O1.1-133

Model of atmospheric gravity wave perturbations and their effect on localization of infrasound field and its sources

Igor Chunchuzov[1], Sergey Kulichkov[1], Oleg Popov[1], Vitaly Perepelkin[1]

A.M. Obukhov Institute of Atmospheric Physics,
119017 Moscow, 3 Pyzhevsky Per., Russia

8 September 2025

Abstract

The influence of anisotropic wind velocity and temperature inhomogeneities on the attenuation of infrasound field intensity with increasing distance from a point source and its altitude distribution is studied. The field is calculated as a function of receiver height and horizontal distance from the source using method of the pseudo-differential parabolic equation for the atmosphere with model realizations of anisotropic effective sound speed fluctuations. These realizations are obtained from the nonlinear shaping model for the gravity wave perturbations which produces the fluctuations with both the vertical and horizontal spectra consistent with the observed spectra. When propagating in the stratospheric and thermospheric wave guides the multiple scattering of infrasound field from the anisotropic fluctuations results in certain vertical wave number spectra of infrasound intensity fluctuations in the stratospheric (altitudes 30-40 km) and mesospheric layers (50-70 km). The statistical characteristics of the intensity fluctuations as a function of distance from the source (up to 2200 km) were studied.

This work was supported by Russian Science Foundation (RSF), grant №25-17-00060.

Chunchuzov I. and S. Kulichkov. Infrasound propagation in an anisotropic fluctuating atmosphere. Cambridge Scolar Publishing, 2020 (Section 4)

Vertical wave number spectra

of the horizontal velocity fluctuations

$$V(k_z) = \beta_0 N^2 k_z^{-3}, \qquad k_z^* << k_z < k_w$$

of the relative temperature fluctuations

$$F_T(k_z) = \beta_0 N^4 g^{-2} k_z^{-3} \qquad \beta_0 \sim 0.2$$

,*N* is BV-frequency

Horizontal wave number spectrum

e_0

of the horizontal velocity fluctuations [Chunchuzov et al. J. Atm. Sci.,v.81(1), 2024; Pure and Applied Geophysics, v.182(1), 2024]

$$\tilde{V}_{E,\perp}(k_x) = 4e_0\beta_0 N^2 k_x^{-3}, \qquad k_x >> k_x^* = 2\sqrt{e_0}\,k_z^*$$

$$l_x / l_z = 1/\sqrt{4e_0} \sim \chi / M \quad >>1$$

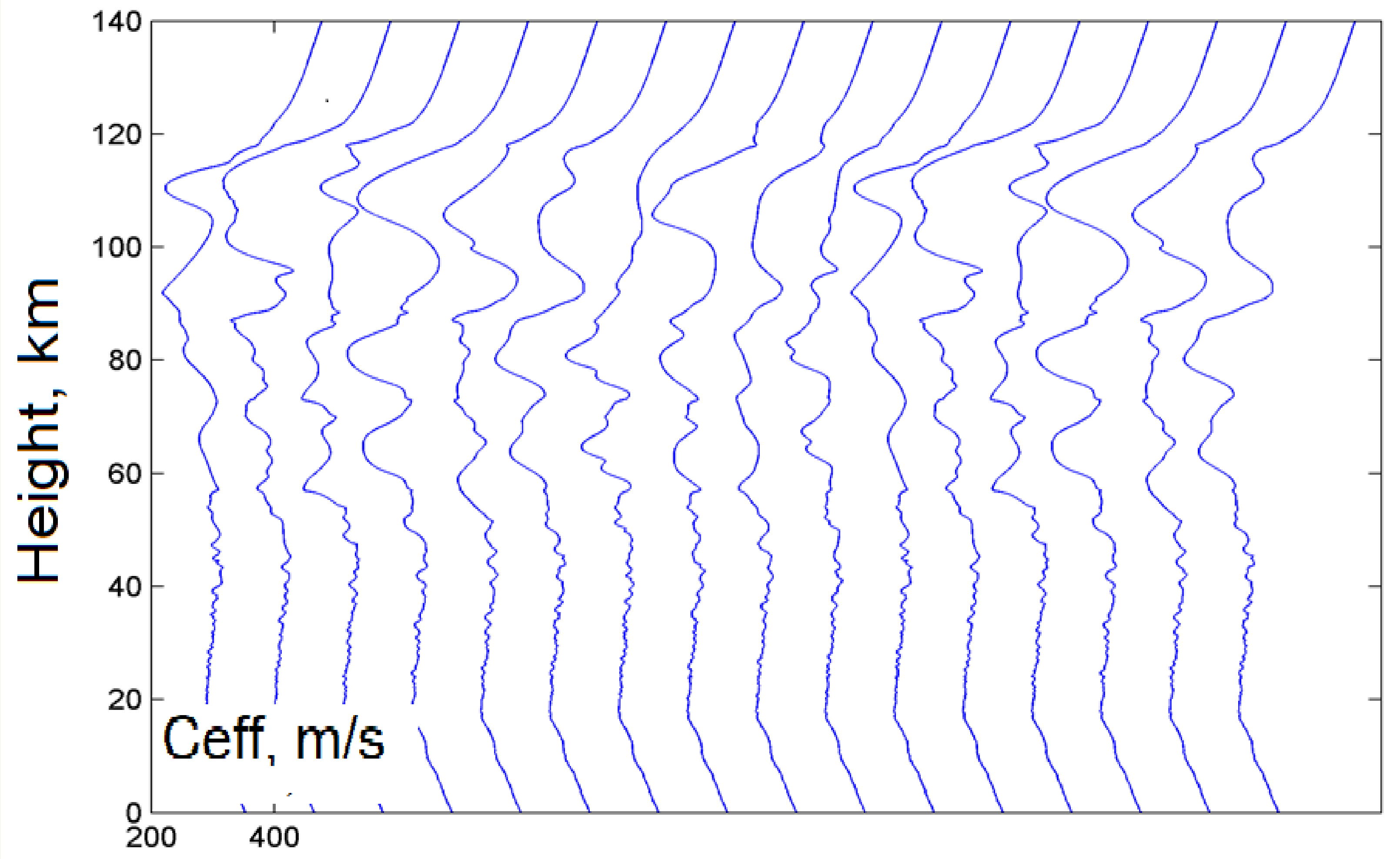
Is the ratio of horizontal-to-vertical scales of anisotropic inhomogeneities, e_0 is anisotropy,

