ShakeMap & Related Products:
Challenges in Real-time Shaking & Loss Estimation

David Wald
(for B. Worden, K. Lin, G. Hayes,…)

U.S. Geological Survey
National Earthquake Information Center
Golden, Colorado

Workshop on
National Geophysical Networks in Latin America
Universidad de Chile, Santiago, Chile
May 25-29, 2015

USGS science for a changing world · IRIS · CSN Centro Sismológico Nacional Universidad de Chile · USAID From the American People

Global variations of “unsafe” buildings

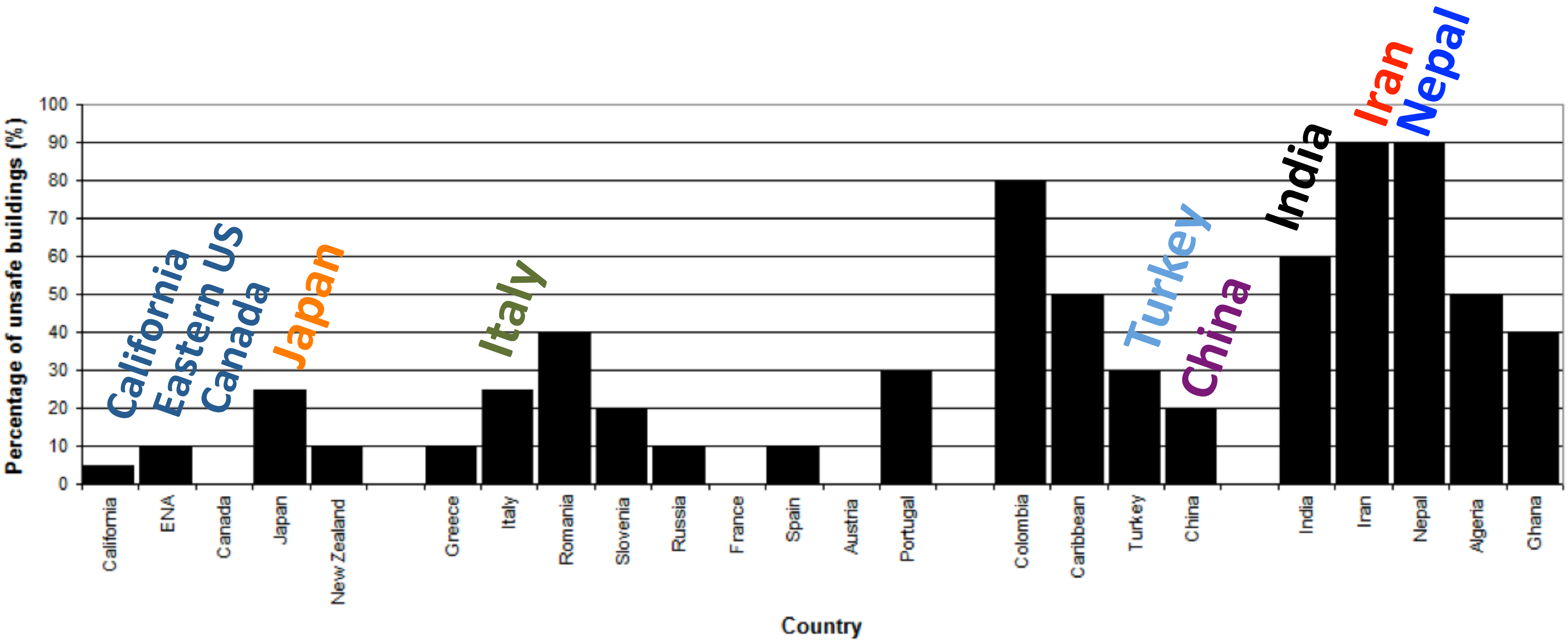
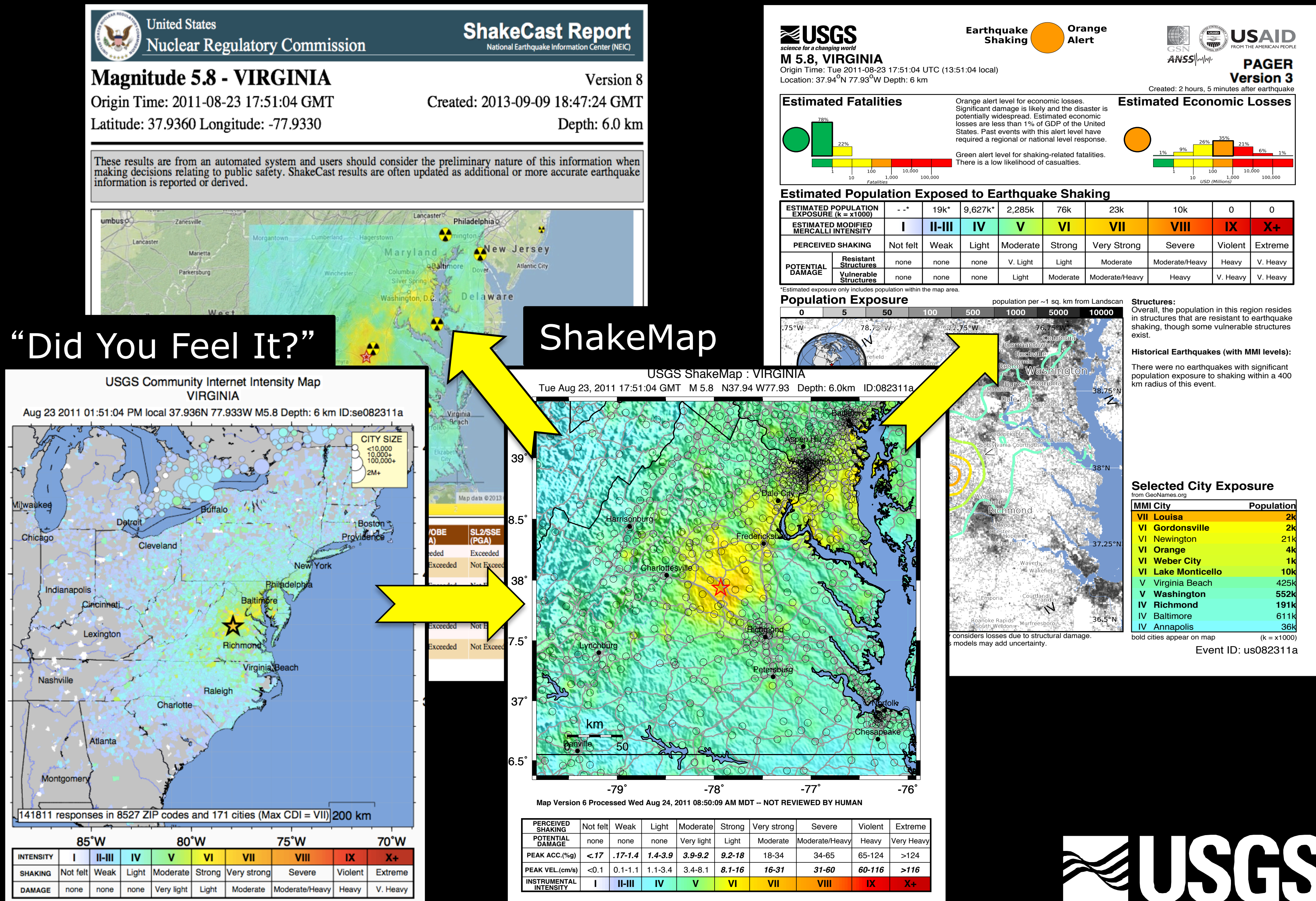


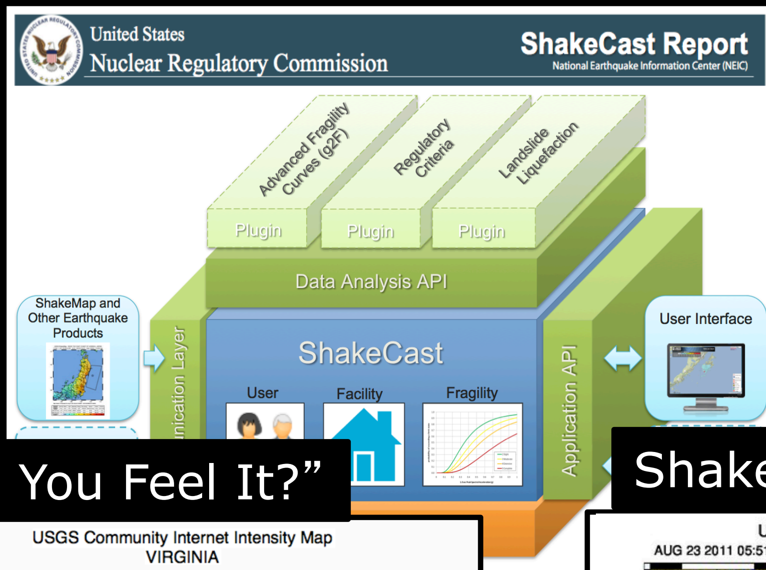
Figure 1.1 Graph summarising responses from international earthquake engineers on percentage of seismically unsafe buildings in their country (Spence, 2007b).

ShakeCast

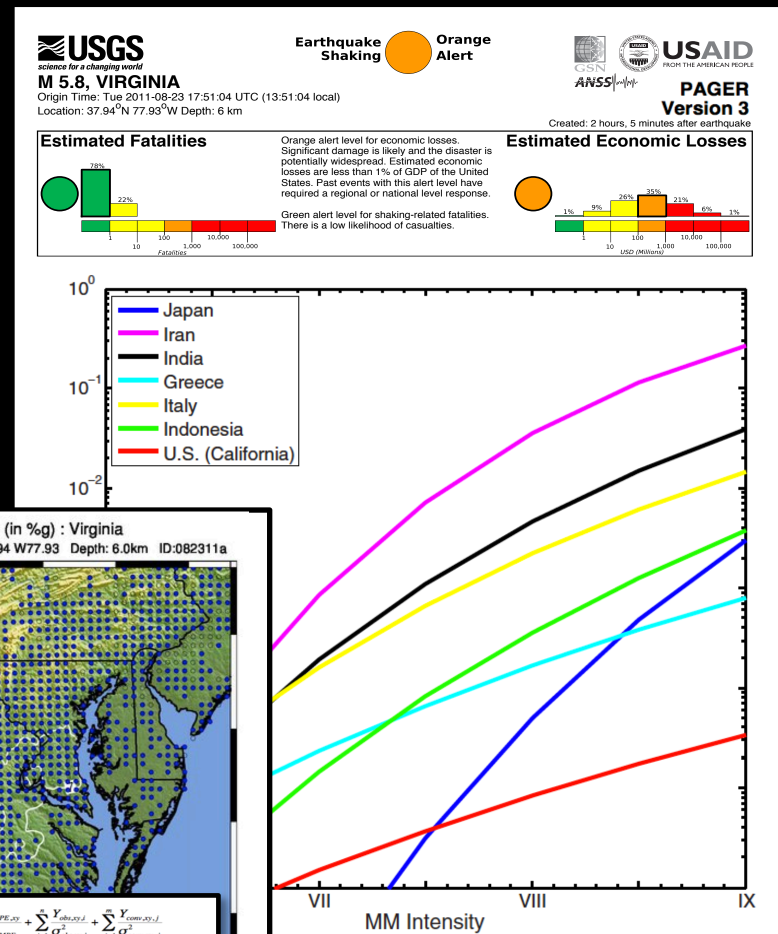
PAGER (Prompt Assessment of Global Earthquakes for Response)



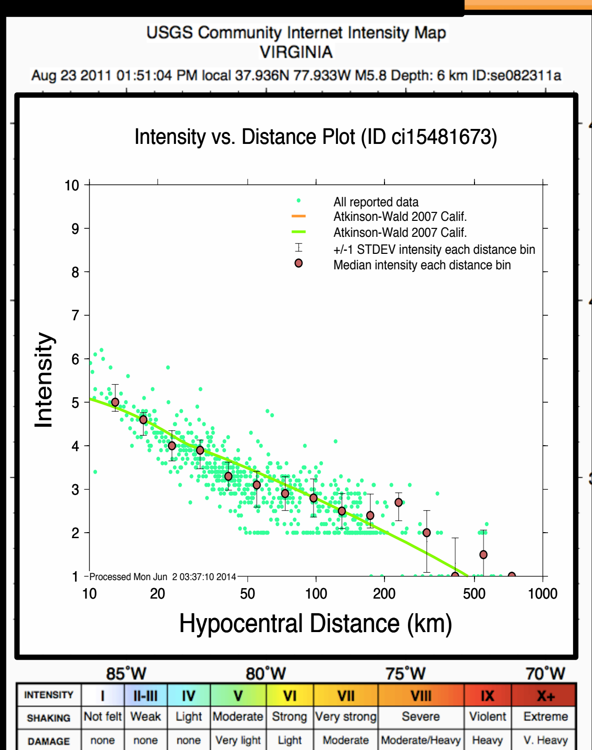
ShakeCast



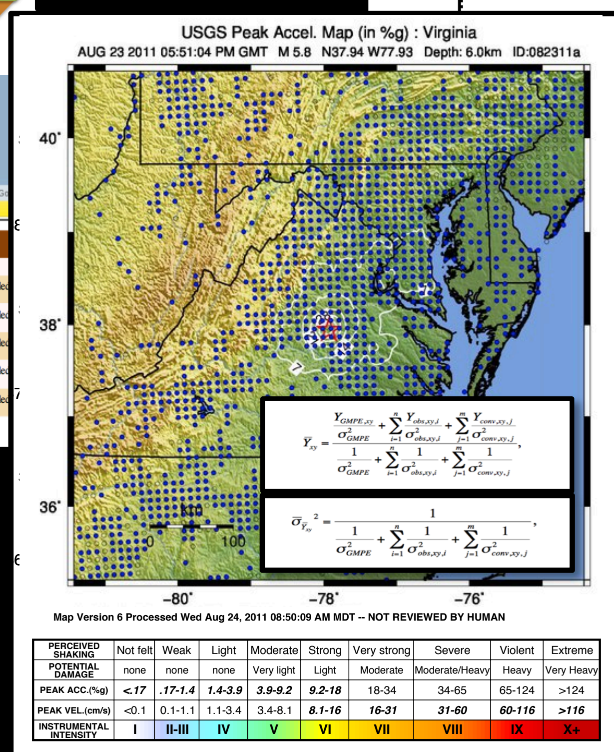
PAGER (Prompt Assessment of Global Earthquakes for Response)



"Did You Feel It?"



ShakeMap



ShakeCast

Walmart
Degenkolb
OSHPD
U.S. Fish & Wildlife Service
Caltrans
Los Angeles Department of Water & Power
The Church of Jesus Christ of Latter-Day Saints
Target
Port of Long Beach — The Green Port
IAEA.org — International Atomic Energy Agency
Travelers
East Bay Municipal Utility District

PAGER (Prompt Assessment of Global Earthquakes for Response)

Southern California Edison — An Edison International® Company
The World Bank — IBRD & IDA: Working for a World
MercyCorps — Be the change
Associated Press
USAID — From the American People
U.S. Department of State
IDB
United States Northern Command — Defending Our Homeland

“Did You Feel It?”

County of Los Angeles Public Works — Public Service That Works
Los Angeles Unified School District — Board of Education
Department of Water Resources
Sempra Energy
United States Department of Veterans Affairs

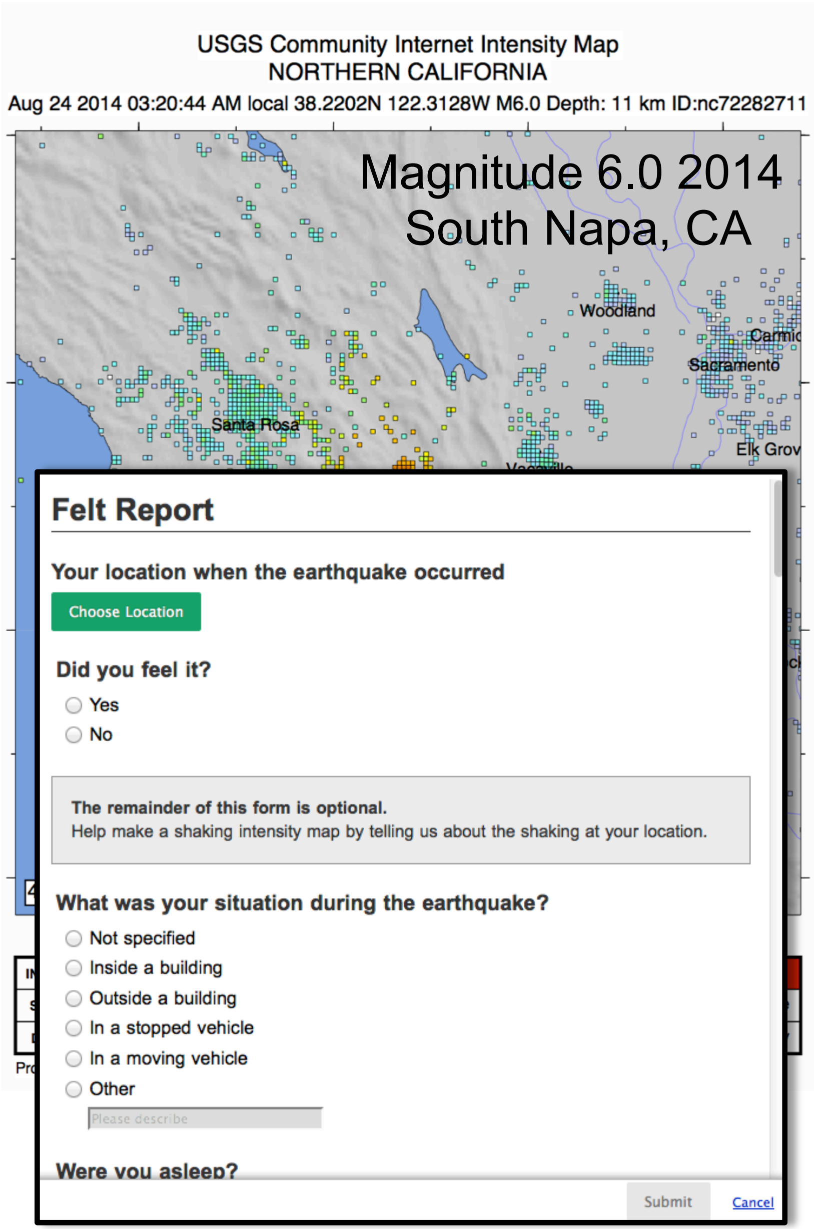
ShakeMap

Cal EMA
FEMA
UPI.com — 100 Years of Journalistic Excellence
U.S. Department of Health & Human Services
ANSS
CEA
Reuters
GeoHazards International — A Nonprofit Working Toward Global Earthquake Safety
GDACS — Global Disaster Alert & Coordination System
The White House — President George W. Bush
The Hartford
RMS
Homeland Security
Swiss Re
U.S.NRC
USGS

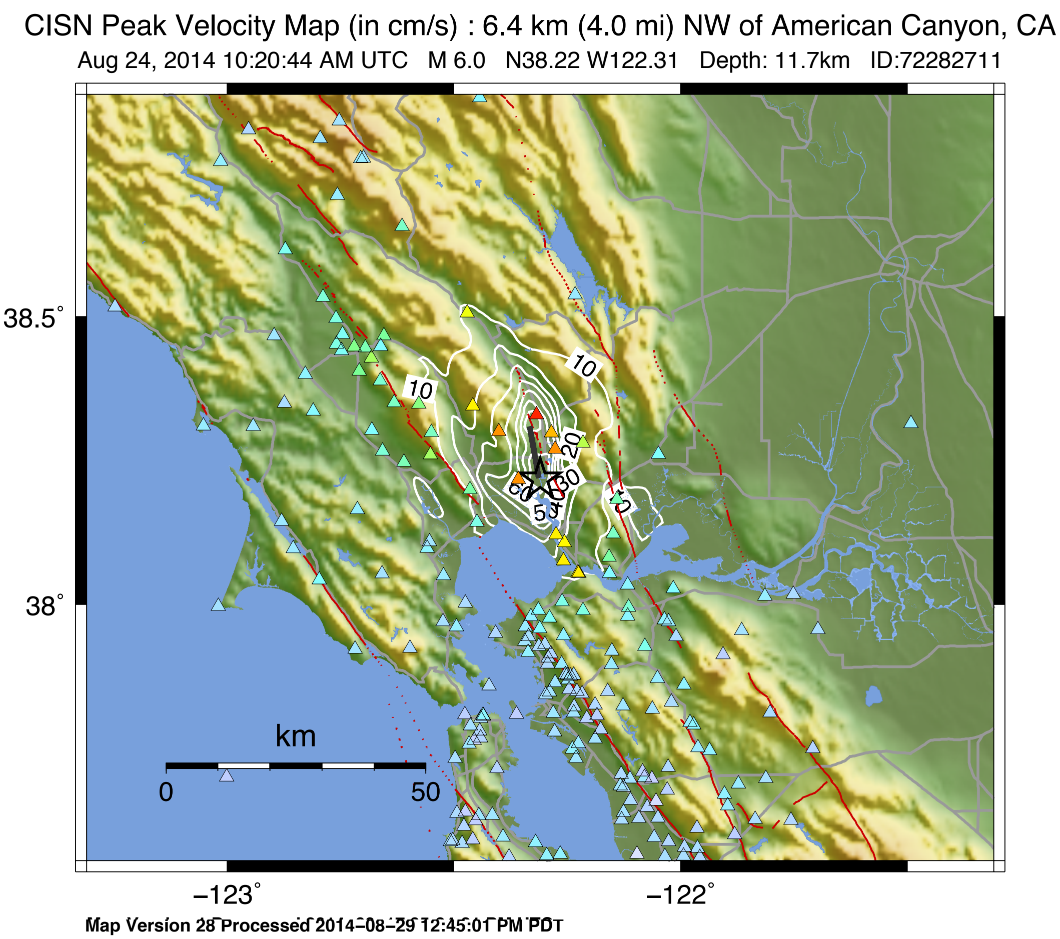
“Did You Feel It?”

ShakeMap

“Did You Feel It?”

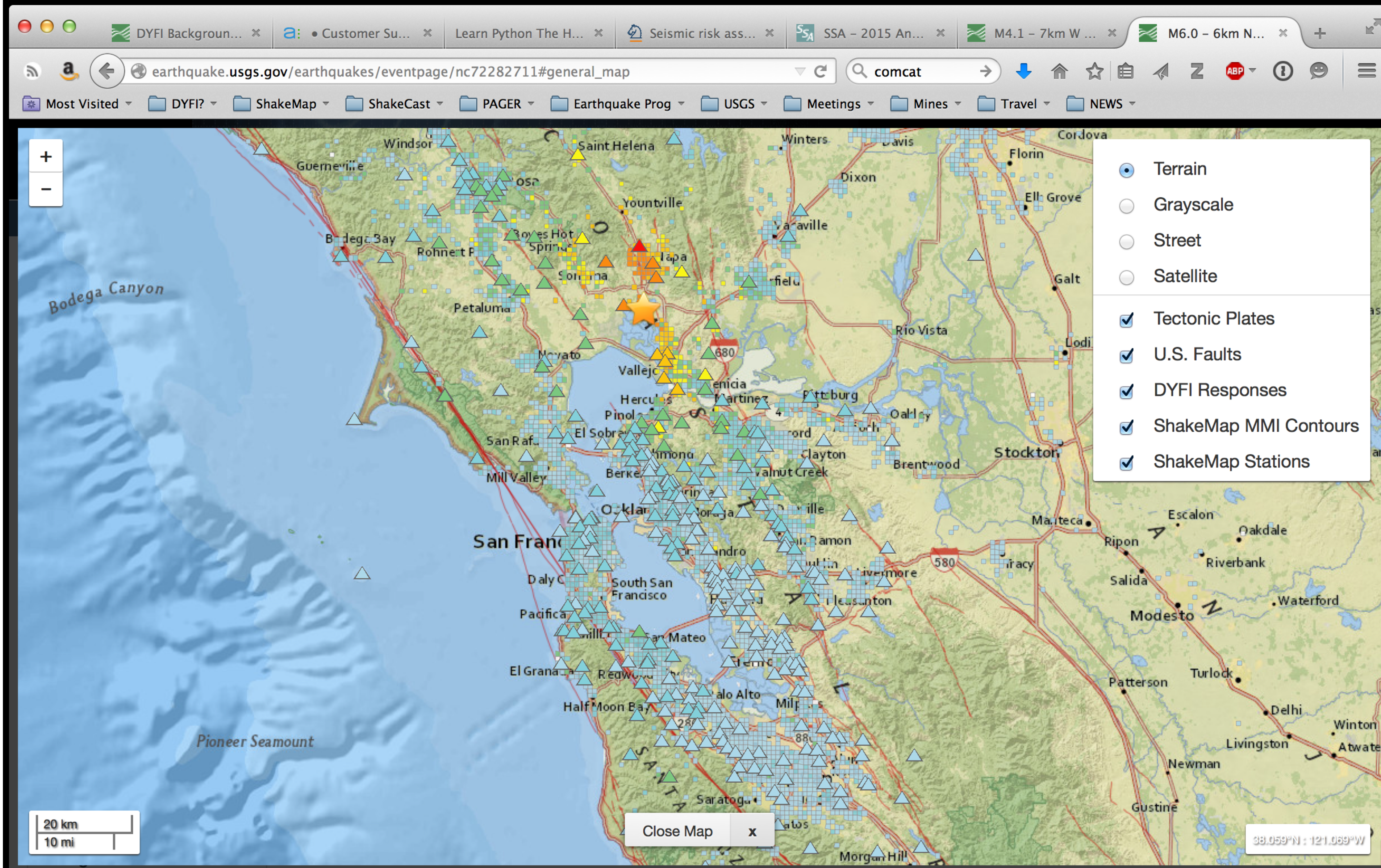


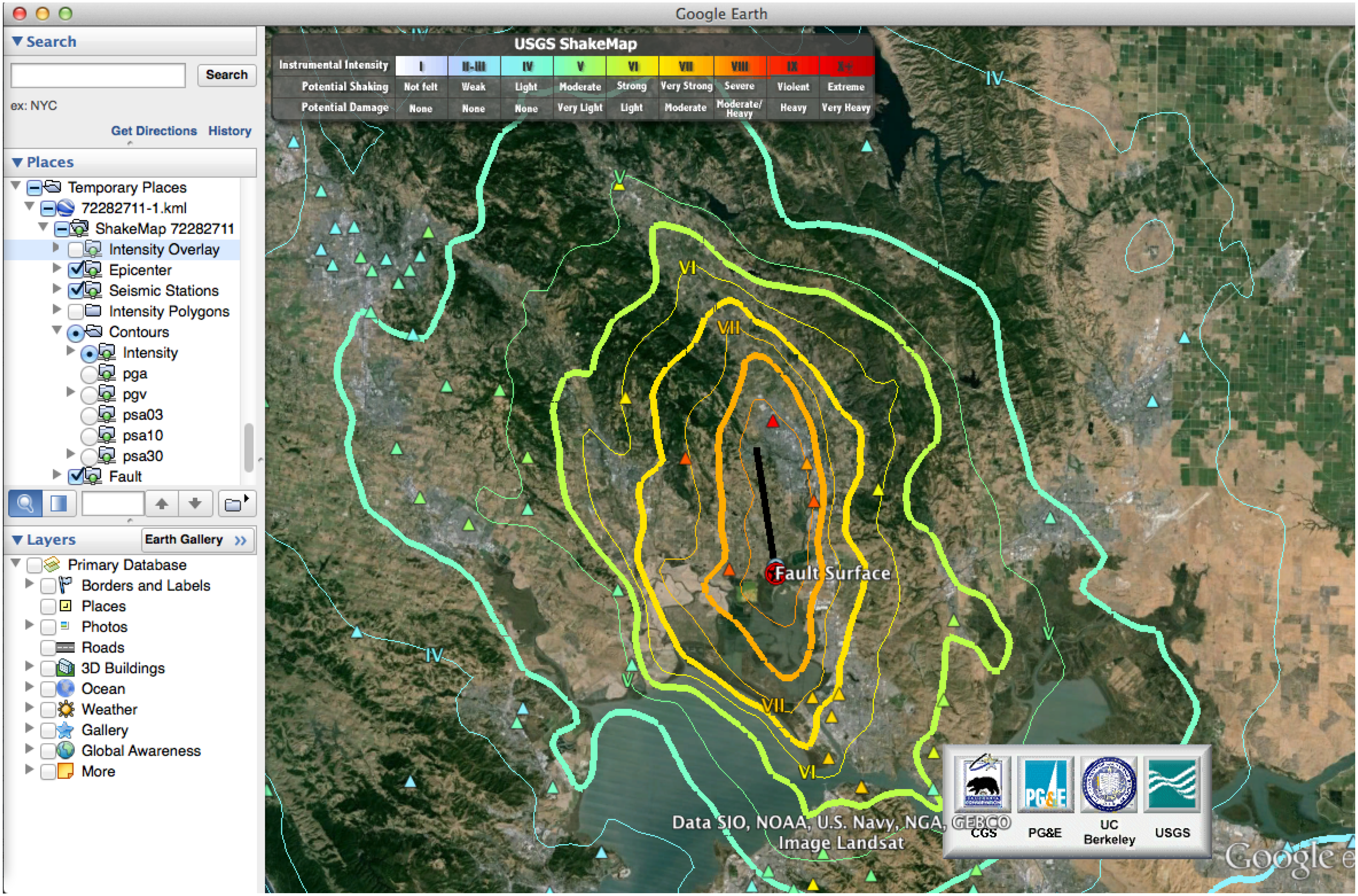
ShakeMap



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)	*<0.1*	*0.5*	*2.4*	*6.7*	*13*	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	*11*	*22*	*43*	*83*	*>160*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

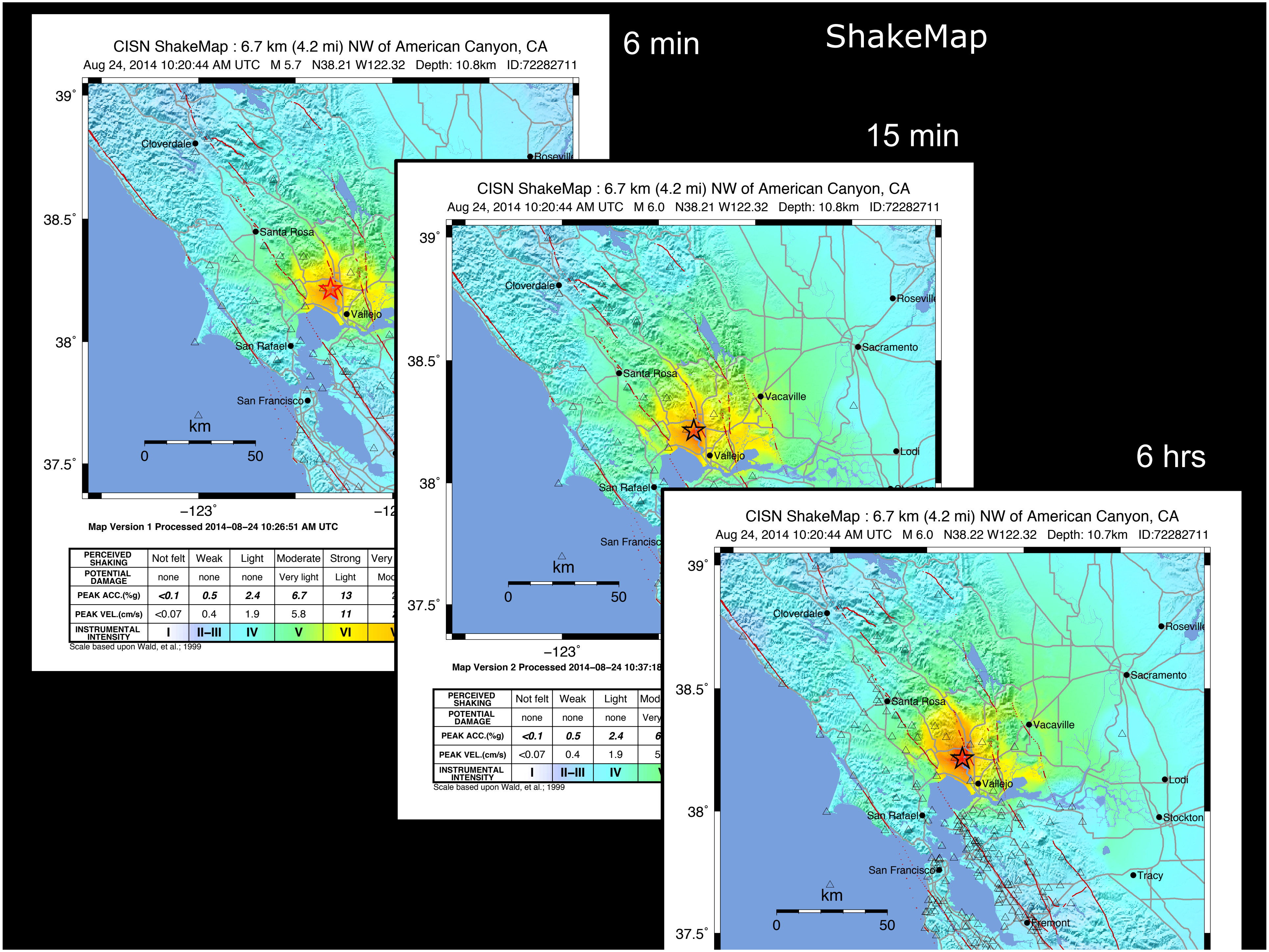
Scale based upon Wald, et al.; 1999


DYFI Backgroun...
Customer Su...
Learn Python The H...
Seismic risk ass...
SSA – 2015 An...
M4.1 – 7km W ...
M6.0 – 6km N...
earthquake.usgs.gov/earthquakes/eventpage/nc72282711#general_map
comcat
Most Visited
DYFI?
ShakeMap
ShakeCast
PAGER
Earthquake Prog
USGS
Meetings
Mines
Travel
NEWS
Terrain
Grayscale
Street
Satellite
Tectonic Plates
U.S. Faults
DYFI Responses
ShakeMap MMI Contours
ShakeMap Stations
Close Map
x
20 km
10 mi
Bodega Canyon
Pioneer Seamount
Windsor
Saint Helena
Winters
Davis
Cordova
Florin
Dixon
Elk Grove
Yountville
Petaluma
Rio Vista
Galt
Lodi
Novato
Vallejo
Stockton
Brentwood
Clayton
Walnut Creek
San Francisco
Daly City
South San Francisco
Pacifica
El Granada
Half Moon Bay
Palo Alto
Saratoga
Morgan Hill
Manteca
Escalon
Oakdale
Ripon
Riverbank
Salida
Modesto
Waterford
Tracy
Livermore
Pleasanton
Patterson
Turlock
Delhi
Winton
Livingston
Atwater
Newman
Gustine
Mill Valley
680
580
38.059°N : 121.069°W



PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al.; 1999

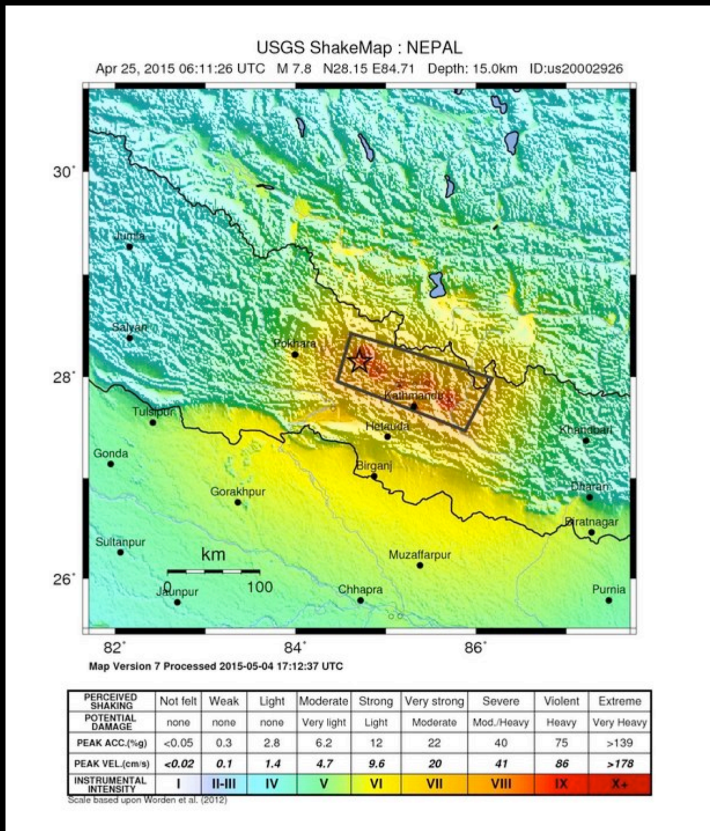


ShakeMap
6 min
15 min
6 hrs
CISN ShakeMap : 6.7 km (4.2 mi) NW of American Canyon, CA
Aug 24, 2014 10:20:44 AM UTC M 5.7 N38.21 W122.32 Depth: 10.8km ID:72282711
Map Version 1 Processed 2014–08–24 10:26:51 AM UTC
CISN ShakeMap : 6.7 km (4.2 mi) NW of American Canyon, CA
Aug 24, 2014 10:20:44 AM UTC M 6.0 N38.21 W122.32 Depth: 10.8km ID:72282711
Map Version 2 Processed 2014–08–24 10:37:18
CISN ShakeMap : 6.7 km (4.2 mi) NW of American Canyon, CA
Aug 24, 2014 10:20:44 AM UTC M 6.0 N38.22 W122.32 Depth: 10.7km ID:72282711
Cloverdale
Santa Rosa
Vallejo
San Rafael
San Francisco
Vacaville
Sacramento
Roseville
Lodi
Stockton
Tracy
Fremont
km
0
50
39˚
38.5˚
38˚
37.5˚
−123˚
PERCEIVED SHAKING
POTENTIAL DAMAGE
PEAK ACC.(%g)
PEAK VEL.(cm/s)
INSTRUMENTAL INTENSITY
Not felt
Weak
Light
Moderate
Strong
none
none
none
Very light
Light
<0.1
0.5
2.4
6.7
13
<0.07
0.4
1.9
5.8
11
I
II–III
IV
V
VI
Scale based upon Wald, et al.; 1999

6 min

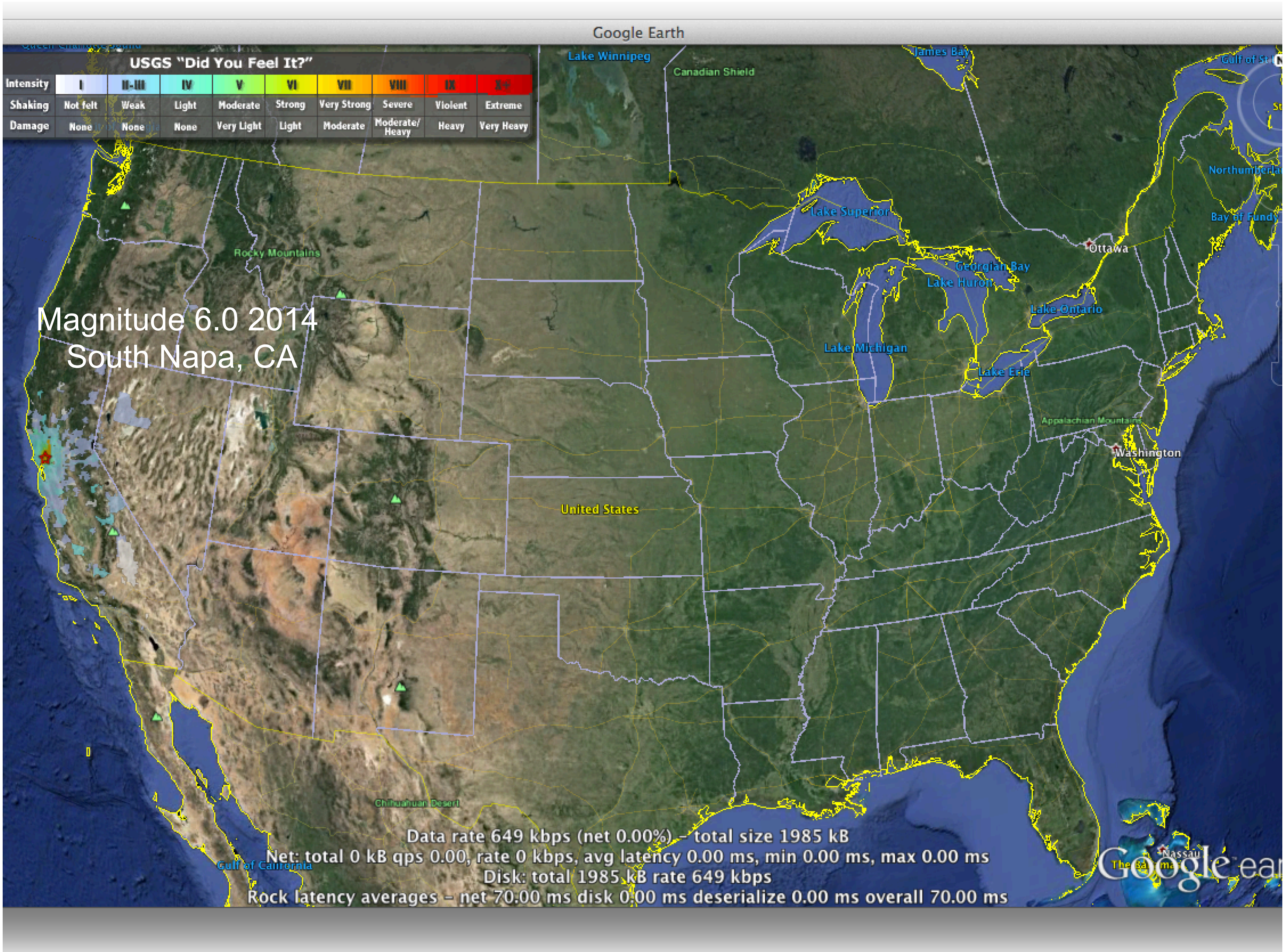
ShakeMap

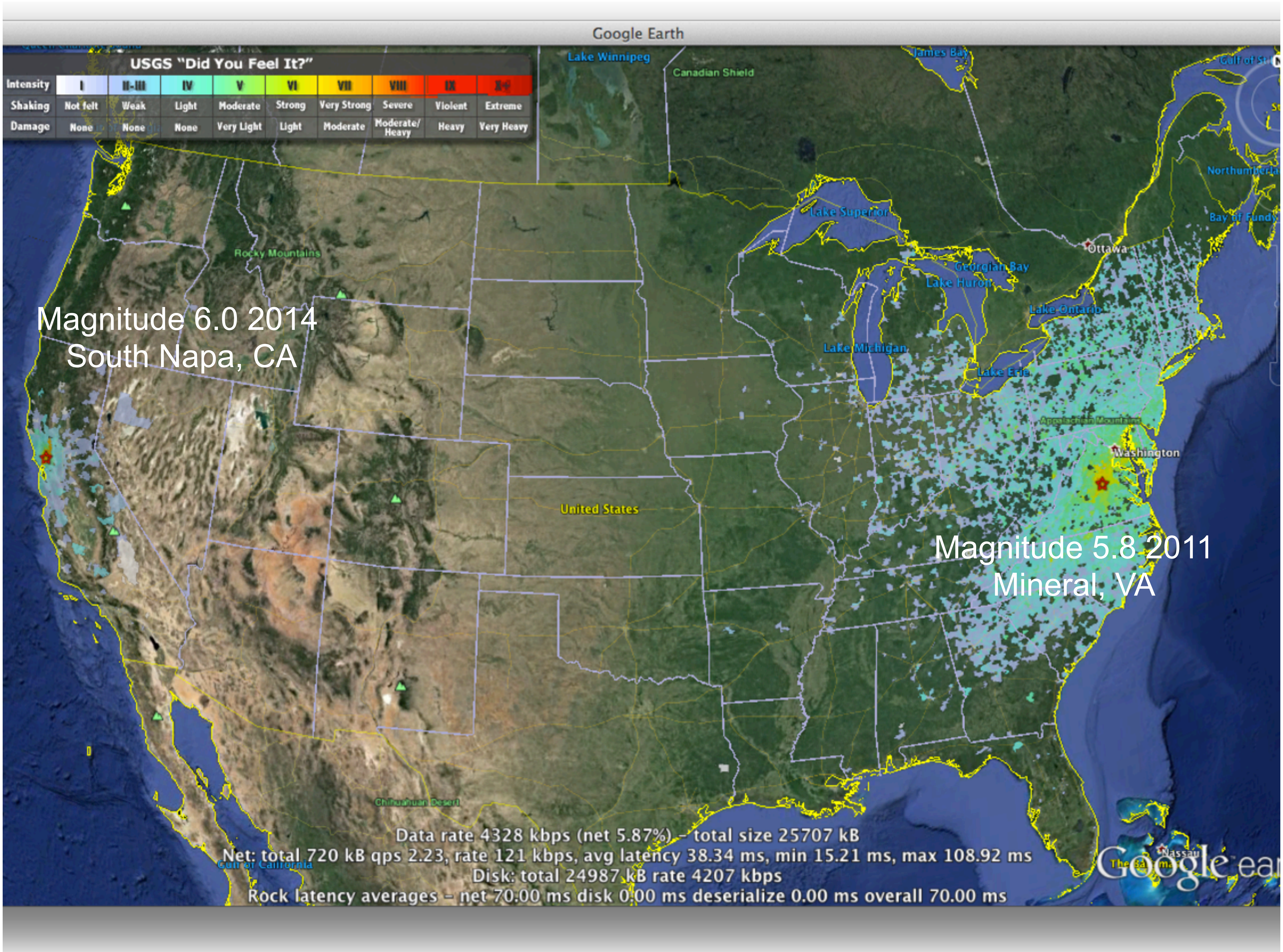
15 min



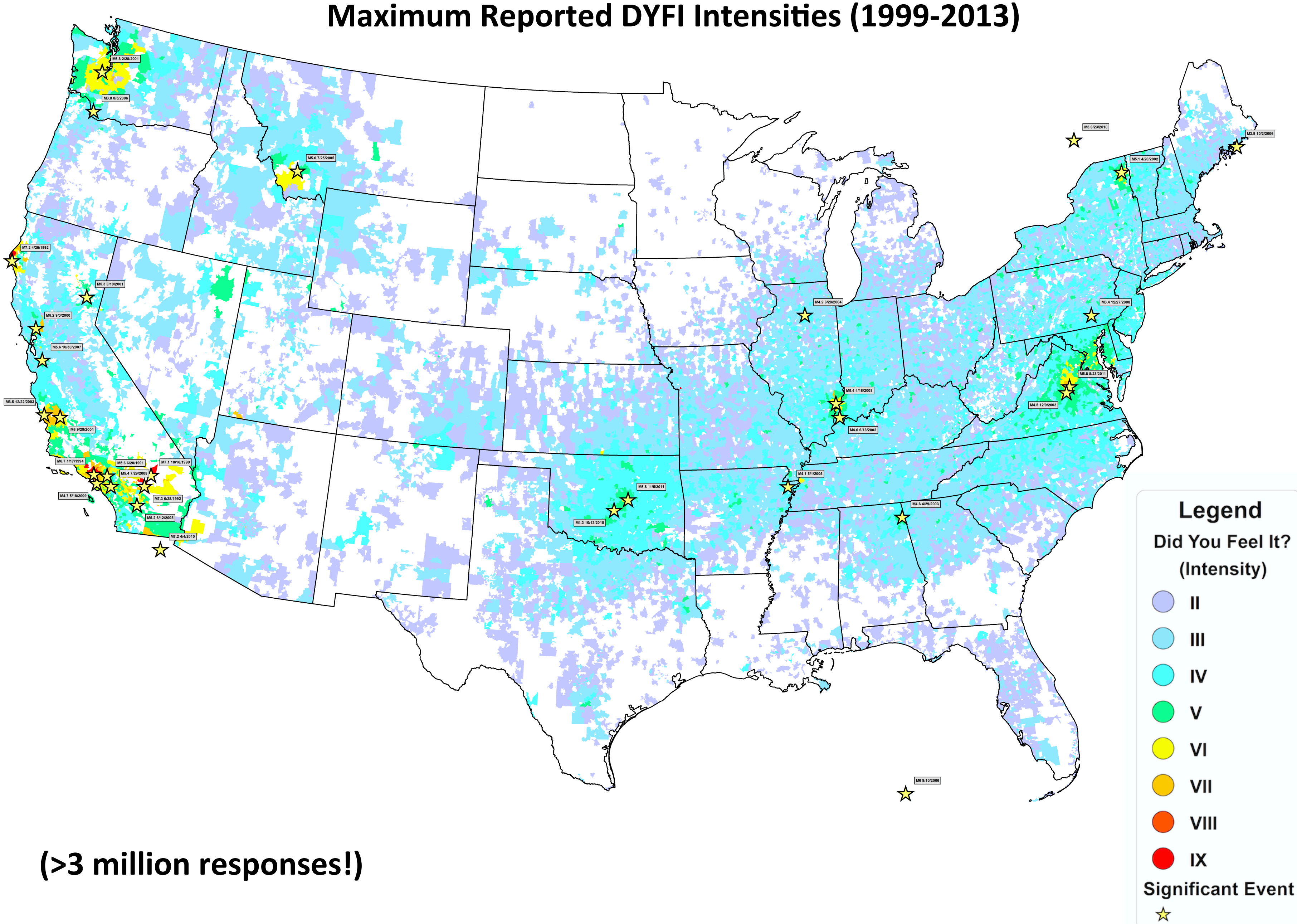
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I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

