Using Cascadia recurrence information for Seismic Hazard Modelling in the next (2015) National Building Code of Canada

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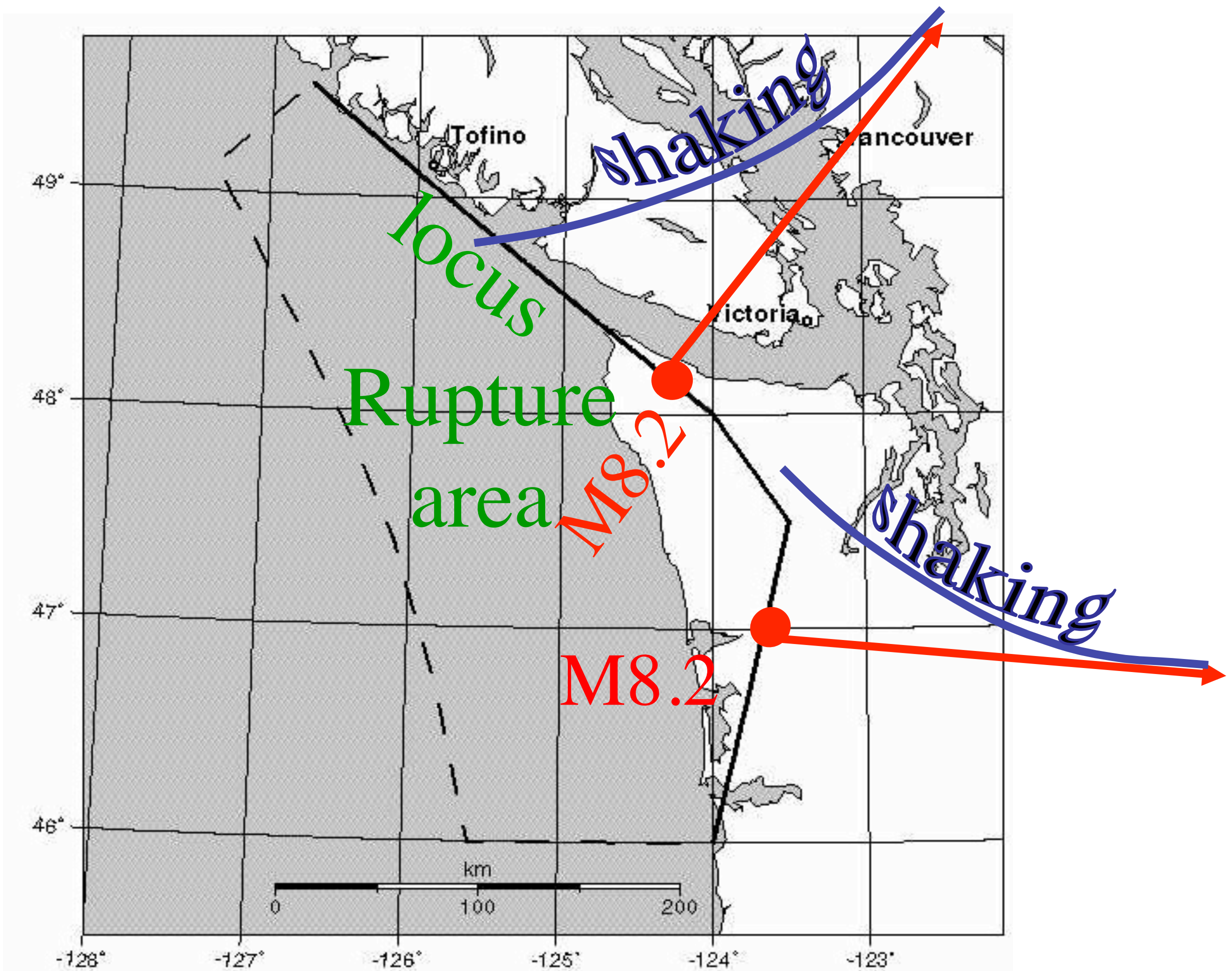
Ressources naturelles Canada

Historical background

The Cascadia source was not modelled in Canada's 3rd Generation hazard model (1985, 1995 maps).

