



Tsunami Preparedness, Response, and Mitigation in California

PCC Harbormaster Conference Eureka, CA

California Tsunami Program

"Planning for the Next Tsunami"

Coordinated with
20 coastal counties,
100 coastal cities,
other states, and
consulting partners.

Brought to you by the
California Tsunami Program

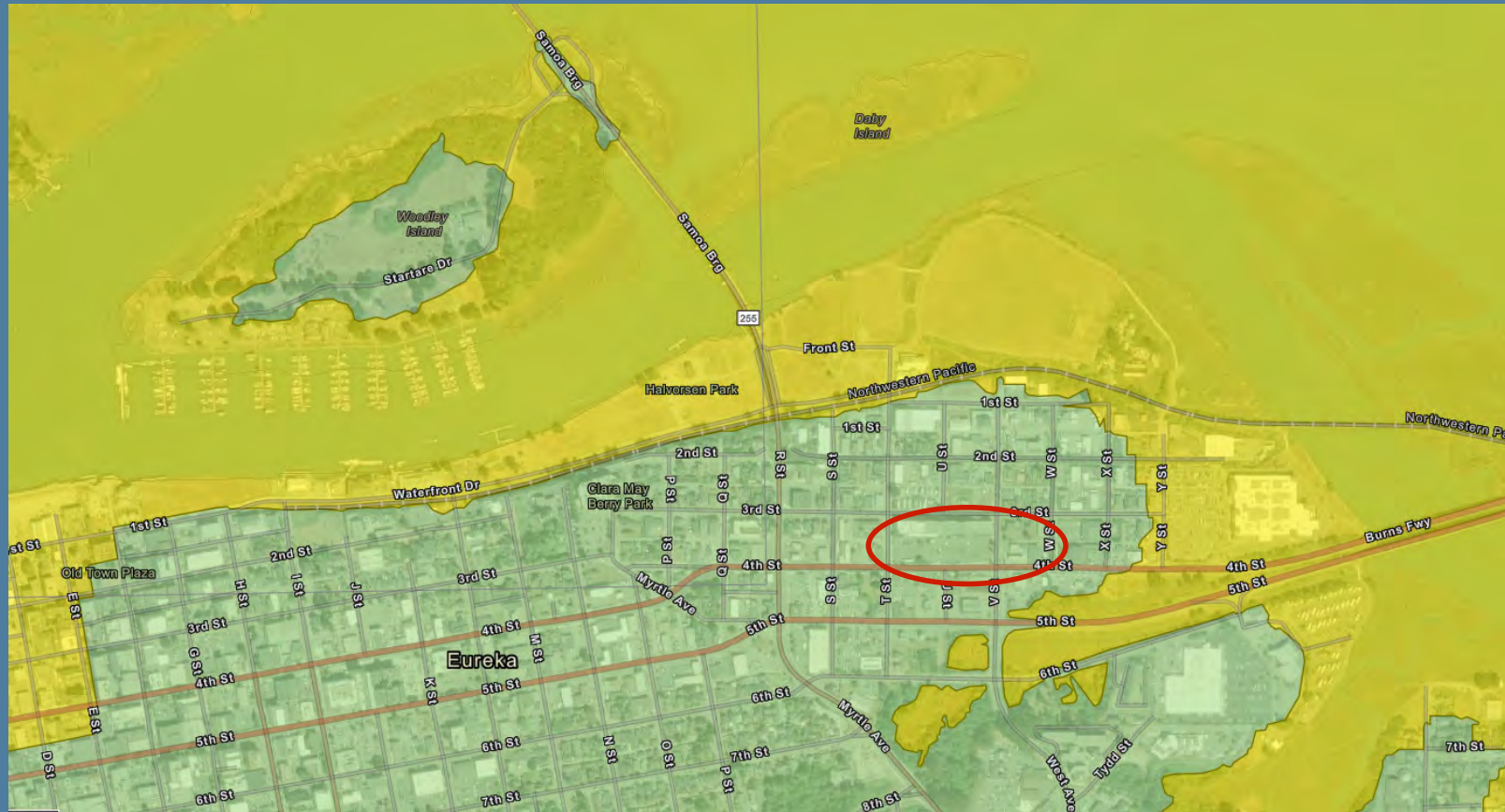


FEMA

AECOM



Are we in the Tsunami Hazard Area Now?



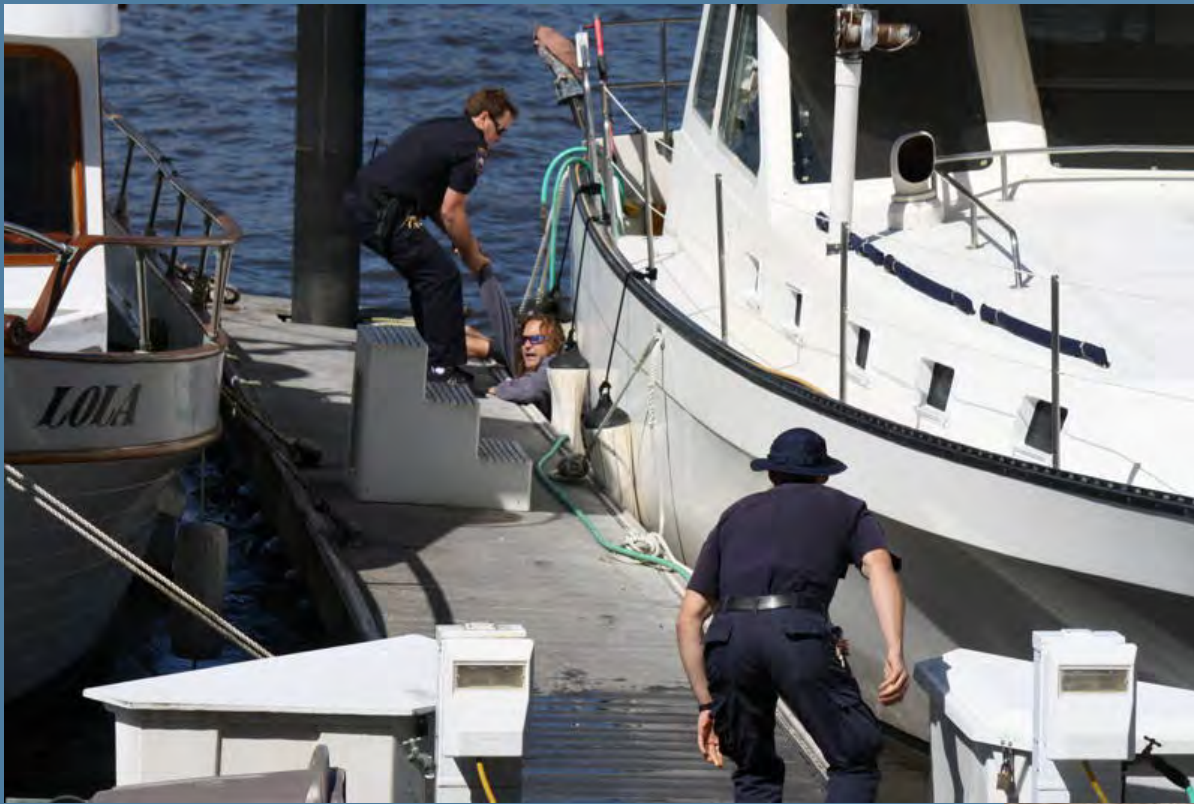
Santa Cruz Harbor - 2011



Santa Cruz Harbor - 2022



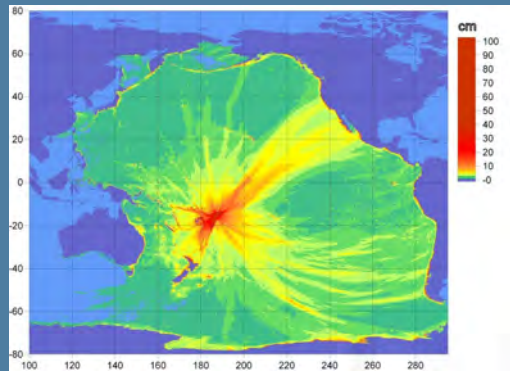
Crowd Control and Keeping People Off Docks



