Department of Conservation

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FAQ About Tsunamis

Introduction

The California Geological Survey (CGS) provides geologic and seismic expertise to the public, other State government offices, such as the California Governor's Office of Emergency Services (CalOES), and local government agencies (cities and counties). For tsunami hazards, CGS works closely with CalOES and the Tsunami Research Center at the University of Southern California to produce statewide tsunami inundation maps and preparedness information for California. CGS is also the Scientific Representative for California on the National Tsunami Hazard Mitigation Program Coordinating Committee, a state and federal cooperative responsible for developing policies and standards for tsunami mitigation efforts in the United States and its territories.

What is a tsunami?

A tsunami is a wave, or series of waves, generated by an earthquake, landslide, volcanic eruption, or even large meteor hitting the ocean (The Japanese word tsu means "harbor"; nami means "wave"). What typically happens is a large, submarine earthquake (magnitude 8 or higher) creates a significant upward movement of the sea floor resulting in a rise or mounding of water at the ocean surface. This mound of water moves away from this center in all directions as a tsunami. A

tsunami can travel across the open ocean at about 500-miles per hour, the speed of a jet airliner. As the wave approaches land and as the ocean shallows, the wave slows down to about 30 miles-per-hour and grows significantly in height (amplitude).

Although most people think a tsunami looks like a tall breaking wave, it actually resembles a flood or surge.

What are the sources for and examples of tsunamis that might affect California?

More than eighty tsunamis have been observed or recorded in California in historic times. Fortunately, almost all of these were small and did little or no damage. Though damaging tsunamis have occurred infrequently in California, they are a possibility that must be considered in coastal communities. There are two sources for California tsunamis, based on distance and warning time:

Local sources - Local tsunami sources, like large offshore faults and massive submarine landslides, can put adjacent coastal communities at the greatest risk of a tsunami because the public must respond quickly with little or no official guidance. The Cascadia Subduction Zone is an example of a local tsunami source that could threaten northern California. Stretching from Cape Mendocino, California, to Vancouver Island, British Columbia, this 700-mile long submarine fault system forms the crustal plate boundary where the offshore Gorda and Juan de Fuca plates dive, or subduct, beneath the North American plate. Examples of local tsunamis that have impacted California include:

January 26, 1700 - An earthquake estimated at a magnitude 9 ruptured the entire length of the Cascadia Subduction Zone, likely causing a 50-foot tsunami in parts of northern California. Though there were no local written accounts, scientists have reconstructed the event based on geologic evidence and oral histories from the Native American people in the area, and determined the exact date and time from Japanese documents that describe the effects of a large tsunami that hit the coast of Japan later that same day.

December 21, 1812 – A tsunami struck the Santa Barbara and Ventura coastline shortly after a large earthquake was felt in the area. Though reports of the size of this tsunami have been debated, the event was large enough to inundate lowland areas and cause damage to nearby ships. One theory is that the tsunami was caused by a nearby submarine landslide triggered by the earthquake.

Distant sources - A tsunami caused by a very large earthquake elsewhere on the Pacific Rim could reach the California coast many (4 to 15) hours after the earthquake. The Alaska-Aleutians Subduction Zone is an example of a distant source that has caused destructive tsunamis in California. Notable distant tsunamis that have impacted California include:

April 1, 1946 – A magnitude 8.8 earthquake in the Aleutian Islands generated a tsunami that caused damage along the coast of California, including flooding over 1000-feet inland in Half Moon Bay.

March 28, 1964 – Twelve people were killed in California when a tsunami was generated by a magnitude 9.2 earthquake off the coast of Alaska. A surge approximately 20-feet high flooded 29 city blocks of Crescent City.

March 11, 2011 – A magnitude 9.0 earthquake in the Tohoku region of Japan produced a moderate amplitude tsunami in California. Although it did not generate significant flooding in California, strong tsunami currents caused one death and over $100-million in damages to 27 harbors statewide, with the most significant damage occurring in Crescent City and Santa Cruz.

The table appended to the bottom of this page contains information on some additional tsunamis in California from 1812 to 2012, compiled from the following website: http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets.

