Вариации поглощения энергии сейсмических волн связанные с изменением вулканической активности вулкана Кизимен

Лемзиков В.К., Шакирова А.А., Лемзиков М.В., Гарбузова В.Т., Ящук В.В., Дрознин Д.В.

Цель: Оценка поглощения сейсмических волн в верхних слоях среды вулканической зоны.

1. Метод.
2. Исходные данные.
3. Результаты.
4. Заключение.

Влияние на спектр различных параметров

Если $\dot{u}(f)$ – спектр мощности скорости движения почвы при воздействии сейсмических волн, полученный в точке регистрации, то зависимость очагового спектра мощности землетрясения $\dot{X}(f)$ от основных функций и параметров можно представить в следующем виде (e.g. Garcia-Garcia, 1996):

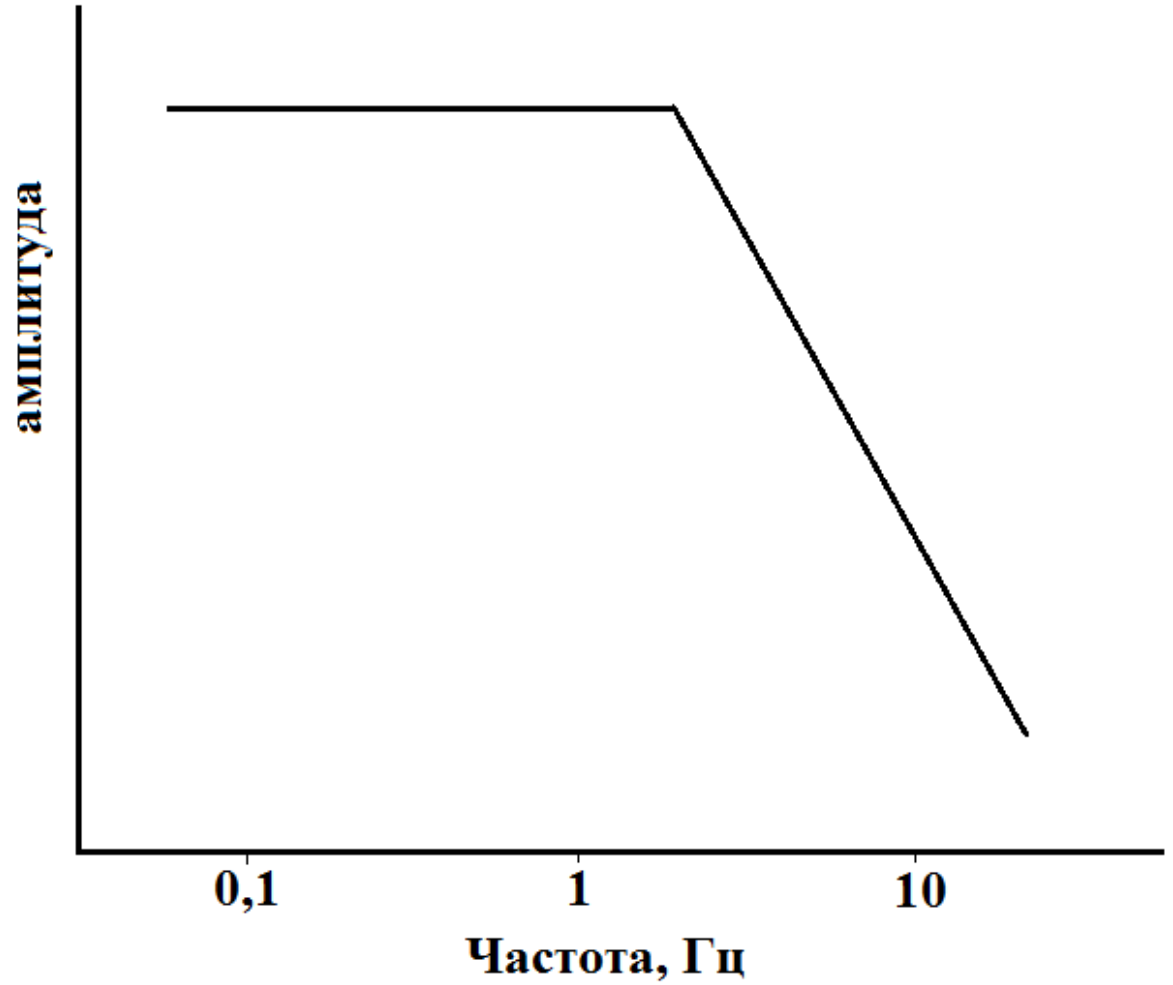
$$\dot{u}(f) = \dot{X}(f) * G(R) * D(f) * S(f) * \Re(f) * I(f),$$

где $G(R)$ – затухание энергии сейсмических волн из-за геометрического расхождения; $D(f)$ – функция, описывающая поглощение их в среде; $S(f)$ – спектральная станционная поправка, $\Re(\omega)$ - направленность излучения очага землетрясения; f – частота колебаний сейсмических волн; R - гипоцентральное расстояние в км.

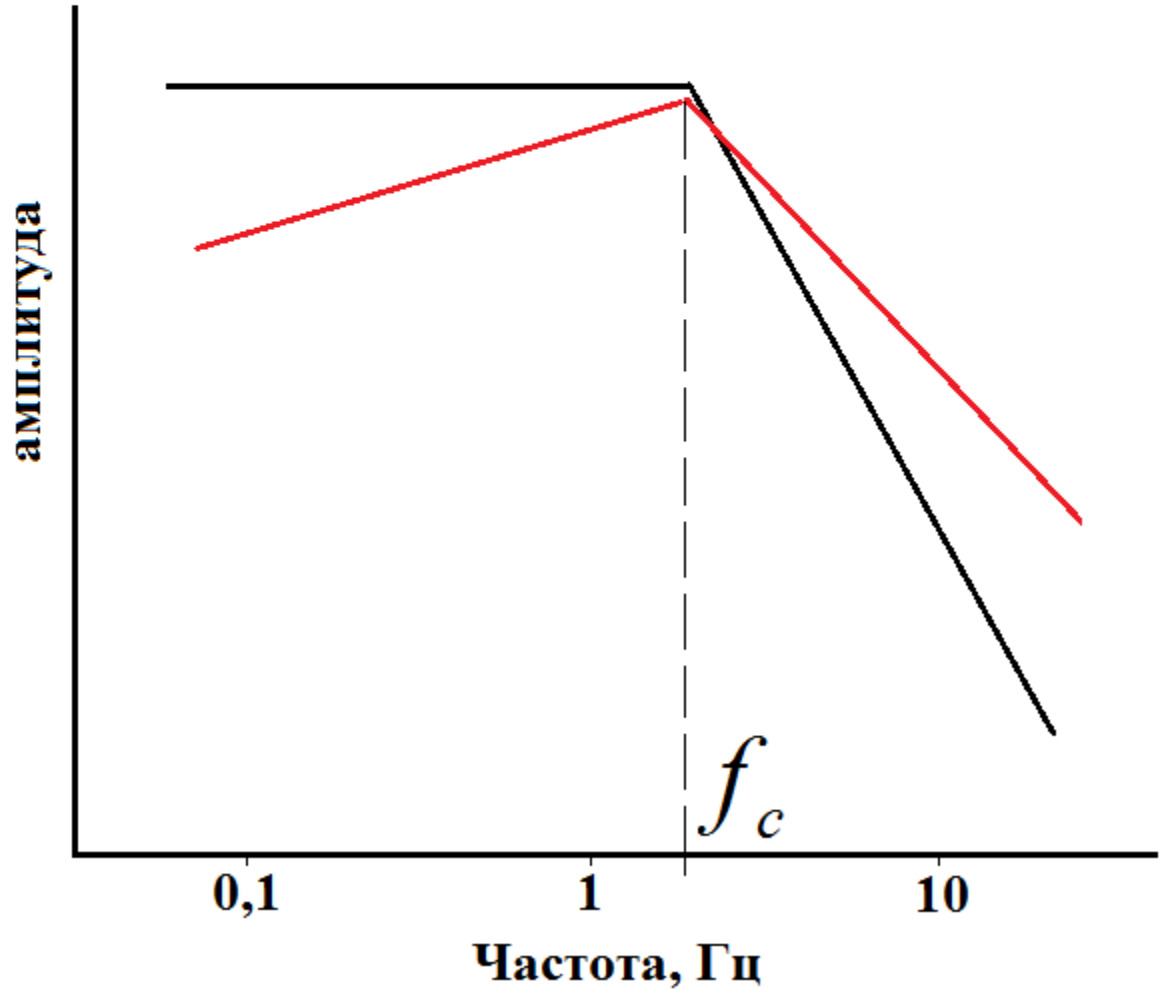
$$\ddot{u}(f) \approx \dot{X}(f) * G(R) * D(f) * S(f)$$

