UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
7-18 August 2023, Honolulu, Hawaii USA

unesco
Intergovernmental Oceanographic Commission

Tsunami Science

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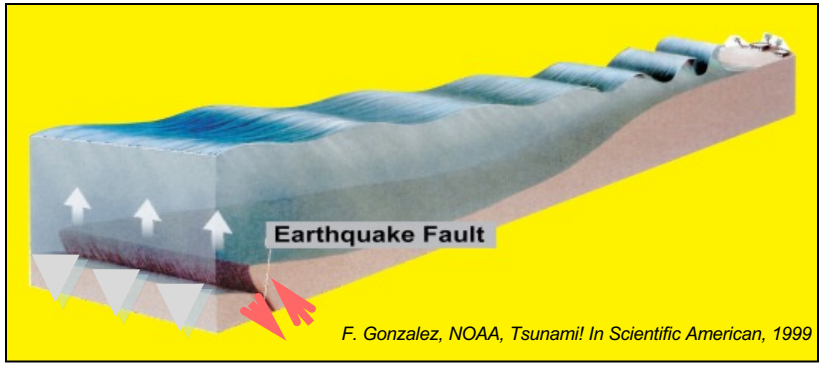
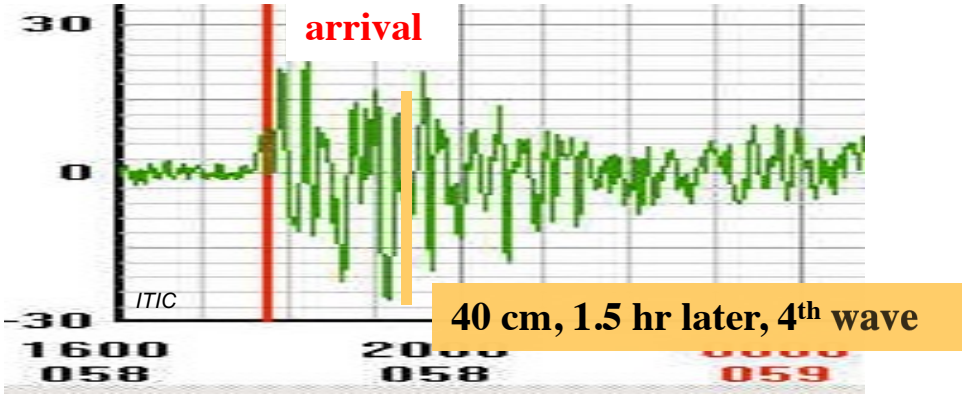
USAID
FROM THE AMERICAN PEOPLE

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

What is a tsunami?

- Japanese for “harbor wave”
  No connection with tides. Not tidal wave.
- Series of long-period waves for hours.
  1st wave may not be largest.

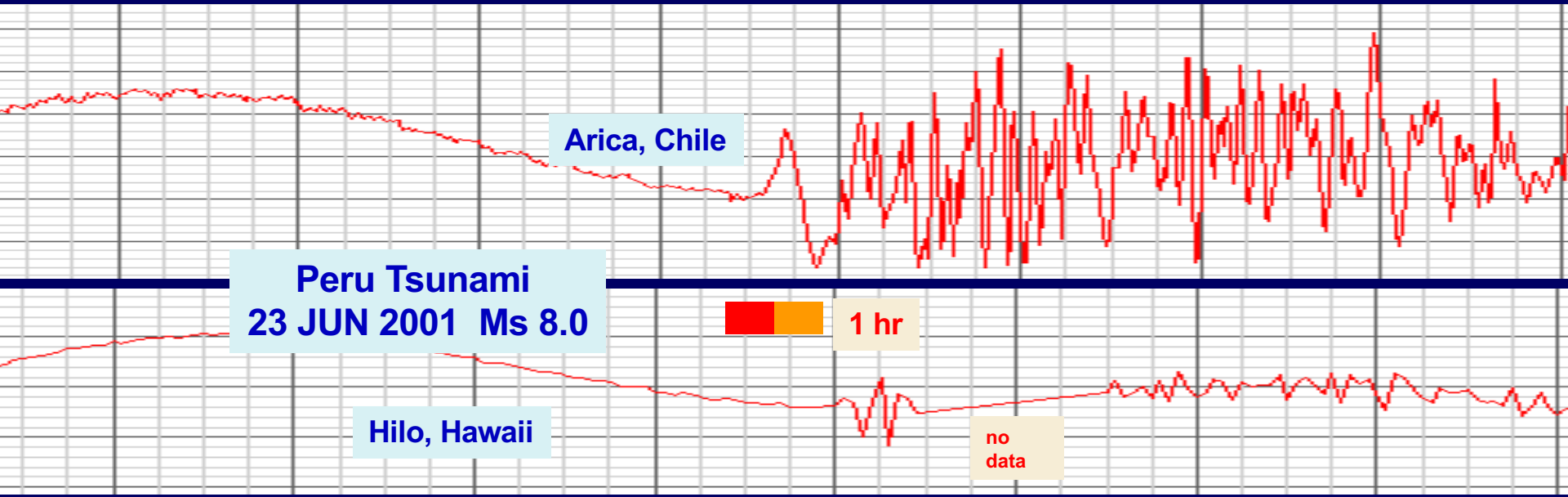




TSUNAMIS - What and How

- *SERIES OF LONG-PERIOD OCEAN WAVES*

  5 TO 60 MINUTES BETWEEN WAVE CRESTS



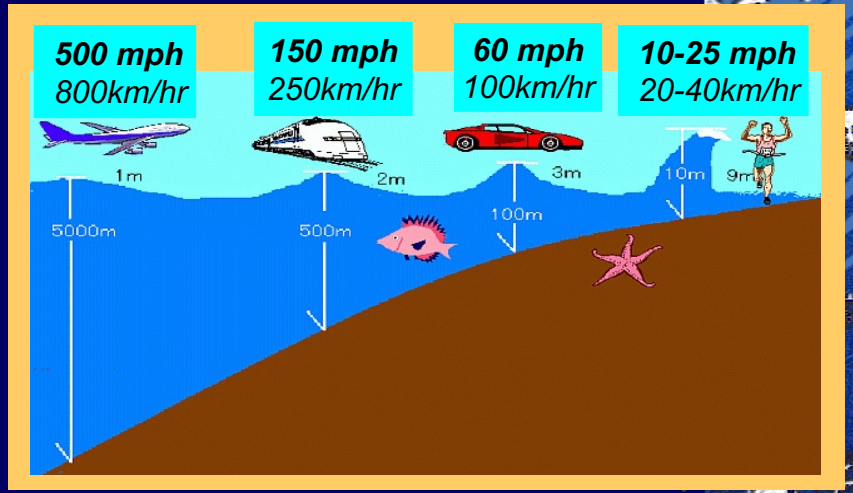
TSUNAMIS - What and How

- ***SPEED DEPENDS ON WATER DEPTH***

  Fast in deep ocean (>1000 km/h)
  Slows near shore (30-50 km/h)

- ***HEIGHT DEPENDS ON WATER DEPTH***

  Small in deep ocean
  (few cm to 1 m)
  Grows near shore
  (can be >30 m)



TSUNAMIS - How fast

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

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

Tsunami vs wind waves vs tides

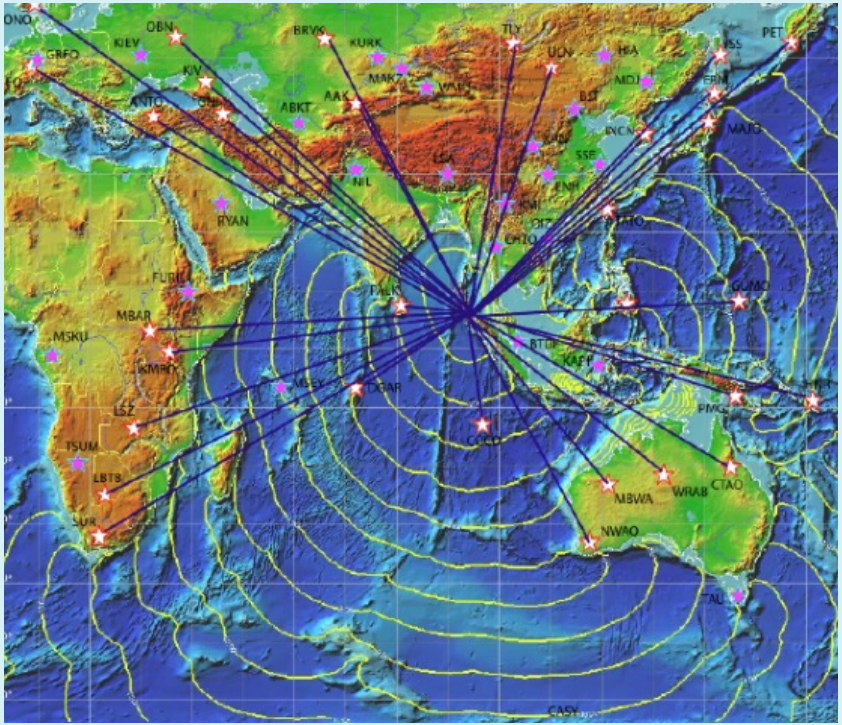
- Wave frequency every 5-60 minutes.

