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Multidisciplinary Geophysical Observations at the Petropavlovsk Site, Kamchatka

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In 1995–1998 the Kamchatkan Experimental Seismological Team (KEST), Geophysical Service (GS), Russian Academy of Sciences (RAN) conducted, in cooperation with other research and production organizations, organizational-technical and methodological work to set up an automated system for multidisciplinary geophysical observations as a basis for earthquake prediction in Kamchatka. This paper is an account of the present-day condition of a geophysical network for earth-current, electromagnetic, ground water, and other observations at the Petropavlovsk Site and of the data acquisition and processing system based on the KEST GS RAN facilities. The potential of the currently operated geophysical observation system for identification of earthquake precursors is discussed using seismic events of 1997–1998 as examples.

INTRODUCTION

The federal target program "Development of the Federal System of Seismological Observations and Earthquake Prediction in 1995-2000" was launched in 1995 [13]. One of the main aims of the program was to set up a regular warning service to inform in due time the services and organizations of the Ministry of Emergencies of Russia and the administrations of earthquake-prone areas concerning forecasts of large earthquakes derived from multidisciplinary geophysical observations.

The implementation of this federal program began by developing an automated geophysical data acquisition and processing system at the Petropavlovsk Site (Fig. 1) to serve as a basis for earthquake prediction in Kamchatka. The 1995-1998 work involved the Kamchatka Center for Monitoring Seismic and Volcanic Activity (KCMSVA) at the

Administration of the Kamchatka Region, the Kamchatkan Experimental Seismological Team (KEST) GS RAN, Institute of Volcanology (IV) Far East Division (FED) RAN, Institute of Volcanic Geology and Geochemistry (IVGG) FED RAN, Institute of Physical Space Research and Radio Wave Propagation (IPSRRWP) FED RAN, and some other organizations.

DESCRIPTION OF THE SYSTEM

The multidisciplinary geophysical observation system mainly relies on modernized and newly installed stations belonging to RAN organizations in Kamchatka. Five stations were operated at the Petropavlovsk Site by 1998 with earth-current, electromagnetic, groundwater, and other observations (Fig. 1, Table 1).

Significant progress in the efficiency of data acquisition and processing was achieved thanks to the radiotelemetric data transmission system as part of an automated receiving center, and to the transmitting and receiving means developed and manufactured at KEST. Three earth-current stations and some kinds of observations at the Karymshina multidisciplinary geophysical expeditionary station were equipped with telemetry.

Earth-current observations (recording of earth-current potentials) are being carried out at Shipunskii, Verkhnyaya Paratunka, and Tundrovyi stations jointly by IVGG and KEST.

The Shipunskii station has three observation lines established by the Institute of Physics of the Earth RAN in the 1960s to record the earth-current field (ECF) intensity: two north–south lines 240 and 210 m in length, and an east–west 310-m line.

The earth-current field is monitored at Verkhnyaya Paratunka (since October 1996) and Tundrovyi (since August 1997) using a technique developed by Yu. F. Moroz [7]. The technique consists in establishing observation stations in locations involving significant geoelectric inhomogeneity and using observation lines having certain azimuths and lengths for recording earth-current potentials. The receiving lines are oriented along the axes of geoelectric symmetry as found from magnetotelluric measurements. This orientation enhances the sensitivity of earth-current components to variations of geoelectric inhomogeneities due to external sources (electrical processes occurring in the ionosphere and magnetosphere) and internal sources (electrical processes occurring in the Earth's crust).

The Verkhnyaya Paratunka recording system consists of four observation lines 50–100 m long striking north–south and east–west. The Tundrovyi system includes six lines 100–120 m long striking N–S, E–W, NW–SE, and NE–SW. The grounding is provided by lead electrodes buried at depths of 2–2.5 m. Earth-current potential differences are measured with a radiotelemetric system to within 0.5 mV at a rate of once per minute.

Earth-current observations can be used for earthquake hazard assessment based on an analysis of the 1992–1997 ECF structure in relation to seismicity. Bay variations in the

