



NOI PERSPECTIVE ASUPRA EVALUĂRII PROBABILISTICE DE HAZARD SEISMIC PENTRU ROMANIA

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Introducere

- Rezultate preliminare ale proiectului de cercetare **BIGSEES** (Bridging the Gap between Seismology and Earthquake Engineering: From the Seismicity of Romania towards a refined implementation of Seismic Action EN1998-1 in earthquake resistant design of buildings); continuare a proiectelor nationale si internationale precedente; in sprijinul proiectantilor de structuri
- Finantator: Ministerul Educatiei Nationale
- Perioada: 2012 – 2016
- Echipa de proiect : INFP, UTCB, URBAN INCERC si Aedificia Carpati

Introducere

- Rezultate preliminare ale proiectului de cercetare **BIGSEES** au fost publicate in reviste internationale precum *Bulletin of the Seismological Society of America*, *Bulletin of Earthquake Engineering*, *Journal of Earthquake Engineering*, *Natural Hazards*, *Earthquakes and Structures*, *Earthquake Engineering and Engineering Vibration* si in volumele conferintelor nationale si internationale de inginerie seismica si seismologie
- Lista publicatiilor proiectului din perioada 2013-2014: <http://infp.infp.ro/bigsees/Publications.html>

Seismicitatea Romaniei

- Sursele seismice ce afecteaza teritoriul Romaniei- definite de INFP - sursa subcrustala Vrancea si 13 surse crustale
- Surse subcrustale – adancime intermediara (de ex., Vrancea 60-200 km), efecte puternice pe suprafete mari
- Surse crustale – adancime mica, efecte puternice pe suprafate reduse (la cutremurul crustal vrancean din noiembrie 2014 cu M_W 5.7 s-a inregistrat la Odobesti 0.28g)
- Cataloagele de cutremure si analiza seismicitatii – revizuite de UTCB si INFP pentru proiectul BIGSEES

Seismicitatea Romaniei



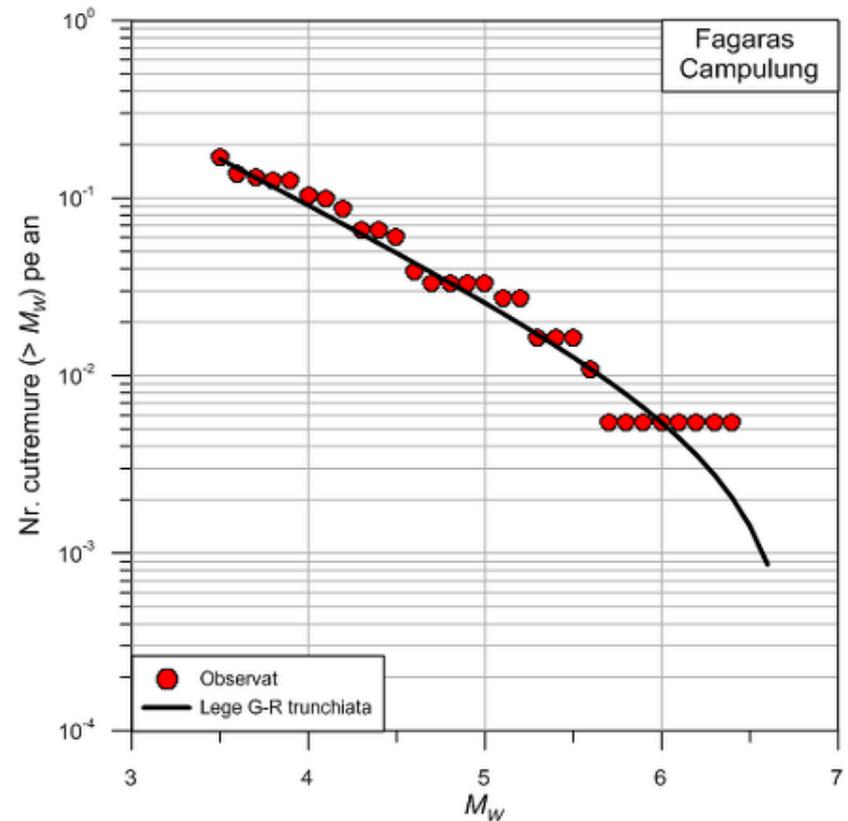
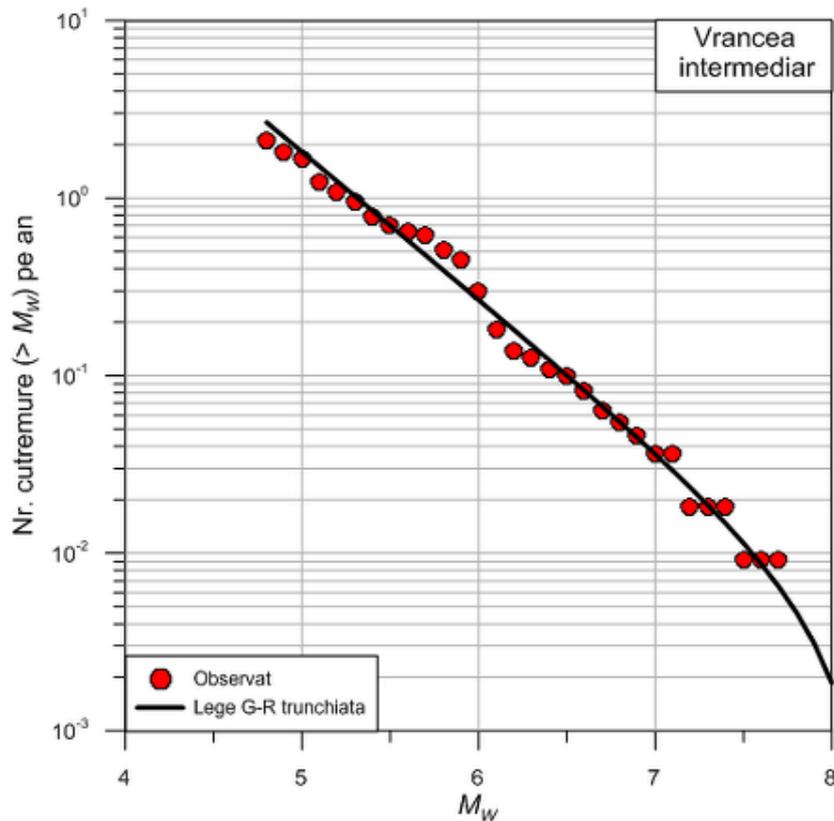
Surse seismice ce afecteaza teritoriul Romaniei (Vacareanu et al. 2014a)

Seismicitatea Romaniei

Sursa seismica	Magnitudinea minima*, M_{\min}	Magnitudinea maxima*, M_{\max}
Banat	3.8	6.4
Depresiunea Barladului	3.2	5.8
Crisana	3.5	6.6
Danubius	3.2	6.0
Fagaras	3.5	6.8
Depresiunea Pre-Dobrogeana	3.1	5.7
Serbia	4.2	6.1
Transilvania	4.5	6.2
Vrancea crustal	3.8	6.3
Vrancea subcrustal (1802-2014)	5.7	8.2
(1901-2014)	4.8	8.1
Dulovo	3.2	7.1
Shabla	4.5	7.8
Gorna	4.1	7.4
Shumen	4.5	6.7

* Valori stabilite pe baza catalogului ROMPLUS (INFP)

Seismicitatea Romaniei



Recurenta observata si legea de distributie Gutenberg-Richter a magnitudinii

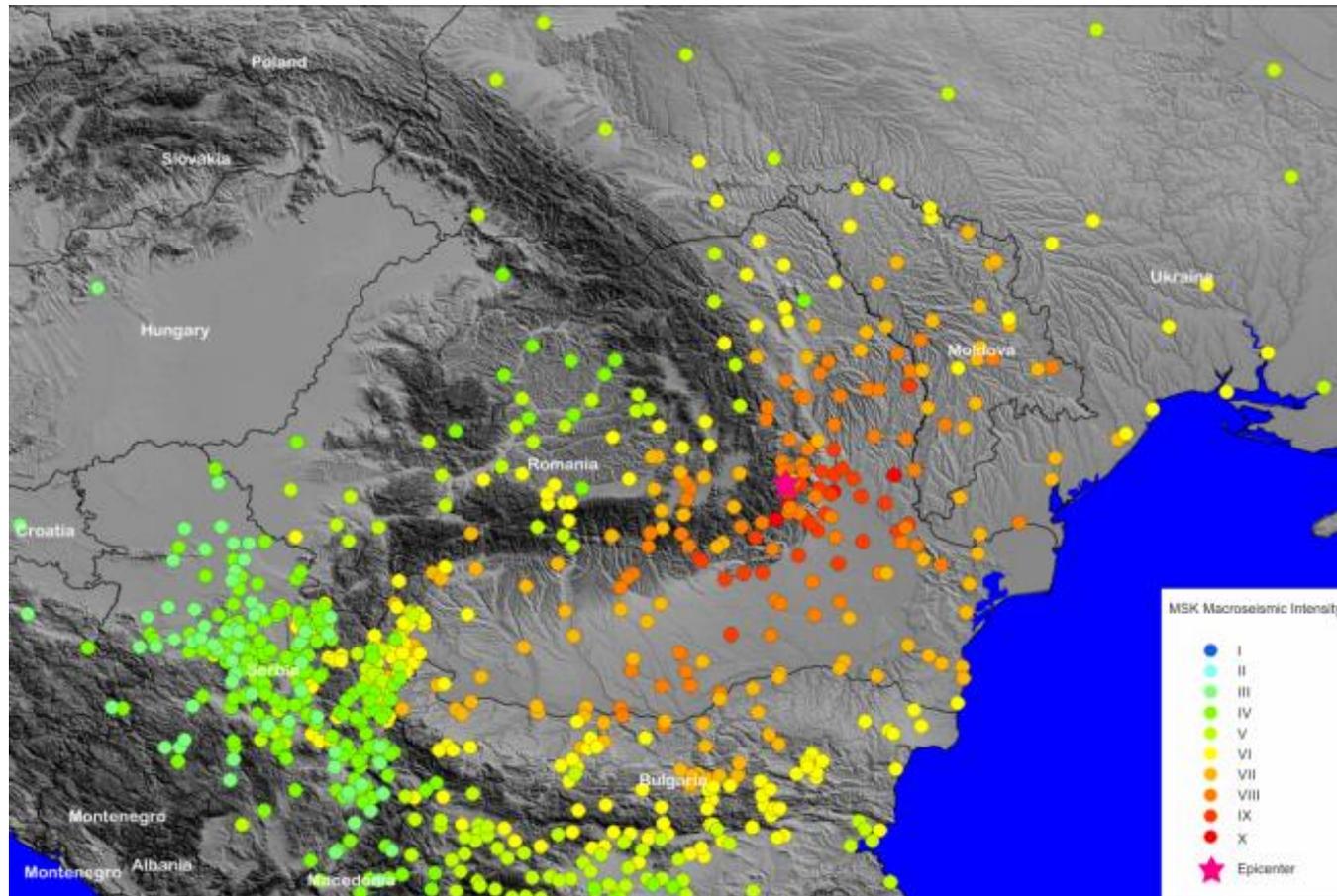
Seismicitatea Romaniei

- Cel mai mare cutremur subcrustal produs in Europa in sec. XX – cutremurul din 10 noiembrie 1940 ($M_w = 7.7$)
- 9 cutremure vrancene cu $M_w \geq 7.0$ in ultimii 200 ani
- Sec. XX:
 - M_0 (Vrancea) $\approx M_0$ (sudul Californiei) (Wenzel et al. 1998)
 - M_0 (Vrancea) $\approx 3 \times M_0$ (Italia)
 - M_0 (Vrancea) $\approx 6 \times M_0$ (13 surse seismice crustale)

M_0 – moment seismic (masura a energiei eliberate)

