Developments in ground motions and scenario ShakeMaps

ICLR Friday Forum, Sept. 23, 2011

Gail Atkinson, University of Western Ontario

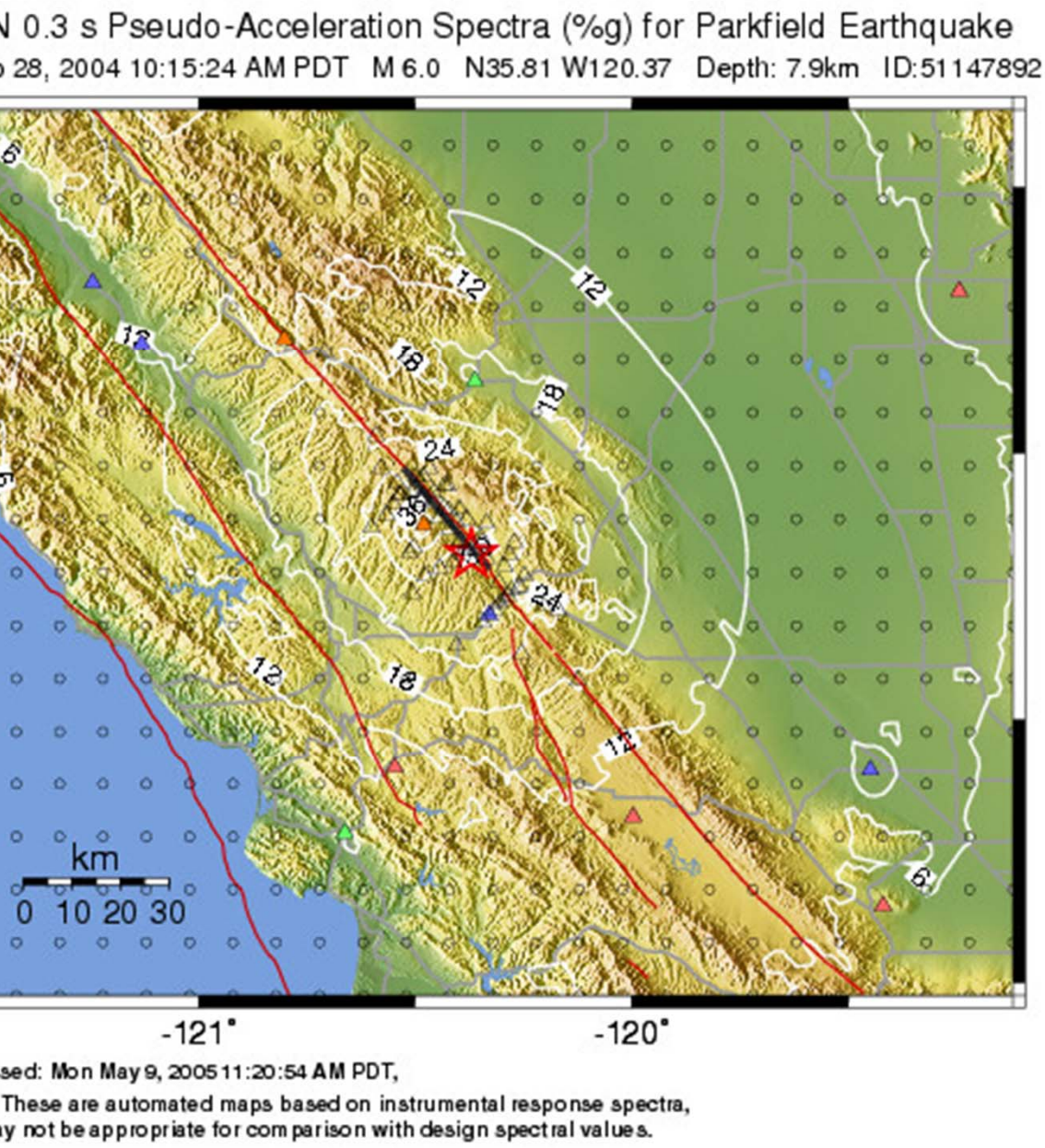
Jalpa Pal (recent M.Sc. Graduate)

Outline

- Overall methodology for estimating ground motions for scenario events (ShakeMaps)
- Illustration of ShakeMap development and validation for Ottawa
- Recent developments in ground motions for the east: Virginia motions

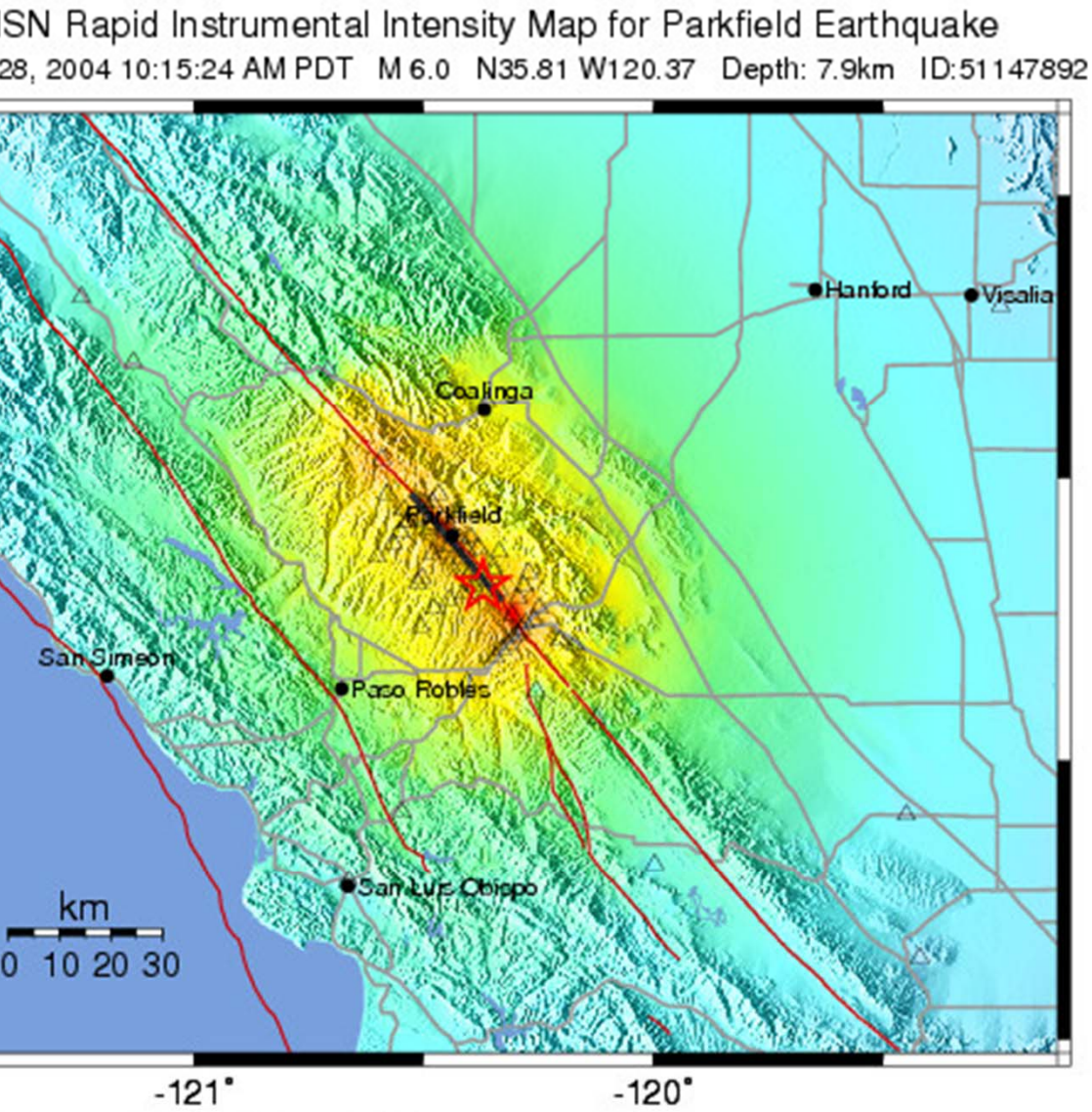
- Recent developments in ground motions: Tohoku **M**9 earthquake
- ShakeMaps, Fraser Delta, B.C.
- Lessons for insurance industry

What is a ShakeMap?



- Example Californ ShakeMap: record M6 Parkfield moti
- Interpolate instrumental data where interpolatio guided by use of regional ground m prediction equatio

What is a ShakeMap?

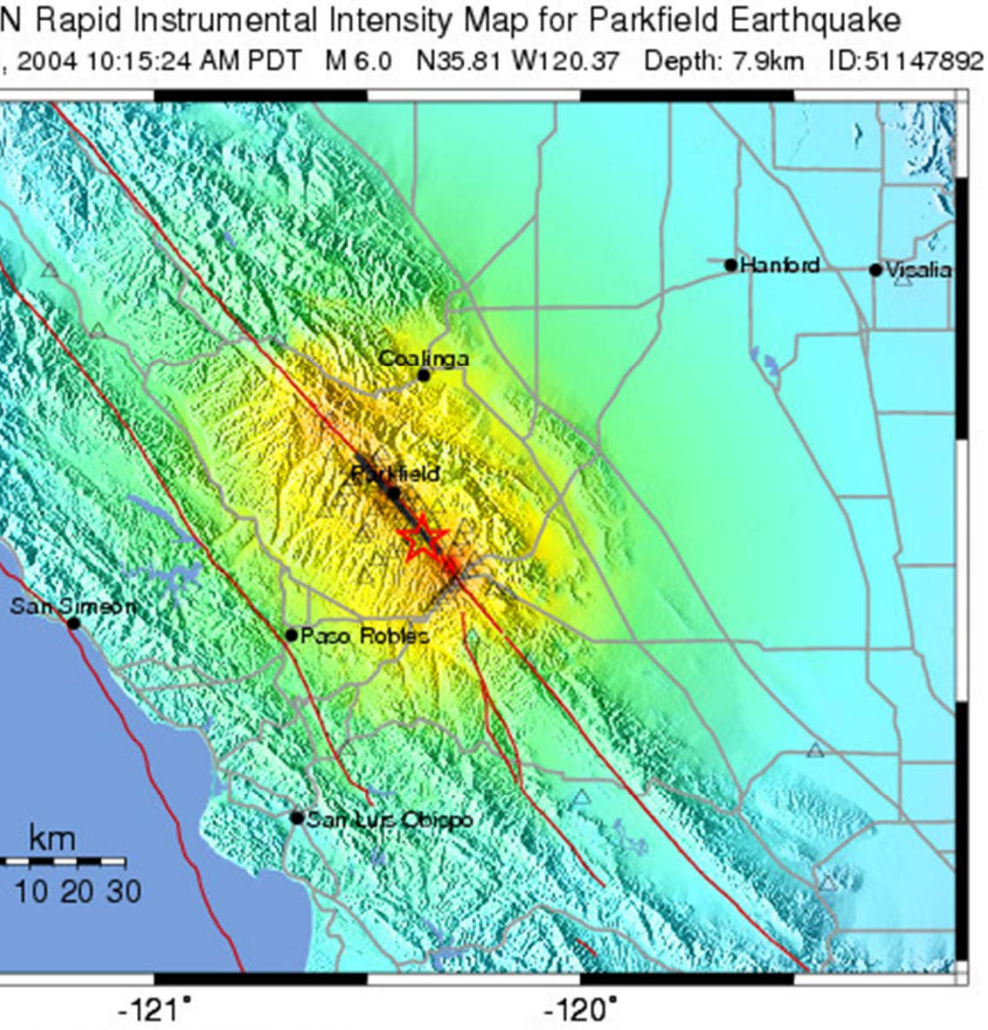


	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124

- Example Californ ShakeMap: record M6 Parkfield
- Instrumental dat used to infer felt e