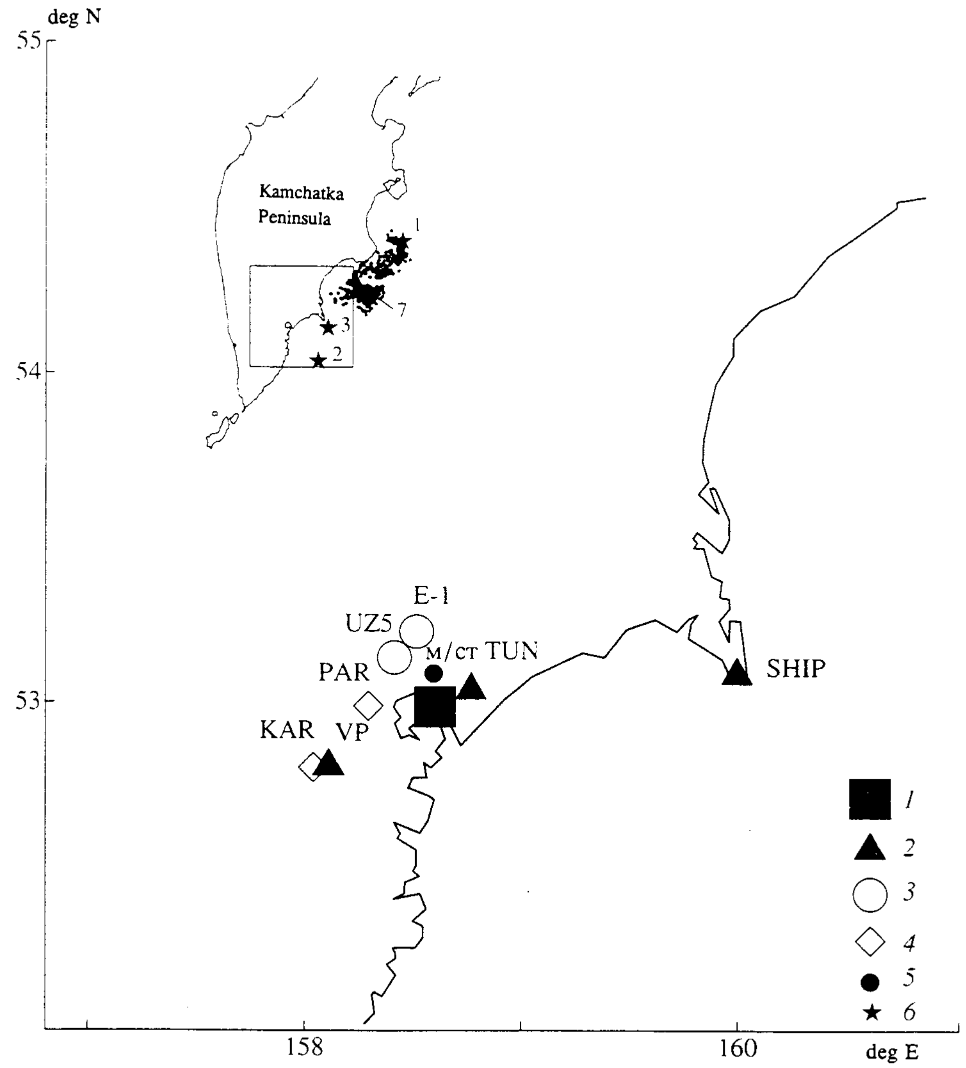


Figure 1 Geophysical stations in the Petropavlovsk Site: *1* - KEST GS RAN geophysical data acquisition and processing center; *2* - earth-current stations (SHIP - Shipunskii, TUN - Tundrovyi, VP - Verkhnyaya Paratunka); *3* - ground-water stations (E1 - well E-1; UZ-5 - well UZ-5); *4* - IPSRRWP FED RAN stations of multidisciplinary electromagnetic observations (PAR - Paratunka, KAR - Karymshina multidisciplinary geophysical station); *5* - Pionerskaya weather station; *6* - instrumental epicenters of large earthquakes (1 - Dec 5, 1997, M = 7.9; 2 - May 27, 1998, M = 6.0; 3 - June 1, 1998, M = 6.3); *7* - aftershocks of the December 5, 1997, earthquake.

Table 1 Network of multidisciplinary geophysical observations at Petropavlovsk Site, Kamchatka.

Station	Number of channels	Parameter*	Sampling rate, min	Reference	Organization
		Earth-current observations			
Shipunskii	3	Earth-current potential (0.5 mV)	1	[7-10]	KEST, IVGG
Verkhnyaya Paratunka	4				
Tundrovyi	6				
		Multidisciplinary geophysical observations			
Karymshina	6	Intensity of electrostatic field in near-ground layer of atmosphere; electromagnetic VLF radiation, hydrogen content, etc. (0.5 mV)	1	[2,10,12]	IPSRRWP
		Ground water investigations			
Well E-1	2	Ground water level (1 mm), air pressure (0.1 mbars)	10	[4,5]	KEST
Well UZ-5	2				

* Measurement error is given in parentheses.

earth-current potential were recorded prior to the June 8, 1993, magnitude 7.3 and November 13, 1993, magnitude 7.0 earthquakes some 1.5–2 months before the events, the anomaly amplitudes ranging between a few hundred and 1500 mV/km or greater [8], [9]. The June 8, 1993, event was preceded 10 days before the shock by the asynchronous behavior of regular 24-, 8-, 6- and 4-hour ECF components observed at the stations. This manifested itself in a decreased standard coherence of earth-current potential variations at the stations, from 1–0.85 to 0.3–0.5. An appreciable decrease in the standard coherence was observed 40 days before the November 13, 1993, earthquake (Yu. F. Moroz, personal communication, 1997). The areas of earth-current anomalies preceding magnitude 7 or greater earthquakes are thus about 250 km across or larger. Various forms of ECF anomalies were recorded a day to a few tens of days before the main shock.

Multidisciplinary geophysical observations at the Karymshina station are conducted by the Institute of Physical Space Research and Radio Wave Propagation, FED RAN, the Paratunka station being operated jointly with KEST. The instrumental observations used to detect anomalous variations of electromagnetic signals in a broad frequency band include slow and rapid geomagnetic variations, electrical characteristics of the near-ground atmospheric layer (electrical intensity in the atmosphere E_z and electric conductance), and natural electromagnetic VLF noise radiation [2].

Measurements of E_z and natural electromagnetic VLF radiation are transmitted telemetrically to the KEST receiving site at a rate of once per minute, the data being subsequently transmitted to IPSRRWP FED RAN.

