USGS
science for a changing world

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

USGS Tsunami Activities 5 Year Review

Craig Weaver
David Oppenheimer

May 16, 2007

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

USGS Tsunami Activities

- **Monitoring** **$12.0M**
  - Includes GSN, partial ANSS, 24/7, NOAA CREST
  - Does not include $4.4M from NSF for GSN
- **Research** **$3.0M**
  - Earthquake and Coast & Marine Programs
  - Significant support for mitigation & education
- **Assessment** **$2.0M**
  - National Earthquake Hazard maps
  - Coastal inundation and tsunami sources
- **Mitigation** **$0.0M**
  - Significant support for state programs thru above

CREST, the USGS portion of the NTHMP

Consolidated Reporting of EarthquakeS *and* Tsunamis

Tsunami Hazard Mitigation Review

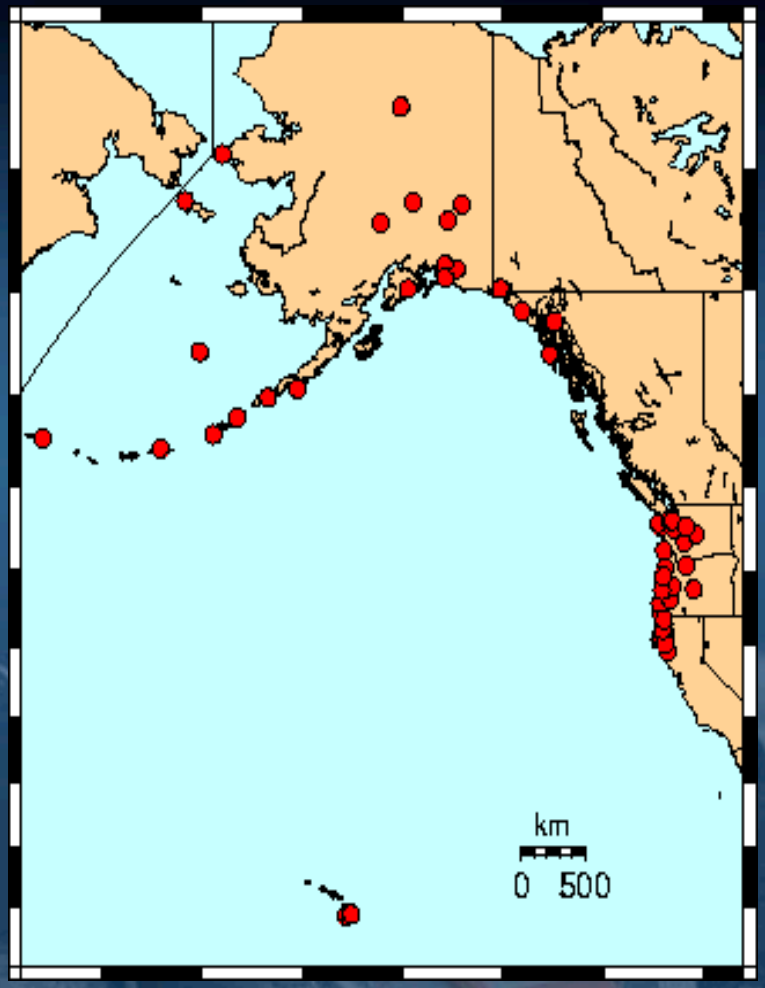
August 7, 2001

Direct Participants

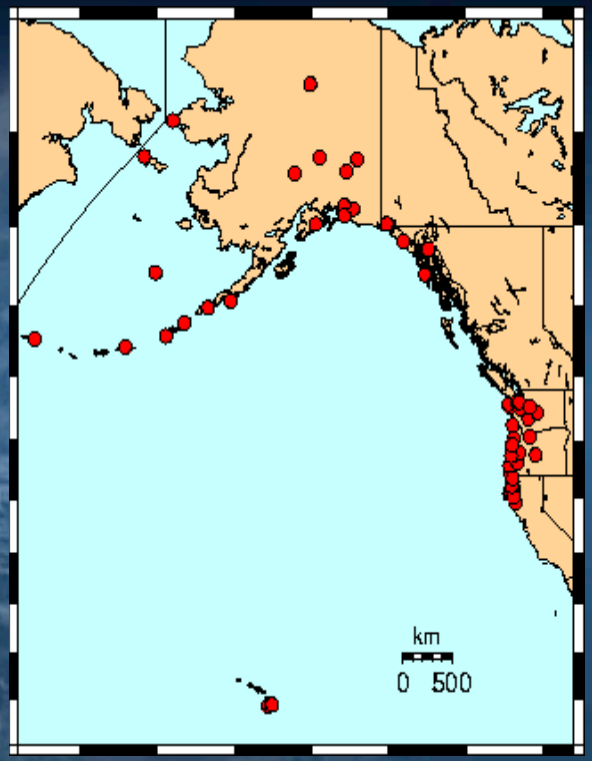
- U.S. Geological Survey, Menlo Park, CA, U.S.A
- U.S. Geological Survey, Golden, CO, U.S.A
- U.S. Geological Survey, HVNP, HI, U.S.A
- University of Alaska, Fairbanks, AK, U.S.A
- University of Washington, Seattle, WA, U.S.A
- Alaska/West Coast Tsunami Warning Center, Palmer, AK, U.S.A
- Pacific Tsunami Warning Center, Eva Beach, HI, U.S.A
- Pacific Geoscience Center, Sidney, BC, Canada
- University of Oregon, Eugene, OR, U.S.A

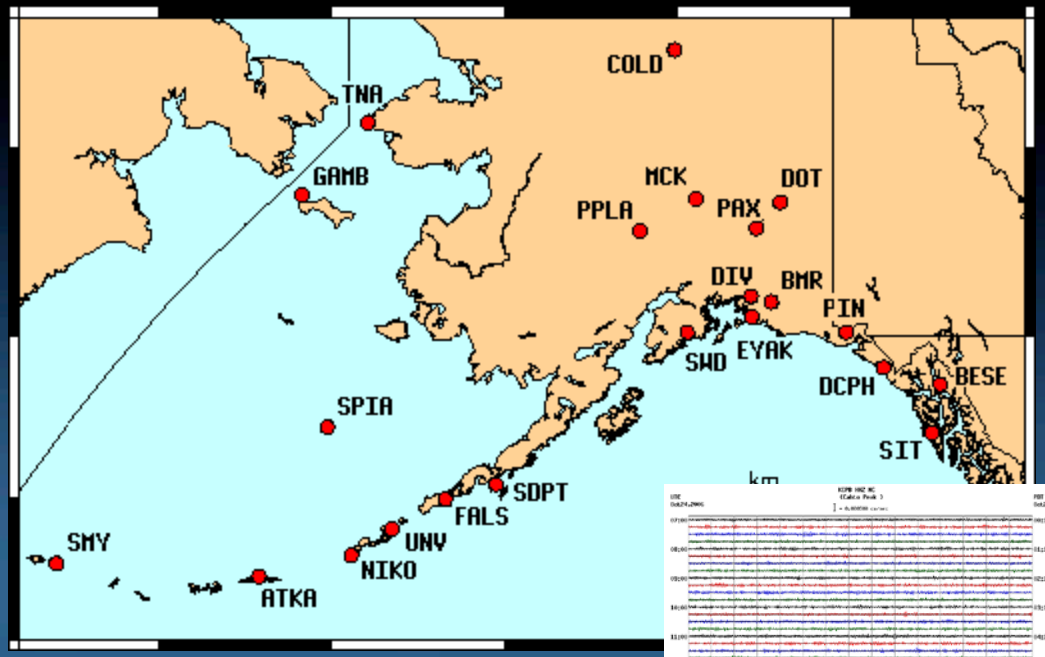
Ongoing Operations

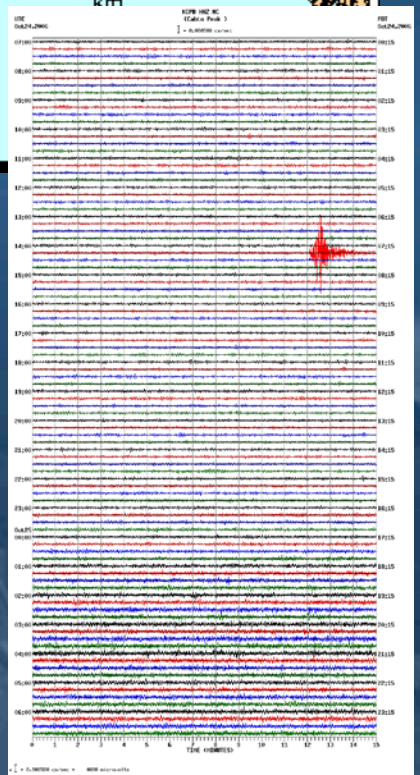
- 54 seismic stations installed during the first five years of program.
- Maintain and repair sites as necessary.
- Dedicated circuits for exchanging seismic data between Golden, Menlo Park, Seattle, Ewa Beach, Fairbanks, and Palmer (free except HVO-Ewa Beach)



http://quake.usgs.gov/waveforms/crest/







CREST Budget by Task

Telemetry	$31.0
Salaries (+ benefits)	$225.3
Site Maintenance	$133.2
Overhead	$213.2
Total	$602.2

