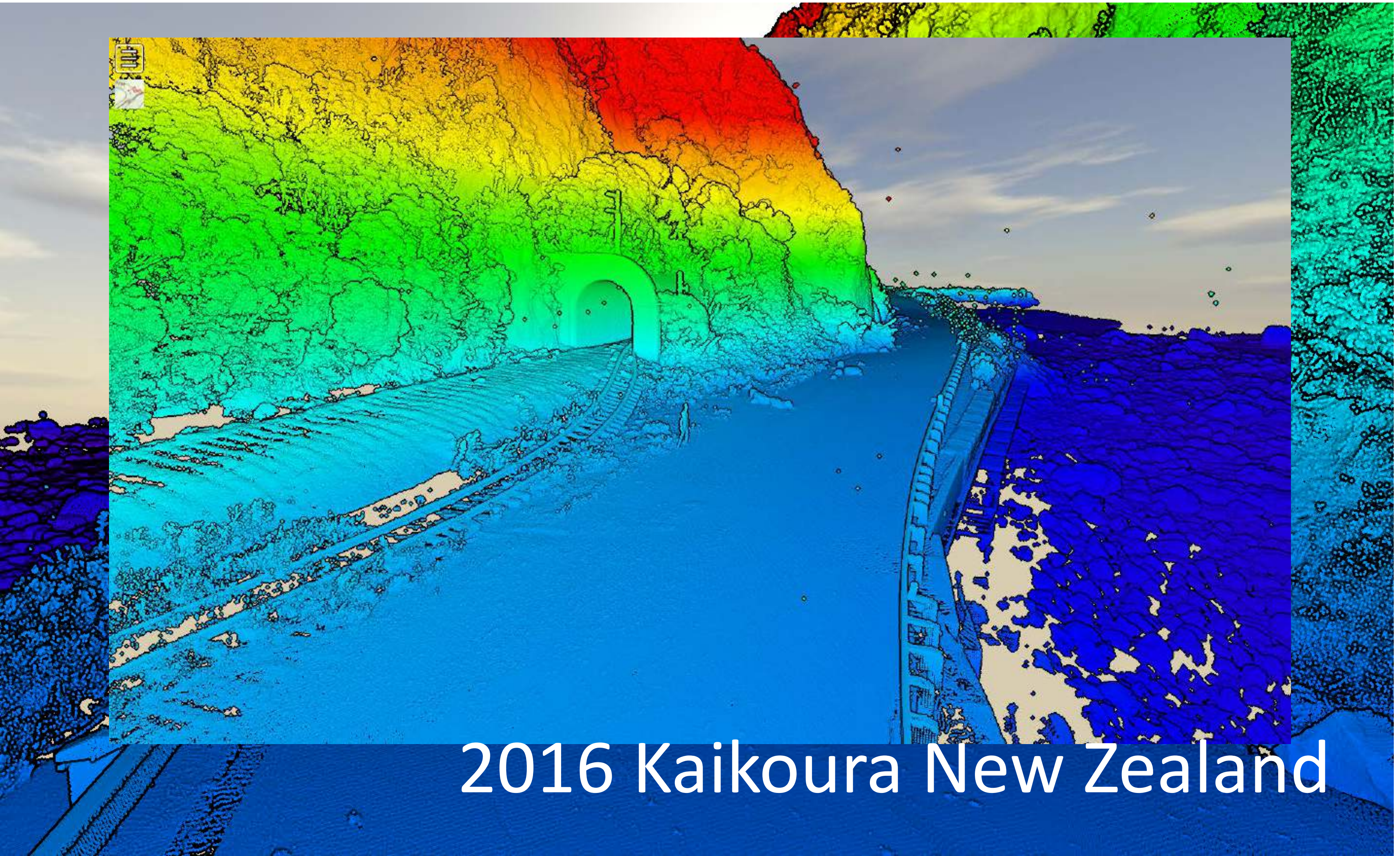
PACTRANS Pacific NW Transportation Consortium Region 10
Transportation & Public Facilities State of Alaska
Oregon Department of Transportation

UAS in Transportation Workshop, Corvallis, OR

Motivation

- Long, isolated highways
- Safety & Mobility concerns
- Proactive Risk Assessment – Performance-based Asset Management
- Identify priority locales for remediation, detailed monitoring
- Limited personnel
- Less money
- More liability, political pressure

Seismic Rockfalls\Landslides



2016 Kaikoura New Zealand

Traditional Assessment

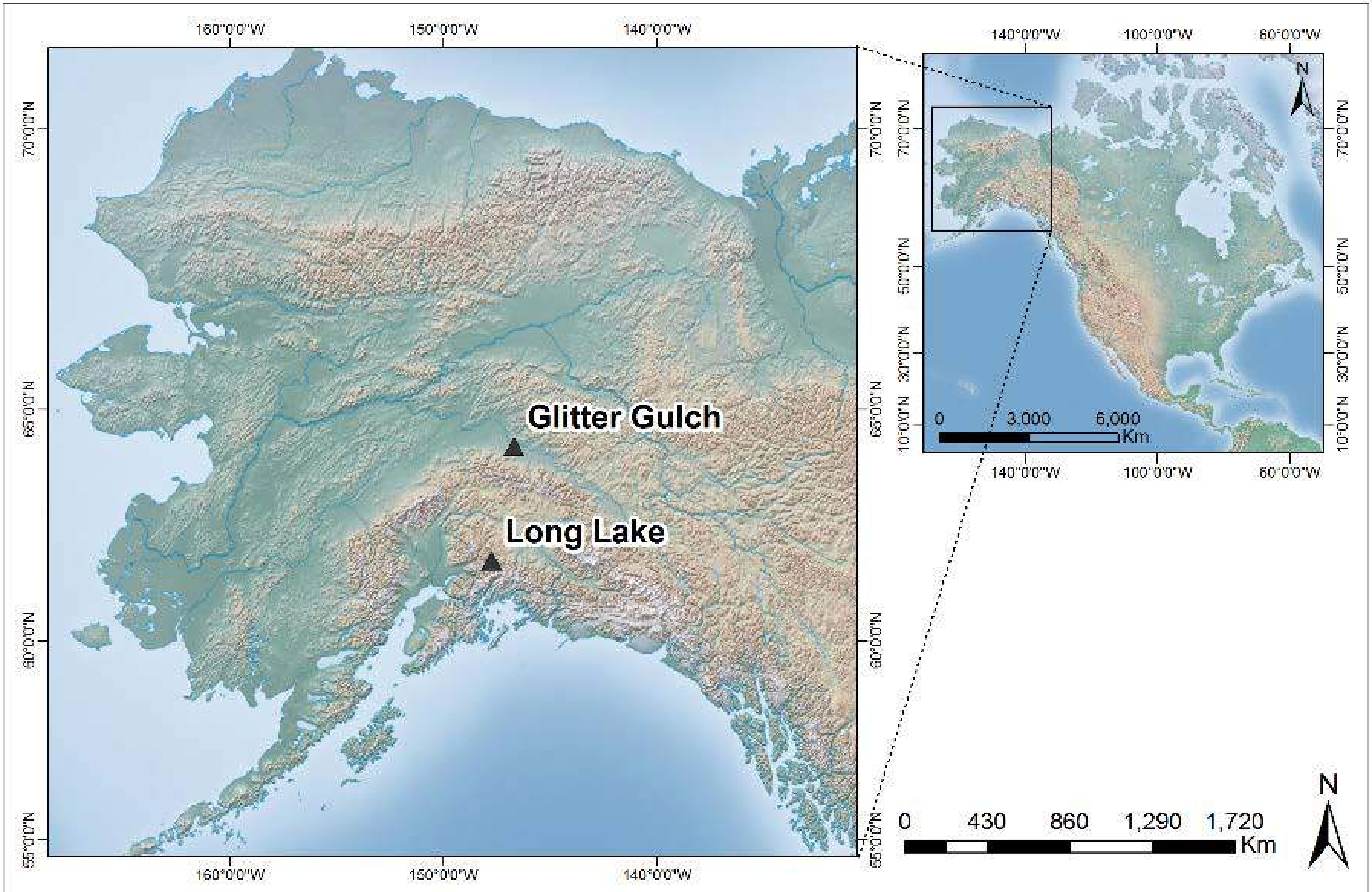
- E.g. Rockfall Hazard Rating System
  - Costly
  - Coarse
  - Subjective