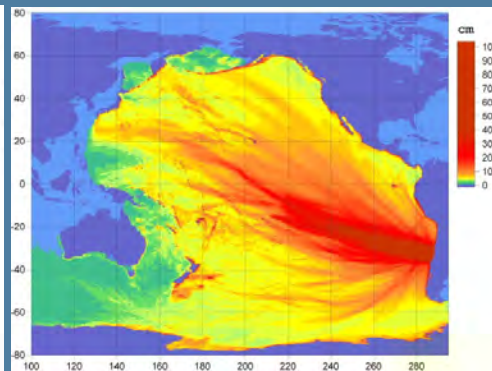
© kimberley bermender

Notable Tsunamis in the Last ~12-Years

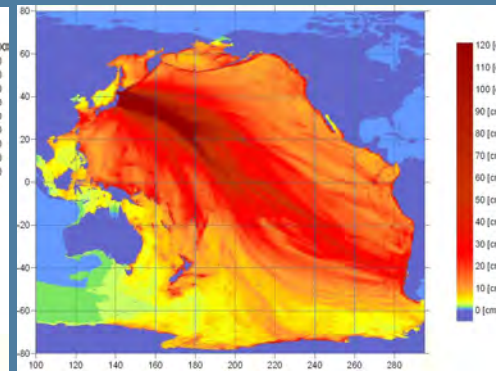
Samoa - Sept 2009



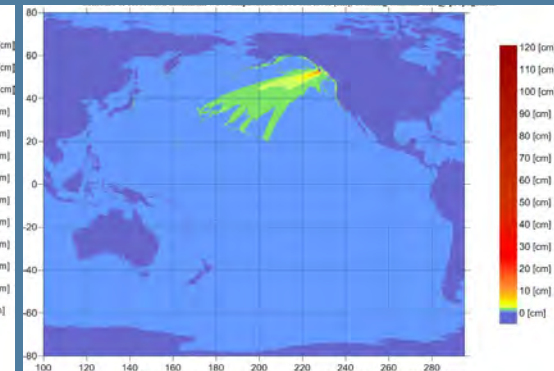
Chile - Feb 2010



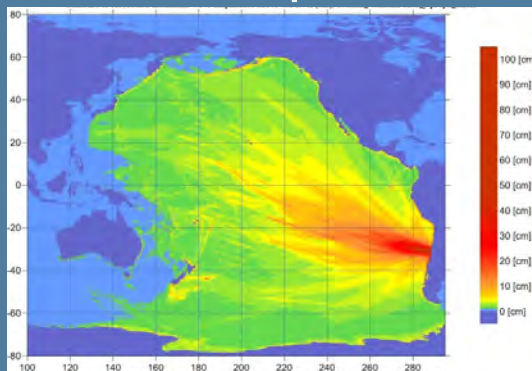
Japan - March 2011



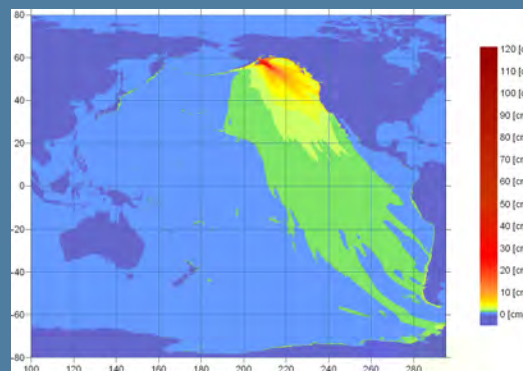
BC Canada - Oct 2012



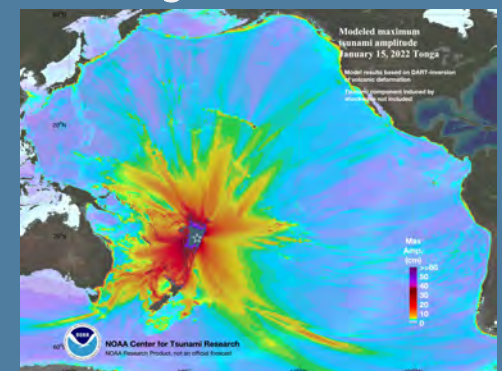
Chile - Sept 2015



Alaska - Jan 2018



Tonga - Jan 2022

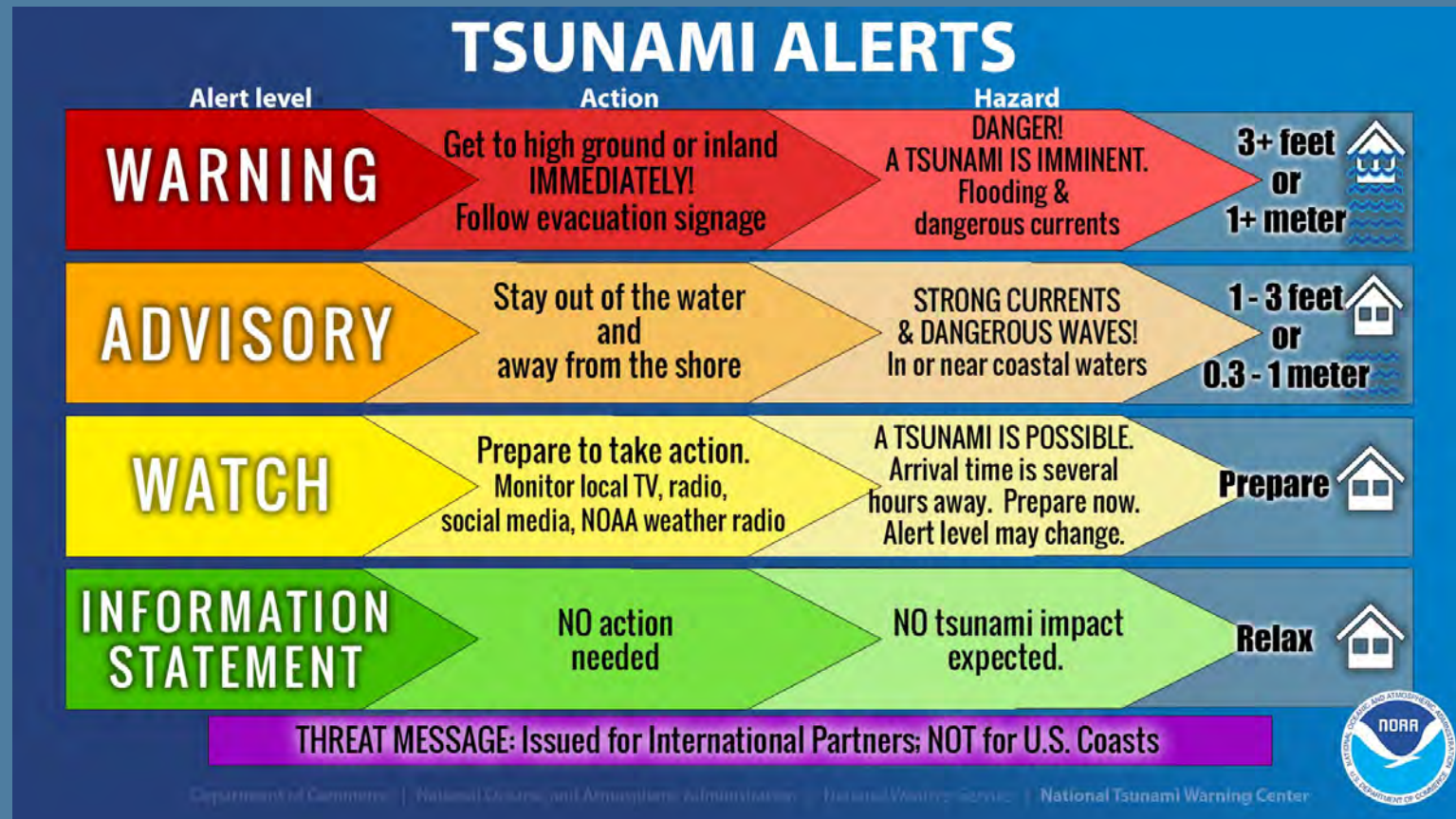




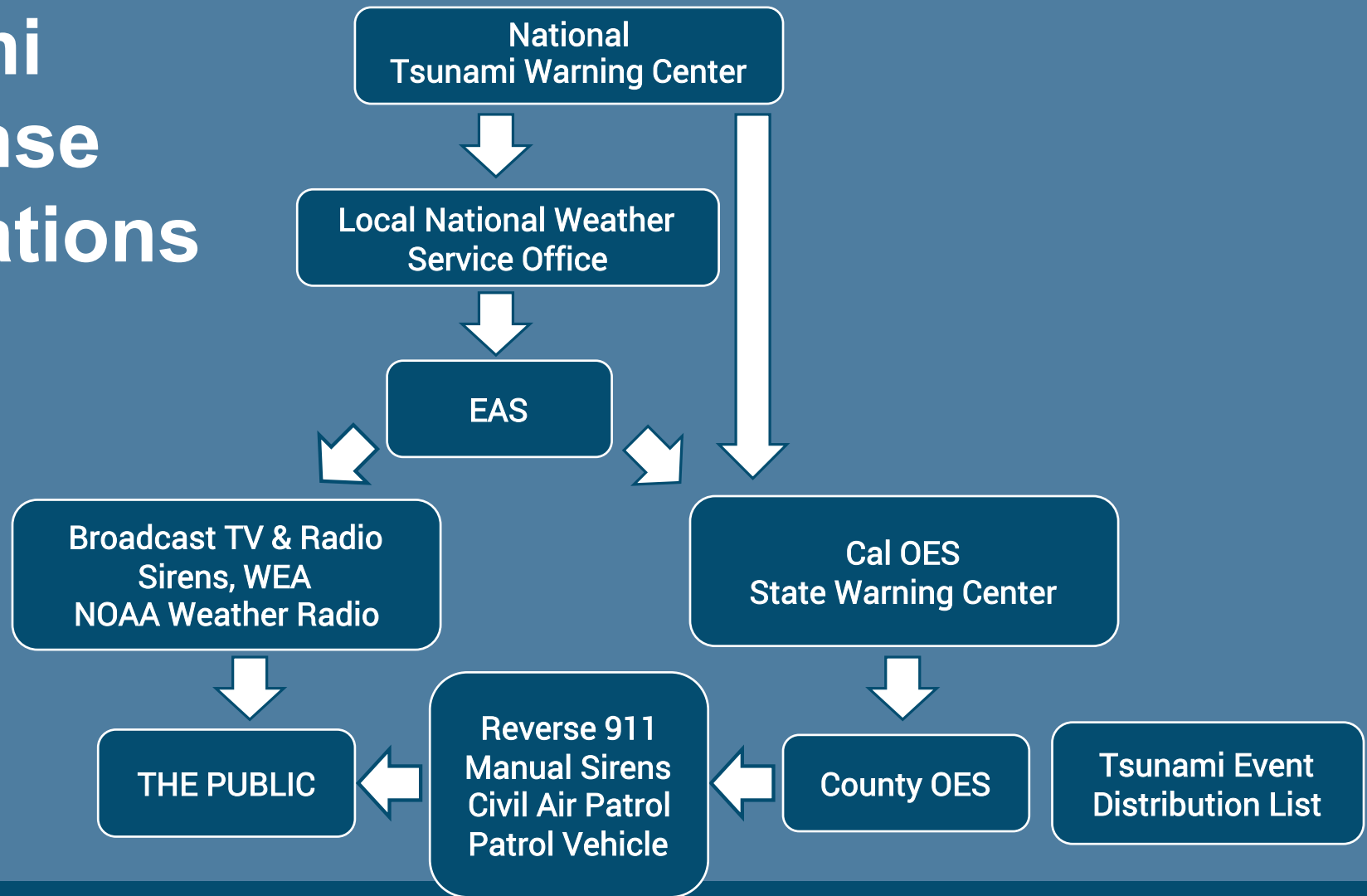
Tsunami Event Communication & Alerting Procedures



Tsunami Notification Process



Tsunami Response Notifications



CA Tsunami Notification Process

California State Warning Center

- ✓ Notification to County Warning Points or PSAPs (Usually Sheriff's Dispatch)

Tsunami Event Distribution List (*secondary or tertiary, not primary*)

- ✓ Tsunami Program Contacts: Text, Email, Phone
- ✓ Notification Contains:
 - Info Regarding Tsunami Event (What we Know)
 - Conference Call Information
 - Online link to data/documents (e.g., Box.com)
 - Playbook Recommendations for Maritime & Evacuation



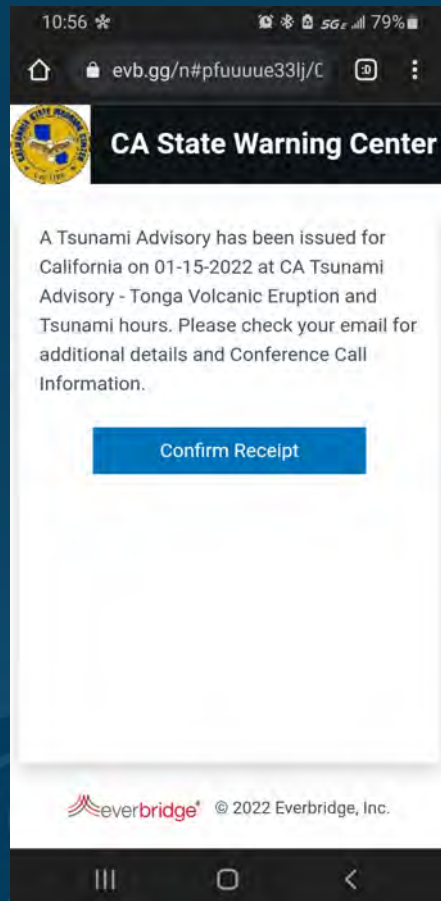
NTWC forecast
information



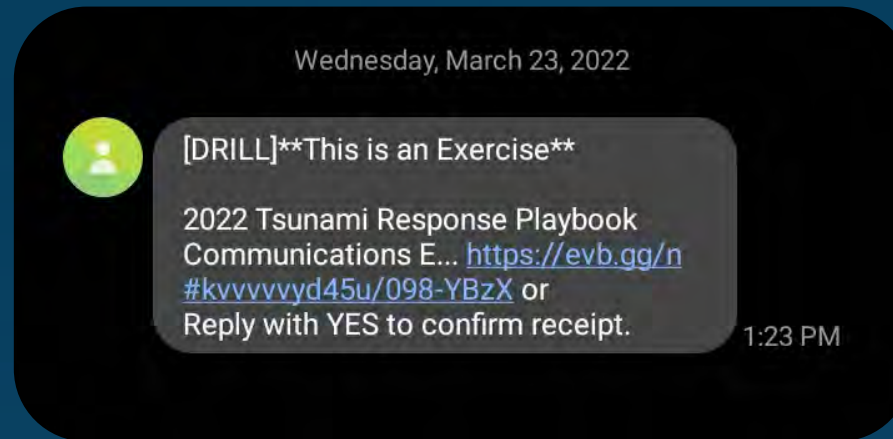
Google Earth &
GIS map data

Begin Conference Call Process

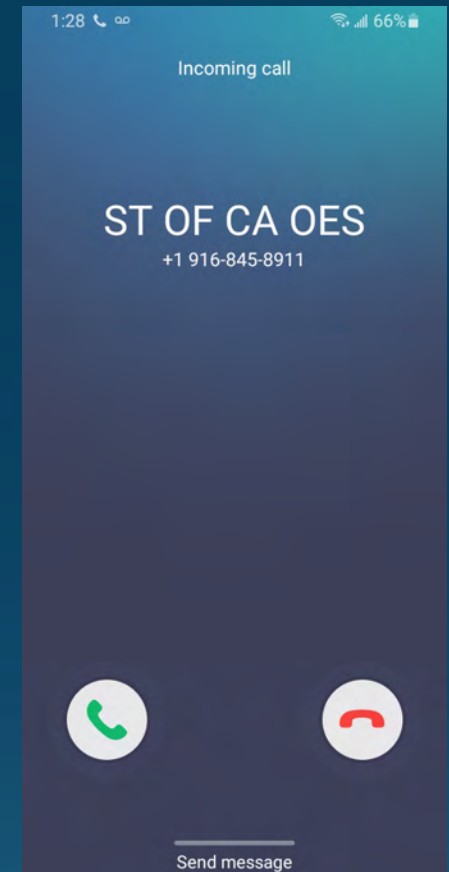
Email from Everbridge



Text from Cal OES TEDL



Call from Cal OES TDEL





Understanding Tsunami Hazards in California

PCC Harbormaster Conference Eureka, CA

Historic California Tsunamis

*More than 150 tsunamis have been recorded
along the California coastline since 1800*

