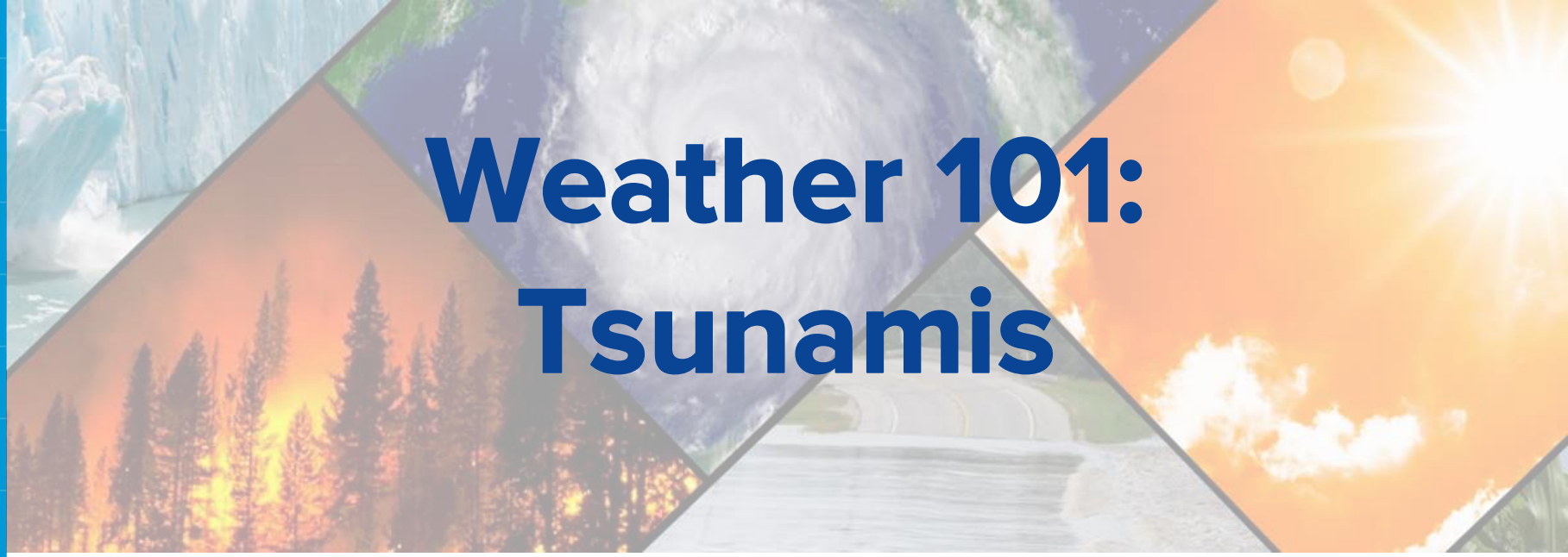

Weather 101: Tsunamis

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April 14, 2025

Historical Tsunamis You May Recall...

Japan Earthquake + Tsunami of March 11, 2011 (Pacific Ocean) with wave height up to 130 feet (~40 m)

Destruction in Japan during the March 2011 tsunami.
Source: NOAA, Tsunami Strike: Japan video series

Devastation in Banda Aceh, Indonesia after the 2004 tsunami.
Source: NOAA Jetstream, Hokkaido University, Yuichi Nishimura

Boxing Day Earthquake + Tsunami of December 26, 2004 (Indian Ocean) with wave height up to 167 feet (~51 m)

Lituya Bay Earthquake, Landslide + Megatsunami of July 9, 1958 (Alaska, USA) with wave height up to 1720 feet (~524 m)

Lituya Bay in 1958 after the tsunami.
Source: NASA Earth Observatory

Tsunami Impacts

- Among the most infrequent, yet most devastating natural disasters on Earth
- Massive losses to life, water/power/communication infrastructure, agriculture
- Changes to shorelines, waterways, population distribution, socioeconomic status
- Extremely difficult, dangerous, and prolonged response and recovery efforts

Tsunami inundation on 9/29/2009 in American Samoa. Source: NOAA/NOS

Tsunami damage in Crescent City, CA from the 2011 tsunami, 10 hrs later
Source: NOAA Jetstream

Tsunamis: What They Are and Aren't

Tsunamis are…

- A **series** of **waves** with 10s to 100s of miles in between crests
- Caused by a **sudden** and **massive displacement** of ocean water
- Are **trackable** after they have started
- Somewhat predictable once they are detected
- Based on the Japanese characters for harbor ("tsu") and wave ("name")

津波

Tsunamis are not…

- **Tidal waves/bores** – caused by the gravitational pull of the Sun and Moon and the presence of a shallow waterway with a large tidal range
- **Rogue/Killer waves** – "Extreme storm waves" which are taller than twice the height of surrounding waves and caused by constructive interference

So What Exactly is a Tidal Wave/Bore?