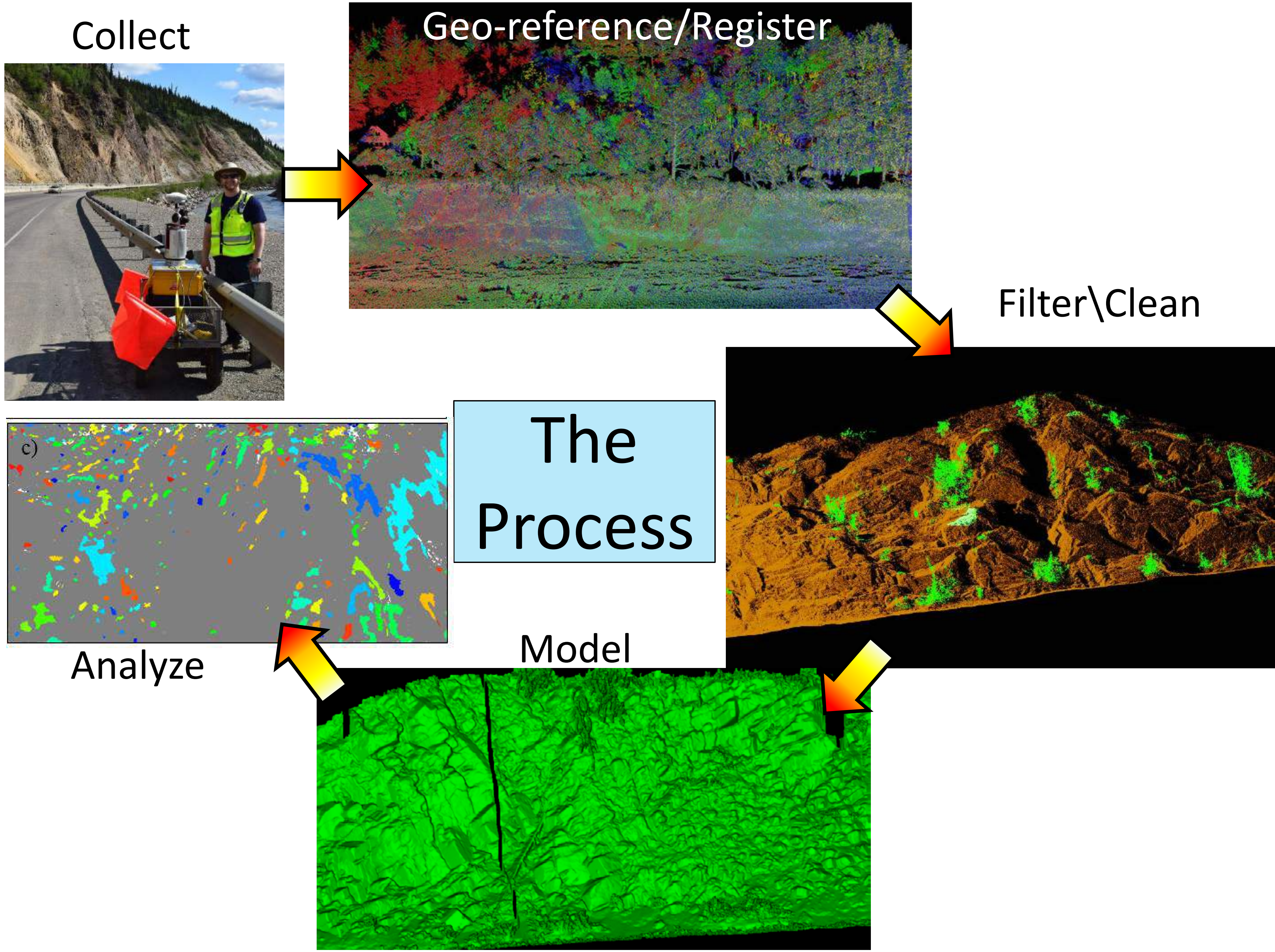
- Detailed Assessments
  - Very Costly
  - Subjective
  - Unsafe

Lidar\UAS – are they a solution?

- High Detail
- High Accuracy
- Rapid acquisition, good coverage
- Challenges with GNSS in canyons
- Skill required for processing and analysis
- Where is the magic button?
- Can we make this more efficient/systematic?

Site Locations




Collect
Geo-reference/Register
Filter\Clean
The Process
c)
Model
Analyze

Data Acquisition

Leica GS14 GNSS Receiver

Riegl VZ-400 Laser Scanner

Leica P40

Leica TS15 Total Station

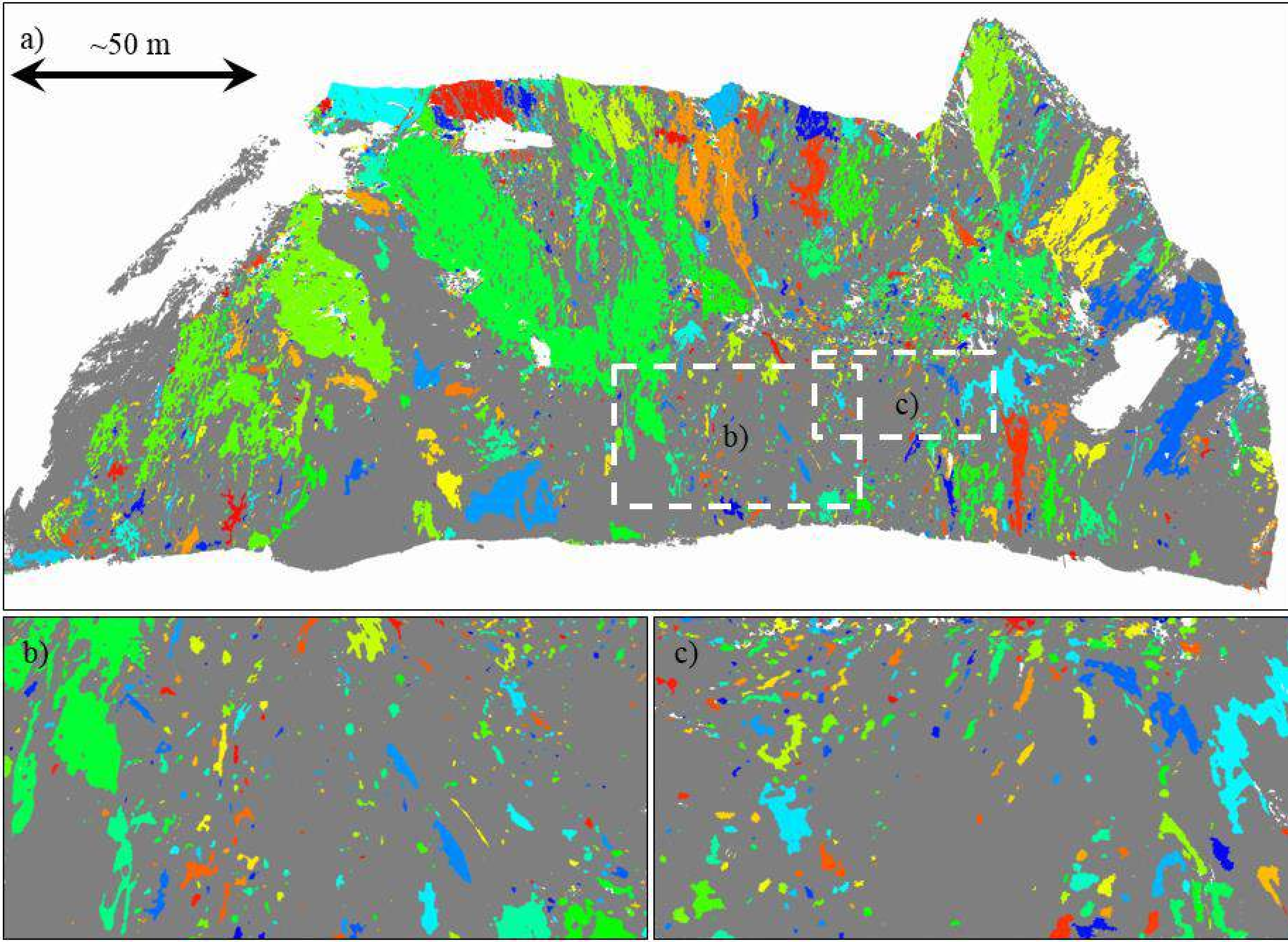
Source: www.dji.com

DJI Phantom Professional 3

Source: www.sony.com

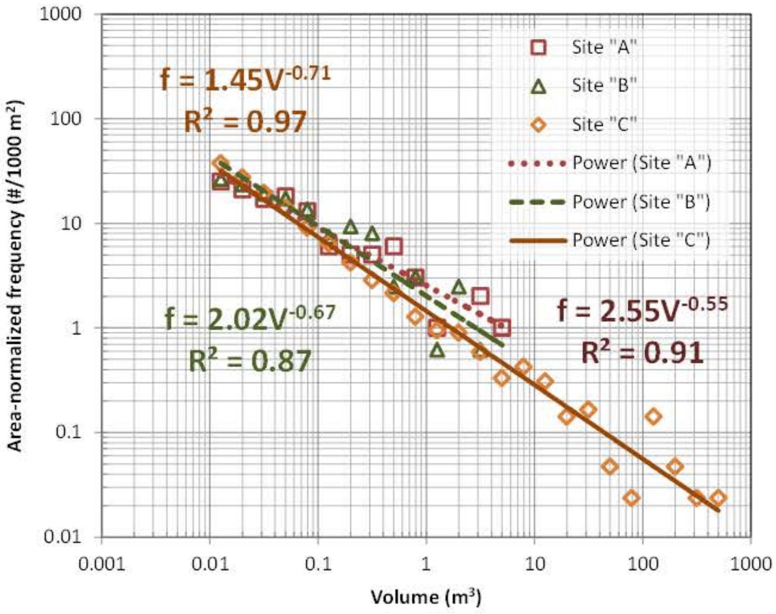
Sony DSC-RXM2 Camera

Site GG239


a)
~50 m
b)
c)
b)
c)

