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Tsunamis from the Arica-Tocopilla source region and their effects on ports of Central Chile

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Abstract The last great earthquake in northern Chile took place in 1877, and the ensuing tsunami affected not only that region but also Central Chile. For example, the Bay of Concepción, which is located 1,500 km south of the tsunami source, experienced an inundation height of around 3 m. Ports are important in the Chilean economy, due to the fact that a large percentage of Chilean exports (excluding copper) use ports located in Central Chile. With this in mind, the authors investigated the potential effect of an 1877-like tsunami on the main ports of Central Chile. To do this, the dispersive wave model Non-hydrostatic Evolution of Ocean WAVEs was used. In addition, the first tsunami forecast model for Talcahuano, inside the Bay of Concepción, was developed by means of numerical simulation of several events of different moment magnitudes. The results showed that most of the important ports (Valparaiso, San Antonio, San Vicente and Coronel) had inundation heights on the order of just 1 m, while inundation levels in Talcahuano reached up to 3.5 m. The forecast model for Talcahuano uses only earthquake magnitude, focal depth and tide level to determine tsunami inundation heights. In addition, the tsunami arrival time was computed to be 3 h, and the maximum tsunami amplitude takes place at 4 h and 45 min after the earthquake.

Keywords 1877 Iquique tsunami · Central Chile · Shelf resonance · Tsunami forecast model · Bay of Concepción

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1 Introduction

Ports are important for the Chilean economy due to the fact that 95 % of the country's exports leave via maritime ports. In addition, 98 % of the exports (not counting copper) use ports located in Central Chile (from Lat 33S to 37S). On these grounds, and considering that Chile is one of the most earthquake-prone countries in the world, the damage due to an earthquake or tsunami should include not only direct damage to port facilities, but also the effect of this damage on the entire economy (Otsuka et al. 2010). Moreover, Chilean geography strongly influences the connectivity of the country, such that only one main highway connects most important cities. In addition, several rivers run from the Andes to the Pacific Ocean, and thus, this highway requires several large bridges. A large earthquake could damage highways and bridges and interrupt land communications. Therefore, ports can become even more important in the distribution of emergency supplies during an emergency, while the land connections are being restored.

On the other hand, the last relevant event (M8.8) in the Arica-Tocopilla seismic region (Lat 18.3S–23.3S) took place in 1877. Historical records of large earthquakes in this rupture zone assign it a return period of 111 $\pm$ 33 years (Comte and Pardo 1991). If the rate of moment deficit is taken into account, the seismic potential over the 1877 rupture area equals an earthquake of minimum moment magnitude of $Mw \sim 8.6$ (Chlieh et al. 2011). The historical records also show that the 1877 event generated a destructive tsunami that affected not only the Chilean coast but also ports in the United States, New Zealand and Japan (Soloviev et al. 1975). The ports located inside the Arica-Tocopilla segment suffered severe damage with a mean inundation height of 10 m. The tsunami was also recorded at ports in Central Chile (Lat 33S to 37S), such as Valparaiso and Talcahuano. The latter is located inside the Bay of Concepción and 1,500 km from the 1877 tsunami source area. Moreover, historical records show that at least five near-field tsunamis have affected the Bay of Concepción since records began, in 1570, 1657, 1751, 1835 and 2010 (Aránguiz et al. 2011). Several far-field tsunamis, such as the events from Valparaiso in 1730, south Peru in 1868, the north of Chile in 1877 and the 2011 Japan tsunami, also entered the Bay. Therefore, the Bay of Concepción seems to be very exposed to the effect of both near-field and far-field tsunamis.

The propagation of tsunamis from the Arica-Tocopilla region to the Bay of Concepción has been studied by Aránguiz and Belmonte (2012). They defined the tsunami source parameters of the 1877 event and used Tohoku University's Numerical Analysis Model for Investigation of Near-field tsunamis (TUNAMI) code with a uniform initial condition to study the tsunami propagation. In a similar manner, Martínez et al. (2012) included in their work the effect of an 1877-like tsunami on the town of Tubul (37.23S 73.44 W) using the Non-hydrostatic Evolution of Ocean WAVEs (NEOWAVE) model. In both cases the arrival time and maximum inundation height of approximately 3 m in Talcahuano were well reproduced. However, none of these studies considered the tide at the moment of maximum inundation, which could be important due to the fact that the tidal range could be as high as 1.8 m in Talcahuano and many significant coastal settlements are located in the extensive flatlands around this area.

On those grounds, when a large earthquake takes place, a forecast model could be very helpful in estimating the maximum inundation height in the main Chilean ports, especially the Bay of Concepción. However, forecast models require precomputing earthquake parameters along potential earthquake zones as well as deep ocean buoys to detect and estimate tsunami sources in real time. For example, the NOAA Center for Tsunami Research (NCTR) has developed an operational tool that provides tsunami forecasts known