Seismic Hazard Maps for the National Building Code of Canada – past and future

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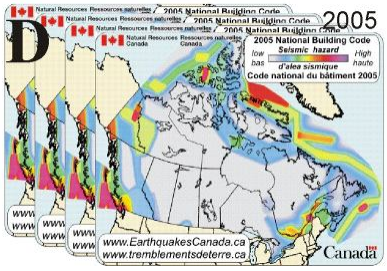
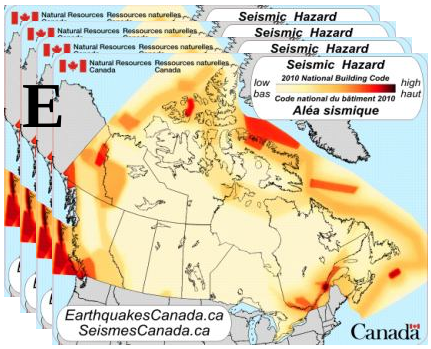
Geological Survey of Canada,
Natural Resources Canada, Ottawa
USGS CEUS Earthquake Sources Workshop
Memphis, 2012 Feb 22 & 23

Natural Resources Canada
Ressources naturelles Canada





2005 4th Generation
Four maps
Spectral Acceleration
(plus Peak Acceleration)
No zones
Firm Ground (Site Class C)
Probabilistic at 2%/50 years
= 1/2475 years

2010

Similar to 2005
(model for eastern ground motion shaking changed from Quadratic to Bob Youngs' 8-parameter fit because this reduced unnecessary conservatism)

NBCC 2005 and 2010 both used the 4th Generation Seismic Hazard Model, created in the early-mid 1990's

A complete re-think was justified

Results are intended for engineering practice at 2%/50yr

Informed by US work

Trial results by April 2012

NBCC 2015: 5th Generation Seismic Hazard Maps

Main changes intended

- New moment magnitude catalog
- Revised seismic source zones
  - Replacement of Robust approach
- Updated Mmax
- New Ground Motion relations
- New spectral values (shorter and longer periods)
- Adjusted reference ground condition to B/C
- Computational code (FRISK) the same
- Logic tree similar (tri-branch uncertainty)
- Likely will use the mean value, replacing median

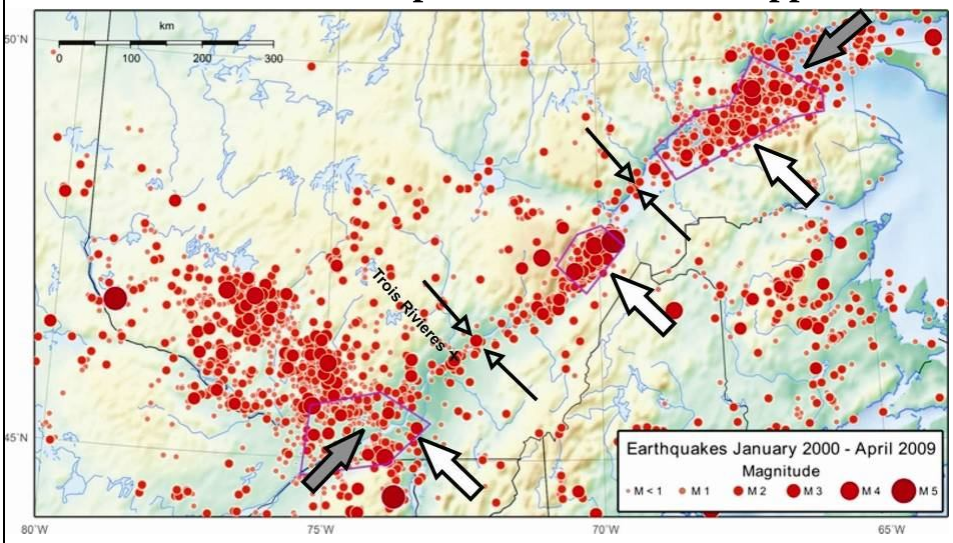
NBCC 2015: 5th Generation Seismic Hazard Maps