$$ui(f) \approx \underline{\dot{X}(f)} * G(R) * D(f) * S(f)$$

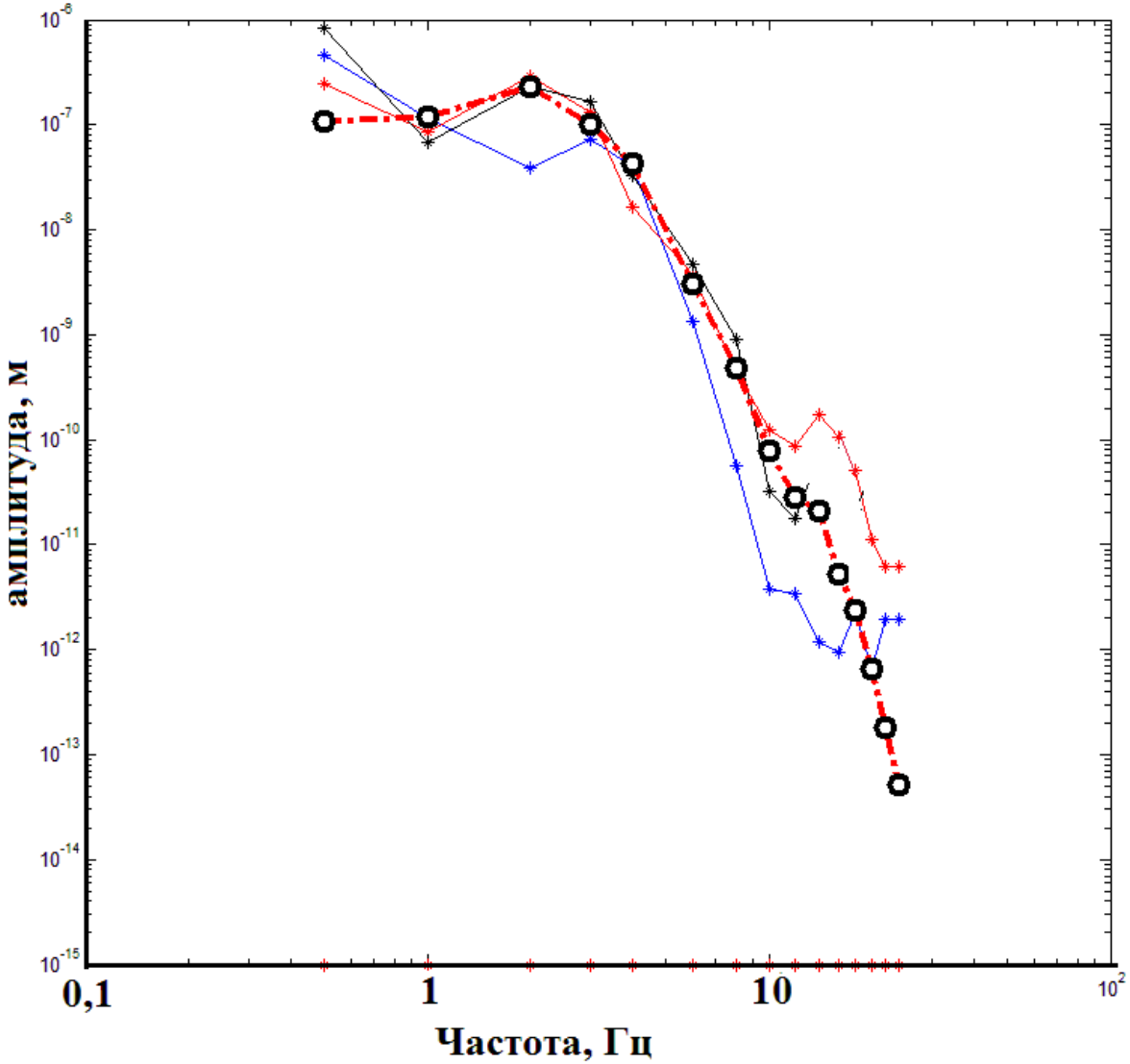
Принимаем в качестве спектра очага модель Брюна.



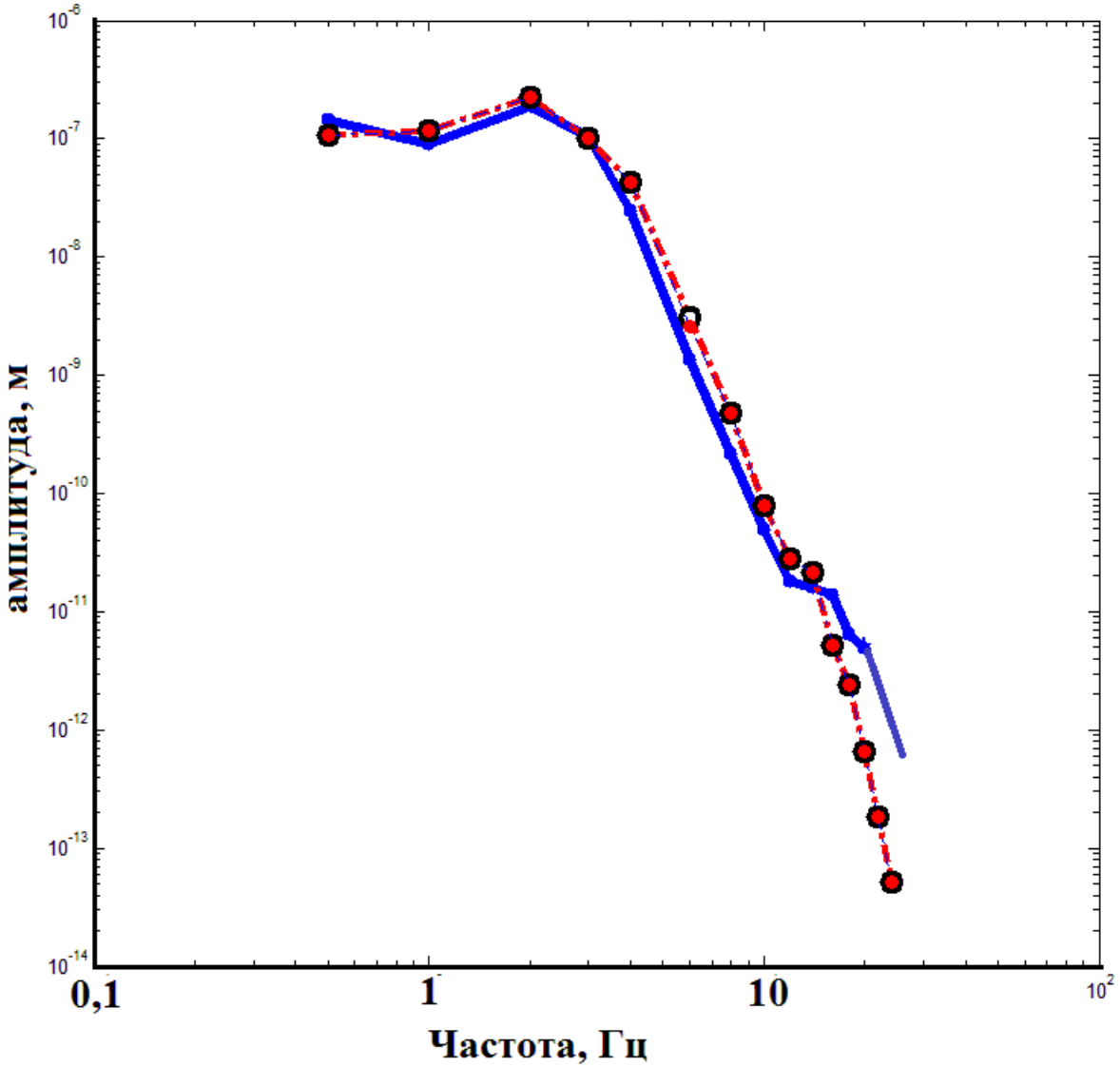
$$\dot{v}(f) = \frac{2\pi f \bar{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}}$$



$$\dot{x}(f) = \frac{2\pi f \bar{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}} * \frac{1}{G(R) * D(f) * S(f)}$$



$$\dot{x}(f) = \frac{2\pi f \bar{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}} * \frac{1}{G(R) * \underline{D(f)} * S(f)}$$

