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In-situ measurement of acoustic wave propagation characteristics in middle and upper atmosphere by PDI on-board S-310-41

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Acoustic wave propagation in the middle and upper atmosphere is mainly characterized by atmospheric temperature and wind. Although they can be derived with empirical atmospheric models like MSIS, the detail propagation process is still unknown (Sutherland et al., 2004). In-situ measurements of acoustic wave propagation are comparatively difficult and previous measurements were extremely limited. In 1960's, the sound propagation between upper atmosphere and multiple ground sites were measured using multiple explosions of grenade on-board a sounding rocket in order to obtain temperature and wind profiles in the middle and upper atmosphere (e.g. Stroud et al.,1960). In 1990's, a measurement method by using MU-Rader with RASS (Radio Acoustic Sounding System) was developed (Tsuda et al., 1994). In order to detect acoustically modulated atmosphere, the RASS transmits low-frequency sound pulses at around 100 Hz from the ground, while in-situ measurement of acoustic waves in the middle and upper atmosphere by using sounding rockets has not been conducted.

The S-310-41 sounding rocket of JAXA was launched from Uchinoura Space Center, Japan, on 7 Aug. 2012. PDI (Propagation Diagnostics in upper atmosphere by Infrasonic/Acoustic waves) was equipped on the rocket as one of 3 sub payloads to measure frequency distribution of sound propagation in the middle and upper atmosphere. The PDI consists of a speaker for generating sound source, one main and two sub microphones as sound detectors, an electric circuit for sound generator, and an absolute pressure sensor. These devices were successfully operated with transmitting 7 fixed-frequency infrasonic/acoustic waves between 10 Hz and 1 kHz at each output power of 1 W for every 0.2 s along with silent period for another 0.2 s, repeating every 1.6 s. Acoustic wave propagation between the speaker and microphones was measured in the payload section. Massive audible sound emitted by the rocket motor burning and impulsive sound signals of nose-cone and payload separations was also detected. Acoustic waves with 50 Hz and 100 Hz were transmitted by the RASS system from the ground to the rocket.

Impulsive sound signal of the rocket motor burning was recorded until about 34 s after the launch (at about 35 km altitude). In a silence situation after the rocket burn-out, the sequential signals generated by the on-board speaker were continuously measured. Faint sound signal was recorded even at the apex of 150 km. Our analyses of measured sound signals showed that the signal strength was attenuated with decreasing of ambient atmospheric pressure (rising in altitude), which was similar tendency of theoretical value by Sutherland et al. (2004). We successfully measured the sound signals of the nose-cone open and the payload separation. Using these pulses, we calculated the sound speed and the temperature of the atmosphere. However, discrepancies between the measured sound speed and the model calculations were found. Transmitted acoustic waves from the ground were not able to be confirmed from measurement by the PDI. In this paper, we will compare the obtained in-situ data with simulated data of laboratory experiments in vacuum chambers before the flight, composing with model calculations by the MSIS.

Keywords: Sounding rocket, S-310-41, Acoustic wave propagation, Middle and Upper atmosphere