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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2005年福岡県西方沖の震源過程のイメージング

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Conventional approaches to investigate the source rupture process of earthquakes are based on inversion of near-fault ground motions. Because these methods rely on the calculation of a large number of Green's functions, slip images of the earthquake are only obtained several days after the earthquake.In this study we introduce a technique for imaging the rupture process of an earthquake shortly after the records from the earthquake become available. We study the source process of the 2005 Fukuoka-ken Seiho Oki Earthquake by using an Isochrons Back-Projection Method (IBM). The idea of the procedure is to back-project amplitudes of seismograms envelopes around the source into a time-space image of the earthquake rupture.We set a grid of possible sources across the fault plane of the Fukuoka earthquake and calculate the theoretical travel times from every grid to every station. We assume a rupture initiation point, that in this case corresponds to the Hi-net hypocenter location, and calculate the rupture time of every grid within the fault plane by assuming some arbitrary rupture velocity value. Then we obtain the isochrones distribution within the fault plane for every station. We choose 55 stations (KiK-net boreholes and K-NET) with distances ranging from 40km to 100km from the epicentre. We calculate the waveforms envelopes using the root-mean-square of the original waveforms and their Hilbert transform and start them at the origin time. We calculate a grid "luminosity" by adding all the envelope amplitudes corresponding to every grid isochron time for all stations. In this way we scan for all possible isochrons time contributions to the grid luminosities from the shortest to the longest possible isochrons time values. The present method is an extension of the source imaging method by Festa et. al.(2006).

We obtained an image of the total luminosity at every grid within the fault plane. We also search for an optimum rupture velocity value by exploring the model with the largest total grid luminosity within the fault plane. We obtained that a rupture velocity of 2.1 km/s maximizes the total fault plane luminosity for the Fukuoka earthquake. Our results show that the grids with the largest luminosity correspond to a region approximately 8 km above and slightly south of the hypocenter. This high luminosity region corresponds approximately to the large slip region (asperity) obtained by a kinematic inversion of the Fukuoka earthquake (Sekiguchi et. al. 2006). Our results show so far that the IBM has the capability to identify asperities within the fault plane. The present method has the advantage that it does not require calculation of Green's functions and therefore is able to identify asperities within the fault plane, soon after the earthquake. Future developments of the method will address the issue of how to relate the outputs of the model with quantitative images of fault slip, as well as extending the search domain to a volume around the hypocenter in order to study the capability of IBM to identify the causative fault plane without any a-priori constraint.

I Method and Data

-We use 31 K-NET and 24 KiK-net stations of NIED, with distances ranging from 40km to 100km from the epicenter, for source imaging.

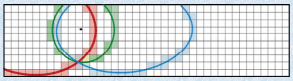
-We calculate all travel times between subfaults and stations using a velocity model obtained for the Fukuoka earthquake source region from a temporal seismic network (Uehira et. al., 2006). All travel times are adjusted by a station correction factor.

-We calculate the rupture time of every grid within the fault plane by a constant rupture velocity and add subfaults rupture times and the corresponding travel times for every station (isochrons times).

-We select waveforms that have clear P and S wavelets, 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.

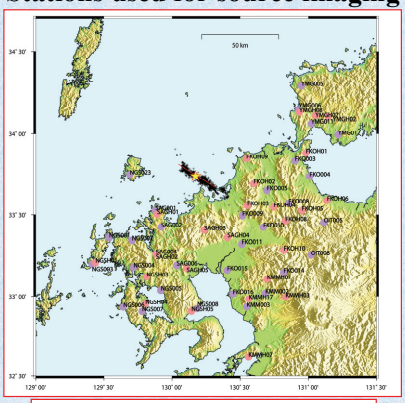
-We band-pass filter the data between 1Hz and 30Hz, and calculate the waveforms envelopes using the root-mean-square of the original waveforms and their Hilbert transform.

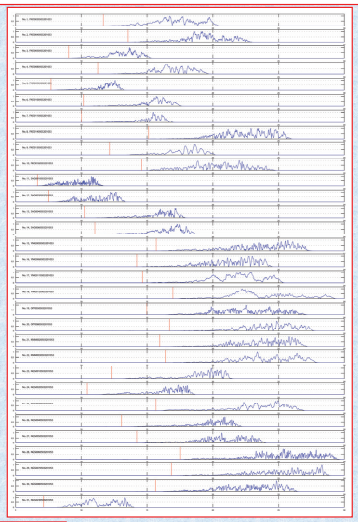
-We calculate a grid "brigthness" by adding all the envelope amplitudes corresponding to every grid isochron time for all stations. Envelope values are obtain by taking the average of a +/- 1.5 sec window around each isochron time. The final result is a distribution of the brightness across the fault plane, which gives us an idea of the location of asperities within the fault plane.