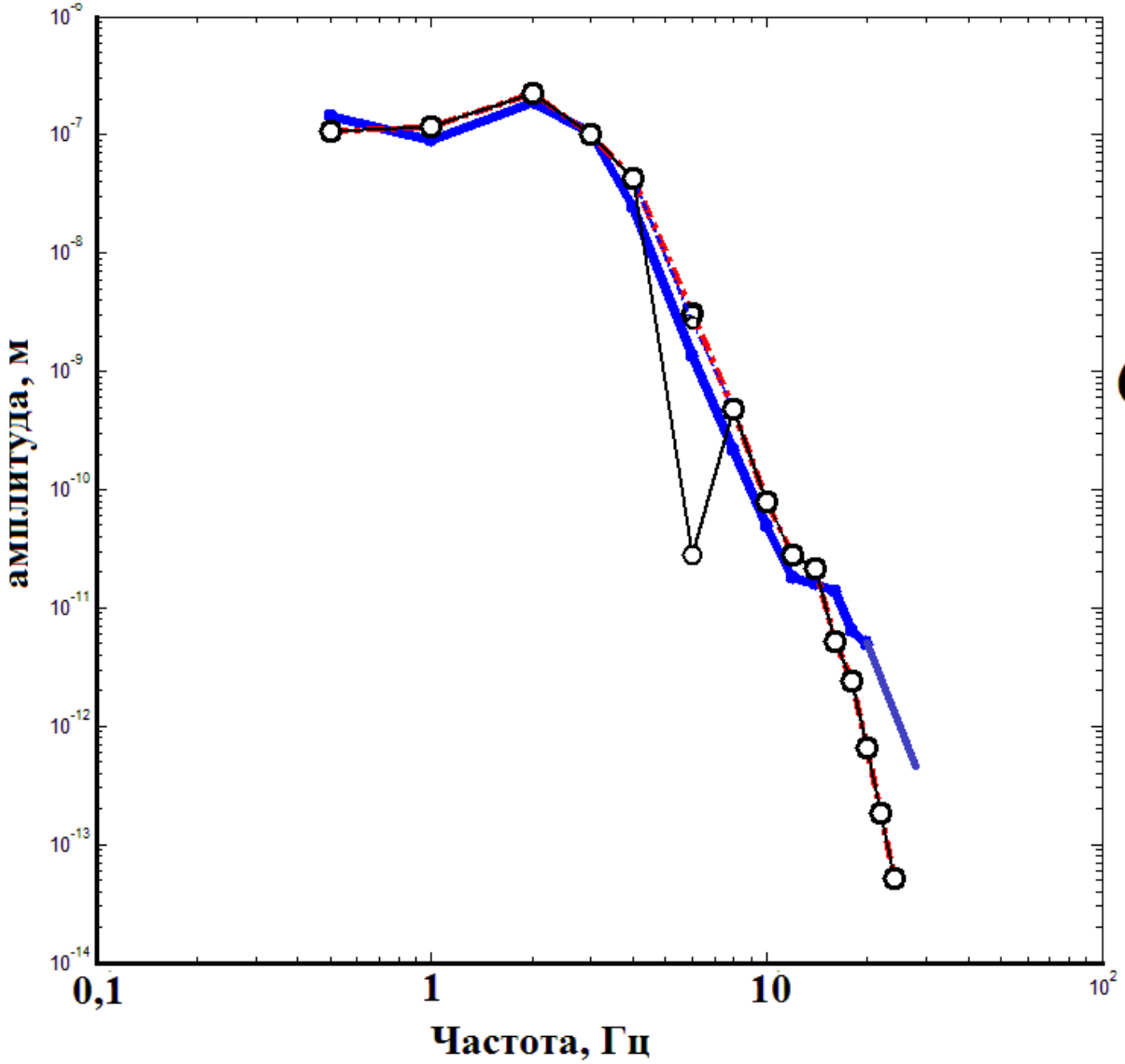


f_c

$G(R) \approx \boldsymbol{r}$

$$\frac{Q}{t^*}$$

$$\dot{x}(f) = \frac{2\pi f \bar{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}} * \frac{1}{G(R) * D(f) * \underline{S(f)}}$$



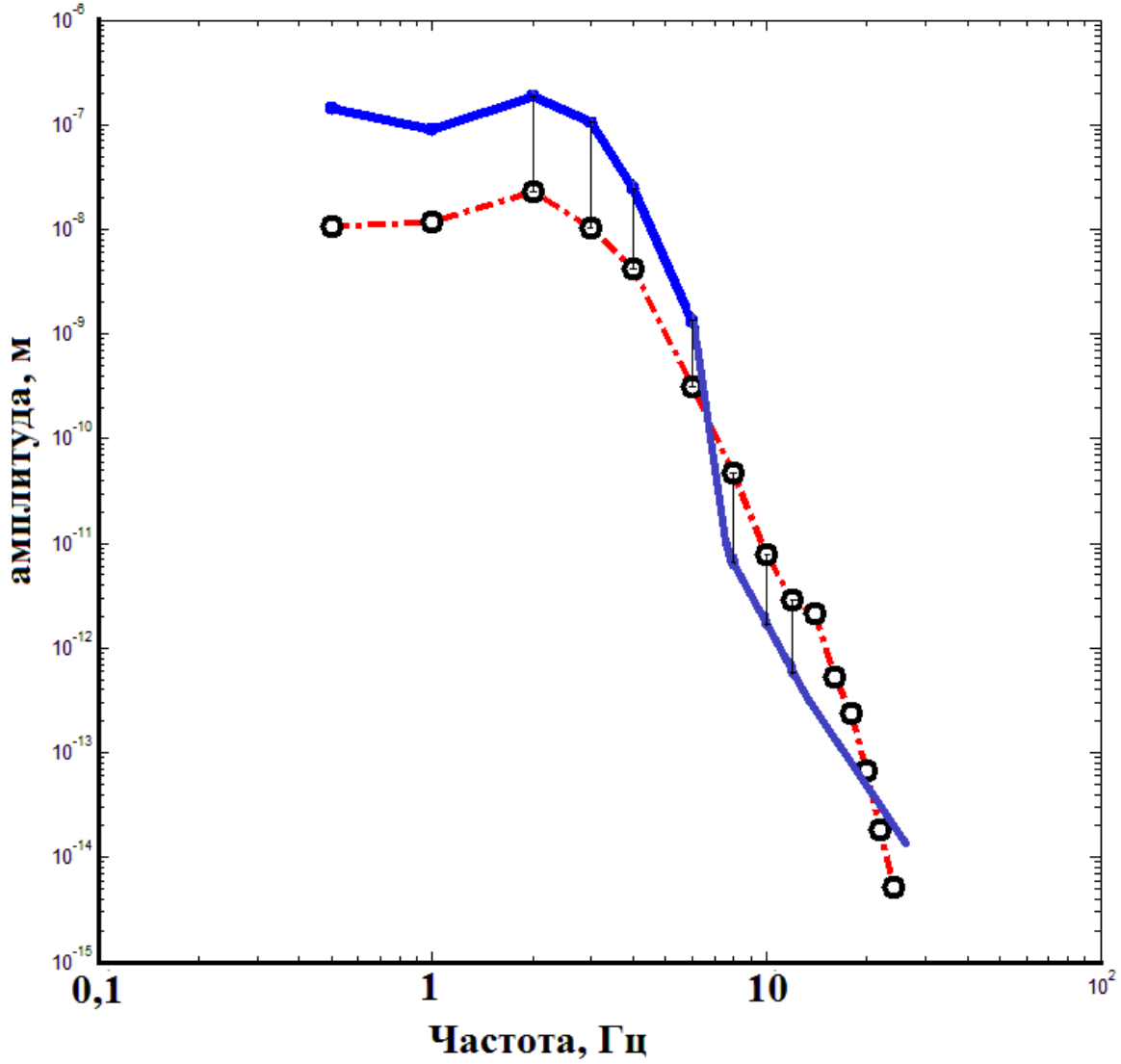
f_c

$G(R) \approx r$

Q

$\underline{t^*}$

$$\dot{x}(f) = \frac{2\pi f \bar{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}} * \frac{1}{G(R) * D(f) * S(f)}$$



