Environmental Modelling & Software 25 (2010) 1874–1880

Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

A synoptic picture of the impact of the 26th December 2004 Indian Ocean tsunami on the coast of Sri Lanka

M. Ioualalen [a,*], W. Rentería [b], K. Ilayaraja [c], M. Chlieh [a], P. Arreaga-Vargas [b]

[a] Institut de Recherche pour le Développement, IRD, GéoAzur, Observatoire Océanologique, 2 Quai de la Darse, BP 48, F-06235 Villefranche-sur-mer Cedex, France
[b] Instituto Oceanografico de la Armada de Ecuador, INOCAR, Av. 25 de Julio-Km 3½, via Pto. Maritimo Base Naval Sur Guayaquil, Ecuador
[c] Department of Applied Geology, University of Madras, Guindy Campus, Chennai 600 025, India

A R T I C L E I N F O

Article history:
Received 17 July 2009
Received in revised form
31 January 2010
Accepted 16 April 2010
Available online 21 May 2010

Keywords:
2004 tsunami
Sumatra
Runup
Numerical simulation
Sri Lanka

A B S T R A C T

A numerical simulation of the 26th December 2004 Indian Ocean tsunami for the entire coast of Sri Lanka is presented. The simulation approach is based on a fully nonlinear Boussinesq tsunami propagation model and a robust coseismic source. The simulation is first confronted to available measured wave height. The agreement between observations and the predicted wave heights allowed a reasonable validation of the simulation. As a result a synoptic picture of the tsunami impact is provided over the entire coast of Sri Lanka. It is found that amplification due to shoaling applies mainly in the Eastern and Southern coast because, here, the wave is propagating across the sea floor slope, while propagating along the slope for the Western coast. Spots of high waves are due to wave focusing in some coastal areas while local submarine canyons in other areas inhibit the wave amplification.

1. Introduction

On Sunday, 26 December 2004 at 00:58:53 UTC, the Mw = 9.1–9.3 Sumatra–Andaman earthquake triggered a large tsunami that severely damaged coastal communities in countries along the Indian Ocean, including Indonesia, Thailand, Sri Lanka, India, Maldives, and Somalia located at more than 6000 km, which corresponds to a wave travel time up to 8 h. The epicenter and first aftershocks indicate that approximately 1300 km of subduction interface ruptured along the northern Sunda Trench. The tectonics and seismicity of the bay of Bengal can be found in Socquet et al. (2006), Stein and Okal (2005) and the recurrence of earthquake-triggered tsunamis is discussed in Altinok and Ersoy (2000). As far as the tsunami is concerned, Sri Lanka was the second area after Sumatra, Indonesia, that encountered most damages and casualties. A series of waves impacted more than two third of the coast. The tsunami left ~31,000 human deaths, ~4110 missing, 440,000 displaced. It provoked severe damages in harbours, infrastructures including housing, livelihoods. Communication and transportation systems were seriously affected. A great level of pollution was observed in the flooded areas (e.g., in drinking water reservoirs). Naturally, the effects were increased or reduced by the shape of the coastline, geomorphologic features and the bathymetric variation, i.e., the physical processes involved. But also and importantly, the effective effects of the hitting were different depending on the level of exposure and vulnerability of the coastal communities to the impact of waves. Such parameters may also vary at a daily time scale, e.g., transport- traffic, rush hours.

The measurements associated to the physical phenomena, the runup and inundation mainly, cannot be taken as a measure of the impact of tsunami because there are other facts that influences in the effects. However, there are cases where the impact magnitude is related strongest to these values. For example, two of the highest values for the height of wave and inundation were observed in Kalmunai and Hambantota (Liu et al., 2005; Fig. 1; Table 1); in the latter location, the number of victims reached 1000 and, as resulted of flooding, the lagoon near to the town was contaminated with debris swept for the tsunami inland. In Kalmunai, the wave flooded and caused damages as far 1500 m inland, within this zone all structures was severely damaged (Liu et al., 2005). In other places like Payagala, were the wave heights were weaker (Liu et al., 2005; Fig. 1; Table 1), the amount of fatalities was significantly high, 800 deaths. Here, a train with numerous passengers happened to circulate along the coast at the time the tsunami reached it. Also, another important feature is the level of protection of a coastal area

* Corresponding author.
E-mail address: Mansour.Ioualalen@geoazur.obs-vlfr.fr (M. Ioualalen).

