USGS Real-time Earthquake Shaking & Impact Estimation

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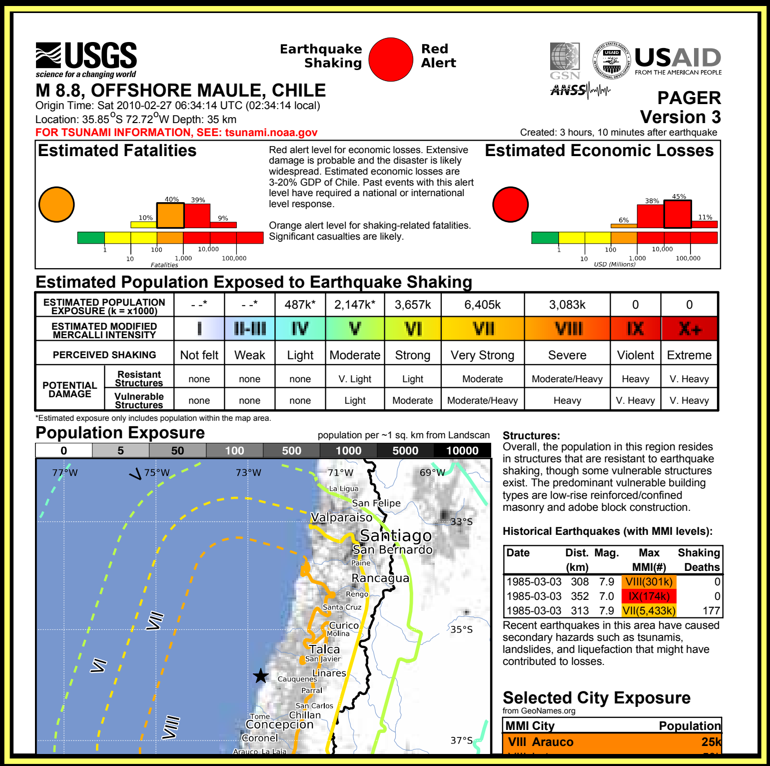
USGS *National Earthquake Information Center*

PAGER

Prompt Assessment of Global Earthquakes for Response



USGS science for a changing world

Earthquake Shaking Red Alert

USAID FROM THE AMERICAN PEOPLE

M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)

Location: 35.85°S 72.72°W Depth: 35 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 3

Created: 3 hours, 10 minutes after earthquake

Estimated Fatalities

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

0 5 50 100 500 1000 5000 10000

Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are low-rise reinforced/confined masonry and adobe block construction.

Historical Earthquakes (with MMI levels):

Date	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1985-03-03	308	7.9	VIII(301k)	0
1985-03-03	352	7.0	IX(174k)	0
1985-03-03	313	7.9	VII(5,433k)	177

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and liquefaction that might have contributed to losses.

Selected City Exposure
from GeoNames.org

MMI	City	Population
VIII	Arauco	25k

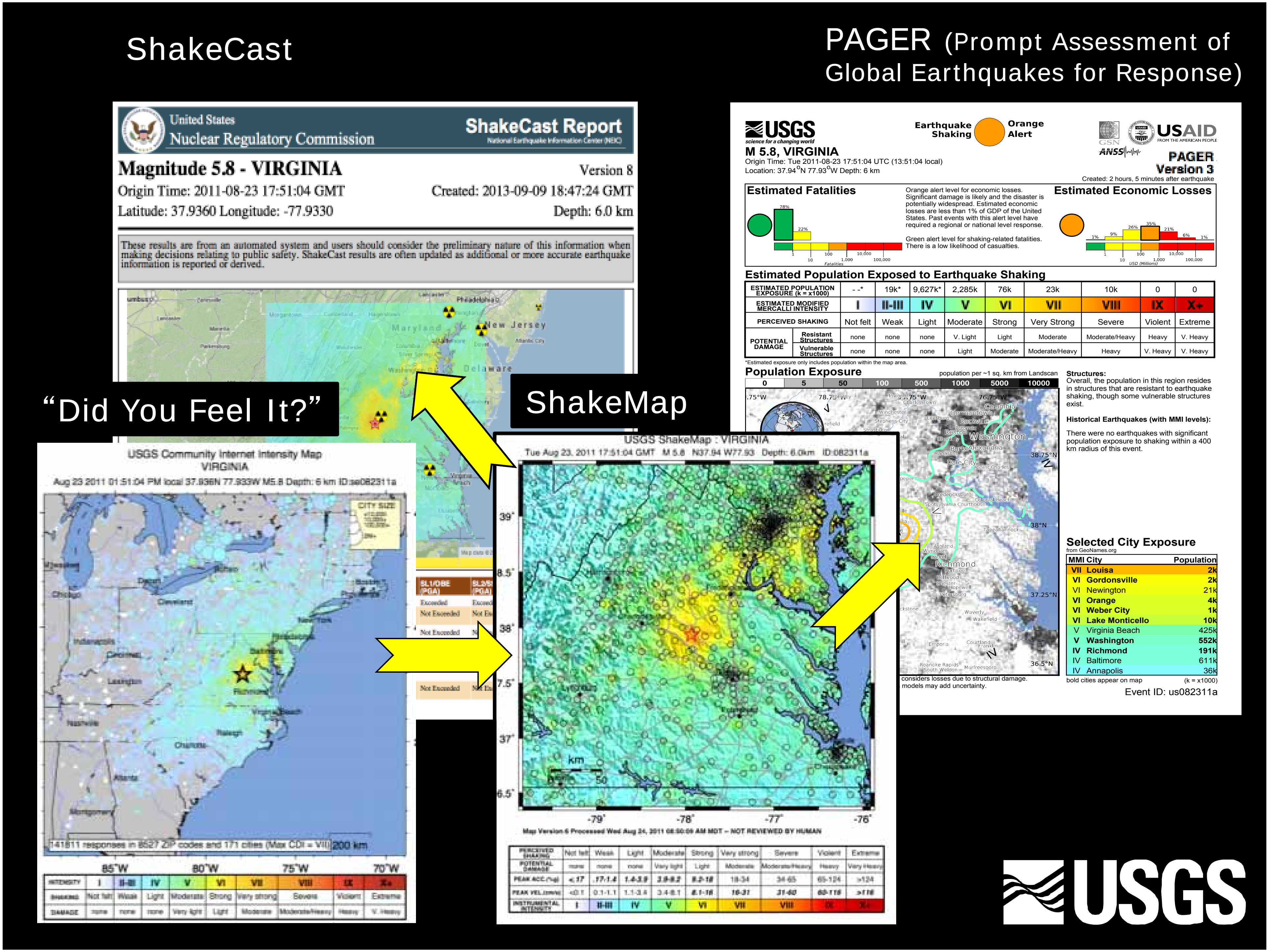
PAGER Status

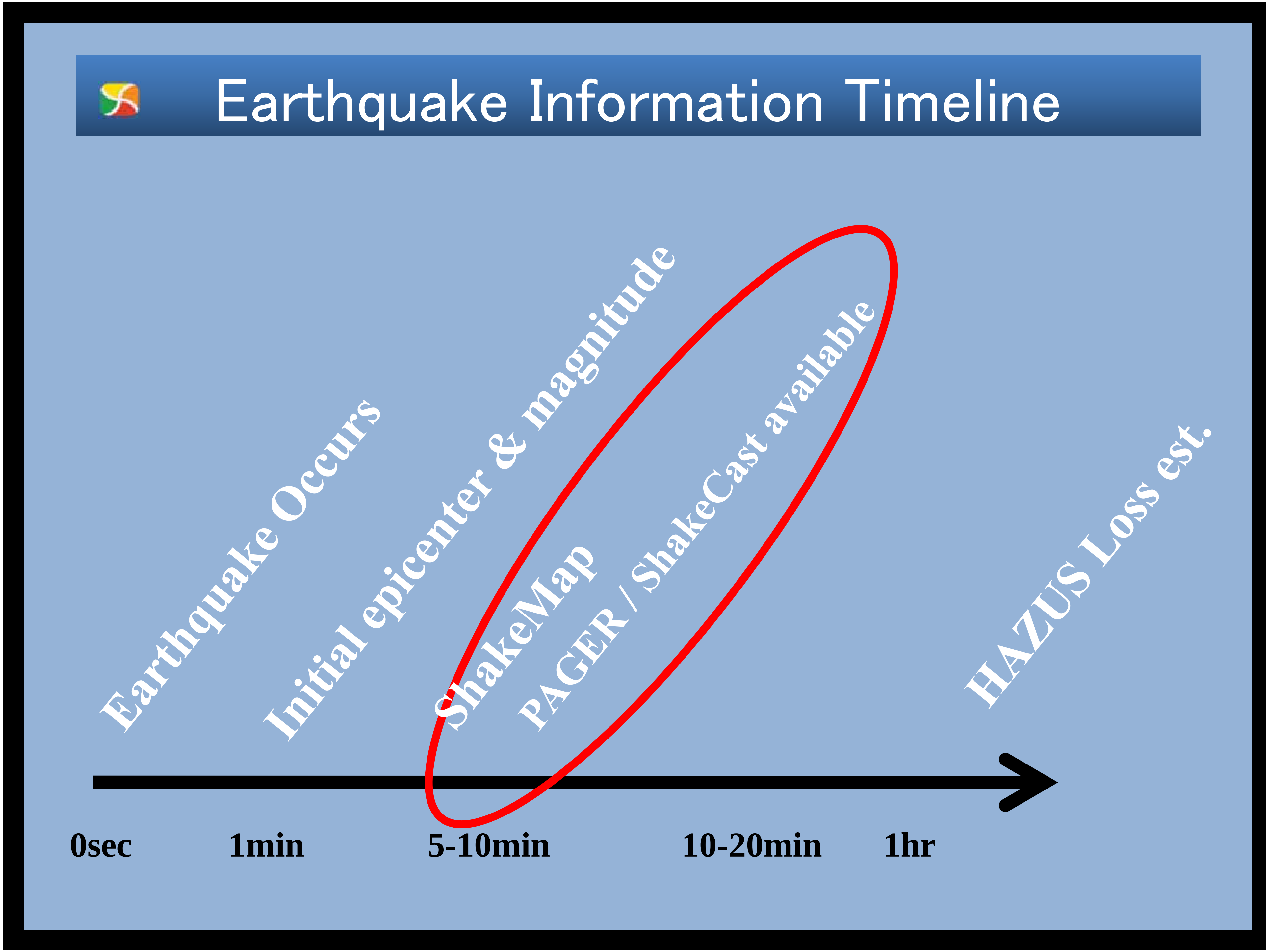
- PAGER provides near-real time shaking-based loss estimates & impact-based alerts based an *Earthquake Impact Scale* for all M5.5+ global earthquakes (& all ShakeMaps domestically in the U.S.).

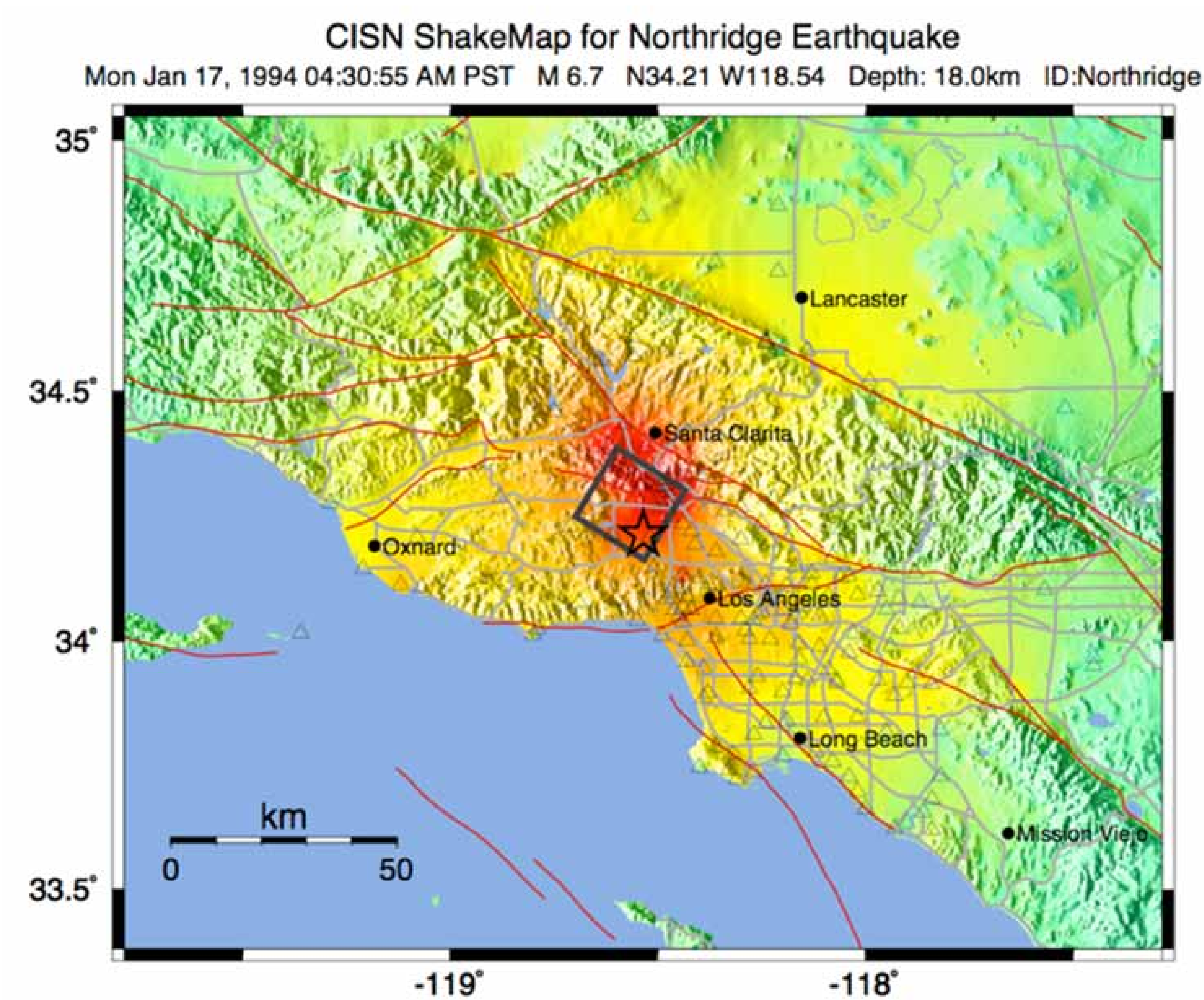
- PAGER relies on earthquake source information, ShakeMap, DYFI, Fast Finite Fault, & other data & inputs. We also gather data opportunistic-ally.

- PAGER data & tools are openly-developed and available. They are also fundamental for other systems, including the Global Earth Model (GEM), commercial loss assessment, & many other global hazard & risk problems. Many international collaborative efforts are involved.

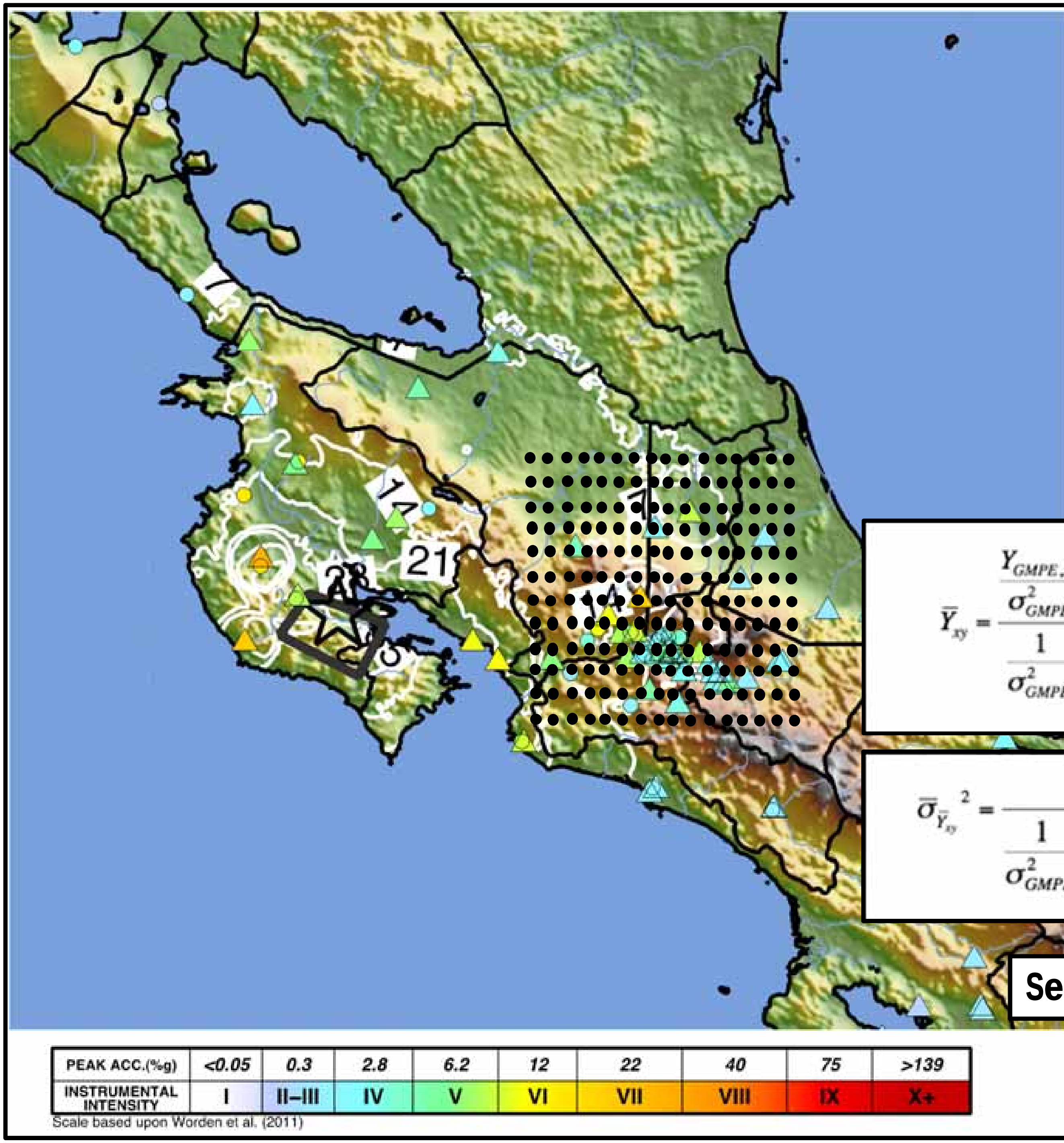
- After three years of impact-based alerts, we are evaluating results & planning strategically about next steps...


ShakeCast
PAGER (Prompt Assessment of Global Earthquakes for Response)
United States Nuclear Regulatory Commission
ShakeCast Report
National Earthquake Information Center (NEIC)
Magnitude 5.8 - VIRGINIA
Version 8
Origin Time: 2011-08-23 17:51:04 GMT
Created: 2013-09-09 18:47:24 GMT
Latitude: 37.9360 Longitude: -77.9330
Depth: 6.0 km
These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.
"Did You Feel It?"
USGS Community Internet Intensity Map
VIRGINIA
Aug 23 2011 01:51:04 PM local 37.936N 77.933W M5.8 Depth: 6 km ID:se082311a
141811 responses in 8527 ZIP codes and 171 cities (Max CDI = VIII)
ShakeMap
USGS ShakeMap : VIRGINIA
Tue Aug 23, 2011 17:51:04 GMT M 5.8 N37.94 W77.93 Depth: 6.0km ID:082311a
Map Version 6 Processed Wed Aug 24, 2011 08:50:09 AM MDT – NOT REVIEWED BY HUMAN
USGS
M 5.8, VIRGINIA
Origin Time: Tue 2011-08-23 17:51:04 UTC (13:51:04 local)
Location: 37.94°N 77.93°W Depth: 6 km
Earthquake Shaking Orange Alert
USAID
PAGER Version 3
Created: 2 hours, 5 minutes after earthquake
Estimated Fatalities
Estimated Economic Losses
Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.
Green alert level for shaking-related fatalities. There is a low likelihood of casualties.
Estimated Population Exposed to Earthquake Shaking
Population Exposure
Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.
Historical Earthquakes (with MMI levels):
There were no earthquakes with significant population exposure to shaking within a 400 km radius of this event.
Selected City Exposure
Event ID: us082311a
USGS


Earthquake Information Timeline
Earthquake Occurs
Initial epicenter & magnitude
ShakeMap
PAGER / ShakeCast available
HAZUS Loss est.
0sec
1min
5-10min
10-20min
1hr



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	***<.17***	***.17-1.4***	***1.4-3.9***	***3.9-9.2***	***9.2-18***	18-34	34-65	65-124	>124
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***	***60-116***	***>116***
INSTRUMENTAL INTENSITY	**I**	**II-III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X+**



ShakeMap V3.5

Intensity Observation

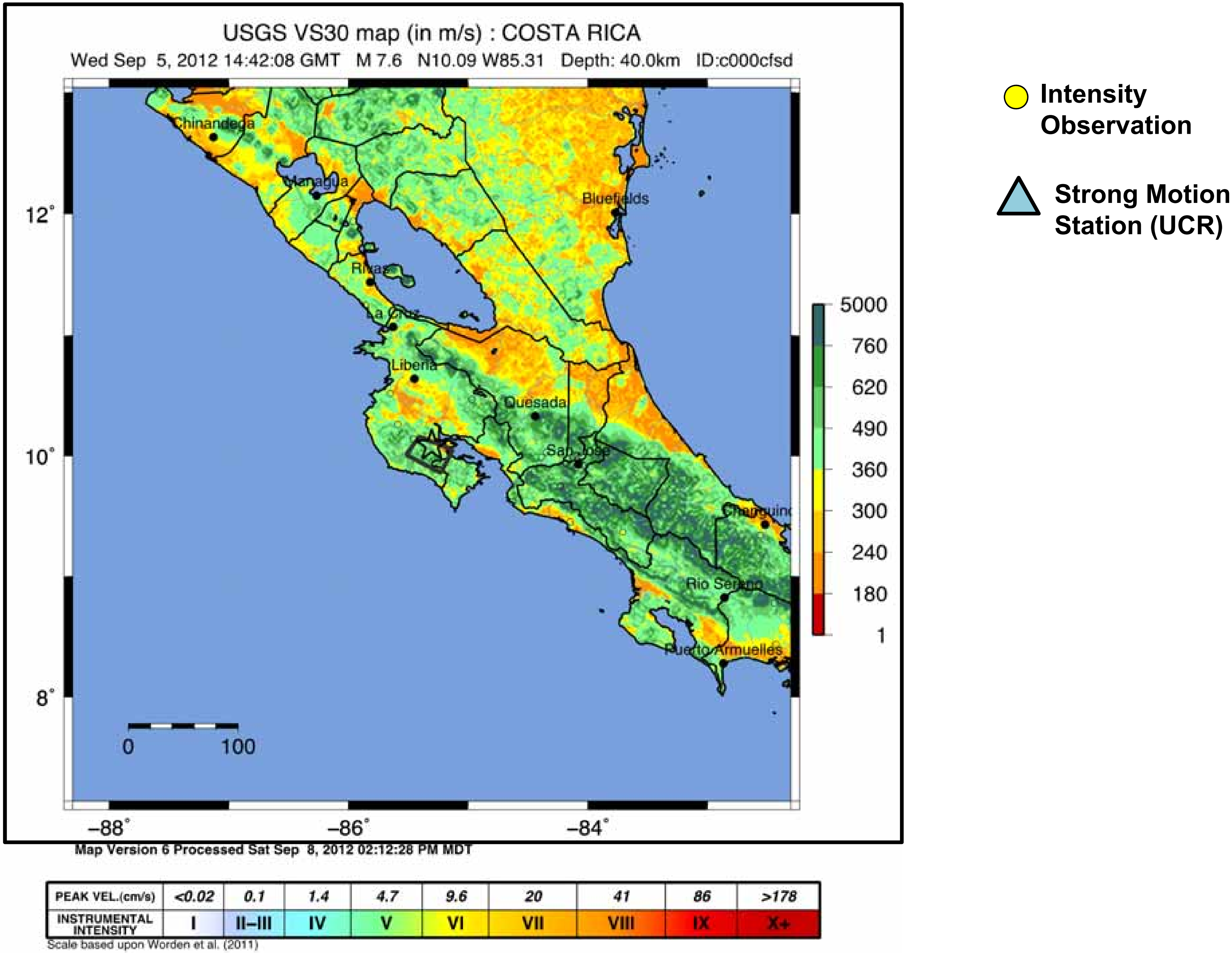
Strong Motion Station (UCR)

Grid & Estimate Point (GMPE)

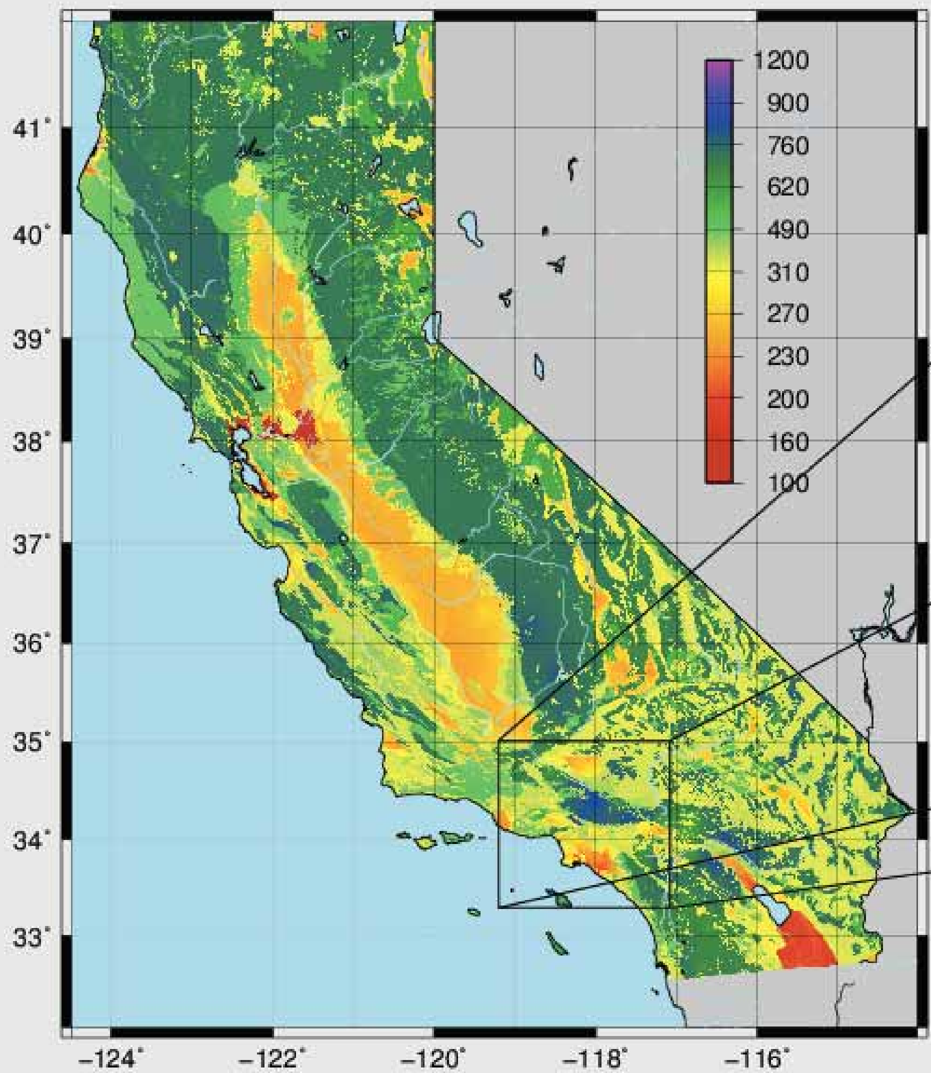
$$\bar{Y}_{xy} = \frac{\frac{Y_{GMPE,xy}}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{Y_{obs,xy,i}}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{Y_{conv,xy,j}}{\sigma^2_{conv,xy,j}}}{\frac{1}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{1}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{1}{\sigma^2_{conv,xy,j}}},$$

$$\bar{\sigma}_{\bar{Y}_{xy}}^{\,2} = \frac{1}{\frac{1}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{1}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{1}{\sigma^2_{conv,xy,j}}},$$

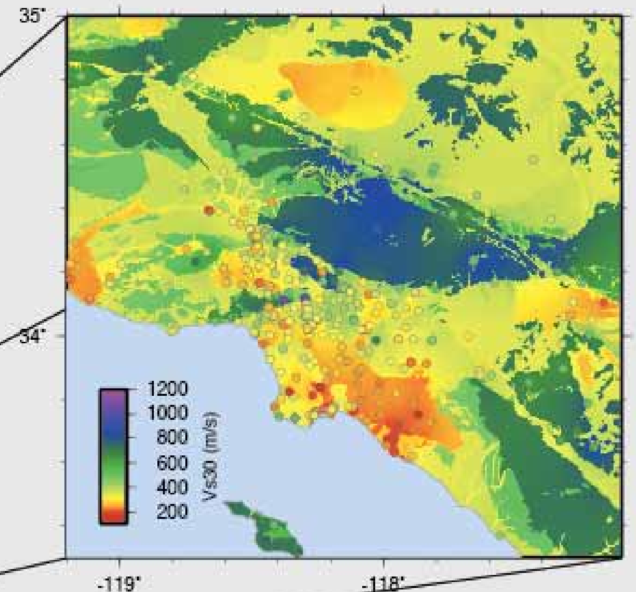
See Worden et al. (2010)


USGS VS30 map (in m/s) : COSTA RICA
Wed Sep 5, 2012 14:42:08 GMT M 7.6 N10.09 W85.31 Depth: 40.0km ID:c000cfsd
Chinandega
Managua
Bluefields
Rivas
La Cruz
Liberia
Quesada
San Jose
Changuinola
Rio Sereno
Puerto Armuelles
12˚
10˚
8˚
−88˚
−86˚
−84˚
0
100
5000
760
620
490
360
300
240
180
1
Map Version 6 Processed Sat Sep 8, 2012 02:12:28 PM MDT
PEAK VEL.(cm/s) <0.02 0.1 1.4 4.7 9.6 20 41 86 >178
INSTRUMENTAL INTENSITY I II–III IV V VI VII VIII IX X+
Scale based upon Worden et al. (2011)
Intensity Observation
Strong Motion Station (UCR)

Refining Vs30 Maps for ShakeMap, but also for liquefaction likelihood, …

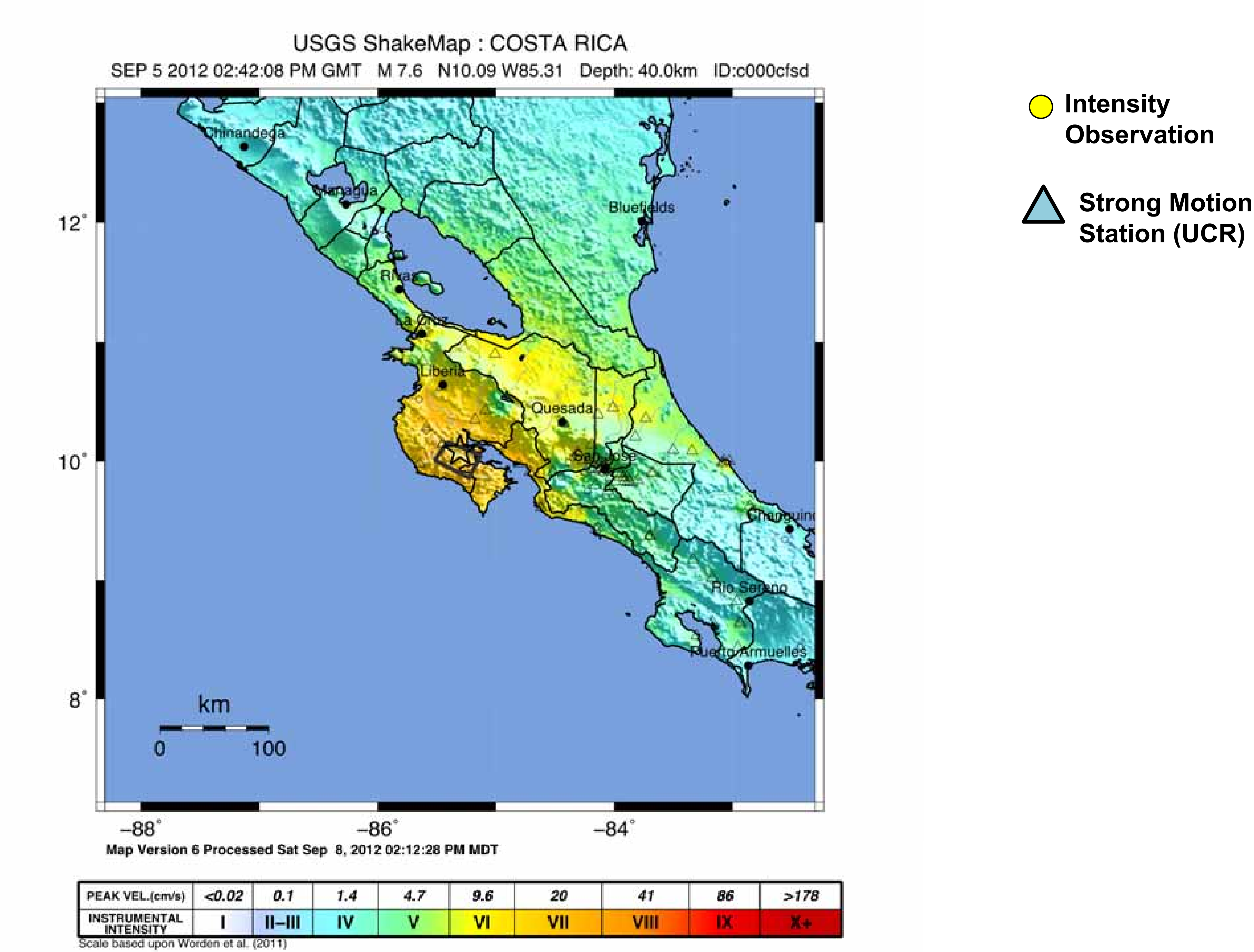


Final map of California resulting from kriging with a trend on the hybrid Wills and Calahan (2006) Vs30 map.

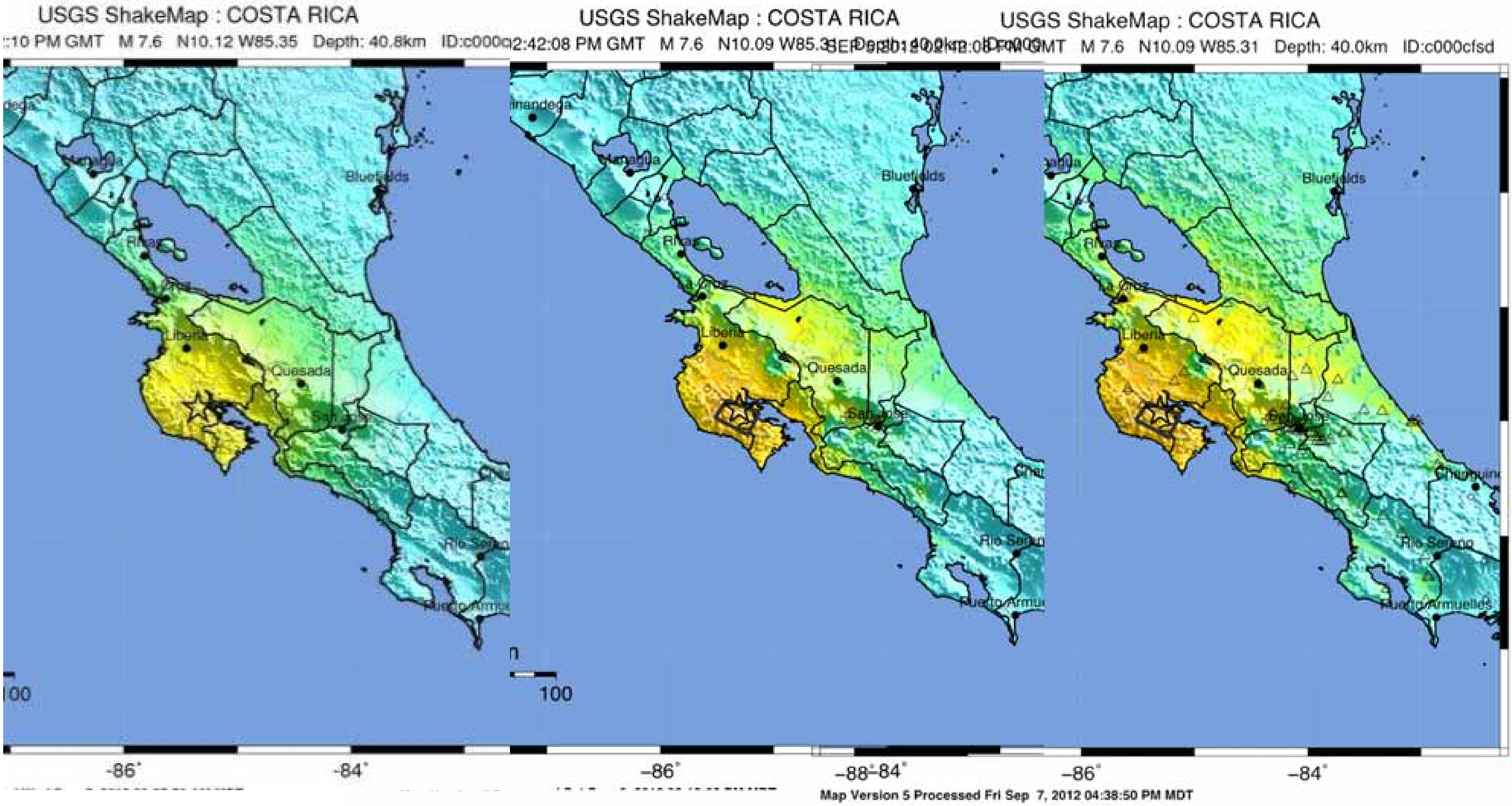


Result of kriging the measured Vs30 profiles (using the correlation structure from the previous step) onto the hybrid map.

[Thompson, Worden & Wald, 2013]


USGS ShakeMap : COSTA RICA
SEP 5 2012 02:42:08 PM GMT M 7.6 N10.09 W85.31 Depth: 40.0km ID:c000cfsd
Chinandega
Managua
Bluefields
Rivas
La Cruz
Liberia
Quesada
San Jose
Changuinola
Rio Sereno
Puerto Armuelles
12°
10°
8°
-88°
-86°
-84°
km
0
100
Map Version 6 Processed Sat Sep 8, 2012 02:12:28 PM MDT
PEAK VEL.(cm/s) <0.02 0.1 1.4 4.7 9.6 20 41 86 >178
INSTRUMENTAL INTENSITY I II–III IV V VI VII VIII IX X+
Scale based upon Worden et al. (2011)
Intensity Observation
Strong Motion Station (UCR)

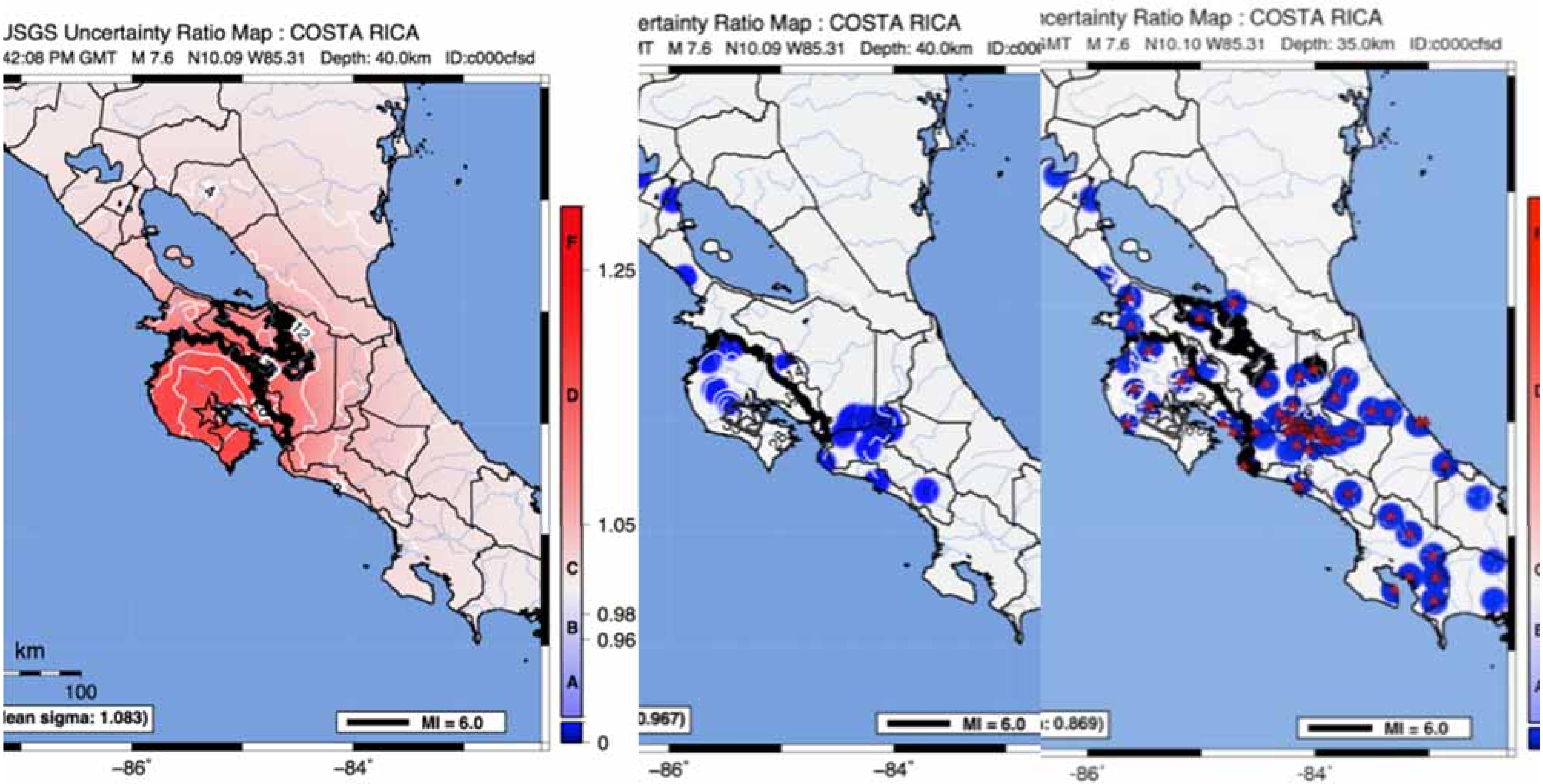
Hypocenter | DYFI? + Finite Fault | + Stations from UCR



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2011)

Hypocenter | **DYFI? + Finite Fault** | **+ Stations from UCR**

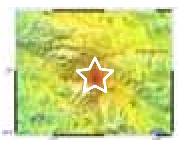


Magnitudes ~ 6, 7, 8

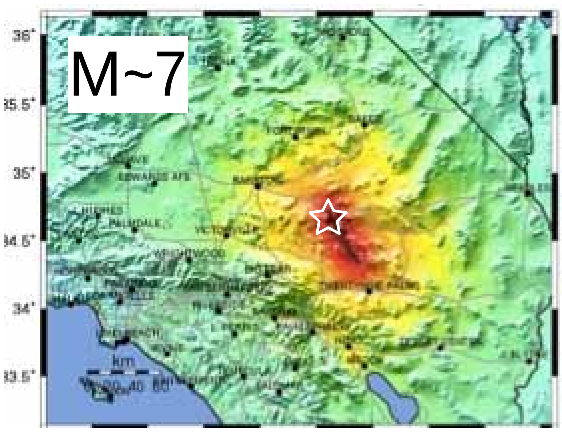
100 Miles

Alaska, 2001

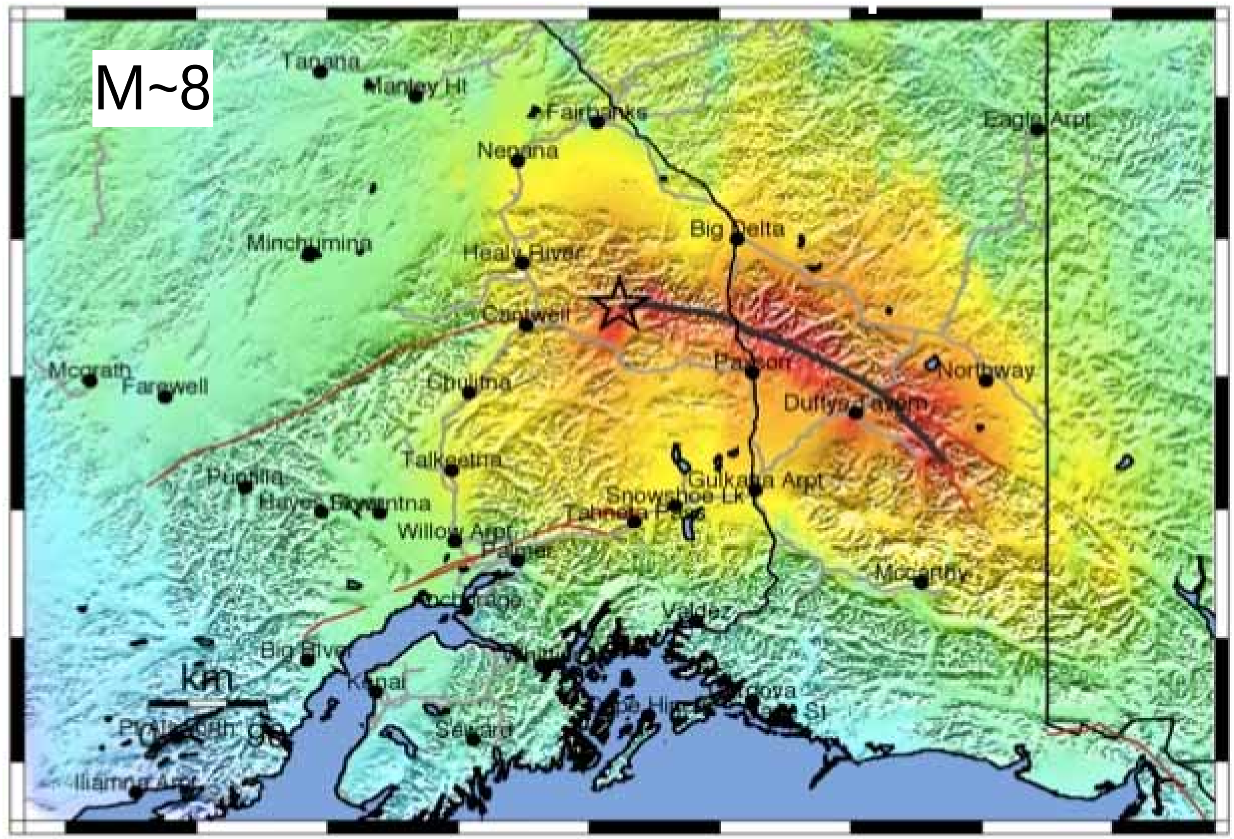
M~6



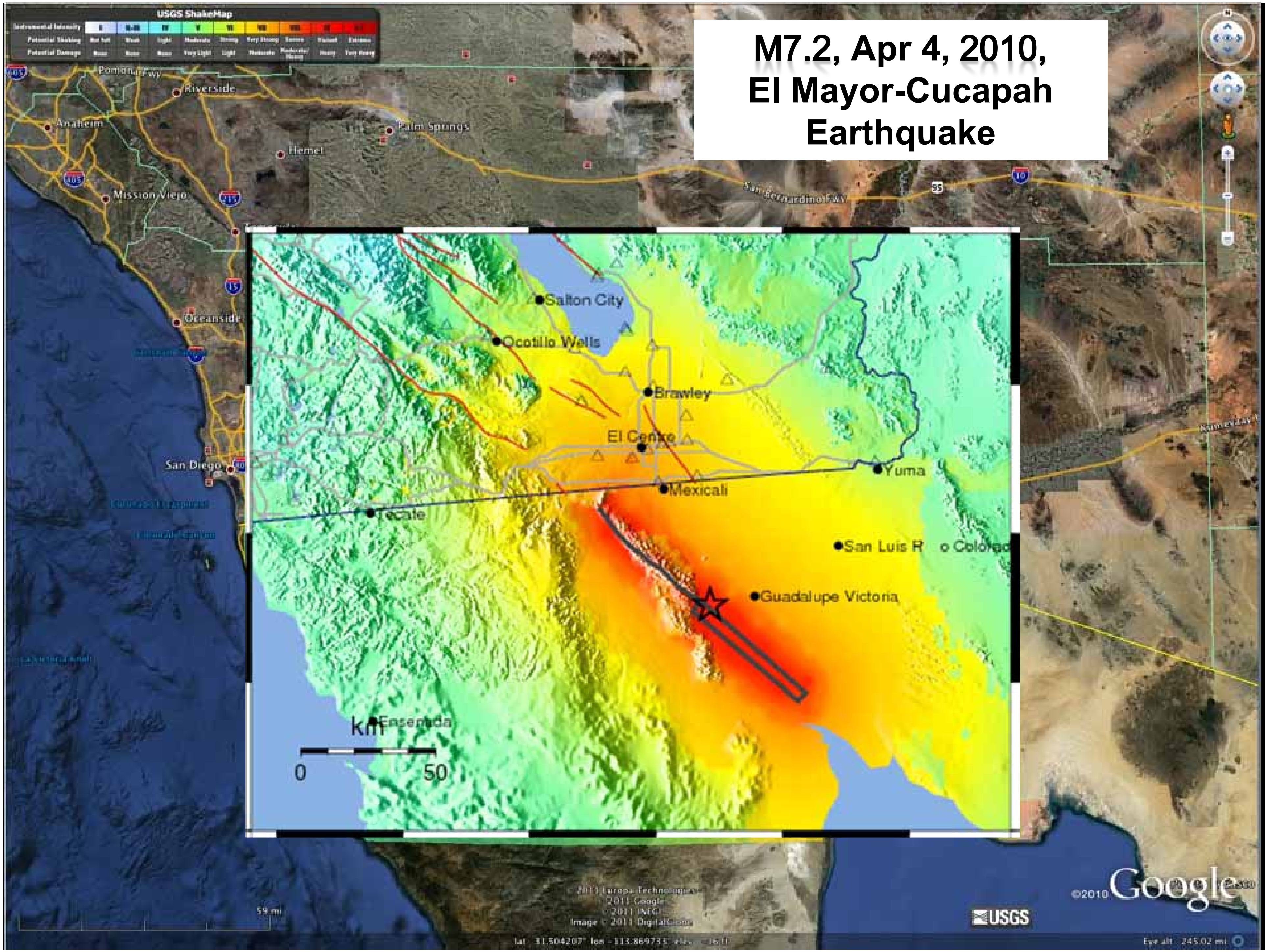
So. Cal., 1986



Southern California, 1999



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
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*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+


M7.2, Apr 4, 2010,
El Mayor-Cucapah
Earthquake
USGS ShakeMap
Pomona Fwy
Riverside
Anaheim
Palm Springs
Hemet
Mission Viejo
Oceanside
San Diego
San Bernardino Fwy
Salton City
Ocotillo Wells
Brawley
El Centro
Yuma
Mexicali
Tecate
San Luis R
o Colorad
Guadalupe Victoria
Ensenada
km
0
50
USGS
©2010
Google

ShakeMap grid.xml file

- <shakemap_grid xsi:schemaLocation="http://earthquake.usgs.gov http://earthquake.usgs.gov/eqcenter/shakemap/xml/schemas/shakemap.xsd" event_id="Northridge" shakemap_id="Northridge" shakemap_version="12" code_version="3.2" process_timestamp="2007-01-30T16:07:03Z" shakemap_originator="ci" map_status="RELEASED" shakemap_event_type="ACTUAL">
<event magnitude="6.7" depth="18" lat="34.213000" lon="-118.535700" event_timestamp="1994-01-17T12:30:55GMT" event_description="Northridge"/>
<grid_specification lon_min="-119.785700" lat_min="33.379666" lon_max="-117.285700" lat_max="35.046333" nominal_lon_spacing="0.016667" nominal_lat_spacing="0.016667" nlon="151" nlat="101" nominal_pga_std="0.520000"/>
<grid_field index="1" name="LON" units="dd"/>
<grid_field index="2" name="LAT" units="dd"/>
<grid_field index="3" name="PGA" units="pctg"/>
<grid_field index="4" name="PGV" units="cms"/>
<grid_field index="5" name="MMI" units="mmi"/>
<grid_field index="6" name="PSA03" units="pctg"/>
<grid_field index="7" name="PSA10" units="pctg"/>
<grid_field index="8" name="PSA30" units="pctg"/>
<grid_field index="9" name="SDPGA" units="pctg"/>
<grid_field index="10" name="SVEL" units="ms"/>