f_c

$G(R) \approx r$

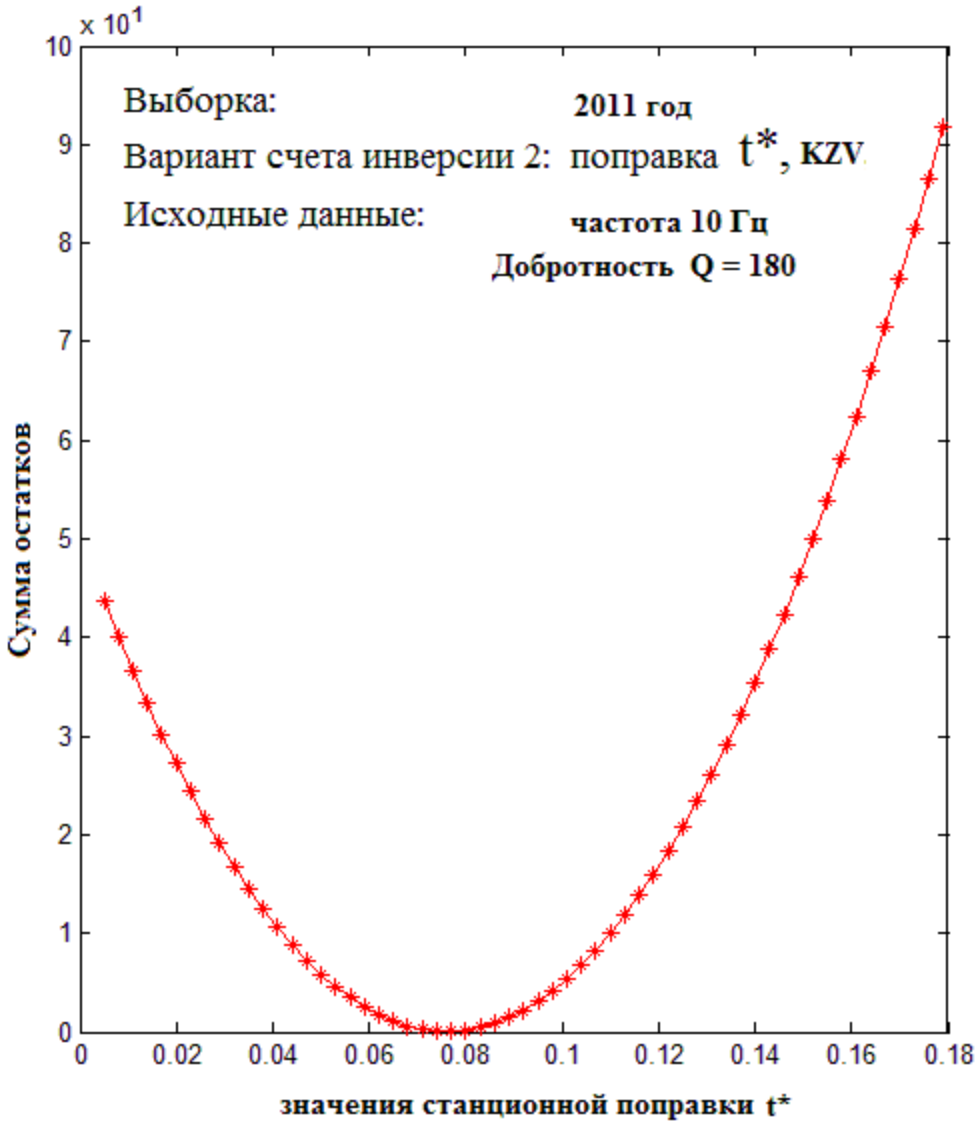
Q

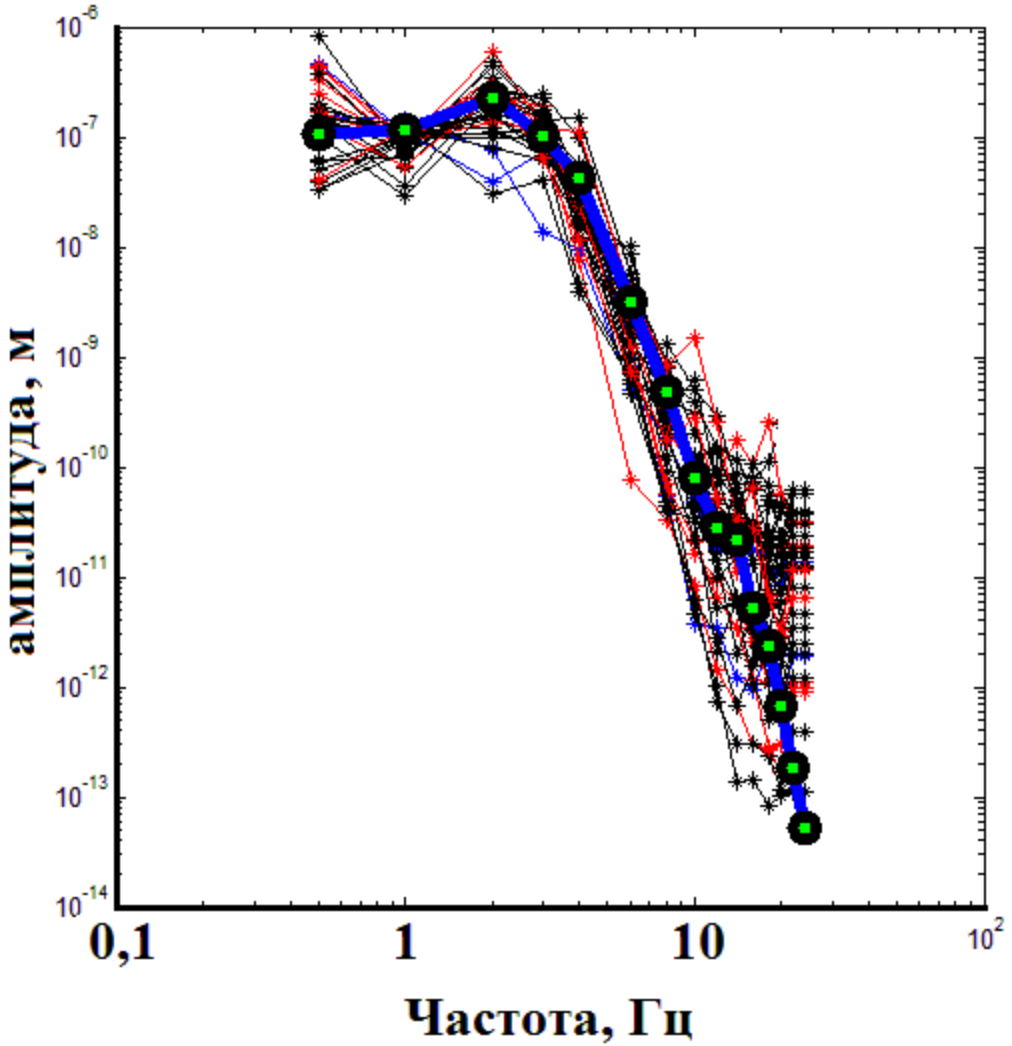
t^*

$$\dot{x}(f) = \frac{2\pi f \overline{u}_0}{\left(1 + (f/f_c)^4\right)^{1/2}} * \frac{1}{r} * e^{-\pi f (t^* + T/Q)}$$

$$\chi^2 = \sum_{k,n} \left| \ln \dot{u}_k(f_n) - \ln \dot{v}_j(f_n) + \ln g\left(r_k, T_k, f_n\right) \right|^2 / \sigma_k^2(f_n)$$

$$\begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_k \end{bmatrix} \cdot \begin{bmatrix} a_{1,1} & 0 & 0 & 0 \\ 0 & a_{2,2} & 0 & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & a_{k,k} \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ \dots \\ d_k \end{bmatrix}$$

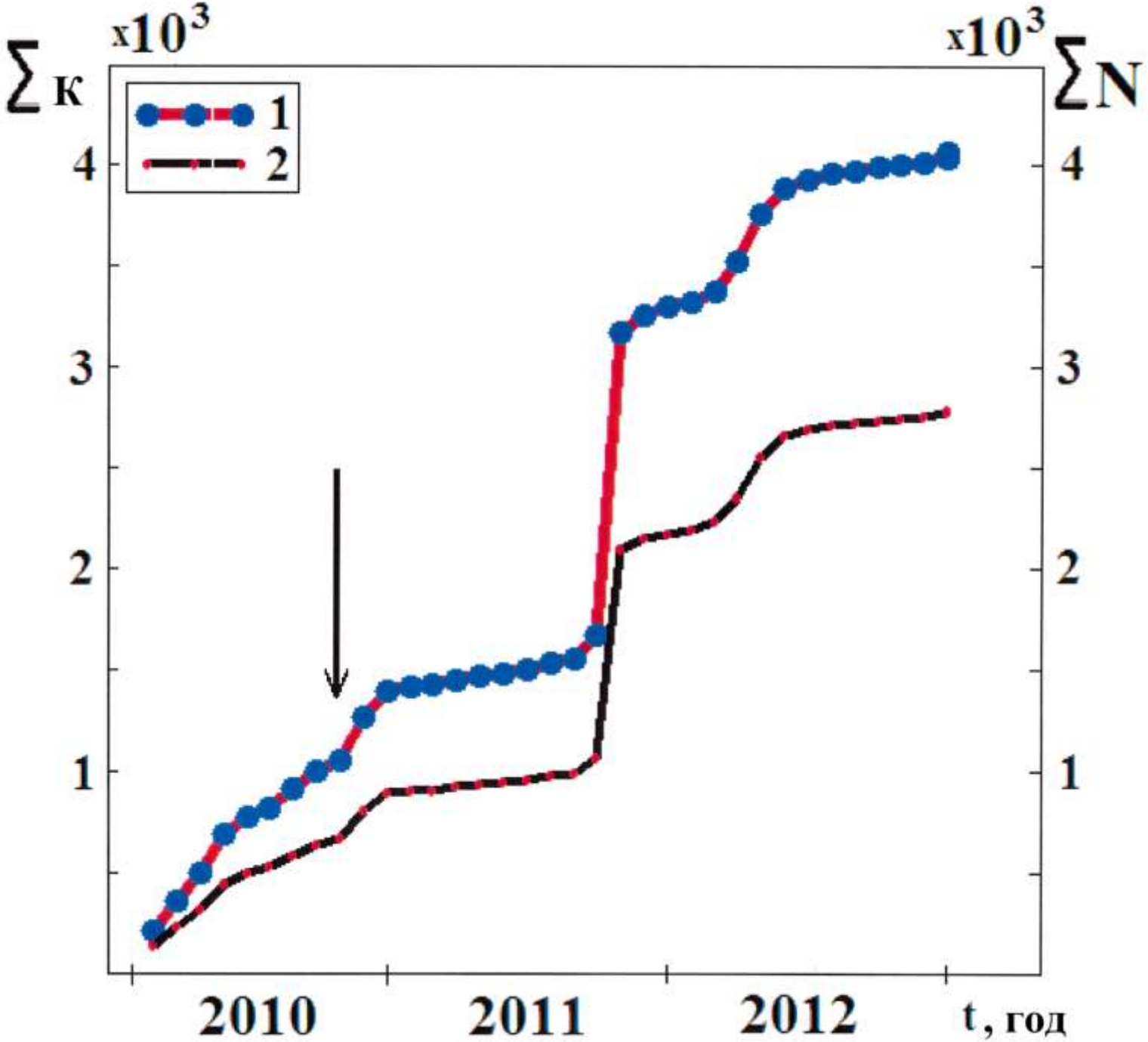

x 10^1
10
9
8
7
6
5
4
3
2
1
0
Выборка:
2011 год
Вариант счета инверсии 2: поправка t*, KZV
Исходные данные:
частота 10 Гц
Добротность Q = 180
Сумма остатков
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
значения станционной поправки t*

