UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-TEWS Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
15-26 September 2025, Honolulu, Hawaii

What tsunami science you need to know to warn for and respond to tsunami warnings?

What, how, where, when, and damage caused

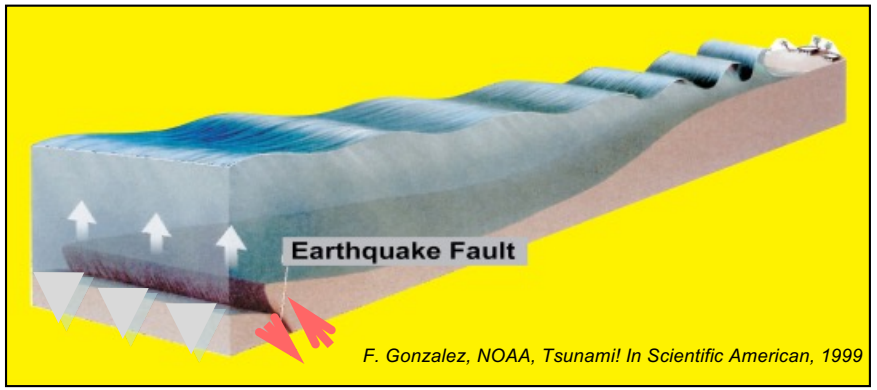
Dr. Laura Kong
Director, ITIC

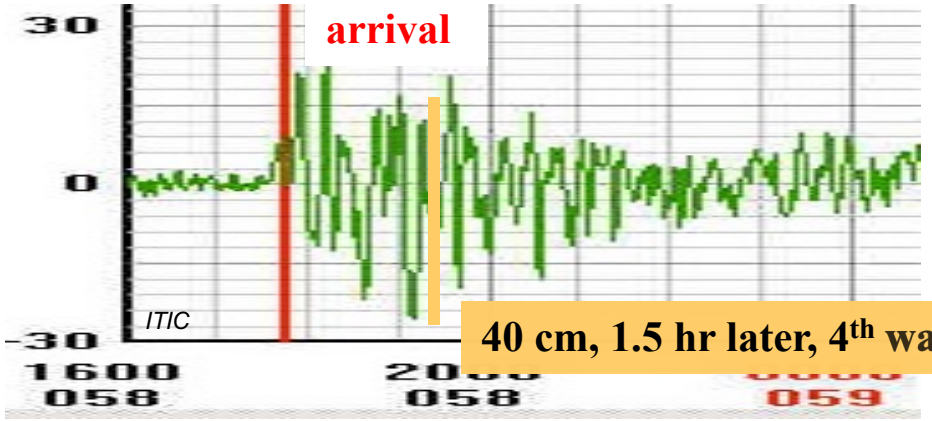
Dr. Dailin Wang
Senior Oceanographer, PTWC

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.



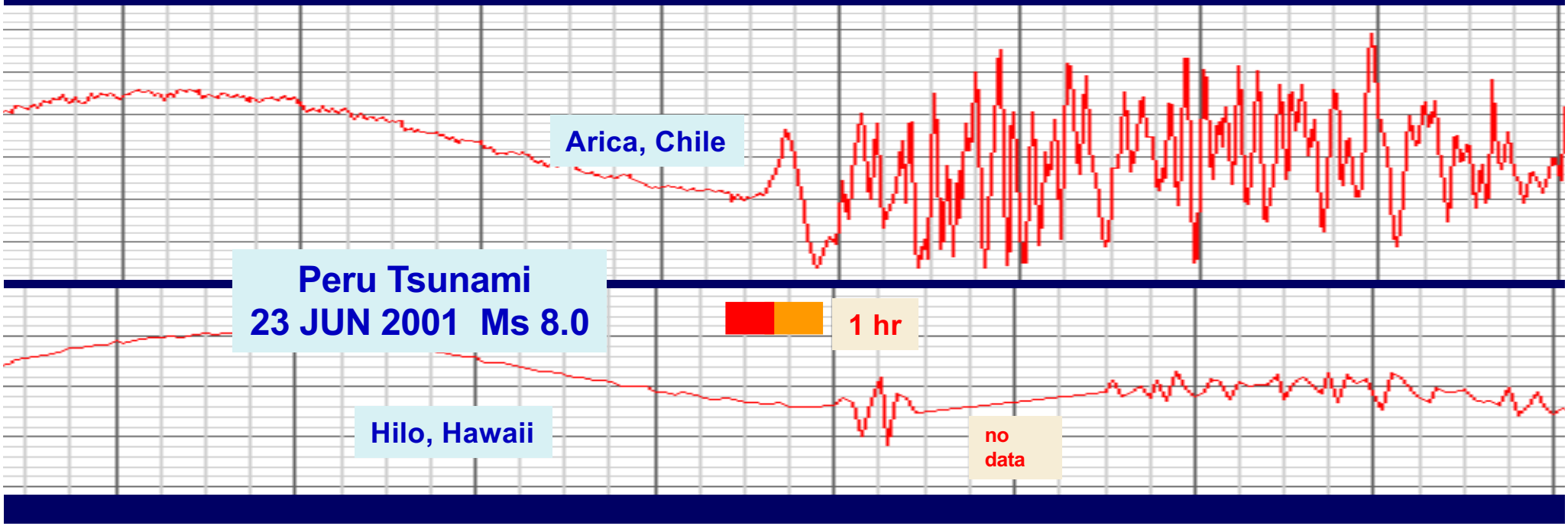


40 cm, 1.5 hr later, 4th wave

TSUNAMIS - What and How

- ***SERIES OF LONG-PERIOD OCEAN WAVES***

  5 TO 60 MINUTES BETWEEN WAVE CRESTS



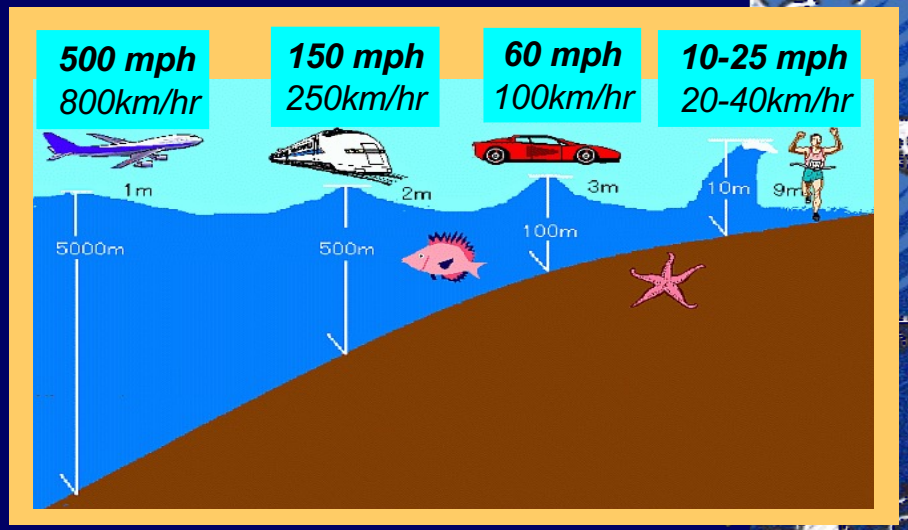
TSUNAMIS - What and How

- ***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

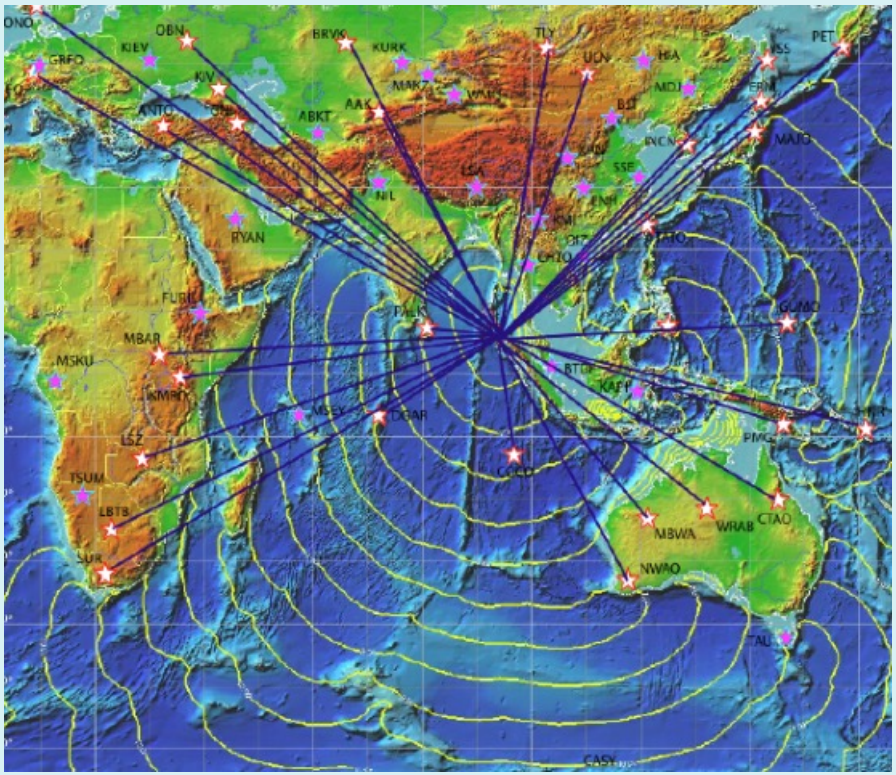
- Wave frequency every 5-60 minutes.