- Can look like a turbulent wall of water moving up a river or other tidal waterway
- Found where tidal ranges (water level between high and low tide) exceed 6 m (20 feet)
- Most common in shallow and narrow waterways which have a wide opening into the sea
- Most pronounced during spring tides – the higher high tides during Full or New Moon phase

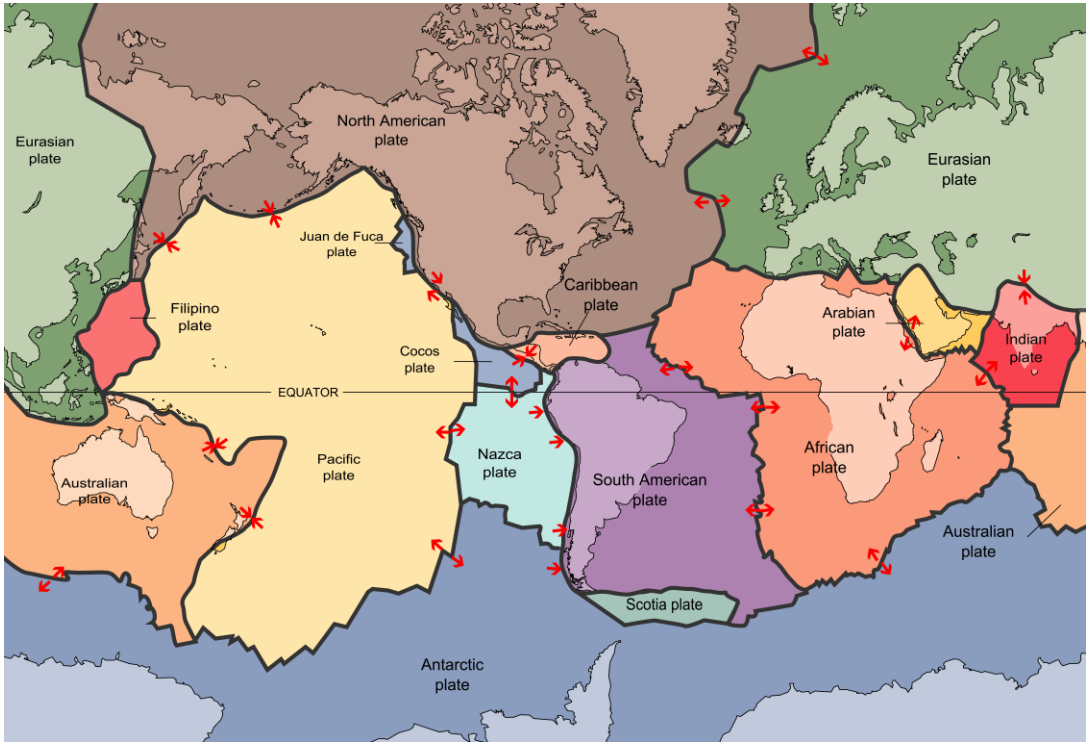
A tidal bore in the Qiantang River, Hangzhou, China. Image courtesy of Gwydion M. Williams, Flickr

A tidal bore at sunset in one of the rivers emptying into the Bay of Fundy between Canadian provinces of New Brunswick and Nova Scotia. Image courtesy of Petra Yaremkowych, National Geographic Society

A tidal bore in the River Ribble, Lancashire, United Kingdom. Image courtesy of Frangle Plazma Goat, Wikimedia Commons

Tsunami Causes: Earthquakes

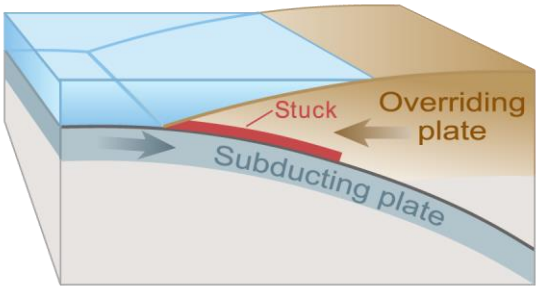
RECALL: Earth's surface is composed of tectonic plates which are slowly but constantly moving

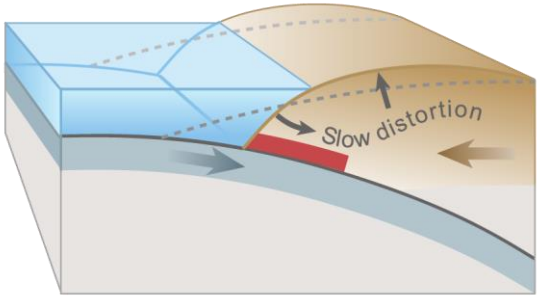


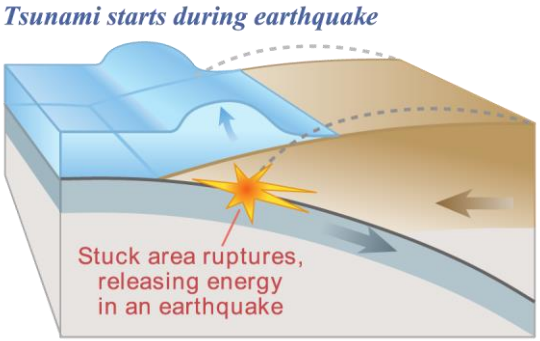
Map of tectonic plates and their directions of motion. Source: USGS

Tsunami Causes: Earthquakes

RECALL: Earthquakes occur when the overriding plate in a subduction zone snaps back.
DID YOU KNOW? Most earthquake-generating tsunamis are M7.0 or greater and less than 100 km (62 mi) below Earth's surface.