Updated Eastern Catalog

- added 18 years of earthquakes
- created moment magnitude catalog
  - reviewed/revised Mw>4.5 event magnitudes (Bent 2009)
  - converted mN for Mw<4.5 (pre- and post-1995)
- Adopted 99+% of USGS solutions in the US (→ Mw)
- SSC catalog has probably arrived too late (sad!)
- probably won't decluster

  (we have played with a catalog where dT=400 years …)

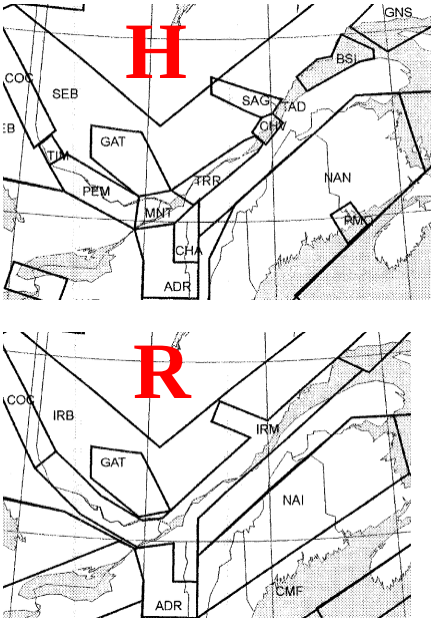
Eastern source zones: Replacement of Robust approach



Not at all convinced past historical seismicity will entirely predict next 100 years (counter examples: Saguenay, Timiskaming……)

4th Generation used "Robust" combination of source models

2005/2010: approach highest of



Locations very different in H model, reflecting local earthquake activity

Locations rather similar in R model

Sa(0.2) in cm/s/s	2005 H	2005 R
La Malbaie	2300	660
Quebec City	520	590*
Trois Rivieres	350	640
Montreal	580	690
Ottawa	450	670

* Low because IRM zone boundary badly placed

For engineering conservatism we took the higher value

(non-probabilisitic)

Canada's view of the problem

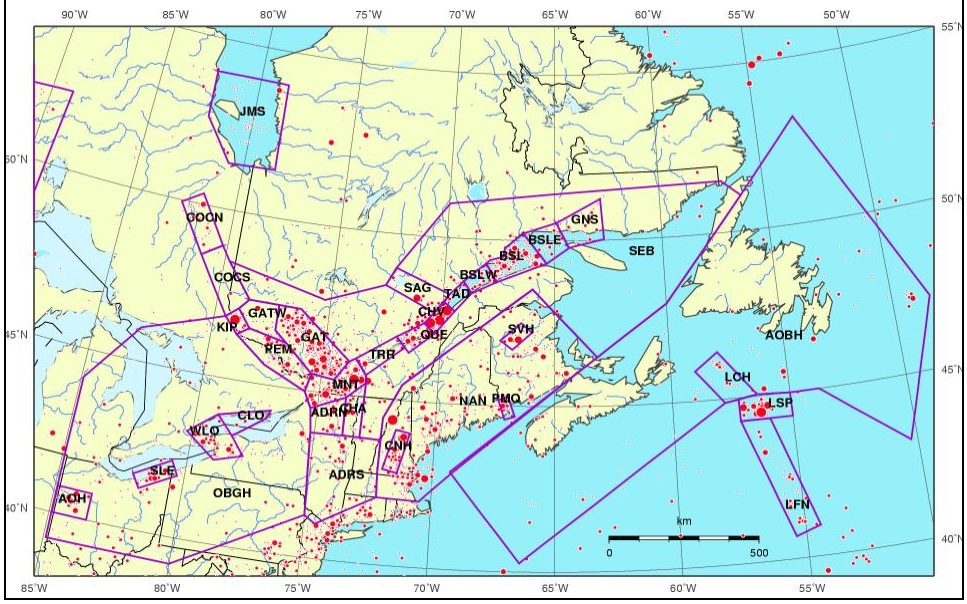
2 seismicity components to future hazard

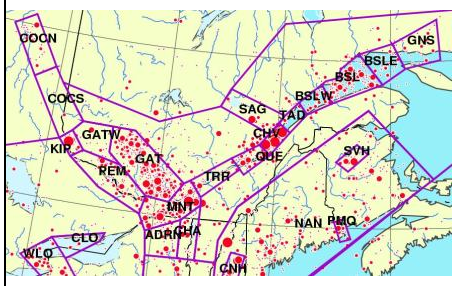
- Continuing activity in clusters well captured by classical seismic source zones or (perhaps) smoothed seismicity
- "random" big earthquakes occurring elsewhere