Cutremure majore in Romania – sec XX

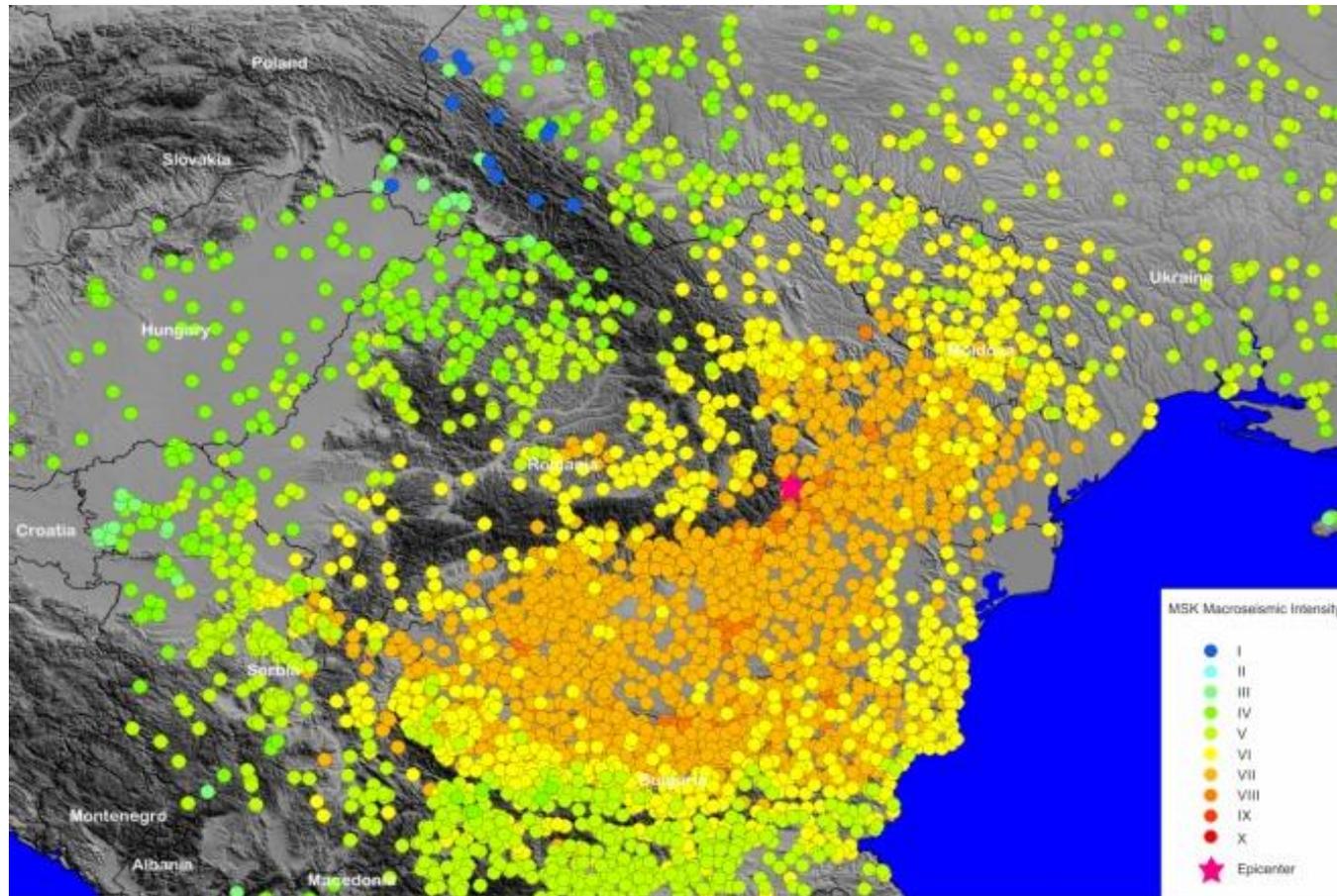
10 noiembrie 1940, $M_w=7.7$, $h=150$ km



Intensitati macroseismice MSK (date din Kronrod et al. 2013)

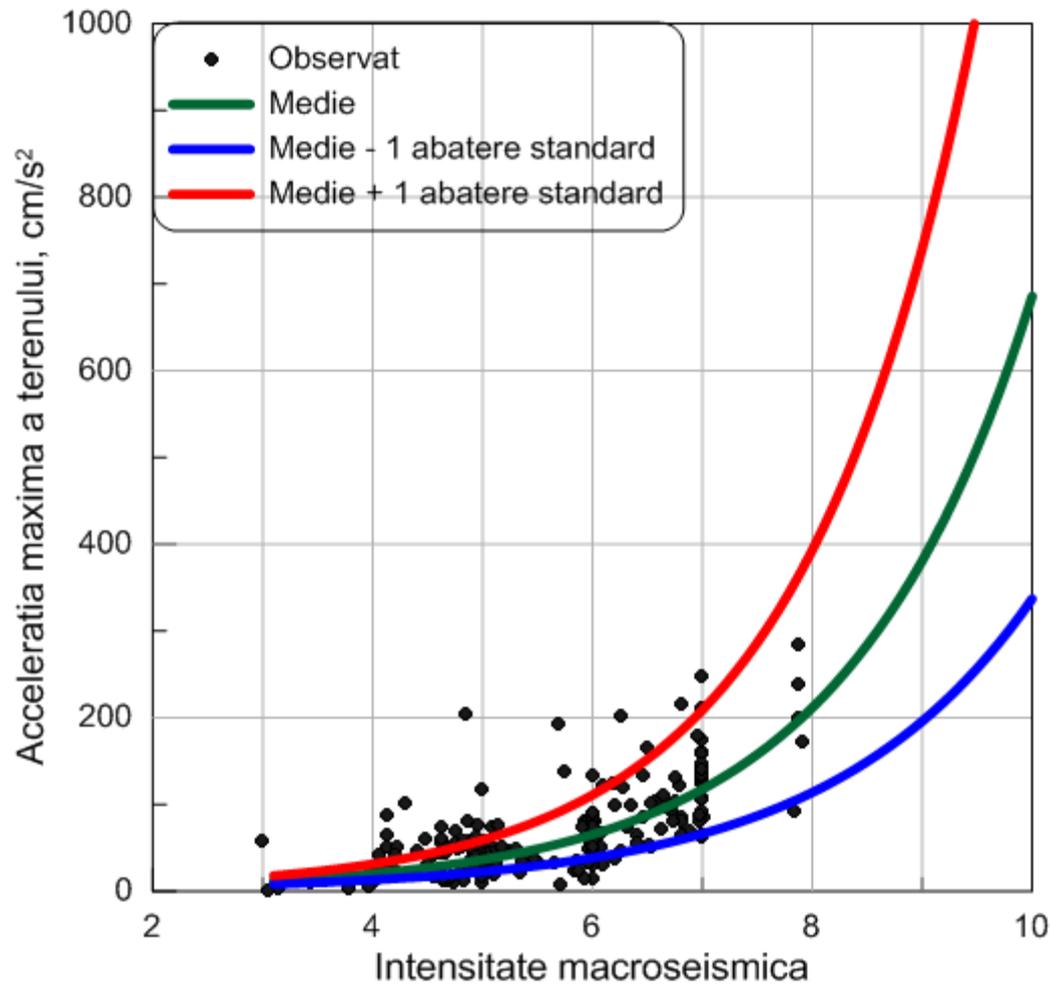
Cutremure majore in Romania – sec XX

4 martie 1977, $M_w=7.4$, $h=94$ km



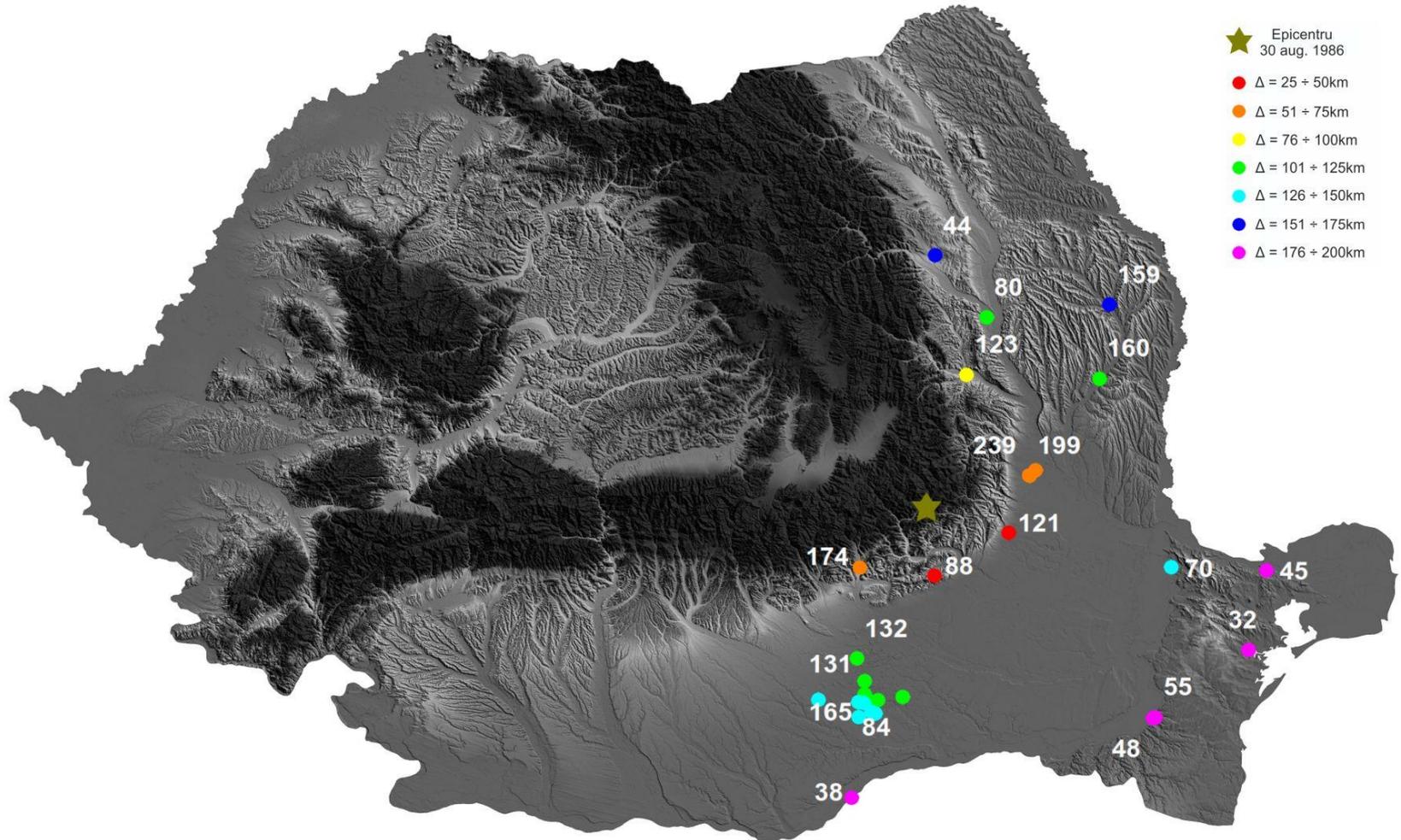
Intensitati macroseismice MSK (date din Kronrod et al. 2013)

Cutremure majore in Romania – sec XX



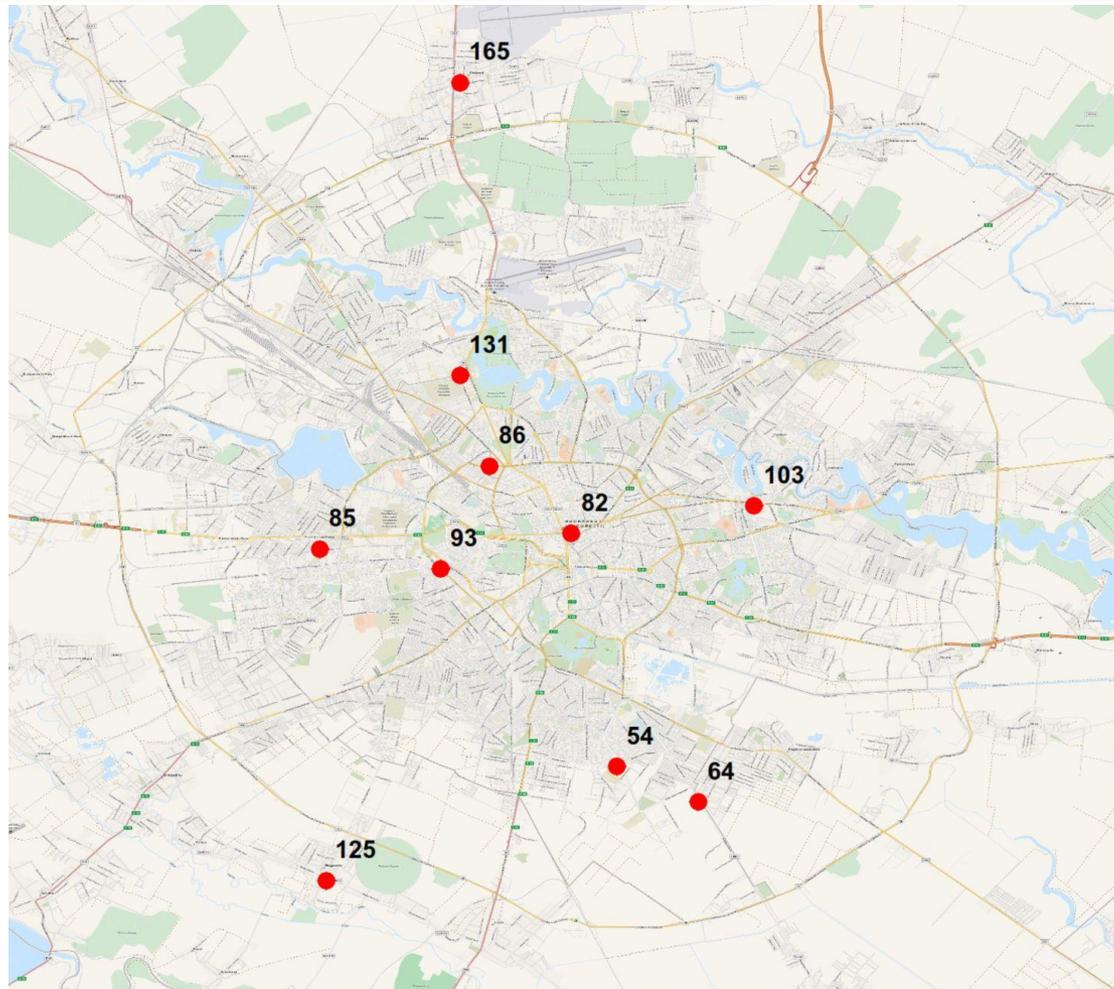
194 perechi de intensitati macroseismice *MSK* si valori *PGA*

