Strong Ground Motions Expected in Los Angeles

Philip J. Maechling

Computer Scientist

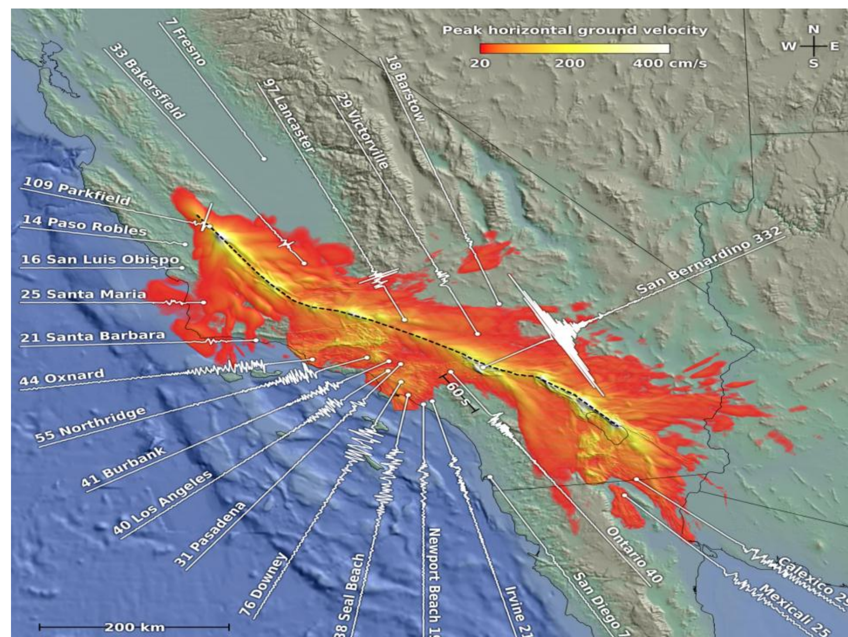
Southern California Earthquake Center (SCEC)

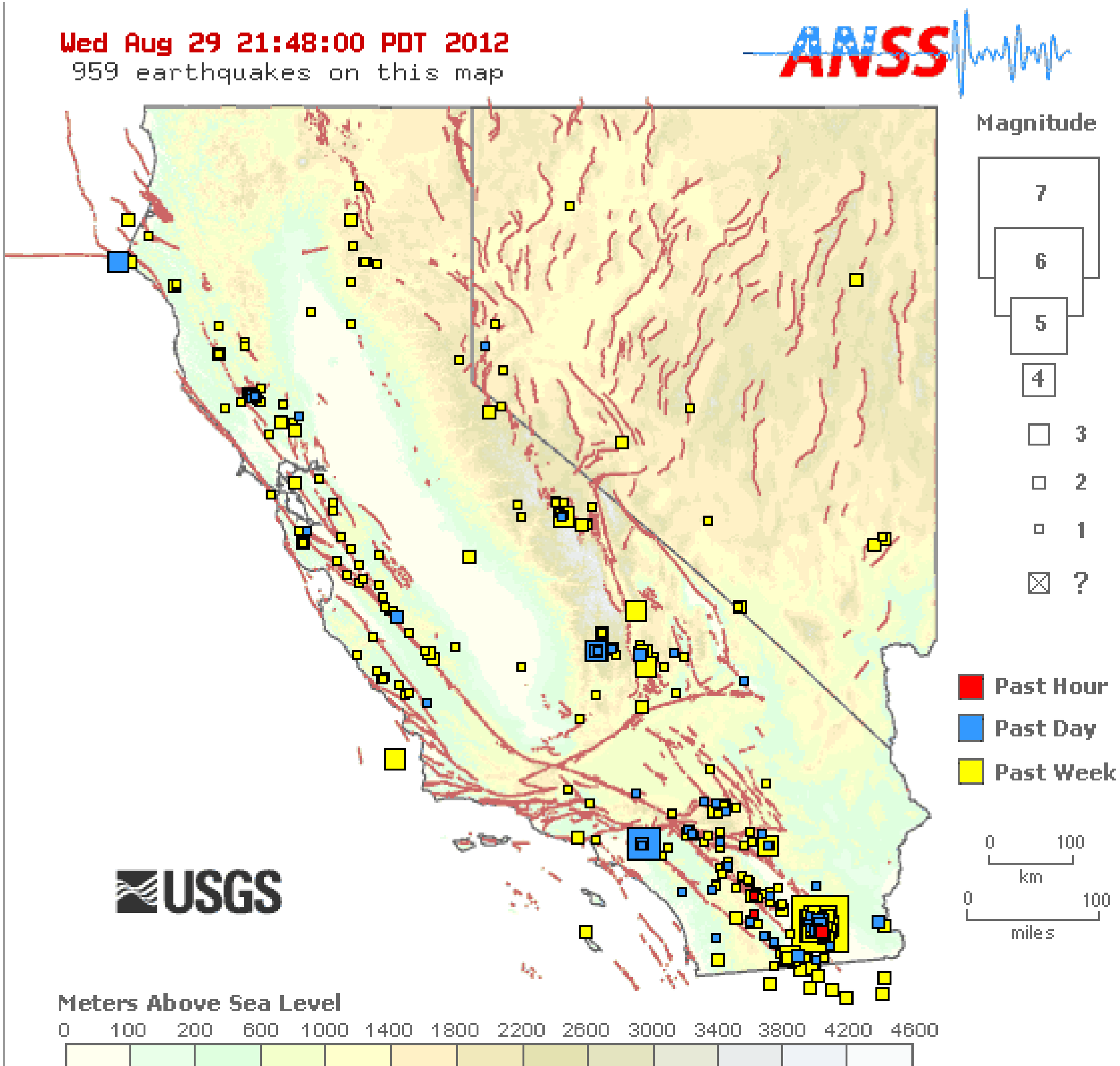
LARA Workshop

30 August 2012

SCEC

an NSF+USGS center




Wed Aug 29 21:48:00 PDT 2012
959 earthquakes on this map
ANSS
Magnitude
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2
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Past Hour
Past Day
Past Week
0 100
km
0 100
miles
USGS
Meters Above Sea Level
0 100 200 600 1000 1400 1800 2200 2600 3000 3400 3800 4200 4600

Presentation Topics

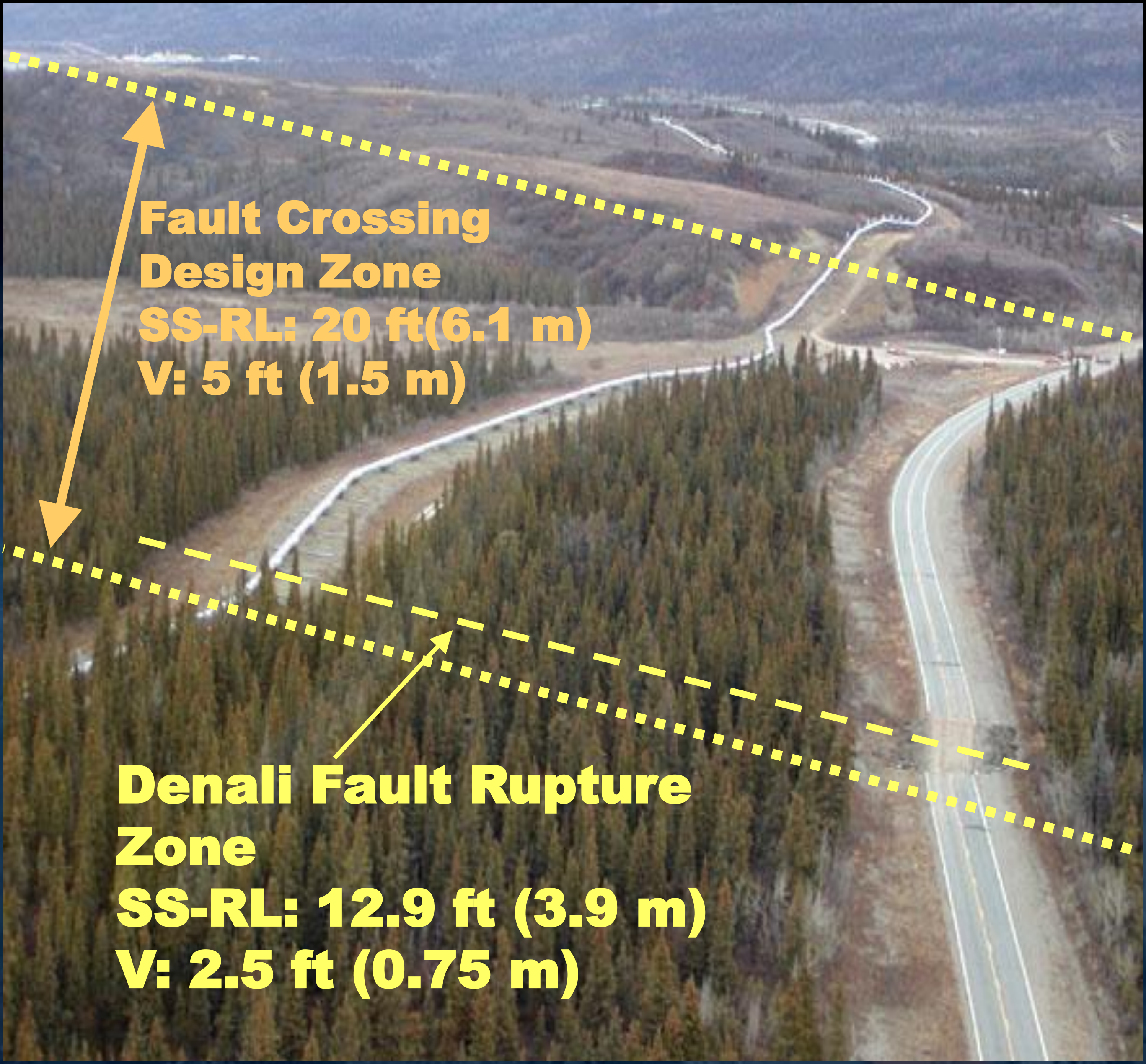
Interesting new developments in seismology, including:

1. Southern California Earthquake Center (SCEC) Background
2. Earthquake Information Used by Experts
3. Simulating Earthquakes using Supercomputers
4. Preparing Your Earthquake Response

TAPS Pipeline

Denali Fault Crossing and Richardson Highway

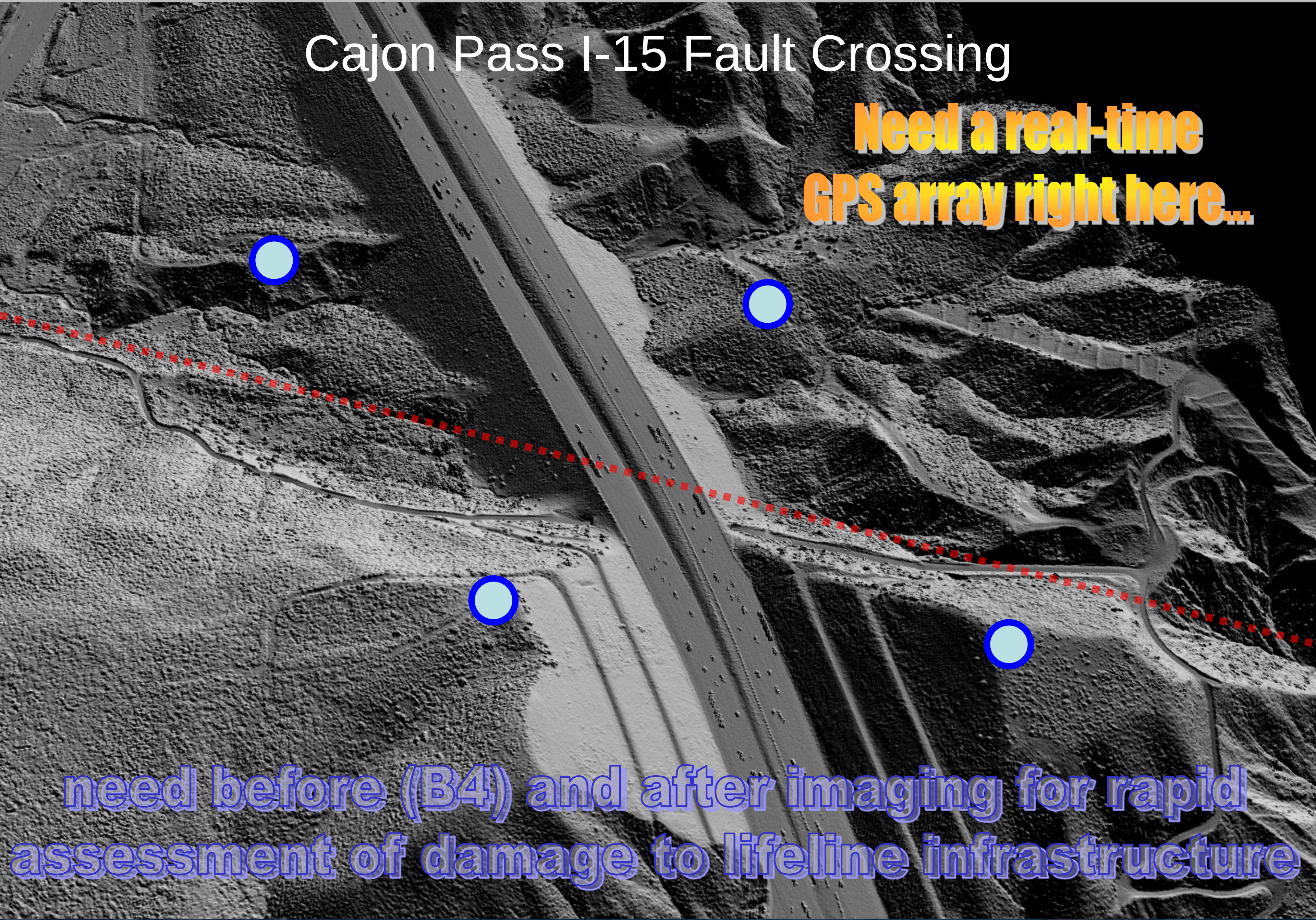
2002 Denali Earthquake



Courtesy of Cluff & Slemmons

Denali Fault Crossing (Before and After)

Courtesy of Gary Fuis


Cajon Pass I-15 Fault Crossing
Need a real-time
GPS array right here...
need before (B4) and after imaging for rapid
assessment of damage to lifeline infrastructure

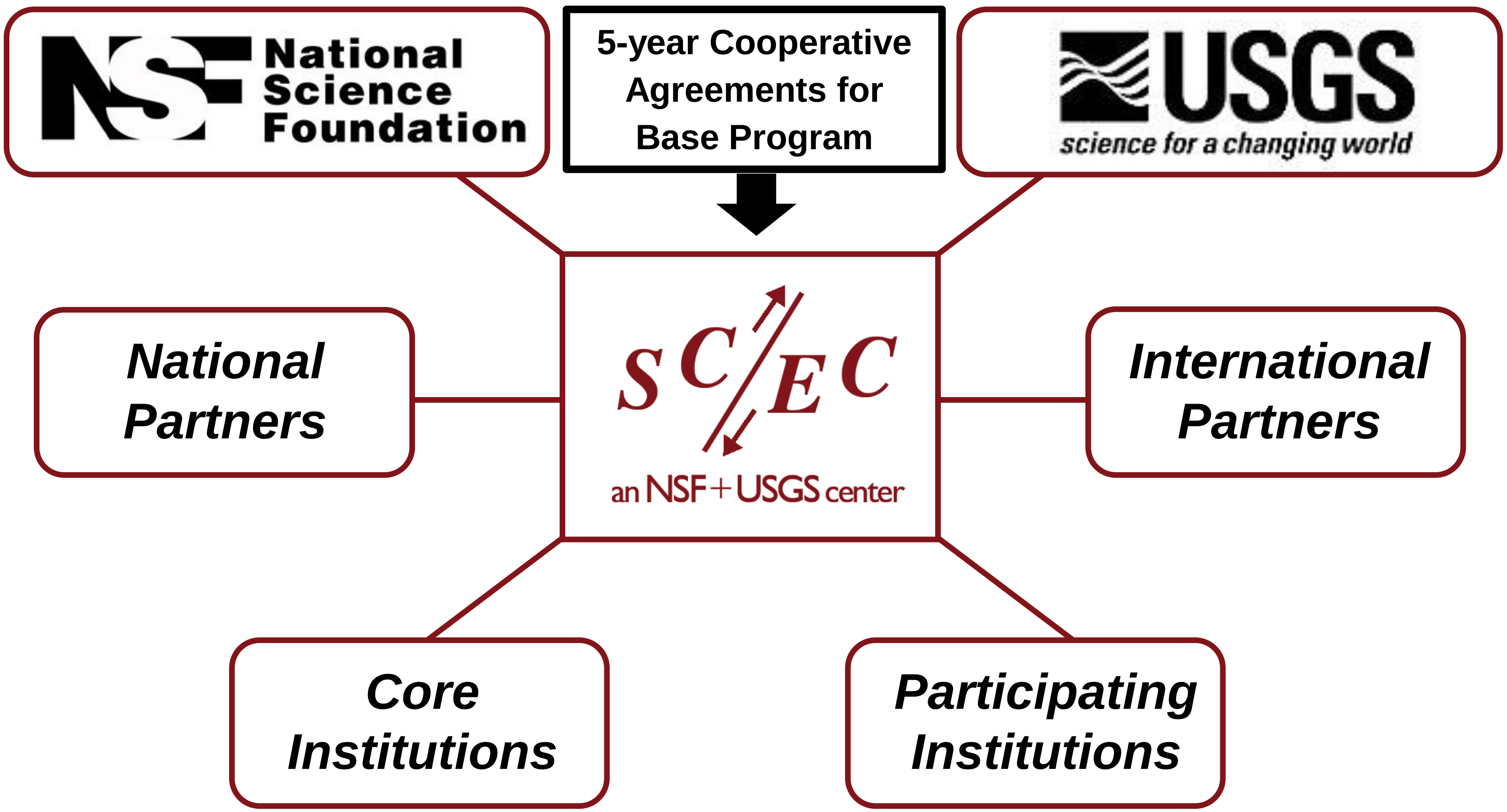
FEMA report series (1991-1992)

FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA - 221 October 1991

Collocation Impacts on the Vulnerability of Lifelines During Earthquakes with Applications to the Cajon Pass, California

Lifeline	Minimum Additional Delay Before Temporary Service is Restored, days
Fiber Optic Telephone Communication	61
High Voltage Electric Power Transmission	19
Natural Gas Bulk Transmission	25
Petroleum Products Transmission	41
Interstate Highway Traffic	35
Railroad Service	17

The SCEC Partnership



SCEC Member Institutions (Sept 1, 2011)

Core Institutions (17)	Participating Institutions (57)
California Geological Survey California Institute of Technology Columbia University Harvard University Massachusetts Institute of Technology San Diego State University Stanford University U.S. Geological Survey, Golden U.S. Geological Survey, Menlo Park U.S. Geological Survey, Pasadena University of California, Los Angeles University of California, Riverside University of California, San Diego University of California, Santa Barbara University of California, Santa Cruz University of Nevada, Reno University of Southern California (lead)	Appalachian State University; Arizona State University; Berkeley Geochron Center; Boston University; Brown University; Cal-Poly, Pomona; Cal-State, Chico; Cal-State, Long Beach; Cal-State, Fullerton; Cal-State, Northridge; Cal-State, San Bernardino; Carnegie Mellon University; Case Western Reserve University; CICESE (Mexico); Cornell University; Disaster Prevention Research Institute, Kyoto University (Japan); ETH (Switzerland); Georgia Tech; Institute of Earth Sciences of Academia Sinica (Taiwan); Earthquake Research Institute, University of Tokyo (Japan); Indiana University; Institute of Geological and Nuclear Sciences (New Zealand); Jet Propulsion Laboratory; Los Alamos National Laboratory; Lawrence Livermore National Laboratory; National Taiwan University (Taiwan); National Central University (Taiwan); Ohio State University; Oregon State University; Pennsylvania State University; Princeton University; Purdue University; SUNY at Stony Brook; Texas A&M University; **University of Alaska**; University of Arizona; UC, Berkeley; UC, Davis; UC, Irvine; University of British Columbia (Canada); University of Cincinnati; University of Colorado; University of Illinois; University of Massachusetts; University of Miami; University of Missouri-Columbia; University of New Hampshire; University of Oklahoma; University of Oregon; University of Texas-El Paso; University of Utah; University of Western Ontario (Canada); University of Wisconsin; University of Wyoming; URS Corporation; Utah State University; Woods Hole Oceanographic Institution

Proposed new SCEC4 Core Institution:

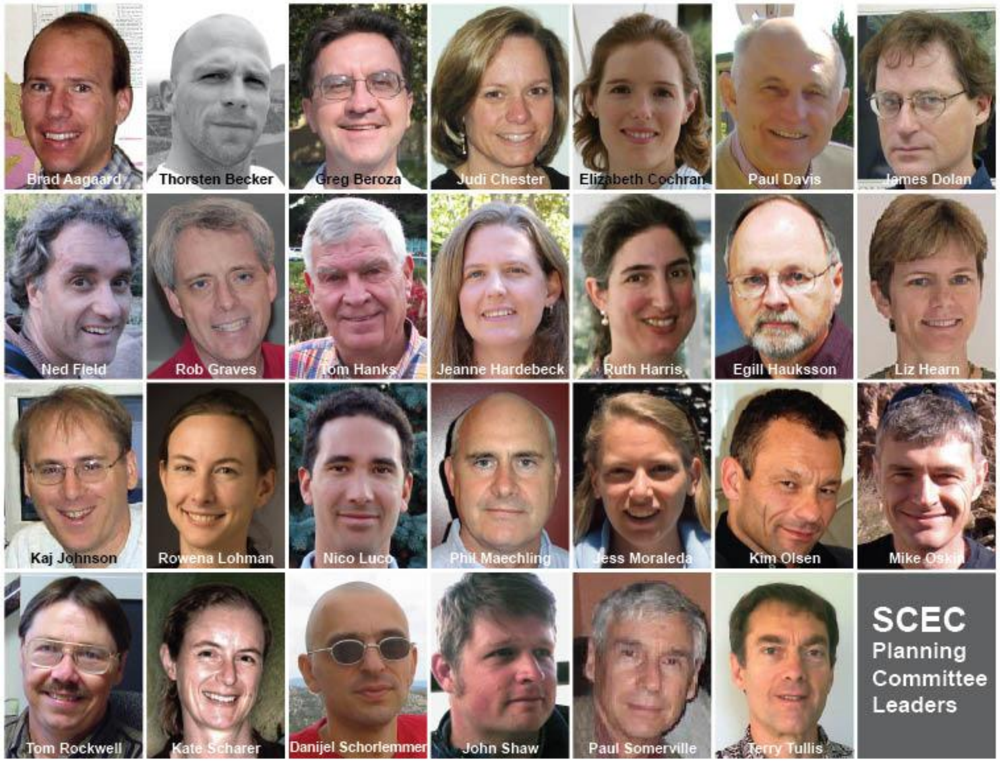
CalState Consortium

SCEC Mission Statement

- **Gather data** on earthquakes in Southern California and elsewhere
- **Integrate information** into a comprehensive, physics-based understanding of earthquake phenomena
- **Communicate understanding** to the world at large as useful knowledge for reducing earthquake risk

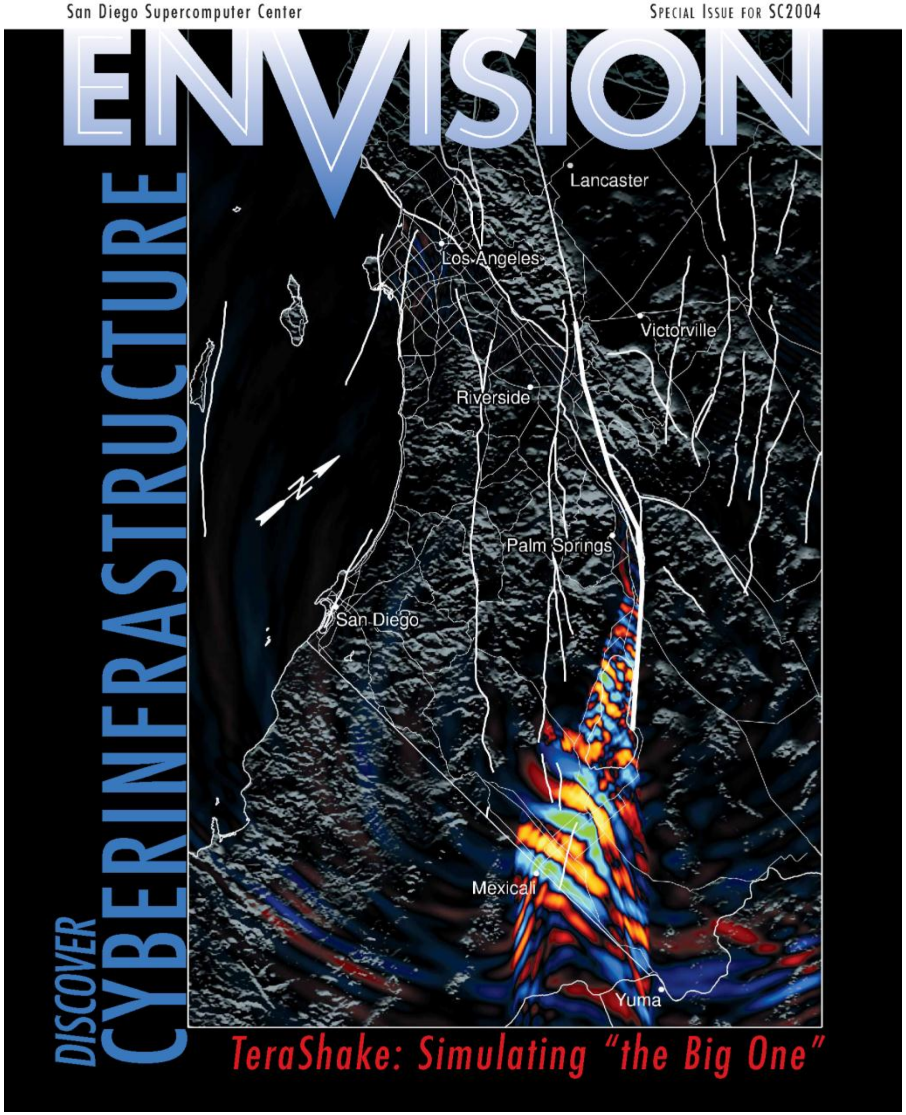
SCEC Leadership Teams

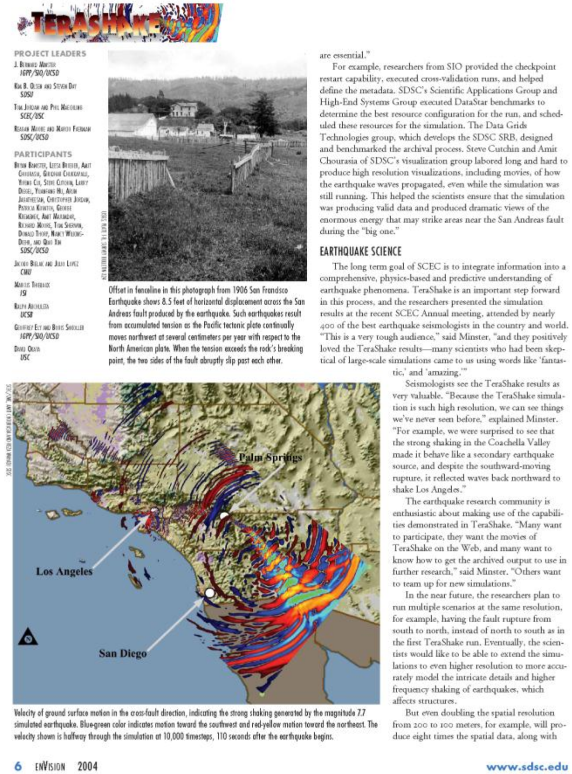
Board of Directors



Planning Committee

Staff




TERASHAKE

PROJECT LEADERS
J. Bernard Minster
IGPP/SIO/UCSD
Kim B. Olsen and Steven Day
SDSU
Tom Jordan and Phil Maechling
SCEC/USC
Reagan Moore and Marcio Faerman
SDSC/UCSD

PARTICIPANTS
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Jacobo Bielak and Julio Lopez
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UCSB
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IGPP/SIO/UCSD
David Okaya
USC

Offset in fenceline in this photograph from 1906 San Francisco Earthquake shows 8.5 feet of horizontal displacement across the San Andreas fault produced by the earthquake. Such earthquakes result from accumulated tension as the Pacific tectonic plate continually moves northwest at several centimeters per year with respect to the North American plate. When the tension exceeds the rock's breaking point, the two sides of the fault abruptly slip past each other.

are essential."

For example, researchers from SIO provided the checkpoint restart capability, executed cross-validation runs, and helped define the metadata. SDSC's Scientific Applications Group and High-End Systems Group executed DataStar benchmarks to determine the best resource configuration for the run, and scheduled these resources for the simulation. The Data Grids Technologies group, which develops the SDSC SRB, designed and benchmarked the archival process. Steve Cutchin and Amit Chourasia of SDSC's visualization group labored long and hard to produce high resolution visualizations, including movies, of how the earthquake waves propagated, even while the simulation was still running. This helped the scientists ensure that the simulation was producing valid data and produced dramatic views of the enormous energy that may strike areas near the San Andreas fault during the "big one."

EARTHQUAKE SCIENCE

The long term goal of SCEC is to integrate information into a comprehensive, physics-based and predictive understanding of earthquake phenomena. TeraShake is an important step forward in this process, and the researchers presented the simulation results at the recent SCEC Annual meeting, attended by nearly 400 of the best earthquake seismologists in the country and world. "This is a very tough audience," said Minster, "and they positively loved the TeraShake results—many scientists who had been skeptical of large-scale simulations came to us using words like 'fantastic,' and 'amazing.'"

Seismologists see the TeraShake results as very valuable. "Because the TeraShake simulation is such high resolution, we can see things we've never seen before," explained Minster. "For example, we were surprised to see that the strong shaking in the Coachella Valley made it behave like a secondary earthquake source, and despite the southward-moving rupture, it reflected waves back northward to shake Los Angeles."

The earthquake research community is enthusiastic about making use of the capabilities demonstrated in TeraShake. "Many want to participate, they want the movies of TeraShake on the Web, and many want to know how to get the archived output to use in further research," said Minster. "Others want to team up for new simulations."

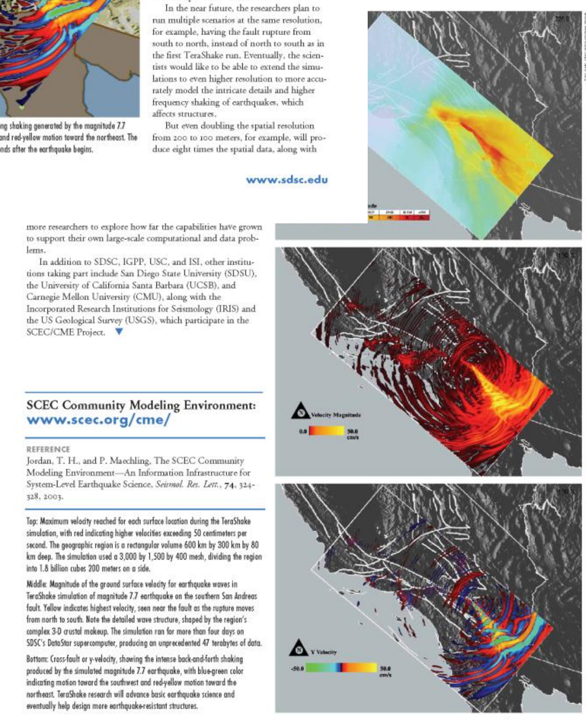
In the near future, the researchers plan to run multiple scenarios at the same resolution, for example, having the fault rupture from south to north, instead of north to south as in the first TeraShake run. Eventually, the scientists would like to be able to extend the simulations to even higher resolution to more accurately model the intricate details and higher frequency shaking of earthquakes, which affects structures.

But even doubling the spatial resolution from 200 to 100 meters, for example, will produce eight times the spatial data, along with

Palm Springs
Los Angeles
San Diego

Velocity of ground surface motion in the cross-fault direction, indicating the strong shaking generated by the magnitude 7.7 simulated earthquake. Blue-green color indicates motion toward the southwest and red-yellow motion toward the northeast. The velocity shown is halfway through the simulation at 10,000 timesteps, 110 seconds after the earthquake begins.

6 ENVISION 2004 www.sdsc.edu


more researchers to explore how far the capabilities have grown to support their own large-scale computational and data problems.

In addition to SDSC, IGPP, USC, and ISI, other institutions taking part include San Diego State University (SDSU), the University of California Santa Barbara (UCSB), and Carnegie Mellon University (CMU), along with the Incorporated Research Institutions for Seismology (IRIS) and the US Geological Survey (USGS), which participate in the SCEC/CME Project. ▼

SCEC Community Modeling Environment:
www.scec.org/cme/

REFERENCE
Jordan, T. H., and P. Maechling, The SCEC Community Modeling Environment—An Information Infrastructure for System-Level Earthquake Science, *Seismol. Res. Lett.*, **74**, 324-328, 2003.

Top: Maximum velocity reached for each surface location during the TeraShake simulation, with red indicating higher velocities exceeding 50 centimeters per second. The geographic region is a rectangular volume 600 km by 300 km by 80 km deep. The simulation used a 3,000 by 1,500 by 400 mesh, dividing the region into 1.8 billion cubes 200 meters on a side.

