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Some observations and analyses of the 2011 Tohoku earthquake and tsunami

Chau, KT, cektchau@polyu.edu.hk, The Hong Kong Polytechnic University

ABSTRACT

First, this article summarizes our field observations made along the coastlines of Miyagi and Iwate Prefectures in the Tohoku areas in 2012, including the cities of Ishinomaki, Onagawa, Minamisanriku, Kesennuma, Rikuzentakata, Ofunato, and Kamaishi. Some peculiar observations are reported, including the overturned buildings at Onagawa. Secondly, tsunami simulations were performed using COMCOT based on linear shallow water equations. The resolution of the bathymetry used is based on 1 min or 1.36 km grid downloadable from NOAA website. Three focal mechanism models proposed by United States Geological Survey (USGS), Chinese Academy of Science (CAS), and Tsukuba University (TU) were used to estimate the seismic moment, slip displacement on the fault plane, and fault rupture length and width by fitting empirical formulas. Tide gage readings were used to compare with these computer simulations. At far south inside the Tokyo Bay (Harumi station), all three USGS, CAS and TU based predictions are in phases with the actual tide gage readings, except that all models overestimate the water level by one to two times (from 1–2 m to 3–6 m). However, the tide gage predictions at Tateyama Mera station (southern tip of the Tokyo Bay and of Chiba Prefecture) are all out of phases from the observation. Further North, the recorded tide gage reading at Choshi (a junction of river mouth and a cape at southern tip of Ibaraki Prefecture) is about 8 m comparing to the simulation of only 2–4 m. Clearly more complicated wave reflections and interferences cannot be predicted at cape area without accurate data of the bathymetry or without including nonlinear effects. In addition, allowance of flow over land must be made along the River Mouth; hence “finite volume method” should be used for this location. Moving further North to Oarai (middle part of Ibaraki Prefecture), the initial wave is in phase with observation with comparable magnitude. The initial phases of simulations basically agree with that of observed data at Soma, and Ayukama of Ishinomaki, Ofunato, but out of phases with observations in Kamaishi, and Miyako (further North of the epicenter of the earthquake). Apparently, the propagating direction or so-called directivity of the fault rupture may play a role in generating the tsunami which was not and could take into consideration by this model. Far up North in the Hachinohe Port of Aomori Prefecture, the simulations are typically two to three times larger than the actual observations and simulations also predict an arrival time of the first wave of 15 min ahead than the actual time. This may suggest a directivity of fault rupture toward the south side of the fault.