UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-TEWS Chile)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
19-30 August 2024, Valparaiso, Chile

Tsunami Science

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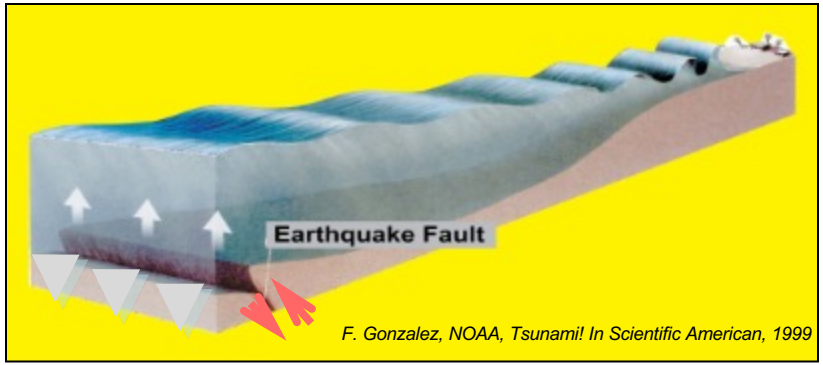
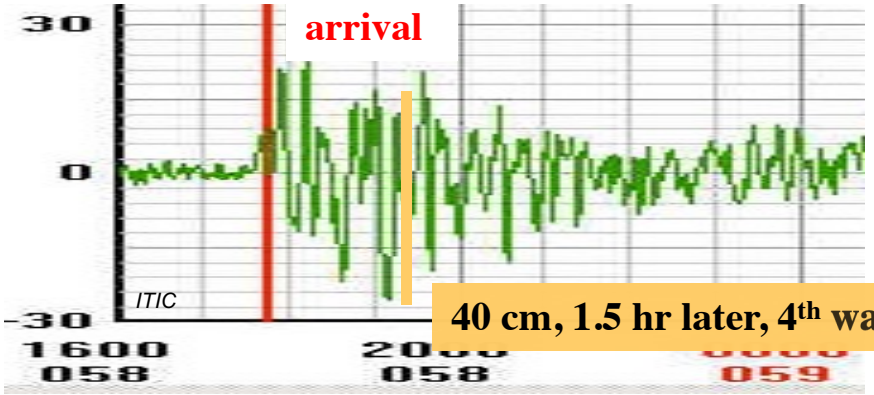
What is a tsunami?
How does a tsunami wave act?

What is a tsunami?

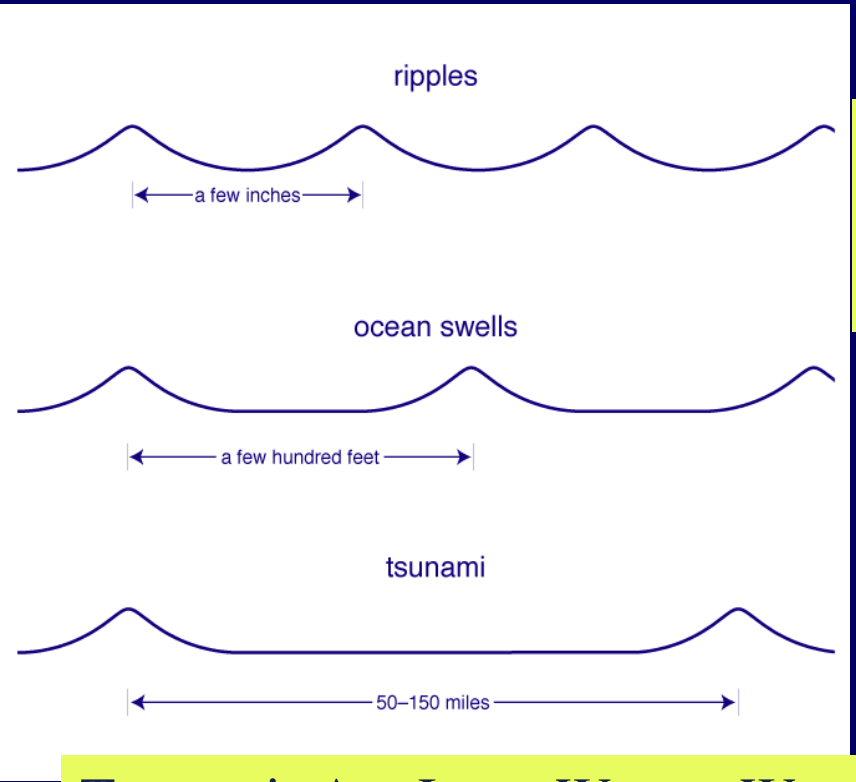
- Japanese for “harbor wave”. No connection with tides. Not a tidal wave.
- Series of long-period waves that may continue for hours. 1st wave may not be largest.
- Generated by any sudden displacement of the water column