Grid uncertainty value, Vs30

Lon Lat PGA PGV MMI SA.3 SA1 SA3 Sig. Vs30

5.046333 6.3811 4.3655 4.9500 10.9535 5.2248 1.0340 1.0000 372.0000
5.046333 6.4854 4.4404 4.9600 11.1607 5.3151 1.0521 1.0000 372.0000
-119.719033 35.046333 6.0571 3.8717 4.9000 10.4353 4.6342 0.9174 1.0000 464.0000 -119.702367 35.046333 6.0963 3.8962 4.9000 10.5136 4.6631 0.9231 1.0000 464.0000
-119.685700 35.046333 6.1375 3.9222 4.9100 10.5959 4.6938 0.9293 1.0000 464.0000 -119.669033 35.046333 6.1914 3.9585 4.9200 10.7029 4.7376 0.9381 1.0000 464.0000
-119.652367 35.046333 6.2471 3.9962 4.9200 10.8134 4.7831 0.9472 1.0000 464.0000 -119.635700 35.046333 6.2991 4.0307 4.9300 10.9167 4.8246 0.9556 1.0000 464.0000
-119.619033 35.046333 7.3392 5.3832 5.1200 12.7334 6.4431 1.2763 1.0000 301.0000 -119.602367 35.046333 7.3890 5.4191 5.1300 12.8329 6.4855 1.2848 1.0000 301.0000
-119.585700 35.046333 7.4410 5.4570 5.1400 12.9372 6.5303 1.2938 1.0000 301.0000 -119.569033 35.046333 6.4927 4.1 11.3035 4.9740 0.9857 1.0000 464.0000
-119.552367 35.046333 6.5532 4.1971 4.970 .0000 464.0000
-119.519033 35.046333 7.7020 5.6563 5.180 .0000 301.0000
-119.485700 35.046333 7.2820 4.9974 5.110 .0000 372.0000
-119.452367 35.046333 7.4205 5.0975 5.130 .0000 464.0000
-119.419033 35.046333 8.0902 5.9490 5.250 .0000 372.0000
-119.385700 35.046333 8.2042 6.0323 5.270 .0000 301.0000
-119.352367 35.046333 8.3626 6.1547 5.300 .0000 301.0000
-119.319033 35.046333 8.5002 6.2587 5.320 .0000 301.0000
-119.285700 35.046333 8.6174 6.3445 5.340 .0000 301.0000
-119.252367 35.046333 8.7839 6.4734 5.360 .0000 301.0000
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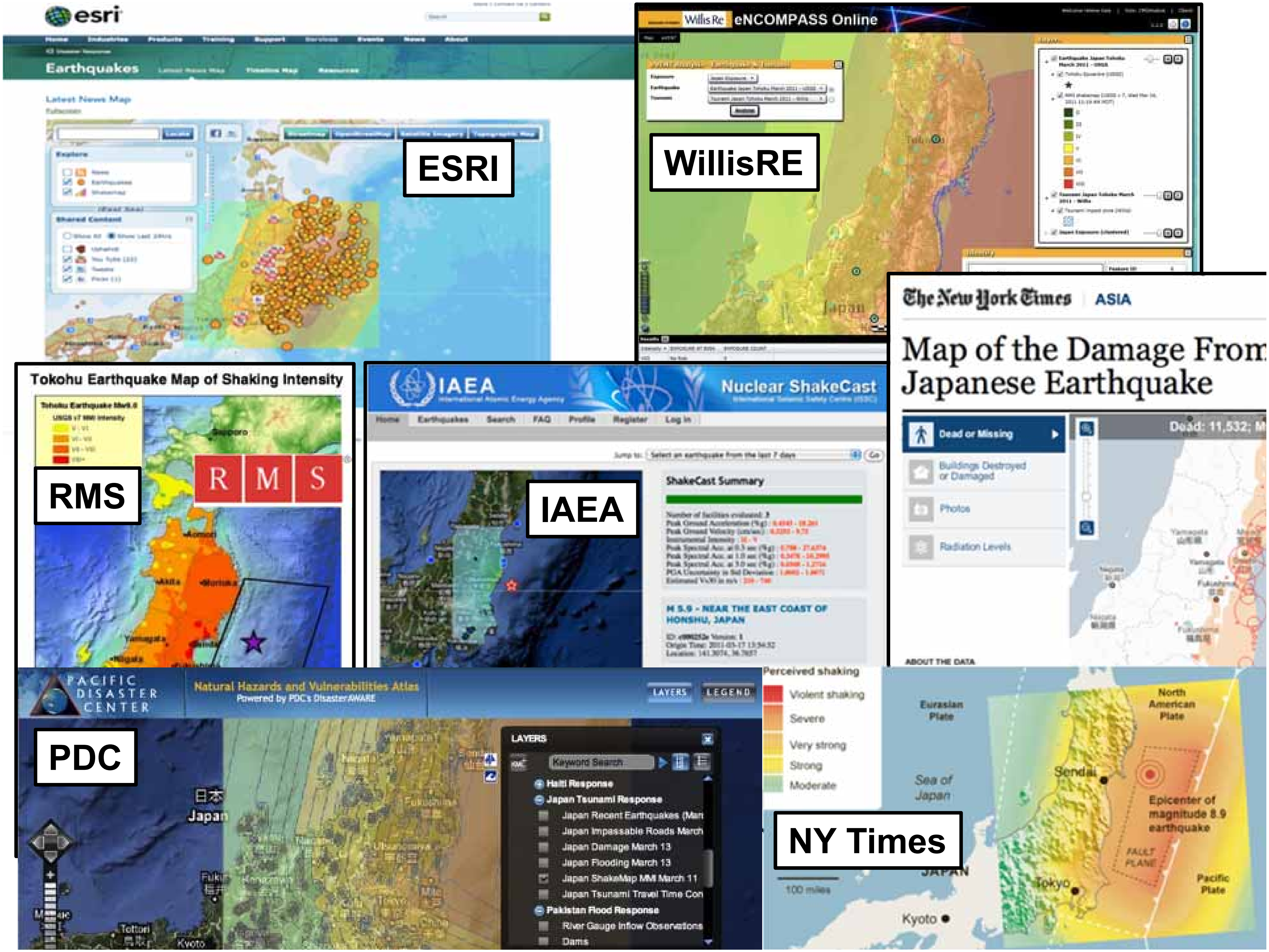
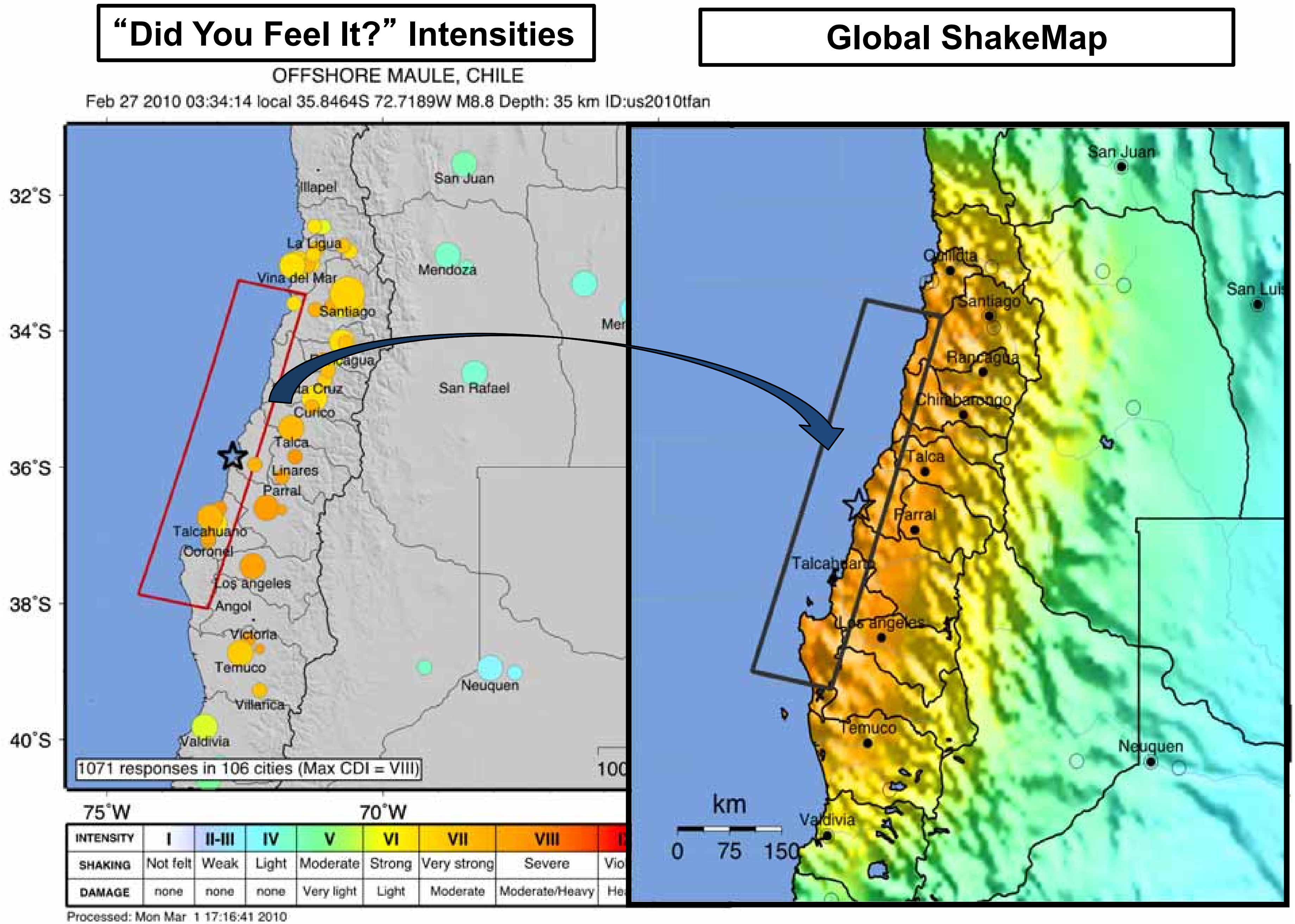
-119.152367 35.046333 9.2139 6.7994 5.430 .0000 301.0000
-119.119033 35.046333 9.3553 6.9068 5.450 .0000 301.0000
-119.085700 35.046333 9.4666 6.9888 5.470 .0000 301.0000
-119.052367 35.046333 9.6375 7.1221 5.490 .0000 301.0000
-119.019033 35.046333 9.7721 7.2250 5.5100 17.6918 8.6458 1.7203 1.0000 301.0000 -119.002367 35.046333 9.8200 7.2604 5.5200 17.7920 8.6879 1.7287 1.0000 301.0000
-118.985700 35.046333 9.8701 7.2979 5.5200 17.8972 8.7327 1.7376 1.0000 301.0000 -118.969033 35.046333 9.9507 7.3618 5.5400 18.0659 8.8099 1.7532 1.0000 301.0000

Ground motion estimates

- Intensity (MMI)
- Peak ground acceleration (PGA)
- Peak ground velocity (PGV)
- Spectral response at 0.3, 1, 3 sec.

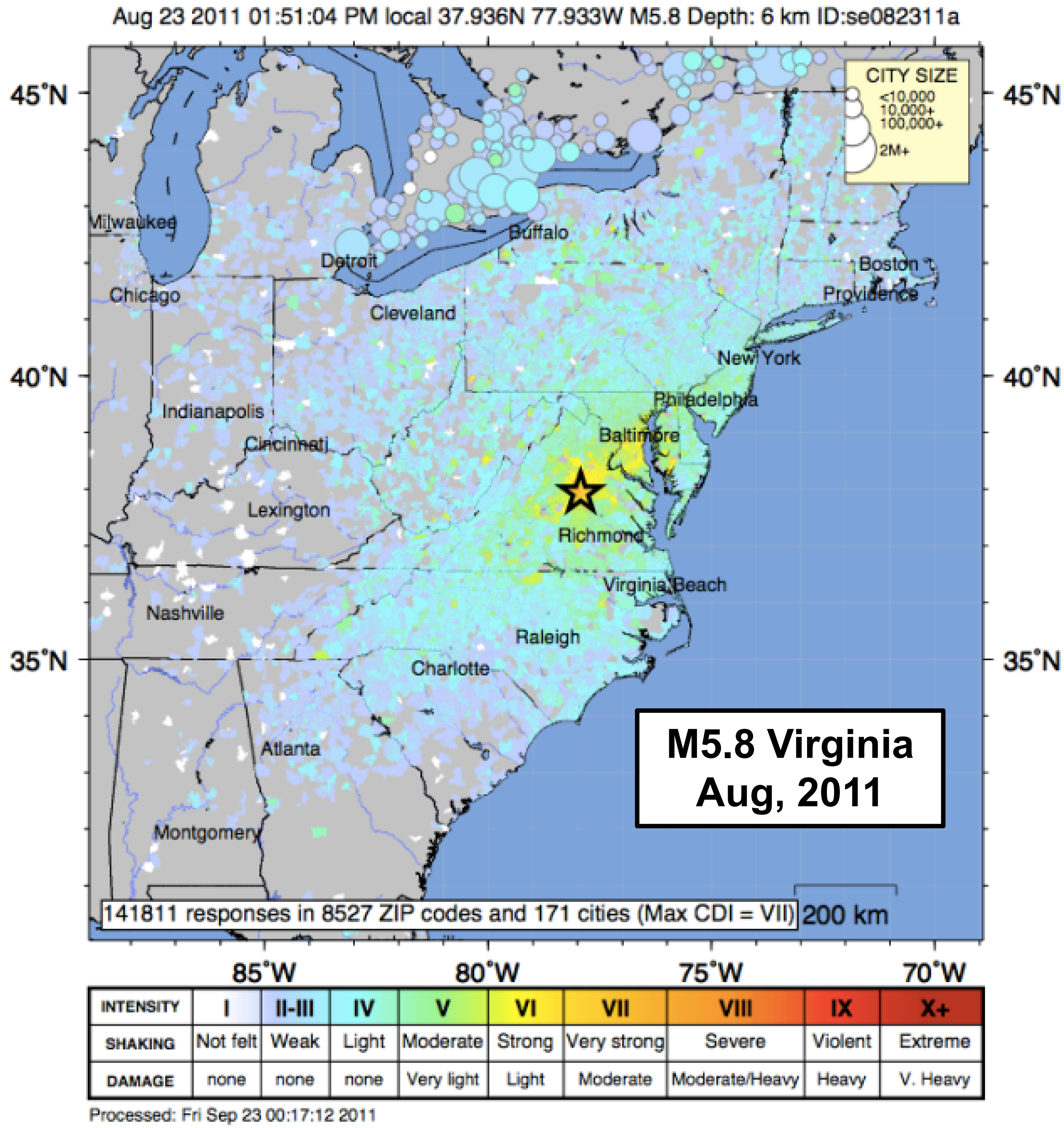
USGS
science for a changing world


esri
Earthquakes
Latest News Map
ESRI
Willis Re eNCOMPASS Online
WillisRE
The New York Times ASIA
Map of the Damage From Japanese Earthquake
Dead or Missing
Buildings Destroyed or Damaged
Photos
Radiation Levels
ABOUT THE DATA
Tokohu Earthquake Map of Shaking Intensity
RMS
R M S
Sapporo
Aomori
Akita
Morioka
Yamagata
Niigata
IAEA
International Atomic Energy Agency
Nuclear ShakeCast
Home
Earthquakes
Search
FAQ
Profile
Register
Log In
ShakeCast Summary
M 5.9 - NEAR THE EAST COAST OF HONSHU, JAPAN
PACIFIC DISASTER CENTER
Natural Hazards and Vulnerabilities Atlas
Powered by PDC's DisasterAWARE
LAYERS
LEGEND
PDC
Keyword Search
Haiti Response
Japan Tsunami Response
Japan Recent Earthquakes (Man
Japan Impassable Roads March
Japan Damage March 13
Japan Flooding March 13
Japan ShakeMap MM March 11
Japan Tsunami Travel Time Con
Pakistan Flood Response
River Gauge Inflow Observations
Dams
Japan
Kyoto
Perceived shaking
Violent shaking
Severe
Very strong
Strong
Moderate
Eurasian Plate
North American Plate
Sea of Japan
Sendai
Epicenter of magnitude 8.9 earthquake
FAULT PLANE
JAPAN
Tokyo
Pacific Plate
100 miles
Kyoto
NY Times

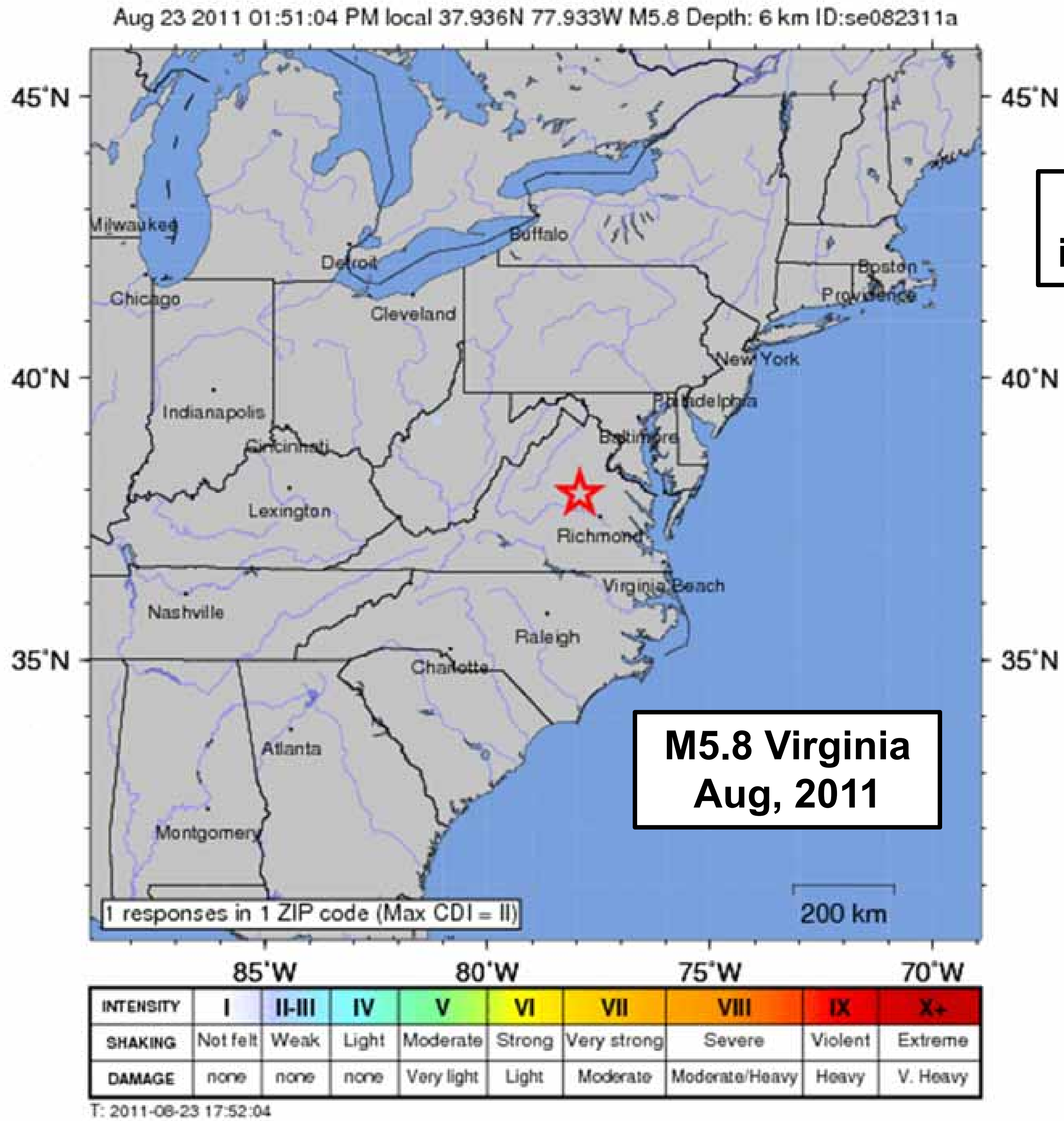


"Did You Feel It?" Intensities
Global ShakeMap
OFFSHORE MAULE, CHILE
Feb 27 2010 03:34:14 local 35.8464S 72.7189W M8.8 Depth: 35 km ID:us2010tfan
32°S
34°S
36°S
38°S
40°S
75°W
70°W
Illapel
San Juan
La Ligua
Mendoza
Vina del Mar
Santiago
San Rafael
Curico
Talca
Linares
Parral
Talcahuano
Coronel
Los angeles
Angol
Victoria
Temuco
Villarica
Neuquen
Valdivia
1071 responses in 106 cities (Max CDI = VIII)
INTENSITY
I
II-III
IV
V
VI
VII
VIII
SHAKING
Not felt
Weak
Light
Moderate
Strong
Very strong
Severe
DAMAGE
none
none
none
Very light
Light
Moderate
Moderate/Heavy
Processed: Mon Mar 1 17:16:41 2010
San Juan
San Luis
Quillota
Santiago
Rancagua
Chimbarongo
Talca
Parral
Talcahuano
Los angeles
Temuco
Neuquen
Valdivia
km
0
75
150

"Did You Feel It?"

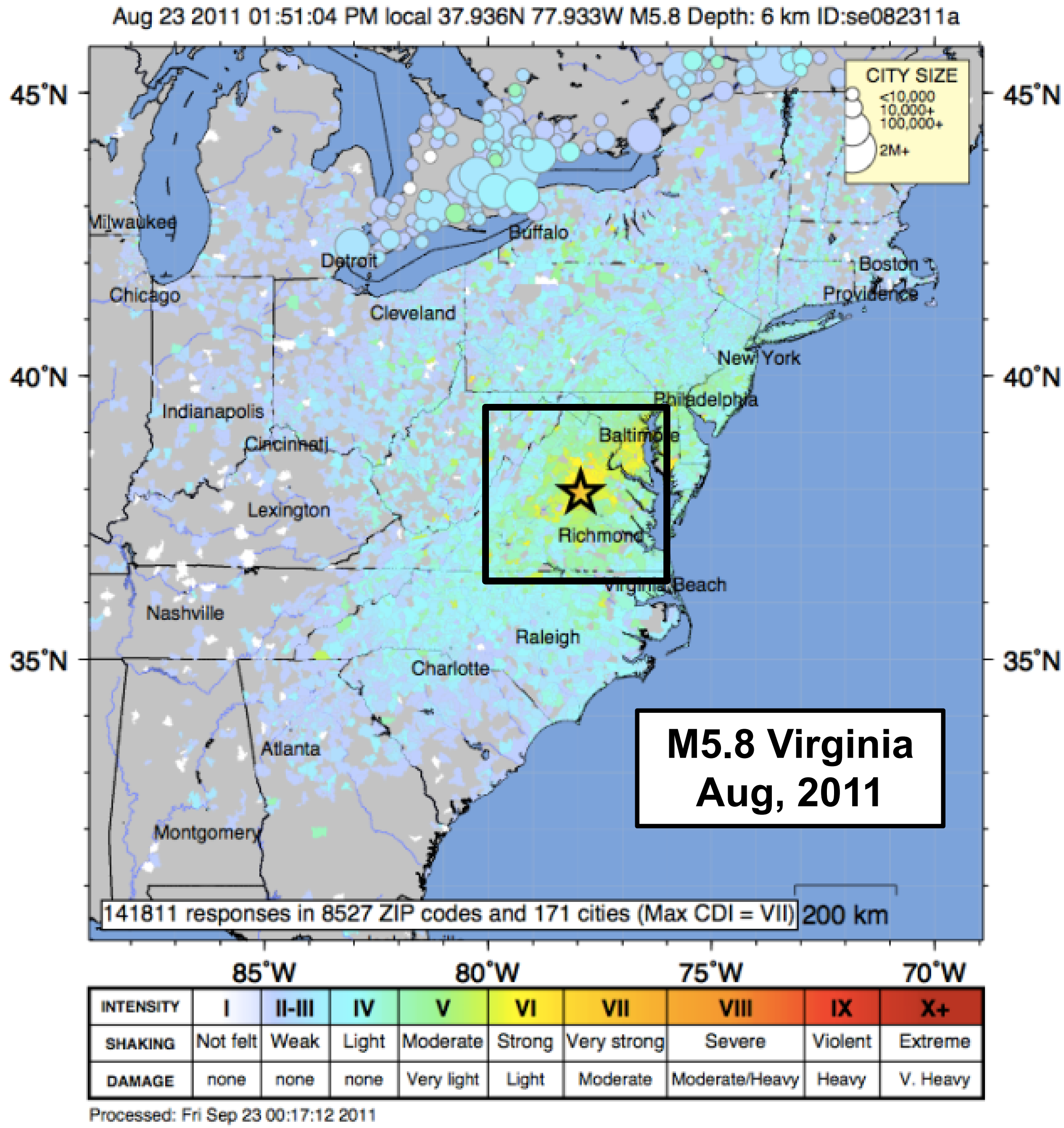


“Did You Feel It?”



(1-min. intervals)

“Did You Feel It?”

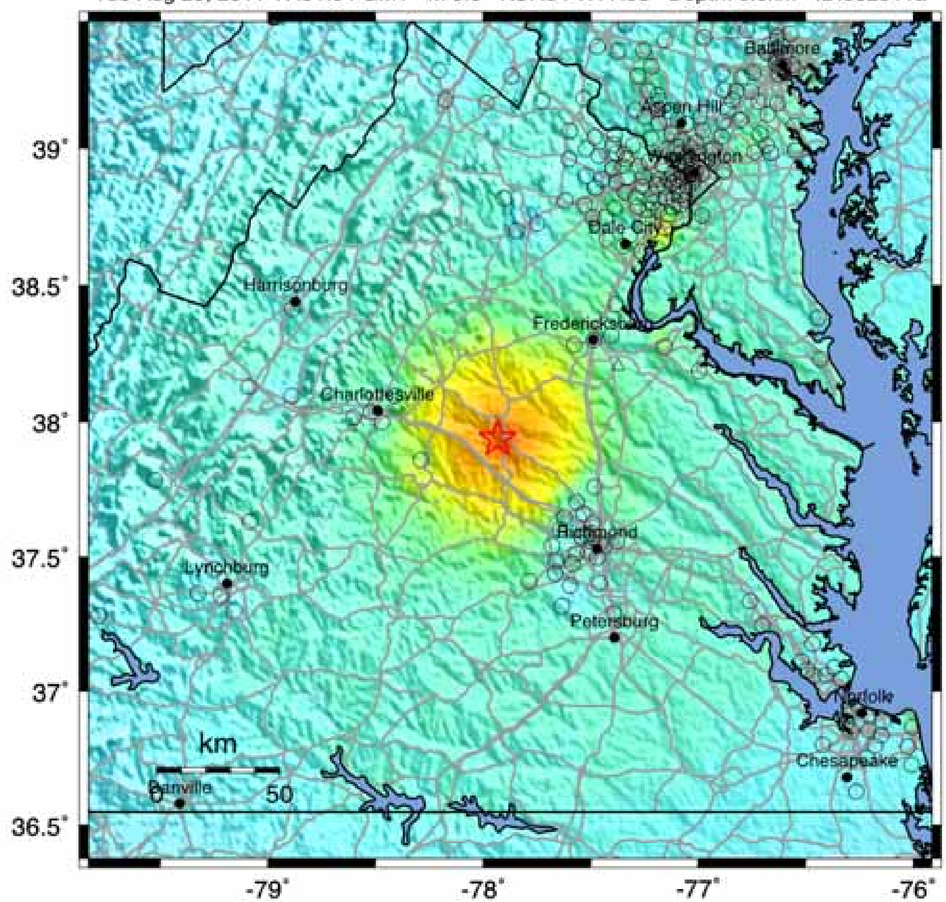


ShakeMap

“Did You Feel It?”

USGS ShakeMap : VIRGINIA

Tue Aug 23, 2011 17:51:04 GMT M 5.8 N37.94 W77.93 Depth: 6.0km ID:082311a

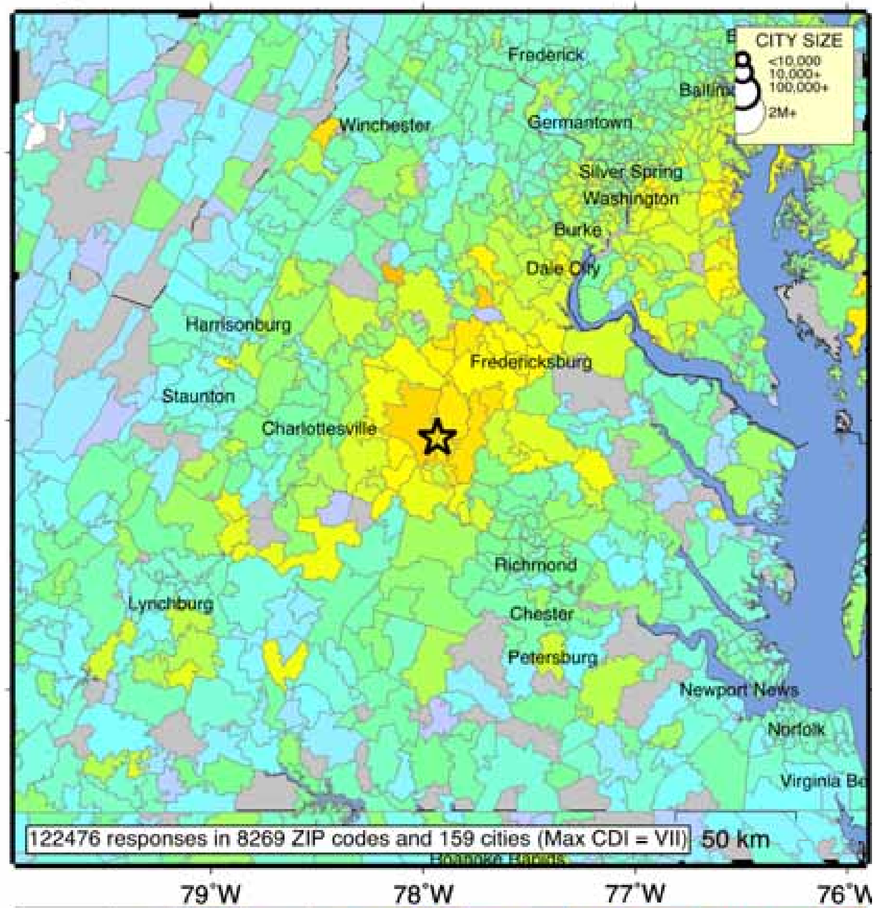


Map Version 4 Processed Tue Aug 23, 2011 01:50:45 PM MDT -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

VIRGINIA

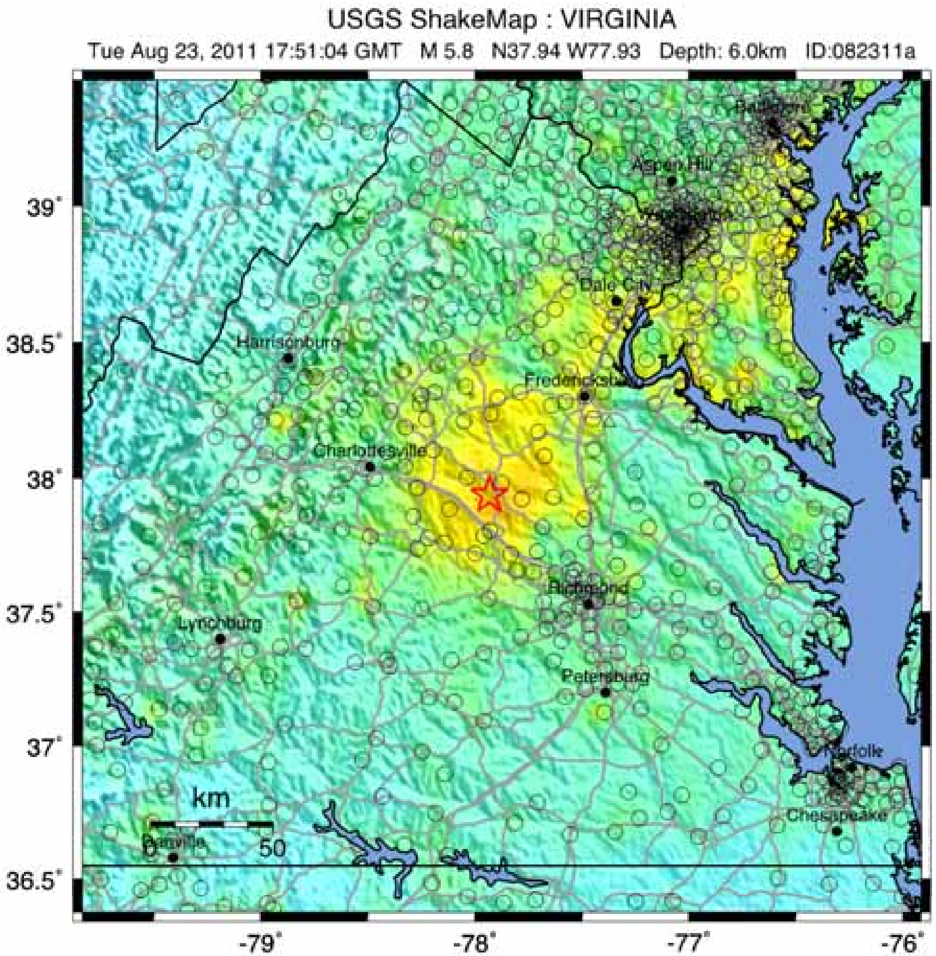
Aug 23 2011 01:51:04 PM local 37.936N 77.933W M5.8 Depth: 6 km ID:se082311a



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Wed Aug 24 11:12:25 2011

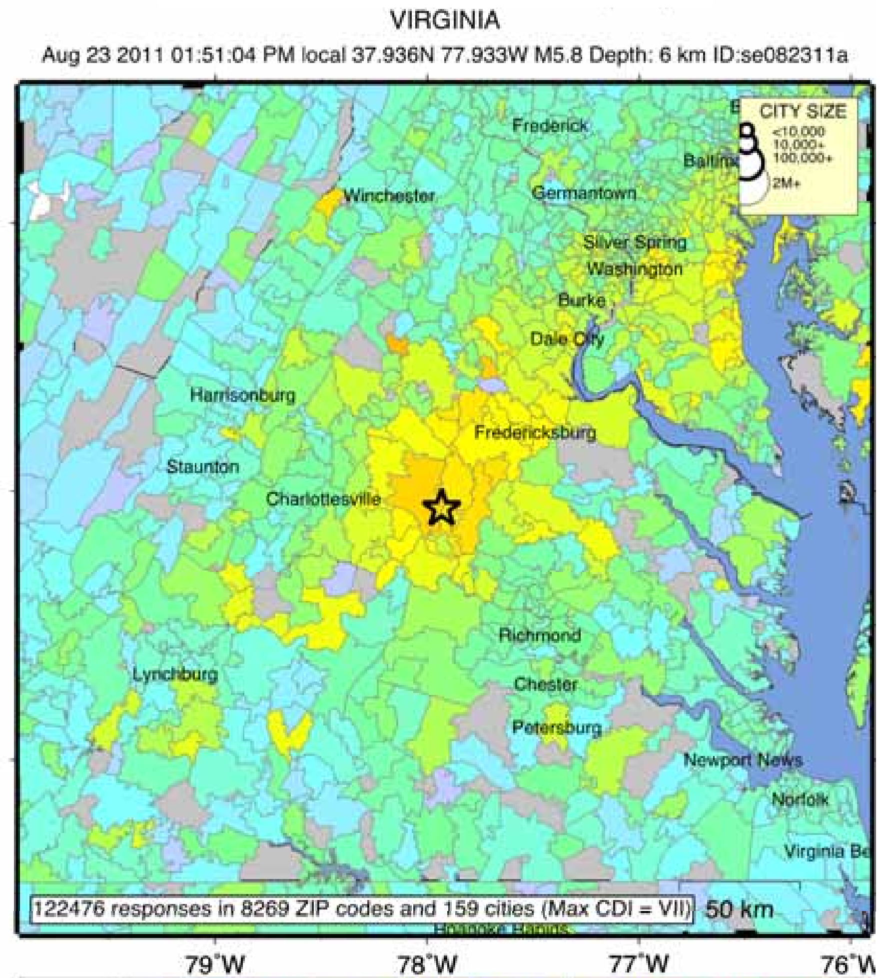
ShakeMap



Map Version 6 Processed Wed Aug 24, 2011 08:50:09 AM MDT -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

"Did You Feel It?"

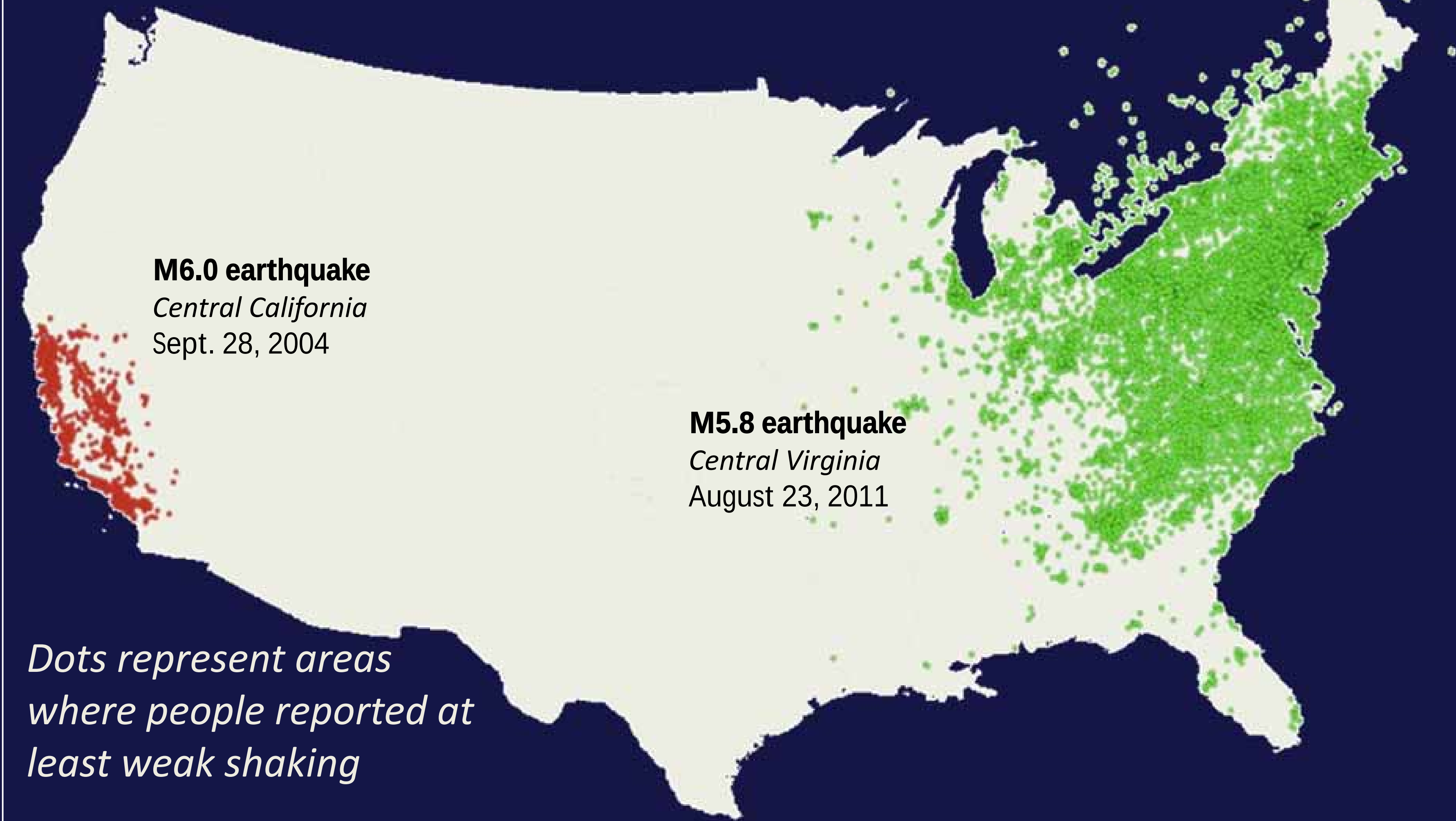


INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Wed Aug 24 11:12:25 2011

Earthquakes are felt over much larger area in Eastern U.S.

USGS "Did you feel it?" comparison



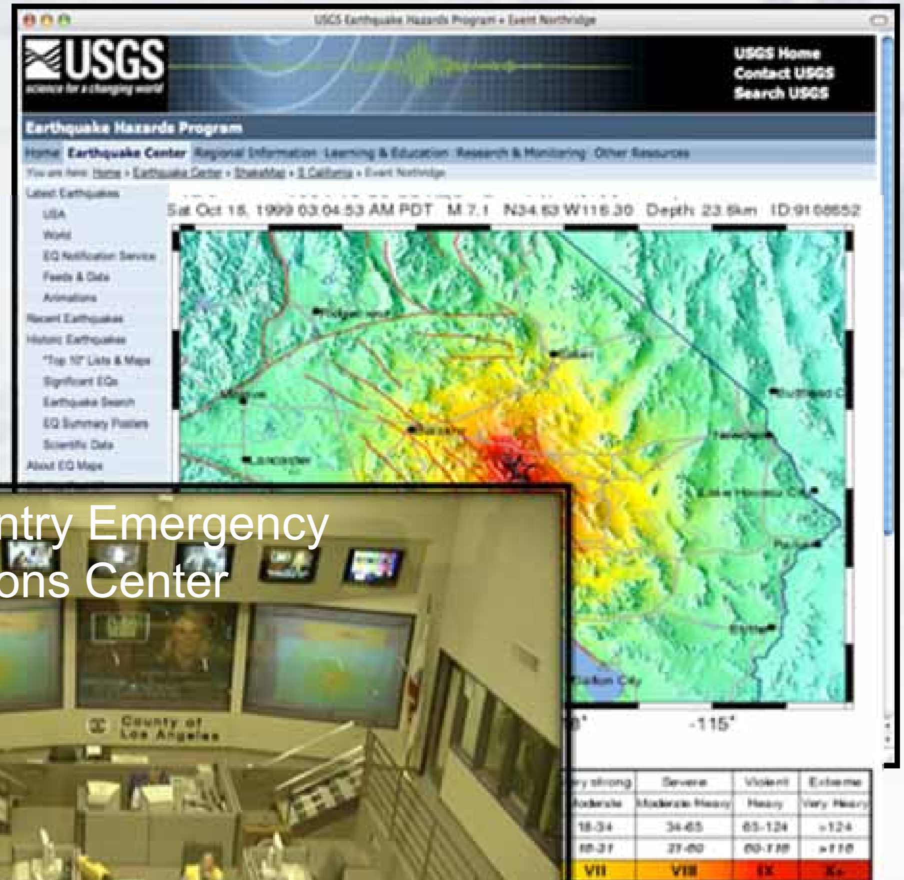
Dots represent areas where people reported at least weak shaking

USGS

What Are the Primary ShakeMap Uses?

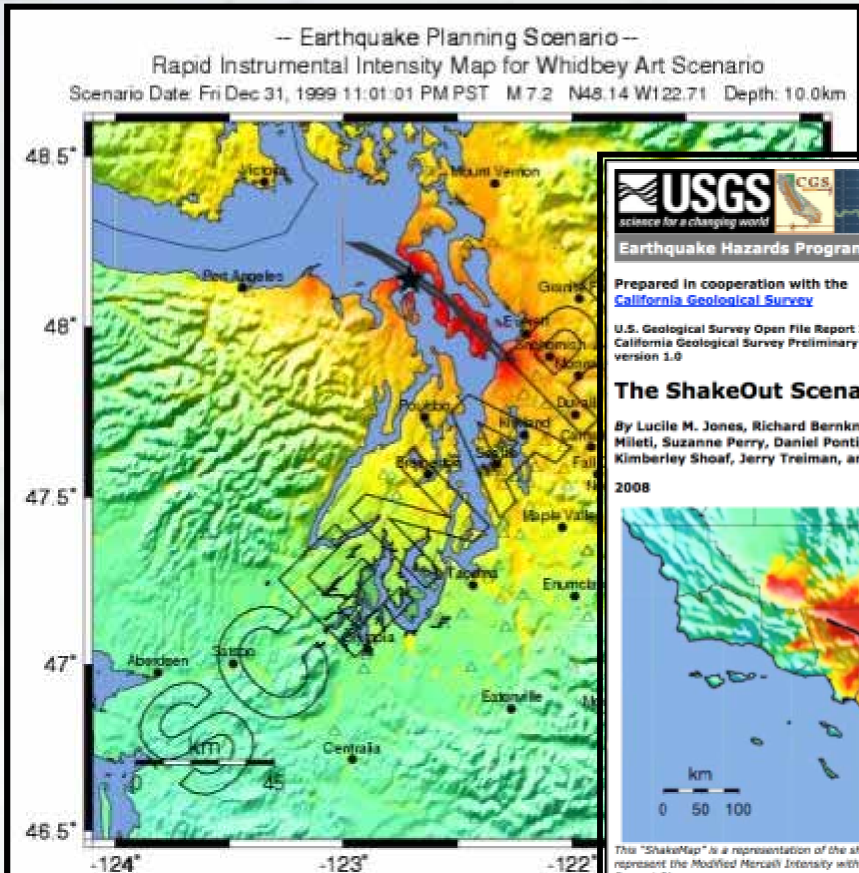
- Rapid, post-earthquake response, coordination, and situational awareness…

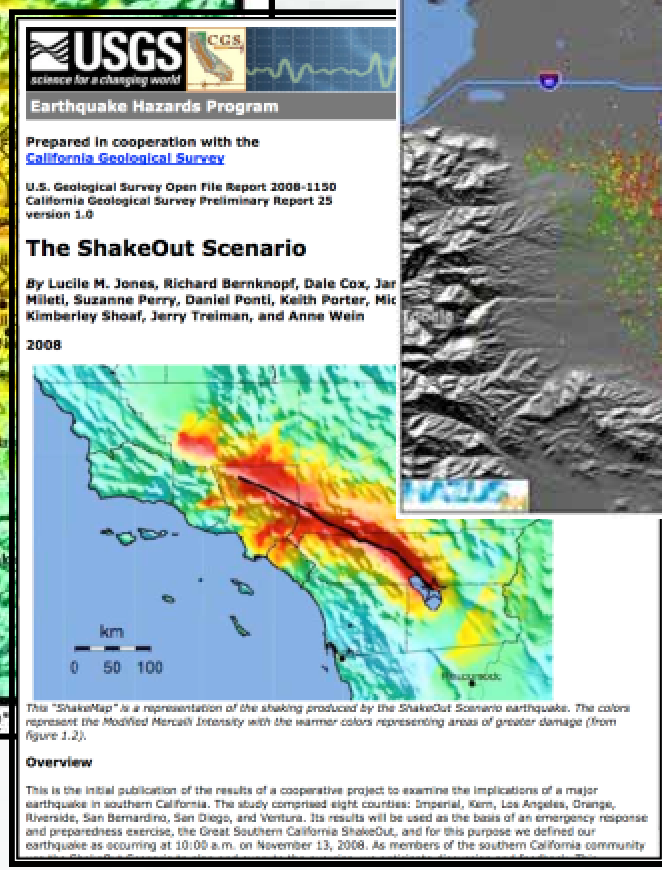
California Governor Schwarzenegger pointing to ShakeMap at his press conference following the M5.4 Chino Hills, Los Angeles, earthquake.



What Are the Primary ShakeMap Uses?

- Mitigation thru earthquake scenarios (response planning, preparedness, education, communication)…





Prepared in cooperation with the
California Geological Survey

U.S. Geological Survey Open File Report 2008-1150
California Geological Survey Preliminary Report 25
version 1.0

The ShakeOut Scenario

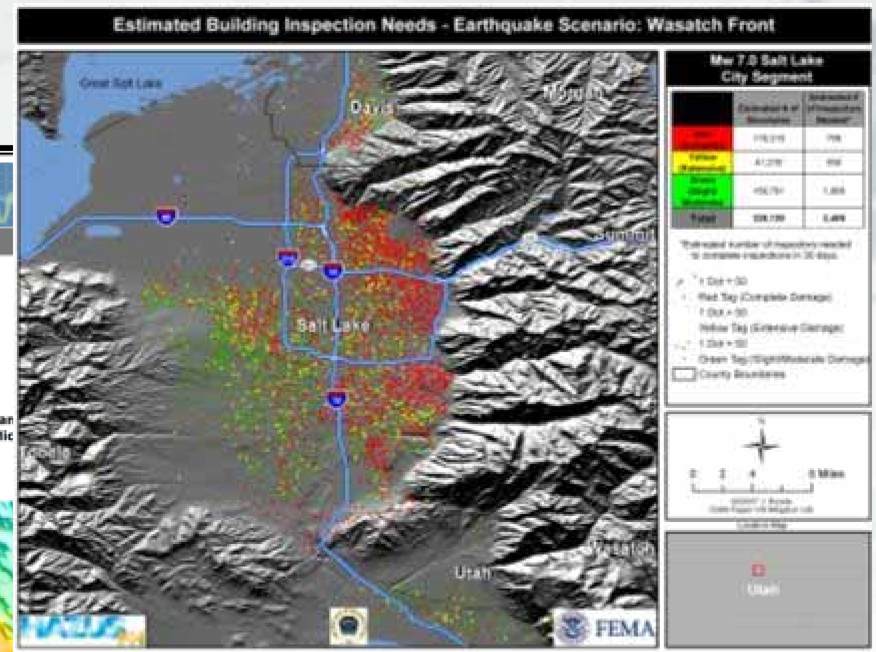
By Lucile M. Jones, Richard Bernknopf, Dale Cox, Jan… Mileti, Suzanne Perry, Daniel Ponti, Keith Porter, Mic… Kimberley Shoaf, Jerry Treiman, and Anne Wein

2008

This "ShakeMap" is a representation of the shaking produced by the ShakeOut Scenario earthquake. The colors represent the Modified Mercalli Intensity with the warmer colors representing areas of greater damage (from figure 1.2).

Overview

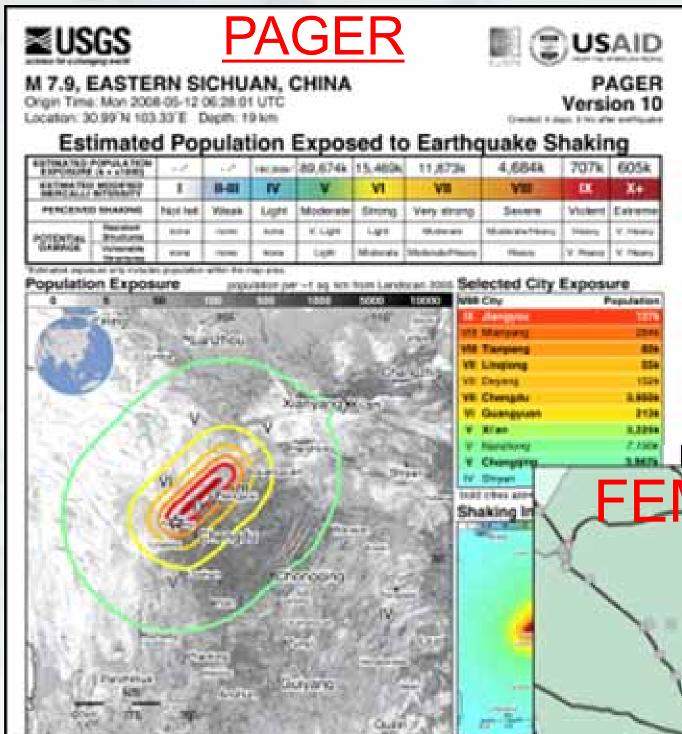
This is the initial publication of the results of a cooperative project to examine the implications of a major earthquake in southern California. The study comprised eight counties: Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura. Its results will be used as the basis of an emergency response and preparedness exercise, the Great Southern California ShakeOut, and for this purpose we defined our earthquake as occurring at 10:00 a.m. on November 13, 2008. As members of the southern California community



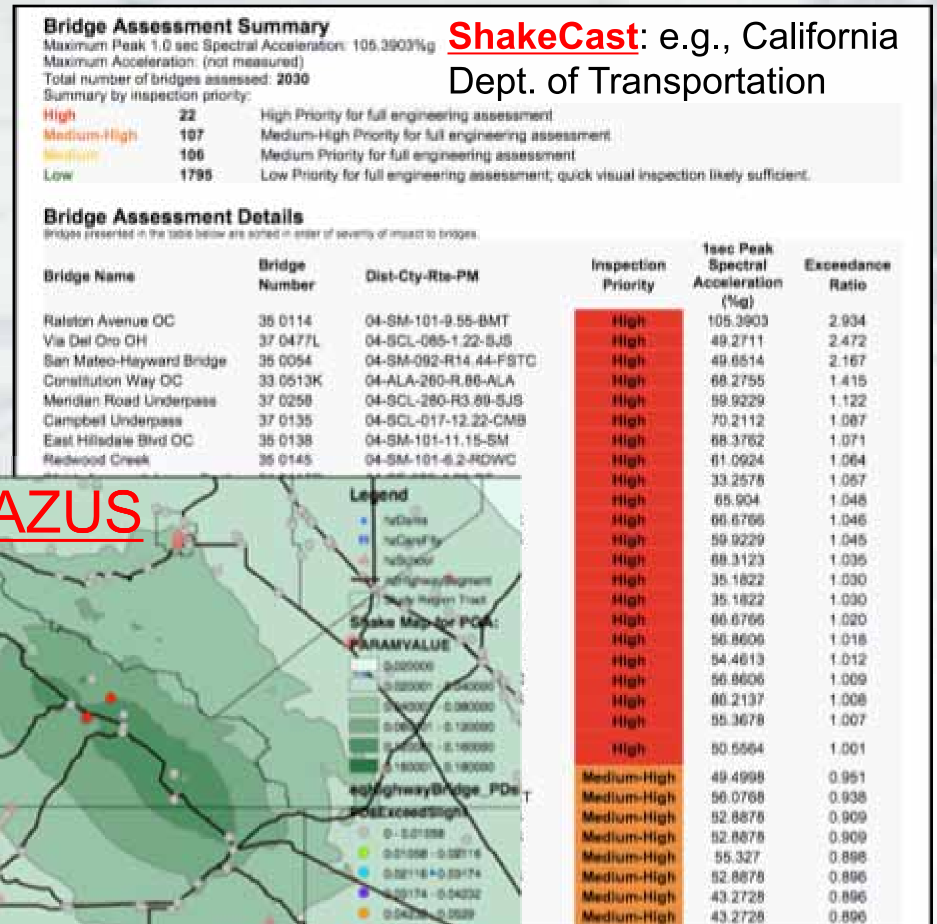
What Are the Primary ShakeMap Uses?

