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Earthquake monitoring using dense local seismic network, AS-net, in northern Tohoku, Japan

S. Noguchi(1), S. Sekine(2), Y. Sawada(3), K. Kasahara(4), S. Sasaki(5), Y. Tazawa(6) and H. Yajima(7)

(1) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), noguchi@8f.adep.or.jp*
(2) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), ssekine@8f.adep.or.jp*
(3) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), sawada@8f.adep.or.jp*
(4) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), kasahara@8f.adep.or.jp*
(5) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), sasaki@8f.adep.or.jp*
(6) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), tazawa@8f.adep.or.jp*
(7) *Research Staff, Association for the Development of Earthquake Prediction (ADEP), yajima@8f.adep.or.jp*

Abstract

We report site characteristics and detailed earthquake activity derived by AS-net, the local high-sensitivity seismic observation network we have installed covering northern Tohoku and southwestern Hokkaido, Japan. The AS-net consists of 36 stations covers the region where the stations have been sparse compared to the other. The AS-net have been installed from 2013 to 2014 and started real-time observation at August 2014. After the installation, we investigated the site characteristics and data quality of each station. We derived averaged P- and S-wave velocity from surface to the seismometer installed at the bottom of ~20 m deep borehole by means of downhole method. We found that the averaged velocities are small at the region covered by thick deposit. We also found that the noise level at each station derived from the root-mean-square for amplitude of ambient noise is higher at the region covered by thick deposit. The noise level at the station which have the averaged S-wave velocity less than 350 m/s is obviously higher than the other. Then we determine the hypocenters for the earthquakes occurring around the AS-net using data derived by AS-net and other stations. The 5003 hypocenters for earthquakes occurred from January 2014 to December 2015 have been determined. In terms of shallow crustal earthquakes, we derived 2.6 times as many earthquakes as that listed in JMA catalogue at the same region and period. This earthquake catalogue shows that we can investigate the earthquake activity in rich detail utilizing AS-net.

Keywords: Earthquake monitoring, Microearthquake, Seismic activity

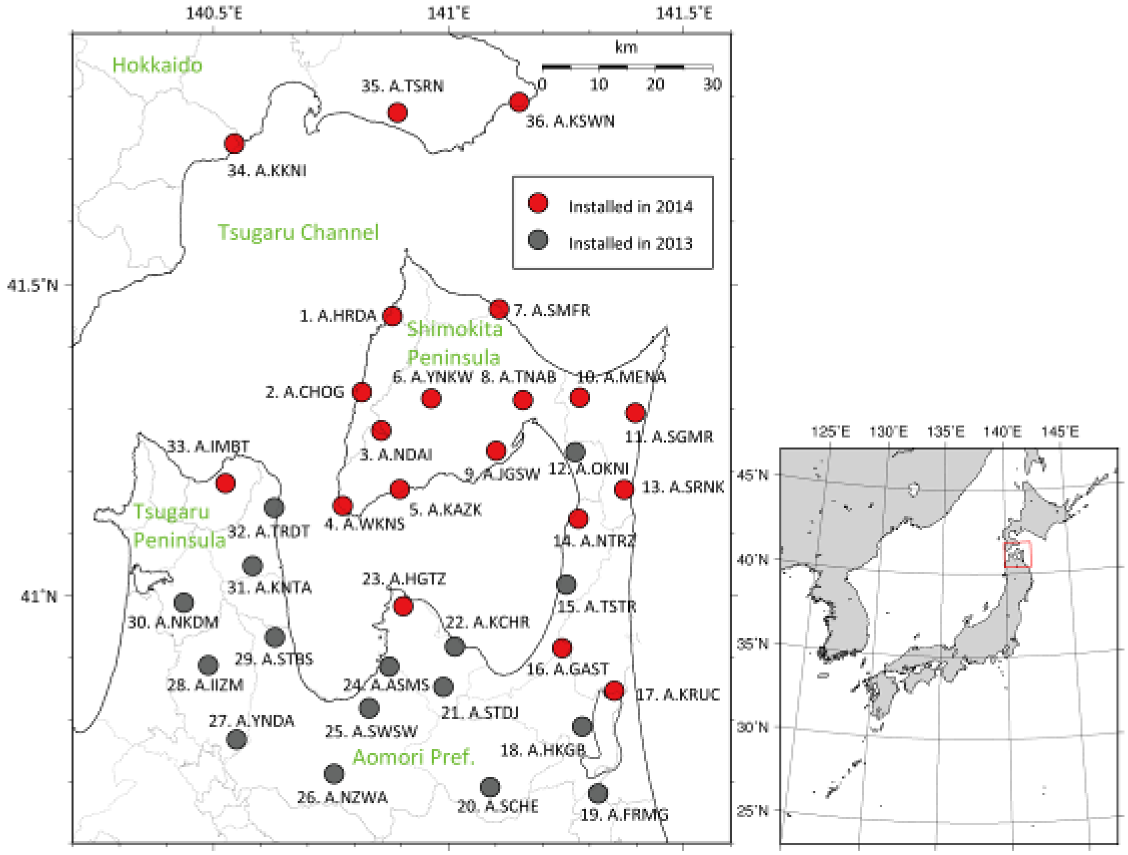

Fig. 1 – AS-net stations

1. Introduction

In Japan, Dense seismic observation networks have been installed including high-sensitivity seismograph network (Hi-net, Okada *et al.*, 2004[1]) after 1995 Kobe earthquake. While these networks were relatively sparse around northern Tohoku and southwestern Hokkaido. Having existed stations in this region operated by JMA, NIED, Universities and local government are distanced 20 ~ 50 km each other. The earthquake detection capability in this region have been decreased compared to the other regions by such sparse location. The observation data needed to investigate subsurface structure including active fault, basement depth and subducting Pacific Plate also have been less than the other region.

