Ground Motion Simulations for Global Analogs of the Hikurangi Subduction Zone

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Subduction Zone Earthquake Potential

- Schellart and Rawlinson (2013) analysed global correlations between maximum magnitudes of subduction zone interface thrust earthquakes and 24 physical parameters of subduction zones
- They made a global map of the active subduction zones, where 200 km trench segments were ranked by their predicted capability of generating a subduction zone earthquake with Mw > 8.5

Schellart, W.P. and N. Rawlinson. Global correlations between maximum magnitudes of subduction zone interface thrust earthquakes and physical parameters of subduction zones. Physics of the Earth and Planetary Interiors Vol. 225, December 2013, Pages 41-67

First 12 of 24 Physical Variables

Parameter	Units	Explanation
vOPD	[cm/yr]	Trench-normal overriding plate deformation rate
OPSC		Overriding plate strain class
vA	[cm/yr]	Trench-normal overriding plate accretion/erosion rate
vSP	[cm/yr]	Trench-normal subducting plate velocity
vOP	[cm/yr]	Trench-normal overriding plate velocity
vT	[cm/yr]	Trench-normal trench migration velocity
vS	[cm/yr]	Trench-normal subduction velocity
vC	[cm/yr]	Trench-normal convergence velocity
vSP\vS\		Subduction partitioning
ASP	[Ma]	Subducting plate age
TTS	[km]	Thickness of the trench sediments
TSS	[km]	Thickness of the subducted sediments

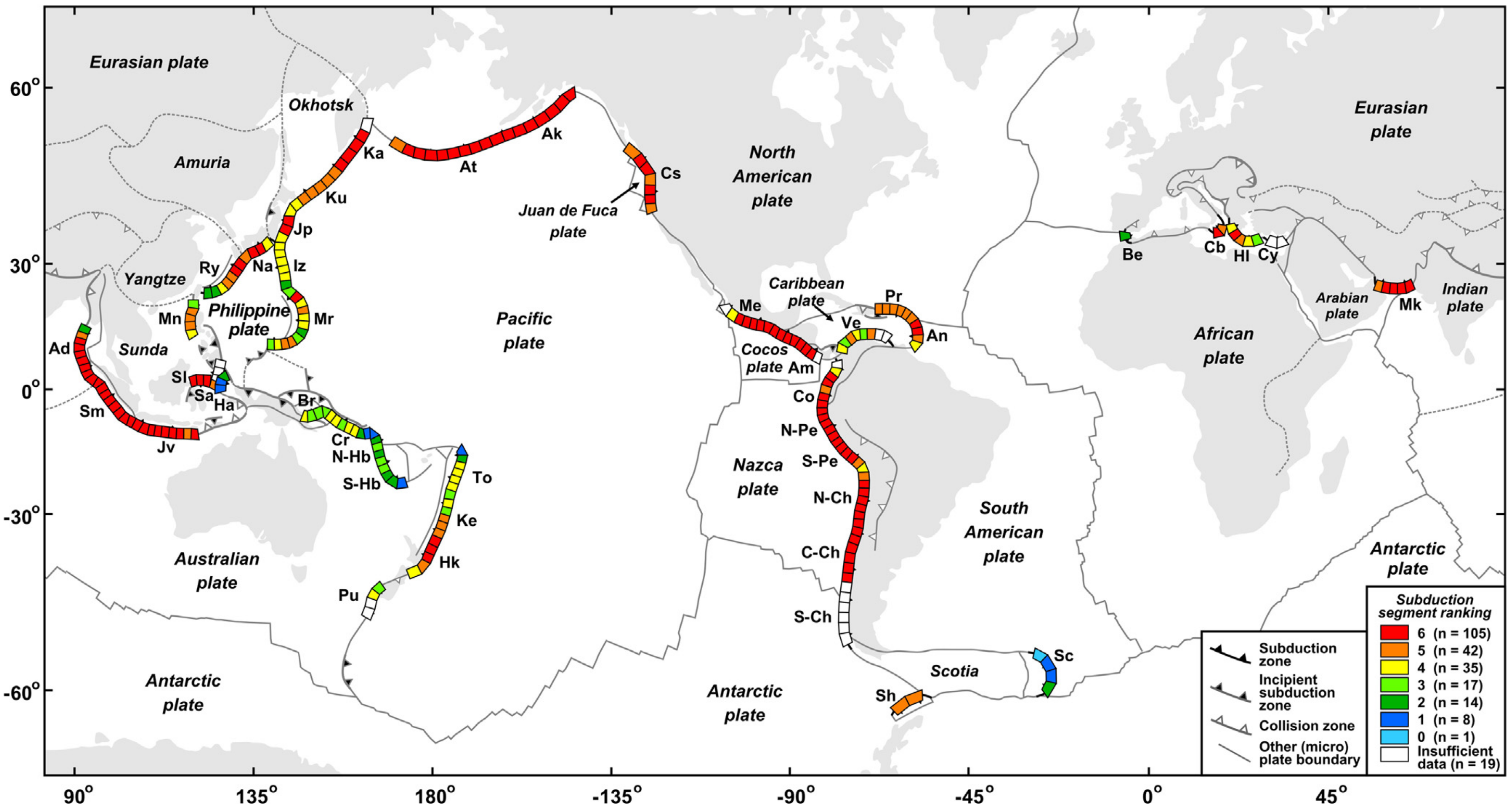
Red: parameters that provide the strongest constraints

