RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

TE TAI WHANAKE

Growing a stronger, more resilient Aotearoa.

Te Papa, Wellington   13 & 14 May 2024

Technology and Innovation

How is technology contributing to resilience building and emergency management, and where are opportunities for innovation for New Zealand?

Speakers:

- David Johnston, Joint Centre for Disaster Research *(Chair)*
- Andrea Wolter, GNS Science
- Max Stephens, University of Auckland
- Murray Ford, University of Auckland
- Tom Robinson, University of Canterbury
- Raj Prasanna, Joint Centre for Disaster Research
- Andy Nicol, University of Canterbury

Slide deck omitted by presenter

Community Engaged Low-Cost EEW

A Decentralised Edge Processing Approach

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

JOINT CENTRE FOR DISASTER RESEARCH

CRISiSLab

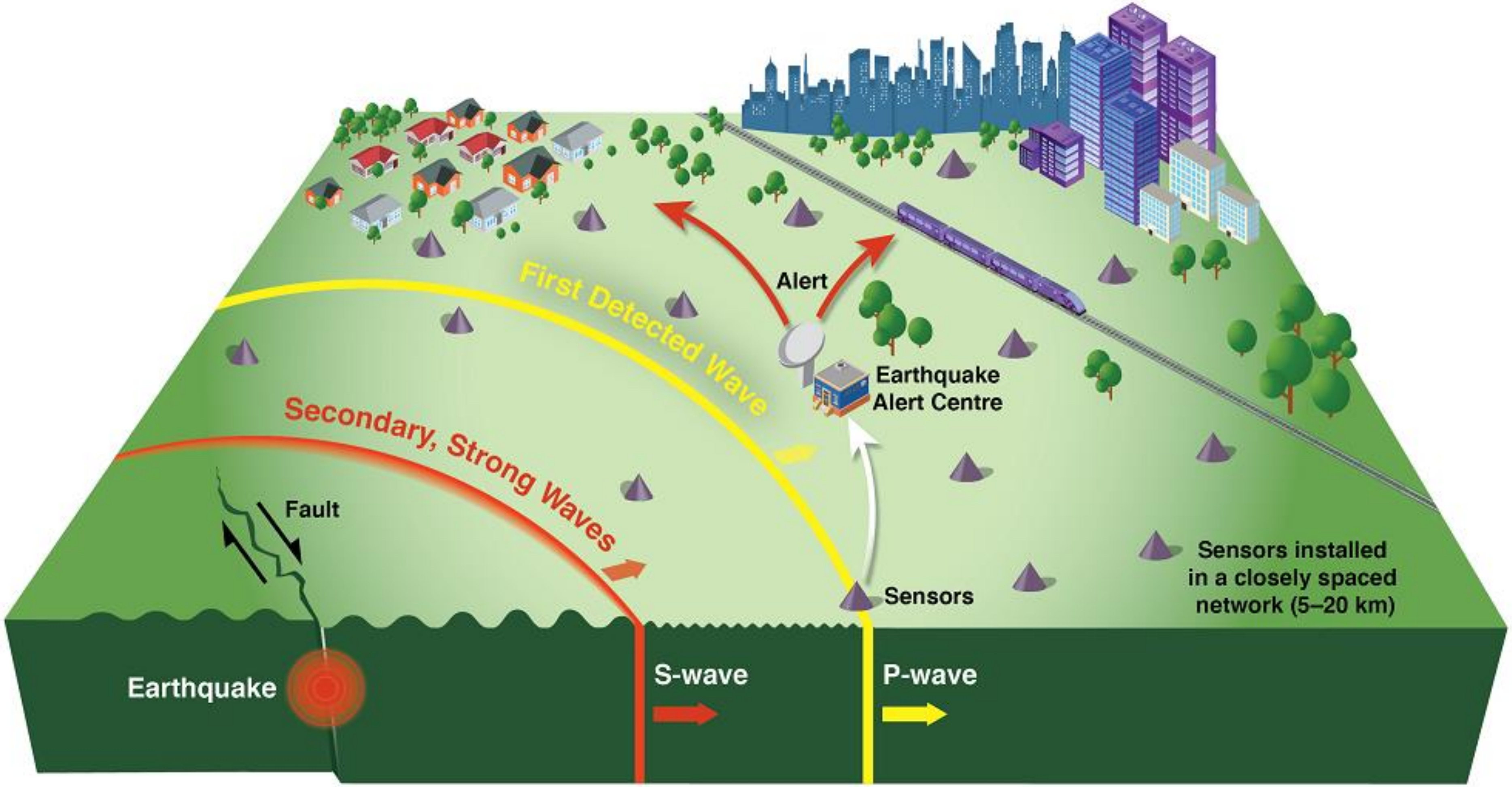
https://www.crisislab.org.nz/

RESILIENCE TO NATURE'S CHALLENGES

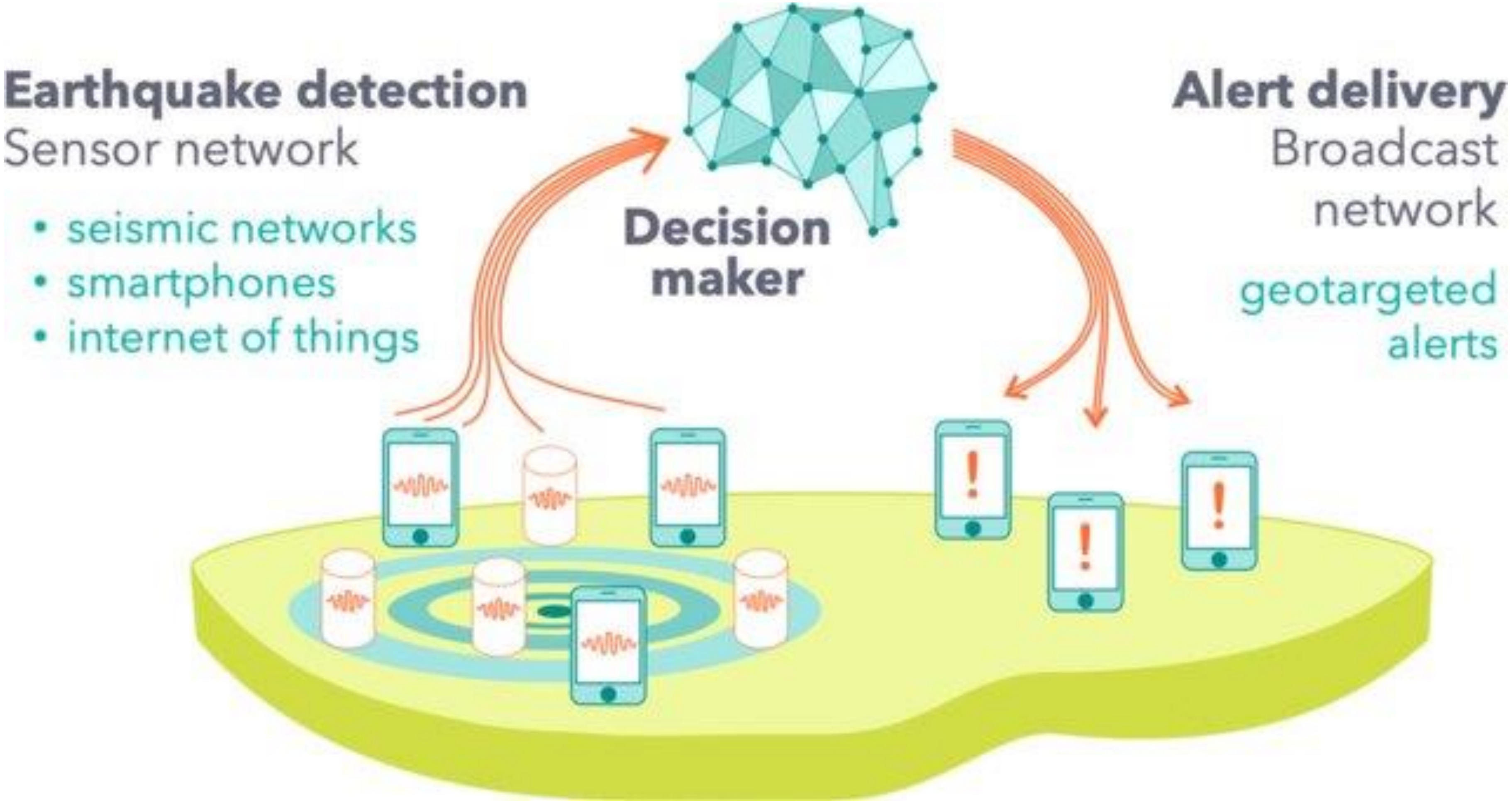
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

National Science Challenges

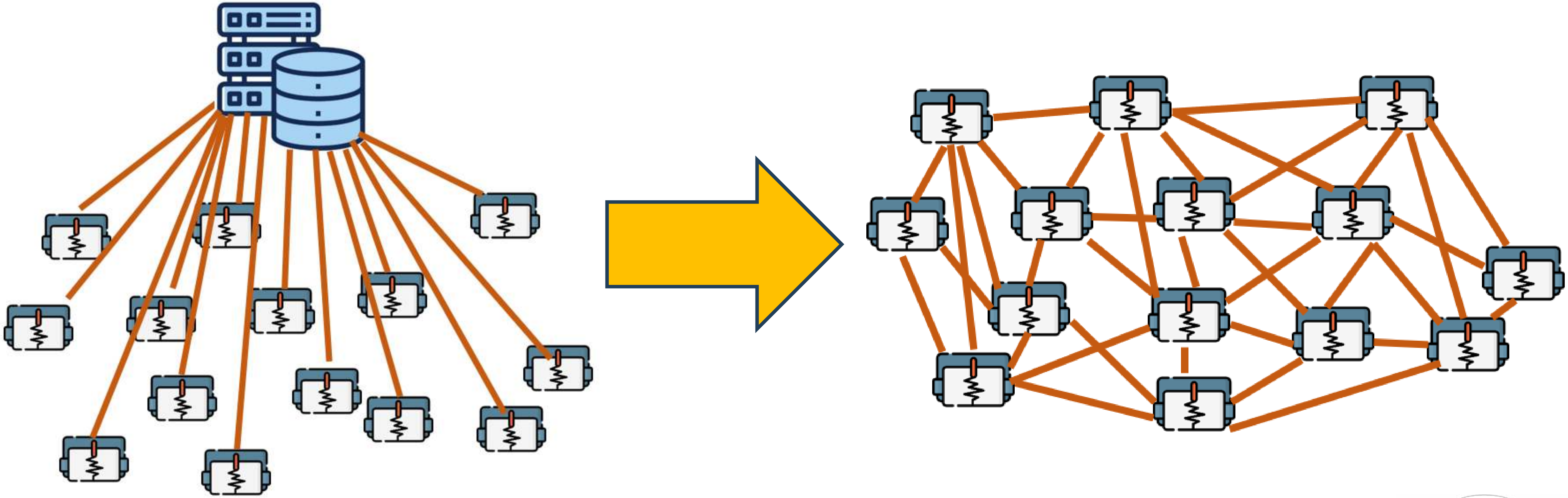
Earthquake Early Warning



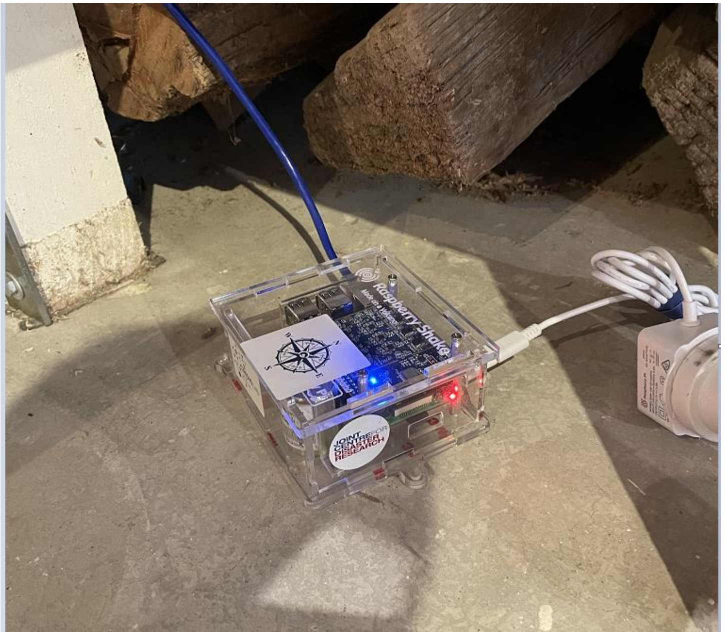
Traditional Approach to EEW Alert Generation & Dissemination

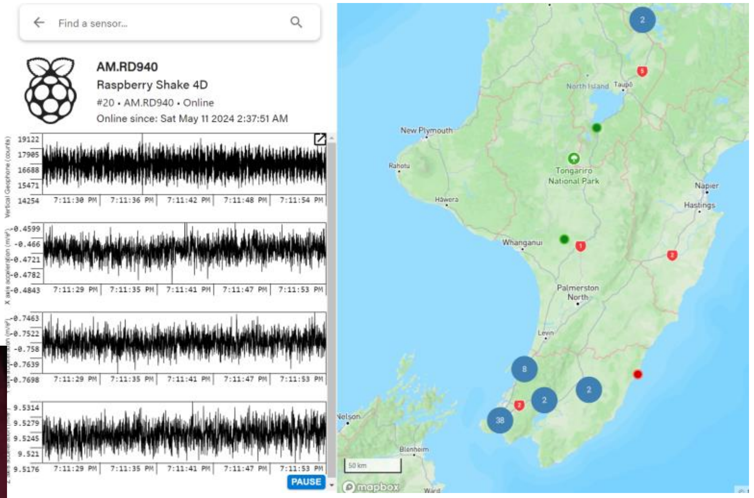


Mesh Network Driven Decentralised Data Processing at the Edge

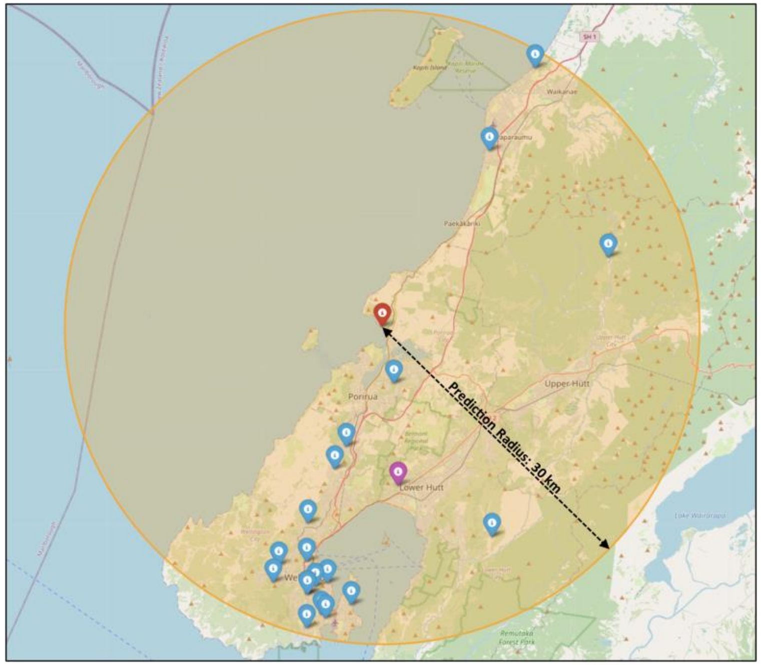


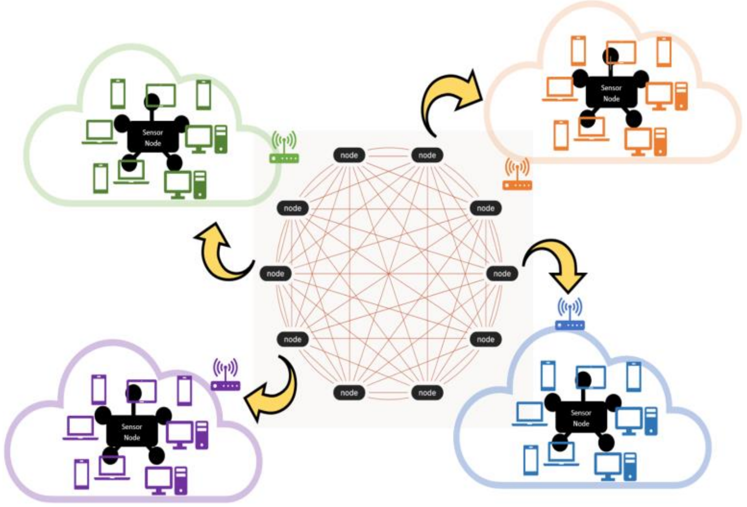
Low-cost Sensors in the Community

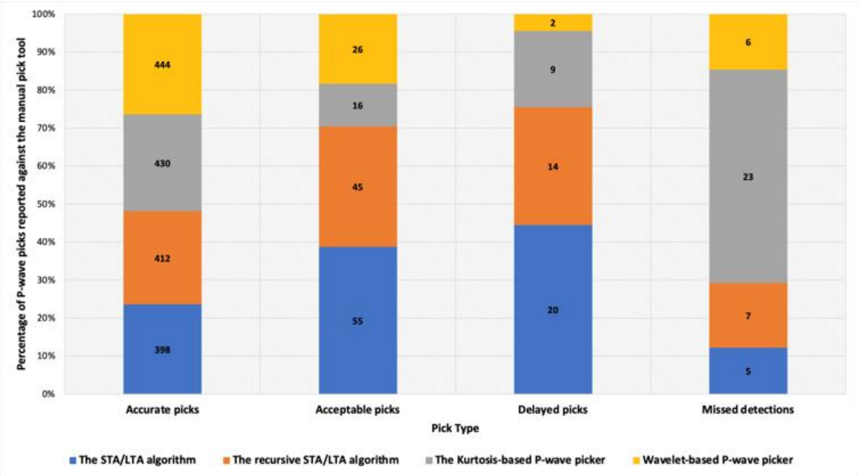




Node-Level Detection and Alert Generation







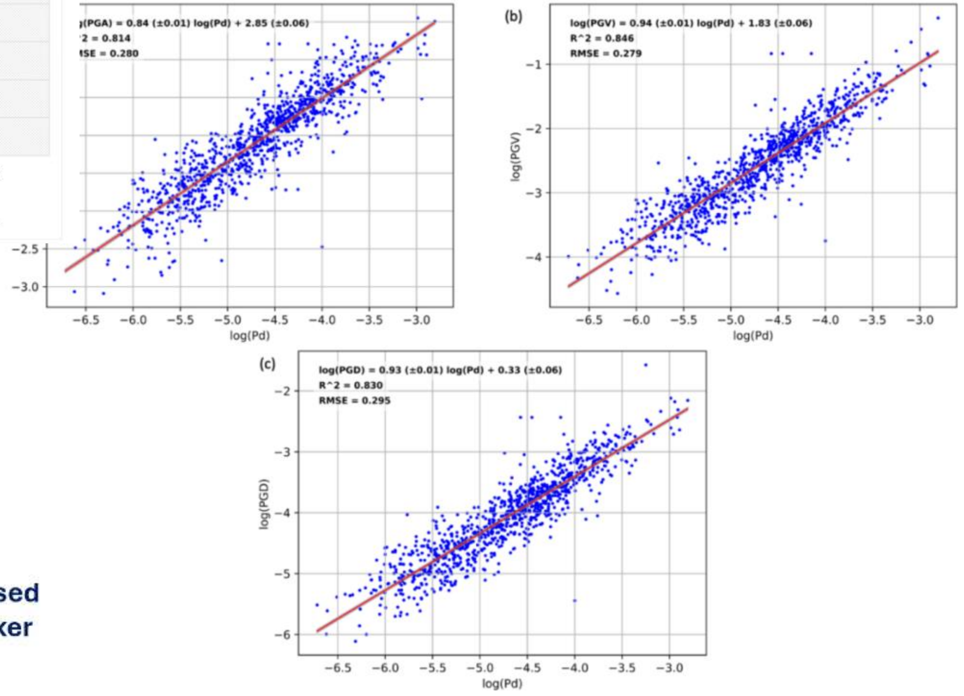
False Detections

Algorithms
The standard STA/LTA
Recursive STA/LTA
Kurtosis-based P-wave picker
Wavelet-based P-wave picker

Missed Detections

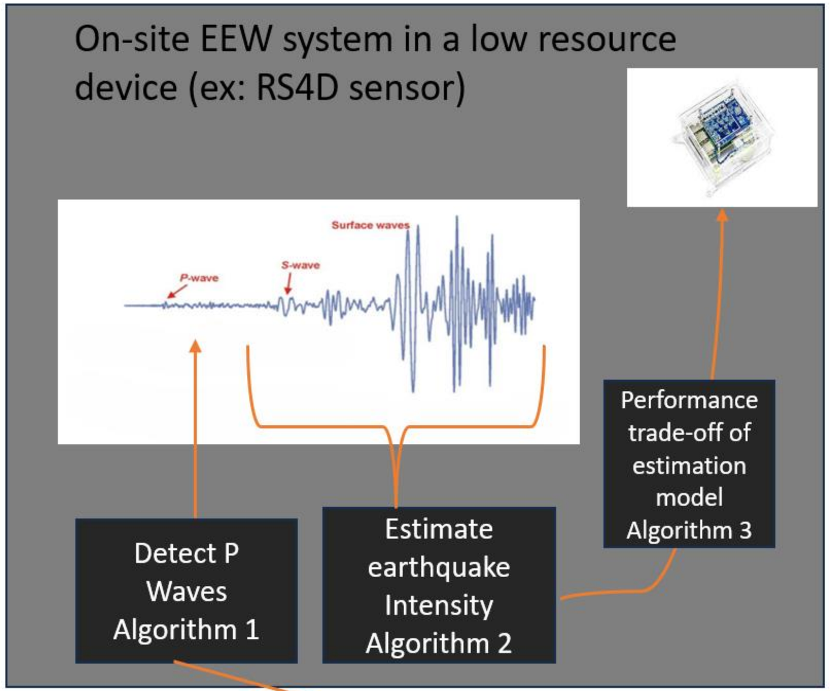
Algorithms
The standard STA/LTA
Recursive STA/LTA
Kurtosis-based P-wave picker
Wavelet-based P-wave picker

