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Infrasound from the El Paso Super-bolide of October 9, 1997

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ABSTRACT

During the noon hour on October 9, 1997 an extremely bright fireball (~ -21.5 in stellar magnitude putting it into the class of a super-bolide) was observed over western Texas with visual sightings from as far away as Arizona to northern Mexico and even in northern New Mexico over 300 miles away. This event produced tremendously loud sonic boom reports in the El Paso area. It was also detected locally by 4 seismometers which are part of a network of 5 seismic stations operated by the University of Texas at El Paso (UTEP). Subsequent investigations of the data from the six infrasound arrays used by LANL (Los Alamos National Laboratory) and operated for the DOE (Department of Energy) as a part of the CTB (Comprehensive Test Ban) Research and Development program for the IMS (International Monitoring System) showed the presence of an infrasonic signal from the proper direction at the correct time for this super-bolide from two of our six arrays. Both the seismic and infrasound recordings indicated that an explosion occurred in the atmosphere at source heights from 28-30 km, having its epicenter slightly to the northeast of Horizon City, Texas. The signal characteristics, analyzed from ~0.1 to 5.0 Hz, include a total duration of ~ 4 min (at Los Alamos, LA) to > ~ 5 min at Lajitas, Texas, TXAR, another CTB IMS array operated by E. Herrin at Southern Methodist University (SMU) for a source directed from LA toward ~ 171-180 deg and from TXAR of ~ 321-4 deg respectively from true north. The observed signal trace velocities (for the part of the recording with the highest cross-correlation) at LA ranged from 300-360 m/sec with a signal velocity of 0.30 ± 0.03 km/sec, implying a Stratospheric (S Type) ducted path. The dominant signal frequency at LA was from 0.20 to 0.80 Hz, with a peak near 0.3 Hz. These highly correlated signals at LA had a very large, peak to peak, maximum amplitude of 21.0 microbars (2.1 Pa). Our analysis, using several methods that incorporate various observed signal characteristics, total distance traveled, etc., indicates that the super-bolide probably had a source energy in the range between 10-100 tons (TNT equivalent). This is somewhat smaller than the source energy estimate made using US DoD satellite data (USAF news release, June 8, 1998).

Keywords: Infrasound; Meteor Acoustics; Blast Waves, Super-bolides, Long-range Sound Propagation

1. INTRODUCTION AND OVERVIEW

1.1 Large Super-bolide Entry and Ground-Based Detection Infrasonic Detection

Large meteor-fireballs or bolides enter the atmosphere quite frequently with an estimated one dozen bolides whose air-coupled explosive energy exceeds 1 kt (TNT equivalent) entering the atmosphere each year and with about one 15 kt event occurring during the same period as determined by ReVelle (1995, 1997). Ceplecha has coined the term super-bolide for these bodies if they brighter than ~ –20 stellar magnitude or > 10(6) brighter than the minimum meteor-fireball threshold of –5. These flux estimates apply to the relatively dense chondritic bodies, whereas the "real" influx may be factors of 2 or more higher for the weaker cometary materials that do not penetrate the atmosphere very deeply. Typically the source of the waves is not a simple line source hypersonic boom, but can also include point source-like effects as well. Our quoted influx rate is very similar to that reported by optical and infrared satellite monitoring of the atmosphere (Tagliaferri, et. al., 1994). Only the largest bodies whose kinetic energy at entry exceeds about 0.01 tons of TNT are capable of penetrating the atmosphere deeply enough to reach a condition of near-continuum flow with associated blast wave formation and decay and strong shock radiation effects, etc. also being expected. We estimate that about 10,000 to as many as 30,000 bolides of this energy or greater enter the atmosphere globally in a year. Typical shower meteors which reoccur on an annual or semi-annual time-scale have source energies that are ~10(7)-10(8) times too small to be detected infrasonically however and do not penetrate the atmosphere deeply enough to reach continuum flow and thus do not even generate a shock wave during entry.

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DISCLAIMER

As the waves disturbances propagates away from the bolide, it decays in strength and increases its wavelength substantially (ReVelle, 1976). As the leading shock propagates, the low frequency tail oscillates and grows in strength as the front shock dissipates (Pierce et. al. 1973). As the wave propagates downward into air of progressively increasing density, its behavior becomes progressively more linear (ReVelle, 1976) and approaches the ordinary acoustic propagation limit at sufficiently high frequencies and long ranges. For blast wave relaxation radii (see below) $\geq$ 10 m and $\leq \sim$ 10 km (at continuum flow heights based on small Knudsen number and large Mach numbers) whose lower limit is approximately the condition for which there is negligibly small wave absorption for realistic bolide sources proposed in ReVelle (1976), the corresponding wave frequencies are in the infrasonic branch of the acoustic-gravity wave (A/G) regime. Such waves in the near-linear limit can propagate for thousands of kilometers before reaching undetectable amplitudes (ReVelle, 1995, 1997). Sources with still larger blast wave radii have signals observed predominantly in the gravity wave branch of the A/G spectrum, for example the case of the detection of the June 30, 1908 Tunguska (Great Siberian meteor) super-bolide event.

