TSUNAMIS

What, How, Characteristics, Arrival & Impact

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What is a Tsunami?

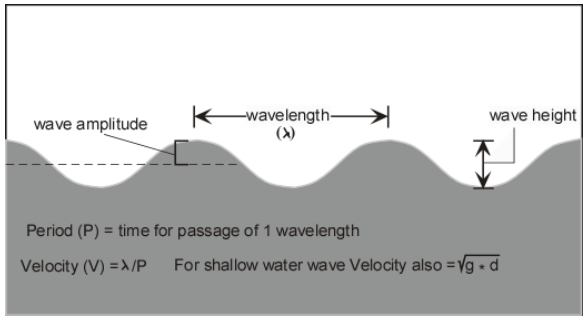
Tsunamis are:

- a **series** of waves that travel outward from origin (where the ocean floor was displaced)
- First wave is NOT always the largest
- caused by undersea earthquakes (80%), volcanos (6%), landslides (5% + 7% EQ caused)
- waves that travel across the deep ocean at speeds up to 500 mi/hour (~ speed of a jet)
- Bore-like when they come onshore, NOT like the curling breaking waves in pictures

Water receding further than usual
can be a sign of approaching tsunami

Tsunamis travel as fast as a jet plane.
You cannot outrun tsunami waves

What is the Meaning of Tsunami Terms



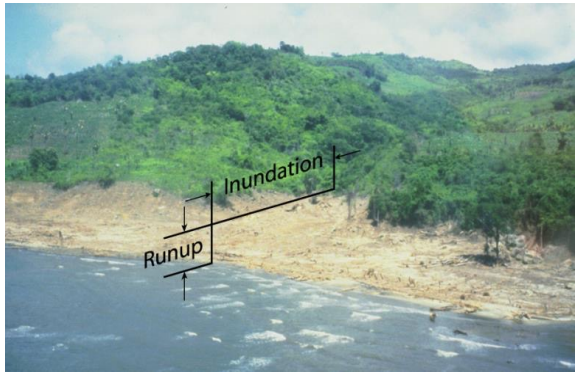
Wavelength – distance between wave crests

Wave Frequency - time for one full wavelength to pass a stationary point.

Wave Speed – Up to 600 mi/hr

Wave amplitude – distance from avg sea lev to wave crest.

Wave height – distance from wave crest to wave trough



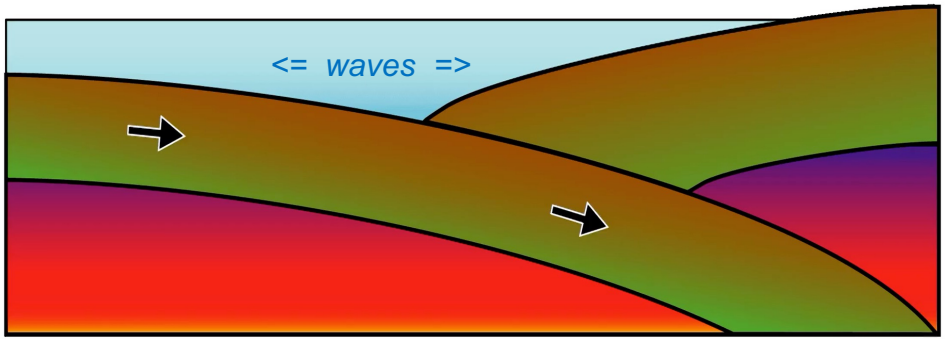
Inundation – furthest extent that water travels from a shoreline

Runup– How far inland water reaches

How Tsunamis are generated

Sudden displacement of ocean, usually from:

- Undersea earthquakes (most common)
- Underwater or sub-aerial landslides (less common)
- Volcanic eruptions (infrequent)
- Meteor impact (rare)



Subduction Zone Tsunami

(Source: G. Fryer)

Characteristics

- 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)

Arrival & Impact

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)

Arrival & Impact

Indian Ocean Tsunami, December 26, 2004

Penang, Malaysia: Relentless surge

Arrival & Damage

- **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

Arrival & Damage

- 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

Arrival & Impact from local tsunamis

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)

Arrival & Impact in Harbors

Strong, unusual currents possible

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

Key Points

Tsunami Waves are dangerous because:

Timing

- Generation cannot be predicted
- No-notice, fast-evolving, can arrive in minutes