Variabilitatea informatiei observate



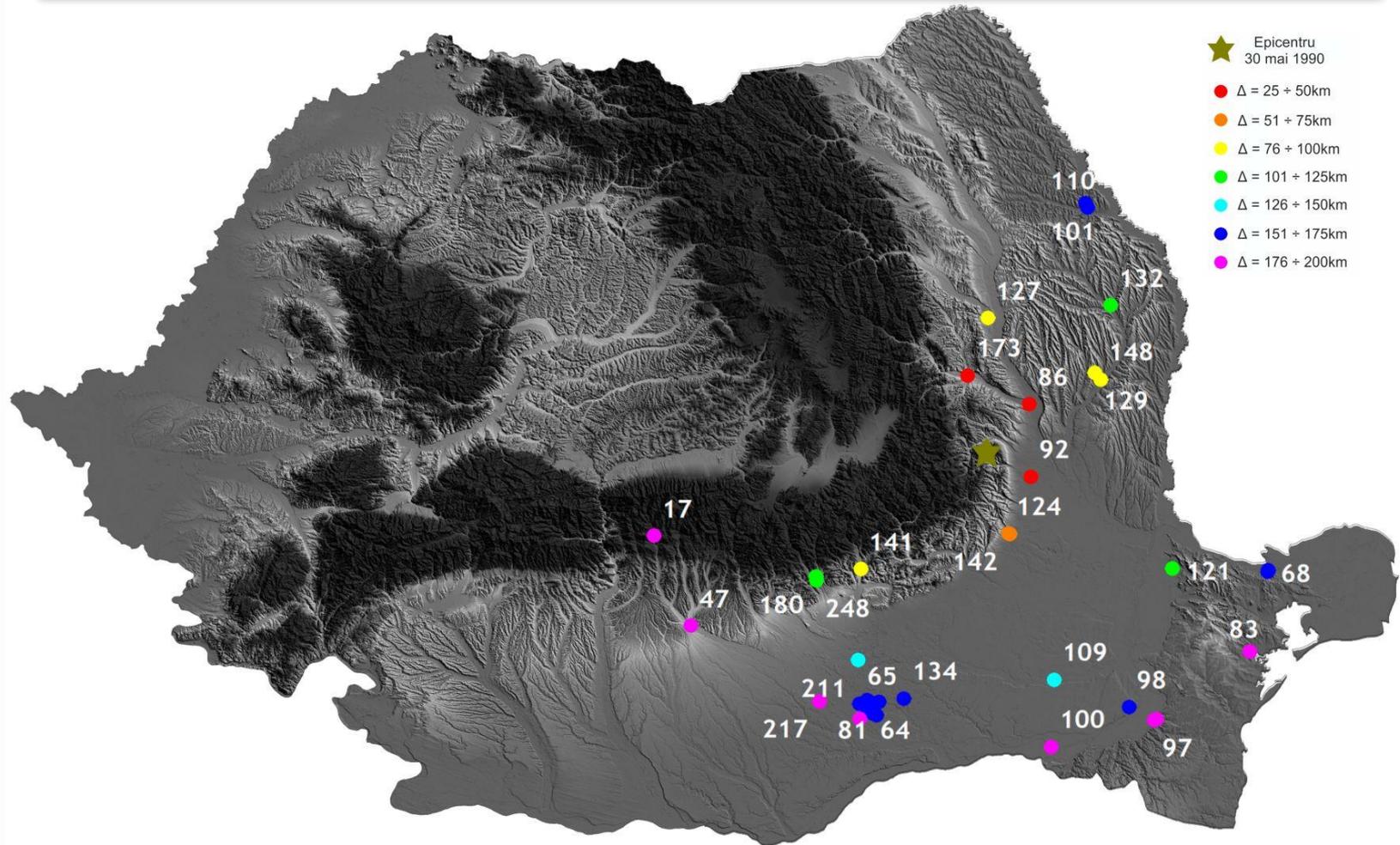
Exemple de medii geometrice ale valorilor *PGA* observate la 30 august 1986, M_W 7.1
(Multumiri Cristi Neagu, *UTC*B)

Variabilitatea informatiei observate



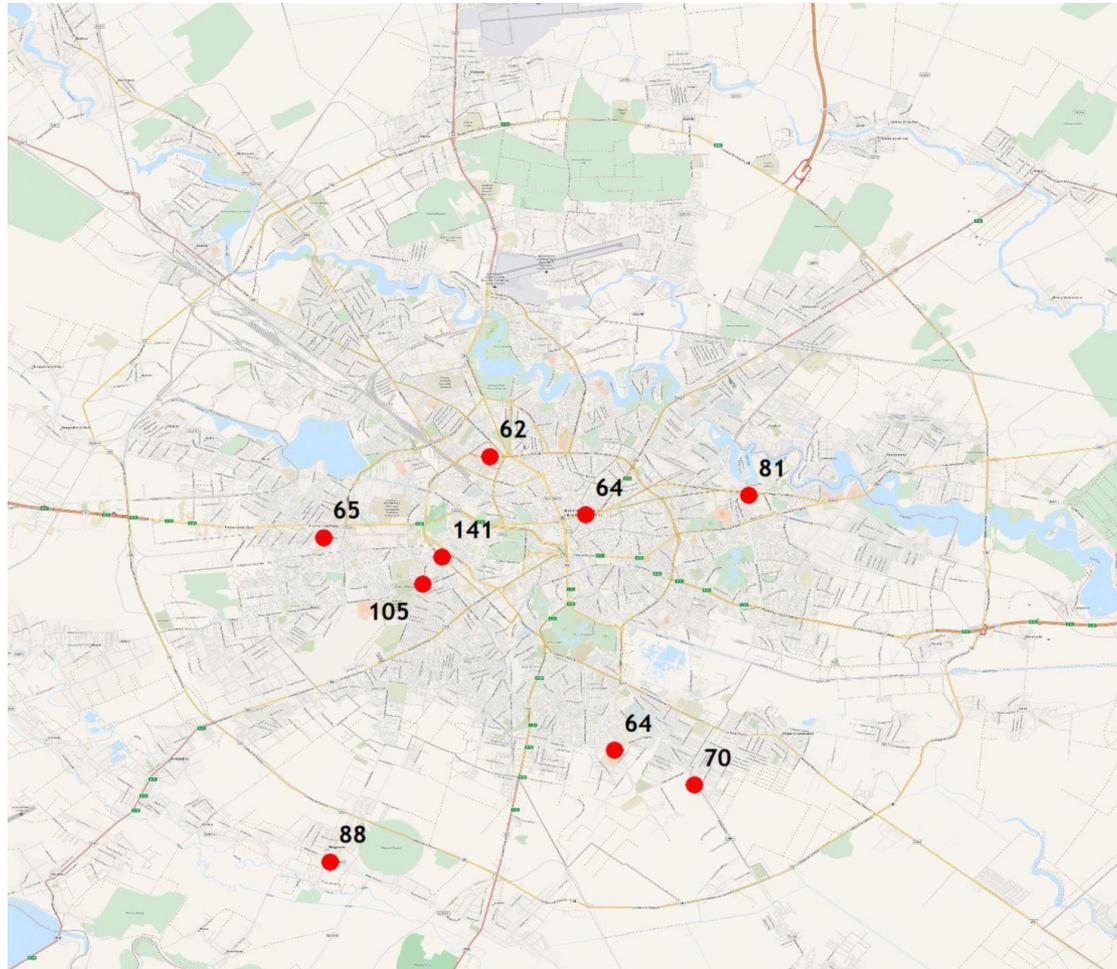
Medii geometrice ale valorilor *PGA* observate la 30 august 1986, M_W 7.1
(Multumiri Cristi Neagu, *UTCB*)

Variabilitatea informatiei observate



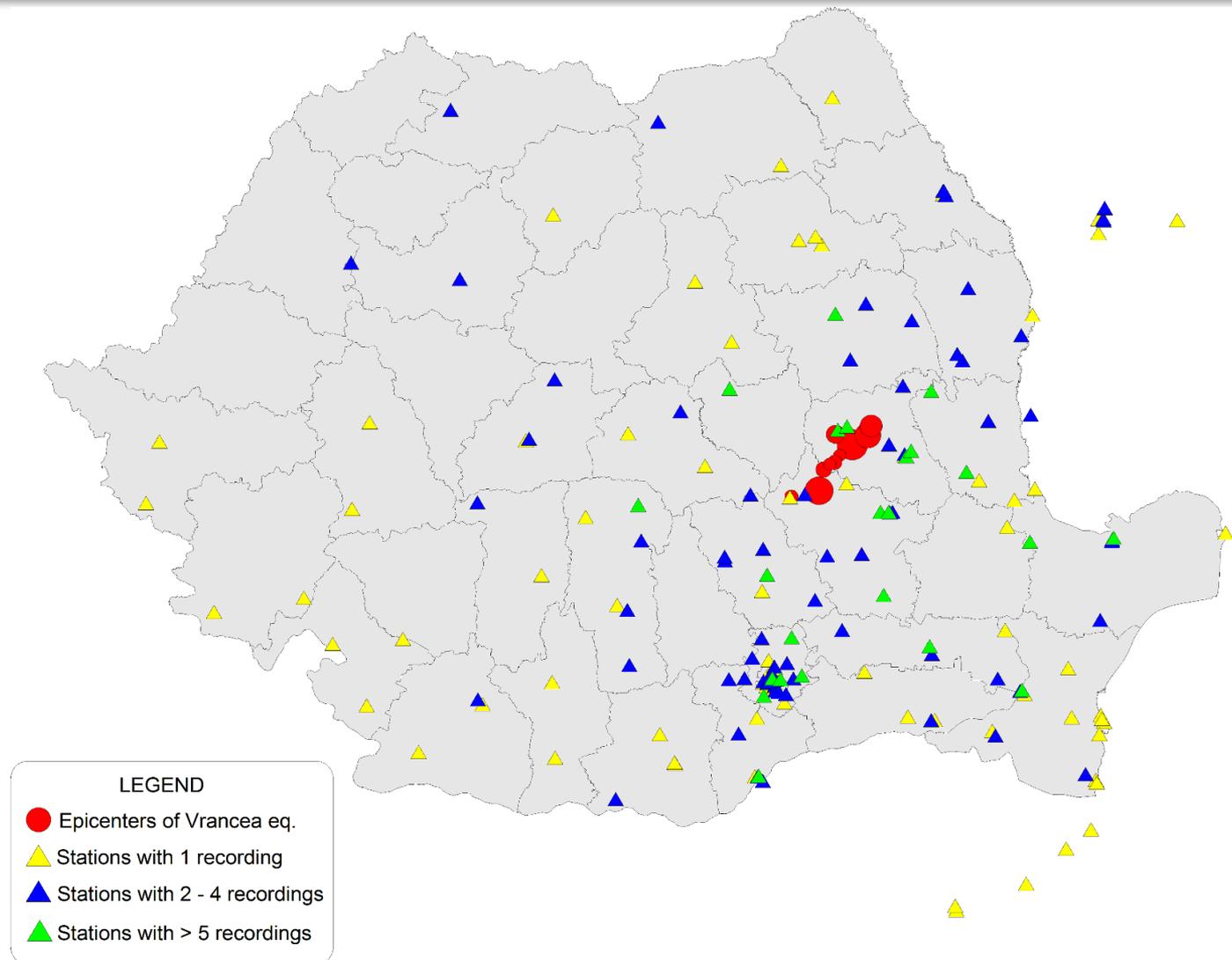
Exemple de medii geometrice ale valorilor PGA observate la 30 mai 1990, M_W 6.9 (Multumiri Cristi Neagu, *UTCB*)