40 cm, 1.5 hr later, 4th wave

Tsunamis – Wavelength & Period

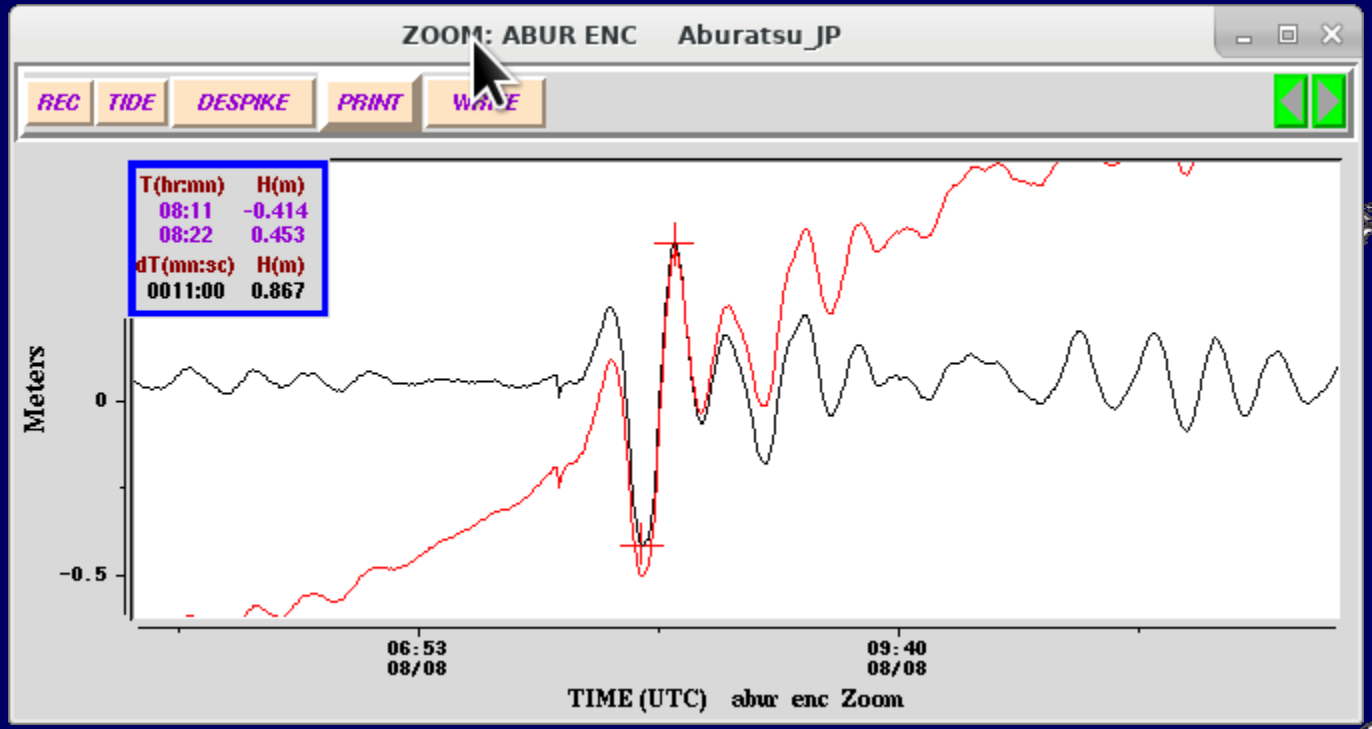


Wavelength: Distance Between Wave Crests

Period: Time Interval Between Wave Crests

Tsunamis Are Long Waves: Wavelength >> Water Depth
Tsunamis Have Long Periods: 5mins to over 60mins

Tsunamis – Wave Height



Tsunamis - How fast

For Long Waves, Like Tsunamis

Wave Speed = $\sqrt{gH}$

g = acceleration of gravity

= 9.81 meters / second^2

H = water depth

If water depth is
5500 meters, then

Speed = $\sqrt{9.81 \times 5500\ m^2/s^2}$

= 232 m/s

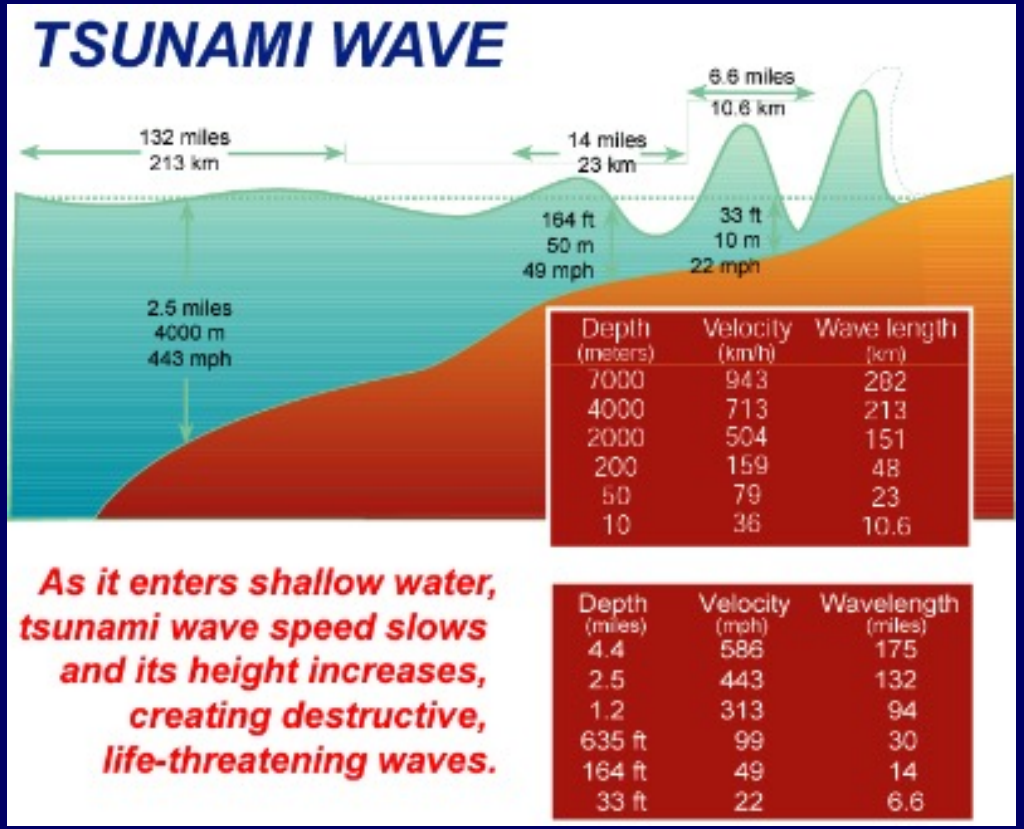
= 519 miles/hour!

about 835 km/hour

=> Speed of a Jetliner!

April 1, 1946 Tsunami , Hilo, Hawaii
Maximum flooding 6 meters

Tsunamis – Propagation

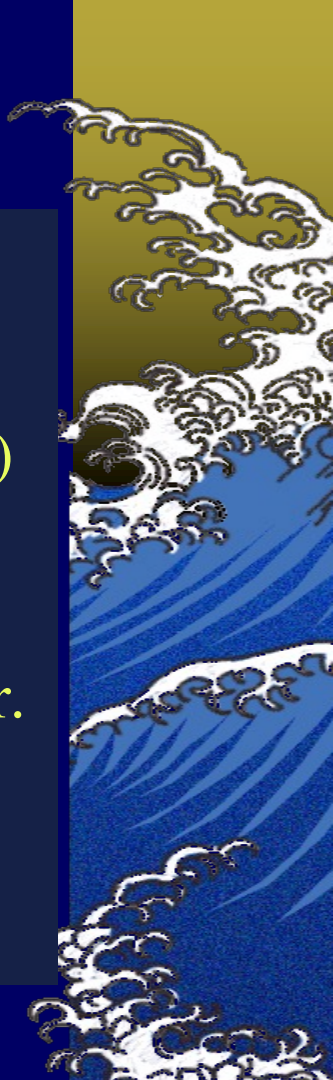


Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

Depth (miles)	Velocity (mph)	Wavelength (miles)
4.4	586	175
2.5	443	132
1.2	313	94
635 ft	99	30
164 ft	49	14
33 ft	22	6.6

