Hawaii Hazards Awareness & Resilience Program

Produced by

Hawaii State Civil Defense

HAWAII HAZARDS AWARENESS & RESILIENCE PROGRAM:

GOAL: To enhance community resilience to multiple hazards through a facilitated education and outreach program that promotes hazard understanding and awareness, and offers tools and information resources to guide mitigation, preparedness, response and recovery.

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EARTHQUAKES

Module 1: Hazard Awareness

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Module 1: Hazard Awareness

WHAT IS AN EARTHQUAKE?

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What is an Earthquake?

- **Earthquake:** *A trembling or shaking of the ground caused by the sudden release of energy stored in the rocks beneath the earth's surface.* (McGraw-Hill)
  - Earthquakes occur on a daily basis
    - Some may not be felt, while others are highly destructive.
- ***Seismology*** is the study of earthquakes; seismologists seek to understand the generation, characteristics, effects, and prediction of earthquakes.

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Causes of Earthquakes

- Through the action of geologic forces, strain builds up in the lithosphere and causes fracturing of rock formations. These fractures are referred to as ***faults***.
- Movement along faults occurs suddenly, as the friction between rock faces is overcome.
- Some faults are more active than others.

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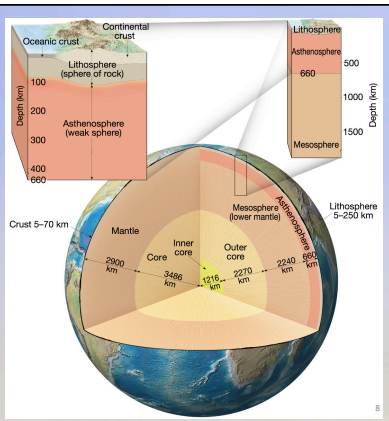
Earth's Layered Structure



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Earthquakes in Hawaii

- Most of Hawaii's earthquakes are directly related to volcanic activity and are caused by magma moving beneath the earth's surface.
- Earthquakes may occur before or during an eruption, or they may result from the underground movement of magma that comes close to the surface but does not erupt.

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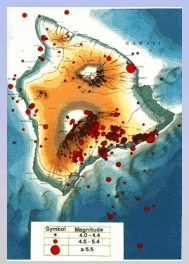
Earthquakes in Hawaii (Continued)

- A few of the island's earthquakes are less directly related to volcanism; these earthquakes originate in zones of structural weakness at the base of the volcanoes or deep within the earth beneath the island.



Source: USGS

Earthquakes on and near the Island of Hawaii, 1962-1985.

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Earthquake Characteristics

- The earthquake ***focus*** is the point within the earth where seismic waves originate. Earthquake foci can range in depth from several miles beneath the earth's surface, to 430 miles (690 km).
- The earthquake ***epicenter*** is the point at the earth's surface directly above the focus.

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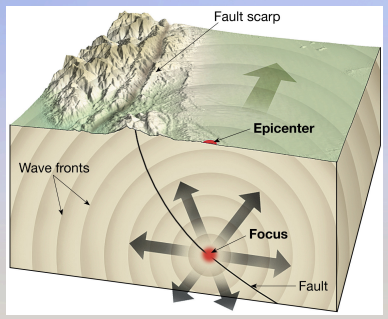
Earthquake Focus and Epicenter



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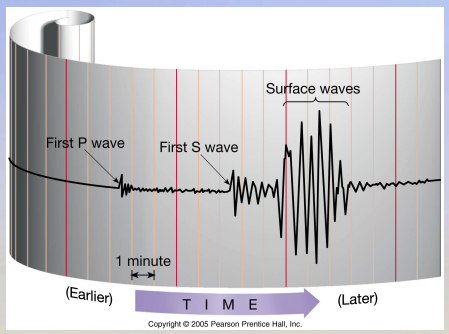
Detecting Earthquakes

Illustration of a Seismogram



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Earthquake Characteristics

- The "strength" of an earthquake is measured in terms of:
  - ***Intensity*** – measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.
    - Expressed using the Modified Mercalli Intensity (MMI) Scale.
  - ***Magnitude*** – measures the amount of energy released at the source of the earthquake.
    - Richter Scale – developed in 1935; most familiar.
    - Moment Magnitude – now used by scientists to measure earthquake magnitude.