To achieve more earthquake detection capability and derive dense seismic data, we installed high-sensitivity seismic network (AS-net) in this region, around Shimokita, Tsugaru and southwestern Hokkaido (Fig. 1) and started real-time monitoring for earthquake activity (Sekine *et al.*, 2014[2], Noguchi *et al.*, 2015A[3], Noguchi *et al.*, 2015B[4] and Noguchi *et al.*, 2016[5]). In this report, we first introduce AS-net and site characteristics for each station. Then we show the earthquake activity based on hypocenters determined using data derived by AS-net.

2. AS-net

We have started the installation of the AS-net at 2013, then completed at August 2014. The AS-net consists of 36 stations, 33 stations located at Shimokita and Tsugaru region and 3 stations at the southwestern Hokkaido (Fig. 1). Each station has three-component high-sensitivity seismometer and three-component strong-motion seismometer at the bottom of ~20 m deep borehole (Fig. 2 (b)). Control unit, digitizer, power unit, backup battery, network router and other instruments are placed in the box at ground surface (Fig. 2). Seismic data recorded by AS-net are distributed in real time at the nation-wide real-time distribution network for seismic data, JDX-net, via a server at Earthquake Research Institute, The University of Tokyo. From January 2015, it became able to download the seismic data by AS-net via continuous seismic data download web service managed by NIED (http://www.hinet.bosai.go.jp/).

