SEISMOTRANSMITTANCE EFFECTS IN APPLICATION TO ECOLOGICAL MONITORING

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Received November 27, 1995

The main task of seismoecology – the forecast of strong earthquakes – is discussed in the paper. Based on known earthquake forerunners in the lithosphere and the atmosphere, we propose the spectral transmittance of the atmosphere to be treated as an earthquake forerunner. Variations in the statistical characteristics of the spectral transmittance before and after seismic events are analyzed. Space systems are proposed to be applied to monitor the atmospheric spectral transmittance.

The problems of organization of an effective ecological monitoring of local regions are much complicated. Among them are a wide variety of problems connected with providing safe living conditions on the earth. Recently such direction of ecology as seismoecology has evolved. It is aimed mainly at the forecast of strong earthquakes and the diagnostics of geophysical fields in different earth's envelopes.

In the theory of the Sun-to-Earth relations two main approaches are used to explain the mechanisms of interaction between perturbations in geophysical fields. They are based on the theory of propagation of internal gravitational waves (IGW) and infrasound in the atmosphere and the interaction through the perturbation of the earth's electromagnetic field.

At present vast material has been compiled on perturbation of geophysical fields before earthquakes or, in other words, on earthquake forerunners.

Appearance of earthquake forerunners and aftereffects in geophysical fields reflects the stages of a seismic cycle and evolution of a seismotectonic anomaly (STA).[1] Natural perturbations of the geophysical fields complicate the isolation of the forerunners. Analysis of the structure of the perturbations in the parameters under control may be an additional source of information for STA detection and diagnostics.

In the near-ground lithosphere the position of the majority of forerunners of strong earthquakes is oriented about STA and results in anomalous changes of the following parameters[1]:

– characteristics of the natural earth's electromagnetic field;

– intensity and spectrum of acoustic emission;

– deformations and stresses of the near-ground layer of the lithosphere;

– electric resistance of rocks and tellurian currents;

– magnetic field;

– gravitational potential;

– microseism level and changes in speed of seismic waves;

– hydrogeochemical regime;

– temperature;

– radiation background.

Unusual seismo-gravitational pulsations have been revealed in the regime of natural earth's oscillations. From some unconfirmed data it follows that the zones of development of strong underwater lithospheric earthquakes are characterized by an elevated water level.

In the troposphere among the meteorological forerunners of strong earthquakes are seismoclimatic anomalies, appearance of forerunning unusual longfibred cirrus clouds over the sites of earthquakes origin,[2] unusual pressure pulsations, effect of violation in an equilibrium dependence of pressure and temperature variations in the near-ground atmospheric layer,[3] an increase in the number of days with dense hazes and fogs and poorer visibility,[4] significant barometric gradients between neighbouring regions, approach of frontal boundaries,[5] unusual light phenomena, bright bursts, lightning in the atmosphere over STA several seconds or minutes before the main event.[6]

As to the stratosphere, the study of seismo-ozone effects should be noted, as well as the increase in the flux of the ionizing component of space rays and charged particles.[7,8]

From the viewpoint of ecological monitoring, the meteorological earthquake forerunners, which characterize the state of the atmosphere, deserve certain attention. Atmospheric turbidity, more frequent dense hazes and fogs, formation of near-ground cyclones on the background of small-gradient diffuse pressure field were noticed several days before strong earthquakes.[4] But the quantitative characteristics of these effects are unknown. Therefore the subject for study in this paper is only the diagnostics of the characteristics of the atmospheric spectral transmittance (AST) over earthquake zones before and after them.

0235-6880/96/04 328-04 $02.00

According to Ref. 9, by the AST we mean the ratio of the flux of quasimonochromatic radiation, passed through the atmosphere to the earth's surface as a parallel beam in the direction Φ_0 to the vertical, to the radiation flux at the same wavelength at the upper boundary of the atmosphere Φ_u. For AST we use the symbol P_λ, where subscript λ denotes the wavelength.

The network of stations for measuring AST was organized in the USSR in 1969–1972, and since that time the data on AST are published in year-books.[10] However, this information in its immediate form is not suitable for statistical processing, because of the presence of a great number of missings in the observation data. They are due to the technique of AST measurements, which was proposed in Ref. 9 and requires the observations to be performed against the Sun in cloudless days or through breaks in cloudiness. That is why we have selected the Middle Asian region for quantitative diagnostics of the seismotransmittance effects. In this region strong earthquakes often take place and a largest number of sunny days is observed.

As a result of analysis of the initial data, six matrices have been formed from the AST characteristics. In them we have collected 28 series of observations of AST for periods ±7 days from a seismic event. Selected were only sufficiently strong near-surface earthquakes in the Middle Asia in 1973–1982.

It should be noted that there are many missings in the data on AST. In five cases, we had to unite several days with the series of earthquakes occurring in them into one common "reference" day. As the initial data, we used the data on AST from the year-books for station Chardzhou (39°05′N, 63°36′E)[10] and the data on seismic regime for the Middle Asian region.[11] AST measurement data correspond to the wavelengths: 344, 369, 463, 530, 572, and 627 nm. An example of initial information for a given wavelength is listed in the Table I.