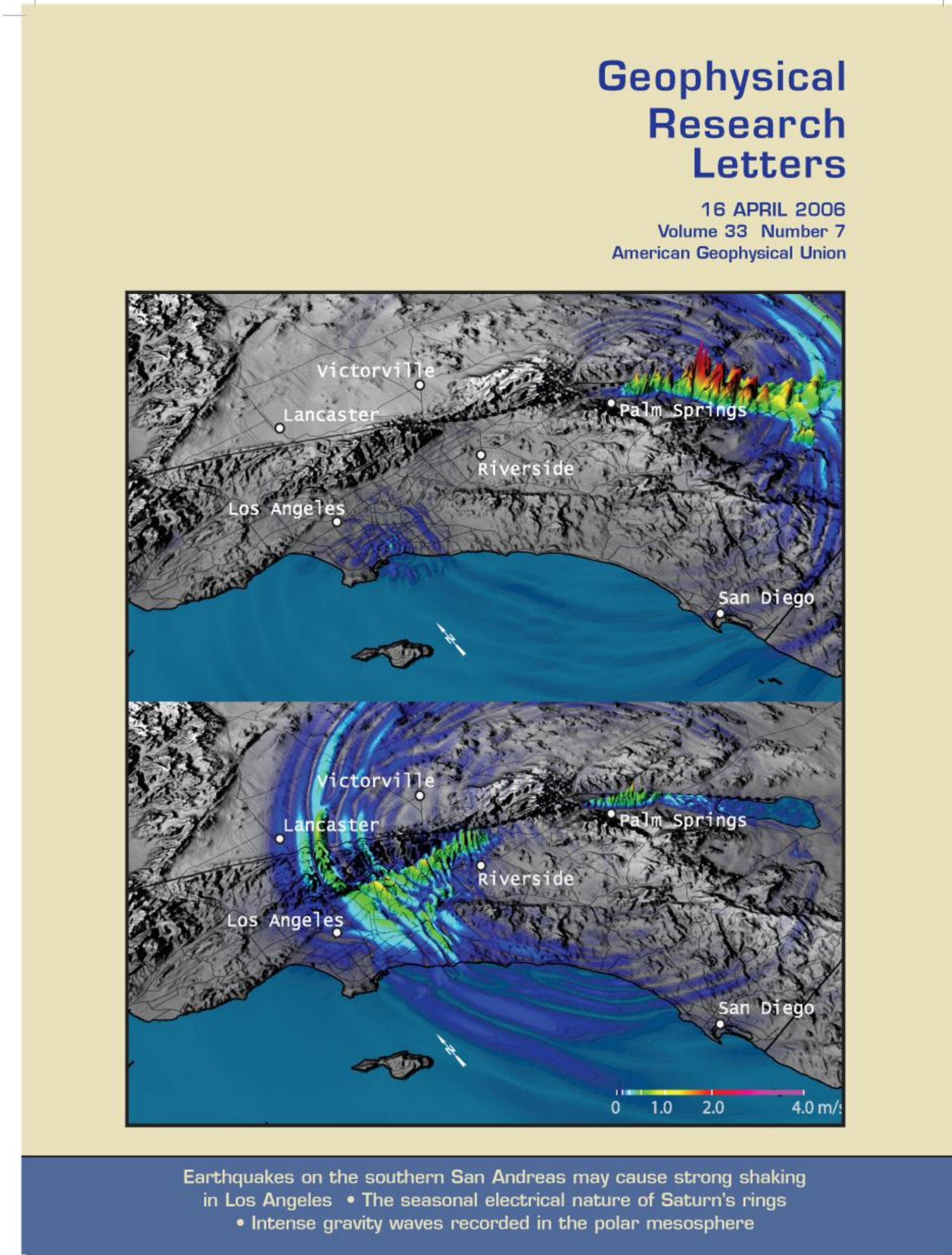
Middle: Magnitude of the ground surface velocity for earthquake waves in TeraShake simulation of magnitude 7.7 earthquake on the southern San Andreas fault. Yellow indicates highest velocity, seen near the fault as the rupture moves from north to south. Note the detailed wave structure, shaped by the region's complex 3-D crustal makeup. The simulation ran for more than four days on SDSC's DataStar supercomputer, producing an unprecedented 47 terabytes of data.

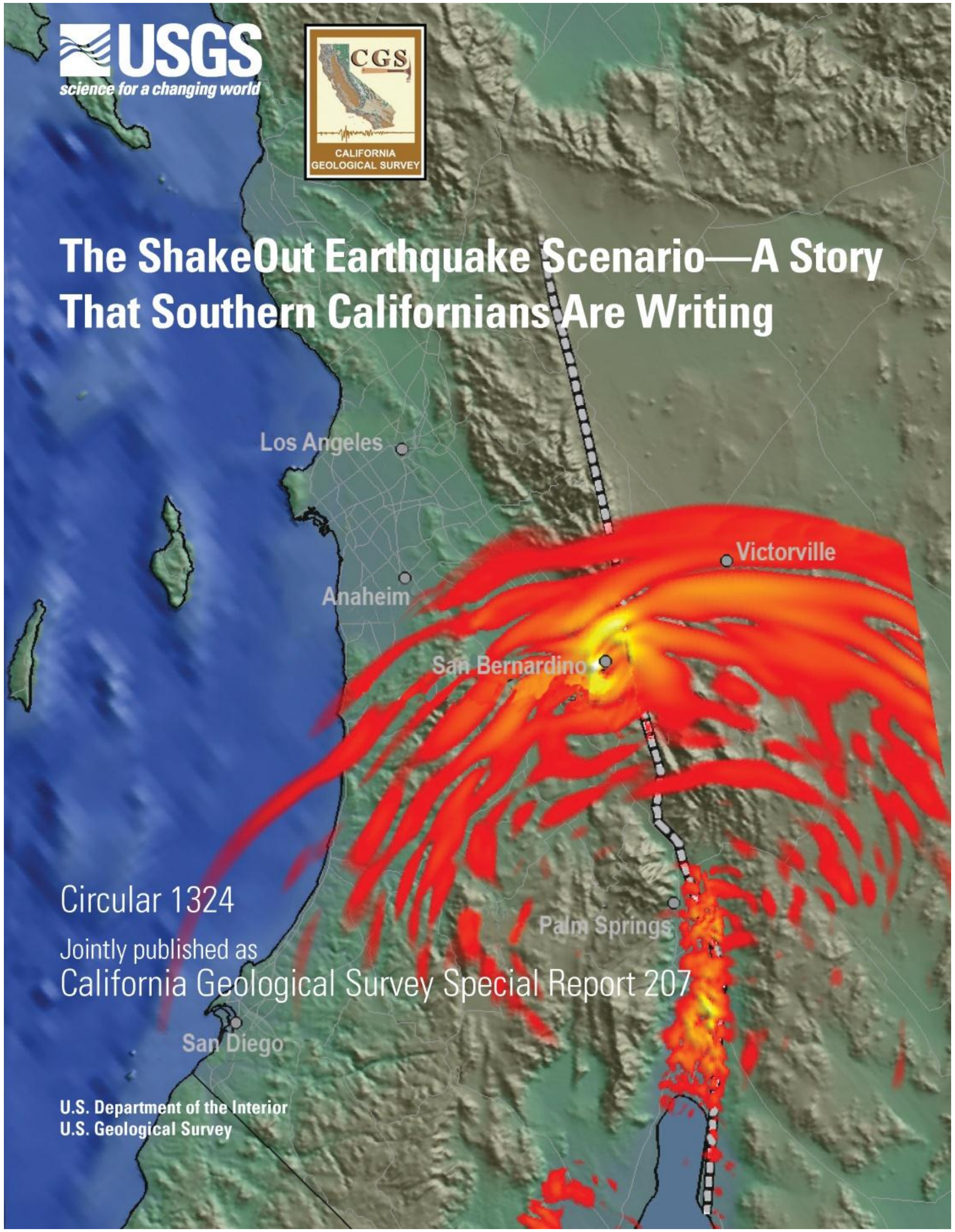
Bottom: Cross-fault or y-velocity, showing the intense back-and-forth shaking produced by the simulated magnitude 7.7 earthquake, with blue-green color indicating motion toward the southwest and red-yellow motion toward the northeast. TeraShake research will advance basic earthquake science and eventually help design more earthquake-resistant structures.

www.sdsc.edu ENVISION 2004 7

San Diego Supercomputer Center (SDSC) article on SCEC Research (2004)

Discovery of the TeraShake Wave Guide Effect (2006)





The Great Southern California ShakeOut (2008) involved collaborative research objectives and coordination of research activities.

TEXAS ADVANCED COMPUTING CENTER

Powering Discoveries That Change The World

THE UNIVERSITY OF TEXAS AT AUSTIN

Tomorrow's Forecast: Clear with a Chance of Tremors

CyberShake computations at TACC produce dynamic ground motion map for Southern California

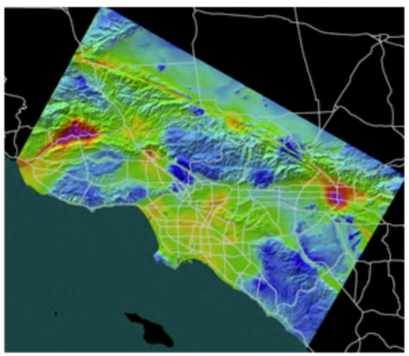
Imagine if the nightly news featured an earthquake forecast alongside your local weather outlook.

The *CyberShake* project, based at the Southern California Earthquake Center (SCEC), is advancing geophysics toward that goal. Five years into a giant, multi-institutional effort led by SCEC director, Thomas Jordan, *CyberShake 3.0* is producing maps that predict how much ground motion can be expected throughout the L.A. basin over the next 50 years.

The *CyberShake* predictions, called seismic hazard maps, have the potential to preserve thousands of lives and save billions of dollars in the case of a catastrophic earthquake. Emergency response managers count on these predictions to determine what areas will be hardest hit in a quake, and where to deploy resources. Building engineers rely on them as well to construct structurally sound buildings.

Story Highlights:

- The Southern California Earthquake Center (SCEC) used the *Ranger* supercomputer at TACC to explore the effect of earthquakes on structures in Southern California over long time-scales.
- Their computational simulations form the basis for new probabilistic seismic hazard analysis maps used by the U.S. Geological Survey, which impact building codes and zoning.
- The new hazard analysis maps predict more shaking in heavily populated regions of the Los Angeles basin.



More than 220 CyberShake physics-based PSHA hazard curves were assimilated into a background UCERF2 (2008) and NGA-based (2008) PSHA map above. New analyses tend to raise hazard estimates in the Los Angeles and Ventura Basins and reduce hazard estimates for mountainous regions in southern California.

"We want buildings to last at least 50 years," explained Philip Maechling, information technology architect for SCEC, which is associated with the University of Southern California. "We ask, 'What are the peak ground motions that this building, or this site, will experience over that timeframe?'"

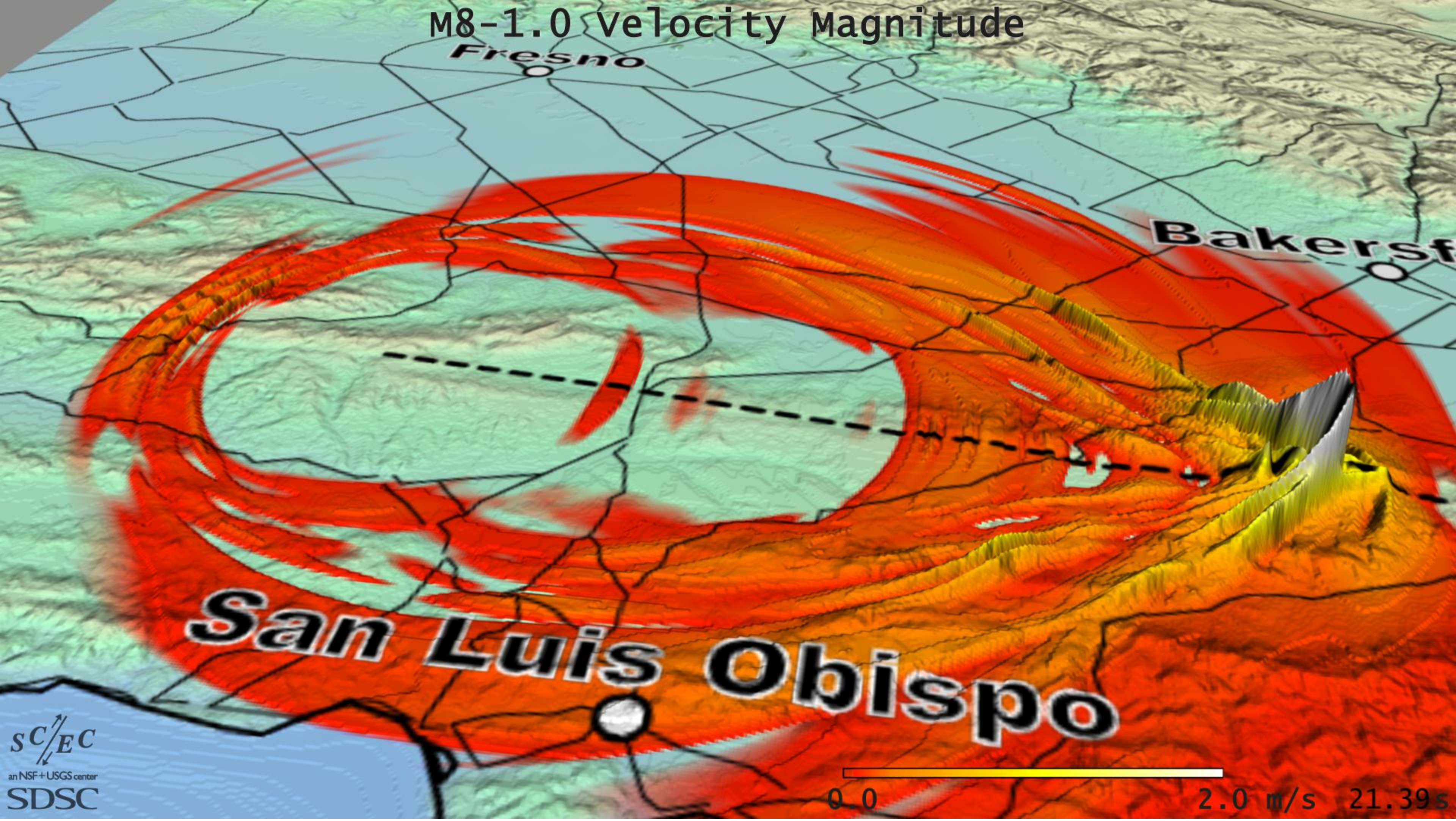
Seismologists have developed a technique to answer this question called probabilistic seismic hazard analysis (PSHA). PSHA has traditionally been based on attenuation models, in which historical records are extrapolated to create maps of unstable zones. For Southern California, however, the range of different types of soil and rock make it difficult to produce accurate maps. So, for nearly a decade, seismologists have been using numerical algorithms and computer simulations to predict future ground motions with far greater detail than traditional methods based on their knowledge of earthquake physics.

Computational PSHA combines the results of millions of virtual earthquake simulations into a map that tells a builder what will likely happen at their site in the future. To create their latest maps for *CyberShake*, SCEC teamed with the Texas Advanced Computing Center (TACC), whose massive supercomputer, *Ranger*, enabled the creation of next-generation hazard predictions that are more comprehensive than anything that has been created before.

Mapping Potential Quakes

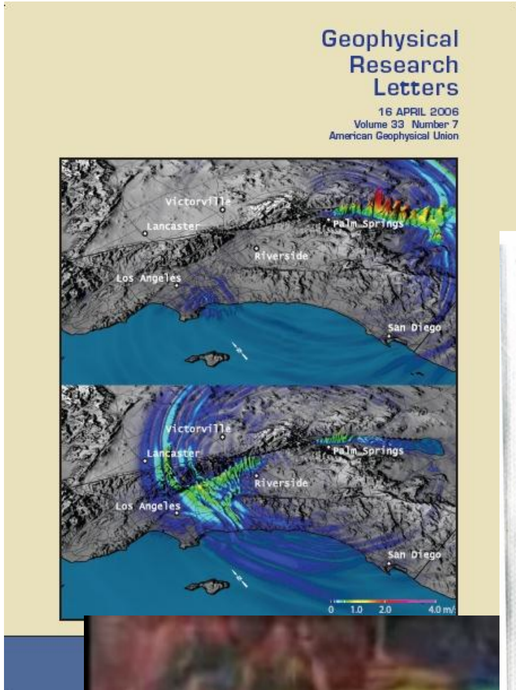
PSHA requires two inputs: a velocity or earth structure model, and an earthquake rupture forecast. The first input uses information about the geology of the area being studied to determine how earthquakes would interact with the soil and substructure of the region: how fast seismic waves would travel, and how much shaking they would cause. The second input involves identifying where all the active faults in a region are, and determining the probability of each fault rupturing.

TACC article on CyberShake (Feb 2010)



M8 visualization showing mach cone at front of supershear dynamic rupture. Velocity magnitude is shown as exaggerated local elevation.

Scientific Publications and Public Outreach raise awareness and improve preparedness.




Los Angeles Times

CALIFORNIA

LOS ANGELES EDITION

Saturday, May 27, 2006

latimes.com/calif

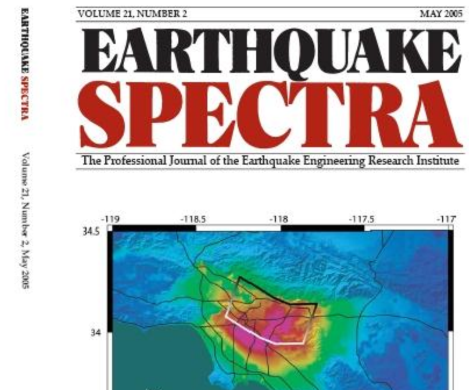
Computer Pictures 'the Big One'

Elaborate simulation of 7.7 quakes on the San Andreas fault may be expanded to calculate risks to neighborhoods or even specific blocks.

By Sharon Bernstein

Fox Makes Rounds for Immigration

The Mexican president meets with mayor, union leaders and Mahony to



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SPECIAL PUBLICATION 42
Interim Revision 2007

FAULT-RUPTURE HAZARD ZONES IN CALIFORNIA

Alquist-Priolo Earthquake Fault Zoning Act
with Index to Earthquake Fault Zones[1] Maps

[1] Name changed from Special Studies Zones January 1, 1994

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CALIFORNIA GEOLOGICAL SURVEY
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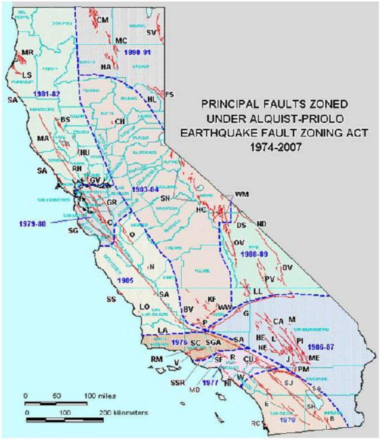
STATE GEOLOGIST

For the purposes of this Act, an *active fault is defined by* the State Mining and Geology Board as one which has "had surface displacement within Holocene time (about the last 11,000 years)" (see Appendix B, Section 3601).