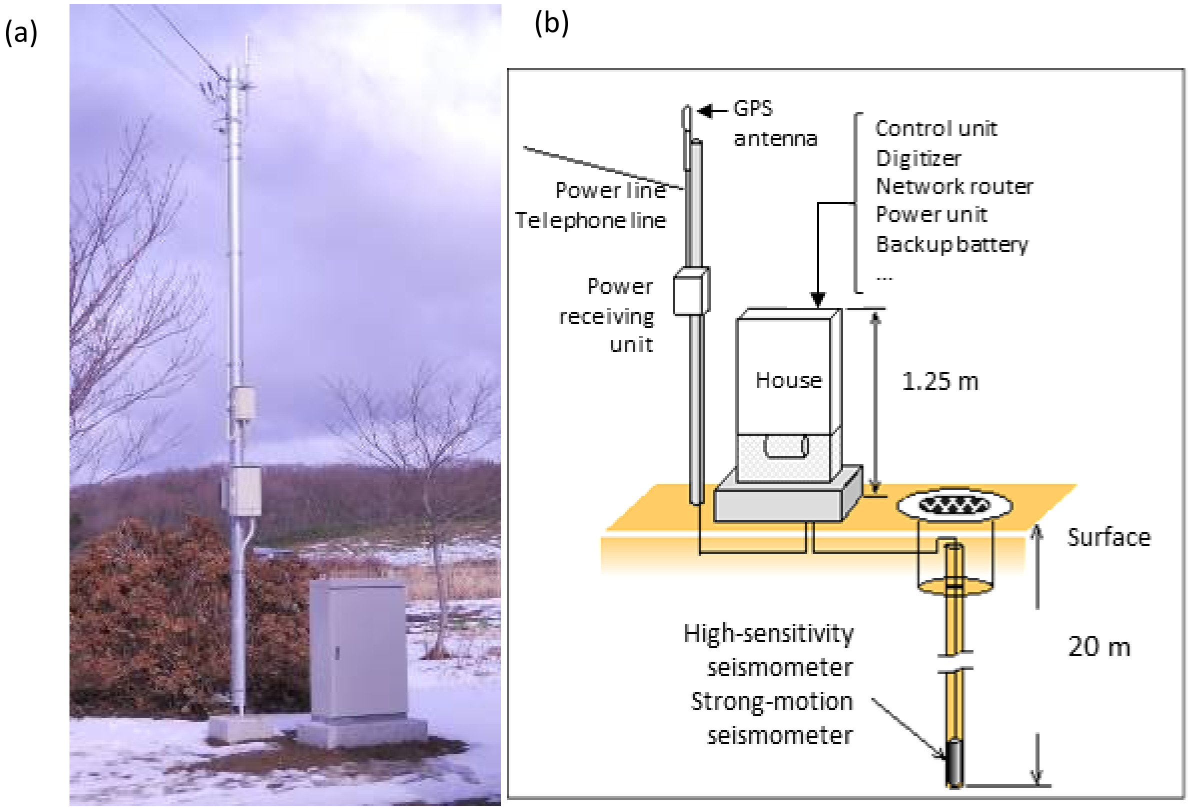

Fig. 2 – (a) AS-net station view and (b) instruments

3. Site characteristics at AS-net stations

After the installation of each AS-net station, we measured averaged P- and S-wave velocity (AVP and AVS) between surface and borehole bottom by means of downhole seismic method; simple plank-hammering method. Because almost all stations have a ~20 m deep borehole, we could obtain the AVS for 20 m depth (AVS20) at these stations. Among them, A.CHOG and A.SMFR have around 15 m deep boreholes because rock appears shallower than 10 m deep (Table 1). We also estimated background noise level using ambient noise data to evaluate the quality of observation to detect microearthquakes. In this section, we show site characteristics of AS-net stations and comparison between AVS and noise level.

The AVP and AVS obtained by plank-hammering method are shown in Table 1 and Fig. 3. The result shows that the stations whose borehole reaches sand layer tends to show smaller AVP and AVS generally. On the other hand, the stations whose borehole reaches rock show relatively larger AVP and AVS. The localized distributions of AVP and AVS (Fig. 3) indicate that stations located on relatively thick deposit tend to show lower AVS as soft soil sites (ex. west side of southern Shimokita Peninsula).

The noise level at each stations are calculated using 3600 s of ambient noise records derived by high-sensitivity seismometer. We use the observation data from 0am to 1am in JST at November 21st, 2014 as midnight data and that from 1pm to 2pm at the same day as daytime data respectively. We use the root-mean-square (RMS) of wave amplitude through these records as a noise level at each station. The result is shown in Table 1 and Fig. 4. We can see first that the noise level at daytime is larger than that for midnight. It is due to that the noise amplitude at daytime is increased by artificial noise at higher frequency band while microseism at lower frequency band less than 1 Hz is dominant in noise amplitude at midnight. But the noise level at midnight and daytime also show localized distribution similar to AVS, including Hi-net stations (Fig. 4). It can be said that noise level reflects the site condition at each station.

