

Current status of Seismic Hazard Map in Korea

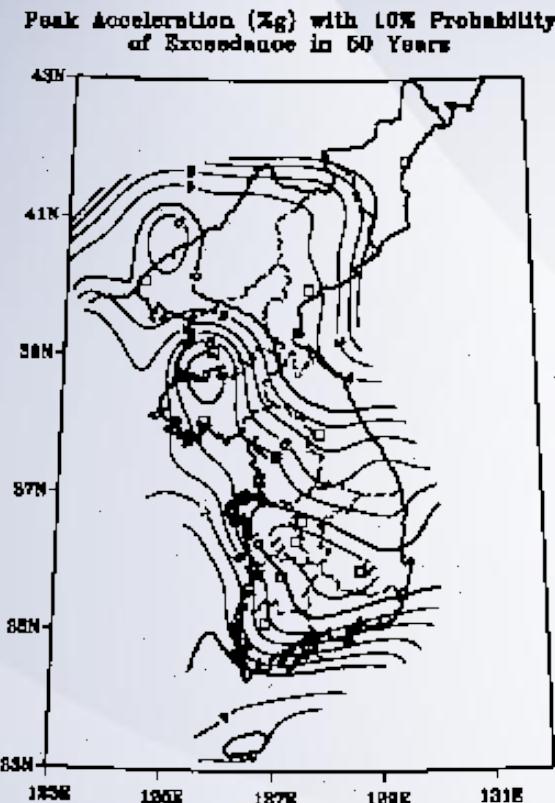
2011. 11. 25.

Jeong Soo JEON

Earthquake Research Center
Korea Institute of Geoscience and Mineral Resources (KIGAM)

Background of Korean PSHM

- 1995. 1. 17. Hyogo EQ. (M 6.9)
- 1995. 12. 6. Countermeasure Act for Natural Disaster
- 1997. 12. 1st PSHM made by Ministry of Construction and Transportation (Supported by Earthquake Engineering Society of Korea)
- 2004 Sumatra EQ. (M 9.1), 2005 Pakistan EQ.(M 7.6)
- 2008. 3. 28. Countermeasure Act for Earthquake Disaster
 - Recommendation for renewal of PSHM every 5 years
 - Recommendation for supplying an Active fault map
- 2009. 3. 1. ~ 2012. 8. 31.
 - Project Title : "Making an Active fault map and Seismic hazard map"
 - Principal Institute : KIGAM
 - Agency : National Emergency Management Agency (NEMA)



PGA(%g) with 10% probability of exceedance in 50 years

Seismic Source

- Only using Historical & Instrumental Earthquake Catalog
- Without considering the geological & geodetical data
- Without considering the incompleteness of historical earthquake catalog

Path

- Because of no adequate seismic attenuation formula for Korean peninsula,
- Using the attenuation formula of US Eastern region
- Without considering the frequency dependency

Site effect

- Without considering the site effect

Annual objects & contents of PSHM Project

	1 st Year (2009)	2 nd Year (2010)	3 rd Year(2011)
Annual objects	<ul style="list-style-type: none"> • Collect whole available seismic data and information • Analysis of the previous research results 	<ul style="list-style-type: none"> • Historical Earthquake Catalog • Collect and sensitivity analysis of input parameters 	<ul style="list-style-type: none"> • Revision of PSHM
Contents	<ul style="list-style-type: none"> • Analysis the present PSHM • Comparison with the various procedures including foreign countries method to make Korean PSHM • Operation of specialist committee to develop future research direction and contents 	<ul style="list-style-type: none"> • Operation of specialist committee & holding the public hearing to make an unified historical earthquake catalog • Sensitivity analysis of the input parameters for PSHM • Collect & Analysis of the data related to the site amplification 	<ul style="list-style-type: none"> • Preparing the Logic tree & input parameter • Operation of specialist committee & holding the public hearing to make an PSHM • Collect & Analysis of the data related to the site amplification
Product		<ul style="list-style-type: none"> • Historical & Instrumental Earthquake Catalog 	<ul style="list-style-type: none"> • National PSHM • Site amplification map for 5 metropolitan cities

1. PSHM Methodology

- Comparison with various PSHM Methodology

2. Sensitivity Analysis of Input Parameters

- Historical & Instrumental EQ Catalog
- Attenuation Formula
- Intensity-Magnitude Conversion Formula
- Depth, etc

3. Calculation of PSHM

- Applying Logic Tree method & Preparing the basic input data/parameter
- Open consensus-building process
 - ; Operation of specialists committee including the variety major
 - ; Holing the public hearing

Evaluation of the Spatially Smoothed Method

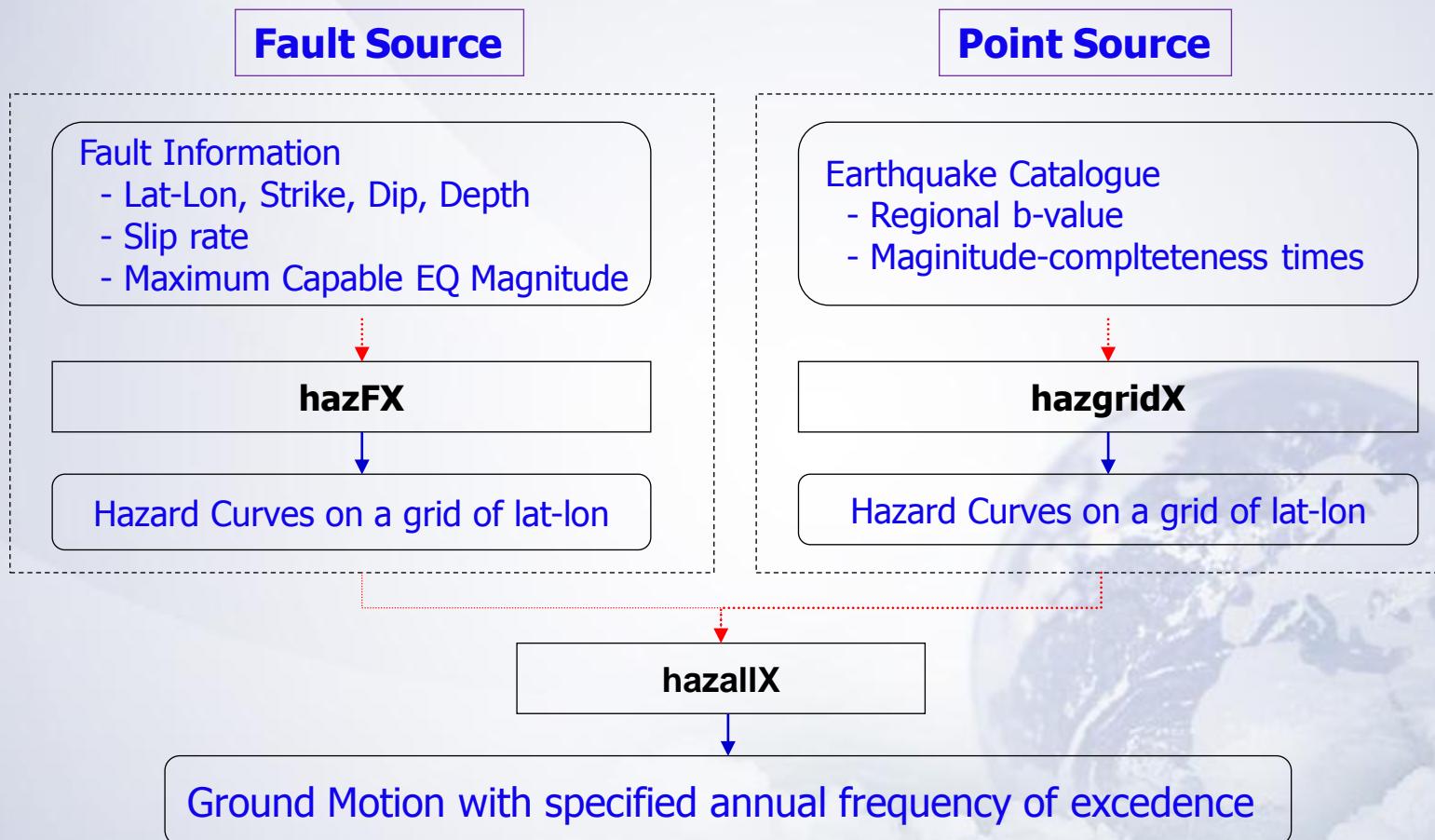
- . Criteria for seismic design(II), Ministration of Construction & Transportation, Earthquake Engineering Society of Korea, 1997.
- . Peterson, M.D., and others, 2008, United States National Seismic Hazard Maps
- . Frankel, A. and others, Documentation for the 2002 Update of the National Seismic Hazard Maps
- . Frankel, A. and others, 1996, National Seismic Hazard Maps

Evaluation of the Seismic Zoninig Method

- . Cornell, C.A., 1968, Engineering seismic risk analysis
- . SSHAC, 1997, Recommendations for PSHM, US Nuclear Regulatory Commission report
- . Klugel, 2009, Probabilistic seismic hazard analysis for nuclear power plants
- . KOPEC, 2003, Probabilistic seismic hazard analysis for SHINWOLSONG 1&2 nuclear power plant site.

