Practical method to determine relative orientation of horizontal
components of ocean bottom seismometer in an array

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Japan Trench is one of typical subduction margins with fast and slow seismic activities, such as M9
Tohoku-Oki megathrust event, slow slip events [Kato et al., 2012], low frequency tremors [Ito et al., 2015]
and very low frequency earthquakes [Matsuzawa et al., 2015]. To observe such offshore seismicity with
high precision and resolution, we installed three arrays of ocean bottom seismometers (OBS) on offshore
Fukushima prefecture near the trench axis. Each array consists of one broad band OBS, and six 1Hz short
period OBSs. Those seven OBSs form triangular array with diameter of 1km, and 500m of interstation
distance. Continuous observation was performed between September 2016 and October 2017.

We have processed data with beamforming, which is a method allows us to reveal azimuth and apparent
velocity of incoming wave observed by an array. It has been used to detect tremors in Cascadia
subduction zone [Ghosh et al., 2009; 2012] and San Jacinto Fault [Hutchison and Ghosh, 2017].
Beamforming was applied to OBS array dataset in previous study [Ohta et al., 2017, EGU]. However, only
waveforms of vertical components had been used, because of unknown orientation of horizontal
components due to free-fall deployment of the OBSs. Definite orientation of horizontal components can
be obtained using particle motion of regional or teleseismic earthquakes [e.g., Scholz et al., 2016].
However, associated uncertainty is too large to satisfy required condition of beamforming, which is
horizontal components of all seismometers in an array must oriented in a same direction. Here, we align
the orientation of horizontal components of all OBSs within each array by cross correlating observed
waveforms. On each array, we pick one OBS as a reference. Horizontal components of the other OBSs in
an array are rotated every 1 degree, and cross correlated with the horizontal components of the reference
OBS using first several seconds of P-wave radiated from regional and local earthquakes. As a result, we
obtained relative orientation where waveforms of horizontal components of the other OBSs correlate for
the best with the reference OBS. We verified these orientation angles are accurate enough for
beamforming through beamform of local, regional and teleseismic earthquakes.

Our method can determine relative orientation of horizontal components of OBSs in the array accurately,
which is a crucial condition for any array analysis technique. Analysis of waveforms of horizontal
components would be a huge advantage for study of low frequency tremors, since S-wave dominates its
waveform [Obara, 2002; La Rocca et al., 2005] and thus expected to be more energetic in horizontal
components rather than vertical.

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