$M =$ 0.35-0.4 parameter of nonlinearity of wave field

Main parameters of the spectra $N, \quad f, \quad \sigma, \quad \chi = \sigma / \sigma_w$

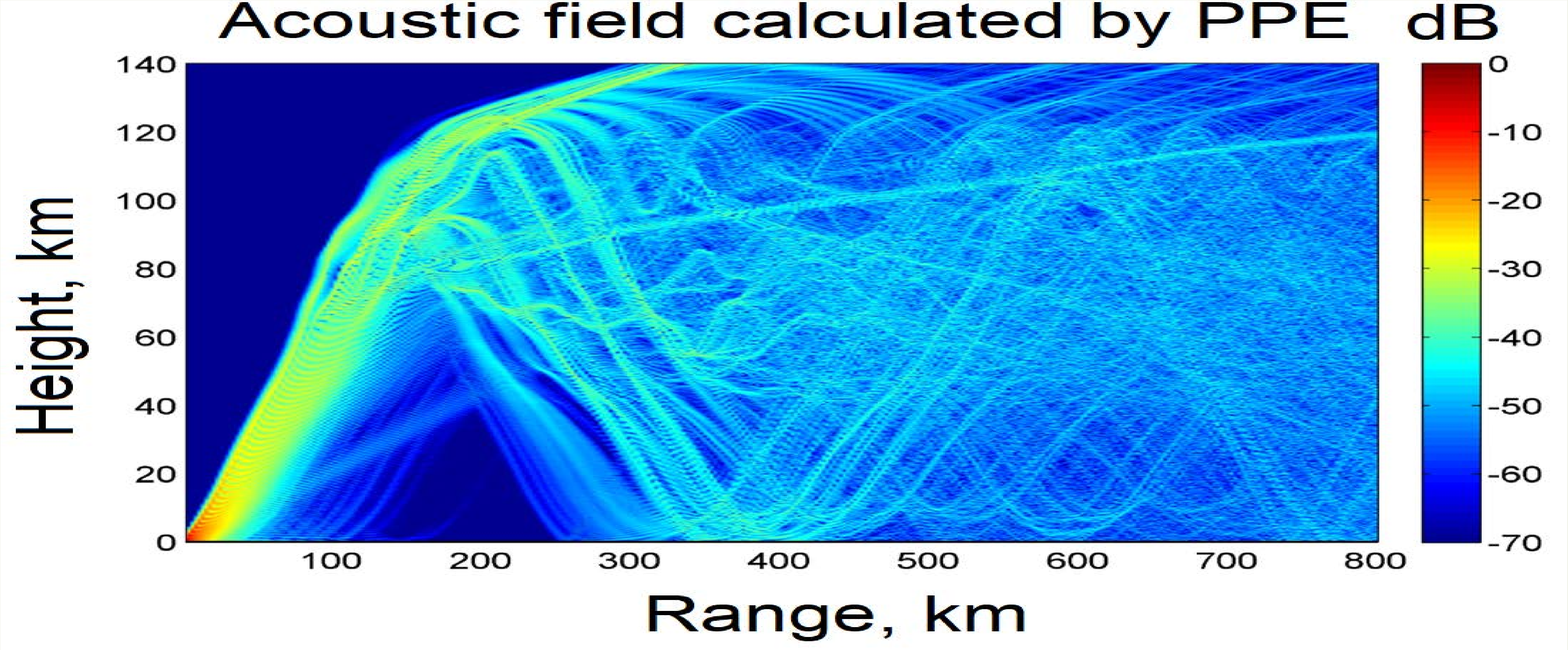
Vertical Ceff-profiles with a step of 28 km taken from the model

Vertical Ceff-profiles taken with a horizontal step of 28 km from the model of gravity wave perturbations