1. PSHM Methodology

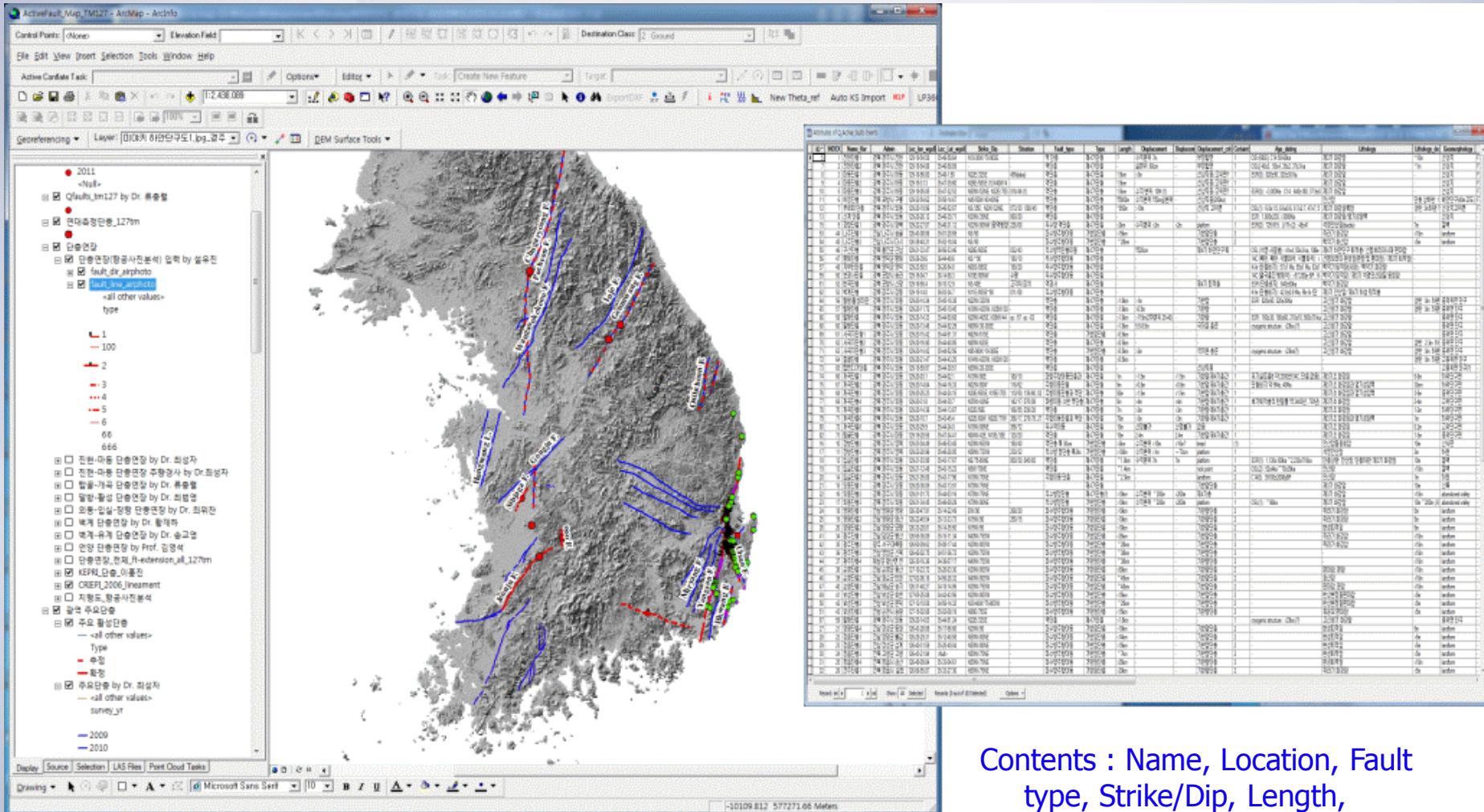
USGS PSHA Method



1. PSHM Methodology

KIGAM

Active Faults D/B

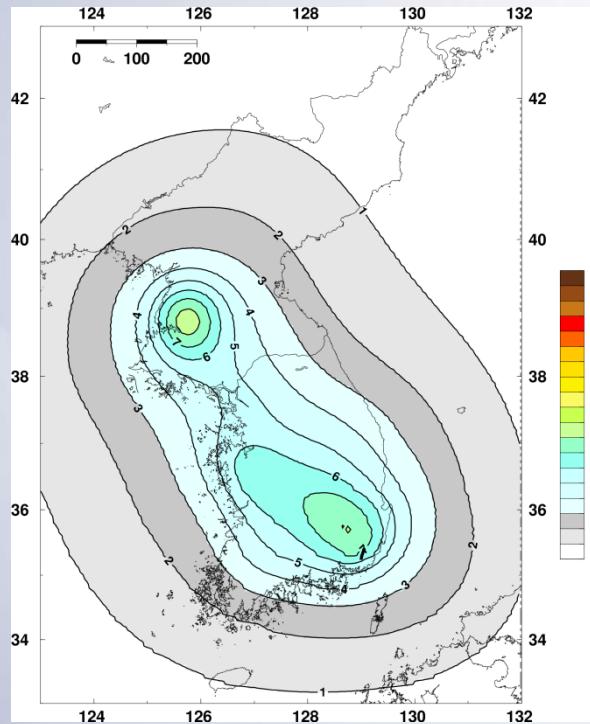


Contents : Name, Location, Fault type, Strike/Dip, Length, Displacement, Age dating, Lithology, etc

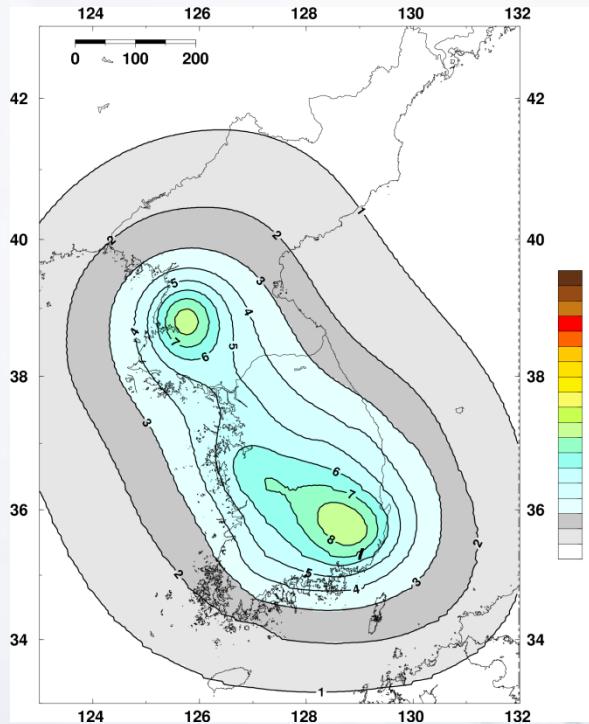
1. PSHM Methodology

Sensitivity Analysis of PSHM using by USGS Method

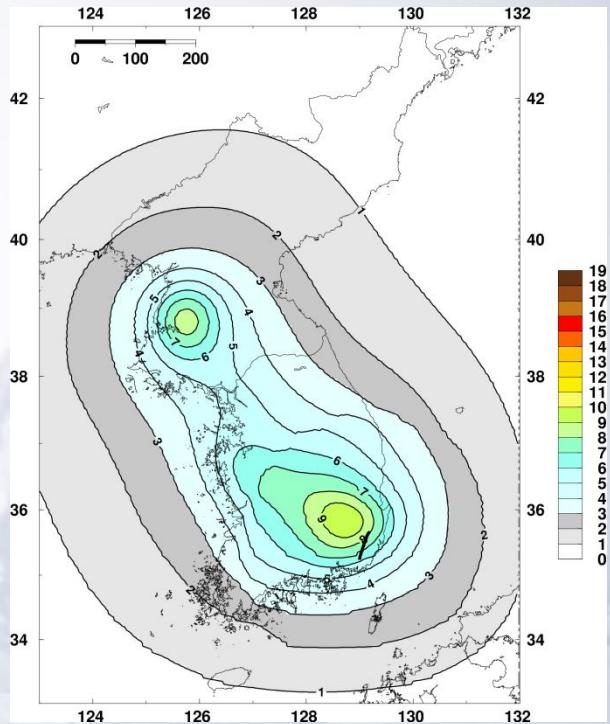
- Slip Rate : 7.0 mm/year



[Length: 10km, Mmax : 6.0]



[Length: 20km, Mmax : 6.5]



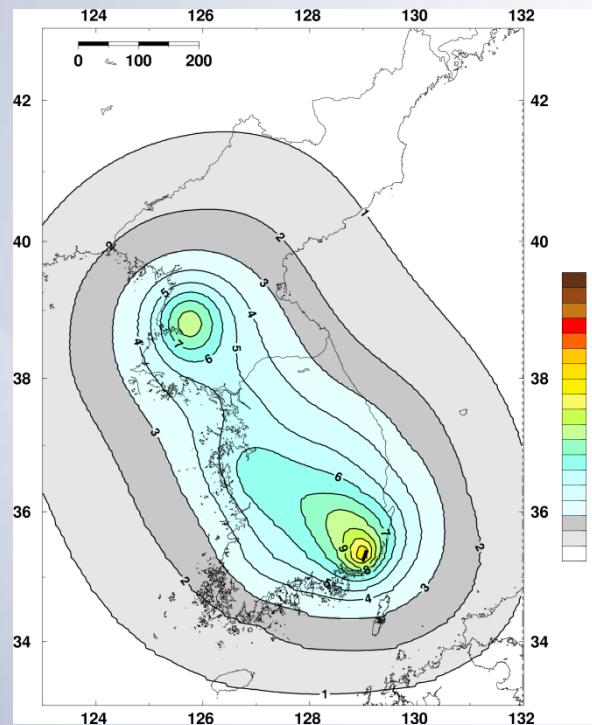
[Length: 50km, Mmax : 7.0]