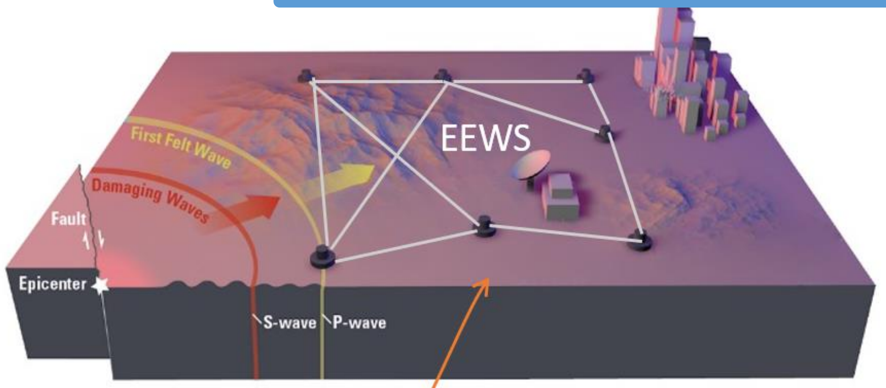
Wavelet-based P-wave picker

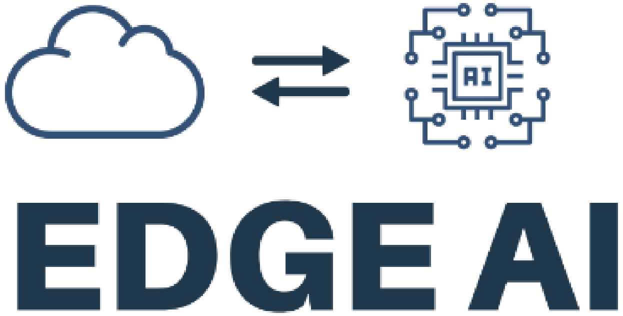


Machine Learning Models for Resource-Constrained Edge Devices of On-site EEWS

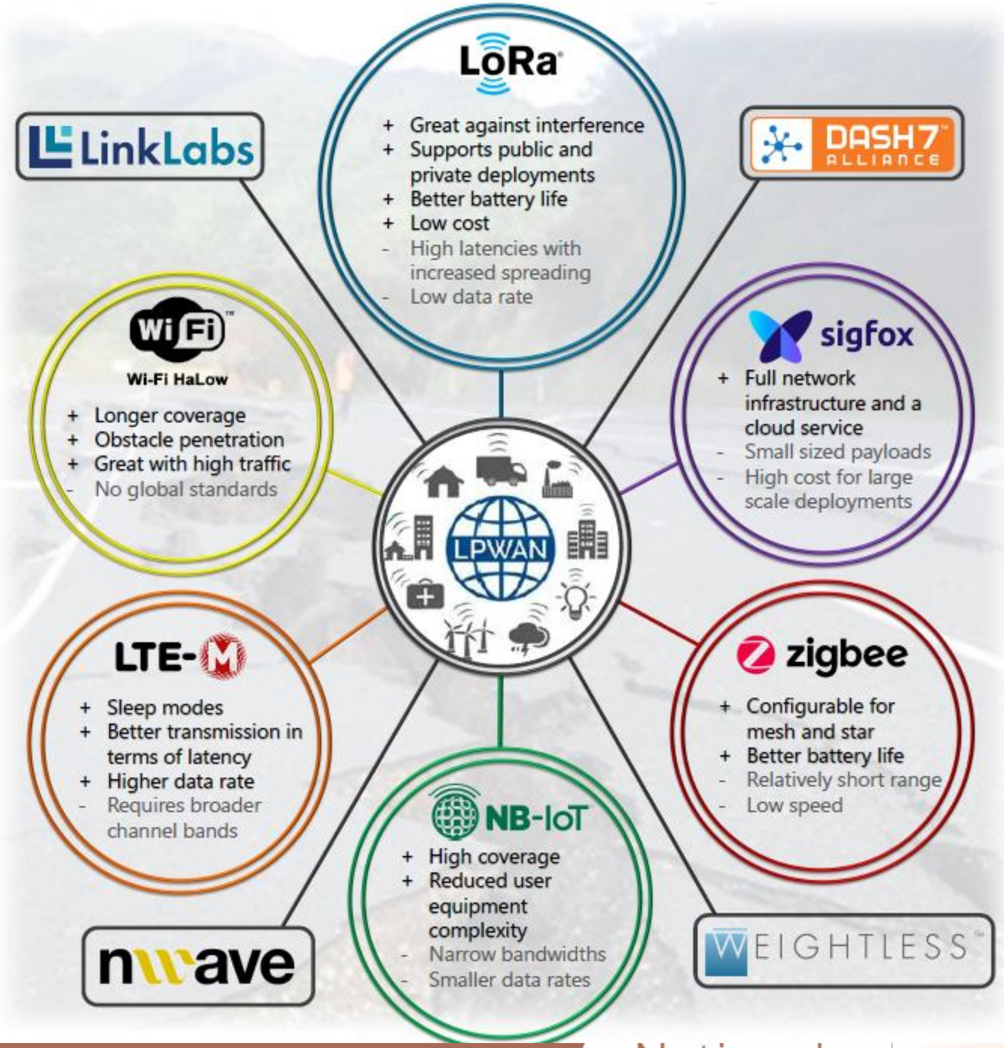
Develop reliable ML algorithms for
1. P Wave-based earthquake detection
2. Earthquake intensity predictions

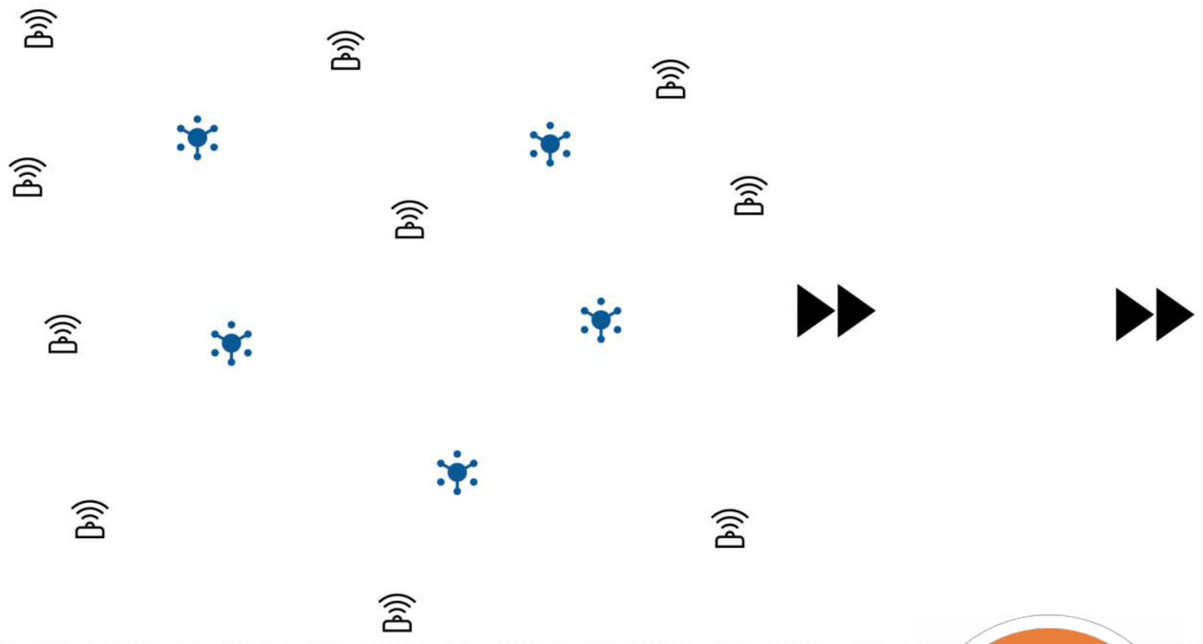






Alternative Long-Range Data Communication Solutions When Limited or No-access to the Internet





National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Using earthquake simulators to understand earthquake and tsunami hazard

Andy Nicol, Bill Fry, Andy Howell, Camilla Penney, Bruce Shaw, Laura Hughes, Jade Humphrey, Jack Williams, Mark Stirling (and 13 others)

UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha

TE PŪ AO GNS SCIENCE

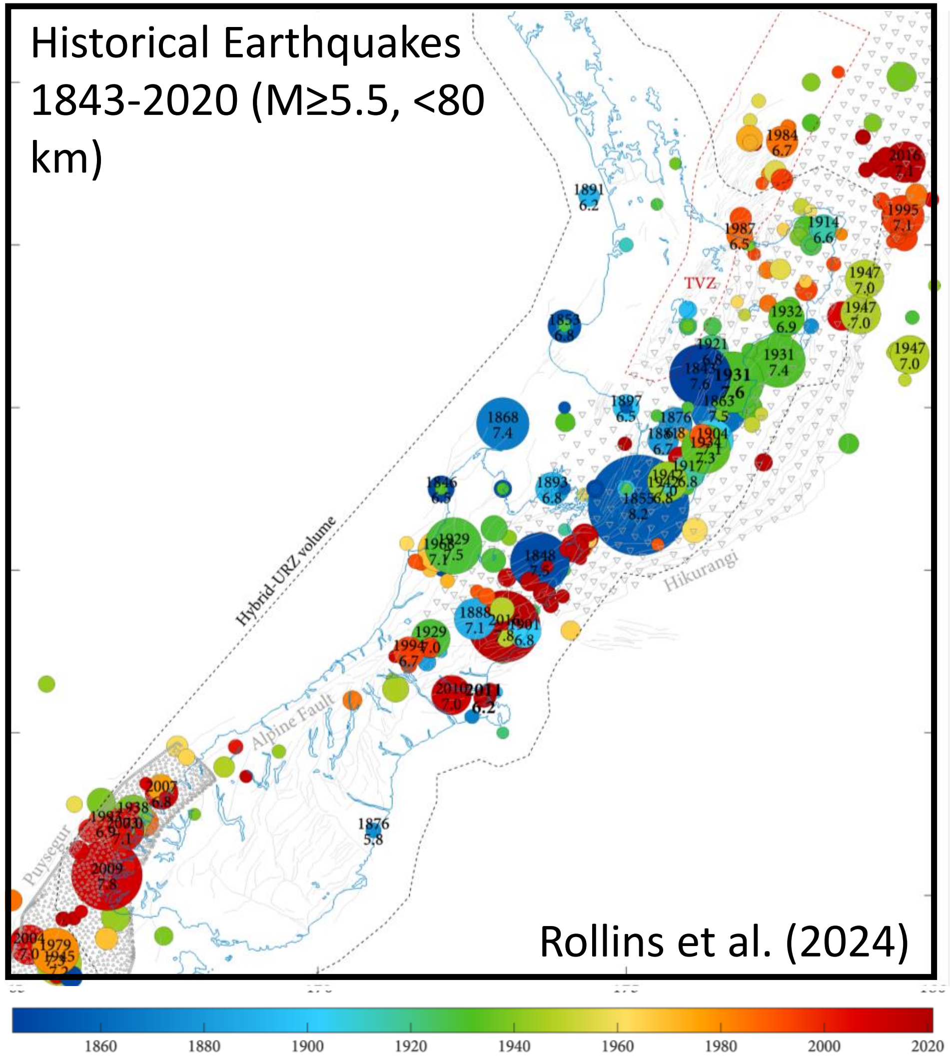
NIWA Taihoro Nukurangi

Lamont-Doherty Earth Observatory COLUMBIA UNIVERSITY | EARTH INSTITUTE

VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA

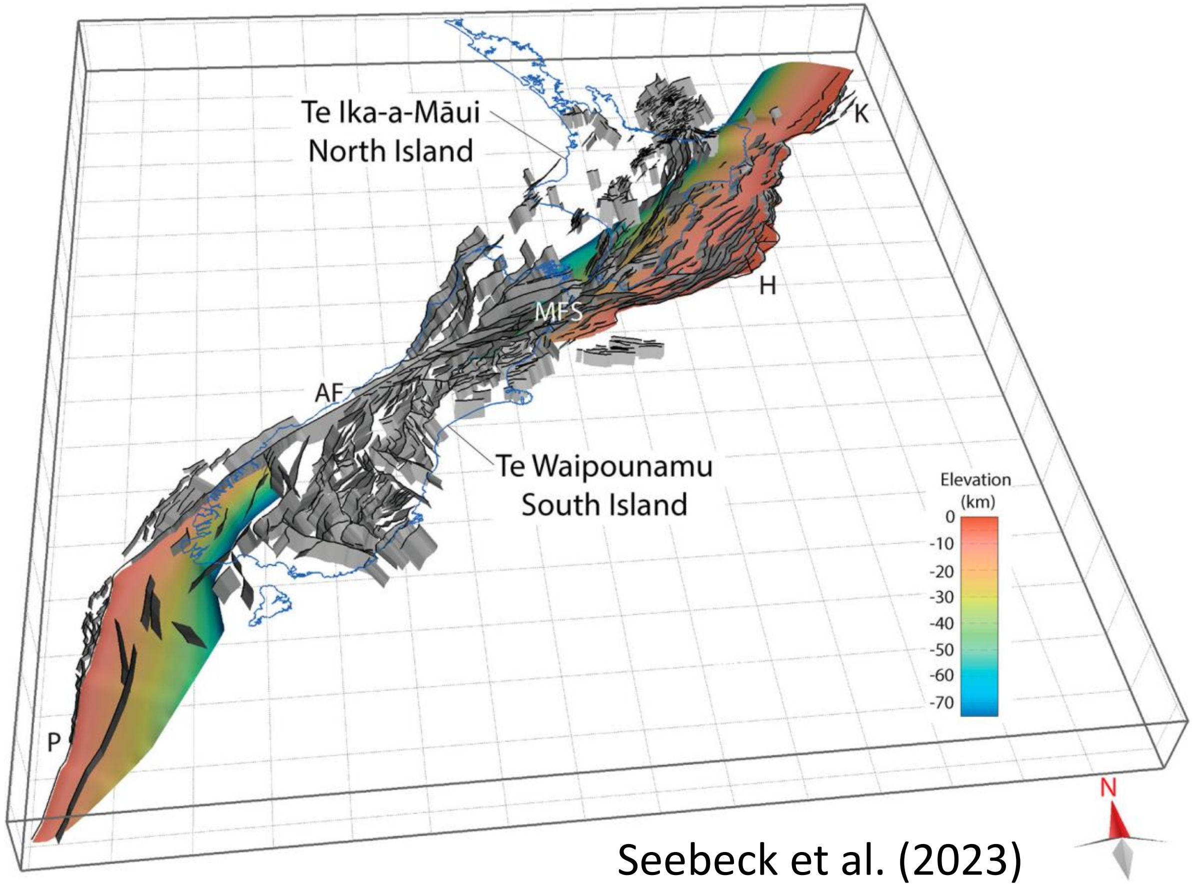
RNC Symposium 2024

Earthquake and Tsunami Hazard Forecasts



- **Seismic hazard information is typically derived from historical and prehistorical earthquakes.**
- **Datasets have limitations.**
- **Historical record short duration (~180 yrs).**
- **Paleoarthquake information for <100 of 880 known active faults (~<10%).**
- **Uncertainty about what earthquakes are possible/likely.**

Earthquake Simulators – What, How & Why?



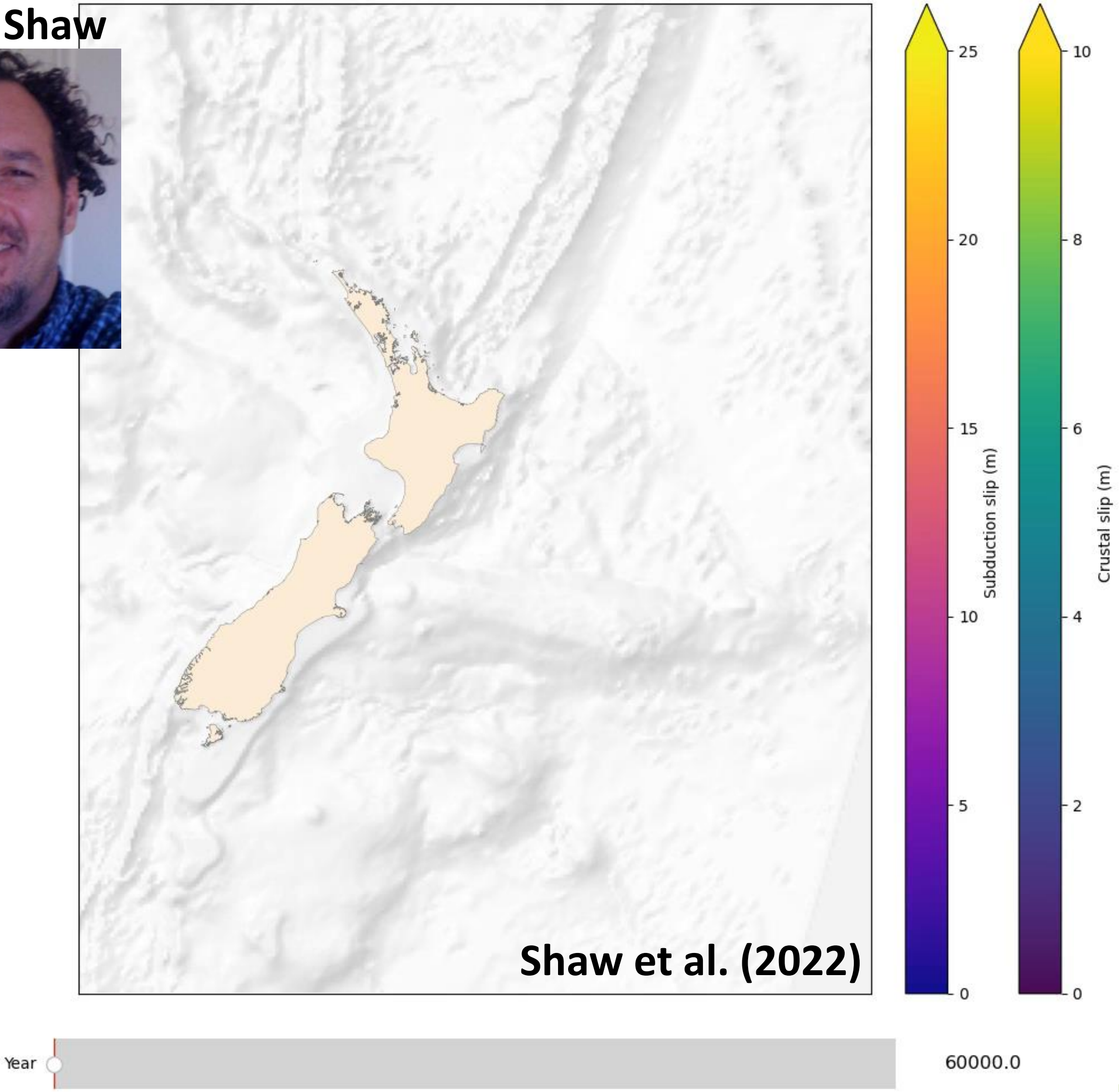
Seebeck et al. (2023)

RNC contributed to building of A-NZ Community Fault Model (~880 faults).

- **Earthquake simulators - computer programs that use physics to produce synthetic earthquakes.**
- **'First-generation' multi-cycle models using RSQSim software.**
- **Use 3D representations of known faults and earthquake slip, timing and slip rate for many faults across Aotearoa-NZ.**
- **Models produce displacement and shaking of ground surface.**
- **Results used to model earthquake, tsunami, landslide and sea-level hazards (multi-peril – see Bill Fry's talk tomorrow).**

Earthquake Simulator Models for Aotearoa New Zealand

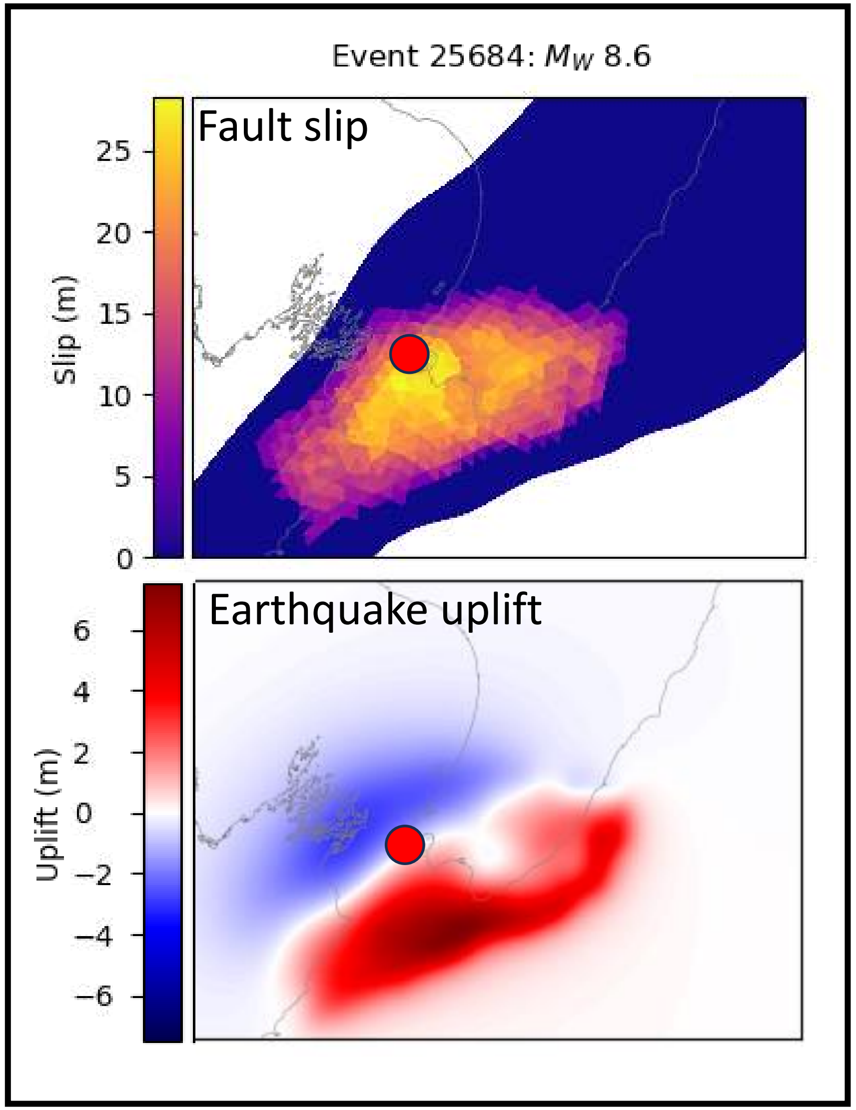
Bruce Shaw



Shaw et al. (2022)

- Generated in total 7 models for all of A-NZ and specific regions.
- Models run for up to 1 Million years (most commonly 200-500 thousand years).
- Models contain millions of earthquakes >M5.5.
- Synthetic earthquakes show many of the features of real earthquakes.
- Testing and model improvements ongoing.

Earthquake Simulator Models for Aotearoa New Zealand



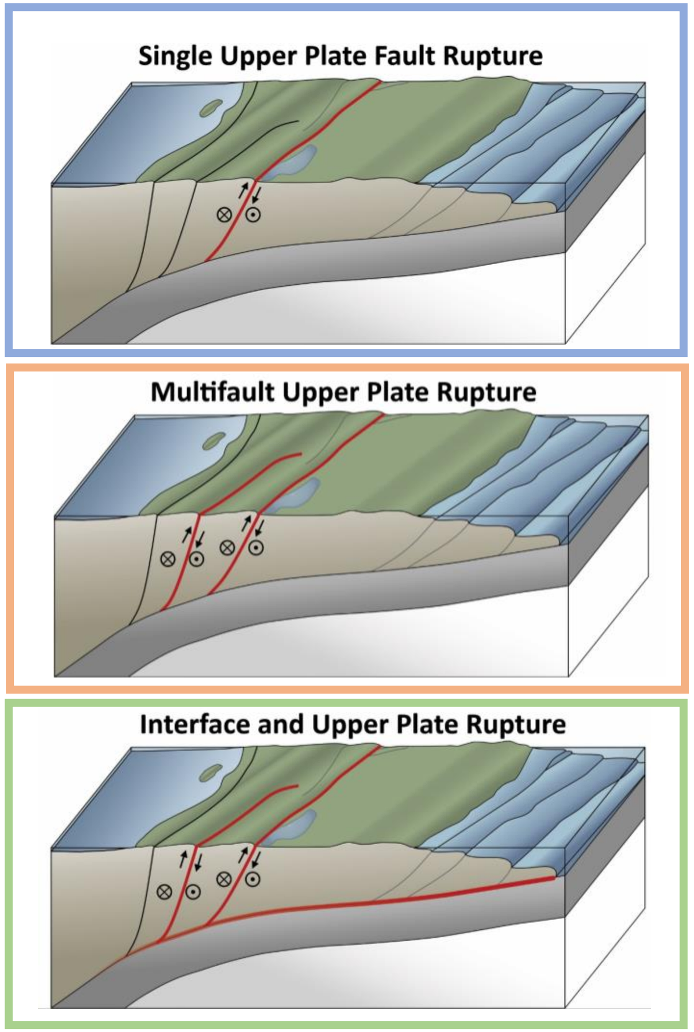
Simulator catalogues used for tsunami hazard modelling (this study, RCET), inform aspects of earthquake hazard in NSHM, develop of earthquake scenarios for central A-NZ (e.g., Building Resilience to earthquake sequences), estimate sea-level changes (e.g., Our Changing Coast).

