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A case study of sound propagations in consideration of ocean fluctuations

海洋変動の影響を考慮した音波伝搬の事例解析

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1. Introduction

Ocean environmental monitorings scuh as water temperature, current and salinity are important to understand global climate changes. They are also useful for fishery and acuaculture industry because ocean environmental changes directly concerns ocean ecosystem. Acoustic methods have been used in many ways such as signal communication, environmental monitoring tools, and detection system because of its advantage that it is less attenuation than optics or radiowave. We had analyzed reciprocal sound data which was traveling more than 100 km retrieved in the equatorial central Pacific Ocean while a whole year in 2000[1-4]. However, refraction and reflection from the sea surface and seabed complicate the received signals especially at the shallow water. Therefore, many ocean experiment[5, 6] and simulation[7] were executed to clarify these effect and sound propagation. In this study, we show some results of a small scale sound propagation experiment at Hashirimizu port in summer of 2008.

2. Experimental settings

A pair of a sound propagation system was placed on either bank of Hashirmizu port with the distance of about 110 m as shown in **Fig. 1**. Depth of the port is about 5 m in average. **Fig. 2** explains the block diagram of the sound propagation system. The systems alternate sending and receiving every 30 s; we can get reciprocal sound propagation data every 1 min. Received signal is recorded for 300 ms after the sending start with the sampling rate of 1 MHz. To synchronize both side of the system, a global positioning system (GPS) clock generates 1 pulse per second signal with accuracy of ± 200 ns. Therefore, it is able to detect the accurate travel time between the systems. Transducer was placed at the depth of about 0.9 m from the seabed. Sending signal is seventh order M-sequence and repeated for four times. The signal was sent with the career frequency of 12.5 kHz. M-sequence modulated signal has an advantage in measuring accurate travel time in the noisy environment because it can be treated as a pulse after demodulation by the original M-sequence. As sending signal include 4 times of M-sequence signal, recorded signal was cut the length of one cycle M-sequence and added all of the cut signals. Effects of spicular noises and other noises can be almost removed by these processes. The added signal were demodulated with M-sequence and transformed to get amplitude components.

3. Results

Fig. 3(a), (b) shows the travel time changing through the experimental period of 2th-21th August in 2008. Because reciprocal propagations were recorded, Fig.3(a) shows the sounds from the land side to the sea side, and Fig.3(b) shows the sounds

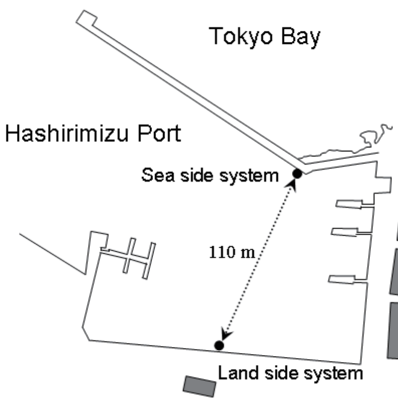

Fig. 1 Arrangements of the experimental equipments.

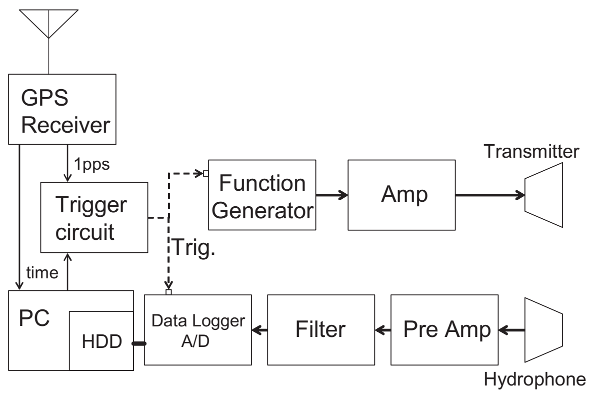

Fig.2 Sound propagation system.

