

# Ground Motion Estimation with Antelope

European Antelope Users' Group  
Meeting

November 29, 2004

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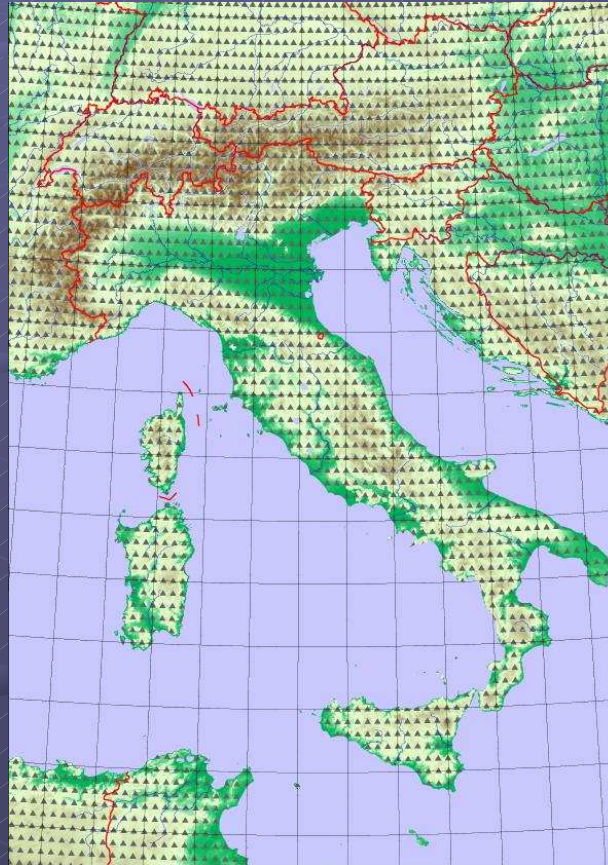
*Lindquist Consulting*

# Goal

Understand the true 2D ground motion  
right after an earthquake

# Ideal Solution: Measure It!

One station  
every 20 km



# Challenges

- Active research field
- Operational requirements
- Limited ground-motion data
  - augment by modeling
  - (perfect solution: stations everywhere!)

# DBGME

**DB** *Database*

**G** *Ground*

**M** *Motion*

**E** *Estimation*

# DBGME

**DB** *Database*

**G** *Ground*

**M** *Motion*

**E** *Estimation*

**QuakeMap**  
**QuakeMap**  
**QuakeMap**

# Requirements

- Algorithmic flexibility
- Robustness
- Near-real-time automation
- Ease of operation
- Integration into analyst review
- Self-contained and Maintainable

# Intent

- Provide an infrastructure
- Take care of:
  - How to run GME algorithm in near-real-time
  - How to support varying approaches
- Allow user to concentrate on:
  - What was the ground motion
  - How should we improve the technique



# Approach

- Complete orthogonality between  
Computation and Presentation
- GME Separate from Waveform-  
measurements
- Self-contained software
- Recipe/Delegate structure
- Default or User-generated delegates
- Database driven

# Inputs

- Earthquake Location and Magnitude (ML)
- Ground-motion measurements: PGA, PGV
- A-priori inputs
  - Vs30: 2-dimensional grid, shear-wave velocity
  - Station Corrections
  - Regression formula
  - Regression constants
  - Assembly strategy (delegate implementation)

# Real-time System Context

SSN Strong-Motion Monitoring Network

Local Average: 1min 0.24, 5min 0.25, 15min 0.14

System is up

Cpu Usage: 113 processes

Memory Usage: 100.0

Disk Usage: 100.0

Orb Ring Buffer Status: 14 connections

Processing Tasks

Task	Pid	cpu	cpu	rss	To Orb	From Orb	Latency
rtexec	5030	0.00	1.00	4.2	10.00		
rtexec	5031	0.00	1.00	1.7	10.00		
rtexec	5047	0.00	1.50	2.8	10.00	1.000	1.000
rtexec	5054	0.00	1.50	1.9	10.00	1.000	1.000
rtexec	5061	0.00	1.50	1.9	10.00	1.000	1.000
rtexec	5070	0.00	1.50	1.9	10.00	1.000	1.000
rtexec	5081	0.00	1.50	2.0	10.00	1.000	1.000
rtexec	5090	0.00	1.50	1.9	10.00		

Network Operation

processes ORB\_Clients ORB\_Sources ORB\_Data Etna

**Orbserver**

**orbwfmeas**

**wfmgme table**

**orbdetect**  
**orbtrigger**  
**orbassoc**  
**orbmag**

**dbgme**

**gme1.0: qgrid table**

ssn.orign

id	lat	lon	depth	time	orid	avid	idate	nacci	ndat	dtype	mt	mltd
33.477	-116.454	16.000	5/6/2003 (122)	6:10:31.802	1	2003122	6	8	8			
33.765	-117.023	8.000	5/6/2003 (122)	10:07:05.386	2	2003122	4	4	4			
33.426	-117.259	12.000	5/6/2003 (122)	10:08:11.818	3	2003122	11	11	11			
33.091	-116.312	24.000	5/6/2003 (122)	10:27:29.452	4	2003122	5	5	5			
34.058	-117.111	16.000	5/6/2003 (122)	14:18:11.386	5	2003122	11	11	11			
32.812	-116.182	16.000	5/6/2003 (123)	14:54:39.385	6	2003123	11	11	11			
32.947	-115.462	12.000	5/6/2003 (124)	0:54:30.794	7	2003124	6	6	6	2.38	2	
32.632	-116.182	12.000	5/6/2003 (124)	0:54:30.794	8	2003124	6	6	6	2.38	3	
33.477	-116.454	6.000	5/6/2003 (124)	6:10:31.802	9	2003124	6	6	6	1.05	5	
33.091	-116.759	20.000	5/6/2003 (124)	14:05:08.592	11	2003124	8	8	8	1.46	5	
33.477	-116.454	14.000	5/6/2003 (124)	6:10:31.802	12	2003124	6	6	6	1.29	6	
32.771	-116.179	14.000	5/6/2003 (125)	4:05:15.462	13	2003125	8	8	8	2.62	8	
33.091	-116.759	12.000	5/6/2003 (125)	4:05:03.024	14	2003125	4	4	4	2.97	8	
34.110	-116.870	20.000	5/6/2003 (125)	17:21:39.337	15	2003125	7	7	7	2.22	10	
33.091	-116.759	6.000	5/6/2003 (126)	17:18:15.739	16	2003126	8	8	8	0.91	11	
33.793	-116.699	24.000	5/6/2003 (126)	4:34:21.664	17	2003126	7	7	7	1.48	12	
34.262	-117.040	12.000	5/6/2003 (126)	13:21:54.170	18	2003126	10	11	11	2.62	13	
33.353	-116.140	20.000	5/6/2003 (126)	2:00:39.380	19	2003126	8	8	8	2.55	14	
41.005	-115.861	30.000	5/16/2003 (130)	0:34:11.882	20	2003130	10	10	10			
32.876	-116.316	6.000	5/16/2003 (130)	7:30:21.936	21	2003130	5	5	5	1.71	15	
33.474	-116.453	10.000	5/16/2003 (130)	15:20:25.176	22	2003130	11	11	11	1.29	16	
34.027	-117.497	10.000	5/17/2003 (131)	14:19:25.733	23	2003131	7	7	7	2.71	17	
33.278	-116.057	2.000	5/17/2003 (132)	02:31:14.331	24	2003132	8	8	8	2.35	18	
33.278	-116.260	2.000	5/17/2003 (133)	6:34:01.271	25	2003133	5	5	5	1.35	19	

