Several insights from a decade of earthquake reconnaissance and response in New Zealand

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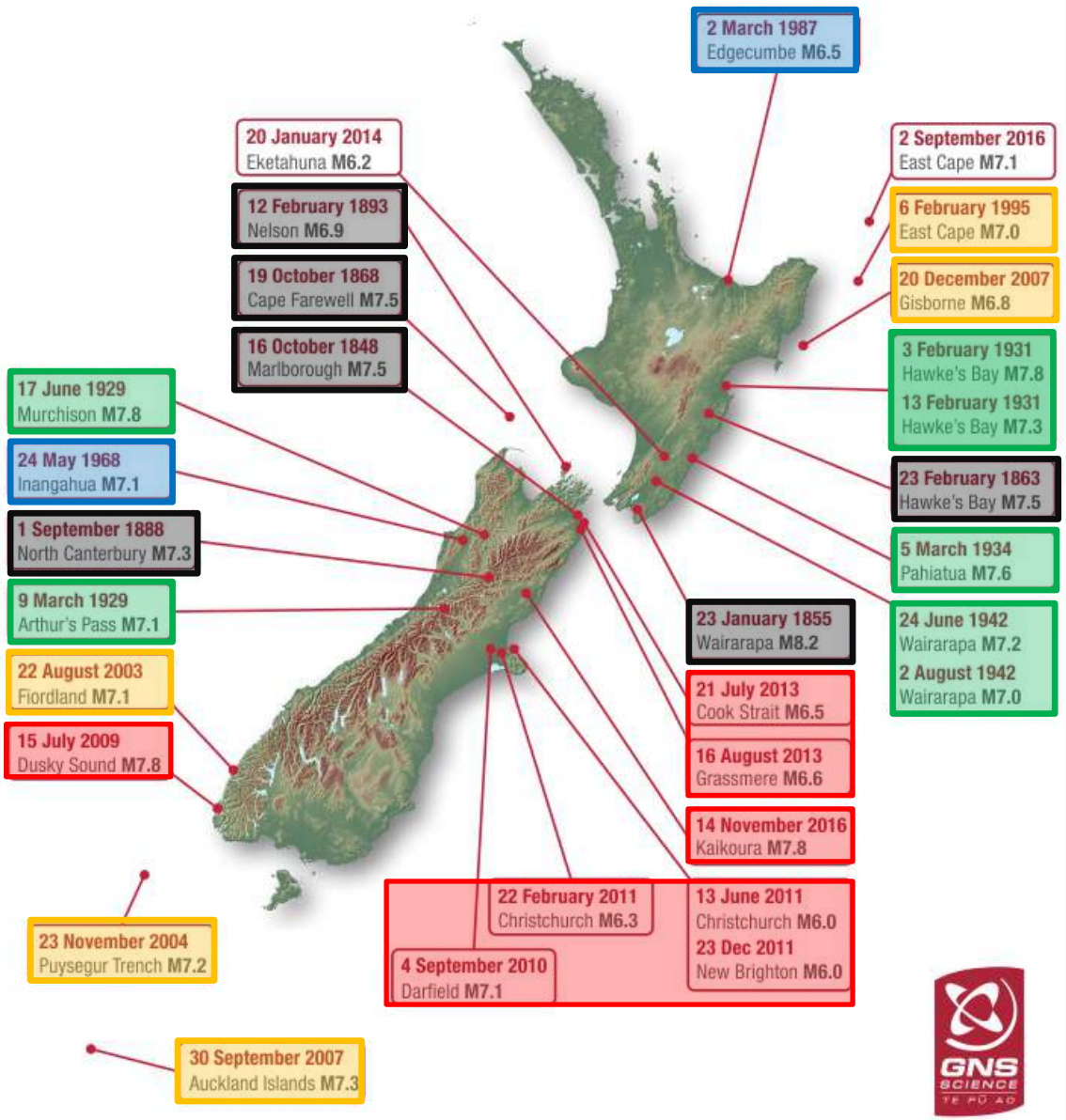
Aim

- In light of the recent 2019 Ridgecrest earthquake sequence …
- Provide some insights from experience dealing with impactful earthquakes in New Zealand from the past decade that are hopefully relevant for the near future in responding to larger events in the US / CA.

Large New Zealand Earthquakes

Notable shallow (generally less than 30km deep) earthquakes since 1848



https://www.geonet.org.nz/earthquake/story

Three themes

1. Logistical challenges

2. Public and professional engagement opportunity

3. Technological transformations in reconnaissance and response

(Loose) definitions

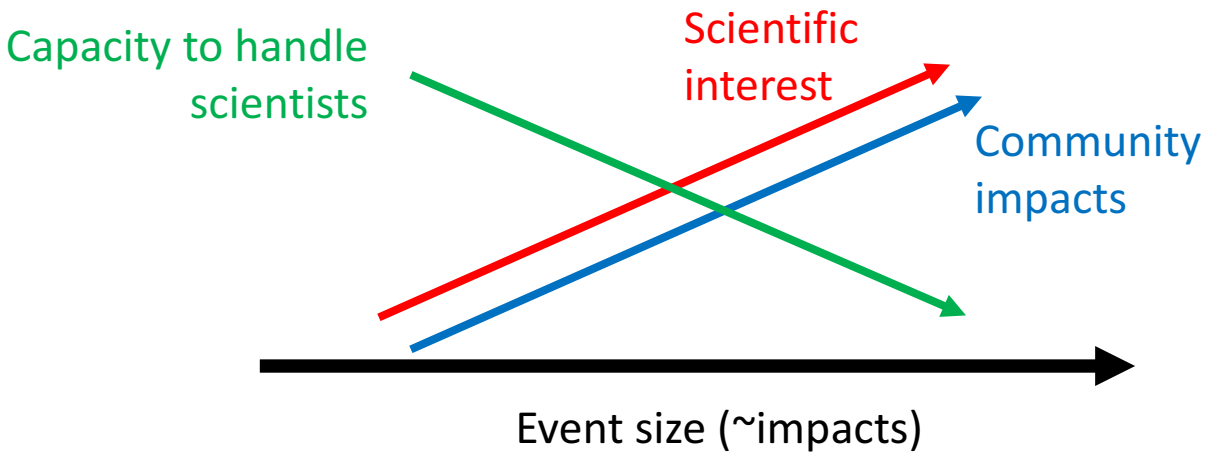
- *Reconniassance*: The scientific effort in the immediate aftermath of the event to collect perishable data
- *Response*: Emergency and other agency mobilization immediately for life safety and infrastructure make-safe activities
- *Recovery*: Re-instatement of infrastructure and services, societal activities etc., aiming to 'return to normal'

1. Logistical challenges

coordination mechanisms for low-impact events do not extrapolate easily to high-impact events, avoiding over-exposure of stakeholders and affected parties, and the challenges of unforeseen data access restrictions;

