Lecture 8:
Tsunami Case Examples and Preparedness

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Is there any warning for an approaching tsunami? How can we possibly know when a tsunami has been generated somewhere on Earth? In the case of the most common cause of tsunami – earthquakes – there is a worldwide seismic network that monitors global earthquakes and determines the likelihood of a tsunami having been produced (based on earthquake magnitude and the type of fault that produced the earthquake).

A tsunami watch is posted by an agency such as the Pacific Tsunami Warning Center if the magnitude of an earthquake exceeds ~7. If a tsunami hazard is confirmed, the tsunami watch is raised to a tsunami warning. Such alerts are also posted even if there is no tsunami hazard from a particular earthquake event.

Close-proximity tsunami: In the case of coastlines immediately adjacent to the source of a tsunami, there is typically very little warning and not much preparation may be possible other than to let citizens know that large earthquakes can produced tsunami within 10s of minutes. People should know the tell-tale signs such as the sudden retreat of the shoreline (drawdown as the water is sucked into the approaching wave).

Far-field tsunami: For tsunami that happen very distant to a coastline ultimately at risk, it is important to know the travel time from the point of origin as well as the likely wave height of the tsunami.

Tsunami heights are measured by pressure transducers on the ocean floor that relay information to surface buoys and then to satellites overhead (e.g., DART (Deep-Ocean Assessment And Reporting of Tsunami).

If the risk is considered high, warning klaxons sound in coastal areas that are prepared. People must then move to higher elevations or at least several km inland. This poses problems in locations frequented by oblivious tourists or locals who have become complacent. Also: tsunamis travel at ~55 kph across land. World-record sprinters run at ~42 kph.

People should also be made aware that the first wave is not necessarily going to be the biggest one. The citizens of Hilo, Hawaii learned this the hard way during the 1960 tsunami, which killed 61.

So what happened in the Indian Ocean? What precedents were there for such large earthquakes / tsunami in the Indian Ocean? There is clear geologic evidence that this subduction zone has produced M>8 earthquakes in the past (e.g. raised coral reefs).

Why was there no warning? Although the PTWC monitors worldwide earthquakes and determines related tsunami hazards, the 26 member countries of the tsunami warning network are all around the Pacific Rim. There was no such network in place for the Indian Ocean. The added problem at Banda Aceh is that the first tsunami wave arrived a mere 15 minutes after the earthquake. But could the other Indian Ocean nations have been warned in time? Yes. Tens of thousands of lives could have been saved.

What were the reasons for no warning?

- **Historical:** No historic reason to think that the Indian Ocean basin was prone.
- **Political:** Unfamiliarity with the political norms of the affected countries.
- **Infrastructural:** No system in place to warn people (either procedural or equipment).
- **Educational:** Locals had never been educated as to the link between tsunami & EQs.
- **Economic:** The cost of a warning system is very high. Also, loss of tourist revenue.
- **Scientific:** The actual magnitude of the EQ cannot be determined for > 1 hour. The geologic evidence for past tsunami was not well disseminated.
**What is the evidence for paleotsunami?** Historical tsunami such as the 1960 wave created by the M9.5 Chile earthquake left evidence in the form of sand deposits on top of soil horizons. Do we see similar evidence for pre-historic tsunami events? Yes...

**Welcome to Cascadia:** The Cascadia subduction zone is 1200 km long and caused a M~9 earthquake at 9 p.m. on January 26th, 1700, causing a tsunami. To determine the recurrence interval of such events, geologists used evidence of pre-1700 events along the coasts of British Columbia, Washington, Oregon, and northern California.

**Tsunami at Cascadia:** Layers of coastal sediments along the entire 1200 km length of the subduction zone show repeating patterns that tell a story. What could they mean? Peat forms in coastal swamps ABOVE sea level. The sand represents tsunami deposits from the incoming waves. The mud settled gently from sea water. Some sand sheets have been found 18 m above sea level.

**Other evidence for paleotsunami at Cascadia:** Coastal forests were broken by tsunami or killed by subsidence that forced the root systems into salt water. Expected wave heights along Cascadia would be 7-8 m, but as much as 20 m in narrow coastal inlets and bays.

**What’s the outlook for Cascadia?** The plate boundary is accumulating strain at a rate of about 3 cm/yr. Radiocarbon dating of 12 tsunami deposits in the past 4,600 years gives an average recurrence interval of 380 years. The range of time between past events is 300 to 900 years. Time since last event: **310 years**.