**origin table**

ssn.qgrid

id	qgridname	recipe	time	qgridfmt	units	maxval	dir	dfile
orb1.2	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.2_trinetns_ess9.as
orb1.3	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.3_trinetns_ess9.as
orb1.4	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.4_trinetns_ess9.as
orb1.5	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.5_trinetns_ess9.as
orb1.6	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.6_trinetns_ess9.as
orb1.7	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.7_trinetns_ess9.as
orb1.8	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.8_trinetns_ess9.as
orb1.9	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.9_trinetns_ess9.as
orb1.10	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.10_trinetns_ess9.as
orb1.11	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.11_trinetns_ess9.as
orb1.12	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.12_trinetns_ess9.as
orb1.13	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.13_trinetns_ess9.as
orb1.14	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.14_trinetns_ess9.as
orb1.15	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.15_trinetns_ess9.as
orb1.16	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.16_trinetns_ess9.as
orb1.17	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.17_trinetns_ess9.as
orb1.18	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.18_trinetns_ess9.as
orb1.19	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.19_trinetns_ess9.as
orb1.20	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.20_trinetns_ess9.as
orb1.21	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.21_trinetns_ess9.as
orb1.22	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.22_trinetns_ess9.as
orb1.23	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.23_trinetns_ess9.as
orb1.24	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.24_trinetns_ess9.as
orb1.25	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.25_trinetns_ess9.as
orb1.26	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.26_trinetns_ess9.as
orb1.27	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.27_trinetns_ess9.as
orb1.28	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.28_trinetns_ess9.as
orb1.29	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.29_trinetns_ess9.as
orb1.30	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.30_trinetns_ess9.as
orb1.31	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.31_trinetns_ess9.as
orb1.32	trinetns_ess9	5/6/2003 (124)	0:54:30.794	as	9	0.05	2003/06/07/14	orb1.32_trinetns_ess9.as

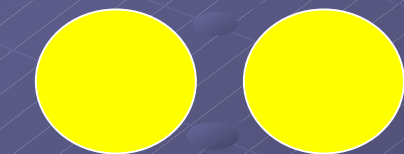
# Dbgme structure

- One parameter file: **recipes**

**dbgme**



**Dbview, parameter file**



recipe1

recipe2

recipe3

trinetsm\_es99

**Delegate A**

**Delegate B**



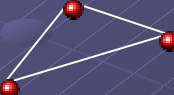
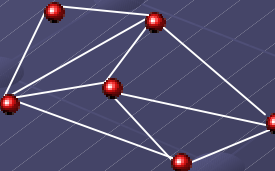

**Trinetsm\_es99**

**cggrid2db()**

**Delegates: C, Matlab, Shell**

# Computational Geometry Library

- Written from first principles
- Entities:

- Point 
- Pointset 
- Polygon 
- Partition 
- Grid 

Each point can:

- **Carry Data Values**
- **Carry Void Pointers**

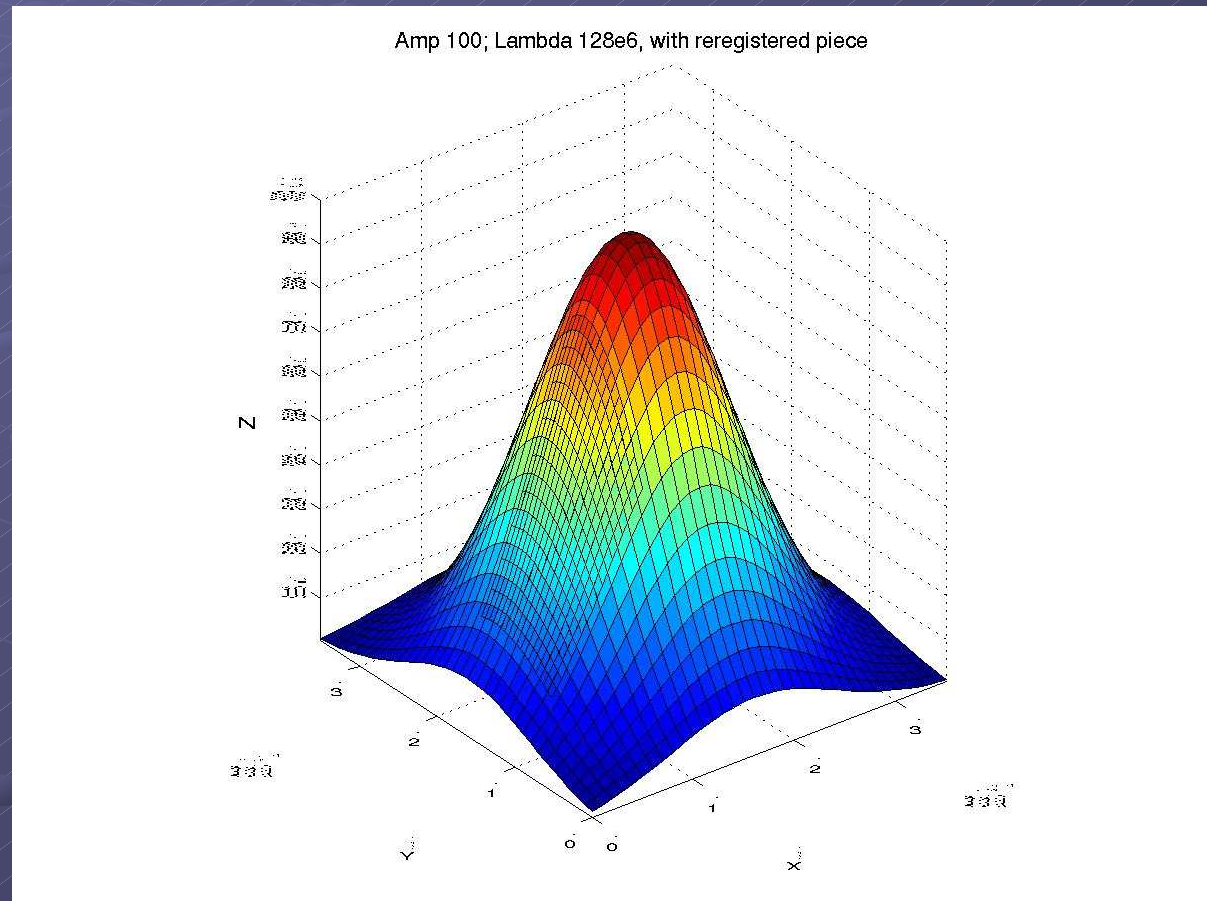
Grid Regularization

# Libcgeom: abilities

- Polygon containment
  - Is (x,y) in a given polygon
  - Which polygon of a partition contains (x,y)
- Triangulation of a set of points
  - Delaunay  $O(n^4)$
- Bicubic overrelaxed **tensioned spline interpolation** (*Smith/Wessel Geophys. 1990*)
- Database links, e.g.  
*db2cgpointset(3), cggrid2db(3)*

# Libcgeom: various utilities

for example:  
re-registration  
of grids,  
Interpolation,  
Generic  
functions