2. INFRASOUND OBSERVATIONS ON OCTOBER 9, 1997

2.1 The Los Alamos Infrasound Arrays

The five Los Alamos research arrays are located at the Nevada Test Site (NTS), at the Pinedale Seismic Research Facility (PSRF), Pinedale, Wyoming (PDL) operated by the Air Force Technical Applications Center (AFTAC), at St. George, Utah (STG), and two separate arrays on LANL property (LA). The first of these Los Alamos arrays is the original research array (using Globe 100-C pressure sensors) mentioned in earlier reports (ReVelle et. al, 1996). The second array is the new, state of the art digital CTB prototype array with a baseline of about 1 km compared to about 150 m for the older, higher frequency system developed earlier for the monitoring of underground nuclear tests. The original array coordinates are as listed in earlier publications (ReVelle et. al., 1996). The new prototype array and the older array at LA are basically collocated however so the earlier coordinates are essentially correct for most source ocation purposes.

2.2 The El Paso super-bolide of October 9, 1997

On October 9, 1997 an extremely bright super-bolide event occurred over western Texas. Most observers did not see the super-bolide directly in flight, but rather heard the extremely loud explosion that also triggered numerous automatic car theft alarms, rattled windows, knocked over small appliances, etc. Being alerted to the event by the very loud noise, many observers suddenly looked up at the clear sky during the noon hour on October 9. They were rewarded with a spectacular view of a dramatic smoke trail that lasted for about 1/2 hr after the explosion. A few observers actually reported being stunned for up to ~1/2 hr by the loudness of the sounds which ranged from either a single or double very loud sonic boom type signal all the way to the description of a repeated, rapid fire type noise without the direct booms (near the terminal point of the super-bolide explosion). In one location, glass windows were actually broken form the blast noise as well which is indeed characteristic of a very large explosion (pressure amplitude in the 4-5 millibar range).

2.3 Infrasonic Detection of the El Paso Super-bolide

We used three fundamental signal detection methods, including maximum cross-correlation of the signal, the f statistic approach and the composite signal power method. We have reported our final results using the standard cross-correlation approach with a value of 0.75 chosen for the minimum detection threshold, cross-correlation coefficient. A summary of results is given in Table 2. We examined the records expecting a source location of nearly constant azimuth since we were so far away from the event (the typical detection situation. Slight variations in signal azimuth were observed for this case however, at both the CTB-IMS arrays at LA and TXAR. The LA research array showed a nearly constant back azimuth of 180 deg. Closer to the source a rapidly changing azimuth and elevation angle are more likely to be expected.

Signals from the 1847 UTC October 9 1997, El Paso super-bolide were found at 2 of our 6 arrays, namely at LA (original research array) and at the LA CTB-IMS array. A summary of data at the CTB-IMS LA array for the frequency range from 0.1 to 5 Hz is given in Table 1. Results for the LA research array are identical except for the back azimuth value as noted above.

Table 1. LANL infrasound for the 1847 UTC El Paso Super-bolide.

Deduced Parameters	CTB IMS Prototype Array: LA
Total signal duration	1 minute (strongest signals)- Total: 4 minutes
Source azimuth	171-180 deg
Range to super-bolide	484 km
Signal trace speed	300 m/s
Signal velocity	0.30 +/- 0.03 km/s; S Type return
Dominant frequency content	0.20-0.80 Hz (0.33)
Maximum cross-correlation, r	0.99
Maximum Signal/Noise Ratio	400
Maximum signal amplitude	21.0 microbars (0.4 Pa)

In Figure 1. below is a plot of the temporal analysis of the signals arriving at the CTB-IMS LA array from the 1847 UTC Texas super-bolide. The very large excursions in the upper panel indicate the arrival of the signal of the super-bolide well above the background noise level with a S/N of about 400.

