



science for a changing world

NATURAL HAZARDS MISSION AREA

USGS within NEHRP

Earthquake Hazards Program

Global Seismographic Network

Program

NEHRP ACEHR

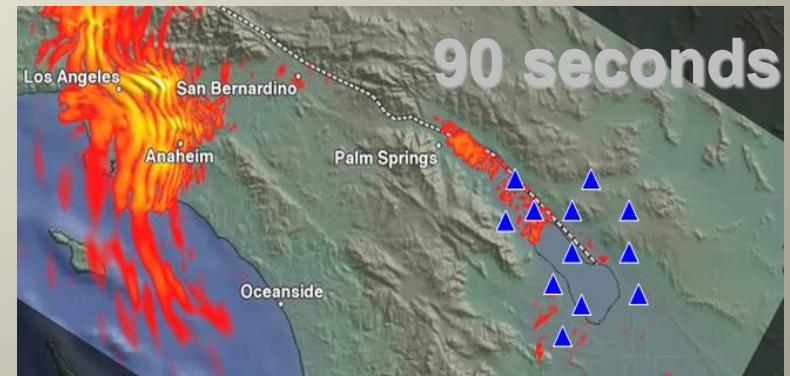
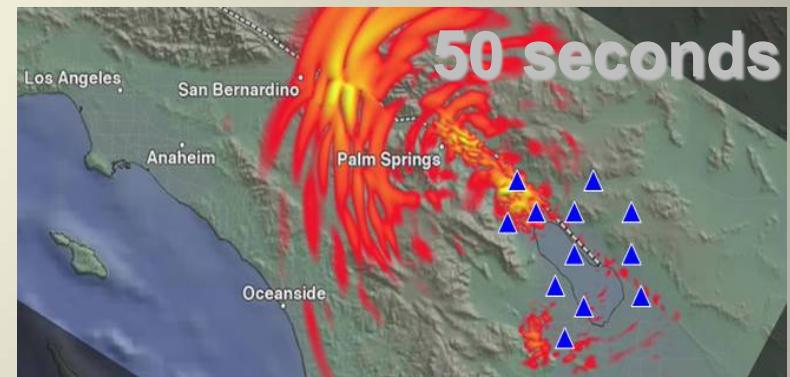
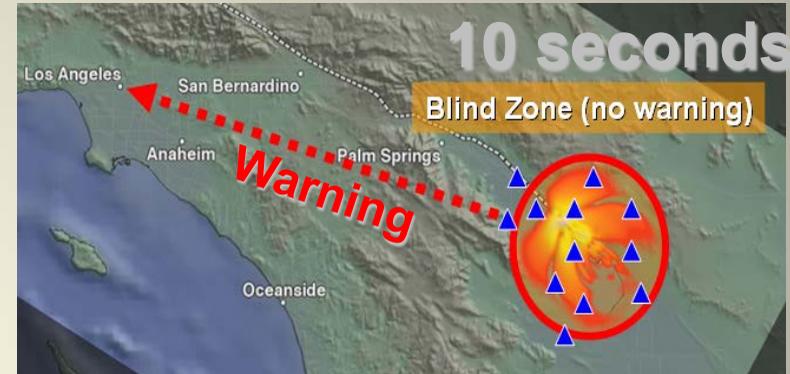
17 August 2014

Bill Leith

*Senior Science Advisor for Earthquake
and Geologic Hazards*

U.S. Geological Survey

wleith@usgs.gov

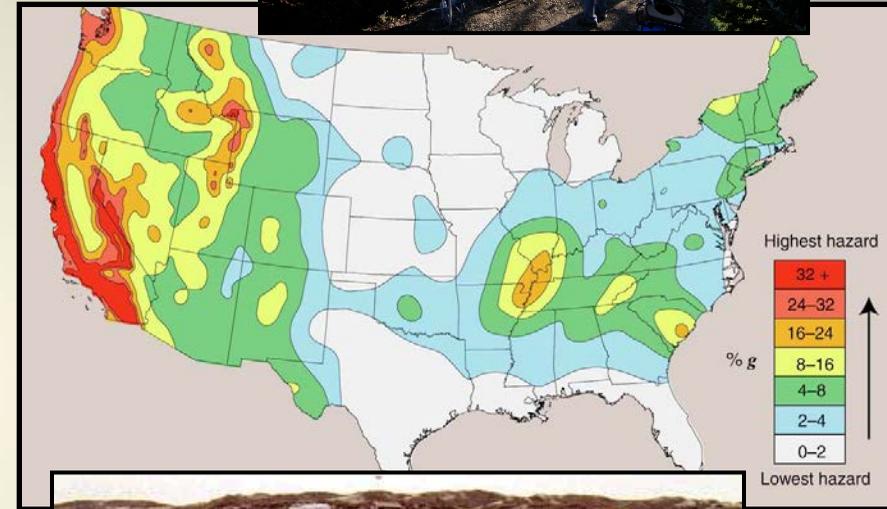


Outline

- **Program Overview**
 - Global Seismographic Network Program
 - Earthquake Hazards Program
- **Budget Overview**
- **Hot Topics, Issues and Opportunities**
 - GSN Primary Sensor Replacement
 - National Seismic Hazard Model
 - Central and Eastern U.S. Seismic Monitoring
 - Induced Seismicity
 - Response to ACEHR Recommendations
 - Earthquake Early Warning

USGS within NEHRP

Provide earthquake monitoring and notifications,
assess seismic hazards,
conduct targeted research needed to reduce the risk from earthquake hazards nationwide, and with other NEHRP agencies and many other partners, support public awareness of earthquake hazards and impacts.



FEMA

NIST
National Institute of
Standards and Technology

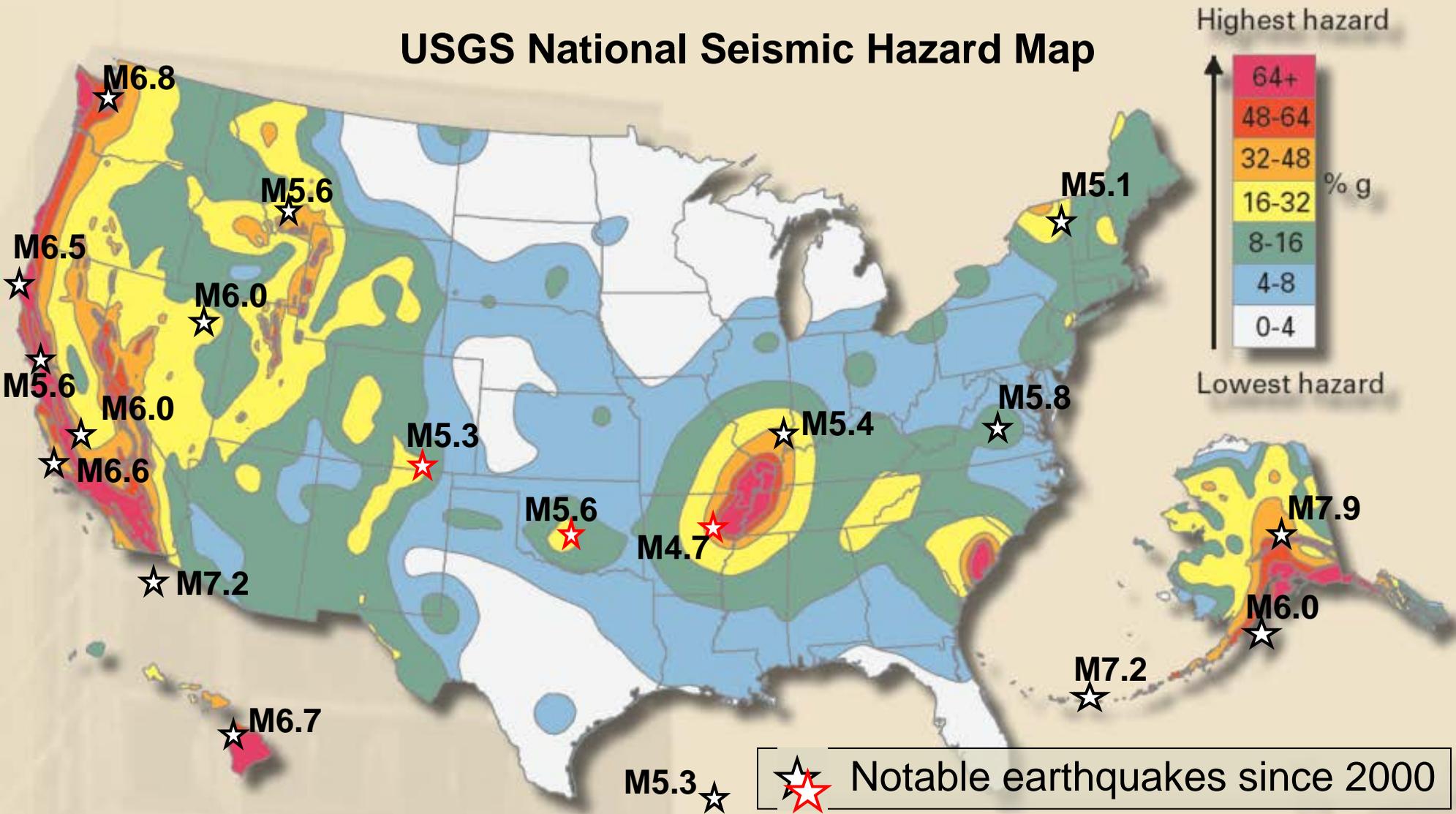


USGS
science for a changing world

national **earthquake** hazards reduction program

National Seismic Hazard Model

USGS National Seismic Hazard Map



FEMA

NIST

National Institute of Standards and Technology

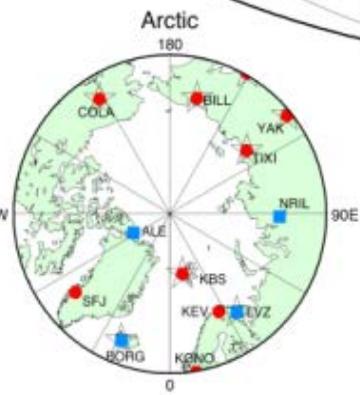
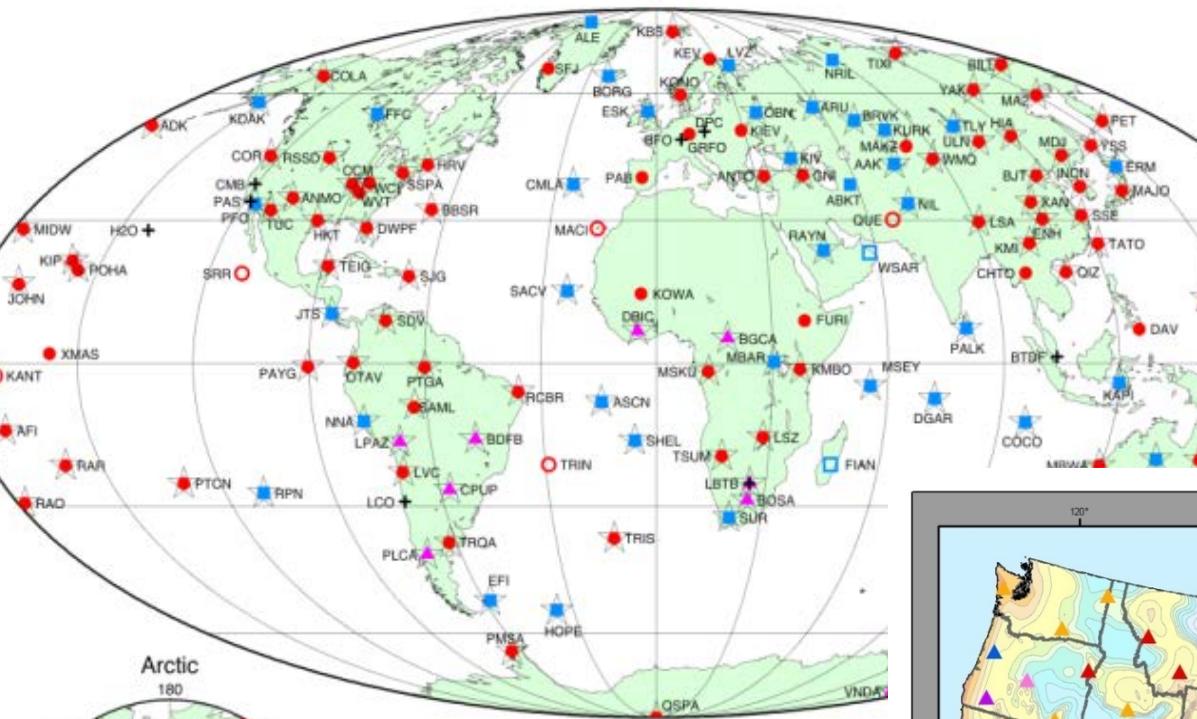


