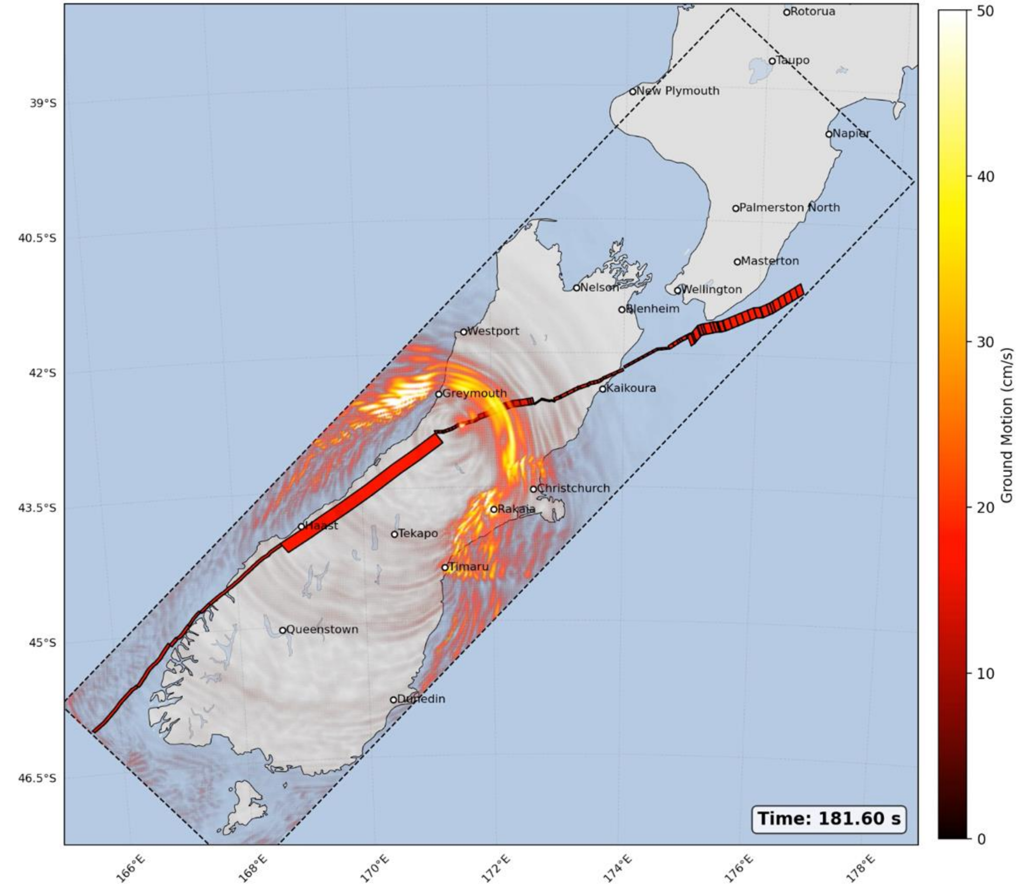
Ground-motion modelling of Alpine fault earthquakes that rupture into the Marlborough Fault Zone



Brendon Bradley, University of Canterbury, New Zealand

AF8 Webinar, 22 Oct 2025

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Overview

1. Project objectives and milestones
2. Definition of rupture geometries
3. Development of simulation inputs
   A. Crustal velocity model
   B. Kinematic rupture on multi-segment faults
4. Illustrative simulation results
5. Interpretative framework
6. Next steps to complete project

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū
AF8
ALPINE FAULT MAGNITUDE 8
IT'S OUR FAULT
NŌ MĀTOU TE HAPA

1. Project objectives

Extend on the success of the AF8 project to perform ground-motion simulations of the earthquakes on the Alpine fault that:

A. Rupture further northward such that they pose a serious threat to Wellington

B. Incorporate advances in ground-motion simulations in NZ since the 2015 Alpine fault simulations were performed.

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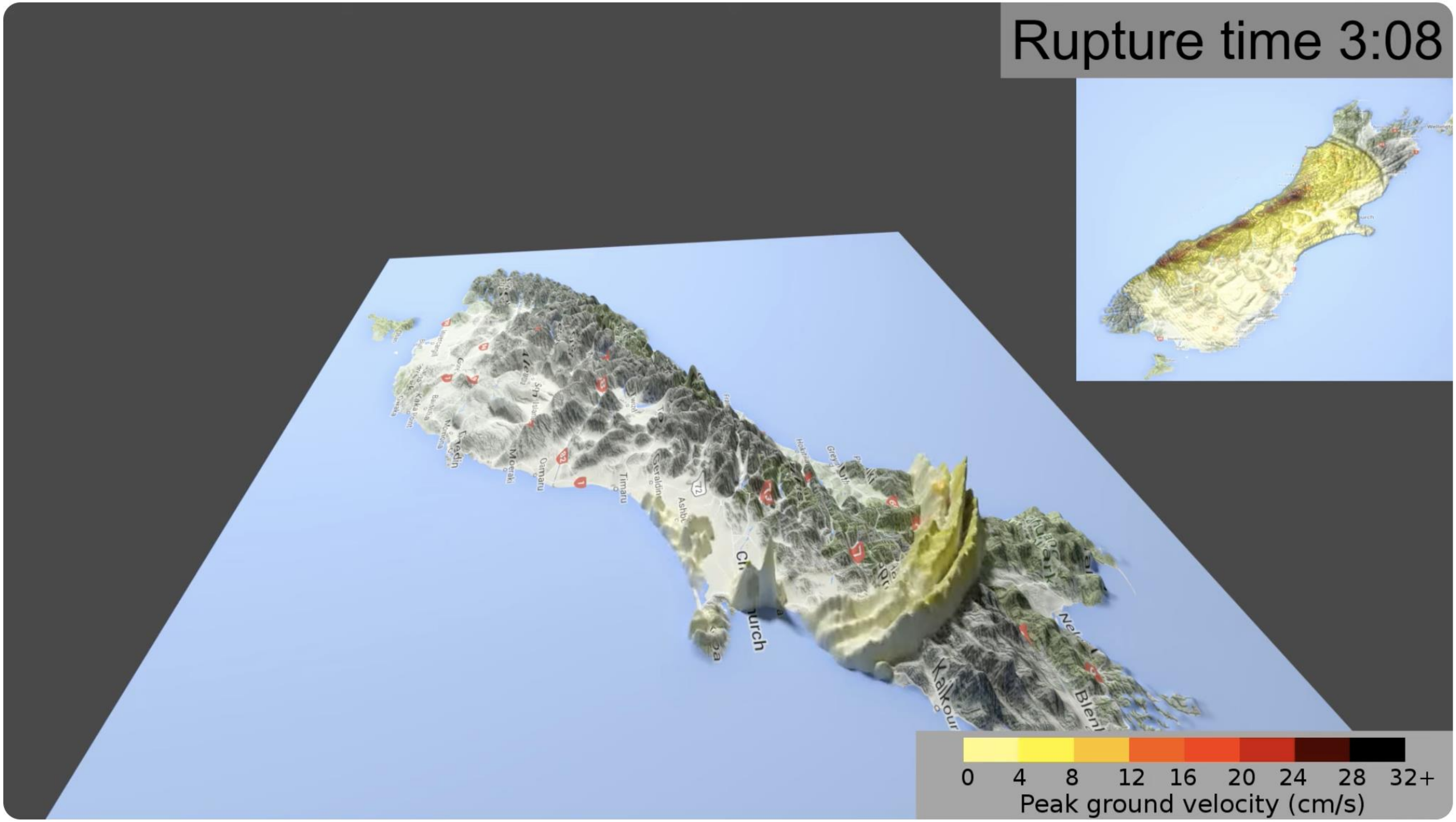
Visualisation of rupture from 2015 work



