The USGS PAGER System: Overview & Update

DAVID WALD
United States Geological Survey
wald@usgs.gov

EERI/WHE/PAGER Workshop
September 23, 2009
Oakland, Colorado

USGS *National Earthquake Information Center, Golden, Colorado*

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Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

Prompt Assessment of Global Earthquakes for Response

PAGER

USGS science for a changing world

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GEM Global Earthquake Model

EERI Earthquake Engineering Research Institute

PAGER Goals

- *To fundamentally* change the nature of post-earthquake information from USGS/NEIC: move *beyond* magnitude & hypocenter to rapidly estimate losses for situational awareness.
- *Primarily*, be a tool for post-earthquake, rapid impact assessment; priority is in the developing world where fatalities are greatest.
- *Also*, provide the basis for earthquake loss mitigation, thru earthquake scenarios & vulnerability assessment.
- ***Collaborative***, international effort, including EERI/WHE, GEM, NEHRP, Cambridge, MunichRe, UN, and many others.
- ***Open*** model & data environment; develop intermediate products, tools, & data sets for other uses/users.

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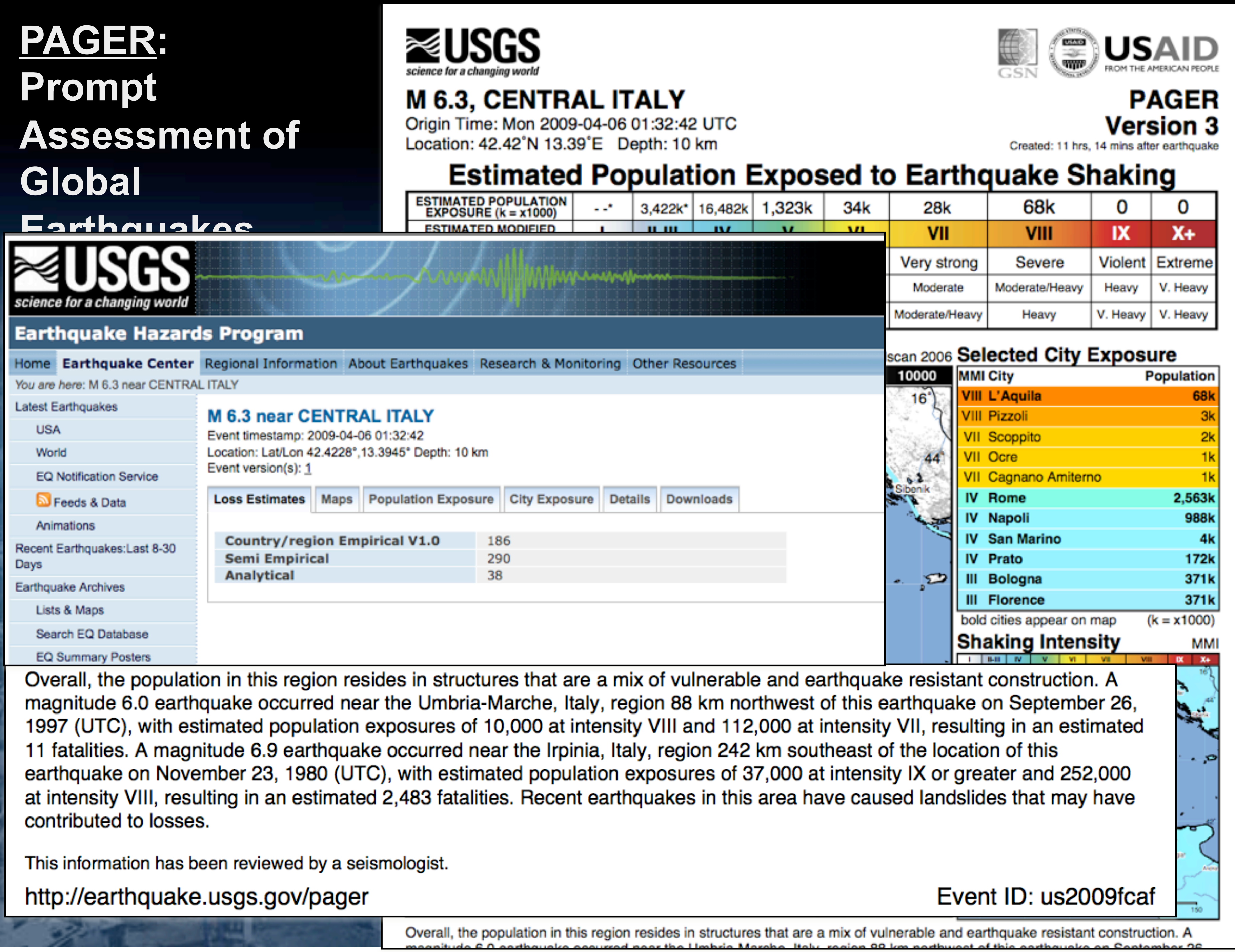
PAGER: Prompt Assessment of Global Earthquakes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GSN

M 6.3, CENTRAL ITALY
Origin Time: Mon 2009-04-06 01:32:42 UTC
Location: 42.42˚N 13.39˚E Depth: 10 km

PAGER
Version 3
Created: 11 hrs, 14 mins after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)	- -*	3,422k*	16,482k	1,323k	34k	28k	68k	0	0
ESTIMATED MODIFIED	I	II-III	IV	V	VI	VII	VIII	IX	X+
						Very strong	Severe	Violent	Extreme
						Moderate	Moderate/Heavy	Heavy	V. Heavy
						Moderate/Heavy	Heavy	V. Heavy	V. Heavy

Selected City Exposure

MMI	City	Population
VIII	L'Aquila	68k
VIII	Pizzoli	3k
VII	Scoppito	2k
VII	Ocre	1k
VII	Cagnano Amiterno	1k
IV	Rome	2,563k
IV	Napoli	988k
IV	San Marino	4k
IV	Prato	172k
III	Bologna	371k
III	Florence	371k

bold cities appear on map (k = x1000)

Shaking Intensity MMI

scan 2006
10000

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You are here: M 6.3 near CENTRAL ITALY

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  - World
  - EQ Notification Service
  - Feeds & Data
  - Animations
- Recent Earthquakes:Last 8-30 Days
- Earthquake Archives
  - Lists & Maps
  - Search EQ Database
  - EQ Summary Posters

M 6.3 near CENTRAL ITALY
Event timestamp: 2009-04-06 01:32:42
Location: Lat/Lon 42.4228°,13.3945° Depth: 10 km
Event version(s): 1

Loss Estimates | Maps | Population Exposure | City Exposure | Details | Downloads

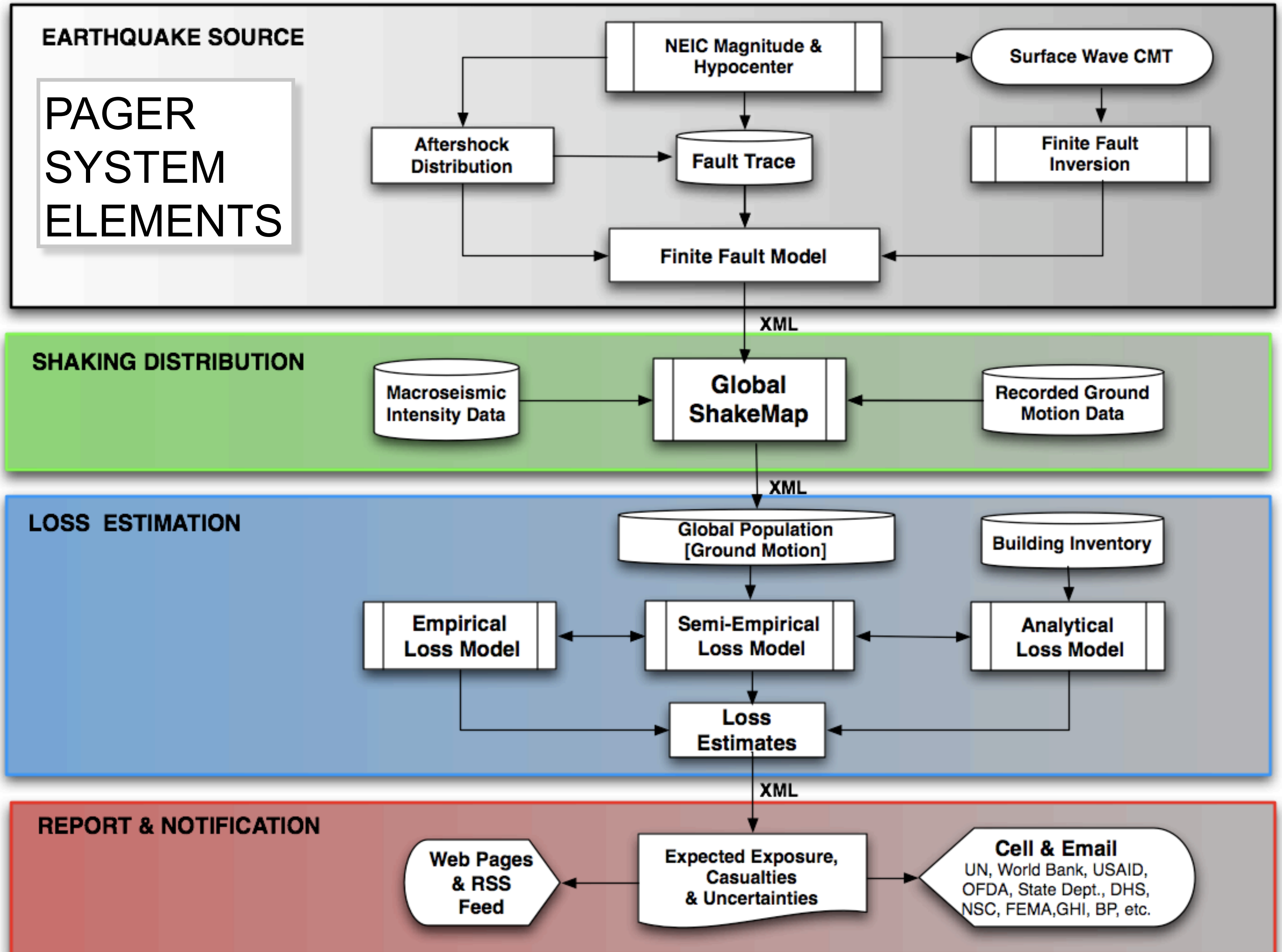
Country/region Empirical V1.0	186
Semi Empirical	290
Analytical	38

Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. A magnitude 6.0 earthquake occurred near the Umbria-Marche, Italy, region 88 km northwest of this earthquake on September 26, 1997 (UTC), with estimated population exposures of 10,000 at intensity VIII and 112,000 at intensity VII, resulting in an estimated 11 fatalities. A magnitude 6.9 earthquake occurred near the Irpinia, Italy, region 242 km southeast of the location of this earthquake on November 23, 1980 (UTC), with estimated population exposures of 37,000 at intensity IX or greater and 252,000 at intensity VIII, resulting in an estimated 2,483 fatalities. Recent earthquakes in this area have caused landslides that may have contributed to losses.

This information has been reviewed by a seismologist.

http://earthquake.usgs.gov/pager Event ID: us2009fcaf

Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. A


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
Global Population [Ground Motion]
Building Inventory
Empirical Loss Model
Semi-Empirical Loss Model
Analytical Loss Model
Loss Estimates
XML
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.

Database/Product	Description	Use	Reference
Earthquake Source			
Fast Finite Faults	Rapid (few hours) slip models for major earthquakes	Constrain shaking; tsunami generation, stress changes	Ji et al (2004); Hayes & Wald (2008)
PAGER-Cat	Quality composite earthquake catalog (1900-2006)_	Source input for ShakeMap Atlas; ExposureCat	Allen et al (2008)
Shaking Distribution			
Global Slope Data	Topographic slope	Landslides, Vs30	Verdin et al (2007)
Global Vs30 Server	Vs30 values for the globe	Estimating site amplification	Allen & Wald (2008); Wald & Allen (2008)
Global "Did You Feel It" Intensities	Rapid intensities from Internet users	Constrains Shake-Map & event bias	Wald et al (2006)
ShakeMap Atlas	ShakeMaps important global earthquakes (1970-present)	Scenarios, planning, hazard calculations	Allen et al (2008)
Rapid Global ShakeMaps (GSM)	Estimated ShakeMaps for all global earthquakes (M>5.5)	Shaking input for loss estimation, decision making	Wald et al (2006)
Loss & Impact Estimation			
Deadly Earthquake List	Online resource list (1900-2006)	General Reference	On Wikipedia: see "List of Deadly Earthquakes"
Exposure-Cat	Population exposure to intensity for each Atlas ShakeMap	Fatality rates calculations	Allen et al. (2008)
	[illegible]	[illegible]	

PAGER Modules: Products & Tools

USGS Pager products

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  - World
  - EQ Notification Service
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- About EQ Maps
- Did You Feel It?
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- Media Info
- PAGER
  - Home
  - Background
  - FAQ
  - Archives
  - Products & References
  - Team Members
- Seismogram Displays
- ShakeMaps

Products and References

Database/Product	Description	Use	Reference
PAGER Overview			Earle *et al.* (2008); Wald *et al.* (2008a), Earle and Wald (2007)
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ShakeMap Uncertainty	Quantitative & qualitative shaking values	Computing loss uncertainty	Wald *et al.* (2008b)
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Landslide Hazard	Spatial probability of landslides	Secondary loss assessments	Godt *et al.* (2008); Marano *et al.* (in press)
Ground Motion Modeling	Comparison of ground motion prediction equations	Improvement of ShakeMap	Allen and Wald (2009)
Loss & Impact Estimation			
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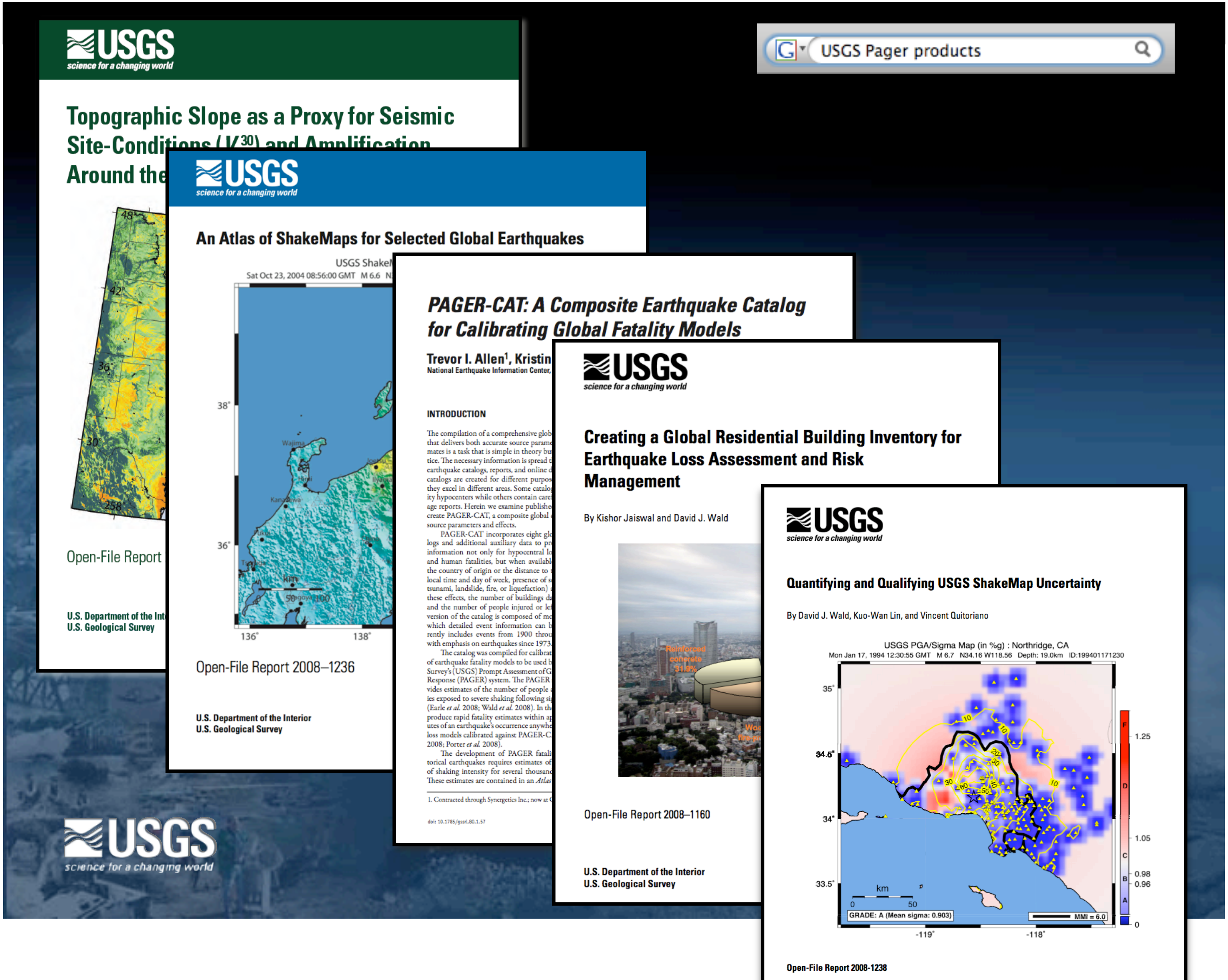
Global Building Inventory	Country-based data on buildings & collapse rates	Country-specific loss estimation	Jaiswal & Wald (2008a, 2008b); Porter *et al.* (2008b)
Empirical Loss Model	Country-specific fatality rates	Fatality estimates given exposure	Porter *et al.* (2008a); Jaiswal *et al.* (in prep)
Semi-Empirical Loss Model	Country-specific, building vulnerability	Fatality estimates based on structures	Jaiswal and Wald (in prep)
Analytical Loss Model	HAZUS vulnerability functions	Structure-dependent loss computations	Porter (in review)
Reporting & Notifications			
OnePAGER	Population exposure notifications	Post-earthquake decision making	Earle & Wald (2007)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Topographic Slope as a Proxy for Seismic
Open-File Report
U.S. Geological Survey
An Atlas of ShakeMaps for Selected Global Earthquakes
Sat Oct 23, 2004 08:56:00 GMT M 6.6
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
Mon Jan 17, 1994 12:30:55 GMT M 6.7 N34.16 W118.56 Depth: 19.0km ID:199401171230
GRADE: A (Mean sigma: 0.903)
MMI = 6.0
Open-File Report 2008-1238