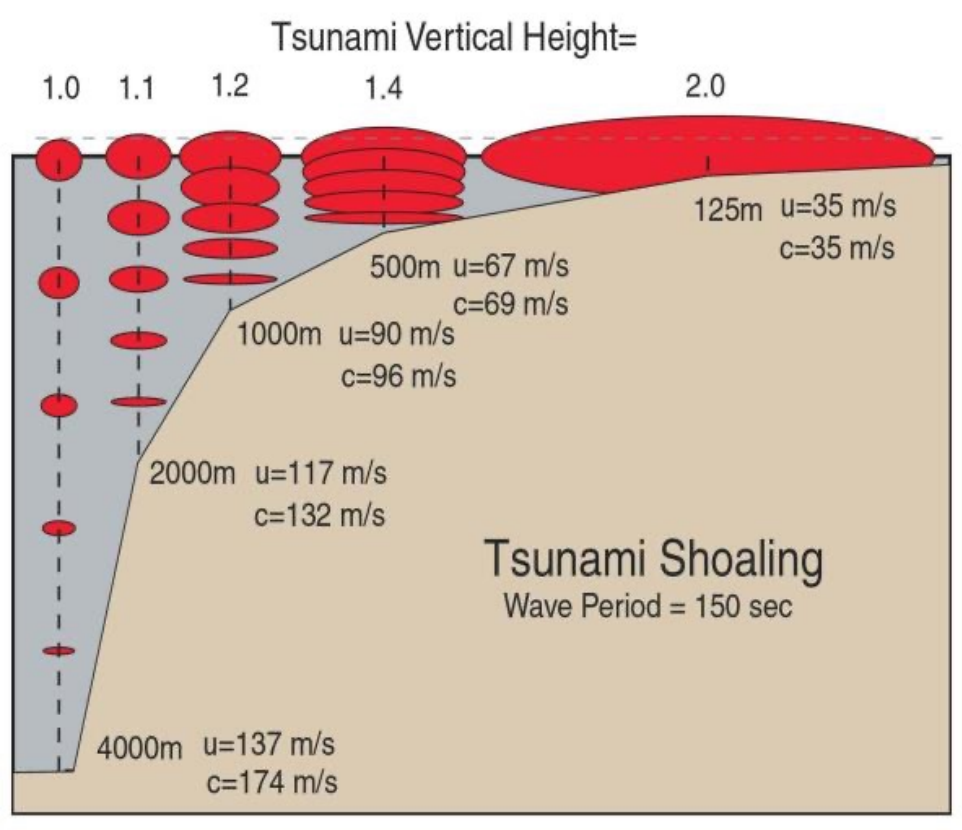
TYPE	*CAUSE*	*TIME / CYCLE*
SEA & SWELL	WIND	2 - 25 SEC
TSUNAMIS	RAPID OCEAN DISPLACEMENT	5 - 60 MIN
TIDES	ASTRONOMICAL CYCLES	> 12 HRS

Seismic and Tsunami Waves

Seismic Waves
~20,000 mph

Tsunami Waves ~
500 mph





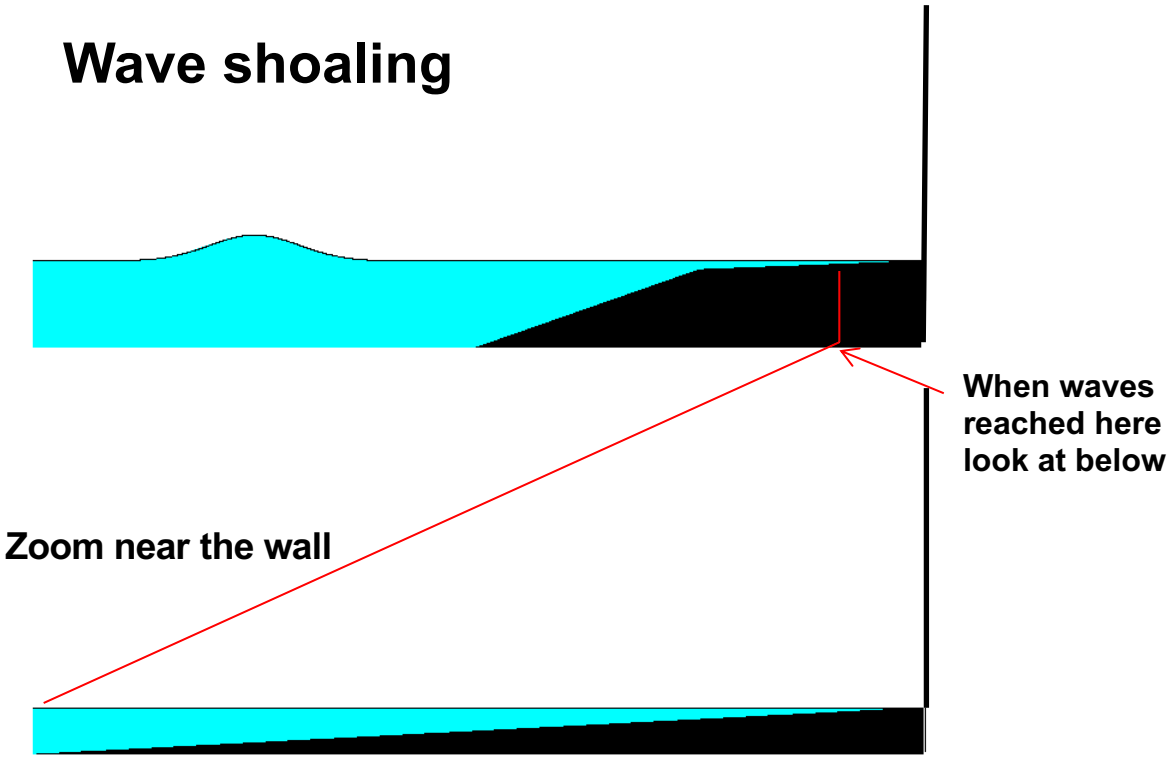
- Tsunami steepen in shallow water, but generally do not become steep enough to break.
- **Tsunami slow and grow as they near the coast.**
- **In deep water, V~500 mph**
- **They come ashore ~ 30-50 mph.**

