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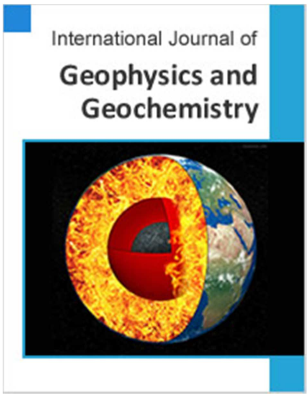

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Acoustic Process in the Earth Crust Between Sunrise & Sunset

Askold Belyakov

Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia

Email address

askbel32@gmail.com

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Abstract

Experimentally, observations in Petropavlovsk-Kamchatsky (53.0529, 158.6666), RF (well 1035 m) and New Delhi (28.6857, 77.2154), Republic of India (100m well) have revealed that when the Sun crosses the horizon line, strange changes in the acoustic noise level occur. Observations are made by a magnetoelastic inertial geophone, which allows recording high-frequency mechanical vibrations in a solid medium of the earth's crust with amplitudes of 10^{-14} m or less. The changes presented in the form of absolute values of the means for 1 minute of acoustic noise amplitudes were observed in the frequency bands 30, 160, 560 and 1250 Hz. Continuous monitoring revealed a strange frequency-dependent relationship between the solar terminator and acoustic noise in the upper part of the Earth's crust, whose amplitudes sharply increase at sunset and also decrease sharply at sunrise. The overwhelming majority of processes on the Earth have a daily regularity, which, in one way or another, is connected with the Sun; in any case, if not the processes themselves, then their variability in time is related to the rhythm of the sun's impact on the Earth. Therefore, the relationship of seism-acoustic processes in the upper part of the earth's crust with the solar rhythm was investigated. It was previously established that the deformation processes in the earth's crust associated with lunar-solar gravity cause seism acoustic emission, which, depending on the recording method, is well synchronized either with an inverted tidal strain rate or with a square of the tidal strain rate, both in summer, both in winter and in winter. In the days of the spring and autumnal equinoxes, synchronization is temporarily disrupted, since the ratio of the amplitudes of the day and night phases of the gravitational wave changes.

1. Methods and Apparatus

The method was based on borehole observations of acoustic noise in the frequency band from 1 to 1250 Hz by a three-component geophone, which was pressed by an electromechanical device to the wall of the borehole. To avoid problems with the registration and storage of a large amount of digital information, a scheme was chosen that provided analog separation of four narrow frequency bands of 30, 160, 500 and 1250 Hz, shown in Figure 1, and detection of the selected signals.

Detected signals in four selected frequency bands along two horizontal (X, Y) and one vertical (Z) directions were digitized, averaged over 1 minute and stored on the hard disk of the computer. Such a scheme, with the automatic restart of the registration program in the event of an emergency disconnection of the mains power, made it possible to perform long-term monitoring in an autonomous mode.

In both cases, the original magnetoelastic inertial geophone MIG-3S with a unique amplitude-frequency characteristic was used for the measurement. Uniform for three orthogonal components, inertial mass and rigid magnetoelastic sensor ensured minimum phase shifts between components and a large (at least 240 dB) dynamic range with high sensitivity and low output impedance. The sensor does not require power, and the term of its trouble-free battery life exceeds 25 years [1].

