Developing Tsunami Damage Estimation and Mitigation Technologies

Tsunami Research Group

JST/JICA Science and Technology Research Partnership for Sustainable Development
Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru
Kickoff Meeting, 10 June, 2009

Tsunami Group Member

- Dr. Shunichi Koshimura (Tohoku Univ., Tsunami engineering, Team Leader)
- Dr. Gaku Shoji (Tsukuba Univ., Structural and earthquake engineering)
- Dr. Yushiro Fujii (BRI, Seimology and Tsunami modeling)
- Dr. Yuji Yagi (Tsukuba Univ., Seismology)

Objectives and Goals

- To assess the potential tsunami disaster and its impact to the Peruvian coast
- To develop practical technologies to mitigate tsunami risks in Peru
- Implementation to the strategic plans for disaster mitigation of Peruvian government
- Contributions to Pacific tsunami disaster mitigation strategies

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Research Plan (Scientific phase)

- Assessing historical tsunami events and its impact in Peru
  - Tsunami sources
  - Tsunami hazard (Tsunami generation, near-shore propagation and coastal inundation)
  - Damage (Casualties, Structural damage)
- Indentifying potential tsunamis and the worst case scenarios
  - Tectonic settings and tsunami source scenarios
  - Potential tsunami exposure (Exposed population)
  - Potential impact
- Mapping tsunami hazard and its impact
  - Inundation modeling
  - Damage estimation (Casualties, Structural damage)
  - Hazard maps, Cartography

Research Plan (Implementation Phase)

- Developing a general procedure for mapping tsunami hazard
  - Training program (Tsunami modeling and mapping)
  - Warning, guidance and public education
- Strategic planning to mitigate tsunami risks and damage
  - Tsunami disaster mitigation program for Peruvian government
  - Tsunami countermeasures
  - Design for tsunami evacuation facilities
  - Tsunami evacuation strategies

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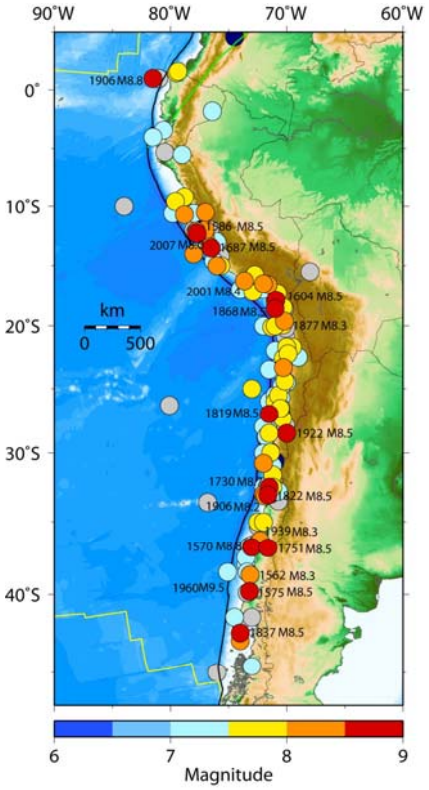
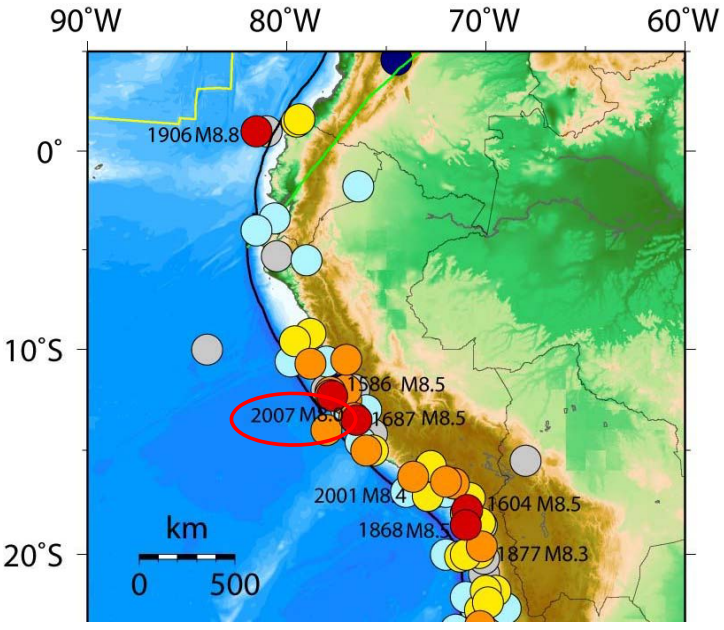
Past Events in Peru