How can I determine whether tsunamis are possible where I live, and what kind of warning could I get?

Tsunamis generally affect coastal communities and low-lying (low-elevation) river valleys in the vicinity of the coast. Buildings closest to the ocean and near sea level are most at jeopardy. Type in an address or city using the CGS Information Warehouse to access Statewide Inundation Maps to see if areas where you live, work, or visit are in tsunami inundation areas.

In order to determine whether a tsunami has been generated following a large earthquake, scientists from the West Coast and Alaska Tsunami Warning Center monitor an array of buoys and tide gauges that measure vertical changes to the ocean surface (more info on ocean tides and currents). If a potentially damaging tsunami is headed towards California, a warning will be broadcast through the Emergency Alert System and the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) Weather Radio (http://www.nws.noaa.gov/nwr/). Check with your local city or county to see what ways they will notify you of a tsunami.

In situations where tsunami travel times are short (due to nearby earthquakes or landslides), it is difficult for government agencies to identify and warn the public. Individuals should know what the natural warning signs of a tsunami are and have a plan to evacuate if necessary.

Are there any warning signs of an impending tsunami?

One noticeable, but not universal, sign is the rapid receding of ocean water from the beach before the first tsunami wave hits. In many accounts (including the current Indian Ocean tsunami), this effect has caused greater loss of life because it became a curiosity that attracted people to the oceanfront.

Very strong ground shaking along the coast is an indication of an earthquake that could cause seafloor displacements and/or a submarine landslide large enough to generate a tsunami. Though many large earthquakes have occurred along the coast without causing a tsunami, you should still be aware of the potential and plan accordingly. In the event you are at the coast and feel strong shaking, it may be prudent to move to higher ground.

What should I do before, during, and after a tsunami in my area?

Education and preparation are the best ways to avoid injury and increase your chances for survival. Know whether you are in a potential tsunami zone by observing street signs or looking online to see if you are in a zone. Know the evacuation routes for your area. Contact your local city and/or county government to see what the evacuation plan is for your area and where you will be expected to evacuate to. Have a “to go bag” ready, in the event you have to evacuate. Do not return to the evacuated zone until officials tell you it is safe to do so. The first tsunami is not always the largest, and tsunami waves, flooding and strong currents can last for several hours.

For more information about tsunami preparedness to go www.tsunamizone.org.

Historic Tsunamis in California

The chart below shows data from some of the tsunamis recorded in central and southern California from 1812 to 2012 (from

http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets):

Date	Travel Time (hours)	(minutes)	Tsunami Location	Height (meters)	Source Location	Source Event	Source Magnitude (Ms)	Source Magnitude (Mw)
12/21/1812			EL REFUGIO (GAVIOTA), CA	3.4	CA	Purisima	7.7	
12/21/1812			SANTA BARBARA, CA	2	CA	Purisima	7.7	

