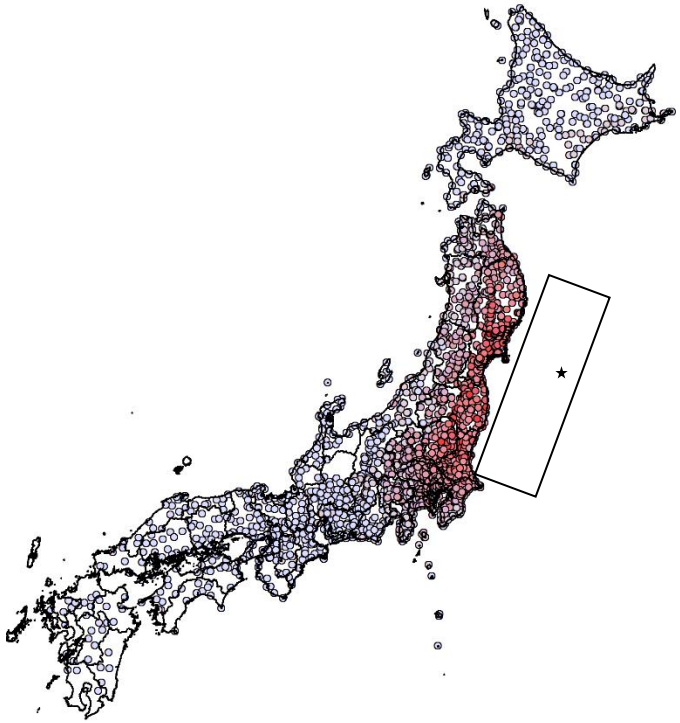
5th IASPEI / IAEE International Symposium: Effects of Surface Geology on Seismic Motion
August 15-17, 2016