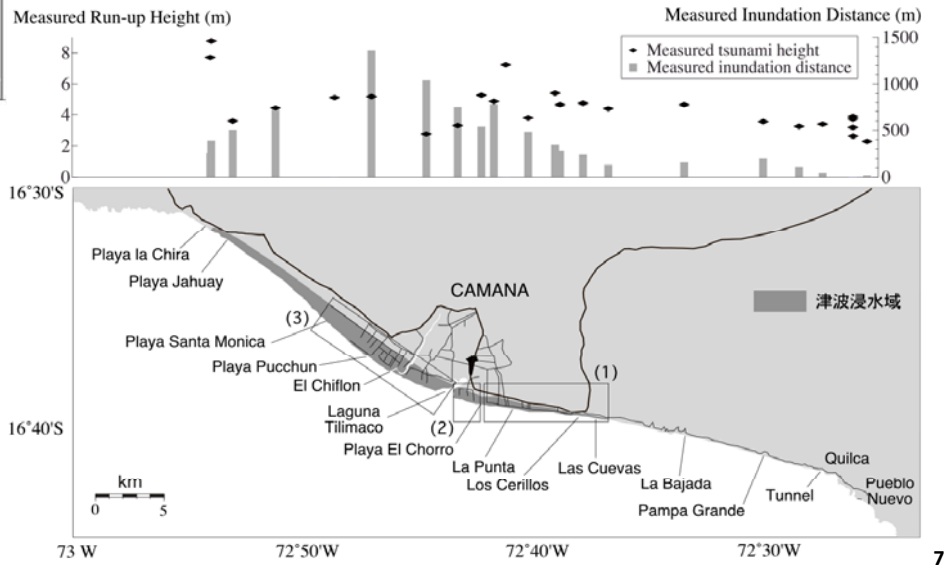




NGDC Tsunami Database
http://www.ngdc.noaa.gov/hazard/tsu_db.shtml

2001 Tsunami (Camana, Peru)

Casualty			House damage	
Dead	Missing	Injury	Major/Minor	Collapsed
24	62	41	760	2915



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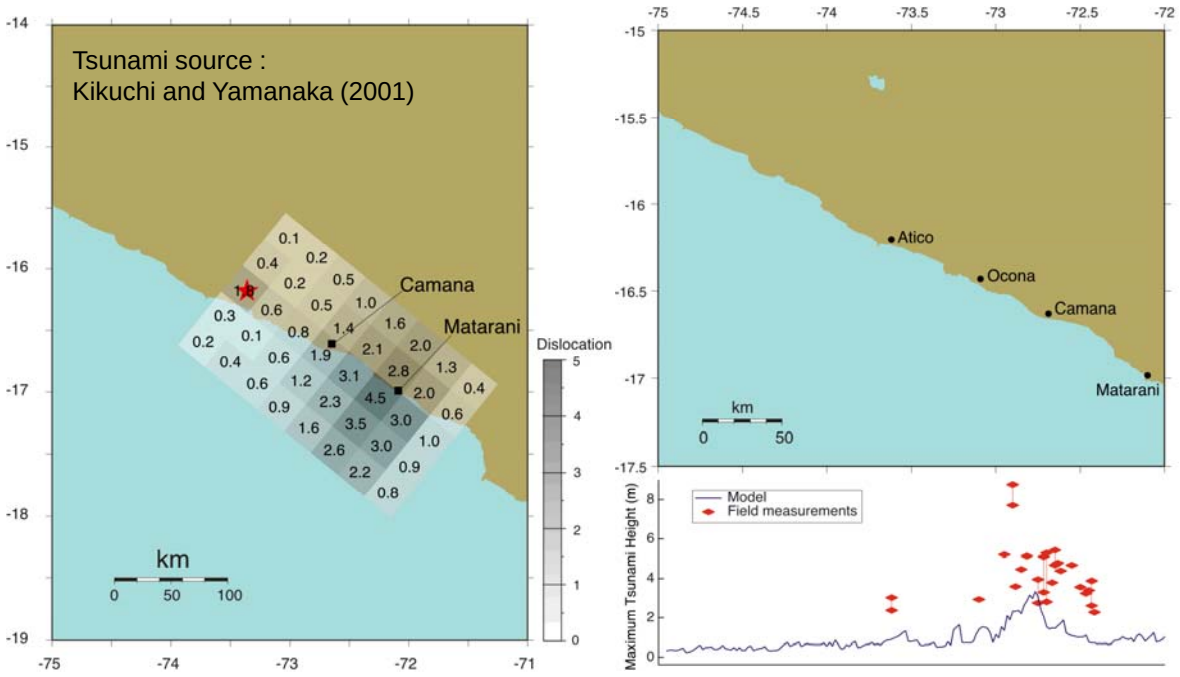
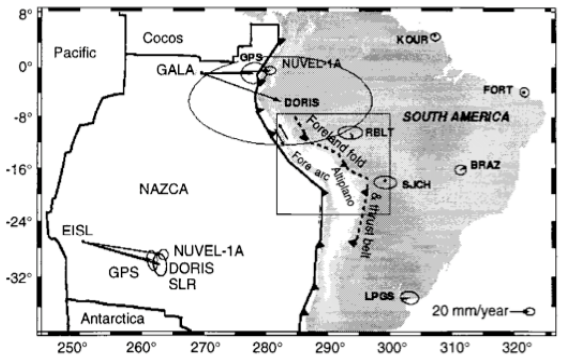
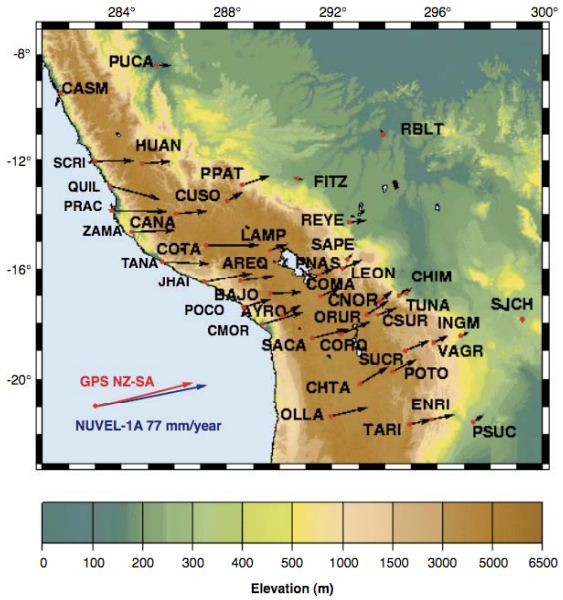
Post-tsunami survey in Camana