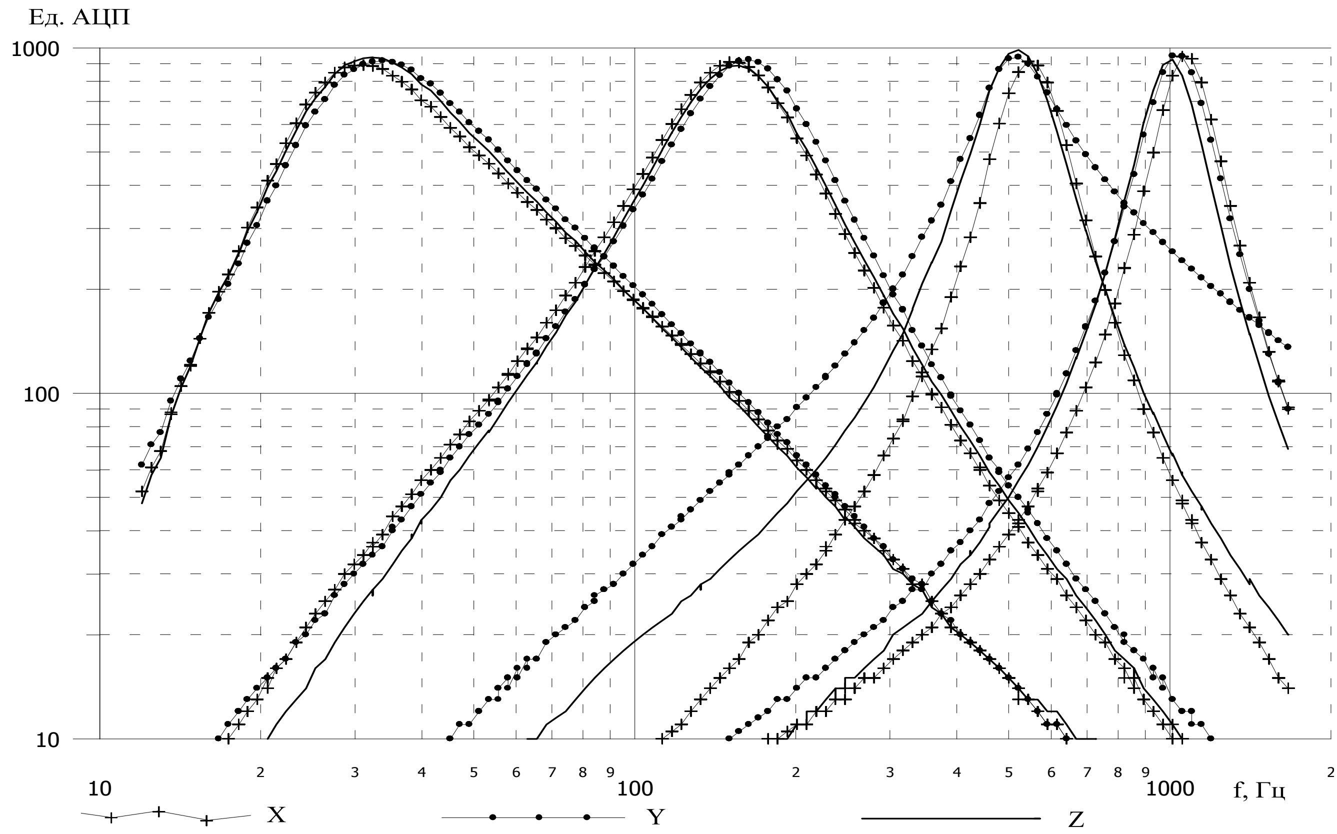

Figure 1. Amplitude-frequency characteristics of channels.

2. Experimental Data

In the data that were obtained in mid-August and early September 2001 in the well G1 at a depth of 1035 m in Petropavlovsk-Kamchatsky [2, 3], strange phenomena were frequently observed in which vertical amplitudes of acoustic noise at a frequency of 160 Hz increased sharply (Figure 2). On the horizontal axis of Figure 2 shows 30 days in August and early September 2001, and along the vertical axis the average amplitude per minute is 160 Hz in conventional units. It was strange that the beginning of the increase in the amplitudes was sharp and coincided with the decline of the sun, and a decrease in the amplitudes with the sunrise (the passage of the solar terminator lines for the observation site). These oddities were violated before earthquakes and restored after earthquakes. It was not possible to understand and satisfactorily explain the origin of these phenomena.

Unexpectedly in 2009, similar strange phenomena began to be observed in a well 100 m deep in the southern spurs of the Himalayas (New Delhi, Republic of India). There, within the framework of the Interstate Long-Term Program (ILTP) agreement, in the end of 2007, Kamla Nehru Ridge seismic observatory was specially drilled and sealed with a steel sealed pipe, which installed an original Russian geophone with a unique characteristic similar to that found in Kamchatka [6]. From the time it was installed to the beginning of November 2009, the recorded data was mainly of the nature of random anthropogenic (technogenic) noise. The data for September 2009 was very revealing for judging about man-made hindrances of high energy. For example, in September 2009, an intense industrial noise was observed almost continuously for 11 days in two low-frequency bands of all three (X, Y and Z) recording channels, the level of which often exceeded the range of the recording system. In all these cases, the process begins between 8 and 9 local time. A similar picture was observed in November 2008, but the beginning of the processes was less regular. In general, during the registration period until November 2009, bursts of powerful industrial noise were observed in each month from 1 to 17 times.