Case Study Applications

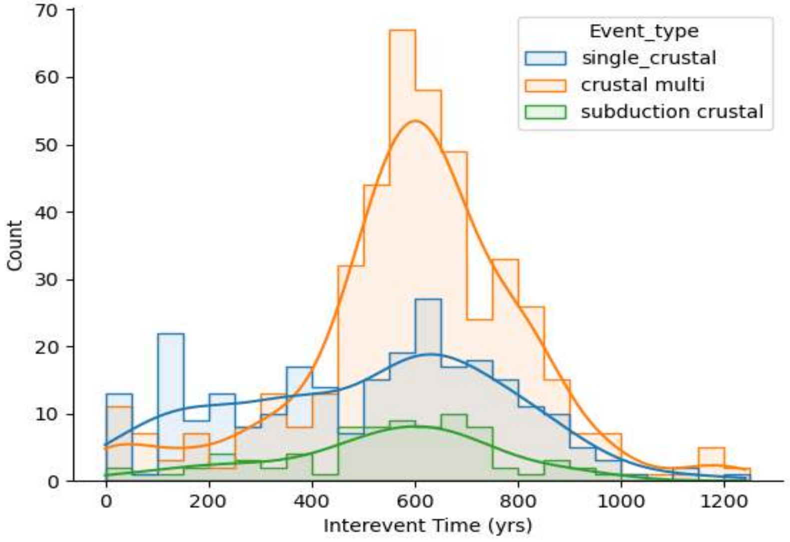
1) **Understanding relationships between subduction and upper crust earthquakes.**
2) **Identifying potential earthquake scenarios and sequences.**
3) **Quantifying seismic hazards in low seismicity regions.**
4) **Modelling tsunami wave heights.**

1) Relationships Subduction Thrust and Upper Plate Earthquakes

Wellington Region



Wellington Fault Eqs (>M7)



Jade Humphrey

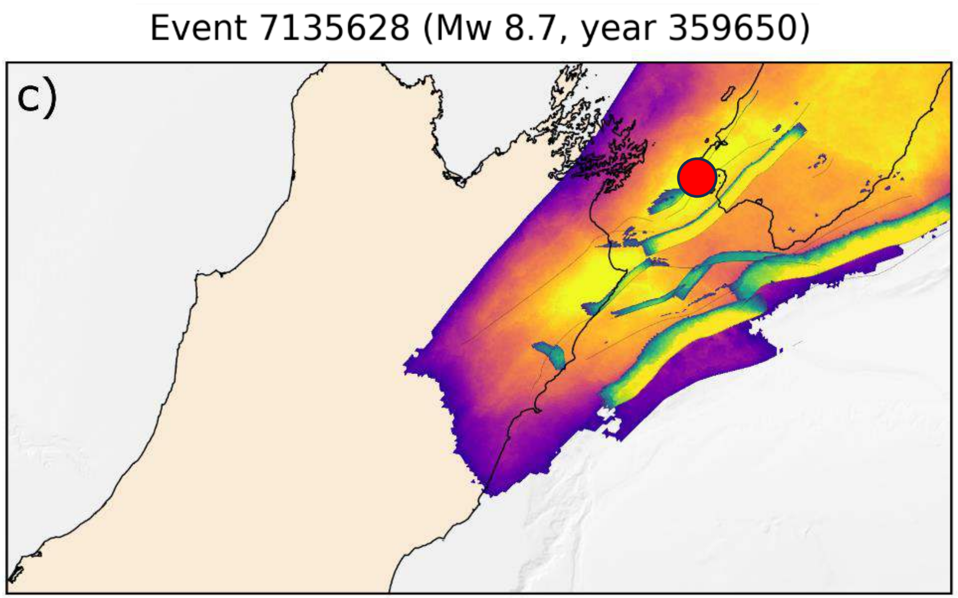
Camilla Penney

- **Most large earthquakes (>M7) involve multiple faults (i.e., Kaikōura type).**
- **Co-rupture of subduction interface and upper plate faults common.**

Jade Humphrey Wellington Collaboratory meeting for 18 June 2024

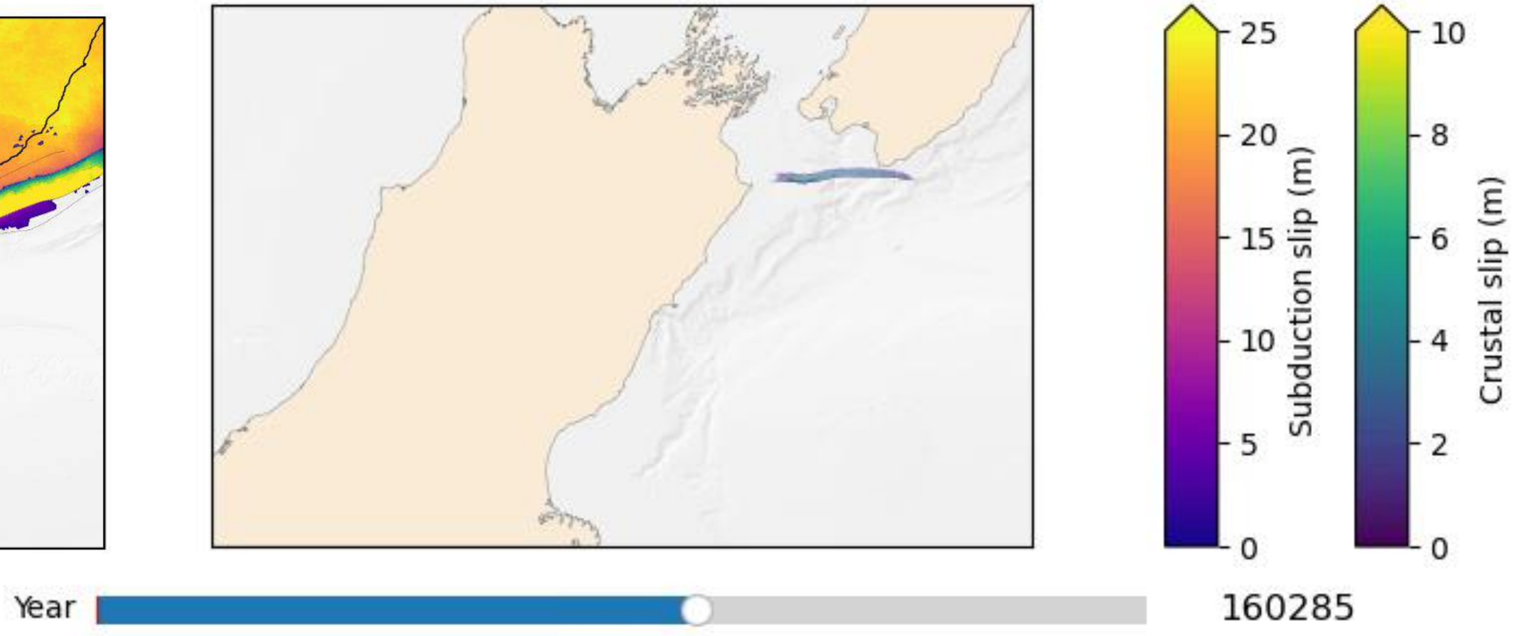
2) Earthquake Scenarios and Sequences

Earthquake Scenarios



Camilla Penney **Andy Howell**

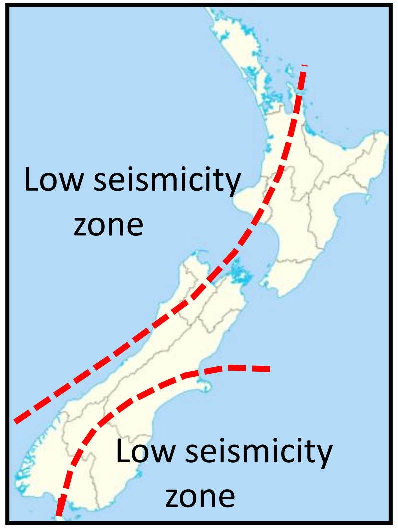
Earthquake Sequences

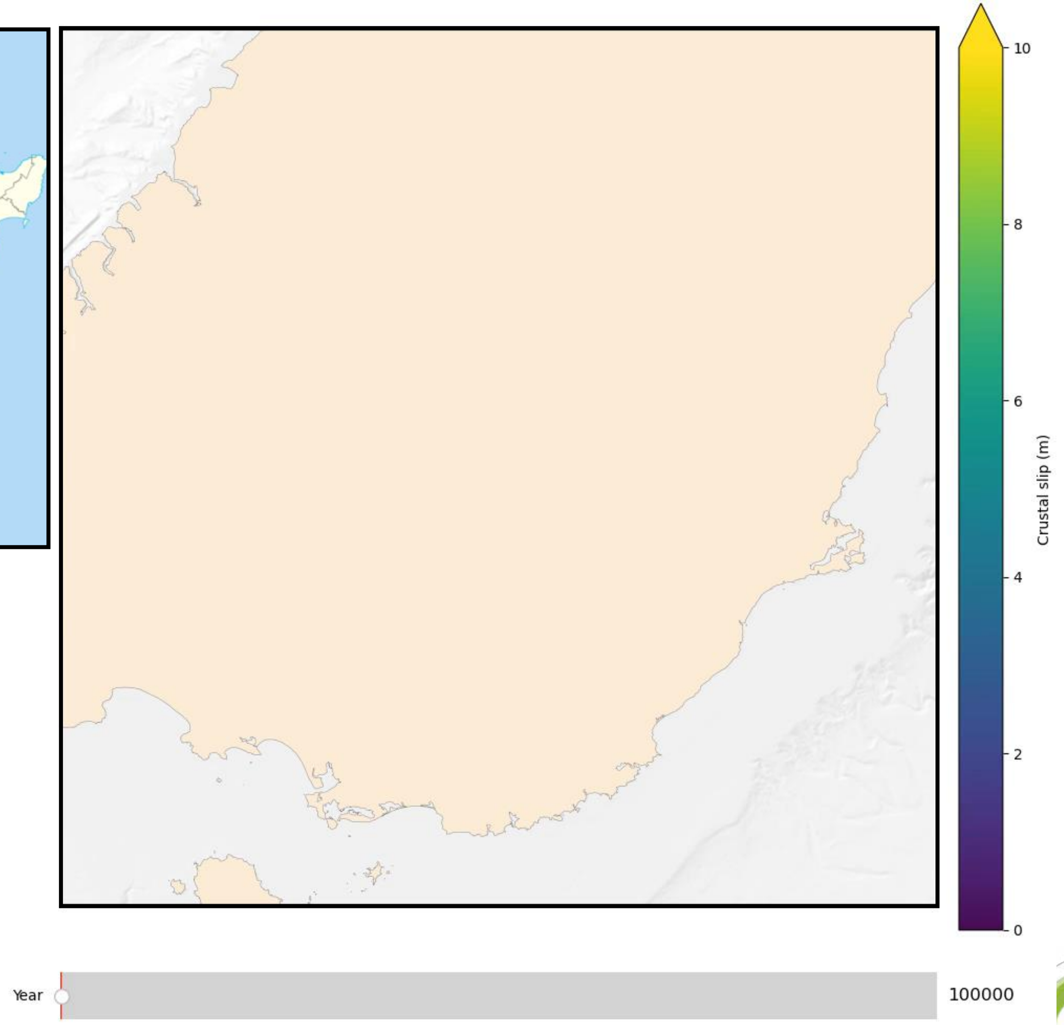


Penney et al., in prep

3) Simulated Earthquakes in Low Seismicity Areas

- Otago seismicity model.
- Model run 1 million years to investigate many earthquakes.
- Large dataset suitable for statistical analysis.
- Comparison with observations and NSHM rupture sets being led by Jack Williams.



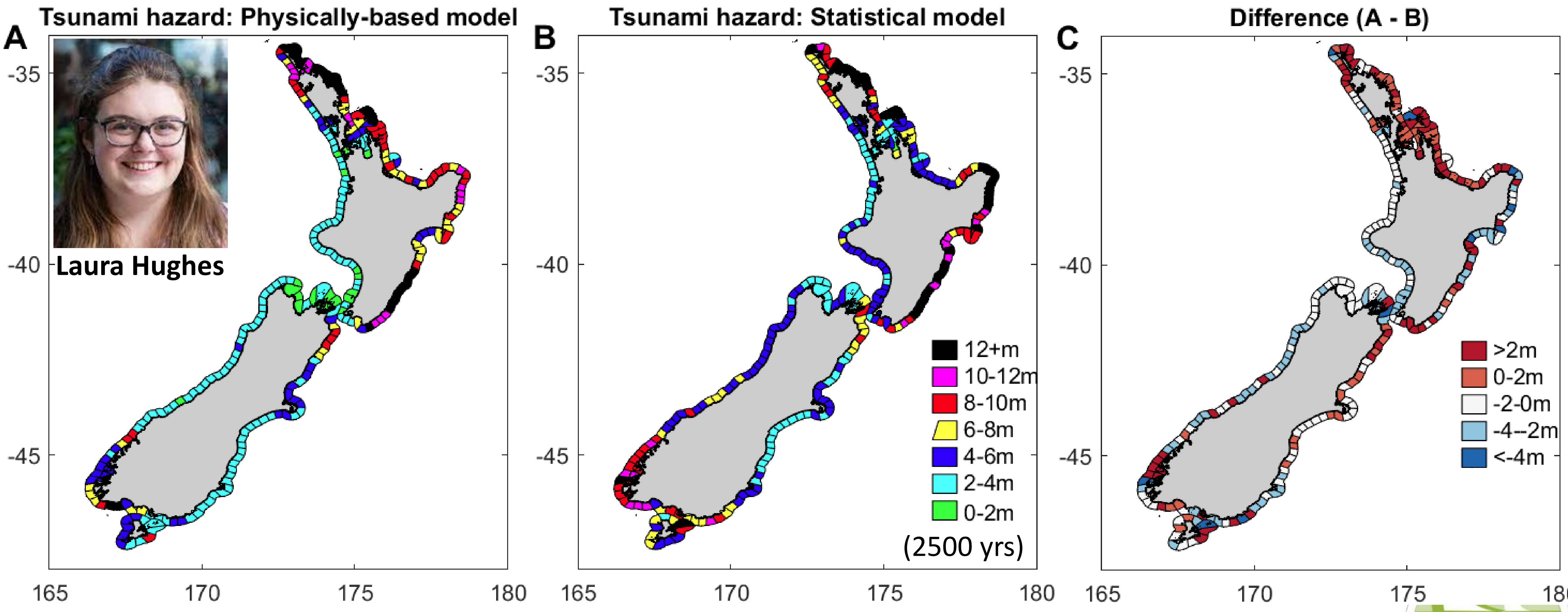


Jack Williams

Mark Stirling

Andy Howell

4) Synthetic Earthquake Catalogues for Tsunami Hazard Assessments



Concluding remarks

- During RNC we have produced multiple synthetic earthquake catalogues for Aotearoa New Zealand.
- Earthquake models have widespread applications including earthquakes, tsunami, landslides and sea rise (See Bill Fry talk tomorrow).
- The earthquakes may provide key information about earthquake processes, earthquake sequences and earthquake scenarios.
- Our earthquake models are ‘first-generation’. Future research will develop the hazard/risk outputs and test their ability to replicate real earthquake processes.

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

So we have some building data, now what?

Max Stephens, Senior Lecturer
University of Auckland

Amin Ghasemi, Soon to be PhD
University of Auckland

Many others
Massey, Victoria, etc.

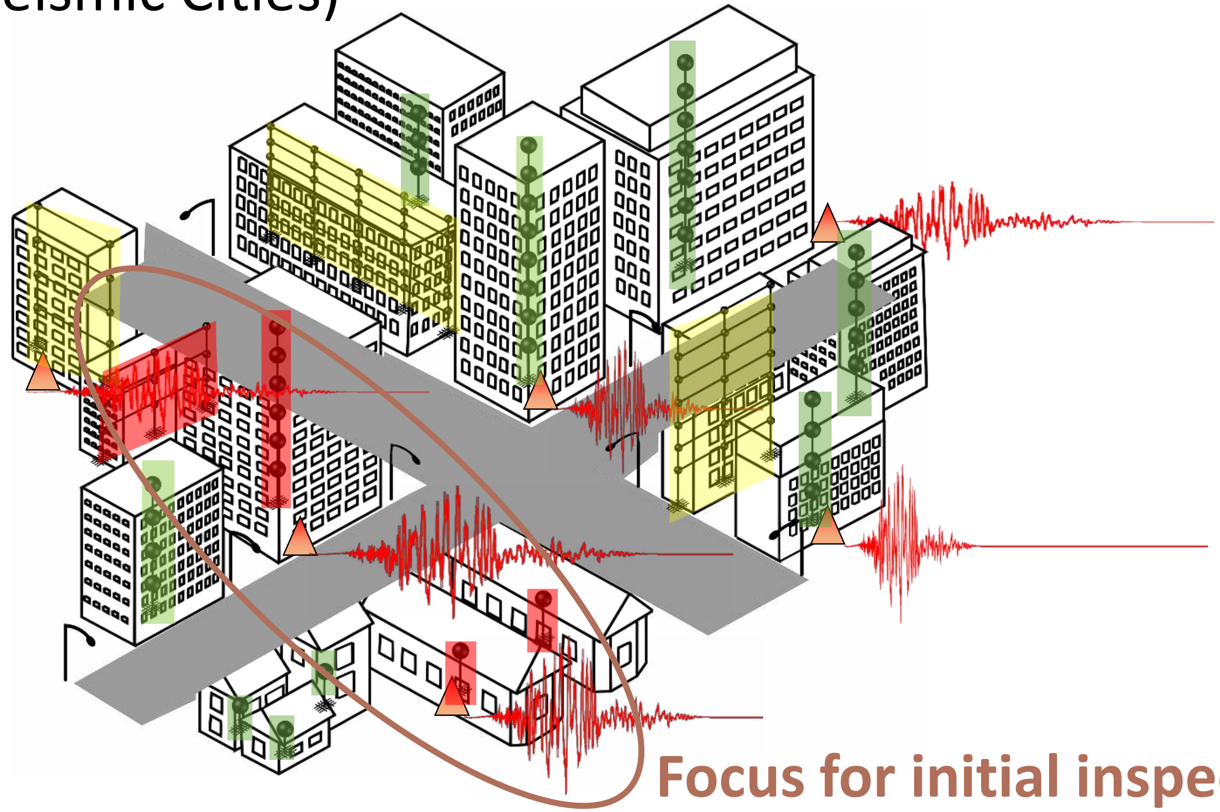
RNC Symposium 2023

QuakeCoRE
NZ Centre for Earthquake Resilience

Toka Tū Ake EQC

A Wellington near real-time impact tool

In mid 2016, the concept of developing a near real-time seismic impact tool for Wellington was proposed (Smart Seismic Cities)



Focus for initial inspections

Then this happened

Kaikōura Earthquake 2016 – M7.8 >200km from Wellington, New Zealand

10% of commercial space in CBD was closed, 20 demolitions

NEW ZEALAND (/NEWS/NATIONAL) / KAIKŌURA EARTHQUAKE (/NEWS/KAIKOURA-EARTHQUAKE)

New round of earthquake checks ordered for 80 Wellington buildings

8:10 am on 20 December 2016

rter

Anne Gibson

Property editor of the NZ Herald

Revealed: 16 Wellington blocks shut by quake

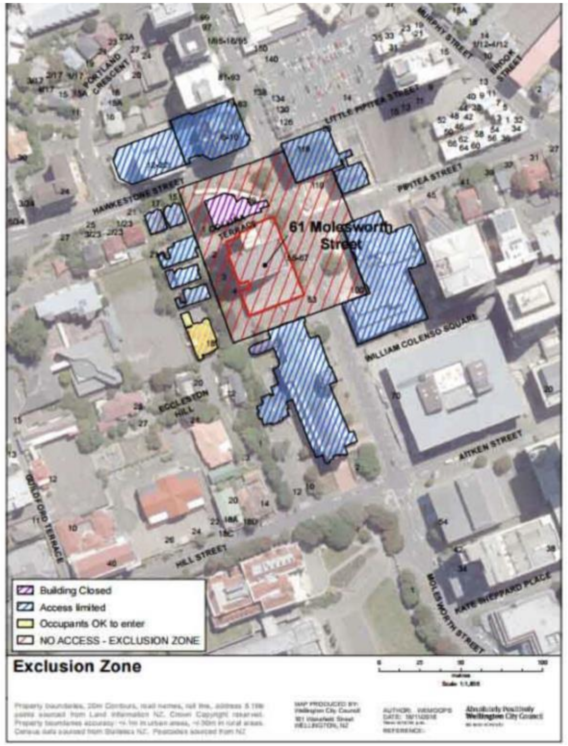
Wednesday, 07 December 2016

The New Zealand Herald

Wellington Reading Cinemas carpark building 'likely to collapse' in large aftershock

