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How can the eruption of a volcano affect the ocean everywhere on Earth?

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Abstract

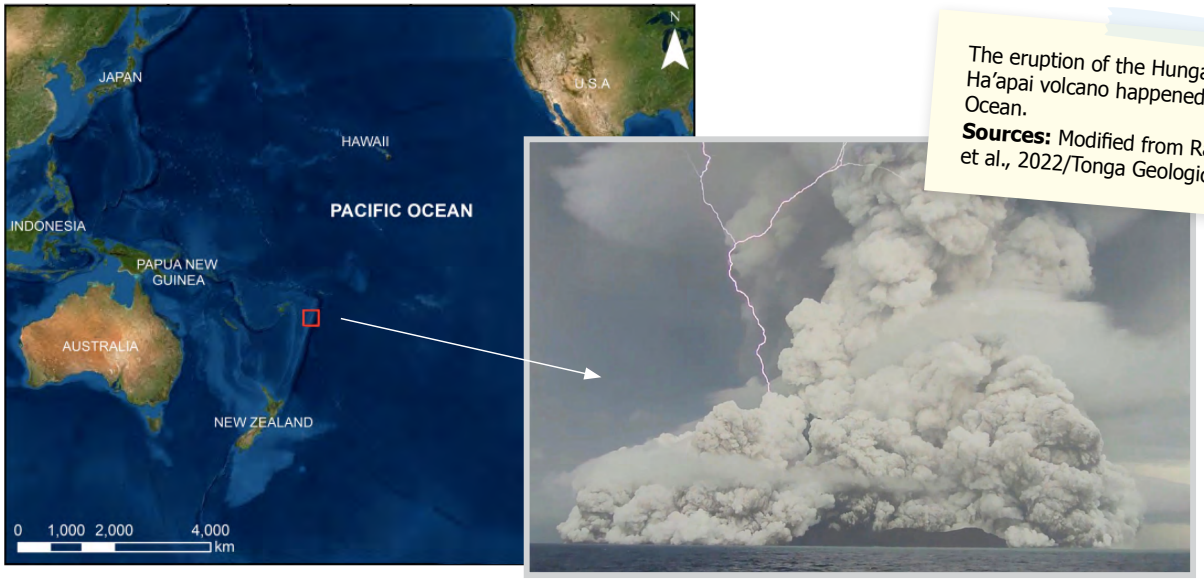
UPPER READING LEVEL

Did you know that a volcanic eruption can affect the entire world? When the Hunga Tonga-Hunga Ha'apai volcano erupted on January 15, 2022, it affected the ocean everywhere. That's because it created an atmospheric wave that disturbed the ocean. It also generated a tsunami. We analyzed weather station and tidal gauge data to learn more about the effects of the Hunga Tonga-Hunga Ha'apai volcanic eruption on Mexico. We learned that the atmospheric wave moved across the world many times. We also learned that the tsunami reached heights of up to 2 meters (6.5 feet) along the Pacific coast of Mexico. Our analysis of the tsunami warning system in Mexico showed that most people were not informed to stay away from the ocean. Based on our analysis, we recommend making changes to tsunami warning systems.

Introduction

On January 15, 2022, the Hunga Tonga-Hunga Ha'apai volcano erupted, affecting countries all over the Pacific Ocean. How? This volcanic eruption was so violent that it created a **shock wave** and a **tsunami**.

A shock wave is a high pressure wave created when a disturbance moves so fast through a **medium** that the waves pile up. When waves pile up, the high pressure regions add up to have even higher pressure. People experience



The eruption of the Hunga Tonga-Hunga Ha'apai volcano happened in the Pacific Ocean.
Sources: Modified from Ramirez-Herrera et al., 2022/Tonga Geological Services

these areas of extreme pressure as a **sonic boom**. People heard the sonic boom from the Hunga Tonga-Hunga Ha'apai volcanic eruption as far away as Alaska and Canada.

A tsunami is a wave caused by a large displacement of ocean water. These waves are different from regular ocean waves, which form when the wind disturbs the ocean's surface. Ocean waves transfer energy while the water molecules move in a circular motion. In a tsunami, the water itself is moving. When a tsunami reaches land, it can cause a lot of damage to buildings along the coast. It also floods freshwater environments with ocean water. Because the Hunga Tonga-Hunga Ha'apai volcano is a **submarine** volcano, it displaced a lot of ocean water when it erupted. This displacement of water sent the tsunami in all directions across the Pacific Ocean.