Variabilitatea informatiei observate

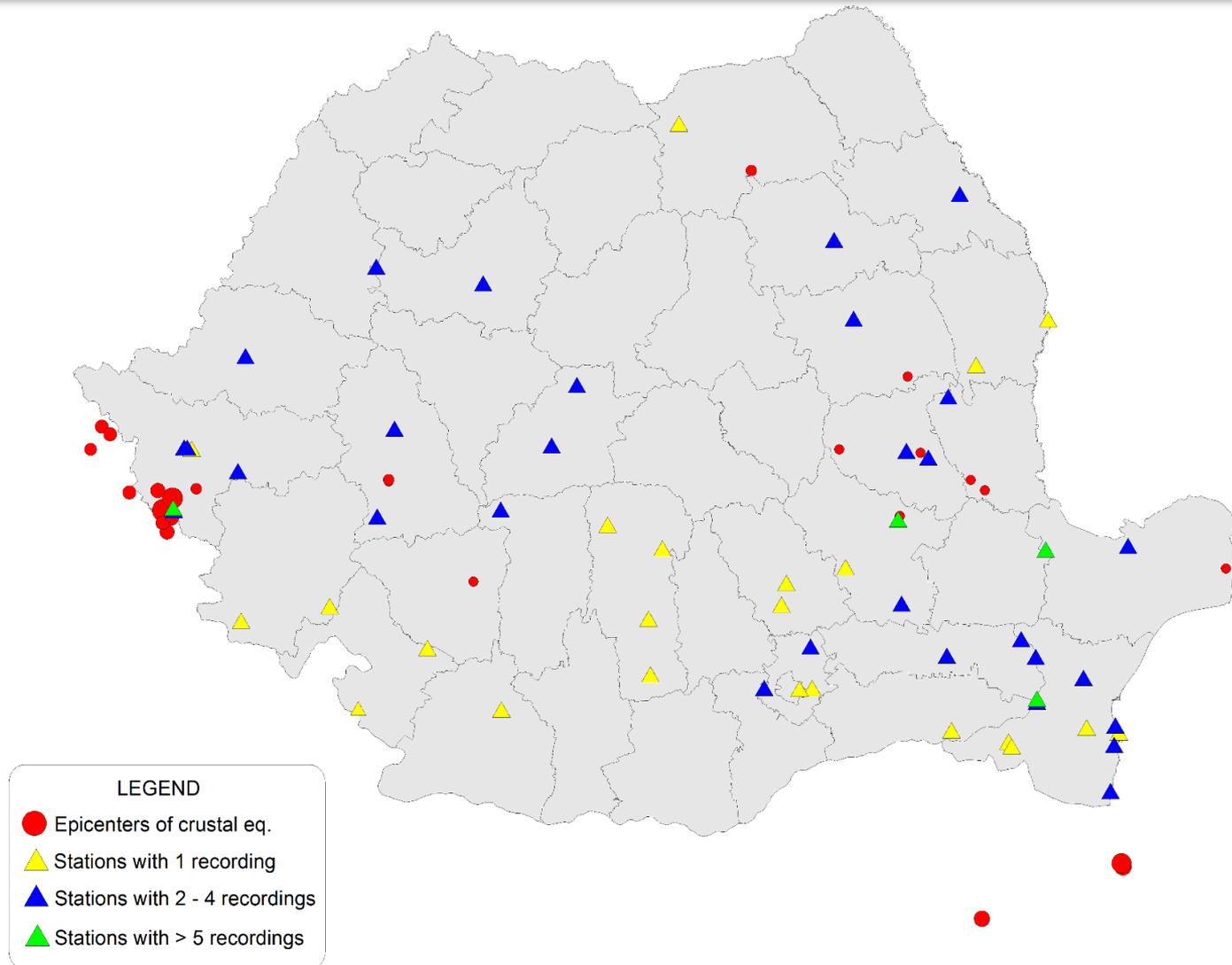


Medii geometrice ale valorilor *PGA* observate la 30 mai 1990, M_W 6.9
(Multumiri Cristi Neagu, *UTCB*)

Baza de date – accelerograme (VN)



Baza de date – accelerograme (CR)



Relatii de atenuare

- Relațiile de atenuare - descriu amplitudinea miscării seismice (valoarea mediana și abatere standard) așteptate pe amplasament
- Parametrii din relațiile de atenuare:
 - magnitudinea cutremurului
 - distanța dintre sursa și amplasament
 - adâncimea focarului
 - condițiile de teren
 - alți parametri (directivitate, mecanism de faliere, etc.)

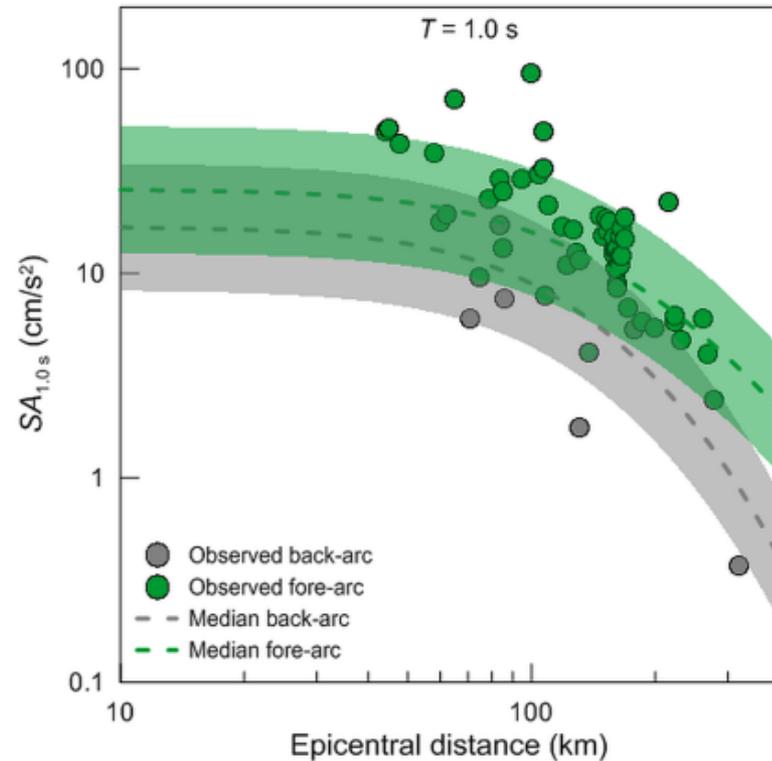
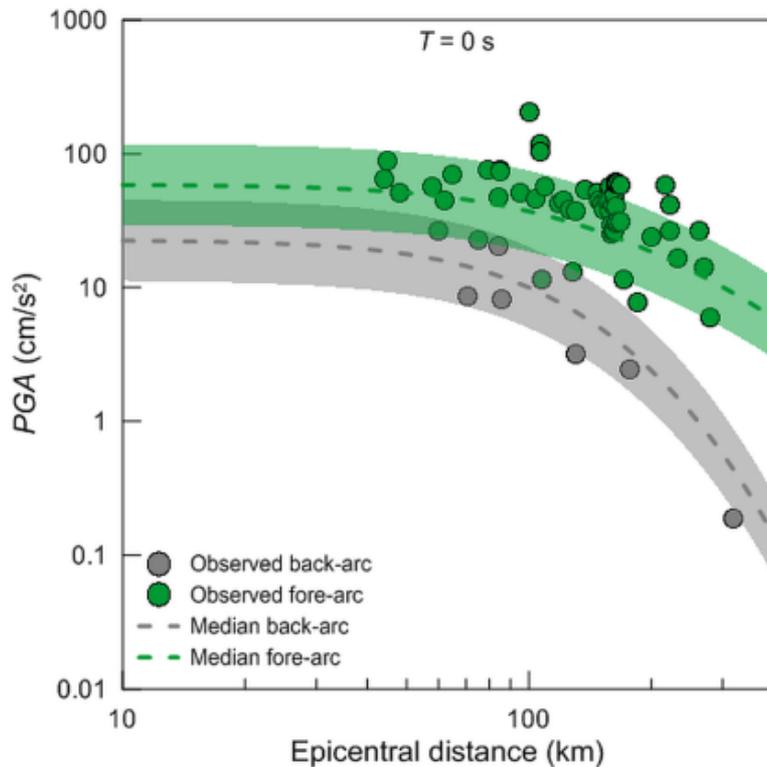
Relatii de atenuare

Forme functionale relatii de atenuare (de ex., Vacareanu et al. 2015):

$$\ln y_{ij}(T) = c_1(T) + c_2(T)(M_{w,i} - 6) + c_3(T)(M_{w,i} - 6)^2 + c_4(T) \ln R_{ij} + c_5(T)(1 - ARC_j)R_{ij} + c_6(T)ARC_jR_{ij} + c_7(T)h_i + c_8(T)Sb_j + c_9(T)Sc_j + c_{10}(T)Ss_j + \eta_i + \varepsilon_{ij}$$

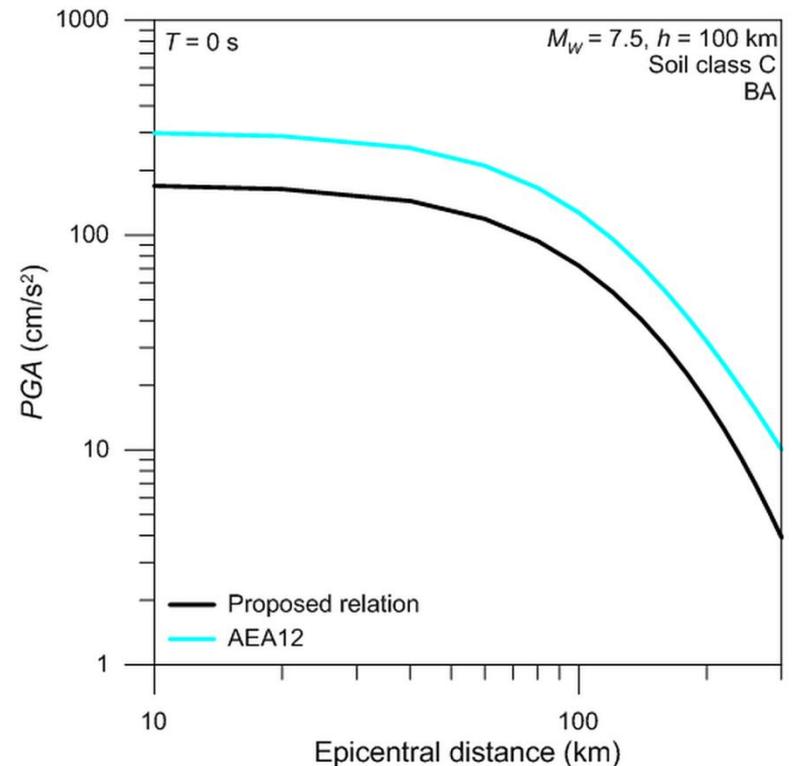
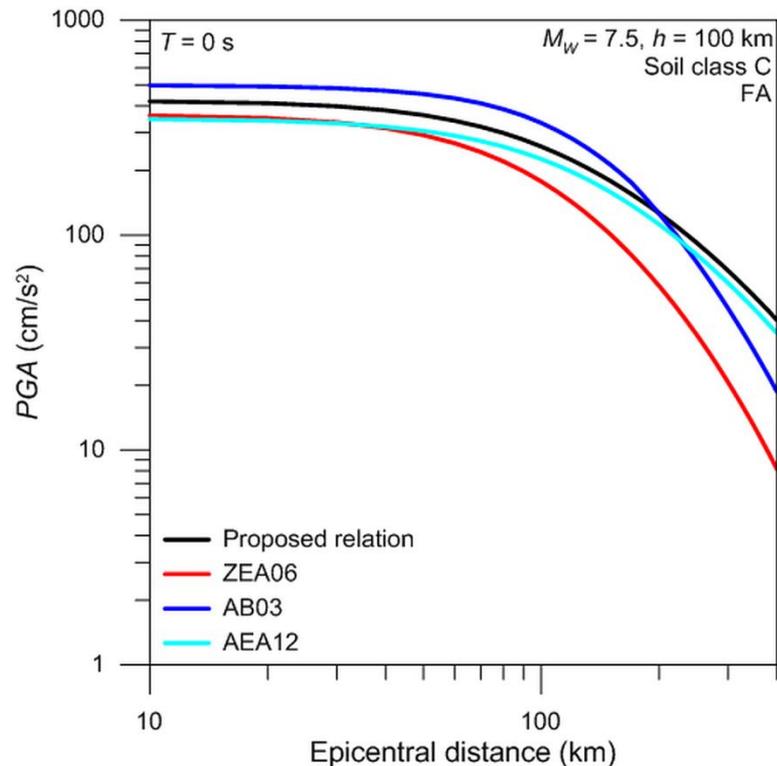
- $\ln y_{ij}$ – amplitudinea miscarii seismice (medie geometrica)
- M_w – magnitudinea moment a cutremurului
- R – distanta hipocentrala
- H – adancimea de focar
- $ARC = 1$ pentru zonele din exteriorul arcului carpatic si $ARC = 0$ pentru zonele din interiorul arcului carpatic
- Sb , Sc , Ss – coeficienti care tin cont de clasa de teren (conform Eurocodului 8)
- Coeficientii determinati prin metoda verosimilitatii maxime; variabilitate considerata explicit (inter- si intra-evenimente)