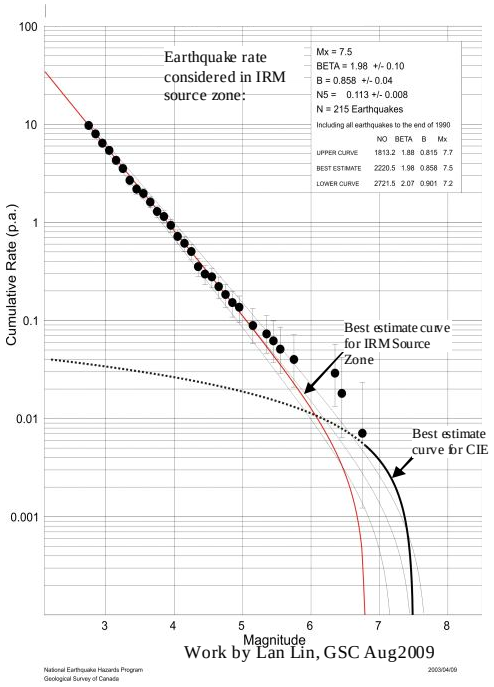
The "random" earthquakes do have some pattern in terms of

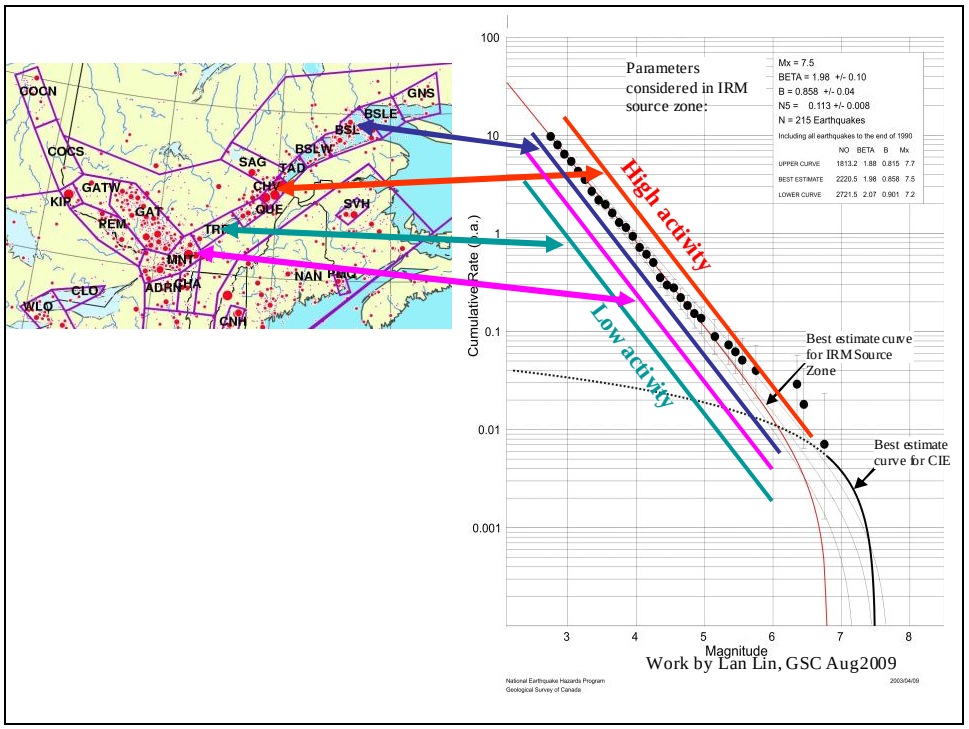
- Geographic probability
- Maximum size

2015 draft Historical seismic source model

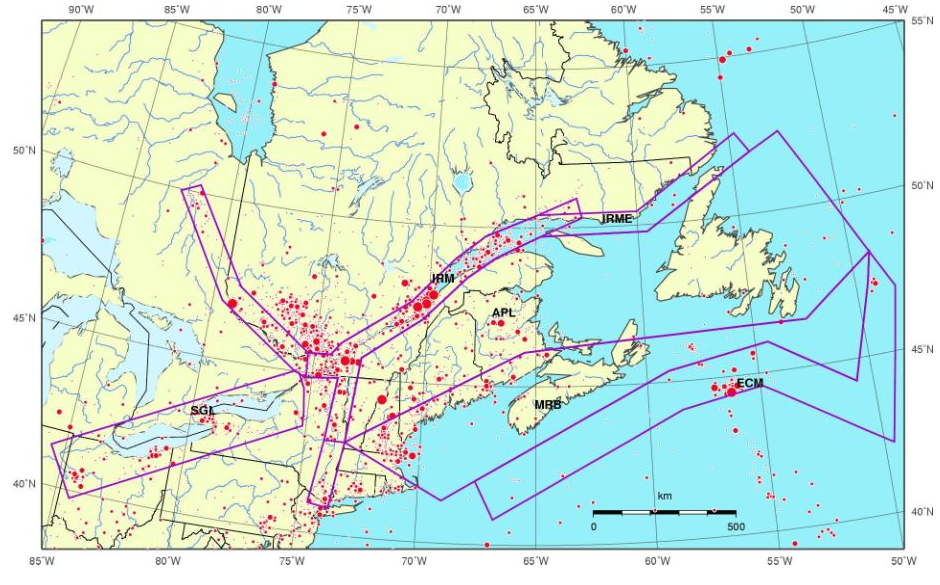