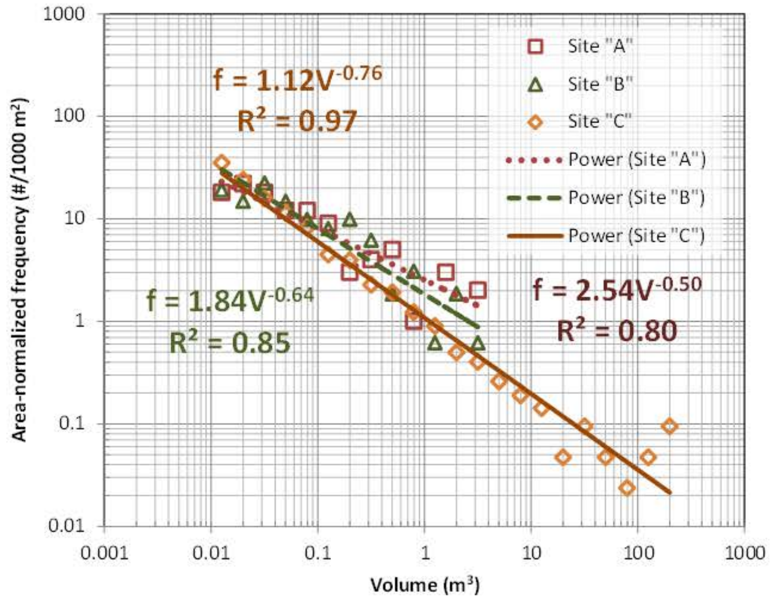
Magnitude Frequency Relationships

HOLES FILLED



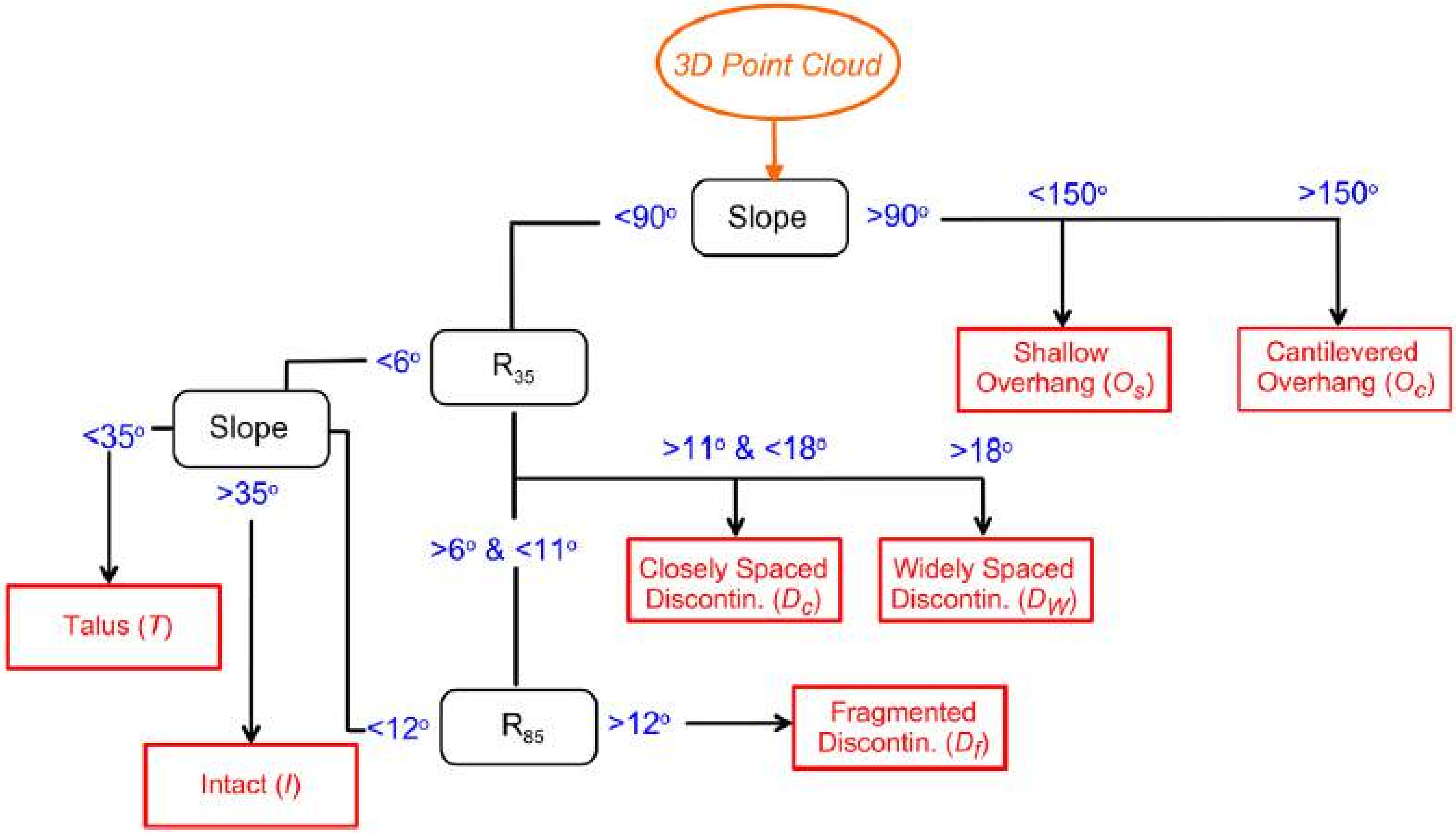
(c)

HOLES NOT FILLED



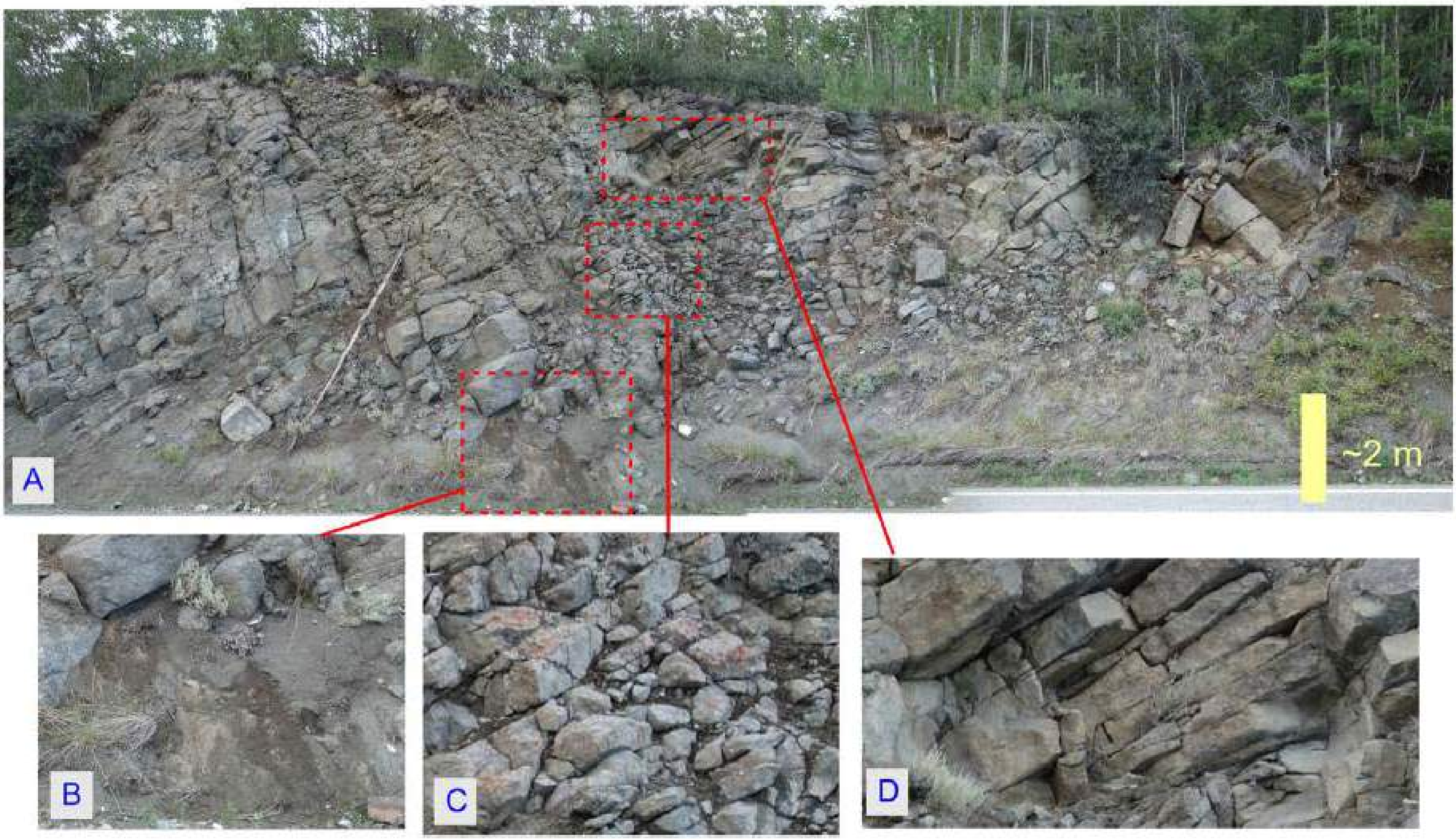
(d)

Rockfall Activity Index (RAI)