SITE EFFECTS ON STRONG MOTION RECORDS OF THE 2011 TOHOKU, JAPAN EARTHQUAKE

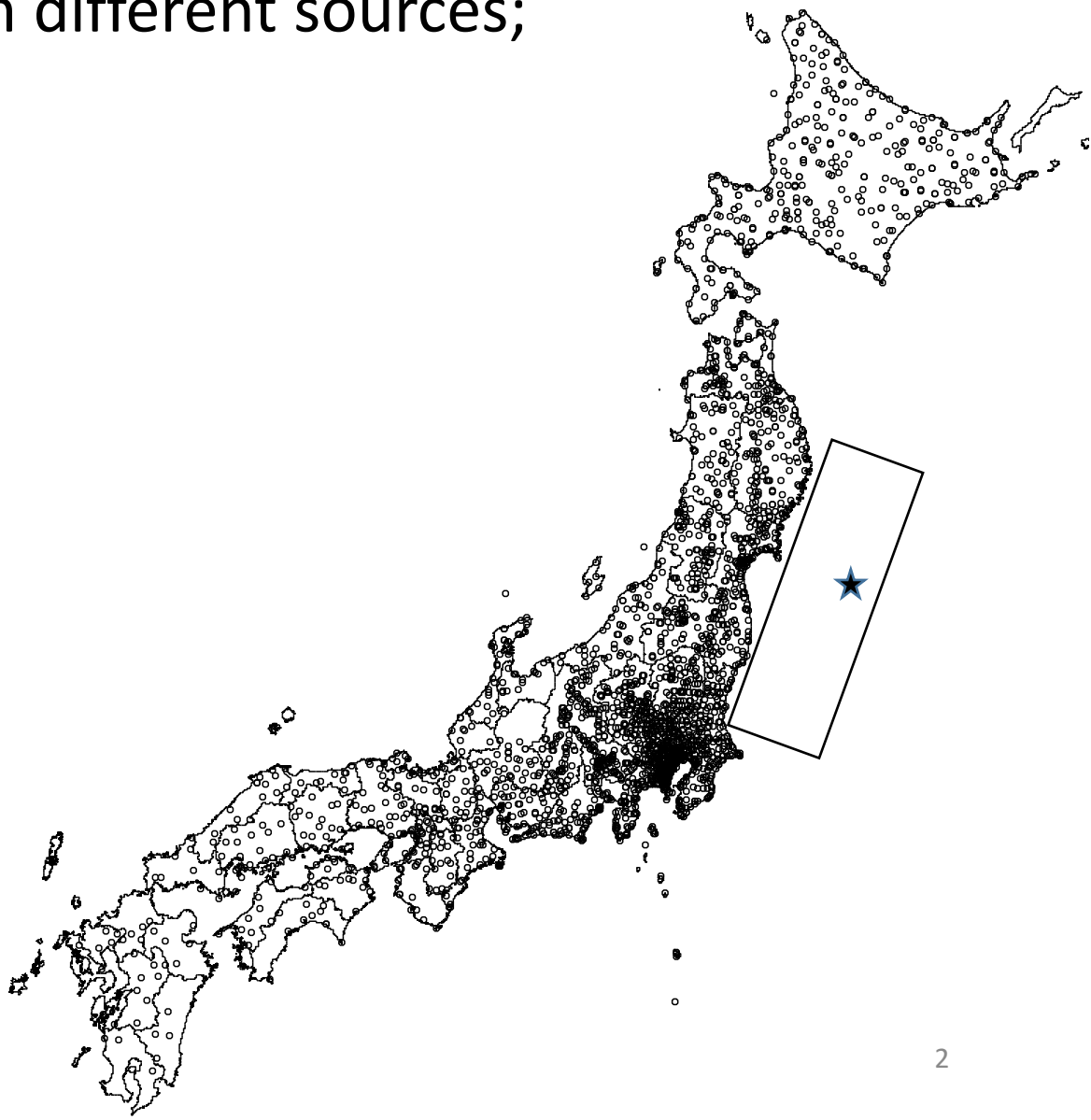


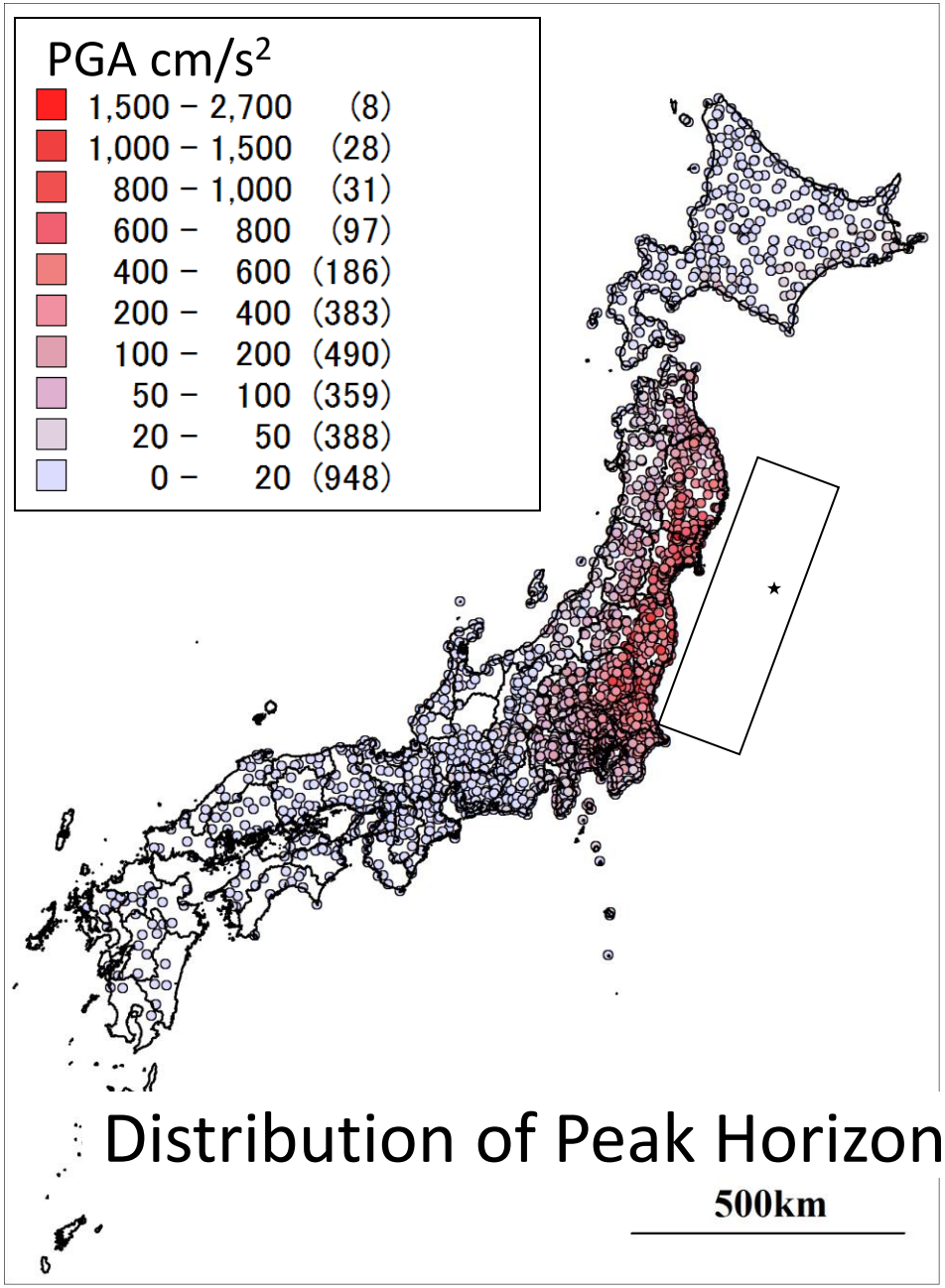
Saburoh Midorikawa and Yoshihiro Nogi

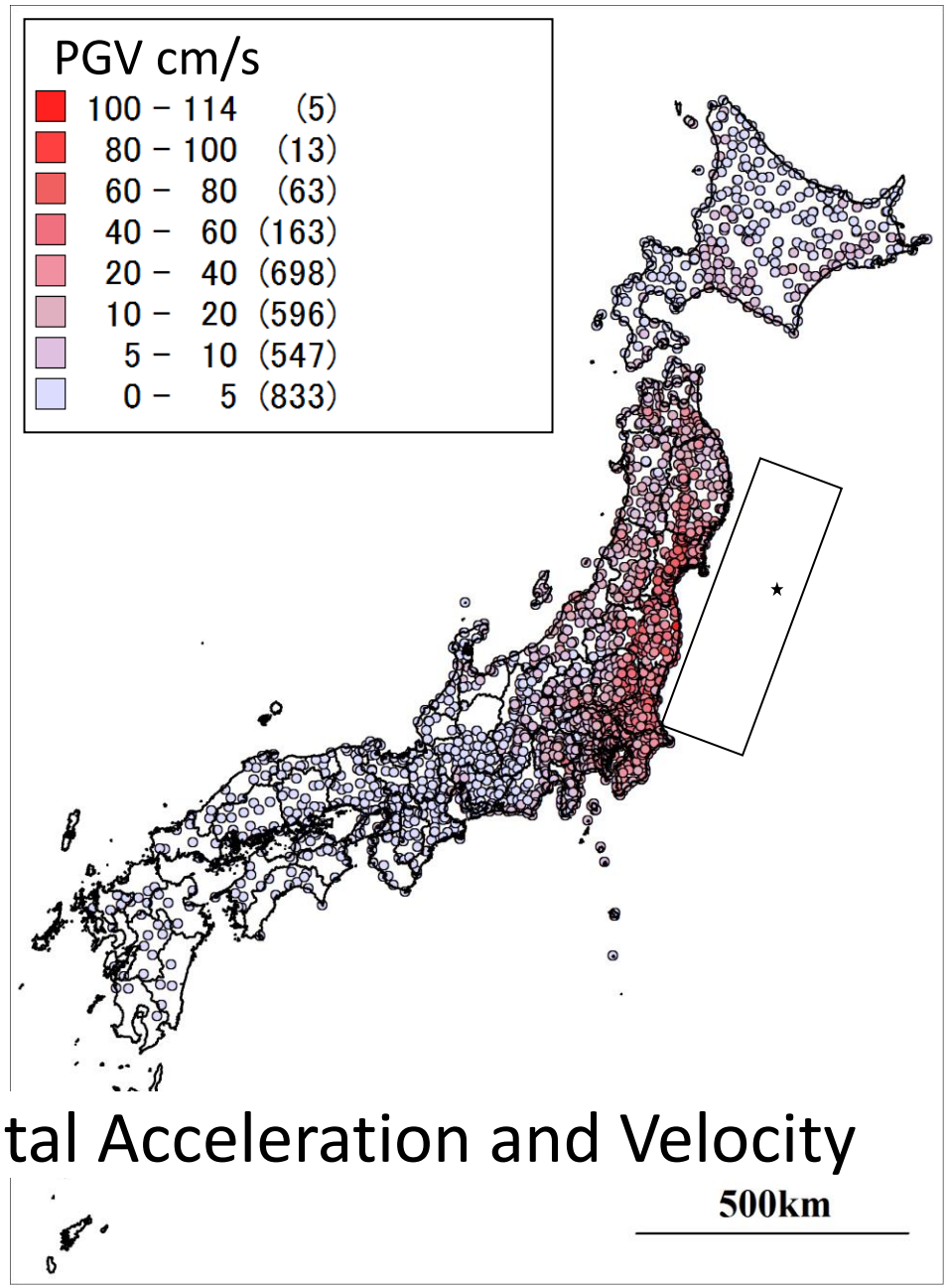
Tokyo Institute of Technology

The 2011 Tohoku earthquake of Mw9.0 produced many strong motion records. We have collected about 3000 records on ground from different sources;

K-NET	673
KiK-net	511
JMA	396
Pref.-net	952
MLIT	153
NEXCO-East	126
PARI	37
BRI	25
Tohoku Tech	17
Tohoku Univ.	16
JR-East	12
Total	2918







Distribution of Peak Horizontal Acceleration and Velocity

The dataset includes records with large amplitudes. The records provide a unique opportunity for better understanding of ground motion at strong shaking level.

Objectives

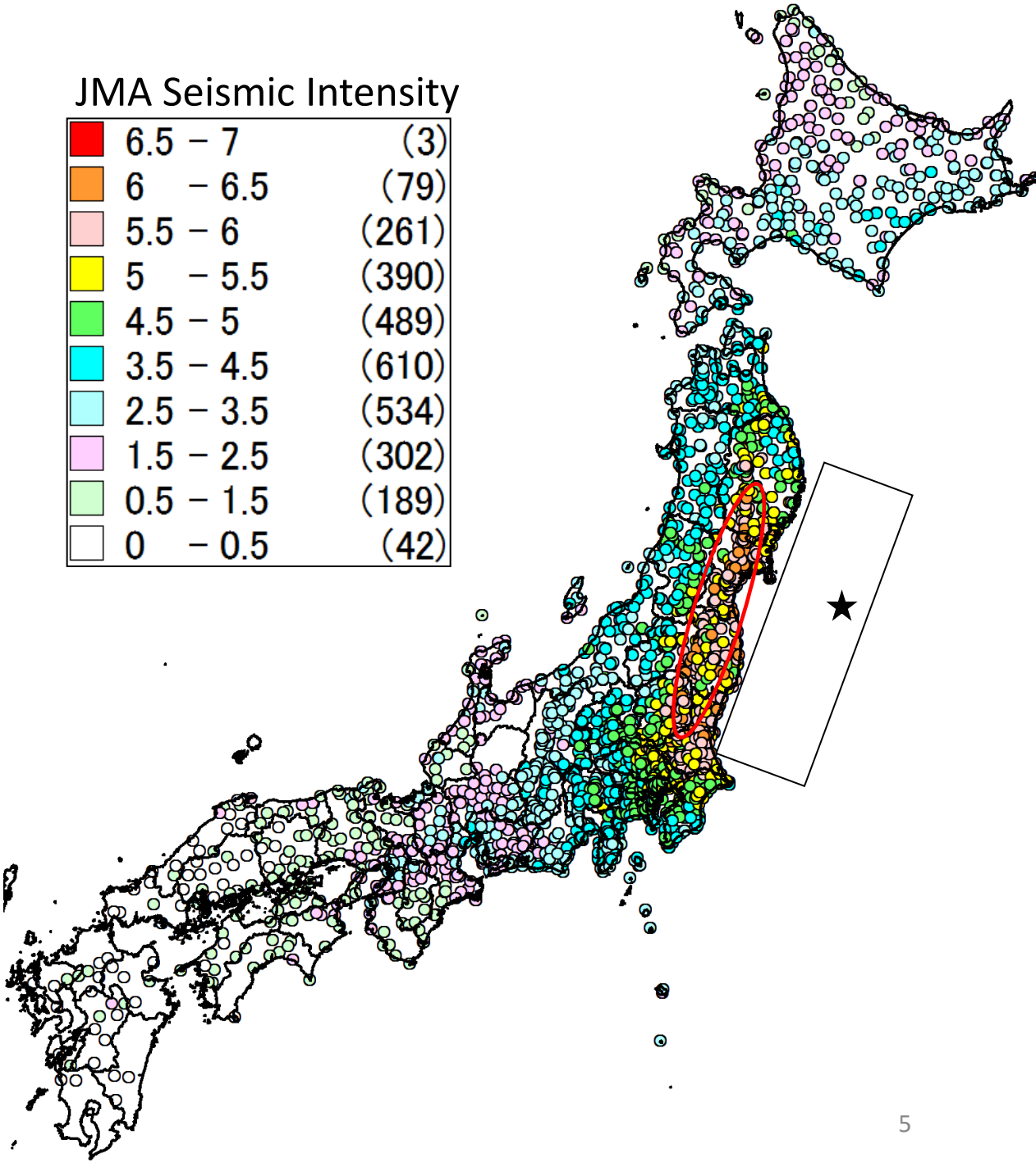
Site effects on ground motion have been studied using observed ground motion records. In many cases, weak motion records not strong ones were used because of the data availability.

To examine site effects at strong shaking level, nonlinear soil response analyses have been also conducted. The validity of the nonlinear analyses, however, have not fully examined by observed strong motion records.