STEP 1

Subducting plate catches rocky edge of overriding plate.

STEP 2

Subducting plate pulls back edge of overriding plate, building up elastic potential energy, like pulling back a slingshot.

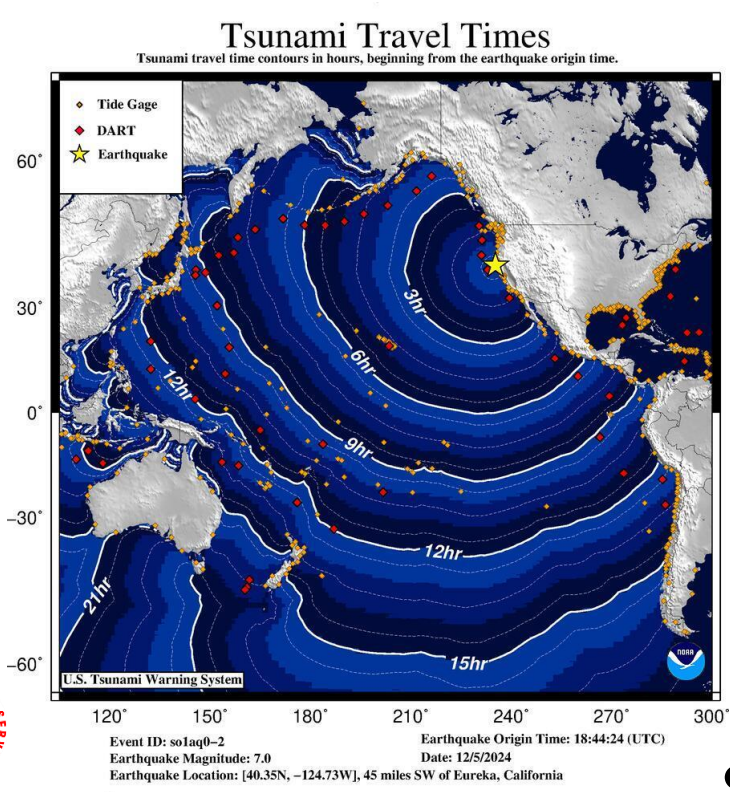
STEP 3

Overriding plate edge ruptures and rapidly springs back, causing an earthquake and displacement of water above it.