To improve the homogeneity of the observation series, the data on AST were normalized as

$$Y_{ij} = (X_{ij} - \bar{X}_i)/\sigma_i, \qquad (1)$$

where Y_{ij} is the normalized value from the ith row corresponding to ith earthquake; X_{ij} is the corresponding value before the normalization; $\bar{X}_i$ is the mathematical expectation of the ith row; σ_i is the rms deviation of the ith row.

TABLE I. Spectral transmittance of the atmosphere $P_\lambda \cdot 100$ at λ = 344 nm.

No.	Date	Magnitude	Days														
			−7	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	7
1	08.02.73	–	00	00	00	40	00	00	43	42	00	43	47	47	48	48	44
2	18.02.73	5.1	47	47	48	48	44	48	46	46	48	00	38	00	00	45	47
3	14.04.73	4.5	46	47	00	00	00	45	37	34	41	46	43	00	42	46	38
4	21.04.73	4.5	34	41	46	43	00	42	46	38	00	00	00	00	39	39	38
5	08.05.73	4.5	00	43	43	00	00	40	37	40	42	45	41	41	45	46	39
6	01–10.06.73	5.5	00	44	47	47	48	47	46	39	41	43	46	43	40	41	38
7	11.08.73	4.6	47	43	41	48	44	43	42	43	49	48	48	47	46	46	41
8	01.09.73	4.5	45	43	49	49	43	40	47	45	00	46	49	45	00	44	51
9	11–14.09.73	4.5	44	45	00	44	51	48	37	48	51	49	47	46	46	45	00
10	12.10.73	5.6	41	40	42	39	39	46	35	39	42	00	46	49	50	00	39
11	24.10.73	4.5	50	00	39	47	48	47	47	48	47	45	00	46	38	00	48
12	03.06.74	5.1	48	43	47	45	44	44	47	42	00	41	43	42	41	00	49
13	02–05.07.74	5.0	44	43	43	44	43	00	46	47	43	41	44	44	44	44	48
14	23.07.74	4.8	45	41	45	49	00	00	00	48	49	48	45	43	00	00	51
15	29.07.74	4.6	00	48	49	48	45	43	00	00	51	00	00	52	52	48	00
16	09.06.75	5.7	00	42	43	40	00	00	41	32	27	00	36	42	41	44	40
17	26.06.75	4.8	40	44	45	41	46	44	36	42	42	42	46	44	47	45	00
18	28–31.07.75	5.1	39	38	43	48	45	44	38	42	46	45	41	47	44	44	44
19	09.09.75	5.8	54	46	47	00	50	48	45	00	39	00	38	40	45	43	46
20	17–20.06.76	5.3	44	43	46	44	00	40	43	42	40	44	41	42	44	39	36
21	03.08.76	5.7	49	47	44	49	00	48	49	47	48	49	49	00	46	49	44
22	03.09.76	5.3	83	00	51	47	42	41	45	46	41	43	42	46	47	44	00
23	14.07.77	6.1	43	00	42	42	32	00	46	48	52	49	45	49	48	45	49
24	08.10.78	6.0	46	00	42	41	00	44	37	41	39	42	48	45	42	34	00
25	19.10.78	5.1	45	42	34	00	45	00	35	39	40	41	00	38	46	00	00
26	10.07.79	4.6	49	43	39	38	41	38	45	44	43	45	11	48	41	46	45
27	31.05.82	–	33	00	39	31	00	00	00	31	29	28	00	29	31	32	35

Days with gaps in observations were prefixed and taken into account in the further processing of the normalized AST values. Nonuniformity of AST data was also taken into account through the weighting factors for different-accuracy observations and the coefficient of data completeness. When constructing a generalized pattern of seismotransmittance effects, the different accuracy of observations was taken into account via the following expression:

$$\bar{Y}_j = \sum_{i=1}^{28} Y_{ij} \left[\frac{1}{\sigma_i^2} \Big/ \left(\sum_{i=1}^{28} \frac{1}{\sigma_i^2} \right) \right], \tag{2}$$

where $\bar{Y}_j$ is the value averaged over the matrix column, i.e. over all 28 events, in the fixed jth day; σ_i^2 is the variance of the normalized AST for every row (event). The coefficient P_j was introduced to compensate for incompleteness of data in the jth column:

$$P_j = (28 - n_j)/28, \tag{3}$$

where n_j is the number of gaps in the jth column. An additional assumption implies that the total weight of an observation averaged over the jth day is the product of the above weighting factors for the different accuracy of observations and the column completeness. The statistical processing of the ozonometric data following the above scheme was accepted appropriate in Ref. 7.

