MODELING ACOUSTIC-GRAVITY WAVES FROM BOLIDES. D. O. ReVelle[1] , W.N. Edwards[2] and Peter G. Brown[2] , [1]Earth and Environmental Sciences Division, Los Alamos National Laboratory, MS D-401, Los Alamos, New Mexico 87545 USA. (revelle@lanl.gov). [2]Department of Physics and Astronomy, University of Western Ontario, 1151 Richmond Street, London, Ontario, Canada N6A 3K7.

Introduction: We have developed a numerical computer code to model acoustic-gravity waves (with dominant periods from ~3 hr to 0.10 s) produced during bolide entry into the atmosphere. This work is an extension of work presented at Meteoroids2007 [1]. The equations being solved (in Cartesian coordinates) were developed self-consistently to model conditions applicable to the smallest bolides detectable at ground level at close ranges for any source height as well as the largest, deeply penetrating bolides, at ranges up to ~one earth radius from the source.

Source Modeling: Source modeling expressed in terms of the size of the line source blast wave radius is allowed to vary reliably from ~1 m to 40 km. This blast radius is proportional to the square root of the energy deposited by the bolide per unit length of trail divided by the ambient pressure at any height. The fundamental wavelength (at maximum signal amplitude) can be expressed as a constant times the blast wave radius. In this work we make use of our entry modeling capability [2] that links satellite and/or ground-based photometry of the bolide in the near-field to either linear or quasi-linear far-field locations.

Full Wave Theory versus Geometrical Acoustics: The techniques necessary to model these signals can be evaluated using the ratio of twice the square of the vertical thickness of a homogeneous waveguide divided by the disturbance wavelength. If the observed horizontal range is smaller than this critical ratio, the geometrical acoustics regime is evident and wave normal theory can fully describe the directional propagation characteristics. In the opposite extreme, the full wave nature of the signals must be considered. Thus, for progressively smaller blast wave radii, this critical distance scale becomes larger and geometrical acoustics techniques are sufficiently precise to very great distances from the source. Usually the geometrical acoustics solutions of the Eikonal equation in the WJKB limit, are not sufficiently accurate for reliable amplitude modeling (due to inaccuracies in the computed ray-tube areas in media where the environmental properties are only approximately known, and in addition, time-varying). Thus, alternative approaches such as Gaussian beam tracing theory [3] are needed to accurately model the smallest bolides.

Atmospheric Acoustic-Gravity Waves:
Atmospheric waves produced during bolide entry (assuming a Dirac Delta function or a Heaviside step function type impulsive source model) include a) Lamb waves or highly dispersed internal gravity waves with normal dispersion and where the lowest frequencies arrive initially [4,6], b) Weak shock waves at relatively close range [7], c) Inversely dispersed infrasonic acoustical waves with the highest frequencies arriving initially [5] as well as ducted [1,5] acoustical signals propagating between the ground and ~55 km (stratospheric sound channel) or between the ground and ~110 km (thermospheric sound channel). The ducted waves were initially modeled using the predicted near-field, line source, amplitude time series [1], allowing for weakly nonlinear propagation effects, appropriate dispersion as a function of range, etc. For the ducted waves we used exact, ideal waveguide mode theory solutions (in perfectly stratified, steady state, range-independent media). These later solutions predict the possible ducted modes that are allowed for a specified atmospheric sound and horizontal wind speed profile.

Applications and Comparisons with Observations: In this paper we will compare our predictions against the bolides detected at the Elgin Field Observatory (a part of the Southern Ontario Meteor Network, SOMN) operated by the Physics and Astronomy Department of the University of Western Ontario. Over the last 2 years these bolides have been detected with optical video cameras, meteor patrol radar, seismically as well as using infrasonic arrays at an average rate of about 1 bolide/month during the nighttime hours. Photometric masses deduced for this dataset range from ~1 g to >146 kg at heights from 55.6-103 km for entry velocities from ~13 to 73 km/s [8].

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