An integrated approach to studying seismic activations in the Baikal Rift Zone based on processing emanation monitoring data

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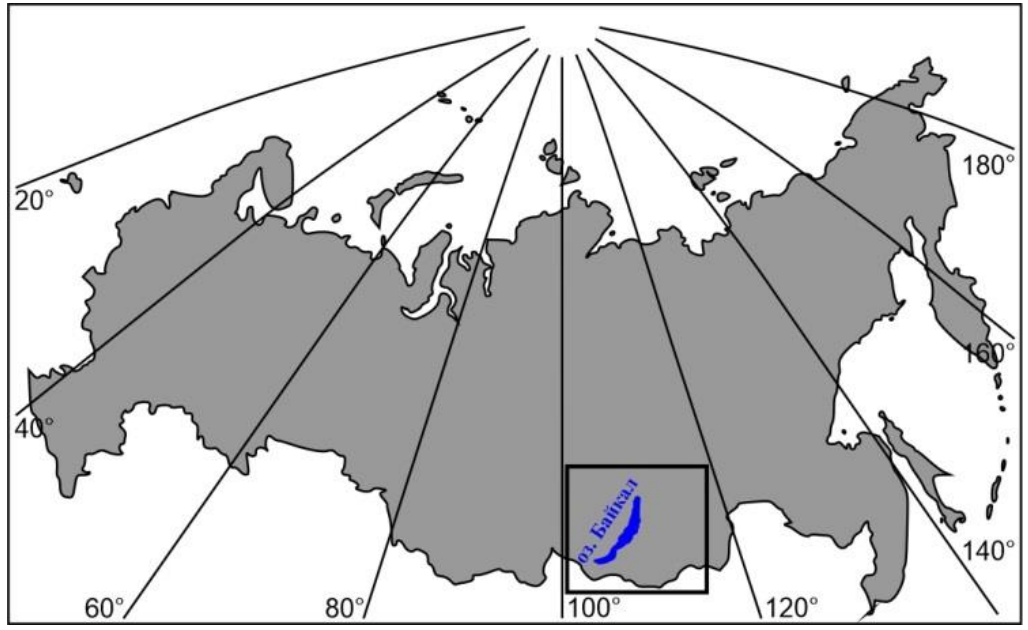
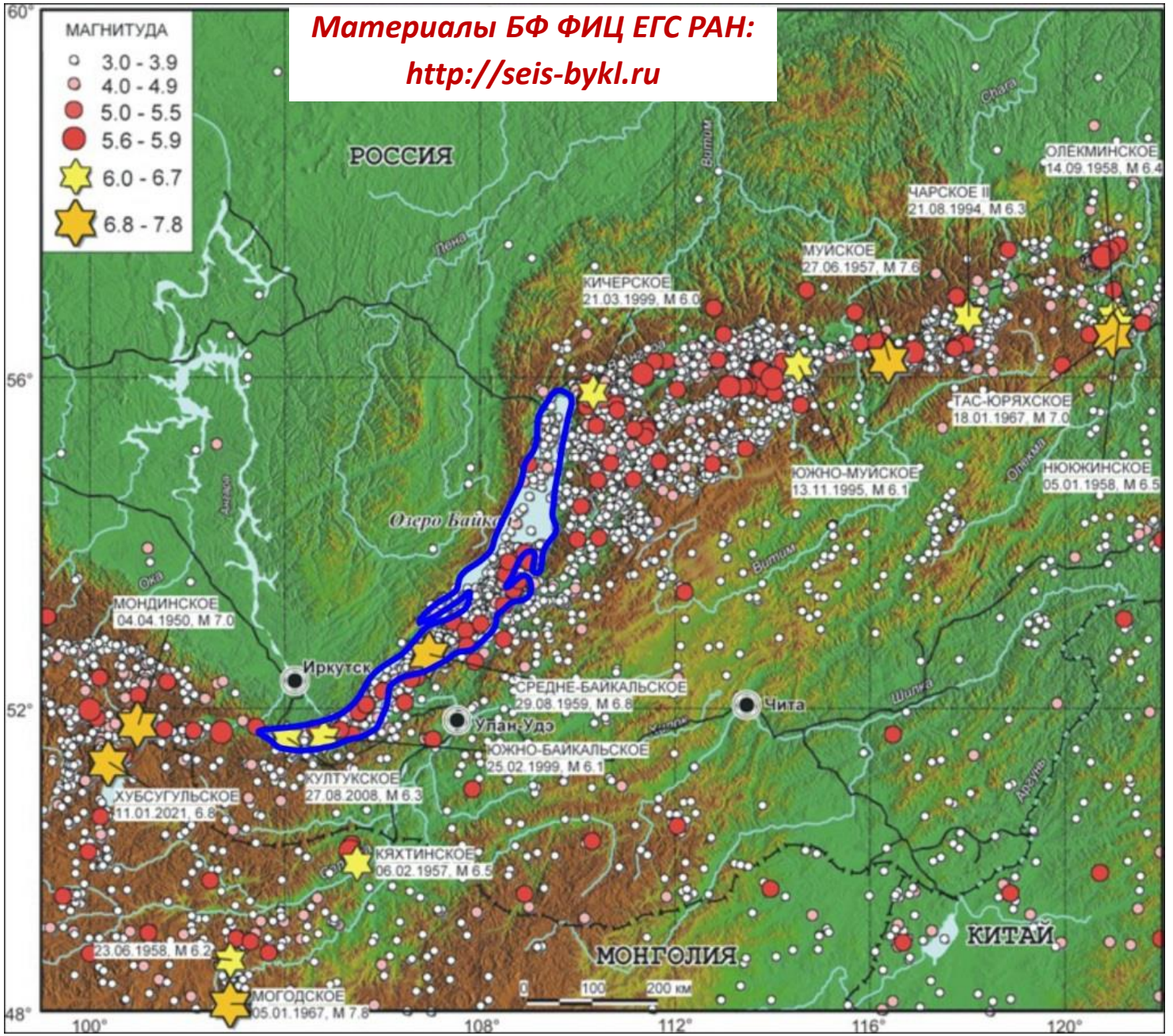
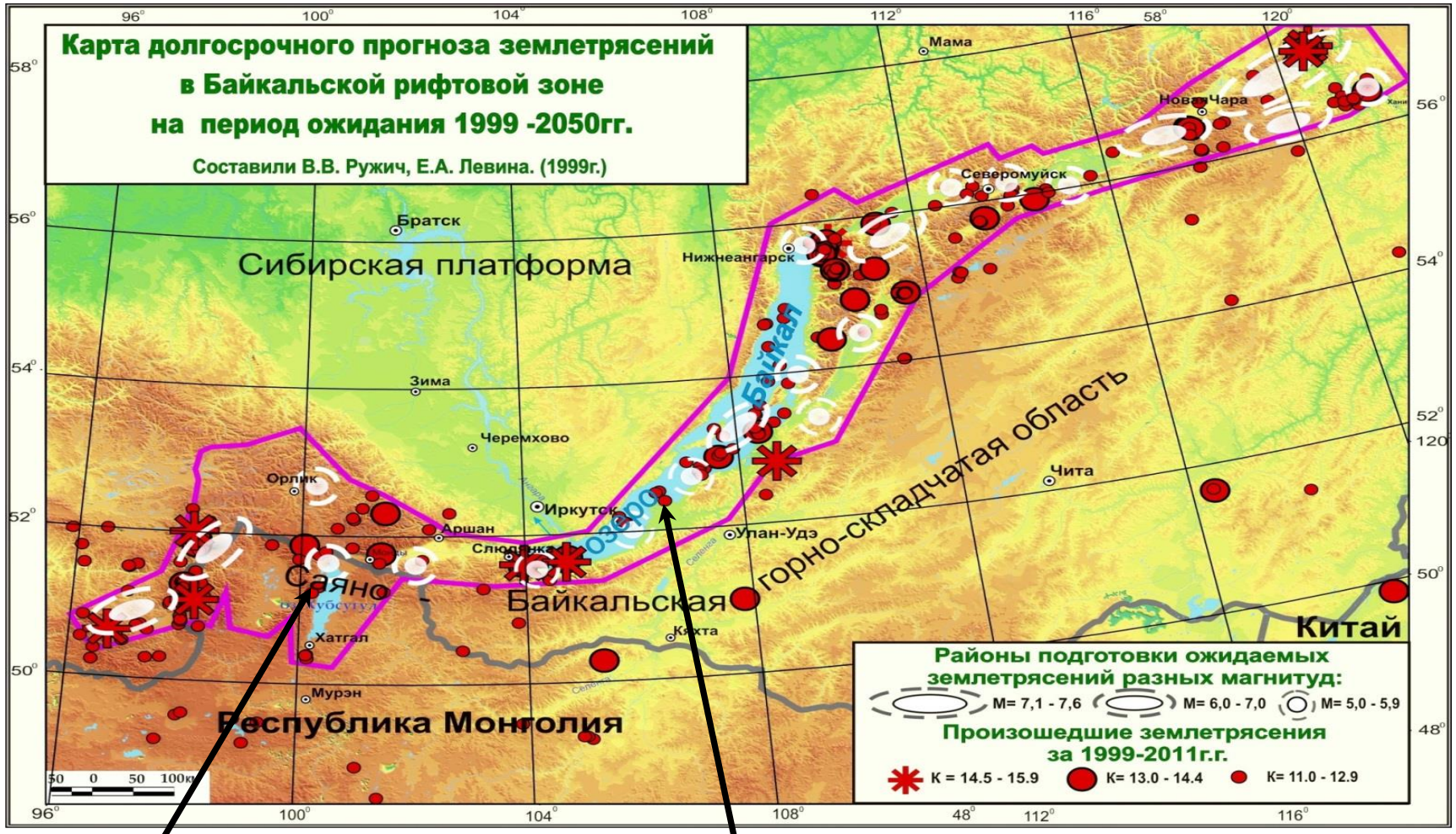
Map of earthquake epicenters with M>3 in the Baikal Rift Zone for the period 1950-2022