MAP SYMBOL	NAME OF PRINCIPAL FAULT
B	*Brawley
BS	Bartlett Springs
BV	*Buena Vista
C	*Calaveras
CA	Calico
CH	*Cleveland Hill
CM	Cedar Mtn.
CU	Cucamonga
DS	Deep Springs
DV	Death Valley
E	Elsinore
FS	*Fort Sage
G	*Garlock
GR	*Greenville
GV	*Green Valley and Concord
H	*Hayward
HA	Hat Creek
HC	*Hilton Creek & related
HE	Helendale
HL	Honey Lake
HU	Hunting Creek
I	*Imperial
J	*Johnson Valley & related
KF	*Kern Front & related
L	Lenwood
LA	Los Alamos
LL	*Little Lake
LO	Los Osos
LS	Little Salmon
M	*Manix
MA	*Maacama
MB	Malibu
MC	McArthur
ME	Mesquite Lake
MR	Mad River
N	*Nunez
ND	Northern Death Valley
NF	North Frontal
NI	*Newport-Inglewood
O	Ortigalita
OV	*Owens Valley
P	Pleito & Wheeler Ridge
PI	*Pisgah-Bullion
PM	Pinto Mountain
PV	Panamint Valley
R	Raymond Hill
RC	Rose Canyon
RH	Rodgers Creek-Healdsburg
RM	Red Mountain
SA	*San Andreas
SC	San Cayetano
SF	*San Fernando
SG	San Gregorio
SGA	San Gabriel
SH	*Superstition Hills
SJ	*San Jacinto
SN	Sierra Nevada (zone)
SS	San Simeon
SSR	Simi-Santa Rosa
SV	Surprise Valley
W	Whittier
WM	*White Mtns
WW	*White Wolf
V	Ventura



Faults zoned through August 2007

Approximate boundaries of work-plan regions and year studied

Note: Other faults may be zoned in the future and existing zones may be revised when warranted by new fault data

Figure 1. Principal active faults in California zoned under the Alquist-Priolo Earthquake Fault Zoning Act. Asterisk indicates faults with historic surface rupture

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E	Elsinore
FS	*Fort Sage
G	*Garlock
GR	*Greenville
GV	*Green Valley and Concord
H	*Hayward
HA	Hat Creek
HC	*Hilton Creek & related
HE	Helendale
HL	Honey Lake
HU	Hunting Creek
I	*Imperial
J	*Johnson Valley & related
KF	*Kern Front & related
L	Lenwood
LA	Los Alamos
LL	*Little Lake
LO	Los Osos
LS	Little Salmon
M	*Manix
MA	*Maacama
MB	Malibu
MC	McArthur
ME	Mesquite Lake
MR	Mad River
N	*Nunez
ND	Northern Death Valley
NF	North Frontal
NI	*Newport-Inglewood
O	Ortigalita
OV	*Owens Valley
P	Pleito & Wheeler Ridge
PI	*Pisgah-Bullion
PM	Pinto Mountain
PV	Panamint Valley
R	Raymond Hill
RC	Rose Canyon
RH	Rodgers Creek-Healdsburg
RM	Red Mountain
SA	*San Andreas
SC	San Cayetano
SF	*San Fernando
SG	San Gregorio
SGA	San Gabriel
SH	*Superstition Hills
SJ	*San Jacinto
SN	Sierra Nevada (zone)
SS	San Simeon
SSR	Simi-Santa Rosa
SV	Surprise Valley
W	Whittier
WM	*White Mtns
WW	*White Wolf
V	Ventura

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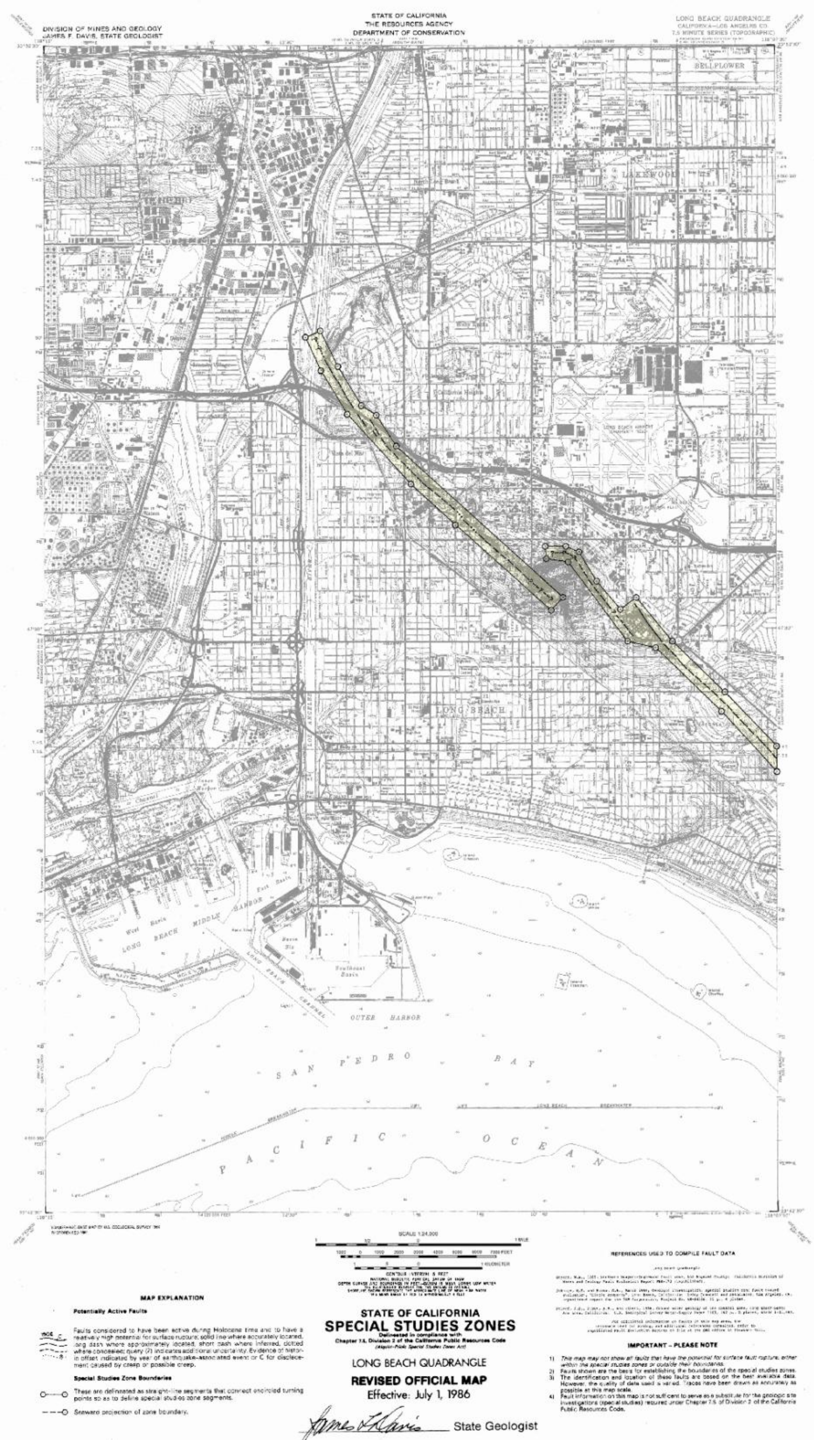

Alquist-Priolo Earthquake Fault-Zoning Act Rupture Hazard Zones near Long Beach, CA.

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LONG BEACH

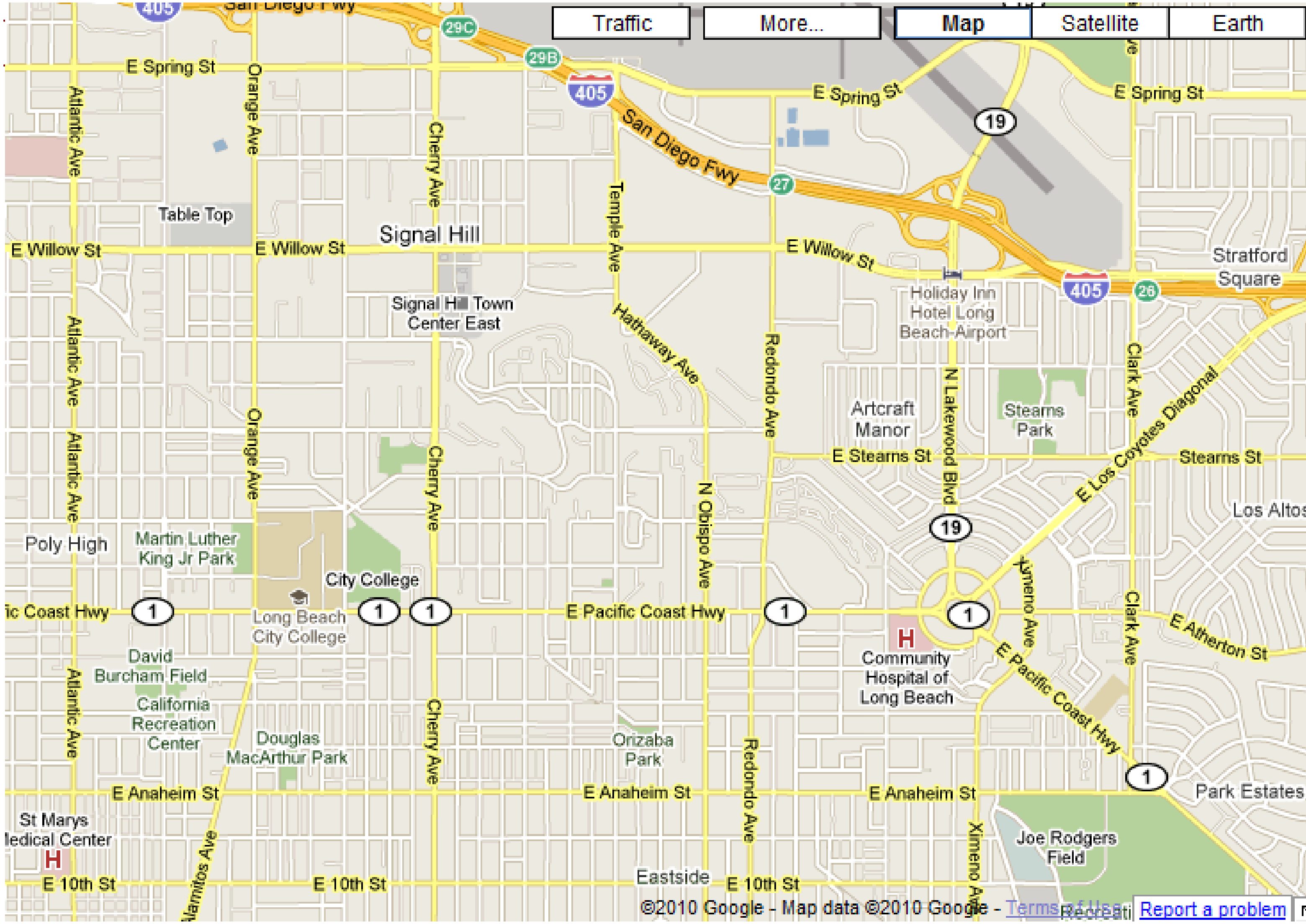
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Table Top
Signal Hill
E Willow St
Signal Hill Town Center East
Hathaway Ave
Redondo Ave
Holiday Inn Hotel Long Beach-Airport
N Lakewood Blvd
Clark Ave
Stratford Square
Artcraft Manor
Stearns Park
E Stearns St
Stearns St
E Los Coyotes Diagonal
Los Altos
N Obispo Ave
Poly High
Martin Luther King Jr Park
City College
Long Beach City College
E Pacific Coast Hwy
Ximeno Ave
E Atherton St
Community Hospital of Long Beach
E Pacific Coast Hwy
David Burcham Field
California Recreation Center
Douglas MacArthur Park
Orizaba Park
E Anaheim St
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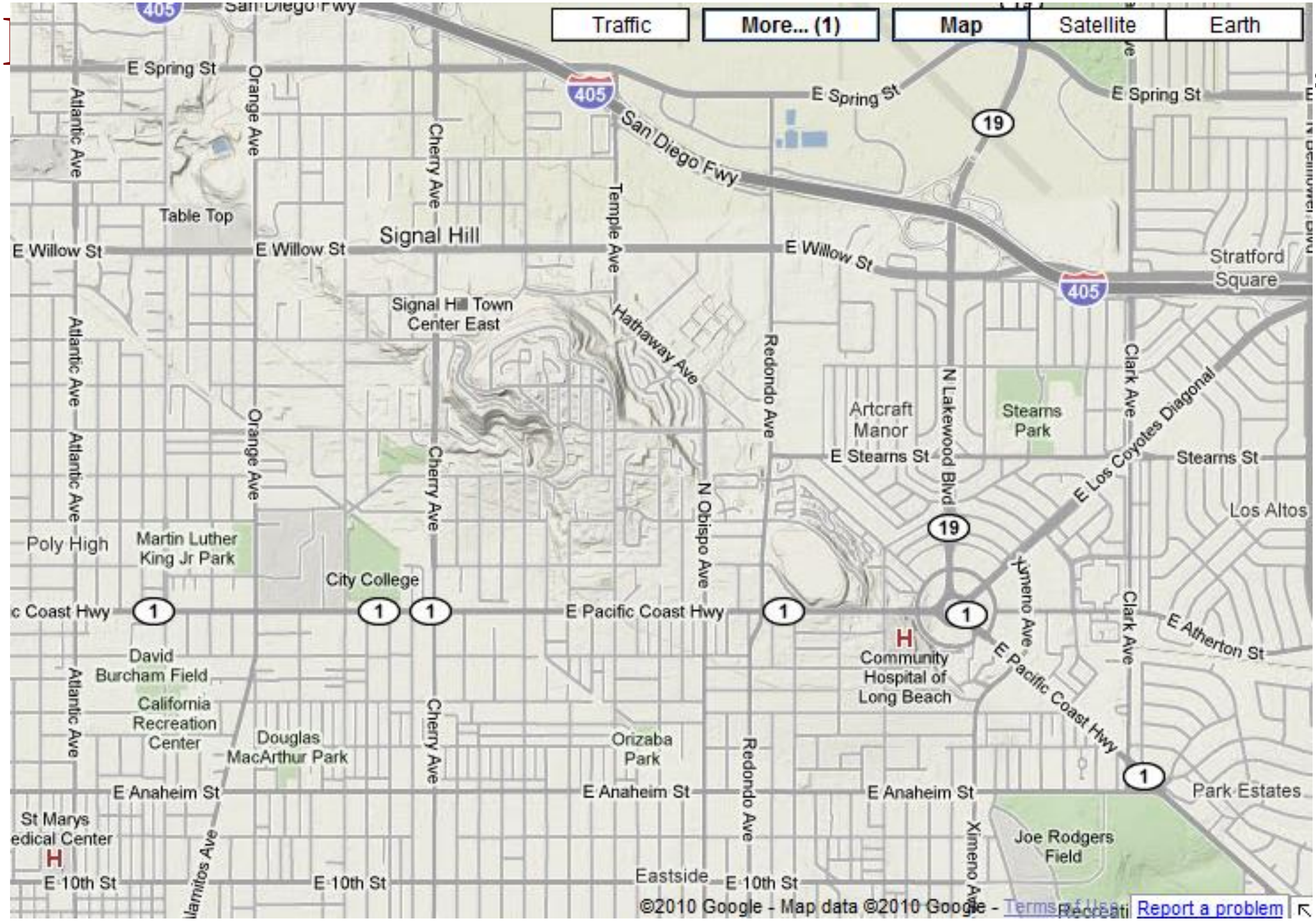
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Redondo Ave
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Artcraft Manor
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N Obispo Ave
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Poly High
Martin Luther King Jr Park
City College
c Coast Hwy
E Pacific Coast Hwy
Ximeno Ave
E Atherton St
David Burcham Field
California Recreation Center
Community Hospital of Long Beach
E Pacific Coast Hwy
Douglas MacArthur Park
Orizaba Park
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Report a problem