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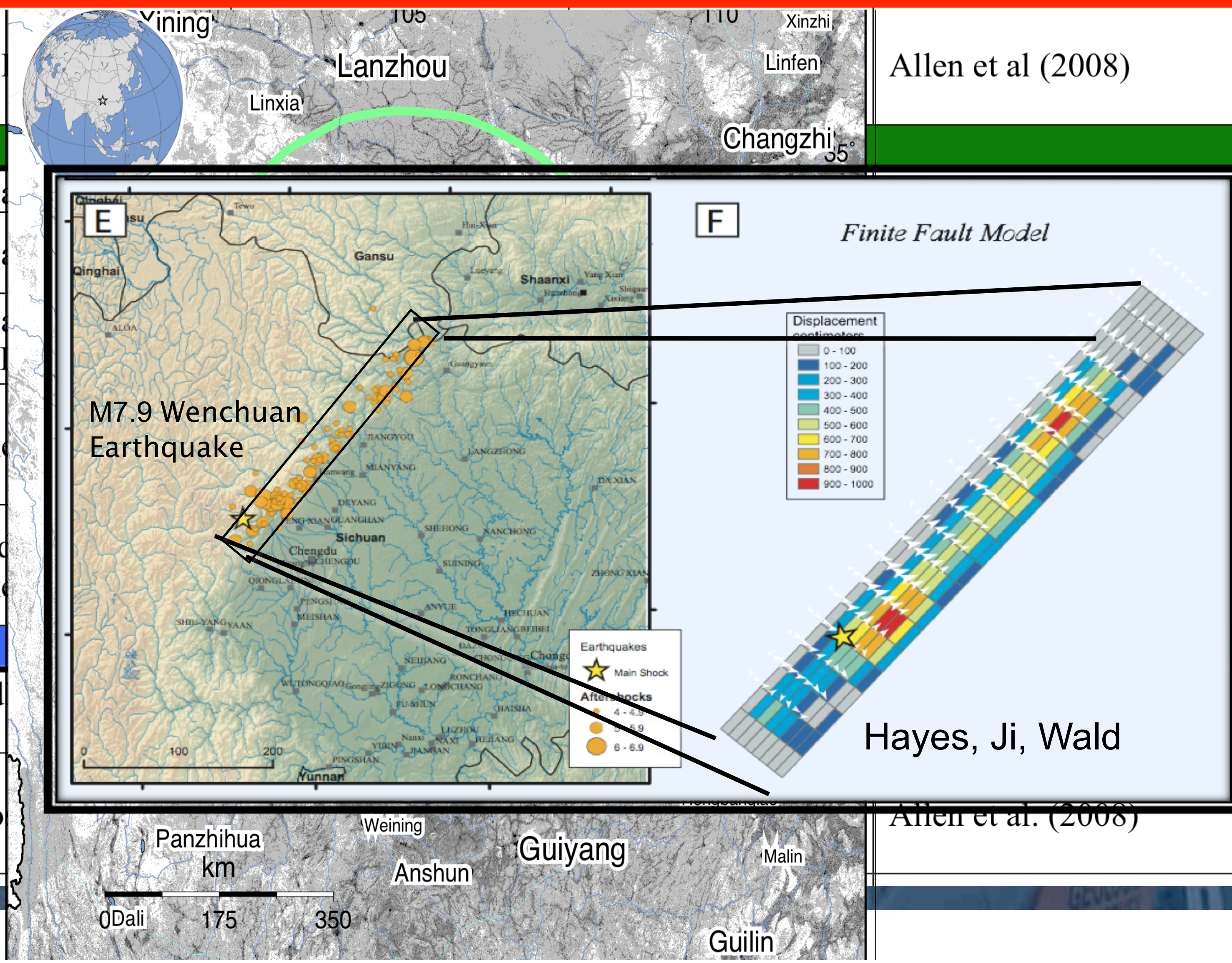
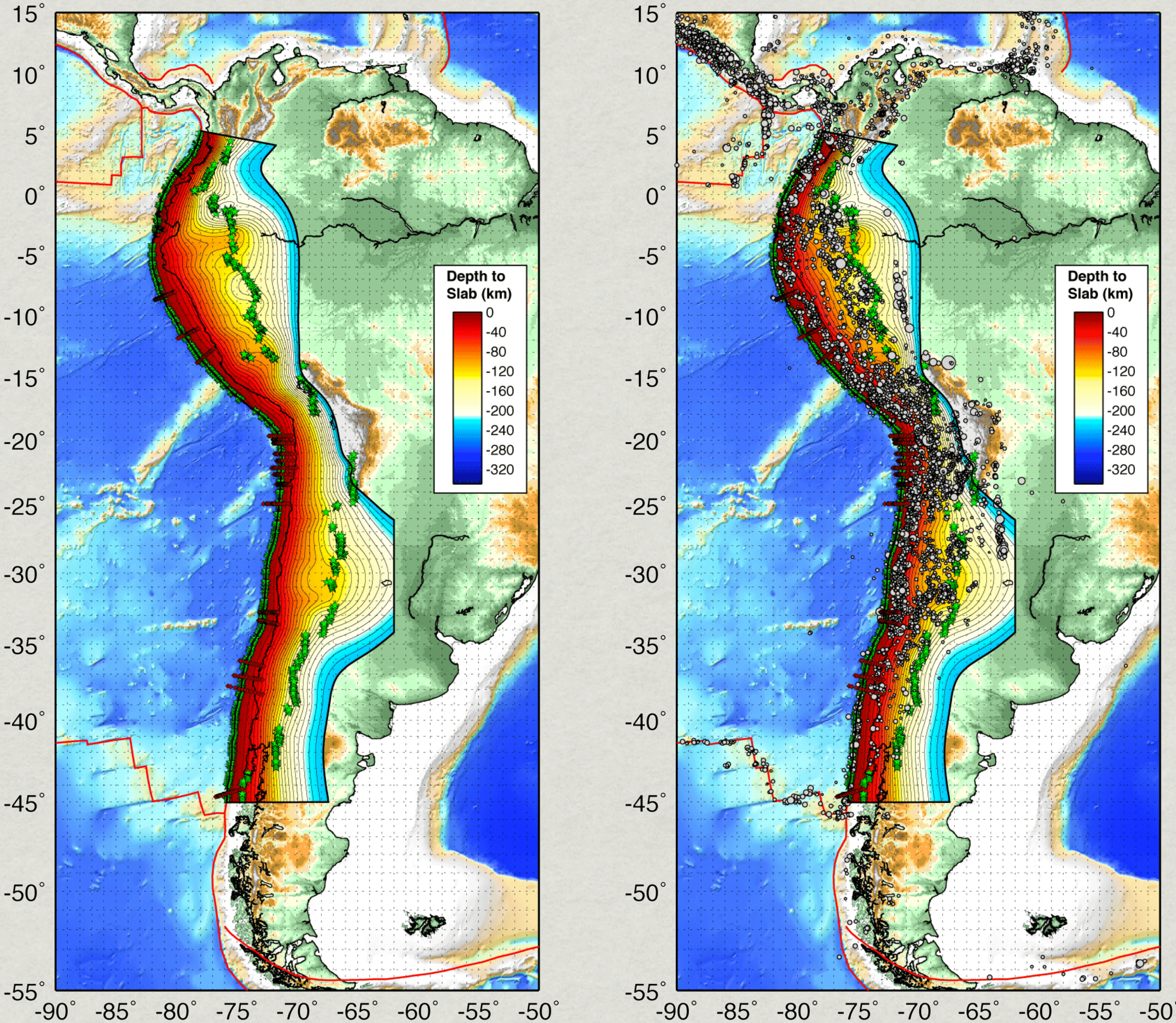
PAG			Allen et al (2008)
Globa			
Globa			
Globa Feel I			
Shak			
Rapid Shake			
Dead List			
Expo			Allen et al. (2008)



Example - Building a 3D Surface - SLAB1.0



Hayes & Wald, 2009

Products and References

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PAGER-CAT: A Composite Earthquake Catalog for Calibrating Global Fatality Models

Trevor I. Allen[1], Kristin D. Marano, Paul S. Earle, and David J. Wald
National Earthquake Information Center, U.S. Geological Survey

INTRODUCTION

The compilation of a comprehensive global earthquake catalog that delivers both accurate source parameters and fatality estimates is a task that is simple in theory but challenging in practice. The necessary information is spread throughout numerous earthquake catalogs, reports, and online databases. Earthquake catalogs are created for different purposes, and consequently they excel in different areas. Some catalogs provide high-quality hypocenters while others contain carefully researched damage reports. Herein we examine published global catalogs and create PAGER-CAT, a composite global catalog of earthquake source parameters and effects.

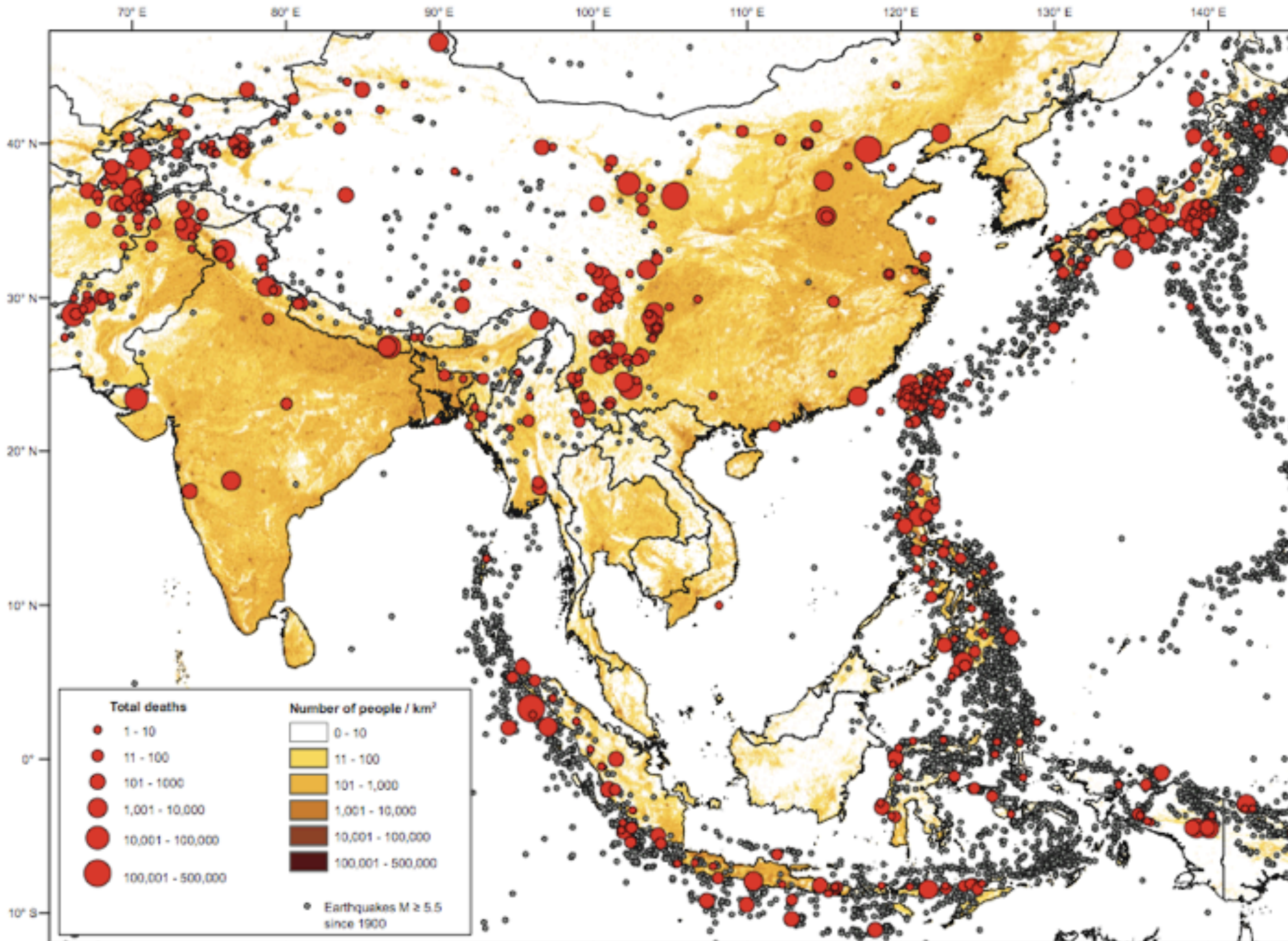
PAGER-CAT incorporates eight global earthquake catalogs and additional auxiliary data to provide comprehensive information not only for hypocentral locations, magnitudes, and human fatalities, but when available, focal mechanisms, the country of origin or the distance to the nearest landmass, local time and day of week, presence of secondary effects (*e.g.*, tsunami, landslide, fire, or liquefaction) and deaths caused by these effects, the number of buildings damaged or destroyed, and the number of people injured or left homeless. The first version of the catalog is composed of more than 140 fields in which detailed event information can be recorded and currently includes events from 1900 through December 2007, with emphasis on earthquakes since 1973.

The catalog was compiled for calibration and development of earthquake fatality models to be used by the U.S. Geological Survey's (USGS) Prompt Assessment of Global Earthquakes for Response (PAGER) system. The PAGER system currently provides estimates of the number of people and the names of cities exposed to severe shaking following significant earthquakes (Earle *et al.* 2008; Wald *et al.* 2008). In the future, PAGER will produce rapid fatality estimates within approximately 20 minutes of an earthquake's occurrence anywhere on the globe, using loss models calibrated against PAGER-CAT (*e.g.*, Jaiswal *et al.* 2008; Porter *et al.* 2008).

The development of PAGER fatality models from historical earthquakes requires estimates of the spatial variation of shaking intensity for several thousand global earthquakes. These estimates are contained in an *Atlas of ShakeMaps* (Allen

1. Contracted through Synergetics Inc.; now at Geoscience Australia

doi: 10.1785/gssrl.80.1.57



▲ **Figure 2.** PAGER-CAT fatal earthquakes for the Asia-Pacific region with respect to the LandScan 2005 population distribution database (*e.g.*, Dobson *et al.* 2000). Deadly earthquakes are sized relative to the total number of fatalities and overlay the epicenters for the entire catalog.