Wave Physics

- Height increases as water depth shallows
- Series of waves (hours). Long period (up to 1-hr between waves). 1st wave may not be largest. Seiches in bays, bores up rivers.
- Long wavelength so can wrap around islands

Impacts

- Death: Drowning (from waves, currents, impact with floating debris)
- Damage: Flooding, infrastructure collapses, fire

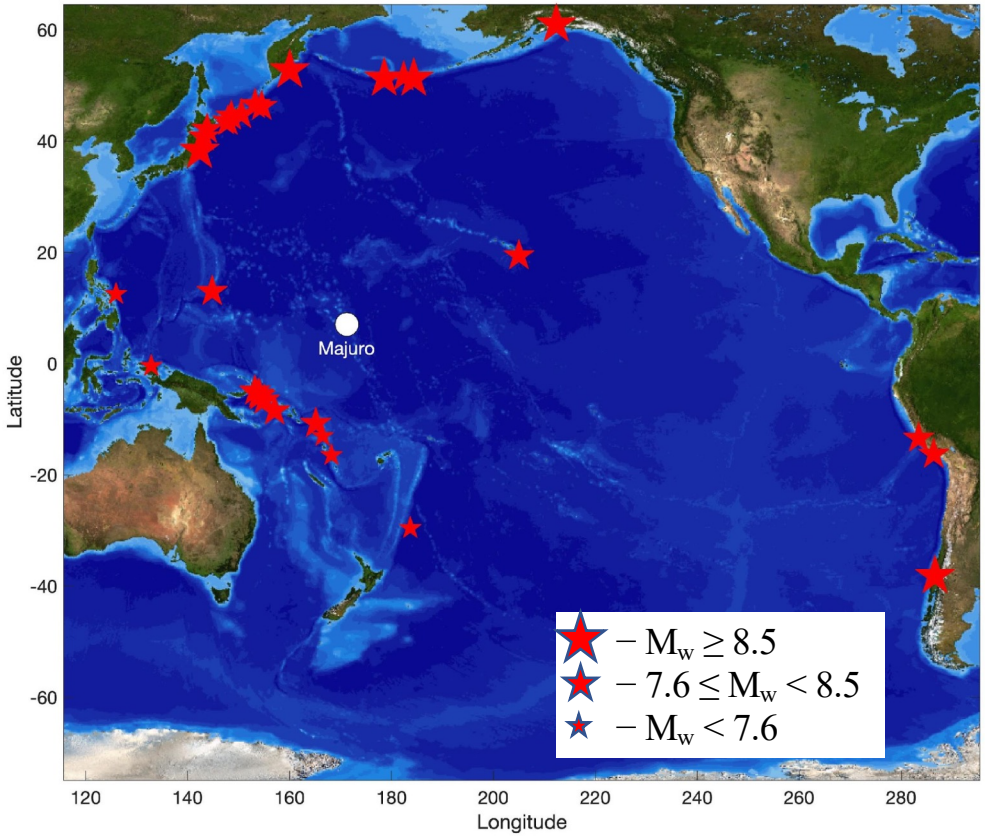
Majuro
Tsunami Hazard Assessment

Conducted by: Natalia Sannikova[1,2], Christopher Moore[1]

[1] NOAA Center for Tsunami Research/Pacific Marine Environmental Laboratory (PMEL), Seattle, WA
[2] Cooperative Institute for Marine and Atmospheric Research (CIMAR), Honolulu, HI

Historic Earthquake Generated Tsunami That Ever Affected Marshall Islands

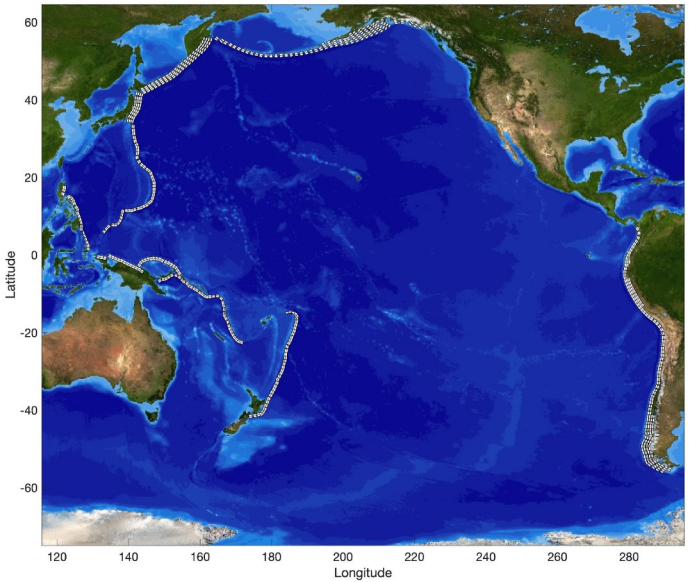
NOAA National Centers for Environmental Information Global Historical Tsunami Database (NCEI, 2022)