By Susan Strongman in Wellington, NZME

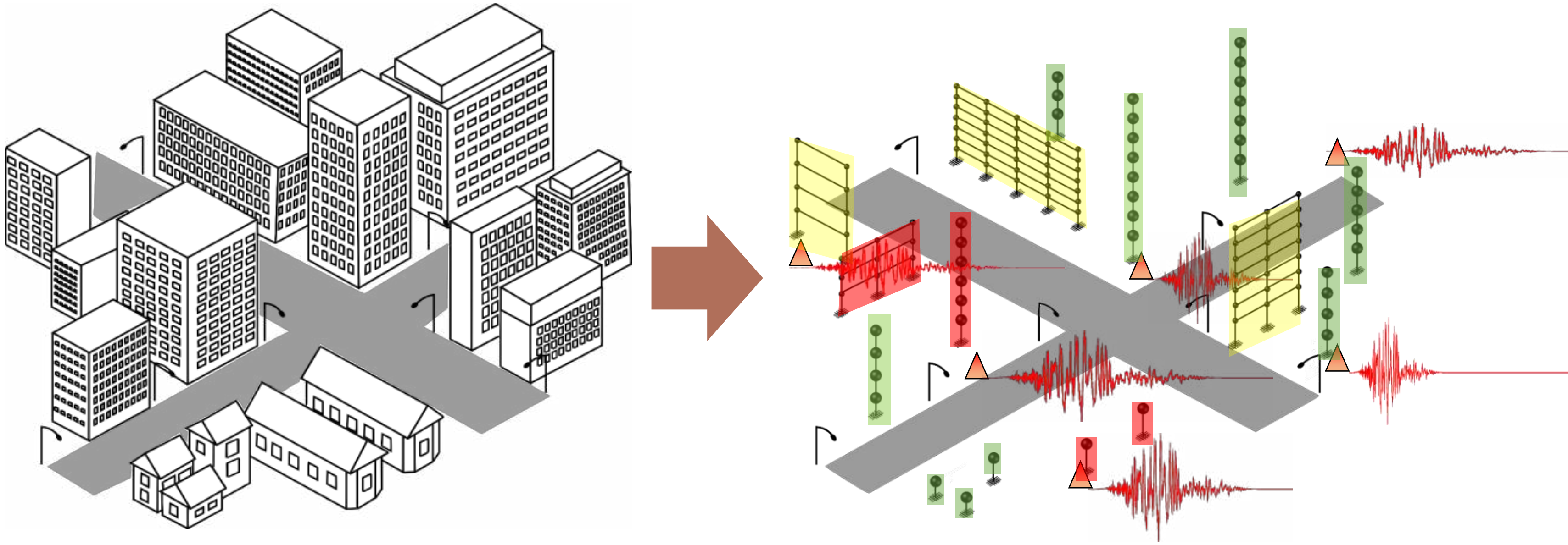
Cordons



Ok, so it seems like this might be useful

Clearly a useful tool following earthquakes

Not clear exactly where we wanted to go after data collection…

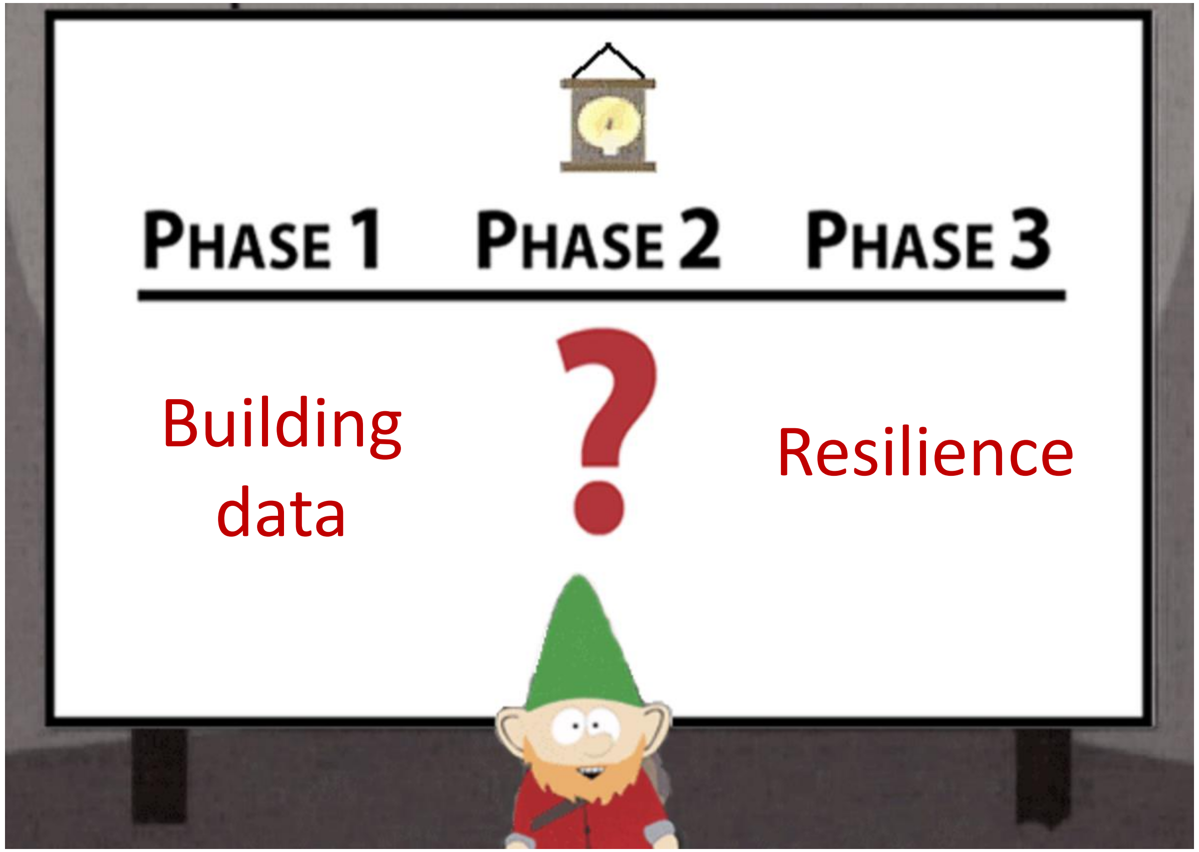


Ok, so it seems like this might be useful

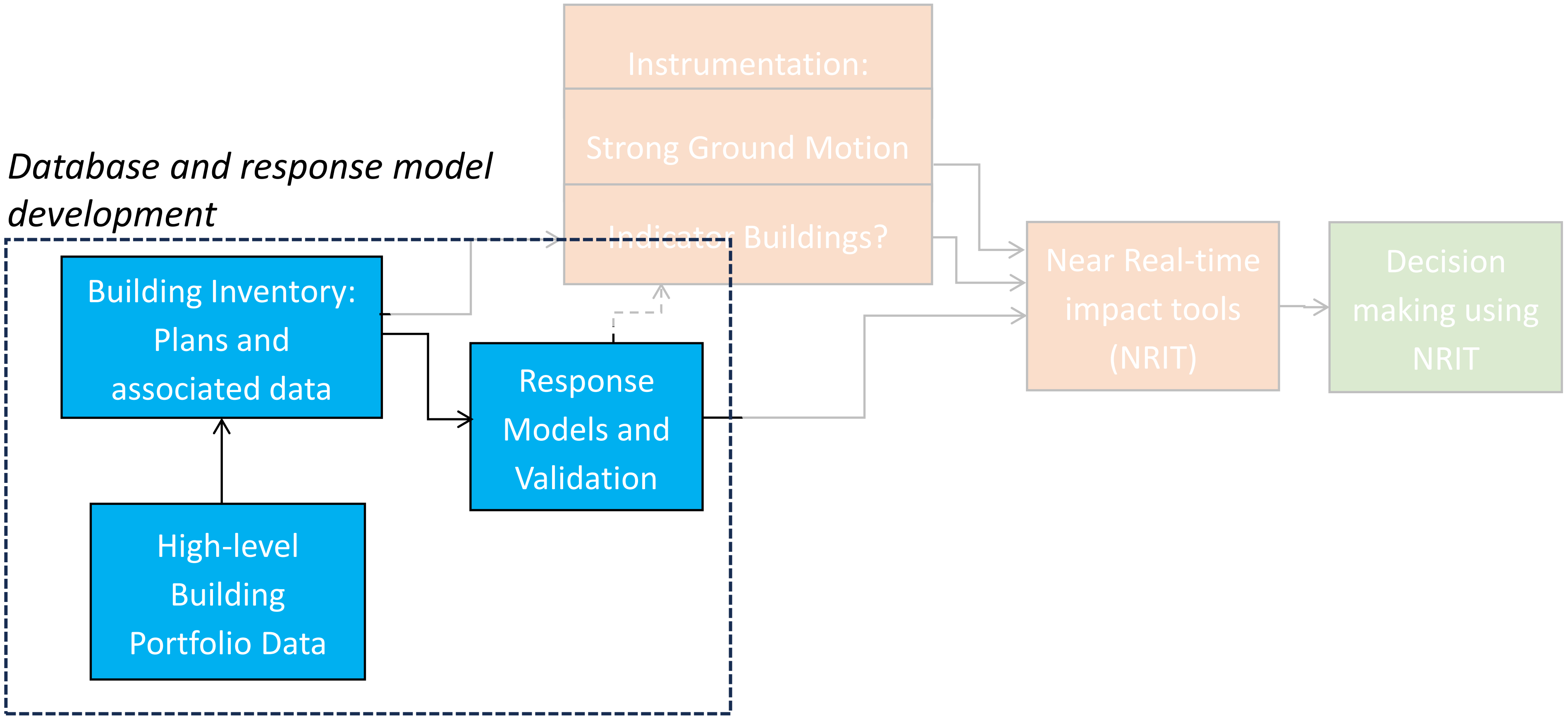
Clearly a useful tool following earthquakes

Not clear exactly where we wanted to go after data collection…

Understanding that question mark is important



The original plan



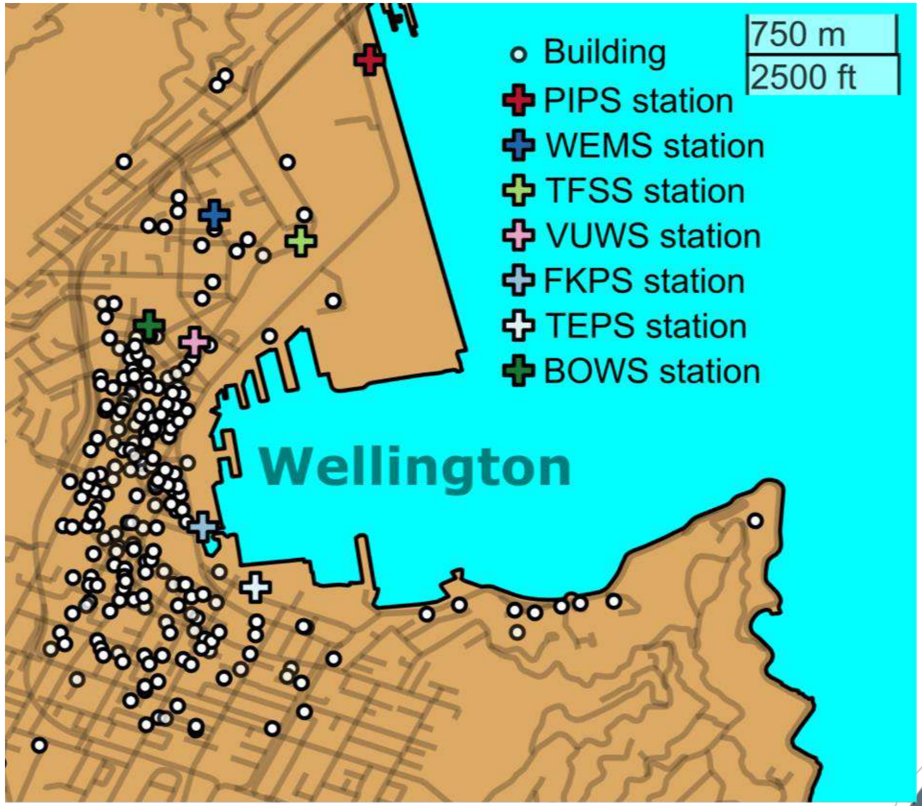
The Wellington building inventory

'Simple' objective was to develop an inventory of concrete buildings over 5-storeys

Timeline This took so long, we basically stopped here!

- **2016** - WCC provides 247 drawing sets
- **2017-2020** – data extraction, compiling existing databases, data quality checking, development of online interface
- **2020-2021** – adding additional response modelling parameters
- **2021** – WCC provides and additional 250 drawing sets
- **2021** – Use existing databases to add ~500 1 and 2 storey buildings

Initial tranche of buildings



The Wellington building inventory

A comment about the difficulties of using the data provided…

Proposed Industry Enlistment

QuakeCoRE
NZ Centre for Earthquake Resilience

- Structural Drawings
  - drawings for 260 buildings in hand, another 200 (approx) incoming (all vintages)
  - currently includes buildings over 5-storeys only because…
  - detailed information provided, allowing for development of informative MDOF models
  - man-hours required to parse all drawings for necessary information…
    - many hands make light work!
  - confirmation required for information within drawing packages – current and accurate

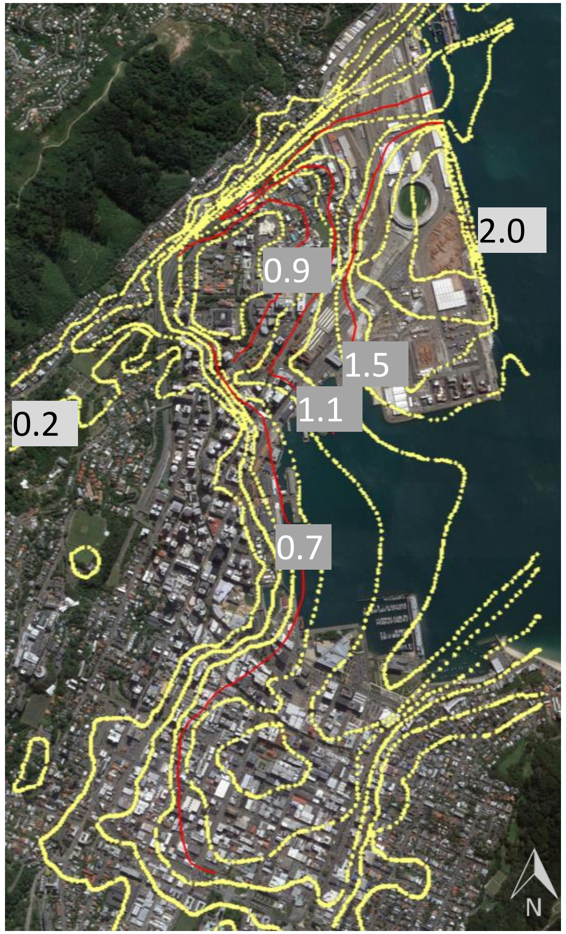
The Wellington building inventory - modified

In its original inception, site characteristics not included in the database

How do we tie earthquake acceleration demands to a given structure?

For more recent structures, how do we determine the design loads?

So we had to go back and add these…

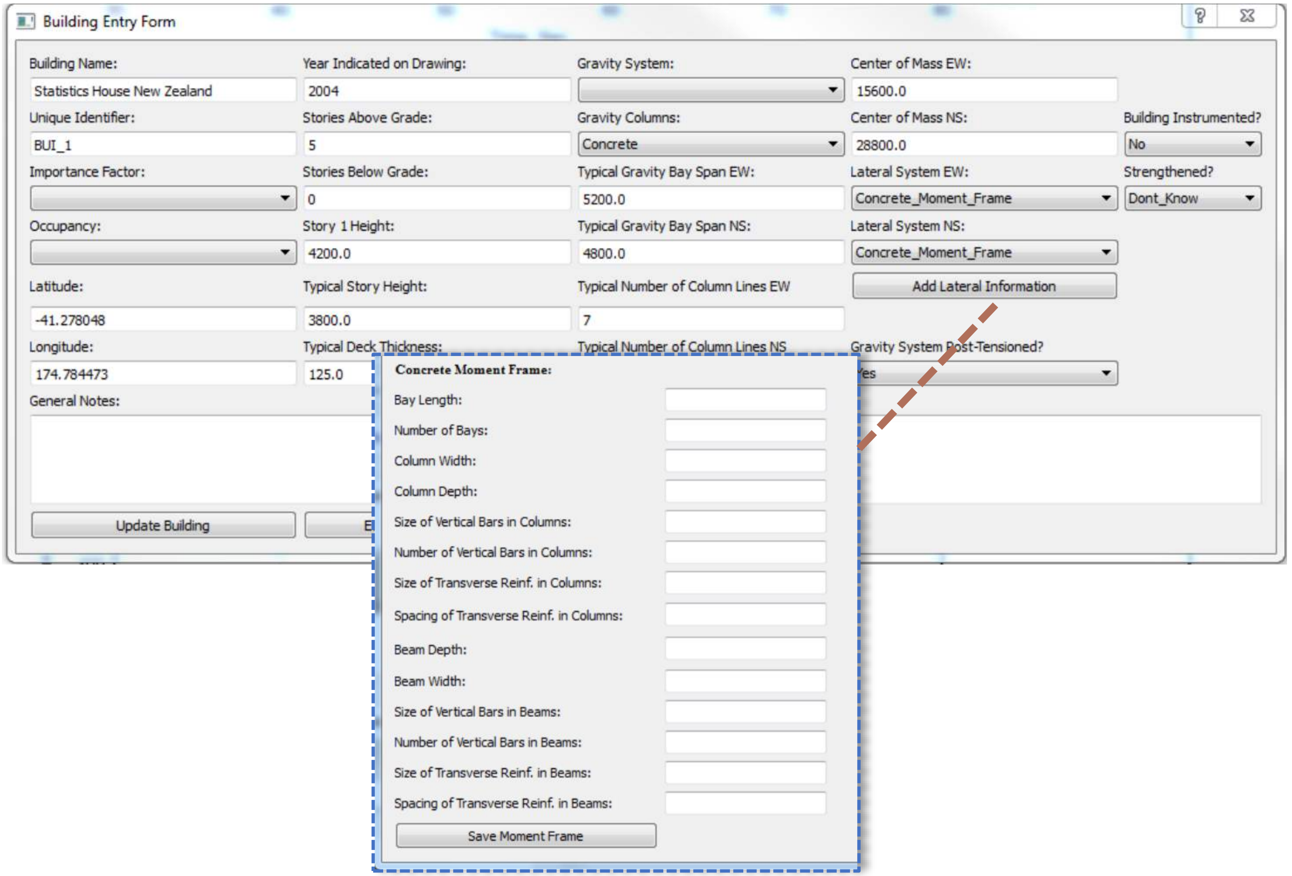


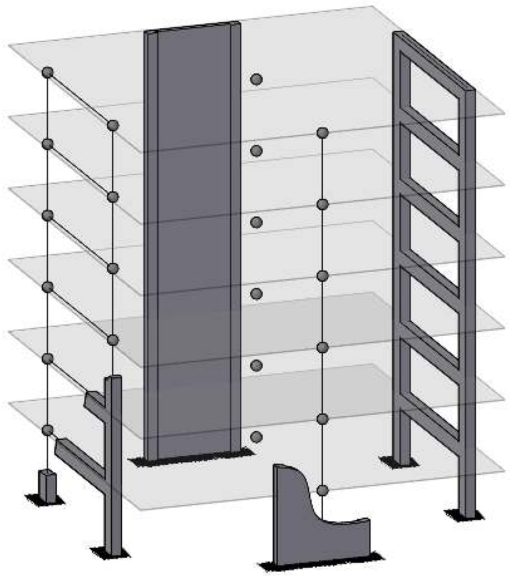
Site Period

Strong Motion Stations

Response model

We developed a GUI for data entry and automatic macro model generation…





Macro models in OpenSees,
This was the goal!

Rethinking the approach (really, after 5 years!?)

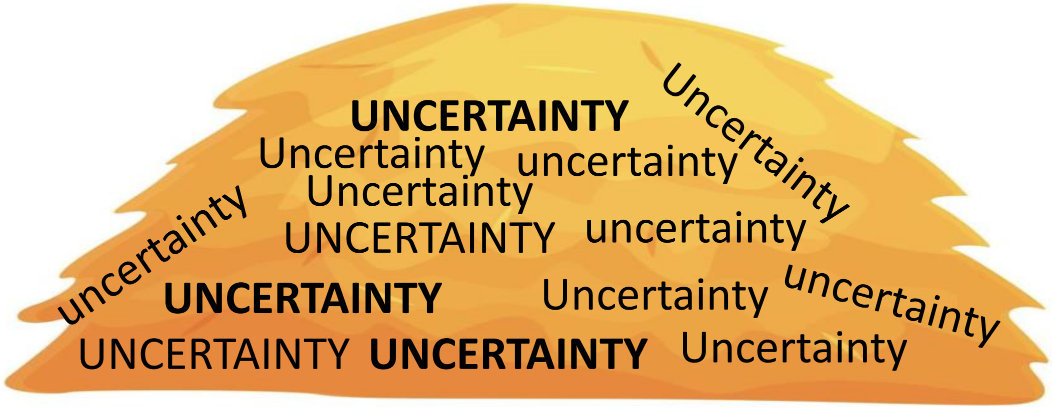
So now we have everything we need!

But do we have an uncertainty problem?

- Uncertainty in the building data
- Uncertainty in the site data
- Uncertainty in the demand data
- Uncertainty in the modelling

Does it make sense to develop a nonlinear response model for each structure?

Can we make this more practical and scalable?

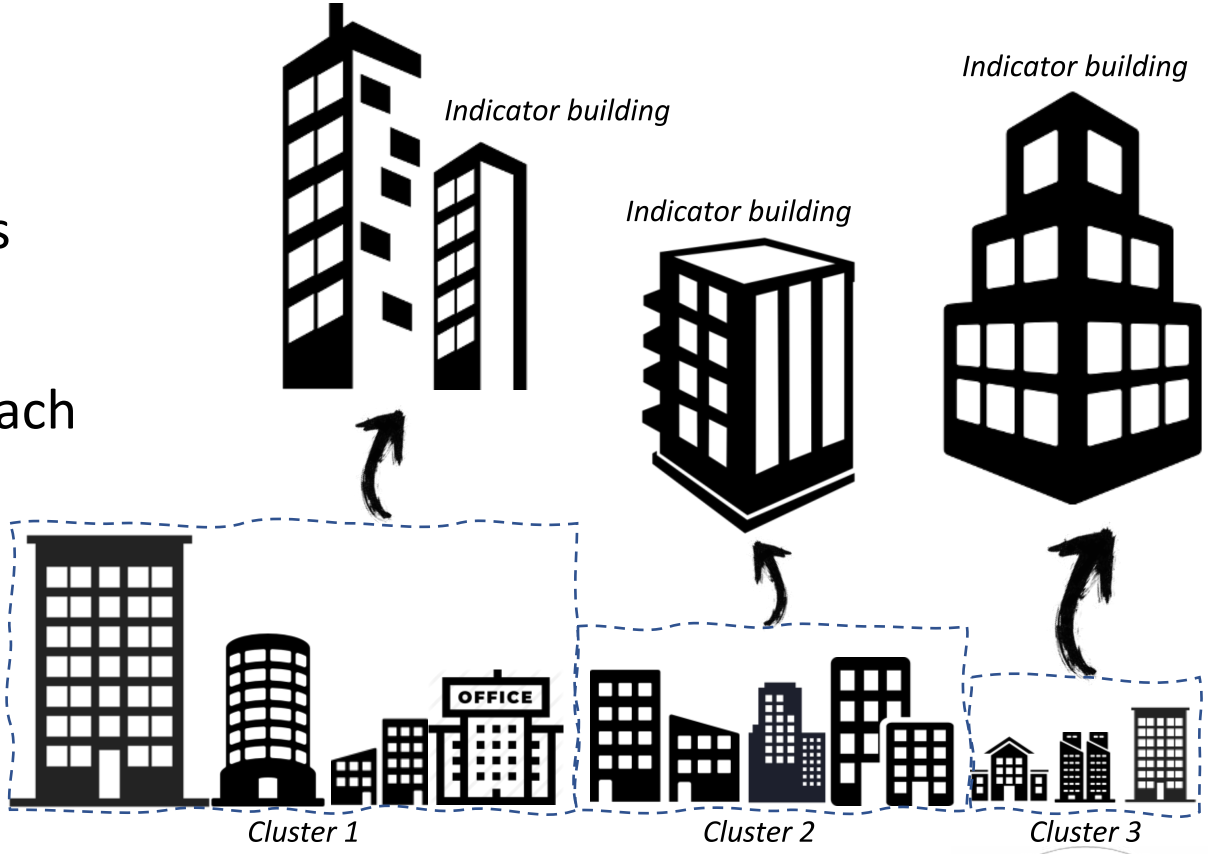


Uncertainty stack

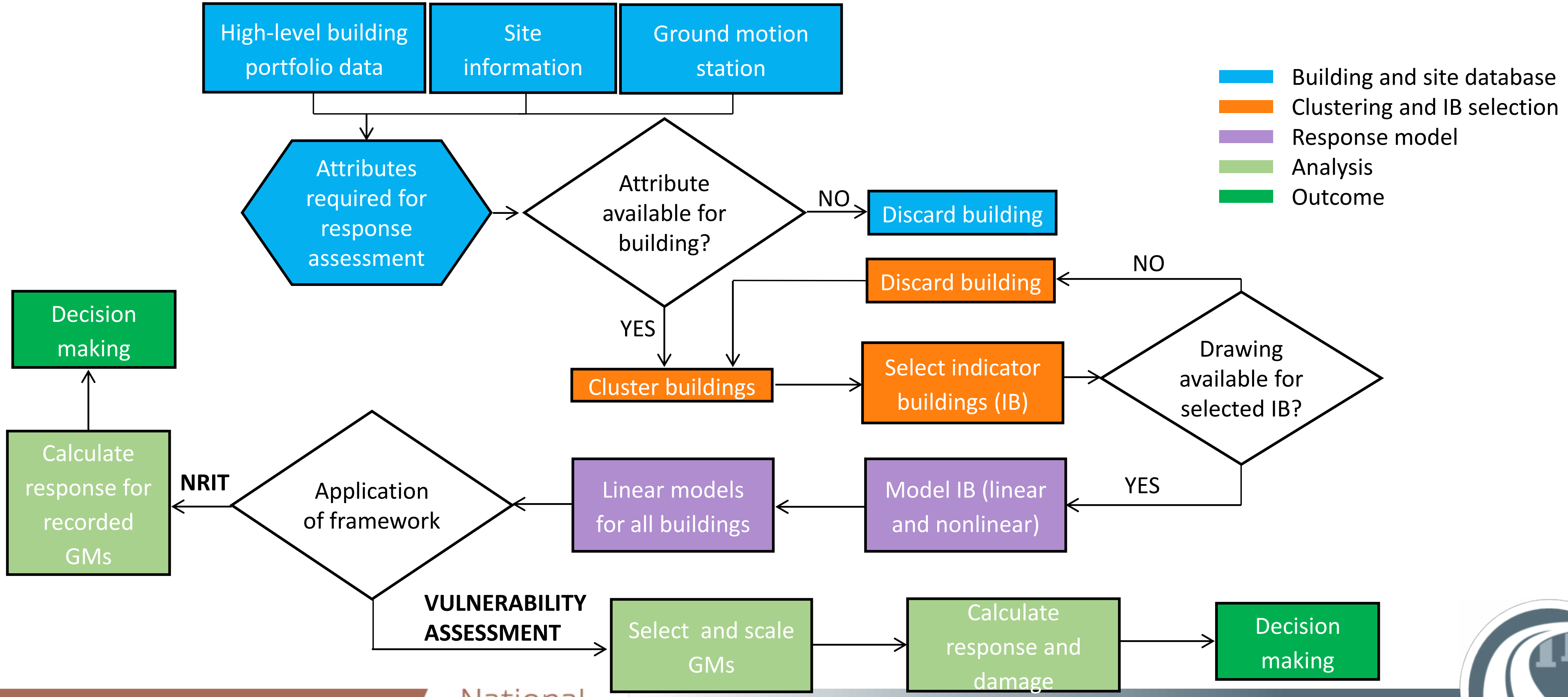
We had to modify the approach – indicator buildings

Indicator building approach:

- Cluster buildings into typologically similar groups
- Select a representative indicator building from each cluster
- Use indicator building to estimate response/damage/loss/etc. across each cluster