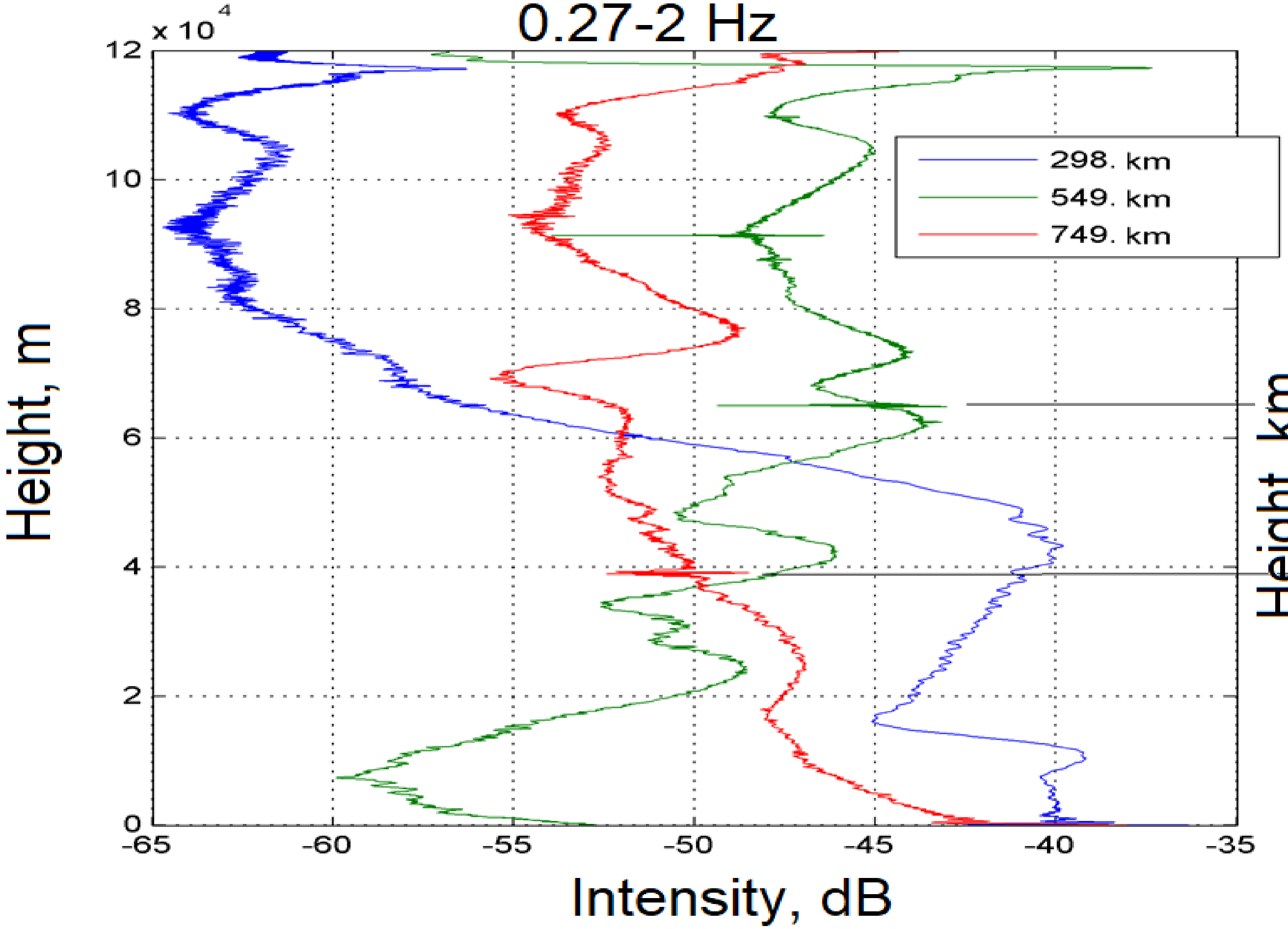
[Chunchuzov I.P.. On the nonlinear shaping mechanism for gravity wave spectrum in the atmosphere. *//Ann. Geophys*. 2009. V. 27, P. 4105-4120.]

