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Author(s): Douglas O. ReVelle
Sergey N. Kulichkov

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On Lamb Wave Propagation From Small Surface Explosions in the Atmospheric Boundary Layer.

Douglas O.ReVelle[1], Sergey N.Kulichkov[2]

[1]Atmospheric and Climate Sciences Group Los Alamos National Laboratory
[2] A.M.Obukhov Institute of Atmospheric Physics Russian Academy of Sciences,
3 Pyzevsky,Moscow 109017,Russia, Tel: 7(095) 953-4876; Fax: 7(095) 953-1652.,
e-mail: snk@omega.ifaran.ru; root@iaph.msk.su

1.Abstract
The problem of Lamb waves propagation from small explosions in the atmospheric boundary layer are discussed. The results of Lamb waves registrations from surface explosions with yields varied from 3 tons up to a few hundred tons (TNT equivalent) are presented . The source-receiver distances varied from 20 km up to 310 km. The most of the explosions were conducted during the evening and early morning hours when strong near-surface temperature and wind inversions existed. The corresponding profiles of effective sound velocity are presented.
Some of the explosions had been realized with 15 minutes intervals between them when morning inversion being destroyed. Corresponding transformation of Lamb waves was observed.
The Korteveg-de Vrize equation to explain experimental data on Lamb waves propagation along earth surface is used.

2. Introduction and Overview
It's well known that the principal energy-bearing mode in the theory of the earth atmosphere oscillation is fundamental mode representing passage of the acoustic-gravity wave along the surface, constituting an analog of the two-dimensional Lamb wave for real atmospheric stratification. The general theory of lamb wave propagation in the atmosphere had been developed in Garent (1969), Pierce and Posey (1971), ReVelle and Whitaker (1996), Kulichkov (1987). The dispersion law for the fundamental mode (zero-order normal wave) has the form

$$k(\omega) = \omega/c\ (1+ \alpha\, \omega^2 + O(\varepsilon^3)\ );\ \alpha = S\ (qH)^{1/2}/c^{1/2}\ ;q= [\ (c^2(H)- c^2(0))\ /\ c^2(0)] \qquad (1)$$

ω - angular frequency; k - wave number; c - effective sound velocity.
To develop (1) it had been supposed that vertical wave number is small quantity of the order of ε, compared with the horizontal wave number (Pierce and Posey,1971). The dispersion law (1) coincides with the well known dispersion law for waves described by the linear Korteweg-de Vries equation.

Lamb waves with wavelengths of several hundred kilometers propagating over super long distances in the atmosphere equivalent to several passages around the earth have been observed after volcanic eruptions or large nuclear explosions. In these cases the values of c and α in (1) characterize irregularities of stratification of temperature (sound velocity) and wind velocity averaged through whole atmosphere and along all wave trajectory in the atmosphere (Garent,1969; Pierce and Posey ,1971).

3.Lamb waves from small surface explosions
Infrasound wave lengths from small surface explosions are order of dozens and several hundreds of meters that corresponds to vertical scales of temperature and wind irregularities in the atmospheric boundary layer. In this case fundamental mode is effective generated in the surface waveguide formed by inversion of temperature and wind velocity when (Chunchuzov,1986)

$$t_0 = 2\ q^{1/2}\ k\ H < 1$$

$$f_1 = 3/16[c/(q^{1/2}H)] > f_0 \qquad (2)$$

H - vertical scale of the surface inversion; f_1 -first characteristic frequency of the waveguide;
f_0 - central frequency of the spectrum of the initial acoustic pulse near explosion.

The existence of a general dispersion law (1) leads to general propagation laws for infrasonic perturbation independently of the stratification profile of the surface wave-guide.

According to (1) the profile of infrasound packet recorded at a distance r from surface explosion is described in terms of Airy's function that leads to a specific relationship between the quantities $T_{1,2}$ and $T_{2,3}$ that are , respectively the intervals between the first and second and the second and third maxima in the signal (Pierce and Posey,1971). At the distances $r > L_d = 2(c\, t_0)^3/(qH)^2$ these values equal to

$$T_{1,2} \sim 4t; \quad T_{2,3} \sim 2.6\, t; \quad T_{1,2} / T_{2,3} \sim 1.53$$

$$t = [\, 1.5\, (qH)^2 r / c^3]^{1/3}; \quad T_0/t \ll 1 \qquad (3)$$

4. Experiments

Samples of the infrasound records corresponded to Lamb and tropospheric waves propagation from surface small energy explosions are presented in fig.1-2. Samples of corresponded profiles of the effective sound velocities are also presented in fig.1 for some of experiments. The curves 4-5 in fig.1 corresponds to results of comparison between experimental records of Lamb wave at the distance of 45 km from surface explosion with yield of 260 ton and theoretical record obtained according to Korteweg-de Vries equation (Chunchuzov,1986).

