Ground Motion Estimation with Antelope

European Antelope Users' Group Meeting

November 29, 2004

Dr. Kent Lindquist

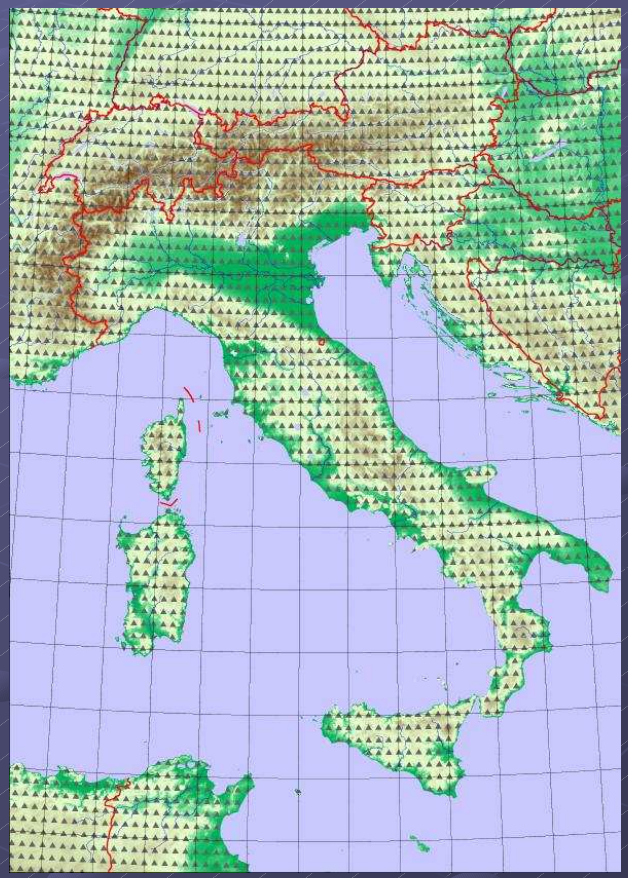
Lindquist Consulting

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

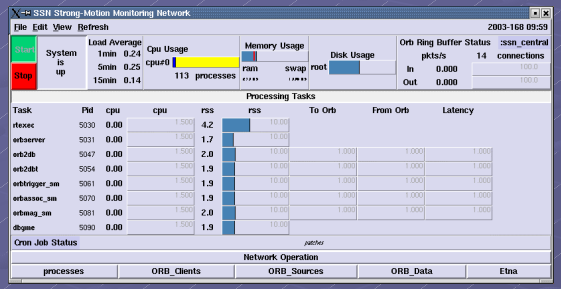
Approach

- 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)