*1964 tsunami from a M9.2 earthquake from Alaska
12 lives lost in California*

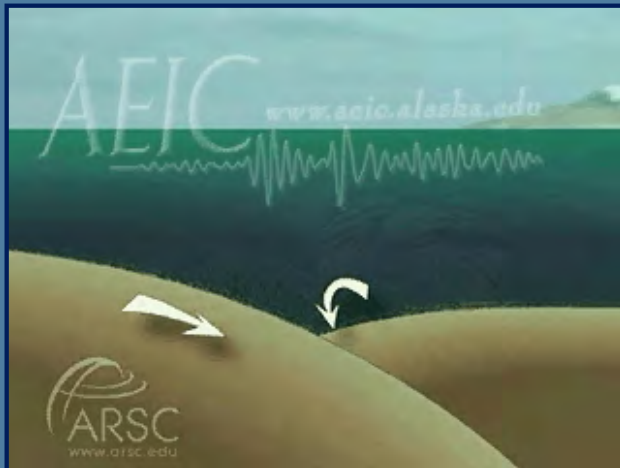
*2011 tsunami from a M9.1 earthquake offshore from Japan
caused more than \$100 million in damage to CA, there was one
fatality*

*2022 tsunami from Tonga volcanic eruption
caused ~\$11.5 million in damage in CA*

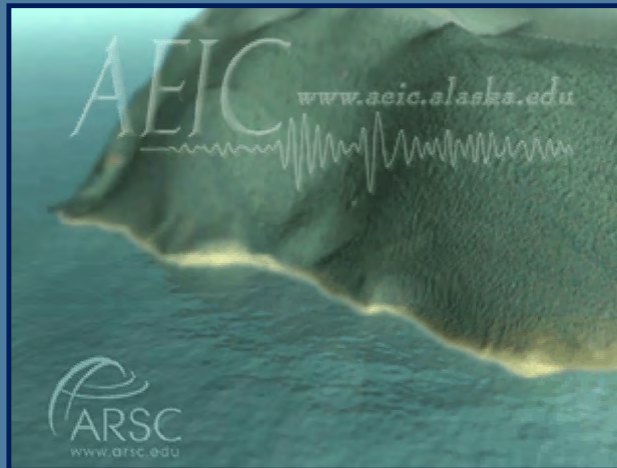
How are tsunamis generated?

~85% of tsunamis are caused by earthquakes below the ocean floor.

~15% of tsunamis comes from landslides, volcanic eruptions, meteors, and meteotsunamis (weather), and other significant water disruptions.



Earthquakes



Landslides



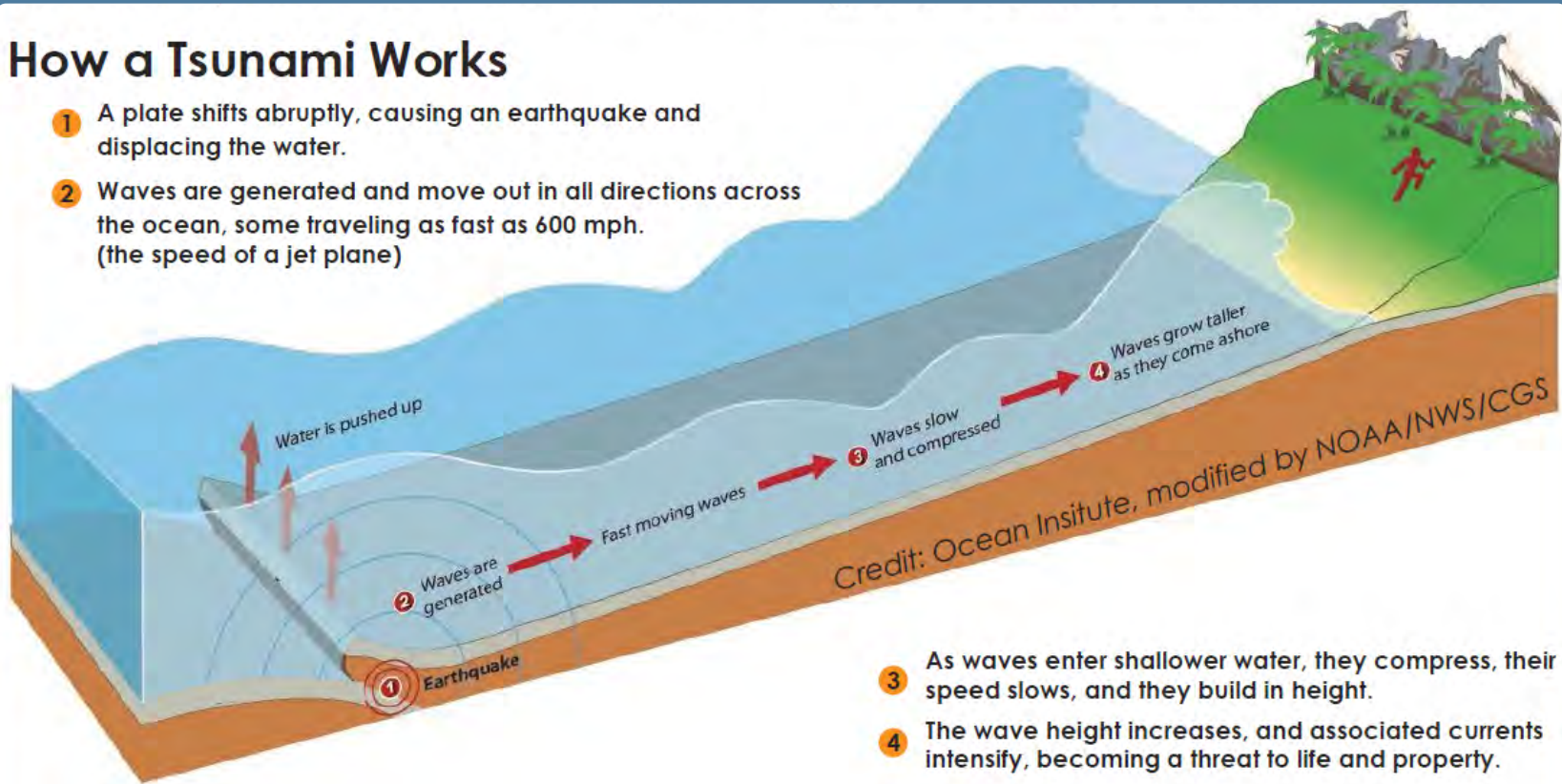
Meteotsunami

How are tsunamis generated?

Most tsunamis are caused by earthquakes below the ocean floor

How a Tsunami Works

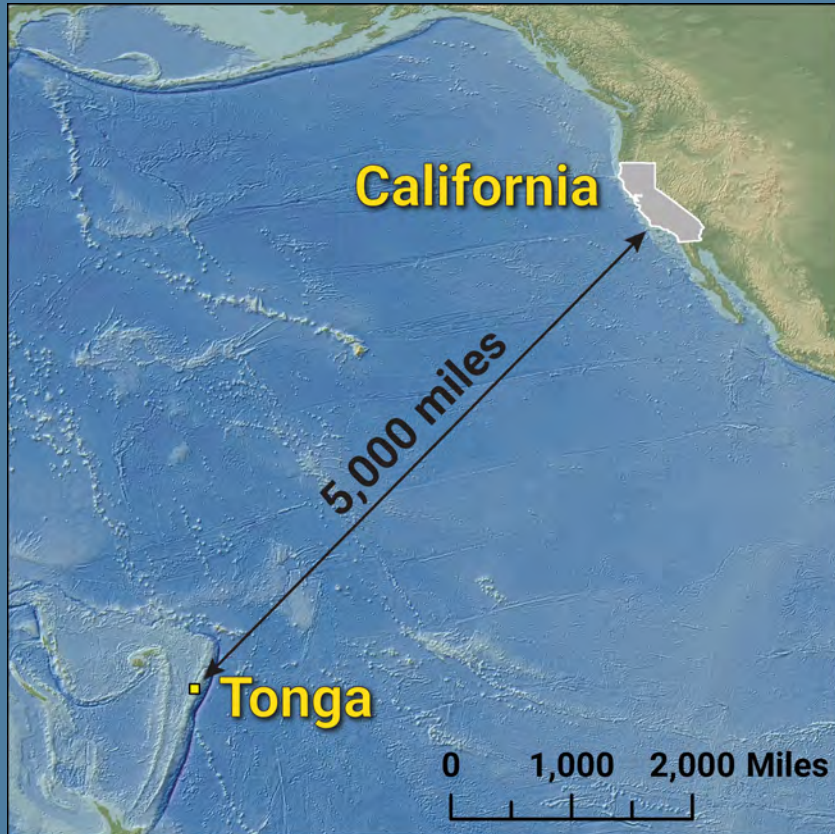
- 1 A plate shifts abruptly, causing an earthquake and displacing the water.
- 2 Waves are generated and move out in all directions across the ocean, some traveling as fast as 600 mph. (the speed of a jet plane)



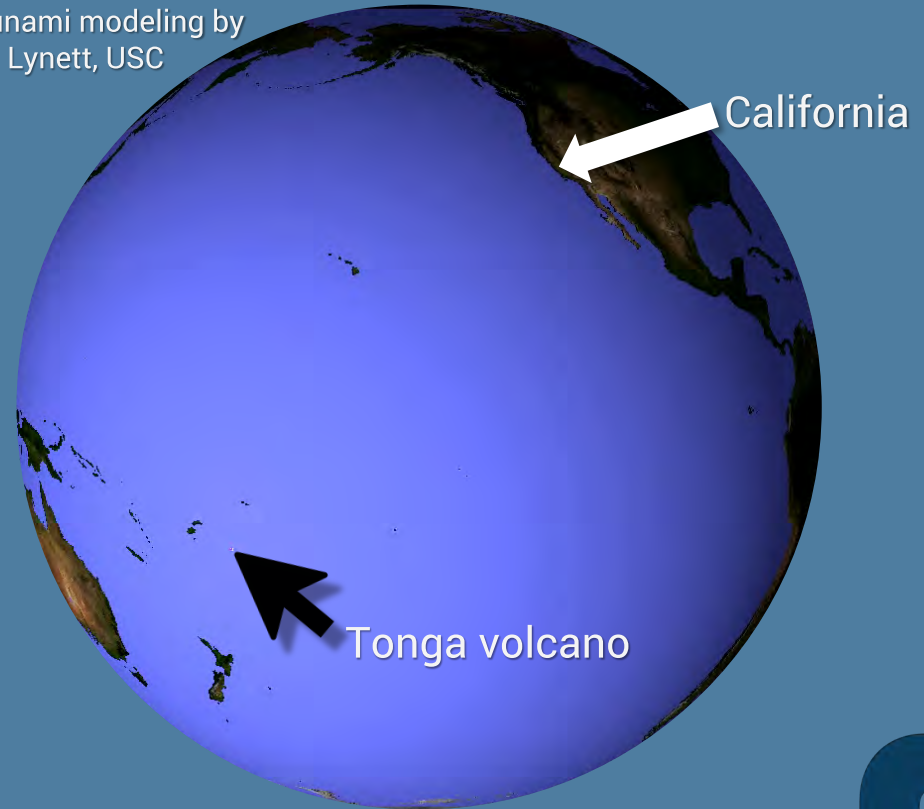
- 3 As waves enter shallower water, they compress, their speed slows, and they build in height.
- 4 The wave height increases, and associated currents intensify, becoming a threat to life and property.

How are tsunamis generated?