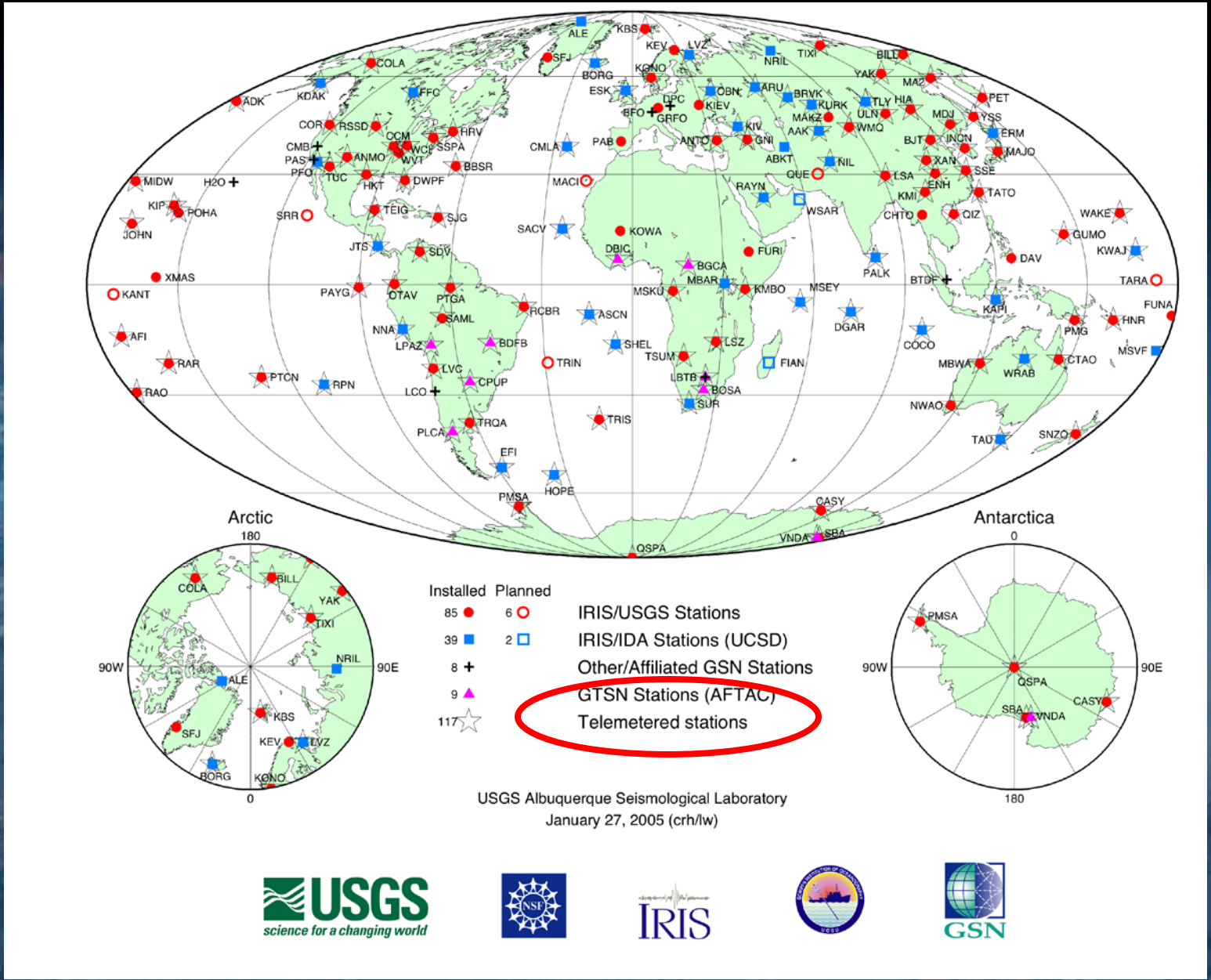
CREST Budget by Institution

USGS	$213.6
U. of Washington	$74.0
U. of Oregon	$44.5
U. of Alaska	$270.6
Total	$602.7

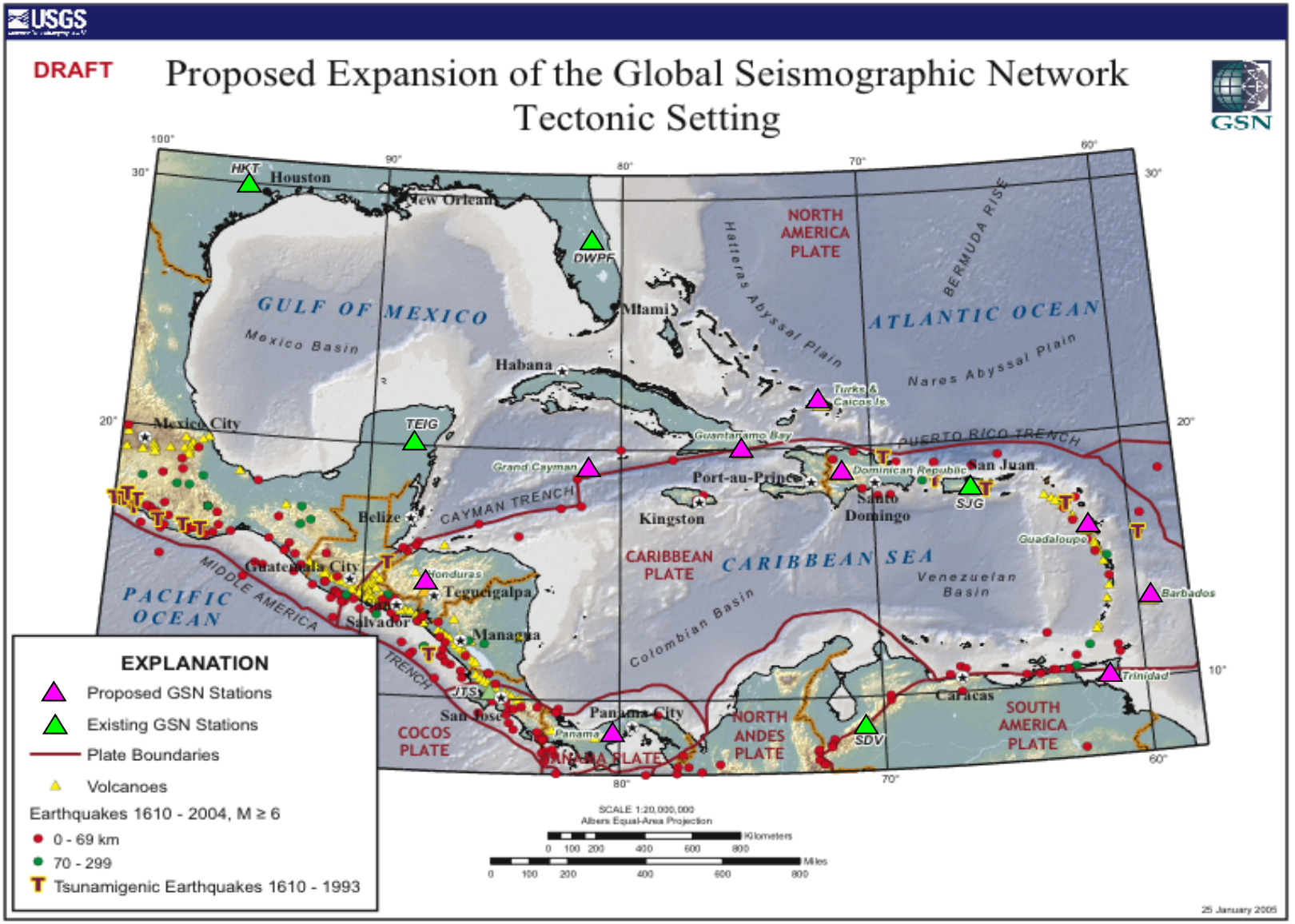
Other Activities in support of NTHMP

- 7X24 Response:
  - Two NEIC staff members are on duty at all times
  - review automated global earthquake solutions within 20 minutes from the NEIC Hydra system.
  - The response time using the Hydra software has decreased by 50%.
    - Reviewed information on teleseisms now released in about 20 minutes
    - Automated information available faster, but not being released

Global Seismographic Network Telemetry Upgrades



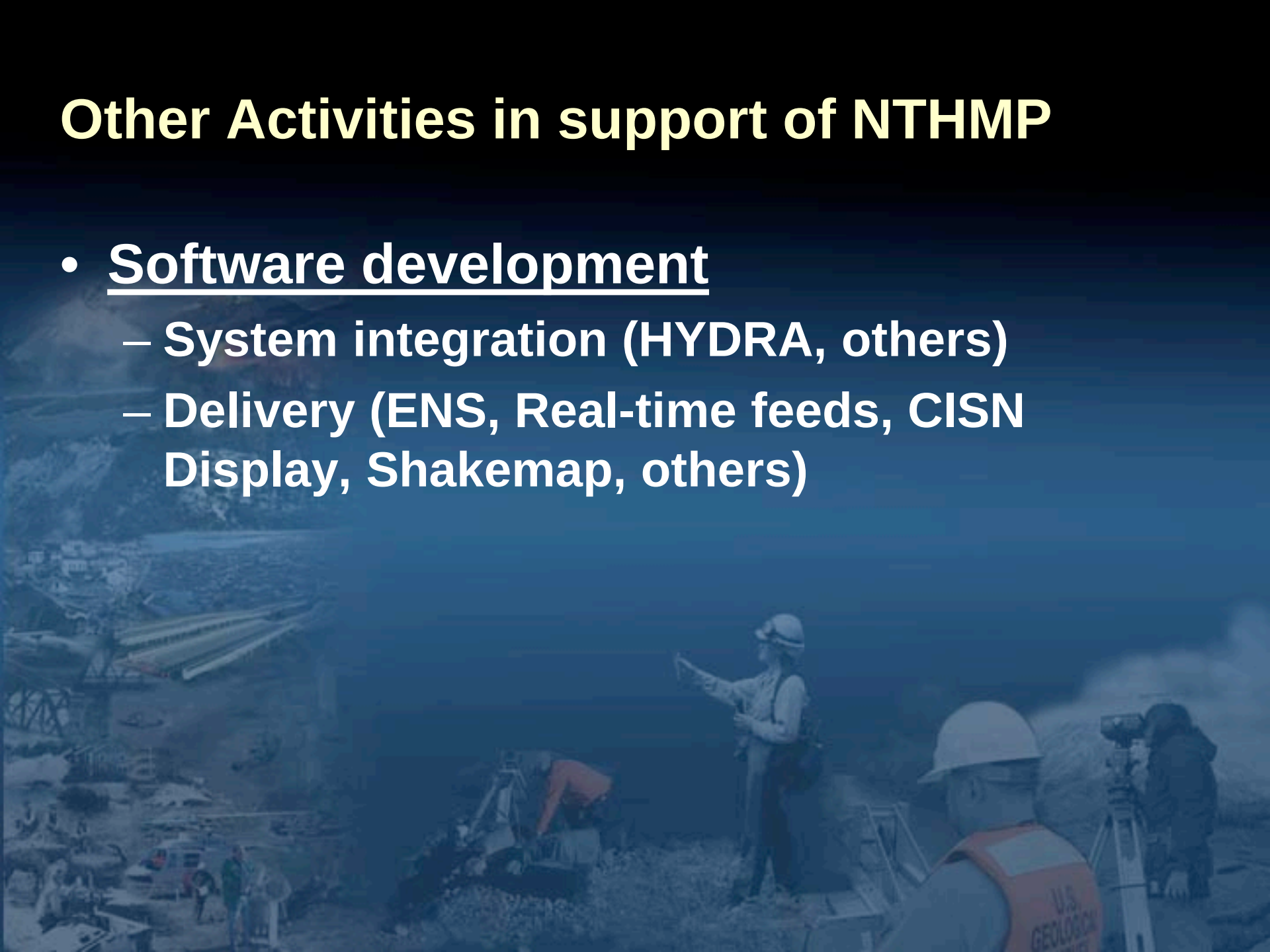
GSN Caribbean Station Installations



Metric	Units	Mod-High Hazard Areas	Non-US
Seismic Monitoring/Strong Earthquake Shaking			
Magnitude Completeness Level	**M**	**2.5**	**4.5**
Location Uncertainty	**km**	**5**	**20**
Depth Uncertainty for M≥4.5	**km**	**10**	**20**
Product Generation (Automated/Reviewed Post Time)			
Hypocenter	**min.**	**4/10**	**15/20**
Magnitude	**min**	**4/10**	**15/20**
Moment Tensor M≥4.5 (M≥5.5 non-US)	**min.**	**15/30**	**30/30**
ShakeMap	**min.**	**10/30**	**20/60**