USGS
science for a changing world

national earthquake hazards reduction program

Global and National Earthquake Monitoring

Global Seismographic Network



- | | | |
|-------|-----|-------------------------------|
| 85 ● | 6 ○ | IRIS/USGS Stations |
| 39 ■ | 2 □ | IRIS/IDA Stations (UCSD) |
| 8 + | | Other/Affiliated GSN Stations |
| 9 ▲ | | GTSN Stations (AFTAC) |
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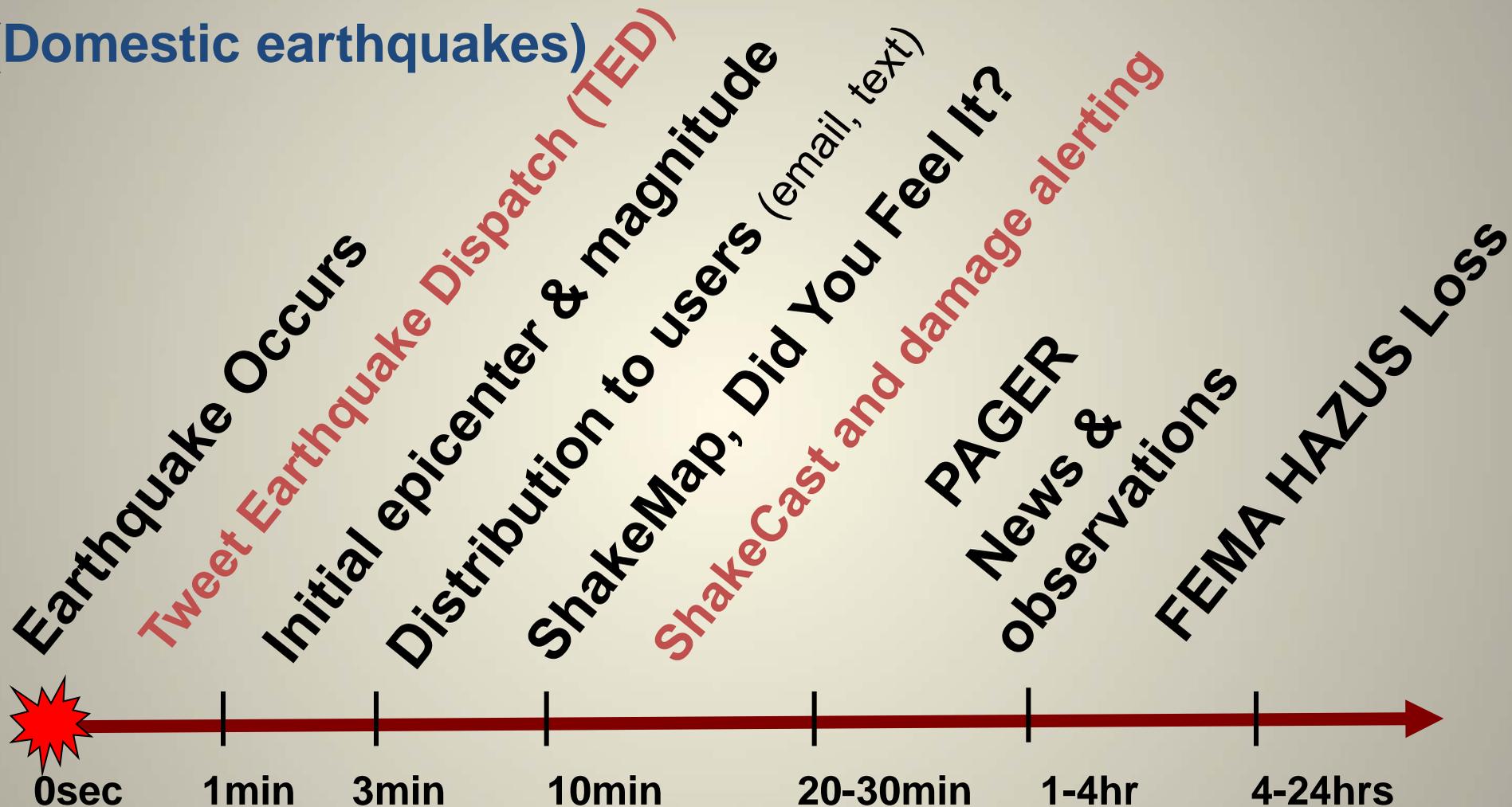
USGS Albuquerque Seismological Laboratory
January 27, 2005 (crh/lw)



- Station Categories**
- ▲ USGS Backbone stations operated and maintained by USGS
 - ▲ GSN - Global Seismographic Network, data contributed to NEIC

Earthquake Monitoring Information Timeline

(Domestic earthquakes)



Virginia Earthquake M 5.8 of August 23, 2011

The USGS “Did You Feel It?” software crowd-sources observations from people who experienced the earthquake

Anyone can report through a DYFI? web page

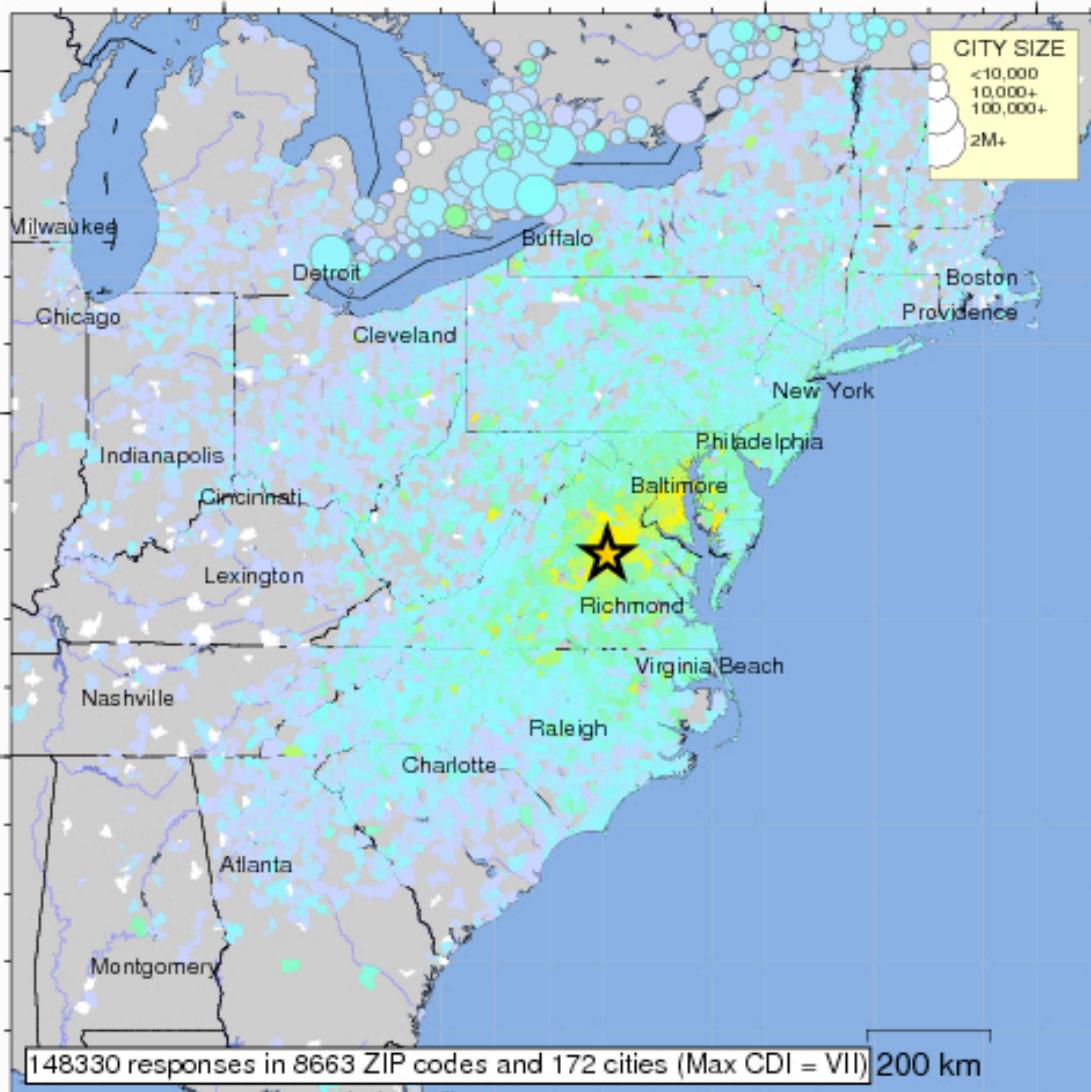
The web page takes a person through a detailed set of questions that links their experience to ground-shaking intensity

These reports are averaged by postal (zip) code, for domestic earthquakes, or city.

More than 150,000 felt reports were obtained for the 2011 Virginia quake

USGS Community Internet Intensity Map VIRGINIA

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



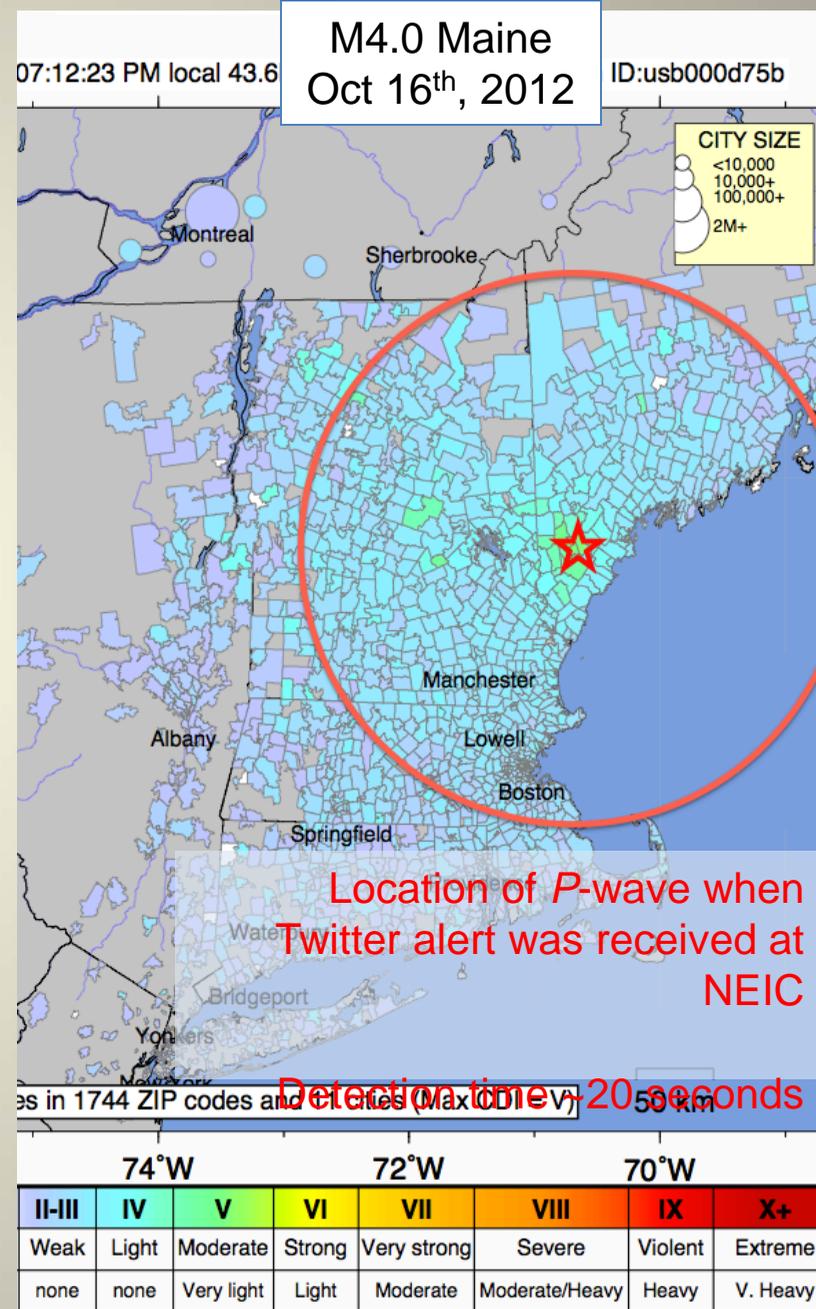
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Mon Oct 31 13:32:46 2011



USGS Twitter EQ Detections

- Twitter-based system detects 2 or 3 earthquakes per day, on average.
- Frequently it is the USGS's first indication of a widely felt event
- 90% of detections occur in under 2 minutes
- 50% of detections occur in under 1 minute
- Detects small felt events in sparsely instrumented places of the world that are missed by traditional monitoring systems
- Provides earthquake detections from an independent source
- Provides rapid *qualitative* indication of earthquake effects



ShakeCast

Situational awareness for ground shaking at critical facilities.