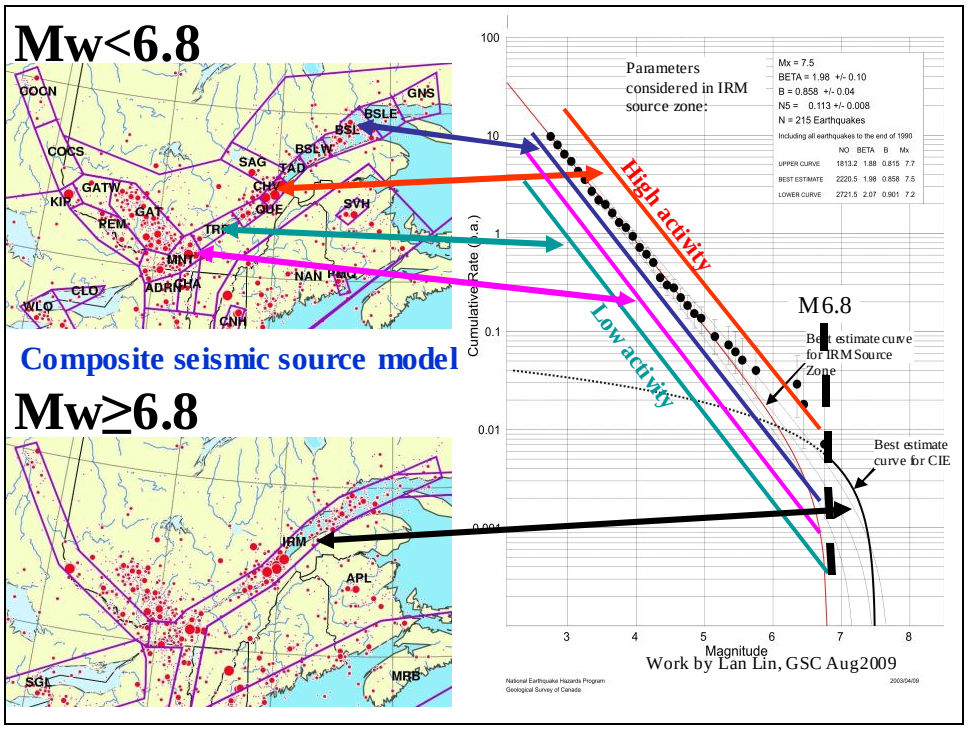






Seismotectonic (Random Big Earthquake = RBE) seismic source model from GSC (5 large zones)





Composite seismic source model

In most zones the hazard is not very sensitive to the transition magnitude (6.8)
Getting the rates for Random Big Earthquakes is hard!

