Seismic Hazard Assessment Methodologies for Turkey

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SciNetNatHazPrev - Project Workshop

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Istanbul, Turkey

Venue: Maçka Social Center, Istanbul Technical University Foundation

C T I V I T I E S 1	Aim and purpose *(general description of the GA)*	*The aim of the joint Action is to share resources and competencies for environmental protection resulting from earthquake, landslide and flood hazards. Another basic aim of the Joint Action is to establish a strong regional cooperation to protect the Environment and to promote sustainable development. In this perspective it is essential to set a sound basis for a scientific network regarding earthquake, landslide and flood prevention.* *The aim of GA1 ban be summarized in the following items:* *a. recording of the existing legislation framework in every one of the participant countries regarding landslide, earthquake and flood hazard prevention and management,* *b. review of the available bibliography (existing projects, relative publications, registered events) regarding seismic hazard, landslide hazard and flood hazard at regional and local scales is deemed necessary in order to achieve a common base of data and state of art or/and practice,* *c. evaluation of existing models and methodologies assessing seismic, landslide and flood hazards in terms of scientific soundness, data demands and credibility of produced results. Therefore, the aforementioned hazard assessment models will be modified, adapted, or even new one smay be developed according to the local conditions in order to assess hazards at a regional scale.* *GA1 will provide the necessary base for scientific exchange and transport of technical kwoledge with regard to the above hazard assessment, taking into account the experience and expertise of each partner.*
	Activities description	Partners involved

GROUP OF ACTIVITIES 1		
G R O U P of A	Name	**Current Status Assessment**
	Responsible partner(P): IPA Partner	Bogazici University, Turkey
	Involved partners	
	Partner IPA:	Bogazici University, Turkey
	Partner Applicant (LP):	Technological Education Institute of Serres, Greece
	Partner no 1:	Democritus University of Thrace, Greece
	Partner no 2:	Earthquake Planning and Protection Organization (EPPO) - Thessaloniki's Branch / Former Institute of Engineering Seismology and Earthquake Egineering (ITSAK) - Greece
	Partner no 3:	University of Burgas, Bulgaria
	Partner no 4:	"Ovidius" University of Constanta, Romania
	Partner no 5:	Institute of Electronic Engineering and Nanotechnologies "D. Ghitu", Academy of Sciences of Moldova, Moldova
	Partner no 6:	Black Sea (Odessa) Branch of Ukrainian Environmental Academy of Science, Ukraine
	Applicant:	TECHNOLOGICAL EDUCATION INSTITUTE of SERRES, GREECE

Activity 9:	Evaluation of existing seismic hazard assessment models in terms of scientific soundness, data demands and result credibility. Widely accepted seismic hazard assessment models will be evaluated in the proposed areas of the project, in order to define the most appropriate; theoretical results will be confronted to empirical data collected per country, as a consequence of seismic events	*Partner P2 will evaluate models used in Greece and also he will coordinate all partners' deliverables and evaluation of the most successful and efficient models according to the data provided by the rest of the partners.* *IPA beneficiary: evaluation of models used in Turkey with local data* *LP, IPA, P1, P3, P4, P5 and P6: data providers to P2*

The aims of workshop are:

- to evaluate methodologies that may be used to assess **Earthquake**, Landslide and Flood Hazards in order to assess the most reliable way to estimate those hazards.
- To select seismic hazard assessment methodologies applied to specific national case studies

Regional Scale: Marmara Region

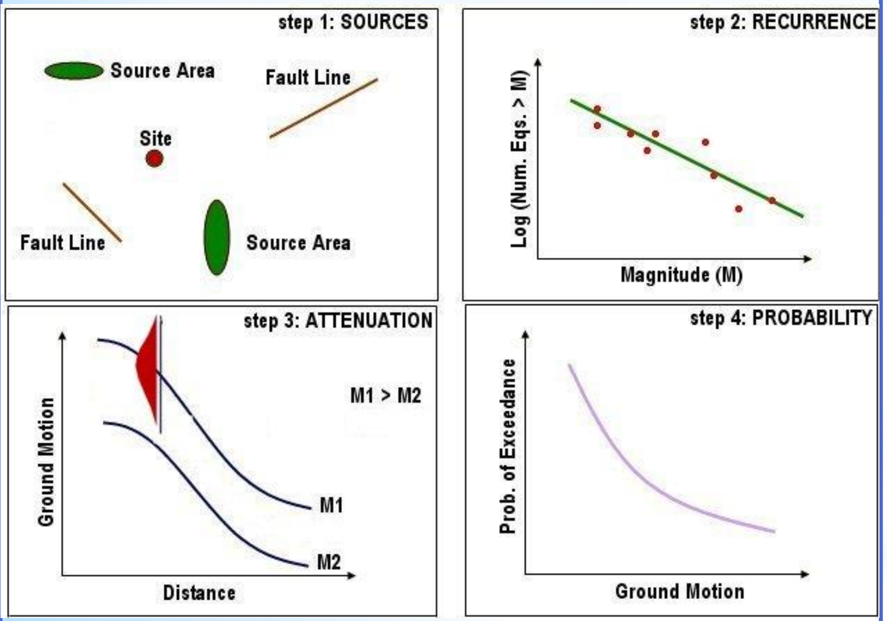
- **ISTANBUL**
- **TEKİRDAĞ**

Local Scale:

- **SAMSUN**

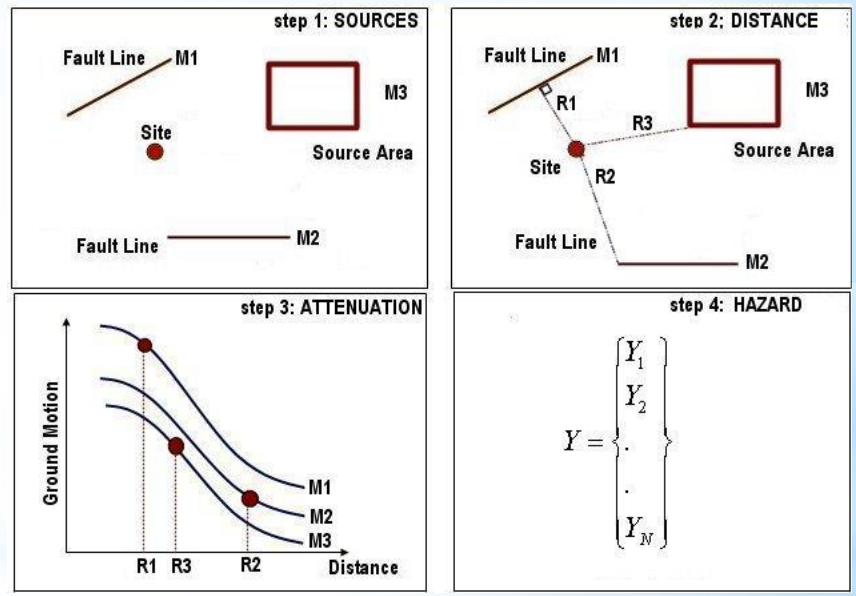
Seismic Hazard Analysis

- ## Probabilistic SHA - PSHA



Step of the analysis (1) Definiton of the seismic sources (2) earthquake recurrence characteristics for each source, (3) GMPEs with magnitude and distance, and (4) ground motions for specified probability of exceedance levels (calculated by summing probabilities ovel all the sources, magnitude and distances)

- ## Deterministic SHA - DSHA



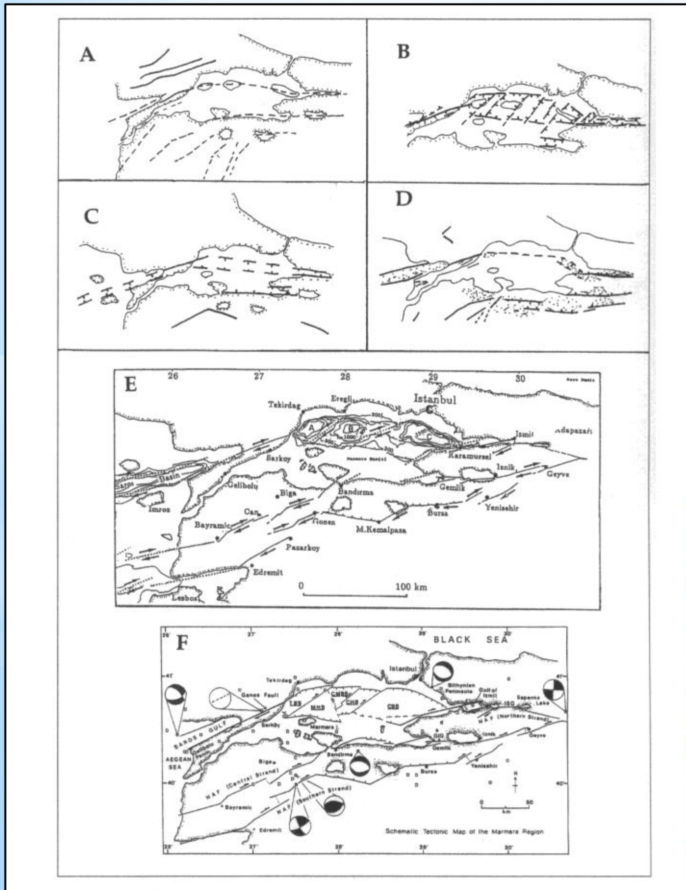
Step of the analysis (1) Definiton of the seismic sources (2) selection of a source to site distance parameter for each source zone, (3) Selection of the controlling earthquake (GMPEs with magnitude and distance), and (4) Definition of the hazard at site in terms of the ground motions produced at the site by the controlling earthquake.

SHA

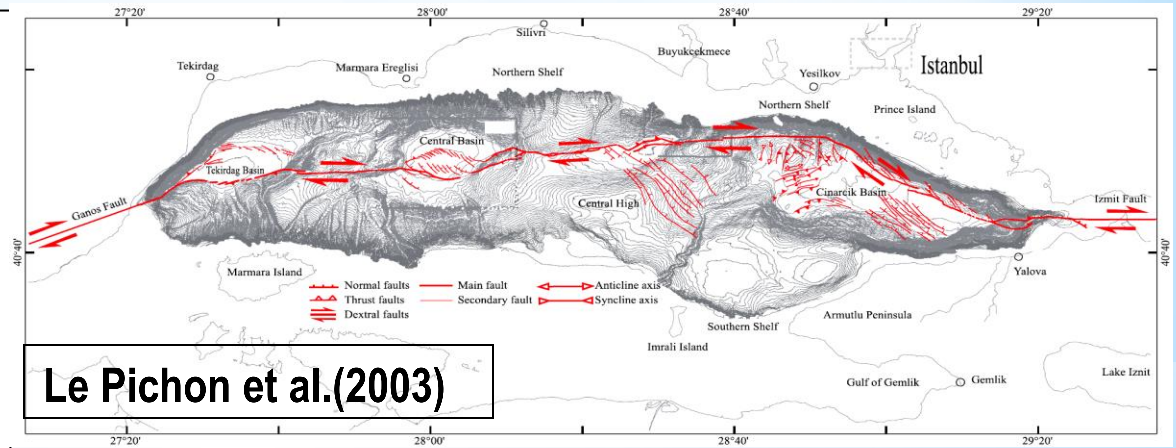
- PSHA
  - Time Dependent (Renewal Model)
    - Considers the time since the last event in estimating the probability of future events.
    - By using this model, the occurence of large earthquake is assumed to have some periodicity
    - Conditional probability calculated based on the mean reccurence interval of the characteristic earthquake, the elapsed time since the last major earthquake and the exposure period (taken as 50 years)
  - Time Independent (Poissonian Model)
    - No Memory
    - Probability is independent of past (recent) earthquake history
- DSHA
  - For "worst case" scenarios the maximum event size can be adopted
  - For intrinsically probabilistic applications, the selection of scenario earthquake is based on the deaggregation of the hazard to show which events contribute most to the loss

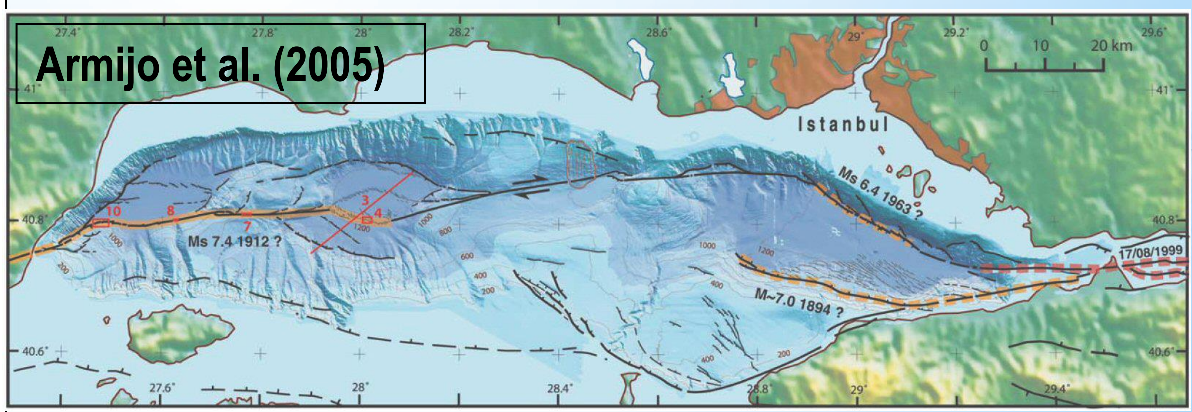
Seismic Hazard Assessment: *For the Source Model:* Tectonic Settings

The most prominent models are the "pull apart" model (A) proposed by Armijo et al. (2005) and the "single fault" model (B) proposed by Le Pichon et al. (2003).