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1. Project milestones

The project milestones are:

- M1: Using the NSHM2022 rupture set, obtain a subset of approximately 3-5 rupture geometries that initiate on the Alpine fault and extend northward toward Wellington
- M2:Perform ground-motion simulations of the selected scenario ruptures
- M3: Compare and contrast the obtained results with those from empirical ground-motion models used in the 2022 NSHM

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How the rupture scenarios were determined

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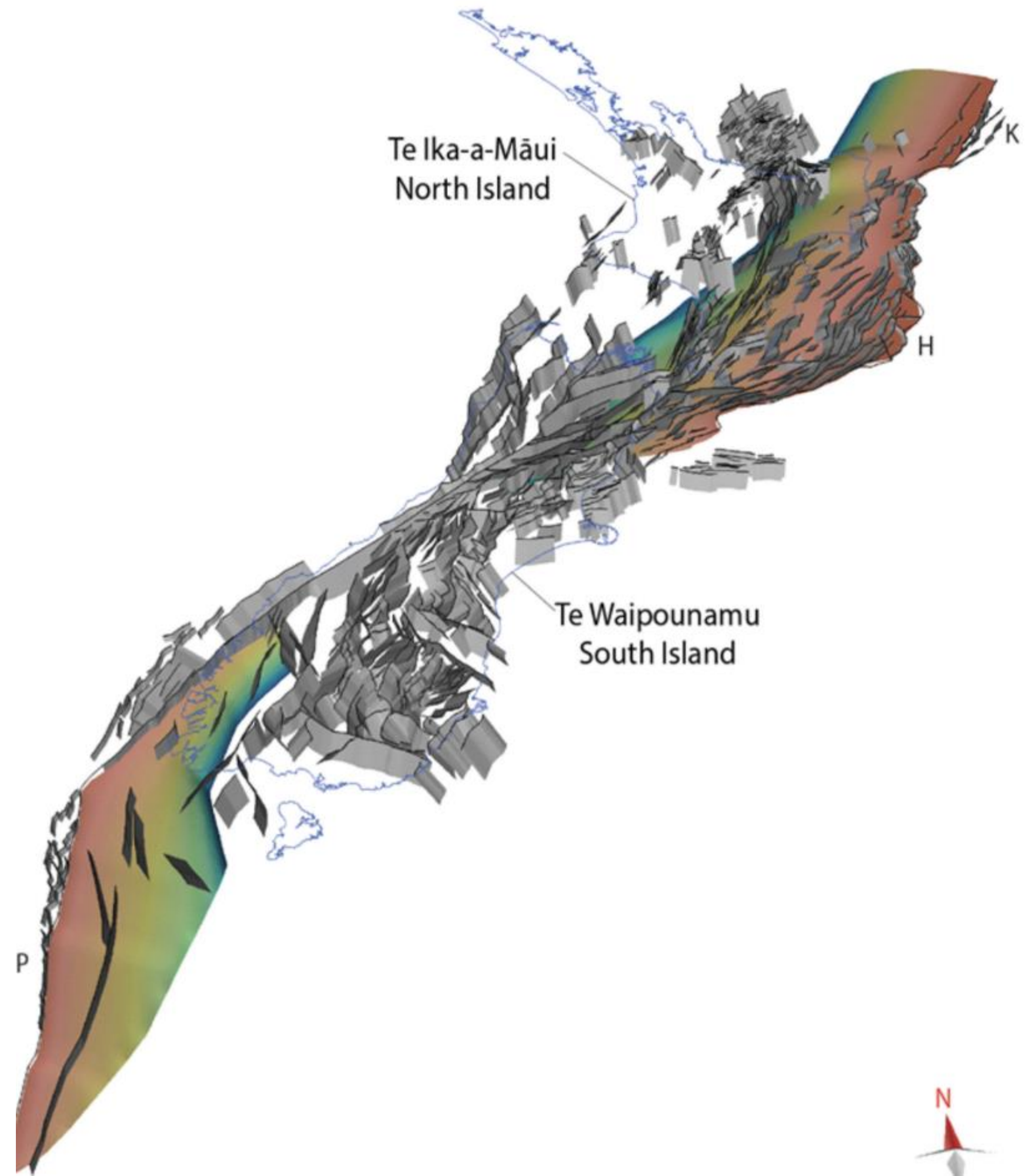
NSHM2022 non-characteristic sources



Development of rupture geometries

- There are infinite possibilities for future earthquake scenarios ….
- Used rupture geometries from the 2022 NSHM to bound the problem.
- Additionally, imposed the following constraints:
  – Must rupture the same fault segments as the AF8 base scenario (Alpine: Caswell – Kaniere segments): 1,113 unique rupture geometries
  – Must rupture to within 100 km of Wellington: Essentially 3 'meta' geometries.