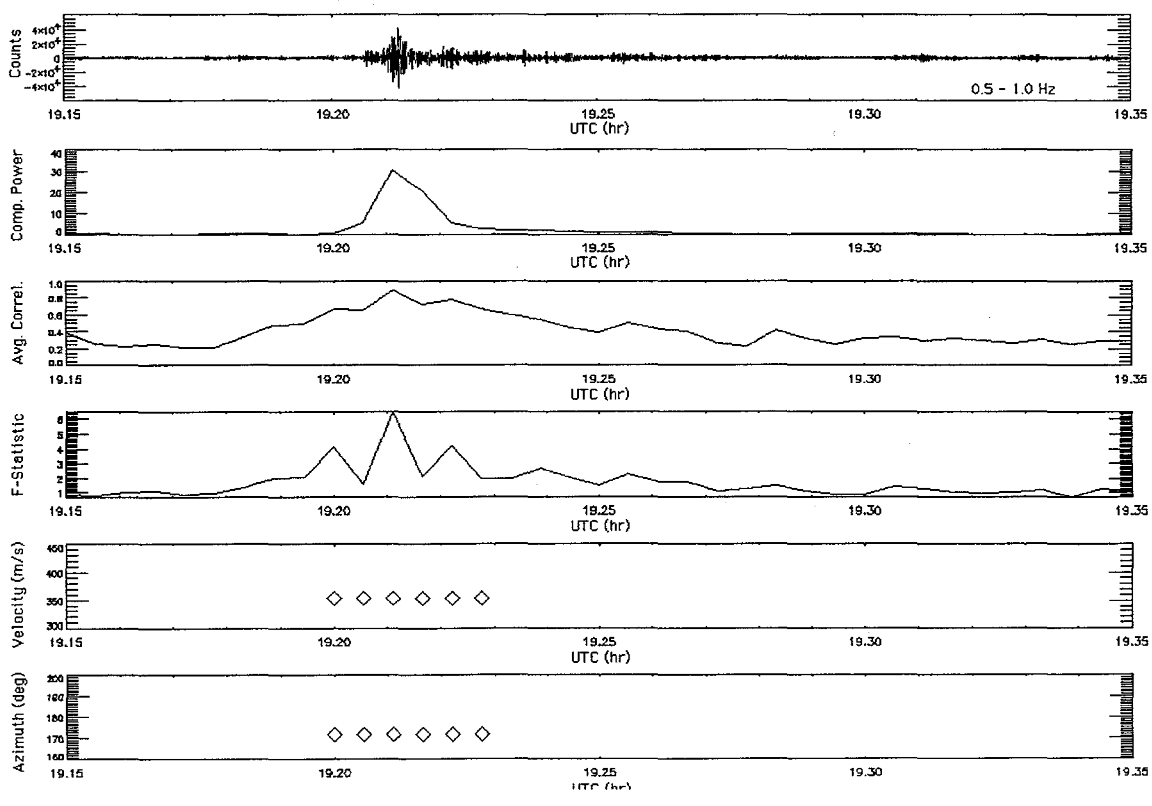

Figure 1. Temporal analysis from 19:15 to 19:35 UTC of the pressure waves arriving (of ~ 4 minute duration) at the LA CTB-IMS array (upper panel) from the 1847 UTC El Paso super-bolide. The respective methods of detection that are presented include composite power, standard beam-forming using the cross-correlation technique and finally using the related f statistic method. In the final two panels the trace velocity and azimuth of the arriving signals are plotted versus time.

2.4 Ancillary Information

A research team consisting of about eight members from Los Alamos National Laboratory (D. O. ReVelle), Sandia National Laboratory (M. Boslough and D. Crawford), from the University of New Mexico and from the University of Western Ontario (P. Brown) as well as from the Geological Survey of Canada (A. Hildebrand) arrived at the scene of the explosion within 2 days of the event. We interviewed numerous individuals form the El Paso area as well as from the nearby military reservations on Ft. Bliss and on Ft. Biggs Army Air Station. Although there were numerous "ordinary" sound reports only a single report of electrophonic sound was obtained which is quite unusual for such a bright fireball. Historically these electrophonic reports have only been received from observers of very bright fireballs, ones which are even brighter than the full moon (Keay, 1992). The general direction of the fireball heading as deduced from ground observers reports was generally from S to N (within +/- 10 degrees). In addition, data were also available this for event from US DoD satellites (E. Tagliaferri, personal communication, 1997, and from a USAF news release, 1998) and these are listed in Table 2. below. Fortunately, a unique altitude could be identified for this case, namely about 28-30 km. As noted earlier, seismic signals were recorded at 4 stations operated in the El Paso area by UTEP (A. Hildebrand, personal communication, 1997). These recordings indicated that an explosion occurred aloft, positioned slightly to the north and east of the town of Horizon City, TX and indicate an explosive source in this height range as well.

Local temperature and wind speed/direction data taken some seven hours before the super-bolide entry by the National Weather Service and archived at the National Climatic Data Center in Asheville, north Carolina up to altitudes of ~ 33 km from the El Paso rawinsonde site at Santa Theresa are plotted in Figures 2, 3 and 4. These environmental data are essential for the recovery of meteorites, especially small samples (< ~100 g) because they clearly show the northeasterly drift of the particles that would be expected following the explosive detonation near the end of the luminous flight of this super-bolide. In addition, these data are essential to understanding the possible infrasonic ray path arrivals as will be discussed below.