Table 1 – Averaged V_P and V_S, and noise level for AS-net stations

No.	Code	Borehole bottom soil type	Borehole depth m	AVP m/s	AVS m/s	00:00-01:00JST Horizontal μcm/s	00:00-01:00JST Vertical μcm/s	13:00-14:00JST Horizontal μcm/s	13:00-14:00JST Vertical μcm/s
1	A.HRDA	Rock	20.89	1116	749	5.1	6.2	7.6	9.1
2	A.CHOG	Rock	15.00	701	354	3.3	4.2	3.9	4.6
3	A.NDAI	Rock	21.14	1062	284	17.3	5.1	14.7	10.2
4	A.WKNS	Sand	21.00	1185	461	6.3	9.4	4.7	6.3
5	A.KAZK	Gravel	20.46	934	284	21.9	11.6	11.5	9.0
6	A.YNKW	Rock	21.10	1177	453	2.9	2.9	4.0	3.7
7	A.SMFR	Rock	14.83	850	330	7.0	5.7	9.5	8.8
8	A.TNAB	Gravel	21.03	664	341	10.8	6.4	16.0	12.6
9	A.JGSW	Gravel	21.27	1406	455	10.1	11.4	13.9	18.9
10	A.MENA	Gravel	21.50	812	267	19.7	25.0	28.2	40.7
11	A.SGMR	Rock	21.71	1346	478	2.6	2.7	4.1	4.1
12	A.OKNI	Sand	20.78	1060	279	26.2	22.8	67.9	83.2
13	A.SRNK	Rock	21.41	1265	423	6.4	5.1	9.9	10.0
14	A.NTRZ	Sand	21.22	833	339	25.7	27.7	43.4	68.4
15	A.TSTR	Sand	20.71	730	258	27.3	29.2	71.4	103.7
16	A.GAST	Sand	21.30	629	264	31.0	32.0	57.2	57.1
17	A.KRUC	Sand	20.41	503	282	23.0	37.6	43.9	71.6
18	A.HKGB	Sand	20.08	735	289	20.3	34.4	73.3	111.4
19	A.FRMG	Gravel	20.81	657	227	32.4	54.9	73.2	121.4
20	A.SCHE	Silt	20.78	730	157	16.6	12.5	32.0	39.3
21	A.STDJ	Rock	20.90	847	354	2.1	2.2	4.2	3.5
22	A.KCHR	Gravel	20.34	896	535	7.3	10.6	6.8	9.7
23	A.HGTZ	Rock	21.16	1771	799	6.0	4.9	4.9	4.3
24	A.ASMS	Rock	20.74	1042	357	7.3	3.4	8.2	4.3
25	A.SWSW	Rock	20.81	1244	186	7.7	4.9	55.6	48.5
26	A.NZWA	Gravel	20.74	906	459	4.5	5.2	9.4	11.6
27	A.YNDA	Gravel	21.03	822	226	13.1	13.1	40.0	47.9
28	A.IIZM	Sand	20.78	994	306	14.0	19.1	25.9	32.6
29	A.STBS	Gravel	20.76	841	304	21.3	34.0	29.9	44.2
30	A.NKDM	Sand	20.59	1124	236	18.1	19.3	80.6	135.9
31	A.KNTA	Gravel	20.53	1185	122	36.0	34.9	54.2	53.8
32	A.TRDT	Gravel	20.73	879	318	18.9	23.2	25.4	35.7
33	A.IMBT	Silt	21.13	884	465	23.3	14.8	35.5	26.1
34	A.KKNI	Rock	21.42	1076	482	17.1	20.3	67.5	116.8
35	A.TSRN	Sand	21.35	692	246	3.3	2.9	6.1	4.8
36	A.KSWN	Rock	21.32	738	397	7.3	8.6	24.3	29.8