*PGA[%g] for 50years

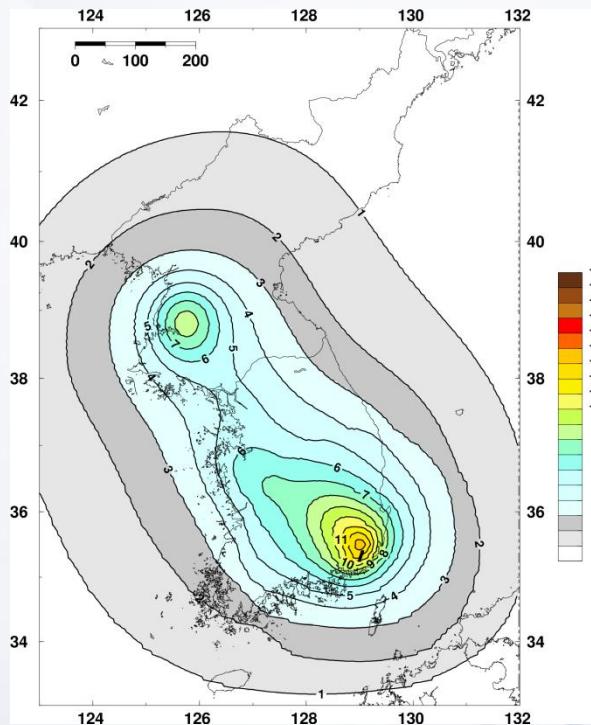
1. PSHM Methodology

Sensitivity Analysis of PSHM using by USGS Method

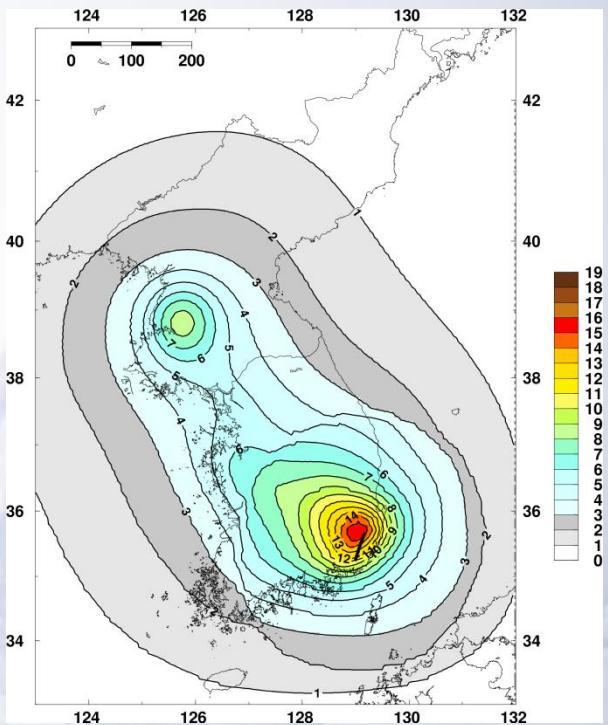
- Slip Rate : 14.0 mm/year



[Length: 10km, Mmax : 6.0]



[Length: 20km, Mmax : 6.5]



[Length: 50km, Mmax : 7.0]

*PGA[%g] for 50years

2. Input Data/Parameters

USGS(2008)

- ; combine earthquakes from several (reformatted) source catalogs, choose one preferred record for each event that is listed more than once, and decluster to remove aftershocks and foreshocks
- Western North America(WNA) Catalog
 - Central & Eastern North America(CENA) Catalog

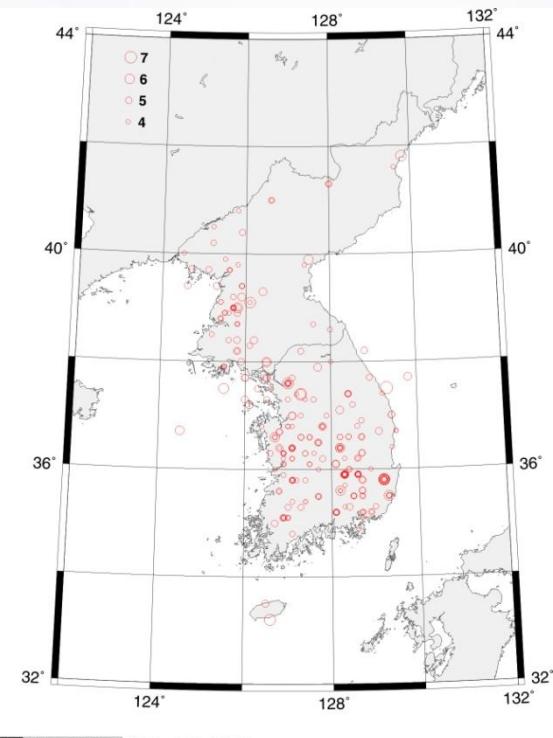
Japan NIED(2009)

- ; Chronological Scientific Tables(自然科學研究機構 國立天文臺 編)
- ~1884 : Tatsuo Usami Catalog(宇佐美龍夫)
 - 1885~1925 : Tokuji Utsu(宇津德治)
 - 1926~ : JMA

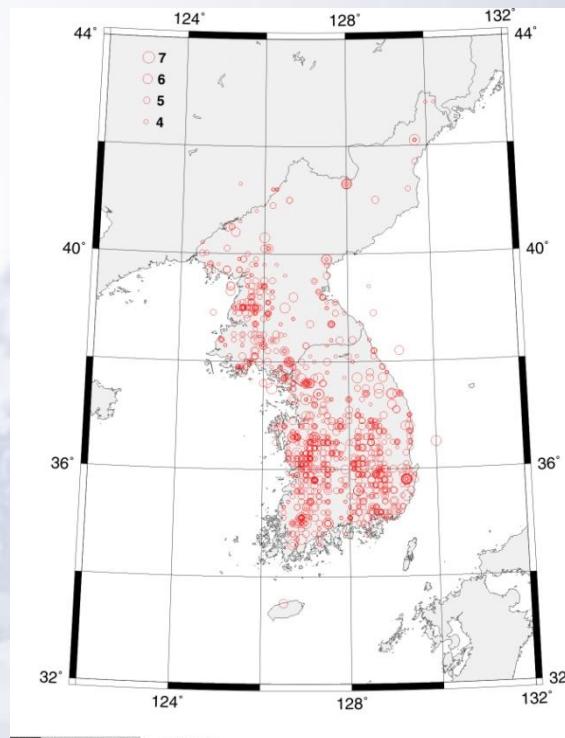
2. Input Data/Parameters

Collection & Analysis of available earthquake list and research results

- 嚴相鎬(1978), 金昭九(1978)
- 鄭鳳一(1981)
- 韓國動力資源研究所(1983)
- 朝鮮地震研究所(1984, 1987)
- 李基和(1985, 1998, 2003, 2005, 2006)
: 2,186 historical earthquake list
- 慶在福(1989, 2009)
: 2,113 historical EQ. List
- 建設交通部(1997)
- 國立防災研究所(1999)
- 原子力安全研究院(2000)



朝鮮地震研究所(1987)



李基和外(2006)

2. Input Data/Parameters

KIGAM

Historical EQ D/B Construction

- Collect all available lists & Publications
- Collect EQ information from National & University D/B related to historical record
- Adjacent countries D/B and List

Microsoft Excel - 역사지진총합_2010-15.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	
1994	1523	1681-6-22	속종 07/05/07(기준)			1681-5-7	37.9	127.2																				
1995	1524	1681-6-24	속종 07/05/09(기준)			1681-5-9	36.5	127.1																				

Picture 5

Microsoft Excel - 역사지진총합_2010-15.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	
1994	1523	1681-6-22	속종 07/05/07(기준)			1681-5-7	37.9	127.2																				
1995	1524	1681-6-24	속종 07/05/09(기준)			1681-5-9	36.5	127.1																				