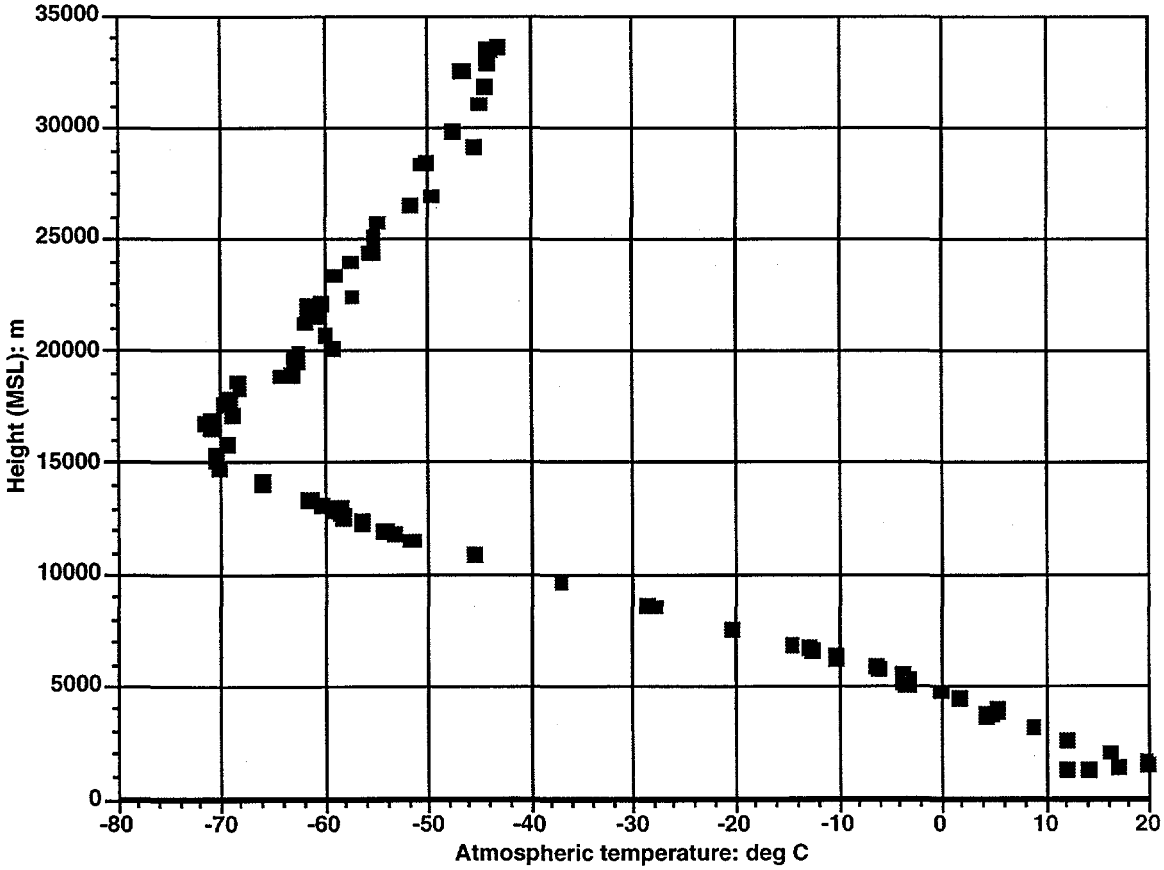

Figure 2. Vertical temperature profile: El Paso, 11 UTC, October 9, 1997

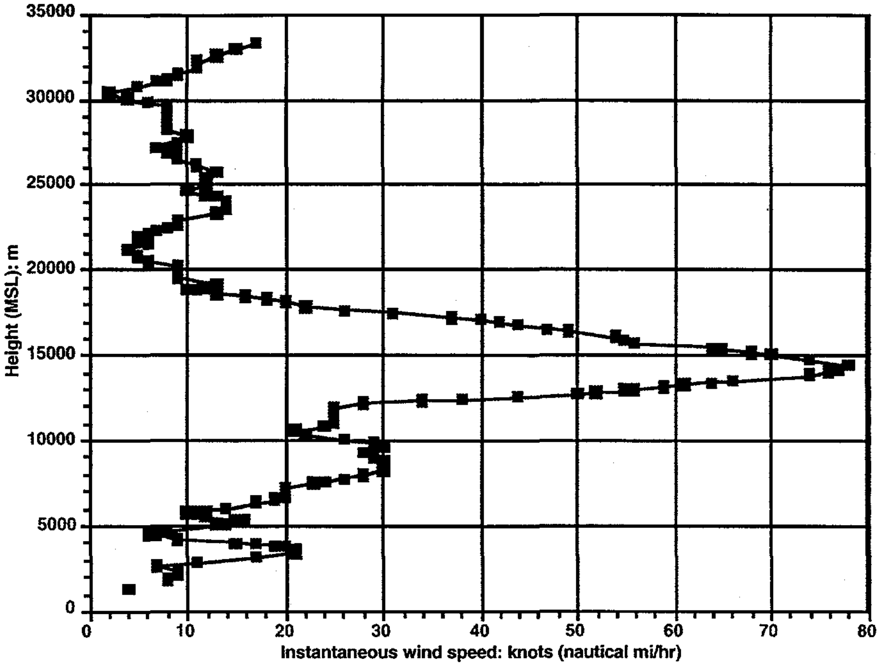

Figure 3. Vertical Profile: Horizontal wind speed- El Paso, 11 UTC, 10/09/1997.

The general synoptic scale weather at the time of the event can be summarized on the basis of forecast charts at the surface and in the upper air near the Tropopause. A synoptic scale frontal passage occurred at the surface shortly after the super-bolide entry. Surface data clearly show the presence of a strong, near-surface wind shift from SW to NW after the frontal passage. The front was quite strong at this time of the year with an associated surface low pressure in far western Ontario, Canada near the Saskatchewan border with a strong cold front extending from the surface low in an arc as far south and west as southern Arizona. Quite heavy precipitation was falling in the warmer air out in advance of the cold front in eastern Texas and northward through Arkansas, Illinois and in Michigan at 12 UTC on October 9. By 00 UTC on October 10, the cold front had become quasi-stationary and had advanced into central Texas and quite heavy precipitation was falling even in the cold air behind the surface front with some of it not very far from the El Paso area. A quite strong double-barreled surface high pressure system followed in the wake of the advancing frontal system. Infrared photos taken at the time of the these two soundings also showed extensive regions of quite thick clouds along the advancing frontal boundary which moved westward and intensified as the day progressed. In the upper air from 850 mb to the 300 mb level winds were generally westward switching to southwesterly aloft during the time of the frontal passage and after its passage. The polar frontal boundary could readily be seen aloft in association with the passage of the surface front and readily explains its quite strong characteristics as well. The 850 mb winds were generally much weaker than those further aloft however. Thus, wind effects aloft could have clearly influenced the local propagation of acoustic signals from this super-bolide. Thus, a combination of asymmetric source effects and propagation asymmetries due to winds combined to produce a highly variable acoustic signal surrounding the super-bolide detonation height as briefly discussed above.

