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アイソクロン・バックプロジェクション法による2007新潟県中越沖地震の震源過程
（改訂 ver.2）

Rupture process of the Niigata Chuetsu-oki Earthquake, by using an Isochrones Back-projection Method (IBM) and KiK-net, K-NET Strong motion data (*version 2*)

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1- Method

The IBM method differs from conventional earthquake source inversion approaches, in that the calculation of Green's functions is not required. The idea of the procedure is to directly back-project amplitudes of seismograms envelopes around the source into a space image of the earthquake rupture (Pulido et al. 2007).

The method requires the calculation of theoretical travel times between a set of grids points distributed across the source, and every station. For this purpose and for simplicity we assume a multi-layered 1D model. All travel times are adjusted by a station correction factor, calculated by taking the average difference between observed and theoretical travel times at each station. Next we calculate the rupture time of every grid within the source by assuming some arbitrary constant rupture velocity value, and obtain the isochrones distribution by adding subfaults rupture times and the corresponding travel times for every station. We select waveforms that have clear P and S wavelets, which means stations located approximately between 40 km and 100km from the epicenter. We extract P-wave windows between the origin time of the earthquake and the theoretical arrival of the S-wave, and taper 1s of the waveforms at the end. We band-pass filter the data between 1Hz and 30Hz, and calculate the waveforms envelopes using the root-mean-square of the original waveforms and their Hilbert transform. We calculate a grid "***luminosity***" by adding all the envelope amplitudes corresponding to every grid isochron time for all stations. The final result is a distribution of the luminosity across the source area, which gives us an idea of the regions with the largest radiation of seismic waves within the source area.

2- Imaged volume

We estimated the source process of the 2007/7/16 Niigata Chuetsu-oki earthquake (latitude 37.5397, longitude 136.6091 and depth 8 km, estimated by DD method [Yukutake et. al. 2007]) by using an Isochron Backprojection Method (IBM) and K-NET, KiK-net waveforms (Pulido et. al. 2007). In this study we search for the largest luminosity regions within a volume centered at the hypocenter (33km along the N49 strike x 20km normal to the strike x 16km of depth) and containing grids spaced at 1km, in order to investigate the capability of the IBM to identify the causative fault plane with no a priori constraints.

3- Data

To estimate the source process we choose 28 K-NET and 21 KiK-net stations, with distances ranging from 40km to 100km from the epicentre (Figure 1). For the calculation of travel times we used a velocity model developed for the Niigata Chuetsu region (Shibutani et al. 2005). Envelopes of EW components of K-NET and KiK-net stations used for source imaging are shown in Figure 2.

4- Results

Figure 3 shows the luminosity radiation across the scanned volume for rupture velocities of 2.6 km/s and 3.0 km/s. Two slices across the volume corresponding to the two complementary F-NET fault plane solutions are shown. It may be observed from this Figure that the main radiation of seismic waves originates from a region SE of the hypocenter. Namely the IBM solution favors the NW dipping fault plane as causative fault of the 2007 Niigata-ken Chuetsu-oki earthquake. We obtained that a rupture velocity of 3.0 km/s maximizes the total volume luminosity for the Niigata-ken Chuetsu-oki earthquake (Figure 4). Figure 5 shows the horizontal projection of the luminosity radiation for the F-NET fault plane solutions, together with the first day of aftershocks.

IBM has the capability to identify the causative fault plane with no a priori constraints. This is particularly useful for cases like the Niigata-ken Chuetsu-oki earthquake, where there is ambiguity in defining the causative fault among the two complementary fault plane solutions.

5- References

Pulido, N., S. Aoi, and H. Fujiwara, 2007. Rupture process of the 2007 Notohanto Earthquake by using an Isochrones Back-projection Method and K-NET and KiK-net data, (submitted).

Shibutani et. al., 2005. Aftershock distribution of the 2004 Mid Niigata Prefecture Earthquake derived from a combined analysis of temporary online observations and permanent observations, Earth Planets and Space, 57, 545-549.