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

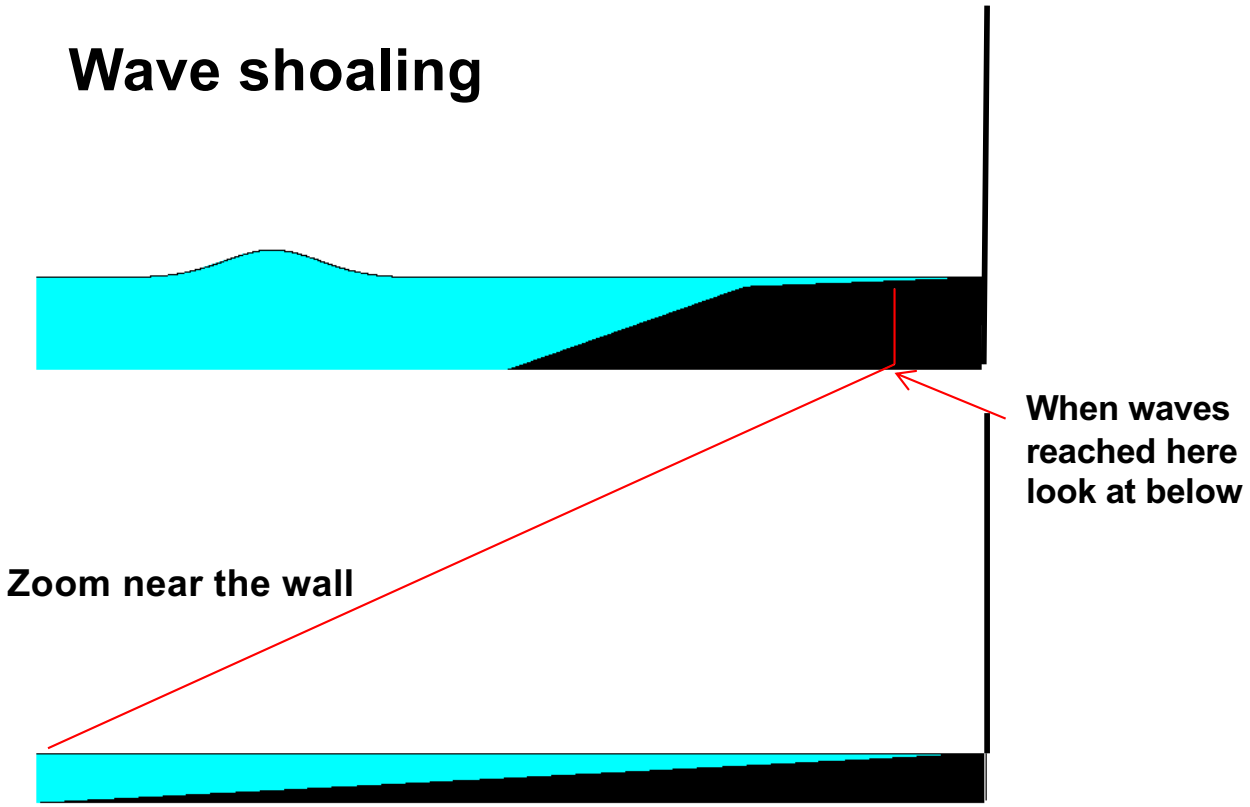
Tsunami Waves
~ 500 mph



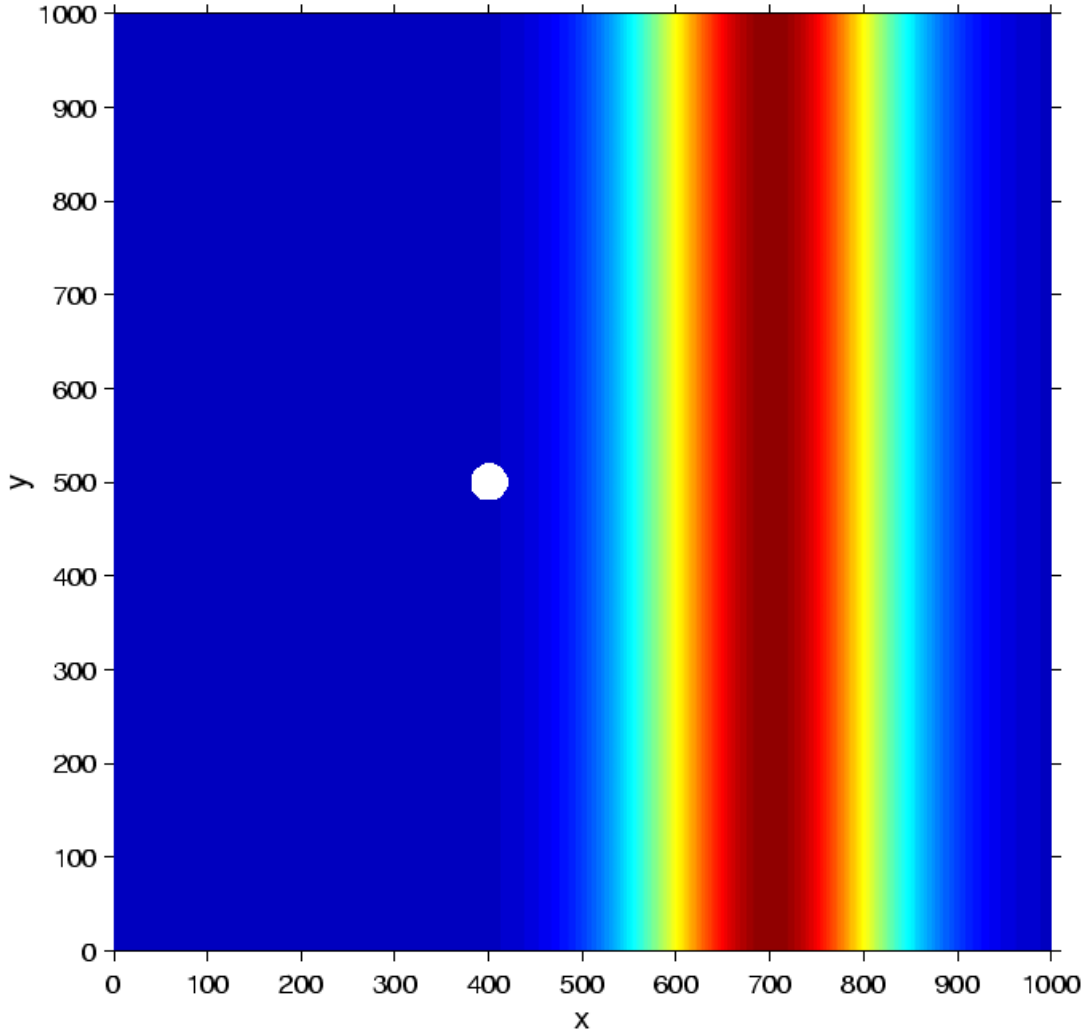
Tsunami Wave Simulations

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

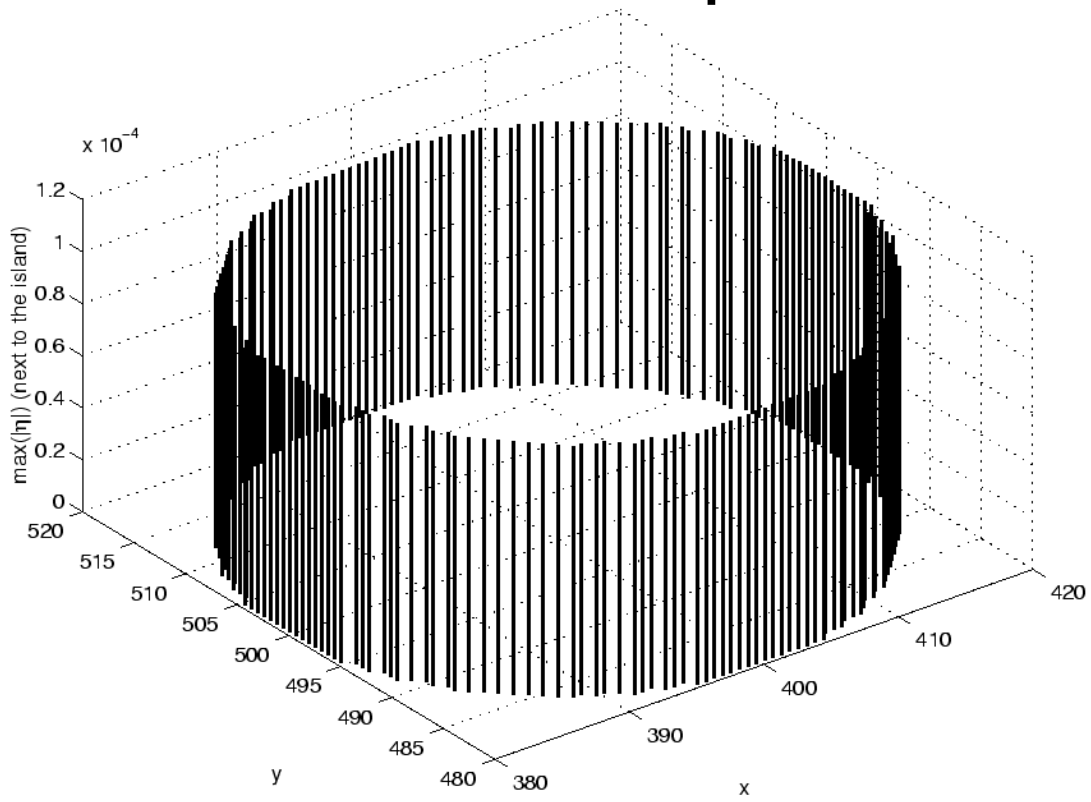
Wave shoaling



Waves wraps around a skinny cylinder without much runup

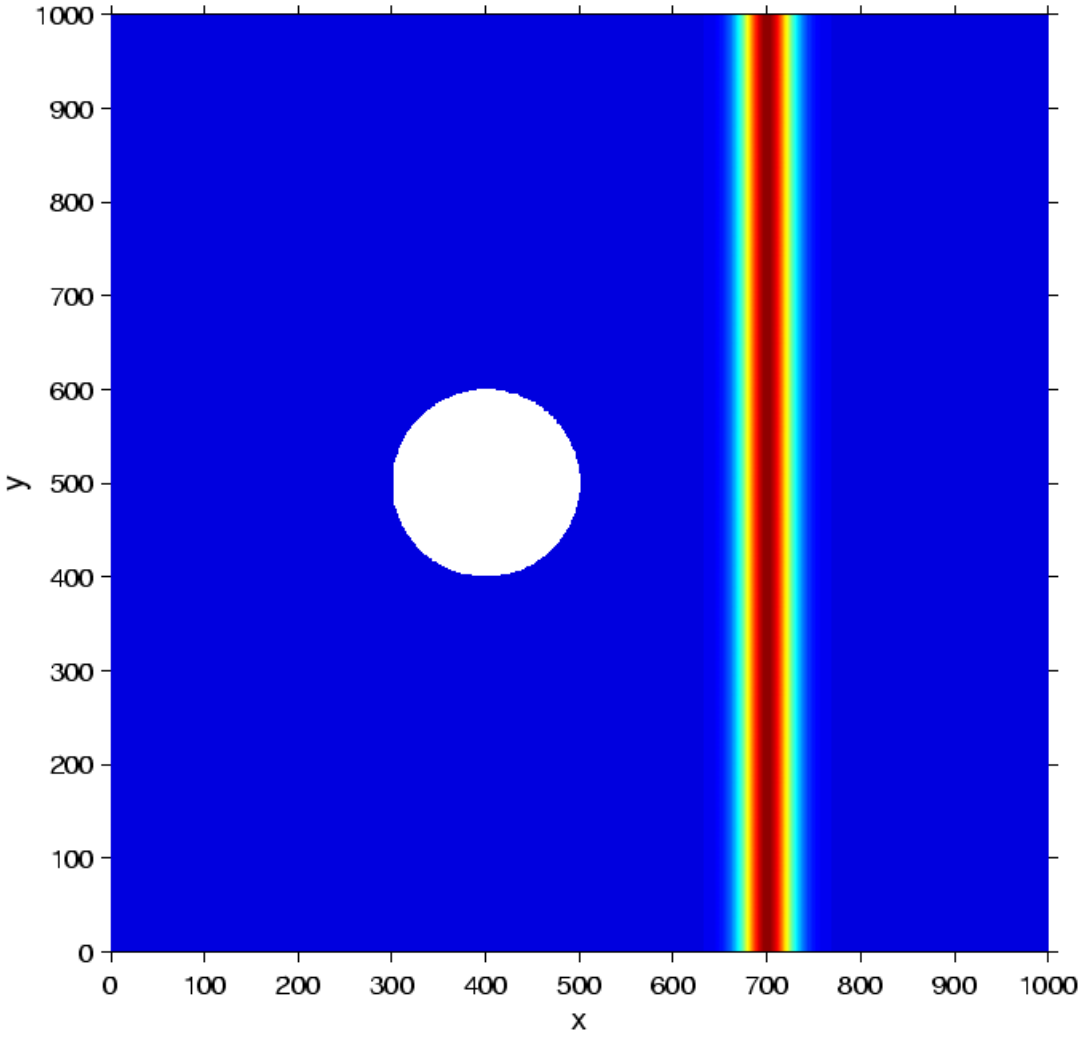


For a skinny island/cylinder (compared to wavelengths), there will be minimal wave runup.