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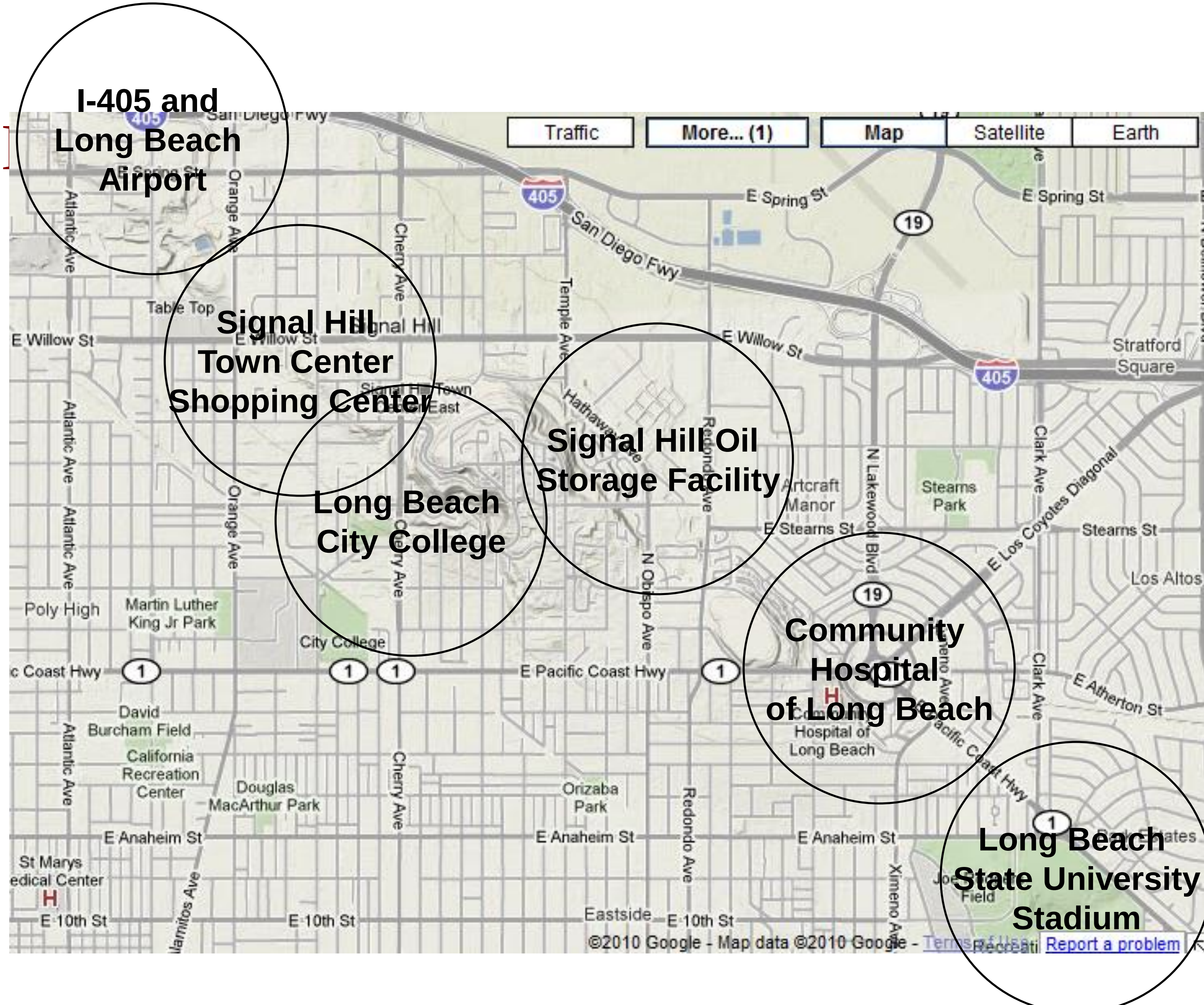
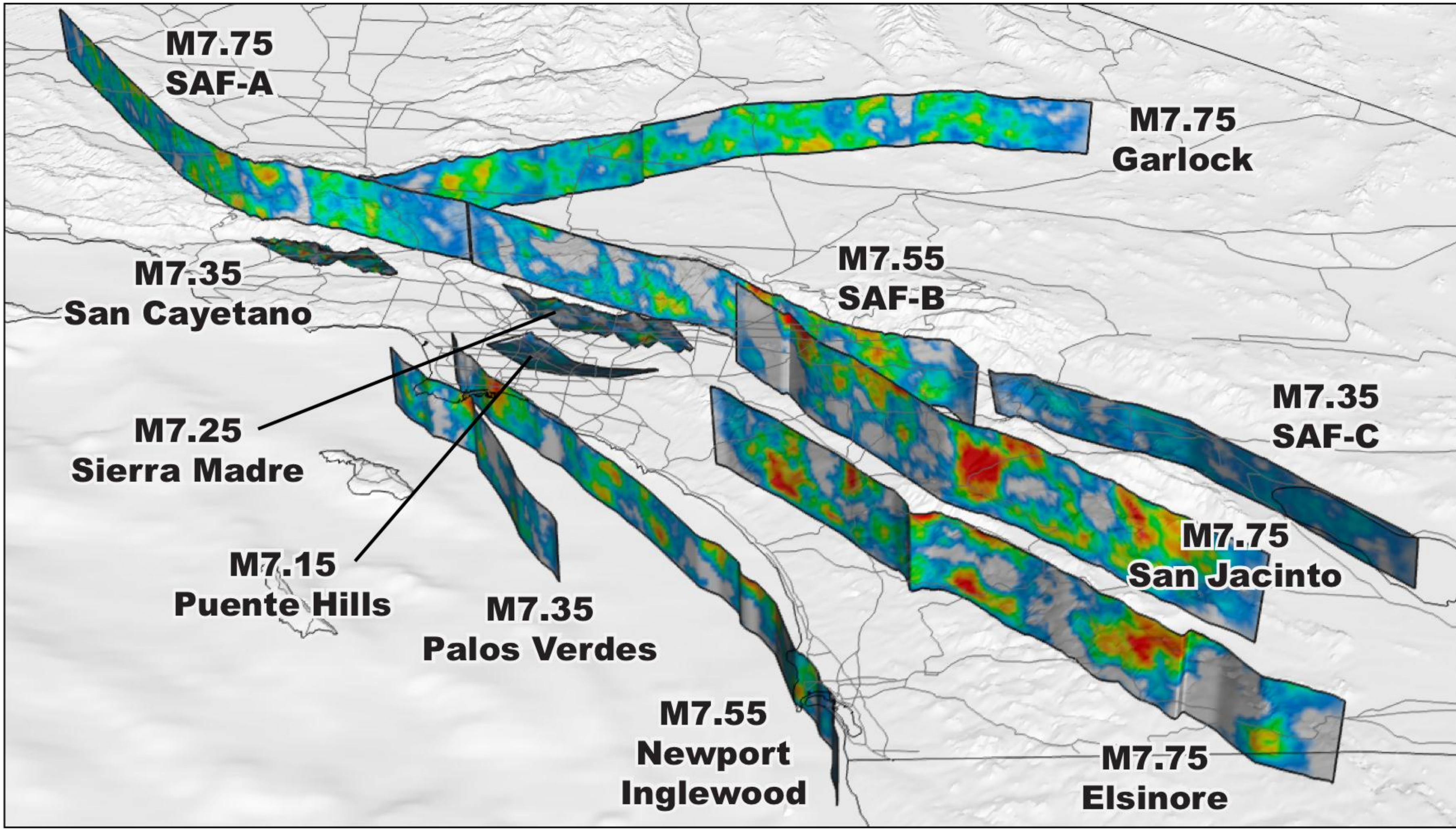
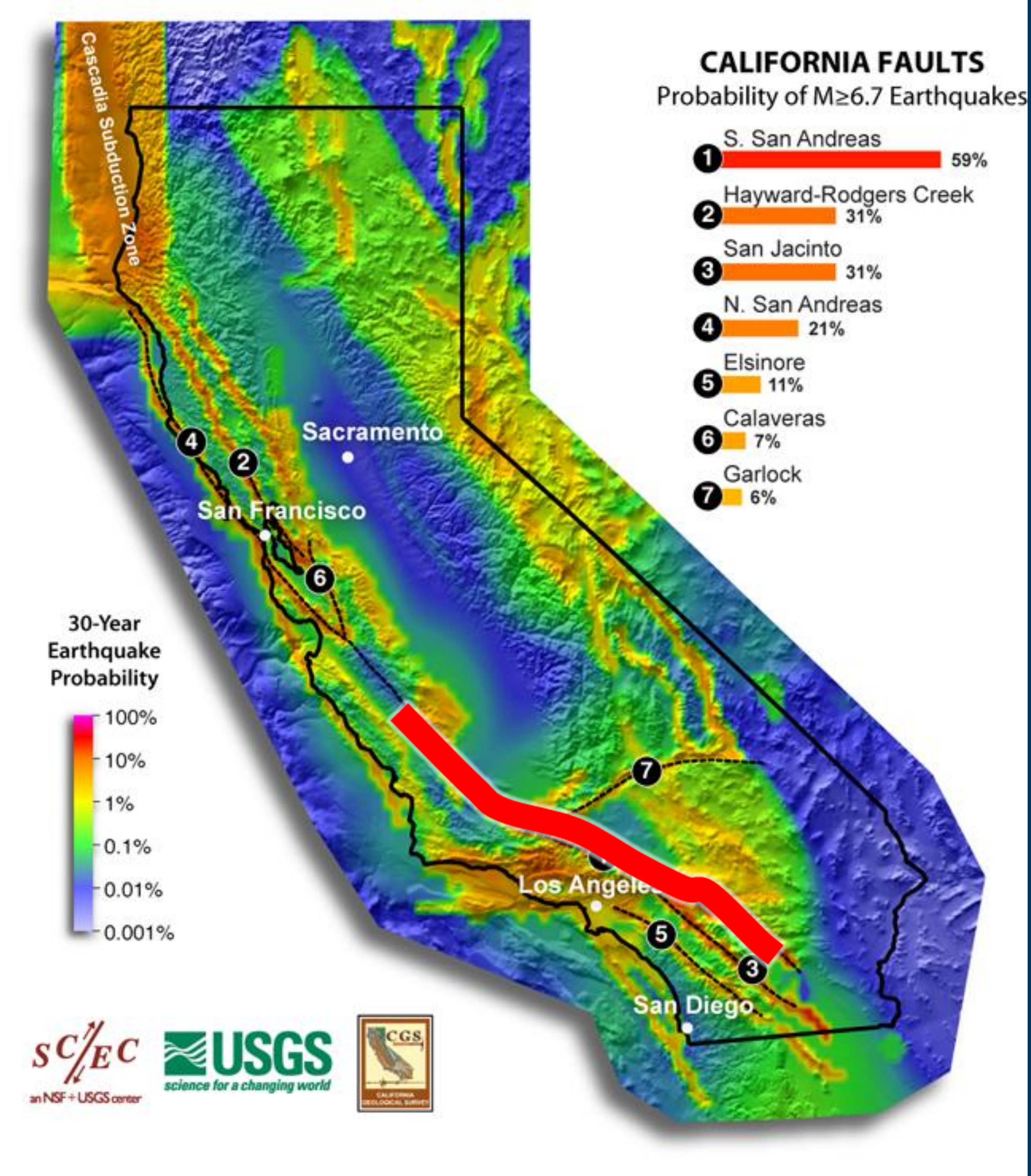


I-405 and Long Beach Airport
Signal Hill Town Center Shopping Center
Long Beach City College
Signal Hill Oil Storage Facility
Community Hospital of Long Beach
Long Beach State University Stadium
Traffic
More... (1)
Map
Satellite
Earth

s


M7.75
SAF-A
M7.75
Garlock
M7.35
San Cayetano
M7.55
SAF-B
M7.25
Sierra Madre
M7.35
SAF-C
M7.15
Puente Hills
M7.75
San Jacinto
M7.35
Palos Verdes
M7.55
Newport
Inglewood
M7.75
Elsinore


CALIFORNIA FAULTS
Probability of M≥6.7 Earthquakes
1 S. San Andreas 59%
2 Hayward-Rodgers Creek 31%
3 San Jacinto 31%
4 N. San Andreas 21%
5 Elsinore 11%
6 Calaveras 7%
7 Garlock 6%
Cascadia Subduction Zone
Sacramento
San Francisco
Los Angeles
San Diego
30-Year Earthquake Probability
100%
10%
1%
0.1%
0.01%
0.001%
SCEC
an NSF + USGS center
USGS
science for a changing world
CGS

ShakeOut

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Earthquake Hazards Program

Prepared in cooperation with the
California Geological Survey
and the
Southern California Earthquake Center

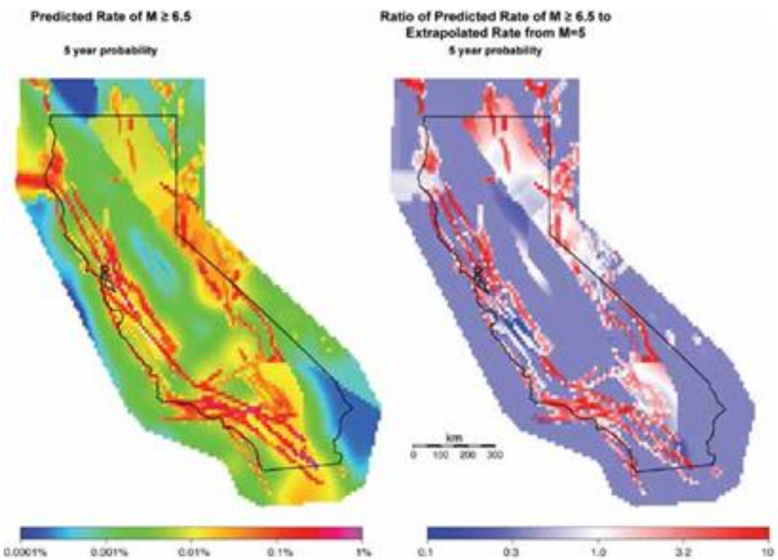
USGS Open File Report 2007-1437
CGS Special Report 203
SCEC Contribution #1138
Version 1.1

The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2)

By 2007 Working Group on California Earthquake Probabilities*

2008

*Edward H. Field, Timothy E. Dawson, Karen R. Felzer, Arthur D. Frankel, Vipin Gupta, Thomas H. Jordan, Tom Parsons, Mark D. Petersen, Ross S. Stein, Ray J. Weldon II, and Chris J. Wills

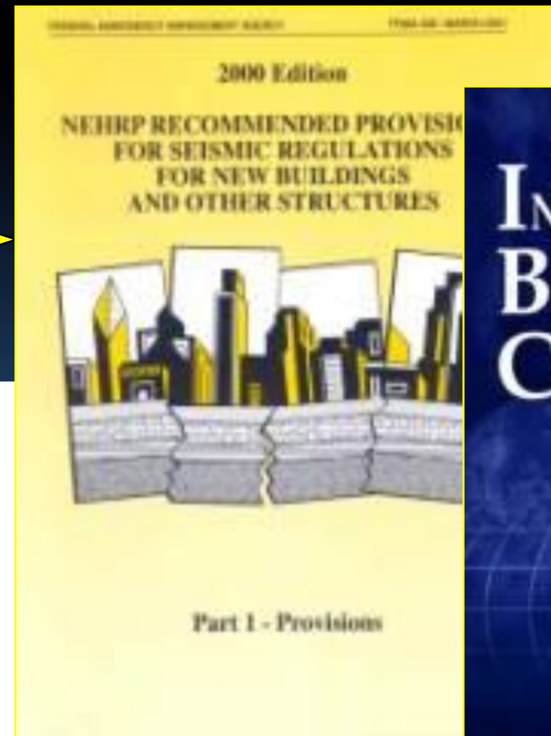


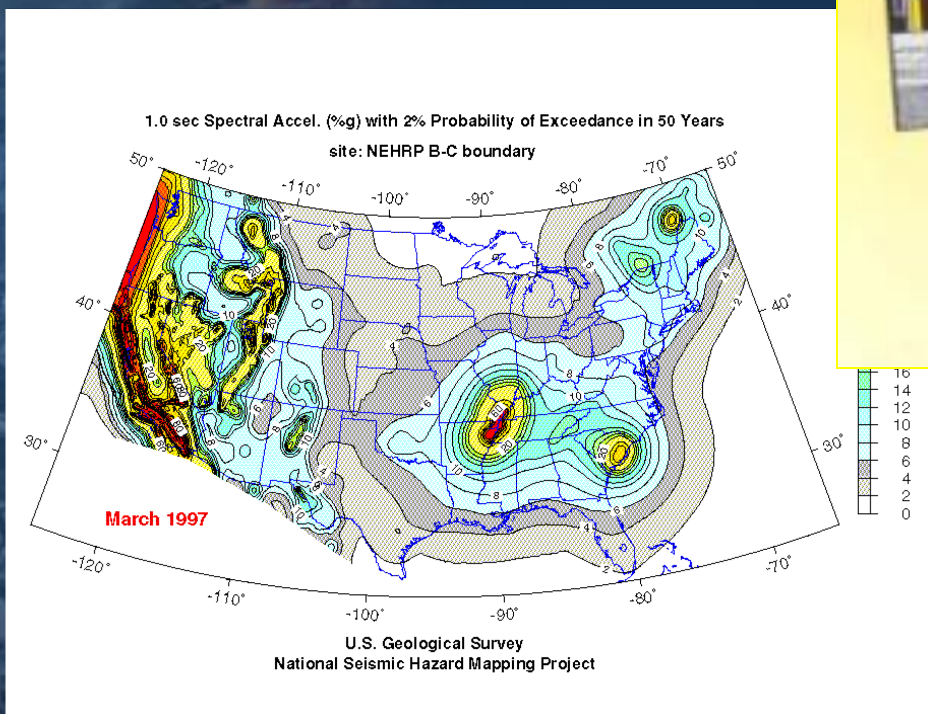
California's 35 million people live among some of the most active earthquake faults in the United States. Public safety demands credible assessments of the earthquake hazard to maintain appropriate building codes for safe construction and earthquake insurance for loss protection. Seismic hazard analysis begins with an earthquake rupture forecast—a model of probabilities that earthquakes of specified magnitudes, locations, and faulting types will occur during a specified time interval. This report describes a new earthquake rupture forecast for California developed by the 2007 Working Group on California Earthquake Probabilities (WGCEP 2007).

Working Group on California Earthquake Probabilities leads development of UCERF2.0, an Earthquake Rupture Forecast for California.