Dangerous earthquakes in the Baikal region and their long-term forecast



Хубсугульское землетрясение 11.01.2021г. Mw=6.8

Кударинское землетрясение 09.12.2020г. Mw=5.5

п.Тибельти, 2020 г., 6 б
(фото О.В.Луниной)

п. Култук, 2020 г., 6-7 б
(фото О.В.Луниной)

Повторяемость землетрясений: 7-8 баллов ~ 50 лет;
6 баллов ~ 15 лет, 5 баллов ~ 5 лет, 4 балла ~ 2 года.

Soil radon monitoring points

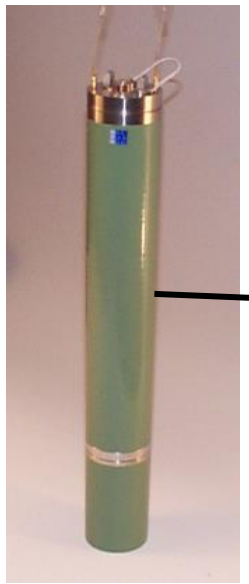
Organization of sampling of subsurface air

Radiometer «Barasol MC-2»,
(sensitivity – 50 Бк/м^3)

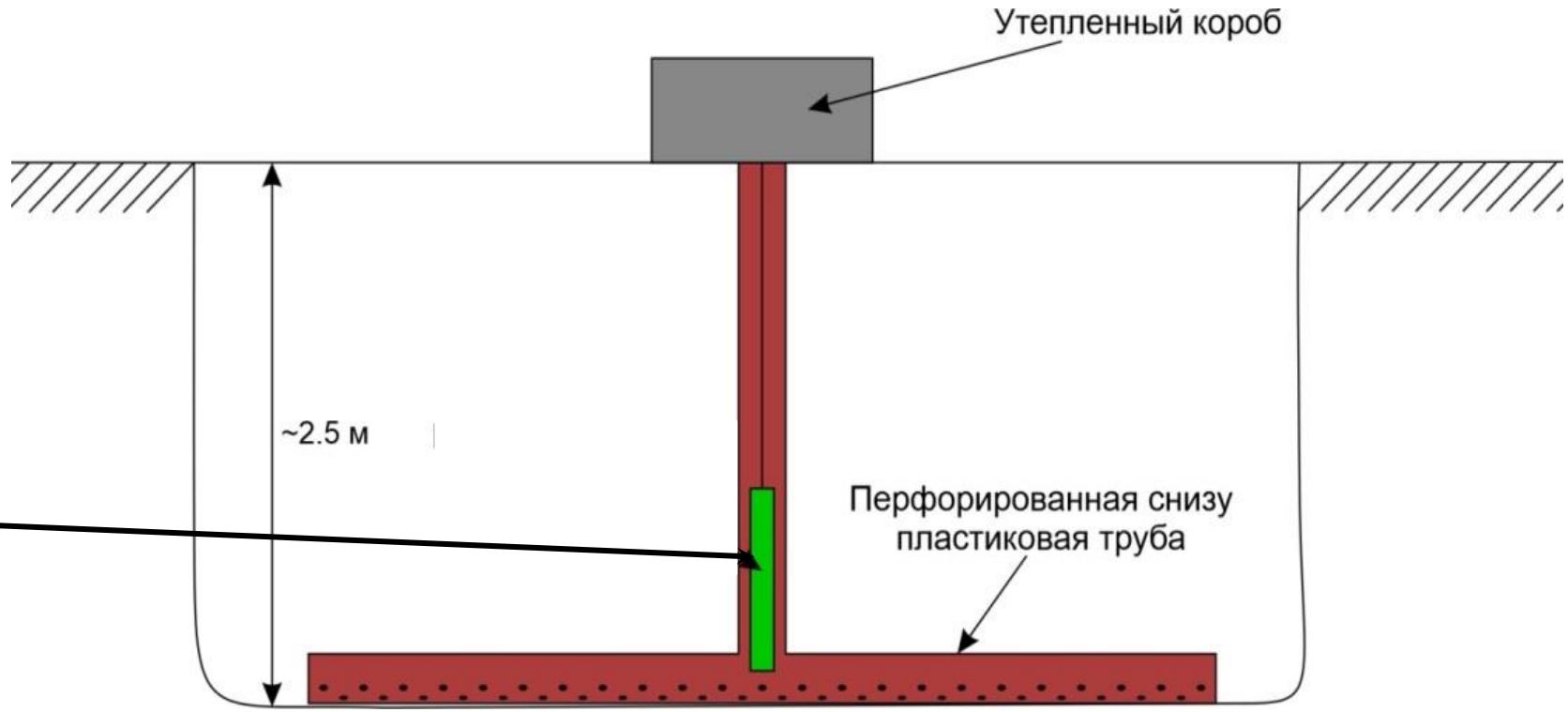
1 measurement per hour for:

Q – radon volume activity,

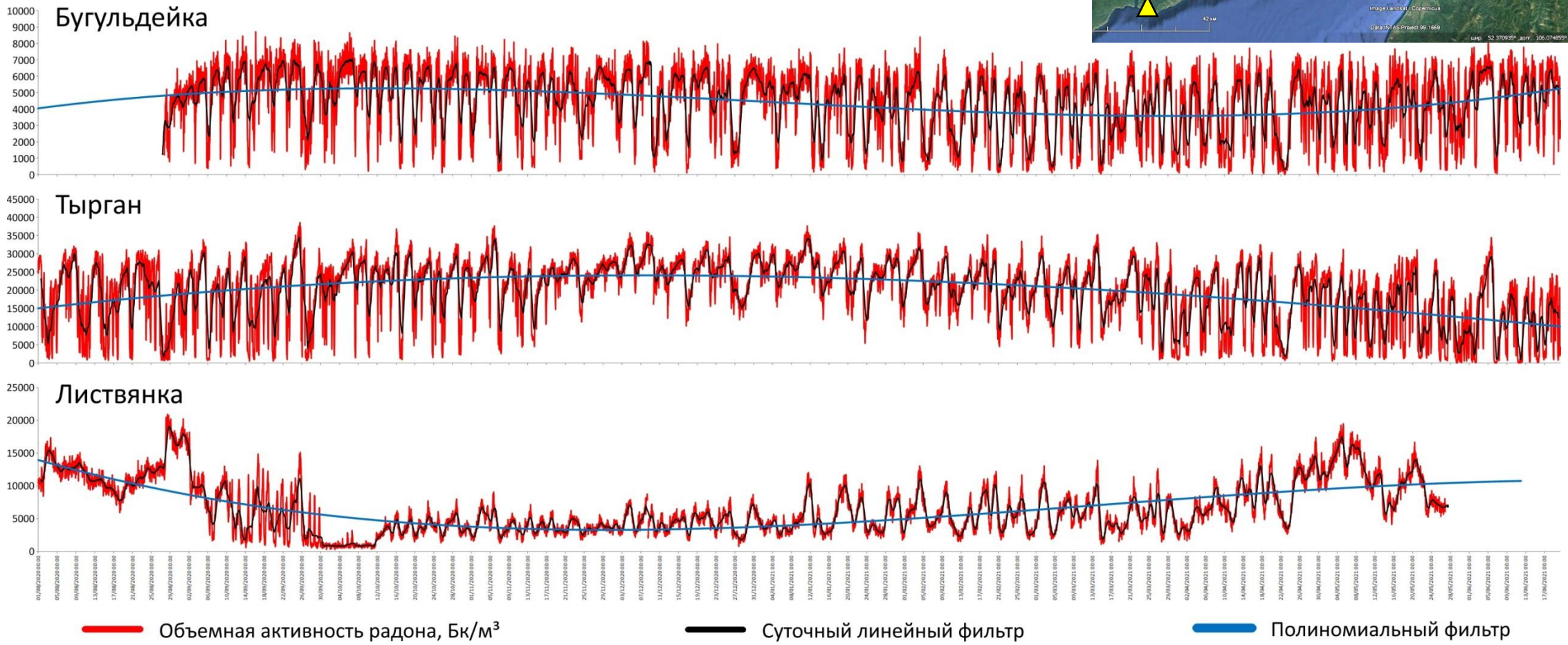
P **– atmospheric pressure**



Installation of the BMC-2 radiometer at the monitoring station



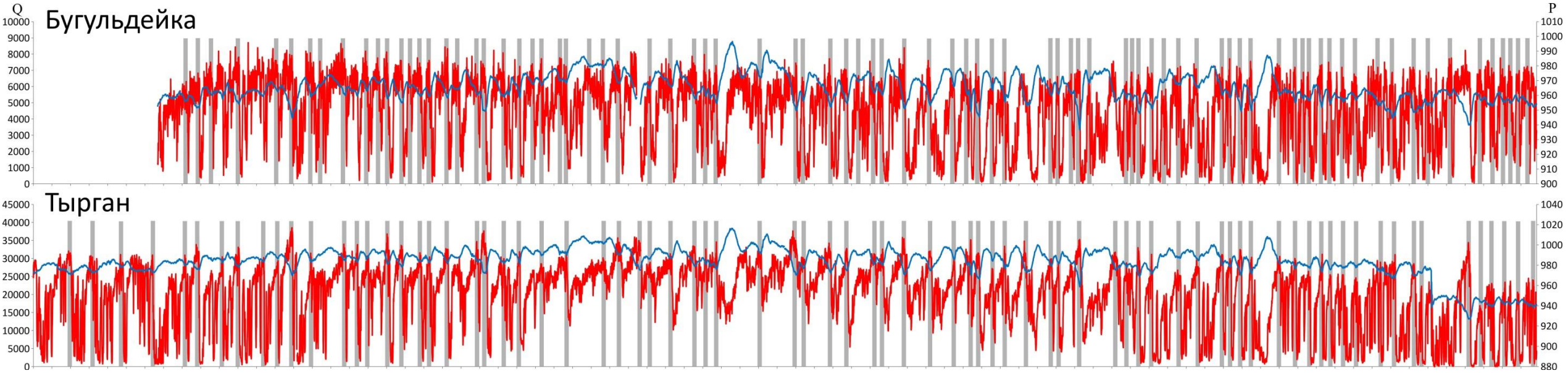
Graphs of variations in radon volume activity at three monitoring stations



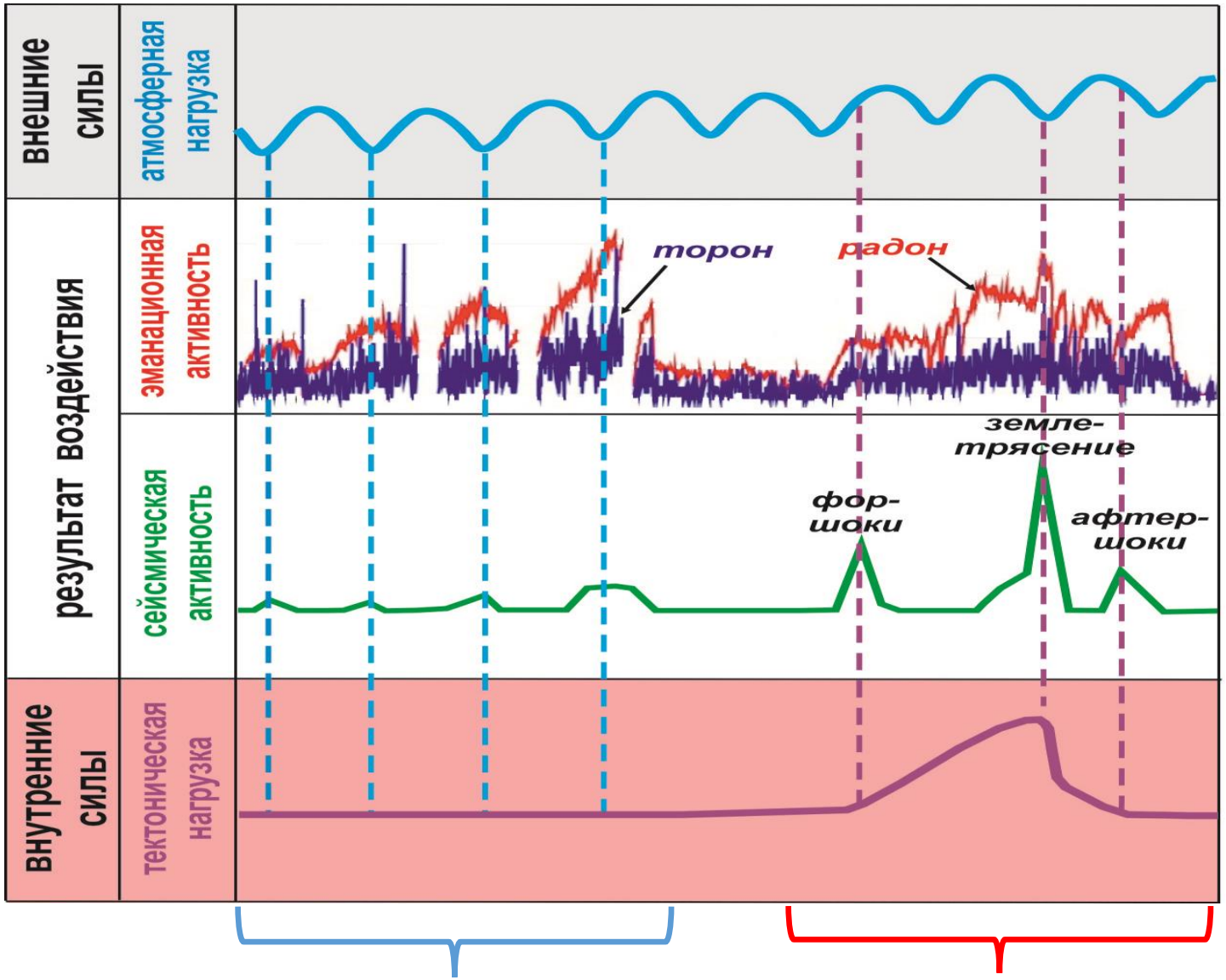
Relationship between radon volume activity and atmospheric pressure at the Buguldeika and Tyrgan stations

