THE 6th GENERATION SEISMIC HAZARD MODEL OF CANADA

Michal Kolaj[(1)], John Adams[(2)], Stephen Halchuk[(3)]

[(1)] *Seismologist, Natural Resources Canada, michal.kolaj@canada.ca*
[(2)] *Seismologist, Natural Resources Canada, john.adams@canada.ca*
[(3)] *Seismologist, Natural Resources Canada, stephen.halchuk@canada.ca*

Abstract

In support of the 2020 National Building Code of Canada (NBCC 2020), a new seismic hazard model has been developed for Canada. The new model includes recent advancements in our understanding of: recurrence of great subduction earthquakes; revisions in the geometry of deep inslab earthquakes; inclusion of newly-discovered potentially active faults; and the adoption of new ground motion models. Moreover, the model has now been fully transitioned from legacy software to the OpenQuake platform which offers numerous technical advantages such as the movement away from point sources to finite-sized ruptures. For the first time in Canada, seismic hazard is also computed directly for various site conditions and provided to the end-user for their specific Site Class and/or Vs_{30} (time-averaged shear wave velocities in the upper 30 m of the crust). This approach removes the need for separate site amplification look-up tables in the building code, improves the reliability of the results and simplifies the way end-users will determine seismic design values. This paper outlines the broad changes in the new model and discusses their impact on our understanding of seismic hazard in Canada.

Keywords: Seismic Hazard, Canada, Building Code, Site Amplification, Cascadia

1. Introduction

A national seismic hazard model is a necessary element of a risk reduction strategy to minimize human casualties and economic loses from future earthquakes. Natural Resources Canada and its predecessors have been estimating seismic hazard in Canada for over 65 years and have developed a long-standing process of collaboration with the National Building Code of Canada (NBCC) and Canada's engineering community. The latest hazard assessment, the 6th Generation Seismic Hazard Model of Canada (CanadaSHM6) is currently proposed as the basis for seismic design values for the 2020 edition of the NBCC[1].

As the knowledge of, and sophistication in, probabilistic seismic hazard analyses have grown, Canada's national mapping efforts have also become increasingly more complex (Fig. 1). The first national map was a zonation map (ranging from no risk of damage to major damage) based on a qualitative assessment of historical earthquakes and their potential regional extent. With the 2nd generation assessment in 1970, Canada introduced a fully probabilistic assessment of seismic hazard for peak ground acceleration (PGA) at a probability of 40%-in-50 years based on extreme-value statistics. In 1985, extreme valued statistics were replaced by the Cornell-McGuire method, it added peak ground velocity (PGV) in addition to PGA, and lowered the probability level to 10%-in-50 years. The CanadaSHM4 (2005) introduced spectral accelerations, introduced epistemic uncertainty, included the hazard posed by Cascadia megathrust subduction events (in a deterministic manner) and lowered the probability level. The new level – 2%-in-50 years – was needed as it is the appropriate probability to achieve the desired level of reliability uniformly across Canada. CanadaSHM5 and NBCC 2015 further refined the model by incorporating Cascadia and all four seismic source models into a probabilistic framework and updated the ground motion and site amplification relationships. As the evaluation of earthquake engineering and seismic hazard have evolved through the six generations of models and fifteen editions of the NBCC, the number of maps (i.e., unique hazard values per location) has also greatly increased (Table 1).

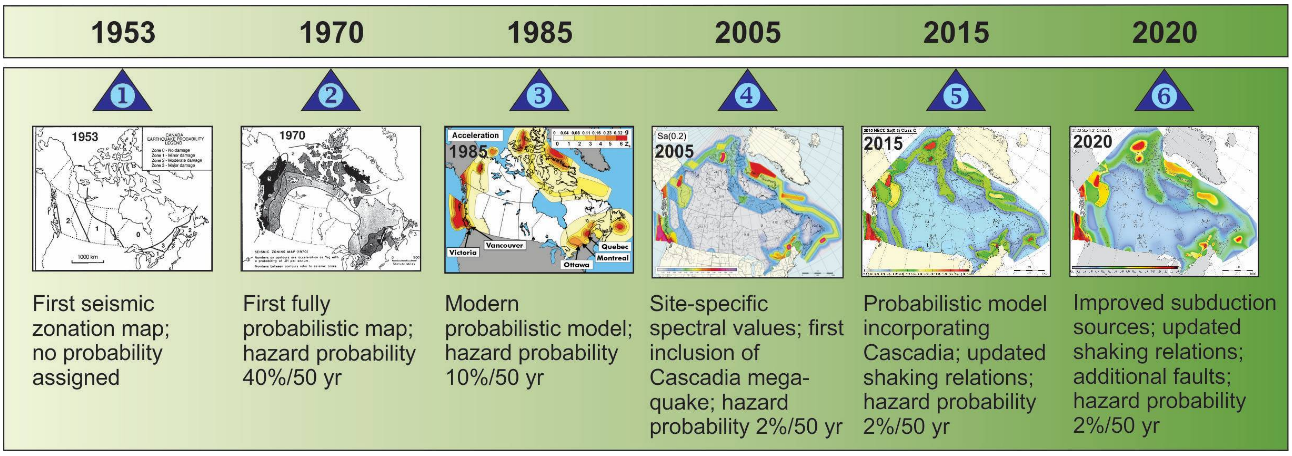

Fig. 1 – Six generations of seismic hazard models for Canada.