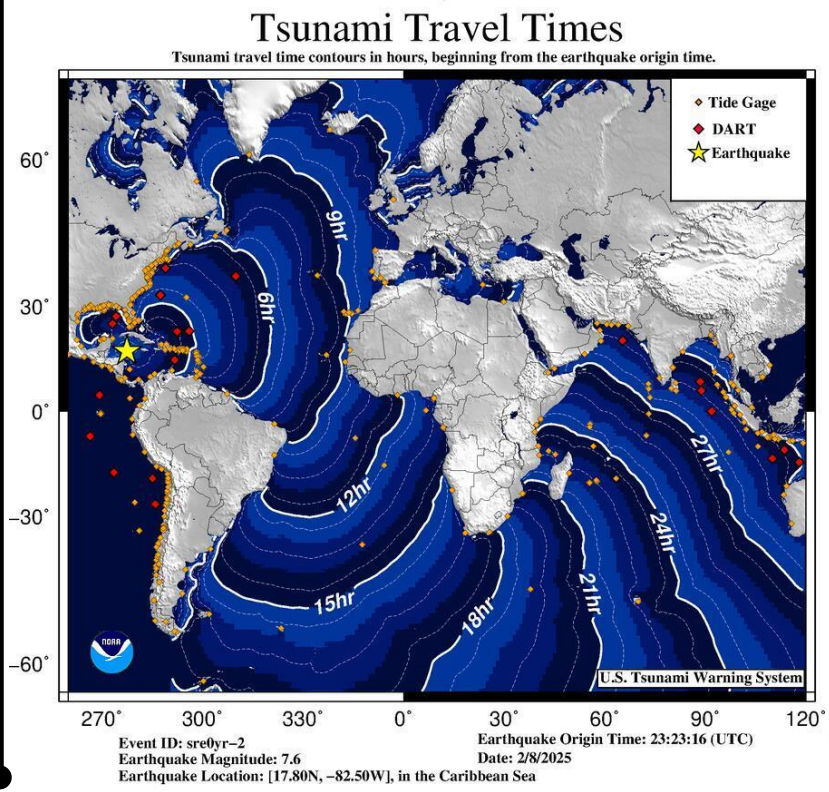
Graphics' source: NOAA Jetstream

Recent Earthquakes with No Tsunami

December 5, 2024: 7.0M off northern California coast

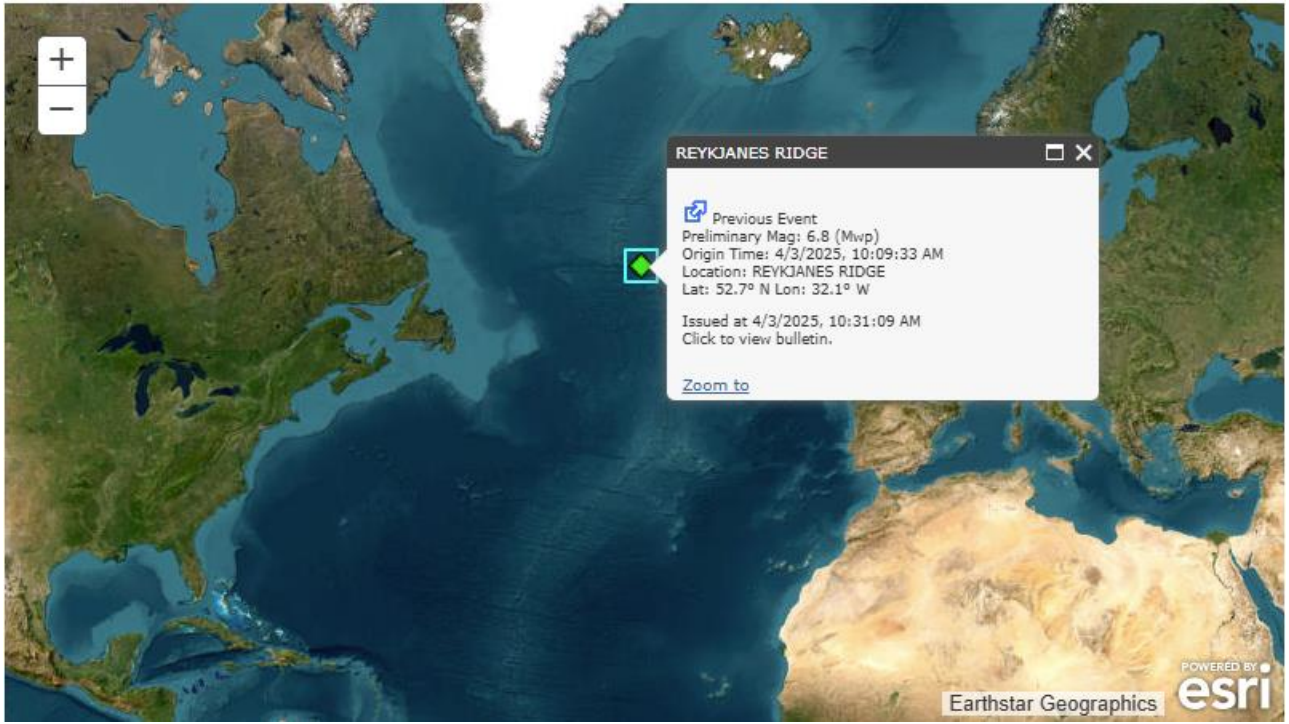


February 8, 2025: 7.6M in the Caribbean Sea between Honduras and the Cayman Islands



Recent Earthquakes with No Tsunami

April 3, 2025: 6.8M in North Atlantic Ocean – Reykjanes Ridge



Tsunami Causes: Landslides

RECALL: Landslides occur when rock, soil, and/or debris slide down a hill or mountainside above OR below water.

DID YOU KNOW? Even if an earthquake does not directly cause a tsunami by uplifting the ocean along a fault, a landslide resulting from an earthquake can still cause a tsunami, whether that landslide is above (subaerial) or below (submarine) water.

In November 1929, a magnitude 7.3 earthquake in the Atlantic Ocean triggered a submarine landslide that generated a tsunami. Waves up to 43 feet (13 meters) high were responsible for 28 deaths and $14 million (2017 dollars) in damage along the coast of Newfoundland, Canada. Source: Natural Resources Canada; Harris M. Mosdell, from the collection of W.M. Chisholm