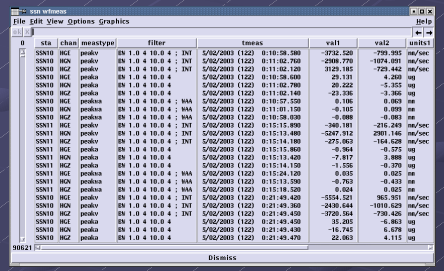
Real-time System Context



Orbserver

orbwfmeas

wfmgme table



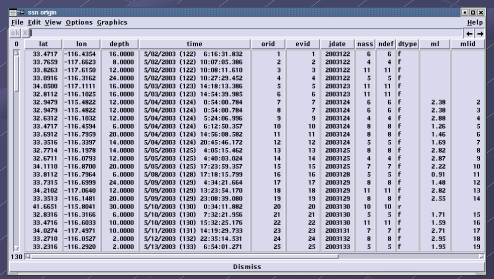
dbgme

orbdetect

orbtrigger

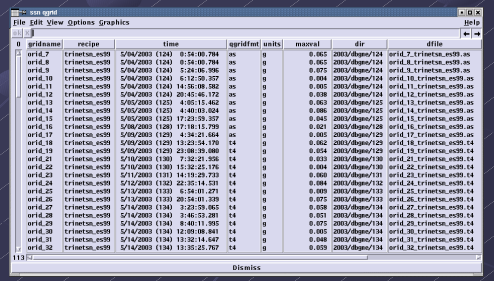
orbassoc

orbmag



origin table

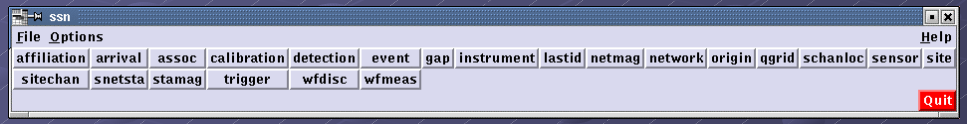
gme1.0: qgrid table



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

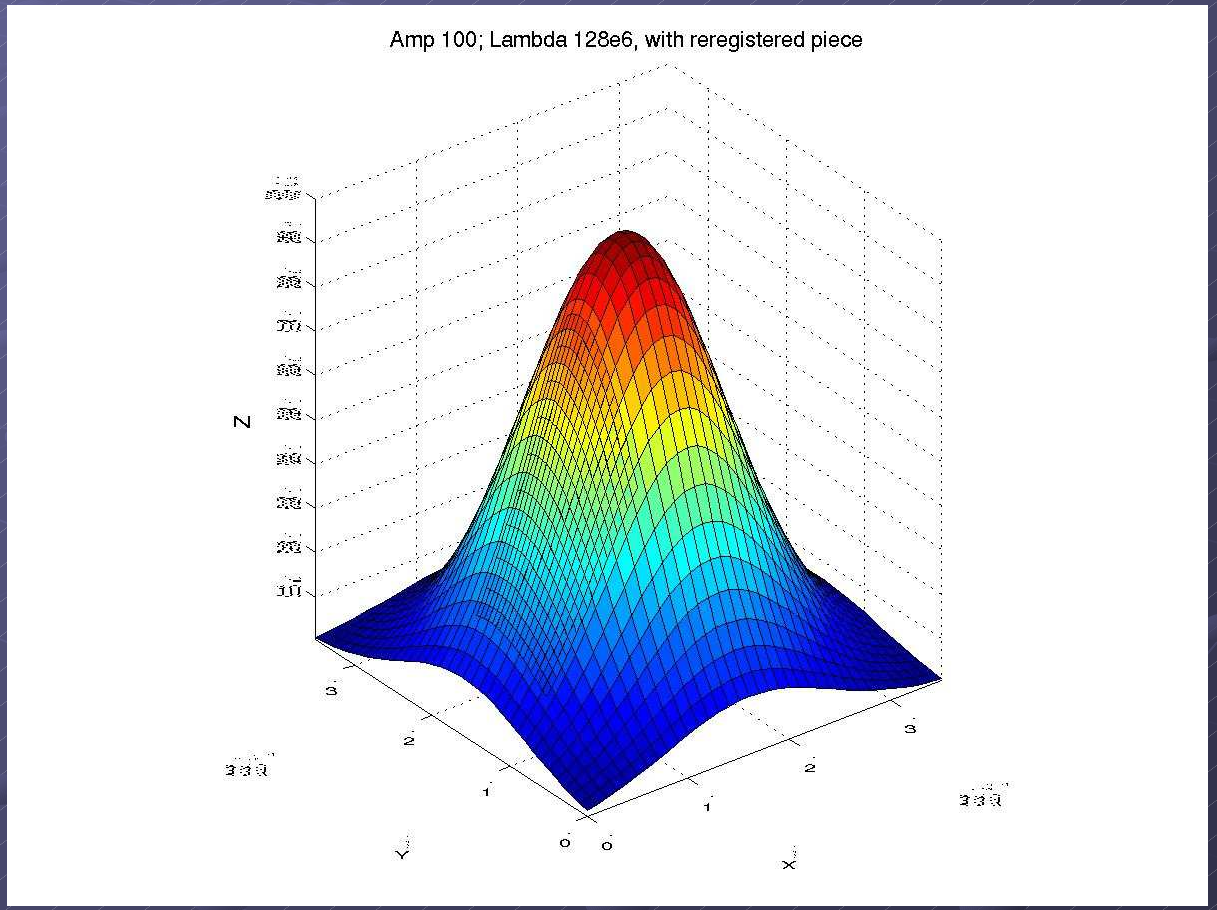
Libcgeom: abilities

- 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 <tension> 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

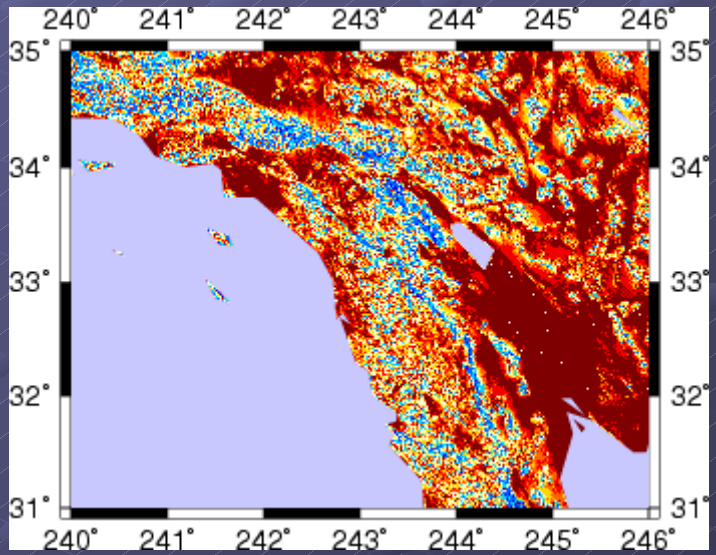
2D Shear-wave velocity

- 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 ~ 300 m/s + abs(norm(grad(topo))) * 900 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

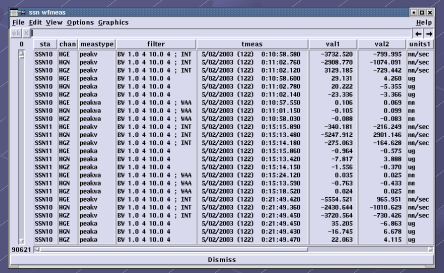
Sabetta/Pugliese (1987) attenuation

- Configurable parameters

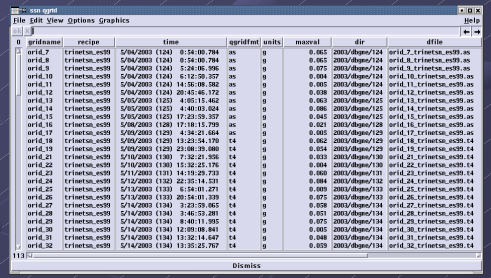
Computation and Presentation are Separated