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EFFECTS OF EARTHQUAKES

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Effects of Earthquakes

- Ground motion can collapse buildings and elevated roadways, break pipes, and knock down power lines.
- The degree of damage is dependent upon the amount of energy released and the earth materials through which the seismic waves pass.
  - Greater damage potential for buildings constructed on sedimentary soil;
  - Less for those constructed of reinforced concrete, or built on solid bedrock.

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Effects of Earthquakes

- Soil composition and water content are contributing factors to ***liquefaction*** that can occur during severe shaking.
- ***Liquefaction*** is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking, where the space between particles of soil becomes filled with water, allowing the particles to move readily with respect to one another.

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Effects of Earthquakes

- Aftershocks
  - Common after a large earthquake, and can topple damaged structures and hamper rescue efforts.
- Fires
  - Frequently break out after an earthquake.
  - 1906 San Francisco and 1923 Tokyo fires caused more damage and loss of life than the earthquakes that triggered them.

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Effects of Earthquakes

- Permanent displacement of the land surface:
  - *Land subsidence* - a gradual or sudden lowering of the land surface.
  - Landslides, mud flows, and avalanches.

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Effects of Earthquakes

- *Tsunamis* or seismic sea waves:
  - Result from vertical displacement along a fault located on the ocean floor or a large undersea landslide triggered by an earthquake.
  - In the open ocean height is usually < 3 feet.
  - In shallower coastal waters the water piles up to heights over 90 feet.

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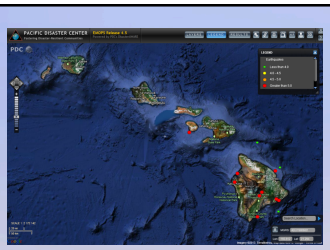

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HISTORICAL EARTHQUAKES IN HAWAII

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Destructive Earthquakes in Hawai`i County since 1868

Date	Epicenter Location	Maximum Intensity	Magnitude	Number of Deaths	Damage
Mar 28, 1868	South Hawai`i	IX	7.0	0	Extensive (S. Hawai`i)
Apr 02, 1868	South Hawai`i	XII	7.9	81	>100 homes destroyed, tsunami
Oct 05, 1929	Hualalai	VIII	6.5	0	Extensive (Kona)
Aug 21, 1951	Kona	VIII	6.9	0	Extensive (Kona)
Apr 26, 1973	North of Hilo	VIII	6.2	0	Extensive (Hilo), $5.6M
Nov 29, 1975	Kalapana	VIII	7.2	2	Extensive (Hilo), $4.1M
Nov 16, 1983	Ka`oiki	IX	6.7	0	Extensive (S. Hawai`i), > $6M
Jun 25, 1989	Kalapana	VII	6.2	0	SE Hawai`i, near $1M
Oct 15, 2006	Kiholo Bay	VIII	6.7, 6.0	0	NW Hawai`i, >$100M

Source: USGS HVO, http://hvo.wr.usgs.gov/earthquakes/destruct/

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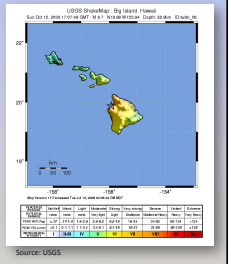
October 15, 2006 – M6.7

- Kiholo Bay, Big Island
- Depth – 18.0 miles (29 km)
- Felt on all islands
- Damages - $100 million
  - Major Disaster Declaration – FEMA
  - Damage to infrastructure
  - Roads and bridges damaged
  - 4 inches (10 cm) tsunami at Kawaihae Harbor
- Fatalities:
  - None reported



Source: USGS

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Questions?

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FLOODS

Module 1: Hazard Awareness

Contents

- What is a Flood?
  - Types of Flooding in Hawaii
- Effects of Flooding
- Hawaii's Flood History

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Module 1: Hazard Awareness

WHAT IS A FLOOD?

What is a Flood?

- **Flood:** An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics:
  - The inundation of land is temporary; and
  - The land is adjacent to and inundated by overflow from a river, stream, lake, or ocean. (USGS)
- ***Hydrology*** is the science dealing with the occurrence, circulation, distribution, and properties of the waters of the earth and its atmosphere.