Table 2.
Summary of Ancillary Observations of the El Paso Super-bolide:
US DoD Satellite data (E. Tagliaferri, personal communication, 1997)

Key Parameters:	Values:
Date and Time	1847:15 UTC, October 9, 1997
Latitude	31.8 N
Longitude	106.1 W
Assumed source altitude range	28-31 km: 28.5 km assigned

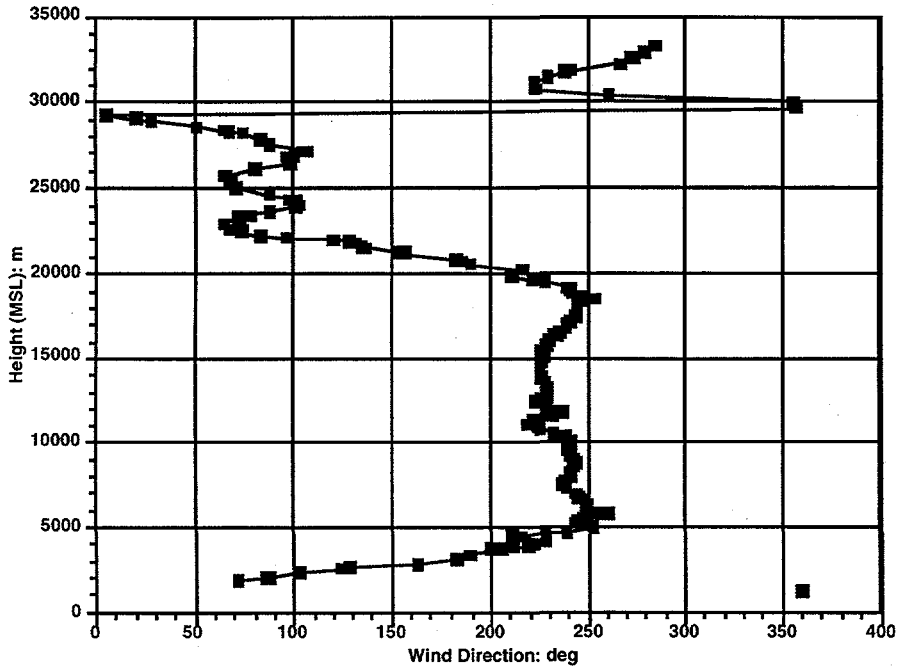

Figure 4. Vertical profile: Horizontal wind direction- El Paso, 11 UTC, 10/09/1997.

3.0 INTERPRETATIONS OF THE INFRASOUND DATA

3.1 Source Location

From our infrasonic bearings we have also determined that Horizon City, Texas is very near to the site of a major explosion along the fireball trajectory. We can not explicitly determine the source altitude of the infrasonic signals without detailed ray tracing efforts, but the time delay of the arrival of the infrasound is consistent with a waveguide ducting in the sound channel between the ground and about 50 km altitude, similar to what was observed for the November 21, 1995 Colorado Fireball (ReVelle and Whitaker, 1996b). The source location of the El Paso super-bolide is indicated in Figure 5. The position of the super-bolide detonation was determined from seismic intersecting bearings from 4 stations, from our infrasonic intersecting bearings from three distant arrays and from U.S. DoD satellite data. The latter data given in Table 2. was kindly provided to us by Dr. Edward Tagliaferri of E.T. Space Systems, Inc., of Los Angeles, California (personal communication, 1997). Note that the intersection of the bearings (back azimuth) from two of our infrasonic arrays occurs within a few km of Horizon City, Texas and very near to the location of the intersection of the bearings from 4 seismometers operated by UTEP and by the seismic and acoustic arrays in Lajitas, Texas (CTB-IMS Station, TXAR) operated by SMU.