4th Generation model (2005 and 2010 maps) used a deterministic approximation, placing a magnitude 8.2 earthquake at various places along the locus of closest approach



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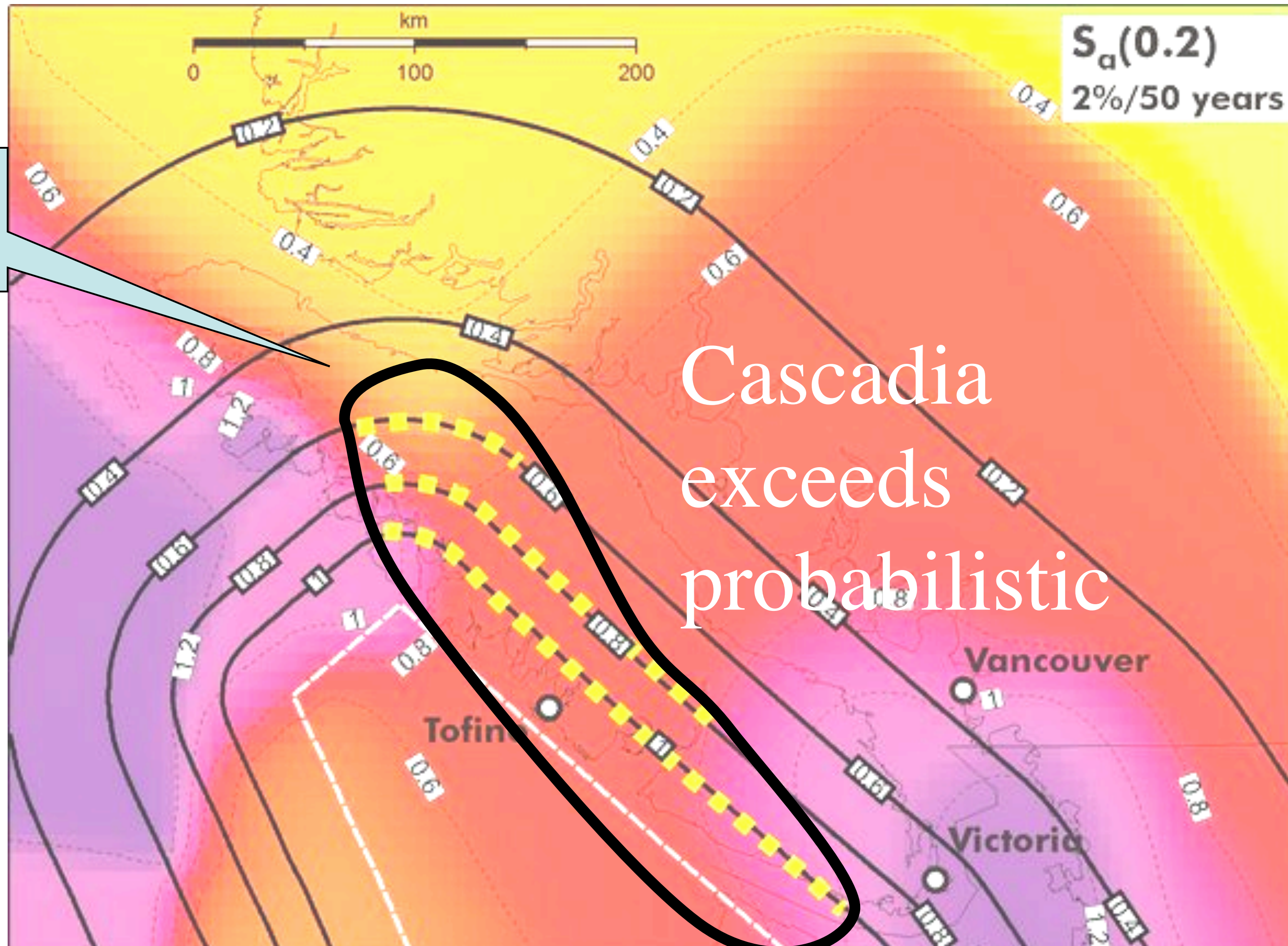
Seismic hazard from that deterministic event was then combined in a 'robust' fashion with other probabilistic hazard values (i.e. conservatively taking the higher of the two values for design)

– this was **not conservative everywhere**

Just replacing "or" by "and" increases hazard ~40% along this line



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For the Penrose conference in 2000 Adams, Halchuk and Weichert generated a probabilistic model for Cascadia, showed that its predicted hazard and the deterministic hazard were reasonably similar, and concluded that the deterministic approximation did not compromise safety.