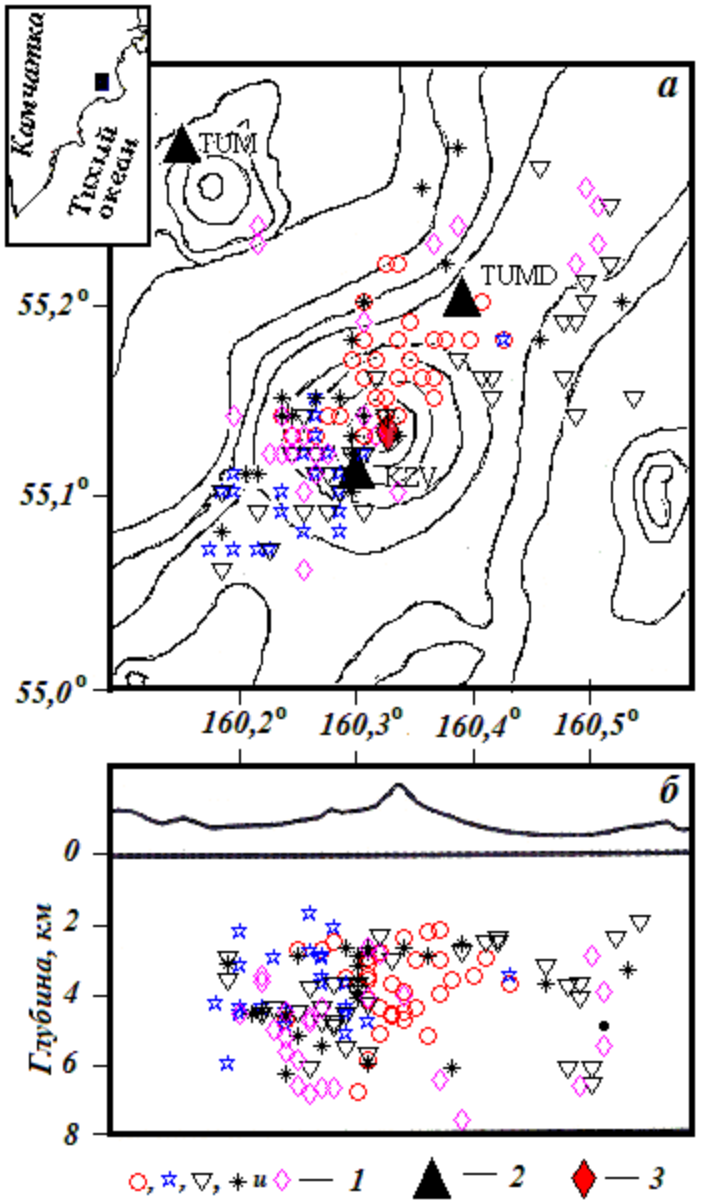

амплитуда, м
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
0,1
1
10
10^2
Частота, Гц

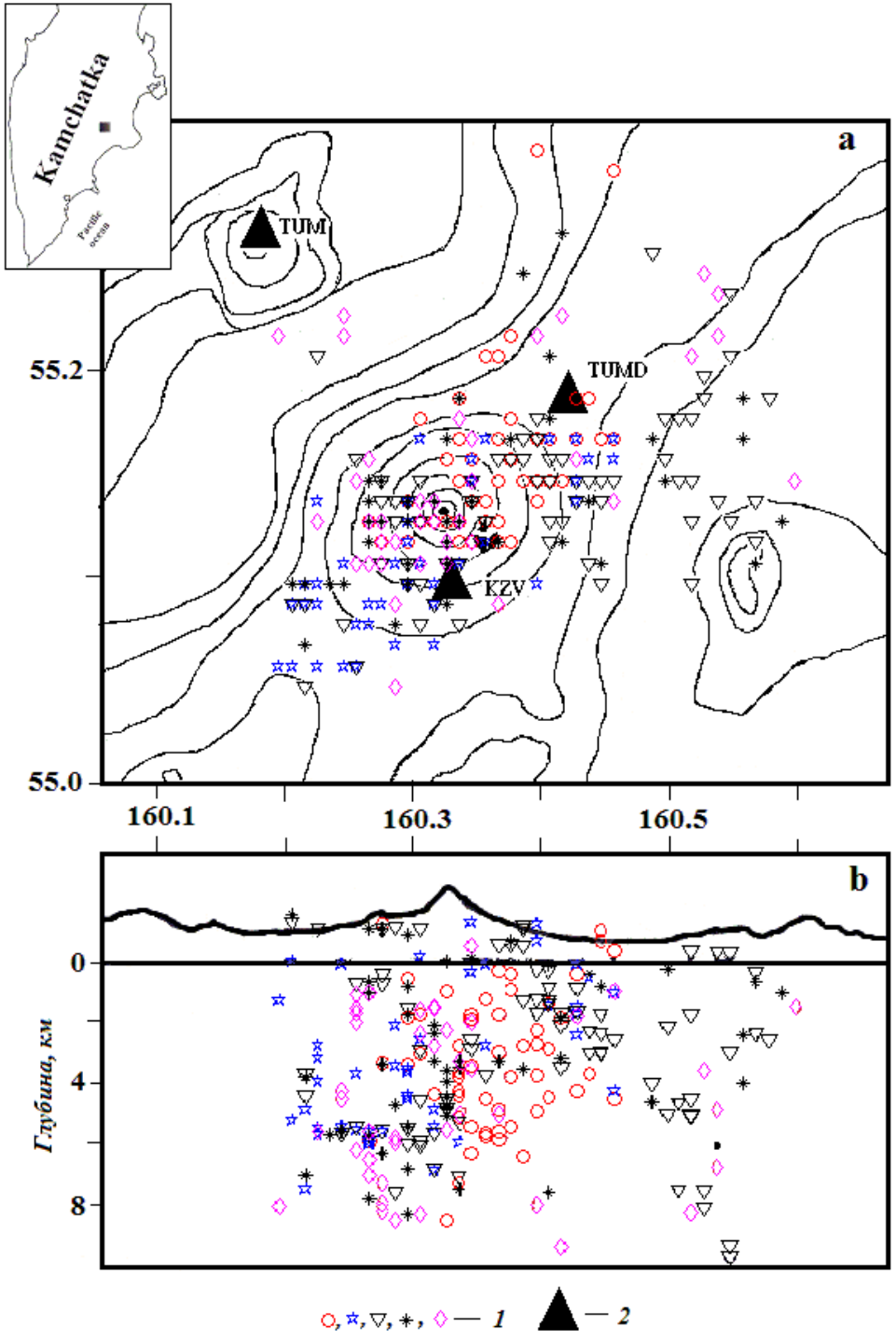
Допущения

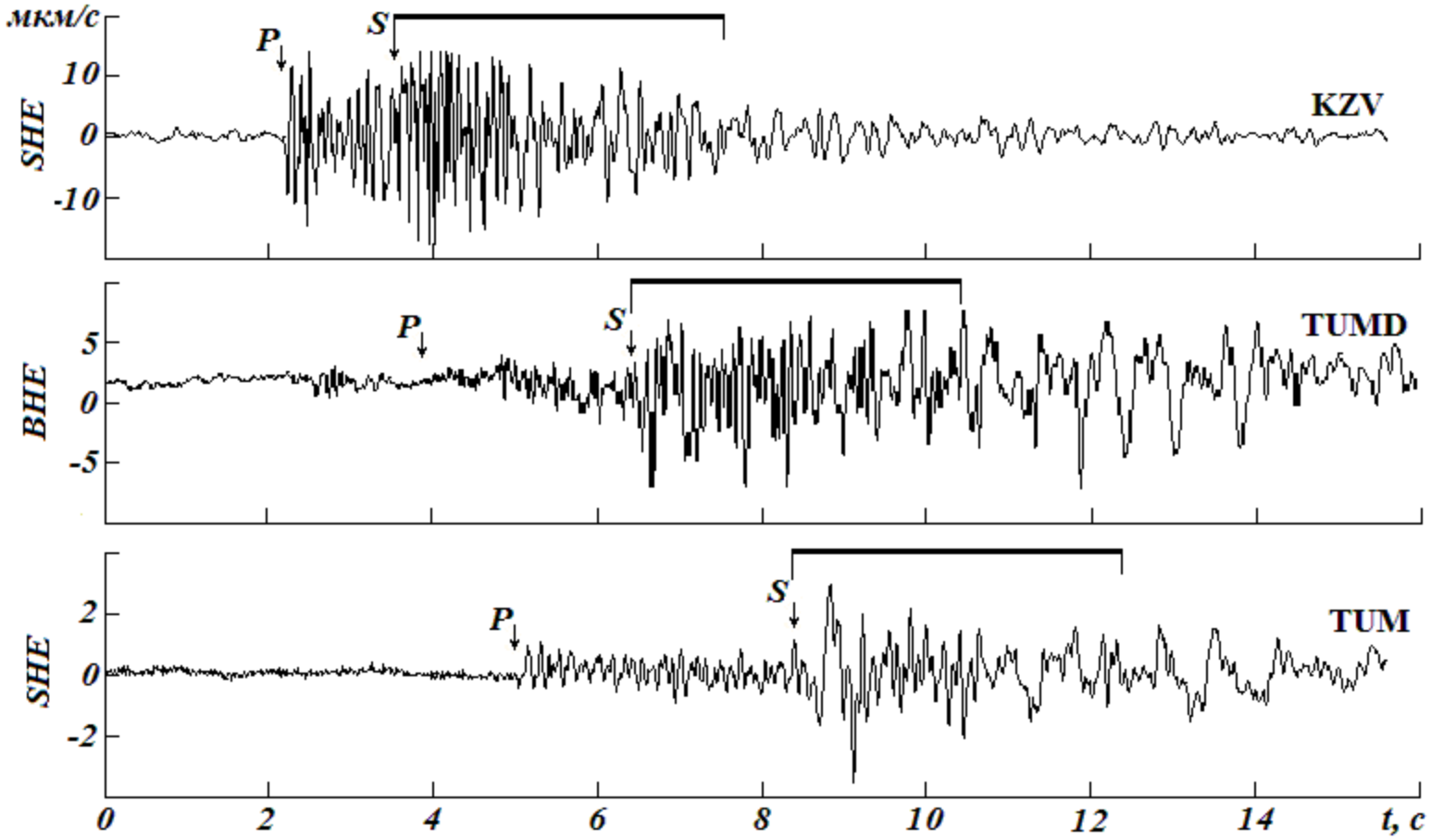
1. Записи одного землетрясения должны иметь только один спектр очага, следовательно определить одно значение f_c