Microsoft Excel - 역사지진총합_2010-15.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1563	1675-12-12	39.7	125.8			1675	12	39.8	125.8	II~IV	3.5																
1564	1495	1675-12-15				1675	12	39.8	125.8	II~IV	3.5																
1565	1496	1676-5-7				1676	5	36.5	127.1	V	4.7																
1566	1497	1676-5-22	39.1	125.3		1676	5	32.8	125.3	III	3.5																
1567	1498	1676-5-23	38.5	127.1		1676	6	29	36.8	127.1	II~IV	3.5															
1568	1499	1676-7-1	37.1	125.9	5		1676	7	37.1	125.9	II~IV	3.5															
1569	1500	1677-8-14	40	124.6		1677	8	14	40.0	124.6	V	4.1															
1570	1501	1677-8-18				1677	9	14	36.1	127.5	IV	4.1															
1571	1502	1677-9-9				1677	10	14	38.5	125.8	V	5.2															
1572	1503	1678-2-11				1678	1	18	36.0	127.1	V	4.1															
1573	1504	1678-2-15				1678	2	17	37.7	128.5	VI	5.2															
1574	1505	1678-7-17	37.6	128.5		1678	7	17	37.7	128.5	VI	5.2															
1575	1506	1678-9-29	37.5	126.9		1678	9	29	37.6	127.0	II~IV	3.5															
1576	1507	1679-1-1	35.7	127.5		1679	1	35	37.5	127.5	IV	4.1															
1577	1508	1679-1-1				1679	2	35	37.5	127.5	IV	4.1															
1578	1509	1679-6-29	36.2	127.1		1679	6	29	36.2	127.1	II~IV	3.5															
1579	1510	1679-7-11	36.4	127.2		1679	7	11	36.3	127.1	IV	4.1															
1580	1511	1680-1-31				1680	2	15	39.4	126.0	IV	4.1															
1581	1512	1680-2-15	39.4	126		1680	6	15	35.0	127.5	V	4.7															
1582	1513	1680-5-15				1680	7	15	35.0	127.5	II~IV	3.5															
1583	1514	1681-1-6	36.6	127.5		1681	2	1	35.2	127.4	V	4.7															
1584	1515	1681-2-1	35.3	127.4		1681	5	19	35.1	126.8	V	4.7															
1585	1516	1681-5-19	35.1	126.8		1681	6	12	35.1	126.9	VII~IX	6.7															
1586	1517	1681-6-12	37.6	126.9	5	1681	6	12	35.1	126.9	VII~IX	6.7															
1587	1518	1681-6-15	37.9	126.5		1681	6	15	38.0	126.6	VII~IX	6.7															
1588	1519	1681-6-17	37.9	126.5		1681	6	17	38.0	126.6	VII~IX	6.7															
1589	1520	1681-6-18	37.3	127.2		1681	6	18	37.4	127.3	II~IV	3.5															
1590	1521	1681-6-19	37.7	127.6		1681	6	19	37.7	126.5	II~IV	3.5															
1591	1521	1681-6-19	37.7	126.5		1681	6	20	37.7	127.0	V	5.2															
1592	1522	1681-6-20	37.7	126.5		1681	6	21	36.8	127.0	VII	6.3															
1593	1523	1681-6-21	37.9	127.2		1681	6	22	36.7	127.2	VII	6.3															
1594	1524	1681-6-24	35.6	127.1		1681	6	24	36.6	127.2	VII	5.8															
1595	1525	1681-6-26	37.2	128.6	8	1681	6	26	37.4	129.0	VII~IX	6.7															
1596	1526	1681-6-27	37.6	128.6	8	1681	6	27	37.4	129.0	VII	5.8															
1597	1527	1681-6-29				1681	6	29	37.1	129.1	VII	5.2															
1598	1528	1681-7-1				1681	7	1	35.1	126.8	VII	5.2															
1599	1529	1681-7-7				1681	7	13	37.1	129.1	VII	5.2															
1600	1530	1681-7-13				1681	7	13	36.7	128.7	V	4.7															
1601	1531	1681-7-14				1681	7	14	36.7	128.7	V	4.7															
1602	1532	1681-7-15				1681	7	15	36.7	128.8	V	4.7															
1603	1533	1681-7-16				1681	7	16	36.7	128.7	V	4.7															
1604	1534	1681-7-17				1681	7	17	36.7	128.7	V	4.7															
1605	1535	1681-7-18				1681	7	18	36.7	128.7	V	4.7															
1606	1536	1681-7-19				1681	7	19	36.7	128.7	V	4.7															
1607	1537	1681-7-20	37.3	127		1681	7	21	31	127.1	VII	4.7															
1608	1538	1681-8-1	37.5	126.9		1681	8	1	37.2	127.1	VII	4.7															
1609	1539	1681-8-10	36.8	129		1681	8	10	36.8	129.4	VII	5.8															
1610	1540	1681-12-21	37.4	129.1		1681	12	20	37.4	129.1	V	5.2															
1611	1541	1681-12-21	35.9	127.8		1681	12	21	36.5	130.0	VII	6.4															
1612	1542	1681-12-23	36.9	129.4		1681	12	23	36.9	129.4	V	4.1															
1613	1543	1681-12-24	36.9	129.4		1682	1	23	36.8	127.2	V	4.1															
1614	1544	1682-1-23	36.8	127.1	5	1682	1	23	36.8	127.2	V	4.1															
1615	1545	1682-2-14	38.7	125.7		1682	2	14	38.7	125.8	V	4.7															
1616	1546	1682-3-19	37.1	128.9	8	1682	3	19	37.4	128.4	V	5.2															
1617	1547	1682-6-27	35.9	128.6	8	1682	5	27	35.9	128.6	VII	4.7															
1618	1548	1682-6-27	35.3	128.4		1682	5	27	35.8	127.6	VII	4.5															

Picture 5

Microsoft Excel - 역사지진총합_2010-15.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	
1994	1523	1681-6-22	속종 07/05/07(기준)			1681-5-7	37.9	127.2																				
1995	1524	1681-6-24	속종 07/05/09(기준)			1681-5-9	36.5	127.1																				

(주)경기도지정부, 江陰 蘇州 三陟 刺史 11日二日懸 連有地圖 (5.25正書)

NUM

2. Input Data/Parameters

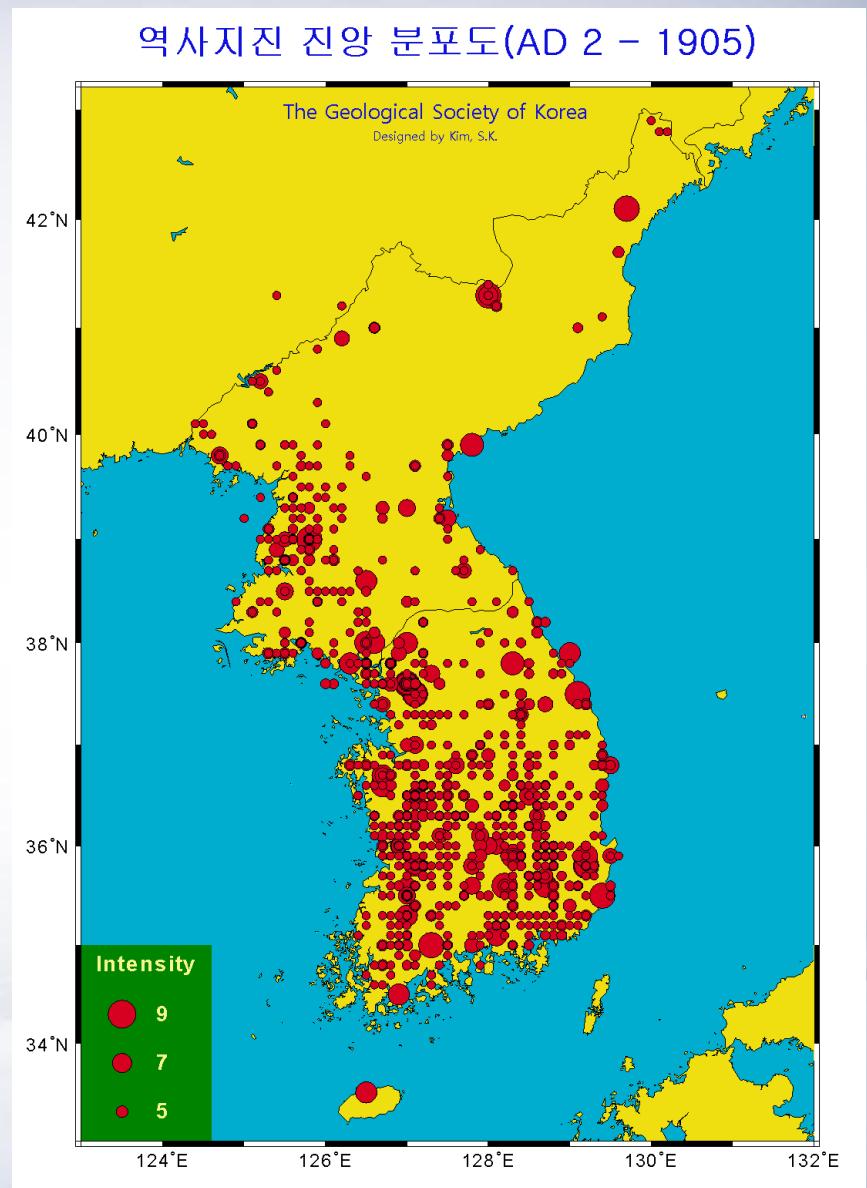
Setup specific criteria for

- Unified Event List
- Epicenter determination
- Intensity determination
 - ; Felt-area–Intensity relationship
 - ; according to the description for Human & Animal Building (castle, fortress, house, wall, etc)
 - Natural phenomenon (surface rupture, shaking, liquefaction, etc)