- Enhanced post-earthquake loss-estimation…

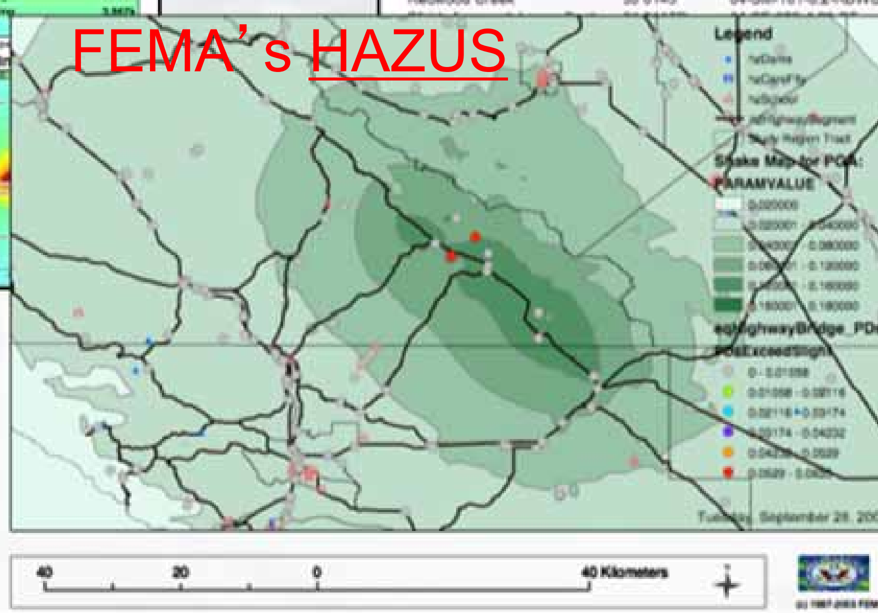
PAGER



ShakeCast: e.g., California Dept. of Transportation



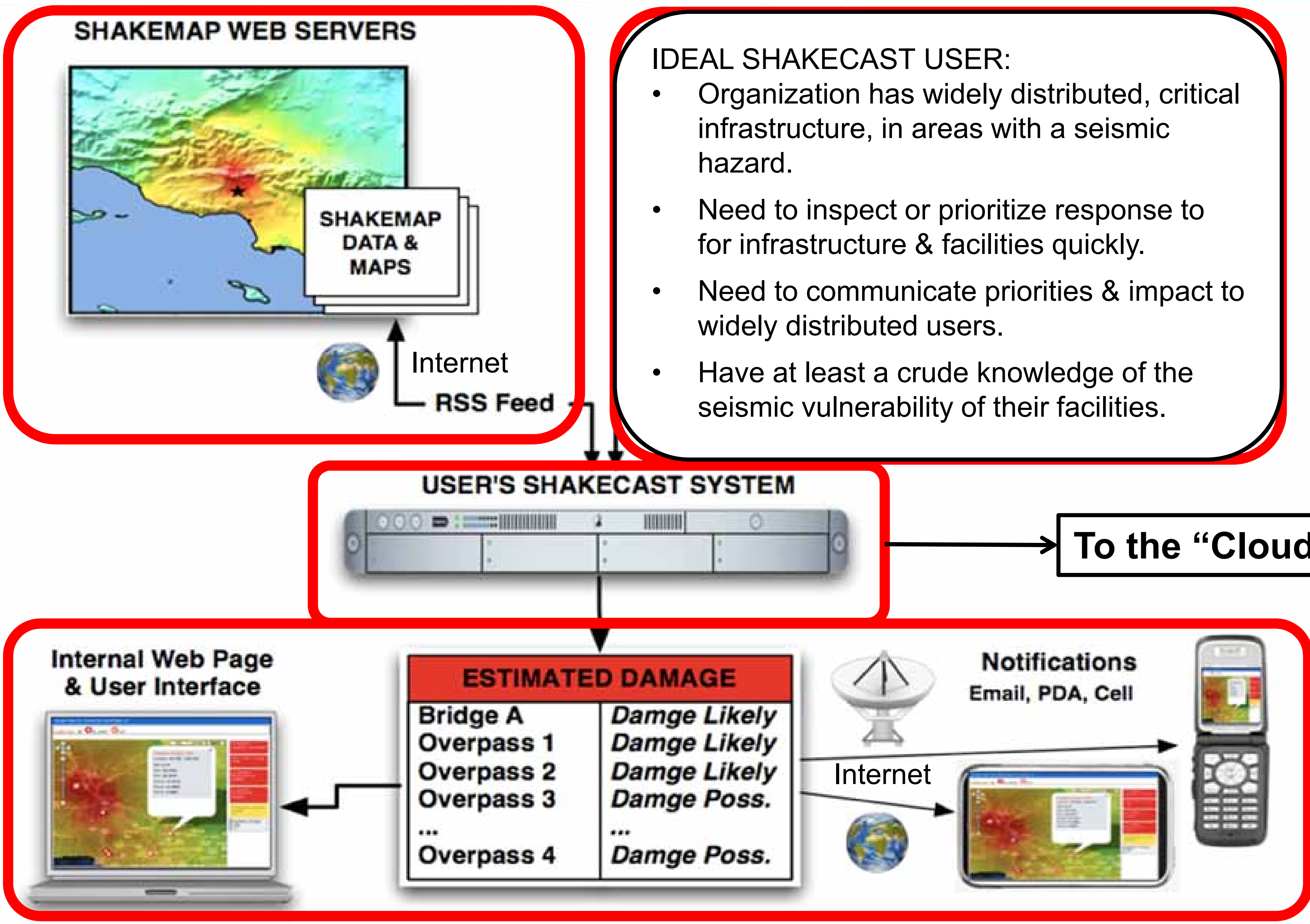
FEMA's HAZUS



+ Loss Modelers

USGS
science for a changing world

ShakeMap/ShakeCast Flowchart



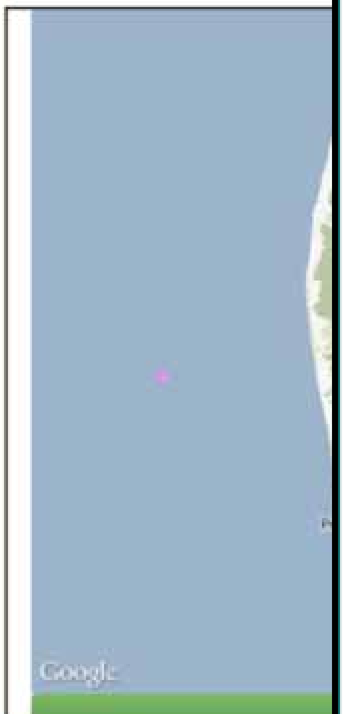
USGS
science for a changing world

Magnitude 6.6 - NEAR

Origin Time: 2013-11

Latitude: 54.6812 Lo

These results are from an a
making decisions relating t
information is reported or d



Type	ID	Name
FAT	68225	RU_Ust'-Kamchatsk Stary
ECO	68225	RU_Ust'-Kamchatsk Stary

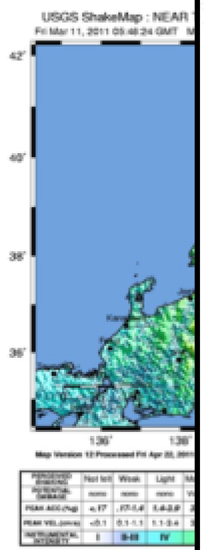
IAEA.org
International Atomic Ene

Magnitude 9.0 - NE

Origin Time: 2011-0

Latitude: 38.297 Lo

These results are from an
making decisions relating
information is reported or



FACILITY_TYPE	FACILITY_ID
NUCLEAR	JPN15
NUCLEAR	JPN10
NUCLEAR	JPN2
NUCLEAR	JPN1
NUCLEAR	JPN5
NUCLEAR	JPN7
NUCLEAR	JPN8
NUCLEAR	JPN17
NUCLEAR	JPN12
NUCLEAR	JPN9

* - MMI level may extend be

United States
Nuclear Regulatory Commission

ShakeCast Report
National Earthquake Information Center (NEIC)

Magnitude 5.8 - VIRGINIA

Version 8

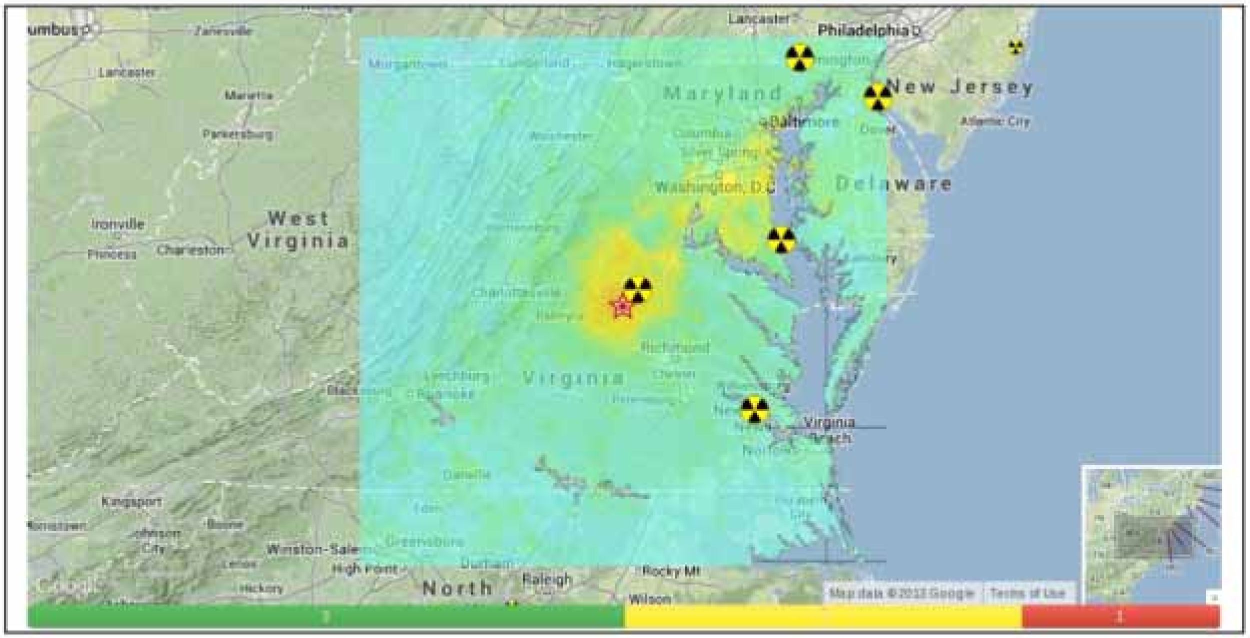
Origin Time: 2011-08-23 17:51:04 GMT

Created: 2013-09-09 18:47:24 GMT

Latitude: 37.9360 Longitude: -77.9330

Depth: 6.0 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.



Type	ID	Name	Ep. Distance (km)	Latitude	Longitude	Concern Level	PGA (%g)	SL1/OBE (PGA)	SL2/SSE (PGA)	Design Value	MMI	RG 1.166 App. A
NPP	USA37	North Anna	18.08	38.0573	-77.7956	Concerned	28.046	Exceeded	Exceeded		VI	Exceeded
NPP	USA42	Peach Bottom	248.68	39.7575	-76.2657	Slight potential for concern	3.9917	Not Exceeded	Not Exceeded		V	Exceeded
NPP	USA8	Calvert Cliffs	141.73	38.4319	-76.4424	Slight potential for concern	6.942	Not Exceeded	Not Exceeded		V	Exceeded
NPP	USA56	Surry	139.06	37.1633	-76.6942	No potential for concern	4.6099	Not Exceeded	Not Exceeded		V	Exceeded
NPP	USA50	Salem	269.01	39.4662	-75.5352	No potential for concern	3.5558	Not Exceeded	Not Exceeded		IV	Exceeded
NPP	USA28	Hope Creek	269.01	39.4662	-75.5352	No potential for concern	3.5558	Not Exceeded	Not Exceeded		IV	Exceeded

ShakeCast Summary Report:

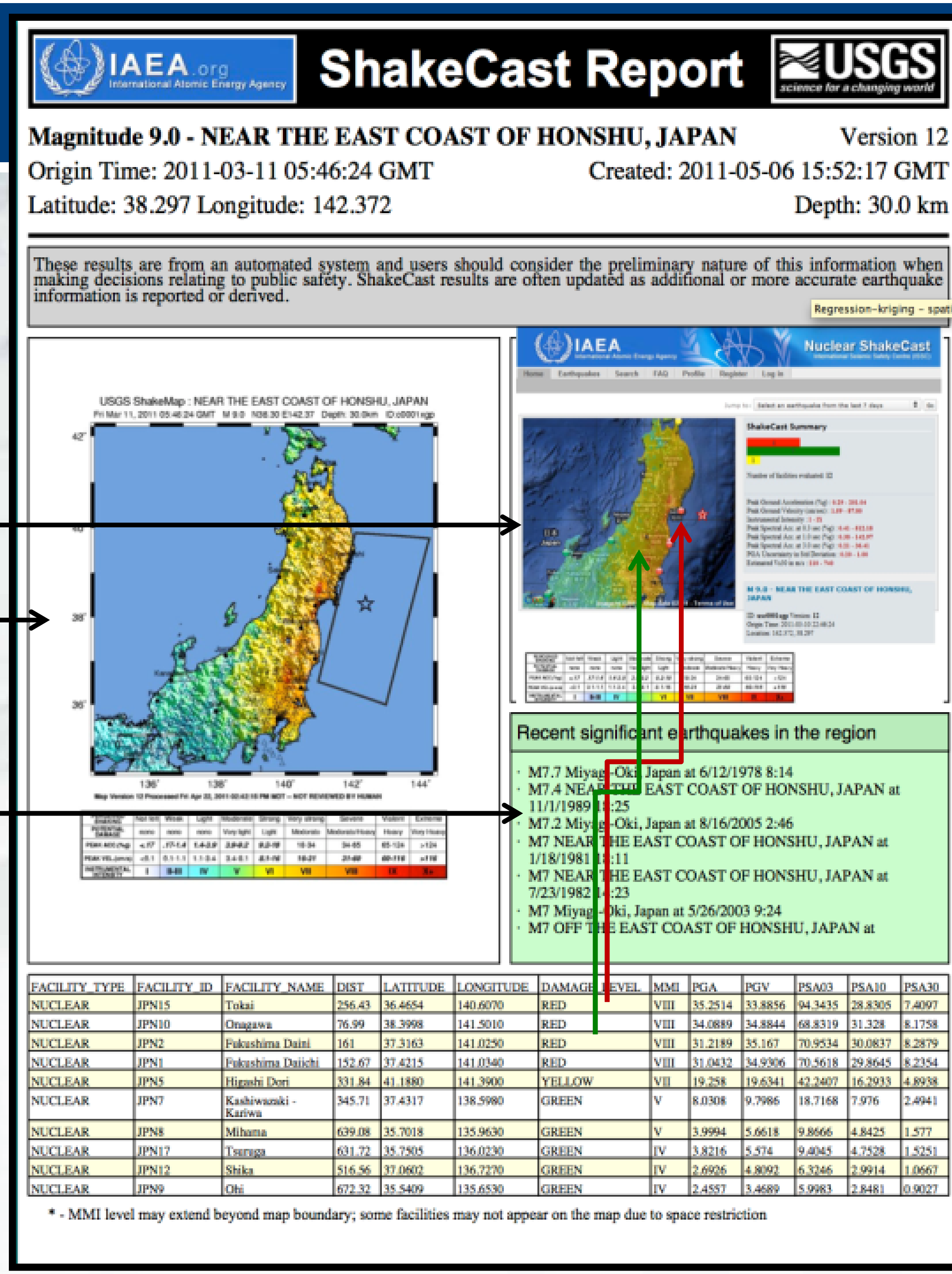
<u>USER</u>: International Atomic Energy Agency (IAEA)

Facility Map (color coded)

ShakeMap

Recent Earthquakes Nearby

Facility Shaking Summary



IAEA.org International Atomic Energy Agency — **ShakeCast Report** — USGS science for a changing world

Magnitude 9.0 - NEAR THE EAST COAST OF HONSHU, JAPAN Version 12

Origin Time: 2011-03-11 05:46:24 GMT Created: 2011-05-06 15:52:17 GMT

Latitude: 38.297 Longitude: 142.372 Depth: 30.0 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

Recent significant earthquakes in the region

- M7.7 Miyagi-Oki, Japan at 6/12/1978 8:14
- M7.4 NEAR THE EAST COAST OF HONSHU, JAPAN at 11/1/1989 1:25
- M7.2 Miyagi-Oki, Japan at 8/16/2005 2:46
- M7 NEAR THE EAST COAST OF HONSHU, JAPAN at 1/18/1981 1:11
- M7 NEAR THE EAST COAST OF HONSHU, JAPAN at 7/23/1982 1:23
- M7 Miyagi-Oki, Japan at 5/26/2003 9:24
- M7 OFF THE EAST COAST OF HONSHU, JAPAN at

FACILITY_TYPE	FACILITY_ID	FACILITY_NAME	DIST	LATITUDE	LONGITUDE	DAMAGE_LEVEL	MMI	PGA	PGV	PSA03	PSA10	PSA30
NUCLEAR	JPN15	Tokai	256.43	36.4654	140.6070	RED	VIII	35.2514	33.8856	94.3435	28.8305	7.4097
NUCLEAR	JPN10	Onagawa	76.99	38.3998	141.5010	RED	VIII	34.0889	34.8844	68.8319	31.328	8.1758
NUCLEAR	JPN2	Fukushima Daini	161	37.3163	141.0250	RED	VIII	31.2189	35.167	70.9534	30.0837	8.2879
NUCLEAR	JPN1	Fukushima Daiichi	152.67	37.4215	141.0340	RED	VIII	31.0432	34.9306	70.5618	29.8645	8.2354
NUCLEAR	JPN5	Higashi Dori	331.84	41.1880	141.3900	YELLOW	VII	19.258	19.6341	42.2407	16.2933	4.8938
NUCLEAR	JPN7	Kashiwazaki - Kariwa	345.71	37.4317	138.5980	GREEN	V	8.0308	9.7986	18.7168	7.976	2.4941
NUCLEAR	JPN8	Mihama	639.08	35.7018	135.9630	GREEN	V	3.9994	5.6618	9.8666	4.8425	1.577
NUCLEAR	JPN17	Tsuruga	631.72	35.7505	136.0230	GREEN	IV	3.8216	5.574	9.4045	4.7528	1.5251
NUCLEAR	JPN12	Shika	516.56	37.0602	136.7270	GREEN	IV	2.6926	4.8092	6.3246	2.9914	1.0667
NUCLEAR	JPN9	Ohi	672.32	35.5409	135.6530	GREEN	IV	2.4557	3.4689	5.9983	2.8481	0.9027

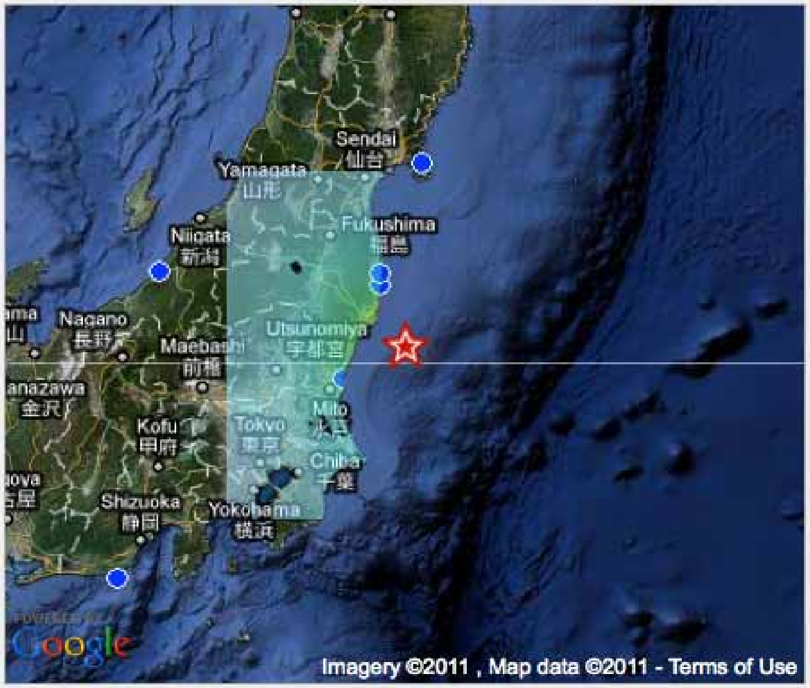
* - MMI level may extend beyond map boundary; some facilities may not appear on the map due to space restriction

IAEA
International Atomic Energy Agency

Nuclear ShakeCast
International Seismic Safety Centre (ISSC)

Home | Earthquakes | Search | FAQ | Profile | Register | Log in

Jump to: Select an earthquake from the last 7 days Go



ShakeCast Summary

Number of facilities evaluated: **3**
Peak Ground Acceleration (%g) : 0.4543 - 18.261
Peak Ground Velocity (cm/sec) : 0.3293 - 9.75
Instrumental Intensity : II - V
Peak Spectral Acc. at 0.3 sec (%g) : 0.788 - 27.6374
Peak Spectral Acc. at 1.0 sec (%g) : 0.3478 - 10.2995
Peak Spectral Acc. at 3.0 sec (%g) : 0.0568 - 1.2716
PGA Uncertainty in Std Deviation : 1.0002 - 1.0071
Estimated Vs30 in m/s : 210 - 740

M 5.9 - NEAR THE EAST COAST OF HONSHU, JAPAN

ID: **c000252e** Version: **1**
Origin Time: 2011-03-17 13:54:52
Location: 141.3074, 36.7657

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Log in

Username: Password: Log me on automatically each visit Log in

U.S.NRC **ShakeCast Report** USGS

science for a changing world

GINIA

Version 7

1:04 GMT

Created: 2011-08-26 14:50:40 GMT

77.9330

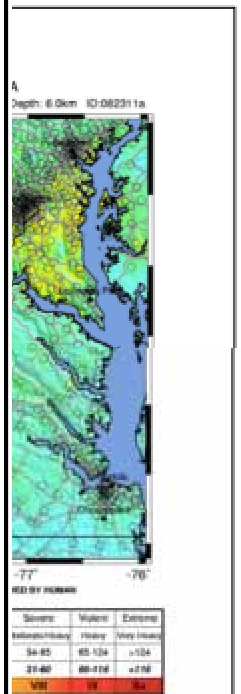
Depth: 6.0 km

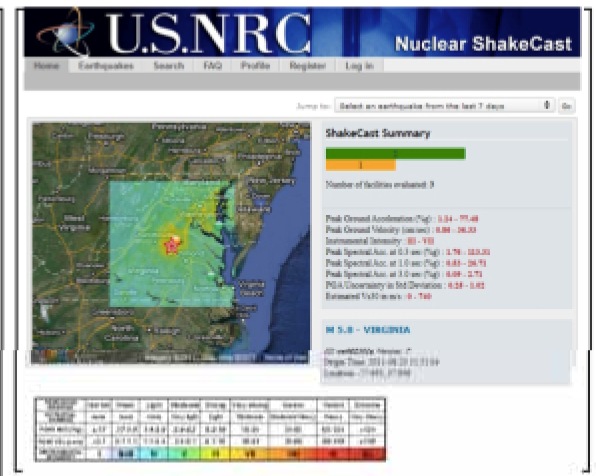
ystem and users should consider the preliminary nature of this information when ty. ShakeCast results are often updated as additional or more accurate earthquake

Probabilistic Relationships between Ground-Motion Parameters and Modified Mercalli Intensity in California

by C. B. Worden, M. C. Gerstenberger, D. A. Rhoades, and D. J. Wald

Abstract We use a database of approximately 200,000 modified Mercalli intensity (MMI) observations of California earthquakes collected from USGS "Did You Feel It?" (DYFI) reports, along with a comparable number of peak ground-motion amplitudes from California seismic networks, to develop probabilistic relationships between MMI and peak ground velocity (PGV), peak ground acceleration (PGA), and 0.3 s, 1 s, and 3 s 5% damped pseudospectral acceleration (PSA). After associating each ground-motion observation with an MMI computed from all the DYFI responses within 2 km of the observation, we derived a joint probability distribution between MMI and ground motion. We then derived reversible relationships between MMI and each ground-motion parameter by using a total least squares regression to fit a bilinear function to the median of the stacked probability distributions. Among the relationships, the fit to peak ground velocity has the smallest errors, though linear combinations of PGA and PGV give nominally better results. We also find that magnitude and distance terms reduce the overall residuals and are justifiable on an information theoretic basis. For intensities MMI ≥ 5, our results are in close agreement with the relations of Wald, Quitoriano, Heaton, Kanamori (1999); for lower intensities, our results fall midway between Wald, Quitoriano, Heaton, Kanamori (1999) and those of Atkinson and Kaka (2007). The earthquakes in the study ranged in magnitude from 3.0 to 7.3, and the distances ranged from less than a kilometer to about 400 km from the source.



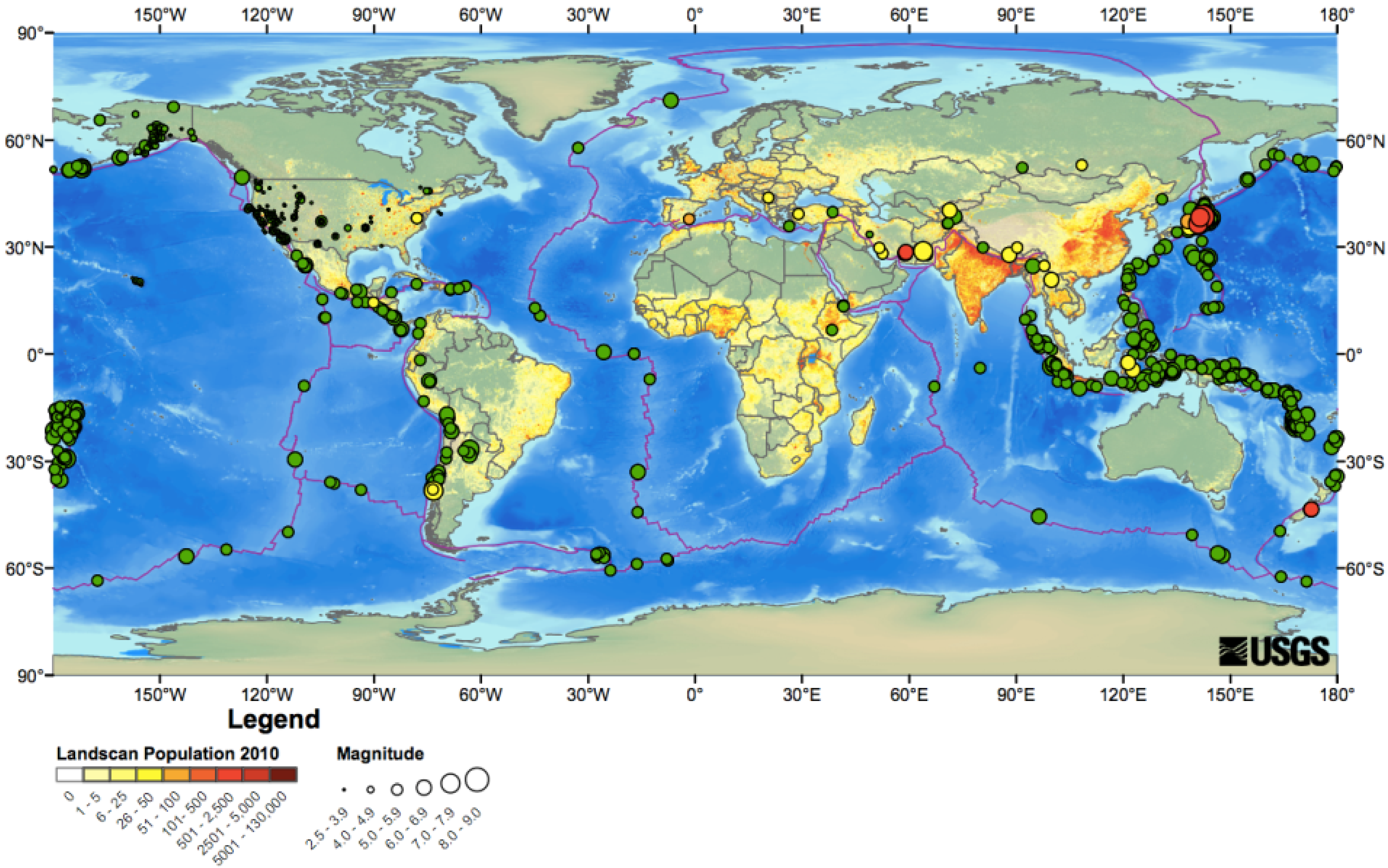


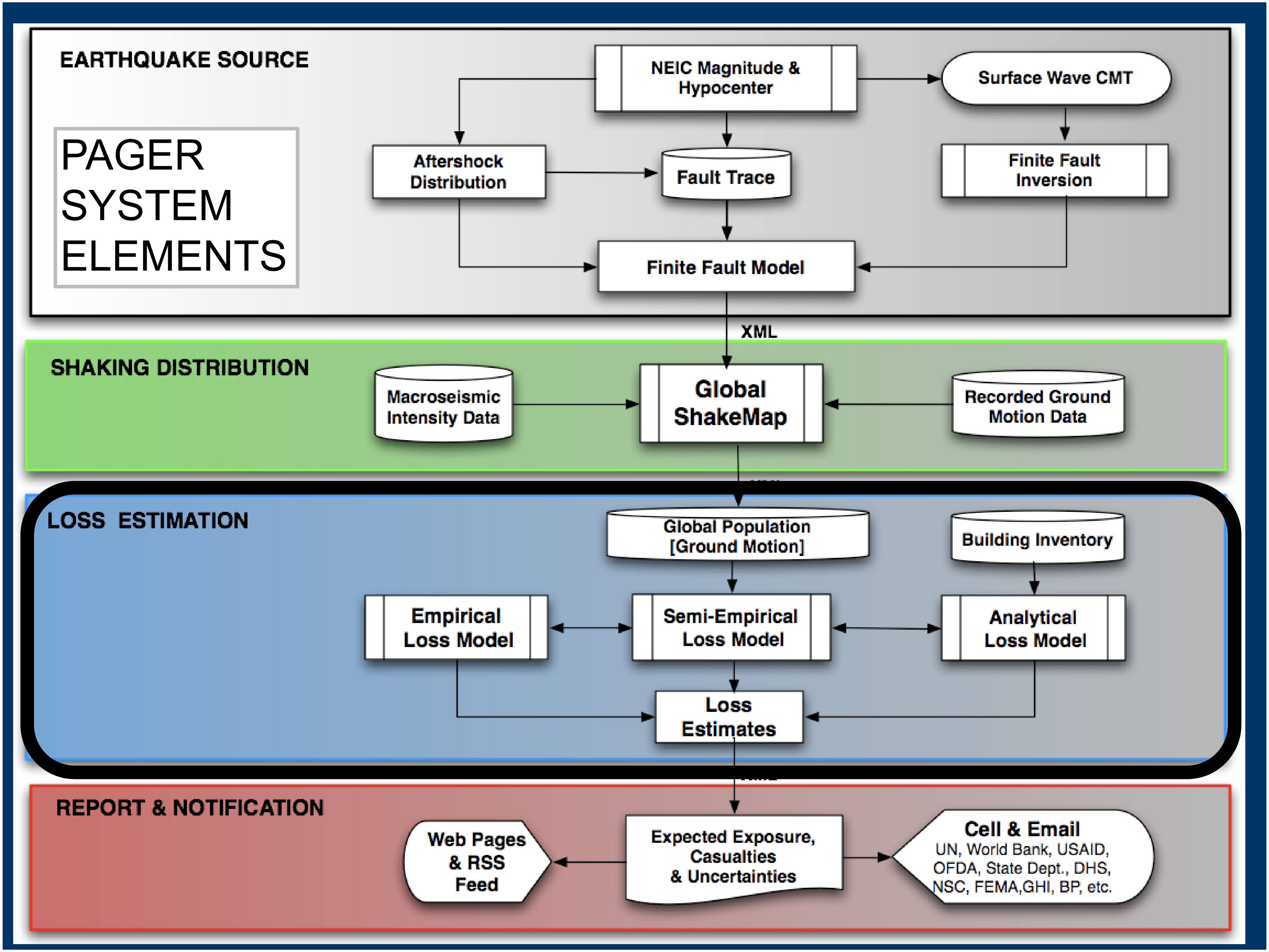
Recent significant earthquakes in the region

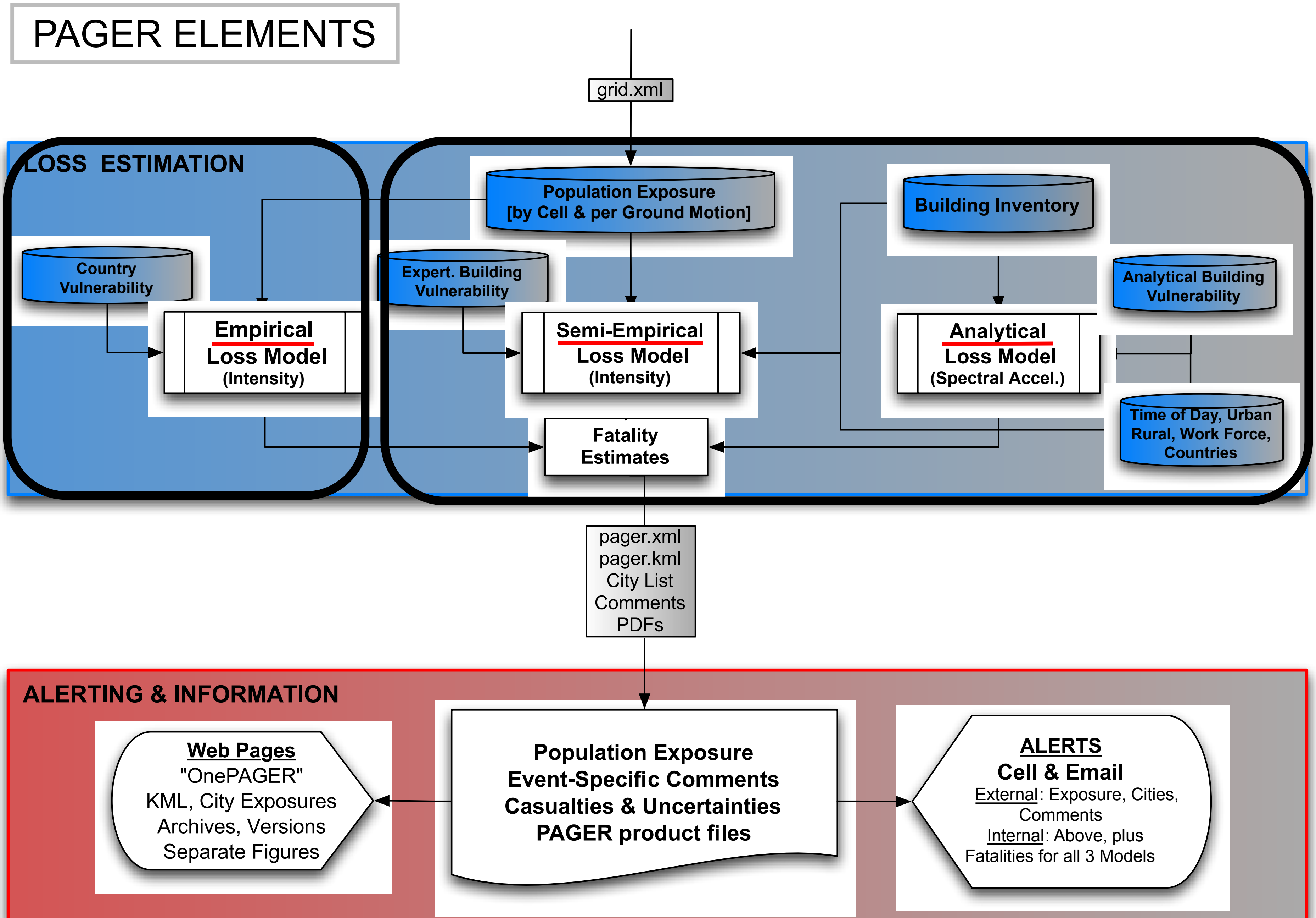
- M4.5 VIRGINIA at 12/9/2003 20:59

FACILITY_TYPE	FACILITY_ID	FACILITY_NAME	DIST	LATITUDE	LONGITUDE	DAMAGE_LEVEL	MMI	PGA	PGV	PSA03	PSA10	PSA30
NUCLEAR	USA37	North Anna	18.08	38.0573	-77.7956	ORANGE	VI	26.8102	11.3386	35.8552	8.6664	0.8605
NUCLEAR	USA8	Calvert Cliffs	141.73	38.4319	-76.4424	GREEN	V	4.9185	3.4933	5.0906	1.4573	0.1529
NUCLEAR	USA56	Surry	139.06	37.1633	-76.6942	GREEN	V	4.534	3.7797	5.8834	1.9297	0.202

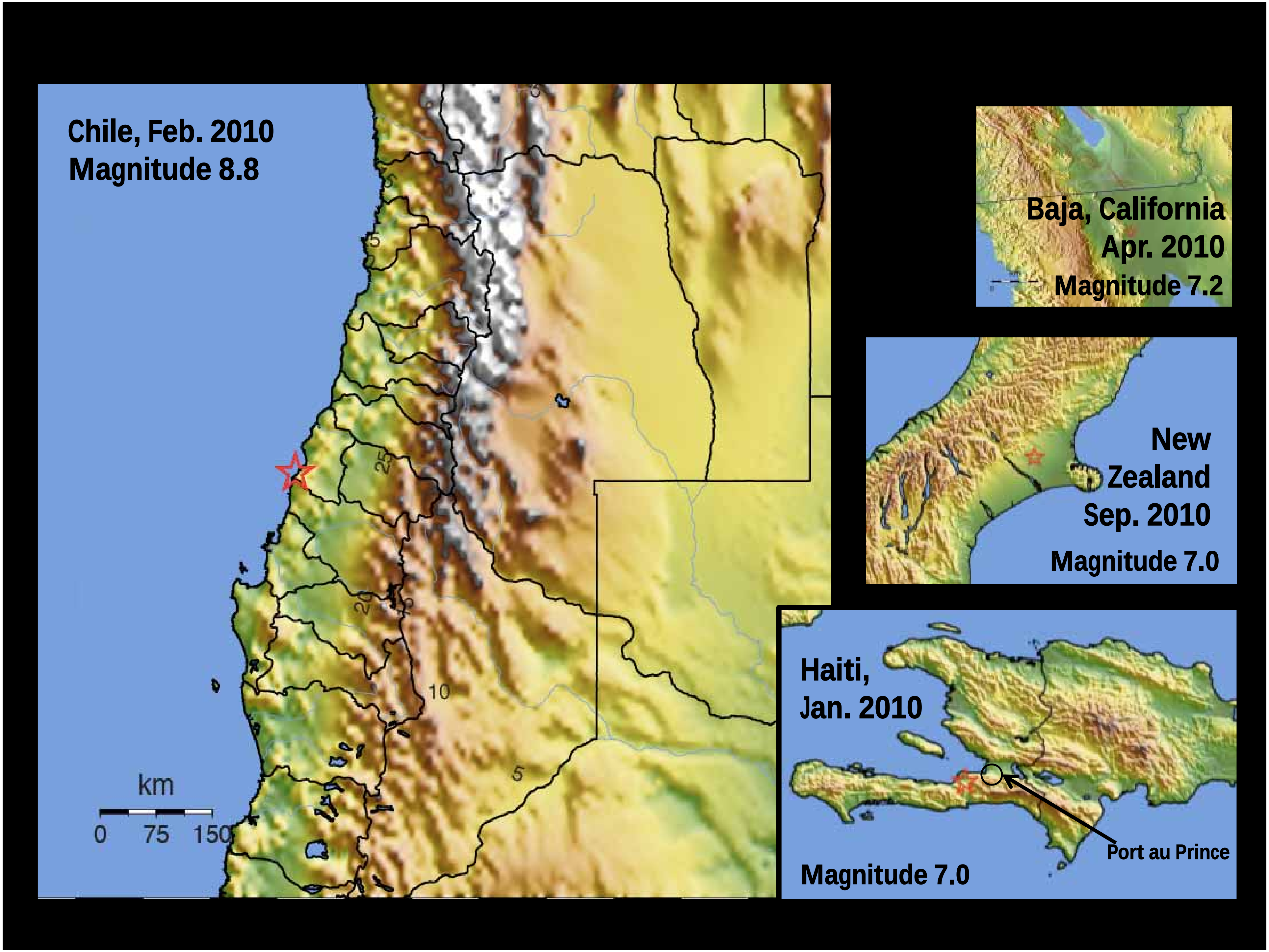
PAGER Alerts (Sept 2010 to Sept 2011)




PAGER SYSTEM ELEMENTS
EARTHQUAKE SOURCE
NEIC Magnitude & Hypocenter
Surface Wave CMT
Aftershock Distribution
Fault Trace
Finite Fault Inversion
Finite Fault Model
XML
SHAKING DISTRIBUTION
Macroseismic Intensity Data
Global ShakeMap
Recorded Ground Motion Data
LOSS ESTIMATION
Global Population [Ground Motion]
Building Inventory
Empirical Loss Model
Semi-Empirical Loss Model
Analytical Loss Model
Loss Estimates
REPORT & NOTIFICATION
Web Pages & RSS Feed
Expected Exposure, Casualties & Uncertainties
Cell & Email
UN, World Bank, USAID, OFDA, State Dept., DHS, NSC, FEMA,GHI, BP, etc.

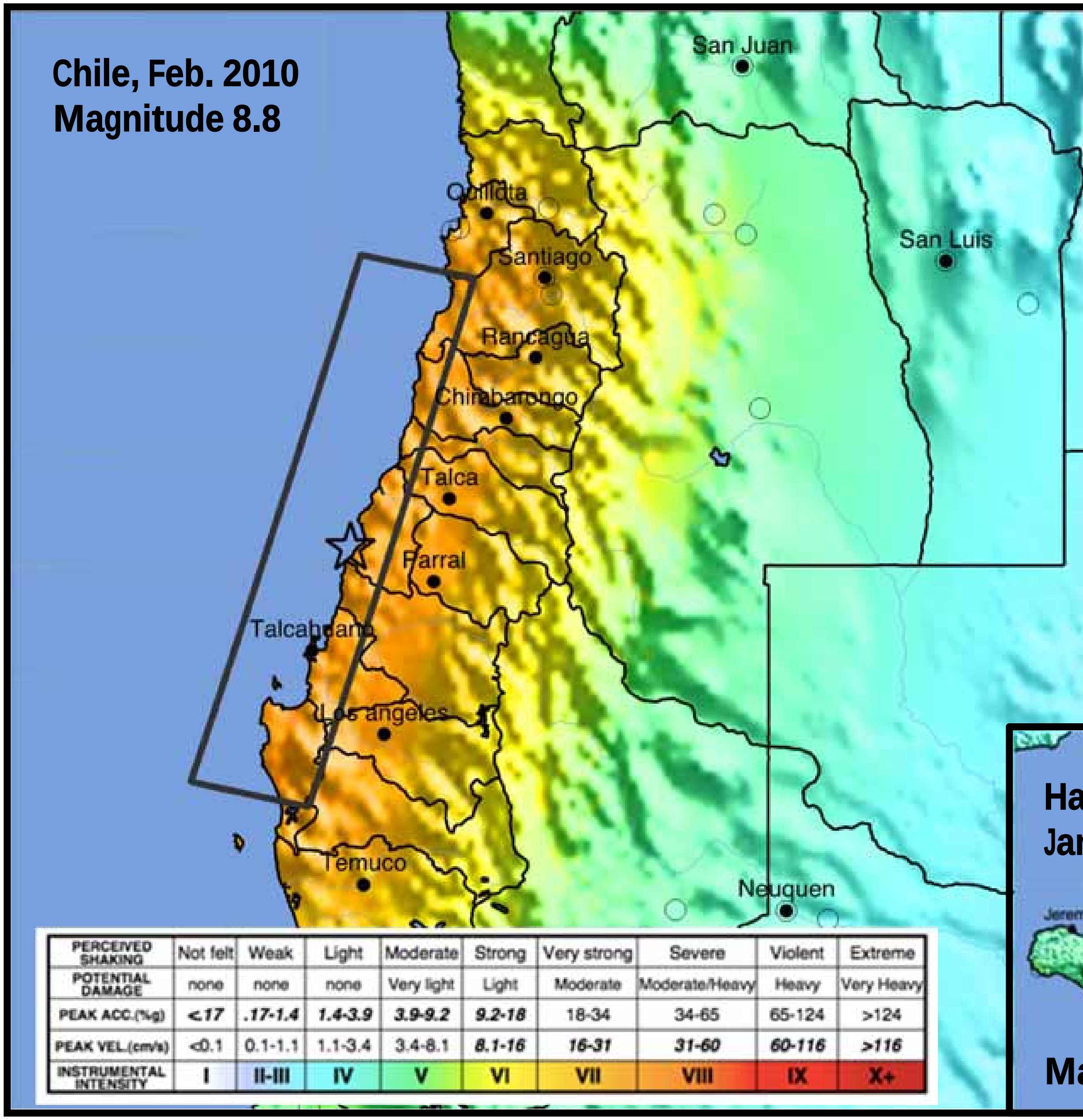


PAGER ELEMENTS
grid.xml
LOSS ESTIMATION
Population Exposure
[by Cell & per Ground Motion]
Building Inventory
Country Vulnerability
Expert. Building Vulnerability
Analytical Building Vulnerability
Empirical Loss Model (Intensity)
Semi-Empirical Loss Model (Intensity)
Analytical Loss Model (Spectral Accel.)
Time of Day, Urban Rural, Work Force, Countries
Fatality Estimates
pager.xml
pager.kml
City List
Comments
PDFs
ALERTING & INFORMATION
Web Pages
"OnePAGER"
KML, City Exposures
Archives, Versions
Separate Figures
Population Exposure
Event-Specific Comments
Casualties & Uncertainties
PAGER product files
ALERTS
Cell & Email
External: Exposure, Cities, Comments
Internal: Above, plus
Fatalities for all 3 Models

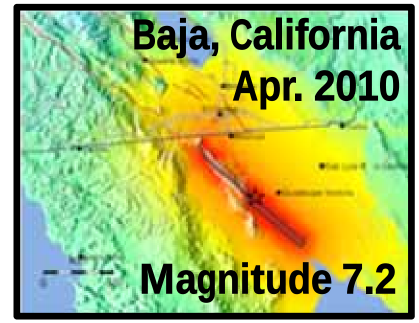

Chile, Feb. 2010
Magnitude 8.8
km
0 75 150
Baja, California
Apr. 2010
Magnitude 7.2
New
Zealand
Sep. 2010
Magnitude 7.0
Haiti,
Jan. 2010
Port au Prince
Magnitude 7.0

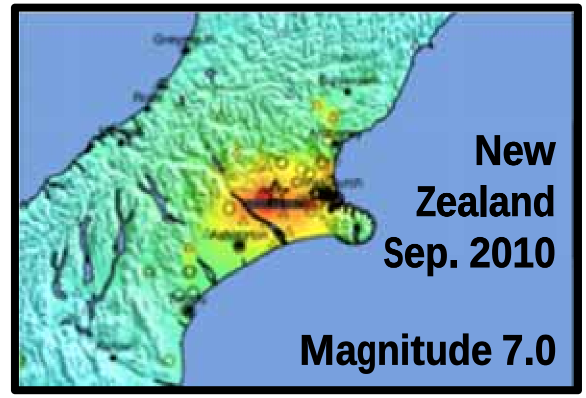
USGS ShakeMap Estimated Shaking Intensities

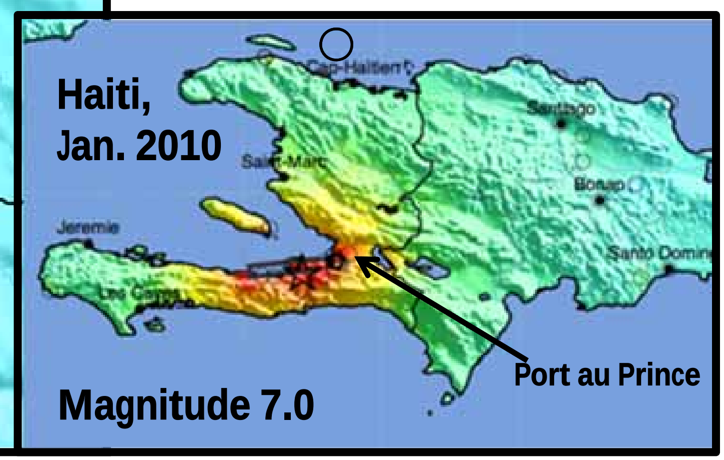
[Same Map Scales!]



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

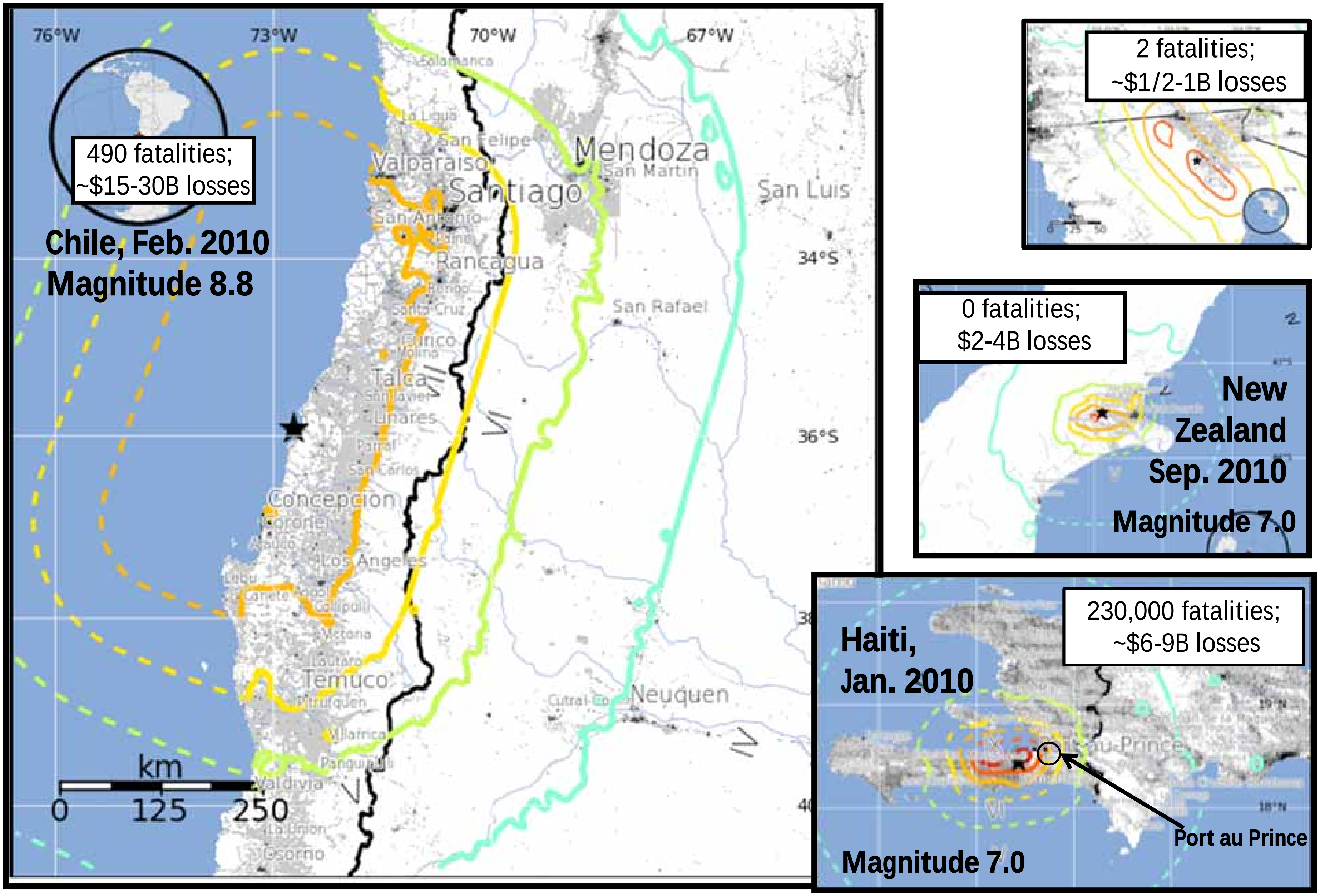






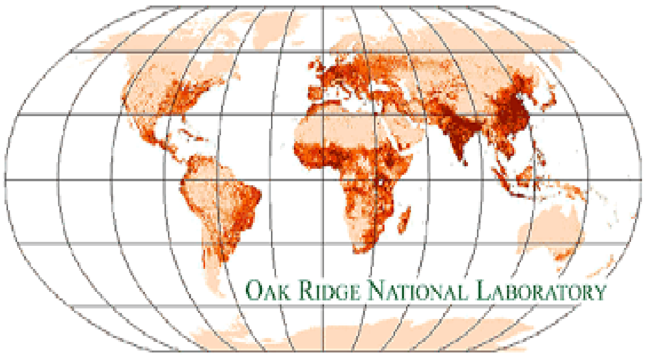
Epicenter and Magnitude

[Same Map Scales!]