2. Записи по одной станции землетрясений, очаги которых находятся примерно в одной точке пространства определяют только одно значение Q и t^*


x10^3
x10^3
∑к
∑N
1
2
4
3
2
1
2010
2011
2012
t, год


Камчатка
Тихий океан
а
TUM
TUMD
KZV
55,2°
55,1°
55,0°
160,2°
160,3°
160,4°
160,5°
б
0
2
4
6
8
Глубина, км
○, ☆, ▽, ✳ и ◇ — 1
— 2
— 3

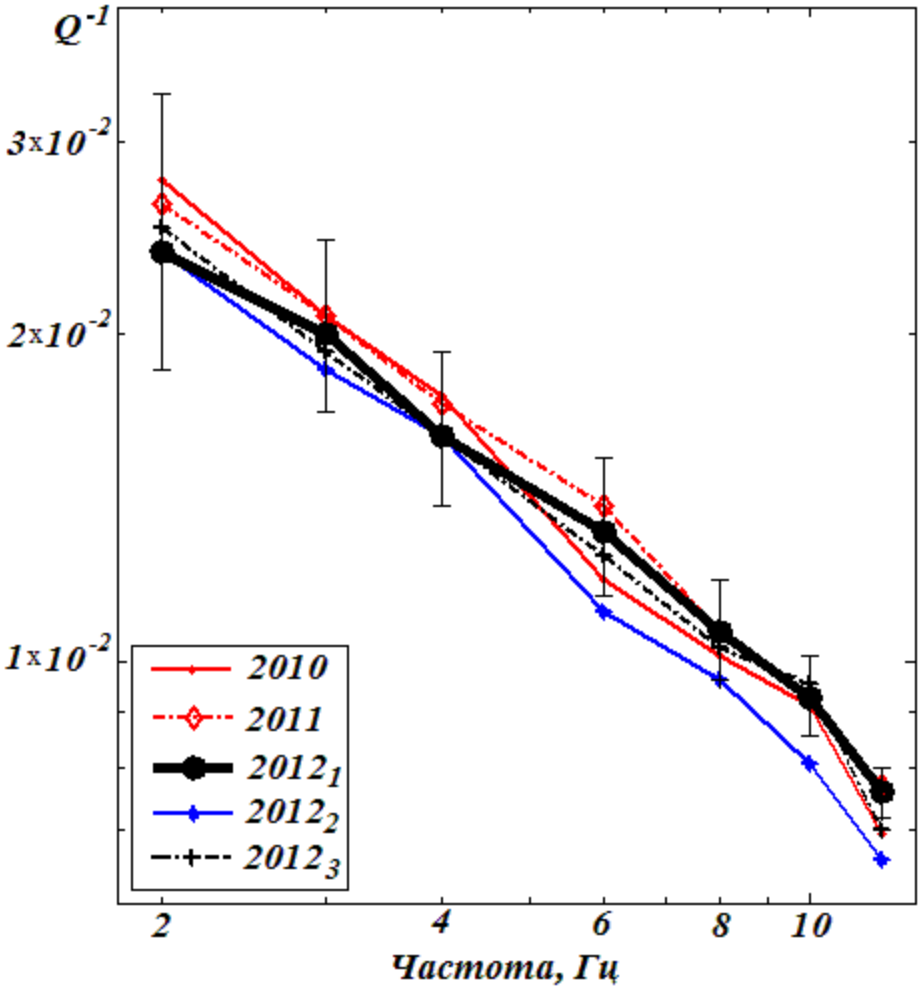

Kamchatka
Pacific ocean
a
TUM
TUMD
KZV
55.2
55.0
160.1
160.3
160.5
b
0
4
8
Глубина, км
— 1
— 2

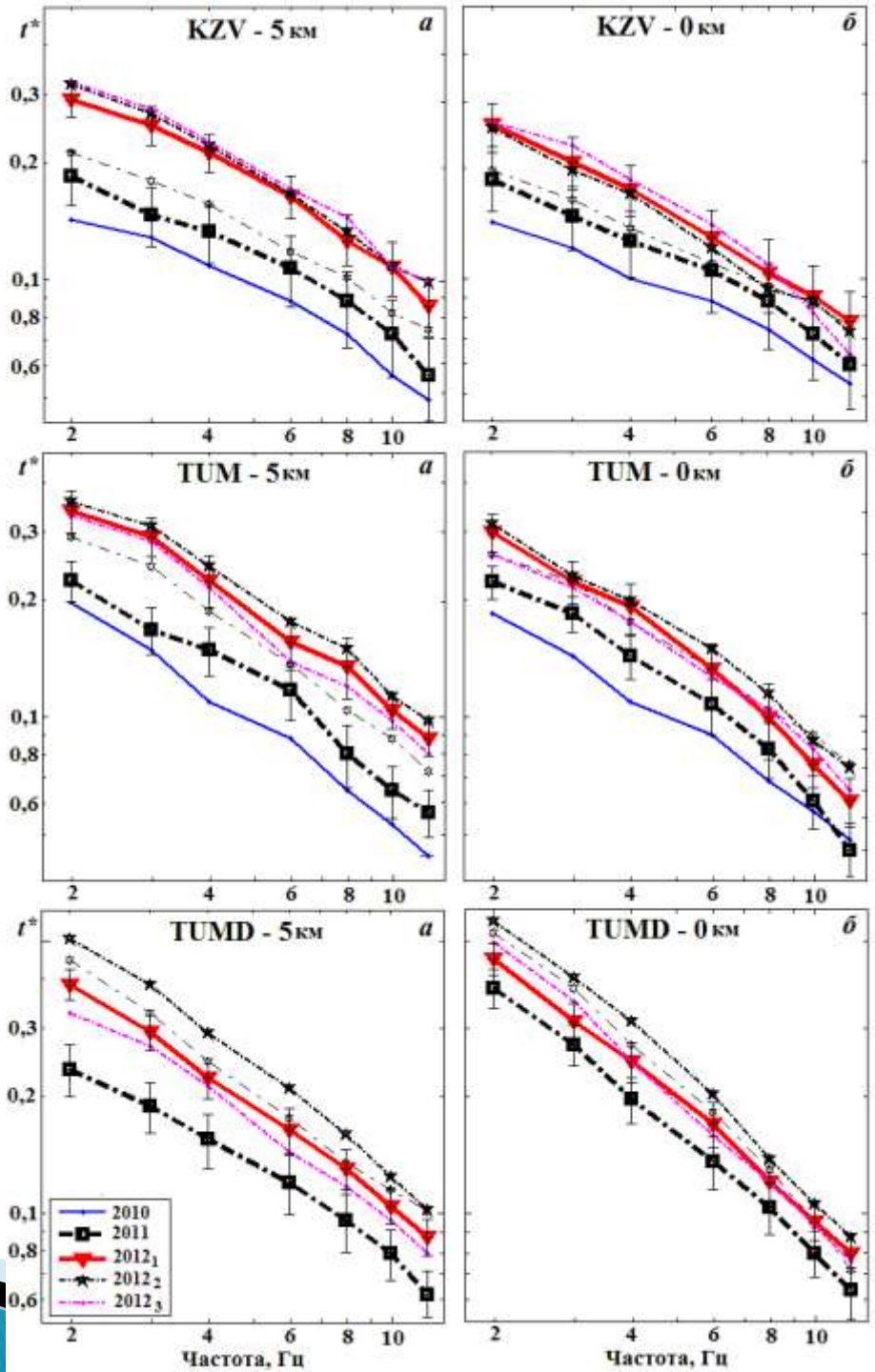


Выбирались землетрясения с $5{,}7 < K < 6{,}3$.
Выборки обозначены: 2010, 2011, 2012_1, 2012_2 и 2012_3

