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# Study on seafloor surface seismic wave velocity estimation and baleen whale call detection at cabled observatories in Japan Trench Area
# 日本海溝域の海底ケーブル型観測点における海底表層地震波速度推定と鯨類鳴音の検出

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## 1. Introduction

Recently a large cabled observatory ”S-net” (Seafloor observation network for earthquakes and tsunamis along the Japan Trench), consisting of 150 stations in a vast area in the Pacific Ocean on the east coast of Japan from off Hokkaido to Boso Peninsula, was installed by National Research Institute for Earth Science and Disaster Resilience (NIED). It started operation in 2016, and the waveform data obtained with ocean bottom seismometers (OBSs) of the observatory are released to public since October in 2018.

Meanwhile, fin whale calls, whose frequency ranges are 17–25 Hz[1)], have been found by several OBSs of the existing cabled observatories[2)]. However, since those existing observatories are installed in a very limited area, regional distribution and temporal changes of the whale calls off east Japan Pacific Ocean are still unknown. Therefore, S-net may contribute not only to the early detection of earthquakes and tsunamis, but also to the elucidation of migration behaviors of the baleen whales in the waters of Japan.

In addition, it is desirable that not only to detect whale calls but also to know individual movement based on sound source localization becomes possible. However, unlike earthquakes, the source sound pressure level of the whale vocalization is usually not so large as to be detected at multiple stations constituting the cabled observatory. Therefore, it is necessary to localize at a single station. One of the authors examined a sound source localization method based on a particle motion obtained from the waveform data of a single three component OBS at the cabled observatory offshore of Kamaishi in Sanriku[3),4)]. In this method, both the angle and the azimuth of the incident underwater sound at seafloor are estimated based on the particle motion of the single OBS. The horizontal distance of the sound source is estimated from the incidence angle. However, the OBS can only observe the apparent emergence angle of the transmitted wave, which is a composite of a pressure wave (P-wave) and a vertical shear wave (SV wave), which are both converted at the seafloor provided that the incidence angle is less than the critical angle. Therefore, the relationship between the incidence angle and the apparent emergence angle depends not only on the P-wave velocities in the water and the sediment of the seafloor surface but also on the S-wave velocity in the sediment. Thus, both the P-wave velocity and the S-wave velocity in the sediment are necessary which are usually unknown. In Ref. 3, the seismic wave velocities in the sediment were estimated *in situ* based on the observation of the transmitted wave of air gun signal with known sound source location, i.e. both the horizontal range and the azimuth of the sound source. Specifically, the seismic velocities were estimated by comparing the apparent emergence angle of the transmitted wave, which was obtained from the observed particle motion, with the theoretical emergence angle based on the Zoeppritz equation assuming plane-wave incidence at fluid-solid boundary.

In this study, in order to estimate seismic wave velocities in the sediment of seafloor surface, the same method in Ref. 3 are examined to the S-net stations. Also, preliminary survey of the whale call detection from the waveform data of the S-net OBSs is conducted

## 2. Data and Results

After the S-net operation started, the seismic reflection survey with the air gun was carried out in the cruises YK18-12 of the research vessel (R/V) “Yokosuka”, KM17-05 and KM18-06 of R/V “Kaimei” in the S-net installation area. The track data of those cruises are released to public on the web of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). 12 stations of the S-net are examined in this study, in the vicinity of which the tracks of those cruises passed while oscillating the air gun. The S-net station has two types of OBS: velocimeter and accelerometer. Since both the inclination and orientation of the OBS are arbitrary, the accelerometer is used in order to convert raw data to those on geographical coordinates (north-south, east-west, up-down) on the basis of the direction of gravity derived from the offsets of acceleration. The observed value of emergence angle and orientation are derived from the particle motion by principal component analysis[5]. The orientation of the OBS is estimated by comparing the observed value of emergence orientation with the ship location derived from the track data. The incidence angle of the underwater sound associated with the ship location is calculated by ray tracing with the vertical sound velocity profile obtained in accordance with the UNESCO equation[6] using conductivity, water temperature, and water depth (CTD) data observed at KR12-19 cruise of R/V "Kairei" and at MR14-04 cruise of R/V "Mirai".