➔ **Still – Cannot outrun tsunami to high ground.**

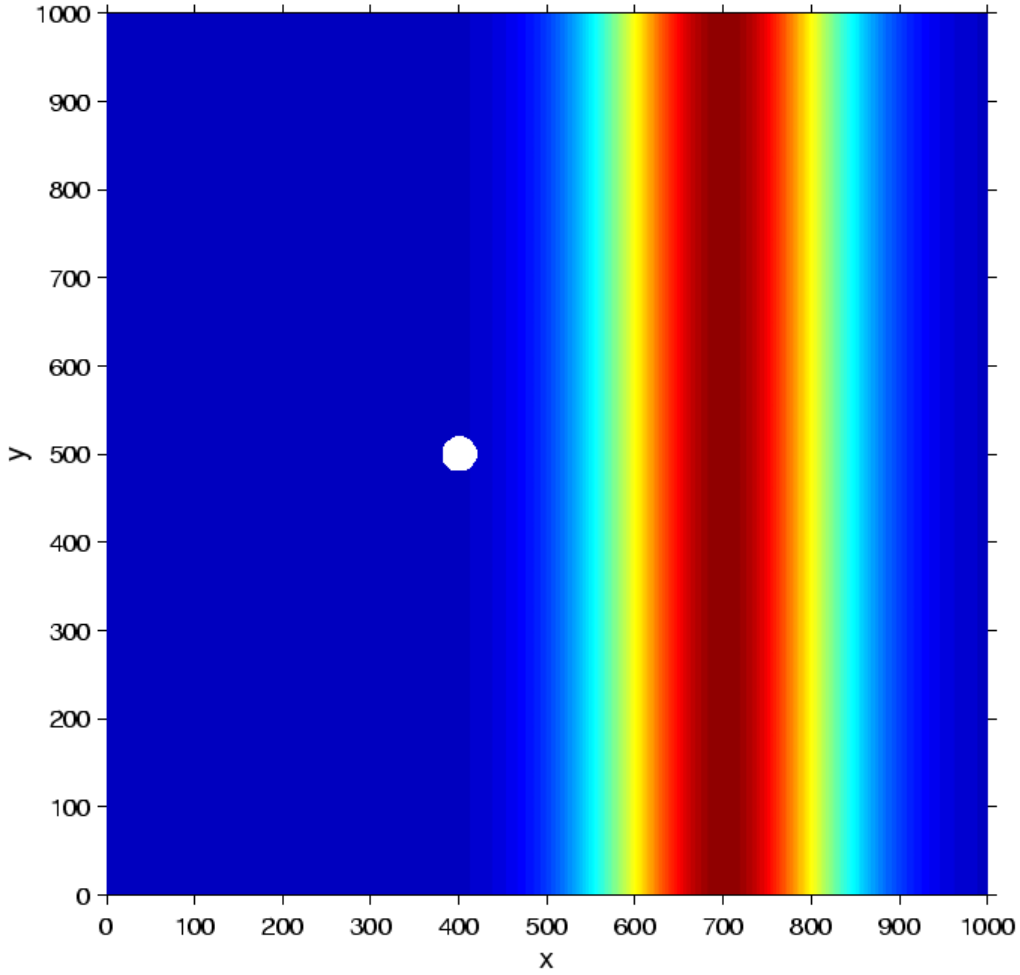
Tsunami Wave Simulations

- Shoaling
- Wrap-around skinny cylinder
- Wrap-around conic island
- Wrap-around island chain (Hawaii)

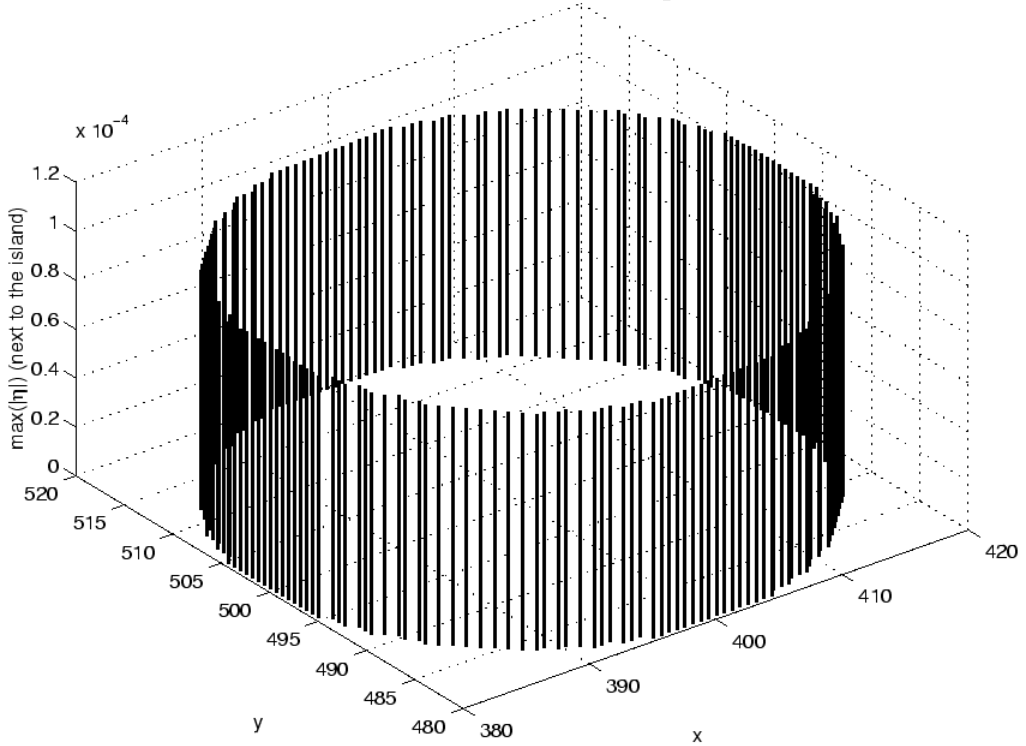
Wave shoaling



Waves wraps around a skinny cylinder without much runup

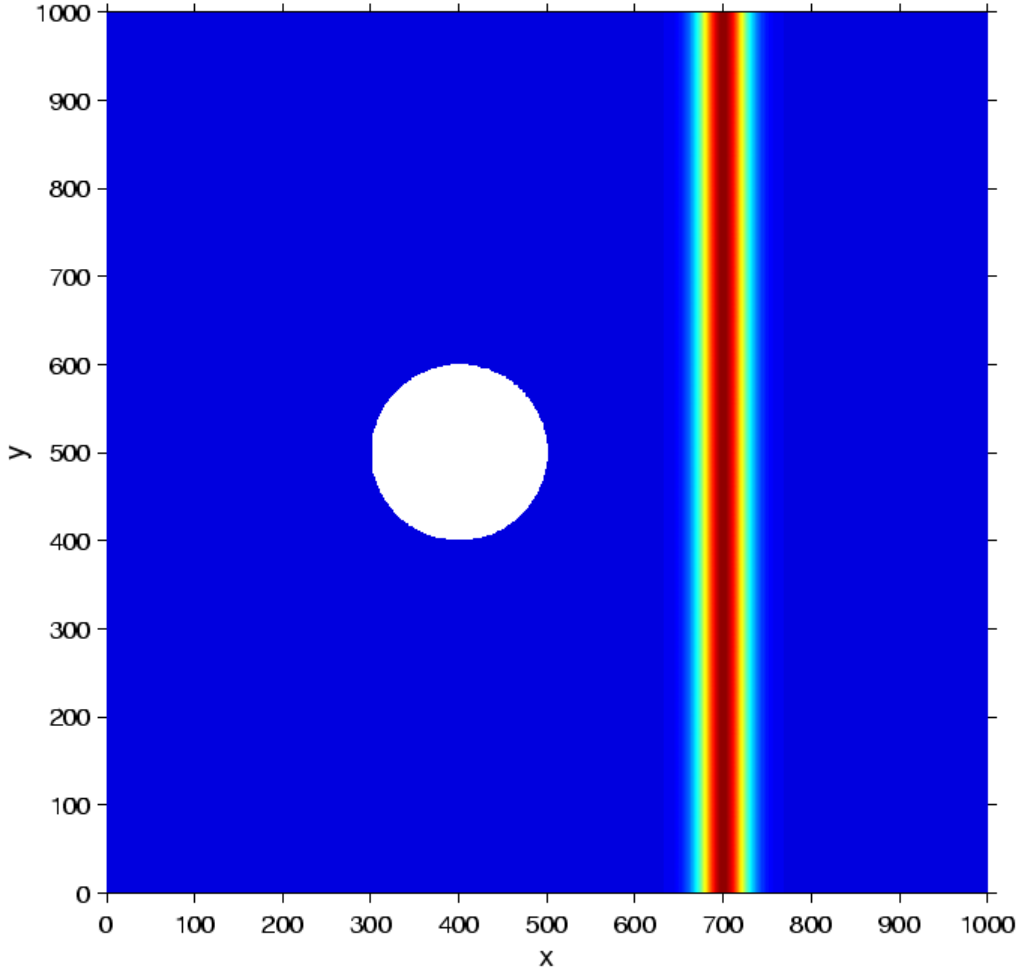


For a skinny island/cylinder (compared to wavelengths), there will be minimal wave runup.



