Stability of Ocean Bottom Seismograph data exposed to strong shaking: Effort for utilizing OBS for Earthquake Early Warning

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1. Introduction

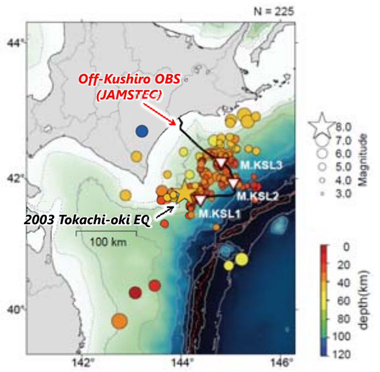
Installation situation of In-line cable type OBS

In-line cable type Ocean Bottom Seismograph (OBS) is expected to be useful for rapid ***Earthquake Early Warning (EEW)*** issuance. However, since OBSs are installed on unconsolidated sediments, we should take notice of the differences between the installation environment of OBSs and those of land stations.

The stability of OBS data exposed to strong ground motion is one of the important factors. The attitude angle of one of Off-Kushiro OBS (deployed by JAMSTEC) was changed about 5 degree by strong ground motion during the 2003 Tokachi-oki earthquake (M_{jma}8.0, *Yamamoto et al. (2004, AGU)*). Since the processing of the EEW is ongoing in real-time, it is difficult to detect abnormal data appropriately.

In this study, we investigate ***the characteristics of OBS data exposed to strong shaking*** at the Off-Kushiro OBSs, and estimate ***the influence of applying these data to EEW Magnitude estimation***.

2. Materials and Methods



Station and Hypocenter distribution map used in this study. Black line indicates the cable line of Off-Kushiro OBS.

※We regard the acceleration offset as a component of gravitational acceleration.

$$\mathrm{Pitch}(\theta) = \sin^{-1}\left(\frac{x_{offset}}{g}\right), \quad \mathrm{Roll}(\lambda) = \tan^{-1}\left(\frac{-y_{offset}}{-z_{offset}}\right)$$

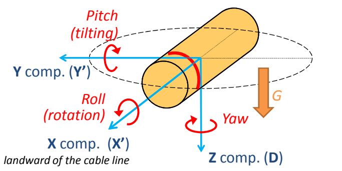


Image of sensor direction of three component acceleration seismographs enclosed within a cylindrical pressure housing.

Specifications of Off-Kushiro OBS:

Sensor: 3 comp. acceleration seismometer (JA-5 type III, Japan Aviation Electronics Industry)

Cylindrical pressure housing: length 169.5cm, diameter 26.5cm

Range: DC – 40Hz

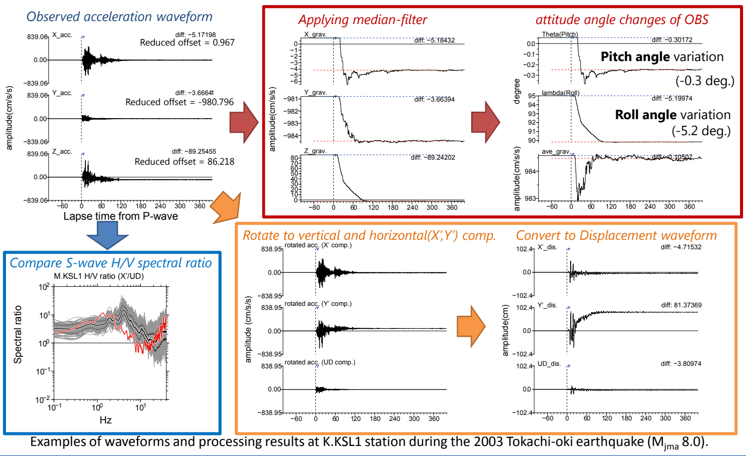
Installed in 1999, Buried in 2002

2.1 Data

We analyze waveforms of ***Off-Kushiro OBS (JAMSTEC)***. Three-component acceleration seismographs installed within a cylindrical pressure housing are able to record ground motion up to DC in frequency range.

2.2 Methods

1. Estimate ***the attitude angle change of OBS housing*** from amount of acceleration offsets.
   i. Apply cascaded median-filter (2s and 50s) for the original acceleration record
   ii. Estimate the rotation and tilting of OBS housing during the EQs.
2. ***Convert waveforms to vertical and horizontal components (X', Y')*** to estimate influence for Magnitude estimation.
3. Calculate ***H/V and H/H spectral ratio*** from S-wave portion to check the coupling between the OBSs and seafloor.

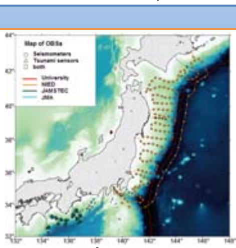


Examples of waveforms and processing results at K.KSL1 station during the 2003 Tokachi-oki earthquake (M_{jma} 8.0).

6. Future works

In Japan, large-scale OBS networks, that is, ***DONET/DONET2*** (deployed by JAMSTEC) and ***S-net*** (NIED) are now under construction.

Our future research will focus on utilization of those dense OBS systems for EEW.



Station map of OBS systems in Japan.

The OBS distribution map was made by HERP(Headquarters for Earthquake Research Promotion) using data of ERI(Earthquake Research Institute, The University of Tokyo), NIED, JAMSTEC and JMA.