6 hrs

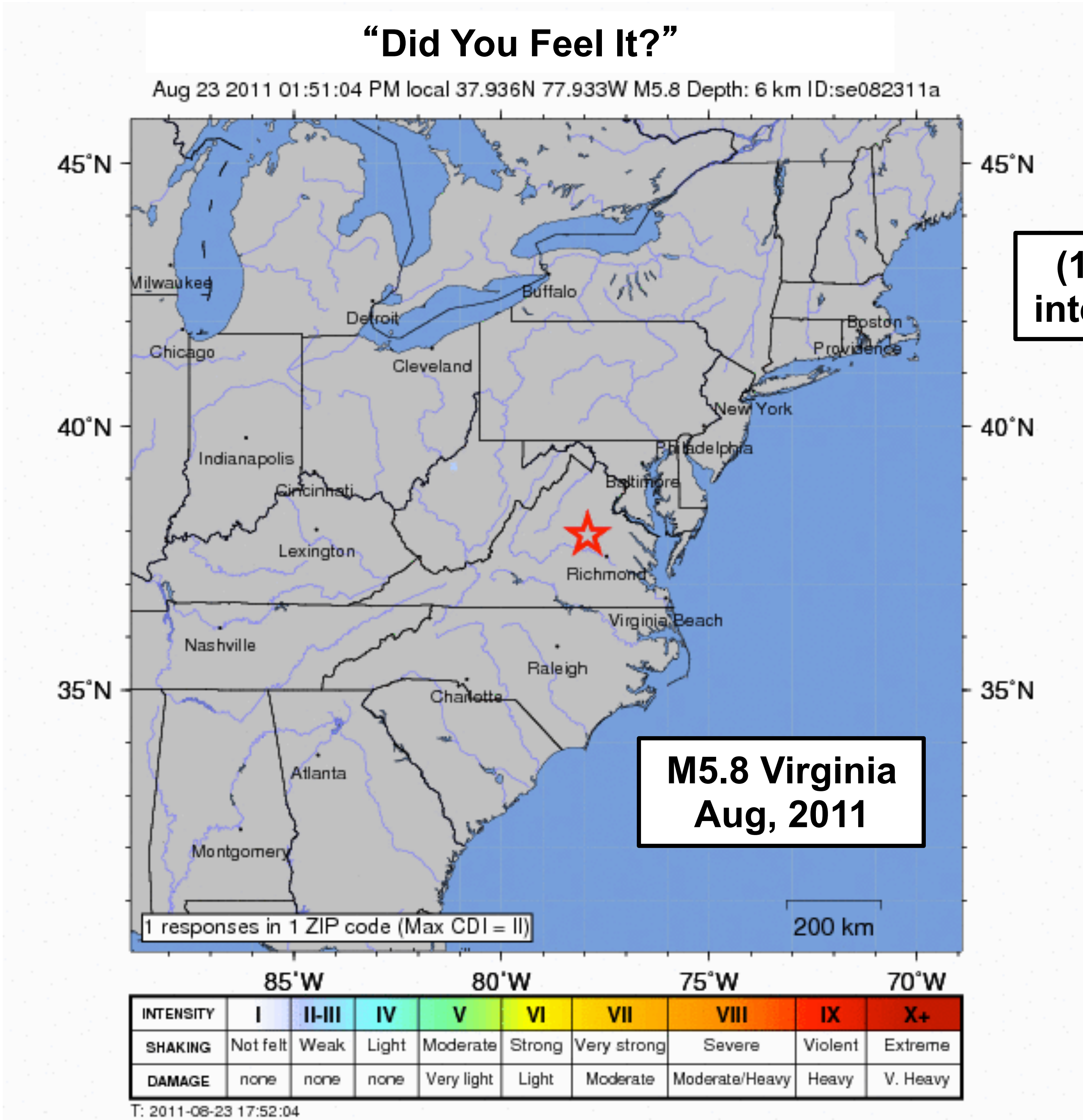

Google Earth
USGS "Did You Feel It?"
Intensity | I | II-III | IV | V | VI | VII | VIII | IX | X+
Shaking | Not felt | Weak | Light | Moderate | Strong | Very Strong | Severe | Violent | Extreme
Damage | None | None | None | Very Light | Light | Moderate | Moderate/Heavy | Heavy | Very Heavy
Magnitude 6.0 2014
South Napa, CA
Lake Winnipeg
Canadian Shield
James Bay
Lake Superior
Rocky Mountains
Ottawa
Georgian Bay
Lake Huron
Lake Ontario
Lake Michigan
Lake Erie
Appalachian Mountains
Washington
United States
Chihuahuan Desert
Gulf of California
Northumberland
Bay of Fundy
Nassau
Data rate 649 kbps (net 0.00%) - total size 1985 kB
Net: total 0 kB qps 0.00, rate 0 kbps, avg latency 0.00 ms, min 0.00 ms, max 0.00 ms
Disk: total 1985 kB rate 649 kbps
Rock latency averages - net 70.00 ms disk 0.00 ms deserialize 0.00 ms overall 70.00 ms


Google Earth
USGS "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
Very Heavy
Magnitude 6.0 2014
South Napa, CA
Magnitude 5.8 2011
Mineral, VA
Lake Winnipeg
Canadian Shield
James Bay
Rocky Mountains
Lake Superior
Ottawa
Georgian Bay
Lake Huron
Lake Ontario
Lake Michigan
Lake Erie
Appalachian Mountains
Washington
United States
Northumberland
Bay of Fundy
Chihuahuan Desert
Gulf of California
Nassau
Data rate 4328 kbps (net 5.87%) - total size 25707 kB
Net: total 720 kB qps 2.23, rate 121 kbps, avg latency 38.34 ms, min 15.21 ms, max 108.92 ms
Disk: total 24987 kB rate 4207 kbps
Rock latency averages - net 70.00 ms disk 0.00 ms deserialize 0.00 ms overall 70.00 ms

Maximum Reported DYFI Intensities (1999-2013)

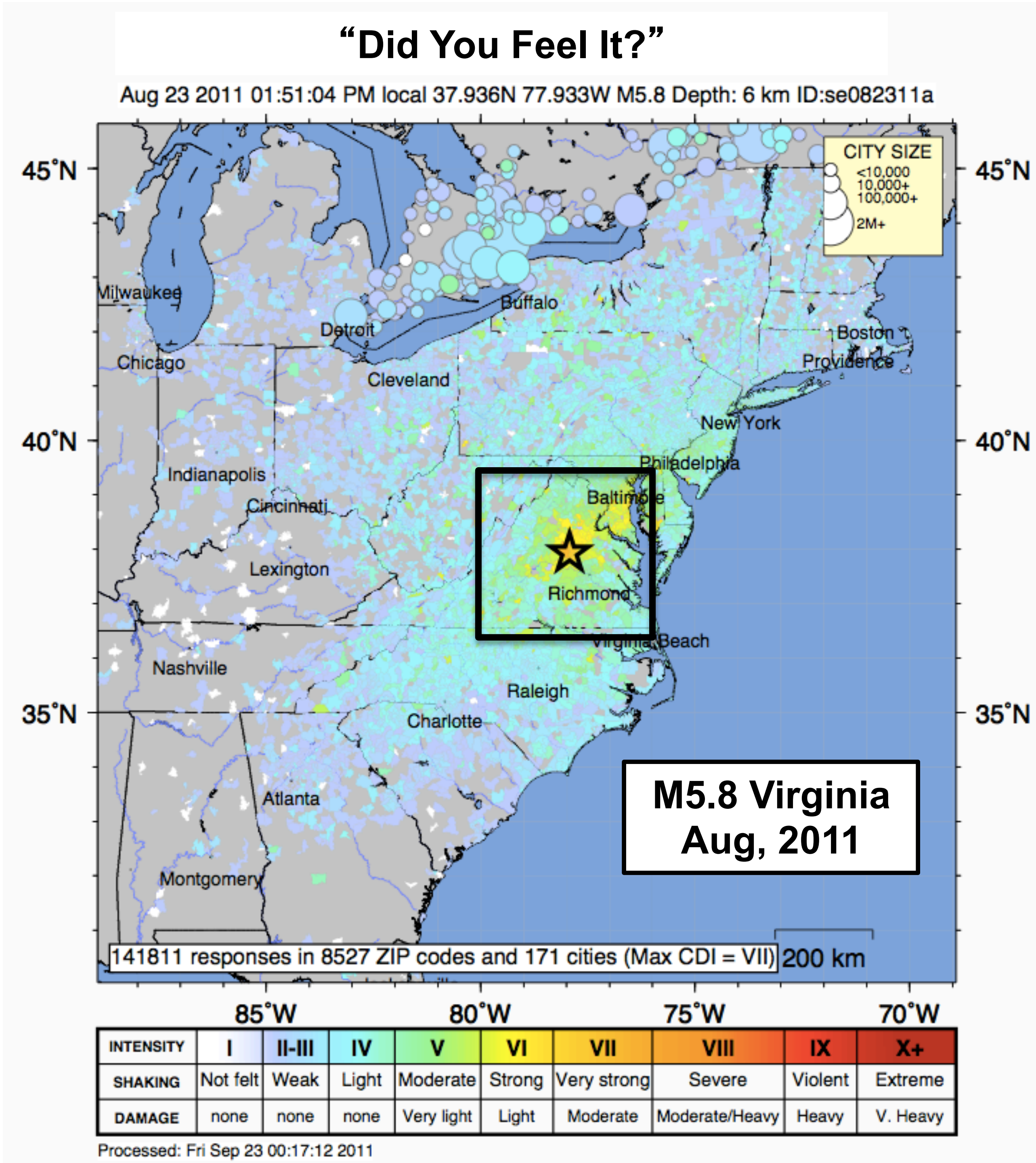


(>3 million responses!)



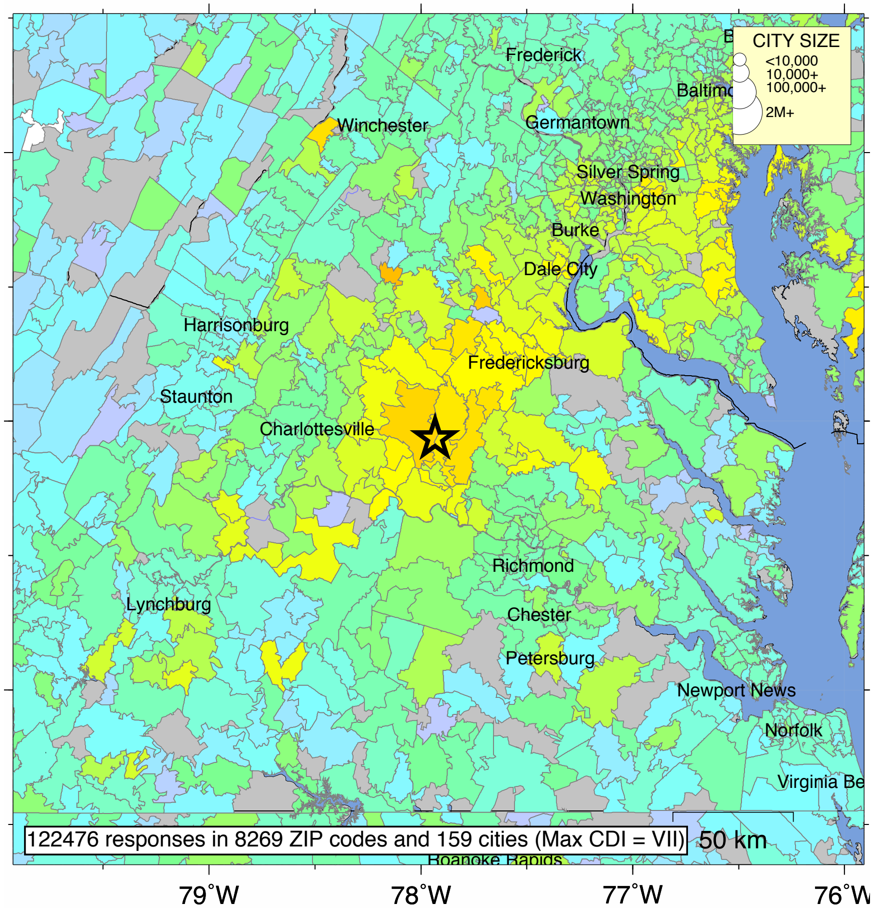
(1-min. intervals)

M5.8 Virginia Aug, 2011


"Did You Feel It?"
Aug 23 2011 01:51:04 PM local 37.936N 77.933W M5.8 Depth: 6 km ID:se082311a
CITY SIZE
<10,000
10,000+
100,000+
2M+
45°N
40°N
35°N
85°W
80°W
75°W
70°W
Milwaukee
Chicago
Detroit
Buffalo
Boston
Providence
Cleveland
New York
Philadelphia
Indianapolis
Baltimore
Cincinnati
Lexington
Richmond
Virginia Beach
Nashville
Raleigh
Charlotte
Atlanta
Montgomery
M5.8 Virginia
Aug, 2011
141811 responses in 8527 ZIP codes and 171 cities (Max CDI = VII)
200 km
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: Fri Sep 23 00:17:12 2011

“Did You Feel It?”

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



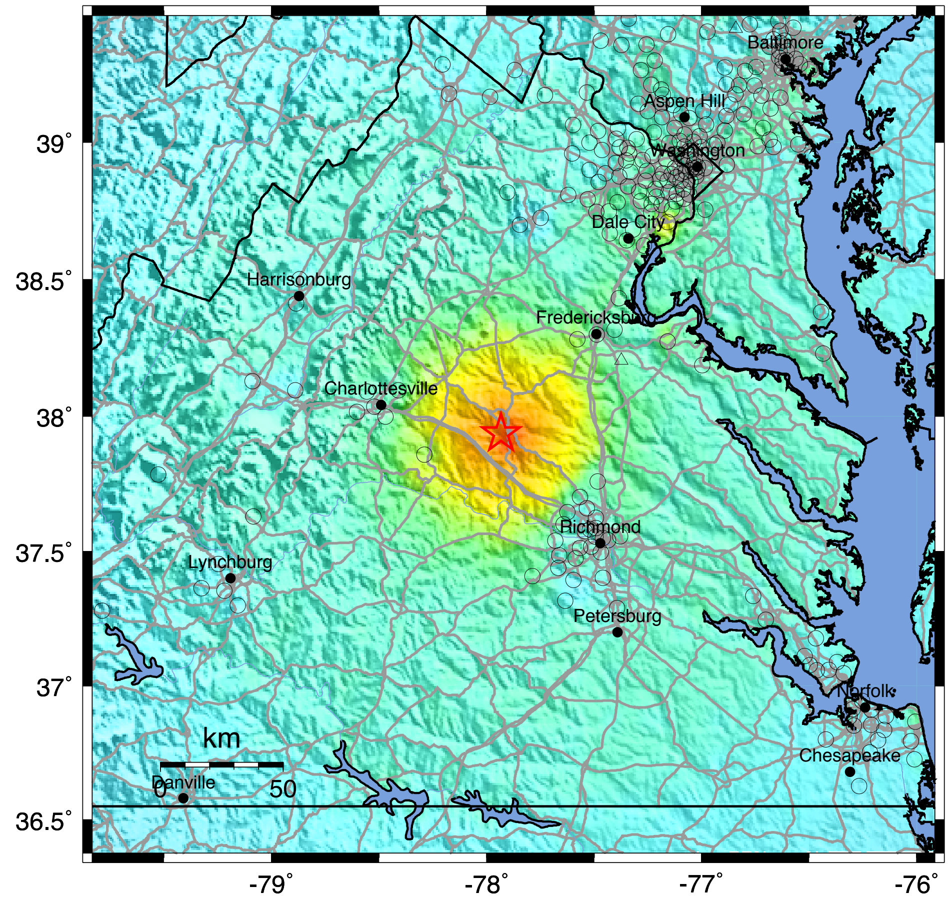
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Wed Aug 24 11:12:25 2011

ShakeMap

USGS ShakeMap : VIRGINIA

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

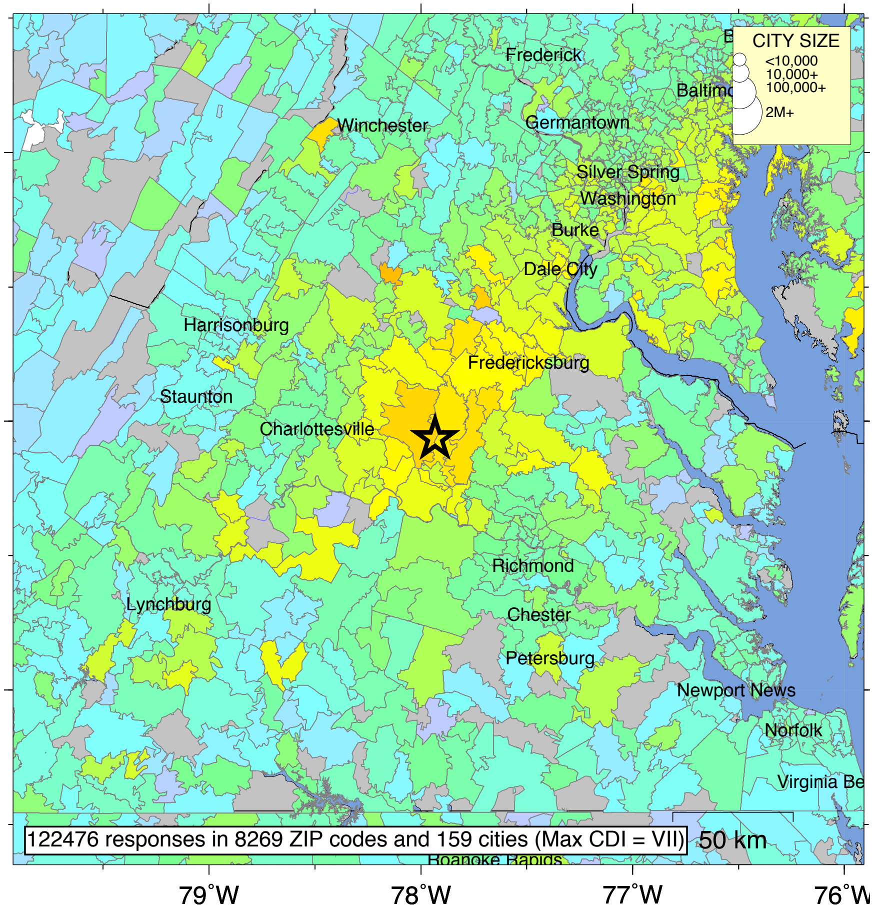


Map Version 4 Processed Tue Aug 23, 2011 01:50:45 PM MDT -- NOT REVIEWED BY HUMAN

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+

“Did You Feel It?”

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



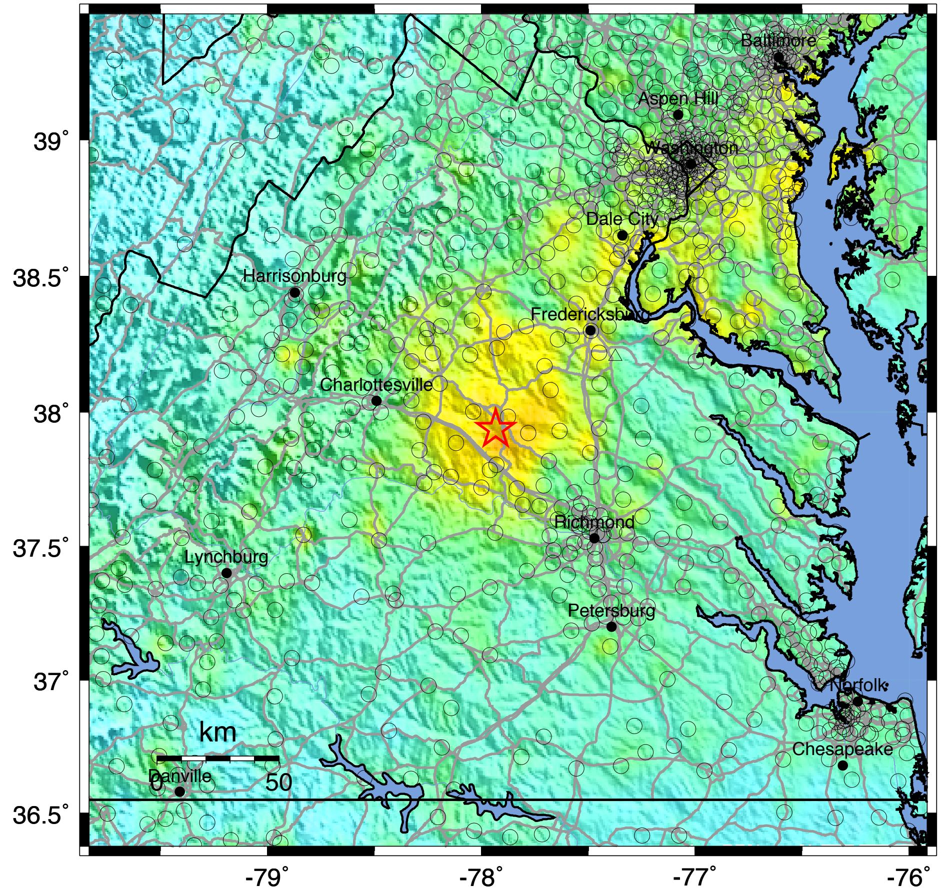
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Wed Aug 24 11:12:25 2011

ShakeMap

USGS ShakeMap : VIRGINIA

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

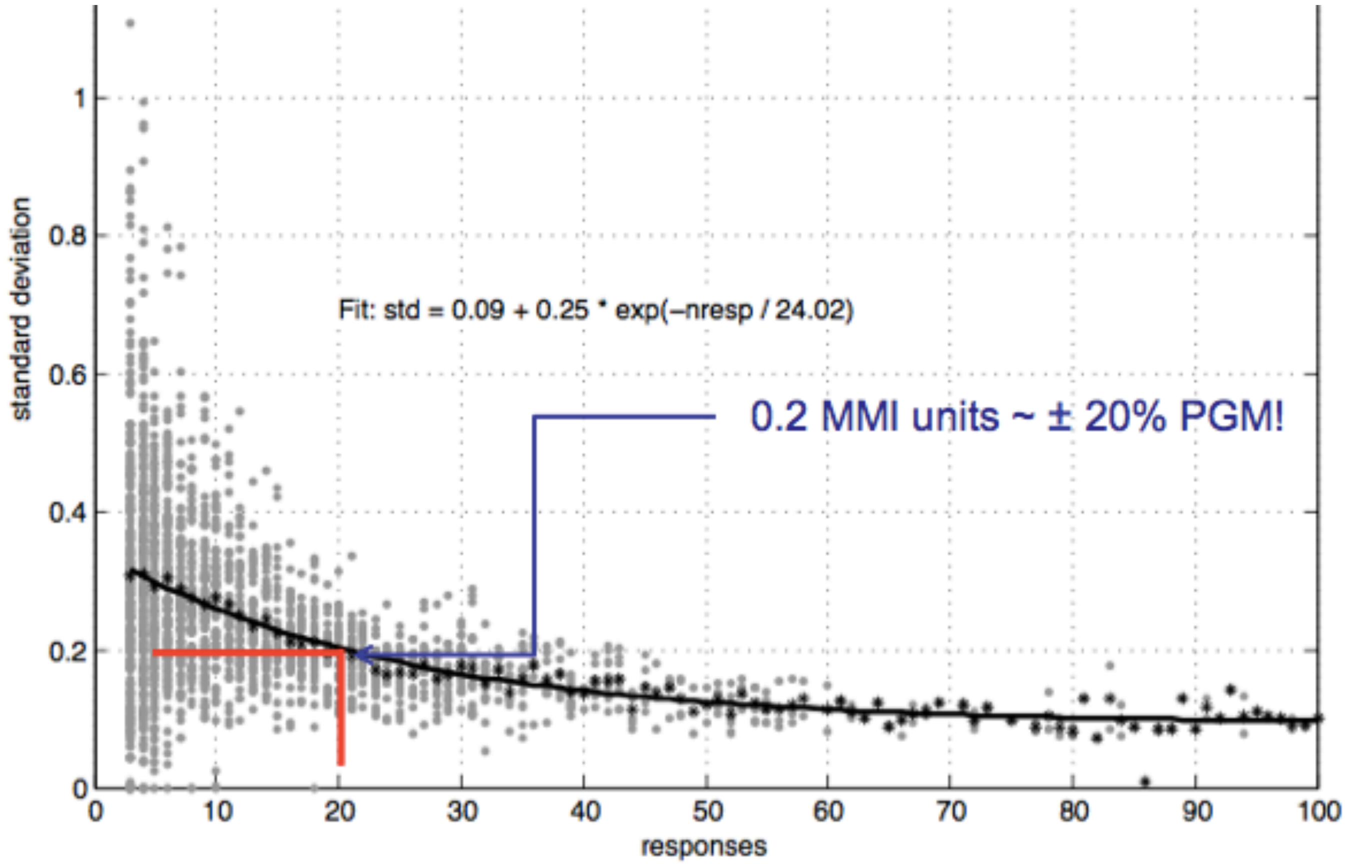


Map Version 6 Processed Wed Aug 24, 2011 08:50:09 AM MDT -- NOT REVIEWED BY HUMAN

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+

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)	***<0.1***	***0.5***	***2.4***	***6.7***	***13***	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	***11***	***22***	***43***	***83***	***>160***
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al.; 1999

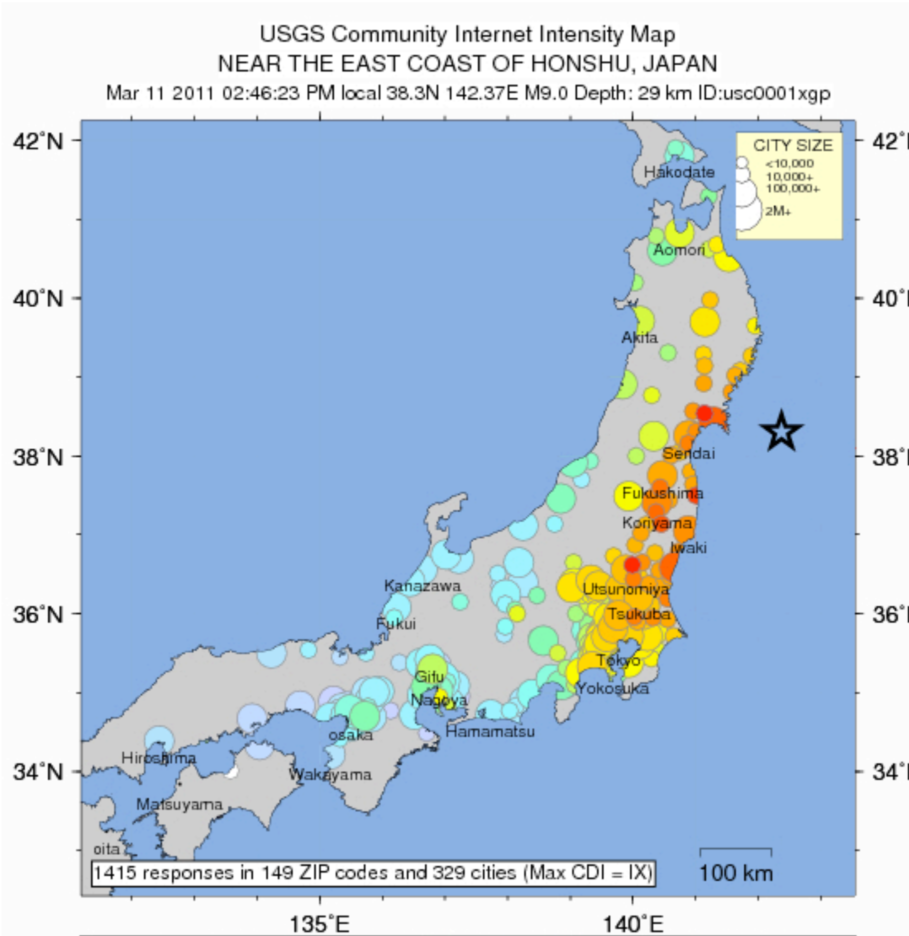


USGS science for a changing world

GNS SCIENCE

[Worden, Gerstenberger, Rhodes & Wald, 2011]

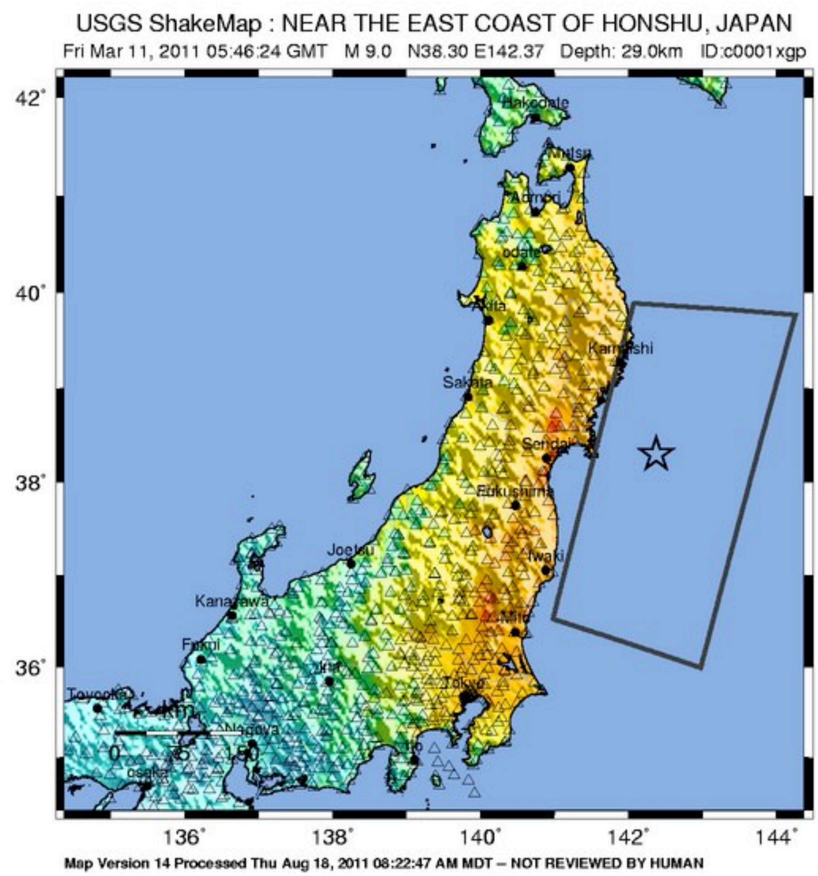
“Did You Feel It?”



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

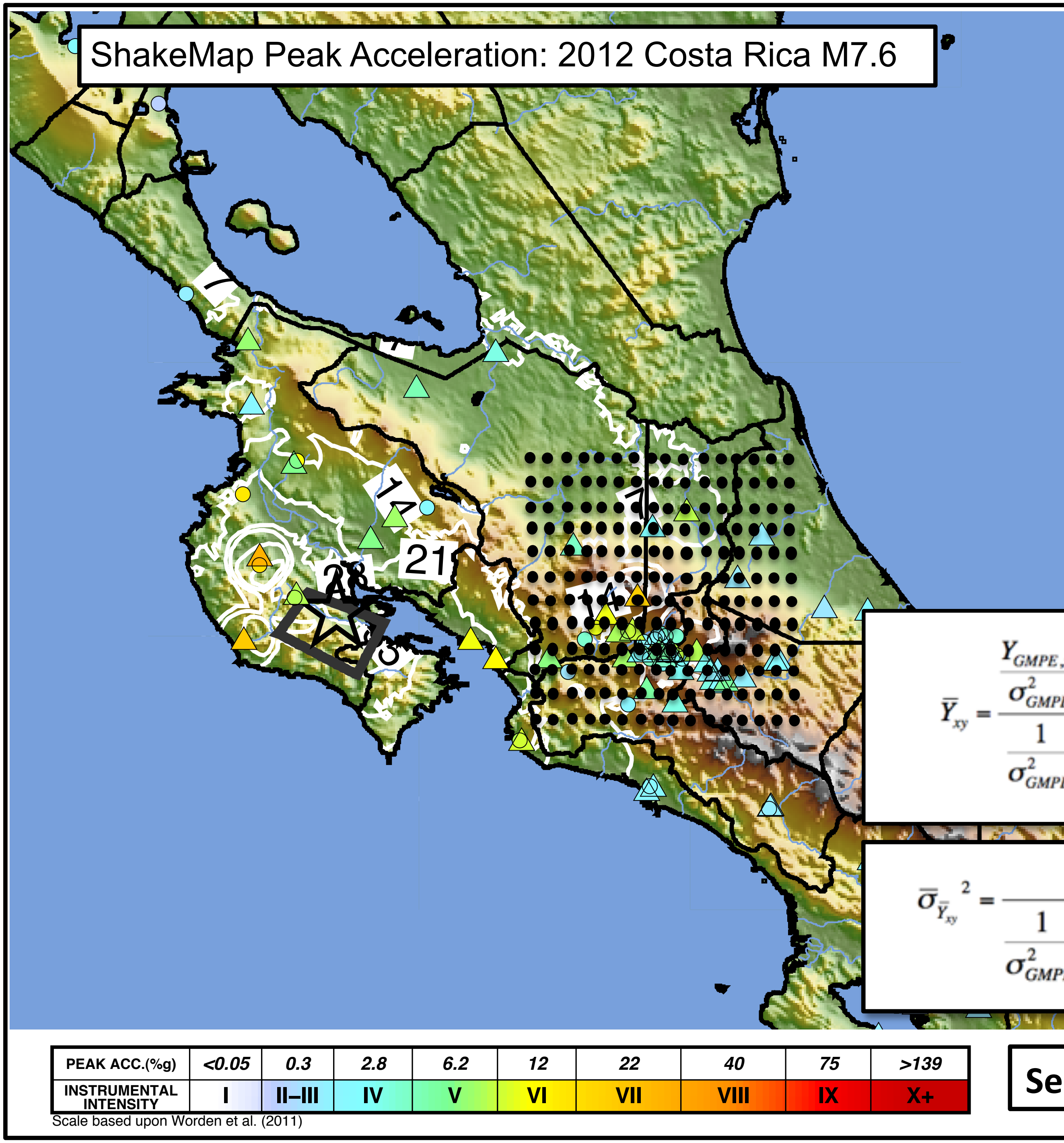
Processed: Tue Jul 23 01:17:46 2013

ShakeMap



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)

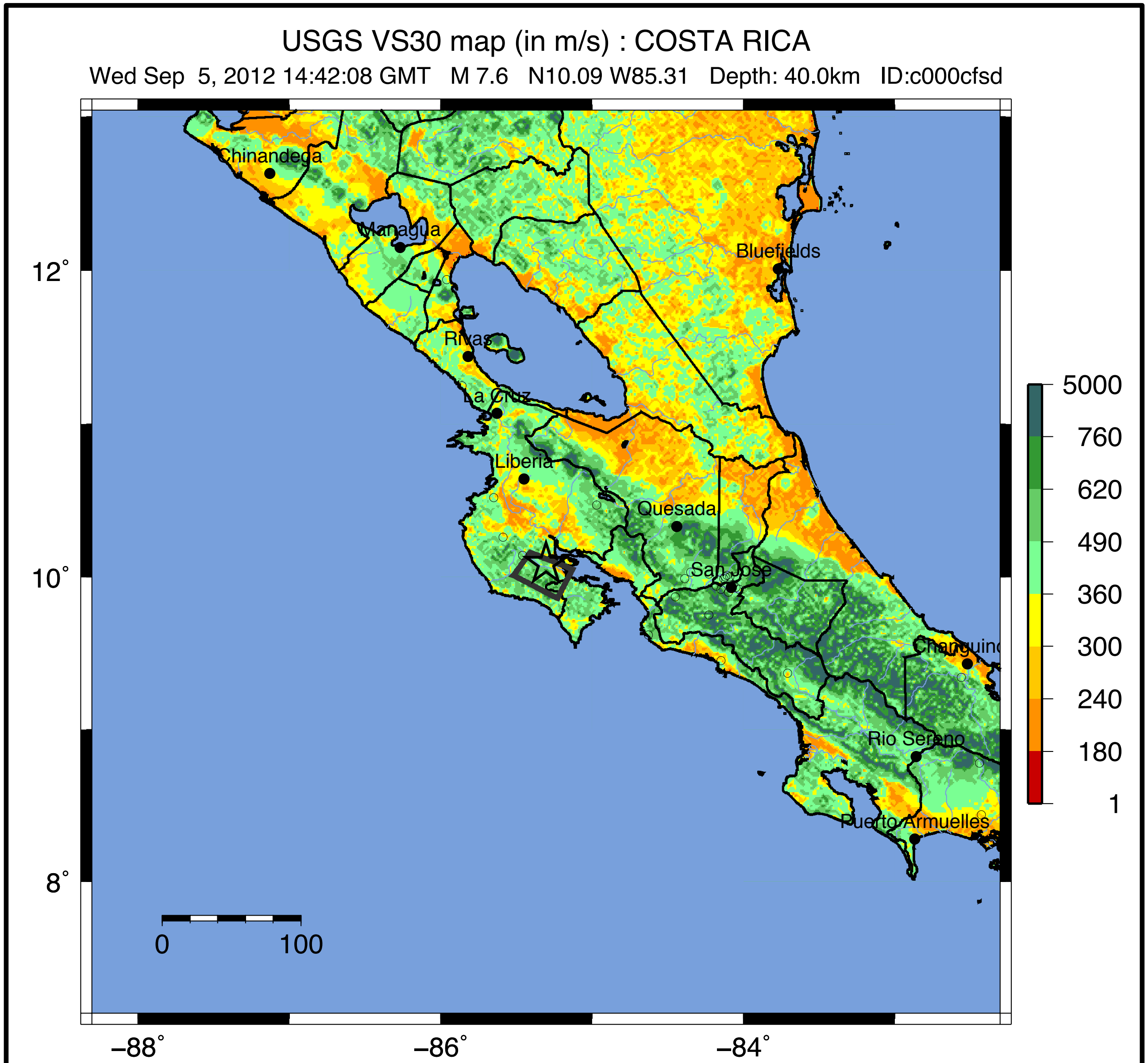
Fault Plane

Epicenter

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

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

See Worden et al. (2010)



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)

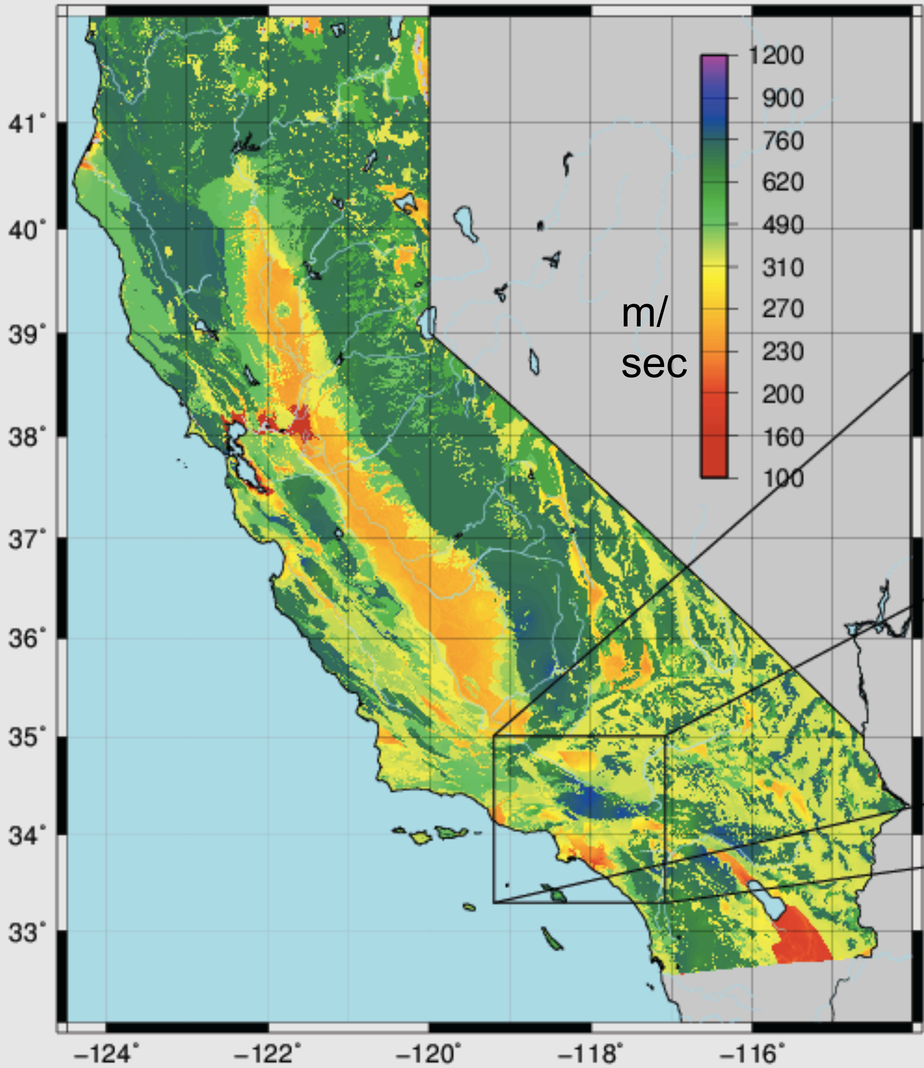
Fault Plane

Epicenter

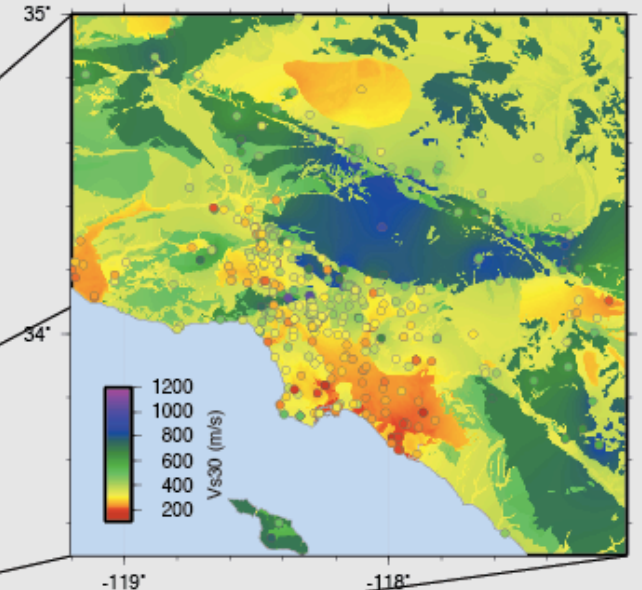
Vs30 Site amplification map from topographic slope

(Wald & Allen, 2007)

Refined Vs30 Maps



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

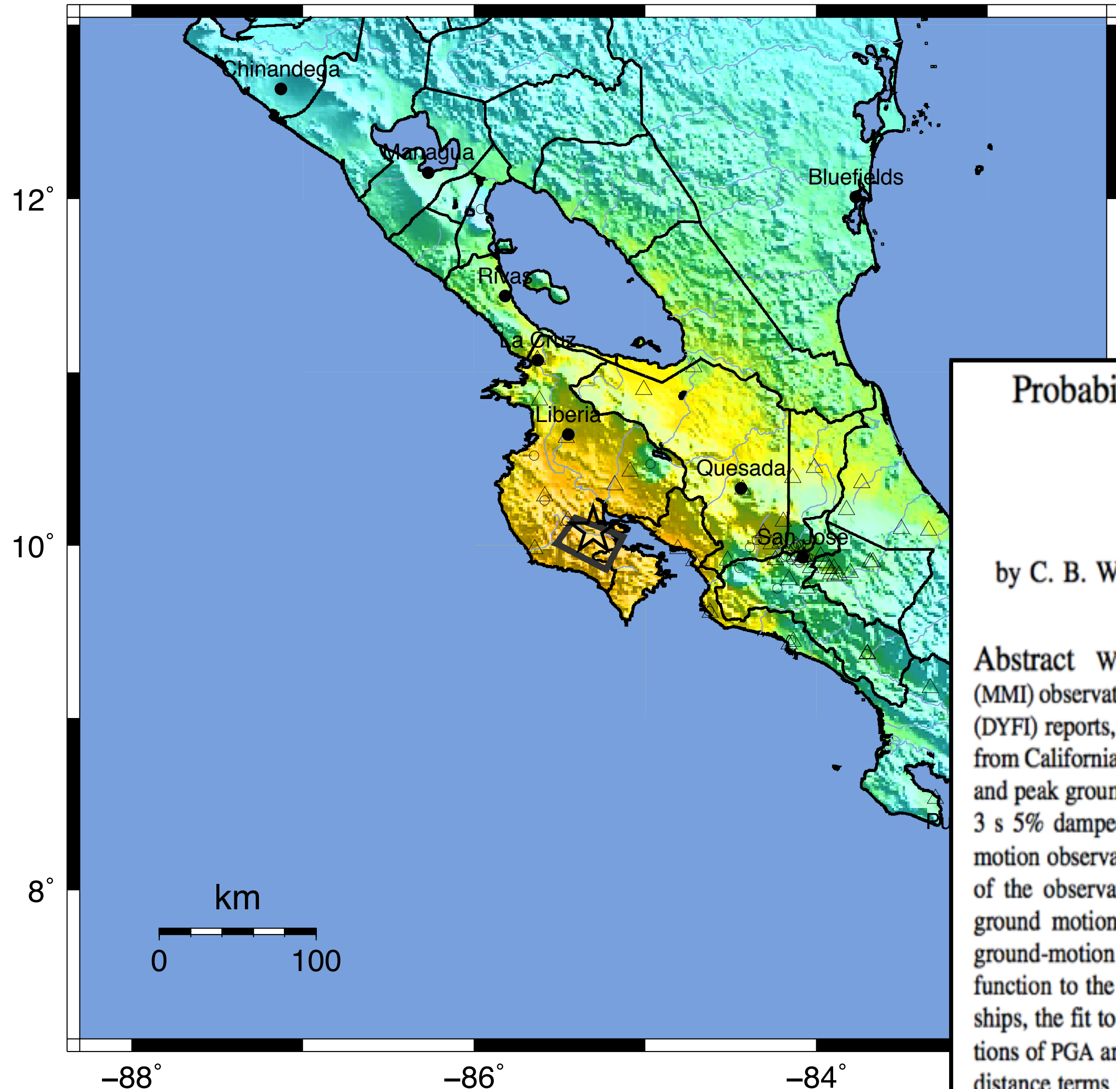


Result of kriging the measured Vs30 profiles (using the correlation structure from the previous step) onto the hybrid map.

[Thompson, Worden & Wald, 2014]

USGS ShakeMap : COSTA RICA

SEP 5 2012 02:42:08 PM GMT M 7.6 N10.09 W85.31 Depth: 40.0km ID:c000cfsd



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
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII

Scale based upon Worden et al. (2011)

Intensity Observation

Strong Motion Station (UCR)

Fault Plane

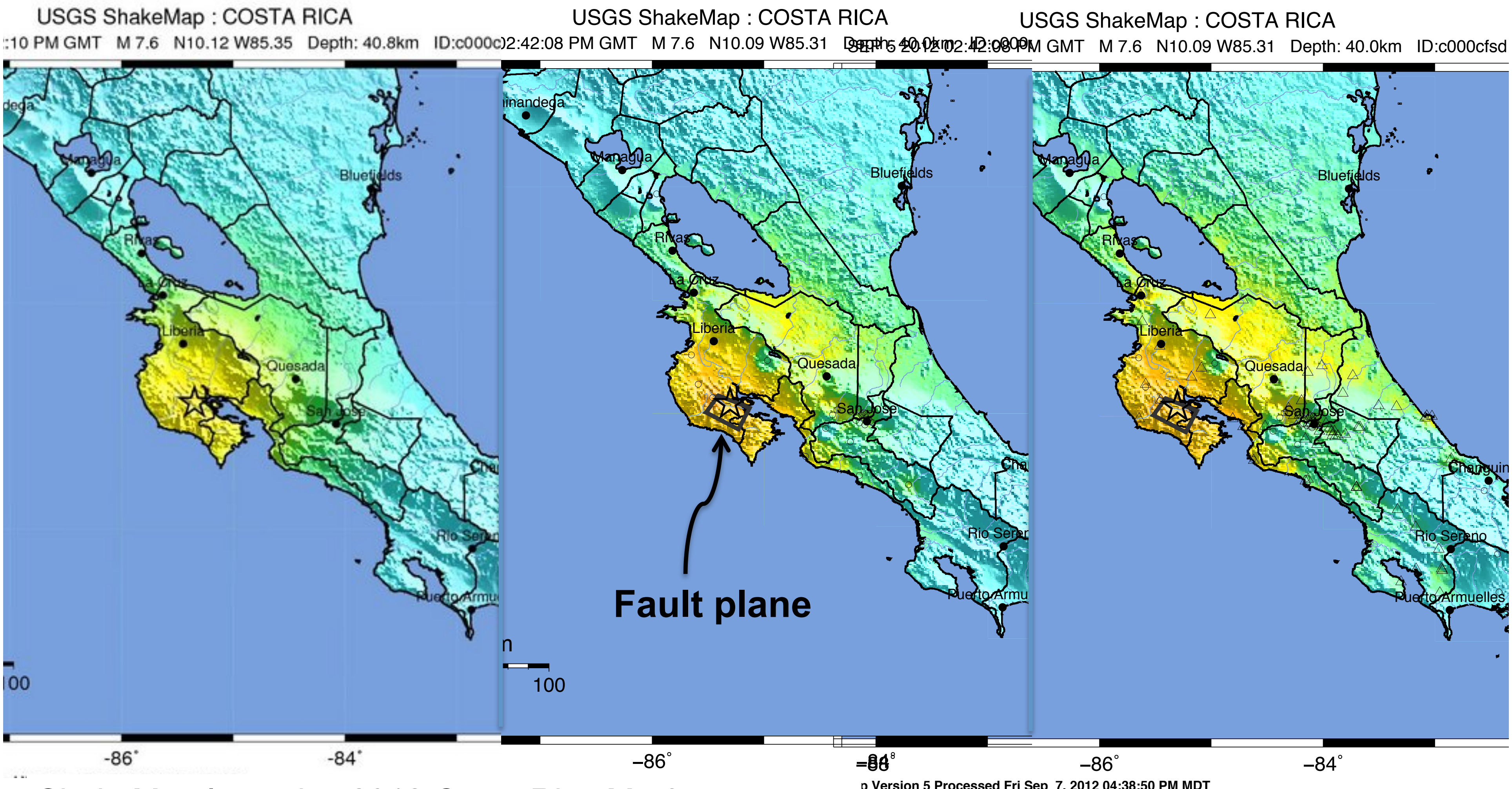
Probabilistic Relationships between Ground-Motion Parameters and Modified Mercalli Intensity in California

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

Bull. Seism. Soc. Am. (2010)

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.