Refraction and scattering of infrasound field by gravity wave perturbations

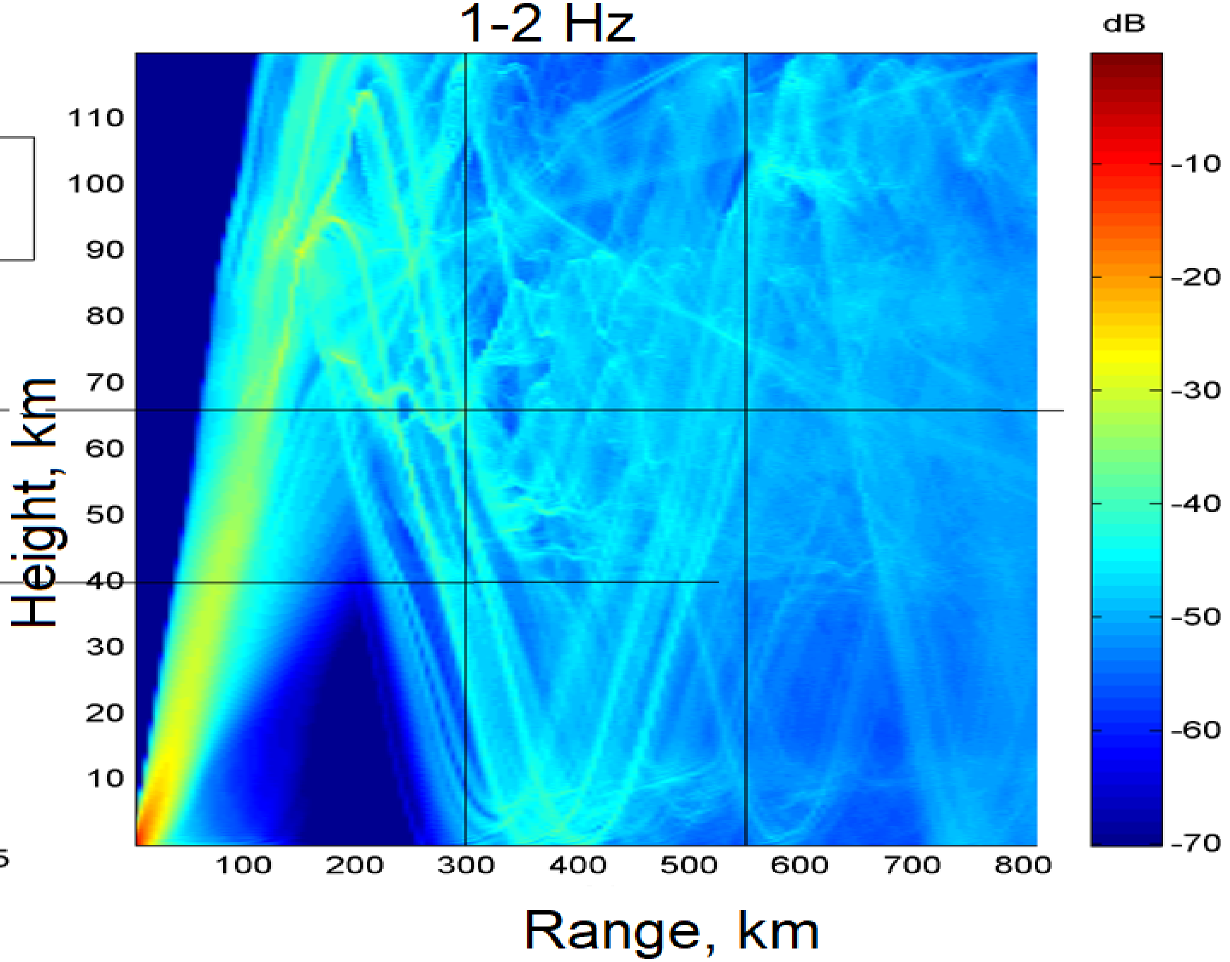


Localization of the infrasound intensity caused by anisotropic inhomogeneities

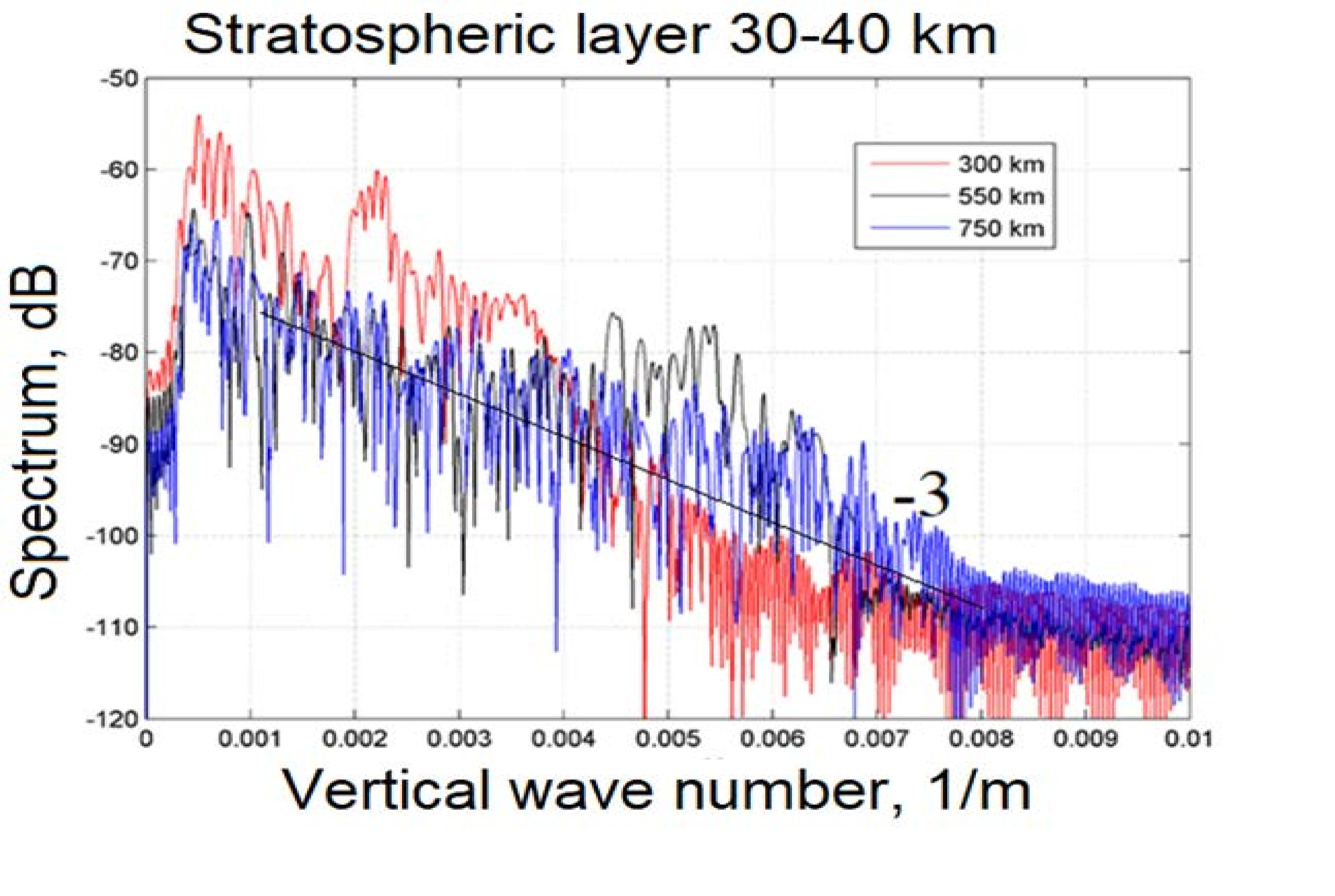
Vertical profiles of infrasound intensity
0.27-2 Hz