Coordination of scientific reconnaissance

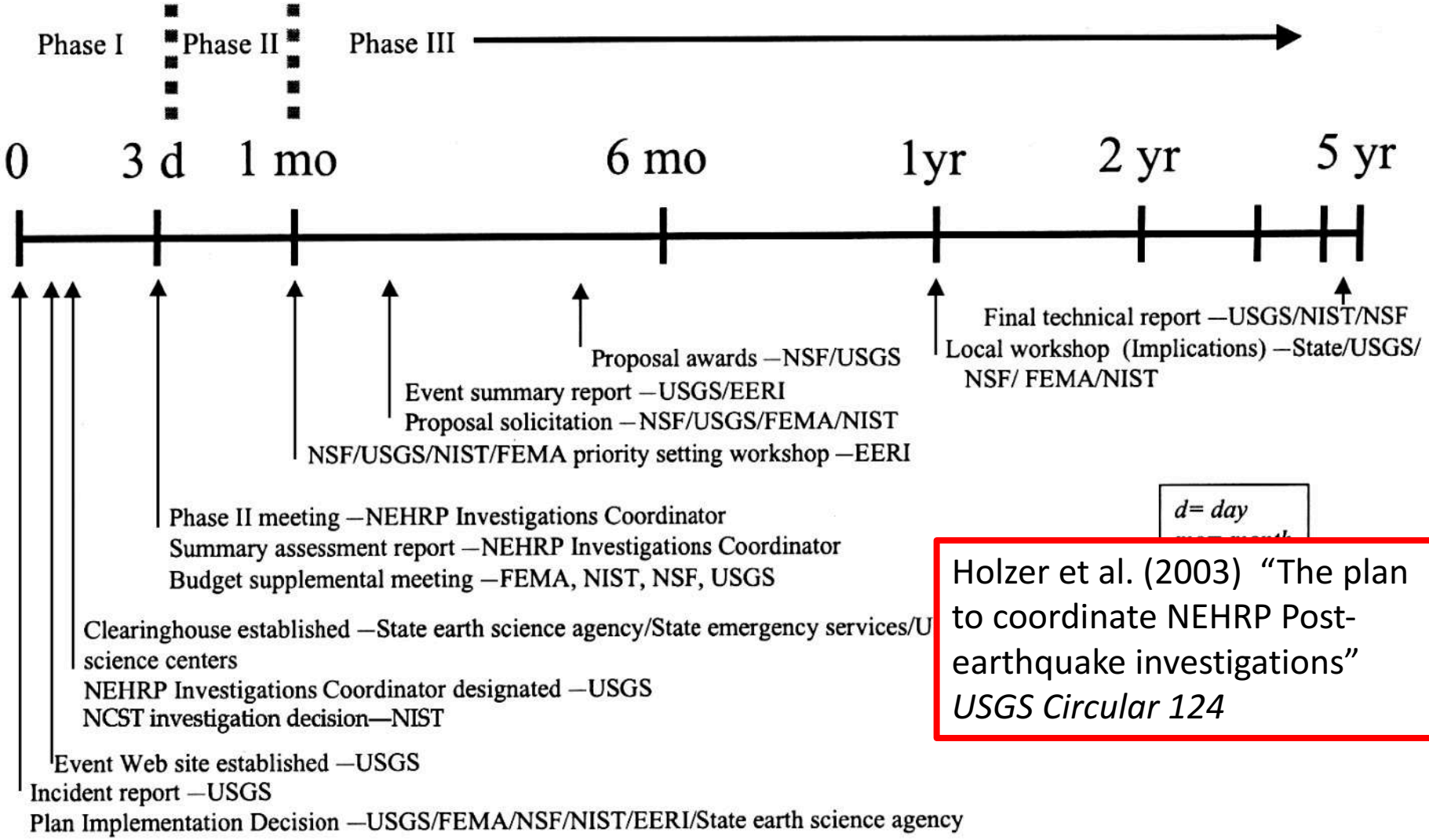
Coordination mechanisms for low-impact events do not extrapolate easily to high-impact events…..



<u>Decentralized coordination</u>
Among established networks is possible (and common)

Do you know your plan ?

Do you know your plan ?

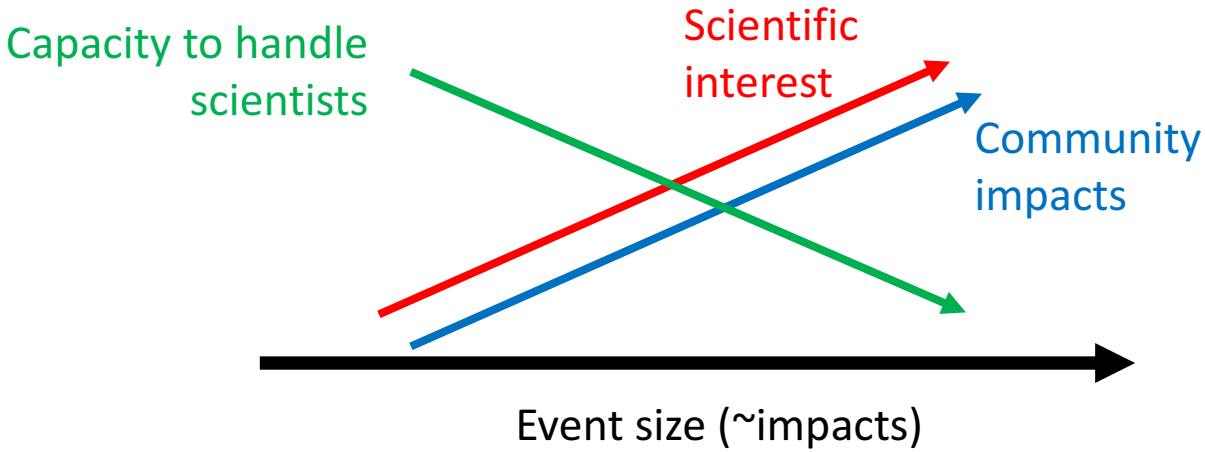


Holzer et al. (2003) "The plan to coordinate NEHRP Post-earthquake investigations" *USGS Circular 124*

Figure 1. Activities timeline for NEHRP Post-Earthquake Coordination Plan—Domestic earthquakes.

Coordination of scientific reconnaissance

Coordination mechanisms for low-impact events do not extrapolate easily to high-impact events…..



<u>Decentralized coordination</u>

Among established networks is possible (and common)

<u>Centralized coordination a necessity</u>

- Emergency response phase period
- Limited access for 'local' researchers to avoid over-exposure to affected communities
- 'Internationals' in partnership with 'local' researchers.

Strong coordination and governance is necessary to ensure collected information is widely shared. 'Boundary organisations' like SCEC play a key role

Challenges of unforeseen data access restrictions

- 2016 Kāikoura Eq: As a result of no state of emergency being declared, high-level understanding of building damage in Wellington unknown due to client confidentially

"Confusion and lack of clarity around assessing quakedamaged buildings". Stuff (Fairfax Media). 8 December 2016.

- Wellington's Critical Buildings team initated a 'collaboration in confidence' process by which owners' engineers interacted to share information without disclosing specific buildings

- Regulations changed to avoid this specific occurrence in future, but other challenges will surely occur

Naval base access as an example in Ridgecrest

"Wellington building owners on notice to get earthquake inspections done". Stuff (Fairfax Media). 7 April 2017.