Building on the work of implementing the 5th Generation model outside of our legacy (GSCFRISK) hazard code [1], CanadaSHM6 is fully implemented within the OpenQuake platform [2]. Our hope is that through the open-source platform, the seismological and engineering community will benefit from easy access to the models and transparency in the hazard calculation. Moreover, through the Global Earthquake Model (GEM), the OpenQuake platform also allows others to integrate CanadaSHM6 into the global earthquake hazard and risk framework.

In this paper, we provide a high-level overview of the changes in seismic source (Section 2) and ground motion (Section 3) characterization and discuss our new assessment of seismic hazard in Canada (Section 4).

Table 1 — Evolution in the number of hazard products in the NBCC.

Generation	NBCC Year	Shaking parameters	Probabilities	Site designations	"Maps"
1	1953	1	1	1	1
2	1970	1	1	1	1
3	1985	2	1*	3	2
4	2005	5	1*	5	25
5	2015	11	1*	5	55
6	2020 (proposed)	11	3*	20	660

*Seismic hazard at other probabilities was calculated but not used in the code

2. Seismic source characterization

As with the previous generations, the source model consists of areal and fault sources. For all areal source zones, the truncated Gutenberg-Richter (G-R) distribution is used with three separate activity rates (*a* and *b* pairs; estimated from the catalogue of [3] and three M_{max} values to represent uncertainty in the estimation of the magnitude-recurrence parameters. Fault sources use a combination of characteristic rates and truncated G-R distributions as described in [4] and [5].

For the south-eastern Canada seismic source model, the model from CanadaSHM5 [6] is retained and is briefly described here. It is composed of three alternative source models based on different interpretations of long-term seismicity rates in stable intraplate settings. These models, further detailed in an accompanying paper [7], are:

a) a historical model (weight = 0.4) based on the historical catalogue (of roughly 150 years),

b) a regional model (weight = 0.2) that assumes that future large events are equally likely to occur in areas of similar seismotectonic setting (e.g., [8][9]), and

c) a hybrid model (weight = 0.4) which assumes that the historical rates are adequate proxies to predict smaller earthquakes (M < 6.8) but that regional seismotectonic features govern the spatial occurrence of larger earthquakes (M > 6.8).

For western Canada, the CanadaSHM6 model builds on the CanadaSHM5 model, which is composed of a single source model with alternative hypotheses for variations in the geometry of subduction fault sources. Implicitly there is no distinction between historical and regional models, as historical activity plus the paleoseismic record of large events (governing the rates of the subduction sources) are believed to be reasonably representative of long-term rates. The CanadaSHM6 updates: a) the rate of great-Cascadia earthquakes, b) the spatial geometry of inslab earthquakes and c) adds a potentially-active fault in southern Vancouver Island. These source changes are described in further detail below.

2.1 Updates to Cascadia

The Cascadia subduction interface was modelled as three sources in CanadaSHM5 [6][10], each named for the plate subducting under the North American continent. North of the Juan de Fuca source, which extends from northern California to central Vancouver Island, there is the Explorer source, and north of the Explorer source is the Winona. The Explorer and Winona sources were not updated from CanadaSHM5; the former is expected to generate M~7.7 earthquakes about every 330 years and the latter's very young oceanic crust may (or may not) be too hot to generate M~7.5 earthquakes. The Juan de Fuca source is known to have had a M~9 earthquake in 1700 [11] and has a remarkably long paleoseismic history [12][13] of rupture extents and their ages. For CanadaSHM5 the 2012 version of Goldfinger et al.'s paleoseismic record was converted into a history of earthquake magnitudes by adopting values for fault length, fault width, crustal rigidity and the fraction of the convergence rate released by great earthquakes. Uncertainty was represented crudely by three values for each parameter, resulting in three catalogs. For seismic hazard in Canada, the complexity of the record near California is irrelevant, and so only the complete-rupture events were considered. The resultant catalogs had a 10,100-year history comprising 18 earthquakes, with a roughly normal distribution of magnitudes. The expected earthquake had a magnitude of 8.9 and occurred every 530 years. The catalogs were fitted by magnitude-recurrence curves, as were required by the FRISK program. As M<8.4 earthquakes appear to be lacking off western Canada, an approximately-characteristic recurrence model was imposed by using negative beta values.

CanadaSHM6 uses the updated paleoseismic history of Goldfinger et al. [13]. Our implementation of their results adds 4 extra complete-rupture earthquakes to the 18 included in CanadaSHM5 (Fig. 2). The additional earthquakes reduce the average inter-event period from 532 to 432 years. In addition, the evidence for temporal event clustering now appears weaker than previously thought, supporting the CanadaSHM5 decision not to implement a clustered seismicity model. Instead of the fitted cumulative curve required by GSCFRISK, and its implied distribution model, we can now use the derived incremental rates in OpenQuake, thus representing the underlying paleoseismic data without imposing a model distribution.