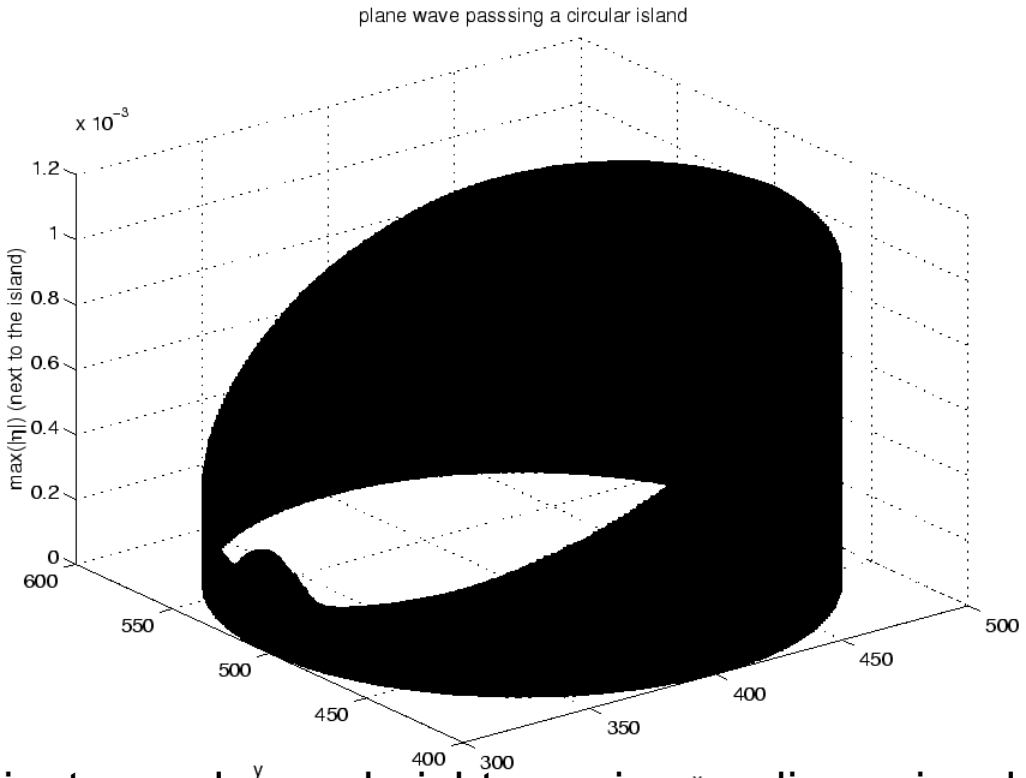
Coordinates and wave heights are in non-dimensional units

Waves wraps around a conic island



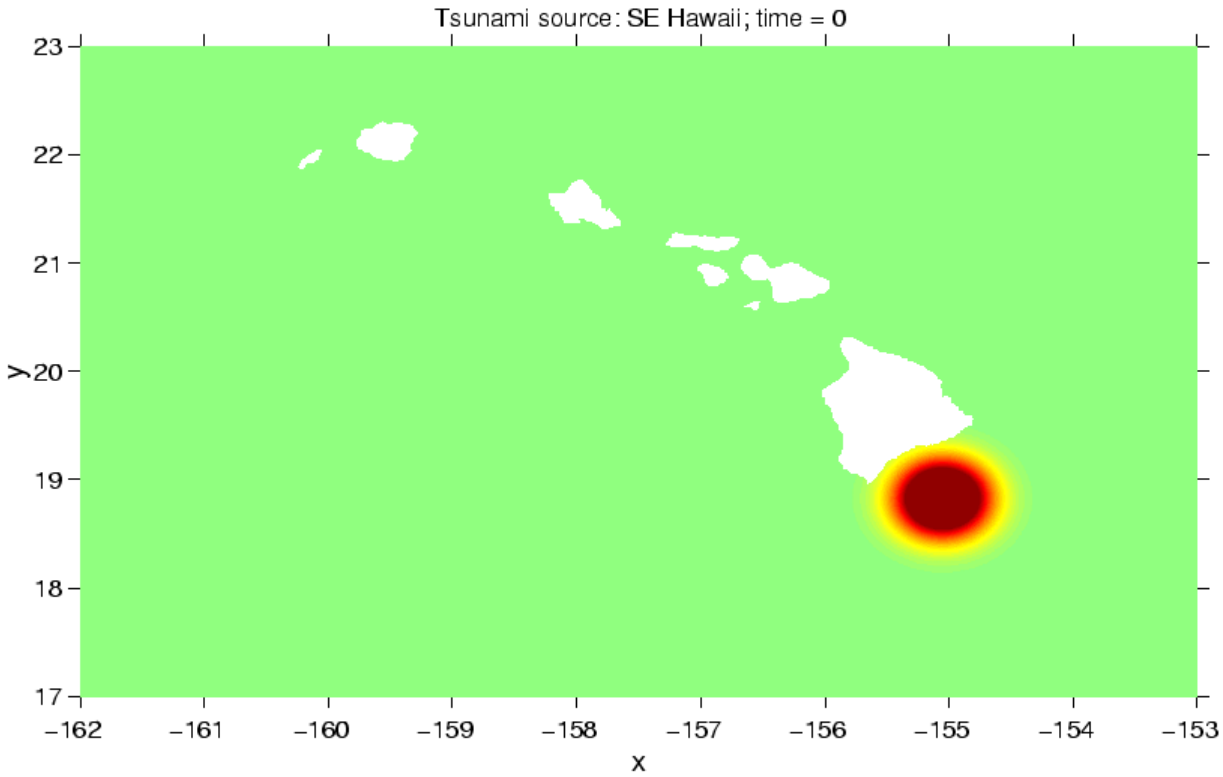
Wave run-up on a conic island.

The under water portion of the island is in conic shape but the landmass is assumed to be vertical walls.



Coordinates and wave heights are in non-dimensional units

Waves wraps around Hawaii island

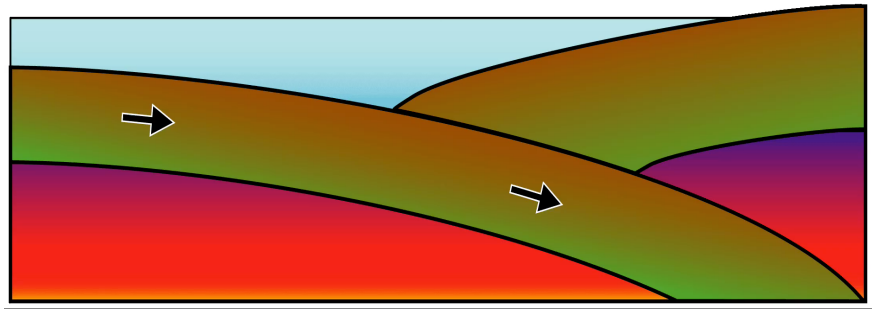


How are tsunamis generated?