AVP	AVS	Noise level
500	100	1
800	300	10
1000	400	50
1500	500	100

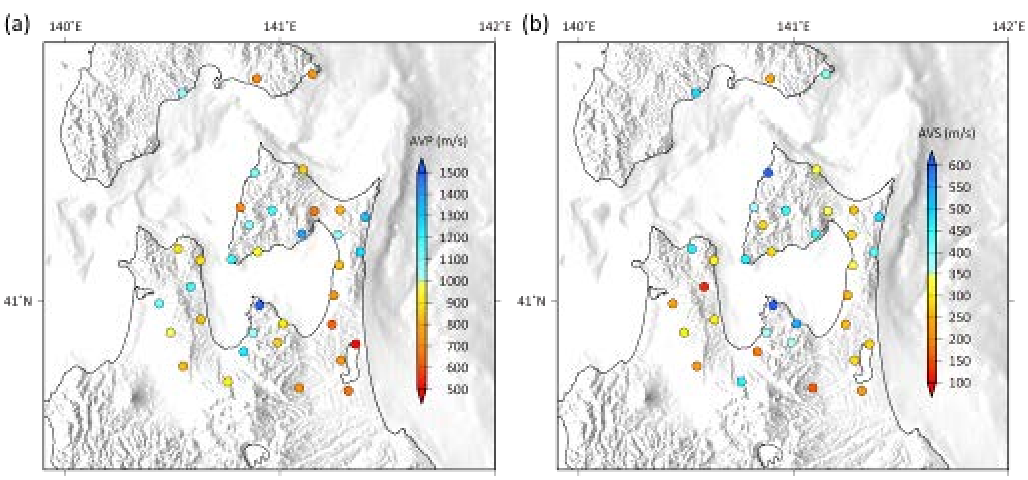

Fig. 3 – (a) Averaged V_P and (b) V_S for AS-net stations

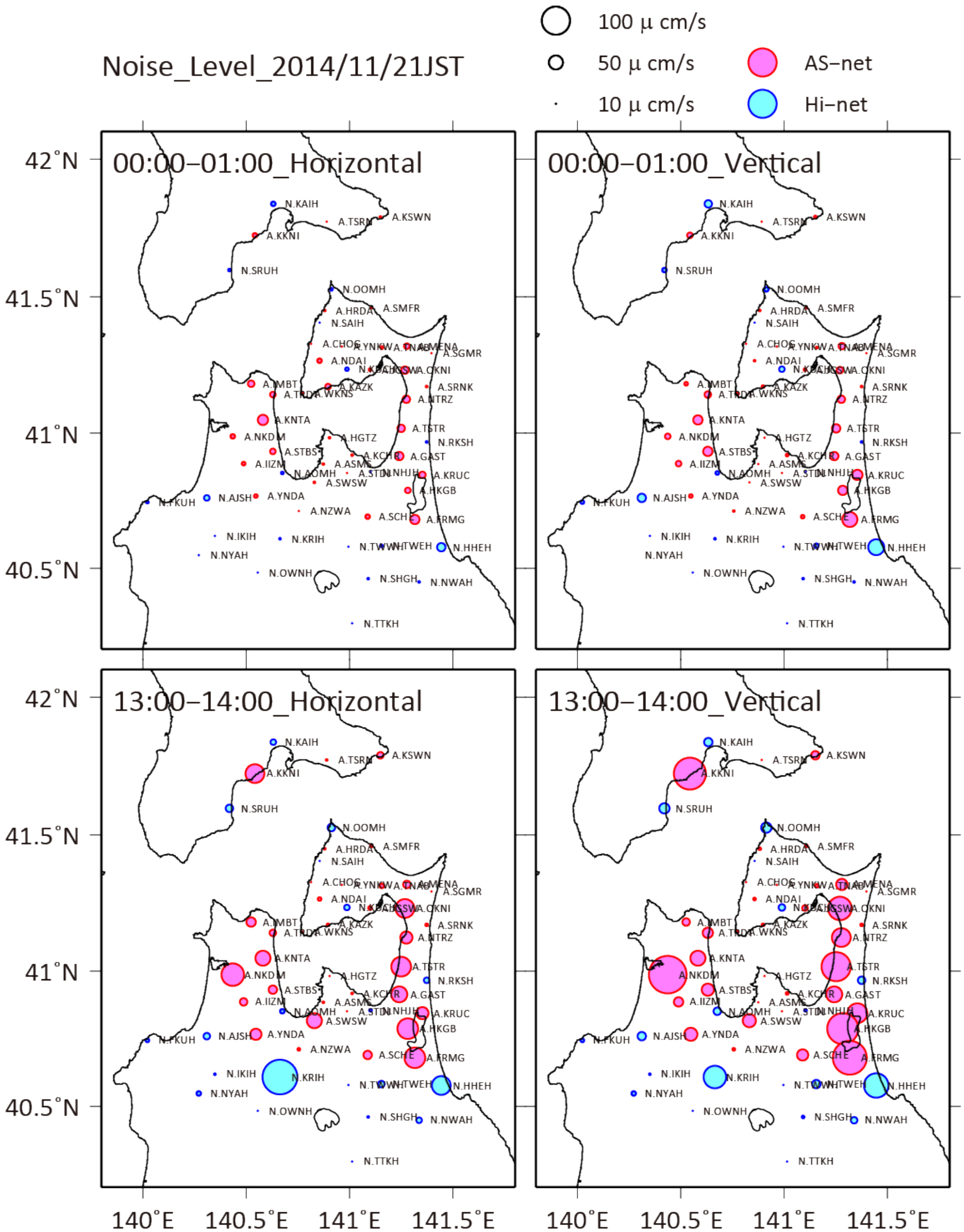

Fig. 4 – Distribution for noise level at AS-net stations

The comparison between AVS and noise level is shown in Fig. 5. We can see clearly that the stations which have smaller AVS less than 350 m/s show obviously higher noise level at both daytime and midnight. We found that the sites with small AVS not only show larger microseism but also amplify artificial noise at daytime. Among them, A.KKNI which has 482 m/s of AVS shows high noise level over 100 µcm/s at daytime. We confirmed that it was due to the temporal highway construction nearby. The relationship between noise level and AVS means that the soft soil site has smaller AVS and higher noise level and the stiff site has larger AVS and lower noise level. It also indicates that it would be possible to estimate noise level at a site by investigating AVS, and to estimate site stiffness using noise level.