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Conditions Contributing to Floods

- Rate of precipitation
- Topography (slope)
- Ground conditions (soil type and condition)
- Vegetation (presence or lack there of)
- Water levels in rivers and streams prior to rainfall
- Condition of hydraulic structures (e.g., dams)
- Conditions of coastal areas (e.g., distance and elevation in relation to the ocean)

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Flood Magnitude & Frequency

- Flood magnitude is often described in terms of recurrence intervals or probability of occurrence.
- Flood events are commonly referred to as "10-year," "25-year," "50-year," "100-year," or "500-year" floods.
  - A "500-year flood" has a 0.2% chance of occurring in any given year.
  - A "100-year flood" has a 1% chance of occurring in any given year.
  - A "50-year flood" has a 2% chance of occurring in any given year.
  - A "25-year flood" has a 4% chance of occurring in any given year.
  - A "10-year flood" has a 10% chance of occurring in any given year.
- Special Flood Hazard Area (SFHA)
  - Area defined using the 100-year flood event. SFHAs are used by the National Flood Insurance Program (NFIP) to determine flood insurance requirements.

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Types of Flooding in Hawaii

- Flash flooding
- Riverine
- Coastal
- Urban
- Inundation caused by Dam Failure

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EFFECTS OF FLOODING

Effects of Flooding

- **High water** can result in damage to infrastructure, homes and property, and loss of life. It only takes six inches of rapidly moving water to knock a person off his/her feet or sweep a vehicle off the road.
- **Debris** (rocks, tree branches, cars) submerged or caught up in the flow of water can cause damage and block drainage systems.
- **Landslides/Mudslides** can result when super-saturated soils along steep slopes fail. This can result in damage to houses and roads, and loss of life.

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Effects of Flooding

- **Contaminated Water** – Water may become contaminated with sewage, chemicals or other threats. Drinking water may be affected if flood waters contaminate water tanks, or pipes fail in flooded areas.
- **Erosion** by heavy rains and associated flooding can wash out roadways, damage bridges, as well as cause significant damage to property and agriculture.
- **Falling Trees and high-voltage power poles** can result from over-saturated soils.

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HAWAII'S FLOOD HISTORY

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Flooding in Hawaii

- Flooding occurs frequently in all counties and is sometimes very destructive.
- Flash floods occur during or within a few hours of extended rainfall events.
- The rapid flooding of streams, valleys, and other flood-prone areas can occur during any month of the year, but are more frequent during the period between October and April.

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Historical Flood Events

- 1960 to the Present (August 2013):
  - 14 Major Disaster Declarations in Hawaii
    - Two in the 1960s
    - Two in the 1970s
    - Three in the 1980s
    - One in the 1990s
    - Five between 2000 – 2009
    - One between 2010 – 2013
  - 1 Emergency Declaration
    - 1996 flood

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March 3 - 11, 2012

- Disaster Declaration for islands of Kauai and Oahu.
- Three days of steady rainfall
- Significant flooding
- Schools closed
- Damages ~$12 million
  - Heavy rains
  - Sewage spill
  - Dangerous surf
- Fatalities:
  - None reported

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Questions?

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TROPICAL CYCLONES

Module 1: Hazard Awareness

Contents

- What is a Tropical Cyclone?
- Tropical Cyclone Impacts
- Historical Hurricanes in Hawaii

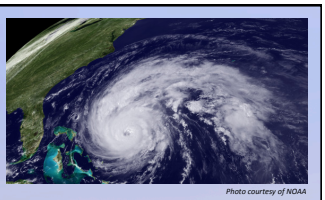

Photo courtesy of NOAA

Module 1: Hazard Awareness

WHAT IS A TROPICAL CYCLONE?

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What is a Tropical Cyclone?