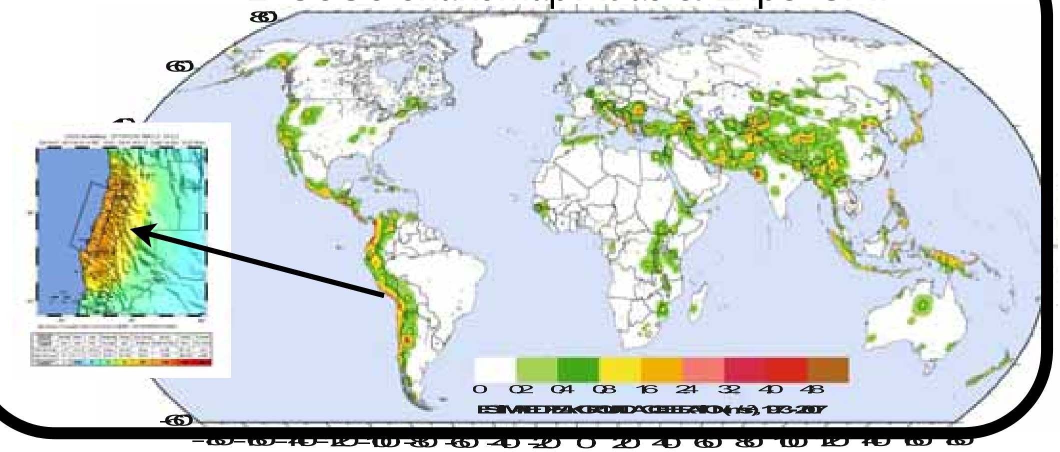


Empirical Fatality Model Input Datasets:

1. LandScan Population 2008

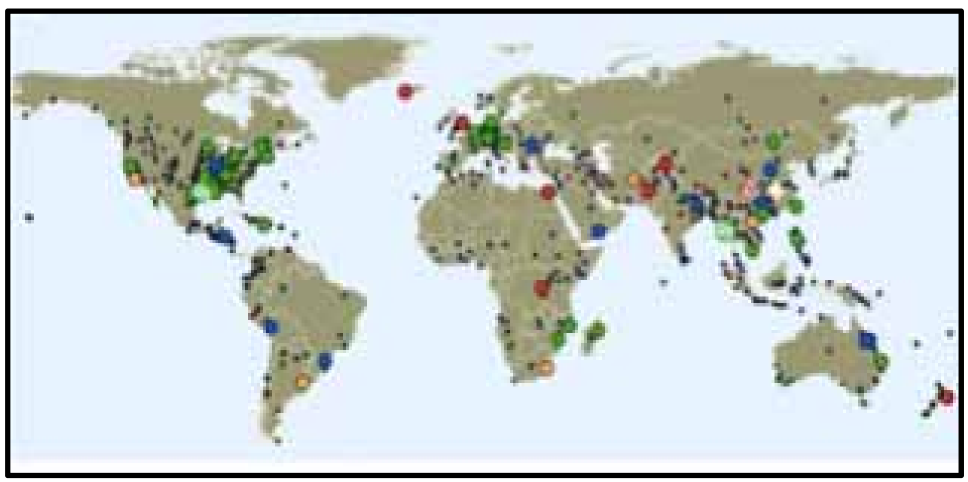


2. USGS ShakeMap Atlas & Expo-CAT



3. PAGER-CAT

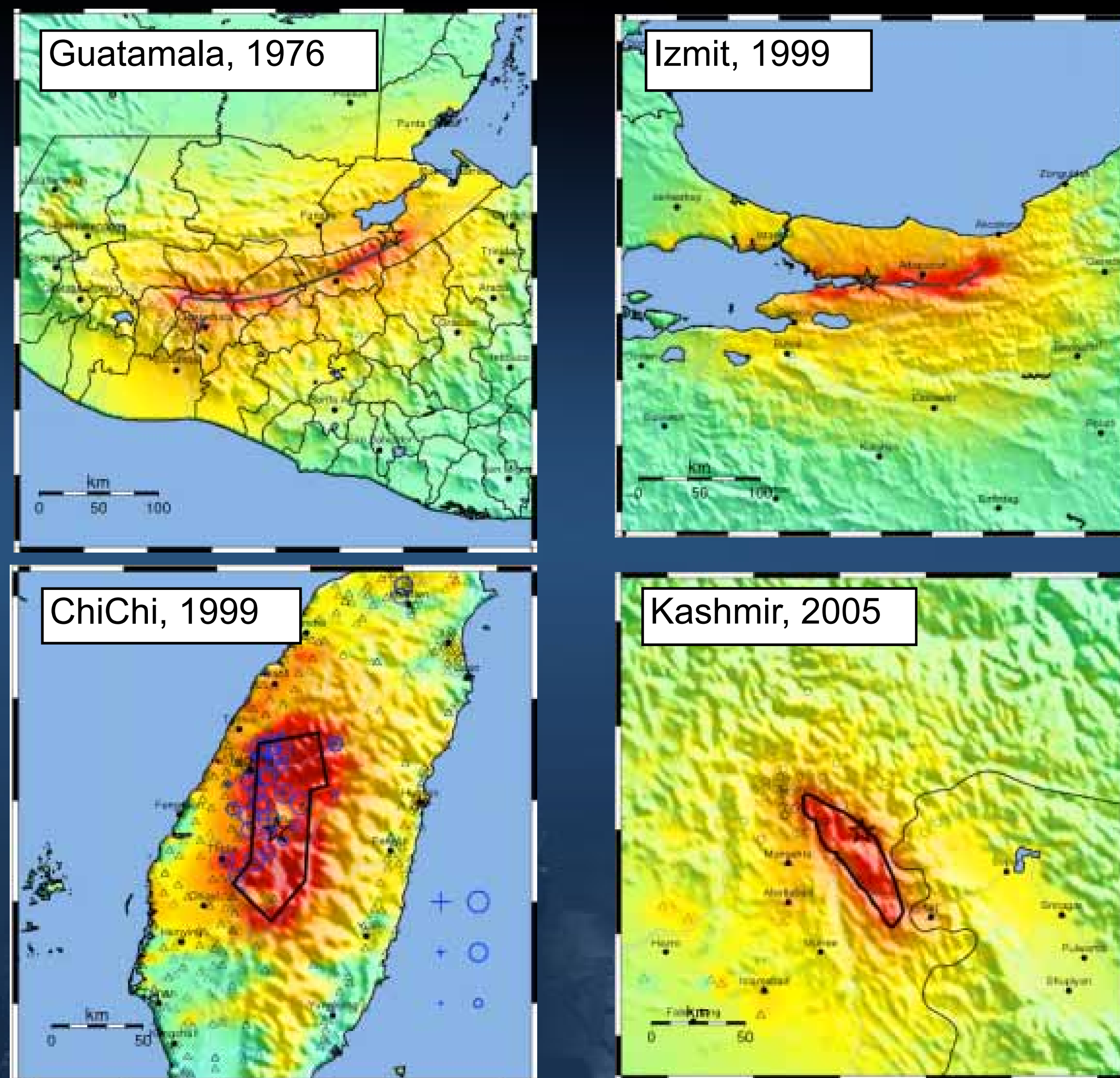
(Event catalogue, with **fatalities** and **$ losses** for 35 years of events)



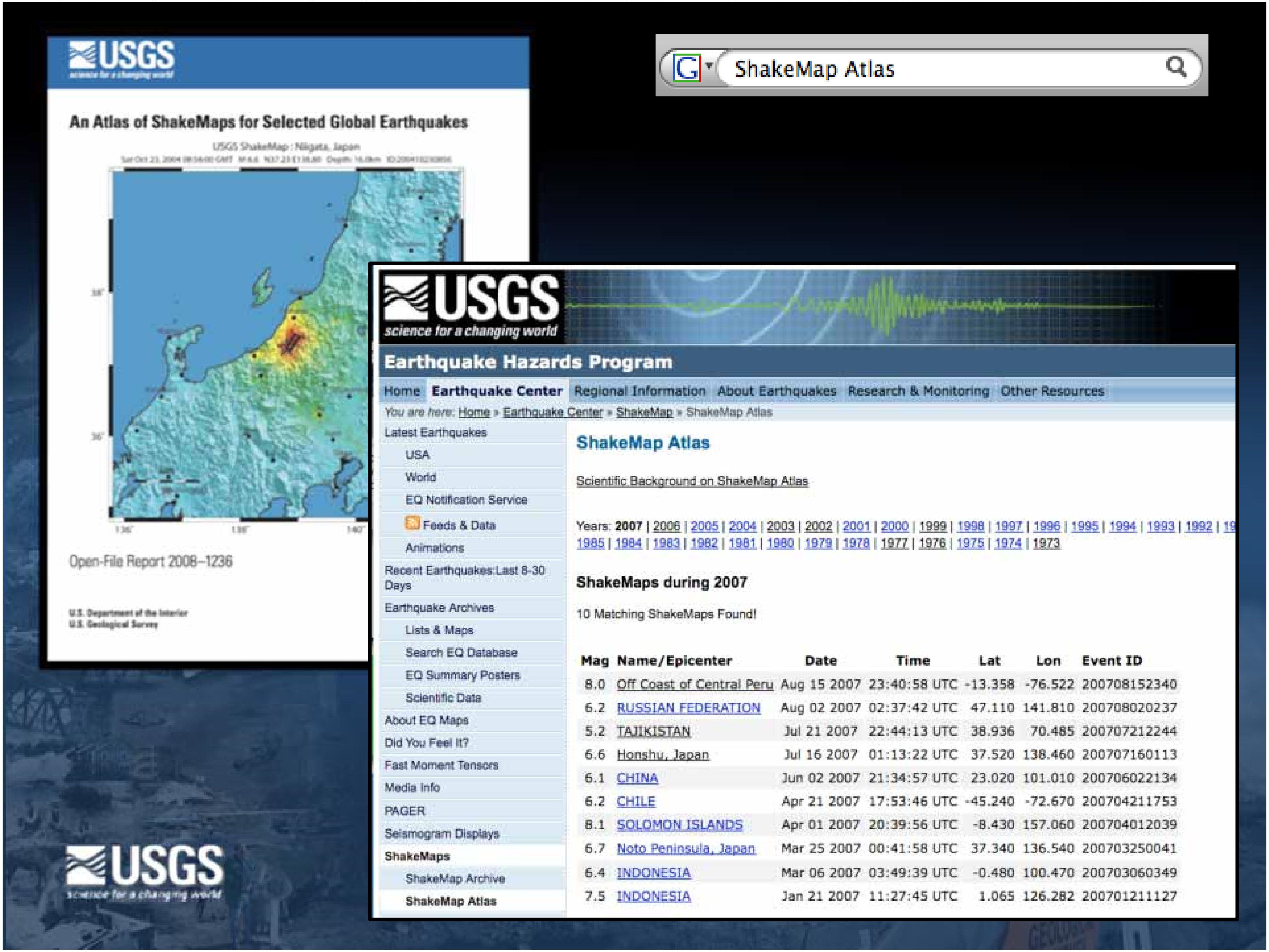
ShakeMap Atlas 1.0: ShakeMaps for >5,600 Earthquakes (1973-2008)

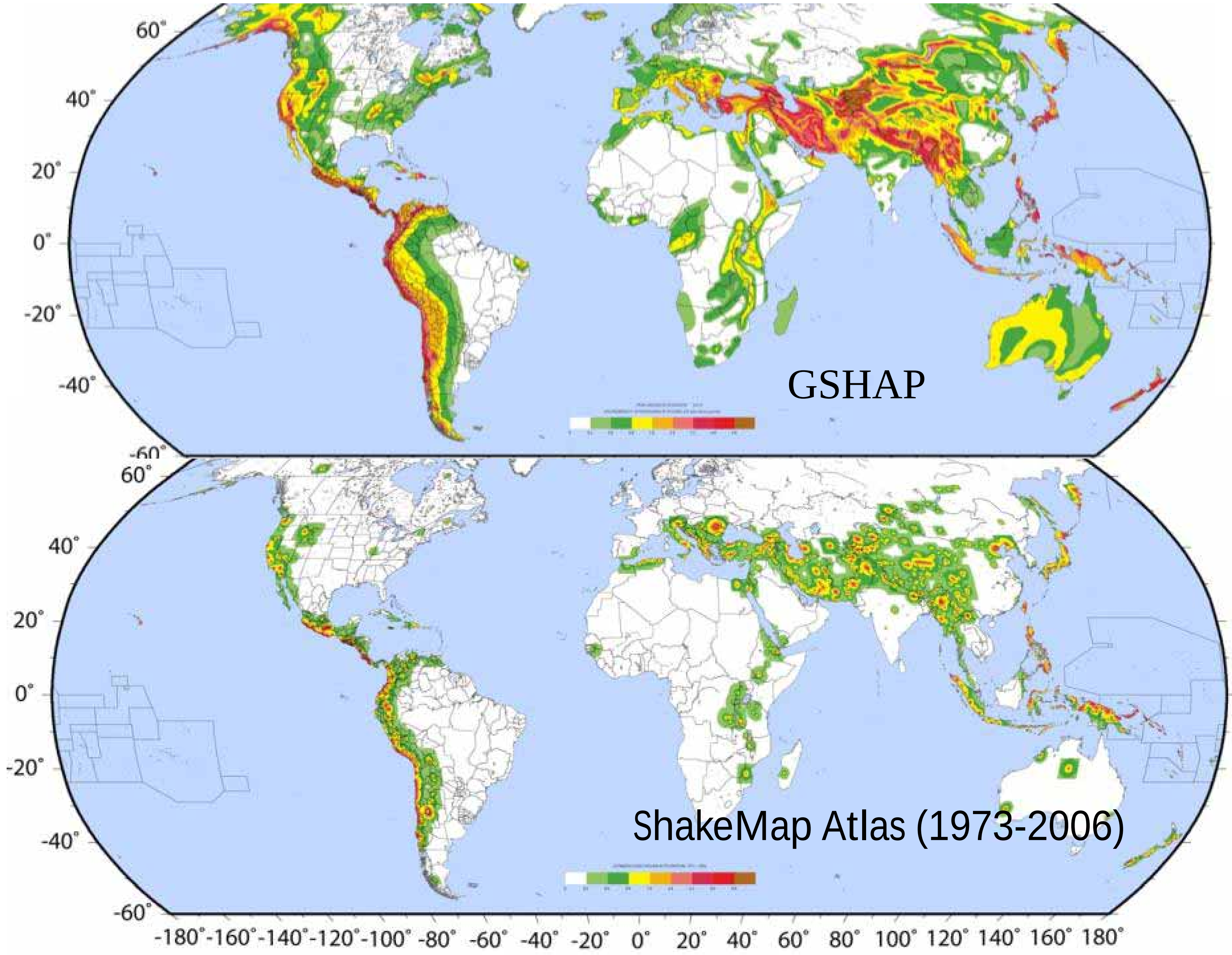
- All available data (ground motion, intensity, fault plane)
- Site conditions from topographic-slope proxy
- Standard ShakeMap approach to combine observed, estimated ground motions

Uses other than PAGER: GEM, loss estimation, secondary hazards, insurance, mitigation, response planning, …



USGS
science for a changing world


USGS
An Atlas of ShakeMaps for Selected Global Earthquakes
USGS ShakeMap : Niigata, Japan
Open-File Report 2008–1236
U.S. Department of the Interior
U.S. Geological Survey
ShakeMap Atlas
USGS
science for a changing world
Earthquake Hazards Program
Home
Earthquake Center
Regional Information
About Earthquakes
Research & Monitoring
Other Resources
You are here: Home » Earthquake Center » ShakeMap » ShakeMap Atlas
Latest Earthquakes
USA
World
EQ Notification Service
Feeds & Data
Animations
Recent Earthquakes:Last 8-30 Days
Earthquake Archives
Lists & Maps
Search EQ Database
EQ Summary Posters
Scientific Data
About EQ Maps
Did You Feel It?
Fast Moment Tensors
Media Info
PAGER
Seismogram Displays
ShakeMaps
ShakeMap Archive
ShakeMap Atlas
ShakeMap Atlas
Scientific Background on ShakeMap Atlas
Years: 2007 | 2006 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1996 | 1995 | 1994 | 1993 | 1992 |
1985 | 1984 | 1983 | 1982 | 1981 | 1980 | 1979 | 1978 | 1977 | 1976 | 1975 | 1974 | 1973
ShakeMaps during 2007
10 Matching ShakeMaps Found!
Mag Name/Epicenter Date Time Lat Lon Event ID
8.0 Off Coast of Central Peru Aug 15 2007 23:40:58 UTC -13.358 -76.522 200708152340
6.2 RUSSIAN FEDERATION Aug 02 2007 02:37:42 UTC 47.110 141.810 200708020237
5.2 TAJIKISTAN Jul 21 2007 22:44:13 UTC 38.936 70.485 200707212244
6.6 Honshu, Japan Jul 16 2007 01:13:22 UTC 37.520 138.460 200707160113
6.1 CHINA Jun 02 2007 21:34:57 UTC 23.020 101.010 200706022134
6.2 CHILE Apr 21 2007 17:53:46 UTC -45.240 -72.670 200704211753
8.1 SOLOMON ISLANDS Apr 01 2007 20:39:56 UTC -8.430 157.060 200704012039
6.7 Noto Peninsula, Japan Mar 25 2007 00:41:58 UTC 37.340 136.540 200703250041
6.4 INDONESIA Mar 06 2007 03:49:39 UTC -0.480 100.470 200703060349
7.5 INDONESIA Jan 21 2007 11:27:45 UTC 1.065 126.282 200701211127
USGS
science for a changing world



60°
40°
20°
0°
-20°
-40°
-60°
GSHAP
ShakeMap Atlas (1973-2006)
-180° -160° -140° -120° -100° -80° -60° -40° -20° 0° 20° 40° 60° 80° 100° 120° 140° 160° 180°

Empirical Approach

Fatalities estimated as a function of fatality rate of population exposed at each intensity level:

 # People **Fatality rate/intensity level**

$$\text{Fatalities} = \sum_{i=VI-IX} P_{intensity} \times FR_{intensity}$$

Empirical Fatality Estimation Approach:

Fatality rate is parameterized with a two-parameter lognormal CDF:

$$y(S_i) = \phi\left(\frac{1}{\beta}\ln\left(\frac{S_i}{\theta}\right)\right)$$

Where s_i **is intensity** at level *i* and Θ & β distribution parameters. The total number of fatalities for an earthquake can be estimated as:

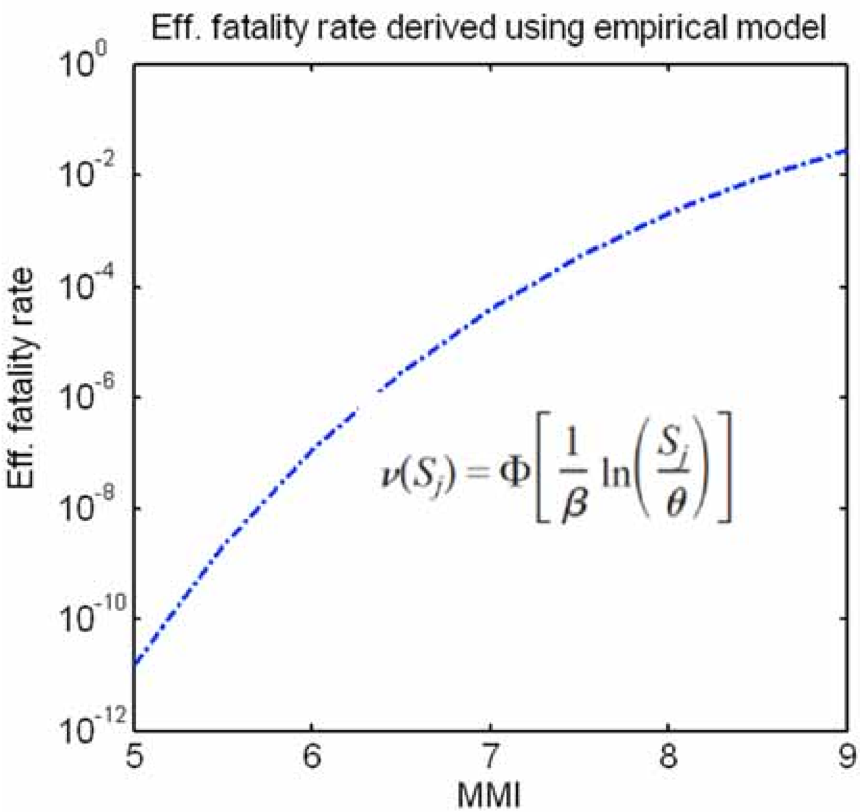
$$Fatalities \quad E = \sum_i y(s_i).P(s_i)$$

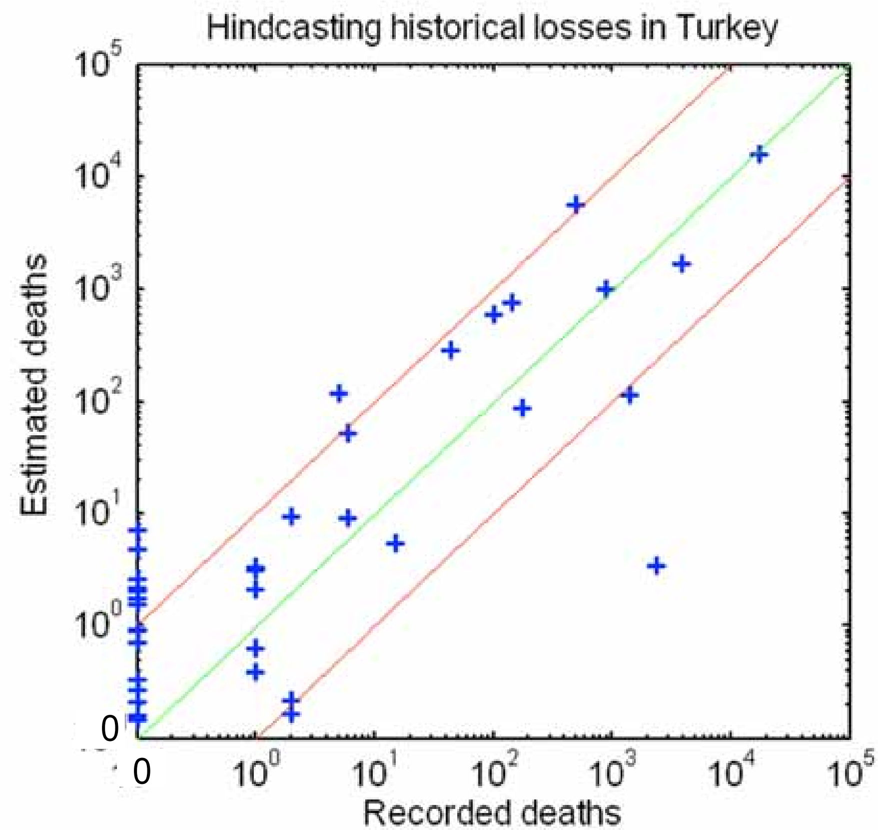
For a given region/country, we use several historical earthquakes in order to derive parameters θ & β.

We solve for the two parameters which minimizes norm *e:*

$$e_k = \ln\left(\sqrt{\frac{1}{N}\sum_j \left(E_j - O_j\right)^2}\right) + \sqrt{\frac{1}{N}\sum_j \left[\ln\left(E_j / O_j\right)\right]^2}$$

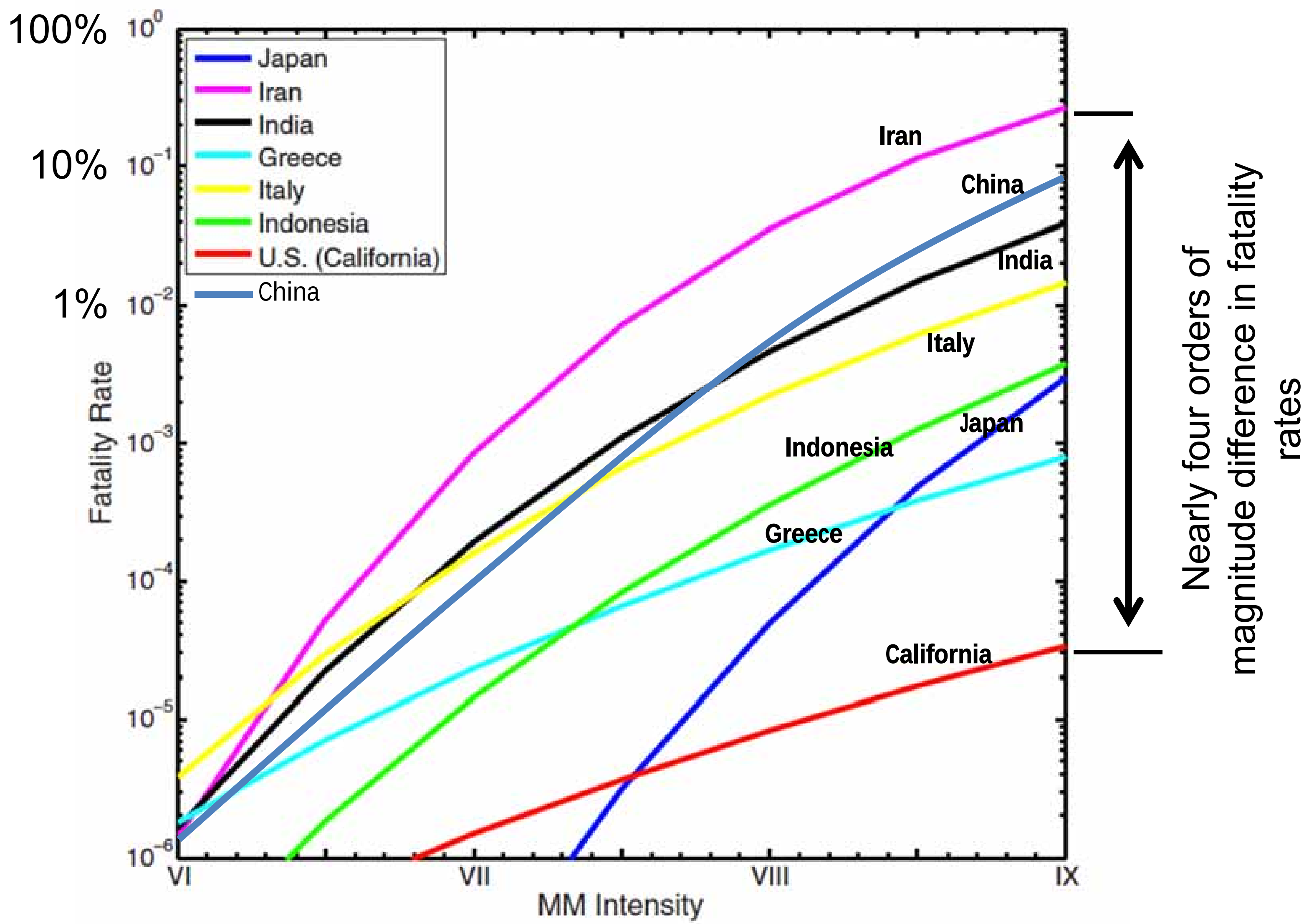
PAGER's Empirical Fatality Estimation Approach:



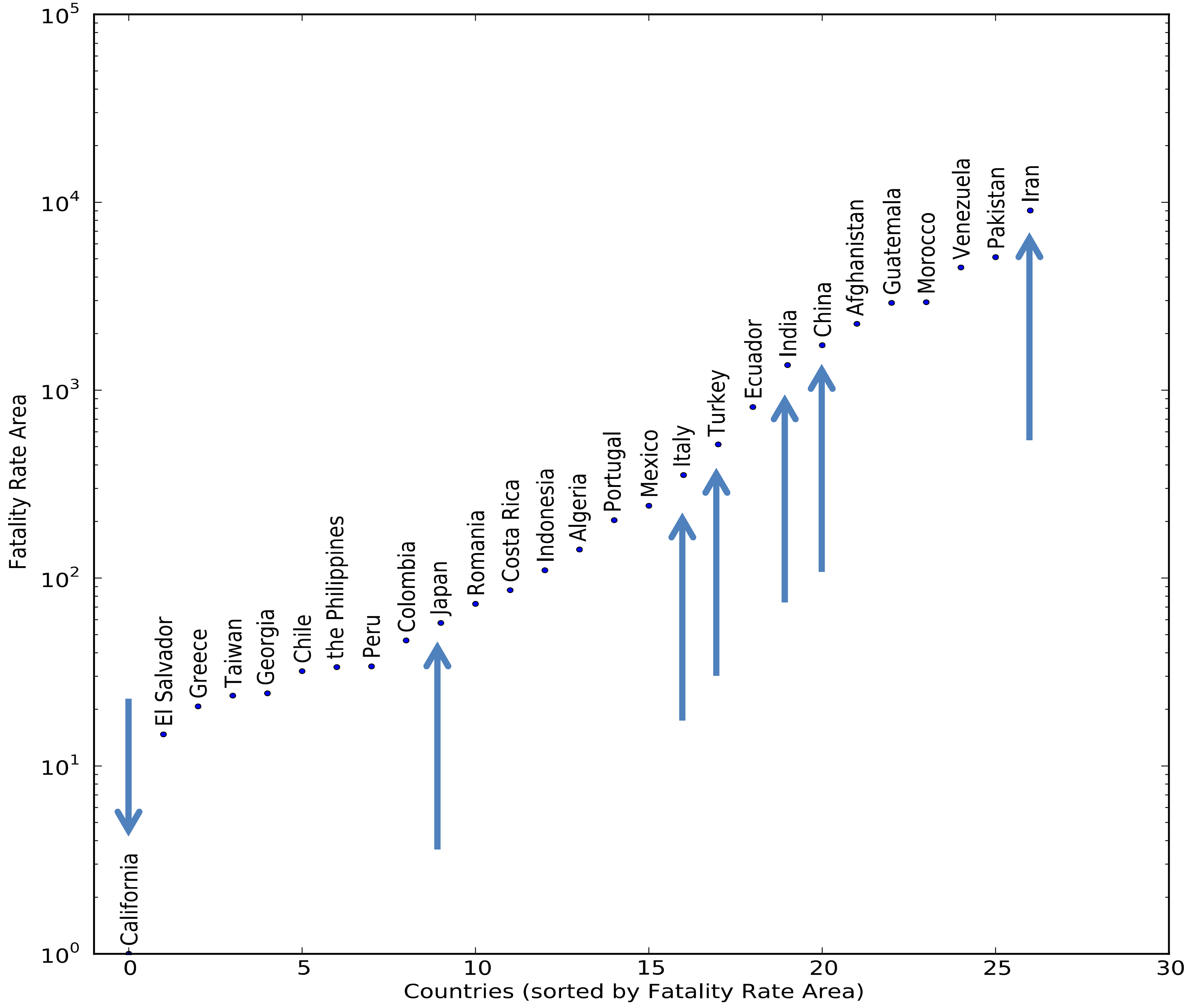


Jaiswal et al. (2009) & Jaiswal and Wald (2010)

PAGER Empirical National Methodology



Fatality rates as a function of intensity for selected countries



Fatality Rate Area
Countries (sorted by Fatality Rate Area)
10^0
10^1
10^2
10^3
10^4
10^5
0
5
10
15
20
25
30
California
El Salvador
Greece
Taiwan
Georgia
Chile
the Philippines
Peru
Colombia
Japan
Romania
Costa Rica
Indonesia
Algeria
Portugal
Mexico
Italy
Turkey
Ecuador
India
China
Afghanistan
Guatemala
Morocco
Venezuela
Pakistan
Iran

1994 NORTHRIDGE, CA (M6.7):

VIII & IX 33 killed in 2 M (~ 0.002% fatalities)

2005 PAKISTAN (M7.6):

VIII & IX: 77,000 killed in 1.2 M (~6% fatalities)

(Fatality rate ratio of ~3,000 x)

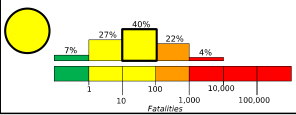
USGS science for a changing world — Earthquake Shaking **Red Alert** — USAID FROM THE AMERICAN PEOPLE — ANSS — **PAGER Version 1**

M 6.7, Northridge, California

Origin Time: Mon 1994-01-17 12:30:55 UTC (05:30:55 local)
Location: 34.16°N 118.56°W Depth: 19 km

Created: 870 weeks, 1 day after earthquake

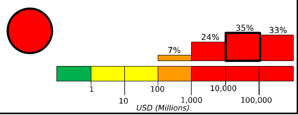
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-4% GDP of the United States. Past events with this alert level have required a national or international level response.

Yellow alert level for shaking-related fatalities. Some casualties are possible.

Estimated Economic Losses



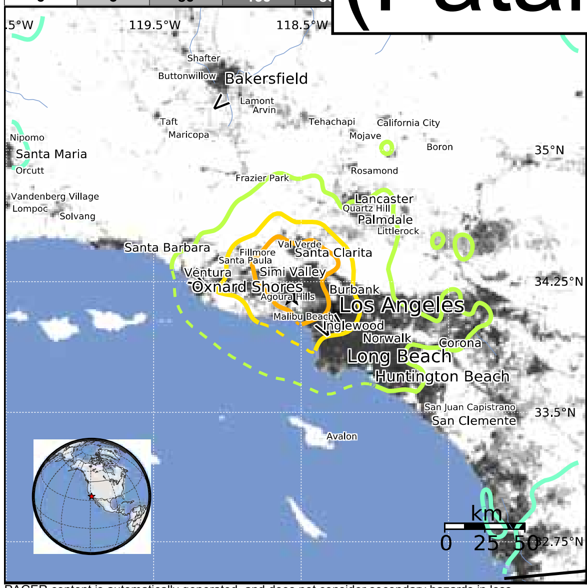
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	1,168k*	5,178k	7,233k	2,885k	2,093k	74k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none							

*Estimated exposure only includes population within the map area.

Population Exposure

0 | 5 | 50 | 100 | 50



...structures exist. The predominant vulnerable building types are unreinforced brick masonry and reinforced masonry construction.

Historical Earthquakes (with MMI levels):

Date	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1999-10-16	199	7.1	IX(17k)	0
1987-10-01	41	5.9	VIII(20k)	8
1994-01-17	1	6.7	IX(181k)	33

Recent earthquakes in this area have caused secondary hazards such as landslides and liquefaction that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI	City	Population
VIII	San Fernando	25k
VIII	Santa Monica	88k
VII	**Simi Valley**	**119k**
VII	**Santa Clarita**	**169k**
VII	**Val Verde**	**1k**
VII	**Burbank**	**105k**
VII	**Los Angeles**	**3,695k**
VI	**Long Beach**	**483k**
V	Santa Ana	343k
IV	San Diego	1,223k
IV	Tijuana	1,376k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: us199401171230

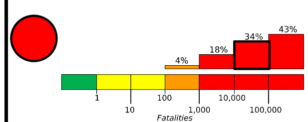
USGS science for a changing world — Earthquake Shaking **Red Alert** — USAID FROM THE AMERICAN PEOPLE — ANSS — **PAGER Version 1**

M 7.6, Kashmir, Pakistan

Origin Time: Sat 2005-10-08 03:50:40 UTC (08:44:32 local)
Location: 34.38°N 73.47°E Depth: 12 km
FOR TSUNAMI INFORMATION, SEE: tsunami.gov

Created: 361 weeks, 1 day after earthquake

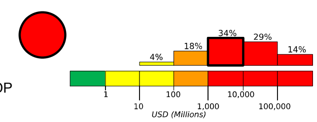
Estimated Fatalities



Red alert for shaking-related fatalities and economic losses. High casualties and extensive damage are probable and the disaster is likely widespread. Past red alerts have required a national or international response.

Estimated economic losses are 1-8% GDP of Pakistan.

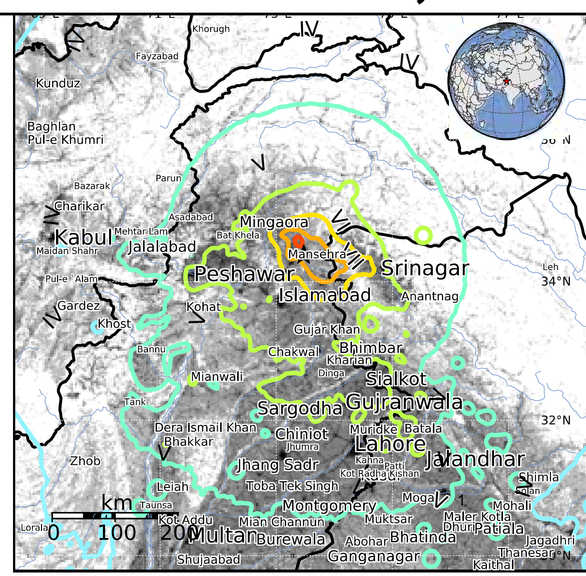
Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking:

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	2,193k*	62,959k*	68,442k*	43,181k	4,585k	1,274k	136k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures								V. Heavy	V. Heavy

...tion in this region resides in ... highly vulnerable to ...g, though some resistant structures exist. The predominant vulnerable building types are adobe and rubble stone masonry construction.



Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
2005-10-08	50	6.4	IX(73k)	0
1974-12-28	88	6.2	VIII(6k)	5300
2005-10-08	13	7.6	IX(290k)	87351

Recent earthquakes in this area have caused secondary hazards such as landslides and liquefaction that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI	City	Population
VIII	Muzaffarabad	20k
VIII	Baffa	14k
VIII	Bagh	< 1k
VIII	**Mansehra**	**66k**
VII	Uri	7k
VII	Batgram	< 1k
VI	**Srinagar**	**976k**
VI	**Peshawar**	**1,219k**
V	**Lahore**	**6,311k**
V	Chandigarh	914k
IV	**Kabul**	**3,044k**

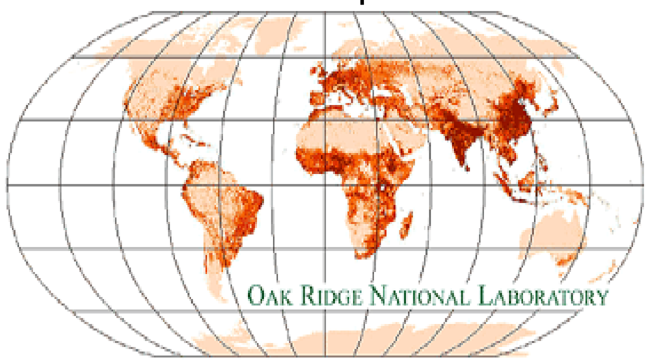
bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

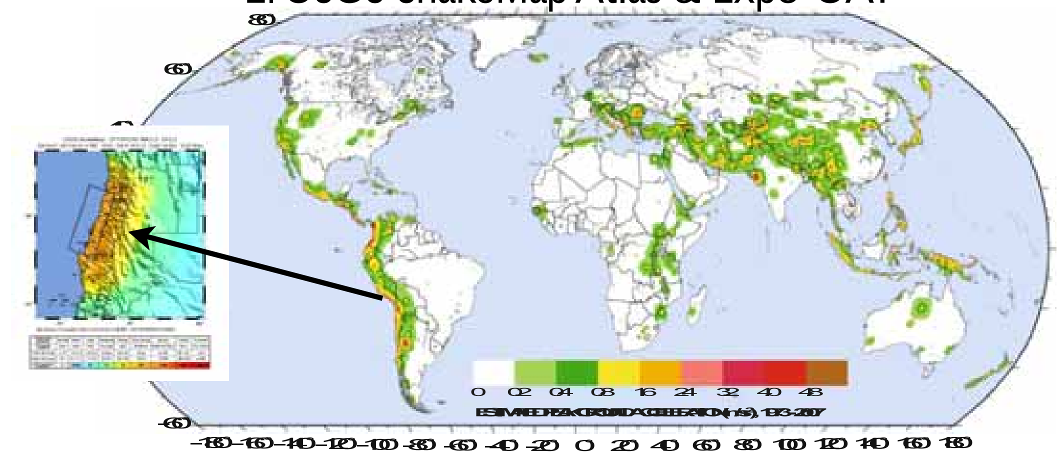
Event ID: us200510080350

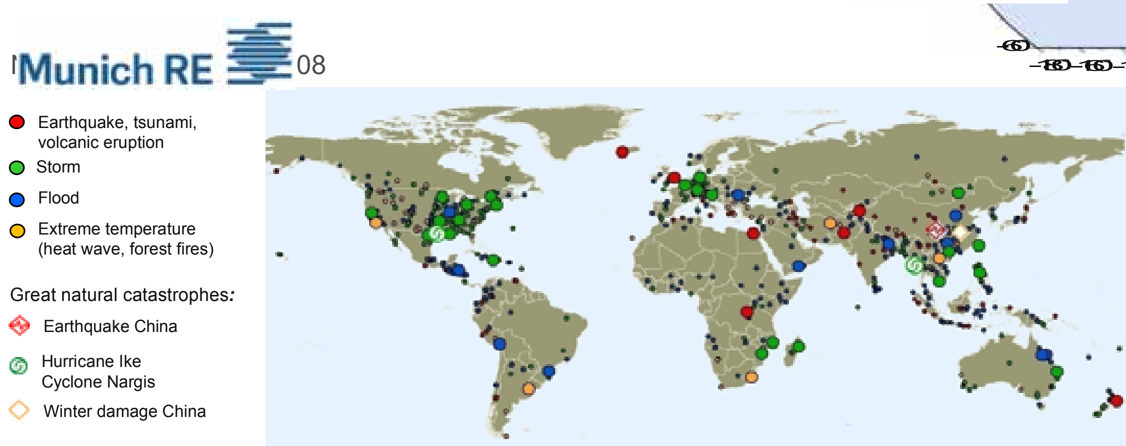
Economic Model Input Dataset:

1. LandScan Population 2008



2. USGS ShakeMap Atlas & Expo-CAT



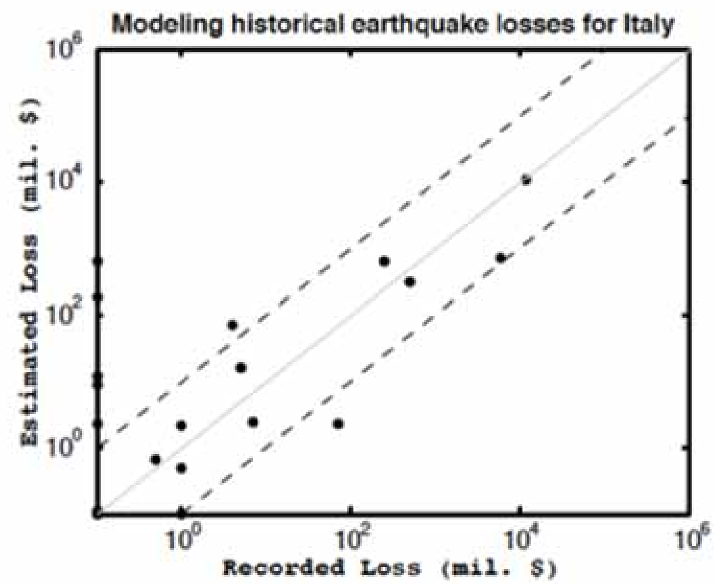


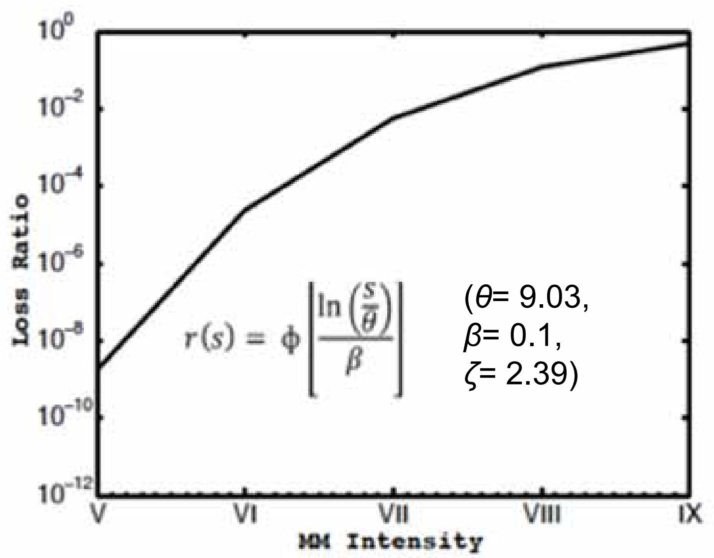
3. Munich Re NatCAT Service 1980-2007 available through-- GEM

4. Gross Domestic Product by Country (1970-2007)

UNdata
A world of information

PAGER's Empirical Economic Loss Model





Example for Italy: **59 earthquakes from 1980-2007**)1**9 with damage > $100k)** (Source: Munich Re NatCAT)

<u>Economic Loss Model Development:</u>

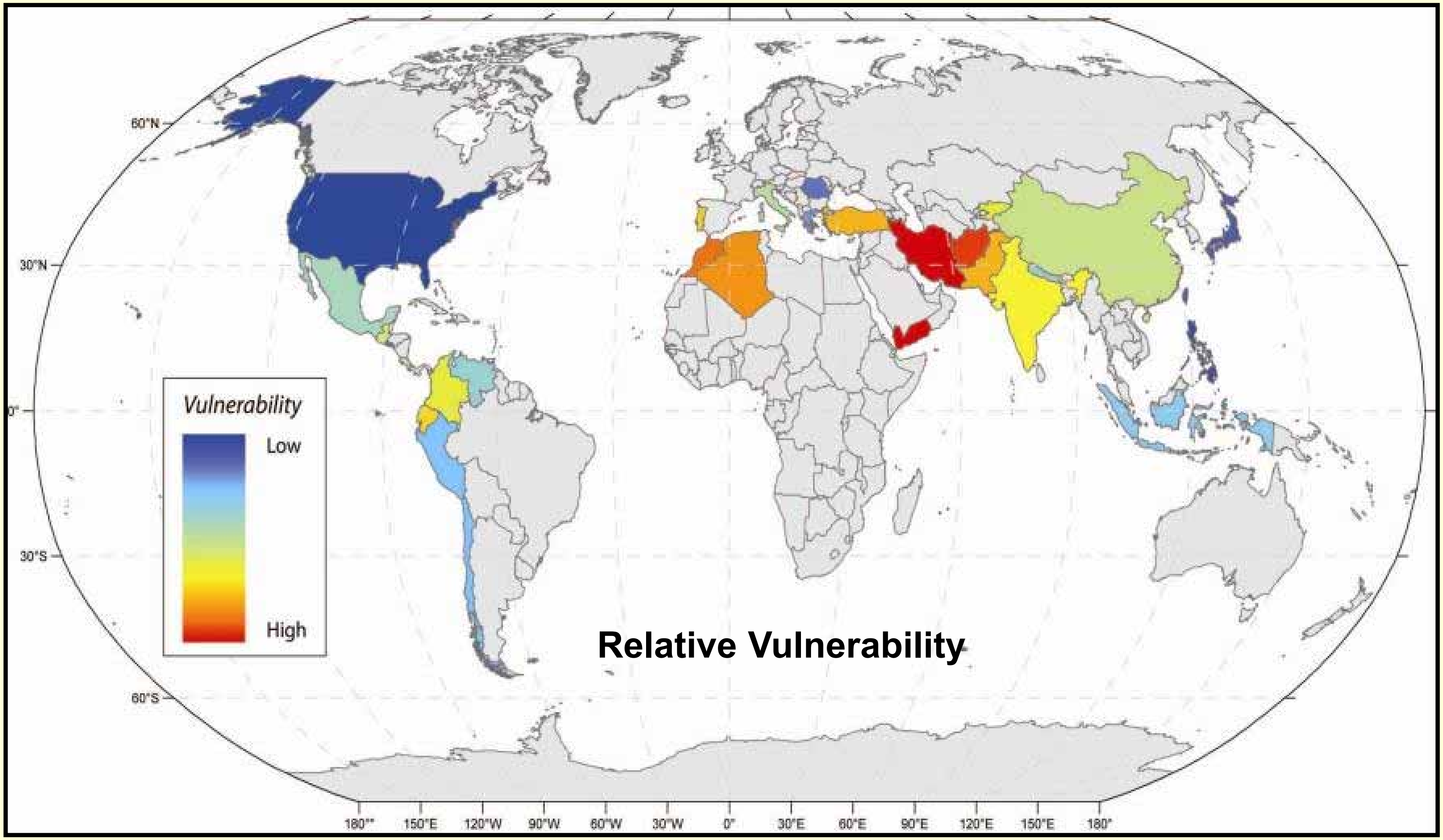
1. For each earthquake, estimate economic exposure in the affected area:
   - using **per capita GDP** of Italy (at time of earthquake),
   - exposed population per intensity level.
   - determine correction factor to accommodate disparity between GDP & per capita wealth.