- Very little constraints from data, paleoseismic or otherwise
- St. Lawrence rift source: expect one Mw≥6.8 per 300 years
- Other "best" rates for Mw≥6.8 by judgement based on seismicity levels
- Large uncertainty – taken as factor of 3 up and down
- Can infer unreasonable maximum rates from history
  (additional constraint on upper limit)

1/300 years

1/3000 years

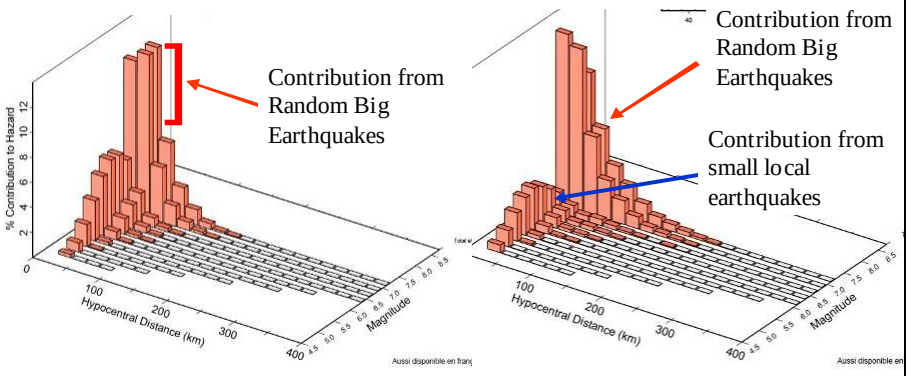
1/1000 years

	APL	ECM2	IRM	MRB	SGL
best N(6.8)	0.0010000	0.0030000	0.0030000	0.0003000	0.0003000
upper N(6.8)	0.0032000	0.0060000	0.0060000	0.0009200	0.0009200
lower N(6.8)	0.0003200	0.0009200	0.0003200	0.0000920	0.0000920
N_0 (best)	36.8	110.3	110.3	11.0	11.0
N_0 (upper)	117.8	220.5	220.5	33.8	33.8
N_0 (lower)	11.8	33.8	11.8	3.4	3.4

DRAFT

Effect of Composite model is more evident in low seismicity regions like Trois Rivieres

Montreal | **Trois Rivieres**



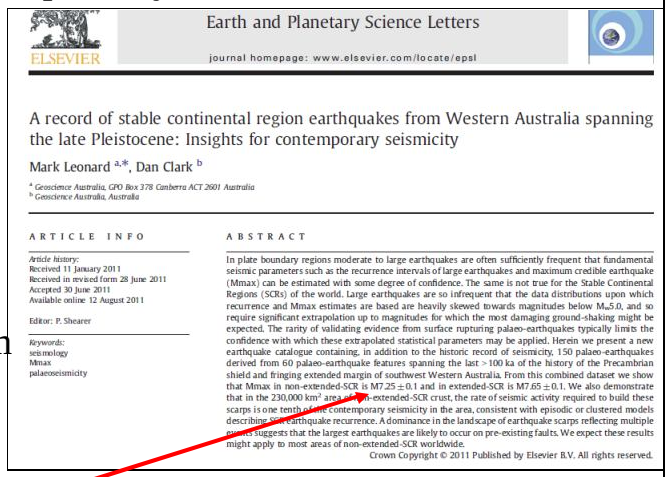
Change in hazard still being modelled, but….

- Montreal not the same as Ottawa
- Trois Rivières lower than Montreal and Quebec City
- Charlevoix still high, but less high than before

Seismic hazard - especially RBE-sources - needs Mmax

Canadian experience with its 3rd Generation drives the high Mmax in Canada

Prefer choices from global analogs



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A record of stable continental region earthquakes from Western Australia spanning the late Pleistocene: Insights for contemporary seismicity