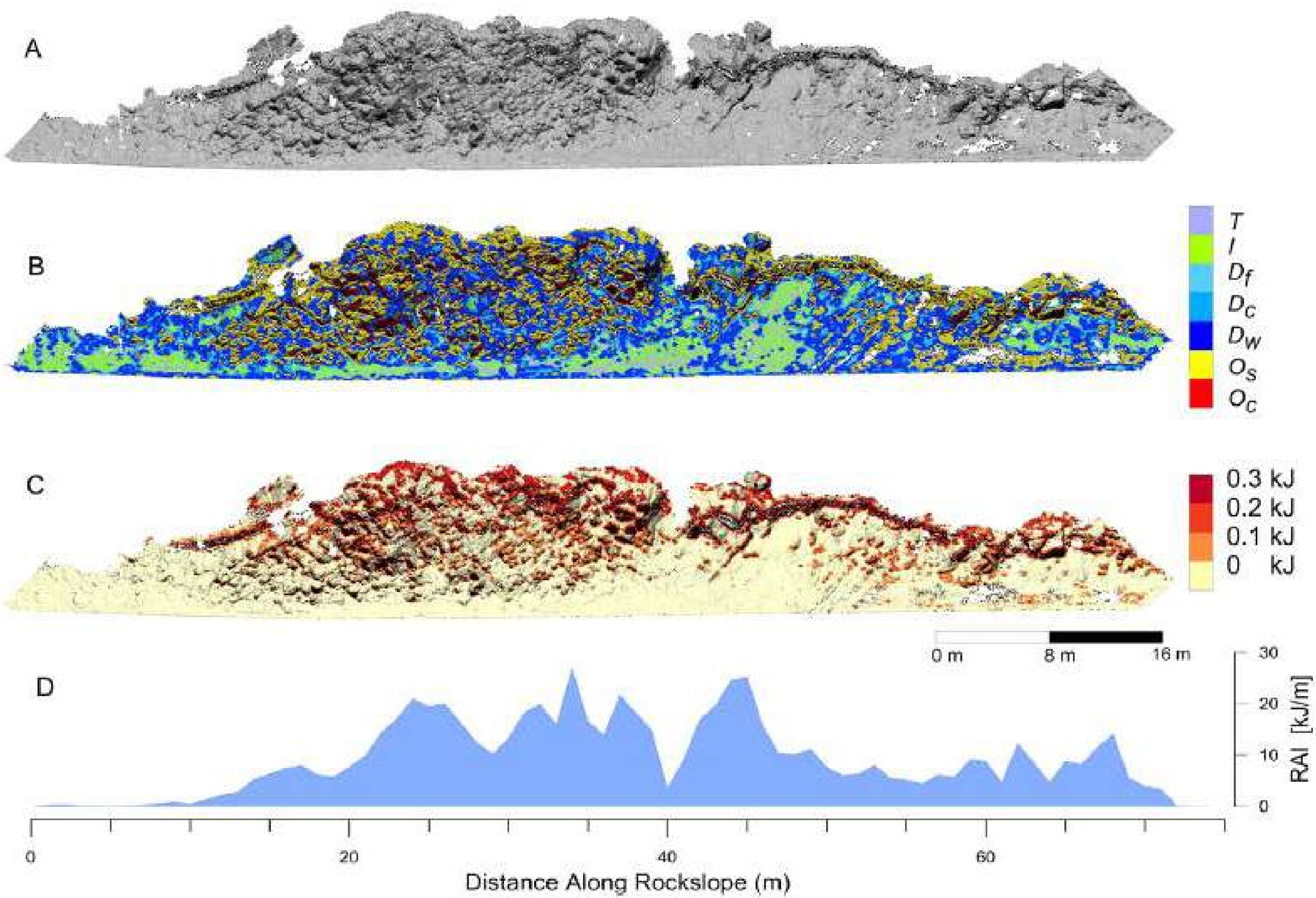


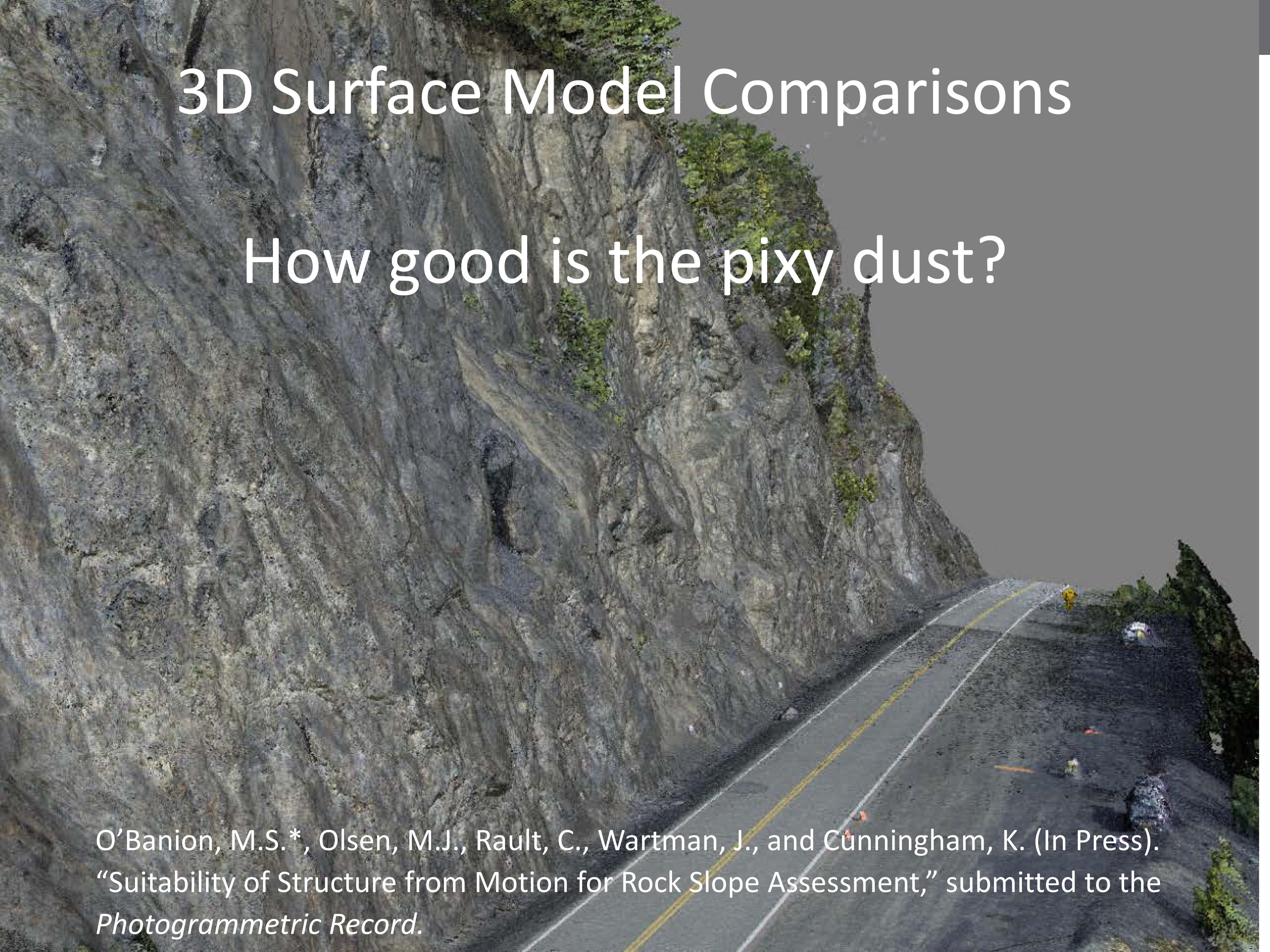
Dunham, L., Wartman, J., Olsen, M.J., O'Banion, M.S*, & Cunningham, K. (2017). "Rockfall Activity Index (RAI): A Lidar-derived, morphology-based hazard assessment system," *Engineering Geology,* 221, 184-192. **https://doi.org/10.1016/j.enggeo.2017.03.009**

Surface Morphology



RAI


A
B
C
D
T
I
D_f
D_c
D_w
O_s
O_c
0.3 kJ
0.2 kJ
0.1 kJ
0 kJ
0 m
8 m
16 m
0
10
20
30
RAI [kJ/m]
0
20
40
60
Distance Along Rockslope (m)



3D Surface Model Comparisons

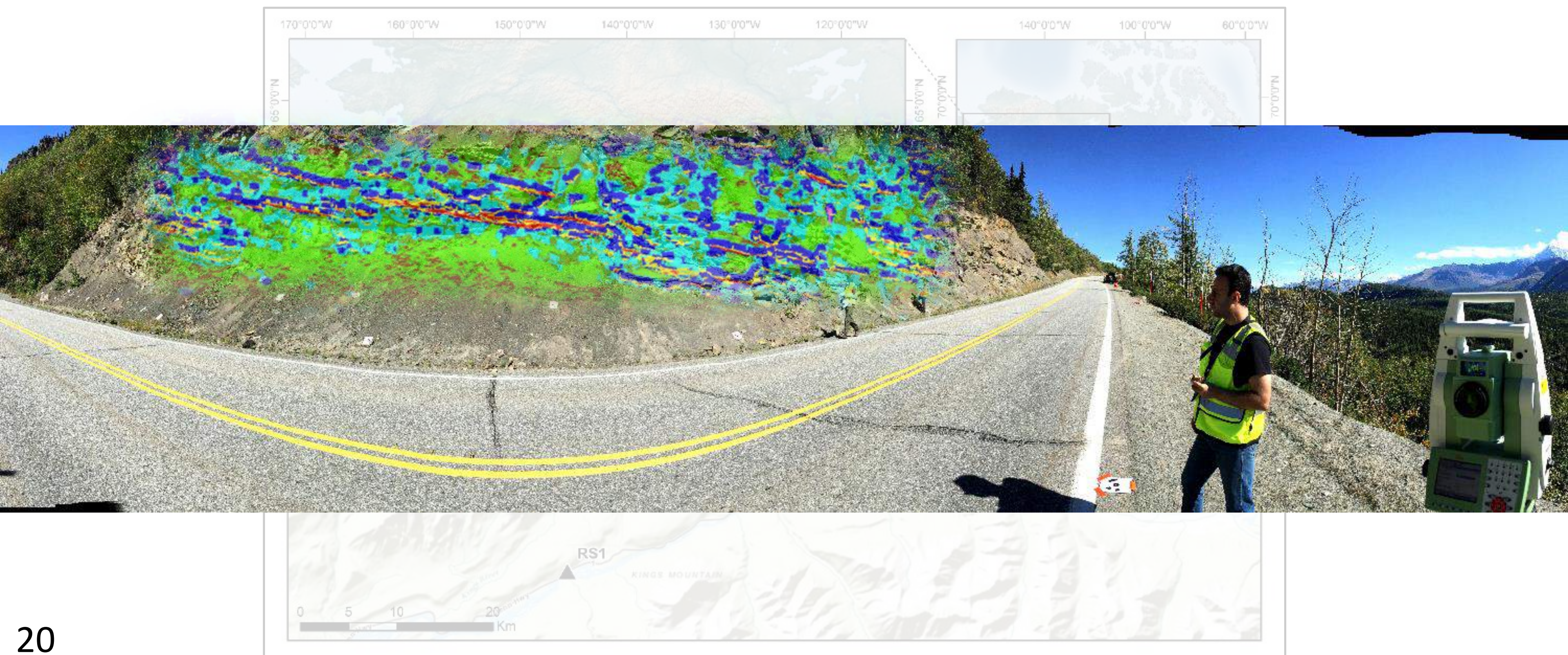
How good is the pixy dust?

