U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves

Update

Will be shipped to Printers next week

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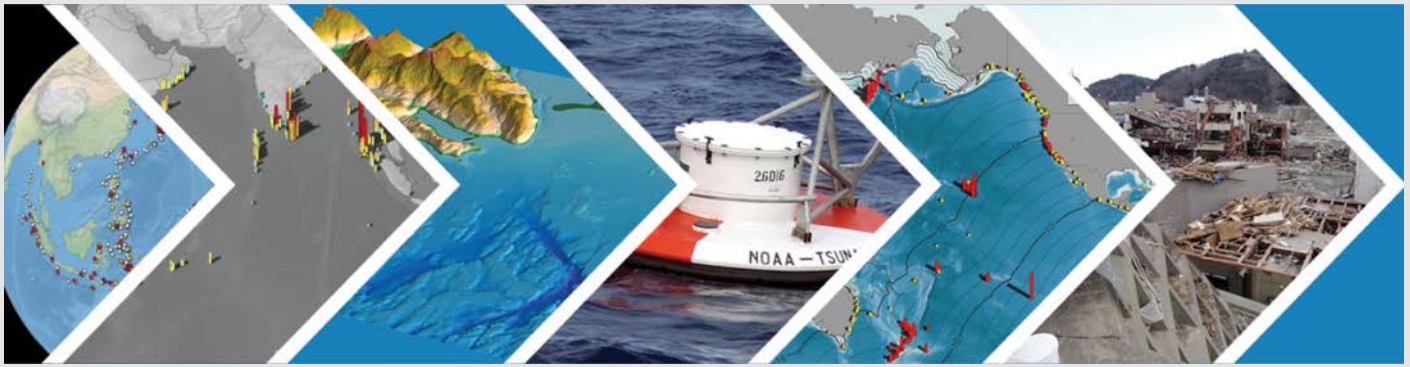
NOAA/NCEI and ICSU World Data System

- NOAA/NCEI Boulder, Colorado, USA and co-located World Data Service (WDS) for Geophysics provide **long-term archive, data management, and access to global tsunami data**
  - **global historical tsunami data**, damage photos, raw and processed water level data from NOAA observational networks, and development of digital elevation models (DEMs)



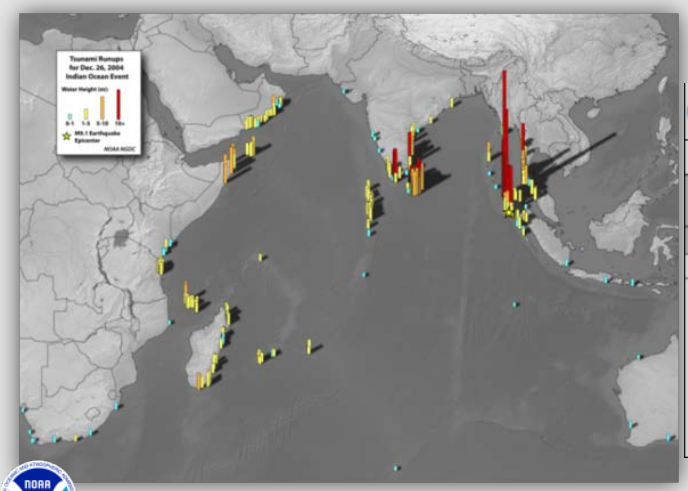
Global Historical Tsunami Data

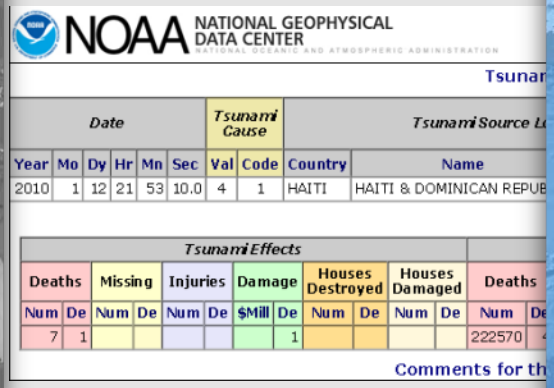
Know the past to better understand the future

The historical tsunami database is a scientifically curated list of tsunami source events and water height locations throughout the world that range in date from 2000 B.C. to the present. These data support:

- Forecast and Warning, media response, tsunami model validation, coastal hazard assessments and community resiliency

- ***Authoritative source*** for historical tsunami event data
- Database is continuously updated based on new sources
- **doi:10.7289/V5PN93H7**





NOAA NATIONAL GEOPHYSICAL DATA CENTER

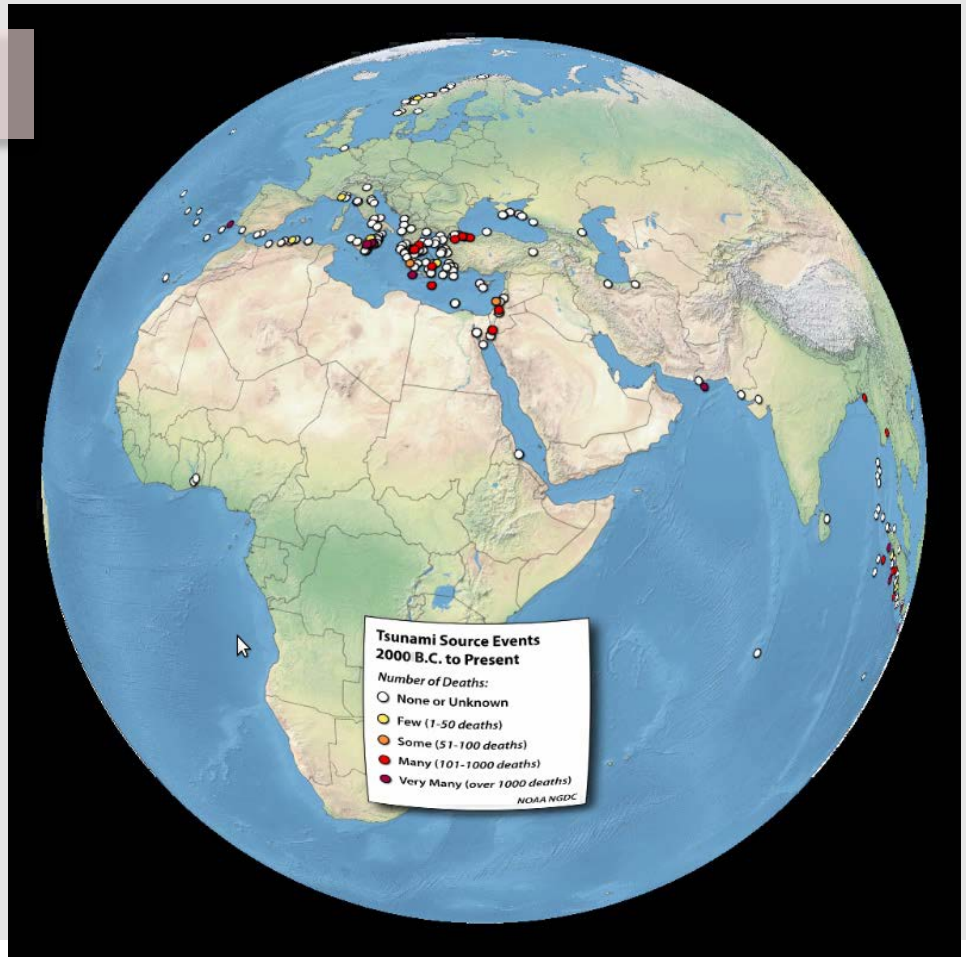
Date						Tsunami Cause		Tsunami Source Lo	
Year	Mo	Dy	Hr	Mn	Sec	Val	Code	Country	Name
2010	1	12	21	53	10.0	4	1	HAITI	HAITI & DOMINICAN REPUB