Tsunamis – Propagation

- In deep water, tsunamis are non destructive but propagate with the **speed of a jetliner**
- Have long wavelengths … (on the order of 100's of km)
- Have long Periods…. (on the order 10's of minutes)
- Only become destructive when they enter shallow water.
  => This is because the tsunami slows down, causing the wavelength to shorten while energy is mostly conserved

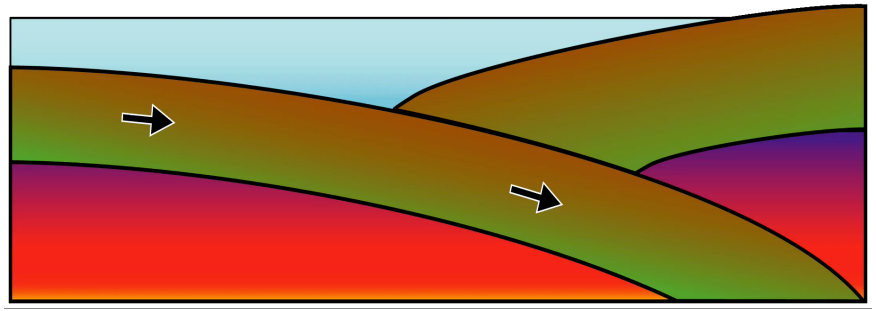


How are tsunamis generated?

How are tsunamis generated?

Created by an abrupt displacement of the ocean, such as from

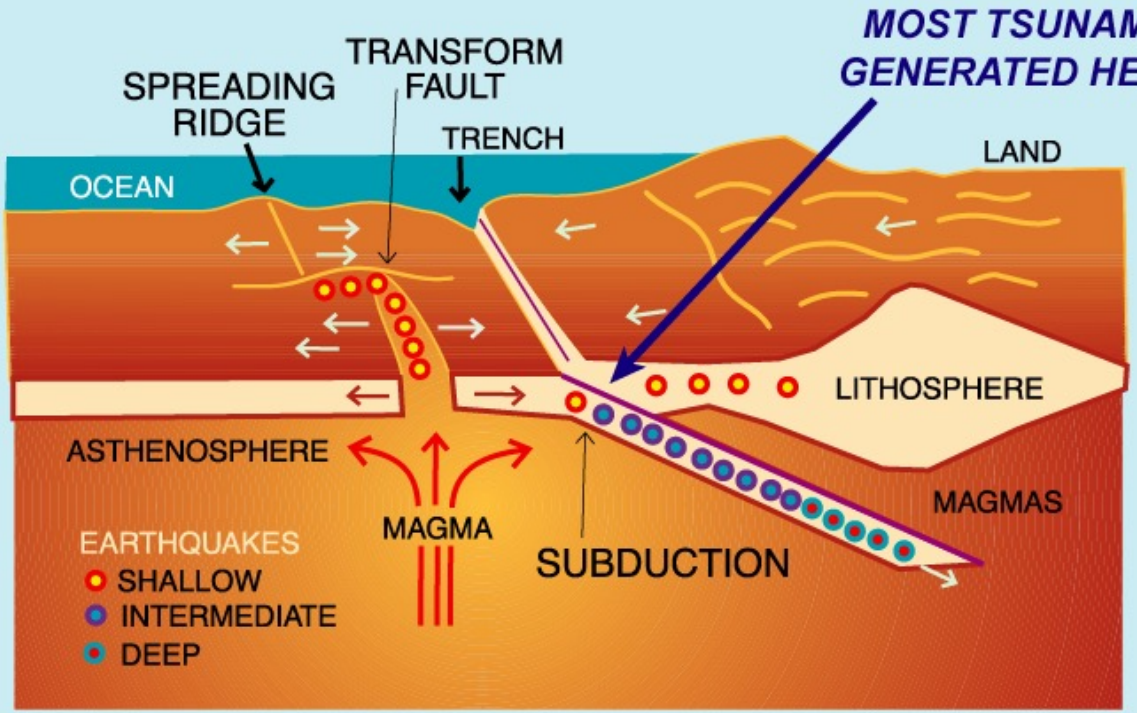
- Shallow, undersea earthquakes (most common)
- Underwater or sub-aerial landslides (less common)
- Volcanic eruptions (infrequently)
- Meteor impact (rarely)
- Weather Phenomena (?)