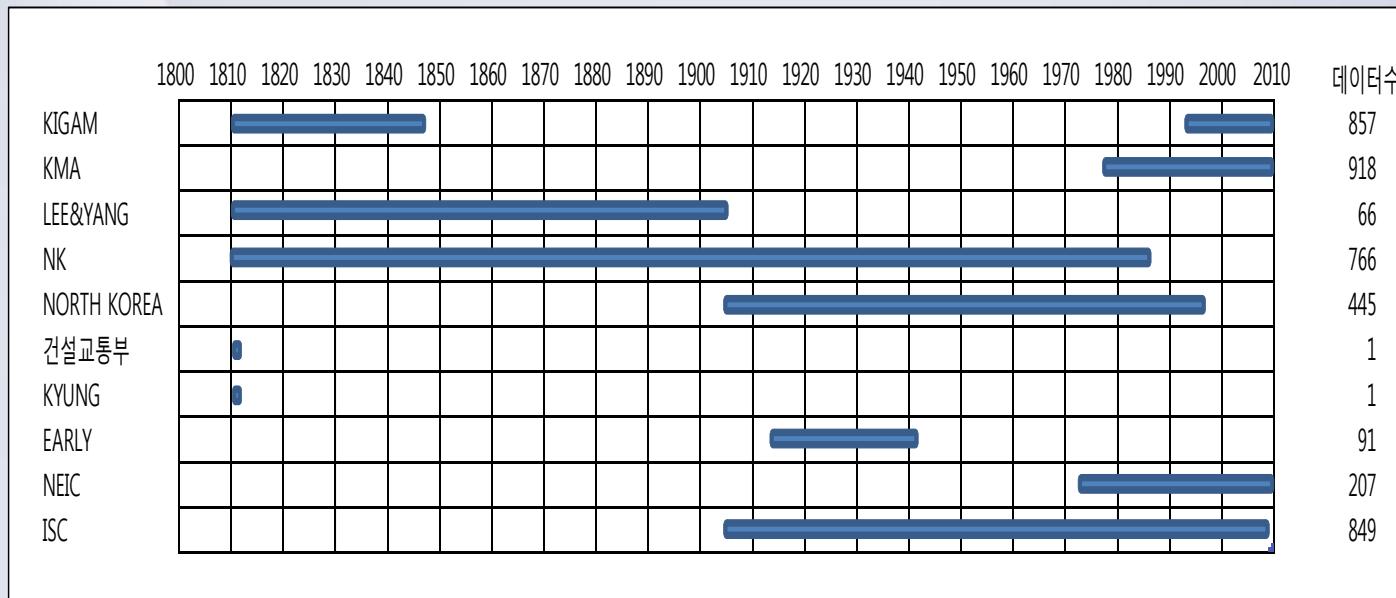
Operation of specialist committee

- Confirmation above criterion
- Review the final historical EQ catalog
- Revaluation for the 64 big historical EQ

Holding the public hearing to make an unified(acceptable?) historical earthquake catalog

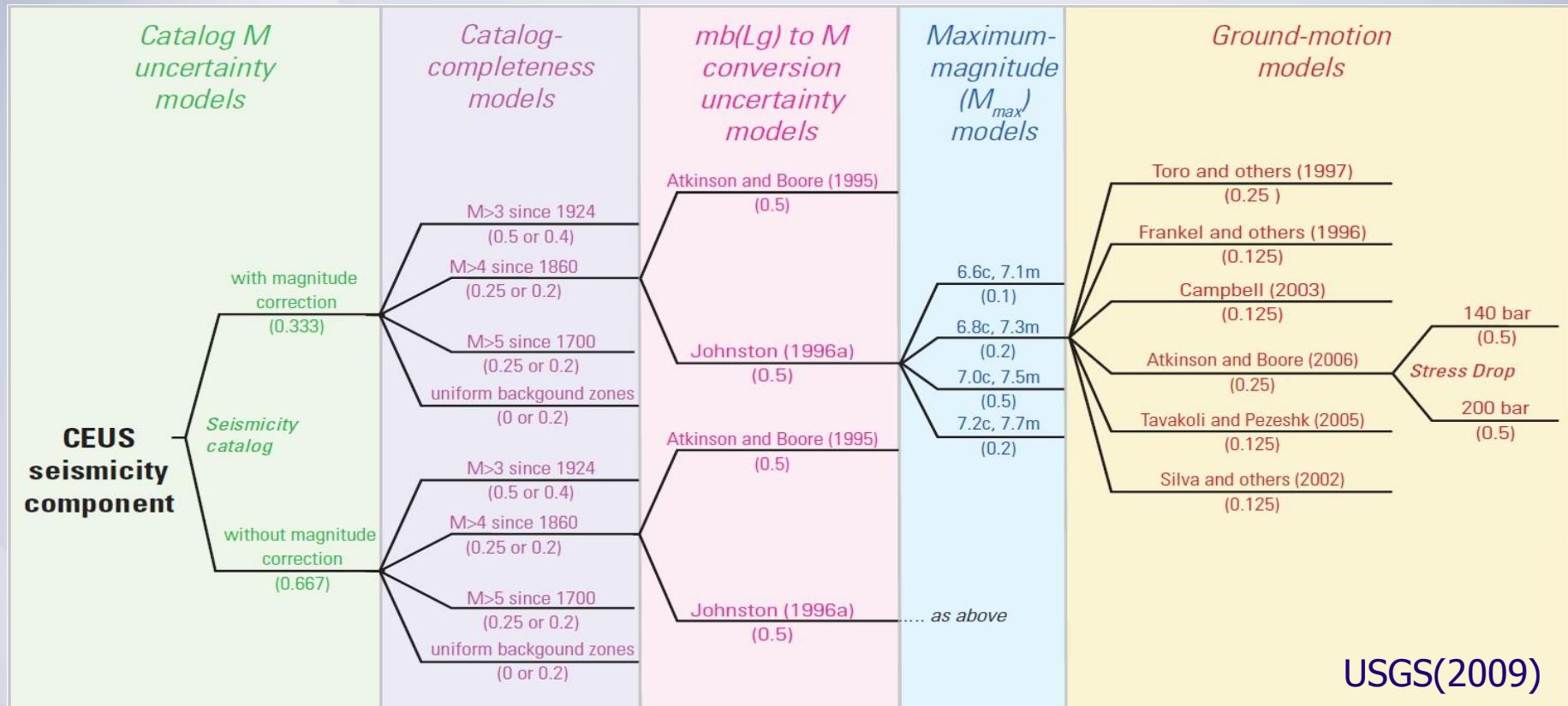


2. Input Data/Parameters



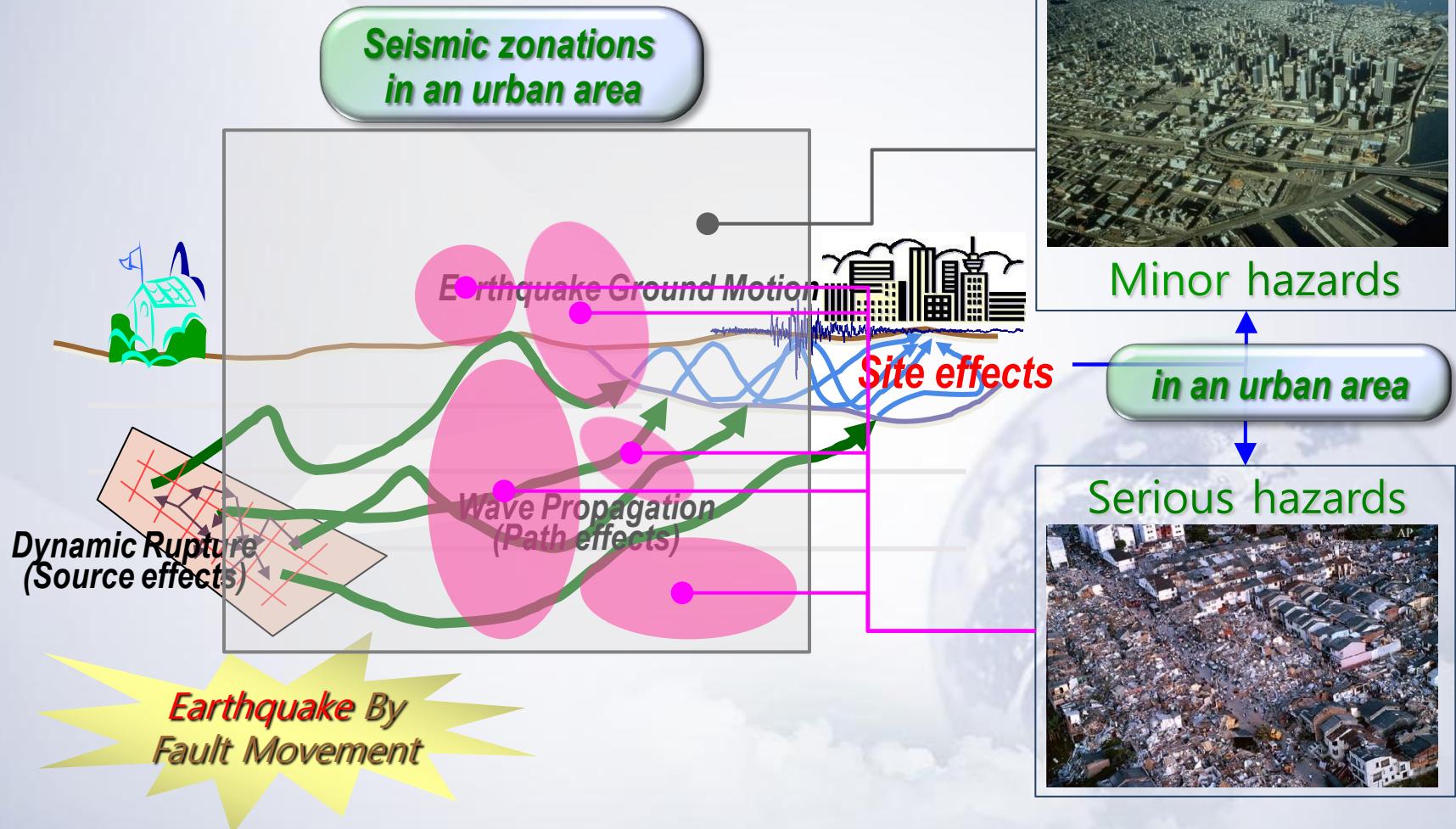
Organization	No. of Events	Duration
KIGAM	2437	02-08 ~ 2010-11-28
KMA	918	1978-08-30 ~ 2010-12-20
LEE&YANG	1928	02-08 ~ 1904-03-23
NK	1057	27-10 ~ 1985-12-23
NORTH KOREA	445	1905-08-25 ~ 1996-11-17
Ministry of Construction	389	27-00 ~ 1810-01-20
KYUNG	449	27-00 ~ 1810-02-19
EARLY	91	1913-05-12 ~ 1941-12-15
NEIC	207	1973-09-10 ~ 2009-08-10
ISC	849	1905-08-25 ~ 2009-05-01