Tsunami Effects													
Deaths		Missing		Injuries		Damage		Houses Destroyed		Houses Damaged		Deaths	
Num	De	Num	De	Num	De	$Mill	De	Num	De	Num	De	Num	De
7	1						1					222570	

Tsunami Source Events

- Date, location, latitude/longitude, cause (e.g. earthquake, volcanic eruption), maximum water height, socio-economic data (deaths, injuries, damage), references

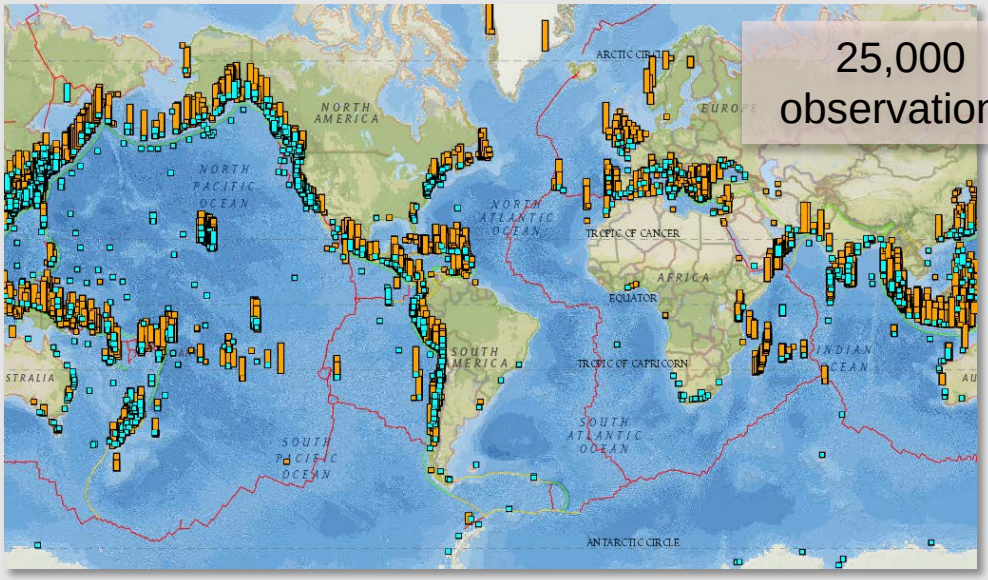
1,017 (validity 1-2)
1,228 (validity 3-4)

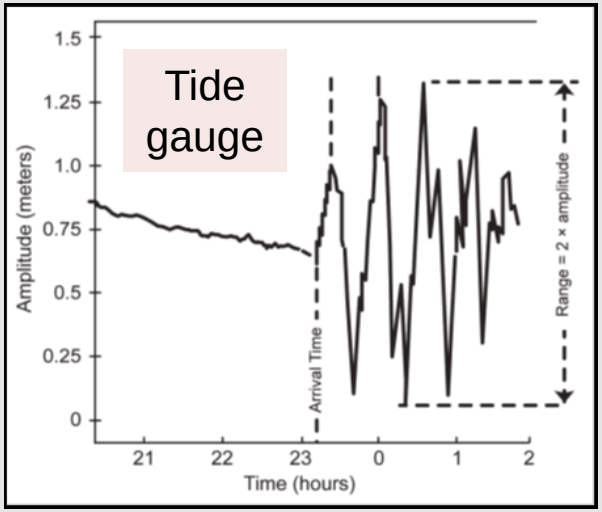


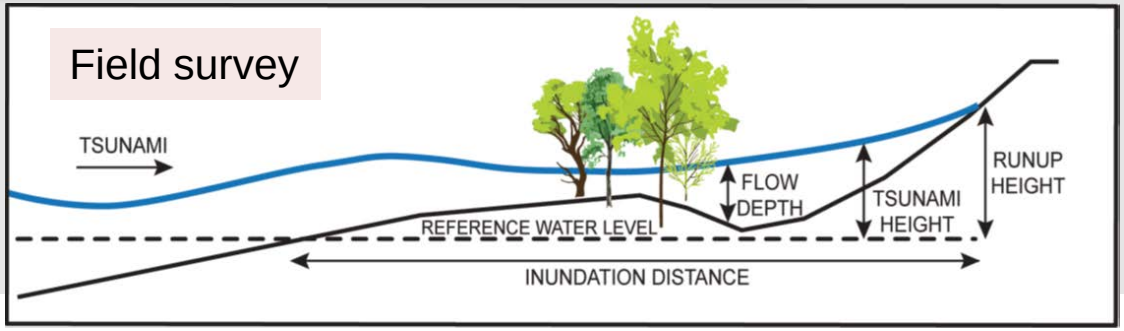
249 confirmed fatal tsunami events. Deadliest event: 2004 Sumatra with over 227,000 deaths

Tsunami Wave Observations

- Eyewitness, field survey, tide gauge, DART
  - Location name, latitude/longitude, wave arrival time, wave height, inundation distance, socio-economic (deaths, injuries, damage), references



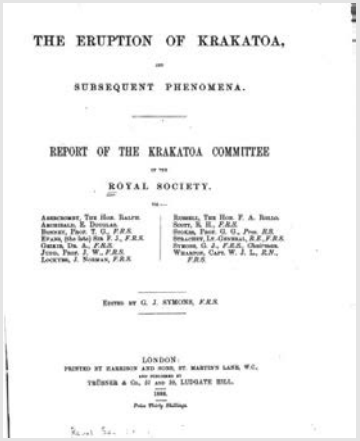


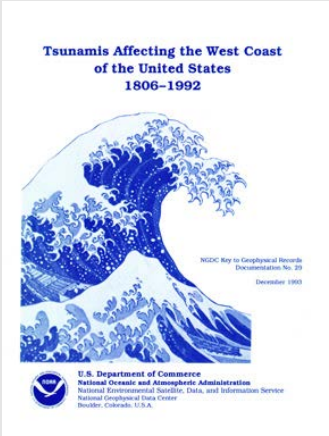


Source Documents

Over 3,000 documents that describe damage and effects from tsunami, earthquake, and volcano events. Types of documents:

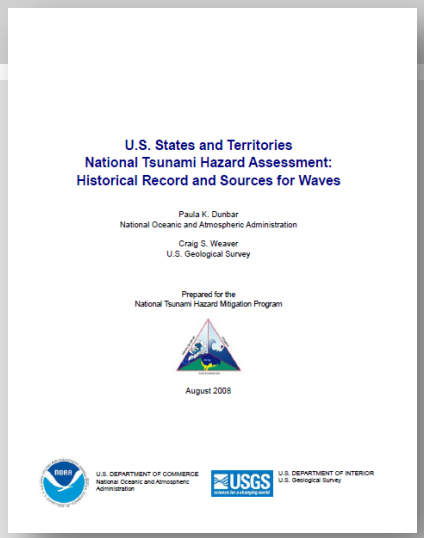
- NOAA National Weather Service Tsunami Warning Centers
- US Geological Survey National Earthquake Information Center
- NOAA/IOC/UNESCO International Tsunami Information Center
- National and International Tsunami Survey Teams
- Journal articles, newspaper reports, web articles, e-mail, diaries, ships logs
- Tsunami, Earthquake, Volcano catalogs





Background, 1st Assessment

- The U.S. National Tsunami Hazard Mitigation Program (NTHMP) requested 1st Assessment
  - NTHMP: federal, state, territorial agencies
  - Natl Science & Technology Council released report ***Tsunami Risk Reduction for the United States***
    - Develop tsunami hazard and risk assessments for all coastal regions of the U.S. States and Territories


U.S. States and Territories
National Tsunami Hazard Assessment:
Historical Record and Sources for Waves

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Prepared for the
National Tsunami Hazard Mitigation Program

August 2008

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

USGS

U.S. DEPARTMENT OF INTERIOR
U.S. Geological Survey

- NOAA's National Centers for Environmental Information (NCEI)
  - Catalogs information on global historical tsunamis
- U.S. Geological Survey (USGS)
  - Conducts research on earthquake hazards facing the U.S.
- NCEI & USGS conducted the 1st U.S. Tsunami Hazard Assessment, published 2008

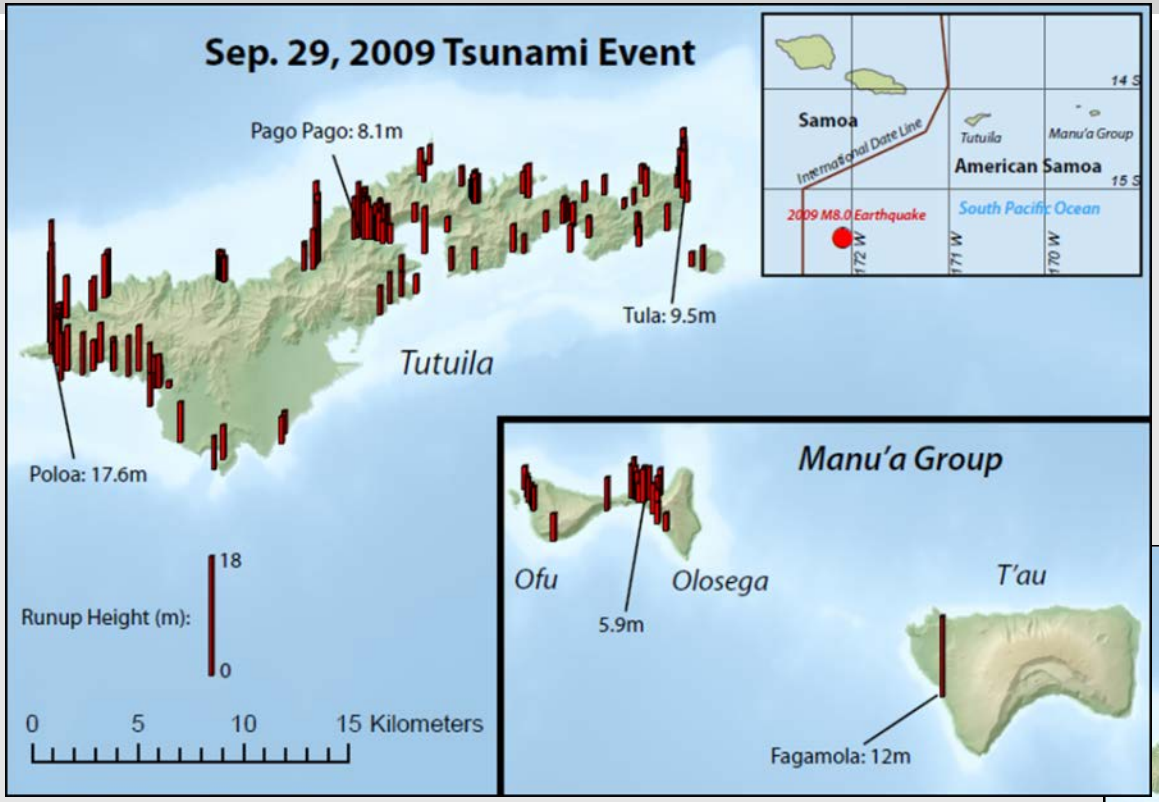
Since the 1st Assessment

- Significant events
  - 2009 Samoa, Mw 8.1
    - American Samoa: 3-18m runups, 39 Deaths, $126 million
  - 2010 Maule, Chile Mw 8.8
    - California: 1m runups & strong currents, $3 million
  - 2011 Great East Japan, Mw 9.0
    - Hawaii: 3-5m runups, $31 million
    - California: 1-2.5m runups & strong currents, 1 Death, $50 million

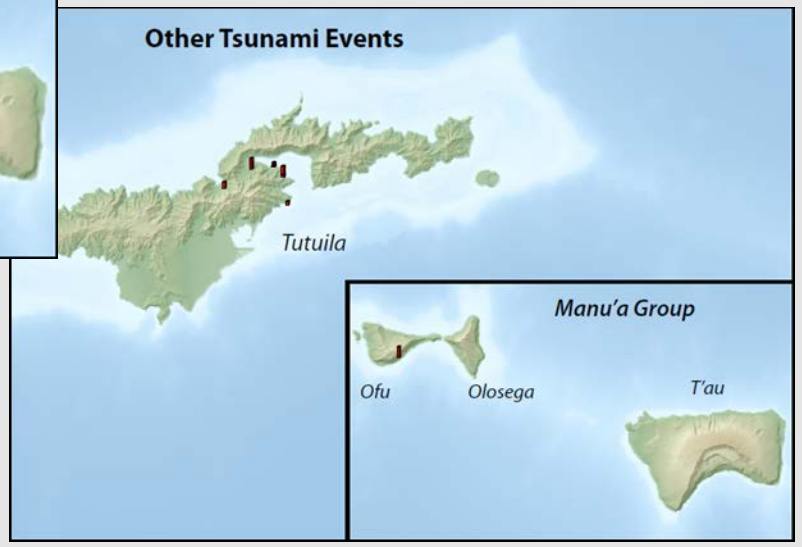
Crescent City Harbor damage from 2011 Japan, tsunami. Credit: Rick Wilson, California Geological Survey.