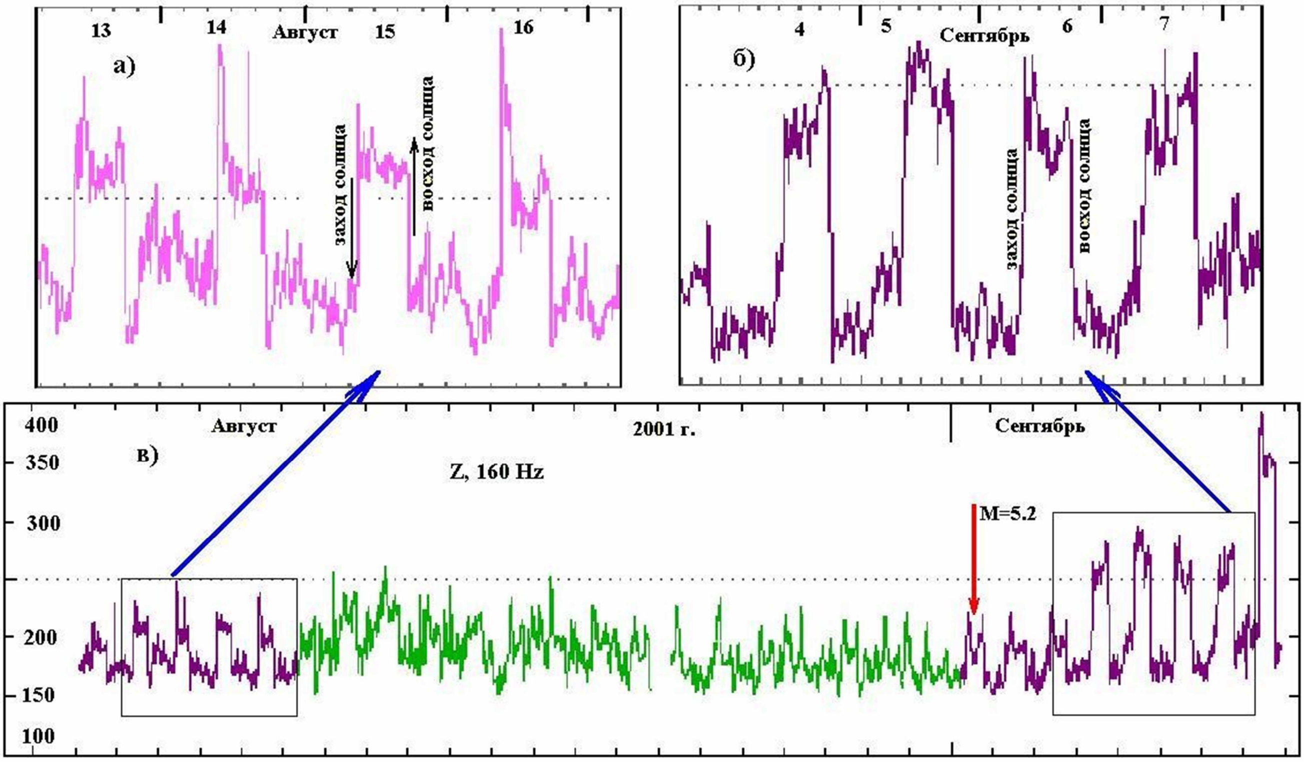

Figure 2. *Acoustic noise at a frequency of 160 Hz.*

In October 2009, for no apparent reason, the situation changed dramatically. Industrial noise did not begin to be observed. What was happening at that time on the nearest territory to the well remained unknown. Chaotic noise in its nature has disappeared, and in the data, since November 2009, there have been regular increases in noise (Figure 3), where the horizontal axis indicates the time from February 4, 2008 to March 10, 2010. On the vertical axes of 12 graphs the average per minute acoustic noise amplitude in ADC units (maximum 2047) for the frequency bands: 30, 160, 560 and 1250 Hz and three directions. Attention is drawn to the fact that low-frequency recording bands (30 and 160 Hz) are most susceptible to industrial (anthropogenic) noise. High frequency bands (560 and 1250 Hz) are less susceptible to industrial noise, especially 560 Hz bands, in which the measurement range was exceeded only once at the end of November 2008. At the same time, the amplitudes of strange signals in 560 Hz frequency bands most clearly respond to solar terminator. The appearance and termination of these strange, almost rectangular signals was associated with the sunset and sunrise (as in Kamchatka in 2001, Figure 2). In early February 2010, the amplitude of strange signals increased dramatically and for no apparent reason. These phenomena were clearly visible in all 12 frequency bands of registration. However, they were most contrasted in a band with a frequency of 560 Hz, where the displacement amplitudes increased by almost an order of magnitude from 10^{-13} to 10^{-12} m in 1-2 minutes. It is very regrettable that the experiment ended in early March. It was not possible to observe the effect of changes in gravity on the days of the vernal equinox, which are associated with March 20, on the observed process. The points of the spring or autumnal equinox could provide additional data on the relationship of the solar terminator to high-frequency seismic emission.

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In Figure 3 shows a fragment of the data from November 1, 2009 to March 10, 2010, where the vertical axes indicate the average acoustic noise amplitude per minute in ADC units in the 560 Hz frequency band for three directions and the solar component of the relative volumetric deformation in the "nanostrain" (10^{-9}). Multiple, at first glance, spontaneous, noise increase in early February 2010 also has no explanation.