Hypocenter & Magnitude only | **+ DYFI? Data & Fault** | **+ Strong Motion Stations from Univ. CR**

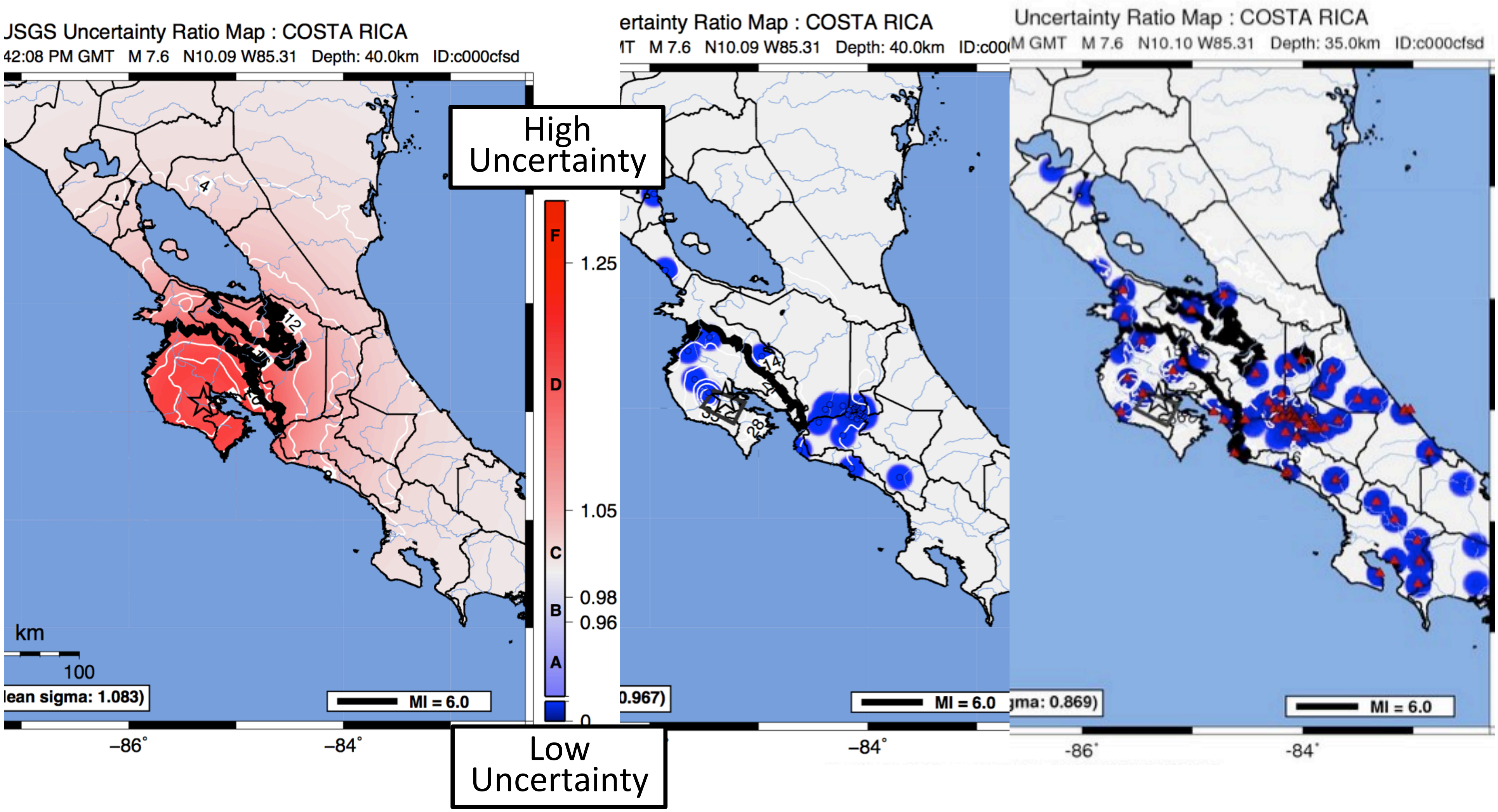


ShakeMap Intensity: 2012 Costa Rica M7.6

CEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extre
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very He
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>13
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>17*
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