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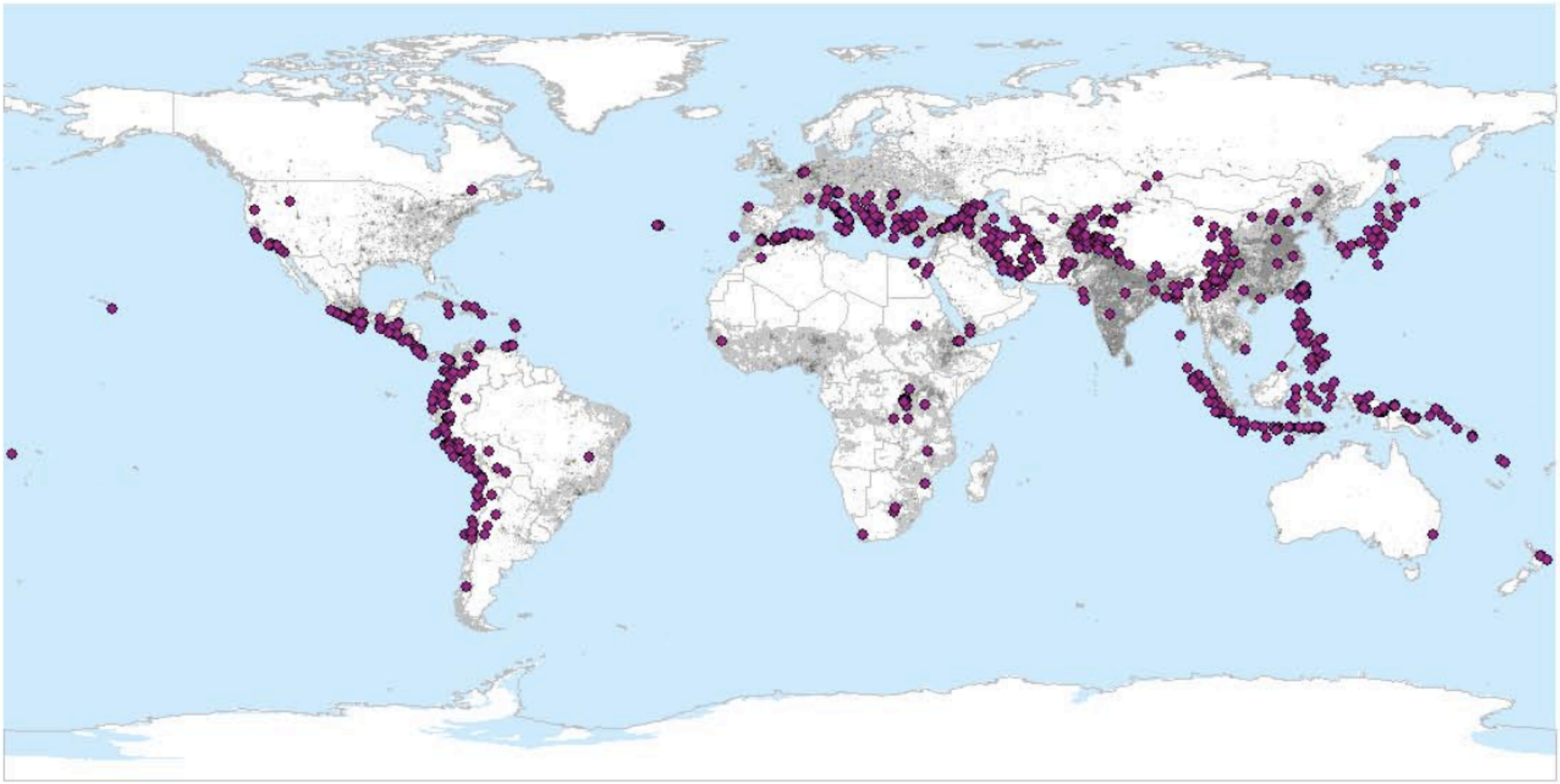
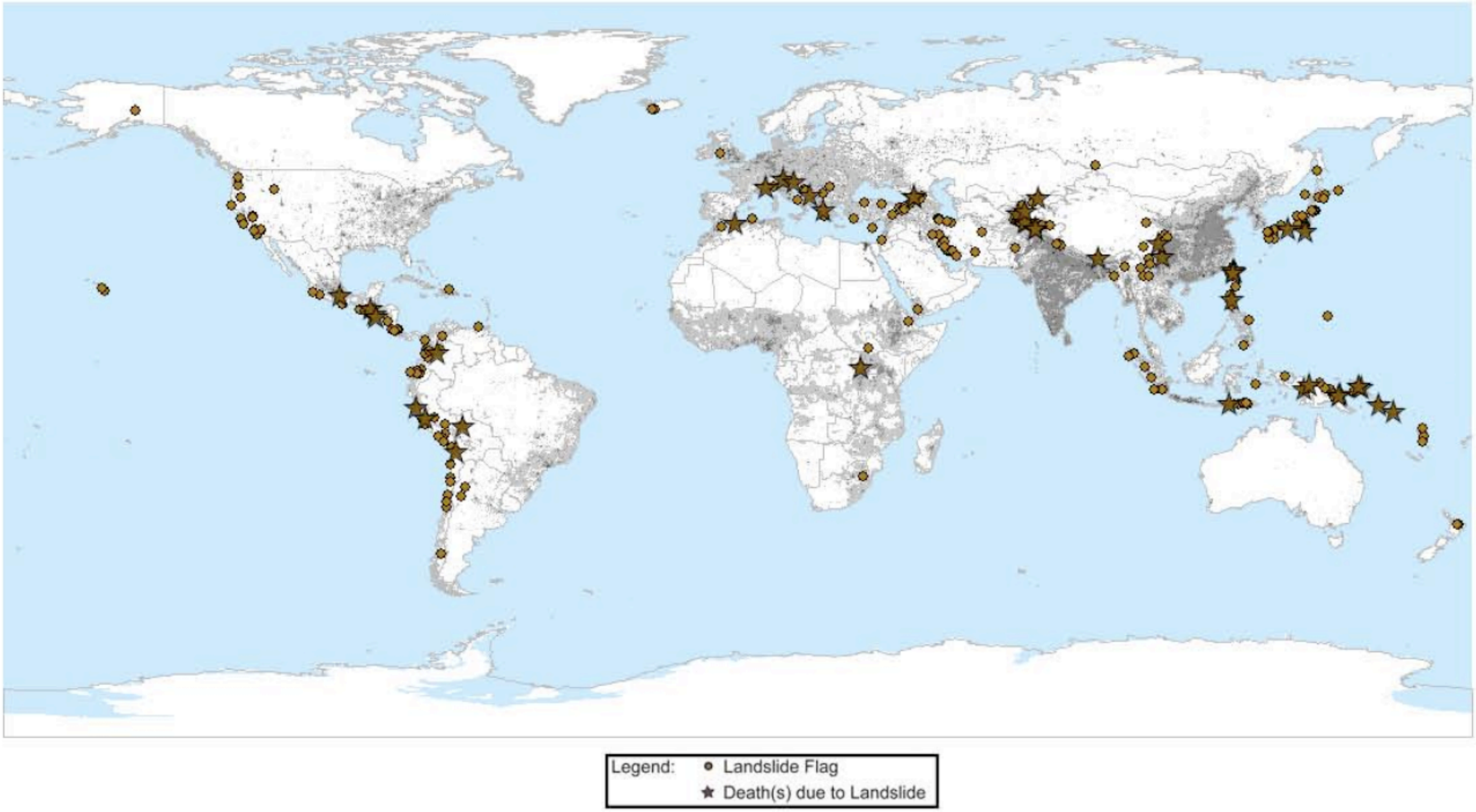


Epicenters of **<u>FATAL</u>** earthquakes, September 1968 – June 2008, from PAGER-CAT.

From Marano, and others (2009)



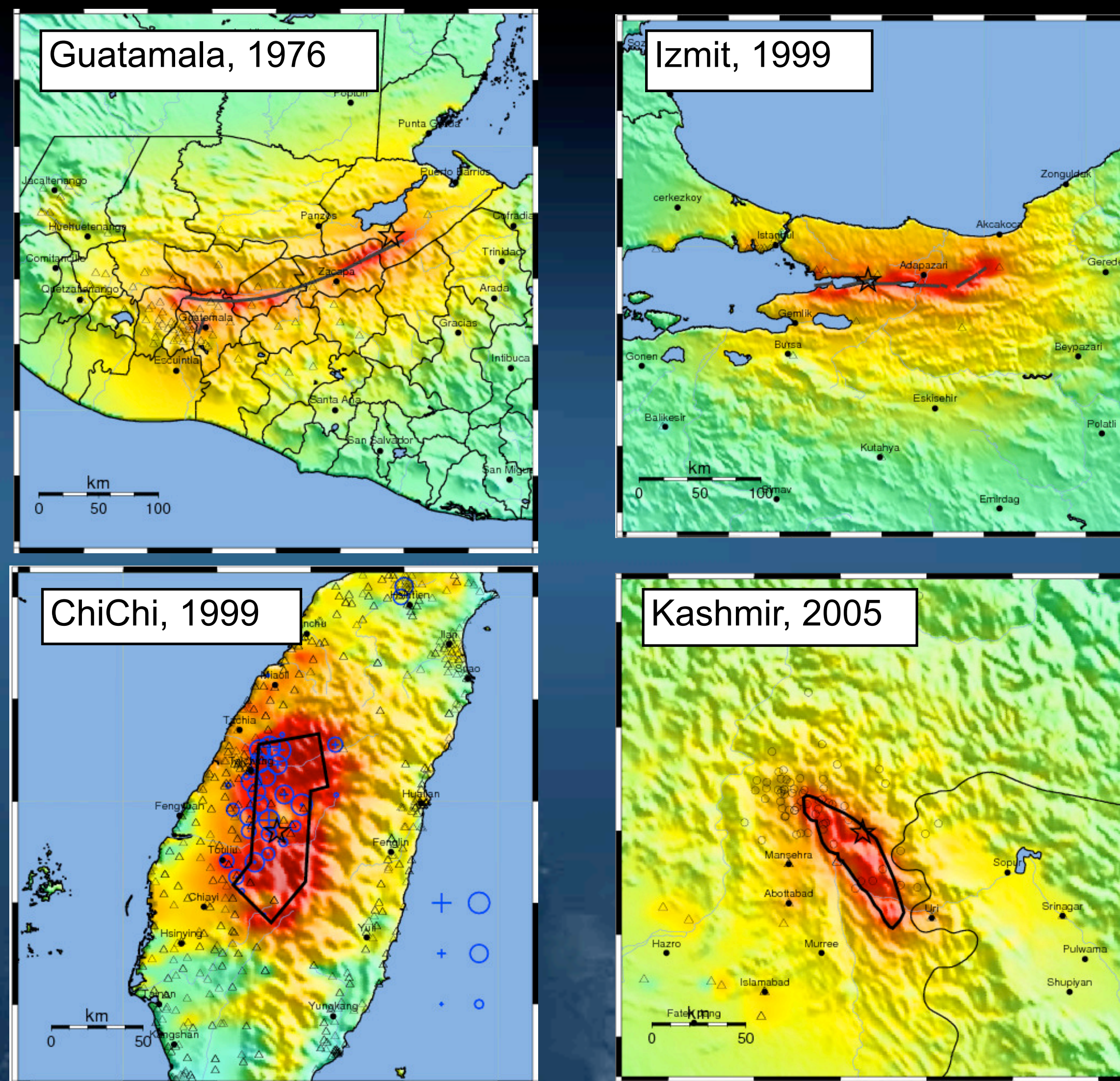
Epicenters of **Landslide** earthquakes, September 1968 – June 2008, from PAGER-CAT.

From Marano, and others (2009)

ShakeMap Atlas

ShakeMaps for >5,600 Earthquakes (1973-2008)

- All available data (ground motion, intensity, fault plane)
- Site conditions from topo-graphy
- Standard ShakeMap approach to combine observed/estimated ground motions



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M 7.9, EASTERN SICHUAN, CHINA

Origin Time: Mon 2008-05-12 06:28:01 UTC
Location: 30.99°N 103.36°E Depth: 19 km

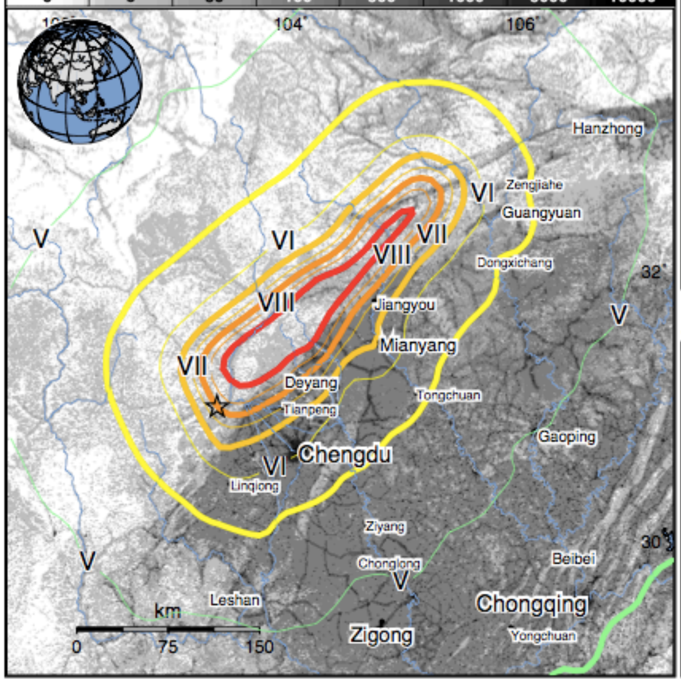
PAGER
Version 12
Created: 210 days, 15 hrs after earthquake

Estimated Population Exposed to Earthquake Sha

ESTIMATED POPULATION EXPOSURE (k = x1000)	--*	--*	1,563k*	63,137k*	18,662k	3,815k	1,124k	53
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	I
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Vio
POTENTIAL DAMAGE — Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	He
POTENTIAL DAMAGE — Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. H

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan 2006

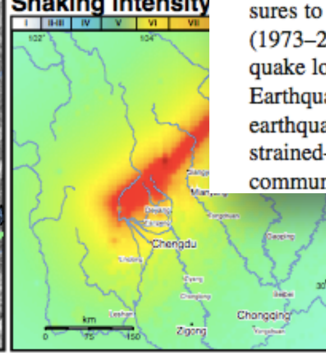


Selected City Exp

MMI	City
VII	Tianpeng
VII	Jiangyou
VII	Mianyang
VI	Chengdu
VI	Guangyuan
VI	Linqiong
VI	Deyang
V	Nanchong
V	Zigong
V	Neijiang
V	Chongqing

bold cities appear on map

Shaking Intensity



Overall, structures in this region are vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 6.4 earthquake struck the Sichuan, China region on August 23, 1976 (UTC), with estimated population exposures of 1,500 at intensity IX or greater and 5,700 at intensity VIII, resulting in 41 deaths. Additionally, a magnitude 7.3 struck this region in 1933 killing 6,800 people. Recent earthquakes in this area have also triggered landslide hazards that have contributed to losses. Users should consider the preliminary nature of this information and check for updates as additional data becomes available.

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager Event ID: us2008ryan

Bull Earthquake Eng
DOI 10.1007/s10518-009-9120-y

ORIGINAL RESEARCH PAPER

An Atlas of ShakeMaps and population exposure catalog for earthquake loss modeling

Trevor I. Allen · David J. Wald · Paul S. Earle · Kristin D. Marano · Alicia J. Hotovec · Kuowan Lin · Michael G. Hearne

Received: 18 December 2008 / Accepted: 25 April 2009

Abstract We present an Atlas of ShakeMaps and a catalog of human population exposures to moderate-to-strong ground shaking (EXPO-CAT) for recent historical earthquakes (1973–2007). The common purpose of the Atlas and exposure catalog is to calibrate earthquake loss models to be used in the US Geological Survey's Prompt Assessment of Global Earthquakes for Response (PAGER). The full ShakeMap Atlas currently comprises over 5,600 earthquakes from January 1973 through December 2007, with almost 500 of these maps constrained—to varying degrees—by instrumental ground motions, macroseismic intensity data, community internet intensity observations, and published earthquake rupture models. The

Example Use of ShakeMap Atlas: CUEDD

UNIVERSITY OF CAMBRIDGE

Cambridge University Earthquake Damage Database

Edit

Home About Use Analysis Contact

Earthquakes > Greece 2003 » Karababa 2007

Earthquake
Greece 2003
Lefkada

Study
Karababa 2007

Survey Location
Drimonas

Lat
38.769

Long
20.627

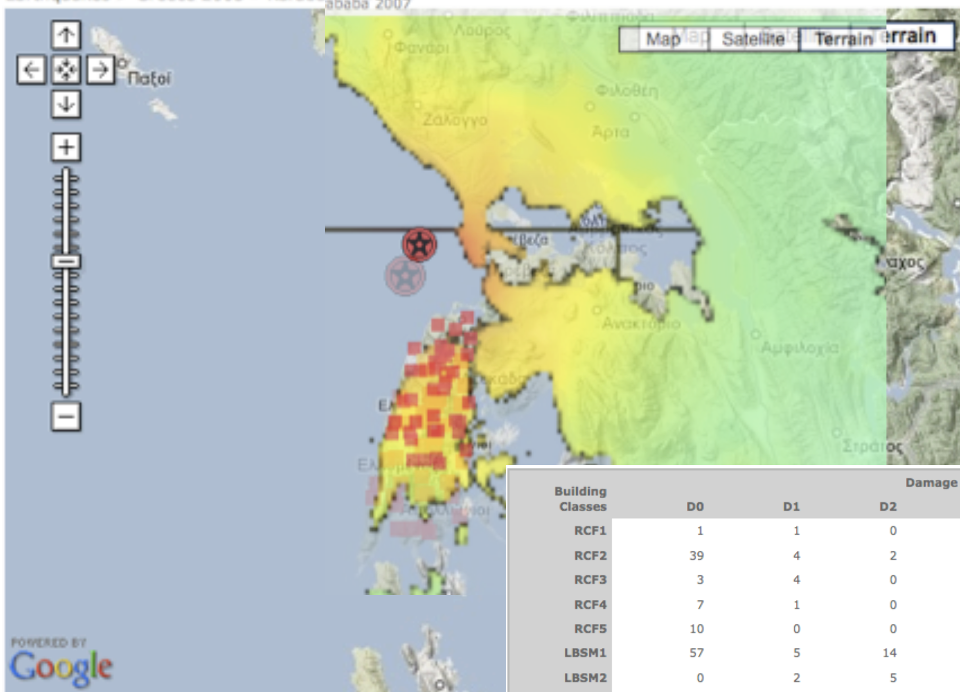
Lat/Long Accuracy
[drop down list]

Distance from Epicentre (Km)
19

USGS PGA
16.0525

USGS PGV
17.7699

USGS MMI
6.59



Map Overlays

- USGS Intensity
- USGS Epicenter
- USGS Fault

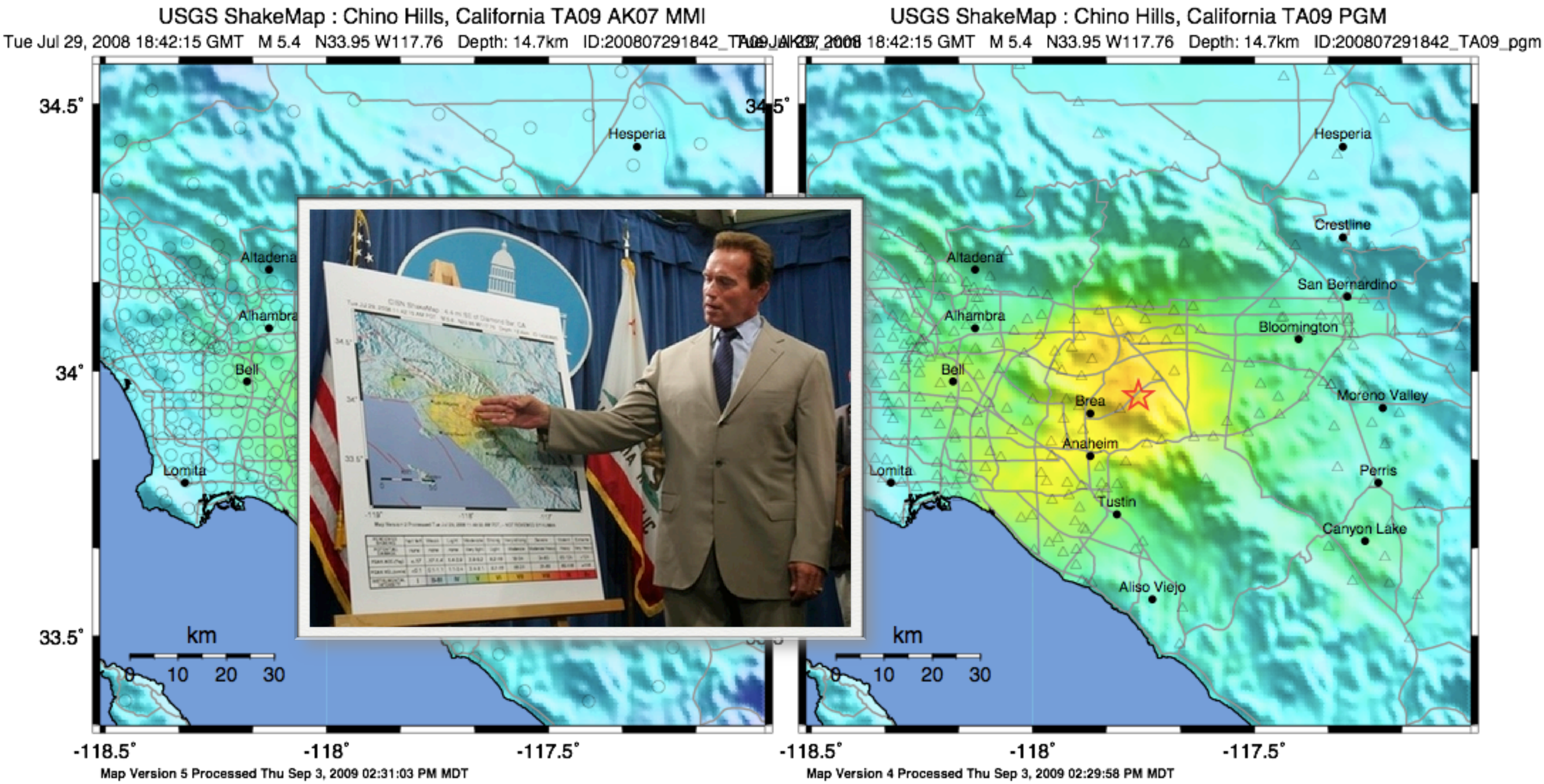
Study Locations

Aghios Ilias
Aghios Nikitas
Aghios Petros
Alexandros
Apolpaina
Asprogerakata
Athani
Charadiatika
Chortata
Dragano
Drimonas
Tsoukalades