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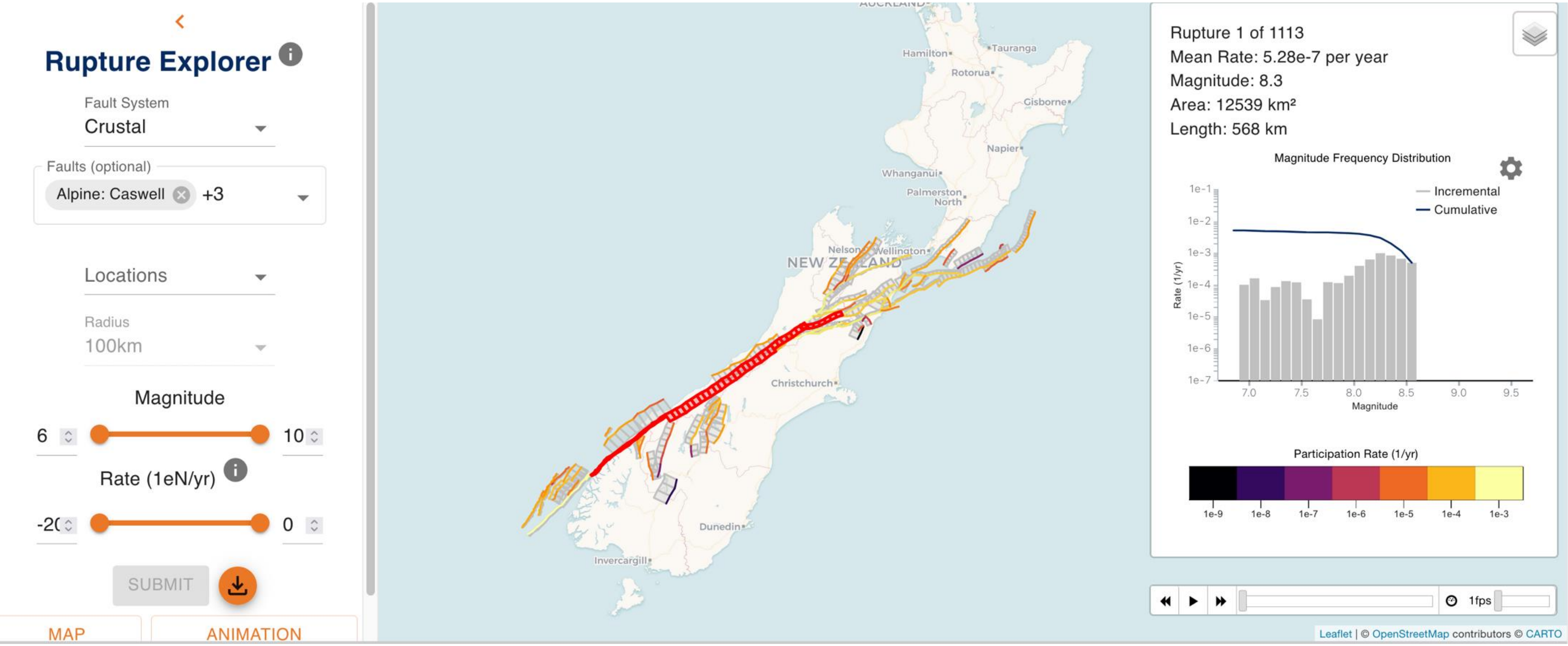
Rupture geometries

1,113 unique rupture geometries



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Rupture geometries: <100km of WEL

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Multi-segment kinematic rupture generation

- As part of this work, we developed a new formulation to enable the generation of kinematic ruptures on multi-segment geometries (Bradley and Faulkner, 2025)
- Extends on single plane approaches:
  - How seismic moment is apportioned
  - How rupture jumps between segments
  - Where jumping on segments occurs, and any time delays
- (Further details available on request)

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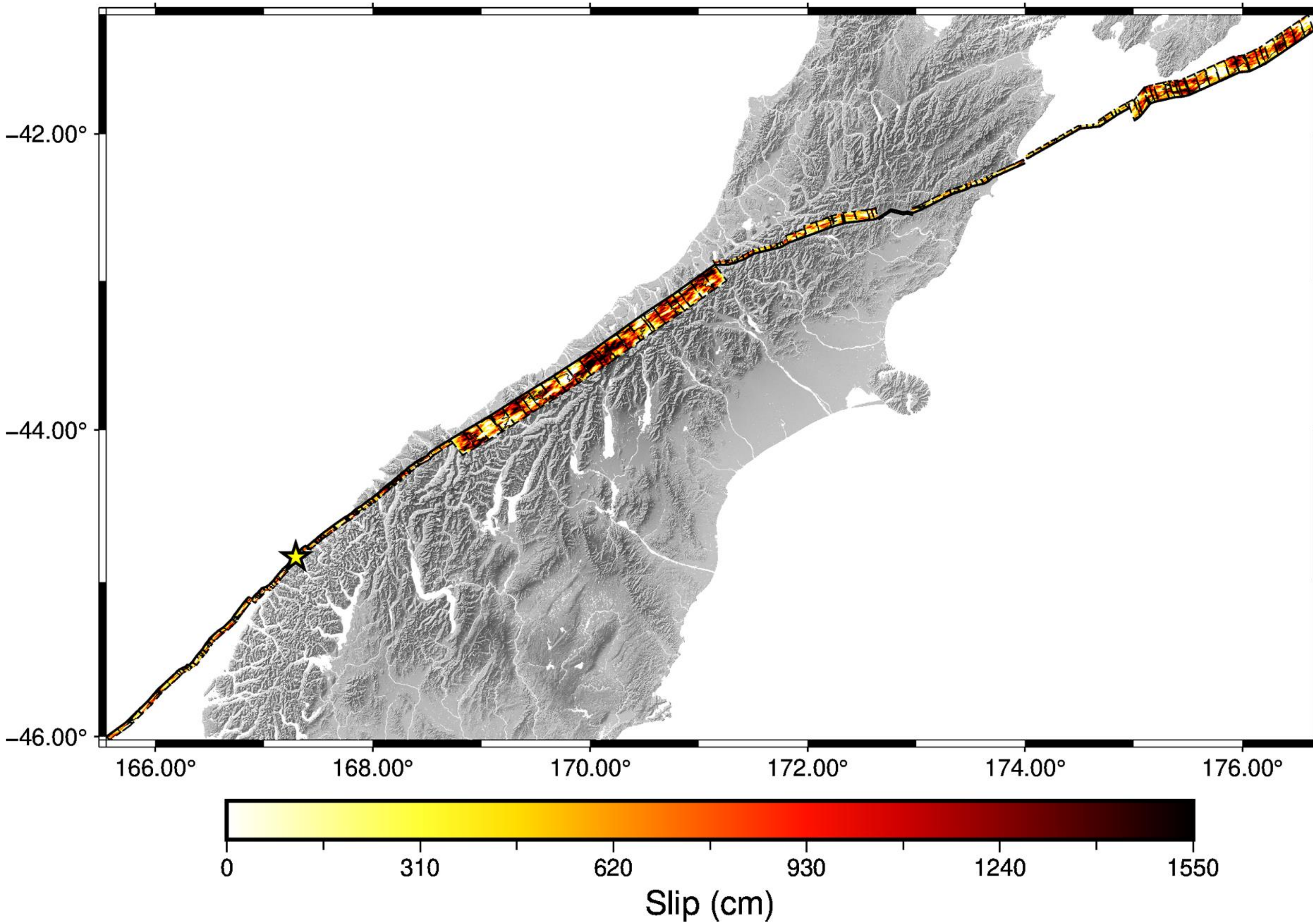
Alpine Hope: Slip Distribution