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

wfmgme table



gme1.0: qgrid table

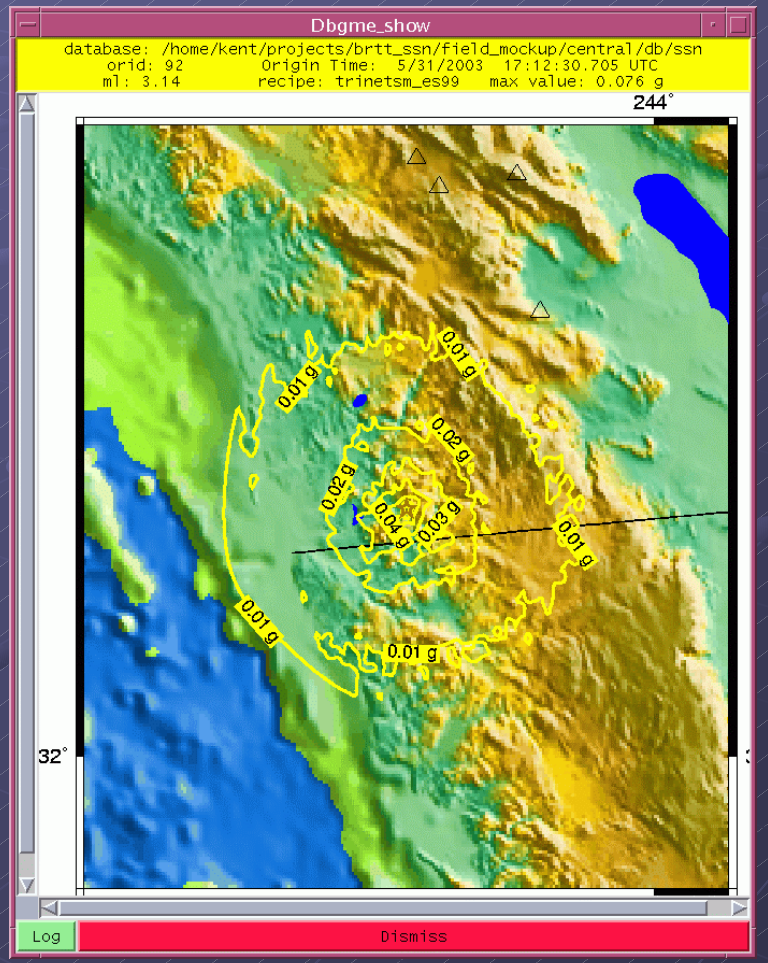


Dbgme_show

Peak Ground Acceleration

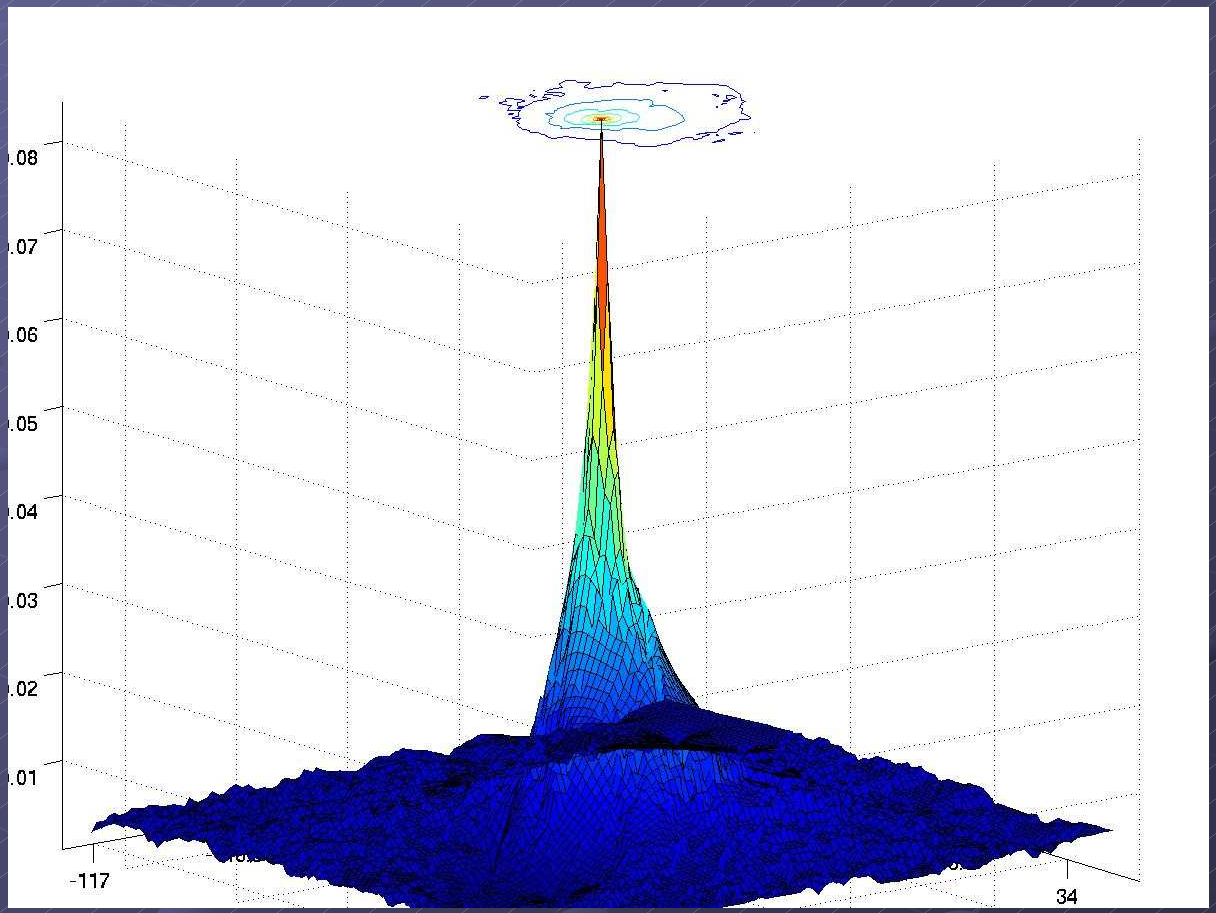
Trinetsm_es99 delegate

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

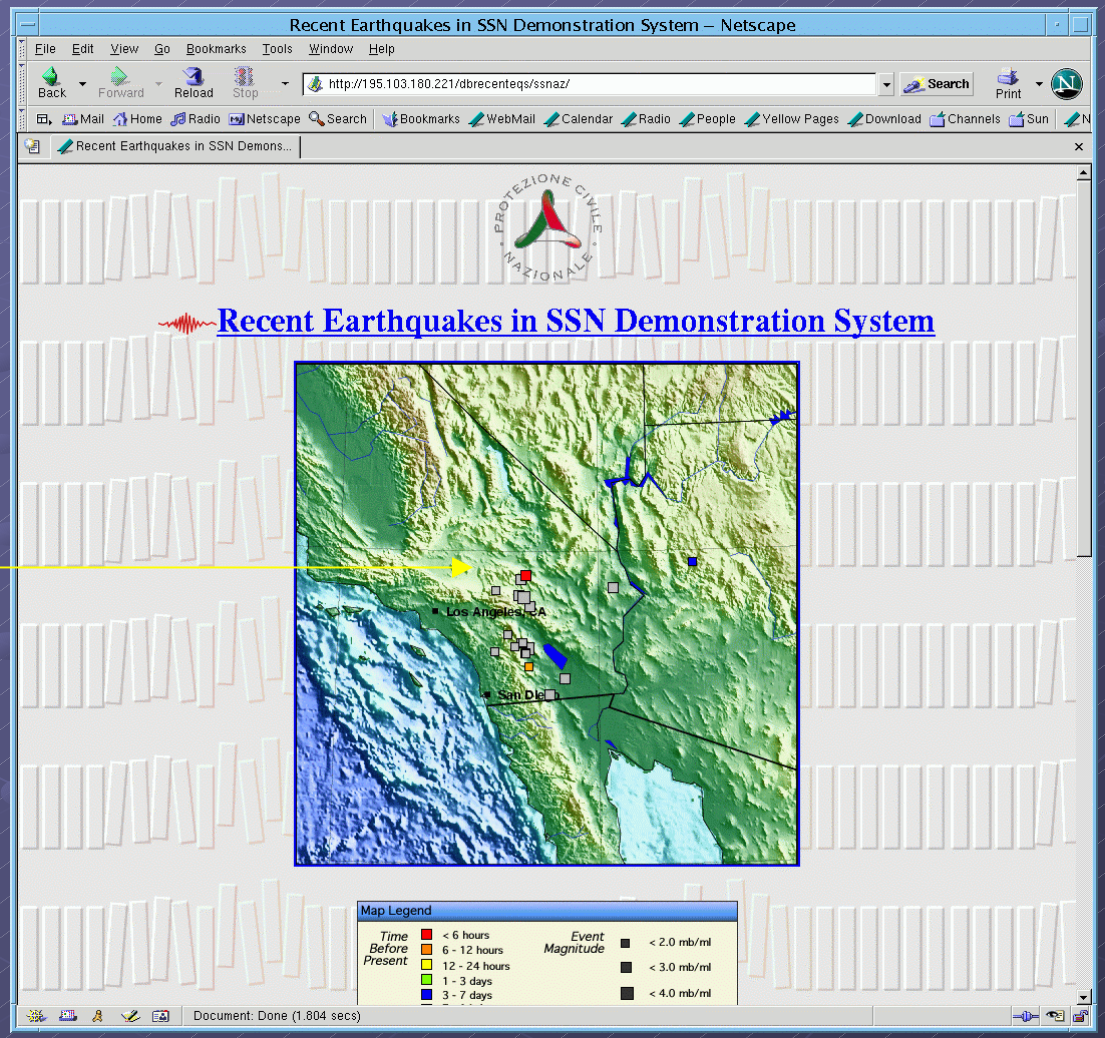



```
db=dbopen('ssn','r');
db=dblookup(db,'','qgrid','orid','24');