- New research results
- National Academies Assessment of Tsunami Program, 2011
  - Periodic assessment of the sources of tsunamis that threaten the U.S.
- NTHMP requested an Update

American Samoa



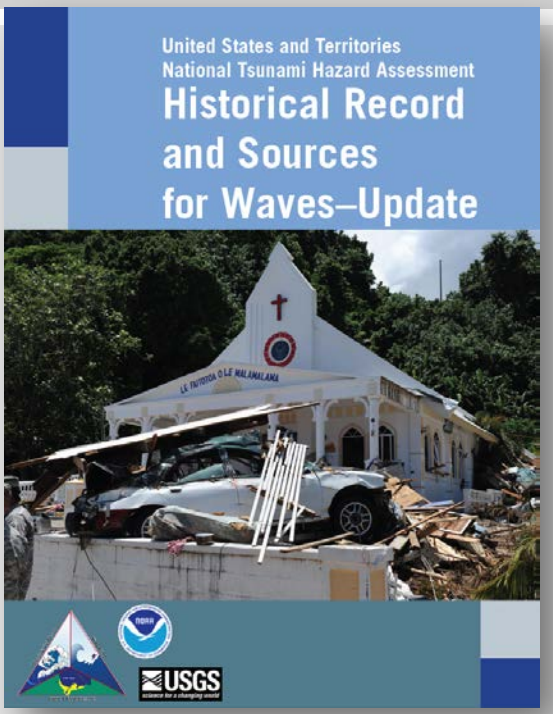
- Sept 29, 2009
  - Tide gauge 2.7 m
  - 218 field survey points
    - **>3m – 169**
    - **>10m - 10**



- 59 events observed in AS < 2009
  - 56 tide gauge (Pago Pago):
    - **majority < 0.3m**
  - 9 eyewitness: < 3.0 m

Tsunami Hazard Assessment

- Probabilistic tsunami hazard analysis
  - Historical and Prehistorical (paleo) tsunami data
  - Quantitative probabilistic models of local and far-field tsunami sources (earthquake, landslide, volcano)
  - High-resolution DEMs (topography, bathymetry, tidal information)
  - Numerous propagation and inundation simulations for tsunami sources
- Goal of the ***First Assessment***
  - Qualitative assessment of the hazard at the state/regional level
- Goal of the ***Second Assessment***
  - Update the qualitative assessment with new database searches, provide an overview of latest research, evaluate hazard levels



Database Quality Control

- Tsunami source events affecting the U.S. and runups were reviewed for accuracy
  - Check original sources, crosscheck with earthquake, volcano, hurricane catalogs
  - Check Deaths, damage, water heights
- Events were selected for further examination
  - Validity 3 or 4
  - Runup not flagged as doubtful
  - Waves reported on inland waters were not counted
  - Not meteorologically caused – not enough data to include
    - Oct 2008 and June 2013 Atlantic meteotsunamis discussed
  - All dates were included - 1690 Virgin Islands earliest report

Examine the Historical Tsunami Record

- Count tsunami events affecting each state
  - Bin tsunami events based maximum measured runup
    - Undetermined
    - 0.01 m ≤ runup ≤ 0.3 m
    - 0.3 m < runup ≤ 1.0 m ⟵ ***Advisory - U.S. Tsunami Warning Centers***
    - 1.0 m < runup ≤ 3.0 m ⟵ ***Warning - U.S. Tsunami Warning Centers***
    - 3.0 m < runup
- Tsunami event could be counted in several states
  - 1952, 1960, 1964, etc.
- Although not a vulnerability or risk assessment
  - Examine the severity of tsunamis by counting total number of deaths and dollar damage due to tsunamis in each state

Tsunami Runup Events

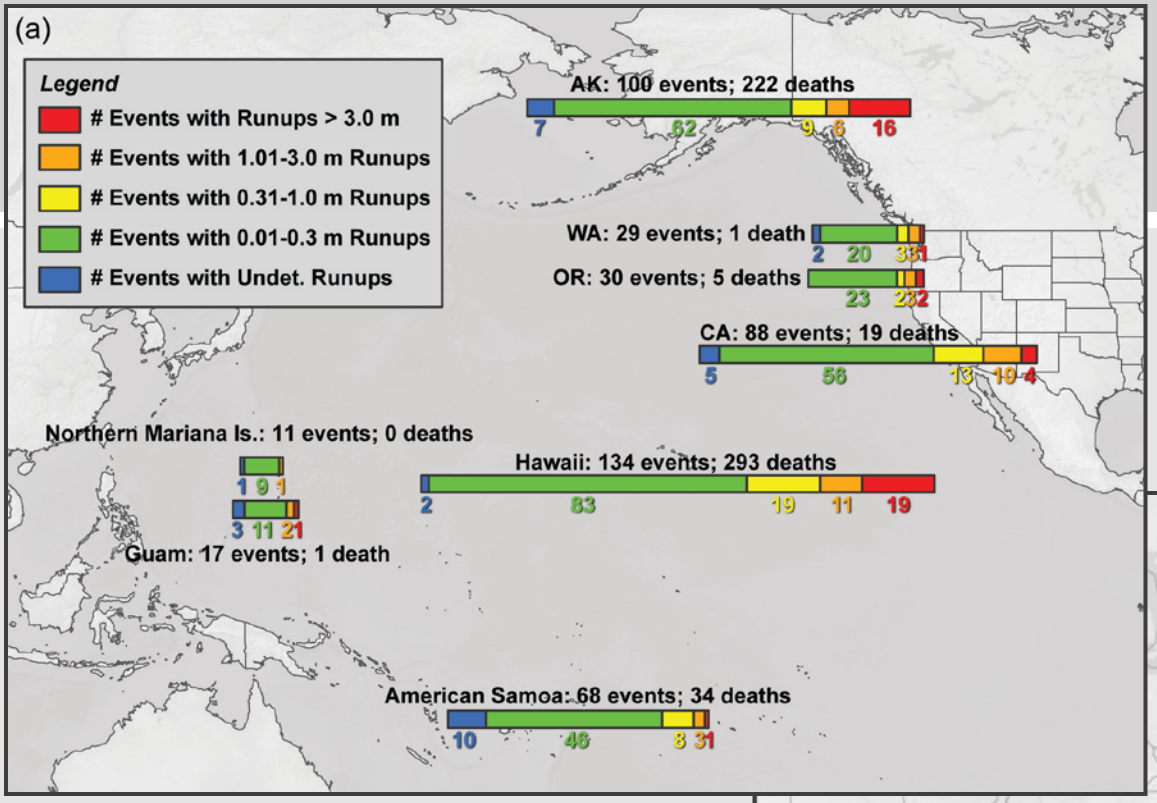
- State tsunami runup events range from **none** in PA, DE, VA, NC, GA, AL, MS, and LA to **134** in Hawaii
- Change from 1st
  - Added year of 1st tide gauge installation
  - Pacific Island Territories grouping
  - Added Alaska Arctic Coast

Table 2-1. Tsunami runup events, total number of runups, deaths, and dollar damage by state/territory and region from the NOAA/NCEI tsunami database (extracted January 9, 2015). Dollars have not been adjusted for inflation. See Section 2.3.3 for an explanation of the counts. For more information on specific tsunamis, access the online database at http://www.ngdc.noaa.gov/hazard/tsu_db.shtml.