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‘Final’ simulation scenarios

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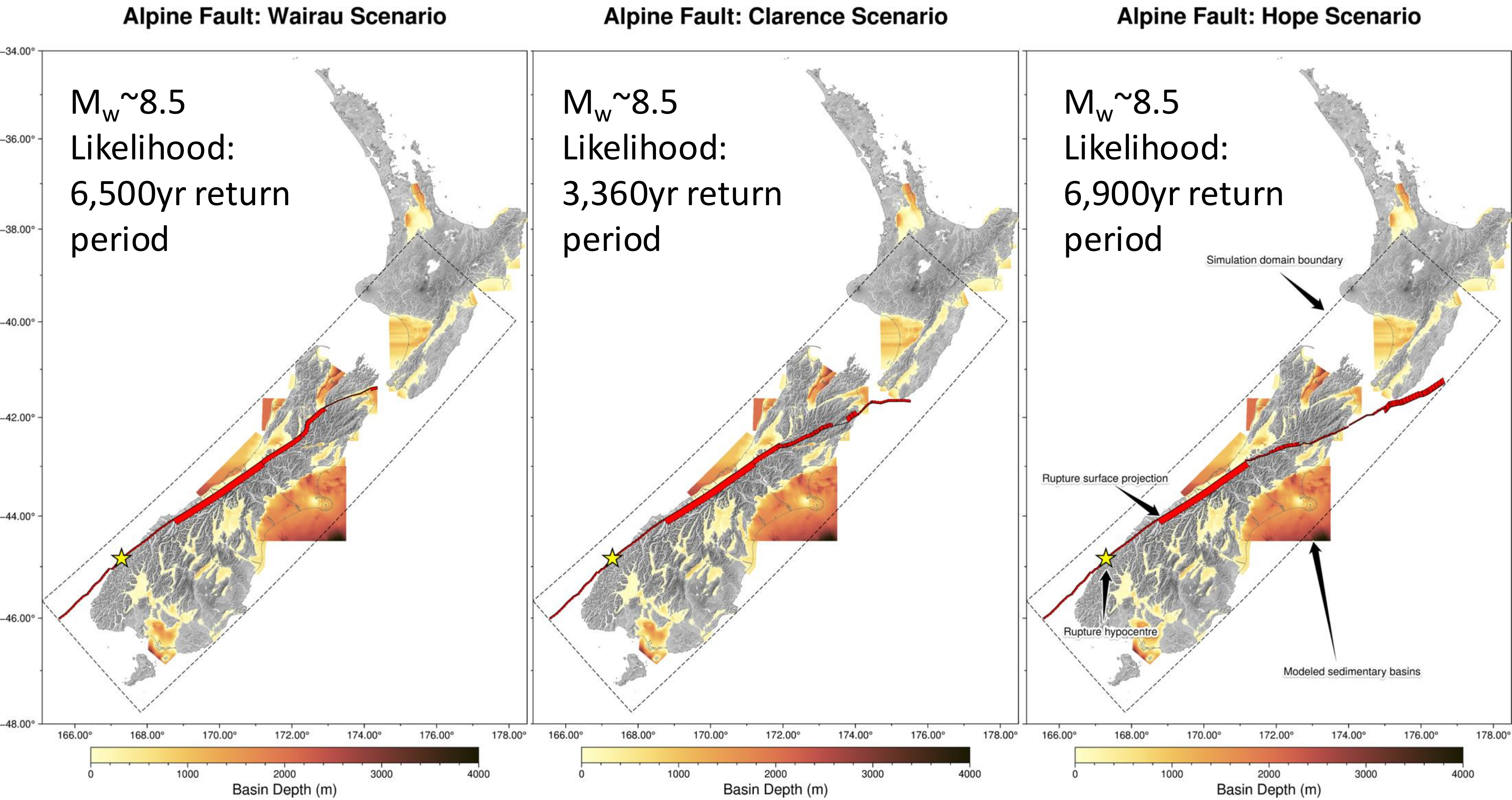
3 rupture scenarios



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3 rupture scenarios - notes

- Rupture likelihoods:
  - The three M8.5 Alpine fault scenarios have aggregated annual likelihoods of 1/6900 to 1/3360.
  - For reference, the long-term annual likelihood of major ruptures (M~>7) events on the Alpine fault is ~1/300. Therefore, these M8.5 scenarios occur on the order of 1-in-10 to 1-in-20 times for major Alpine fault ruptures.
  - Ruptures that include the Hutt Valley section of the Wellington fault (i.e., through Wellington city) have a 1/10,000 annual probability (NSHM2022). Therefore these M8.5 Alpine fault events are ~2-3 times as likely to occur.
  - M=7.5-8 ruptures on the Hikurangi subduction interface have a ~1/500 annual likelihood (NSHM2022)

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3 rupture scenarios - notes

- Ground-motion modelling
  - The 2015 Alpine Fault ground motion simulation work (and visualization used widely) included only detailed modeling of the Canterbury sedimentary basin – resulting in sedimentary basin reverberation only in this region.
  - The updated modelling now used includes 44 sedimentary basins in New Zealand (as illustrated with the 'basin depth' coloring in the previous figure).