GROUND MOTION UNCERTAINTY

ShakeMap grid.xml file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-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 4.9600 11.3035 4.9740 0.9857 1.0000 464.0000
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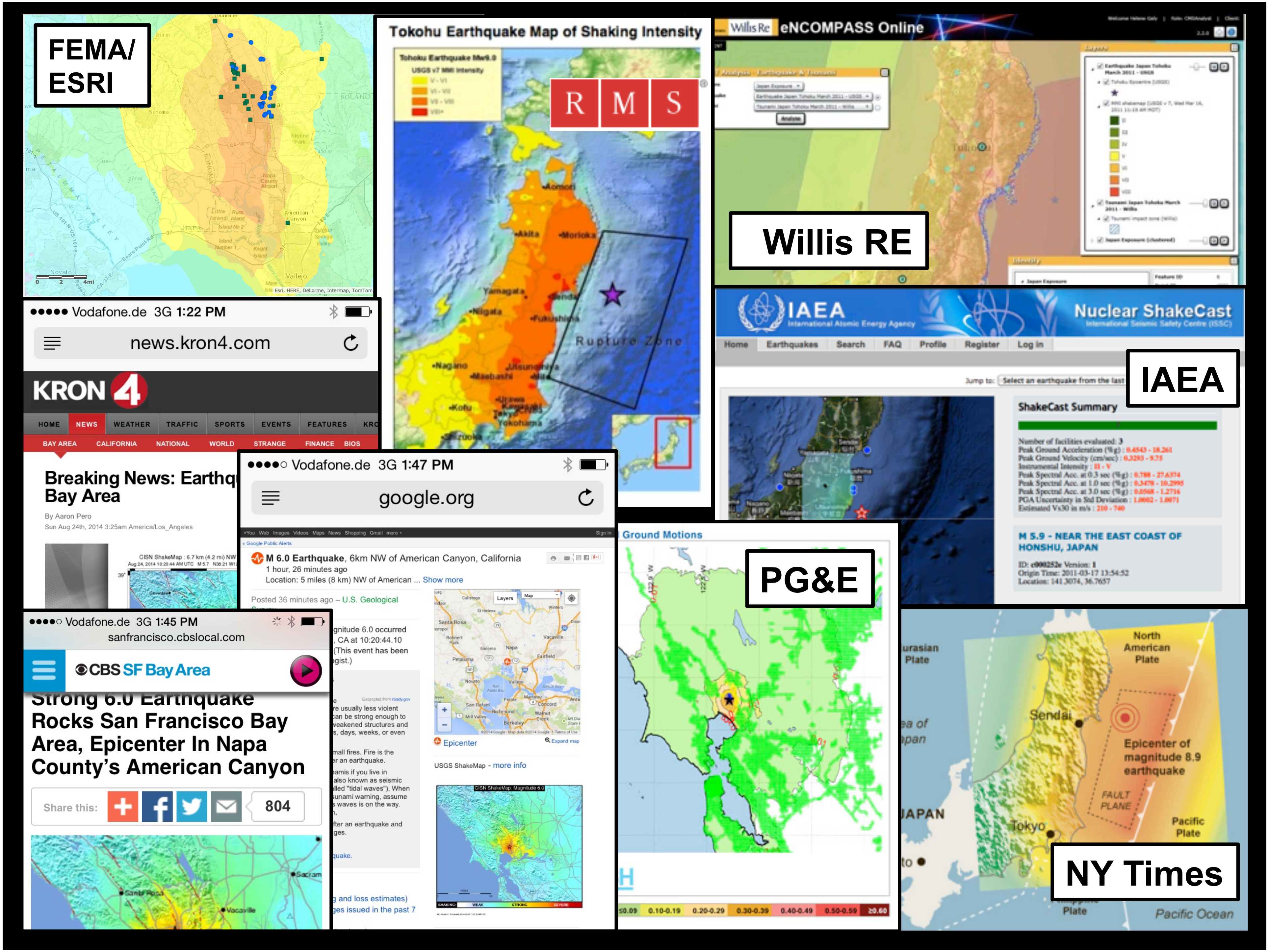
```


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

Grid uncertainty value, Vs30

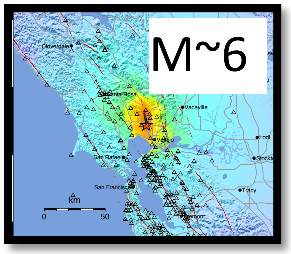
Ground motion estimates

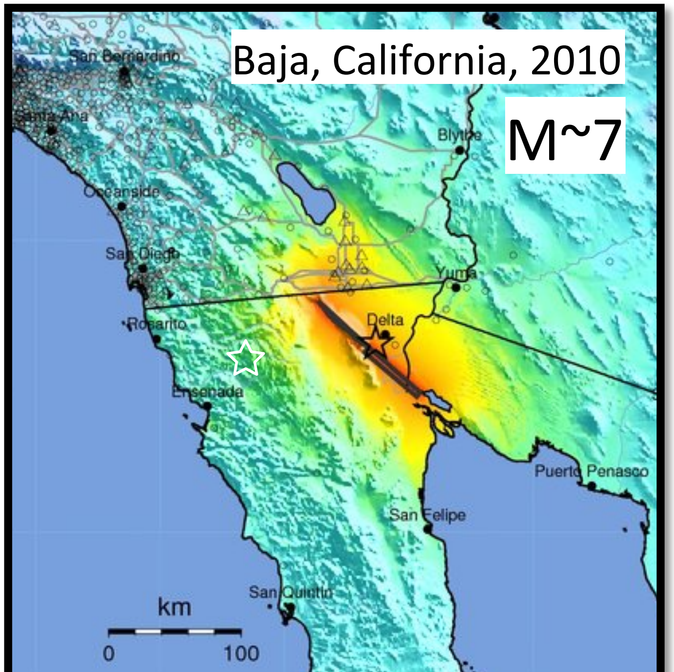
- Intensity (MMI)
- Peak ground acceleration (PGA)
- Peak ground velocity (PGV)
- Spectral response at 0.3, 1, 3 sec.

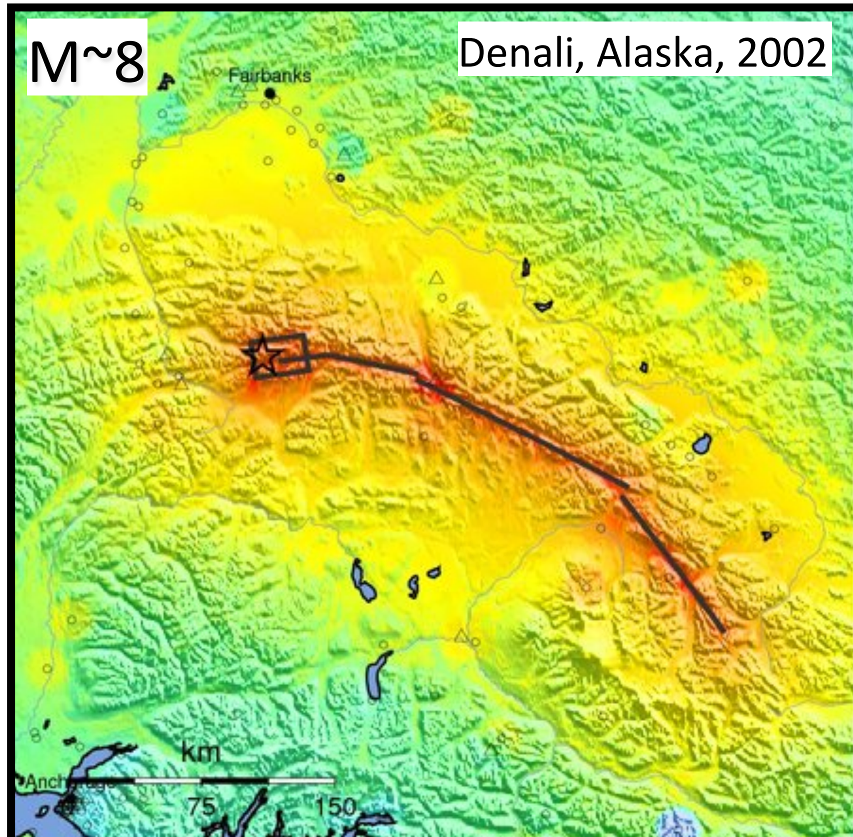

FEMA/ ESRI
Tokohu Earthquake Map of Shaking Intensity
RMS
Rupture Zone
Willis Re eNCOMPASS Online
Willis RE
Vodafone.de 3G 1:22 PM
news.kron4.com
KRON 4
HOME NEWS WEATHER TRAFFIC SPORTS EVENTS FEATURES
BAY AREA CALIFORNIA NATIONAL WORLD STRANGE FINANCE BIOS
Breaking News: Earthq
Bay Area
By Aaron Pero
Sun Aug 24th, 2014 3:25am America/Los_Angeles
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
Vodafone.de 3G 1:47 PM
google.org
M 6.0 Earthquake, 6km NW of American Canyon, California
1 hour, 26 minutes ago
Location: 5 miles (8 km) NW of American ... Show more
Posted 36 minutes ago – U.S. Geological
Epicenter
USGS ShakeMap - more info
Vodafone.de 3G 1:45 PM
sanfrancisco.cbslocal.com
CBS SF Bay Area
Strong 6.0 Earthquake Rocks San Francisco Bay Area, Epicenter In Napa County's American Canyon
Share this:
804
Ground Motions
PG&E
North American Plate
Eurasian Plate
Sendai
Epicenter of magnitude 8.9 earthquake
FAULT PLANE
JAPAN
Tokyo
Pacific Plate
Pacific Ocean
NY Times

Fault size (black line) scaling with magnitude

Napa, California 2014



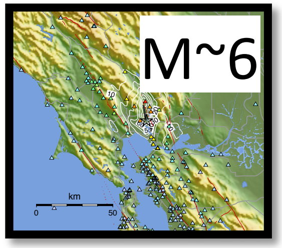


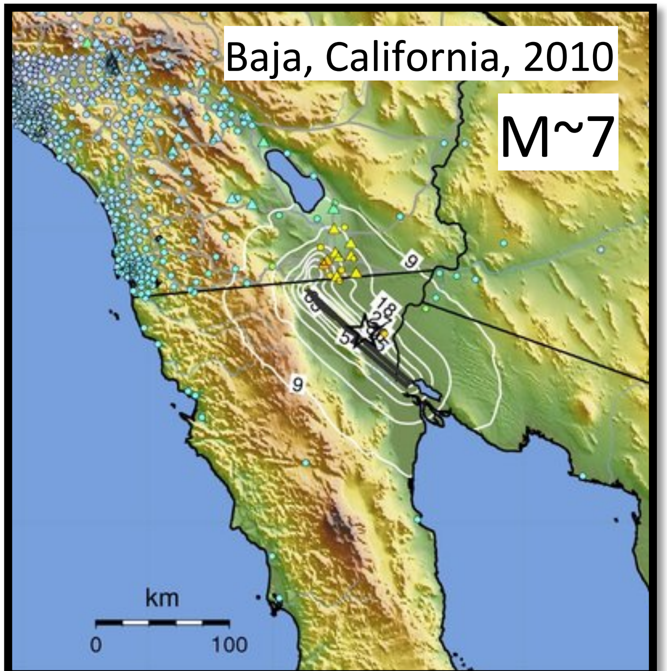


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	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+

Fault Size (black line) scaling with magnitude

Napa, California 2014

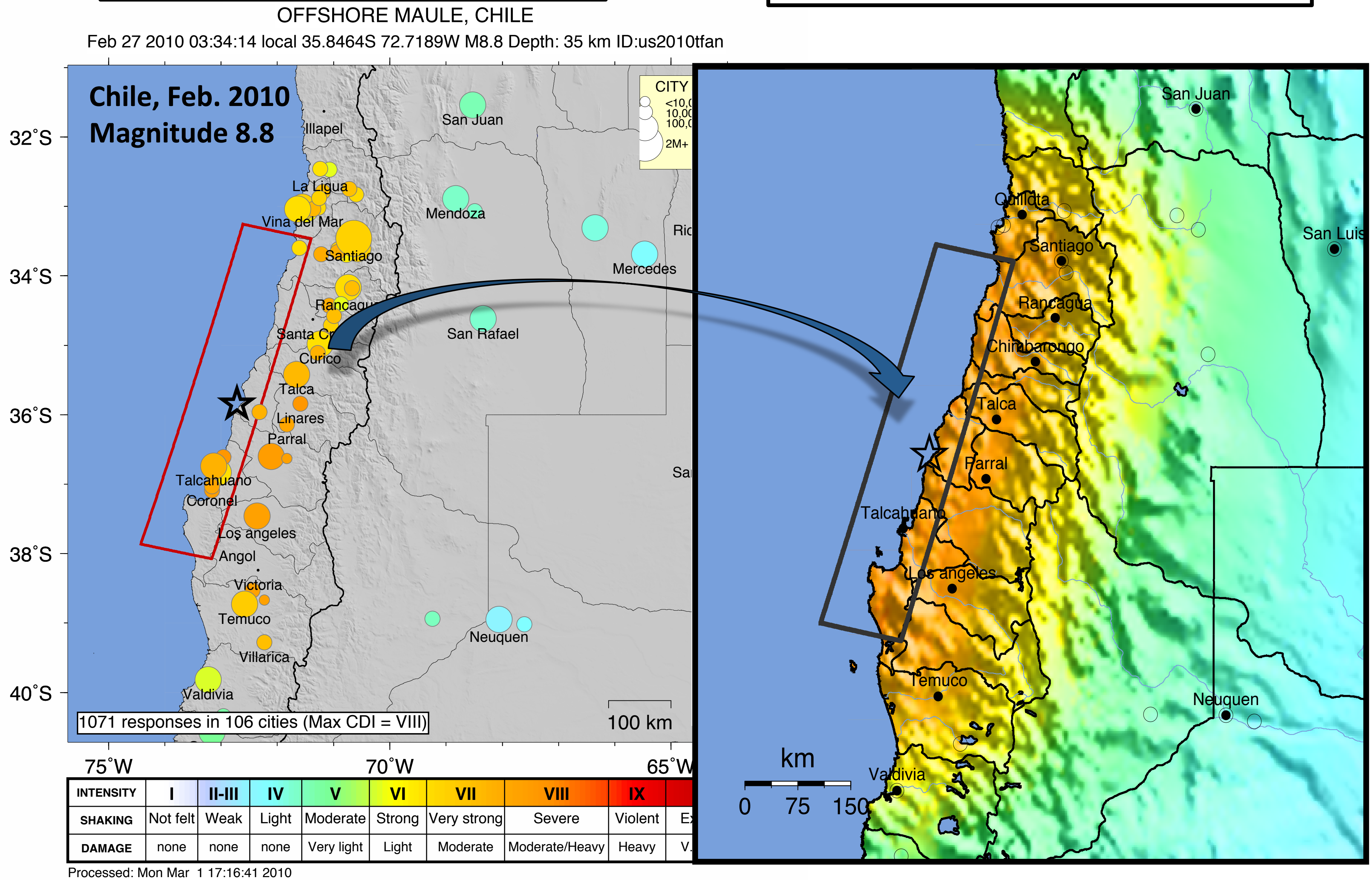




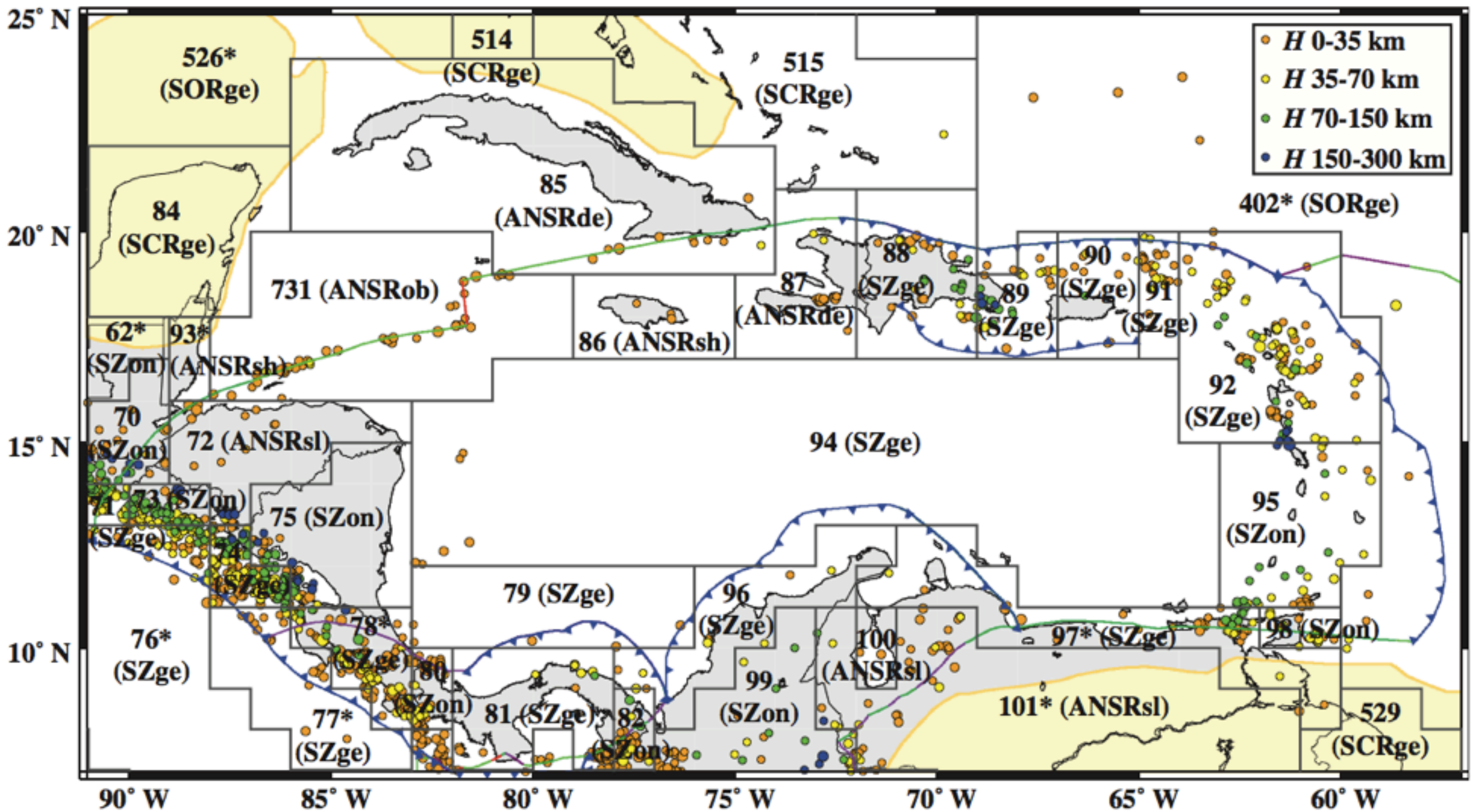
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	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?” Intensities

Global ShakeMap



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

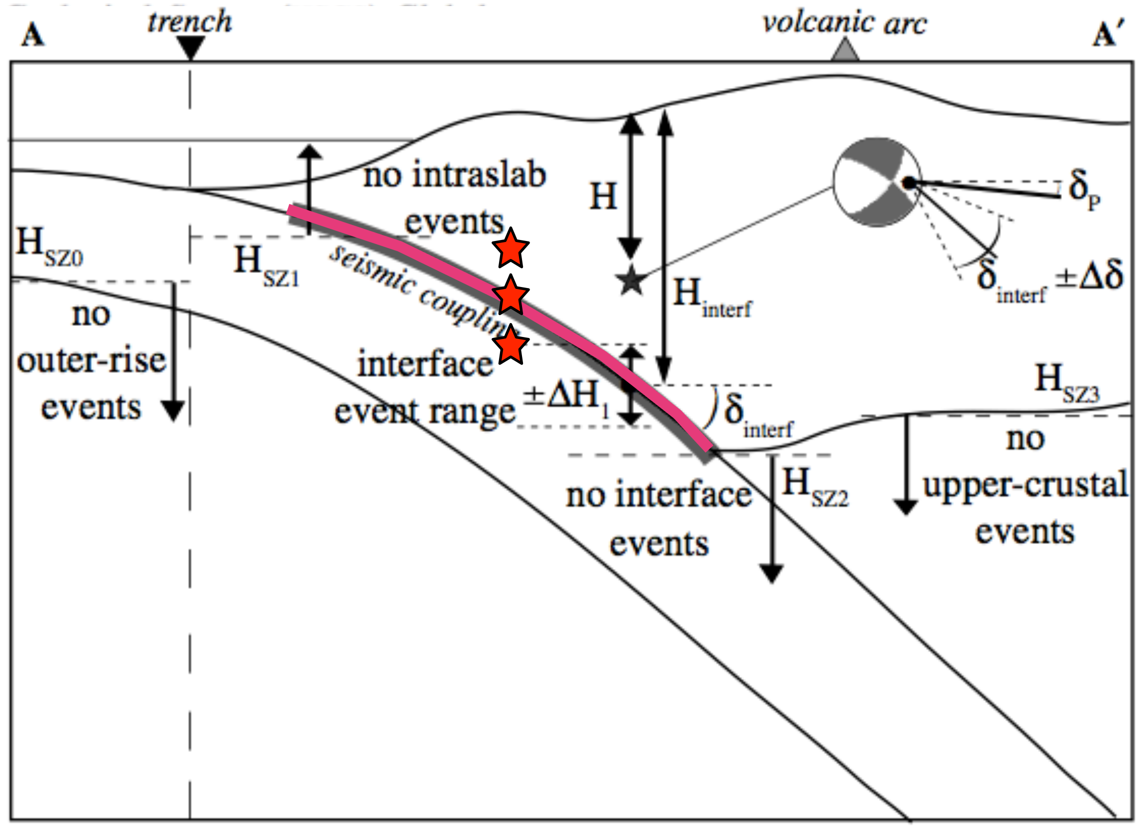
A Global Earthquake Discrimination Scheme to Optimize Ground-Motion Prediction Equation Selection

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

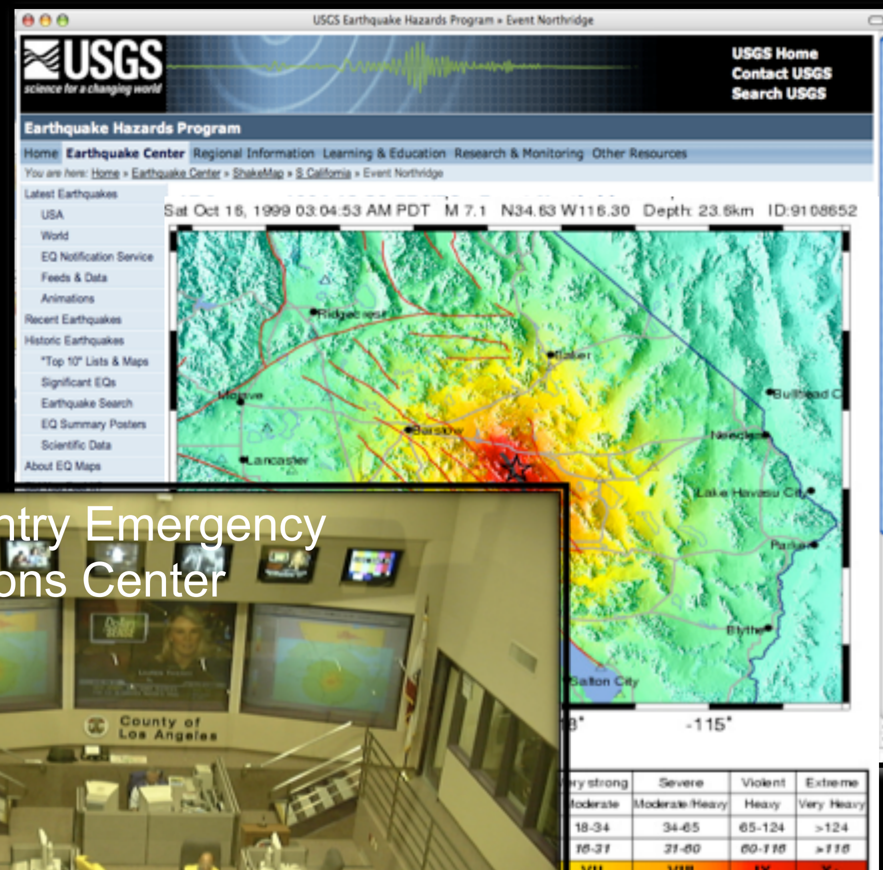
Online Material: Tables and figures summ
scheme and its performance.



What Are the Primary ShakeMap Uses?

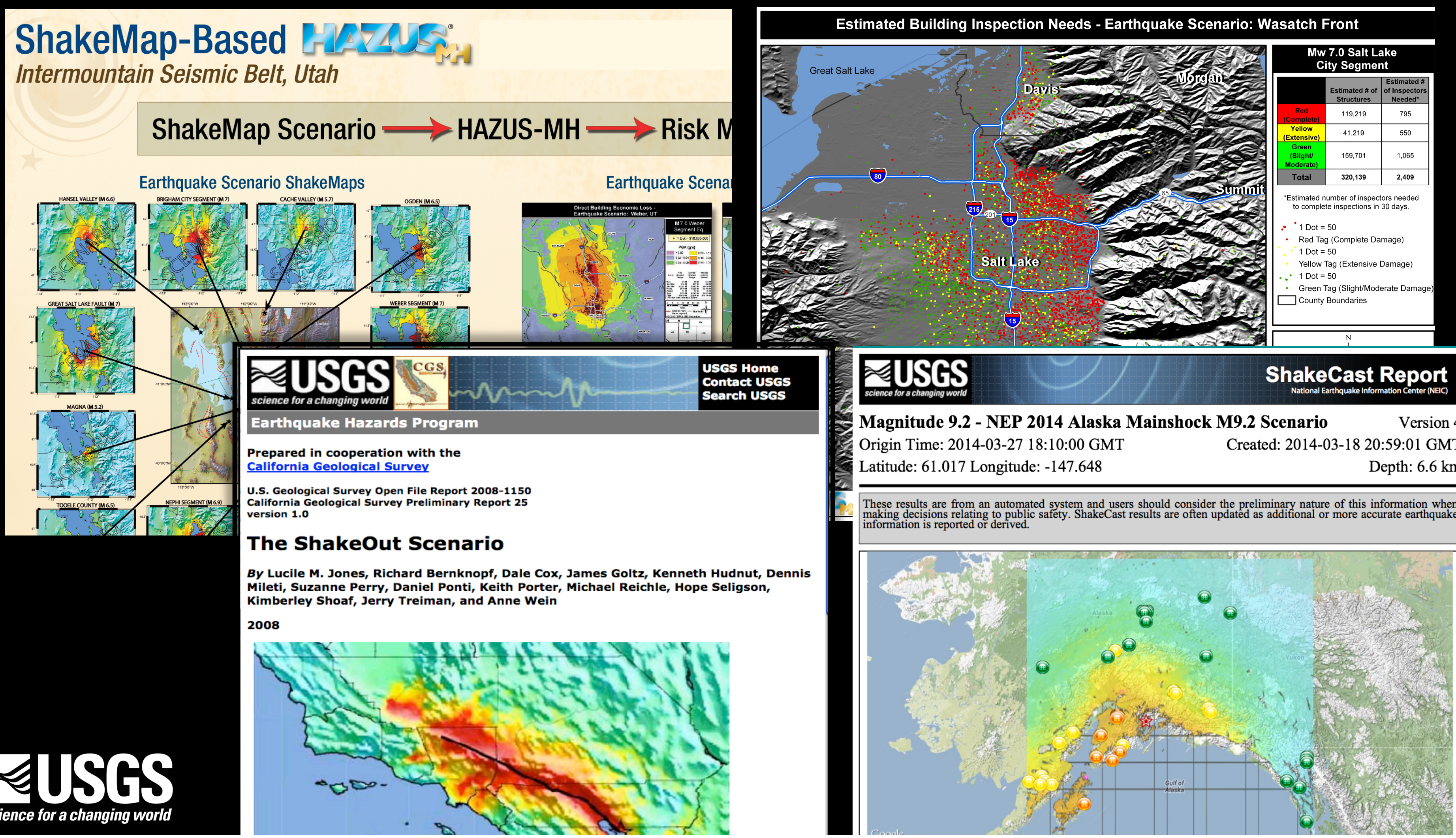
Rapid, post-earthquake response, coordination, & situational awareness…

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



What Are the Primary ShakeMap Uses?

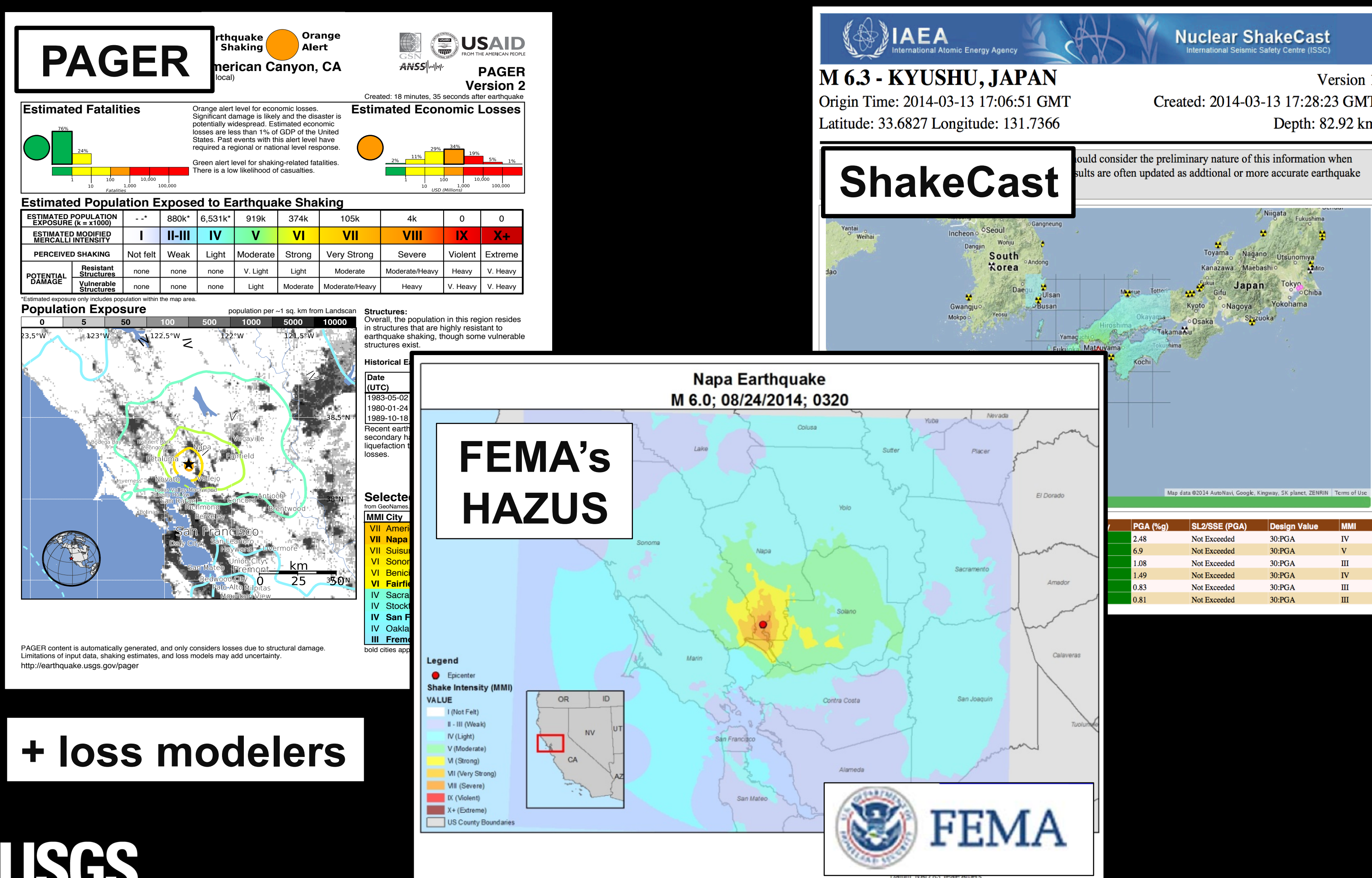
Mitigation thru earthquake scenarios (planning, response exercises, education) …



USGS science for a changing world

What Are the Primary ShakeMap Uses?

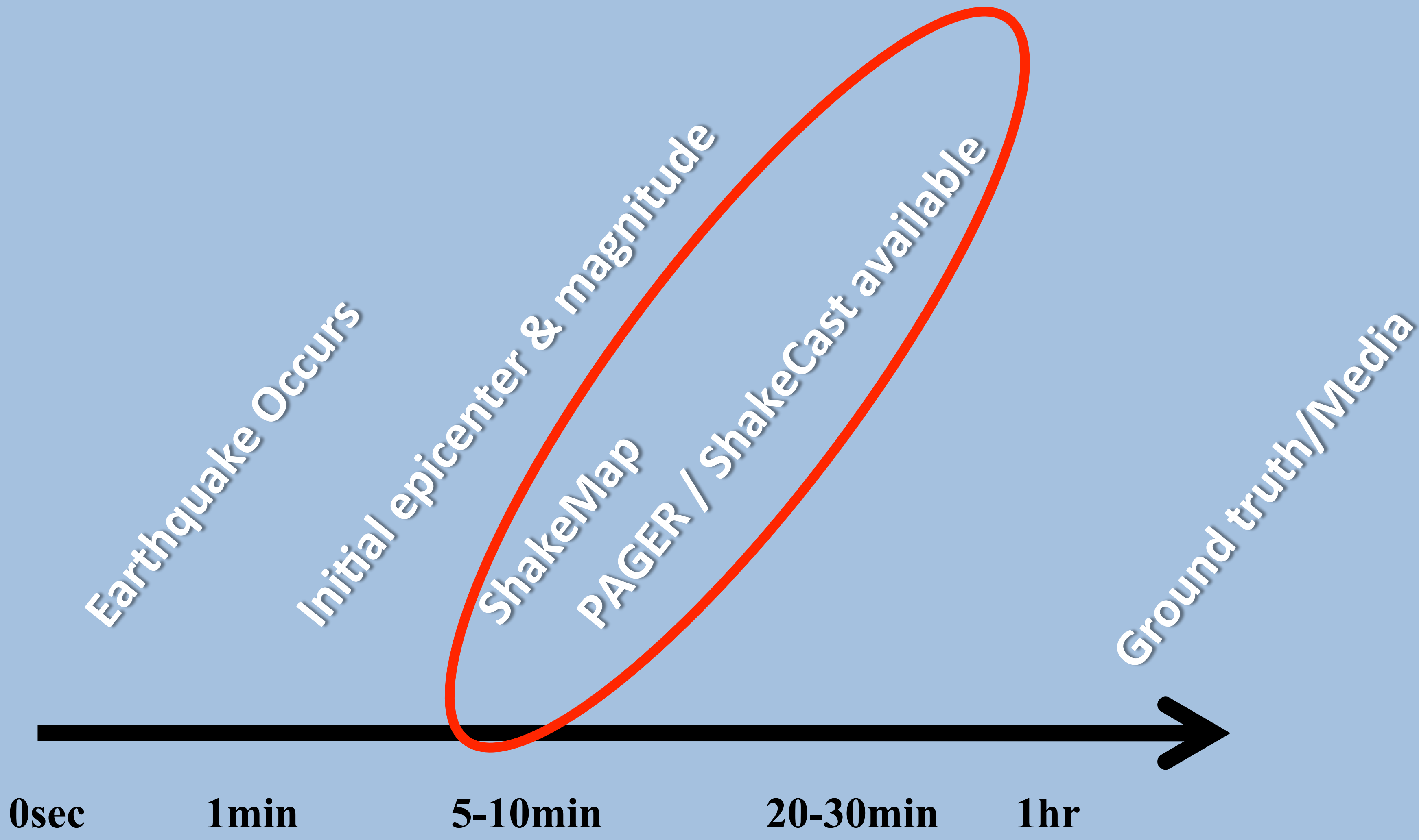
Enhanced post-earthquake loss-assessment…



+ loss modelers

USGS
science for a changing world

Earthquake Information Timeline



ShakeCast

What is ShakeCast?

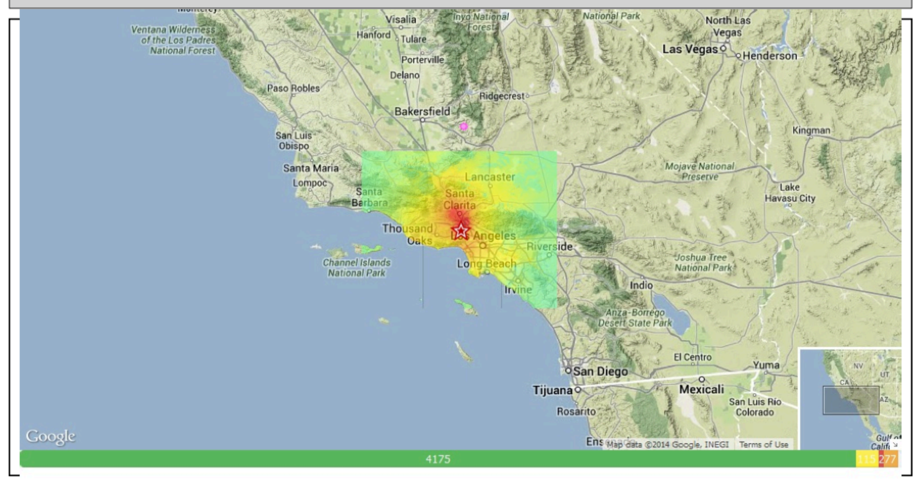
- Open-source USGS software.
- Automatically retrieves ShakeMap & compares shaking levels with unique facility fragilities.
- Generates web pages & hierarchical lists & maps of likely impacted facilities (right).
- Sends notifications to specified personnel/responders.
- Raises post-earthquake situational awareness; represents key information in first min to hrs following an event.

California Department of TRANSPORTATION

ShakeCast Report
National Earthquake Information Center (NEIC)

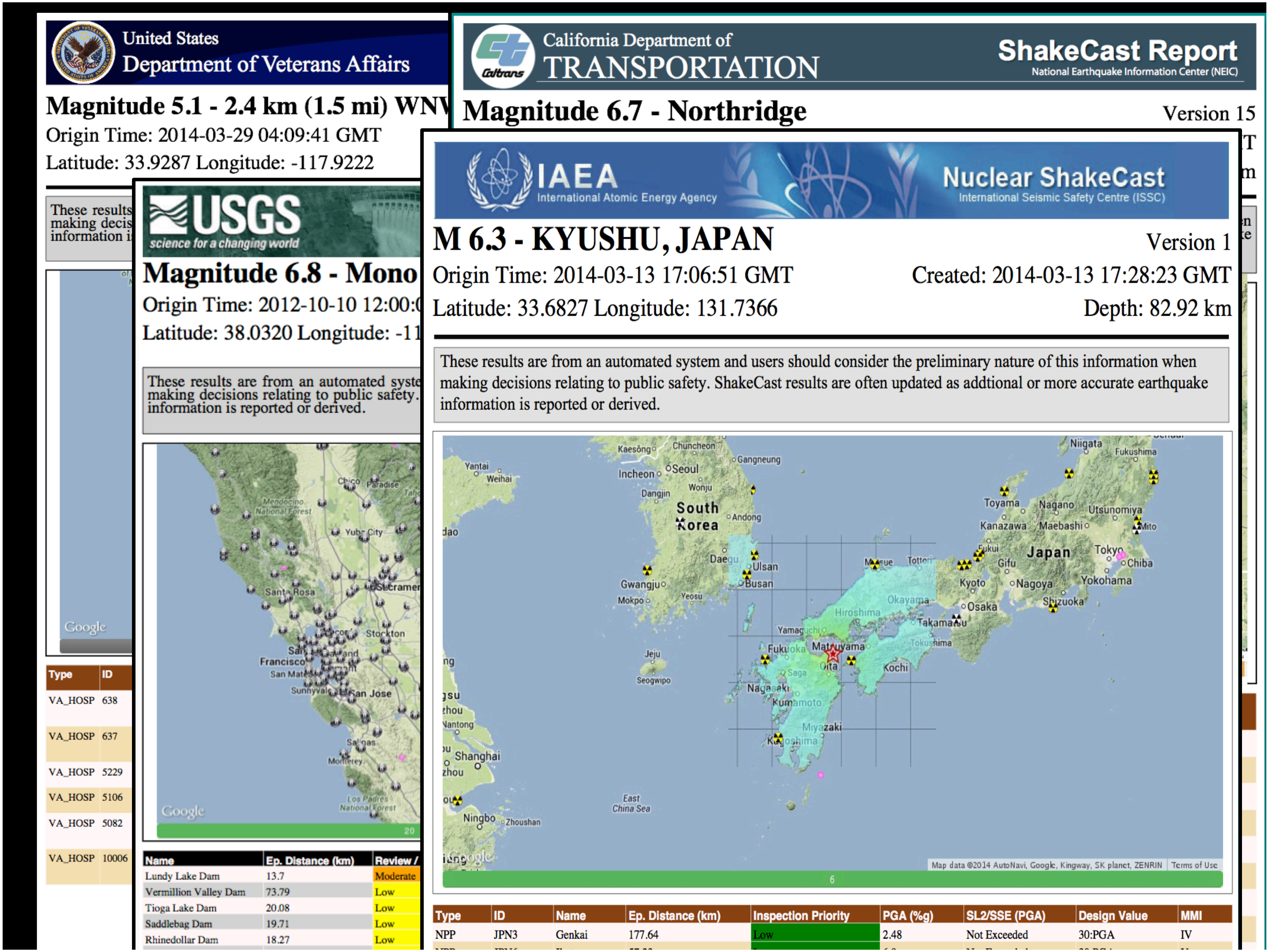
Magnitude 6.7 - Northridge Version 15
Origin Time: 1994-01-17 12:30:55 GMT Created: 2014-02-21 22:17:50 GMT
Latitude: 34.213 Longitude: -118.5357 Depth: 18 km

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.

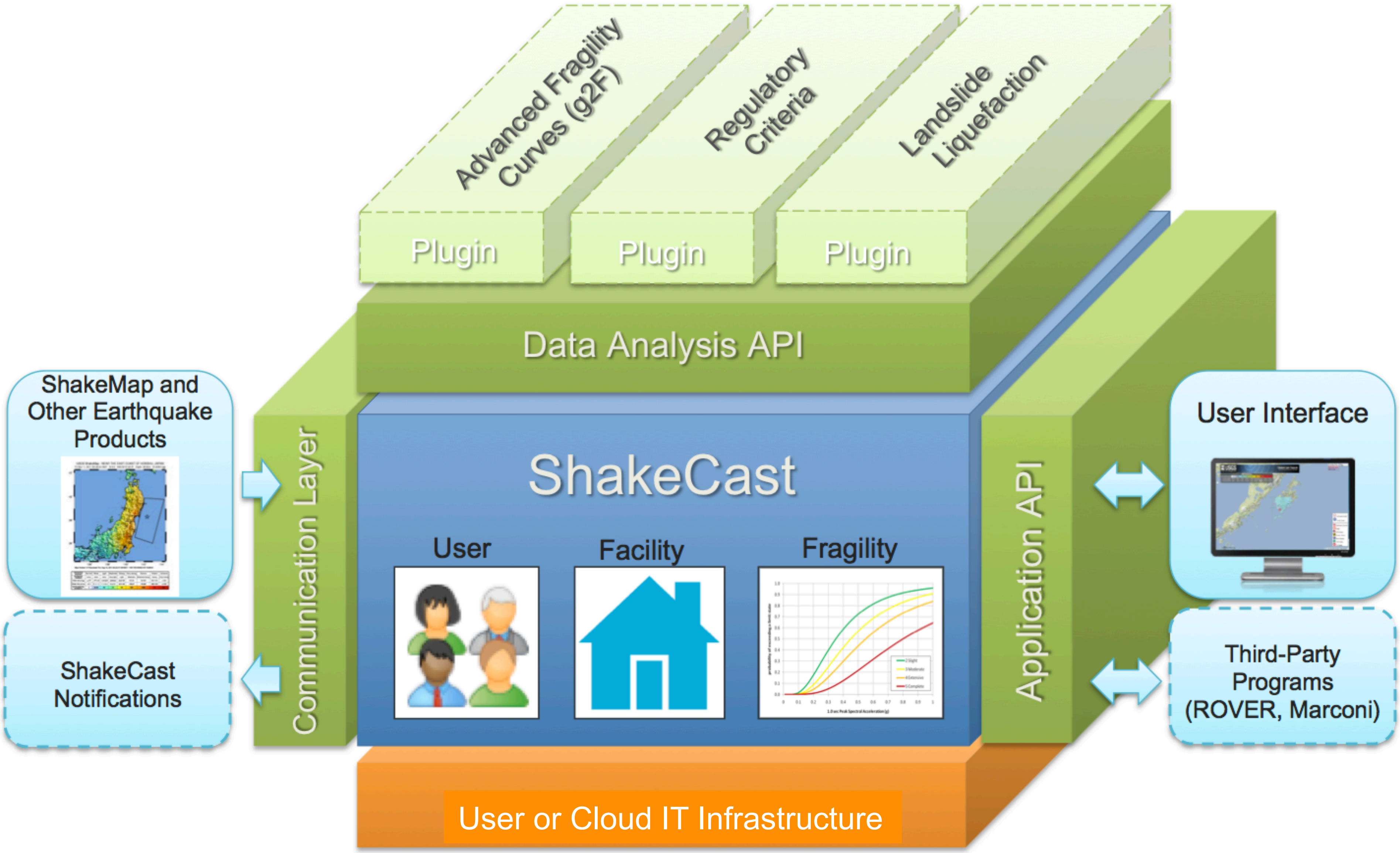


Type	ID	Name	Ep. Distance (km)	Inspection Priority	MMI	PGA (%g)	PGV (cm/s)	PSA .3s (%g)	PSA 1s (%g)	PSA 3s (%g)	Vs30 (m/s)
BRIDGE_ST	53 2794R	53 2794R - BULL CREEK CANYON CHANNEL	7.72	High	X+	75.9863	148.4741	189.1374	171.7947	28.8124	301
BRIDGE_ST	53 2794L	53 2794L - BULL CREEK CANYON CHANNEL	7.72	High	X+	75.9863	148.4741	189.1374	171.7947	28.8124	301
BRIDGE_ST	53 2793R	53 2793R - MISSION-GOTHIC UC	7.78	High	X+	79.3788	183.6967	169.894	198.7484	29.5617	464
BRIDGE_ST	53 2793L	53 2793L - MISSION-GOTHIC UC	7.78	High	X+	79.3788	183.6967	169.894	198.7484	29.5617	464
BRIDGE_ST	53 2217H	53 2217H - E118-S405 CONNECTOR UC	8.23	High	X+	77.1994	116.4843	205.812	140.0625	26.7054	301
BRIDGE_ST	53 2208	53 2208 - GAYNOR AVENUE UC	7.81	High	X+	75.9863	148.4741	189.1374	171.7947	28.8124	301
BRIDGE_ST	53 2207	53 2207 - WOODLEY AVENUE UC	7.68	High	X+	75.9863	148.4741	189.1374	171.7947	28.8124	301
BRIDGE_ST	53 2204	53 2204 - HAYVENHURST AVENUE UC	7.9	High	X+	79.3788	183.6967	169.894	198.7484	29.5617	464
BRIDGE_ST	53 2016R	53 2016R - FOOTHILL BLVD UC	12.67	High	IX	77.3149	111.3801	132.0711	129.9639	36.4198	301

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


United States
Department of Veterans Affairs
Magnitude 5.1 - 2.4 km (1.5 mi) WNW
Origin Time: 2014-03-29 04:09:41 GMT
Latitude: 33.9287 Longitude: -117.9222
These results
making decis
information i
Type
ID
VA_HOSP 638
VA_HOSP 637
VA_HOSP 5229
VA_HOSP 5106
VA_HOSP 5082
VA_HOSP 10006
USGS
science for a changing world
Magnitude 6.8 - Mono
Origin Time: 2012-10-10 12:00:0
Latitude: 38.0320 Longitude: -11
These results are from an automated syste
making decisions relating to public safety.
information is reported or derived.
Name | Ep. Distance (km) | Review /
Lundy Lake Dam | 13.7 | Moderate
Vermillion Valley Dam | 73.79 | Low
Tioga Lake Dam | 20.08 | Low
Saddlebag Dam | 19.71 | Low
Rhinedollar Dam | 18.27 | Low
California Department of
TRANSPORTATION
Caltrans
ShakeCast Report
National Earthquake Information Center (NEIC)
Magnitude 6.7 - Northridge
Version 15
IAEA
International Atomic Energy Agency
Nuclear ShakeCast
International Seismic Safety Centre (ISSC)
M 6.3 - KYUSHU, JAPAN
Version 1
Origin Time: 2014-03-13 17:06:51 GMT
Created: 2014-03-13 17:28:23 GMT
Latitude: 33.6827 Longitude: 131.7366
Depth: 82.92 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 addtional or more accurate earthquake information is reported or derived.
South Korea
Japan
East China Sea
Map data ©2014 AutoNavi, Google, Kingway, SK planet, ZENRIN
Terms of Use
Type | ID | Name | Ep. Distance (km) | Inspection Priority | PGA (%g) | SL2/SSE (PGA) | Design Value | MMI
NPP | JPN3 | Genkai | 177.64 | Low | 2.48 | Not Exceeded | 30:PGA | IV

ShakeCast Software: “primarily a database”



ShakeCast Cloud Workflow

Create an Amazon Cloud (AWS) Account, get approval, & load the ShakeCast Instance

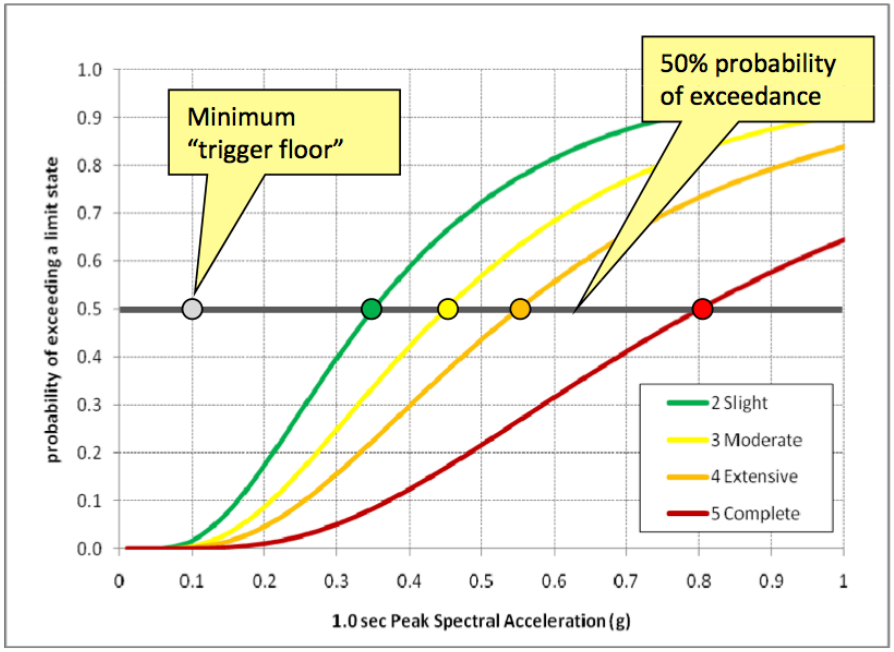
Configure access/security settings

Input inventory, fragility, & notification databases (drag & drop)

Customize your monitoring regions, user notifications, products, & GUI

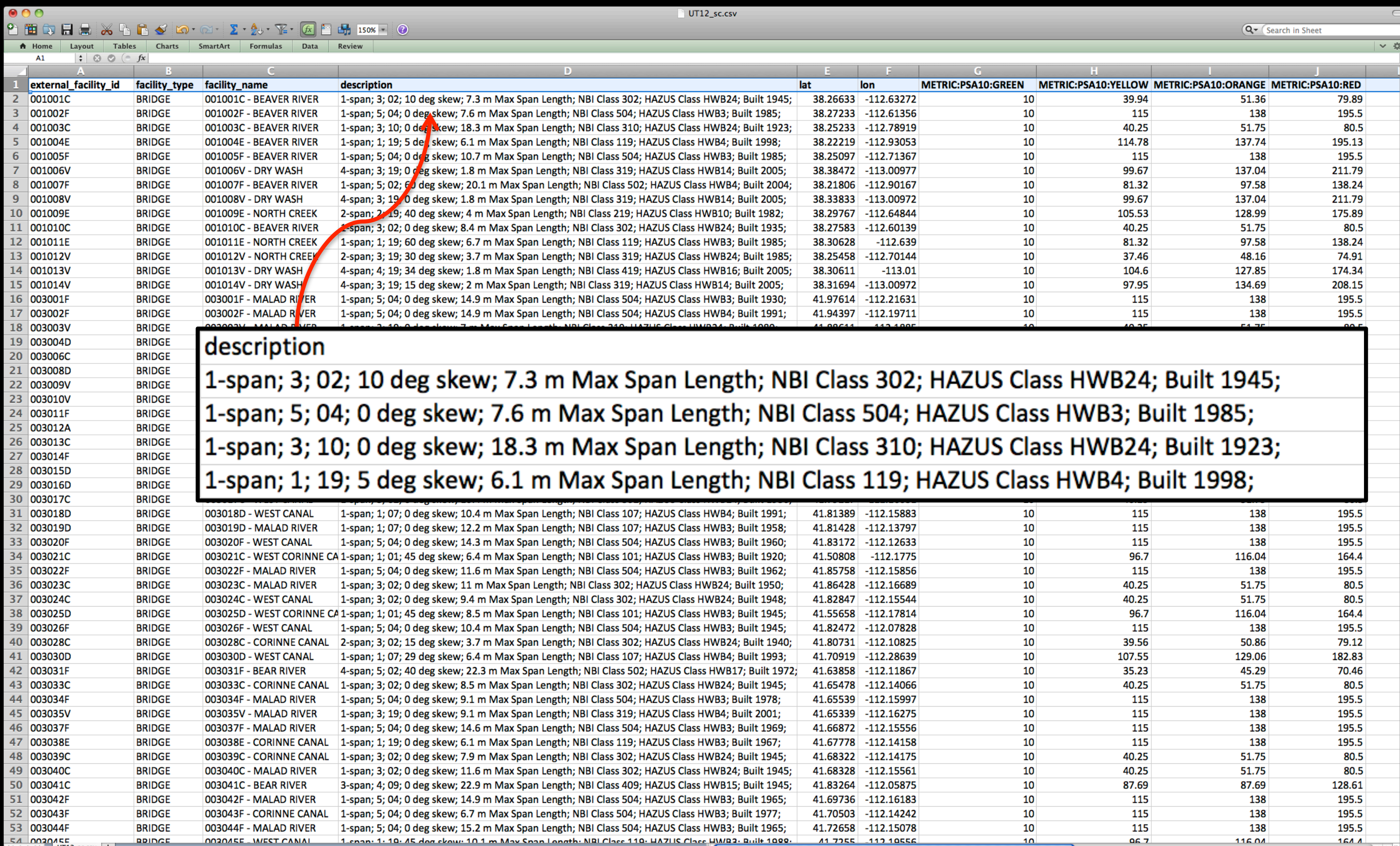
Bridge Fragility

- Bridge fragility method is based upon work originally published by Basöz and Mander.
- Method was implemented in FEMA's HAZUS-MH software.
- Uses data from National Bridge Inventory (NBI) as inputs:
  - Year built
  - Year improved or retrofit
  - Angle of skew
  - Bridge type
  - Number of spans
  - Maximum span length
  - Total bridge length
  - Deck width



L. Turner, Caltrans

Federal Highway (FHWA)/DOT National Bridge Inventory (NBI) → ShakeCast Fragility look-up tables



UT12_sc.csv

	external_facility_id	facility_type	facility_name	description	lat	lon	METRIC:PSA10:GREEN	METRIC:PSA10:YELLOW	METRIC:PSA10:ORANGE	METRIC:PSA10:RED
2	001001C	BRIDGE	001001C - BEAVER RIVER	1-span; 3; 02; 10 deg skew; 7.3 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1945;	38.26633	-112.63272	10	39.94	51.36	79.89
3	001002F	BRIDGE	001002F - BEAVER RIVER	1-span; 5; 04; 0 deg skew; 7.6 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1985;	38.27233	-112.61356	10	115	138	195.5
4	001003C	BRIDGE	001003C - BEAVER RIVER	1-span; 3; 10; 0 deg skew; 18.3 m Max Span Length; NBI Class 310; HAZUS Class HWB24; Built 1923;	38.25233	-112.78919	10	40.25	51.75	80.5
5	001004E	BRIDGE	001004E - BEAVER RIVER	1-span; 1; 19; 5 deg skew; 6.1 m Max Span Length; NBI Class 119; HAZUS Class HWB4; Built 1998;	38.22219	-112.93053	10	114.78	137.74	195.13
6	001005F	BRIDGE	001005F - BEAVER RIVER	1-span; 5; 04; 0 deg skew; 10.7 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1985;	38.25097	-112.71367	10	115	138	195.5
7	001006V	BRIDGE	001006V - DRY WASH	4-span; 3; 19; 0 deg skew; 1.8 m Max Span Length; NBI Class 319; HAZUS Class HWB14; Built 2005;	38.38472	-113.00977	10	99.67	137.04	211.79
8	001007F	BRIDGE	001007F - BEAVER RIVER	1-span; 5; 02; 60 deg skew; 20.1 m Max Span Length; NBI Class 502; HAZUS Class HWB4; Built 2004;	38.21806	-112.90167	10	81.32	97.58	138.24
9	001008V	BRIDGE	001008V - DRY WASH	4-span; 3; 19; 0 deg skew; 1.8 m Max Span Length; NBI Class 319; HAZUS Class HWB14; Built 2005;	38.33833	-113.00972	10	99.67	137.04	211.79
10	001009E	BRIDGE	001009E - NORTH CREEK	2-span; 2; 19; 40 deg skew; 4 m Max Span Length; NBI Class 219; HAZUS Class HWB10; Built 1982;	38.29767	-112.64844	10	105.53	128.99	175.89
11	001010C	BRIDGE	001010C - BEAVER RIVER	1-span; 3; 02; 0 deg skew; 8.4 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1935;	38.27583	-112.60139	10	40.25	51.75	80.5
12	001011E	BRIDGE	001011E - NORTH CREEK	1-span; 1; 19; 60 deg skew; 6.7 m Max Span Length; NBI Class 119; HAZUS Class HWB3; Built 1985;	38.30628	-112.639	10	81.32	97.58	138.24
13	001012V	BRIDGE	001012V - NORTH CREEK	2-span; 3; 19; 30 deg skew; 3.7 m Max Span Length; NBI Class 319; HAZUS Class HWB24; Built 1985;	38.25458	-112.70144	10	37.46	48.16	74.91
14	001013V	BRIDGE	001013V - DRY WASH	4-span; 4; 19; 34 deg skew; 1.8 m Max Span Length; NBI Class 419; HAZUS Class HWB16; Built 2005;	38.30611	-113.01	10	104.6	127.85	174.34
15	001014V	BRIDGE	001014V - DRY WASH	4-span; 3; 19; 15 deg skew; 2 m Max Span Length; NBI Class 319; HAZUS Class HWB14; Built 2005;	38.31694	-113.00972	10	97.95	134.69	208.15
16	003001F	BRIDGE	003001F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 14.9 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1930;	41.97614	-112.21631	10	115	138	195.5