Similar electromagnetic measurements are made at the Paratunka Site by IPSRRWP.

Previous studies of relations between atmospheric electricity and Kamchatkan seismicity revealed typical changes in E_z before the following three earthquakes: March 5, 1992, M = 6.0, R = 120 km [12]; November 13, 1993, M = 7.0, R = 170 km [11]; June 21, 1996, M = 7.0, R = 180 km (V. V. Bogdanov, personal communication). The E_z variation consisted in a sharp decrease a few hours before the earthquakes followed by a return to the previous values. Synchronous anomalous spikes in VLF noise radiation and in E_z were recorded 3 hours before the November 13, 1993, earthquake [11].

Geochemical observations at the Karymshina station include monitoring of hydrogen concentration (KEST since 1998) and measurements of radon concentration (since 1998). The measurement technique consists of recording hydrogen and radon concentrations in two observation chambers, subsoil gas being collected into one of them and free gas liberating from the water of a deep geothermal well, into the other.

A hydrogen sensor and a temperature sensor are installed in an observation chamber placed in a pit 1.5 m below the ground surface. Subsoil hydrogen is recorded with a VSG-2 hydrogen geophysical indicator providing a dynamic concentration range of 0.5–50 ppm with a resolution of 0.5 ppm. Temperature is measured in the chamber by an ADM663 microchip having a sensitivity of 2.5 mV/deg. The range of temperature measurement is −40 to +85 degrees centigrade. The sampling rate for the hydrogen sensor and the temperature sensor is once per minute. Measurements are transmitted by telemetry to the KEST receiving center.

Volumetric radon activity (Rn-222) is recorded using a portable automatic PPA-3 radiometer in its hard-disk storage at a sampling rate of once per hour.

Ground water observations are conducted by KEST in two deep wells, E-1 (depth 665 m, water table at 28 m depth, filtration at 625–647 m) and UZ-5 (depth 1001 m, water table at 2 m depth, filtration at 310–1001 m). The E-1 well taps weakly mineralized, gas-rich water from Upper Neogene tuffs, UZ-5, fresh ground water from Upper Cretaceous metamorphosed volcanogenic-sedimentary rocks. The wells are equipped with instruments for the simultaneous digital recording of water table and air pressure at a sampling rate of once every 10 min. The equipment includes a GIP-3 recorder (a geophysical measuring device), a DU water level sensor, and a DA air pressure sensor. The DU and DA sensors are similar differential pressure transformers with frequency transformation and capacitance recording [1]. Water table and air pressure data are stored in hard-disk storage in the form of removable ENZU 16K cassettes (ENZU is the Russian abbreviation for Energy-Independent Storage Device). The sensitivity is better than 1 mm of water column for water table and 0.05 mbars for air pressure.

Continuous observations have been conducted at E-1 since January 1996 and at UZ-5 since September 1997. Previously (1984–1994) water table at E-1 was monitored using a mechanical float-level recorder. An analysis of the data acquired at E-1 showed that earthquakes of M $\geq$ 6.0 that satisfied the requirement M $\geq 2.51 \lg R + 0.6$ gave rise to coseismic and (occasionally) preseismic water table variations lasting a few weeks to a few months [4].

Additional information that is needed for the rapid analyses of geophysical parameter variations includes data of daily hydrometeorological observations (precipitation, air temperature, air pressure, etc.) conducted at the Pionerskaya weather station, Kamchatka Environmental Monitoring and Control Department and data contained in the KEST Preliminary Earthquake Catalog for Kamchatka. The sampling rate of air temperature and pressure observations at Pionerskaya is 8 times per day, precipitation being measured twice every 24 hours. Hydrometeorological observations are transmitted via telephone daily to KEST. Current information on recent earthquakes is obtained by addressing to the KEST seismological data base via a local network.

TECHNICAL OPERATION OF MULTIDISCIPLINARY GEOPHYSICAL NETWORK

Technical work aimed at modernizing and installing observational stations have been conducted since 1995. Along with the technical basis of observations, an organizational and methodological basis had been prepared by 1997 for simultaneous observations under special contracts among the organizations engaged in the federal program "Development of Seismological Network" and under special regulations concerning the regular transmission of data and evaluations of earthquake hazard based on this evidence. Multidisciplinary analysis of incoming information was carried out by the Interdepartmental Technical and Research Council, KCMSVA, in 1996–1997 and, since 1998, by the Kamchatka Division of Federal Earthquake Prediction Center, KEST (KD FEPC).

The flow chart in Fig. 2 characterizes the operation of the geophysical data acquisition and processing system all the way from acquisition to the final result, namely, evaluation of earthquake hazard in Kamchatka Region.

Data from telemetry stations are coming in real time to the receiving center of geophysical radiotelemetric stations and are decoded as often as at least once every two hours, resulting in standard daily files. Ground water observations are taken and processed once every two weeks. The data files are transmitted to researchers engaged in various kinds of observations to be processed and interpreted.

A special team in KEST is engaged in routine processing and visualization of earth-current observations, E_z data (at least as often as twice every 24 hours), and groundwater observations (once every two weeks) along with hydrometeorological and seismological data. This team is known as a Geophysical Data Processing and Visualization Team. The team is concerned with the processing and preliminary analysis of currently recorded observations, as well as with the support and updating of earth-current, ground water, and other data records. The team operates in close association and interaction with the researchers of particular kinds of observations.

