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Hydrodynamics of tsunamis in subduction zones. The differences between the Chile 2010 and Japan 2011 tsunamis

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Tsunamis due to large earthquakes in subduction zones have different hydrodynamic behaviors, depending on the location, the bathymetry and the geometry of the rupture associated to the large earthquake. When the width of the rupture (related to the length of the tsunami) is larger than its distance to the shore, the hydrodynamics in the near zone is completely different than the alternate case. In the first case, the earthquake triggers a tsunami composed by one or a group of a few waves with a few minutes in between propagating from the rupture, which reach the coast a few minutes after the earthquake. In the second case, the earthquake triggers a deformation in the water surface which cannot create a complete tsunami wave; there is not enough distance to complete it. Then, a succession of secondary effects are triggered, which are composed by several floods, up to seven or eight, separated several minutes (up to forty or more) and propagate parallel to the coast, which can be even perpendicular to the coast. This case is still poorly understood, even it has been observed and described in the literature over the past three centuries.

The difference in hydrodynamic behavior was evidenced in the tsunamis of February of 2010 in Chile and March of 2011 in Japan. In this work we show a theory, which has been validated by field observations and numerical simulations based only on the hydrodynamics of the area, that explains the phenomena and it has been extended to other historical tsunamis in Chile.

The effects of the Chile 2010 tsunami in the near field zone were complex. The small township of Cobquecura, located at 20 km from the epicenter, did not suffer major damage from the tsunami. The major port zone of Talcahuano at 100 km from the epicenter, received four destructive waves every forty minutes approximately, and lasted three hours after the occurrence of the earthquake, while the bay of San Vicente, adjacent to the above, only suffered a minor, but abrupt, rise in the sea level about 20 minutes after the end of the earthquake. Flux in general was reported to be parallel to the coast, from the north.

In the case of Japan 2012 tsunami, the first wave arrived to shore from 1 to 50 min after the earthquake, depending on the distance to the rupture. This first wave was in the order of a few centimeters. The maximum wave arrived from 30 minutes to two hours after the earthquake, with high waves larger than 3 m, with flux perpendicular/diagonal to the coast.