Выборки сделаны для двух диапазонов глубин: -2 до 2 км; 2 до 9 км

Станция **KZV**


Q-1
3x10-2
2x10-2
1x10-2
2010
2011
2012 1
2012 2
2012 3
2
4
6
8
10
Частота, Гц


t*
KZV - 5 км
а
KZV - 0 км
б
TUM - 5км
TUM - 0км
TUMD - 5км
TUMD - 0км
0,3
0,2
0,1
0,8
0,6
2
4
6
8
10
2010
2011
2012 1
2012 2
2012 3
Частота, Гц
Частота, Гц

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Pre-eruption deformation caused by dike intrusion beneath Kizimen volcano, Kamchatka, Russia, observed by InSAR

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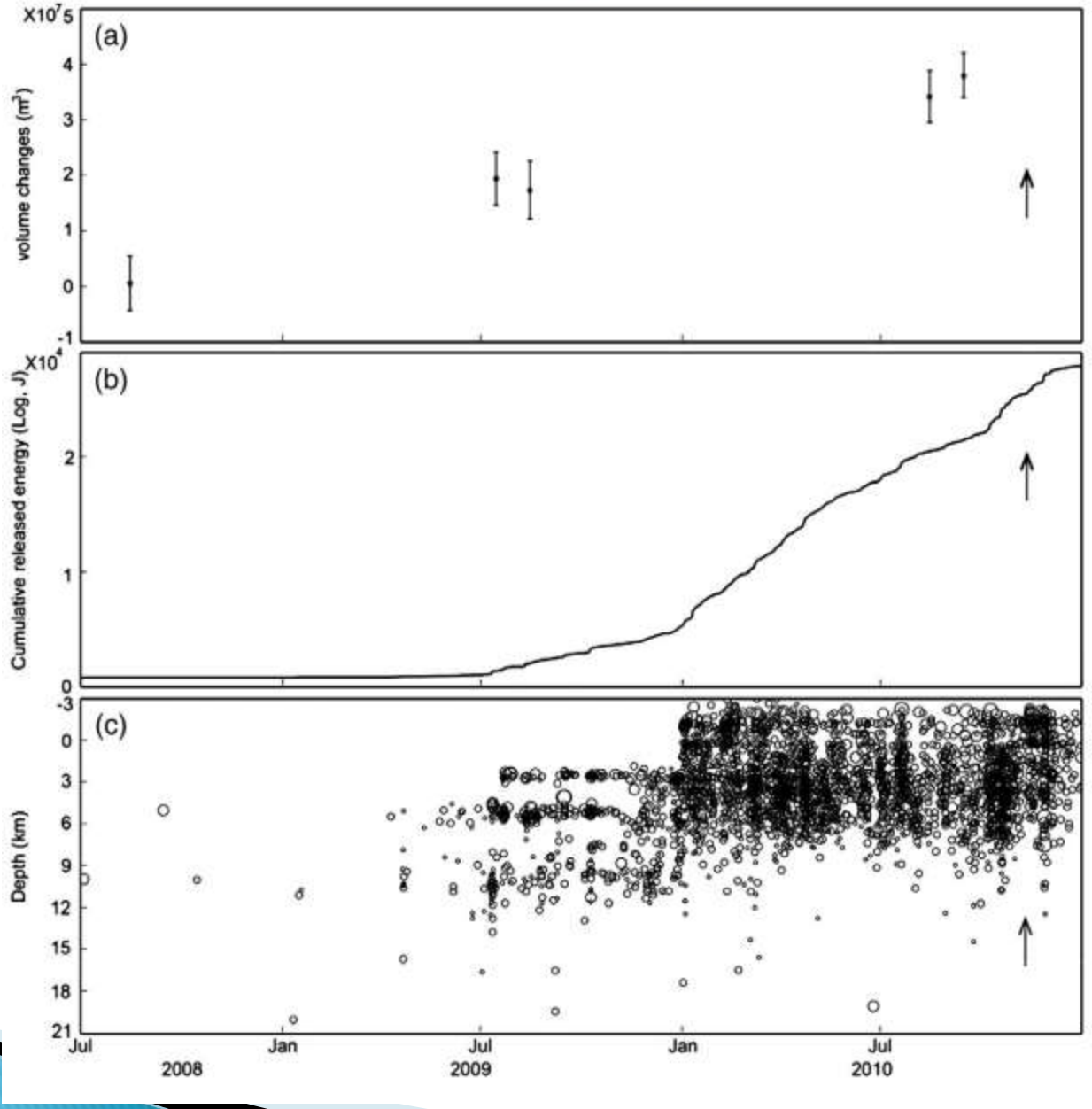
ABSTRACT

Interferometric synthetic aperture radar (InSAR) images reveal a pre-eruption deformation signal at Kizimen volcano, Kamchatka, Russia, where an ongoing eruption began in mid-November, 2010. The previous eruption of this basaltic andesite-to-dacite stratovolcano occurred in 1927–1928. InSAR images from both ascending and descending orbital passes of Envisat and ALOS PALSAR satellites show as much as 6 cm of line-of-sight shortening from September 2008 to September 2010 in a broad area centered at Kizimen. About 20 cm of opening of a nearly vertical dike provides an adequate fit to the surface deformation pattern. The model dike is approximately 14 km long, 10 km high, centered 13 km beneath Kizimen, and strikes NE–SW. Time-series analysis of multi-temporal interferograms indicates that (1) intrusion started sometime be-


(a)
X10^7
volume changes (m^3)
5
4
3
2
1
0
-1
(b)
X10^4
Cumulative released energy (Log, J)
2
1
0
(c)
Depth (km)
-3
0
3
6
9
12
15
18
21
Jul
2008
Jan
Jul
2009
Jan
Jul
2010

