2014 KISS Workshop: Gazing at the Solar System

Imaging for Geotechnical Engineering: Applications to Landslides and Liquefaction

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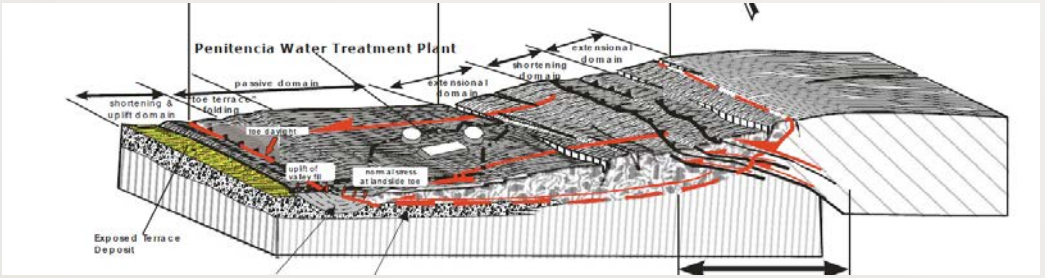
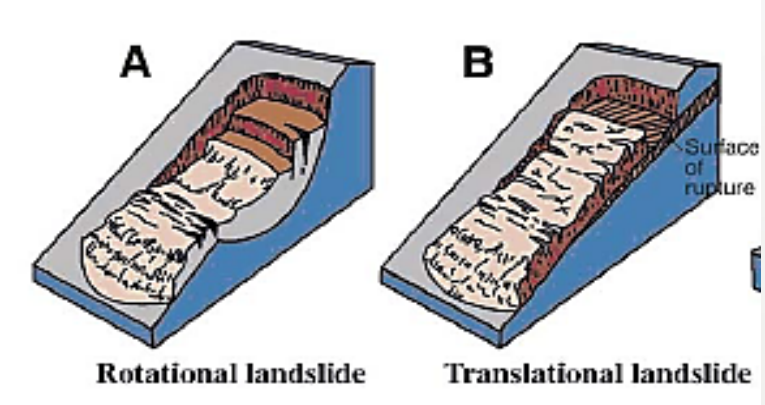


Landslides



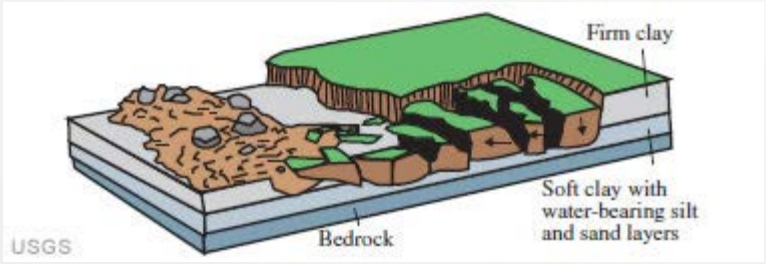
Cruden and Varnes (1996)

Oso Landslide, Washington

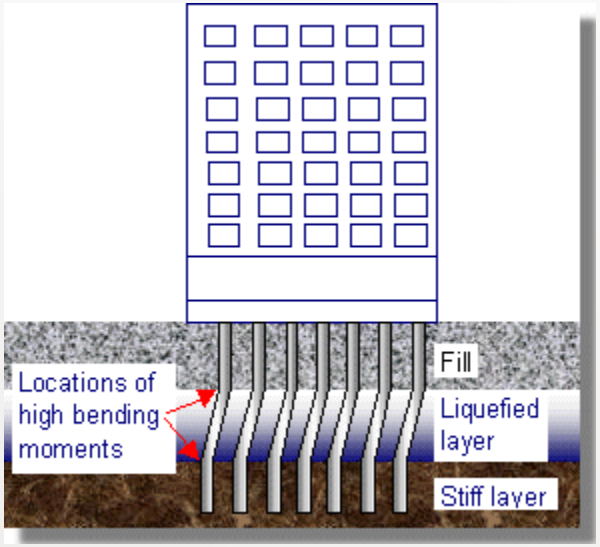
Role of Remote Sensing

- Complement/expand field monitoring techniques
- Improve numerical models of landslide deformations

Liquefaction: Lateral Spreading



Cruden and Varnes (1996)



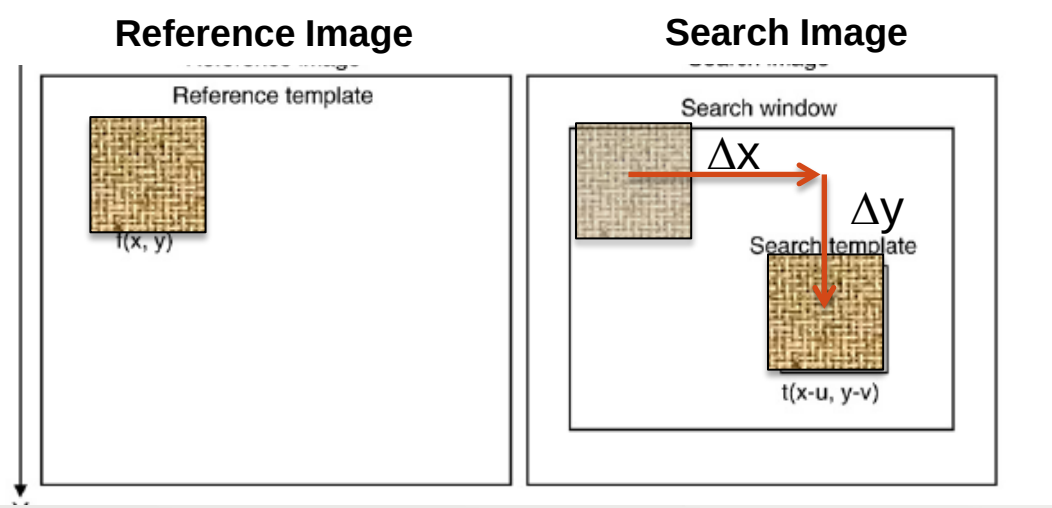
www.ce.washington.edu

Role of Remote Sensing

- Measure liquefaction movements
- Improve numerical models to predict these movements

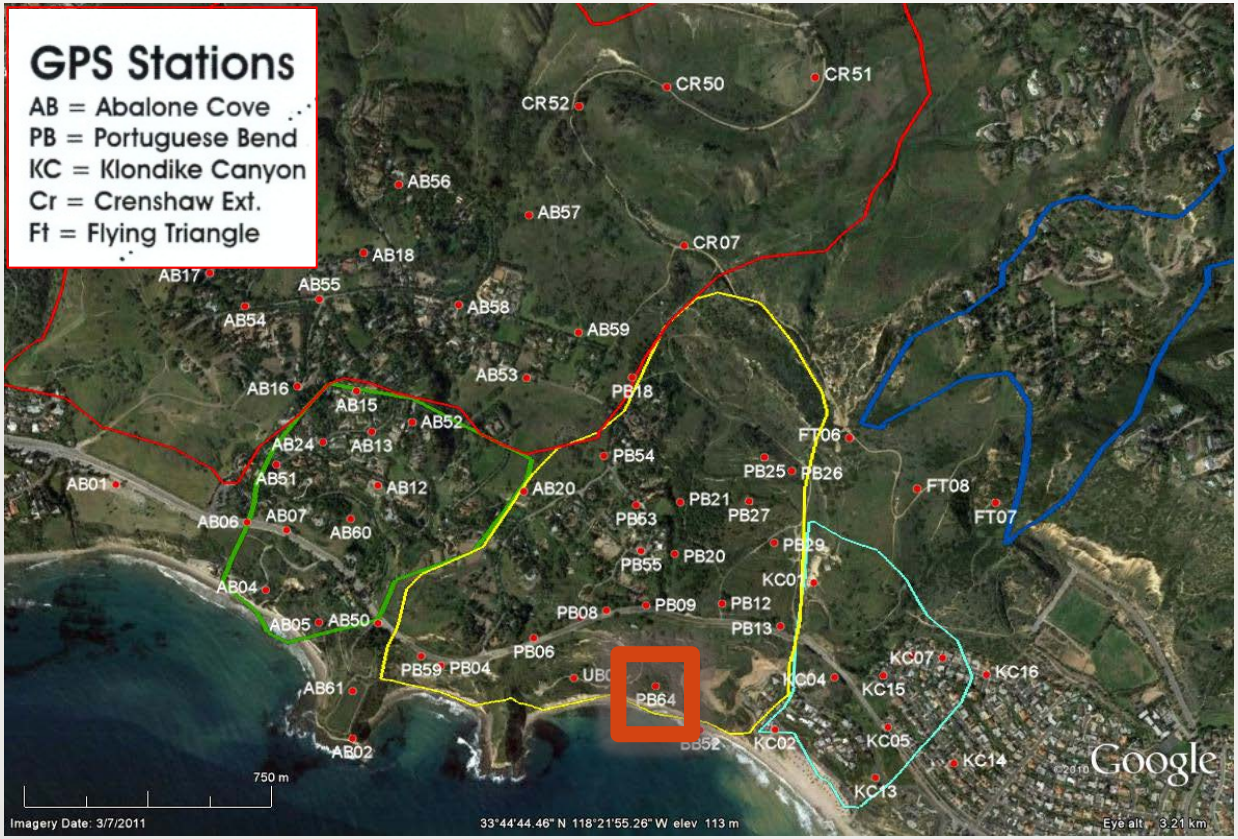
Image Correlation Analysis

- 0.5-m panchromatic images
- Orthorectification using 30-m SRTM DEM
- Images co-registered using ENVI
- Horizontal correlation performed using COSI-Corr (Leprince et al. 2007)