Example for nuclear power plants: Shaking from Virginia M5.8 earthquake.

U.S.NRC ShakeCast Report



Magnitude 5.8 - VIRGINIA

Version 6

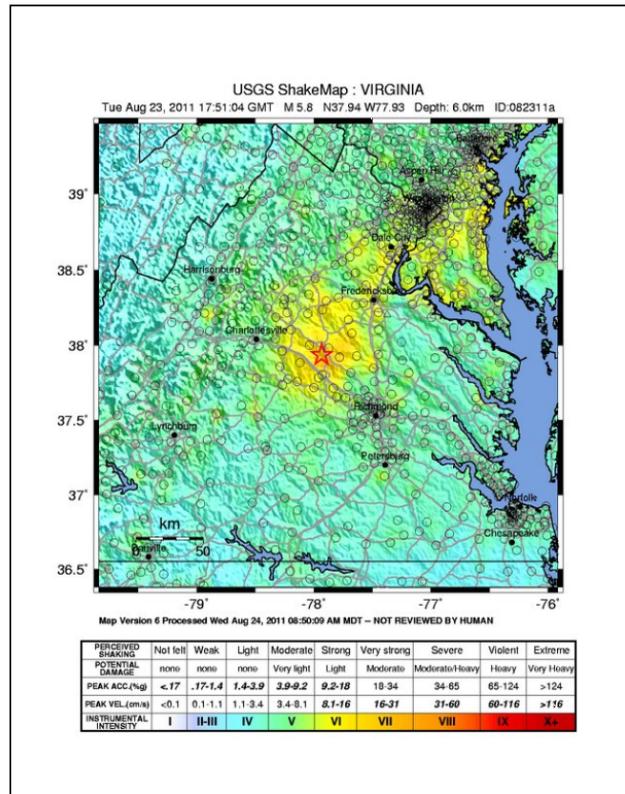
Origin Time: 2011-08-23 17:51:04 GMT

Created: 2011-08-24 15:11:29 GMT

Latitude: 37.9360 Longitude: -77.9330

Depth: 6.0 km

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



U.S.NRC Nuclear ShakeCast

Home Earthquakes Search FAQ Profile Register Log In

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

ShakeCast Summary

Number of facilities evaluated: 3

Peak Ground Acceleration (g): 1.81 - 82.46
 Peak Ground Velocity (cm/sec): 0.91 - 27.82
 Instrumental Intensity: III - VII
 Peak Spectral Acc. at 0.3 sec (g): 1.23 - 63.39
 Peak Spectral Acc. at 1.0 sec (g): 0.40 - 12.29
 Peak Spectral Acc. at 3.0 sec (g): 0.08 - 1.25
 PGA Uncertainty in Std Deviation: 0.29 - 1.02
 Estimated V330 in m/s : 0 - 740

M 5.8 - VIRGINIA

ID: 082311a Version: 6
 Origin Time: 2011-08-23 17:51:04
 Location: -77.933, 37.936

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	3.4-9.1	9.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Recent significant earthquakes in the region

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

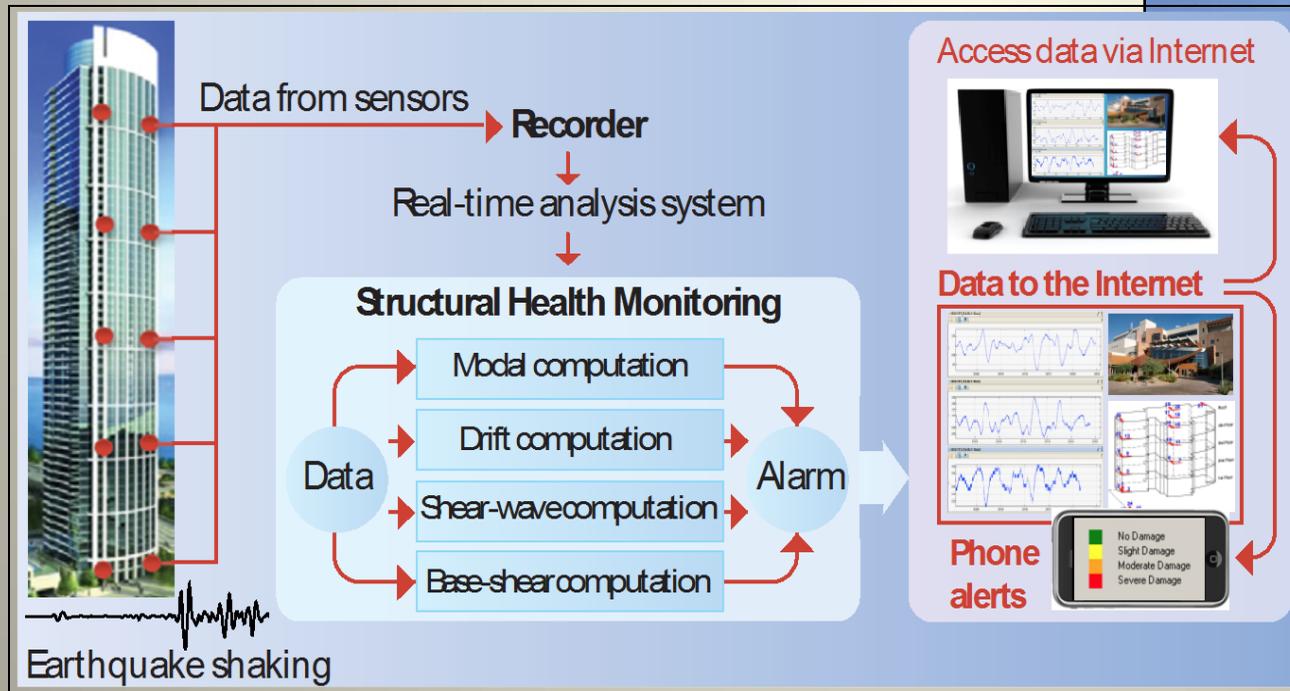
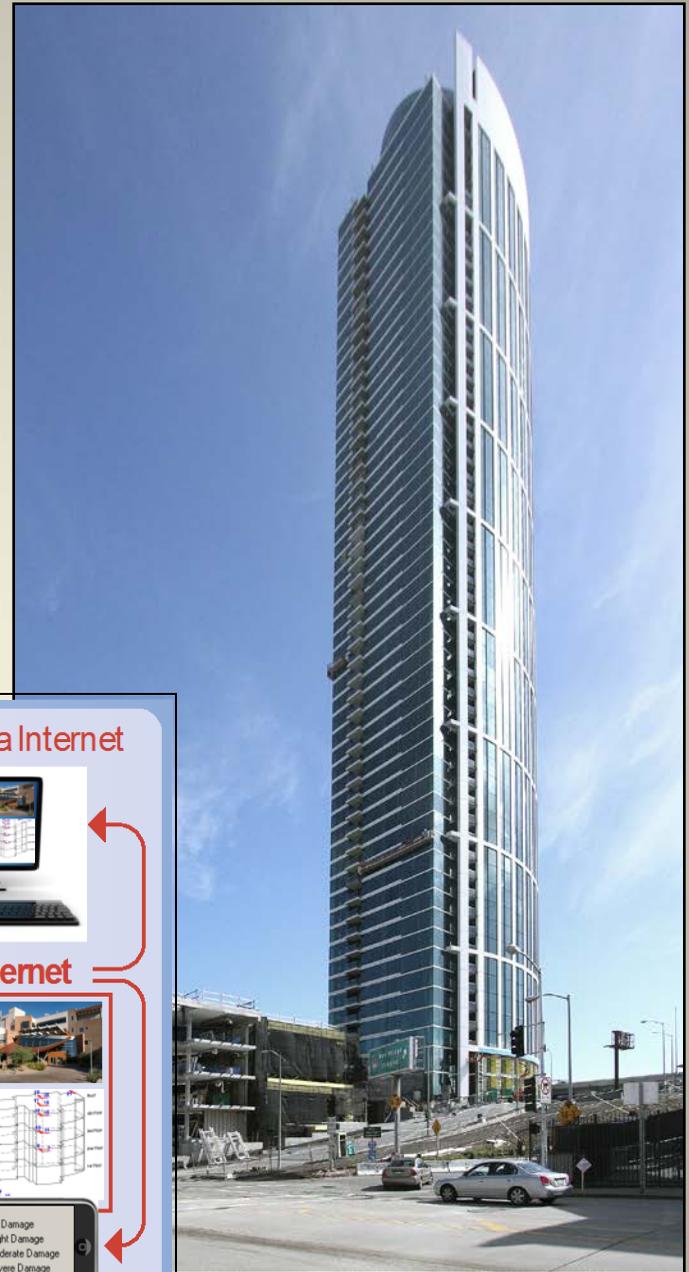
FACILITY_TYPE	FACILITY_ID	FACILITY_NAME	DIST	LATITUDE	LONGITUDE	DAMAGE_LEVEL	MMI	PGA	PGV	PSA03	PSA10	PSA30
NUCLEAR	USA37	North Anna	18.08	38.0573	-77.7956	YELLOW	VI	19.9918	12.2568	26.0078	5.9443	0.5989
NUCLEAR	USA8	Calvert Cliffs	141.73	38.4319	-76.4424	GREEN	V	6.8436	6.7083	3.5967	1.4285	0.1501
NUCLEAR	USA56	Surry	139.06	37.1633	-76.6942	GREEN	V	6.1296	6.5473	3.5591	1.4118	0.1482



Structural Monitoring Damage Alerting Systems

One Rincon, San Francisco
and V.A. Medical Centers

- Dense real-time monitoring array
 - 72-channels of 200sps motion
- Structural health monitoring
- Damage Alerting System





Earthquake Shaking **Red Alert**



PAGER
Version 3

M 8.8, OFFSHORE MAULE, CHILE

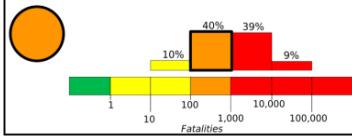
Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)

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

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

Created: 3 hours, 10 minutes after earthquake

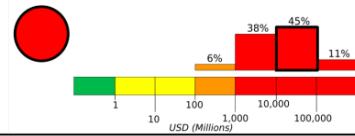
Estimated Fatalities



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

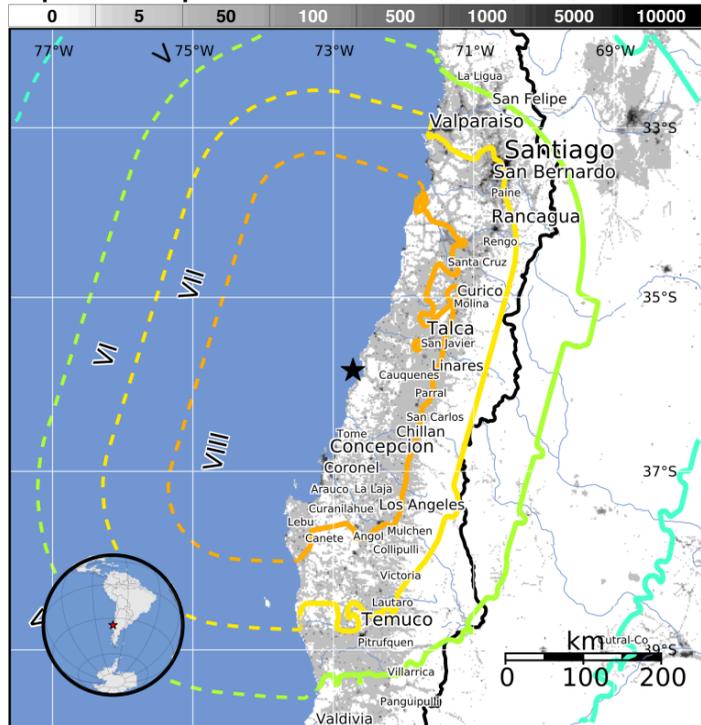


Estimated Population Exposed to Earthquake Shaking

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



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 Shaking MMI(#)	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

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

PAGER

Prompt Alerting of Global Earthquakes for Response

Continually updated databases for loss calculations

Heavy use for earthquake scenario planning

Potential applications in the insurance sector



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>

PAGER loss estimates

a basis for FEMA alert levels in the U.S.

