Local tsunami warning system in South Korea and its ongoing improvement

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1. Introduction

The Korean peninsula experienced damage by tsunmai originated in Japan. Large Japanese earthquakes (M7.5-8) affected to the eastern coast of the peninsula by the tsunami in 1940, 1964, 1983 and 1993. Among them, the 1983 Akita tsunami generated by M7.7 earthquake produced and loss of lives as well as property damage with 2-5 m high waves (Choi et al., 2009). Influenced by the 1983 tsumai, the Korea Meteorological Administration (KMA) started to operate tsunami warning system and issued tsunami warning when the M7.8 earthquake occurred in 1993 driving no loss of lives. Since then, the tsunami warning system of KMA has been modified and is still under improvement to take action against large Pacific tsunamis.
In this paper, we will introduce the status of tsunami warning system of KMA and the on-going improvement.

2. Local Tsunami Warning System

KMA has developed tsunami warning system based on scenario tsunami database to forecast tsunamis in surrounding seas. Earthquakes at 5,965 locations (Fig. 1) with magnitudes of 6.0 ~ 9.0 in 0.2 interval were assumed and the tsunami was simulated. Geometries of the fault planes near the Japanese Islands were assumed using previous studies and those in other areas were assumed to be parallel to the coast lines of the peninsula. Then database was constructed with tsunami arrival time and maximum height at about 950 points around the coastal line at a depth of 50 m. When an earthquake occurs, tsunami information is searched from the database (Fig. 2) and tsunami warning is issued for some major cities along the coastal line.
Limitation of present tsunami warning system is that only the information on several major cities can be provided. Therefore we reconstructed tsunami database to have the information of tsunami arrival time and maximum height at about 3,200 grid points close to the coastal lines. For the tsunami simulation, we used COMCOT (COrnell Multi-grid COupled Tsunami model) and the unit tsunami method (Lee et al., 2005; Kim et al., 2013). We also classified 25 districts for tsunami forecast according to marine weather forecast regions of KMA.
Tsunami information would be provided in district base in the near future (Fig. 3) by dividing the grid points (about 3,200) into the classified 25 districts and taking the earliest tsunami arrival time and the range of tsunami heights in each district.

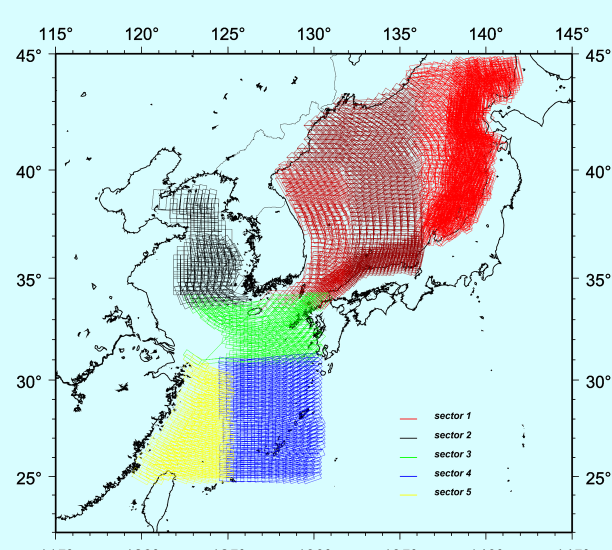

Fig. 1 Distribution of assumed fault planes for M7.8 earthquake to construct tsunami database