Relatii de atenuare



Valori observate si valori analitice cu 68% incredere -
27 octombrie 2004, Vrancea $M_W = 6$ (Vacareanu et al. 2015)

Relatii de atenuare



Comparatii intre valorile mediane ale mediei geometrice a PGA
(Vacareanu et al. 2015)

Relatii de atenuare

- Testarea si selectia relatiilor de atenuare – etapa cheie in evaluarea hazardului seismic
- Baza de date:
 - > 400 inregistrari de la cutremure vrancene
 - > 100 inregistrari de la cutremure crustale
- Testarea si selectia relatiilor de atenuare (Scherbaum et al., 2004, Delavaud et al., 2012, Kale & Akkar, 2013):
 - sursa seismica Vrancea: fore-arc & back-arc
 - surse seismice crustale

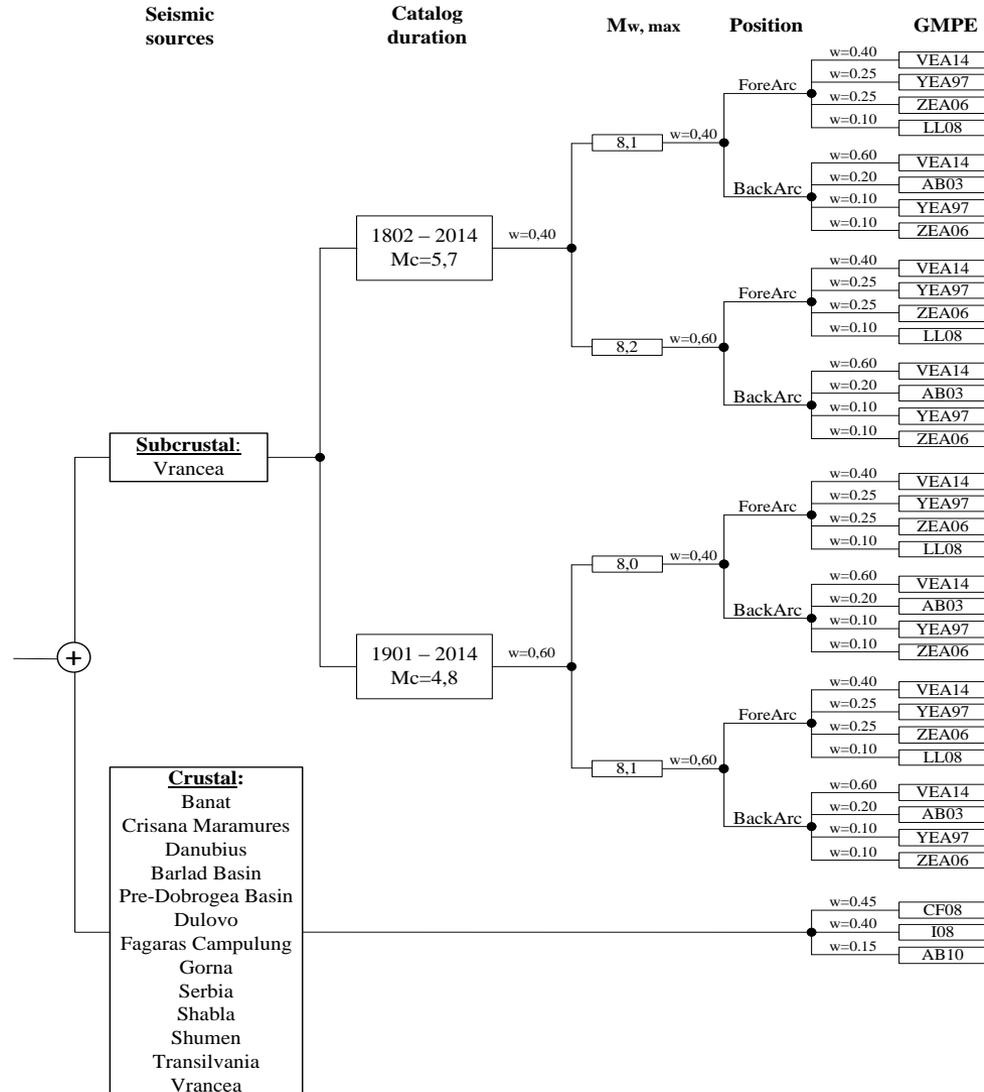
Relatii de atenuare

- Rezultatele testarii: selectia relatiilor de atenuare si stabilirea ponderilor pentru analiza probabilistica de hazard

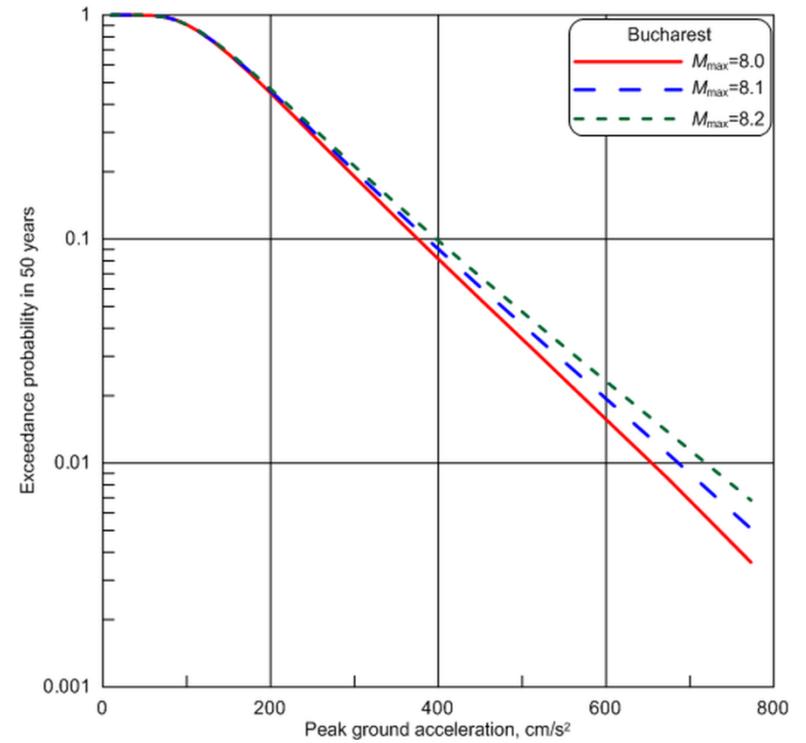
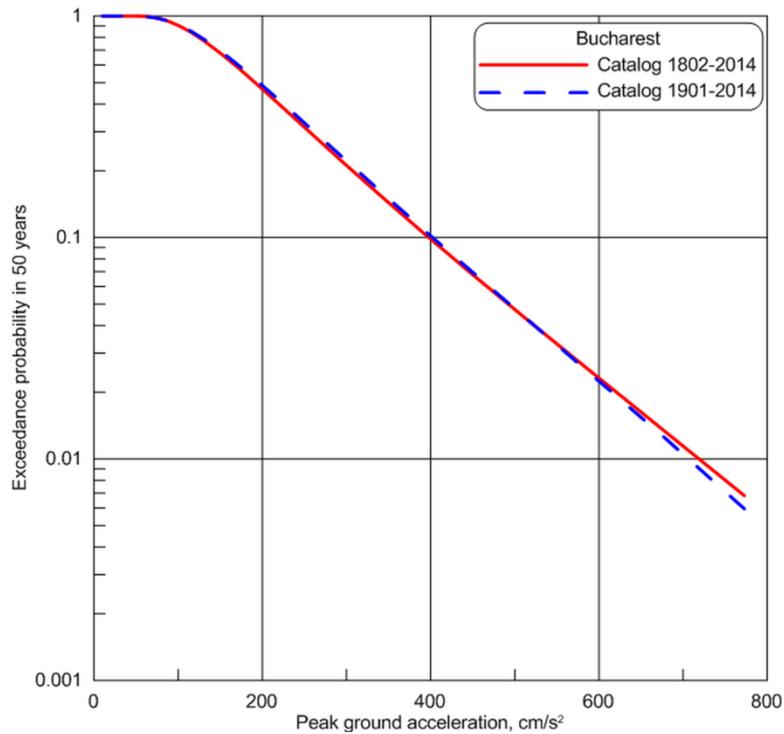
Fore-arc		Back-arc		Crustal	
Relatie de atenuare	Ponderi	Relatie de atenuare	Ponderi	Relatie de atenuare	Ponderi
Vacareanu et al. (2015)	0.40	Vacareanu et al. (2015)	0.60	Cauzzi & Faccioli (2008)	0.45
Youngs et al. (1997)	0.25	Atkinson & Borre (2003)	0.20	Idriss (2008)	0.40
Zhao et al. (2006)	0.25	Youngs et al. (1997)	0.10	Akkar & Bommer (2010)	0.15
Lin & Lee (2008)	0.10	Zhao et al. (2006)	0.10		

(Pavel et al. 2014)

Arbore de evenimente

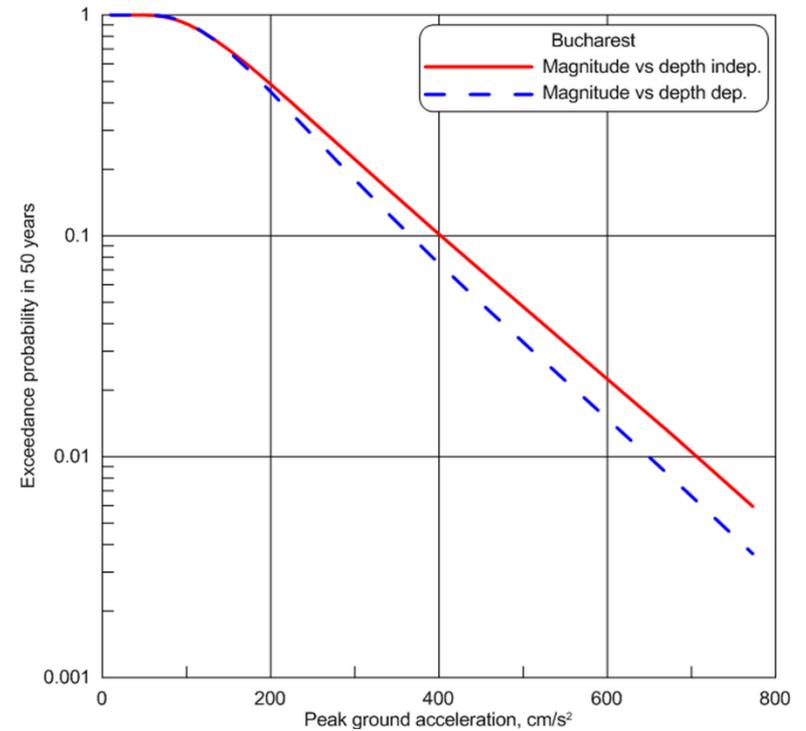
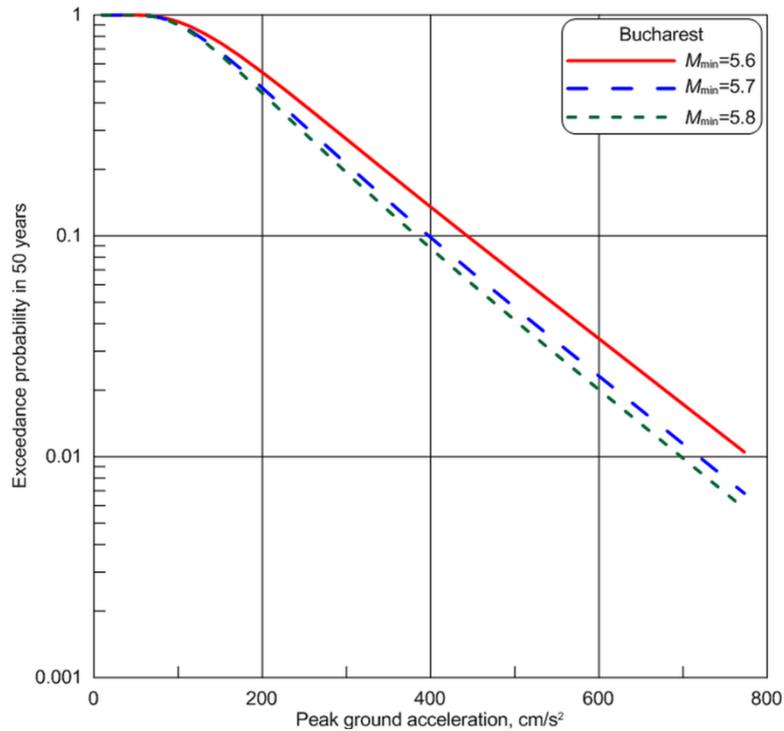