O'Banion, M.S.*, Olsen, M.J., Rault, C., Wartman, J., and Cunningham, K. (In Press). "Suitability of Structure from Motion for Rock Slope Assessment," submitted to the *Photogrammetric Record.*

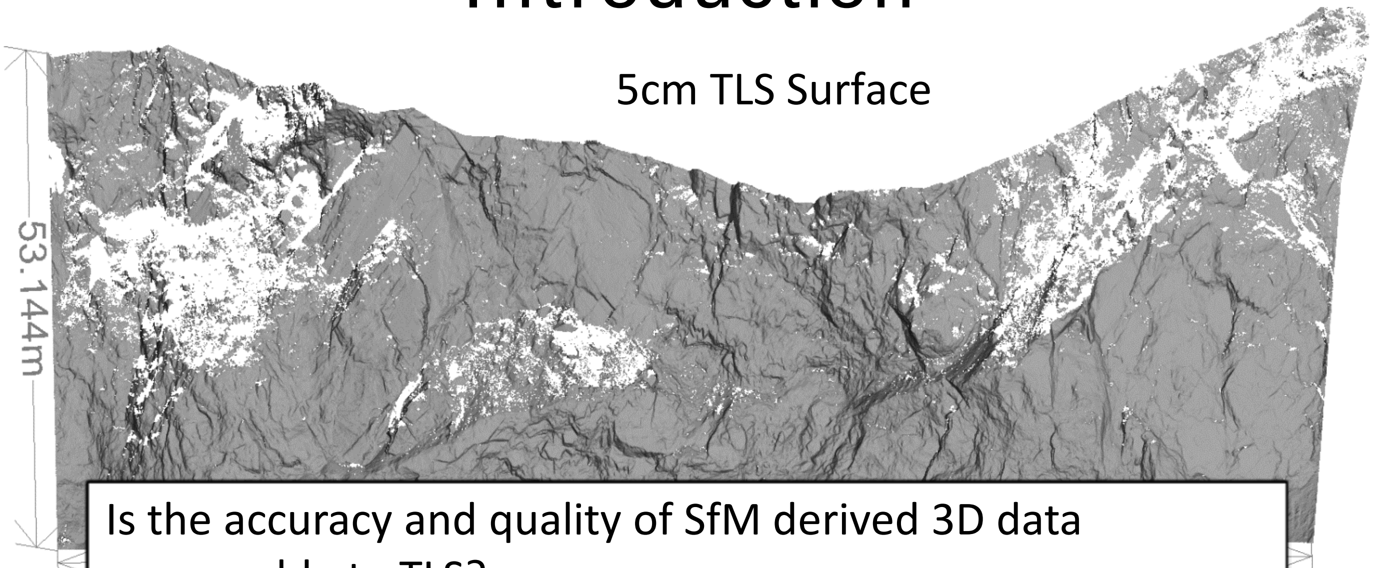
Background

Goal: Assess and monitor unstable rock slopes along the Parks Highway (Glitter Gulch) and Glenn Highway (Long Lake) in Alaska

- **Summer 2012:** Mobile lidar data
- **Summer 2013 & 2014:** Terrestrial lidar data (TLS)
- **Summer 2015:** TLS, unmanned aircraft system (UAS) imagery
- **Summer 2017:** TLS, unmanned aircraft system (UAS) imagery

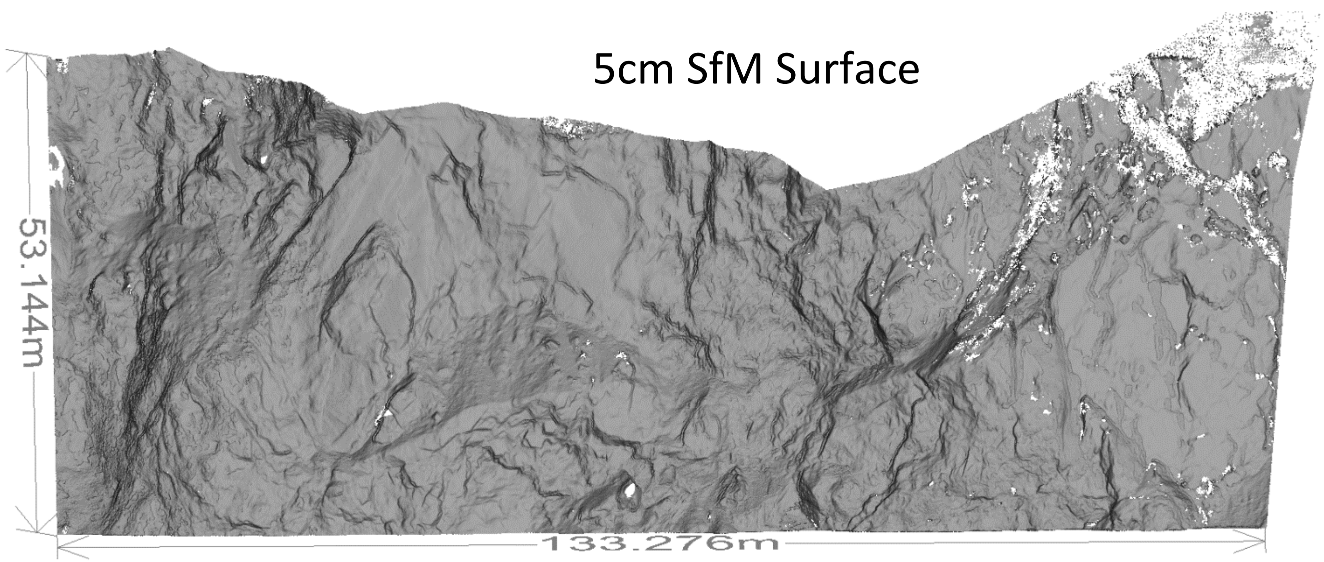


Introduction



5cm TLS Surface

Is the accuracy and quality of SfM derived 3D data comparable to TLS?



5cm SfM Surface

Introduction

Suitability of SfM for rock-slope assessment

Accuracy Assessment (Total Accuracy)

Quality Evaluation

- Completeness
- Point Density
- Surficial Properties
- Rock-slope Morphology Classification

Accuracy Assessment

Two Independent References

1. TLS-derived 5 cm Surface Models
2. Total Station Cliff Points

Structure From Motion (SfM) Image Reconstructions

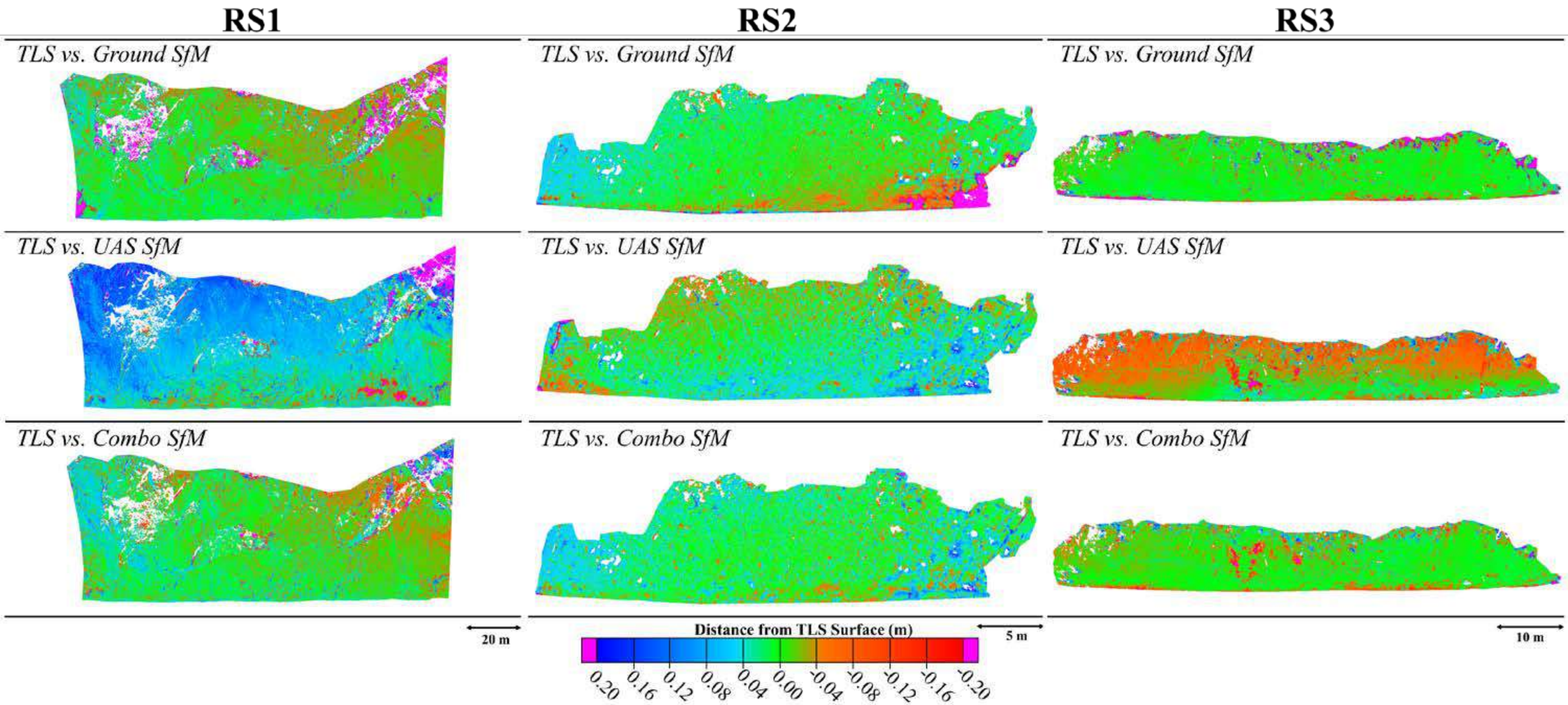
- **Combo**: Both UAS and ground-based images
- **UAS**: Only UAS-based images
- **Ground**: Only ground-based images

RS1
~9,300 m²

RS2
~450 m²

RS3
~1,680 m²

TLS and SfM Surface Comparison - Results



TLS and SfM Surface Comparison - Results

SfM Model	*Type*	*Mean Diff. (m)*	*σ (m)*	*RMSE (m)*	*Error 95% Conf. (m)*	*% of SfM in Front of TLS*
RS1	Ground SfM	-0.003	± 0.029	± 0.029	± 0.047	55.4
	UAS SfM	-0.051	± 0.046	± 0.069	± 0.112	94.1
	Combo SfM	-0.006	± 0.029	± 0.030	± 0.048	60.5
RS2	Ground SfM	-0.002	± 0.027	± 0.027	± 0.044	58.3
	UAS SfM	-0.010	± 0.028	± 0.030	± 0.048	65.3
	Combo SfM	-0.010	± 0.023	± 0.025	± 0.041	72.9
RS3	Ground SfM	0.000	± 0.030	± 0.030	± 0.048	56.9
	UAS SfM	0.020	± 0.036	± 0.041	± 0.066	23.0
	Combo SfM	0.003	± 0.026	± 0.027	± 0.043	43.8