USGS hazard mapping results in dramatic change in building codes

Seismic element of 1996 Building Codes based on 1970's maps

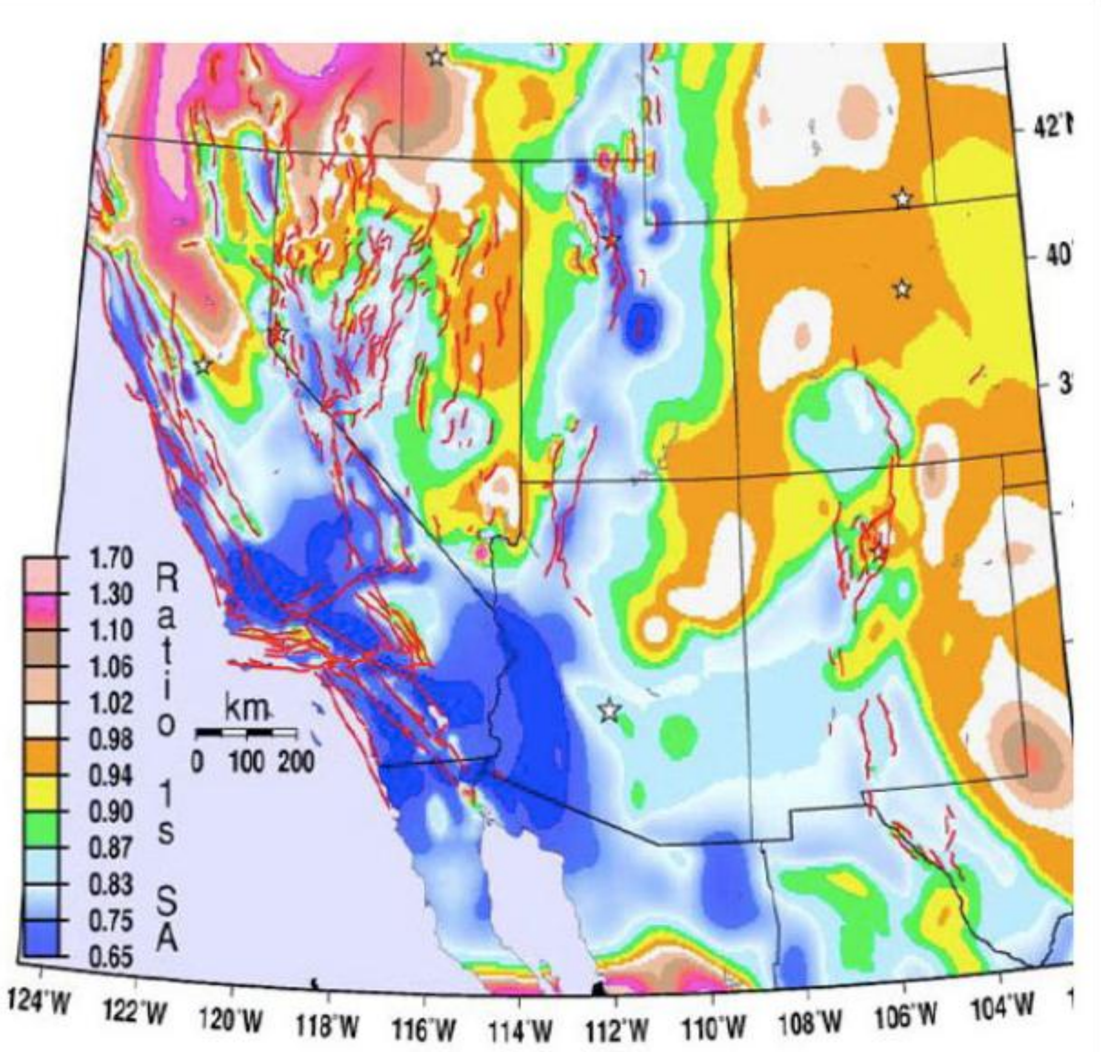




Seismic element of 2000 & 2003 Int'l Building Code based on the 1996 USGS national seismic hazard map

USGS

Change to National Seismic Hazard Map



Ratio of New/Old

New design ground motions are, for the most part, less intense.

This is a big deal: will impact $1 trillion in construction over next 5 years.

Earthquake Response Information

Information available after an earthquake.

Intensity Scale - Earthquakes

- The **Mercalli intensity scale** is a seismic scale used for measuring the intensity of an earthquake. It measures the *effects* of an earthquake

- It is distinct from the earthquake **magnitude** usually reported for an earthquake, which is a measure of the *energy* released.

- **Intensity information** is commonly used in post-earthquake decision making. Intensity information about your locations of interest may be much more useful than earthquake magnitude.

Intensity Scale - Earthquakes

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 slight	Light	Moderate	Moderate/ heavy	Heavy	Very heavy
Peak Acc	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak Vel	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16 - 31	31-60	60-116	>116

Peak Acc = Peak ground acceleration (g), Peak Vel = Peak ground velocity (cm/s)

HOW AN EARTHQUAKE FEELS

The Modified Mercalli Intensity (MM) scale is a means of categorising the effects of shaking on people, structures and the environment.

MM 5

Generally felt outside.
Small unstable objects displaced.
Some windows and pipes crack.

MM 6

Felt by everybody.
Difficulty experienced in walking.
Objects from shelves tend to fall.
Slight damage to poorly constructed buildings.

MM 7

Difficulty standing.
Noticed by drivers of cars.
Furniture movement.
Tiles, water tanks, walls and some buildings damaged.

MM 8

Steering of cars affected.
Buildings damaged, including some damage to earthquake resistant buildings.
Cracks in ground.

MM 9

Heavy damage to buildings, bridges and roads.
Larger cracks in ground.
Landslides on steep slopes.
Liquefaction effects intensify.

MM 10

More intense damage, including serious damage to earthquake resistant buildings and bridges.
Most unreinforced masonry structures destroyed.

Intensity Scale - Wind

- The **Beaufort scale** relates wind speed to observed conditions at sea or on land. Its full name is the **Beaufort wind force scale**.

Force 0: Wind Speed less than 1 knot

Sea: Sea like a mirror

Force 1: Wind Speed 1-3 knots

Sea: Wave height .1m (.25ft); Ripples with appearance of scales, no foam crests

Force 2: Wind Speed 4-6 knots

Sea: Wave height .2-.3m (.5-1 ft); Small wavelets, crests of glassy appearance, not breaking

Force 3: Wind Speed 7-10 knots

Sea: Wave height .6-1m (2-3 ft); Large-wavelets, crests begin to break, scattered whitecaps

Force 4: Wind Speed 11-16 knots

Sea: Wave height 1-1.5m (3.5-5 ft); Small waves becoming longer, numerous whitecaps

Force 5: Wind Speed 17-21 knots

Sea: Wave height 2-2.5m (6-8 ft); Moderate waves, taking longer form, many whitecaps, some spray

Force 6: Wind Speed 22-27 knots

Sea: Wave height 3-4m (9.5-13 ft); Larger waves forming, whitecaps everywhere, more spray

Force 7: Wind Speed 28-33 knots

Sea: Wave height 4-5.5m (13.5-19 ft); Sea heaps up, white foam from breaking waves begins to be blown in streaks along direction of wind

Force 8: Wind Speed 34-40 knots

Sea: Wave height 5.5-7.5m (18-25 ft); Moderately high waves of greater length, edges of crests begin to break into spindrift, foam is blown in well marked streaks

Force 9: Wind Speed 41-47 knots

Sea: Wave height 7-10m (23-32 ft); High waves, sea begins to roll, dense streaks of foam along wind direction, spray may reduce visibility

Force 10: Wind Speed 48-55 knots (storm)

Sea: Wave height 9-12.5m (29-41 ft); Very high waves with overhanging crests, sea takes white appearance as foam is blown in very dense streaks, rolling is heavy and shocklike, visibility is reduced.

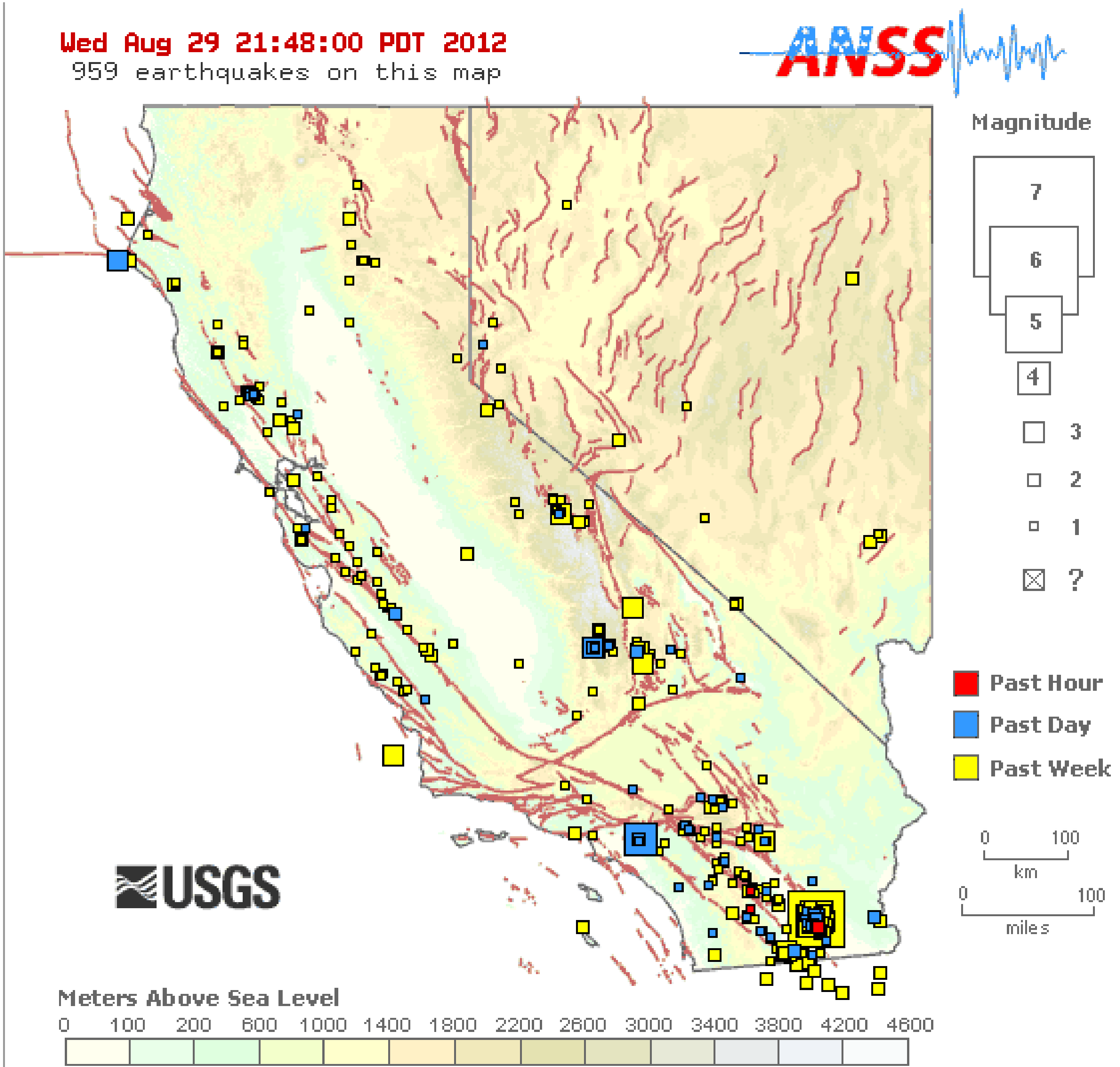
Force 11: Wind Speed 56-63 knots

Sea: Wave height 11.5-16m (37-52 ft); Exceptionally high waves, sea covered with white foam patches, visibility still more reduced

USGS Earthquake Information Data Products

USGS is responsible for public statements about earthquake hazards in US. Best USGS Earthquake Response information includes:

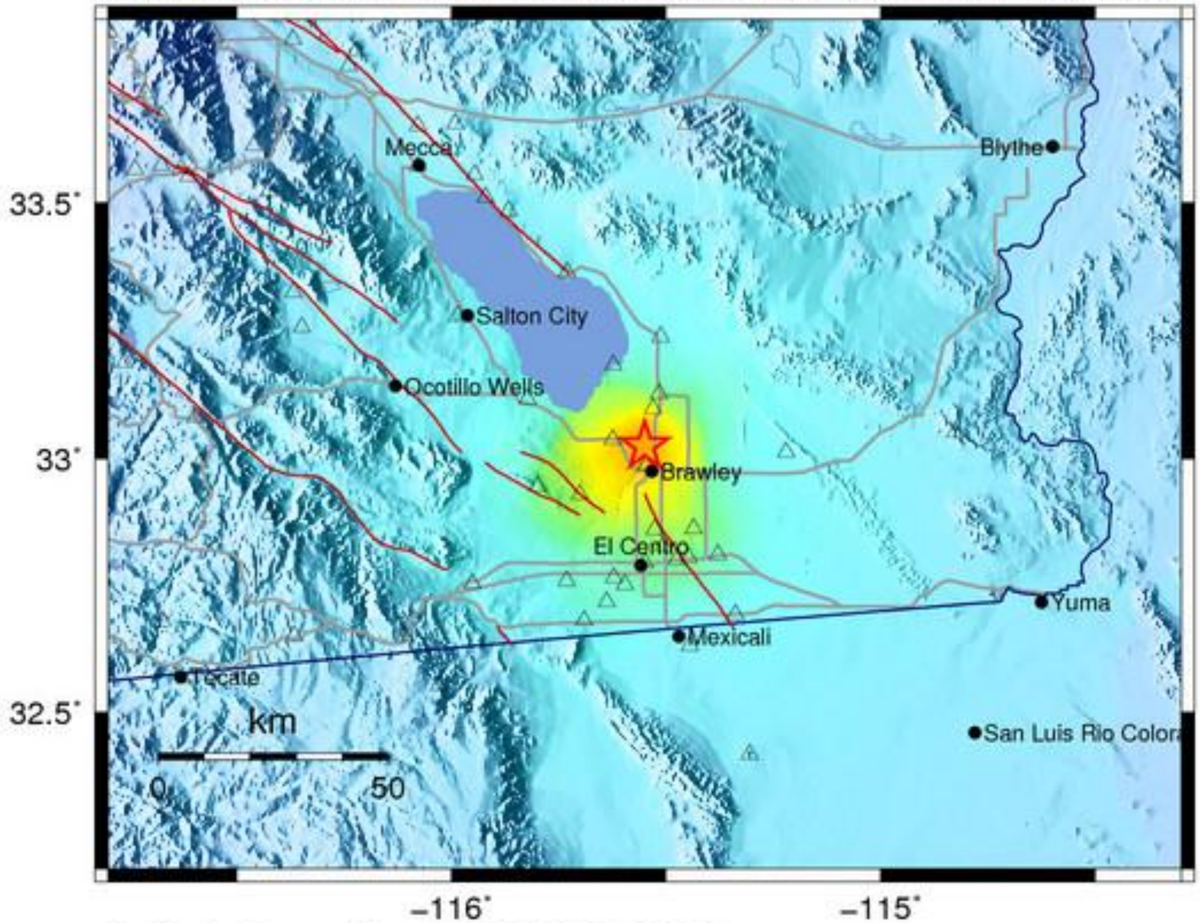
1. Recent Earthquakes (Web) and Earthquake Notification (ENS) Subscription (Email):
   - http://earthquake.usgs.gov/earthquakes/recenteqscanv/
   - https://sslearthquake.usgs.gov/ens/
2. ShakeMap:
   - http://earthquake.usgs.gov/earthquakes/shakemap/
3. Pager:
   - http://earthquake.usgs.gov/earthquakes/pager/
4. Did you Feel It:
   - http://earthquake.usgs.gov/earthquakes/dyfi/



Wed Aug 29 21:48:00 PDT 2012
959 earthquakes on this map
ANSS
Magnitude
7
6
5
4
3
2
1
?
Past Hour
Past Day
Past Week
0 100
km
0 100
miles
USGS
Meters Above Sea Level
0 100 200 600 1000 1400 1800 2200 2600 3000 3400 3800 4200 4600

CISN/sc ShakeMap : 6.9 km (4.3 mi) ESE of Westmorland, CA

AUG 26 2012 08:57:58 PM GMT M 5.5 N33.02 W115.55 Depth: 9.0km ID:15200401



Map Version 8 Processed Mon Aug 27, 2012 09:37:02 PM GMT

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

Scale based upon Worden et al. (2011)

USGS
science for a changing world

Earthquake Shaking **Yellow Alert**

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

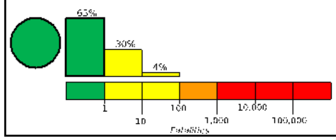
M 5.3, 6.5 km (4.0 mi) N of Brawley, CA

Origin Time: Sun 2012-08-26 19:31:22 UTC (12:31:22 local)
Location: 33.02°N 115.55°W Depth: 12 km