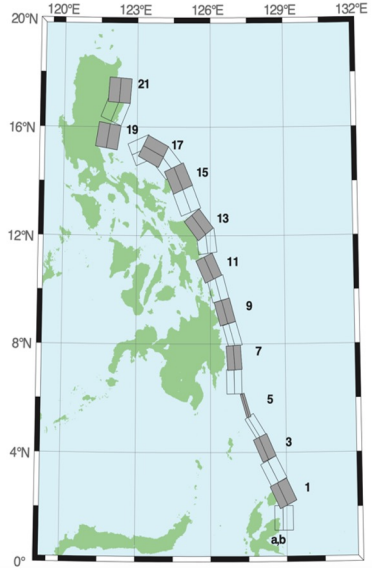


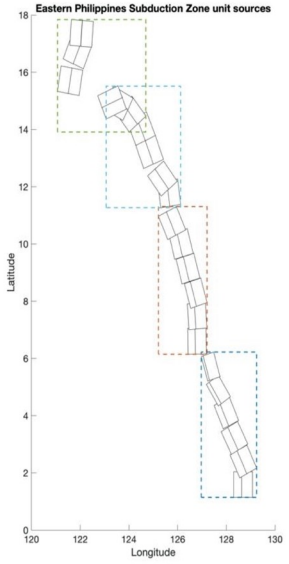
- 32 earthquake generated events
- Tsunami originated from subduction zones: Aleutian (1), Kamchatka-Kuril-Japan-Mariana-Yap (2), Eastern Philippines (3), New Guinea (4), Manus (5), New Britain-Solomons-Vanuatu (6), New Zeland-Kermadec-Tonga (7), South America (8)
- The biggest measured runups – 66 cm at Kwajalein, 51 cm at Majuro from 03/11/2011 Tohoku Tsunami, 38 cm at Kwajalein from 05/22/1960 Chile Tsunami and 30 cm at Kwajalein and Enewetak from 03/09/1957 Andreanof Islands Tsunami
- Majuro – three measured runups: 03/11/2011 Tohoku (51 cm), 10/07/2009 Vanuatu (2 cm), 11/15/2006 S. Kuril Islands (8 cm)

Tsunami Sources

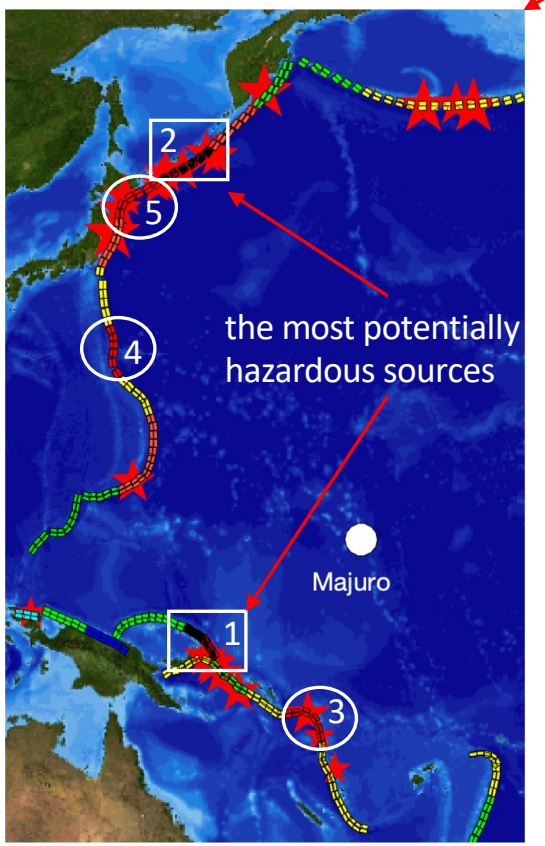
- **A pre-computed propagation database consisting of water level and flow velocities at all grid points for potential seismic unit sources has been developed for the world ocean basins by the NOAA Center for Tsunami Research.**
- **In the sensitivity study 77 Mw 9.1 synthetically generated tsunami sources received as a combination of the 6 x 2 consecutive unit sources from around the Pacific Basin were modeled with computationally optimized grids (nested grids ~ 42, 10 and 3 arcsec).**