Modeling the 2001 Peruvian Tsunami



Crustal Deformation in Peru





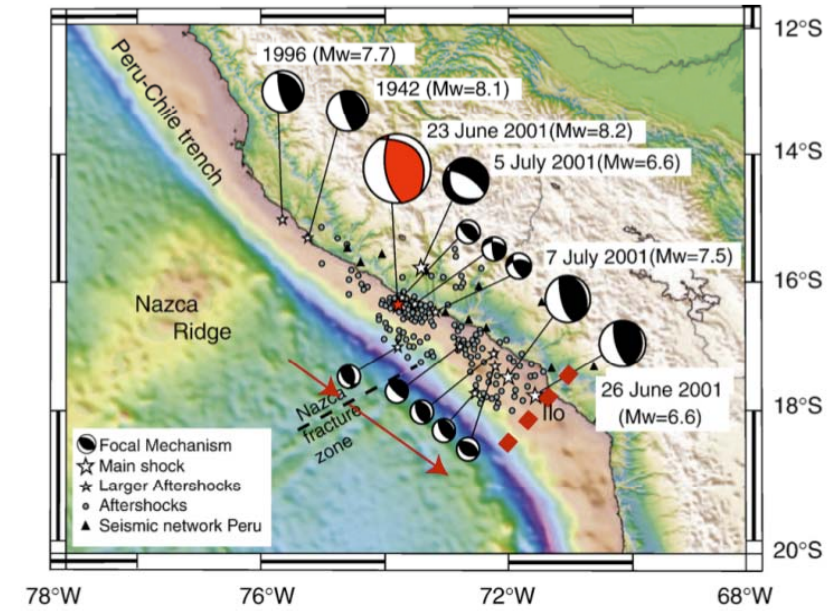
Roughly half of the overall convergence, about 30 to 40 mm/y, accumulated on the locked plate interface

Fig. 2. Global positioning system–derived velocities relative to stable South America (SA) from sites in the survey, compared with convergence velocities predicted by NUVEL-1A and the plate-wide space geodetic data (Fig. 1). NUVEL-1A vector gives rate scale. NZ, Nazca.

E. Norabuena et al. (Science, 1998)

2001 Peru Earthquake

Focal mechanism and aftershocks



23rd of June 2001 earthquake and its aftershocks from Peruvian network data, after Tavera et al. (2006). The Nazca fracture zone is reported, being a seismic barrier that stalled the propagation of the main shock rupture as discussed by Robinson et al. (2006) (as on Fig. 1).

L. Audin et al. (Tectonophysics, 2008)

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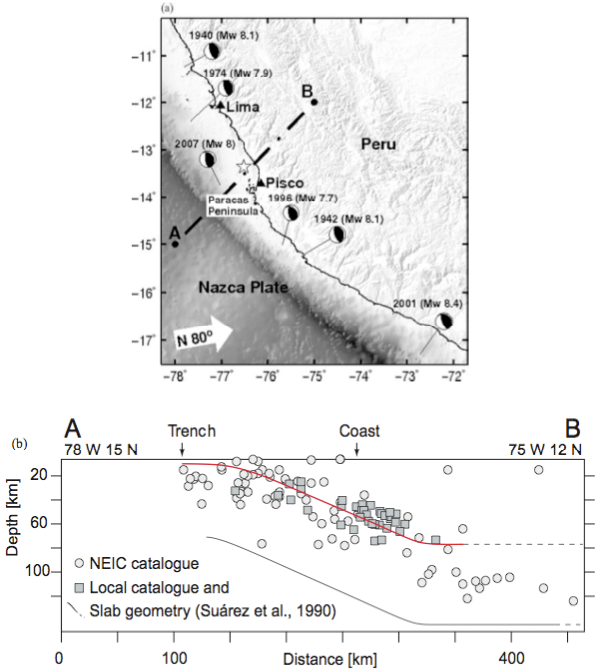
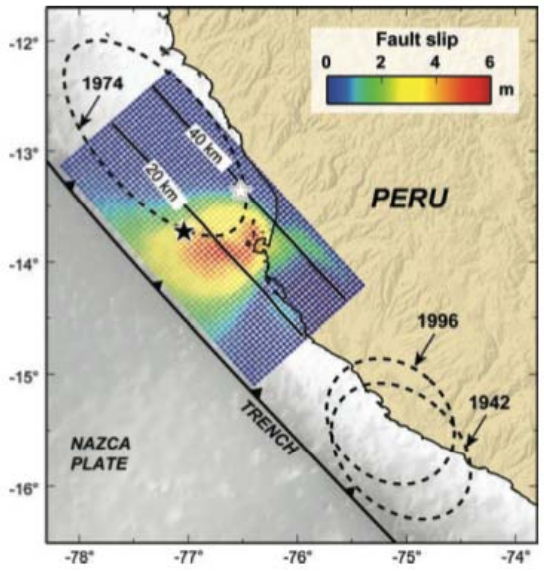
2007 Peru Earthquake