cgg=cggrid(dbfilename(db));
[x,y,z]=cggrid_getmesh(cgg);
mysurfc(x,y,z)
```

dbrecenteqs

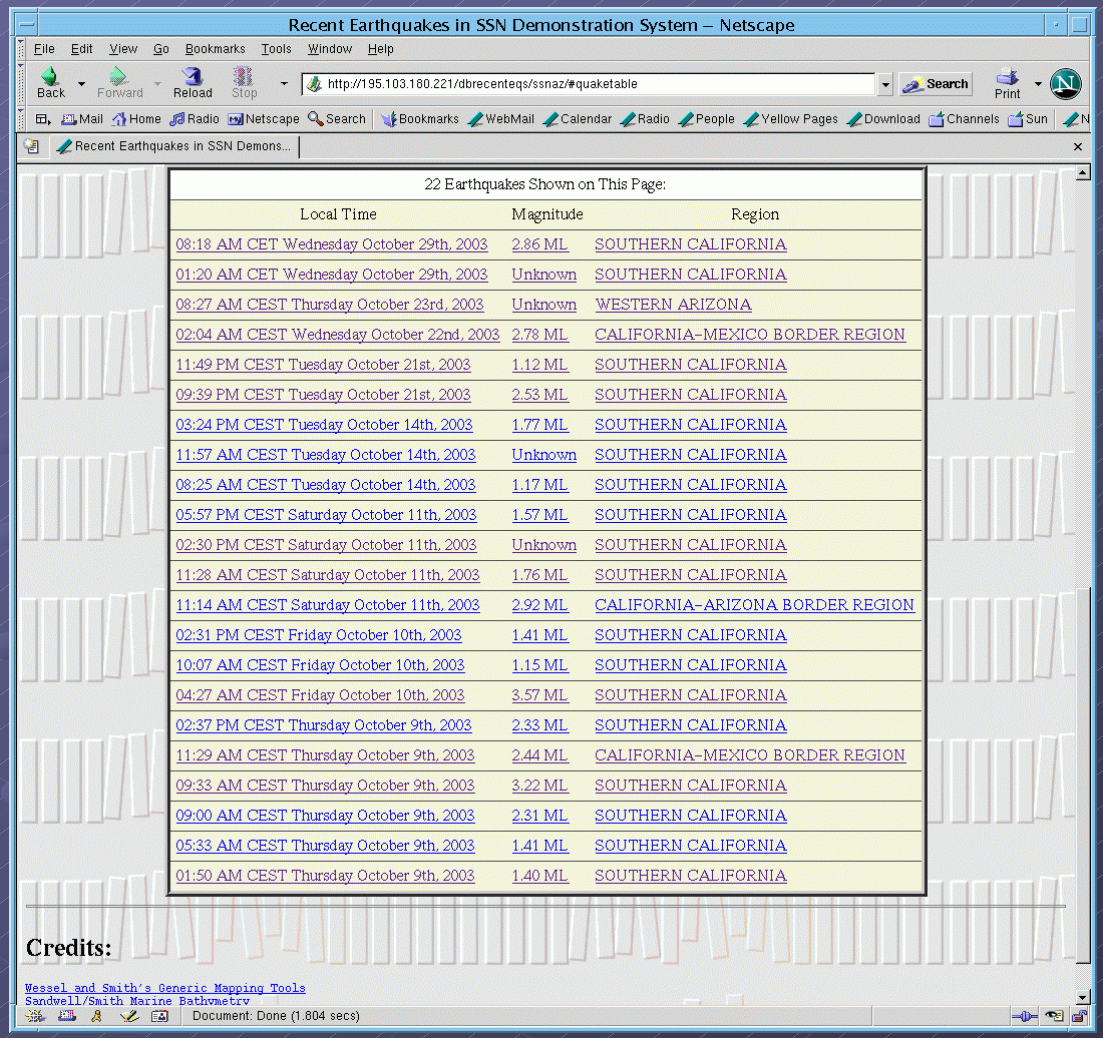
- Automated, dynamic web-page creation
- Database Driven
- Perl, Antelope, GMT
- Configurable Architecture
- Technologies:
  - RDBMS->XML->XSLT->HTML
- Enhanced for SSN:
  - Includes Actual Station Measurements
  - Multiple Maps for different Qgrids
- Part of Antelope contrib: source code is here