Modified from Debella-Gilo and Kaab (2011)

Portuguese Bend Landslide (PBL)



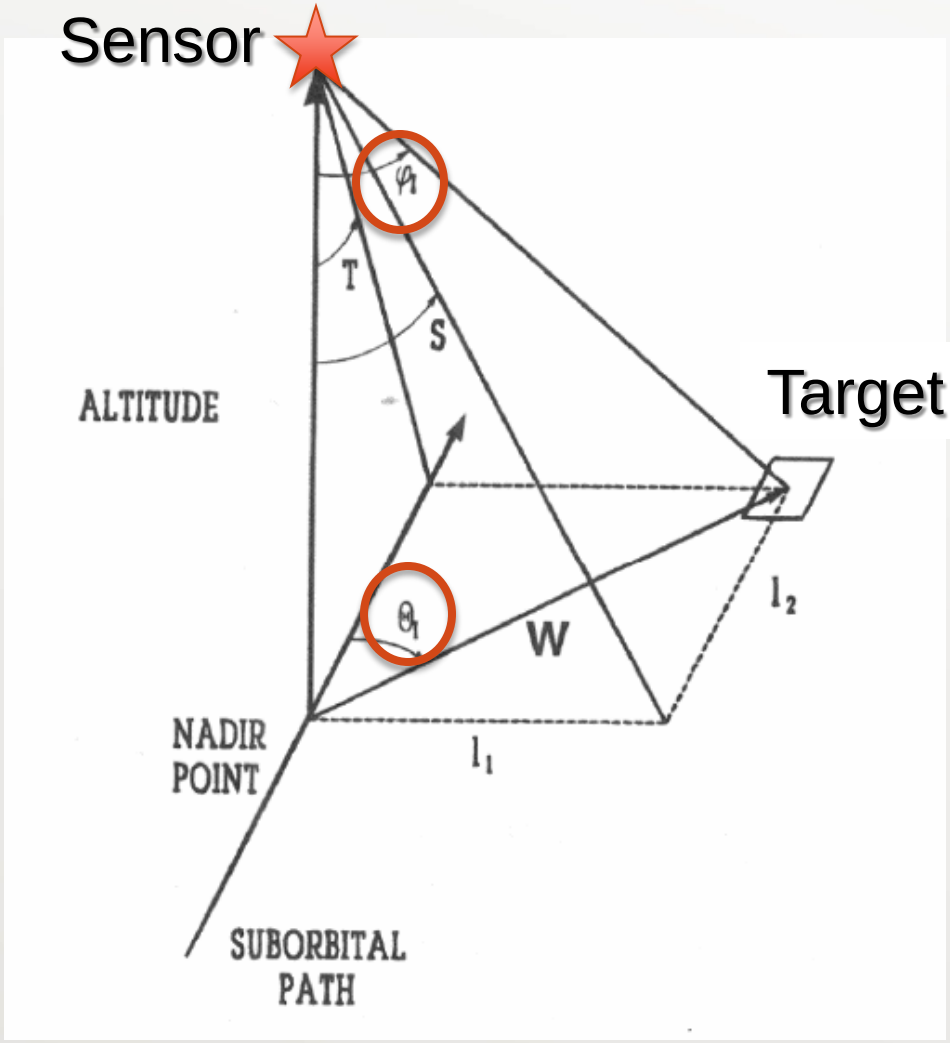
Deformations

August 2010 – May 2011

GPS Station	Def. (m)	GPS Station	Def. (m)
AB20	0.03	PB21	0.53
BB52	0.02	PB25	0.05
PB04	0.17	PB26	0.04
PB06	0.37	PB27	0.86
PB07	0.45	PB29	0.58
PB08	0.41	PB53	0.44
PB09	0.48	PB54	0.04
PB12	0.83	PB55	0.50
PB13	0.53	[illegible]	[illegible]
PB18	0.05	PB64	6.01
PB20	0.73	UB02	1.06

Rates: 0.5 – 6.0 m/yr

Acquisition Geometry



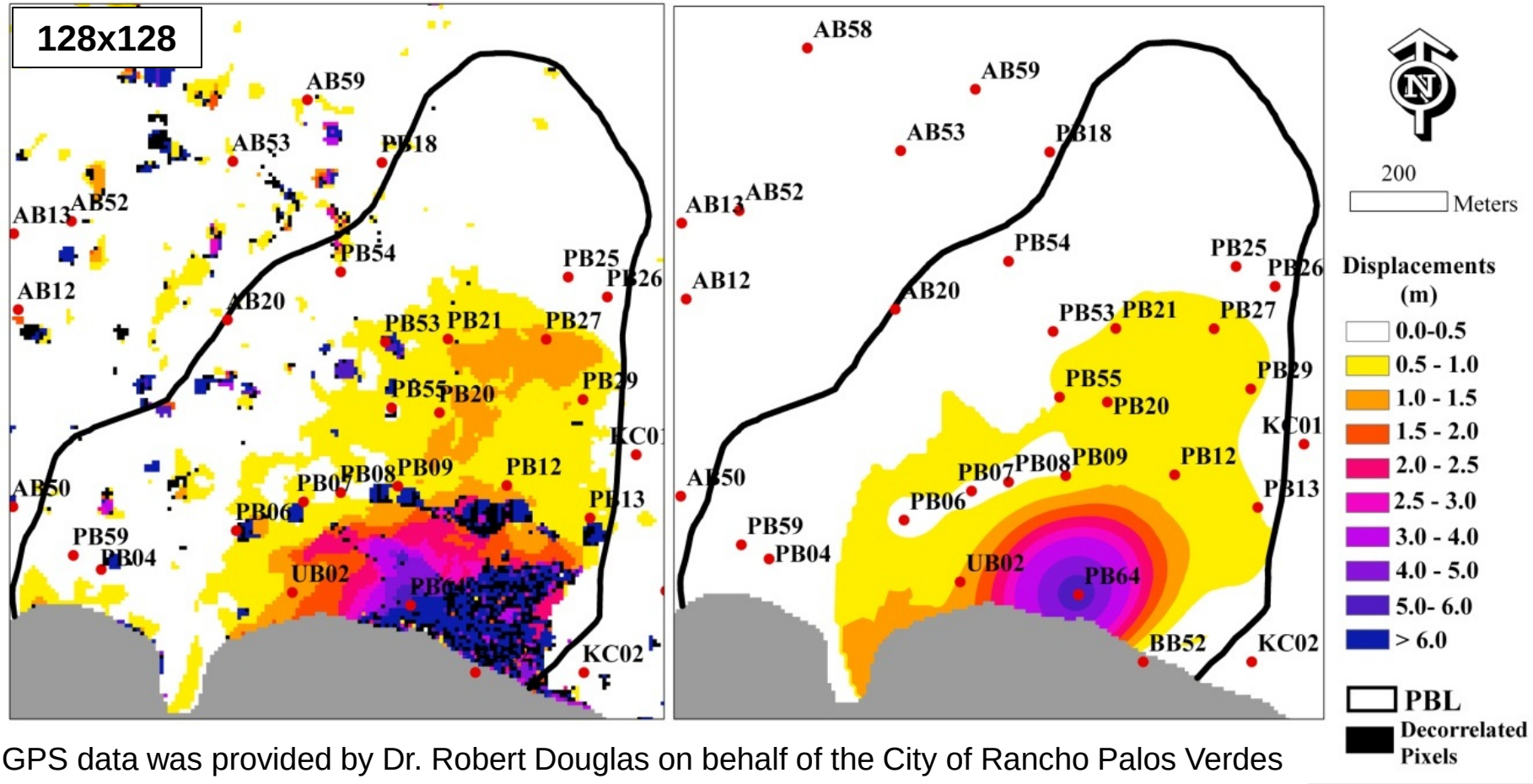
- θ_I = viewing azimuth
- φ_I = off-nadir angle

	Azimuth	Off-Nadir
Image 1	96.7°	14.7°
Image 2	94.2°	14.6°

Bukata et al. (1995)