2. Using estimated economic exposure & trial loss ratio function, we estimate total economic loss at the time of the earthquake,

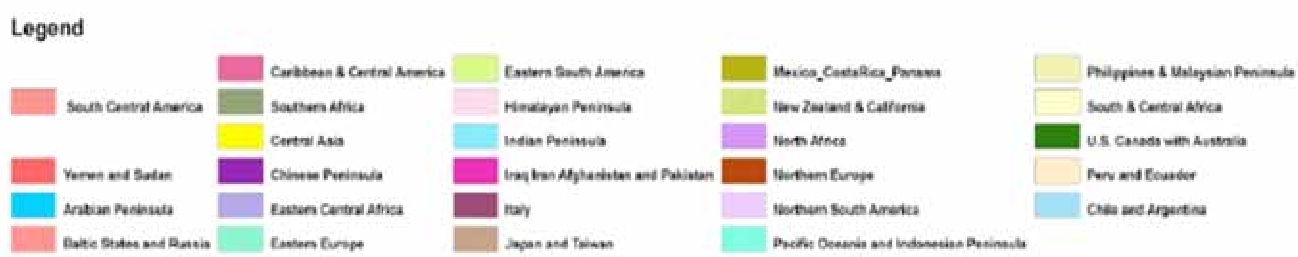
3. Solve for best theta & beta to minimize hindcasting,

4. Estimate the normalized standard deviation (zeta) in hindcasting historical losses for uncertainty estimates.

Countries with Sufficient Earthquake Fatality Data



PAGER Regionalization Scheme (V2.0, Dec.. 20100



Semi Empirical Approach

Earthquake fatalities caused due to collap
of structures can be given as -

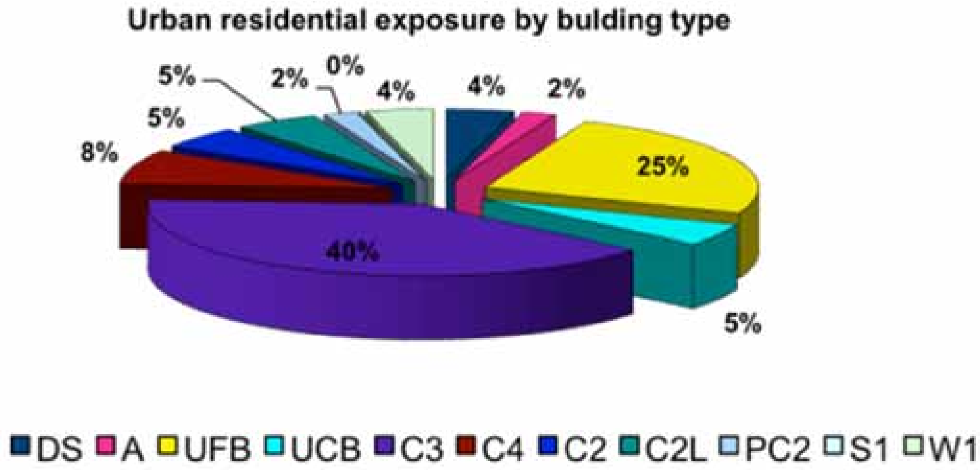
 # People/structure | **collapse rate/ intensity level** | **fatalities/collapse**

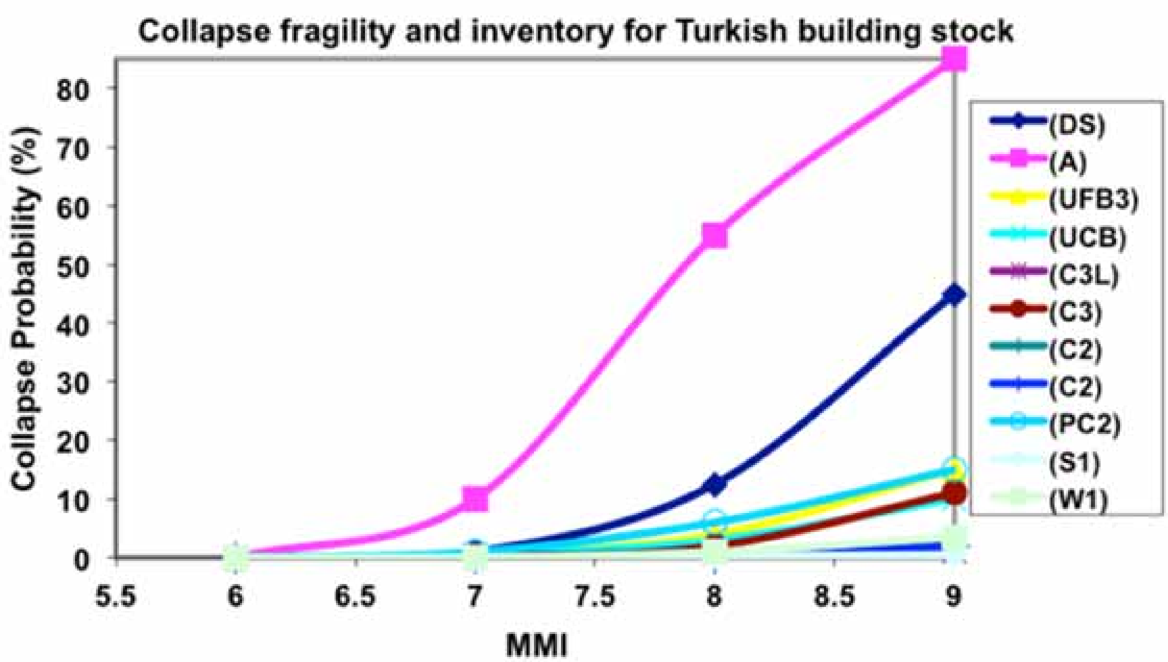
$$Fatalities = \sum P_{str.\ type} \times CR_{str.\ type,\ intensity} \times FR_{str.\ type}$$

PAGER: Semi-Empirical Model

Ah, but this model requires:

(1) Building Stock Taxonomy & Inventory
(3) Collapse Fragility
(2) Occupancy of structures at time of earthquake
(4) Fatality rates fo collapse of different structures





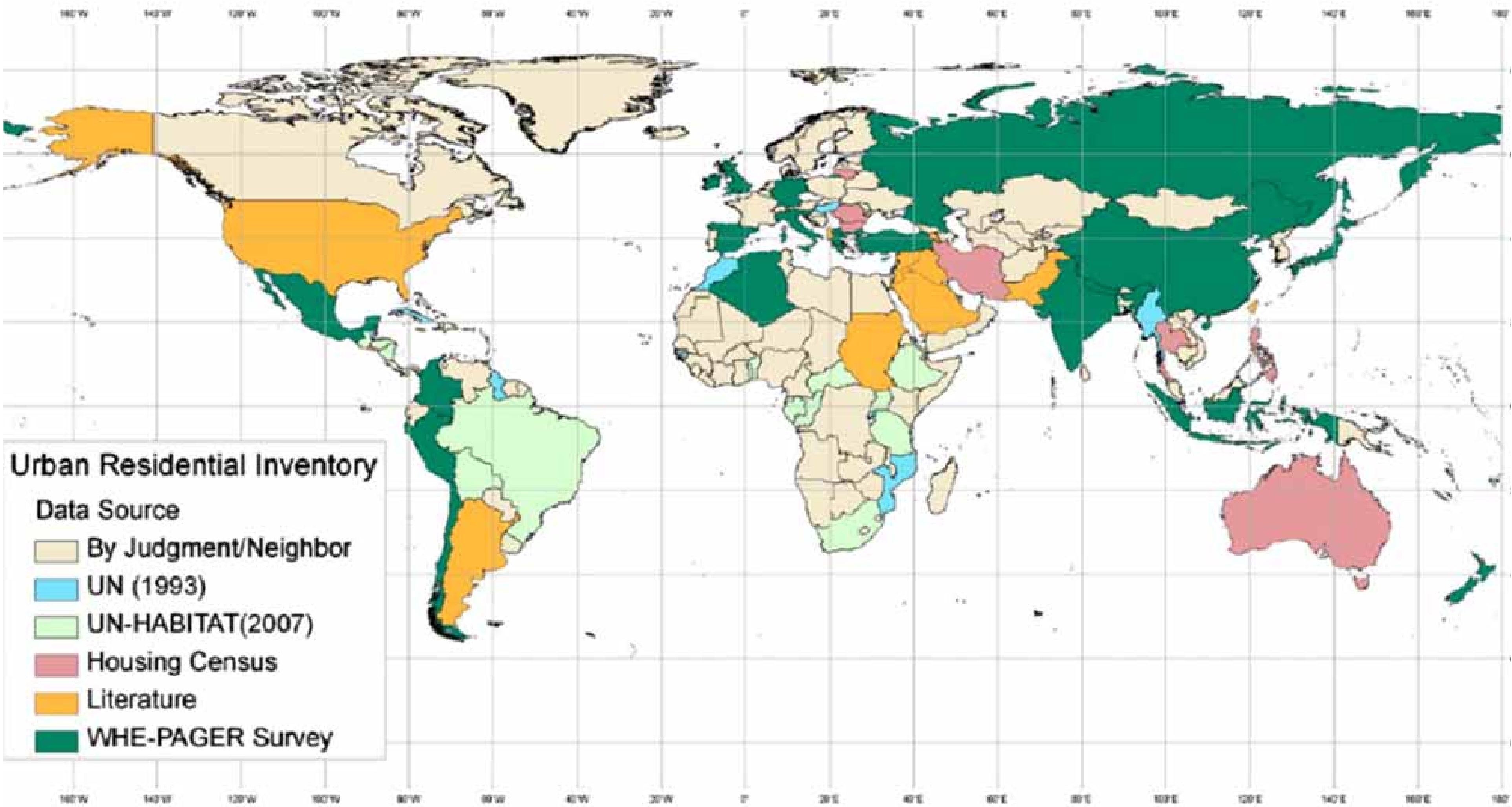
Jaiswal and Wald (2008)

PAGER Structure Types ("PAGER-STR")

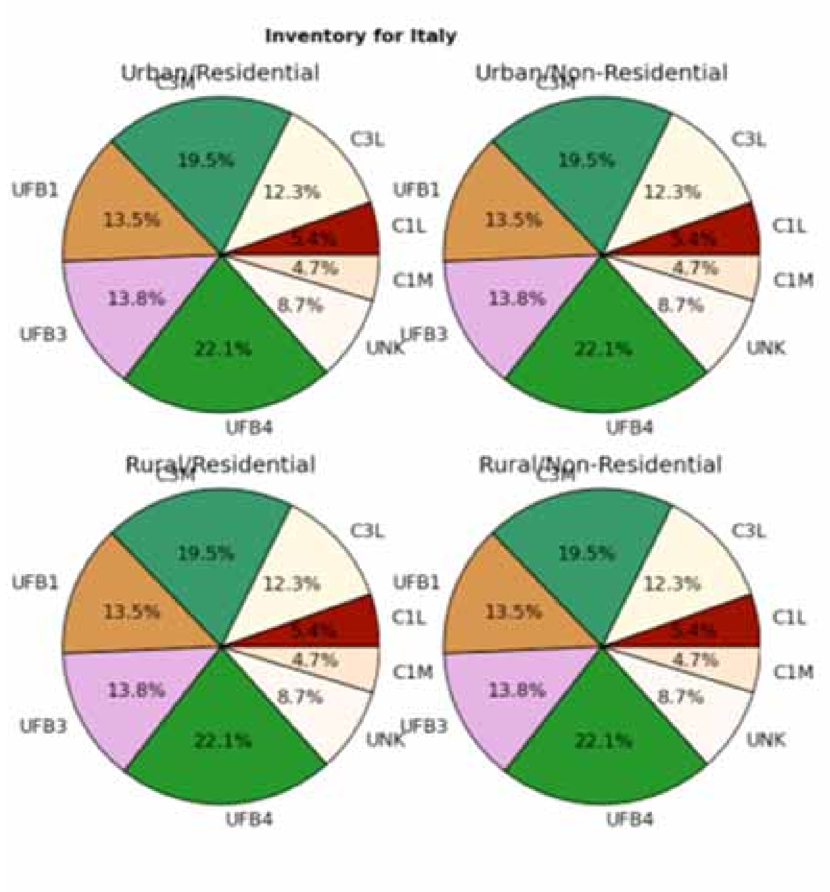
Label	Description	Detailed Classification (Based on ATC-13, HAZUS 1999, WHE 2003, EMS 1998 and newly added for PAGER Inventory database 2008)
W	Wood	**W1** (Wood with stucco, veneer), **W2** (Heavy wood frame, >=5000 sf), **W3** (Wood with metal strong wall) and **W4** (log building)
S	Steel	**S1** (Steel moment frame of low, mid and high rise), **S2** (Steel braced frame of low, mid and high rise), **S3** (Steel light frame), **S4** (Steel frame with concrete shear wall of low, mid and high rise), **S5** (Steel frame with URM wall of low mid and high rise)
C	Reinforced Concrete	**C1** (Ductile RC moment frame of low, mid and high rise), **C2** (RC shear-wall of low, mid and high rise), **C3** (Nonductile RC frame with infill of low, mid and high rise), **C4** (Nonductile RC frame without infill of low, mid and high rise), **C5** (Steel reinforced concrete frame of low mid and high ri
RM	Reinforced Masonry	**R1** (Reinforced masonry bearing wall with flexib rigid diaphragm of low, mid and high rise)
MH	Mobile Homes	Mobile homes
M	Mud	**M1** (Mud wall without wood), **M2** (Mud wall wi
A	Adobe	**A1** (Adobe mud mortar with wood roof), **A2** (Ad (Adobe wall with concrete bond beam), **A5** (Ado
RE	Rammed Earth	Rammed earth construction
RS	Rubble (Field) Stone	**RS1** (Rubble stone without mortar), **RS2** (Rubble stone with cement mortar), **RS5** (Rubble stone wi
DS	Dressed Stone, blocks	**DS1** (Stone block with mud mortar), **DS2** (Stone block with concrete bond beam)
UFB	Unreinforced Fire Brick	**UFB1** (Unreinforced brick with mud mortar without timber), **UFB2** (Unreinforced brick with mud mortar and timber), **UFB3** (Unreinforced brick with cement mortar and wood diaphragm), **UFB4** (Unreinforced brick with cement mortar and concrete diaphragm)
UCB	Unreinforced Concrete Block	Unreinforced concrete block construction
MS	Massive Stone	Massive stone masonry construction

- **Structure "Taxonomy"**
- **>100 Structure Types**
- **Composite of**
  - **ATC-13**, ***California***
  - **FEMA' 99 (HAZUS)**, ***U.S.***
  - **EMS' 98**, ***Euro-Med, but not structural***
  - **WHE' 03**, ***Global***
  - **PAGER definitions**, ***Missing types***

Global Inventory & Coverage



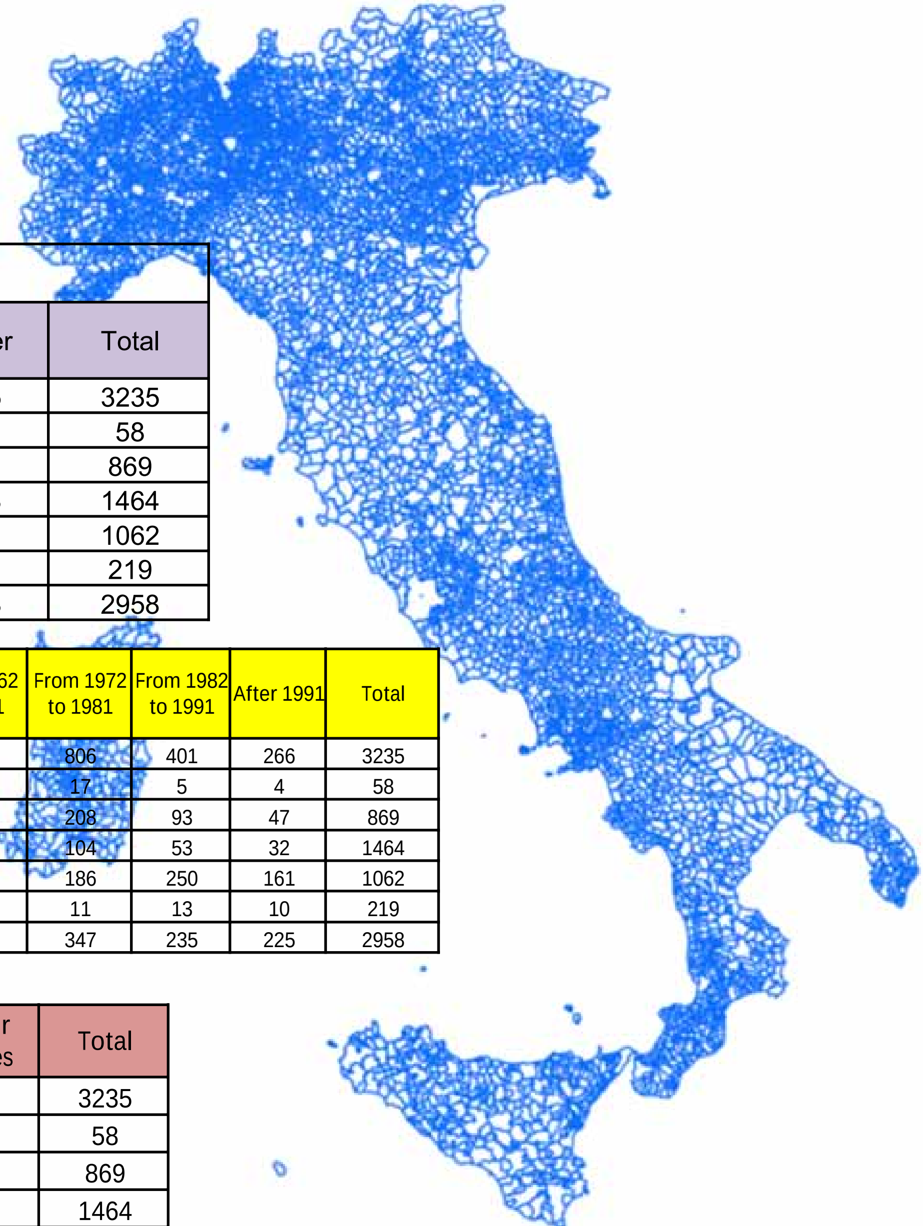
Example: Expert-opinion-based building Inventory for Italy



Goretti, Bramerini, Di Pasquale, Dolce, Lagomarsino et al. (2008) The Italian Contribution to the EERI/USGS PAGER project, *14WCEE*, China

ITALY: Based on

ISTAT 2001 Population Census



MUNICIPALITY	ISTAT Code	Vertical Structure			
		Masonry	Reinforced Concrete	Other	Total
Abano Terme	05028001	2040	710	485	3235
Abbadia Cerreto	03098001	27	31	0	58
Abbadia Lariana	03097001	344	450	75	869
Abbadia San Salvatore	09052001	754	577	133	1464
Abbasanta	20095001	1023	38	1	1062
Abbateggio	13068001	164	36	19	219
Abbiategrasso	03015002	1227	1378	353	2958

MUNICIPALITY	ISTAT Code	Before 1919	From 1919 to 1945	From 1946 to 1961	From 1962 to 1971	From 1972 to 1981	From 1982 to 1991	After 1991	Total
Abano Terme	05028001	141	117	704	800	806	401	266	3235
Abbadia Cerreto	03098001	13	2	8	9	17	5	4	58
Abbadia Lariana	03097001	120	97	111	193	208	93	47	869
Abbadia San Salvatore	09052001	556	260	251	208	104	53	32	1464
Abbasanta	20095001	102	157	106	100	186	250	161	1062
Abbateggio	13068001	65	79	27	14	11	13	10	219
Abbiategrasso	03015002	474	364	670	643	347	235	225	2958

MUNICIPALITY	ISTAT Code	One Story	Two Story	Three Story	> Four Stories	Total
Abano Terme	05028001	499	2175	425	136	3235
Abbadia Cerreto	03098001	6	46	6	0	58
Abbadia Lariana	03097001	122	466	247	34	869
Abbadia San Salvatore	09052001	134	596	488	246	1464
Abbasanta	20095001	539	479	44	0	1062
Abbateggio	13068001	77	116	23	3	219
Abbiategrasso	03015002	557	1544	422	435	2958

Population Distribution

Data/Expert Judgment Similar to HAZUS Principle

Time of day vs. occupancy type	Residential Occupancy	Non-residential Occupancy	Outside (Outdoors)
Day (10 am-5 pm)	$P_i *(0.4* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.01* F_{wf} * F_{agr}) P_i *(0.75* F_{nwf} +0.20* F_{wf} * F_{ind} +0.25* F_{wf} * F_{ser} +0.45* F_{wf} * F_{agr}) P_i *(0.999* F_{nwf} +0.84* F_{wf} * F_{ind} +0.89* F_{wf} * F_{ser} +0.998* F_{wf} * F_{agr})$	$P_i*(0.89* F_{wf} * F_{ind} +0.89* F_{wf} * F_{ser}+ 0.34* F_{wf} * F_{agr}+ 0.25* F_{nwf} * F_{sch}) P_i*(0.25* F_{wf} * F_{ind} +0.25* F_{wf} * F_{ser}+ 0.01* F_{wf} * F_{agr}) P_i*(0.15* F_{wf} * F_{ind} +0.10* F_{wf} * F_{ser}+ 0.001* F_{wf} * F_{agr})$	$P_i*(0.35* F_{nwf} +0.10* F_{wf} * F_{ind} +0.10* F_{wf} * F_{ser} +0.65* F_{wf} * F_{agr}) P_i*(0.25* F_{nwf} +0.55* F_{wf} * F_{ind} +0.50* F_{wf} * F_{ser} +0.54* F_{wf} * F_{agr}) P_i*(0.001* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.001* F_{wf} * F_{agr})$
Transit (5 am-10 am & 5 pm- 10 pm)	$P_i *(0.4* F_{nwf} +0.01* F_{wf}$ [illegible] $+0.01* F_{wf} * F_{ser} +0.01* F_{wf}$ [illegible] $F_{agr}) P_i *(0.75* F_{nwf} +0.20* F_{wf}$ [illegible] $F_{ind} +0.25* F_{wf} * F_{ser} +0.45* F_{wf}$ [illegible] $F_{agr}) P_i *(0.999* F_{nwf} +0.84* F_{wf}$ [illegible] $F_{ind} +0.89* F_{wf} * F_{ser} +0.998*$ [illegible] $* F_{agr})$	$P_i*(0.89* F_{wf} * F_{ind} +0.89* F_{wf} *$ [illegible]	$P_i*(0.35* F_{nwf} +0.10* F_{wf} * F_{ind}$ [illegible]
Night (10 pm- 5 am)	$P_i *(0.4* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.01* F_{wf} * F_{agr}) P_i *(0.75* F_{nwf} +0.20* F_{wf} *$ [illegible] $F_{ind} +0.25* F_{wf} * F_{ser} +0.45* F_{wf}$ [illegible] $F_{agr}) P_i *(0.999* F_{nwf} +0.84* F_{wf} * F_{ind} +0.89* F_{wf} * F_{ser} +0.998* F_{wf} * F_{agr})$	[illegible] $* F_{ser}+ 0.01* F_{wf} * F_{agr}) P_i*(0.15* F_{wf} * F_{ind} +0.10* F_{wf} * F_{ser}+ 0.001* F_{wf} * F_{agr})$	[illegible] $F_{ind} +0.50* F_{wf} * F_{ser} +0.54* F_{wf} * F_{agr}) P_i*(0.001* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.001* F_{wf} * F_{agr})$

$$P_i *(0.4* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.01* F_{wf} * F_{agr})$$
$$+ P_i *(0.75* F_{nwf} +0.20* F_{wf} * F_{ind} +0.25* F_{wf} * F_{ser} +0.45* F_{wf} * F_{agr})$$
$$+ P_i *(0.999* F_{nwf} +0.84* F_{wf} * F_{ind} + 0.89* F_{wf} * F_{ser} +0.998* F_{wf} * F_{agr})$$

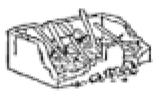
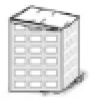
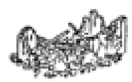
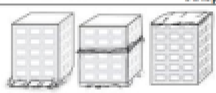
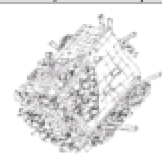
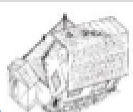
Fatality Rates

Ongoing efforts by Dr. Emily So (USGS, now at Cambridge Univ.)

PAGER Structure Type	Fatality Rates	Reference
W, W1	0.007	Spence (2007)
W2, W3, W4	0.013	Spence (2007)
S, S1, S1L, S2, S2L, S3, S4, S4L, S5, S5L	0.14	Spence (2007)
S1M, S2M, S4M, S5M	0.228	Spence (2007)
S1H, S2H, S4H, S5H	0.328	Spence (2007)
C, C1, C1L, C2, C2L ,C3, C3L, C4, C4L C5, C5L	0.15	Spence (2007)
C1M, C2M, C3M, C4M, C5M	0.22	Spence (2007)
C1H, C2H, C3H, C4H, C5H	0.28	Spence (2007)
PC1	0.1	NIBS AND FEMA (2003)
PC2, PC2L	0.15	Spence (2007)
PC2M	0.22	Spence (2007)
PC2H	0.28	Spence (2007)
RM, RM1	0.06	Spence (2007)

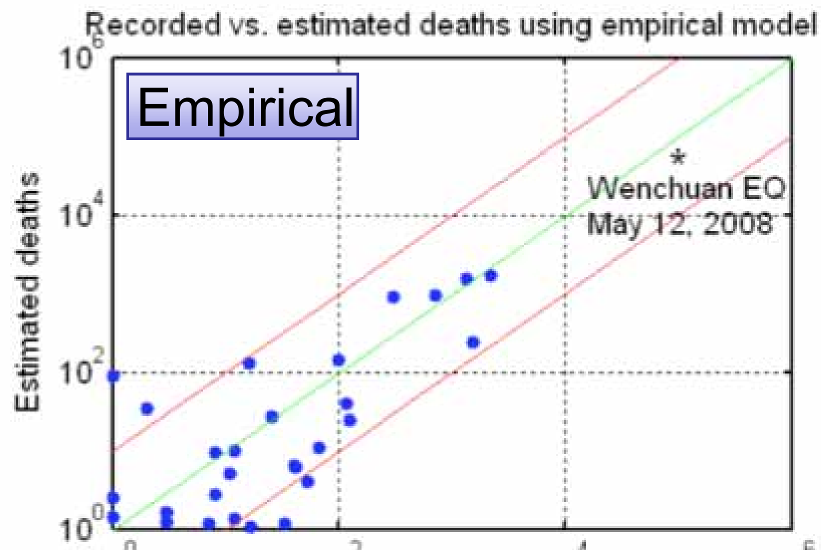
Global variations of building collapse

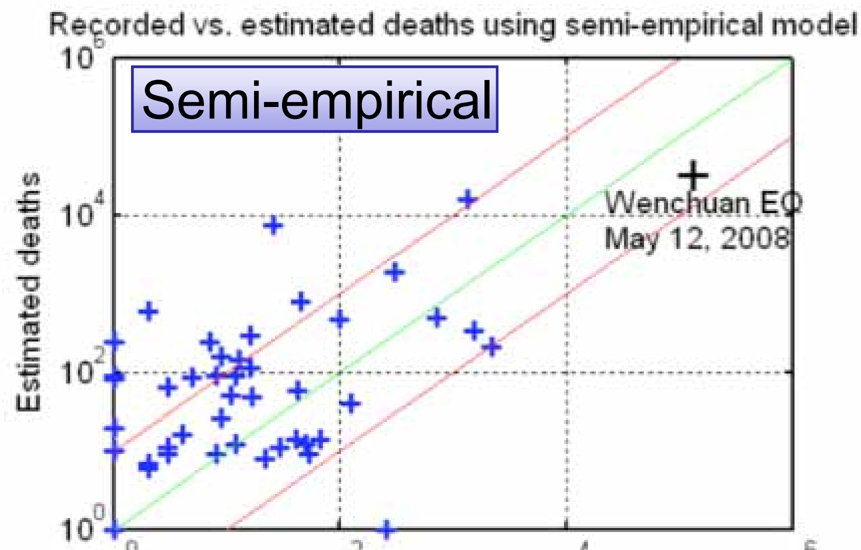
Table 2.1 Damage types encompassed in D5 (collapsed buildings) sketches are being re-drawn at the moment

Damage Categories	Variations in collapses	Instantaneous volumetric reduction	Affected buildings types	Reference earthquakes (not exhaustive)
Single wall failure/ roof failure	 single wall failure (masonry)	<10%	Timber, weak masonry, structural masonry RC frames, Steel frames	Ghir 1972, Tabas 1978, Athens 1999, Chi Chi 1999, Bhuj 2001 etc.
	 roof collapse (masonry)  roof failure (frame buildings)	10- 30%		
Multi-wall/ vertical support failure (with or without roof failure)	 outspread multi-layer collapse  multiple fractures in masonry	>90%		
Soft Storey Collapse	 one storey for RC and timber frame  (timber frame)	10-50%	RC frame, mixed steel LMF	Kobe 1995, Kocaeli 1999, Bourmedes 2003, Christchurch 2011
	 multi -storeys	30-90%	RC frame, Steel LMF	
Complete failure of structural elements (pancake collapse)	 pancake with roof intact (frames)  (timber frame)	60-100%	Masonry, RC frames	Kashmir 2005, Wenchuan 2008
	 complete failure (masonry)  failure of all structural elements (timber)	>90%	Weak masonry, timber frame, catastrophic RC collapses	
Overturn	 overturn (framed buildings)  possible variation for timber	>10%	RC frame, timber frame, steel frames	Kobe 1995, Chi Chi 1999, Maule 2010

Courtesy, Dr Emily So, USGS/Cambridge

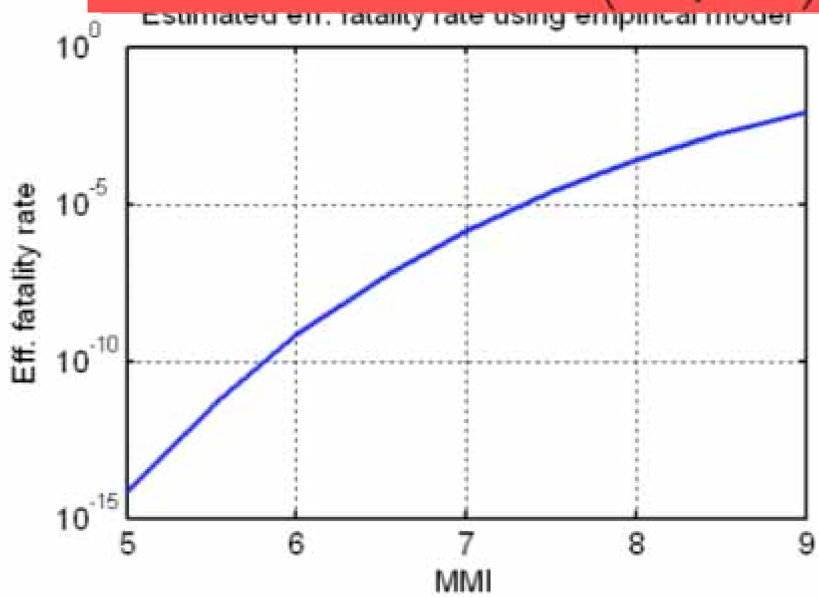
Country: China

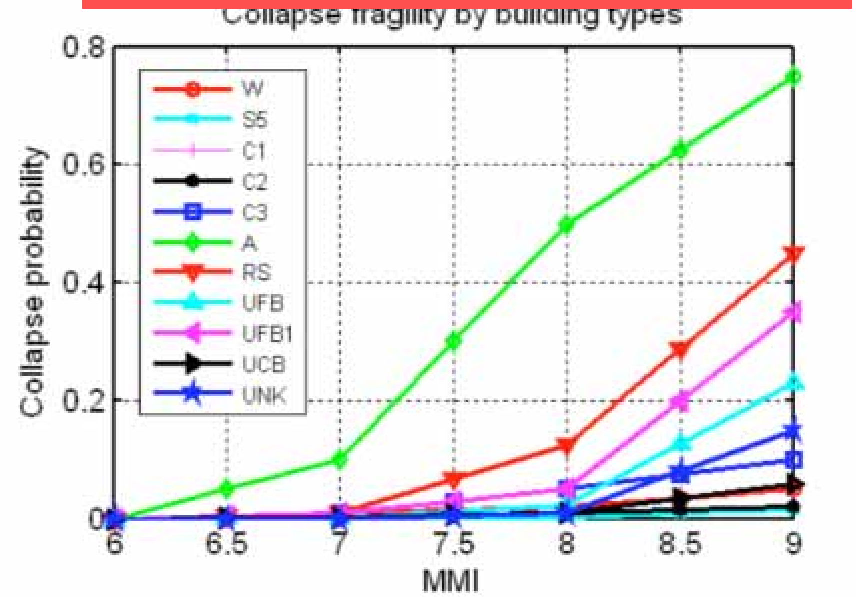


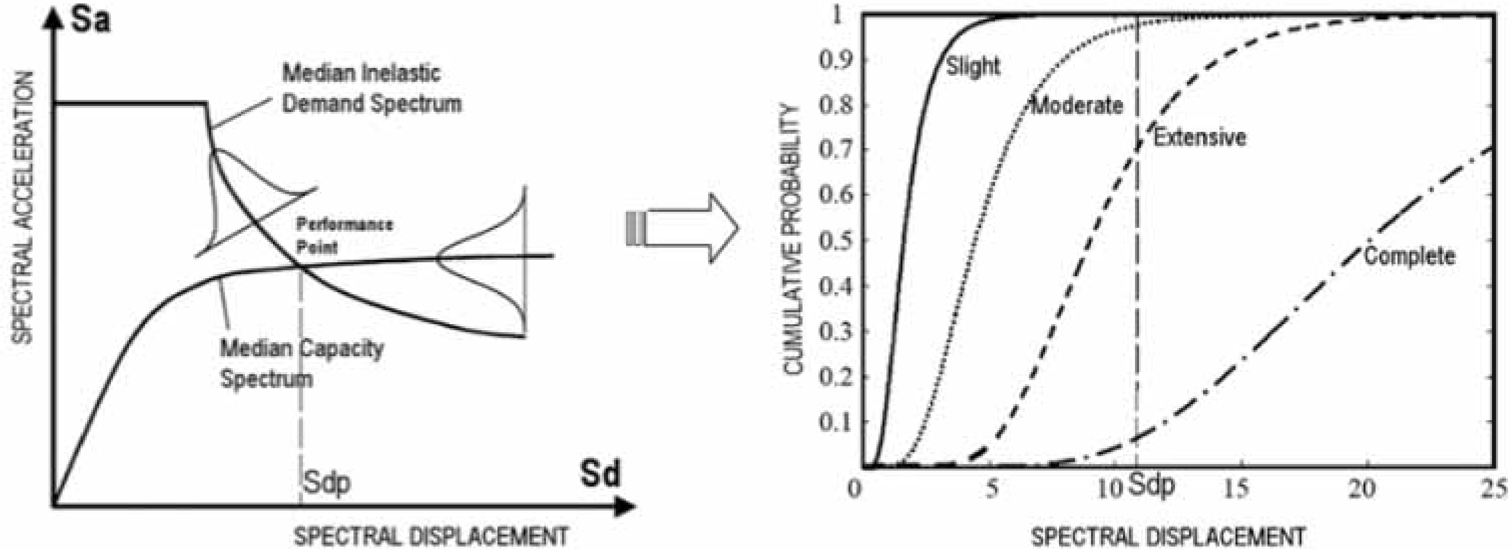


$$Fatality\ \ rate\ \ y(x_i) = \phi\left(\frac{\ln(x_i/\theta)}{\beta}\right)$$

Fatalities $= \sum P_{str.\ type} \times CR_{str.\ type,\ mmi} \times FR_{str.\ type}$







$$\text{Fatalities} = \sum P_{\text{str. type}} \times CR_{\text{str. type, intensity}} \times FR_{\text{str. type}}$$

HAZUS MH
EARTHQUAKE • WIND • FLOOD
FEMA

Yet more parameters are required! (many structural characteristics)

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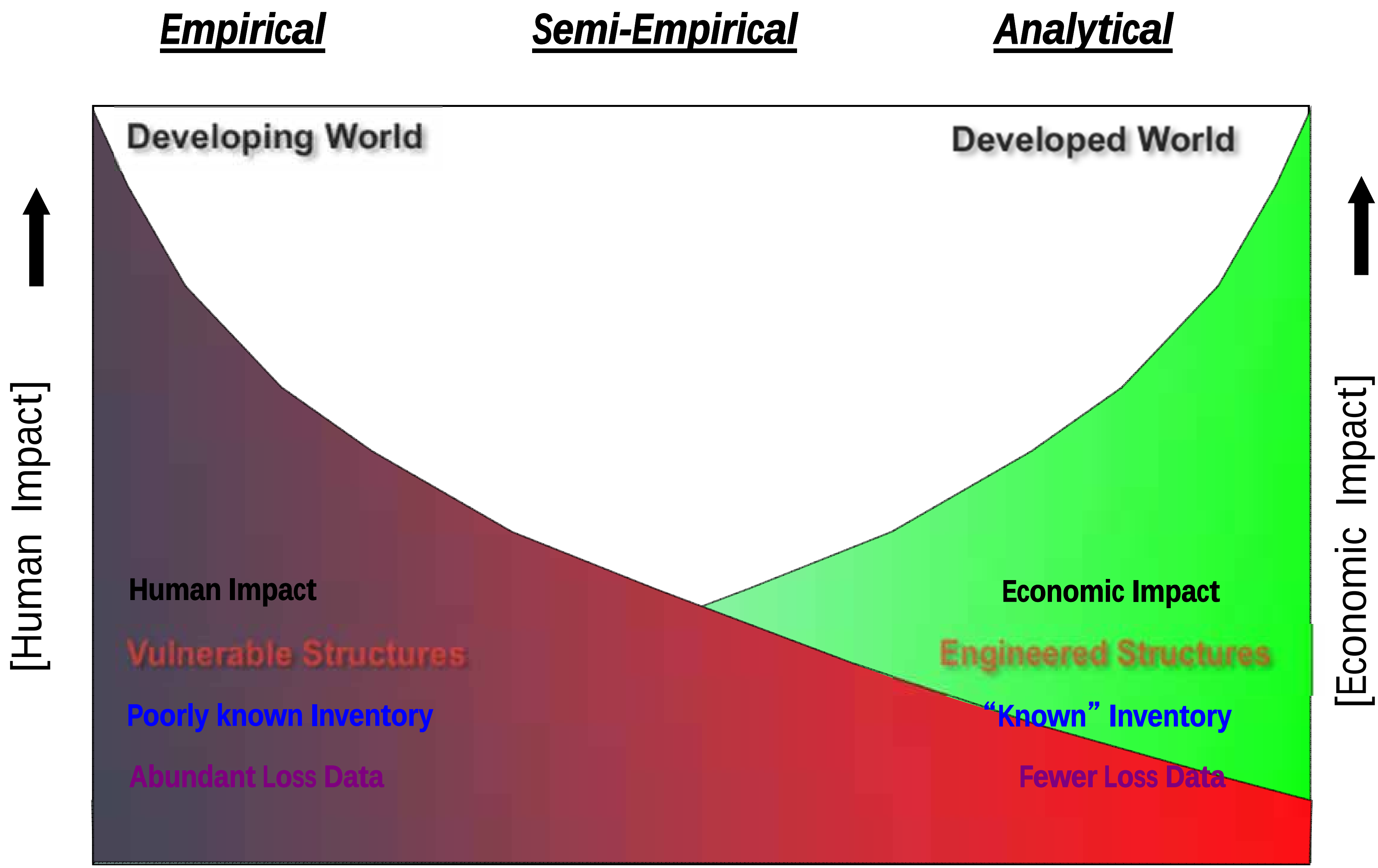
Why 3 Loss Approaches?



PAGER Regionalization Scheme (V2.0, Dec.. 2010)

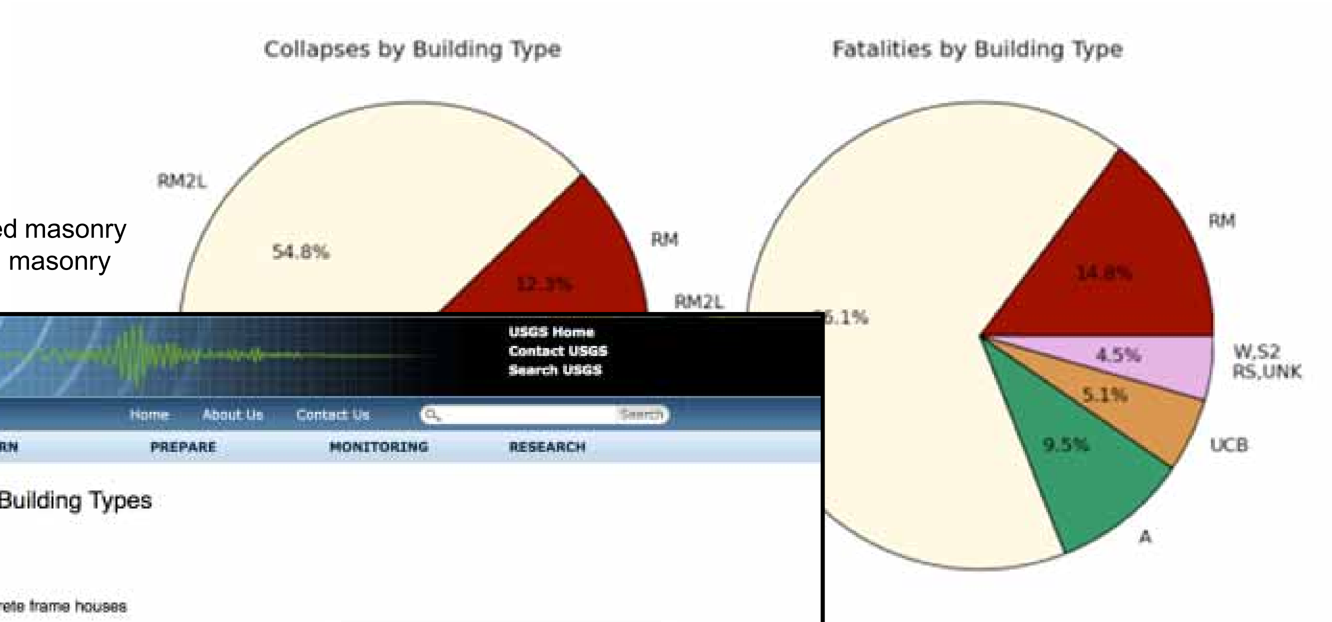
Legend

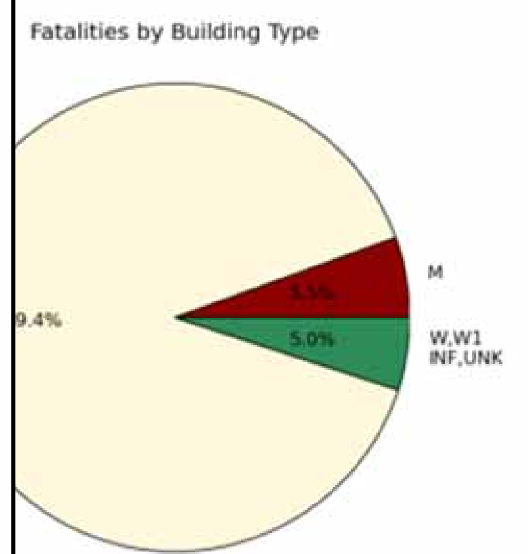
- South Central America
- Yemen and Sudan
- Arabian Peninsula
- Baltic States and Russia
- Caribbean & Central America
- Southern Africa
- Central Asia
- Chinese Peninsula
- Eastern Central Africa
- Eastern Europe
- Eastern South America
- Himalayan Peninsula
- Indian Peninsula
- Iraq Iran Afghanistan and Pakistan
- Italy
- Japan and Taiwan
- Mexico_CostaRica_Panama
- New Zealand & California
- North Africa
- Northern Europe
- Northern South America
- Pacific Oceania and Indonesian Peninsula
- Philippines & Malaysian Peninsula
- South & Central Africa
- U.S. Canada with Australia
- Peru and Ecuador
- Chile and Argentina

PAGER **estimates** of buildings contributing to casualties

2010 M8.8 Chile

RM & RM2L – Reinforced masonry (commonly low-rise) and masonry with frames (dual)





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EARTHQUAKES | HAZARDS | LEARN | PREPARE | MONITORING | RESEARCH

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- onePAGER Information
- Team Members
- Data, Products, and References
- Common Building Types
- FAQ
- Disclaimer
- Contact Us

PAGER - Common Building Types

Algeria

Single-family reinforced concrete frame houses

This privately owned housing constitutes about 60 to 70% of the housing stock and is widespread throughout northern Algeria, the region of the country's highest seismic risk. Generally, these buildings are one to three stories high. The ground floor is used for parking or for commercial purposes. The structural system consists of reinforced concrete frames with masonry infill walls made out of hollow brick tiles. The infill walls are usually provided in the residential part of the building (upper floors). Due to the limited amount of infill walls at the ground floor level, these buildings are characterized by soft-story behavior during earthquakes. These buildings have most often been built after the development of the 1981 Algerian seismic code. However, the seismic code is not enforced in private construction and most of the buildings have been built without seismic strengthening provisions and historically have been severely affected in Algerian earthquakes, including the May 21, 2003 Boumerdes earthquake.

Reference: EERI and IAEE's World Housing Encyclopedia (Report #[illegible]) - Mohammed Farsi, Farah Lazzali

Stone masonry apartment building

This is a typical residential construction type found in most Algerian urban centers, constituting 40-50% of the total urban housing stock. This construction, built mostly before the 1950s by French contractors, is no longer practiced. Buildings of this type are typically four to six stories high. The slabs are wooden structures or shallow arches supported by steel beams (jack arch system). Stone masonry walls, usually 400-600 mm thick, have adequate gravity load-bearing capacity; however, their lateral load resistance is very low. As a result, these buildings are considered to be highly vulnerable to seismic effects.

Reference: EERI and IAEE's World Housing Encyclopedia (Report #[illegible]) - Mohammed Farsi, Farah Lazzali, Yasmina Ait-Mi

ngs for Chile & Haiti

HAZUS-MH Default Inventory Data

Default inventory data includes:

- **"General building stock" - proxy representation of all buildings in the U.S.**
- Essential facilities* – hospitals, schools, etc.
- Transportation lifelines* – highway, railway, etc.
- Utility Lifelines* – water, power, gas, etc.
- Demographics
- Economic values

* In some cases, default data may be limited or unavailable

[Modified from Hope Seligson, MMI Engineering]

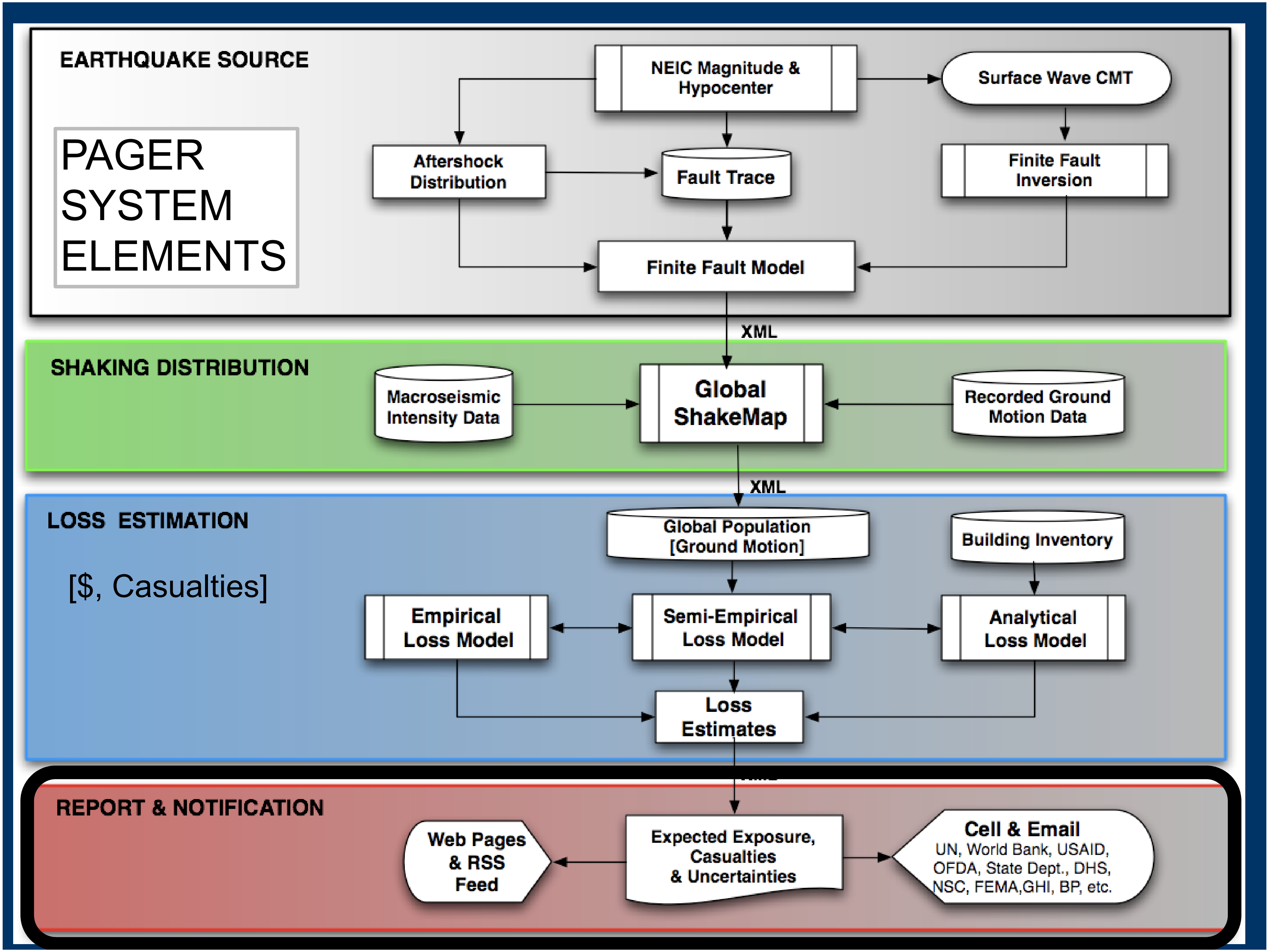
Building Inventory Data in HAZUS

Building data: for each census tract, we know only total square footage of all buildings & cost by occupancy category for entire US.

→ We call this "proxy data"

- → Proxy data requires "mapping schemes": for each occupancy, estimated building distribution across "model" structure types, & estimate distribution of occupants.
- → Note: HAZUS only has two fatality rates (5% & 10% of building occupants).

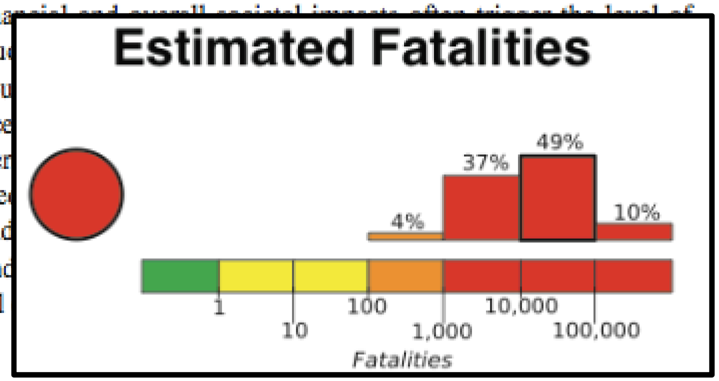
[Modified from Hope Seligson, MMI Engineering]


EARTHQUAKE SOURCE
PAGER SYSTEM ELEMENTS
NEIC Magnitude & Hypocenter
Surface Wave CMT
Aftershock Distribution
Fault Trace
Finite Fault Inversion
Finite Fault Model
XML
SHAKING DISTRIBUTION
Macroseismic Intensity Data
Global ShakeMap
Recorded Ground Motion Data
XML
LOSS ESTIMATION
[$, Casualties]
Global Population [Ground Motion]
Building Inventory
Empirical Loss Model
Semi-Empirical Loss Model
Analytical Loss Model
Loss Estimates
REPORT & NOTIFICATION
Web Pages & RSS Feed
Expected Exposure, Casualties & Uncertainties
Cell & Email
UN, World Bank, USAID, OFDA, State Dept., DHS, NSC, FEMA,GHI, BP, etc.