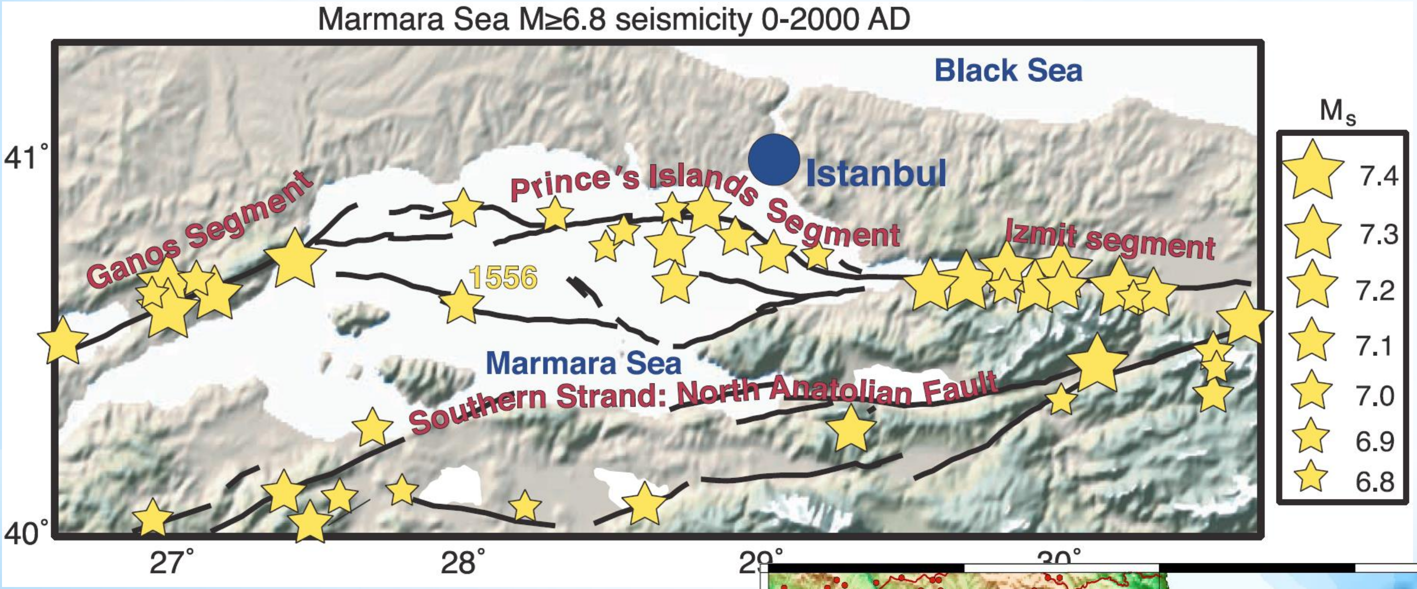


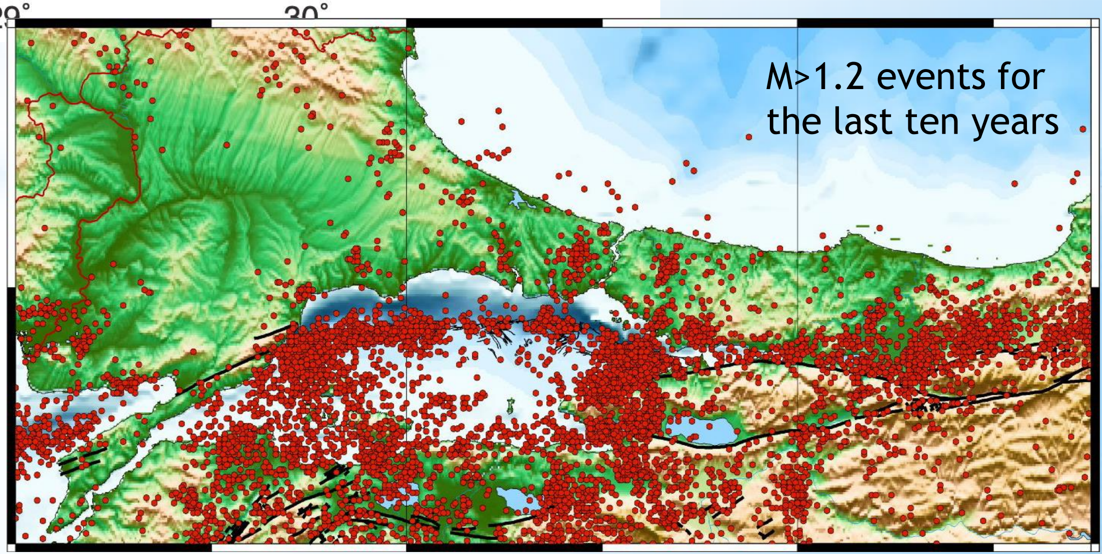
Comparison of the structural models suggested for the Marmara region. (a) Pınar (1943), (b) Pfannenstiel (1944), (c) Crampin and Evans (1986), (d) Şengör (1987), (e) Barka and Kadınsky-Cade (1988), f) Wong et al. (1995), Ergün and Özel (1995).