1364-8152/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsoft.2010.04.010

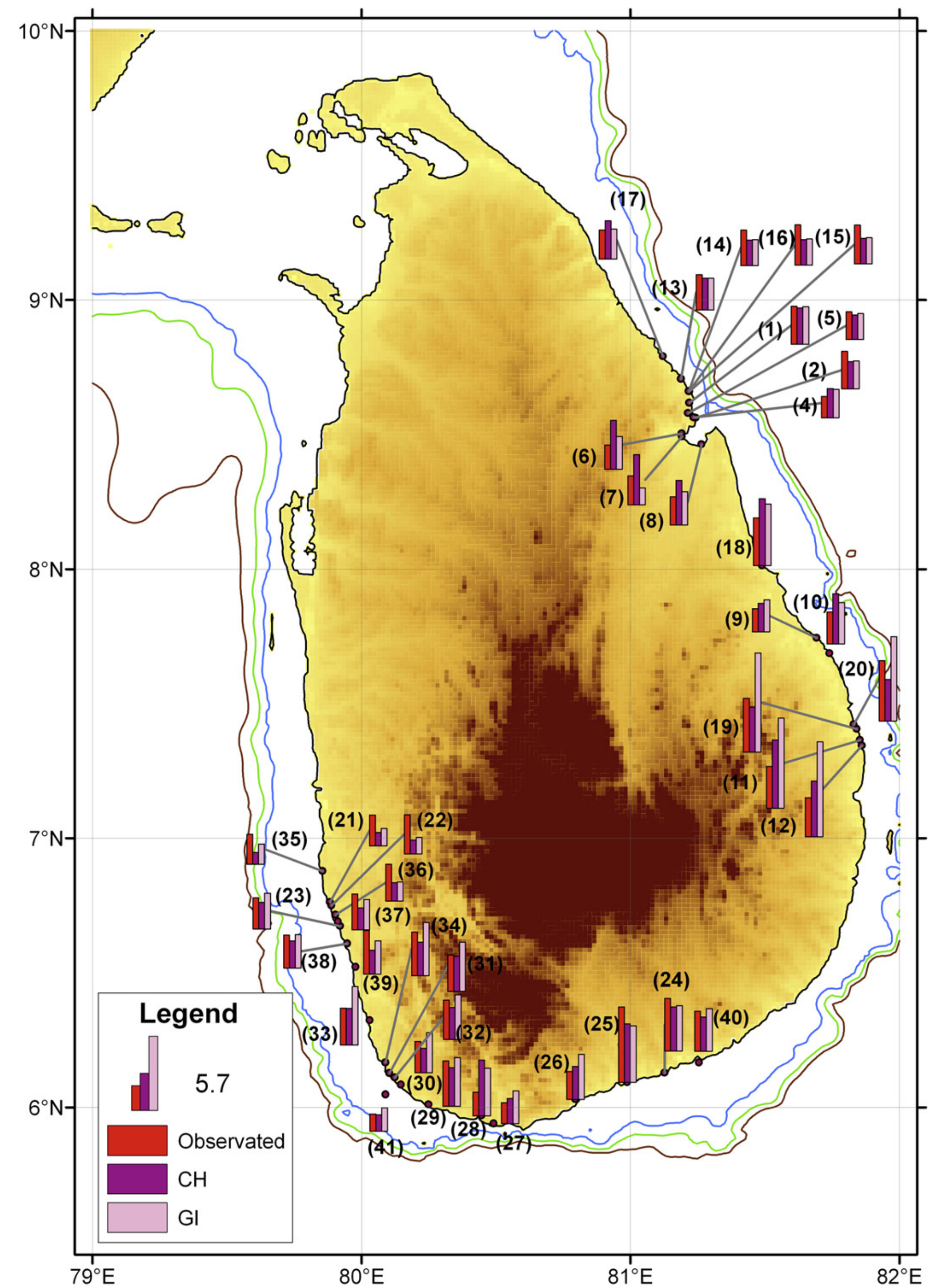

Fig. 1. Plotted measured and simulated wave height at locations mentioned in Table 1. GI and CH stand for the simulations based on the coseismic source of Grilli et al. (2007) and Chlieh et al. (2007) respectively. Isobathes 1000 m (brown curve), 500 m (green) and 300 m (blue) are reported. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

by natural barriers, like coral reef, mangroves and sand dunes, whatever is the wave height. Contrary to the southern and eastern coastline, in the eastern coast, where none of them exist, the damages were more important. In that area, poor housing situated over the coastline were converted by the tsunami in debris that yielded the re-enforcement of the damages.

The numerical simulation that we present here for the Sri Lanka case study has two objectives: The first purpose is to provide a synoptic picture of the event and, in particular, the runup or wave height maxima distribution along a coastline. It is suitable that the numerical simulation is not constrained by runup observations in order to assess a predicted runup distribution (this is the case in the present study). The other interest of numerical modeling is to identify physical processes that are responsible for local wave amplification or attenuation. Then the picture reveals vulnerable areas as well as sheltered ones. These issues are crucial in regions