3. PSHM Calculation



- Construction of specialist committee to conduct the logic tree evaluation, consisted of various major field
- Now, finalizing the logic tree & preparing input data and parameters

4. Site Amplification



4. Site Amplification

Current Site Classification Scheme in Most Codes

- Western Region of US

Soil Profile Type	Generic Description	$\overline{V_S}$ (Vs30) (m/s)	Average Soil Prop		Short-Period		Mid-Period	
			Z = 0.11	Z = 0.07	Z = 0.11	Z = 0.07		
			C_a	F_a	C_v	F_v	C_v	F_v
S _A (Site Class A)	Hard Rock	> 1,500	0.09	0.82	0.05	0.71	0.09	0.82
S _B (Site Class B)	Rock	760 - 1,500	0.11	1.00	0.07	1.00	0.11	1.00
S _C (Site Class C)	Very Dense and Soft Rock	360 - 760	0.13	1.18	0.08	1.14	0.18	1.64
S _D (Site Class D)	Stiff Soil	180 - 360	0.16	1.45	0.11	1.57	0.23	2.09
S _E (Site Class E)	Soft Soil	< 180	0.22	2.00	0.17	2.43	0.37	3.36
S _F (Site Class F)	Soil Requiring Site-specific Evaluation							

C : Seismic Coefficient

Short Period : 0.1 ~ 0.5 sec,

F : Site Amplification Factor

Mid-Period : 0.4 ~ 2.0 sec

Z : Seismic Zone Factor

4. Site Amplification

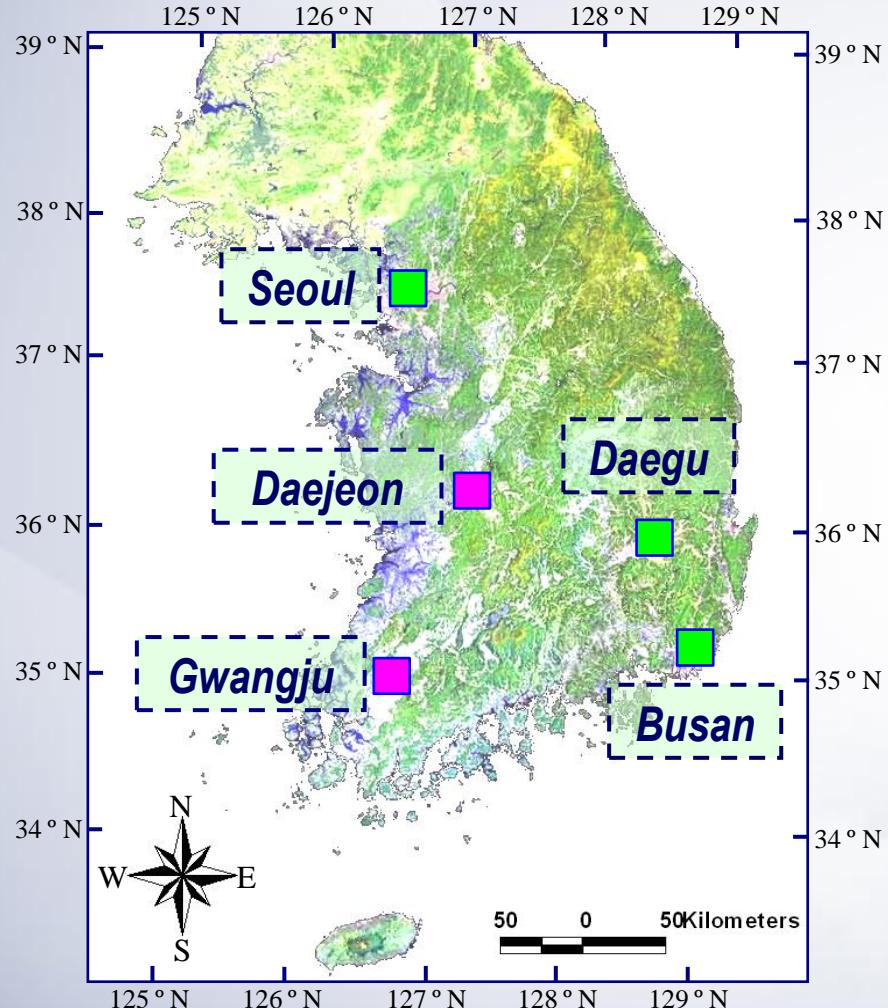
Modification of Site Classification

$$T_G = 4 \sum_{i=1}^n \frac{D_i}{V_{Si}}$$

Generic Description	Site Class	Criteria		Site Coefficients	
		V_{S30} (m/s)	T_G (s)	F_a	F_v
Rock	B	> 760	< 0.06	1.00	1.00
Weathered Rock and Very Stiff Soil	C	C1	> 620	< 0.10	1.28
		C2	> 520	< 0.14	1.45
		C3	> 440	< 0.20	1.65
		C4	> 360	< 0.29	1.90
Intermediate Stiff Soil	D	D1	> 320	< 0.38	2.08
		D2	> 280	< 0.46	2.26
		D3	> 240	< 0.54	2.48
		D4	> 180	< 0.62	2.86
Deep Soft Soil	E	≤ 180	≥ 0.62	1.50	2.00

4. Site Amplification

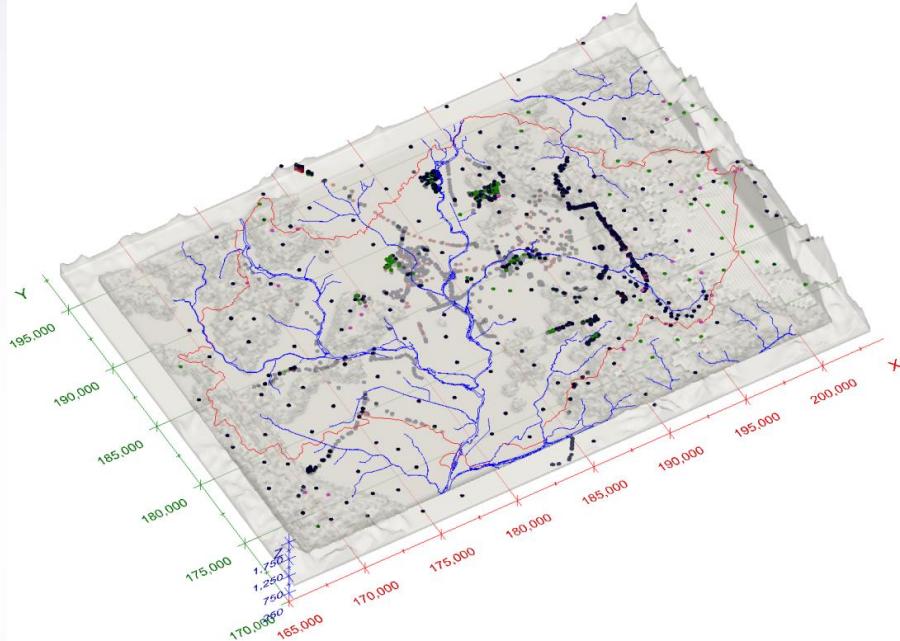
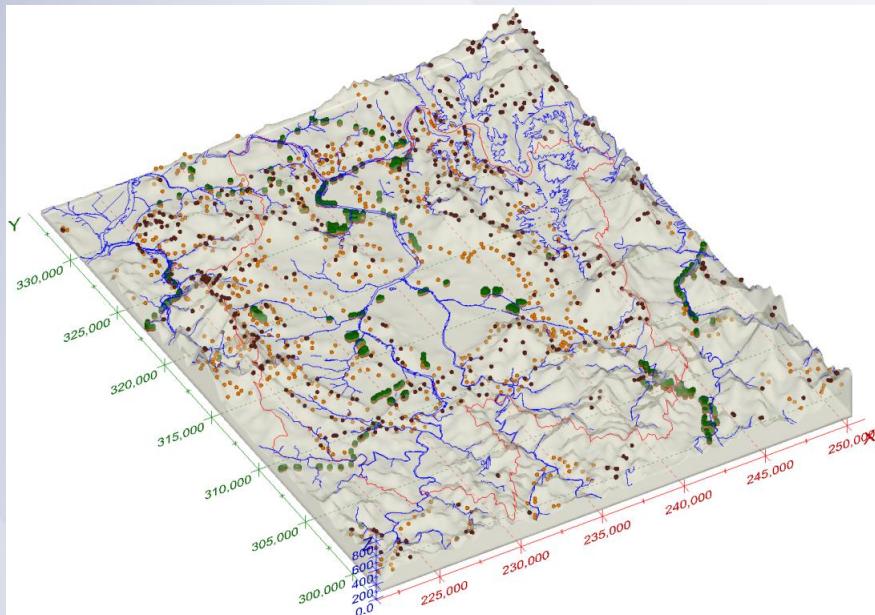
For five metropolitan cities, Seoul, Daejeon, Gwangju, Daegu, Busan