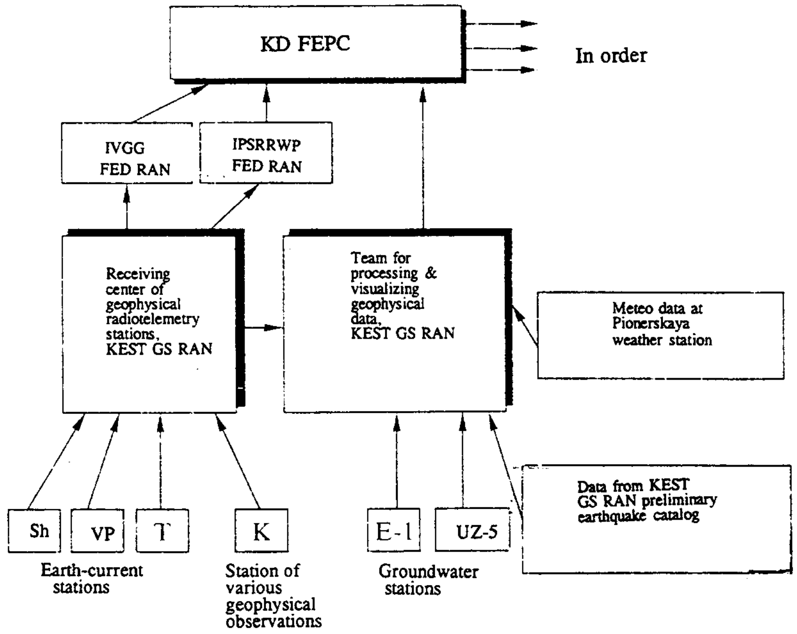


Figure 2 A functional diagram showing the acquisition, processing and visualization of geophysical data.

Processing and visualization of geophysical data coming via telemetry. Decoded earth-current data are stored in standard-type .DAT files, which contain records of self-potentials for 24 hours or less. A .DAT file consists of columns of numeric values providing information on recording time and the magnitudes of the potentials (in μV).

When data are missing for some technical factors, .DAT files do not perform automatic encoding of the missing values. The result is that the meaningful information of a file (values of the potential) is not uniformly distributed over time and has a rather limited use for subsequent processing.

Preliminary data processing involves the automatic encoding of missing values in the raw data, if any, and the creation of standard daily, monthly, and yearly files of electromagnetic data. These procedures are implemented by a Trans program. The input data for Trans are .DAT files, the output being standard .TXT files usually stored in the archive of electromagnetic data in two types: daily data sampled at 1-min intervals with encoded missing values and monthly data sampled at 1-hour intervals with encoded missing values. One-hour values are derived by averaging 1-min data, provided there are more than or a half of their values per hour.

The data formats in .TXT files and .DAT files are the same, the difference being that a complete 1-min .TXT file always contains the same number of records (1440), while a complete 1-hour .TXT file has 24 records times the number of days in a month, i.e., 672 to 744 records. The resulting .TXT files can easily be used for subsequent graphic representations and mathematical processing.

A pipeline system can be used in Trans for the faster processing of .DAT files, their transformation to .TXT files, and the updating of the respective archival directories. The Trans tools can perform a number of auxiliary operations: the automatic removal of information for the last day from a monthly file, its updating based on daily 1-min files, the creation of a file as long as 500 000 records based on daily and monthly .DAT and .TXT files, the creation of a file containing information on the number of missing values and the respective time intervals in the .DAT file being processed, and data viewing and editing.

The phase of data representation and preliminary analysis includes the rapid plotting of currently recorded data versus time, the comparison of the variations of geophysical parameters to hydrometeorological parameters and seismicity, and the identification of anomalies.

Observations can be displayed on the screen by using a Diagnos program, the input data being either standard archival .TXT files or any other ASCII files containing data uniformly distributed over time, as well as data from the Kamchatka earthquake catalog. When a nonstandard file is used as input to Diagnos, the start of recording time and the interval of data discretization should first be specified.

The Diagnos program can display up to 256 files simultaneously with a total number of records up to 500 000; they can be merged, and selected time segments can be examined in detail. The screen can also be printed and saved in .bmp format. Examples of such plots can be seen in Figs 3–5.

The total amount of daily data is processed during 10-15 min or less after the .DAT files come from the receiving center until 1-min and 1-h plots (together with weather parameters) are displayed.

Processing of ground water observations includes the separation of raw digital files into channels, the conversion of numerical water-table and air-pressure variations to proper physical values (in mm of water column and in mbars), the elimination of 12-h and 24-h components and water table variations due to air pressure in the frequency ranges of a few hours to a few days to a few tens of days, and the plotting of the raw data and the variations of compensated water-table level against precipitation and seismicity. The compensation of air pressure effects on water table is based on an algorithm from [6] taking into account certain individual features of specific well–aquifer systems [5]. Plotting

