1. Introduction

Recently, ocean dynamical changes attract attention in field of meteorology, oceanography and fishery because it has great influence for those fields. Long period monitorings of oceanic structure have to be performed to reveal correlation between the oceanic structure variations and other phenomena; weather, wind speed, fish behavior, and so on. For those purpose, ocean acoustic tomography (OAT) is a useful method using the inverse of acoustic propagation times through the multipaths of the ocean.1) OAT experiments from 1999 to 2000 were promoted by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in the central equatorial Pacific Ocean2,3) shown in Fig. 1.

The tidal effects of the received data were investigated by the spectrum analysis of travel times.4) Then, estimated current speed from reciprocal travel time and compared with Levitus’ seasonal oceanographic data set and ADCP data measured by TAO project5). In this paper, we estimate current speed between three pairs of transceivers from reciprocal sound travel time and compare the difference of current speed.

2. Original Data Information

Figure 1 shows the arrangement of seven transceivers for OAT experiment in the central Pacific Ocean. All transceivers consisted of a 200 Hz sound source, a hydrophone array, a surface buoy with an antenna for global positioning system (GPS) and other necessary instruments for OAT experiment, and were moored at the depth around 1000 m which was in the sound fixing and ranging (SOFAR) axis. Sound sources sent 11th-order M-sequence signal at the same time every four hours in one day with 3 day intervals. M-sequence signal were repeated 7 times at one shot. As some of recorded signals dropped out the first signal of the 7 repeated signals, we use the second signal for current speed estimation.

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3. Current Estimation

As sound from a sound source propagates toward receivers with refraction, travel time becomes different due to the difference in the sound speed depending on depth. In this study, we focus on the sound travel time between the transceiver 6 (T6), the transceiver 7 (T7), and the transceiver 8 (T8). As seven transceivers were not manufactured at the same time, S/N ratio and receiving performance were different. Thus, some received data must be verified their reliabilities before analysis6). These selected three transceivers were good conditions compare with others. For current speed estimation, the rays the maximum amplitude which propagated near the SOFAR axis were used as the first step. Fig. 2 shows amplitude of second received signal at T8 from T7.

Suppose, distance between the two transceivers $T_A$ and $T_B$ increases $\delta L$ from the standard distance $L$, the reciprocal travel times $t_A$ and $t_B$ can be written as

\[ t_A = \frac{L + \delta L}{c - u} = \frac{L + \delta L}{c} + \frac{u}{c} t_A, \]

\[ t_B = \frac{L + \delta L}{c + u} = \frac{L + \delta L}{c} - \frac{u}{c} t_B, \]

where $c$ is the sound speed, $u$ is the current speed
component along the propagation direction, and \( t_A \) and \( t_B \) are the travel times from \( T_B \) to \( T_A \) and from \( T_A \) to \( T_B \), respectively. Therefore, the sum of the reciprocal travel times \( s \) is
\[
\frac{1}{2} (t_A + t_B) = \frac{L}{c} + \frac{\partial L}{c} - \frac{1}{2} \frac{u}{c} (t_A - t_B).
\]
As the third term on the right-hand side of eq. (2) is markedly smaller than the other terms, \( s \) can be approximated as
\[
s \cong \frac{L}{c} + \frac{\partial L}{c} - \frac{L}{c_0} - \frac{L}{c_0} \delta c.
\]
In this equation, the sound speed \( c \) is separated into the average sound speed \( c_0 \) and fluctuation component \( \delta c \). In addition, \( |\delta L| \ll L \) and \( |\delta c| \ll c_0 \).

4. Conclusion

Meridional current speeds between three pairs of transceivers were estimated from the reciprocal travel time. In future, we will investigate the effect of internal tides from measured travel time using tidal model.

References