Image Gallery | Damage Matrix

Building Classes	Damage Level D0	D1	D2	D3	D4	D5	Total
RCF1	1	1	0	0	0	0	2
RCF2	39	4	2	0	0	0	45
RCF3	3	4	0	0	0	0	7
RCF4	7	1	0	0	0	0	8
RCF5	10	0	0	0	0	0	10
LBSM1	57	5	14	10	5	0	91
LBSM2	0	2	5	3	1	0	11
LBSM3	2	2	4	1	0	0	9
LBSM4	2	1	0	0	0	0	3
SBM RC1	1	0	0	0	0	0	1
SBM RC2	12	0	0	1	0	0	13
SBM RC3	1	0	0	0	0	0	1
TF	0	0	1	0	0	0	1
LBSM TF1	3	1	0	0	0	0	4
LBSM TF2	7	4	1	1	0	0	13
Total	145	25	27	16	6	0	219

European Macroseismic Scale (Conseil de L'Europe)



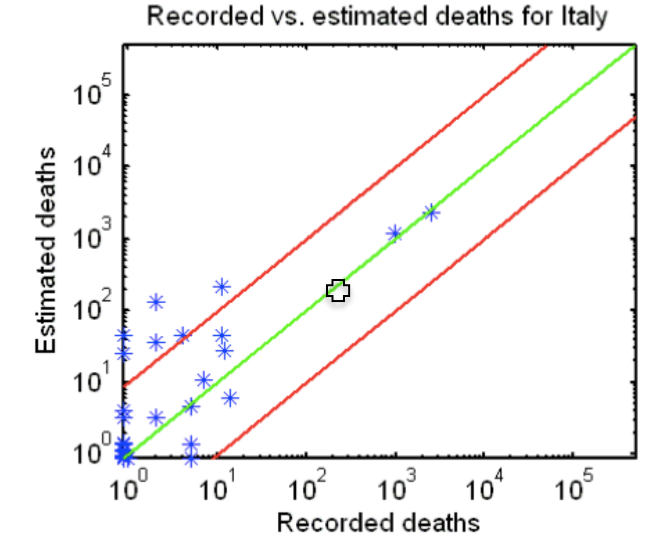
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.02	0.02-0.4	0.4-2.2	2.2-7	7-12	12-20	20-36	36-63	>63
PEAK VEL.(cm/s)	*<0.01*	*0.01-0.2*	*0.2-1.3*	*1.3-4*	*4-9*	*9-20*	*20-43*	*43-93*	*>93*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

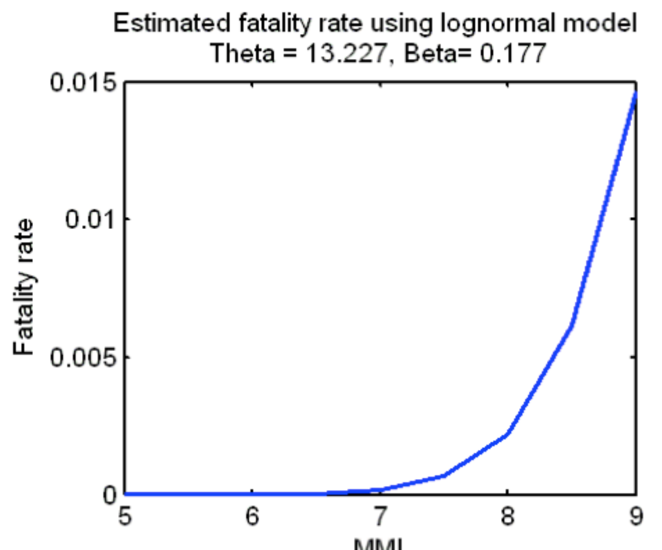
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

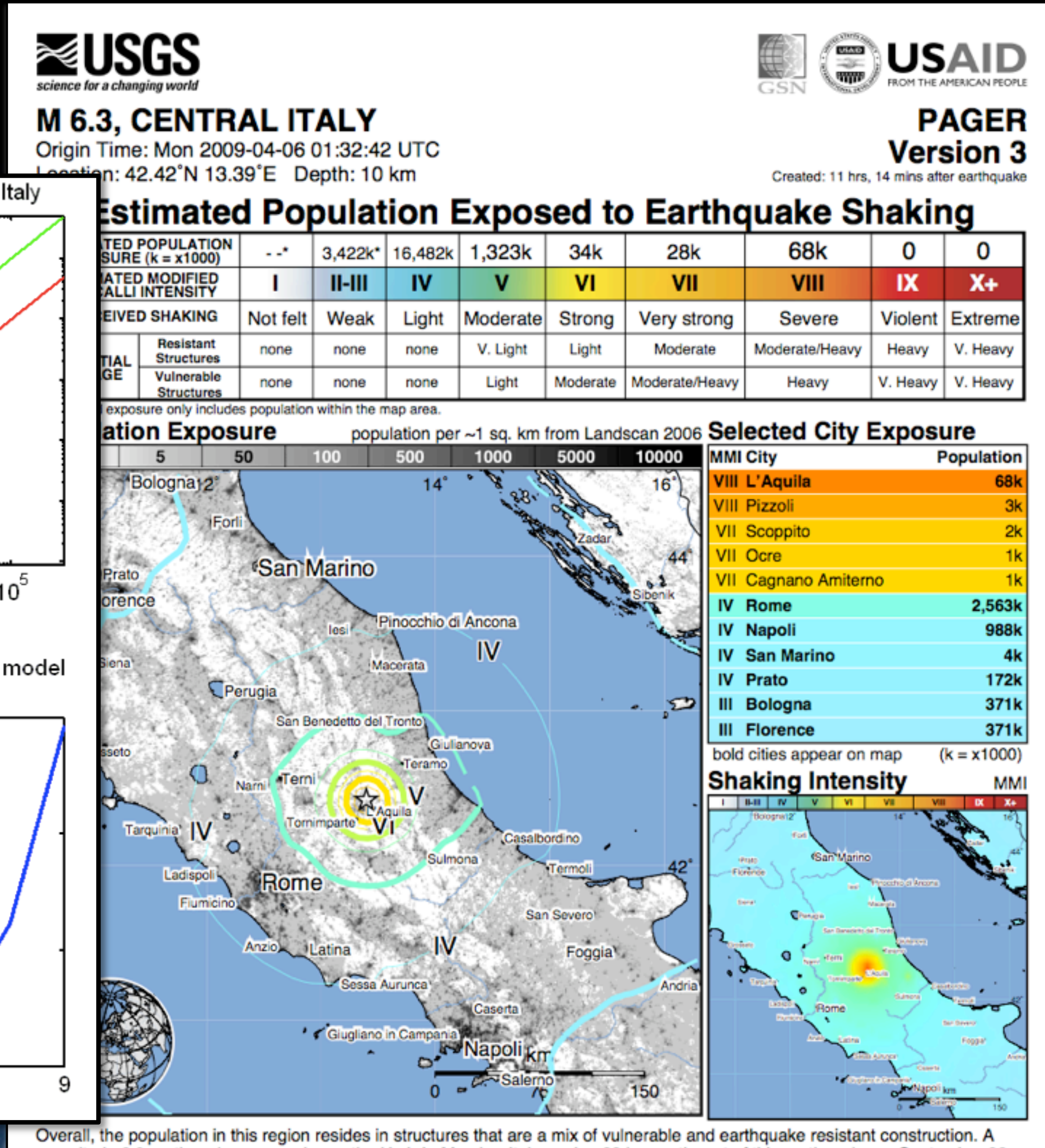
MMI Only

PGM Only

Empirical Fatality Model







USGS science for a changing world

GSN USAID FROM THE AMERICAN PEOPLE

M 6.3, CENTRAL ITALY

Origin Time: Mon 2009-04-06 01:32:42 UTC

Location: 42.42°N 13.39°E Depth: 10 km

PAGER Version 3

Created: 11 hrs, 14 mins after earthquake

Estimated Population Exposed to Earthquake Shaking

TED POPULATION SURE (k = x1000)		- -*	3,422k*	16,482k	1,323k	34k	28k	68k	0	0
ATED MODIFIED ALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
EIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
TIAL GE	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

exposure only includes population within the map area.

ation Exposure population per ~1 sq. km from Landscan 2006

Selected City Exposure

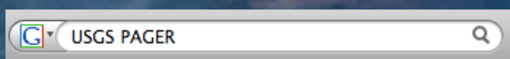
MMI	City	Population
VIII	L'Aquila	68k
VIII	Pizzoli	3k
VII	Scoppito	2k
VII	Ocre	1k
VII	Cagnano Amiterno	1k
IV	Rome	2,563k
IV	Napoli	988k
IV	San Marino	4k
IV	Prato	172k
III	Bologna	371k
III	Florence	371k

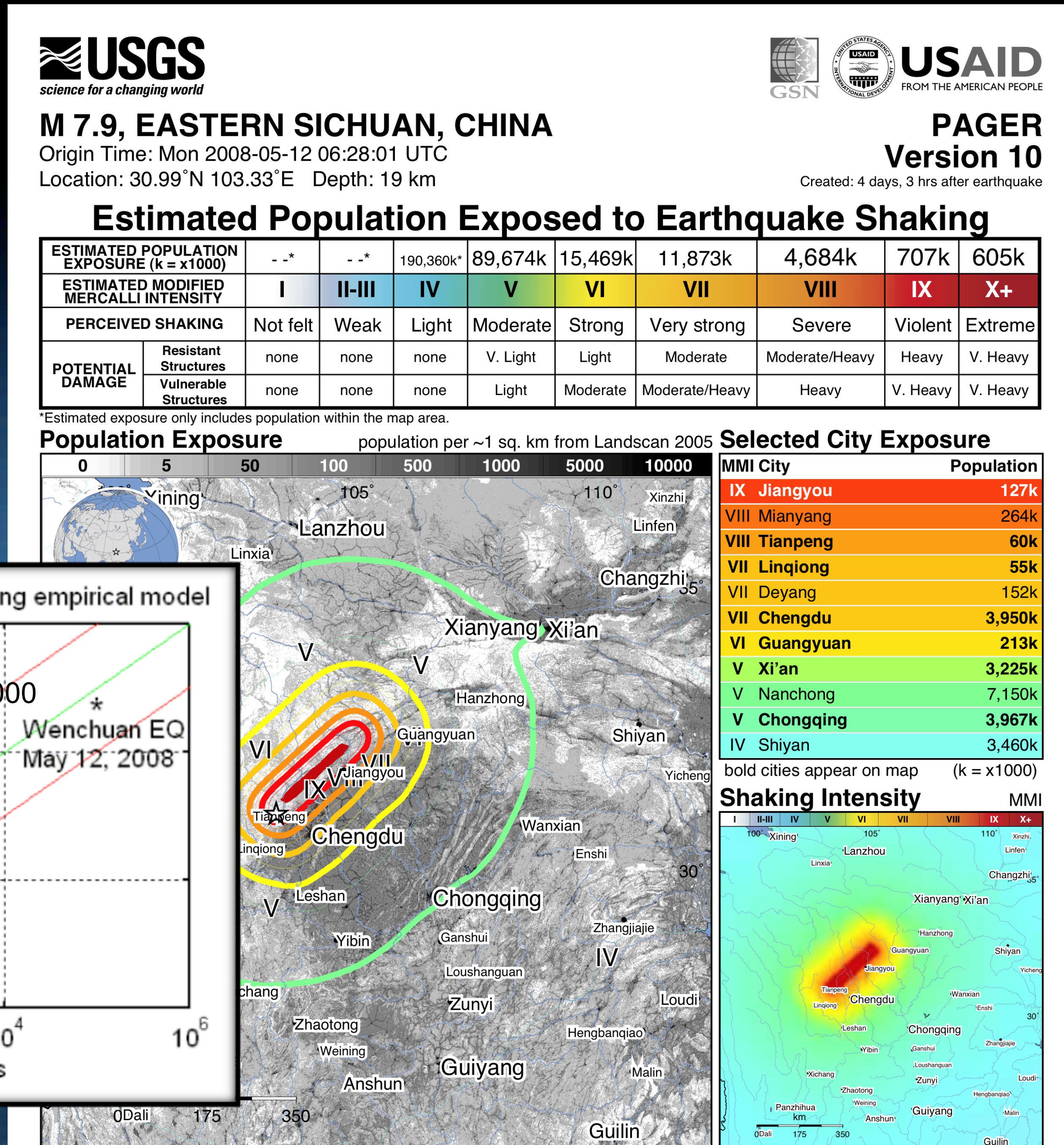
bold cities appear on map (k = x1000)

Shaking Intensity MMI

Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. A

PAGER: Prompt Assessment of Global Earthquakes for Response





USGS science for a changing world

GSN USAID FROM THE AMERICAN PEOPLE

M 7.9, EASTERN SICHUAN, CHINA

Origin Time: Mon 2008-05-12 06:28:01 UTC
Location: 30.99˚N 103.33˚E Depth: 19 km

PAGER Version 10
Created: 4 days, 3 hrs after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	190,360k*	89,674k	15,469k	11,873k	4,684k	707k	605k
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.

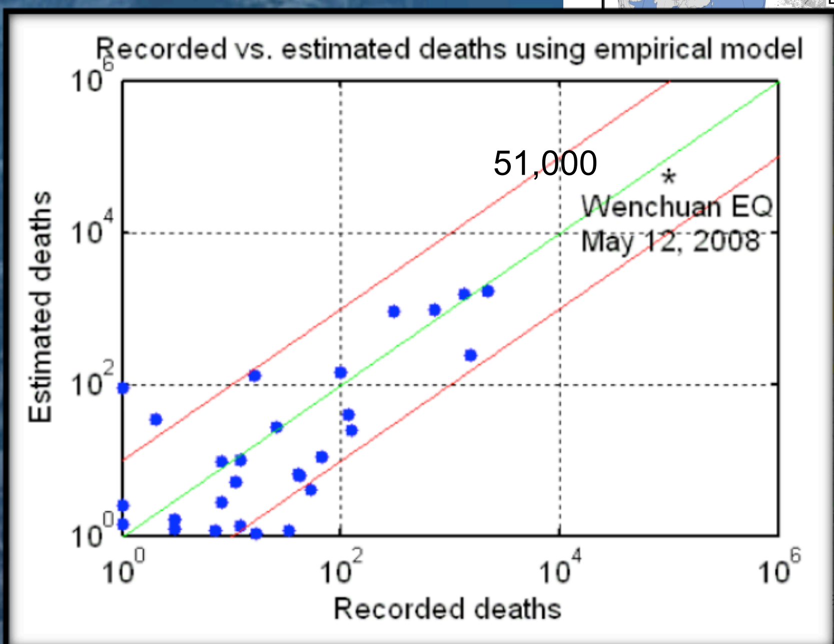
Population Exposure population per ~1 sq. km from Landscan 2005