Alert Level & Color	FEMA's Activation Level	Estimated Losses (\$M)	Number of Alerts per year
Red	Level I	> 1,000 (\$1B)	0.1 (1/10 yrs)
Orange	Level II	100 – 1,000	0.2 (1/5 yrs)
Yellow	Level III	1-100 (\$1M)	0.5 (1/2 yrs)
Green	No Activation (or Standby)	< 1	1 - 2

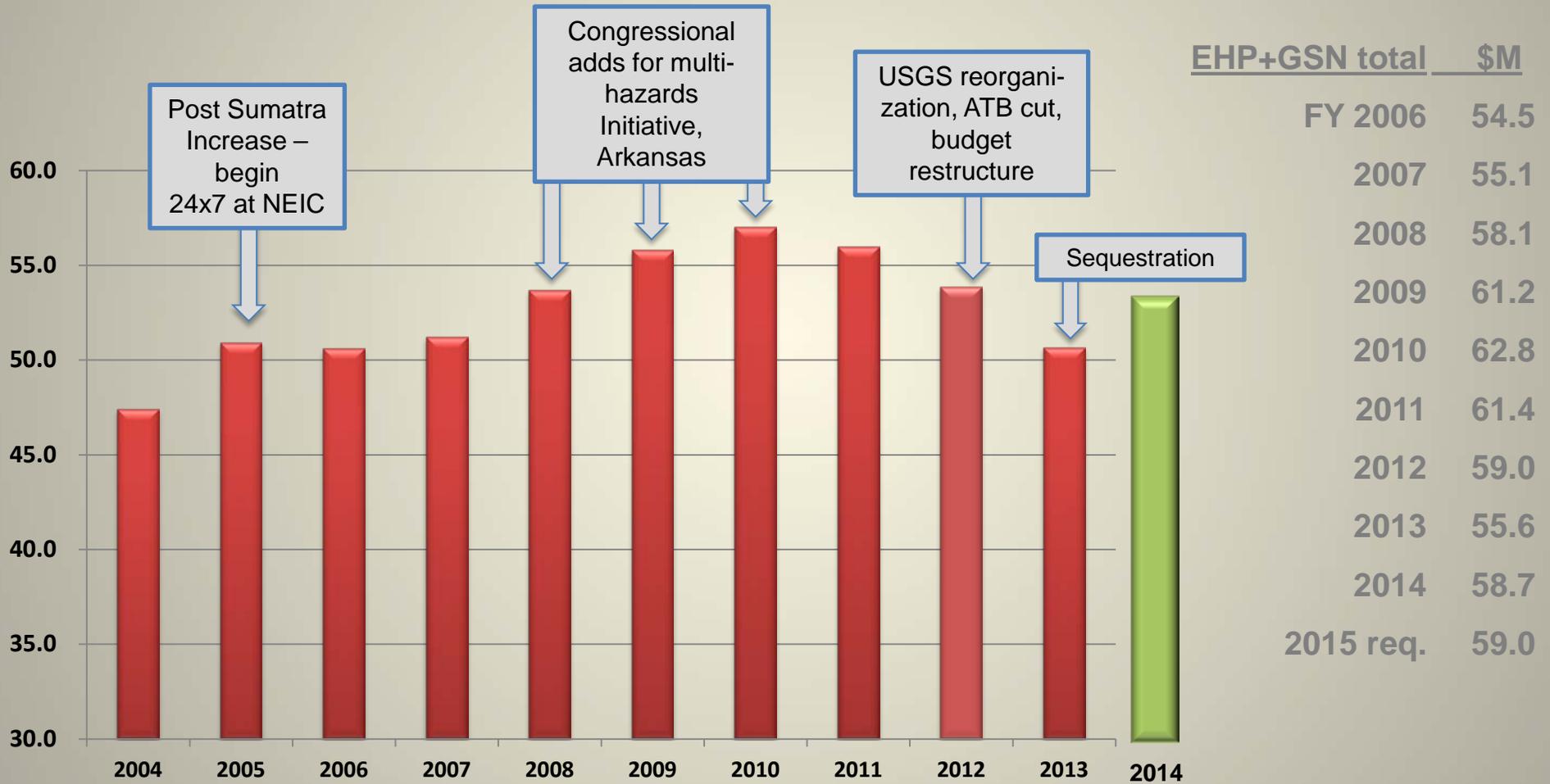
Correlations based on past losses, FEMA response activities & inferred response levels

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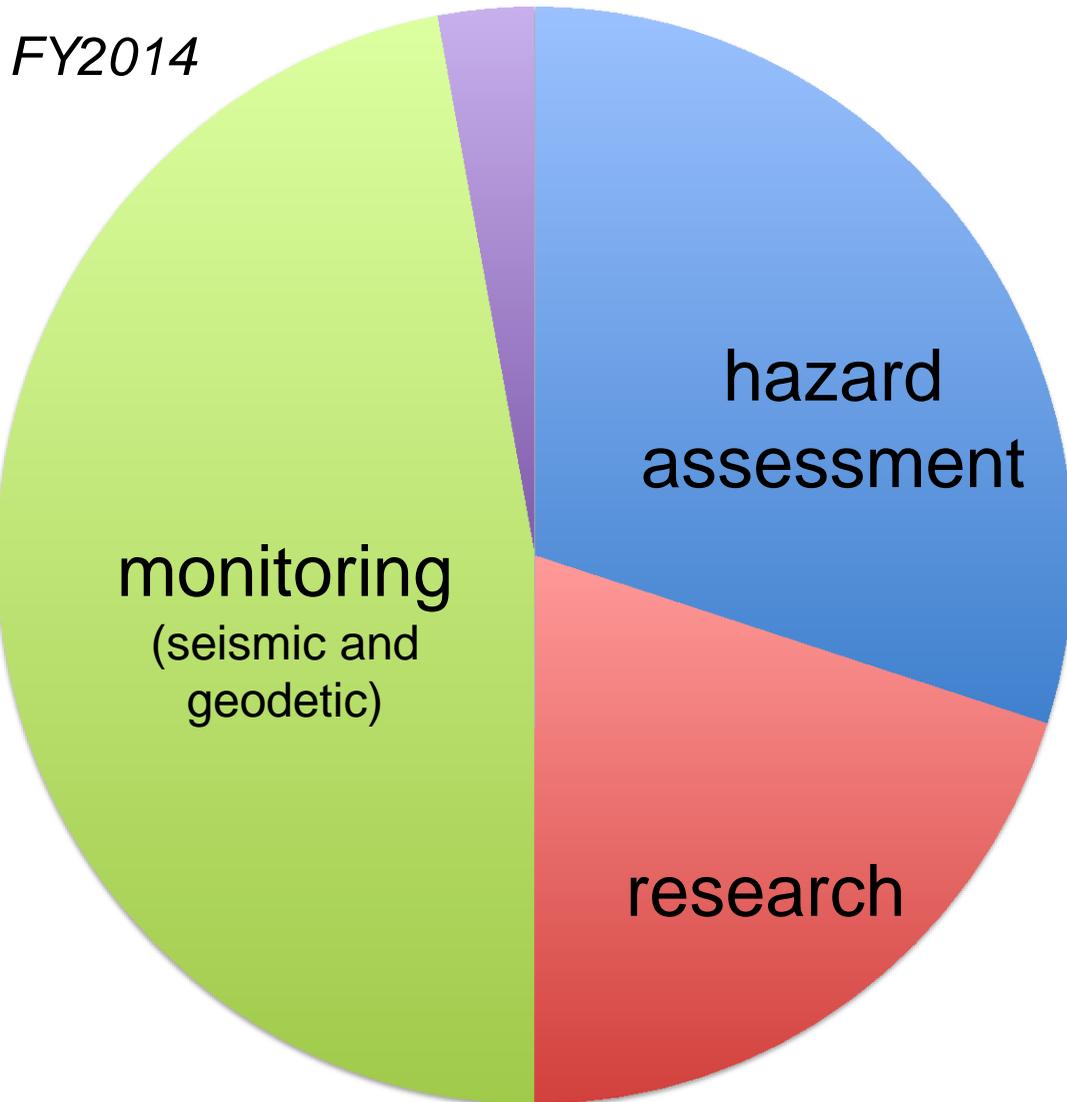
Ten-Year Budget Trend – Gross Appropriation

USGS Earthquake Hazards Program



Does not include
~\$30M of economic
stimulus funds spent
from 2009-2011

EHP Budget by Major Work Category



The SESAC has advised that USGS keep earthquake monitoring to <50% of its portfolio, and that USGS maintain a healthy external research activity.

External funding was restored in 2014 to about 25% of the portfolio (post-sequestration)

USGS is re-competing regional seismic and geodetic monitoring networks in 2014

Code	Work	Gross	Percent
N8	Haz. ass'mt	15,536,885	30.0%
N7	Research	10,416,190	20.1%
J7	Seis. mon.	24,409,446	47.1%
Z3	Public/policy	1,507,248	2.9%
<i>Total</i>		<i>51,869,769</i>	<i>100.0%</i>

USGS Budget Initiatives in 2014-2015

Congress funded the following initiatives in 2014, which remain in the Administration's request for 2015:

+\$1.2M for enhancing earthquake products and improved monitoring in the central & eastern US (partnership with NSF)

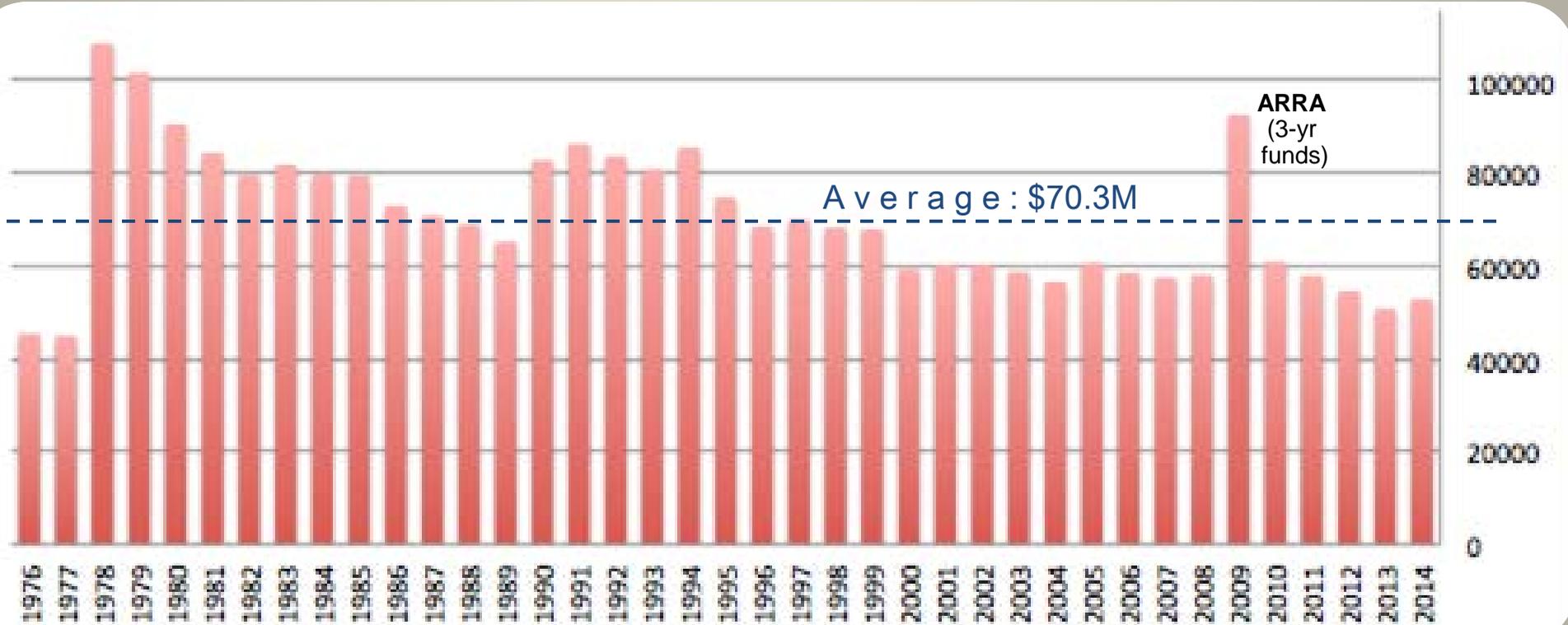
+\$1.0M for induced seismicity monitoring and research (\$1.8M total)
Part of a larger initiative on hydrofracturing
Proposed to increase to \$2.5M in 2015

• FY15: Congress agreed to administration's proposal

+\$2.7M for rapid disaster response capabilities, including earthquake early warning (+\$0.85M), debris flow warning, volcanic ash response, disaster scenarios and strategic science crisis response, and geomagnetic observatories.