The Cascadia updates increase the seismic hazard from the Juan de Fuca segment to southern British Columbia by about 8% relative to CanadaSHM5, for all periods and probabilities. The great earthquakes are still satisfactorily modelled as time-independent events, but because of the shortened inter-event periods a time-dependent model should be considered for future version of the model.

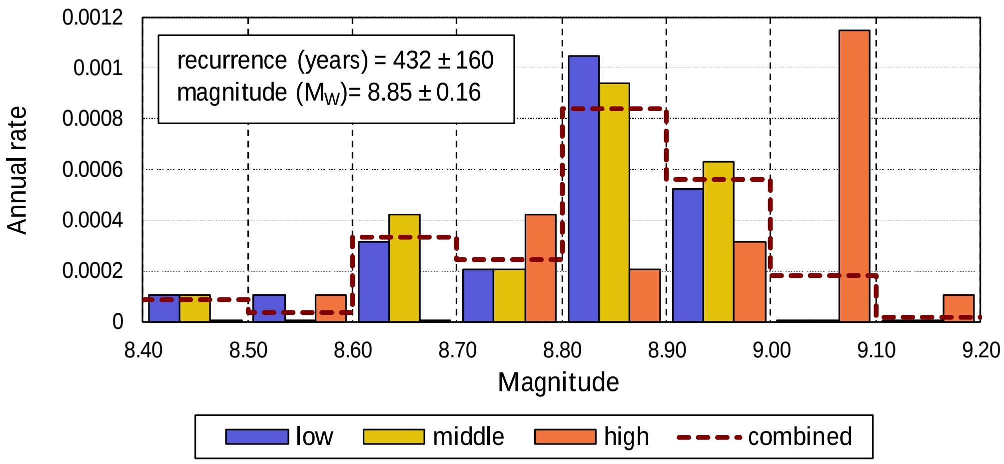

Fig. 2 – Incremental recurrence rates (binned in magnitude increments of 0.1) for the Cascadia subduction zone using low, middle and high alternative catalogs and their weighted combination (respective weights 0.16, 0.68 and 0.16). Mean recurrence and magnitude shown in top left corner.

2.2 Updates to inslab seismicity and inclusion of the Leech River Valley Fault system

In the CanadaSHM5 the inslab source beneath the Strait of Georgia (GTP) was set at a single depth of 50 km and had a uniform distribution of earthquakes (Fig. 3). In the CanadaSHM6, GTP is replaced by three separate sources (GTPW, GTPC and GTPE) set at 50, 55, and 60 km depths to better model the dip of the inslab source and the spatial variation in activity rate (i.e., lower activity in the deeper, hotter, portion of GTPE; Fig. 3). The consequence of the model change is an approximately 5 - 10% increase in short-period hazard in the Victoria and Vancouver region [14].