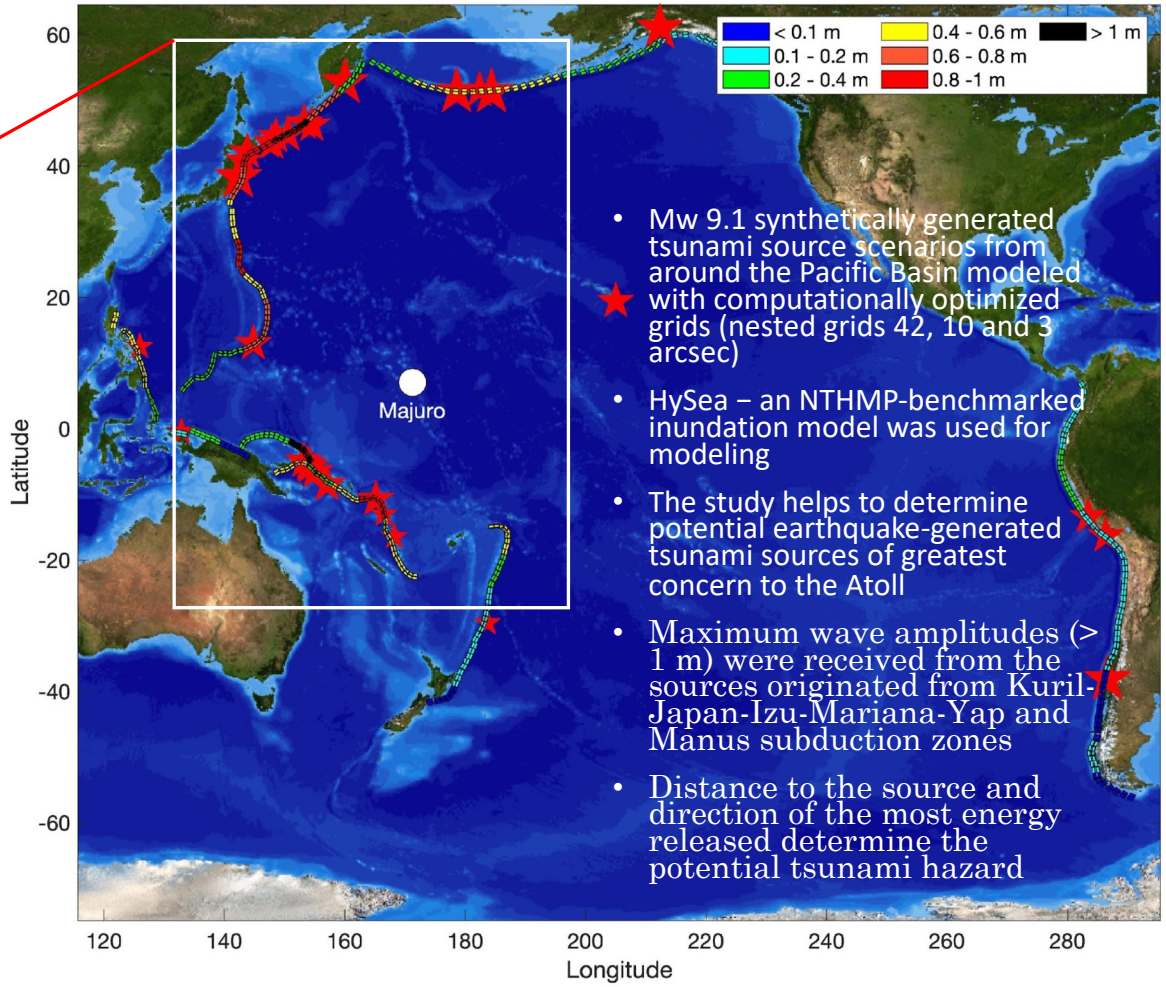






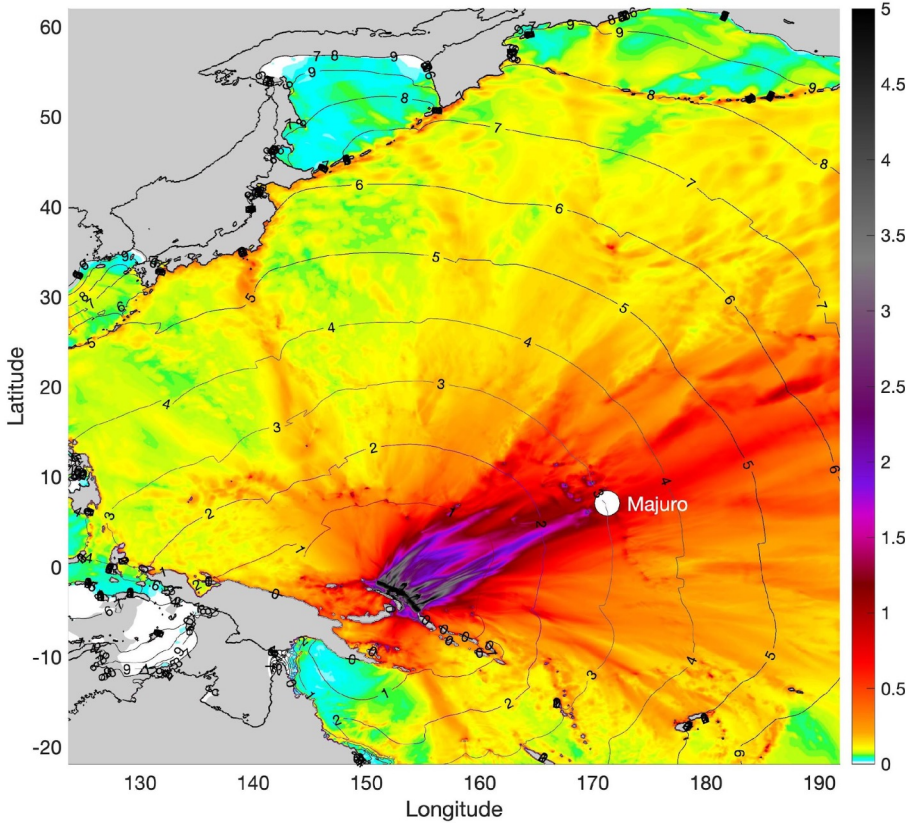
Sensitivity Study

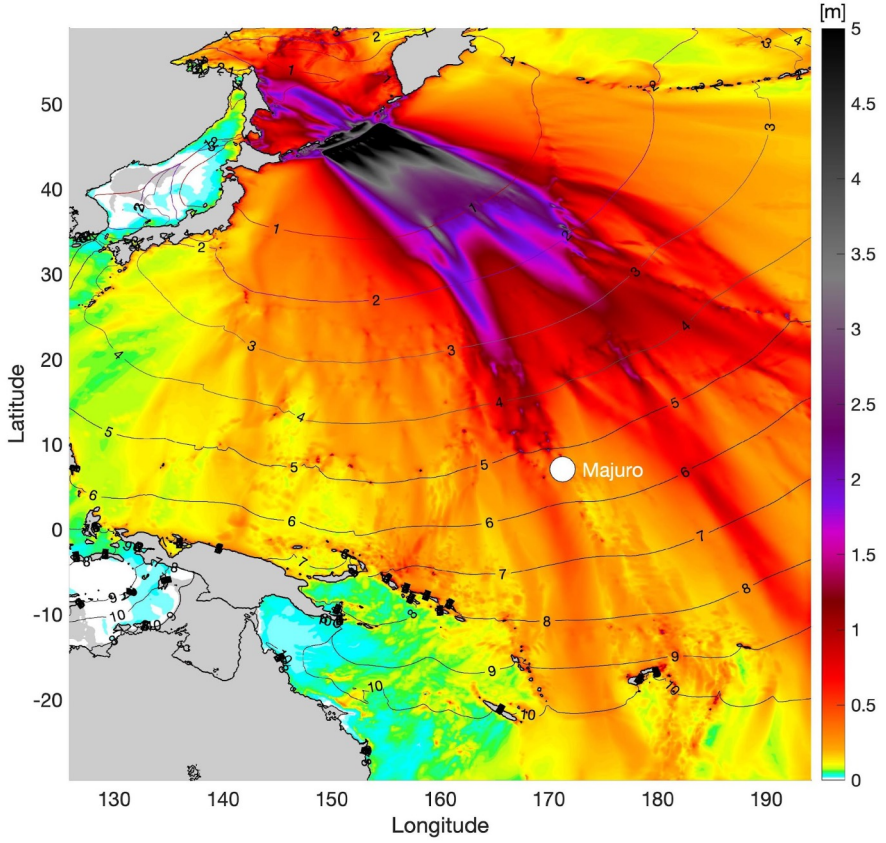




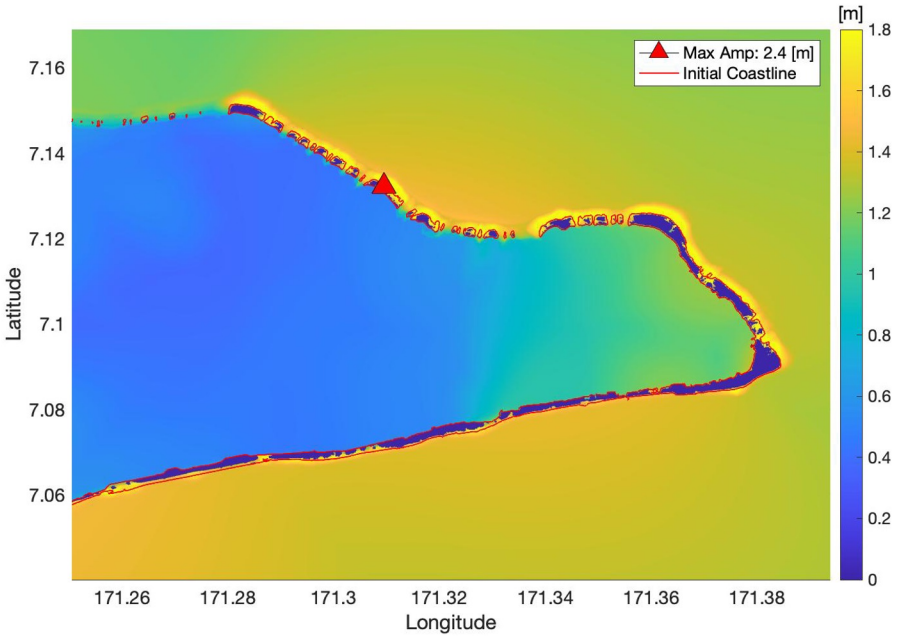
- Mw 9.1 synthetically generated tsunami source scenarios from around the Pacific Basin modeled with