12/21/1812			VENTURA, CA	2	CA	Purisima	7.7	
9/24/1856			SAN DIEGO, CA	3.6	Japan	Tokaido		
9/24/1859			HALF MOON BAY, CA	4.6	N. CA			
5/27/1862			SAN DIEGO, CA	1.2	S. CA		5.8	
10/21/1868			SAN FRANCISCO BAY, CA	4.5	SF area		6.8	
8/13/1868			SAN PEDRO, CA	1.8	N. Chile		8.5	
8/13/1868			WILMINGTON, CA	1.8	N. Chile		8.5	
4/16/1877			ANAHEIM LANDING, CA	1.8	CA			
4/16/1877			CAYUCOS, CA	3.6	CA			
5/10/1877			GAVIOTA, CA	1.8	N. Chile		8.3	
5/10/1877			SAN PEDRO, CA	1	N. Chile		8.3	
5/10/1877			WILMINGTON, CA	1.7	N. Chile		8.3	
11/22/1878			WILMINGTON, CA	1	S. CA			
12/17/1896			SANTA BARBARA, CA	2.5	S. CA			
6/15/1896			SANTA CRUZ, CA	1.5	Japan	Sanriku	7.6	
11/4/1927			SURF, CA	1.8	CA		7.3	
4/1/1946			ARENA COVE, CA	2.4	Alaska	E. Aleutian Islands	7.3	
4/1/1946	5	36	AVILA BEACH, CA	1.3	Alaska	E. Aleutian Islands	7.3	
4/1/1946			DRAKES BAY, CA	2.6	Alaska	E. Aleutian Islands	7.3	
4/1/1946			HALF MOON BAY, CA	2.6	Alaska	E. Aleutian Islands	7.3	
4/1/1946			MORRO BAY, CA	1.5	Alaska	E. Aleutian Islands	7.3	
4/1/1946	5	36	SAN LUIS OBISPO, CA	1.3	Alaska	E. Aleutian Islands	7.3	
4/1/1946			SANTA CATALINA ISLAND, CA	1.8	Alaska	E. Aleutian Islands	7.3	
4/1/1946			SANTA CRUZ, CA	1.5	Alaska	E. Aleutian Islands	7.3	
11/4/1952	8	36	AVILA BEACH, CA	1.4	Russia	Kamchatka	8.2	9
5/22/1960			MONTEREY, CA	1.1	Chile	Central Chile		9.5
5/22/1960			PACIFICA, CA	1.2	Chile	Central Chile		9.5

5/22/1960			PISMO BEACH, CA	1.4	Chile	Central Chile		9.5
5/22/1960	14	4	PORT HUENEME, CA	1.3	Chile	Central Chile		9.5
5/22/1960	14	12	SANTA MONICA, CA	1.4	Chile	Central Chile		9.5
5/22/1960			STINSON BEACH, CA	1.5	Chile	Central Chile		9.5
5/22/1960	13	43	WILSON COVE, CA	1.2	Chile	Central Chile		9.5
3/28/1964			ARENA COVE, CA	1.8	Alaska	Gulf of Alaska		9.2
3/28/1964	5	10	AVILA BEACH, CA	1.6	Alaska	Gulf of Alaska		9.2
3/28/1964			CAPITOLA, CA	2.1	Alaska	Gulf of Alaska		9.2
3/28/1964			MARTINS BEACH, CA	3	Alaska	Gulf of Alaska		9.2
3/28/1964			MONTEREY, CA	1.4	Alaska	Gulf of Alaska		9.2
3/28/1964			MOSS LANDING, CA	1.4	Alaska	Gulf of Alaska		9.2
3/28/1964			PACIFICA, CA	1.4	Alaska	Gulf of Alaska		9.2
3/28/1964	5	6	SAN FRANCISCO, CA	1.1	Alaska	Gulf of Alaska		9.2
3/28/1964			SAN RAFAEL, CA	1.5	Alaska	Gulf of Alaska		9.2
3/28/1964			SANTA CRUZ, CA	1.5	Alaska	Gulf of Alaska		9.2
3/28/1964	5	39	SANTA MONICA, CA	1	Alaska	Gulf of Alaska		9.2
3/28/1964			SAUSALITO, CA	1.2	Alaska	Gulf of Alaska		9.2
3/28/1964			SEA VIEW, CA	3.8	Alaska	Gulf of Alaska		9.2
3/28/1964			TOMALES BAY, CA	1	Alaska	Gulf of Alaska		9.2
11/29/1975			SANTA CATALINA ISLAND, CA	1.4			7.2	
10/18/1989			MOSS LANDING, CA	1	CA	Loma Prieta	7.1	