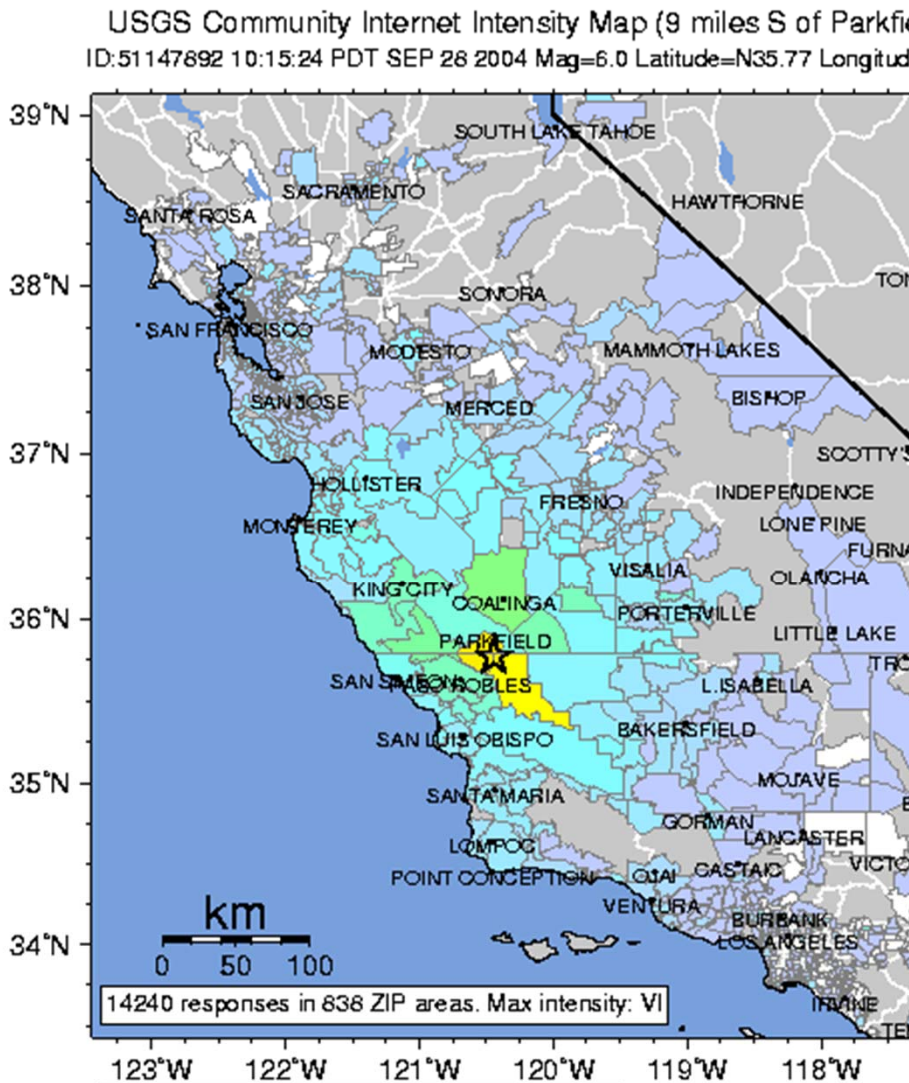
Comparison with actual felt effects

Instrumental ShakeMap



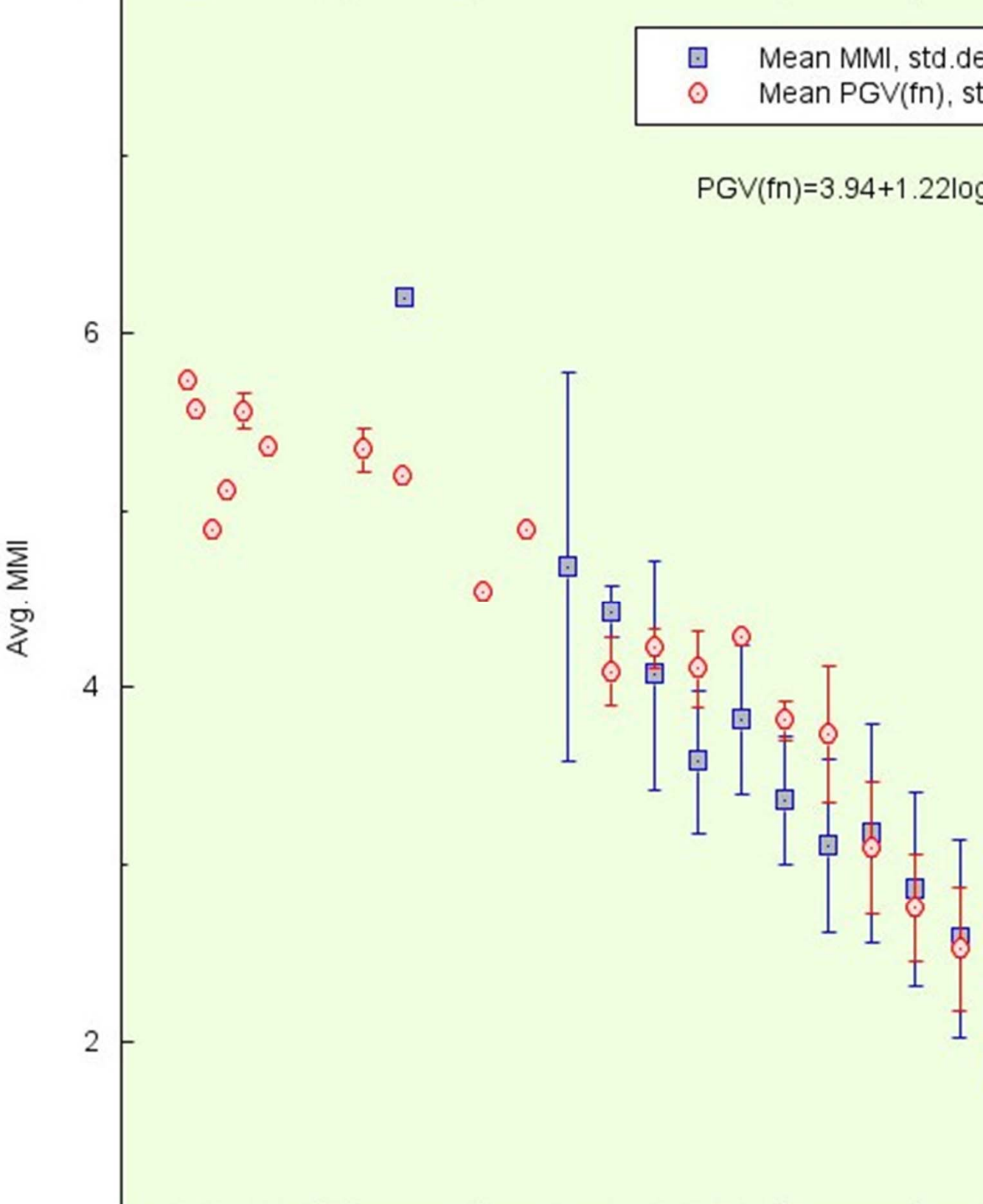
	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
	<.17	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124

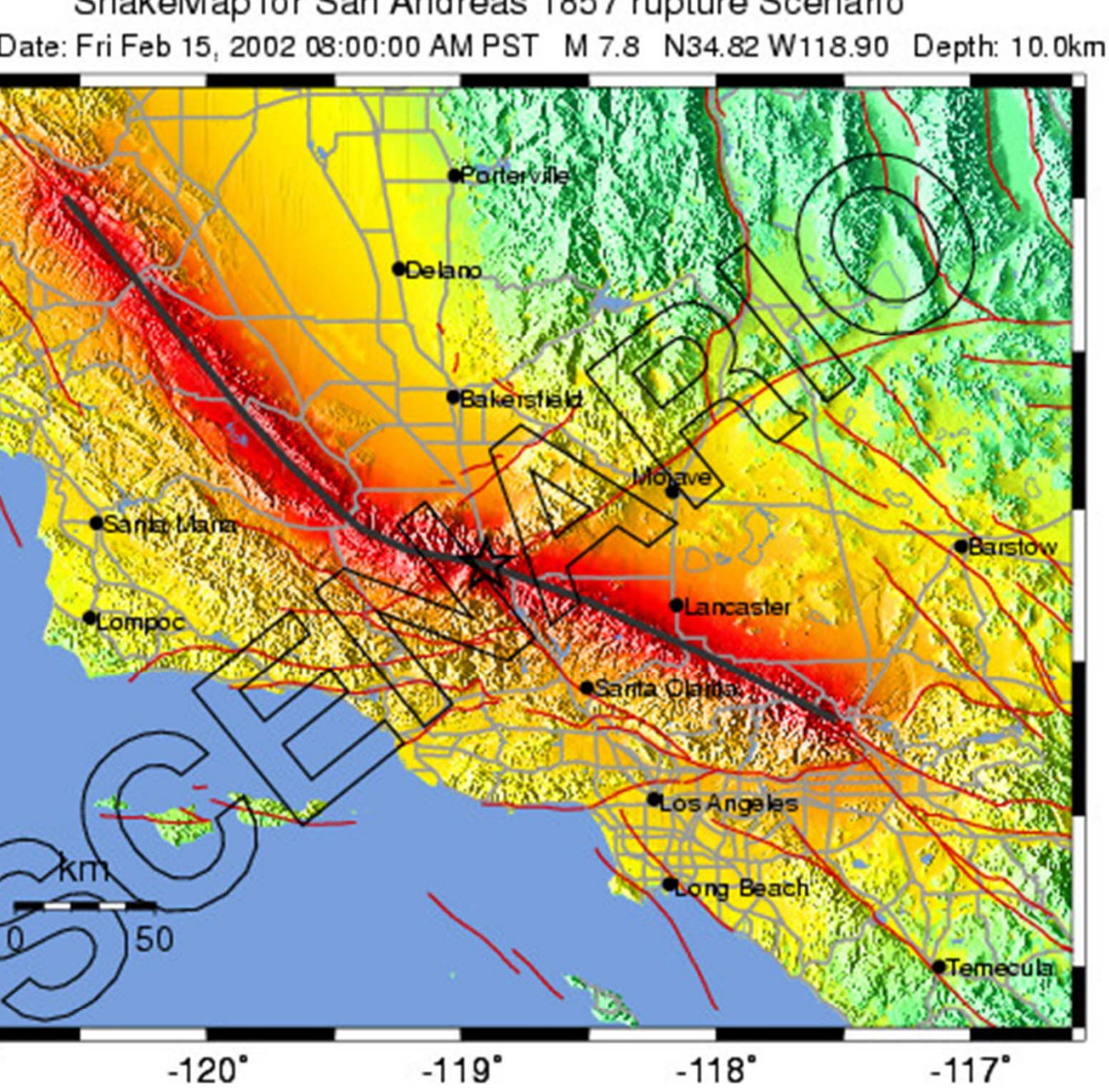
•DYFI felt reports



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX

omparing ground motions: recorded elocity vs. FI intensity Parkfield)





	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
-	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
n's)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*

Scenar ShakeMa

- California ShakeMap: scenario ever
- M7.8 on San Andreas faul (1857 ruptur
- Predict seve shaking and heavy damag (MMI=9) alo fault, light to moderate

ow is a scenario ShakeMap constructe

ecify the scenario event in terms of magnitude a
stance

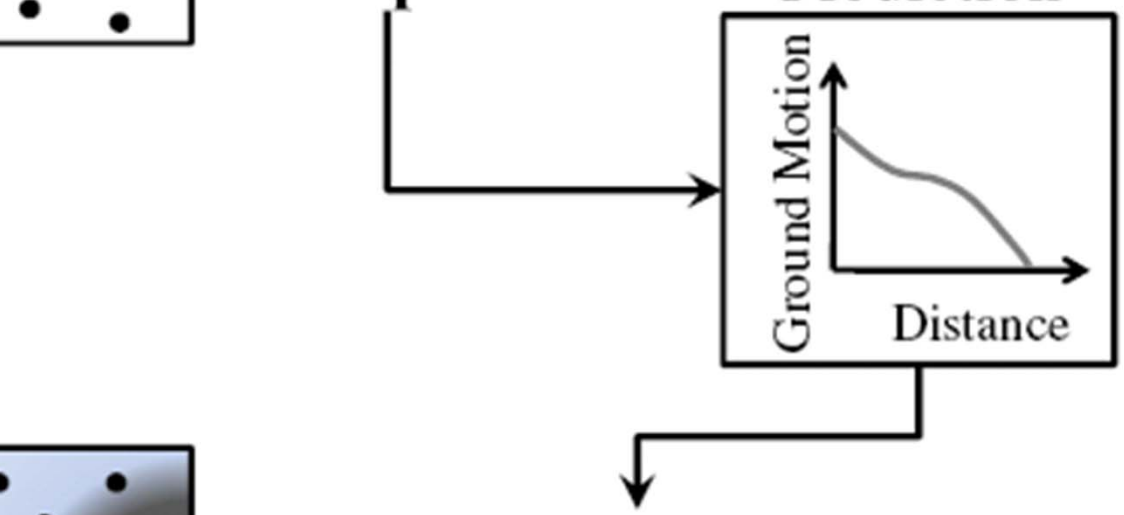
timate the ground motions (PGA, PGV and
gineering parameters like response spectra) for
ference ground condition (eg. Rock), from regio
uations or simulations, across the region of inte