Comparison of 4th Generation and trial 5th Generation hazard at a Canadian city

Median Values Subduction source
Sa in %g for 2%/50 year

Period	2015 trial Probabilistic	2005/2010 Deterministic	ratio
2	0.2	0.1	2.02
1	0.3	0.2	1.42
0.5	0.5	0.5	1.00
0.2	0.5	0.6	0.88

Paleohistory of Great Cascadia Events – after Goldfinger et al. 2012

Table 9. Magnitude calculated from time interval, plate motion and rupture zone dimensions

Turbidite number	mean age	northern margin following interval years	northern margin slip from following time (m)	southern margin interval years	southern margin slip from time (m)	average northern & southern slip	Segment name	rupture length km	rupture width km	seismic moment	Mw
1	250					16.0	A	1000	83	398.4E+27	9.00
2	412	162	5.9	162	5.9	4.6	A	1000	83	113.6E+27	8.64
2a	579			167	6.1	4.7	C	450	55	55.8E+27	8.43
3	784	373	13.6	205	7.5	8.1	A	1000	83	202.7E+27	8.81
3a	1062			278	10.2	7.8	B	660	75	69.0E+27	8.50
4	1189	405	14.8	127	4.6	7.5	A	1000	83	186.5E+27	8.78
4a	1364			175	6.4	4.9	C	450	55	71.2E+27	8.50
5	1626	437	16.0	262	9.6	9.8	A	1000	83	245.1E+27	8.86
5a	1818			193	7.0	5.4	B	660	75	164.7E+27	8.75
5b	2121			303	11.1	8.5	C	450	55	72.1E+27	8.51
5c	2386			265	9.7	7.5	C	450	55	40.8E+27	8.34
6	2536	911	33.3	150	5.5	14.9	A	1000	83	372.2E+27	8.98
6a	2767			230	8.4	6.5	C	450	55	91.9E+27	8.58
7	3105	568	20.8	338	12.4	12.8	A	1000	83	318.1E+27	8.94
7a	3350			245	9.0	6.9	B	660	75	128.7E+27	8.68
8	3587	482	17.6	237	8.7	10.1	A	1000	83	252.2E+27	8.87
8a	3946			359	13.2	10.1	D	250	55	39.9E+27	8.34
9	4211	624	22.8	265	9.7	12.5	A	1000	83	311.8E+27	8.93
9a	4509			299	10.9	8.4	D	250	55	53.1E+27	8.42
10	4861	650	23.8	352	12.9	14.1	A	1000	83	351.4E+27	8.97
10a	5159			299	10.9	8.4	C	450	55	29.3E+27	8.25
10b	5267			108	3.9	3.0	C	450	55	80.7E+27	8.54
10c	5564			297	10.9	8.4	C	450	55	5.4E+27	7.76
10d	5584			20	0.7	0.6	D	250	55	3.0E+27	7.59
10e	5604			20	0.7	0.6	D	250	55	10.4E+27	7.95
10f	5673			69	2.5	1.9	C	450	55	60.8E+27	8.46
11	5897	1036	37.9	224	8.2	17.8	A	1000	83	442.1E+27	9.03
12	6476	579	21.2	579	21.2	16.3	A	1000	83	406.5E+27	9.01
12a	6893			417	15.3	11.7	D	250	55	36.6E+27	8.31
13	7136	659	24.1	243	8.9	12.7	A	1000	83	316.4E+27	8.94
14*	7625	489	17.9	489	17.9	13.8	A	1000	83	343.4E+27	8.96
14a	7968			343	12.6	9.7	D	250	55	32.3E+27	8.28
15	8182	557	20.4	214	7.8	10.9	A	1000	83	270.5E+27	8.89
15a	8552			370	13.6	10.4	D	250	55	57.4E+27	8.44
16	8933	751	27.5	380	13.9	15.9	A	1000	83	396.8E+27	9.00
16a	9094			161	5.9	4.5	D	250	55	3.7E+27	7.65
17	9119	186	6.8	25	0.9	3.0	A	1000	83	74.0E+27	8.52
17a	9284	165	6.0	165	6.0	4.7	A	1000	83	115.8E+27	8.65
18	9817	534	19.5	534	19.5	15.0	A	1000	83		
n=39											
total time		9817		9817							
total slip		353	350.2		350.2	350.7					
total plate boundary slip											
scale factor	0.77										

* = age constrained by Mazama ash age from Zdanowicz et al., 1999

Intervals for complete rupture events

Dates for past events (10,000 year history)

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Cascadia Magnitude-Recurrence for complete-rupture events

10,000 year history (we have one sample of the 1/10,000 year event!)