Comparison with GPS Data

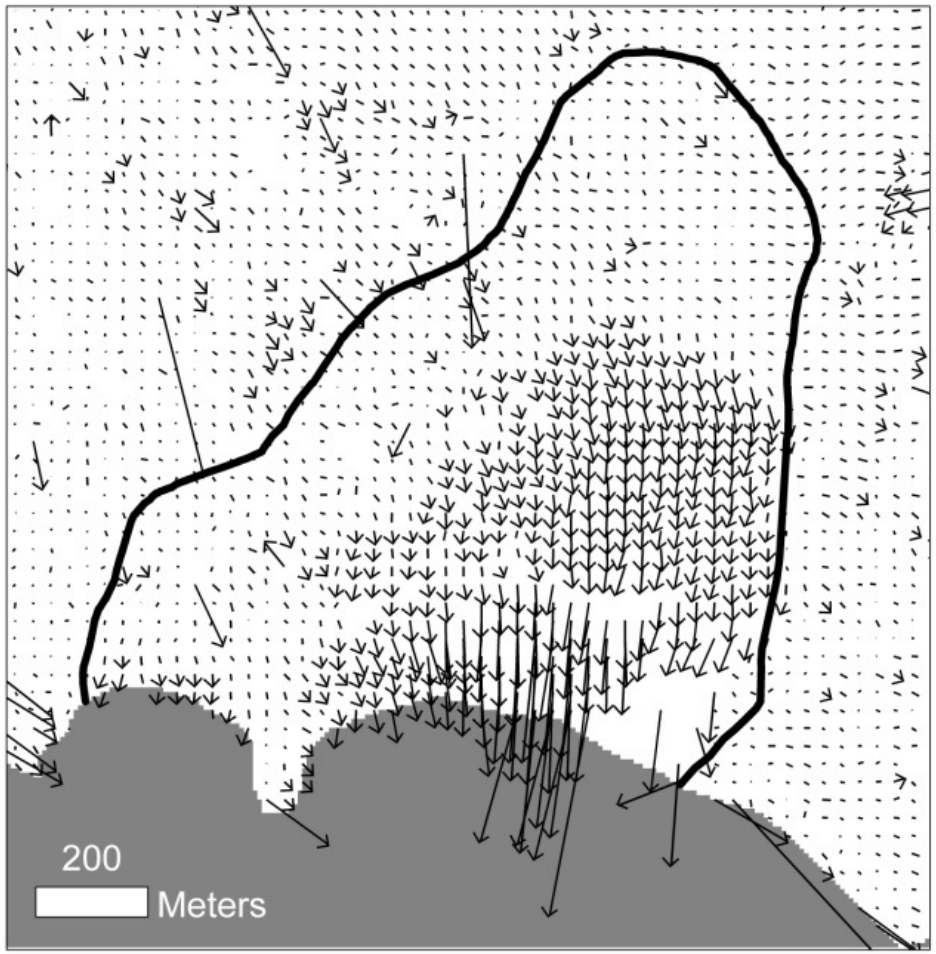
Optical Image Correlation ***GPS***



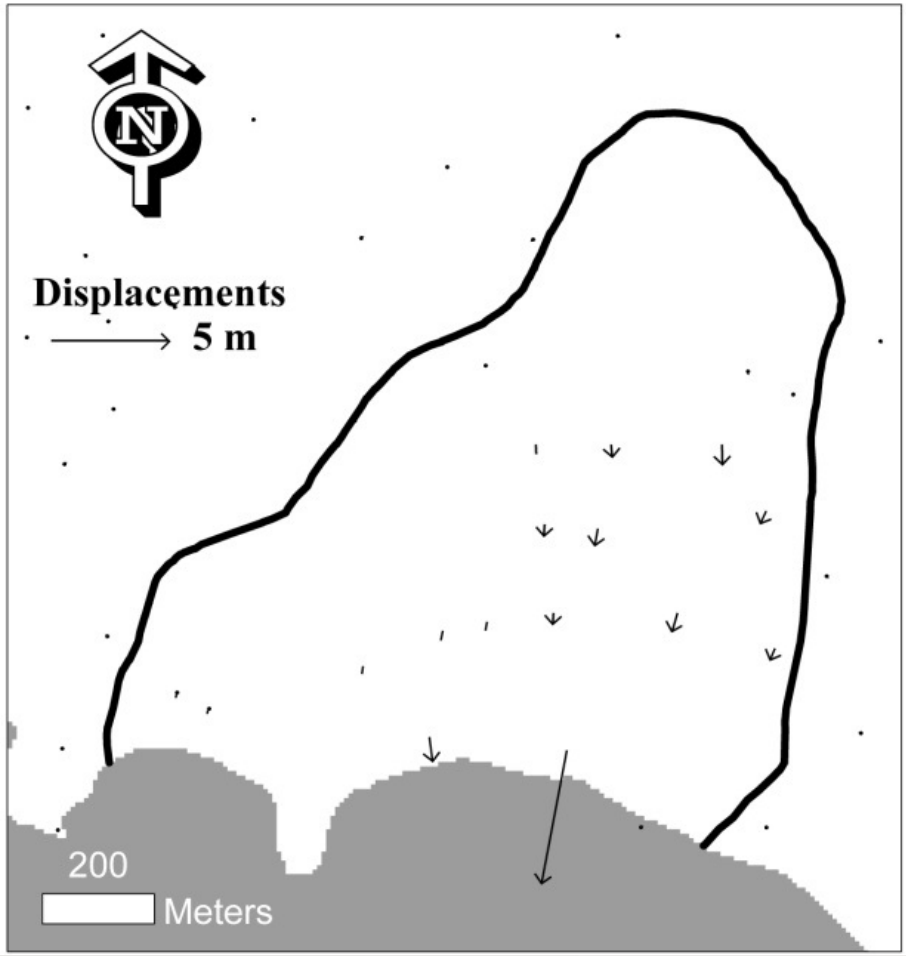
GPS data was provided by Dr. Robert Douglas on behalf of the City of Rancho Palos Verdes and the Abalone Cove Landslide Abatement District (ACLAD).

Deformation Vectors

Optical Image Correlation



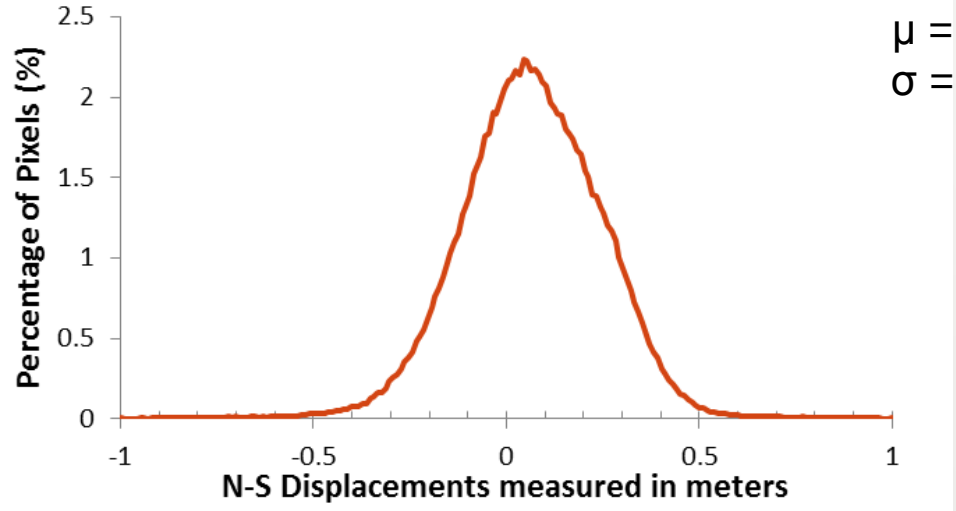
GPS



Smallest Resolvable Displacement

- RMSE for co-registration: ~0.2 pixel (0.1 m)
- Measure displacements outside of the landslide