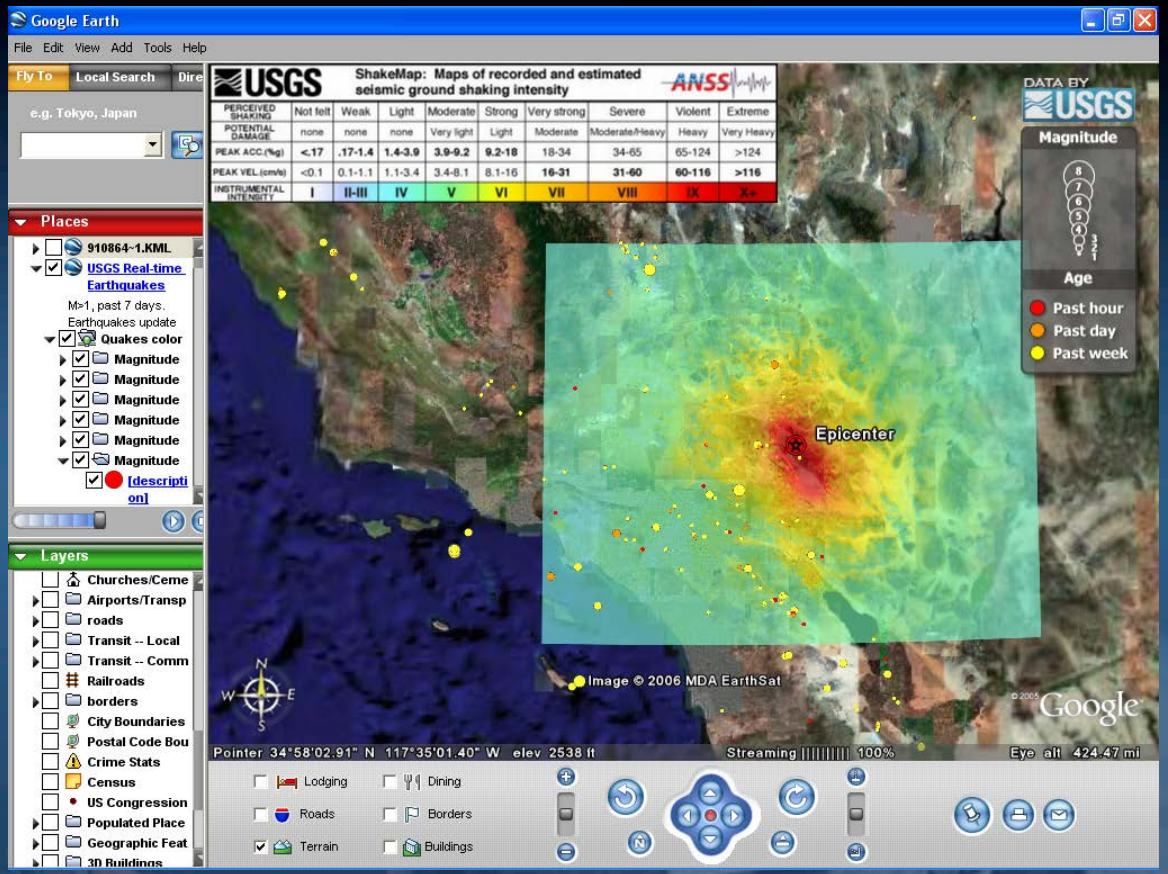
Other Activities in support of NTHMP

- **Software development**
  - System integration (HYDRA, others)
  - Delivery (ENS, Real-time feeds, CISN Display, Shakemap, others)



Near-Realtime Data Feeds

- CAP (web & DMIS)
- KML (Google Earth)
  - Eqs
  - ShakeMaps
- EIDS



Earthquake Notification Service

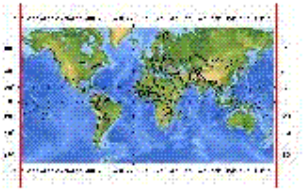
http://earthquake.usgs.gov/eqcenter/ens/

Earthquake Notification Service: Customizable Earthquake Alerts

My Notification Profiles | My Account | Help

Earthquake Notification Profiles Associated with oppen@usgs.gov's Account

Shallow M7's (Custom region)



View with Google maps

Depth: 0.00 to 40.00km
Networks:
CI,NC,NN,UU,UW,AK,NM,HV,AT,PR,SE,US,LD,MB,WY,AR

Geographic Bounds: rectangle

South Latitude:	-90.000
North Latitude:	90.000
East Longitude:	180.000
West Longitude:	-180.000
Mag:	7 (All Times)
Address 1:	6502832747@tmomail.net (short) 08:00-22:00

DELETE PROFILE EDIT PROFILE

Welcome oppen@usgs.gov!

Log Out

Change Password

Recent Events Sent to Me

Map of Recent Events

My Email Addresses

6502832747@tmomail.net (short) (08:00-22:00)

