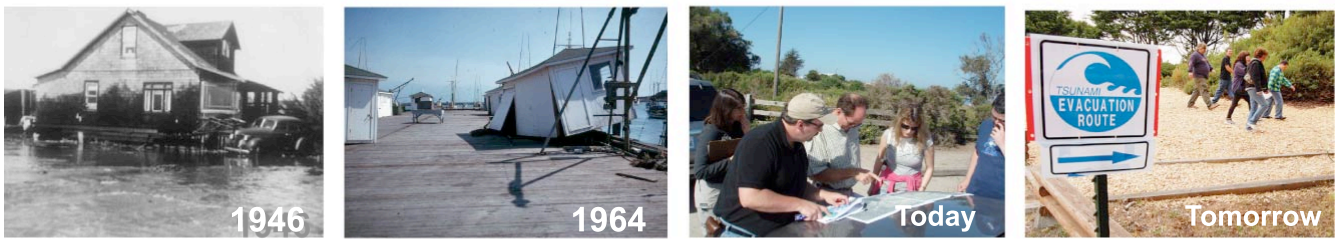
CALIFORNIA TSUNAMI PROGRAM

Tsunami Hazard Mapping Efforts

Hazard Identification → **Mitigation and Preparedness**



Rick Wilson, California Geological Survey

Aggeliki Barberopoulou and Costas Synolakis, Univ. of Southern California

Kevin Miller, California Emergency Management Agency

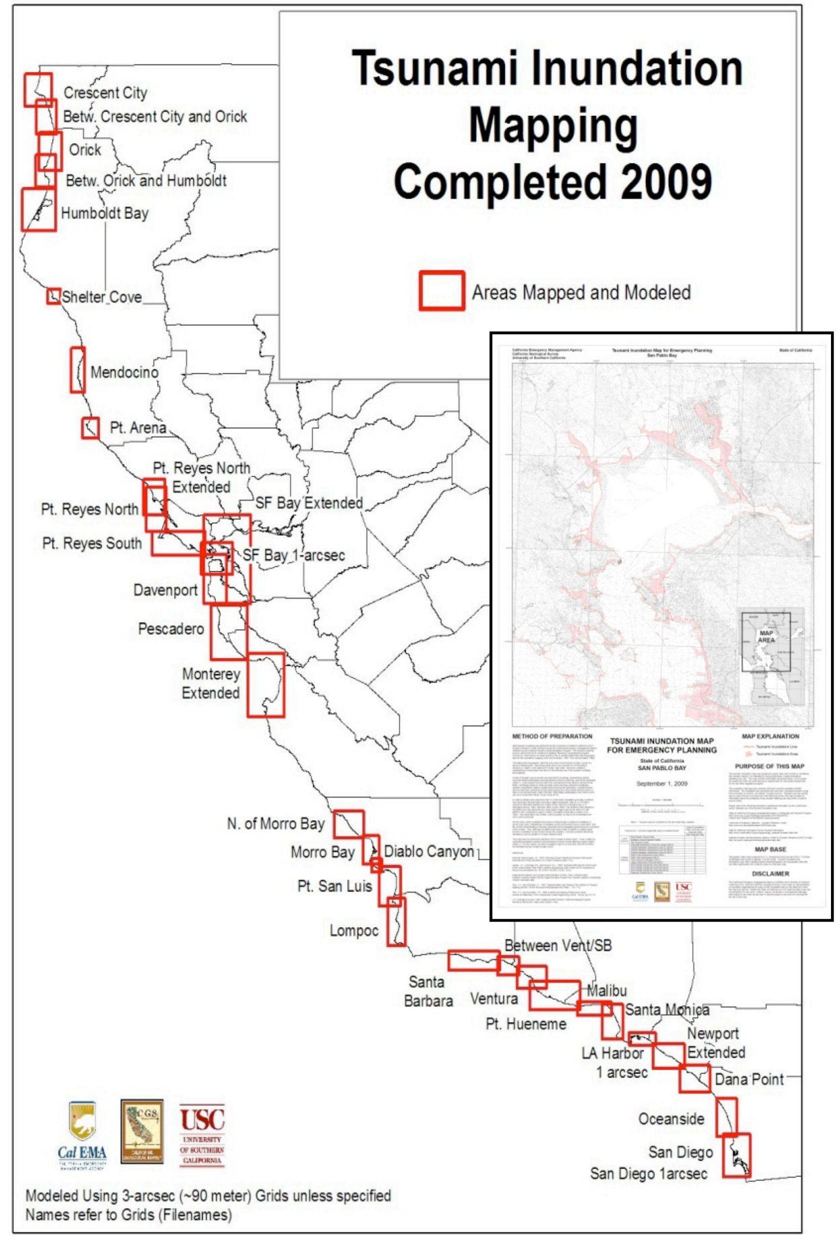
PEER PTHA Meeting, UC Berkeley
June 17, 2010

Tsunami Inundation Maps

For Emergency Response Planning

Available at **www.tsunami.ca.gov**

- Multi-year project covers all **low-lying populated coastal areas**
- **20 counties and over 75 cities/communities**
- **Collaboration between:**
  - CalEMA – overall program management, official map production and distribution, and help workshop coordination
  - USC – original source determination and numerical tsunami modeling
  - CGS – science and field coordinator, source determination, data transfer and enhancement in GIS, and final inundation line determination
  - Counties – local knowledge/concerns, map implementation, and workshop coordination



PEER PTHA Meeting, UC Berkeley
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Milestones in Understanding Tsunami Hazards in California from the "academic" point of view.

- 1970s - Houston and Garcia assessment of tsunamis from Alaska and Chile - estimates every 5 miles of coastline at 500m offshore depth.
- 1992 - McCarthy, Legg & Bernard assessment of risk in the aftermath of the Cape Mendocino event.
- 1995 - First simulation of local tsunami in Southern California - presentation to SSC in 1996. SSC->FEMA->USC&LLNL&SLC local offshore faults.
- 1997 - Synolakis, Titov & McCarthy re-assessment of Houston & Garcia estimates - factor of 5 difference in inundation distances.
- 1998 Papua New Guinea tsunami focuces attention to offshore landslides. Funding from NOAA->OES->USC for first modern inundation maps.
- 2001 McCarthy et al simulations in NATO ARW on California. Eisner et al in ITS.
- 2002 Analysis of Skagway tsunami.
- 2005 Refocusing of thinking on distant sources in the aftermath of Sumatra.
- 2006 Damage to Crescent City underscores the impact of "marginal" events.
- 2009 Completion of "most" maps, dissemination under way

California has been affected from tsunamis that have been caused by farfield and nearfield earthquakes.

Faults only recently identified as active complicate tsunami hazard assessment studies

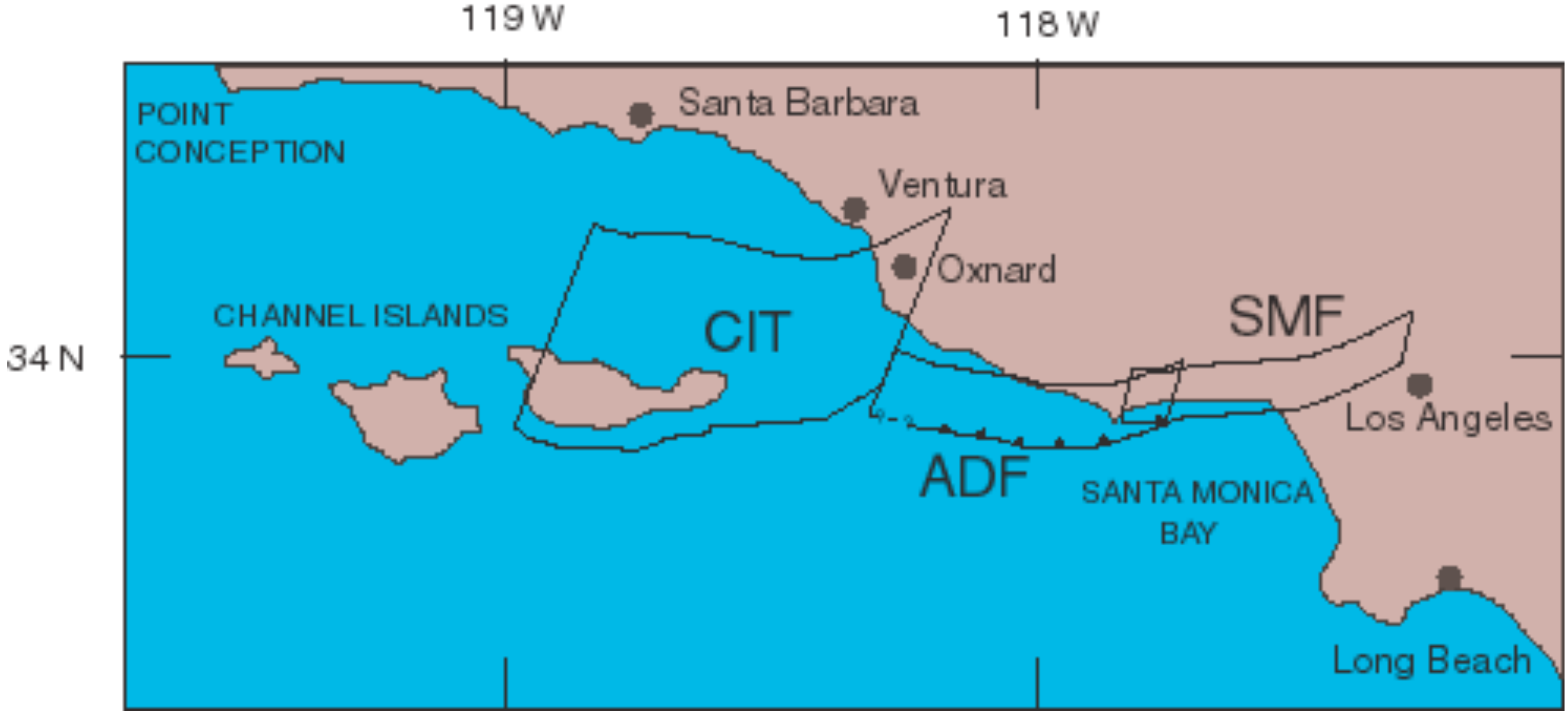
Exposure - not just the population on the 1200km coastline

