NORTH SUMATRA – ANDAMAN ISLANDS TSUNAMIS of December 2004 and March 2005

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Dec 26, 2004 North Sumatra Tsunami

- The most devastating tsunami in modern time was triggered by the Magnitude 9 North Sumatra-Andaman Island earthquake at 6:58 AM local time on Sunday December 26, 2004
- It killed approximately 272,000 people

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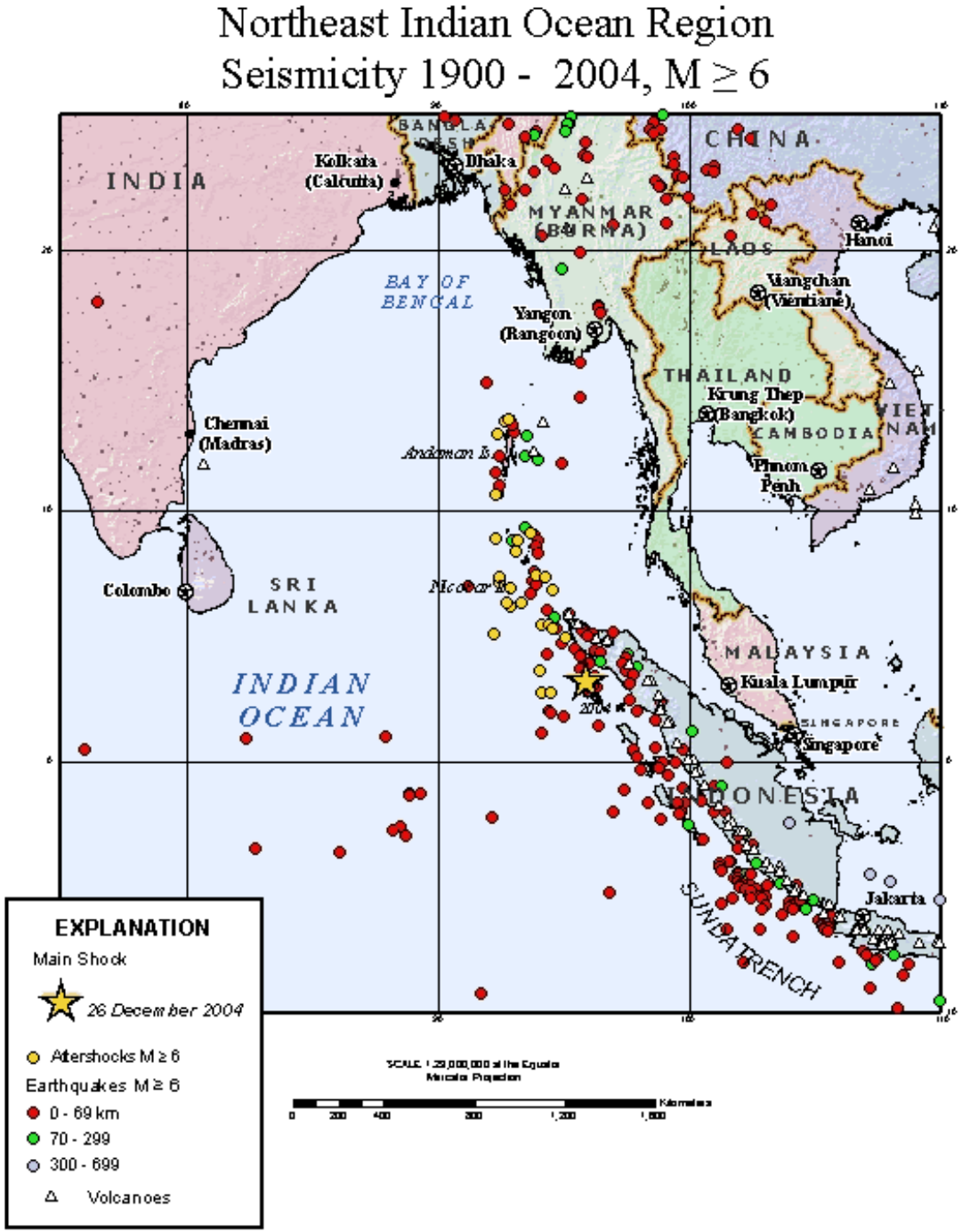

Historic Seismicity Eastern Indian Ocean 1900 - 2004

- The Indian Plate moves northeasterly about 60 mm/yr relative to the Burma Plate, resulting in oblique convergence with the Sunda Trench
- The last major earthquake in the Sunda Trench was in southeastern Sumatra in 1833.
- The tsunamis generated by that quake were directed southerly, towards Antarctica.

Magnitude 9.0 Sumatra-Andaman Islands Earthquake of Dec 26, 2004

- The distribution of main and aftershock events suggests that approximately 1200 km of the plate boundary slipped as a result of the 12-26-04 earthquake
- The average displacement on the fault plane was about 15 m, with the sea floor overlying the thrust fault being lifted several meters
- Energy release equivalent to 31,622 atom bombs used on Hiroshima in 1945.