computationally optimized grids (nested grids 42, 10 and 3 arcsec)
- HySea – an NTHMP-benchmarked inundation model was used for modeling
- The study helps to determine potential earthquake-generated tsunami sources of greatest concern to the Atoll
- Maximum wave amplitudes (> 1 m) were received from the sources originated from Kuril-Japan-Izu-Mariana-Yap and Manus subduction zones
- Distance to the source and direction of the most energy released determine the potential tsunami hazard

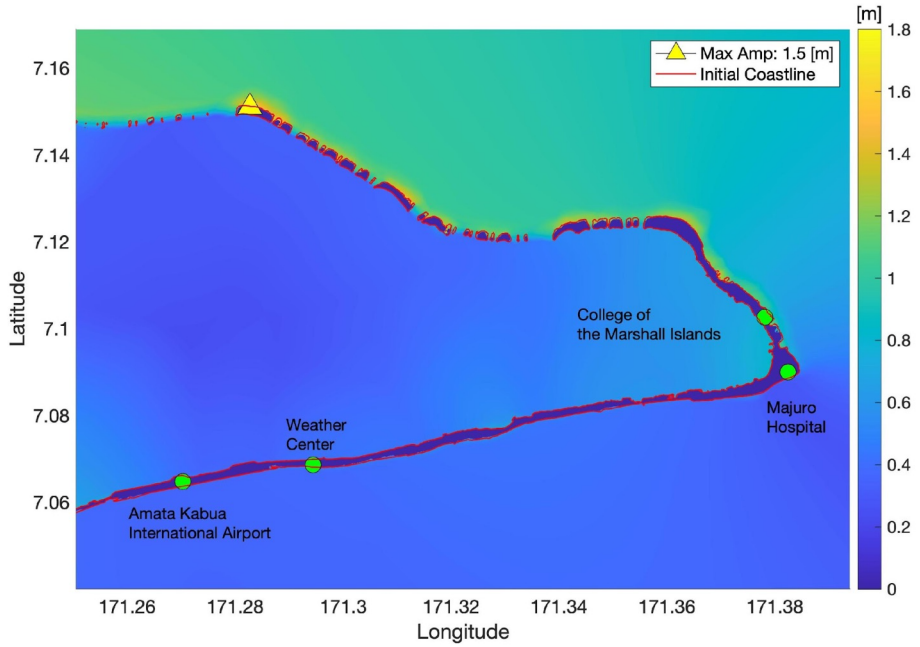
Maximum Tsunami Amplitudes from the Most Potentially Hazardous Sources