Объемная активность радона (Q), Бк/м^3 Атмосферное давление (P), мБар

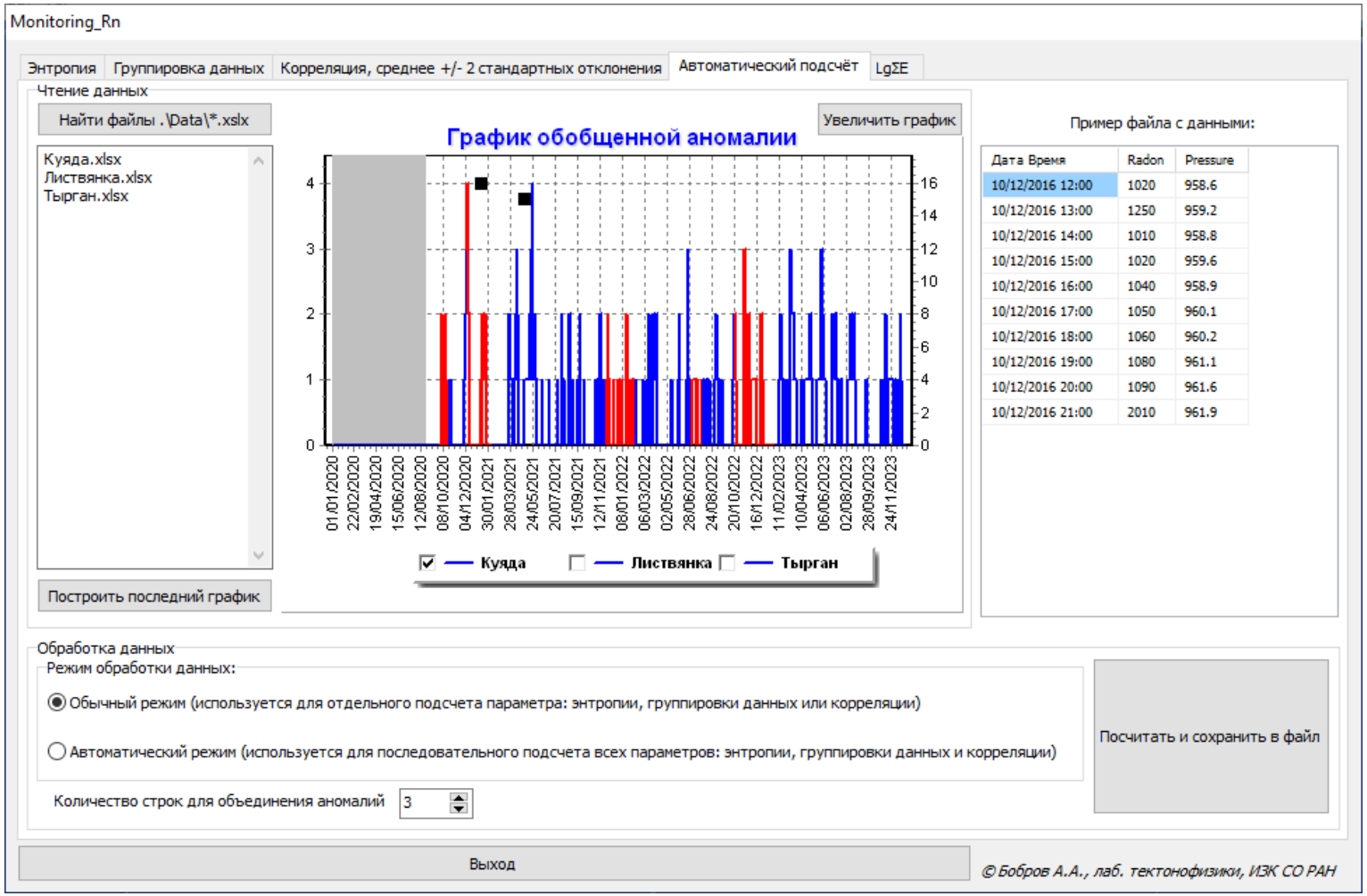
Области локальных максимумов радона и минимумов атмосферного давления



Model of dependence of soil radon activity on the impact of external and internal forces on a section of the earth's crust



The program «Monitoring_Rn» for processing emanation monitoring data



РОССИЙСКАЯ ФЕДЕРАЦИЯ

СВИДЕТЕЛЬСТВО

о государственной регистрации программы для ЭВМ

№ 2025668094

«Monitoring_Rn»

Правообладатель: *Федеральное государственное бюджетное учреждение науки Институт земной коры Сибирского отделения Российской академии наук (RU)*

Автор(ы): *Бобров Александр Анатольевич (RU)*

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Руководитель Федеральной службы по интеллектуальной собственности

Ю.С. Зубов

Methodology for processing emanation monitoring data using the Monitoring_Rn program

When studying the manifestation of such a large seismic activation as Kudarinskaya or Khubsugulskaya in the radon volumetric activity field, high-frequency fluctuations of the parameter caused by smaller seismic events occurring near monitoring stations should be considered as a complicating factor.

To eliminate it, **measurements were averaged with a window equal to 1 day**. The data series processed in this way can be used to identify emanation precursors related to the category of medium-term and, in part, short-term.

Statistical processing of emanation monitoring data

In addition to the volumetric activity of radon (*Q*) and atmospheric pressure (*P*), their information entropies S_Q and S_P, respectively, were used. This increases the efficiency of the analysis of the dependence of variations in *Q* and *P*, which, with the same measurement frequency, are characterized by significantly different oscillation intensities.

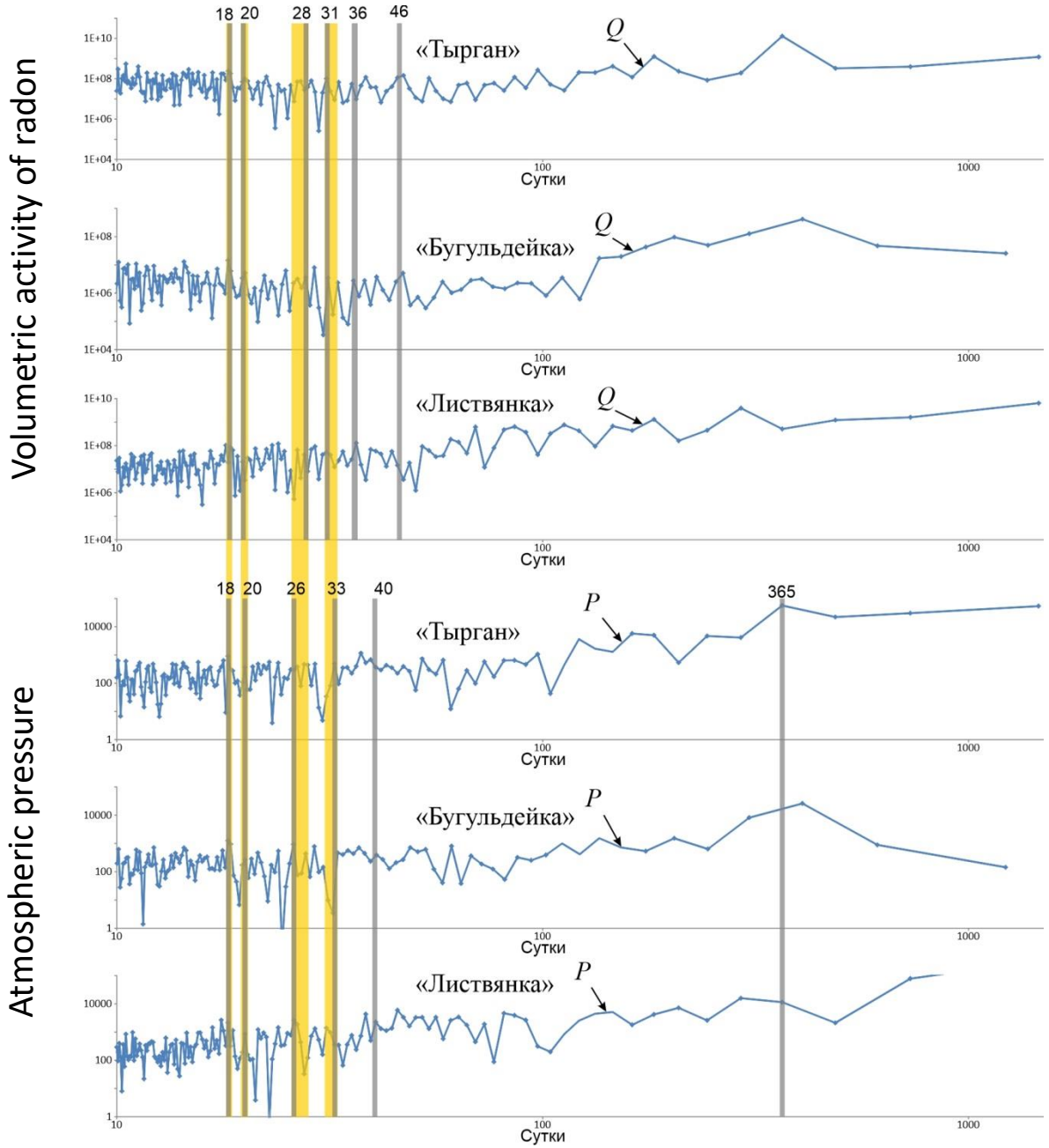
Information entropy was calculated using the formula:

$$S_{\text{inf}} = -\sum_{i=1}^{K} w_i \cdot \log_2 w_i \quad ,$$

w_i – discrete probability distribution for K

independent elementary events satisfying the condition $\sum_{i=1}^{K} w_i = 1$ [Shannon, 1963].