# Tensioned Spline Fitting

- Like the GMT *surface* Command
  - Not multigrid approach (modern workstations)
  - Harmonic sol'n <green> Min. Curvature sol'n



# TriNet ShakeMap approach

- Wait for earthquake detection
- Collect PGA etc. measurements for earthquake
- Compute strong-motion centroid
- Reduce measurements to solid-rock equivalent
- Create a uniformly spaced (30 km) grid of phantom stations from attenuation relations
- Spline fit to Interpolated, fine grid
- Correct to local site amplification
- Contour plot

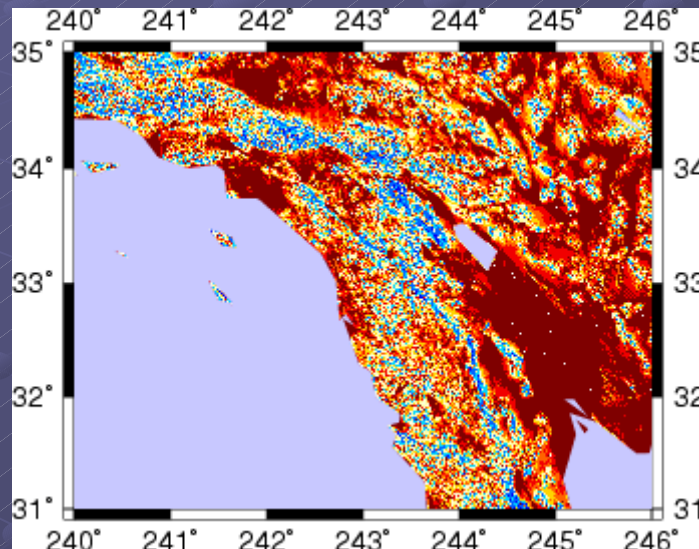
# 2D Shear-wave velocity

- Current input: 2D ASCII grid for region
- Normal Approach:
  1. Acquire GIS Geologic Map of region
  2. Assign Vs30 values to Geologic Units
  3. Create grid of assumed Vs30 values
  4. Benchmark with boreholes and geologists
- Test approach:
  - Artificial input

# Artificial Vs30: Southern CA

Guess Vs30 from GTOPO30:

**Steep = Fast. Flat = Slow.**



$$Vs30 \sim 300 \text{ m/s} + \text{abs}(\text{norm}(\text{grad}(\text{topo}))) * 900 \text{ m/s}$$

# Trinetsm\_es99 delegate

- Computing an approximate version of the TriNet algorithm
  - No strong-motion centroid calculation
  - Fake geology => exact comparison hard
- Running for three months on Anza data
- PGAs and PGVs
- Eyeball comparisons reasonable for adequately sized quakes

# Sp\_bssa87 delegate

- Computing an approximate version of the TriNet algorithm; *except:*
- Replace Joyner/Boore (1981) attenuation  
*with*  
Sabetta/Pugliese (1987) attenuation
- Configurable parameters

# Computation and Presentation are Separated

- Raw measurements are in Database
- Computed grids are in Database

wfmgme table

sta	chas	measstype	filter	times	val1	val2	units1
SNN1	HCE	pskwr	IN	5/02/2003 12:23	0:10:38.200	-2732.220	-739.893 m/s
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:11:02.700	-2089.770	-1074.091 m/s
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:11:02.120	9720.165	-729.442 m/s
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:10:38.200	29.131	4.350 m
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:11:02.700	20.222	-5.255 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:11:02.120	-23.336	-3.366 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:10:37.520	0.166	0.269 m
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:11:03.100	-0.105	0.099 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:10:38.000	-0.268	-0.383 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:15:15.000	-340.181	-216.249 m/s
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:15:15.400	-5437.912	2891.146 m/s
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:15:15.400	-0.364	-0.271 m
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:15:14.120	-7.817	3.488 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:15:14.120	1.256	0.279 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:15:14.120	-0.712	-0.433 m
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:15:14.120	0.815	0.425 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:15:14.120	0.024	0.025 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:21:40.400	-2524.221	965.311 m/s
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:21:40.380	-2636.644	-1010.229 m/s
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:21:40.400	-3720.354	-739.425 m/s
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:21:40.400	35.205	-6.363 m
SNN1	MON	pskwr	INT	5/02/2003 12:23	0:21:40.400	-16.745	0.678 m
SNN1	HCE	pskwr	INT	5/02/2003 12:23	0:21:40.400	22.263	4.115 m

gme1.0: qgrid table

gridname	recipe	time	aprifmt units	maval	dir	dfile
or14.2	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.062 2003/Vdgrn/124 or14.2.Trinetra.ec99.as
or14.8	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.062 2003/Vdgrn/124 or14.8.Trinetra.ec99.as
or14.9	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.9.Trinetra.ec99.as
or14.10	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.094 2003/Vdgrn/124 or14.10.Trinetra.ec99.as
or14.11	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.095 2003/Vdgrn/124 or14.11.Trinetra.ec99.as
or14.12	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.096 2003/Vdgrn/124 or14.12.Trinetra.ec99.as
or14.13	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.063 2003/Vdgrn/124 or14.13.Trinetra.ec99.as
or14.14	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.096 2003/Vdgrn/124 or14.14.Trinetra.ec99.as
or14.15	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.044 2003/Vdgrn/124 or14.15.Trinetra.ec99.as
or14.16	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.062 2003/Vdgrn/124 or14.16.Trinetra.ec99.as
or14.17	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.043 2003/Vdgrn/124 or14.17.Trinetra.ec99.as
or14.18	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.062 2003/Vdgrn/124 or14.18.Trinetra.ec99.as
or14.19	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.054 2003/Vdgrn/124 or14.19.Trinetra.ec99.as
or14.20	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.063 2003/Vdgrn/124 or14.20.Trinetra.ec99.as
or14.21	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.044 2003/Vdgrn/124 or14.21.Trinetra.ec99.as
or14.22	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.084 2003/Vdgrn/124 or14.22.Trinetra.ec99.as
or14.23	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.099 2003/Vdgrn/124 or14.23.Trinetra.ec99.as
or14.24	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.24.Trinetra.ec99.as
or14.25	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.25.Trinetra.ec99.as
or14.26	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.26.Trinetra.ec99.as
or14.27	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.27.Trinetra.ec99.as
or14.28	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.095 2003/Vdgrn/124 or14.28.Trinetra.ec99.as
or14.29	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.075 2003/Vdgrn/124 or14.29.Trinetra.ec99.as
or14.30	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.095 2003/Vdgrn/124 or14.30.Trinetra.ec99.as
or14.31	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.096 2003/Vdgrn/124 or14.31.Trinetra.ec99.as
or14.32	Trinetra.ec99	5/04/2003 12:00	0:54:00.764	as	0	0.059 2003/Vdgrn/124 or14.32.Trinetra.ec99.as