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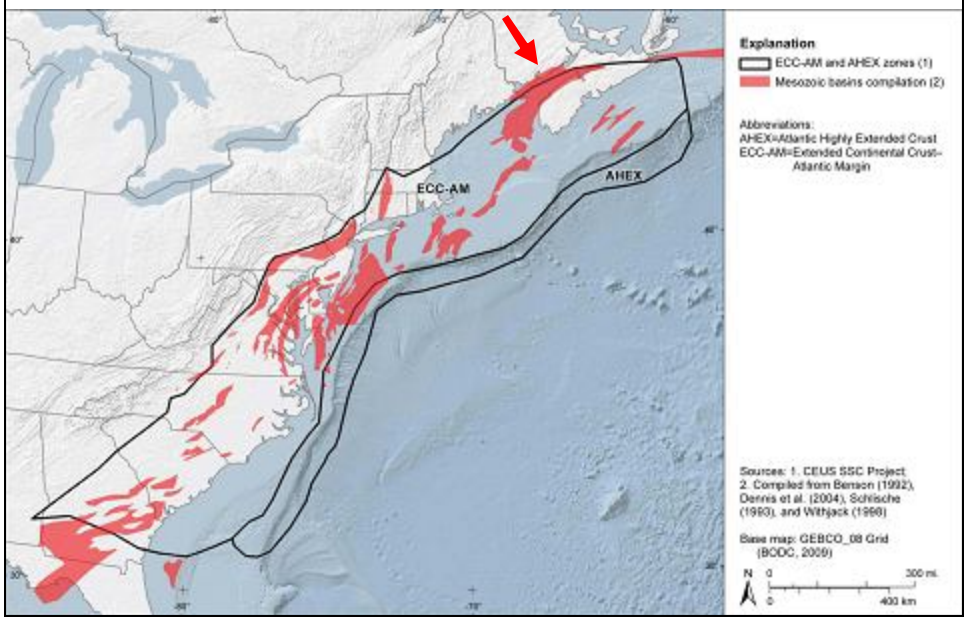
ABSTRACT

In plate boundary regions moderate to large earthquakes are often sufficiently frequent that fundamental seismic parameters such as the recurrence intervals of large earthquakes and maximum credible earthquake (Mmax) can be estimated with some degree of confidence. The same is not true for the Stable Continental Regions (SCRs) of the world. Large earthquakes are so infrequent that the data distributions upon which recurrence and Mmax estimates are based are heavily skewed towards magnitudes below M_w5.0, and so require significant extrapolation up to magnitudes for which the most damaging ground-shaking might be expected. The rarity of validating evidence from surface rupturing palaeo-earthquakes typically limits the confidence with which these extrapolated statistical parameters may be applied. Herein we present a new earthquake catalogue containing, in addition to the historic record of seismicity, 150 palaeo-earthquakes derived from 60 palaeo-earthquake features spanning the last > 100 ka of the history of the Precambrian shield and fringing extended margin of southwest Western Australia. From this combined dataset we show that Mmax in non-extended-SCR is M7.25 ± 0.1 and in extended-SCR is M7.65 ± 0.1. We also demonstrate that in the 230,000 km² area of non-extended-SCR crust, the rate of seismic activity required to build these scarps is one tenth of the contemporary seismicity in the area, consistent with episodic or clustered models describing fault earthquake recurrence. A dominance in the landscape of earthquake scarps reflecting multiple events suggests that the largest earthquakes are likely to occur on pre-existing faults. We expect these results might apply to most areas of non-extended-SCR worldwide.

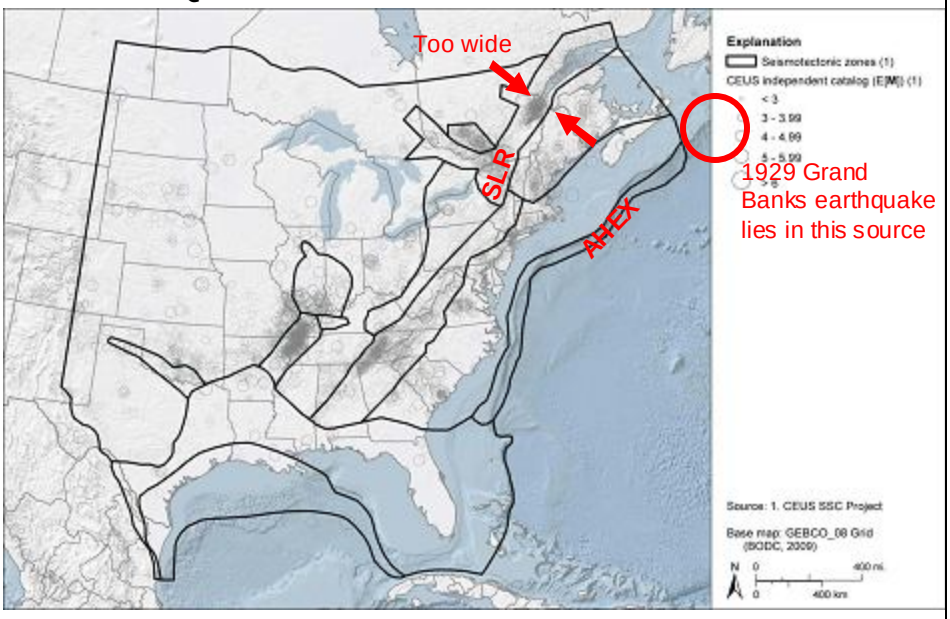
Mmax in non-extended-SCR is M**7.25±0.1** and