The geometry of the subducted slab and distribution of seismicity.



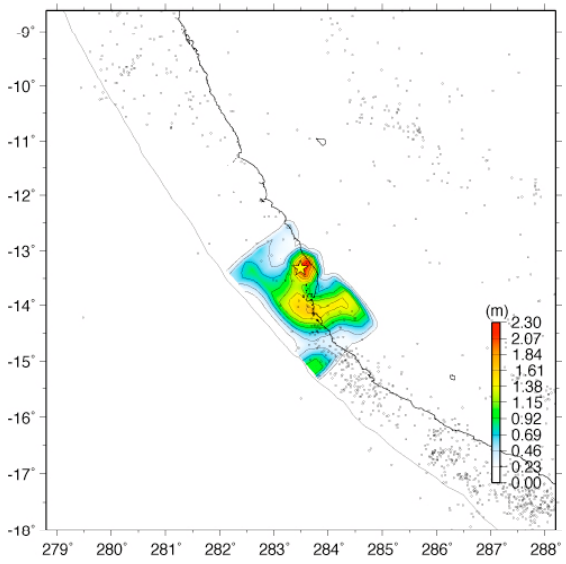
Slip distribution obtained by In SAR



M. Motagh et al. (GJI, 2008)

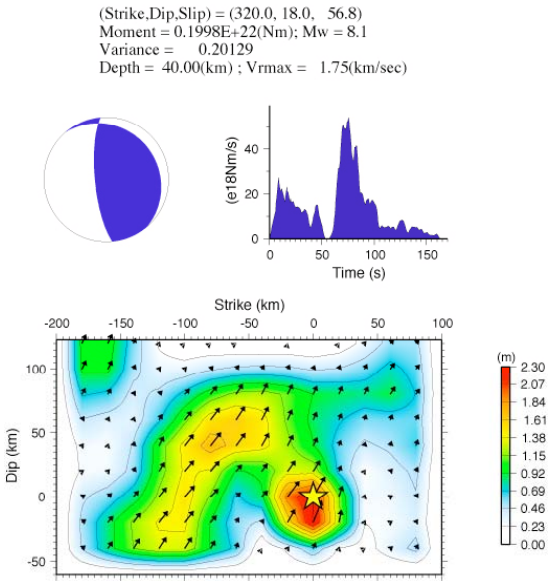
Source Process of 2007 Peru Earthquake obtained by inversion of tele-seismic body wave

Slip distribution (Map view)



Yagi (2007)

Focal mechanism, Source time function, Slip distribution on fault plane



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Historical Earthquake in Peru

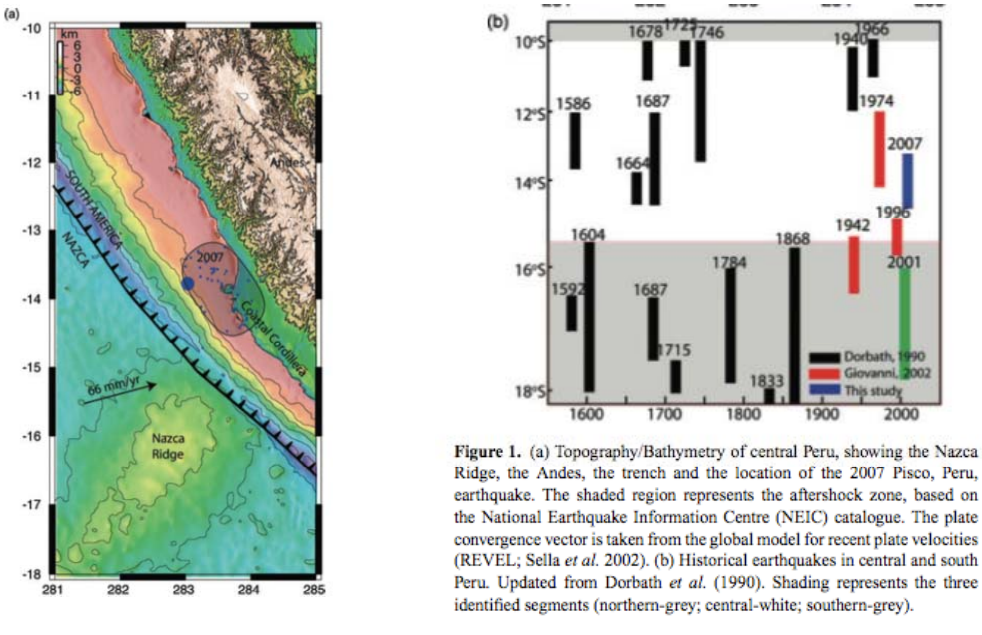
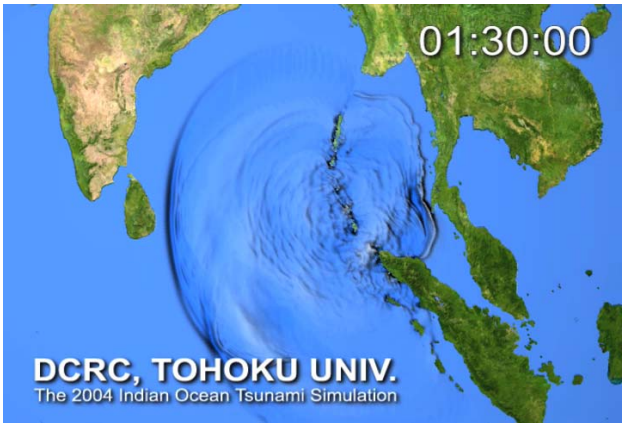