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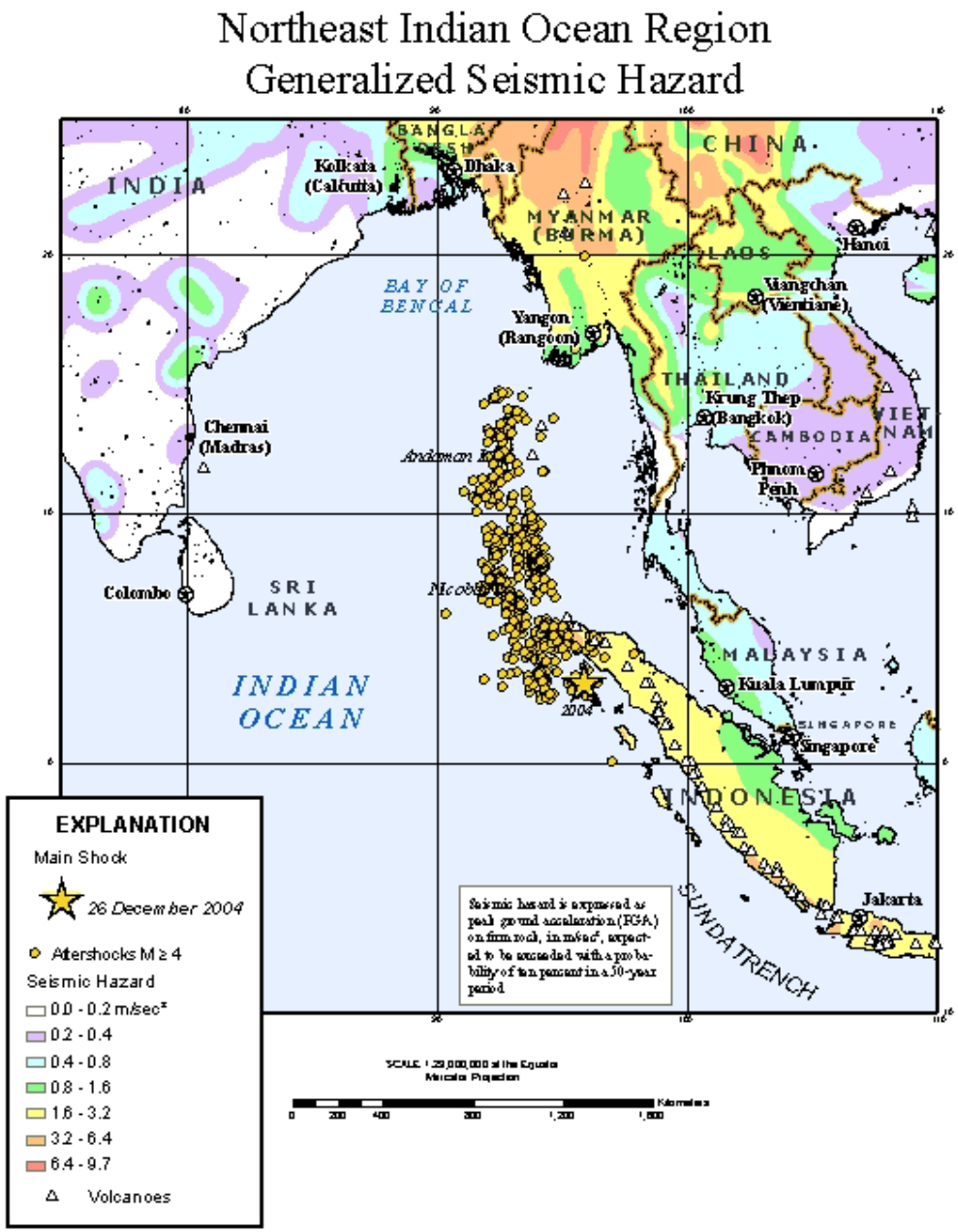

- **This map shows main and aftershock epicenters along with expected variations in site acceleration**
- **The fault-rupture was unimodal, propagating hundreds of kilometers northwesterly from the epicenter (star).**
- **The data upon which the USGS modeling is based do not permit confident resolution of the extent of rupture beyond about 500 km northwest of the main-shock epicenter.**