- A **Tropical Cyclone** is a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation. Tropical cyclones rotate counterclockwise in the Northern Hemisphere. (NOAA NWS)

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Tropical Cyclone Designations

- "Tropical cyclone" is a general term. Designations vary according to maximum sustained wind speeds:

Tropical Cyclone Designations	Maximum Sustained Wind Speeds
Tropical Depression	Less than 39 mph (34 knots)
Tropical Storm (assigned a name)	39 to 73 mph (34 to 63 knots)
Hurricane – Category 1	74 to 95 mph (64 to 82 knots)
Hurricane – Category 2	96 to 110 mph (83 to 95 knots)
Hurricane – Category 3	111 to 129 mph (96 to 112 knots)
Hurricane – Category 4	130 to 156 mph (113 to 136 knots)
Hurricane – Category 5	157+ mph (137+ knots)

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Hurricane Characteristics

- Sustained wind speeds of 74 to 157+ mph (64 to 137+ knots)
- Require warm ocean water of at least 80°F (26°C) to supply thermal energy.
- May have a diameter of 100 to 300 miles (160 to 480 km).
- Viewed from a satellite perspective, hurricanes have a circular appearance with cloud bands spiraling toward the storm center.

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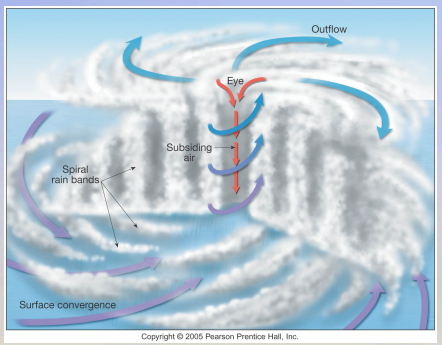
Illustration of a Hurricane



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Saffir-Simpson Scale

Category	Wind Speed	Storm Surge	Description of Damages
Cat 1	74-95 mph (64-82 kt)	Storm surge generally 1.2 – 1.5 m (4-5 ft) above mean sea level.	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Some coastal road flooding and minor pier damage.
Cat 2	96-110 mph (83-95 kt	Storm surge generally 1.8 – 2.4 m (6-8 feet) above mean sea level.	Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees. Considerable damage to mobile homes, poorly constructed signs, and piers.
Cat 3	111-129 mph (96-112 kt)	Storm surge generally 2.7 – 3.7 m (9-12 ft) above mean sea level.	Some structural damage to small residences and utility buildings. Damage to shrubbery and trees with large trees blown down. Mobile homes and poorly constructed signs destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by battering from floating debris.
Cat 4	130-156 mph (113-136 kt)	Storm surge generally 4 - 5.5 m (13-18 ft) above mean sea level.	More extensive curtain wall failures with some complete roof structure failures on small residences. Shrubs, trees, and signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows.
Cat 5	Greater than 157 mph (137+ kt)	Storm surge generally greater than 5.5 m (18 ft) above mean sea level.	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage.

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TROPICAL CYCLONE IMPACTS

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Tropical Cyclone Impacts

- Damage and losses due to:
  - High winds
  - Heavy rainfall
  - Flooding
  - Large breaking waves and high seas
  - Storm surge



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Tropical Cyclone Impacts

- High winds
  - Hurricane winds can tear apart structures, down trees, and hurl loose debris that can cause further damage.


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Tropical Cyclone Impacts

- Heavy rainfall and Flooding
  - Can bring intense precipitation over a short period of time.
  - Slow-moving storms concentrate rainfall over one area for a period of time.
  - Sudden, heavy rainfall causes stream levels to rise swiftly and result in flash flooding in downstream areas.
  - Ground saturation can cause landslides to occur.

Image source unknown

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Tropical Cyclone Impacts

- Large breaking waves and high seas
  - Large ocean swells are capable of capsizing large ships out at sea.
  - Large waves reaching the shore can inundate shallow coastal areas with salt water, damage or destroy port facilities and other infrastructure, and erode beaches.



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Tropical Cyclone Impacts

- Storm surge
  - An abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide. (NHC)

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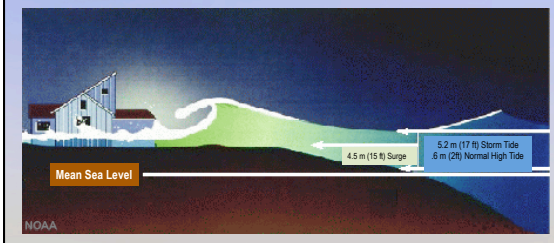
Storm Surge Illustration