Figure 1. (a) Topography/Bathymetry of central Peru, showing the Nazca Ridge, the Andes, the trench and the location of the 2007 Pisco, Peru, earthquake. The shaded region represents the aftershock zone, based on the National Earthquake Information Centre (NEIC) catalogue. The plate convergence vector is taken from the global model for recent plate velocities (REVEL; Sella *et al.* 2002). (b) Historical earthquakes in central and south Peru. Updated from Dorbath *et al.* (1990). Shading represents the three identified segments (northern-grey; central-white; southern-grey).

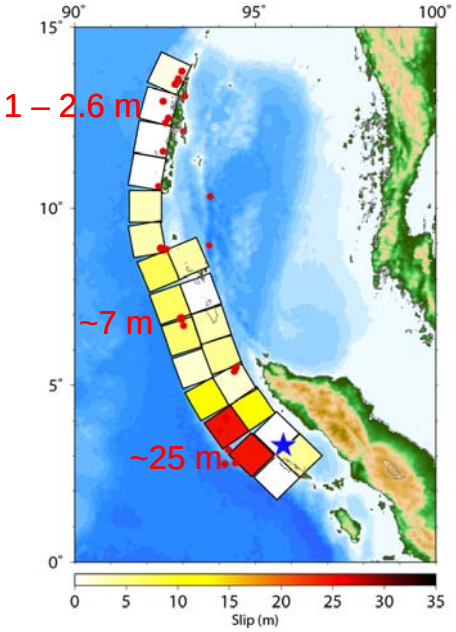
J. Biggs et al. (GJI, 2009)

Tsunami modeling technology

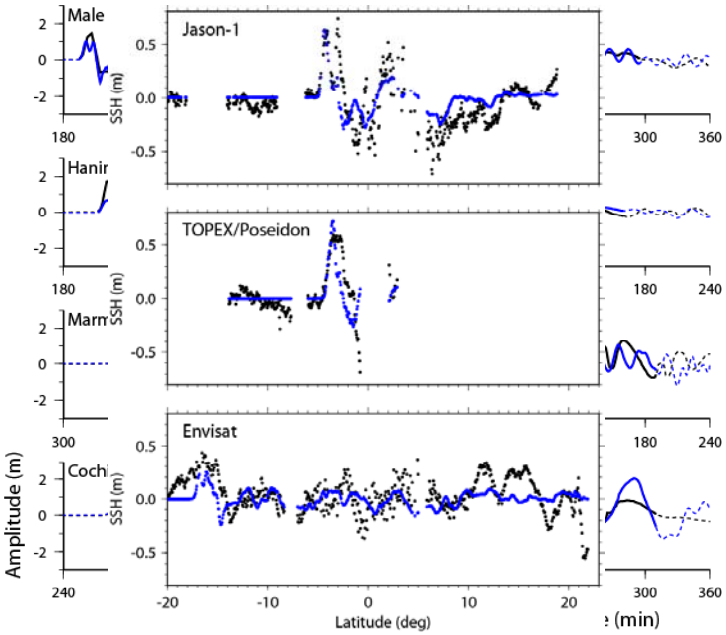
- Tsunami Modeling techniques (Tsunami-code to simulate tsunami generation, off-shore/near-shore propagation and coastal inundation)