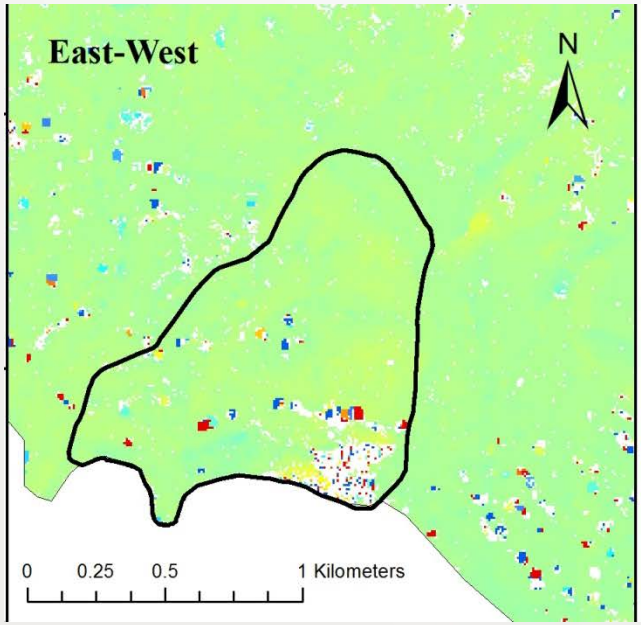
NS Displacements outside landslide zone

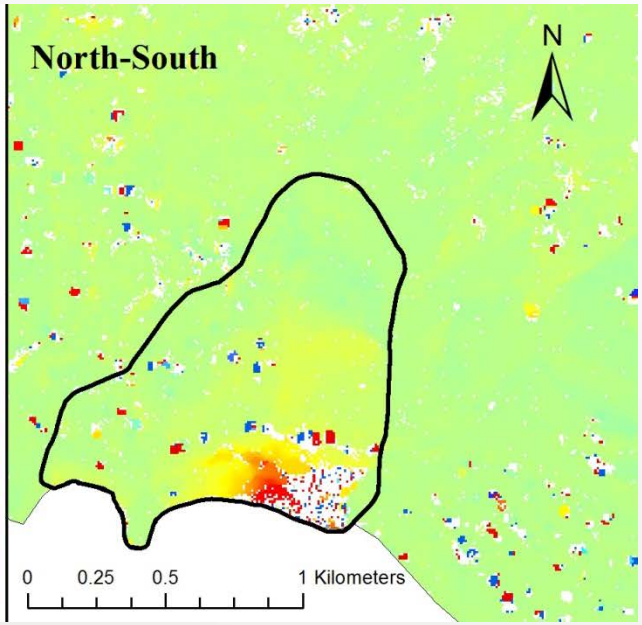


Influence of Acquisition Geometry

4 Different Imagery Pairs

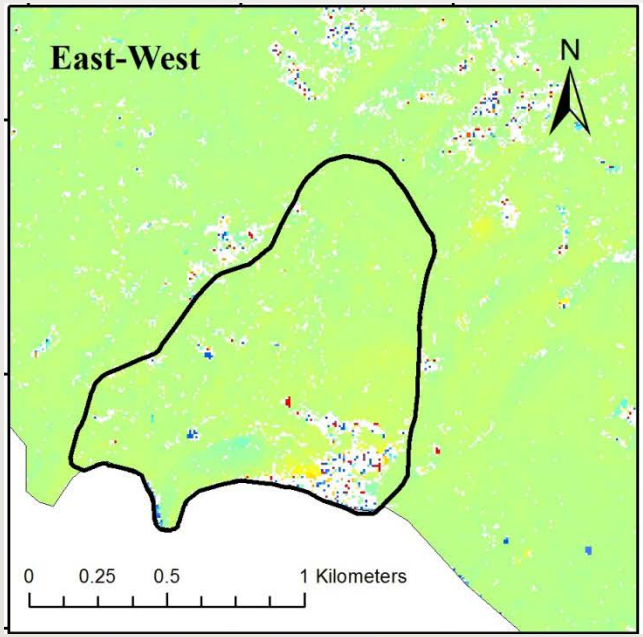
	Azimuth	Off-Nadir	EW Angle	NS Angle	
Best Pair	96.7	14.7	14.6	-1.8	ΔEW ~ 0.0°
	94.2	14.6	14.6	-1.1	ΔNS ~ 0.7°
Pair 2	9.3	21.9	3.7	21.6	ΔEW ~ 0.1°
	11.7	17.5	3.6	17.2	ΔNS ~ 4.5°
Pair 3	9.3	21.9	3.7	21.6	ΔEW ~ 11.1°
	41.1	21.9	14.8	16.9	ΔNS ~ 4.8°
Pair 4	113.9	12.0	11.0	-4.9	ΔEW ~ 7.6°
	15.8	12.3	3.4	11.9	ΔNS ~ 16.8°

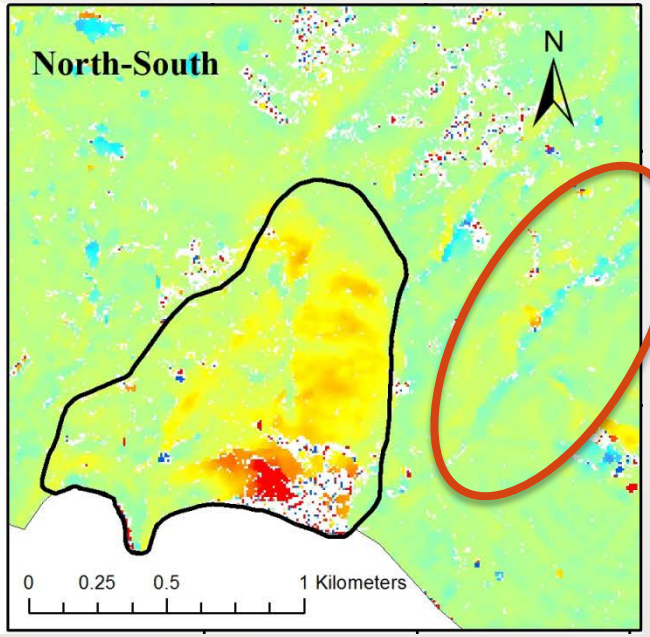




Best Pair

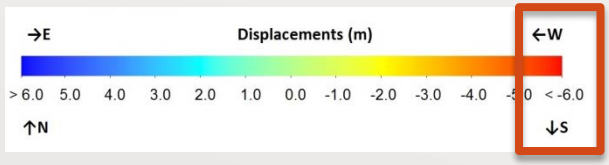
ΔEW ~ 0.0°
ΔNS ~ 0.7°

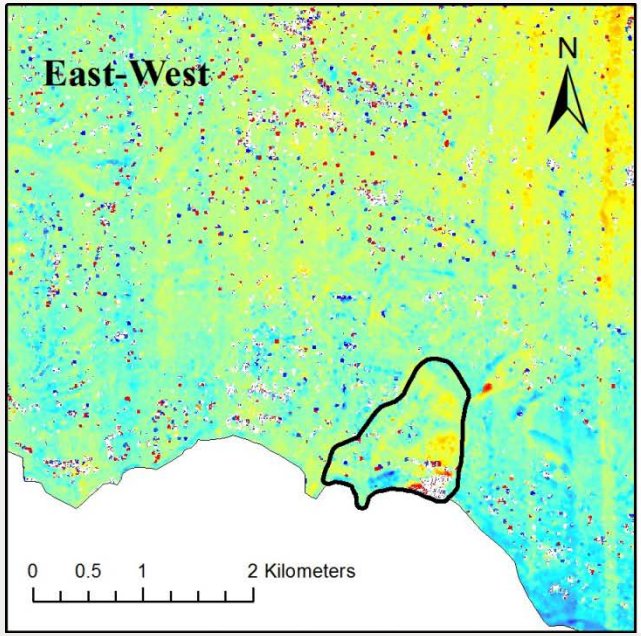


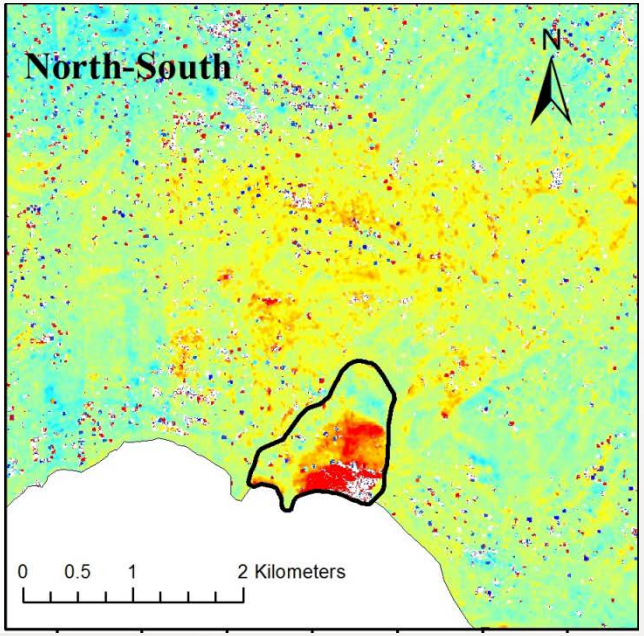


Pair 2

ΔEW ~ 0.1°
ΔNS ~ 4.5°







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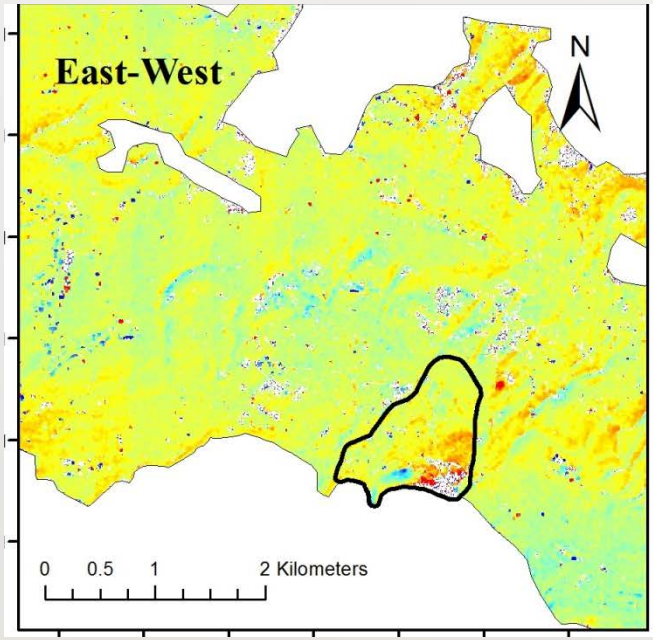