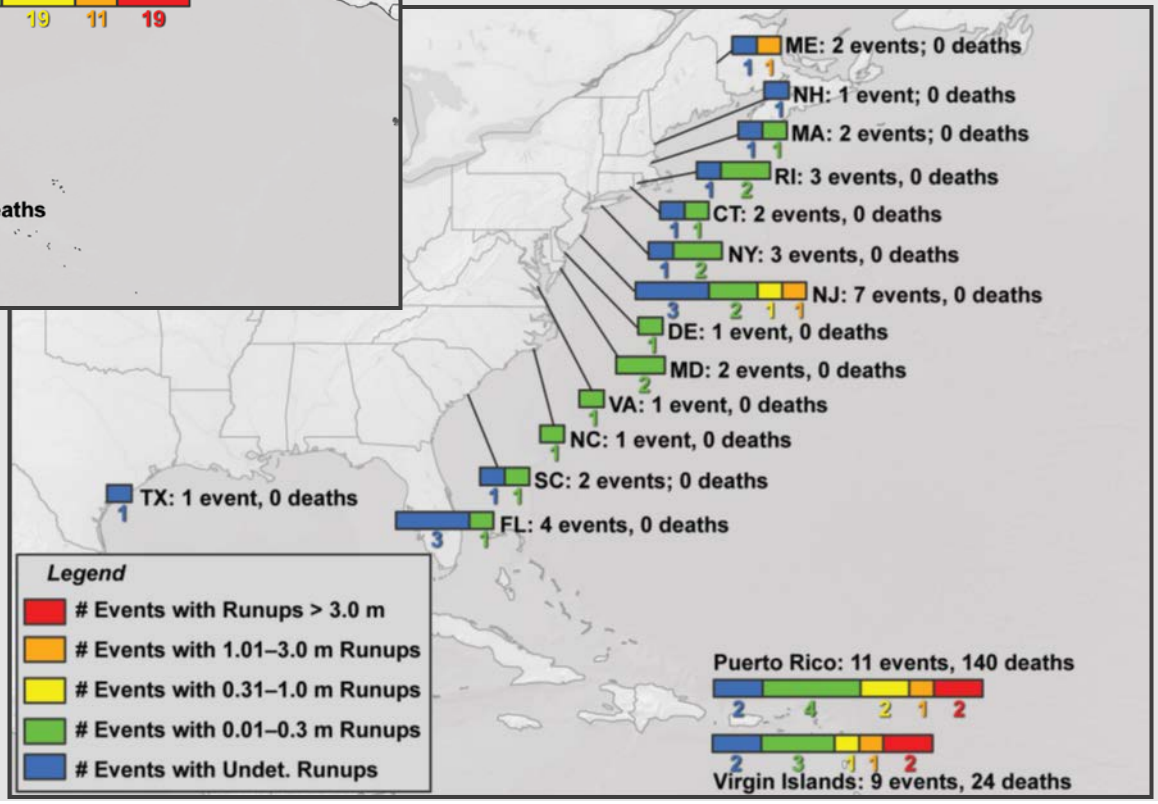
Location (year of tide gauge installation, first confirmed report)	Total Events	Undetermined	Runups (m)				Total Runups	Reported Deaths	$Million Damage Reported
			0.01 to 0.3	0.31 to 1.0	1.01 to 3.0	>3.0			
Maine (1847, 1929)	1	1					3		
New Hampshire (1926, 1929)	1	1					1		
Massachusetts (1847, 1929)	1	1					2		
Rhode Island (1844, 1929)	2	1	1				3		
Connecticut (1932, 1964)	1	1					1		
New York (1844, 1895)	2	1	1				7		
New Jersey (1844, 1918)	6	3	2	1			8		
Pennsylvania (1922 , _)									
Delaware (1896 , _)									
Maryland (1844, 1929)	1		1				1		
Virginia (1844 , _)									
North Carolina (1882, _)									
South Carolina (1850, 1886)	2	1	1				2		
Georgia (1851, _)									
Florida (1855, 1886)	4	3	1				5		
U.S. Atlantic Coast Totals	**21**	**13**	**7**	**1**	**0**	**0**	**33**	**0**	**$0**
Florida (1858, _)									
Alabama (1846, _)									
Mississippi (1848, _)									
Louisiana (1932, _)									
Texas (1852, 1918)	1	1					1		
U.S. Gulf Coast Totals	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**$0**
Puerto Rico (1954, 1867)	10	2	3	2	1	2	36	140	$4
Virgin Islands (1975, 1690)	9	2	3	1	1	2	23	24	
PR & VI Totals	**19**	**4**	**6**	**3**	**2**	**4**	**59**	**164**	**$4**
Washington (1855, 1891)	29	2	20	3	3	1	100	1	$1
Oregon (1853, 1854)	30		23	2	3	2	106	5	$1
California (1853, 1812)	88	5	56	13	10	4	641	19	$80
U. S. West Coast Totals	**147**	**7**	**99**	**18**	**16**	**7**	**847**	**25**	**$82**
Guam (1948, 1849)	17	3	11		2	1	26	1	
Northern Mariana (1978, 1990)	11	1	9		1		12		
Guam & N. Mariana Is. Totals	**28**	**4**	**20**	**0**	**3**	**1**	**38**	**1**	
American Samoa (1922, 1837) Totals	**68**	**10**	**46**	**8**	**3**	**1**	**293**	**34**	**$126**
Alaska Arctic Coast (1993, _) Totals	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**$0**
Alaska (1872, 1737) Totals	**100**	**7**	**62**	**9**	**6**	**16**	**492**	**222**	**$110**
Hawaii (1872, 1812) Totals	**134**	**2**	**83**	**19**	**11**	**19**	**2002**	**293**	**$90**
AMERICAN Totals	**518**	**48**	**323**	**58**	**41**	**48**	**3765**	**739***	**$412**

**Includes 5 indirect deaths: Hawaii in 1957 (2) and 2012 (1), California in 1960 (1) and 1964 (1)*

Tsunami Runup Events



90% - Pacific Basin
10% - Atlantic Basin



U.S. experience with tsunamis is greatest in the Pacific Basin

Difference 1st and 2nd Tsunami Counts

- Most changes occurred in Pacific
- Changes in American Samoa from 2009 tsunami
- Improved accounting
  - 1868 California: 34 deaths counted twice
  - 1867 Virgin Is: 24 vs 30 deaths
  - 1918 Puerto Rico: 140 vs 142 deaths
  - 1964 Alaska: Kodiak Naval Station $10.3 million counted twice, Point Whitshed $1.7million error

Regional Totals	Total Tsunami Events	Total Runups for all Events	Deaths	$Million Damage Reported
U.S. Atlantic Coast	0	0	0	$0
U.S. Gulf Coast	0	0	0	$0
Puerto Rico and the Virgin Islands	3	11	–8	$0
U.S. West Coast	34	297	1	$60
Guam and N. Mariana Is.	12	14	0	$0
American Samoa	12	233	34	$126
Alaska Arctic Coast	0	0	0	$0
Alaska	19	140	0	–$12
Hawaii	20	410	–33	$31
American Totals	99	1104	–7	$205

