Observations by the International Tsunami Survey Team Regions VII-VI and V of Chile

Patricio A. Catalán[1], Rodrigo Cienfuegos[2], Patricio Winckler[3], Manuel Contreras[4], Rafael Almar[2], Juan Carlos Domínguez[2], Hermann M. Fritz[5], Catherine M. Petroff[6], Nikos Kalligeris[7], Robert Weiss[8], Carl Ebeling[9], Thanasis Papadopoulos[7], Sergio E. Barrientos[11], Costas Synolakis[7, 10]

Abstract

On Saturday, February 27, 2010 at 06:34 UTC (03:43 local time) an 8.8 Mw magnitude earthquake occurred off the central coast of Chile, offshore Maule. The earthquake triggered a tsunami that affected more than 500 km of the Chilean coastline and also affected the Juan Fernández archipelago and Easter Island. Both events caused significant damage along a large stretch of the Chilean coast and islands, with the resulting death toll reaching nearly 500, with the majority of these due to the tsunami.

An international tsunami survey plan was initiated within few days of the event, with scientists from the United States, Greece, Germany and Chile, and coordinated by UNESCO –ITIC. The main goal of this team was to collect relevant hydrodynamic data, including maximum tsunami heights, maximum run up heights, inundation distances and inundation areas, as well as collecting witness accounts of the events. Owing to the long spatial extent of the affected area, sub teams were formed to maximize efficiency and area coverage. The present work will present the results of this survey effort for the area north from the epicenter, specifically between Constitución and Quintero, where nearly 50 transects with run up heights and water depths were collected.

Our results highlight a large variability in the maximum runup along the coast, where several hot spots are identified, in some cases suggesting amplification due to local effects. Typically, the maximum runup ranged between 4 to 6 m and showed a decaying trend north of Constitución. However, in the vicinity of Pichilemu (VI Region) the runup increased significantly and reached up to 10 m . Further north, the maximum runup decayed again. These overall trends are consistent with witnesses accounts that at least two large wave events were originated with opposing traveling directions originating at the southern and northern edges of the rupture zone. The variability was also expressed in terms of the arrival times of the observed waves.

Methods

Hydrodynamic Data

Hydrodynamic data were collected along transects by visually identifying tsunami markings, such as the debris line, inundation marks on buildings and structures, and unusual placement of floating objects.

The products of this survey were

- *run up*, identifying the maximum vertical level the tsunami reached along the transect
- *maximum inundation*, measured horizontally from the instantaneous water level to the run up
- *inundation depth*, measured vertically when possible at several points along the transect

Special care was taken to distinguish sustained inundation levels from splash, as shown in the inset figure.

Interviews

Witnesses account of the events were recorded when possible. These provide valuable information with regards to the timeline of the events, as well as to the population preparedness and actual evacuation response.

Observations Summary

Run Up and Maximum Water Depth

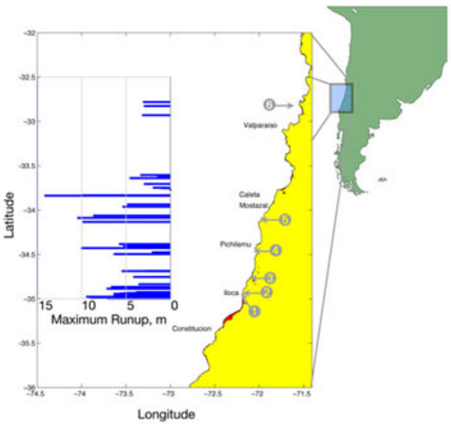
Run up information was collected at 42 transects distributed between the Mataquito River Mouth (VII Region) and Ritoque, a few km north from Valparaiso (V Region)

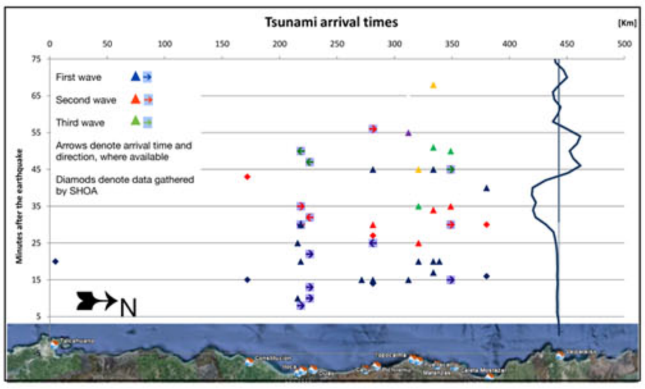
The resulting run up distribution shown in the figure is referred to the water level at the time of the measurement. However, the narrow tidal range of the area suggests that overall trends will not be affected by tidal corrections.