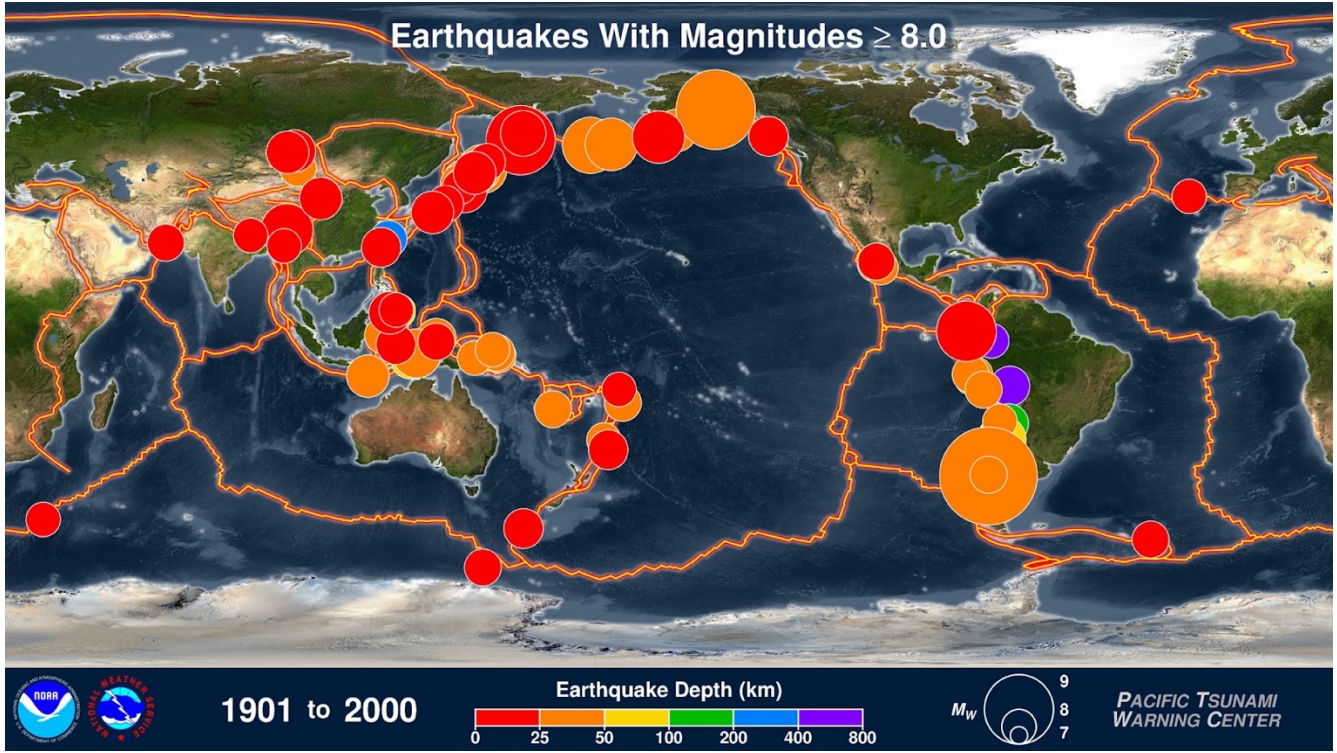
Subduction Zone Tsunami

G. Fryer, Pacific Tsunami Warning Center

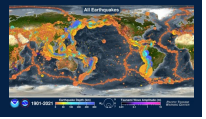
TSUNAMI GENERATION AROUND PACIFIC RIM



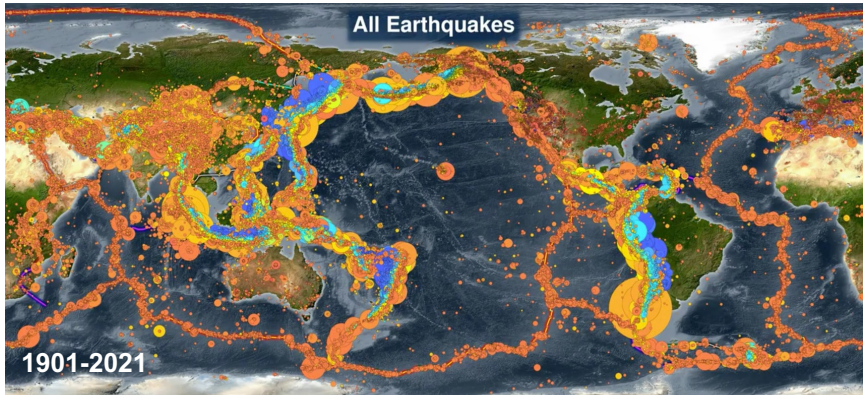
DANGEROUS EARTHQUAKES & TSUNAMIS

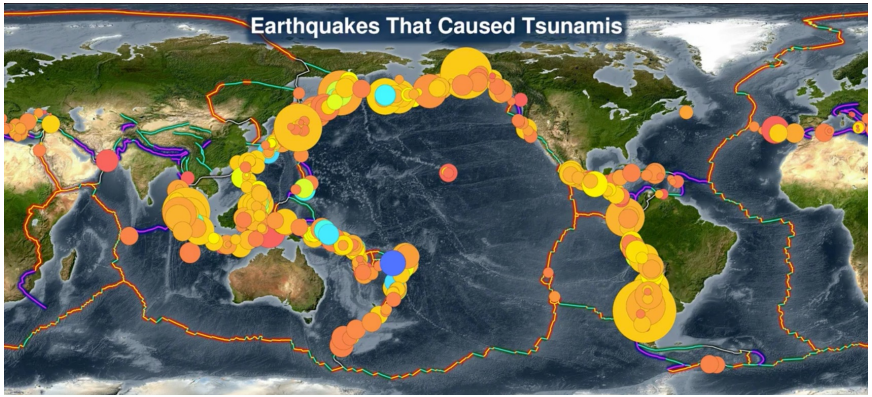


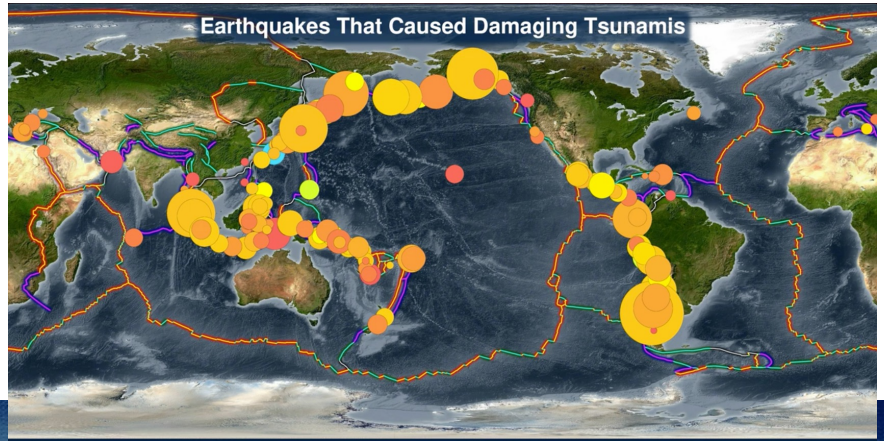
Click for video