Add New Email Address

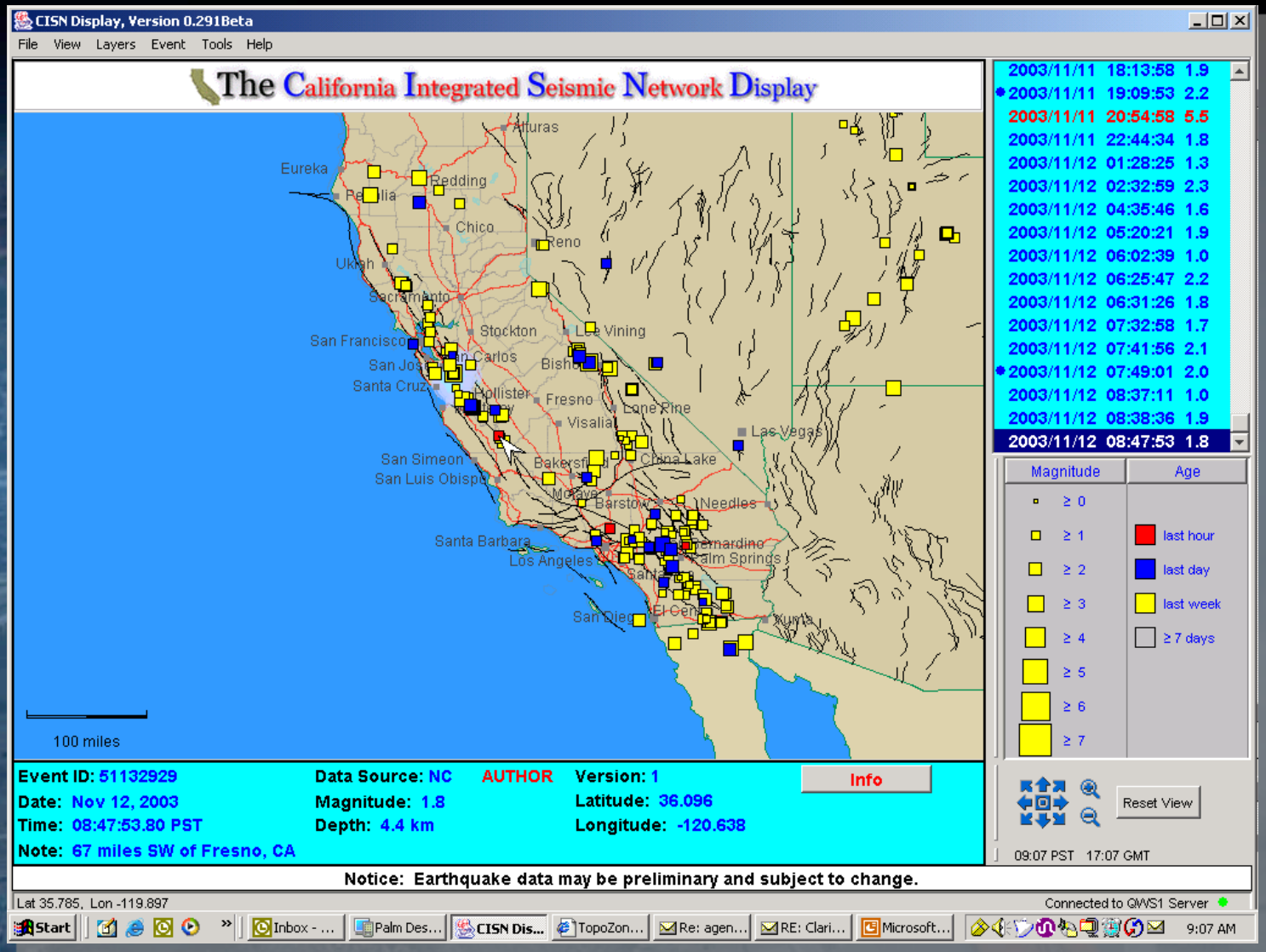
Add New Profile

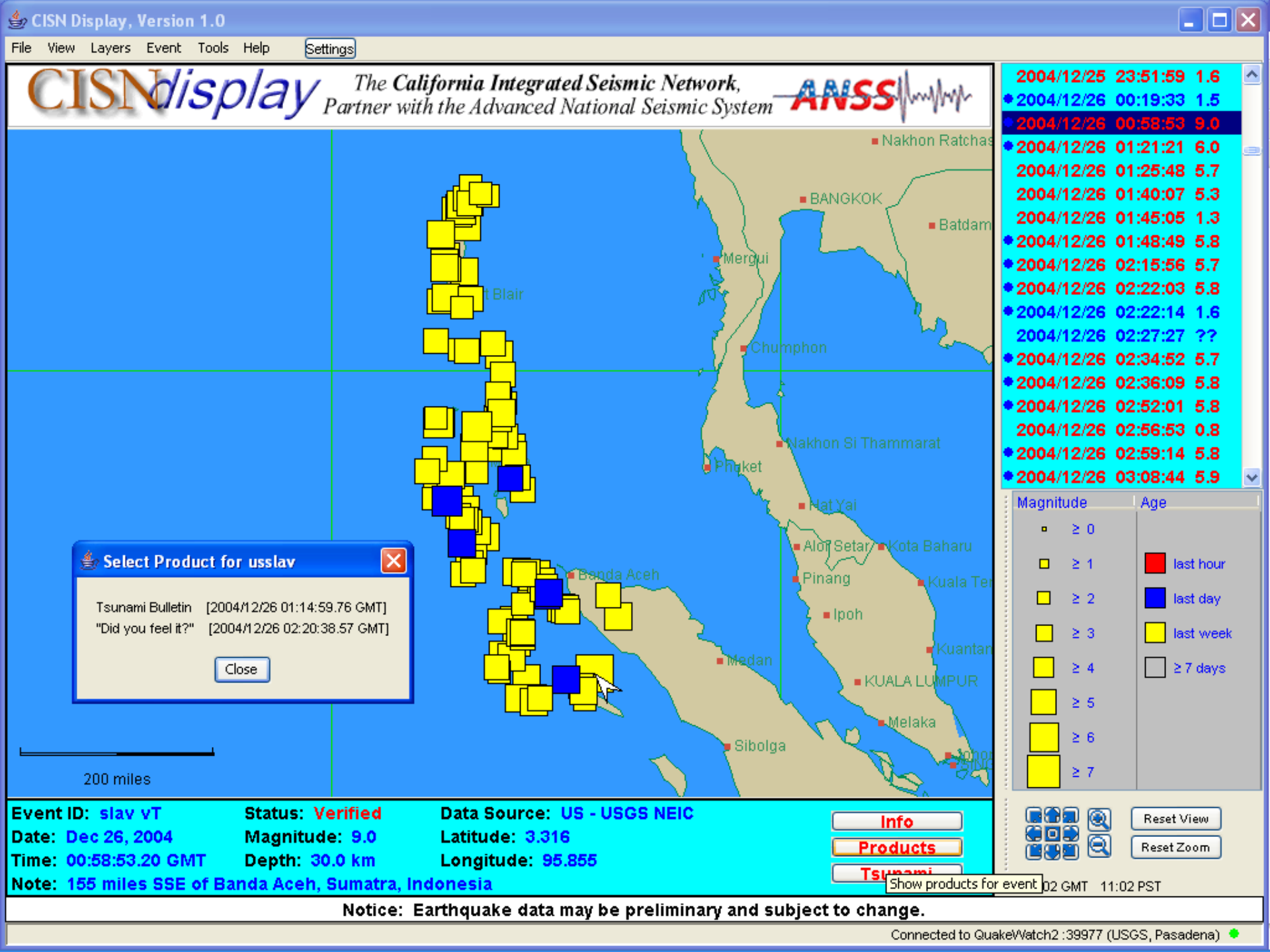
- Predefined Profile
- Rectangle Profile
- Circle Profile
- Polygon Profile

CISN Display

- **Version 1.3 released 8/2006**
  - **Higher resolution shape file layers with scale dependent display**
  - **Improved ShakeMap selection**
  - **full-screen map mode**
  - **fully integrated, and customizable email capability.**
- **Tsunami warning notification with regional targeting awaits contributions of warning messages by PTWC.**

Incorporating NOAA tsunami information into CISN Display automated map delivery




CISN Display, Version 1.0
File View Layers Event Tools Help Settings
CISN display
The California Integrated Seismic Network,
Partner with the Advanced National Seismic System
ANSS
2004/12/25 23:51:59 1.6
2004/12/26 00:19:33 1.5
2004/12/26 00:58:53 9.0
2004/12/26 01:21:21 6.0
2004/12/26 01:25:48 5.7
2004/12/26 01:40:07 5.3
2004/12/26 01:45:05 1.3
2004/12/26 01:48:49 5.8
2004/12/26 02:15:56 5.7
2004/12/26 02:22:03 5.8
2004/12/26 02:22:14 1.6
2004/12/26 02:27:27 ??
2004/12/26 02:34:52 5.7
2004/12/26 02:36:09 5.8
2004/12/26 02:52:01 5.8
2004/12/26 02:56:53 0.8
2004/12/26 02:59:14 5.8
2004/12/26 03:08:44 5.9
Nakhon Ratchas
BANGKOK
Batdam
Mergui
Blair
Chumphon
Nakhon Si Thammarat
Phuket
Hat Yai
Alor Setar
Kota Baharu
Banda Aceh
Pinang
Kuala Ter
Ipoh
Kuantan
Medan
KUALA LUMPUR
Melaka
Sibolga
Select Product for usslav
Tsunami Bulletin [2004/12/26 01:14:59.76 GMT]
"Did you feel it?" [2004/12/26 02:20:38.57 GMT]
Close
200 miles
Magnitude
Age
≥ 0
≥ 1
≥ 2
≥ 3
≥ 4
≥ 5
≥ 6
≥ 7
last hour
last day
last week
≥ 7 days
Event ID: slav vT
Status: Verified
Data Source: US - USGS NEIC
Date: Dec 26, 2004
Magnitude: 9.0
Latitude: 3.316
Time: 00:58:53.20 GMT
Depth: 30.0 km
Longitude: 95.855
Note: 155 miles SSE of Banda Aceh, Sumatra, Indonesia
Info
Products
Tsunami
Reset View
Reset Zoom
Show products for event
02 GMT 11:02 PST
Notice: Earthquake data may be preliminary and subject to change.
Connected to QuakeWatch2 :39977 (USGS, Pasadena)

WEPA43 PAAQ 260114
TIBWCA

TO - TSUNAMI WARNING SYSTEM PARTICIPANTS IN
ALASKA/BRITISH COLUMBIA/WASHINGTON/OREGON/CALIFORNIA
FROM - WEST COAST AND ALASKA TSUNAMI WARNING CENTER/NOAA/NWS
SUBJECT - TSUNAMI INFORMATION BULLETIN
BULLETIN NUMBER 1
ISSUED 12/26/2004 AT 0114 UTC

...THIS TSUNAMI INFORMATION BULLETIN IS FOR ALASKA - BRITISH
COLUMBIA - WASHINGTON - OREGON AND CALIFORNIA ONLY...

NO - REPEAT NO - WATCH OR WARNING IS IN EFFECT.

EARTHQUAKE DATA
PRELIMINARY MAGNITUDE - 8.5
LOCATION - 3.4N 95.7E - OFF W COAST OF NORTHERN SUMATERA
TIME - 1559 AST 12/25/2004
1659 PST 12/25/2004
0059 UTC 12/26/2004

EVALUATION
BASED ON LOCATION AND MAGNITUDE THE EARTHQUAKE WAS NOT
SUFFICIENT TO GENERATE A TSUNAMI DAMAGING TO CALIFORNIA -
OREGON - WASHINGTON - BRITISH COLUMBIA OR ALASKA. SOME AREAS MAY
EXPERIENCE SMALL SEA LEVEL CHANGES. IN AREAS OF INTENSE
SHAKING LOCALLY GENERATED TSUNAMIS CAN BE TRIGGERED BY SLUMPING.

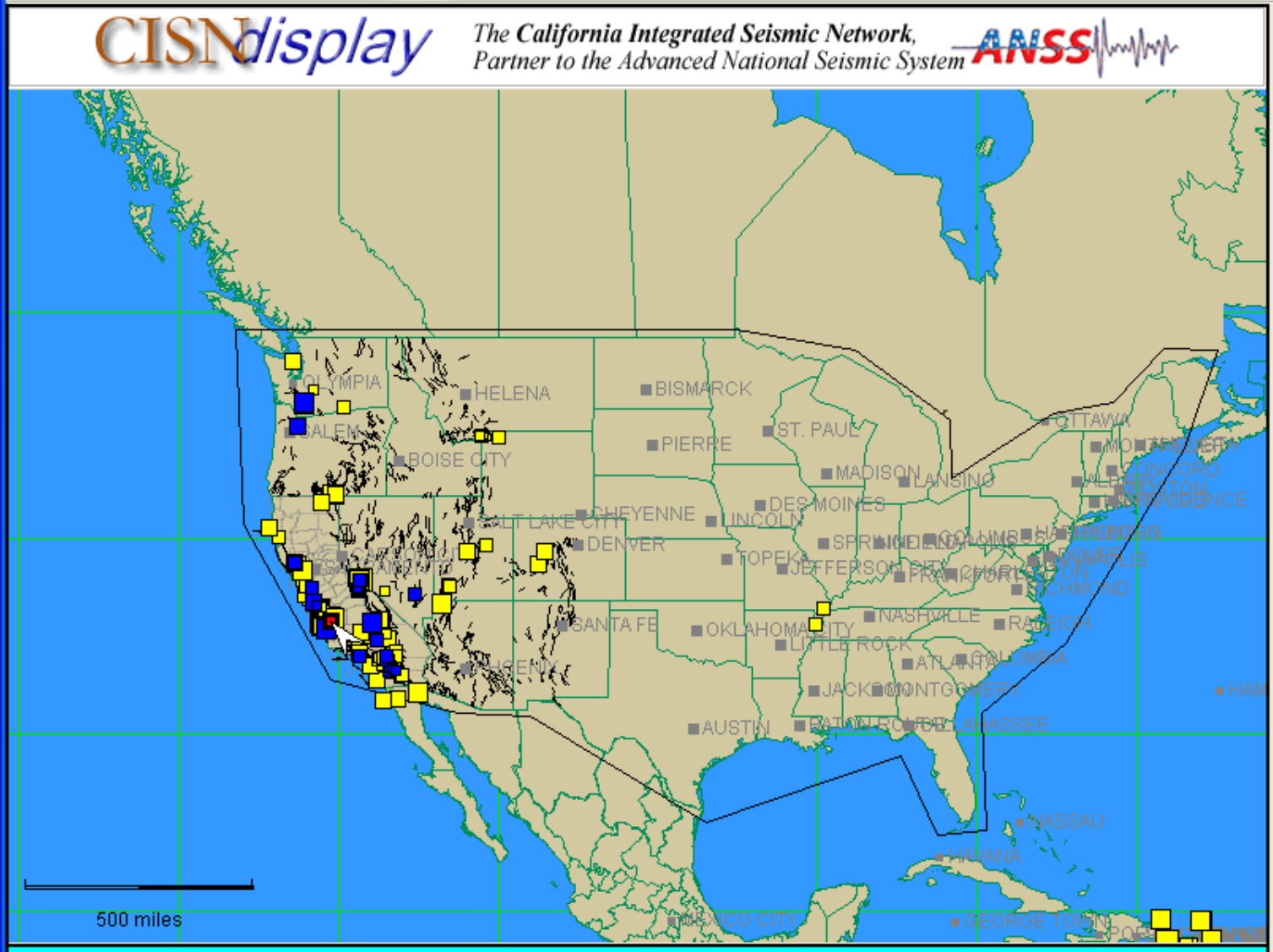
THE PACIFIC TSUNAMI WARNING CENTER WILL ISSUE TSUNAMI BULLETINS
FOR HAWAII AND OTHER AREAS OF THE PACIFIC.

THIS WILL BE THE ONLY BULLETIN ISSUED FOR THIS EVENT BY THE
WEST COAST AND ALASKA TSUNAMI WARNING CENTER UNLESS CONDITIONS
WARRANT. REFER TO THE INTERNET SITE HTTP://WCATWC.ARH.NOAA.GOV
FOR MORE INFORMATION.