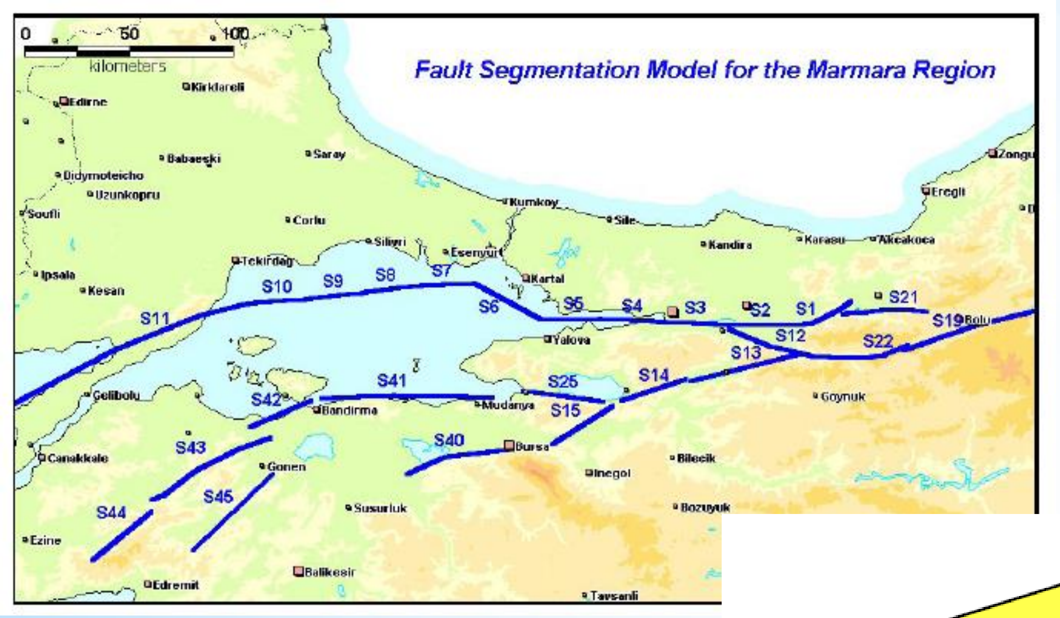


Seismic Hazard Assessment: *For the Source Model:* Distribution of Seismicity



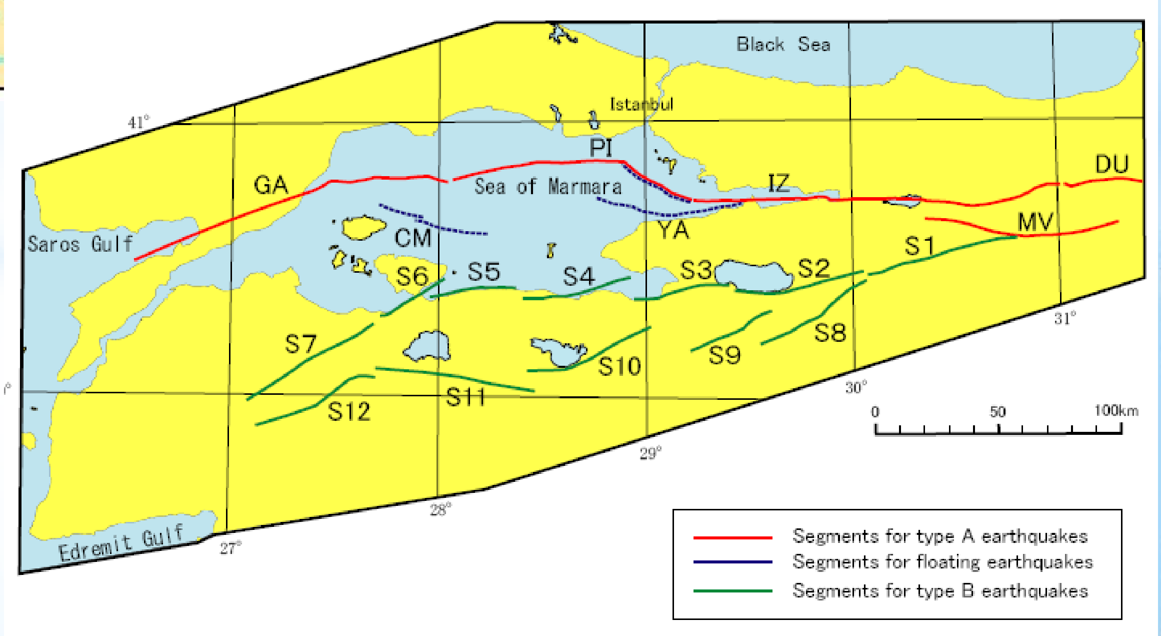


Seismic Hazard Assessment: *Two Source Model for Marmara Region:*



Bogazici University

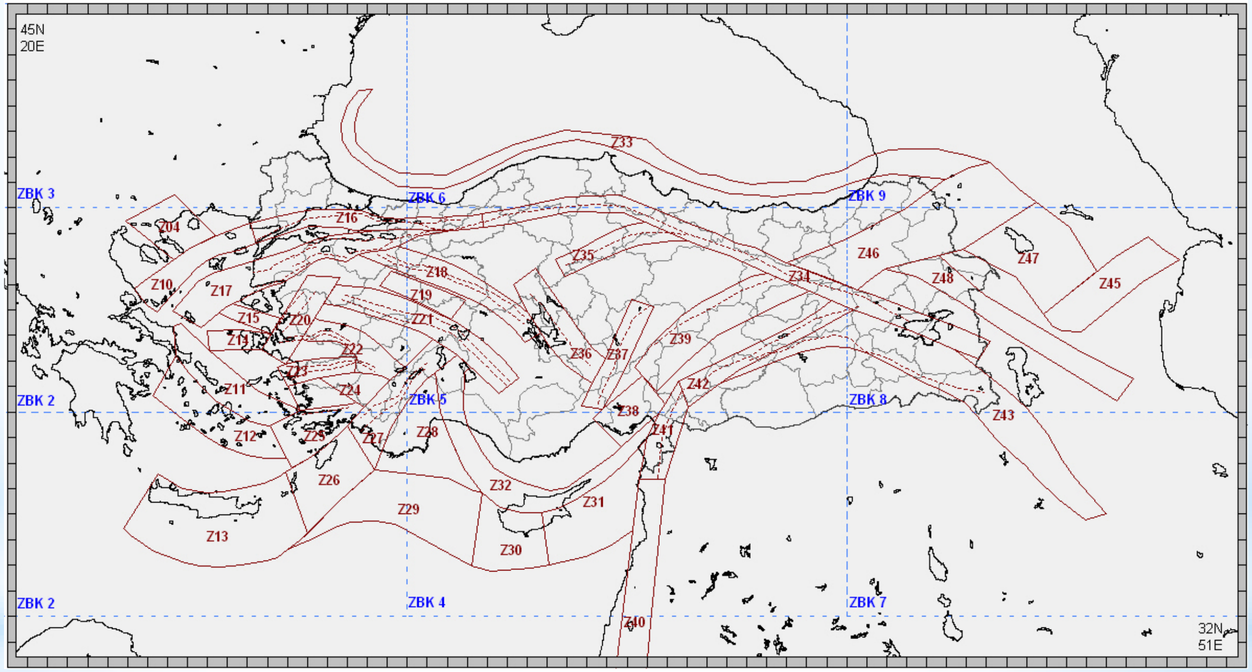
and Istanbul Metropolitan Municipality



FAULT SEGMENTATION MODELS

Seismic Hazard Assessment: Source Model for Turkey

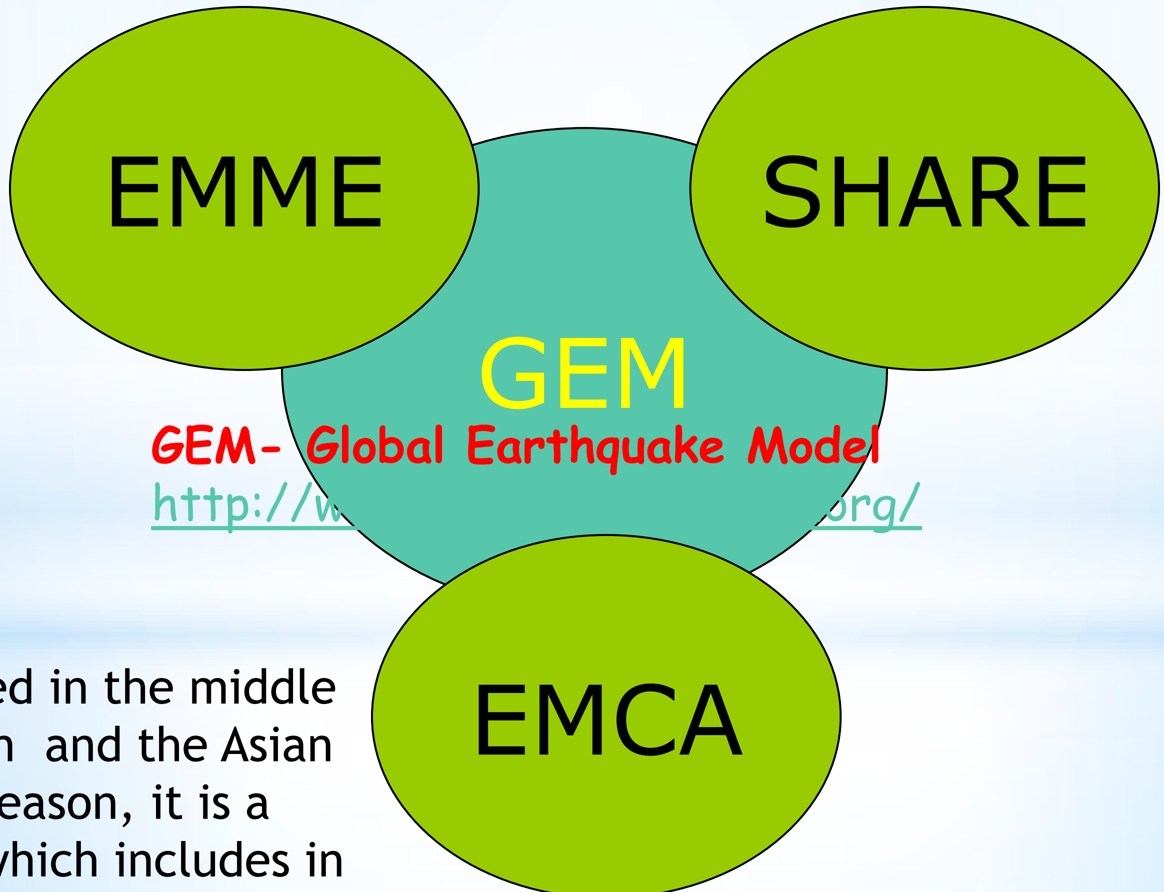
The seismic source zonation model of Turkey developed within the context of a project conducted for the Ministry of Transportation Turkey, aiming the preparation of an earthquake resistant design code for the construction of railways, seaport and airport. (DLH, 2007)



- The earthquakes with magnitude > 6.5 are assumed to take place on the linear zones (Purple line), whereas the smaller magnitude events associated with the same fault are allowed to take place in the surrounding larger areal zone(Green Line).
- In addition to linear and areal source zones, background seismicity zones are defined to model the floating earthquakes that are located outside these distinctly defined source zones and to delineate zones where no significant earthquake has taken place.

EMME - Earthquake Model of the Middle East region:
Hazard, Risk Assessment, Economics & Mitigation
http://www.emme-gem.org/

Seventh Framework Programme
Theme 6: Environment
Seismic Hazard Harmonization in Europe (SHARE)
http://www.share-eu.org/



GEM- Global Earthquake Model
http://w org/

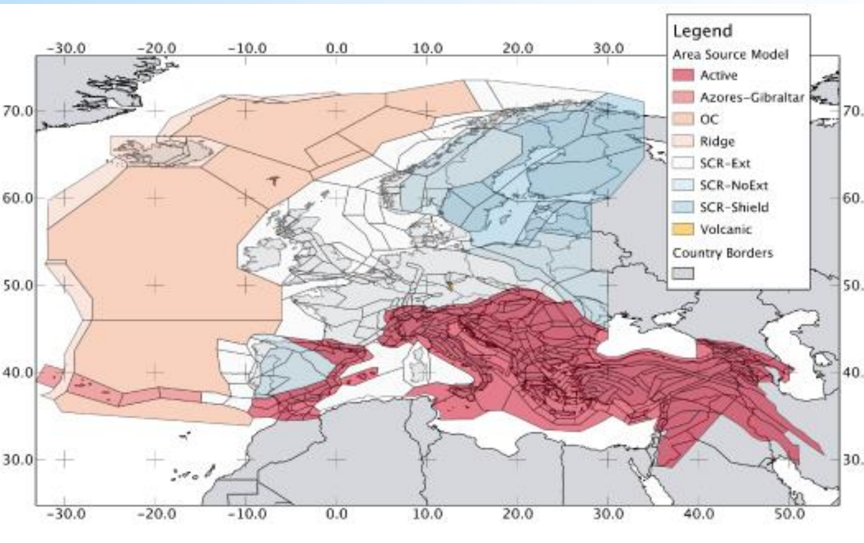
Turkey is located in the middle of the European and the Asian side. For that reason, it is a pilot country, which includes in the major projects such as GEM, EMME, and also SHARE

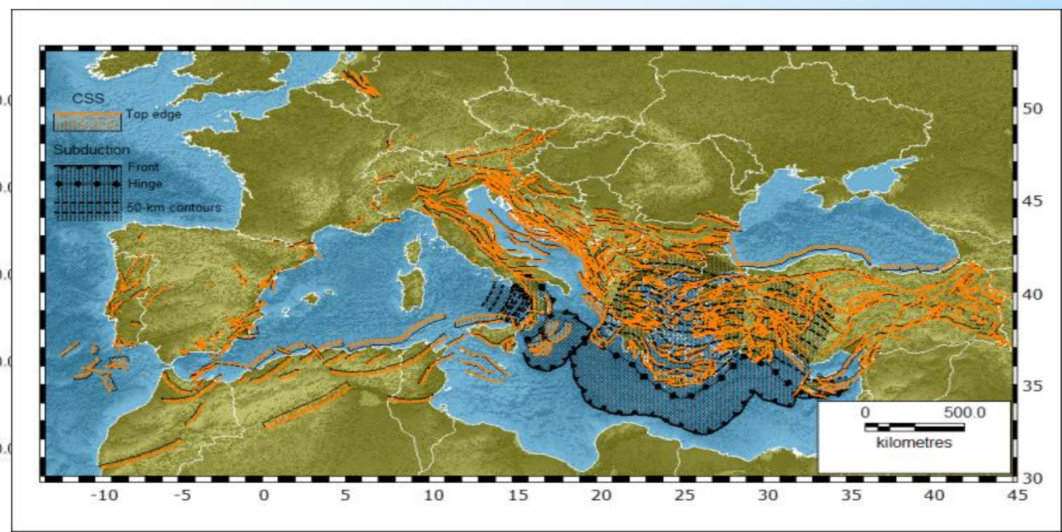
EMCA - The Earthquake Model Central A
http://www.emca-gem.org/

Seismic Hazard Assessment: Source Model for Turkey

SHARE - Seismic Hazard Harmonization in Europe” (www.share-eu.org) is a Collaborative Project in the Cooperation programme of the Seventh Framework Program of the European Commission.
SHARE's main objective is to provide a community-based seismic hazard model for the Euro-Mediterranean region with update mechanisms. The project aims to establish new standards in Probabilistic Seismic Hazard Assessment (PSHA) practice by a close cooperation of leading European geologists, seismologists and engineers:

For the first time, a Euro-Mediterranean wide model considers three approaches to assess the occurrence of earthquake activity:
•a classic Area Source (AS) Model,
•a model that combines activity rates based on fully parameterized faults imbedded in large background seismicity zones, the Fault-Source & Background (FSBG) Model, and
•a kernel-smoothed model that generates earthquake rate forecasts based on fault slip and smoothed seismicity (SEIFA).





Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

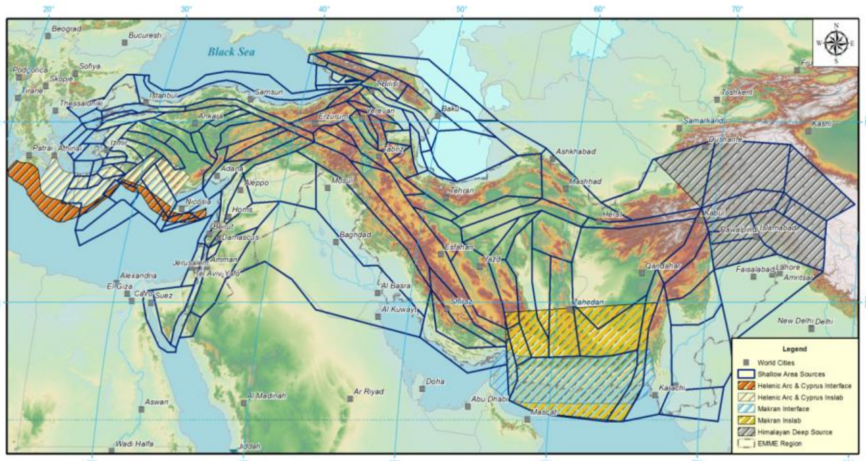
Black Sea CROSS BORDER COOPERATION

Seismic Hazard Assessment: Source Model for Turkey

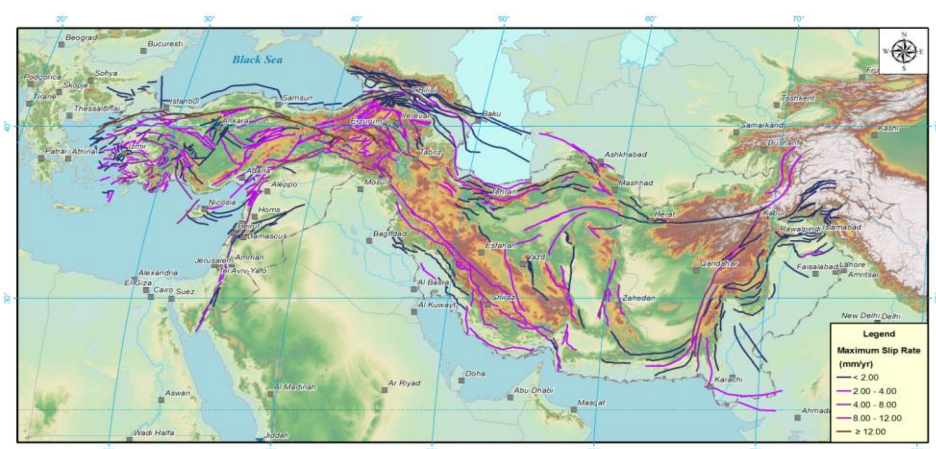
Another regional project is EMME "Earthquake Model of Middle East" (www.emme-gem.org) , which aims at the assessment of earthquake hazard, the associated risk in terms of structural damages, casualties and economic losses and also at the evaluation of the effects of relevant mitigation measures in the Middle East region in concert with the aims and tools of GEM (Global Earthquake Model). The Project started on April 2009 and will end on September 2013.

A Middle East wide model considers three approaches to assess the occurrence of earthquake activity:

- a classic Area Source (AS) Model
- a model that combines activity rates based on fully parameterized faults imbedded in large background seismicity zones, the Fault-Source and various kernel smoothed model and
- a fix kernel-smoothed



EMME Area Source Model



EMME Fault Sources

ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL

- Development of one catalog from several catalogs
- Declustering
- Use of catalog: Calculation of the Gutenberg-Richter "*a*" and "*b*" values for the background
  Assignment of major earthquakes to the segments in the fault segmentation model

Magnitude Frequency Distributions

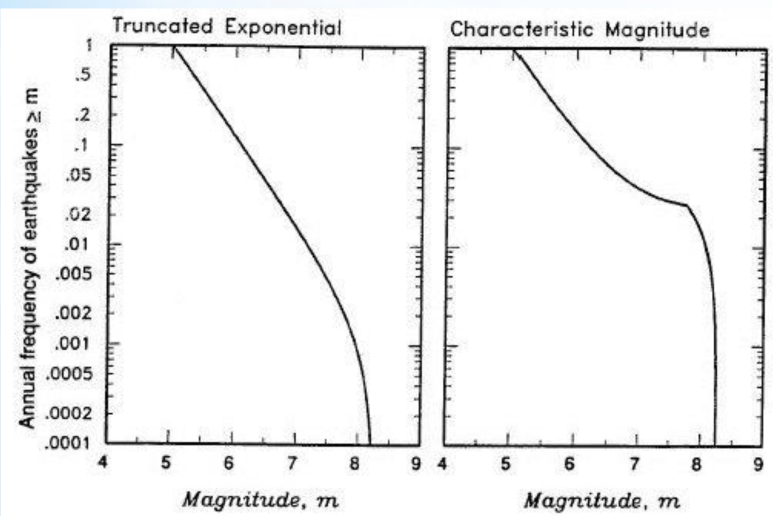
- Background
  - Gutenberg-Richer distribution
  - Smoothed seismicity model
    - Accounts for the activity not associated with the main tectonic entities,
    - Assumes that each cell of grid is a potential source for moderately sized events,
    - Gutenberg- Richter parameters determined by the observed seismicity,
    - A Gaussian smoothing function with a correlation distance of 50 km is used
- Ruptures along well defined from the length of the segment,
  - Characteristic distribution
    - Maximum magnitude determined from the length of the segment,
    - Return period determined by the moment of the characteristic earthquake and the moment rate of the segment.

* ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL

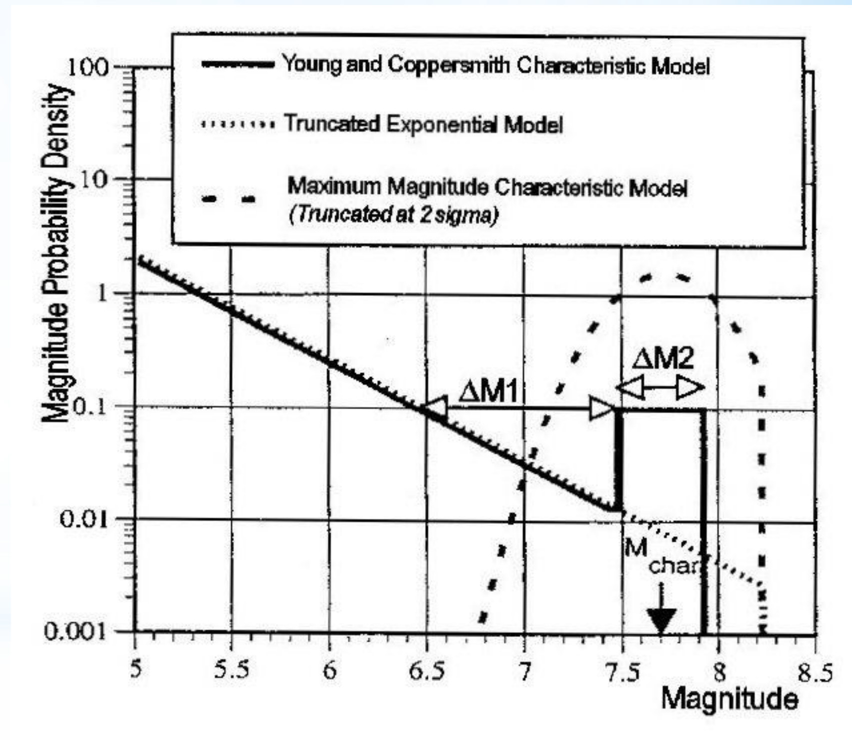
Three probability density function on magnitude f(m) are currently used in the literature:

(a) The truncated exponential model (GR) based on the results of Gutenberg and Richter (1944), with a lower and upper magnitude cut-off.

(b) The maximum magnitude model (CE) based on seismological data compiled by Schwartz and Coppersmith (1984) and Wesnousky (1994), which suggests that some individual faults and fault segments tend to repeatedly generate earthquakes of comparable magnitudes



The definition of the magnitude probability density for characteristic earthquake model



* ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL

The earthquake recurrence model for the fault segments

- **Poisson Model**
  - characteristic earthquake recurrence is assumed,
  - probability of occurrence of the characteristic event does not change in time
  - The annual rate is calculated as:

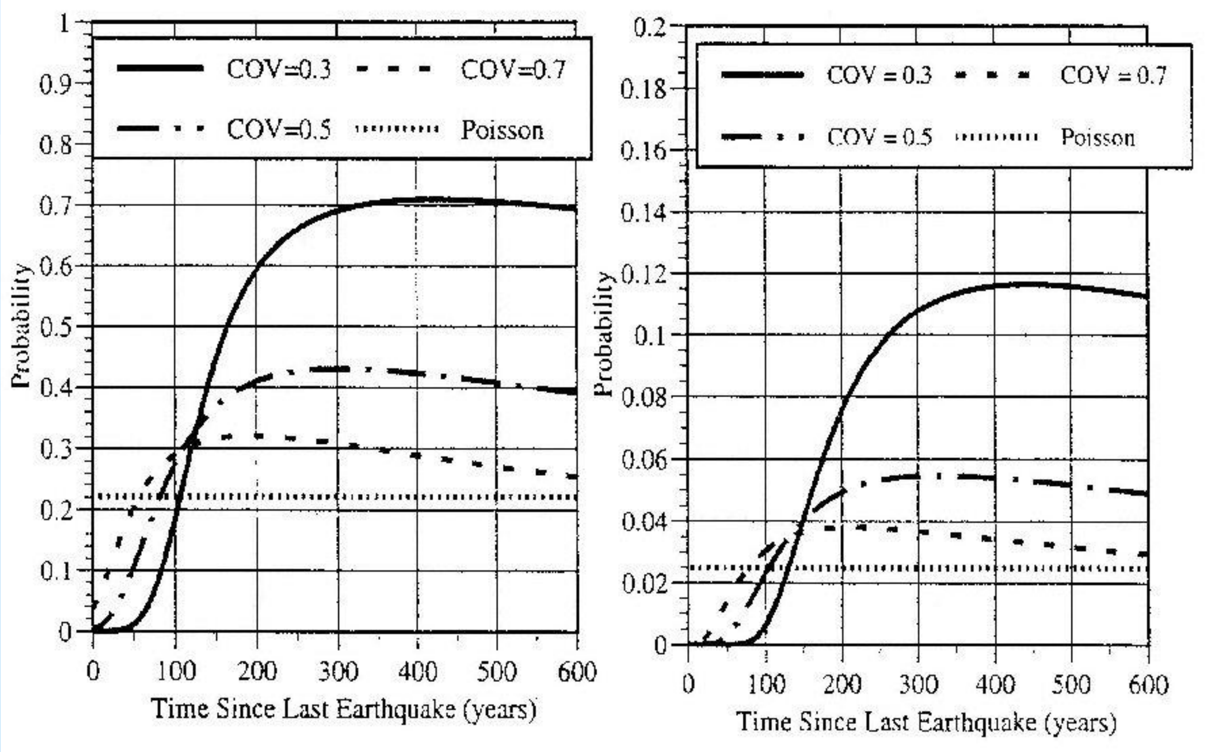
R=1/ mean recurrence interval

- **Time Dependent (Renewal model)**
  - the probability of occurrence of the characteristic event increase s as a function of the time elapsed since the last characteristic event,
  - A lognormal distribution with a coefficient of variation of 0.5 is assumed to represent the earthquake probability density distribution.
  - The annual rate is calculated as:

Reff=-ln(1-Pcond) / T

* Time dependent (Renewal) Model

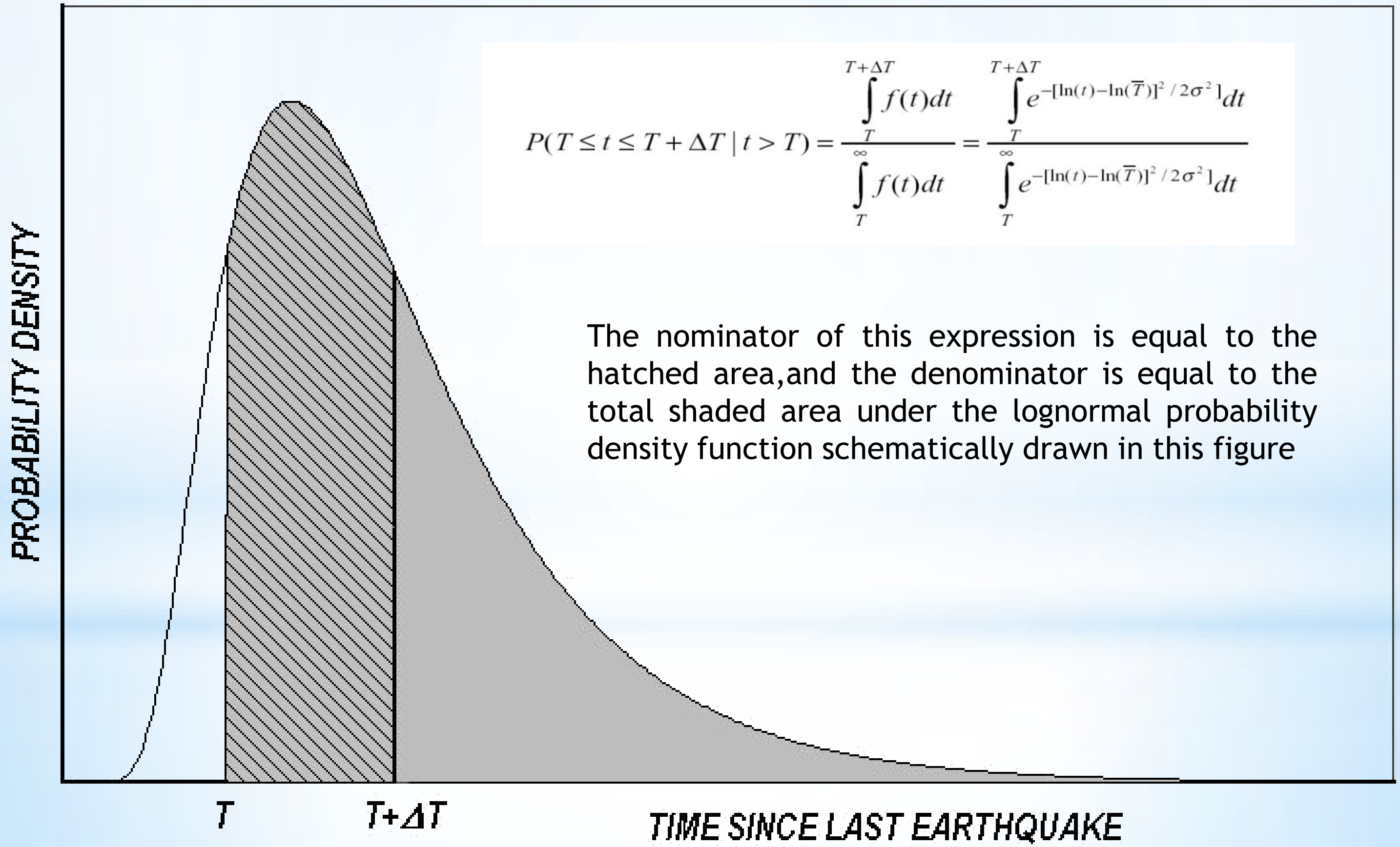
- considers the time since the last event in estimating the probability of future events
- by using this model, the occurrence of large earthquakes is assumed to have some periodicity
- conditional probability calculated based on the mean recurrence interval of the characteristic earthquake, the elapsed time since the last major earthquake and the exposure period (taken as 50 years)



Sensitivity of the time dependent probabilities for a renewal model with 50 and 5 year exposure periods (After Abrahamson, 2000).

* ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL

Calculation of conditional probability from a probability density function



$$P(T \le t \le T+\Delta T \mid t > T) = \frac{\int_{T}^{T+\Delta T} f(t)dt}{\int_{T}^{\infty} f(t)dt} = \frac{\int_{T}^{T+\Delta T} e^{-[\ln(t)-\ln(\overline{T})]^2/2\sigma^2]}dt}{\int_{T}^{\infty} e^{-[\ln(t)-\ln(\overline{T})]^2/2\sigma^2]}dt}$$

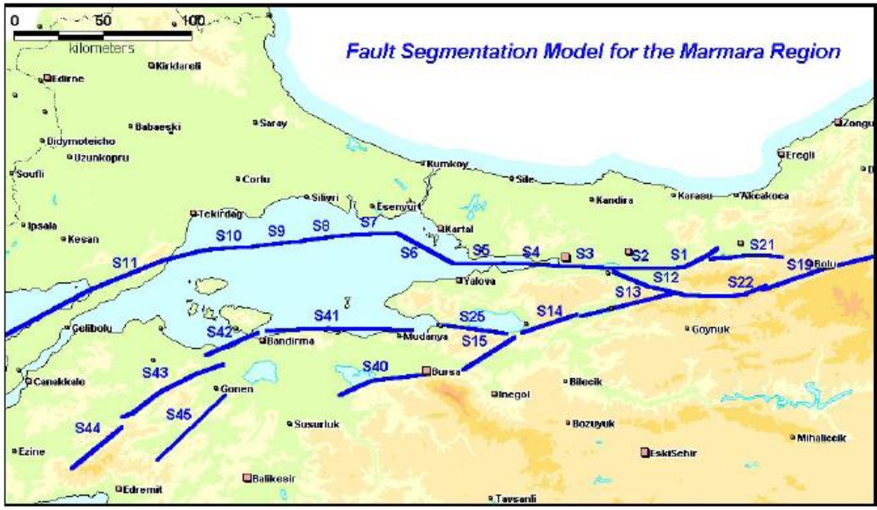
The nominator of this expression is equal to the hatched area,and the denominator is equal to the total shaded area under the lognormal probability density function schematically drawn in this figure

* ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL for (Time-dependent method - the Marmara region)

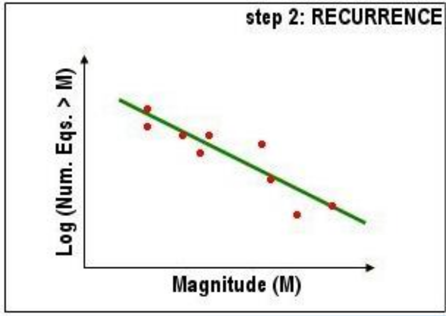
Renewal model characteristic earthquake parameters associated with the segments.