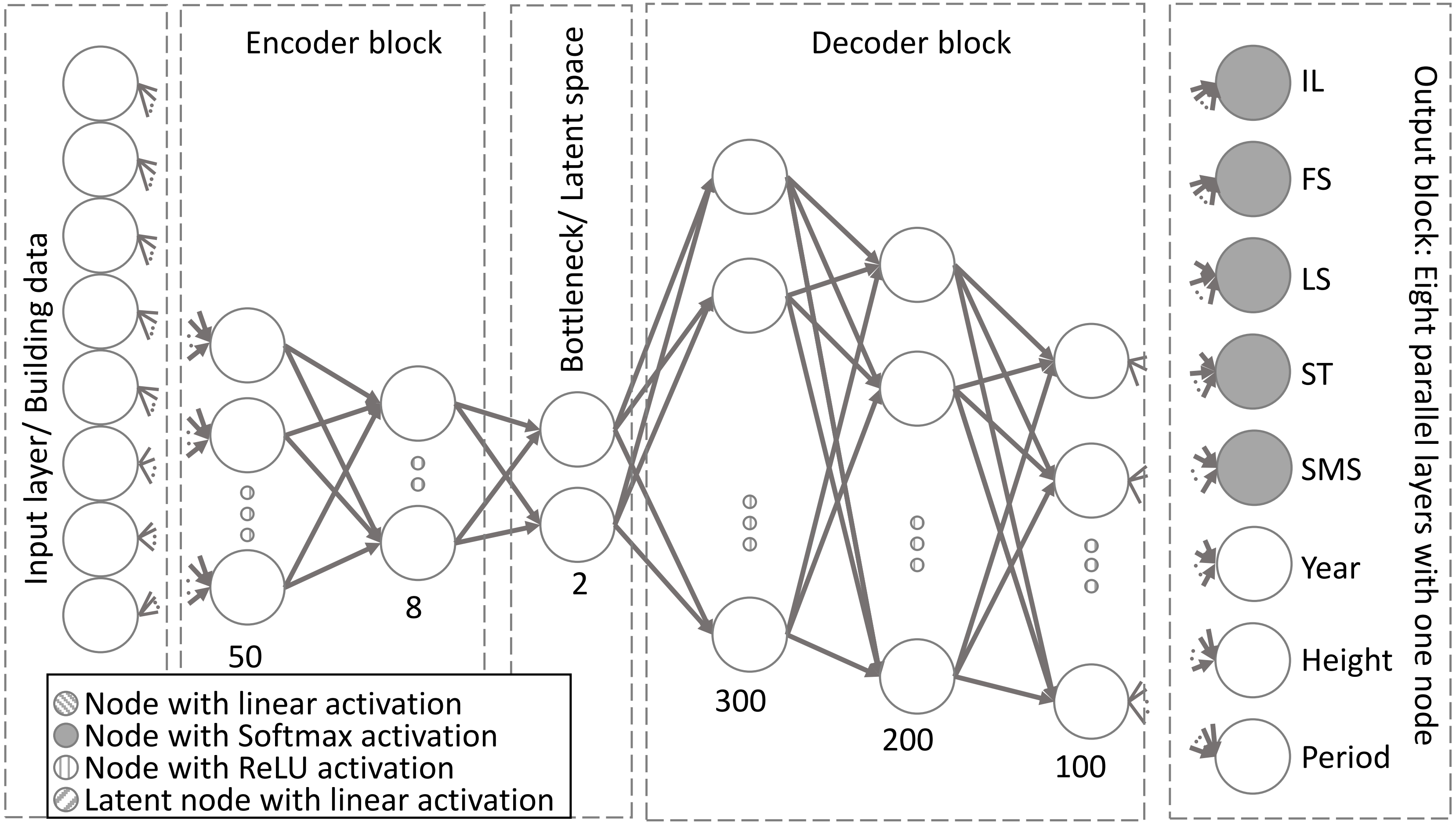


Indicator building workflow

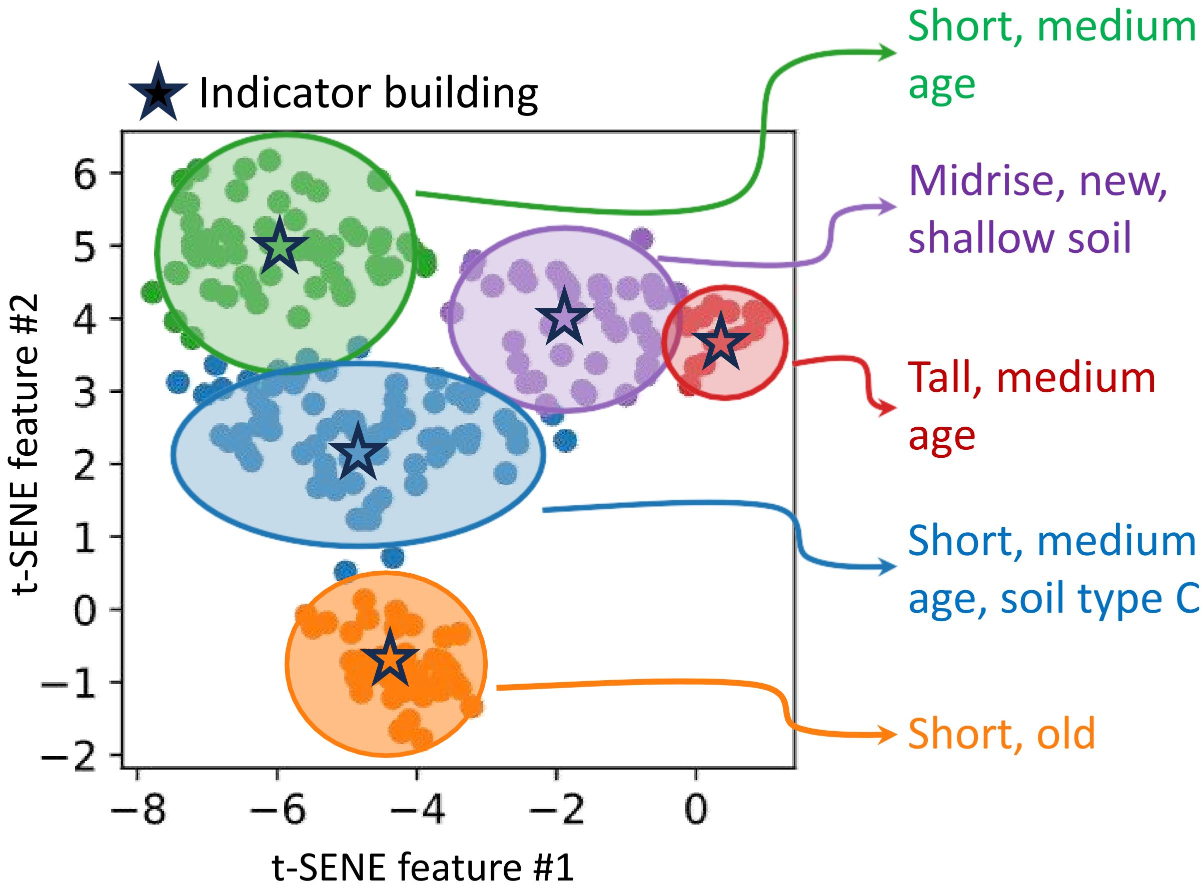


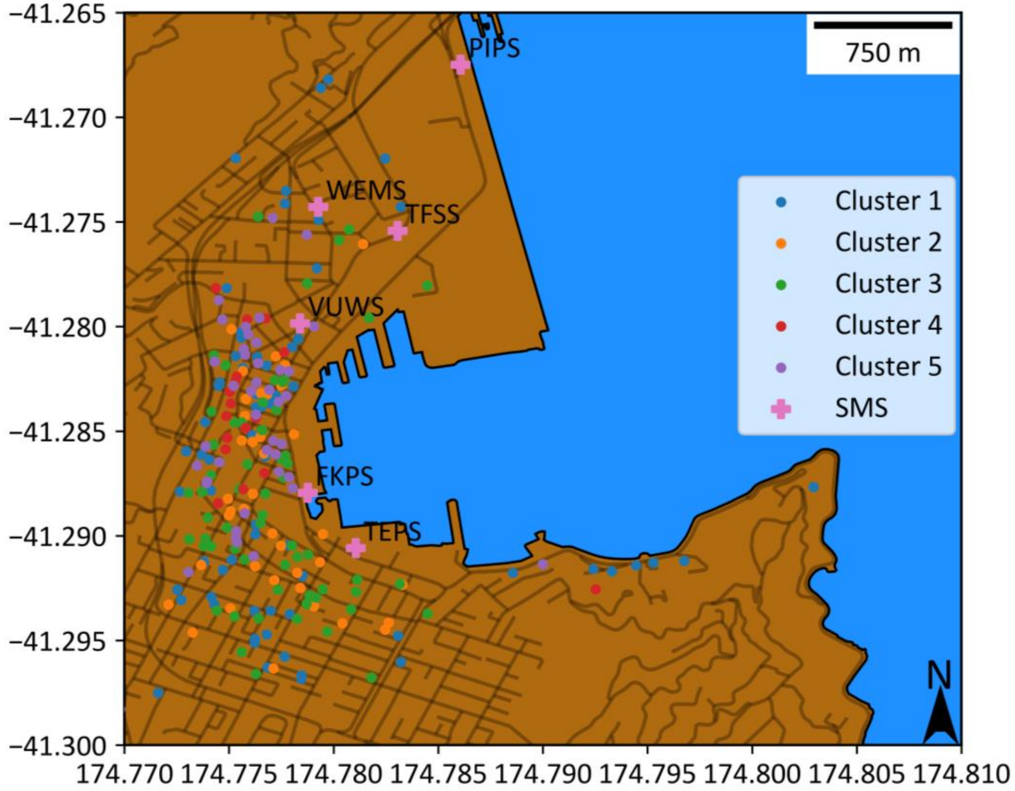
Building clustering

Autoencoder neural network to efficiently cluster mixed numerical/categorical attributes

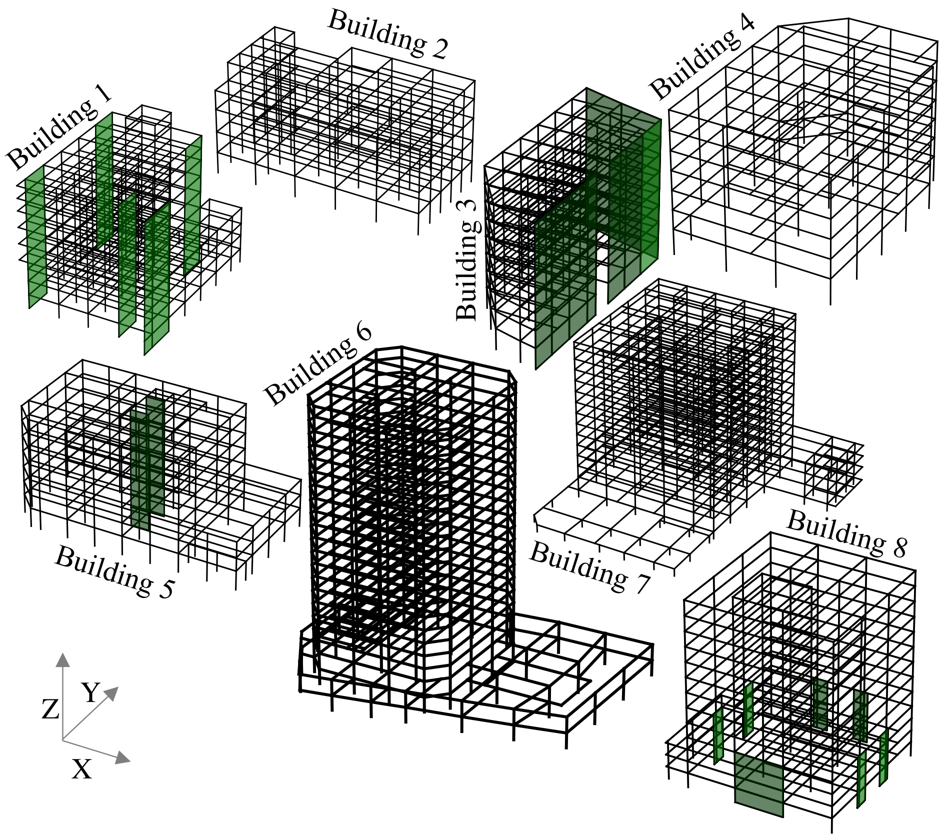


Building clustering and indicator building selection

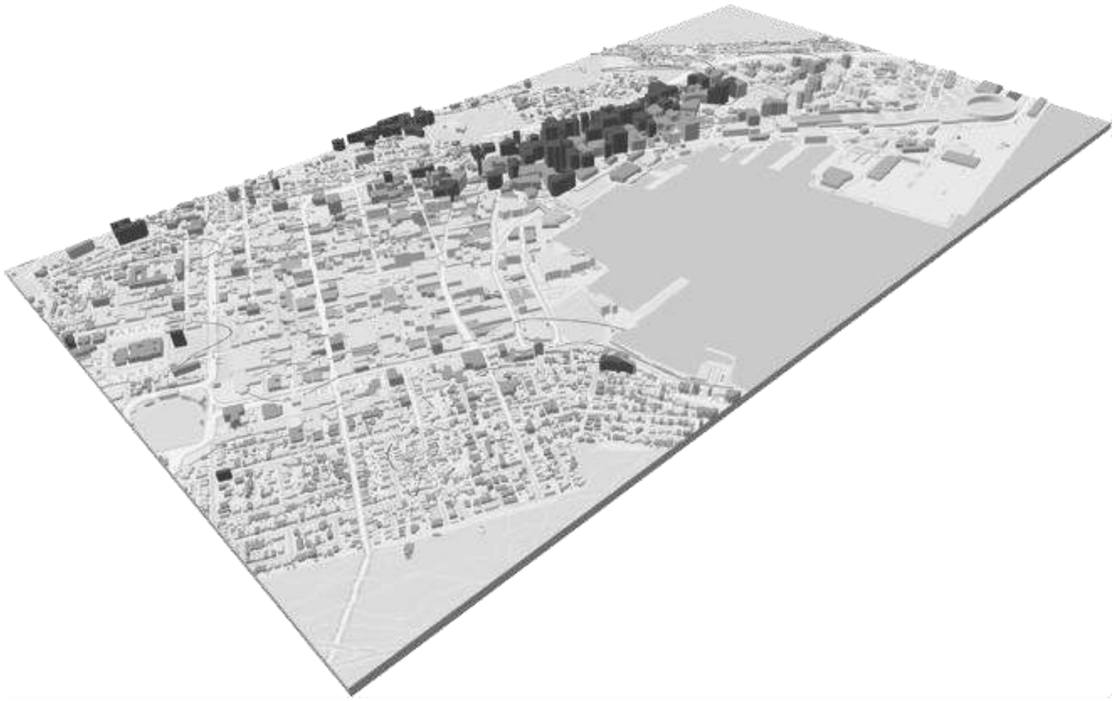




Building response models



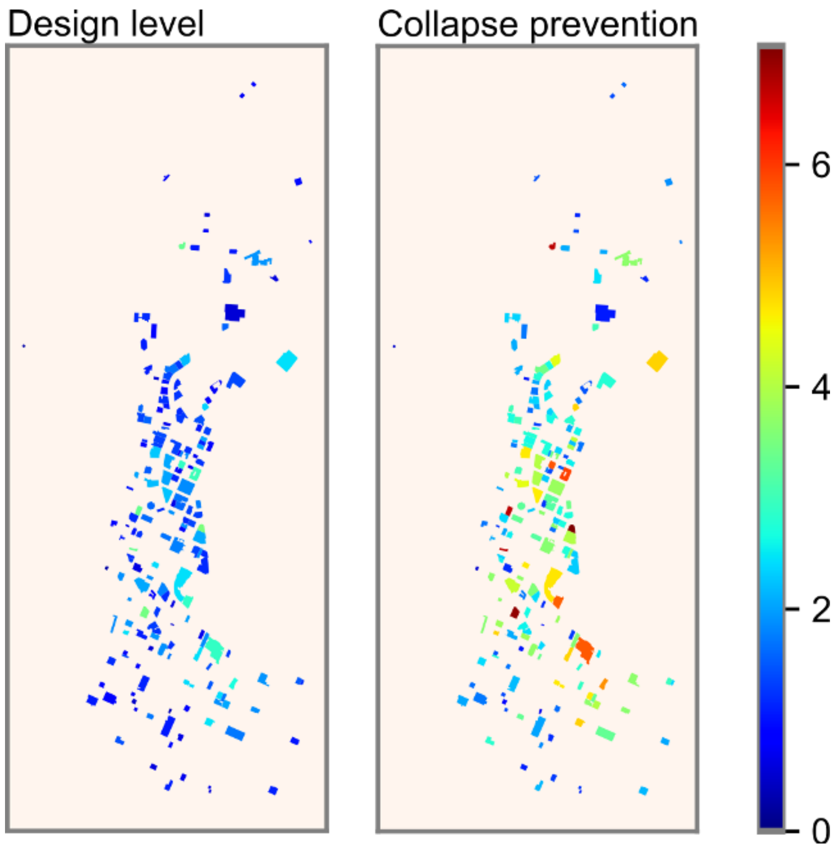
Indicator building models



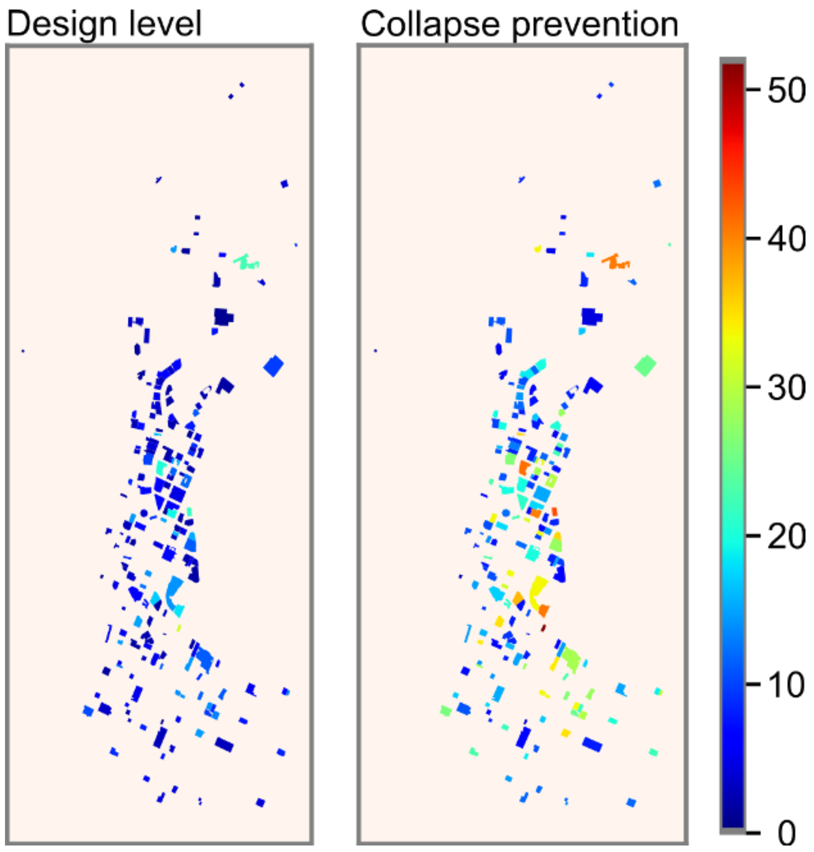
Response models for all buildings in inventory

Response and damage maps

Structural response and damage can be estimated across the inventory



Estimated drifts

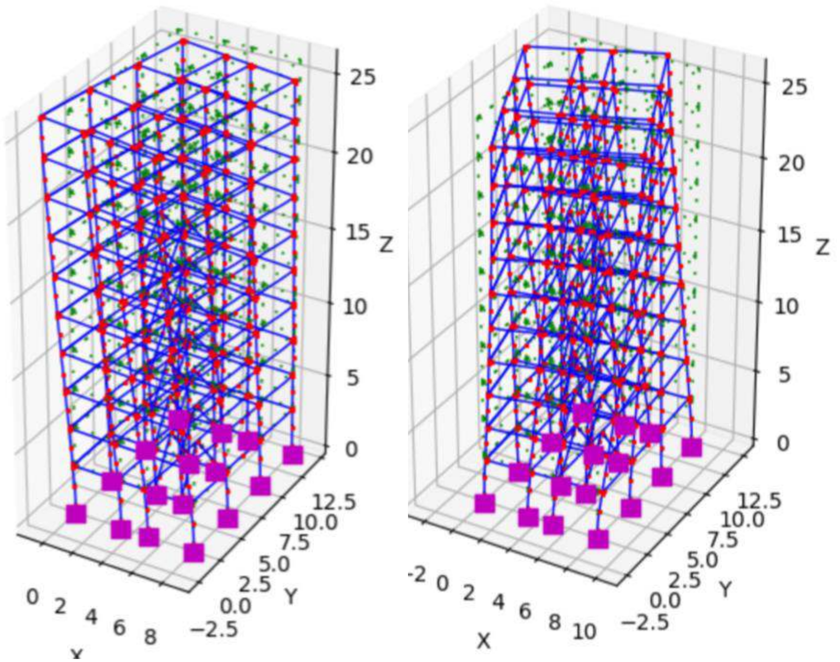


Estimated damage

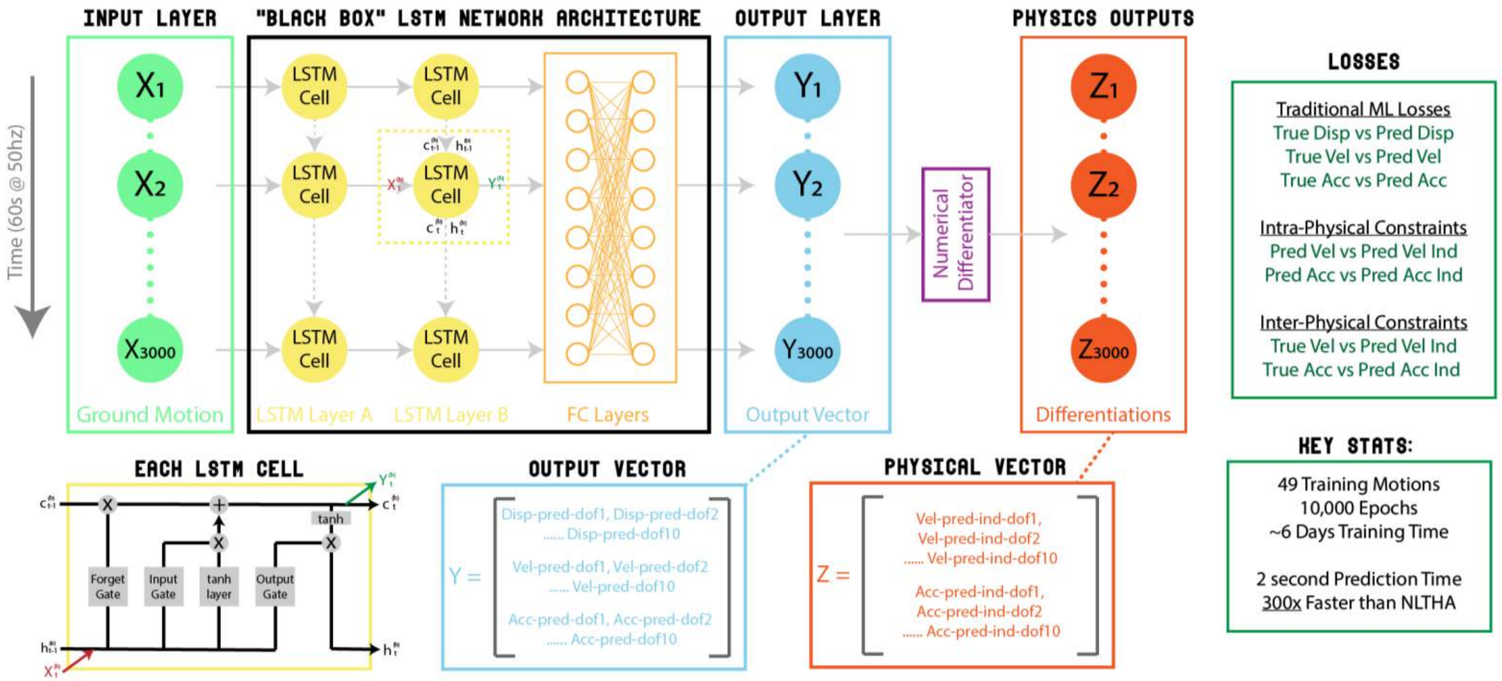
Next steps

Using machine learning for hyper efficient response modelling

Traditional physics-based model



LSTM network

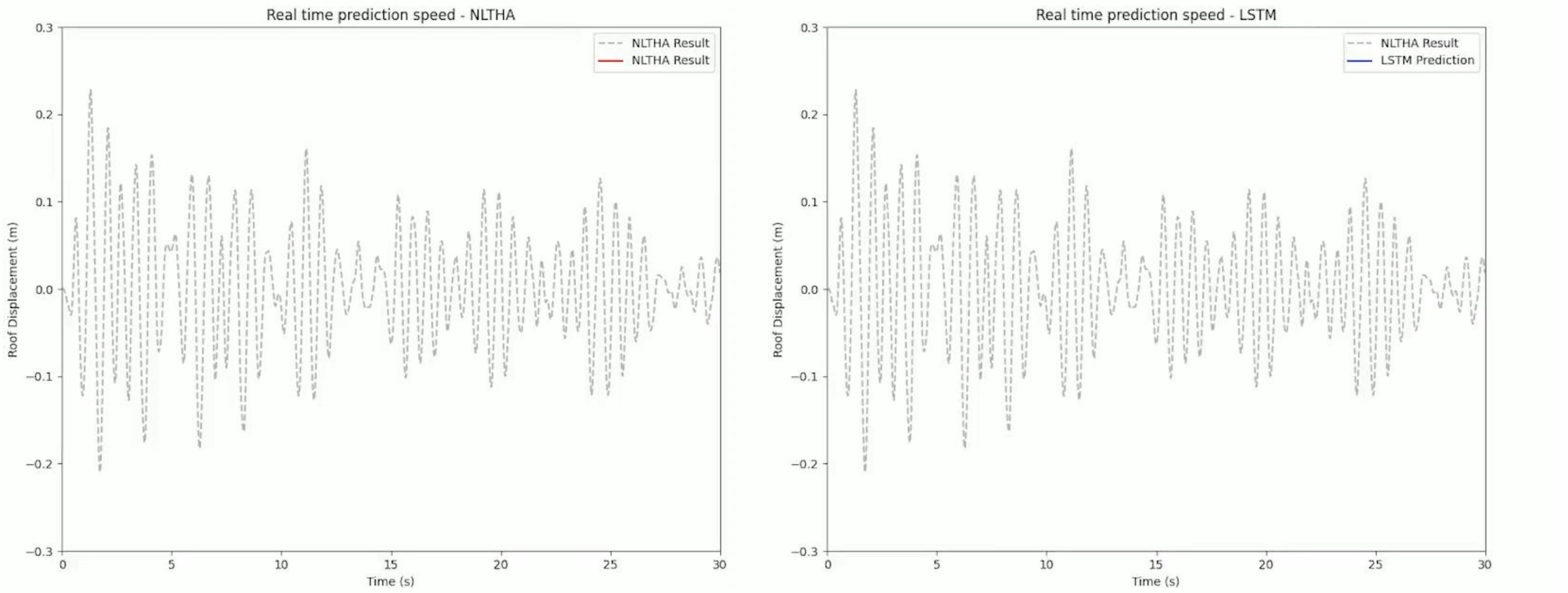


Next steps

Using machine learning for hyper efficient response modelling

Study building
(10-storey, full scale test)