Acknowledgement:

The strong motion acceleration data are collected from JAMSTEC (Off-Kushiro OBS) and NIED (K-NET, Kik-net). The ROV pictures of OBS were obtained from JAMSTEC E-library of Deep-sea Images (J-EDI). This work was supported in part by JSPS KAKENHI Grant Number 25282114.

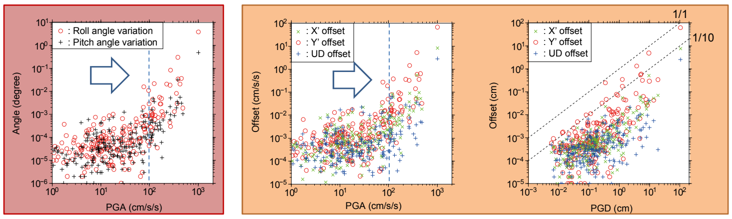
5. Summary

- ✓ Acceleration offsets caused by inclination of OBS are larger on the **horizontal component Y'** (perpendicular to the cable line) than the other components when OBS exposed to strong ground motion (over 100cm/s^2).
- ✓ S-wave H/V spectral ratio for strong ground motion shows typical characteristics of **nonlinear soil response**.
- ✓ Response characteristics of two horizontal components (X',Y') are different for frequency range larger than 10Hz.
- ✓ Large offset due to inclination may **cause the overestimation of EEW Magnitude (M_{eew})**. By using **vertical component**, we can reduce their overestimation for magnitude estimation.

3. Results

3.1 Acceleration offsets caused by OBS Inclination

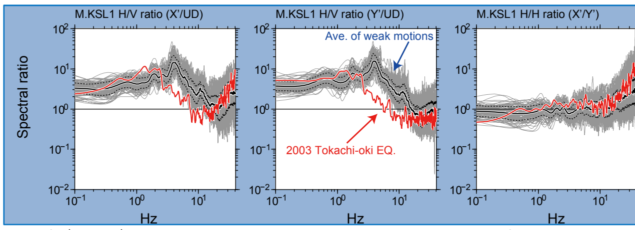
We find that the acceleration offset caused by slight inclination of OBS **increases with increasing input acceleration (PGA)**. When OBS exposed strong ground motion(over 100cm/s^2), the roll angle variations are larger than the pitch angle variations, and the acceleration offsets on the horizontal component Y'(perpendicular to the cable line) are conspicuously larger than that on the other horizontal component X'(along cable line).



Correlation diagram of angle variation and PGA(Peak Ground Acceleration) (a), acceleration offsets and PGA (b), and displacement offsets and PGD (c).

3.2 Characteristics of S-wave H/V and H/H spectral ratio

S-wave H/V spectral ratio of the 2003 Tokachi-oki EQ (M_{jma} 8.0) are different from that of weak motions in the following two characteristics, that is, the dominant peak shifts lower frequency and the amplification at high frequency decrease. There are **typical characteristics of nonlinear soil response**. Another remarkable feature are also found in almost all H/H spectral ratios for frequency range larger than 10Hz.

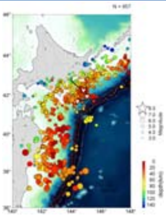


Comparison of H/V and H/H spectral ratio at each component. Red line indicate the ratio of the 2003 Tokachi-oki EQ. (M8.0)

4. Discussion

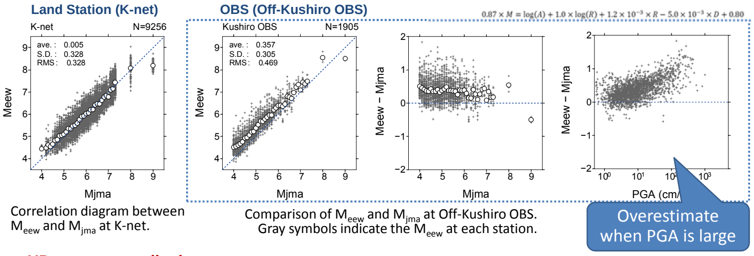
4.1 Influence on Magnitude estimation

The differences between S-wave EEW magnitude (M_{eew}) at OBSs and M_{jma} increase with PGA. In our conversion process using the recursive filter, the acceleration offset remains as an offset to the displacement waveform. Hence these overestimation may occur as the result of the remaining offsets on horizontal displacement component. Alternatively, By using ***vertical component*** displacement waveform, we can reduce their overestimation for magnitude estimation.



Hypocenter distribution map used in magnitude estimation.

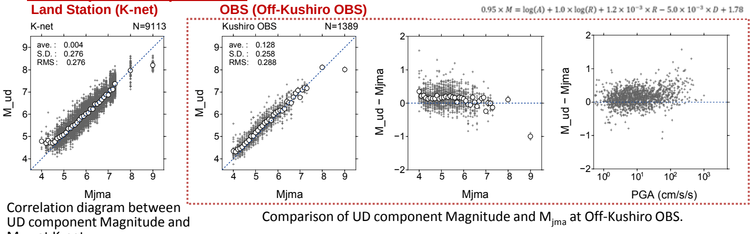
3 component displacement



Correlation diagram between M_{eew} and M_{jma} at K-net.

Comparison of M_{eew} and M_{jma} at Off-Kushiro OBS. Gray symbols indicate the M_{eew} at each station.

UD component displacement



Correlation diagram between UD component Magnitude and M_{jma} at K-net.

Comparison of UD component Magnitude and M_{jma} at Off-Kushiro OBS.