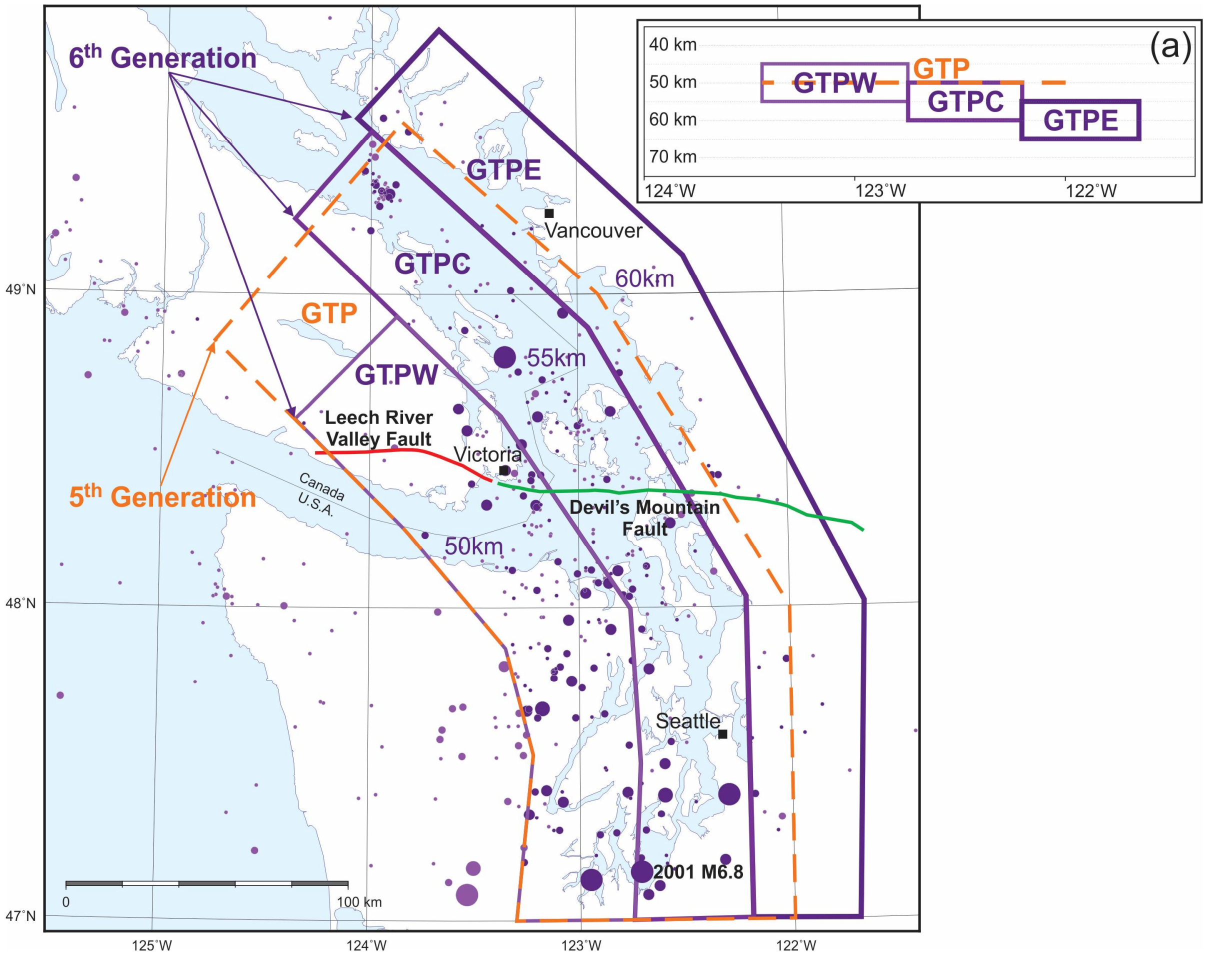

Fig. 3 – CanadaSHM5 and CanadaSHM6 versions of inslab sources of seismicity in southwestern Canada. The relative depths of the sources (at 48°N) are shown in inset (a). The new CanadaSHM6 Leech River Valley and Devil's Mountain fault sources are indicated by the red and green lines, respectively.

Halchuk et al., [5] discuss the recent studies that have identified the active Devil's Mountain and potentially-active Leech River Valley faults in the southern Vancouver Island region (Fig. 3). The CanadaSHM6 adopted a logic tree model for the Leech River Valley Fault – Devil's Mountain Fault system (LRVF-DMF) representing different scenarios and fault lengths, including whether the LRVF could be inactive. Although the slip rate is relatively low (0.25 +/- 0.1 mm/yr) for an active tectonic region, the fault system passes through greater Victoria and contributes to the overall seismic hazard for southernmost Vancouver Island. The hazard increment due to the LRVF-DMF is quite small (< 10% increase), even very close to the fault, and its contribution to the hazard decreases away from the fault so that at ~25 km distance it is insignificant. This is in part due to the fact that the hazard in this region is already high, coming mainly from inslab sources at short periods and the Cascadia subduction zone at long periods.

3. Ground motion characterization

The CanadaSHM6 incorporates published GMMs into a logic tree to sample the uncertainty in ground motion characterization. The model has also moved away from the representative suite approach used in CanadaSHM5 [15] in order to improve the sampling of both the variability in median relations and in published aleatory and site amplification models. The model includes GMMs for subduction interface, subduction inslab, active crust, and stable crust earthquakes. A brief description is provided below and further details on the changes to median ground motions can be found in [16].

Following the approach described above, CanadaSHM6 incorporated four alternative GMMs within each of the western tectonic regions. For subduction earthquakes, the GMMs are largely the same as were considered in the development of the representative suite used in CanadaSHM5. For western (active) crustal earthquakes, the updated NGA-West2 models [17] were incorporated. For stable crust (eastern, central and Arctic Canada; Fig 1 of [14]) the preliminary, 13-branch version of NGA-East [18] was adopted, because the final version was not available in time for the NBCC 2020 schedule. In general, the NGA-East-13 GMMs predict larger median motions than the GMMs adopted in CanadaSHM5, particularly for larger magnitude events. NGA-East-13 was used at 0.5 weight, together with the CanadaSHM5 GMMs of Atkinson and Adams [15], also at 0.5 weight. The split in weighting was to recognize that the NGA-East GMMs should be included, but not at full weight as they have not yet had a chance to be scrutinized by the wider seismological community.

Another change in CanadaSHM6 is the decision to (mostly) use the aleatory uncertainty (commonly referred to as sigma) model of the chosen GMMs. This in contrast to the approach used in CanadaSHM5 which used the same aleatory model for all GMMs, based on the argument that the aleatory uncertainty may not vary between regions (i.e., active versus stable crust). We do not aim to contend this reasoning, but rather to highlight that using the sigma of each GMM better captures the epistemic variability in what the aleatory model should be. In western Canada, using this approach increases the aleatory model by a mean of roughly 0.1 to 0.25 natural log units, and becomes one of the major drivers for the increase in hazard. Taking an example from [16]; the updated aleatory uncertainty model increased the 2%-in-50-year short-period hazard by roughly 30% in Vancouver. We deviated from this approach in eastern Canada, where we retained the CanadaSHM5 aleatory model. This was largely done based on our view that a no more appropriate model was available for eastern Canada and our judgement that the adopted balance between epistemic and aleatory uncertainty was appropriate.