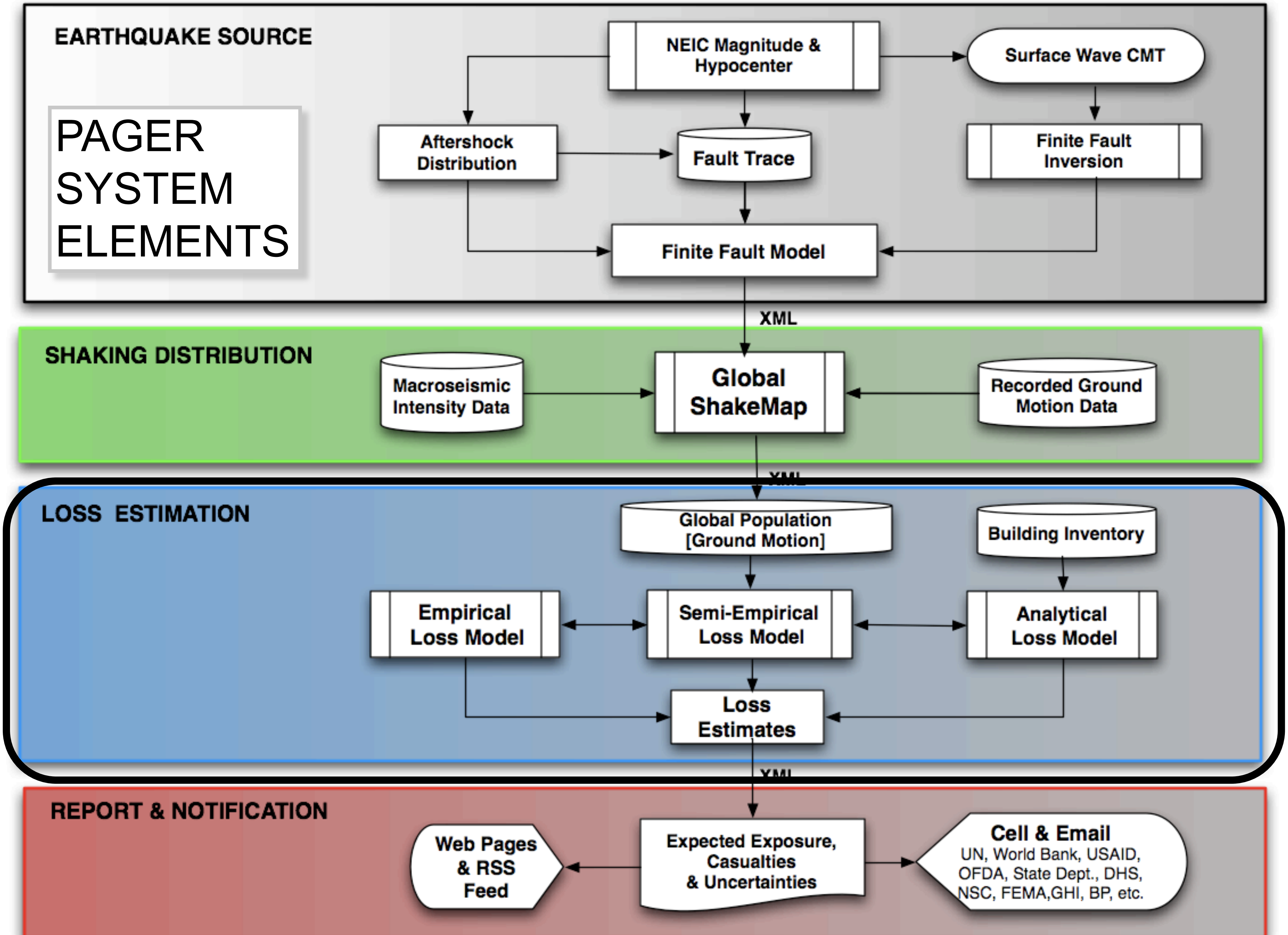
Selected City Exposure

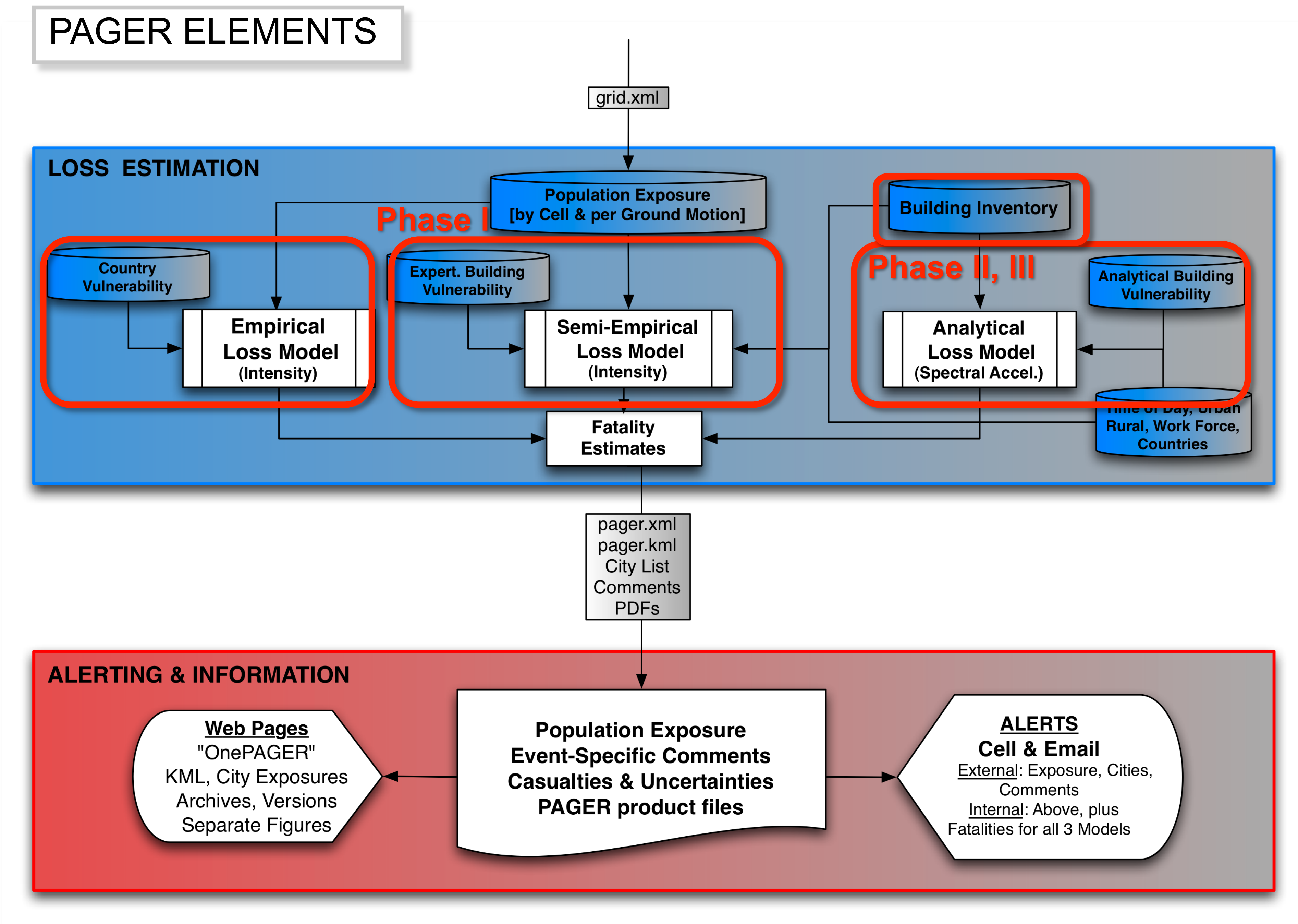
MMI	City	Population
IX	**Jiangyou**	**127k**
VIII	Mianyang	264k
VIII	**Tianpeng**	**60k**
VII	**Linqiong**	**55k**
VII	Deyang	152k
VII	**Chengdu**	**3,950k**
VI	**Guangyuan**	**213k**
V	**Xi'an**	**3,225k**
V	Nanchong	7,150k
V	**Chongqing**	**3,967k**
IV	Shiyan	3,460k

bold cities appear on map (k = x1000)

Shaking Intensity MMI



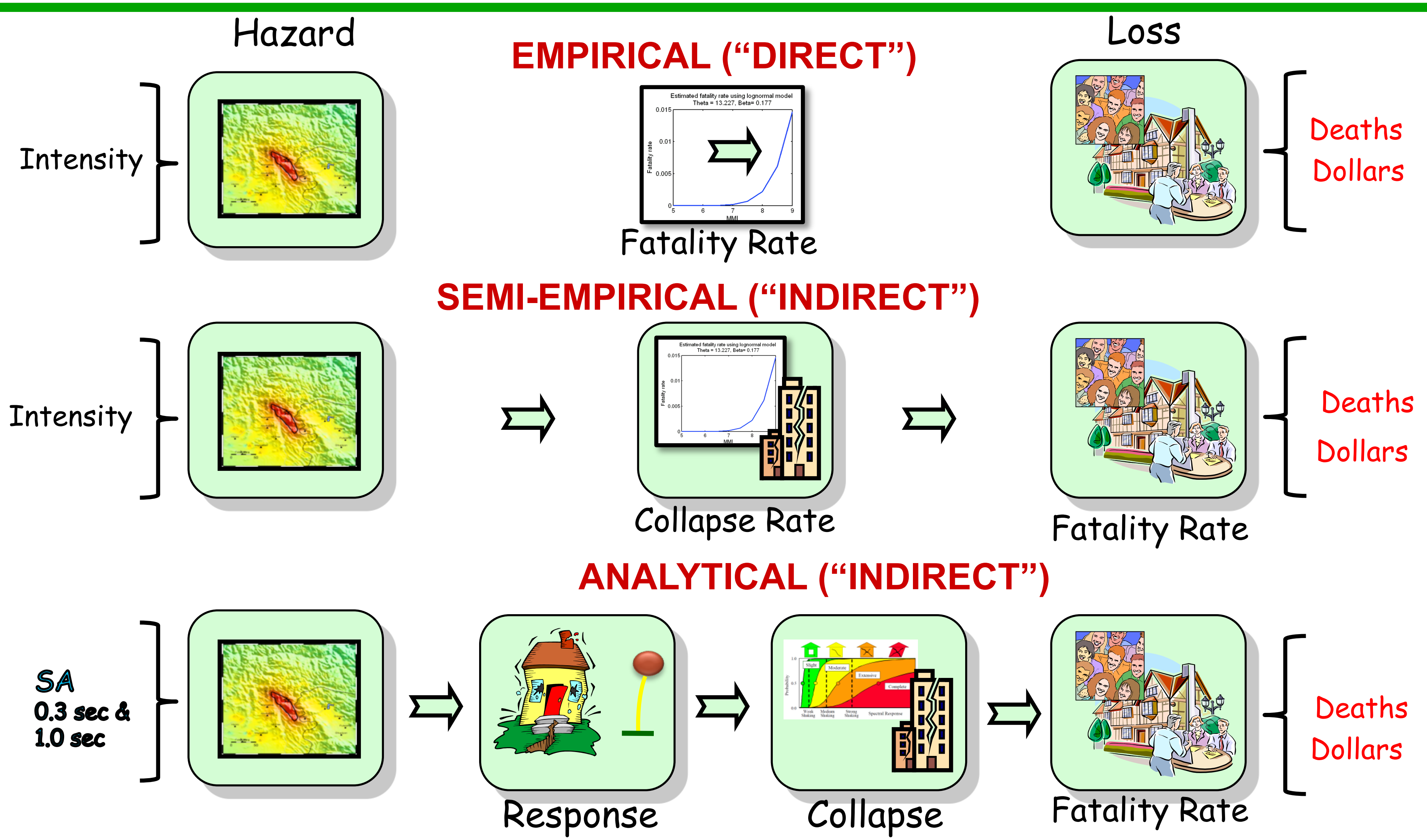

EARTHQUAKE SOURCE
PAGER SYSTEM ELEMENTS
NEIC Magnitude & Hypocenter
Surface Wave CMT
Aftershock Distribution
Fault Trace
Finite Fault Inversion
Finite Fault Model
XML
SHAKING DISTRIBUTION
Macroseismic Intensity Data
Global ShakeMap
Recorded Ground Motion Data
XML
LOSS ESTIMATION
Global Population [Ground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


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

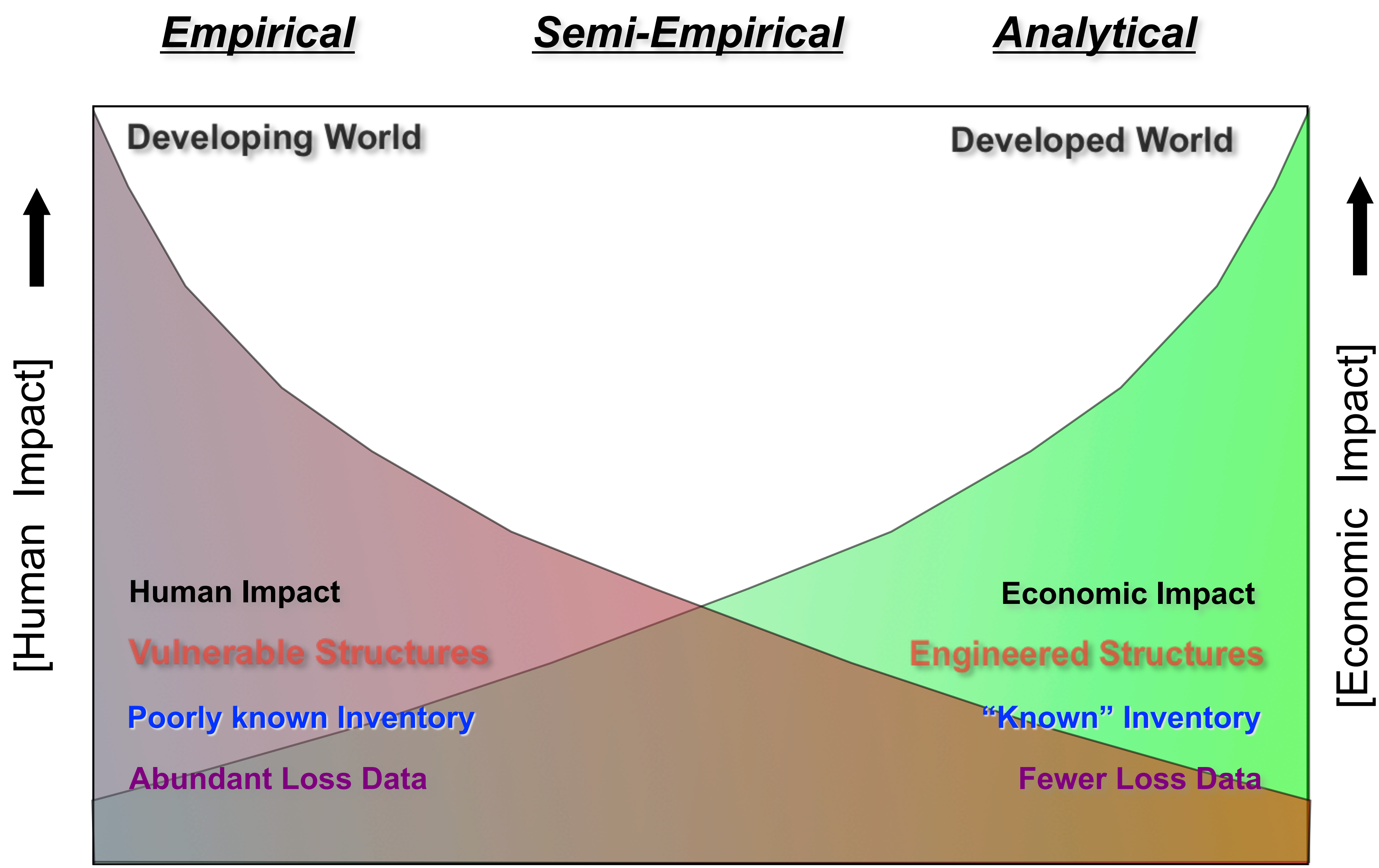
EER/WHE-PAGER "Phases"

- **Phase I**:
  - For PAGER ***Semi-empirical*** loss model.
  - Solicited experts on country-wide relative building distribution, occupancy, and intensity-based collapse functions.
  - Revised questionnaires for PAGER-STR, other clarifications.
  - Sept 2007- Dec 2008, covered 26 countries; still getting additional data.
  - USGS/PAGER funded.
- **Phase II**:
  - For PAGER ***Analytical*** loss model.
  - Solicited expert input on CSM parameters for non-US buildings.
  - USGS/PAGER funded.
- **Phase III**:
  - For PAGER ***Analytical*** loss model.
  - Reviewed initial input, also requested capacity boundary parameters.
  - Current phase, input coming in presently.
  - USGS/NEHRP Funded

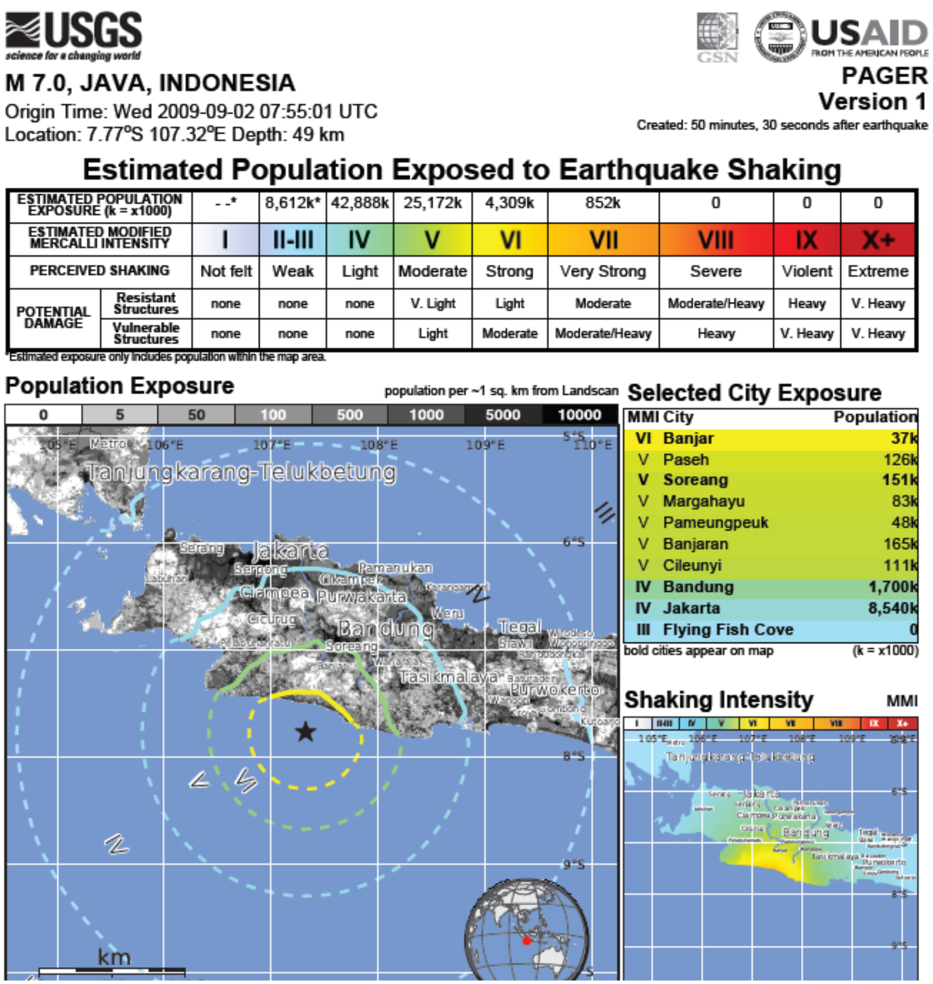
PAGER Loss Estimation



Why 3 Loss Approaches?