Earthquake Impact Scale

D. J. Wald[1]; K. S. Jaiswal, A.M.ASCE[2]; K. D. Marano[3]; and D. Bausch[4]

Abstract: With the advent of the USGS prompt assessment of global earthquakes for response (PAGER) system, which rapidly assesses earthquake impacts, U.S. and international earthquake responders are reconsidering their automatic alert and activation levels and response procedures. To help facilitate rapid and appropriate earthquake response, an Earthquake Impact Scale (EIS) is proposed on the basis of two complementary criteria. On the basis of the estimated cost of damage, one is most suitable for domestic events; the other, on the basis of estimated ranges of fatalities, is generally more appropriate for global events, particularly in developing countries. Simple thresholds, derived from the systematic analysis of past earthquake impact and associated response levels, are quite effective in communicating predicted impact and response needed after an event through alerts of green (little or no impact), yellow (regional impact and response), orange (national-scale impact and response), and red (international response). Corresponding fatality thresholds for yellow, orange, and red alert levels are 1, 100, and 1,000, respectively. For damage impact, yellow, orange, and red thresholds are triggered by estimated losses reaching $1M, $100M, and $1B, respectively. The rationale for a dual approach to earthquake alerting stems from the recognition that relatively high fatalities, injuries, and homelessness predominate in countries in which local building practices typically lend themselves to high collapse and casualty rates, and these impacts lend to prioritization for international response. In contrast, fina
response in regions or countries in which prevalent earthquake resistant constru
fatalities. Any newly devised alert, whether economic- or casualty-based, shou
procedures. Useful alerts should also be both specific (although allowably unce
both simple and intuitive color-coded alerting criteria; yet the necessary uncer
the alert to be over- or underestimated are preserved. The essence of the propose
is now available in the immediate aftermath of significant earthquakes world
EIS, PAGER's rapid loss estimates can adequately recommend alert levels and
tainties; demanding or awaiting observations or loss estimates with a high level
NH.1527-6996.0000040. *© 2011 American Society of Civil Engineers.*

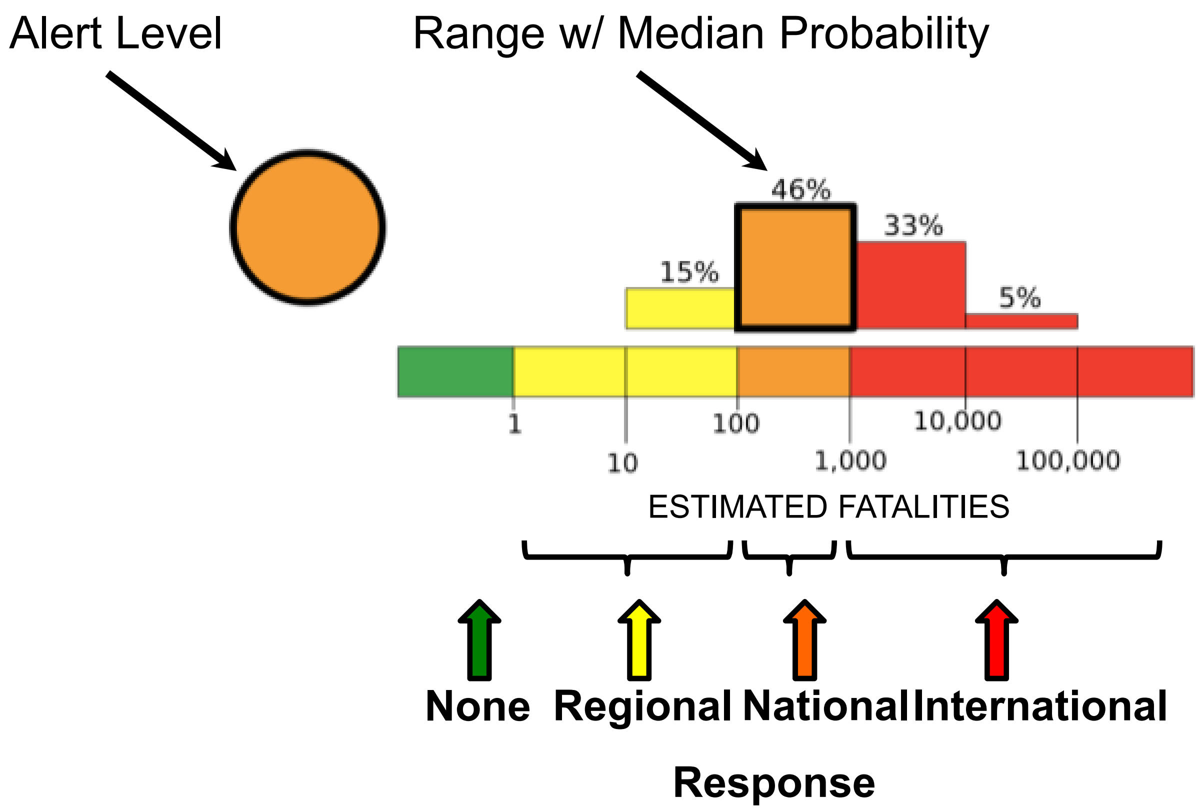


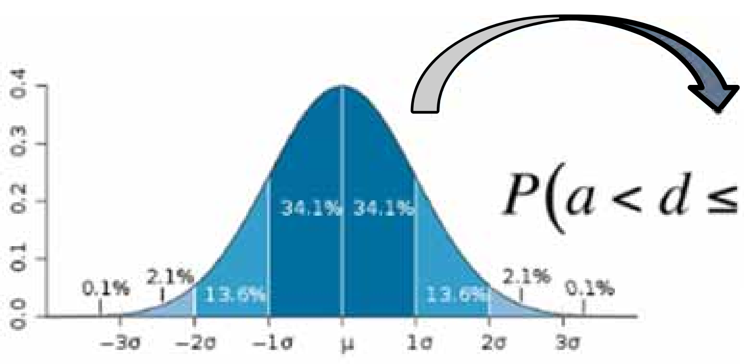
CE Database subject headings: Earthquakes; Hazards; Emergency services.

Author keywords: PAGER; Impact scale; Earthquake.

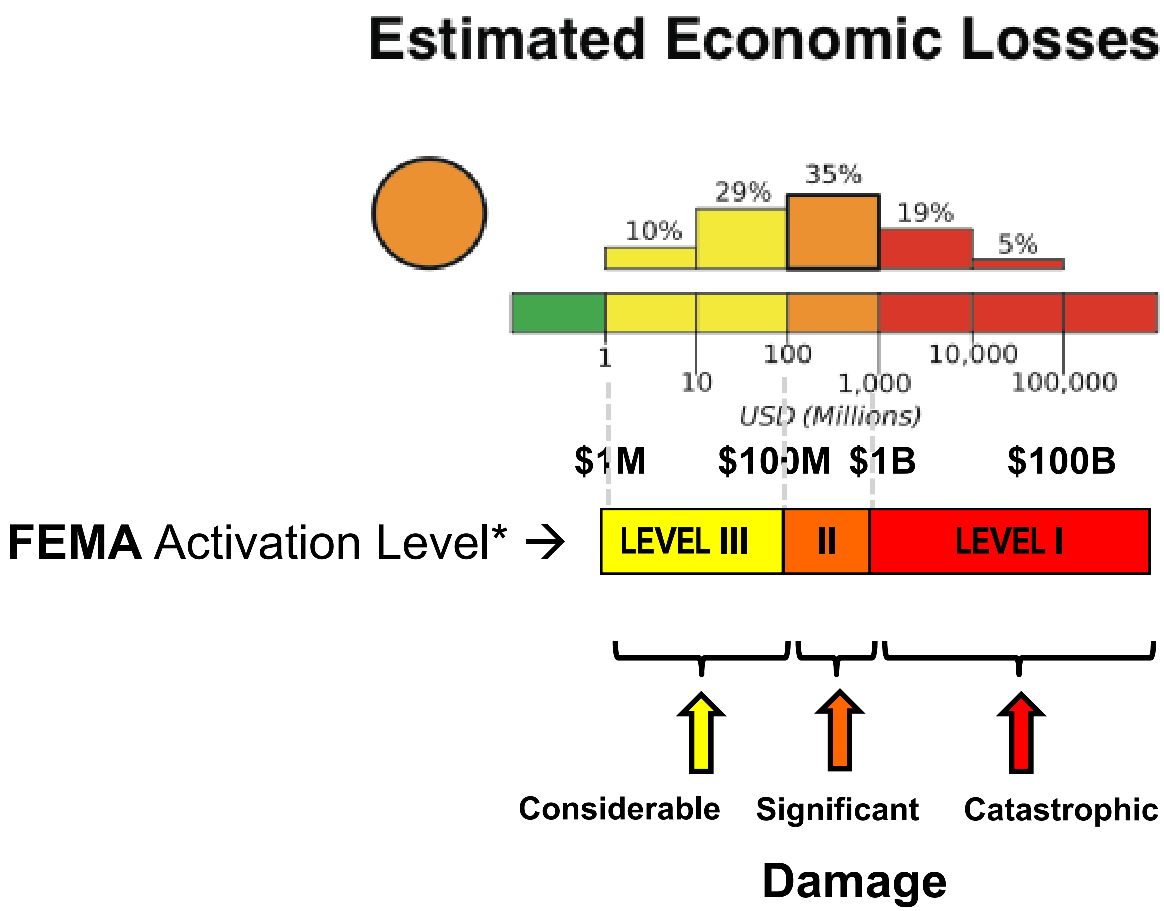
Introduction

Neither earthquake magnitude nor macroseismic intensity provides sufficient information to judge the overall impact of an earthquake. Whereas higher magnitude earthquakes have greater energy release vulnerability of the built environment, and the resilience of the communities affected. Whereas these factors can now, in part, be rapidly assessed following significant earthquake disasters, communicating the impact is still hampered by the lack of an appropriate lexicon.





$$P\left(a < d \leq b\right) = \Phi\left[\frac{\log(b) - \log(e)}{\xi}\right] - \Phi\left[\frac{\log(a) - \log(e)}{\xi}\right]$$



*Based on past losses, FEMA response activities & inferred response levels

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Earthquake Shaking — **Red Alert**

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

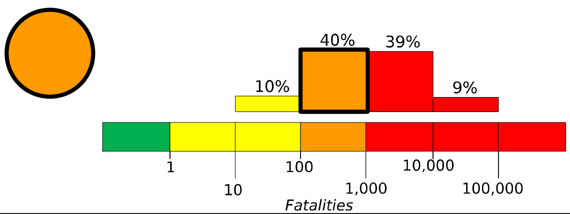
M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)
Location: 35.85°S 72.72°W Depth: 35 km
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 3

Created: 3 hours, 10 minutes after earthquake

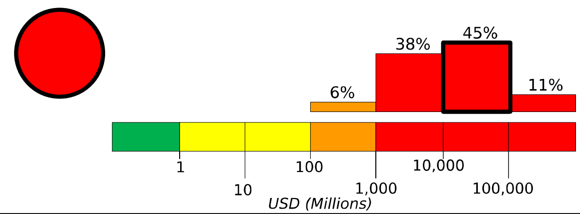
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

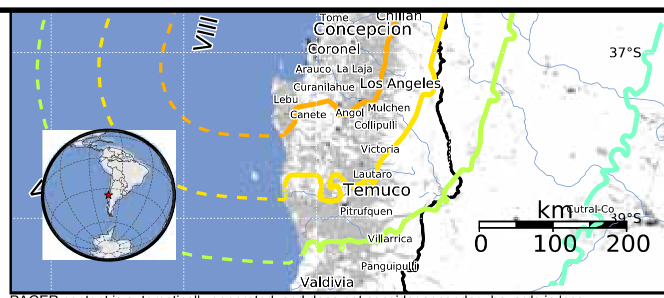
Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

		I	II-III	IV	V	VI	VII	VIII	IX	X+
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.



MMI	City	Population
VIII	**Arauco**	**25k**
VIII	Lota	50k
VIII	**Concepcion**	**215k**
VIII	Constitucion	38k
VII	Bulnes	13k
VII	Cabrero	18k
VI	**Temuco**	**238k**
VI	**Valparaiso**	**282k**
VI	**Santiago**	**4,837k**
IV	Mendoza	877k
III	Neuquen	242k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: us2010tfan

USGS PAGER

AUG 31, 2012, **M7.6** PHILIPPINES

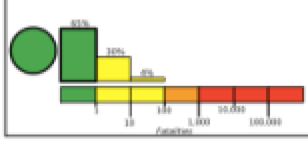
USGS science for a changing world — Earthquake Shaking **Green Alert** — USAID — ANSS

M 7.6, PHILIPPINE ISLANDS REGION

Origin Time: Fri 2012-08-31 12:47:34 UTC (20:47:34 local)
Location: 10.84°N 126.70°E Depth: 34 km
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

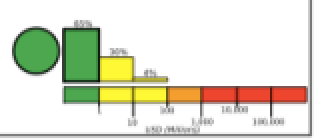
PAGER Version 2
Created: 51 minutes, 30 seconds after earthquake

Estimated Fatalities



Green alert for shaking-related fatalities and economic losses. There is a low likelihood of casualties and damage.

Estimated Economic Losses

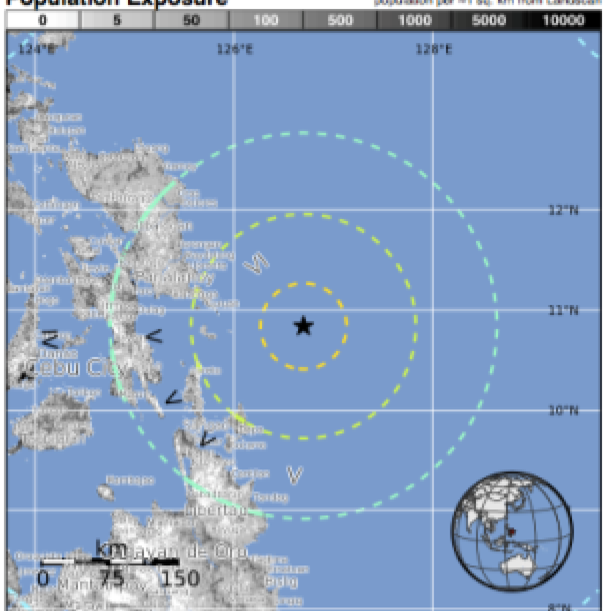


Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		--*	271k*	15,446k	3,094k	117k	0	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan



Structures:
Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. The predominant vulnerable building types are reinforced concrete and heavy wood frame construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1995-07-12	245	5.8	VII(236k)	0
1987-05-23	338	5.7	VII(70k)	1
1989-12-15	274	7.5	VIII(1k)	2

Recent earthquakes in this area have caused secondary hazards such as tsunamis and landslides that might have contributed to losses.

Selected City Exposure
from GeoNames.org

MMI	City	Population
VI	Sulangan	3k
VI	**Guiuan**	11k
VI	Santa Monica	2k
VI	Salcedo	4k
VI	San Benito	2k
V	Pilar	2k
IV	**Libertad**	250k
IV	Mandaue City	289k
IV	**Cebu City**	799k
IV	**Cagayan de Oro**	445k
IV	**Mantampay**	265k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: usc000cc5m

(1 landslide fatality, some injuries & damage)

SEP 11, 2012, **M7.6** COSTA RICA

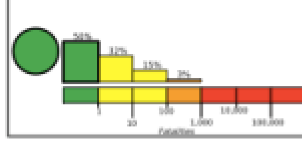
USGS science for a changing world — Earthquake Shaking **Yellow Alert** — USAID — ANSS

M 7.6, COSTA RICA

Origin Time: Wed 2012-09-05 14:42:10 UTC (08:42:10 local)
Location: 10.12°N 85.35°W Depth: 40 km
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER Version 2
Created: 1 hour, 47 minutes after earthquake

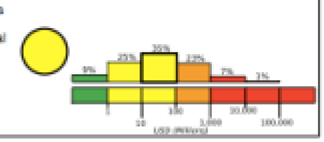
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of Costa Rica. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses

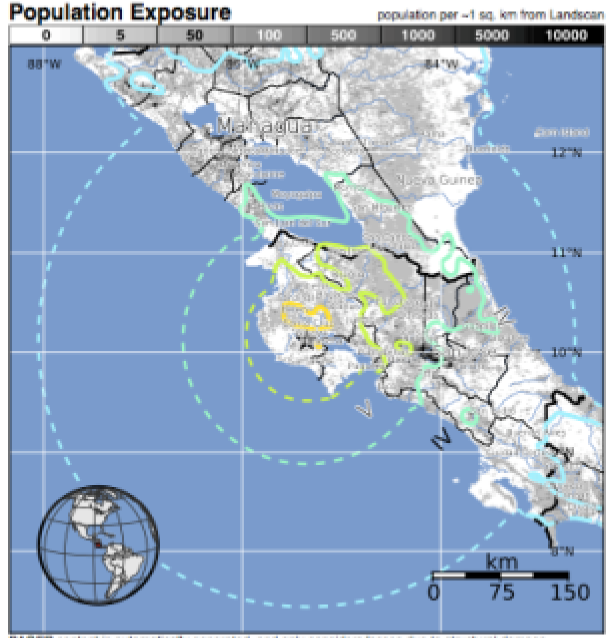


Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		--*	431k*	5,513k	2,945k	806k	55k	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan



Structures:
Overall, the population in this region resides in structures that are vulnerable to earthquake shaking, though some resistant structures exist. The predominant vulnerable building types are adobe block and mud wall construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
2000-02-20	188	5.6	VI(19k)	0
1993-07-10	193	5.8	VIII(893)	1
1991-04-22	254	7.6	VII(213k)	75

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and liquefaction that might have contributed to losses.

Selected City Exposure
from GeoNames.org

MMI	City	Population
VII	Nandayure	2k
VII	**Santa Cruz**	12k
VII	**Nicoya**	15k
VI	**Belen**	3k
VI	**Canas**	20k
VI	**Bagaces**	4k
V	**San Jose**	335k
IV	**Managua**	973k
IV	**Masaya**	130k
IV	Leon	145k
III	David	83k

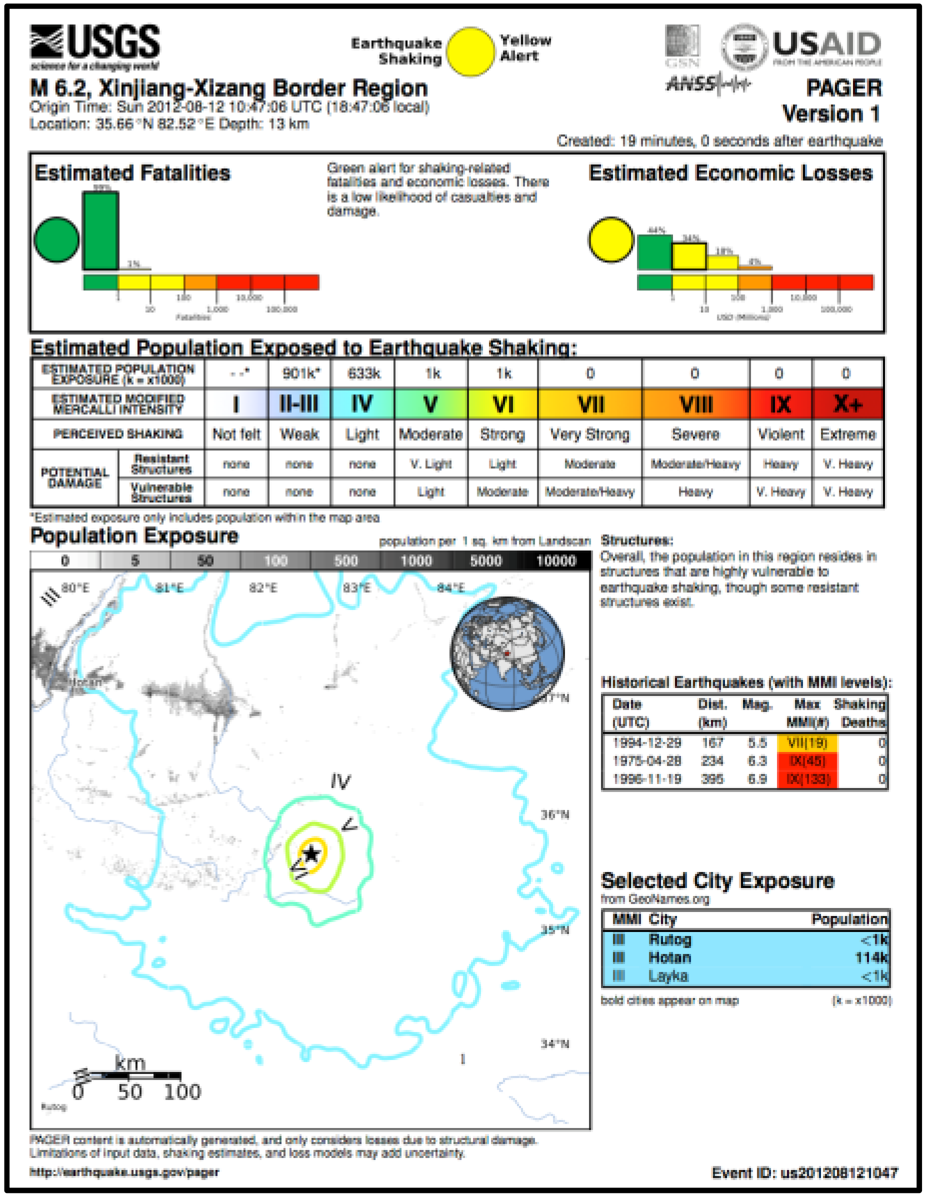
bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: usc000cfsd

(1 heart attack, distributed damage)

Aug 12, 2012, **M6.2** China



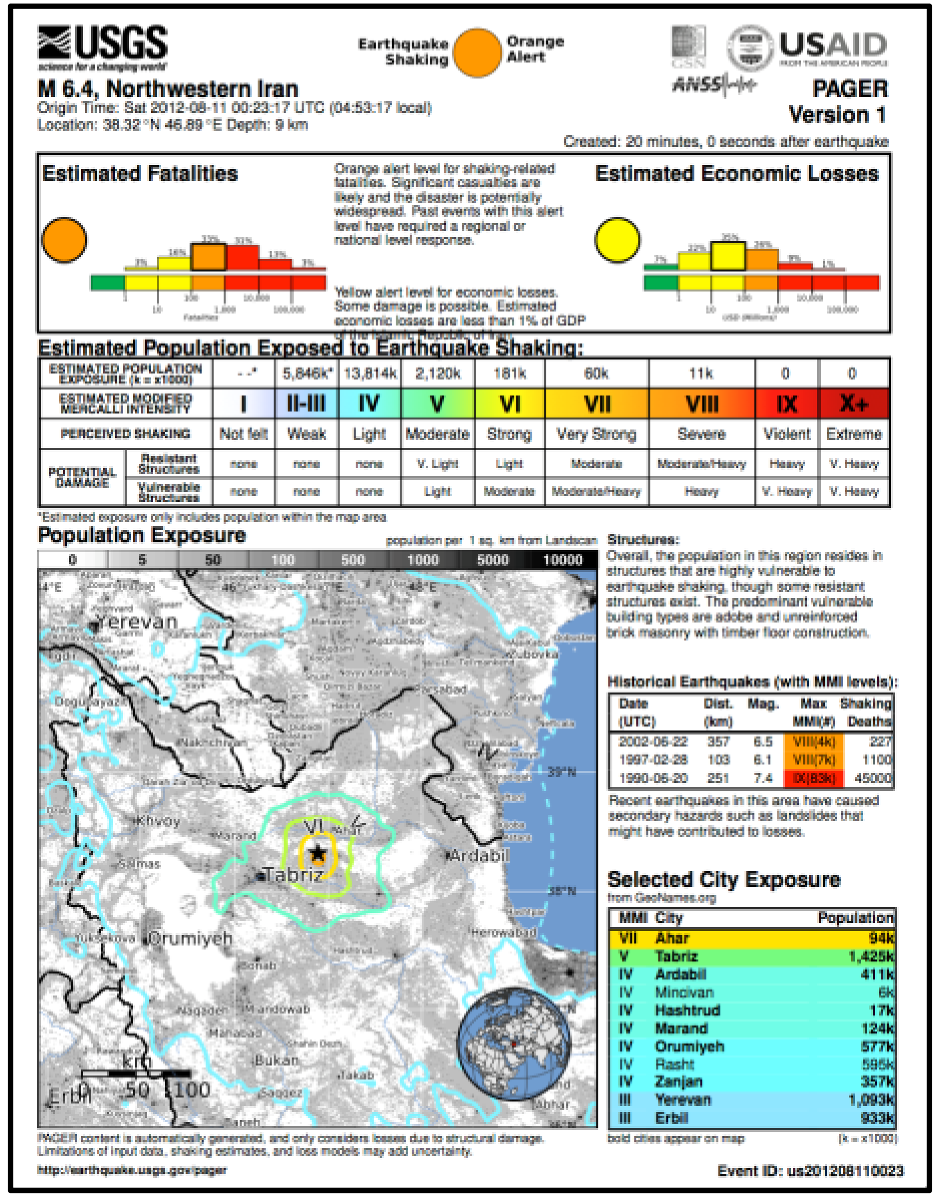
ESTIMATED POPULATION EXPOSURE (k = x1000)	-- *	901k*	633k	1k	1k	0	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE: Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
POTENTIAL DAMAGE: Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1994-12-29	167	5.5	VII(19)	0
1975-04-28	234	6.3	IX(45)	0
1996-11-19	395	6.9	IX(133)	0

MMI	City	Population
III	Rutog	<1k
III	Hotan	114k
III	Layka	<1k

(No fatalities, some injuries & damage)

Aug 11, 2012, **M6.4** Iran



ESTIMATED POPULATION EXPOSURE (k = x1000)	-- *	5,846k*	13,814k	2,120k	181k	60k	11k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE: Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
POTENTIAL DAMAGE: Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
2002-06-22	357	6.5	VIII(4k)	227
1997-02-28	103	6.1	VIII(7k)	1100
1990-06-20	251	7.4	IX(83k)	45000

MMI	City	Population
VII	Ahar	94k
V	Tabriz	1,425k
IV	Ardabil	411k
IV	Mincivan	6k
IV	Hashtrud	17k
IV	Marand	124k
IV	Orumiyeh	577k
IV	Rasht	595k
IV	Zanjan	357k
III	Yerevan	1,093k
III	Erbil	933k

(300 fatalities, extensive damage to 60 settlements)

PAGER

Prompt Assessment of Global Earthquakes for Response

USGS

USAID
FROM THE AMERICAN PEOPLE

USGS
science for a changing world

Earthquake Shaking Yellow Alert

USAID FROM THE AMERICAN PEOPLE

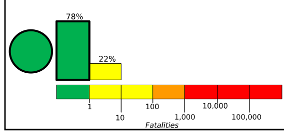
M 5.9, VIRGINIA

Origin Time: Tue 2011-08-23 17:51:03 UTC (13:51:03 local)
Location: 37.97°N 77.97°W Depth: 1 km

PAGER Version 1

Created: 20 minutes, 20 seconds after earthquake

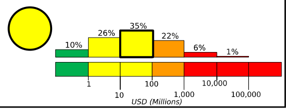
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

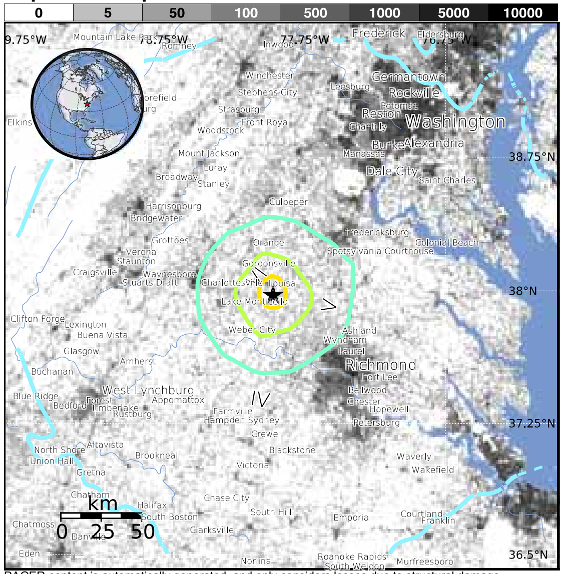
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	3,150k*	8,850k	313k	23k	10k	865	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

0	5	50	100	500	1000	5000	10000



Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.

Historical Earthquakes (with MMI levels):

There were no earthquakes with significant population exposure to shaking within a 400 km radius of this event.

Selected City Exposure
from GeoNames.org

MMI	City	Population
VII	**Louisa**	**2k**
V	**Gordonsville**	**2k**
V	**Orange**	**4k**
V	**Lake Monticello**	**10k**
V	**Weber City**	**1k**
IV	**Richmond**	**191k**
IV	**Washington**	**552k**
III	Virginia Beach	425k
III	Annapolis	36k
III	Baltimore	611k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage.
Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: usc0005ild

USGS
science for a changing world

Earthquake Shaking Orange Alert

USAID FROM THE AMERICAN PEOPLE

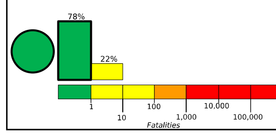
M 5.8, VIRGINIA

Origin Time: Tue 2011-08-23 17:51:04 UTC (13:51:04 local)
Location: 37.94°N 77.93°W Depth: 6 km

PAGER Version 3

Created: 2 hours, 5 minutes after earthquake

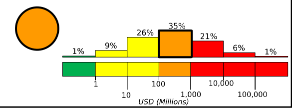
Estimated Fatalities



Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

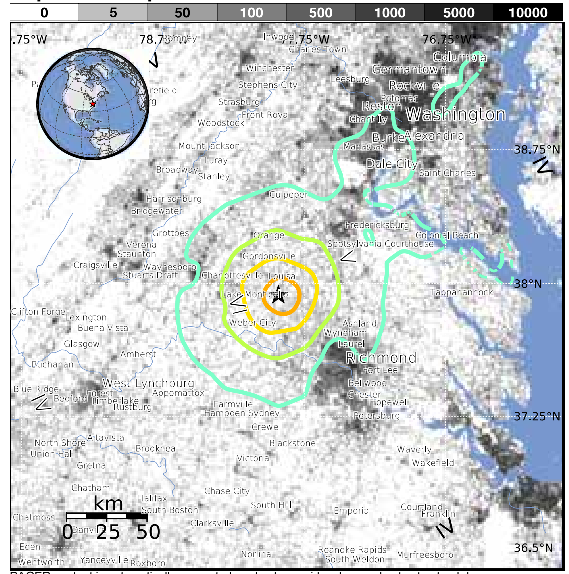
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	19k*	9,627k*	2,285k	76k	23k	10k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

0	5	50	100	500	1000	5000	10000



Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.

Historical Earthquakes (with MMI levels):

There were no earthquakes with significant population exposure to shaking within a 400 km radius of this event.

Selected City Exposure
from GeoNames.org

MMI	City	Population
VII	**Louisa**	**2k**
VI	**Gordonsville**	**2k**
VI	Newington	21k
VI	**Orange**	**4k**
VI	**Weber City**	**1k**
VI	**Lake Monticello**	**10k**
V	Virginia Beach	425k
V	**Washington**	**552k**
IV	**Richmond**	**191k**
IV	Baltimore	611k
IV	Annapolis	36k

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage.
Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

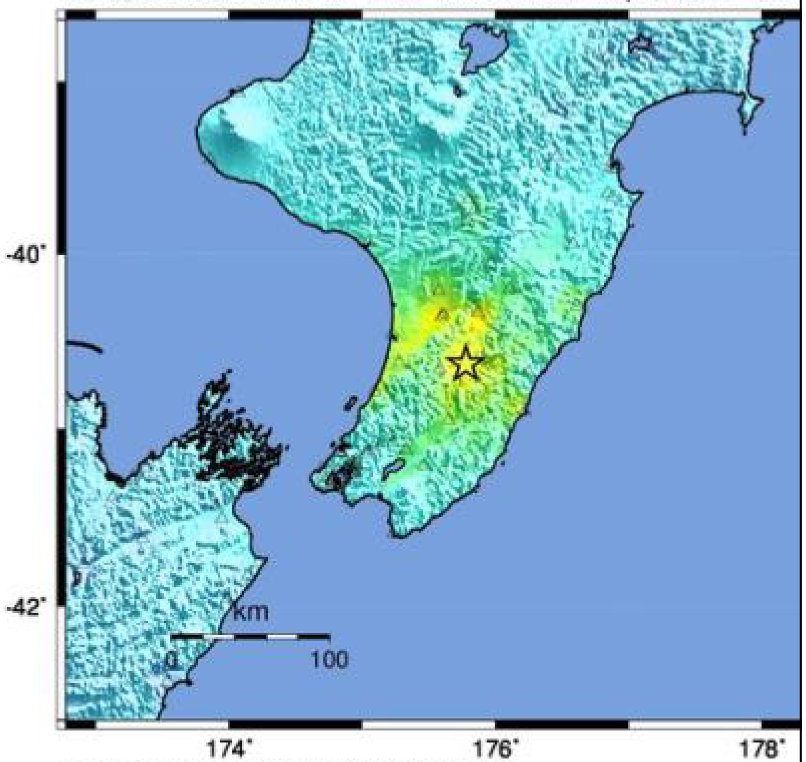
Event ID: us082311a

20 Minutes: mainly predictive (some DYFI)

2 hours, 5 min: constrained by many(!) DYFI data

USGS ShakeMap : NORTH ISLAND OF NEW ZEALAND

Jan 19, 2014 06:52:45 PM PST M 6.2 S40.63 E175.78 Depth: 28.0km ID:b0



Map Version 5 Processed Tue Feb 4, 2014 12:02:09 PM PST

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX

Scale based upon Worden et al. (2012)

USGS science for a changing world

Earthquake Shaking **Yellow Alert**

GSN USAID FROM THE AMERICAN PEOPLE ANSS

PAGER

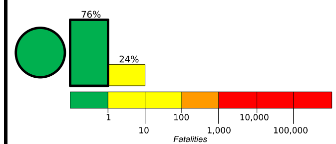
Version 1

M 6.2, NORTH ISLAND OF NEW ZEALAND

Origin Time: Mon 2014-01-20 02:52:45 UTC (14:35:51 local)
Location: 40.63˚S 175.78˚E Depth: 28 km

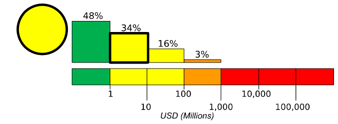
Created: 2 weeks, 1 day after earthquake

Estimated Fatalities



Green alert for shaking-related fatalities and economic losses. There is a low likelihood of casualties and damage.

Estimated Economic Losses



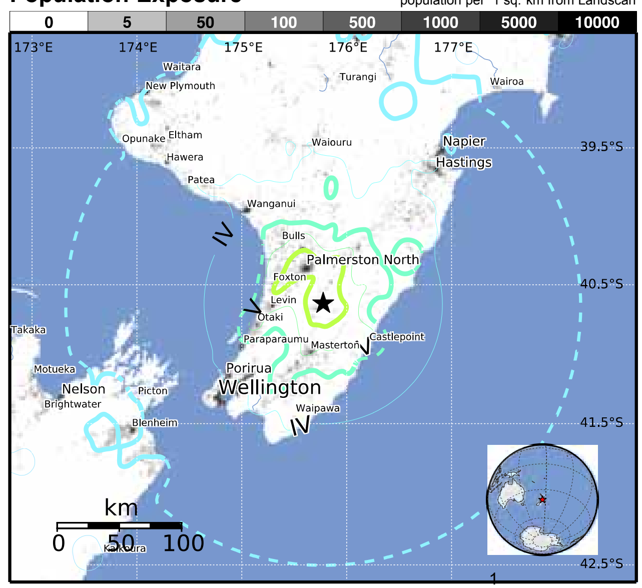
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	146k*	835k	132k	111k	0	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area

Population Exposure

population per 1 sq. km from Landscan



Structures:

Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1977-01-18	169	6.1	VI(57k)	0
1987-03-02	302	6.5	IX(389)	0
2004-07-18	296	5.4	VII(667)	1

Recent earthquakes in this area have caused secondary hazards such as landslides that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI	City	Population
VI	**Palmerston North**	**76k**
VI	**Otaki**	**6k**
V	**Levin**	**20k**
V	**Foxton**	**5k**
V	**Masterton**	**21k**
V	**Castlepoint**	**2k**
IV	**Wellington**	**382k**
IV	**New Plymouth**	**49k**
IV	Gisborne	34k
IV	**Napier**	**57k**
III	**Nelson**	**59k**

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/pager

Event ID: usb000m4i4

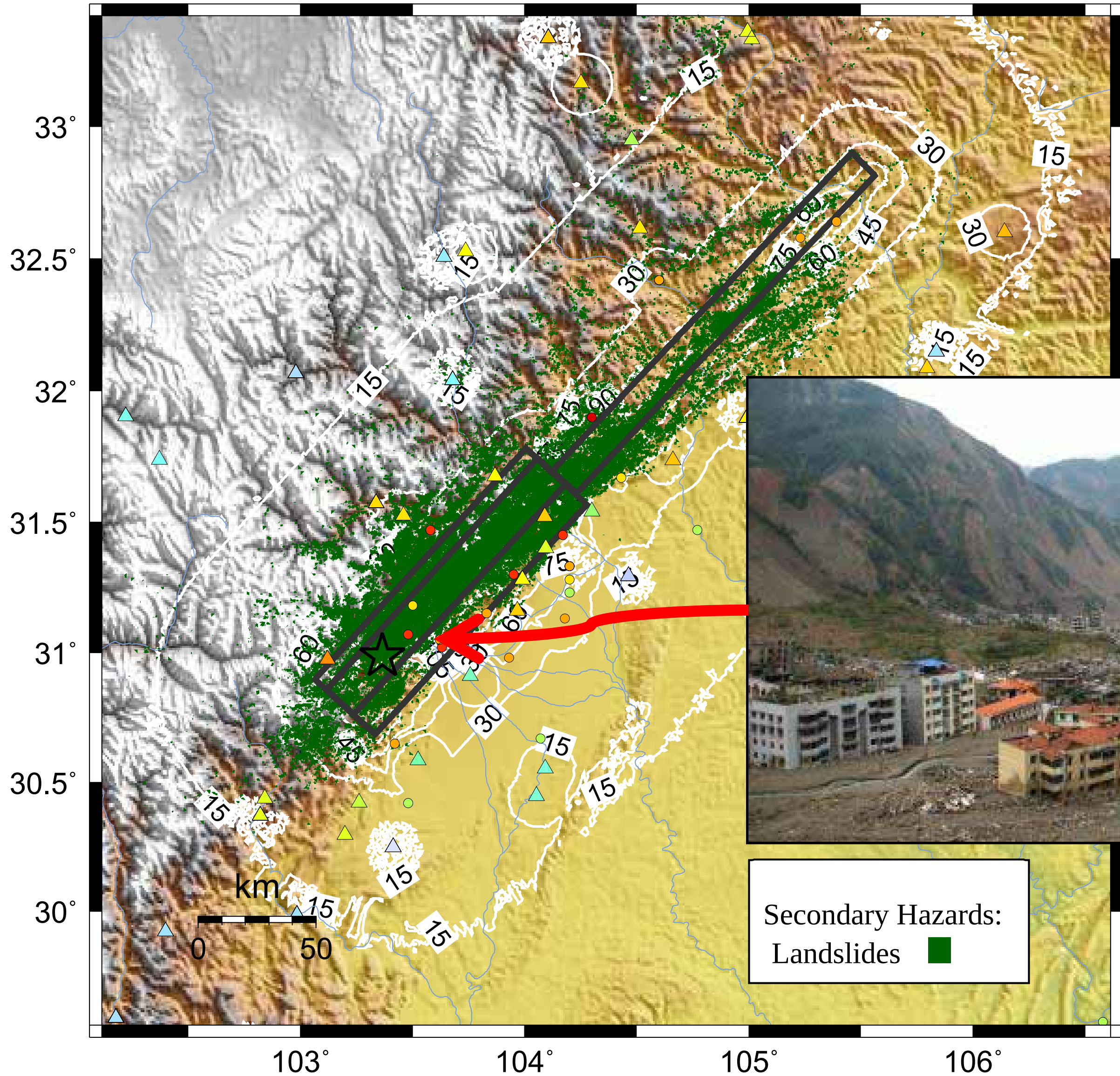
USGS Peak Accel. Map (in %g) : Wenchuan, China

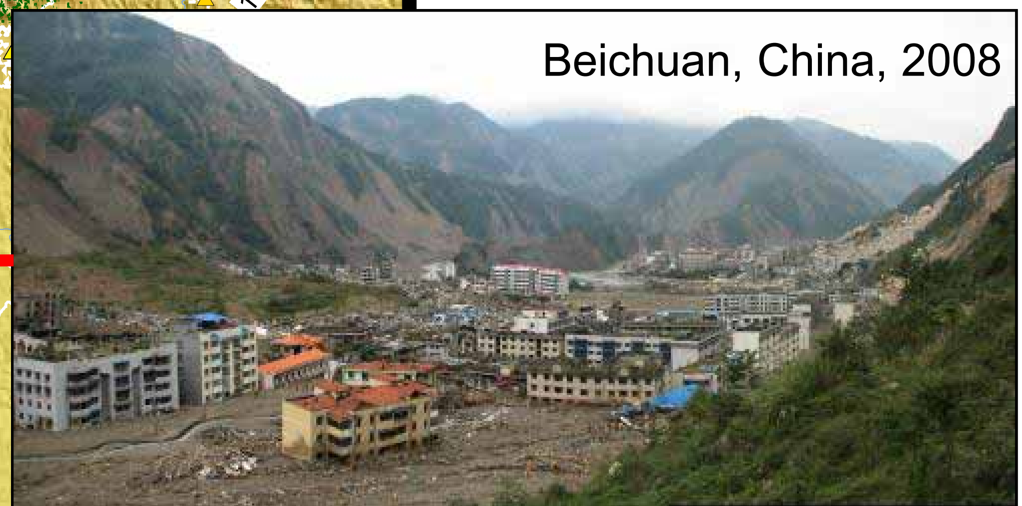
MAY 12 2008 06:28:01 AM GMT   M 7.9   N30.99 E103.36   Depth: 19.0km   ID:200805120628

Secondary Hazards

Wenchuan, China
Mw 7.9. 2008

20,000 landslide fatalities

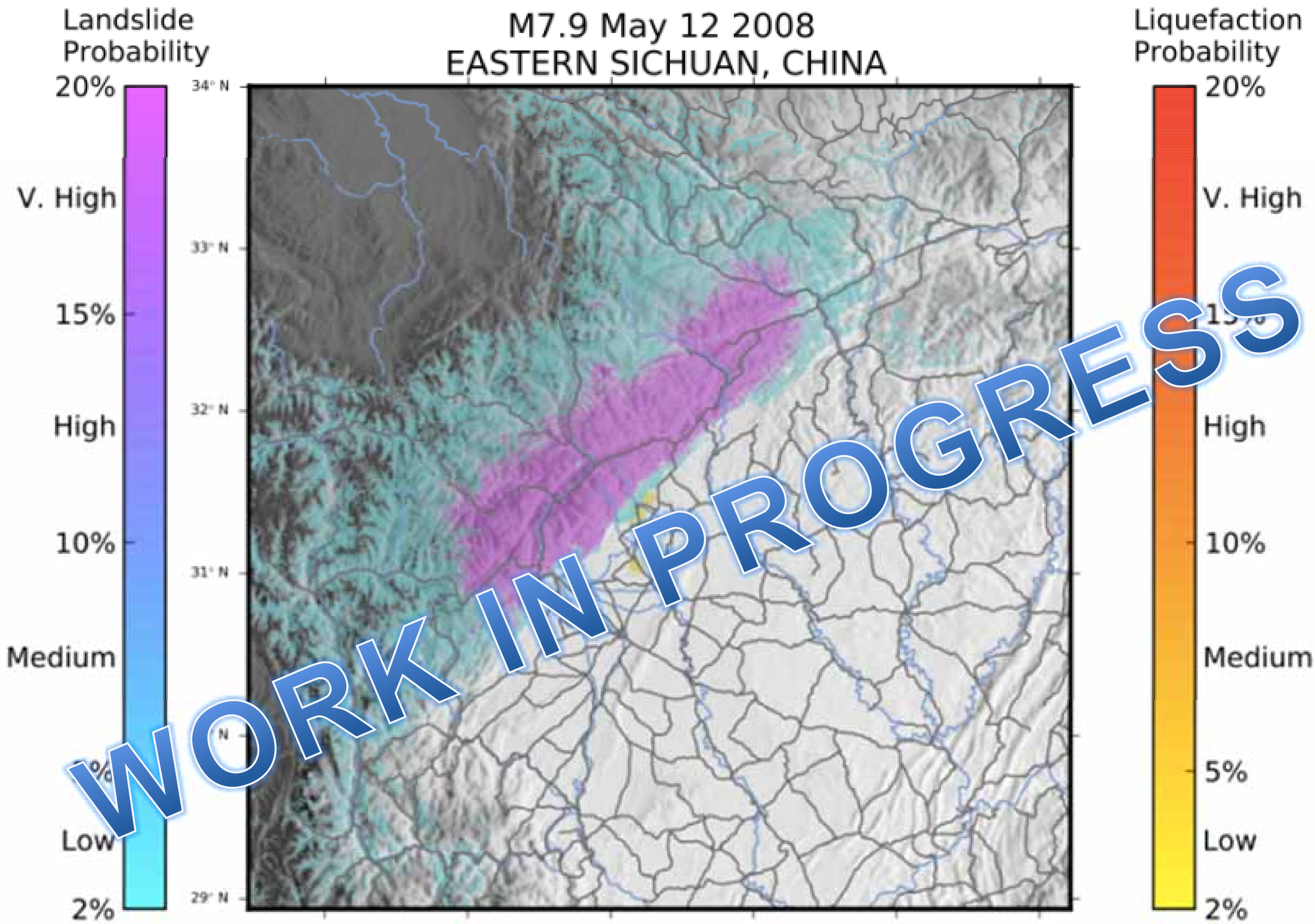




Map Version 1 Processed Mon Jun 18, 2012 02:31:03 PM MDT

PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2011)



Distribution of landslide and liquefaction likelihood. This methodology is being developed for use in ShakeCast and PAGER.

Tweet from the Head of FEMA

SAMPLE PAGER ALERT RECIPIENTS

The World Bank
IBRD & IDA: Working for a World F

csem emsc

Nat' l Urban Search & Recue
China's earthquake emergency rescue center

USAID
FROM THE AMERICAN PEOPLE

MercyCorps
Be the change

Australian Government
Geoscience Australia

Mexico Civil Protection
Sistema Nacional de Protección Civil
MÉXICO

GEOHAZARDS INTERNATIONAL
A Nonprofit Working Toward Global Earthquake Safety

IDB
Inter-American Develop. Bank

UPI.com
100 YEARS OF JOURNALISTIC EXCELLENCE

AP Associated Press

EERI Earthquake Engineering Research Institute

GDACS
Global Disaster Alert & Coordination System

REUTERS

Aid Agencies/NGO

International

State & Federal Government

THE WHITE HOUSE

ANSS

U.S. DEPARTMENT of STATE

FEMA

Cal EMA
CALIFORNIA EMERGENCY MANAGEMENT AGENCY

USNORTHCOM
DEFENDING OUR HOMELAND

Homeland Security

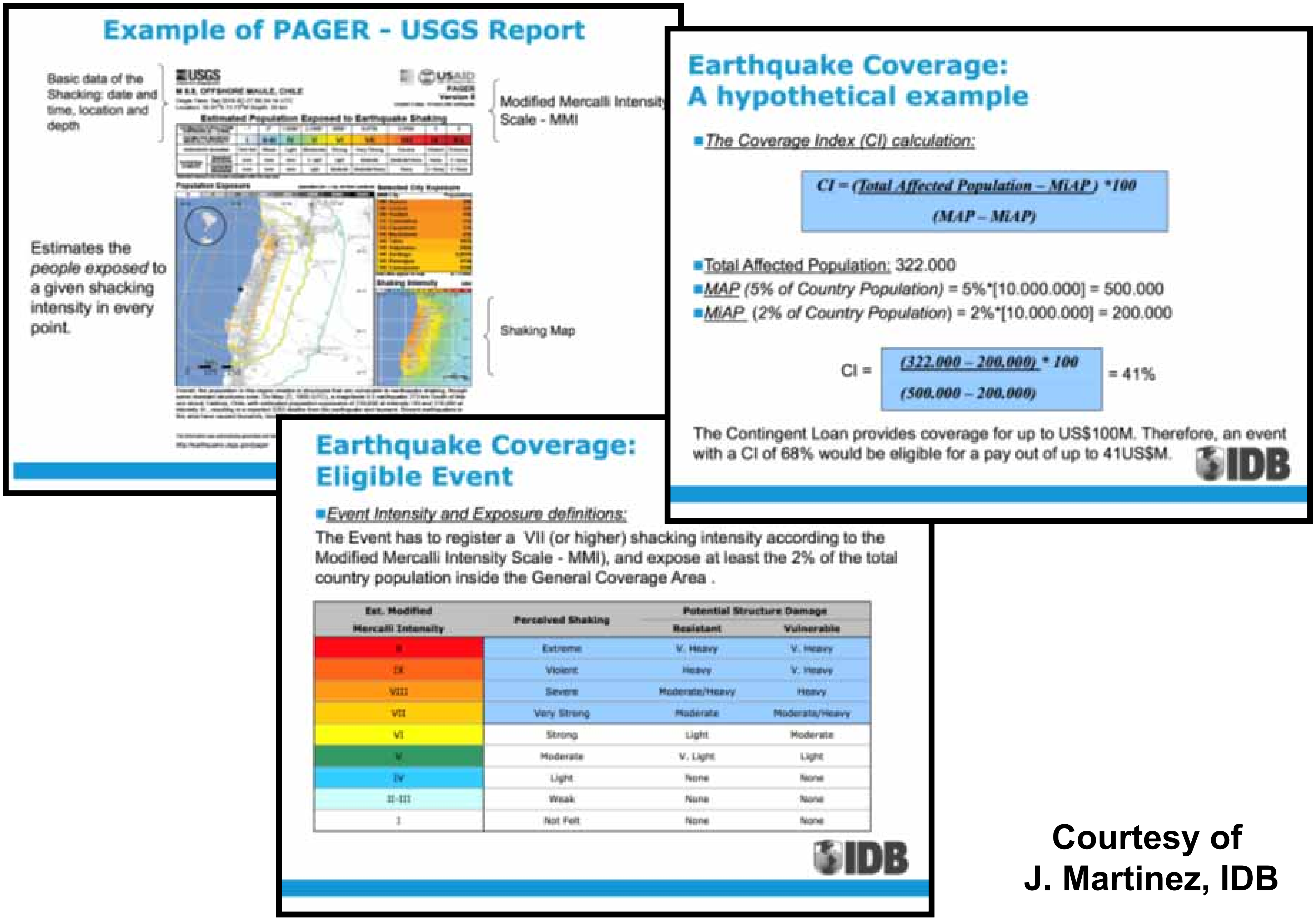
US AIR FORCE

U.S. Pacific Command

U.S. Department of Health & Human Services

Office of Science and Technology Policy

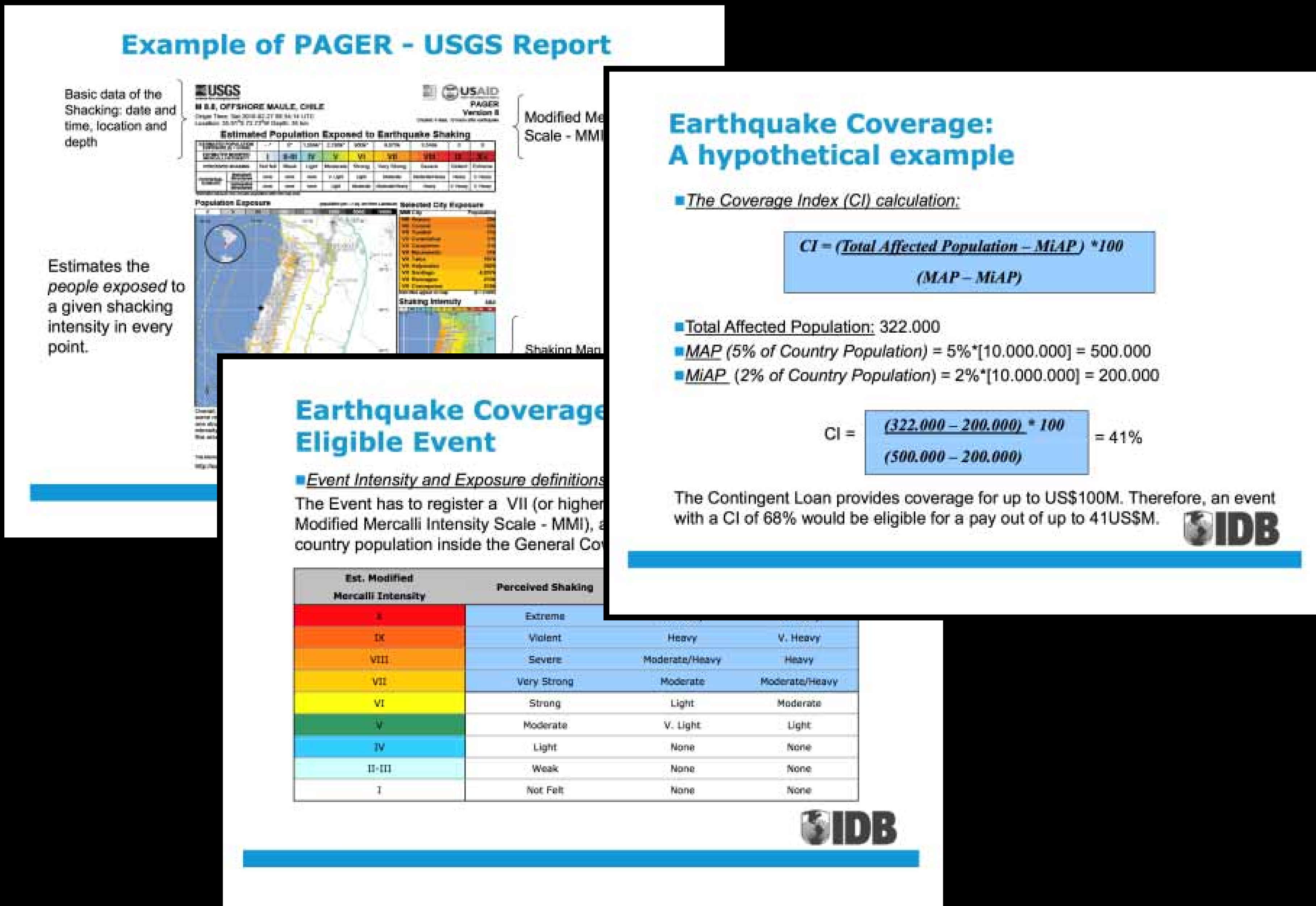
Example PAGER users: *Inter-American Development Bank*