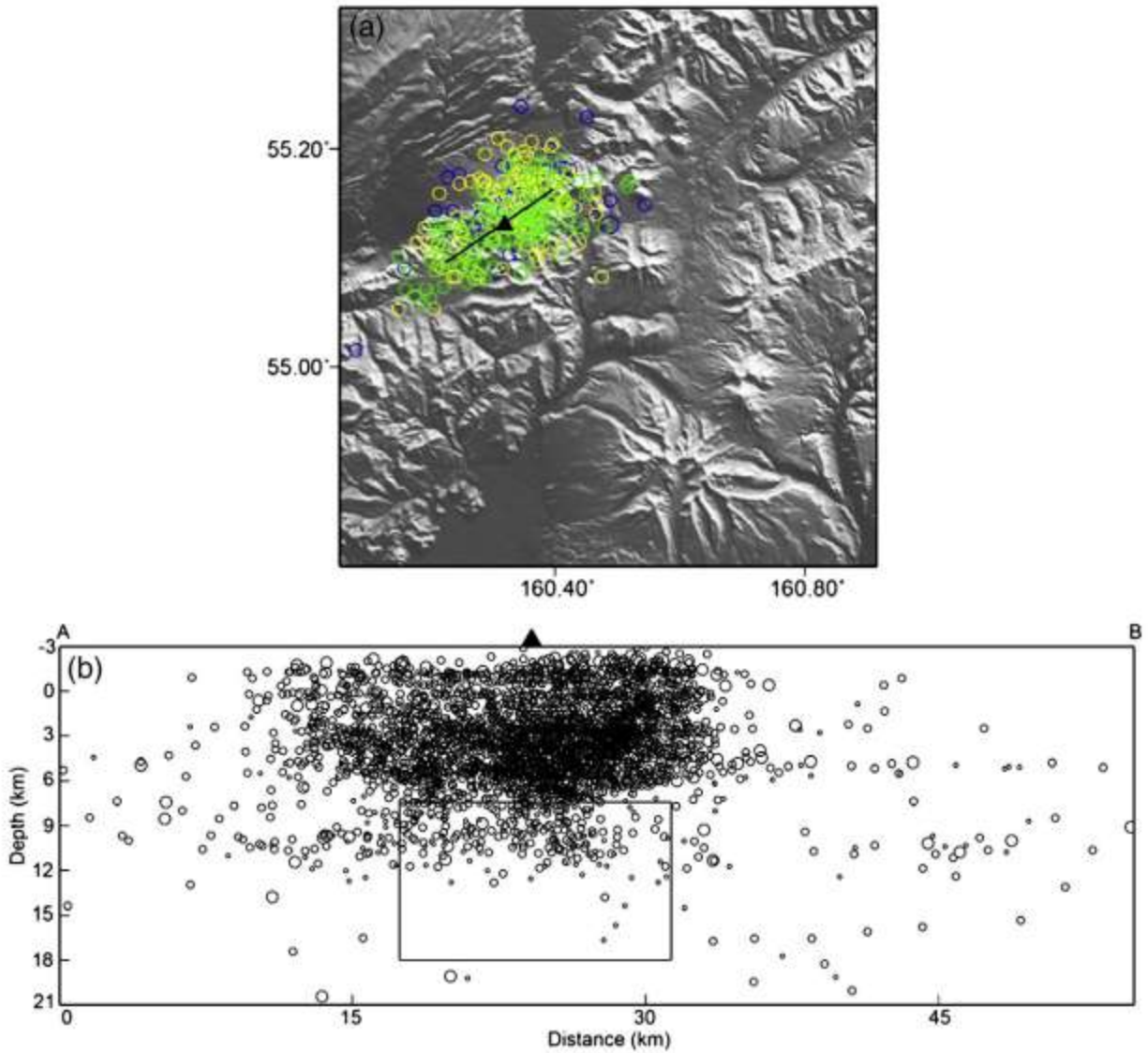
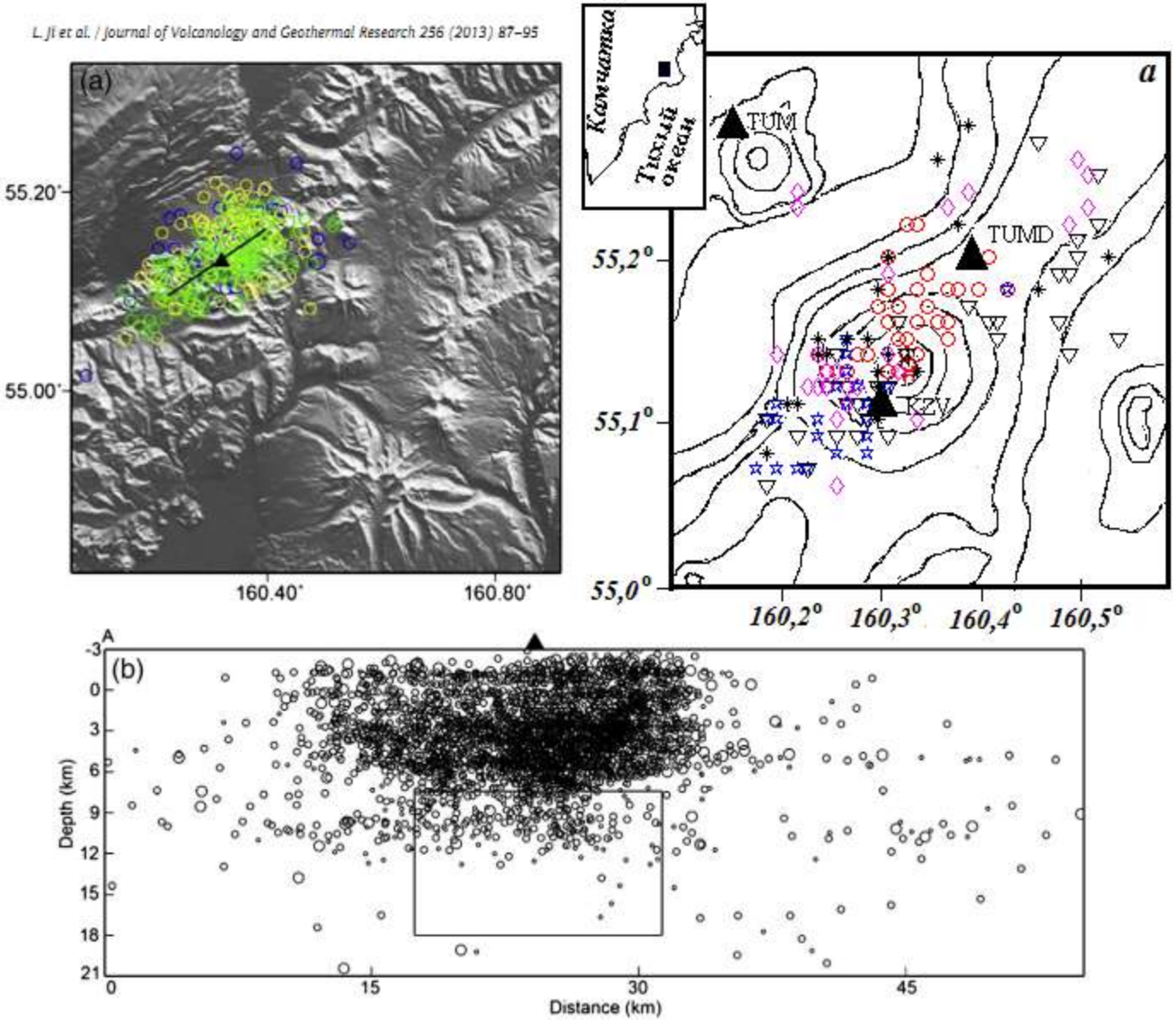


Fig. 7. (a) Epicentral distribution of earthquakes near Kizimen. Blue, yellow, and green circles represent earthquakes that occurred during July–December 2009, January–June 2010, and July 2010–November, 2011, respectively. For clarity, only earthquakes with $M_L > 3$ are shown. (b) Cross-section showing the depth distribution of earthquakes recorded from July 2009 to November 2010. Hypocenters were projected onto profile A–B (see Fig. 4b). Kizimen volcano is marked with black triangle, with surface projection of best-fit dike indicated by black line. Rectangle below shows boundaries of best-fit dike prior to its ascent to the surface. Open circles have same meaning as in Figs. 5 and 6. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



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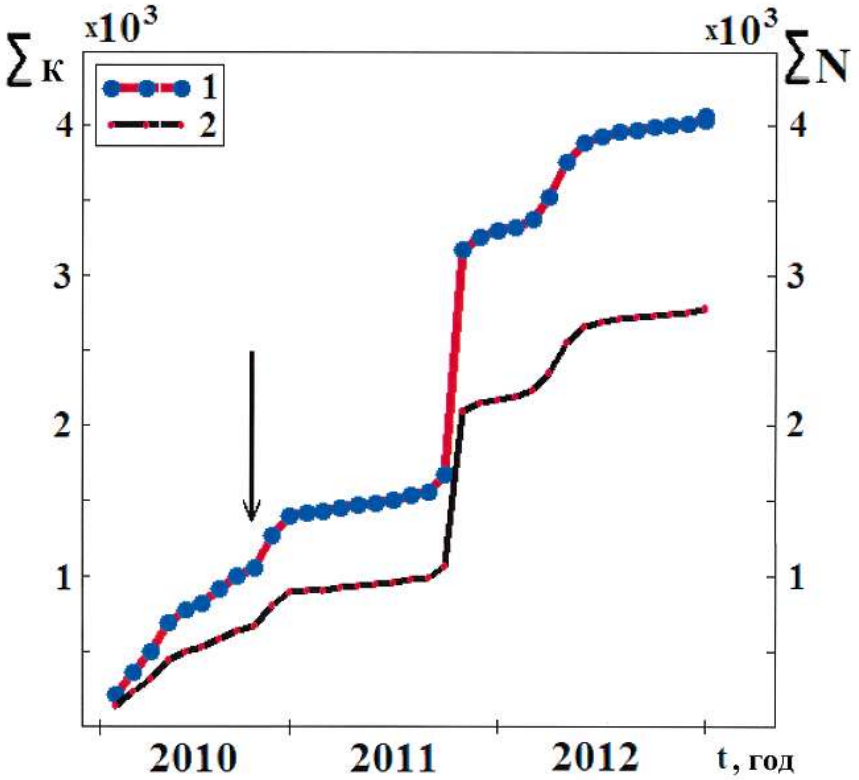
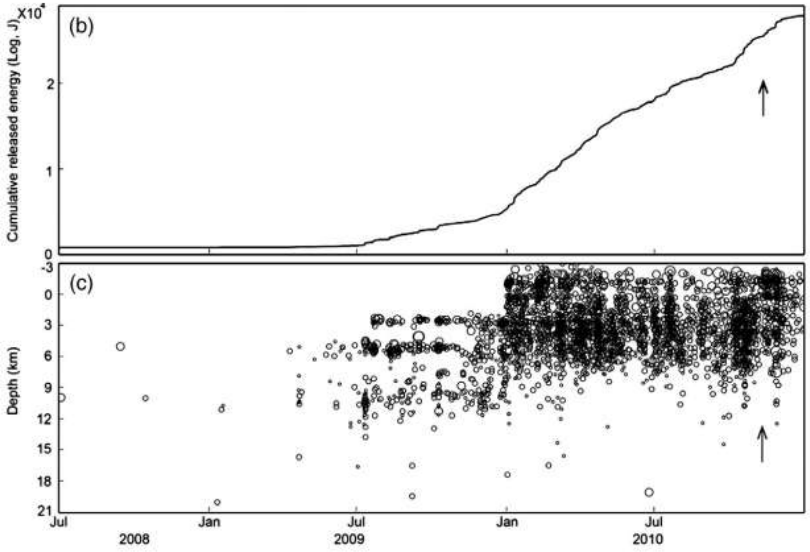

x10^3
∑к
x10^3
∑N
1
2
4
3
2
1
2010
2011
2012
t, год


(b)
Cumulative released energy (Log, J)
X10^4
2
1
0
(c)
Depth (km)
-3
0
3
6
9
12
15
18
21
Jul
2008
Jan
Jul
2009
Jan
Jul
2010

Заключение

Определено значимое изменение станционной поправки t^*, что означает сильное изменение условий распространение сейсмических волн в верхних слоях вулканической зоны вулкана Кизимен, связанное с увеличением его вулканической активности.

Спасибо за внимание!!!