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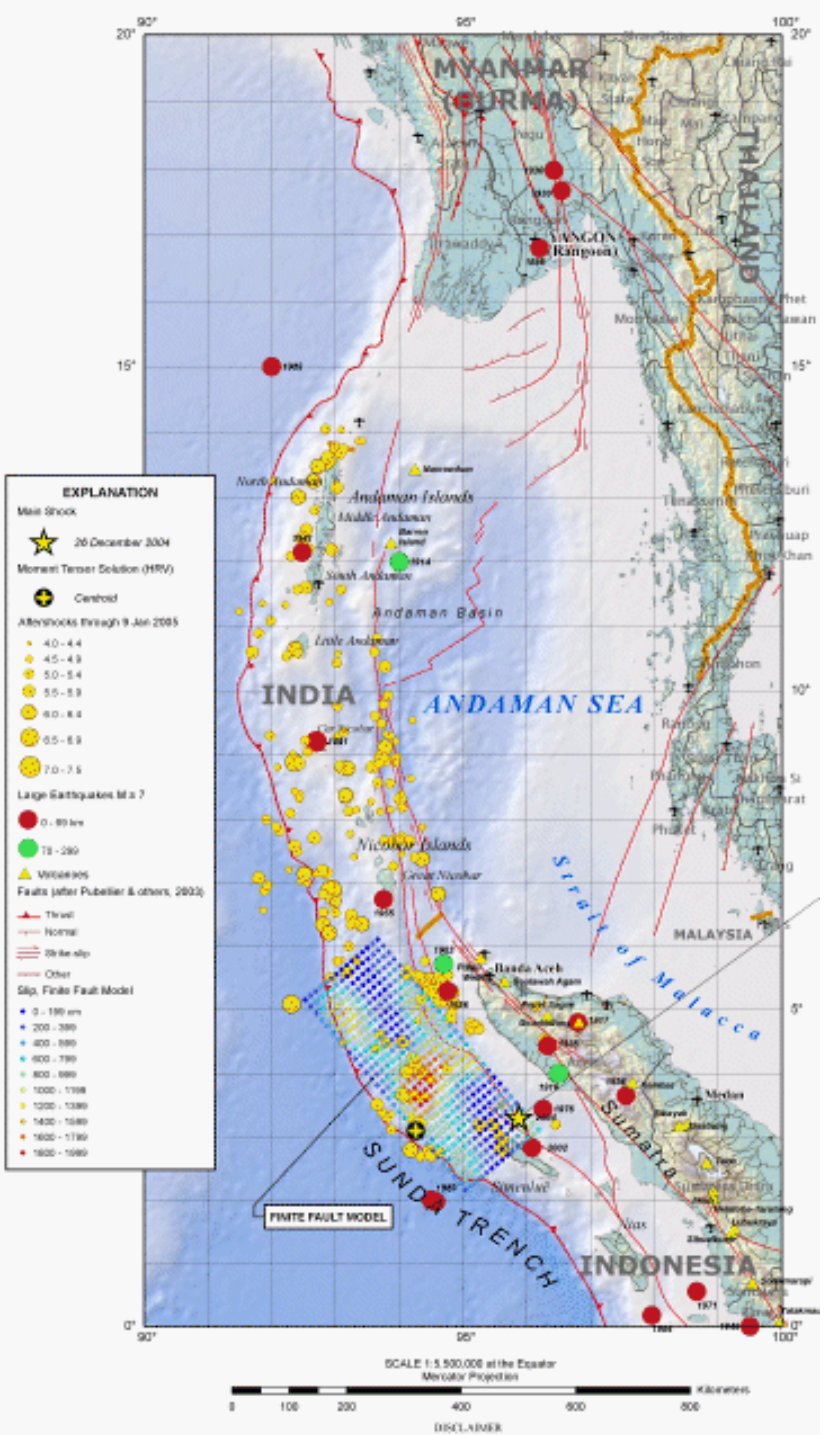
Finite Fault Model of the M9.0 Sumatra-Andaman Islands Earthquake of Dec 26, 2004



- The USGS finite fault model shown here implies that the width of the earthquake rupture, measured perpendicular to the Sunda trench, was about 150 kilometers, and that the maximum displacement on the fault plane during the 12-26-04 event was about 20 meters.
- The sea floor overlying the thrust fault would have been uplifted by several meters as a result of the earthquake.
- The 12-26-04 event has seen some of the largest aftershocks ever recorded in modern time.

- **Advancing crest of the initial tsunami wave gains height as water depth decreases, reflecting off islands, promontories and the coastline itself.**

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- One of the 572 emerald isles of the Nicobar and Andaman Islands, a chain of atolls, cays and islets 700 km long between Burma and Indonesia, northwest and parallel to the quake epicenters. These islands are only 1 or 2 meters above sea level, and the tsunami waves passed over them

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Don’t Be a Curious Bystander

Curious bystanders standing on a hardened seawall flock to witness the tsunami waves as they break against a protective breakwater structure

Most people have little idea how powerful enormous waves of water can be

Never underestimate the unrelenting force of water – it is an incompressible fluid

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- **Before and after images of coast in northern Banda Aceh, the capital of Ache Province in Northern Sumatra (Indonesia), about 155 miles form the main shock epicenter**

- Before and after views of Banda Aceh shoreline
- Note erosion of shallow unconsolidated sands along the coastline
- This kind of damage is typical of tsunami waves

- Before (April 12, 2004) and after (January 2, 2005) images of promontory south of Banda Aceh in northern Sumatra
- This point was able to deflect incoming waves, but enormous tracts of low lying coastal valleys behind it were devastated

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- **Enlargements of before and after images of Sumatran coast near Gleebruk Village, south of Banda Aceh. Note how wave runup zone mimics the tree line, suggesting past tsunamis have wrought similar patterns of devasatation**