Tsunami Runup Eevents

- Runup Event Heights
  - **Very Low**: Zero events
  - **Low**: all runups **≤1.0m**
  - **Moderate**: runups **>1.0m** & no runups >3.0m
  - **High**: runups **>3.0m**
  - **Very High**: runups **>3.0m**& >50 total events
- Runup Event Heights Per Year
  - **Very Low**: Zero events
  - **Low**: all events >0.0 and no events with runups >1.0m
  - **Moderate**: >0.01 for runups **>1.0m** and no runups >3.0m
  - **High**: ≥0.01 for runups **>3.0m**
  - **Very High**: ≥0.02 for runups **>3.0m**
    ~ >3m at least once every 50 years

	Location (year of tide gauge installation, first confirmed report)	Total Events	Time Interval (Years)	Total Events per Year	Total Events >1.0m	Events with >1.0m per year	Total Events >3.0m	Events with >3.0m per year
Atlantic Coast	Maine (1847, 1929)	1	168	0.01	0	0.00	0	0.00
	New Hampshire (1926, 1929)	1	89	0.01	0	0.00	0	0.00
	Massachusetts (1847, 1929)	1	168	0.01	0	0.00	0	0.00
	Rhode Island (1844, 1929)	2	171	0.01	0	0.00	0	0.00
	Connecticut (1932, 1964)	1	83	0.01	0	0.00	0	0.00
	New York (1844, 1895)	2	171	0.01	0	0.00	0	0.00
	New Jersey (1844, 1918)	6	171	0.04	0	0.00	0	0.00
	Pennsylvania (1922 , _)	0	93	0.00	0	0.00	0	0.00
	Delaware (1896 , _)	0	119	0.00	0	0.00	0	0.00
	Maryland (1844, 1929)	1	171	0.01	0	0.00	0	0.00
	Virginia (1844 , _)	0	171	0.00	0	0.00	0	0.00
	North Carolina (1882, _)	0	133	0.00	0	0.00	0	0.00
	South Carolina (1850, 1886)	2	165	0.01	0	0.00	0	0.00
	Georgia (1851, _)	0	164	0.00	0	0.00	0	0.00
	Florida (1855, 1886)	4	160	0.03	0	0.00	0	0.00
Gulf Coast	Florida (1858, _)	0	157	0.00	0	0.00	0	0.00
	Alabama (1846, _)	0	169	0.00	0	0.00	0	0.00
	Mississippi (1848, _)	0	167	0.00	0	0.00	0	0.00
	Louisiana (1932, _)	0	83	0.00	0	0.00	0	0.00
	Texas (1852, 1918)	1	163	0.01	0	0.00	0	0.00
	Puerto Rico (1954, 1867)	10	148	0.07	3	0.02	2	0.01
	Virgin Islands (1975, 1690)	9	325	0.03	3	0.01	2	0.01
West Coast	Washington (1855, 1891)	29	160	0.18	4	0.03	1	0.01
	Oregon (1853, 1854)	30	162	0.19	5	0.03	2	0.01
	California (1853, 1812)	88	203	0.43	14	0.07	4	0.02
	Guam (1948, 1849)	17	166	0.10	3	0.02	1	0.01
	N. Mariana Is (1978, 1990)	11	37	0.30	1	0.03	0	0.00
	American Samoa (1922, 1837)	68	178	0.38	4	0.02	1	0.01
	Alaska Arctic Coast (1993, _)	0	22	0.00	0	0.00	0	0.00
	Alaska (1872, 1737)	100	278	0.36	22	0.08	16	0.06
	Hawaii (1872, 1812)	134	203	0.66	30	0.15	19	0.09

Qualitative Tsunami Hazard Assessment based on the Historical Record

Table 2-6. Qualitative tsunami hazard assessment based on runup height.

Hazard Based on Runup Height	State/Territory
Very Low	Pennsylvania, Delaware, Virginia, North Carolina, Georgia, Florida (Gulf coast), Alabama, Mississippi, Louisiana, Alaska Arctic coast
Low	Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, South Carolina, Florida (Atlantic coast), Texas
Moderate	Northern Mariana Islands
High	Puerto Rico, Virgin Islands, Washington, Oregon, Guam
Very High	California, American Samoa, Alaska, Hawaii

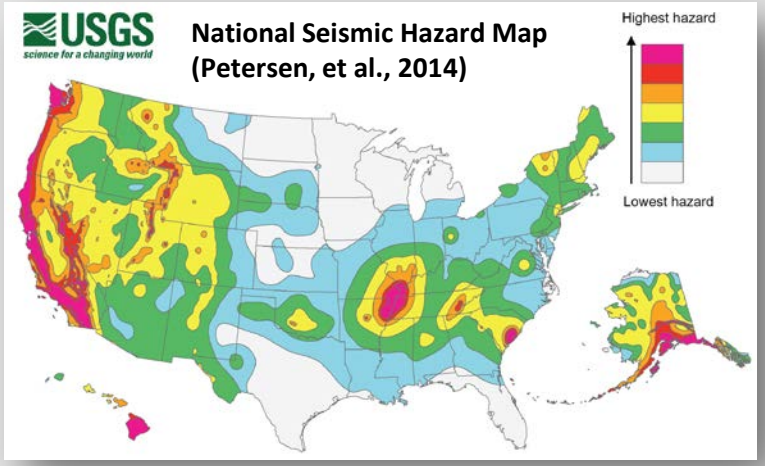
Table 2-7. Qualitative tsunami hazard assessment based on runup frequency.

Hazard Based on Runup Frequency	State/Territory
Very Low	Pennsylvania, Delaware, Virginia, North Carolina, Georgia, Florida (Gulf coast), Alabama, Mississippi, Louisiana, Alaska Arctic coast
Low	Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, South Carolina, Florida (Atlantic coast), Texas
Moderate	Northern Mariana Islands
High	Puerto Rico, Virgin Islands, Washington, Oregon, Guam, American Samoa
Very High	California, Alaska, Hawaii

Hazard Based on Historical Record	State/Territory
Very Low	Pennsylvania, Delaware, Virginia, North Carolina, Georgia, Florida (Gulf coast), Alabama, Mississippi, Louisiana, Alaska Arctic coast
Low	Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, South Carolina, Florida (Atlantic coast), Texas
Moderate	none
High	Puerto Rico, Virgin Islands, Washington, Oregon, Guam, Northern Mariana Islands, American Samoa
Very High	California, Alaska, Hawaii

USGS National Seismic Hazard Maps (NSHM)

Earthquake databases can be used to extend the historical tsunami record backward in time. No change in tsunamigenic earthquakes in NSHM since 2008 report.