3.1 Updates to site amplification

A history of site amplification in the NBCC is provided in [19] and [20] and is briefly summarized below. Foundation factors (*F*) to scale reference ("rock or firm ground") hazard depending on soil conditions were first introduced into the NBCC in 1965 and had a value of 1.5 for high compressible soils and a value of 1.0 for all other ground conditions. In NBCC 1975, an intermediate category (F=1.3) was introduced to account for compact coarse-grained or stiff fine grained-soils with a depth greater than 15 m. In 1990, a higher category (F=2.0) was introduced for very soft and fine-grained soils (with a depth greater than 15 m) to recognize the large amplification above deep soil basins, as was recorded during the 1985 earthquake in Mexico City. NEHRP Site Classes, the frequency dependence of amplification and the recognition of non-linear effects were incorporated into the 2005 edition, which separated short (F_a) from long (F_v) period amplification and added dependence on the strength of shaking. The Canadian F_a and F_v factors were relative to Site Class C (dense soil or soft rock) and ranged from 0.5 to 2.1. The 2015 edition of the NBCC further refined the factors by making them specific to each of the peak ground and spectral acceleration periods (e.g., $F(T=0.2)$), scaled non-linearity by the amplitude of PGA at the reference condition, and further increased the range of values ($0.57 < F < 2.93$).

Issues identified with the previous approaches are [16]:

1. It is problematic to use probabilistic estimates of PGA to estimate the degree of non-linearity as they:
   A. tend to overestimate the deamplifying effects, and,
   B. are inappropriate in regions where the dominant source type changes depending on the intensity measure (e.g. PGA from local crustal earthquakes, but long-period hazard from great subduction earthquakes).
2. The five adopted Site Classes tended to produce large step changes in design hazard values.
3. A single set of values for all of Canada does not allow for the consideration of how site amplification may vary regionally (related to regional differences in near-surface geology) and does not capture the epistemic uncertainty in site amplification models.

In order to address points 1 and 3, in CanadaSHM6 (and in the proposed edition of NBCC 2020) there is a major shift in how site amplification is considered. Rather than using tables which scale reference hazard, site amplification functions embedded within each GMM (or added if it did not include one; [16]) are used to calculate hazard directly for a range of site conditions. The specifics of the site amplification functions used in CanadaSHM6 are described in [16].

Point 2 is addressed by providing hazard directly for a continuous range of V_{S30} values in addition to the NEHRP Site Classes. V_{S30} is the time-averaged shear wave velocity in the upper 30 m of the site, and is the most commonly used parameter in GMMs to account for site amplification. An example of the variation in hazard with V_{S30} and Site Classes in Vancouver and Montreal is shown in Fig 4. Note that the hazard is a continuous function of V_{S30} (as are the underlying GMMs) and that discretizing it using NEHRP Site Classes A-E produces large steps in hazard.

The problem is exacerbated in regions where the local conditions straddle a Site Class boundary. For example, in certain regions in downtown Vancouver V_{S30} is ~760 m/s and an increase in V_{S30} from 770 m/s (Site Class B) to 750 m/s (Site Class C) would result in roughly 50% increase in Sa(0.2) using the CanadaSHM5 (NBCC 2015) approach to Site Classes. It is our opinion that since the engineering community routinely determines V_{S30} to assess site conditions and that most new GMMs are developed as (roughly) continuous functions of V_{S30}, it is preferred to simply provide hazard directly to the practitioner for the value of V_{S30} rather than to discretize it into coarse Site Classes. As such, with CanadaSHM6 (and the proposed code language for NBCC 2020) hazard is provided directly for a continuous range of V_{S30} (provided that it is calculated from *in-situ* measurements of V_S) between 140 and 3000 m/s. As it is currently not practical to calculate hazard "on-the-fly", the hazard values are instead pre-calculated for fifteen values of V_{S30} as shown in Fig 4 (circle markers). An online webtool (which provides the hazard values) will interpolate the hazard for the desired value of V_{S30}. Our findings suggest that fifteen V_{S30} values are adequate and that linear interpolation (the preferred approach by the engineering community in Canada) is sufficiently precise.