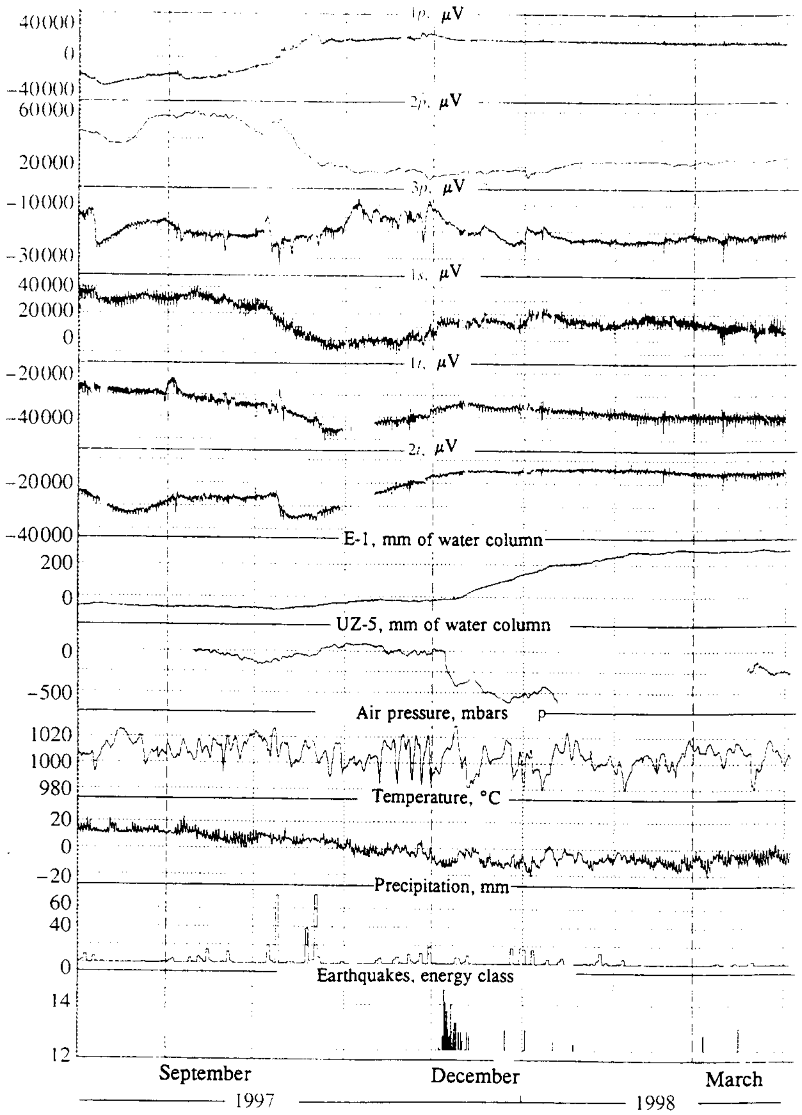
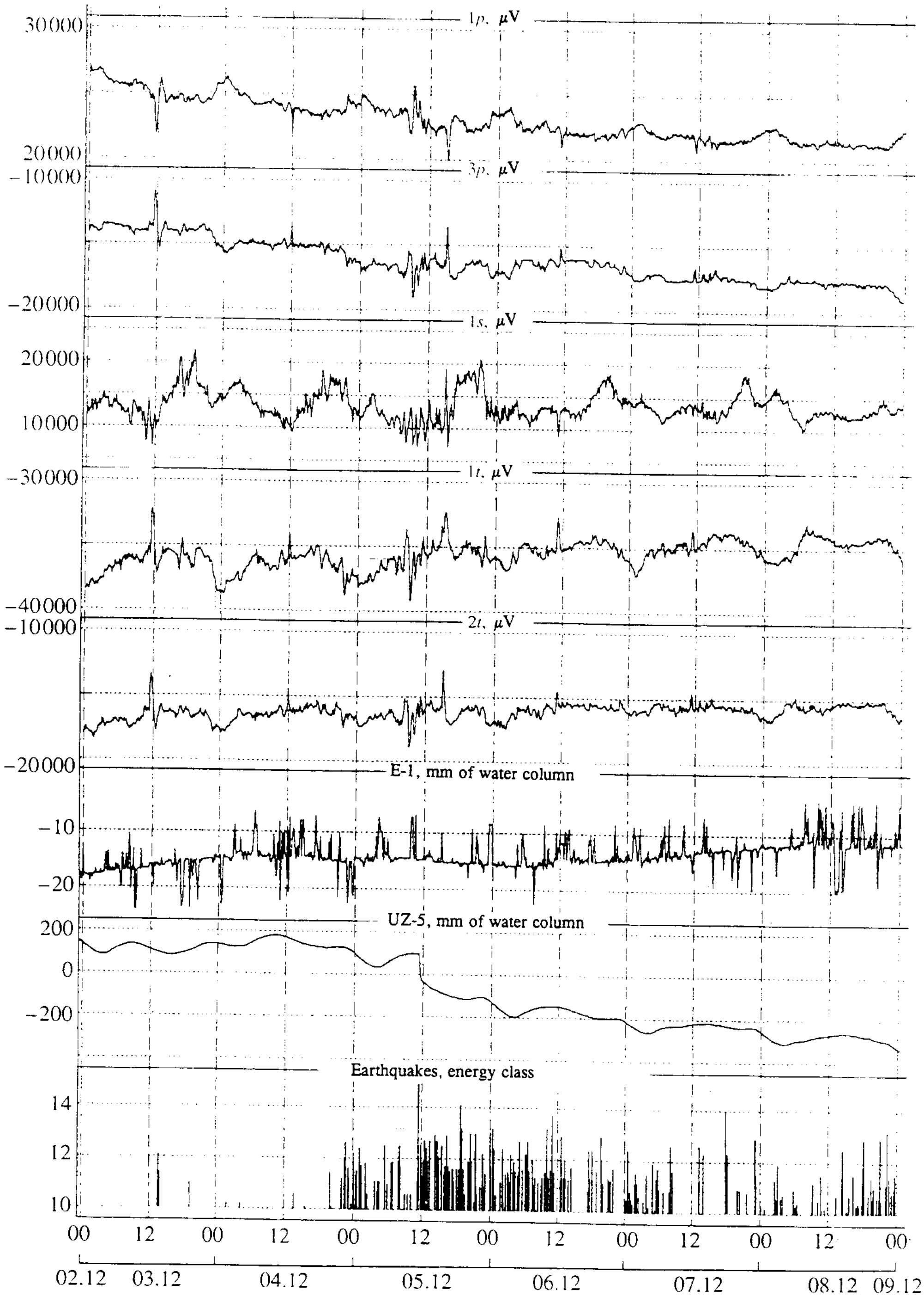