Periodograms of radon volume activity (Q) and atmospheric pressure (P) for the monitoring stations «Tyrgan», «Buguldeyka» and «Listvyanka», obtained using Fourier analysis

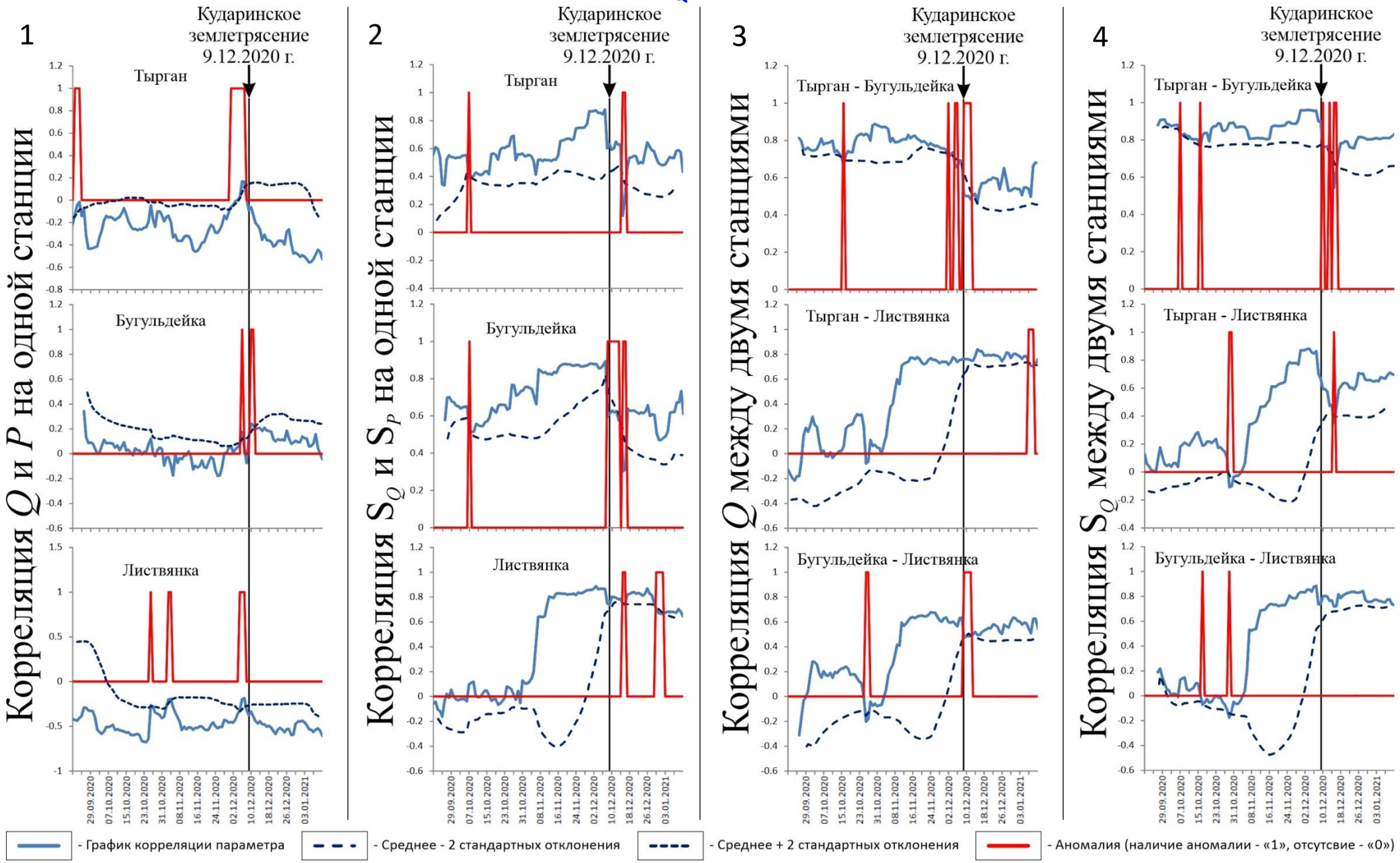


Gray stripes indicate local maxima corresponding to similar periods for each of the parameters Q and P at the three stations.
Yellow stripes indicate common periods for both parameters Q and P.

Previous studies have shown that in order to identify medium-term precursors of such strong seismic events for the region, for example, as Kudarinskoye, it is necessary to use a time interval of at least 24 days for correlation [Seminsky, Bobrov, 2023].

Taking into account the periods identified according to the Fourier analysis data, when calculating the correlations between radon (*Q*), atmospheric pressure (*P*), the **sliding window value of 31 days (month) was used**.

Graphs of changes in the correlation coefficients between the values of radon volume activity (Q), atmospheric pressure (P) and their information entropies (S_Q and S_P), calculated with a sliding window equal to 31 days

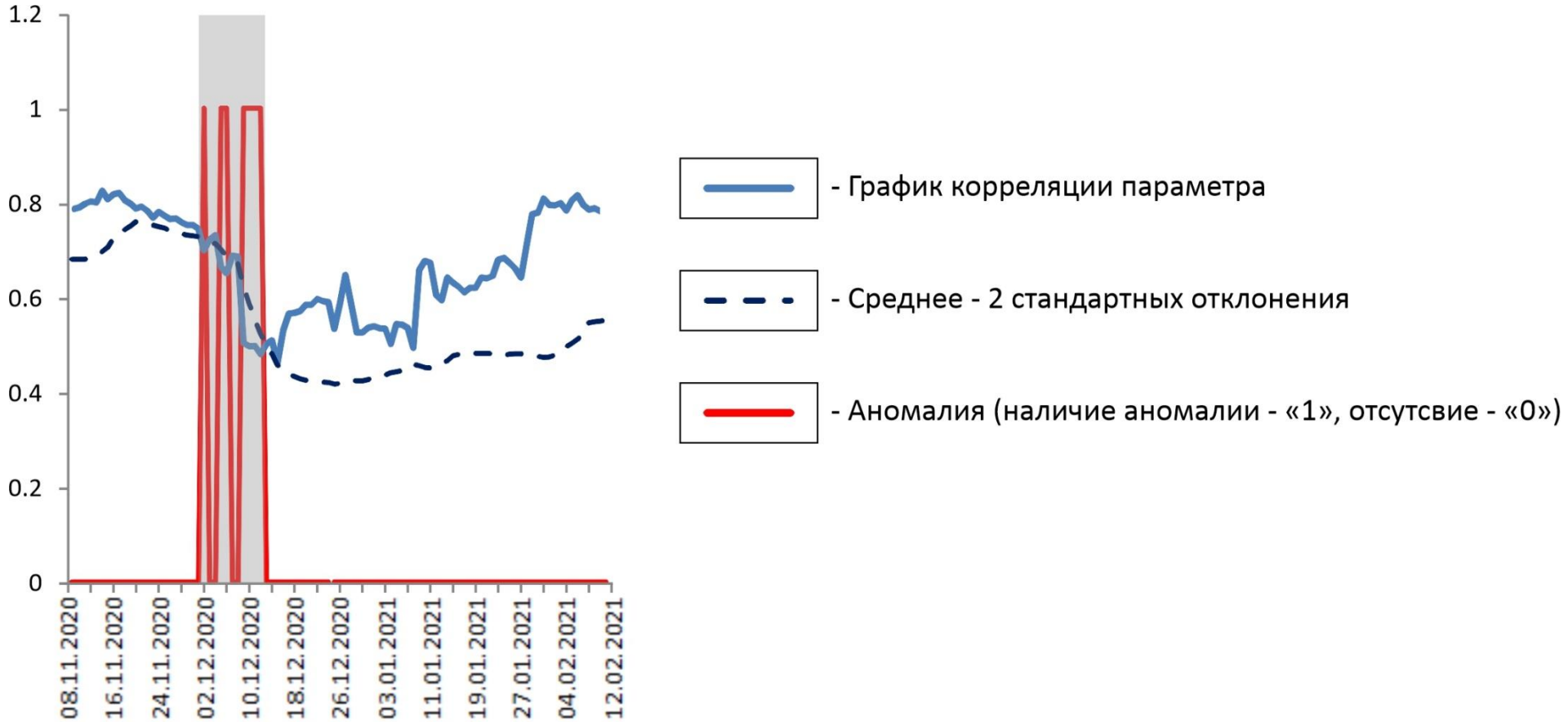


Anomalies on the graphs were considered deviations from the trends of the correlation coefficient by the value of the average plus/minus two sigma, depending on the nature of the dependence under consideration.