- California has 11 cargo seaports and 27 small craft harbors
- More than 500,000 jobs statewide and US$30 Billion contribution to California economy.

The 2001 OES/USC maps

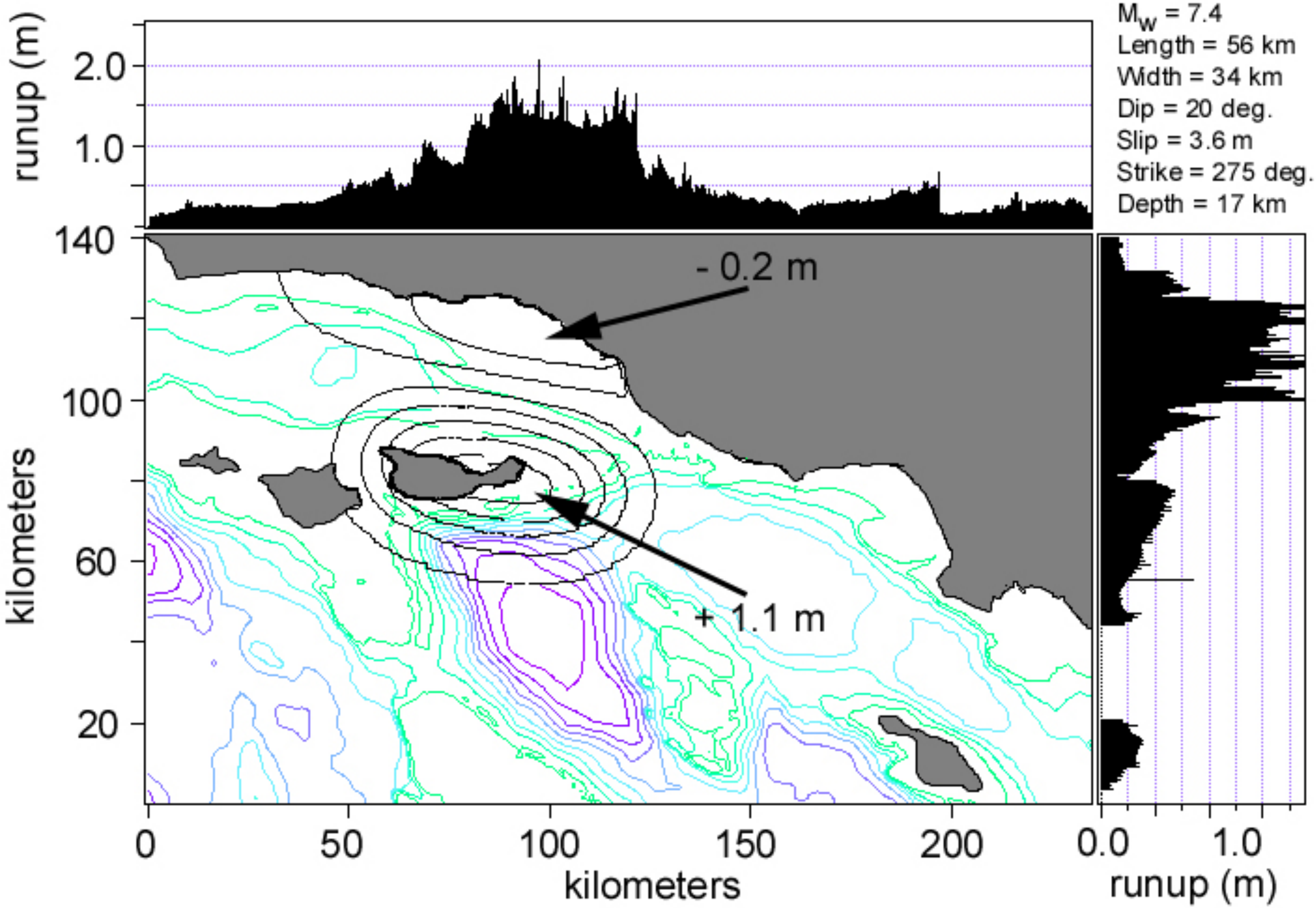
Emphasis in the period 1998-2004 was on local sources.

Three faults were considered potentially tsunamigenic.

