How can a shock wave with a 2 cm pressure disturbance lead to a tsunami larger than 40 cm in the Tonga Volcanic Tsunami Event in 2022?

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Hunga Tonga - Hunga Ha'apai eruption on January 15, 2022, caused sea levels and pressure to change globally, especially in the Pacific. Based on the Himawari-8 satellite images, a massive explosion occurred between 4:00 and 4:10 UTC. Within about 30 minutes, the surface of the ocean was raised 58 kilometers above sea level by the initial burst. According to observations and in-situ data, shockwaves propagating across the globe from eruptions are concentric. According to the data, a shock wave with 2hPa pressure disturbance, which is equivalent to 2cm hydrostatic pressure, created tsunami waves with a height of 40cm. In addition, tsunami waves were detected in Taiwan following the peak of the air pressure disturbance. These phenomena were also observed in the Atlantic Ocean, Caribbean Sea, and the Mediterranean Sea.

In this paper, numerical methods are used to explore the causes of tsunamis after the eruption of the Tonga volcano on January 15, 2022. Navier-Stokes equations and shallow water equations are solved numerically, and a shock wave moving at the speed of sound is used to simulate sea surface disturbances. We use the atmospheric pressure data from the Central Weather Bureau of Taiwan and the pressure data from the ten-meter meteorological tower of the Central University to determine boundary conditions. Model verification is based on free-surface elevation data from the tide station recorded by the Central Weather Bureau of Taiwan, as well as pressure data from the undersea cable. The simulation results will help explain how a minor air pressure disturbance can create tsunami waves that are nearly 20 times higher than usual.

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