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)



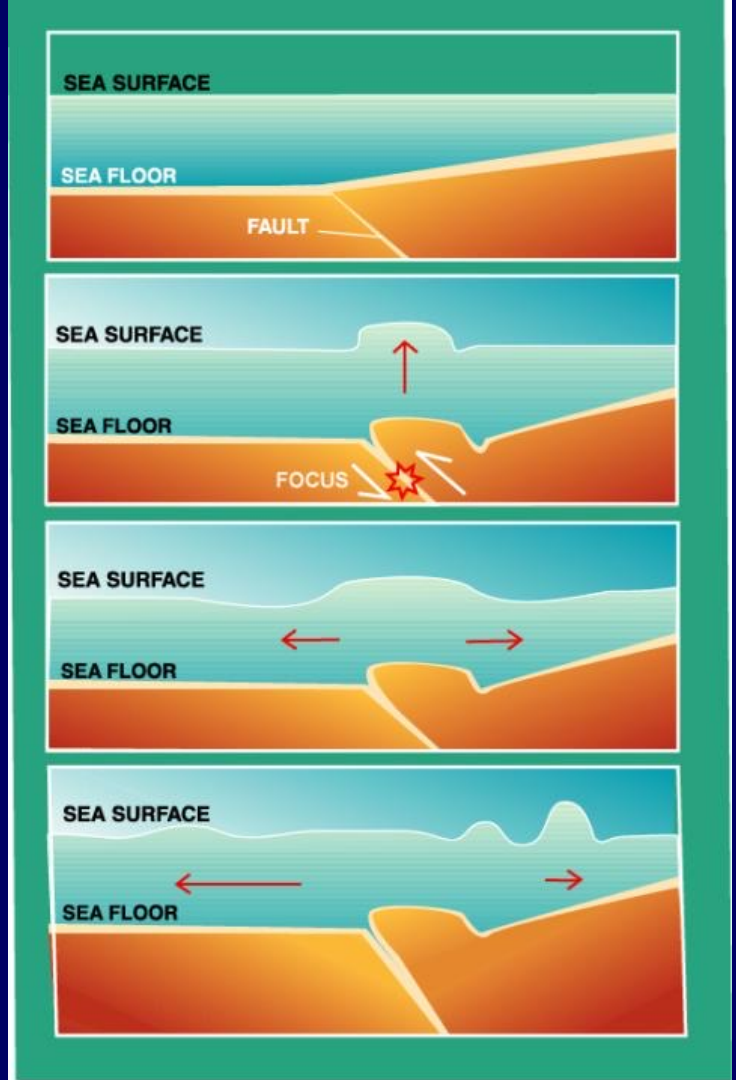
Subduction Zone Tsunami

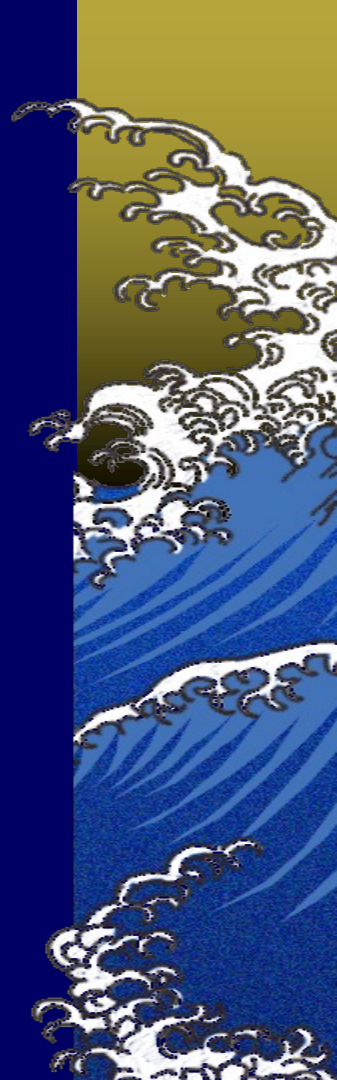
G. Fryer, Pacific Tsunami Warning Center

TSUNAMIS GENERATED BY EARTHQUAKES

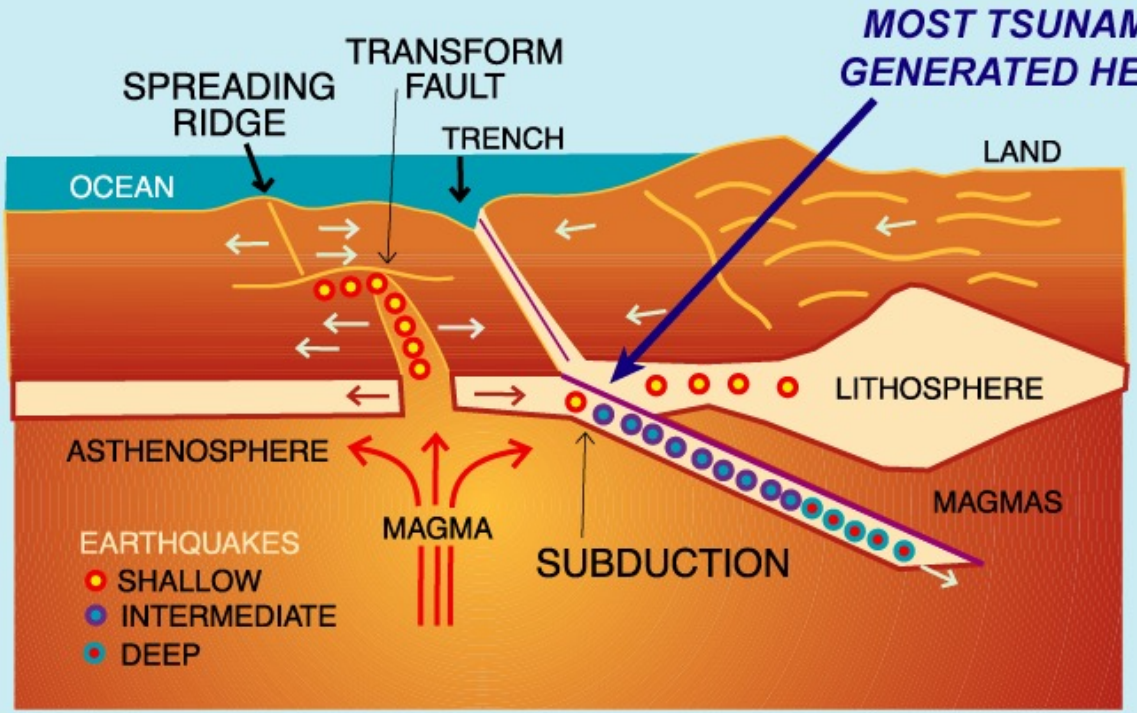
Large EQ (>7.5)
Shallow EQ – at or near the seafloor (< 50 km)
Subduction zones