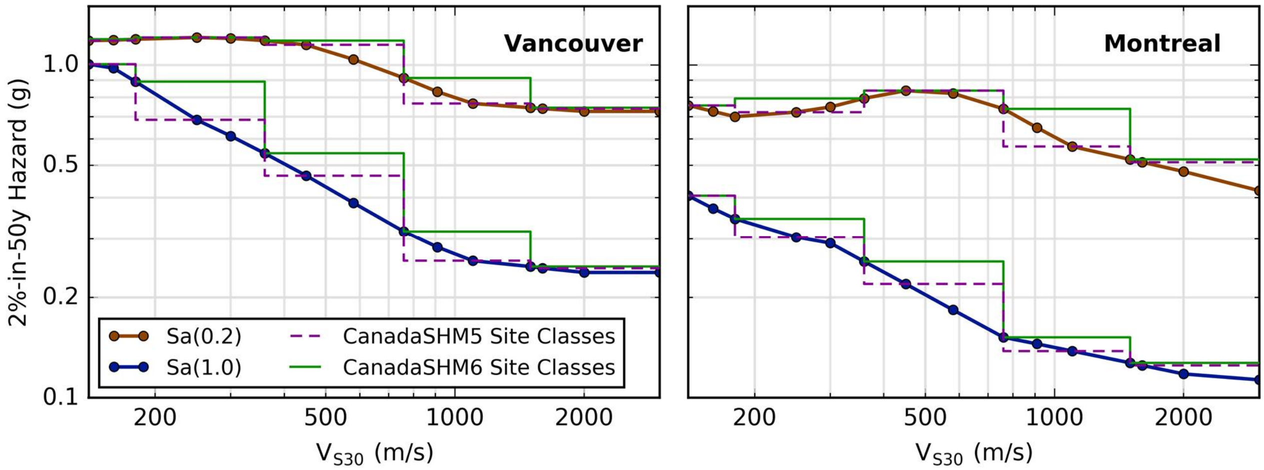

Fig. 4 – Hazard as a function of V_{S30} for Vancouver (left) and Montreal (right) for Sa(0.2) and Sa(1.0). Site Class definitions using the CanadaSHM5 and CanadaSHM6 approaches shown with dashed-purple and solid-green lines, respectively.

CanadaSHM6 will also continue to provide Site Class hazard but their definition has changed from the approach used in CanadaSHM5. Instead of using representative V_{S30} values for each Site Class, hazard within each Site Class will instead be equal to the maximum hazard value within the V_{S30} bounds of the Site Class (i.e., green line in Fig. 4 replacing the dashed-purple line). While Site Classes are still permitted in NBCC 2020 under certain cases, this approach will encourage practitioners to assess their site condition by determining V_{S30}, as it will almost always result in reduced hazard values.

One additional consideration is in regards to point 3 which allows us to incorporate different site amplification models in different regions. The majority of embedded site amplification functions within GMMs applicable to Canada are based on velocity profiles that gradually increase with depth (e.g., the dominant velocity profile in California). The corresponding site amplification factors from "gradational-type" velocity profiles tend to be broadband and increase with decreasing V_{S30}. However, a velocity profile characterized by a step increase in velocity (e.g., thin layer of soft soil overtop bedrock) is often encountered in parts of Canada (particularly, the glaciated regions of central and eastern Canada) in which case the site amplification tends to be peaked due to resonance about a predominant site-period (cf., Mexico City earthquakes in 1985 and 2017). In CanadaSHM6 we include a hybrid site amplification model which is the larger of a gradient- and step-like velocity profile for the NGA-East GMMs [16]. However, the ideal way to incorporate this would have been to include an additional parameter for the estimation of site amplification such as the site period; a parameter not available for NBCC 2020. As such, the hybrid site amplification model only includes the effect of a step velocity profile to the extent that it can be resolved using a V_{S30}-based model. It is also important to note that step-like velocity profiles are not unique to eastern Canada and similar profiles also exist in western Canada (e.g., in Victoria). Improved site characterization should be a major focus of the next model update, and future editions of the model (and the NBCC) should consider expanding the site model to include site period (or similar proxy) in addition to V_{S30}.

4. Seismic hazard estimates

4.1 Results from CanadaSHM6

The improved understanding of: a) seismic sources in southwestern British Columbia, b) median ground motion models, c) aleatory uncertainty, and d) site amplification has led to significant changes in estimated hazard relative to those of CanadaSHM5 (Fig. 5). Table 2 compares CanadaSHM5 and CanadaSHM6 hazard values for broad regions of Canada at the CanadaSHM5 reference condition (V_{S30} = 450 m/s = Site Class C) for two periods important for building design. The exact changes for a particular site depends on the spectral period and the specific site condition, so the changes in Table 2 may not be representative of all sites. The percent differences needs to be also considered in conjunction with the absolute hazard value, as a large percentage change in a low hazard region can be of less consequence than smaller percentage changes in a high hazard region. In almost all places, the new hazard estimates are higher than from CanadaSHM5. The predominant reasons for the changes in hazard in each region is provided in Table 2.

Table 2 ─ Change of CanadaSHM6 seismic hazard values from CanadaSHM5 for selected regions. Approximate percentage change is given for mean hazard at 2% in 50 years on a V_{S30} = 450 m/s site.

Region	Hazard level	% change Sa(0.2)	Reason	% change Sa(2.0)	Reason
Atlantic Canada	low	90	A	50	B
Central Quebec	high	55	A	45	B
Southeastern Canada	moderate	70	A	45	B
Central Canada	low	50	A	15	B
Interior British Columbia	low	25	B,C	5	B,C,D
Southwestern British Columbia	high	40	B,C,D,E,*	15	B,C,D,*

A: New median GMMs and site terms   B: New median GMMs
C: Sigma in new GMMs   D: Juan de Fuca activity rate
E: Changes in inslab (GTP) source   *: Leech River Valley Fault for Victoria only