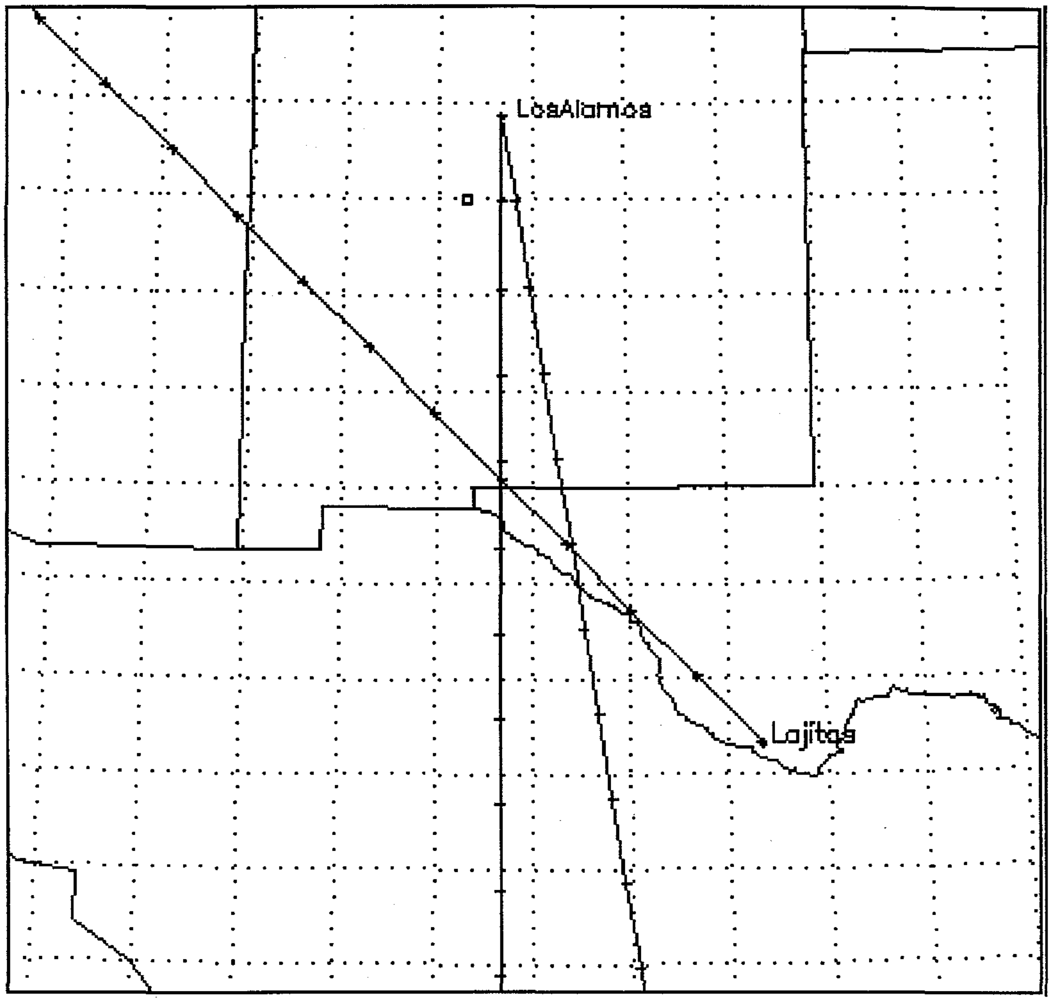

Figure 5. Map of the intersection of the infrasonic bearings (at maximum correlation) from the LA and TXAR infrasonic arrays for the 1847 UTC El Paso super-bolide. The intersection occurs to the north and east of the town of Horizon City, Texas and near the location of the intersecting bearings from 4 seismographs operated by the University of Texas at El Paso. In this figure we have plotted the full band of azimuths deduced at LA, but only the single mean back azimuth (321 deg) deduced from TXAR. The source location deduced from US DoD satellites in Table 2. is quite close to all of these intersecting bearings as well.

In our ray theory calculations discussed below, we have used the detailed temperature and wind data in Figures 2.-4. (at 11 UTC, about 7 hrs before the bolide entry) in order to compute the possible arrivals at Los Alamos from a super-bolide source 400+ km to the south of LA and slightly north and east of El Paso at an elevation of 28.5 km. We have also used source altitudes as high as 35 km in our ray tracing efforts and have found that such height values will not change our deduced conclusions below. Above 30 km we have used the standard, White Sands Missile Range monthly mean, temperature and wind profiles for the month of October (given in McCullough and Novlan, 1977), since White Sands is located so close to El Paso.

Using ray tracing techniques, we have also been able to further understand the origin of some of our infrasonic signals from the El Paso super-bolide. These results are given in Figure 6. below. There are still significant problems however in understanding these signals using the range-independent ray tracing model that we currently utilize. The strong Polar jet stream winds near the Tropopause (peak magnitude of 40 m/s with a significant southwesterly flow direction, i.e., with nearly equal zonal and meridional wind components) provided a very large shear aloft such that only the steepest rays could successfully penetrate this wind speed barrier. The results clearly show a strong duct between ~18 km and ~45 km altitude which is produced by the combination of the presence of these strong jet stream winds and by the height of the source itself. Farther to the north on this date, the Polar jet was much weaker however. Thus, this is a clear case of range-dependent signal propagation that needs to be examined more closely for the CTB-IMS network. For these more northerly and weaker winds at the Tropopause, far more rays would be able to reach the ground and thus could be used to help explain our observed arrivals at LA. In addition, our results clearly show returns from the lower Thermosphere (Th type phase) at the correct horizontal range that are also evident in our analysis of the observed wave arrivals below as well. Additional rays in Figure 6. were also found to penetrate quite close, i.e., within 2-4 km of the ground, but do not intersect the surface. Through diffraction and scattering processes however, which are not considered in conventional ray theory, significant wave energy is likely to reach the ground in any event.

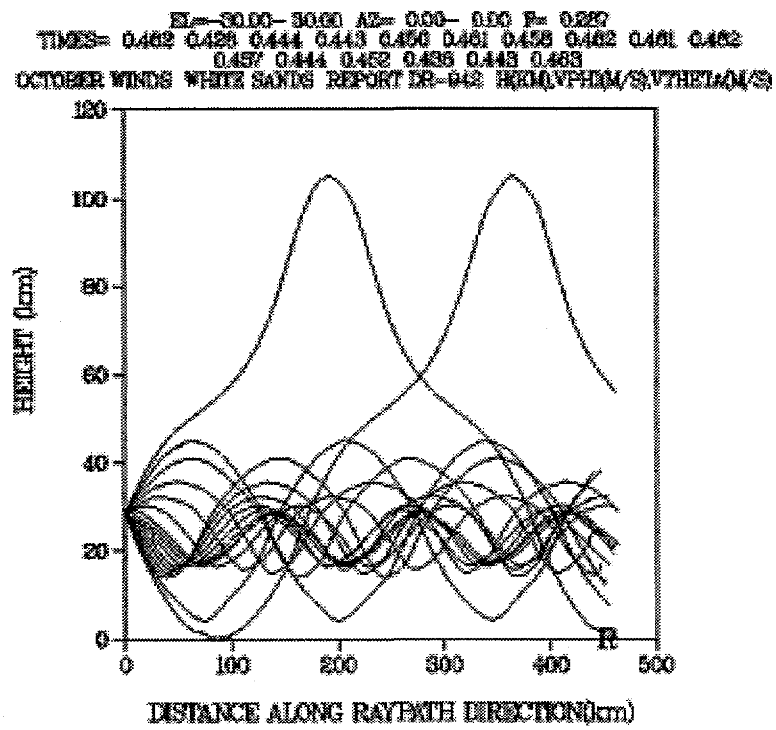

Figure 6. Plane-view of height versus downrange distance for rays from a point source explosion at 28.5 km altitude launched to the north toward LA, for the October 9, 1997 El Paso super-bolide.