Influenta datelor de intrare



(Aldea et al. 2014)

Influenta datelor de intrare

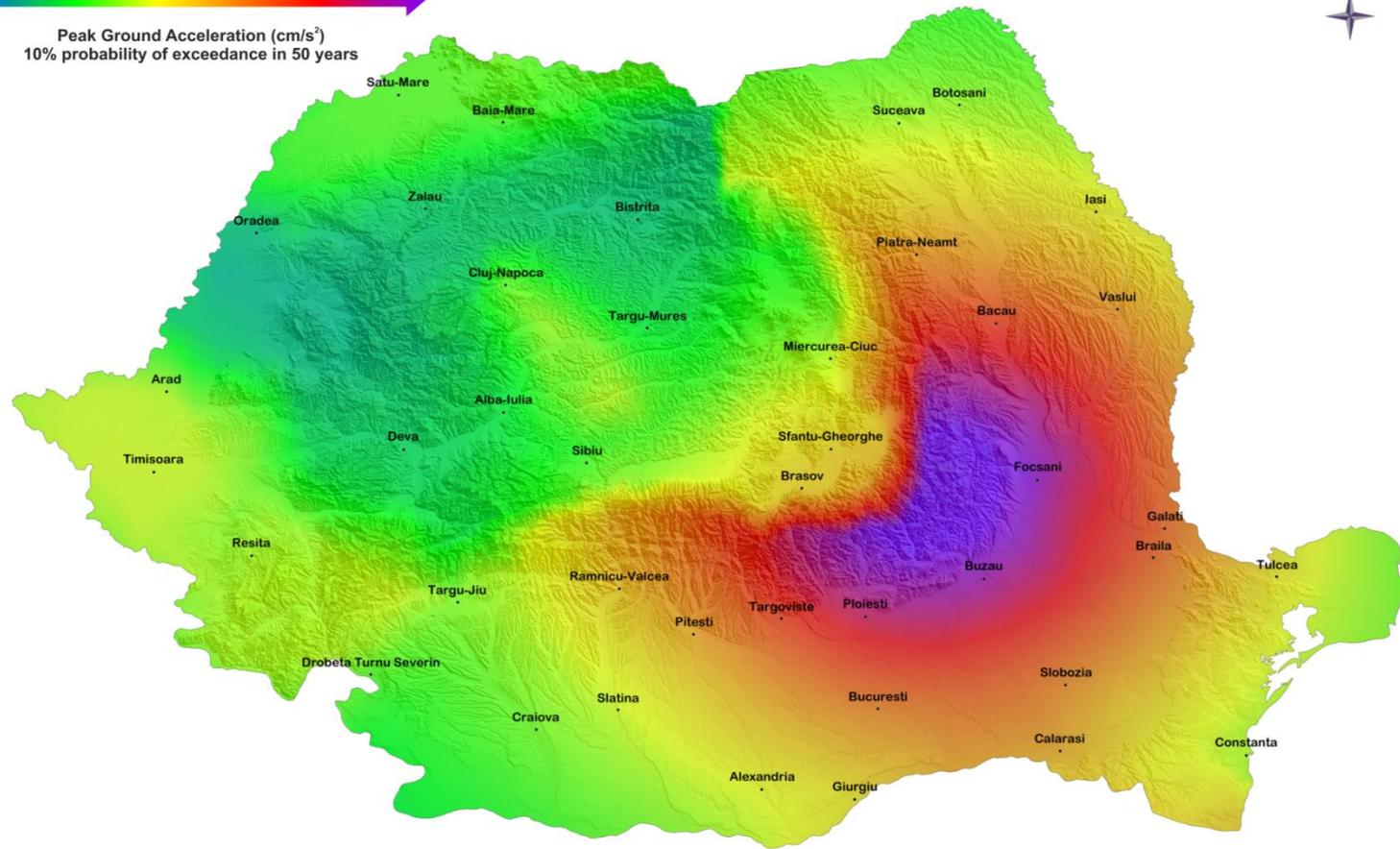
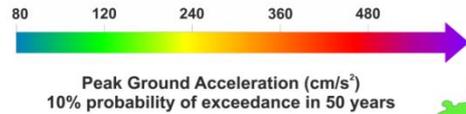


(Aldea et al. 2014)

Hazardul seismic

- Studii precedente pentru evaluarea hazardului seismic pentru Romania: Mârza et al. (1991), Lungu et al. (1999 & 2006), Radulian et al. (2000), Musson (2000), Mäntyniemi et al. (2003), Marmureanu et al. (2004), Ardeleanu et al. (2005), Leydecker et al. (2008), Sokolov et al. (2009)
- Parametrul considerat anterior: acceleratia maxima a terenului si intensitati macroseismice
- Studiul prezentat considera variabilitatea aleatoare (prin recurenta seismicitatii si relatiile de atenuare) si epistemica (prin arborele de evenimente)

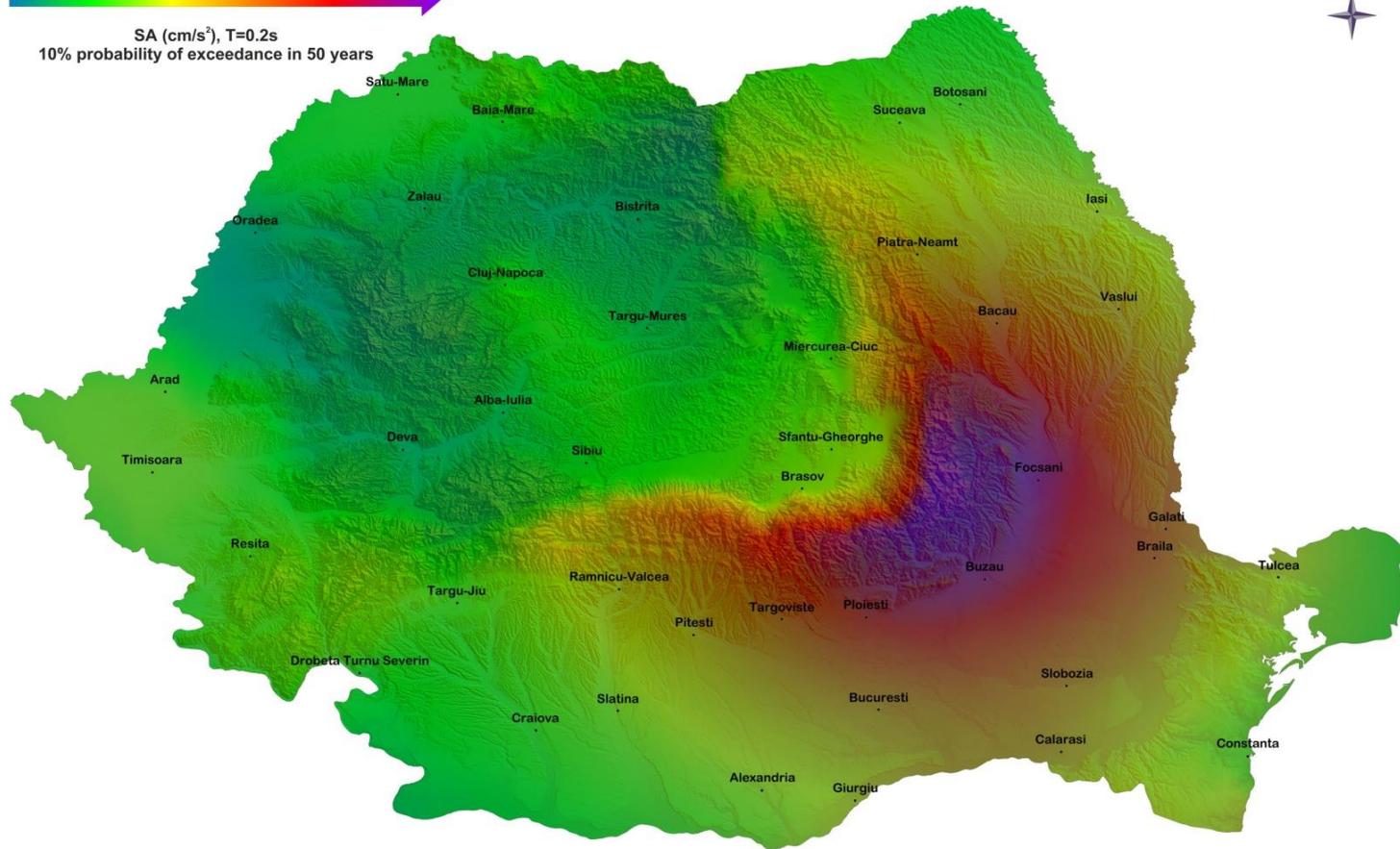
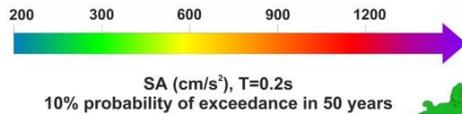
Hazardul seismic



UTCB, BIGSEES 2014

Harta de hazard seismic pentru *PGA* 10%/50

Hazardul seismic

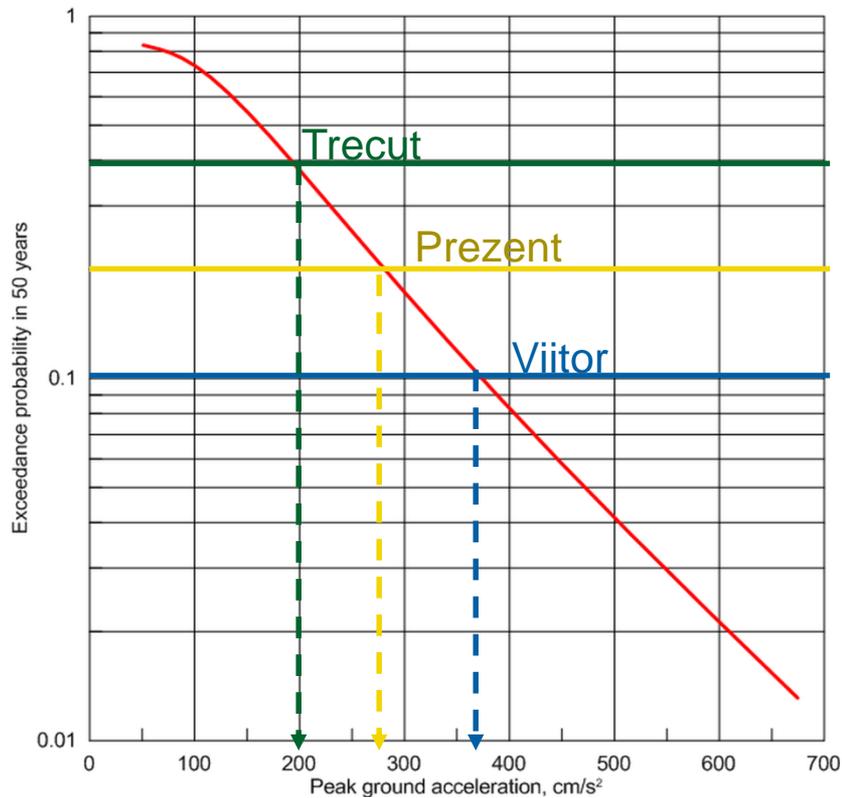


UTCB, BIGSEES 2014

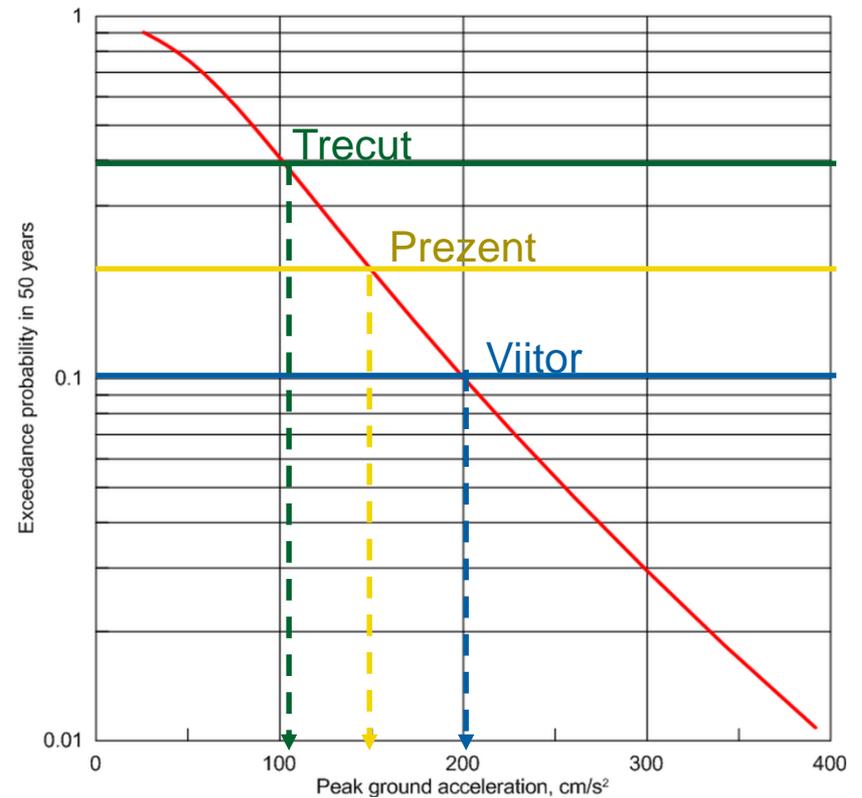
Harta de hazard seismic pentru $SA(T=0.2s)$ 10%/50