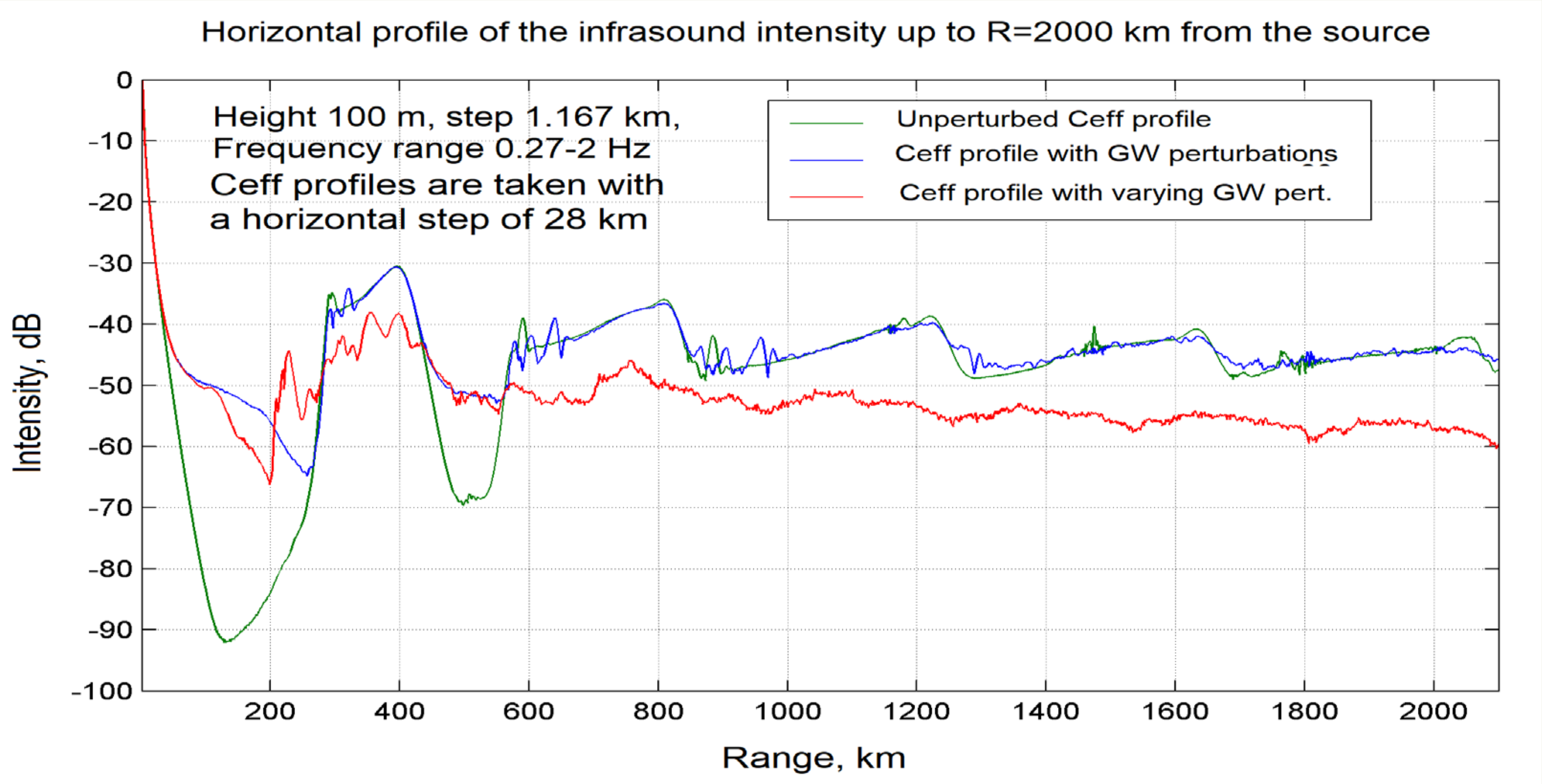
Intensity in the frequency range
1-2 Hz



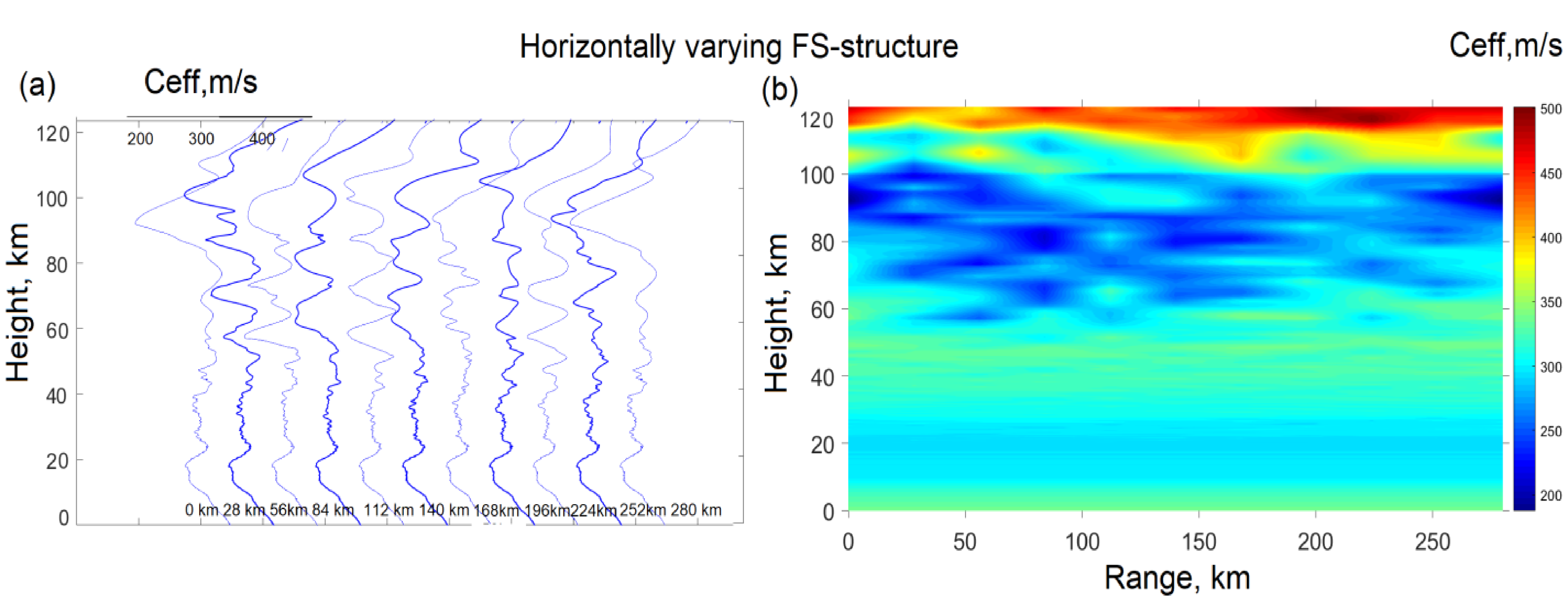
Vertical wave number spectra of the intensity fluctuations