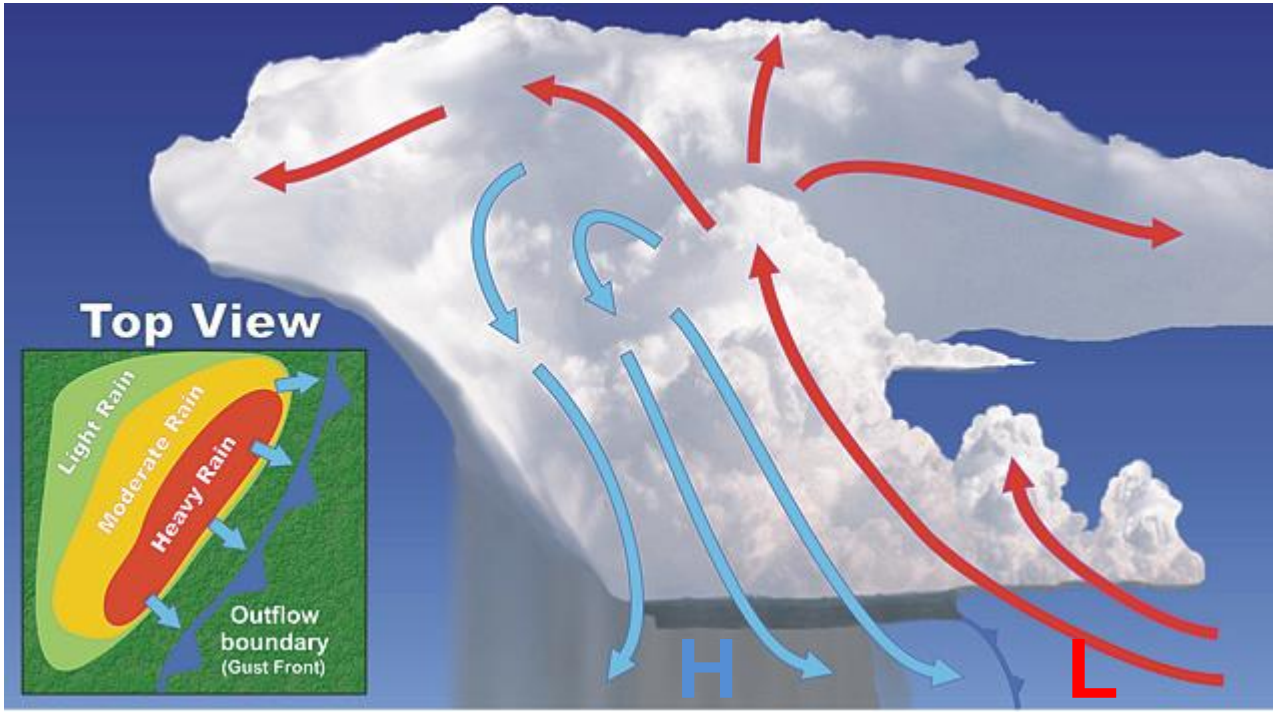
Tsunami Causes: Volcanoes

RECALL: Volcanic eruptions often produce a mass of lava, rock, and ash, called pyroclastic flow.
DID YOU KNOW? Landslides, pyroclastic flows, or a collapse of a volcano's walls can cause a landslide large enough to produce a local tsunami.
Submarine explosions near the surface and sideways eruptions out of volcanic vents can also cause local tsunamis.

The Augustine Volcano in Alaska (2006). In 1883, a debris flow from the collapse of the north face of the Augustine Volcano's peak caused a local tsunami. Damage to homes and fishing boats was reported. Source: U.S. Geological Survey, Game McGimsey

Tsunami Causes: Weather

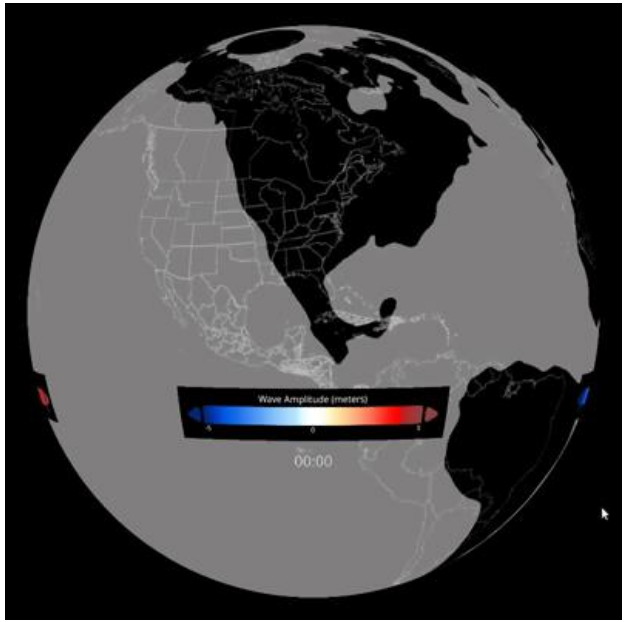
RECALL: Intense lines of thunderstorms produce large pressure changes over a short distance. **DID YOU KNOW? In some cases, this air pressure disturbance can cause a local tsunami in a similar fashion to an earthquake, but from above the water surface instead of below.**



Tsunami Causes: Meteorites

RECALL: Any major displacement of water can result in a tsunami, including large meteorites
DID YOU KNOW? ~66 million years ago, a 6+ mile wide meteorite is widely accepted to have hit Earth and caused a megatsunami which wiped out most dinosaurs and about 75% of all plants and animals on Earth.