Total Station Cliff Point Comparison

Site	*Type*	*Mean Diff. (m)*	*σ (m)*	*RMSE (m)*	*Error 95% Conf. (m)*	*% of Surface in Front of TS Points*
RS1	Ground SfM	-0.001	± 0.015	± 0.015	± 0.025	57.14
	UAS SfM	-0.032	± 0.041	± 0.052	± 0.084	82.69
	Combo SfM	-0.006	± 0.020	± 0.021	± 0.033	56.19
	TLS	0.002	± 0.009	± 0.010	± 0.015	41.90
RS2	Ground SfM	0.002	± 0.024	± 0.025	± 0.040	48.98
	UAS SfM	0.006	± 0.029	± 0.029	± 0.047	36.73
	Combo SfM	-0.001	± 0.024	± 0.024	± 0.039	57.14
	TLS	0.003	± 0.009	± 0.009	± 0.015	31.25
RS3	Ground SfM	-0.001	± 0.008	± 0.008	± 0.013	63.86
	UAS SfM	0.013	± 0.025	± 0.028	± 0.046	22.89
	Combo SfM	-0.001	± 0.011	± 0.011	± 0.017	53.01
	TLS	0.001	± 0.009	± 0.009	± 0.014	55.42

Completeness

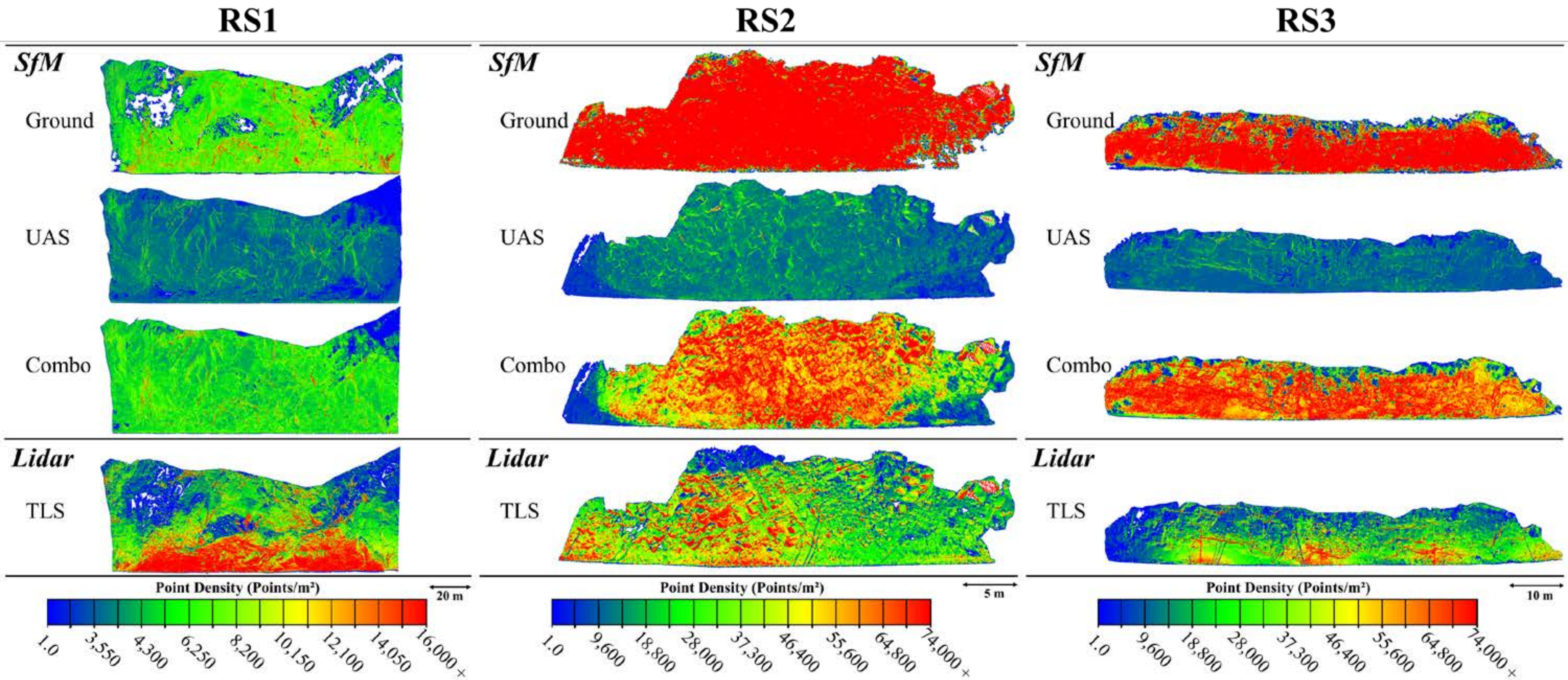
$$Completeness = \left(\frac{Surf.\,Area\ of\ Model\ with\ out\ Holes\ Filled}{Surf.\,Area\ of\ Combo\ SfM\ Model\ with\ Holes\ Filled}\right) \times 100$$

RS1	
Model	**Completeness (%)**
Combo SfM	99.05
UAS SfM	99.46
Ground SfM	89.43
Lidar	92.38

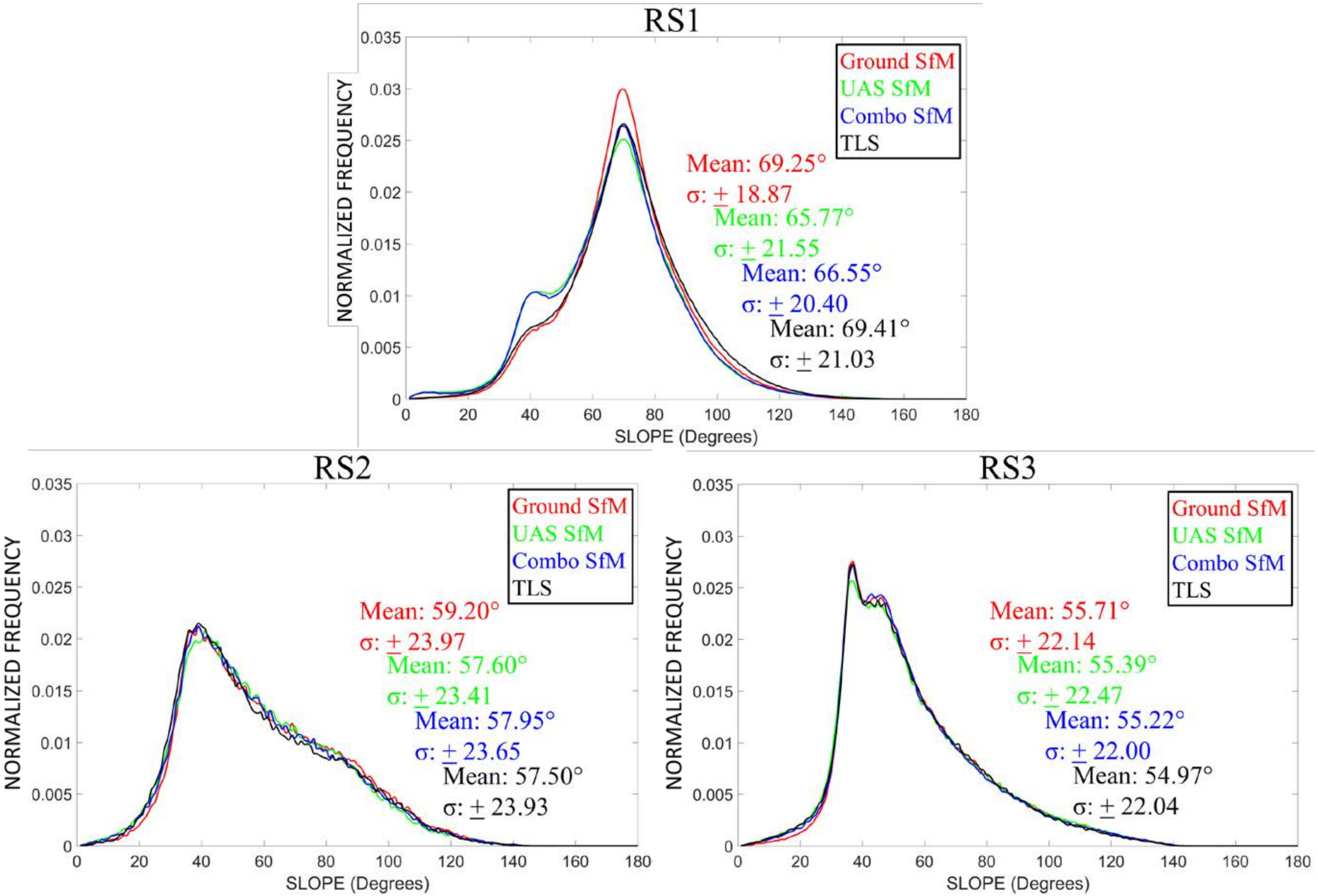
RS2	
Model	**Completeness (%)**
Combo SfM	99.74
UAS SfM	99.77
Ground SfM	96.92
Lidar	99.61

RS3	
Model	**Completeness (%)**
Combo SfM	99.54
UAS SfM	99.54
Ground SfM	94.41
Lidar	98.61

