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Tsunami wave estimation using GPS-TEC back projection

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1. Introduction

Large tsunami generates an acoustic wave and shakes the atmosphere layer around a focal region. The generated acoustic wave propagates to ionosphere layer which is located at about 300km hight and causes a ionospheric disturbance. So, a generated acoustic wave causes the density of total electron content (TEC) inside ionospheric layer to be change. The changing TEC inside ionospheric layer can be measured by dense GPS network, such as GEONET. TEC can be easily measured as the phase differences of the L band carrier waves in two frequencies from GPS satellites. A kind of TEC disturbance widely appear in relating with solar activities, acoustic wave, gravity wave and so on. For example, Heki (2006) estimates an explosion energy of the 2004 eruption of the Asama volcano from changing of TEC, which is measured by GPS observation.

We focus on a large tsunami such as the 2011 March 11 Tohoku-Oki earthquake (Mw 9.0) , which caused vast damages to the country. Large events beneath dense observation networks could bring breakthroughs to seismology and geodynamics. Tsunami wave due to the 2011 Tohoku-Oki earthquake generates acoustic wave which propagates to ionospheric layer. The Japanese dense network of GPS detected clear anomaly of ionospheric TEC due to Tsunami wave around the focal region. We assume that acoustic wave cause the ionospheric disturbance and estimate tsunami wave propagation using Back Projection (BP) method of ionospheric disturbance.

2. GPS-TEC data

The Japanese dense array of GPS recorded ionospheric disturbances as changes in TEC due to the 2011 Tohoku-Oki earthquake. In this study, we try to reveal the detail of generating tsunami propagation using changing TEC from GPS observation network. At first, we process GPS-TEC above focal region by 1 sec sampling of GEONET. We remove slant GPS-TEC effects using filter out second degrees polynomial fitting. After this, for noise reduction, we adapt a band pass filter from 5 sec to 300 sec. We try to process for all combination between GEONET sites and GPS satellites. The number of combination is over 10,000. In particular, GPS-TEC is measured over 1,000 points above the focal region.

3. GPS-TEC Back Projection

We assume tsunami wave due to the event cause the anomaly of GPS-TEC. The large tsunami waves generate acoustic waves above focal region. It is propagating to ionosphere as compressional wave. In order to estimate Tsunami wave propagation, we adapt the BP method to the observed anomaly of TEC time series. The BP method has the experience of seismic wave analysis (e.g., Ishii *et al.* (2005)). We make image of spatio-temporal source distribution of acoustics wave using the BP method based on acoustic wave velocity.

We try to adapt back projection (BP) method for GPS-TEC time series. The BP product shows the beam formed time history and location of coherent acoustic-wave energy generated by large tsunami observed at ionospheric layer regional arrays and across the GPS Network. BPs are performed by beam forming (stacking) energy to a flat grid around the source region with variable spatial resolution scaled by the magnitude of generating tsunami velocity for each second.

4. Results

In result, we can obtain the generating tsunami wave due to a large earthquake. The method is perfectly new and provide detail of tsunami propagating wave distribution from huge GPS-TEC data. We can obtain in-direct measurement Tsunami wave generation from ionospheric disturbances. So, this result will bring a revolution of tsunami study.

Keywords: GPS, TEC, Back Projection, Tsunami