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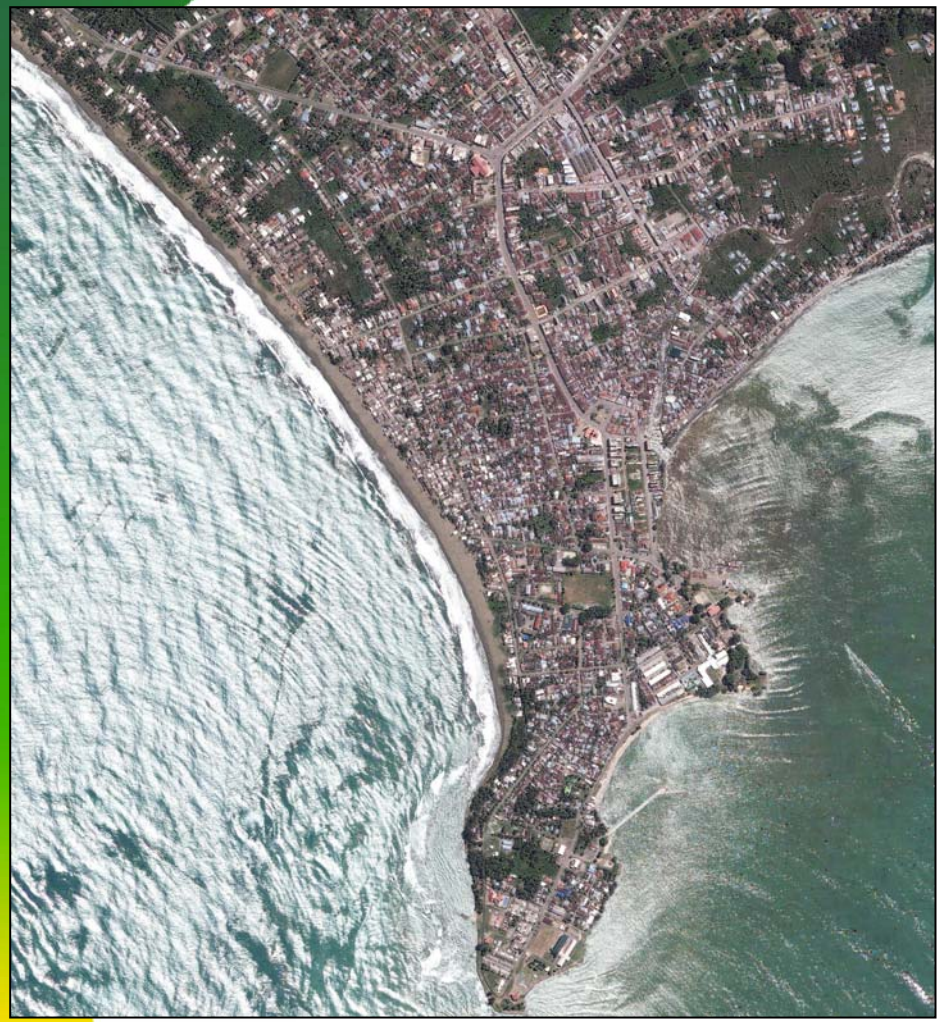

- Coastal promontory in Meluaboh, in northern Sumatra, before tsunami (at left, taken on May 18, 2004) and after the tsunami (at right, taken on January 7, 2005)

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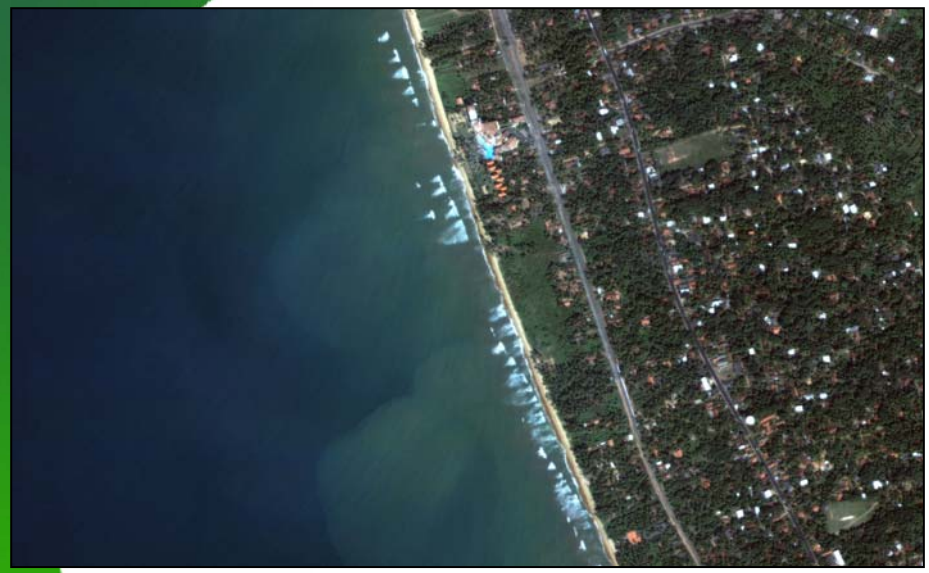

Before tsunami on January 1, 2004

Surf begins to pull back from coastline

Four views of shoreline in Kaulutara on the western coast of Sri Lanka, upper right and lower two imaged by satellite during the tsunami on 12-26-04.