PAGER Version 12

Created: 1 day, 1 hour after earthquake

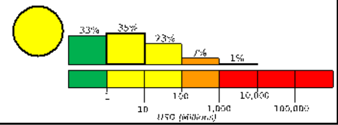
Estimated Fatalities



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

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

Estimated Economic Losses



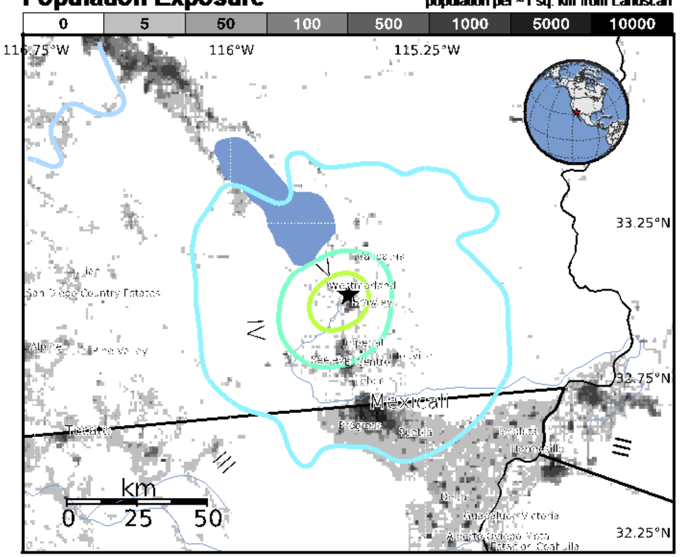
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		--*	1,104k*	745k	25k	21k	6k	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan



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

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1989-01-19	307	5.2	VI(14k)	0
1991-06-28	264	5.6	VII(8k)	1
1994-01-17	306	6.7	IX(181k)	33

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

Selected City Exposure

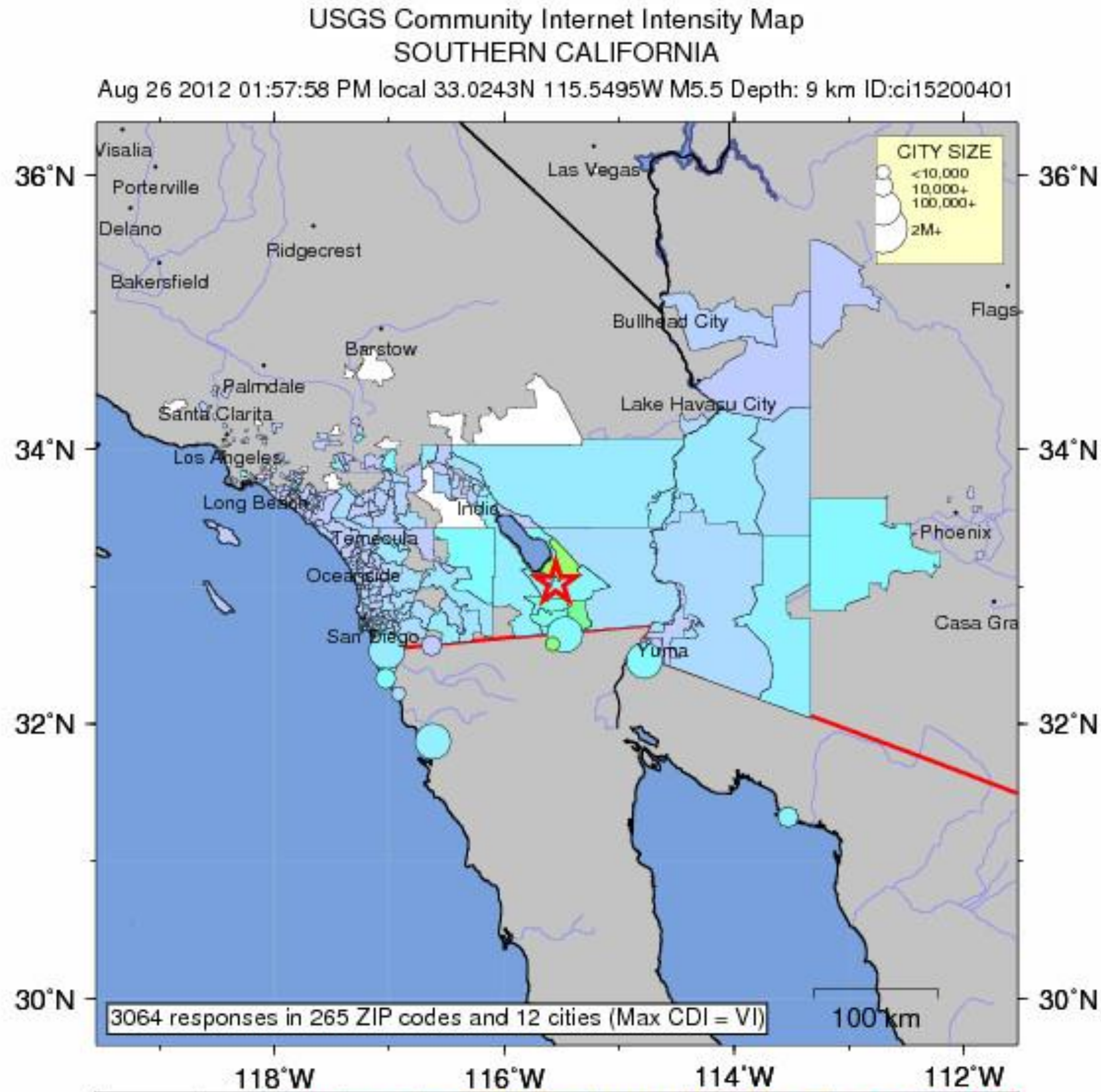
from GeoNames.org

MMI	City	Population
VI	**Brawley**	22k
VI	**Westmorland**	2k
V	**Calipatria**	8k
V	**Imperial**	10k
IV	**El Centro**	38k
IV	**Seeley**	2k
IV	**Mexicali**	597k
III	Yuma	84k
III	Indio	66k
III	**Tecate**	58k

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: ci15199681



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

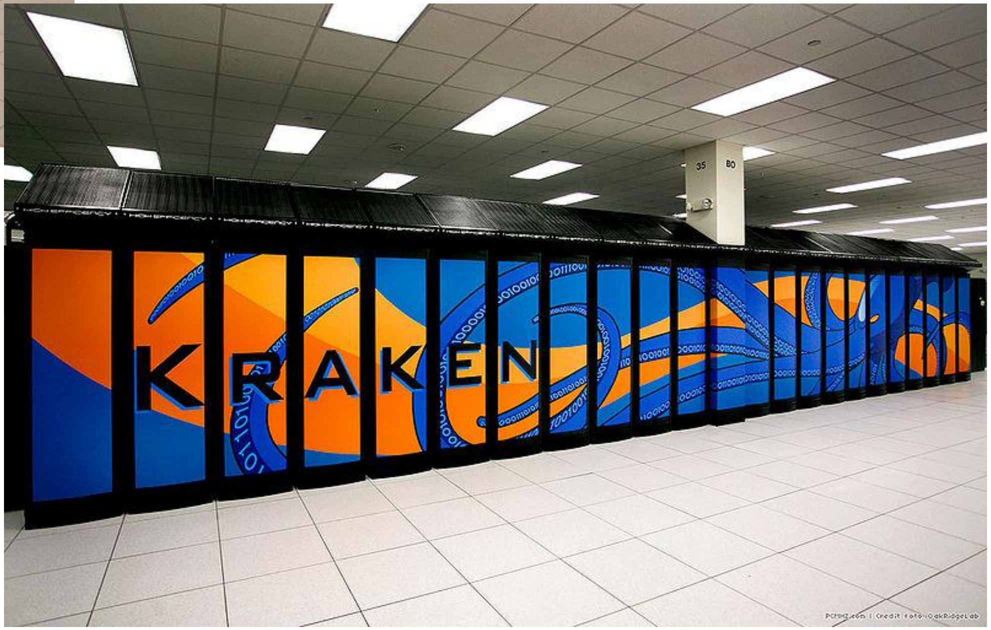
Processed: Thu Aug 30 00:55:38 2012

Presentation Topics

Interesting new developments in seismology, including:

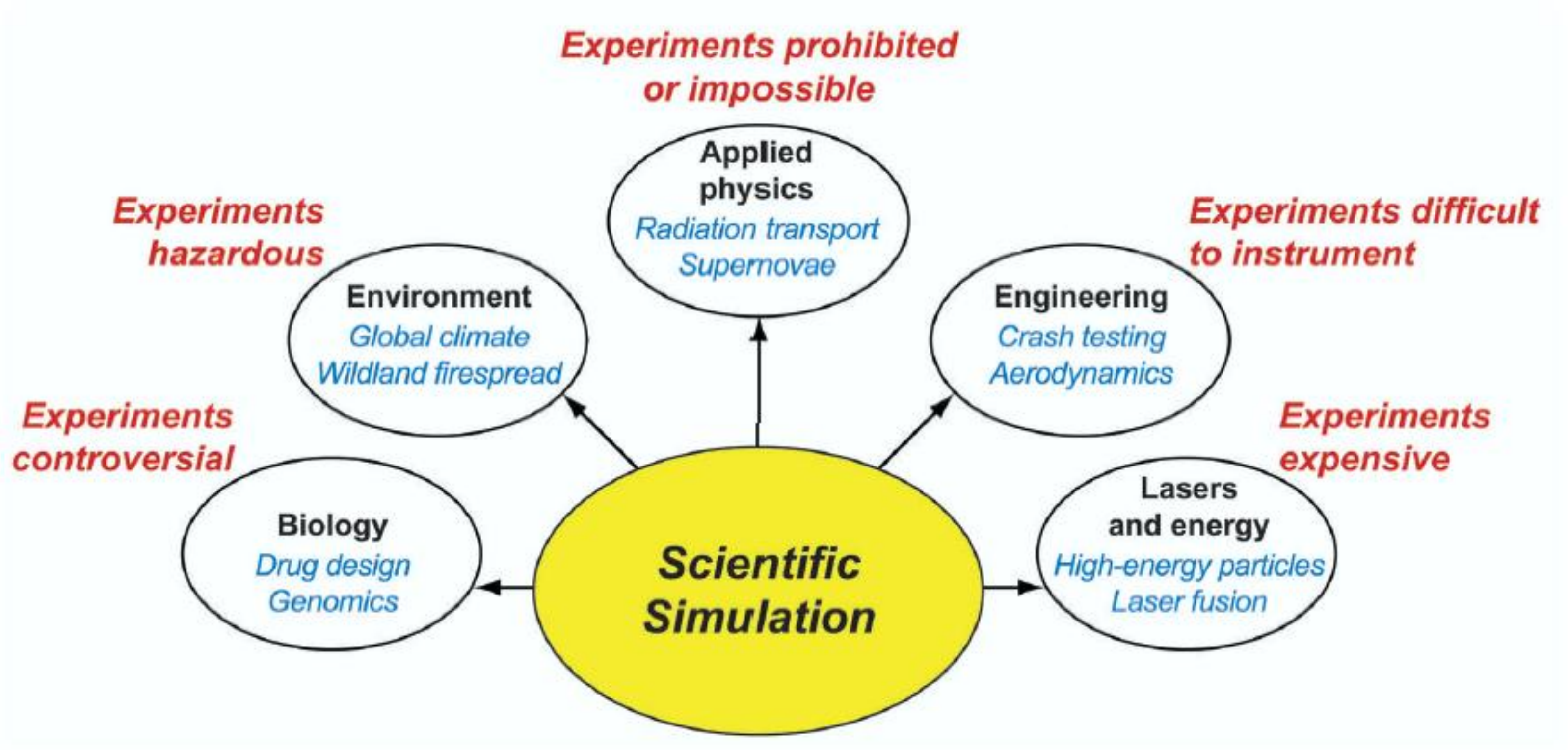
1. Southern California Earthquake Center (SCEC) Background
2. Earthquake information Used by Expert
3. Simulating Earthquakes using Supercomputers
4. Preparing your Earthquake Response

Using Supercomputers to Study Earthquakes



Characteristics of Scientific Simulations

The reasons seismologists and earthquake engineers want to make better use of simulations are shared with other domains.



The information value ladder

Data >>> Information >>> Insight

>>> Increasing value >>>

Forecasting

Reporting

Analysis

Integration

Done poorly

Distribution

Aggregation

Done poorly to moderately

Quality assurance

Collation

Monitoring

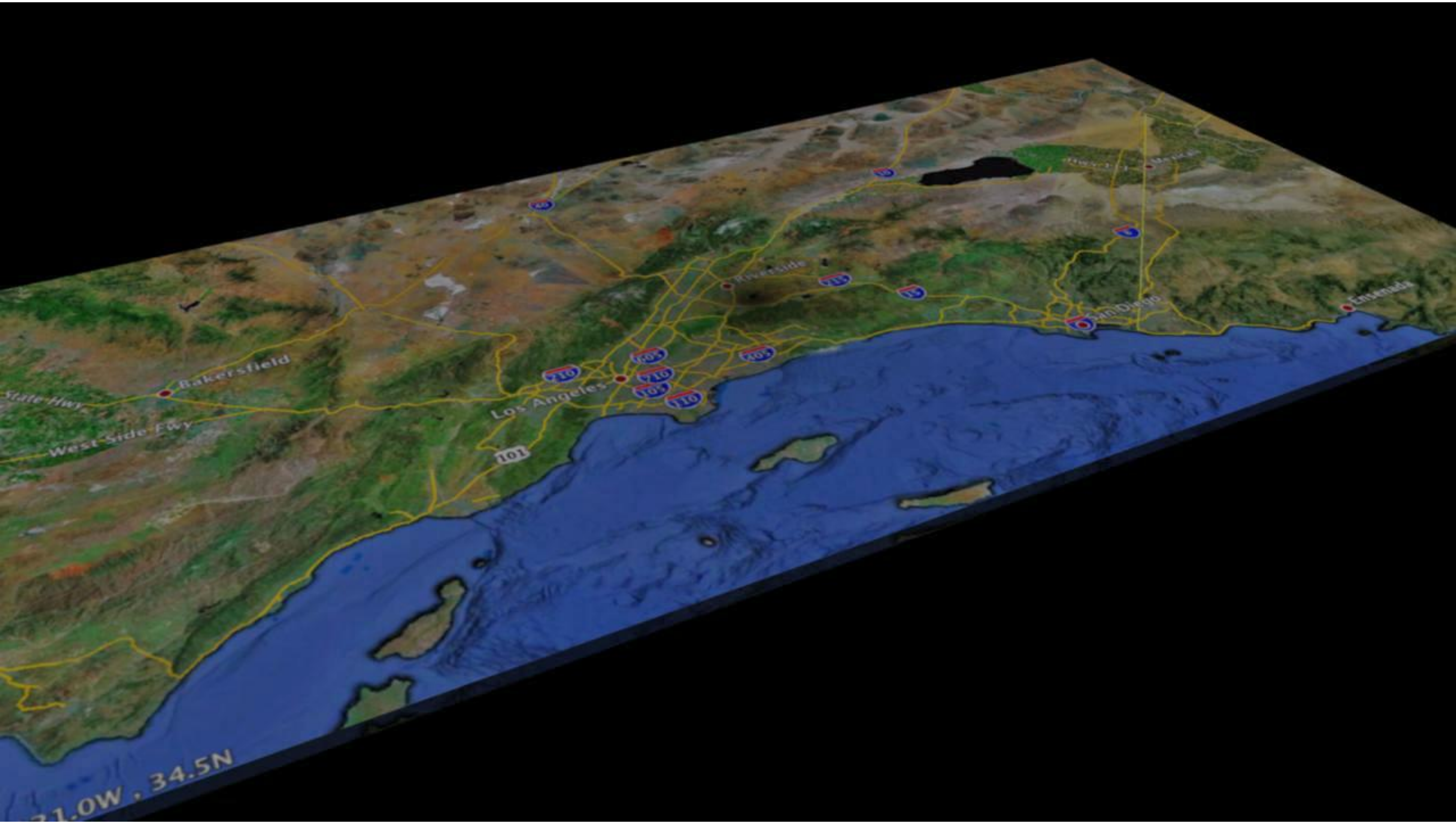
Sometimes done well, by many groups, but could be vastly improved