Segment	Last Char. Eq.	COV	Mean Recurrence Time	Char. Magnitude	Time since Last Char. Eq.	Time dependent (Renewal) 50year Prob.	Time dependent (Renewal) Annual Rate
1	1999	0.5	140	7.2	6	0.0344	0.0007
2	1999	0.5	140	7.2	6	0.0344	0.0007
3	1999	0.5	140	7.2	6	0.0344	0.0007
4	1999	0.5	140	7.2	6	0.0344	0.0007
5	1894	0.5	175	7.2	111	0.3723	0.0093
6	1754	0.5	210	7.2	251	0.4095	0.0105
7	1766	0.5	250	7.2	239	0.3374	0.0082
8	1766	0.5	250	7.2	239	0.3374	0.0082
9	1556	0.5	200	7.2	449	0.4191	0.0109
10	-	0.5	200	7.2	1000*	0.3340	0.0081
11	1912	0.5	150	7.8	93	0.4206	0.0109
12	1967	0.5	250	7.4	38	0.0203	0.0004
13	-	0.5	600	7.4	1000*	0.1771	0.0039
14	-	0.5	600	7.4	1000*	0.1771	0.0039
15	-	0.5	1000	7.2	1000*	0.0974	0.0020
19	1944	0.5	250	7.9	61	0.0597	0.0012
21	1999	0.5	250	7.2	6	0.0012	0.0000
22	1957	0.5	250	7.2	48	0.0347	0.0007
25	-	0.5	1000	7.2	1000*	0.0974	0.0020
40	1855	0.5	1000	7.5	150	0.0006	0.00001
41a			1000	7.2			0.0020
41b	-	0.5	1000	7.3	1000*	0.0974	0.0020
42	-	0.5	1000	7.2	1000*	0.0974	0.0020
43	1737	0.5	1000	7.5	268	0.0086	0.0002
44	-	0.5	1000	7.2	1000*	0.0974	0.0020

Date of the last characteristic earthquake is unknown.



* # ESTIMATION OF THE SOURCE SEISMICITY PARAMETERS AND PROBABILISTIC MODEL for time-independent model (Turkey)



N is the number of the earthquakes above the magnitude M in a given region and within a given period
“a “ and “b” are regression constants.

$$\log N = a + b\ M$$

Table 1. Source Zone Information

ZONE	FAULT NAME	MECHANISM**	a	b	M_{min} - M_{maks}
Z04	Chalkidiki	Normal	2.7	0.6	5.0 – 7.0
Z10	NAF (Aegean Sea)	RLSS + Normal	6.5	1.2	5.0 – 7.8
Z11	Sisam	Normal	2.6	0.8	5.0 – 7.6
Z12	Cyclades	Normal	3.2	0.7	5.0 – 7.2
Z13	Hellenic Arc	Deep Earthquake Subduction Zone	5.7	1.1	5.0 – 8.3
Z14	Sakiz (Chios) Fault	Normal	3.8	0.9	5.0 – 7.0
Z15	Midilli (Lesbos) Fault	Normal	4.5	1.0	5.0 – 6.8
Z16 OZ	NAF (Marmara Sea, Northern Strand)	RLSS + Normal	5.3	0.9	5.0 – 6.9
Z16 IL					7.0 – 7.9
Z17 OZ	NAF (Southern Strand in Marmara region)	RLLS and Normal Segments	4.7	0.9	5.0 – 6.6
Z17 IL					6.7 – 7.4
Z18 OZ	Eskişehir Fault	RLSS + Normal	4.3	1.0	5.0 – 6.6
Z18 IL					6.7 – 7.0
Z19	Kütahya Fault	Normal	3.8	1.0	5.0 – 5.8
Z20 OZ	Bergama_Foça Fault	LLSS	3.8	0.8	5.0 – 6.6
Z20 IL					6.7 – 7.0
Z21 OZ	Simav-Sultandağ Fault System	Normal and Reverse	5.4	1.1	5.0 – 6.9
Z21 IL					7.0 – 7.3
Z22 OZ	Gediz Fault	Normal	4.0	0.9	5.0 – 6.9
Z22 IL					7.0 – 7.3
Z23 OZ	Menderes Fault	Normal	4.1	1.0	5.0 – 6.8
Z23 IL					6.9 – 7.6
Z24	Muğla-Yatağan Fault	Various (Strike Slip, Normal)	4.8	1.1	5.0 – 6.8
Z25 OZ	Gökova Fault	Normal	5.3	1.0	5.0 – 6.8
Z25 IL					6.9 – 7.8
Z26	Hellenic Arc	LLSS + Normal	6.0	1.2	5.0 – 6.7
Z27 OZ	Fethiye-Burdur Fault	LLSS +Normal l	5.0	1.0	5.0 – 6.8
Z27 IL					6.9 – 7.4
Z28	Antalya Fault	Strike Slip	5.6	1.2	5.0 – 7.0
Z29	Cyprean Arc-Florence Rise	Various (Strike Slip, Thrust)	5.9	1.3	5.0 – 5.9
Z30	Cyprean Arc-Trodos Mount.	Various (Strike Slip, Thrust)	4.8	1.0	5.0 – 6.8
Z31	Hecataeus Ridge-region name-	Undefined	3.4	0.8	5.0 – 6.6
Z32	Cyprus Trough	Strike Slip+Thrust	2.7	0.7	5.0 – 6.8
Z33	Black Sea Fault	Thrust and Normal?-	3.8	0.9	5.0 – 7.3
Z34 OZ	North Anatolian Fault Zone(NAF)	RLSS	5.0	0.8	5.0 – 6.7
Z34 IL					6.8 – 7.9
Z35 OZ	Alaca Ezinepazarı Fault	RLSS	3.2	0.8	5.0 – 6.7
Z35 IL					6.8 – 7.9
Z36 OZ	Tuz Lake Fault	RLSS	2.9	0.8	5.0 – 6.7
Z36 IL					6.8 – 7.9
Z37 OZ	Ecemis Fault	LLSS	3.9	0.9	5.0 – 6.7
Z37 IL					6.8 – 7.9
Z38	Adana Region Fault Zone	LLSS	3.1	0.8	5.0 – 7.0
Z39 OZ	Goksun Fault	LLSS	2.7	0.7	5.0 -6.9
Z39 IL					7.0 – 7 .5
Z40	Dead Sea Fault	LLSS	4.7	0.9	5.0 – 7.7
Z41 OZ	Dea Sea-Hatay Fault	LLSS +Normal	3.6	1.0	5.0 – 6.7
Z41 IL					6.8 – 7.9
Z42 OZ	East Anatolian Fault (EAF)	LLSS	4.6	0.9	5.0 – 6.7
Z42 IL					6.8 – 7.9
Z43 OZ	Bitlis_Zagros Fault Zone	Thrust	4.7	1.0	5.0 – 6.6
Z43 IL					6.7 – 7.0
Z45	Araxis Fault	LLSS	4.2	1.0	5.0 - 7.8
Z46	North East Anatolian Fault	LLSS	5.6	1.1	5.0 - 7.7
Z47	Pambak Sevan Fault	RLSS and Thrust	3.9	0.9	5.0 - 7.3
Z48	NW Fault System	RLSS	4.4	1.0	5.0 - 7.3

*OZ: Outer Areal Zone, IL: Inner Linear Zone
**RLSS: Right Lateral Strike Slip, LLSS: Left Lateral Strike Slip

* GROUND MOTION PREDICTION EQUATIONS

- GMPEs are used in earthquake hazard assessments predict ground motion parameters (such as peak ground acceleration –PGA; peak ground velocity –PGV and spectral accelerations -SA) as a function of source parameters (magnitude and fault mechanism), propagation path (fault distance) and site effects (site class). Site classes are generally based on shear wave velocity of soil media or code-based site class descriptions, such as NEHRP (2003). In almost all attenuation relationship studies the strong ground motion parameters are assumed to have a log-normal distribution and a random error term is provided with zero mean and a standard deviation

- Next Generation attenuation relationships (NGA, 2008):
  - Boore and Atkinson (updating Boore at.al., 1997 model)
  - Campbell and Bozorgnia (updating their 2003)
  - Chiou and Youngs (updating Sadigh et.al., 1997 model)
  - Abrahamson and Silva (updating Sadigh et.al., 1997 model))
  - Idriss (2008)

Regional GMPEs:

* *Ulusay et al. (2004)*
* Kalkan and Gulkan (2004)
* Ozbey et al (2004)
* Akkar and Cagnan (2010)
* Akkar, Sandikkaya and Bommer (2012) etc..

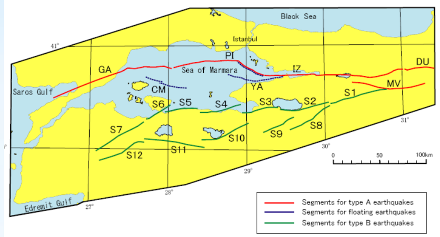
For the Marmara region, the average of the results obtained from Boore, et al., (1997), Sadigh et. al.(1997) and Campbell (1997) attenuation relationships for the computation of Peak Ground Acceleration and the average of Boore et al., (1997) and Sadigh et. al.(1997) attenuation relationships for the computation of Spectral Accelerations at 0.2s and 1s (Ss and S1) have been used.

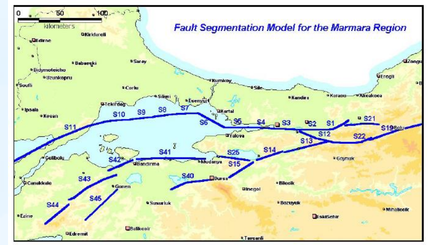
In the DLH code, , The average of the results obtained from Boore, et al., (1997), Sadigh et. al.(1997) and Campbell (2003) attenuation relationships for the computation of PGA, ans spectral accelerations have been used.