2. Public and professional engagement opportunity

complacency, engagement across disciplinary boundaries, and the tension of scientific uncertainty vs. timely science-informed decision making;

Complacency:

Canterbury's months of earthquake innocence

Martin van Beynen • 13:18, Sep 03 2015

(MSM article: 5 years following the M7.1 Darfield earthquake)

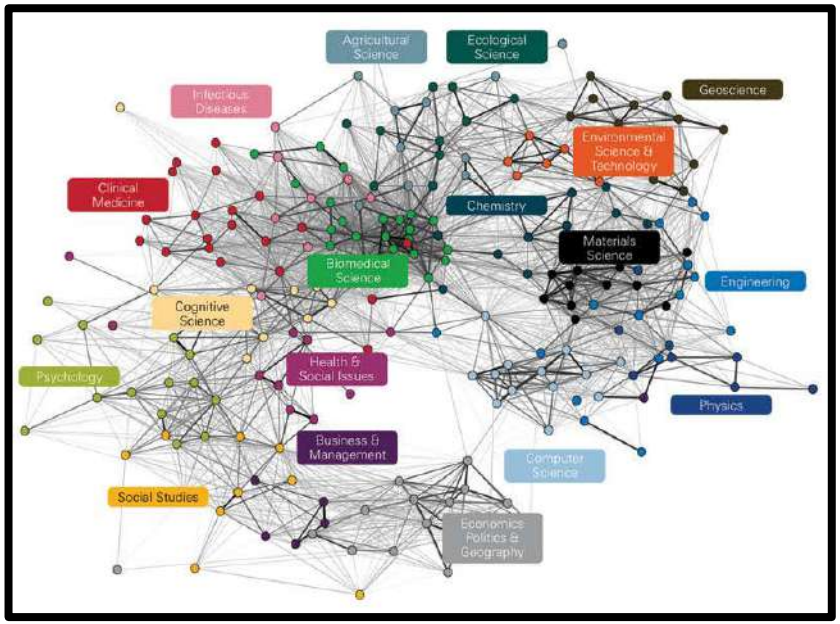
Quote: "We believed we had seen the worst. ….

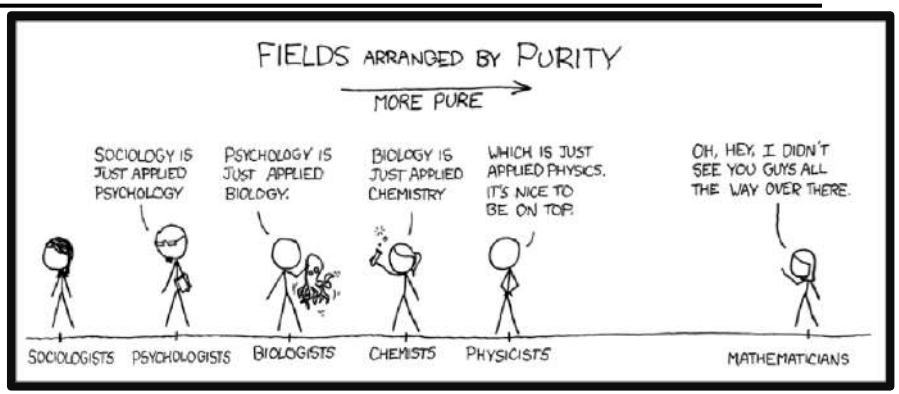
An engineering professor referred to Christchurch and the country generally as being the best prepared in the world for an earthquake. ….

We felt, it must be said, just a little complacent."

Multi-/inter-/trans-disciplinary research

Perception vs. reality



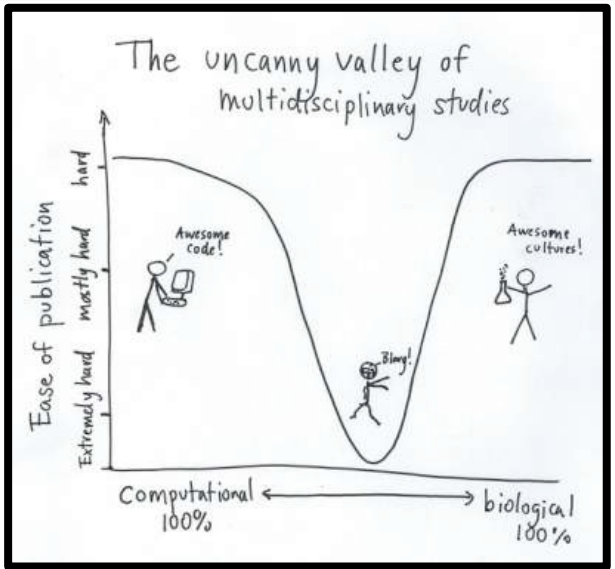


Interdisciplinary research has consistently lower funding success

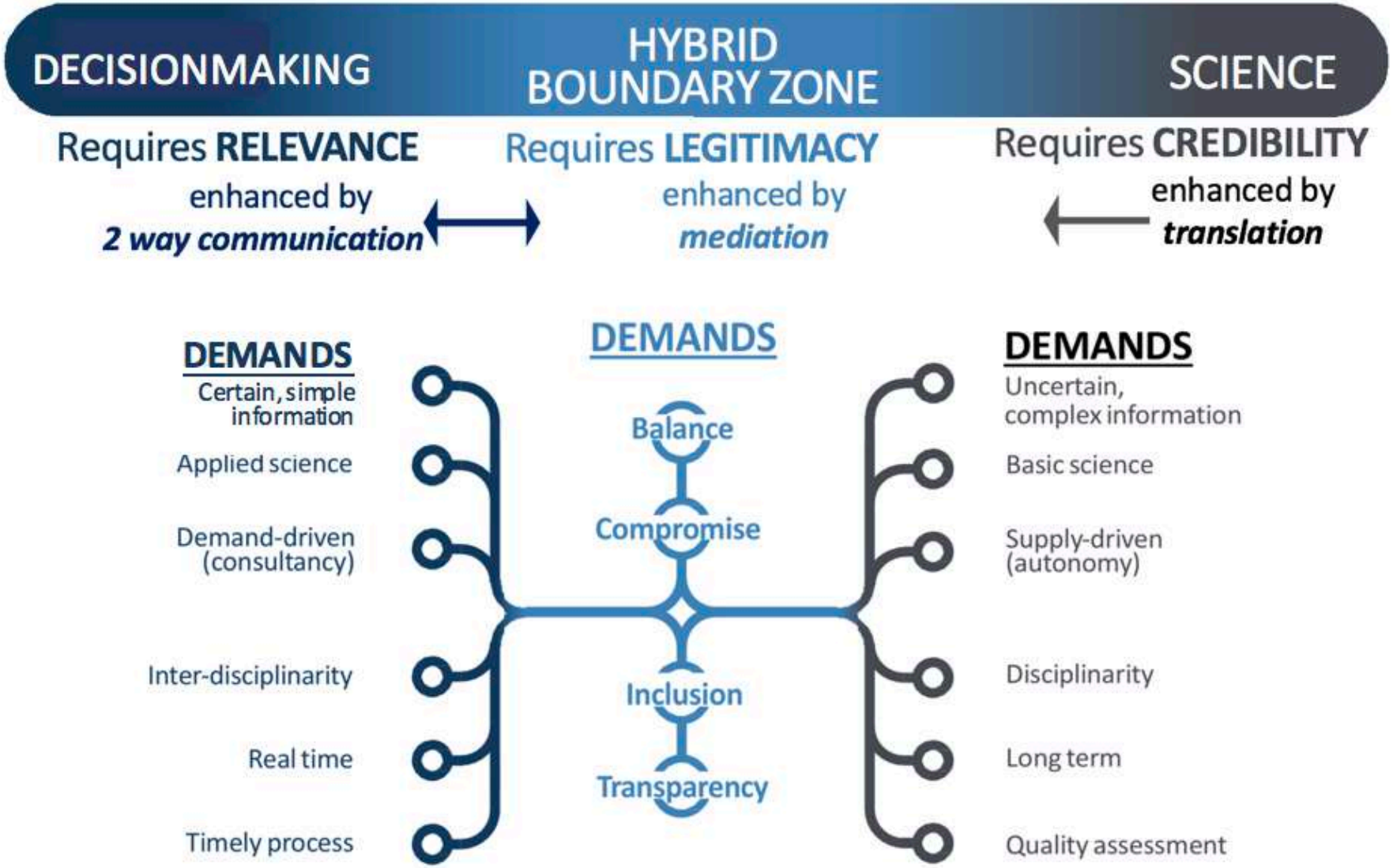
Lindell Bromham, Russell Dinnage & Xia Hua