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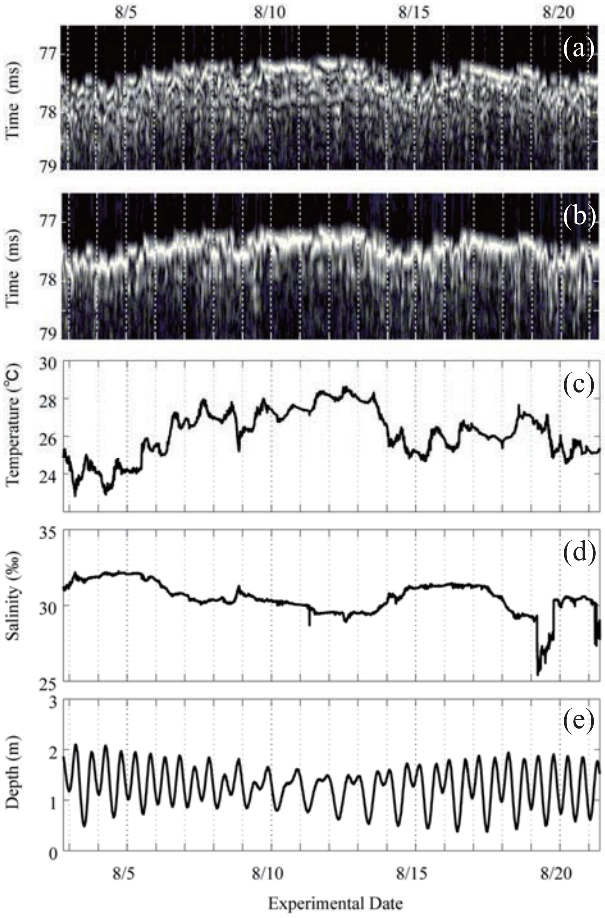

Fig. 3 (a)Time series of the sound travel time from the land side system to the sea side system. (b) Time series of the sound travel time from the sea side system to the land side system. (c) Water temperature near transducer at the sea side system. (d) Salinity near the transducer at the sea side system. (d) Depth between the transducer and sea surface at the sea side system.

from the sea side to the land side. At the same time, water temperature, salinity and the distance from the sea surface to the transducer, were measured by CTD (Conductivity Temperature Depth meter) every 5 min and figured on Fig. 3(c), (d), (e), respectively. The white area around 77.5 ms on Fig.3(a,b) shows the arrival sound arrival time changes of the first signal of the M-sequence. As there many reflected waves occurred by shallow water area, many peaks appeared as white color after 77.5 ms.

The reciprocal travel time t_A and t_B between two points can be written as

$$t_{AB} = \frac{L}{c+u}, \quad t_{BA} = \frac{L}{c-u},$$

where, c is sound speed, L is distance between the two points and u is current between the points. Thus, the current speed can be written over as

$$u = c\frac{t_{BA} - t_{AB}}{t_{AB} + t_{BA}}.$$

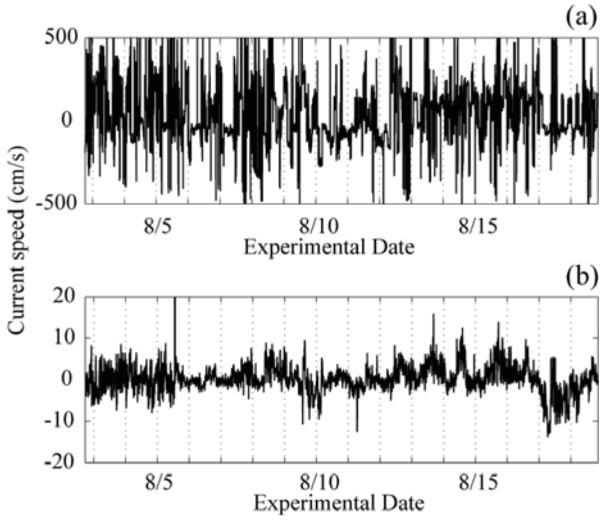

Fig.4 (a) Current speed estimated from reciprocal sound travel time. (b) Current speed measured by ADCP.

Using this equation, current speed at the experimental area is estimated as **Fig.4** (a). Fig. 4(b) shows current speed measure by ADCP which was located middle point between the two systems. Although current estimated by the arrival time has many outliners, pattern of the current changes similar to that of measured by ADCP. For more accuracy, the algorism of the peak detection of the arrival time have to improve because at this moment, arrival time was decided at the moment of the max value was recorded.

4. Conclusion

Reciprocal arrival time were monitored at Hashirimizu port. From the first arrival time, current speed between the system were estimated. As the value of the estimated current had many outliners, current speed changes follows the results of ADCP. Peak detection of the arrival time can expect to estimate accurate current speed.

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