17	003002F	BRIDGE	003002F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 14.9 m Max Span Length; NBI Class 504; HAZUS Class HWB4; Built 1991;	41.94397	-112.19711	10	115	138	195.5
18	003003V	BRIDGE								
19	003004D	BRIDGE								
20	003006C	BRIDGE								
21	003008D	BRIDGE								
22	003009V	BRIDGE								
23	003010V	BRIDGE								
24	003011F	BRIDGE								
25	003012A	BRIDGE								
26	003013C	BRIDGE								
27	003014F	BRIDGE								
28	003015D	BRIDGE								
29	003016D	BRIDGE								
30	003017C	BRIDGE								
31	003018D	BRIDGE	003018D - WEST CANAL	1-span; 1; 07; 0 deg skew; 10.4 m Max Span Length; NBI Class 107; HAZUS Class HWB4; Built 1991;	41.81389	-112.15883	10	115	138	195.5
32	003019D	BRIDGE	003019D - MALAD RIVER	1-span; 1; 07; 0 deg skew; 12.2 m Max Span Length; NBI Class 107; HAZUS Class HWB3; Built 1958;	41.81428	-112.13797	10	115	138	195.5
33	003020F	BRIDGE	003020F - WEST CANAL	1-span; 5; 04; 0 deg skew; 14.3 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1960;	41.83172	-112.12633	10	115	138	195.5
34	003021C	BRIDGE	003021C - WEST CORINNE CA	1-span; 1; 01; 45 deg skew; 6.4 m Max Span Length; NBI Class 101; HAZUS Class HWB3; Built 1920;	41.50808	-112.1775	10	96.7	116.04	164.4
35	003022F	BRIDGE	003022F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 11.6 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1962;	41.85758	-112.15856	10	115	138	195.5
36	003023C	BRIDGE	003023C - MALAD RIVER	1-span; 3; 02; 0 deg skew; 11 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1950;	41.86428	-112.16689	10	40.25	51.75	80.5
37	003024C	BRIDGE	003024C - WEST CANAL	1-span; 3; 02; 0 deg skew; 9.4 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1948;	41.82847	-112.15544	10	40.25	51.75	80.5
38	003025D	BRIDGE	003025D - WEST CORINNE CA	1-span; 1; 01; 45 deg skew; 8.5 m Max Span Length; NBI Class 101; HAZUS Class HWB3; Built 1945;	41.55658	-112.17814	10	96.7	116.04	164.4
39	003026F	BRIDGE	003026F - WEST CANAL	1-span; 5; 04; 0 deg skew; 10.4 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1945;	41.82472	-112.07828	10	115	138	195.5
40	003028C	BRIDGE	003028C - CORINNE CANAL	2-span; 3; 02; 15 deg skew; 3.7 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1940;	41.80731	-112.10825	10	39.56	50.86	79.12
41	003030D	BRIDGE	003030D - WEST CANAL	1-span; 1; 07; 29 deg skew; 6.4 m Max Span Length; NBI Class 107; HAZUS Class HWB4; Built 1993;	41.70919	-112.28639	10	107.55	129.06	182.83
42	003031F	BRIDGE	003031F - BEAR RIVER	4-span; 5; 02; 40 deg skew; 22.3 m Max Span Length; NBI Class 502; HAZUS Class HWB17; Built 1972;	41.63858	-112.11867	10	35.23	45.29	70.46
43	003033C	BRIDGE	003033C - CORINNE CANAL	1-span; 3; 02; 0 deg skew; 8.5 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1945;	41.65478	-112.14066	10	40.25	51.75	80.5
44	003034F	BRIDGE	003034F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 9.1 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1978;	41.65539	-112.15997	10	115	138	195.5
45	003035V	BRIDGE	003035V - MALAD RIVER	1-span; 3; 19; 0 deg skew; 9.1 m Max Span Length; NBI Class 319; HAZUS Class HWB4; Built 2001;	41.65339	-112.16275	10	115	138	195.5
46	003037F	BRIDGE	003037F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 14.6 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1969;	41.66872	-112.15556	10	115	138	195.5
47	003038E	BRIDGE	003038E - CORINNE CANAL	1-span; 1; 19; 0 deg skew; 6.1 m Max Span Length; NBI Class 119; HAZUS Class HWB3; Built 1967;	41.67778	-112.14158	10	115	138	195.5
48	003039C	BRIDGE	003039C - CORINNE CANAL	1-span; 3; 02; 0 deg skew; 7.9 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1945;	41.68322	-112.14175	10	40.25	51.75	80.5
49	003040C	BRIDGE	003040C - MALAD RIVER	1-span; 3; 02; 0 deg skew; 11.6 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1945;	41.68328	-112.15561	10	40.25	51.75	80.5
50	003041C	BRIDGE	003041C - BEAR RIVER	3-span; 4; 09; 0 deg skew; 22.9 m Max Span Length; NBI Class 409; HAZUS Class HWB15; Built 1945;	41.83264	-112.05875	10	87.69	87.69	128.61
51	003042F	BRIDGE	003042F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 14.9 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1965;	41.69736	-112.16183	10	115	138	195.5
52	003043F	BRIDGE	003043F - CORINNE CANAL	1-span; 5; 04; 0 deg skew; 6.7 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1977;	41.70503	-112.14242	10	115	138	195.5
53	003044F	BRIDGE	003044F - MALAD RIVER	1-span; 5; 04; 0 deg skew; 15.2 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1965;	41.72658	-112.15078	10	115	138	195.5

description
1-span; 3; 02; 10 deg skew; 7.3 m Max Span Length; NBI Class 302; HAZUS Class HWB24; Built 1945;
1-span; 5; 04; 0 deg skew; 7.6 m Max Span Length; NBI Class 504; HAZUS Class HWB3; Built 1985;
1-span; 3; 10; 0 deg skew; 18.3 m Max Span Length; NBI Class 310; HAZUS Class HWB24; Built 1923;
1-span; 1; 19; 5 deg skew; 6.1 m Max Span Length; NBI Class 119; HAZUS Class HWB4; Built 1998;

DIVISION OF RESEARCH AND INNOVATION

Caltrans

I-TEAM BRIEF

The Innovation Team (I-Team) at the Caltrans Division of Research and Innovation, in cooperation with its partners, develops proven, ready-to-deploy innovations in methods, materials, and technologies that enable Caltrans to provide the most effective management of public services, resources, and infrastructure.

SEPTEMBER 2010

Updated: October 2010

ShakeCast

A post-earthquake decision-making and rapid-response tool

After a major earthquake, one of Caltrans' most critical tasks is to assess the impact on the condition of all bridges and roadway corridors in the state highway system. Timely response ensures public safety, guides emergency vehicle traffic, and reestablishes critical lifeline routes. Without sufficient data, initial reconnaissance takes up precious time. ***The Caltrans I-Team adopted ShakeCast, a tool that uses data from an earthquake event to support rapid post-earthquake response.***

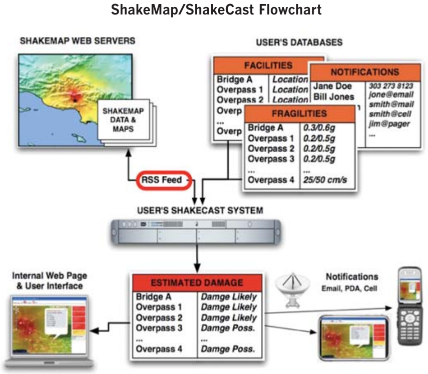
READY TO DEPLOY

ShakeCast is a Web-based application that automatically retrieves measured earthquake shaking data and analyzes the data in relation to individual bridge performance characteristics. By focusing inspection efforts on the most damage-susceptible infrastructure in the most severely shaken areas, ShakeCast has drastically reduced Caltrans' response time to assess potentially damaged structures after an earthquake.

NEW AND IMPROVED

- Retrieves measured shaking data within minutes after an earthquake.
- Compares shaking distribution with unique bridge vulnerabilities.
- Provides hierarchical lists and maps of bridges most likely impacted.
- Emails bridge and facility location and inspection priority information to responders within 15 minutes following events with a magnitude greater than 4.0.
- Automatically generates products for direct use in Google Earth®, ArcGIS®, and Excel®.
- Provides a suite of tools on ShakeCast website.

ShakeMap/ShakeCast Flowchart



Performance of the Caltrans ShakeCast System in the 2014 Napa M6.0 Earthquake

September 19, 2014

Prepared by:

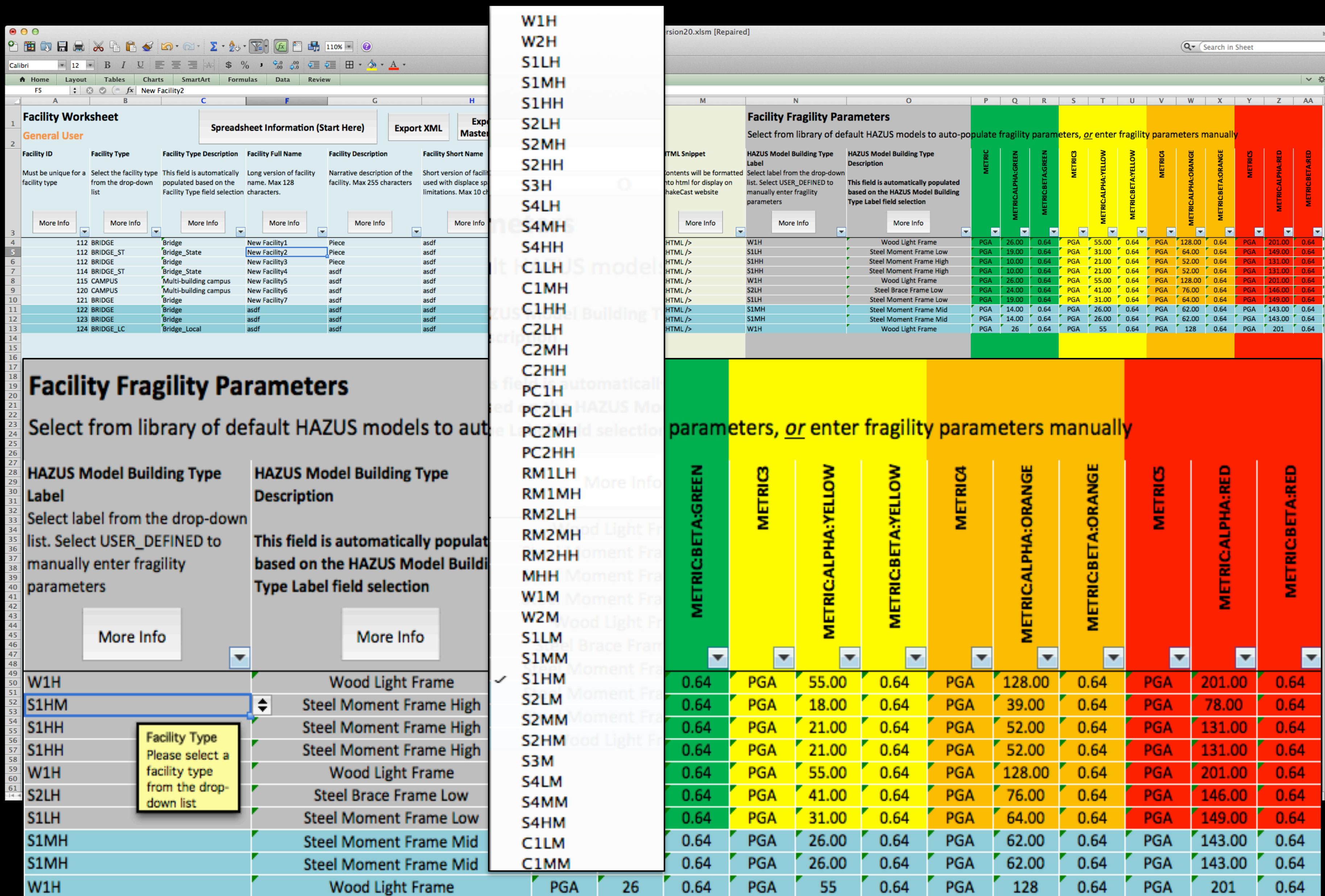
Loren L. Turner, P.E.
Division of Research, Innovation & System Information
5900 Folsom Blvd, MS-5, Sacramento, CA 95819
loren.turner@dot.ca.gov

Caltrans

DRISI

Caltrans Division of Research, Innovation and System Information

ShakeCast Import Spreadsheet

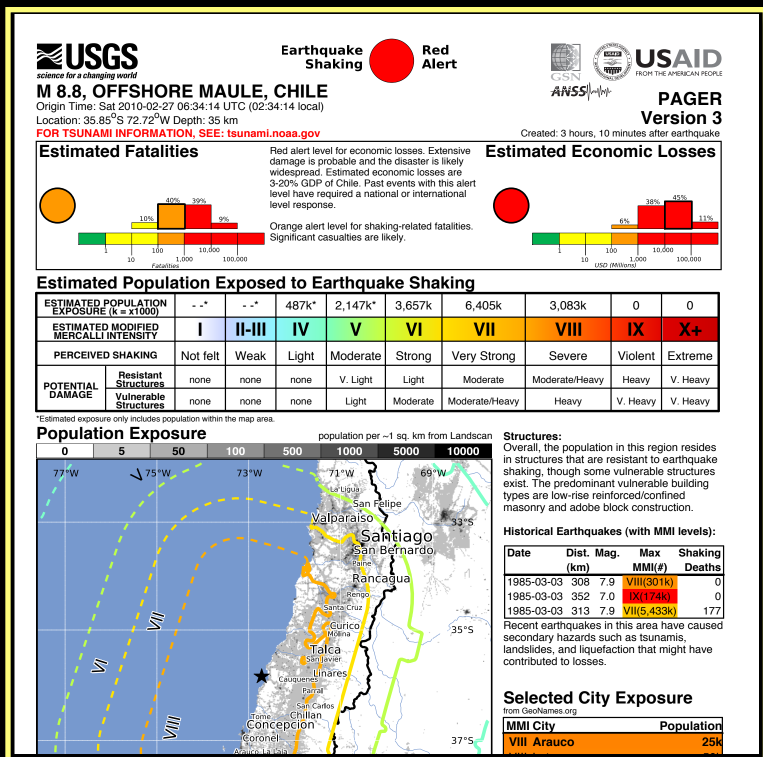


Example ShakeCast User Sectors, Users, Facility Types & Uses

Critical Facilities	U.S. Nuclear Regulatory Commission (**USNRC**)	U.S. Nuclear Power Plants (NPP)	Awareness of regulatory shaking thresholds at domestic NPPs
	International Atomic Energy Agency (**IAEA**)	Global Nuclear Power Plants (NPP)	Awareness of shaking at NPPs for IAEA's External Event Notification System at International Seismic Safety Center, Vienna
	Veteran's Administration (**VA**)	VA Hospitals	Alerts sent to specific responsible personnel
	California's Office of Statewide Health Planning and Development (**OSHPD**)	California's Healthcare infrastructure	Notification to engineering experts
Transportation	California Department of Transportation (**Caltrans**)	20,000 overpasses & bridges statewide	Prioritize bridge inspection; Alert >300 engineers, inspectors, maintenance crews
	Port of Long Beach (**POLB**)	Port infrastructure & utilities	Activate incident management for rapid inspections; work-around strategies for impacted infrastructure; ensure POLB remains open for business
Lifelines/Utilities	Los Angeles Dept. of Power & Water (**LADPW**)	Over 5000 county facilities, including dams, water tanks, buildings, & survey monuments.	Used by the Earthquake Bridge Inspection Teams to prioritize inspections; >150 administrators, inspectors, engineers, & coordinators receive structure reports.
	East Bay Metro. Utility District (**EBMUD**)	100's of dams, pipelines, control buildings, & facility structures	
Private/Business	**Walmart**	4,200 retail outlets,148 distri-bution centers, 50 corporate facilities; 1.6M associates	Situational awareness for emergency operations; "Taking care of our people, operations, communities"
	Target	1700+ Locations	Rapid reporting of earthquake damage potential, prioritization of assessment and inspection
Education	LA Unified School District (**LAUSD**)	1096 Schools/Office locations serving 740,000 students; 80,000 employees	Generate priority list for inspection; schools that can receive displaced students; clarify locations for Red Cross Shelters.
	University of Southern California (**USC**)	Campus buildings	
Engineering	Degenkolb Engineering	Hospitals, varied engineered structures	Post earthquake inspection, priorities, as a customer service
	ImageCat, Inc.	varied engineered portfolios	trigger in-house loss-estimation software as customer service

PAGER

Prompt Assessment of Global Earthquakes for Response


USGS
science for a changing world
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

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
POTENTIAL DAMAGE: 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. 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

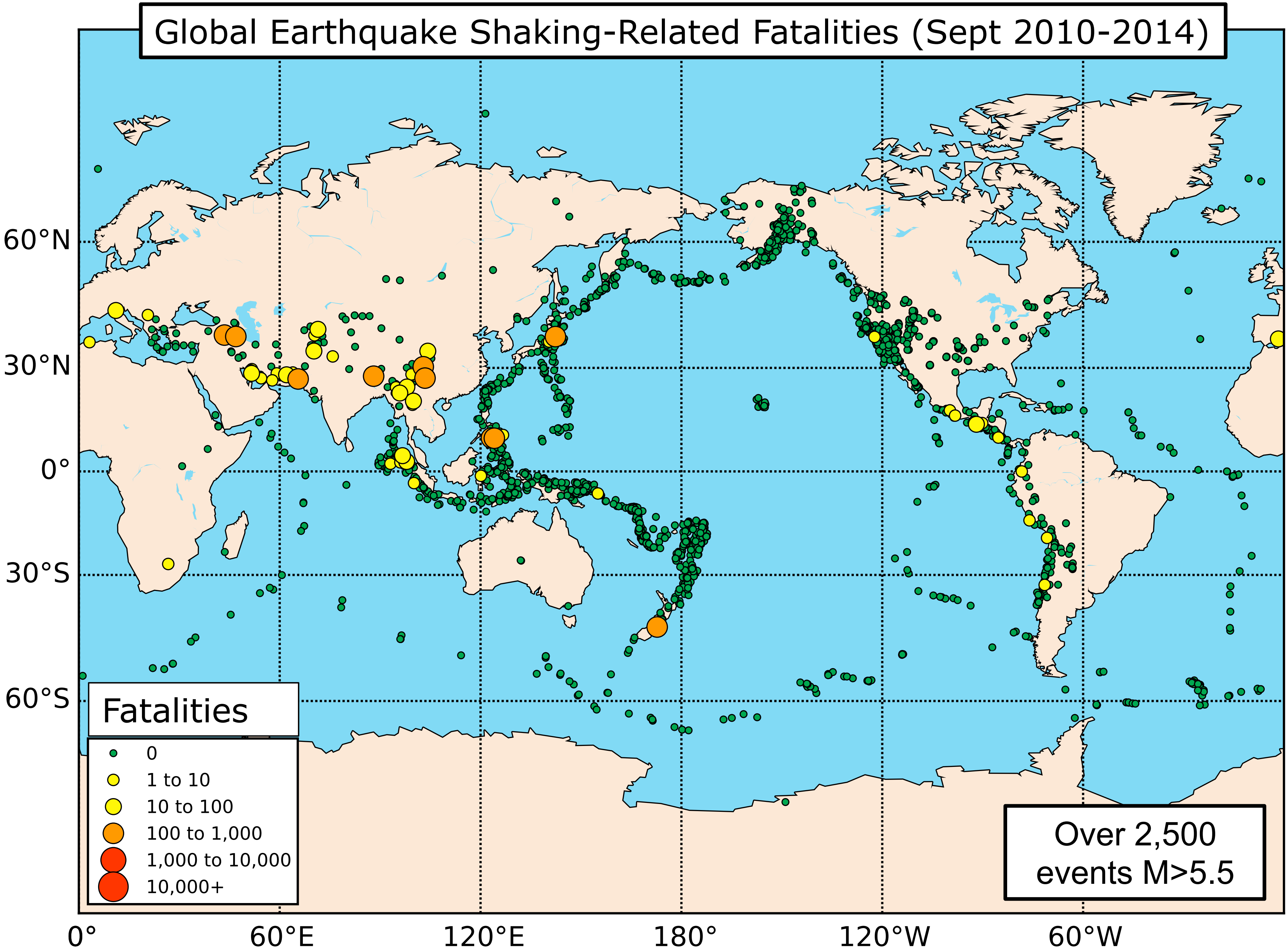
Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and liquefaction that might have contributed to losses.

Selected City Exposure
from GeoNames.org

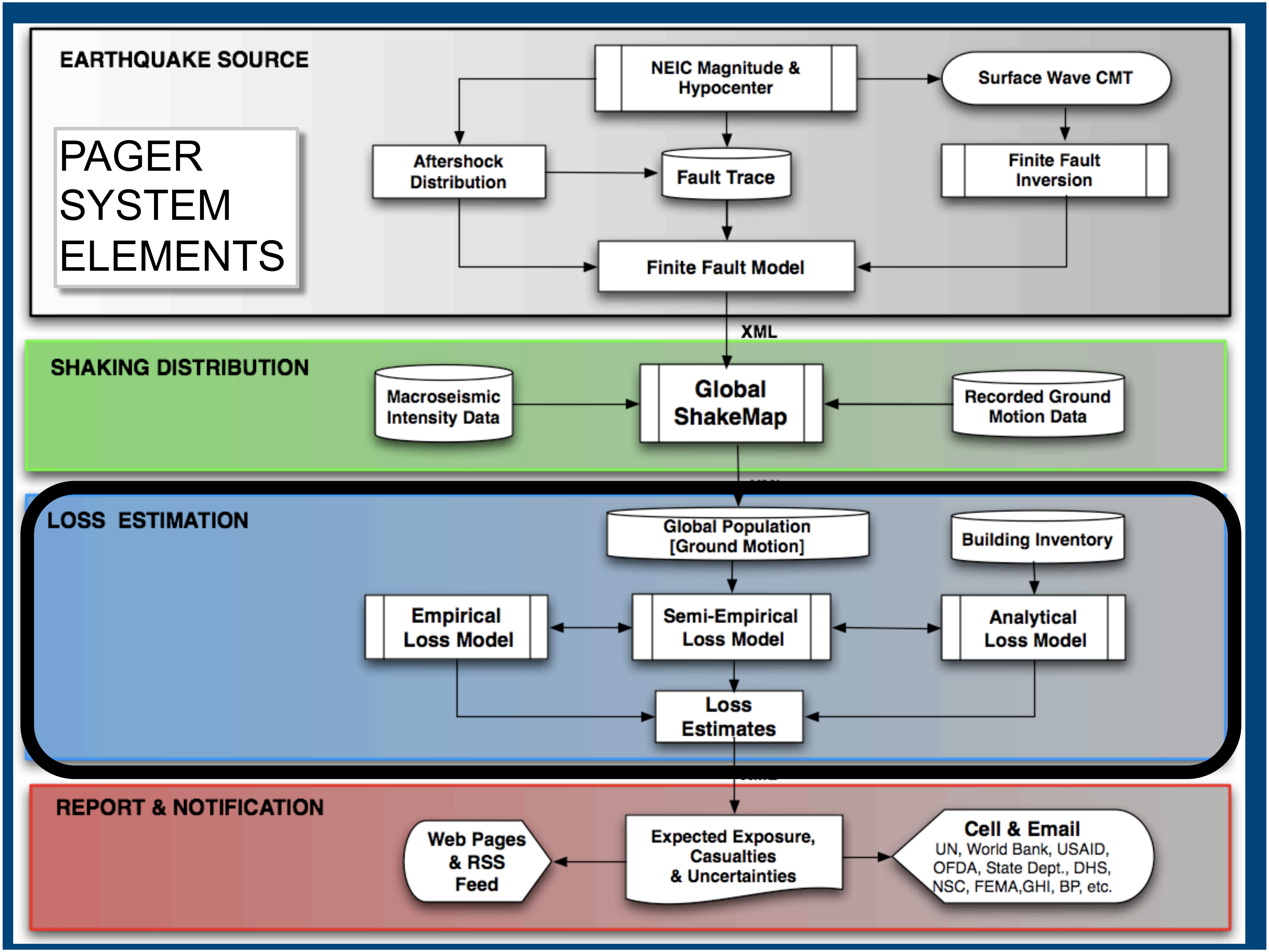
MMI City	Population
VIII Arauco	25k

USGS

USAID
FROM THE AMERICAN PEOPLE

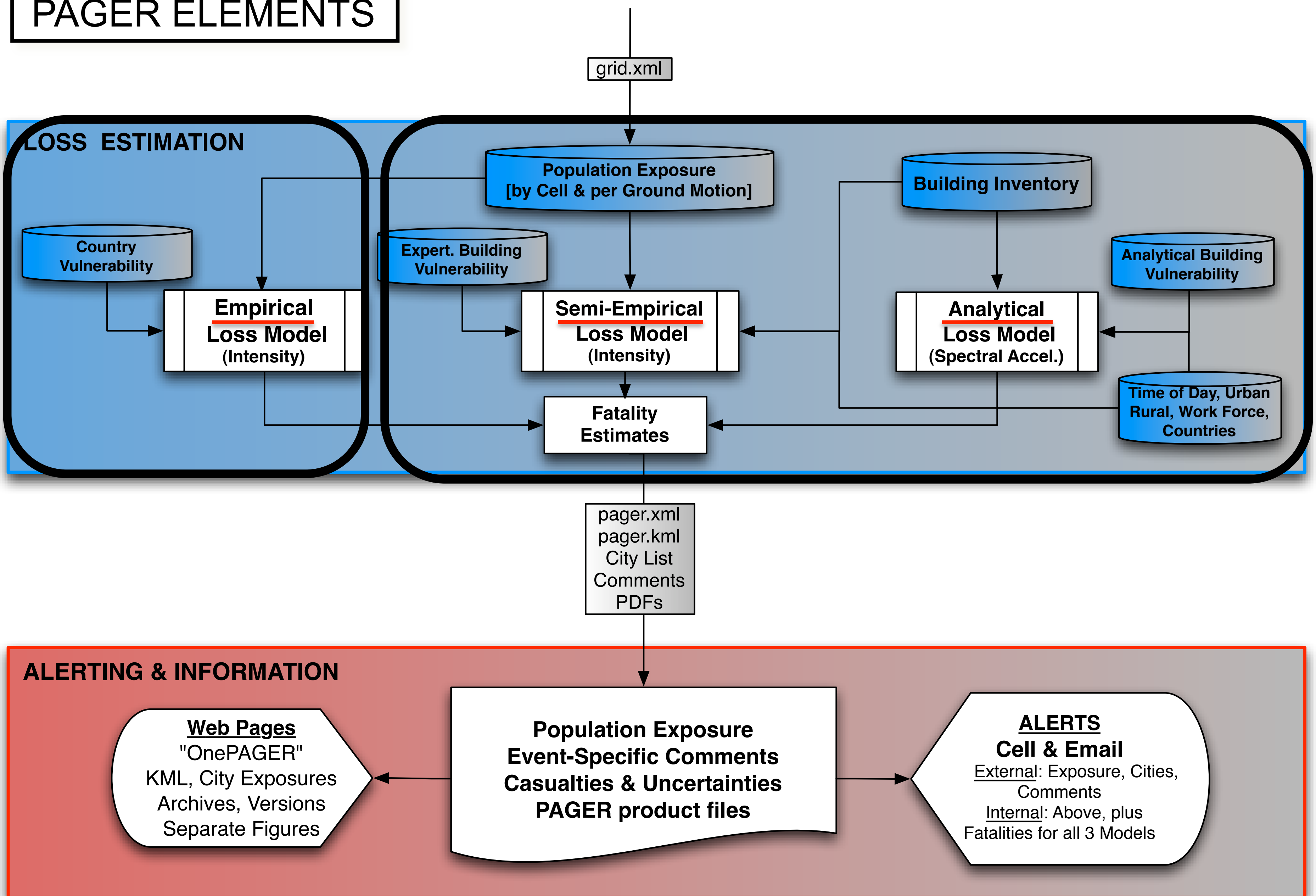


Global Earthquake Shaking-Related Fatalities (Sept 2010-2014)
60°N
30°N
0°
30°S
60°S
0°
60°E
120°E
180°
120°W
60°W
Fatalities
0
1 to 10
10 to 100
100 to 1,000