In this study, we select about 500 strong motion records observed in the high seismic intensity area of the Tohoku earthquake. Then we discuss preliminarily site factors at strong shaking level from the average spectra at different site classes.

Target Area

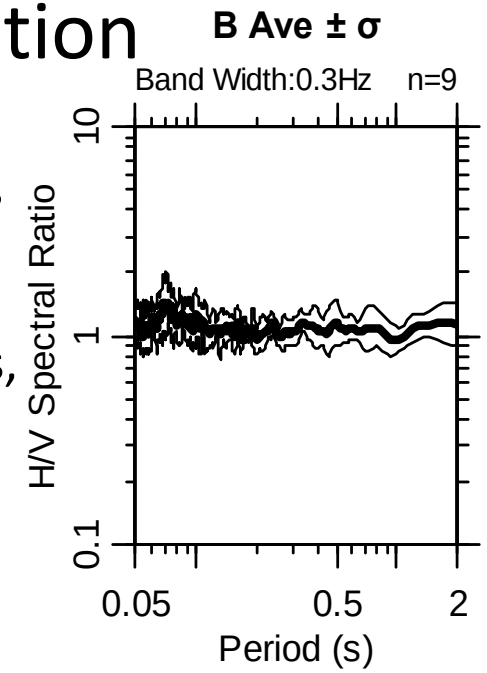
We selected the high intensity area where the JMA seismic intensity of 6 lower (MMI 9) or greater is observed as the target of the study.
The number of the sites in the area is 467. At most of the sites, the recorded PGA is higher than 300 cm/s^2.

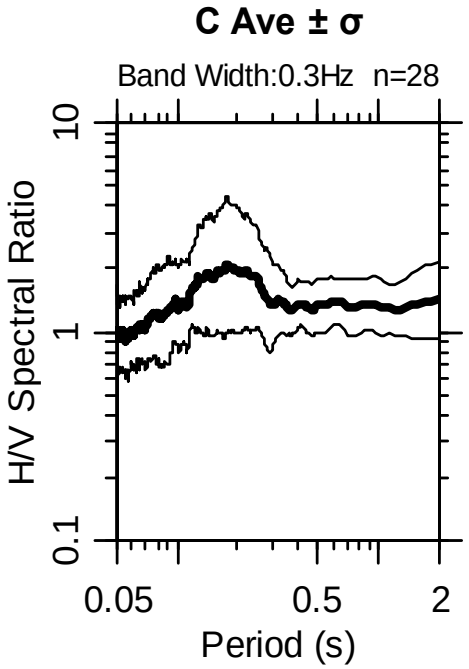


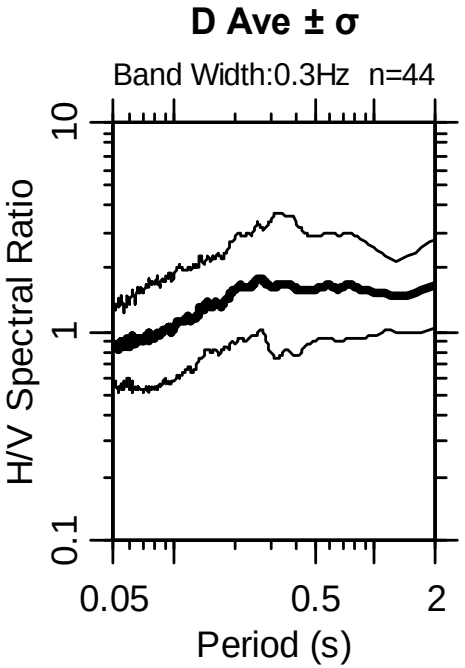
Site Classification

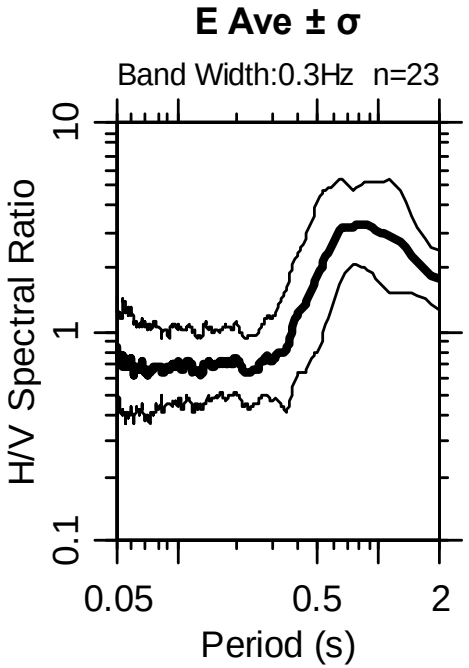
Among the 467 sites, the soil profile data is available only at 92 sites.
At the other 375 sites, the NEHRP site class is determined by the H/V spectral ratio of microtremors.
The criteria for site classification from the H/V spectral ratio have been proposed (Nogi and Midorikawa, 2016).

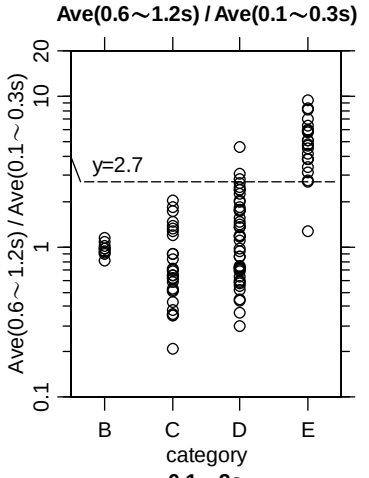
Site Class	V_{s30} (m/s)
A	$1500 < V_{s30}$
B	$760 < V_{s30} \leqq 1500$
C	$360 < V_{s30} \leqq 760$
D	$180 < V_{s30} \leqq 360$
E	$V_{s30} \leqq 180$