We wanted to better understand the impact of this volcanic eruption on the country of Mexico. We also wanted to learn what the tsunami warning system did to try to keep people safe.

Methods

We used three sets of data to figure out what happened as a result of the volcanic eruption. They include:

- atmospheric pressure data from the National Weather Service weather stations.
- ocean height data from the National Tide Gauge Service **tidal gauges**.
- tsunami warnings and information from online news, social media, and official websites.

Using these data, we tracked the size and timing of both the shock wave and the tsunami. We also determined what information people received to stay safe during these events.

Results

Shock wave:

The weather stations on the Pacific coast of Mexico, in the Gulf of Mexico, and in the Caribbean Sea all recorded the shockwave about 7.5 hours after the volcanic eruption. The stations recorded up to eight peaks of high pressure over about a 5-day period.

Tsunami:

The tsunami hit the Pacific coast of Mexico. It arrived at many locations about 8.2 hours after the volcanic eruption. Eight tidal gauges measured tsunami heights greater than 1 meter (3 feet). The maximum height exceeded 2 meters (6 feet), which is taller than the average person's height (see Figure 1). The sea disturbance caused by the tsunami lasted for five days.

The tidal gauges also recorded ocean height changes in the Gulf of Mexico and the Caribbean Sea. The maximum height change was less than 0.40 meters (about 16 inches).

Warnings and information:

The Center of Tsunami Warning issued a warning in Mexico about 36 hours after the eruption occurred. The warning stated that the volcano had erupted, but they didn't expect any significant sea level changes. Still, there might be strong currents at the ports on the Pacific coast. People received this information from social media and news websites.

In Mexico, the Civil Protection offices are in charge of public safety. Two offices told people to avoid going to the sea until further notice. Most offices issued statements to be careful because of higher sea levels and stronger currents.