1,000 to 10,000
10,000+
Over 2,500 events M>5.5



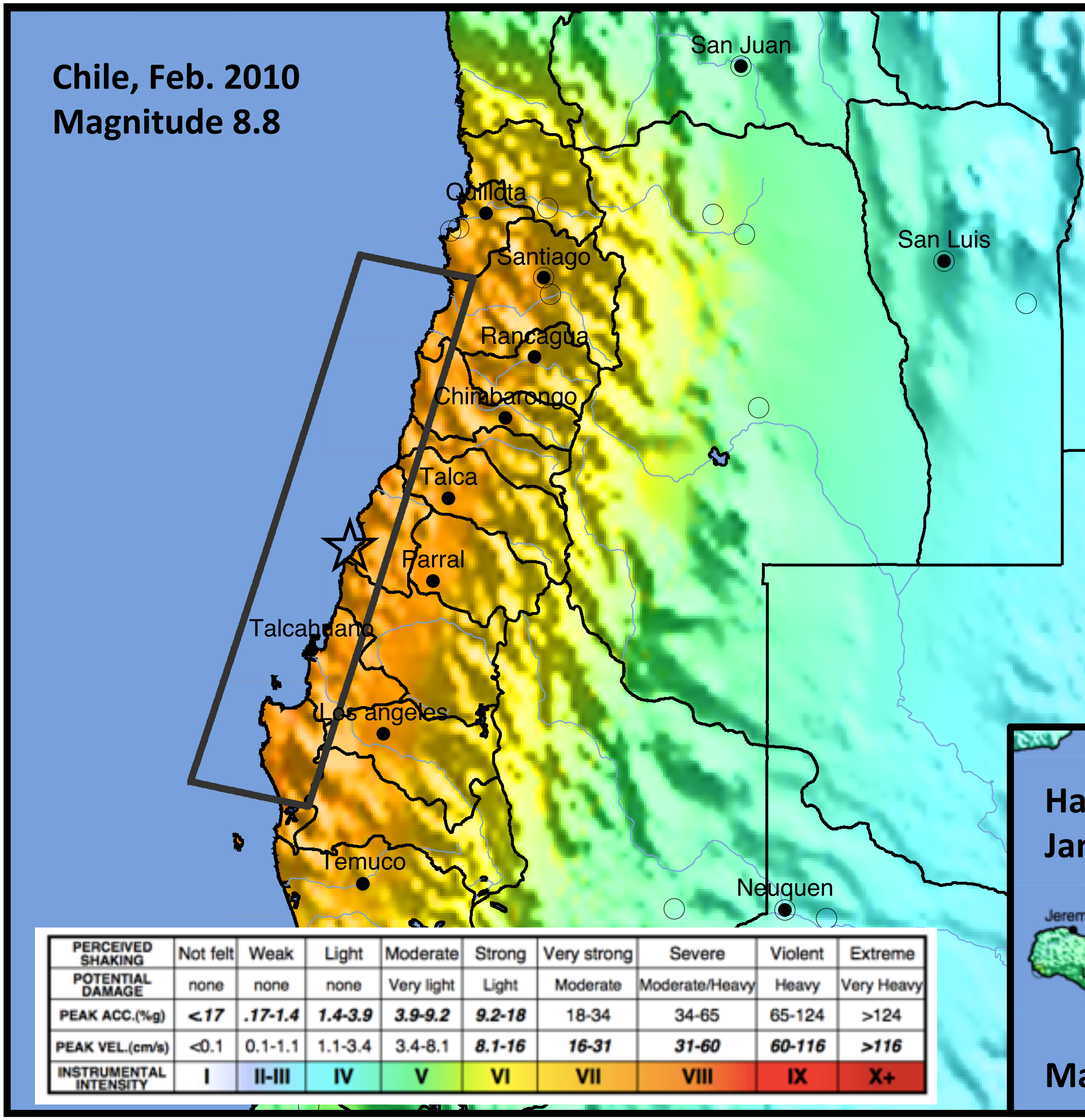
EARTHQUAKE SOURCE
PAGER SYSTEM ELEMENTS
NEIC Magnitude & Hypocenter
Surface Wave CMT
Aftershock Distribution
Fault Trace
Finite Fault Inversion
Finite Fault Model
XML
SHAKING DISTRIBUTION
Macroseismic Intensity Data
Global ShakeMap
Recorded Ground Motion Data
LOSS ESTIMATION
Global Population [Ground 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

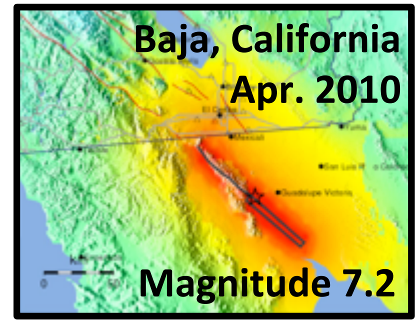


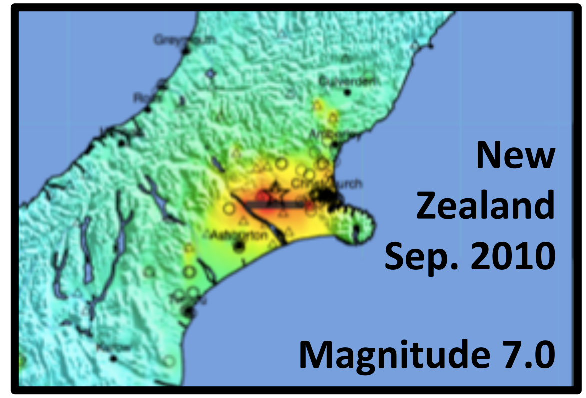
USGS ShakeMap Estimated Shaking Intensities

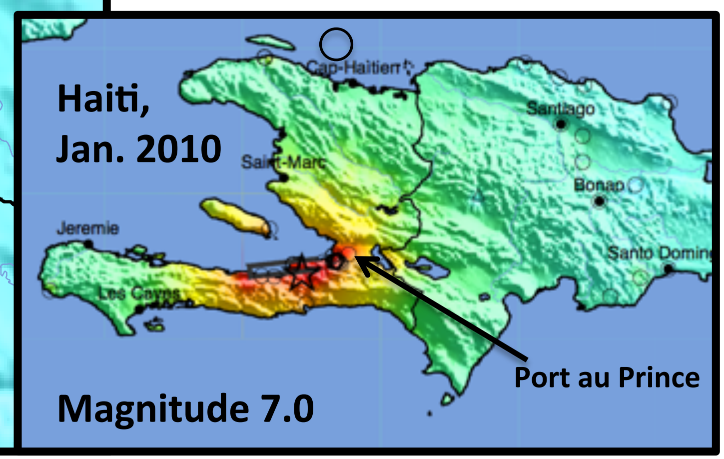
[Same Map Scales!]



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+

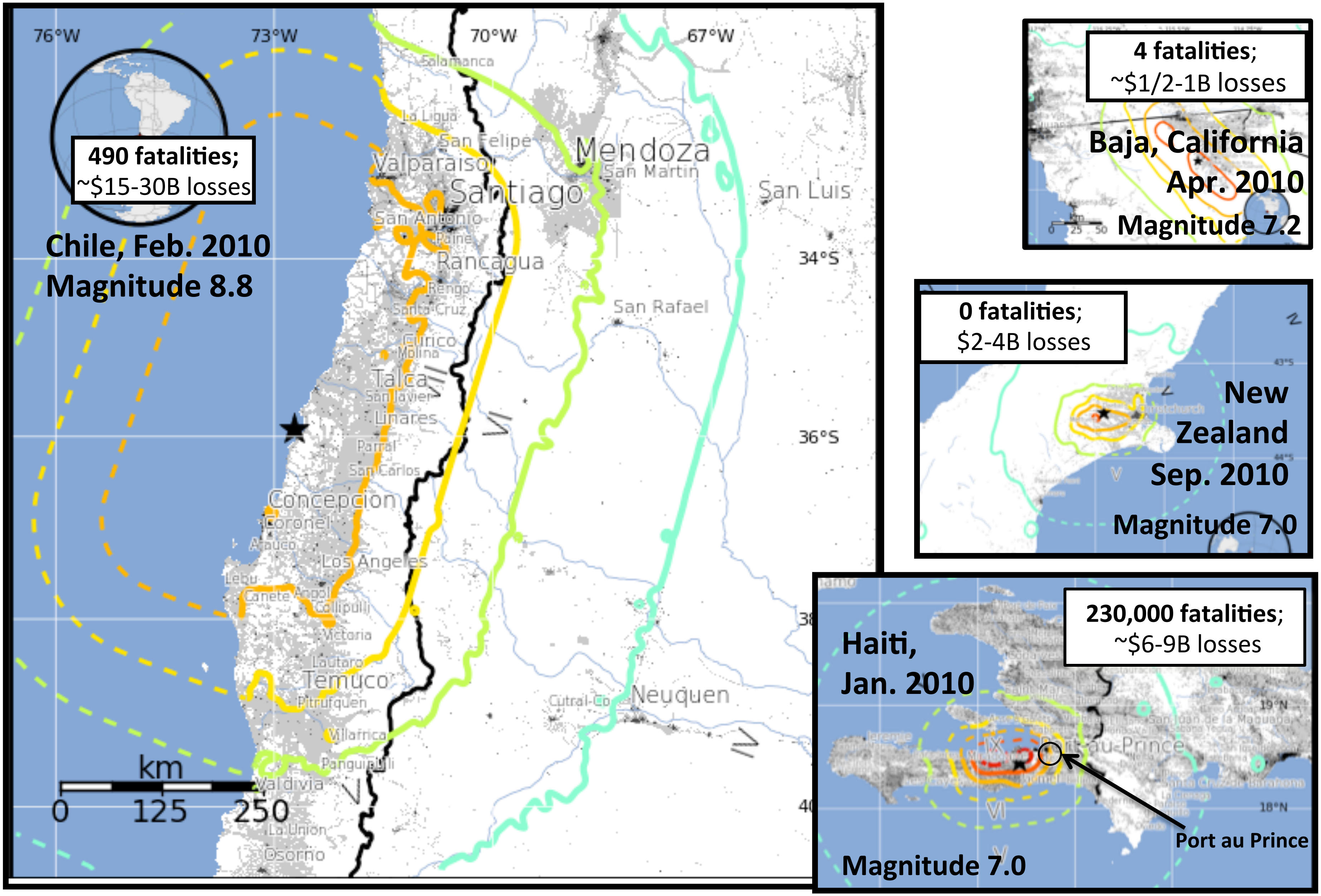




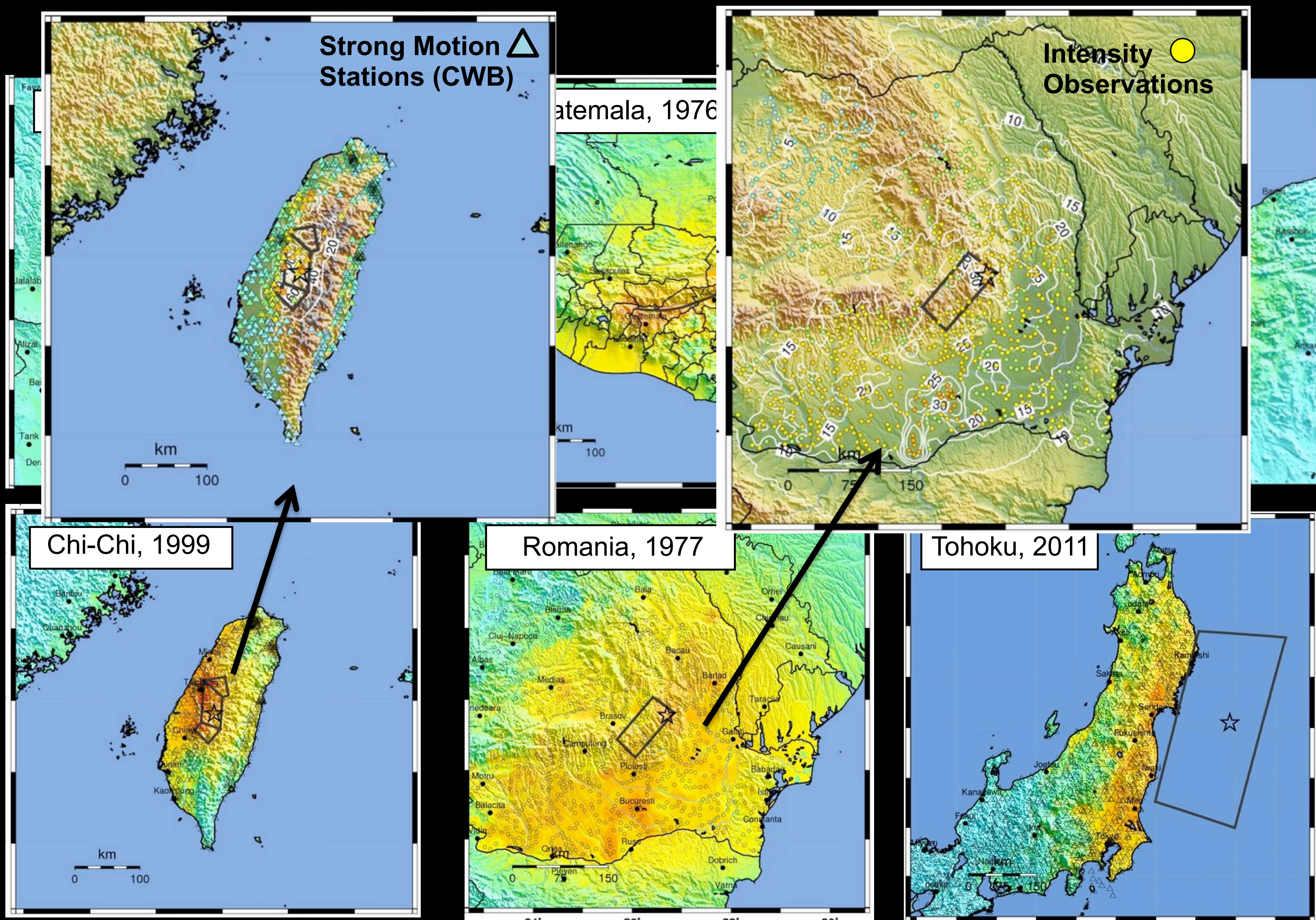


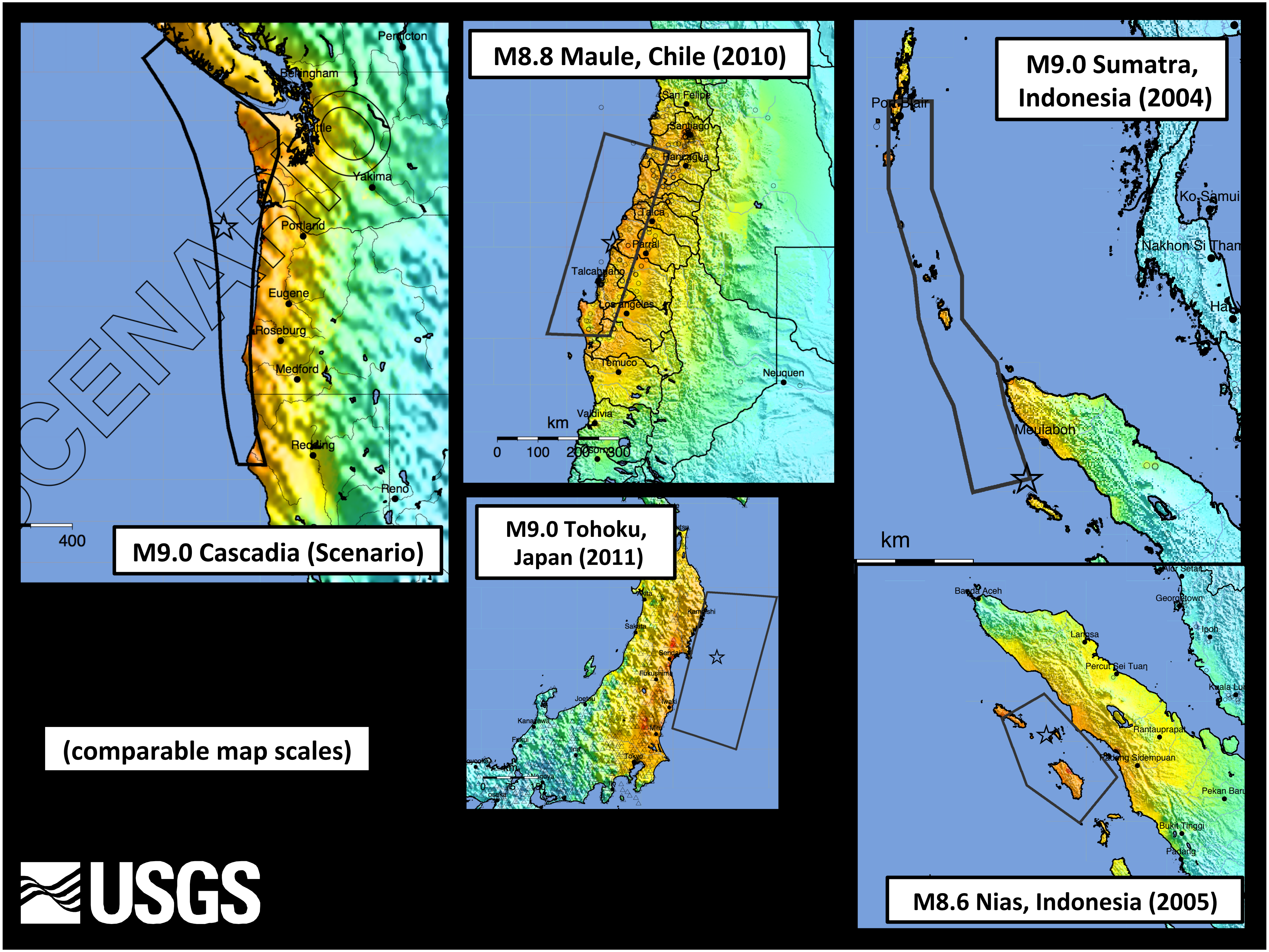
Epicenter and Magnitude

[Same Map Scales!]

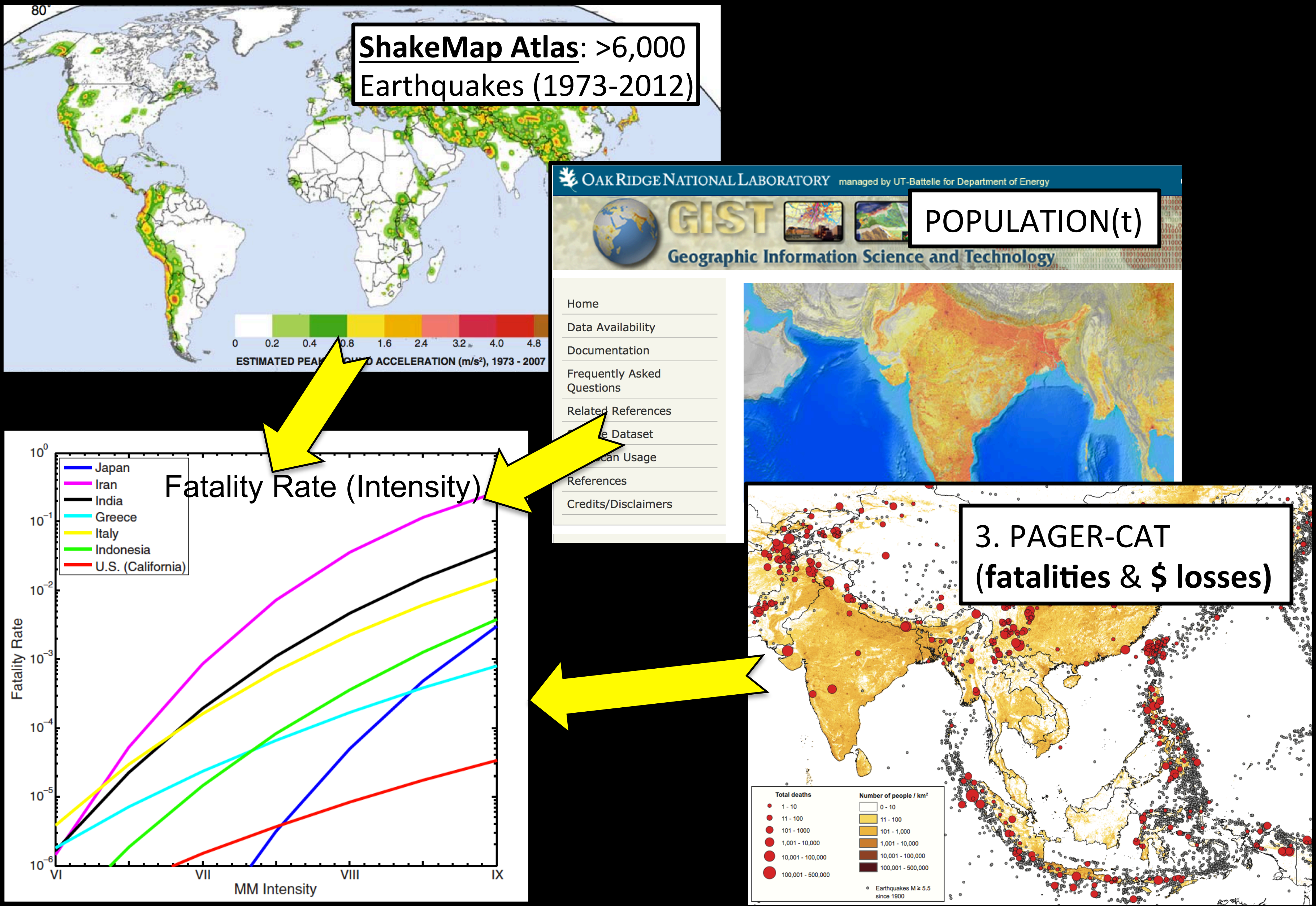


ShakeMap Atlas: ShakeMaps for >6,000 Earthquakes (1973-2012)

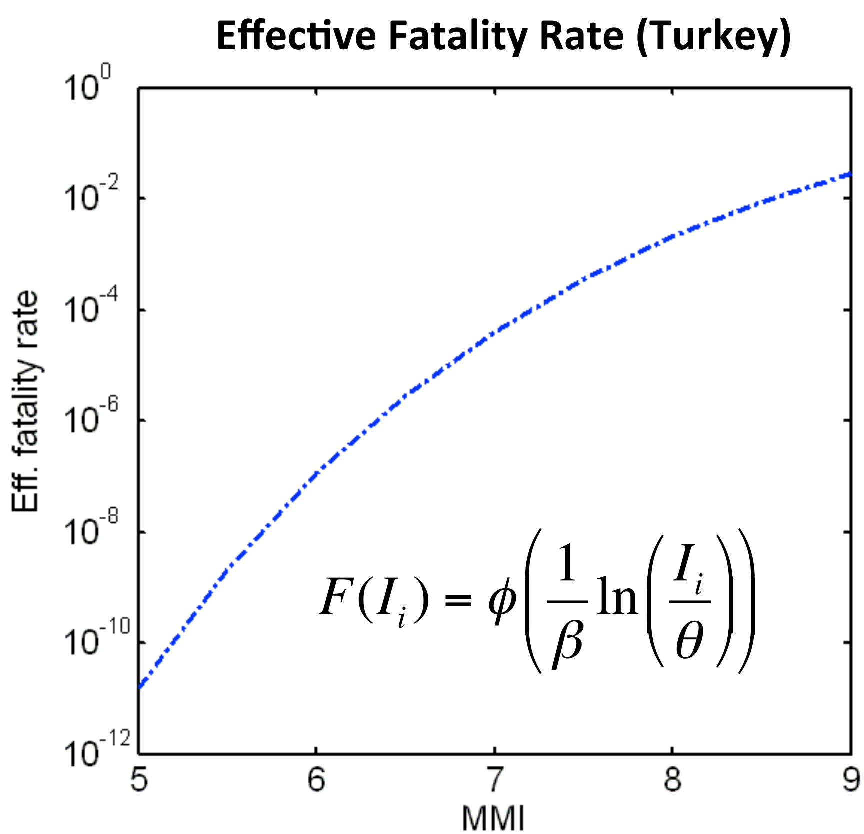


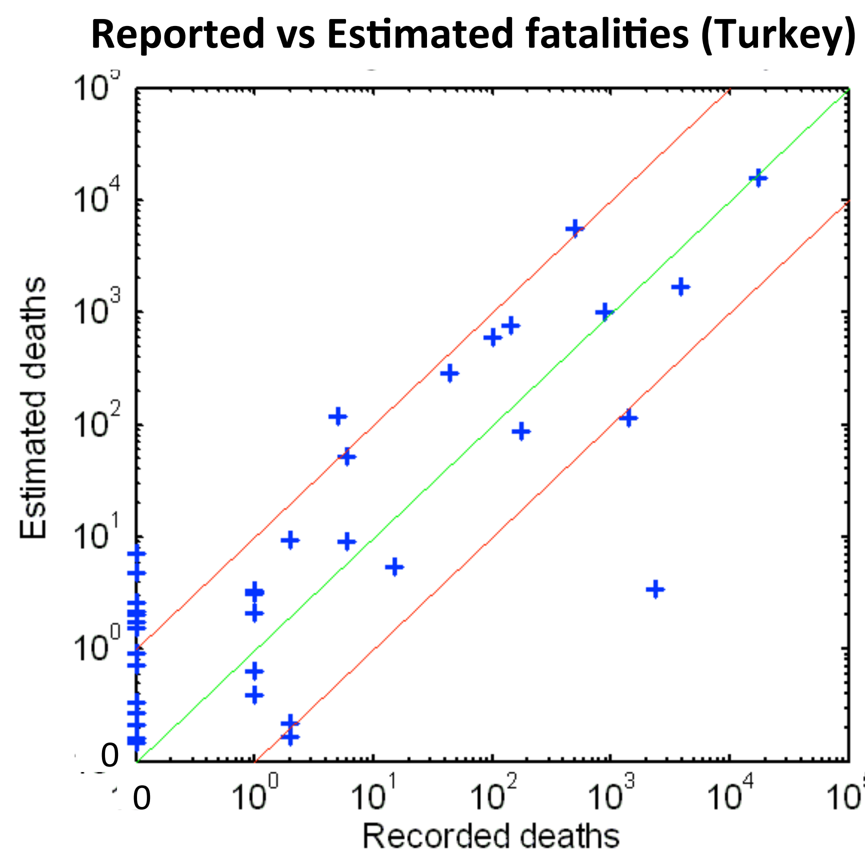

M9.0 Cascadia (Scenario)
M8.8 Maule, Chile (2010)
M9.0 Sumatra, Indonesia (2004)
M9.0 Tohoku, Japan (2011)
M8.6 Nias, Indonesia (2005)
(comparable map scales)
SCENARIO
Penticton
Bellingham
Seattle
Yakima
Portland
Eugene
Roseburg
Medford
Redding
Reno
400
San Felipe
Santiago
Rancagua
Talca
Parral
Talcahuano
Los Angeles
Temuco
Neuquen
Valdivia
Osorno
km
0
100
200
300
Port Blair
Ko Samui
Nakhon Si Tham
Meulaboh
km
Banda Aceh
Georgetown
Ipoh
Langsa
Percut Sei Tuan
Rantauprapat
Padang Sidempuan
Pekan Baru
Bukit Tinggi
Padang
Akita
Kamaishi
Sakata
Sendai
Fukushima
Joetsu
Iwaki
Kanazawa
Fukui
Mito
Tokyo
Nagoya
Osaka
USGS

PAGER Empirical Fatality Model Ingredients



PAGER's Empirical Fatality Estimation Approach:





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

Empirical Fatality Estimation Approach:

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

$$F(I_i) = \phi\left(\frac{1}{\beta}\ln\left(\frac{I_i}{\theta}\right)\right)$$

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

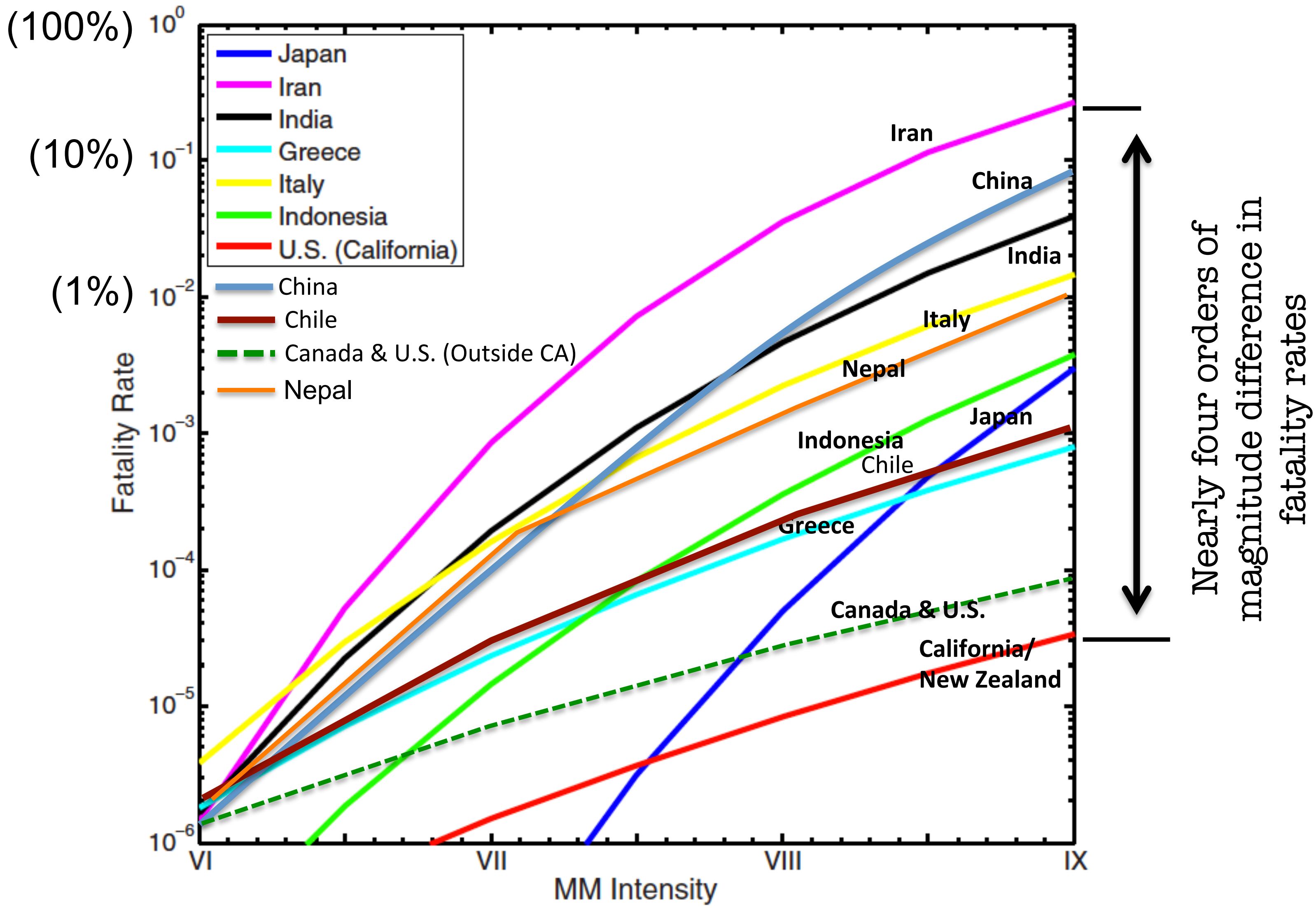
$$Fatalities \quad E = \sum_i F(s_i) P(s_i)$$

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:*

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

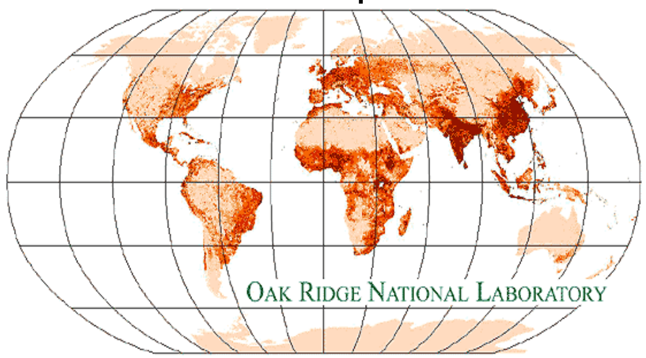
PAGER Empirical National Methodology



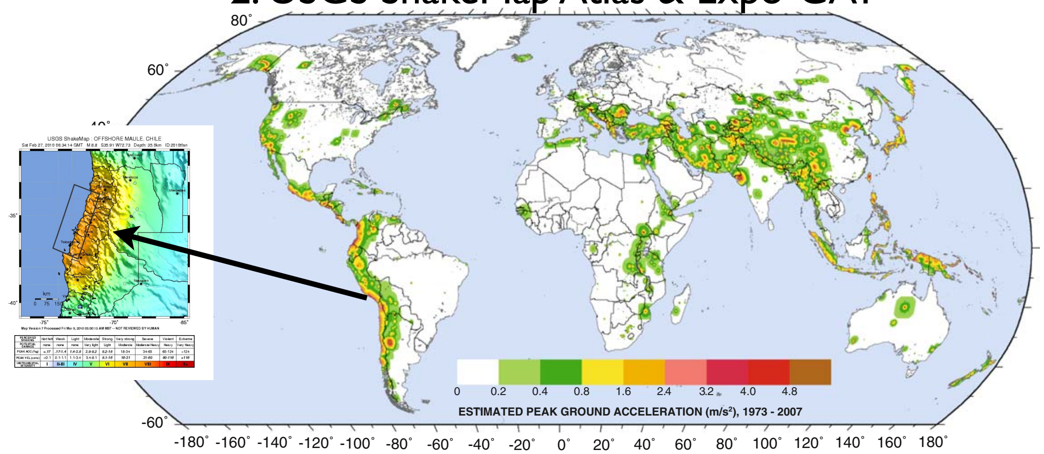
Fatality rates as a function of intensity for selected countries

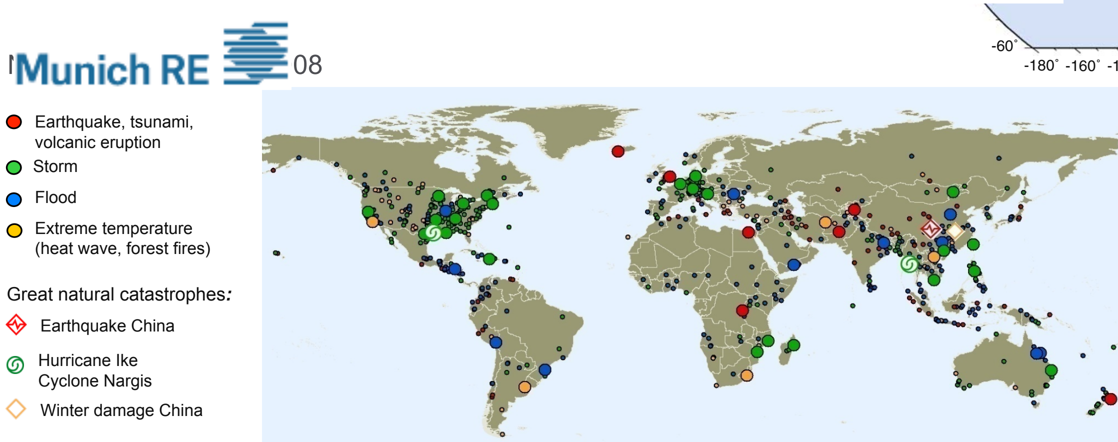
Economic Model Input Dataset:

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)

PAGER: Semi-Empirical Model

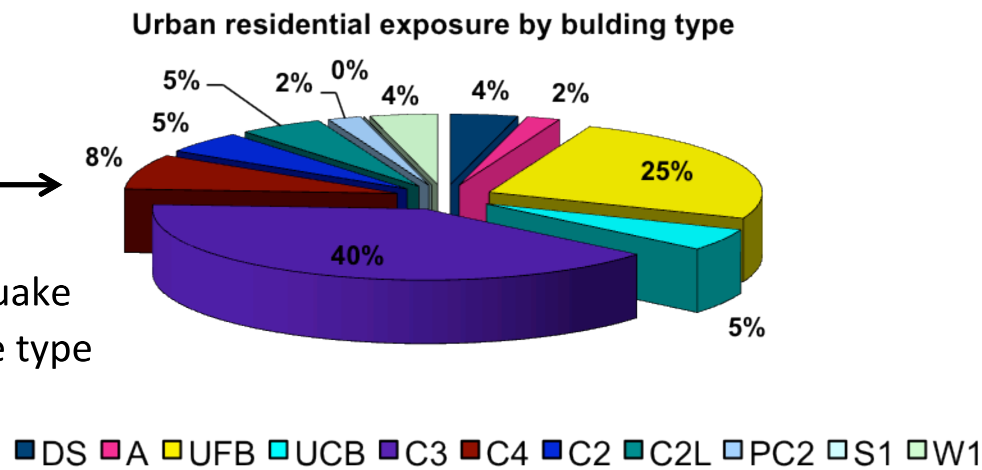
This model ***requires***:

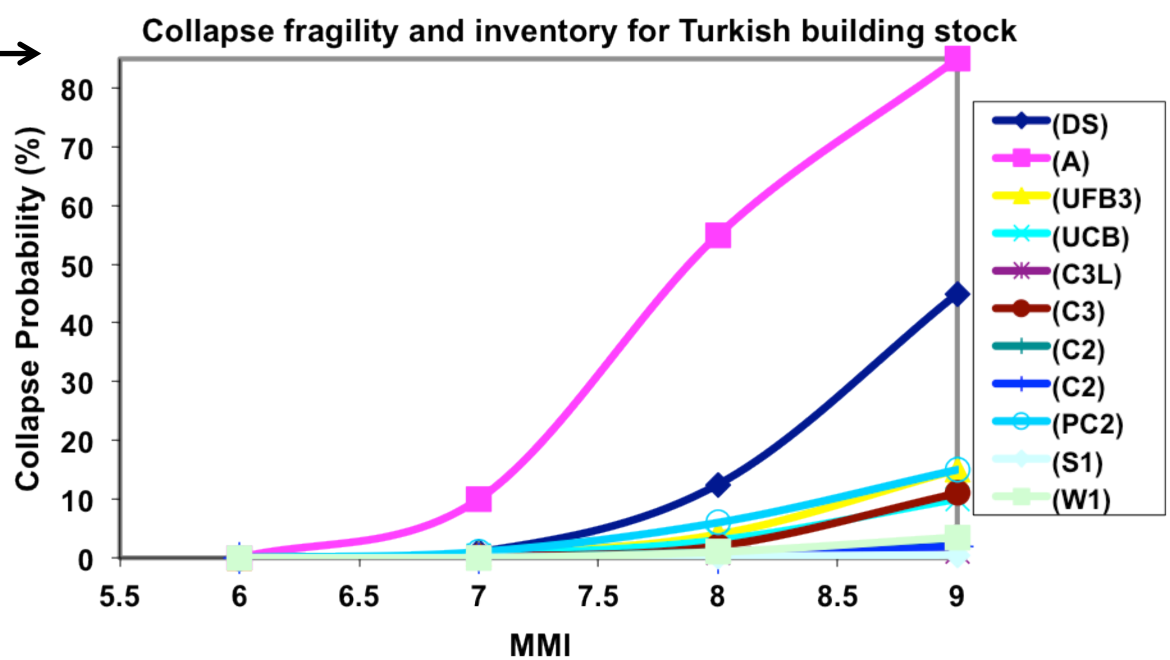
(1) Building Stock Taxonomy & Inventory

(2) Collapse Fragility

(3) Occupancy of structures at time of earthquake

(4) Fatality rates for collapse of each structure type





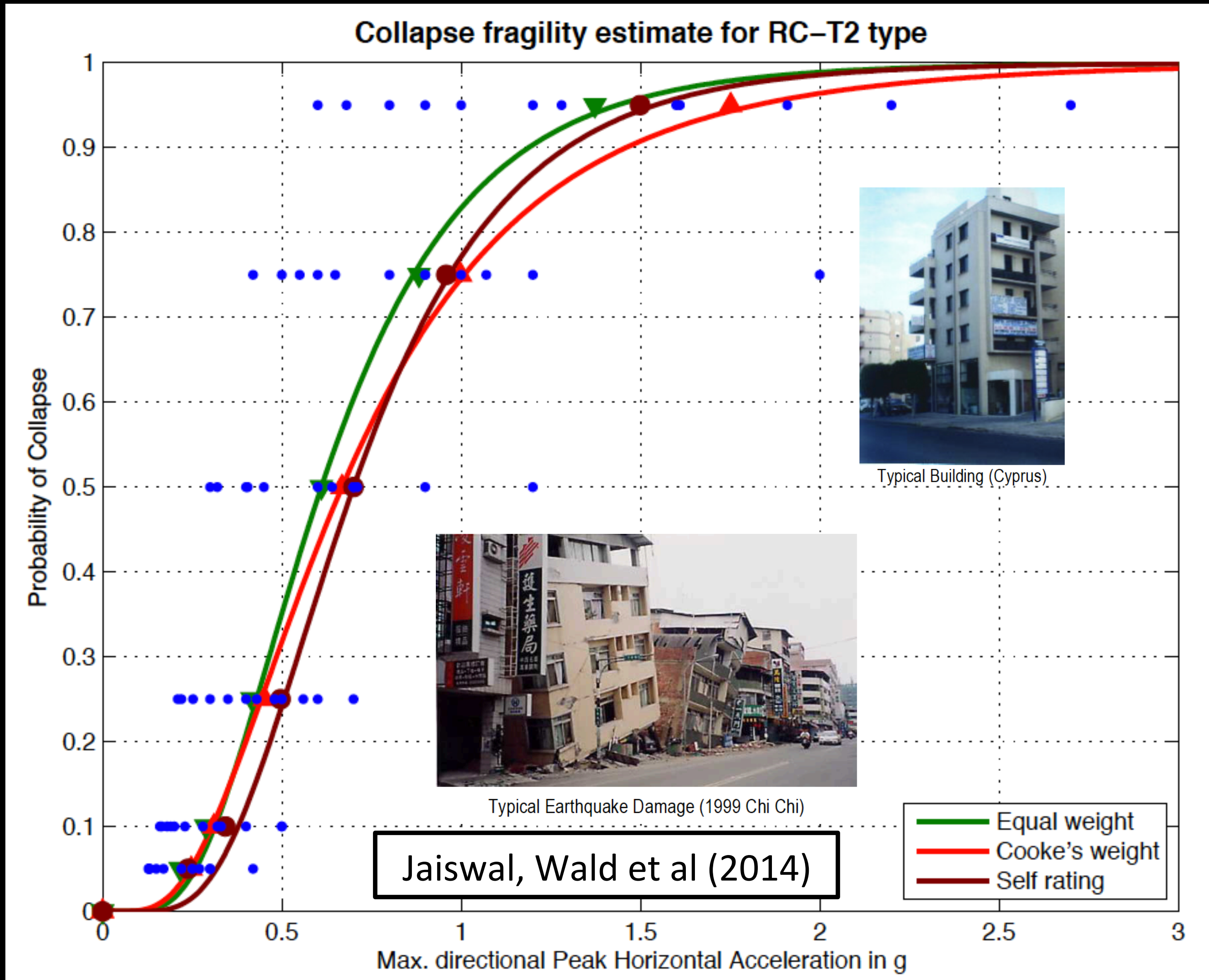
Jaiswal and Wald (2008)

PAGER Structure Taxonomy ("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
RM	Reinforced Masonry	**R1** (Reinforced masonry bearing wall with flex rigid diaphragm of low, mid and high rise)
MH	Mobile Homes	Mobile homes
M	Mud	**M1** (Mud wall without wood), **M2** (Mud wall
A	Adobe	**A1** (Adobe mud mortar with wood roof), **A2** ((Adobe wall with concrete bond beam), **A5** (A
RE	Rammed Earth	Rammed earth construction
RS	Rubble (Field) Stone	**RS1** (Rubble stone without mortar), **RS2** (Rub stone with cement mortar), **RS5** (Rubble stone
DS	Dressed Stone, blocks	**DS1** (Stone block with mud mortar), **DS2** (Sto 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
  - EERI/WHE'03, Global
  - PAGER definitions, missing types

Collapse Fragility Modeling



RC-T2: Nonductile gravity-load bearing RC regular frame with masonry infill walls (4 to 7 stories)

Population Distribution

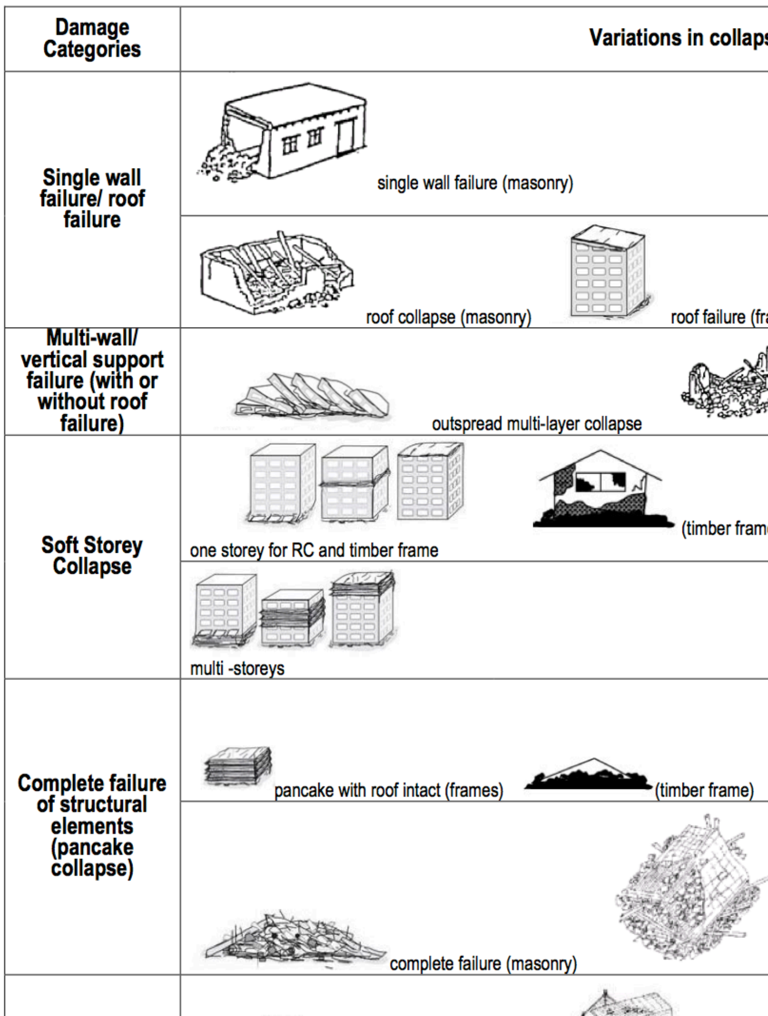
- Data/Expert Judgment Similar to HAZUS Principles

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]	$P_i*(0.35* F_{nwf} +0.10* F_{wf} * F$ [illegible]
Night (10 pm- 5 am)	$P_i *(0.4* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.01* F_{wf} * F_{agr})P_i *(0.75* F_{nwf} +0.20* F_{wf} * F_{ind} +0.25* F_{wf} * F_{ser} +0.45* F_{wf} * F_{agr})P_i *(0.999* F_{nwf} +0.84* F_{wf} * F_{ind} +0.89* F_{wf} * F_{ser} +0.998* F_{wf} * F_{agr})$	[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] $F_{ind} +0.50* F_{wf} * F_{ser} +0.54* F_{wf} * F_{agr})P_i*(0.001* F_{nwf} +0.01* F_{wf} * F_{ind} +0.01* F_{wf} * F_{ser} +0.001* F_{wf} * F_{agr})$

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

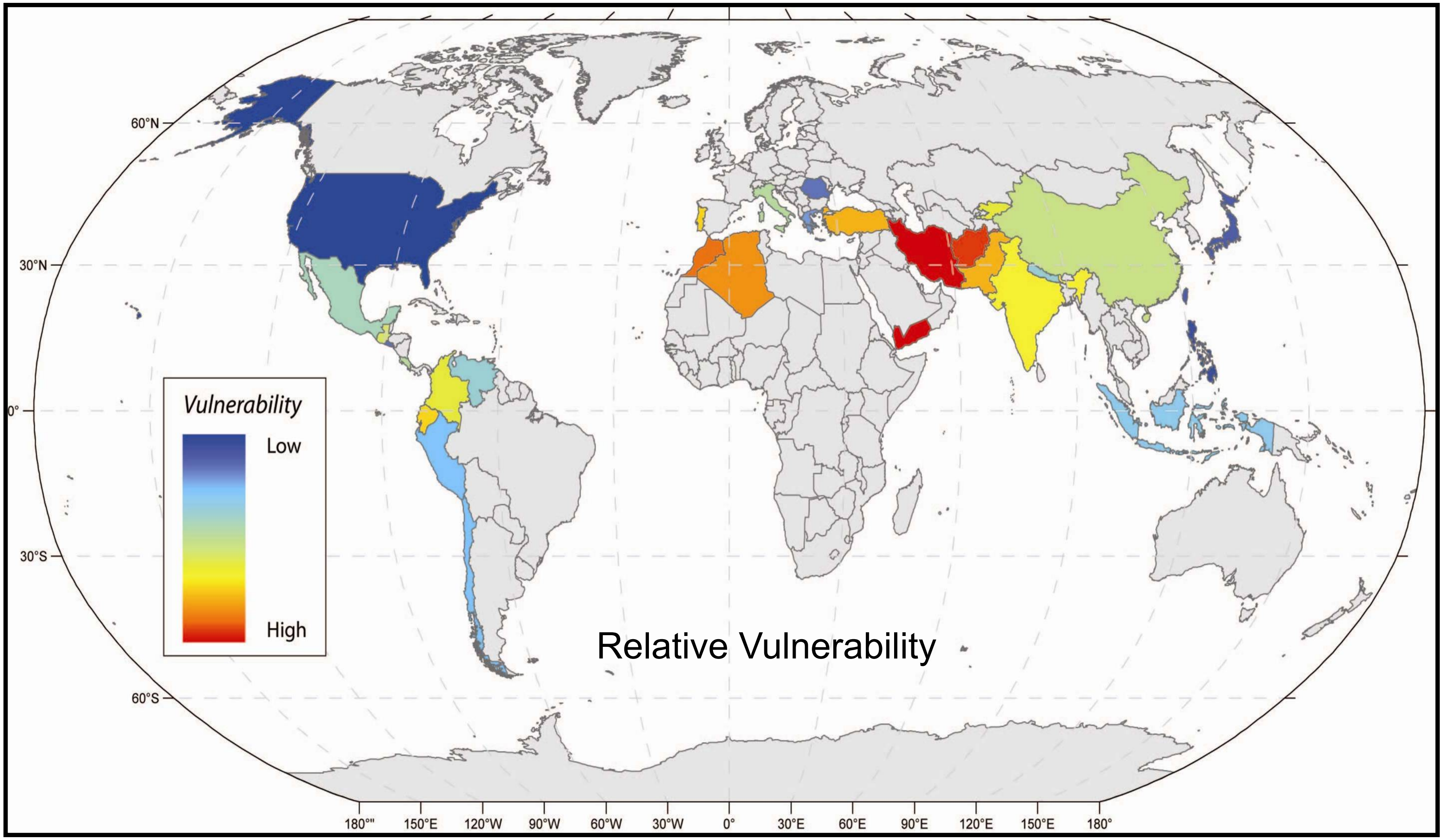
Fatality Rates

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

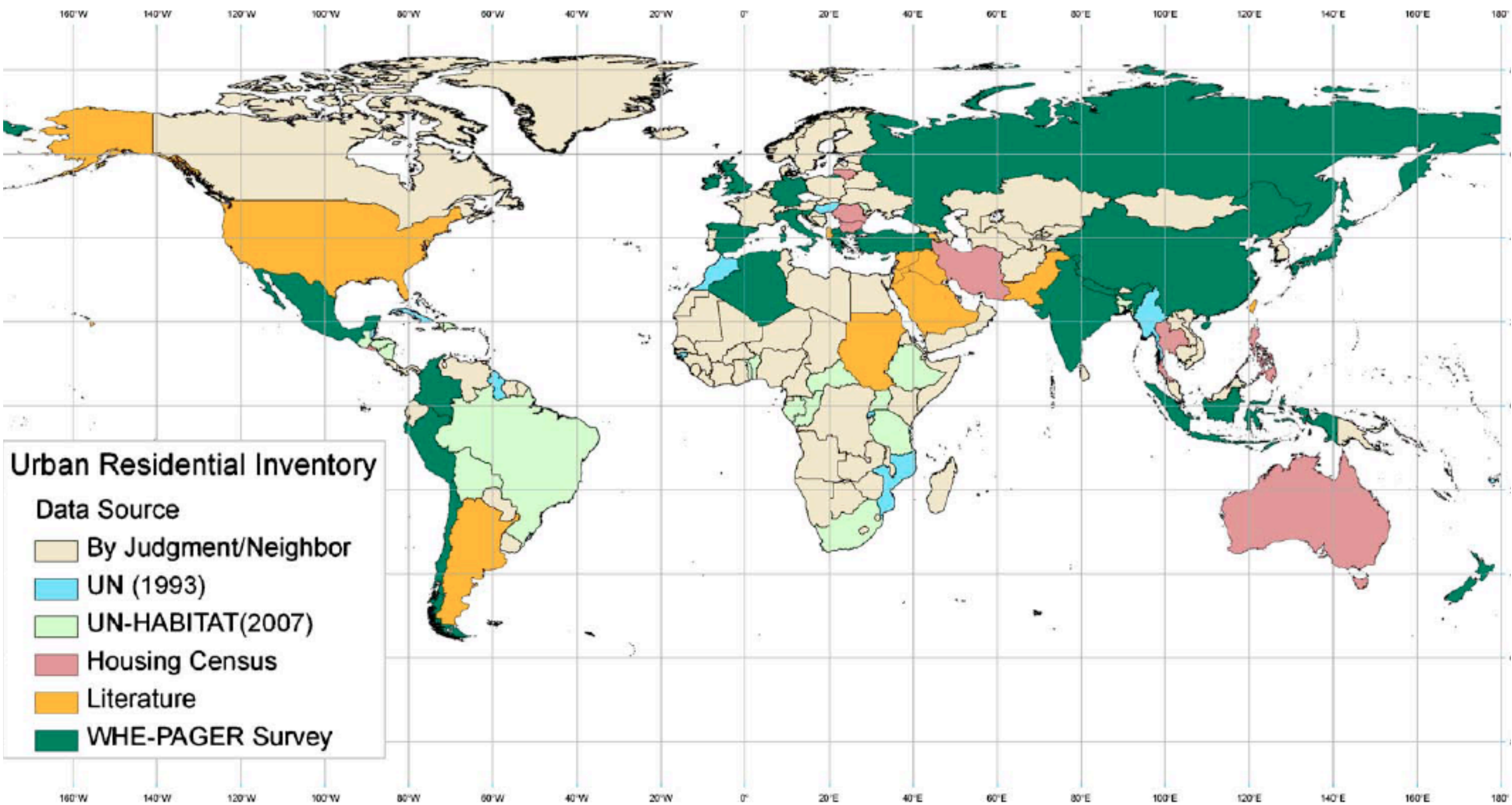


PAGER Structure Type	Fatality Rates	Re
W, W1	0.007	Spe
W2, W3, W4	0.013	Spe
S, S1, S1L, S2, S2L, S3, S4, S4L, S5, S5L	0.14	Spe
S1M, S2M, S4M, S5M	0.228	Spe
S1H, S2H, S4H, S5H	0.328	Spe
C, C1, C1L, C2, C2L ,C3, C3L, C4, C4L C5, C5L	0.15	Spe
C1M, C2M, C3M, C4M, C5M	0.22	Spe
C1H, C2H, C3H, C4H, C5H	0.28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

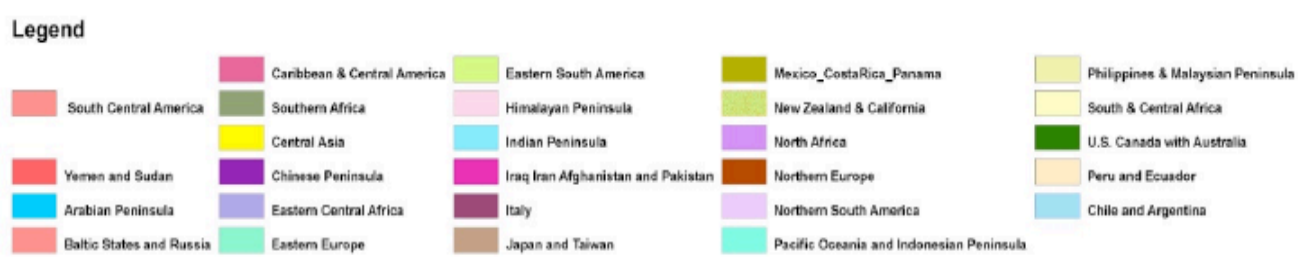
Countries with Sufficient Earthquake Fatality Data



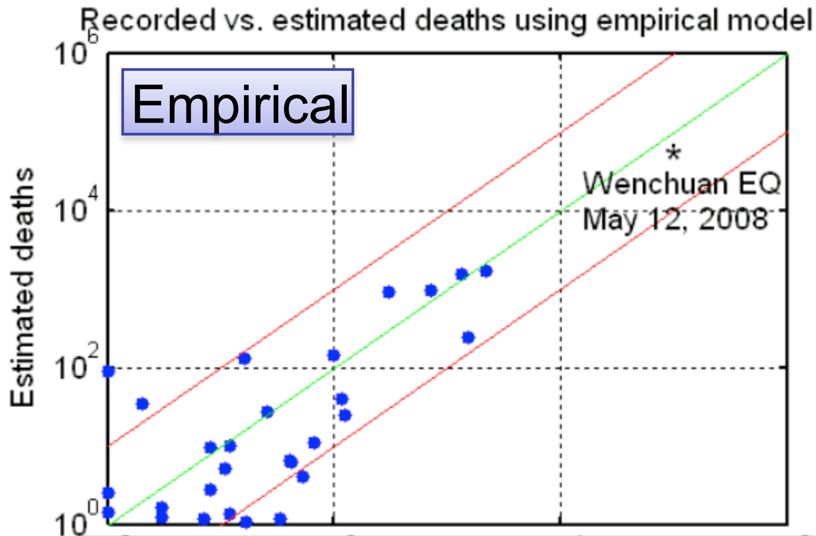
Global Inventory & Coverage

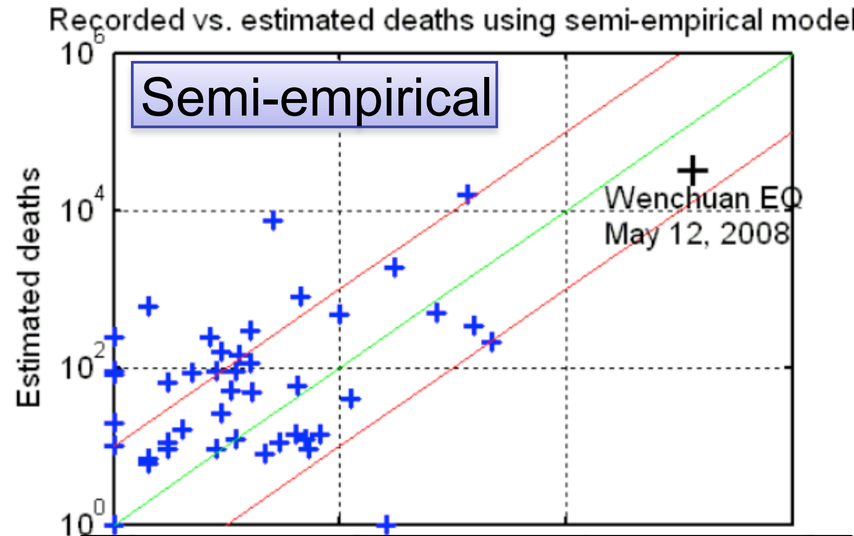


PAGER Regionalization Scheme (V2.0, Dec. 2010)



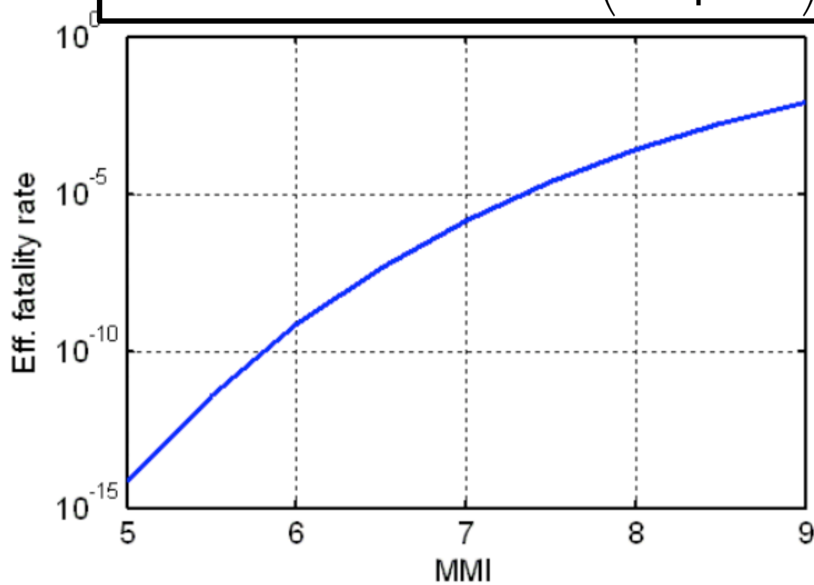
Country: China

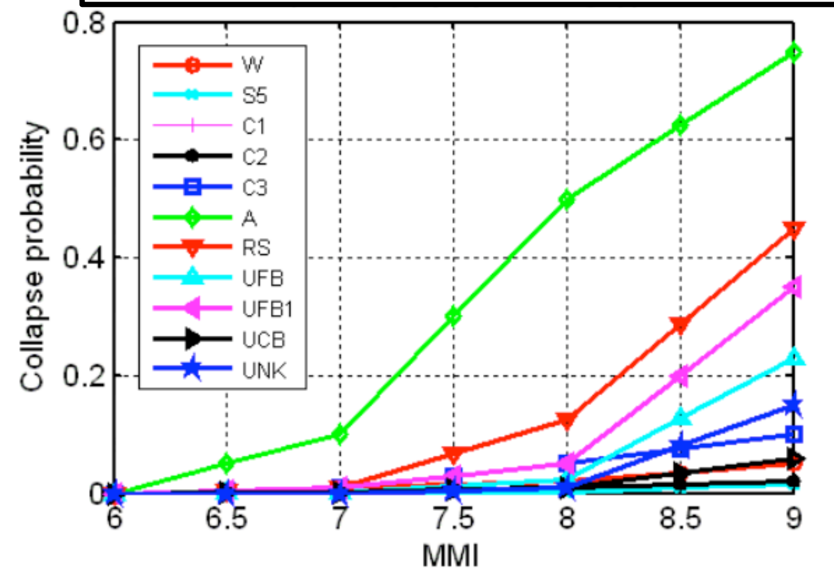




$$Fatality\ \ rate\ \ y(x_i) = \phi\left(\frac{\ln(x_i/\theta)}{\beta}\right)$$

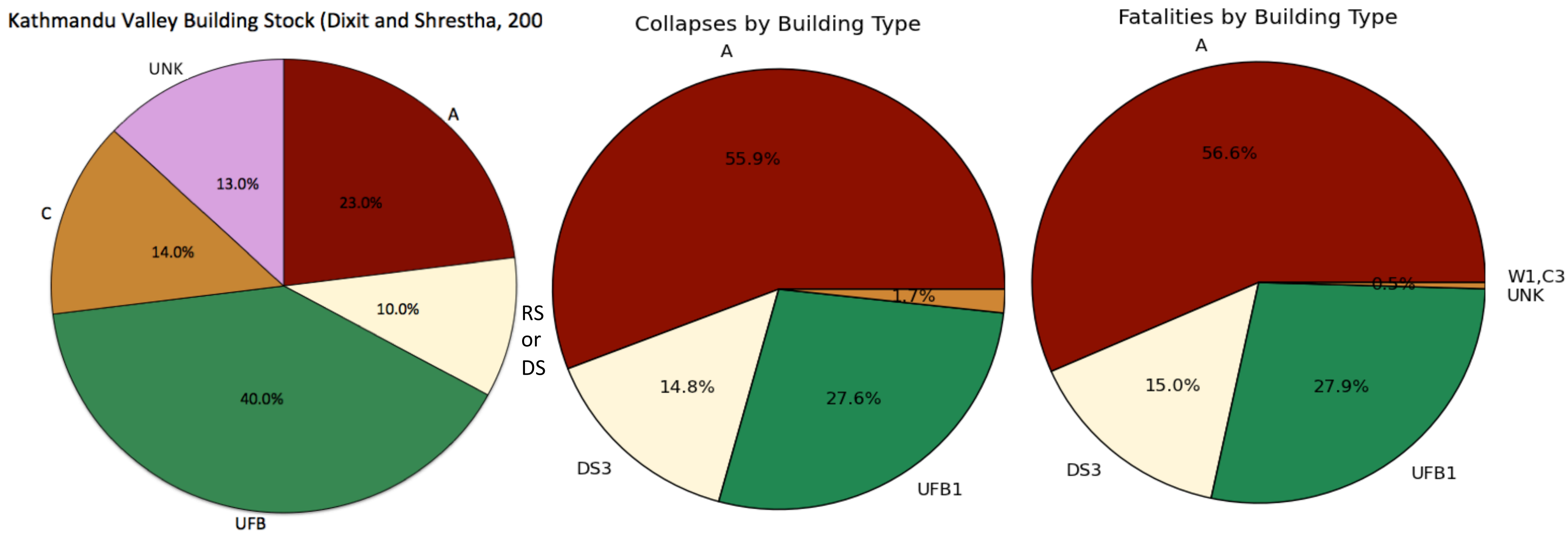
$$\text{Fatalities} = \sum P_{\text{str. type}} \times CR_{\text{str. type, mmi}} \times FR_{\text{str. type}}$$





Kathmandu, Nepal, M8.1

General distribution of building types in the Kathmandu Valley (Dixit and Shrestha, 2005).



A: Adobe block
UFB: Unreinforced fired brick masonry walls with mud, lime, or cement mortar and timber joists used to support floor or roof (**UFB1** mud mortar with no timber joists)
DS: Dressed stone masonry walls (**DS3** concrete mortar with timber floors and roof)
RS: Rubble stone masonry walls
W: Wood construction
C: Reinforced concrete frame construction (**C1** engineered, **C3** non-engineered)
UNK: Unknown construction

Kathmandu, Nepal, M8.1

Figure 7. A typical adobe (**A**) building in Jantanagar, Nepal (Photo Courtesy: Auroville Earth Institute, http://www.earth-auroville.com/nepal_june_2008_en.php).

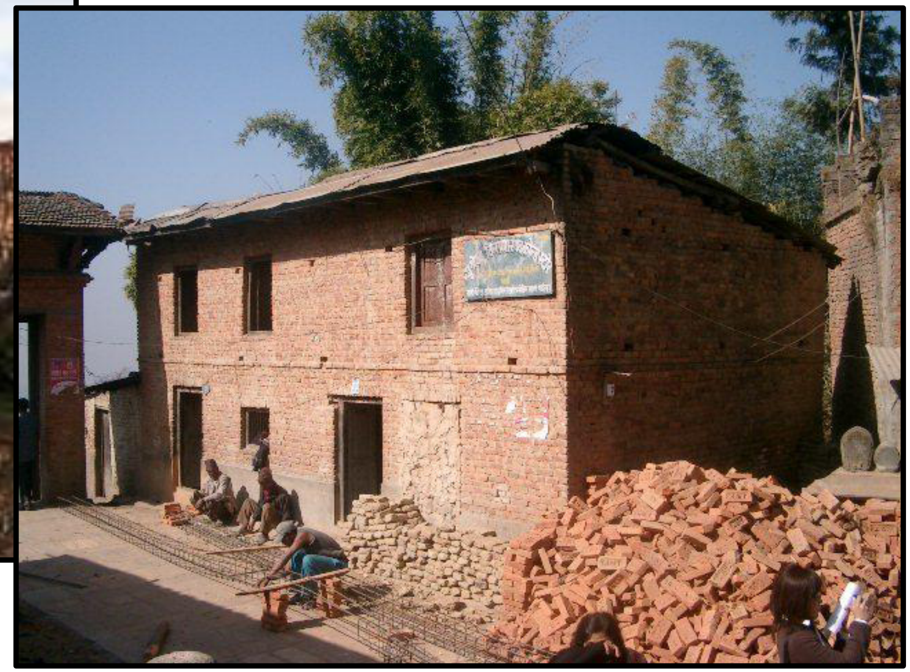


Figure 8. Example of an unreinforced fired brick (**UFB**) masonry building in Nepal (Photo Courtesy: NSET, Nepal).

Kathmandu, Nepal, M8.1

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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 #103) - Mohammed Farsi, Farah Lazzali

Stone masonry apartment building

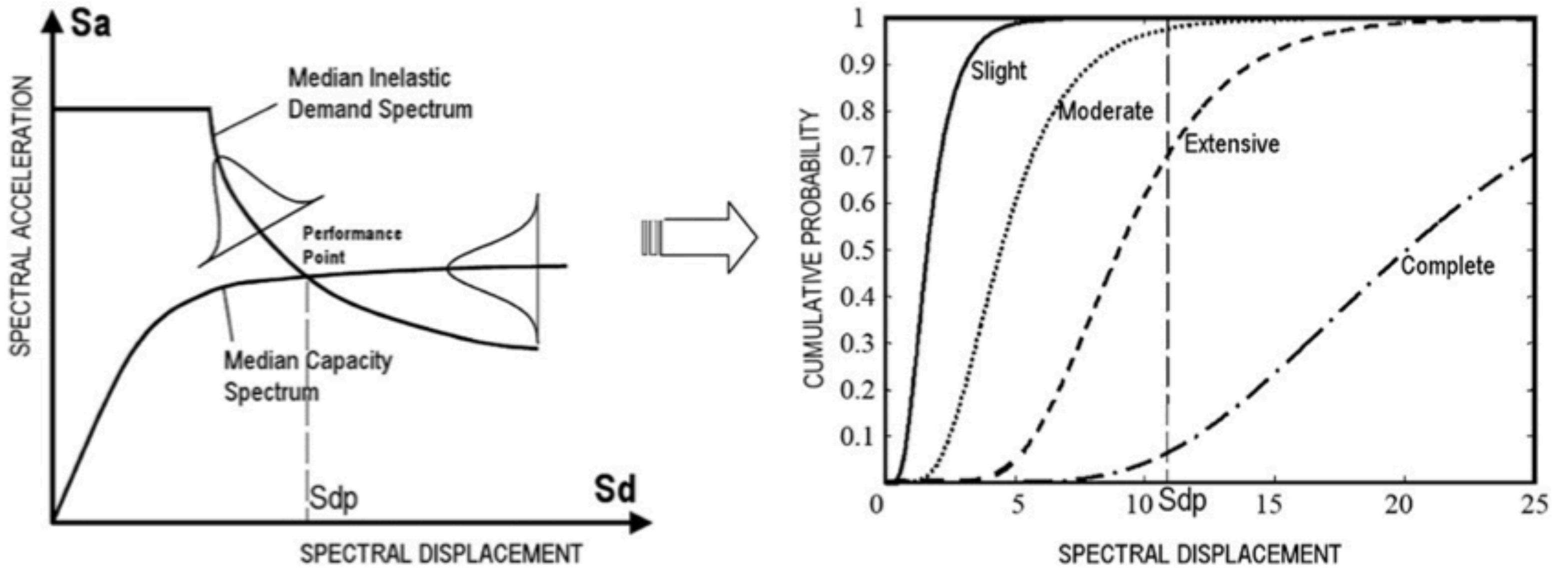
This is a typical residential construction type found in most Algerian urban centers, constituting 40-50% of the total urban housing stock. This construction, built mostly before the 1950s by French contractors, is no longer practiced. Buildings of this type are typically four to six stories high. The 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 #75) - Mohammed Farsi, Farah Lazzali, Yamina Ait-M

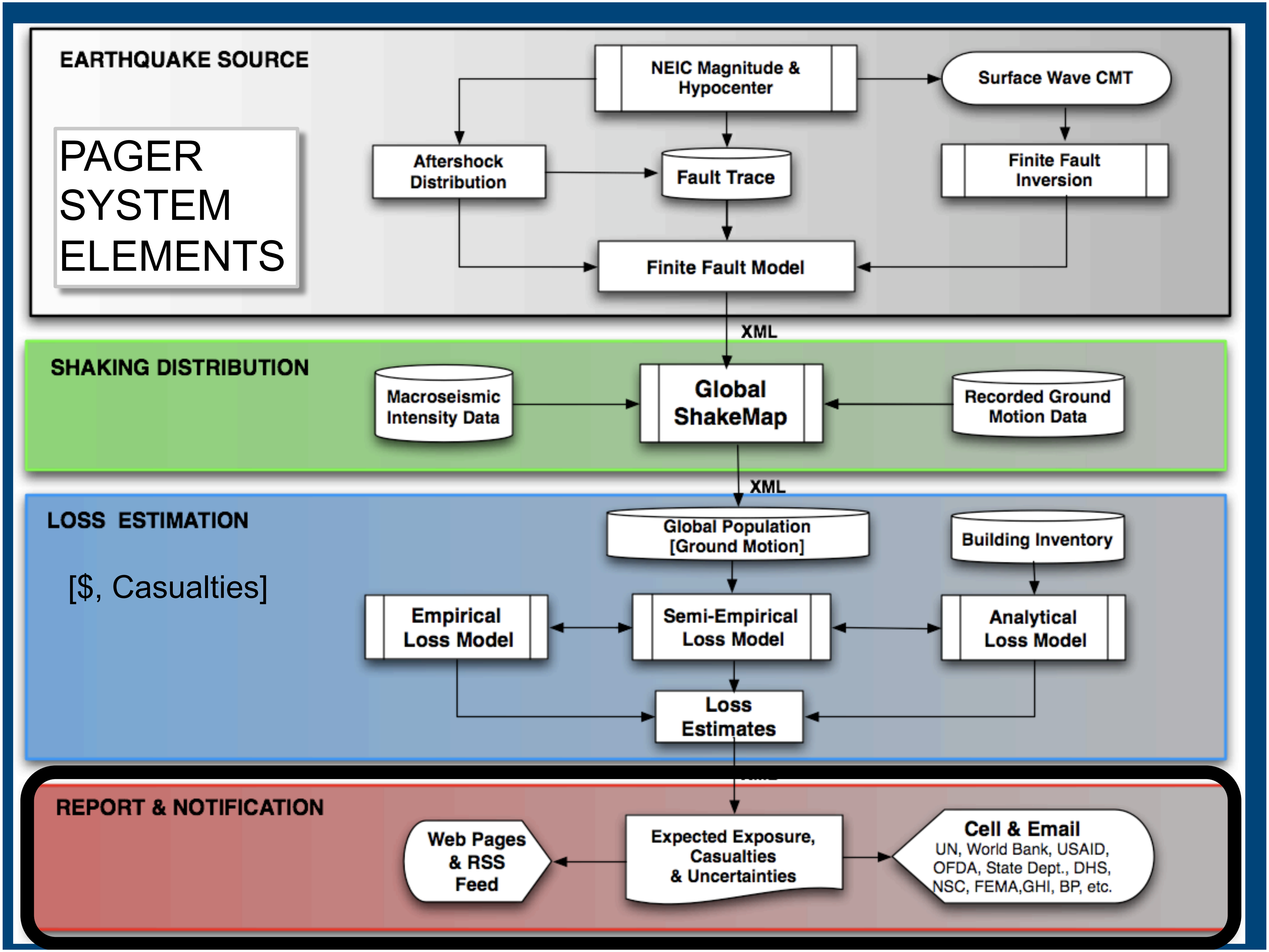
Figu
(DS
Nep
Dixit, NSET Nepal).

Non-
orced
concrete frame with
masonry infill (**C3**)
construction (Photo
Courtesy: NSET Nepal).

Analytical Approach



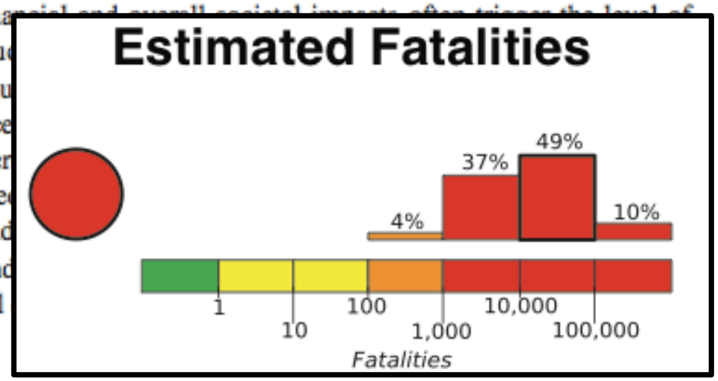
Yet more parameters are required! (many structural characteristics)


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.



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

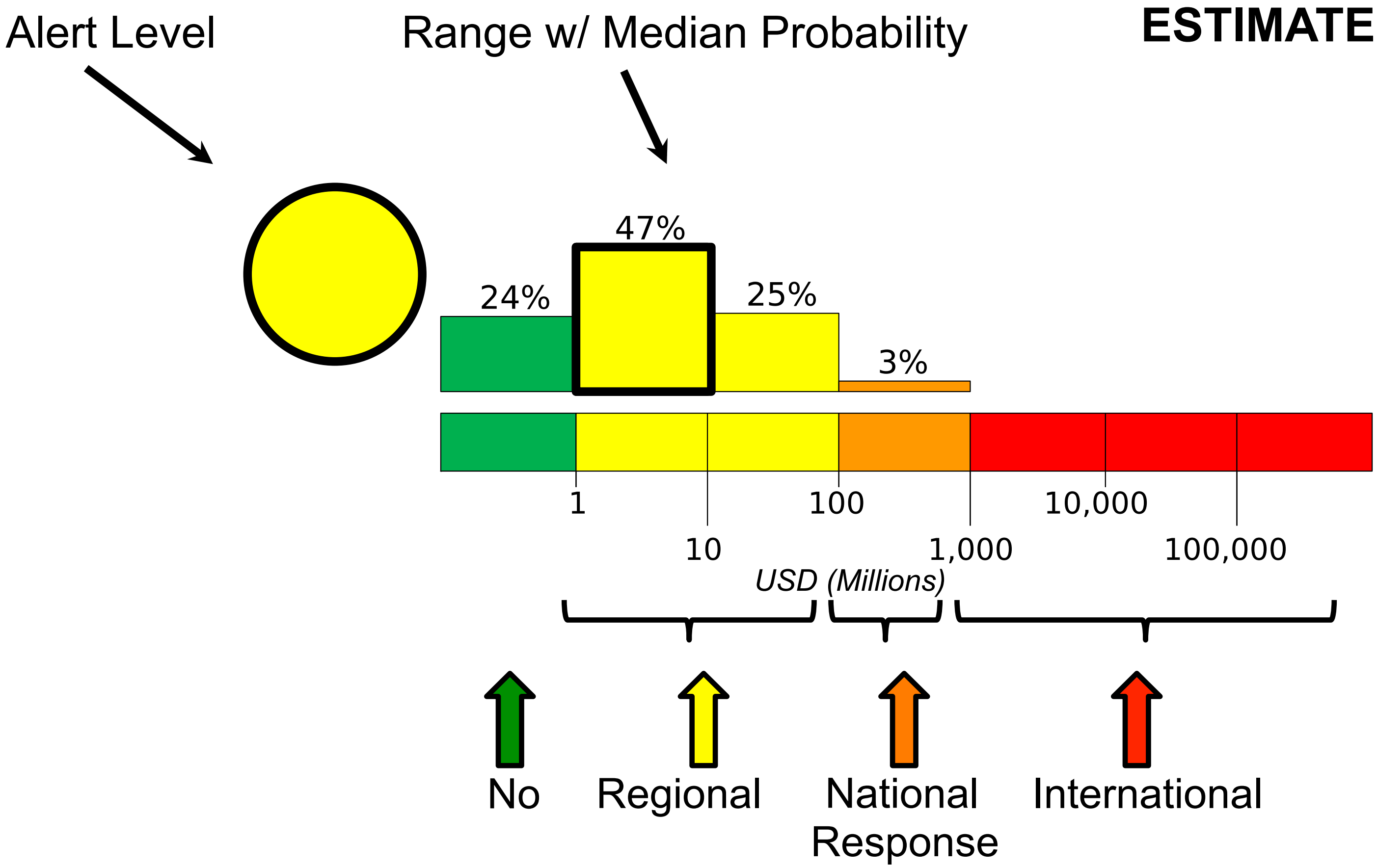
Author keywords: PAGER; Impact scale; Earthquake.

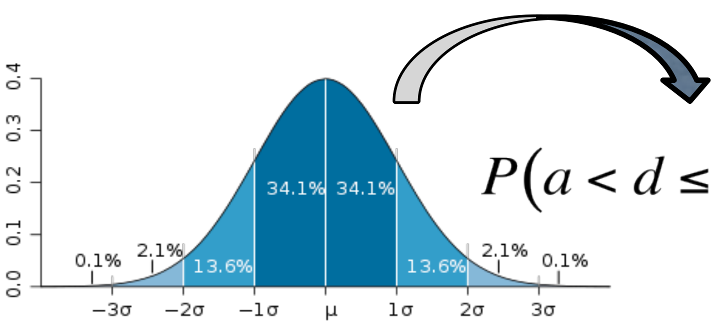
Introduction

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.

ESTIMATED $ LOSSES

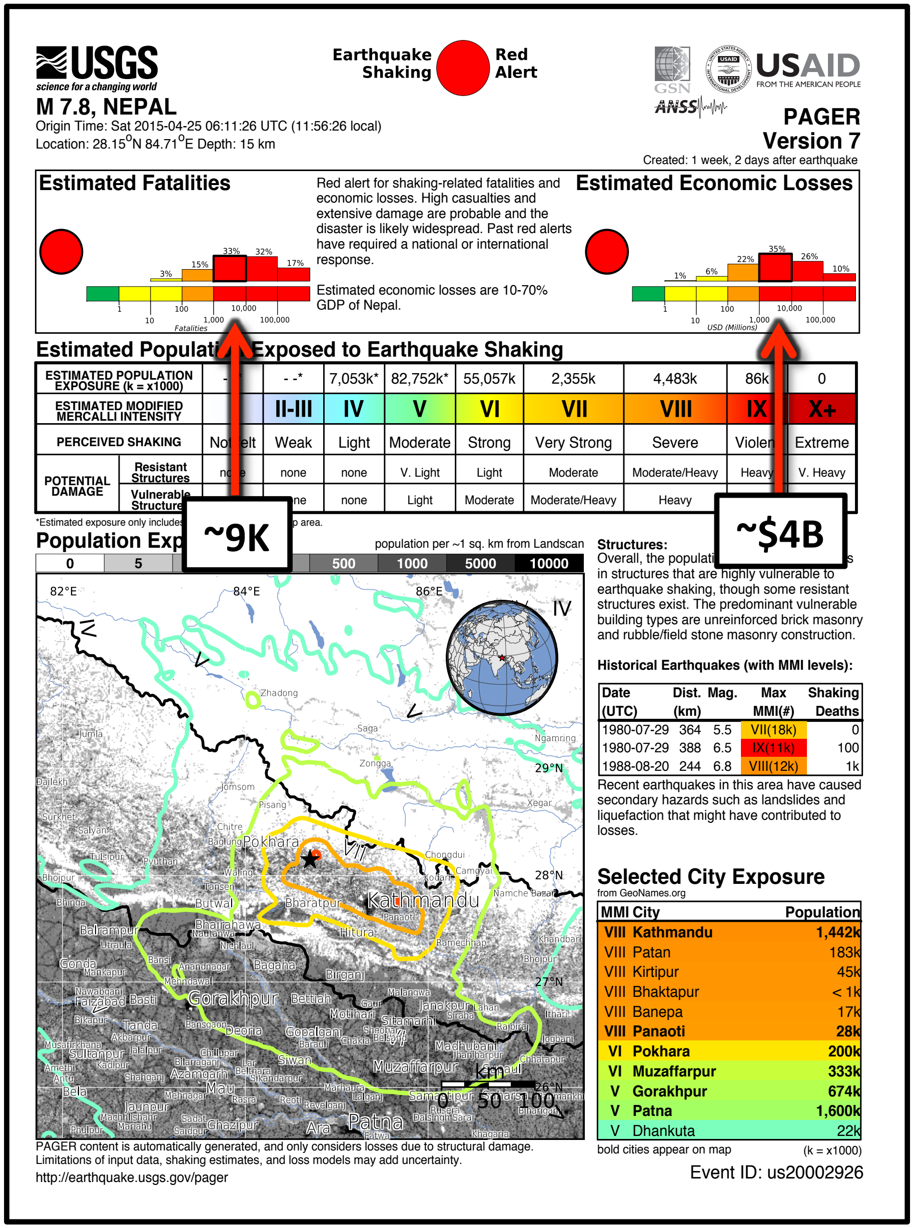




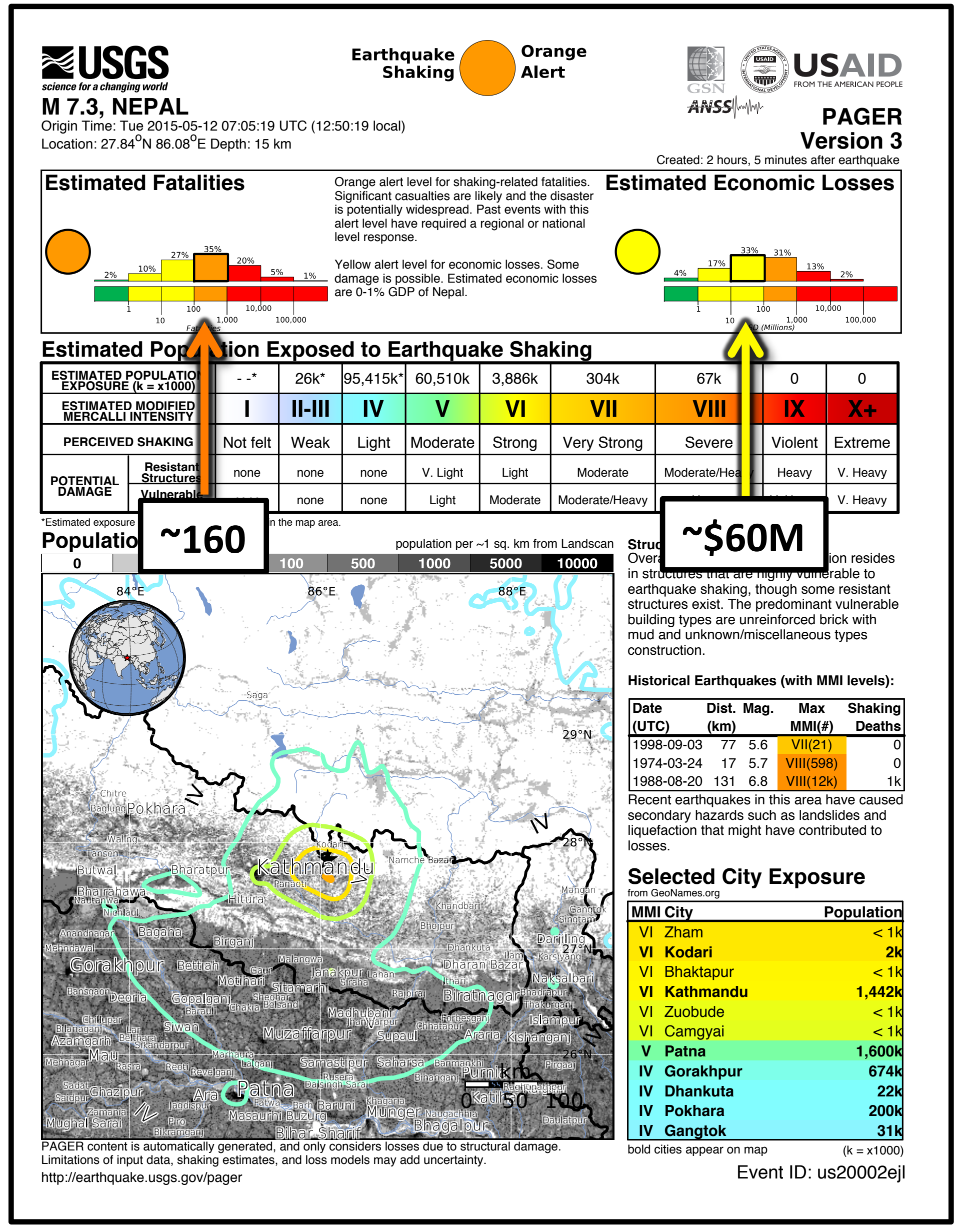
$$P(a < d \leq b) = \Phi\left[\frac{\log(b) - \log(e)}{\xi}\right] - \Phi\left[\frac{\log(a) - \log(e)}{\xi}\right]$$

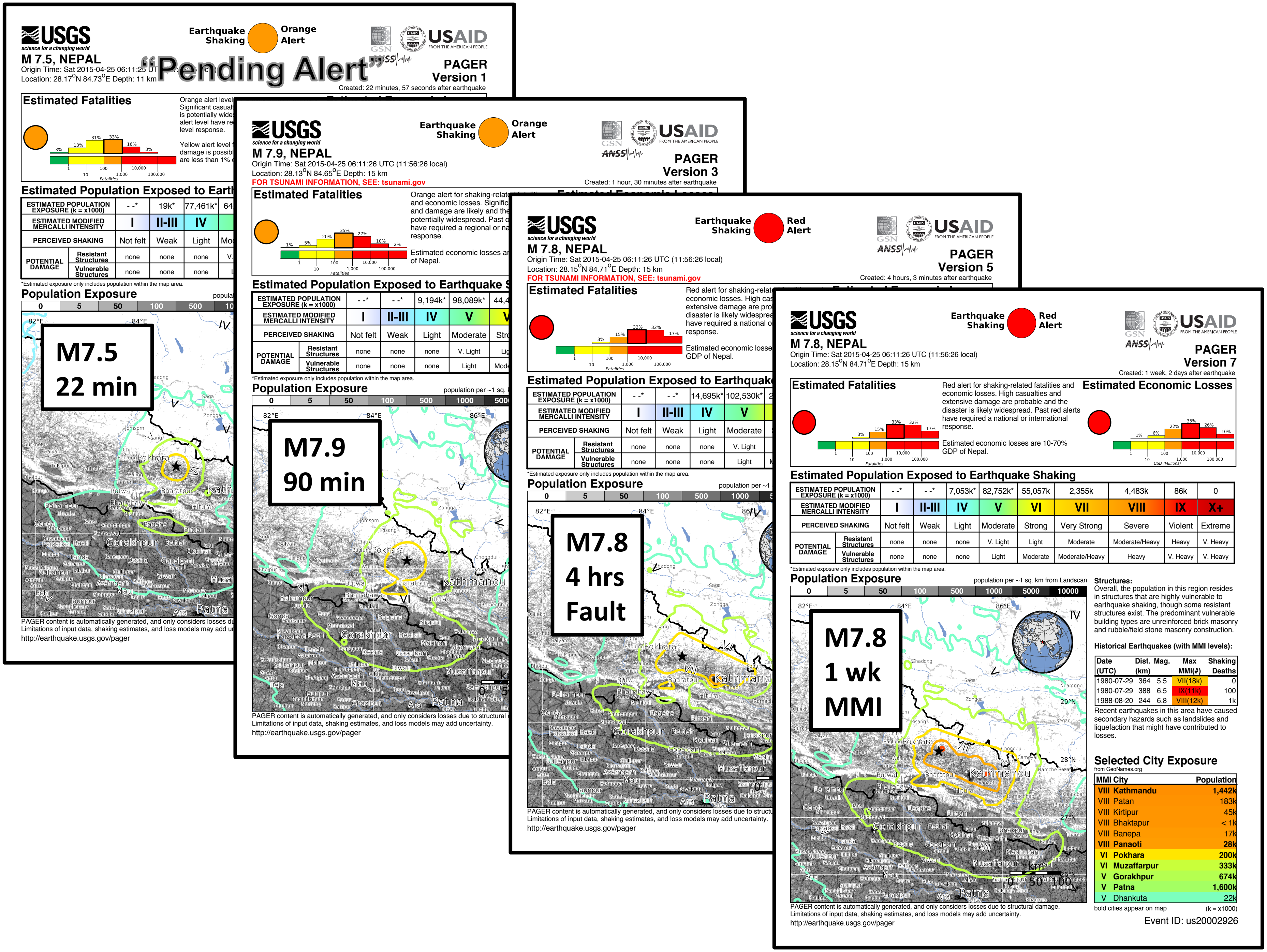
[Wald et al (2011) *Natural Hazards Review*]

M7.8 Nepal Mainshock



M7.3 Nepal Aftershock





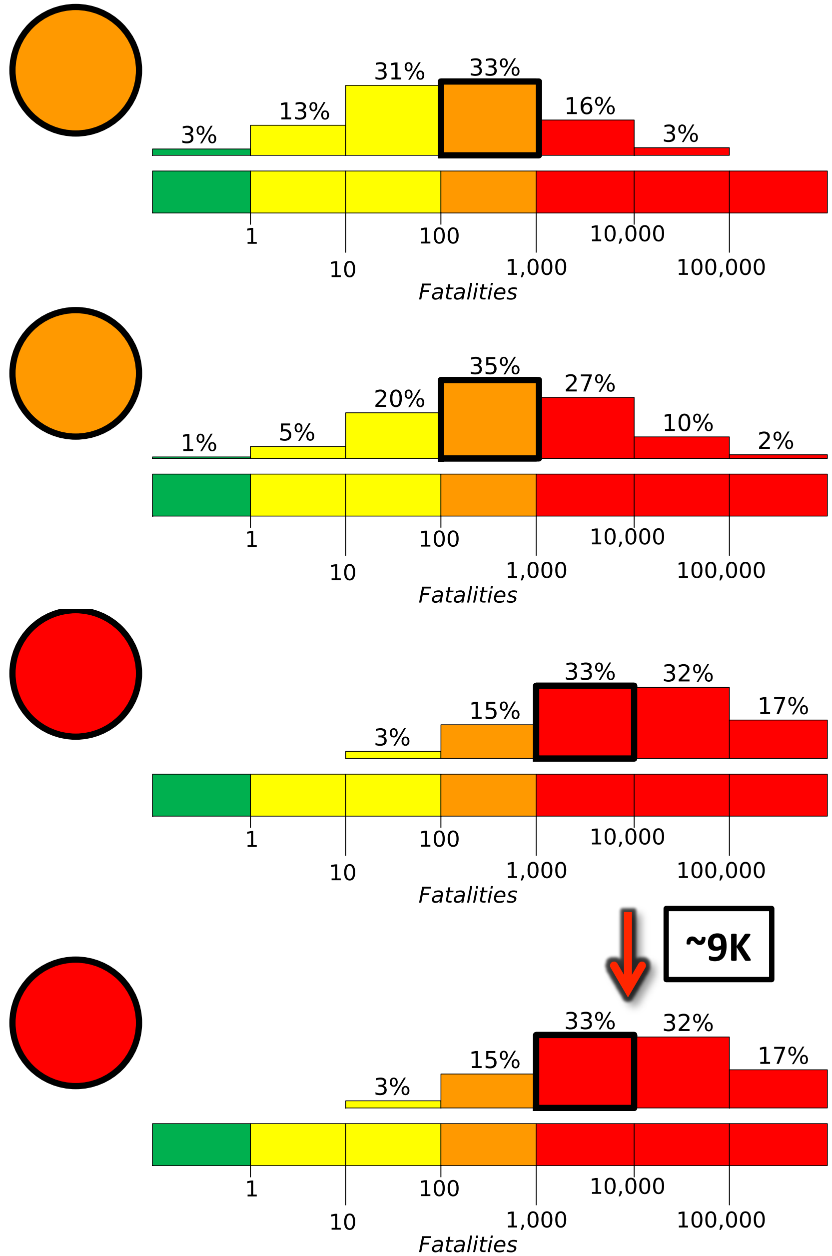
"Pending Alert"
M 7.5, NEPAL
Earthquake Shaking Orange Alert
PAGER Version 1
Created: 22 minutes, 57 seconds after earthquake
M7.5
22 min
M 7.9, NEPAL
Earthquake Shaking Orange Alert
PAGER Version 3
Created: 1 hour, 30 minutes after earthquake
M7.9
90 min
M 7.8, NEPAL
Earthquake Shaking Red Alert
PAGER Version 5
Created: 4 hours, 3 minutes after earthquake
M7.8
4 hrs
Fault
M 7.8, NEPAL
Earthquake Shaking Red Alert
PAGER Version 7
Origin Time: Sat 2015-04-25 06:11:26 UTC (11:56:26 local)
Location: 28.15°N 84.71°E Depth: 15 km
Created: 1 week, 2 days after earthquake
Estimated Fatalities
Estimated Economic Losses
Estimated Population Exposed to Earthquake Shaking
Population Exposure
Structures:
Historical Earthquakes (with MMI levels):
Selected City Exposure
M7.8
1 wk
MMI
Event ID: us20002926

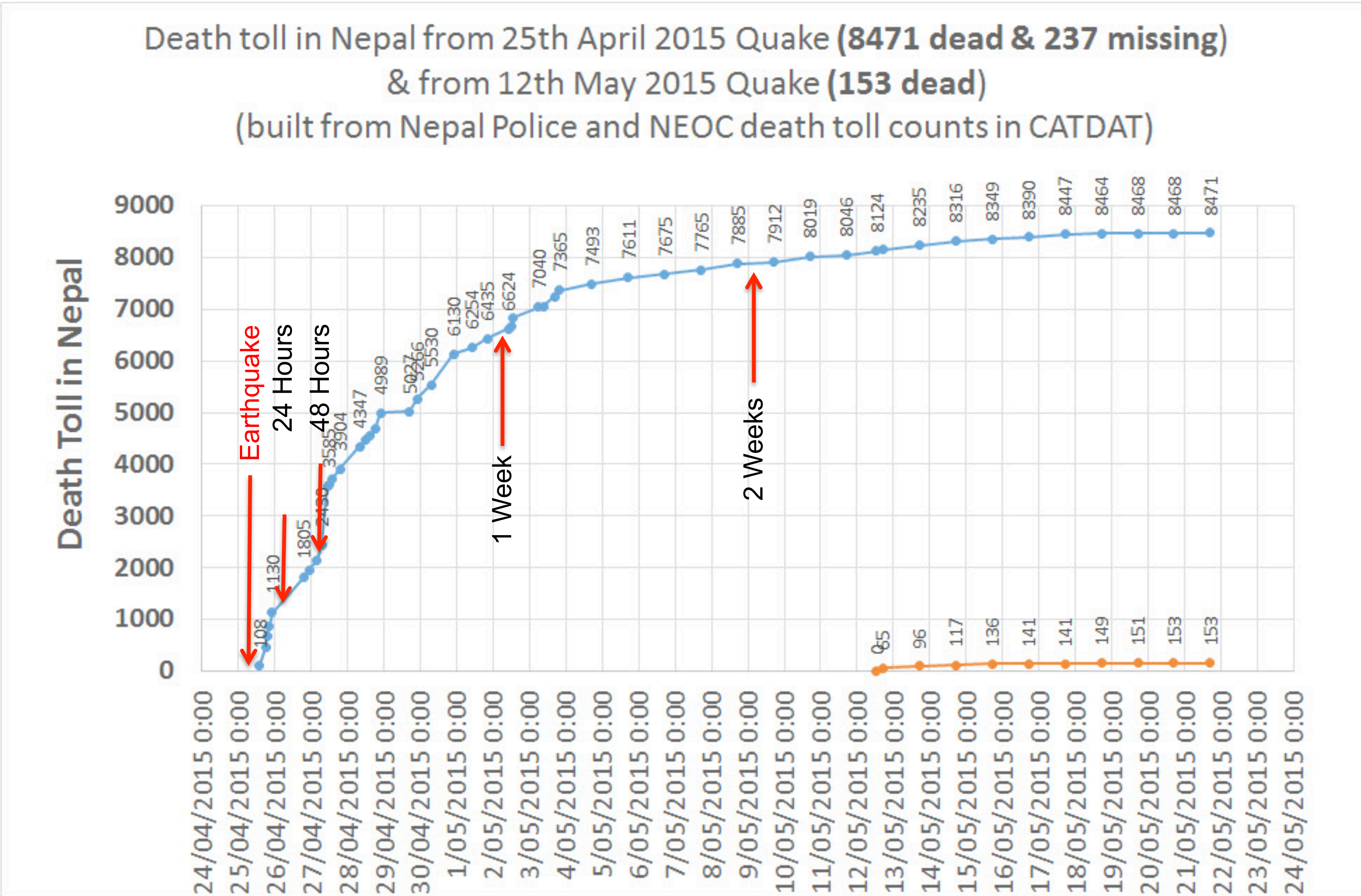
V1 M7.5, 22 min
Hypocenter

V3 M7.9, 90 min
Hypocenter

V5 M7.8, 4 hours
Fault Added

V7 M7.8, 1 week
MMI Added





Modified from J. Daniels, CatDat

BREAKING NEWS

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At least 39 dead after another powerful earthquake hits Nepal

By Jethro Mullen, Greg Botelho and Moni Basu, CNN

Updated 9:16 AM ET, Tue May 12, 2015

Source: CNN

Now Playing — US Geological Survey: magnitude 7.3 earthquake hits Nepal

01:03 — 5 most powerful recorded earthquakes

01:38 — Why aren't earthquake warnings better?

Powerful earthquake strikes Nepal

Nepal earthquake

- Faces of Nepal: Tales of loss and survival
- Mountain villages are cut off from almost everything
- 101-year-old man rescued one week later
- Camera captures Everest avalanche
- Aerial images show Nepal quake damage
- Photos of the devastation
- How to help the quake victims

Story highlights

NEW: Official: The death toll in Nepal rises to at least 36, with more than 1,100 injured

The magnitude-7.3 quake is followed by a series of aftershocks, the USGS says

The quake causes buildings to collapse, sets

Have you been affected? Tell us your experiences but stay safe

(CNN)—Latest developments:

• At least 36 people have died in Nepal and another 1,129 have suffered injuries due to the latest earthquake, said Nepalese Home Ministry Spokesman Laxmi Prasad Dhakal. Three other deaths were reported in neighboring