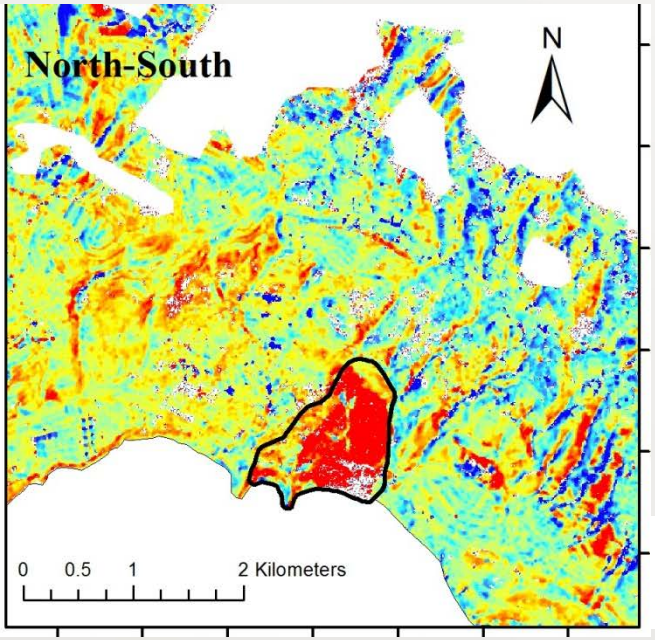

Pair 2

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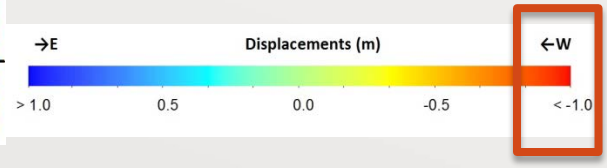
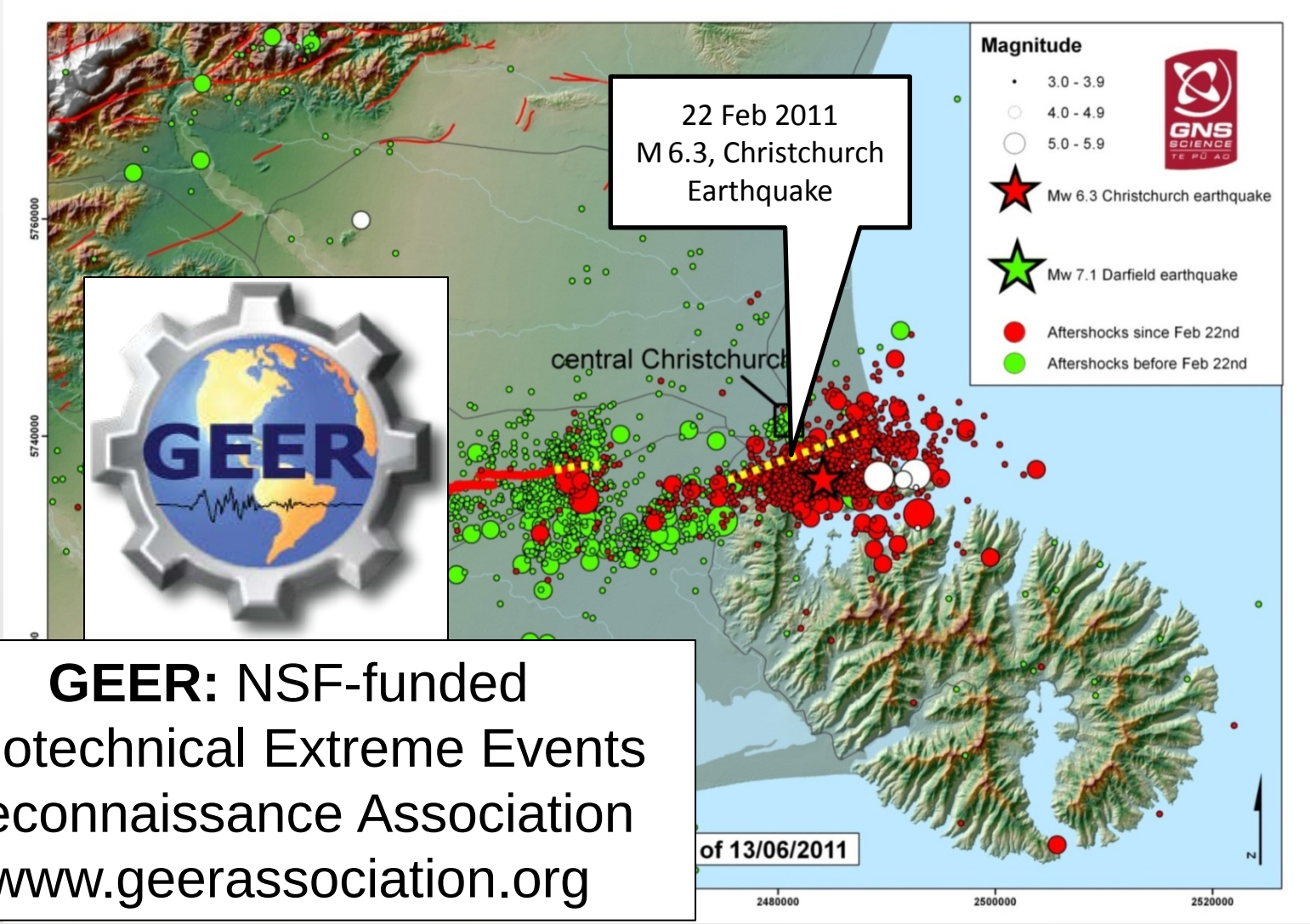


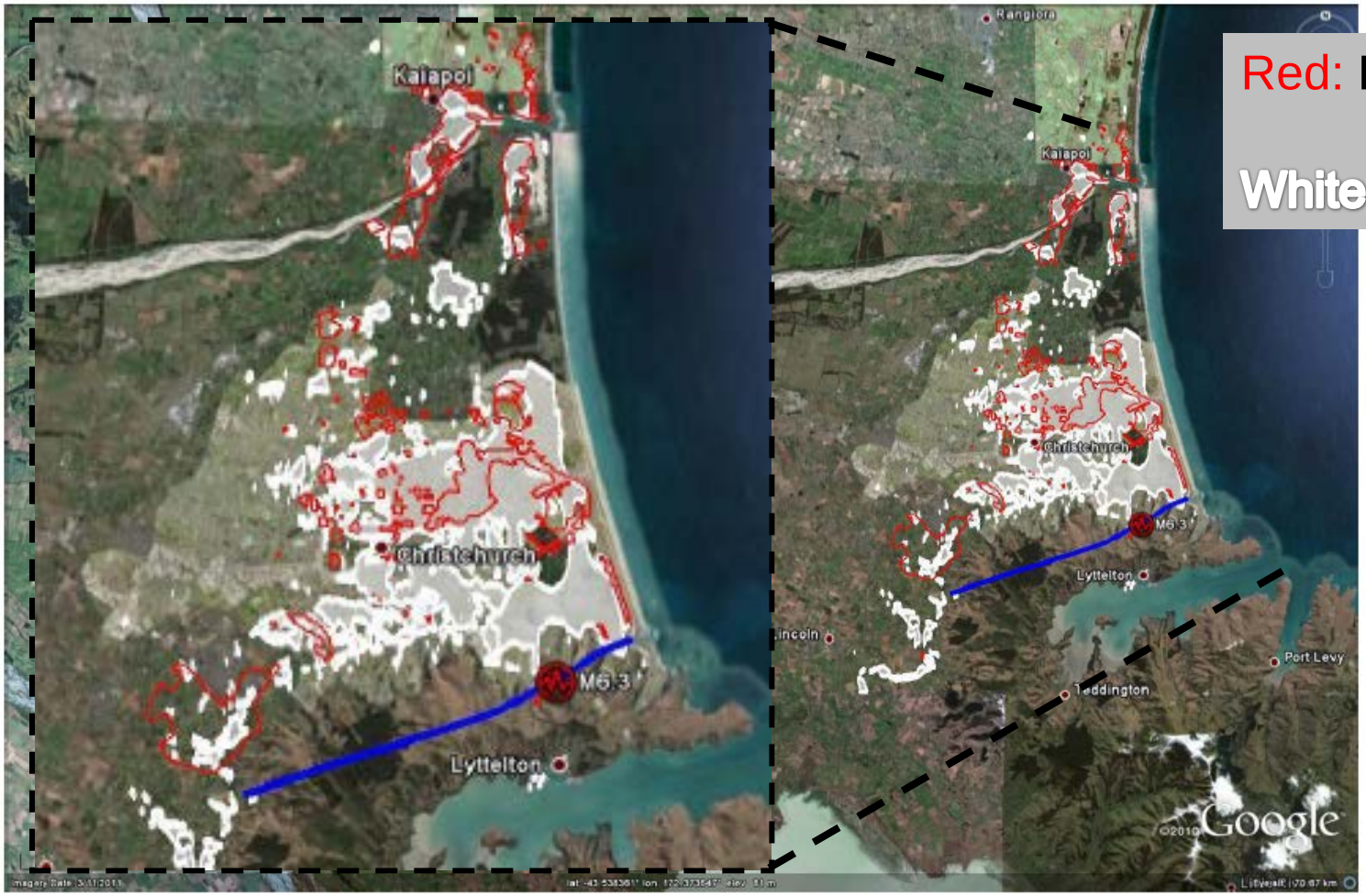
2011 Christchurch Earthquake



GEER: NSF-funded Geotechnical Extreme Events Reconnaissance Association
www.geerassociation.org