For clarity and simplicity of analysis, the **absence of anomalies on the graphs corresponded to the number "0", and the presence of anomalies corresponded to the number "1" (red color).**

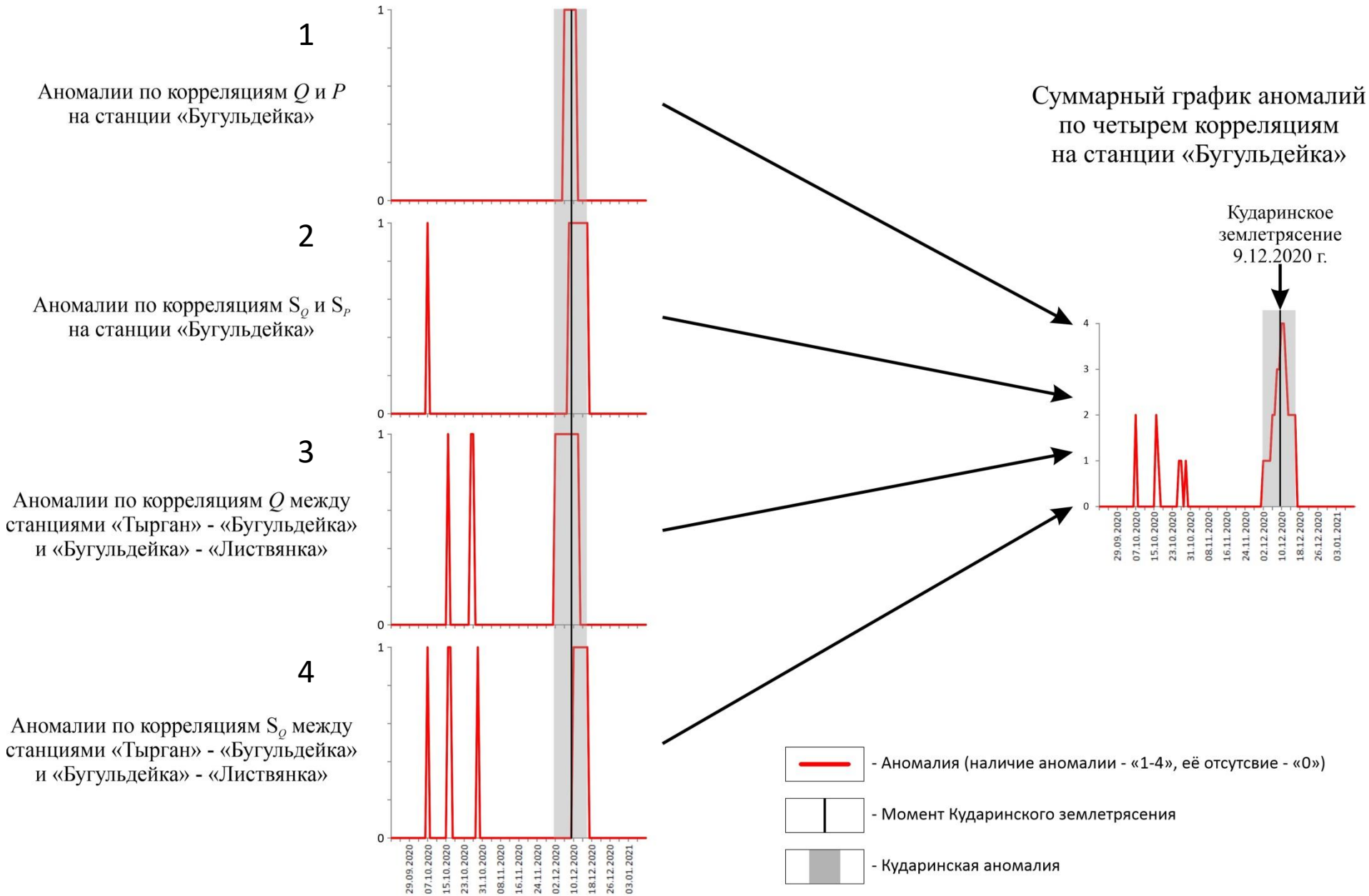
An example of combining a series of local anomalies

Three closely spaced local anomalies stand out on the curve, the trend of which indicates a decrease in the parameter.

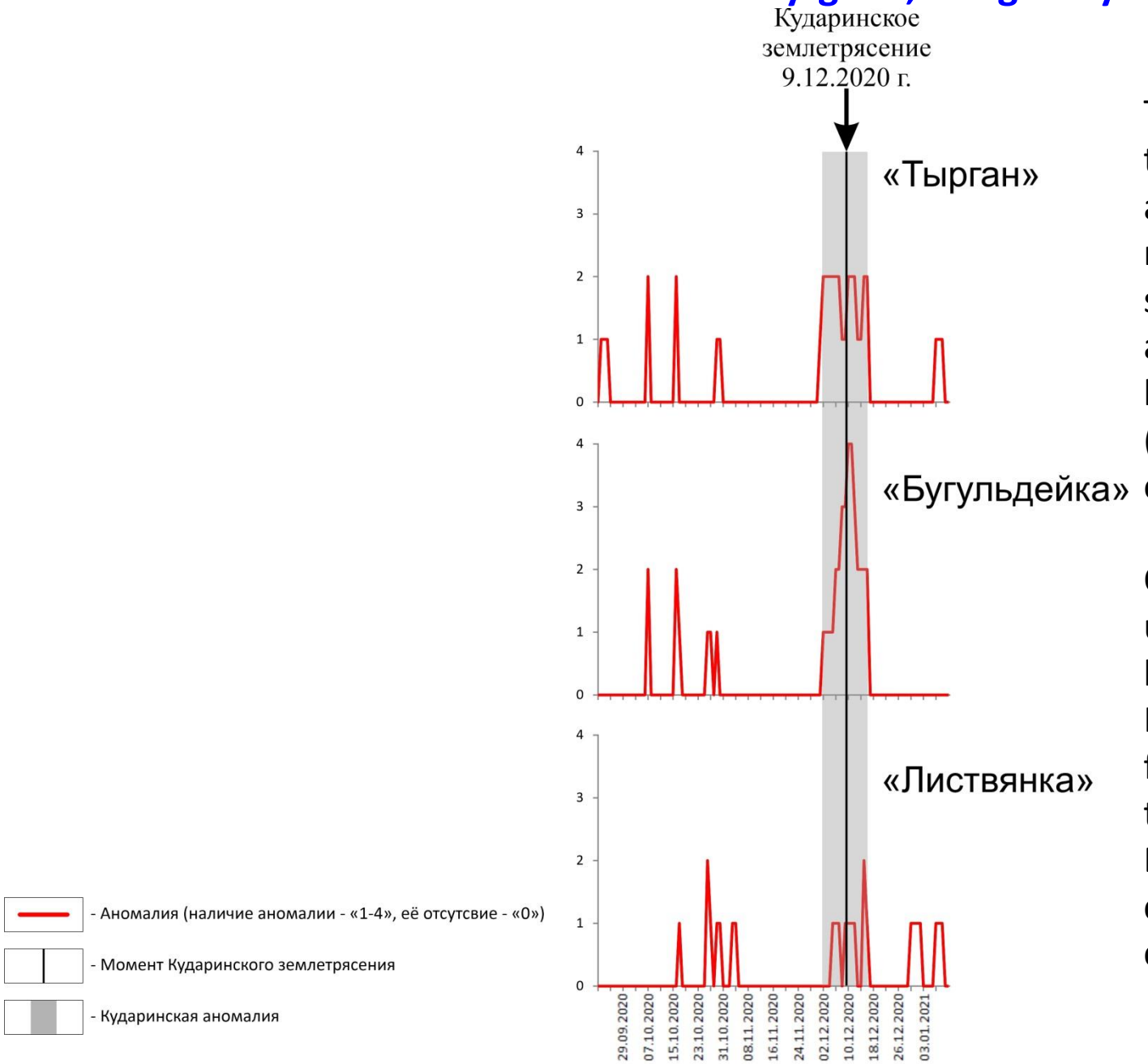


The division into three parts is due to high-frequency variations with the intersection of the mean line minus two sigma. In most such situations, the distance between a series of local anomalies is from 1 to 3 days. In further analysis, with such a frequency of peaks and belonging to a single trend, local anomalies were combined into one (gray strip).