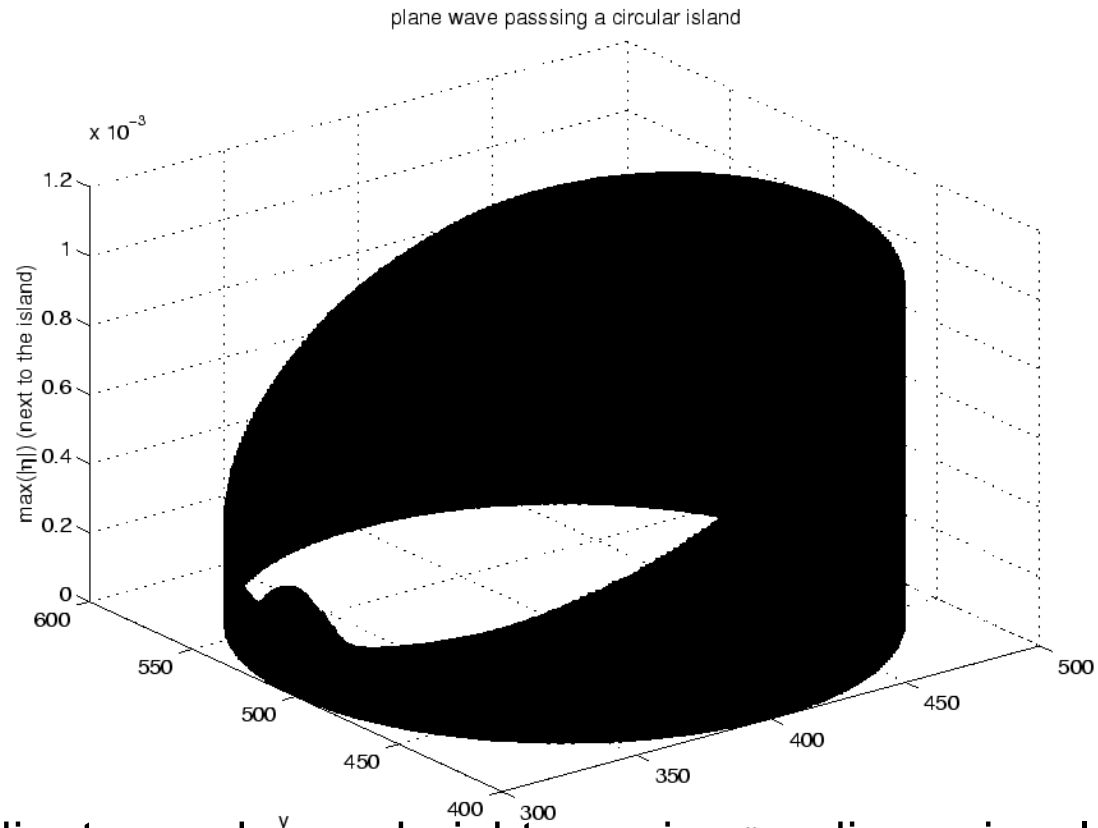
Coordinates and wave heights are in non-dimensional units

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.



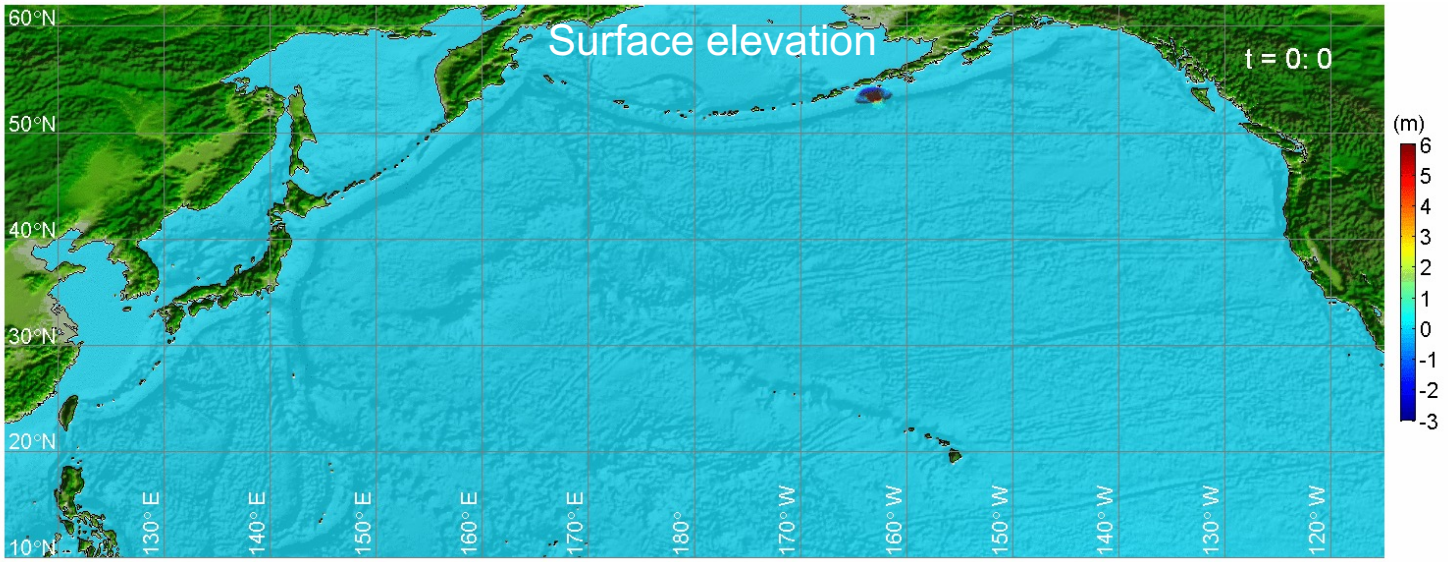
Coordinates and wave heights are in non-dimensional units