Inversion Result using Both (TG+SA) Data



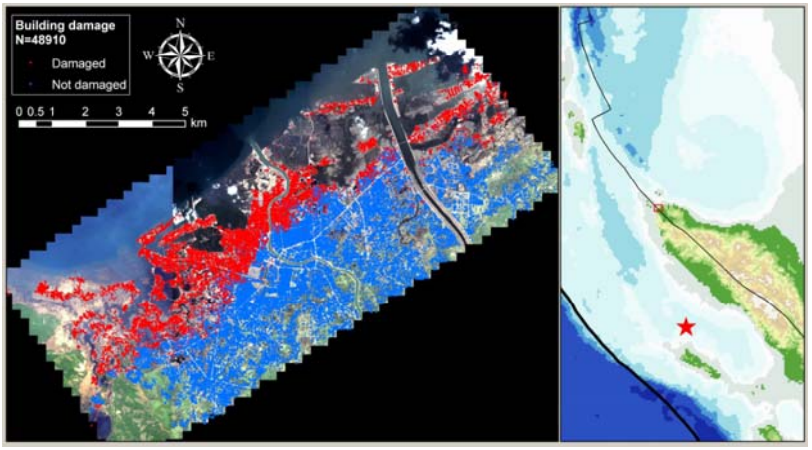
Vr=1.0 km/s *M*w=9.1

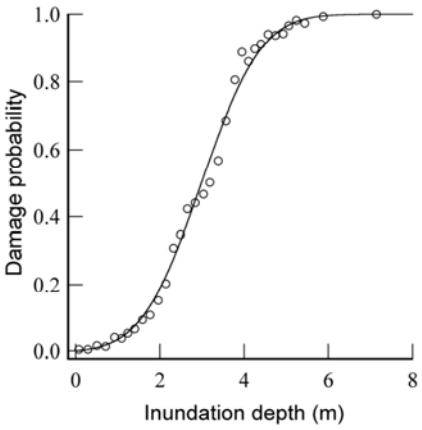


Black: Observed, Blue: Synthetic

Tsunami Fragility Curves

- Structural damage probabilities in terms of flow depth, current velocity and hydrodynamic force





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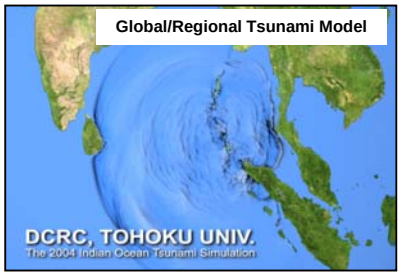
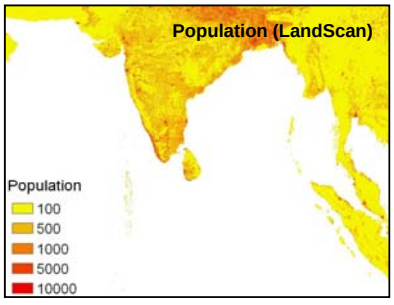
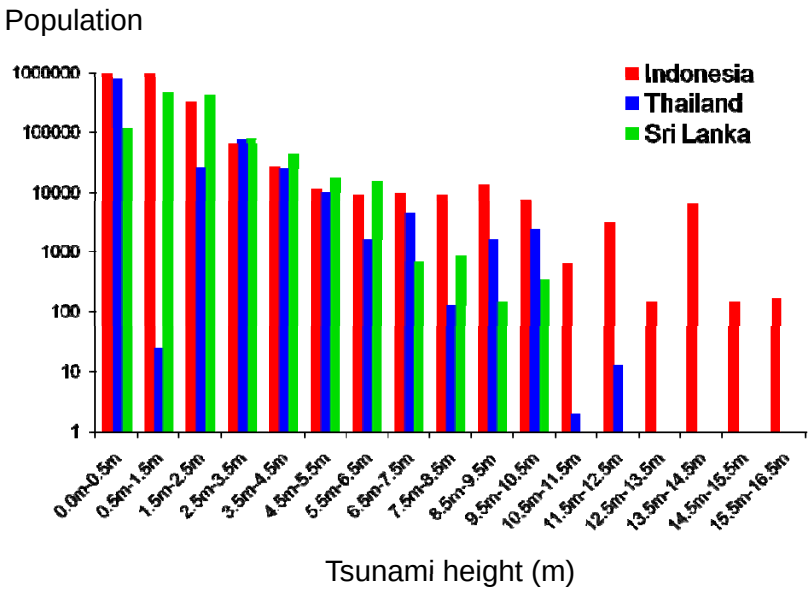
Potential Tsunami Exposure