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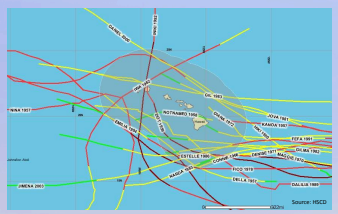

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HISTORICAL HURRICANES IN HAWAII

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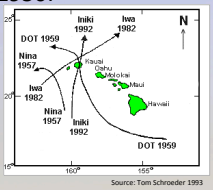
Historical Hurricane Events

- On average, between four and five tropical cyclones are observed in the Central Pacific every year. (CPHC)
- Five most damaging since 1950:
  - Hurricane Nina – 1957
  - Hurricane Dot – 1959
  - Hurricane Estelle – 1986
  - Hurricane Iwa – 1982
  - Hurricane Iniki - 1992



Source: Tom Schroeder 1993

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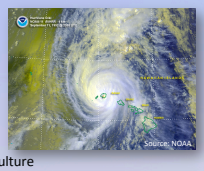
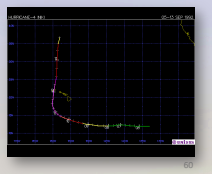
Hurricane Iniki

- September 10-11, 1992
- Category 4
- Landfall on Kauai
- Damages – $3 billion
  - Kauai
    - Extensive – wind and wave damage
    - Heavy losses to infrastructure and agriculture
  - Oahu
    - Flood and wave damage
  - Maui/Hawaii
    - Wave damage
- Fatalities
  - 2 Kauai
  - 2 Oahu
  - 2 aboard a fishing vessel off Kauai





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Questions?

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TSUNAMIS

Module 1: Hazard Awareness

Contents

- What is a Tsunami?
- Tsunami Impacts
- Tsunami Events in Hawaii

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Module 1: Hazard Awareness

WHAT IS A TSUNAMI?

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What is a Tsunami?

- Pronounced: *Tsoo-nah-mee*
- Japanese word meaning 'harbor wave'
- Also known as a 'seismic sea wave'
- You may hear a tsunami erroneously referred to as a 'tidal wave.'
- A series of traveling waves of extremely long length and period, usually generated by disturbances associated with earthquakes occurring below or near the ocean floor. (IOC, UNESCO)

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Terms & Definitions

- Inundation
  - The horizontal distance inland that a tsunami penetrates, generally measured perpendicularly to the shoreline. (IOC, UNESCO)
- Runup
  - The difference between the elevation of the maximum tsunami penetration (inundation line) and the sea level at the time of the tsunami. (IOC, UNESCO)
- Tsunami Evacuation Zones
  - Areas that might be affected by a tsunami, beyond which people must be evacuated to avoid harm from tsunami waves.

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Illustration of Tsunami Terms

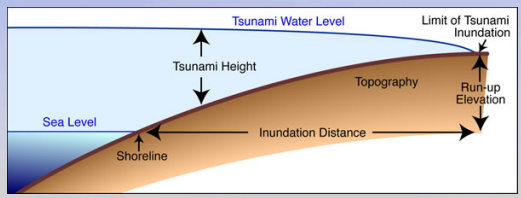

Image source: USGS, Illustration by Bruce Jaffe

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Tsunami Causes

Tsunami events result from a sudden displacement of water caused by:

- Earthquakes
  - Movement of the plates along the sea floor
  - Most destructive tsunamis are associated with earthquakes of magnitude 7.5 and higher (USGS)
    - Sumatra – December 2004
    - Chile – May 1960
- Landslides
  - Displacement of a large amount of sediment/material usually triggered by an earthquake
    - Alaska – April 1946
- Submarine Volcanic Eruptions
  - Catastrophic eruption of undersea volcanoes
    - Krakatoa – August 1883

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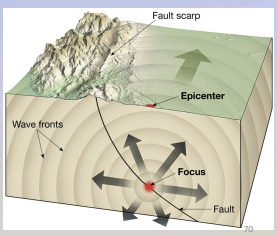
Tsunami Causes (Continued)

Tsunami waves are typically triggered by shallow earthquakes (with a focus depth of 12 miles or less).

- The earthquake *focus* is the point within the earth where seismic waves originate.
- The earthquake *epicenter* is the point at the earth's surface directly above the focus.