Fatality Estimation Using PAGER System



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GSN USAID FROM THE AMERICAN PEOPLE

M 7.0, JAVA, INDONESIA

Origin Time: Wed 2009-09-02 07:55:01 UTC
Location: 7.77°S 107.32°E Depth: 49 km

PAGER
Version 1
Created: 50 minutes, 30 seconds after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	8,612k*	42,888k	25,172k	4,309k	852k	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

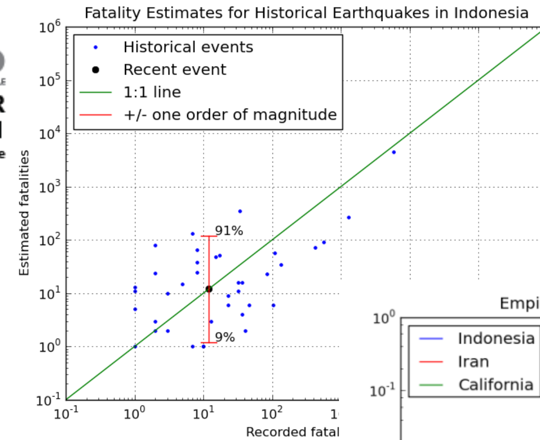
0 | 5 | 50 | 100 | 500 | 1000 | 5000 | 10000

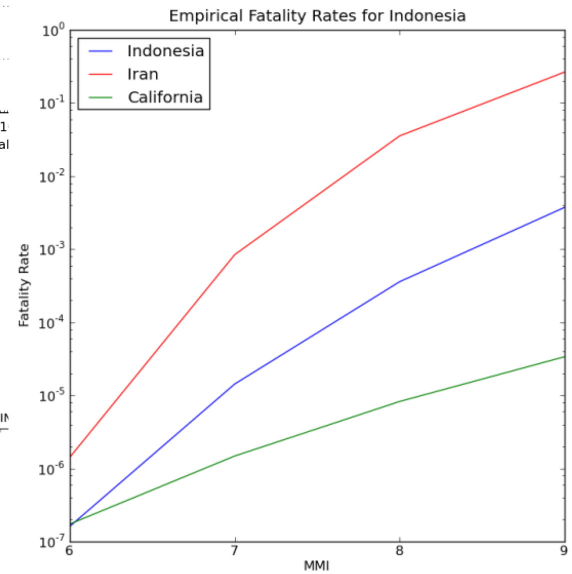
Selected City Exposure

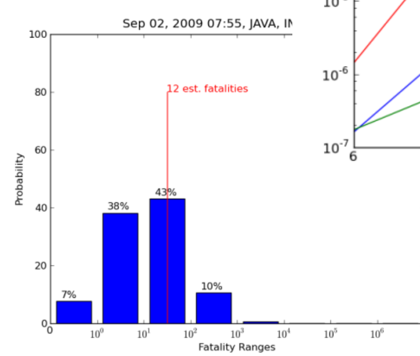
MMI	City	Population
VI	Banjar	37k
V	Paseh	126k
V	Soreang	151k
V	Margahayu	83k
V	Pameungpeuk	48k
V	Banjaran	165k
V	Cileunyi	111k
IV	Bandung	1,700k
IV	Jakarta	8,540k
III	Flying Fish Cove	0

bold cities appear on map (k = x1000)

Shaking Intensity MMI



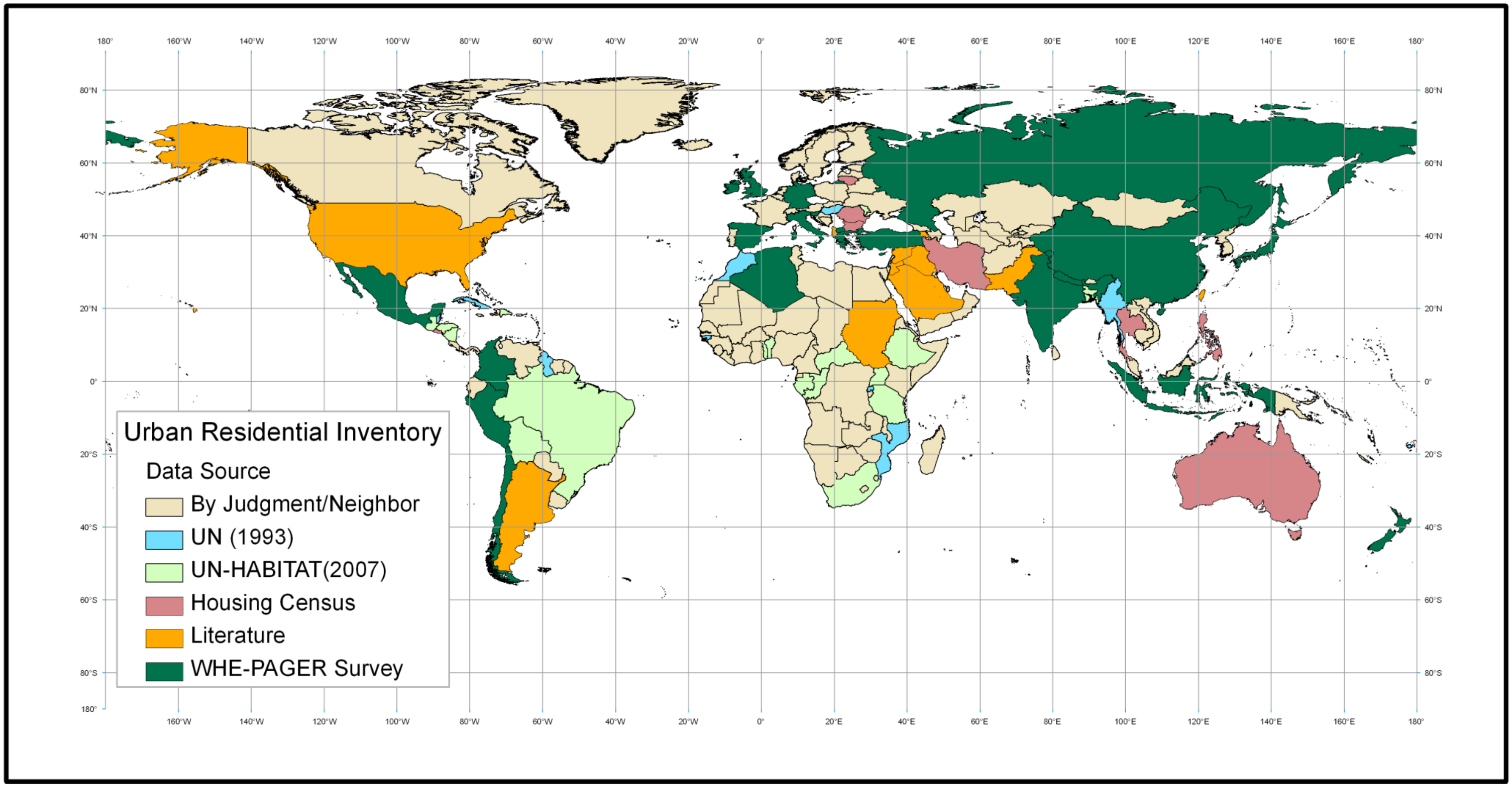




PAGER Structure Types (PAGER-STR)

Label	Description	Detailed Classification (Based on ATC-13, HAZUS 1999, WHE 2003, EMS 1998 and newly added for PAGER Inventory database 2008)
W	Wood	W1 (Wood with stucco, veneer), W2 (Heavy wood frame, >=5000 sf), W3 (Wood with metal strong wall), W4 (log building) W5 (Wattle & Daub), W6 (Unbraced post and beam frame with infill), and W7 (Braced wood frame with load bearing wall system)
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 rise)
RM	Reinforced Masonry	R1 (Reinforced masonry bearing wall with flexible diaphragm of low and mid rise), R2 (Reinforced masonry bearing wall with rigid diaphragm of low, mid and high rise)
MH	Mobile Homes	Mobile homes
M	Mud	M1 (Mud wall without wood), M2 (Mud wall with wood)
A	Adobe	A1 (Adobe mud mortar with wood roof), A2 (Adobe mud mortar with thatch roof), A3 (Adobe wall with cement mortar), A4 (Adobe wall with concrete bond beam), A5 (Adobe with reinforcement)
RE	Rammed Earth	Rammed earth construction
RS	Rubble (Field) Stone	RS1 (Rubble stone without mortar), RS2 (Rubble stone with mud mortar), RS3 (Rubble stone with lime mortar), RS4 (Rubble stone with cement mortar), RS5 (Rubble stone with concrete bond beam)
DS	Dressed Stone, blocks	DS1 (Stone block with mud mortar), DS2 (Stone block with lime mortar), DS3 (Stone block with cement mortar), DS4 (Stone block with concrete bond beam)
UFB	Unreinforced Fire Brick	UFB1 (Unreinforced brick with mud mortar without timber), UFB2 (Unreinforced brick with mud mortar and timber), UFB3 (Unreinforced brick with cement mortar and wood diaphragm), UFB4 (Unreinforced brick with cement mortar and concrete diaphragm)
UCB	Unreinforced Concrete Block	Unreinforced concrete block construction
MS	Massive Stone	Massive stone masonry construction
PC	Precast	PC1 (Precast concrete tilt up walls), PC2 (Precast concrete frame of low, mid and high rise), TU (Tiltup)
INF	**Informal**	**Informal constructions (Plastic, polythene, miscellaneous)**

PAGER Global Inventory Coverage



- Based on multiple sources (carry source and vintage information)
- Uses structural system rather than the generic vulnerability classes (through PAGER STR)
- Provides distribution by broad occupancy type and density class at country/regional level

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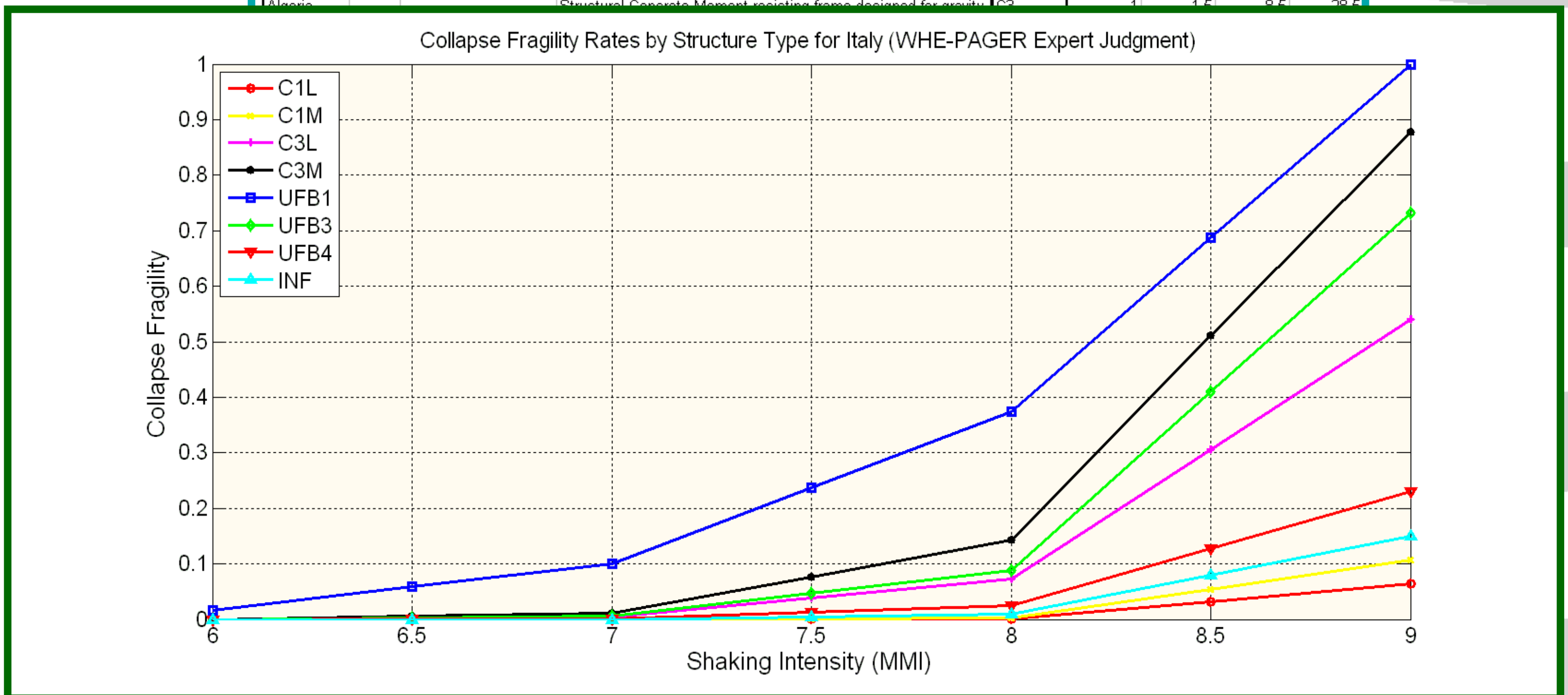
Population Distribution

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)	$P_i*(0.4*F_{nwf}+0.01*F_{wf}*F_{ind}+0.01*F_{wf}*F_{ser}+0.01*F_{wf}*F_{agr})P_i*(0.75*F_{nwf}+0.20*F_{wf}*F_{ind}+0.25*F_{wf}*F_{ser}+0.45*F_{wf}*F_{agr})P_i*(0.999*F_{nwf}+0.84*F_{wf}*F_{ind}+0.89*F_{wf}*F_{ser}+0.998*F_{wf}*F_{agr})$	$P_i*(0.89*F_{wf}*F_{ind}+0.89*F_{wf}*F_{ser}+0.34*F_{wf}*F_{agr}+0.25*F_{nwf}*F_{sch})P_i*(0.25*F_{wf}*F_{ind}+0.25*F_{wf}*F_{ser}+0.01*F_{wf}*F_{agr})P_i*(0.15*F_{wf}*F_{ind}+0.10*F_{wf}*F_{ser}+0.001*F_{wf}*F_{agr})$	$P_i*(0.35*F_{nwf}+0.10*F_{wf}*F_{ind}+0.10*F_{wf}*F_{ser}+0.65*F_{wf}*F_{agr})P_i*(0.25*F_{nwf}+0.55*F_{wf}*F_{ind}+0.50*F_{wf}*F_{ser}+0.54*F_{wf}*F_{agr})P_i*(0.001*F_{nwf}+0.01*F_{wf}*F_{ind}+0.01*F_{wf}*F_{ser}+0.001*F_{wf}*F_{agr})$
Night (10 pm- 5 am)	$P_i*(0.4*F_{nwf}+0.01*F_{wf}*F_{ind}+0.01*F_{wf}*F_{ser}+0.01*F_{wf}*F_{agr})P_i*(0.75*F_{nwf}+0.20*F_{wf}*F_{ind}+0.25*F_{wf}*F_{ser}+0.45*F_{wf}*F_{agr})P_i*(0.999*F_{nwf}+0.84*F_{wf}*F_{ind}+0.89*F_{wf}*F_{ser}+0.998*F_{wf}*F_{agr})$	$P_i*(0.89*F_{wf}*F_{ind}+0.89*F_{wf}*F_{ser}+0.34*F_{wf}*F_{agr}+0.25*F_{nwf}*F_{sch})P_i*(0.25*F_{wf}*F_{ind}+0.25*F_{wf}*F_{ser}+0.01*F_{wf}*F_{agr})P_i*(0.15*F_{wf}*F_{ind}+0.10*F_{wf}*F_{ser}+0.001*F_{wf}*F_{agr})$	$P_i*(0.35*F_{nwf}+0.10*F_{wf}*F_{ind}+0.10*F_{wf}*F_{ser}+0.65*F_{wf}*F_{agr})P_i*(0.25*F_{nwf}+0.55*F_{wf}*F_{ind}+0.50*F_{wf}*F_{ser}+0.54*F_{wf}*F_{agr})P_i*(0.001*F_{nwf}+0.01*F_{wf}*F_{ind}+0.01*F_{wf}*F_{ser}+0.001*F_{wf}*F_{agr})$