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Before tsunami on January 1, 2004

During tsunami wave flood surge

During turbulent ebb flow back out to sea

Macro turbidity caused by ebb flow scour

Additional images of Kaulutara, Sri Lanka imaged during the tsunami

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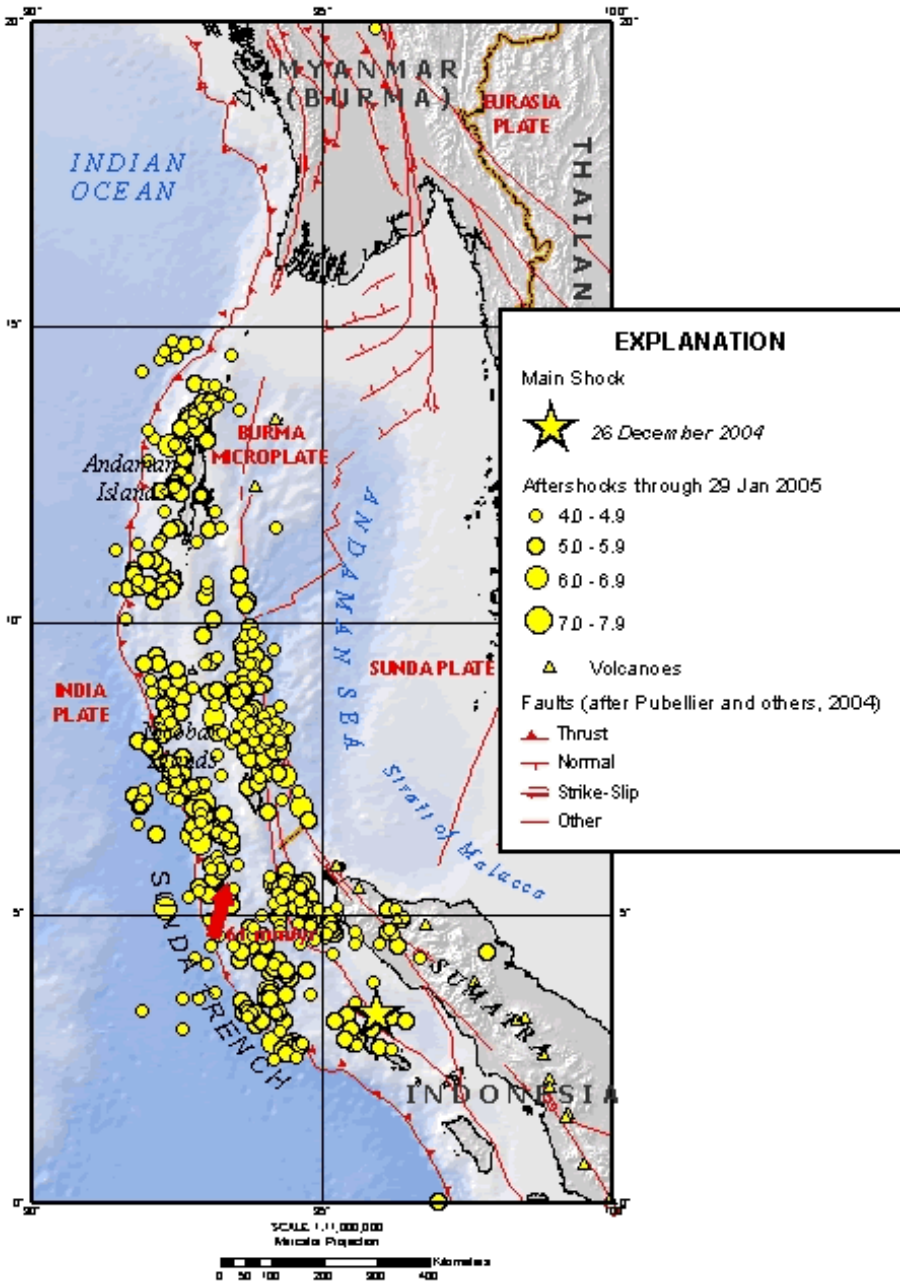

Aftershocks of the M 9.0 Sumatra-Andaman Islands Earthquake of Dec 26, 2004

- There have been 13 aftershocks of Magnitude > 6.0 since the main shock.
- The zone of aftershocks is over 1300 km long. Because aftershocks occur on and very near the fault planes of main shocks, the length of the aftershock zone suggests that main-shock fault-rupture may have extended north of epicenter by an amount significantly larger than 500 km.
- However, a great earthquake may also trigger earthquake activity on faults that are distinct from the main-shock fault plane and separated from it by tens or even hundreds of kilometers.