Subduction zones, 2008 report

State/Territory	Non-subduction earthquake with mag > 6.5 in 500 years within 50 km of coast	Subduction zone event with mag >msubduct in 500 years within 150 km of coast	Maximum magnitude observed or estimated for nearshore or offshore	Comment
Puerto Rico and the Virgin Islands, msubduct = 7.5				
Puerto Rico	100%	~100%	7.5	1918 Mona Passage, severe tsunami**
Virgin Islands	100%	~100%	7.5	1867 Virgin Islands, severe tsunami
Pacific Coast--Cascadia, msubduct = 8.1				
Washington	30% to 90%	~100%	9+	1700 Cascadia, severe tsunami
Oregon	10% to 100%	~100%	9+	1700 Cascadia, severe tsunami
California	100%	~100%	9+	1700 Cascadia, severe tsunami
Pacific Coast--Alaska, msubduct = 7.5				
Alaska	100%*	~100%	9.2	1964 Alaska, severe tsunami
Western Pacific, msubduct = 7.8				
Guam	N/A	~100%	7.8	1993 Guam, non-destructive tsunami
Northern Mariana	N/A	~100%	7.8	1993 Guam, non-destructive tsunami
American Samoa	N/A	~100%	8.5	1917 Northern Tonga trench, moderate tsunami

Alaska calculation for mag>6.5 includes subduction interface events
*Events as large as magnitude ~8 are estimated in the Puerto Rico trench

Non-Subduction zones, 2008 report

State/Territory	Earthquake with Mag > 6.5 in 500 years within 50 km of coast	Earthquake with Mag > 6.5 in 5000 years within 50 km of coast	Historical maximum magnitude observed nearshore or offshore	Comment
U.S. Atlantic Coast				
Maine	<3%	<30%	<6	
New Hampshire	<3%	<30%	<6	
Massachusetts	<3%	<25%	<6	
Rhode Island	<2%	<15%	<6	
Connecticut	<2%	<30%	<6	
New York	<4%	<30%	<6	
New Jersey	<4%	<30%	<6	
Pennsylvania	<3%	<15%	<6	
Delaware	<3%	<15%	<6	
Maryland	<2%	<15%	<6	
Virginia	<1%	<4%	<6	
North Carolina	<1 to 5%	<5%	<6	
South Carolina	<35%	100%	7.3	1886 Charleston, non-destructive tsunami
Georgia	<1%	<10%	<6	
Florida	<1%	<3%	<6	
U.S. Gulf Coast				
Florida	<1%	<3%	<6	
Alabama	<1%	<4%	<6	
Mississippi	<1%	<5%	<6	
Louisiana	<1%	<5%	<6	
Texas	<1%	<4%	<6	

Hawaii, S. California, and Arctic Coast of Alaska, 2008 report

State/area	Mag > 6.5 in 500 years within 50 km of coast	Mag > 7.5 in 500 years within 50 km of coast	Maximum magnitude observed or estimated for nearshore or offshore	Comment
Hawaii and Southern California				
Hawaii	~100%	~100%	7.9	1868 Ka'u district, severe tsunami
Southern California	~100%	~100%	7.1	1927 Lompoc, moderate tsunami
Arctic Coast—Alaska				
Alaska	<1%	N/A	<6	Arctic coast rated no tsunami risk by Alaska

Qualitative Tsunami Hazard Assessment based on USGS NSHM databases

Table 2-9. Qualitative tsunami hazard assessment based on USGS NSHM databases. [Table 3-4 in first assessment (Dunbar and Weaver, 2008).]	
Region	Probability that an Earthquake Generates a Local Tsunami In 500 Years by Seafloor Displacement
U.S. Atlantic Coast	Very Low to Low
U.S. Gulf Coast	Very Low
Puerto Rico and the Virgin Islands	High
U.S. West Coast	High
Alaska	High
Hawaii	High
U.S. Pacific Island Territories	High

Qualitative Tsunami Hazard Assessment based on NCEI and USGS NSHM database searches

Hazard Based on Historical Record	State/Territory
Very Low	Pennsylvania, Delaware, Virginia, North Carolina, Georgia, Florida (Gulf coast), Alabama, Mississippi, Louisiana, Alaska Arctic coast
Low	Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, South Carolina, Florida (Atlantic coast), Texas
Moderate	none
High	Puerto Rico, Virgin Islands, Washington, Oregon, Guam, Northern Mariana Islands, American Samoa
Very High	California, Alaska, Hawaii

Region	Probability that an Earthquake Generates a Local Tsunami In 500 Years by Seafloor Displacement
U.S. Atlantic Coast	Very Low to Low
U.S. Gulf Coast	Very Low
Puerto Rico and the Virgin Islands	High
U.S. West Coast	High
Alaska	High
Hawaii	High
U.S. Pacific Island Territories	High

Region	Hazard based on Historical Record and Earthquake Probabilities	Number of Reported Deaths
U.S. Atlantic Coast	Very Low to Low	None
U.S. Gulf Coast	Very Low	None
Puerto Rico and the Virgin Islands	High	164
U.S. West Coast	High to Very High	25*
Guam and N. Mariana Islands	High	1
American Samoa	High	34
Alaska Arctic Coast	Very Low	None
Alaska	High to Very High	222
Hawaii	High to Very High	293

* Does not include any deaths caused by the 1700 Cascadia tsunami on the U.S. West Coast.

Comparison of 2008 and 2015 Tsunami Hazard Assessments

- U.S. Pacific Is region dropped
- American Samoa, Guam and N. Mariana Is: raised to High – history and tectonics
- U.S. West coast: raised to High to Very High based on California runup height and frequency

Region	*Hazard based on runups*	*Hazard based on frequency*	*Hazard based on local earthquakes*	*Number of reported deaths*
U.S. Atlantic coast	Very low to low	Very low	Very low to low	None
U.S. Gulf coast	Very low	Very low	Very low	None
Puerto Rico and the Virgin Islands	High	High	High	172
U.S. west coast	High	High	High	25
Alaska	Very high	Very high	High	222
Hawaii	Very high	Very high	High	326
U.S. Pacific island territories	Moderate	High	High	1

2008 Assessment

2015 Assessment

Region	Hazard based on Historical Record and Earthquake Probabilities	Number of Reported Deaths
U.S. Atlantic Coast	Very Low to Low	None
U.S. Gulf Coast	Very Low	None
Puerto Rico and the Virgin Islands	High	164
U.S. West Coast	High to Very High	25*
Guam and N. Mariana Islands	High	1
American Samoa	High	34
Alaska Arctic Coast	Very Low	None
Alaska	High to Very High	222
Hawaii	High to Very High	293

* Does not include any deaths caused by the 1700 Cascadia tsunami on the U.S. West Coast.