January 15, 2022 - Hunga Tonga-Hunga Ha'apai Eruption

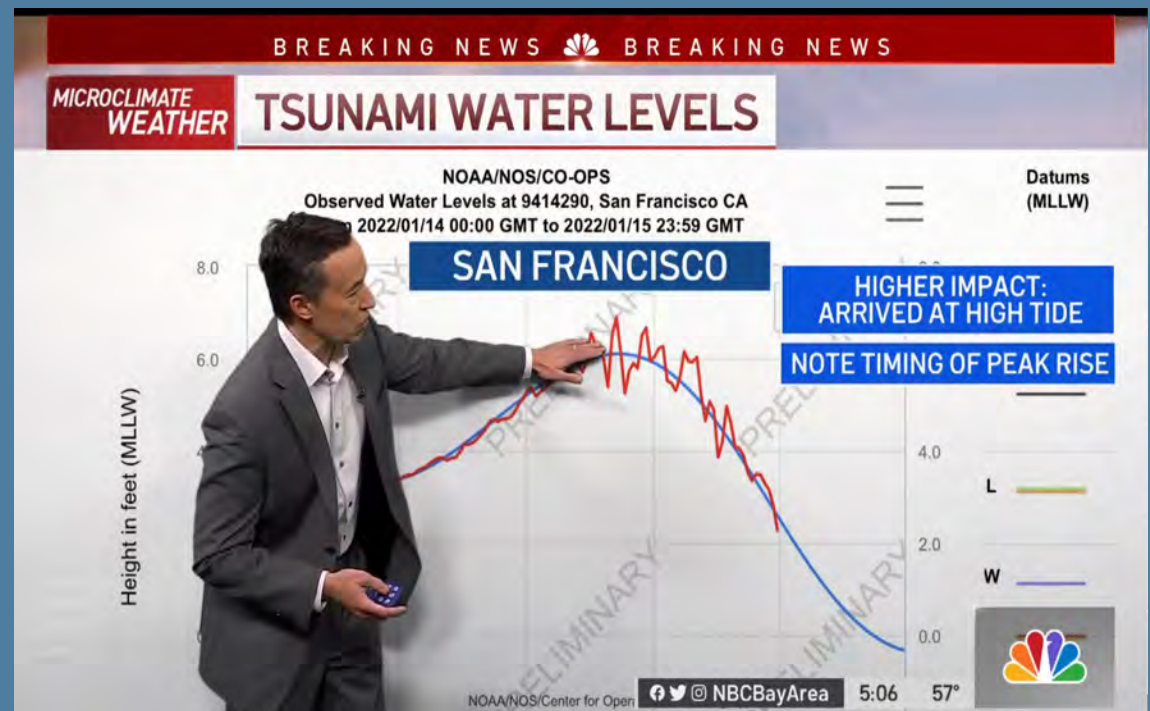


Tsunami modeling by
Pat Lynett, USC



How are tsunamis generated?

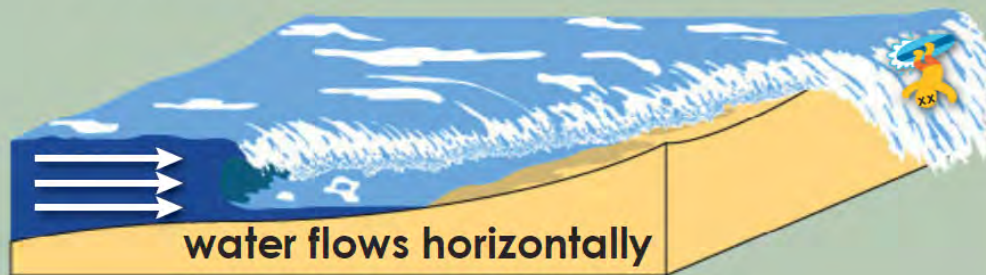
January 15, 2022 - Hunga Tonga-Hunga Ha'apai Eruption



How is a tsunami different from regular waves?

Tsunami Waves

- dangerous, unpredictable, and no face to surf
- waves flood the land like a wall of water



- A tsunami has many surges
- This first surge is almost never the largest
- The danger period can last 24 hours or more
- Tidal levels can affect the impacts of a tsunami

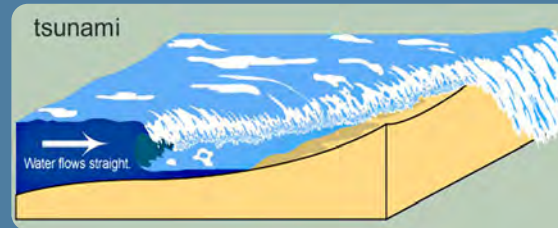
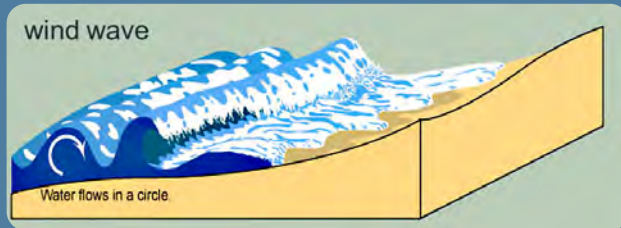
Regular Waves

- waves come and go without flooding higher areas

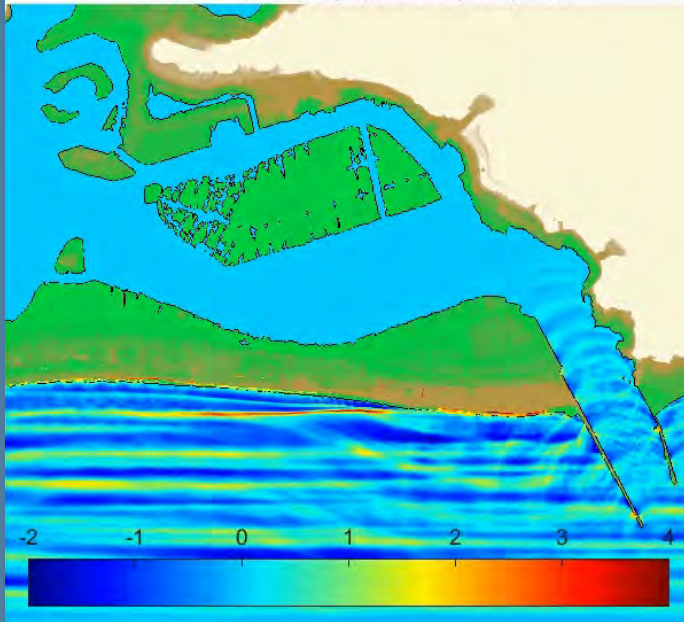


- A regular wave breaks along the coast creating a circular, curling wave
- Waves flow on shore then out in less than a minute
- You can surf a regular wave

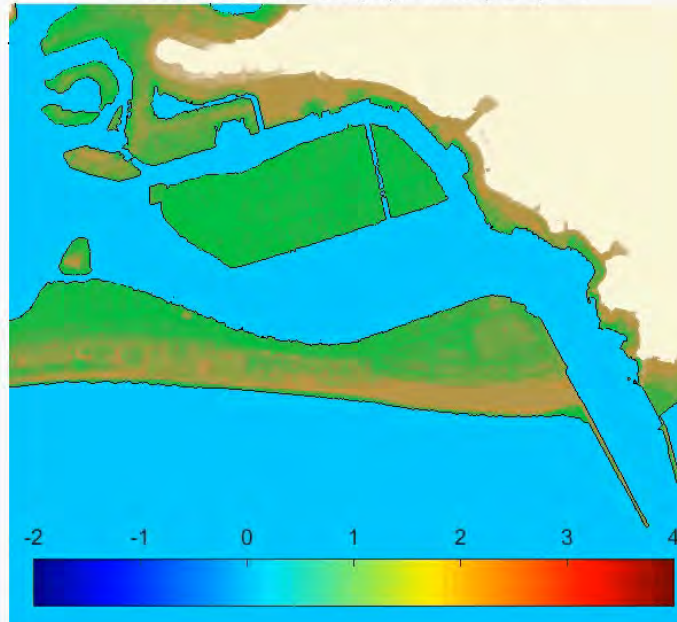
Coastal Impacts – Swell vs Tsunami



Swell Elevation (m), Time (min) = 5



Tsunami Elevation (m), Time (min) = 5



*Modeling at
Newport Beach
performed by
Pat Lynett,
USC*

Tsunami **Hazards** *for* Ports, Harbors, & Boaters

- Strong and unpredictable currents
- Eddies/whirlpools
- Sudden water-level fluctuations
- Tsunami bores and amplified waves
- Drag on deep draught boats
- Collision
- Scour and sedimentation
- Long lasting dangerous tsunami conditions
- Environmental hazards



March 2011 Santa Cruz Harbor

Can I surf a tsunami?



Some of the rescue swimmers dispatched by the San Francisco Fire Department at Ocean Beach.
San Francisco Fire Department/Twitter

"You have to understand that we usually don't rescue surfers," he added. "It's usually people who go out in the water for the first time. These are all vetted, experienced surfers who went out... That's just how aggressive the waves were."

NO! Tsunami waves are different from regular waves.

What does a tsunami look like?

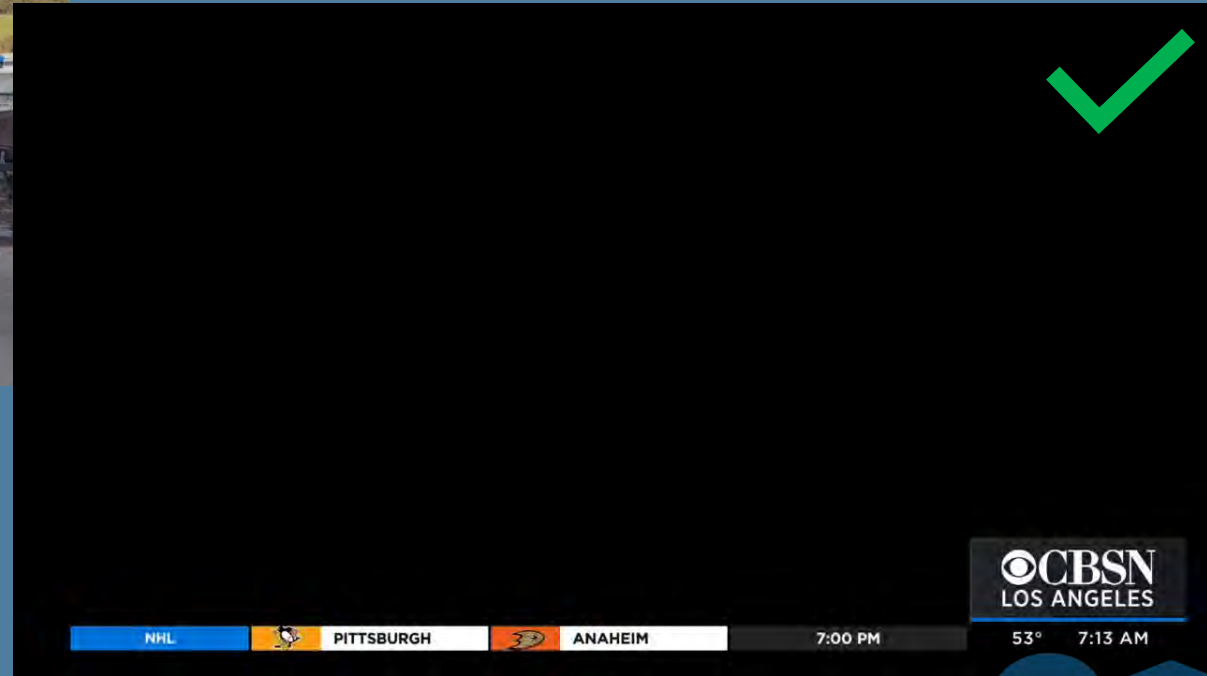
<https://www.youtube.com/watch?v=317zsAvoEts>