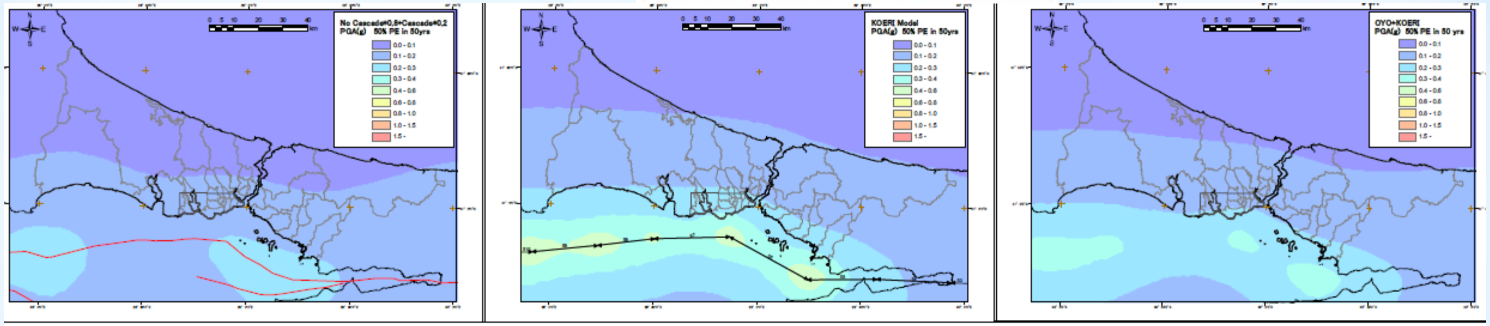
Time dependent PSHA: Armijo Model

Le Pichon Model

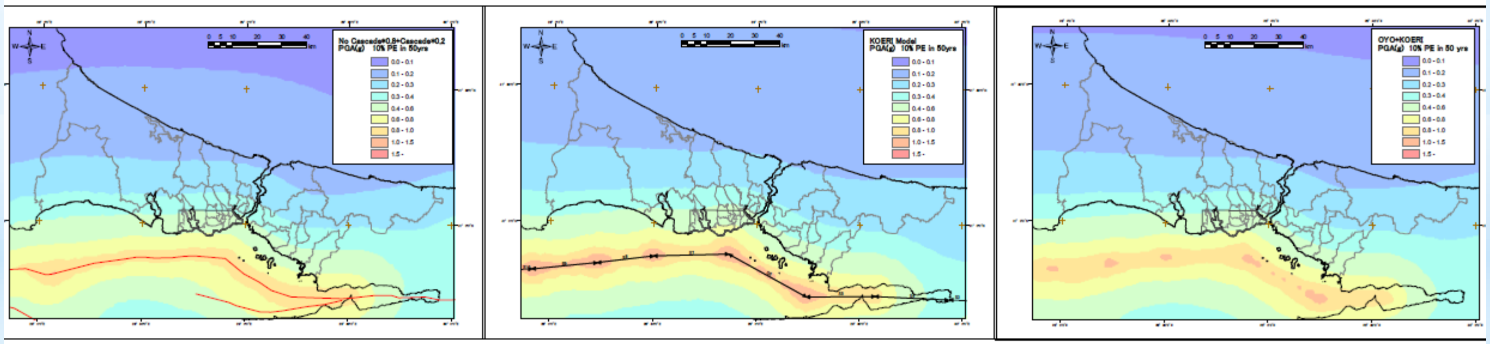
Average



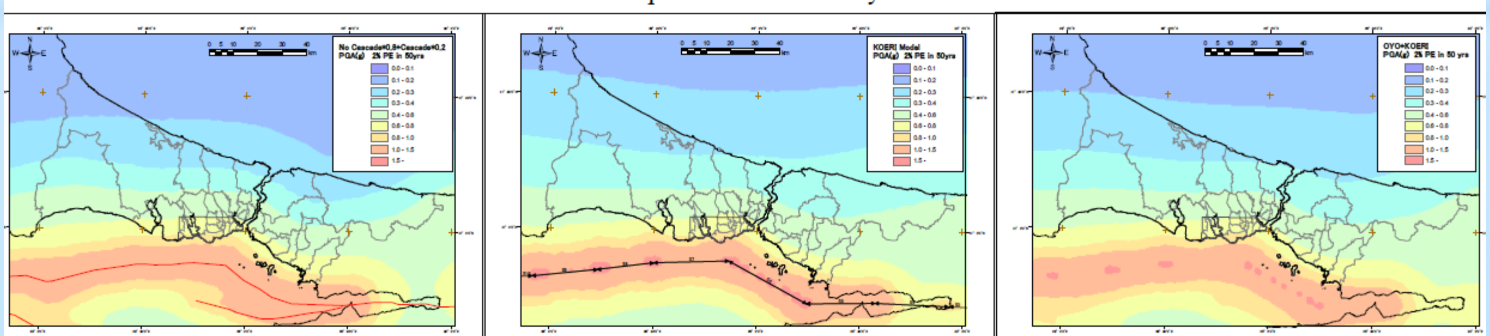




PGA map for 50% PE in 50 years



PGA map for 10% PE in 50 years



PGA map for 2% PE in 50 years

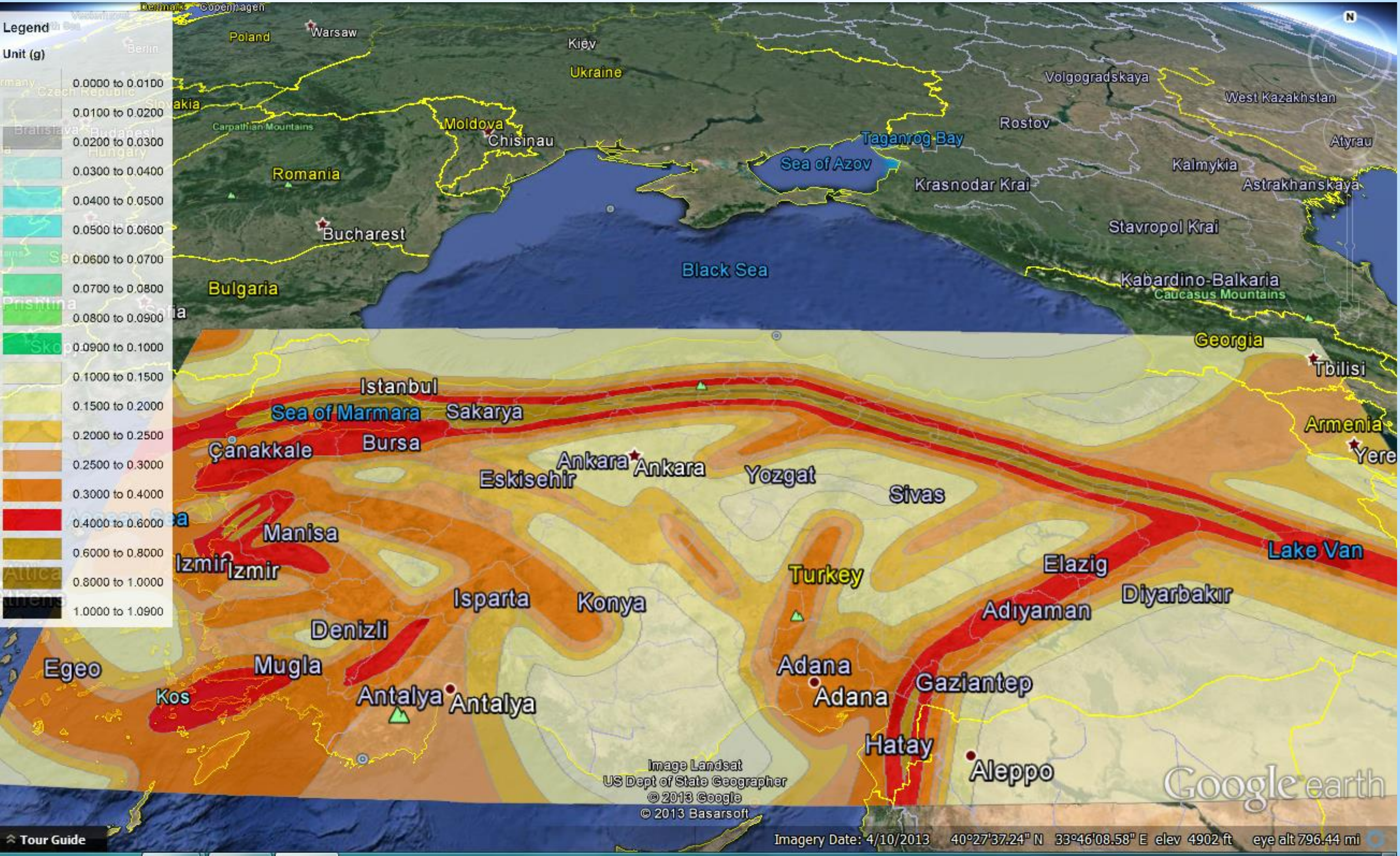
Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

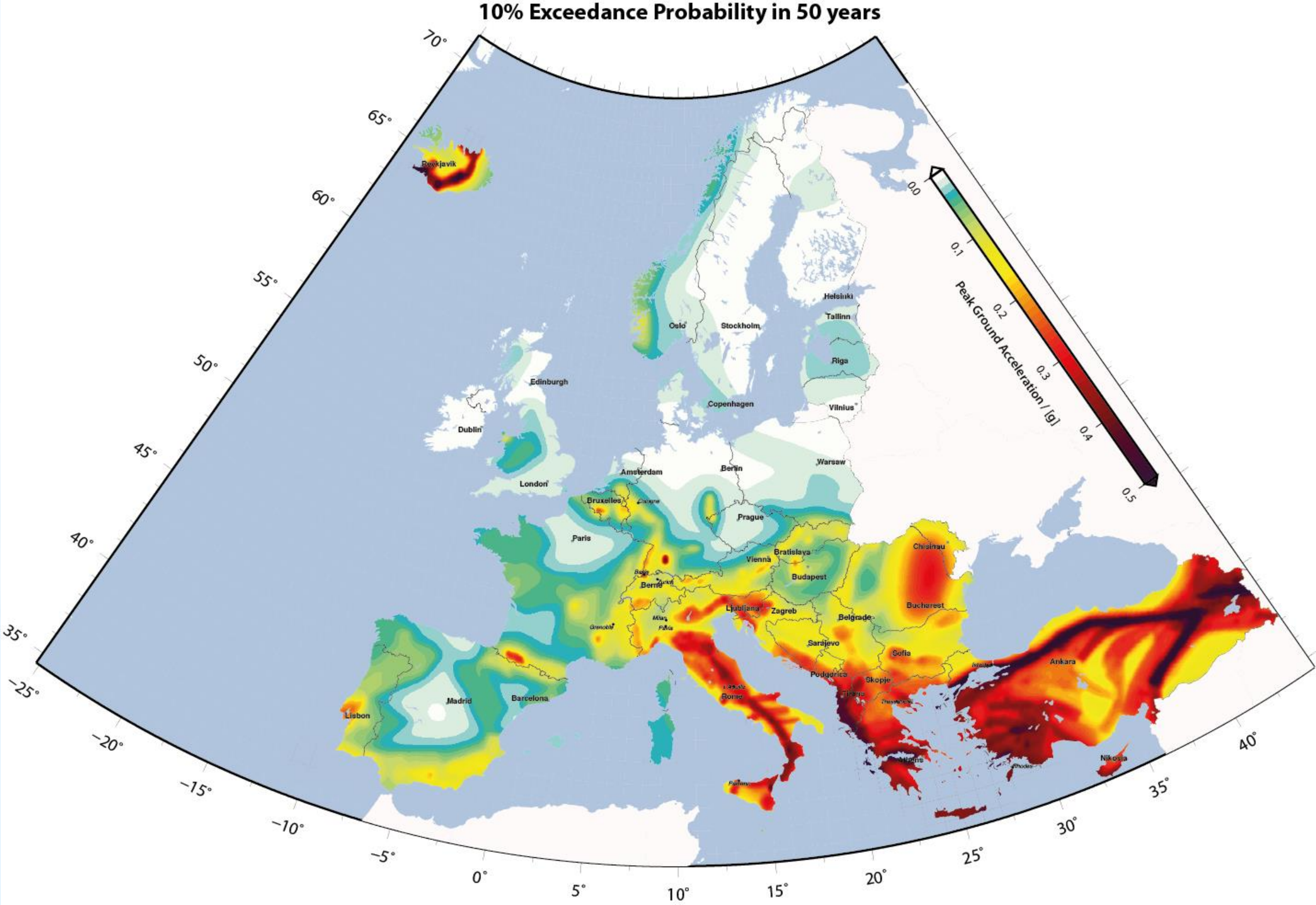
Black Sea CROSS BORDER COOPERATION

Time-independent model (from the study of DLH, 2007) – PGA, 475 yrs

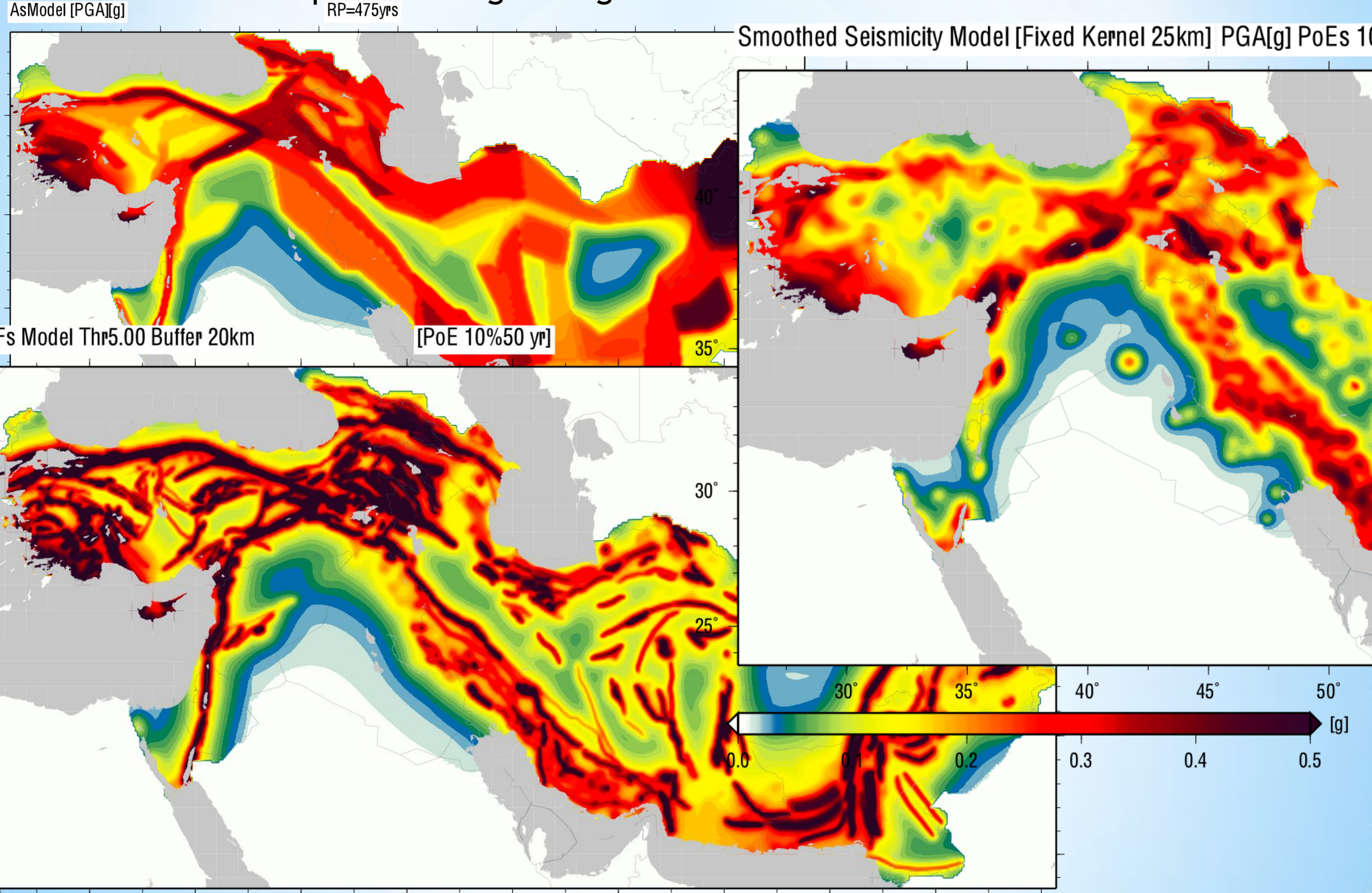
http://www.koeri.boun.edu.tr/YayInlar/YonetmelIkler_4_12.depmuh



SHARE PROJECT: http://www.share-eu.org/
Please visit EFEHR at www.efehr.org.