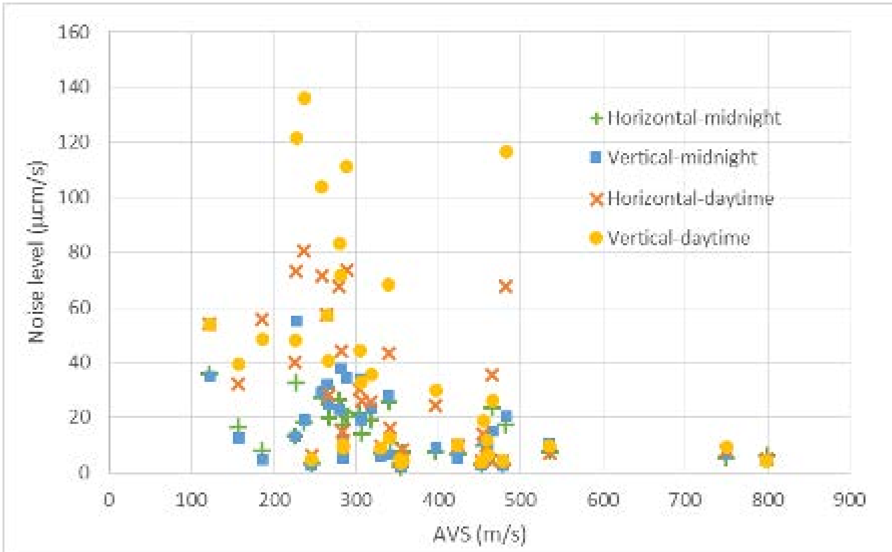

Fig. 5 – Relationship between AVS and noise level at AS-net stations

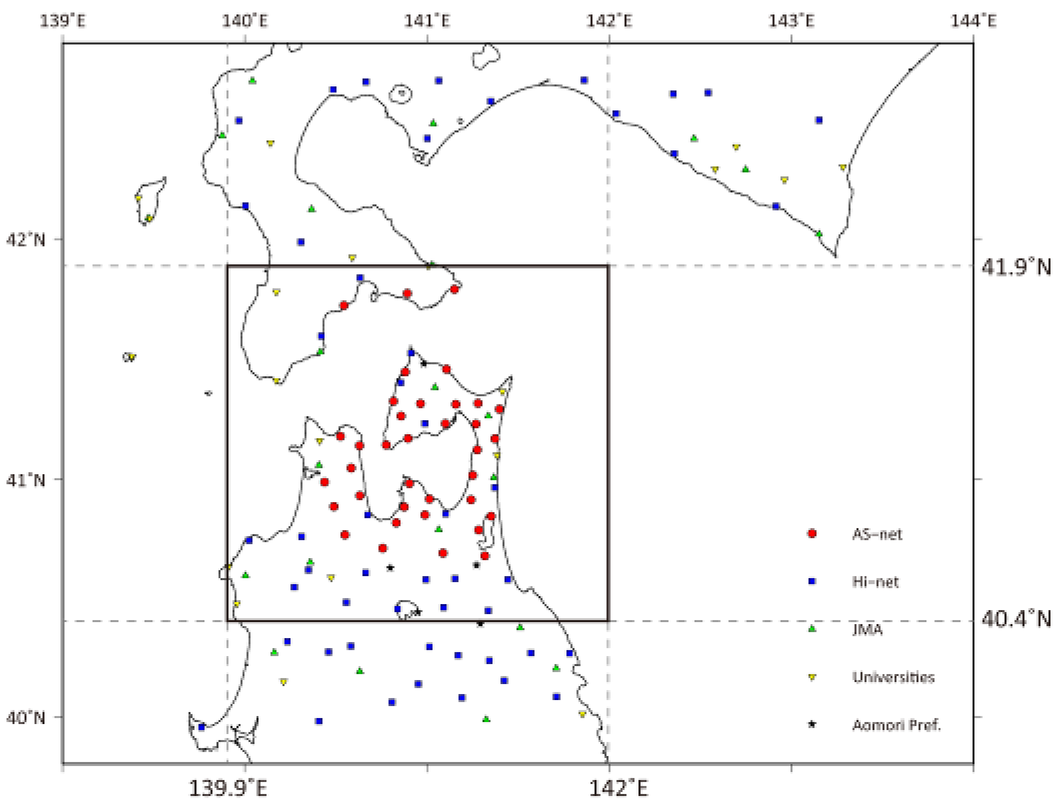

Fig. 6 – Stations used for hypocenter determination and objective area

4. Seismic activity around AS-net

We conduct hypocenter location using AS-net in addition to the other seismic networks. We determine the hypocenters by manual pick and relocation for the hypocenters which are detected and determined automatically. We show the seismic activity from January 1st, 2014 to December 31st, 2015 at Shimokita, Tsugaru, southwestern Hokkaido and Tsugaru channel using hypocenters we have determined.

4.1 Hypocenters determined automatically

We use 134 seismic stations including 36 stations of AS-net in addition to networks operated by JMA, NIED, Hirosaki University, Tohoku University, Hokkaido University and Aomori Prefecture (Fig. 6). We conduct hypocenter location for events occurring around Shimokita, Tsugaru and southwestern Hokkaido (square in Fig. 5). Site corrections for travel time at each stations are not taken into account until we obtain enough number of manual picks, which are essential for the estimation of site correction. 8948 events are determined automatically for the period of 2 years.

The distribution of shallow events (H < 50 km) determined automatically are shown in Fig. 7(a). In this figure, 5666 events except event with larger determination error are plotted. Nearly half of shallow events, regardless determination error, are artificially induced earthquakes; blast, seismic exploration and so on. But we can see that the other events show natural earthquake activities generally by comparing the distribution with that for JMA catalogue (Fig. 7(c)).

4.2 Hypocenters determined by manual pick

Then we check all auto-picks and relocate the 8948 events detected automatically. As a result, we derived 5003 earthquakes for the period of 2 years. The JMA hypocenter catalogue has 2394 events in the same region and period. More than half of 5003 events determined manually are not listed in JMA catalogue. On the other hand, we relocated similarly 367 events which have not been detected automatically while they are listed in JMA catalogue. They are contained in 5003 events. In terms of the number of events, the AS-net enhanced the earthquake detection capability double in this region. Especially for shallow inland earthquakes (H < 50 km), we determined about 2.6 times as many earthquakes as that listed in JMA catalogue. In addition, we found 170 low frequency events at the depth of 0-50 km.

The distribution of shallow events relocated manually are shown in Fig. 7(b). 3846 events are plotted in Fig. 7(b). Compared to the JMA catalogue (Fig. 7(c) showing 1473 events), the earthquake activities in this region are represented clearly. For example, we determined more than 6 times as many earthquakes as that for JMA catalogue around Wakinosawa, surrounded by AS-net stations (Fig. 8). The earthquake activities at such area are shown much clearly compared to that from JMA catalogue. The frequency-magnitude distributions for shallow events determined manually and JMA catalogue are shown in Fig. 9. Considering Gutenberg-Richter law, it can be said that we can detect earthquakes whose M is 0.8 or more using AS-net in this region, while M1.0 or larger earthquakes are listed almost fully in JMA catalogue.

5. Conclusion

We have installed high-sensitivity local seismic observation network, AS-net, to investigate the earthquake activity and subsurface structure in northern Tohoku and southwestern Hokkaido, Japan. We first investigated the site characteristics for AS-net stations. We found a relationship between the noise level and averaged S-wave velocity (AVS) for 20 m depth; the stations which have AVS less than 350 m/s show higher noise level obviously for both microseism and artificial noise. We determined hypocenters for 5003 events occurred around AS-net at the period from January 1st, 2014 to December 31st, 2015 using AS-net data in addition to the other seismic network by means of manual pick. We determined around twice as many earthquakes as JMA catalogue. Especially for shallower earthquakes and the region surrounded by AS-net, the earthquake detection capability was increased much more.

Because enough number of manual pick are becoming available, we will derive the site corrections for travel time and relocate hypocenters considering the correction at first. We will also investigate the earthquake activity and subsurface structure in detail in this region utilizing some methods; tomography, double-difference method and so on.