Overview Map of Recent Quakes

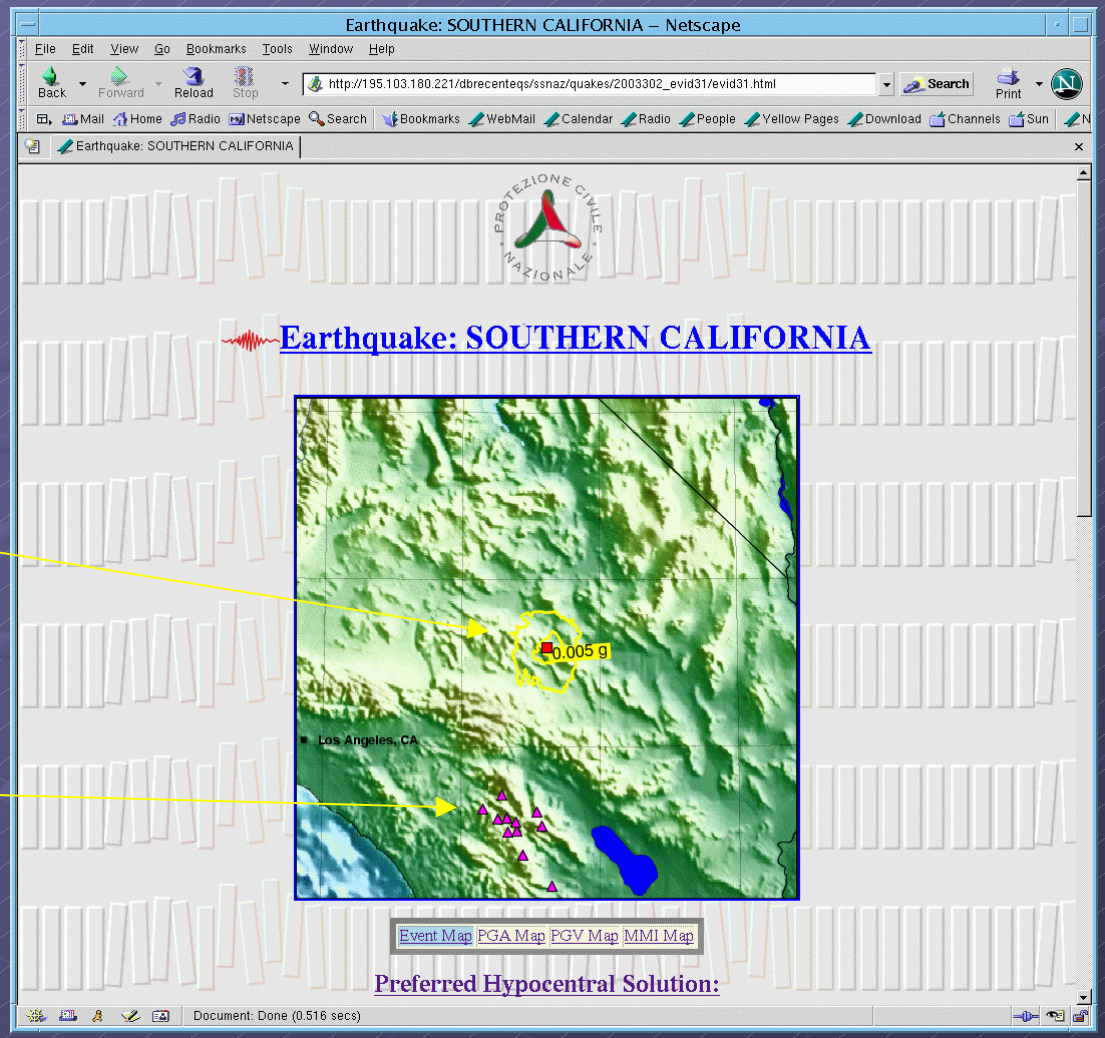


Recent Earthquakes

Quick-link List of Recent Quakes



Oct. 29, 2003 ML 2.86