11/4/2000			POINT ARGUELLO, CA	unknown	CA	Pt. Arguello		
11/15/2006	8	16	Arena Cove,	0.61	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	8	31	Crescent City	0.88	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	9	41	La Jolla	0.1	Russia	So.Kuril Islands	7.8	8.3
11/15/2006			Los Angeles	0.11	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	9	418	North Spit Humboldt Bay	0.17	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	8	36	Point Reyes,	0.33	Russia	So.Kuril Islands	7.8	8.3
11/15/2006			Port San Luis	0.56	Russia	So.Kuril Islands	7.8	8.3
11/15/2006			Richmond	0.09	Russia	So.Kuril Islands	7.8	8.3
11/15/2006			San Diego	0.09	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	9	6	San Francisco, CA	0.16	Russia	So.Kuril Islands	7.8	8.3
11/15/2006			Santa Barbara	0.4	Russia	So.Kuril Islands	7.8	8.3
11/15/2006	10	8	Santa Monica	0.15	Russia	So.Kuril Islands	7.8	8.3
8/16/2007	12	11	Crescent City	0.16	Peru	Peru	7.9	8
9/30/2009	10	27	Arena Cove	0.44	Samoa	Samoa Islands	8.1	8
9/30/2009	10	56	Crescent City	0.33	Samoa	Samoa Islands	8.1	8
9/30/2009			Los Angeles	0.13	Samoa	Samoa Islands	8.1	8
9/30/2009	11	38	Monterey	0.15	Samoa	Samoa Islands	8.1	8
9/30/2009	11	2	Point Reyes	0.39	Samoa	Samoa Islands	8.1	8
9/30/2009	11	43	Port San Luis	0.28	Samoa	Samoa Islands	8.1	8
9/30/2009	11	0	San Francisco	0.1	Samoa	Samoa Islands	8.1	8

9/30/2009			Santa Barbara	0.25	Samoa	Samoa Islands	8.1	8
9/30/2009			Santa Cruz	0.7	Samoa	Samoa Islands	8.1	8
9/30/2009	10	51	Santa Monica	0.15	Samoa	Samoa Islands	8.1	8
2/27/2010	14	14	Arena Cove	0.36	Chile	Central Chile	8.5	8.8
2/27/2010	15	6	Crescent City	0.64	Chile	Central Chile	8.5	8.8
2/27/2010			Dana Point Harbor	0.7	Chile	Central Chile	8.5	8.8
2/27/2010			Half Moon Bay	0.6	Chile	Central Chile	8.5	8.8
2/27/2010	13	28	La Jolla	0.6	Chile	Central Chile	8.5	8.8
2/27/2010	13	41	Los Angeles	0.42	Chile	Central Chile	8.5	8.8
2/27/2010	13	57	Monterey	0.36	Chile	Central Chile	8.5	8.8
2/27/2010			Morro Bay Harbor	0.5	Chile	Central Chile	8.5	8.8
2/27/2010			Moss Landing	0.3	Chile	Central Chile	8.5	8.8
2/27/2010			Marina Del Rey	0.1	Chile	Central Chile	8.5	8.8
2/27/2010			Mission Bay San Diego	0.6	Chile	Central Chile	8.5	8.8
2/27/2010	15	2	North Spit Humboldt Bay	0.23	Chile	Central Chile	8.5	8.8
2/27/2010			Newport Beach	0.5	Chile	Central Chile	8.5	8.8
2/27/2010			Oxnard	1	Chile	Central Chile	8.5	8.8
2/27/2010			Oceanside Harbor	0.6	Chile	Central Chile	8.5	8.8
2/27/2010			Pismo Beach	1.2	Chile	Central Chile	8.5	8.8
2/27/2010	14	25	Point Reyes	0.46	Chile	Central Chile	8.5	8.8
2/27/2010			Port Hueneme	0.7	Chile	Central Chile	8.5	8.8