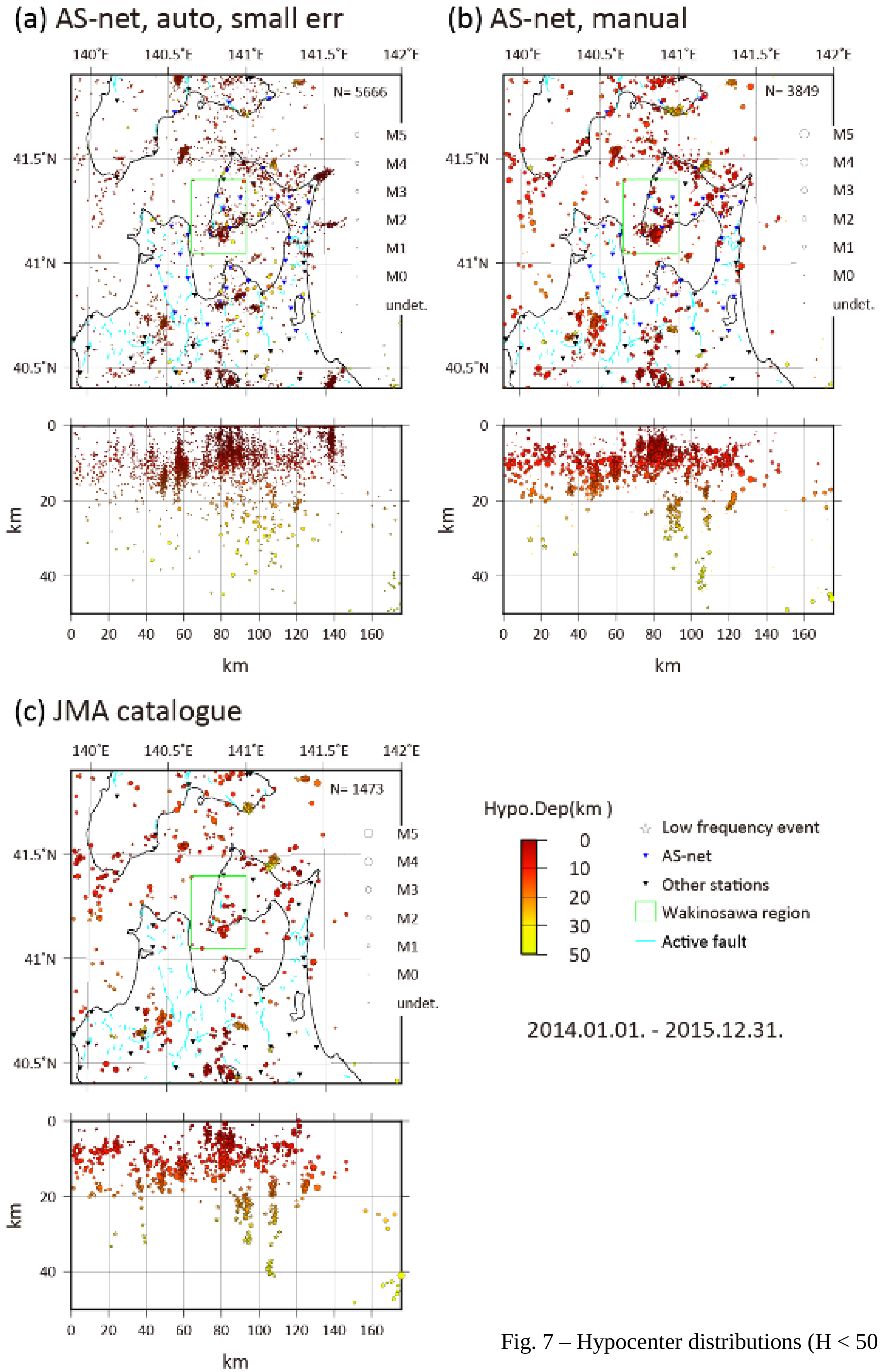

Fig. 7 – Hypocenter distributions (H < 50 km)