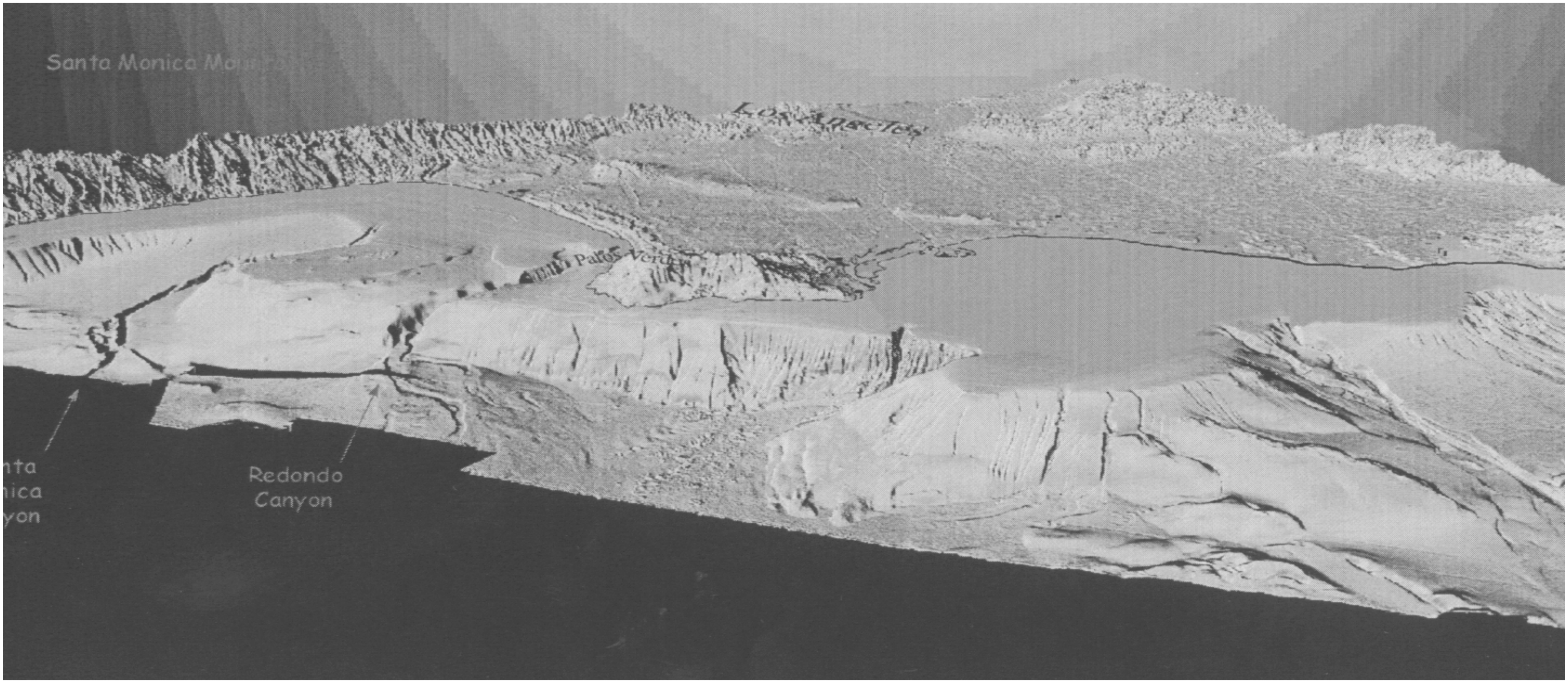


CIT - Channel Islands Thrust
ADF - Anacapa-Dume Fault
SMF - Santa Monica Fault

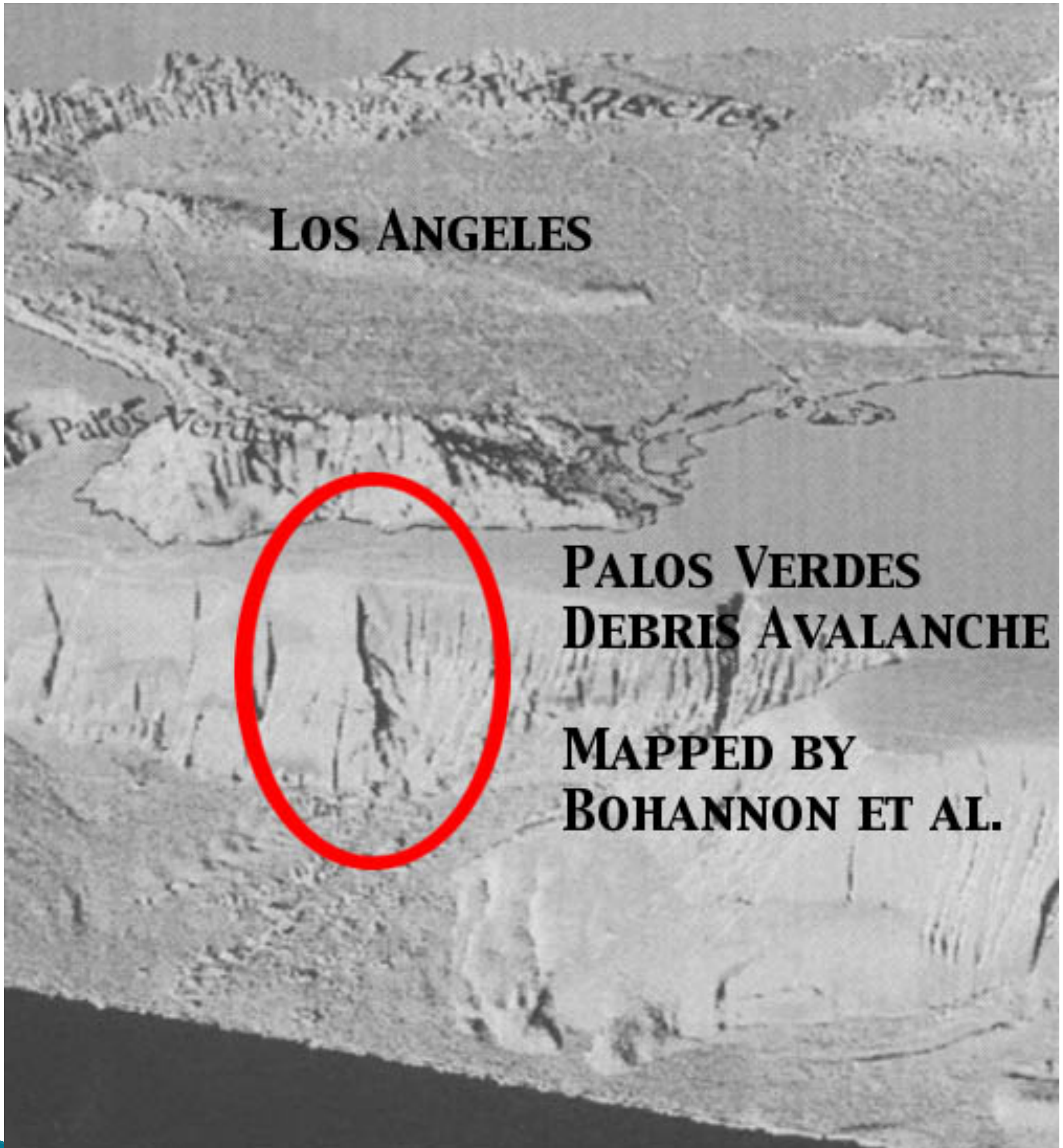
Channel Islands Thrust



Another potential tsunami source:

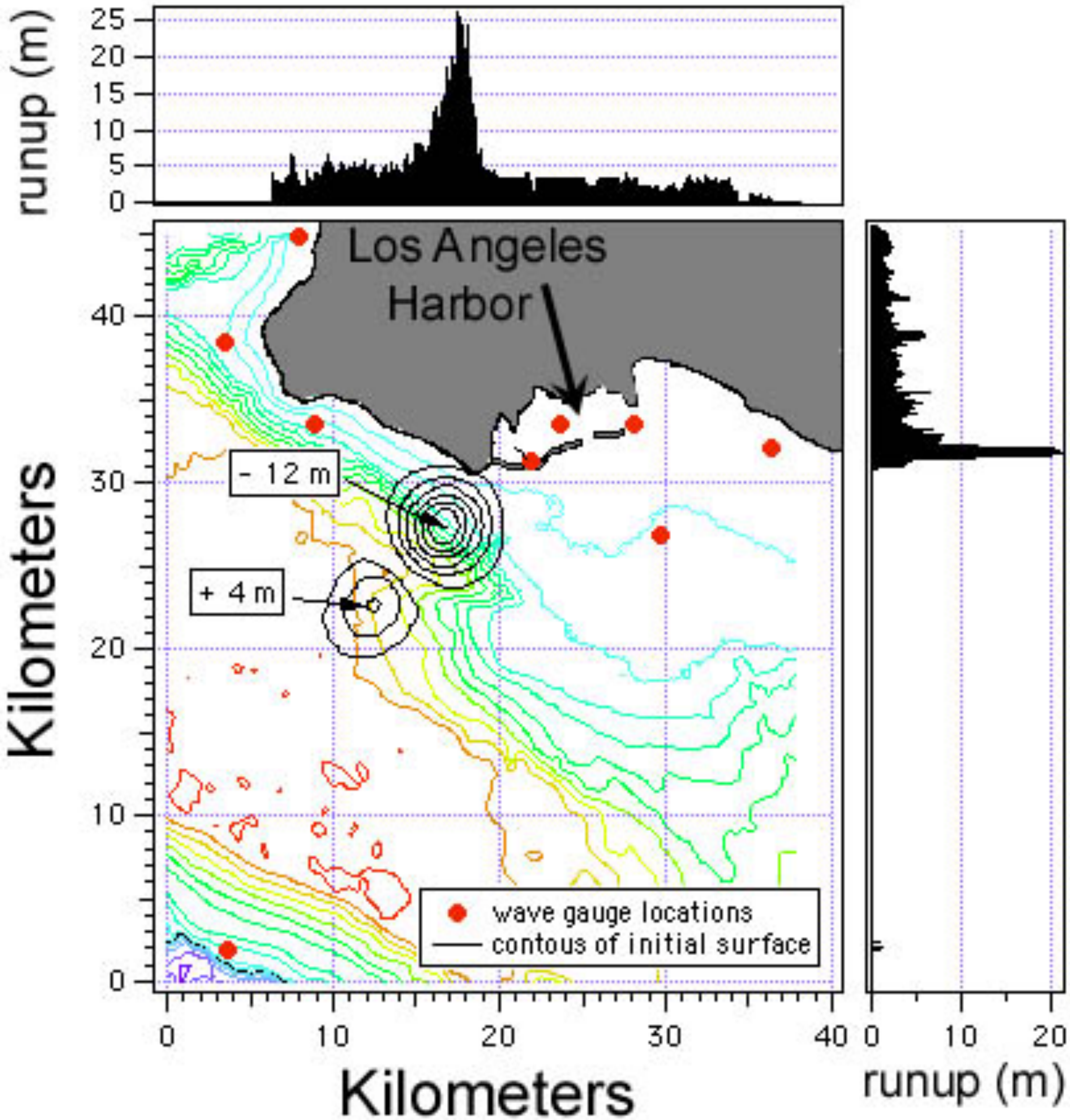


Underwater landslides or slumps

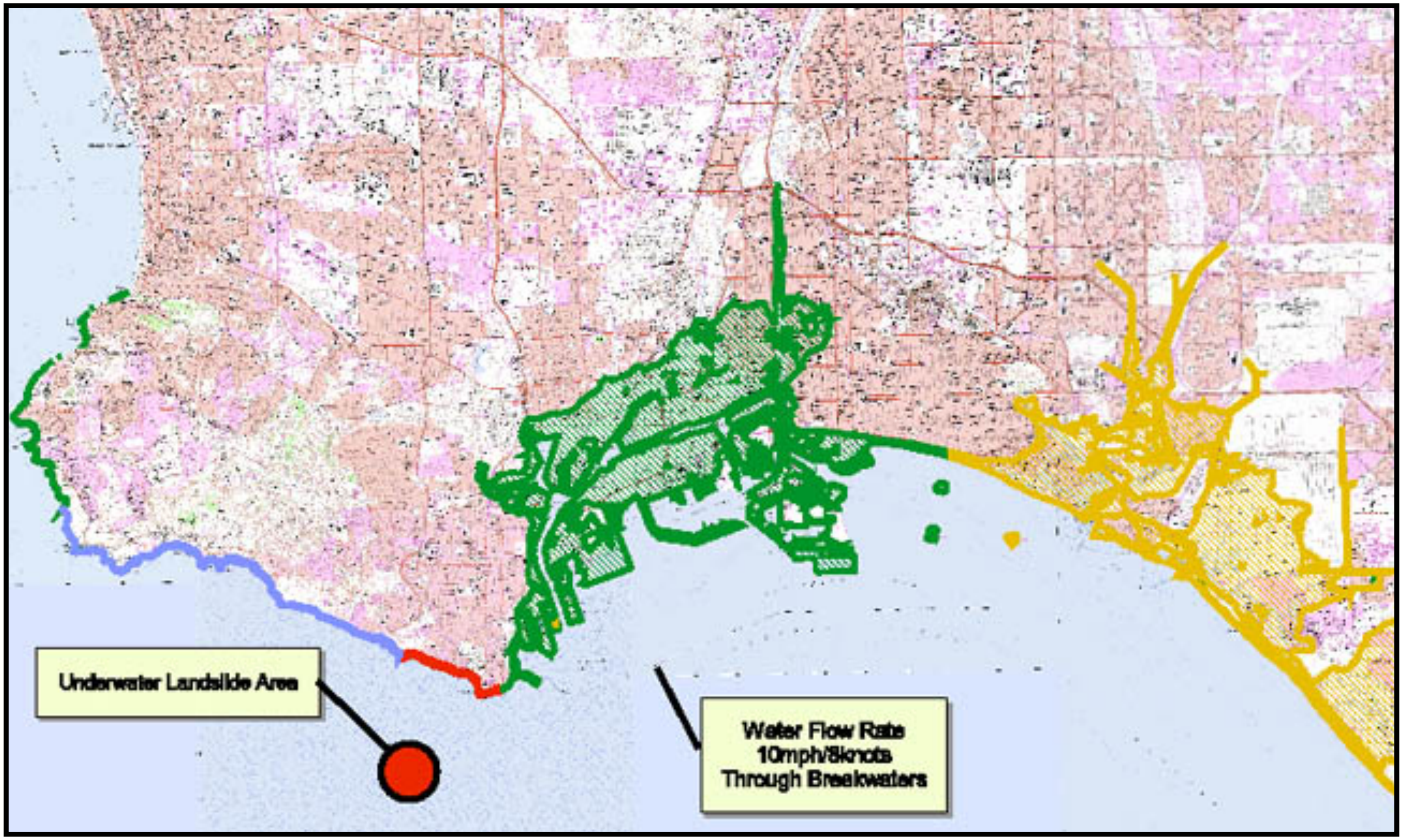


Palos Verdes
Slide Characteristics

- 2km wide
- 4.6km long
- 60m thick
- volume .35 to .72 km^3
- depth -100m to -800m


runup (m)
25
20
15
10
5
0
Los Angeles
Harbor
- 12 m
+ 4 m
wave gauge locations
contous of initial surface
Kilometers
40
30
20
10
0
0
10
20
30
40
Kilometers
0
10
20
runup (m)

Palos Verdes Tsunami Inundation



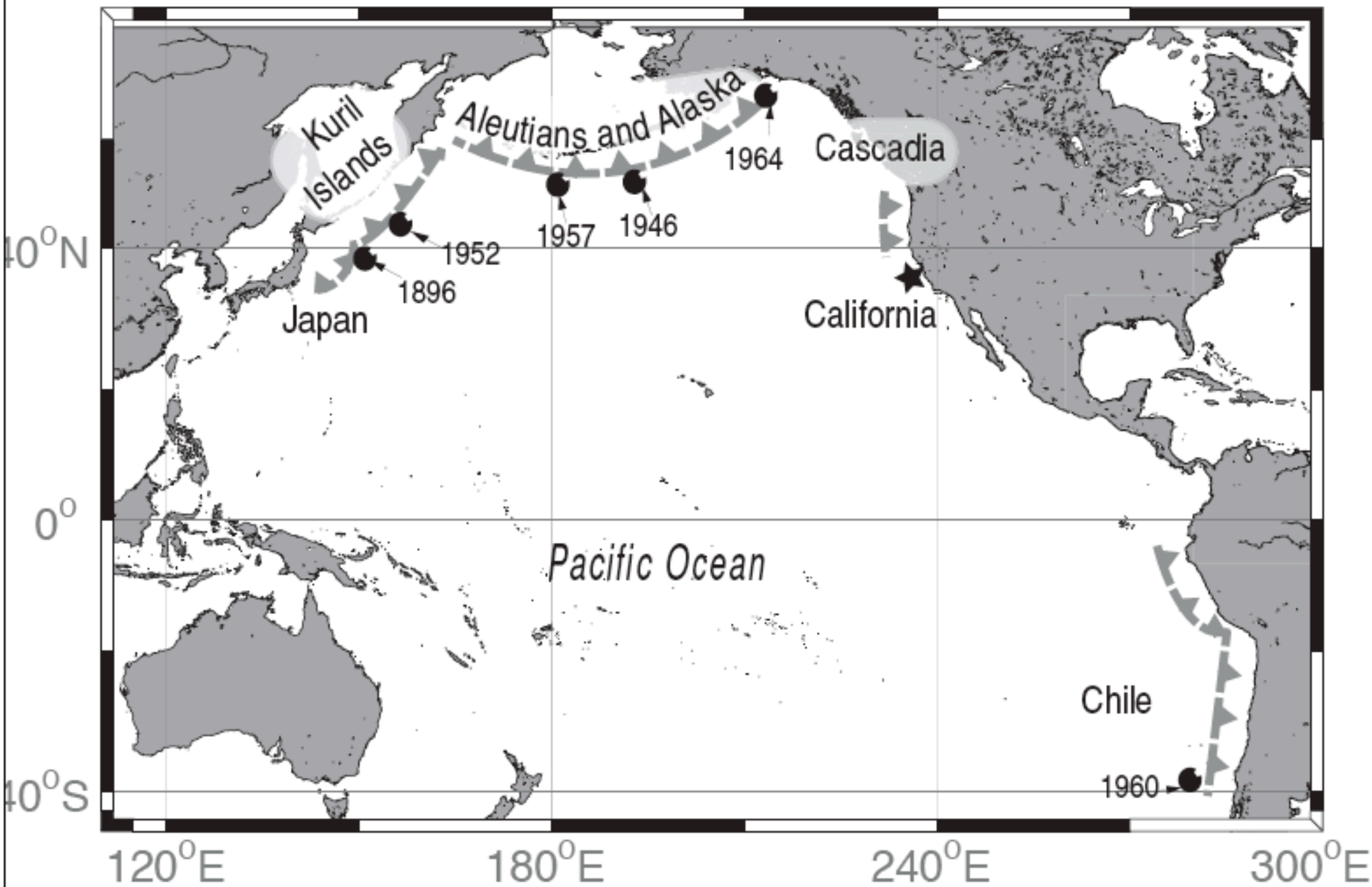
Tsunami Exposure:
74,600 people
4.5 Billion Dollars

Dam Break Flood:
15,200 people
1 Billion Dollars
(~5 times less than tsunami)