EMME PROJECT: http://emme-gem.org/



DEAGGRAGATION OF SEISMIC HAZARD

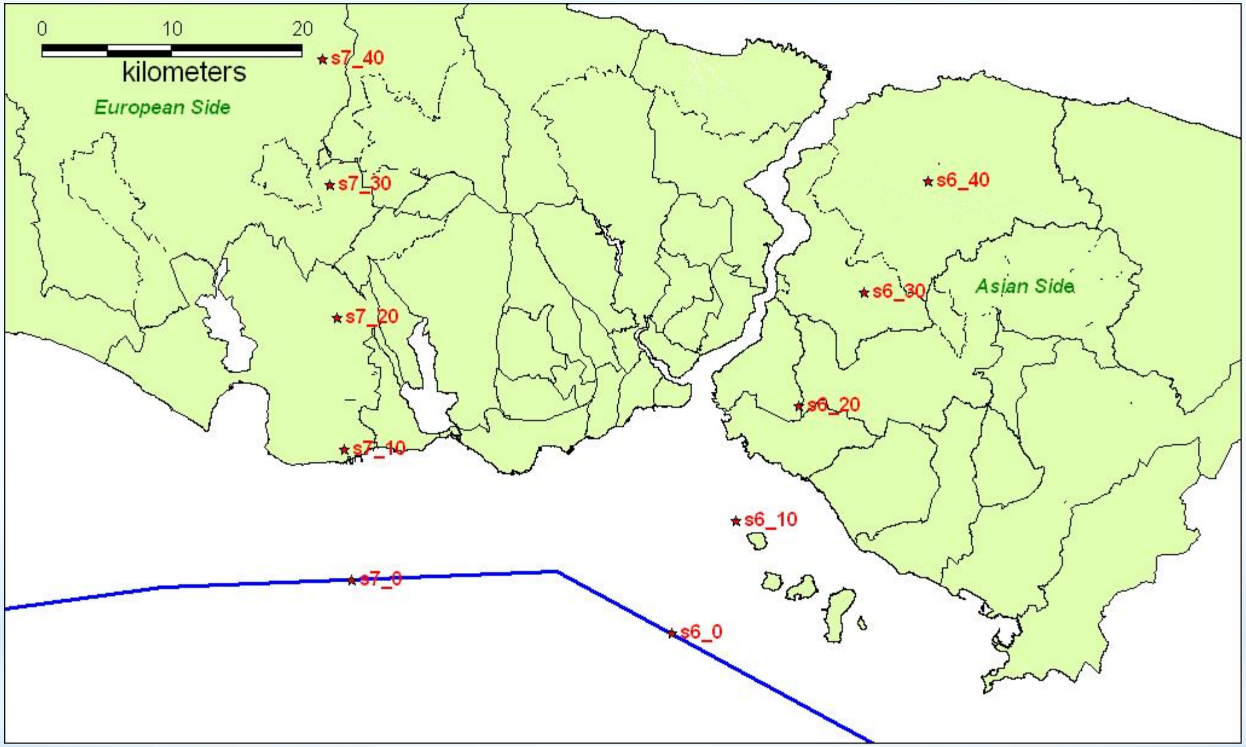
Probabilistic seismic-hazard deaggregation involves determining earthquake variables, principally magnitude, distance and values of other random variables defining seismic events that contribute to a selected seismic-hazard level (McGuire, 1995; Bazzurro and Cornell, 1999).

The hazard at a specific level of the ground motion parameter at a site (SA(T)) and for a given source can be deaggregated with respect to contributions by magnitude (M), distance (R) and an error term (so-called, Epsilon) in terms of their probability distributions (i.e. probability densities against M, R and e).

Epsilon is defined as the number of standard deviations by which an observed logarithmic spectral acceleration differs from the mean logarithmic spectral acceleration of a ground-motion prediction (attenuation) equation.

$$\varepsilon(SA_0(T)) = \frac{\ln(SA_0(T)) - \ln(\mu)}{\sigma}$$

DEAGGRAGATION OF SEISMIC HAZARD



The results of the hazard deaggregation in terms of mean and modal values of magnitude, M, distance, D, and epsilon, E, for peak ground acceleration (PGA) and the 5%-damped spectral acceleration, SA(T), for periods of 0.2s, 1s, 6s and 10s corresponding to the average return periods of 72, 475 and 2475 years (associated respectively for 50%, 10% and 2% probabilities of exceedance in 50 years) for points at 10, 20 30 and 40 km from the causative fault for the Asian and European side of Istanbul respectively.

DEAGGRAGATION OF SEISMIC HAZARD

From these tables the following summary table (Table 2) can be created for the modal Epsilon values for PGA (SA(0.2)) and SA(1s) corresponding to 72, 475 and 2475 year average return periods. The modal value for the magnitude is Mw=7.25.

TABLE 2

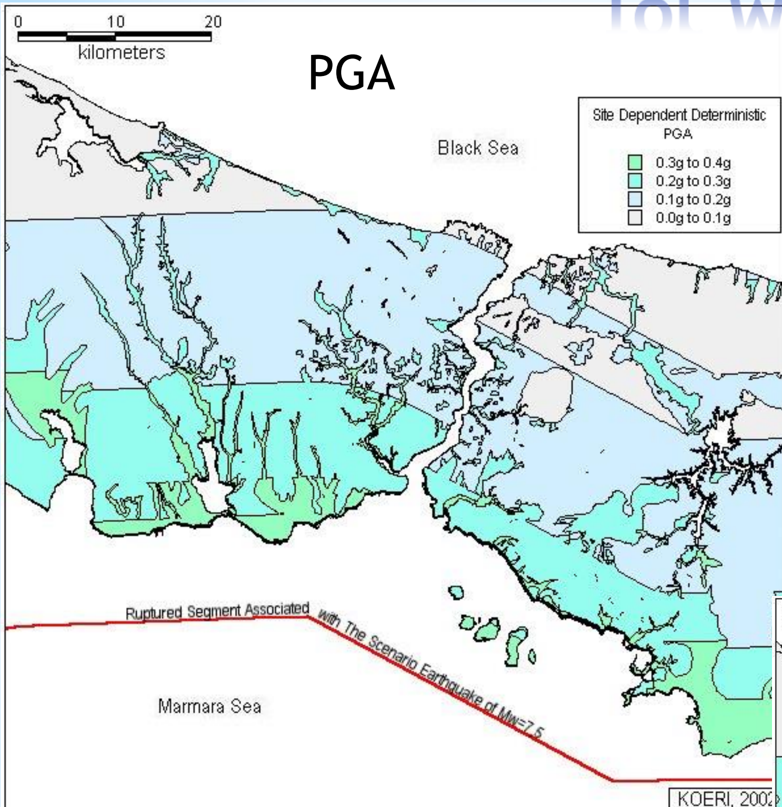
Average Return Period (Years)	Ground Motion Parameter	Fault Distance			
		10km	20km	30km	40km
72	PGA	-0.5	-0.1	0.3	-0.1
	SA(1s)	-0.3	-0.1	0.5	0.5
475	PGA	1.1	1.2	1.4	1.2
	SA(1s)	1.4	1.3	1.5	1.5
2475	PGA	1.9	2.0	1.9	1.9
	SA(1s)	1.9	2.1	2.1	2.2

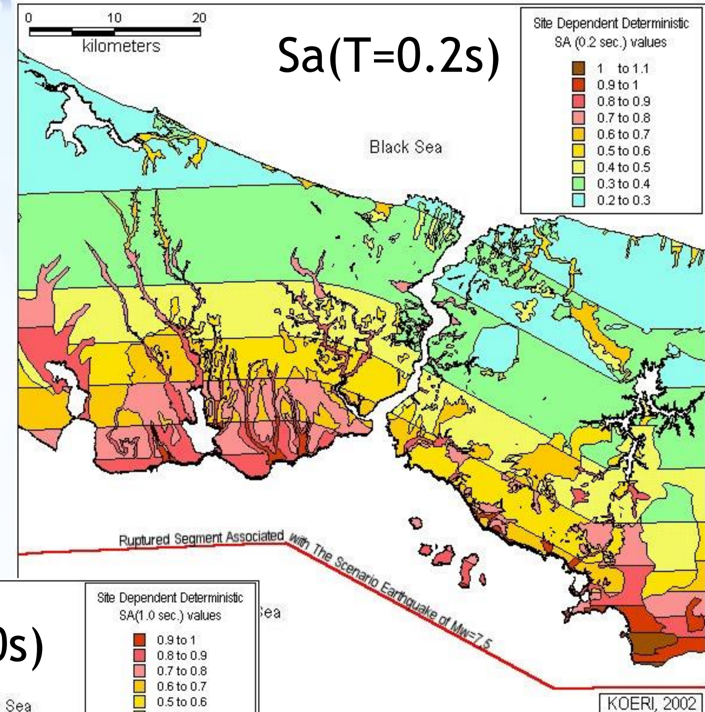
The average Epsilon values are respectively 0.0, 1.4 and 2.0 for the 50%, 10% and 2% probabilities of exceedance in 50 years (Could be lower for Poisson Model)

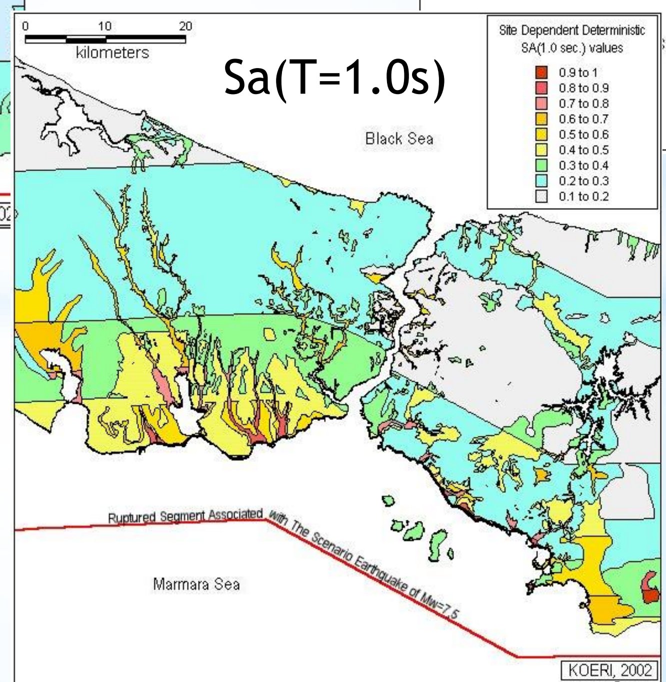
50%/50 earthquake has an average return period of 72 years, roughly corresponding to that of the expected "Istanbul" earthquake.

Deterministic Scenario Earthquake for Marmara Region

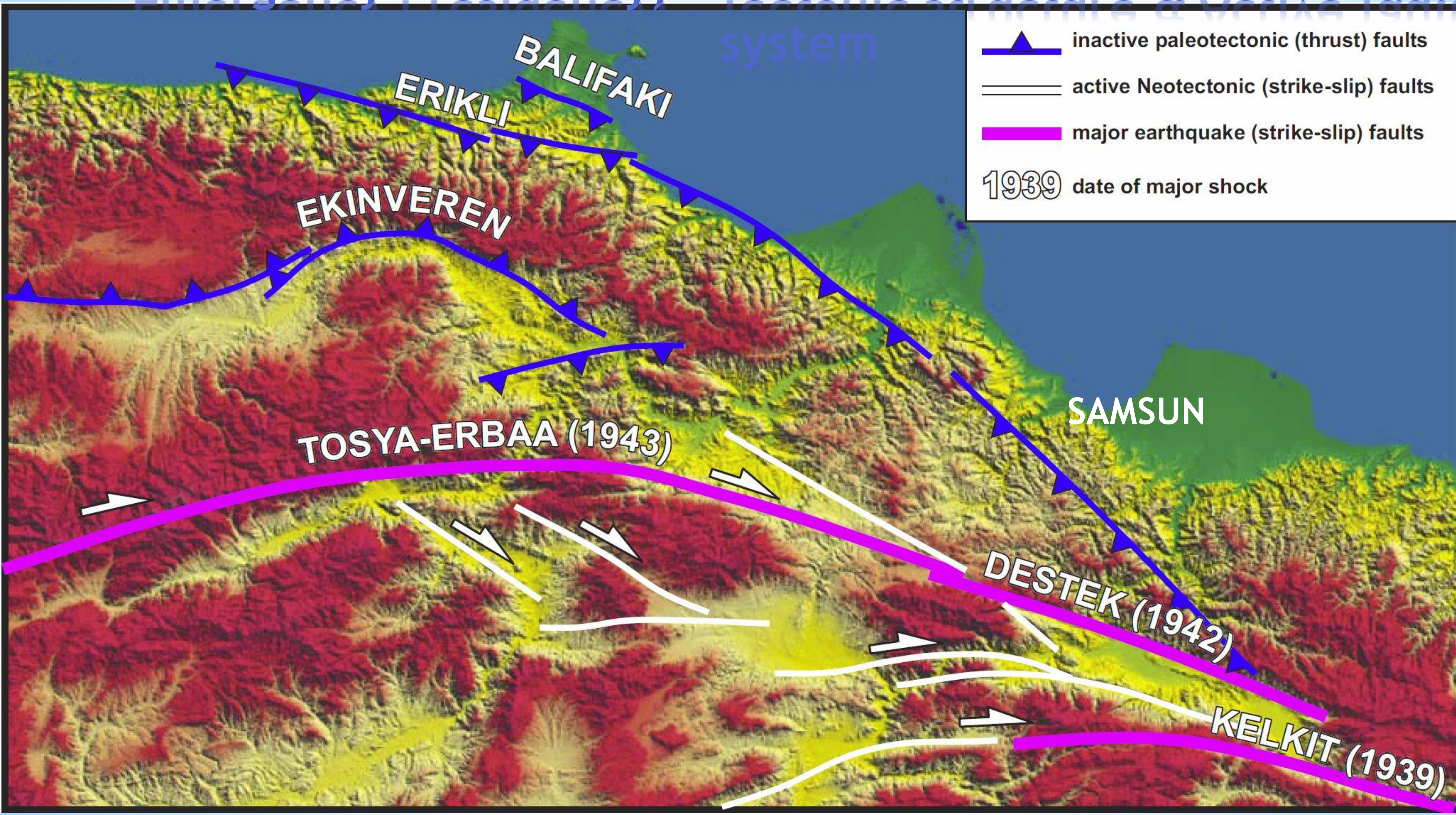
* Deterministic Scenario Earthquake for Marmara Region