Affiliations | Contributions | Corresponding author

Nature **534**, 684–687 (30 June 2016) | doi:10.1038/nature18315



The tension of scientific uncertainty & timely science-informed decision making



(Beavan et al. 2019, unpublished; after Beavan et al. 2016)

3. Technological transformations in reconnaissance and response

sensing and machine learning, the irreplaceable value of first-hand observation for scientific understanding and intrinsic motivation.

Reconnaissance advances 2000-2010

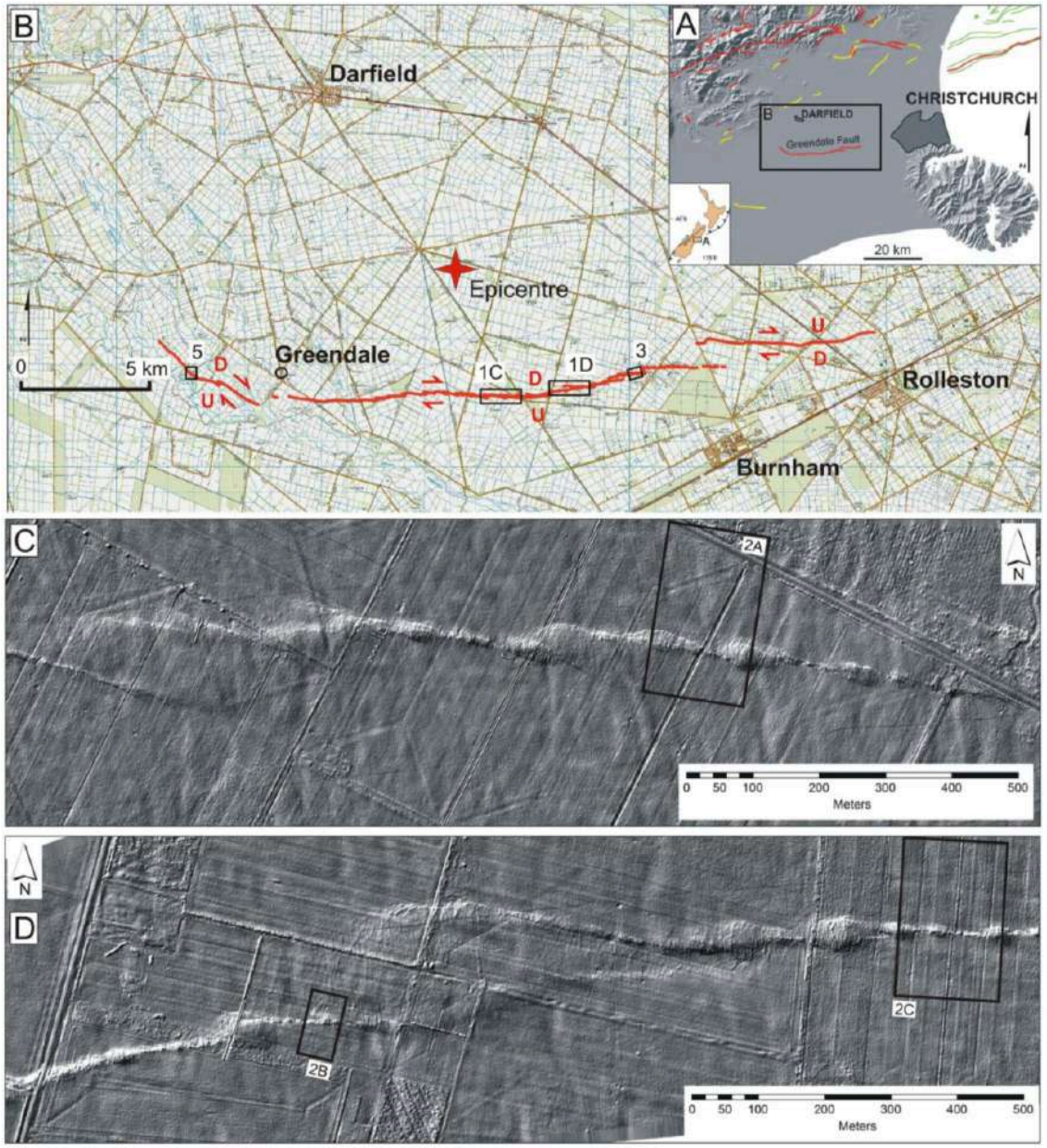
(Bray et al. 2019)**Central Business District, Christchurch, New Zealand**

Reconnaissance advances 2010-2020+

- Active photon generation methods
  - DEM and differencing: LiDAR, lnSAR

    (techniques pre-2000, but explosion in application and fidelity)

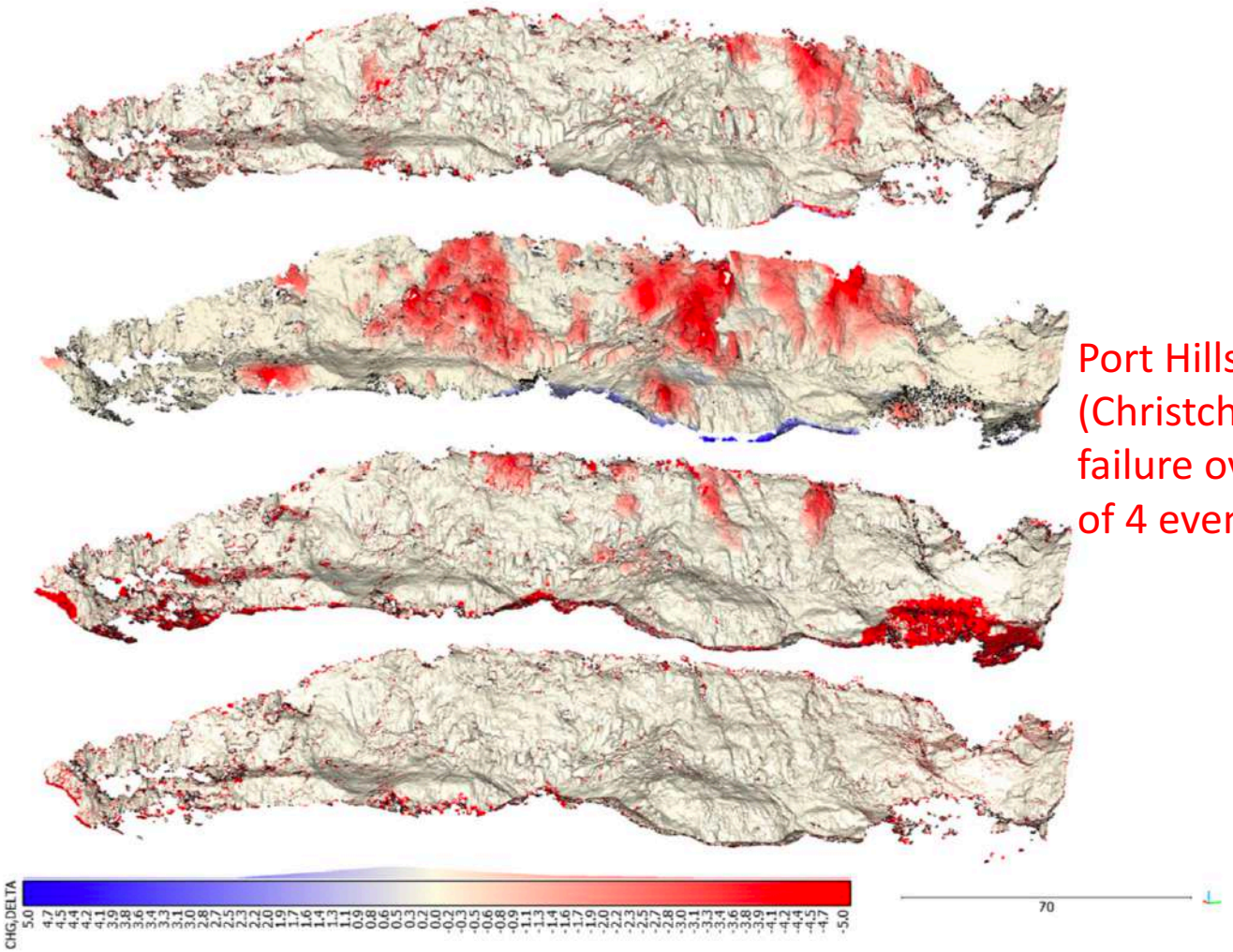
LiDAR for surface rupture characterization