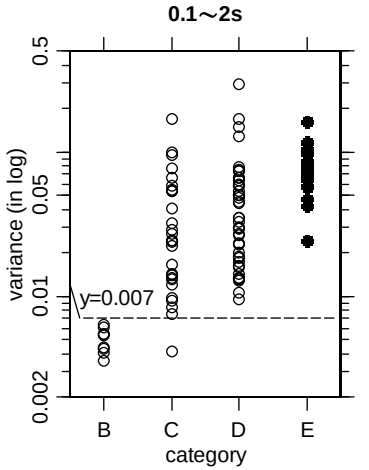


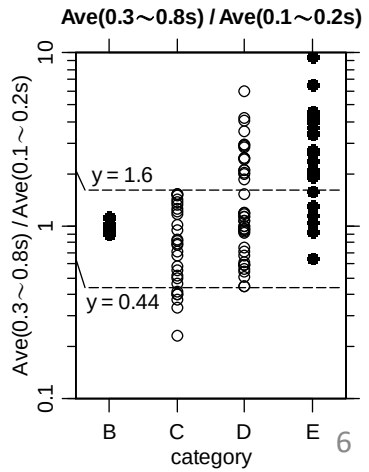






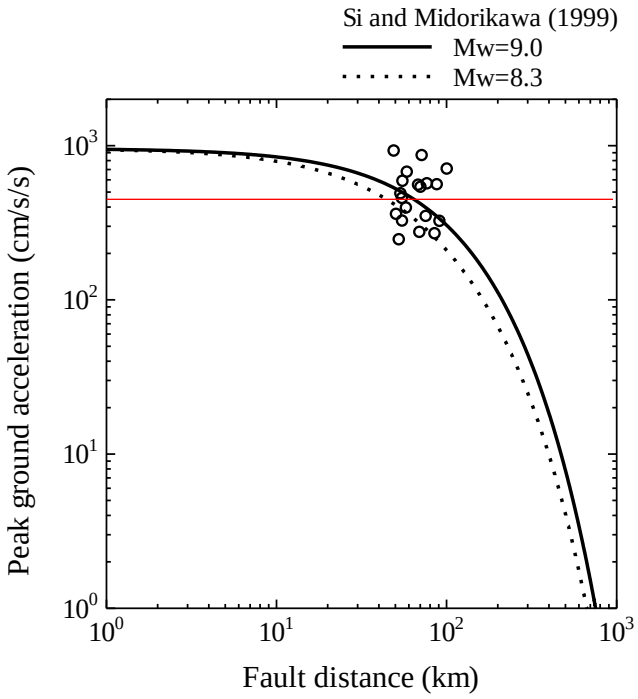


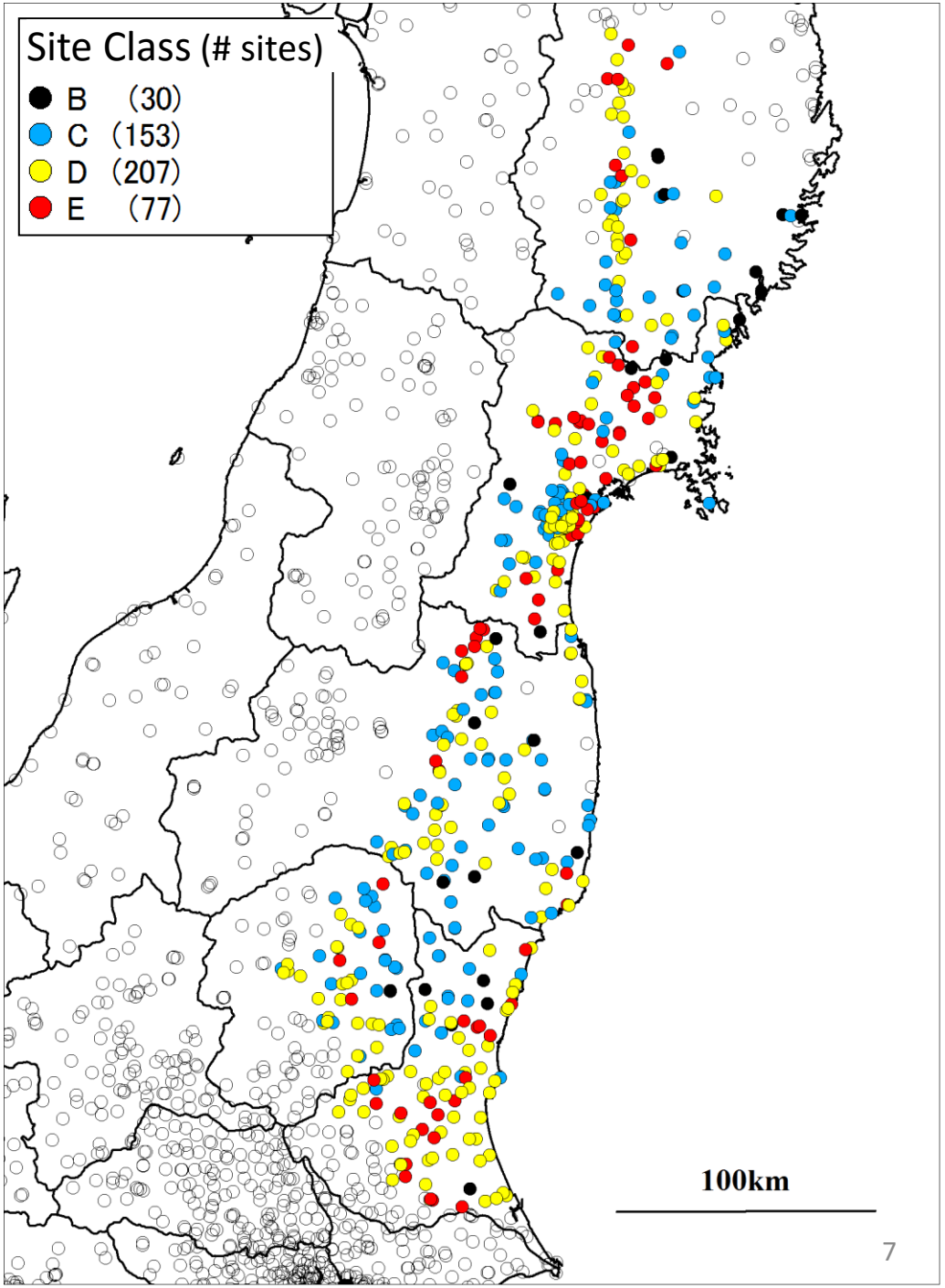


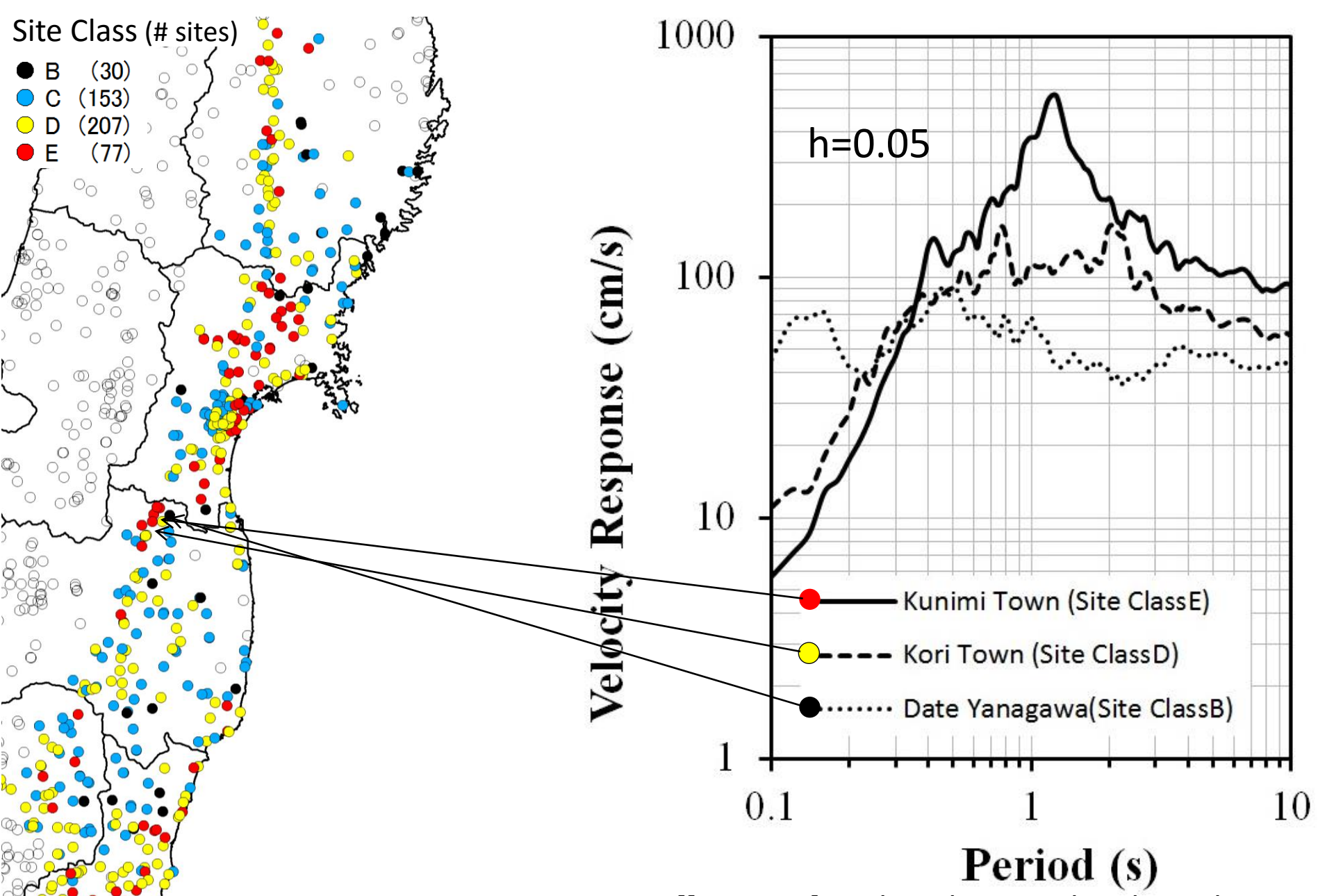


Finally, using the soil profile data and microtremor data, the sites are classified into 30 class B sites, 153 class C sites, 207 class D sites and 77 class E sites.

The PHAs and PHVs at site class B which is considered to be a reference site are about 0.45 g and 25 cm/s in average, respectively.