Please see Figure 1 on page 3

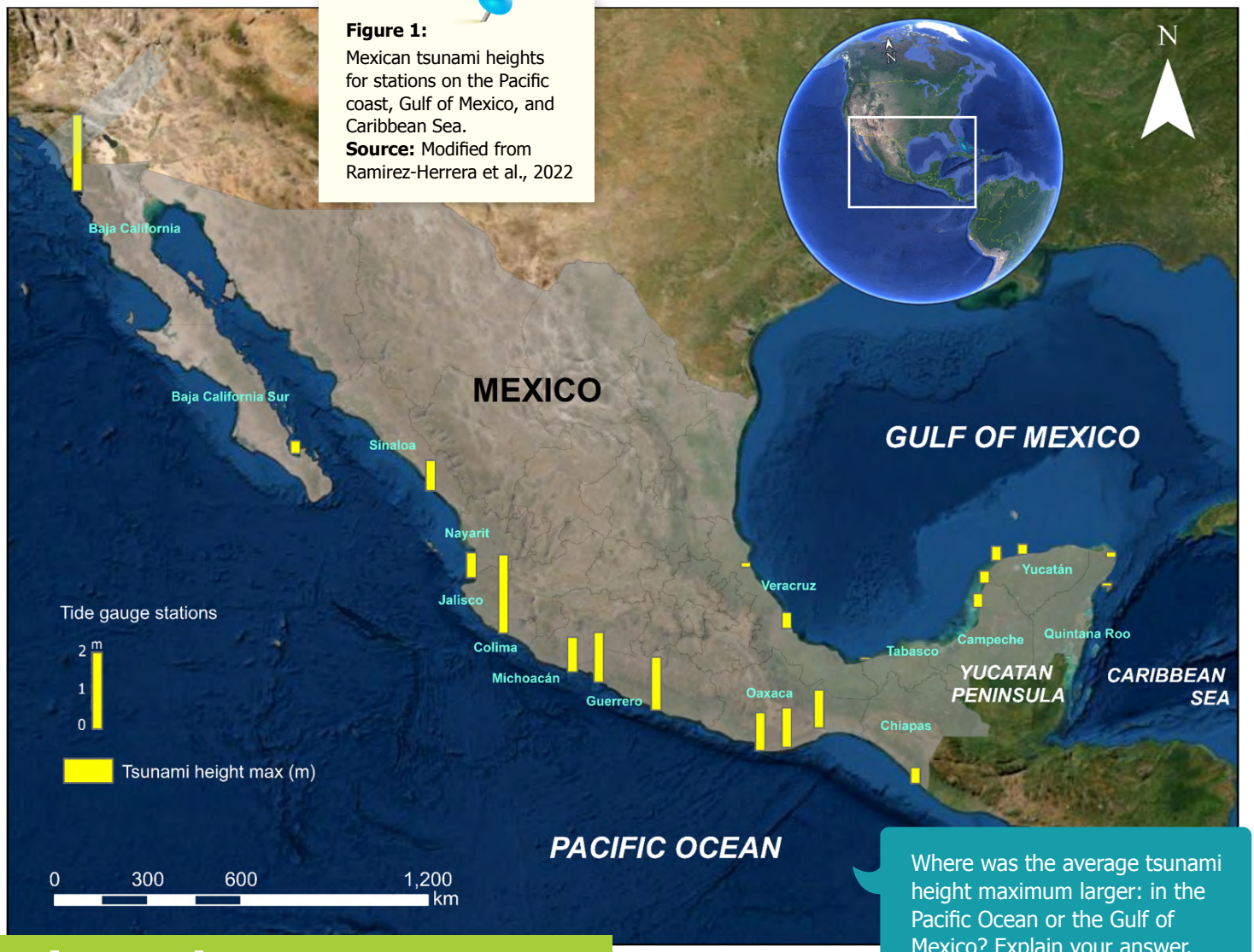


Figure 1:
Mexican tsunami heights for stations on the Pacific coast, Gulf of Mexico, and Caribbean Sea.
Source: Modified from Ramirez-Herrera et al., 2022

Where was the average tsunami height maximum larger: in the Pacific Ocean or the Gulf of Mexico? Explain your answer.

Discussion

Our data analysis showed that the Hunga Tonga-Hunga Ha'apai volcanic eruption generated a shock wave. It moved back and forth across the Earth many times. As the wave traveled, it caused sea disturbances, such as the ones recorded in the Gulf of Mexico and the Caribbean Sea. It is also likely that the effect of the shock wave on the ocean combined with the tsunami in the Pacific. This created greater water heights.

Tidal gauge data showed that tsunami heights varied based on location. That is because the shape of the shoreline is different at each location. As the tsunami reaches the shore, it interacts with the ocean floor. The tsunami slows down, causing the wave to grow in height. Mexico did not report any damage or injuries from the tsunami.

Tsunamis and shock waves generated by volcanic eruptions are rare. That is why they are often excluded from tsunami warning systems. Instead, these systems focus on underwater earthquakes, the main cause of tsunamis. But the Hunga Tonga-Hunga Ha'apai volcanic eruption did create a tsunami. That means warning systems should include these types of eruptions. We suggest stronger recommendations for people to remain away from the shoreline during a tsunami event. We also recommend that scientists and local organizations track underwater volcanoes.

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Conclusion

Being by the ocean always carries some risk. If you live on the coast, check with your local government to find out about tsunami risks. Make sure that you have access to your local tsunami warning system and that you have a plan on how to stay safe during a tsunami event. And whenever you are by the ocean, make sure you follow all swimming and safety rules. Staying safe will make your time in the ocean more enjoyable!

Glossary of Key Terms

Medium – a substance or material that carries a wave. For example, light waves can travel through air, water, and glass. Air, water, and glass are media for light.

Shock wave – a high pressure wave created when a disturbance moves so fast through a medium that the waves pile up.

Sonic boom – a loud explosive noise caused by the shock wave. Aircraft create a sonic boom when they travel faster than the speed of sound.

Submarine – existing or happening beneath the ocean surface.

Tidal gauge – a sensor that records the height of the ocean surface.

Tsunami – a giant wave caused by the displacement of water. They are typically caused by earthquakes and underwater volcanic eruptions.

Check your understanding

1. Not all volcanic eruptions cause a tsunami. Why did the Hunga Tonga-Hunga Ha'pai volcano generate one?
2. Why did the ocean levels change in the Gulf of Mexico and the Caribbean Sea?
3. Why were we concerned about the tsunami warning that was received by the people in Mexico?
4. Why haven't volcanic eruptions typically been included in the tsunami warning systems?
5. The Hunga Tonga-Hunga Ha'pai volcanic eruption is an example of a natural hazard. With a partner, identify a type of natural hazard that is common where you live. Then brainstorm ways that people can be prepared when this natural hazard occurs.

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