LECTURE #9: Tsunami Monitoring & Mitigation

Date: 12 February 2025

I. Exam 1

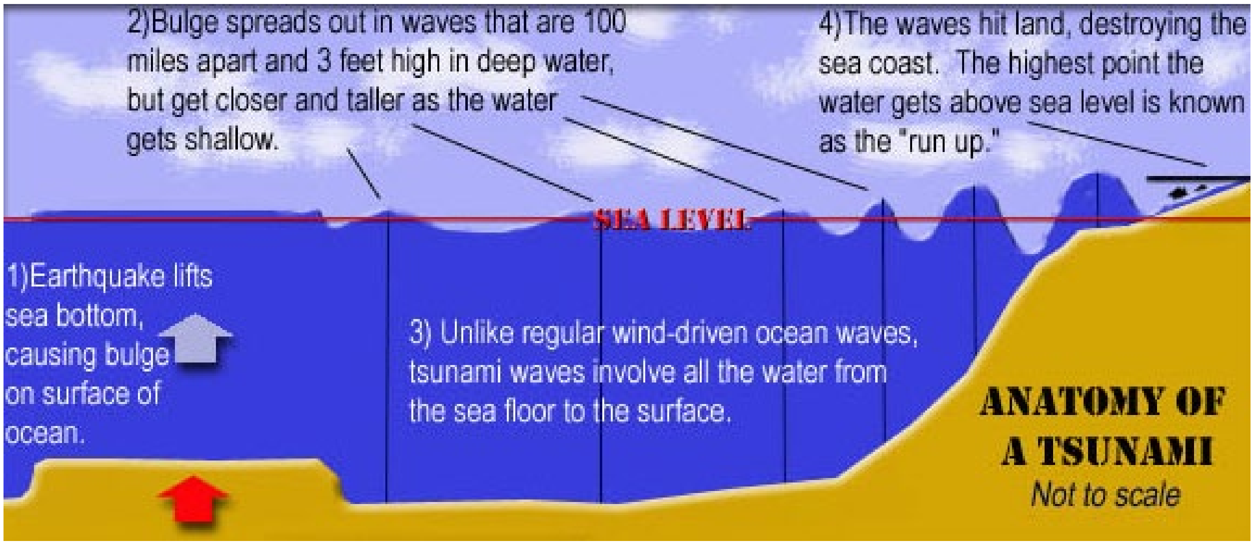
- grades will be posted once I have all the names matching the grades
  - there were two that came back without names meaning something was wrong with how the Peoplesoft number was written on the scantron
  - I need to check those manually

- results
  - average: 75
  - high: 98
  - low: 26
  - did not take: 11

- if you did not do well
  - you will have the lowest of the two mid-term grades dropped
  - come talk me leading up to the next exam
  - and make sure you understand all the concepts

II. Tsunami Characteristics *(continued from last lecture)*:

- shoaling:
  - process of increasing wave height followed by "breaking" as the water depth <u>decreases</u> *(near shore)*
  - energy transfer (from speed to height, KE → PE)
  - tsunami wave shoaling occurs further from land than wind-driven waves
    - because of the longer wavelength and larger amount of energy