Assume that each rupture of interest to Canada is complete, end-to-end

(i.e. all M~9, not some M9 + many M~8)

Use time interval * plate tectonic rate to get the slip per event magnitude

Protypical event happens every 550 years, ruptures length of 1020 km and width of 125 km, has slip of 25 m and has magnitude of ~9

Events range in magnitude from 8.5 - 9.3 or larger depending on input assumptions

– but seismic hazard is not very sensitive to exact magnitudes when earthquakes get this big

Simple choices for input parameters (not full logic tree)

Fault length =1050 km

Fault width = 125 km (range 105-145)

mu = 1, 2, 3 $\times 10^{11}$ dyne-cm^2

Displacement Convergence rate 37 or 45 mm/yr

%coseismic 50, 100

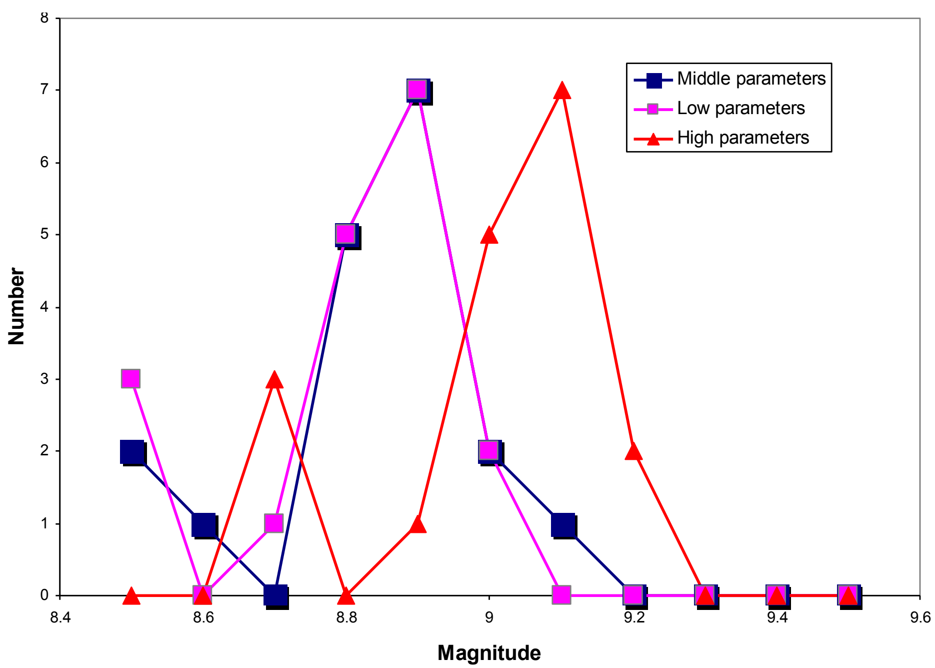
Time intervals from Goldfinger et al without considering uncertainty

Magnitudes are a mapping from the time intervals

Magnitudes are normally distributed plus 3 low values representing short intervals