• FY15: Congress proposed +\$5M for EEW

Earthquake Hazards Program Funding profile in 2013 dollars



post-San Fernando quake

post - Loma Prieta quake

ARRA

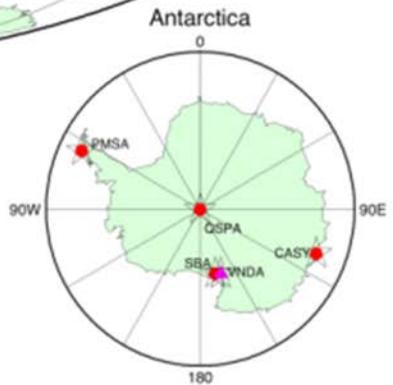
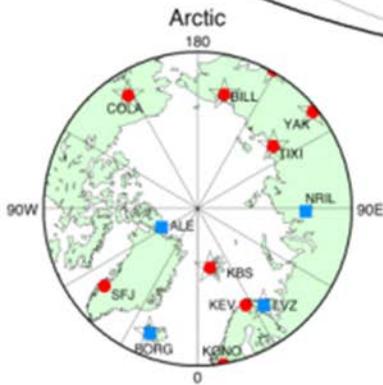
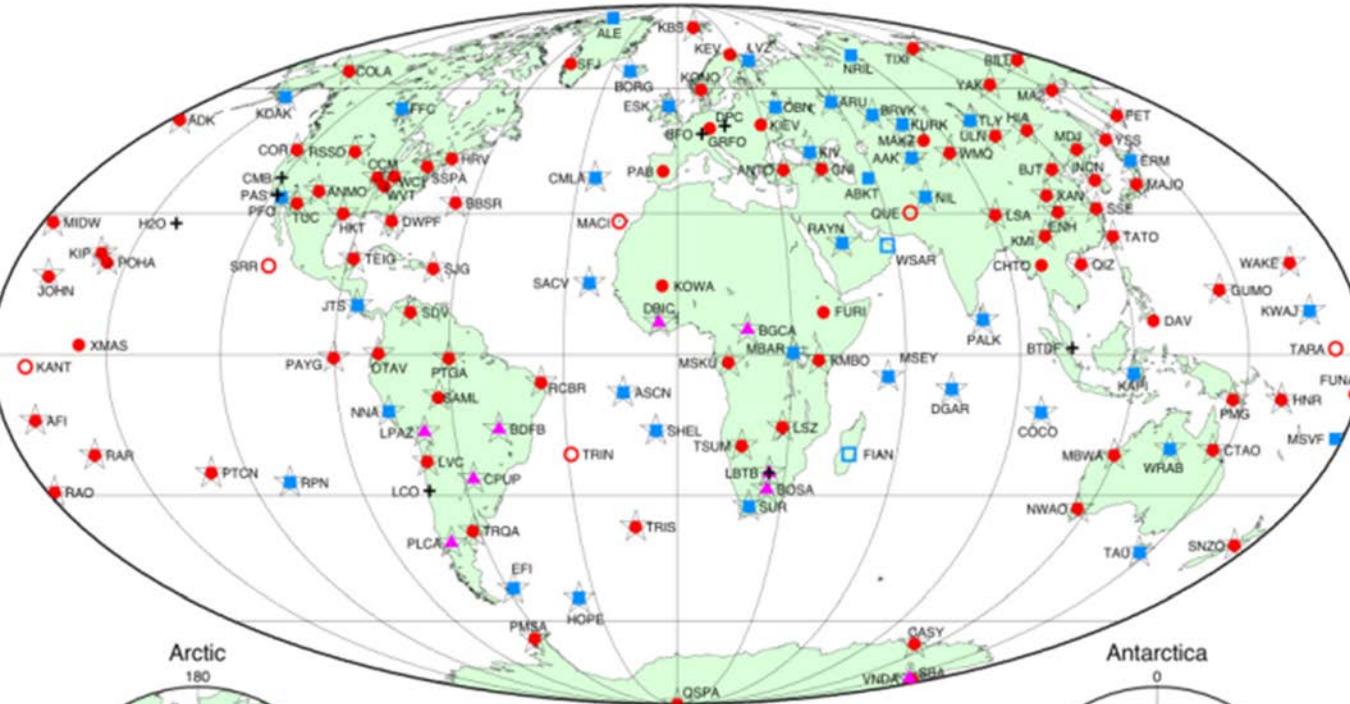
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GSN Primary Sensor Replacement

GSN borehole sensors need to be replaced. DOE provided \$5.7M for purchase but no funds for installation.

Global Seismographic Network



- | | | |
|-------|-----|-------------------------------|
| 85 ● | 6 ○ | IRIS/USGS Stations |
| 39 ■ | 2 □ | IRIS/IDA Stations (UCSD) |
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USGS Albuquerque Seismological Laboratory
January 27, 2005 (crh/lw)



CMG-3TB

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National Seismic Hazard Model Release of 2014 Maps

Science Features : TOP STORY

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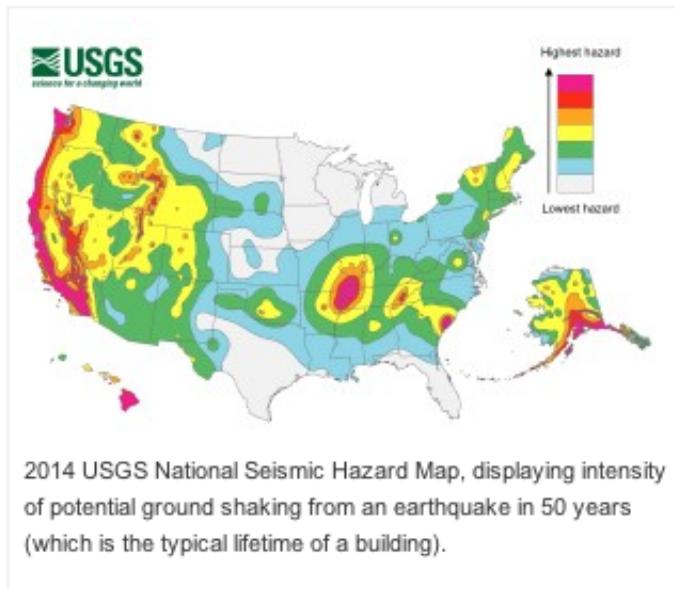
New Insight on the Nation's Earthquake Hazards



CATEGORIES: [FEATURED](#), [NATURAL HAZARDS](#)

POSTED ON JULY 17, 2014 AT 9:35 AM

LAST UPDATE 11:45 AM BY: [JESSICA ROBERTSON \(JROBERTSON@USGS.GOV\)](#) AND [MARK PETERSEN \(MPETERSEN@USGS.GOV\)](#)



To help make the best decisions to protect communities from earthquakes, new display how intense ground shaking could be across the nation.

The USGS recently [updated their U.S. National Seismic Hazard Maps](#), which reflect the most current understanding of where future earthquakes will occur, how often they will occur, and how hard the ground will likely shake as a result.

42 States at Risk; 16 States at High Risk

While all states have some potential for earthquakes, 42 of the 50 states have a reasonable chance of experiencing damaging ground shaking from an earthquake in 50 years (the typical lifetime of a building). Scientists also conclude that 16 states have a relatively high likelihood of experiencing damaging ground shaking. These states have historically experienced earthquakes with a magnitude 6 or greater.

The hazard is especially high along the west coast, intermountain west, and in several active regions of the central and eastern U.S., such as near New Madrid, MO, and near Charleston, SC. The 16 states at highest risk are Alaska, Arkansas, California, Hawaii, Idaho, Illinois, Kentucky, Missouri, Montana, Nevada, Oregon, South Carolina, Tennessee, Utah, Washington, and Wyoming.



Students conduct the "drop, cover, hold on" during an earthquake preparedness drill. Photo by Jessica Robertson, USGS

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Improving earthquake monitoring in the Eastern U.S.

Convert 160 NSF-funded portable seismic stations to permanent

Plan approved by OMB and OSTP (NSF, USGS, NRC, DOE and OSTP)

NSF to fund capitalization and O&M thru 2016

USGS contributing to O&M costs in 2014-2016



FY 14 Increase: Enhancing earthquake products and improved monitoring in the central and eastern US (+\$1.2M - Earthquake Hazards Program)

“Improve earthquake monitoring in the eastern US and enhance delivery of earthquake information products”

- Leverages investments by NSF, DOE, and the US Nuclear Regulatory Commission.
- Up to \$600k of these funds will support long-term operation of the CEUSN



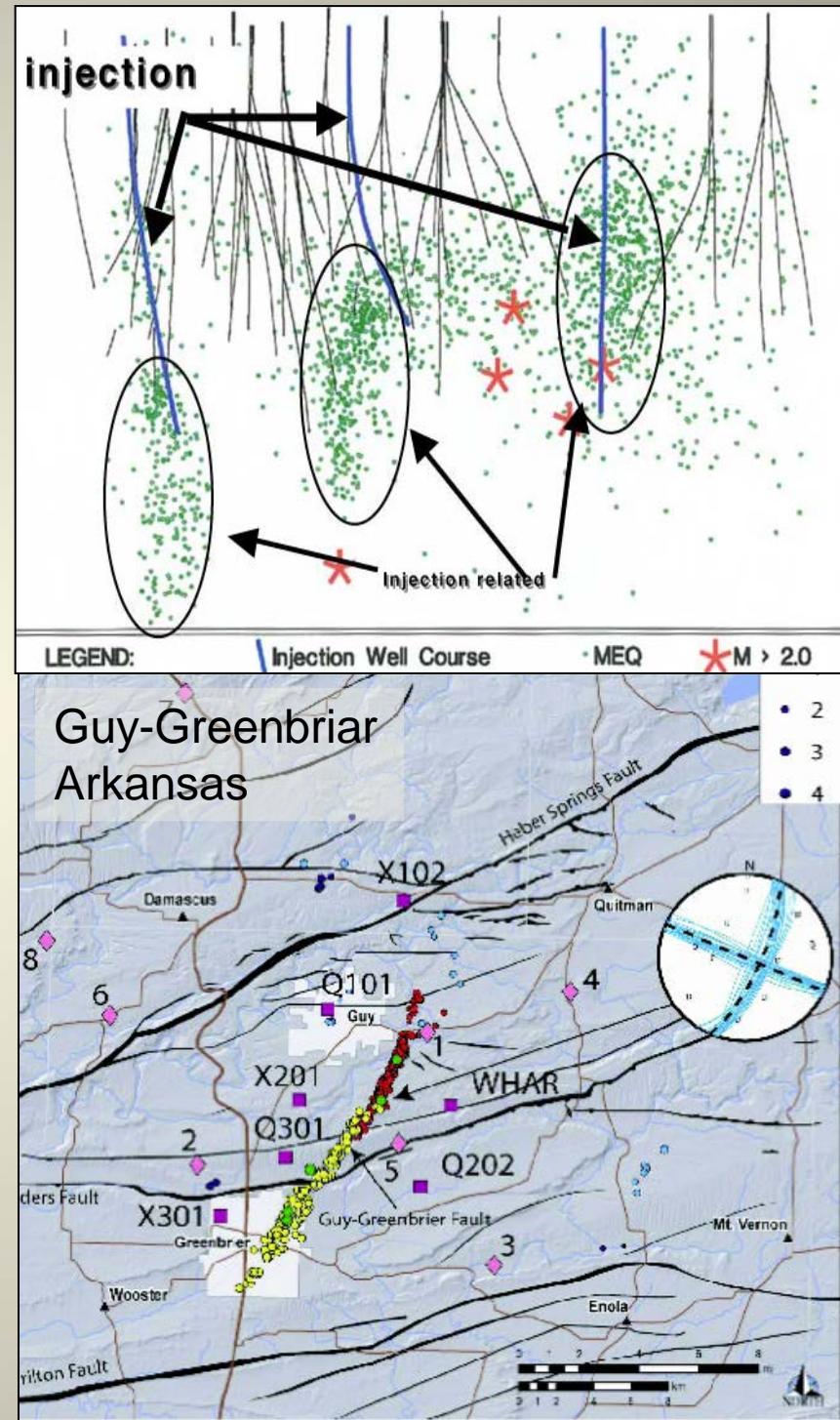
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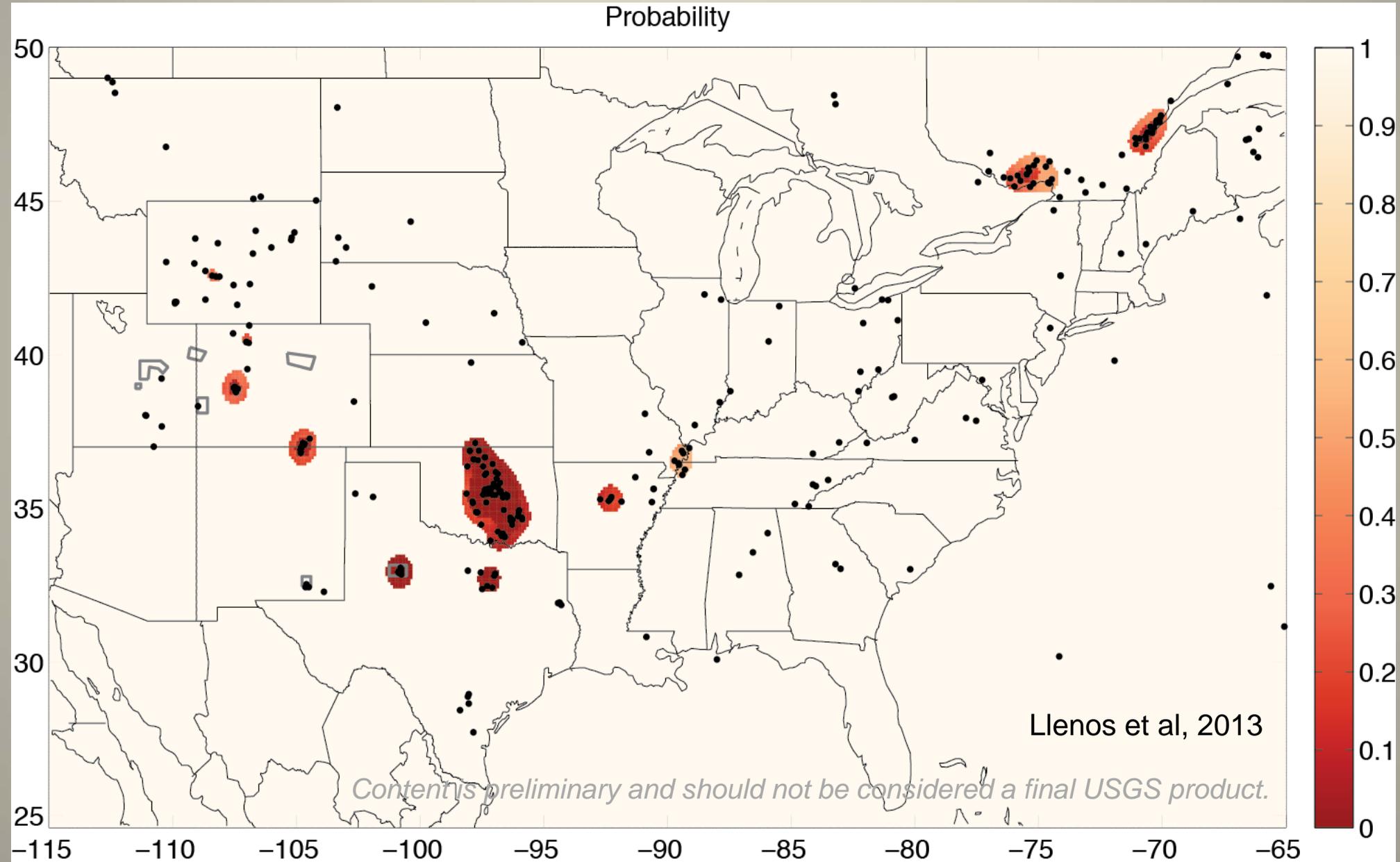
Induced Seismicity