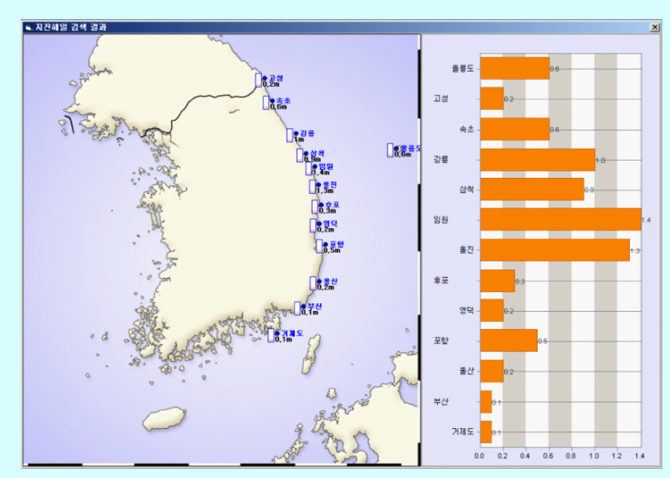

Fig. 2 Example of searched result of scenario tsunami database

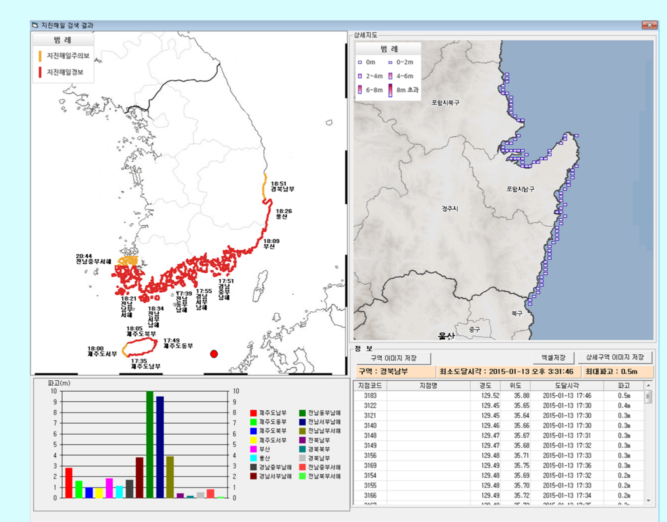

Fig. 3 Example of searched result of scenario tsunami database in district base which would be adopted in the near future

3. Development of Global Tsunami Simulation Model

National Institute of Meteorological Research (NIMR), KMA is developing global tsunami warning system to predict tsunami heights and arrival times to South Korea by tsunamis occurred in the Pacific Ocean. Our developing global tsunami warning system consists in mainly two stages.

First stage is to estimate slip distribution on the fault plane generating the earthquake.
Usually slip distribution is obtained by seismic waveform inversion using Green's functions from each grid point on the fault plane to stations and matching the synthetic waveforms with observed data. To get slip distribution soon after the occurrence of a large earthquake, fault size is estimated from the magnitude using empirical relationship and then Green's functions from subfaults within the fault range are used for the inversion. For real-time operation, Green's functions are calculated in advance.
Spectral Element Method (SEM; Komatitsch et al., 2005) based on 3D velocity model, S362ANI (Kustowski et al., 2008), was used for the calculation of Green's functions from each unit subfault to station (Baag et al., 2015). Unit subfault is assumed to have dimension of 50 km × 50 km along major subduction zones (Fig. 4) and to vary dip angle as the depth deepens, using Slab 1.0 model (Hayes et al., 2012). When a large earthquake occurs, the slip distribution on the fault plane is obtained in a few minutes using the already calculated Green's functions and is used to estimate the surface deformation which can be assumed to be the same as the initial tsunami height.

Second stage is to simulate tsunami propagation and calculate tsunami heights and arrival times on the coast of South Korea.
To secure the accuracy on tsunami height, fine grid of bathymetry in the surrounding seas of the peninsula is considered in tsunami propagation model.
We are developing tsunami simulation model based on Finite Volume Coastal Ocean Model (FVCOM) to construct fine grid around the Korean peninsula as well as around the fault plane (Fig. 6). Because FVCOM is parallelized code-based algorithm, it is expected to get tsunami simulation result before the tsunami in the Pacific Ocean reaches to the Korean peninsula.