e.g. mean=8.86 SD=0.16
Without 3 low values
e.g. mean=8.92 SD=0.08

Largest event = 9.09, 9.10, 9,28



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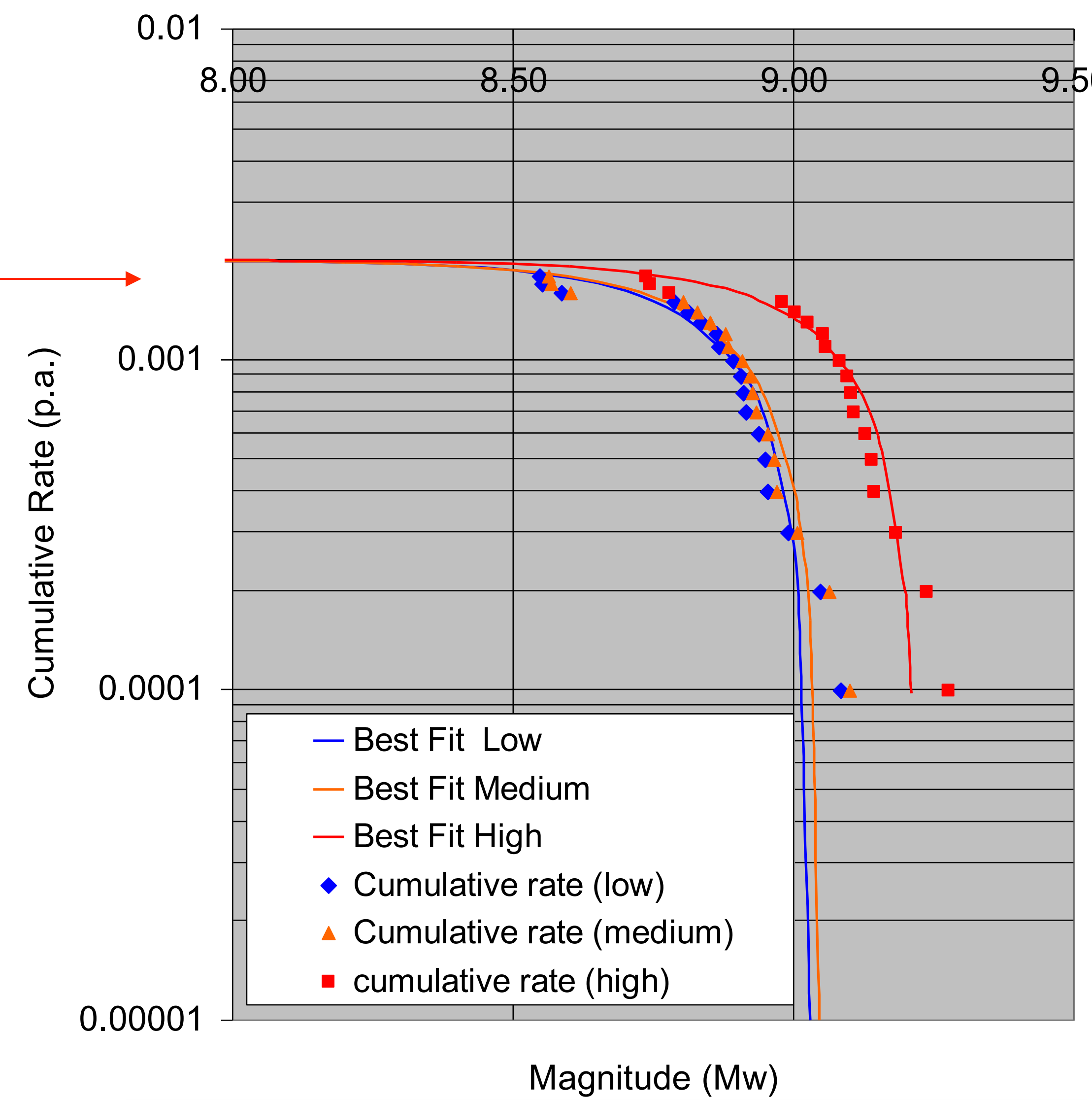
Magnitude-recurrence for complete rupture events

using 3 sets of possible input parameters

1/550 yr

1/10,000 yr



Mmin=8.5

Mmax =9.02, 9.11, 9.22

Beta =-5

N8.5 = 0.002 p.a.