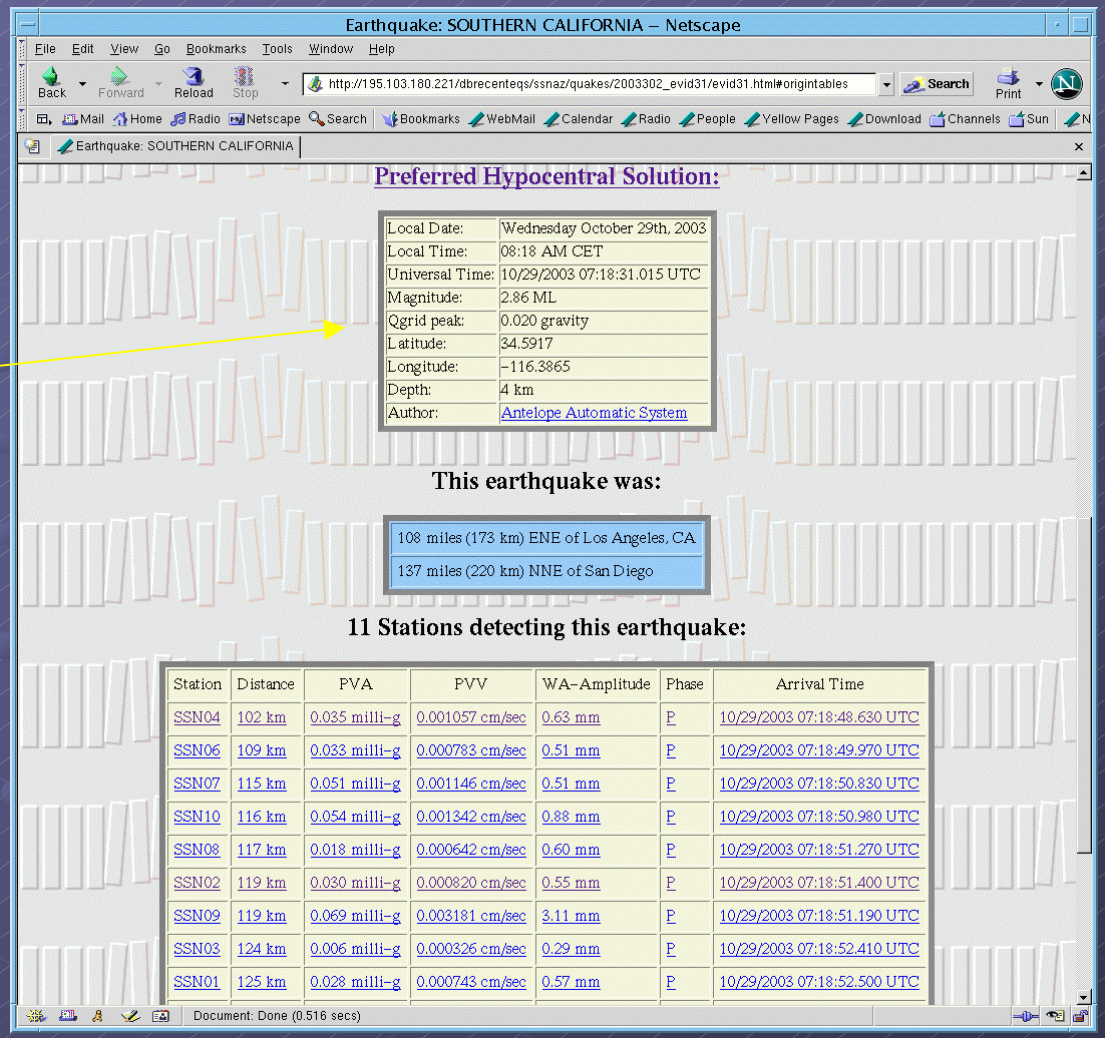


PGA Contours

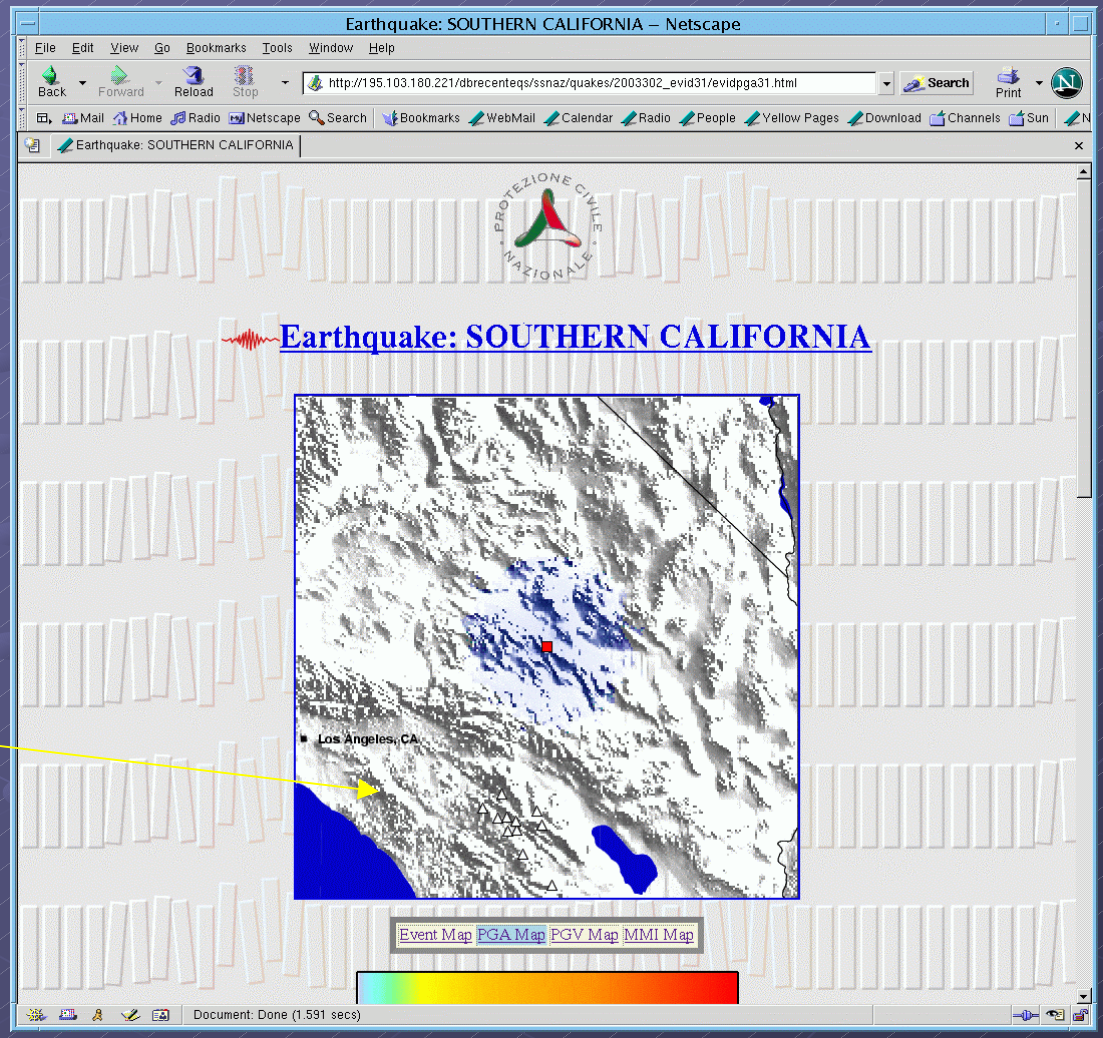
Detecting Stations

Vital Statistics for Oct. 29 Event

20 milli-g
Qgrid Peak