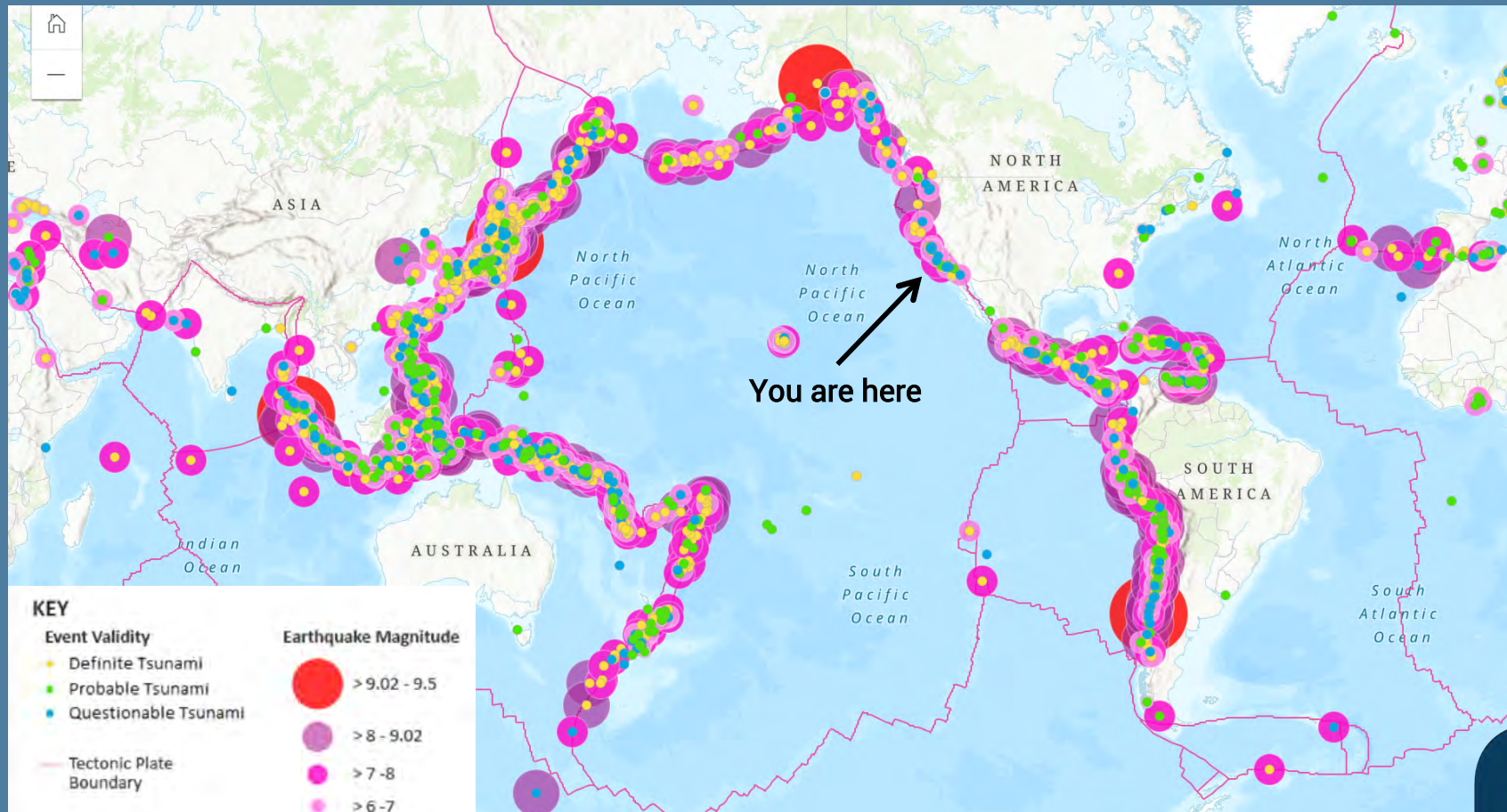
What does a tsunami look like?



What does a tsunami look like?



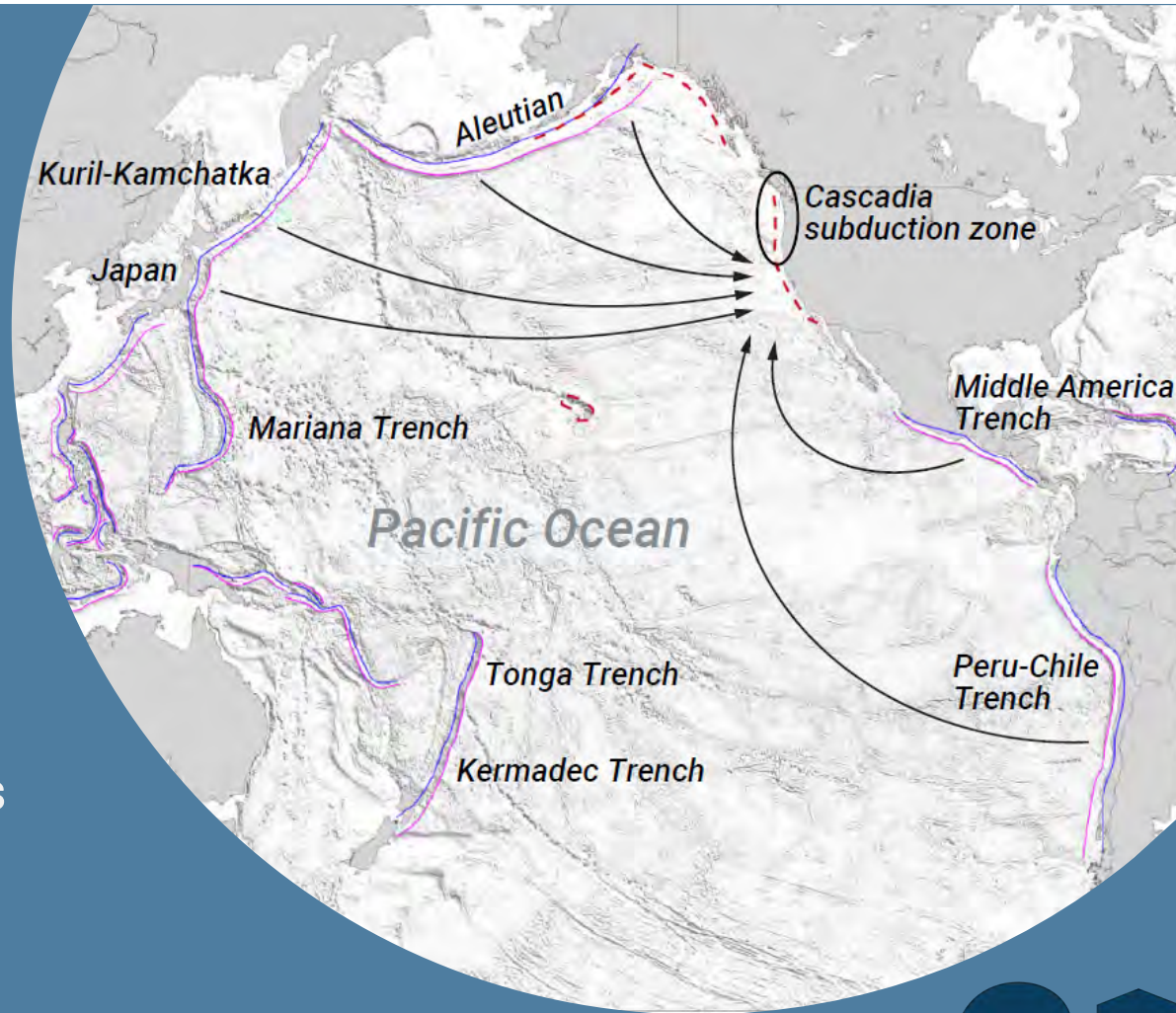
Where do tsunamis occur?



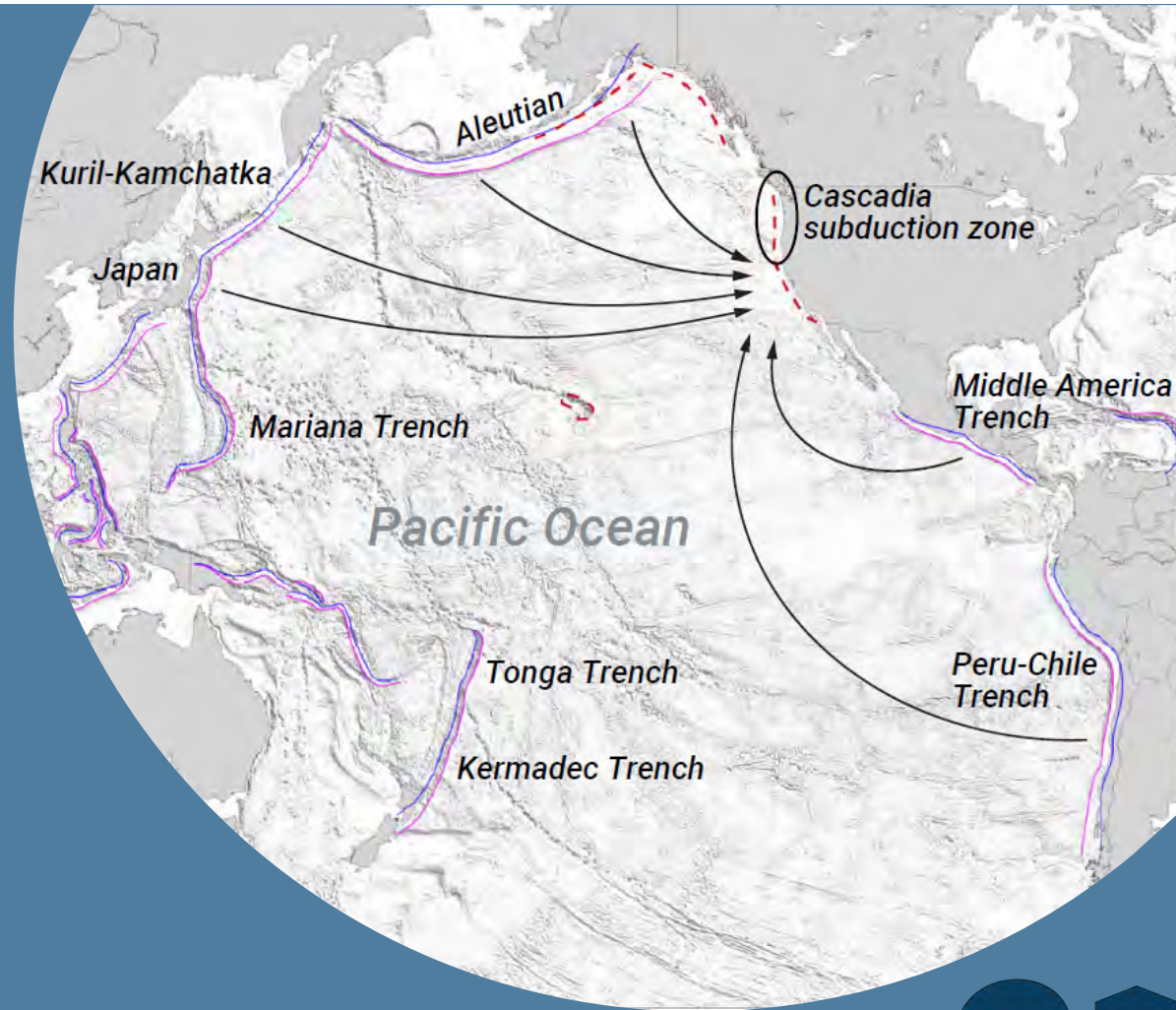
Distant vs Local Tsunamis

Distant source tsunamis

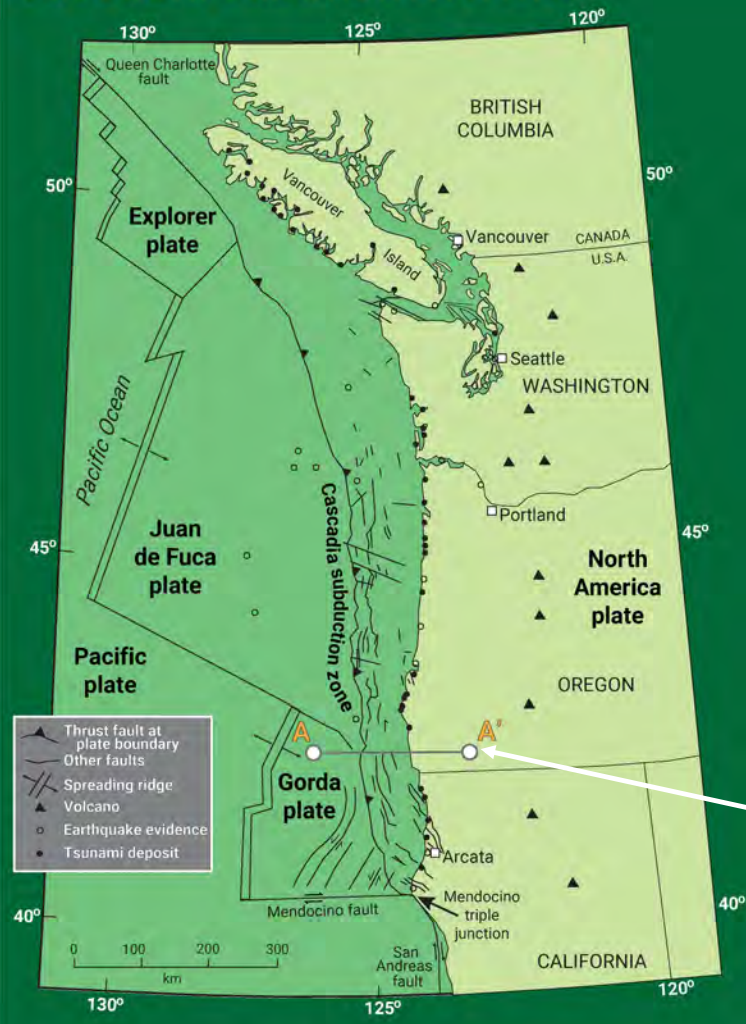
- Earthquake will not be felt
- Tsunami can arrive in 4-13 hours
- There will be time for official notifications to go out



