ACOUSTIC EMISSION OF BOOMING SAND

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A booming sand dune manifests itself when an avalanche is initiated from the leeward face of a large dune. The resulting loud, low-frequency booming noise is penetrating and resembles a low-flying propeller airplane. The sound is surprisingly monotone with one dominant audible frequency. It may continue for up to a minute after initiation, even after all visible motion has ceased.

Although many qualitative accounts of this booming phenomenon have been made, there is no accepted scientific explanation yet for the underlying physics. Furthermore, it is still unknown why only certain dunes boom and others with similar characteristics remain silent. Previous theories proposed a relation between the booming frequency and the grain diameter with explanations ranging from arguments based on shearing and dilatation in a slip plane [1] to a fluid mechanical theory based on the existence of slip channels [2]. These theories are difficult to validate as the documented quantitative data on booming dunes compromises only three booming locations [3].

Field research done at Caltech indicates that the dominant frequency ranges from 70 - 105 Hz, depending on the desert location and the time of year. The slip plane and slip channel theories cannot account for the seasonal variations in frequency. Quantitative research done at Caltech at four additional locations in different seasons further invalidates the dependance of booming frequency on grain diameter. In order to find an explanation of this geographical and seasonal variation, an alternative mechanism for the explanation for booming sand is proposed based on a wave-guide analysis. This theory anticipates the existence of a resonant length scale in the order of 2 to 3 meters, based on the measured frequency range and propagation speed in sand (~ 230 m/s). This length scale is consistent with observations made during field measurements using ground penetrating radar, frequency measurements and subsurface soil sampling for water content and particle size. These measurements show that there exists indeed a higher water strata or bedded sub-layer at this depth. Hence, the acoustic characteristics of the wave-guide model appear to be consistent with the field measurements.

Analytic modeling indicates that a coupling exist between the ground waves and the air waves resulting from the booming sound. Although atmospheric acoustic waves are nearly non-dispersive, the dispersion relation indicates that for surface wave modes the frequency does depend on the horizontal angular wavenumber. If the fundamental seismic mode branch crosses the atmospheric mode branches, the eigenfrequencies give rise to enhanced coupling and thus excite strong atmospheric sources. These cross-over points are determined by the density, compression and shear velocity in the sand layer as a function of depth. Changing these three variables, for example because of seasonal variations, will alter the booming frequency.

References

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