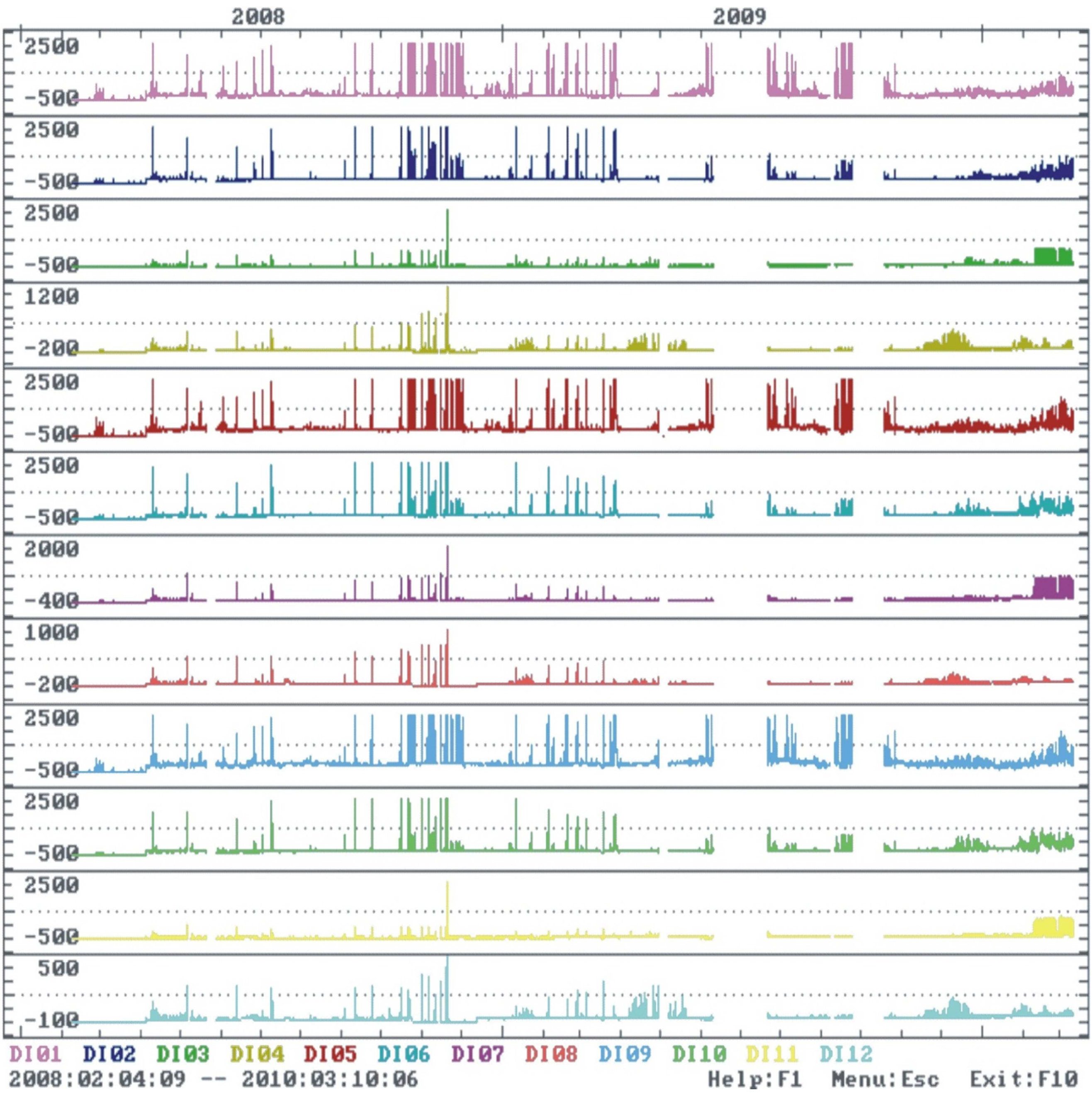

Figure 3. *The 100 m downhole logging data, X, Y and Z channels, frequency bands: 30, 160, 560 and 1250 Hz (from top to bottom, respectively).*

In Figure 4 shows a fragment of data from November 1, 2009 to March 10, 2010, where the vertical axes indicate the average per minute amplitude of acoustic noise in ADC units in the frequency band 560 Hz for three directions and the solar component of the relative volumetric strain in the “nanostrain” (10^{-9}). Multiple, at first glance, spontaneous, noise increase in early February 2010 also has no explanation.