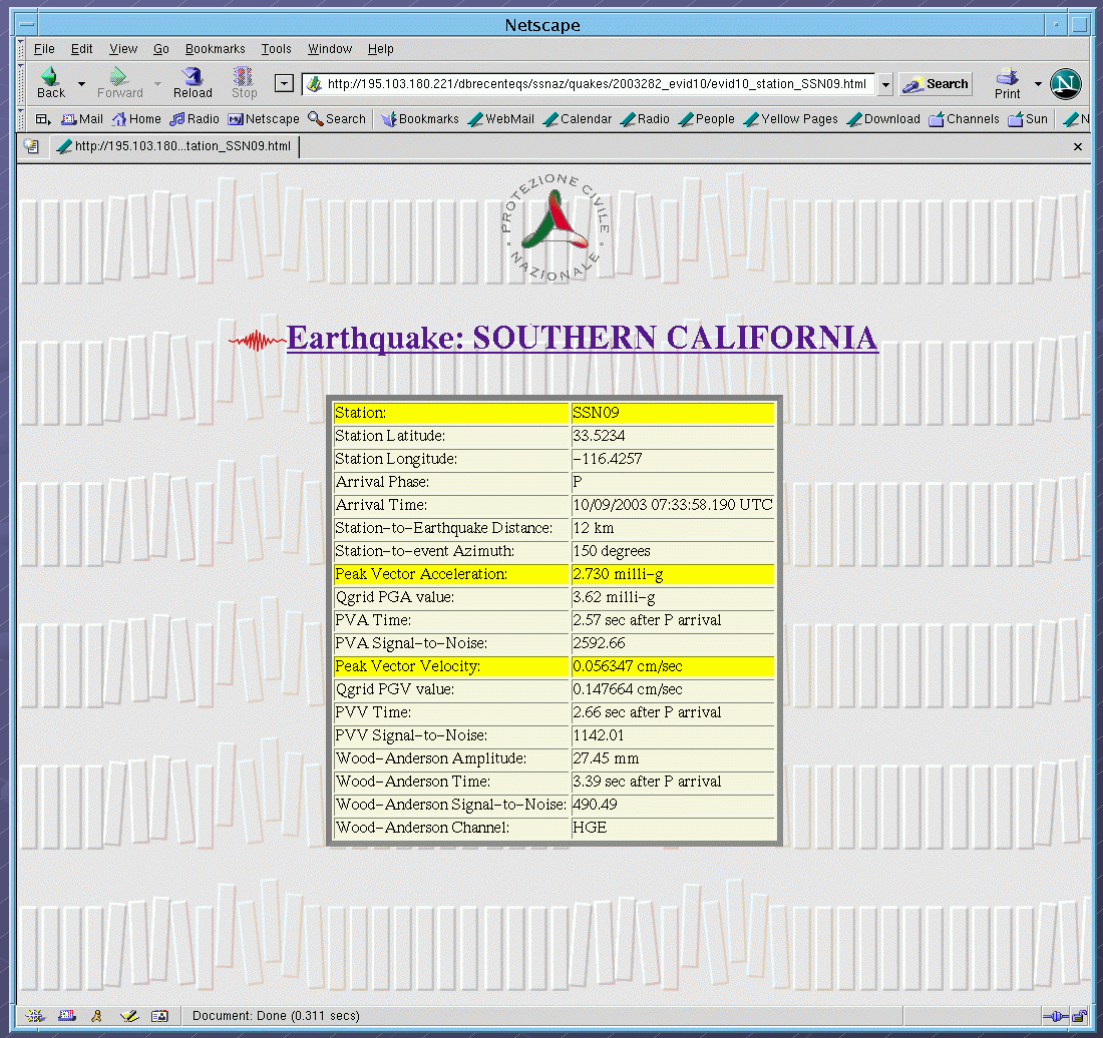


Shaded Contours of PGA



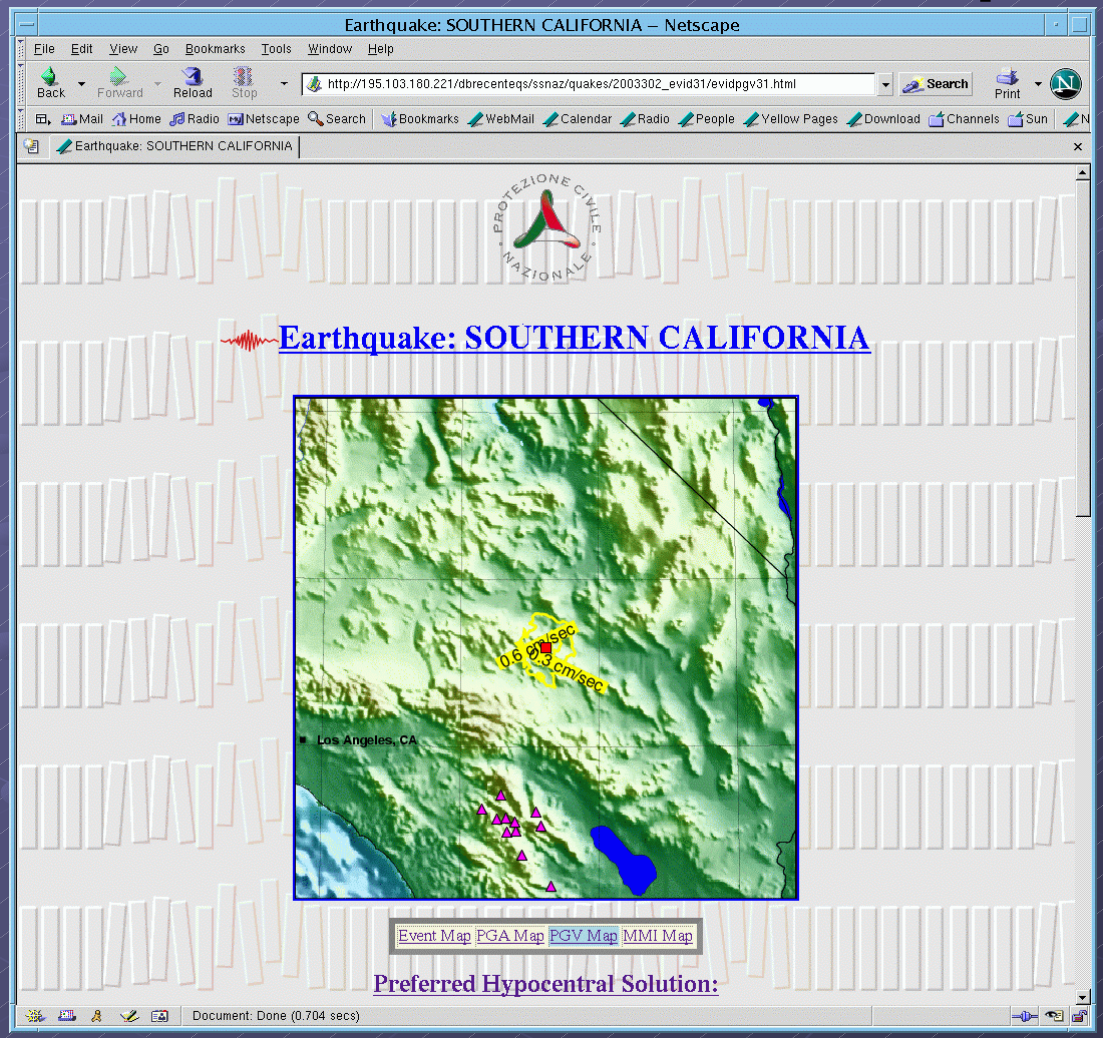
Measured PGAs
At stations plotted
On Same color
scale