# Dbgme\_show

*Peak Ground Acceleration*

*Trinetsm\_es99 delegate*

May 31, 2003

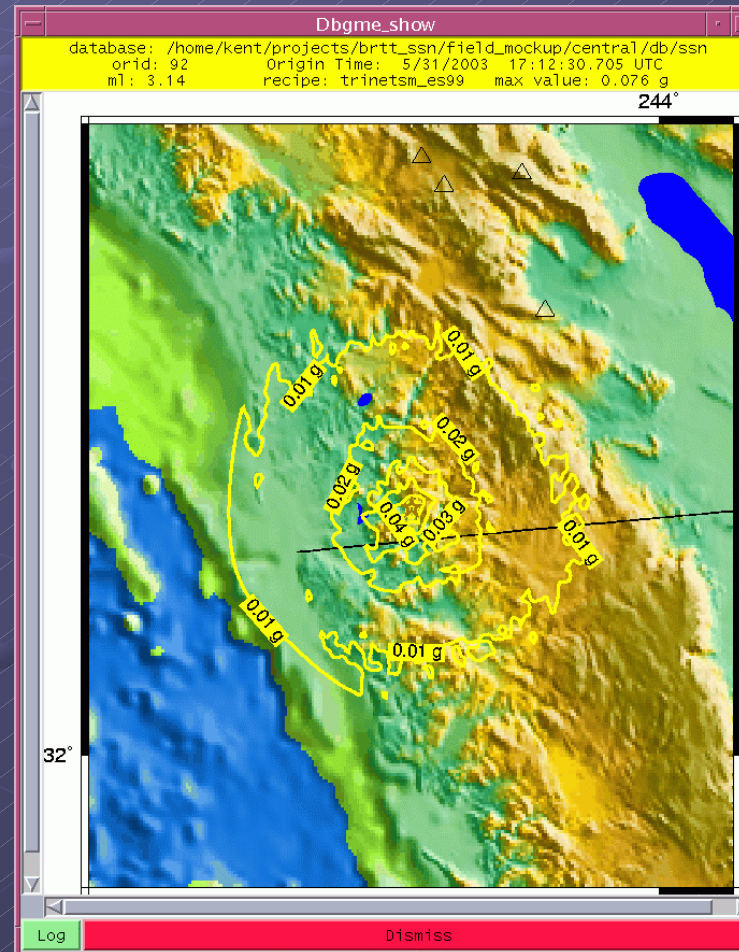
17:12 GMT

ML 3.14

Max 0.076 g

Lat 32.6513

Lon -116.7682



# Matlab Links

May 12, 2003

22:35 GMT

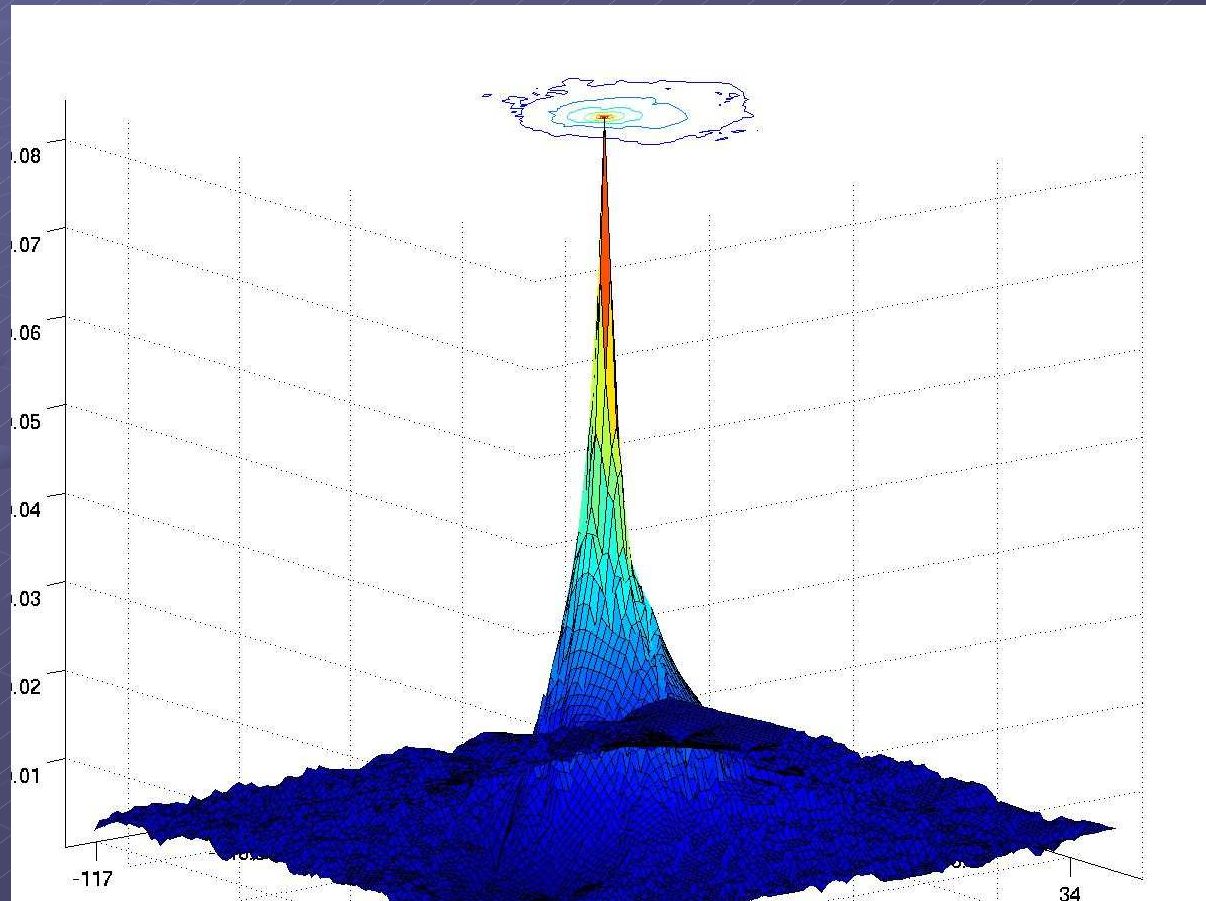
ML 2.95

Max 0.084 g

Lat 33.2710

Lon -116.0527

```
db=dbopen('ssn','r');  
db=dblookup(db,','qgrid','orid','24');  
cgg=cggrid(dbfilename(db));  
[x,y,z]=cggrid_getmesh(cgg);  
mysurfc(x,y,z)
```