FY14 total \$1.8M; FY15 proposed \$2.5M

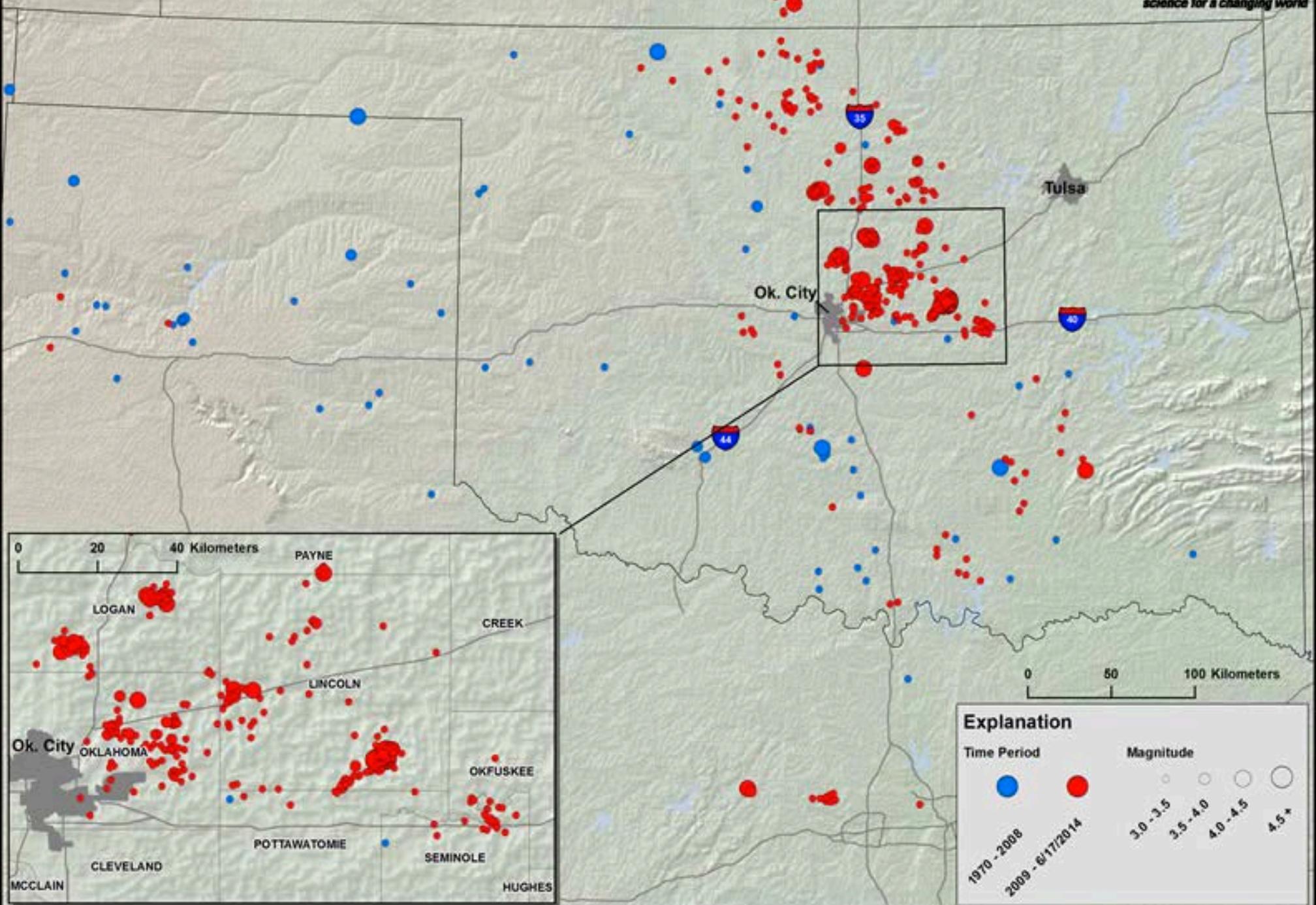
- Funding Context: Administration's "all of the above" energy strategy
- USGS efforts are part of a multi-agency research initiative on hydrofracturing effects
- EHP proposed research to more fully understand factors controlling induced seismicity and to assess hazards
- Can USGS inform protocols for the siting of and operation of injection wells that will reduce earthquake risks?
- Parallel research on induced quakes related to enhanced geothermal and carbon sequestration



Areas of the U.S. with high seismicity rates compared to the National Seismic Hazard Model

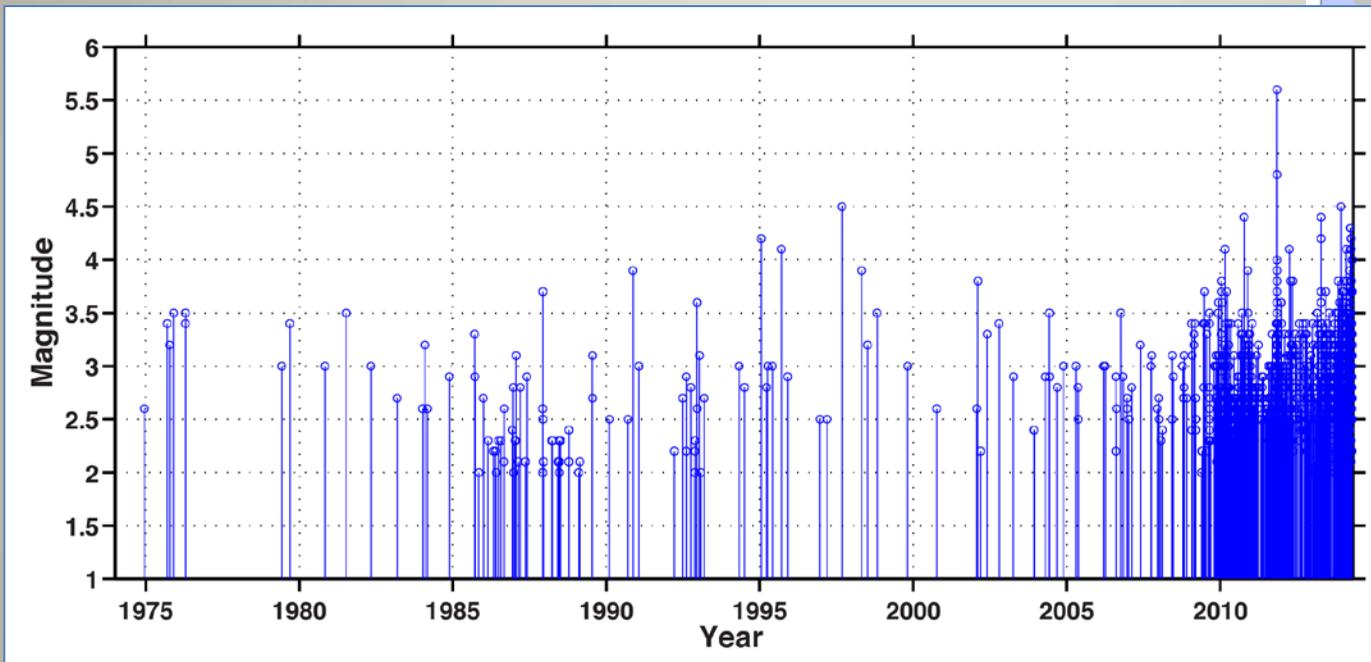
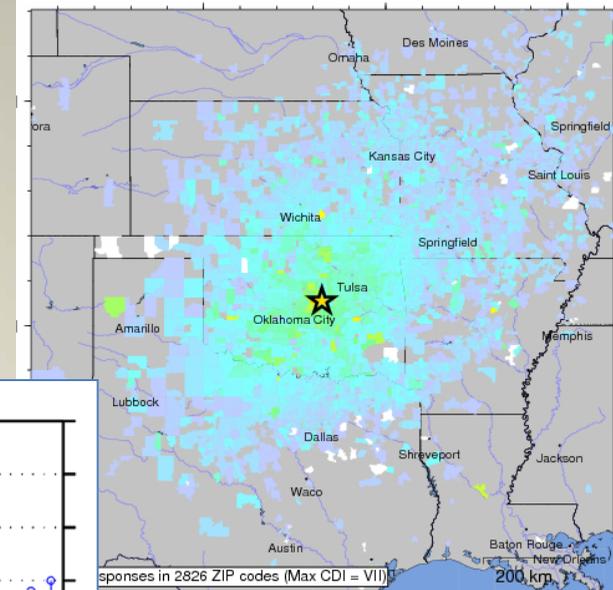


Oklahoma Seismicity (1970 - 6/17/2014)



Oklahoma Earthquakes from 1973-2014

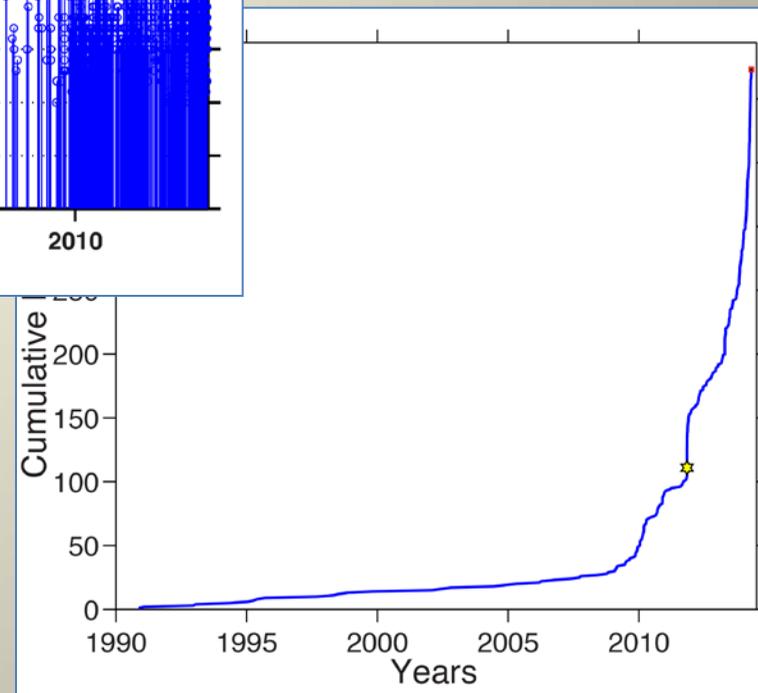
~1300 earthquakes obtained from the USGS COMCAT