2/27/2010			Port San Luis	0.8	Chile	Central Chile	8.5	8.8
2/27/2010	13	30	San Diego	0.4	Chile	Central Chile	8.5	8.8
2/27/2010	14	46	San Francisco	0.32	Chile	Central Chile	8.5	8.8
2/27/2010	13	56	Santa Barbara	0.91	Chile	Central Chile	8.5	8.8
2/27/2010			Santa Cruz	0.9	Chile	Central Chile	8.5	8.8
2/27/2010	13	51	Santa Monica	0.64	Chile	Central Chile	8.5	8.8
2/27/2010			Sunset	0.5	Chile	Central Chile	8.5	8.8
2/27/2010			Ventura	0.9	Chile	Central Chile	8.5	8.8
3/11/2011	10	49	ALAMEDA, CA	0.51	Japan	Honshu	8.3	9
3/11/2011	9	44	ARENA COVE, CA	1.74	Japan	Honshu	8.3	9
3/11/2011			Albion, CA	0.8	Japan	Honshu	8.3	9
3/11/2011			Ballona Creek, CA	0.6	Japan	Honshu	8.3	9
3/11/2011			Berkeley Marina, CA	0.51	Japan	Honshu	8.3	9
3/11/2011			Bodega Bay/Spud Point Marina, CA	0.7	Japan	Honshu	8.3	9
3/11/2011			Bolinas Stinson Beach, CA	0.9	Japan	Honshu	8.3	9
3/11/2011	9	47	CRESCENT CITY, CA	2.47	Japan	Honshu	8.3	9
3/11/2011			Carlsbad, CA	0.6	Japan	Honshu	8.3	9
3/11/2011			Channel Islands Harbor, CA	1.2	Japan	Honshu	8.3	9
3/11/2011			Chula Vista Marina, CA	0.2	Japan	Honshu	8.3	9
3/11/2011			Clipper Yacht Harbor, Sausalito, CA	0.8	Japan	Honshu	8.3	9
3/11/2011			Coronado Island Lifeguard HQ, CA	0.6	Japan	Honshu	8.3	9
3/11/2011			Dana Point Harbor, CA	0.6	Japan	Honshu	8.3	9
3/11/2011			Del Mar, CA	0.9	Japan	Honshu	8.3	9

3/11/2011			Dolphin Isle Marina, Noyo River, CA	0.8	Japan	Honshu	8.3	9
3/11/2011			Emery Cove Yacht Harbor, CA	0.6	Japan	Honshu	8.3	9
3/11/2011			Encinitas Batiquitos, San Elijo, C	1	Japan	Honshu	8.3	9
3/11/2011			HALF MOON BAY, CA	0.7	Japan	Honshu	8.3	9
3/11/2011			Harbor Island West Marina, CA	0.3	Japan	Honshu	8.3	9
3/11/2011			Huntington Harbor, CA	0.72	Japan	Honshu	8.3	9
3/11/2011			Imperial Beach	0.5	Japan	Honshu	8.3	9
3/11/2011			Jenner Russian River	1	Japan	Honshu	8.3	9
3/11/2011			KLAMATH RIVER	2.5	Japan	Honshu	8.3	9
3/11/2011			King Harbor , Redondo Beach	0.7	Japan	Honshu	8.3	9
3/11/2011	11		La Jolla	0.39	Japan	Honshu	8.3	9
3/11/2011			La Jolla	0.9	Japan	Honshu	8.3	9
3/11/2011			Long Beach Marina	0.7	Japan	Honshu	8.3	9
3/11/2011			Los Angeles	0.49	Japan	Honshu	8.3	9
3/11/2011			Mare Island	0.07	Japan	Honshu	8.3	9
3/11/2011			Martinez	0.06	Japan	Honshu	8.3	9
3/11/2011	10	1	Monterey	0.7	Japan	Honshu	8.3	9
3/11/2011			Morro Bay Harbor	1.6	Japan	Honshu	8.3	9
3/11/2011			Marina Del Rey	1	Japan	Honshu	8.3	9
3/11/2011			Mission Bay	0.9	Japan	Honshu	8.3	9
3/11/2011			Moss Landing	2	Japan	Honshu	8.3	9
3/11/2011			North Spit Humboldt Bay	0.97	Japan	Honshu	8.3	9
3/11/2011			Coronado Naval Air Base	0.3	Japan	Honshu	8.3	9
3/11/2011			New Port Beach Harbor	0.3	Japan	Honshu	8.3	9
3/11/2011			Noyo River Harbor	1	Japan	Honshu	8.3	9
3/11/2011			OXNARD	1.2	Japan	Honshu	8.3	9
3/11/2011			Ocean Beach	1	Japan	Honshu	8.3	9