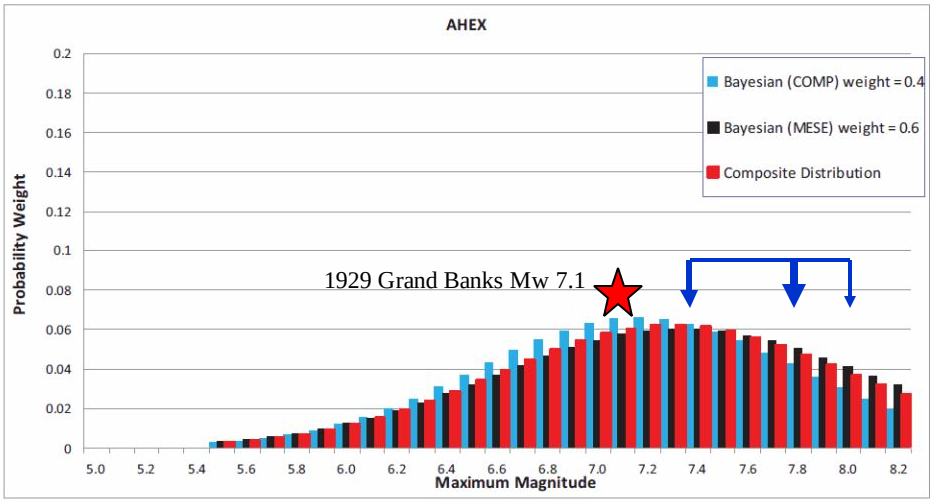
in extended-SCR is M**7.65±0.1**

CEUS-SSC: So happy to see seismotectonic sources that we've had in Canada for a while (Canada's R model)