In this case $f_0 \sim 0.77$ *Hz*; $q \sim 1.6\times10^{-2}$; $H = 150$ *m*; $t_0 \sim 0.5$; $t_1 \sim 2.2$ *Hz*; $T_0/t \sim 1.35$.

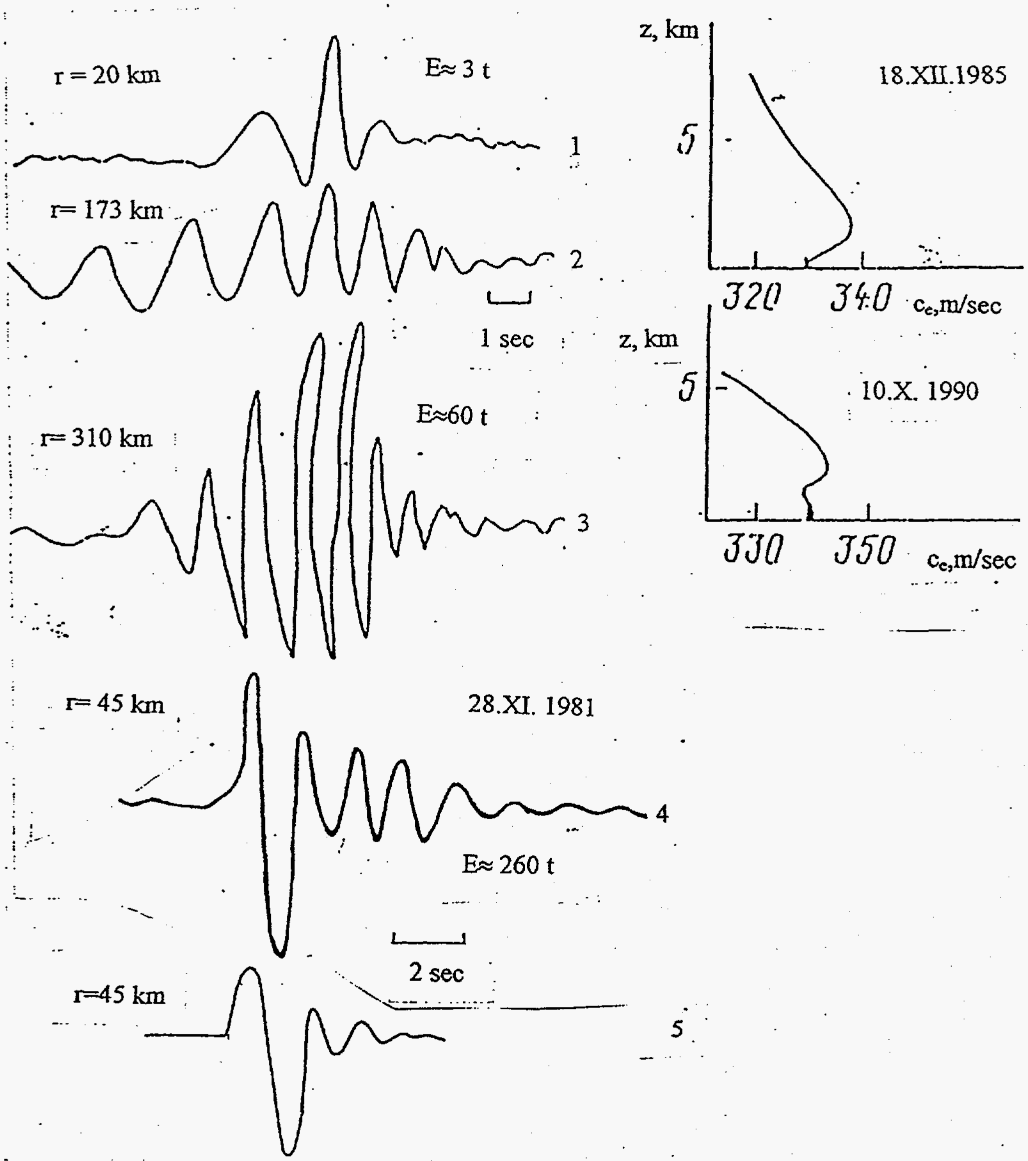

Figure 1. Samples of Lamb waves from surface explosions (1-4). Theoretical curve obtained using Korteweg-de Vries equation (5).