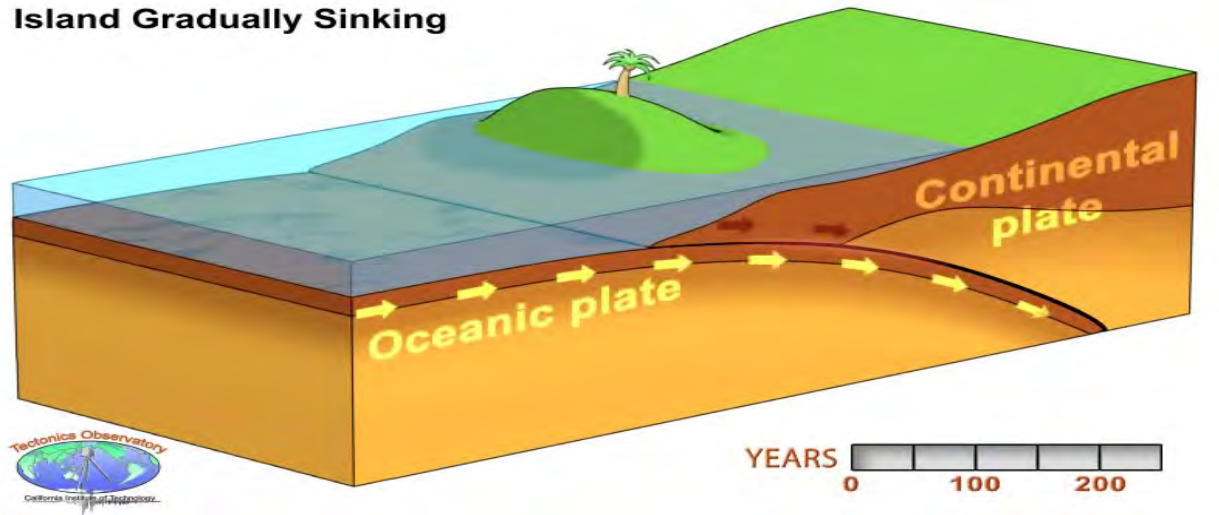
Cascadia subduction zone



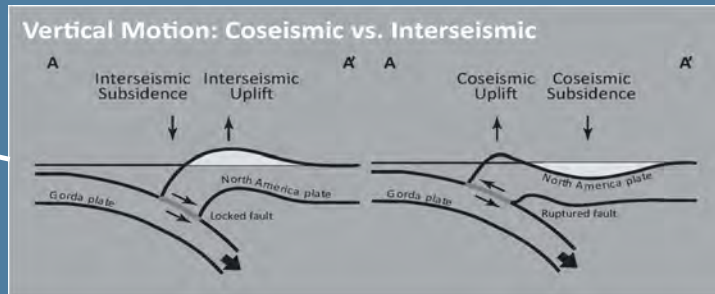
Cascadia subduction zone



Island Gradually Sinking



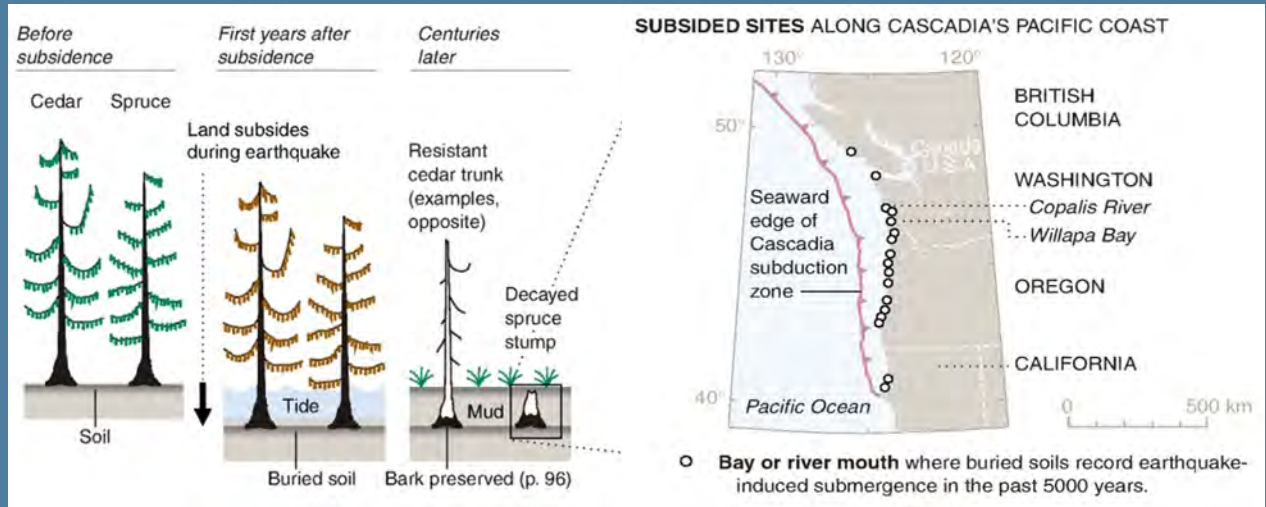
Subduction zones produce earthquakes that can generate tsunami that cross the Pacific ocean



Cascadia subduction zone



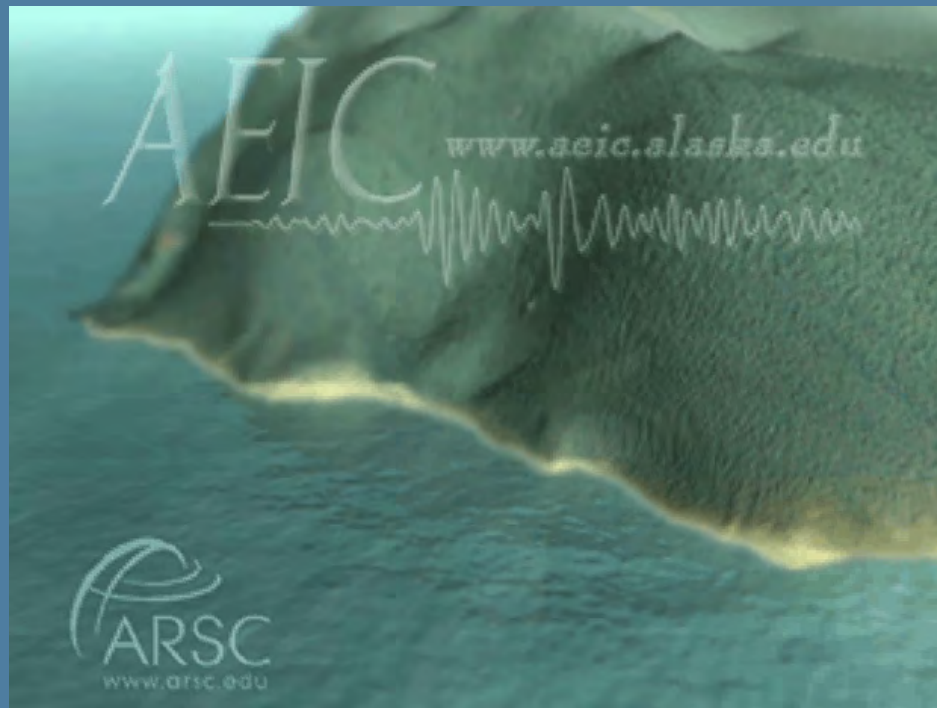
Scientists have geologic evidence that the CSZ has generated over 40 earthquakes in the past 10,000 years. The most recent earthquake and tsunami was in January 1700.



Atwater & Satake, 2005

Local Source Tsunami

Local tsunami can be generated by the sudden movement of offshore faults and by submarine or coastal landslides





- CGS Home
- About the CGS
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- Forest Biomass to Carbon-Negative Biofuels
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- Geological Modeling
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 - Tsunami Maps & Data
 - Educational Materials & FAQ
 - Preparedness: What to do Before, During, and After a Tsunami
 - Tsunami Technical Reports
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 - The 2011 Tōhoku-oki Earthquake and Tsunami
 - The 2022 Tonga Tsunami
 - Tsunami Program Contact Information
 - Geologic Reviews

Tsunamis

Announcing Updated and New Tsunami Products



OCTOBER 7, 2022

New Tsunami Maps for California

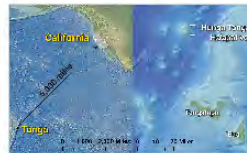
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MARCH 11, 2021

California Tsunami Preparedness Guide

Appropriate for all ages, our updated multimedia guide is packed with videos, images, and maps. September is National Preparedness Month...this is a good time to determine if you live in, work in, or visit a Tsunami Hazard Area, and to prepare for a tsunami.



JANUARY 31, 2022

The Tonga Tsunami of January 15, 2022

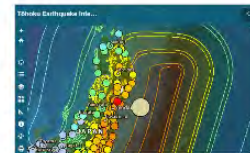
Our summary of effects in California, and the state's response.



MARCH 11, 2021

California Remembers the 2011 Tōhoku-oki Earthquake and Tsunami

Our three-part retrospective examines the 2011 event, and the lessons California learned that are helping us prepare for the next one.



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A scientific perspective of the event, including details of what happened in Japan and subsequently in California.





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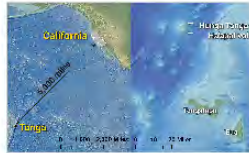
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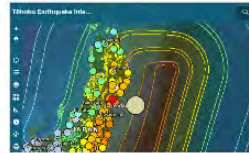
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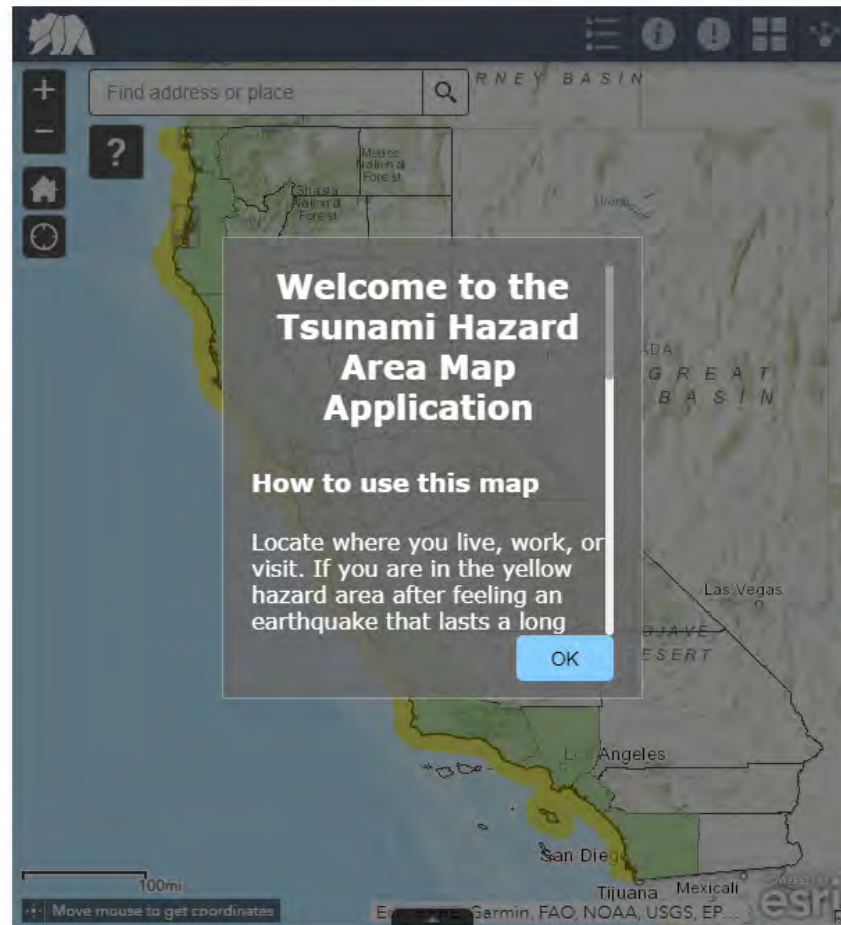
A scientific perspective of the event, including details of what happened in Japan and subsequently in California.