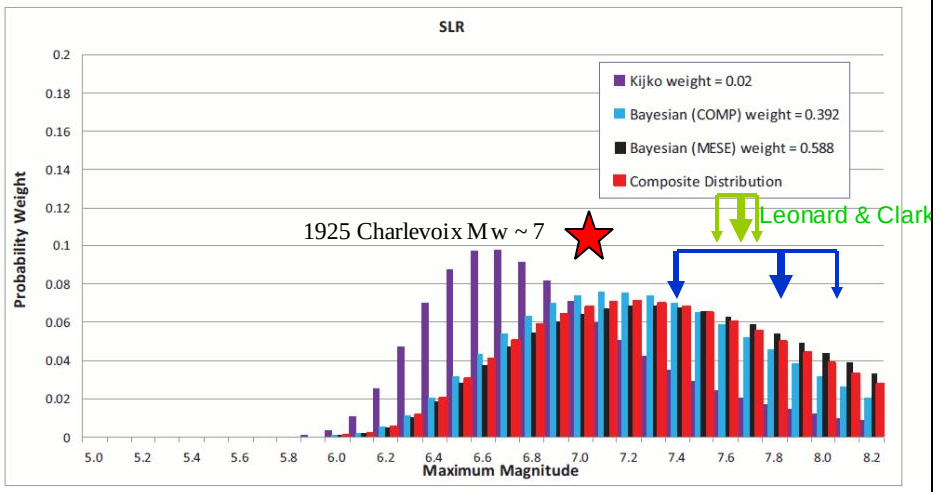


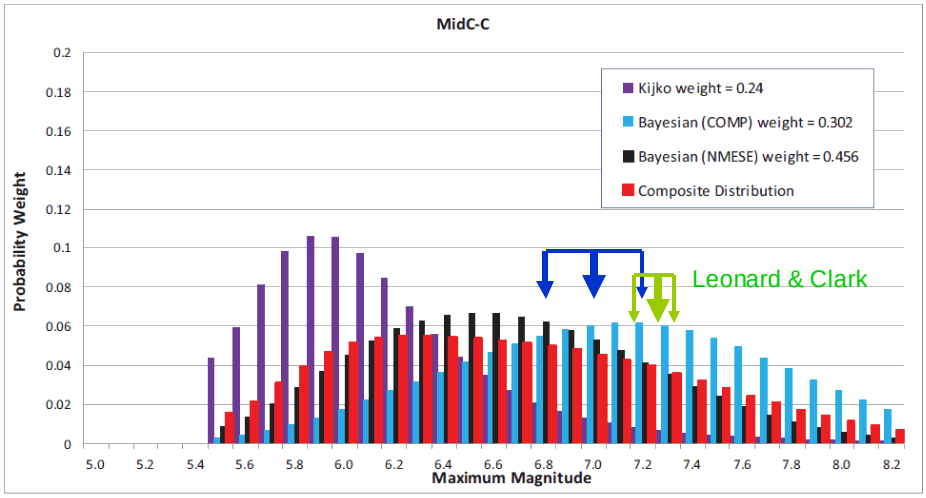
Quibbles….

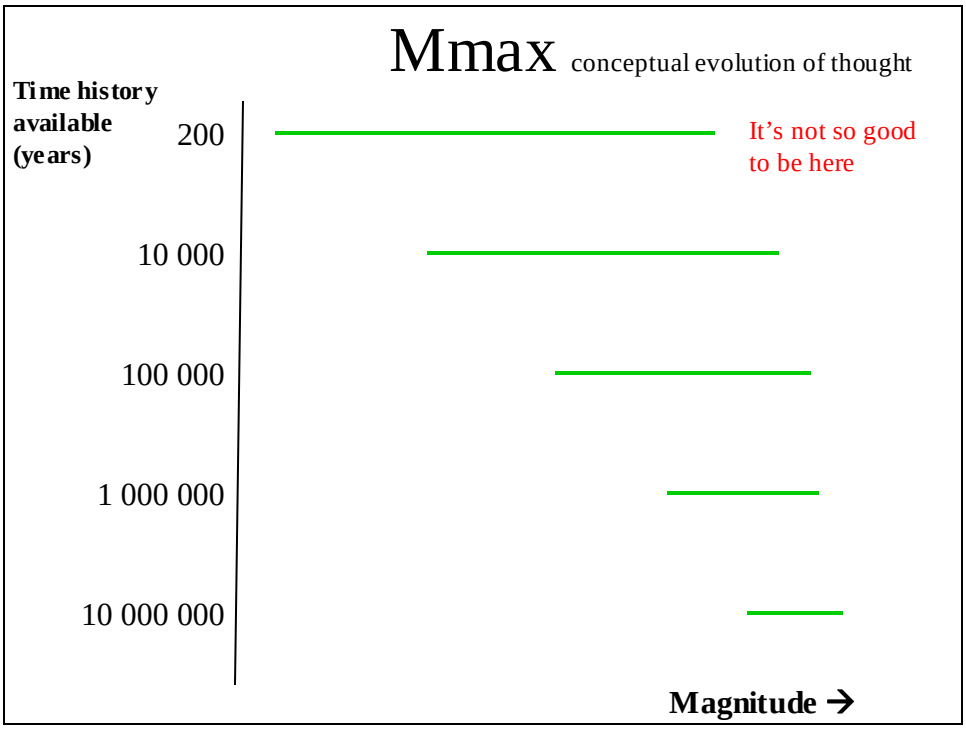




Blue = possible ranges and weights for Mmax in the next Canadian model




MidC-C
Probability Weight
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
Maximum Magnitude
Kijko weight = 0.24
Bayesian (COMP) weight = 0.302
Bayesian (NMESE) weight = 0.456
Composite Distribution
Leonard & Clark


Mmax conceptual evolution of thought
Time history available (years)
200
10 000
100 000
1 000 000
10 000 000
It's not so good to be here
Magnitude →