Estimated roof drift



Physics based model | **Trained LSTM model**

Lessons learnt (a summary)

Extracting and organising ‘big’ data is extremely resource intensive but also extremely important (which can be frustrating)

When developing your dataset, make sure you consider your ultimate objective (e.g. collect the data you need)

Have a plan to future proof your data (this is hard)

Understand uncertainties when setting objectives for the data

National Science Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Thank you

Opportunities to understand dynamic changes in population exposure

Learnings from 790 days of listening at Piopiotahi | Milford Sound

Darling M J[1], **Robinson T[1]**, Wilson T[1], Adams B[2] and Orchiston C[3]

[1]School of Earth and Environment, University of Canterbury | Te Whare Wānanga O Waitaha

[2] Computer Science and Software Engineering , University of Canterbury | Te Whare Wānanga O Waitaha

[3] Centre for Sustainability, University of Otago | Ōtākou Whakaihu Waka

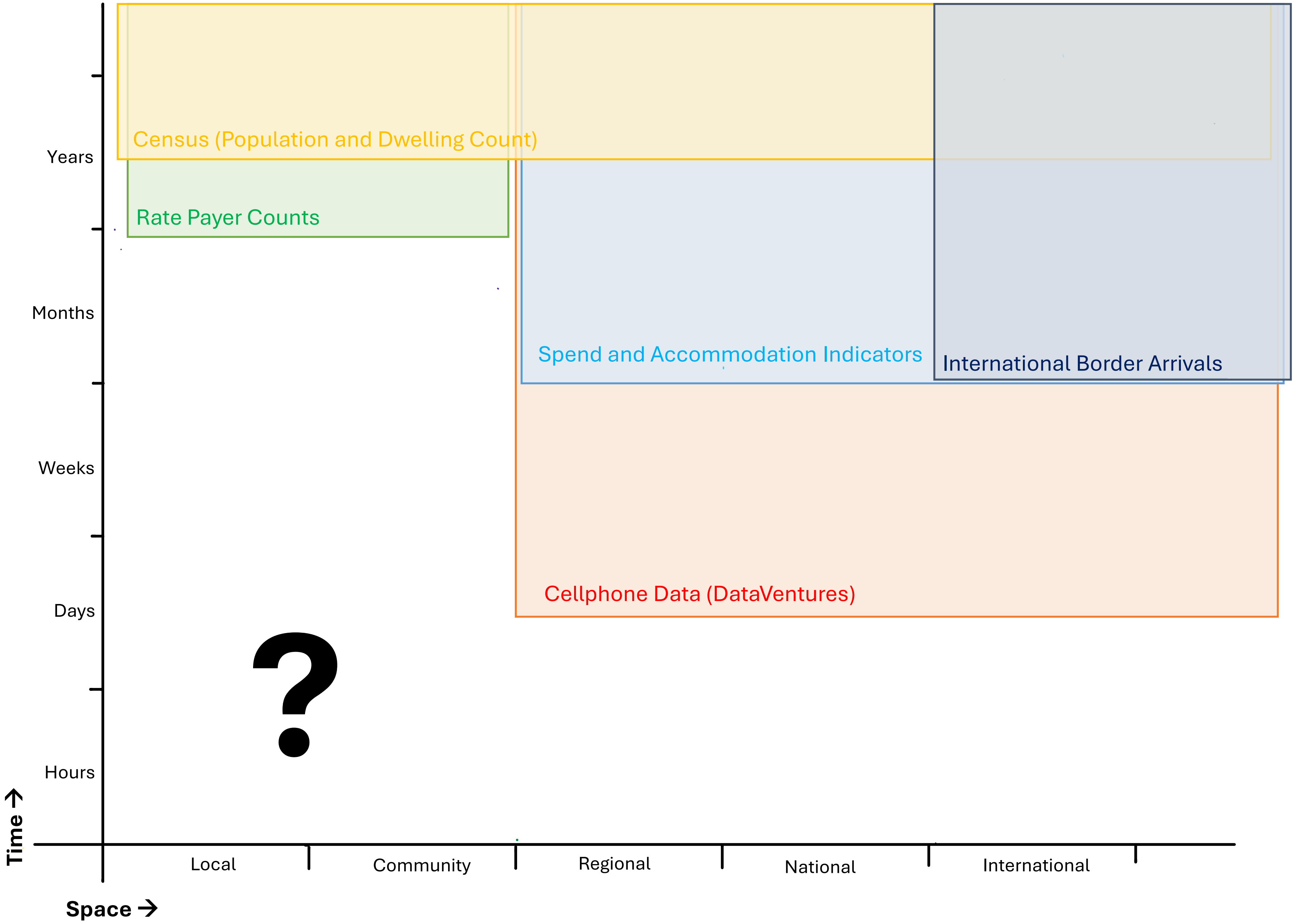
AF8 ALPINE FAULT MAGNITUDE 8

Te Hiranga Rū
NZ Centre for Earthquake Resilience
QuakeCoRE

RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa
National Science Challenges

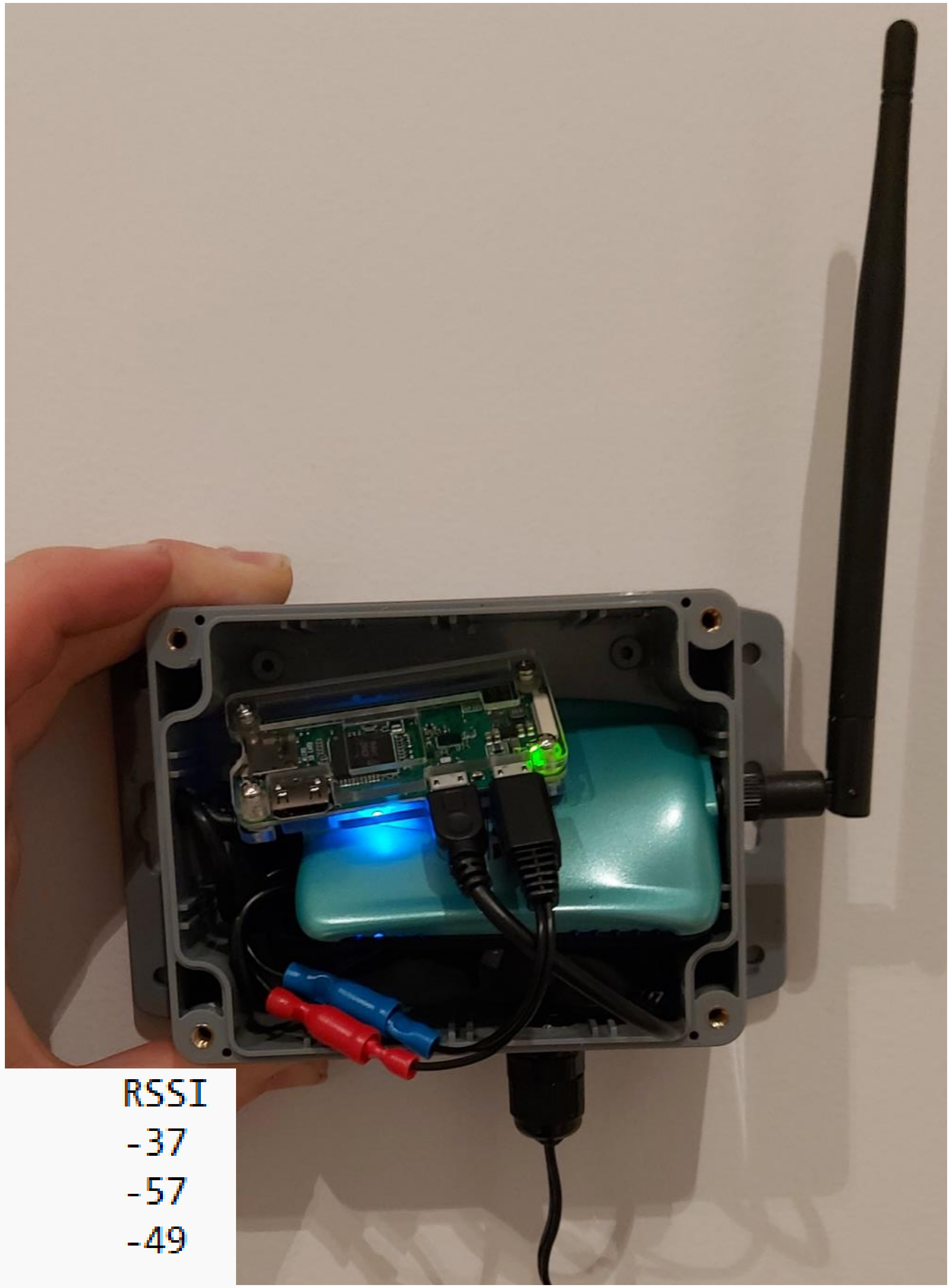
Population Exposure

- Current data for population exposure in risk analysis is limited
- High spatial resolution *OR* high temporal resolution
- Data is static – provides a **snapshot** of population at a time and place
- Population is dynamic at multiple timescales
- Need to understand local-scale population dynamics over short-time scales to understand risk



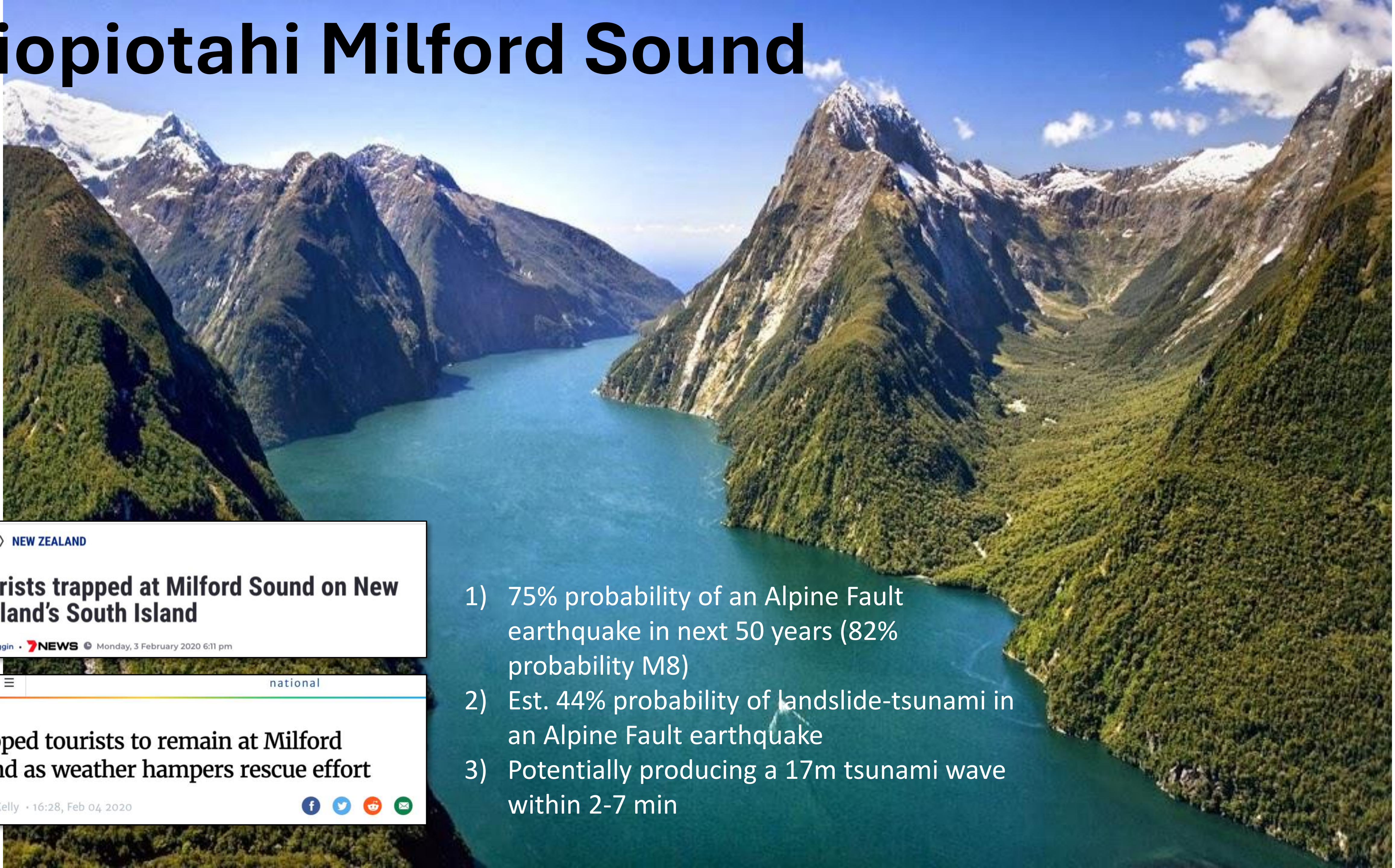
WiFi Probes

- Simple, low cost technology
- Built using reasonably simple computing module and antenna
- WiFi capable devices send a periodic probe request
- Devices periodically anonymise their identifier, so no privacy issues
- Installed in multiple locations throughout South Island
- What a typical probe "sounds" like



Date Time	MAC Address	Type	RSSI
2023-05-07T11:48:27.640820	c2:8e:dd:ec:ad:a4	UNKNOWN	-37
2023-05-07T11:48:28.454428	9c:32:ce:81:10:2c	UNKNOWN	-57
2023-05-07T11:48:29.616139	94:e2:3c:40:97:f5	UNKNOWN	-49

Piopiotahi Milford Sound



NEWS 〉 NEW ZEALAND

Tourists trapped at Milford Sound on New Zealand's South Island

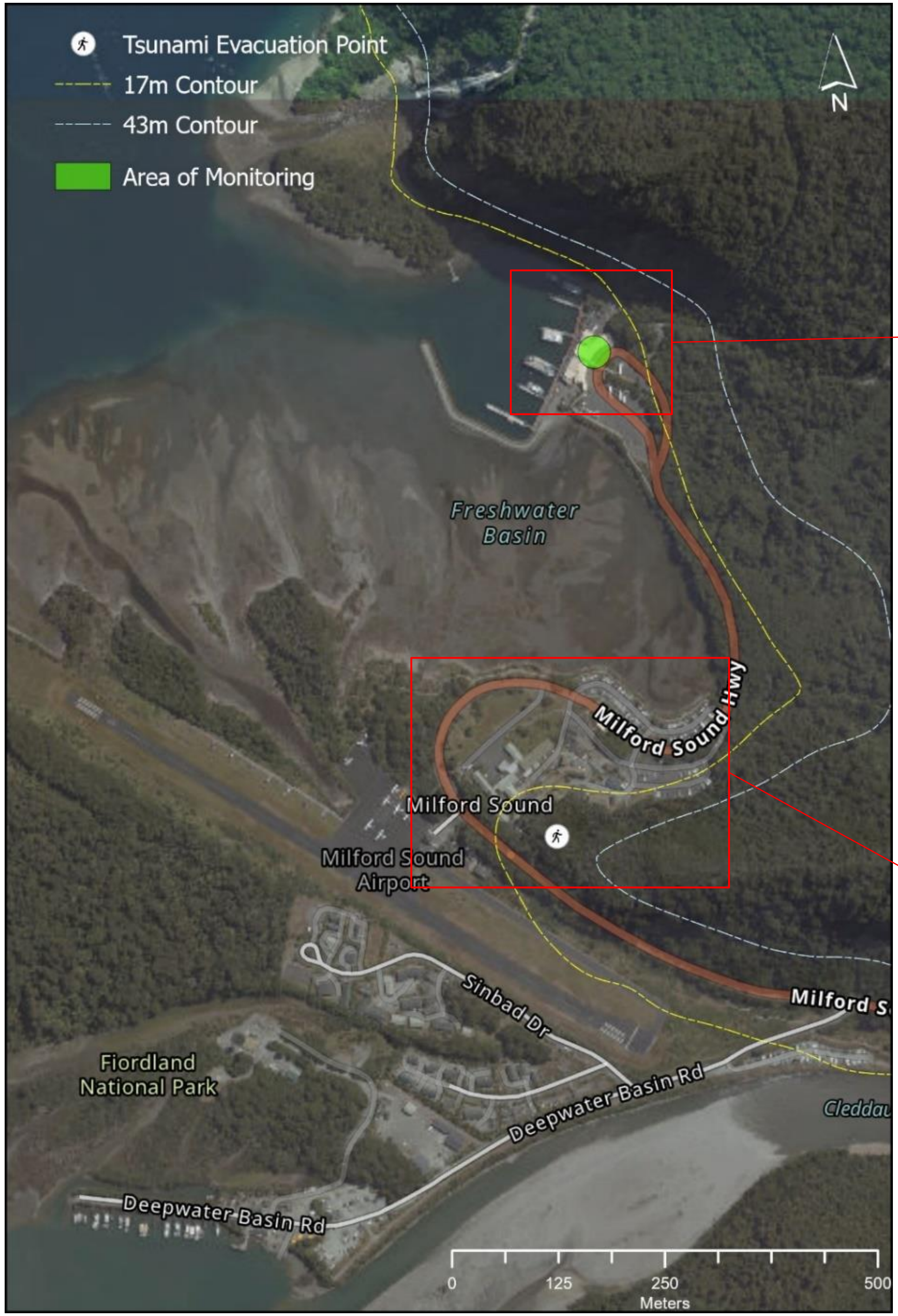
Lucy Quaggin • 7NEWS Monday, 3 February 2020 6:11 pm

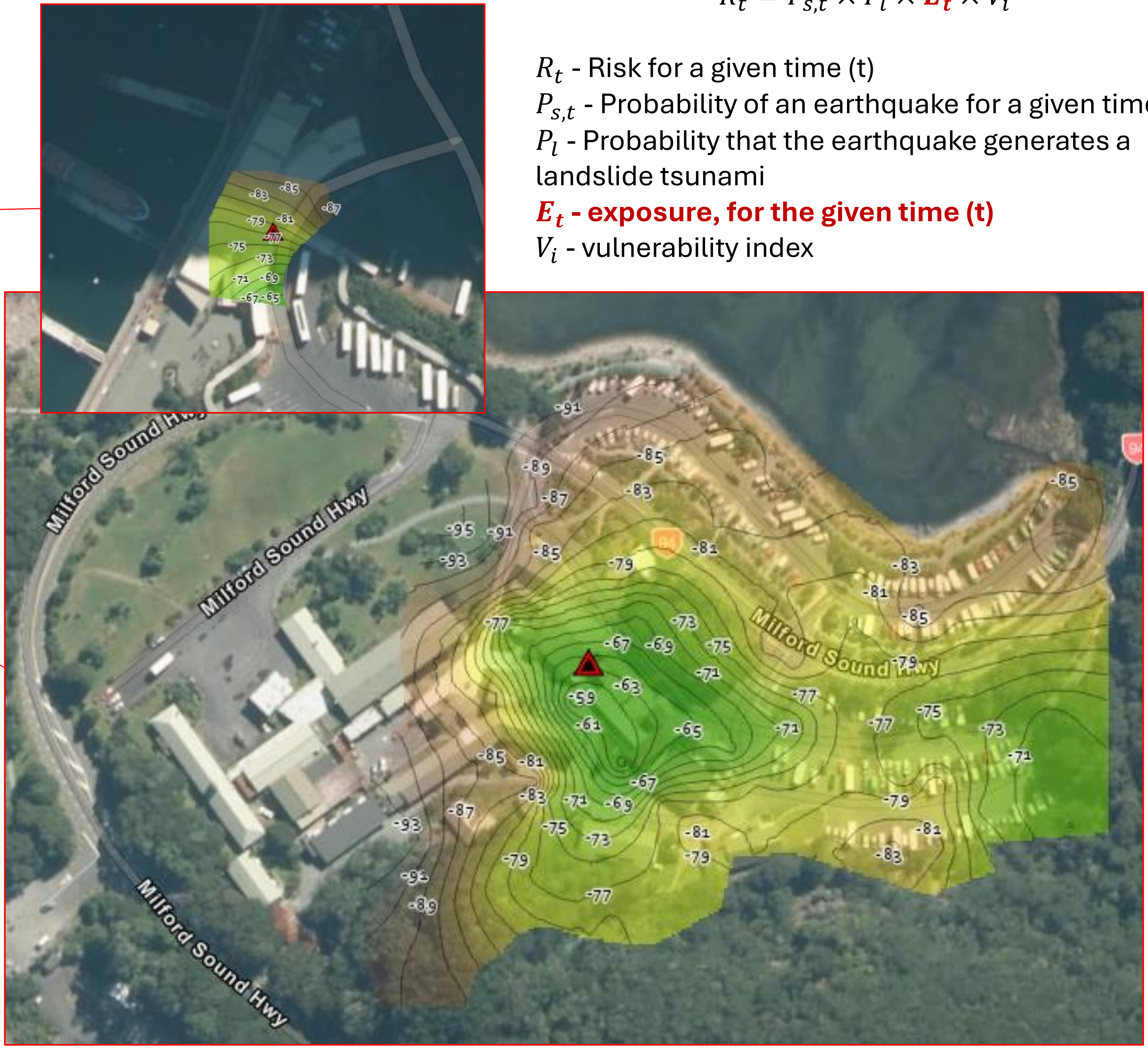
stuff ☰ national

Trapped tourists to remain at Milford Sound as weather hampers rescue effort

Rachael Kelly • 16:28, Feb 04 2020

1) 75% probability of an Alpine Fault earthquake in next 50 years (82% probability M8)
2) Est. 44% probability of landslide-tsunami in an Alpine Fault earthquake
3) Potentially producing a 17m tsunami wave within 2-7 min





$$R_t = P_{s,t} \times P_l \times \boldsymbol{E_t} \times V_i$$

R_t - Risk for a given time (t)

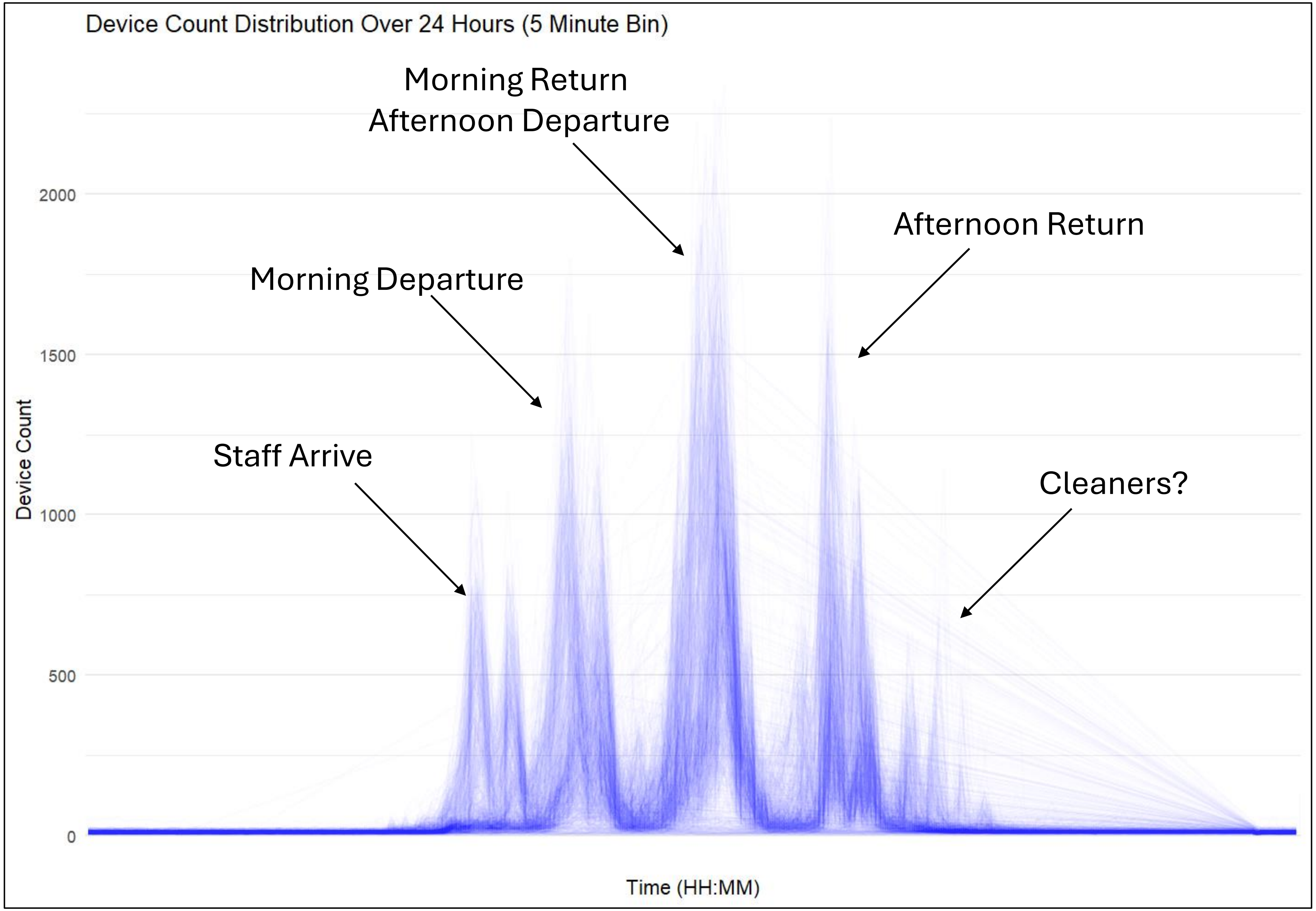
$P_{s,t}$ - Probability of an earthquake for a given time