Post the 2004 Indian Ocean tsunami

Emphasis returned to far field events

Seismic sources with known historic tsunamis affecting California



Numerical modeling of tsunami propagation and inundation

$$h_t + (uh)_x + (vh)_y = 0$$

$$u_t = uu_x + vu_y + gh_x = gd_x$$

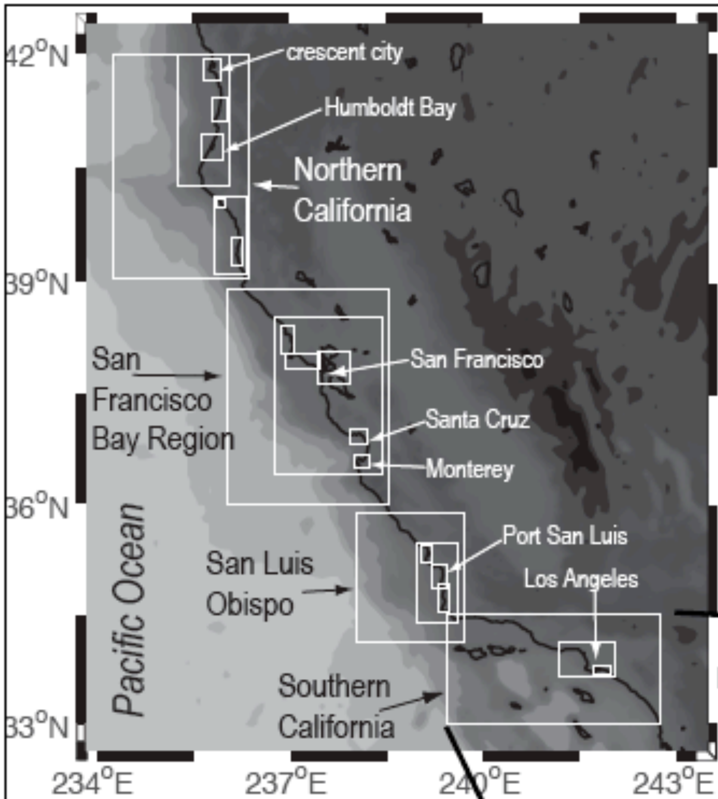
$$v_t + uv_x + vv_y + gh_y = gd_y$$

We use MOST (Method of Splitting Tsunami)

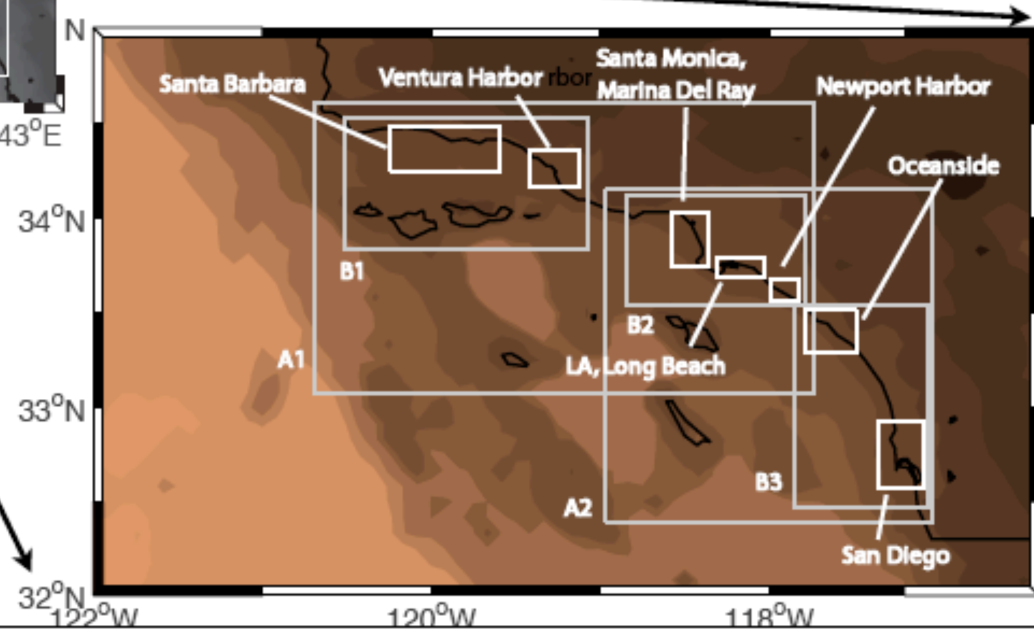
A finite difference model based on the nonlinear shallow water equations - benchmarked with the NOAA/Nuclear Regulatory Commission standards and guidelines for tsunami models.

where $h = \eta(x, y, t) + d(x, y, t)$; $\eta(x, y, t)$ = wave amplitude; $d(x, y, t)$ = undisturbed water depth; $u(x, y, t)$ and $v(x, y, t)$ = depth-averaged velocities in the onshore x and long-shore y directions, respectively; and g = acceleration of gravity.

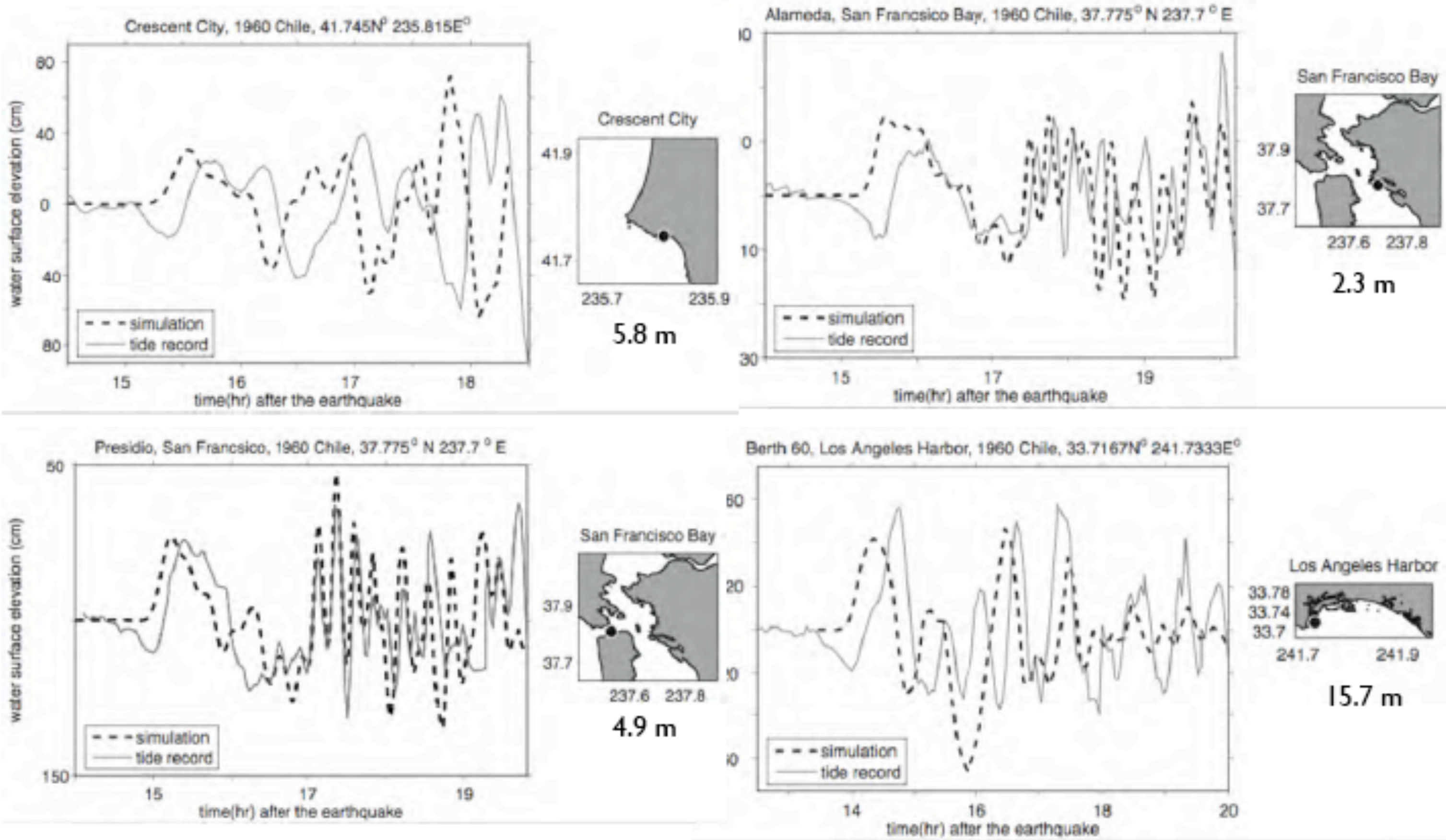
MOST solves the Nonlinear Shallow Water Wave equations (NSW) and uses nested grids developed for ports and harbors.