Despite the significant amount of scatter, the data show a south-north decaying trend between Iloca and Pichilemu. North of Pichilemu the run up increases to find a local maxima in Bucalemu.

Northward of Bucalemu, run up decays swiftly at first followed by sustained run up levels of about 2-3 m until Ritoque.

An overall maxima is found at Caleta de Mostazal, which is attributed to splash or local amplification effects.





Arrival Times

Multiple interviews were conducted within the surveyed area. Interviewees provided their recollection of the events, including the estimated arrival times, number of waves an wave characteristics.

As expected, the results show significant scatter, although some underlying trends are discernible.

For instance, many suggest the occurrence of a first wave propagating from the south (blue triangles). The estimated arrival time appears to increase as northwards.

This is consistent with the tide gage record at Valparaíso, which shows the first signal nearly 25 minutes after the earthquake.

A second wave was reported travelling from the north in locations south of Pichilemu, whereas located north from Pichilem report it traveling in the opposite direction (red symbols). Consistent with this, the arrival times for this wave seem to have a minimum near Pichilemu,

A third wave propagating from the north was reported on many locations, and in some cases it was mentioned that this wave was responsible for most of the damage.

Some reports mention a larger number of waves, which is consistent with the tide gage record. This highlights the complex nature of the event.

Sample Locations and Depth Profiles

Rancura ①

Date: 2010 / 03 / 11 18:44

Rancura is a small community directly south of Iloca. The local morphology was that of a wide beach terrace at the base of the coastal range. The inundation reached nearly 300 m inland with runups reaching 6 m above the water datum.

Iloca ②

Date: 2010 / 03 / 12 10:30

Iloca sustained widespread damage, although the maximum run up was about 4.7 m. Debris a floating bodies caused damage to the small dam used for the town's water supply, located a few kilometers inland along the Iloca river. Although some of the residential areas were protected by a coastal dune, the tsunami entered from the back side of the dune.
Despite the damage, no casualties were reported here due to the appropiate community response and training.

Boyeruca ③

Date: 2010 / 03 / 12 10:30

The coastal configuration of Boyeruca is typical of central Chile, where the interaction between a stream and waves tends to form bars and dunes at the discharge. These were completely reconfigured due to the tsunami, which propagated several kilometers inland as shown by boats found in crop fields. The most destructive waves were reported to be of bore-like nature approaching from the north.

Topocalma ④

Date: 2010 / 03 / 20 10:00

Topocalma is located a few kilometers north from Pichilemu. Here locals reported the wave approaching directly into the beach. Run up levels showed a significant increase with respect to communities located further south, reaching up to 10 m locally.

Puertecillo ⑤

Date: 2010 / 03 / 12 10:30

Puertecillo reported waves propagating from the south, with run uo levels reaching up to 10.5 m.
A casualty was reported in this area

Ritoque-Higuerillas ⑥

Date: 2010 / 03 / 17 16:40

While the passage of the first waves went unnoticed, the effects of the tsunami could be felt several hours after the earthquake. Locals watched and recorded several flooding events at 8 am, nearly 5 hours after the earthquake. Some of these late events had run up levels up to 3 m, and caused some damage on coastal infrastructure.

Summary

Our results highlight a large variability in the maximum runup along the coast, where several hot spots are identified, in some cases suggesting amplification due to local effects. Preliminary analysis of the witness accounts and tide gage records suggest the presence of at least two tsunami sources. One located south of the area surveyed, and the second near Bucalemu. This appears to be consistent with a very inhomogeneous uplift pattern along the 500 km rupture zone.

Despite the tsunami being near field and the lack of an alarm system, the population response was adecuate. This was attributed to both learning through tradition and specific tsunami awareness education campaigns carried out at community level.

Affiliations

1. Departamento de Obras Civiles, Universidad Santa Maria, Valparaiso, Chile.
2. Departamento de Ingenieria Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Santiago, Chile.
3. School of Ocean Engineering, Universidad de Valparaiso, Viña del Mar, Chile.
4. Facultad de Ingenieria, Universidad de Playa Ancha, Valparaiso, Chile.
5. Civil & Environmental Engineering, Georgia Institute of Technology, Savannah, GA, United States.
6. LP4 Associates LLC, Mercer island, WA, United States
7. Department of Environmental Engineering, Technical University of Crete, Chanea, Greece.
8. Department of Geology and Geophysics, Texas A&M University, College Station, TX, United States.
9. Geological Sciences, Northwestern University, Evanston, IL, United States.
10. Civil & Environmental Engineering, University of Southern California, Los Angeles, CA, United States.
11. Departamento de Geofisica, Universidad de Chile, Santiago, Chile.

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