3/11/2011			Oceano Dunes SRA	1	Japan	Honshu	8.3	9
3/11/2011			Oceanside Harbor	0.5	Japan	Honshu	8.3	9
3/11/2011			PISMO BEACH	1	Japan	Honshu	8.3	9
3/11/2011			PLATFORM HARVEST	0.15	Japan	Honshu	8.3	9
3/11/2011			POINT ARENA	1.74	Japan	Honshu	8.3	9
3/11/2011	10	6	POINT REYES	1.35	Japan	Honshu	8.3	9
3/11/2011			PORT CHICAGO	0.04	Japan	Honshu	8.3	9
3/11/2011			PORT HUENEME	1.4	Japan	Honshu	8.3	9
3/11/2011			PORT OF LONG BEACH		Japan	Honshu	8.3	9
3/11/2011	10	23	PORT SAN LUIS	2.02	Japan	Honshu	8.3	9
3/11/2011			Pacifica	1	Japan	Honshu	8.3	9
3/11/2011			Pier 39, San Francisco	0.6	Japan	Honshu	8.3	9
3/11/2011			Pillar Point Harbor	0.7	Japan	Honshu	8.3	9
3/11/2011			Pt Loma Sub Base/Ballast Pt	0.5	Japan	Honshu	8.3	9
3/11/2011	11	54	REDWOOD CITY	0.12	Japan	Honshu	8.3	9
3/11/2011			RICHMOND	0.35	Japan	Honshu	8.3	9
3/11/2011			Rio Del Mar/Aptos		Japan	Honshu	8.3	9
3/11/2011	11	20	SAN DIEGO	0.63	Japan	Honshu	8.3	9
3/11/2011			SAN FRANCISCO	0.62	Japan	Honshu	8.3	9
3/11/2011	10	40	Santa Barbara	1.02	Japan	Honshu	8.3	9
3/11/2011	10	56	SANTA MONICA	0.85	Japan	Honshu	8.3	9
3/11/2011			SHELTER COVE MARINA, SAN DIEGO	0.3	Japan	Honshu	8.3	9
3/11/2011			SHELTER I. DOCK, SAN DIEGO	0.8	Japan	Honshu	8.3	9
3/11/2011			Smith River	2	Japan	Honshu	8.3	9
3/11/2011			Santa Ana River		Japan	Honshu	8.3	9
3/11/2011			Santa Cruz Harbor	1.9	Japan	Honshu	8.3	9
3/11/2011			Scripps	0.25	Japan	Honshu	8.3	9
3/11/2011			Silver Strand State Beach	0.6	Japan	Honshu	8.3	9
3/11/2011			Tijuana River Wetlands	0.2	Japan	Honshu	8.3	9
3/11/2011			Two Harbors Catalina		Japan	Honshu	8.3	9

3/11/2011			Ventura Harbor	1.3	Japan	Honshu	8.3	9
3/11/2011			Waldo Point Marina, Sausalito	1.5	Japan	Honshu	8.3	9
10/28/2012	4	8	ALAMEDA	0.11	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	2	57	ARENA COVE	0.35	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	2	40	CRESCENT CITY	0.44	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	4	37	LA JOLLA	0.05	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	4	24	LOS ANGELES	0.08	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	3	30	MONTEREY	0.14	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	2	42	NORTH SPIT, HUMBOLDT BAY	0.12	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	3	15	POINT REYES	0.24	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	3	54	PORT SAN LUIS	0.27	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	4	4	RICHMOND	0.09	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	6		SAN DIEGO	0.05	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	3	48	SAN FRANCISCO	0.14	Canada	Queen Charlotte Islands	7.5	7.7
10/28/2012	4	19	SANTA MONICA	0.08	Canada	Queen Charlotte Islands	7.5	7.7

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California Geological Survey

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Tsunamis (Note 55)

Faults and Earthquakes in California (Note 31)

How Earthquakes Are Measured (Note 32)

California Integrated Seismic Network (CISN)

Related Links

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Tsunami Research Center at University of Southern California

National Tsunami Hazard Mitigation Program

Redwood Coast Tsunami Work Group

National Ocean and Atmospheric Administration Tsunami Page

U. S. Geological Survey Tsunami Page

International Tsunami Information Center Page