- Building the geotechnical DB composed of the existing borehole drilling data and surface geo-knowledge data
- Implementing the GIS-based geotechnical information system for spatial geotechnical (geo-) layers using the geotechnical DB
- Creating a variety of spatial zoning maps for quantifying the site effects in terms of the site period within GIS-based tools
- Annual Target Area
 - ✓ 2010 : Daejeon, Gwangju
 - ✓ 2011 : Seoul, Daegu, Busan

4. Site Amplification

Geotechnical database (2010)

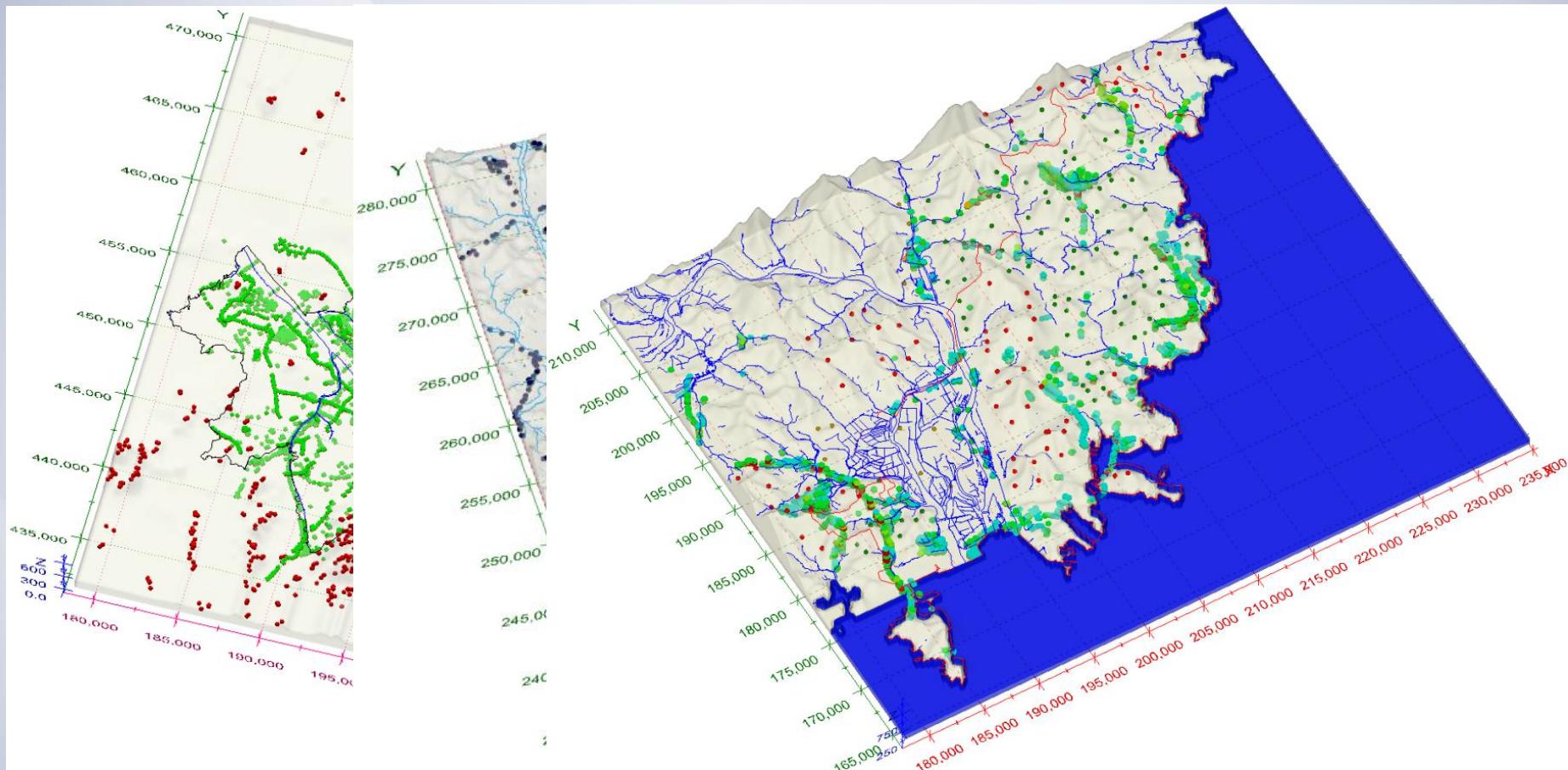


Daejeon : Collecting more than 1,300 existing Borehole drilling data and acquiring about 300 surface goe-knowledge data for each target area

Kwangju : More than 1,900 borehole data and about 300 surface data

4. Site Amplification

Geotechnical database (2010)



Seoul : More than 10,800 borehole data & about 900 surface data

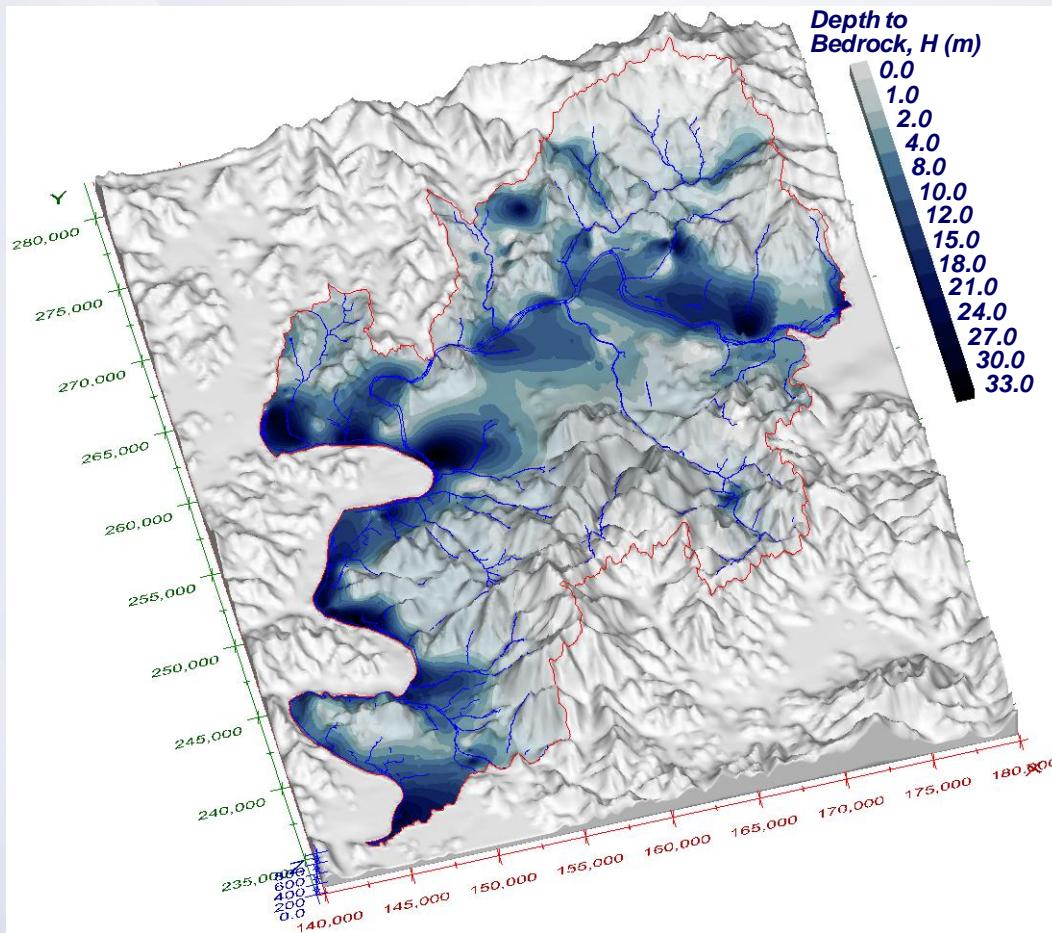
Daegu : More than 1,800 borehole data and about 300 surface data