As a result of using this scheme for computations, the characteristics of seismotransmittance effects were obtained at six above-listed wavelengths. As an example of the results obtained, Fig. 1 presents the "portraits" of mathematical expectation, while Fig. 2 shows that for the rms deviation of the normalized and weighted AST data at two wavelengths: 344 and 572 nm.

Analyzing the plots it is possible to draw the interesting conclusions about the feasibility of using the AST and its statistical characteristics in the seismic monitoring of local areas.

1. At shorter wavelengths (λ = 344, 369, and 443 nm) the minimum mathematical expectation of the normalized AST value is noticed one day before an earthquake, whereas at longer wavelengths (λ = 530, 572, and 627 nm) it is observed during the day of a seismic event.

2. The run of the mathematical expectation is significantly more smoothed and informative than that of the rms deviation.

3. Total energy of oscillations of the AST rms deviation, defined as an area below the corresponding curve, is greater before an earthquake than after it. And at longer waves the rms deviation reaches its minimum almost two days after an earthquake.

Thus, the turbidity of the atmosphere on the day of an earthquake is confirmed, on the whole, by calculations with the use of the Student criterion. On that day, the averaged value of the AST is out of the 95% confidence interval.

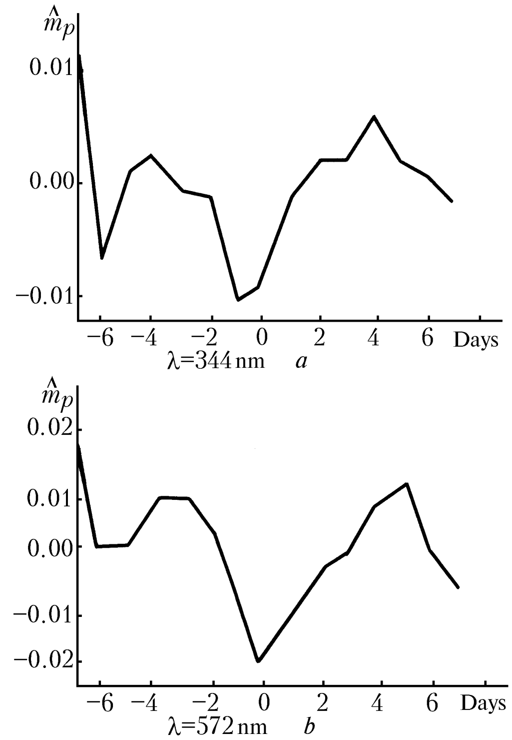

FIG. 1. Mathematical expectation of the normalized AST for 344 *and* 572 nm *wavelength ranges in the seismogenic sequence. (The earthquake occurred on zeroth day.)*

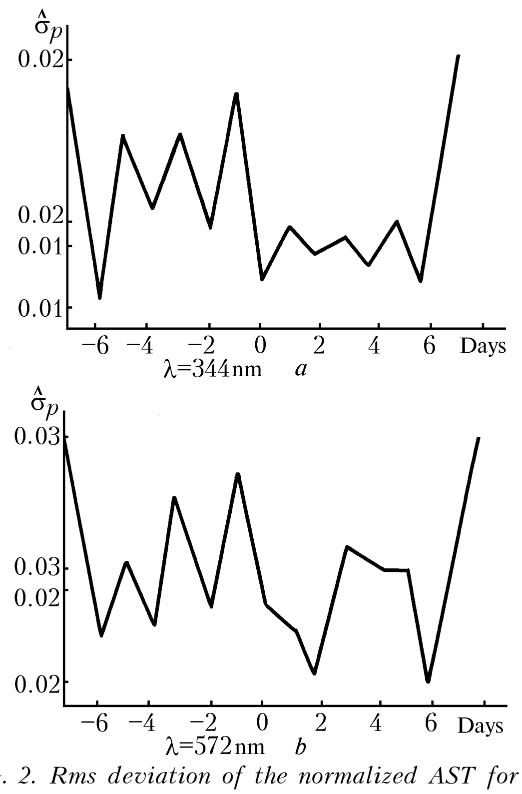

FIG. 2. Rms deviation of the normalized AST for 344 *and* 572 nm *wavelength ranges in the seismogenic sequence. (The earthquake occurred on zeroth day.)*

The results obtained allow us to expect that the problem of AST monitoring will be included into the list of specific problems of the nature study from space presented in Ref. 12. This monitoring can be carried out using different techniques: spectrometric, photographic, and TV in all the six wavelength ranges, mentioned above, as well as visual-instrumental ones in four longwave spectral ranges. As follows from Ref. 12, each of these techniques has its advantages and disadvantages in solving specific problems of the nature study from space. Therefore, it is worthwhile to combine the above techniques and to carry out the complex space-time measurements.

Use of space systems in indirect observations over the seismic regime via the detection of changes in the AST may increase the AST observation series and thus help to separate out new forecasting effects.

On the whole, it should be noted that diagnostics and monitoring of the atmospheric transmittance allow one to obtain indirect information about the seismic regime in a region.

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