modified from M. Cubrinovski, J. Bray, R. Green

Observed Liquefaction



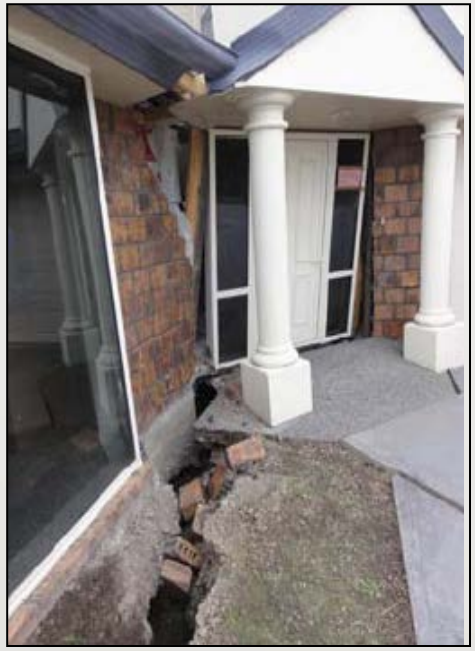
Red: Darfield EQ

White: ChCh EQ

M. Cubrinovski & R. Green et al. (2011)

http://geerassociation.org/Post_EQ_Reports.html

Observed Liquefaction: ChCh EQ



- ~ 1.5 m wide cracks
- Severe damage to foundations & houses

from M. Cubrinovski and J. Bray

Traditional Deformation Surveys

(a) Measuring crack width

(b) Tracing crack with GPS

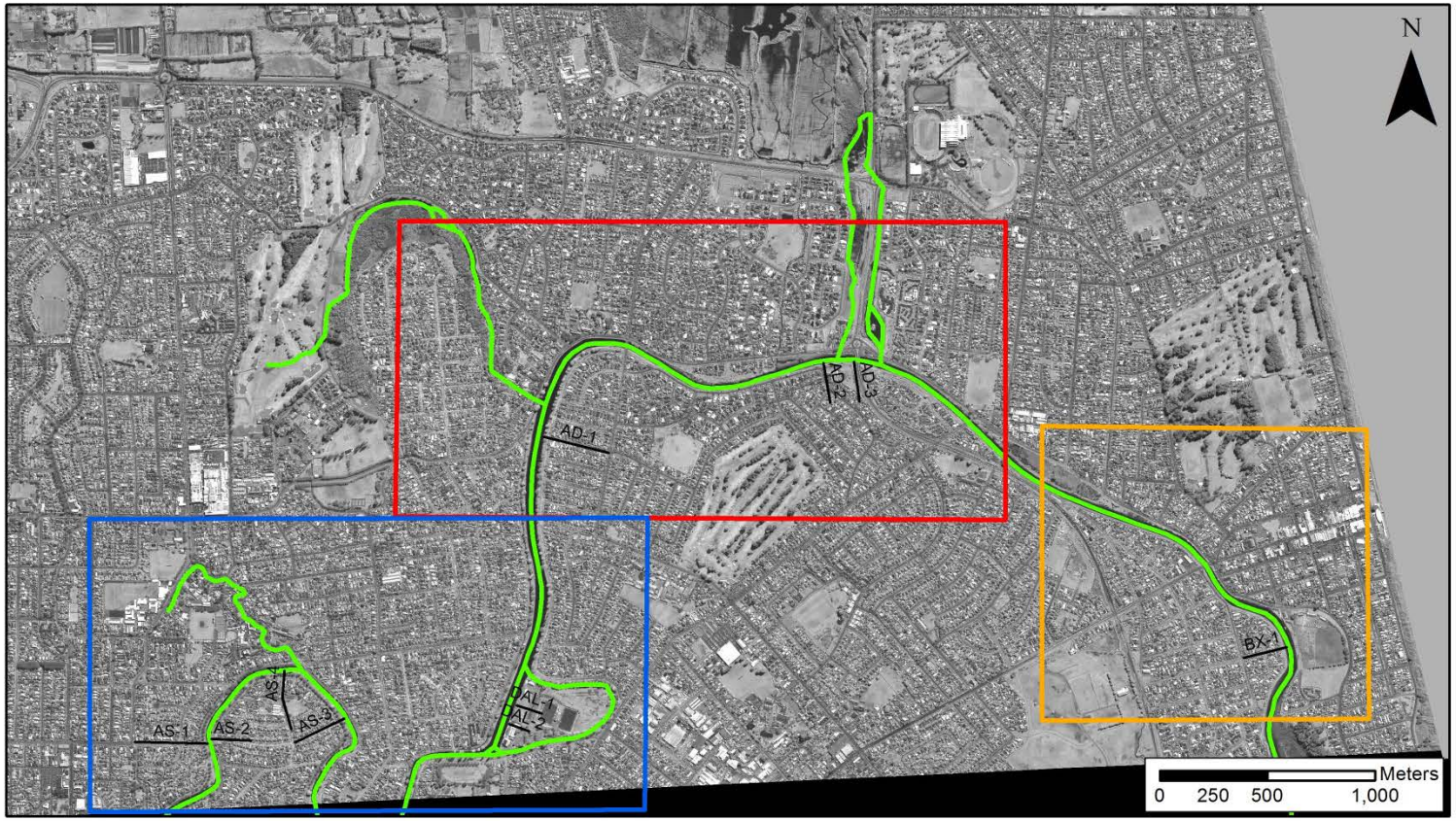
Robinson et al. 2011

Crack widths are summed along a transect to measure lateral displacement patterns