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Trial run

Probabilistic Cascadia motions

Sa(0.X) for 2%/50 years

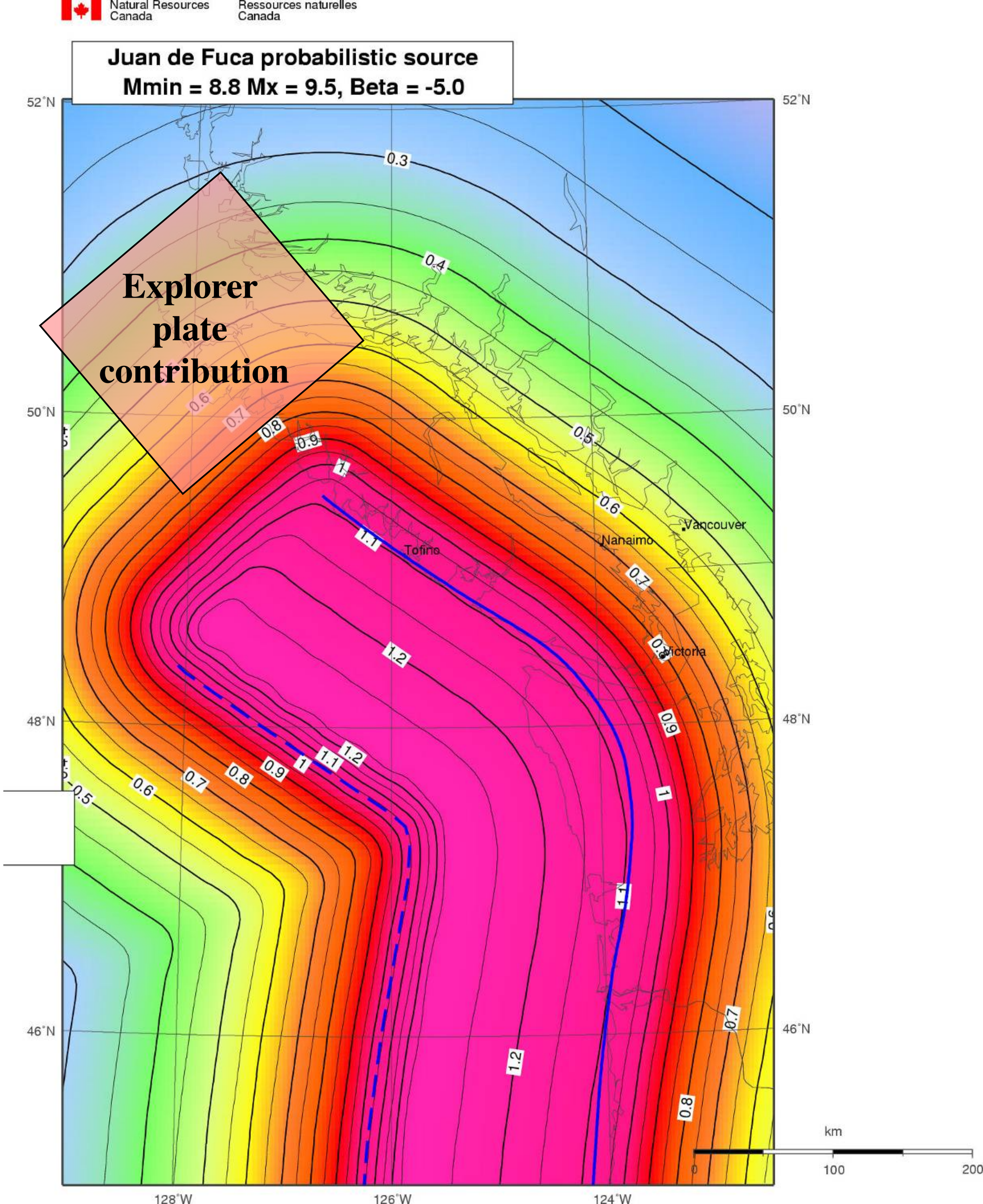
2011 geometry

Youngs' GMPE

Results indicative only

Locus is uncertain by ~20 km,

See Rogers' next presentation

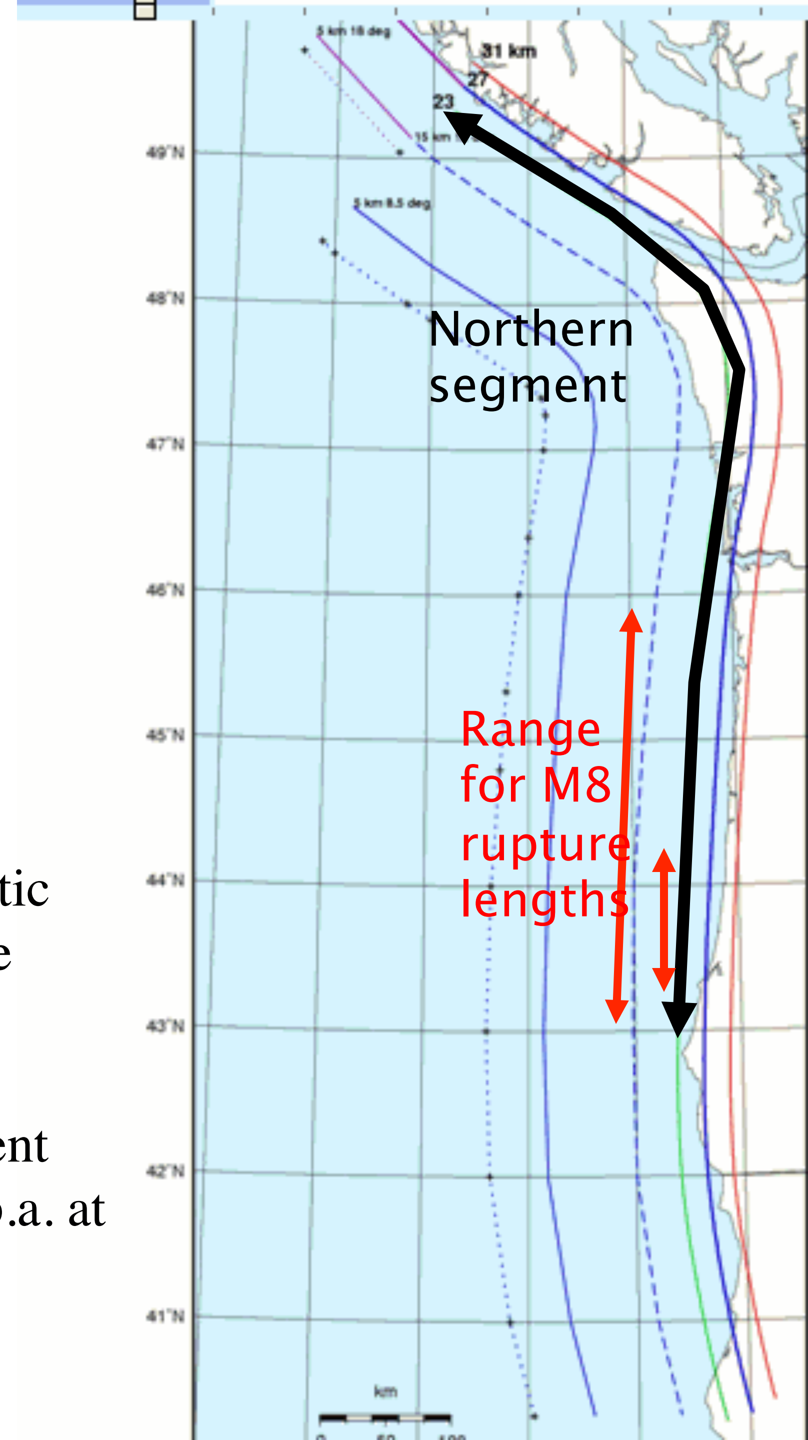


It has been suggested that in addition to complete ruptures there are also M>8 ruptures of the northern segment like the ~10 in the southern segment

Rates about 2 to 3 per 10,000 years (Atwater cited in Frankel 2012)

Proposed model

- Short extra source (Cape Blanco & north)
- Change the fault length parameters to be realistic
- Mmax = 8.5 (no overlap with complete-rupture events)
- Min = 8.0
- Devise magnitude-recurrence curves to represent cumulative rates of 0.0001, 0.0002 and 0.0003 p.a. at Mw=8.0 (rates of 1, 2, 3 events in 10,000 years)
- Might we have to worry about M7s?