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5th largest earthquake ever recorded

The earthquake of Dec.26th 2004 was the fifth largest in the world since 1900. The other four earthquakes that were larger are:

- 1. 1960 May 22, Southern Chile, M=9.5
- 2. 1964 March 28, Prince William Sound, Alaska, M=9.2
- 3. 1957 March 9, Andreanoff Islands Alaska, M=9.1
- 4. 1952 Nov 4, Kamchatka M=9.0
- 5. 2004 Dec 26, Off west coast of Northern Sumatra, M=9.0. This magnitude may be upgraded to 9.3, based on studies now underway.

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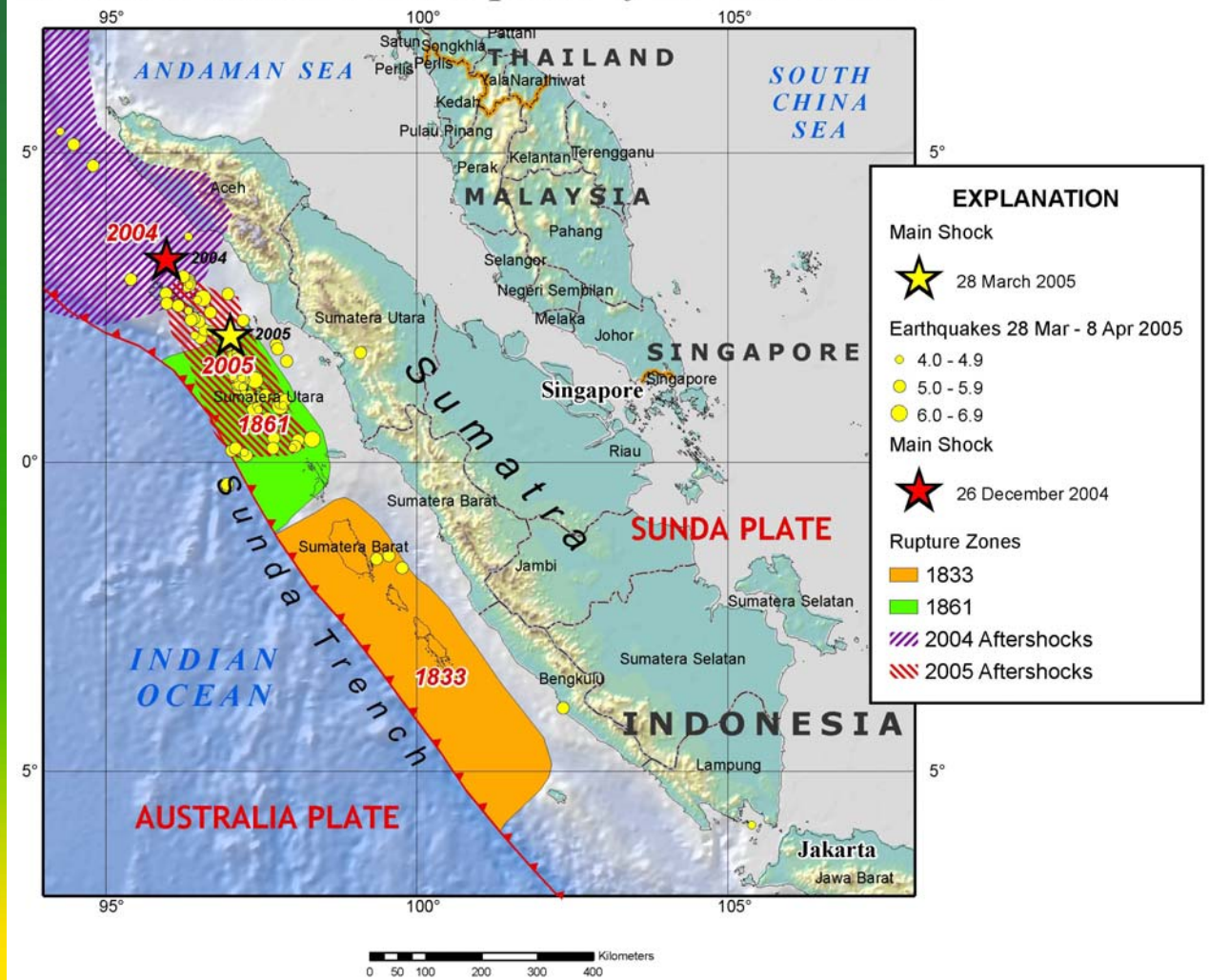
Deadliest Earthquakes

- 1. 1556 Jan 23, Senshi, China, 830,000 casualties (M=~8.0)
- 2. 2004 Dec 26, Off west coast of N-Sumatra, between 228,000 and 310,000 casualties (M=9.0)
- 3. 1976 July 27, Tangshan, China, 255,000 casualties (M=7.5)
- 4. 1780 Feb 28, Iran, 200,000 casualties (M=?)
- 5. 1920 Dec 16, China, Gansu, 200,000 casualties (M=8.6)
- 6. 1927 May 22, Tsinghai, China, 200,000 casualties (M=7.9)
- 7. 1923 Sept 1, Japan Kanto (Tokyo fire), 143,000 casualties (M=7.9)
- 8. 1948 Oct 5, Ashgabat, Turkmenistan, 110,000 casualties (M=7.3)