P_l - Probability that the earthquake generates a landslide tsunami

E_t - exposure, for the given time (t)

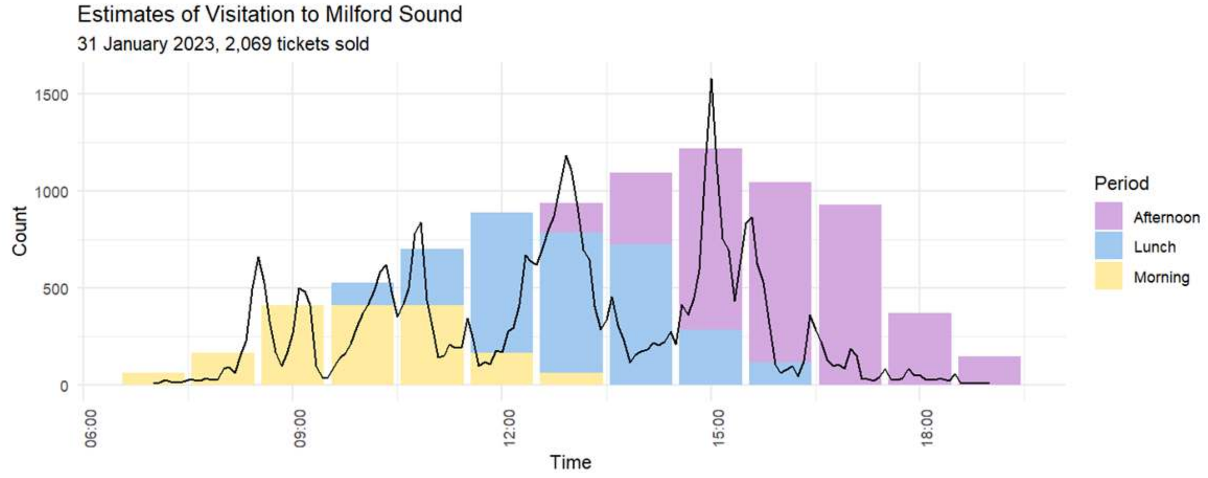
V_i - vulnerability index

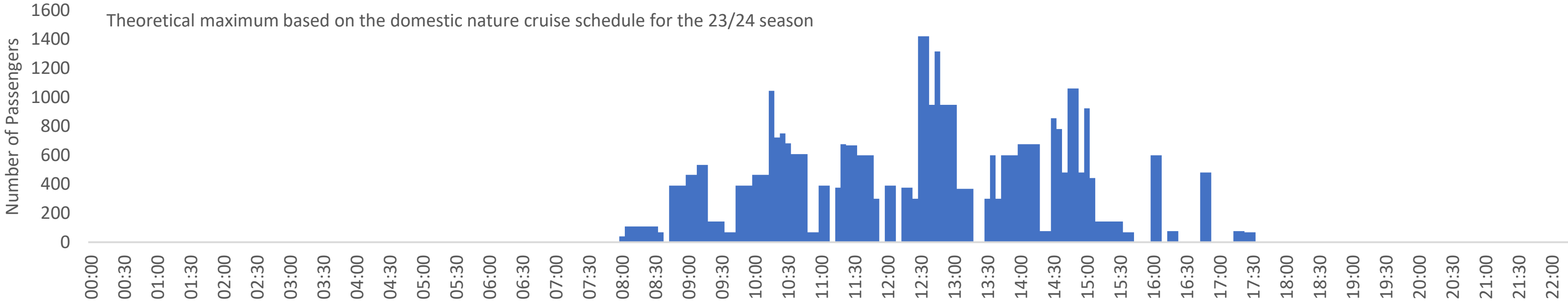
Temporal changes in population

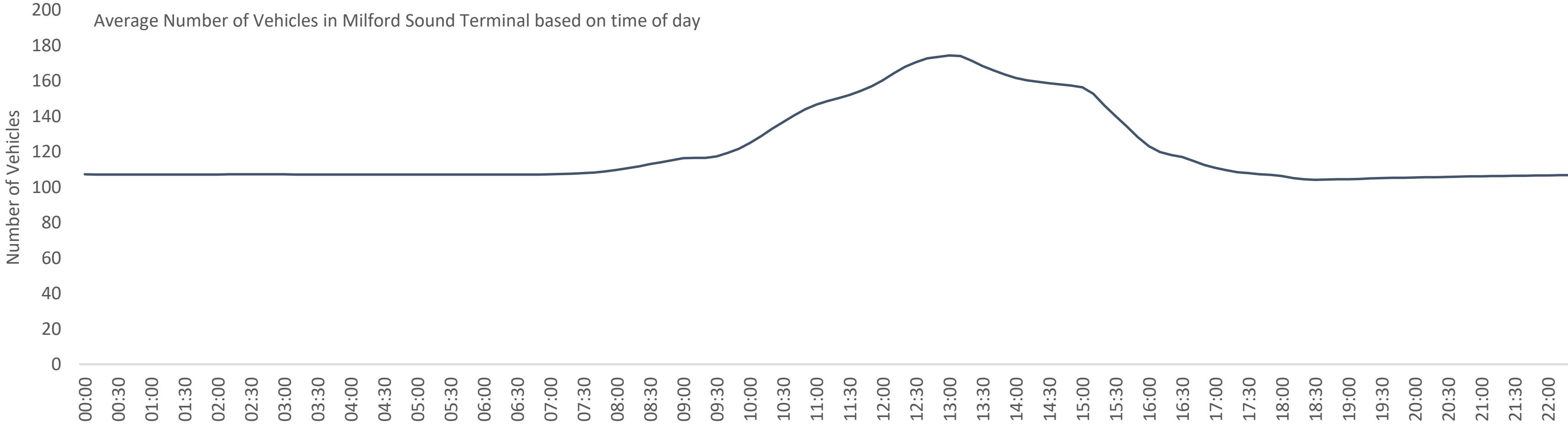


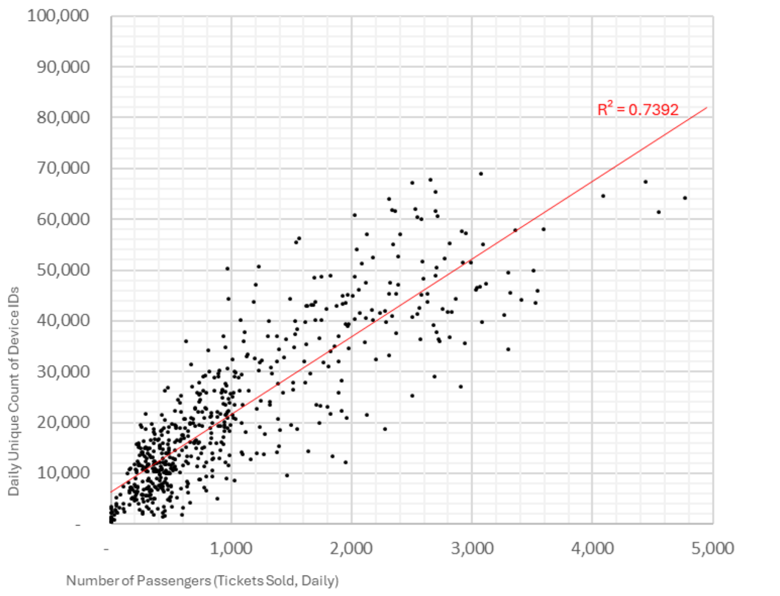
Validation of Approach

Comparing to known “signals”







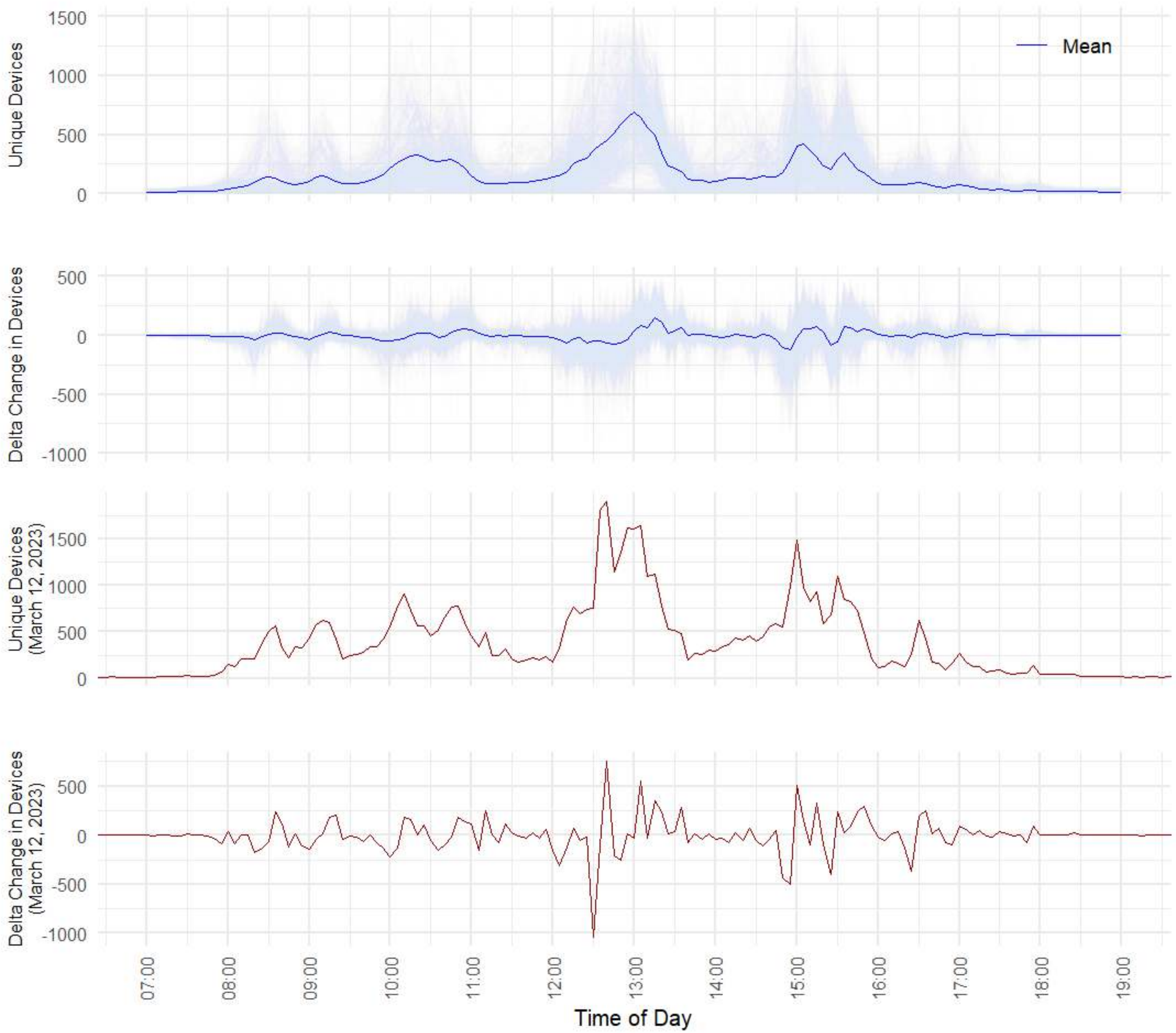


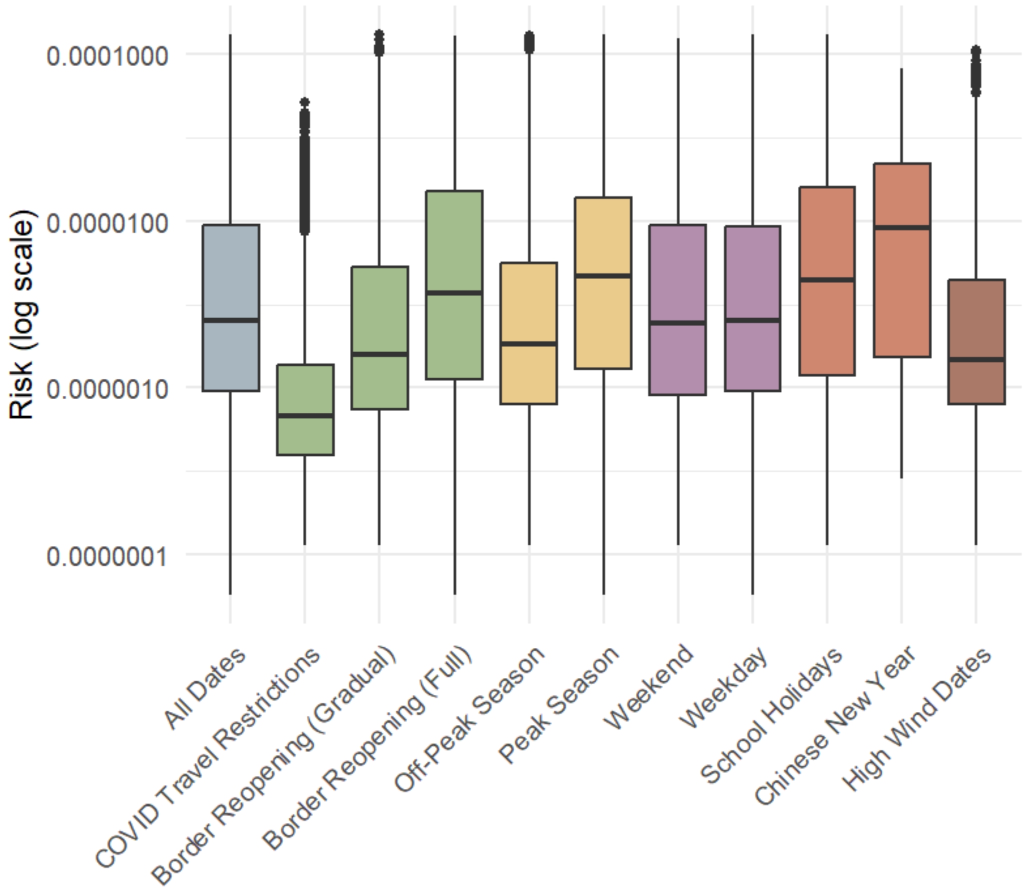
Correlation between Ticket Sales and Unique Devices, Milford Sound

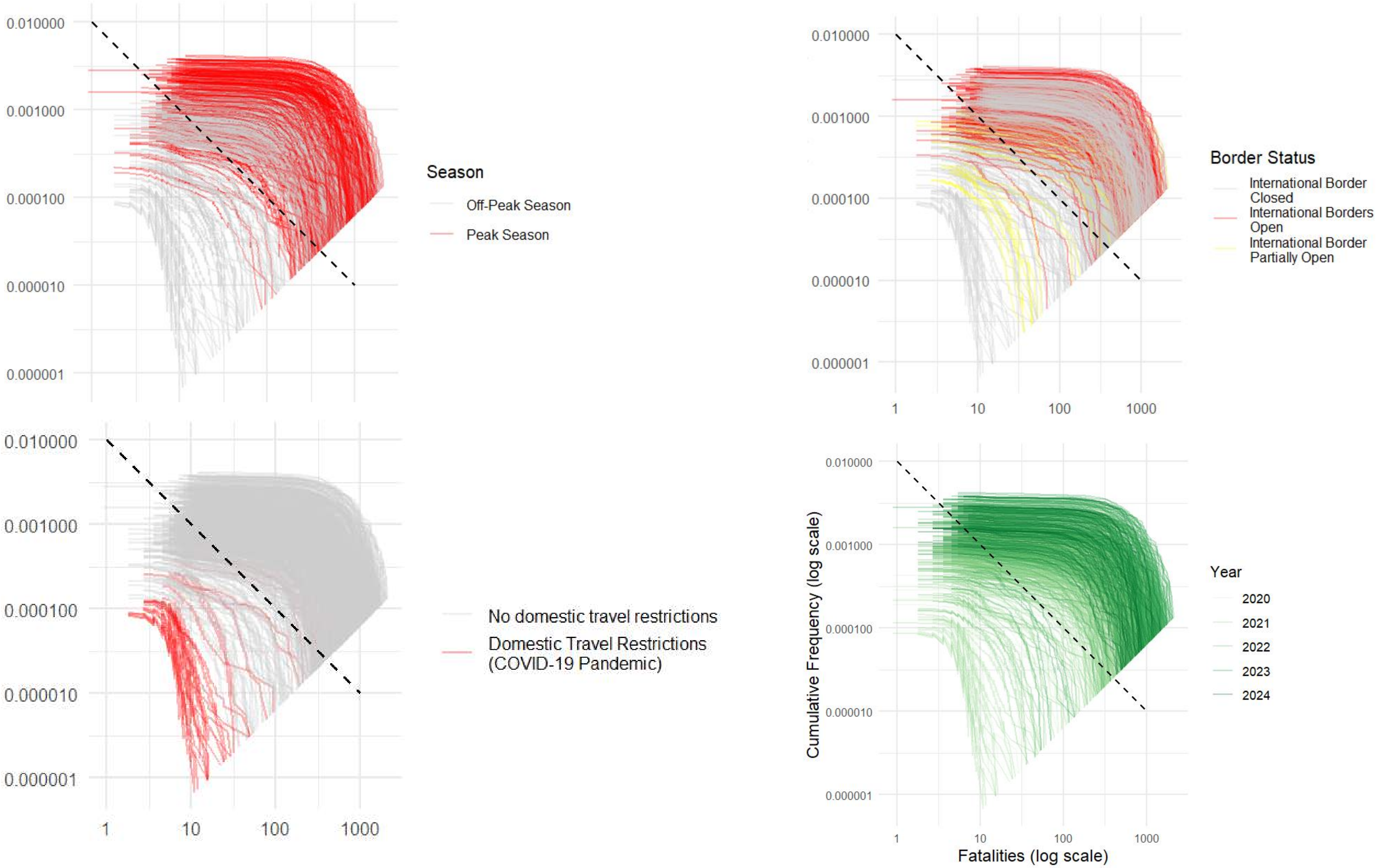
Implications for Risk

$$R_t = P_{s,t} \times P_l \times \boldsymbol{E_t} \times V_i$$

R_t - Risk for a given time (t)
$P_{s,t}$ - Probability of an earthquake for a given time
P_l - Probability that the earthquake generates a landslide tsunami
E_t - exposure, for the given time (t)
V_i - vulnerability index







0.010000
0.001000
0.000100
0.000010
0.000001
Season
Off-Peak Season
Peak Season
1
10
100
1000
Border Status
International Border Closed
International Borders Open
International Border Partially Open
No domestic travel restrictions
Domestic Travel Restrictions (COVID-19 Pandemic)
Cumulative Frequency (log scale)
Fatalities (log scale)
Year
2020
2021
2022
2023
2024

Ngā mihi! Pātai?

AF8
ALPINE FAULT MAGNITUDE 8

Te Hiranga Rū
NZ Centre for Earthquake Resilience
QuakeCoRE

RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa
National SCIENCE Challenges

Be Careful What You Wish for: Navigating Coastal Change Amid Rapid Advancements in Remote Sensing

Murray Ford and several others…

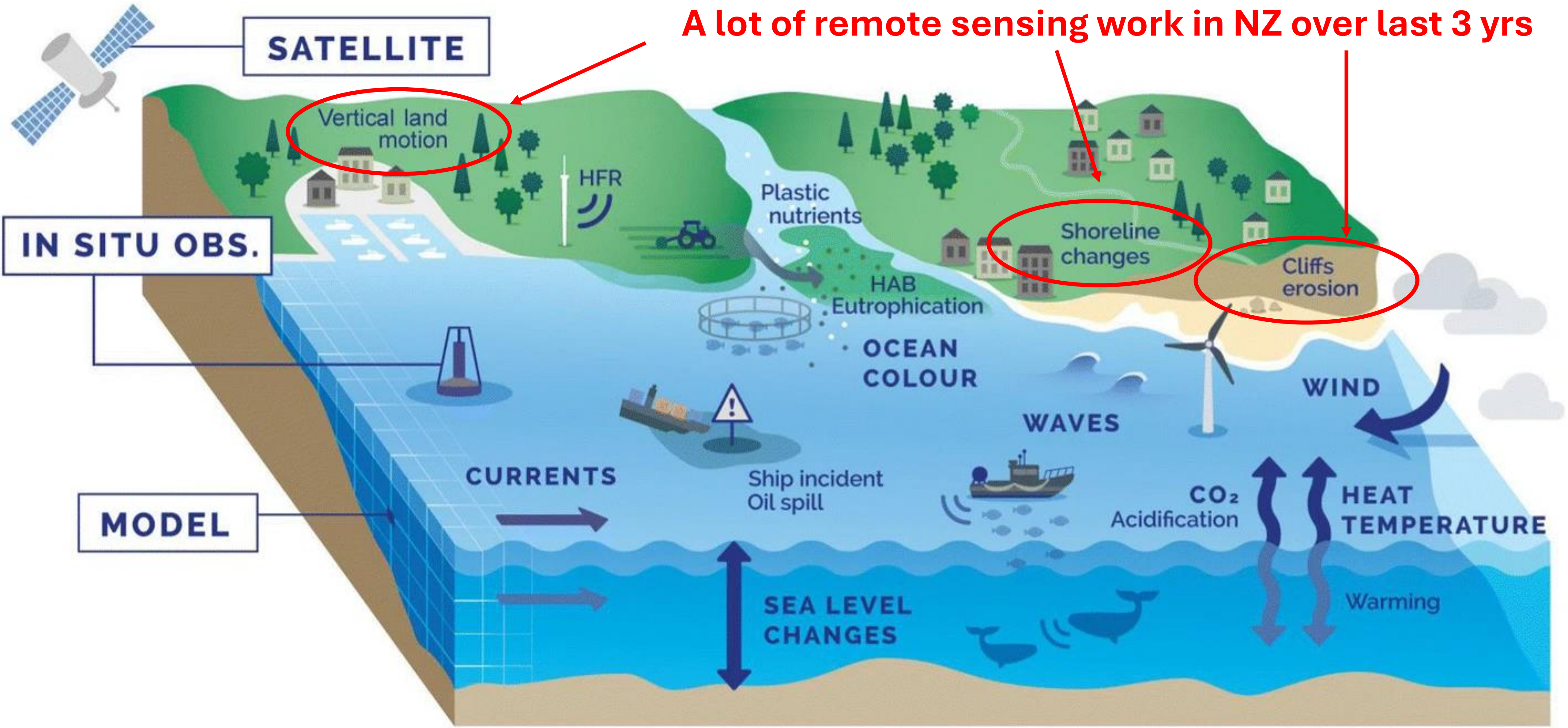
University of Auckland

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

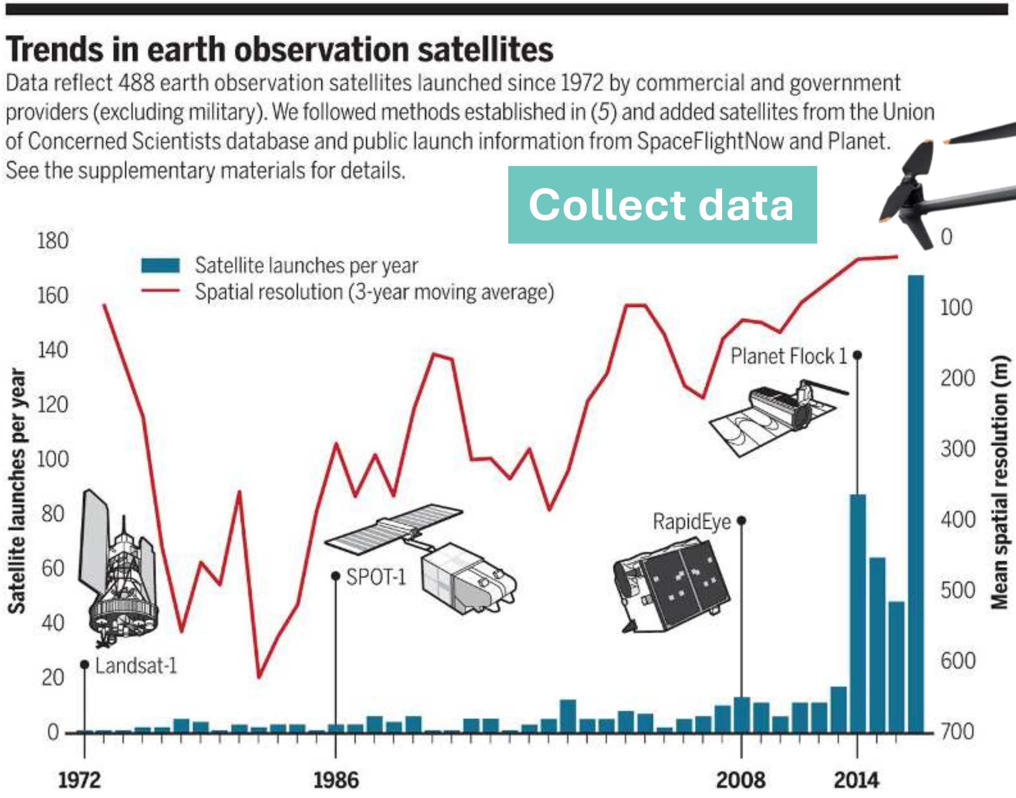
Remote sensing of our coast



Melet, A., Teatini, P., Le Cozannet, G., Jamet, C., Conversi, A., Benveniste, J., & Almar, R. (2020). Earth observations for monitoring marine coastal hazards and their drivers. *Surveys in Geophysics*, *41*, 1489-1534.