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Tsunami Characteristics

- In the open ocean
  - Height is usually < 3 feet
  - Extremely long wavelength: > 60 miles
  - Travel at great speeds: ~ 500+ mph (jet plane)
- In shallow coastal waters
  - Runup can reach heights over 100 feet
  - Inundation can be several miles

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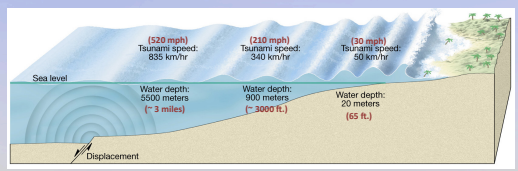
Illustration of a Tsunami



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Tsunami Characteristics (Continued)

- Tsunami bore waves
  - A steep, turbulent, rapidly moving tsunami wave front, typically occurring in a river mouth or estuary. (IOC, UNESCO)
- A tsunami may have *MORE THAN ONE* wave!
  - Multiple waves
  - First may not be the largest
  - Time between waves could be 10 to 60 minutes.

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Distant vs. Local Tsunami

- Distant Tsunami or Teletsunami
  - A tsunami originating from a far away source (> 620 miles or 1000 km away).
  - Arrival of first wave expected within *hours*.
- Local Tsunami
  - A tsunami originating from a nearby source, with destructive effects confined to coasts within 62 miles (100 km) of the source.
  - Arrival of first wave expected within *minutes*.

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TSUNAMI IMPACTS

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Tsunami Impacts

- Loss of life to unsuspecting observers unable to outrun fast-moving, steadily rising floodwater carrying debris.
- Destruction of coastal resources
  - Permanent changes to beaches and coastal features.
- Salinization of land in the inundation area
  - Agricultural land rendered useless.
- Partial or complete damage to infrastructure
  - Built environment (homes and other structures).
  - Roads, bridges, etc.
- Can trigger cascading effects
  - Example: Japan tsunami, March 11, 2011.

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TSUNAMI EVENTS IN HAWAII

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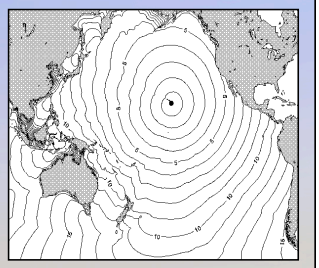
Tsunami Travel Times to Hawaii

Approximate Travel Times For Distant Tsunami Events:

Japan	7 hours
Alaska	5 hours
S. Pacific	7 hours
Chile	14 hours
U.S. West Coast	5 hours



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Local Tsunami Events

- May be caused by earthquake or submarine landslides.
- Danger is greater due to the limited warning time.
  - *Minutes*, not hours before arrival of first wave.
- Most significant local event for Hawaii:
  - November 29, 1975
  - Runup to 40 feet
- The animation on the next slide shows how quickly a locally generated tsunami can travel through the Hawaiian Islands.

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Hawaii's Tsunami History

- Thirteen (13) significant tsunami events from 1819 to 2000
  - Most generated by earthquakes
- More people killed by tsunamis than by any other natural disaster in Hawaii.
- Statistics from 1900 to 1998:
  - Tsunami deaths
    - ~221 people (~159 of these occurred in the 1946 event).
  - Hurricane deaths
    - 7 people

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Hawaii's Tsunami History

- Two Major Tsunamis:
  - April 1, 1946 – Alaska – M 8.1 earthquake
  - May 22, 1960 – Chile – M 9.5 earthquake
- Other Events (smaller waves):
  - March 27, 1964 – Alaska M 9.2
  - Nov 29, 1975 – Local M 7.2
  - May 7, 1986 – Alaska M 8.0
  - February 26, 2010 – Chile M 8.8
  - March 11, 2011 – Japan M 9.0

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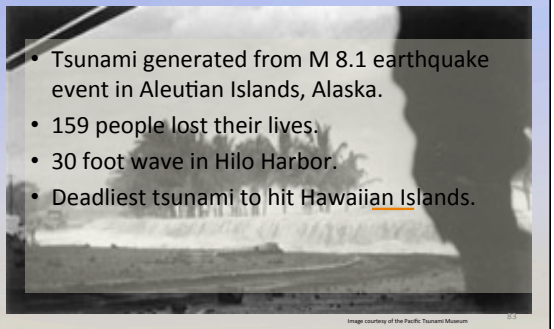
April 1, 1946 – Distant Tsunami



- Tsunami generated from M 8.1 earthquake event in Aleutian Islands, Alaska.
- 159 people lost their lives.
- 30 foot wave in Hilo Harbor.
- Deadliest tsunami to hit Hawaiian Islands.