From our standard analysis of the observed infrasound signals from the El Paso super-bolide we can also readily identify four distinct arrival phases (groupings) of the signals at LA. These are listed in Table 3. below.

Table 3.
Summary of infrasonic signals arriving at LA from the El Paso super-bolide of October 9, 1997.

Arrival ID	Signal velocity: km/s	Elevation Arrival Angle: deg	Characteristic (Trace) Velocity	Infrasonic Phase Identification
Arrival A	0.320	14	0.340	T Type
Arrival B	0.299	25	0.364	S Type
Arrival C	0.260	35	0.405	Th Type
Arrival D	0.242	43	0.450	Th Type

In Table 3, we have used the phase type designations of S, Th, etc. from earlier work (ReVelle and Whitaker, 1996c). with the original Type I designation having been changed toTh. Note the observed and expected behavior of progressively decreasing signal velocities combined with concomitant increases of both the elevation arrival angle and of the trace velocity across the array as the discrete acoustic phases progress from arrivals A through D. Using our current ray tracing efforts, we have only been able to confirm the C and D type arrivals directly however. The use of a ray tracing model with full-range dependence in the future will hopefully allow us to further understand this discrepancy between observations and ray theory.

3.2 Source Energy Estimates

Using the approaches discussed in ReVelle (1976), ReVelle, Whitaker and Armstrong (1997) and in ReVelle and Whitaker (1996a, 1996b, 1996c), we can also make estimates of the super-bolide source energy. The five approaches used are:

POINT source approaches (near-surface explosions assumed):

1) **Acoustic efficiency approach** (Cox, 1958; ReVelle and Whitaker, 1996a).
2) **Period at maximum amplitude approach** (ReVelle, 1995; 1997- Empirical AFTAC approach).
3) **Empirical, explosive yield, wind-corrected amplitude method** (Mutschlecner and Whitaker, 1990)

LINE source approaches:

4) **Line source weak shock wave model** (ReVelle, 1976): Only observed wave period utilized.
5) **Line source, weak shock wave model** (ReVelle, 1976; ReVelle, Whitaker and Armstrong, 1997): Both observed wave amplitude and period utilized.

A summary of all of our results for source energy estimates for the El Paso super-bolide is given in Table 4 below. For all methods we have used an observed amplitude (peak to peak) of 21 μbars and an observed, acoustic ducted wave period at maximum signal amplitude of 3.33 s (assuming S type ducting) at an estimated horizontal range of 440 km and an estimated total slant range of 484 km. In addition, in point source method 1), ground reflection factors from 0.7-0.9 were used and the acoustic efficiency was assigned to be 1% based on the work of ReVelle and Whitaker (1996a). For example, for a 10X reduction in the acoustic efficiency, our corresponding source energy estimate will increase 10 times. This small a value of the acoustic efficiency seems unlikely, but is certainly possible (ReVelle and Whitaker, 1996a). Also in the results for line sources using methods 4) and 5), we have assumed a source speed of 11.2 km/s, a chondritic bulk density (3.7 g/cc) for a spherical, stony body of unchanging shape. Our combined source energy estimates using all of these methods, ranges from ~1 t - 2.3 kt.

We would like to be able to reduce the spread of possible values of these source energy estimates further, but without more precise velocity measurements, etc., it isn't possible to do so. Clearly, methods assuming a near-surface source (or empirical correlation based solely on surface or near-surface shots) are more suspect, as are methods based on amplitude alone, but these relations were not devised for this purpose in all fairness. The most reliable expressions for super-bolides should be the AFTAC empirical approach (assuming that the stationary, point source geometry is applicable) and the line source methods, which unfortunately are very sensitive to source altitude (method 5)). Thus, the spread of energy values using only these better suited source energy estimation methods, is reduced to a factor of ~10-100 (using methods 2, 4 and 5). Given all these factors, we feel the most consistent source energy estimate is between ~10 and 100 tons (TNT equivalent).

Table 4. Summary of Source Energy Estimates for the El Paso Super-bolide: 10/09/1997, 0847 UTC

Approach Used:	Los Alamos Data: Source Energy: t TNT equivalent	
1) Acoustic efficiency: 1 % used: <Cs>= 340 m/s (near ground level)	Ground reflection= 0.9 = 3.24 t	Ground reflection= 0.7 = 11.72 t
1) Acoustic efficiency: 1 % used: <Cs> = 315 m/s (near ground level)	Ground reflection= 0.9 = 3.50 t	Ground reflection= 0.7 = 10.86 t
5) Weak shock line source: Wave period and amplitude used. Source height = 30 km <Cs> = 315 m/s (Height averaged)	= 0.615 t Predicted N wave period= 0.735 s Ro= 9.84 m, Super-bolide radius= 0.138 m Super-bolide mass= 41.05 kg	
5) Weak shock line source: Wave period and amplitude used. Source height = 40 km <Cs> = 315 m/s (Height averaged)	= 10.71 t Predicted N wave period= 1.501 s Ro= 25.5 m, Super-bolide radius= 0.359 m Super-bolide mass= 714.7 kg	
3) Empirical yield-amplitude	= 2,303 t (2.303 kt)	
2) Period at maximum amplitude (AFTAC empirical relationship)	= 291.6 t	
4) Weak shock line source: Wave period only <Cs>= 315 m/s (Height averaged)	= 520.6 t Ro= 73.9 m; Super-bolide radius= 1.04 m Predicted wave period = 3.33 s	

