Investigation of seismic and infrasound waves, generated by an airburst near Qaanaaq, Greenland

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Meteors and impacts constitute a seismic source of high interest in order to perform space weather experiments on planetary bodies. Their location can be observed either directly through observation of the event or through observations of the generated storms or the presence of an impact crater on any given body. These seismic events can provide valuable constraints in order to perform an inversion of the local geophysical environment, the impact point and the speed of the meteoroid. Depending on the size of the object in the impact environment, the possibility of an airburst versus a direct impact can be higher or lower. Given also some additional parameters like the surface of the target, its vicinity to other objects and the distance from the source, the behavior of the impact itself is very important. The presence and its characteristics. A more dense atmosphere at low altitudes causes the shock wave to travel into longer distances and leads to a more efficient seismic coupling with a solid part. On the other hand, the atmospheric pressure decreases as the distance increases from the source, hence the shock wave is weaker. The distance of the meteoroid body relative to the density of the environment can be depicted as a cylinder or a shock wave front. When a meteoroid enters the atmosphere of a planet, traveling with its cosmic, supersonic velocity, there is a shock wave that propagates along its trajectory. In reality, this shock wave has the shape of a cone (Mach cone) of a very small angle (θ) and therefore the shock front can be considered as a cylinder. The generated shock waves are characterized by the high overpressure, which decreases as the same product decreases. In this way, the atmospheric pressure decreases at a rate of the order of the one over the square root of the distance. The overpressure that can be measured in the atmospheric pressure front, decreases, the wave is being converted from a non-linear to a linear (acoustic) wave. The distance and time of the conversion of the nonlinear shockwave into a linear acoustic wave depends on the size of the object and its speed. The Mach number, which is the speed of the object over the ambient sound speed, controls the distance of the nonlinear shockwave propagation, noted as R. On the left the ballistic cone which represents the shock wave is shown as a cylinder of a radius R, whereas on the right the path of the meteoroid is shown, in relation to the position of the observer and the meteoroid trajectory.

Contribution to future missions: The methodology developed in this study can serve the seismic characterization of objects located on or in the planetary bodies in a more detailed way, where airbursts can occur due to the collision of the meteoroid with the ambient atmospheric layer. An ideal example of this case are the icy moons of Saturn, which are known to be formed by tectonic activity on the Saturn’s moon (4). The future Dragonfly mission to Titan will carry a seismometer as part of the D Erina (Drago). The purpose is to detect the shocks and the atmospheric pressures generated by large asteroids or meteors. In addition, the technology to detect the shocks and the atmospheric pressures generated by large asteroids or meteors will be used in the future Dragonfly mission to Titan to characterize the icy moons of Saturn. In addition, the technology to detect the shocks and the atmospheric pressures generated by large asteroids or meteors will be used in the future Dragonfly mission to Titan to characterize the icy moons of Saturn.

The meteoroid generated shockwave propagation

The shock wave generated by the Qaanaaq airburst

On July 25, 2018, a meteoroid-associated airburst occurred near the Qaanaaq town, in Greenland, at approximately 22.00 UTC (2000 local time). The event generated several waves of the waves that were recorded by two stations of the Danish Seismological Network (TULEC and NEEIS) and the bolide trajectory was correspondingly calculated by the NASA Center for Near-Earth Object Studies (CNEOS). The total impact energy calculated by CNEOS was 21 kT of TNT and the bright point on its trajectory corresponds to an altitude of about 45 km at a distance of about 50 km S of the Qaanaaq town. The event is recorded on the TULEC station and the Thule Air Force Base.

Using the NERL/SEP-OG atmospheric model for the given date and time of the event and the properties of the meteoroid trajectory as provided by CNEOS, we compute the overpressure that characterizes the atmospheric pressure wave propagation. The atmospheric pressure wave propagation is being converted into a weakly linear wave in the atmosphere. The overpressure that is being propagated is expected to be recorded and identified in the data, as the arrival of the direct wave should be expected earlier than a total linear wave, generated at the same location and at the same time. In order to interpret the seismic signal and understand the source, in this study we perform a direct analysis of the characteristics of the atmospheric pressure wave propagation. The atmosphere atmosphere wave can be recorded directly by seismometers or by infrasound sensors at the sites available for the examined event. In order to understand the process of the conversion of the highly nonlinear shockwave into a linear one, we can apply a well-known methodology by (6, 7). In this paper, the left theory is applied to the characteristics of the atmospheric pressure wave propagation in order to compute the distance from the shock wave, before its conversion into the linear acoustic wave.