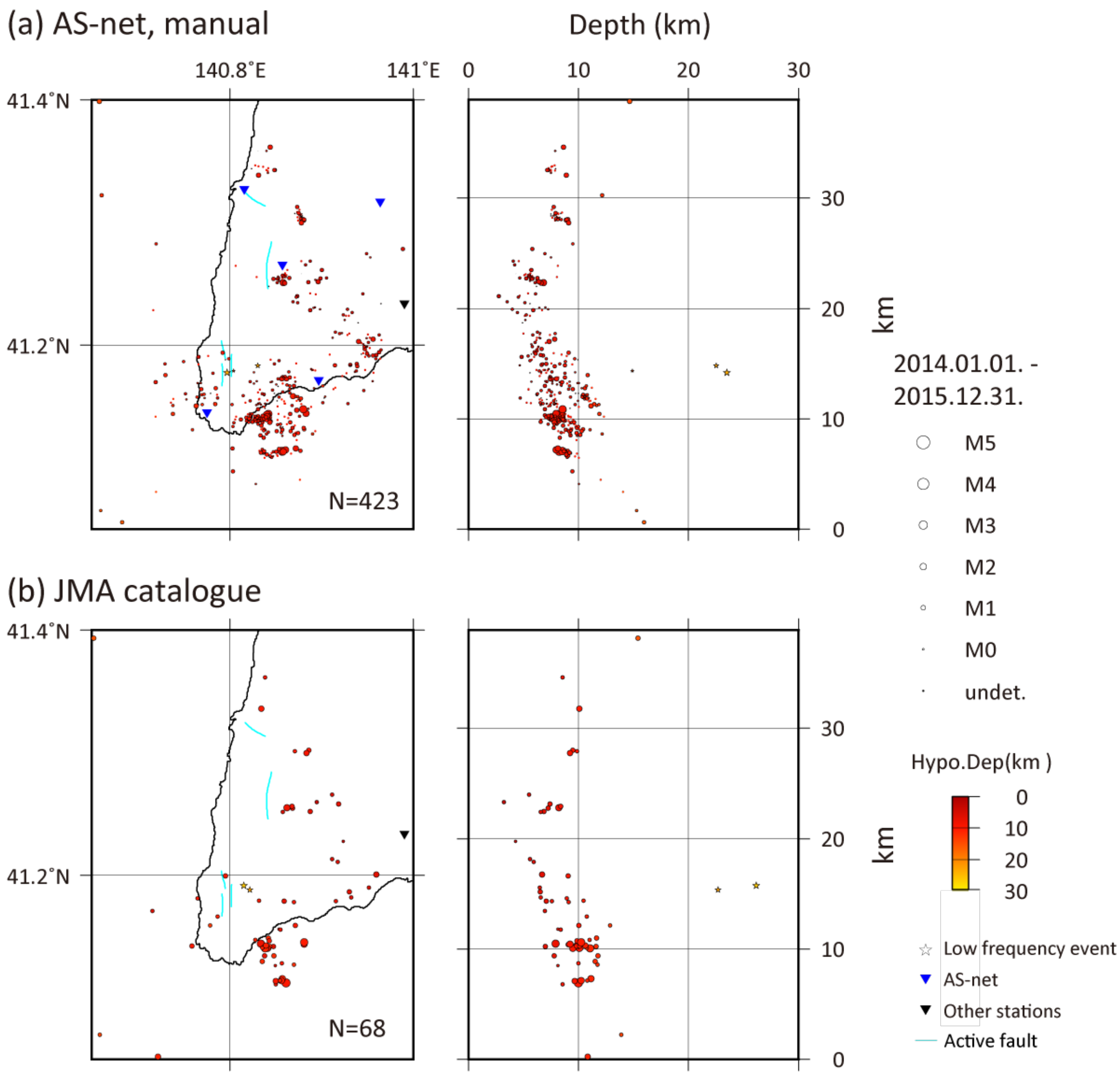

Fig. 8 – Hypocenter distributions (H < 30 km) around Wakinosawa region

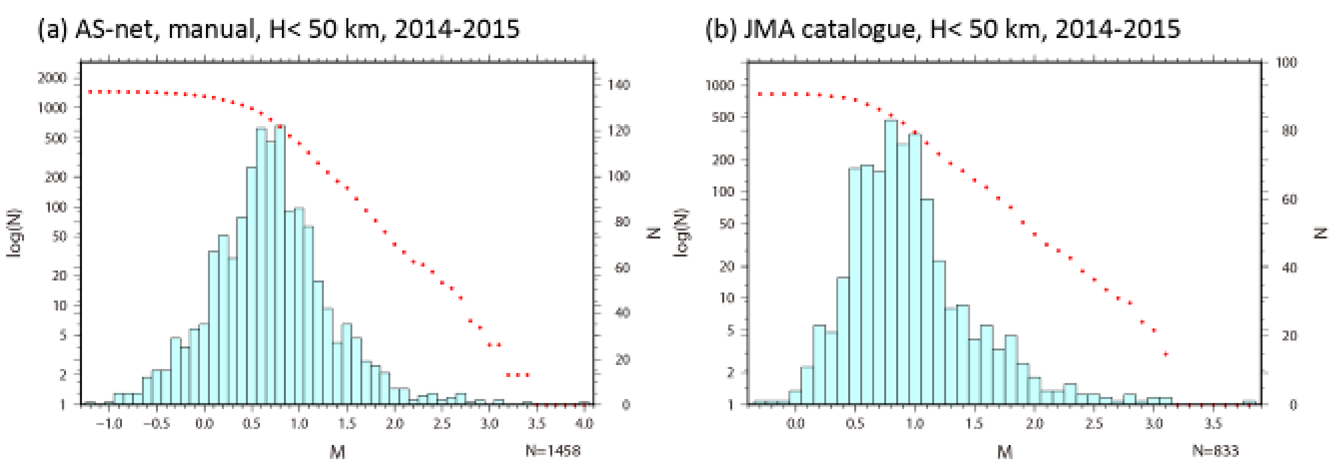

Fig. 9 – Frequency-magnitude distribution (blue bars) and cumulative frequency magnitude distribution (red dots)

6. Acknowledgement

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7. References

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