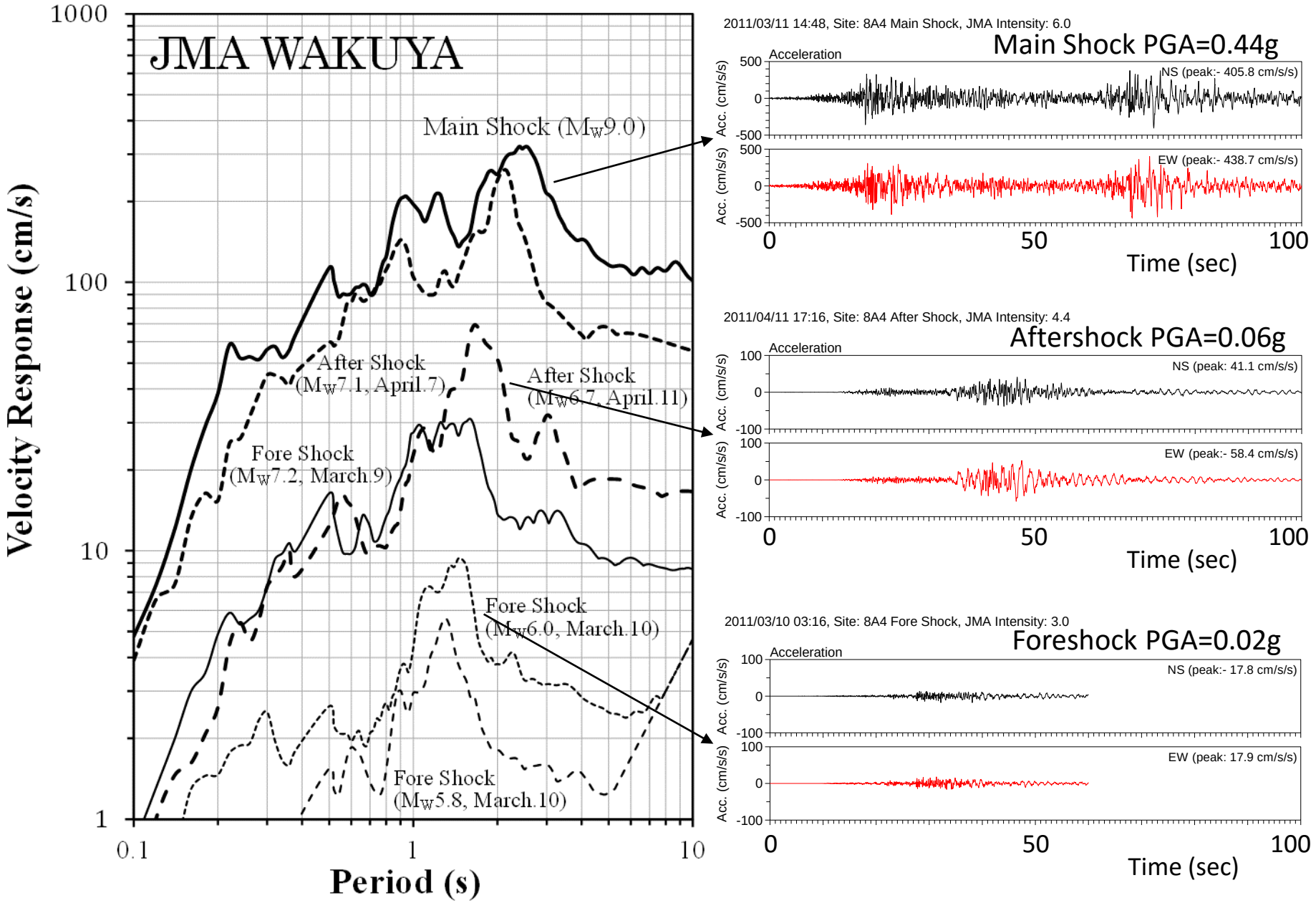






Strong site effects are found on the records. These three sites are located within several kilometers, and the difference in the spectra is mainly due to site effects.

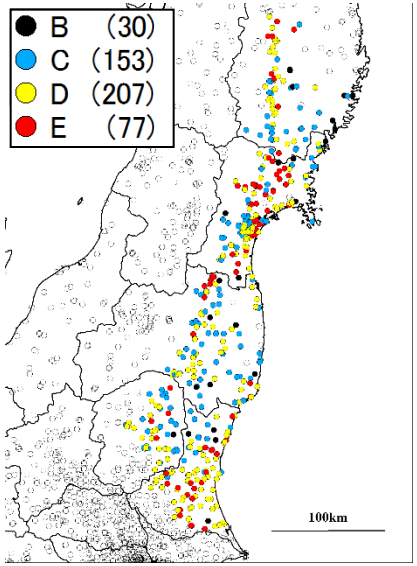
Kunimi Town Office Building was damaged and demolished.

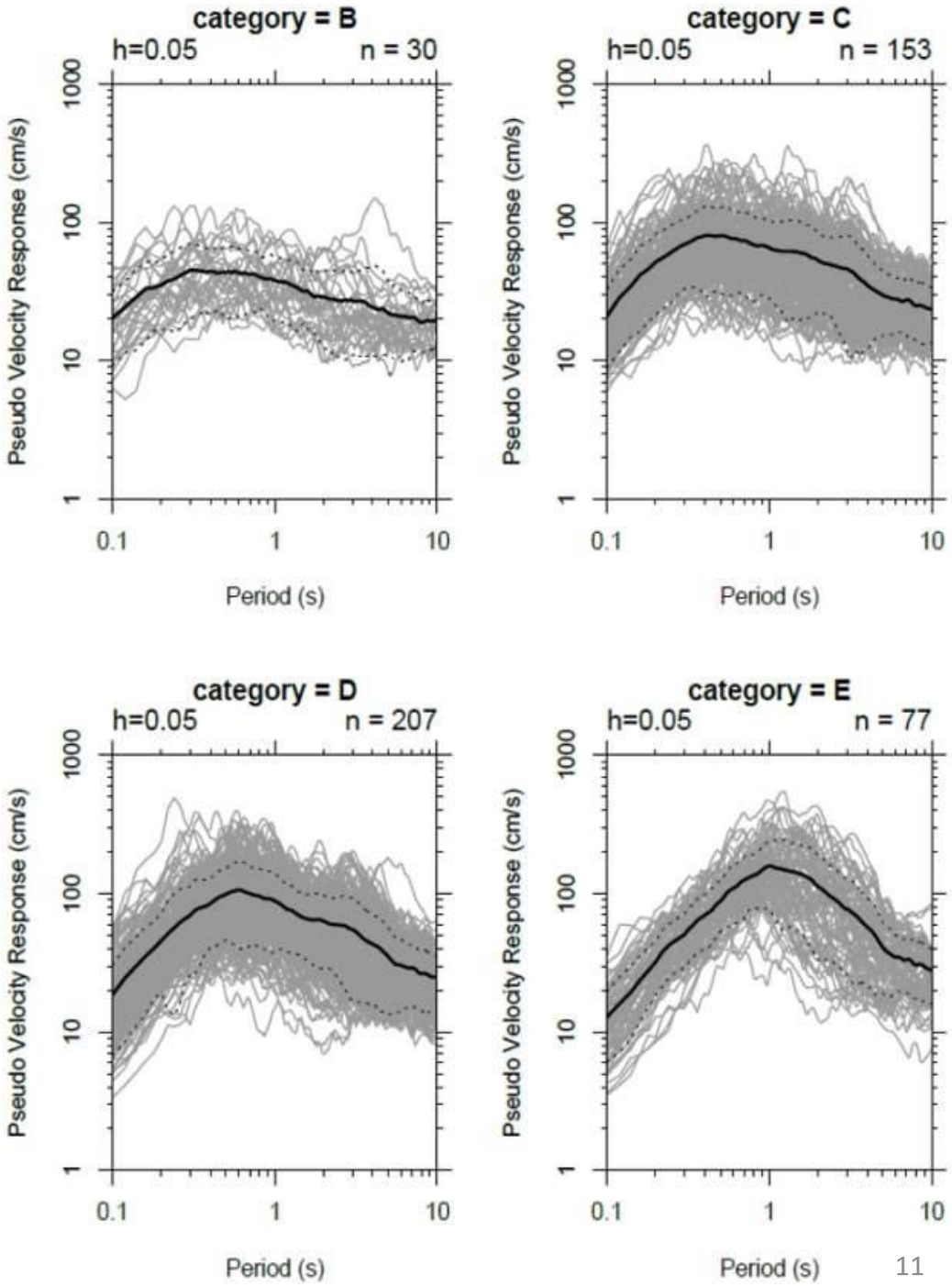


Nonlinear behavior of site response is also found on the records. This figure shows comparison of response spectra of the main shock, foreshock and aftershock records at JMA Wakuya. The site is located on the alluvial lowland, and classified to the site class E.

Average Response Spectra

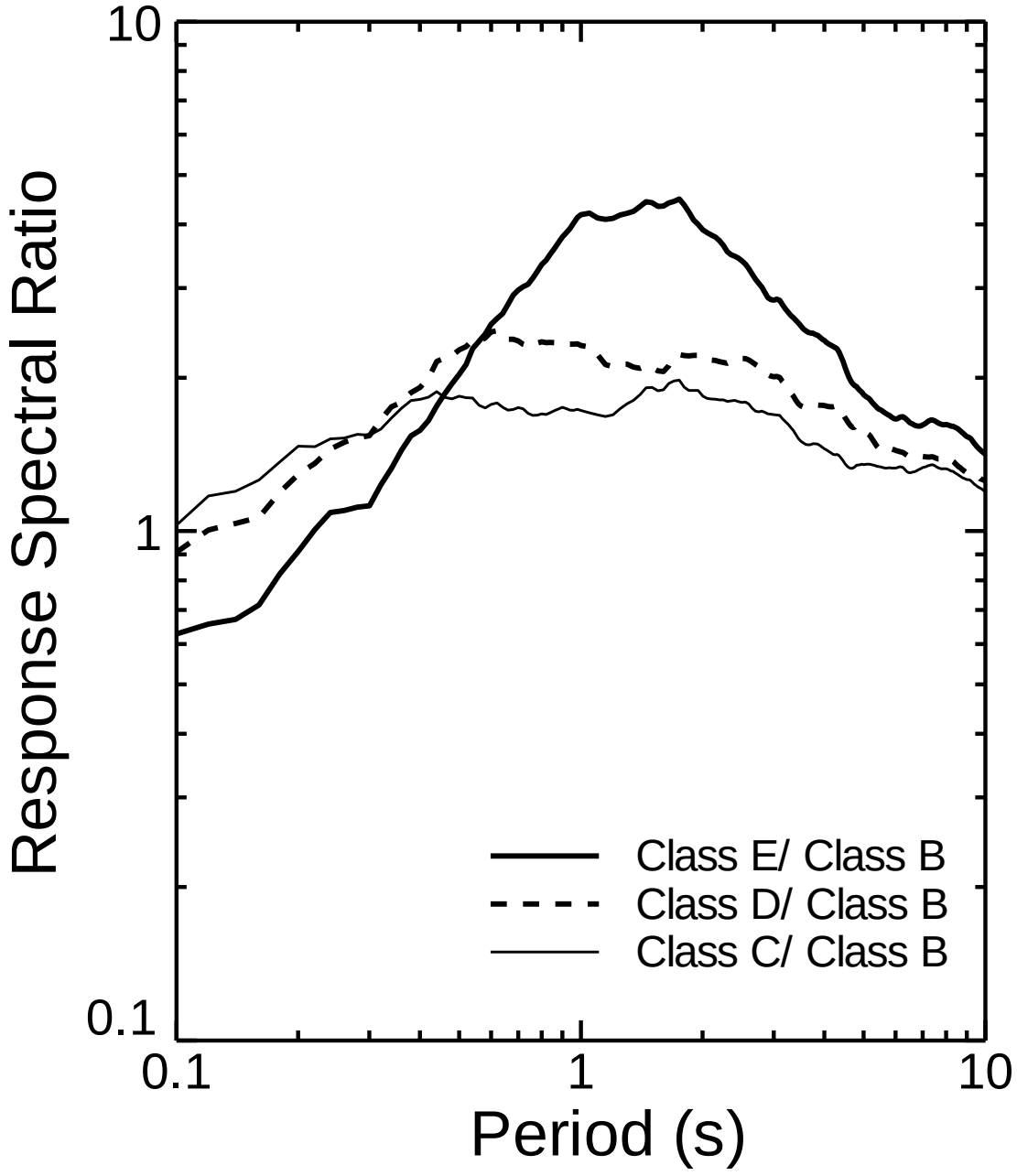
To generalize the site effects on the main shock records, the average spectrum for each site class is calculated. The velocity response spectra tend to be constant with period at class B. The spectral amplitudes become larger at softer site classes. At site class E, the amplitudes tend to be larger at around 1 second.