M7.1 2010 Darfield earthquake surface rupture

(Quigley et al. 2010)

LiDAR for landslide characterization

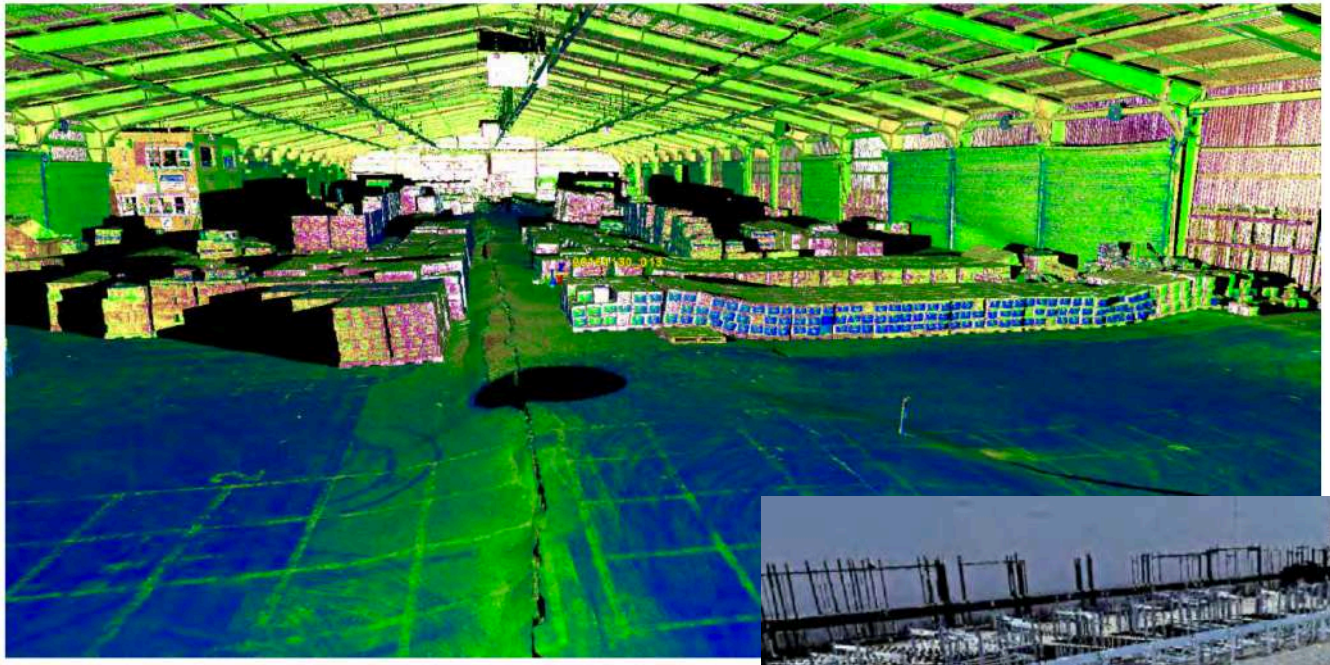


Port Hills (Christchurch) slope failure over sequence of 4 events

Figure 7-13: Change Analysis for the Redcliffs Southwest site for changes between (a) 3/6/2011 and 5/3/2011, (b) 5/3/2011 and 6/15/2011, (c) 6/15/2011 and 1/18/2012, and (d) 1/18/2012 and 5/1/2012

(Olsen et al. 2019; Massey et al. 2015)