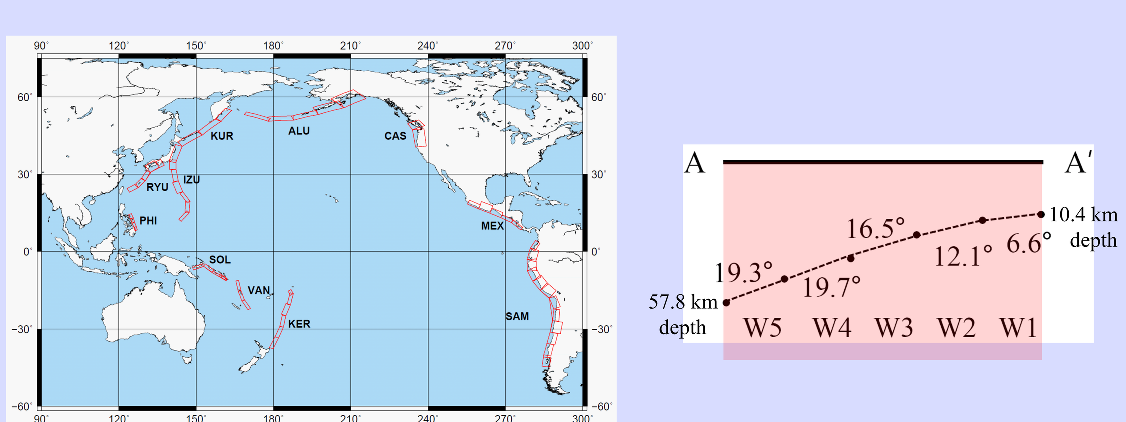

Fig. 4 Regions that subfaults are assumed along subduction zones and example of slab model varying dip angle (NIMR, 2013)

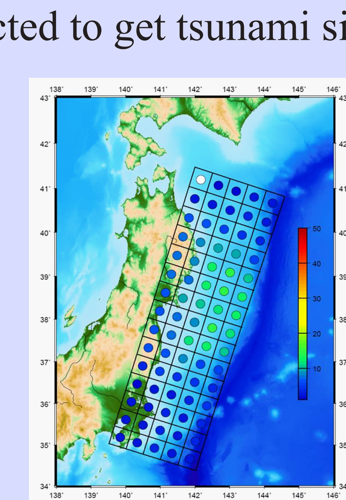

Fig. 5 Slip distribution of the 2011 Tohoku, Japan earthquake (NIMR, 2013)

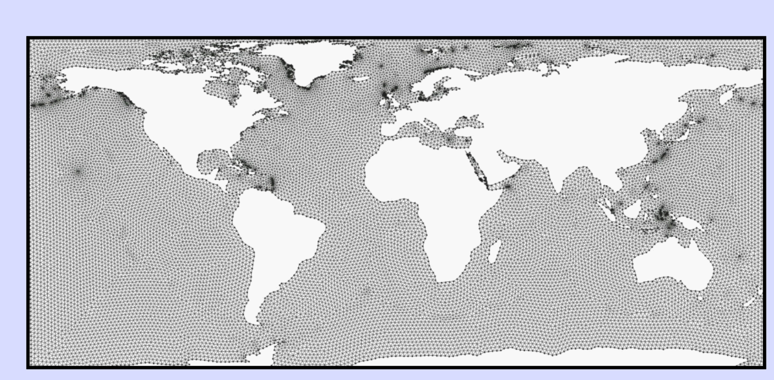

Fig. 6 Unstructured grid for global tsunami simulation (NIMR, 2014)

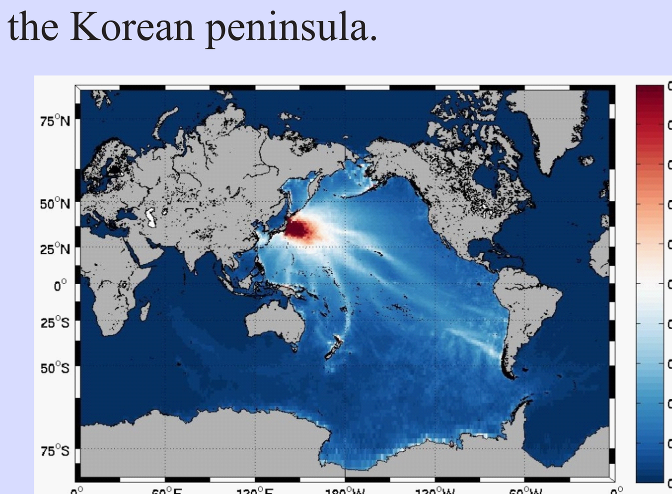

Fig. 7 Distribution of maximum height of the 2011 Tohoku tsunami (NIMR, 2014)

4. Tsunami Observation

KMA has not an automatic or instrumental tsunami observation system at present. To observe tsunami quantitatively, we are developing a tsunami detect and observation algorithm using real-time tidal and surge data. The algorithm consists of several processes, which are de-spiking, gap-filling for missing data (Lee and Park, 2015), de-tiding, detecting tsunami arrival and measuring tsunami height. For detecting tsunami, we apply two algorithms, one being used for Deep-ocean Assessment and Reporting of Tsunami (DART) system (Mofjeld, 1997; Fig. 8) and the other using slope of wave height (Bressan and Tinti, 2011; Fig. 9). For de-tiding process (Fig. 10), we estimate tide at a tide station using T-TIDE code (Pawlowicz et al., 2002). Tsunami height is measured after de-tiding.