Point Density – Results

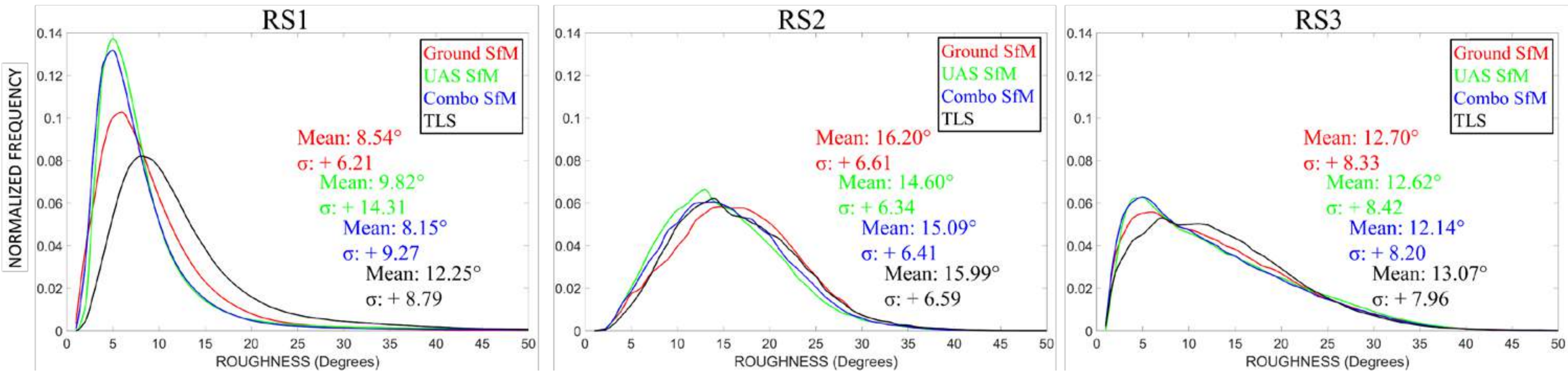


Surface Morphology – Slope

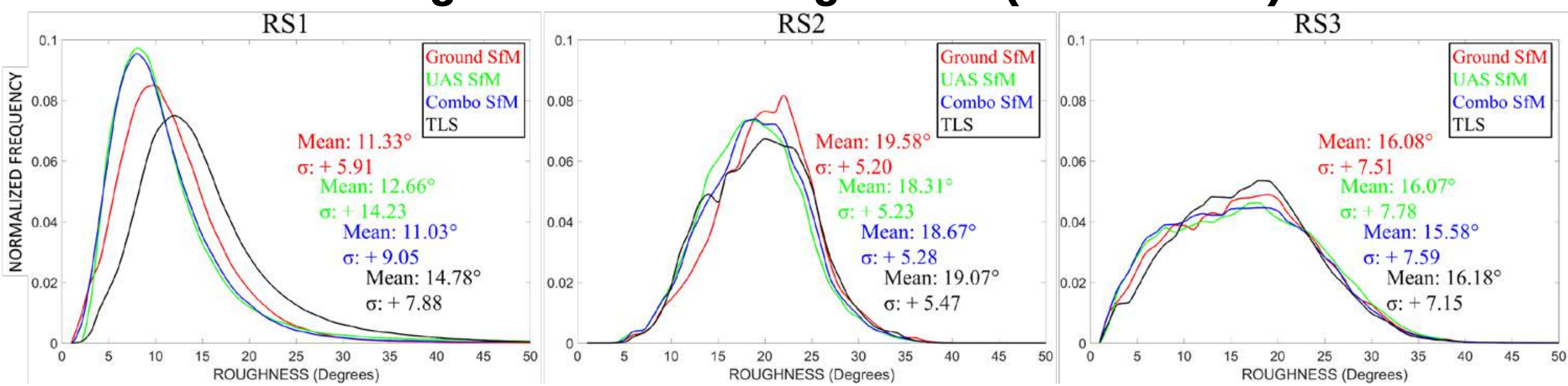


Surface Morphology – Roughness

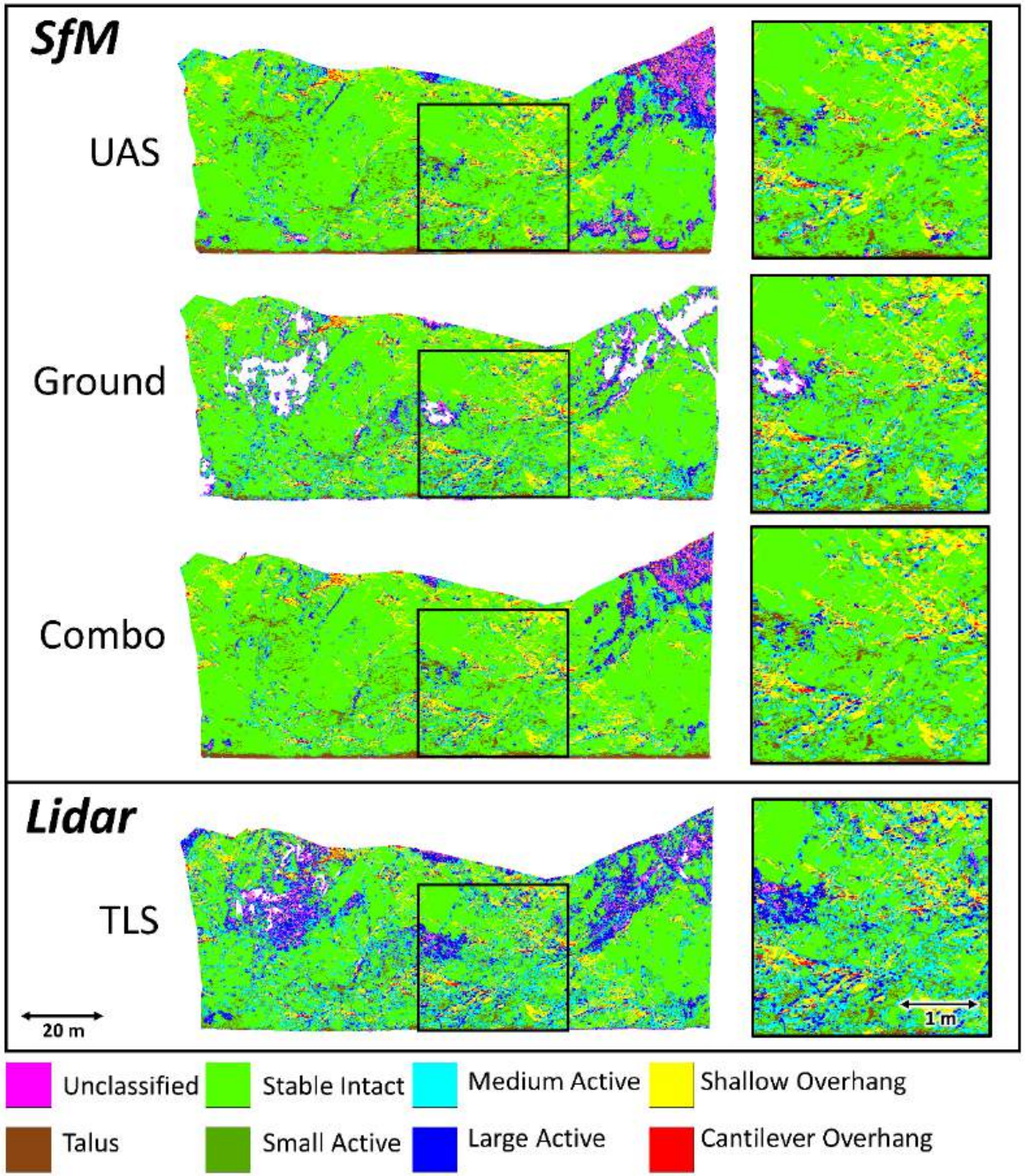
Small Window Roughness (35x35 cm)



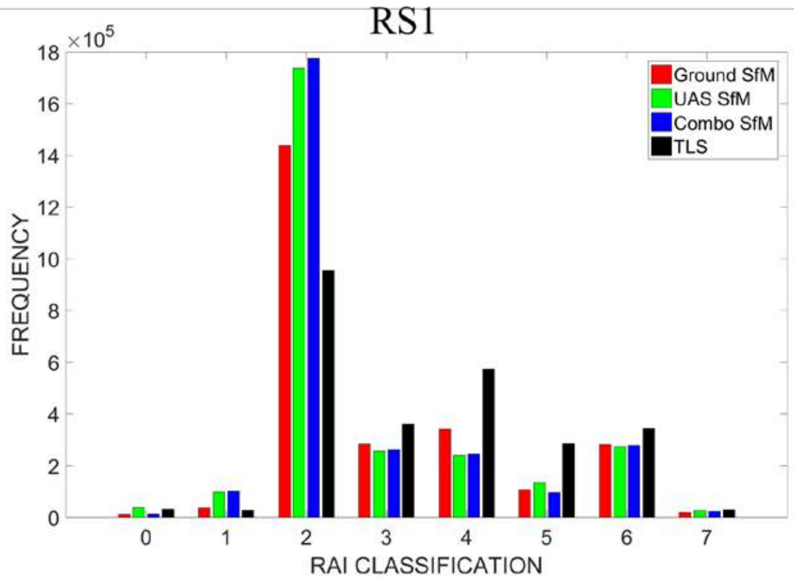
Large Window Roughness (85x85 cm)