- Updated tsunami hazard maps were updated using the best currently available scientific information.
- Maps assist the public and local governments in identifying their tsunami hazard for evacuation planning.
- Use the “find address” box to see if the areas you work, live, visit, or commute are in a Tsunami Hazard Area.

tsunami.ca.gov/map



California Tsunami Maps and Data

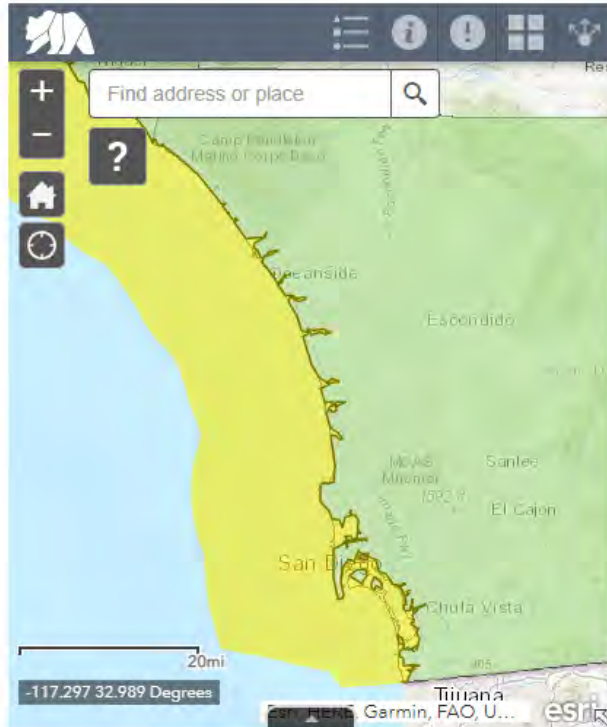


County-Specific Page Links

[Alameda \[2021\]](#)
[Contra Costa \[2021\]](#)
[Del Norte \[2021\]](#)
[Humboldt \[2021\]](#)
[Los Angeles \[2021\]](#)
[Marin **UPDATED 2022**](#)
[Mendocino \[2021\]](#)
[Monterey \[2021\]](#)
[Napa **UPDATED 2022**](#)
[Orange \[2021\]](#)
[San Diego **UPDATED 2022**](#)
[San Francisco \[2021\]](#)
[San Luis Obispo \[2021\]](#)
[San Mateo \[2021\]](#)
[Santa Barbara \[2021\]](#)
[Santa Clara \[2021\]](#)
[Santa Cruz **UPDATED 2022**](#)
[Solano **UPDATED 2022**](#)
[Sonoma **UPDATED 2022**](#)
[Ventura **UPDATED 2022**](#)

San Diego County Tsunami Hazard Areas

Explore your area of interest in the map below. You may also [OPEN THE MAP IN A NEW WINDOW](#)



What to do Before, During, and After a Tsunami in San Diego County

- [San Diego County Emergency Services Website](#)
- Make sure everyone in your home is prepared. **Register your cell phone number and email address with AlertSanDiego**, the County's emergency mass notification system. Emergency responders use AlertSanDiego to send evacuation and important incident information during an emergency in your area.
- [Ready.gov: Tsunamis](#) summarizes how to Prepare NOW, Survive DURING, and Be Safe AFTER.
- [TsunamiZone.org](#) offers suggestions and resources for your family or organization to "know your zone" and to learn how to be safe.
- [The Earthquake Country Alliance](#) develops resources and organizes activities to improve earthquake and tsunami preparedness, mitigation and resiliency. The ECA offers a host of free booklets and other materials in multiple languages.

Each County Tsunami Hazard Map has its own web page with additional local resources listed.

tsunami.ca.gov/map



[CGS Home](#)[About the CGS](#)[Earthquakes](#)[Forest & Watershed Geology](#)[Forest Biomass to Carbon-Negative Biofuels](#)[Geologic Maps & Mapping](#)[Geological Modeling](#)[Landslides](#)[Minerals](#)[Tsunamis](#)[Tsunami Maps & Data](#)[Educational Materials & FAQ](#)[Preparedness: What to do Before, During, and After a Tsunami](#)[Tsunami Technical Reports](#)[The 1992 Cape Mendocino Earthquake and Tsunami](#)[The 2011 Tōhoku-oki Earthquake and Tsunami](#)[The 2022 Tonga Tsunami](#)[Tsunami Program Contact Information](#)[Geologic Reviews](#)[Library](#)

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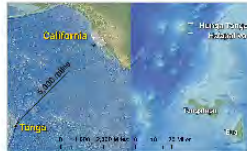
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CALIFORNIA TSUNAMI PREPAREDNESS GUIDE

California Geological Survey (CGS) Tsunami Website    

[Intro](#)

[What is a tsunami?](#)

[Where do tsunamis occur?](#)

[Recent Damaging Tsunami Events in California](#)

[Flood Model vs Hazard Area](#)

[California Tsunami Hazard Maps](#)

[Maritime Response](#)

[Get Prepared](#)

[Credits & Resources](#)

Hazard Area



Outside Hazard Area

If you are in the yellow hazard area, evacuate by foot immediately to a green area after feeling an earthquake that lasts a long time.

Use the "Find address or place" feature on the map to locate where you work, live, or visit to see if you are in a Tsunami Hazard Area (shaded yellow color).

Find address or place




Example: Arcata, CA, USA

- Use this map to **plan a safe evacuation route** outside of the hazard area (to the green area).
- If available in your area, a clickable **black-outlined box** will link you to a detailed community-specific map that you can download and/or print.




CGS Information Warehouse: Tsunami Hazard Area Map [LEARN MORE!!!](#)

Find address or place 

Welcome to the Tsunami Hazard Area Map Application

How to use this map

Locate where you live, work, or visit. If you are in the yellow hazard area after feeling an earthquake that lasts a long time, or you receive an official evacuation notification, evacuate by foot immediately to a green area.

Hazard Area  **Outside Hazard Area**

Use this map to plan a safe evacuation route. Practice evacuating so that you and your family know what to do during a real tsunami. Remember- go on foot as roads are likely to be impassable.

[OK](#)

Tsunami Preparedness Information for Recreational and Commercial Boaters

The information provided here is meant to help educate recreational and commercial boaters about how they should prepare BEFORE the next tsunami arrives on our coast. Watch the included videos and download the boaters brochure and informational poster in this section to help you prepare.

In addition, the California Tsunami Program is working with the State's maritime communities to provide more detailed maps and guidance that will help them improve their tsunami planning.

- [Tsunami Preparedness Brochure for Recreational and Commercial Boaters](#)

Boat Captain Lessons Learned

Video link: https://youtu.be/QEr_ZiVeAKw



A fisherman attempted to escape the 2011 tsunami in his boat as the tsunami was impacting the coast at Crescent City. He was lucky and was able to navigate out of the harbor, but just barely. He learned a lesson and in this video shares his experience to help educate others to never risk their lives as he did.

Boat Captain Lessons Learned Video Credit: National Weather Service Weather Forecast Office Eureka, CA <http://weather.gov/eka>

Maritime Tsunami Preparedness

 Copy link



**The west coast of the U.S. will
experience damaging tsunamis in the
future.**

**The Tōhoku event provided valuable
lessons to help California plan for the
next tsunami.**



Additional Tsunami Maritime Safety Information



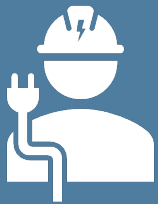
youtu.be/Lyh3ZdxrY

"Whatever you are doing,
don't do what that guy is doing."

-Alan Mello (boat captain)



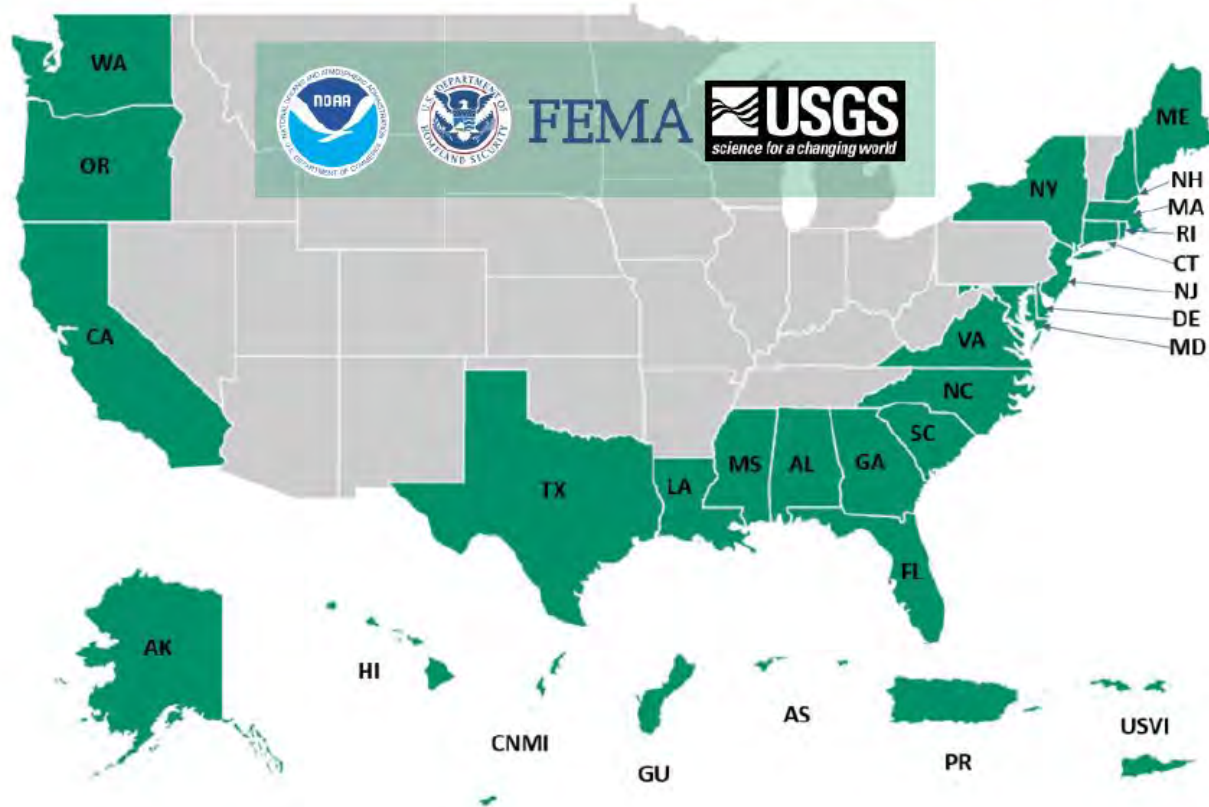
Boat attempting to leave Crescent City
Harbor during the March 11, 2011 tsunami



Get in touch for more info about Maritime Info.