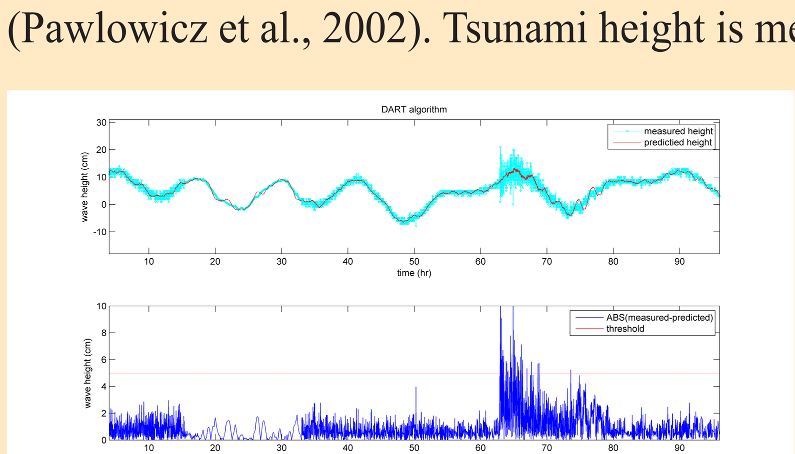

Fig. 8 Example of tsunami detecting using the DART algorithm

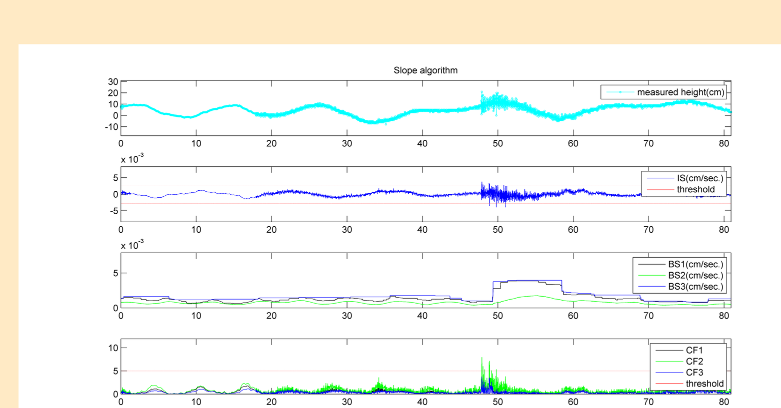

Fig. 9 Example of tsunami detecting using the slope algorithm

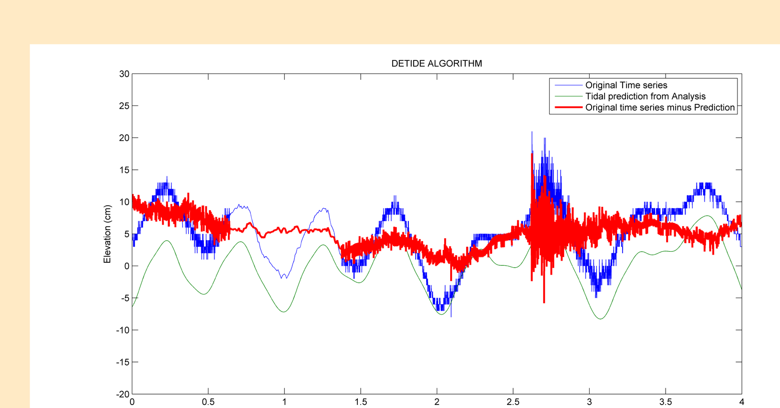

Fig. 10 Example of de-tiding

5. Summary

We are developing several algorithms and systems to modify the tsunami warning system of KMA and to make the tsunami warning process easier to use and faster to get information and the information more accurate. To get the information faster, we use tsunami database and parallelized code-based tsunami simulation algorithm.
We pursue the accuracy by applying seismic waveform inversion process soon after an earthquake and fine grid of bathymetry near the Korean peninsula.
To observe tsunami quantitatively, tsunami observation algorithm with tidal and surge data is developing. All these system will be operated in real-time and automatically as much as possible.
When these systems are adopted for real-time operation of KMA after verification, they may be contributed to the reduction of tsunami hazards in South Korea.

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