LiDAR + photogrammetry for geotechnical and structural deformation

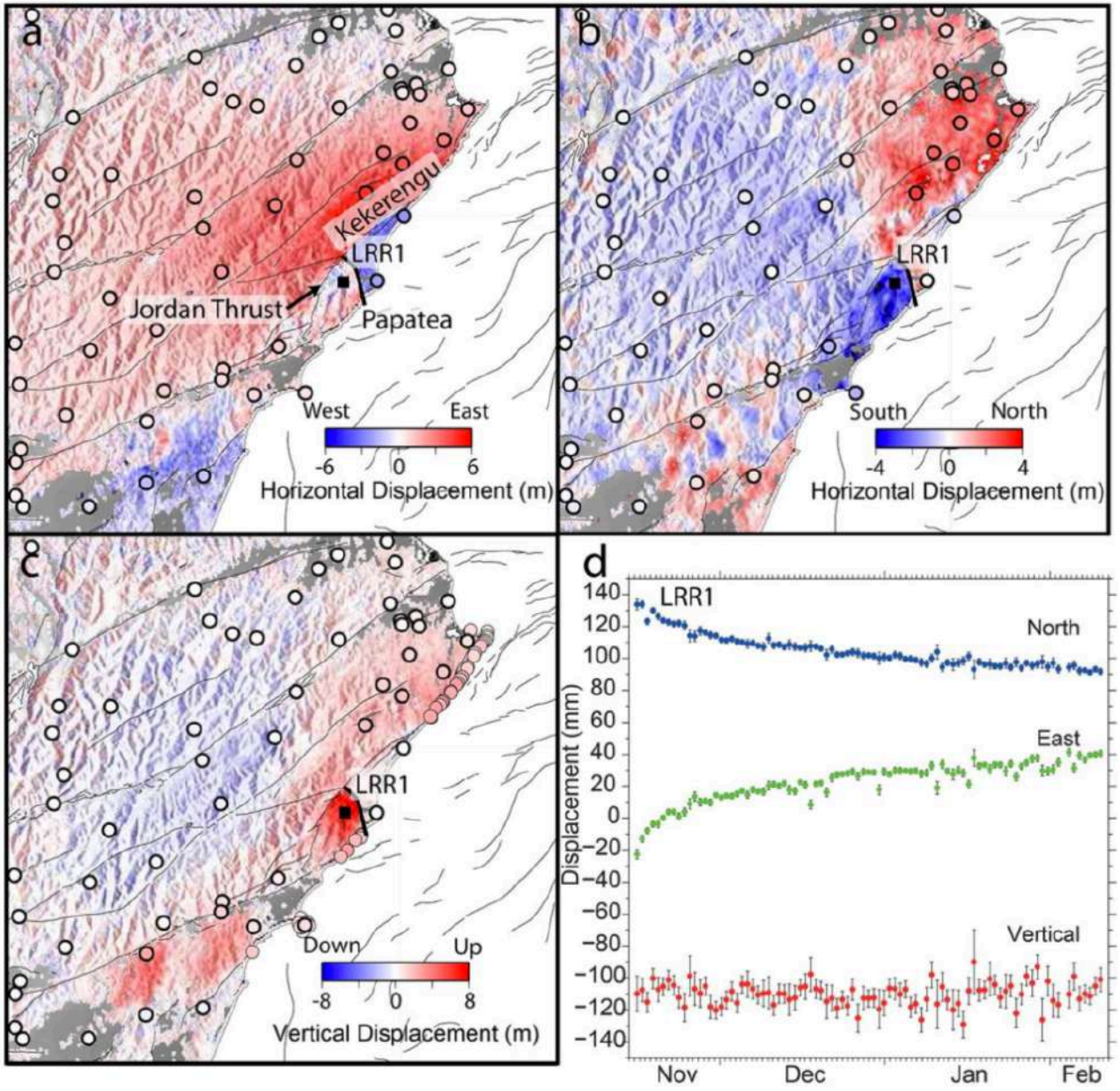


CentrePort Cold Storage Building Interior

Exterior

(Olsen et al. 2017)

InSAR for surface rupture characterization



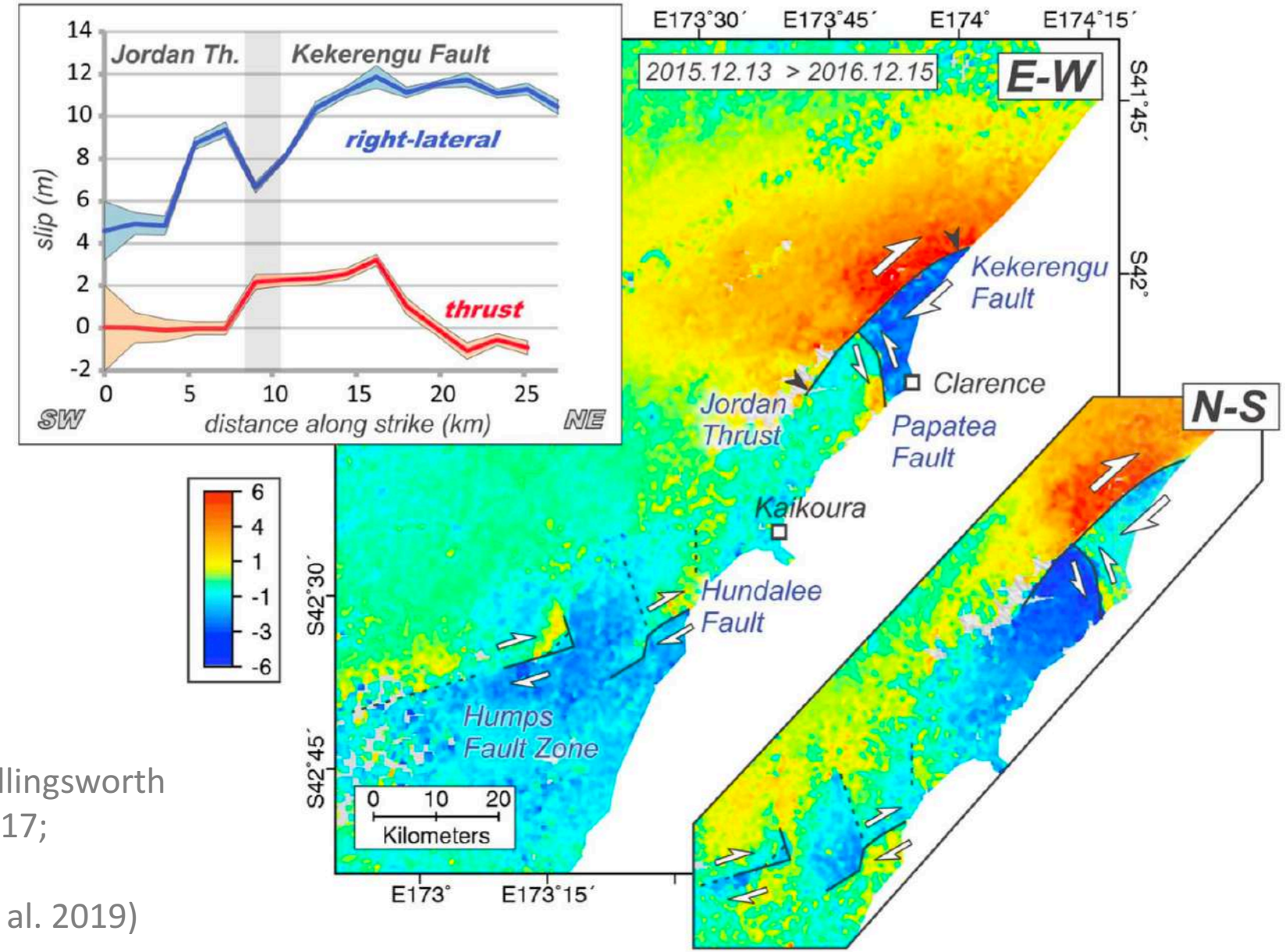
2016 Kaikōura surface deformation

(Hamling et al. 2017)

Reconnaissance advances 2010-2020+

- Active photon generation methods
  - DEM and differencing: LiDAR, lnSAR
- Passive optical methods
  - Image correlation
  - structure-from-motion (SfM) from hand-held cameras and/or drones