November 29, 2004

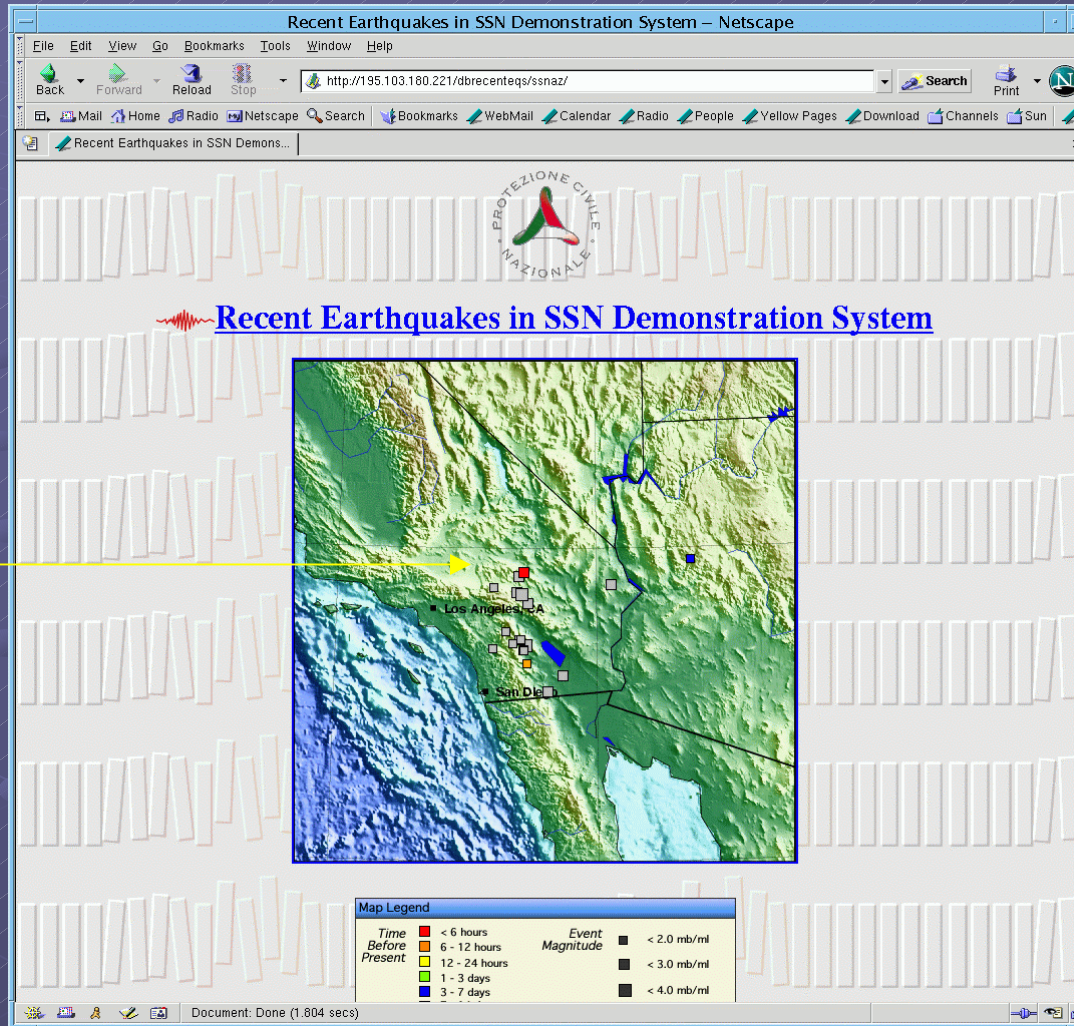
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# dbrecenteqs

- Automated, dynamic web-page creation
- Database Driven
- Perl, Antelope, GMT
- Configurable Architecture
- Technologies:
  - RDBMS->XML->XSLT->HTML
- Enhanced for SSN:
  - Includes Actual Station Measurements
  - Multiple Maps for different Qgrids
- Part of Antelope contrib: source code is here

# Overview Map of Recent Quakes



Recent Earthquakes

November 29, 2004

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QuakeMap

# Quick-link List of Recent Quakes

Recent Earthquakes in SSN Demonstration System – Netscape

http://195.103.180.221/dbrecenteqs/ssnaz/#quakeable

22 Earthquakes Shown on This Page:

Local Time	Magnitude	Region
<a href="#">08:18 AM CET Wednesday October 29th, 2003</a>	<a href="#">2.86 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">01:20 AM CET Wednesday October 29th, 2003</a>	<a href="#">Unknown</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">08:27 AM CEST Thursday October 23rd, 2003</a>	<a href="#">Unknown</a>	<a href="#">WESTERN ARIZONA</a>
<a href="#">02:04 AM CEST Wednesday October 22nd, 2003</a>	<a href="#">2.78 ML</a>	<a href="#">CALIFORNIA-MEXICO BORDER REGION</a>
<a href="#">11:49 PM CEST Tuesday October 21st, 2003</a>	<a href="#">1.12 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">09:39 PM CEST Tuesday October 21st, 2003</a>	<a href="#">2.53 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">03:24 PM CEST Tuesday October 14th, 2003</a>	<a href="#">1.77 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">11:57 AM CEST Tuesday October 14th, 2003</a>	<a href="#">Unknown</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">08:25 AM CEST Tuesday October 14th, 2003</a>	<a href="#">1.17 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">05:57 PM CEST Saturday October 11th, 2003</a>	<a href="#">1.57 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">02:30 PM CEST Saturday October 11th, 2003</a>	<a href="#">Unknown</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">11:28 AM CEST Saturday October 11th, 2003</a>	<a href="#">1.76 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">11:14 AM CEST Saturday October 11th, 2003</a>	<a href="#">2.92 ML</a>	<a href="#">CALIFORNIA-ARIZONA BORDER REGION</a>
<a href="#">02:31 PM CEST Friday October 10th, 2003</a>	<a href="#">1.41 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">10:07 AM CEST Friday October 10th, 2003</a>	<a href="#">1.15 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">04:27 AM CEST Friday October 10th, 2003</a>	<a href="#">3.57 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">02:37 PM CEST Thursday October 9th, 2003</a>	<a href="#">2.33 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">11:29 AM CEST Thursday October 9th, 2003</a>	<a href="#">2.44 ML</a>	<a href="#">CALIFORNIA-MEXICO BORDER REGION</a>
<a href="#">09:33 AM CEST Thursday October 9th, 2003</a>	<a href="#">3.22 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">09:00 AM CEST Thursday October 9th, 2003</a>	<a href="#">2.31 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">05:33 AM CEST Thursday October 9th, 2003</a>	<a href="#">1.41 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>
<a href="#">01:50 AM CEST Thursday October 9th, 2003</a>	<a href="#">1.40 ML</a>	<a href="#">SOUTHERN CALIFORNIA</a>

Credits:

[Wessel and Smith's Generic Mapping Tools](#)  
[Sandwell/Smith Marine Bathymetry](#)