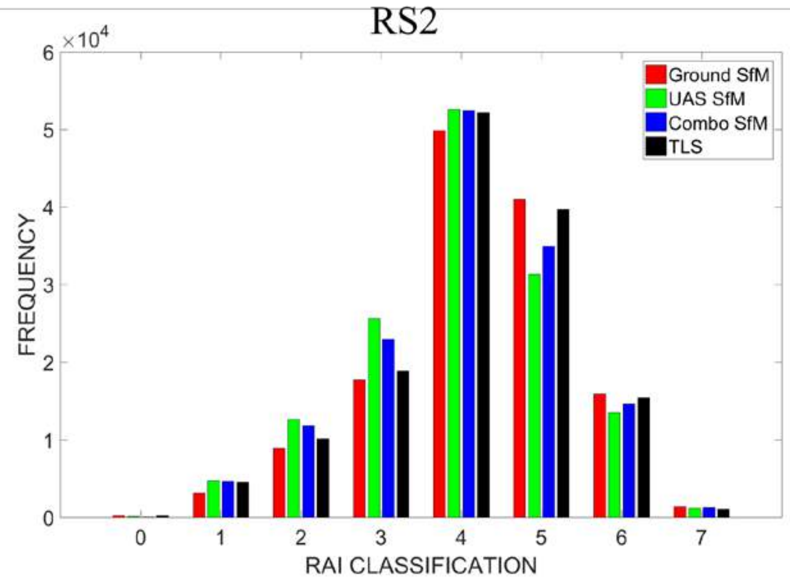


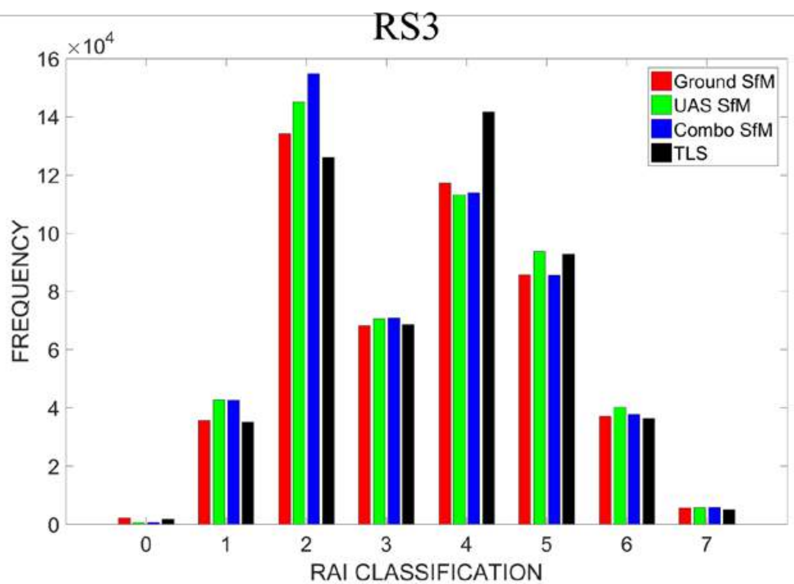
Rock-Slope Morphology Classification



Rock-Slope Morphology Classification







Rock Activity Index (RAI) Classifications

0: Unclassified
1: Talus
2: Stable Intact Rock
3: Small Active Discontinuities
4: Medium Active Discontinuities
5: Large Active Discontinuities
6: Shallow Overhang
7: Cantilever Overhang

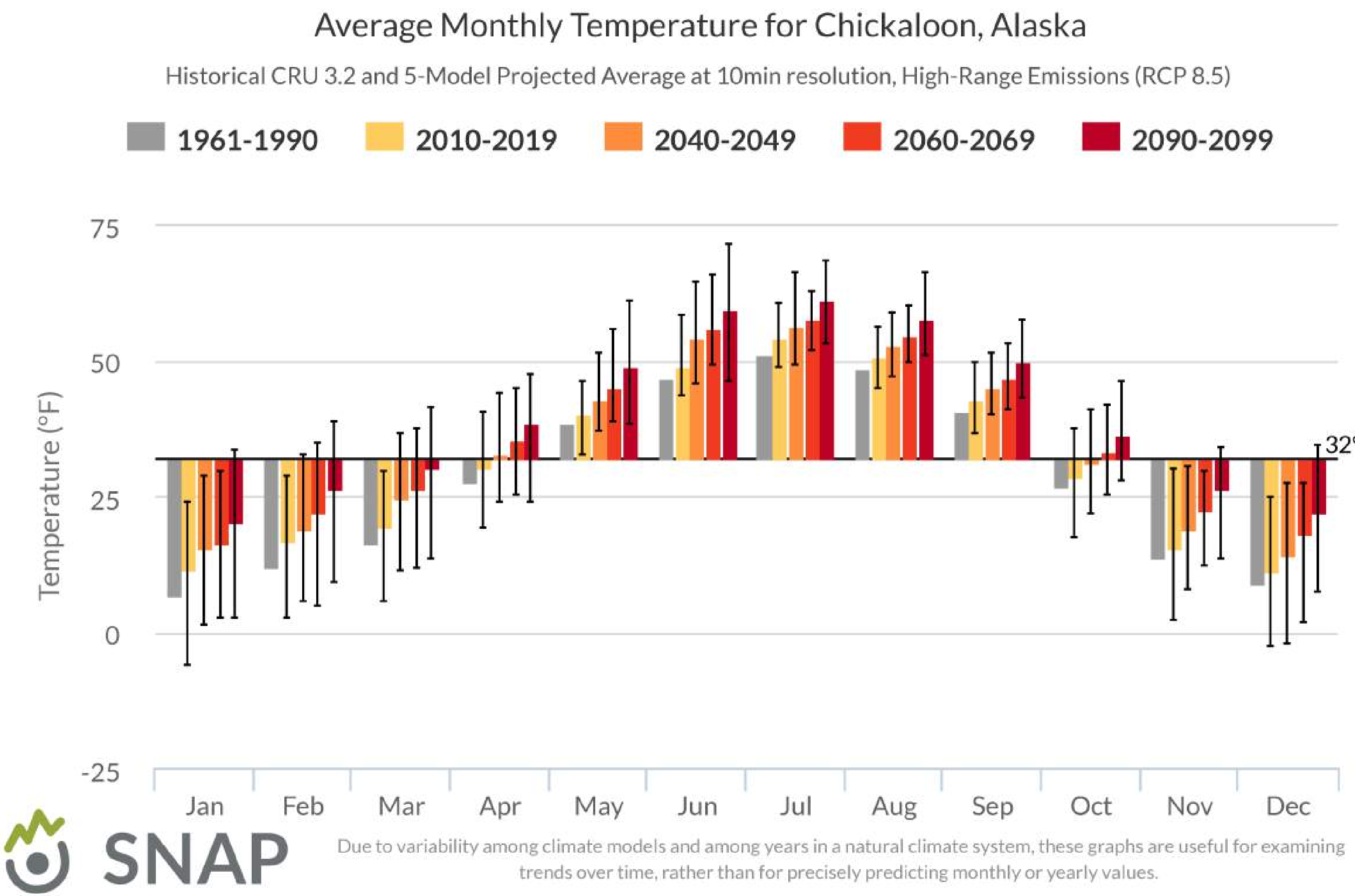
Conclusion

Rock-Slope Assessment:
SfM Pixy dust is not as accurate as TLS, but is an appropriate tool for rock-slope assessment, assuming the images are tied to a survey control network.

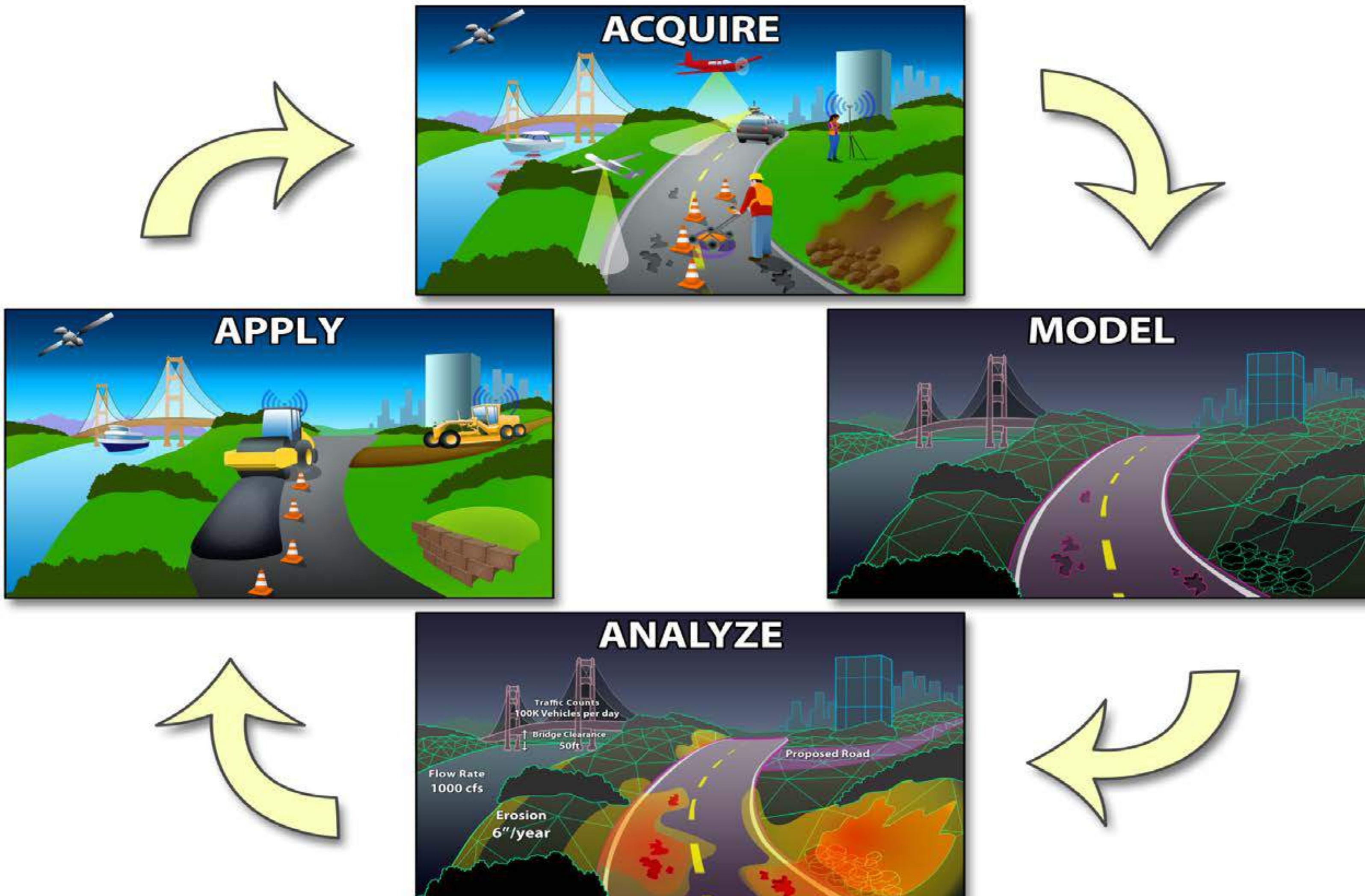
Rock-Slope Monitoring:
Concerns such as over-smoothing and inconsistencies stemming from differences in image acquisition, have potential to introduce error into the detection of small changes ($\geq$ 5 cm).

Advantageous to use both together.

Climate Change Effects



Transportation Asset Lifecycle



NCHRP Synthesis #446

Acknowledgements

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