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Considering rupture variations

- We currently envisage running three realizations of ruptures on each of the three different geometries, resulting in a total of 9 simulations (they are very computationally intensive)
- At the present time, only one production run has been completed for the Alpine-Hope geometry. Quantitative results shown at the end provide my expectation for shaking in Wellington in the remaining scenarios.

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Animation of Alpine-Hope rupture

https://tinyurl.com/AlpineHopeSept25

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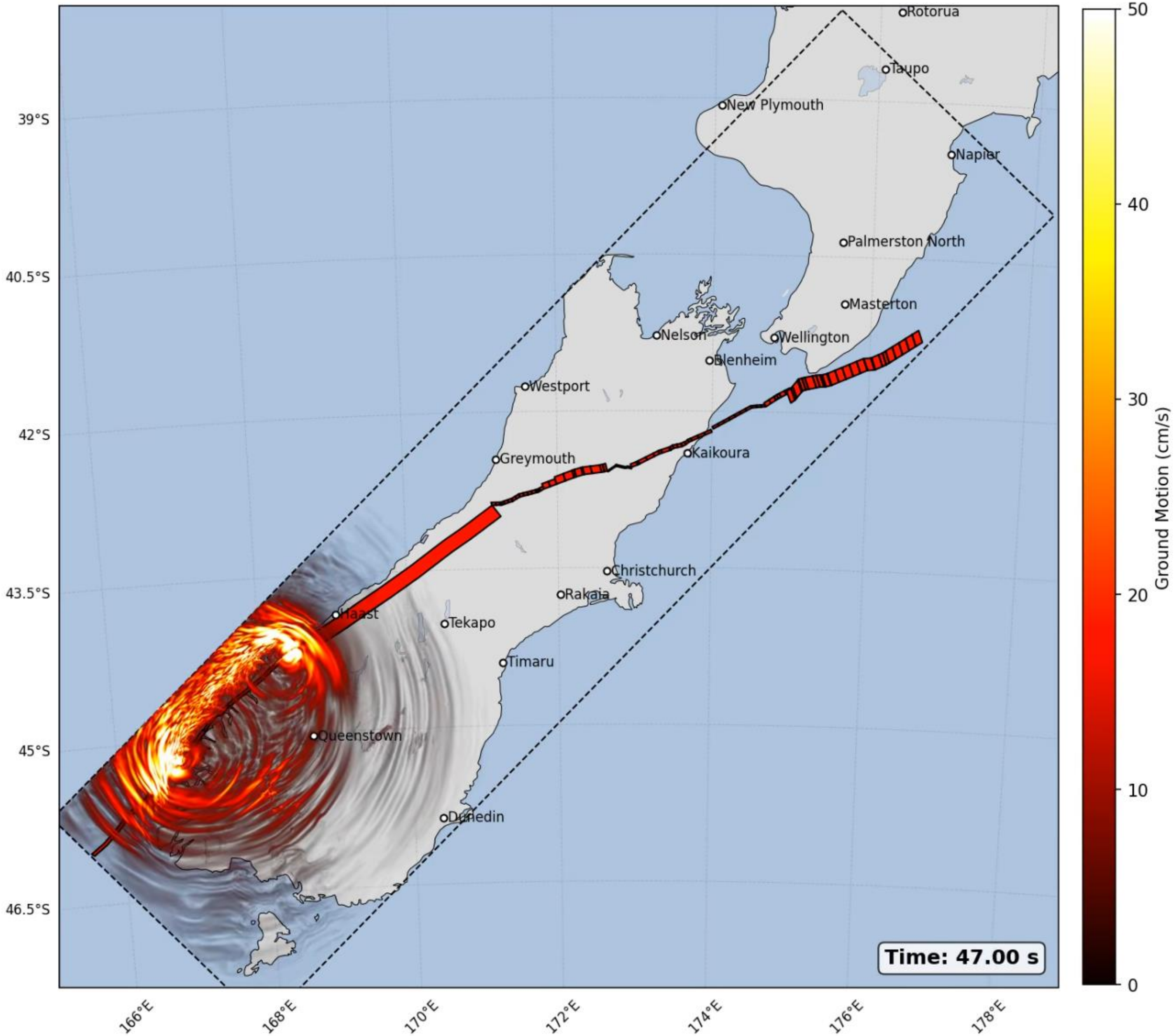
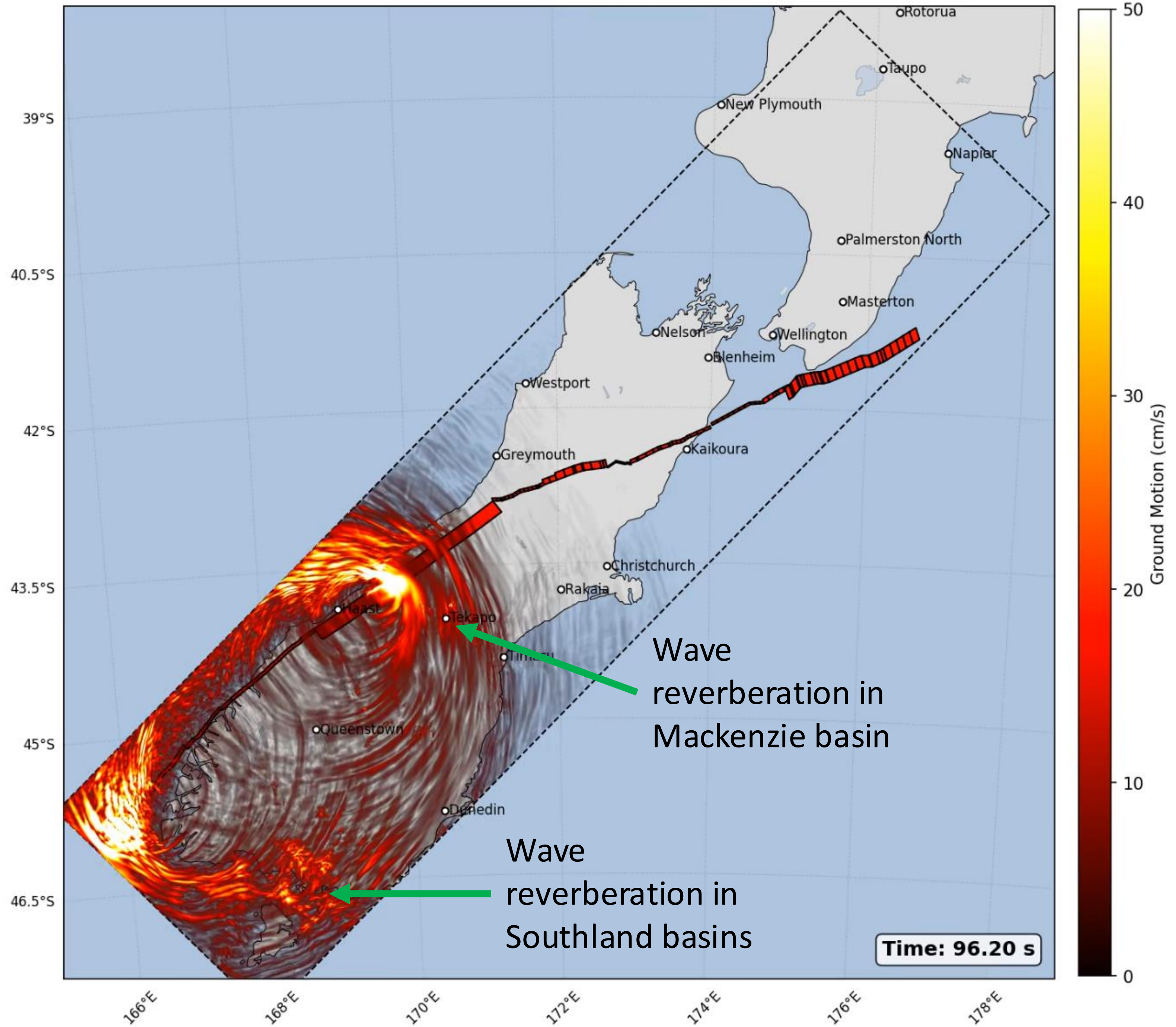