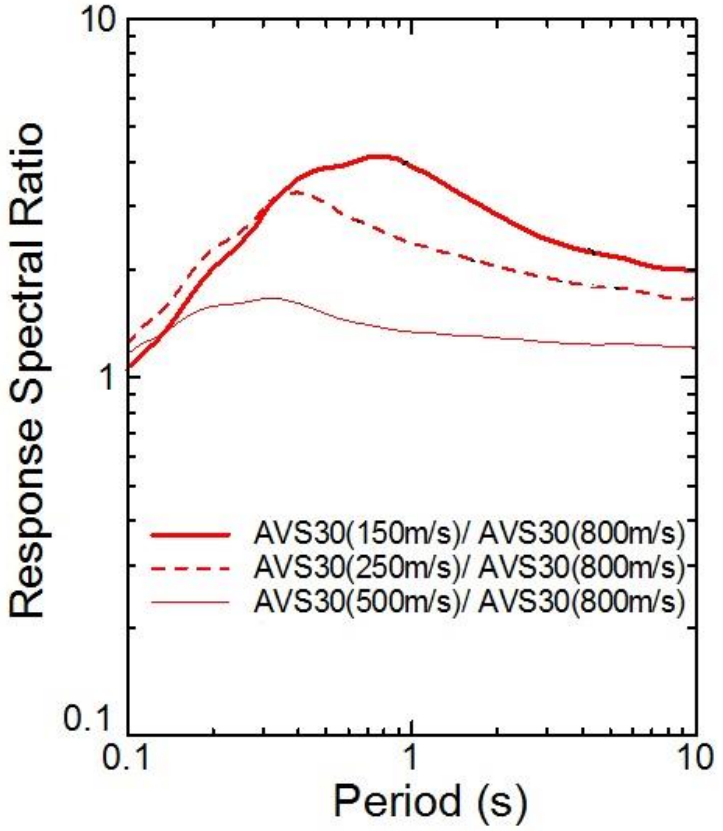
Spectral Ratio of Average Spectra

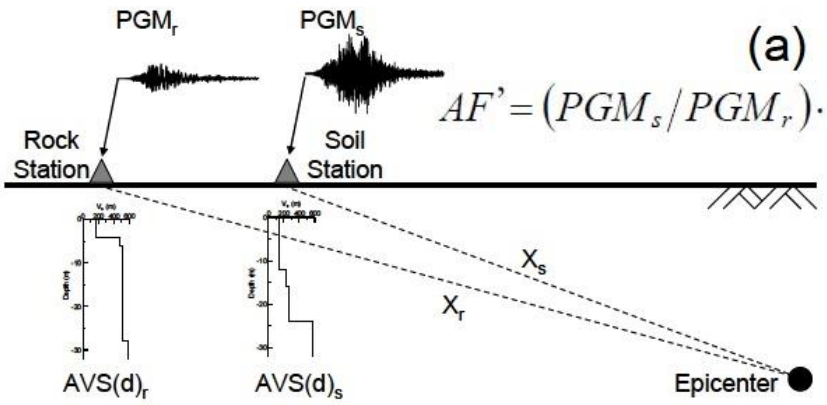
The average and standard deviation of PHAs at site class B are 0.45 g and 0.19 g, respectively. This suggests that the shaking level inputted to the bedrock in the area may not have large difference. Therefore, the ratio of the average spectrum at class C, D or E with respect to that at class B is considered to be an approximate of site amplification at strong motion level. The amplifications of site classes C and D to B are almost two, and rather similar to each other. The amplification of site class E to B, however, is larger at longer periods and smaller at short periods, showing stronger site effects.

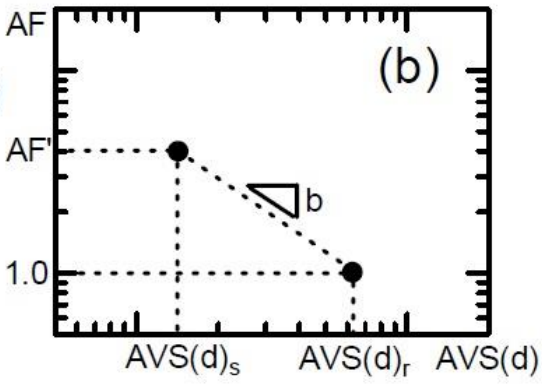


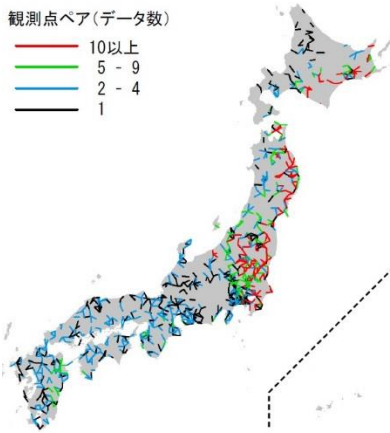
Site Amplification at Weak Motion Level

We have evaluated the amplification factor at weak motion level with respect to Vs30, using small or moderate amplitude records observed at nearby soil-rock station pairs (Yamaguchi and Midorikawa, 2012).

