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Infrasonic observations of a rare earthgrazing fireball

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The Earth's atmosphere is continuously bombarded by extraterrestrial objects (generally referred to as meteoroids) of various sizes and velocities (11.2–72.5 km/s). Such high kinetic energy interactions with exponentially increasing higher density atmosphere result in a visual phenomenon known as a meteor. Optically very bright events, or fireballs, are typically produced by objects larger than about 10 cm in diameter. A rare class of fireballs are earthgrazers which enter the atmosphere at an extremely shallow angle. Depending on their size and velocity, some earthgrazers return to space after a relatively short hypersonic flight through the upper regions of the atmosphere. Due to a variety of factors, including the lack of dedicated observational resources, there are only a handful of documented observations of earthgrazing fireballs in the last 50 years. Nevertheless, this category of extraterrestrial objects is of significant interest to the scientific community for a range of practical reasons, such as the analogous relationship with artificial platforms capable of reaching the boundary of the outer atmosphere. In general, typical fireballs are capable of generating shockwaves that can decay to very low frequency acoustic waves, also known as infrasound. Theoretically, the resulting shockwaves and subsequent infrasound from earthgrazers should have distinct signatures. In principle, fireballs can serve as natural laboratories for testing regional and global infrasound monitoring capabilities and provide an important leverage towards improving high-altitude source detection, characterization and geolocation efforts. Infrasound signatures from earthgrazers should further enhance our understanding of infrasonic signals generated in the upper atmopshere. We report infrasound detection of a rare earthgrazing fireball that was observed by casual witnesses and all-sky cameras across Europe on 22 September 2020. It entered at 03:53:40 UTC over northern Europe, and its luminous path extended from Germany to the UK. Despite the high-altitude trajectory (~100 km), the earthgrazer generated a pressure wave that reached the ground at low frequencies detectable by infrasonic instruments. Three infrasound stations of the Royal Netherlands Meteorological Institute (KNMI) network detected the signal. The airwave swept one of the arrays at a particularly high trace velocity (>1 km/s), indicative of a near-vertical arrival angle from a high-altitude cylindrical line source.
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