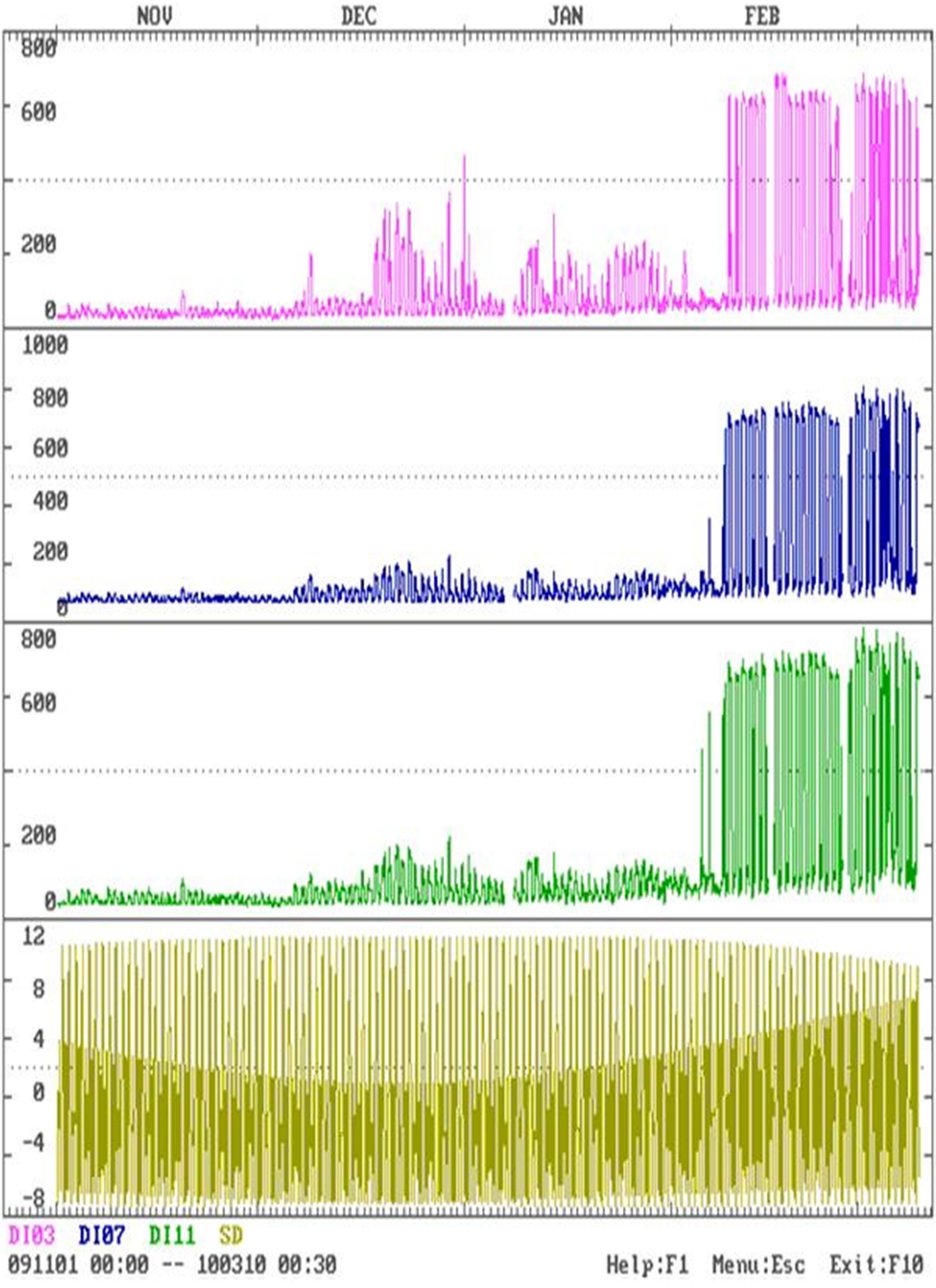

Figure 4. *Fragment of data through the channels X, Y, Z (560 Hz) and amplitude (10^{-9}) of the solar component of the relative volumetric deformation (from top to bottom).*