100°W			95°W			90°W		
I	II-III	IV	V	VI	VII	VIII	IX	X+
Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

on Nov 7 04:19:23 2011

- Seismicity increased 50% in just six months, from Oct. 2013-April 2014
- More M>3 earthquakes in Oklahoma in 2014 than in California



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- [Memphis Hazard](#)
- [Memphis Liquefaction](#)
- [Memphis Geology](#)
- [Regional Hazard](#)
- [Publications](#)
- [Recent Central & Eastern US Earthquakes](#)
- [Urban Hazard Mapping](#)
- [Hazards & Preparedness](#)
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Record Number of Oklahoma Tremors Raises Possibility of Damaging Earthquakes

Updated USGS-Oklahoma Geological Survey Joint Statement on Oklahoma Earthquakes

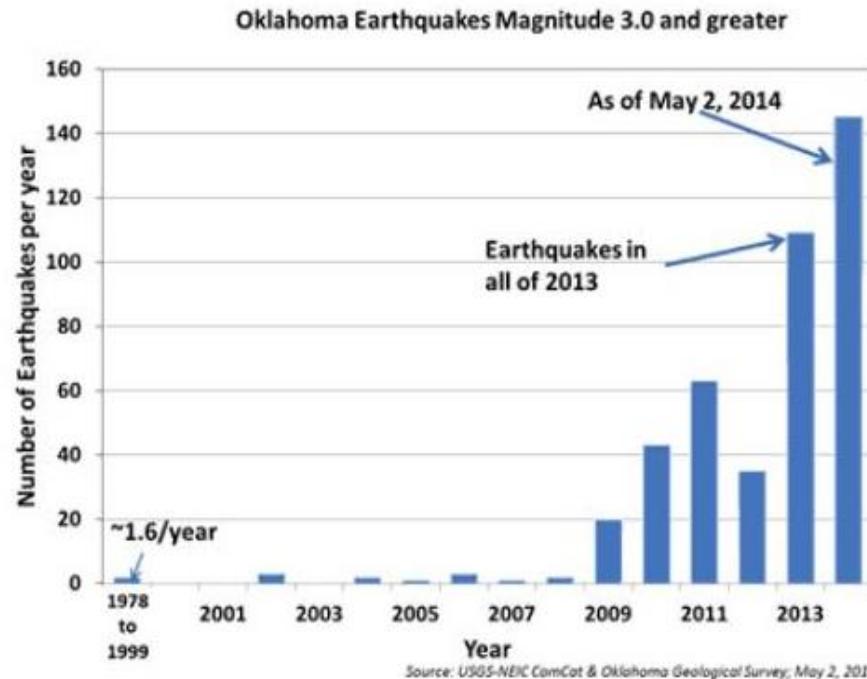
Originally Released: 10/22/2013 1:07:59 PM; Updated May 2, 2014

The rate of earthquakes in Oklahoma has increased remarkably since October 2013 – **by about 50 percent** – significantly increasing the chance for a damaging magnitude 5.5 or greater quake in central Oklahoma.

[View map of Oklahoma seismicity.](#)
[View animation of Oklahoma Seismicity.](#)

A new U.S. Geological Survey and Oklahoma Geological Survey analysis found that 145 earthquakes of magnitude 3.0 or greater occurred in Oklahoma from

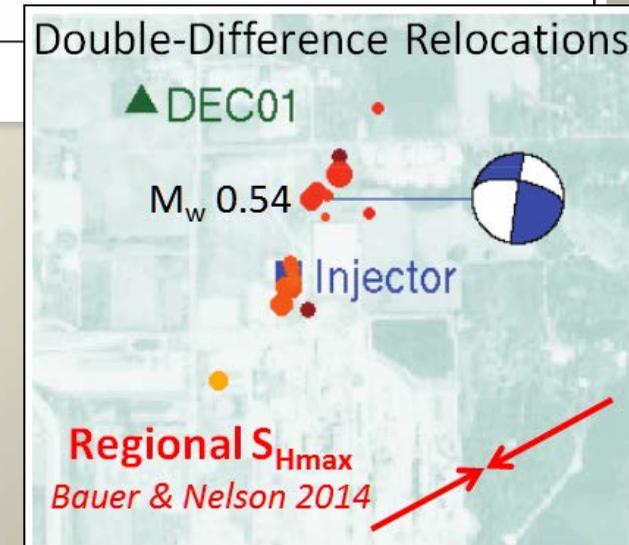
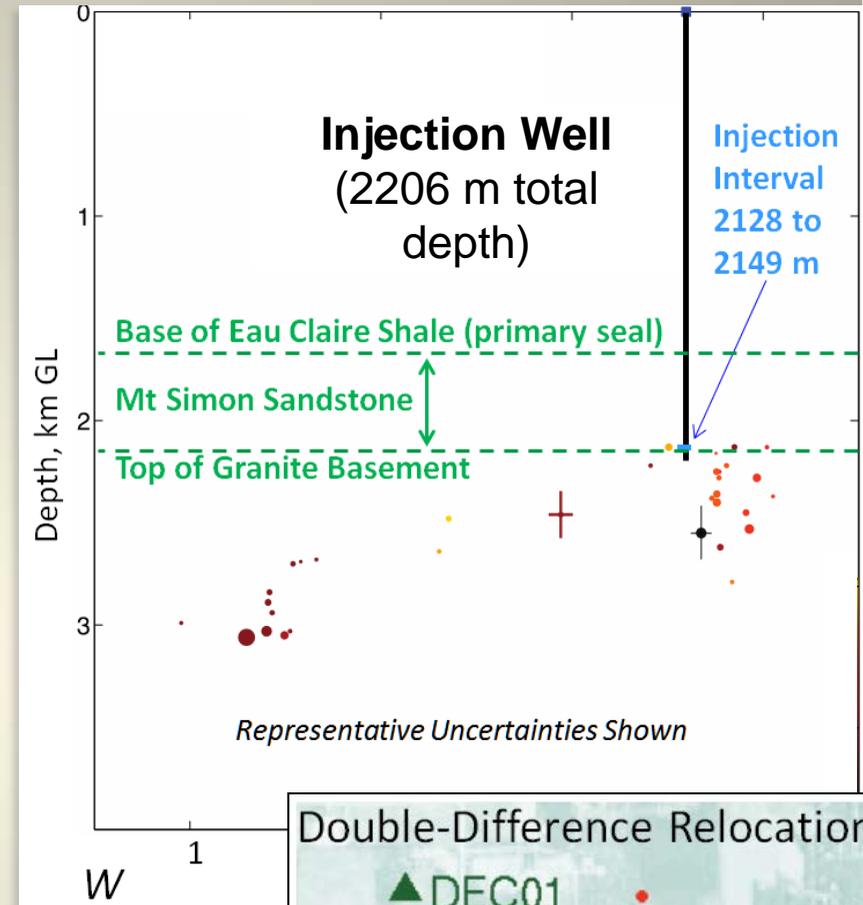
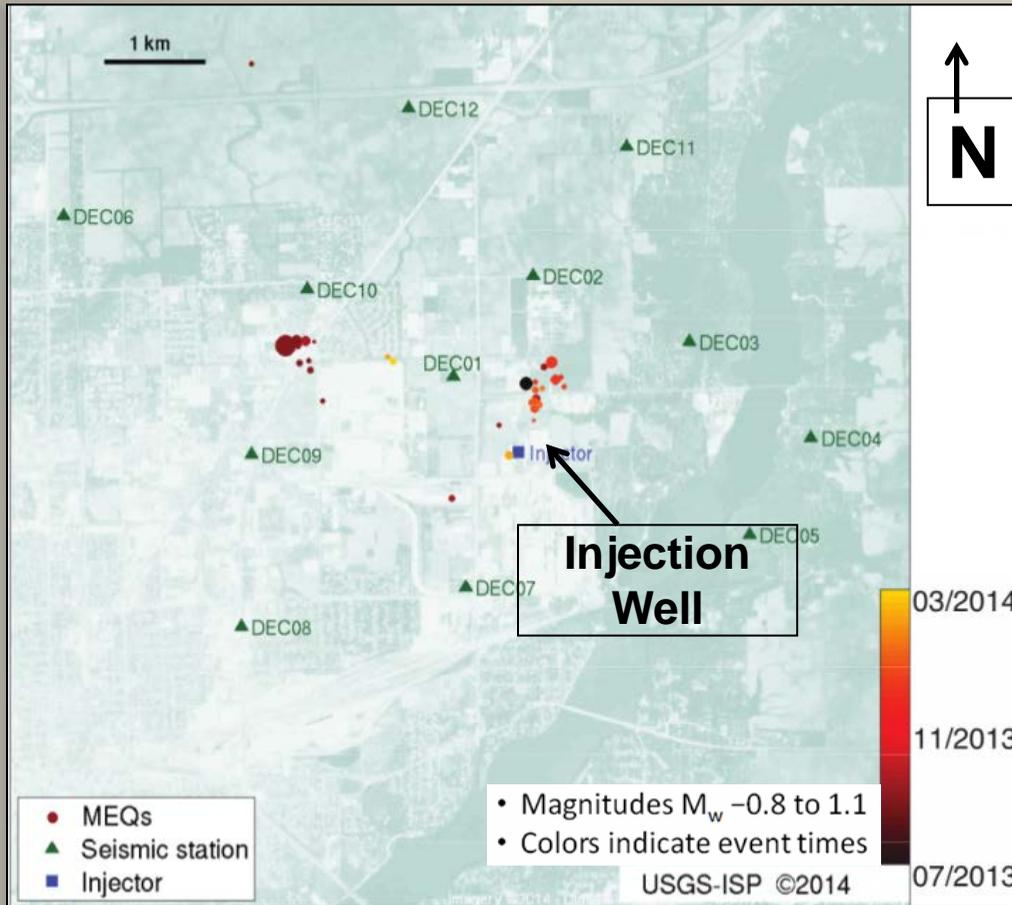
January 2014 (through May 2; see accompanying graphic). The previous annual record, set in 2013, was 109 earthquakes, while the long-term average earthquake rate, from 1978 to 2008, was just two magnitude 3.0 or larger earthquakes per year. Important to people living in central and north-central Oklahoma is that the likelihood of future, damaging earthquakes has increased as a result of the increased number of small and moderate shocks.



Response to ACEHR Recommendations

- Provide Increased Monitoring to Assess the Impact of Induced Seismicity
- Evaluate the impact of induced seismicity on seismicity rate models
- Partner with private industry to provide additional funding for the installation of temporary seismic instrumentation in dense arrays near injection sites to collect ground motion data in the near-source region.
- The ICC should assist the USGS in engaging DOE to create a partnership that will assure access to CO₂ sequestration sites in order to monitor induced seismicity both near and far from the sites, thereby addressing local seismic risks related to injection as well as providing new ground motion data to constrain attenuation models.

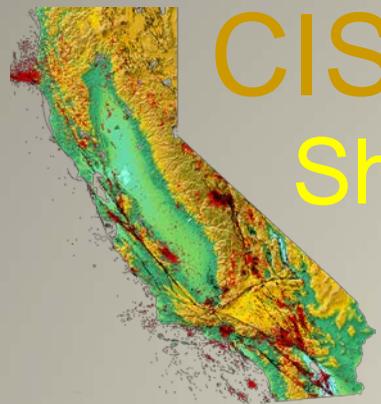
Monitoring at Decatur IL CO₂ Sequestration Site



- 12-station network installed by USGS in 2013 (*green triangles*), using surface and shallow borehole sensors.
- Events to date are very small (M_w -0.8 to 1.1) and group into two clusters: Close to injection well and 1.8 to 2.6 km to the W-NW.
- Most microearthquakes are in granite basement, well below the caprock, and are unlikely to have compromised seal integrity.
- Earthquake relocations, a preliminary focal mechanism and stress directions suggest that some of this activity is due to reactivation of basement faults that are well oriented for slip.

Outline

- **Program Overview**
 - Global Seismographic Network Program
 - Earthquake Hazards Program
- **Budget Overview**
- **Hot Topics, Issues and Opportunities**
 - GSN Primary Sensor Replacement
 - National Seismic Hazard Model
 - Central and Eastern U.S. Seismic Monitoring
 - Induced Seismicity
 - Earthquake Early Warning



CISN

ShakeAlert

Earthquake Early Warning

Status today:

- Prototype system issuing alerts
- System expansion completed in So. California [UASI funding]

Next two years:

- Complete Operational Prototype
- Establish Federal-State-Private Partnership

Receiving alerts today:

- 50 research scientists
- Google.org
- BART
- Metrolink
- Amgen
- So Cal Edison
- CalEMA
- SF DEM
- L.A. City
- L.A. County
- UC Berkeley OEP
- *many more...*



Recent investment in EEW

U.S.G.S.