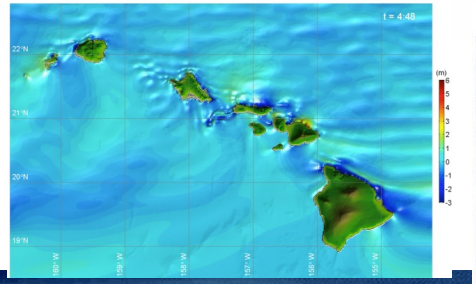
Tsunami Wave Simulations

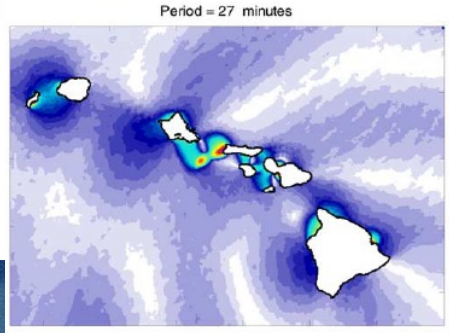
1946 Aleutian Islands
Off Big Island

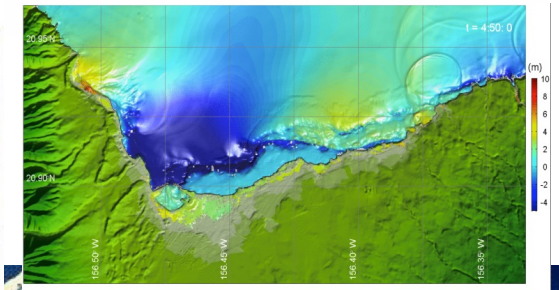
1946 Alaska Tsunami at Hawai‘i

Propagation, Near-Shore Interactions, Inundation





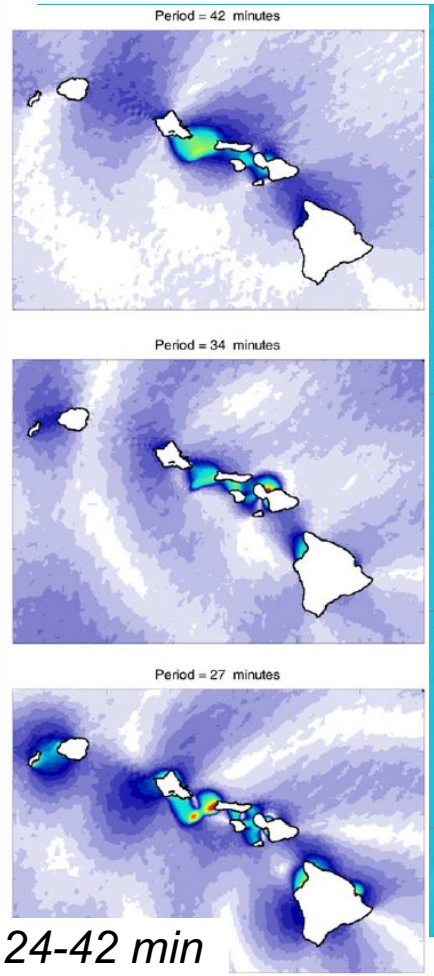


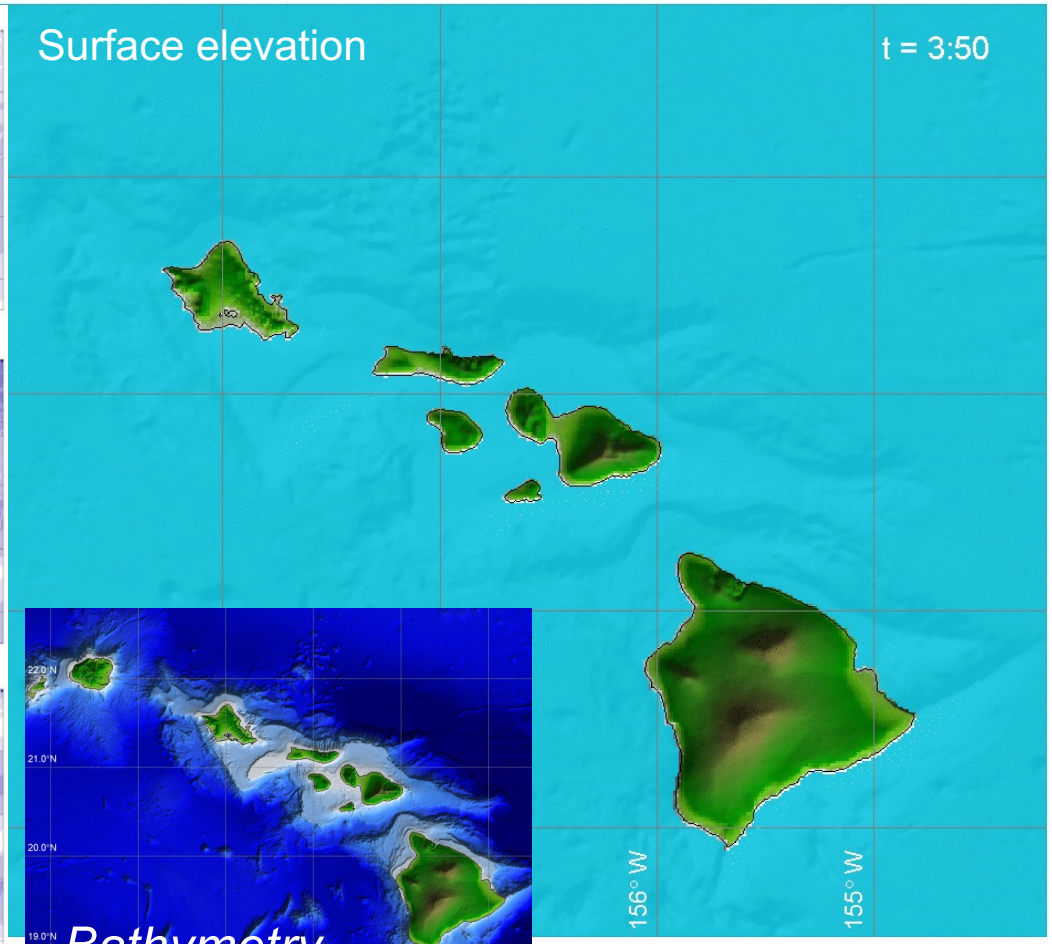


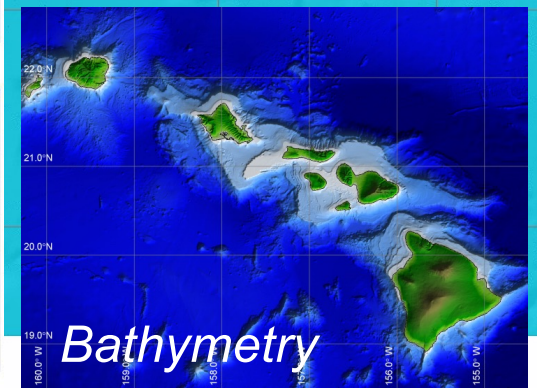
Kwok Fai Cheung, Univ. of Hawaii

1946 Alaska Tsunami at Hawai‘i

Wave wraps around islands - Illustration of Resonance





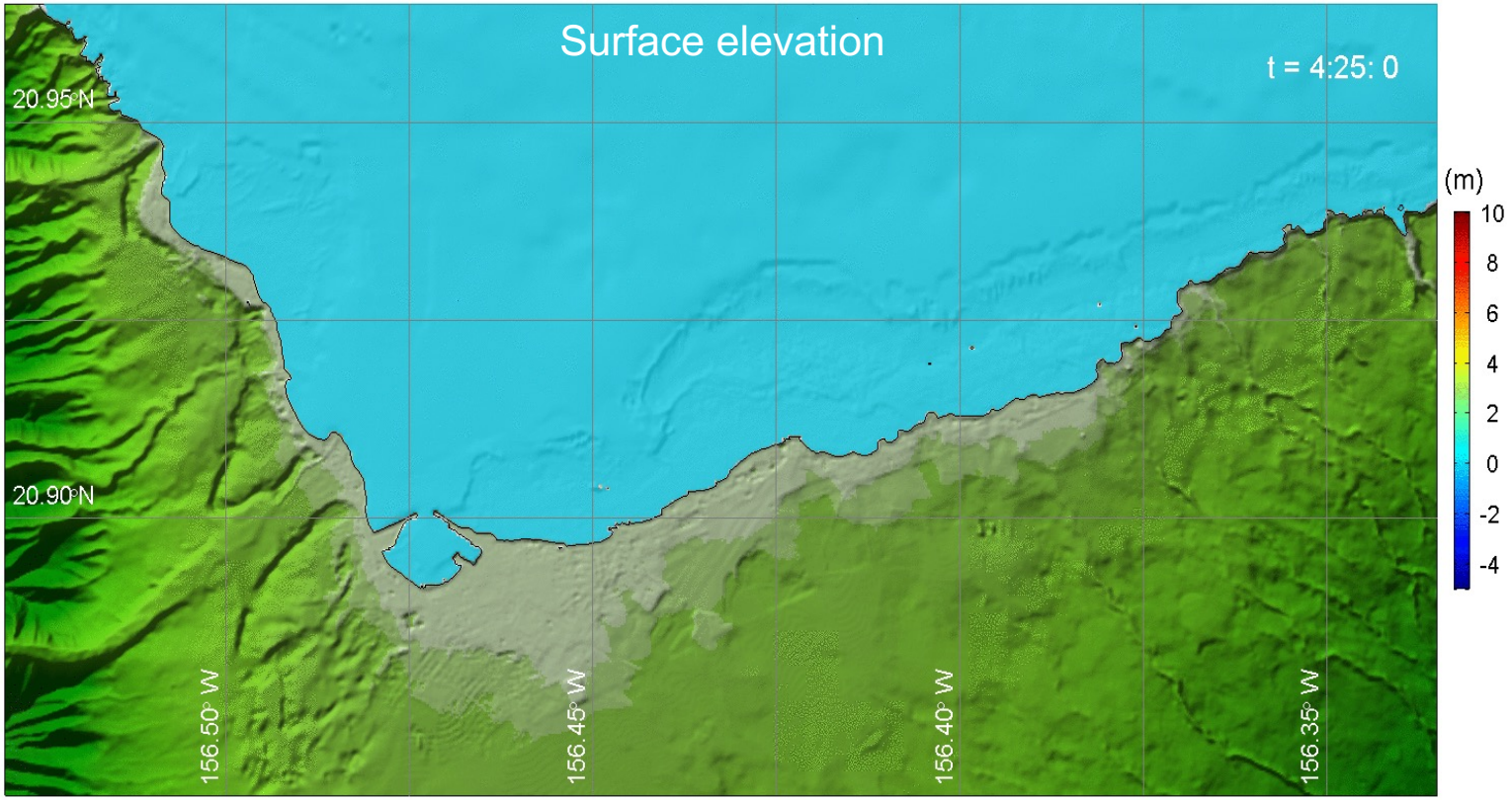


Resonance 24-42 min

Kwok Fai Cheung, Univ. of Hawaii

1946 Alaska Tsunami at Kahalui, Maui, Hawaii

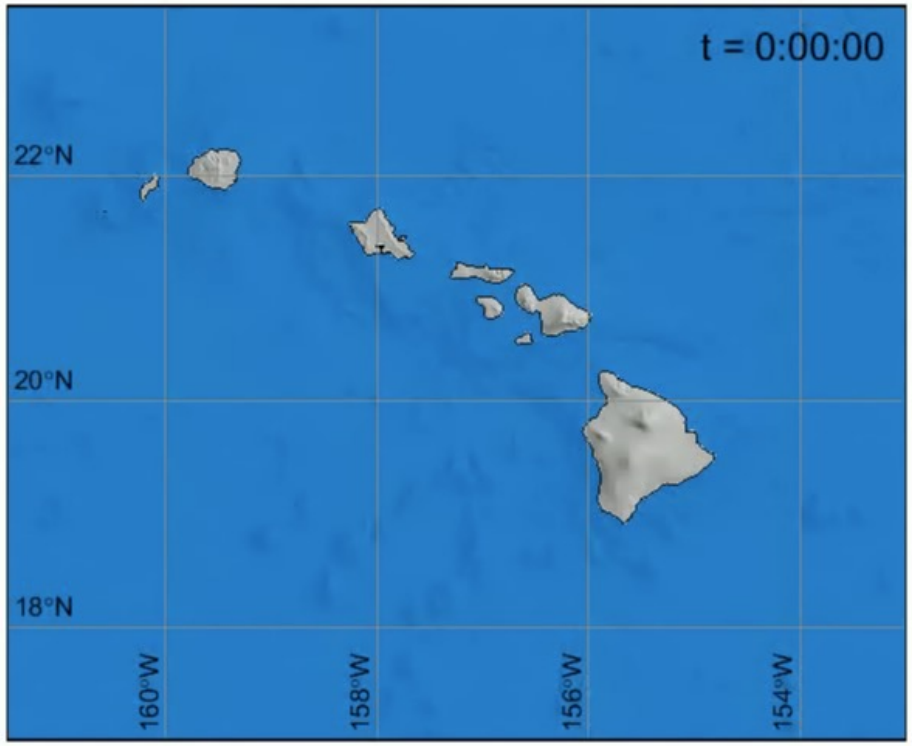
Tsunamis travelling over Reefs and Inundating coasts