Image correlation for surface rupture

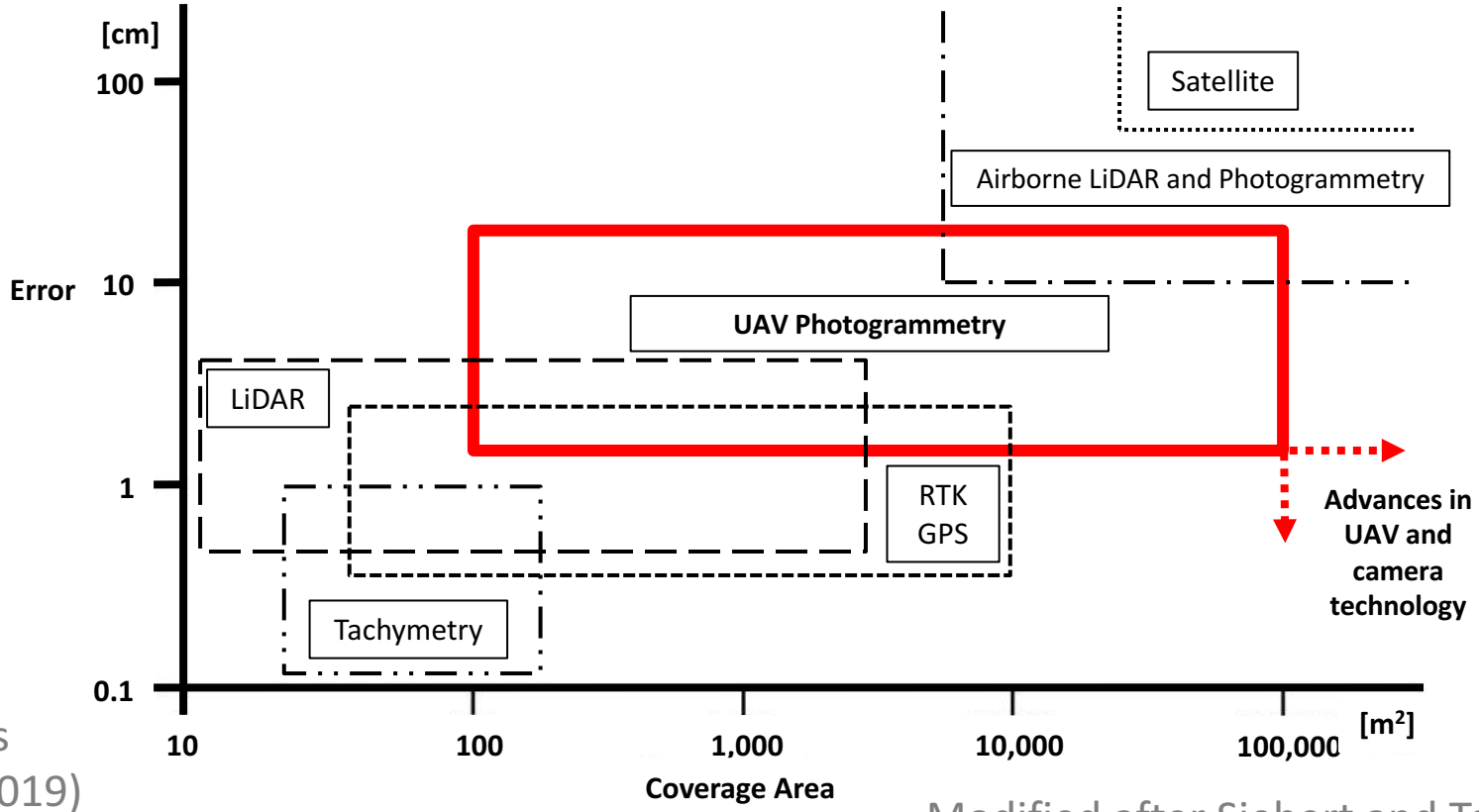


(e.g. Hollingsworth et al. 2017;

Zinke et al. 2019)

Measurement techniques

- Measuring tape, Ground surveys, Airborne and terrestrial LiDAR, satellites
- **UAV Structure-from-Motion surveys**



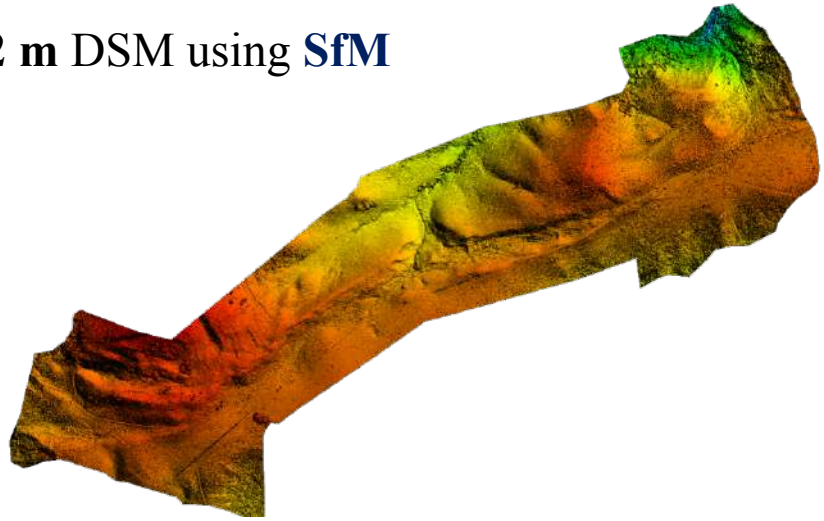
(Zekkos et al. 2019)

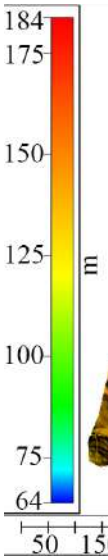
Modified after Siebert and Teizer (2014)

Seafront Landslide – Kaikōura

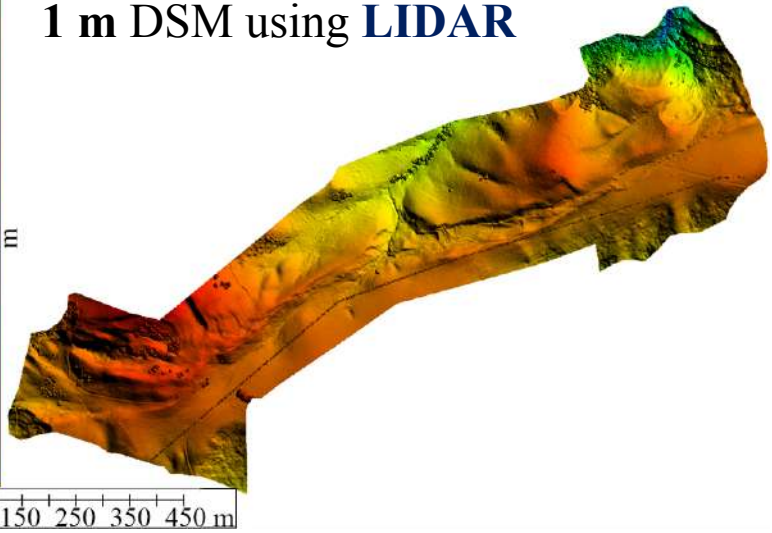
Kekerengu Fault Rupture Mapping: SfM vs. LIDAR