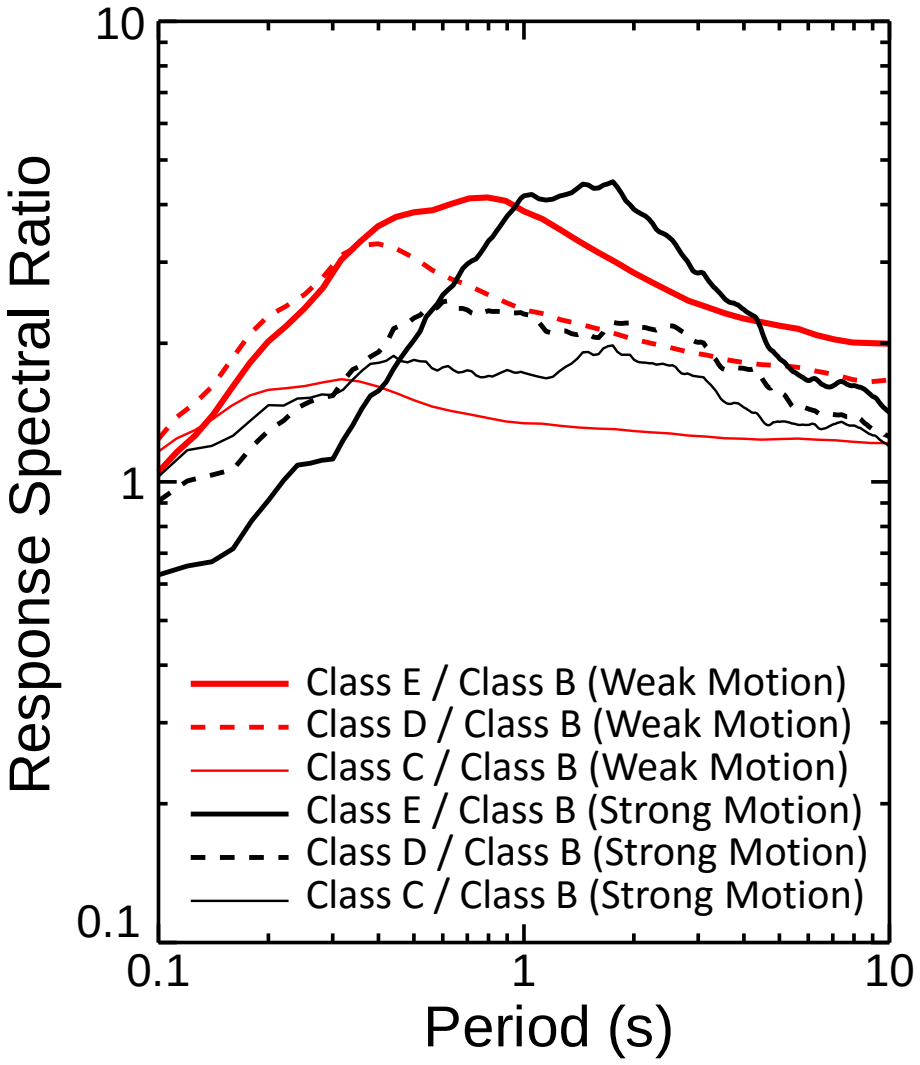








Schematic Figure for Evaluation of Amplification Records at Nearby Station Pairs



The amplifications evaluated for weak motion are shown by red lines. In general, the amplification from strong motion is smaller at short periods and larger at longer periods than that from weak motion. The difference in both amplifications is smaller at site class C (stiff site) and larger at site class E (soft site).

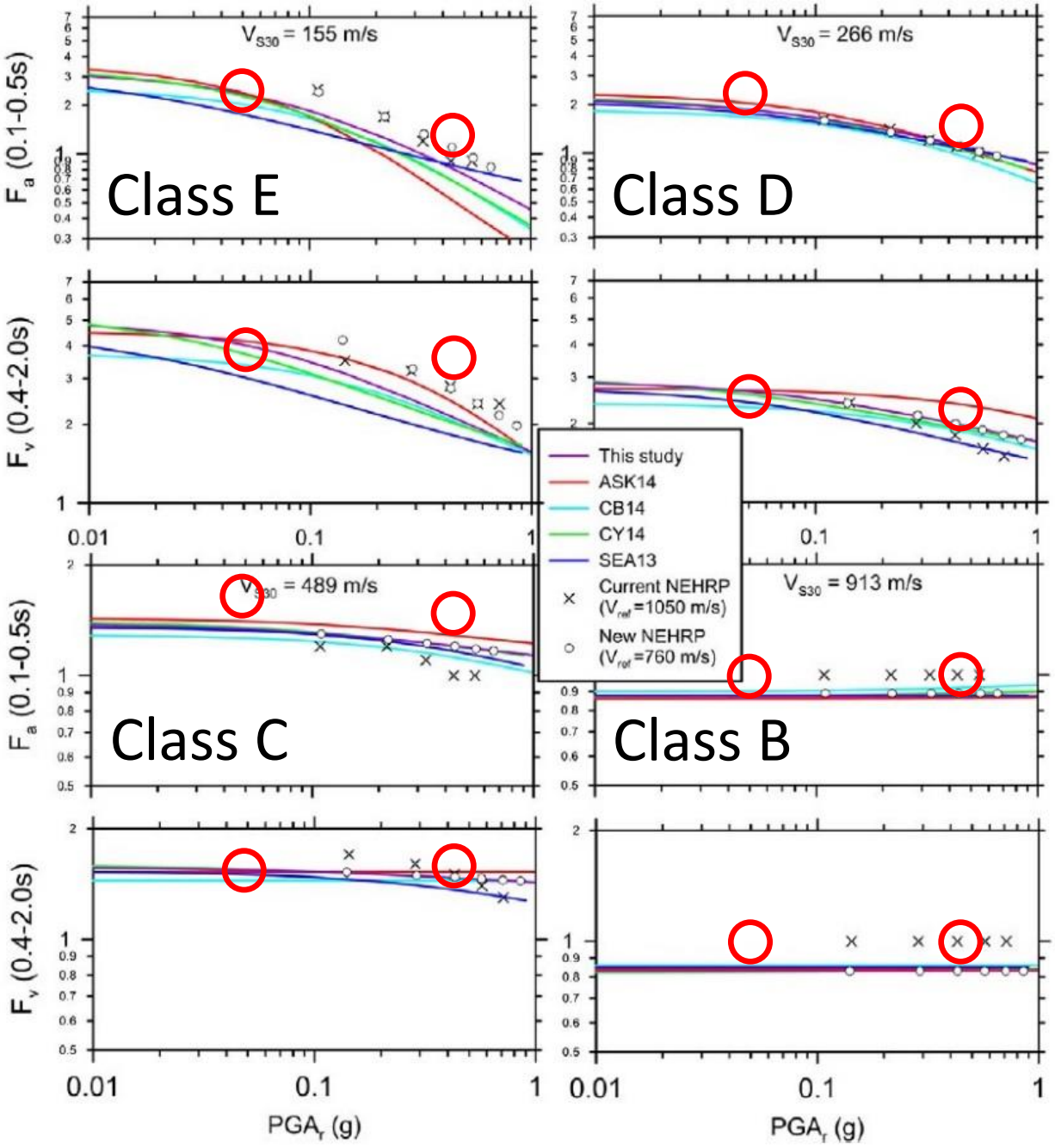
We compared our site factors from Japanese strong motion data with those from NGA2 GMPE and semi-empirically developed by Seyhan and Stewart (2014) . Our results are consistent with those from the U.S. data and simulation, but show weaker nonlinear effects for longer period site factor at site class E.

Shorter Period Amp.

Longer Period Amp.

Shorter Period Amp.

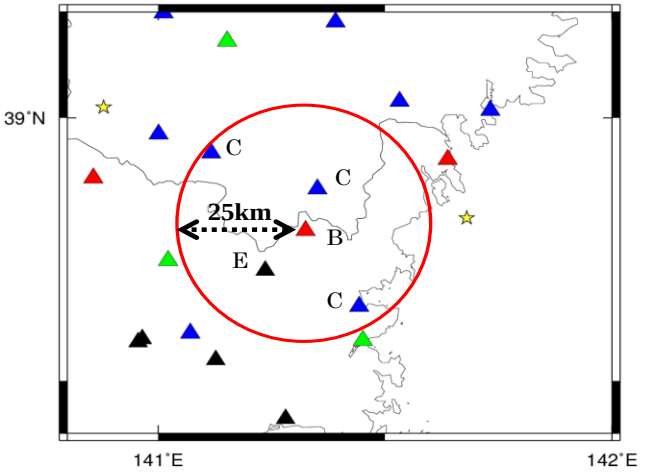
Longer Period Amp.



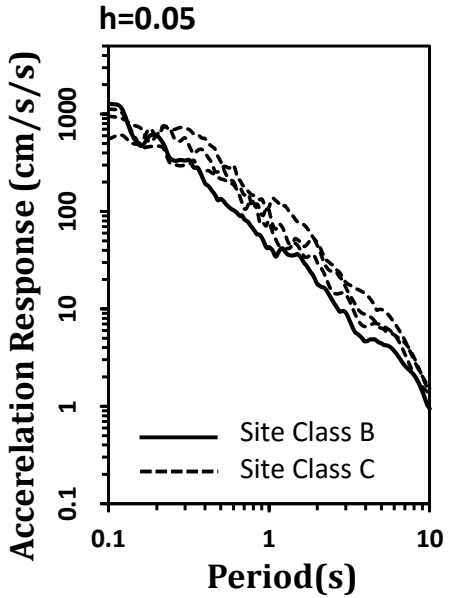
after Seyhan and Stewart (2014)

To examine the amplitude dependence of the site factors more quantitatively, we are evaluating the amplification factors using records observed at nearby station pairs (Hori and Midorikawa, 2016).
We select a site with site class B as a reference rock. For soil sites within 25 km and the rock site, the response spectra are calculated.
From the spectral ratio, the amplifications for short-period Fa and for longer period Fv, are calculated.
The amplification versus the peak ground acceleration at reference rock, PGAr, is plotted.