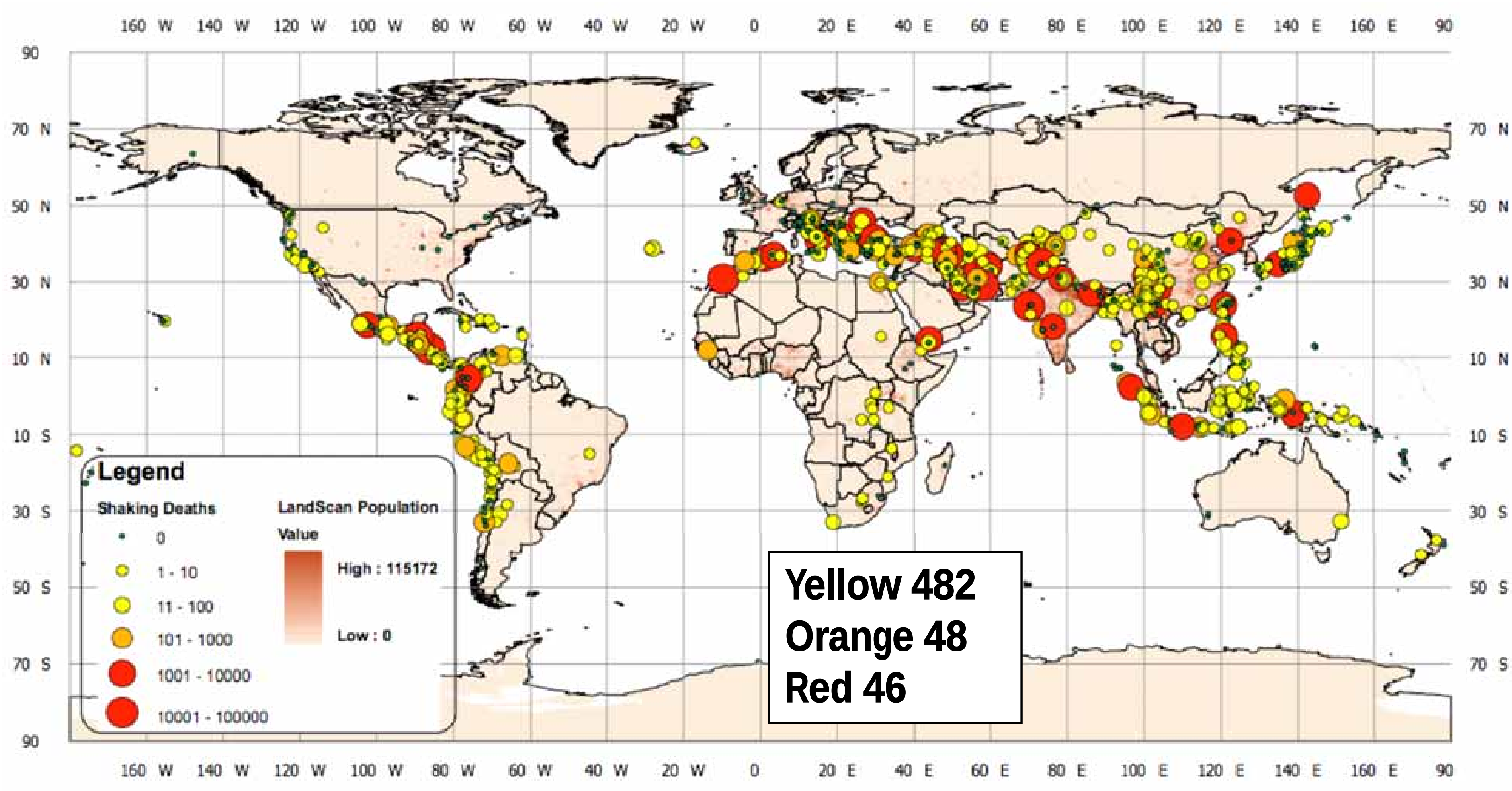
Est. Modified Mercalli Intensity	Perceived Shaking	Potential Structure Damage: Resistant	Potential Structure Damage: Vulnerable
X	Extreme	V. Heavy	V. Heavy
IX	Violent	Heavy	V. Heavy
VIII	Severe	Moderate/Heavy	Heavy
VII	Very Strong	Moderate	Moderate/Heavy
VI	Strong	Light	Moderate
V	Moderate	V. Light	Light
IV	Light	None	None
II-III	Weak	None	None
I	Not Felt	None	None

Courtesy of J. Martinez, IDB

Example PAGER users: *Inter-American Development Bank*



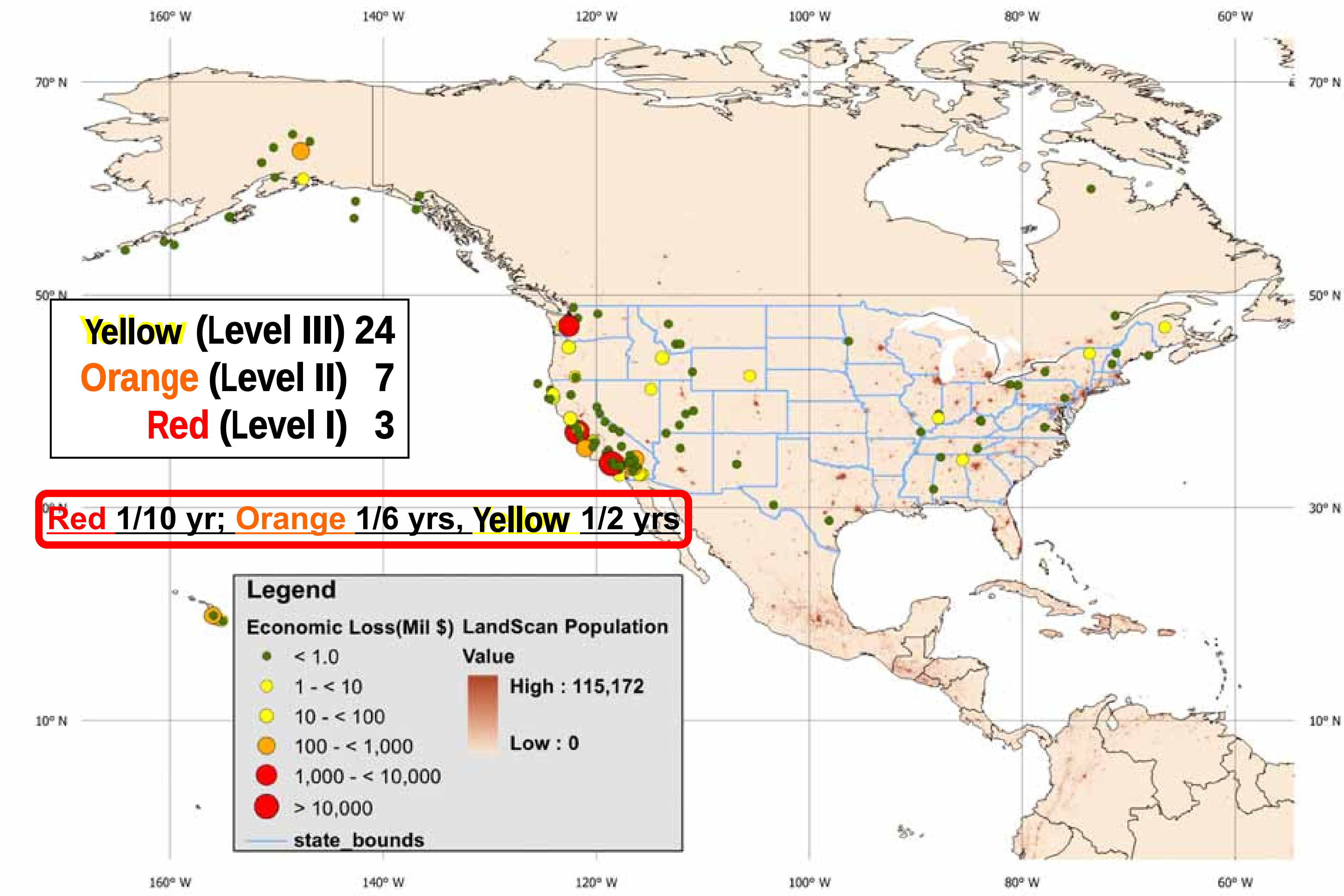
Global **Fatality-based** alerts over the past 40 years



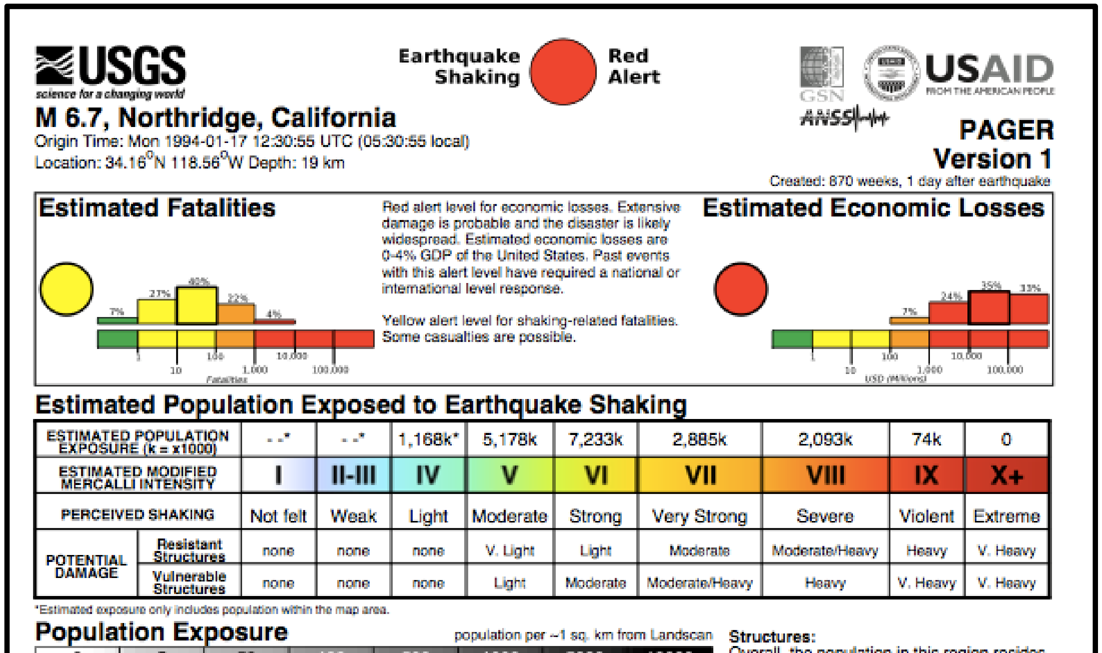
Map of fatality-based alert levels that would be triggered given the observed fatalities for events over the past forty years. The legend provides the fatality threshold for color-coded alert level. There would have been about 5,000 green, 490 yellow, 51 orange, and 48 red alerts (approximately 12 yellow, 1-2 orange, and 1-2 red alerts per year).

US $-Loss-based Activation Levels (past 40 years)

(From comparison of past losses, aid & response)



(33 deaths; >$40B losses)



USGS
science for a changing world

Earthquake Shaking — Red Alert

GSN ANSS USAID FROM THE AMERICAN PEOPLE

M 6.7, Northridge, California

Origin Time: Mon 1994-01-17 12:30:55 UTC (05:30:55 local)
Location: 34.16°N 118.56°W Depth: 19 km

PAGER Version 1

Created: 870 weeks, 1 day after earthquake

Estimated Fatalities

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-4% GDP of the United States. Past events with this alert level have required a national or international level response.

Yellow alert level for shaking-related fatalities. Some casualties are possible.

Estimated Economic Losses

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	1,168k*	5,178k	7,233k	2,885k	2,093k	74k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

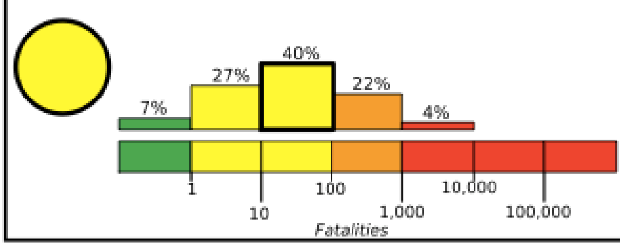
*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

Structures:

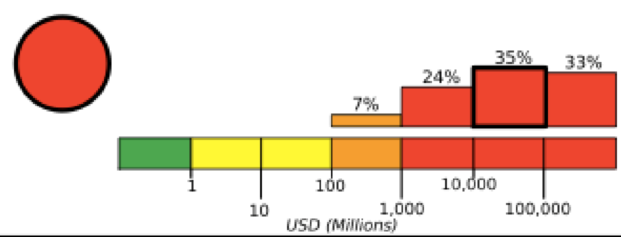
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-4% GDP of the United States. Past events with this alert level have required a national or international level response.

Yellow alert level for shaking-related fatalities. Some casualties are possible.

Estimated Economic Losses

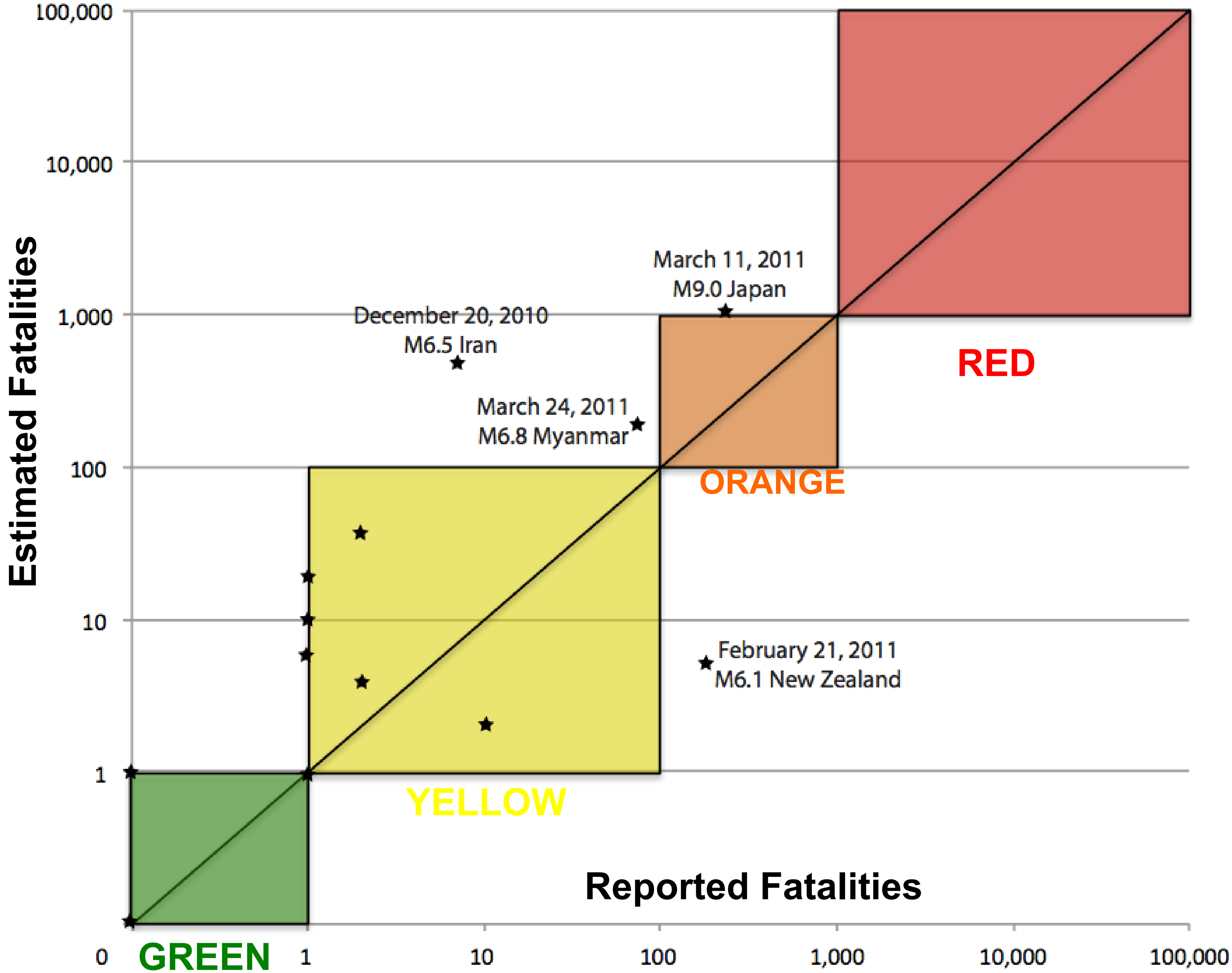


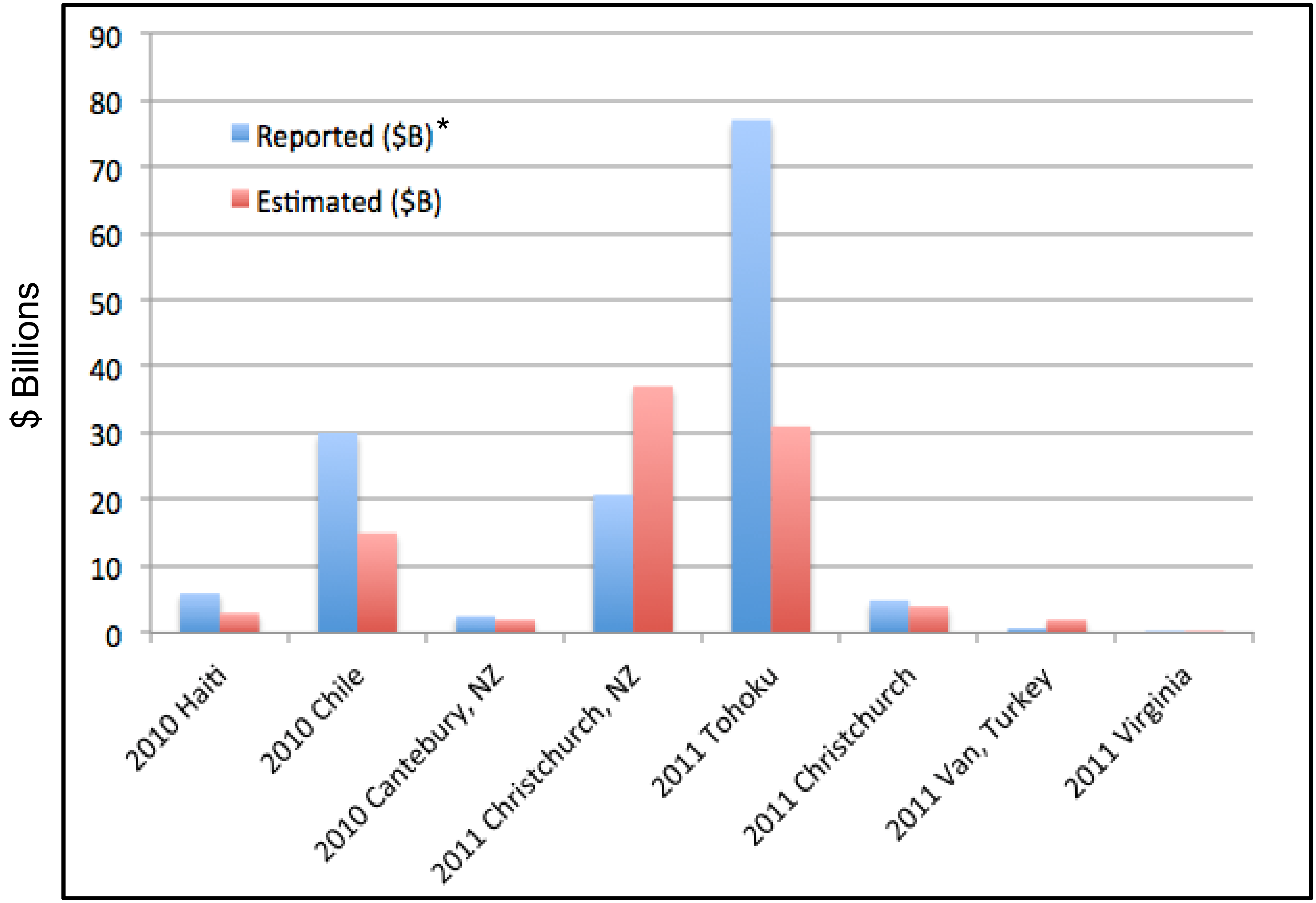
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	1,168k*	5,178k	7,233k	2,885k	2,093k	74k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

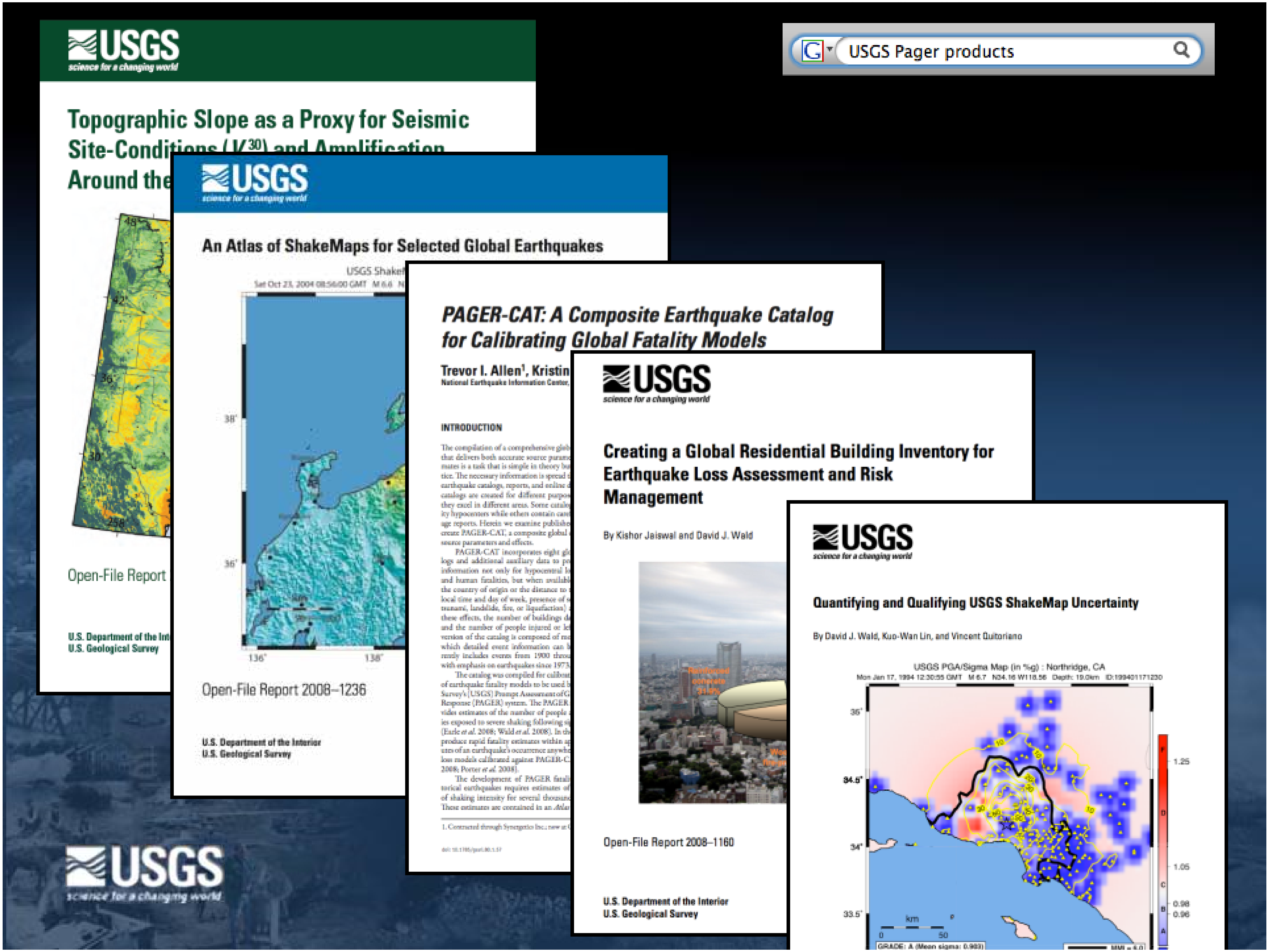
How did we do using EIS? (>2010)





* Median value of shaking-related direct economic losses from most recent version of ShakeMap system

[Jaiswal & Wald (2012) *Earthquake Spectra*]


USGS Pager products
USGS
science for a changing world
Topographic Slope as a Proxy for Seismic
Open-File Report
U.S. Department of the Int
U.S. Geological Survey
USGS
science for a changing world
An Atlas of ShakeMaps for Selected Global Earthquakes
Open-File Report 2008–1236
U.S. Department of the Interior
U.S. Geological Survey
PAGER-CAT: A Composite Earthquake Catalog
for Calibrating Global Fatality Models
Trevor I. Allen
INTRODUCTION
USGS
science for a changing world
Creating a Global Residential Building Inventory for
Earthquake Loss Assessment and Risk
Management
By Kishor Jaiswal and David J. Wald
Open-File Report 2008–1160
U.S. Department of the Interior
U.S. Geological Survey
USGS
science for a changing world
Quantifying and Qualifying USGS ShakeMap Uncertainty
By David J. Wald, Kuo-Wan Lin, and Vincent Quitoriano
USGS PGA/Sigma Map (in %g) : Northridge, CA
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PAGER Modules: Products & Tools

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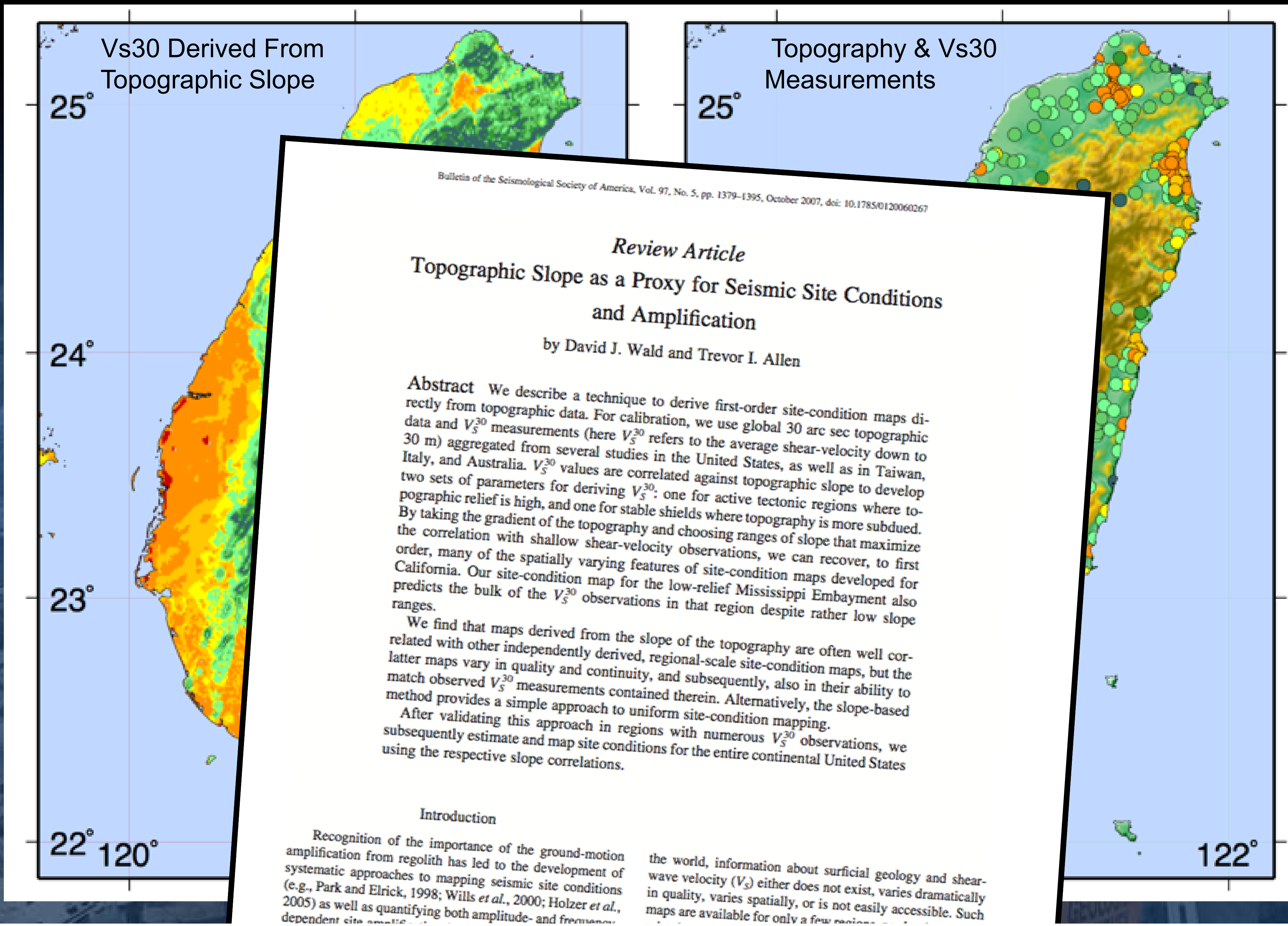
  - Archives
  - **Products & References**
  - Team Members
- Seismogram Displays
- ShakeMaps

Products and References

Database/Product	Description	Use	Reference
PAGER Overview			Earle *et al.* (2008); Wald *et al.* (2008a), Earle and Wald (2007)
Earthquake Source			
Fast Finite Faults	Rapid (few hours) slip models for major earthquakes	Constrain shaking, tsunami generation, stress changes	Ji *et al.* (2004); Hayes & Wald (2009)
PAGER-CAT	Quality composite earthquake catalog (1900–2006)	Source input for ShakeMap Atlas, ExposureCat	Allen *et al.* (2009)
Shaking Distribution			
Global Slope Data	Topographic slope	Landslides, Vs30	Verdin *et al.* (2007)
Global Vs30 Server	Vs30 values for the globe	Estimating site amplification	Wald & Allen (2007); Allen & Wald (2007; in press)
Global "Did You Feel It" Intensities	Rapid intensities from Internet users	Constrains ShakeMap & event bias	Wald and Dewey (2005); Wald *et al.* (2006b); Atkinson and Wald (2007); Wald *et al.* (2008b)
ShakeMap Uncertainty	Quantitative & qualitative shaking values	Computing loss uncertainty	Wald *et al.* (2008b)
ShakeMap Atlas	ShakeMaps important global earthquakes (1970–present)	Scenarios, planning, hazard calculations	Allen *et al.* (2008; in press)
Rapid Global ShakeMaps (GSM)	Estimated ShakeMaps for all global earthquakes (M>5.5)	Shaking input for loss estimation, decision making	Wald *et al.* (2006a)
Landslide Hazard	Spatial probability of landslides	Secondary loss assessments	Godt *et al.* (2008); Marano *et al.* (in press)
Ground Motion Modeling	Comparison of ground motion prediction equations	Improvement of ShakeMap	Allen and Wald (2009)
Loss & Impact Estimation			
Deadly Earthquake List	Online resource list (1900–2006)	General reference	On Wikipedia: see "List of Deadly Earthquakes"
EXPO-CAT	Population exposure to intensity for each Atlas ShakeMap	Fatality rates calculations	Allen *et al* (in press)
Global Building Inventory	Country-based data on buildings & collapse rates	Country-specific loss estimation	Jaiswal & Wald (2008a, 2008b); Porter *et al.* (2008b)
Empirical Loss Model	Country-specific fatality rates	Fatality estimates given exposure	Porter *et al.* (2008a); Jaiswal *et al.* (in prep)
Semi-Empirical Loss Model	Country-specific, building vulnerability	Fatality estimates based on structures	Jaiswal and Wald (in prep)
Analytical Loss Model	HAZUS vulnerability functions	Structure-dependent loss computations	Porter (in review)
Reporting & Notifications			
OnePAGER	Population exposure notifications	Post-earthquake decision making	Earle & Wald (2007)

Taiwan



Bulletin of the Seismological Society of America, Vol. 97, No. 5, pp. 1379–1395, October 2007, doi: 10.1785/0120060267

Review Article

Topographic Slope as a Proxy for Seismic Site Conditions and Amplification

by David J. Wald and Trevor I. Allen

Abstract We describe a technique to derive first-order site-condition maps directly from topographic data. For calibration, we use global 30 arc sec topographic data and V_S^{30} measurements (here V_S^{30} refers to the average shear-velocity down to 30 m) aggregated from several studies in the United States, as well as in Taiwan, Italy, and Australia. V_S^{30} values are correlated against topographic slope to develop two sets of parameters for deriving V_S^{30}: one for active tectonic regions where topographic relief is high, and one for stable shields where topography is more subdued. By taking the gradient of the topography and choosing ranges of slope that maximize the correlation with shallow shear-velocity observations, we can recover, to first order, many of the spatially varying features of site-condition maps developed for California. Our site-condition map for the low-relief Mississippi Embayment also predicts the bulk of the V_S^{30} observations in that region despite rather low slope ranges.

We find that maps derived from the slope of the topography are often well correlated with other independently derived, regional-scale site-condition maps, but the latter maps vary in quality and continuity, and subsequently, also in their ability to match observed V_S^{30} measurements contained therein. Alternatively, the slope-based method provides a simple approach to uniform site-condition mapping.

After validating this approach in regions with numerous V_S^{30} observations, we subsequently estimate and map site conditions for the entire continental United States using the respective slope correlations.

Introduction

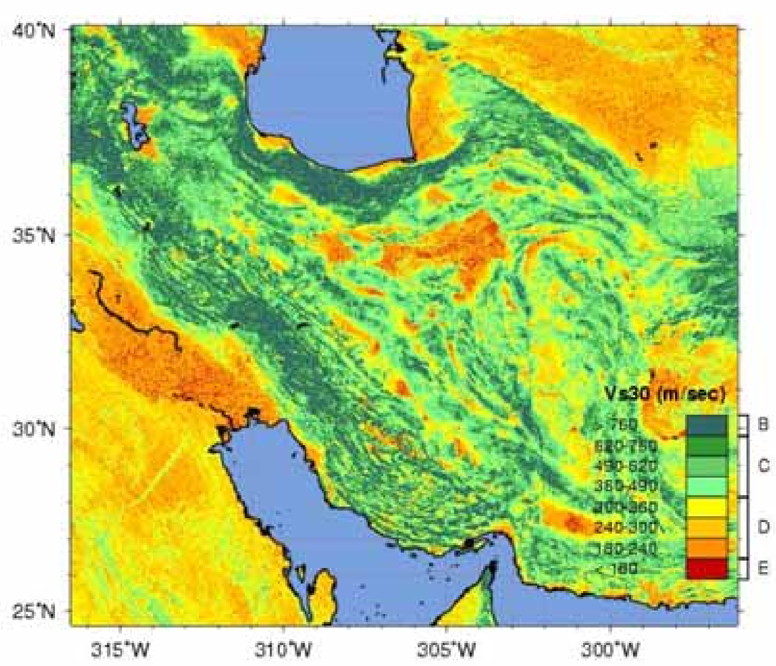
Recognition of the importance of the ground-motion amplification from regolith has led to the development of systematic approaches to mapping seismic site conditions (e.g., Park and Elrick, 1998; Wills *et al.*, 2000; Holzer *et al.*, 2005) as well as quantifying both amplitude- and frequency-dependent site amplification ...

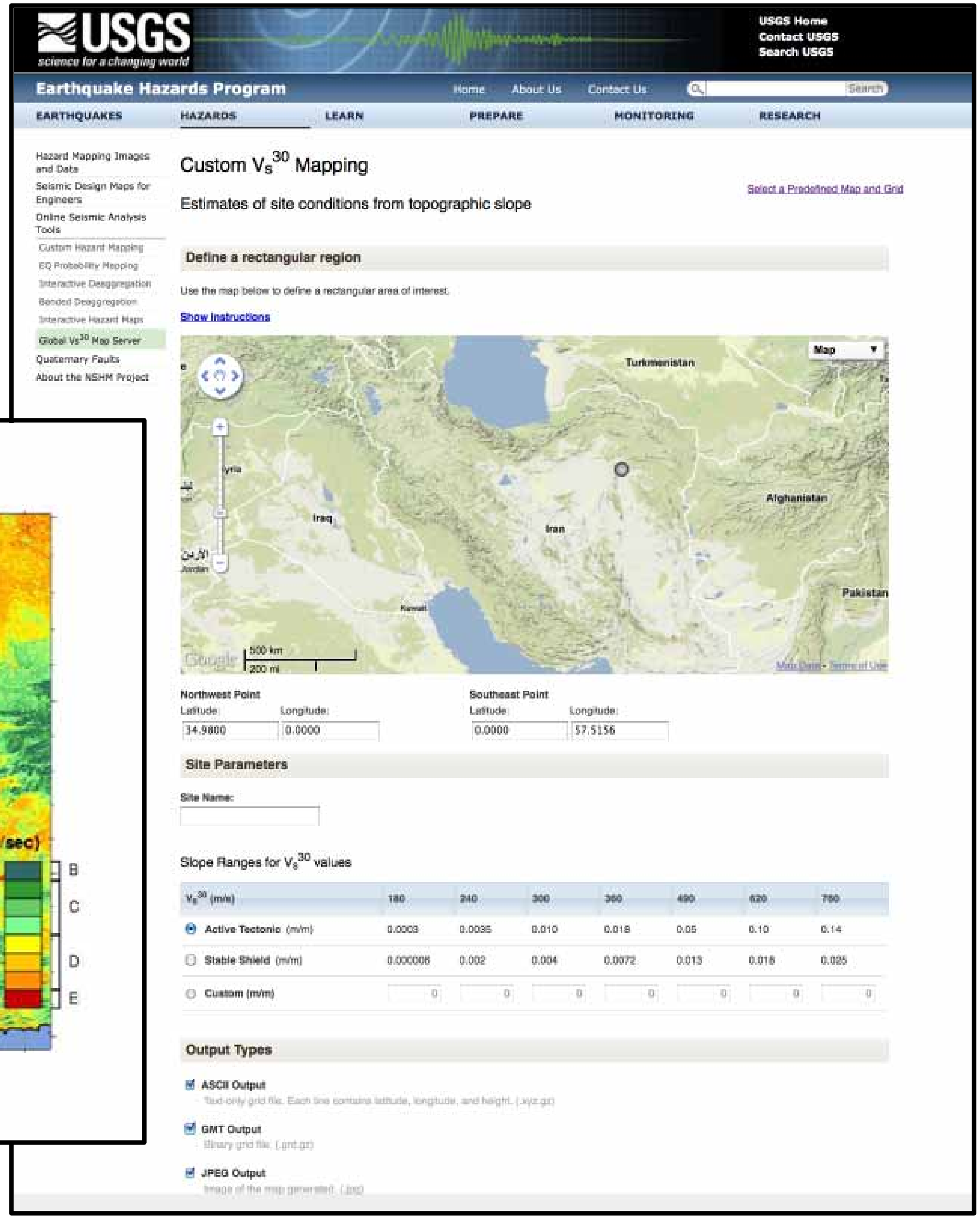
... the world, information about surficial geology and shear-wave velocity (V_S) either does not exist, varies dramatically in quality, varies spatially, or is not easily accessible. Such maps are available for only a few regions ...

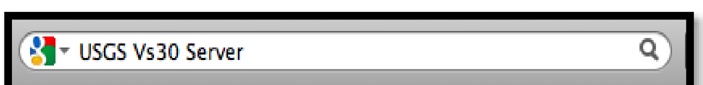
USGS Global Vs30 Server

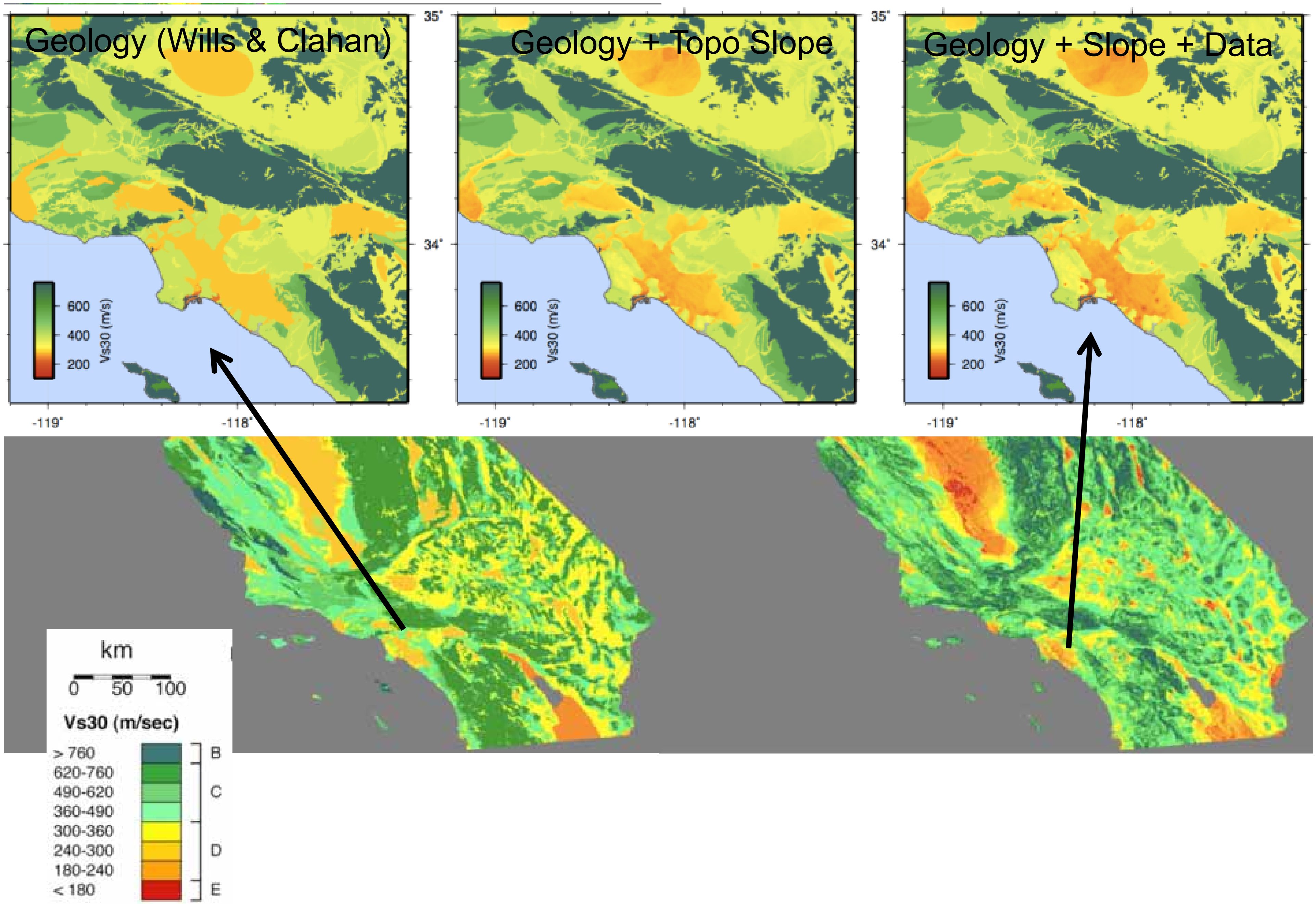
(Vs30 proxy from topographic slope)

Iran – Vs30 from slope









From Thompson & Wald

SLAB1.0 - Depth to subduction interfaces around the globe

Gavin Hayes & David Wald (USGS, Golden)

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- Earthquake Catalogs - Lists
- Earthquake Catalogs - Searchable
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- Regional Data

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External Research Support

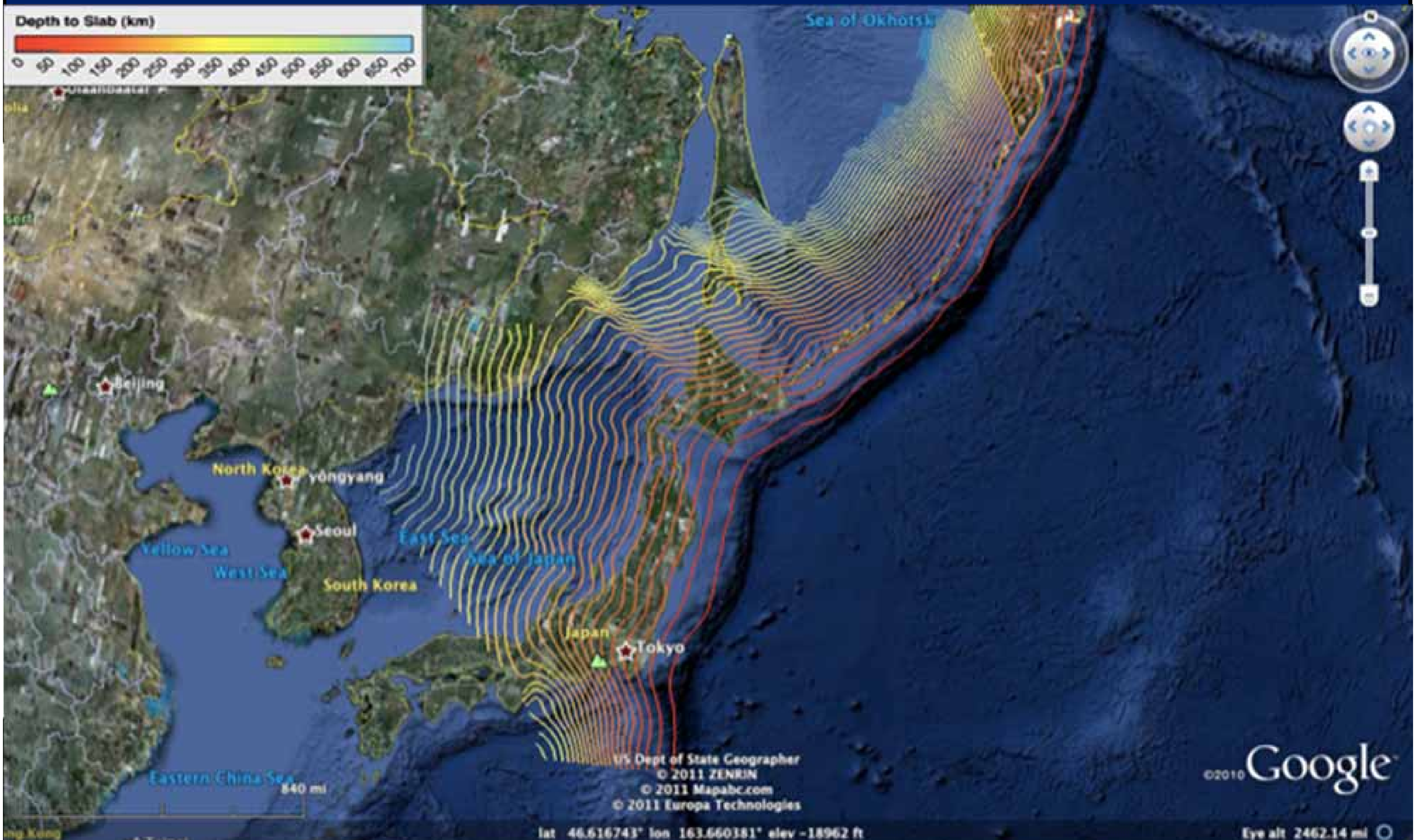
Slab Models for Subduction Zones

Models | Maps | References | Individual Events

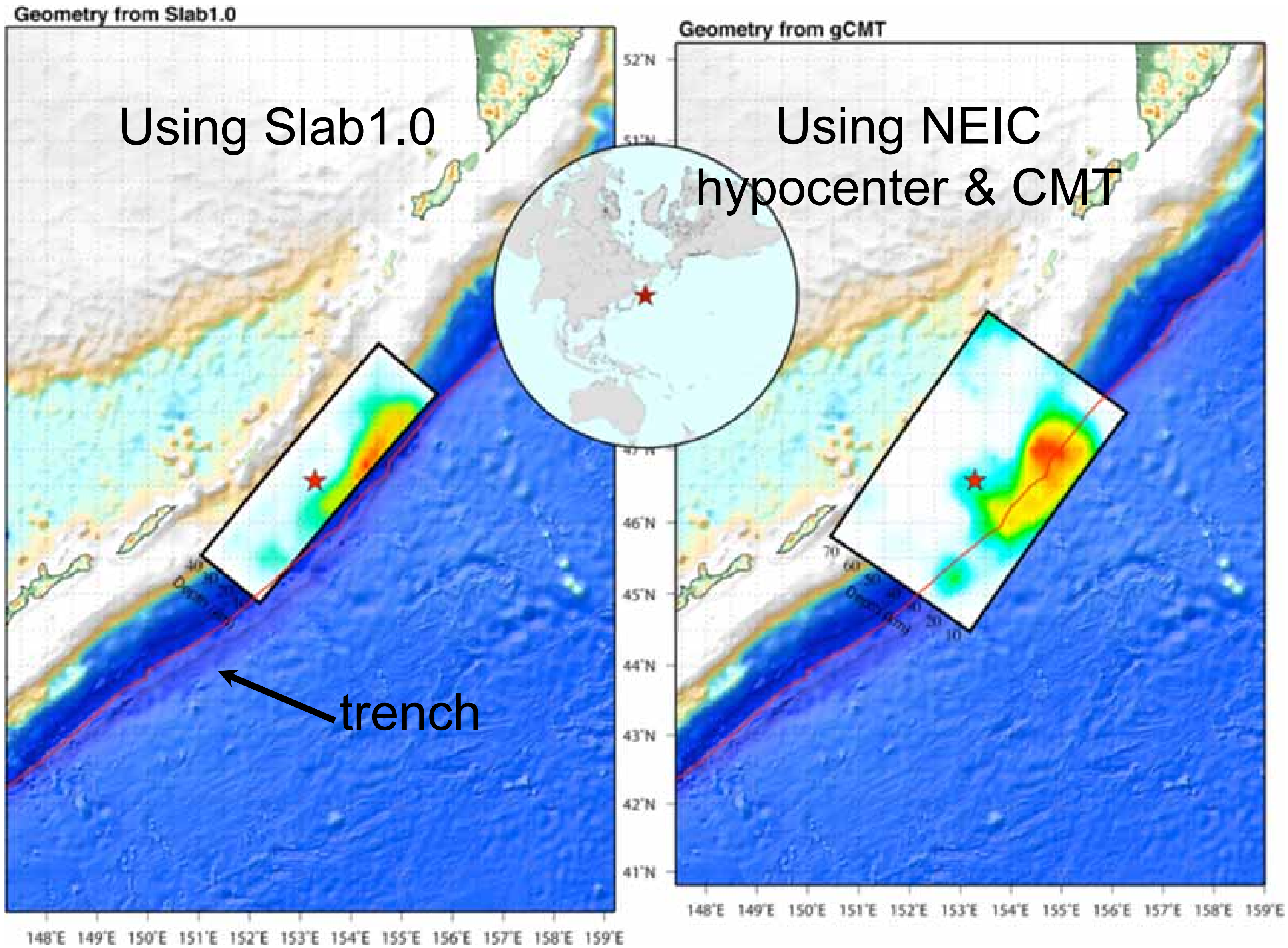
Slab1.0 is a three-dimensional compilation of global subduction geometries, separated into regional models for each major subduction zone. Each model is based on a probabilistic non-linear fit to data from a combined catalog consisting of several independent data sets - historic earthquake catalogs, CMT solutions, active seismic profiles, global plate boundaries, bathymetry and sediment thickness information.