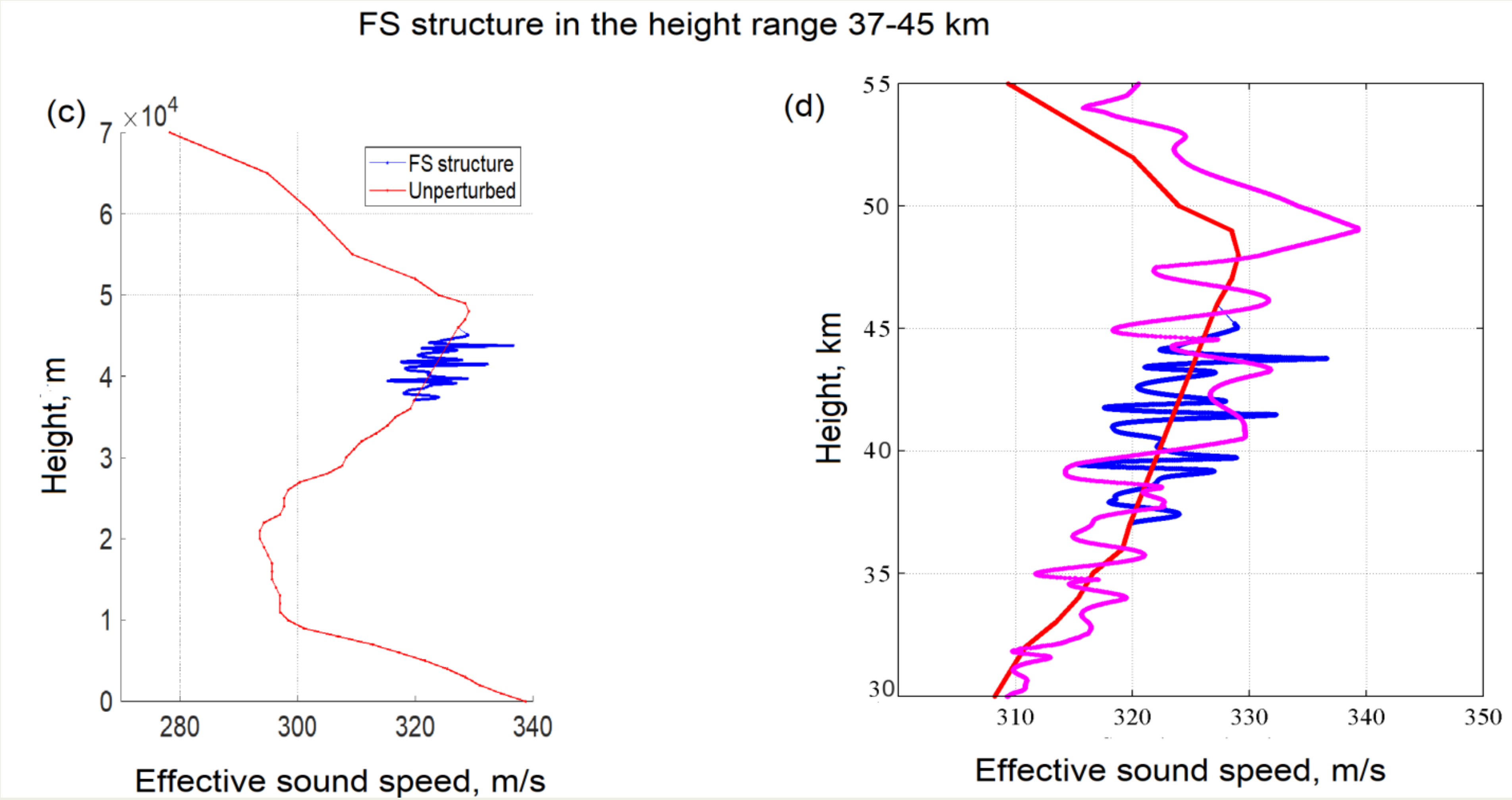
Attenuation of infrasound intensity in a presence of gravity wave perturbations