Graphs of grouped and generalized anomalies calculated using four different correlations with a sliding window of 31 days for the Buguldeyka station



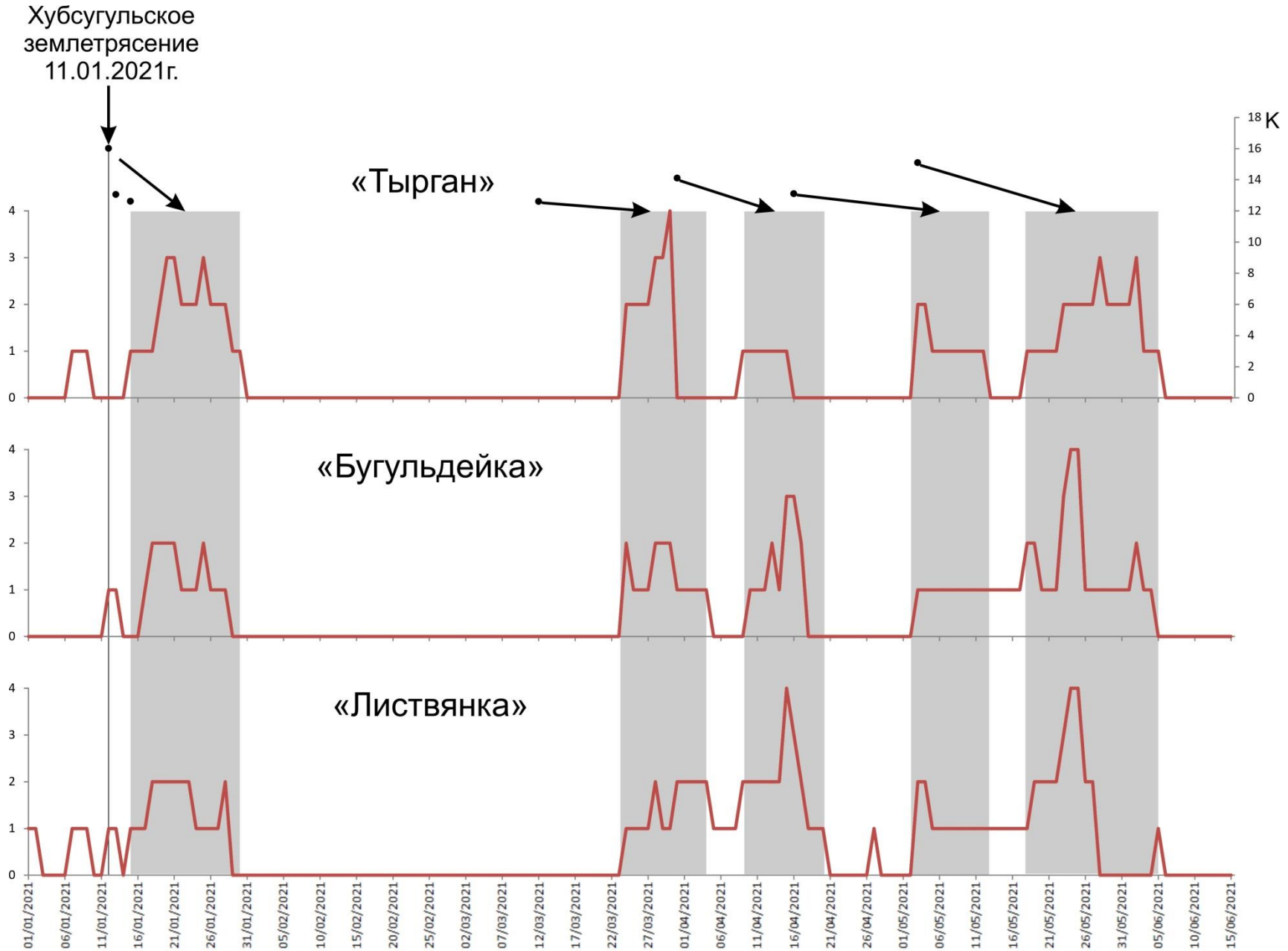
Summary graphs of anomalies of the Kudarinsky earthquake, calculated with a sliding window equal to 31 days for the stations «Tyrgan», «Buguldeyka» and «Listvyanka»



The summary graphs of anomalies indicate that the moment of the Kudarinsky earthquake is associated with a fairly long period of manifestation of anomalies identified during the statistical analysis of emanation monitoring data at each of the stations (gray color). This period begins a week before the seismic event (02.12.2020) and ends a week after the earthquake (16.12.2020).

On the left side of the graphs, anomalies of 2 units are highlighted. On the one hand, they can be considered as the first manifestation of the Kudarinskaya seismic activation in the radon field. On the other hand, they are located in time quite close to the moment of the Bystrinsky earthquake (21.09.2020), i.e. they can be considered effects caused by the consequences of an earlier seismic event.

Summary graphs of anomalies of the Khubsugul earthquake, calculated with a sliding window equal to 31 days for the stations «Tyrgan», «Buguldeyka» and «Listvyanka»

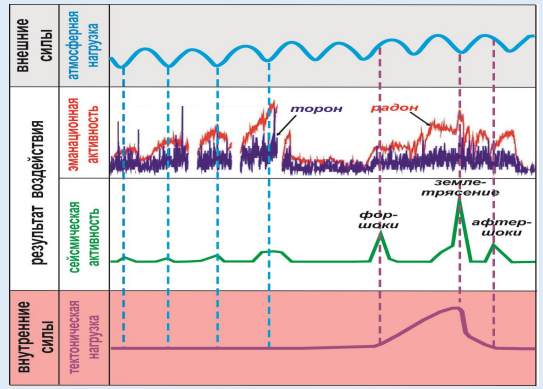


The summary graphs of anomalies show that there is a long period of anomalies at each station (gray color) associated with the Khubsugul earthquake. This period begins 4 days after the seismic event (15.01.2021) and ends 2 weeks later (30.01.2021).

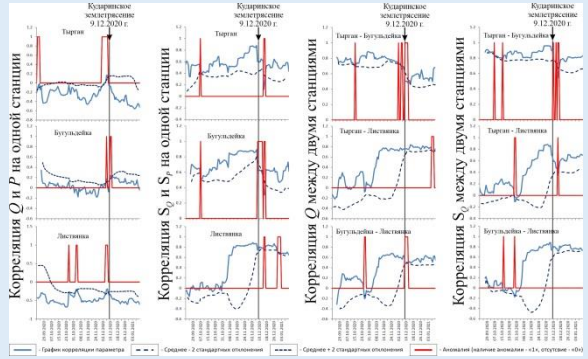
Large aftershocks (K>12.6) of the Khubsugul earthquake are characterized by a similar "lag" of anomalies. On average, the "lag" of anomalies is about 2 weeks.

Conclusions

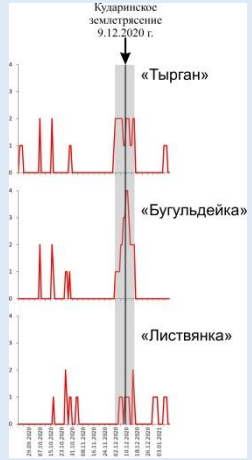
1. The effectiveness and legitimacy of the developed strategy for processing emanation monitoring data is determined by the fact that it is based on a model that explains fluctuations in the volumetric activity of subsoil radon in the Baikal region under the influence of external and internal factors.