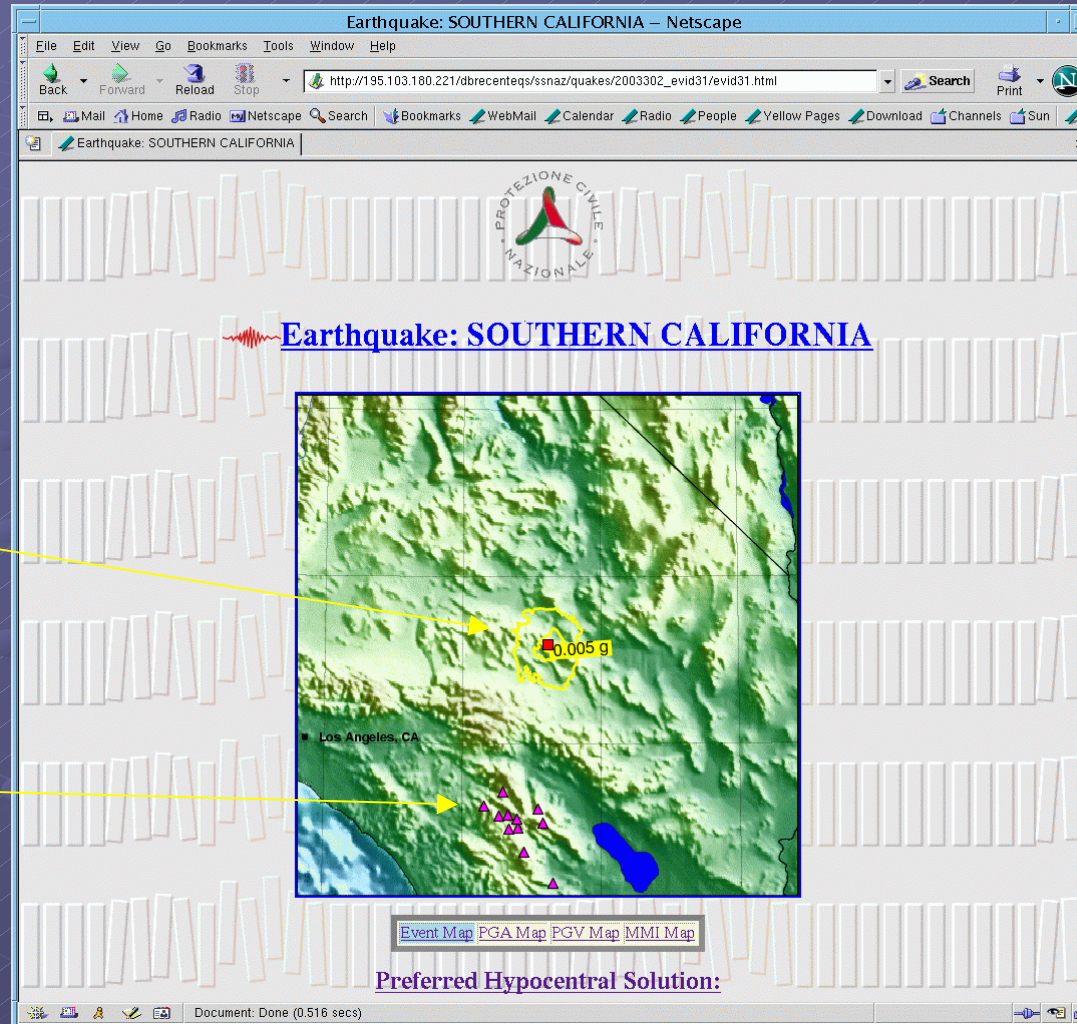
Document: Done (1.804 secs)