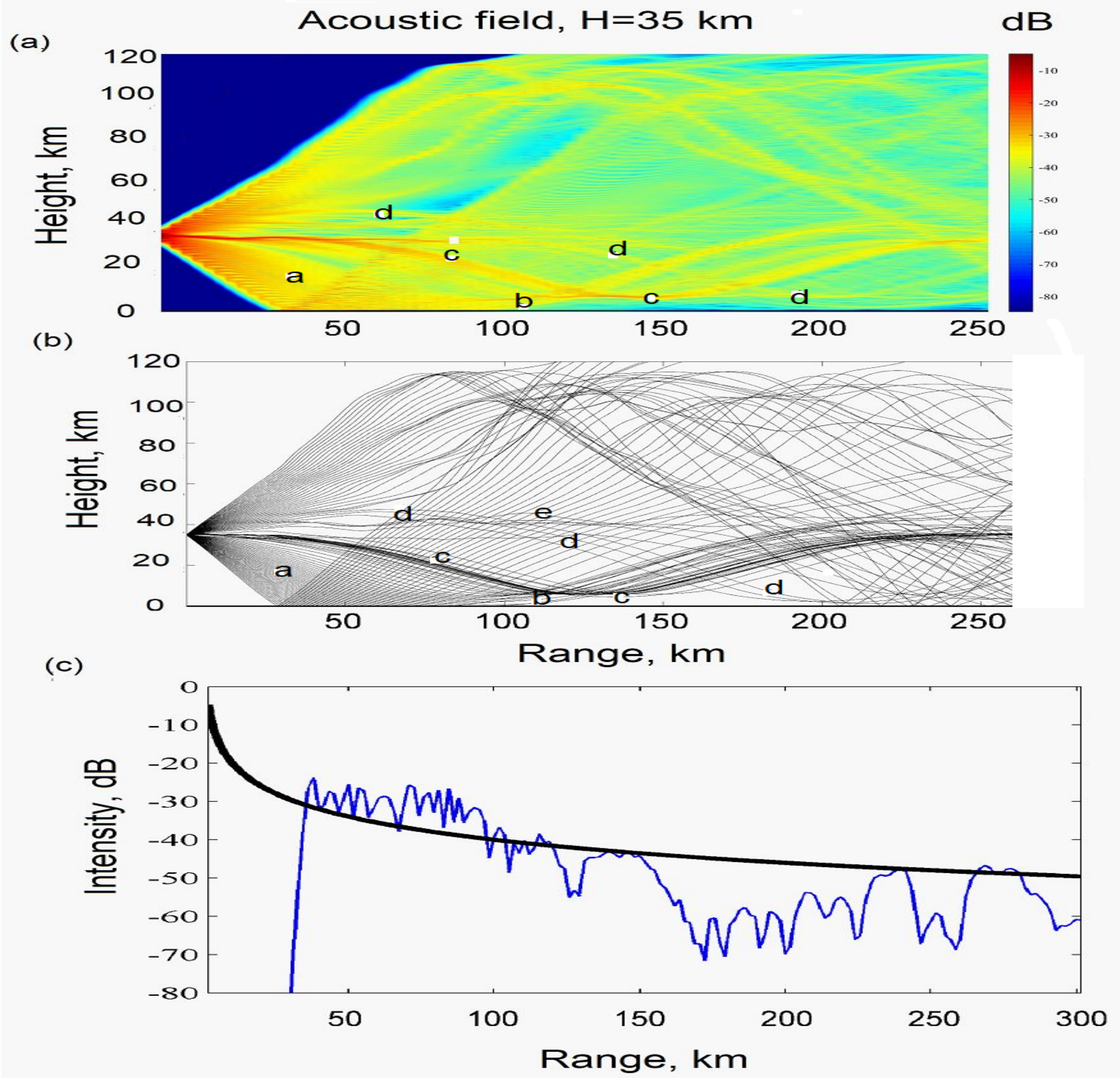
Effect of a fine-scale (FS) layered structure of the atmosphere on infrasound signals from fragmenting meteoroids. [I. P. Chunchuzov, O. E. Popov, E. A. Silber and S. N. Kulichkov. Pure and Applied Geophysics, 2025 (In Press)]



Vertical profile of *Ceff* (*z*) up to 70 km, with added vertical fluctuations caused by FS structure in the 37-45 km stratospheric layer (red line); and (d) its comparison with one of the varying *Ceff*(*z,r*) profiles (magenta).



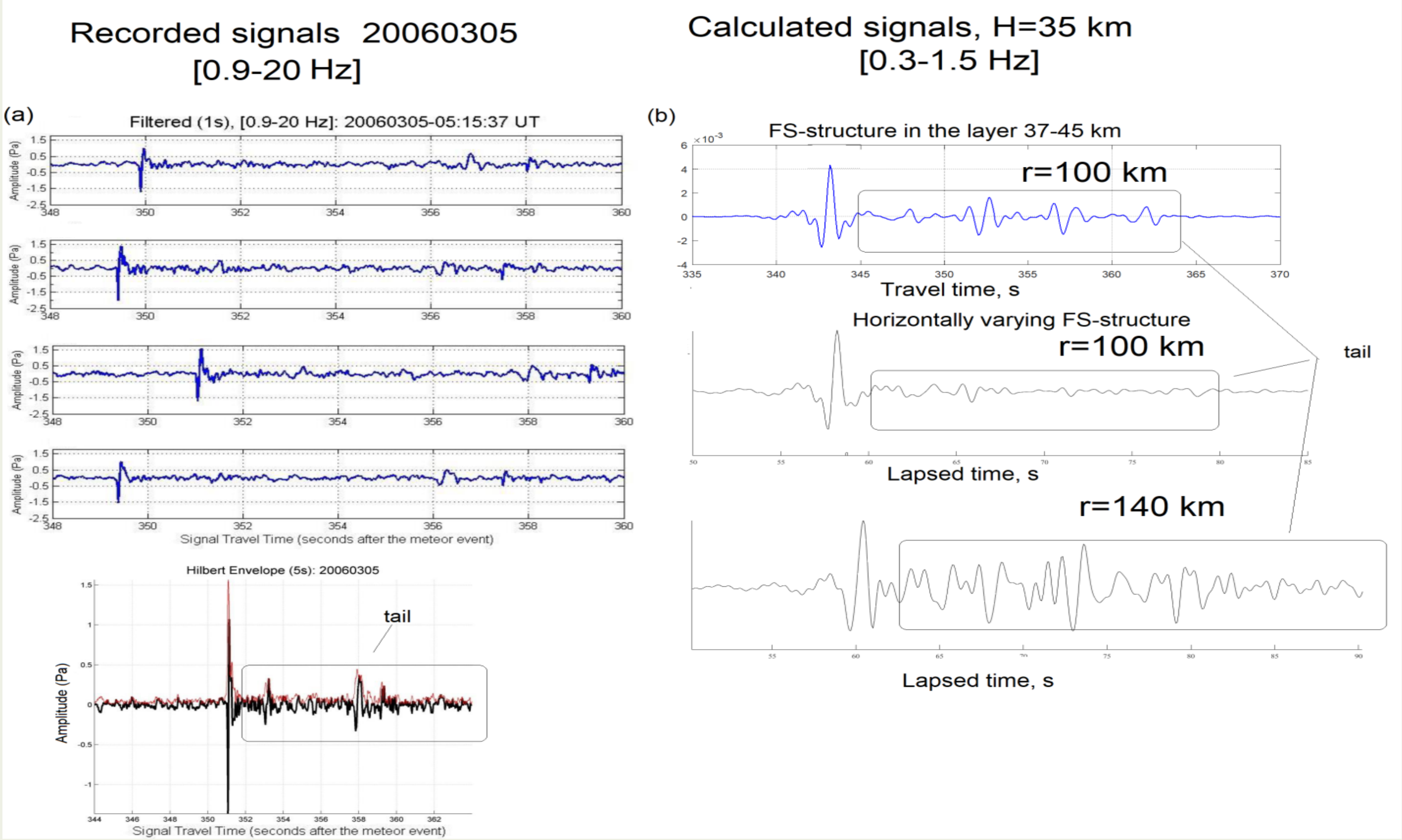
a) Acoustic field at 1 Hz,
b) ray trajectories from the source at 35 km altitude, and
c) horizontal section of the field intensity at 19 m height (blue)compared with the spherical range r^{-2} dependence from a point source at 19 m (black).