Northern Sumatra Earthquake of 28 March 2005



- **How big was the largest aftershock?**
- **Was anyone killed?**

- **A Magnitude 8.7 aftershock occurred on Monday March 28, 2005. At least 1000 people killed, 300 injured and 300 buildings destroyed on Nias; 100 people killed, many injured and several buildings damaged on Simeulue; 200 people killed in Kepulauan Banyak; all in Sumatra. Tsunami waves 2 m high**

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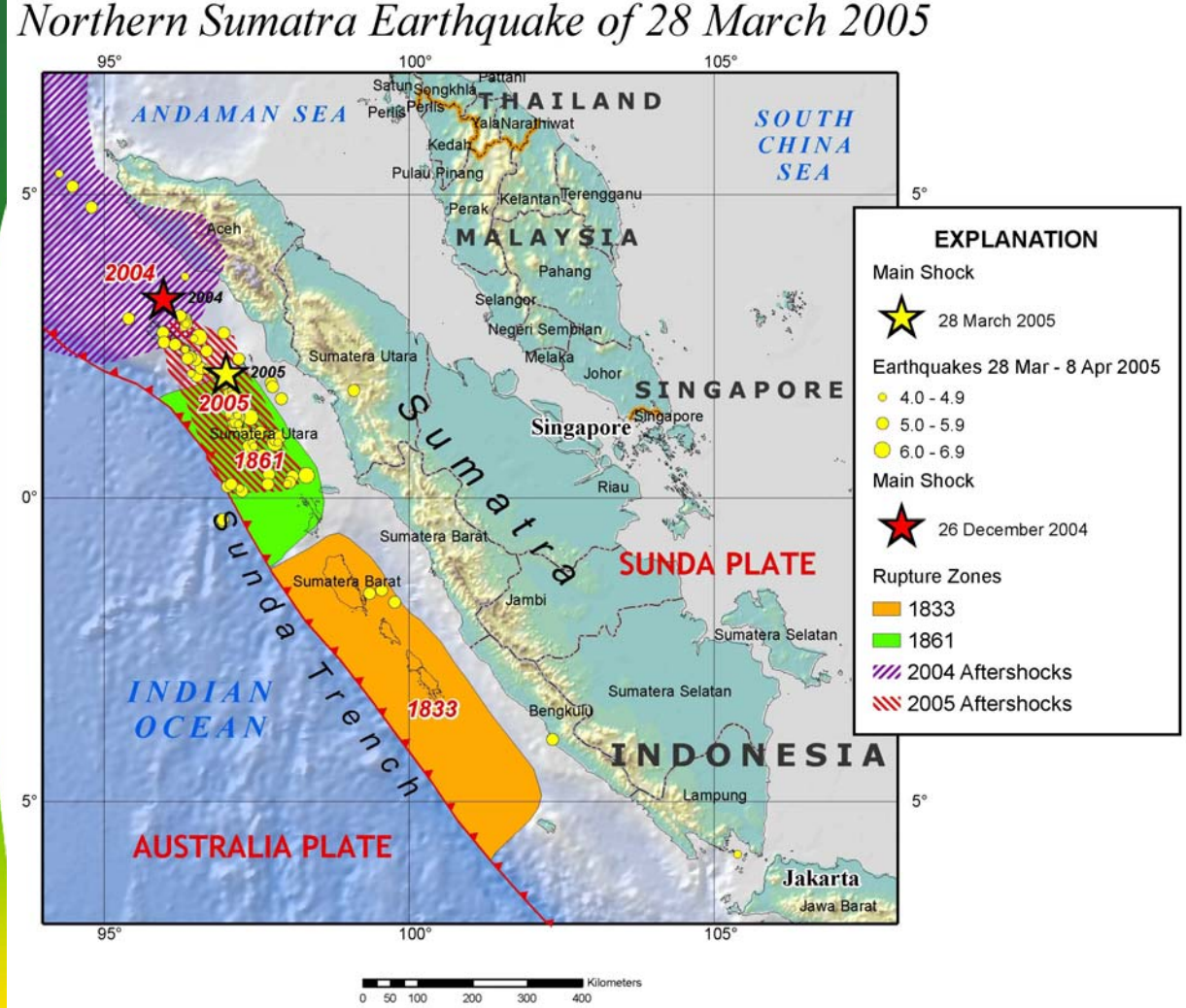

- **When was the last big one?**
- **How often do they occur?**

- **Prior to December 26th, the largest earthquake along the subduction zone from southern Sumatra to the Andaman Islands occurred in 2000 and had a magnitude of 7.9. A magnitude 8.4 earthquake occurred in 1797, a magnitude 8.5 in 1861 and a magnitude 8.7 in 1833 . All three ruptured sections of the subduction zone to the south of the recent earthquake. Interestingly, the 1797 and 1833 quakes are believed to have ruptured roughly the same area with only 36 years separating the events. Paleoseismic evidence shows that great earthquakes or earthquake couplets occur about every 230 years.**

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ESTABLISHING AN INTERNATIONAL WARNING NETWORK

- American politicians and United Nations representatives were quick in calling for establishment of an international tsunami warning network in Southeast Asia, similar to that operated by NOAA and USGS in the Pacific since the Hilo tsunami in1946.
- Can’t we just make more wave detection buoys and stick them out there in the ocean?

