For scientists, next challenge is to predict how tsunamis will behave

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About 5,000 miles across the Pacific Ocean, the earth erupted more than 15 miles under the sea floor - the fifth most powerful quake ever recorded - unleashing a mammoth train of waves toward North America.

It was 9:46 p.m. PST Thursday in California, and tsunami experts knew exactly when Japan's wall of water, traveling the speed of a jet airliner, would hit the U.S. West Coast. The question was, what would it do when it got here? A new system of sensors and buoys, floating in the Pacific, successfully alerted scientists to the magnitude 8.9 earthquake's punch and then tracked the tsunami's route across the ocean.

But for scientists, the next challenge will be predicting how tsunamis will behave, once they arrive. Tsunamis are a series of "wave trains" of varying sizes and strengths.

They are highly influenced by each region's hidden underwater landscape, which can create powerful currents that pull, push and swirl.

"The forecast was very accurate in terms of the time it takes to reach our coast, but not in terms of amplitude," said U.S. Geological Survey oceanographer Guy Gelfenbaum. "There are a lot of factors that will determine how big the waves will be. Things like harbor orientation, rocky reefs ... these are features we are just starting to understand."

So, scientists knew the first surge would arrive on the California coast about 8 a.m. - right on schedule. In Santa Cruz, boats were ripped from

moorings, while the waves along the San Mateo coast just strengthened their slap on the beach. In Crescent City, near Oregon, the harbor suddenly drained of water, then at least three dozen boats were crushed. A man taking photos on a beach at the mouth of the Klamath River was sucked out to sea - in what may be only the second time a tsunami caused a death in the continental United States. Boats in San Luis Obispo's Avila Beach tipped and tossed like bathtub toys.

Because it was low tide, greater damage was averted. Scientists know, in general, that the depth, orientation and configuration of a coastline influences a tsunami's impact - explaining why Crescent City and Santa Cruz harbors were hardest hit.

In the shallow bay of Crescent City, an offshore "fracture zone" acts as a "wave guide," directing waves into the harbor, said U.S. Geological Survey scientist Eric Geist. "Wave after wave piles up."

In Santa Cruz, "when the tsunami came into the harbor, the water got focused, because the entrance is narrow. So the water sped up and moved the boats and docks around, damaging them. The mooring lines weren't set up to hold them," Gelfenbaum said.

That's why scientists seek to conduct the detailed research needed to produce local measurements that would more precisely predict tsunami behavior.

Before Friday, the only place in the continental United States where people were known to have died in a tsunami was Crescent City. In 1964, a tsunami triggered by an earthquake off Anchorage, Alaska, killed 12 people in the Northern California fishing port. Tsunamis are caused by earthquakes generated in a "subduction zone," where an oceanic plate is being forced down into the earth's mantle by plate tectonic forces. The friction creates stress, and then the overriding plate

ruptures, and snaps - displacing a giant column of water.

"There's a diving motion of the ocean floor under the North Japanese island," said USGS scientist Steve Kirby. It was an Indonesian subduction zone where an earthquake in December 2004 created a tsunami that killed a quarter of a million people. In contrast, some of California's faults - San Andreas, Calavaras and Hayward - are "strike slip" faults, where vertical plates slide past each other. While equally destructive, they do not lurch horizontally and so do not trigger vast volumes of water.

Much has changed since 2004, when scientists stood by helplessly because their mathematical models didn't produce a warning fast enough to prevent the massive tragedy in Indonesia.

Now, a system of underwater sensors, which detect changes in water pressure, transmit that information to buoys - then to teams of scientists, with banks of computers.

Yet even the well-prepared Japan, close to the epicenter, did not have enough time to avert wreckage and death. "This wave is not like a storm wave, or a wind wave, which crashes over and is gone after 5 to 10 seconds," Gelfenbaum said. "This wave has many, many minutes' worth of water behind it. So you get 4 feet of water, but it comes for 10, 15 minutes. It keeps inundating. It is a large volume of water. It doesn't crash and go away."