One can see the satisfactory correlation between experimental and theoretical curves in fig.1.
Samples of Lamb and tropospheric waves from surface explosions with yields of around 60 ton in April 1991 are presented in fig.2.

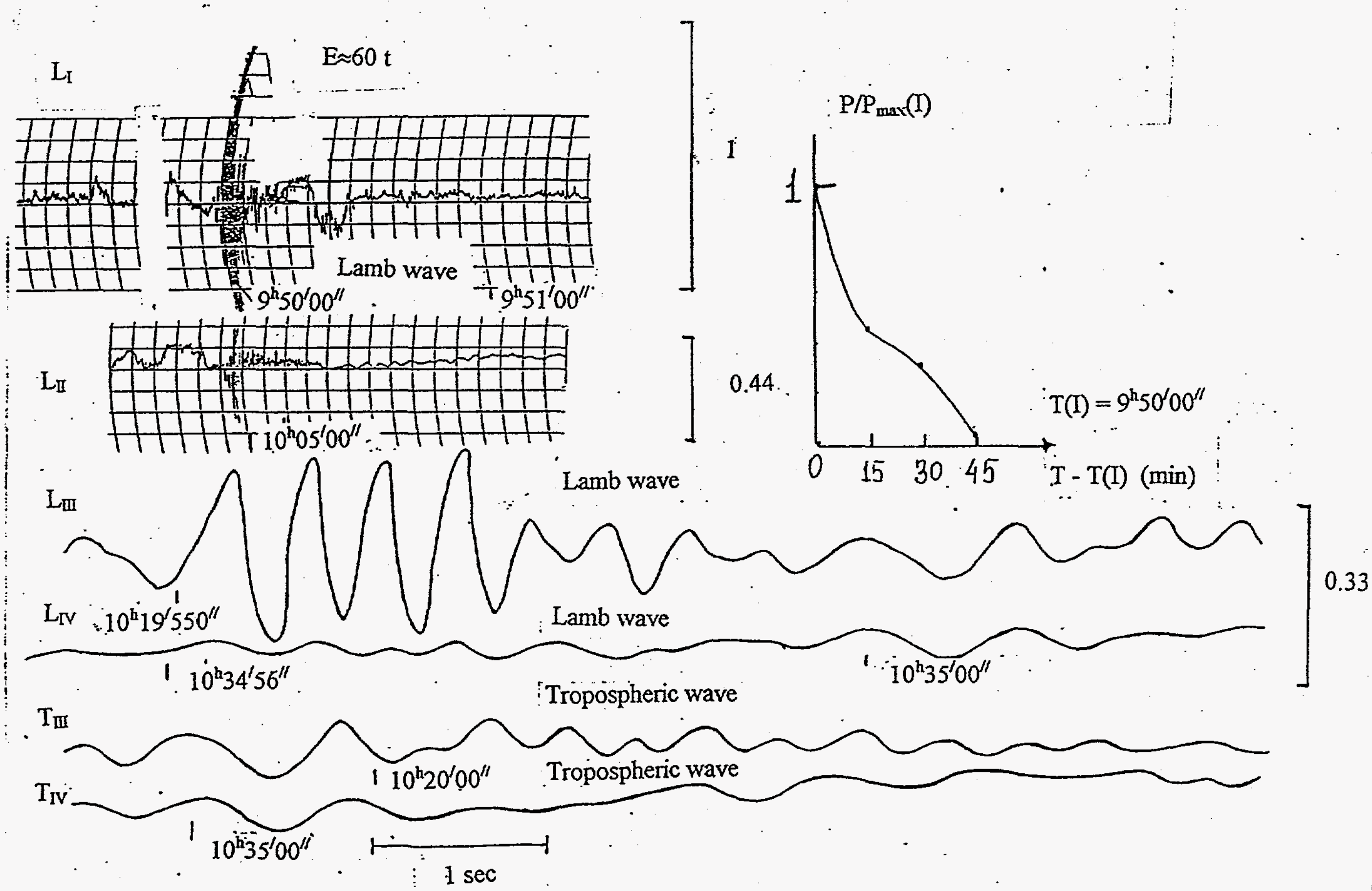

Figure 2. Samples of Lamb and tropospheric waves from surface explosions with yields of around 60 ton realized in April 1991 with 15 min interval between them.

The explosions were all conducted during the early morning hours when strong near-surface temperature inversion (below 250 m) existed. Shots were fired at 15 minute intervals at nearly identical source yields. One can see transformation of Lamb waves when near-surface temperature inversion being destroyed. But the tropospheric waves were stable in this case.

5.References

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