Sudden displacement moves overlying column of water generating wave

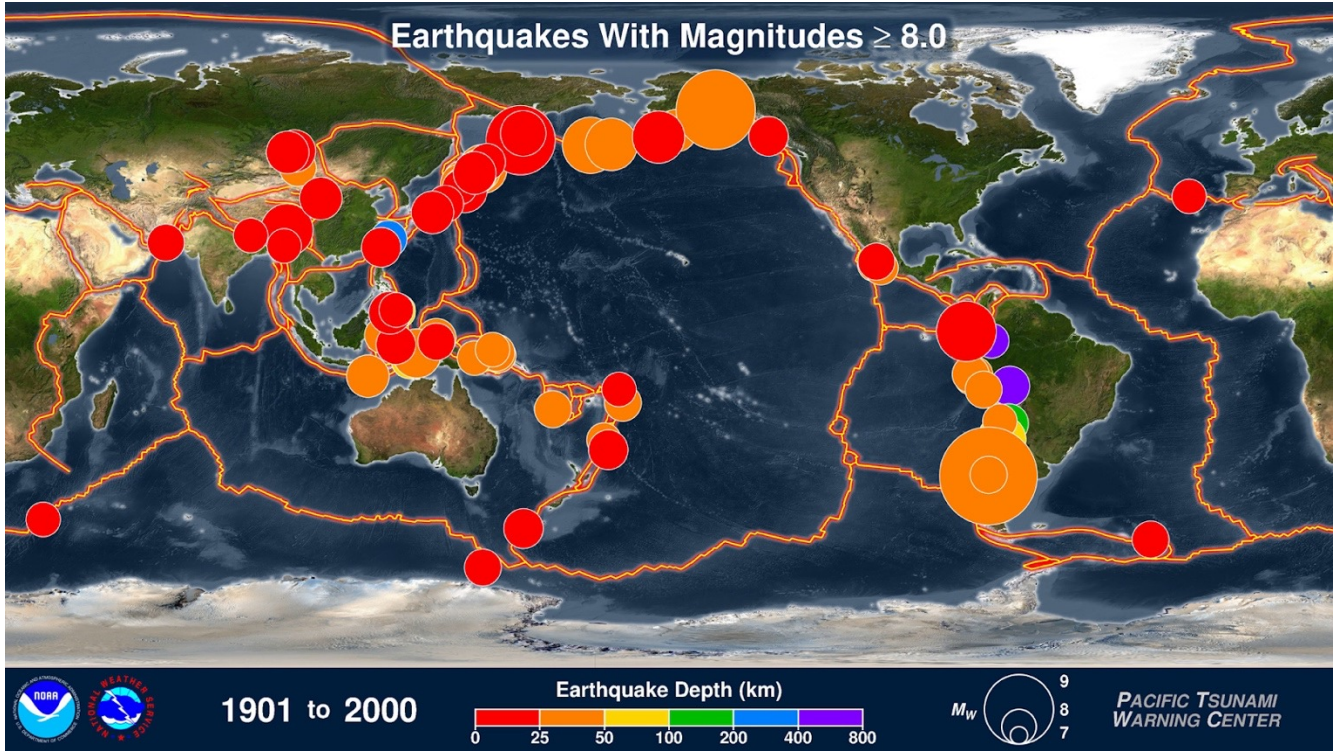




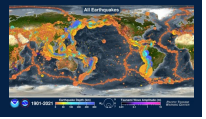
TSUNAMI GENERATION AROUND PACIFIC RIM



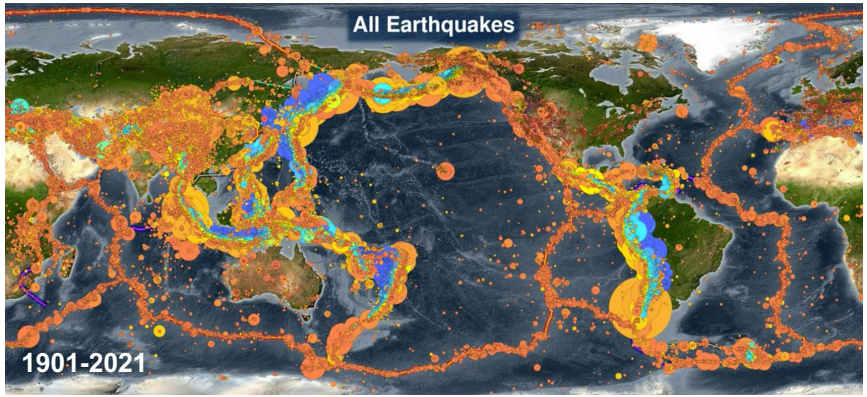
DANGEROUS EARTHQUAKES & TSUNAMIS

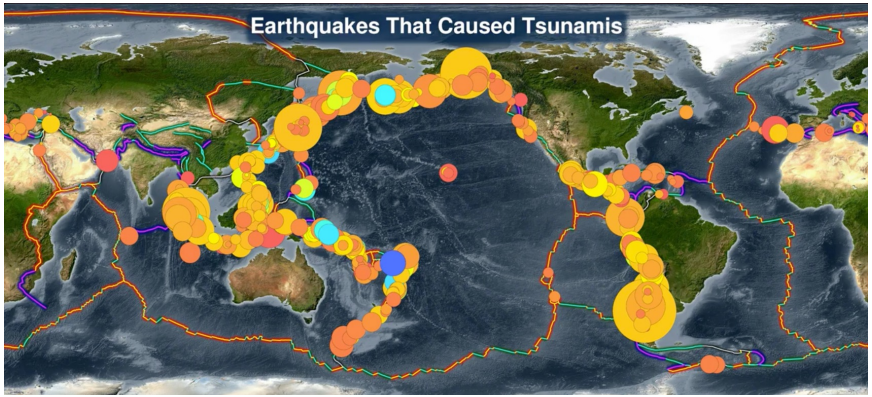


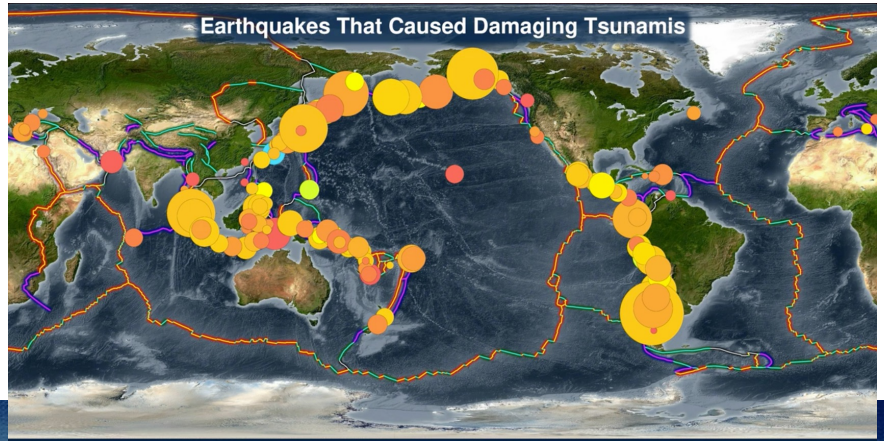
Click for video
EQ-Tsunam1901-2021



DANGEROUS EARTHQUAKES & TSUNAMIS

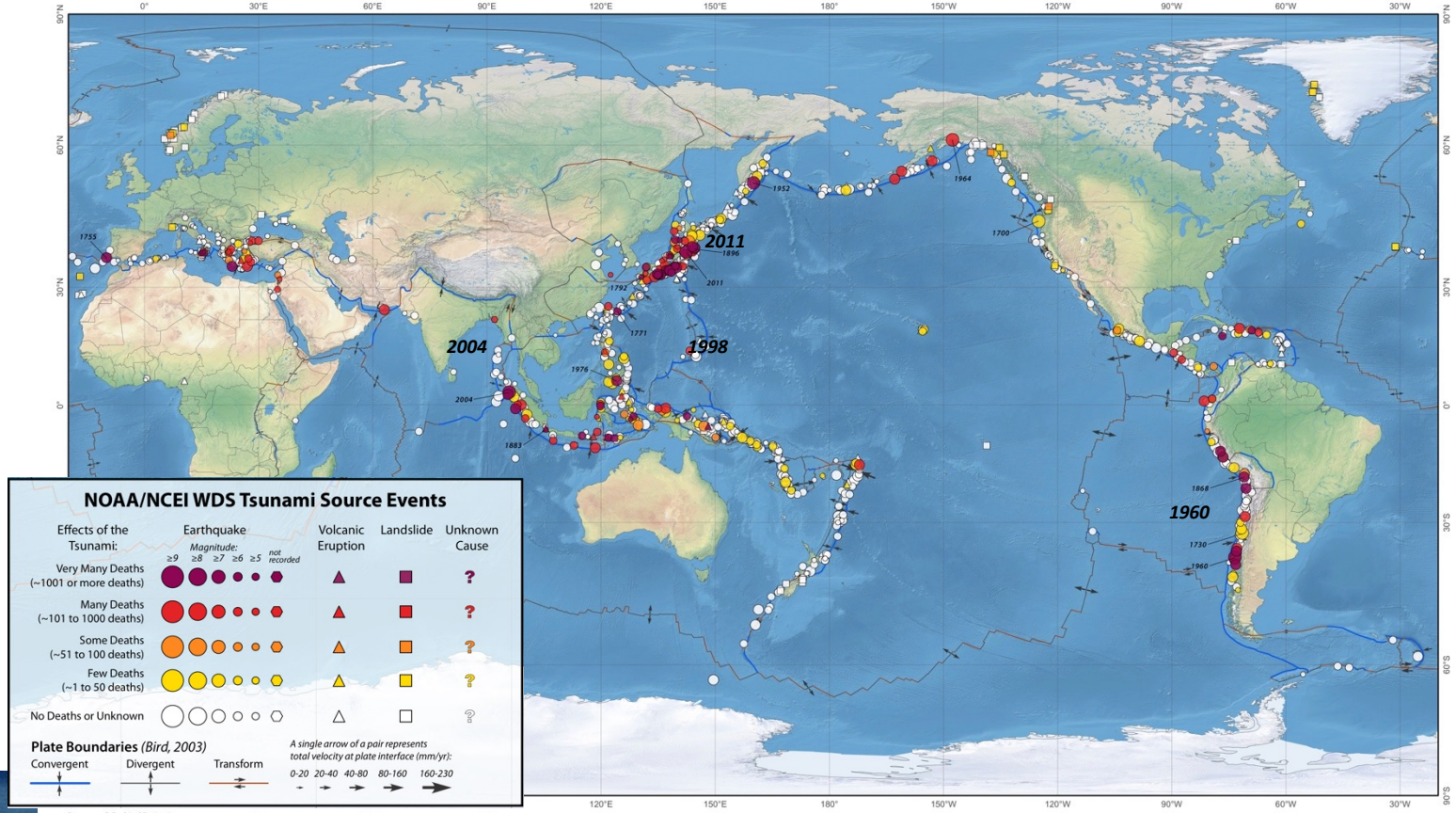