The locations of the 12 stations examined in this study are denoted by black closed dots in **Fig. 1**. Open and close dots denote the all 150 stations.

**Fig. 2** and **Fig. 3** show the examples of the relationship between the incidence angle of the underwater sound and the apparent emergence angle of the transmitted wave into the seafloor at stations S5N08 and S6N04, respectively. By estimating the critical incidence angle from the figures, the P-wave velocity in the sediment is estimated in accordance with Snell's law. Based on Fig. 2 and Fig. 3, P- and S-wave velocities are estimated to be 1.8 km/s and 0.0–0.3 km/s at S5N08 and 1.8 km/s and 0.4 km/s at S6N04, respectively.

Although there are random or systematic large deviations in the observed values at some of the 12 stations, P-wave velocity is estimated to be around 1.8 km/s at most stations, and S-wave velocity is estimated to be less than 0.4 km/s at stations on landward slope and 0.3–0.7 km/s at those on the seaward slope of the trench.

As a preliminary survey of the whale call detection, the waveform data of the velocimeter, which is more sensitive to the whale call signals than accelerometer, are examined. The stations where possible baleen whale calls are detected by the manual inspection of the spectrograms on January 1st 2019 are indicated by the red dots in Fig. 1. Possible baleen whale calls are detected mainly in offshore areas from Hokkaido to Aomori Prefectures and sparse in other areas.

## 3. Concluding remarks

Seismic velocities in the sediment of the seafloor surface at 12 stations of S-net are estimated based on the apparent emergence angle of OBS. The S-wave velocity on the seaward slope of the trench is larger than that on the landward slope, while P-wave velocity is roughly the same. As a result of preliminary survey of the whale call detection, possible baleen whale calls are mainly concentrated in offshore areas from Hokkaido to Aomori Prefectures in winter.

**References**
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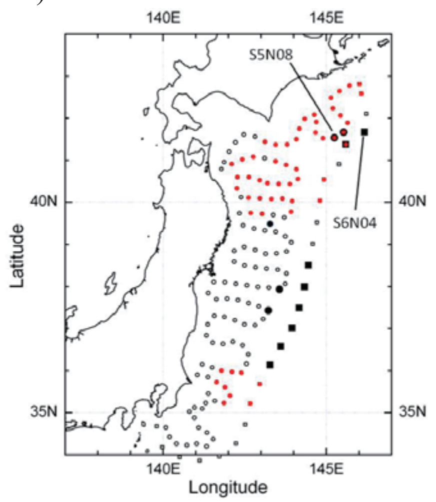


Fig. 1 Locations of S-net stations. Closed black dots denote those used in this study. Red dots denote those where possible whale calls are detected on Jan. 1st 2019.

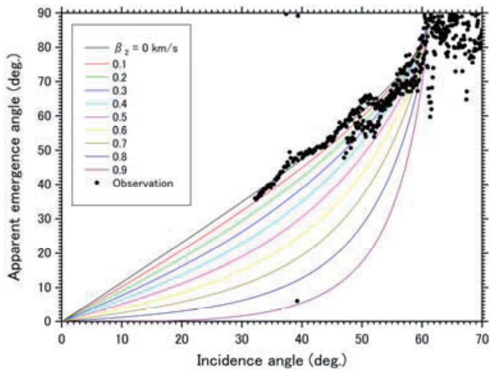


Fig. 2 Relationship between the incidence angle and the apparent emergence angle at S5N08 station.

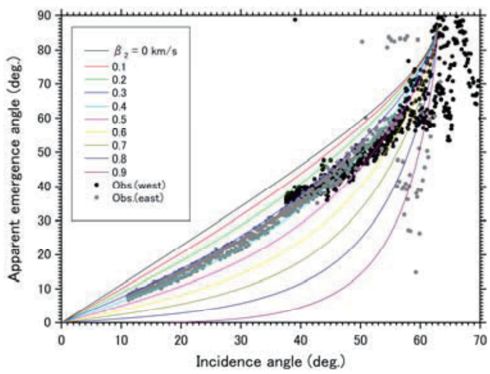


Fig. 3 Relationship between the incidence angle and the apparent emergence angle at S6N04 station.