nplify the motions for site-specific soil informat

press motions in terms of desired parameters,
nvert to MMI intensity if desired

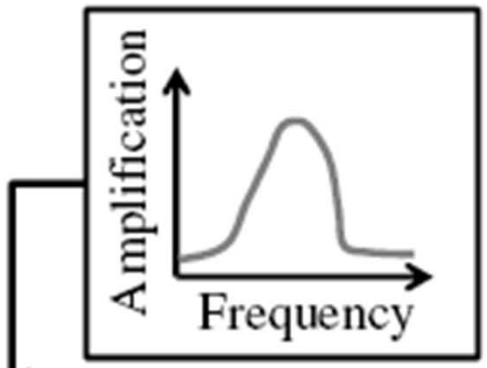
ap the output

Generation



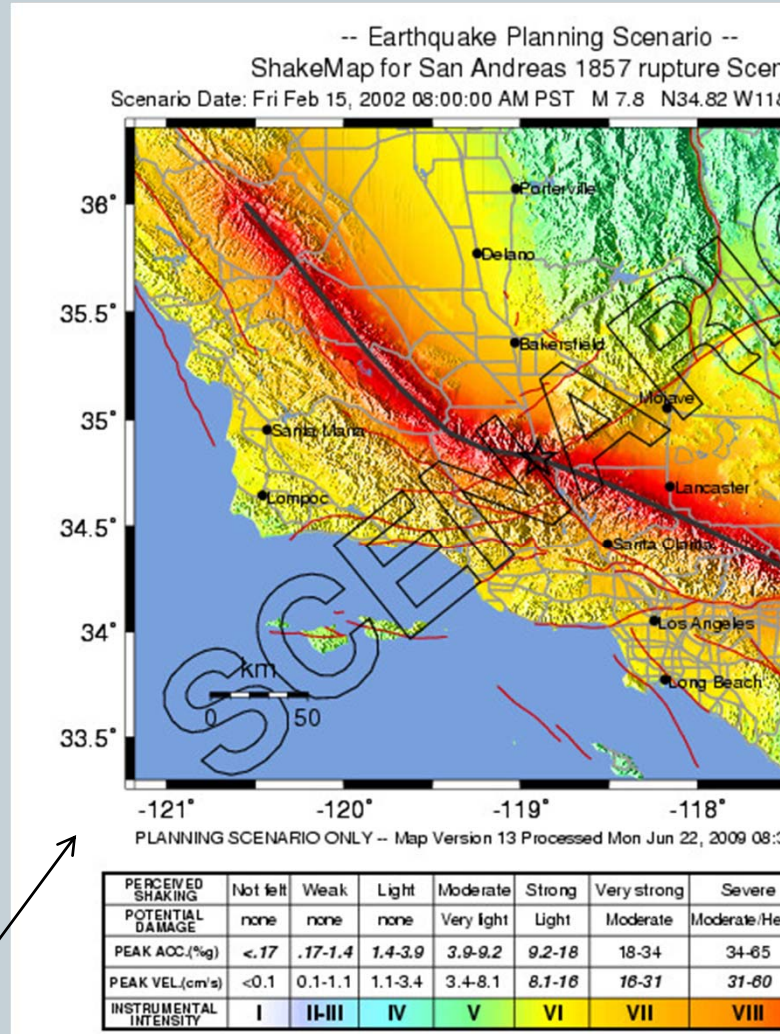
Median Ground Motions Map

× Soil amplification estimation



Corrected Ground Motions Map

Using empirical equations

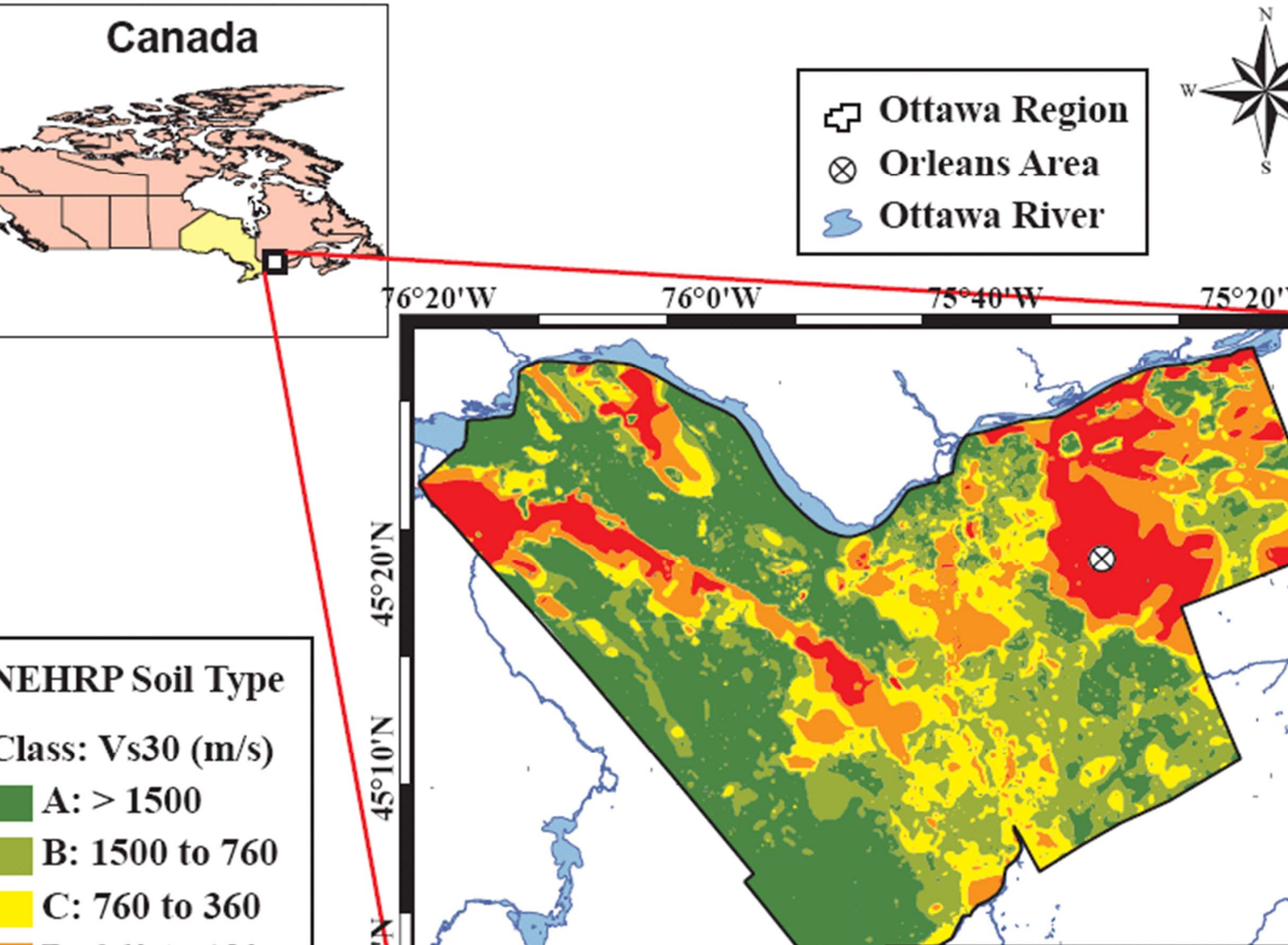


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/He
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII

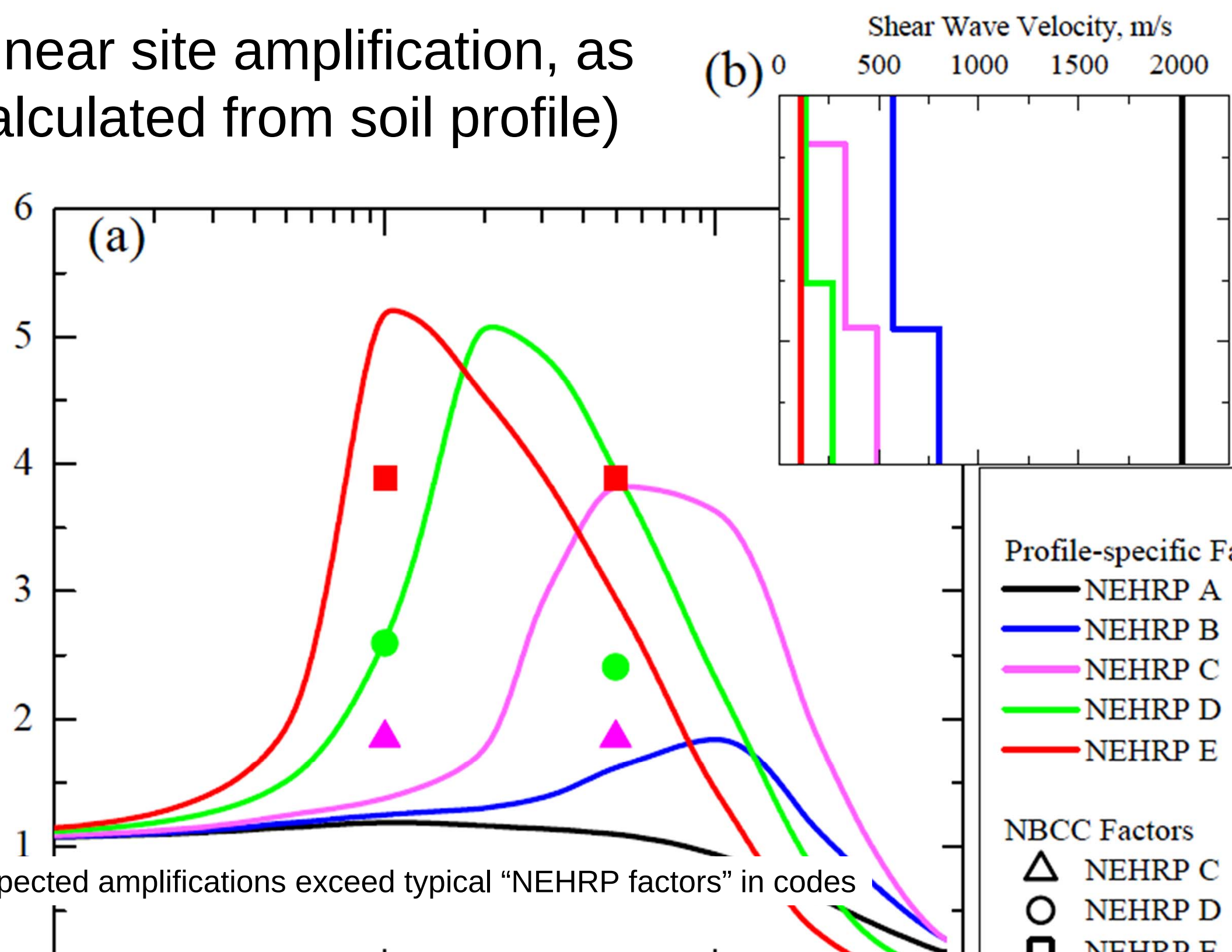
vs. Seismic Hazard maps

- enario ShakeMaps are developed for a specific agnitude and distance
- ten incorporate detailed microzonation formation
- azard maps implicitly integrate contributions fr magnitudes and distances to give motions for a ecific probability
- ay use very similar ground motion input
- azard maps typically produced for a reference ound condition (and might be amplified for a ecific site)

te information from microzonation studies



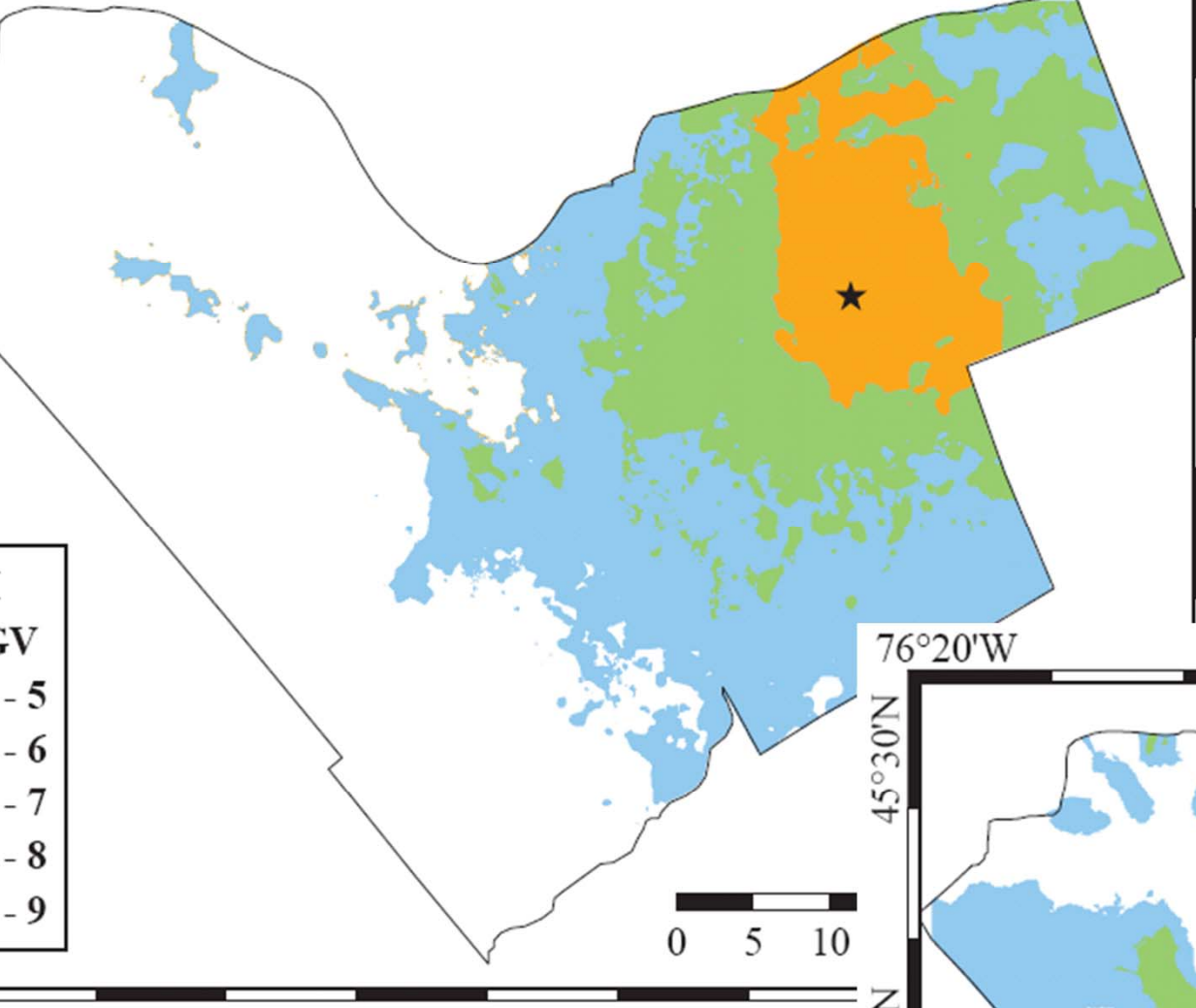
near site amplification, as
alculated from soil profile)



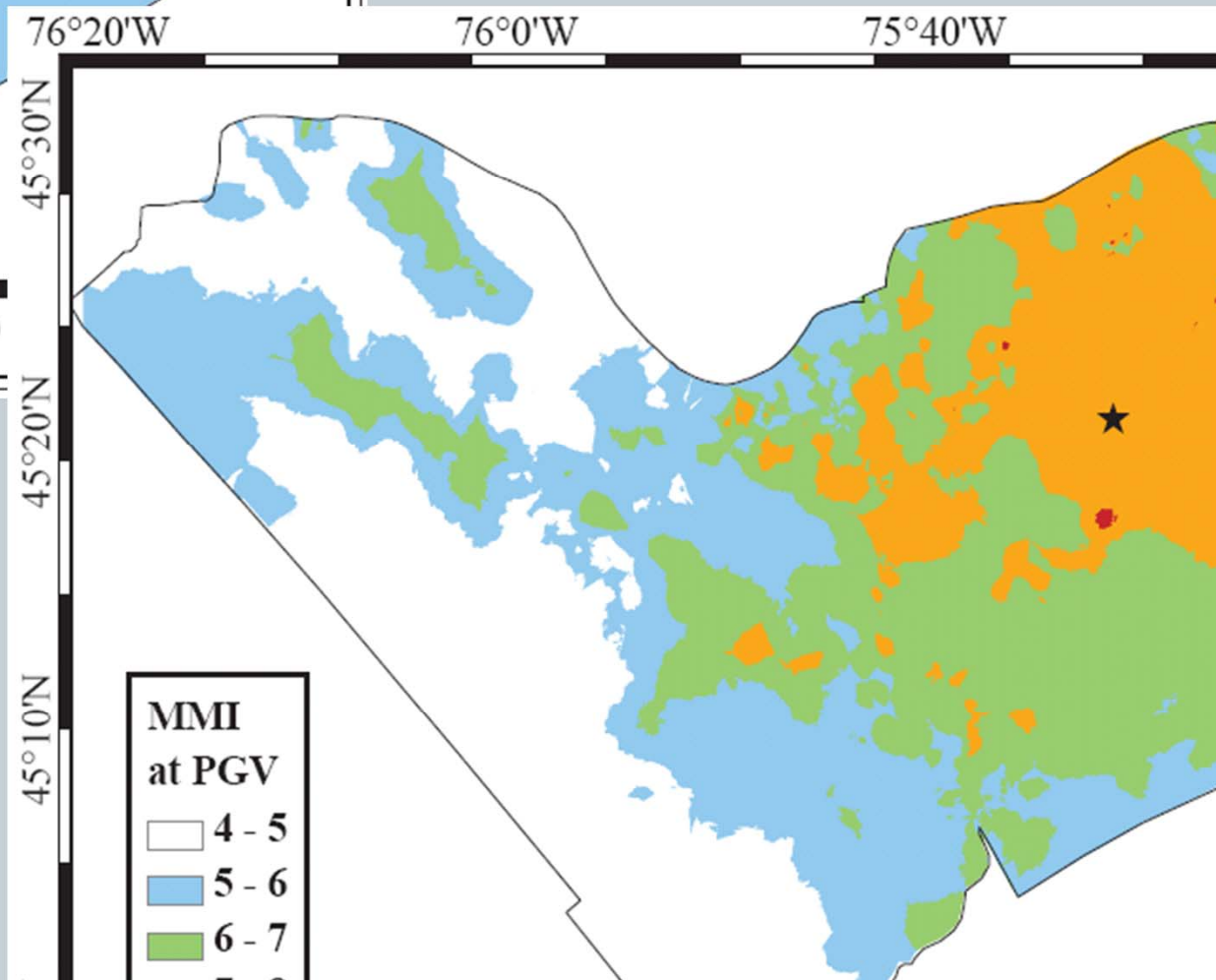
pected amplifications exceed typical “NEHRP factors” in codes