Busan : More than 2,900 borehole data and about 200 surface data

4. Site Amplification

Depth to bedrock in Daegu

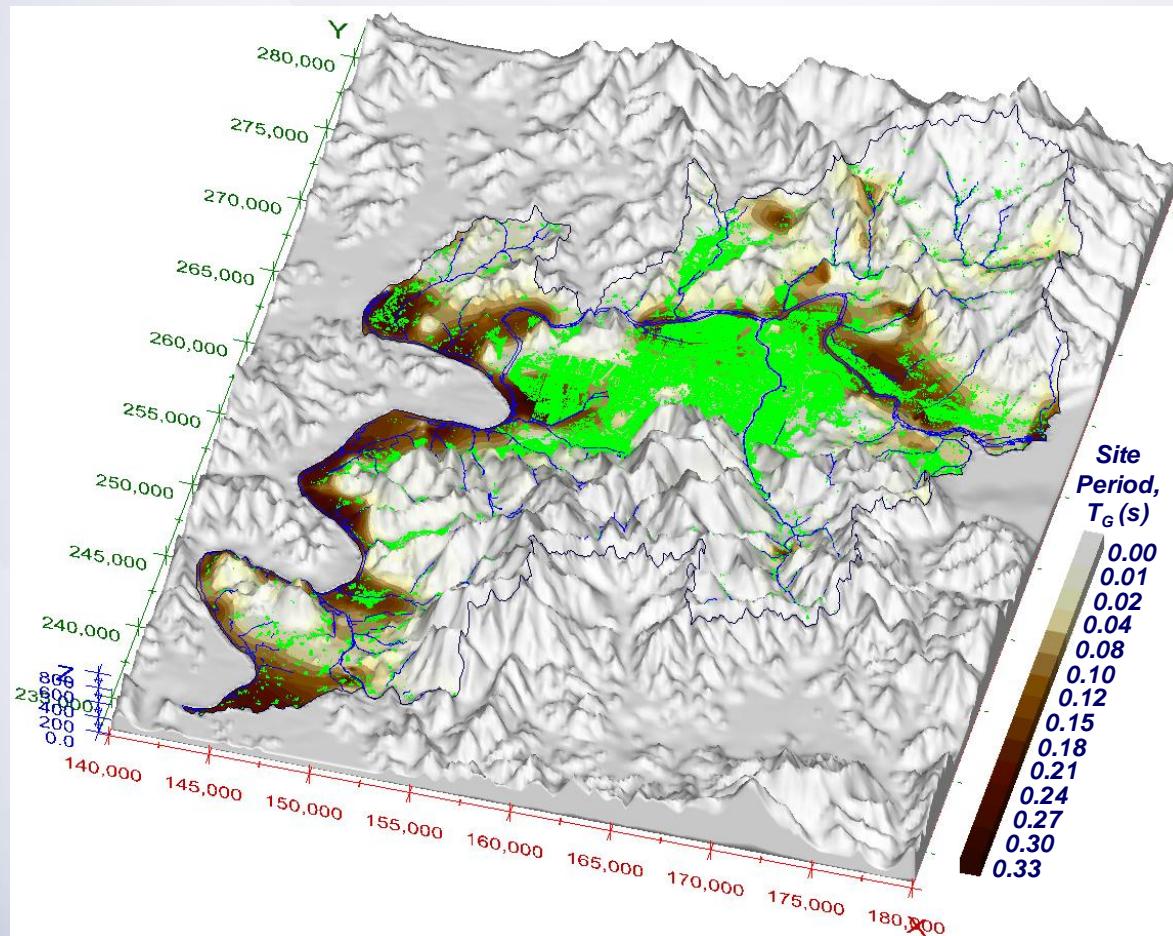
- Maximum depth of deeper than 30m in Daegu basin



4. Site Amplification

Predominant site period in Daegu

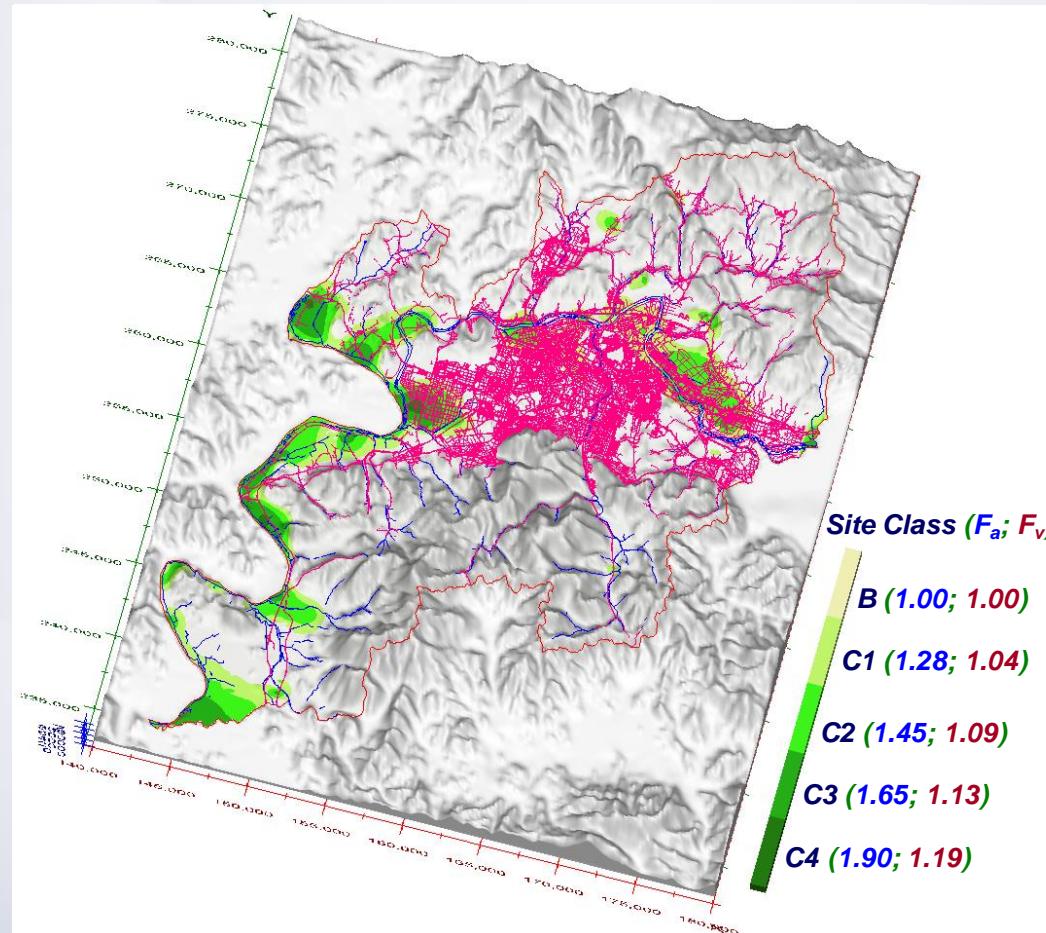
- 0.20 to 0.35 sec in plain and valleys
(vulnerability for 2 to 4 storied buildings during EQ)
- 100m x 100m Grid



4. Site Amplification

Site classes based on predominant site period in Daegu

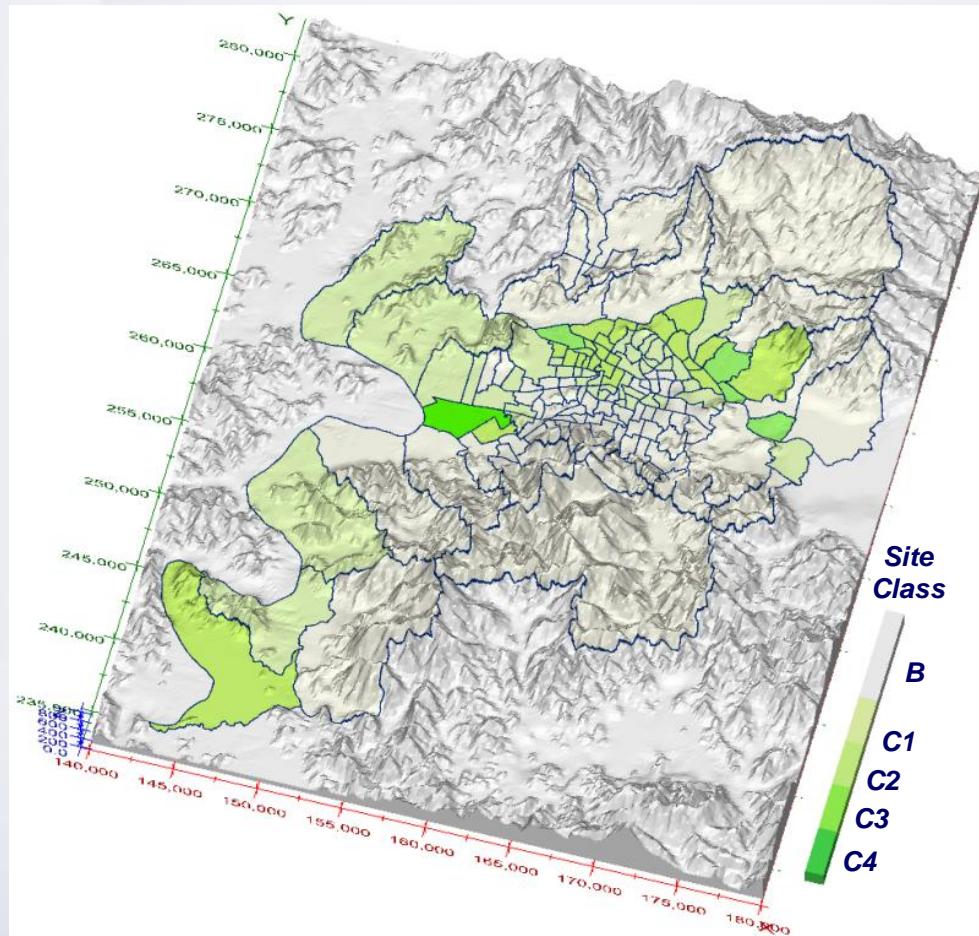
- Site classes C(C1 to C4) in plains
- Max 1.90 for Fa and 1.19 for Fv => Significant Seismic amplification



4. Site Amplification

Representative site classes for rapid response in Daegu

- Site classes averaged with administrative sub-unit
- Site classes C(C1 to C4) in most sub-unit => Significant seismic amplification



Global Seismic Hazard Assessment Program

– Region 8 Eastern Asia