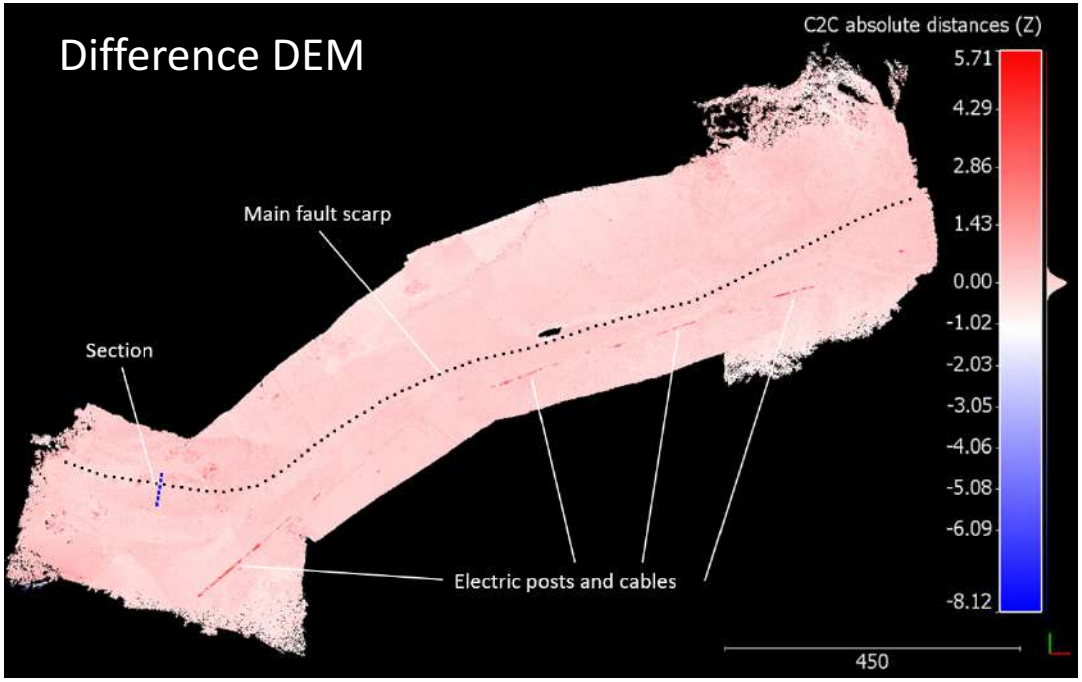
0.2 m DSM using **SfM**





1 m DSM using **LIDAR**





Difference DEM
Mean: 0.02 m
Standard deviation: 0.23 m

(Zekkos et al. 2019)

Reconnaissance advances 2010-2020+

- Active photon generation methods
  - DEM and differencing: LiDAR, lnSAR
- Passive optical methods
  - Image correlation
  - structure-from-motion (SfM) from hand-held cameras and/or drones
- The role of technology infrastructure to harness utilization of collected data

Making LIDAR and SfM easy to use – e.g. potree

Automated damage detection via ML

PEER

Φ Challenge 2018

7. **Damage level**: no/minor/moderate/heavy damage

(a) No

(b) Minor

(c) Moderate

(d) Heavy

PHI=PEER Hub ImageNet

8. **Damage type**: no/flexural/shear/combined damage

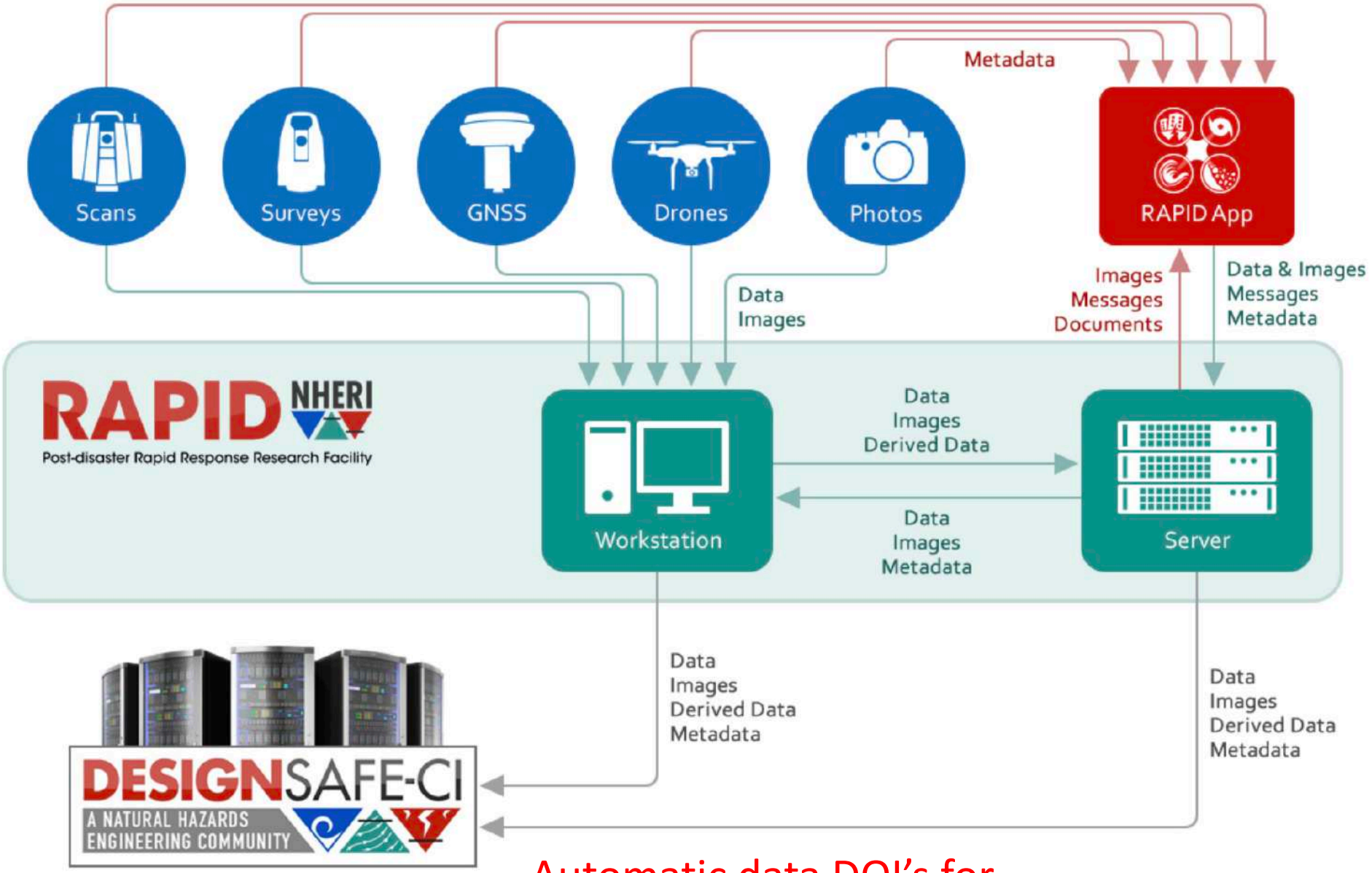
(a) No

(b) Flexural

(c) Shear

(d) Combined

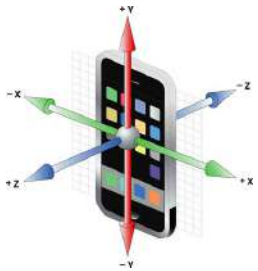
RAPID/DesignSafe - Data workflow



Automatic data DOI's for appropriate attribution

What are we missing?

- Advances in imaging methods are giving extremely high-resolution spatial representation …. at a given instant in time
- Conventional seismic instruments provide high temporal resolution.... but poor spatial coverage (ex. aftershock temp deployment)
- We need to bridge this spatial-temporal divide
- Requires technological and business-model innovation



The irreplaceable value of first-hand reconnaissance experience

"In theory there is no difference between theory and practice, while in practice there is"

(Brewster, 1881)

Closing sentiments

1. Logistical challenges –coordination mechanisms for low-impact events do not extrapolate easily to high-impact events, avoiding over-exposure of stakeholders and affected parties, and the challenges of unforeseen data access restrictions;

2. Public and professional engagement opportunity - complacency, engagement across disciplinary boundaries, and the tension of scientific uncertainty vs. timely science-informed decision making;

3. Technological transformations in reconnaissance and response - sensing and machine learning, the irreplaceable value of first-hand observation for scientific understanding and intrinsic motivation.

Thank you for your attention

Slide deck available at
https://sites.google.com/site/brendonabradley/presentations