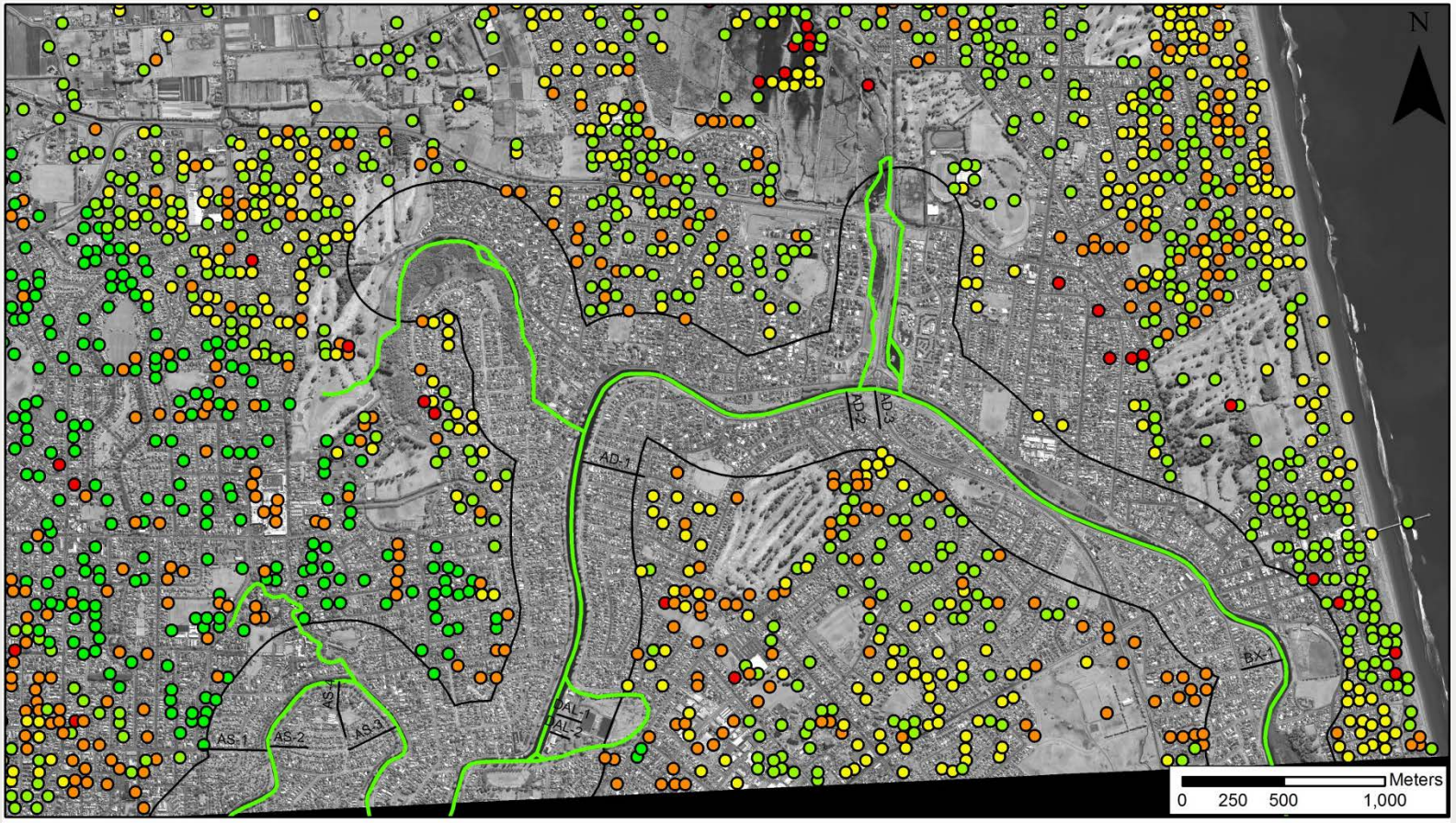
http://www.oregonstate.edu

Christchurch Study Area

0.5-m Pam WV-1/GE-1 images, ΔOff-Nadir = 1.6°, ΔAz = 4°



Tie Points

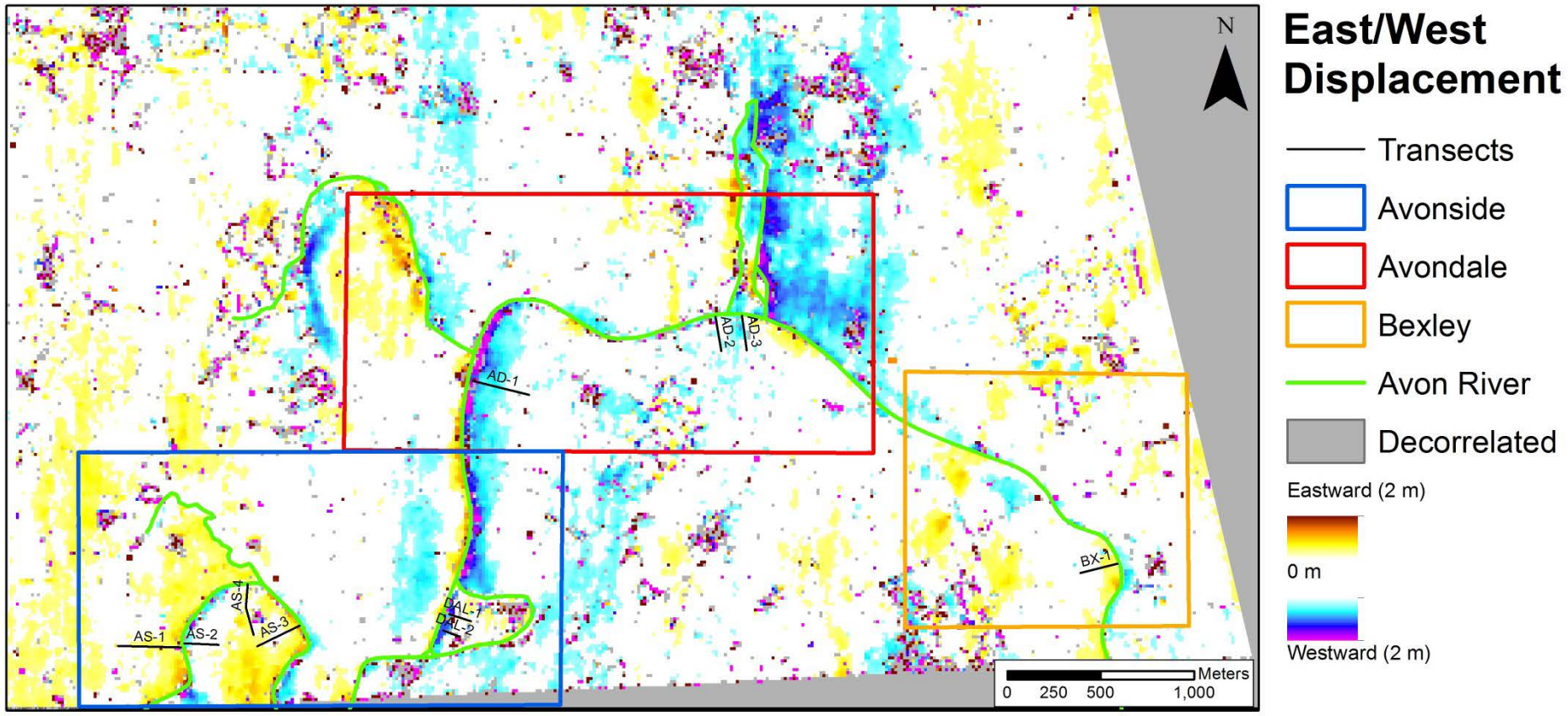


Tie Point Residuals (m)

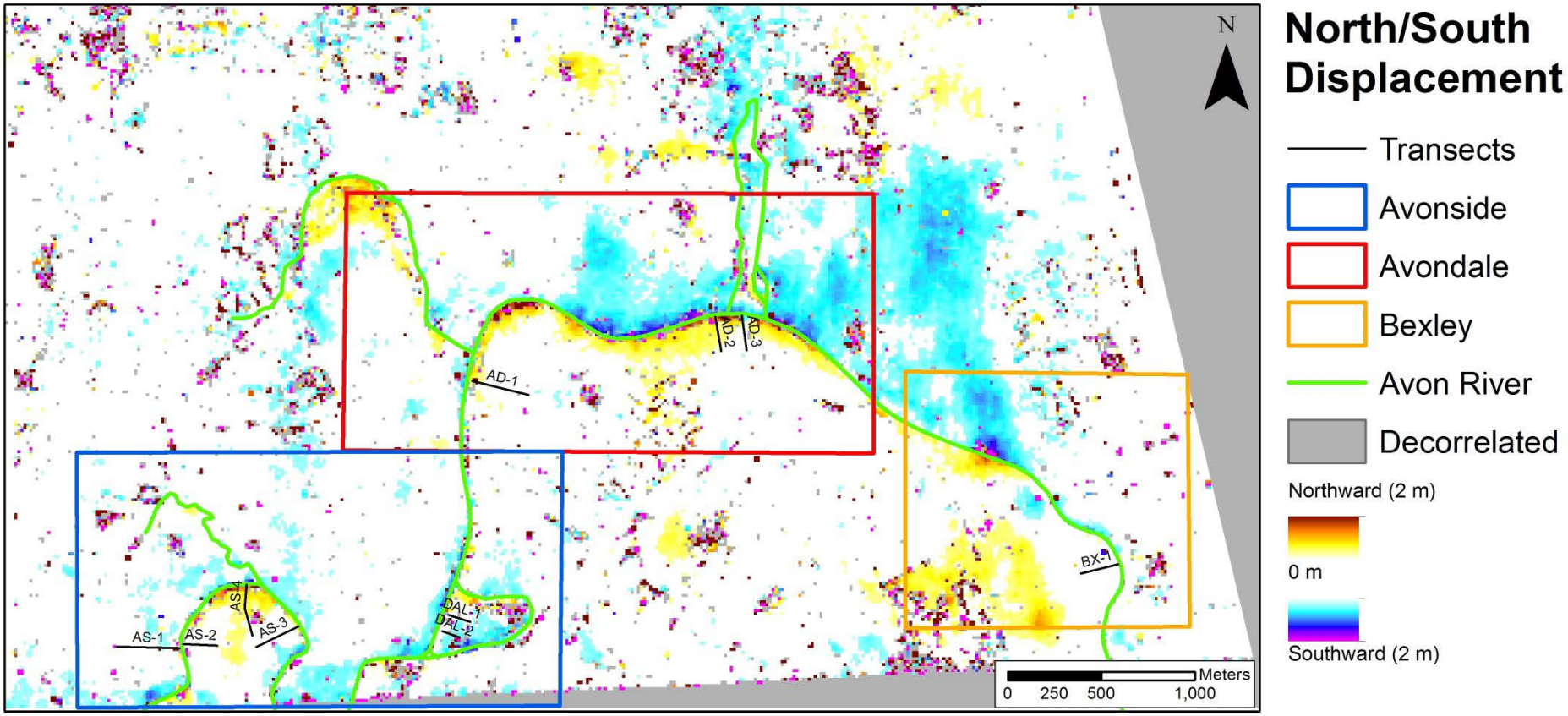
- 0.54 - 0.71
- 0.38 - 0.53
- 0.26 - 0.37
- 0.14 - 0.25
- 0.00 - 0.13