NTHMP

National Tsunami Hazard Mitigation Program Partners



Tsunami Maritime Information

Tsunami Maritime Guidance

Get Link To Share Site



Home

Tsunami Alert Messaging

Boating Community

Response and Exercise

Preparedness

Mitigation

Recovery

TsunamiReady®

Hazard Analysis

Documents, Materials, and References

Partners and Agencies

Tsunami Maritime Guidance

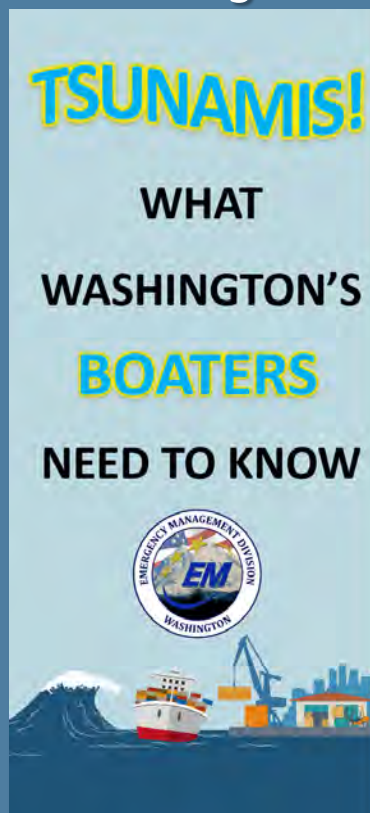
A Resource for Tsunami Hazard Planning and Preparedness for Maritime Communities

scroll down for more information about this site

[Tsunamizone.org/maritime](https://tsunamizone.org/maritime)

Tsunami Information for the Boating Community

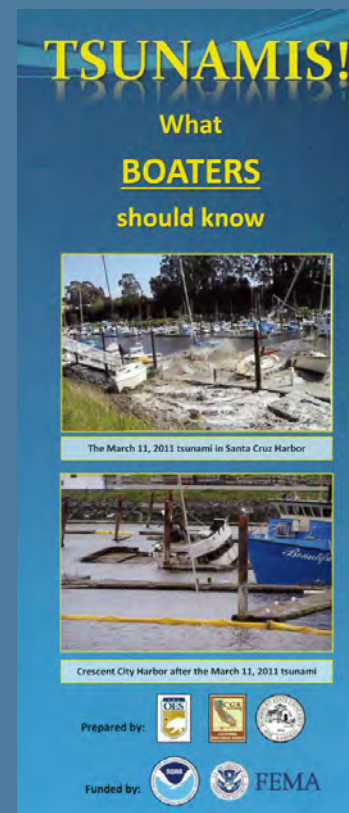
Washington



Oregon



California



Tsunami Response Guidance

Tsunami Maritime Guidance

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General Maritime Guidance

NTHMP Guidance for Safe Minimum Offshore Depth for Vessel Movement for Tsunamis

General Recommendations for Recreational and Commercial Boaters: It is NOT recommended that boaters try to take vessels offshore before or during a tsunami. And, if they are offshore, they should not try to re-enter the harbor until the harbor master or port captain indicates it is safe to do so.

LARGE LOCAL-SOURCE TSUNAMI – Tsunami may arrive in 10-15 minutes

LARGE DISTANT-SOURCE TSUNAMI – Tsunami arrival at least two-hours away

Table of specific regional guidance for minimum offshore safe depths for maritime vessel evacuation prior to the arrival of tsunami shown at right.

Disclaimer: The members of the National Tsunami Hazard Mitigation Program (NTHMP) make no representation or warranties regarding the accuracy of the information provided nor the data from which this information was derived. The NTHMP nor any Federal Agency, state, or territory shall be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or any third party on account of or arising from the use of this information. The user takes full responsibilities for their decisions and actions.

Download the document: [Guidance for Safe Minimum Offshore Depth for Vessel Movement for Tsunamis](#)

State/Territory	Distant Source (ships in harbor)*	Local Source (ships at sea)*	Notes on this Update
California	30 fathoms	100 fathoms	Evaluated; evaluating potential safe areas within large bays and ports
Oregon	30 fathoms	100 fathoms	Evaluated; also evaluating Columbia River
Alaska	30 fathoms	100 fathoms	Evaluated; ships should be at least 1/2 mile from shore for all scenarios
Washington	30 fathoms	100 fathoms	Evaluated; evaluating special conditions exist inside Puget Sound
Hawaii	50 fathoms	50 fathoms	Evaluated; implemented in Coast Guard response plans at some locations
American Samoa	50 fathoms	50 fathoms	Evaluating, guidance from others
Puerto Rico	50 fathoms	100 fathoms	Evaluated
USVI	50 fathoms	100 fathoms	Evaluating; possibly follow PR
Guam	50 fathoms	100 fathoms	Coordinated with USCG Guam Sector
CNMI	50 fathoms	100 fathoms	Coordinated with USCG Guam Sector
Gulf Coast States		100 fathoms	Evaluating; issues with long, shallow shelf complicate getting beyond safe depth
East Coast States		100 fathoms	Evaluating; issues with long, shallow shelf complicate getting beyond safe depth

* Ships also recommended to be a minimum of 1/2 mile from shore or fringing reef

**Before you leave safe harbor,
Remember to ask yourself if you will be
S.A.F.E**



S

SIZE of the tsunami.

For most harbors in California, it is safer to keep your boat docked during a tsunami because most tsunamis are relatively small.

A

ARRIVAL time of tsunami.

Do you have enough time to safely evacuate the tsunami hazard area? Know how long it takes your boat to get to deep water (30 fathoms or 180 feet depth).

F

FITNESS of the boat and its captain.

Are you mentally and physically prepared to remain offshore for 24 hours or longer? Do you have adequate supplies such as water, shelter, food, and fuel?

E

ENVIRONMENTAL conditions.

Weather conditions at sea could be as dangerous as the tsunami itself.

In a distant source tsunami, more than 3 hours before the time of tsunami arrival, the boat owner may consider taking their boat offshore if they follow these S.A.F.E. guidelines. Do not go offshore unless you are very sure that you can get 30 fathoms (180 feet) before the tsunami arrives.

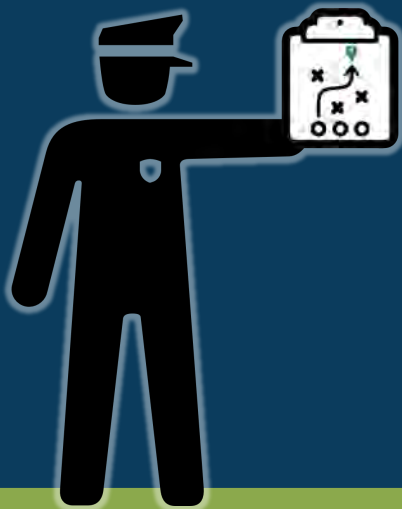
What's the Playbook Purpose?



Evacuation Playbooks (Phase 1, 2, 3, Maximum)

Maximum time for primary-source events with time to prepare for secondary/smaller evacuation

- More than 3-4 hours to prepare



Maritime Playbooks (Plan A, B, C, D, E)

- For all ports, harbors, and marinas susceptible to tsunami damage
- Help maritime officials assess their harbor hazard and develop response/mitigation strategies
- Response plans should only be used if sufficient time exists for strengthening harbor infrastructure and for relocating vessels



What are Playbook Phases?

Evacuation Playbooks



Phase 1, 2, 3, max

Simple and straightforward response options for tsunami evacuation/response.



Google Earth

Invitation to Participate in Study on Quantifying Tsunami Vulnerability of Small Harbors in California

This project is grant-funded by FEMA to help small-boat harbors in California take advantage of harbor improvement funding opportunities.

Harbor Improvement Reports may be used for...

- Pre-disaster recovery planning (identifying areas where damage may occur, anticipated location of sediment scour/transport, and post-event accumulation of debris)
- Port Management Plans (reducing exposure of essential facilities and infrastructure to hazards)
- General Plan-Safety Elements
- Local Coastal Plans
- Long-term planning

If you are interested in participating in this program, please reach out to CGS Engineering Geologist Nick Graehl, the lead for this program.

Nicholas.Graehl@conservation.ca.gov



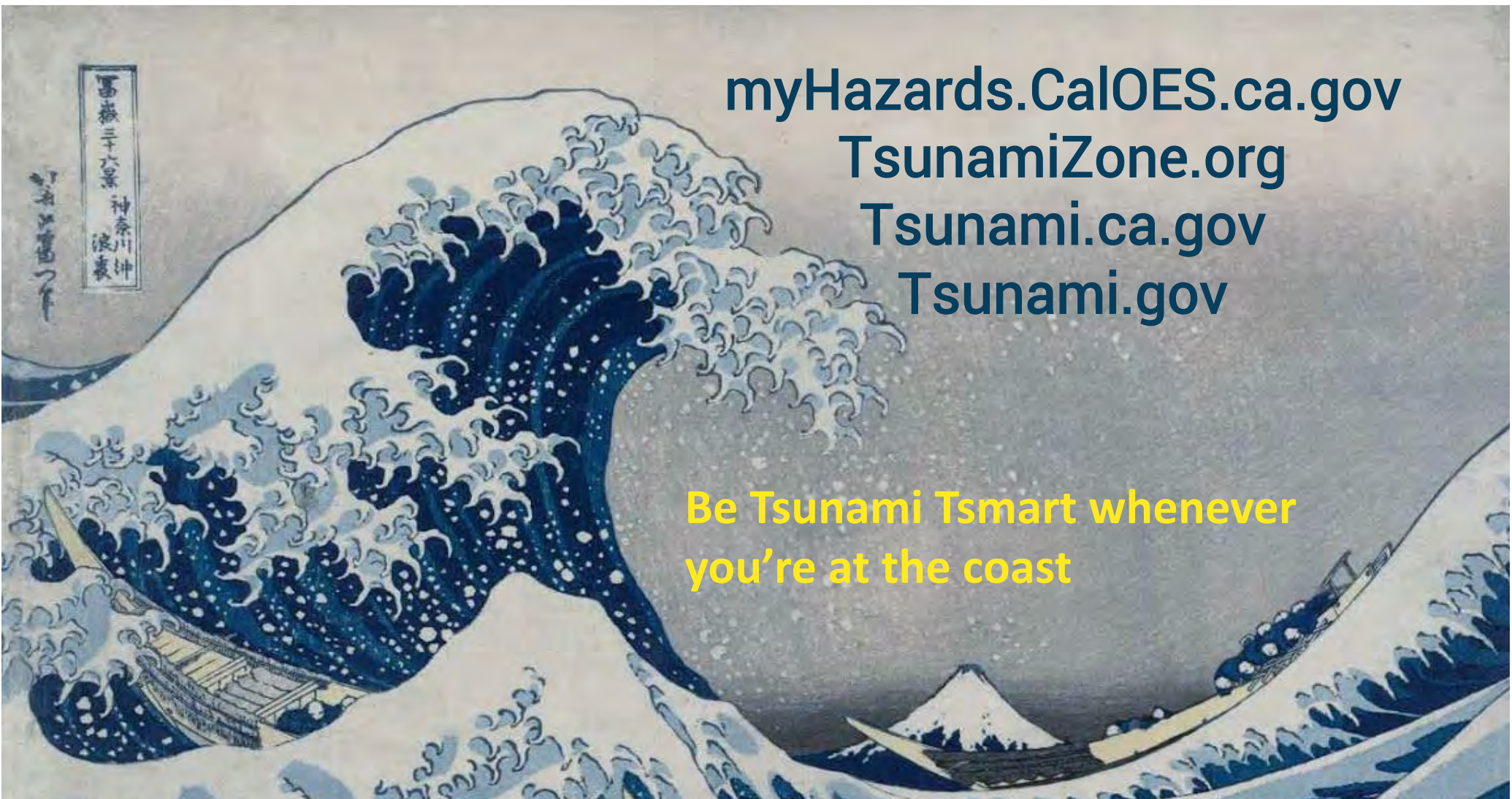


Understanding Tsunami Hazards in California

Even though large tsunamis are rare, the entire California coast is at risk.

California has a history of damaging tsunamis which have resulted in loss of life and severe damage to harbor and coastal areas.

Awareness, planning, and preparedness can save lives and keep communities resilient.

The background of the slide is a reproduction of the famous Japanese woodblock print 'The Great Wave off Kanagawa' by Katsushika Hokusai. It depicts a massive, curling blue wave with white foam, about to crash over three small boats. In the distance, the snow-capped peak of Mount Fuji is visible under a pale, overcast sky. In the upper left corner, there is a small rectangular box containing Japanese text: '富嶽三十六景' (Fujikoku Sanjūrokkai), '神奈川沖' (Kana-gawa no Umi), and '波巻' (Nami Makuru).

myHazards.CalOES.ca.gov
TsunamiZone.org
Tsunami.ca.gov
Tsunami.gov

Be Tsunami Tsmart whenever
you're at the coast