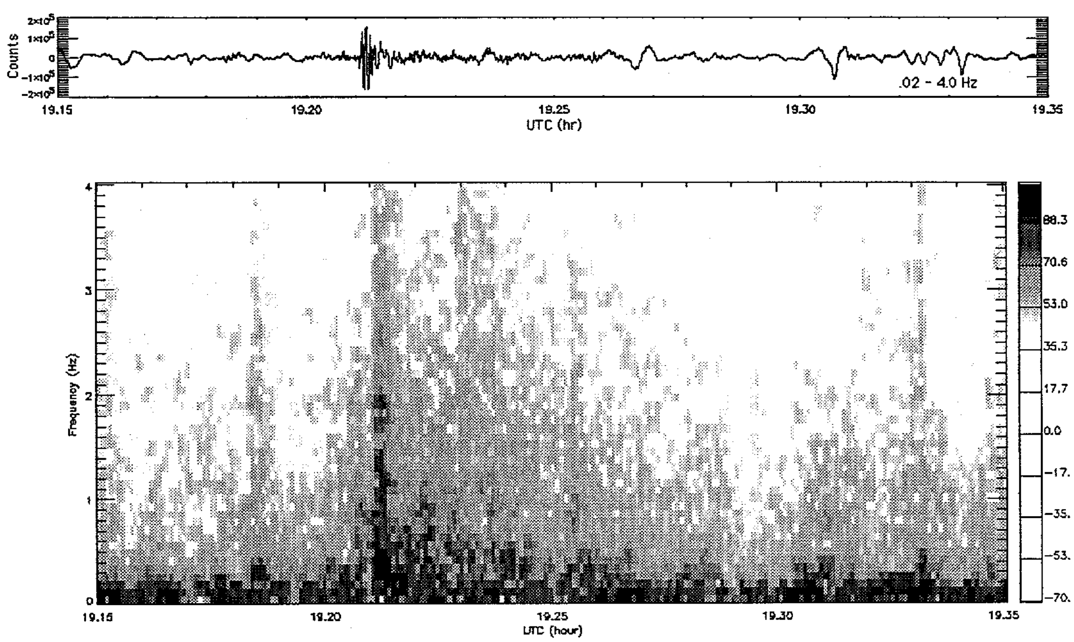

Figure 7. Single channel infrasonic signals and the corresponding spectrograms of the waves from the 1847 UTC, October 9, 1997 El Paso super-bolide as recorded at the CTB-IMS LA array from 19:15 to 19:35 UTC and the corresponding spectrogram computed for this array (lower panel).

In Figure 7. we have also plotted a spectrogram of the signals from the 1847 UTC El Paso super-bolide. This was done using standard digital FFT methods. In the upper panel is a composite signal arriving at LA from the super-bolide and in the lower panel the corresponding spectrogram (wave frequency versus time) is plotted.

4.0. SUMMARY AND CONCLUSIONS

4.1 Large Super-bolide, Near Earth Object (NEO) Influx Rate

On the basis of the AFTAC relationship, we feel that an upper limit to the "true" source energy of the El Paso super-bolide is equivalent to that of a near-surface explosion of 292 tons of TNT being instantaneously released. Thus, we should expect that on the average about 17.6 events of similar or of greater energy should be observed over the entire surface of the Earth in a period of 1 year (ReVelle, 1995; 1997). Over an observing region of 1000 km in radius from the event, we should only expect about 0.108 super-bolides/year of similar or greater energy or an event of this magnitude being possible once, on the average, every 9.22 years. Thus, taken on this basis, events of this magnitude occur relatively rarely. This calculation assumes that the El Paso super-bolide was chondritic in origin, i.e. of relatively strong stony composition.

4.2 Infrasound Detection of Large Super-bolides

The combination of using infrasound, satellite observations in various spectral regimes, seismic techniques and the possible recovery of fallen meteorites, etc. are very promising tools for the study of solar system debris and their rate of impact on the atmosphere. A very recent example of a near-by meteorite fall is that in Monahans, Texas, where on the night of March 22, 1998 at about 7:45 CST, two small pieces of relatively weak meteorites fell within ~ 10 m of children playing outdoors. These pieces have subsequently been confirmed to be of meteoritic origin (personal communication with M. Boslough, Sandia National Laboratory, Albuquerque, 1998). An infrasonic detection of this event was made in Lajitas, TX at the TXAR, array (personal communication with Professor B. Stump, SMU, 1998). We are also still searching our records for signals as well, but this event seems to have been quite small even though audible explosive sounds were reported by local residents at distances of about 50 miles from Monahans. As demonstrated in Table 5, more work is clearly needed to accurately estimate super-bolide source energy reliably under all circumstances. This could include point source modeling using normal mode type analyses, etc. and also super-bolide source modeling efforts (modified line source effects, etc.) as well. Our detection of the October 9, 1997 El Paso super-bolide- similar to our earlier case studies for the November 21, 1995 Colorado super-bolide and for the October 4, 1996 California super-bolide, were improved by incorporating data from three infrasonic arrays at great range- can be used to help in modeling of the expected false alarm rate for bolides and for super-bolides for the operational phase of the CTB-IMS network.

ACKNOWLEDGMENTS

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