EQ-Tsunam1901-2021



DANGEROUS EARTHQUAKES & TSUNAMIS

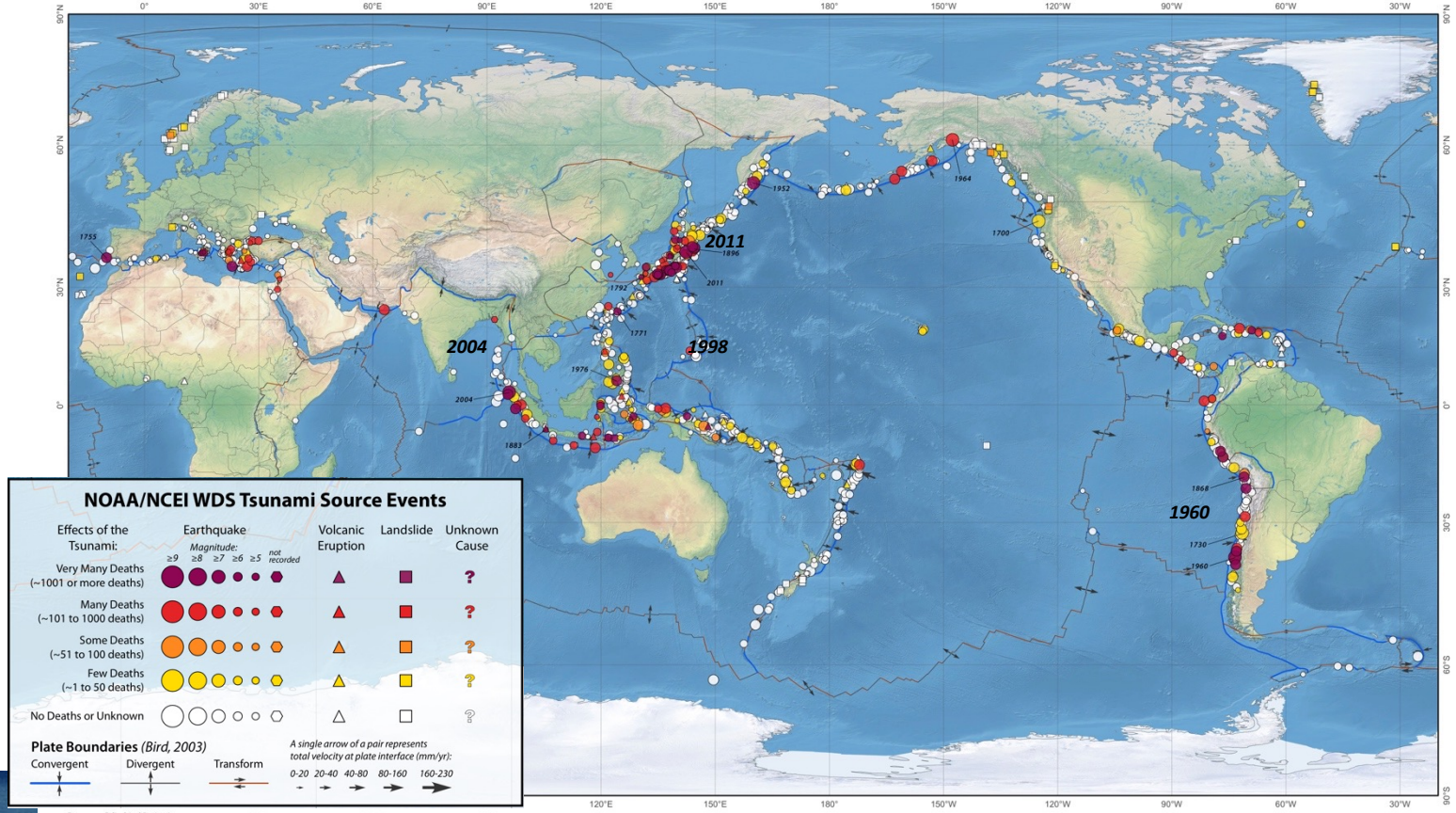






- 80% caused by earthquakes
- Shallow, undersea/near coast
- Magnitude 8+ (M7+)

DEADLY TSUNAMIS – GLOBAL (1620 B.C to A.D. 2022)



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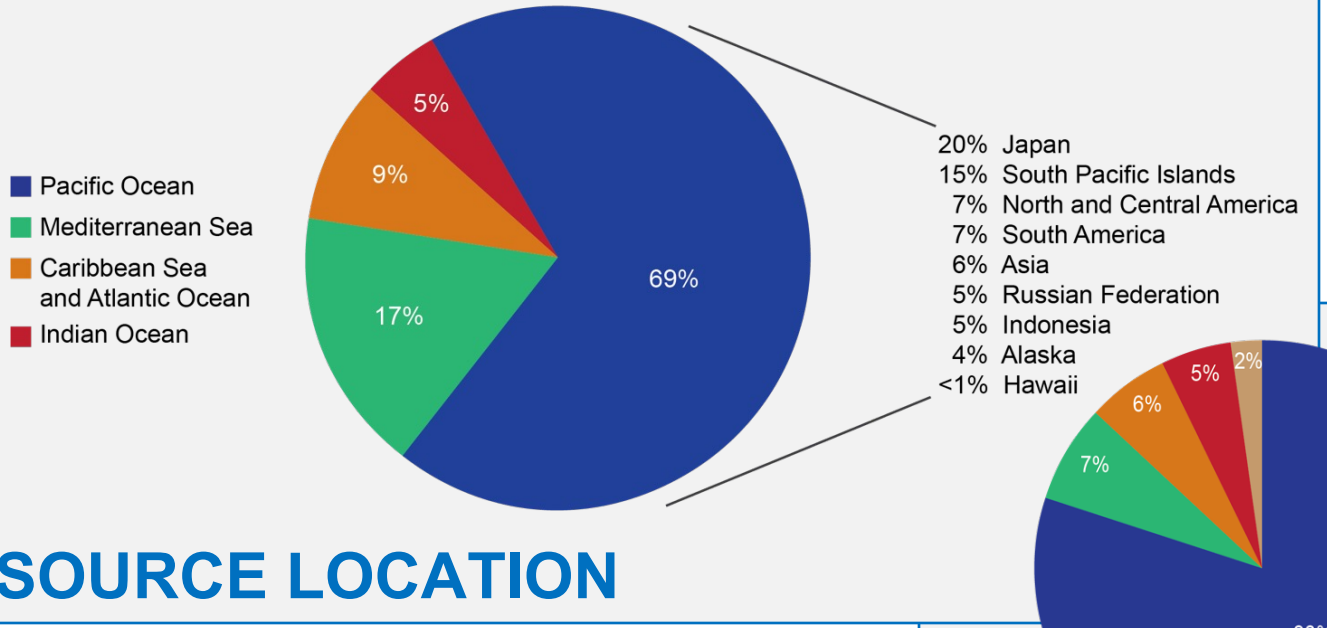
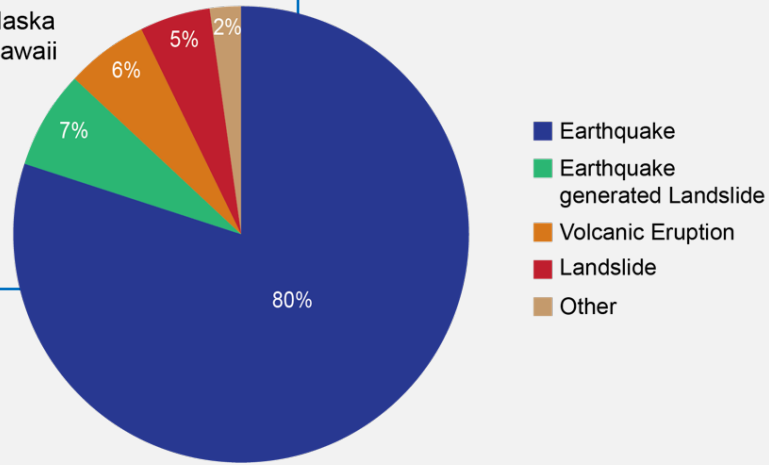