2. An approach has been developed to identify anomalies associated with the preparation and occurrence of strong earthquakes in the Baikal region, based on the comprehensive identification of violations in the relationship between the volumetric activity of radon and atmospheric pressure.

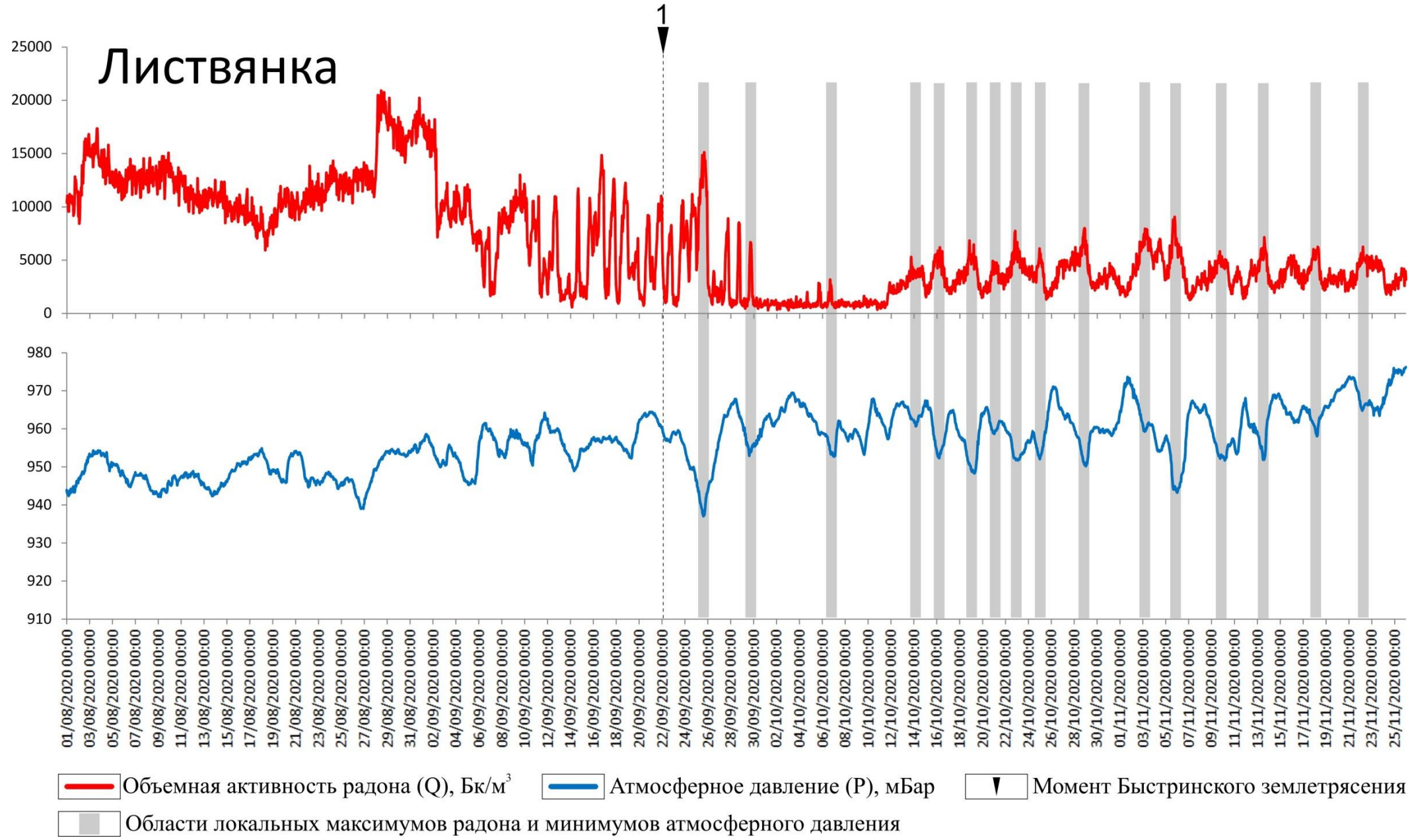


3. The Monitoring_Rn program allows for rapid statistical processing of long series of radon emission data from different stations and the identification of anomalies corresponding to major seismic events in the region.

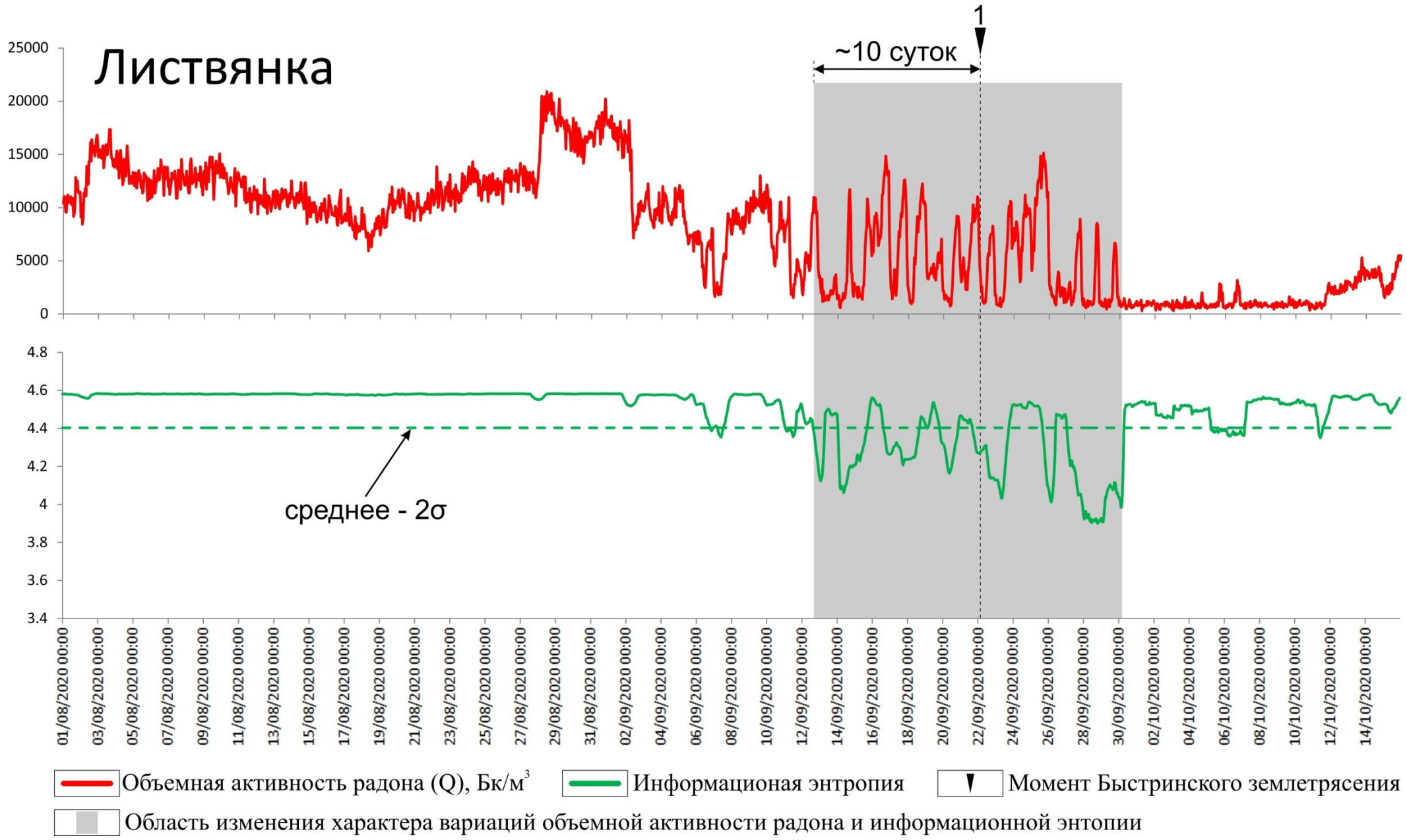


Thank you for your attention!

Нарушение связи объемной активности радона с атмосферным давлением, проявившееся на станции Листвянка перед Быстринским землетрясением



Изменение в характере вариаций объемной активности радона и информационной энтропии на станции Листвянка, ассоциирующееся с Быстринским землетрясением



Повышение амплитуд вариаций объемной активности радона на станции Листвянка после Хубсугульского землетрясения