The coastal science/manager's toolbox has expanded significantly over the last decade.

Collect data



Finer, M., Novoa, S., Weisse, M. J., Petersen, R., Mascaro, J., Souto, T., ... & Martinez, R. G. (2018). Combating deforestation: From satellite to intervention. *Science*, *360*(6395), 1303-1305.

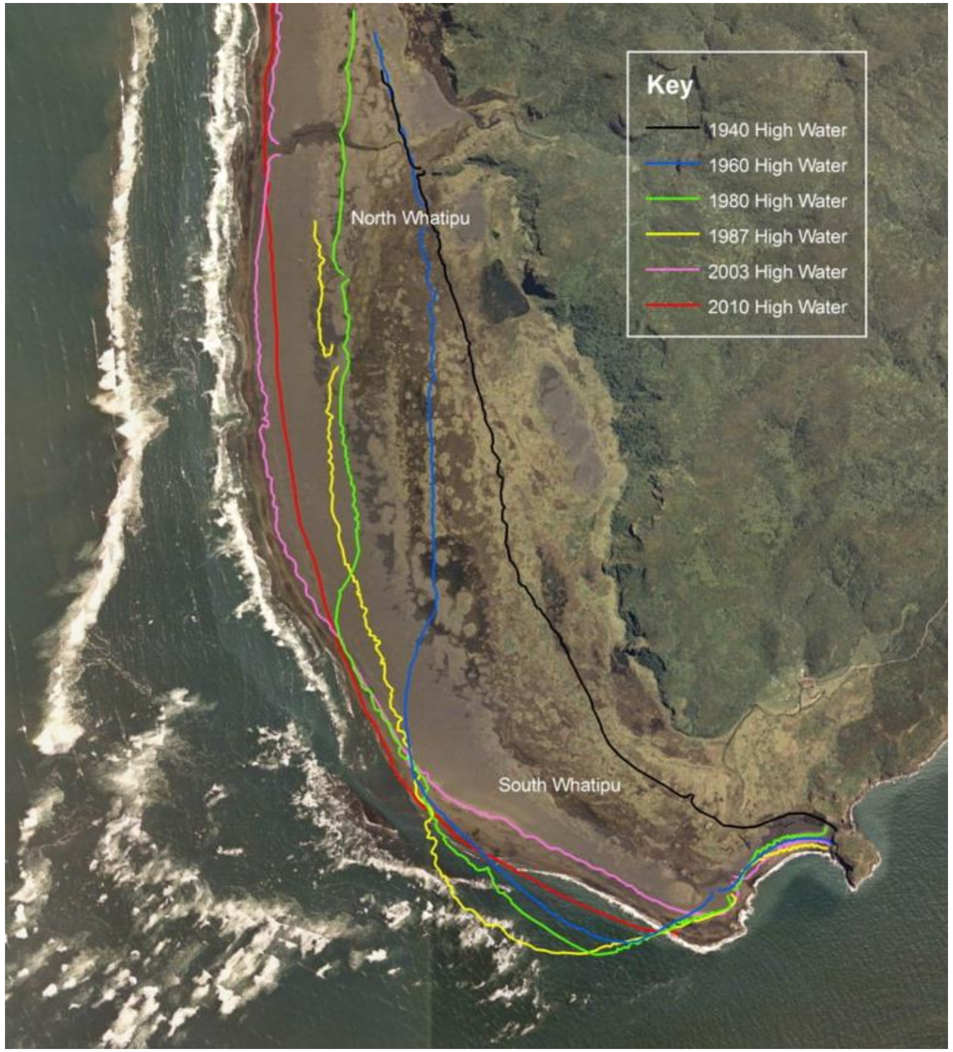
Process data

Various datacubes, high performance computing

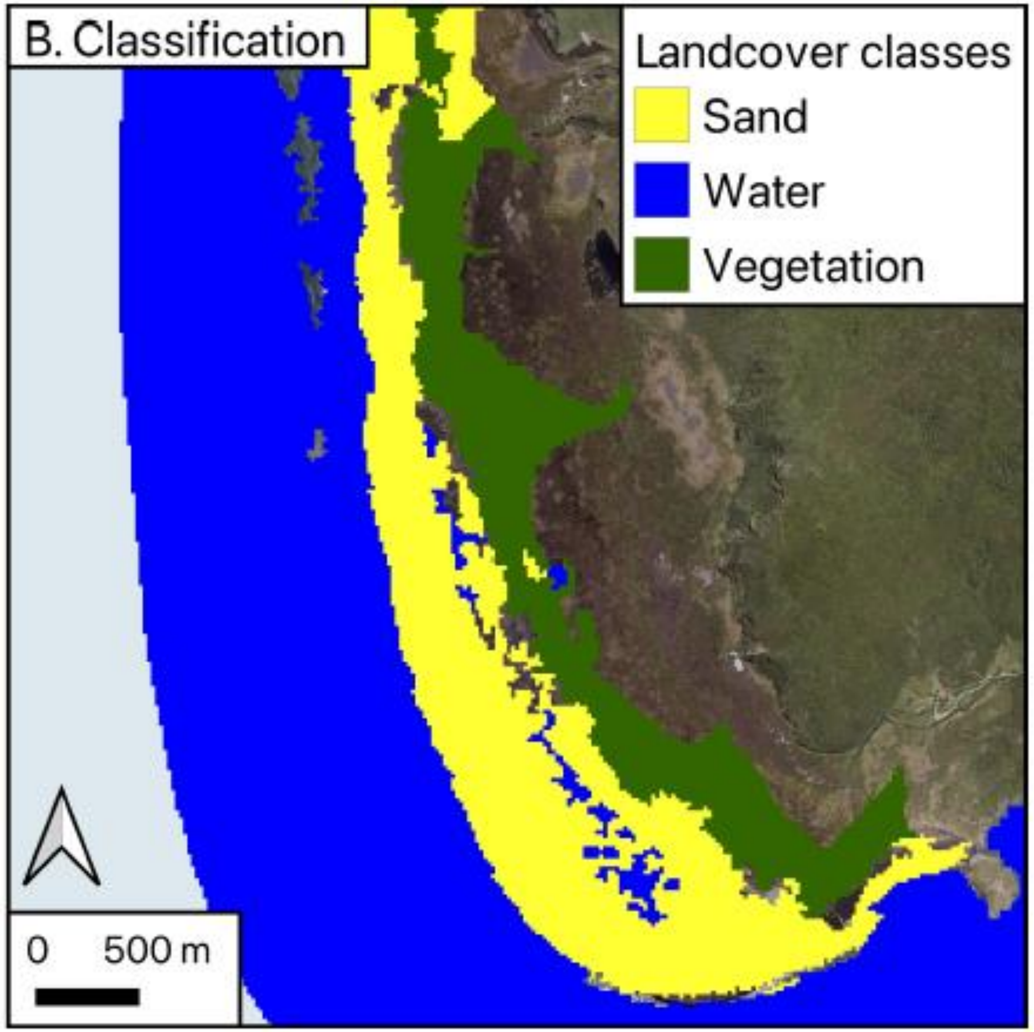
Share data

Endless numbers of platforms to share data with users. Free/cheap and easy

Our remote sensing toolbox now allows us to think beyond the line

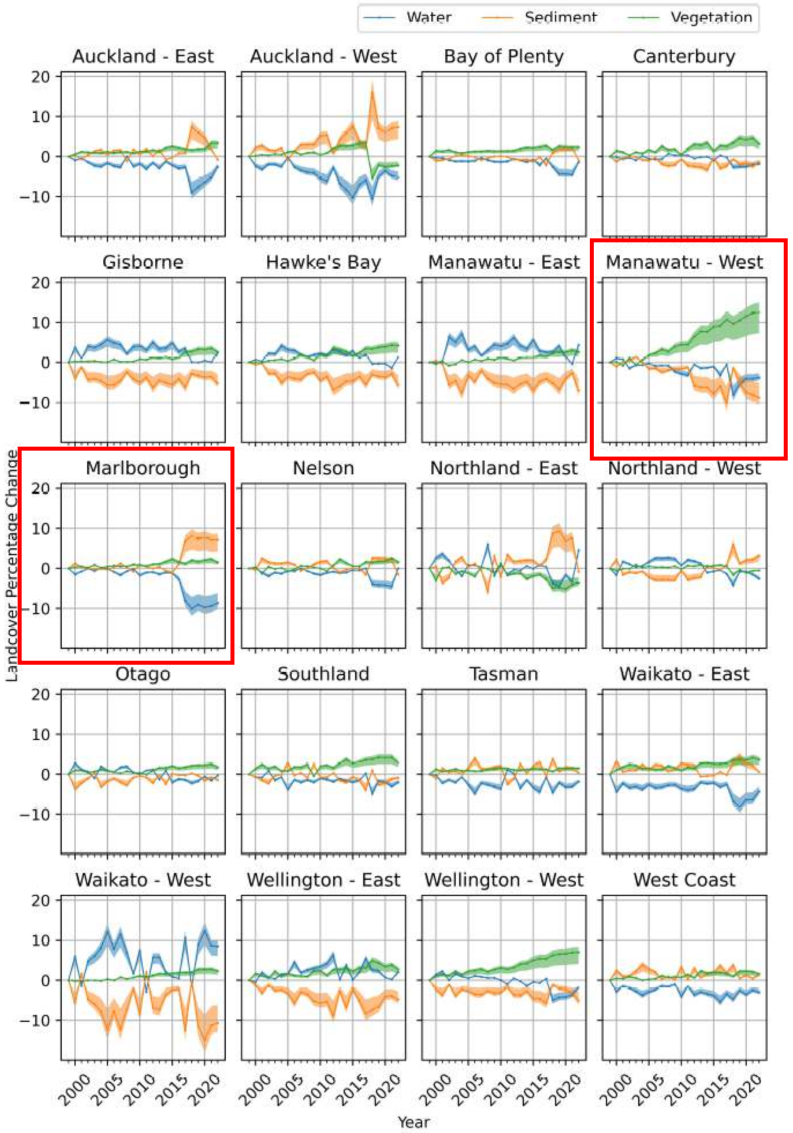


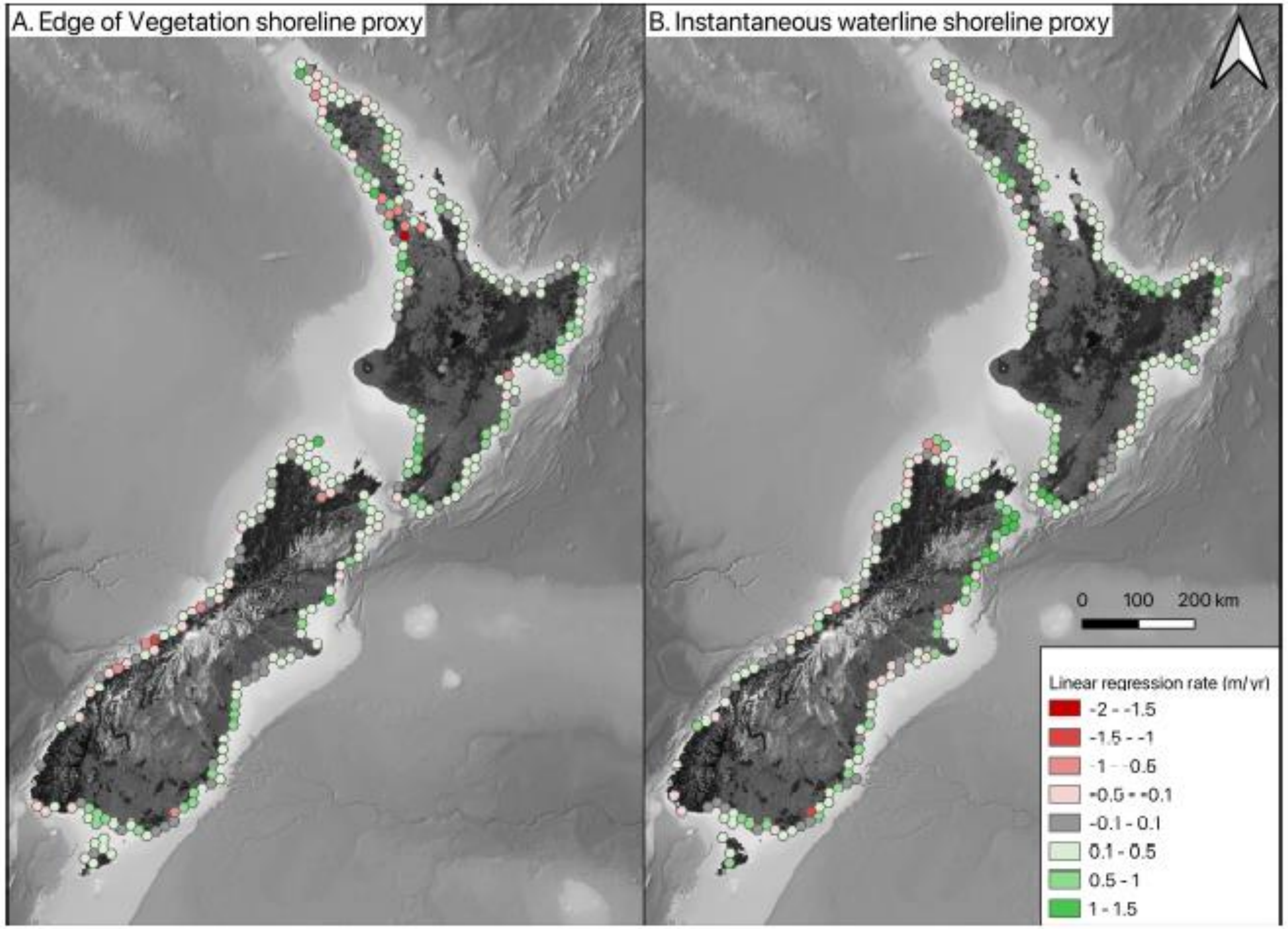
Blue, B., & Kench, P. S. (2017). Multi-decadal shoreline change and beach connectivity in a high-energy sand system. *New Zealand journal of marine and freshwater research*, *51*(3), 406-426.



Ben Collings – RNC2 PhD student

Coastal insights from around NZ.





Ben Collings – RNC2 PhD student

Ben Collings – RNC2 PhD student

The future?

"While manual digitalization of shoreline position is a reliable and accurate method, particularly on high-resolution images, it remains time-consuming and impractical when employed for long stretches of coastline with hundreds of revisits."

Vitousek, S., Buscombe, D., Vos, K., Barnard, P. L., Ritchie, A. C., & Warrick, J. A. (2023). The future of coastal monitoring through satellite remote sensing. *Cambridge Prisms: Coastal Futures*, *1*, e10.

But…

"It isn't necessarily because such studies have any utility; it's simply that the data are there and academicians have worked hard to learn the mathematical skills needed to manipulate them. Once these skills are acquired, it seems sinful not to use them, even if the usage has no utility or negative utility. As a friend said, to a man with a hammer, everything looks like a nail"

Warren Buffet on ~~remote sensing~~ financial studies.

We need to think about spatial scale

SCIENTIFIC REPORTS

Correction: Author Correction

OPEN

The State of the World's Beaches

Arjen Luijendijk[1,2], Gerben Hagenaars[2], Roshanka Ranasinghe[3,4,2], Fedor Baart[2], Gennadii Donchyts[1,2] & Stefan Aarninkhof[1]

Algorithm driven, global scale, coarse resolution

https://www.nzherald.co.nz/northern-advocate/news/northlanders-urged-to-have-a-say-on-future-of-ninety-mile-beach/NH77R6O2VANZ4YRD6O5SC4KS4U/

scientific **data**

Check for updates

OPEN

DATA DESCRIPTOR

Three years of weekly DEMs, aerial orthomosaics and surveyed shoreline positions at Waikīkī Beach, Hawaiʻi

Anna B. Mikkelsen[1] ✉, Kristian K. McDonald[1] ✉, Julianne Kalksma[2], Zachary H. Tyrrell[1] & Charles H. Fletcher[1]

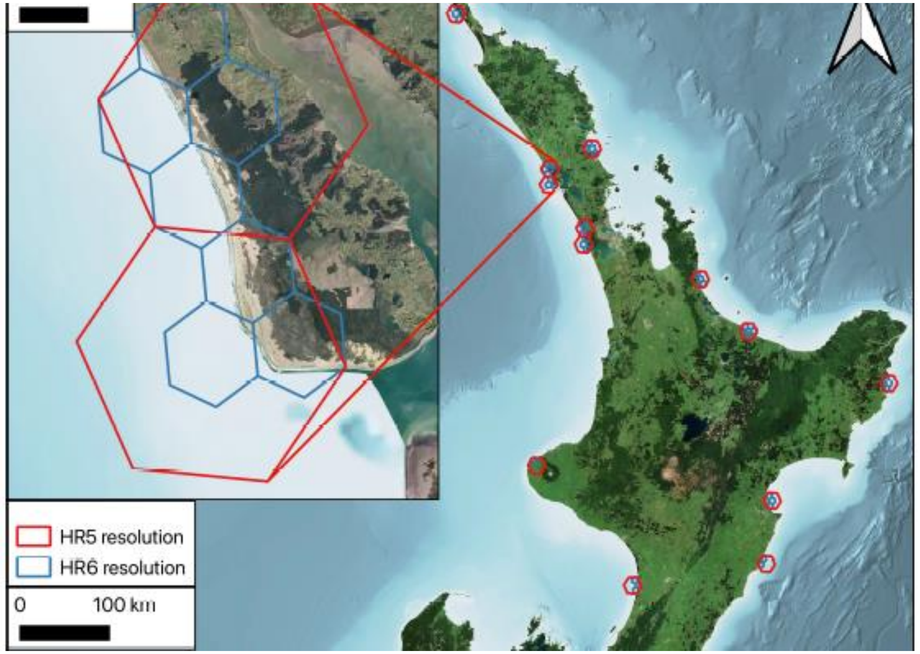
Detailed surveys, small scale, high resolution

https://en.wikipedia.org/wiki/Mission_Bay,_New_Zealand#/media/File:Mission_Bay_Beach_-_Auckland_2017.jpg

We need to work within a hierarchical framework

- There is no single approach to coastal monitoring that is effective across all scales.

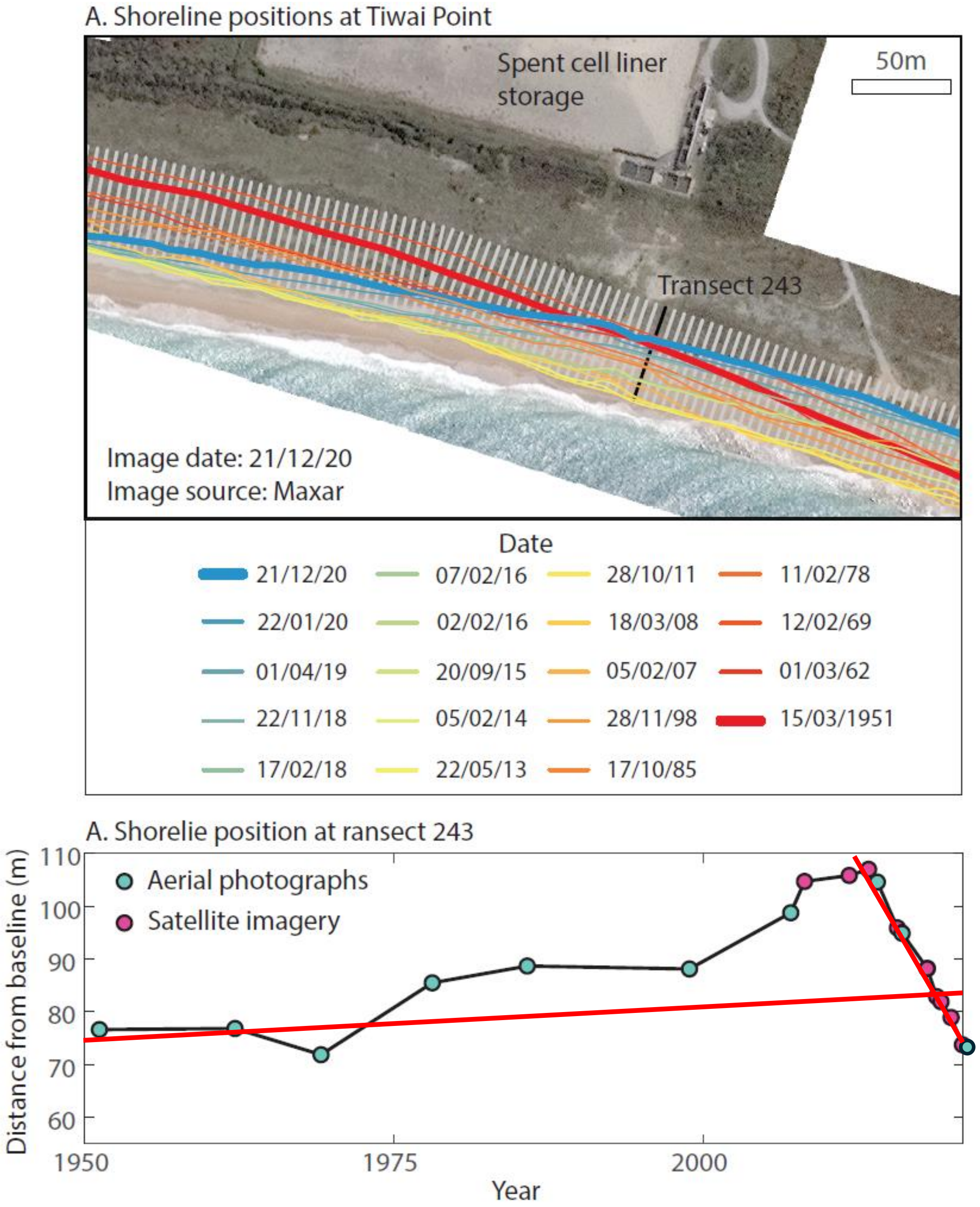
- We need a framework to match the monitoring approach to the scale of the problem/process and what's at stake.



Ben Collings – RNC2 PhD student

We need to think about temporal scale

- We can access high-frequency imagery at near daily timescales from 2013-onwards (more in the last 2-3 years).
- There is a rich collection of coastal change information locked away in the historic aerial photo record that has been widely ignored to date.
- Nesting recent change within the broad historical record provides a context that the short satellite records can't yet provide.



Pathway to decision making is key

There is a widening gap between our ability to collect vast amounts of data and our understanding of the coast and our ability to make good decisions.

https://www.smh.com.au/environment/sustainability/construction-begins-on-northern-beaches-sea-wall-despite-vexed-funding-issues-20210223-p5754a.html

https://www.theguardian.com/australia-news/2022/sep/18/beachfront-homeowners-push-to-extend-collaroy-seawall-to-protect-property-from-erosion

Conclusion

- The coastal monitoring toolbox has expanded considerably.
- There is no best approach to monitoring coastal change using remote sensing. There is no single approach that should be relied on.
- We need to develop a hierarchical approach to pick the right tool.
- We need to address the gap between the availability of remote sensing tools and our understanding of coastal change and decisions this understanding supports.