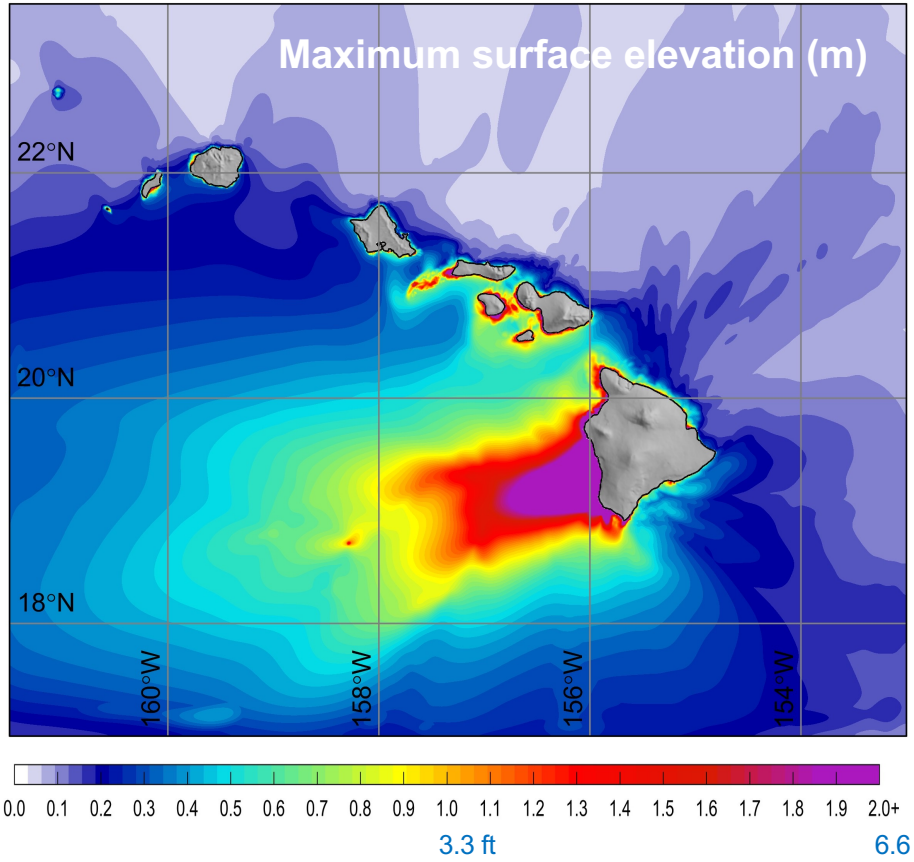


Kwok Fai Cheung, Univ. of Hawaii

Worst-case Hawai‘i Local Tsunami Scenario
M8.1 Off West Coast Big Island

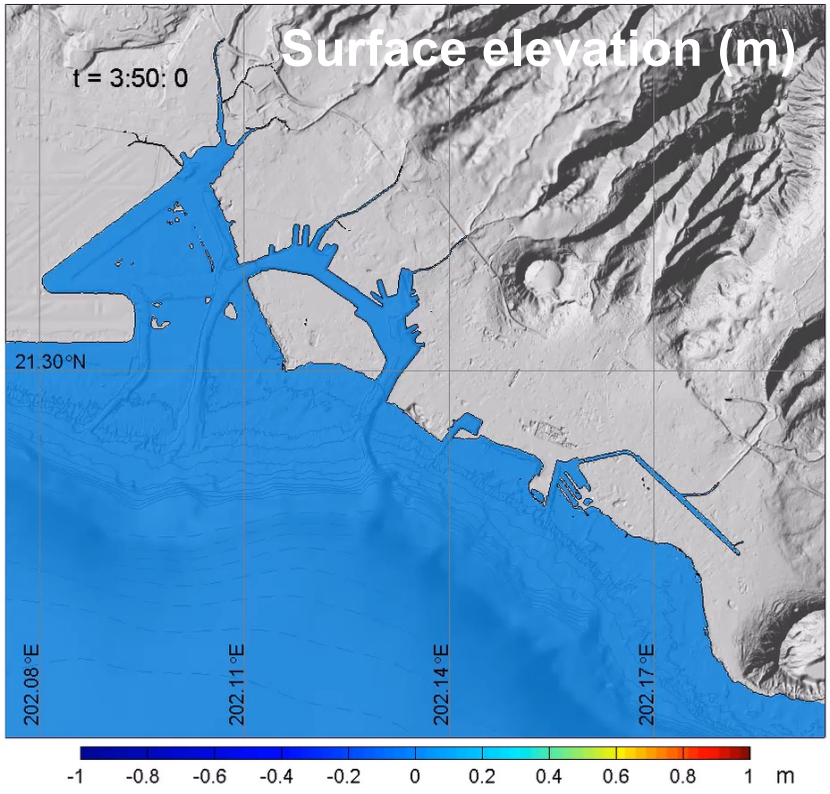
Yoshiki Yamazaki, Univ. of Hawaii



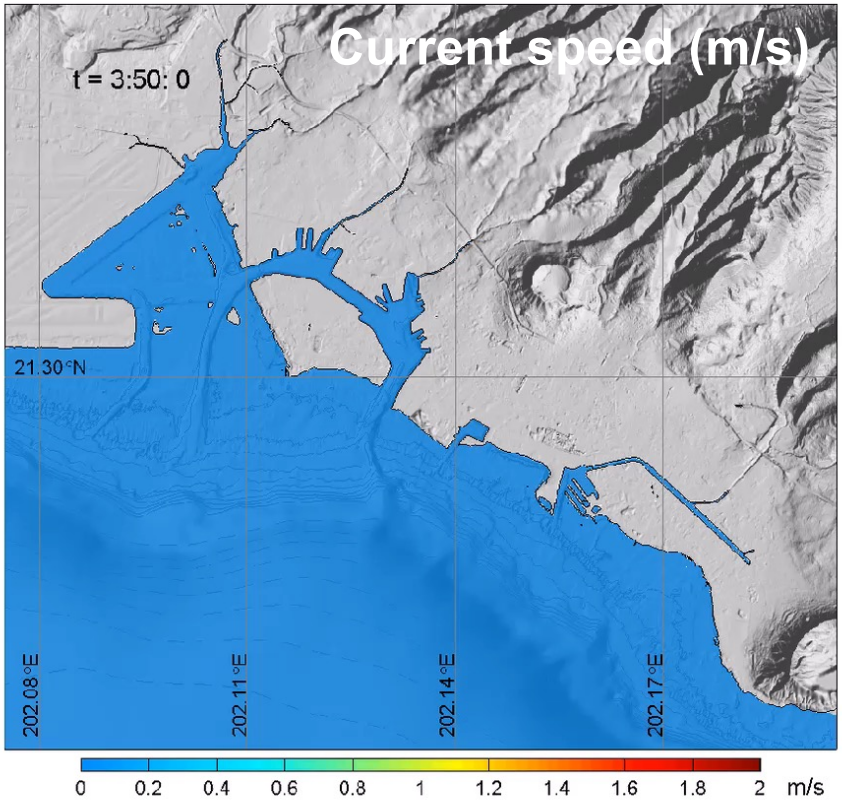


Marine Safety - Modeling Honolulu Harbor using Aleutian Scenario

Yoshiki Yamazaki, Univ. of Hawaii

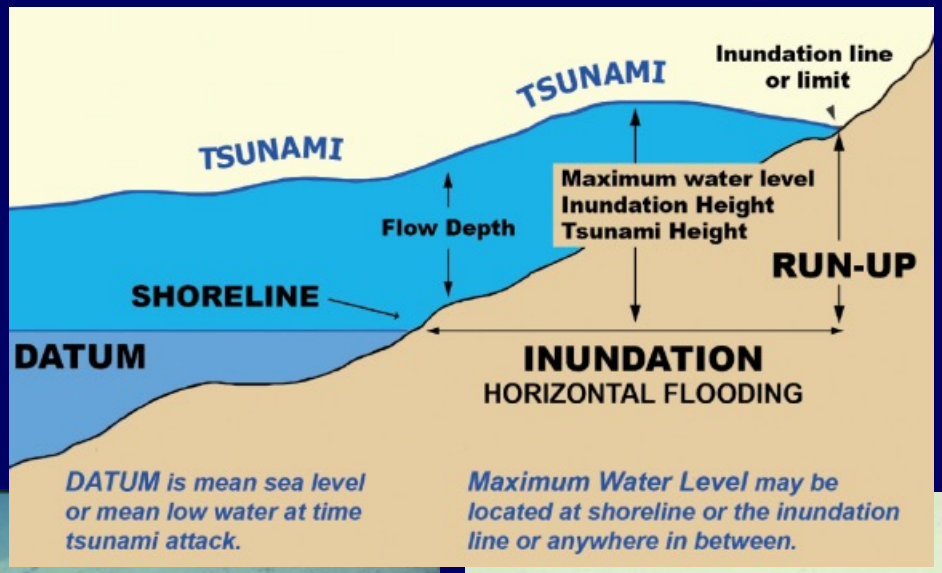


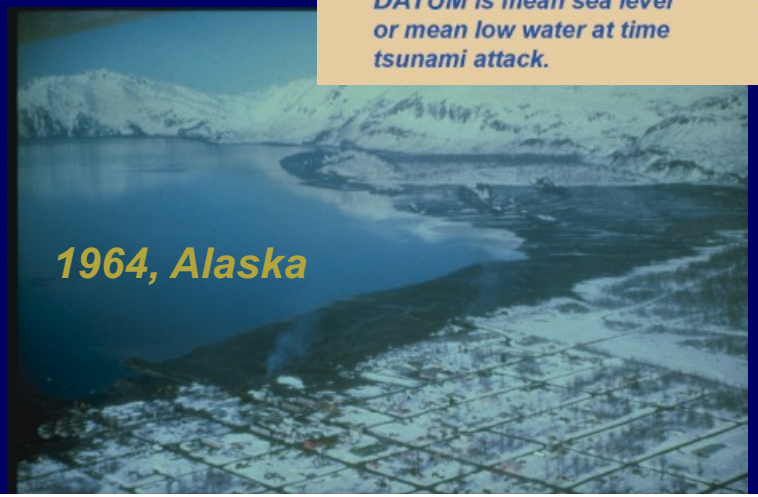
1 m = 3.3 ft



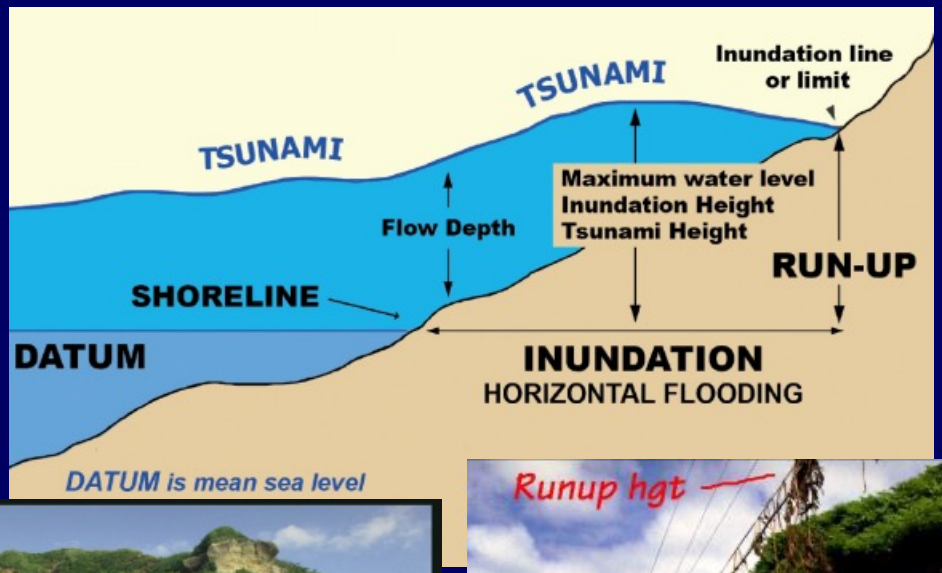
2 m/s = 4.5 mph(3.8 kts)