- Modeled wave reached up to 1.5 km (0.93 mi) high
- First wave may have reached up to 4.5 km (2.8 mi) high
- Black color fill depicts approximate shape and position of continents 66 million years ago



Source: NOAA Pacific Marine Environmental Lab and Geophysical Fluid Dynamics Lab

Tsunami Source Locations

Initiation Points

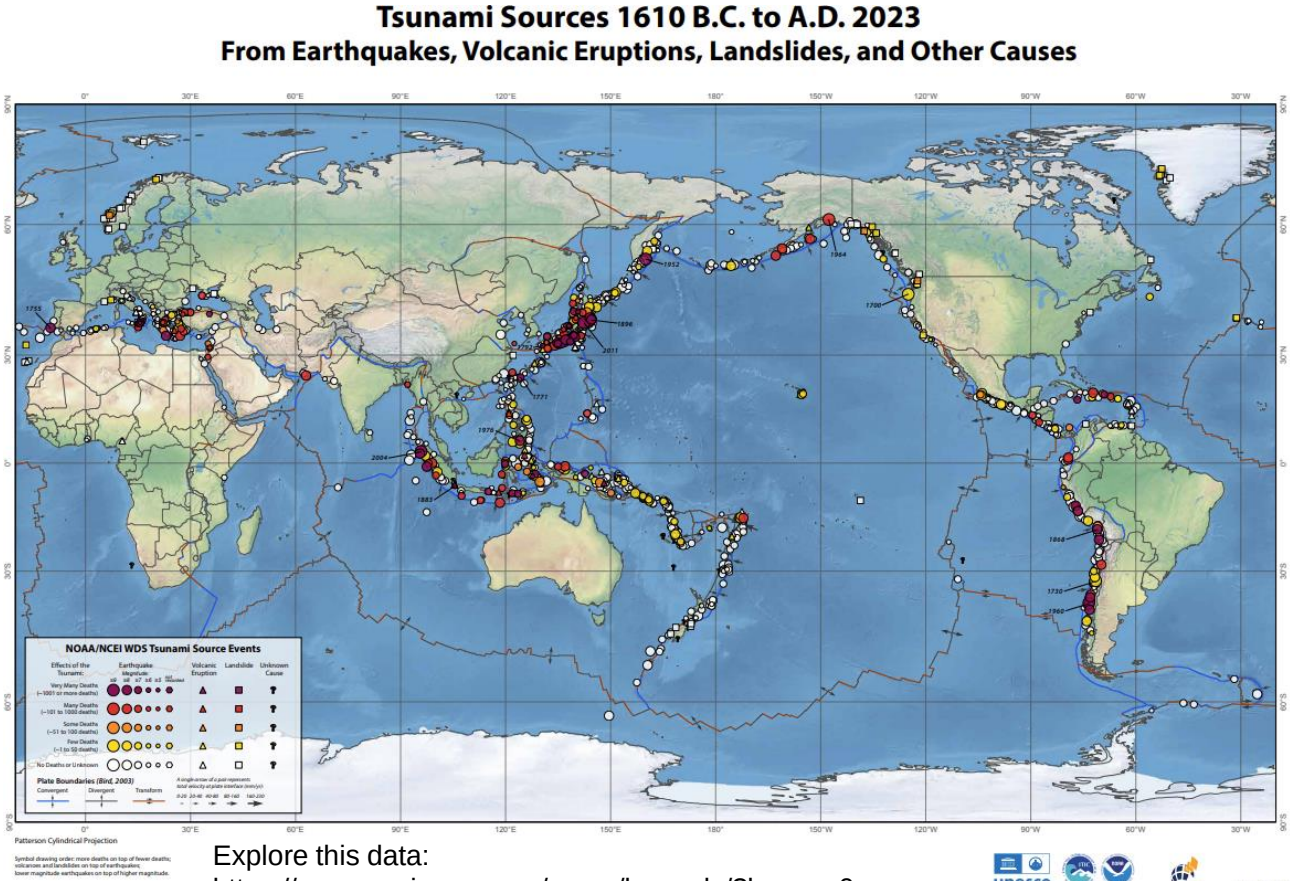
78% - Pacific Ocean