Second 12 of 24 Physical Variables

Parameter	Units	Explanation
dST	[deg]	Subduction zone thrust dip angle
dS	[deg]	Shallow slab dip angle
dD	[deg]	Deep slab dip angle
DUMS	[km]	Upper mantle slab tip depth
LUMS	[km]	Slab length
W	[km]	Slab width
DSE	[km]	Distance to the closest lateral slab edge
FBu	[N/m]	Upper mantle slab negative buoyancy force
CT	[m-2]	Subduction zone trench curvature
CST	[m-2]	Subduction zone thrust curvature
aT	[deg]	Trench segment curvature angle
|aT|	[deg]	The absolute value of the curvature angle

Red: parameters that provide the strongest constraints

Capability of generating a subduction earthquake with Mw > 8.5



Largest Recorded Earthquakes

EVENT	UNILAT / BILAT	Strong Motion Recordings
1952 Kamchatka Mw 8.9	Unilateral	No
1960 Chile Mw 9.5	Unilateral	No
1964 Alaska Mw 9.2	Unilateral	No
2004 Sumatra Mw 9.1	Unilateral	No
2010 Maule, Chile Mw 8.8	Bilateral	Yes
2011 Tohoku Mw 9.0	Bilateral	Yes
Hikurangi - up to Mw 9.0?	Unilateral?	Not yet

Subduction Zones Comparable to Hikurangi

"The three largest historical subduction earthquakes are characterized by unilateral rupture propagation along the subduction zone interface from a region of compressive normal stress towards a region of neutral stress or deviatoric tension."

"If we take the conceptual model developed in Section 5.4 for the three largest subduction zone earthquakes (1960 Chile, 1964 Alaska, 2004 Sumatra) and apply it to other subduction zone regions shown in Fig. 9 with high scores, then several regions jump out due to their comparable tectonic setting. These regions include the Hikurangi-southern Kermadec subduction segment and the Central America subduction segment. Other regions could include the Nankai-northeastern Ryukyu subduction segment, the western Hellenic subduction segment, the Lesser Antilles-Puerto Rico subduction zone and the Manila subduction zone. Below we will describe the Hikurangi-southern Kermadec subduction segment and the Central America subduction segment in more detail."