Image courtesy of the Pacific Tsunami Museum

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Images courtesy of the Pacific Tsunami Museum

May 22, 1960 – Distant Tsunami

- Tsunami generated from earthquake event in Southern Chile
  - Magnitude 9.5 – largest earthquake ever measured
  - First wave arrived 15 hours after earthquake
- 61 people killed
- 282 injured
- 35 foot wave in Hilo Harbor

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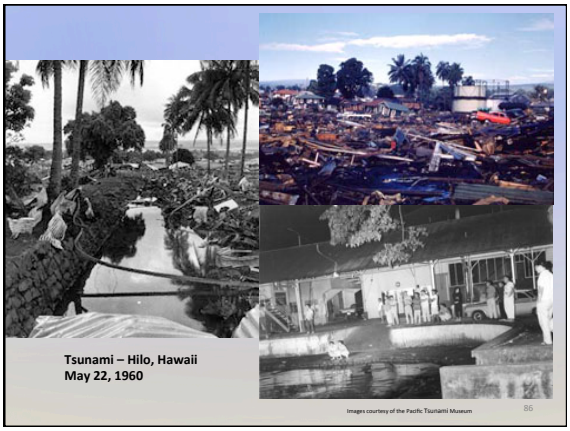

Tsunami – Hilo, Hawaii
May 22, 1960

Images courtesy of the Pacific Tsunami Museum

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March 10, 2011 – Distant Tsunami

- Tsunami generated from earthquake event in Japan
  - Mag 9.0
  - First wave arrived 7 hours after earthquake
  - No loss of life in Hawaii
  - Runup
    - Estimated at 7 to 11 feet on Maui and Big Island
    - 5.7 foot wave measured by tide gauge in Maui
    - 2.3 foot wave measure by tide gauge in Hilo
  - Millions in damages to boat harbors and coastal infrastructure on Oahu, Maui, Molokai and Big Island.

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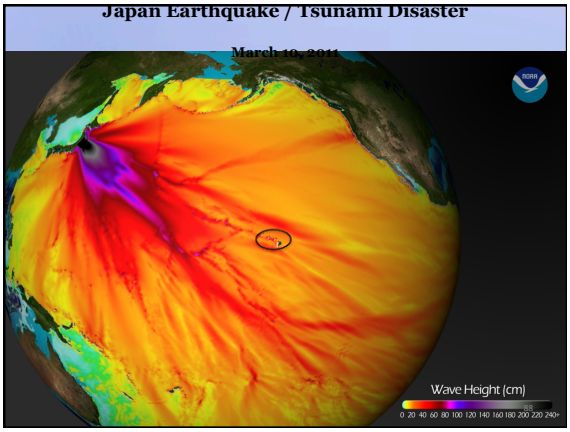

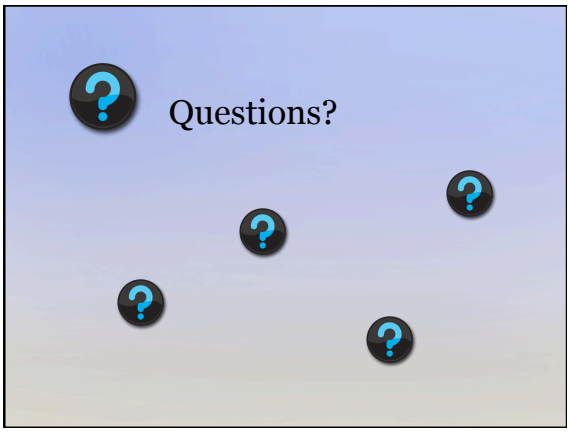

MAHALO

The Hawaii Hazards Awareness & Resilience Program (HHARP) is the result of a collaborative partnership between Hawaii State Civil Defense and the Pacific Disaster Center.

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HHARP Hawaii Hazards Awareness & Resilience Program

PACIFIC DISASTER CENTER

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