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はやぶさリエントリーのインフラサウンド・地震観測
Infrasound and Seismic Observations of the Hayabusa Reentry

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The Hayabusa, the world first sample-return minor body explorer, came back to the Earth, and reentered into the Earth's atmosphere on June 13, 2010. The Hayabusa Sample Return Capsule (H-SRC) was the third direct reentry event from the inter-planetary transfer orbit to the Earth at a velocity of over 11.2 km/s. The H-SRC and the H-S/C reentries are very good analogue for studying bolide size meteors and meteorite falls. We, therefore, conducted a ground observation campaign for aspects of meteor sciences. We carried out multi-site ground observations of the Hayabusa reentry in the Woomera Prohibited Area (WPA), Australia. The observations were configured with optical imaging with still and video recordings, spectroscopies, and shockwave detection with infrasound and seismic sensors. In this study, we report details of the infrasound/seismic observations and those results.

To detect shockwaves from the H-SRC and the H-S/C, we installed three small aperture infrasound/seismic arrays as the main stations. In addition, we also installed three single component seismic sub-stations and an audible sound recorder. The infrasound and seismic sensors clearly recorded sonic boom type shockwaves from the H-SRC and disrupted fragments of the H-S/C. The audible recording also detected those shockwave sounds in the human audible band. Positive overpressure values of shockwaves (corresponding to the H-SRC) recorded at three main stations are 1.3 Pa, 1.0 Pa, and 0.7 Pa with the slant distance of 36.9 km, 54.9 km, and 67.8 km (i.e., the source altitude of 36.5 km, 38.9km, and 40.6 km), respectively. These amplitudes of shockwave overpressures are systematically smaller than those of theoretical predictions. The incident vectors of the shockwave from the H-SRC at all the three arrays are estimated by F-K spectrum and agree well with predicted ones. Particle motions of ground motions excited by the shockwave from the H-SRC show characteristics of typical Rayleigh wave.

We examine the relation between amplitudes of overpressures and ground motions, and consider the transfer function. We define the transfer function as, Z(w)= r$V_S v_z$(w)/p(w), where, w is the angler frequency, p the pressure perturbation, r the density of elastic media, V_S the shear wave velocity of elastic media, and v_z the vertical ground velocity. Here the numerator represents the pressure in the elastic media. The obtained value of transfer function is ~ 2 at frequency of around 8 Hz. We try to search elastic properties of each site (r: 1300 - 1700 kg/m^3, V_P: 1200 - 1700 m/s, V_S: 100 - 300 m/s) to explain the observation. The optimum values are around r of 1500 kg/m^3, V_P of 1400 m/s and V_S of 150 m/s. The effective depth of air-to-ground coupling of this frequency range is very shallow and observation sites are covered with fine soil. Therefore the estimated values are fully suitable.

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