CISN Display, Version 0.903Beta

File View Layers Event Tools Help Settings

CISN display — The California Integrated Seismic Network, Partner to the Advanced National Seismic System — ANSS



2004/11/29	01:54:14	4.2
2004/11/29	01:59:01	0.7
2004/11/29	02:07:55	2.9
2004/11/29	02:19:12	2.2
2004/11/29	02:55:00	0.6
2004/11/29	03:24:26	2.7
2004/11/29	03:25:52	2.4
2004/11/29	03:52:48	1.7
2004/11/29	03:53:44	1.0
2004/11/29	03:59:10	1.8
2004/11/29	04:07:54	2.0
2004/11/29	04:08:07	1.2
2004/11/29	04:15:34	2.1
2004/11/29	04:19:13	1.5
2004/11/29	04:34:10	??
2004/11/29	05:04:53	0.9
2004/11/29	06:00:02	1.8
2004/11/29	06:33:40	3.1

Magnitude: ≥ 0, ≥ 1, ≥ 2, ≥ 3, ≥ 4, ≥ 5, ≥ 6, ≥ 7

Age: last hour, last day, last week, ≥ 7 days

Reset View | Reset Zoom

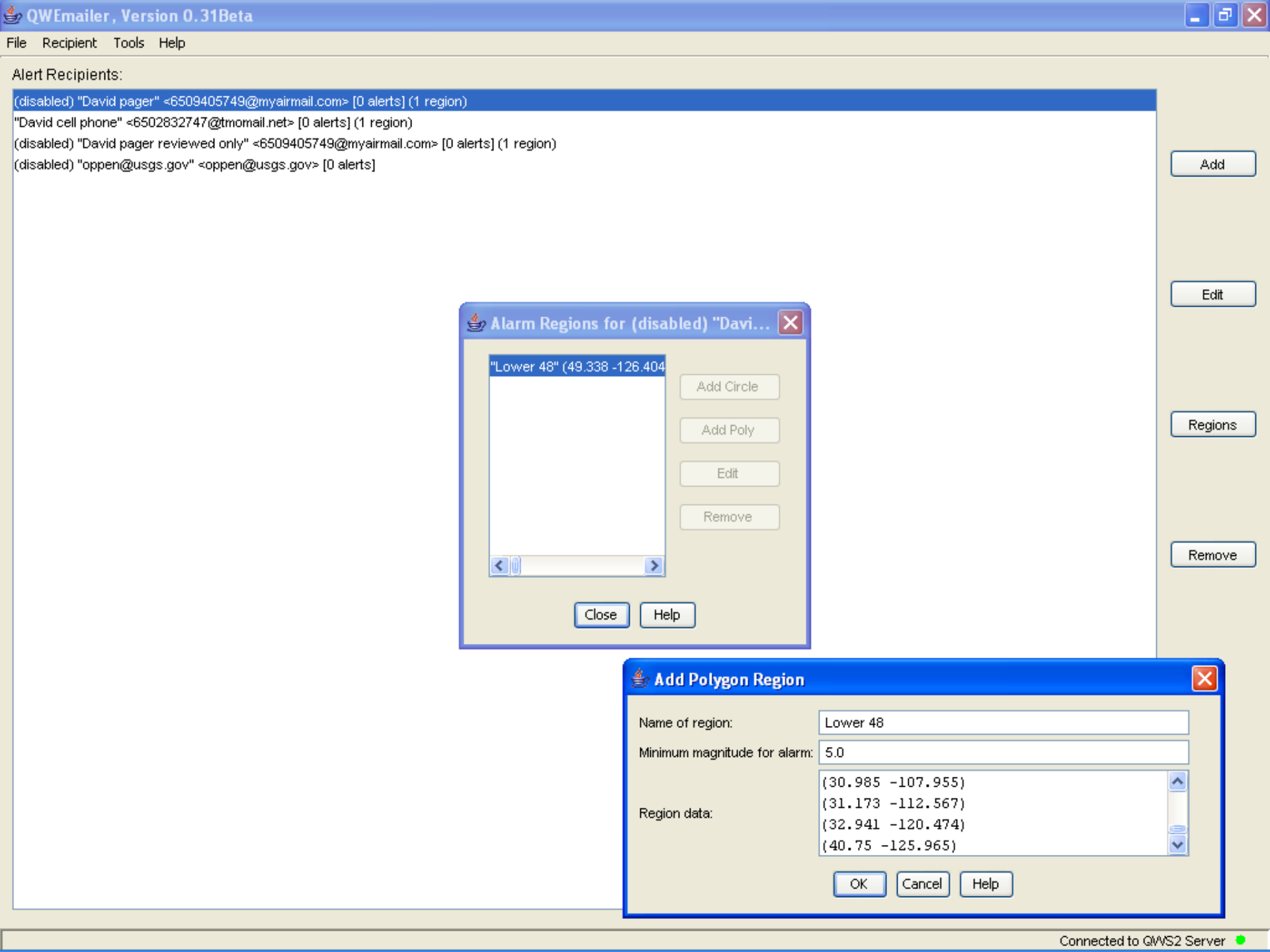
06:16 GMT 22:16 PST

Event ID: 51153873 v3 **Status:** Verified **Data Source:** NC-CISN (UCB/USGS)
Date: Nov 29, 2004 **Magnitude:** 4.2 **Latitude:** 35.944
Time: 01:54:14.50 GMT **Depth:** 10.4 km **Longitude:** -120.492
Note: 5 miles NW of Parkfield, CA

Info | Products | Tsunami

Notice: Earthquake data may be preliminary and subject to change.

Lat 56.082, Lon -69.371 Connected to QWS2 Server 2


QWEmailer, Version 0.31Beta
File
Recipient
Tools
Help
Alert Recipients:
(disabled) "David pager" <6509405749@myairmail.com> [0 alerts] (1 region)
"David cell phone" <6502832747@tmomail.net> [0 alerts] (1 region)
(disabled) "David pager reviewed only" <6509405749@myairmail.com> [0 alerts] (1 region)
(disabled) "oppen@usgs.gov" <oppen@usgs.gov> [0 alerts]
Add
Edit
Regions
Remove
Alarm Regions for (disabled) "Davi...
"Lower 48" (49.338 -126.404
Add Circle
Add Poly
Edit
Remove
Close
Help
Add Polygon Region
Name of region:
Lower 48
Minimum magnitude for alarm:
5.0
Region data:
(30.985 -107.955)
(31.173 -112.567)
(32.941 -120.474)
(40.75 -125.965)
OK
Cancel
Help
Connected to QWS2 Server

Going Forward—Unmet needs

- Current CREST stations nearing end of life cycle, no identified replacement funding
- Integrate PBO GPS stations into rapid assessment of Cascadia events
- Do we need more emphasis on delivery?
- Stream PWTC warnings into CISN
  - Effort is underway
  - Stream CISN feeds to all nations
- Refer to Second Bonus Section

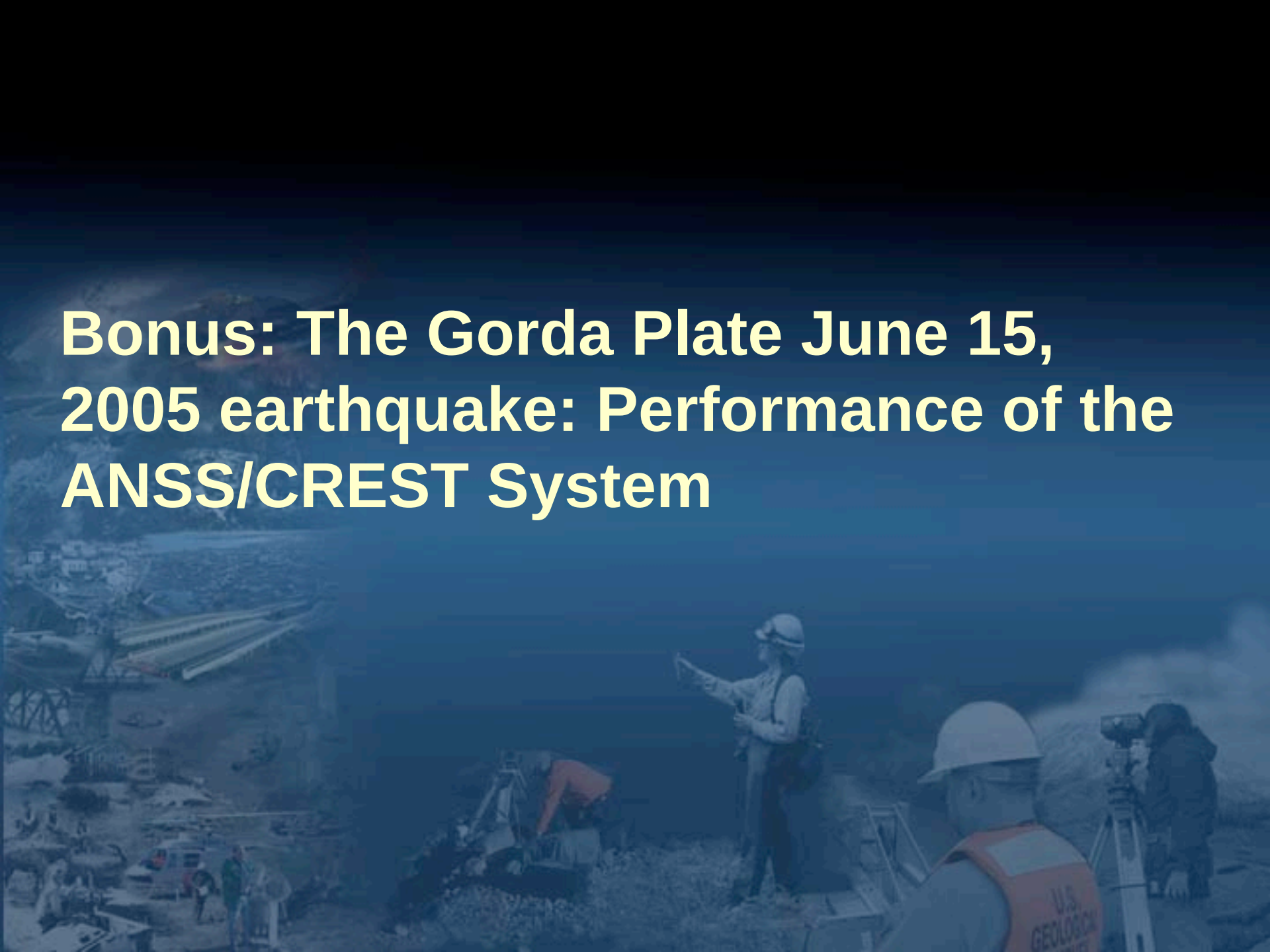
More Focus on Delivery?