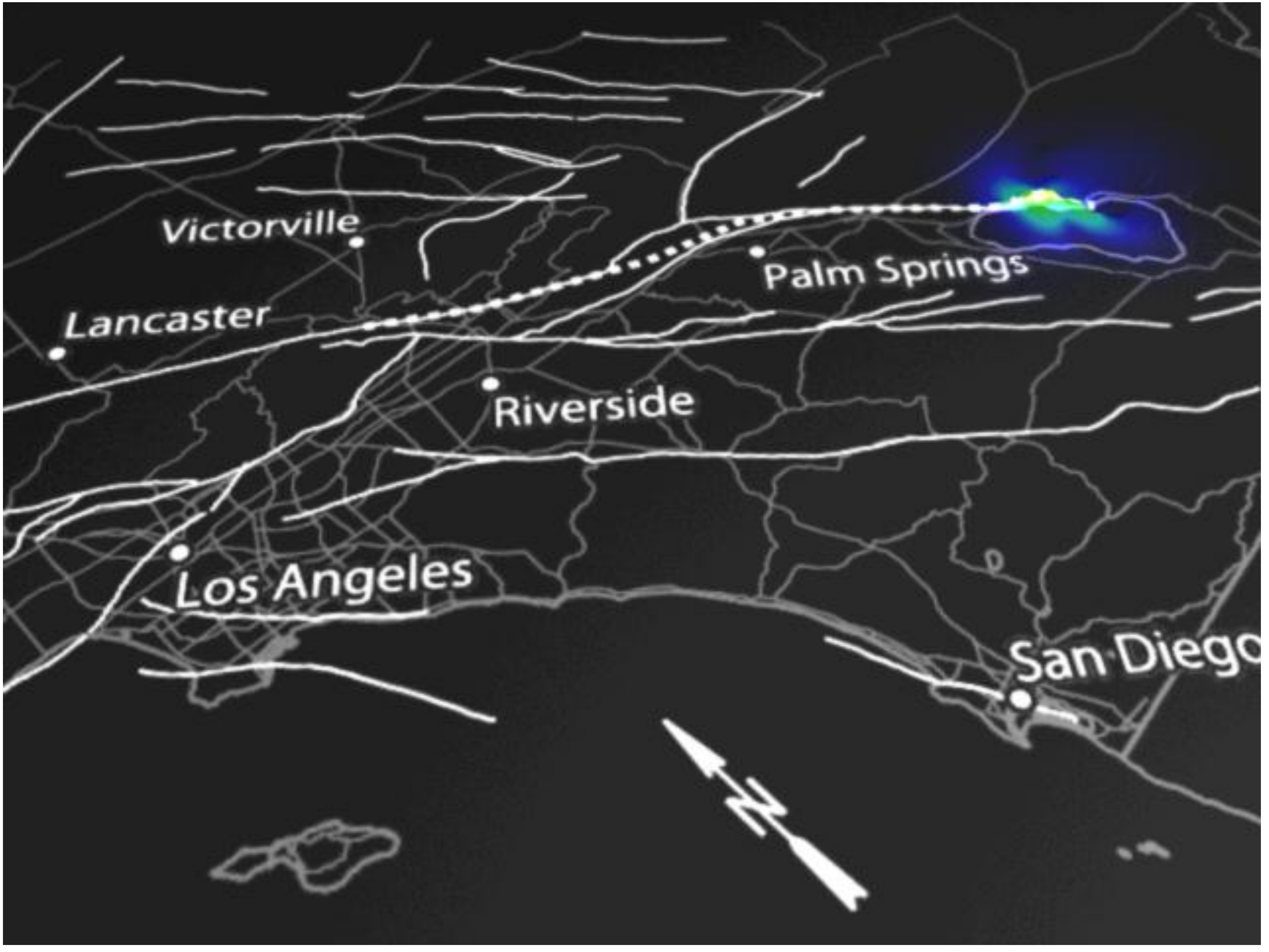
Slide Courtesy CSIRO, BOM, WMO

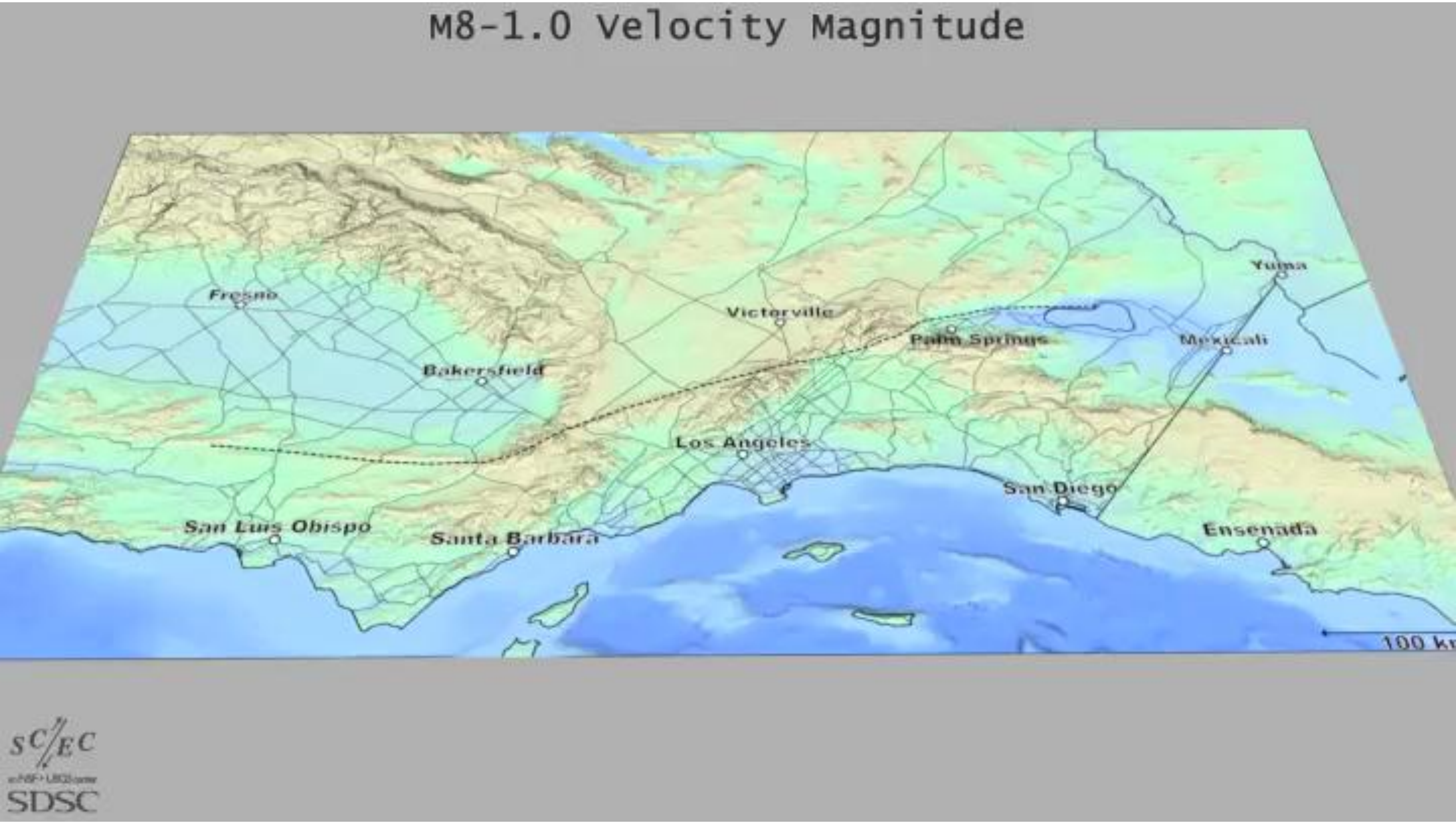
Types of Seismic Hazard Forecasts with Commercial or Governmental Market

Seismic Hazard Forecast Types	Forecast Users
Earthquake Early Warning Forecast	Public, Press, City, State, National Governments
Scenario Earthquake Seismograms Forecasts	Engineering Companies, Insurance Companies, State, National Governments
Short-term earthquake Forecasts	Public, Press, State and National Governments
Long-term Probabilistic Seismic Hazard Forecasts	Engineering Companies, Building Code Developers, Insurance companies, State and National Governments,

SCEC research is improving each forecast type.


Bakersfield
State Hwy
West Side Fwy
Los Angeles
Riverside
San Diego
Ensenada
101
110
710
405
105
21.0W , 34.5N


Victorville
Lancaster
Palm Springs
Riverside
Los Angeles
San Diego
N



SCEC M8 Simulation (Feb 2011)

Presentation Topics

Interesting new developments in seismology, including:

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4. Preparing your Earthquake Response

Southern California in 1857

The most recent ‘big one’ in southern California

Southern California in 2008

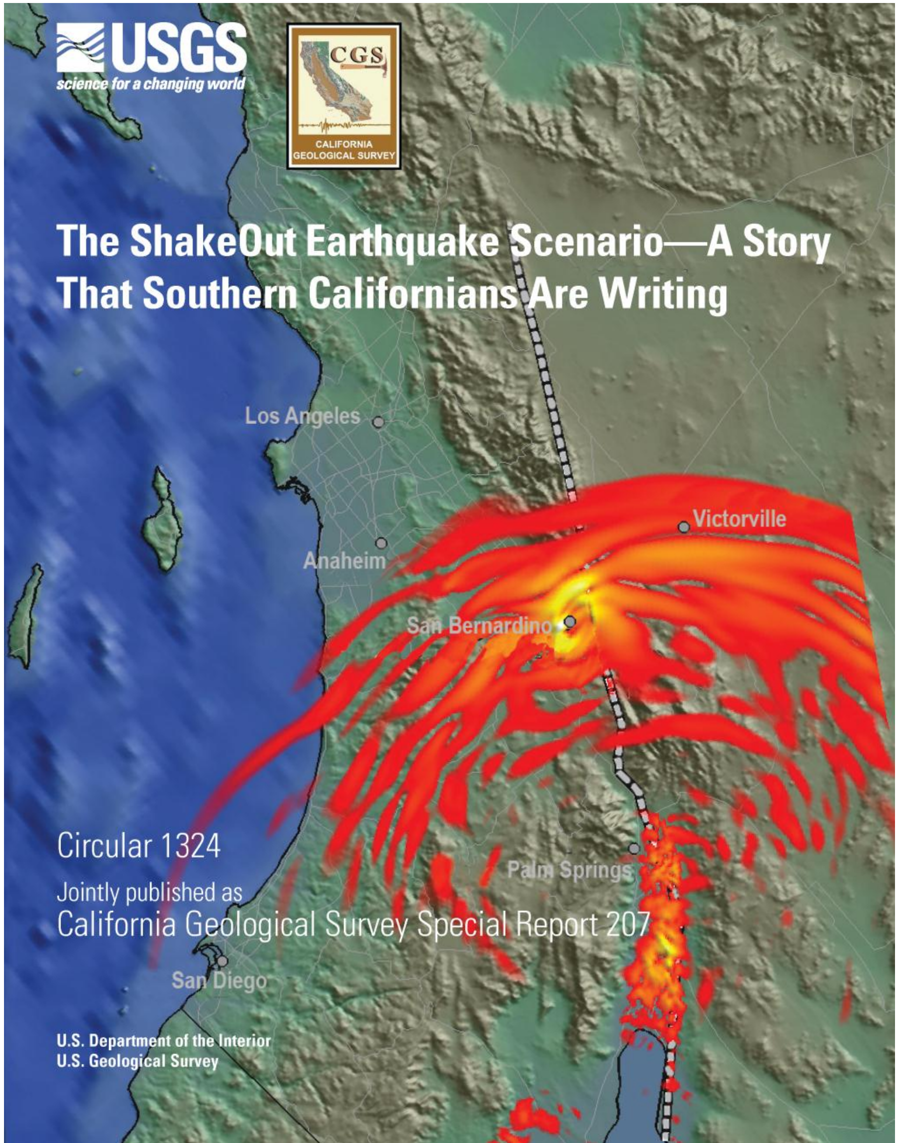
- Over 23 million people
- Fastest growing areas are close to the San Andreas

Interior Secretary Kempthorne and California Governor

USGS
science for a changing world

CGS
CALIFORNIA GEOLOGICAL SURVEY

The ShakeOut Earthquake Scenario—A Story That Southern Californians Are Writing



Circular 1324

Jointly published as
California Geological Survey Special Report 207

U.S. Department of the Interior
U.S. Geological Survey

Shakeout Scenario “Disaster Equation”

Widespread Strong Ground Shaking

+ Shaking of Long Duration =

300,000 buildings significantly damaged

Widespread infrastructure damage

$213 billion damages

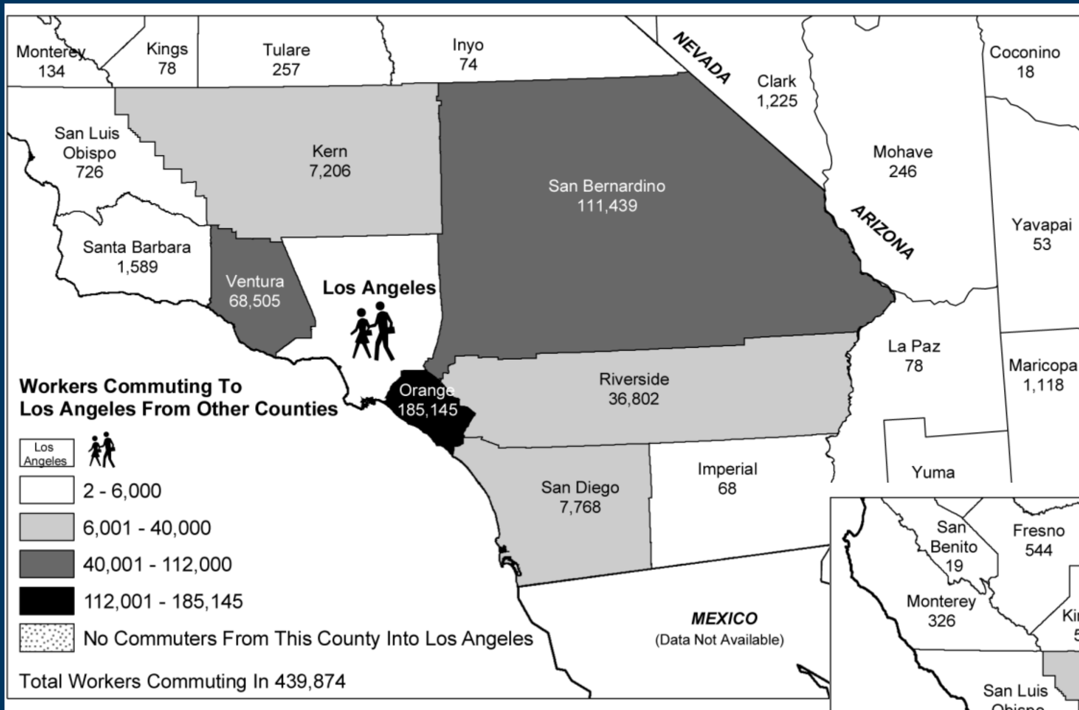
270,000 displaced persons

50,000 injuries

1,800 deaths

ShakeOut

Stranded Commuters (LA example)

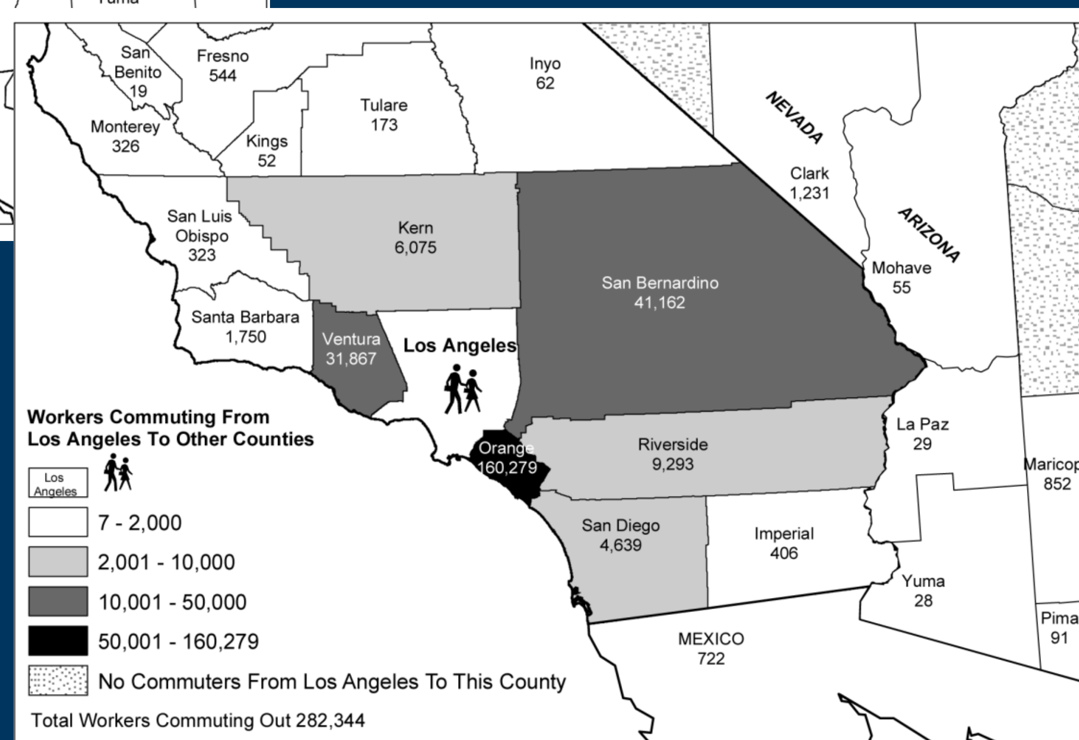


From **other counties into LA ~ 440k**

- 185k from Orange Co.
- 111k from San Bernardino Co.
- 37k from Riverside Co.

LA **to** other counties ~ 280k

- 160k to Orange Co.
- 41k to San Bernardino Co.
- 9k to Riverside Co.



Practice Emergency Management Procedures

Students Duck and Cover

Scientists and Politicians Duck and Cover

ShakeOut – Select Your ShakeOut Region

ShakeOut – Select Your ShakeO...

www.shakeout.org

ShakeOut.org

California | Nevada | Oregon | Washington | Idaho | Alaska | Arizona | SouthEast | British Columbia | Guam | New Zealand | Central US | Puerto Rico | Southern Italy | Utah

SHAKEOUT REGIONS AND CURRENT REGISTRATION LEVELS

Great ShakeOut earthquake drills help people in homes, schools, and organizations practice how to be safe during big earthquakes, and provide an opportunity for everyone to improve their overall preparedness. By participating, you can have **peace of mind** that you, your family, your co-workers and millions of others will **be better prepared to survive and recover quickly** from the next big earthquake in your region! As of today, there are over 12.2 million people that have been registered to participate in ShakeOut drills in 2012, including over 7.8 million people, on October 18th.

To register or learn more, click a ShakeOut region map or choose from this list: Select one...

10/18/2012
As of today: 6.7 million
(2011: 8.6 million)

10/18/2012
As of today: 100,000
(2011: Over 190,000)

10/18/2012
As of today: 46,000
(2011: Over 23,000)

10/18/2012
As of today: 300,000
(First year)

10/18/2012
As of today: 13,000
(2011: Over 86,000)

For More Information Please Visit:

www.scec.org

And Register to Participate in the
2012 Great California ShakeOut
(18 October 2012 at 10:18 am PT)
www.shakeout.org