Figure 3 Variation of mean hourly earth-current potentials at stations Verkhnyaya Paratunka (1*p*, 2*p*, 3*p*), Shipunskii (1*s*), Tundrovyi (1*t*, 2*t*), and compensated water table values in wells E-1 and UZ-5 wells compared with hydrometeorological observations at the Pionerskaya weather station and earthquakes of K $\geq$ 12.0 occurring in August 1997 - March 1998. All seismicity shown here occurred in the source area of the December 5, 1997, magnitude 7.9 earthquake. Bay variations in earth-current potentials were recorded in October–November 1997 along with coseismic water table changes in the wells.


1p, μV
30000
20000
3p, μV
-10000
-20000
1s, μV
20000
10000
1t, μV
-30000
-40000
2t, μV
-10000
-20000
E-1, mm of water column
-10
-20
UZ-5, mm of water column
200
0
-200
Earthquakes, energy class
14
12
10
00 12 00 12 00 12 00 12 00 12 00 12 00
02.12 03.12 04.12 05.12 06.12 07.12 08.12 09.12

is done using the Diagnos means (see Figs 3–5). When a current "piece" of two-week data comes from the wells, the processing and plotting are repeated.

The preliminary analysis of current geophysical data was carried out using the previously identified "signatures" of intermediate-term and presumably short-term earthquake precursors [4], [8], [9], [11], [12]. Possible intermediate-term precursors lasting a few to a few tens of days were searched for by examining on a daily basis the current 1-hour observations lasting 45–60 days or longer at all stations with the obligatory use of hydrometeorological data. Shorter anomalies (mostly in the variation of earth-current potentials) were identified by examining, on a daily basis, the relevant 1-min plots lasting 3–4 days or longer.

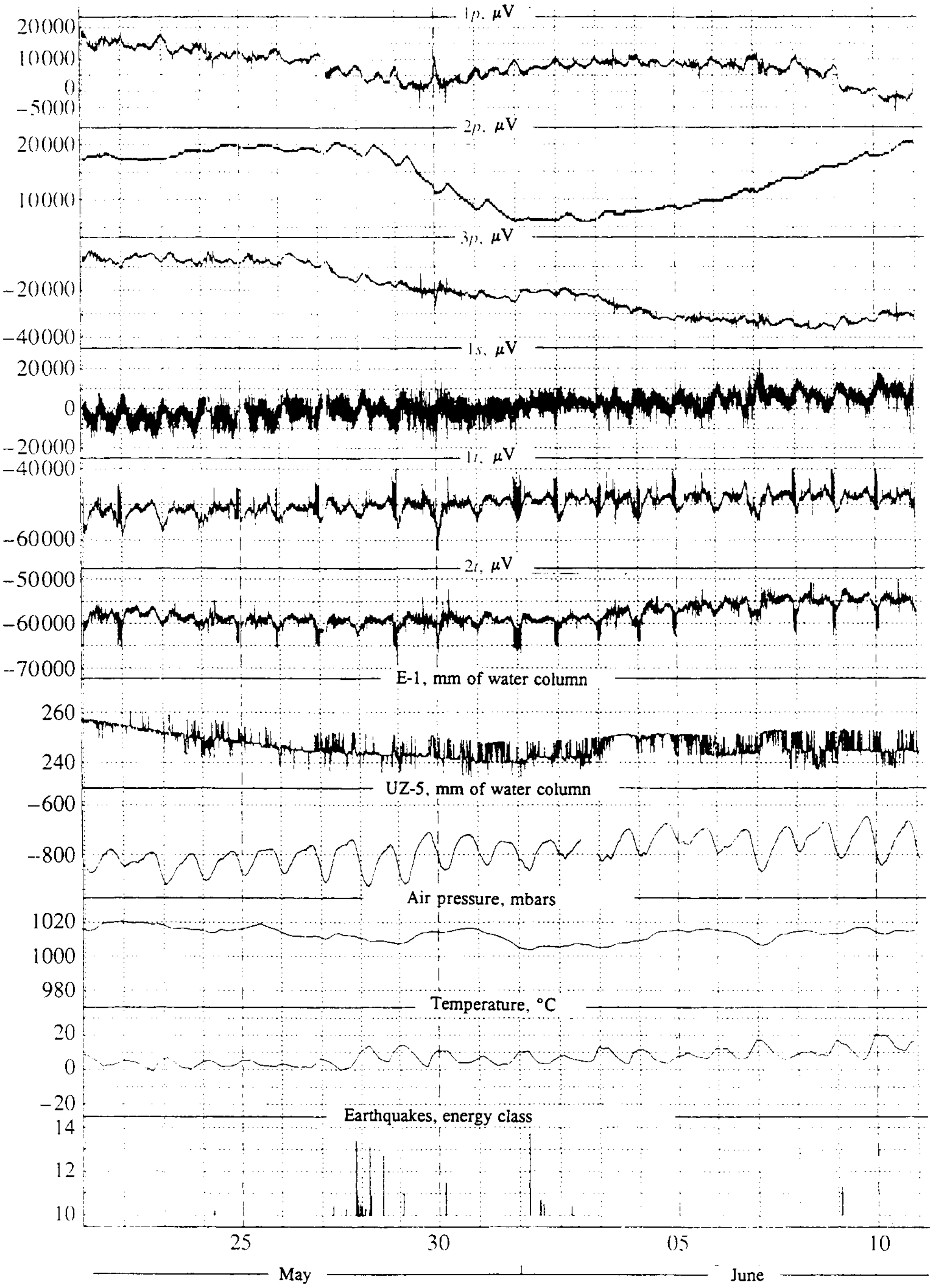
This system for the acquisition, processing and plotting of geophysical data is a basis for the routine evaluations of earthquake hazard in the area of the Petropavlovsk Site at least once a week when the background seismicity alone is present, but can be switched to rapid mode when there is a higher likelihood of a large earthquake.