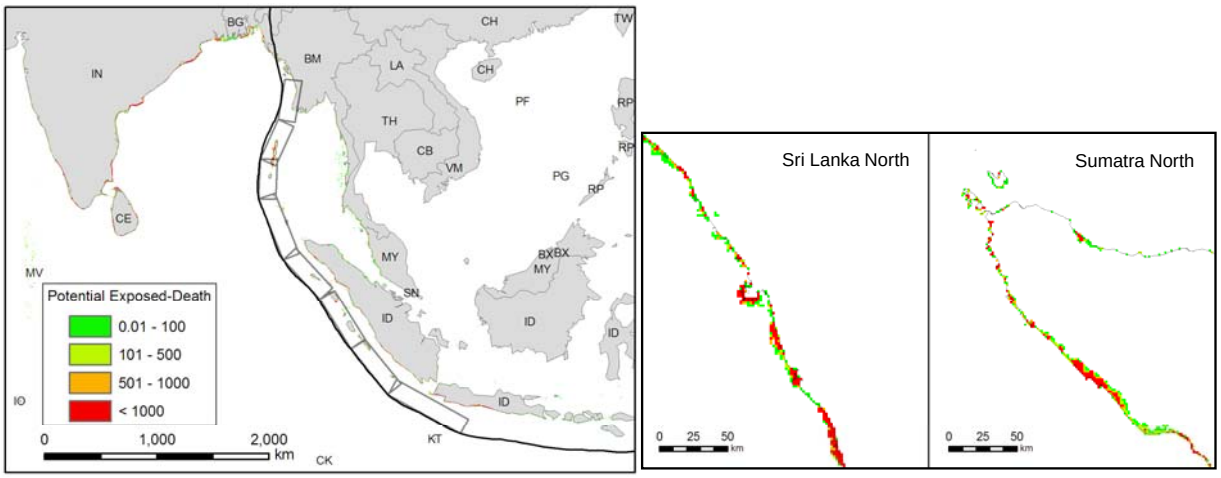




Tsunami Risks for Potential Earthquake Scenarios

$$\textbf{Expectation} = \sum_{i=1}^{N} K_i PED_i \qquad PED_i = \alpha(\eta) \cdot Pop$$

K_i	Probability of Event i
PED_i	Tsunami Casualty
$\alpha(\eta)$	Tsunami Fragility Curve
Pop	Exposed Population



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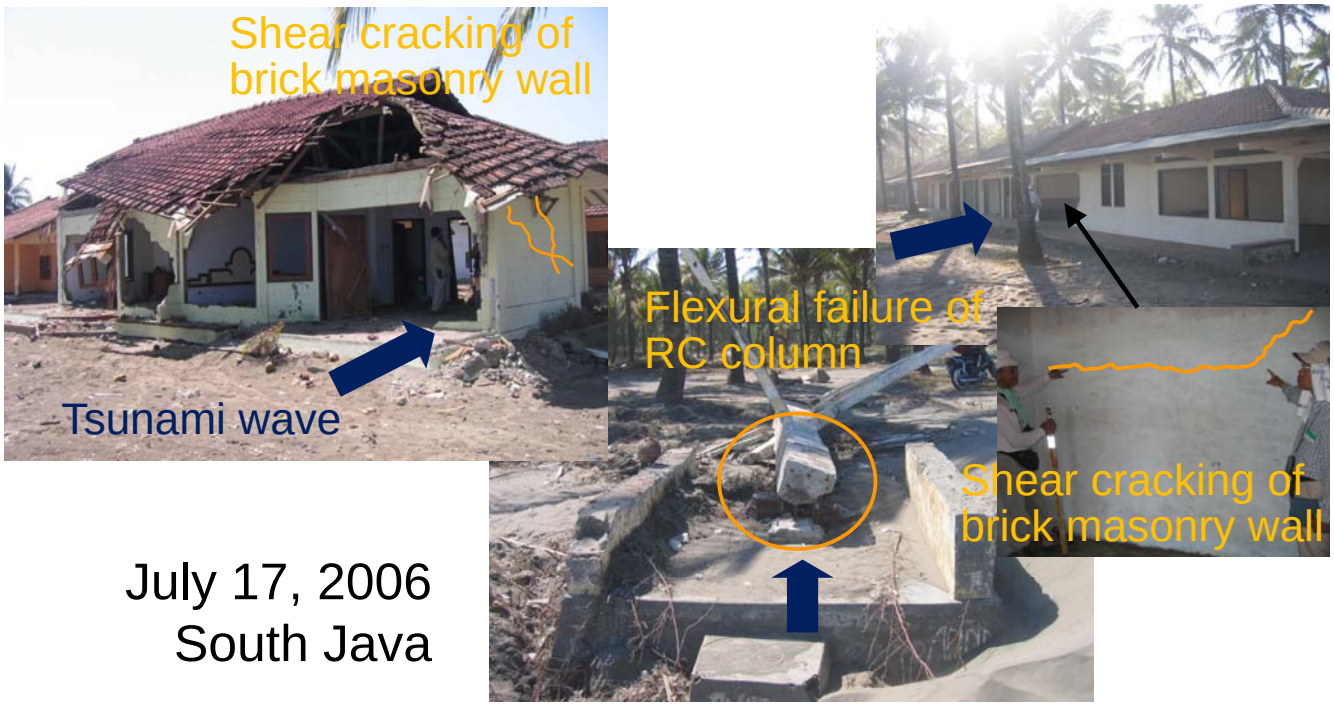
Clarification of Failure Modes of a Structural Component by Tsunamis