Detailed Info for Each Station

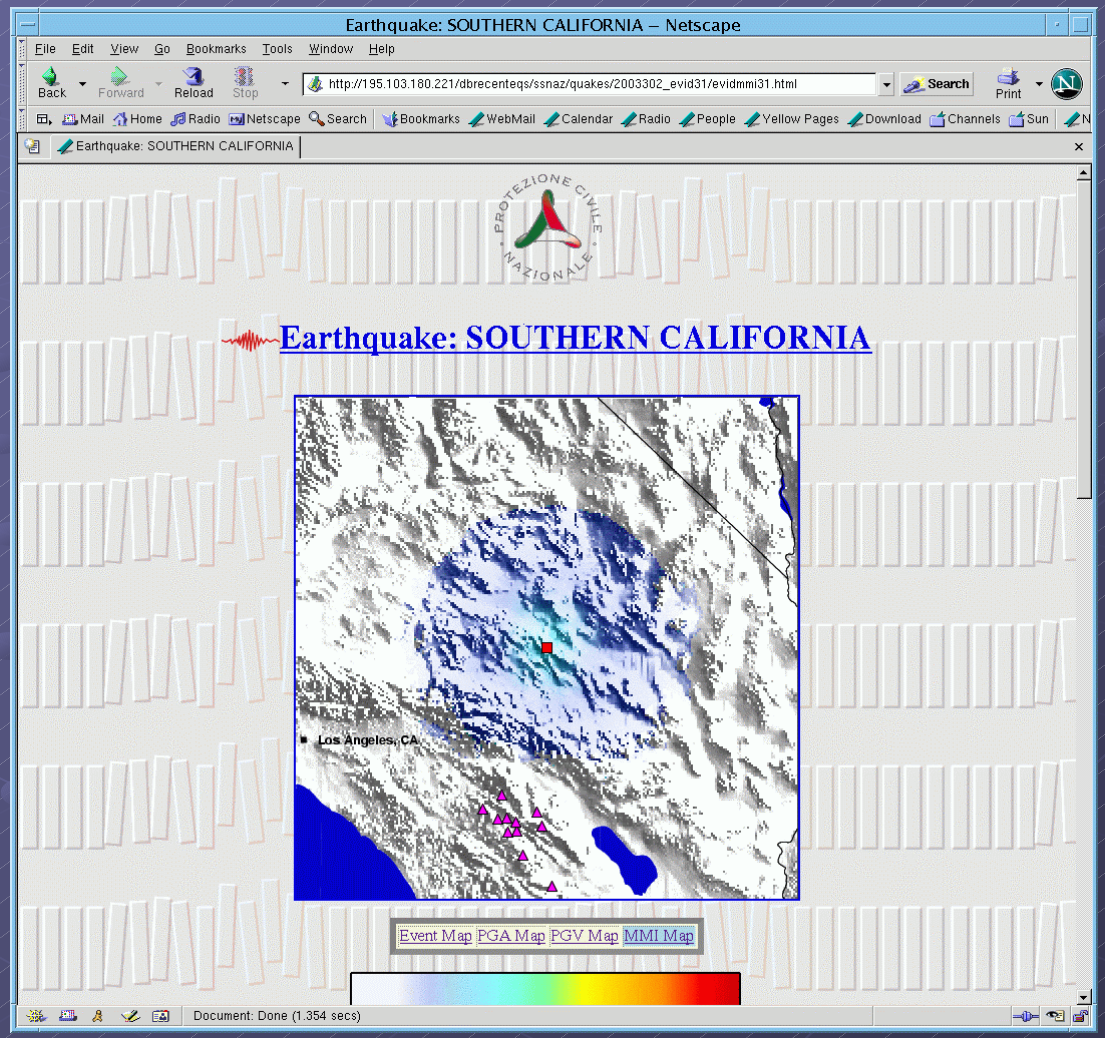


Station:	SSN09
Station Latitude:	33.5234
Station Longitude:	-116.4257
Arrival Phase:	P
Arrival Time:	10/09/2003 07:33:58.190 UTC
Station-to-Earthquake Distance:	12 km
Station-to-event Azimuth:	150 degrees
Peak Vector Acceleration:	2.730 milli-g
Qgrid PGA value:	3.62 milli-g
PVA Time:	2.57 sec after P 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

PGV Contour Map



Instrumental Modified Mercalli Intensity



Summary

- 2-D ground-motion estimates possible
- Requires
  - Multiple real-time stations
  - extensive a-priori data: Vs30, attenuation
- Scientifically complex; active research field