TSUNAMI TERMS - INUNDATION

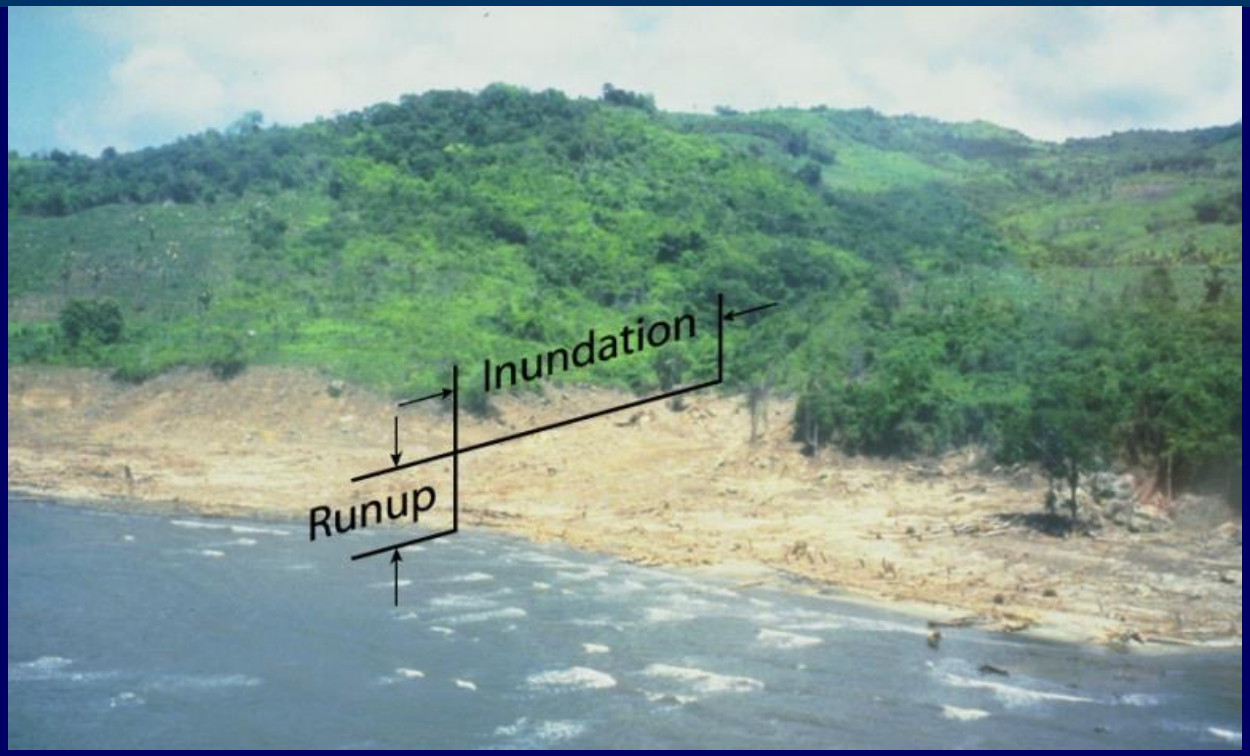




TSUNAMI TERMS - RUNUP



RUNUP and INUNDATION



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

Tsunamis

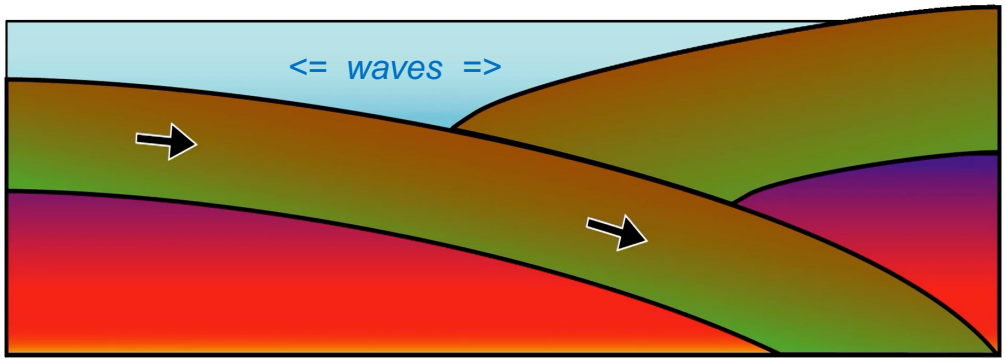
How, where, how often?

How are tsunamis generated?

Created by abrupt displacement of ocean, such as from

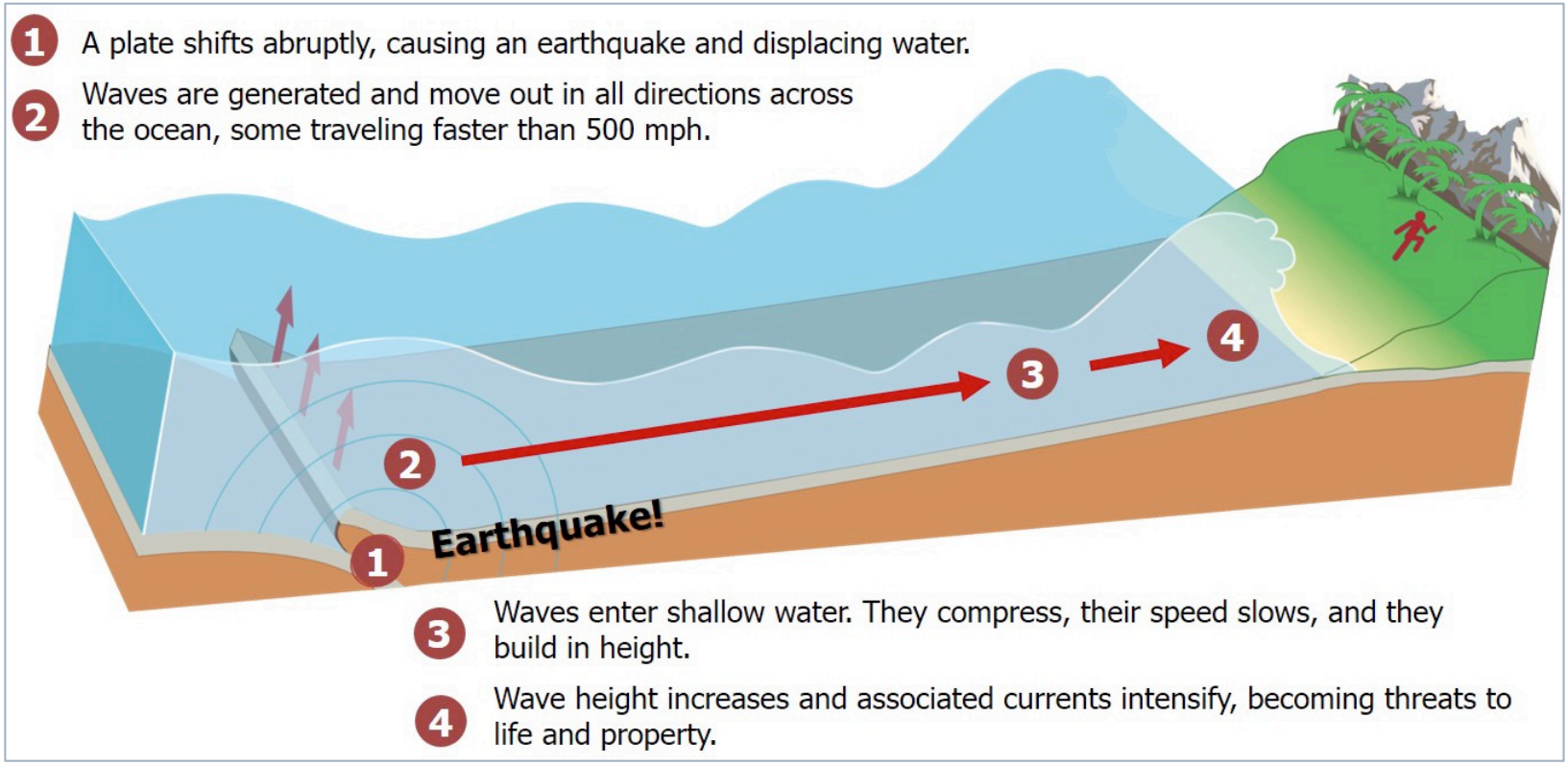
- Shallow, undersea earthquakes (most common)
- Underwater or sub-aerial landslides (less common)
- Volcanic eruptions (infrequently)
- Meteor impact (rarely)

Subduction Zone Tsunami



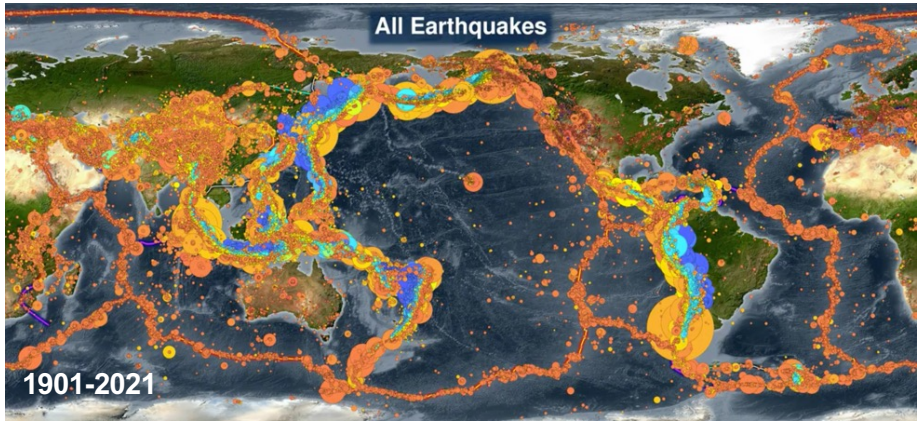
(Source: G. Fryer)

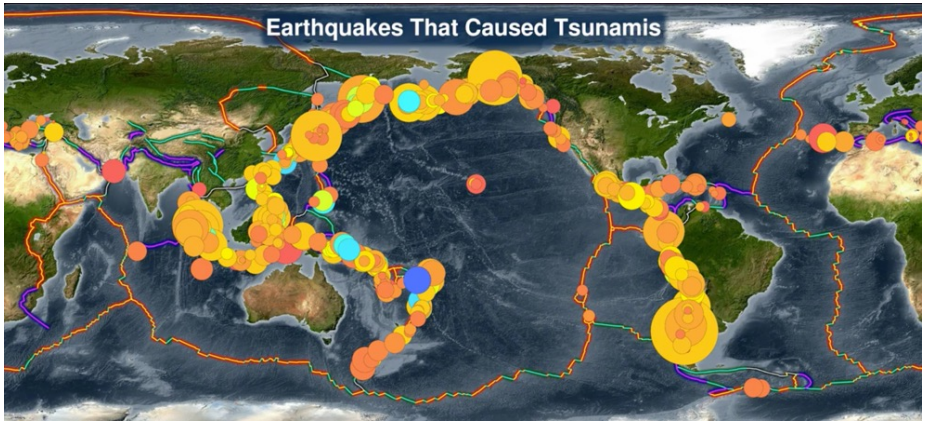
How an earthquake generates a tsunami

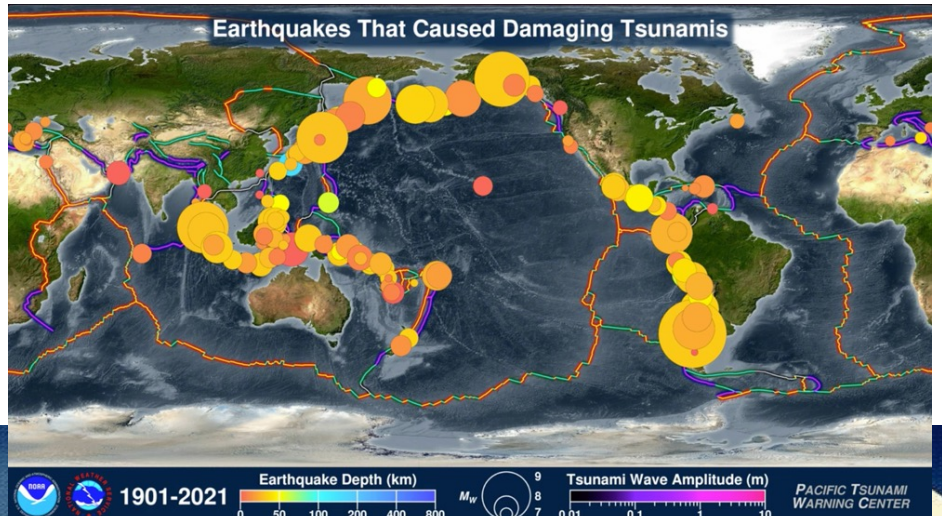


(Source: Ocean Institute, modified by NOAA/National Weather Service for NTHMP Tsunami Information Guide, 2009)