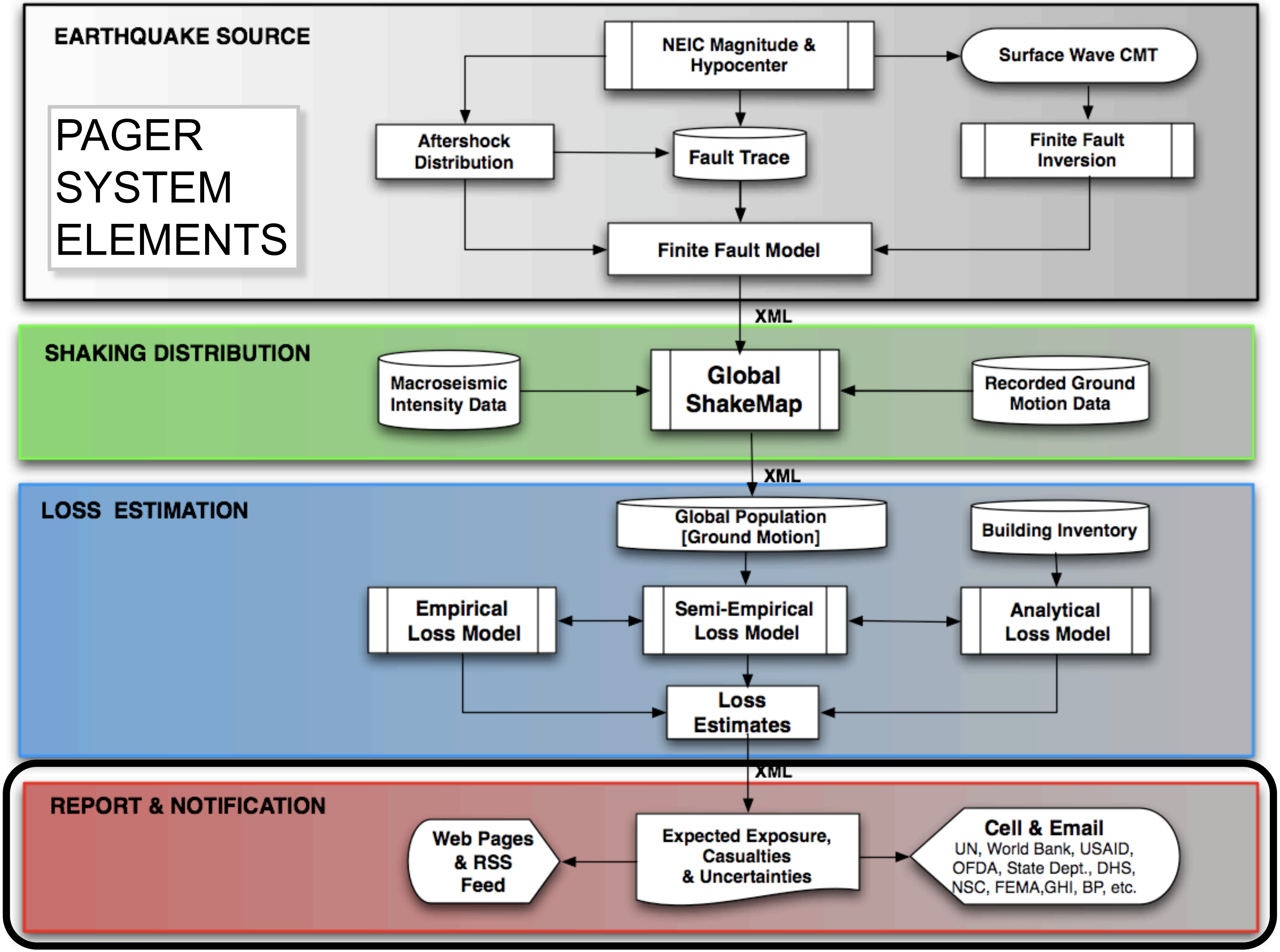
Framework to include complex occupancy patterns

Collapse Fragility for Global Bldg Types

COUNTRY	PAGER	NAME OF AUTHOR	WHE Struture type	PAGER Mapping	MMI/EMS/MSK MMI-6	MMI-7	MMI-8	MMI-9
Algeria	4	Mohammed N. Farsi, F	Masonry- Adobe block walls	A	7	22	50	75
Algeria			Masonry- Field Stone Masonry	RS	3	14	40	65
China			Moment Resisting Frame (15)(16)(17)	C1	0	0	1	5
China			Shear Wall Structure (19)(20)(21)(22)	C2	0	0	1	3
China			Moment Resisting Frame	S5	0	0	2	5
China			Wooden Structures	W	3	9	15	45



EERI-PAGER project 2007-08 (Phase I)


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
Global Population [Ground Motion]
Building Inventory
Empirical Loss Model
Semi-Empirical Loss Model
Analytical Loss Model
Loss Estimates
XML
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.

USGS
science for a changing world

USAID FROM THE AMERICAN PEOPLE

M 7.9, EASTERN SICHUAN, CHINA

Origin Time: Mon 2008-05-12 06:28:01 UTC
Location: 30.99˚N 103.36˚E Depth: 19 km

PAGER Version 12

Created: 210 days, 15 hrs after earthquake

Estimated Population Exposed to Earthquake Shaking

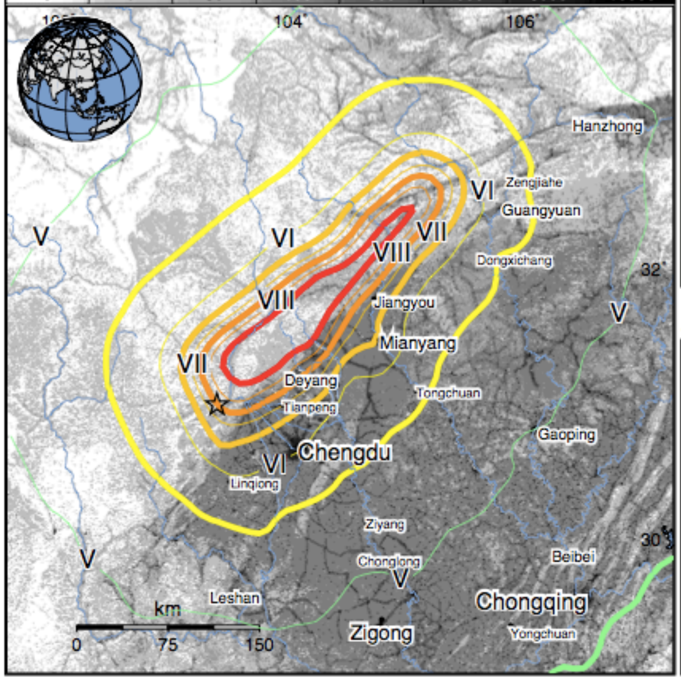
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	1,563k*	63,137k*	18,662k	3,815k	1,124k	530k	2k
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	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 2006

0	5	50	100	500	1000	5000	10000



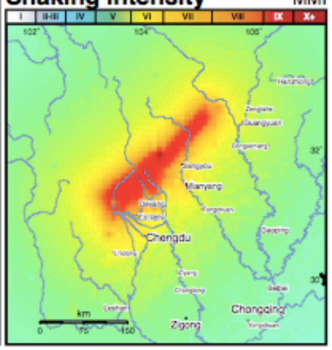
Selected City Exposure

MMI	City	Population
VII	**Tianpeng**	**60k**
VII	**Jiangyou**	**127k**
VII	**Mianyang**	**264k**
VI	**Chengdu**	**3,950k**
VI	**Guangyuan**	**213k**
VI	**Linqiong**	**55k**
VI	**Deyang**	**152k**
V	Nanchong	7,150k
V	**Zigong**	**689k**
V	Neijiang	546k
V	**Chongqing**	**3,967k**

bold cities appear on map (k = x1000)

Shaking Intensity

MMI



Overall, structures in this region are vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 6.4 earthquake struck the Sichuan, China region on August 23, 1976 (UTC), with estimated population exposures of 1,500 at intensity IX or greater and 5,700 at intensity VIII, resulting in 41 deaths. Additionally, a magnitude 7.3 struck this region in 1933 killing 6,800 people. Recent earthquakes in this area have also triggered landslide hazards that have contributed to losses. Users should consider the preliminary nature of this information and check for updates as additional data becomes available.

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager

Event ID: us2008ryan

USGS science for a changing world — Red Alert — GSN — USAID FROM THE AMERICAN PEOP[LE]

M 7.9, EASTERN SICHUAN, CHINA

Origin Time: Mon 2008-05-12 06:28:01 UTC
Location: 30.99°N 103.36°E Depth: 19 km

PAGER Version 1
Created: 1 year, 4 months after earthquak[e]

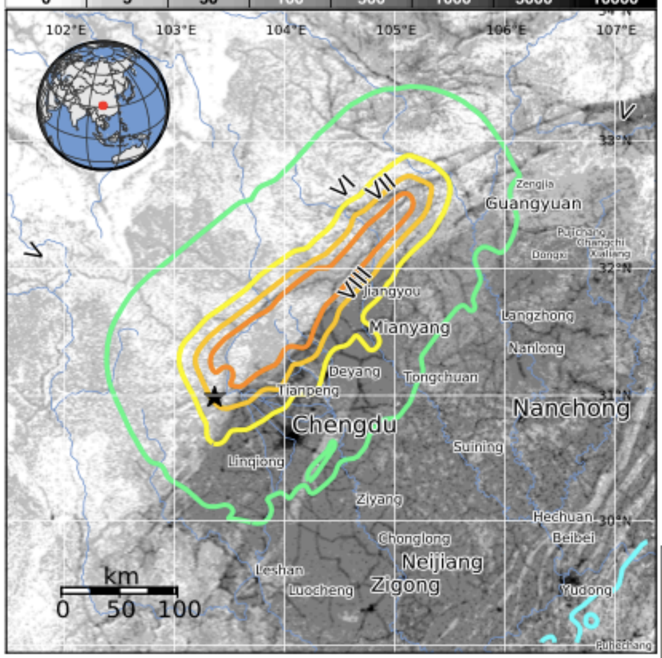
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	1,514k*	63,388k*	18,723k	3,970k	1,236k	541k	2k
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

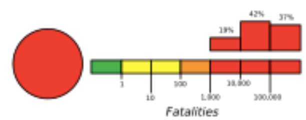
population per ~1 sq. km from Landscan



Overall, the population in this region resides in structures that are highly vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 7.7 earthquake 271 km West of this one struck Luhuo, China on February 06, 1973 (UTC), with estimated population exposures of 31,000 at intensity IX or greater and 19,000 at intensity VIII, resulting in an estimated 2,199 fatalities. Recent earthquakes in this area have caused landslides that may have contributed to losses.

Estimated Fatalities

Alert Likelihood



Based on currently available data, this event is estimated to be a red alert level for fatalities. A red alert indicates high casualties are likely and the disaster is potentially widespread. Past events with this alert level have required a national or international level response.

Estimated Economic Losses

Alert Likelihood

Based on currently available data, this event is estimated to be a red alert level for losses. A red alert indicates widespread damage is likely and the disaster is potentially widespread. Past events with this alert level have required a national or international level response.

Selected City Exposure

MMI	City	Population
VII	Tianpeng	61k
VII	Mianyang	264k
VII	Jiangyou	127k
VI	Chengdu	3,950k
VI	Guangyuan	213k
VI	Linqiong	56k
V	Deyang	152k
V	Tongchuan	58k
V	Dongxi	4k
V	Leshan	154k
IV	Chongqing	3,967k

bold cities appear on map (k = x1000)

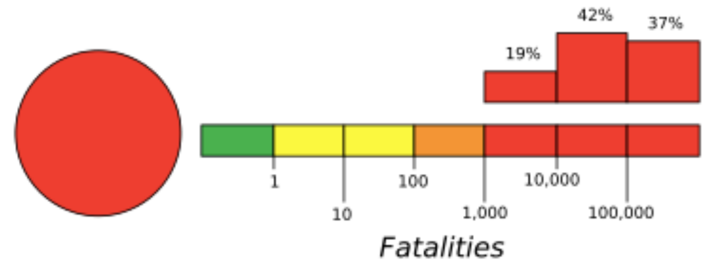
This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager

Event ID: us2008ryan

Estimated Fatalities

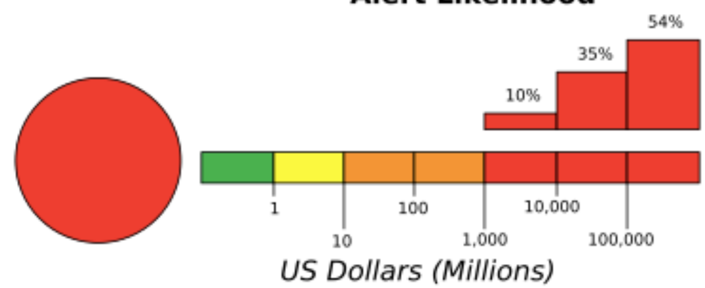
Alert Likelihood



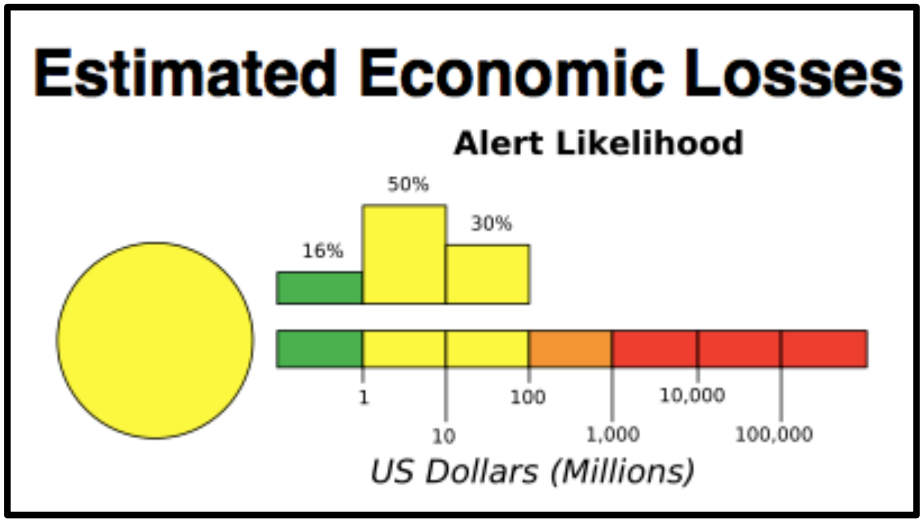
Based on currently available data, this event is estimated to be a red alert level for fatalities. A red alert indicates high casualties are likely and the disaster is potentially widespread. Past events with this alert level have required a national or international level response.

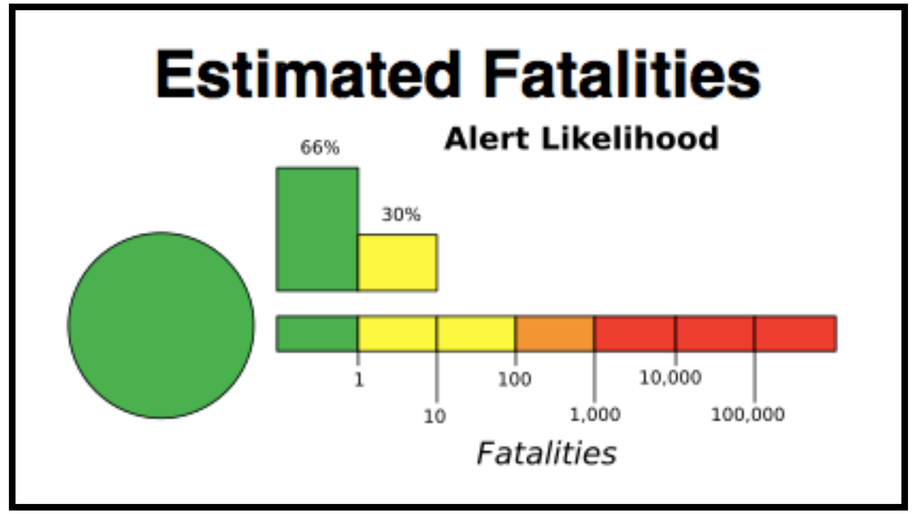
Estimated Economic Losses

Alert Likelihood



Based on currently available data, this event is estimated to be a red alert level for losses. A red alert indicates widespread damage is likely and the disaster is potentially widespread. Past events with this alert level have required a national or international level response.





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

USGS
science for a changing world

Yellow Alert

USAID FROM THE AMERICAN PEOPLE

M 5.2, ILLINOIS

Origin Time: Fri 2008-04-18 09:37:00 UTC
Location: 38.45°N 87.89°W Depth: 11 km

PAGER
Version 1

Created: 1 year, 5 months after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	3,085k*	817k	52k	15k	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

Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. A magnitude 5.1 earthquake 41 km North of this one struck United States on June 10, 1987 (UTC), with estimated population exposures of 6,000 at intensity VI and 147,000 at intensity V, with no reported fatalities.

Estimated Fatalities

Based on currently available data, this event is estimated to be a green alert level for fatalities. A green alert indicates a low likelihood of casualties.

Estimated Economic Losses

Based on currently available data, this event is estimated to be a yellow alert level for losses. A yellow alert indicates some damage is likely and the disaster is relatively localized. Past events with this alert level have required a local or regional level response.