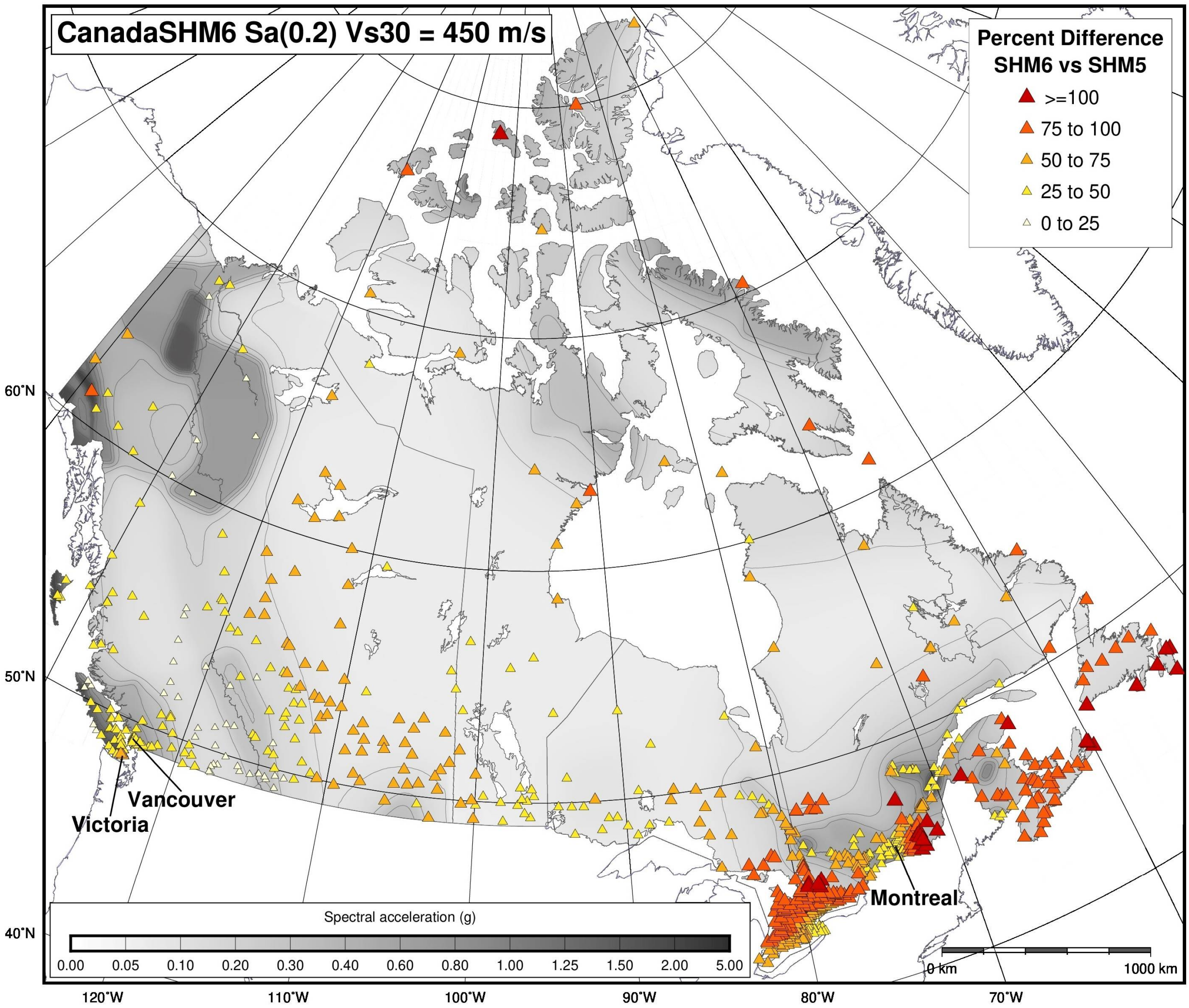

Fig. 5 - Change in Sa(0.2) hazard from CanadaSHM5. Grey shading indicates the CanadaSHM6 Sa(0.2) hazard (in g), while yellow-red scale triangles indicate the percentage change from CanadaSHM5.

4.2 Evolution of Canadian seismic hazard estimates

By inspection of Fig. 1 it can be seen that the overall spatial pattern of seismic hazard has not changed significantly. What is more difficult to discern from the maps is the change in hazard level with time. Adams [21] quantified the change in short-period hazard estimate with time. He adjusted the PGA shaking values at their probability level from the first three generations of model so as to make them consistent with the Sa(0.2) shaking at 2%/50yr that is common to the last three generations (Fig. 6). Estimated hazard for Montreal dropped abruptly in 1970 but has since increased to a level a little above that in 1969. Since 1985, it shows relatively small oscillations about an upward trend. Estimated hazard for Vancouver has increased steadily, with only one reversal in 2015. Estimated hazard for Victoria has increased greatly, with step jumps in CanadaSHM3 (1985) and in CanadaSHM6 (2020).

It can be seen that the general trend is upwards, representing an increase in the estimate of hazard with time. This represents both an increase in knowledge about the likelihood of future earthquakes and their shaking, and an increased awareness at the uncertainties that need to be included in the model. For Montreal and Vancouver, the overall 1953-2020 increase in estimated hazard is about 50%, or about 3% over each 5-year code cycle. Victoria has increased by 150% overall, its larger increase representing progressively improved knowledge that it sits close to an active plate boundary. In all three cities, a large fraction of the increase occurs with the new CanadaSHM6 values; it is possible that the latest hazard estimates have "over-shot" the true value, but this will not be known for a few more cycles.