- USGS/UW/WA EMD partnered to install 12 CISN/Display units (computers, screens, support) along WA coast
  - Tribes
  - Counties
- Funding
  - USGS funding from ANSS
  - UW using new state funding
- Do we need more emphasis on delivery?
  - Costly, in terms of staff support for remote sites
  - Could be expanded to all states, territories

A Few Earthquake Research Needs

- Fast verification of moment tensor to detect tsunami events, e.g., Java
- Near-real time detection of magnitude for possible early warning—Cascadia/AK
  - USGS: month 9 of 36 on early warning evaluation
  - Initial Cascadia magnitude in 8 seconds is goal
- Study of strike-slip events and tsunami generation (15% generate tsunamis)
- Seismic parameters and tsunami generation??

Bonus: The Gorda Plate June 15, 2005 earthquake: Performance of the ANSS/CREST System

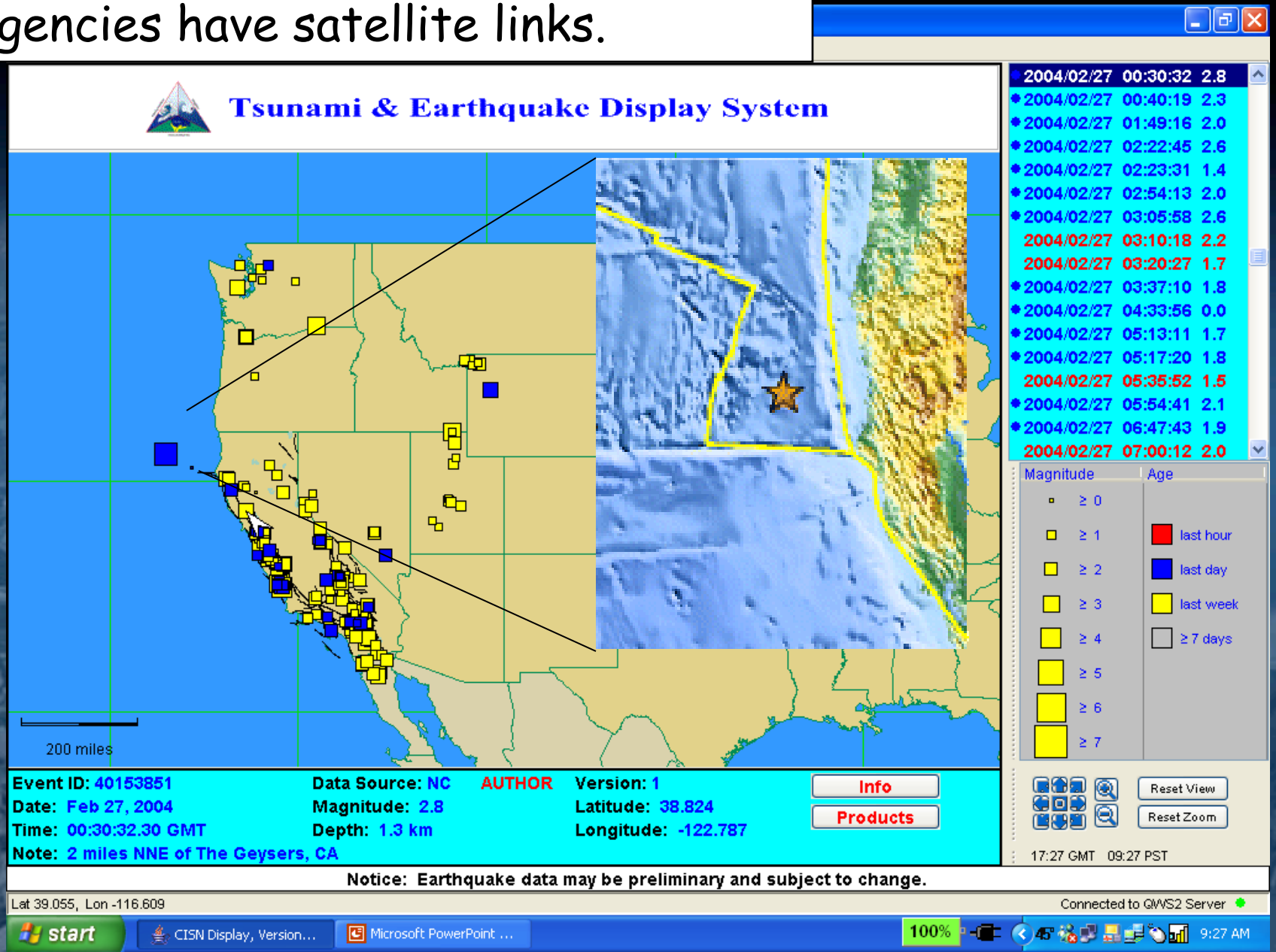


Gorda Plate Earthquake, June 15, 2005

Timeline: Gorda Plate Earthquake, June 15, 02:50 UTC						
Date	**UTC**	**Elapsed Time**	**Event**	**Notes/Comments**		
15-Jun	2:50:54	0:00	Origin Time			
	2:51:50	0:56	NCSN quick location	Distributed to CISN Display and web, but magnitude unknown[1,2]		
	2:52:00	1:06	WC/ATWC alarm and first loc.	good location - Ml 5.8; Duty personnel notified		
	2:52:48	1:54	WC/ATWC first Mwp	Mwp 7.7		
	2:53:54	3:00	WC/ATWC duty personnel arrive at center	Approximate time		
	2:54:02	3:08	refined Mwp	Mwp 7.4		
	2:56:40	5:46	NCSN final location & Md=5.95	Not distributed because location outside NC region of authority[1]		
	2:56:30	5:36	WC/ATWC warning message assembled and delivered	Message sent over several channels		
	2:56:55	**6:01**	**WC/ATWC warning issued for M7.4 on QDDS**	Distributed to CISN Display and web; supercedes NCSN quick look because of magnitude		
	2:57:00	6:06	WC/ATWC initiates call on NAWAS	Call finished at 03:02		
	2:57:18	6:34	UCB ML=6.61	Not distributed because location outside NC region of authority[1]		
	2:58:41	7:47	UCB ML=7.1	same		
	3:00:00	9:06	WC/ATWC on phone with CA OES	CA OES indicates they have warning hardcopy		
	3:02:46	11:52	NCSN duty seismologist responds	Distributed to CISN Display and web but not authoritative because $M_{NCSN} < M_{ATWC}$		
	3:20:23	29:29	NEIC location & Mw=7.0	Distributed to CISN Display and web; supercedes ATWC because NEIC is authoritative		
	~3:40:00	50:00	DART Buoy D130 records negligable wave	452 km from epicenter		
	3:59:24	68:30	NEIC Moment Tensor e-mailed			
	4:00:00	69:06	WC/ATWC verifies no significant tsunami at tide gages			
	~4:09:46	~78:52	Final UCB moment tensor emailed	Originally computed at time of Mw (~7:47 into sequence)		
	~4:09:46	**~78:52**	**WC/ATWC cancels warning**			
	15:50:00	13 hours	Harvard M7.2 moment tensor issued			

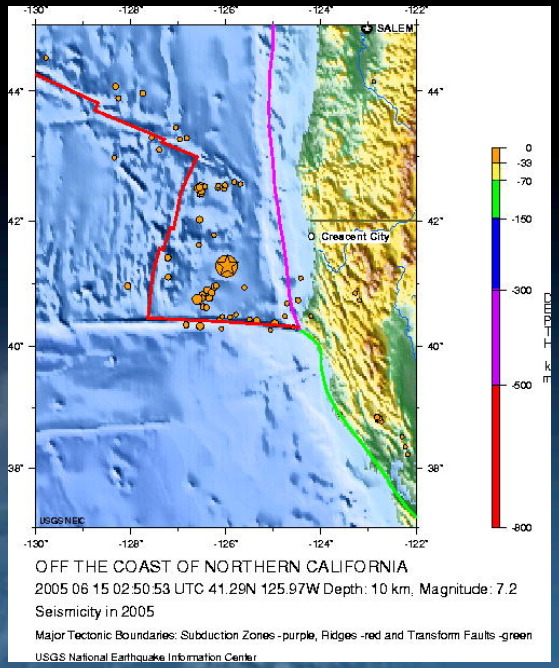
Earthquake information is streamed in real time to CISN/Display. A few agencies have satellite links.

Elapsed Time: 00:56

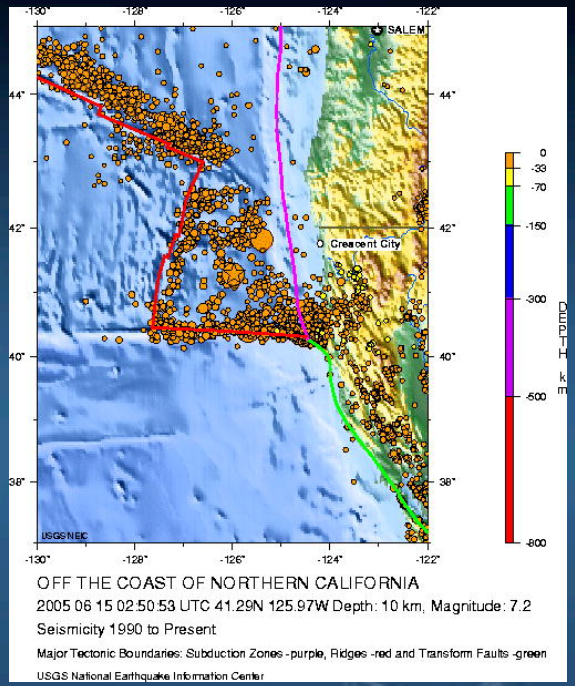


Elapsed Time: 00:56

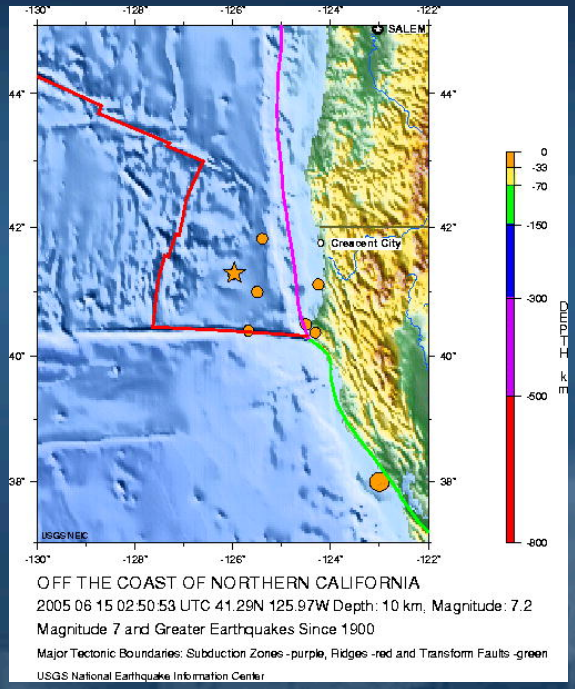
Context—Available at time of quick location for Gorda plate