Show More Information

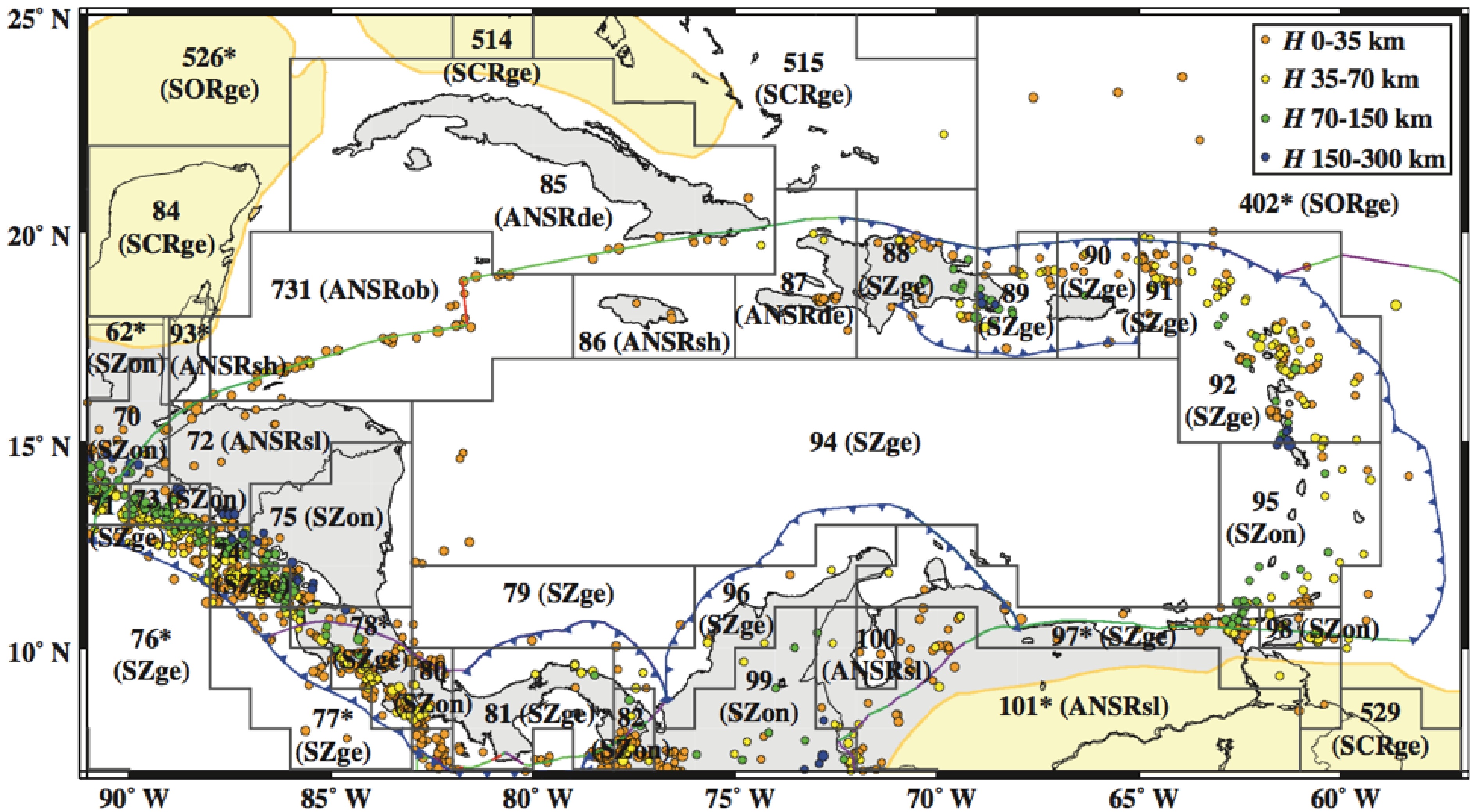
Region	Depth Grid	Strike Grid	Dip Grid	Contours	Model Limits
Alaska-Aleutians  See detailed figure [JPEG] [PDF - 7 MB]	Last Updated: November 5, 2009				
	NetCDF - 5 MB alu_slab1.0_clip.grd [1]	NetCDF - 5 MB alu_slab1.0_strclip.grd [1]	NetCDF - 5 MB alu_slab1.0_dipclip.grd [1]	ASCII - 426 KB alu_contours.in [3]	Perimeter - 12 KB alu_slab1.0.clip [4]
	ASCII - 22 MB alu_slab1.0_clip.xyz [2]	ASCII - 22 MB alu_slab1.0_strclip.xyz [2]	ASCII - 22 MB alu_slab1.0_dipclip.xyz [2]	ArcGIS Shapefile - 94 KB alu_slab.zip [6]	Top - 8 KB alu_top.in [5]
					Base - 8 KB alu_base.in [5]
Central America  See detailed figure [JPEG] [PDF - 7.7 MB]	Last Updated: November 20, 2009				
	NetCDF - 7.9 MB mex_slab1.0_clip.grd [1]	NetCDF - 3.5 MB mex_slab1.0_strclip.grd [1]	NetCDF - 3.5 MB mex_slab1.0_dipclip.grd [1]	ASCII - 225 KB mex_contours.in [3]	Perimeter - 8 KB mex_slab1.0.clip [4]
	ASCII - 26 MB mex_slab1.0_clip.xyz [2]	ASCII - 15 MB mex_slab1.0_strclip.xyz [2]	ASCII - 15 MB mex_slab1.0_dipclip.xyz [2]	ArcGIS Shapefile - 53 KB mex_slab.zip [6]	Top - 8 KB mex_top.in [5]
					Base - 8 KB mex_base.in [5]


Depth to Slab (km)
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
Sea of Okhotsk
Beijing
North Korea
Pyongyang
Seoul
Yellow Sea
West Sea
South Korea
East Sea
Sea of Japan
Japan
Tokyo
Eastern China Sea
840 mi
US Dept of State Geographer
© 2011 ZENRIN
© 2011 Mapabc.com
© 2011 Europa Technologies
©2010 Google
lat 46.616743° lon 163.660381° elev -18962 ft
Eye alt 2462.14 mi

Geometry Matters (for fast-finite-faults)!
Kuril Islands EQ, M8.3, 11/2006



Automatic Global GMPE Selector



Daniel Garcia, USGS

Bulletin of the Seismological Society of America, Vol. 102, No. 1, pp. –, February 2012, doi: 10.1785/0120110124

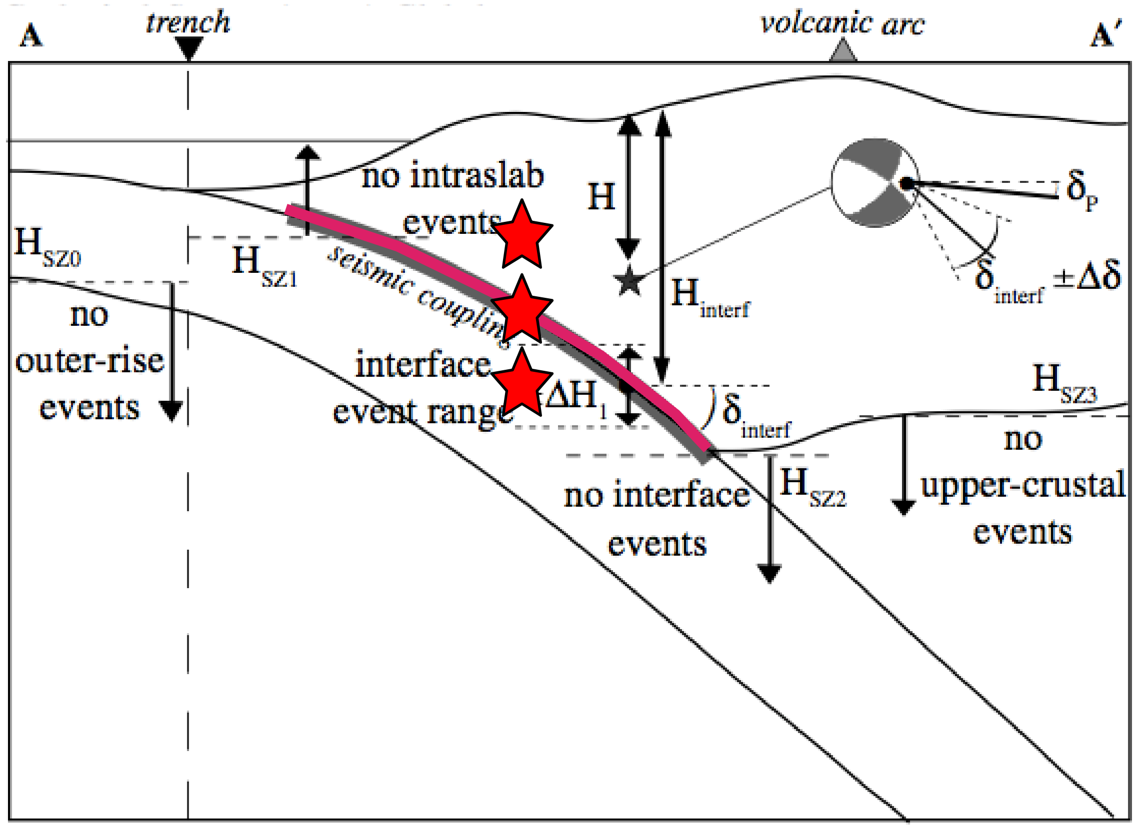
A Global Earthquake Discrimination Scheme to Optimize Ground-Motion Prediction Equation Selection

by D. García, D. J. Wald, and M. G. Hearne

Hayes' Slab1.0

Abstract We present a new automatic earthquake discrimination procedure to determine in near-real time the tectonic regime and seismotectonic domain of an earthquake, its most likely source type, and the corresponding ground-motion prediction equation (GMPE) class to be used in the U.S.
ShakeMap system. This method makes use o
scheme, seismotectonic information (plate bounc
alogs, and regional and local studies), and the s
USGS National Earthquake Information Center in
to give the best estimation of the setting and me
the tectonic setting, additional criteria based on
and regional seismicity may be applied. For sub
the use of focal mechanism information and deta
among outer-rise, upper-plate, interface, and i
validated against a large database of recent histo
to assess GMPE selection in Global ShakeMap
uses for this strategy, from real-time processin
tectonic classification of sources from seismic

Online Material: Tables and figures summ
scheme and its performance.



Logistic Regression:

- Allows categorical or continuous independent variables (X_i),
- The logistic regression has the advantage of being less affected when the basic assumption of normality of the variables is not met,
- Logistic regression is included in a category of statistical models called generalized linear models, which employs the use of independent variables to create a mathematical model that predicts the probability of an event occurrence in a certain area,
- The key to logistic regression is that the dependent variable is generally dichotomous, i.e., it can take only the value 1 or 0, representing the presence/absence of landslides or liquefaction,
- The independent variables in this model are predictors of the dependent variable, and can be measured in a nominal, ordinal, interval, or ratio manner.

$$\text{Logit}(p(Y = 1)) = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3, \qquad (1)$$

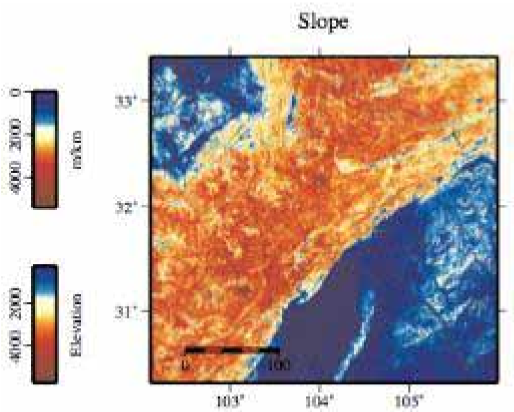
where p is the probability that the dependent variable (Y) is 1, and β_1, β_2, β_3 are coefficients which measure the contribution of independent variables $(X_i, X_2, \ldots, X_n)$ to the variations in Y.

Candidate Explanatory Variables
(Global Application)

Landslide

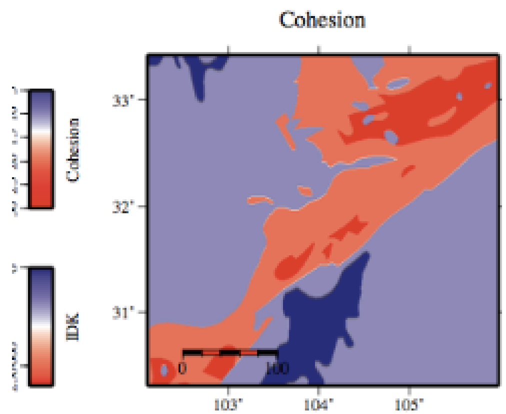
Static Strength

Slope (from Topog.)



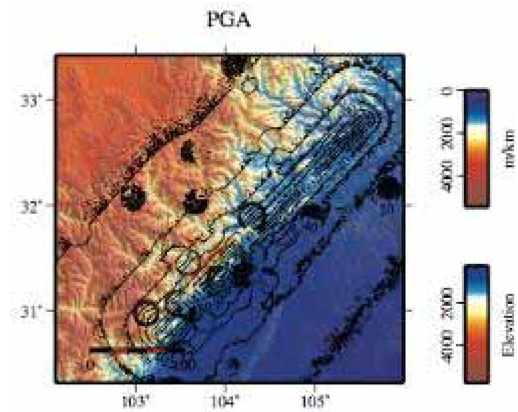
Susceptibility

[Lithology, Geology]



Peak Acceleration (PGA)

ShakeMap



Liquefaction

Soil Strength

Vs30 (from slope)

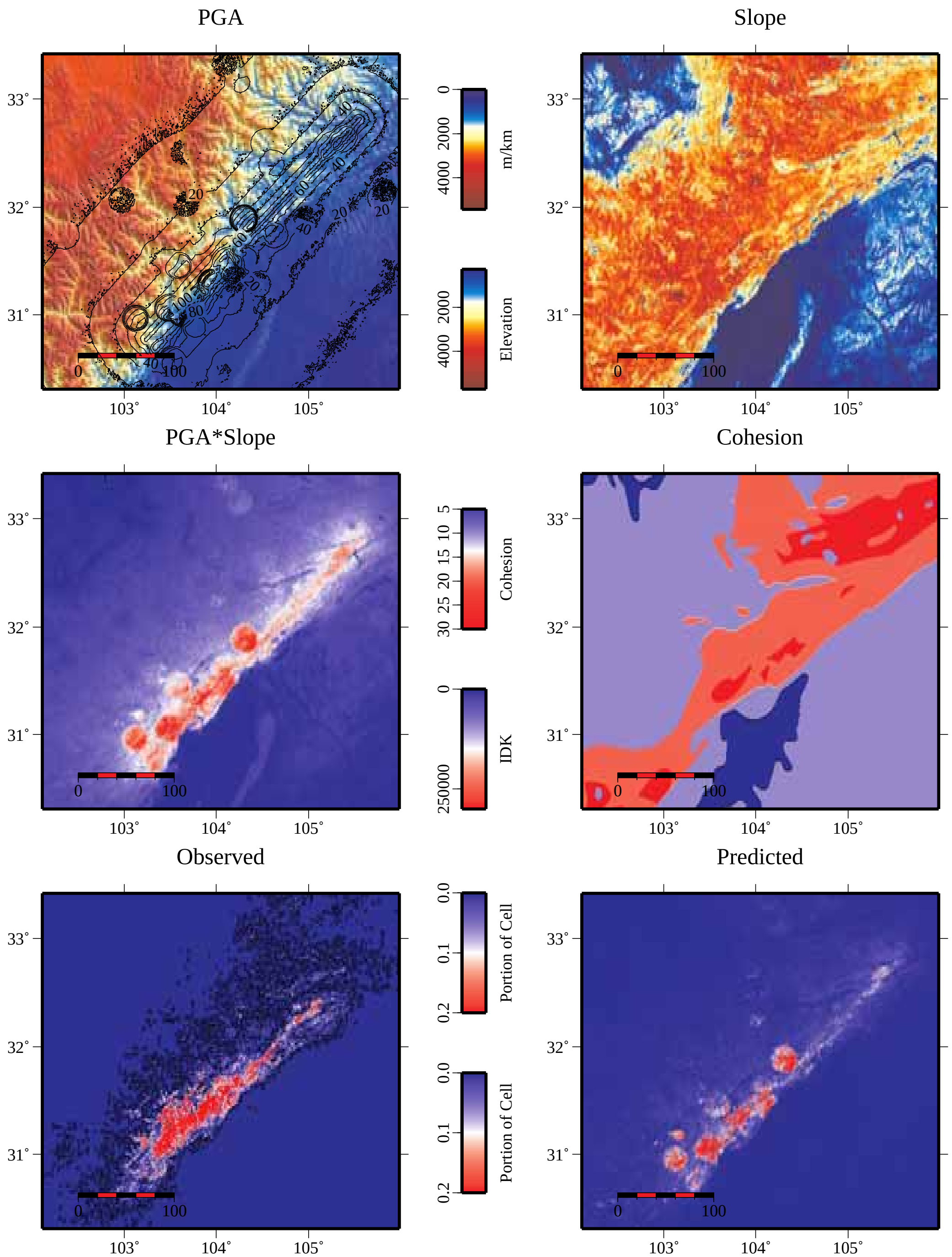
Susceptibility

[“Wetness Index” Compound Topographic Index (CTI)

Distance to Waterbody]

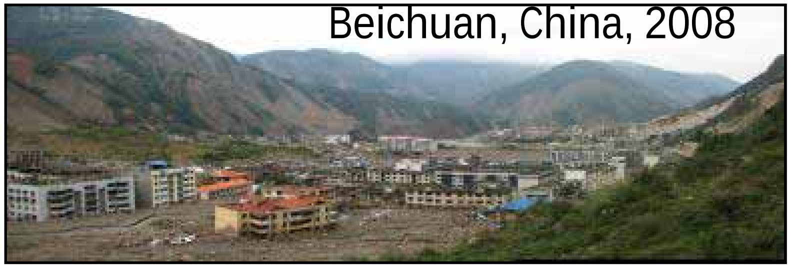
Peak Acceleration (PGA)

ShakeMap

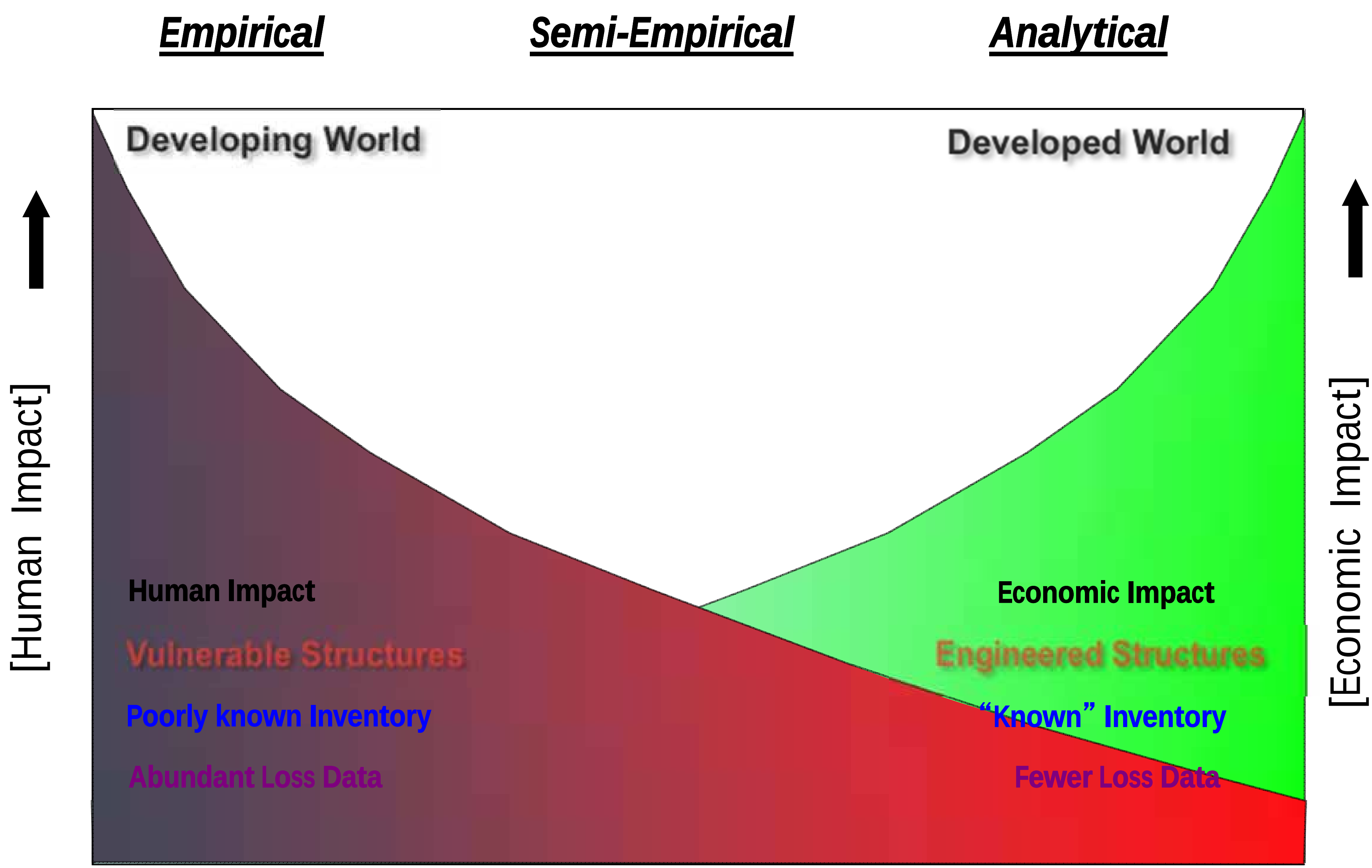


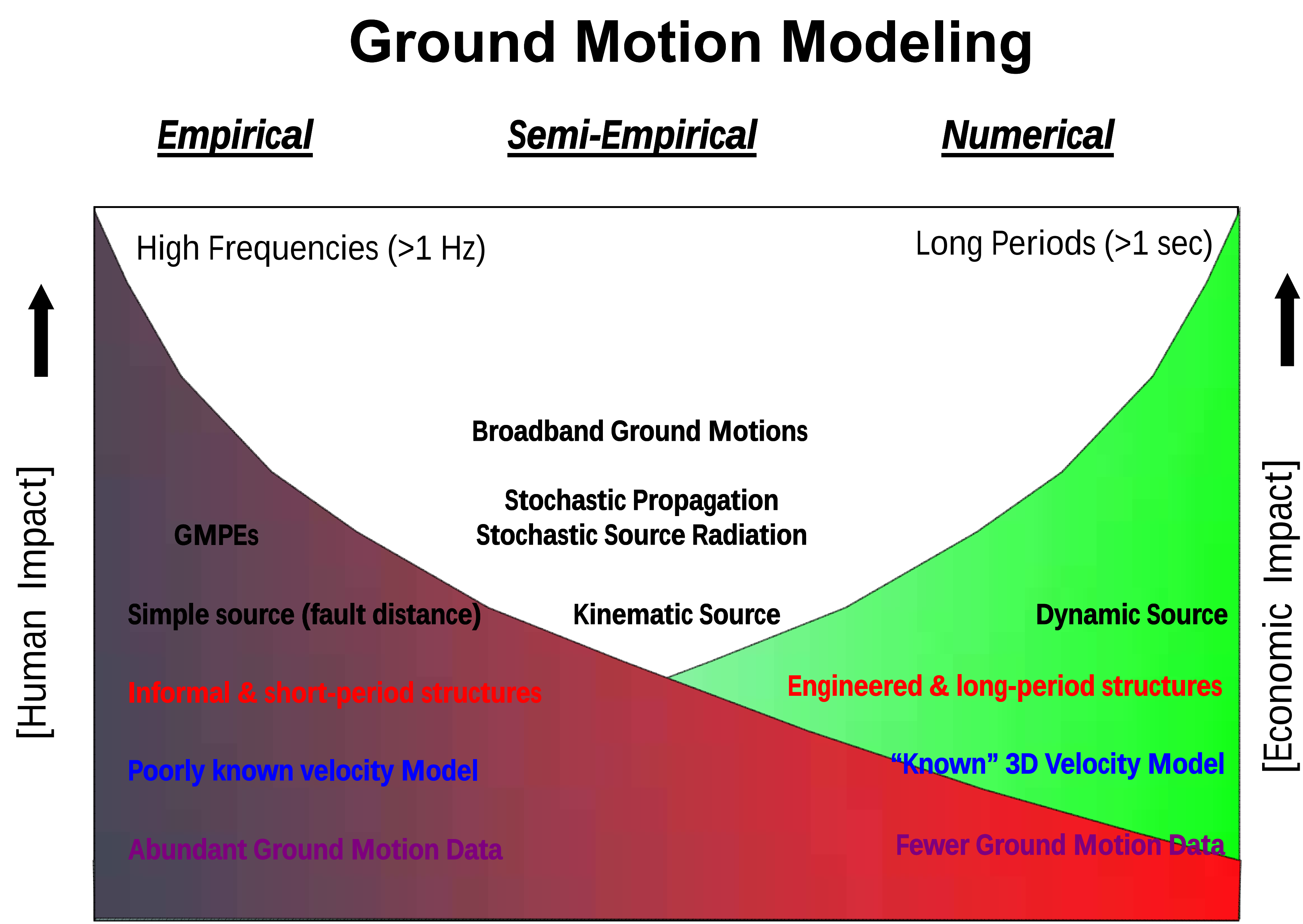
$$\mathrm{Logit}(p) = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3$$

where p is the probability that the dependent variable (Y) is 1, and $\beta_1, \beta_2, \beta_3$ are coefficients which measure the contribution of independent variables $(X_i, X_2, \ldots, X_n)$ to the variations in Y.



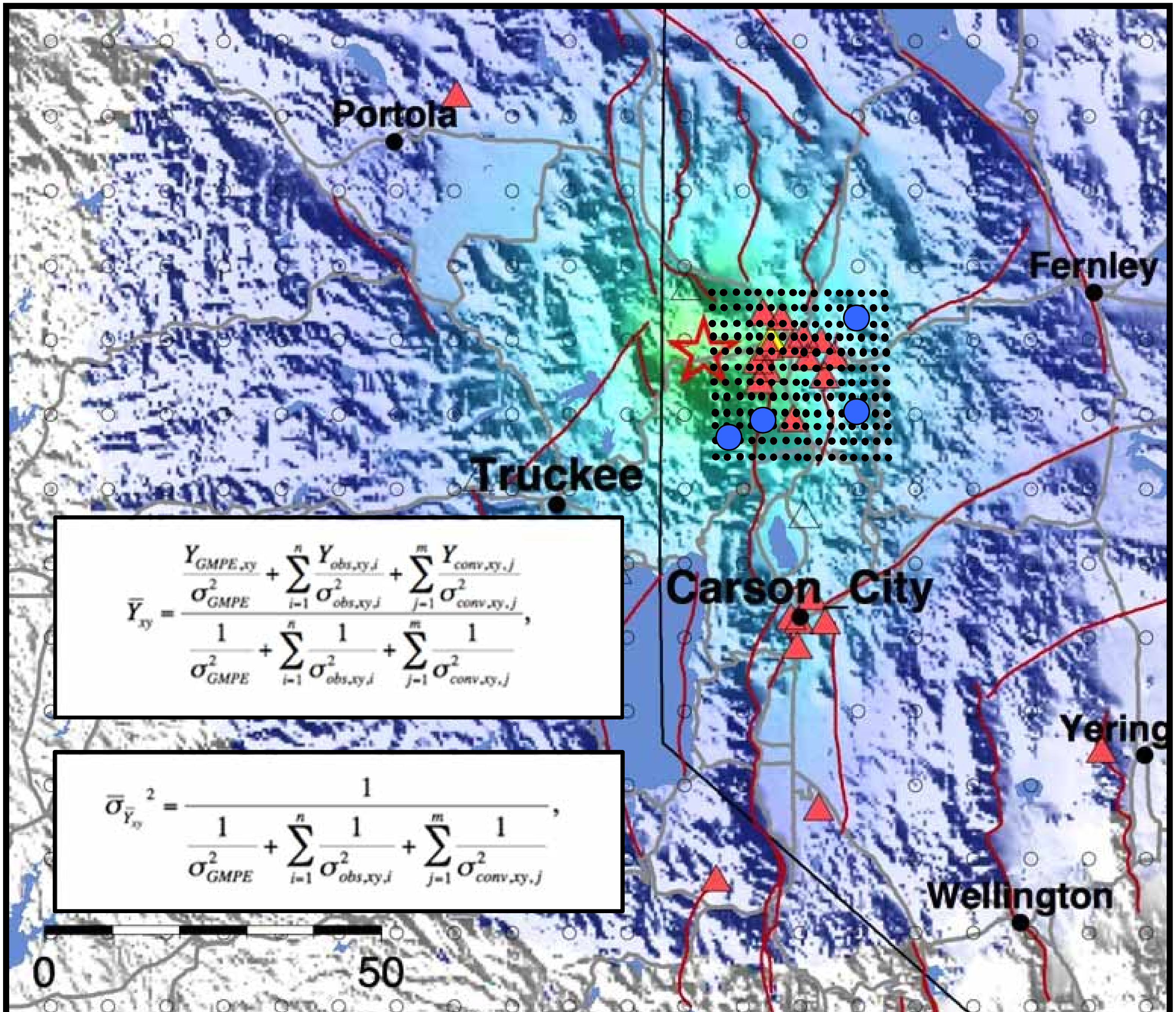
Why 3 Loss Approaches?




Ground Motion Modeling
Empirical
Semi-Empirical
Numerical
High Frequencies (>1 Hz)
Long Periods (>1 sec)
[Human Impact]
[Economic Impact]
Broadband Ground Motions
Stochastic Propagation
Stochastic Source Radiation
GMPEs
Simple source (fault distance)
Kinematic Source
Dynamic Source
Informal & short-period structures
Engineered & long-period structures
Poorly known velocity Model
"Known" 3D Velocity Model
Abundant Ground Motion Data
Fewer Ground Motion Data

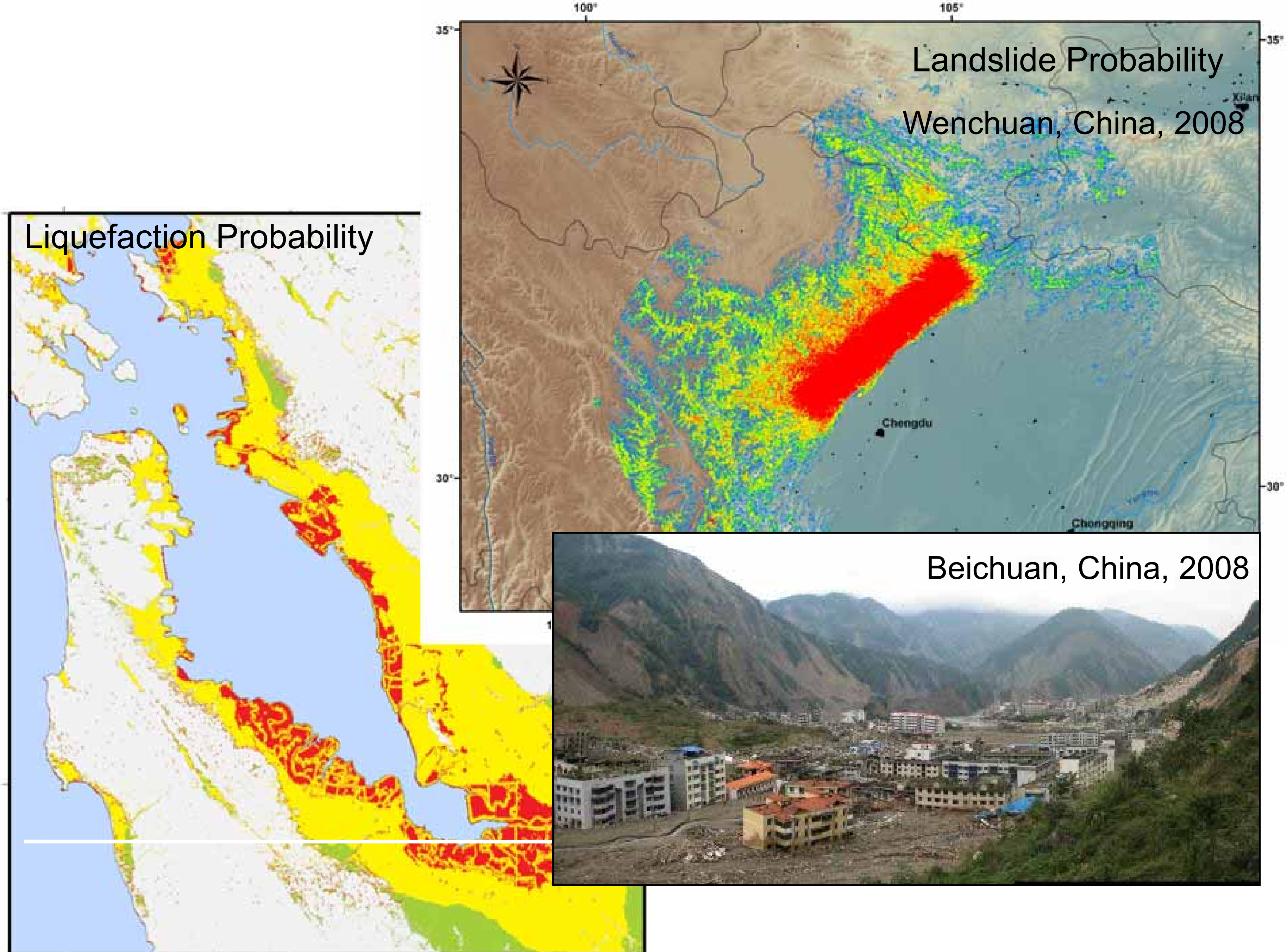
ShakeMap V3.5

- Intensity Observation
- Strong Motion Station
- Grid & Estimate Point (GMPE)



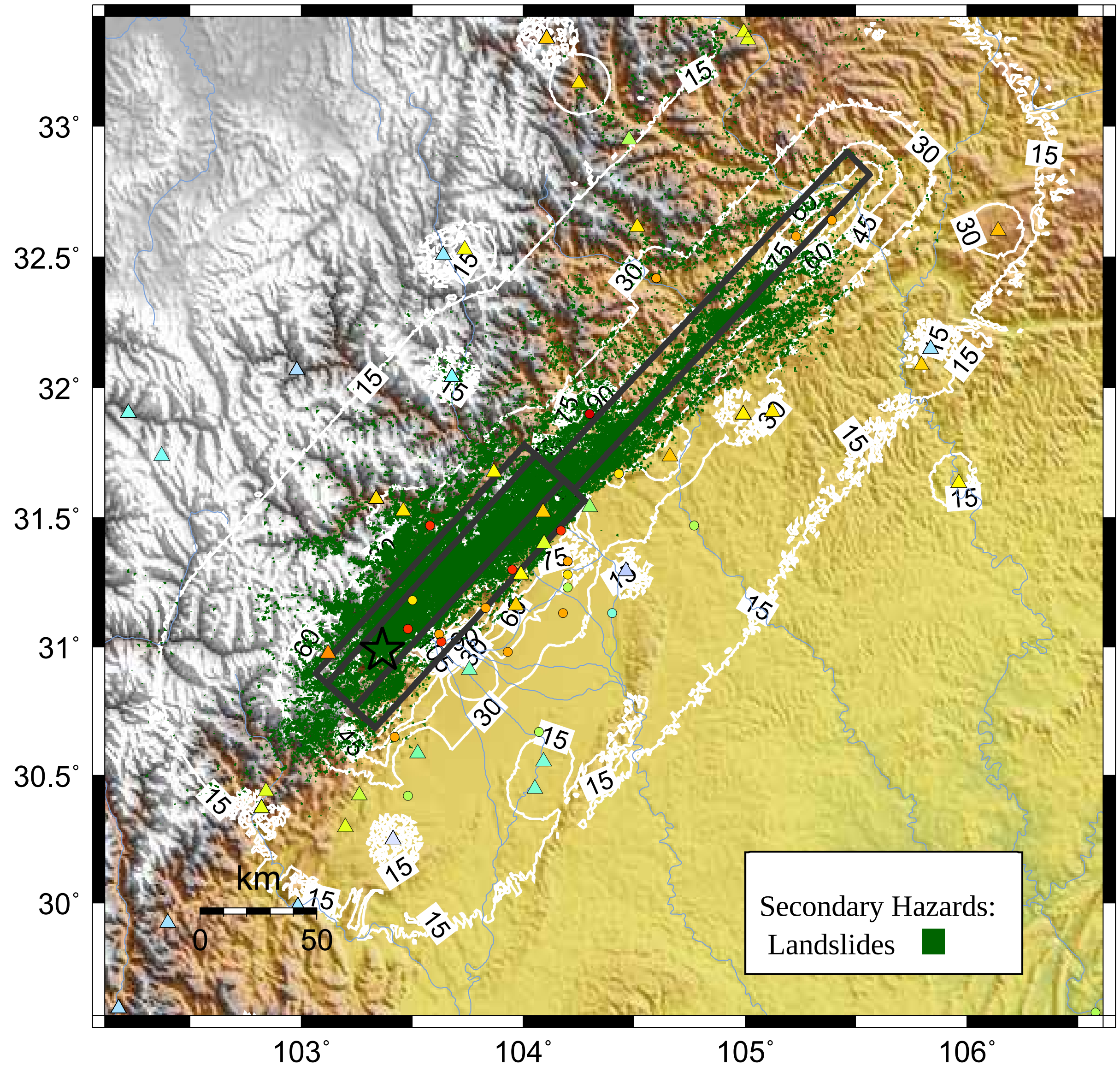
$$\bar{Y}_{xy} = \frac{\frac{Y_{GMPE,xy}}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{Y_{obs,xy,i}}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{Y_{conv,xy,j}}{\sigma^2_{conv,xy,j}}}{\frac{1}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{1}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{1}{\sigma^2_{conv,xy,j}}},$$

$$\bar{\sigma}_{\bar{Y}_{xy}}{}^2 = \frac{1}{\frac{1}{\sigma^2_{GMPE}} + \sum_{i=1}^{n}\frac{1}{\sigma^2_{obs,xy,i}} + \sum_{j=1}^{m}\frac{1}{\sigma^2_{conv,xy,j}}},$$


Liquefaction Probability
Landslide Probability
Wenchuan, China, 2008
100°
105°
35°
30°
Chengdu
Chongqing
Beichuan, China, 2008

USGS Peak Accel. Map (in %g) : Wenchuan, China

MAY 12 2008 06:28:01 AM GMT M 7.9 N30.99 E103.36 Depth: 19.0km ID:200805120628



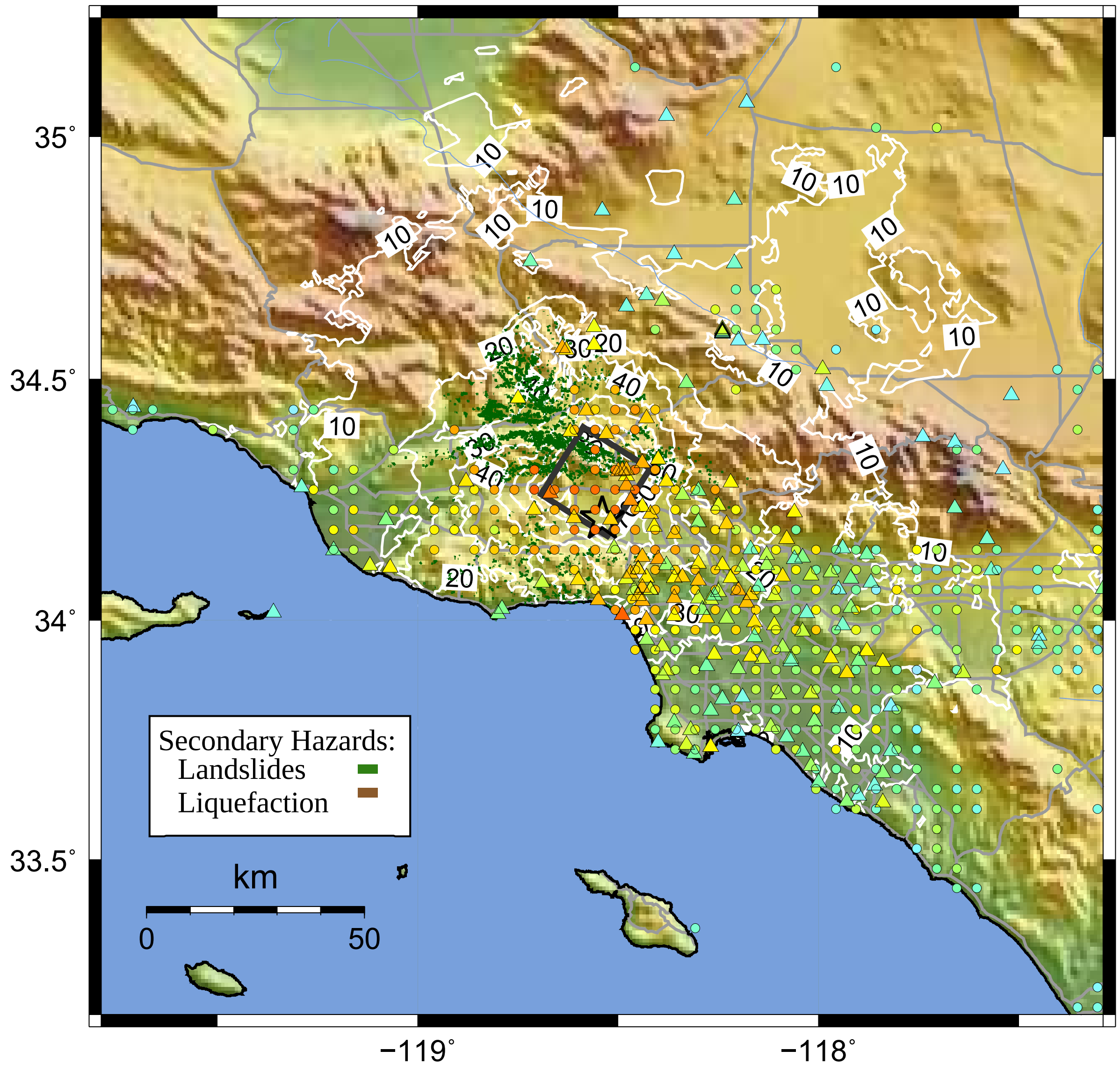
Map Version 1 Processed Mon Jun 18, 2012 02:31:03 PM MDT

PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2011)

USGS Peak Accel. Map (in %g) : Northridge, California

JAN 17 1994 12:30:55 AM GMT M 6.7 N34.21 W118.54 Depth: 19.0km ID:199401171230

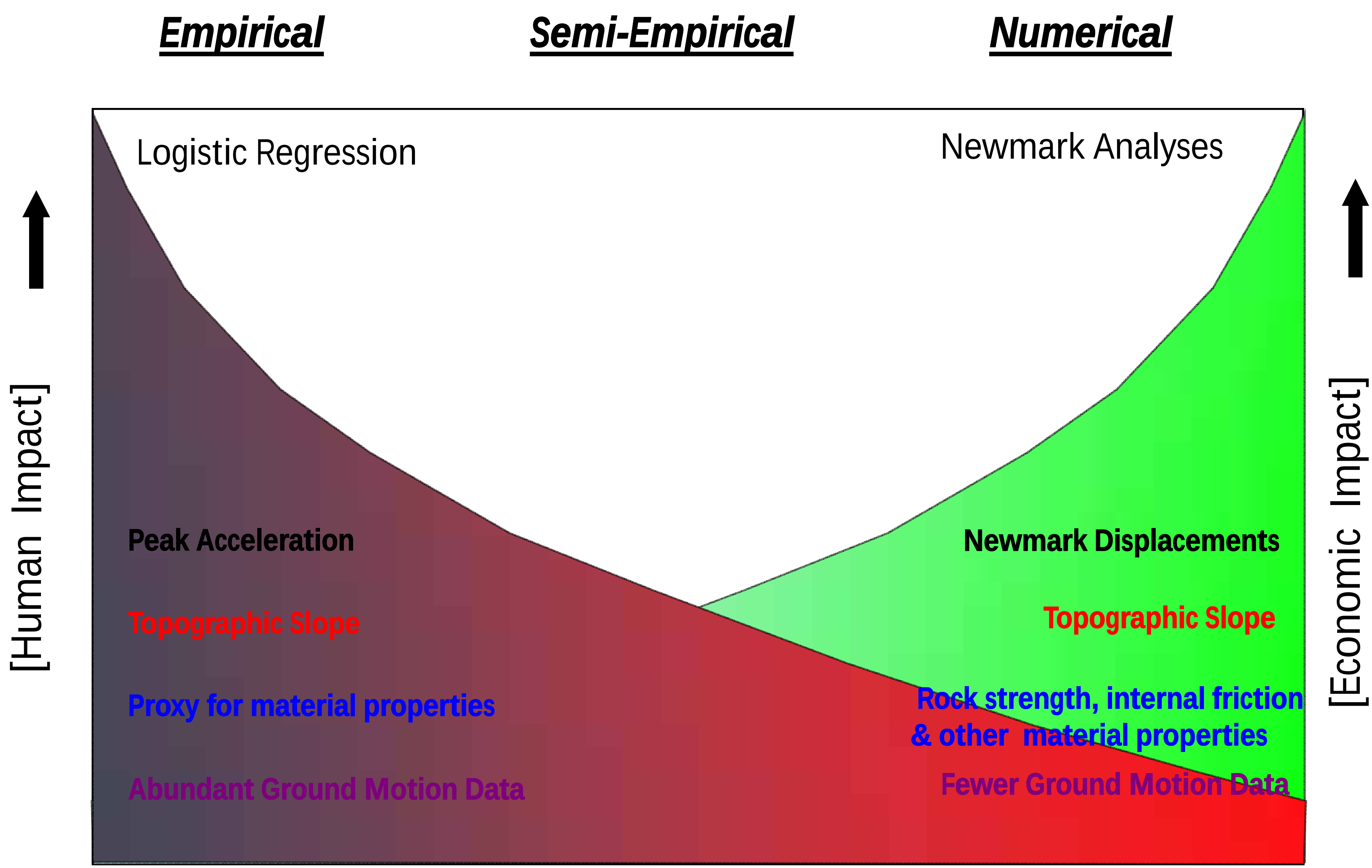


Map Version 1 Processed Fri Jun 15, 2012 02:39:00 PM MDT

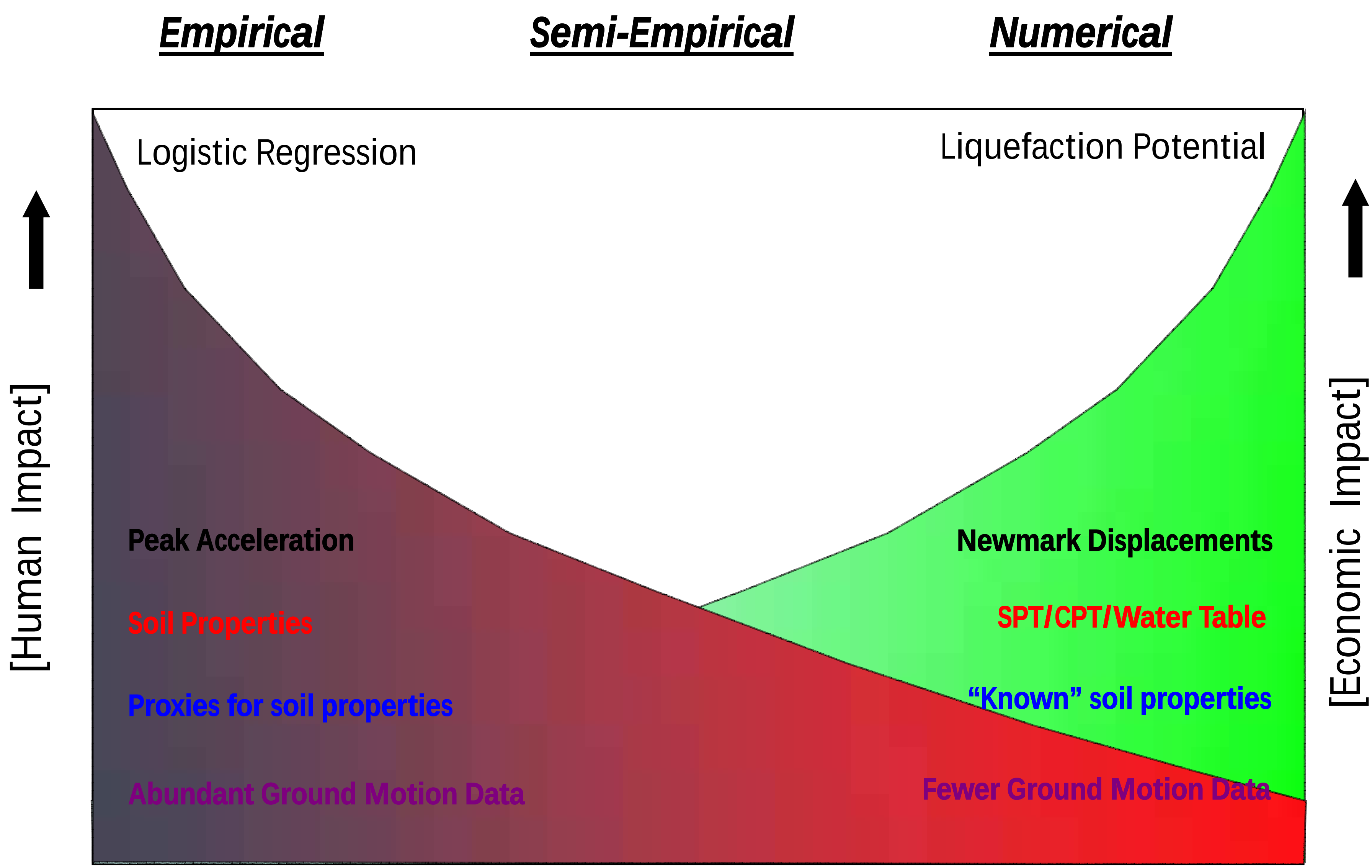
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
INSTRUMENTAL INTENSITY	I	II−III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2011)

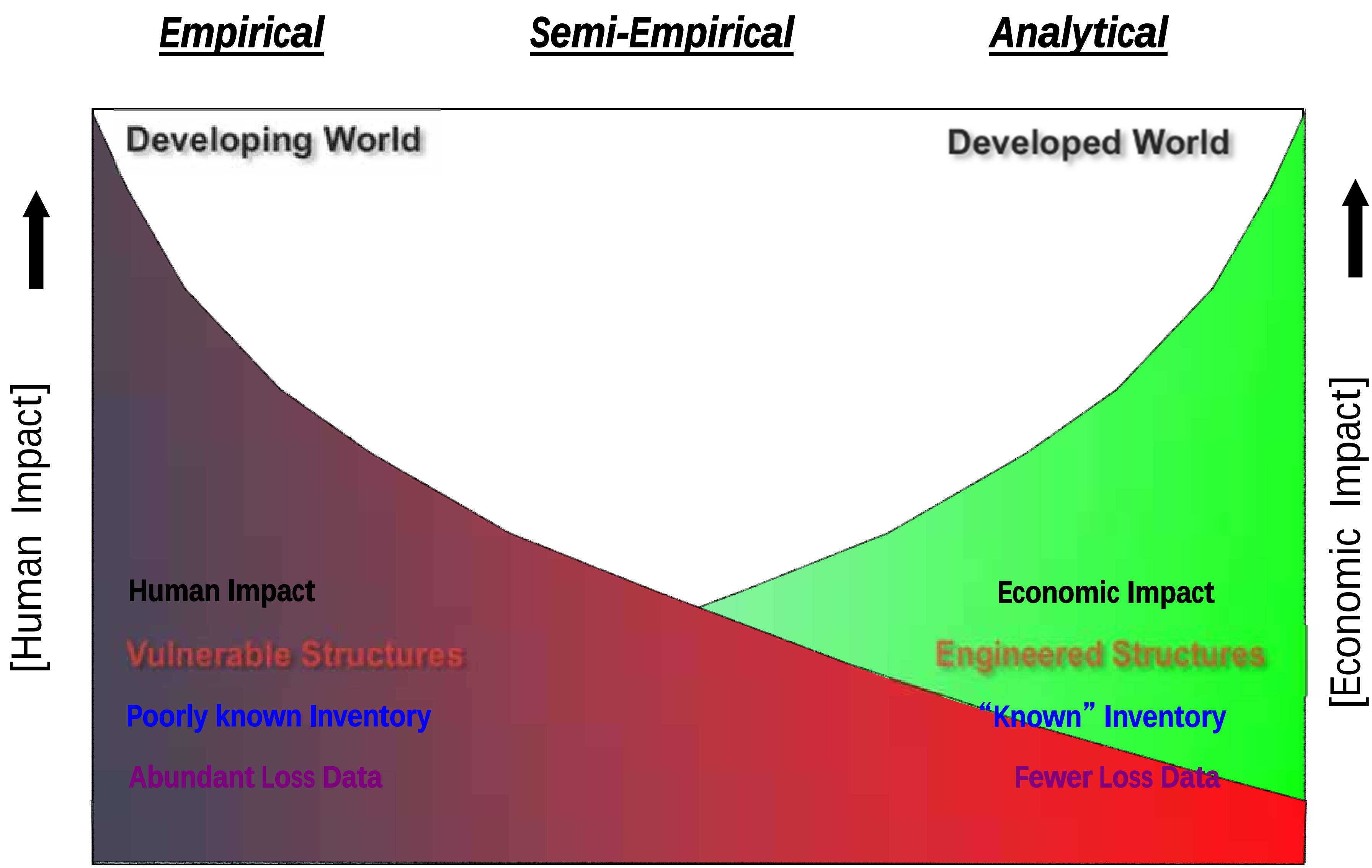
Estimating Secondary Hazards: Landslides



Estimating Secondary Hazards: Liquefaction



Why 3 Loss Approaches?



Acknowledgments

Collaborators

PAGER (USGS)

Kishor Jaiswal
Mike Hearne
Kristin Marano
David Wald

ShakeMap

Bruce Worden USGS
Kuo-wan Lin USGS
Daniel Garcia, USGS
Kendra Johnson, USGS & CSM
Russell Mah, USGS & CSM

Structural Engineering

Nico Luco, USGS
Keith Porter, CU Boulder
Emily So, Cambridge Univ
Robin Spence, Cambridge
Dina D'Ayala, Univ Bath

Buildings/Loss Modeling

EERI/WHE
Douglas Bausch, FEMA

Secondary Hazards & Geotech Eng.

Eric Thompson, Tufts
Anna Nowicki, Indiana Univ
Jon Godt, USGS
Ed Harp, USGS
Keith Knudsen, USGS

Thank You

http://earthquake.usgs.gov/pager/