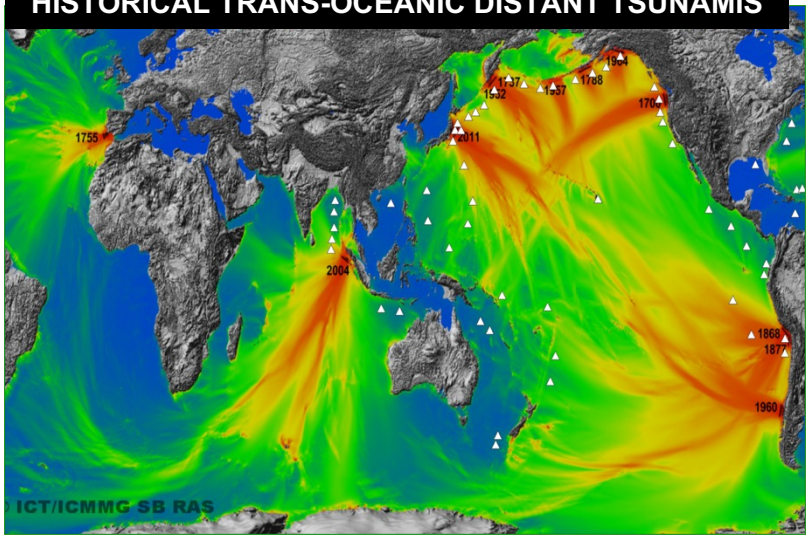
SOURCE LOCATION



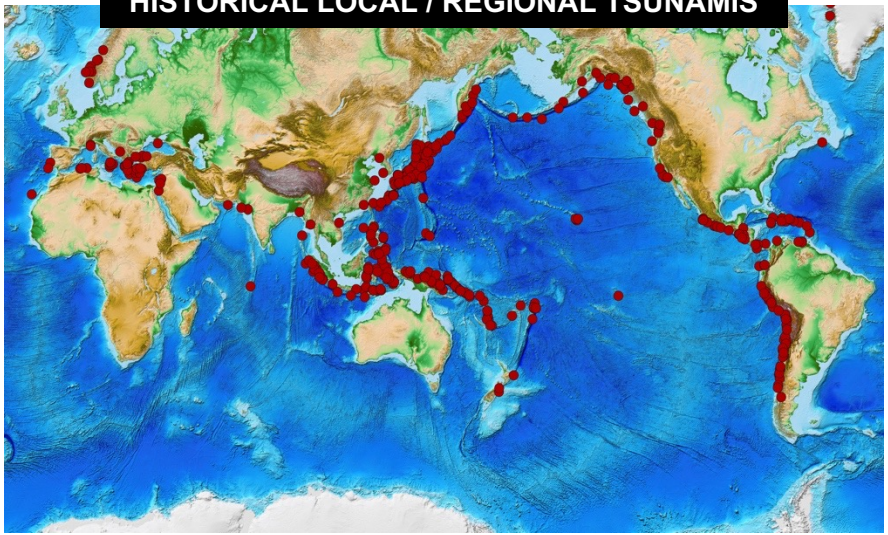
SOURCE GENERATION

DEADLY TSUNAMIS – DISTANT to LOCAL

HISTORICAL TRANS-OCEANIC DISTANT TSUNAMIS



HISTORICAL LOCAL / REGIONAL TSUNAMIS

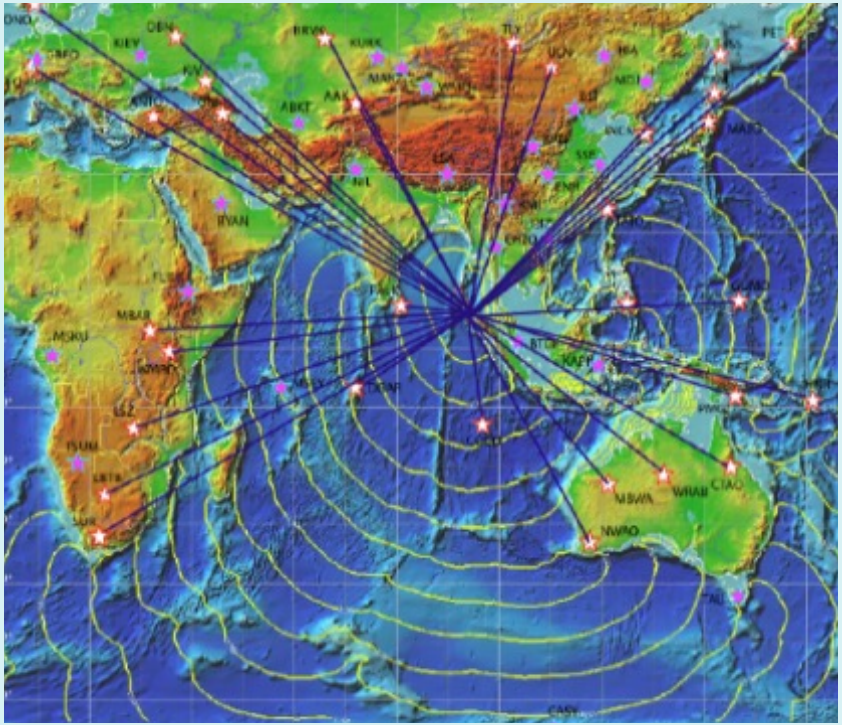


- Most tsunamis are local (< 1 hr) or regional (1-3 hrs)
- Globally, 90% of deaths from local or regional tsunamis (Pacific, 99% of deaths)