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BREAKING NEWS

President Obama speaks at summit on overcoming poverty. Watch live on CNNgo.

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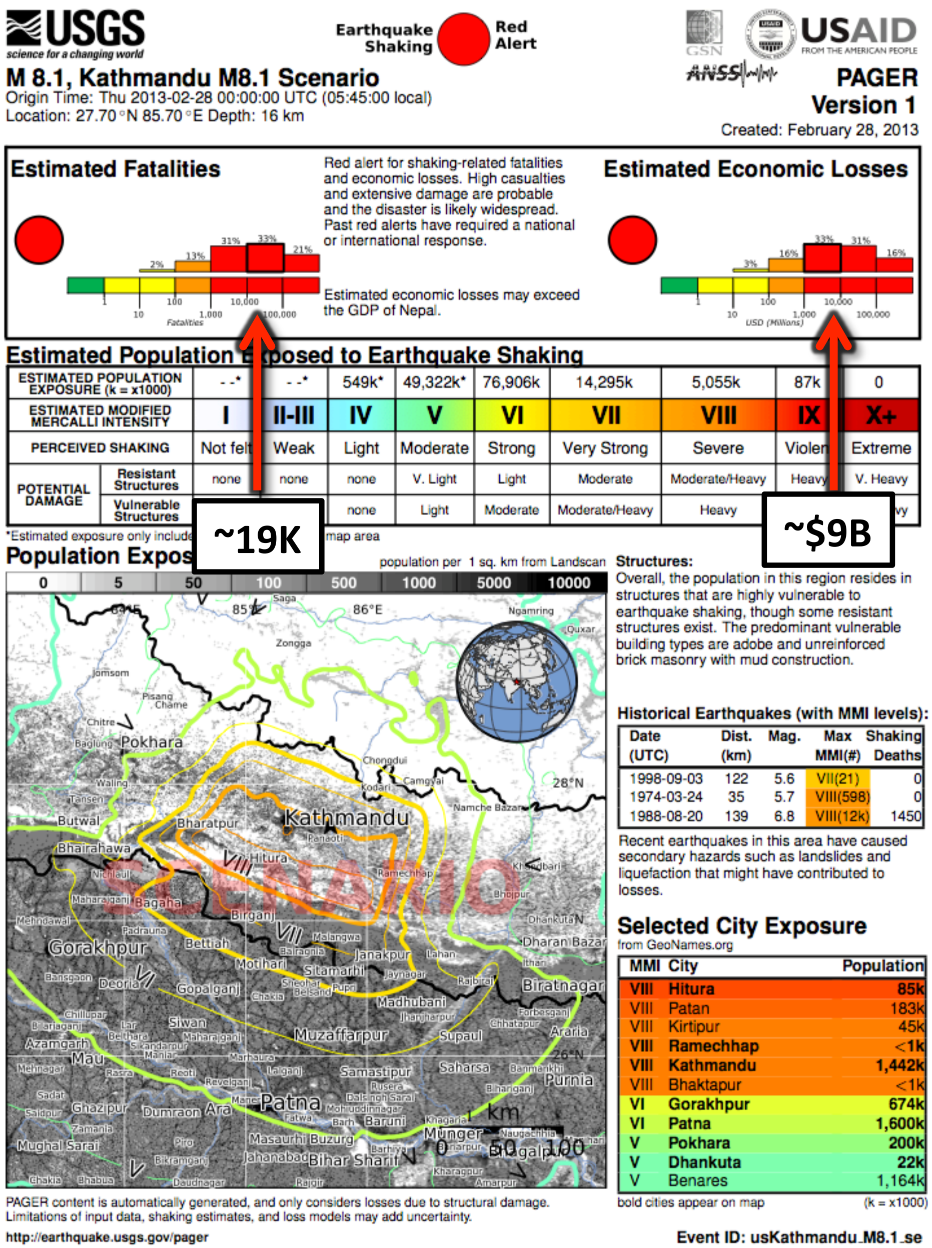
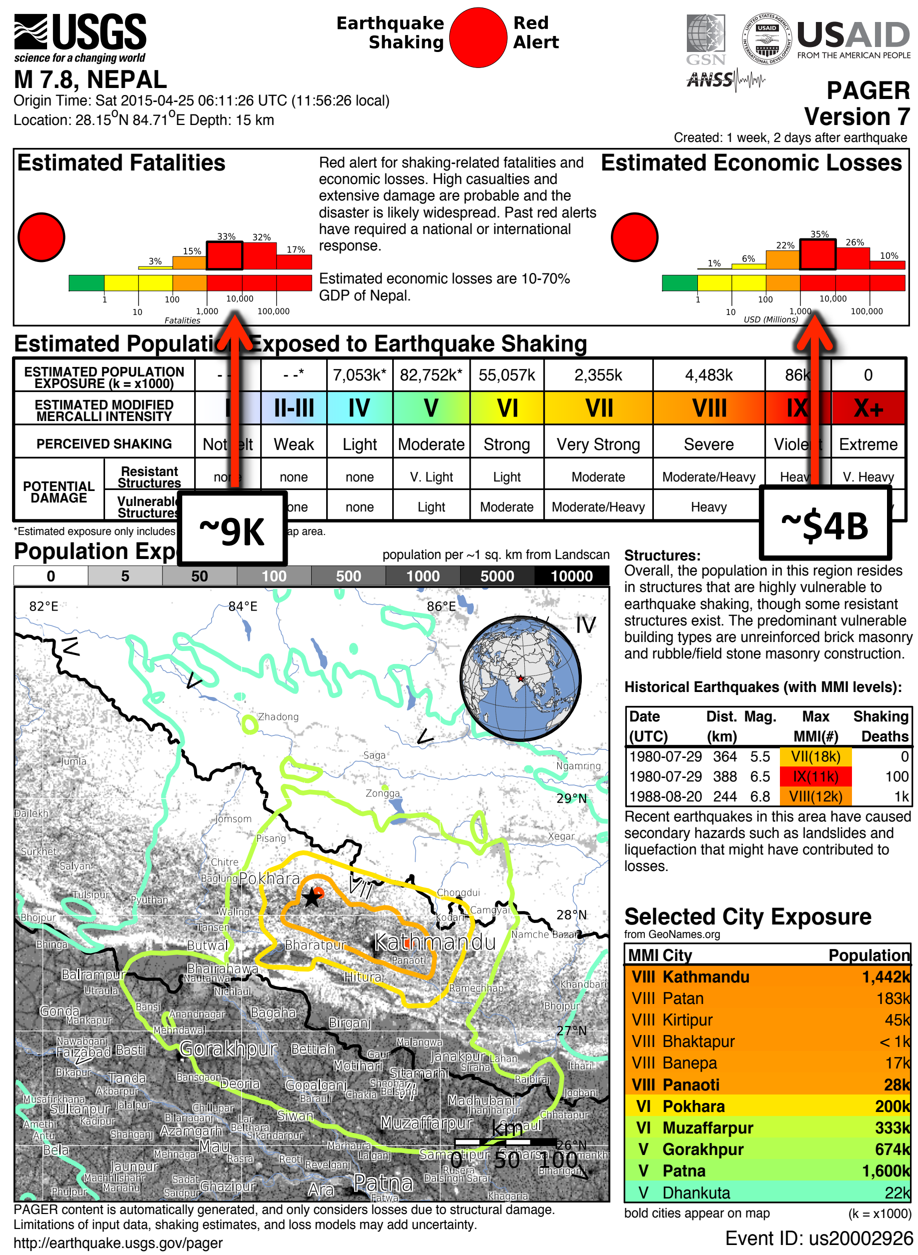
• At least 36 people have died in Nepal and another 1,129 have suffered injuries due to the latest earthquake, said Nepalese Home Ministry Spokesman Laxmi Prasad Dhakal.

M8.1 OFDA SCENARIO (DONE IN 2013)

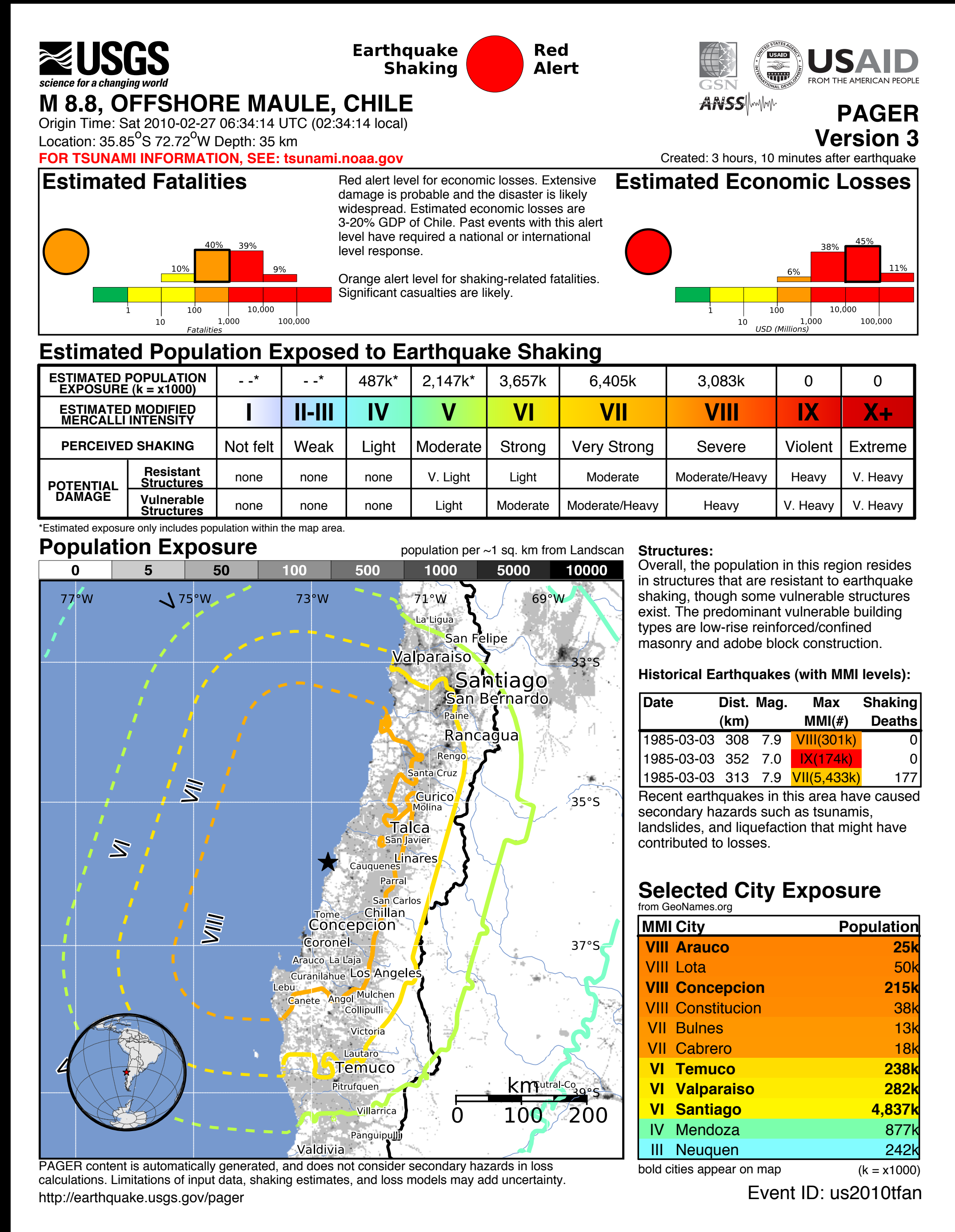


M7.8 Nepal Earthquake



USGS PAGER System

(Prompt Assessment of Global Earthquakes for Response)



USGS
science for a changing world

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

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

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

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

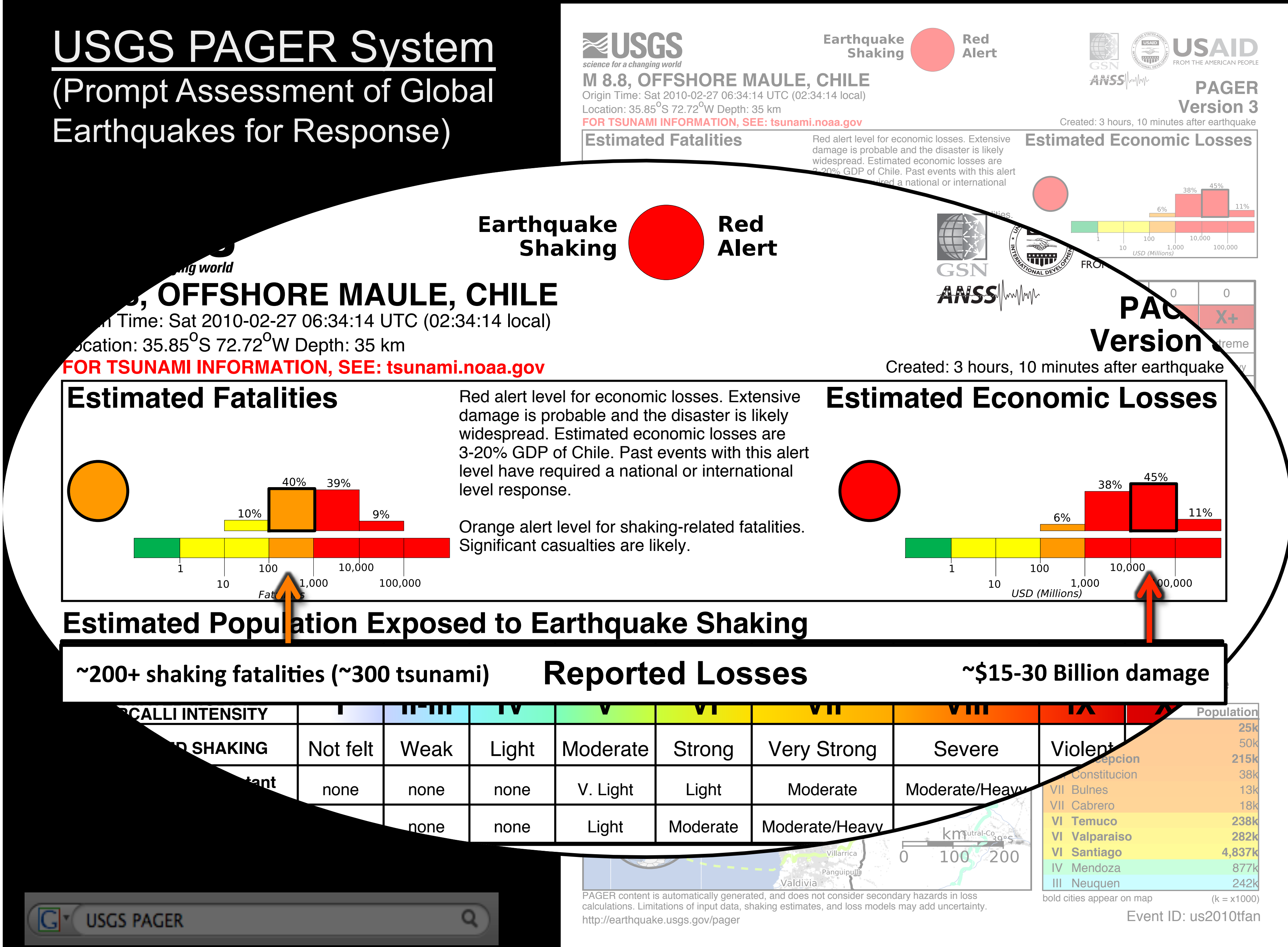
MMI	City	Population
VIII	**Arauco**	**25k**
VIII	Lota	50k
VIII	**Concepcion**	**215k**
VIII	Constitucion	38k
VII	Bulnes	13k
VII	Cabrero	18k
VI	**Temuco**	**238k**
VI	**Valparaiso**	**282k**
VI	**Santiago**	**4,837k**
IV	Mendoza	877k
III	Neuquen	242k

bold cities appear on map (k = x1000)

Event ID: us2010tfan

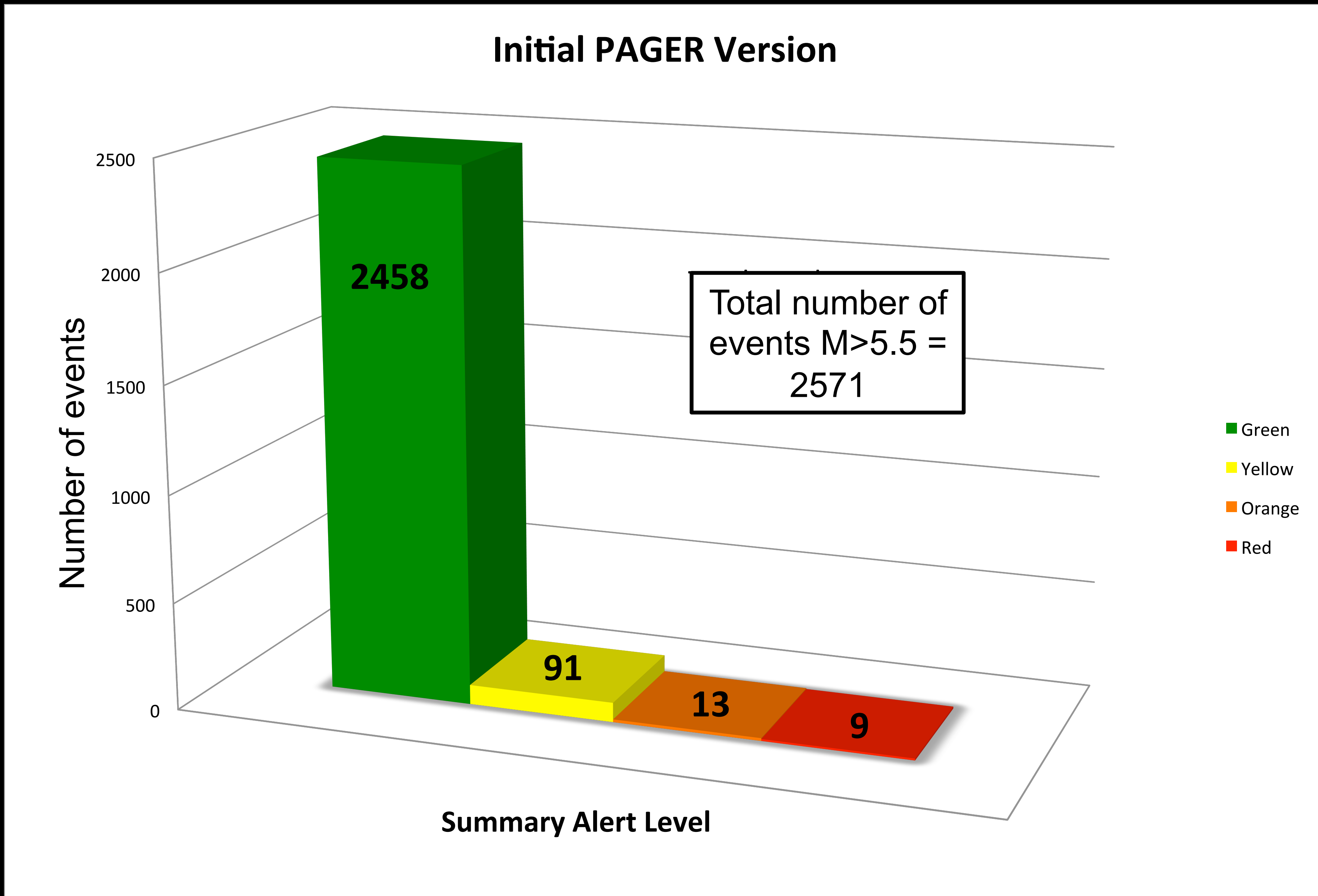
USGS PAGER System

(Prompt Assessment of Global Earthquakes for Response)



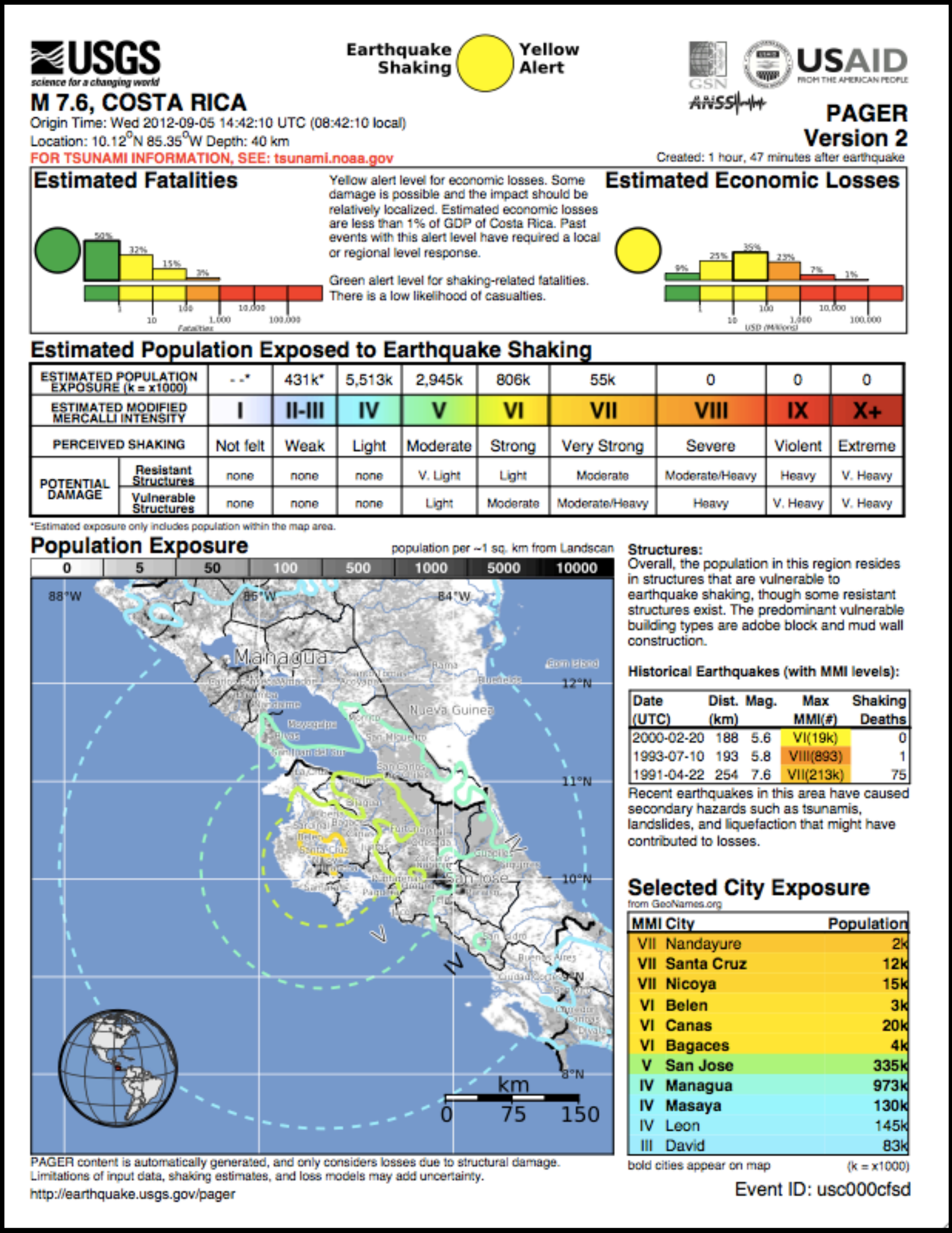
PAGER ALERTS (late 2010-2013)

PAGER (Prompt Assessment of Global Earthquakes for Response)



PAGER

Prompt Assessment of Global Earthquakes for Response



USGS science for a changing world

Earthquake Shaking — Yellow Alert

GSN ANSS USAID FROM THE AMERICAN PEOPLE

PAGER Version 2

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

Created: 1 hour, 47 minutes after earthquake

Estimated Fatalities

50% 32% 15% 3%

1 10 100 1,000 10,000 100,000

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

9% 25% 35% 23% 7% 1%

1 10 100 1,000 10,000 100,000

USD (Millions)

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

0 5 50 100 500 1000 5000 10000

88°W 86°W 84°W 12°N 11°N 10°N 8°N

Managua Nueva Guinea San Jose

km 0 75 150

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

USAID FROM THE AMERICAN PEOPLE

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Earthquake Shaking **Yellow Alert**

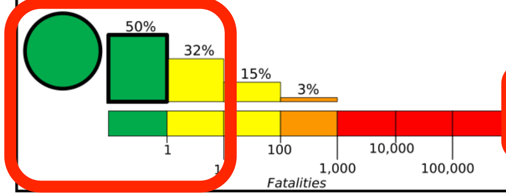
GSN ANSS USAID FROM THE AMERICAN PEOPLE

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

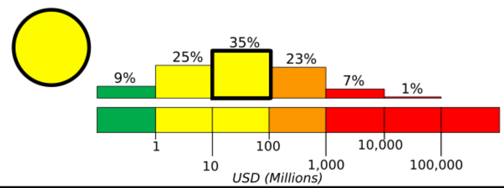
Estimated Fatalities



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

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.

Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

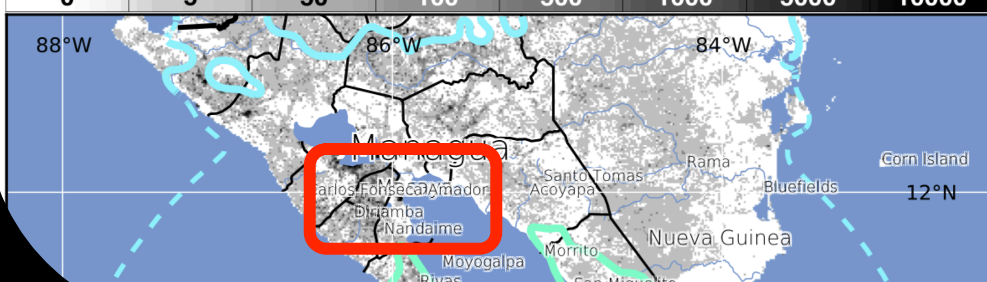
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	431k*	5,513k	2,945k	806k	55k	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light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

0	5	50	100	500	1000	5000	10000



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)	

Event ID: usc000cfsd

USGS PAGER System
(Prompt Assessment of Global Earthquakes for Response)

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Prompt Assessment of Global Earthquakes for Response

USGS

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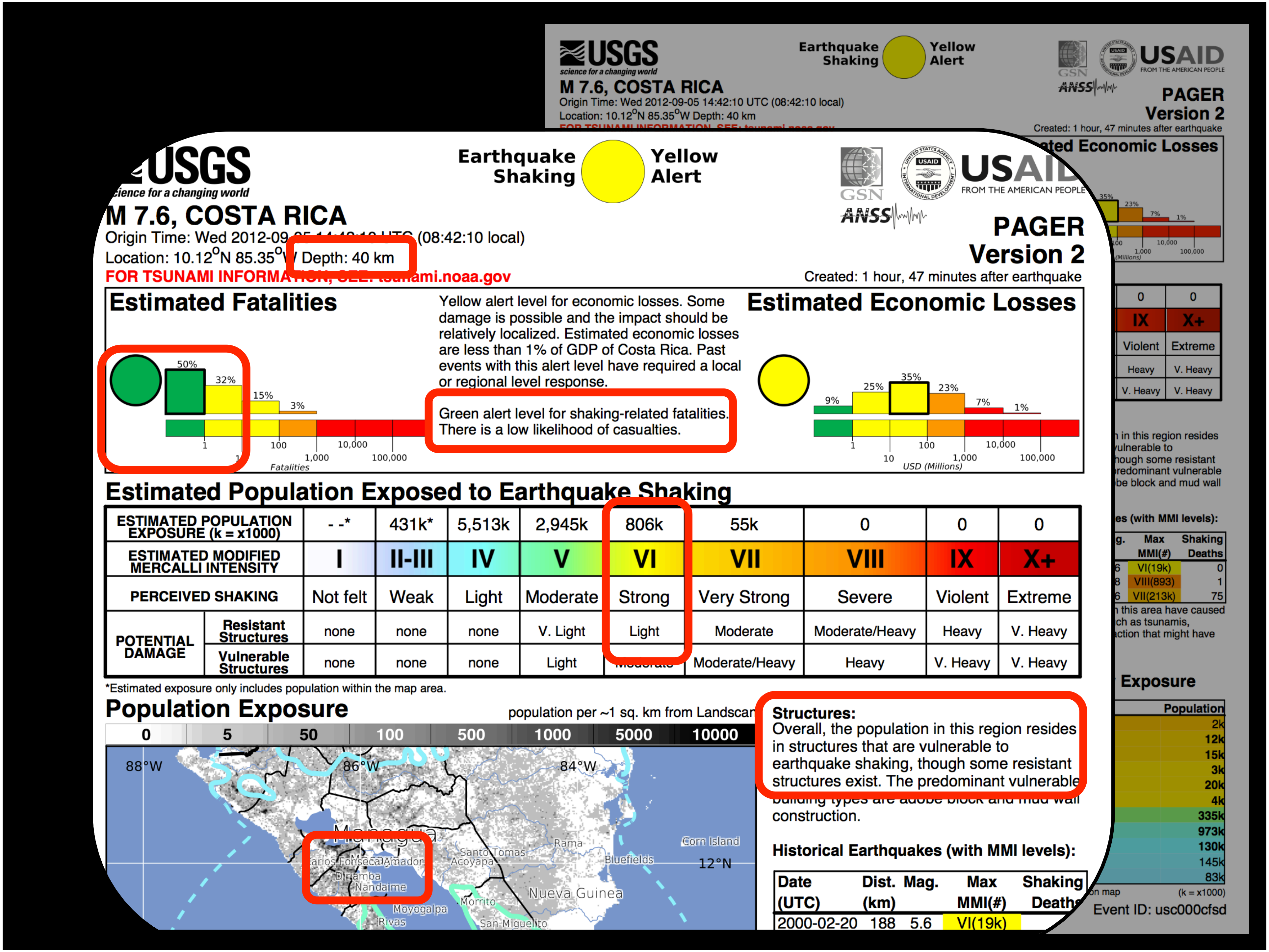

USGS
science for a changing world
Earthquake Shaking Yellow Alert
GSN ANSS USAID FROM THE AMERICAN PEOPLE
PAGER Version 2
M 7.6, COSTA RICA
Origin Time: Wed 2012-09-05 14:42:10 UTC (08:42:10 local)
Location: 10.12°N 85.35°W Depth: 40 km
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov
Created: 1 hour, 47 minutes after earthquake

Estimated Fatalities

50% 32% 15% 3%
1 10 100 1,000 10,000 100,000
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

9% 25% 35% 23% 7% 1%
1 10 100 1,000 10,000 100,000
USD (Millions)

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

0 5 50 100 500 1000 5000 10000

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.

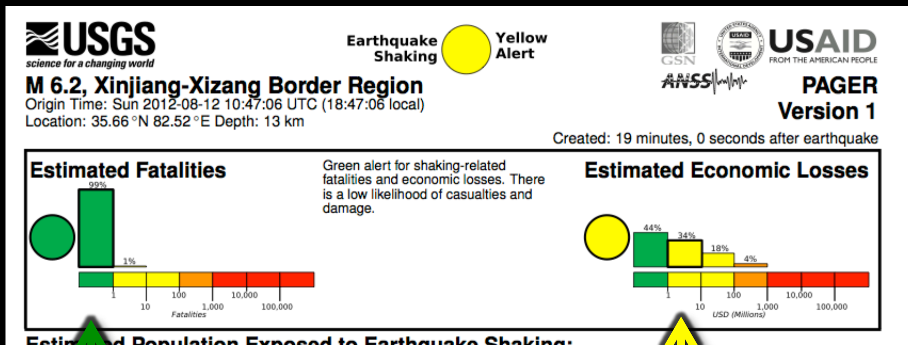
Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
2000-02-20	188	5.6	VI(19k)	

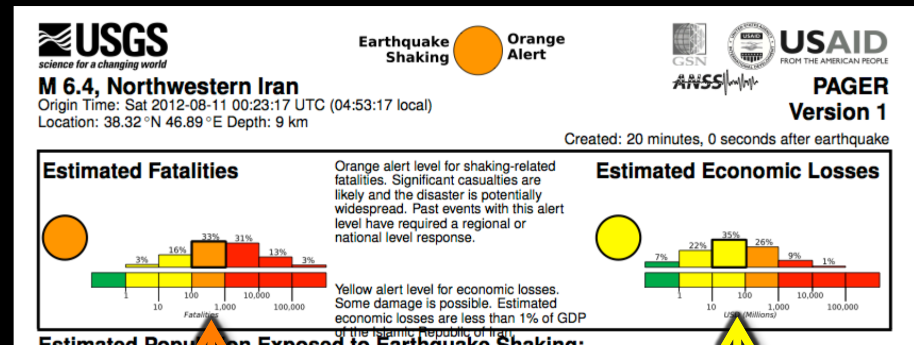
Event ID: usc000cfsd

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

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



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+

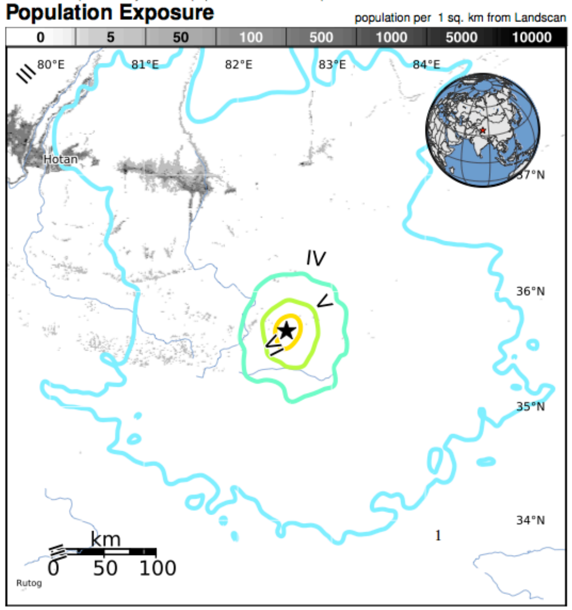


ESTIMATED POPULATION EXPOSURE (k = x1000)	--*	5,846k*	13,814k	2,120k	181k	60k	11k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

No fatalities, some injuries & damage

Reported Losses

300 fatalities, extensive damage



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

Selected City Exposure

from GeoNames.org

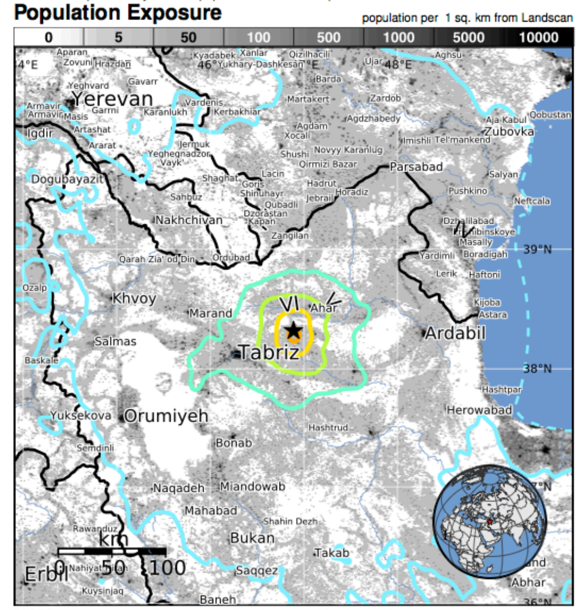
MMI	City	Population
III	**Rutog**	<1k
III	**Hotan**	114k
III	Layka	<1k

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: us201208121047



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

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
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

bold cities appear on map (k = x1000)

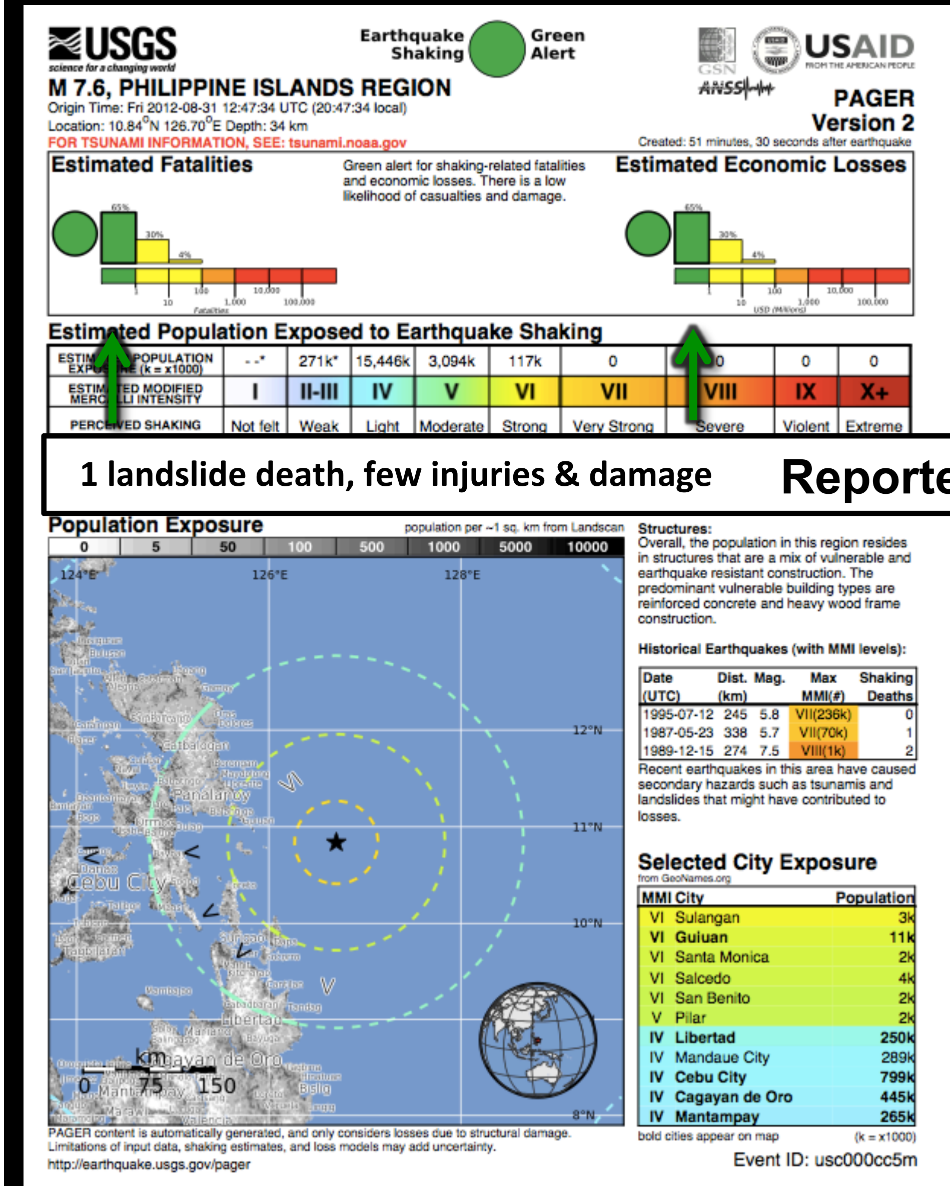
PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

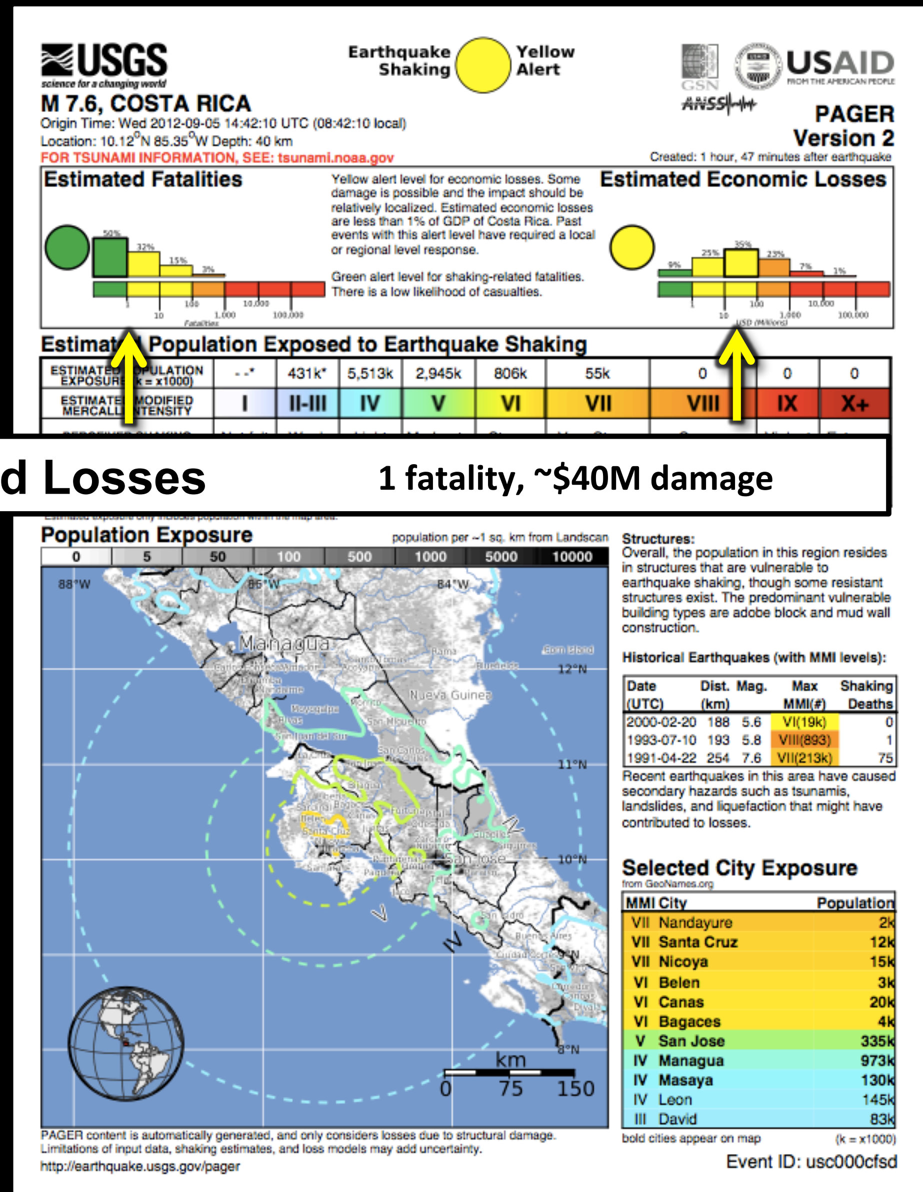
http://earthquake.usgs.gov/pager

Event ID: us201208110023

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

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





Reported Losses

1 landslide death, few injuries & damage

1 fatality, ~$40M damage

USGS
science for a changing world

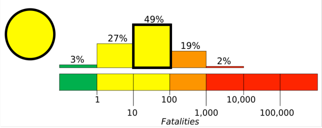
Earthquake Shaking Red Alert

GSN ANSS

M 9.0, Cascadia M9.0 Scenario

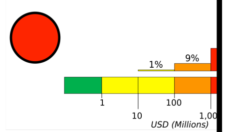
Origin Time: Tue 2011-09-20 12:00:00 UTC (03:39:30 local)
Location: 45.73°N 125.12°W Depth: 0 km
FOR TSUNAMI INFORMATION, SEE: tsunami.gov
Created: 120 minutes, 0 seconds a

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 Economi



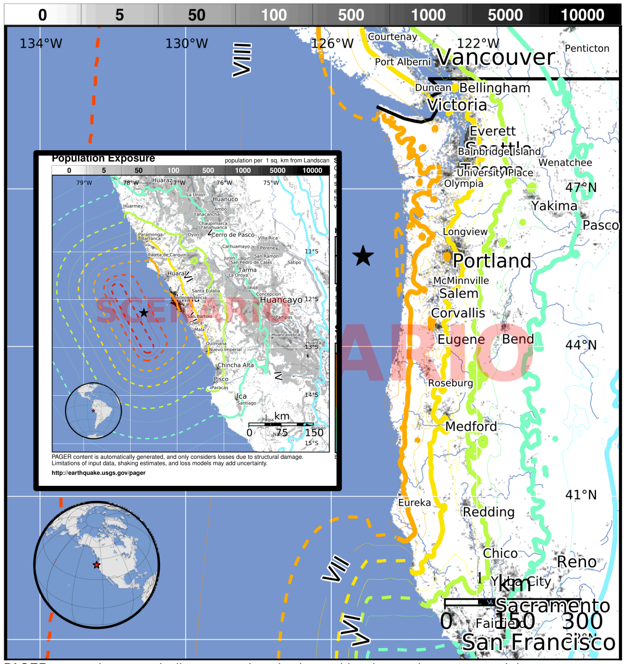
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	15k*	3,403k*	7,822k*	4,001k*	7,913k*	714k*	12
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	I)
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Viol
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Hea
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. He

*Estimated exposure only includes population within the map area

Population Exposure

population per 1 sq. km from Landscan



Structures:

Overall, the population in this r structures that are resistant to shaking, though some vulneral exist.

Historical Earthquakes (w

Date (UTC)	Dist. (km)	Mag.
1999-07-03	206	5.8
1993-03-25	214	5.6
2001-02-28	246	6.8

Recent earthquakes in this are secondary hazards such as la liquefaction that might have co losses.

Selected City Expo

from GeoNames.org

MMI	City
IX	Tillamook
IX	Warrenton
IX	Ocean Shores
IX	Barview
IX	Long Beach
IX	Harbor
VIII	**Salem**
VII	**Olympia**
VII	**Victoria**
V	**Sacramento**
IV	Carson City

bold cities appear on map

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: uscasc9.0

USGS
science for a changing world

Earthquake Shaking Red Alert

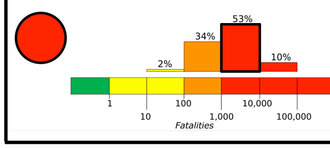
GSN ANSS USAID FROM THE AMERICAN PEOPLE

PAGER
Version 1

M 8.0, Subduction Scenario Offshore Lima, Peru

Origin Time: Thu 2015-01-01 00:00:00 UTC (19:00:00 local)
Location: 12.28°S 77.71°W Depth: 25 km
FOR TSUNAMI INFORMATION, SEE: tsunami.gov
Created: 20 minutes, 0 seconds after earthquake

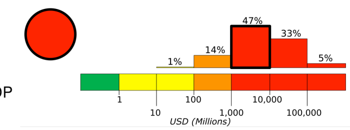
Estimated Fatalities



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 1-9% GDP of Peru.

Estimated Economic Losses



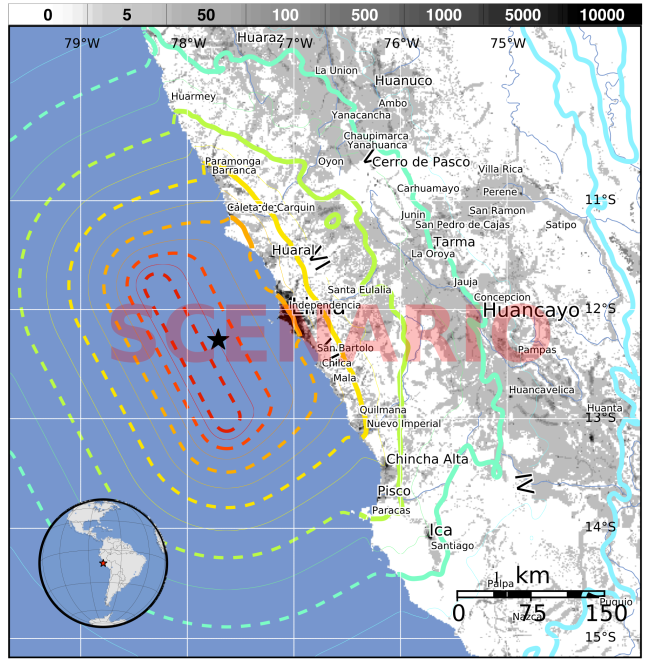
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	214k*	2,405k*	1,668k*	635k	5,613k	4,403k	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 mud wall and reinforced masonry with concrete floor construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1996-11-12	377	7.7	VIII(2k)	14
1974-10-03	20	7.6	VIII(43k)	78
2007-08-15	170	8.0	VIII(493k)	514

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
VIII	Callao	813k
VIII	**Lima**	**7,737k**
VIII	San Isidro	68k
VIII	**Chilca**	**13k**
VIII	**Caleta de Carquin**	**6k**
VIII	Hualmay	27k
V	**Ica**	**247k**
V	**Huancayo**	**377k**
V	**Huaraz**	**87k**
IV	**Huanuco**	**148k**
IV	Ayacucho	140k

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: usPeru_Subduction_se

Magnitude 6.0 2014 South Napa, CA

USGS science for a changing world

Earthquake Shaking **Red Alert**

GSN ANSS USAID FROM THE AMERICAN PEOPLE

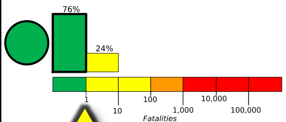
M 6.0, 6.8 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.22°N 122.31°W Depth: 11 km

PAGER Version 26

Created: 4 days, 4 hours after earthquake

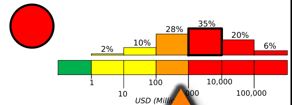
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a national or international 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)	- -*	4,881k*	3,281k	370k	145k	52k	82k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

1 Fatality (Sept 5th) >$450M Damage

Reported Losses

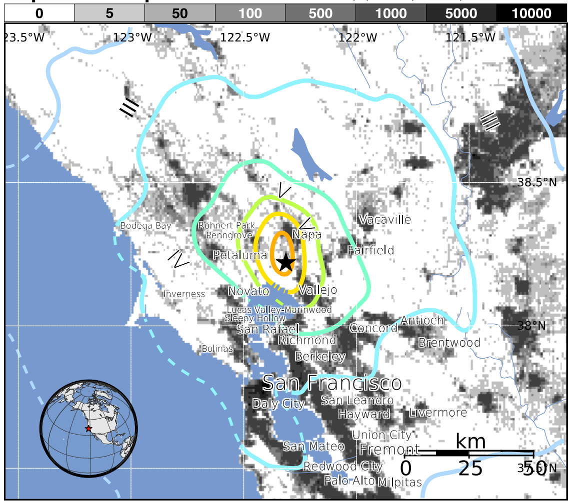
No Fatalities ~$200M Damage

*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 highly resistant to earthquake shaking, though some vulnerable structures exist.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1983-05-02	284	5.7	VIII(1k)	0
1980-01-24	76	5.8	VII(31k)	1
1989-10-18	132	6.9	IX(3k)	62

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	**Napa**	77k
VII	Yountville	3k
VII	American Canyon	19k
VI	El Verano	4k
VI	Sonoma	11k
VI	Temelec	1k
IV	Oakland	391k
IV	**San Francisco**	805k
III	Sacramento	466k
III	**Fremont**	214k
III	Stockton	292k

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: nc72282711

Magnitude 5.8 2011 Mineral, VA

USGS science for a changing world

Earthquake Shaking **Orange Alert**

GSN ANSS USAID FROM THE AMERICAN PEOPLE

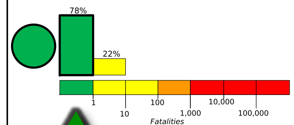
M 5.8, VIRGINIA

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

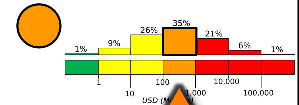
Estimated Fatalities



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

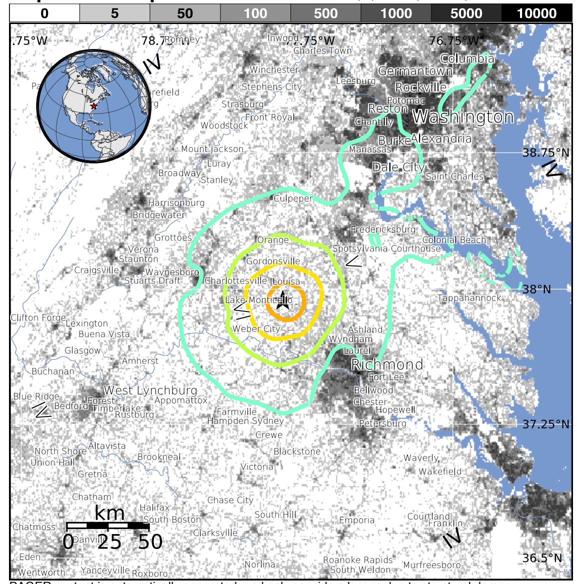
ESTIMATED POPULATION EXPOSURE (k = x1000)	- -*	19k*	9,627k*	2,285k	76k	23k	10k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

*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

Tweet from the Head of FEMA

From: "Bausch, Douglas" <Douglas.Bausch@fema.dhs.gov>
Date: Sep 30, 2014 3:48 PM