in the Orleans Region

Calculated amplifi
factors

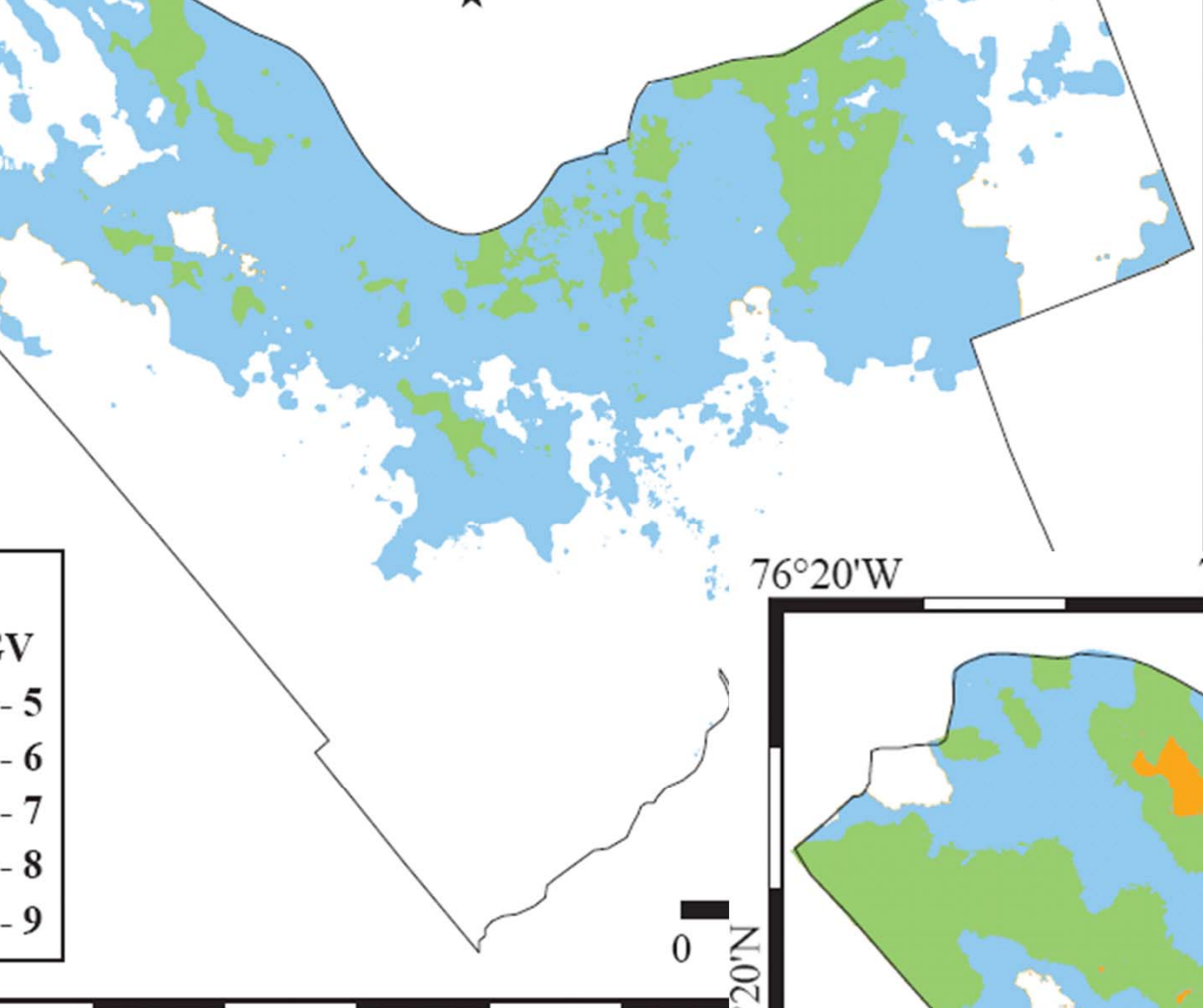


C
ification
rs

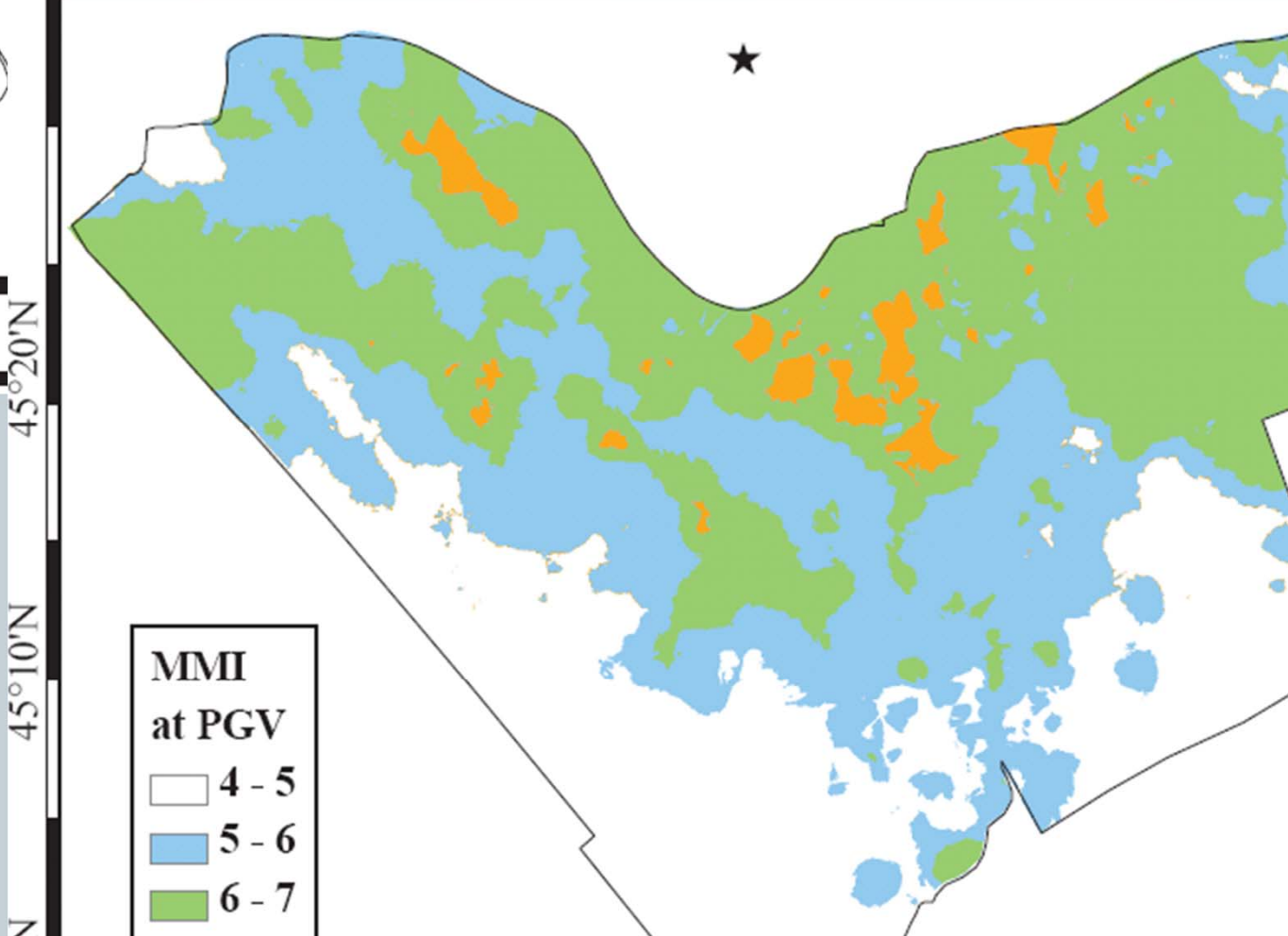


located in the Hull R

calculated amp
factors



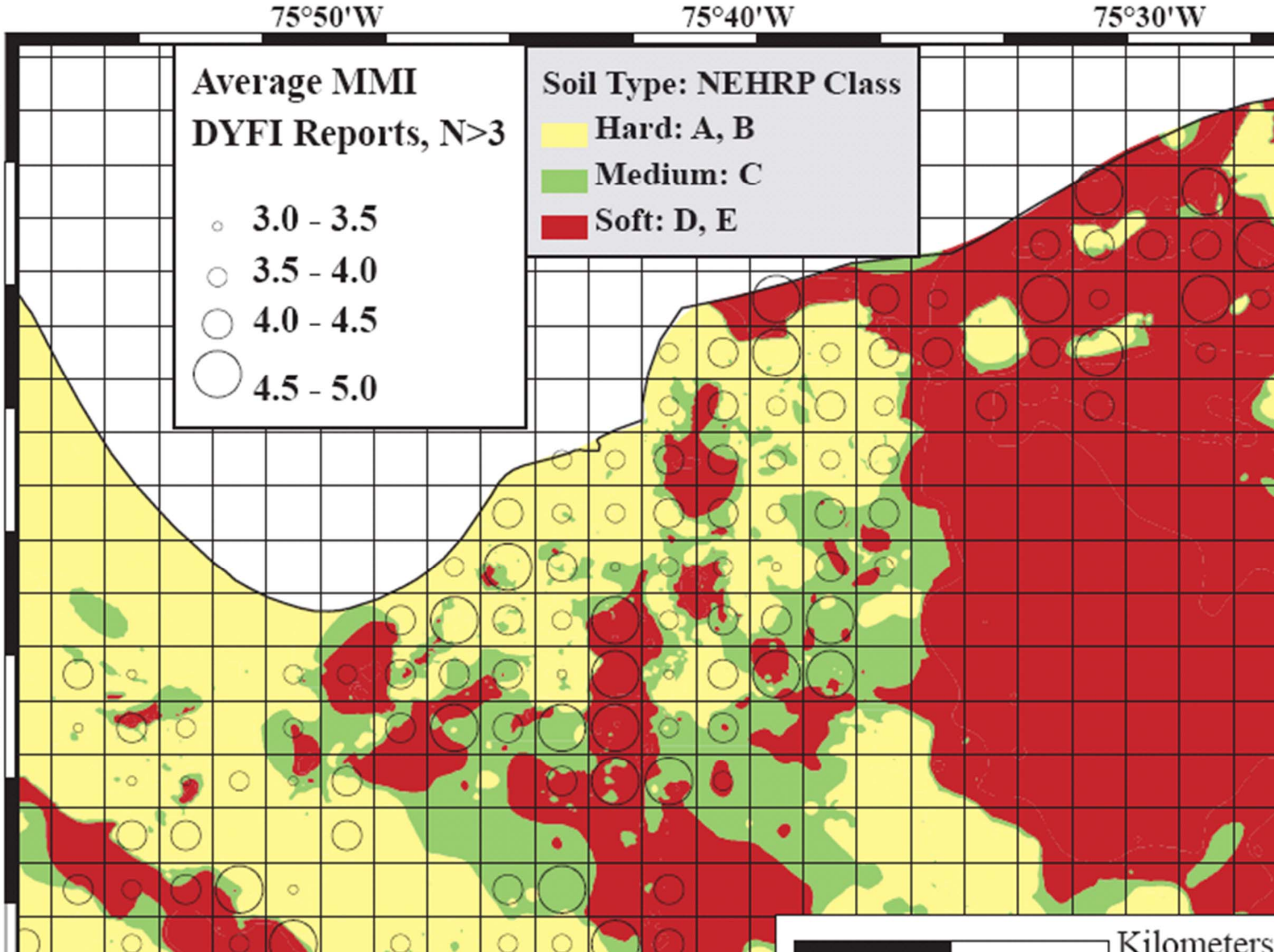
C amp factors

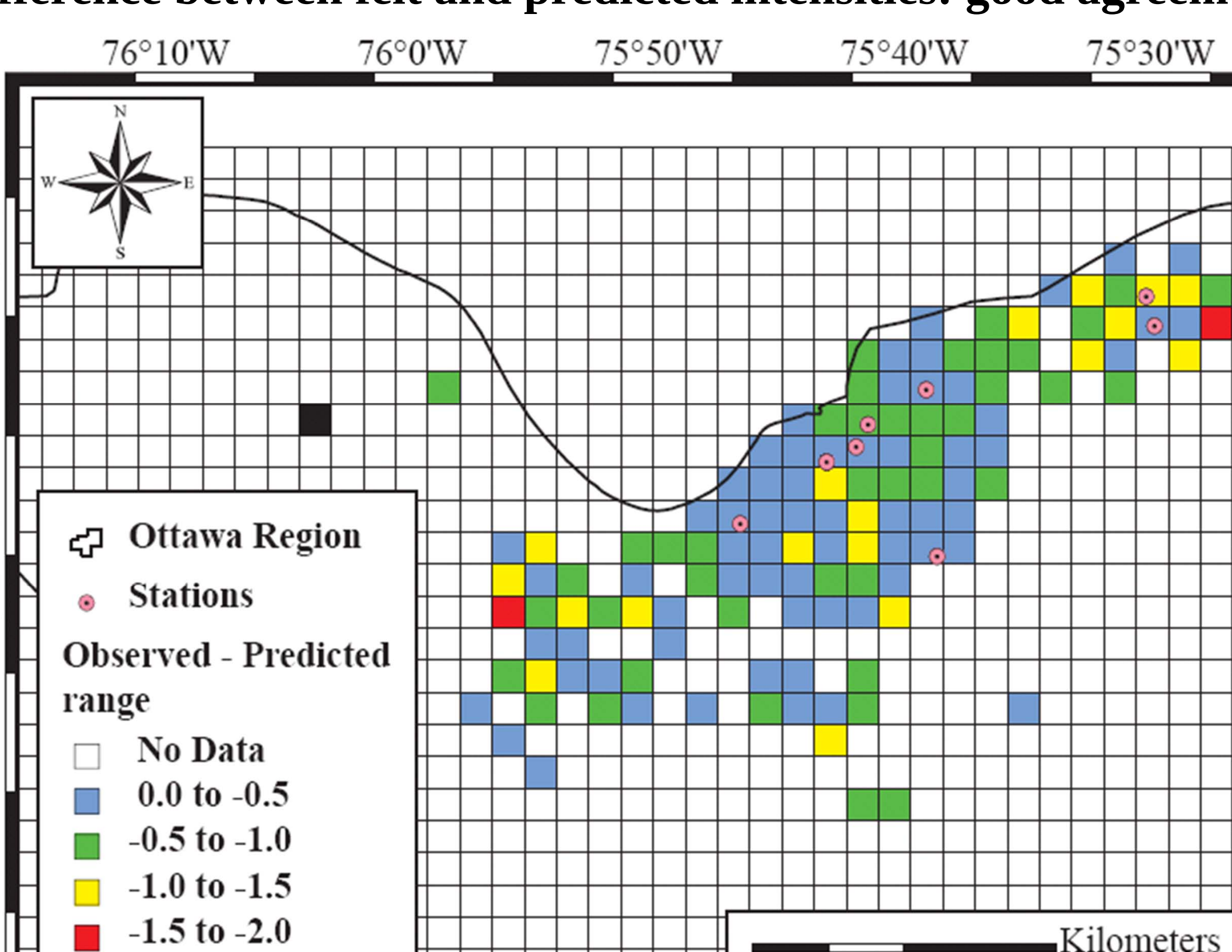


Ottawa earthquake

- ok at site effects on felt motions in Ottawa
- mpare motions predicted for this magnitude an