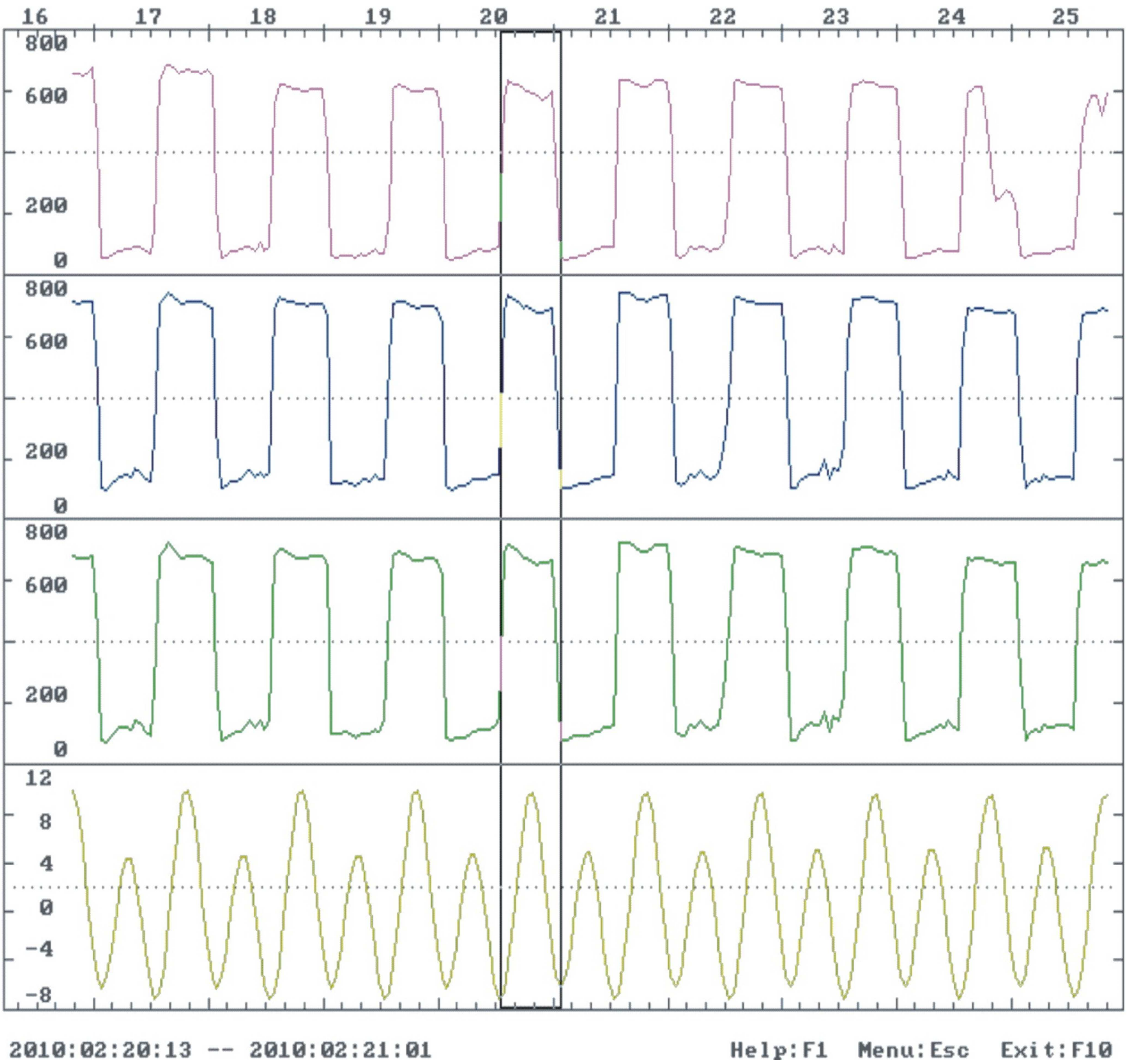

Figure 5. *10 day registration fragment Figure 4.*

In Figure 5 it is clear that the centers of extremes of deformation process and acoustic noise in the earth's crust in the daily cycle coincide with midnight and noon local time (UTC + 5h). The midnight extremum in the winter period is much longer than the midday [4]. It seems strange that the speed with which after sunset (18:14 local time 02/20/2010) increased to its maximum and decreased after sunrise (6:54 local time 02/21/2010) to the original amplitude level of high-frequency noise in each cycle.

3. Discussion

Long (more than 2 years) continuous monitoring at the end made it possible to detect a strange, at times stable, relationship between the solar terminator (gravitational tide) and mechanical (acoustic) oscillations in the Earth's crust. Only to discover, not to study, a phenomenon that, perhaps, deserves more careful and detailed study. The analogue allocation of frequency bands, the recording of the average amplitude values of the signals per minute, made it possible to create a working system of long, survey monitoring designed to search for acoustic earthquake precursors, but a rough registration form made it difficult to study the phenomenon. To obtain more informative data for analysis it is necessary to use monitoring with reduced averaging time (no more than 10 seconds), or to use high-resolution monitoring in amplitude and frequency and to register the initial data without any preliminary processing [7].

4. Conclusion

In conclusion, it should be noted that the registration was carried out in the automatic monitoring mode during the entire observation period. Data processing was performed by a special program "WinABD" for processing long time series [9]. "WinABD" is a software package for tracking and analyzing geophysical