1)



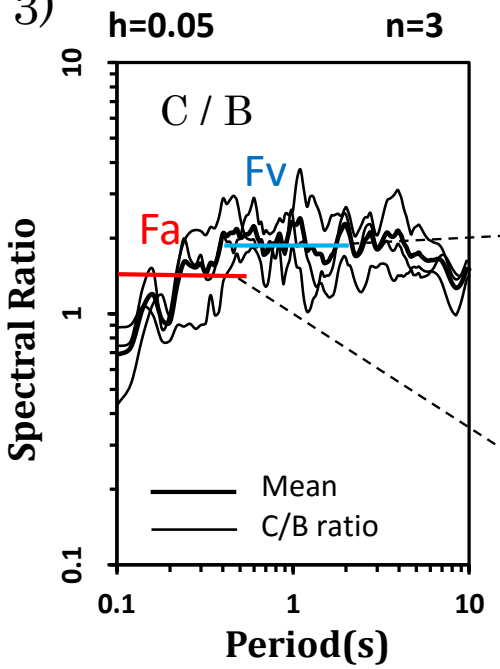
2)



Reference lock (Site Class B)

PGAr =0.272(g)

3)



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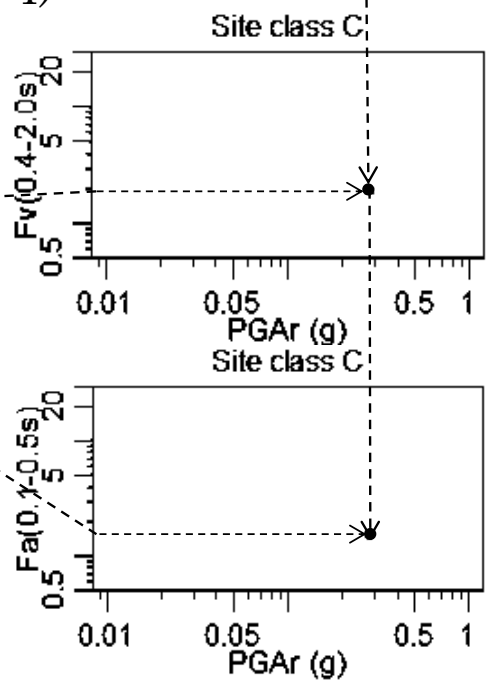
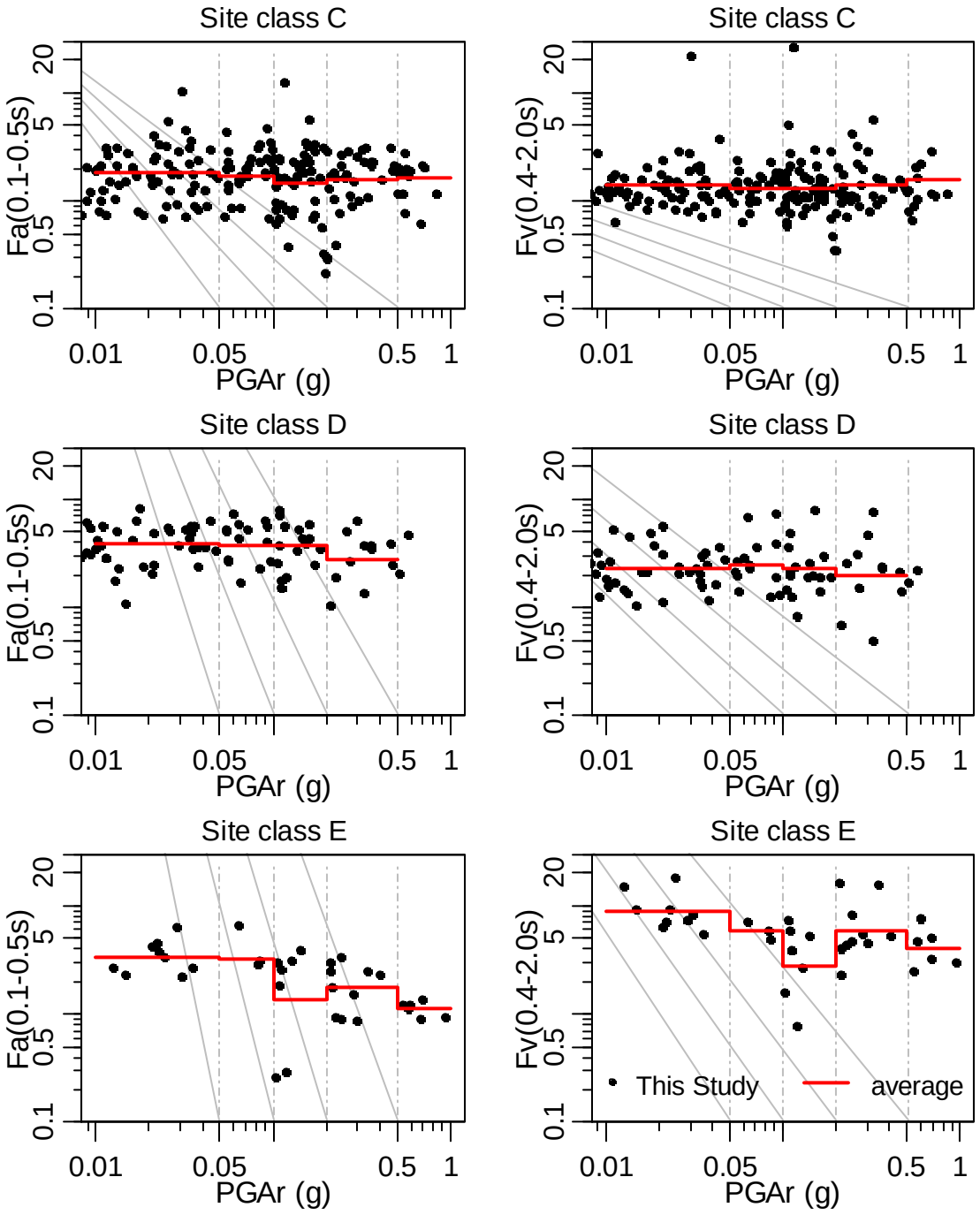




This figure shows the amplifications for short-period Fa and for longer period Fv from the different station pair records.

For site class C, the amplifications are constant with the amplitude.

For site class D, the amplitude dependence of the amplifications is slightly observed.

For site class E, the amplitude dependence is clearly observed at Fa, but weaker at Fv.

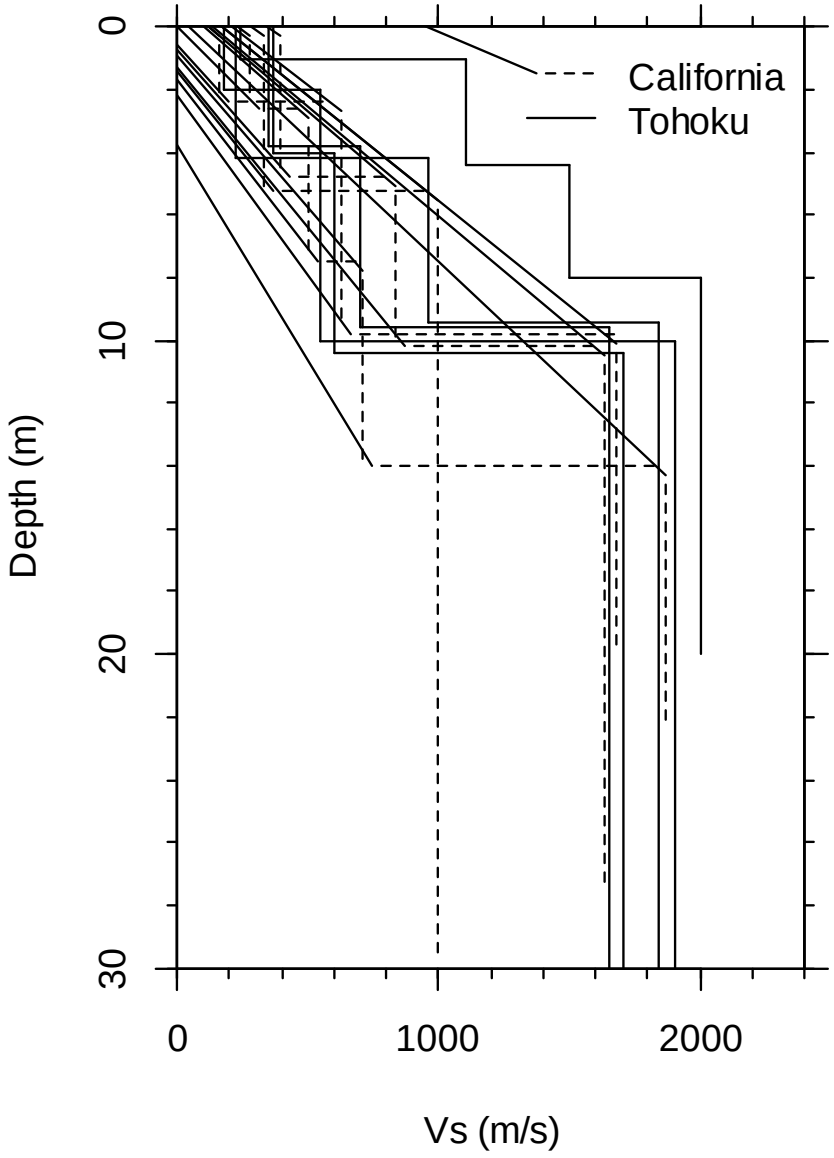
Hori and Midorikawa

Poster Session

P104C

Conclusions

To discuss site effects at strong shaking level, 467 strong motion records observed in the high seismic intensity area of the 2011 Tohoku earthquake are analyzed. The site amplification is preliminarily evaluated from the ratio of the average spectrum at class C, D or E with respect to that at class B. The amplifications of site classes C and D to B are almost two, and rather similar to each other. The amplification of site class E to B, however, is larger at longer periods and smaller at short periods, showing stronger site effect. The amplification is compared with the site amplification derived from weak motion records. The difference in both amplifications is smaller at stiff site and larger at soft site, which is consistent with recent results from the U.S. data.



Examples of Vs Profile at Site Class B