  cation to those that were reported

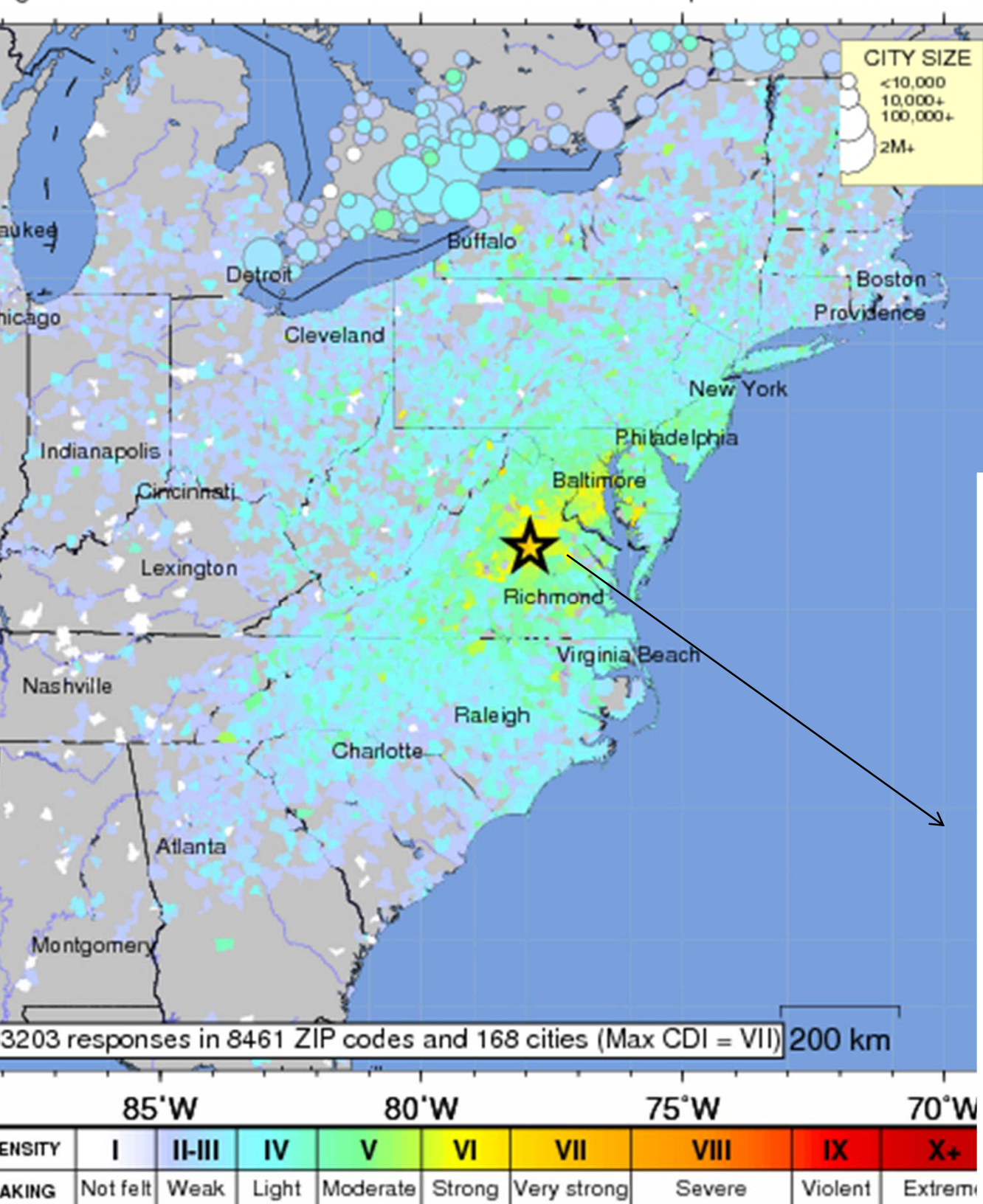
intensities overlaid on the soil map. Most strongly felt on soi

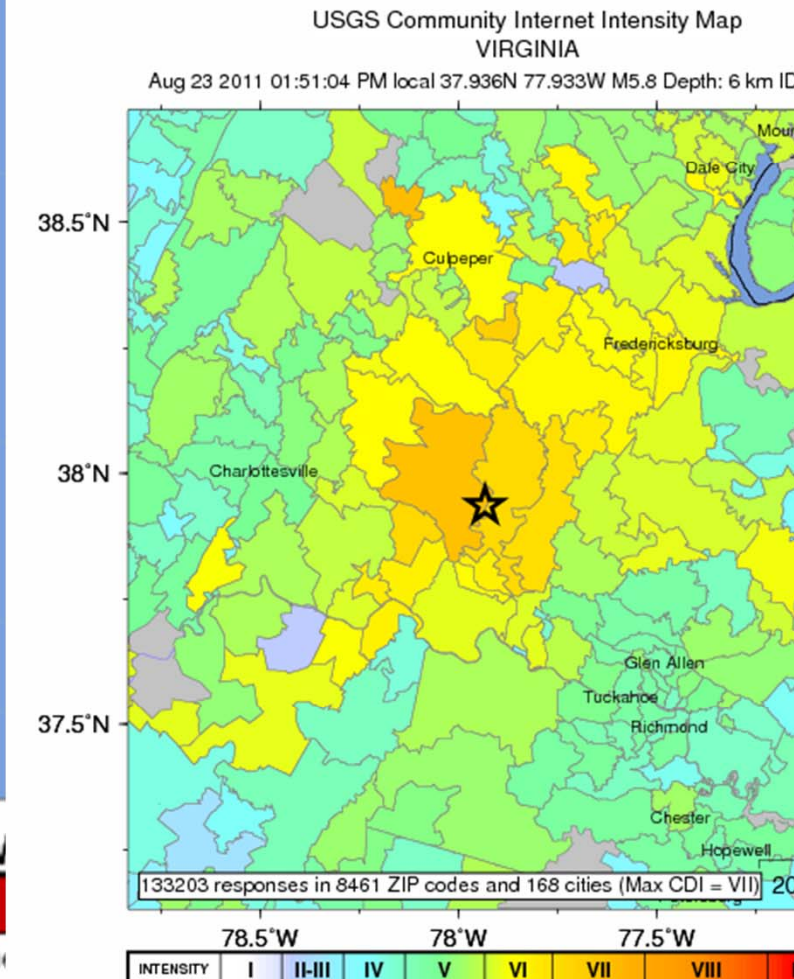


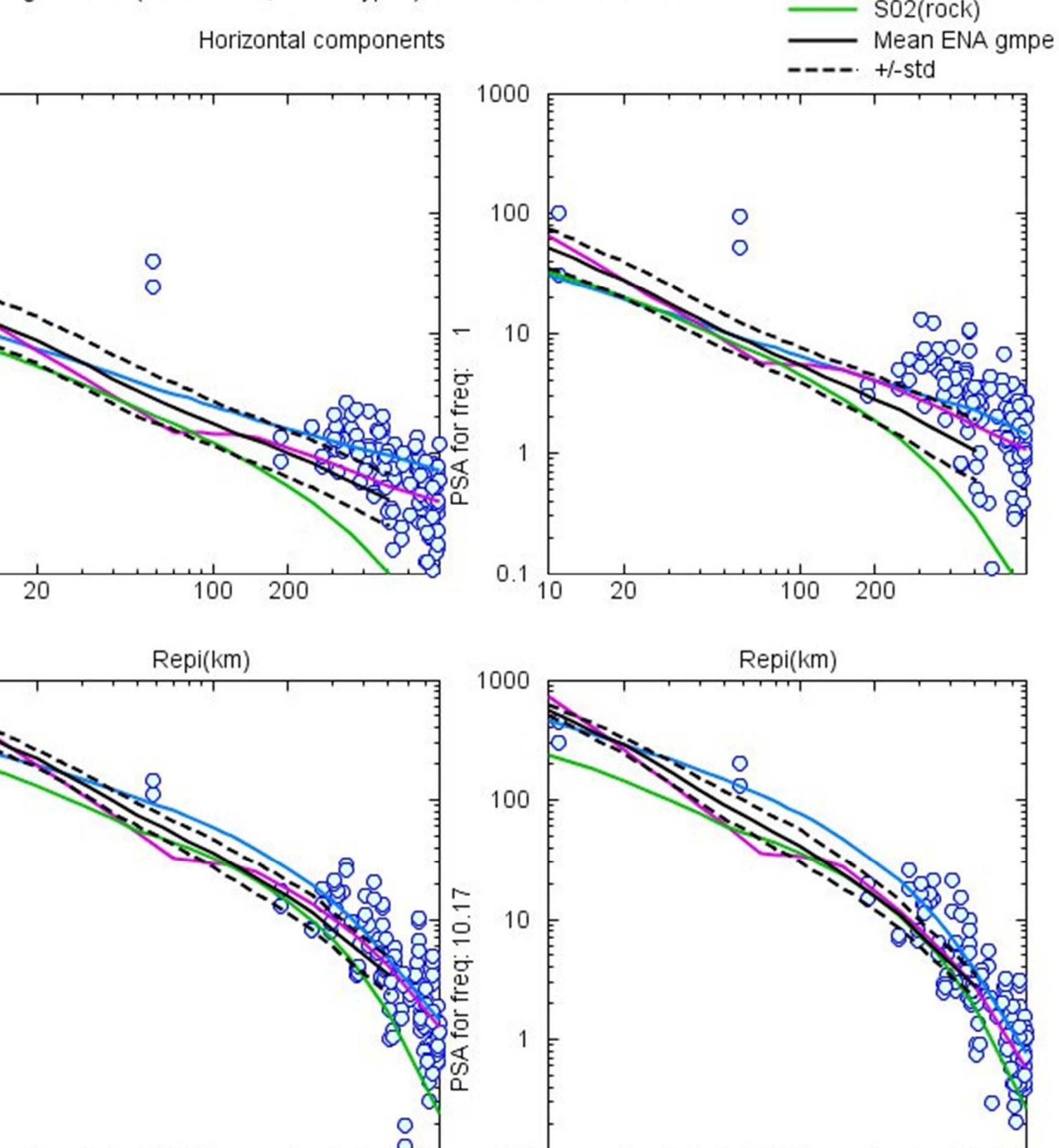

76°10'W
76°0'W
75°50'W
75°40'W
75°30'W
N
W
E
S
Ottawa Region
Stations
Observed - Predicted range
No Data
0.0 to -0.5
-0.5 to -1.0
-1.0 to -1.5
-1.5 to -2.0
Kilometers