monitoring data. The program pact has a large number of data processing and analysis tools. There is no restriction in the analysis of data with omissions, processing is performed in a sliding window, all data operations use calendar time, it is possible to correctly handle the series having different starting dates and a non-coincident periodicity of observations. The data is stored in a compact format (16 or 32 bits per value). On a typical PS, you can work with rows of billions in length. Each series is an infinite sequence of cells that have an accurate calendar reference. The interval between observations is from 0.000001s (1 megahertz) to 999 years. When importing, data can be added to an already existing row in a timeline that is necessary for ongoing observations. There are tools for import automation. It is possible to work with earthquake catalogs. Importing data into the database requires some effort, but later it cannot work with file names (columns), but with well-certified samples, which significantly increases the usability.

Unfortunately, the data was not copied regularly, and at intervals of a week to 6 months were sent for analysis by e-mail, without any comment. The hope that the new data that was expected to be obtained in 2010 will allow us to study in more detail the characteristic properties of the observed process and plan the direction of further research, was not justified in connection with the end of ILTP agreement and termination of funding. Some hope for the continuation of the research is provided by the fact that the device installed in the well is preserved and, if necessary, can be used with a new registration system. The modern registration systems used and tested in the SAFOD well in California [8] allow the original research to resume at a new higher level.

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