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Orientations of DONET seismometers estimated from seismic waveforms

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DONET is a network of permanent ocean-bottom seismic stations aimed at improving the detection capability and earlier detection of earthquakes and tsunamis off the Kii Peninsula, where the Tonankai mega-thrust earthquake is anticipated to occur in the near future. Real-time DONET data is transferred to the Japan Meteorological Agency and the National Research Institute for Earthquake Prevention and Disaster Mitigation, and used for the earthquake early warning in Japan.

DONET consists of 20 stations each of which seismometers and pressure gauges are installed. At each station a broad-band seismometer and a strong-motion seismometer are installed. The orientation of the horizontal components of the seismometer at each station has been measured by using video of ROV, which is difficult to measure again for the confirmations.

We estimated the orientations of DONET seismometers by using the following methods: (1) correlation of long-period seismic waveforms with observations in land, (2) direction of P-wave first motion from distant earthquakes, and (3) particle motion of airgun signal. The methods (1) and (2) are based on the long-period signals from distant earthquakes, and we used data from broad-band seismometers. The method (3) is based on short-period signals, and we estimated the directions of both the broad-band seismometer and the strong-motion seismometer at each station.

The method (1) is the same as that used for the estimations of the orientations of Hi-net and KiK-net borehole seismometers by Shiomi et al. (2003). We estimated the direction of broad-band seismometers relative to the five F-net stations (ABU, KIS, KMT, NOK, and WTR) installed in the Kii Peninsula. We used data from earthquakes that occurred between May, 2010 and October, 2011, with magnitude larger than 7. We applied a Butterworth filter between 0.008 and 0.01 Hz for the waveforms. We estimated seismometer orientations based on the correlation of the waveforms between DONET and F-net on land.

The method (2) uses the particle motion of the direct P-wave from a distant earthquake. The signal from the direct P-wave appears in the vertical and radial components, both waveforms have positive correlation. We rotated the horizontal waveform components to find the direction that have the largest correlation with the vertical component. The waveforms are from earthquakes that occurred between January and November, 2011, with magnitude larger than 5.5 and the epicentral distance between 30 and 90 degrees.

The method (3) uses airgun signals from the seismic investigations carried out off the Kii Peninsula between September and October, 2011 (KR11-09). The acoustic wave in the water radiated from airgun is converted to seismic waves in the crust at the ocean bottom, and the signal appears in the vertical and radial components in the seismometer records. We fitted the horizontal particle motion with a line, and obtained the seismometer direction from the azimuth computed from the coordinates of the shot and station. The nature of the wave is similar to that used in the method (2), but the waveform may not be well correlated with the vertical motion because the airgun signal is dominated in the frequency components higher than several Hz.

The obtained results from the three methods are well consistent with each other with variations at maximum 5 degrees. The difference from the measurement of the ROV video is about 10 degrees for most stations, but in some stations the difference is about 50 degrees.

Keywords: Ocean-bottom seismometer, Nankai trough, seismic investigations