Yukutake, Y., T. Takeda, and K. Obara, 2007. Spatial distribution of aftershocks in the region of Niigata Tyuetsu-oki Earthquake in 2007, by waveform correlation analysis, Fall meeting of the Seismological Society of Japan, P1-063.

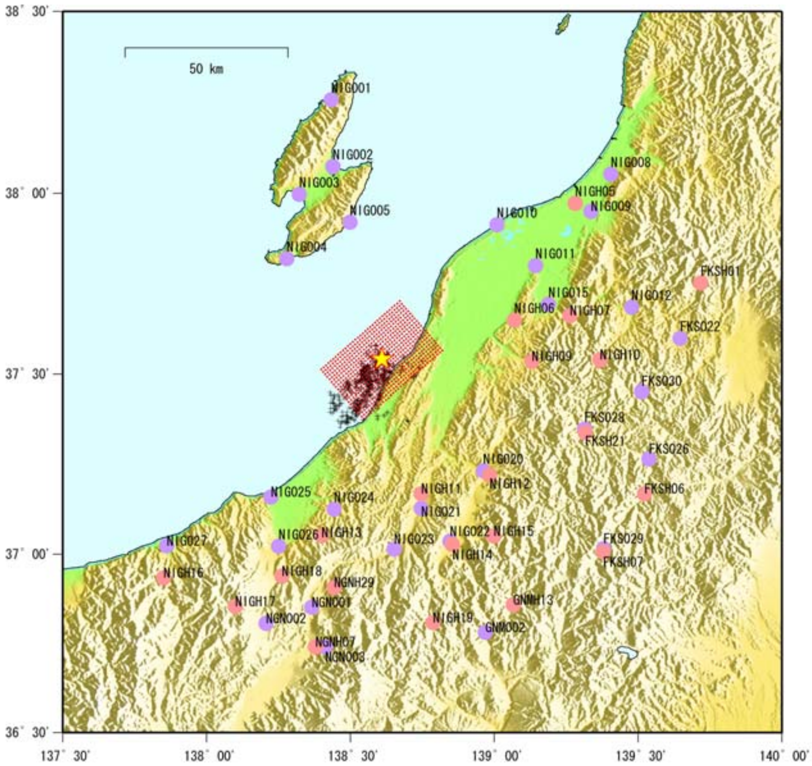

Figure 1. KiK-net and K-NET stations used for the source imaging of the 2007/7/16 Niigata-ken Chuetsu-oki earthquake. The star represents the DD-relocated Hi-net hypocenter (Yukutake, et al. 2007). The shallower grids of the imaged volume are shown by small red dots.