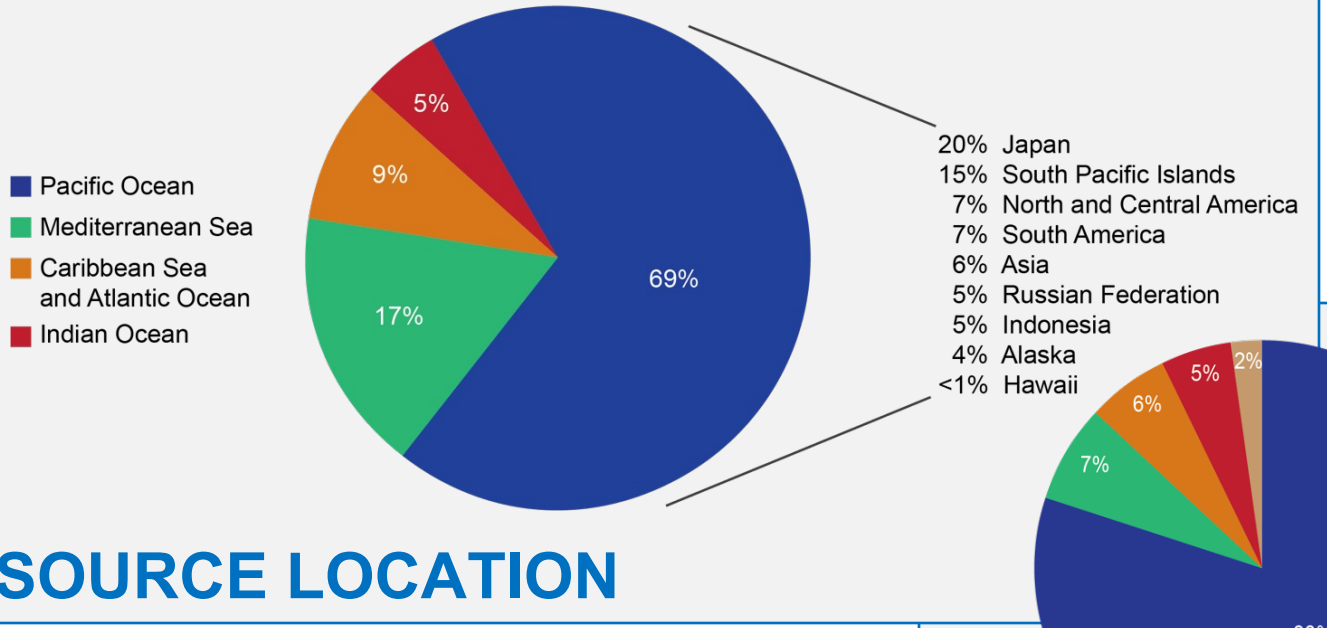


- 80% caused by earthquakes
- Shallow, undersea/near coast
- Magnitude 8+ (M7+)

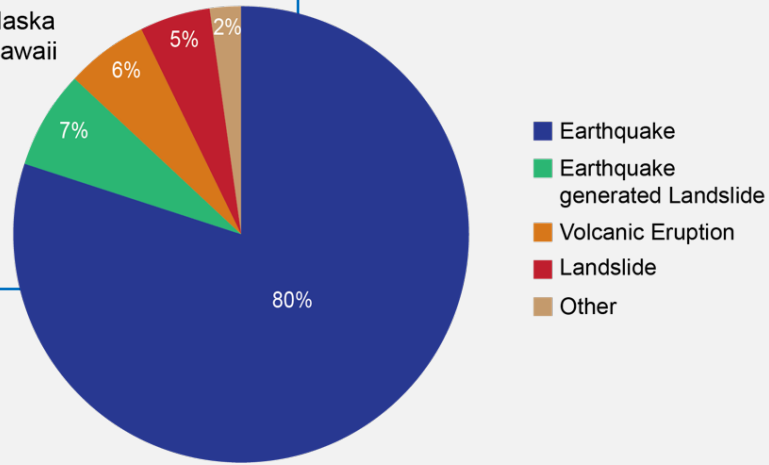
DEADLY TSUNAMIS – GLOBAL (1620 B.C to A.D. 2022)



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



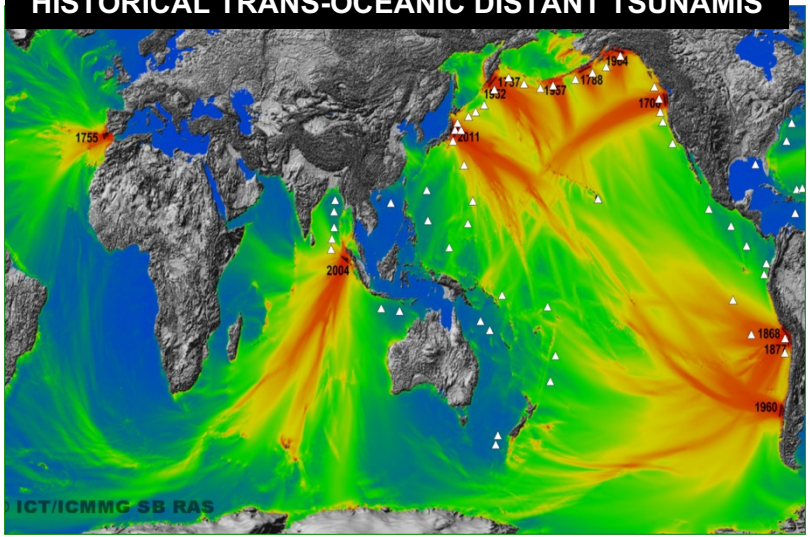
SOURCE LOCATION



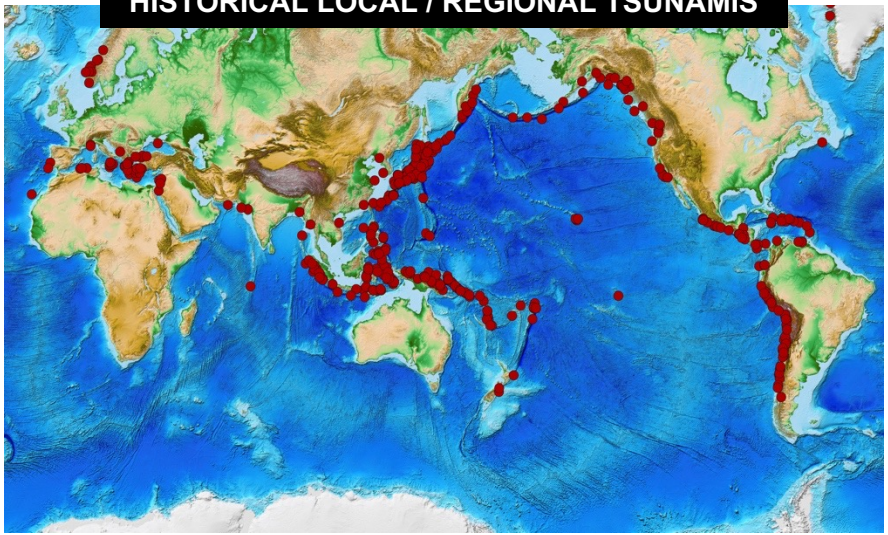
SOURCE GENERATION

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)