9% - Atlantic Ocean and Caribbean Sea

6% - Mediterranean Sea

5% - Indian Ocean

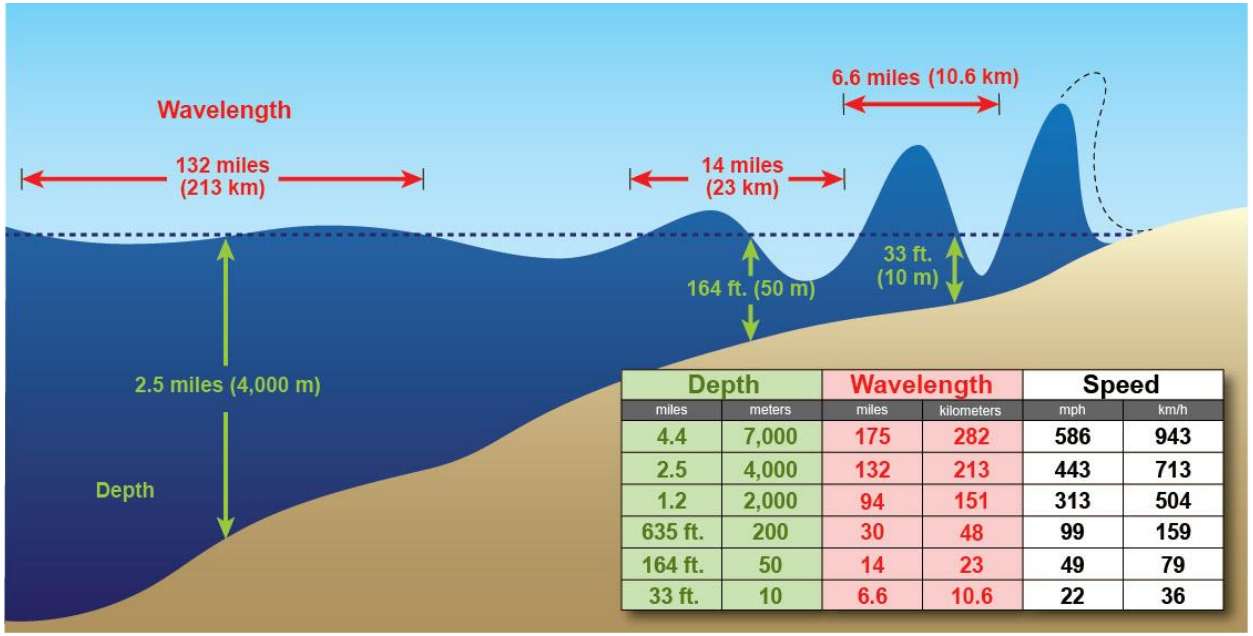
1% - Other Seas



Explore this data:
https://www.ncei.noaa.gov/maps/hazards/?layers=0

Tsunami Propagation: How They Move

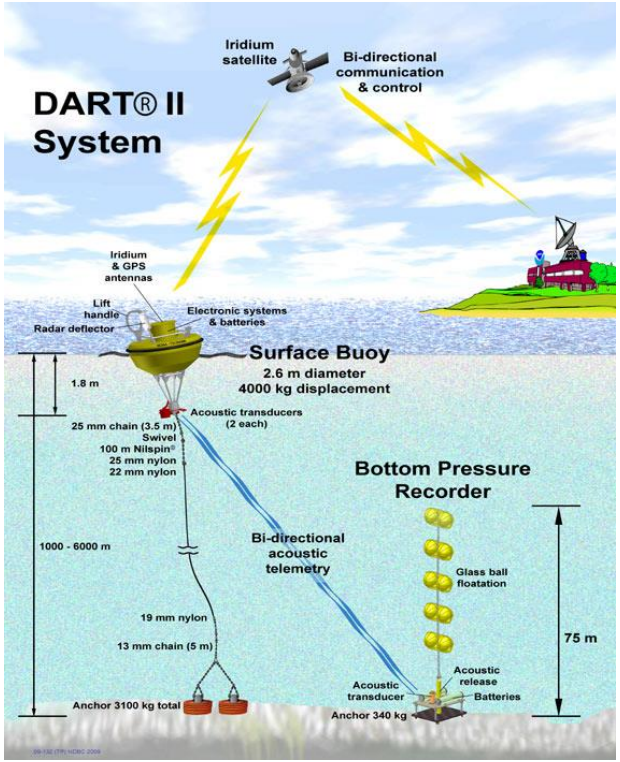
Fact: Tsunamis radiate outward in all directions from their source and travel faster in deep water