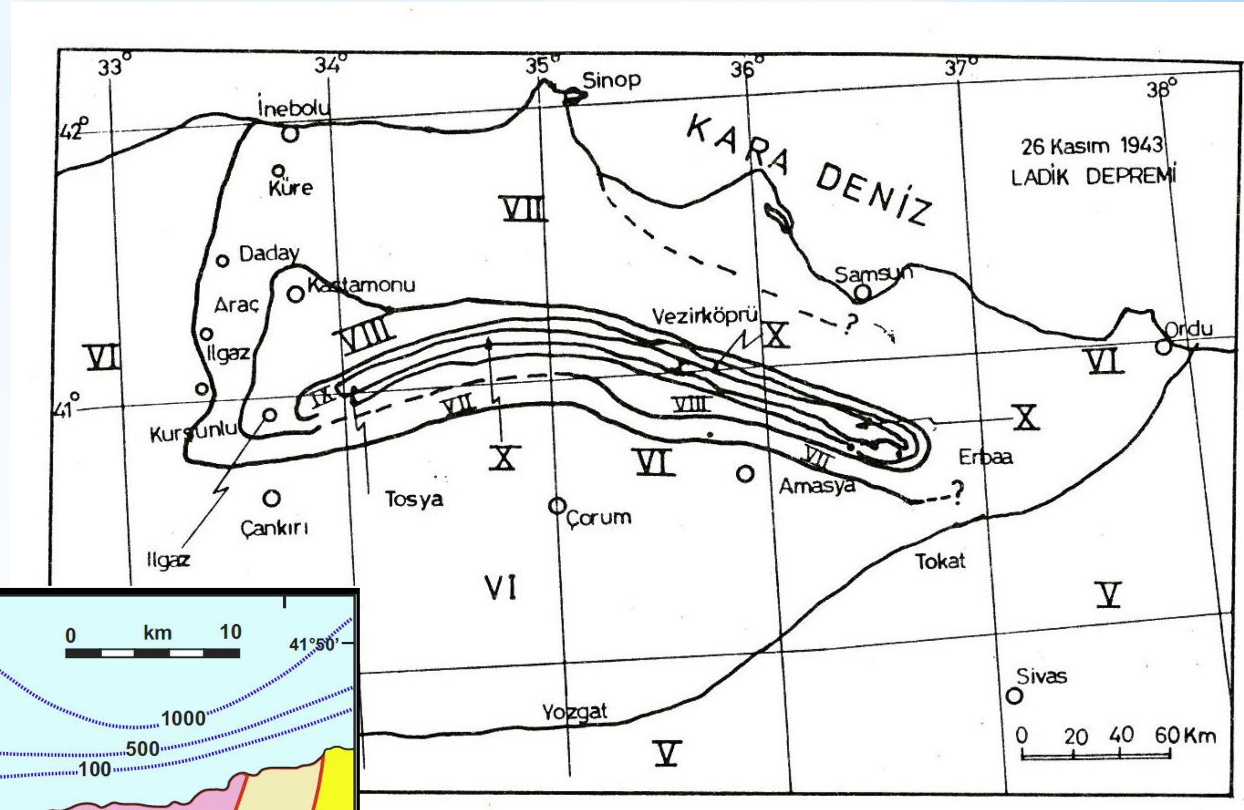


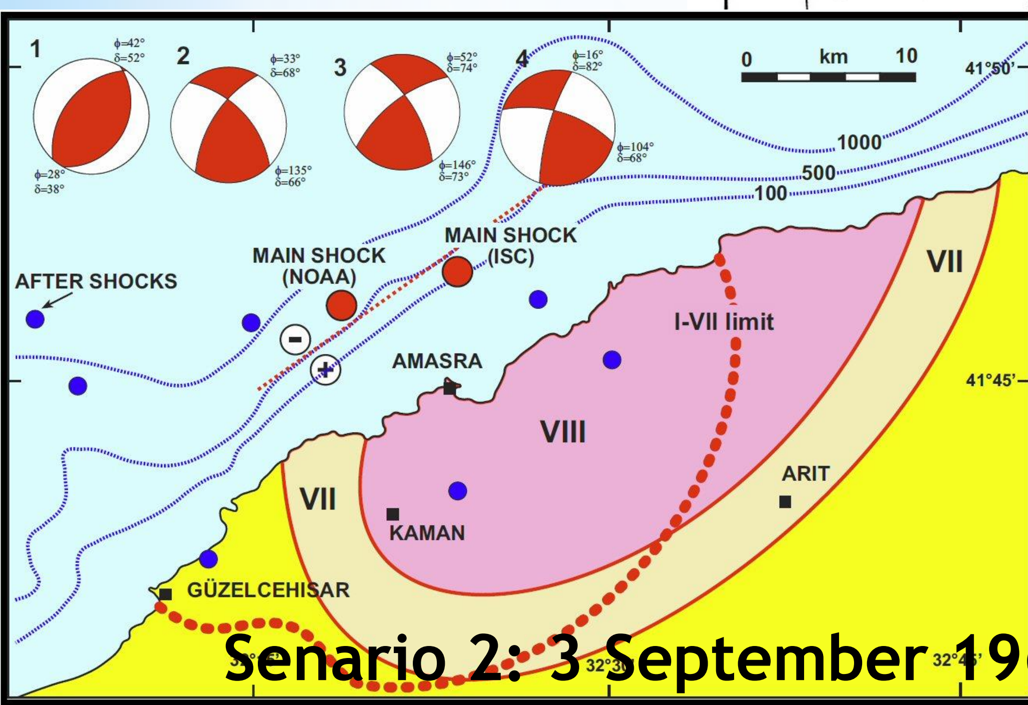
Earthuake Risk Assessment for Samsun (BU& AFAD – Republic of Turkey Prime Ministry Disaster% Emergency Presidency) - Tectonic structure & Active fault system



Kaymakçı, 2009

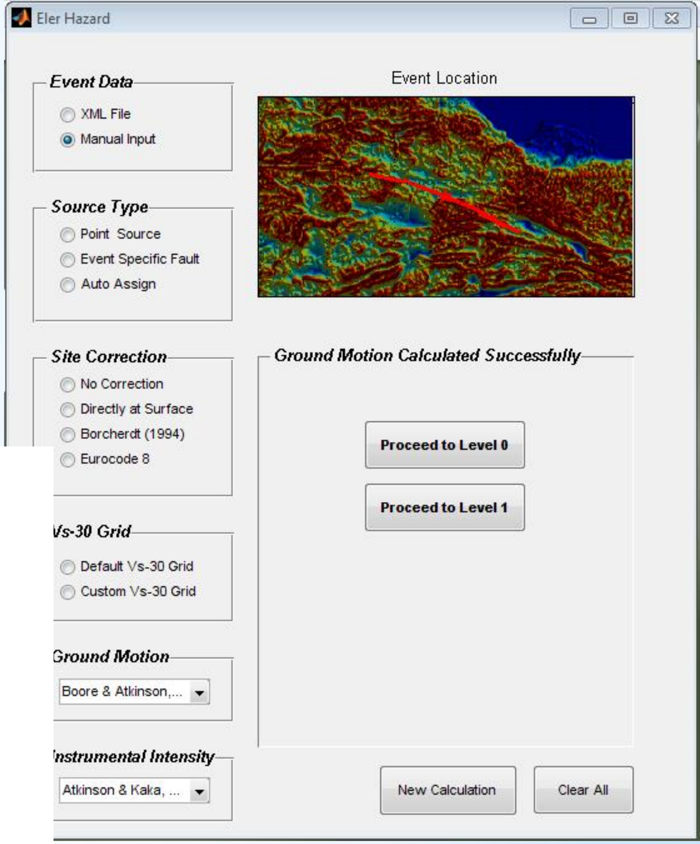
Senario 1 - 26 November 1943 LADİK EQ. Ms =7.2; Mw7.6

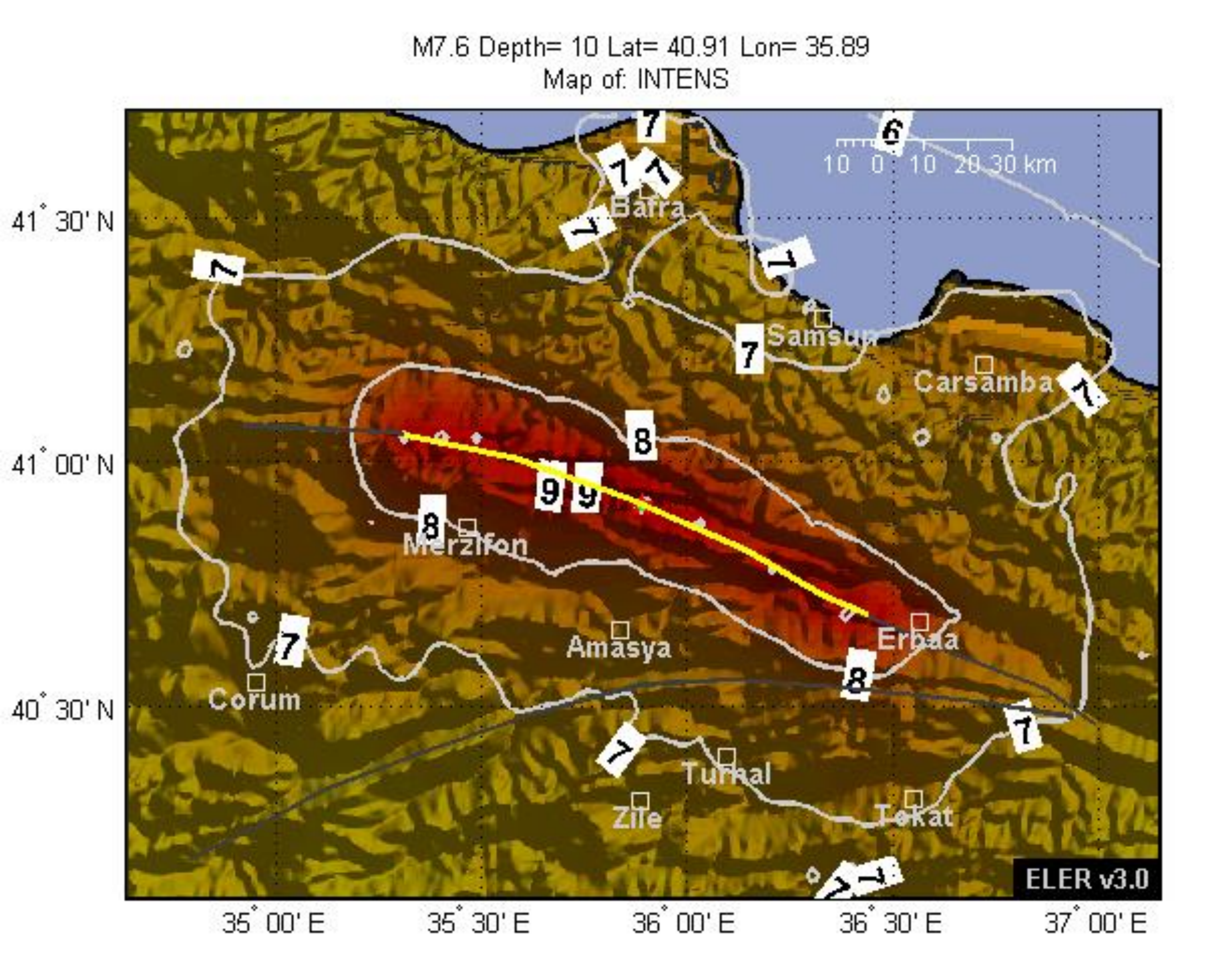




Senario 2: 3 September 1968 BARTIN EQ. Ms=6.6

Senario 1
Southern Samsun - Ladik Eq.
M7.6 - depth 10.0km - Rupture Length =105
Lat: 40.91
Lon: 35.89





Senario 2 –Bartin Eq. M6.6 Intensity Distribution

Project funded by the EUROPEAN UNION

THANK YOU FOR YOUR ATTENTION...

SciNetNatHazPrev - Project Workshop

March 13-14, 2014
Istanbul, Turkey

Venue: Maçka Social Center, Istanbul Technical University Foundation