Subduction Zones Comparable to Hikurangi

- We can use the slip models of these three earthquakes to guide the development of Hikurangi slip models, but we have no ground motion recordings of these three earthquakes. But if we look at three other giant earthquakes (Section 5.4.4) we have on Page 59:
- *"We will now discuss three more giant subduction zone thrust earthquakes in the light of their tectonic setting and the eight physical parameters that provide the strongest constraints on the likelihood of giant earthquakes occurring. These include the 1952 Mw 8.8–9.0 Kamchatka earthquake (Kanamori, 1976; Okal, 1992; Johnson and Satake, 1999), the 2010 Mw 8.8 Maule Chile earthquake (Vigny et al., 2011), and the 2011 Mw 9.0 Japan earthquake (Ide et al., 2011; Ozawa et al., 2011; Simons et al., 2011)."*

Unilateral Hikurangi Rupture

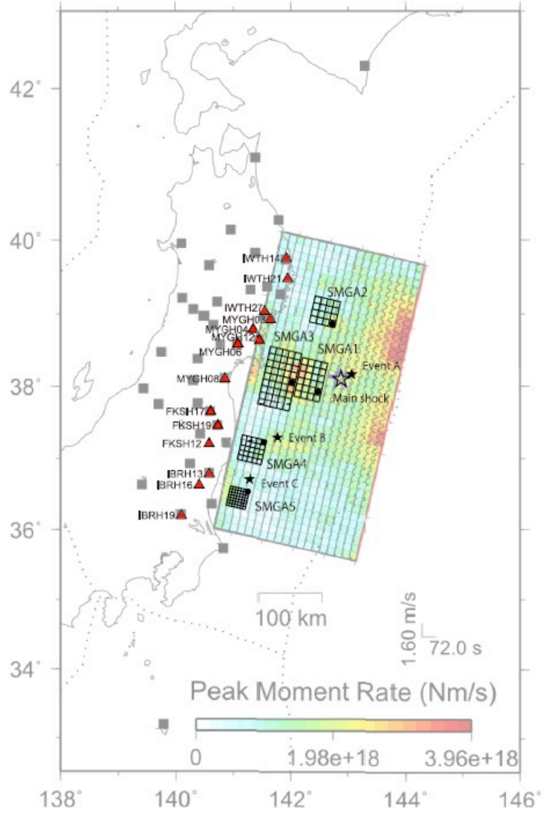
- We have slip models and ground motion recordings of the last two of these events (Tohoku and Maule) and we have already done validations of ground motion simulations for them.
- Page 61 of the paper says:
- *"… In analogy with the tectonic settings of the Chile 1960, Alaska 1964 and Sumatra–Andaman 2004 giant earthquakes, one could expect a giant subduction earthquake with an epicenter at the subduction zone plate interface in the southwest Hikurangi region, and unilateral rupture propagation towards the northeast. Fig. 9 shows relatively high scores (S = 4–5) for the two southernmost Hikurangi segments, and the highest scores for the next three segments to the north (S = 6). Wallace et al. (2009) documented high interseismic coupling coefficients (0.8–1.0) in the south but lower ones (0.1–0.2) in the central and northern Hikurangi region, suggesting higher elastic strain buildup in the south."*

Our Plan

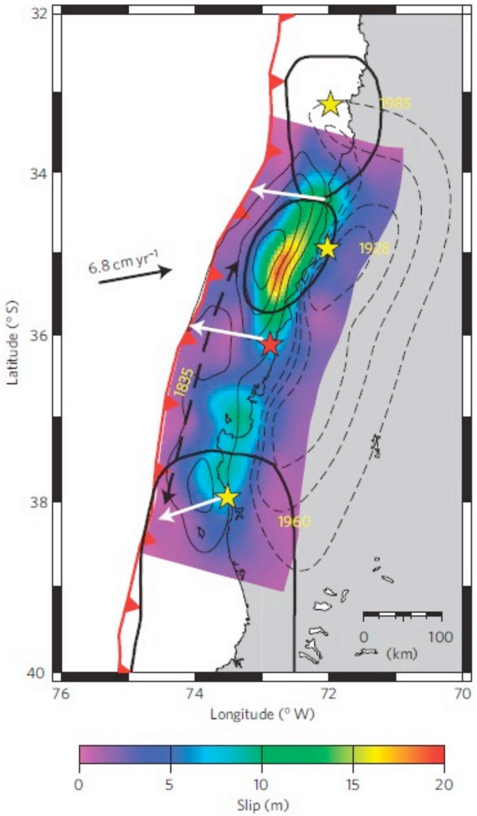
- Our plan is to build a Hikurangi slip model that is compatible with the above description *(“an epicenter at the subduction zone plate interface in the southwest Hikurangi region, and unilateral rupture propagation towards the northeast*”), and use it to simulate ground motions at the recording stations of the Tohoku and Maule earthquakes to check for overall compatibility
- In follow-up work we would like to simulate the ground motions of Hikurangi scenario events based on knowledge on source characterisation that is gained from the Maule and Toholu events

