Tsunami Wave Parameters Calculation before the Wave Approaches Coastal Line

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ABSTRACT

In this paper we provide a possible way to face the challenge of the tsunami wave height evaluation in real time after a seismic event. Our scenario is based on 2011 Japan Earthquake, in which case the wave traveling time after the seismic event to the nearest coast was close to 20 min. Three improvements to the existing data processing technique are proposed: sensor network optimization, fast determination of tsunami wave parameters at source, and to accelerate calculation of tsunami wave propagation. By applying these approaches it is possible to reduce the time required for wave height calculation to 12 minutes.

KEY WORDS: tsunami risk early warning, modern computer architecture.

INTRODUCTION

Friday, March 11, 2011 at 05:46:23 UTC, Japan was struck by an 8.9-magnitude earthquake near its Northeastern coast. This is one of the largest earthquakes that Japan has ever experienced. Tsunami waves swept away houses and cars and caused massive human losses. According to the CEDIM report, over 20,000 people died and about a million people lost their homes, due to earthquakes and their effects. More than one million buildings were damaged in Japan (http://earthsky.org/earth/economic-losses-from-earthquakes-and-natural-disasters-peaked-in-2011). Japan has lost considerable physical and human capital. Physical damage has been estimated to from $250 billion to as much as $309 billion.

Question arises is that possible to reduce human causalities and economy loss by timely warning about tsunami danger even in case of small traveling time from tsunami source to the coast. In other words, we are speaking about Tsunami Early Warning Systems (TEWS). Several of such systems exist over the world. In the sequel we will discuss possible improvements in TEWS built by NOAA (USA), which is based on deep ocean tsunami records, obtained at special buoys (DART). These data are processed to calculate wave parameters and inundation zones. Alternative approach was successfully implemented in Indonesia, see Lauterjung et al. (2010), Behrens et al. (2010) and Taubenböck et al. (2009). This is based on calibration of GPS sensors data. Perhaps, it is effective only at selected geo locations.

We propose a way to improve the quality of tsunami wave parameters prediction and to reduce time required for that. In that way we suggest to improve the quality of existing TEWS systems. Using new algorithms for data processing and facilities of modern computer architectures it is possible to calculate wave heights along the entire cost of Japan before the wave approaches the coastal line. This could be used for tsunami risk mitigation with the goal to reduce human loss by activating urgent evacuation measures in time.

There exists a well-developed system of deep ocean tsunami detectors operating across the Pacific (www.ndbc.noaa.gov/dart.shtml). Pressure sensors (DART buoys and other) provide direct measurements of tsunami-wave time series, which are immediately available for analysis through satellite channels. However, current tsunami-warning systems fail to predict basic parameters of tsunami waves on time. Among the reasons of that we note extended computational resources required for full scale modeling and lack of data for analysis right after a seismic event. In this paper we address both these aspects. In fact, modern computer architectures such as, GPU (graphic processing unit) and FPGA (field programmable gates array), can dramatically improve performance of data processing, which may enhance timely tsunami warning prediction.

We propose to use three new techniques in the existing tsunami warning systems to achieve real-time calculation of tsunami wave parameters. Firstly, the measurement system (DART buoys location, e.g.) should be optimized (both in terms earlier detection of the arriving wave and in order to determine possibly the largest amplitude parameter). The corresponding software application is already developed and is ready for use (Astrakova, Bannikov, Cherny, and Lavrentiev, 2009). In application to the coastal line of Japan numerical tests show that optimal installation of only 4 DART buoys (accounting the existing sea bed cable) will reduce the tsunami wave detection time to only 10 min at most after an underwater earthquake.

According to typical scheme, the measured (or evaluated) data about tsunami wave parameters are recalculated in terms of initial sea bed (or sea surface, preferably) displacement. Then wave propagation is