Virginia M
earthqual

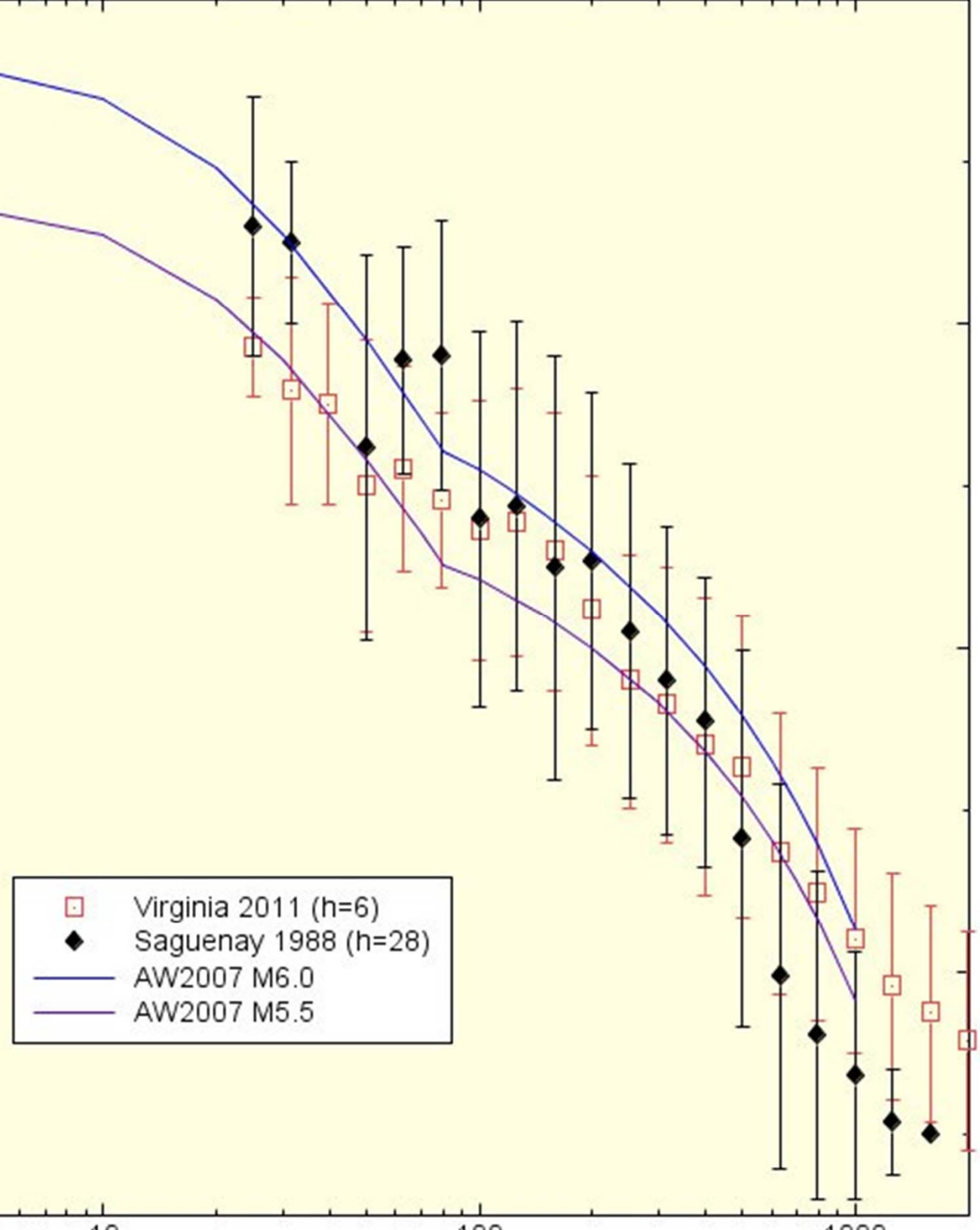
ShakeMa
based on f
intensitie







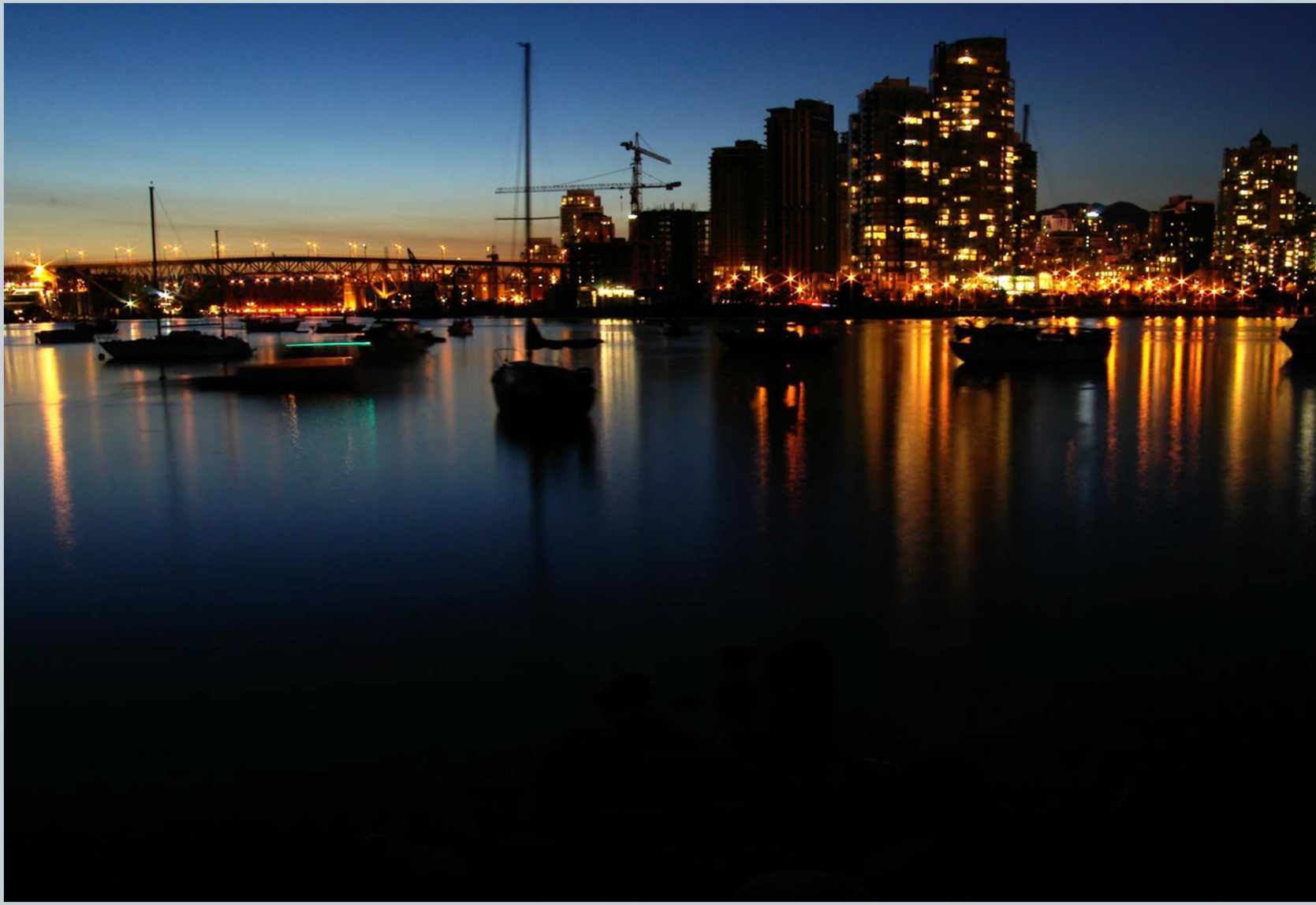
Comparison
recorded
Virginia mot
with predict
equations u
in eastern
ShakeMaps
in eastern
seismic haz
and risk stu



Comparison of M
Virginia felt data
1988 Saguenay (s
magnitude), and
intensity predict
equations (Atkin
and Wald, 2007)
M5.5 and M6.

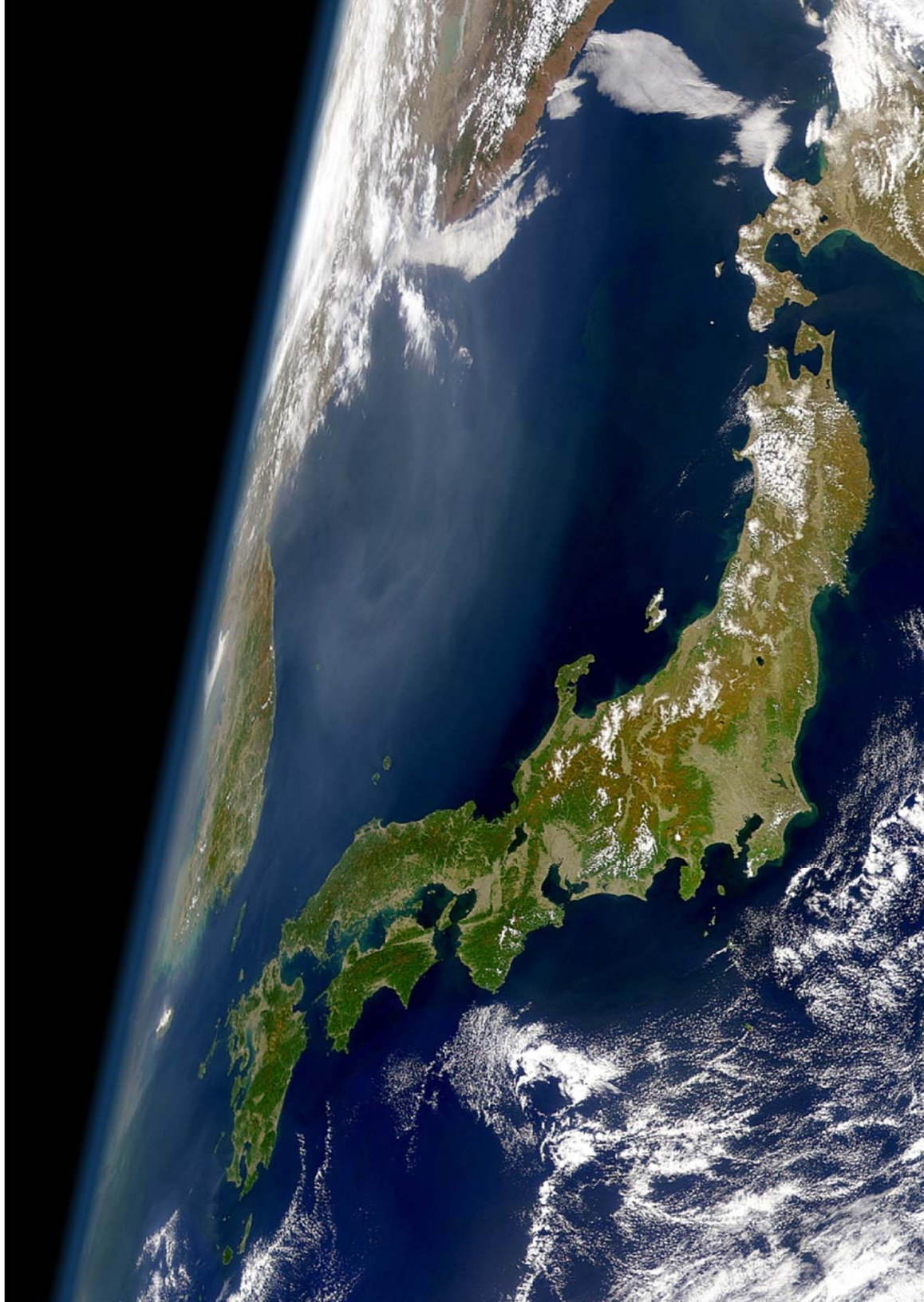
Scenario ShakeMaps for Vancouver

zards
m great
oduction
ents
slab
ents
ustal
ents

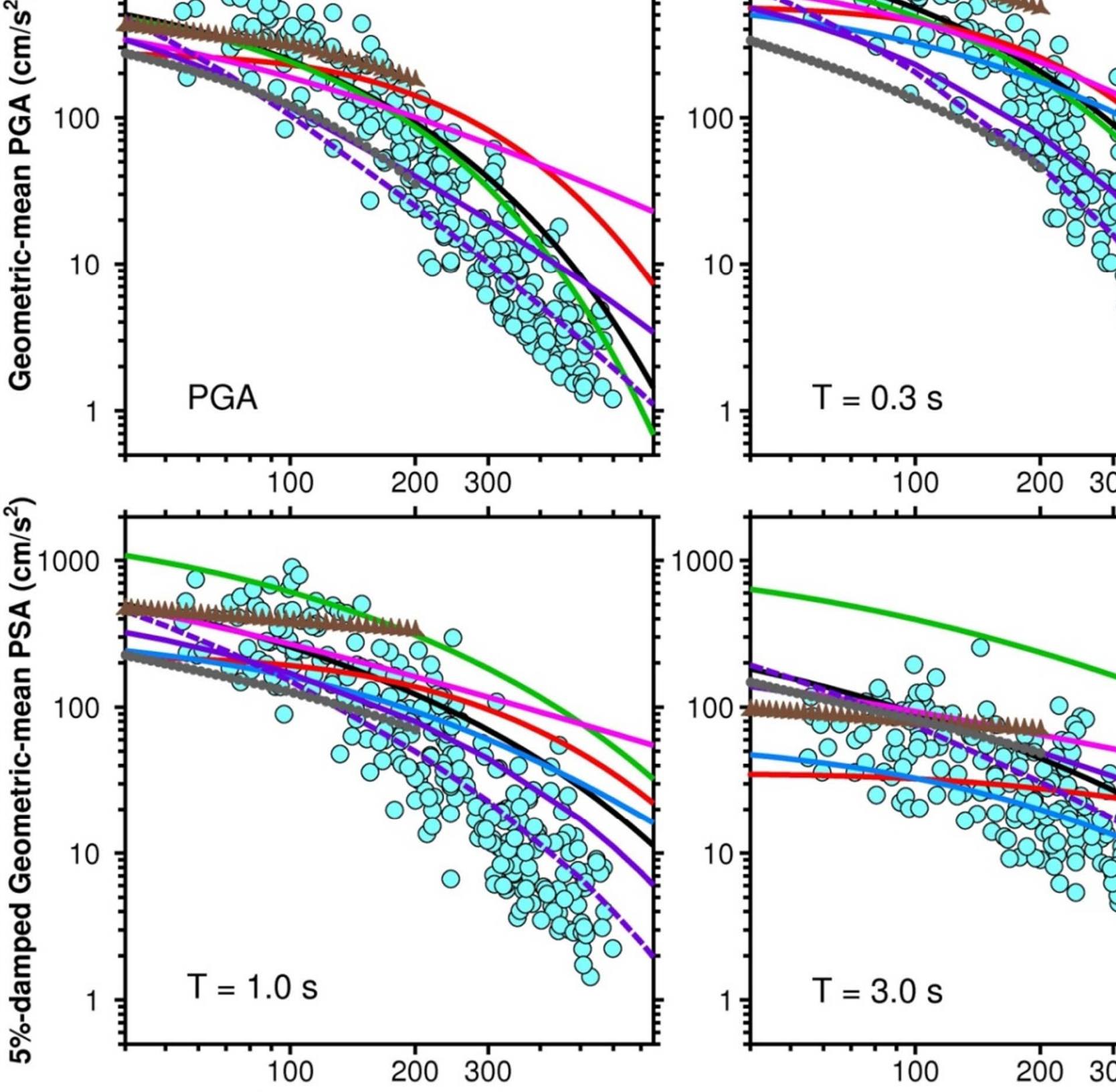


ons from
M9
oku Japan
nquake

ilar to
cted B.C.
athrust
t)