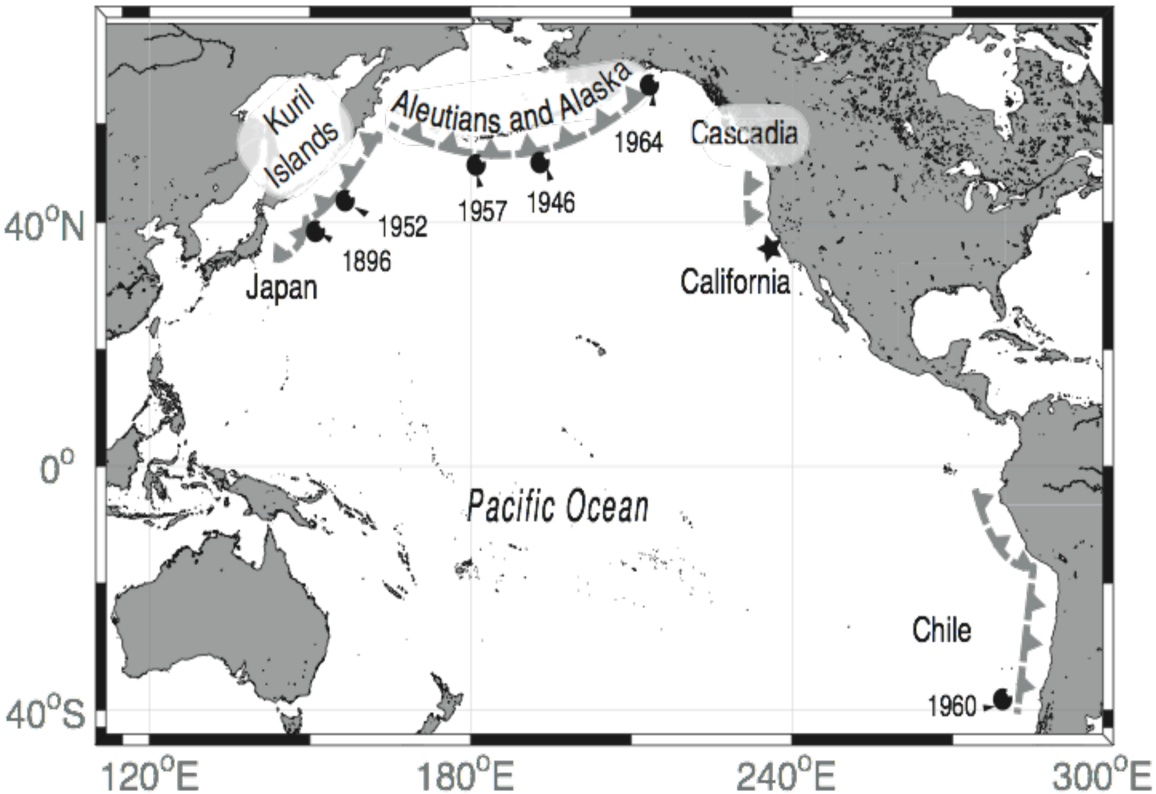
Southern California grids



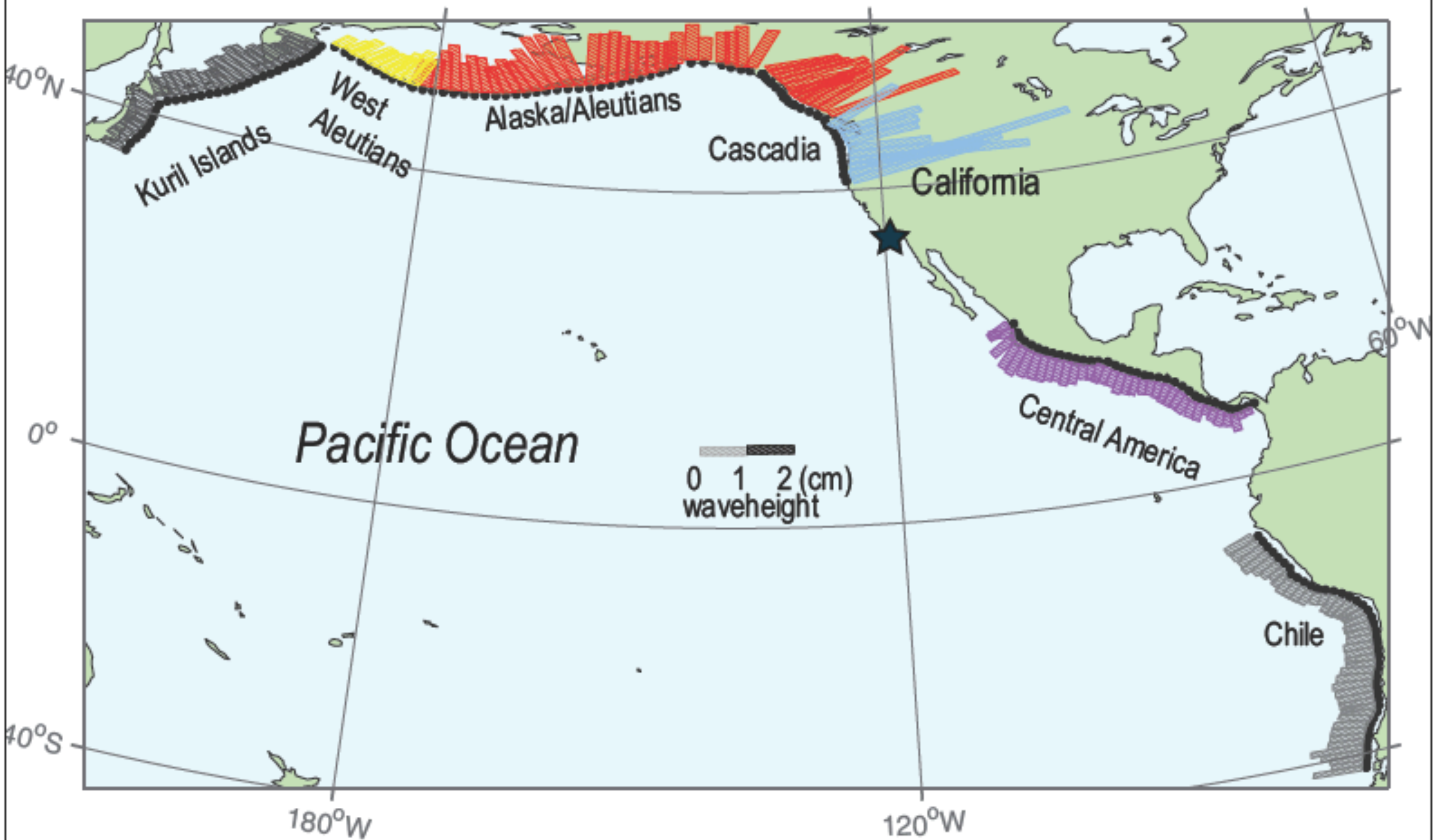
Comparison of tide gage records of 1960 event with MOST predictions based on combinations of 20 farfield unit sources.