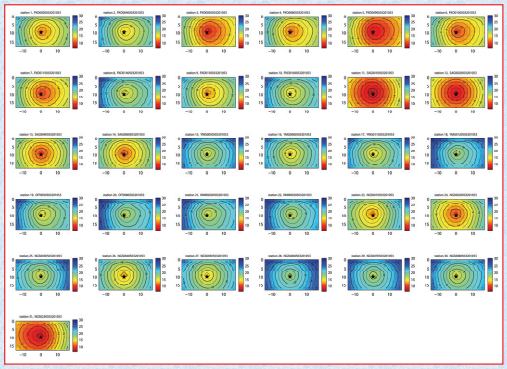
Aftershocks information in the figure to the left by Uehira et al. (2006)

II Stations used for source imaging





III Isochrons and velocity envelopes at K-NET stations



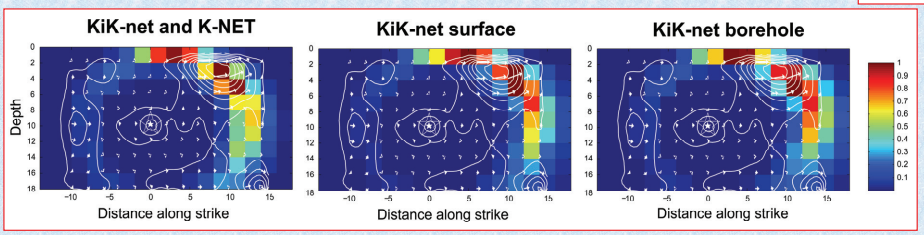
Normalized P-wave velocity envelopes at 31 K-NET sites for the EW component. Envelopes were obtained as follows:

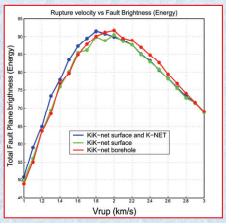
$$E[\dot{u}(t)] = (\dot{u}(t)^2 + H^2[\dot{u}(t)])^{1/2}$$

where $\dot{u}(t)$ is the velocity and H is the Hilbert transform.

Isochrons were obtained for a constant rupture velocity of 2.0 km/s and a multilayered 1D velocity model obtained for the Fukuoka earthquake source region (Uehira et. al 2006).

III Effect of local geology on Source Brightness imaging





In order to explore the effect of local site conditions into the source imaging result we analyzed three different data sets including recordings of KiK-net and K-NET surface sites, as well as KiK-net boreholes recordings. From this analyses we can conclude that the site effects have a small influence on the source imaging result. Source model by Sekiguchi et. al. (2006) is shown as contour lines and vectors.

We explored the optimum rupture velocity defined for the value that maximixes the total fault plane brigthness.

IV Conclusions

-We obtained a source imaging of the Fukuoka Seihou-Oki earthquake by a non-conventional approach that do not requires calculation of Greens functions and inversion.

-Our source model shows a shallow asperity towards the South-East of the hypocenter. Comparison with a source model by an inversion approach, suggests that the fault brightness of the Fukuoka earthquake aproximately corresponds to large slip regions.

-We obtained that a rupture velocity of 2.0 km/s yields the maximum fault plane brigthness for the Fukuoka earthquake. However this result is highly dependent on the assumption of a uniform rupture velocity across the fault plane.

-We found that local site condition at surface sites has a small effect on the result of the IBM source imaging, from a comparison between models obtained from surface and borehole data.

V References

-Sekiguchi, H. S. Aoi, R. Honda, N. Morikawa, T. Kunugi, and H. Fujiwara, 2006. Rupture process of the 2005 West Fukuoka Prefecture earthquake obtained from strong motion data of K-NET and KiK-net, *Earth Planets Space,* 58, 37-43.

-Festa, G., and A. Zollo. 2006. Fault slip and rupture velocity inversion by isochrone backprojection, *Geophys. J. Int.*,166, 745-756.

-Uehira, K. et al., 2006. Precise aftershock distribution of the 2005 West Off Fukuoka Prefecture Earthquake (Mj=7.0) using a dense onshore an ofshore seismic network, *Earth Planets Space,* 58, 1605-1610.