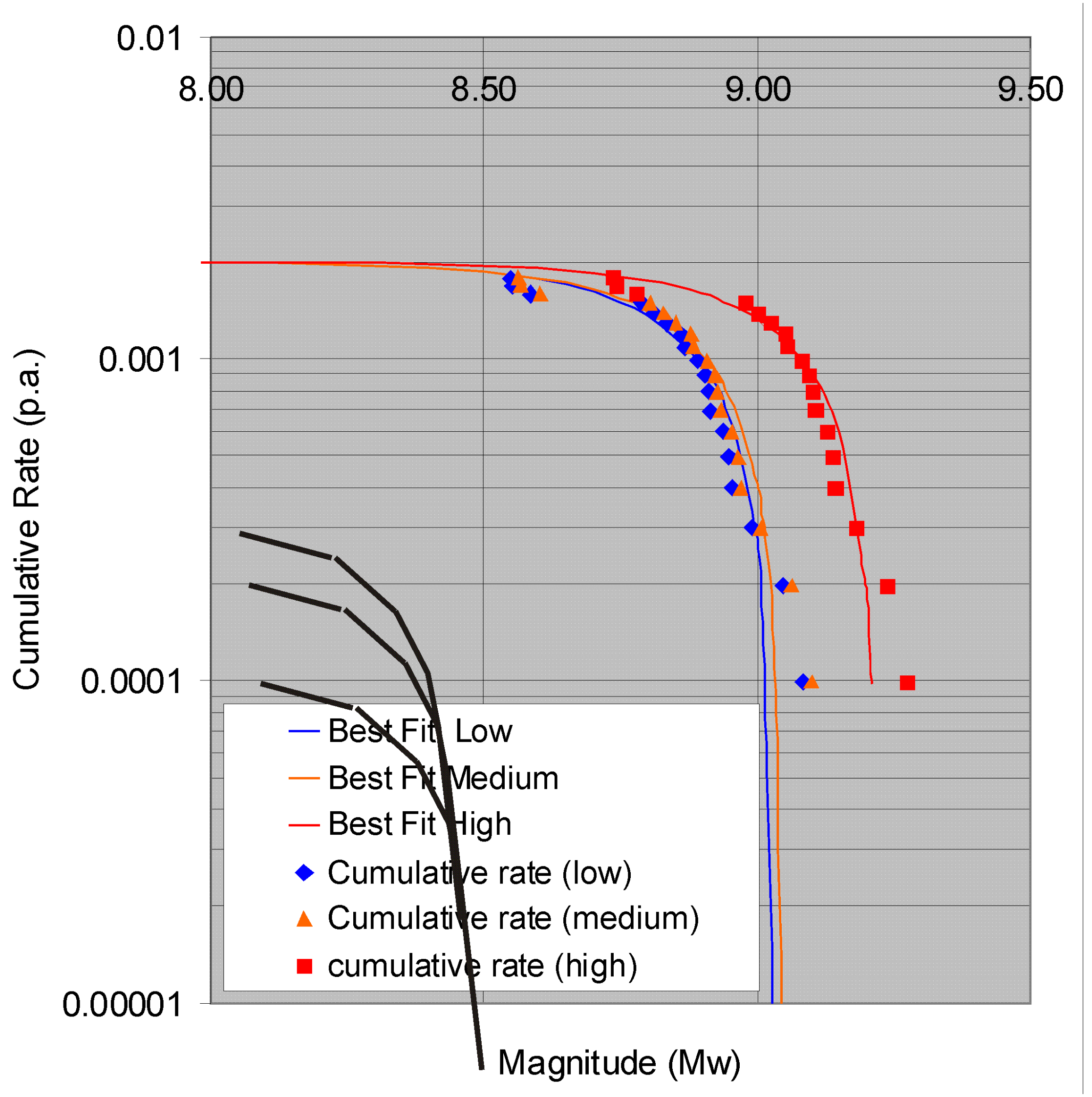


Cascadia "complete-rupture" with added M8 events

These events very unlikely to increase the seismic hazard appreciably because

- the rate is only 1/10th that of complete-rupture events,
- at least some of the events will be near Cape Blanco, too far away to generate appreciable shaking in Canada
- the events are smaller than the complete rupture events

We estimate no more than a 10% increase



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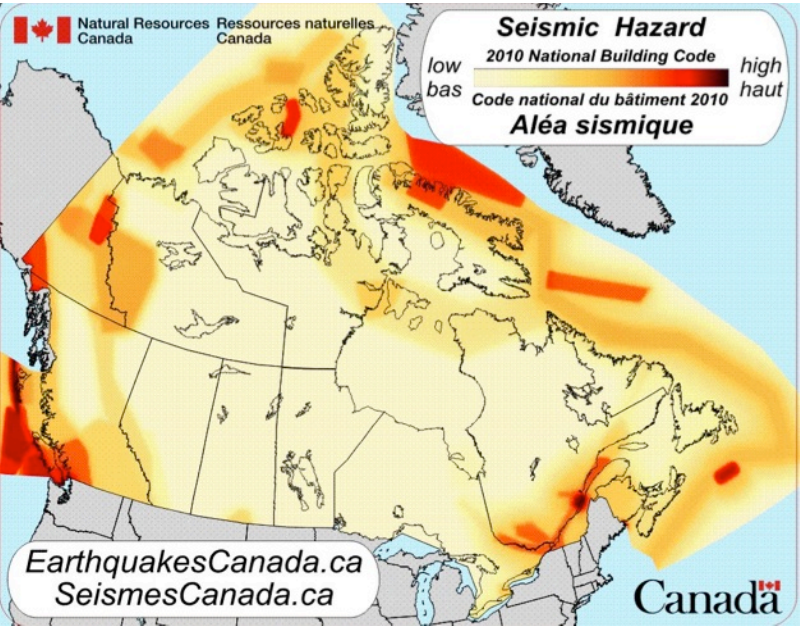
Summary

Fairly robust estimates for magnitude-recurrence

Shape of the mag-rec curve is not ideal given normal distribution of intervals

Shaking should be less sensitive to exact magnitudes than to closeness to rupture

Adding an extra 2-3 M8+ at the northern end unlikely to change the hazard much



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Thank You

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