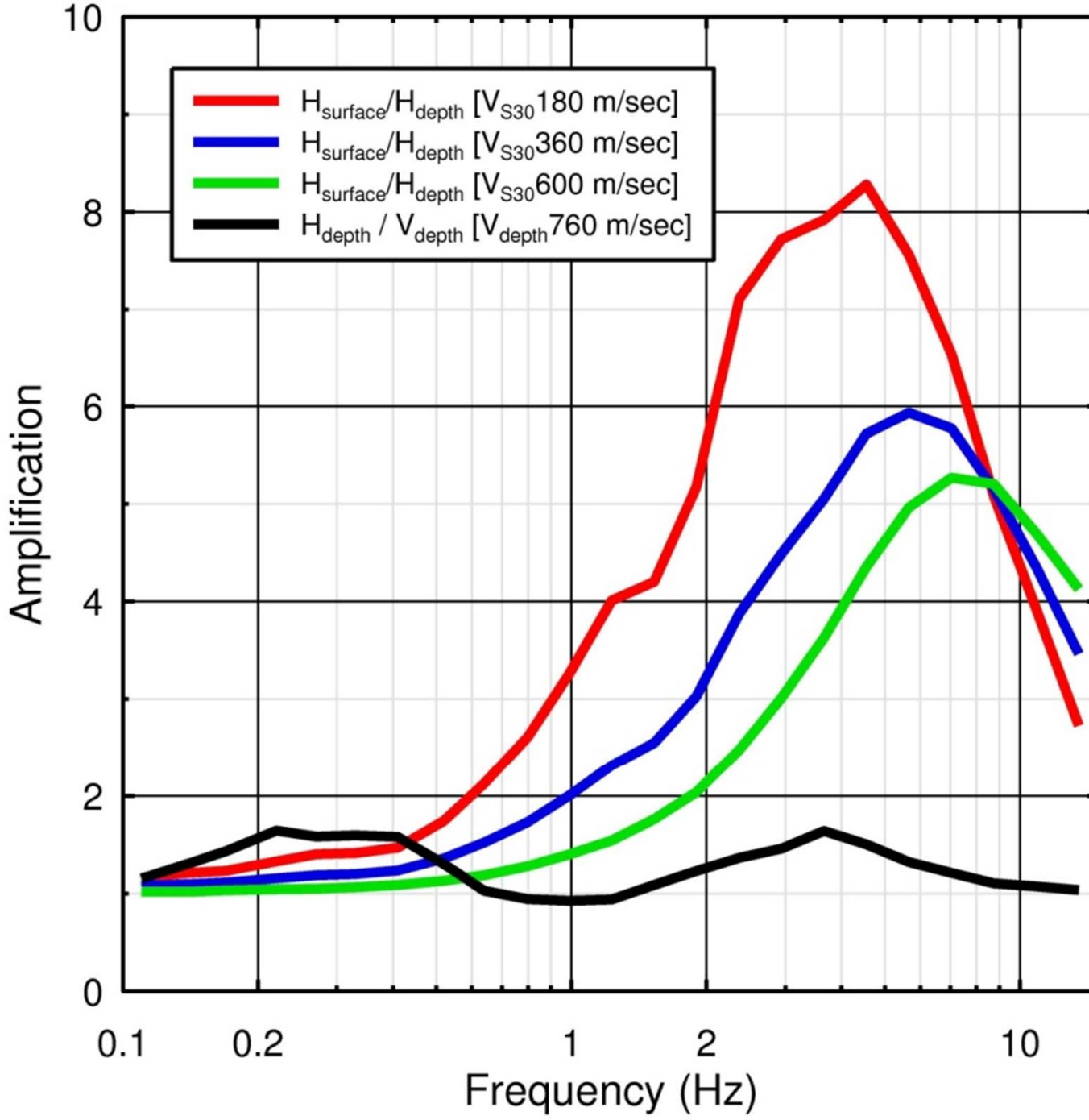


otions
ded to
larger
n many
diction
ns in
e – but
s was
ely due
o site
fects

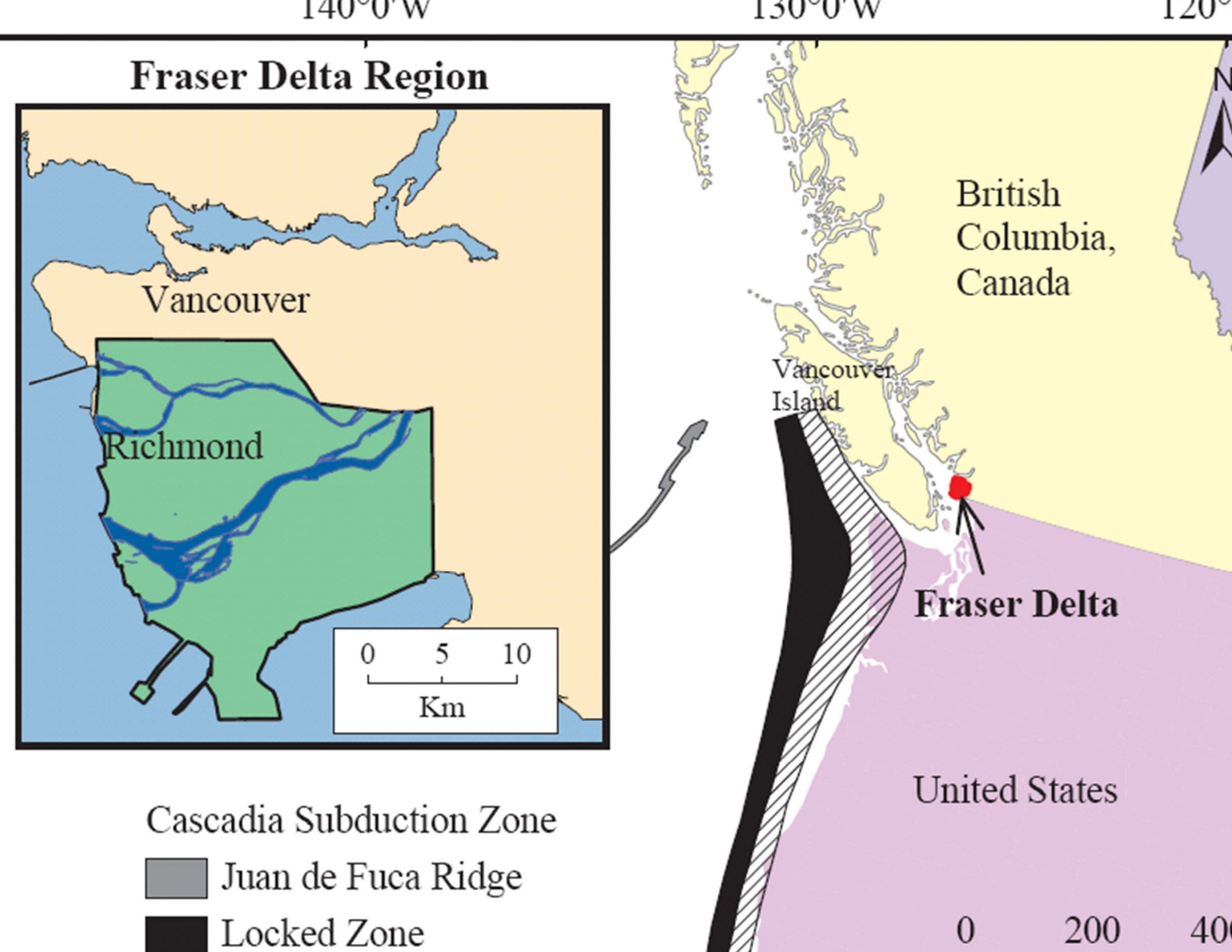


olifications
alculated
a data
rded both
urface and
ottom of
hole.

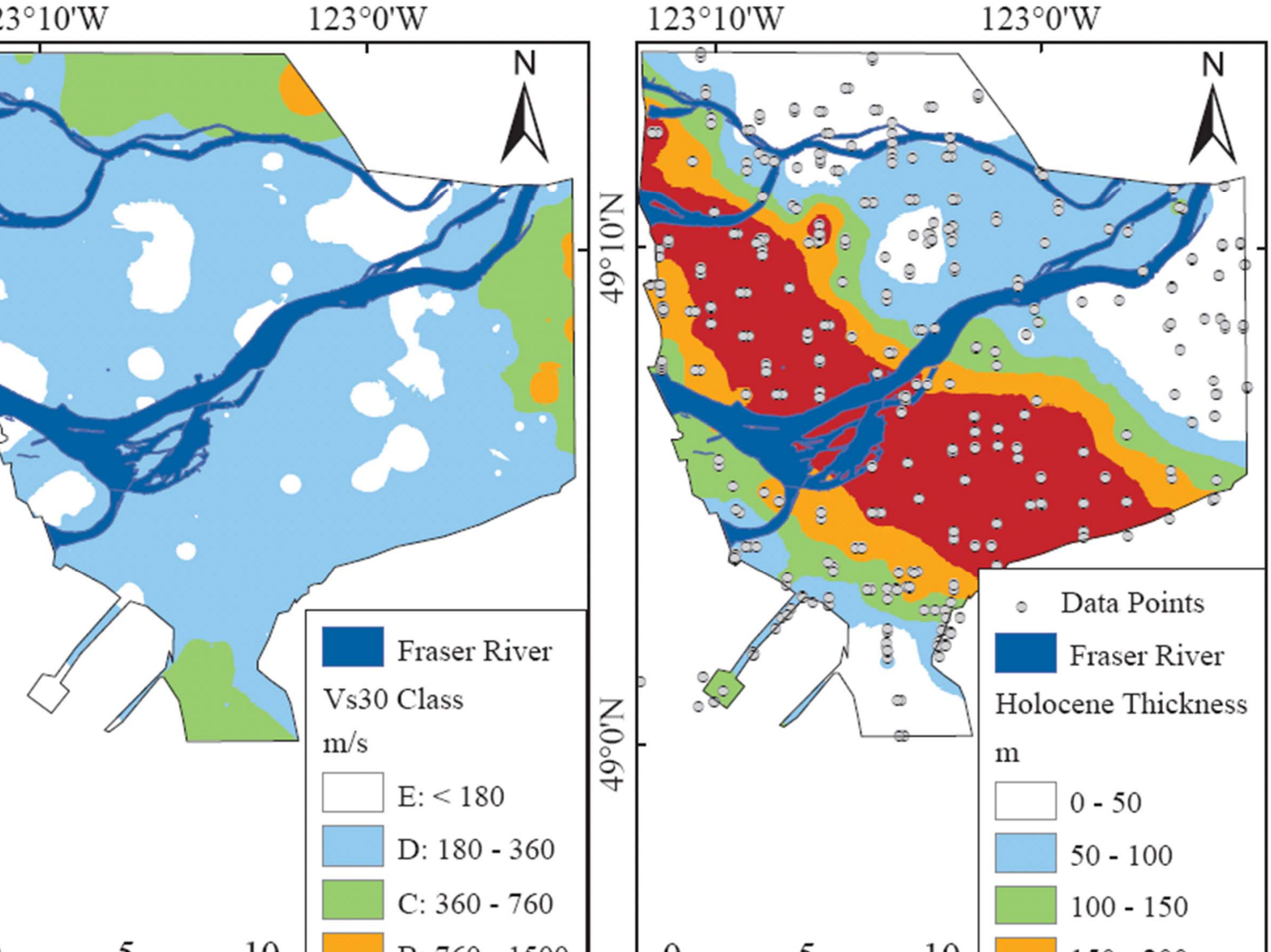
d to
ider
ific site
cts in
keMaps.