Subject: FW: M4.1 Earthquake - Kansas / **Green PAGER issued** / Rural area

FYI. How NWC uses PAGER:

From: FEMA-NWC **Sent:** Tuesday, September 30, 2014 9:32 AM **To: Armed Forces Health Surveillance Center** ; **Army Domestic**; Casey, Wanda; EOC DOC; Daruvalla, Sampson; **Dept of Labor; DOE**; Don Boyce; DSPMO; Dubois, Vincent; EnergyResponseCenter@hq.doe.gov; FEMA-Recovery-Geo; **FEMA TOP LEVEL MANAGERS; FEMA-MOTF; FEMA-NCP-CRC-WATCH; Gunn, Abraham; HHS**; HQ-FEMA-OEA-Senior Staff; Ives, Robert; Jackson, Liz; jfhq.ncrcc@tsa.dhs.gov; Jones, Julius; Judson, Paul; Matia, Matthew; Vineyard, Micheal; Monchek, Rafaela; Moncrief, Jane; NOC.FEMA; NOC.SWO.Restricted; FEMA-nrccps-ocia; Osborne, Andrew; Peerbolte, Stacy; Pendergrass, Michael M; **Pentagon** J3; Pirrone, Joel; Rodriguez, Jose I; RR-FCO; Sabata, Andrew; Shoemate, Justin; Singleton Sr, Jacques; **FAA** Significant Incident Response Group; Soucie, Eric; Stewart, James M (LMD); Sullivan, Robert; Tribble, Ahsha; Zohn, Ashley; Behnke, Matthew; Burkett, Ronald (OGA); **Customs and Border Patrol** (CBP); Villoch, Deborah; Jacques, Richard; **DHS** – Office of Health Affairs (DHS-OHA); DOJ/ATF (ESF 13) ; Erickson, Somer; Hall, Carol (OGA); Hylton, Roberto; FEMA-IGA; Kahley, Matthew (**OGA**); Kimzey, Samuel; Kimzey, Samuel (OGA); Kooper, Ronald LCDR; Hatley, Thomas (OGA); MacIntyre, Anthony (OGA); Macintyre, Anthony; **NOAA**-LNO; FEMA-PSR; Special Advisor for **National Tribal Affairs**; Tamillow, Michael; Sholas, Mac (OGA); Irwin, William (OGA); **USNORTHCOM** (for FEMA Logistics) ; Valcourt, Kenneth (OGA); White, Gregory (OGA); Albright, Thomas; Amparo, Alex; Anderson, Lars; Apodaca, Michael; **Asst Secretary for DOE**; Balint, Thomas; Biasco, Lon; Blanchard-Mbangah, Shauna M; Breslin, Thomas; Bresnahan, Michael; Brewster, Jared; Buras, Ryan; Burgess, Steven; Camp, Gwen; Campbell, Pauline; Carleton, John; Carlyle, Robert; Coen Jr, Michael; Dorko, Jeffrey; Dozor, Joshua; Dunn-Alexander, Roslyn; ESF-06-**MASS-CARE**; Eswood, Louis; FEMA-LRC-Chief; FEMA-NWC-NCR-Watch; FEMA-R8-RRCC-DIRECTOR; FEMA-Recovery-Reports; Fields, Kathy; Fox, Kathleen; **Fugate, Craig**; Gammon, Carla; Geiger, Paul; George, Michael S; Gillis, Carmeyia; Gonzalez, Waddy; Gorman, Chad; Gray, Patricia; Green, Matthew; Grimm, Michael; Gruber, Corey; Hart, Patrick; **HQ-OEA Directors**; Rabin, John; Jones, Berl; Jones, Julius M. Jr; Juskie, John; Kaufman, David; Keldsen, Donald; Kieserman, Brad; Kish, James; Kittrie, Zachary; Koziol, Lauralee; Lapinski, Michael; Lewis, Leviticus; Liggett,

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

AP Associated Press

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

IDB
Inter-American Develop. Bank

UPI.com
100 YEARS OF JOURNALISTIC EXCELLENCE

EERI Earthquake Engineering Research Institute

GDACS
Global Disaster Alert & Coordination System

REUTERS

Aid Agencies/NGO

International

ANSS

State & Federal Government

THE WHITE HOUSE
PRESIDENT GEORGE W. BUSH

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

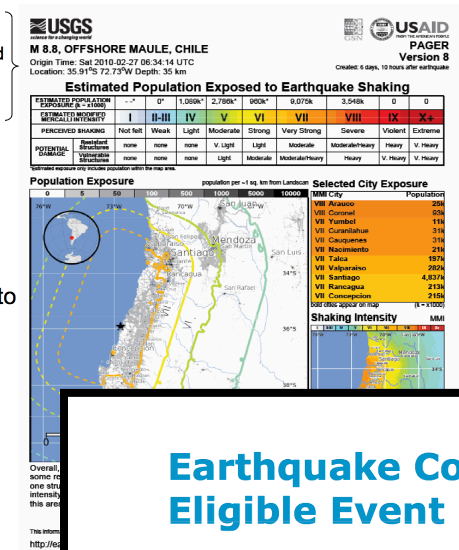
Example PAGER users: *Inter-American Development Bank*

Disaster Contingency Loans

Example of PAGER - USGS Report

Basic data of the Shacking: date and time, location and depth

Estimates the *people exposed* to a given shacking intensity in every point.



Modified Me
Scale - MMI

Shaking Map

Earthquake Coverage
Eligible Event

■*Event Intensity and Exposure definitions*

The Event has to register a VII (or higher
Modified Mercalli Intensity Scale - MMI), a
country population inside the General Co

Est. Modified Mercalli Intensity	Perceived Shaking		
X	Extreme		
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

IDB

Earthquake Coverage:
A hypothetical example

■*The Coverage Index (CI) calculation:*

$$CI = \frac{(\text{Total Affected Population} - MiAP) * 100}{(MAP - MiAP)}$$

■Total Affected Population: 322.000

■*MAP (5% of Country Population)* = 5%*[10.000.000] = 500.000

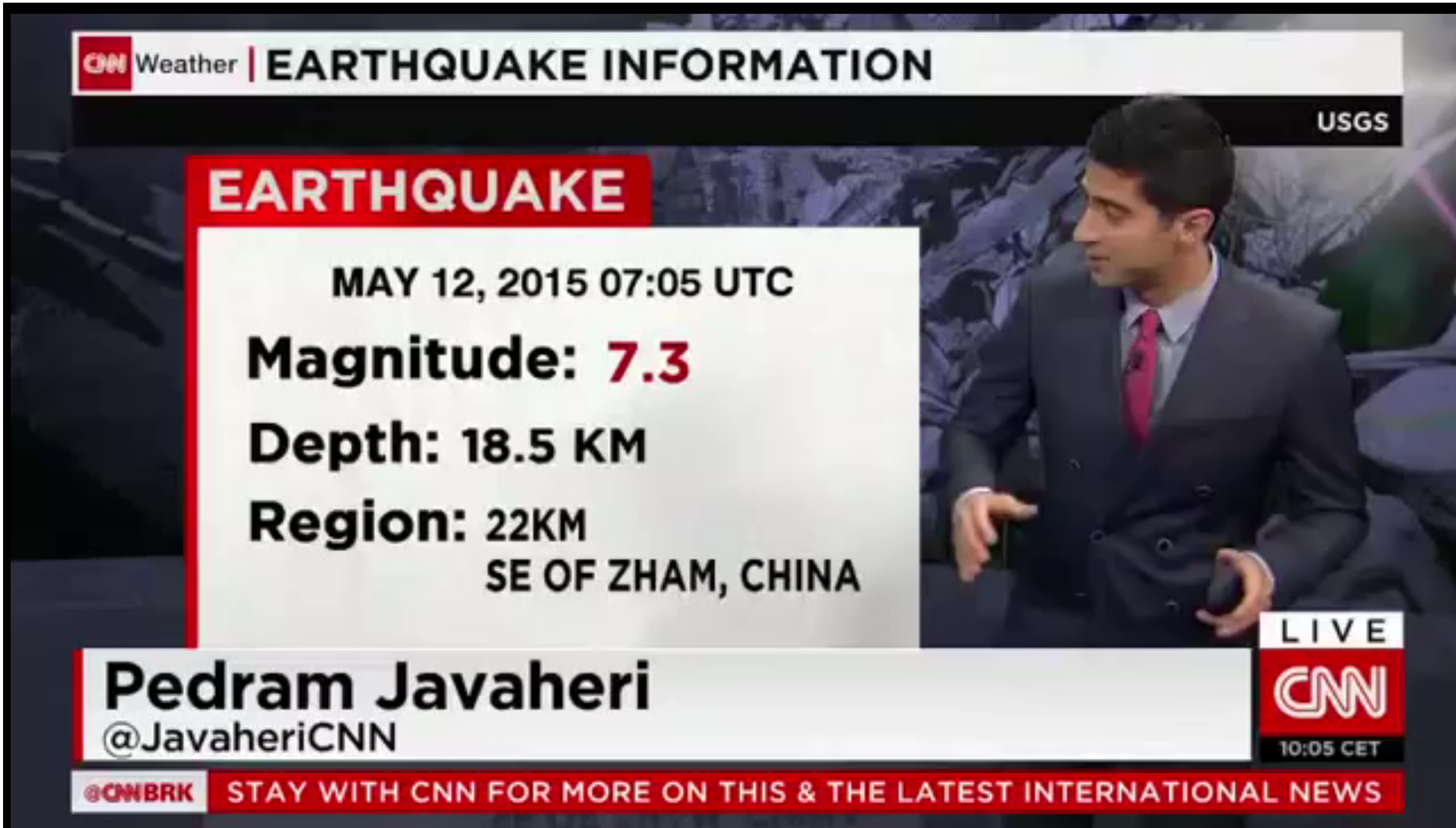
■*MiAP (2% of Country Population)* = 2%*[10.000.000] = 200.000

$$CI = \frac{(322.000 - 200.000) * 100}{(500.000 - 200.000)} = 41\%$$

The Contingent Loan provides coverage for up to US$100M. Therefore, an event with a CI of 68% would be eligible for a pay out of up to 41US$M.

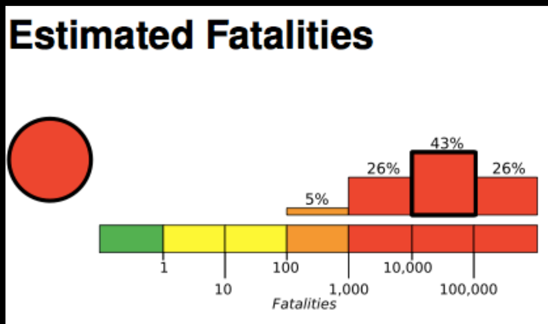
IDB

Courtesy of
J. Martinez, IDB

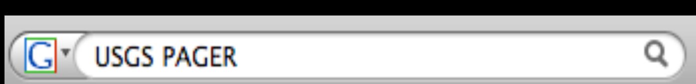

CNN Weather | EARTHQUAKE INFORMATION
USGS
EARTHQUAKE
MAY 12, 2015 07:05 UTC
Magnitude: 7.3
Depth: 18.5 KM
Region: 22KM SE OF ZHAM, CHINA
Pedram Javaheri
@JavaheriCNN
LIVE
CNN
10:05 CET
@CNNBRK
STAY WITH CNN FOR MORE ON THIS & THE LATEST INTERNATIONAL NEWS

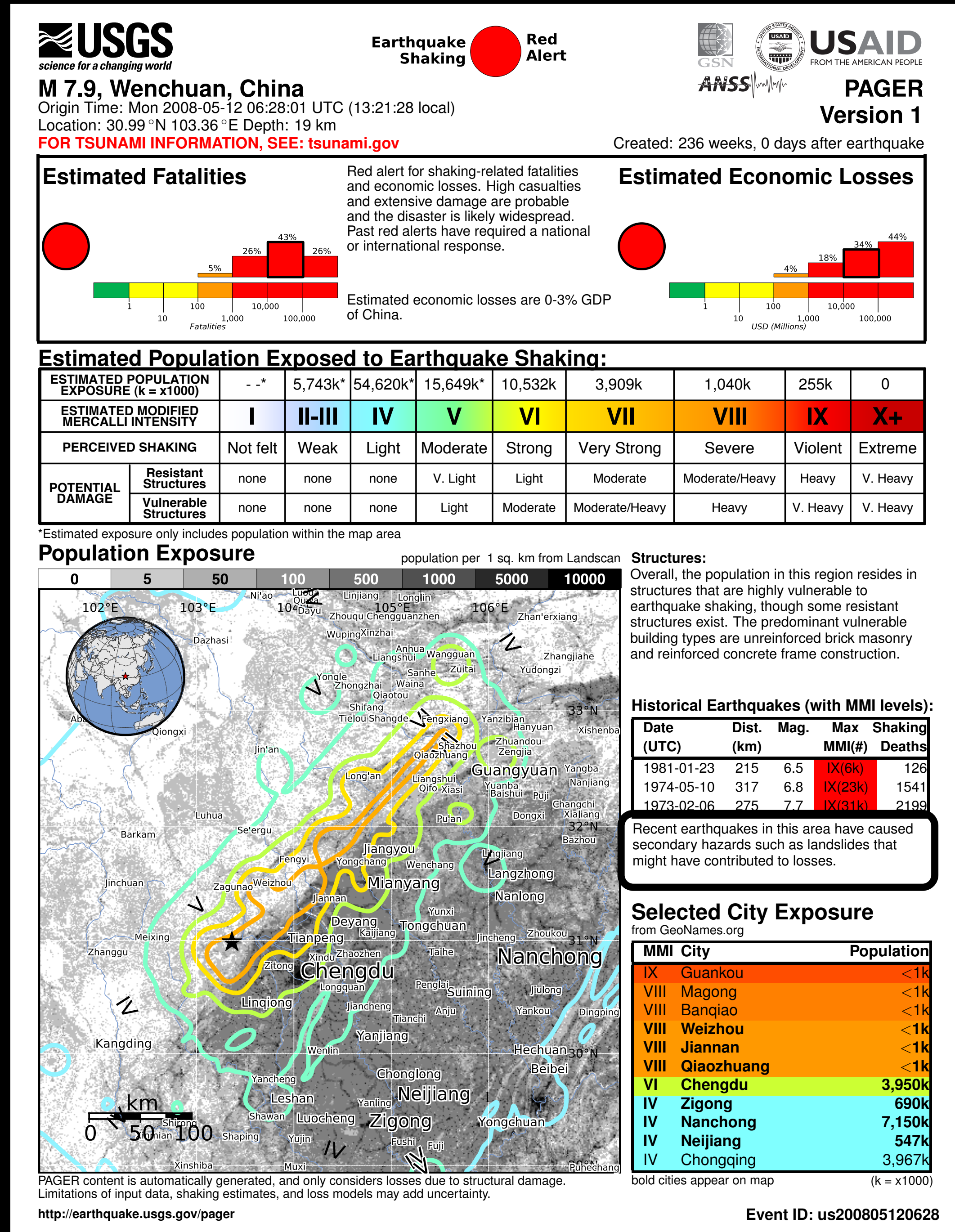
USGS PAGER System

(Prompt Assessment of Global Earthquakes for Response)



Wenchuan, China
Mw 7.9. 2008
87,000 Fatalities
(~20,000 killed by landslides)





USGS
science for a changing world

Earthquake Shaking Red Alert

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

PAGER
Version 1

M 7.9, Wenchuan, China

Origin Time: Mon 2008-05-12 06:28:01 UTC (13:21:28 local)
Location: 30.99 °N 103.36 °E Depth: 19 km
FOR TSUNAMI INFORMATION, SEE: tsunami.gov

Created: 236 weeks, 0 days after earthquake

Estimated Fatalities

5% 26% 43% 26%
1 10 100 1,000 10,000 100,000
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 0-3% GDP of China.

Estimated Economic Losses

4% 18% 34% 44%
1 10 100 1,000 10,000 100,000
USD (Millions)

Estimated Population Exposed to Earthquake Shaking:

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	5,743k*	54,620k*	15,649k*	10,532k	3,909k	1,040k	255k	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 highly vulnerable to earthquake shaking, though some resistant structures exist. The predominant vulnerable building types are unreinforced brick masonry and reinforced concrete frame construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1981-01-23	215	6.5	IX(6k)	126
1974-05-10	317	6.8	IX(23k)	1541
1973-02-06	275	7.7	IX(31k)	2199

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
IX	Guankou	<1k
VIII	Magong	<1k
VIII	Banqiao	<1k
VIII	**Weizhou**	**<1k**
VIII	**Jiannan**	**<1k**
VIII	**Qiaozhuang**	**<1k**
VI	**Chengdu**	**3,950k**
IV	**Zigong**	**690k**
IV	**Nanchong**	**7,150k**
IV	**Neijiang**	**547k**
IV	Chongqing	3,967k

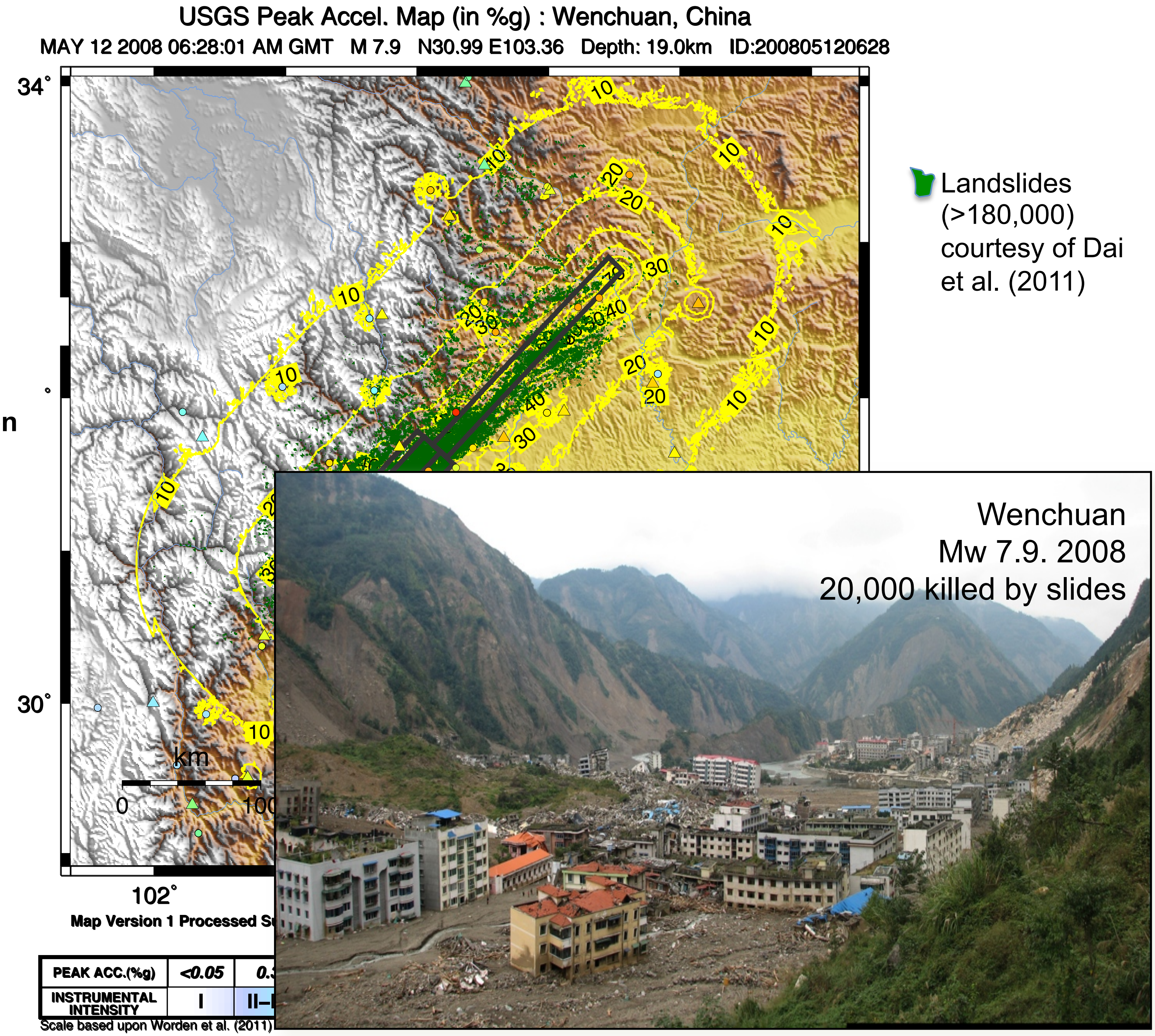
bold cities appear on map (k = x1000)

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: us200805120628

Wenchuan, China, 2008 Mw 7.9

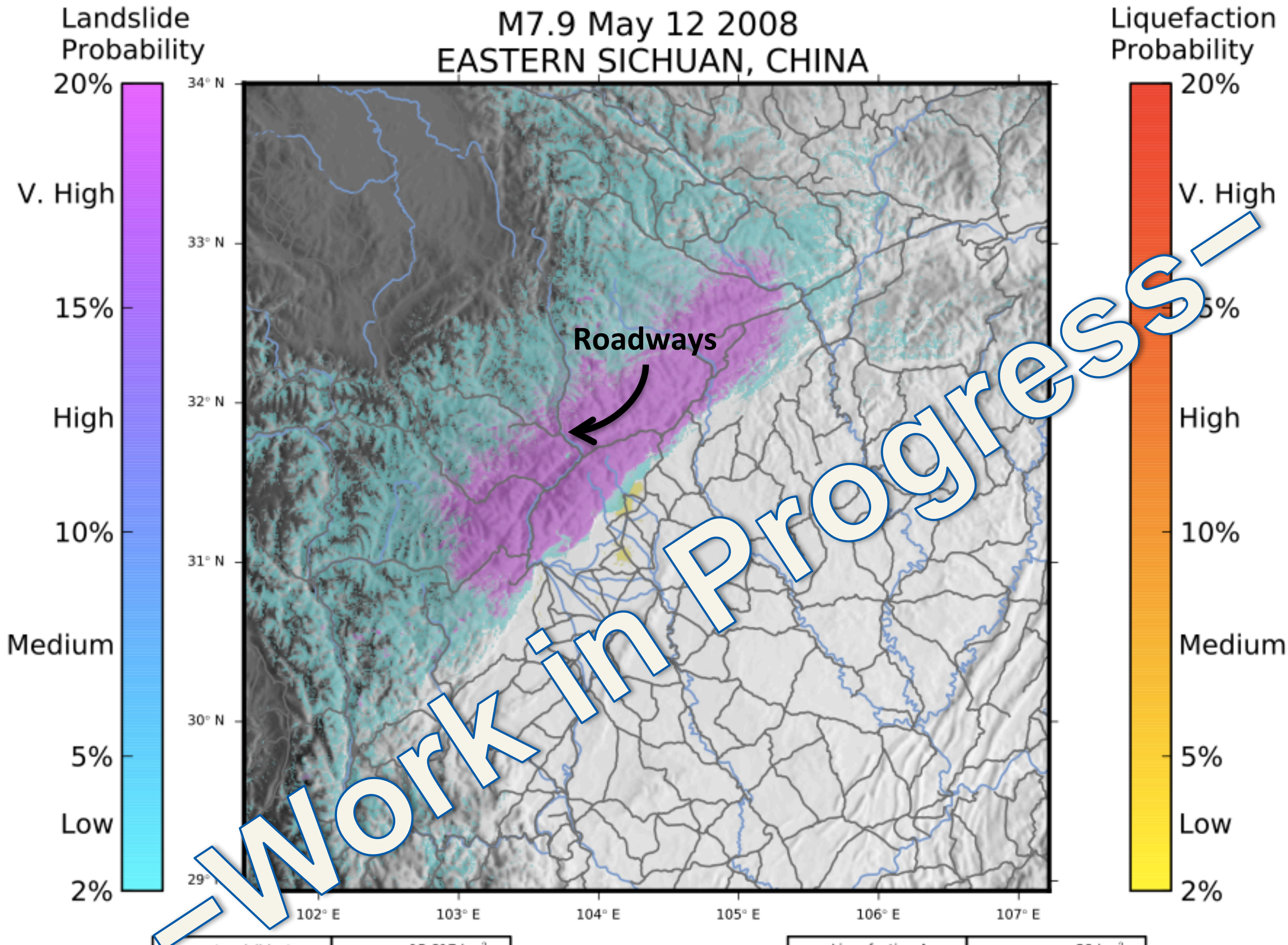


Landslides (>180,000) courtesy of Dai et al. (2011)

Intensity Observation

Strong Motion Station

Fault location



Landslide Area	15,617 km^2
# of cells	181,730
Maximum probability	100.0%
Mean probability	11.7%
Minimum slope	5.0°

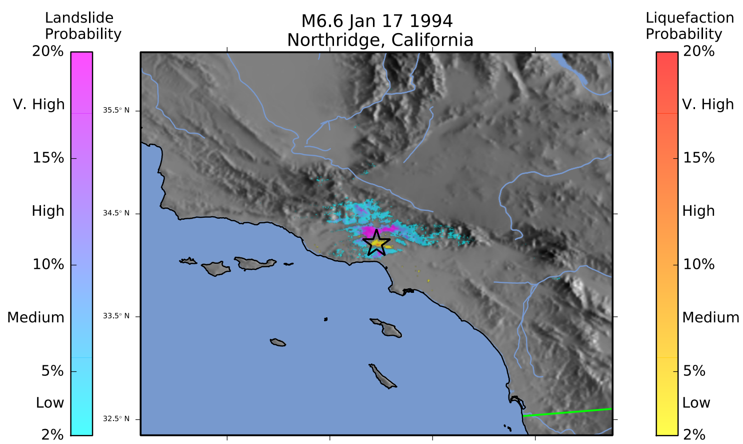
Liquefaction Area	39 km^2
# of cells	1,563
Maximum probability	6.9%
Mean probability	1.7%
Maximum slope	5.0°

Landslides & Liquefaction: ShakeCast Implementation

Requires:

1. USGS provide & distributed landslide & liquefaction likelihoods in ShakeMap-like grid (*geogrd.xml*).

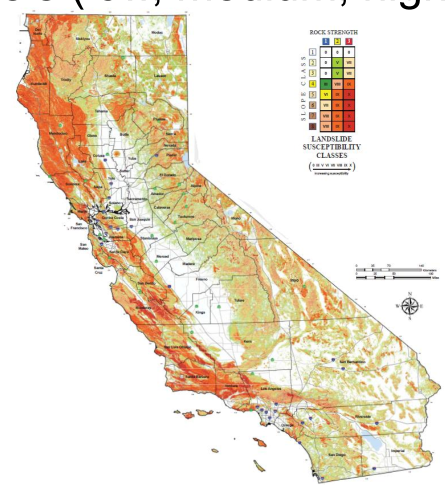
2. ShakeCast retrieves geogrd.xml to provide users with site-specific likelihoods in categories for facility evaluation.



Requires:

1. User has higher resolution/quality geotechnical information, e.g., susceptibility maps (separate landslide & liquefaction maps).

2. Look up tables for peak motion → likelihood levels (low, medium, high, very high).



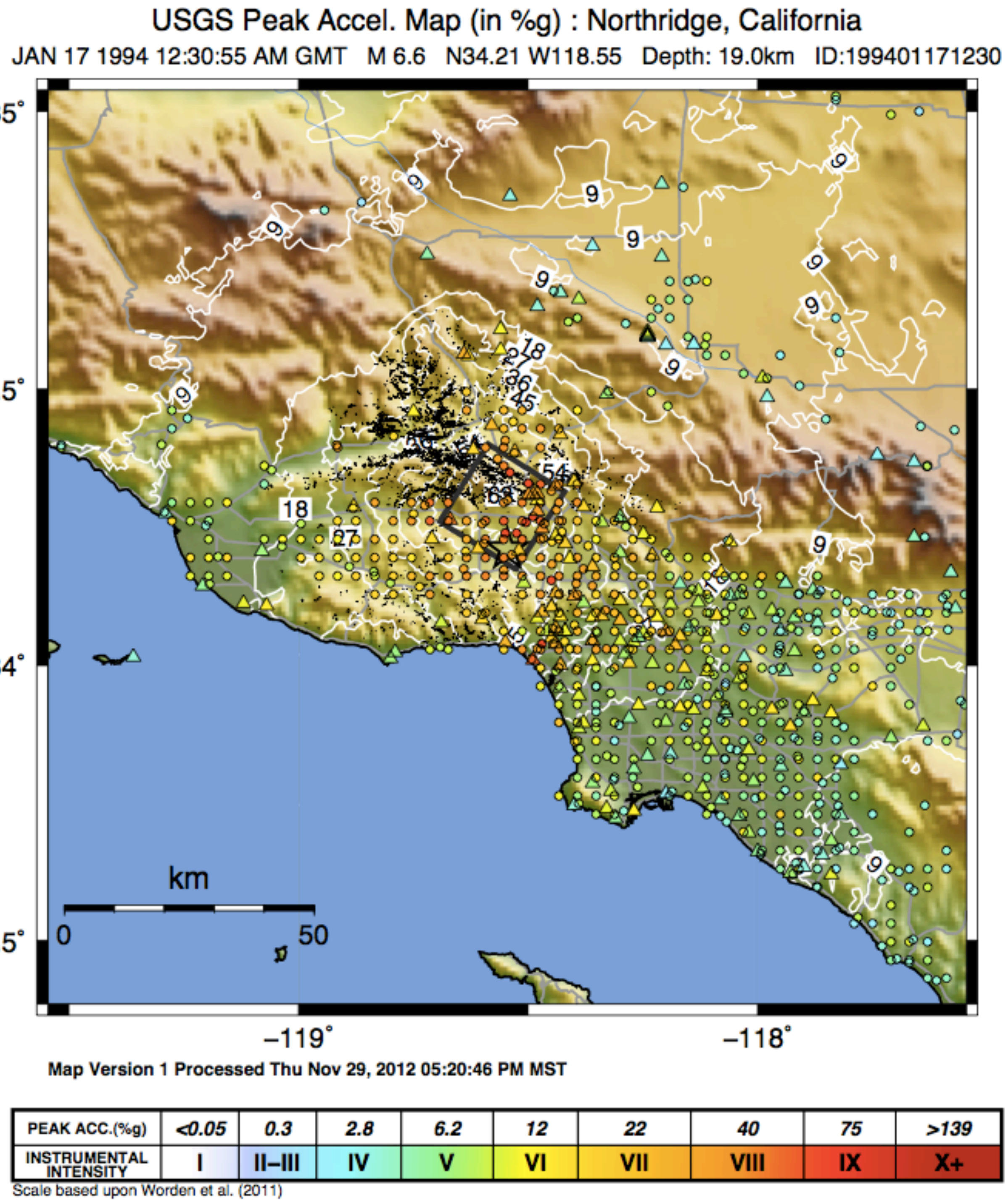
Northridge, California, 1994 Mw 6.7

Intensity Observation

Strong Motion Station

Fault location

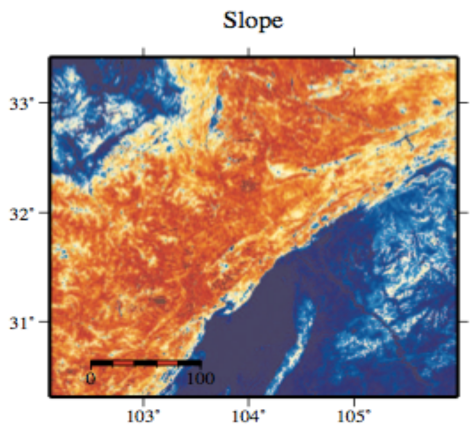
Landslides (Harp & Jibson, 1996)



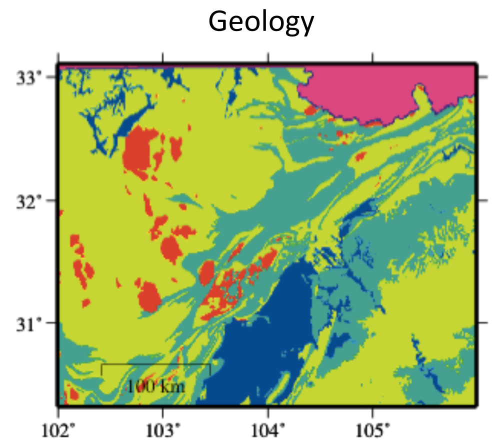
Candidate Explanatory Variables (Logistic Regression)

Landsliding

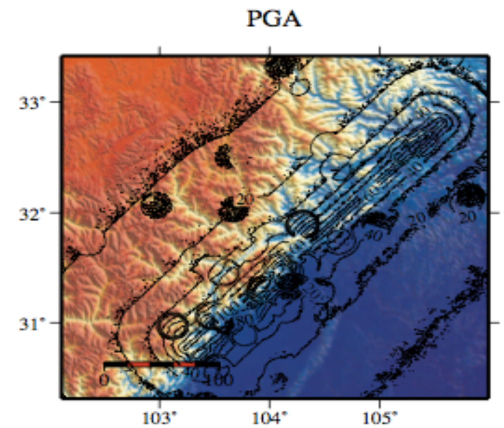
Susceptibility
Slope (from Topog.)



Susceptibility
[Lithology, Geology]



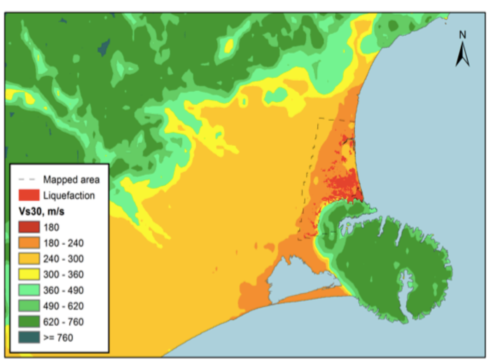
Triggering Input
ShakeMap (PGA)



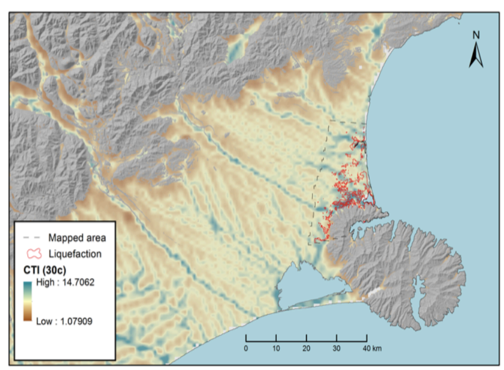
[A. Nowicki et al. (2014)]

Liquefaction

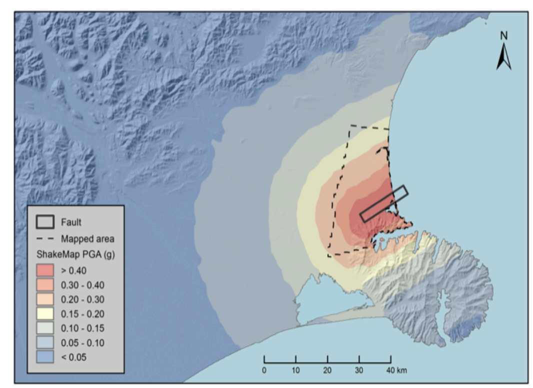
Susceptibility
Soil Strength (Vs30)



Susceptibility
"CTI or Wetness Index"

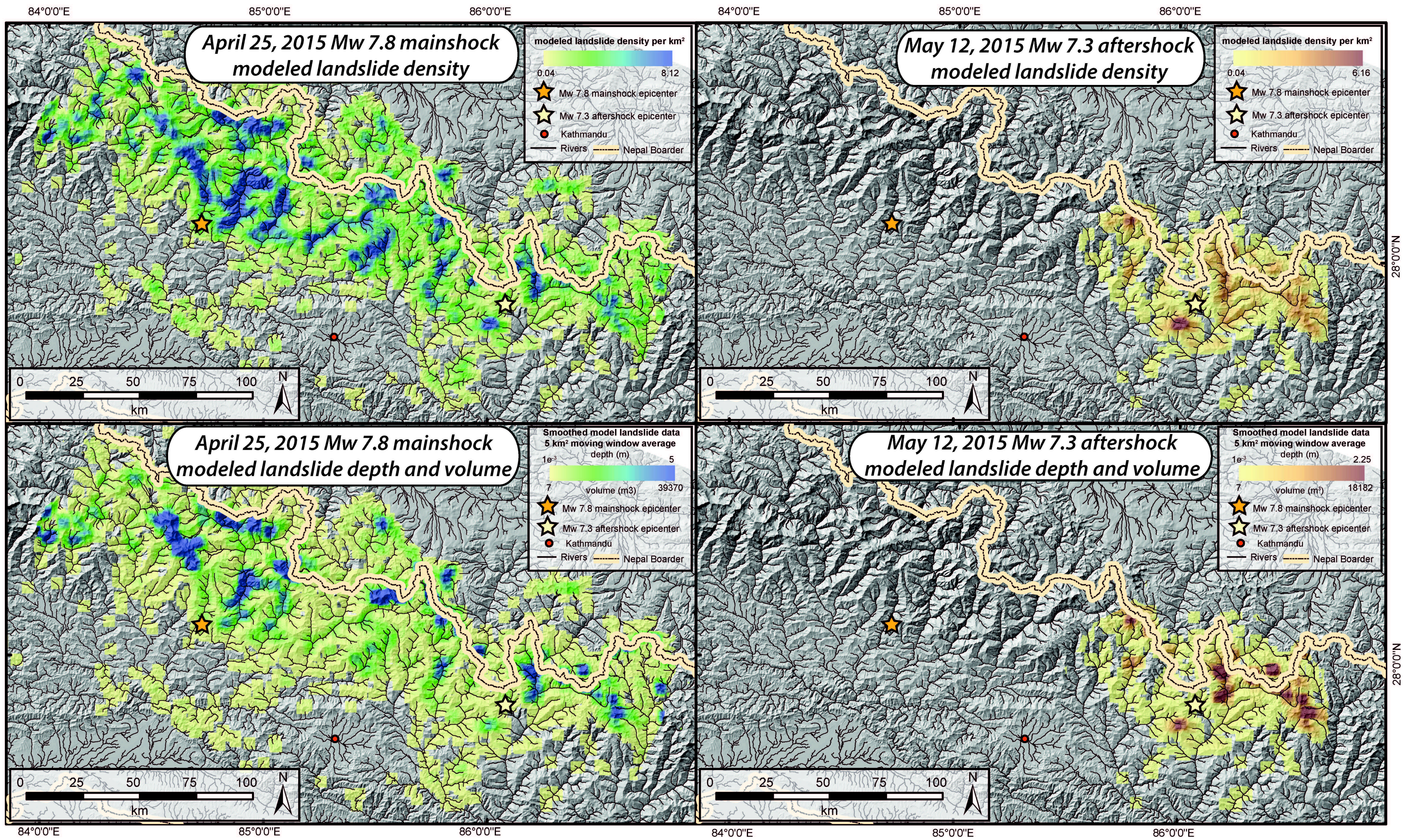


Triggering Input
(PGA)

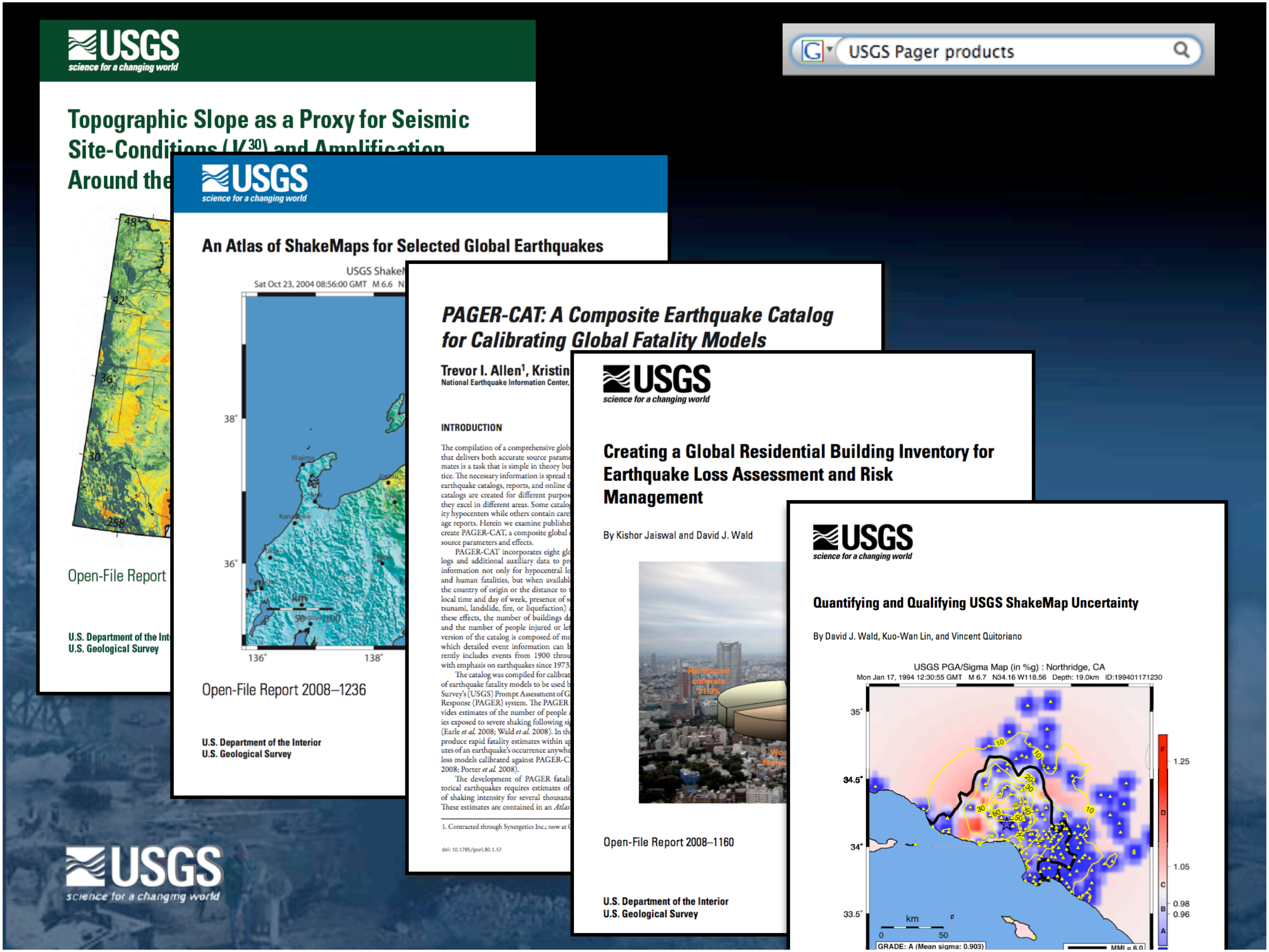


[J. Zhu et al. (2014)]

Nepal Mainshock & Aftershock Modeled Landslide Density



Sean Gallen (Univ. Mich & ETH Zurich)


USGS Pager products
USGS
science for a changing world
Topographic Slope as a Proxy for Seismic
Site-Conditions
Around the
Open-File Report
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
INTRODUCTION
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
Quantifying and Qualifying USGS ShakeMap Uncertainty
By David J. Wald, Kuo-Wan Lin, and Vincent Quitoriano
USGS PGA/Sigma Map (in %g) : Northridge, CA
USGS
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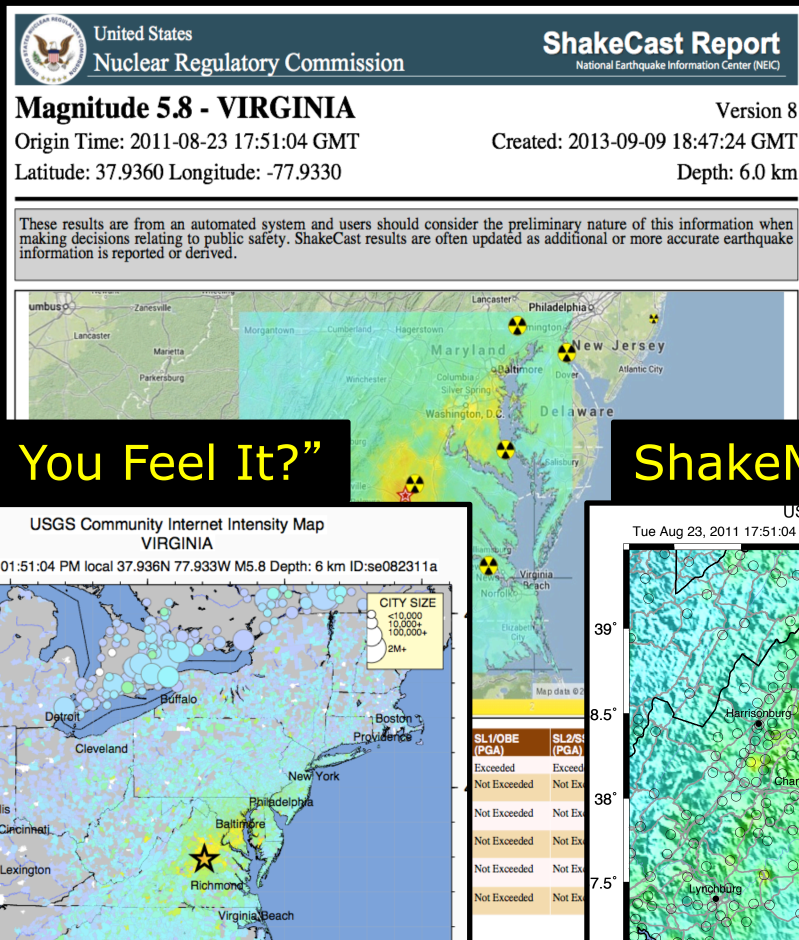
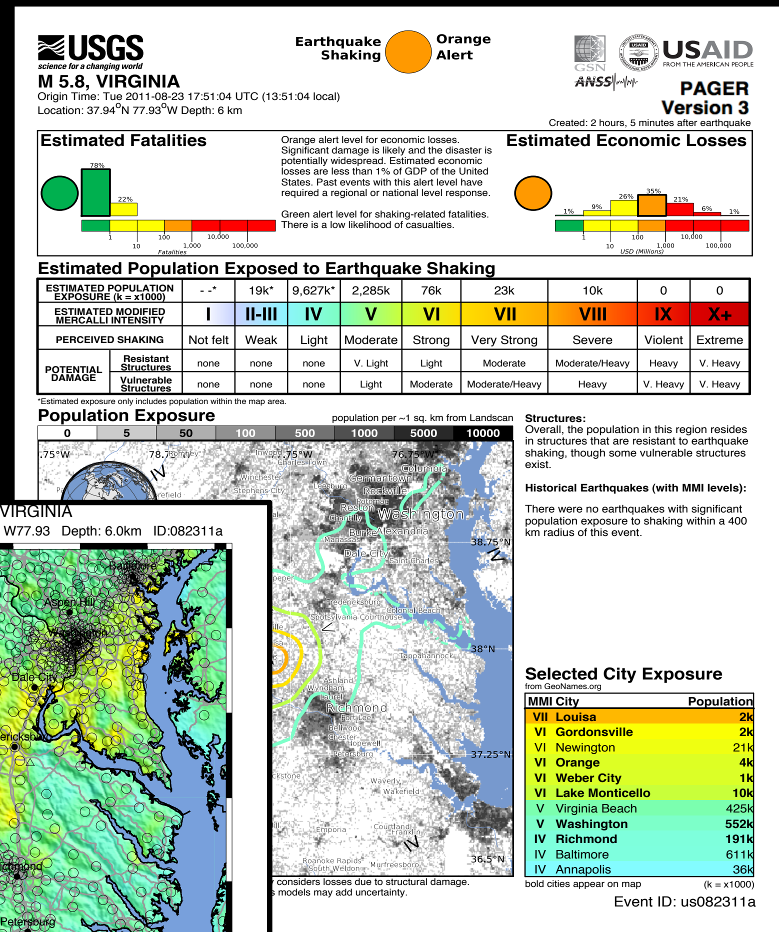
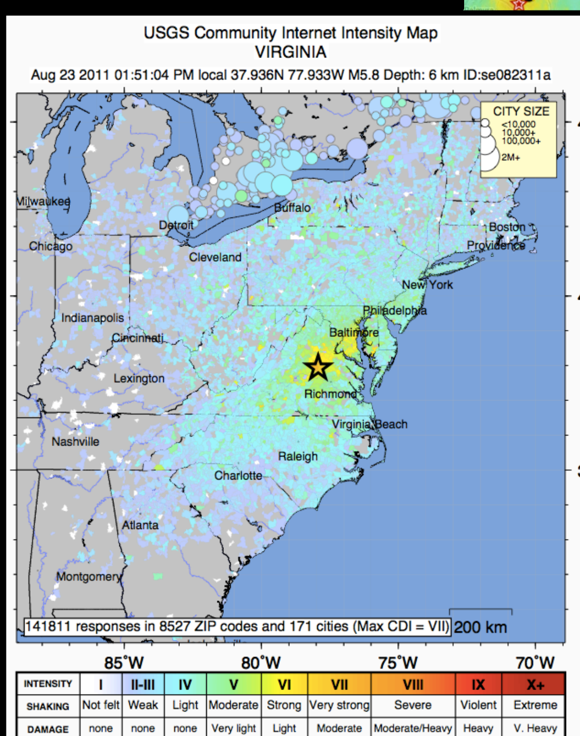
ShakeCast

PAGER (Prompt Assessment of Global Earthquakes for Response)

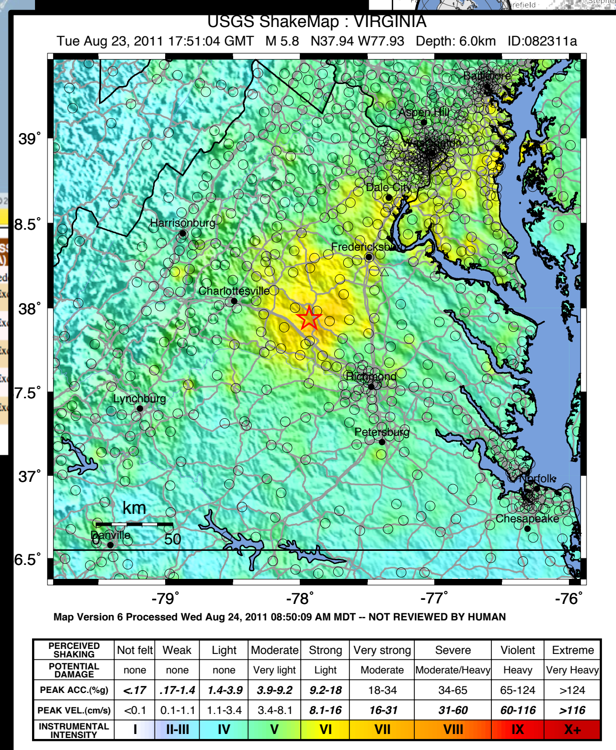




"Did You Feel It?"



ShakeMap



ShakeCast

Kuo-wan Lin
Daniel Slosky
Vikki Appel

PAGER (Prompt Assessment of Global Earthquakes for Response)

Kishor Jaiswal
Mike Hearne
Kristin Marano

"Did You Feel It?"

Vince Quitoriano

ShakeMap

Bruce Worden

Recent Collaborators & students

Nico Luco, USGS
Jing Zhu, Tufts
Emily So, Cambridge Univ
Daniel Garcia, USGS
Trevor Allen, USGS/GA/GSC

EERI/WHE
Global Earthquake Model
Douglas Bausch, FEMA
Kendra Johnson, CSM
Keith Porter, CU Boulder

Eric Thompson, SDSU
Anna Nowicki, Indiana Univ
Keith Knudsen, USGS
Russell Mah, CSM

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ShakeCast

Landslide & Liquefaction
Cloud Services
National Databases (NBI, NID, HSIP)
Stations@facility;
Owner/CSN//QuakeCatcher, etc.

PAGER (Prompt Assessment of Global Earthquakes for Response)

Atlas 2.0
Recalibration (China)
Semi-emp; Analytic Models
Sub-country inventories
Non-shaking Losses
Use cases
Alert accuracy evaluation

"Did You Feel It?"

Responsive/Mobile Web
Animation & Annual Maps
Intensity Prediction Equations
PSHA testing

ShakeMap

Scenario enhancements & standardization
Spatial Variability (esp. scenarios)
Site amplification improvements (empirical, Vs30, numerical)
3D simulations
EEW cost/benefit (warning time probabilities)

Work in progress…

USGS

ShakeCast

PAGER (Prompt Assessment of Global Earthquakes for Response)

Thank You!

"Did You Feel It?"

ShakeMap