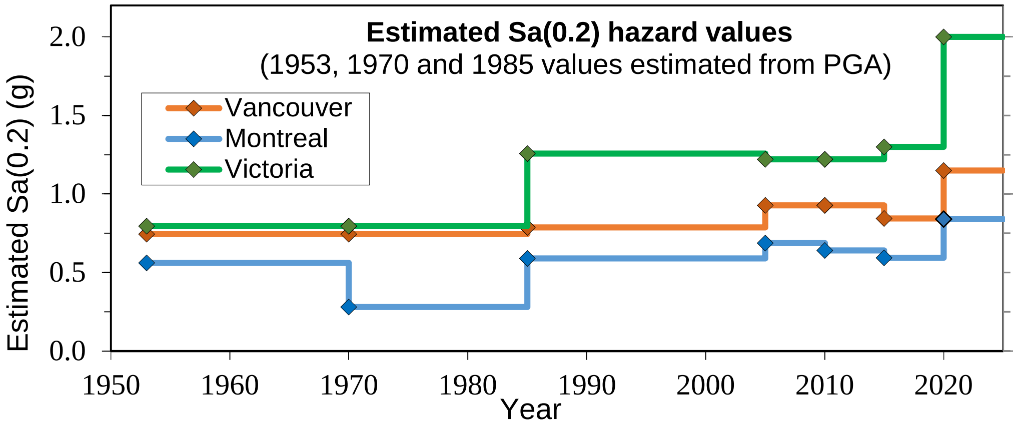

Fig. 6 - Changes in estimated Sa(0.2) for a probability level of 2%/50 years on Site Class C soil (450 m/s) for Victoria, Vancouver and Montreal (Fig. 5). Diamonds represents the hazard value that was in place up until the next code cycle.

4.3 Future directions

A key research question moving towards CanadaSHM7 and beyond is the number of unique hazard estimates required. With CanadaSHM6, the number of unique hazard estimates per location increased from 11 (i.e., the number of spectral parameters) to 660 (Table 1), largely due to the inclusion of site effects within the hazard calculation. There is also a general realization in the Canadian seismological community that it is difficult to characterize site amplification with a single parameter (i.e, V_{S30} or Site Class) and the pressure to include additional predictive parameters is increasing (e.g., depth to a shear wave velocity of 1 km/s or 2.5 km/s, site period or depth to bedrock). If more parameters are included in next generations of the model and the NBCC, the amount of unique combinations will increase. It may become necessary to move away from the pre-calculation of hazard "maps", instead calculating hazard on demand for the particular characteristics of the site.

A large portion of the increase in hazard in CanadaSHM6 is driven by an implicit increase in the uncertainty in the ground motions from future earthquakes. This is reflected in an increase in the aleatory model in western Canada, an increased number of possible GMMs in eastern Canada, and the implementation of a hybrid amplification model which envelopes two end-members of possible velocity profiles. In part, these increases are due to the lack of significant earthquake records (especially in eastern Canada) from which to constrain ground motion models. With the standard ergodicity assumption, we look to models and data from other regions to supplement the lack of data in Canada, thus increasing the inherent uncertainty due to a "mixing" of regional site and source characteristics. The next generation of models should aim to constrain this uncertainty by taking advantage of some of the existing and recent efforts to catalog ground motions and improve the characterization of site effects in Canada.

5. Summary

Significant progress has been made in estimating earthquake hazard in Canada. The new CanadaSHM6 includes new incremental rates of great megathrust earthquakes calculated directly from the paleoseismic record, a revision to the geometry and rate of inslab seismicity, and updated ground motion models including revised aleatory and site amplification models. The interplay between changes in source, ground motion, aleatory, and site amplification models is complex, but, in general has resulted in an increase in the estimate of seismic hazard on the order of 50% in many regions across Canada. Despite the large increase in hazard, a cost analysis for new construction found that the hazard increase proposed in NBCC2020 would result in a national average increase of just 1.2% in the total building cost of new construction [22]. While this is manageable going forward, there is ongoing work to quantify the change in earthquake risk in existing buildings consequent on the updated hazard values.

With CanadaSHM6 (and the proposed code language for NBCC 2020) hazard is provided directly for a continuous range of V_{S30} (when calculated from *in-situ* measurements of V_S) between 140 and 3000 m/s, and for Site Classes E through A. Providing hazard for a range of site designations simplifies the way the Canadian engineering community will determine seismic design values for a given location and site designation. It also removes the need for separate site amplification (i.e., foundation factor) look-up tables in the building code, enabling users to simply supply their location and site condition to a web-based hazard calculator to determine seismic design values.

6. Acknowledgements

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[1] Note that at time of writing this paper, NBCC 2020 (and CanadaSHM6) is currently undergoing public review and is subject to change prior to its release by the end of 2020. Multiple Geological Survey of Canada open-files are slated for release in 2020, and interested readers should refer to the earthquakes Canada website for the authoritative documentation on CanadaSHM6.
https://earthquakescanada.nrcan.gc.ca/hazard-alea/recpubs-en.php.