Selected City Exposure

MMI	City	Population
VI	**Mount Carmel**	8k
VI	**Albion**	2k
VI	**Grayville**	2k
VI	Owensville	1k
V	**Bridgeport**	2k
V	Sumner	1k
IV	**Evansville**	115k
IV	**Springfield**	116k
IV	Indianapolis	773k
IV	**Decatur**	78k
IV	**Bloomington**	71k

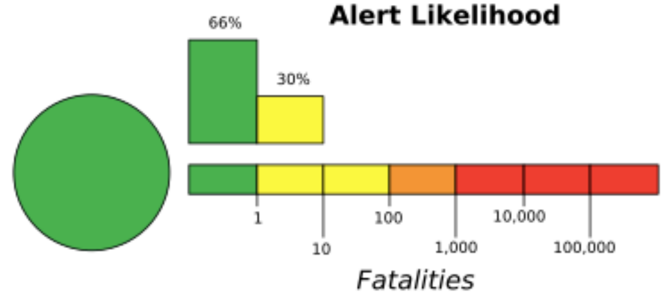
bold cities appear on map (k = x1000)

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager

Event ID: us2008qza6

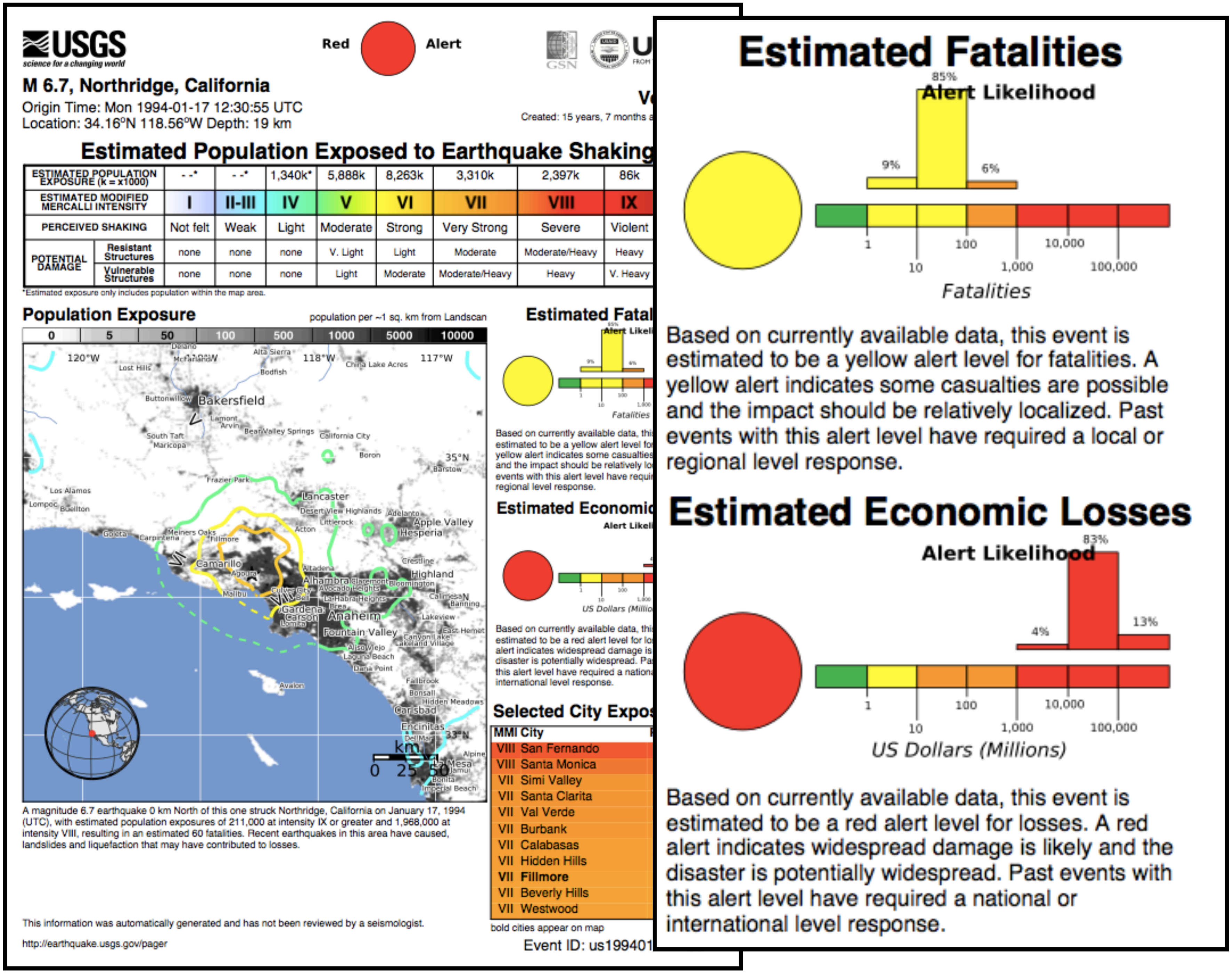
Estimated Fatalities



Based on currently available data, this event is estimated to be a green alert level for fatalities. A green alert indicates a low likelihood of casualties.

Estimated Economic Losses

Based on currently available data, this event is estimated to be a yellow alert level for losses. A yellow alert indicates some damage is likely and the disaster is relatively localized. Past events with this alert level have required a local or regional level response.


USGS
science for a changing world
Red Alert
M 6.7, Northridge, California
Origin Time: Mon 1994-01-17 12:30:55 UTC
Location: 34.16°N 118.56°W Depth: 19 km
Created: 15 years, 7 months a
Estimated Population Exposed to Earthquake Shaking
ESTIMATED POPULATION EXPOSURE (k = x1000) | --* | --* | 1,340k* | 5,888k | 8,263k | 3,310k | 2,397k | 86k
ESTIMATED MODIFIED MERCALLI INTENSITY | I | II-III | IV | V | VI | VII | VIII | IX
PERCEIVED SHAKING | Not felt | Weak | Light | Moderate | Strong | Very Strong | Severe | Violent
POTENTIAL DAMAGE Resistant Structures | none | none | none | V. Light | Light | Moderate | Moderate/Heavy | Heavy
POTENTIAL DAMAGE Vulnerable Structures | none | none | none | Light | Moderate | Moderate/Heavy | 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
Bakersfield
Lancaster
Camarillo
Alhambra
Anaheim
Fountain Valley
Apple Valley
Hesperia
A magnitude 6.7 earthquake 0 km North of this one struck Northridge, California on January 17, 1994 (UTC), with estimated population exposures of 211,000 at intensity IX or greater and 1,968,000 at intensity VIII, resulting in an estimated 60 fatalities. Recent earthquakes in this area have caused, landslides and liquefaction that may have contributed to losses.
This information was automatically generated and has not been reviewed by a seismologist.
http://earthquake.usgs.gov/pager
Selected City Exposure
MMI City
VIII San Fernando
VIII Santa Monica
VII Simi Valley
VII Santa Clarita
VII Val Verde
VII Burbank
VII Calabasas
VII Hidden Hills
VII Fillmore
VII Beverly Hills
VII Westwood
bold cities appear on map
Event ID: us199401
Estimated Fatalities
Alert Likelihood
85%
9%
6%
1 10 100 1,000 10,000 100,000
Fatalities
Based on currently available data, this event is estimated to be a yellow alert level for fatalities. A yellow alert indicates some casualties are possible and the impact should be relatively localized. Past events with this alert level have required a local or regional level response.
Estimated Economic Losses
Alert Likelihood
83%
4%
13%
1 10 100 1,000 10,000 100,000
US Dollars (Millions)
Based on currently available data, this event is estimated to be a red alert level for losses. A red alert indicates widespread damage is likely and the disaster is potentially widespread. Past events with this alert level have required a national or international level response.

Basis for FEMA

(From comparison of pa

PAGER Alert Level	FEMA Activation Level	
Red	Level I	> 1,000 ($1B)
Orange	Level II	100 – 1,000
Yellow	Level III	1-100
Green	No Activation	< 1 ($1M)

*Post-Katrina Emergency Reform Act of 2006 (PKEMRA) entails activating pre-scripted mission assignments & specific earthquake-response actions depending on the initial activation level

Basis for Global Activation Levels

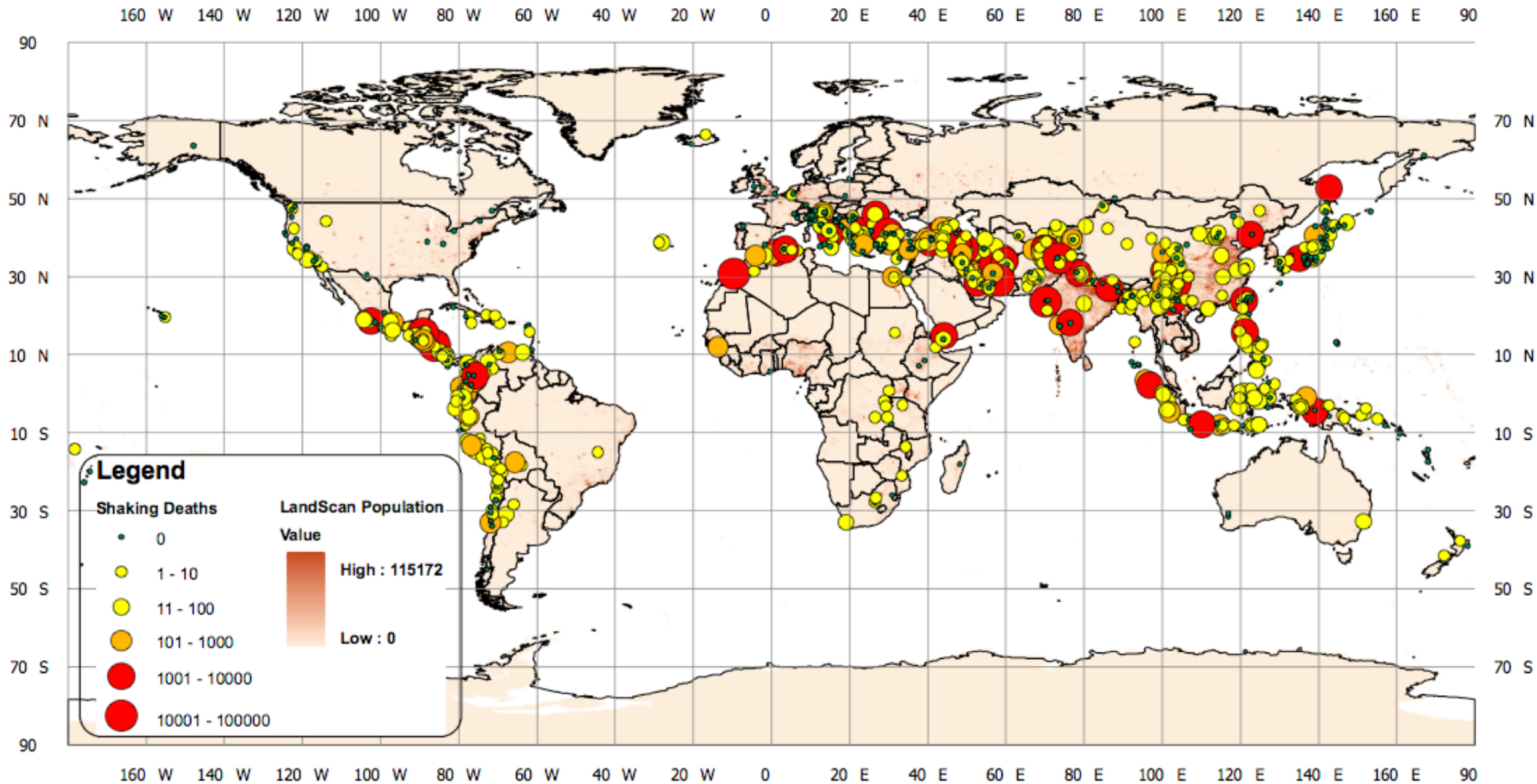
(From comparison of past losses, aid & response)

	PAGER Alert Level	Estimated Fatalities	Estimated Losses ($M)
International Response	Red	> 1,000	> 1,000
National Response	Orange	100 – 1,000	100 – 1,000
Local/Regional Response	Yellow	1-100	1-100
Little to No Response	Green	< 1	< 1

How Often Will These Alerts Occur?

Alert Level & Color	Estimated Fatalities	Number of Global alerts per year [US]	Estimated Losses ($M)	Number of Global alerts per year [US]
Red	> 1,000	1.5 [0.01]	> 1,000	0.9 [0.1]
Orange	100 – 1,000	1.5 [0.01]	10 – 1,000	6.1 [0.5]
Yellow	1-100	14 [0.1]	1-10	6.3 [0.3]
Green	< 1	~1,250 [?]	< 1	56 [4.7]

How Often Will These Alerts Occur?



Map of fatality-based alert levels that would be triggered given the observed fatalities for events over the past forty years. The legend provides the fatality threshold for color-coded alert level. There would have been about 5,000 green, 490 yellow, 51 orange, and 48 red alerts (approximately 14 yellow, 1-2 orange, and 1-2 red alerts per year).

PAGER System: Status Report

- Publishing ShakeMaps for M>5.5 earthquakes globally (lower, variable threshold domestically, ~M>3.5)
- Delivering Alerts/Web Pages of population exposure
  - "onePAGER" with context (related earthquakes), ShakeMap, cities/ populations
  - Getting ready to release lossPAGER (Impact-based alerts)
- Loss Modeling Development
  - Empirical, Semi-Empirical & Analytical models now providing internal loss estimates & alerts; development ongoing.
- Associated databases & tools are published & online
- Long-term: improve source char., ShakeMap Atlas, building inventory, loss models, alerts, add secondary losses (landslides, liquefaction, …)

USGS

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

USAID
FROM THE AMERICAN PEOPLE

MercyCorps
Be the change

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

GDACS
Global Disaster Alert &
Coordination System

United Nations

Aid Agencies/NGO

China's earthquake emergency rescue center

Australian Government
Geoscience Australia

REUTERS

International

Federal Government

THE WHITE HOUSE
PRESIDENT GEORGE W. BUSH

FEMA

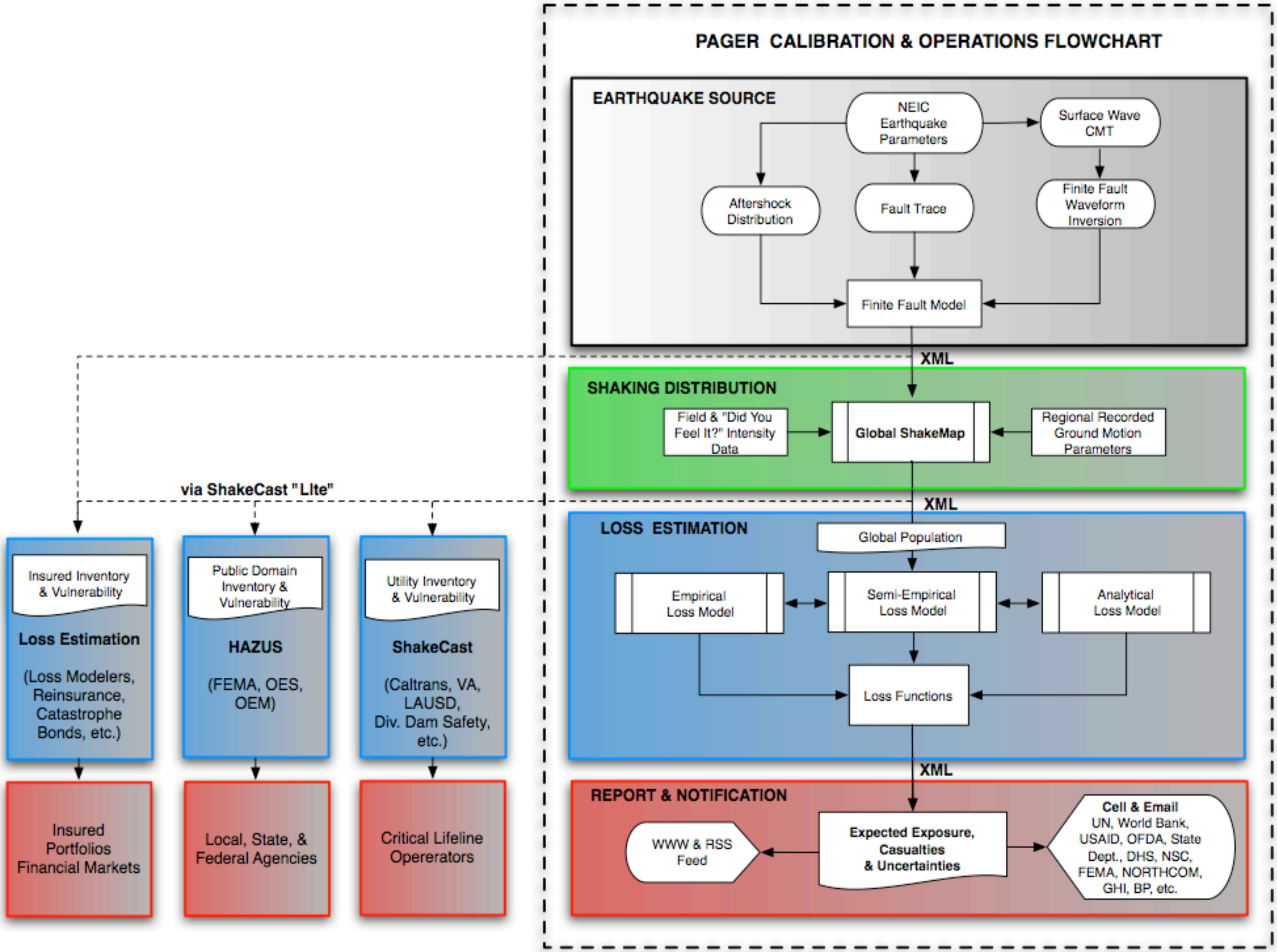
Homeland Security

Air Force Technical Applications Center

US Air Force

U.S. DEPARTMENT of STATE

USNORTHCOM
DEFENDING OUR HOMELAND


PAGER CALIBRATION & OPERATIONS FLOWCHART
EARTHQUAKE SOURCE
NEIC Earthquake Parameters
Surface Wave CMT
Aftershock Distribution
Fault Trace
Finite Fault Waveform Inversion
Finite Fault Model
XML
SHAKING DISTRIBUTION
Field & "Did You Feel It?" Intensity Data
Global ShakeMap
Regional Recorded Ground Motion Parameters
XML
LOSS ESTIMATION
Global Population
Empirical Loss Model
Semi-Empirical Loss Model
Analytical Loss Model
Loss Functions
XML
REPORT & NOTIFICATION
WWW & RSS Feed
Expected Exposure, Casualties & Uncertainties
Cell & Email
UN, World Bank, USAID, OFDA, State Dept., DHS, NSC, FEMA, NORTHCOM, GHI, BP, etc.
via ShakeCast "LIte"
Insured Inventory & Vulnerability
Loss Estimation
(Loss Modelers, Reinsurance, Catastrophe Bonds, etc.)
Public Domain Inventory & Vulnerability
HAZUS
(FEMA, OES, OEM)
Utility Inventory & Vulnerability
ShakeCast
(Caltrans, VA, LAUSD, Div. Dam Safety, etc.)
Insured Portfolios Financial Markets
Local, State, & Federal Agencies
Critical Lifeline Opererators