Seismic and Tsunami Waves

Seismic Waves
~36,000 kph

Tsunami Waves ~
900kph

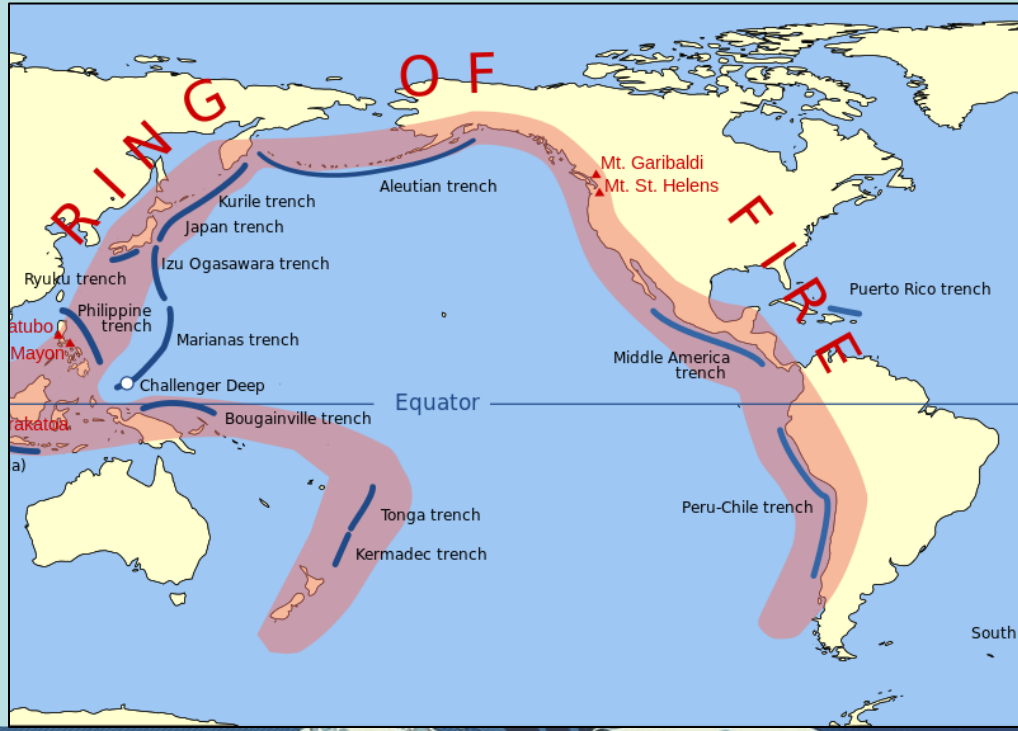


Tsunami Warning Premise

- Most tsunamigenic earthquakes occur in subduction zones, i.e., the ocean deeps.

Seismic waves travel about 30-40 times faster than tsunami waves.

→ Possible to warn for a tsunami well ahead of its arrival!



What does a tsunami look like?
What does a tsunami do?
Why is a tsunami a hazard?

What does a tsunami look like?

- Rapidly rising/falling sea level
- Wall of water (not breaking surf wave)
- Receding wave (seafloor exposed)
- Fast flowing, debris-laden river

What does a tsunami look like?