DANGEROUS EARTHQUAKES & TSUNAMIS

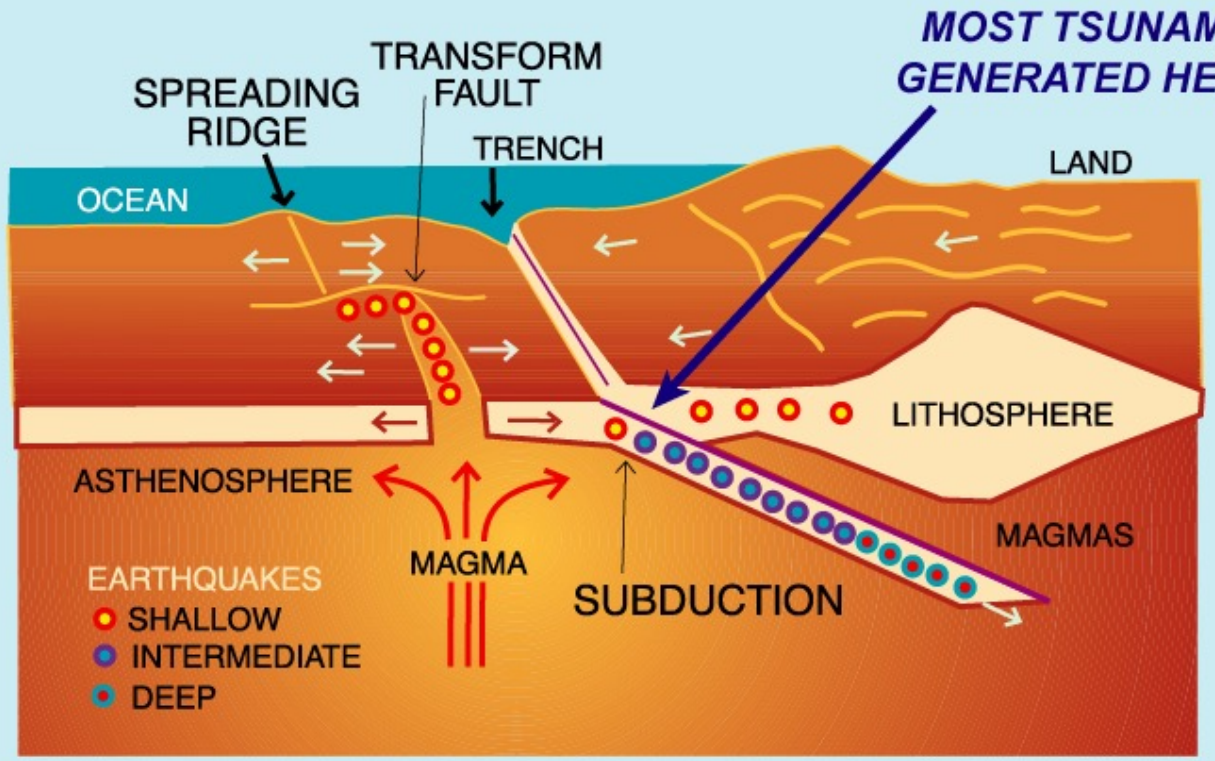




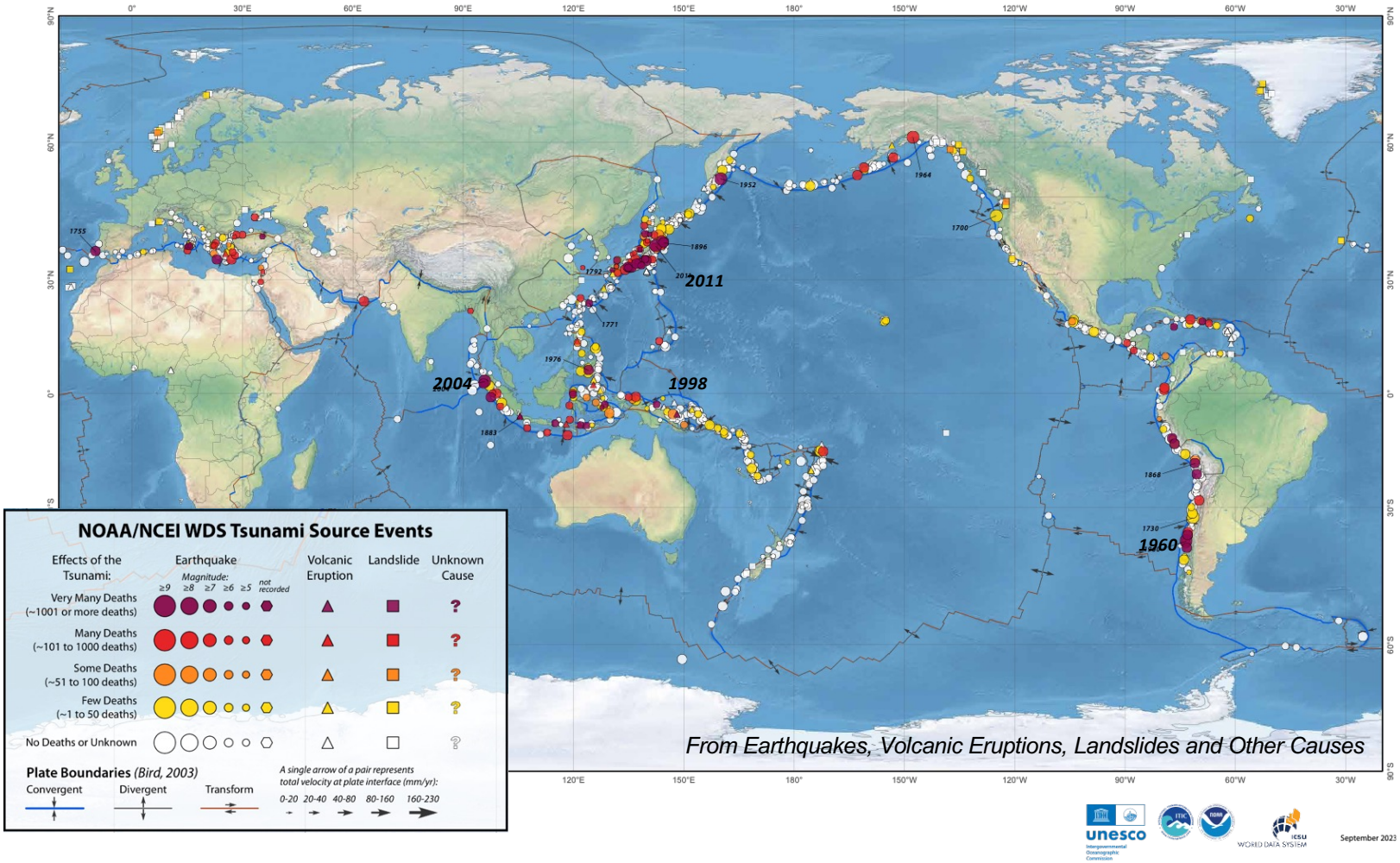


- 80% caused by earthquakes
- Shallow, undersea/near coast
- Magnitude 8+ (M7+)

TSUNAMI GENERATION AROUND PACIFIC RIM



DEADLY TSUNAMIS – GLOBAL (1620 B.C to A.D. 2023)