Overall RMSE 0.3 m

East/West Displacements

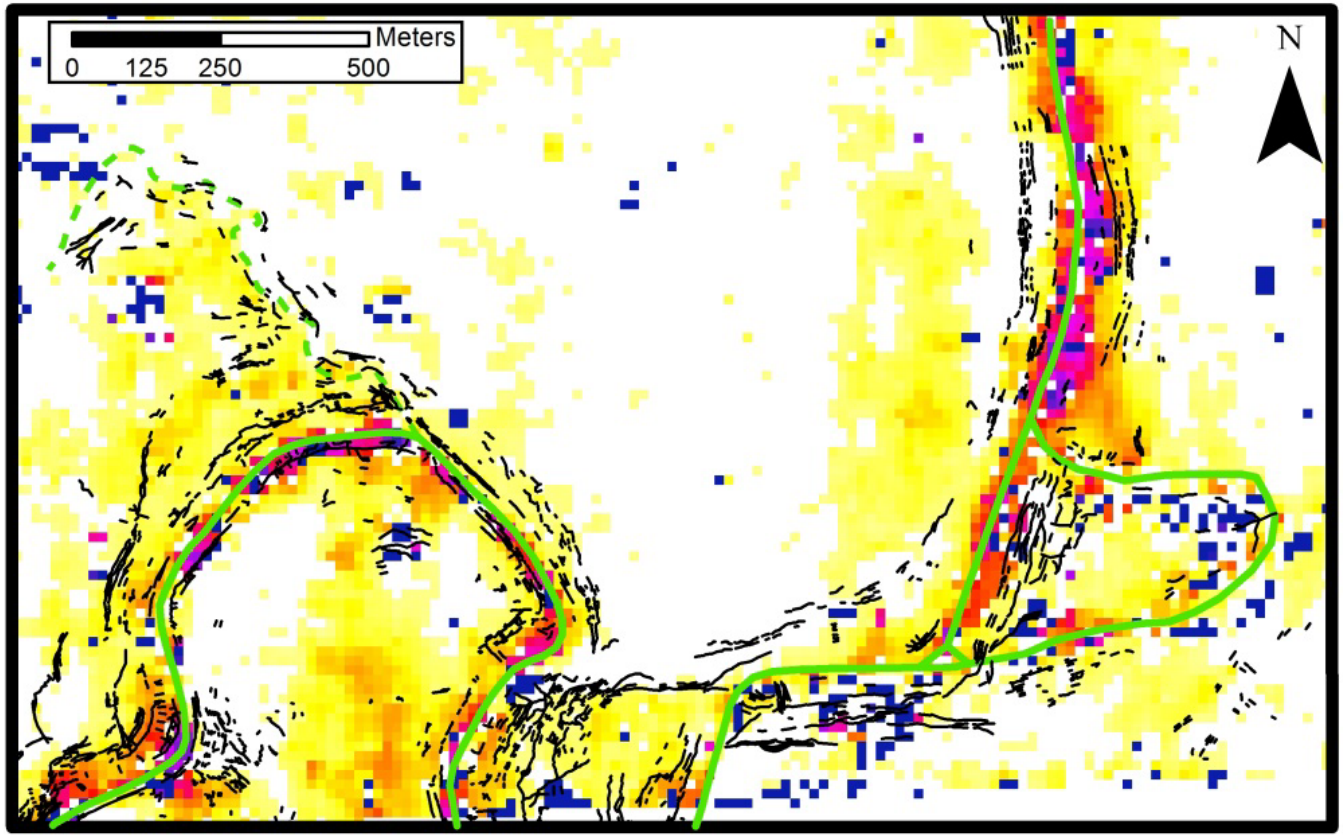


North/South Displacements



Avonside

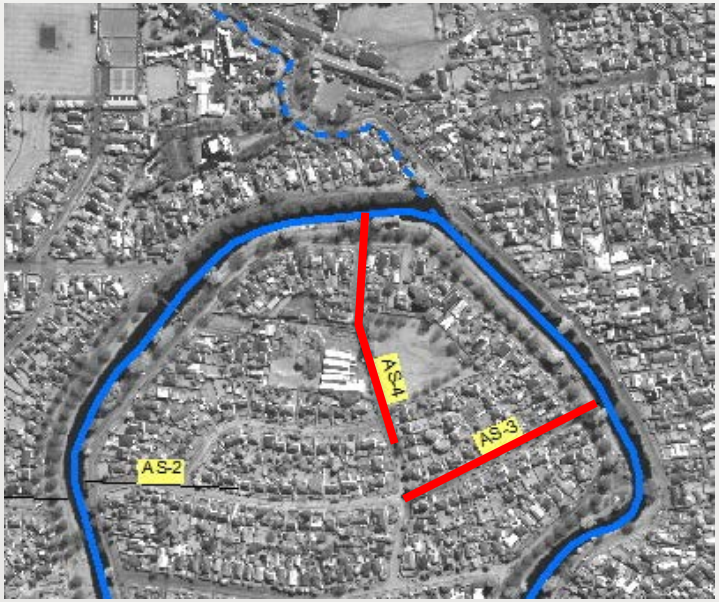
Comparison with Observed Cracking



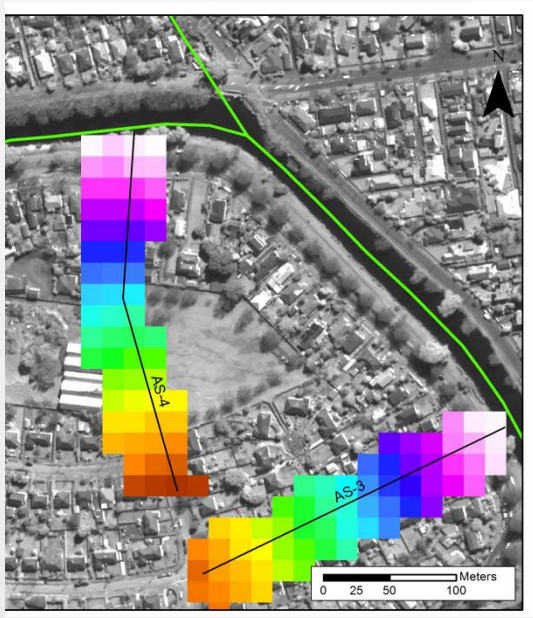
Avonside: Transects

Comparison with Displacements from Crack Widths

Transect Locations



Transect Averaging

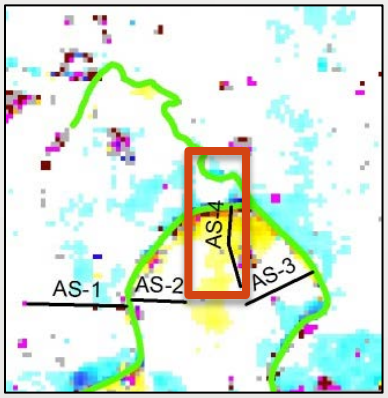


NS and EW displacements rotated to be parallel to the transect

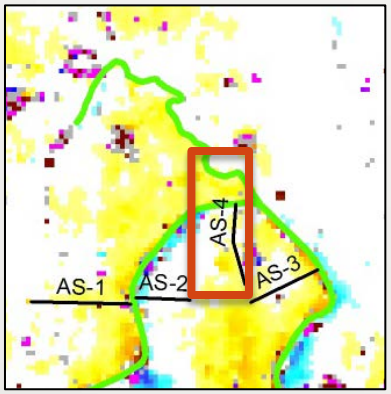
Avonside: Transects

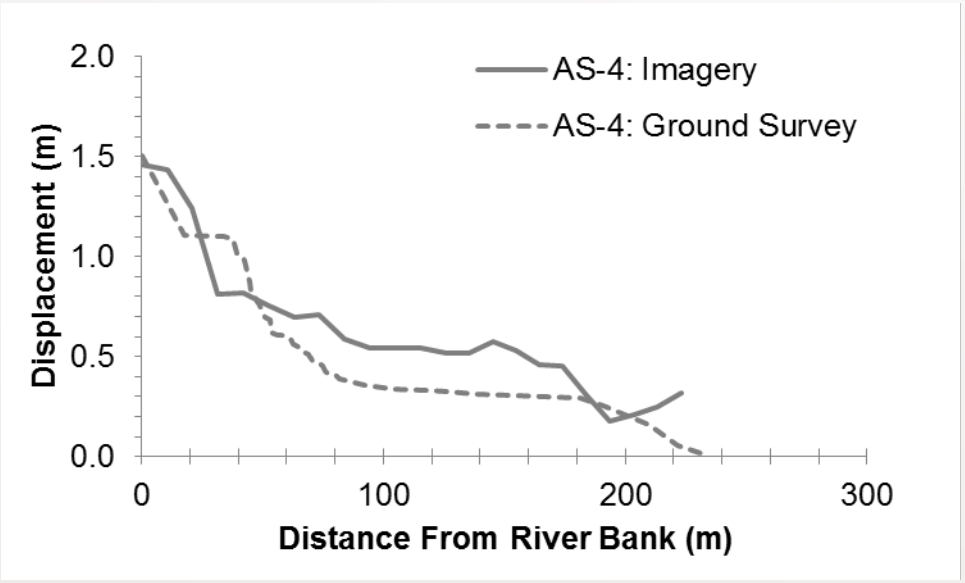
Comparison with Displacements from Crack Widths

NS Displacements



EW Displacements



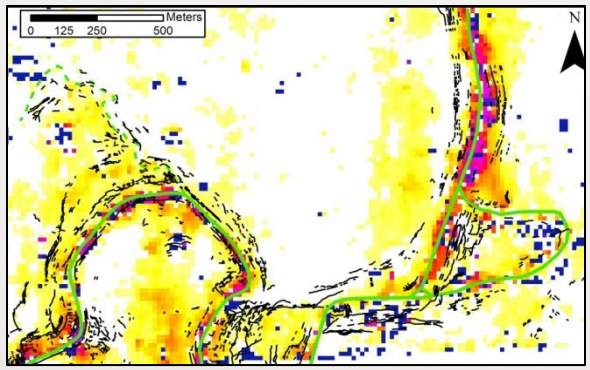


Field displacements from Cubrinovski (personal communication)

Now what can we do?

Liquefaction: Integration of Deformation, Subsurface, and Topographic Data in Christchurch

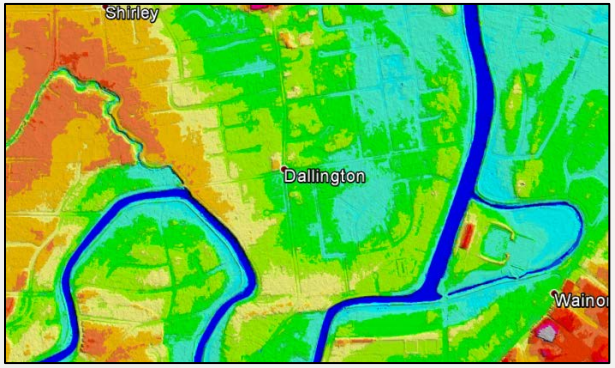
Deformation



Subsurface Characterization

- Liquefaction resistance
- Layering
- Relative density, stiffness
- Soil type
- Lateral Variability

LIDAR DEM



- Slope
- Distance from free-face
- Terrain features
- Geomorphic landforms