Located events in 2005

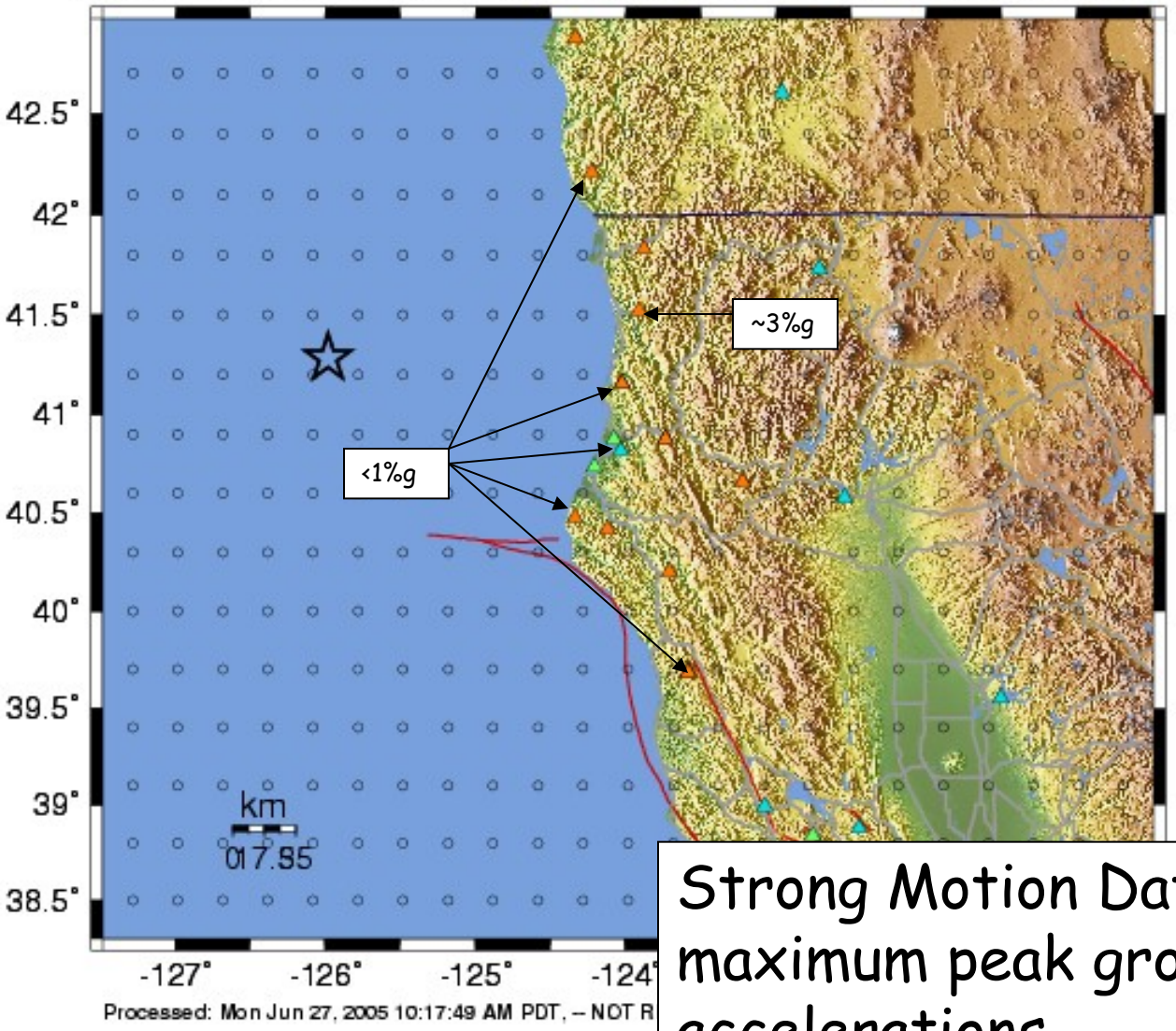


Located events from 1990 to present



Mag > 7 since 1900

Elapsed Time: 00:56 to several minutes

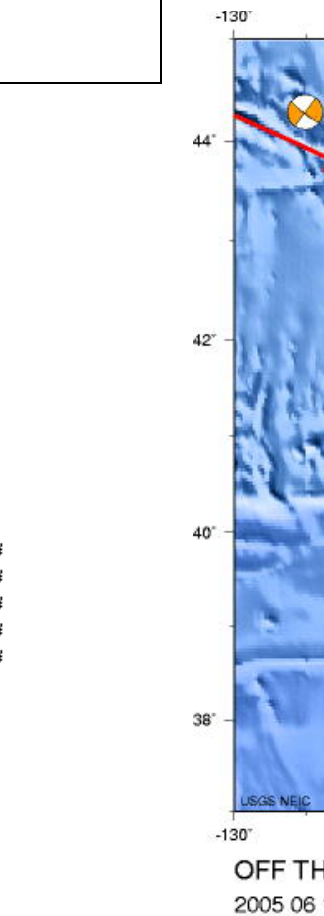


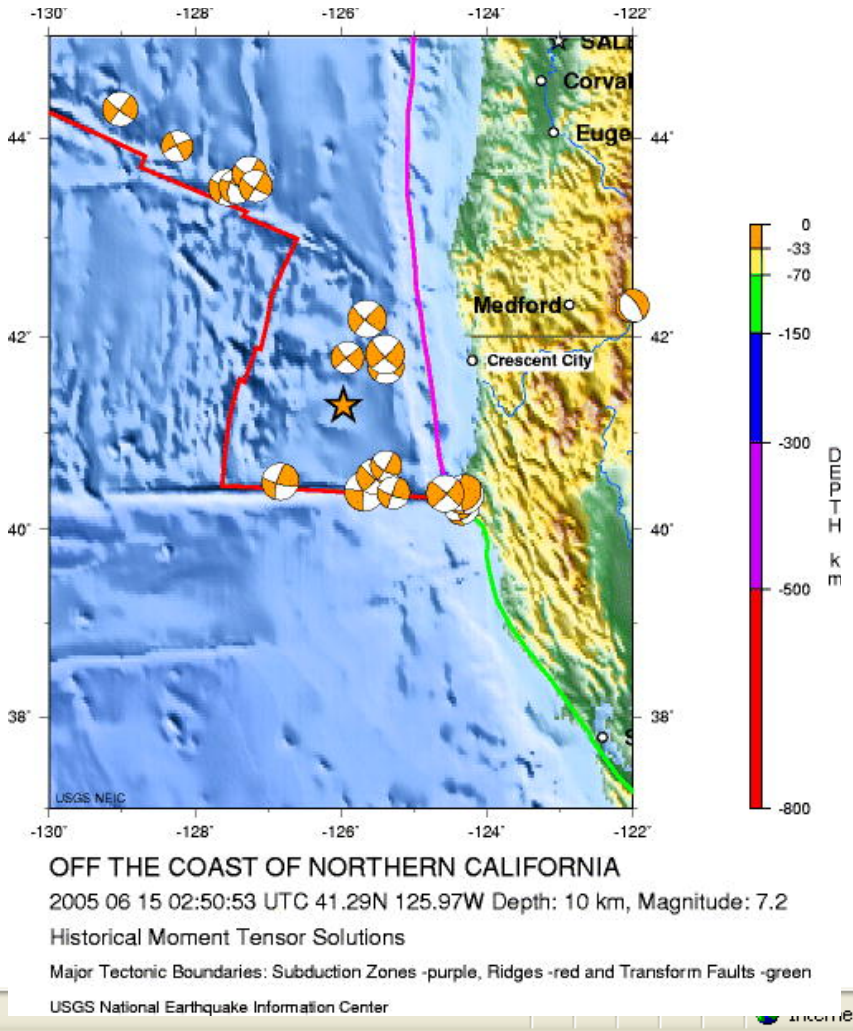
Strong Motion Data—maximum peak ground accelerations

UCB Moment Tensor—not distributed because of network authority issues

Elapsed Time: 07:47

```
Mxy      0.074
Mxz     -0.366
Myy      3.605
Myz      0.821
Mzz      0.148
```





OFF THE COAST OF NORTHERN CALIFORNIA

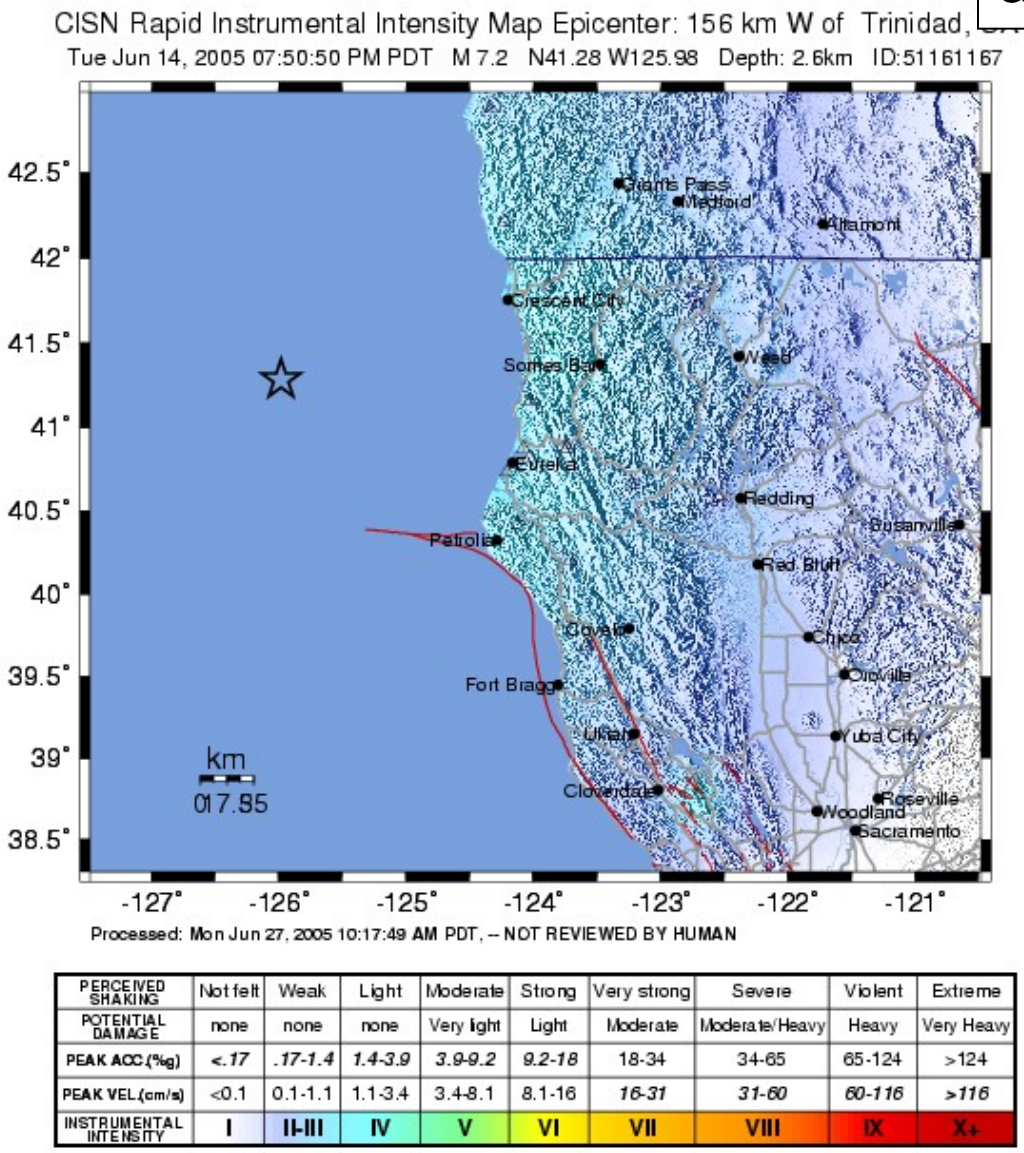
2005 06 15 02:50:53 UTC 41.29N 125.97W Depth: 10 km, Magnitude: 7.2