November 29, 2004

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QuakeMap

# Oct. 29, 2003 ML 2.86

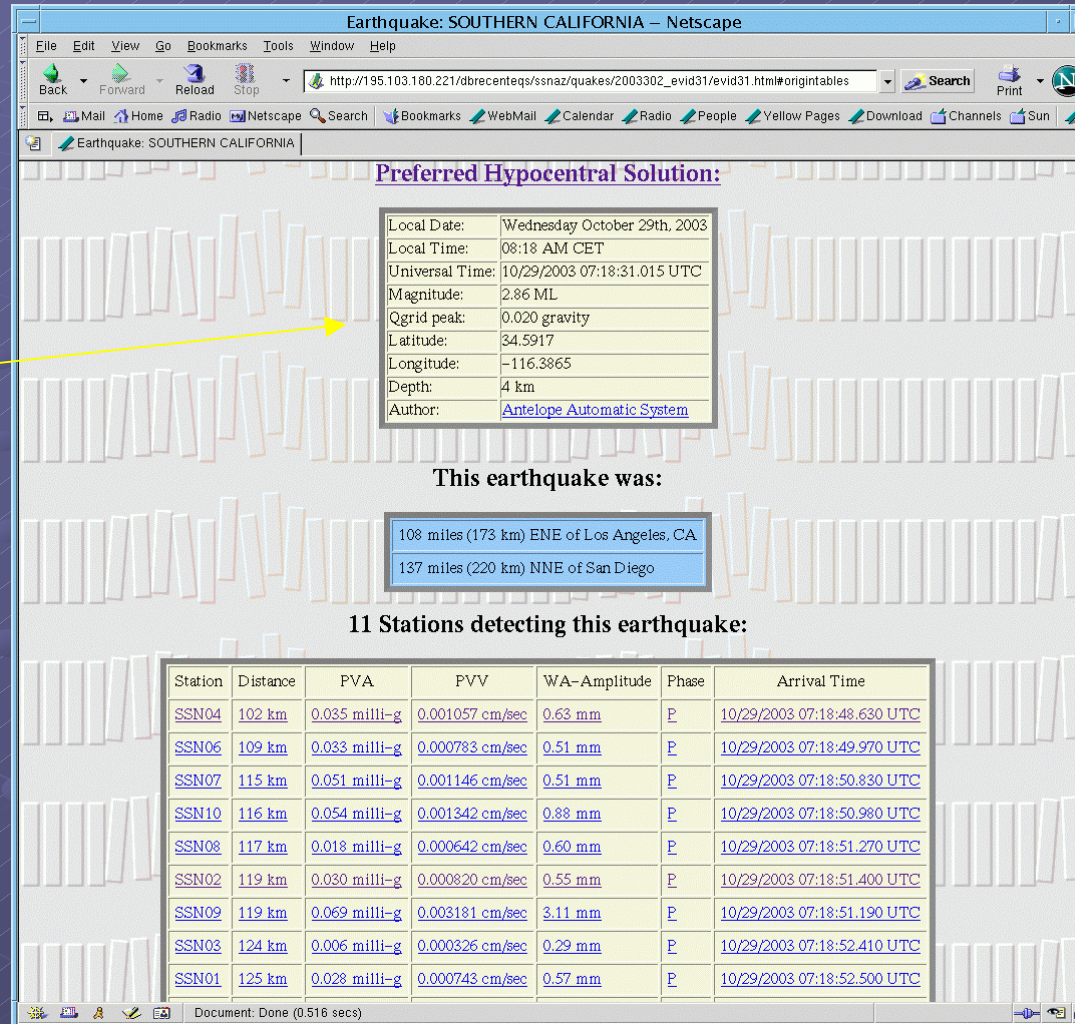


PGA Contours

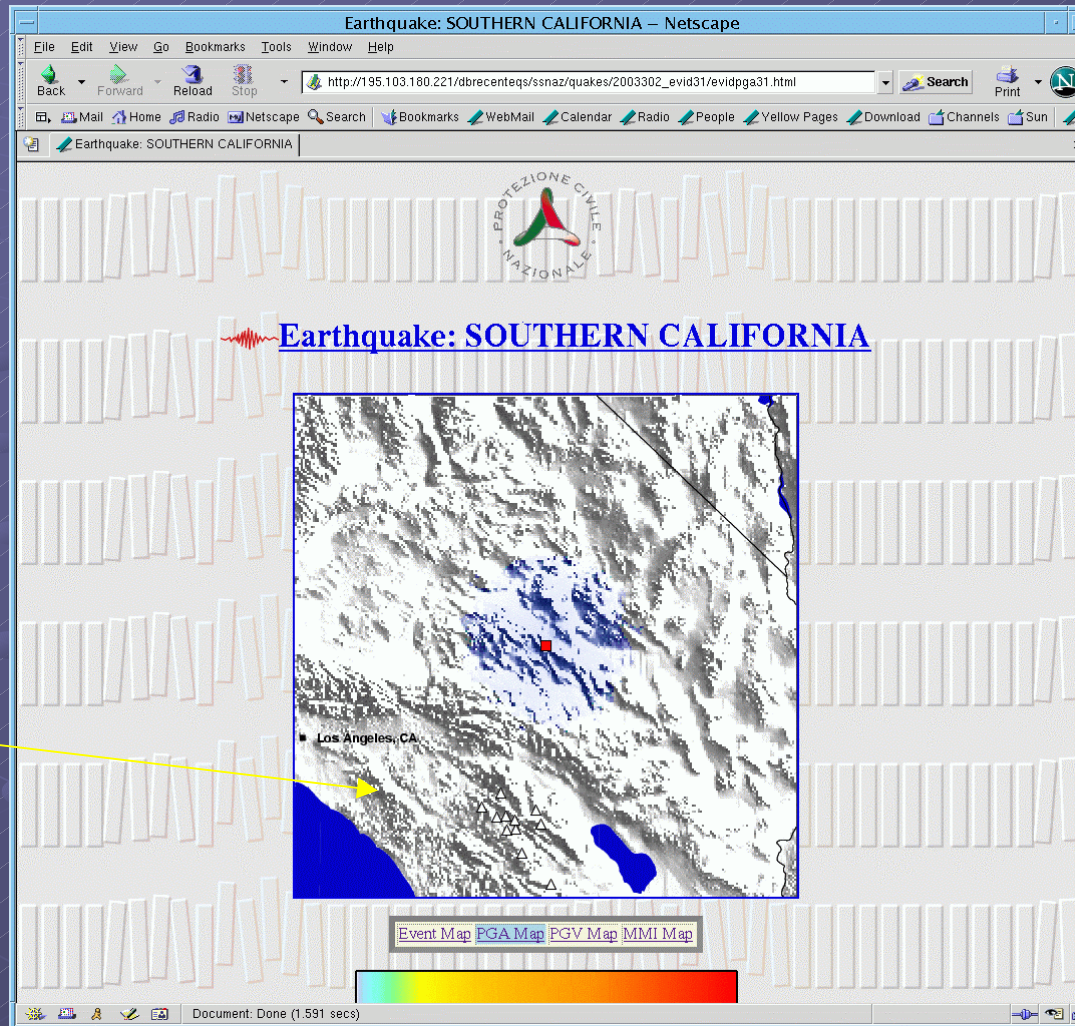
Detecting Stations

# Vital Statistics for Oct. 29 Event

20 milli-g  
Qgrid Peak



# Shaded Contours of PGA



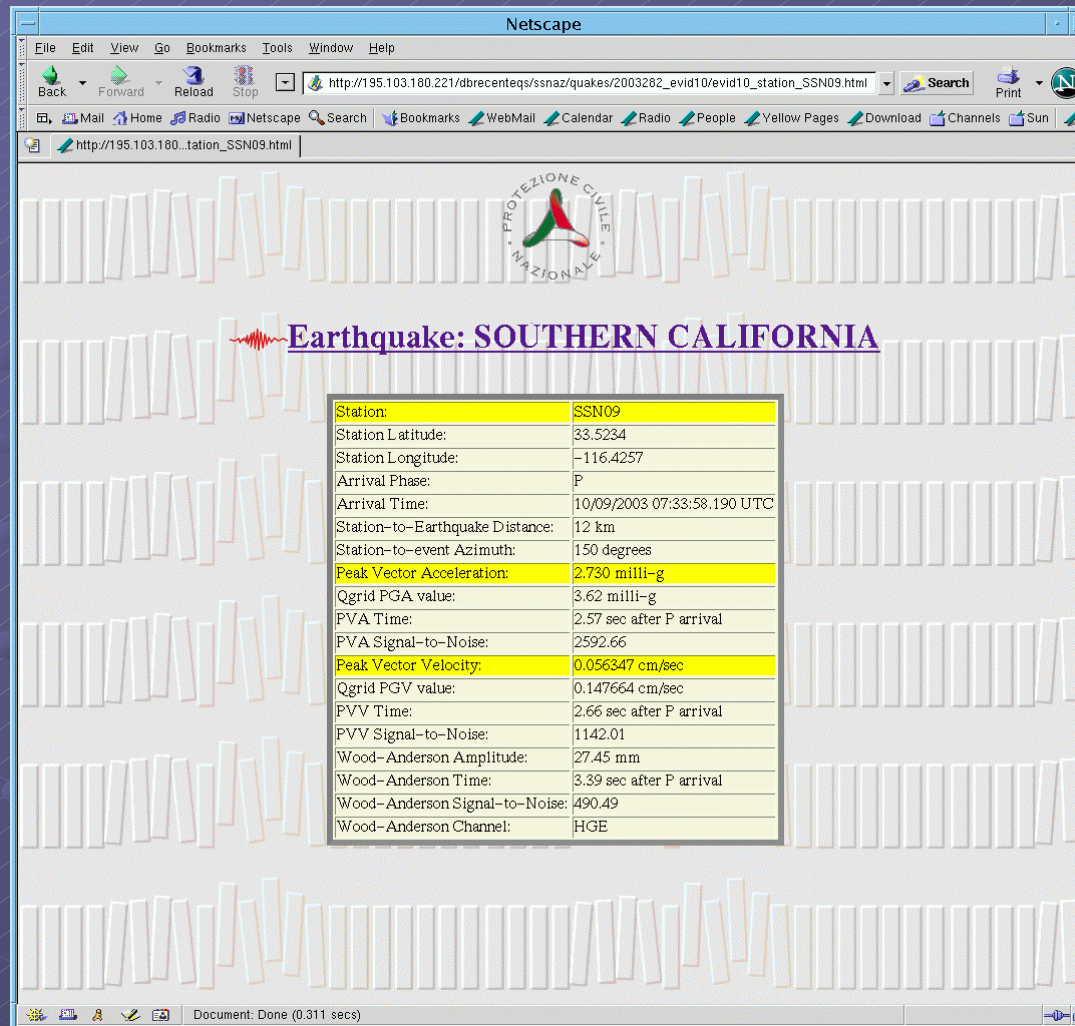
Measured PGAs  
At stations plotted  
On Same color  
scale