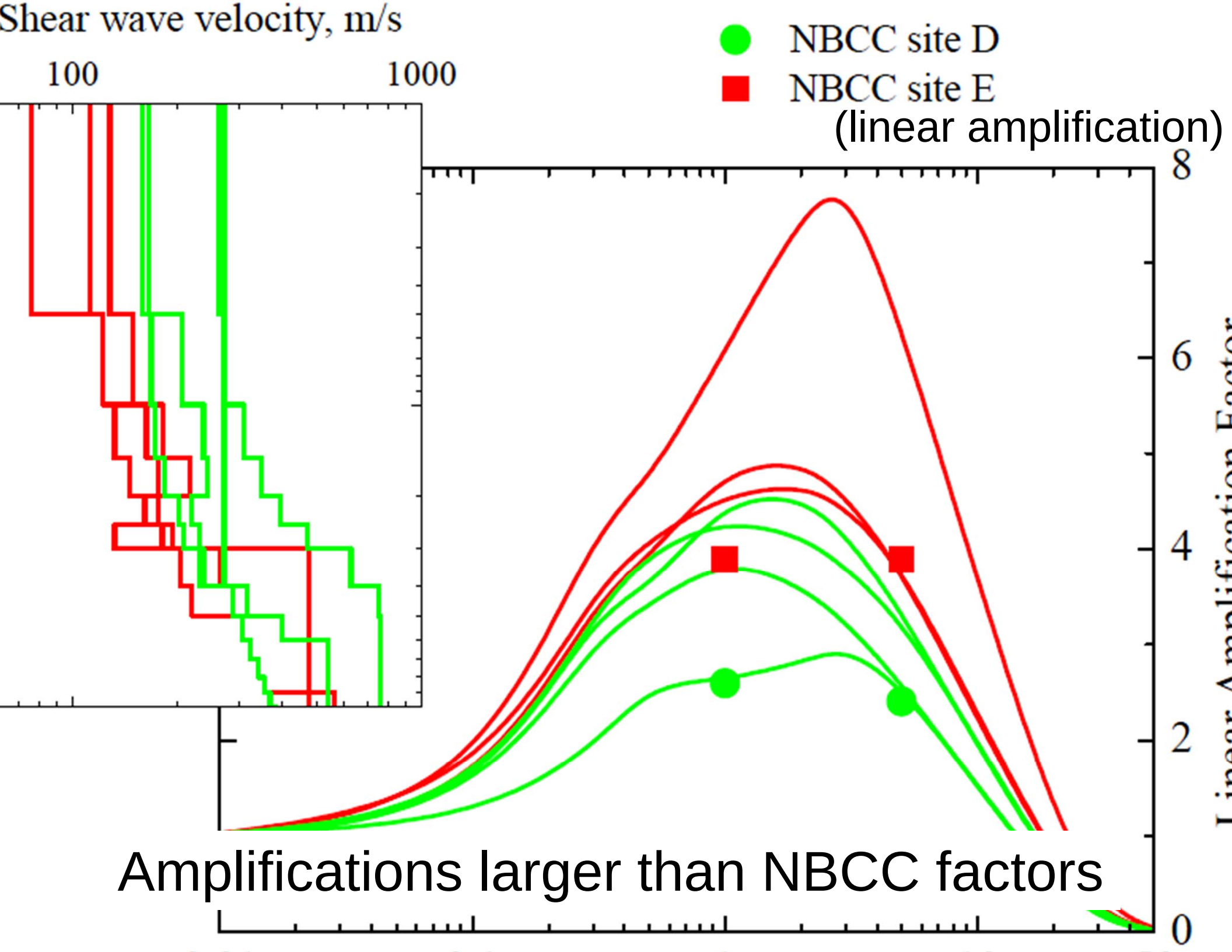


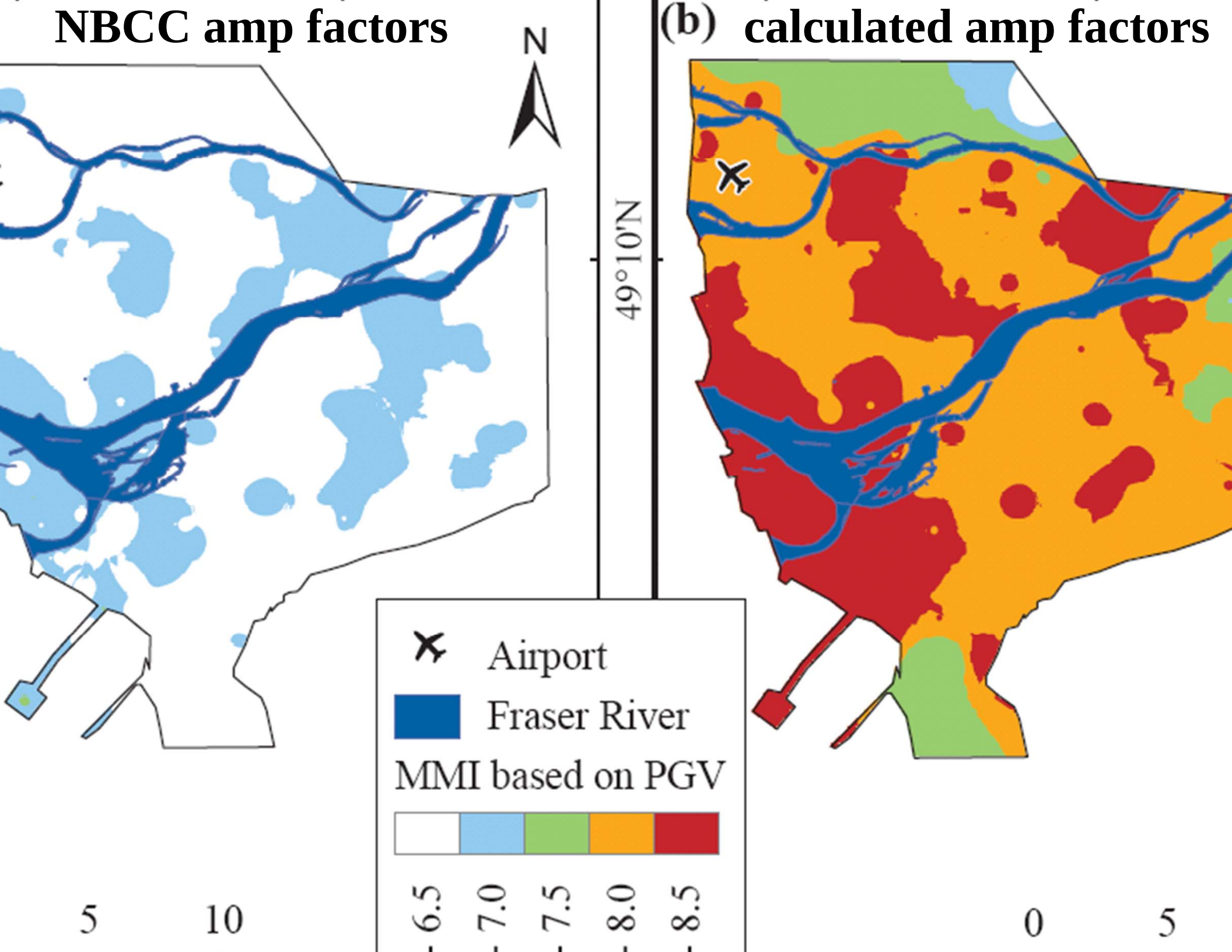
Tohoku site amplifications

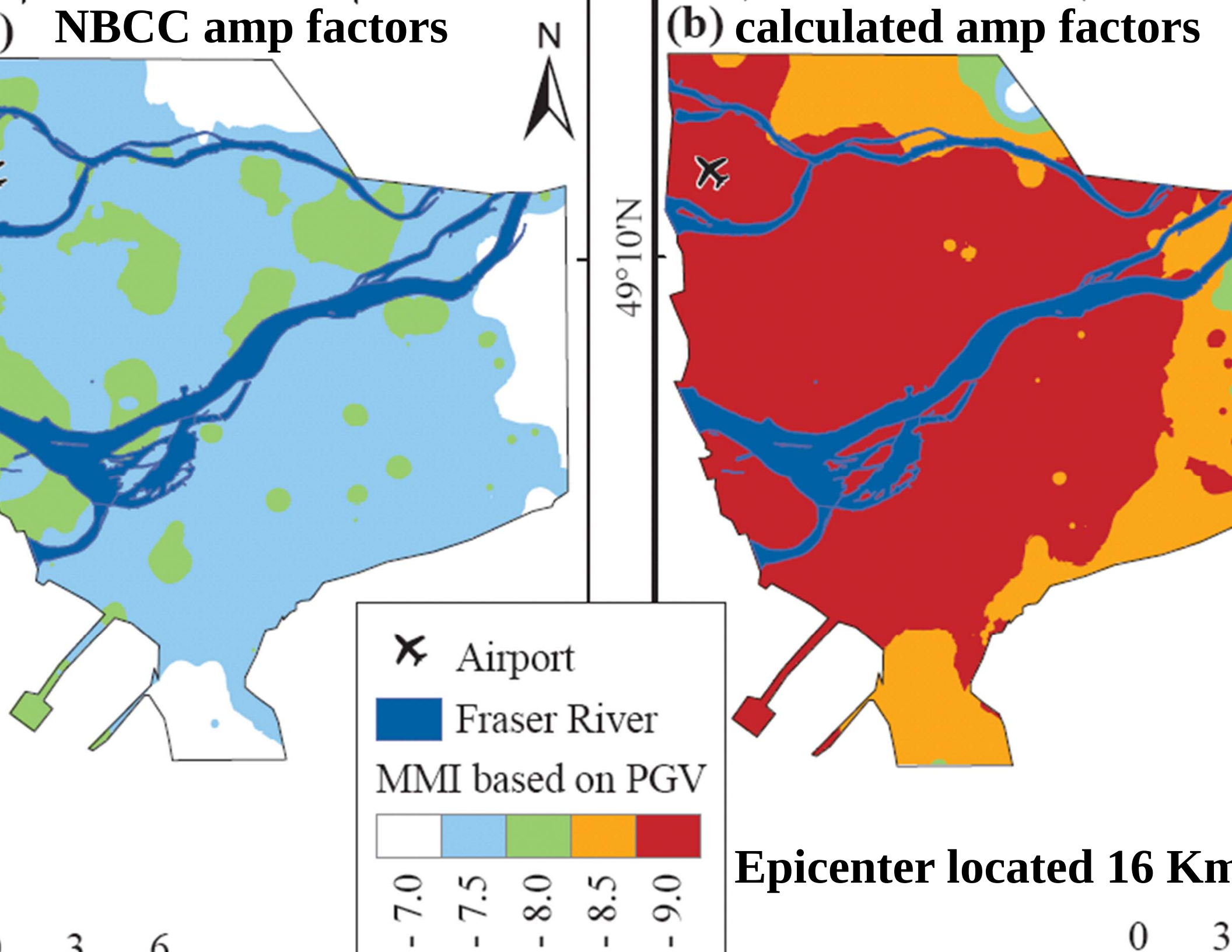

140°0'W
130°0'W
120°
Fraser Delta Region
Vancouver
Richmond
0 5 10
Km
British
Columbia,
Canada
Vancouver
Island
Fraser Delta
United States
Cascadia Subduction Zone
Juan de Fuca Ridge
Locked Zone
0 200 40

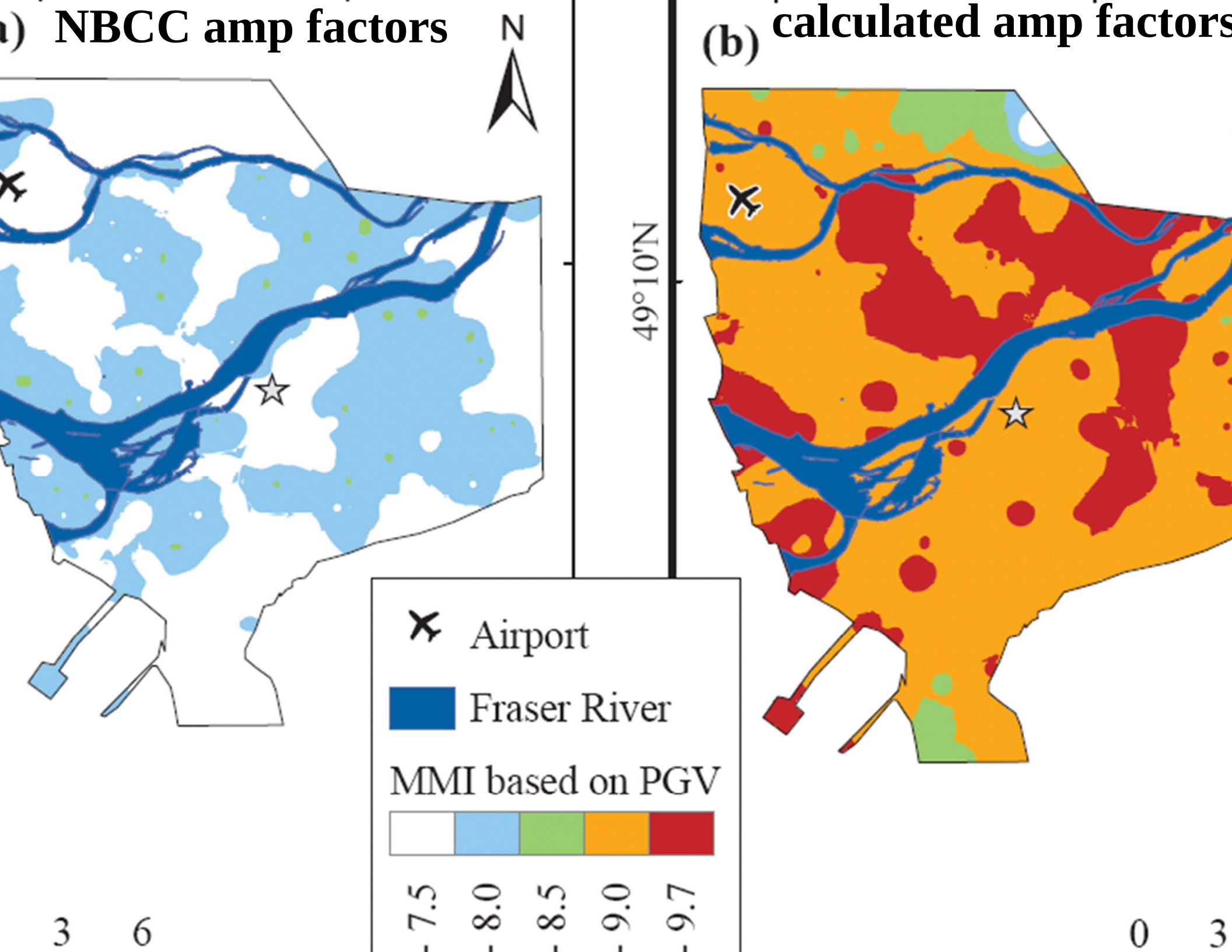
microzonation information




Shear wave velocity, m/s
100
1000
NBCC site D
NBCC site E
(linear amplification)
8
6
4
2
0
Amplifications larger than NBCC factors


NBCC amp factors
(b) calculated amp factors
N
49°10'N
Airport
Fraser River
MMI based on PGV
6.5
7.0
7.5
8.0
8.5
5
10
0
5


(a) NBCC amp factors
(b) calculated amp factors
N
49°10'N
Airport
Fraser River
MMI based on PGV
7.0
7.5
8.0
8.5
9.0
Epicenter located 16 Km
0
3
6


(a) NBCC amp factors
(b) calculated amp factors
N
49°10'N
Airport
Fraser River
MMI based on PGV
7.5
8.0
8.5
9.0
9.7
3
6
0
3

Lessons for Insurance Industry

- enario ShakeMaps useful to assess expected rength of motions for use in risk assessments
- te effects are critical in assessing level of motion d their effects
- eed detailed regional studies to assess site effect
- eed detailed regional models of input ground otions for reference site condition