Historical Moment Tensor Solutions

Major Tectonic Boundaries: Subduction Zones -purple, Ridges -red and Transform Faults -green

USGS National Earthquake Information Center

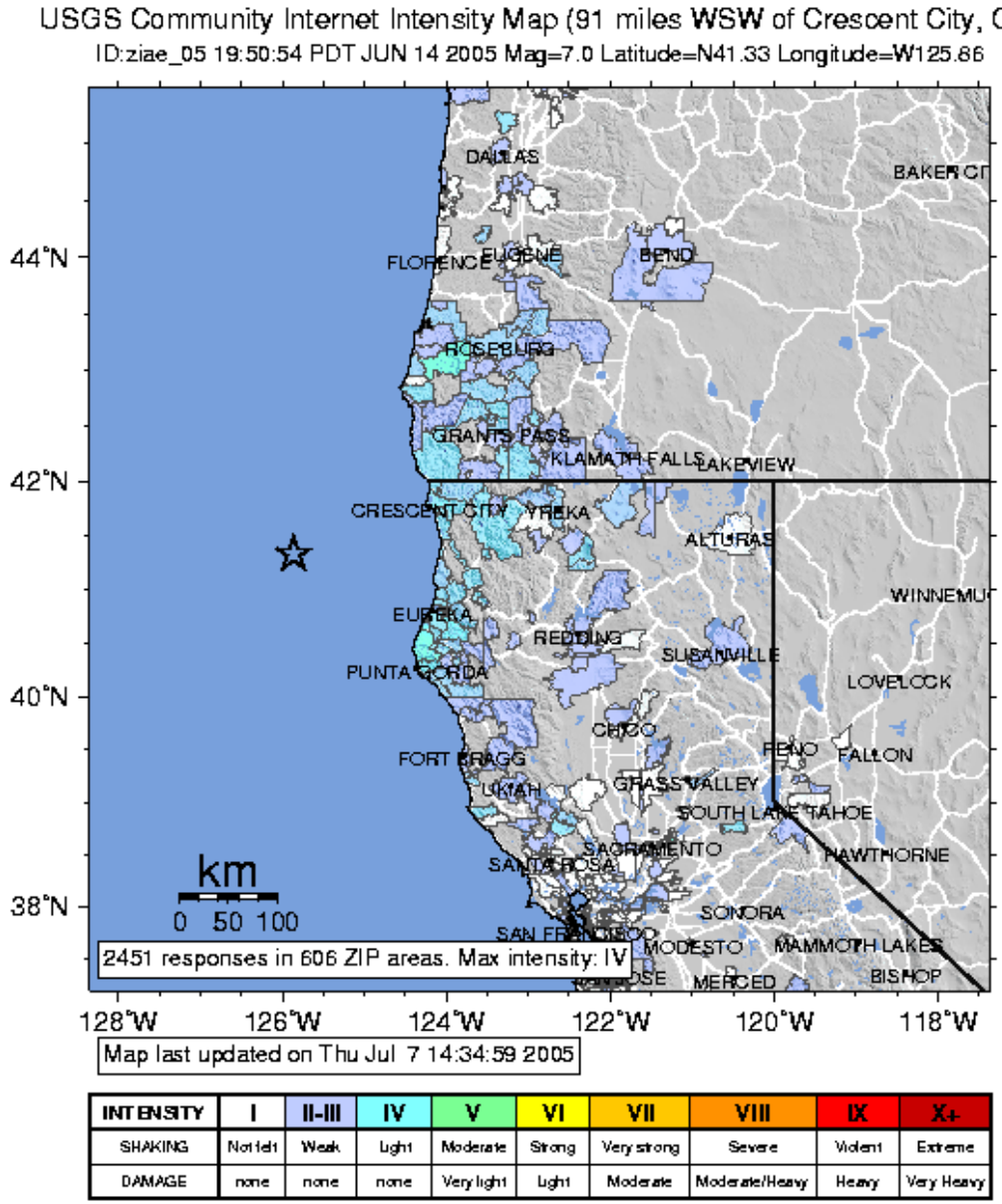
Elapsed Time: ~08:00 and later updates



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

ShakeMap—Not Distributed because of authority issues

Elapsed Time: ~10:00 and continuing



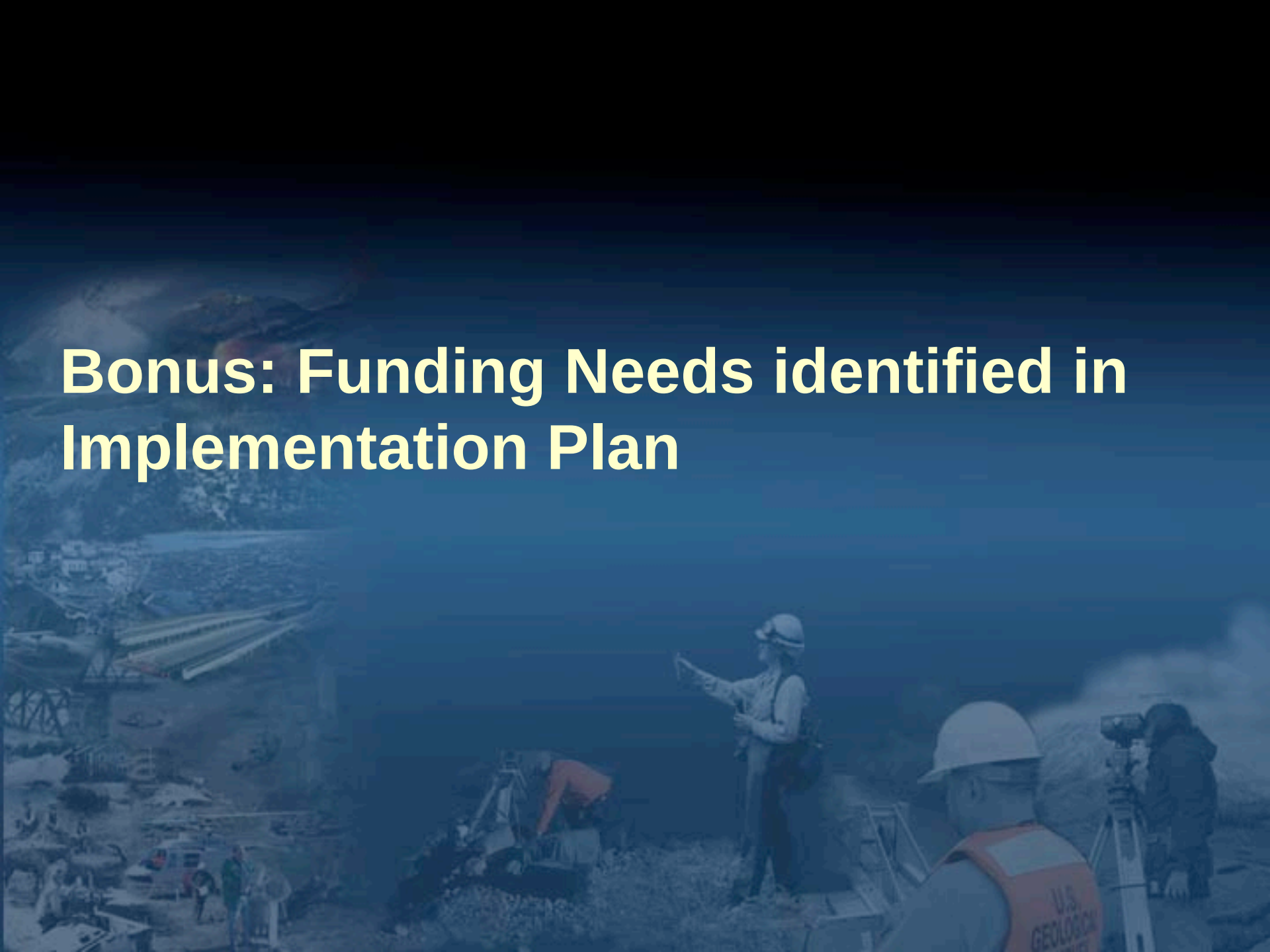
Did You Feel It? (Community Internet Intensity Map)

Gorda Plate-Cape Mendocino—plenty of tests for our systems?

Year	Month	Day	Mag	Comment
1899	April	16	7.0	West of Eureka
1922	Jan	31	7.3	West of Eureka
1923	Jan	22	7.2	Cape Mendocino
1980	Nov	8	7.2	Gorda Plate
1991	Aug	17	7.1	West of Crescent City
1992	April	25	7.2	Cape Mendocino
1994	Sep	1	7.1	Off coast of Northern California
2005	June	15	7.2	Gorda Plate

8 events in 106 years, ~13+ years recurrence

Bonus: Funding Needs identified in Implementation Plan



Identified needs for improving detection and warning

- Complete WC/ATWC seismic network upgrade in Alaska
- Upgrade PTWC seismic network in HI
- Complete Caribbean seismic installation
- Replace existing CREST sensors/recorders
- Integrate PBO stations into seismic networks and WCs for improved situational analysis of Cascadia/AK events

Identified needs for improving detection and warning, continued

- Upgrade CREST stations with higher bandwidth telemetry
- Improved seismic product delivery to WCs
- Upgrade Puerto Rico seismic network
- Increase operations and maintenance funding to reflect new operational requirements and expectations