November 29, 2004

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QuakeMap

# Detailed Info for Each Station



PROTEZIONE CIVILE NAZIONALE

Earthquake: SOUTHERN CALIFORNIA

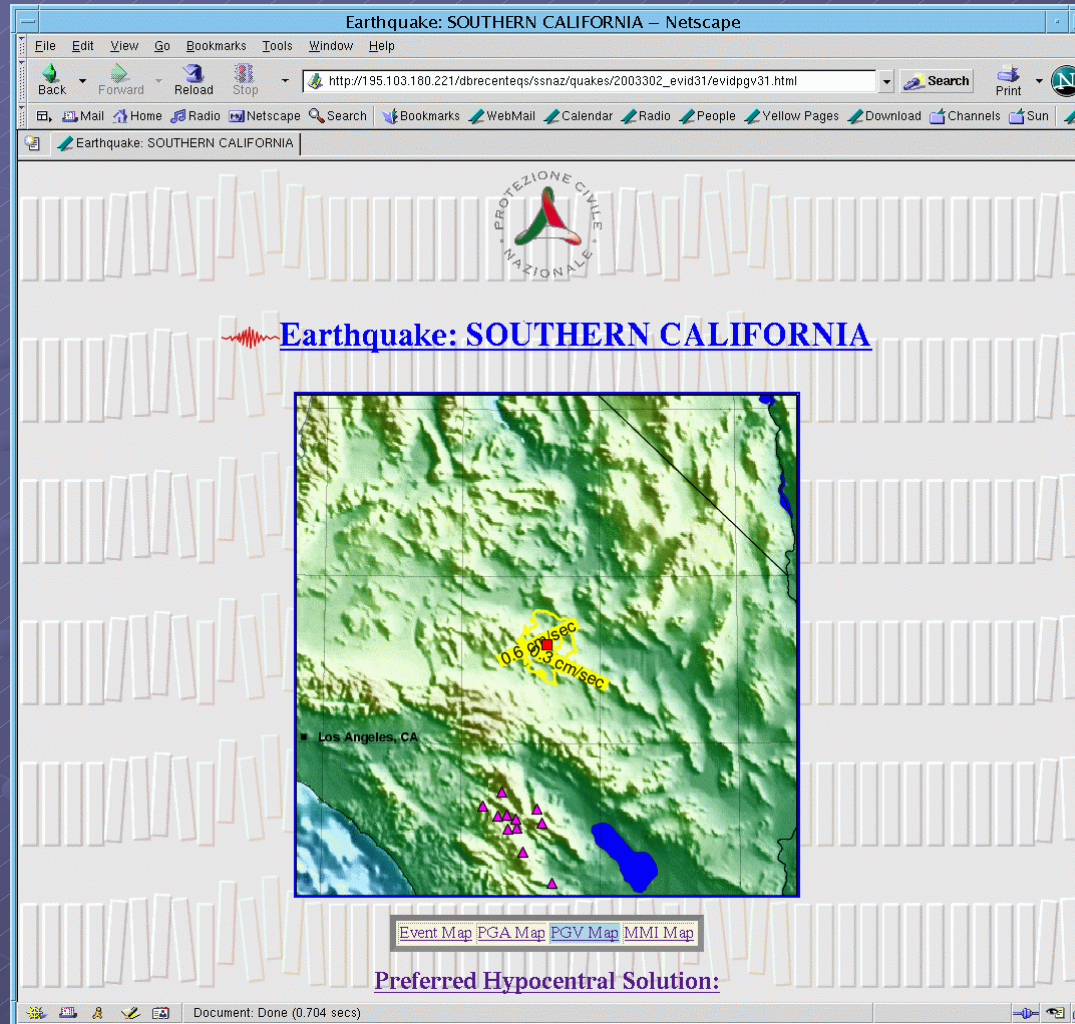
Station:	SSN09
Station Latitude:	33.5234
Station Longitude:	-116.4257
Arrival Phase:	P
Arrival Time:	10/09/2003 07:33:58.190 UTC
Station-to-Earthquake Distance:	12 km
Station-to-event Azimuth:	150 degrees
Peak Vector Acceleration:	2.730 milli-g
Qgrid PGA value:	3.62 milli-g
PVA Time:	2.57 sec after P arrival
PVA Signal-to-Noise:	2592.66
Peak Vector Velocity:	0.056347 cm/sec
Qgrid PGV value:	0.147664 cm/sec
PVV Time:	2.66 sec after P arrival
PVV Signal-to-Noise:	1142.01
Wood-Anderson Amplitude:	27.45 mm
Wood-Anderson Time:	3.39 sec after P arrival
Wood-Anderson Signal-to-Noise:	490.49
Wood-Anderson Channel:	HGE

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# PGV Contour Map



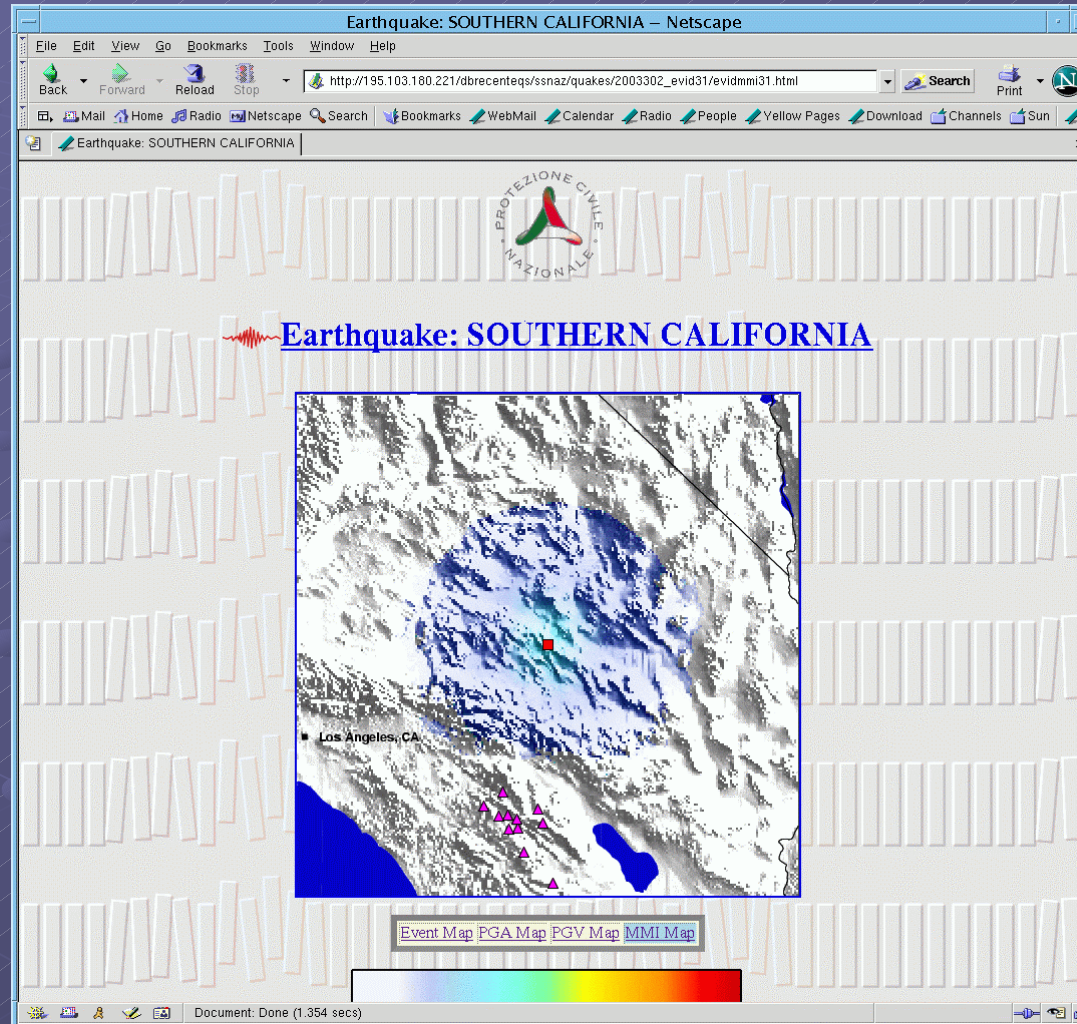
November 29, 2004

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# Instrumental Modified Mercalli Intensity



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**QuakeMap**

# Summary

- 2-D ground-motion estimates possible
- Requires
  - Multiple real-time stations
  - extensive a-priori data:  $V_s30$ , attenuation
- Scientifically complex; active research field