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

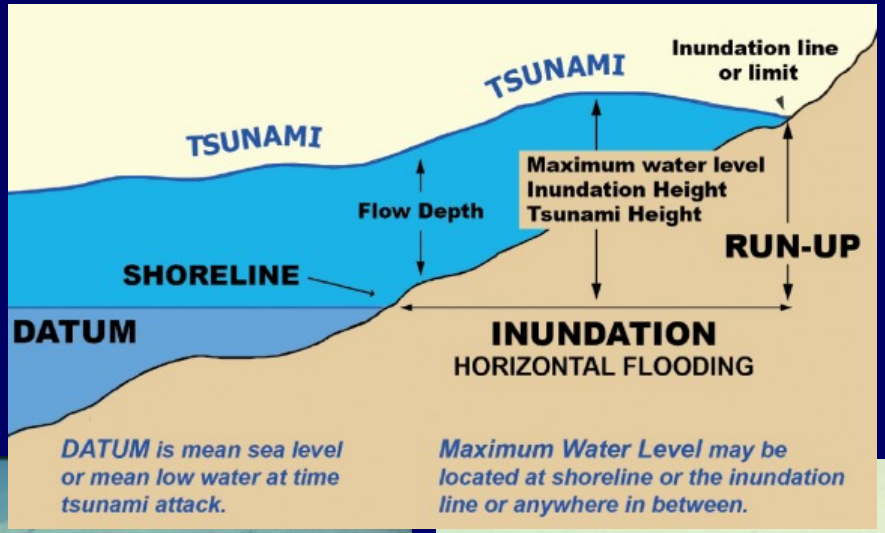
Indian Ocean Tsunami, December 26, 2004

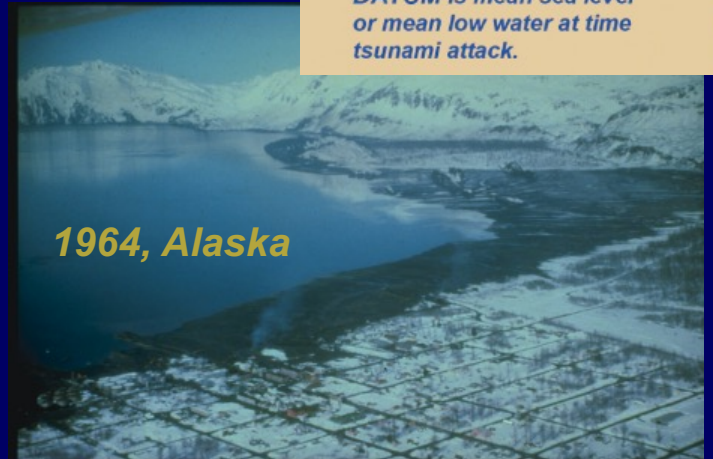
Penang, Malaysia: Relentless surge

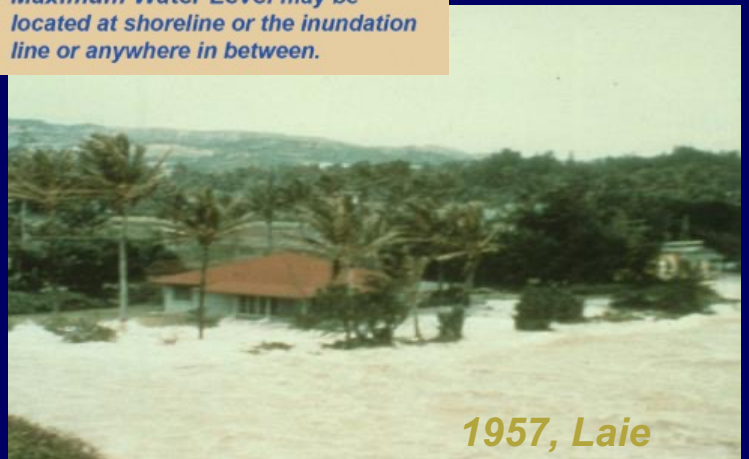
High-tide, Arorae, Kiribati

- Surge

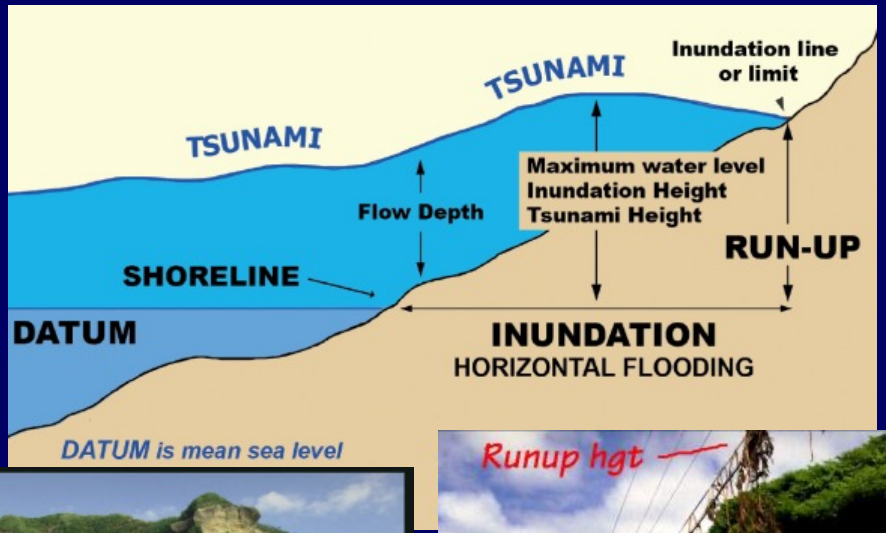
TSUNAMI TERMS - INUNDATION



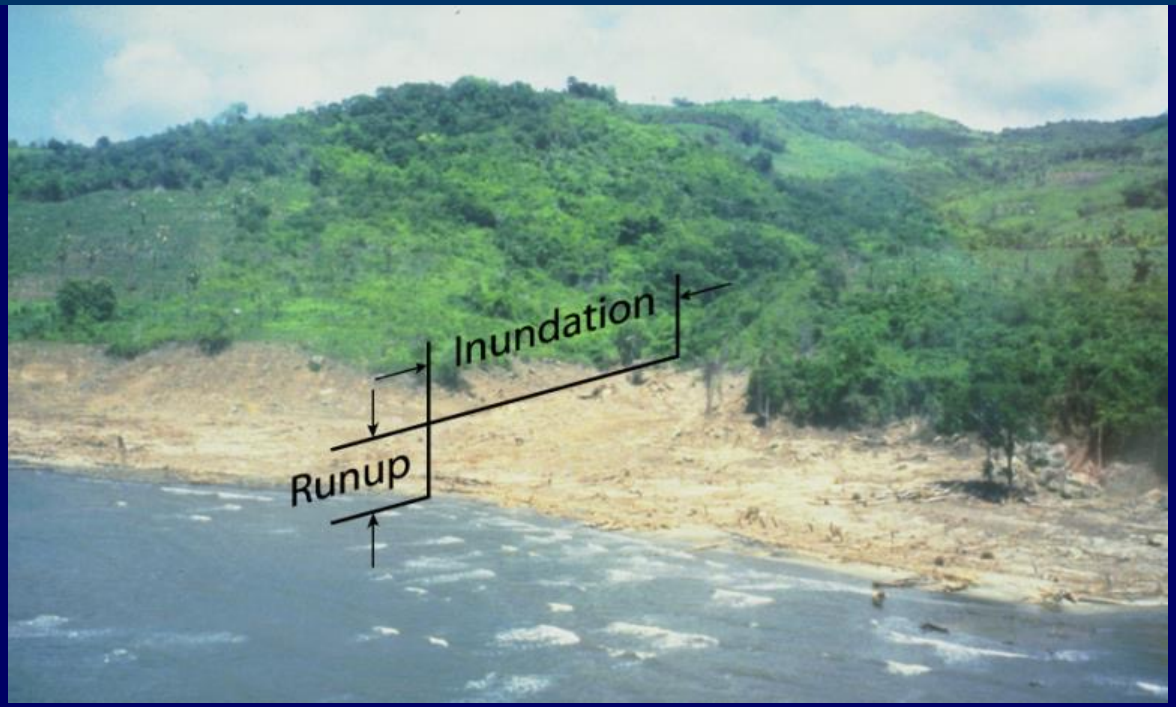




TSUNAMI TERMS - RUNUP



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

Thank You

Dr. Laura Kong
Director, ITIC

Dr. Dailin Wang
Oceanographer, PTWC