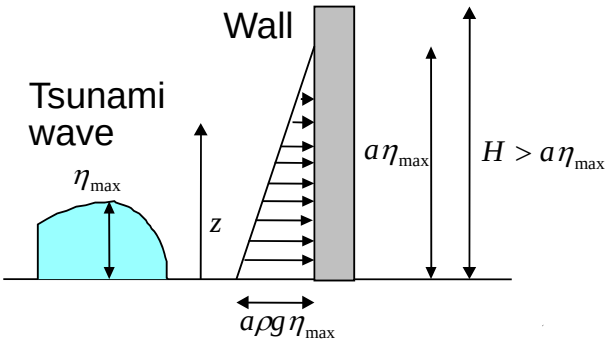


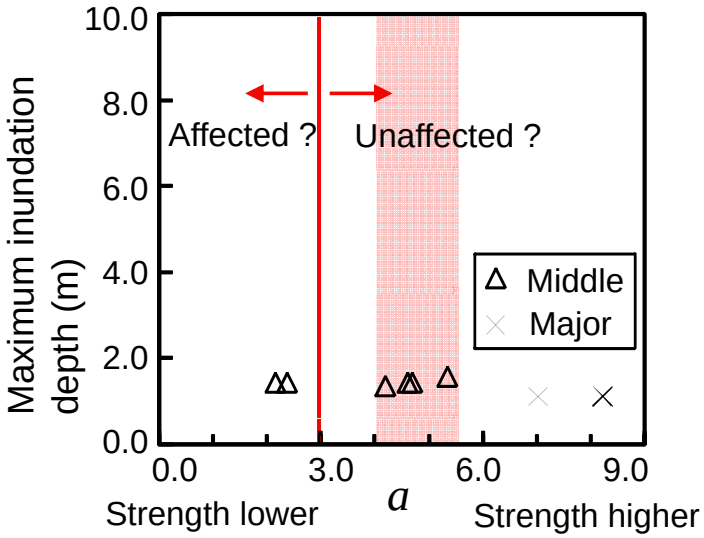
July 17, 2006
South Java

Verification of Formula associated with Evaluation of Tsunami Wave Loads

- Identification of required strength of a structural component subjected to a tsunami wave

$$p_x = \rho g(a\eta_{\max} - z)$$





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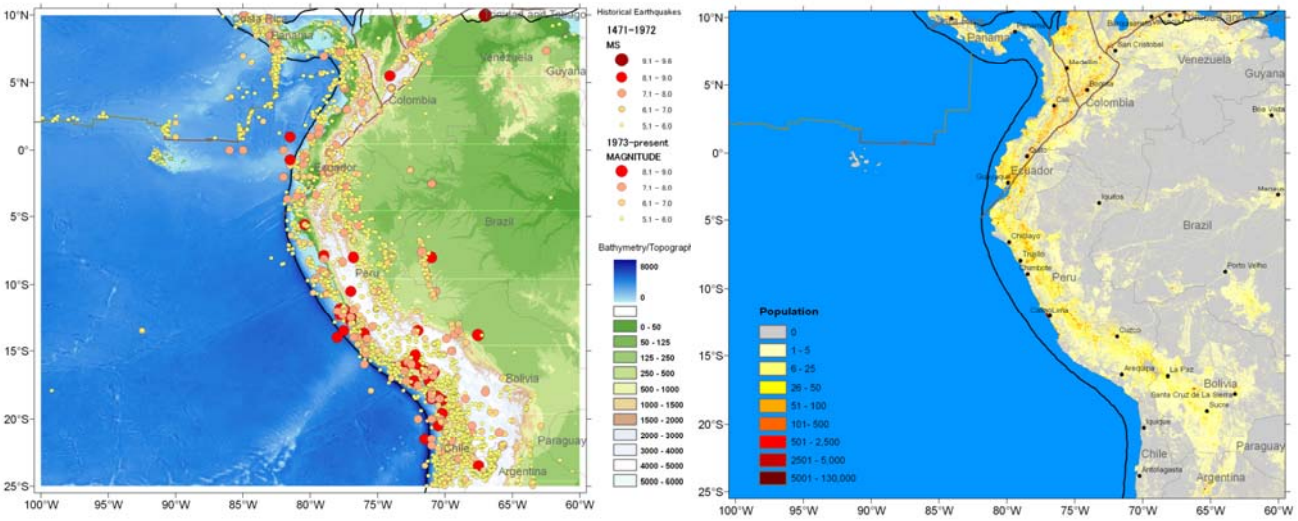
Data

- Population data (LandScan2007)
- Merged bathymetry and topography grid (GEBCO 30-sec. grid)
- Nautical charts
- Historical earthquakes (NGDC, NEIC, USGS ; 1471-present)
- GIS data (Border, Plates, City, …)

Data


Historical Earthquakes
1471–1972
MS
1973–present
MAGNITUDE
Bathymetry/Topograph
6000
0
0 - 50
50 - 125
125 - 250
250 - 500
500 - 1000
1000 - 1500
1500 - 2000
2000 - 3000
3000 - 4000
4000 - 5000
5000 - 6000
Population
0
1 - 5
6 - 25
26 - 50
51 - 100
101 - 500
501 - 2,500
2501 - 5,000
5001 - 130,000
Panama
Venezuela
Guyana
Colombia
Ecuador
Brazil
Peru
Bolivia
Chile
Paraguay
Argentina
10°N
5°N
0°
5°S
10°S
15°S
20°S
25°S
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W