EVALUATION OF THE MULTIDISCIPLINARY GEOPHYSICAL NETWORK FOR FORECASTS OF EARTHQUAKE HAZARD BASED ON THE 1997–1998 RESULTS

Increased seismicity was observed in 1997–1998 on the eastern coast of Kamchatka largely due to the great December 5, 1997, M_W 7.9 earthquake and its aftershocks in the area of the Gulfs of Kamchatka and Kronotskii (Fig. 1). Felt effects in the Petropavlovsk Site ranged between intensity VI–VII (Shipunskii Site) and V (Verkhnyaya Paratunka Site) [3]. The distance between the center of the observation site and the instrumental hypocenter was 370 km, that from the center of the source volume to the site being 270 km.

A sequence of earthquakes with maximum magnitudes of 6.3 and 6.0 occurred in the Gulf of Avacha in late May - early June of 1998. A swarm of $K_s \leq 13.4$ ($M \leq 6.0$) earthquakes was observed in the middle of the Gulf from May 27, 1998, to about June 10 (Fig. 1, symbol *6* (event 2)). Four most significant earthquakes of magnitudes 6.0 to

Figure 4 Changes in earth-current potential at Verkhnyaya Paratunka (*1p*, *3p*), Shipunskii (*1s*), and Tundrovyi (*1t*, *2t*) stations based on 1-min observations and in ground water table in wells UZ-5 and E-1 based on 10-min data as compared with the times of earthquakes ($K \geq 10.0$) occurring in the source area of the December 5, 1997, earthquake. The recorded occurrences include regular less than 24-hour variations in earth-current potential and ground water table in well UZ-5, high frequency earth-current disturbances on December 3 and 5, and a coseismic 120-mm lowering of water table in well UZ-5 at the time (11 h 26 min) of the magnitude 7.9 earthquake. The sawtooth variations in ground-water table in well E-1 with amplitudes of within 10 mm of water column were caused by gas release.


1p, μV
20000
10000
0
−5000
2p, μV
20000
10000
3p, μV
−20000
−40000
1s, μV
20000
0
−20000
1t, μV
−40000
−60000
2t, μV
−50000
−60000
−70000
E-1, mm of water column
260
240
UZ-5, mm of water column
−600
−800
Air pressure, mbars
1020
1000
980
Temperature, °C
20
0
−20
Earthquakes, energy class
14
12
10
25
30
05
10
May
June

4.3 causing shaking of intensity V–VI to III–IV in Petropavlovsk-Kamchatsky City occurred on May 27–28. The epicentral distance from these earthquakes to the center of the site was 130 km.

A K_s = 13.7 (M = 6.3) earthquake occurred on June 1 in the northern Gulf of Avacha near the southernmost extremity of the Shipunskii Peninsula; it caused shaking of intensity IV–V in Petropavlovsk-Kamchatsky City. The epicentral distance of that earthquake to the center of the test site was 115 km (Fig. 1, symbol *6* (event 3)). The earthquake was followed by small ($K_s \leq 9.8$) aftershocks.

Forward forecasts of the three largest seismic events indicated above, based on the data supplied by the geophysical network (materials of KCMSVA and KD FEPC), have not been issued, because the relevant weekly evaluations did not contain definite indications as to the time, location and size of future earthquakes that would be identical with the parameters of the actual earthquakes. Nevertheless, evaluations of earth-current observations as of May 21 and 28 suggested the presence of trends and high frequency disturbances in earth-current potentials prior to the seismicity increase in the Gulf of Avacha. The evaluation as of May 31, 1998, also mentioned some low disturbances in earth-current potentials and the appearance of well-pronounced daily variations in the second channel at the Verkhnyaya Paratunka station since May 23; no such variations had been previously recorded at this channel.