Hazardul seismic

Bucuresti

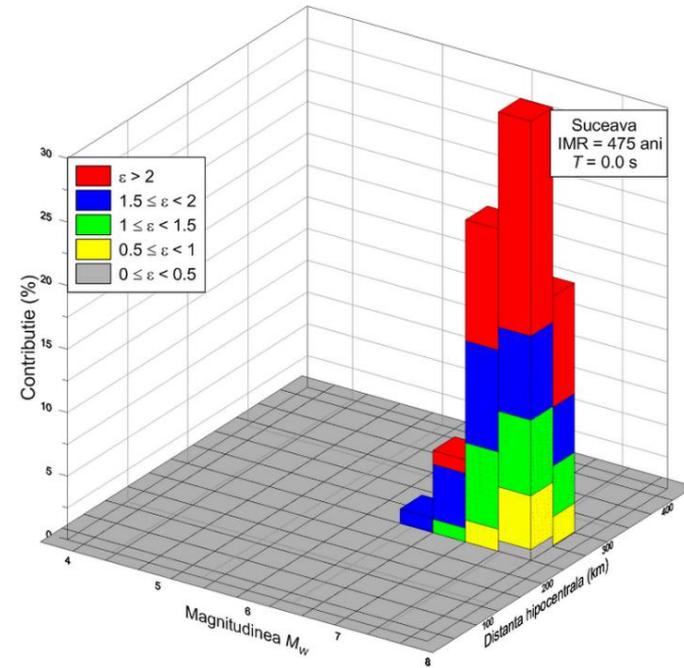
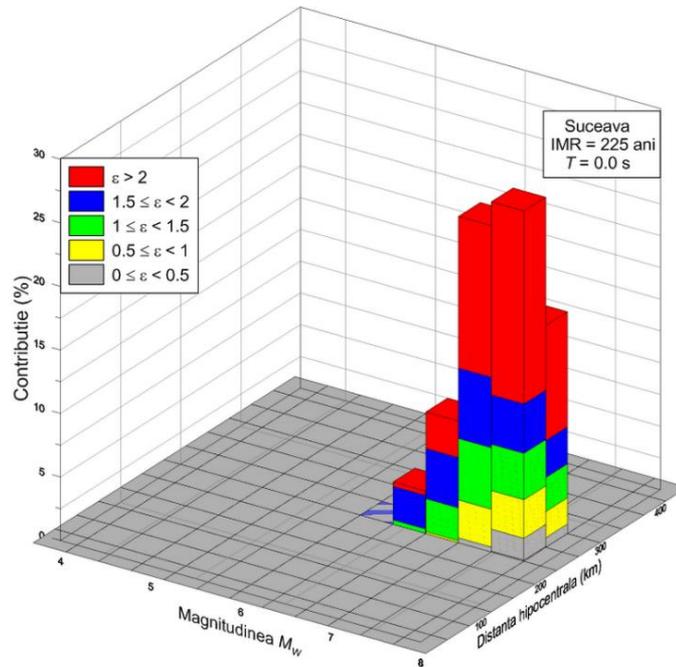


Constanta



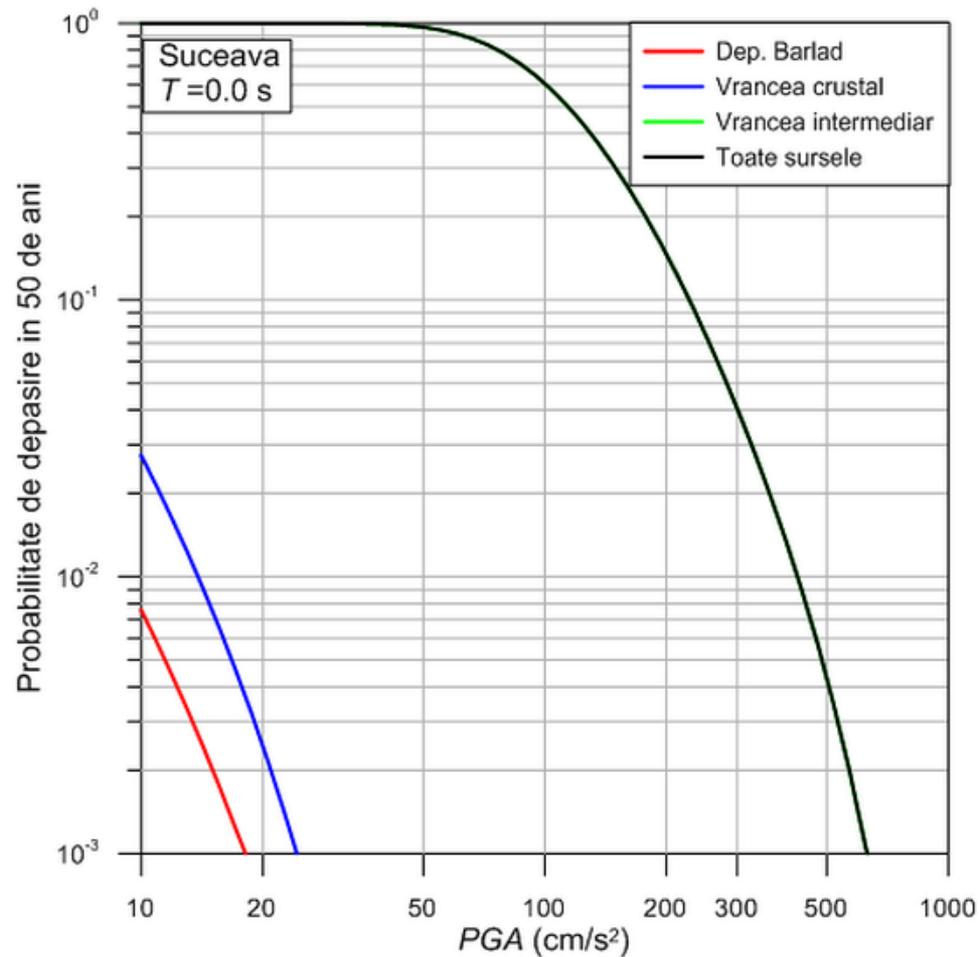
Curbe de hazard seismic

Hazardul seismic



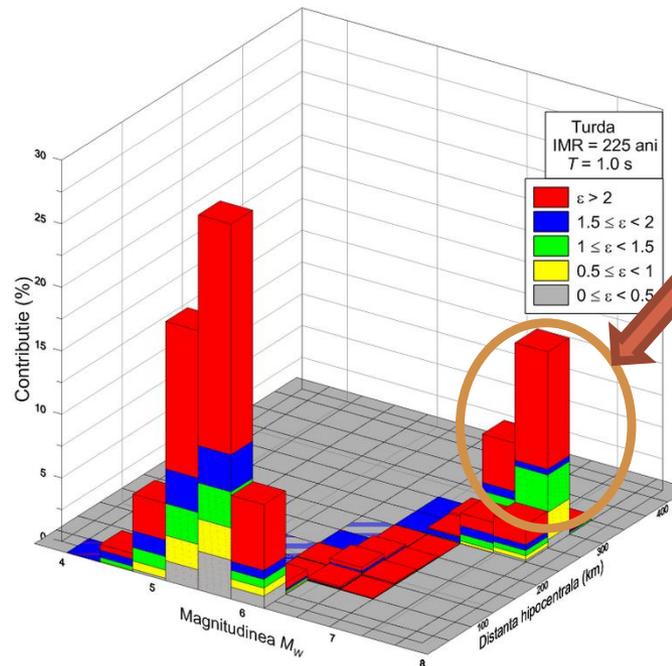
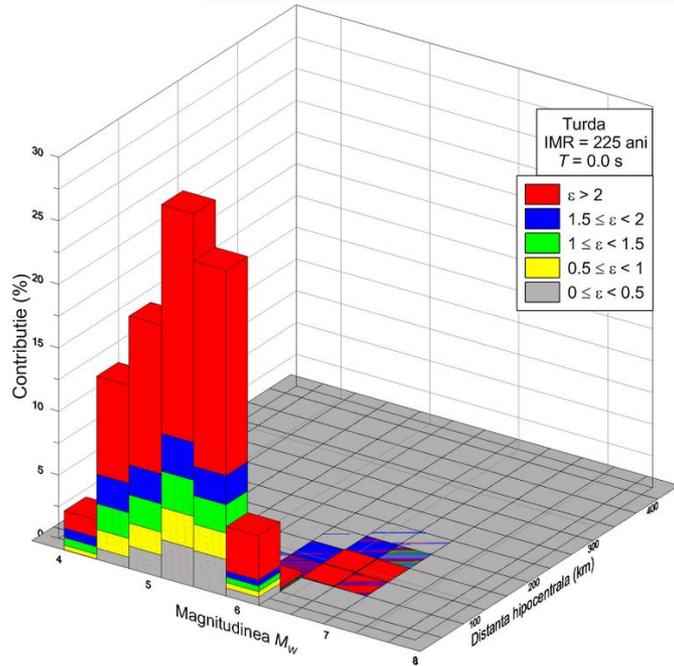
Dezagregarea hazardului seismic pentru municipiul Suceava; contributia magnitudinilor si distantelor hipocentrale