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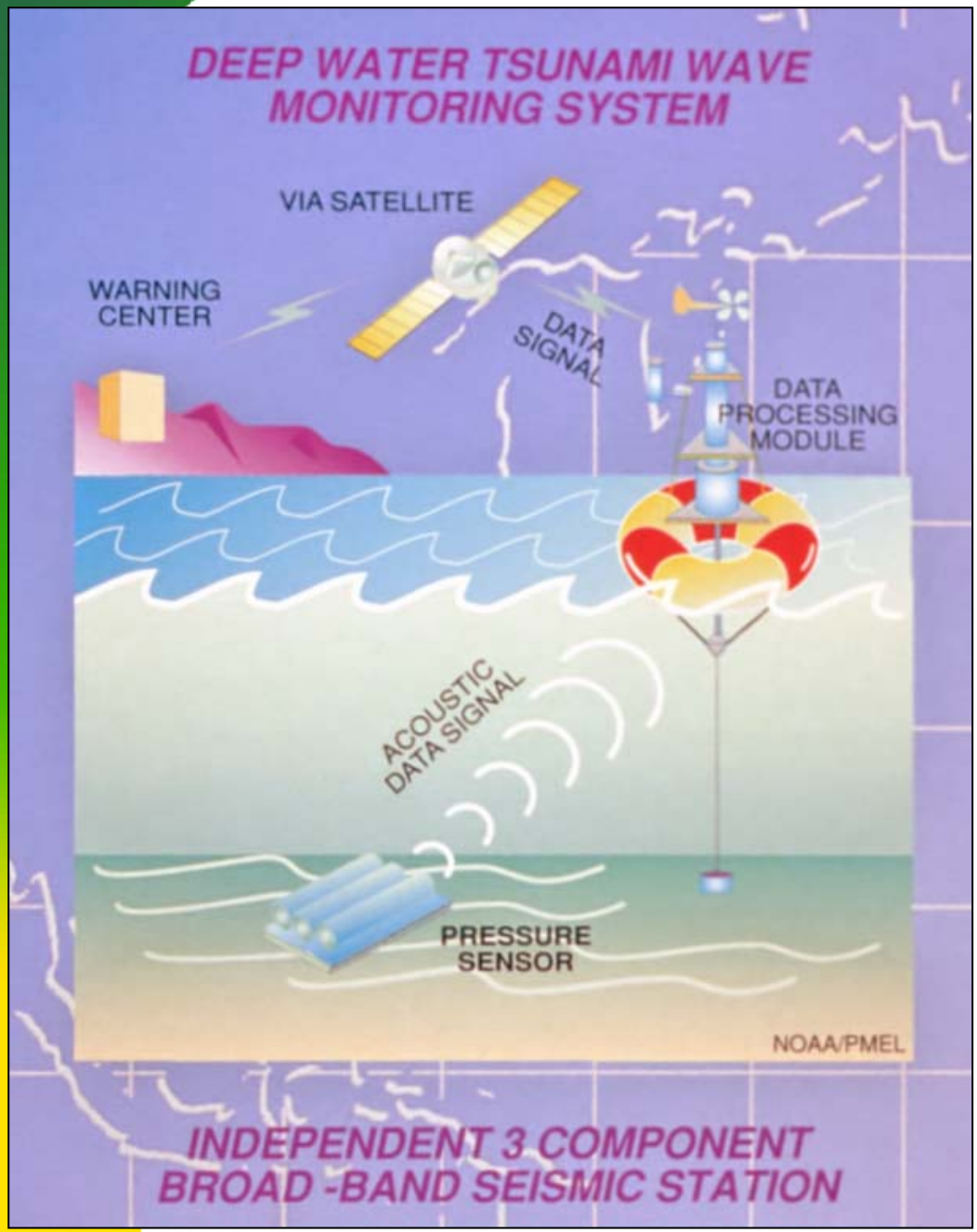

NOAA wave form detection buoys

- Can't we just make more wave detection buoys and stick them out there in the ocean?
- Only 3 of the 5 buoys in Pacific Ocean were working because no funds for upkeep made available by Congress prior to 12-26-04 event

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Problems with Tsunami Warnings

- The greatest number of casualties were in the near shore zone along the western coast of Northern Sumatra, within 20 minutes travel time of the initial tsunami waves
- The preliminary quake magnitude was estimated at 6.6 because the initial rupture was of that scale. Problem was the rupture propagated 1300 km up the Sunda Trench
- People have to have training to know WHAT TO DO in the event of a tsunami warning. They have to have a contingency plan in place. A simple “broadband warning” will not save their lives unless they know where to evacuate immediately