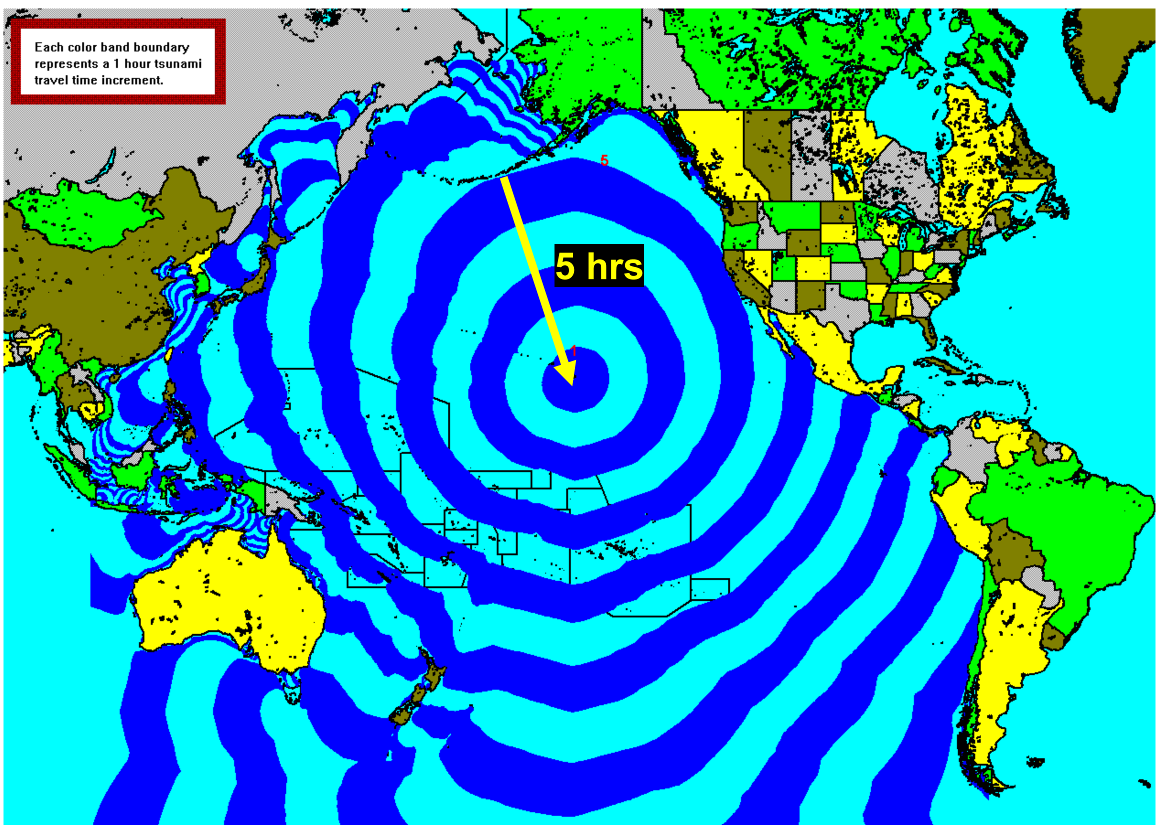


- results in a large withdraw of water near coast prior to wave break
  - water is drawn out to form the wave
  - heights can reach 10s of meters

- period of 15 - 60 minutes
  - dangerously long *(allows people time to return to the devastated area)*

- physics of wave growth
  - v_{wave} is proportional to d_{water}
    - *meaning: wave speed goes up as the water gets deeper*
  - h_{wave} is inversely proportional to d_{water}
    - *meaning: wave height goes up as the water gets shallower*
  - E_{loss} is proportional to wavelength
    - *meaning: energy is greater with shorter wavelengths*
  - ultimate height of a tsunami determined by the local topography of the ocean bottom *(see later in the notes)*

- **tsunami travel time map:**

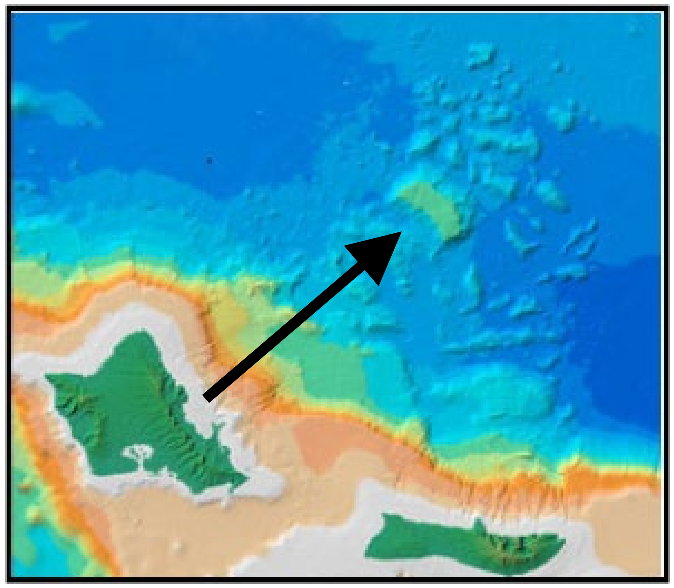


tsunami travel time *(1 color band = 1 hour)*

  - details/notes *(discussed in lecture)*:

III. Avalanche-generated tsunamis

- more attention recently
  - 2018 avalanche-generated tsunami from Krakatau volcano in Indonesia



- also, over the past few decades
  - sonar mapping of the sea floor around the Hawaiian islands
  - HUGE debris avalanches
  - blocks larger than the island of Manhattan
  - the potential to form ~1,000 foot waves locally!

- even smaller avalanches can cause large tsunamis
  - example: Mt. Unzen in 1792 (Japan)
    - landslide volume ~ 1.3 km^3
    - hit the water in the bay creating a tsunami that impacted 77 km of coast
      - killed 9,528 people
      - then reflected back to the other side and killed another ~5,000

IV. Tsunami Case Study #1: 1946 Alaska EQ (M 7.4)

- April 1, 1946, at 3:29 local time
- Pacific-wide tsunami was triggered by the EQ
- focal depth of 25 km
- tsunami took the lives of more than 165 people around the Pacific
  - caused over $26 million (1946 dollars) in damage