(2002-2014)

- External grants R & D for EEW
 - Phase I & II (2002-2012) \$2,093,851
 - Phase III (2013-2015) \$1,577,000
- ARRA California (2009-2011) \$4,426,110
 - Network equipment upgrades
- MultiHazards Project (2008-2014) \$2,607,150
 - San Andreas sensors, digital upgrades, production computers, personnel

TOTAL \$10,607,111

Moore Foundation

(2012-2014)

- Caltech \$1,996,888
- UC Berkeley \$2,040,889
- Univ. of Washington \$1,848,351
- USGS \$ 594,406

TOTAL \$6,480,534

Moore Foundation funding ends in 2014 and will not be renewed



CISN California Integrated
Seismic Network

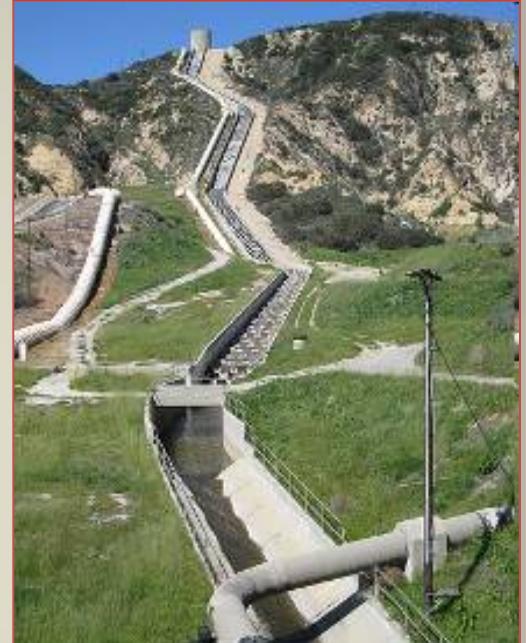
Shake
Alert

EEW Status

- Demo ShakeAlert has been sending EEW notifications since January 2012
- Work is progressing on a production system
- An implementation plan is completed and progress is being made despite limited resources.
- Congress has indicate willingness to partially fund an operational system
- USGS will operate a public system wherever it meets accuracy and reliability specifications.

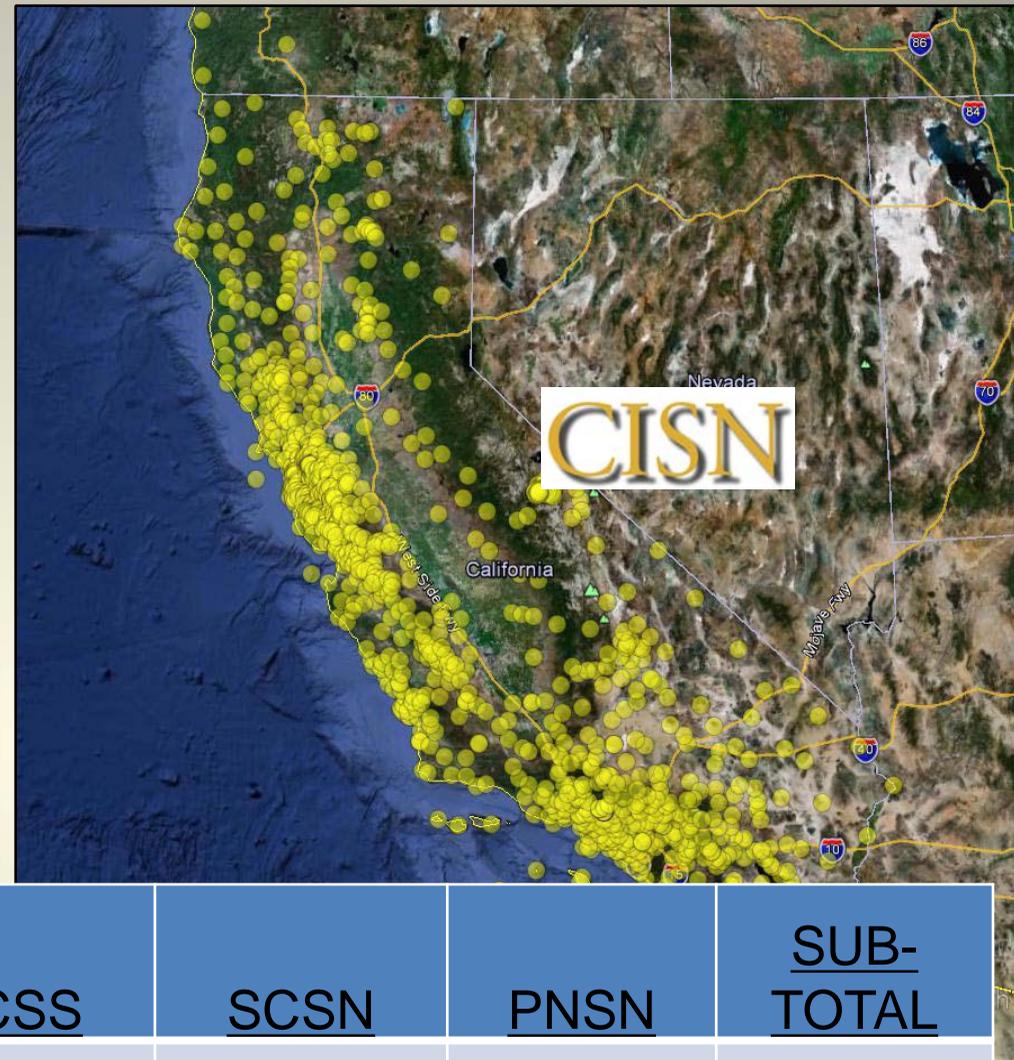
What is needed for early warning:

- Dense sensor network
- Quick, robust telemetry from sensors
- Algorithms for fast evaluation of events including...
 - Large magnitudes
 - Estimation of “finite fault”
 - GPS
- Quick, reliable mass notification
- End user education



Station Density

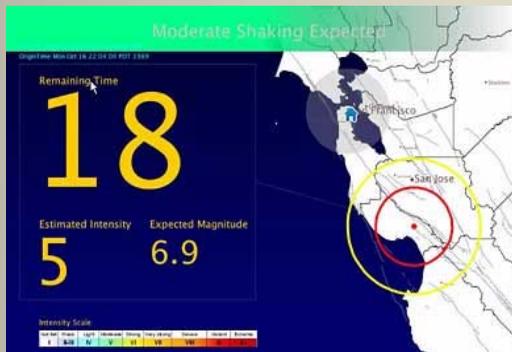
- Upgrade “analog” stations to digital
- Add RT/GPS coverage
- Encouraging users to install sensors
- Add telemetry to non-telemetered sensors



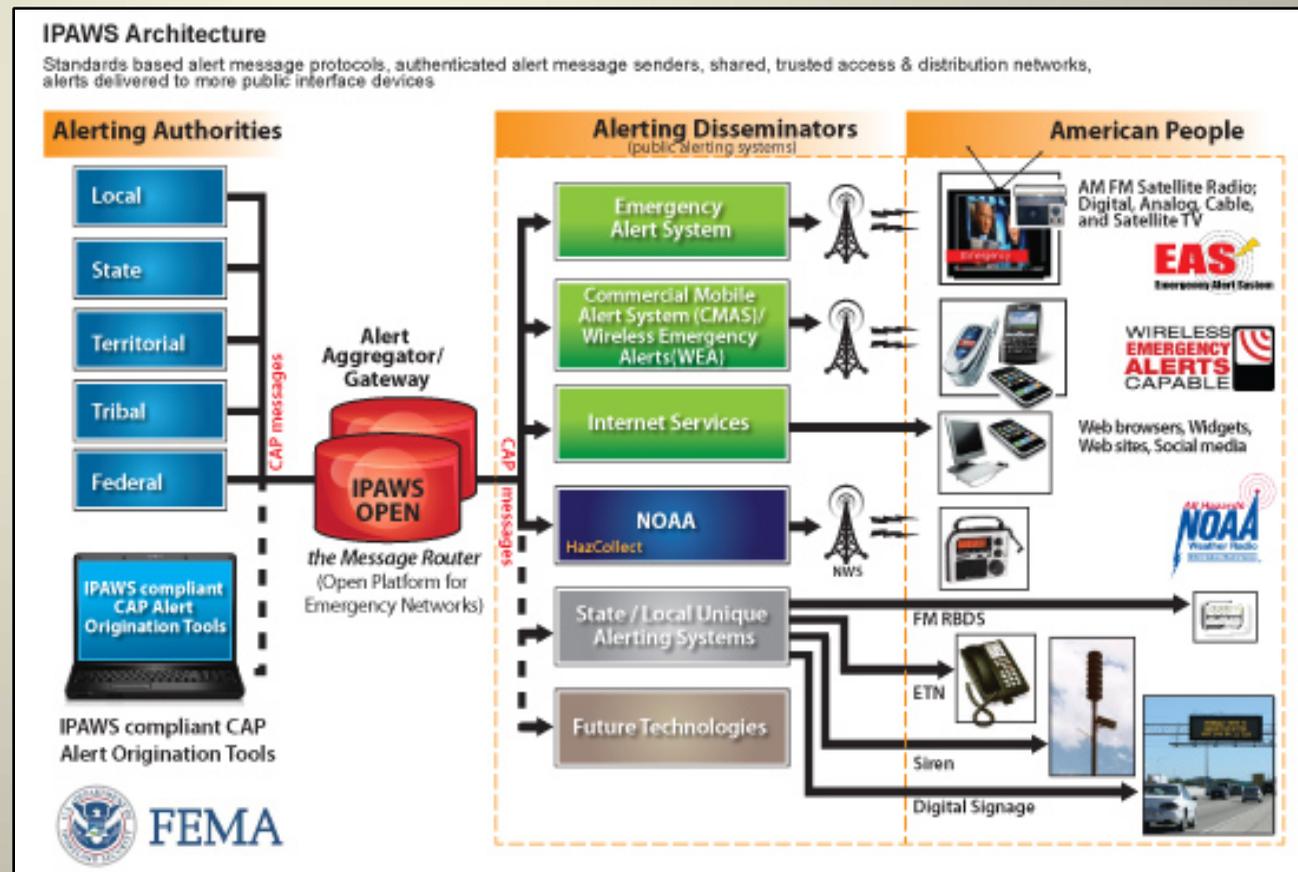
<u>Sensor Type</u>	<u>NCSS</u>	<u>SCSN</u>	<u>PNSN</u>	<u>SUB-TOTAL</u>
Seismic BB+SM	100	25	66	191
Seismic SM	239	75	210	524
GPS	100	50	156	309

Rapid, reliable mass notifications

- UserDisplay (user test)
- USGS became an “alert authority” for FEMA/IPAWS
(Integrated Public Alert Warning System)
- V 0.1 smartphone app (Google Cloud)



CISN EEW “user display”



Other Early Warning System Developments

- Aug. 2012 – BART went “live” with PGA approach to EEW.

Other rail operators are interested

- Began social science testing of CMAS messages for EEW (and testing for Earthquake Likelihood Forecasting)
- Opened EEW Web sites: *shakealert.org* and *earthquake.usgs.gov/research/earlywarning*
- Published west coast EEW Implementation Plan (April 2014)
- Computers were delivered to build the “production system”



Full West Coast Implementation

(estimate from 2014 FFW implementation plan)

	California	Pacific Northwest	West Coast (CA+PNW)
One-Time Construction costs	\$23.1M	\$15.2M	\$38.3M
Annual Operation & Maintenance	\$11.4M	\$4.7M	\$16.1M

- **New personnel**
 - bring ANSS network staffing to robust levels
 - EEW implementation and testing
 - EEW operation and user outreach
- **700 new or upgrades seismic stations & 300 GPS stations**
- **Significant field telemetry upgrades**
- **Support for continued R & D**

Congressional Support for EEW

- House report: “the Committee provides \$5,000,000 from within the funds provided for Earthquake Hazards to transition the earthquake early warning demonstration project into an operational capability on the West Coast.
- Senate report: “Within the Earthquake Hazards Program, an increase of \$5,000,000 is included for development of a public earthquake early warning pilot program, which will support work in both the Los Angeles and San Francisco Bay areas.”

Summary of Issues

- GSN: primary sensor installation
- CEUSN: long-term operating funds
- EEW: Operating costs for public system
- ANSS: decreasing ability to support small, research-focused networks in lower-risk areas.
- NEHRP: Increasing demands for USGS work on broader NEHRP activities
- NEHRP: reauthorization needed

NEHRP Advisory Structure