Comparison of the recorded amd modeled signals from fragmenting meteoroid at altitudes below stratospheric layer (37-45 km) with FS layered structure.

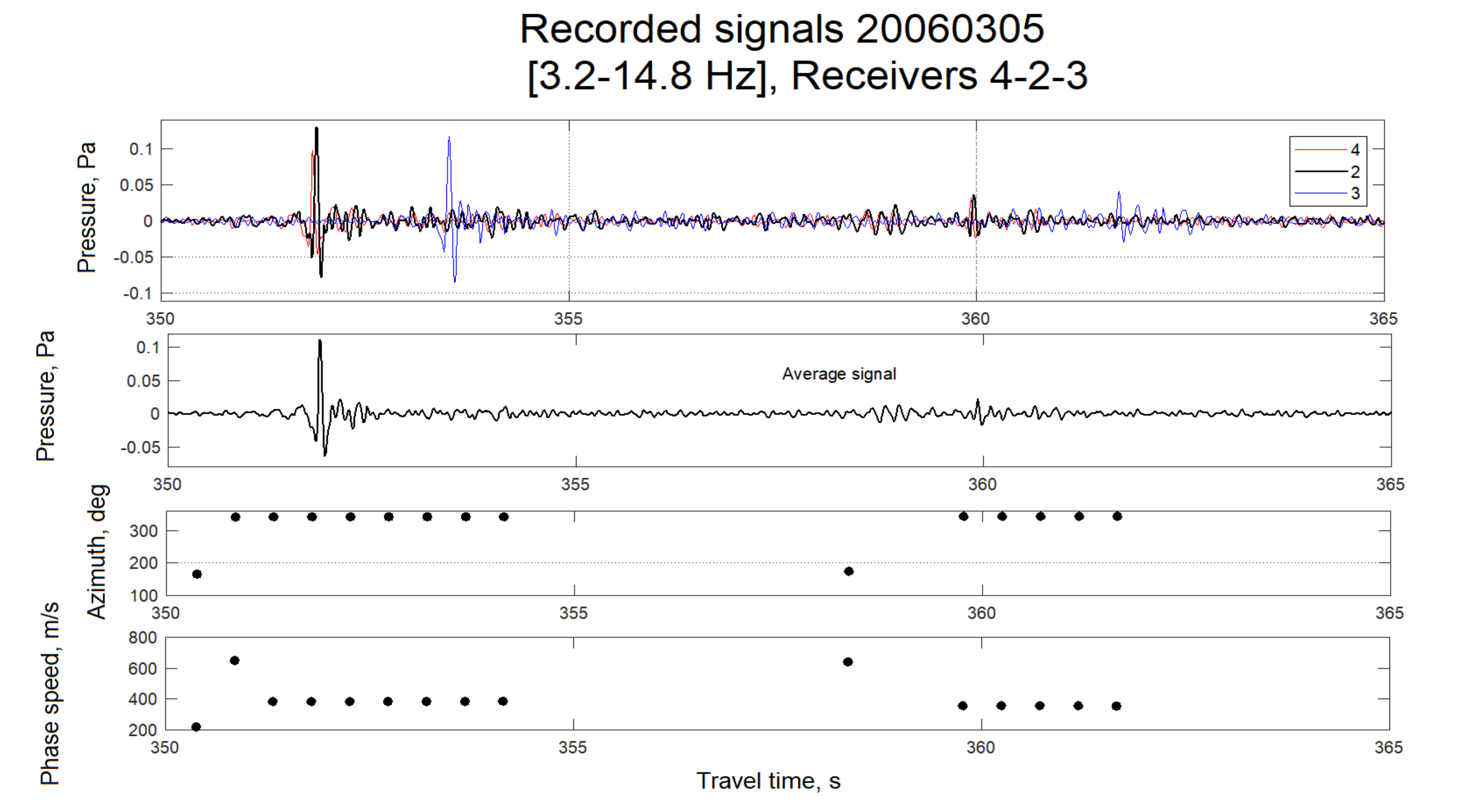
(a)Signal from a meteoroid (*H*=38.1-38.9 km, *r*=107.4-107.7 km) recorded by four receivers (Silber, 2014) and shown with a Hilbert envelope of the signal.

(b) Calculated (PPE) signals at 100 km and 140 km from the source at *H*= 35 km, using (i) a model with FS structure restricted to 37-45 km and (ii) a model with horizontally varying FS structure throughout 0-120 km



Azimuth and horizontal phase speed of the signal vs time

Average signal obtained after time-delay compensation of the 20060305 signals at receivers 4-2-3, along with the azimuth and horizontal phase speed of the signal as a function of time.



Conclusions

- 1.The effects of infrasound intensity intermittency and localization in some atmospheric layers are found.
- 2. Vertical spectra of the intensity oscillations at different distances from the source take a well-defined shape with a mean slope of -3 (scales from a few km to 100 m).
- 3. The additional attenuation of infrasound field with increasing distance from a source (up to 2200 km) due to its multiple scattering by gravity wave perturbations is studied.
- 4. Partial reflections of infrasound signals generated by meteoroids caused by FS fluctuations in the stratosphere form multiple arrivals and a long –lasting tail in the observed signals