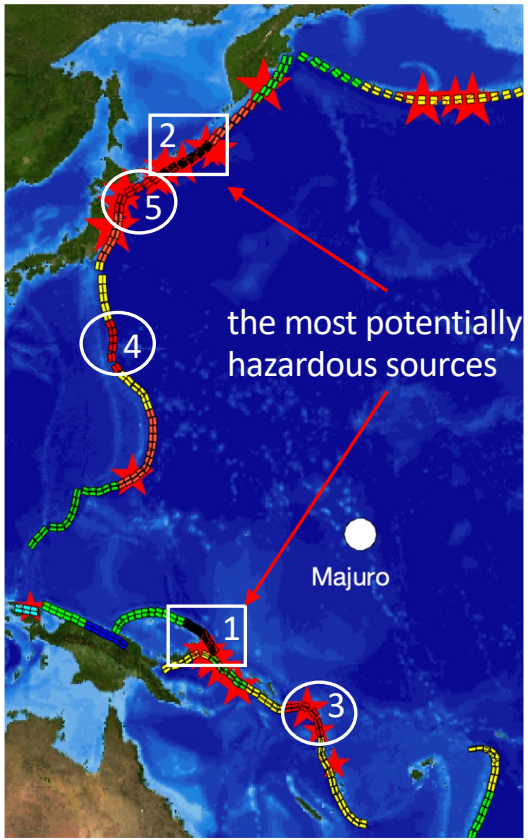


Maximum Tsunami Amplitudes with inundated area highlighted from the most dangerous sources *with calculation grid resolution – 10 m*





Maximum of maximums tsunami amplitudes with inundated area highlighted



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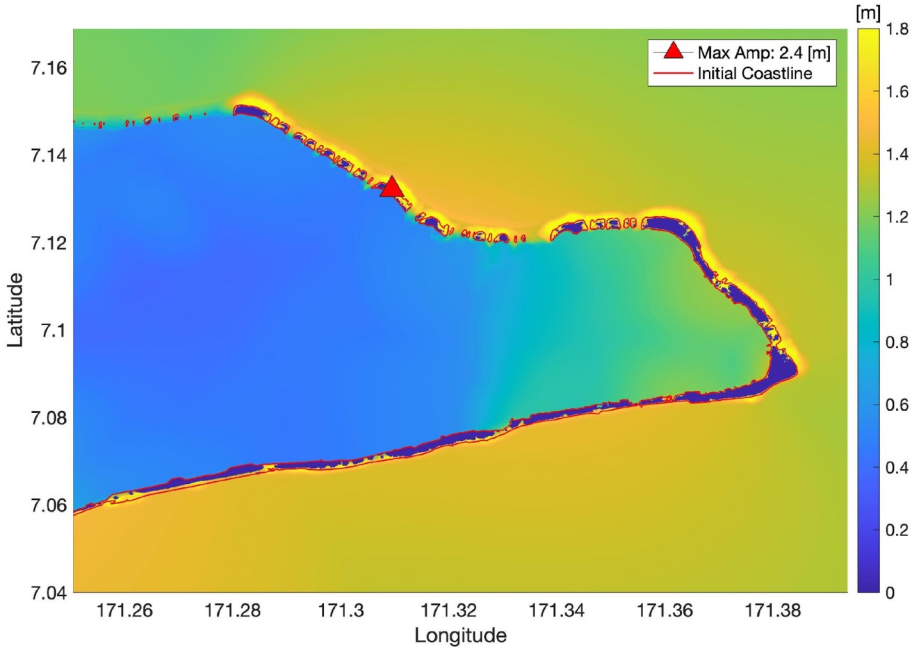