unesco Intergovernmental Oceanographic Commission

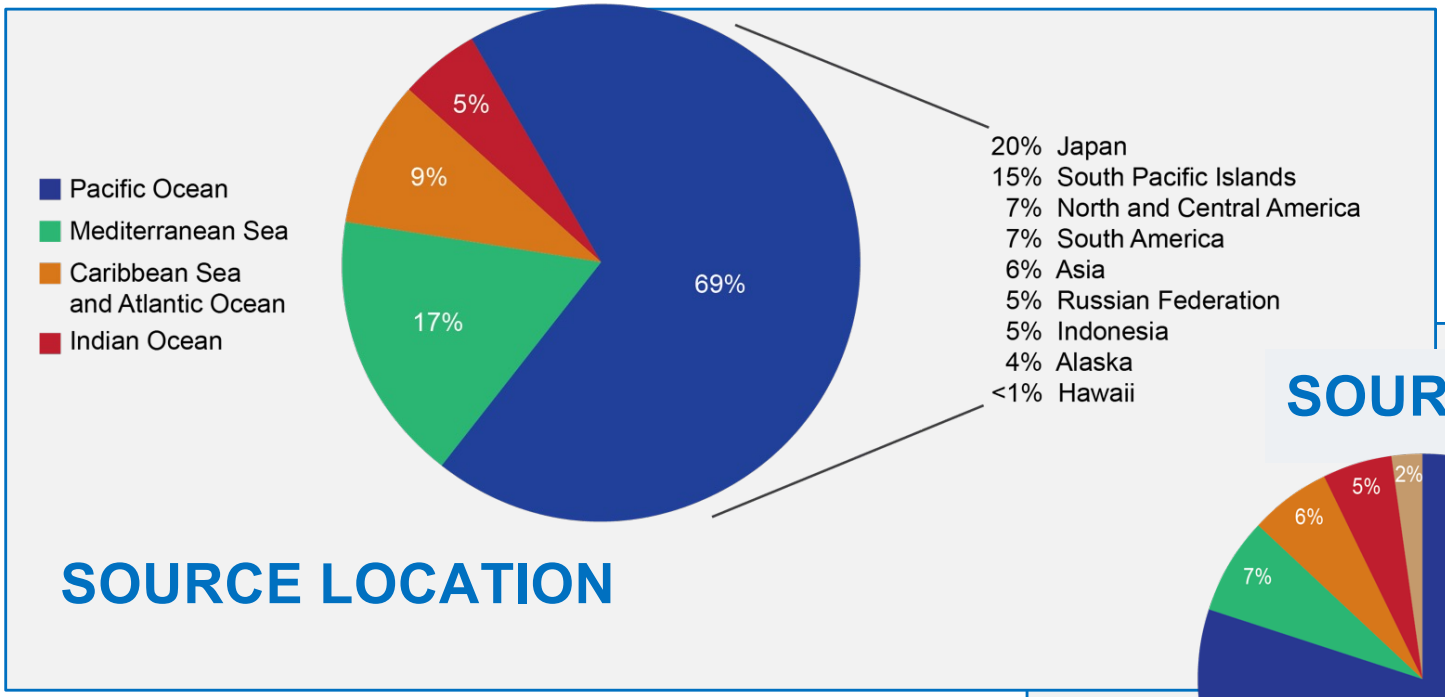
ITIC

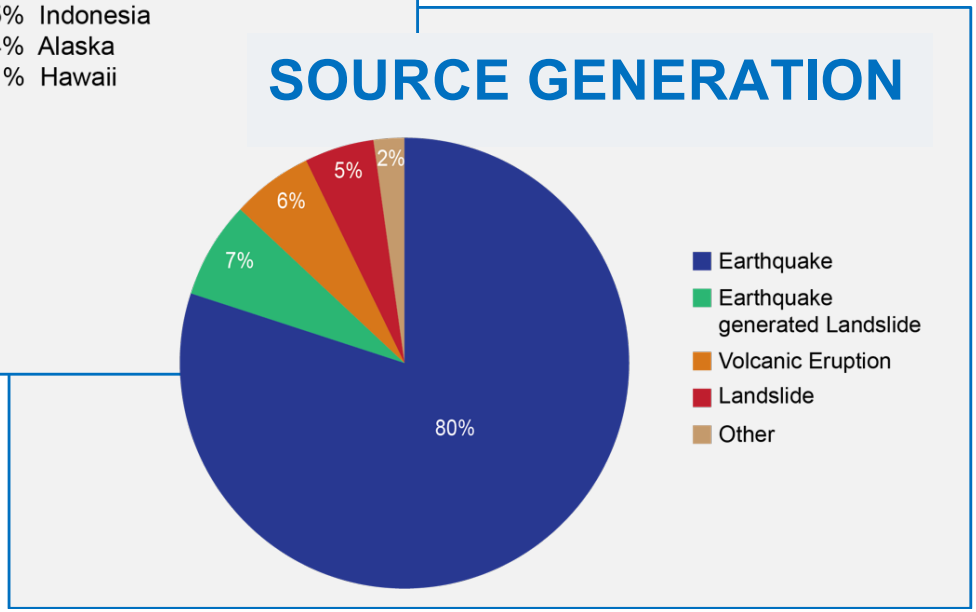
NOAA

ICSU WORLD DATA SYSTEM

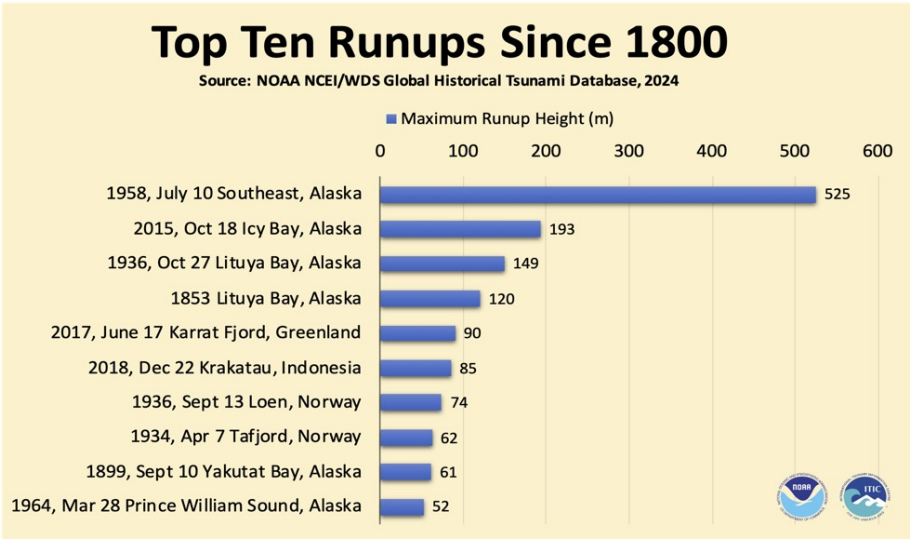
September 2023

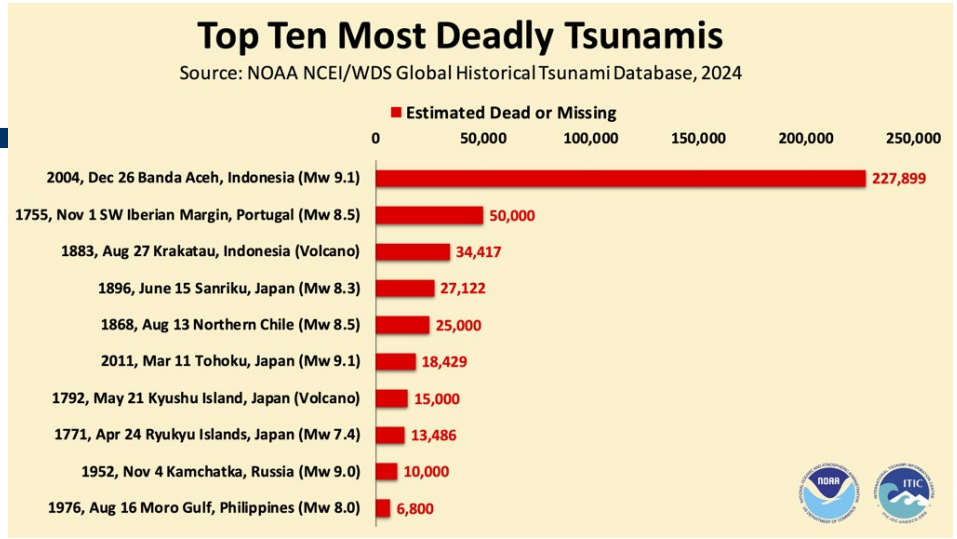
DEADLY TSUNAMIS – GLOBAL (1620 B.C to A.D. 2023)

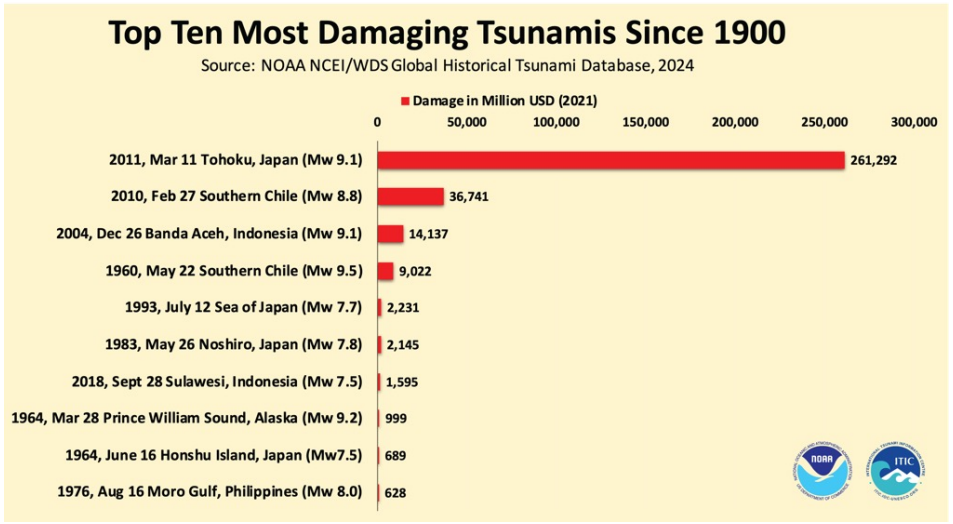




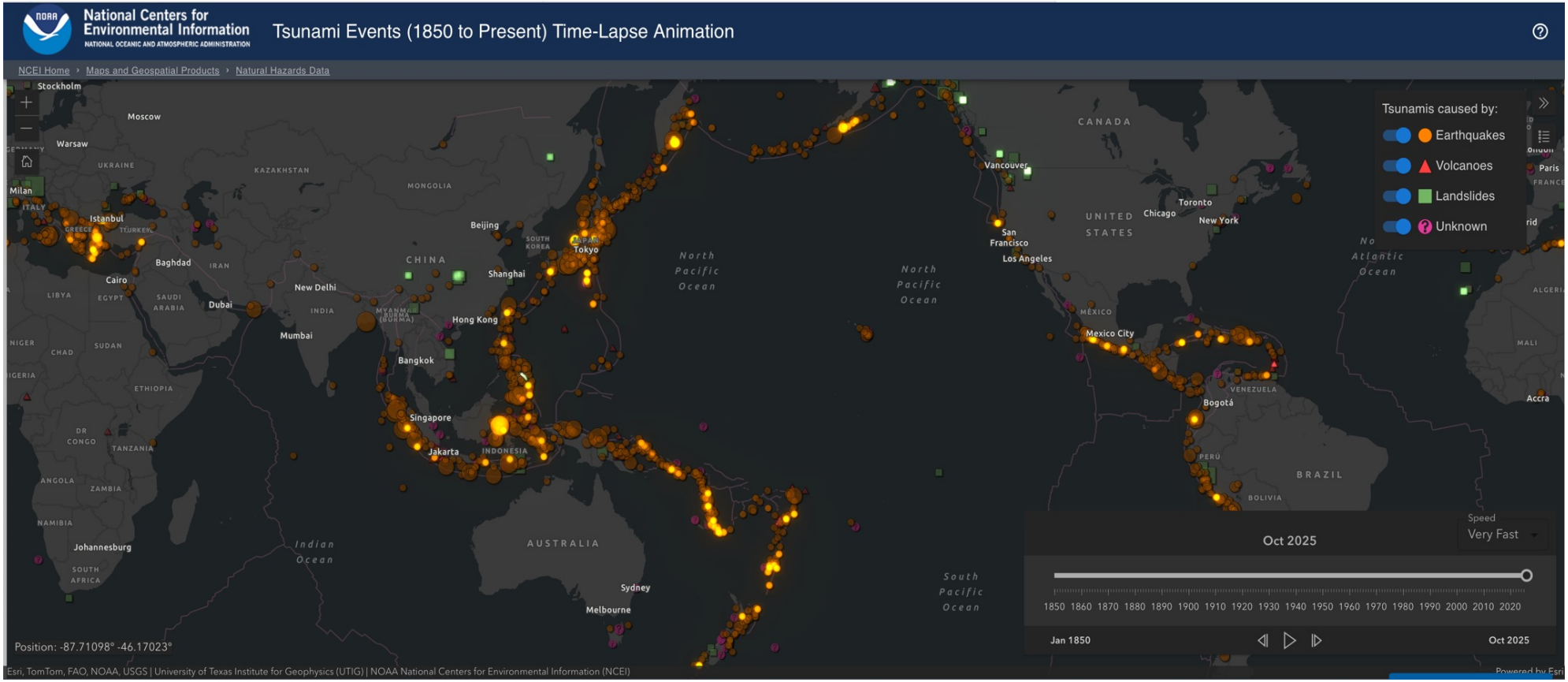
Tsunamis - Top Ten







Tsunamis – History – time lapse



https://www.ncei.noaa.gov/maps/tsunami-events/

Tsunamis

What does a tsunami look like?
What does a tsunami do?

What does a tsunami look like?

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

(Source: Pacific Tsunami Center, 1948)

(Source: ITIC, 1995)

What does a tsunami look like?

Indian Ocean Tsunami, December 26, 2004

Mw9.1 Northern Sumatra, Indonesia - 227,869 deaths in 15 countries (citizens of > 53 countries)

Thailand

Indonesia

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

Indian Ocean Tsunami, December 26, 2004

Penang, Malaysia: Relentless surge

What does a tsunami do?

- **Floating / moving objects become battering rams**
- **Erode, scour, deposit mud**
  - Casualties, debris; Structures/Utilities collapse
  - Secondary impacts (Fire, HAZMAT)

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

Fukushima, Japan, 2011, UN IAEA

Damage from local tsunamis - 2009, 2010, 2011

2nd wave, Pago Pago, American Samoa, 2009
(credit: G. Yamasaki, NOAA)

Dichato, Chile 2010 (credit: K. Bergen, USGS)

Ofunato, Japan, 2011 (credit: L. Kong, ITIC)

What does a tsunami do?

- Quickly inundates low-lying areas
- Flooding, strong currents

Lhoknga, Aceh, Indonesia Dec 26, 2004

(Source: https://www.nasa.gov/vision/earth/lookingatearth/indonesia_quake.html
Credit: konos images copyright Centre for Remote Imaging, Sensing and Processing, National University of Singapore and Space Imaging)

Pago Pago, American Samoa Sept 29, 2009

(Source: J Pughnat)

Santa Cruz, CA, USA March 11, 2011 Japan

(Source: Rick Wilson , CA GGS

Harbor impacts from strong, unusual currents

Tsunami damage in Crescent City, CA, USA from 11 March 2011 Japan tsunami (credit: L. Dengler)

Tsunami are dangerous because

- **Time**
  - No-notice, fast-evolving
  - Cannot be predicted
  - Hits in minutes. Efficient propagation across oceans (for 1 day)
- **Wave Physics**
  - Grows in height as water depth shoals
  - Series of waves (hours). Long period (up to 1 hrs).
    1st wave may not be largest. Seiches in bays, bores up rivers.
  - Long wavelength so can wrap around islands
- **Impacts**
  - Death: Drowning easy. Small waves + strong currents dangerous
  - Damage: Built environment floods, infrastructure collapses, fire destroys

Thank You

Dr. Laura Kong
Director, ITIC

Dr. Dailin Wang
Senior Oceanographer, PTWC