Rotorua
Taupo
New Plymouth
Napier
Palmerston North
Masterton
Nelson
Wellington
Blenheim
Westport
Greymouth
Kaikoura
Christchurch
Rakaia
Haast
Tekapo
Timaru
Queenstown
Dunedin
Time: 47.00 s
39°S
40.5°S
42°S
43.5°S
45°S
46.5°S
166°E
168°E
170°E
172°E
174°E
176°E
178°E
Ground Motion (cm/s)
0
10
20
30
40
50



Rotorua
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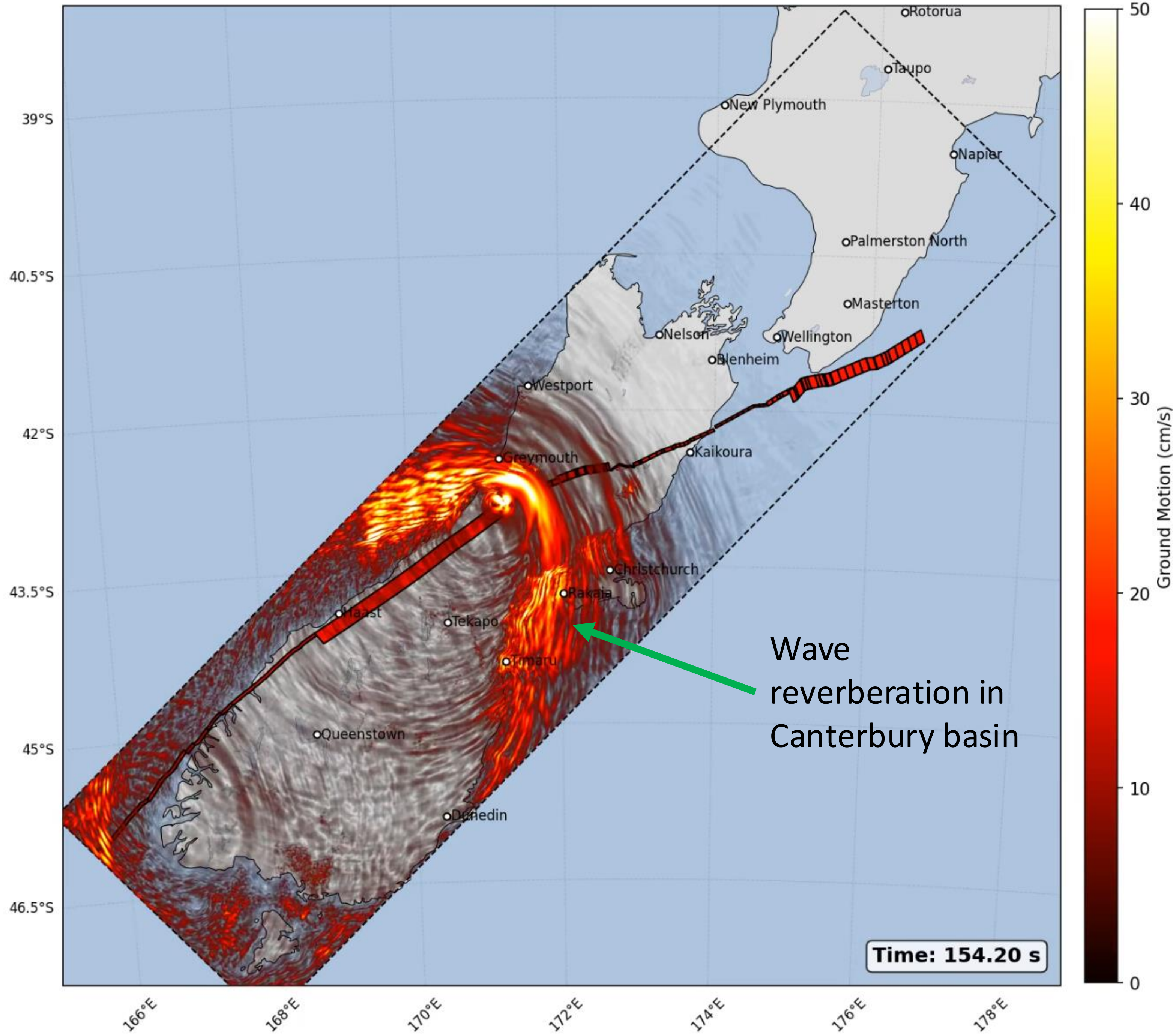
New Plymouth
Napier
Palmerston North
Masterton
Nelson
Wellington
Blenheim
Westport
Greymouth
Kaikoura
Christchurch
Rakaia
Haast
Tekapo
Queenstown
Dunedin
Wave reverberation in Mackenzie basin