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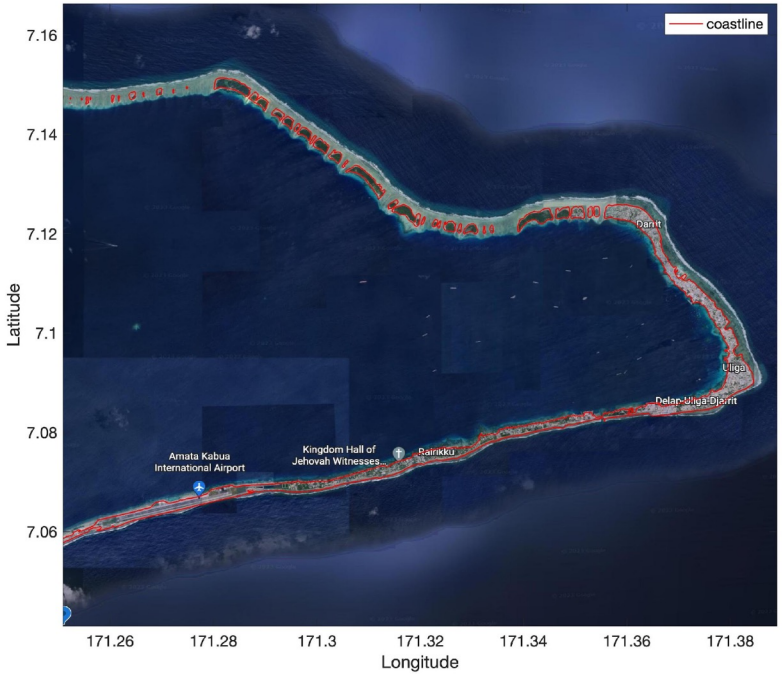

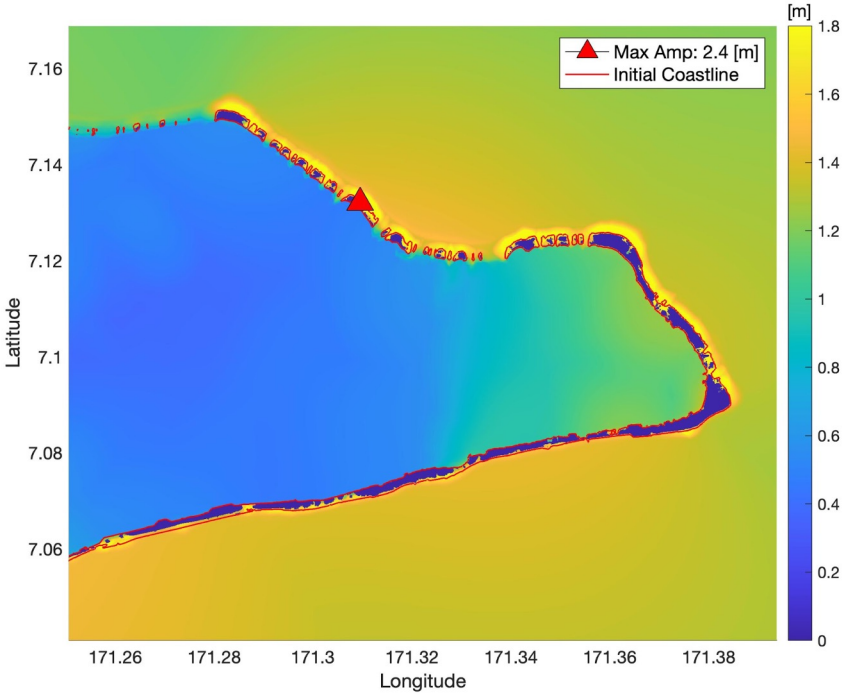

unesco
Intergovernmental
Oceanographic
Commission

Thank You

Marie, Laura, and Landon

,

Pacific
Community
Communauté
du Pacifique

Model Validation (03/10/2011 Tohoku Event)

Nested Calculation Grids Resolution (20.9, 2.6 and 0.3 arcsec (10m))