Figures 3 through 5 present the variations of earth-current potentials at three stations and water-table observations in the two wells along with hydrometeorological data and the times of earthquake occurrence. These plots give an idea of the preseismic and postseismic variations of geophysical parameters for the earthquakes of December 5, 1997 (Figs 3–4) and May 27 to June 1, 1998 (Fig. 5).

Figure 3 presents 1-hour data for a period of August 1997 to March 1998 obtained by averaging 1-min earth-current potential values and 10-min water table observations in the wells. Figure 4 shows the same parameters based on 1-min and 10-min values recorded during December 2–8, 1997. These plots characterize the variations of geophysical parameters which were used to derive routine evaluations of earthquake hazard.

Figure 5 Variations of earth-current potential at Verkhnyaya Paratunka (*1p*, *2p*, *3p*), Shipunskii (*1s*), and Tundrovyi (*1t*, *2t*) based on 1-min data and ground-water table changes in wells E-1 and UZ-5 based on 10-min data for the period May 21 to June 10, 1998, as compared with air pressure and temperature recorded at the Pionerskaya weather station and with K ≥ 10.0 earthquakes occurring in the Gulf of Avacha. The recorded occurrences include regular daily variations in earth-current potential and ground-water table (well UZ-5), trends and high-frequency earth-current disturbances, water table declines in well E-1 before the seismicity increase and a slight postseismic rise. The scale of the figure makes just barely detectable the coseismic 10-mm ground water decline in UZ-5 well at the time of the June 1 magnitude 6.3 earthquake. The sharp noise-like variations in earth-current potential at Tundrovyi on May 21, 24–26, 28, 31, and June 1–4, 7–9 lasting 2–4 hours were caused by technical noise.

The December 5, 1997, earthquake had not been preceded by any dramatic changes in earth-current potentials and water table of possible use for deriving a forecast based on geophysical evidence. One can see two time intervals when high frequency disturbances of earth-current potential were recorded at all stations: December 3 between about 10 to 12 a.m. and December 5 between 8 a.m. to 3 p.m. The former disturbance occurred about 2 hours before the first large foreshock in the epicentral area of the future main shock, and the latter began about 3.5 hours before the earthquake. In Yu. F. Moroz' opinion [10], "these disturbances were probably caused by an ionospheric source excited by preseismic electromagnetic radiations of the lithosphere". The disturbances were noticed in routine work; however, because the amplitude and character of these variations did not significantly differ from similar frequent earth-current potential disturbances, no report on the predictive character of the anomalies was sent.

Routine observations of water table in wells E-1 and UZ-5 did not reveal any significant changes that could cause concern.

A retrospective analysis of earth-current potential and ground water observations using mathematical data processing methods suggested the presence of (mainly) intermediate--term anomalies before the December 5, 1997, earthquake during the time interval of 50 to 20 days before the event [2], [5], [10].

The period of seismicity increase from May 27 to June 1, 1998, (Fig. 5) also involved high frequency disturbances in earth-current potential at all stations observed both before and after the larger events, especially those of May 29–30. We have mentioned trends in the variation of potentials at some channels ($1p$, $2p$, $3p$) and well-pronounced daily variations of potentials at the second channel at the Verkhnyaya Paratunka station since May 23. There was a concurrent $\sim$2-cm lowering in the water table of E-1 well. Judging by previous observations, that might have indicated a starting precursory process for a large (M $\geq$ 6–7) earthquake, but the amplitude and rate of the lowering were not sufficiently large by the time of the May 27 - June 1, 1998, earthquakes to justify an alarm.

CONCLUSIONS

1. A KEST GS RAN system of multidisciplinary geophysical observations is being developed and is operated today to evaluate earthquake hazard in the Petropavlovsk-Kamchatsky City area based on observations carried out at earth-current, ground water, and other stations; updated archives of geophysical data; original software designed for processing and visualizing currently recorded data together with hydrometeorological parameters and data from the preliminary earthquake catalog for Kamchatka.

2. Routine observations of earth-current potentials and ground water levels in wells conducted in 1997–1998 did not reveal any short-term anomalies before the earthquakes of December 5, 1997, M = 7.9 (R = 370 km, intensity V–VI) and May 27 - June 1,

1997, M_{max} = 6.0–6.3 (*R* = 130–115 km, intensity V). The changes in earth-current potentials and ground water table observed before the earthquakes were short-term insignificant variations, so that their predictive value remained unidentified. Retrospective analysis in connection with the December 5, 1997, earthquake revealed preseismic, mostly intermediate-term (50–20 days) changes in earth-current potentials [10], ground water tables in wells [5], several electromagnetic parameters [2], as well as coseismic variations.

3. Our two-year experience shows that examples appearing in the literature ("signatures" of precursory anomalies manifesting themselves in the variation of earth-current potentials and ground water table identified retrospectively) cannot always be used effectively for the routine monitoring of these geophysical parameters. The techniques used to detect and identify precursory anomalies in the variation of earth-current fields and ground water table in wells should probably be seriously modified both by deeper retrospective analyses of the archive of earth-current potential and ground water observations, by the use of all available geophysical observations, and by using experience in routine processing and visualization of currently recorded data.

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