Sources used in Inundation Mapping for California



- Far-field sources (i.e. Alaska-Aleutians, Kuril-Japan, Nazca-South America)
- Near field(i.e. Cascadia, Point Reyes fault, San Clemente)
- Landslides (Goleta-Gaviota, Palos Verdes, Coronado Canyon)

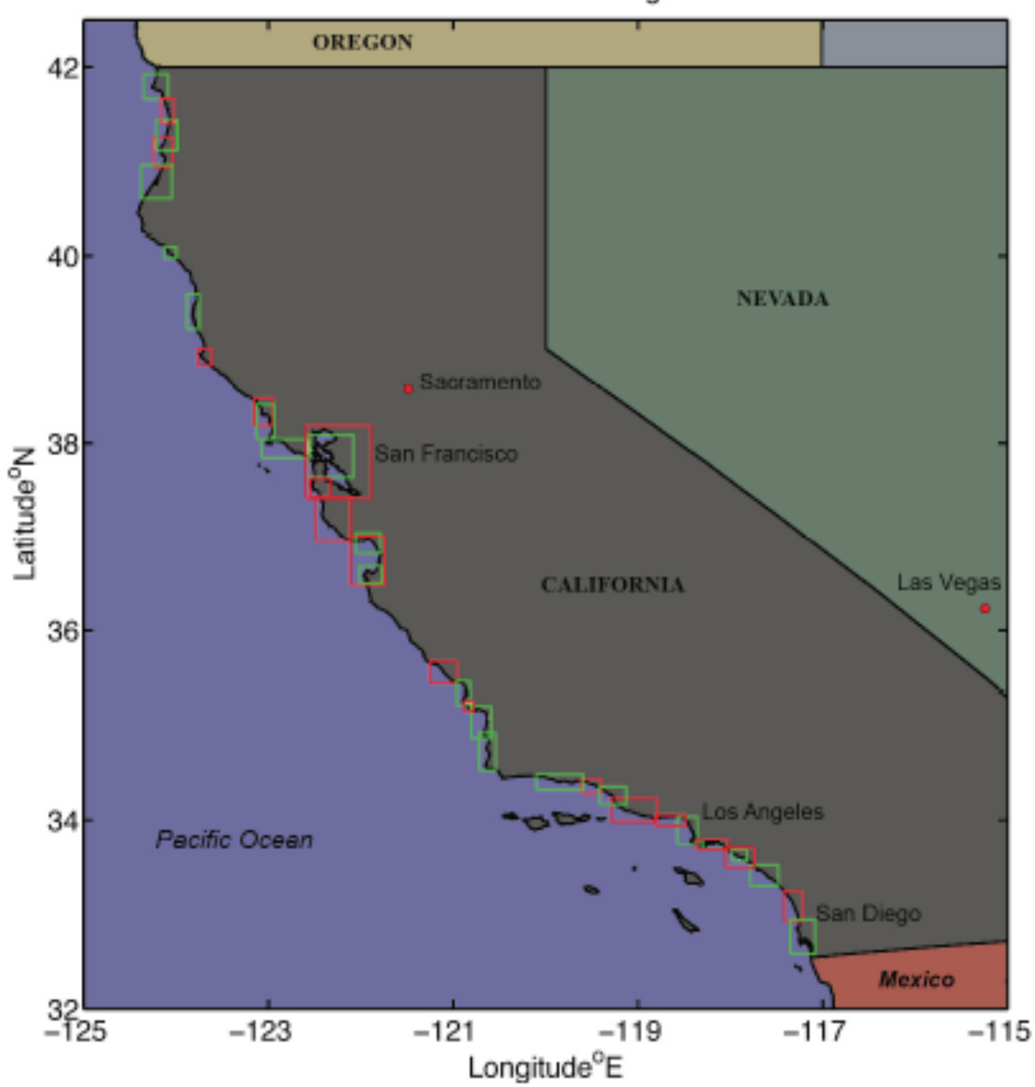


Which source produces the highest tsunami wave off San Francisco ?

Distribution of inundation grids across California

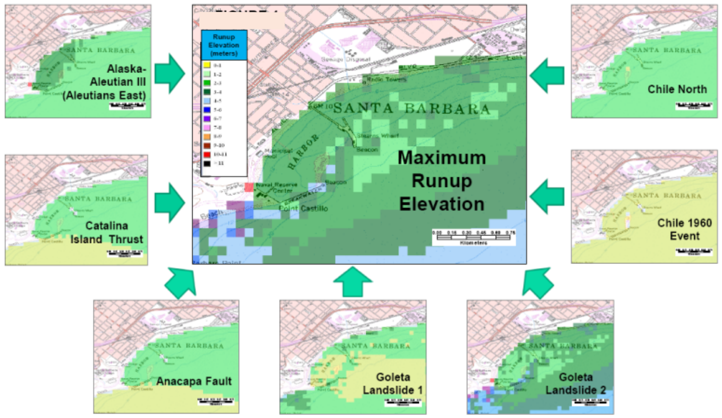
- 35 numerical grids used
- 20 counties covered
- 90 and 30 m resolution used
- 12 distant sources used
- 28 Local Sources
- 21 Local earthquake sources
- 7 landslide sources
- 3 years and more than 400 simulations were needed to produce 130 maps (USGS quadrangle format)

USC Tsunami Modelling Grids

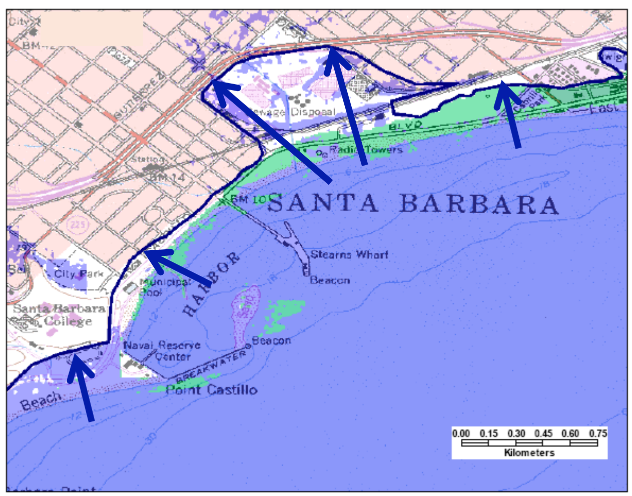


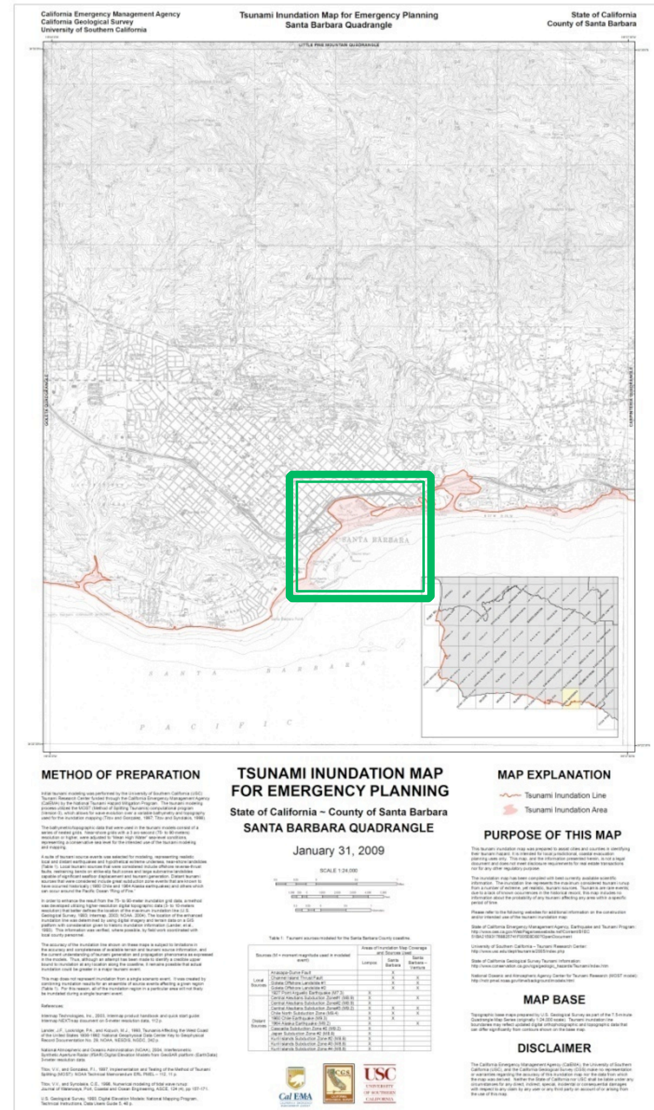
From Modeling to Maps

Create and Combine Run-up Grids



Flood Extension Using High-Resolution DEM Data



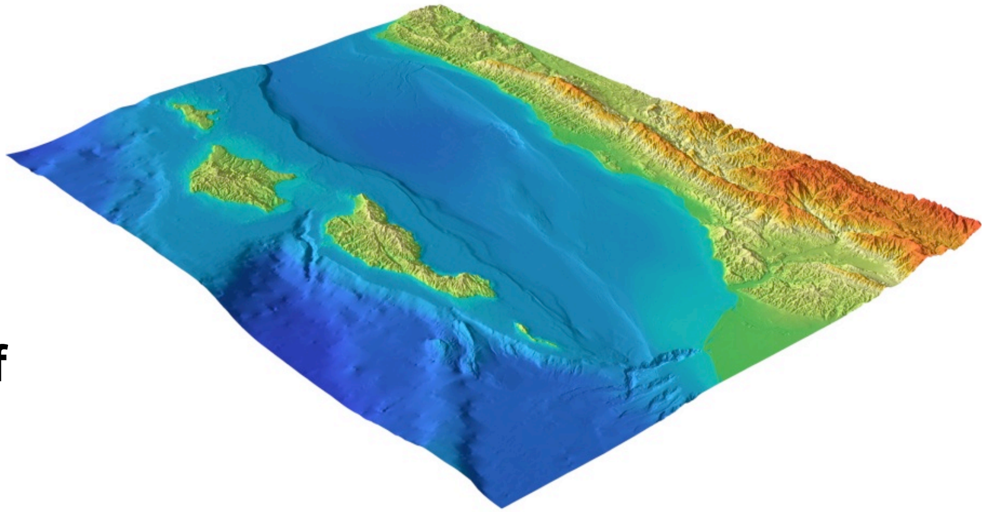


Is Another Generation of Maps for Emergency Response Planning Needed?