Hazardul seismic



Contributia surselor seismice la hazardul pentru municipiul Suceava

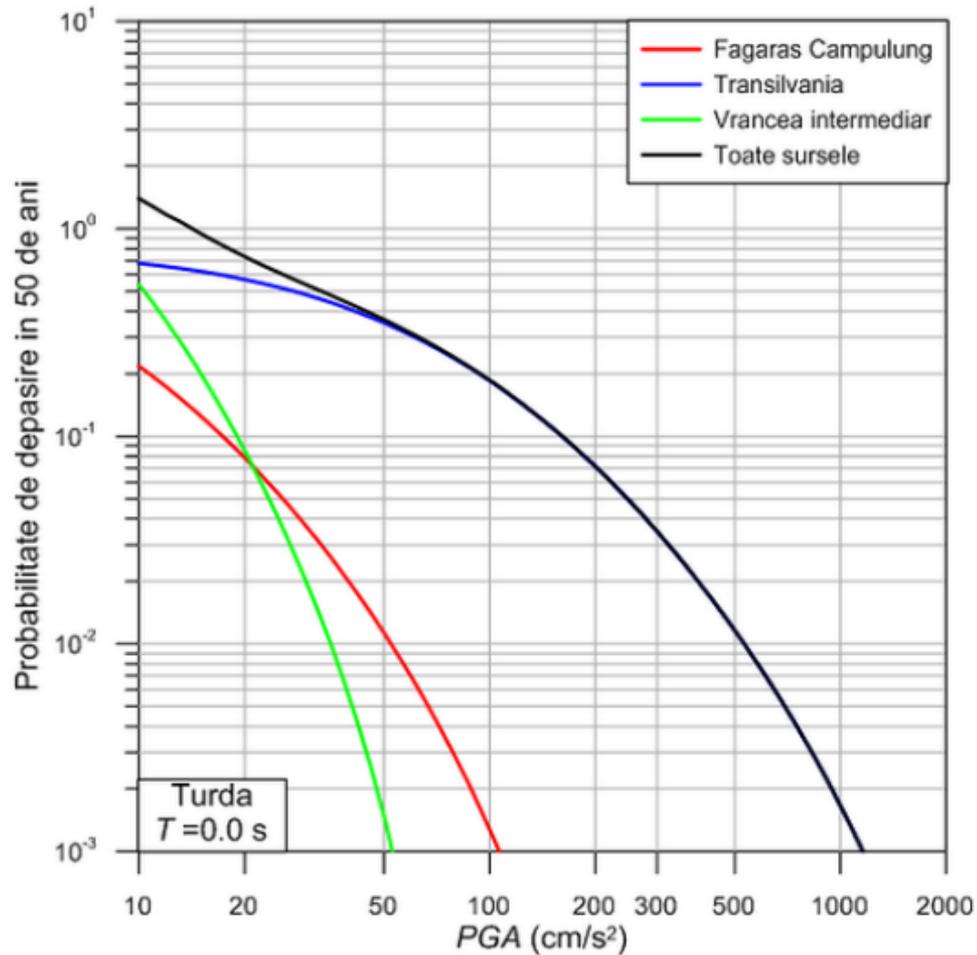
Hazardul seismic



Contributie
Vrancea

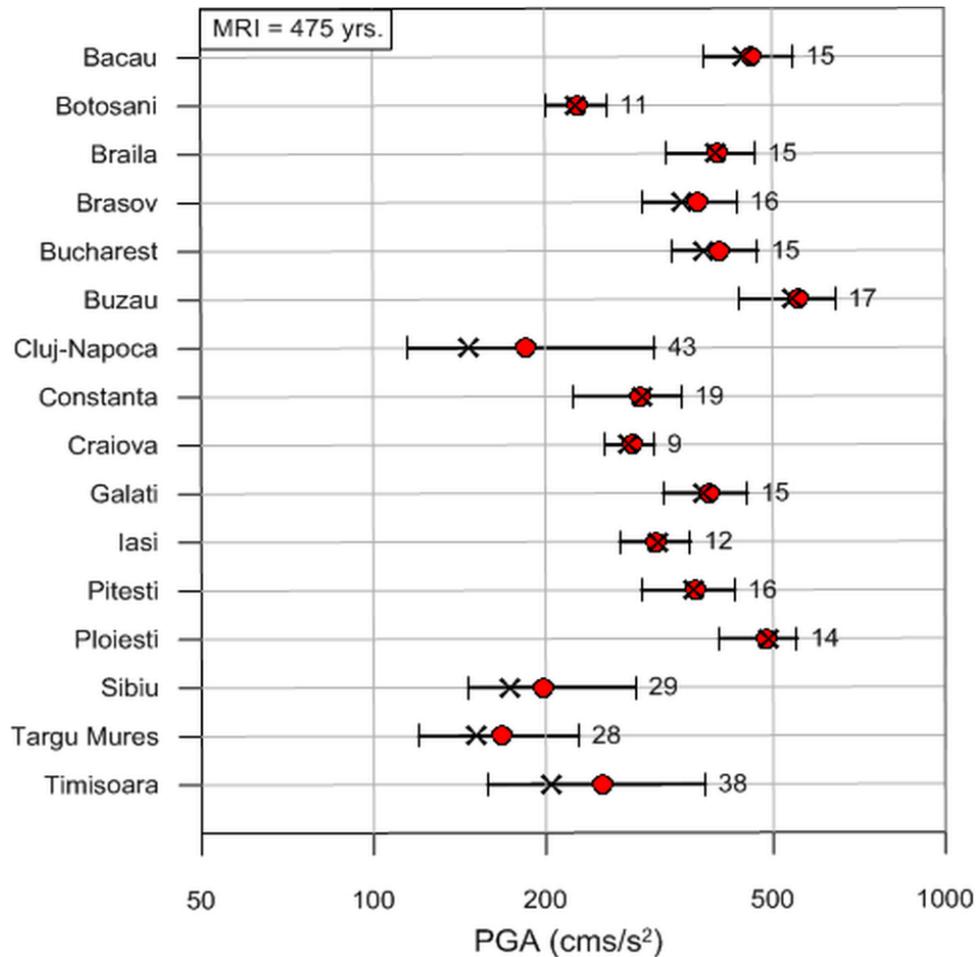
Dezagregarea hazardului seismic pentru municipiul Turda

Hazardul seismic



Contributia surselor seismice la hazardul municipiului Turda

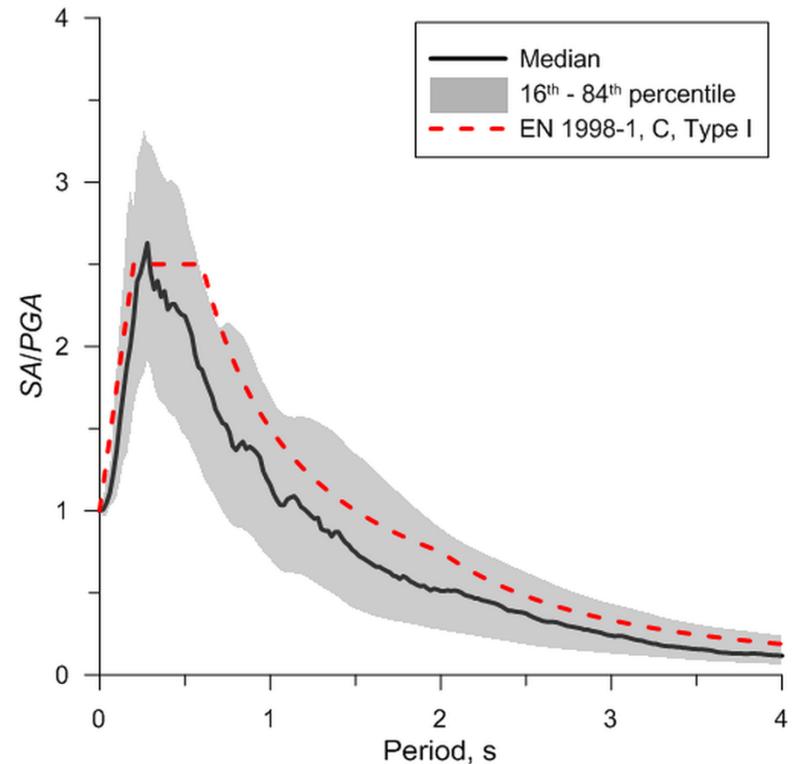
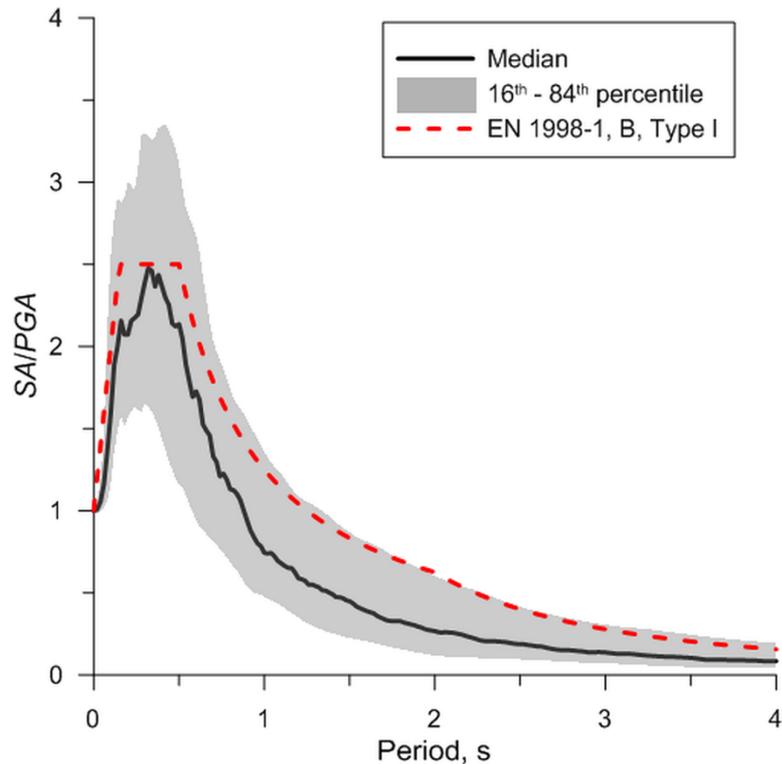
Hazardul seismic



o – medii
 x – mediane
 | – fractilii 0.15 si 0.85
 si incertitudinile
 corespunzatoare

Evaluarea incertitudinilor rezultatelor analizei conform Douglas et al. (2014)

Conditii de teren



Comparatii intre spectrele normalizate de acceleratii absolute din EN 1998-1 pentru clasele de teren B si C si valorile mediane ale inregistrarile obtinute la cutremure vranceane cu $M_W > 6.3$ (zona gri reprezinta intervalul de incredere 68%) (Vacareanu et al., 2014b)

Conditii de teren

Valori ale factorului S pentru conditiile de teren din P100-1/2013
(Vacareanu et al. 2014b)

Conditii de teren	S
$0.7 \text{ s} < T_C \leq 1.0 \text{ s}$	1.03
$T_C > 1.0 \text{ s}$	0.94

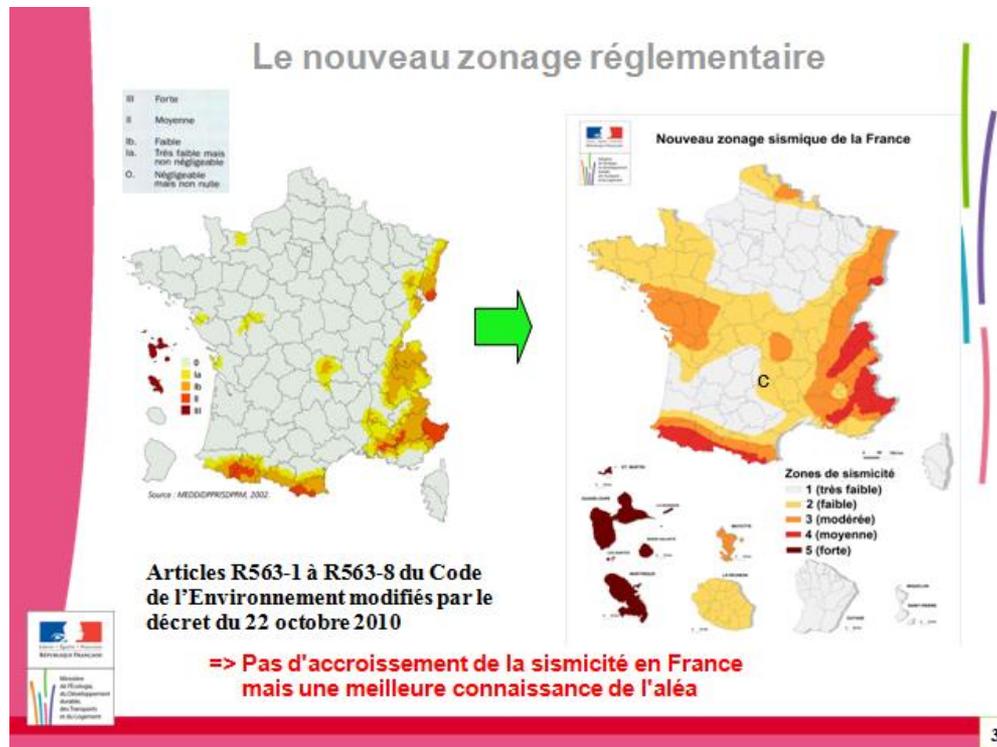
- Definirea actuala a spectrelor normalizate de acceleratii absolute din P100-1/2013 **nu necesita** factori de teren S
- Trecerea la o zonare a conditiilor de teren in functie de $V_{s,30}$ nu poate avea loc pana cand nu va exista un program national de obtinere a datelor din foraje de adancime de pe tot teritoriul Romaniei

Concluzii

- Sursa seismică subcrustală Vrancea – **foarte activă** și capabilă de a genera cutremure de magnitudine mare ($M_W > 7$) de mai multe ori pe secol
- Sursele seismice crustale – activitate mai redusă, dar **influența** lor asupra hazardului seismic **crește** odată cu scăderea probabilităților anuale de depășire
- Metoda Cornell-McGuire de analiză probabilistică de hazard seismic este **independentă** de mecanismul și adâncimea surselor seismice, de mediul de propagare a undelor seismice și de condițiile de teren ale amplasamentelor analizate

Concluzii

- Rezultatele metodei probabilistice de analiza si evaluare a hazardului seismic nu pot fi verificate prin observatii obtinute la evenimente seismice individuale si depind de nivelul de cunoastere si datele de intrare



Le risque sismique :
ce qui change
(présentation Ministère de
l'écologie, du
développement durable,
des transports et du
logement)

Concluzii

- Hanks et al. (2012): “The metric that really matters, however, is whether PSHA, together with the design and construction practices based on it, increases public safety and reduces economic losses.”
- Actuala abordare de zonare a hazardului seismic prin izolinii de acceleratii ale terenului **trebuie inlocuita** cu abordarea USGS (SUA) sau INGV (Italia) (harti interactive online si baze de date ce pot fi interogate de proiectant pentru a obtine valorile de proiectare pe amplasament)

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