Wave reverberation in Southland basins
Time: 96.20 s
39°S
40.5°S
42°S
43.5°S
45°S
46.5°S
166°E
168°E
170°E
172°E
174°E
176°E
178°E
Ground Motion (cm/s)
50
40
30
20
10
0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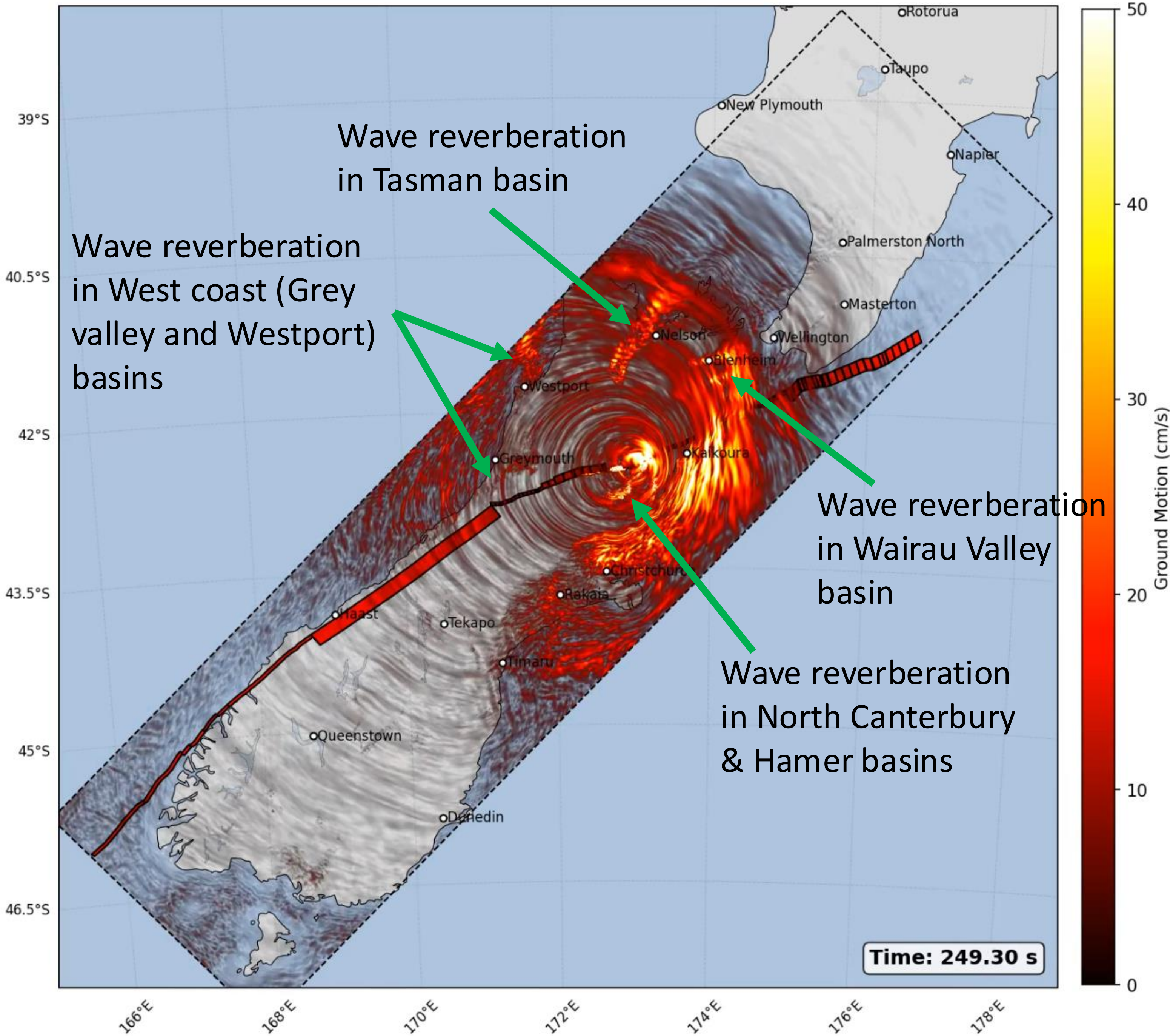
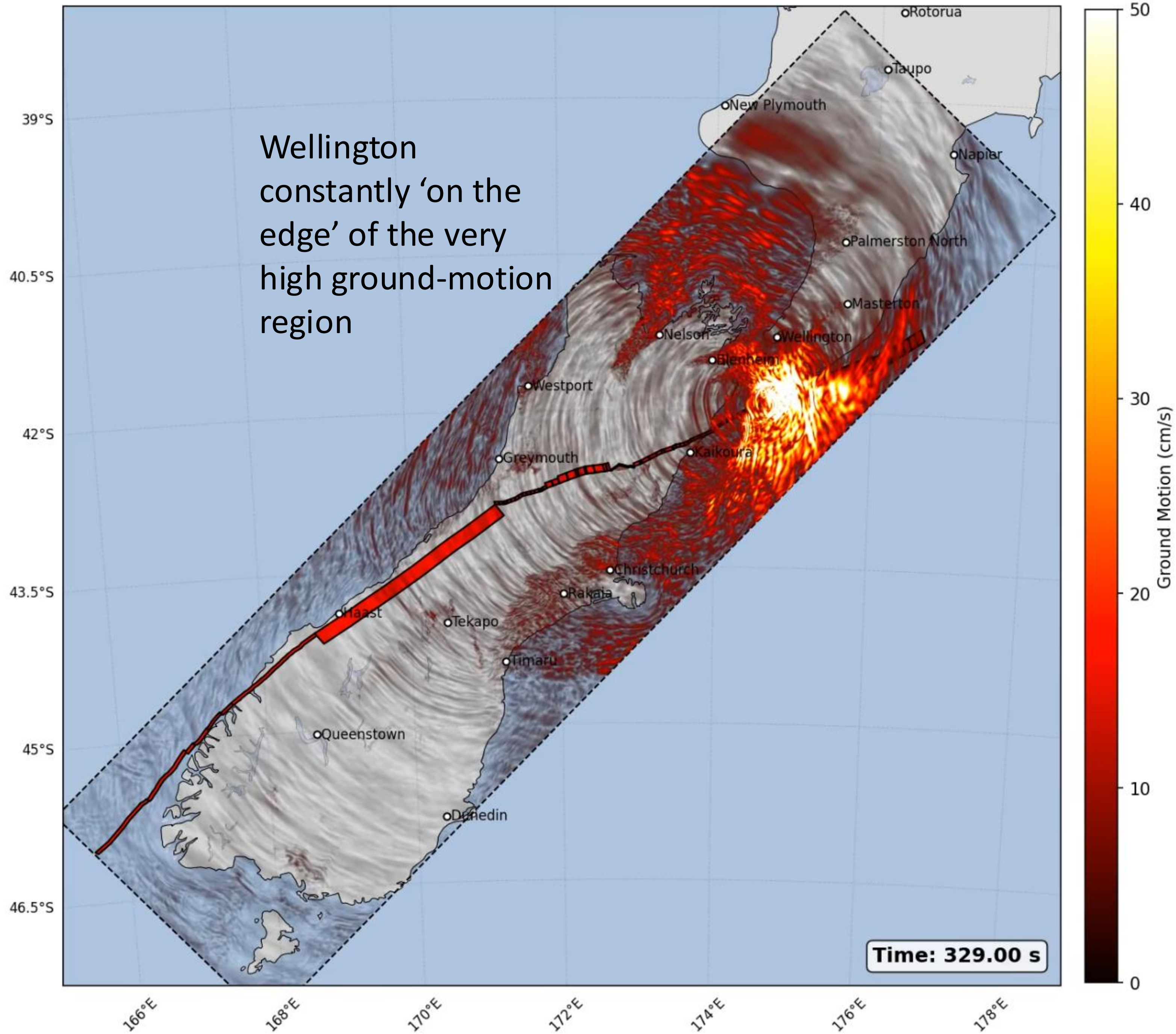
Blenheim
Westport
Greymouth
Kaikoura
Christchurch
Rakaia
Haast
Tekapo
Timaru
Queenstown
Dunedin
39°S
40.5°S
42°S
43.5°S
45°S
46.5°S
166°E
168°E
170°E
172°E
174°E
176°E
178°E
Time: 154.20 s
Ground Motion (cm/s)
0
10
20
30
40
50
Wave reverberation in Canterbury basin