Slip Models – Tohoku & Maule

2011 Tohoku (Kurahashi & Irikura)



2010 Maule, Chile (Lorito et al.)



Source Modeling Details

- Review the outcomes of the Cascadia Mw9 project (Frankel et al., 2018)
- Use Rob Graves' code to create several random models and select the most appropriate one(s)
- Adjust Kx and Ky from Skarlatoudis et al paper
- Adjust other parameters in the derivation of the slip model (fault edge padding, rise time, slip velocity) based on the Tohoku and Maule models
- Adjust the high frequency parameters in order to remove the bias we have seen in our modeling of the 1931 Hawkes Bay and 2009 Dusky Sound events

Maule and Tohoku were not Unilateral

- One problem is that Page 59 of the paper says:
- *"A difference between the Chile 2010 and Japan 2011 earthquakes and the largest three reported in Sections 5.4.1, 5.4.2 and 5.4.3 is that the former two show bilateral rupture propagation."*
- For Maule, we could just model the stations in the northern half of the rupture model which has a large asperity. For Tohoku we could model the stations in the southern part of the rupture model which has a large asperity.
- If we do not use these two events, then we are without any event with M > 8.5 that has strong motion recordings. The only other two events, both without strong motions, are 1952 Kamchatka and 1957 Aleutian.
- If we relax the requirement to simulate very large events then we could use Central America, which has events with Mw up to 8, but this is a severe limitation because we expect much larger events are possible on the Hikurangi and because the focus of the paper is on Mw > 8.5.

Slip Models – Tohoku & Maule

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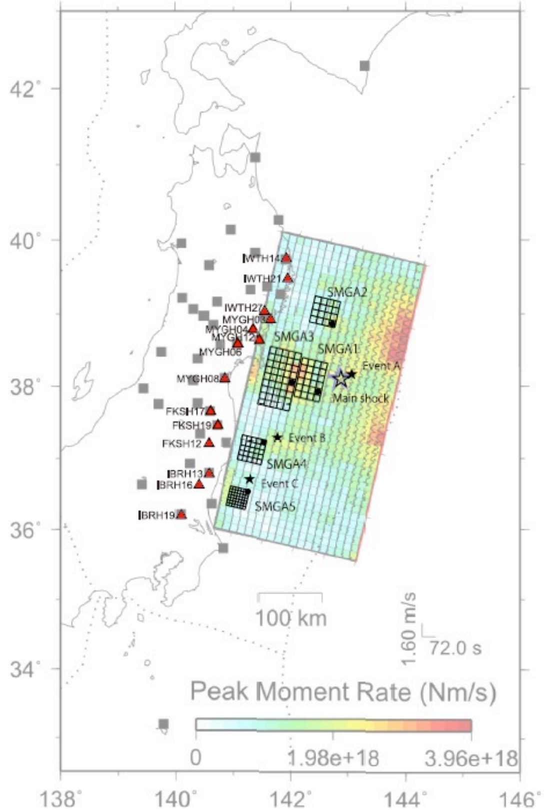

2010 Maule, Chile (Lorito et al.)