Observation of shockwave from the 17 December 2013 Biwako bolide using 3D seismic array

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There are many reports of observation of bolides by using seismic record. Compared with other approaches such as video camera or acoustic microphone, seismological observations have advantages in terms of their ease of multipoint observations and their independence on weather conditions (e.g. Ishihara et al. EPS 2003). In these reports, there is a case of unclear onsets and no distinct N shape in waveforms (Yamada and Mori EPS 2012). That case, a velocity of the fireball was not determined. Here we report seismic records of shockwave from the fireball that appeared on the night of 17 December 2013 around Biwako and determine the moving velocity by using a dense three dimensional seismic array.
We performed a 3D array observation in Mie prefecture since February 2011 to monitor non-volcanic low frequency tremor activity (e.g. Takeda et al. JpGU 2015). The array is composed of a 3-level vertical seismic array at a depth of 25m, 164m, and 595m (Imanishi et al. 2011), and a 46-element surface array centered on the vertical array. The radius of the surface array is 10 km, with a station spacing of about 50 m to 5 km. Seismograms recorded at the surface array show clear onsets of the shock wave with a downward polarity, while those of the vertical (borehole) array have unclear onsets. Therefore, we used only seismograms of the surface array for the determination of a source trajectory.
We manually picked arrival times of the shock wave, and estimated the source location by a grid search, assuming a point source or a moving source with a constant velocity. Theoretical arrival times for the moving source model show better fit to the observations than those for the point source model. We estimated the velocity of source to be 27km/s and an incident elevation angle to be 43 degree. Our result agrees with the estimation by video camera records, which are 25km/s and 47 degree (SonotaCo Network Japan).

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