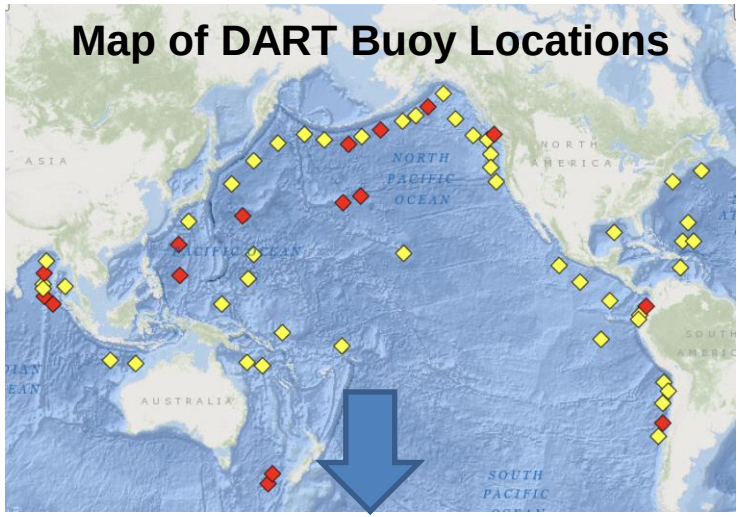


Depth		Wavelength		Speed	
miles	meters	miles	kilometers	mph	km/h
4.4	7,000	175	282	586	943
2.5	4,000	132	213	443	713
1.2	2,000	94	151	313	504
635 ft.	200	30	48	99	159
164 ft.	50	14	23	49	79
33 ft.	10	6.6	10.6	22	36

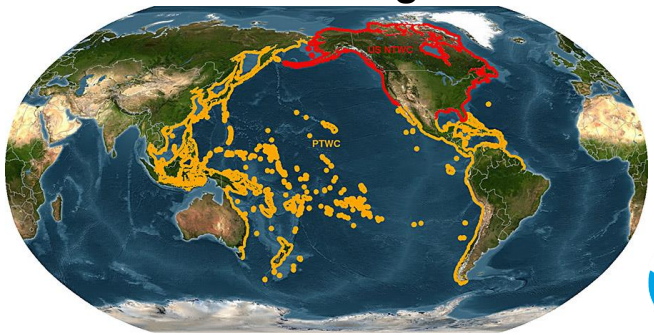
Graphic and chart showing how tsunami wave speed changes with ocean floor depth. Tsunamis travel faster in deep water and slow down in shallow water. Source: NOAA Jetstream

Tsunami Tracking: DART Buoys





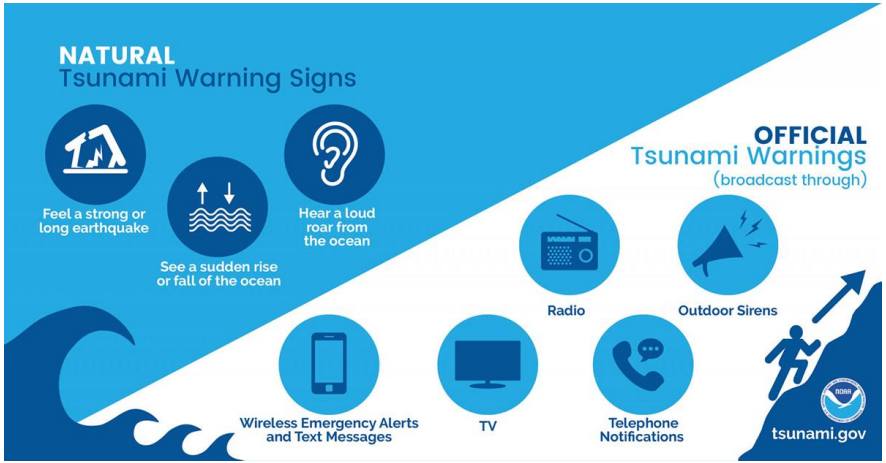
Tsunami Warning Centers

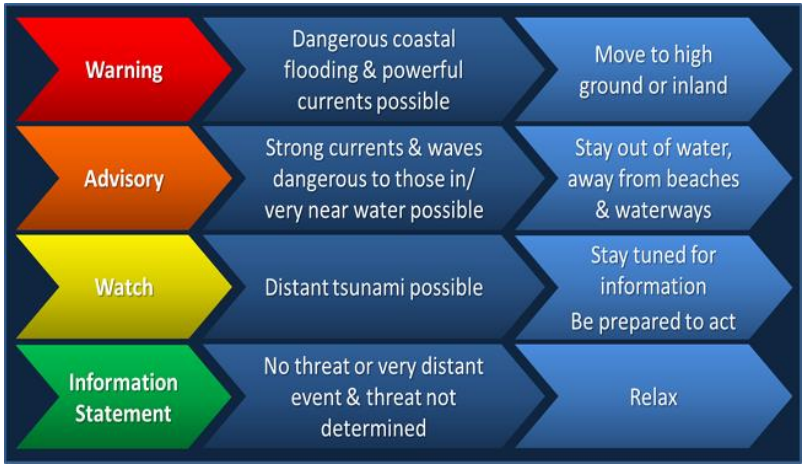


DART = Deep-ocean Assessment and Reporting of Tsunamis

Tsunami Preparedness and Safety

- Understand tsunami warning signals – official tsunami warnings and natural signs
- Have multiple ways to receive earthquake and tsunami alerts
- Know your tsunami risk
- Know your evacuation routes and where to find higher ground
- If on a boat and in a harbor – exit the boat and find higher ground
- If on a boat and on open ocean – move to deeper water





Thank you!

Learn more: www.noaa.gov/jetstream/tsunamis
Find this presentation: www.weather.gov/ohx/weather101presentations

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