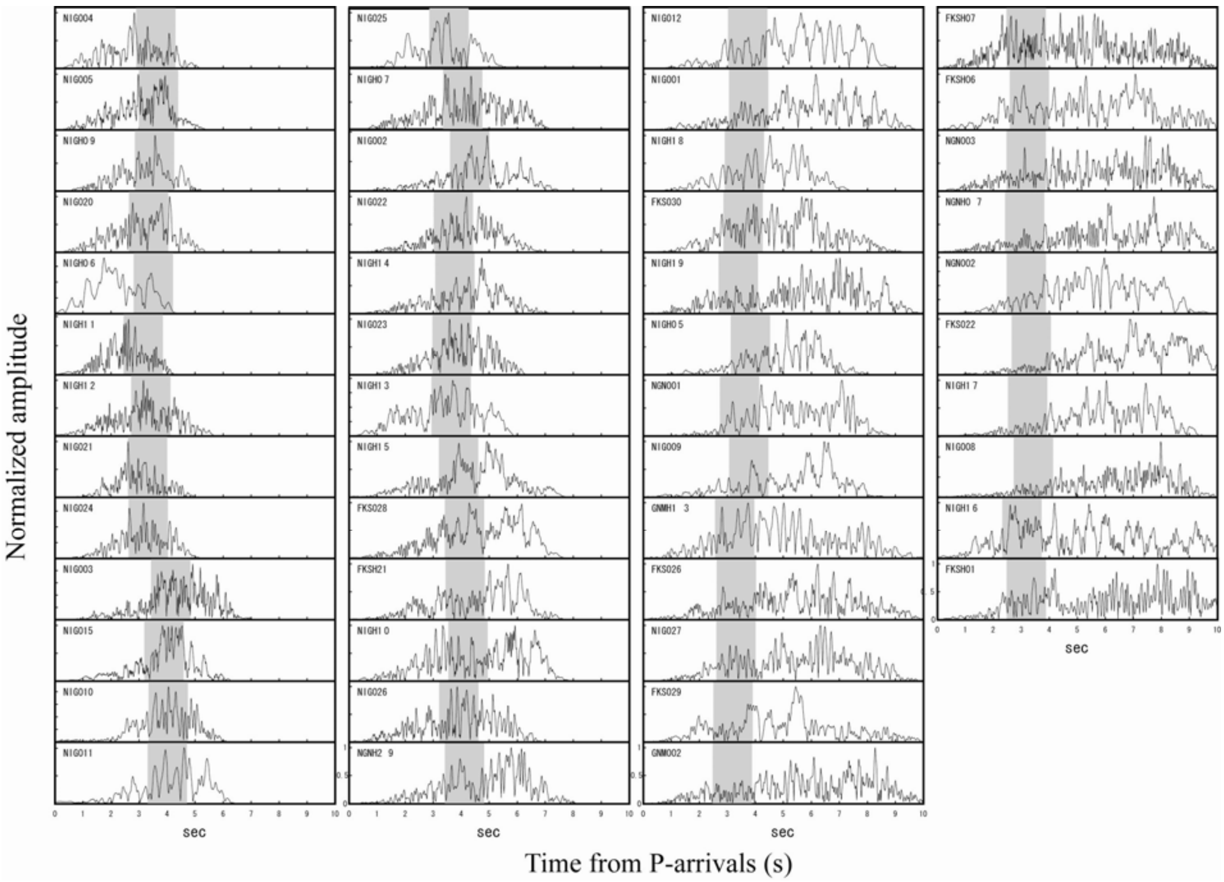

Figure 2. Normalized EW component of velocity envelopes at K-NET and KiK-net sites used for source imaging of the Niigata Chuetsu-oki earthquake. The envelopes are aligned at the P-wave onset and ordered by increasing arrivals. The thick gray lines represent the isochrone time corresponding to the largest luminosity region within the imaged volume.