- **Convergence of modeling**: Compare modeled results from 90m and 30m DEMs to new 10m DEM resolution data

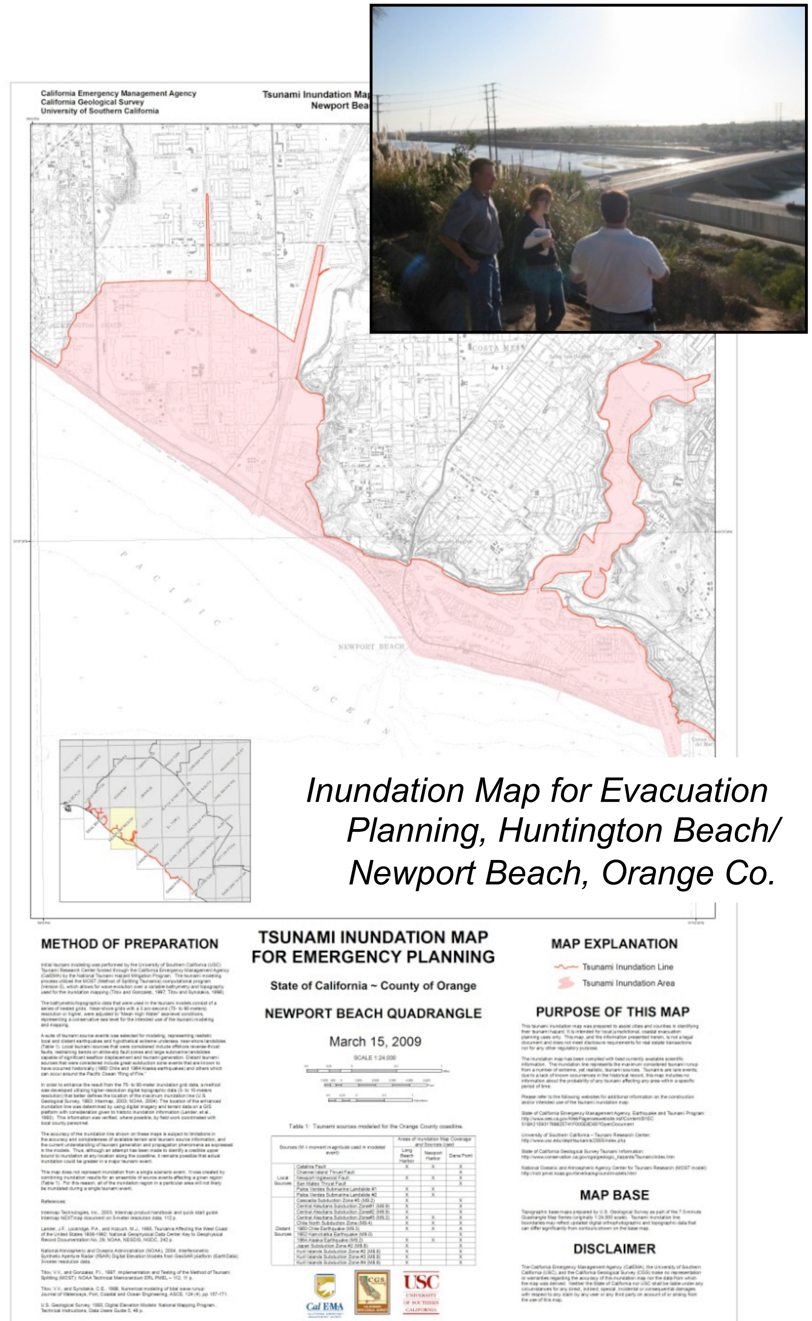
- **Would higher resolution data significantly change location of inundation line?... resulting evacuation line/plans?**

Santa Barbara DEM at 10m resolution, National Geophysical Data Center



Maps for Land-Use Planning

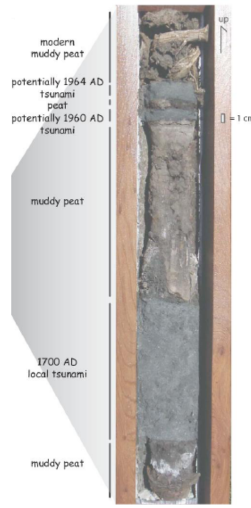
- Requested by local jurisdictions (example from Orange County)
- NTHMP supported project
- **Seismic Hazard Mapping Act**
    - "Zones of Required Investigation"
    - Requires site-specific evaluation
    - If hazard exists, mitigate
    - Real estate disclosure if in zone



Inundation Map for Evacuation Planning, Huntington Beach/ Newport Beach, Orange Co.

Land-Use Planning Maps

- 2010 – engage land-use planning community, evaluate existing PTHA work, develop and utilize tsunami deposit and source DBs and discussion forum
- 2011 – convene workshops, develop working group, determine methodology
- 2012 – conduct pilot study creating maps and implementing program, provide guidance
- 2013 – if pilot successful, complete products for 10% of communities



Non-Cascadia Local Source Names	L (km)	W (km)	Slip (m)	dip (deg)	rake (deg)	strike (deg)	depth(km)	Mw
1-1927 Point Arguello Earthquake	28	14	2.5				3	7
2-Anacapa-Dume Fault	40	18	2.5	55	90	270	5	7.2
3-Carslbad Thrust Fault	30	12	5	30	90	324	1.5	
4-Catalina Fault	164	14	4.5	n/a	n/a	n/a	n/a	7.7
Segment 1	21.9	14	4	89	173	313	0.5	
Segment 2	28.2	14	5	85	143	293	1	
Segment 3	16.1	14.9	4.8	70	124	277	1	
Segment 4	20.2	14	3.6	80	146	303	1	
Segment 5	8.1	14	6.4	80	149	300	1.5	
Segment 6	40.2	14	4.5	80	153	297	1	
Segment 7	29.7	14	4.1	89	166	315	0.5	
5-Channel Islands Thrust Fault	56	34	3.6	20	90	280	17	7.5
6-Coronado Bank Fault								7.3
Segment 1	39.56	10	2.4					
Segment 2	24.55	10	4.2					
Segment 3	29.66	10	2.8					
7-Oceanside Thrust, Lasuen Knoll Fault	16.7	12.5	2.2	n/a	n/a	n/a	0.5	7
Segment 1	8.8	12.8	1.5	70	135	290	0.5	
Segment 2	7.9	12.2	3	80	135	318	0.5	
Segment 3	10	12.2	5	80	135	316	0.5	
8-Newport Inglewood Fault	30	8	4	70	10	315	10	7
9-Point Reyes Thrust Fault	77	12	3.4	50			0.38	7.3
Segment 1	42		3.4	50		333		
Segment 2	35		3.4	50		300		
10-Hayward-Rodgers Creek Fault	10	18	1.5	70	-90	40	5	6.6
11-San Clemente Fault Bend Region	97	10	2.2					
shallow (surface)	30	8		70	162	305	7.6	
deep (blind)	25	14		48	134	270	16	
12-San Clemente Island Fault	30	8	8	70	162	305	7.6	7.5
13-San Gregorio Fault	50	15	2	60	90	320	5	7.1
14-San Mateo Thrust	27.75	12	4				0.5	7.1
Segment 1	5.5	12	4	45	120	293	0.5	
Segment 2	11.4	12	4	45	120	322	0.5	
Segment 3	15	12	4	45	120	350	0.5	
15-Santa Monica Bay Fault	40	18	2.4	55	90	260	15	7.1

Ventura County

Questions we hope to address:

- What PTHA data is available?

- What is suitability of this data for creating land-use planning maps?

- What issues exist with the analyses?

- What data gaps exist?

- How best to address these issues and fill data gaps?

Humboldt County

San Francisco Bay

San Diego County