Indian Ocean Tsunami, December 26, 2004

Thailand Video

Indonesia Video

Asian Tsunami: Disaster of the Century, Asia-Pacific Broadcasting Union, 2005

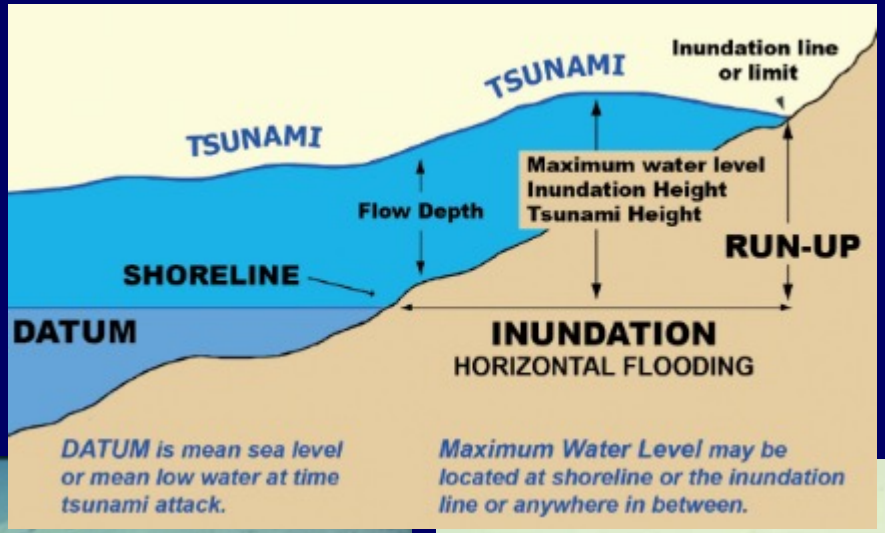
Indian Ocean Tsunami, December 26, 2004

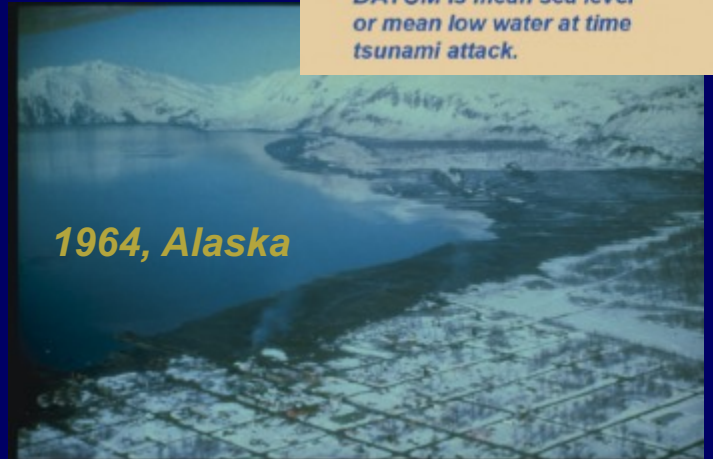
Penang, Malaysia: Relentless surge

High-tide, Arorae, Kiribati

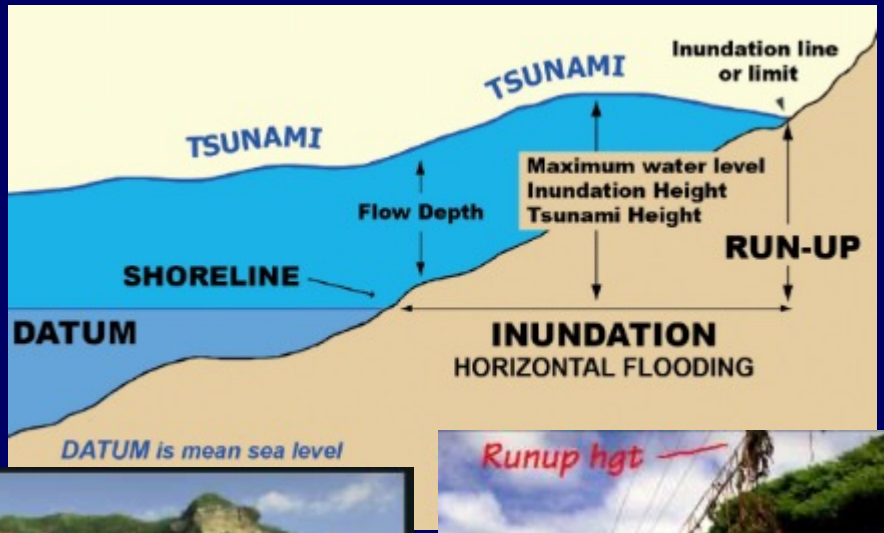
- Surge

TSUNAMI TERMS - INUNDATION

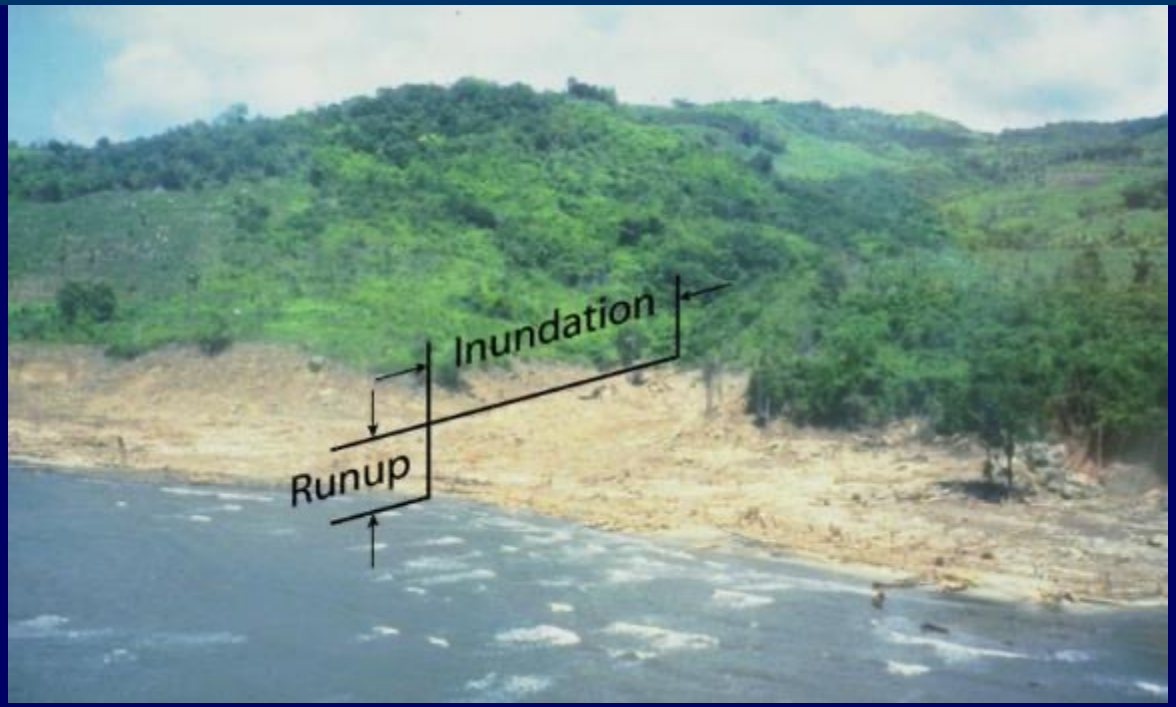




TSUNAMI TERMS - RUNUP



RUNUP and INUNDATION



- Runup: height above sea level reached by water
- Inundation: how far inland water reaches

What does a tsunami do?

- Objects become battering rams
- Erode, scour, deposit mud

  ⇒Death, debris

  ⇒Structures/utilities collapse

  ⇒Fire, HAZMAT

American Samoa, R. Madsen, G. Yamasaki, 2009

Fukushima, Japan, 2011, UN IAEA

What does a tsunami do?

- Quickly inundates low-lying areas

Before After

Banda Aceh, Indonesia Dec 26, 2004

- Flooding, strong currents

Largest wave draining

Pago Pago, American Samoa Sept 29, 2009

John Pughnat

unesco
Intergovernmental Oceanographic Commission

Thank You

Dr. Stuart A. Weinstein
Deputy Director, PTWC

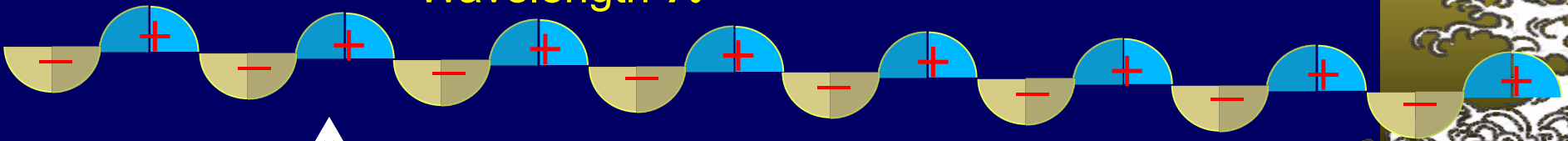
Dr. Dailin Wang
Senior Oceanographer, PTWC

USAID
FROM THE AMERICAN PEOPLE

SMART CABLES
Earth's Pulse

Waves with short wavelengths are not sensed by the DARTs

Wavelength λ = 10m ⟷ 100m



If $\lambda / D << 1$

D = 3km ⟷ 8km

The mass excess and deficit contributions of the crests and troughs of the wave cancel at depth

BPR

DART BPR

Waves with very long wavelengths can be detected by Bottom Pressure Sensors (BPRs, like DARTs)

$\lambda \sim 500$km

D = 3km ↔ 8km

If $\lambda / D >> 1$

The mass excess and deficit contributions of the crests and troughs of the wave do not cancel at depth

Only very long wavelength waves such as the tides and Tsunamis are sensed by the BPR

BPR

DART BPR