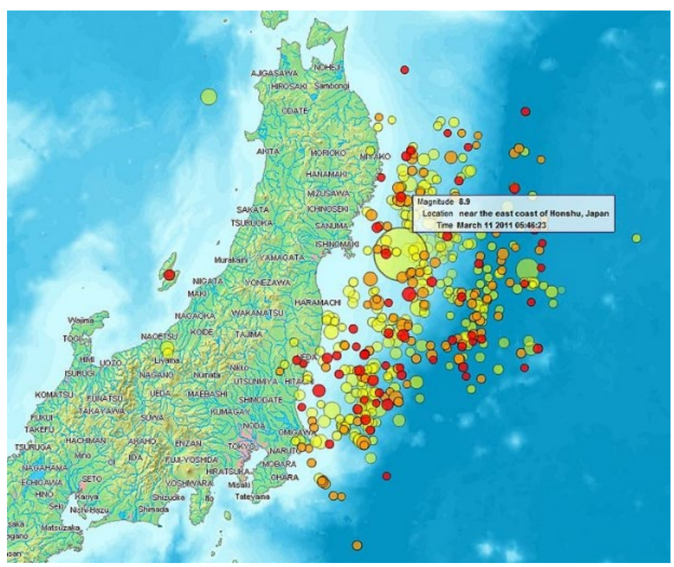
- newly built Scotch Cap Lighthouse on Unimak, Aleutian Islands, Alaska
  - epicenter of the EQ: only 120 miles away *(~ 15 min until the tsunami reached it)*
  - 5 men lost their lives, and the run-up reached 115 ft.

- Hilo, Hawaii received the most damage
  - tsunami arrived at Hilo 4.9 hours
  - produced a 10 meter high tsunami on the north coast of the Big Island
    - Hilo and other smaller villages were devastated
    - 96 people died
    - led to the formation of the Pacific Tsunami Warning Center (PTWC)

V. Tsunami Case Study #2: Sumatra (12/26/2004)

- caused by a subduction zone M9.1 EQ
  - killing over 230,000 people in 14 countries
  - longest duration of faulting/shaking ever observed
    - between 8.3 and 10 minutes
  - inundating coastal communities with waves up to 100 feet
  - worldwide community donated more than $7 billion *(2004 U.S. dollars)*

VI. Tsunami Case Study #3: Japan (3/1/2011)



- subduction zone M9.0 EQ
  - focal depth of ~ 32 km
  - waves heights over 100 feet in certain locations
  - travelled up to 10 km inland
- level 7 meltdowns in the Fukushima I Nuclear Power Plant
- >20,000 deaths
- over 125,000 buildings damaged or destroyed
- *notes:*

VII. Tsunami Damage (depends on):

- size of the event that triggers the tsunami
- offshore bathymetry *(changes in depth of ocean floor)*
  - shoaling can occur in different locations or sooner/later

- distance of coast from the triggering event
  - <u>example:</u> Nicaragua in 1992
    - M7.0 EQ only 35 miles offshore
    - produced a 10 meter high tsunami
    - reached ½ mile inland
    - killed ~200 people

- coastal geomorphology
  - irregular coastline can concentrate wave energy into smaller bays for example

- coastal orientation
  - tsunami arriving perpendicular to coast will be more damaging

- state of the tides at the time of the tsunami

VIII. Monitoring

- process is very technology-intensive
  - high costs for many poorer countries

- no technology available to monitor local tsunamis
- too quick
  - example: Papua New Guinea tsunami in 1998 was not detected

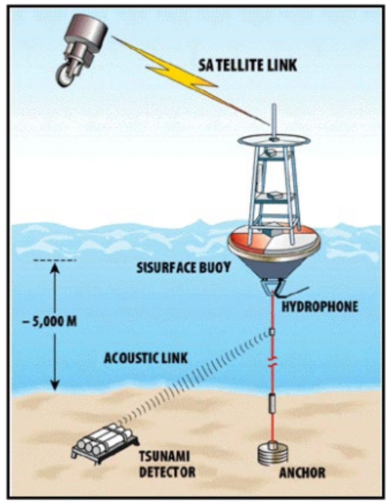
- creation of the Pacific Tsunami Warning Center (PTWC)
- evolved into the U.S. Tsunami Warning System
  - **https://www.tsunami.gov/**
  - joint program of NOAA and the national weather service (NWS)
  - monitors data from all over the Pacific Rim, as well as other oceans
    - seismic, wave heights, weather …

  - estimates the likelihood of tsunami hazard and the travel time
  - issues warnings to local officials and citizens based on available data
    - via sirens and communication

- NOAA's DART system
  - *Deep-Ocean Assessment and Reporting of Tsunamis*

  - bottom pressure recorders detect the tsunami
    - recall that unlike wind-driven waves, the tsunami's energy reaches all the way to the sea floor

  - Information transmitted to surface buoys that relay to stations via satellite



IX. Mitigation

- Hawaii is one of the most at-risk areas in the Pacific for tsunami hazards
  - center of the Pacific (less warning time)
  - vulnerable to tsunami from almost every direction

  - example:
    - the Alaskan EQs in 1946, 1964 and the Chilean EQ in 1960 destroyed much of Hilo and other smaller communities
      - ➢ led to the rebuilding of the downtown on higher ground away from the coast
      - ➢ building restrictions in hazard prone areas (e.g., coastal area is now a green space / park)
      - ➢ building of breakwaters and seawalls for mitigation to prevent wave run up into urban areas

- education
  - audible and media warning systems
  - evacuation routes
    - including vertical evacuation

  - location and structure of all dwellings