Wave reverberation in Tasman basin
Wave reverberation in West coast (Grey valley and Westport) basins
Wave reverberation in Wairau Valley basin
Wave reverberation in North Canterbury & Hamer basins
Rotorua
Taupo
New Plymouth
Napier
Palmerston North
Masterton
Wellington
Nelson
Blenheim
Westport
Kaikoura
Greymouth
Christchurch
Rakaia
Haast
Tekapo
Timaru
Queenstown
Dunedin
39°S
40.5°S
42°S
43.5°S
45°S
46.5°S
166°E
168°E
170°E
172°E
174°E
176°E
178°E
Time: 249.30 s
Ground Motion (cm/s)
0
10
20
30
40
50

Wellington constantly ‘on the edge’ of the very high ground-motion region



Summary of results (including runs to complete)

- Shaking in Wellington (PGA in g, PGV in cm/s)

Scenario	Rock	Soil (Te Papa)
2016 Kaikoura	0.07g, 21 cm/s	0.13g, 30 cm/s
Alpine, AF8	Not in simulation domain (<0.01g, <2 cm/s)	Not in simulation domain (<0.01g, <2 cm/s)
Alpine-Hope M8.5 simulation (Rrup = 54 km)	0.03g, 10-12 cm/s	0.05g, 15-20 cm/s
Alpine-Wairau M8.5 (Rrup = 35 km)	** 0.05-0.15g, 15-30 cm/s	** 0.1-0.2g, 20-50 cm/s
Alpine-Clarence M8.5 (Rrup = 45 km)	** 0.05-0.1g, 10-25 cm/s	** 0.05-0.15g, 15-40 cm/s

** Expectation of runs that are yet to be completed

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Summary of results (including runs to complete)

- Note: Advanced simulations suggest that PGA is overestimated for M8.5 ruptures using traditional empirical models (i.e., 2022 NSHM). In contrast, the PGV values from the 2022 NSHM are generally consistent with simulation results.
- For reference: Wellington Hutt Valley rupture in Wellington is PGA ~ 0.5g and PGV ~ 40 cm/s

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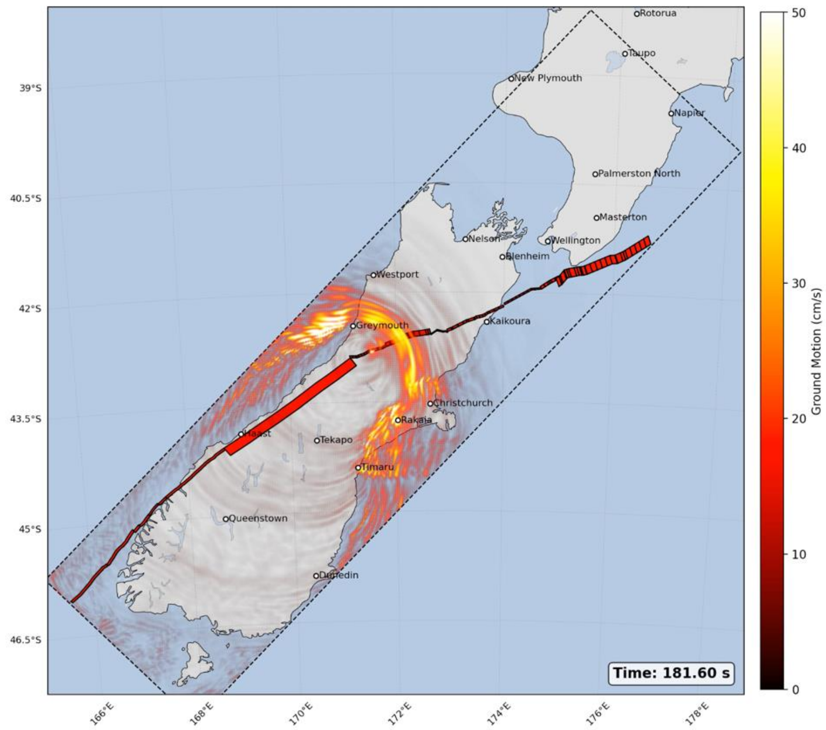

Thank you for your attention

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