Research – Atlantic coast

- Ten Brink et al. (2014) reviewed the research on tsunamis sources in the Atlantic Basin
  - "**Landslide tsunamis** likely constitute the biggest tsunami hazard to the coast"
  - Both deterministic and probabilistic methods tsunami hazard assessments have been developed - but their **implementation requires better data than currently is available**
- Ten Brink et al. (2009) reviewed the research on tsunami sources along the Gulf Coast
  - "Likelihood of a major tsunami was **very small**"
  - The source for potential Gulf Coast tsunamis is underwater landslides, but the current record suggests that the large landslides were probably active prior to **7000 years ago**

Research – Atlantic & Pacific

- Canadian National Tsunami Hazard Assessment (Leonard, et al., 2012)
  - Two maps identify cumulative probabilities of exceedance (in 50 years) of potentially damaging runup (1.5 m and 3 m) on the Pacific and Atlantic coasts from multiple tsunami sources
  - Binned into four groups: <2%, 2-10%, 10-40%, 40-70%
    - Very Low, Low, Moderate, High to Very High
  - Region next to U.S. northwest coast are in the 10-40% (3m) bin
    - Correspond to U.S West Coast assessment of High to Very High
  - Region next to U.S. northeast coast are in the 2-10% (1.5m) bin
    - Correspond to U.S. Atlantic Coast assessment of Very Low to Low

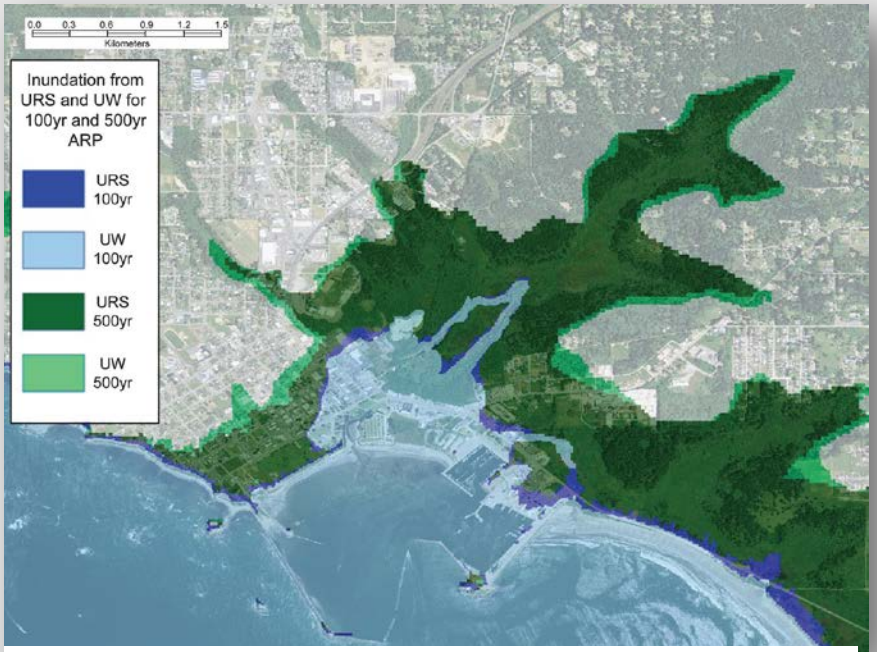
USGS National Seismic Hazard Maps

- Southern portion of the Cascadia subduction zone has a more frequent repeat of large magnitude earthquakes
  - Evidence - **turbidite flows** recorded off the Pacific NW coast
  - USGS Workshop for the 2014 National Seismic Hazard Maps
    - **full weight be given to the larger partial ruptures of southern Cascadia** in hazard calculations
    - Scientific consensus: average recurrence time for full-rupture Cascadia events is well-constrained at between **500 to 550 years** and ***this rate continues to support our current assessment of High to Very High***
  - Periodically re-examine this assessment as the turbidite studies and efforts to correlate these findings with onshore evidence are published

Lori Dengler and her students examine a sediment core taken from Humboldt Bay, California. (Photo credit: Kellie Jo Brown, Humboldt Bay University.)

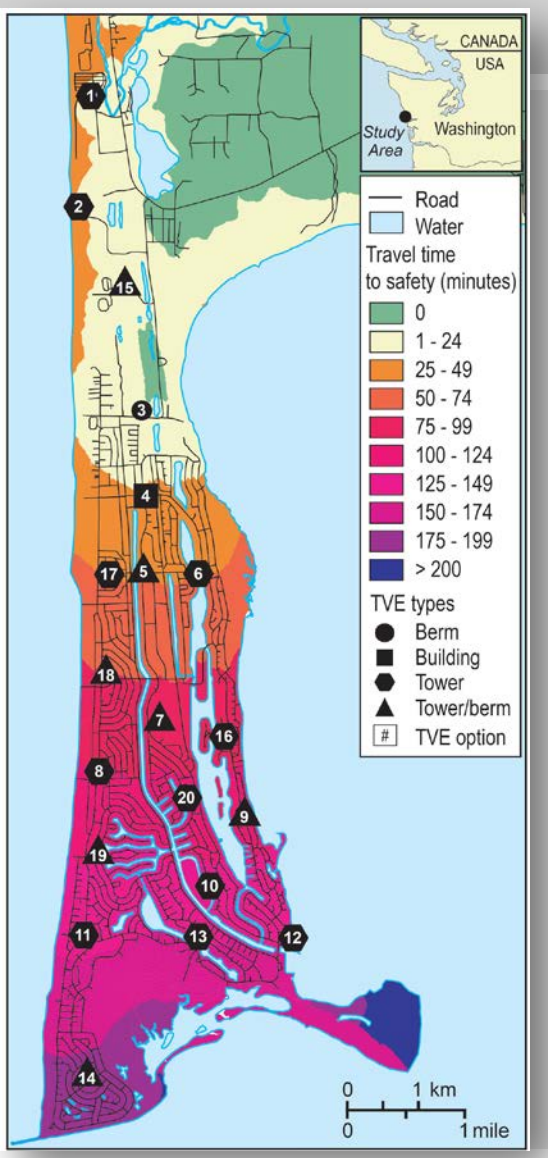
Discussion

- Probabilistic Tsunami Hazard Analysis



Comparison of preliminary tsunami inundation maps for Crescent City, California, developed from the URS Corporation and University of Washington Probabilistic Tsunami Hazard Analysis methodologies for 100-year and 500-year average return periods (modified from California Probabilistic Tsunami Hazard Analysis Work Group, 2015).

- Exposure and vulnerability assessments



Study area map of Ocean Shores, Washington, including modeled pedestrian travel times to safety, vertical-evacuation sites proposed during Project Safe Haven meetings, and regional map. (from Wood, et al., 2014a).

Conclusion and Future

- No change in the assessment except American Samoa, Guam, N. Mariana Islands, and U.S. West Coast
- 2010 Chile and 2011 Japan tsunamis confirmed levels in 1st assessment
- Document Reviewed by: NOAA: C. Rabenold, M. Eble, K. Stroker; USGS: T. Brocher, R. Witter
- NCEI Asheville, NC is printing
- Re-evaluate in the future based on research results
  - Cascadia recurrence intervals
  - East coast landslide assessment
  - Meteotsunamis
  - Document should continue to be a qualitative tsunami hazard assessment
  - Specific areas - Probabilistic tsunami hazard assessments
    - Vulnerability, Risk, Evacuation maps

Cover credits: Front and Back: FEMA/Casey Deshong—September 29, 2009, Samoa tsunami debris in Leone, American Samoa.

Thank you

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