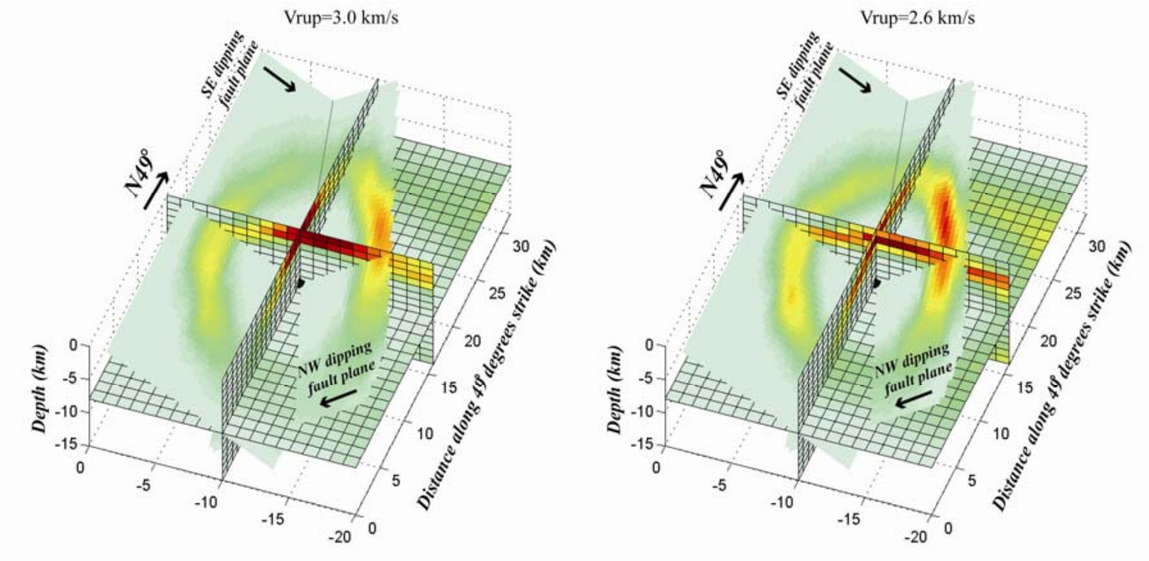

Figure 3. Luminosity distribution obtained by the IBM source imaging procedure for a volume centered around the hypocenter. Solutions for two rupture velocities of 2.6 km/s and 3.0 km/s are shown. The two inclined slices within the volume correspond to the luminosity radiation across the F-NET fault planes solutions; the SE dipping fault plane (49/42/101), and the NW dipping fault plane (215/49/80). The black dot represents the hypocenter.

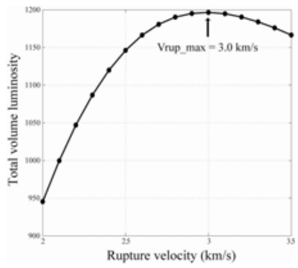

Figure 4. Volume total luminosity for different values of rupture velocity. The total luminosity is a good indicator of the optimum rupture velocity. This idea is supported by the fact that when no radiation is occurring from a grid within the volume, the summation of all envelopes amplitudes for that grid will not add coherently.

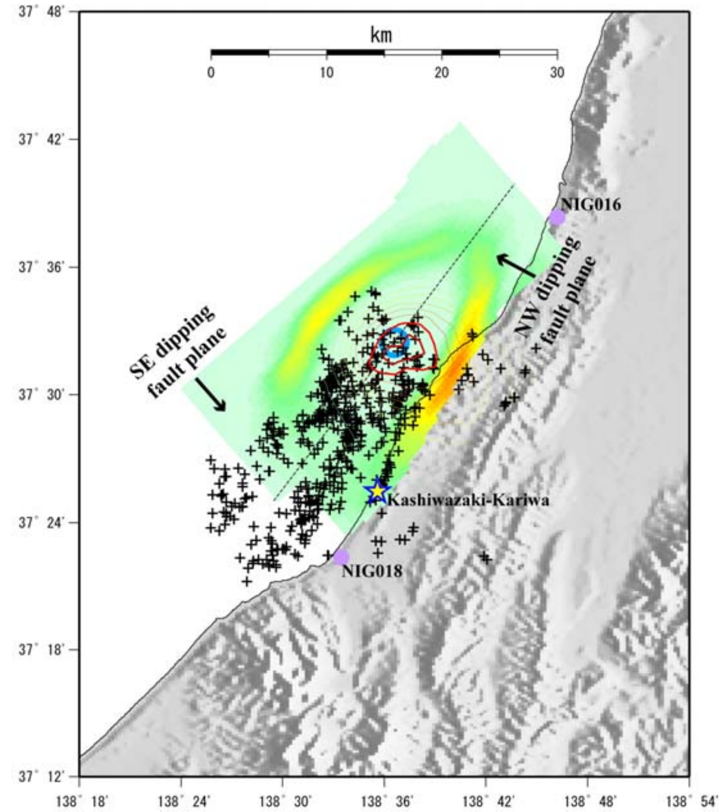

Figure 5. Map projection of the IBM source imaging for the SE and NW dipping fault plane models. The red contours represent the horizontal projection of the maximum luminosity region within the volume. The crosses represent the first day of aftershocks relocated by the DD method (Yukutake et al., 2007). A blue circle represents the hypocenter.