Three-Dimensional Spatio-Temporal Modeling of Geophysical Events and the Movement of Celestial Bodies

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Modern research in the field of Earth sciences is continually developing, from the descriptions of each individual natural phenomenon to the systematic complex research in interdisciplinary areas. For studies of this kind in the form of three-dimensional (3D) systems, the author proposes two modules, each with its own coordinate system: Module 1, a 3D model of Earth, the coordinates of which provide databases of the Earth's events; and Module 2, a compact model of the relative motion of celestial bodies in spacetime on Earth known as the "method of a moving source." Module 2 was developed as a continuation of the geocentric Ptolemaic system of the world, built on the astronomical parameters of heavenly bodies. Based on the aggregation data of space and Earth sciences, systematization, and cooperative analysis, this is an attempt to establish a cause and effect relationship between the position of celestial bodies and Earth's natural events.

1. Introduction

At the start of the twenty-first century, Earth science studies marked the beginning of the world as an open system, that is, as accepting the effect of physical fields' energy on outer space. Periodic and cyclic motion of the sources of gravitational fields (the Sun, Moon, etc.) that produce the tides and related phenomena observed [1] may turn out to yield a significant impact on the inhomogeneity of the Earth (geological, geophysical, etc.), which can lead to earthquakes and other disasters [2, 3].

In this regard, for modern scholars there is inevitably a problem when establishing a connection between the terrestrial events and the position of celestial bodies. Until recently, there existed a heuristic approach to solving this issue, but this approach has gradually been replaced by systematic studies of complex three-dimensional (3D) space. Data in various Earth science fields has grown steadily, and now solving such problems requires not only the ability to share analysis but also experience with large databases.

In this respect, using 3D visualization is promising because it allows for production of a complete spatio-temporal analysis of events occurring simultaneously or sequentially. In connection with this, and along with the desire to solve informational problems, methods of 3D data organization must be developed and represented in a form suitable for analysis.

The algorithm presented in this work, 3D technology, was initially proposed by the author in 1998 in terms of flow vectors that penetrate the sphere [4] for an experiment studying the Earth's internal structure using tomography [5]. It was assumed that in the Sun–Earth system, beams of neutrinos moving straight from the Sun will pass through the body of the Earth and experience changes if the thickness is large enough. Some of them are registered at time t by individual detectors B_c by the means of geographic coordinates φ, λ, R, defined on the surface or underground. The experiment was planned to examine changes in density within the Earth. But the proposed plan of the experiment has not found an application because of low energy and reagent due to the small number of detected particles.

Furthermore, this algorithm was developed in the "method of moving source" [6], logged as part of a 3D spatio-temporal technology, and applied in geophysics [7] and other Earth sciences [8].

The possibility of combining structured geophysical data for the 3D space on the selected criteria and astrometric parameters of celestial bodies using spatio-temporal technology presents new opportunities for a wide range of spatial and temporal problems associated with the Earth.

2. Spatio-Temporal Technology

The problem of combining modern astronomical and geological data in one system has been overcome by the author by developing spatio-temporal technology based on a Ptolemaic geocentric system developed for 3D space.

The author proposed an interdisciplinary research tool [4–8], the use of which allows the viewing of Earth's events with respect to time and direction of the moving sources' impact.

Spatio-temporal technology includes a system of modules. Module 1 is a 3D model of the Earth and Module 2 is a system of vectors with astrometric parameters of the motion of celestial bodies relative to the Earth. According to spacetime technology, the Earth (Module 1) is fixed, and the movement of each of the heavenly bodies relative to the Earth is represented by an individual for each (Module 2) as their vectors.

The peculiarity of the motion of celestial bodies relative to the Earth is that all of them occur simultaneously in a circular motion around the Earth (its rotation axis) and in forward movements up

and down relative to the Earth's equatorial plane, in accordance with their natural cycles.

Cycle time length and motion parameters (circular and translational) of each body are (extraordinary) separate. 3D visualization of the movement of these vectors is directed from the center of the Earth onto the body, and can be represented as moving unenclosed conical surfaces that have been deployed in the plane of the equator and close to the closed cones at the poles (the region near the extreme points in northern and southern hemispheres in the 3D space).

The value of this approach is difficult to overestimate, because now when observed from Earth for several bodies at the same time, scientists at any given time have information about the direction of their vectors, which may be an interaction. For the Sun–Earth system, the vectors of this conical surface show the position of the ecliptic with respect to the Earth's equator.

In modern Earth science, it is accepted that planet Earth is extremely complex and every earthly event occurs as a result of the influence of many factors. Spatio-temporal technology presents new opportunities for a wide range of land-related problems. Now that we have more information about the influence of sources (astrometric parameters of the heavenly bodies) in 3D space as well as the visualization of the statistical distribution of structured geophysical data on selected criteria, we can carry out tests to establish the contribution of each of them in the process of the emergence and development of the event.

For global research of Modules 1 and 2 and their constituent spherical and Cartesian systems, coordinates are at a superposition at the point 0 (the beginning of all coordinate systems) in the center of the Earth. For regional studies, point 0 of Module 2 moves to the point $B(\varphi, \lambda, R)$ of Module 1 (Figure 1). When combined, the axes of the Cartesian coordinate systems of the two modules are parallel to each other.
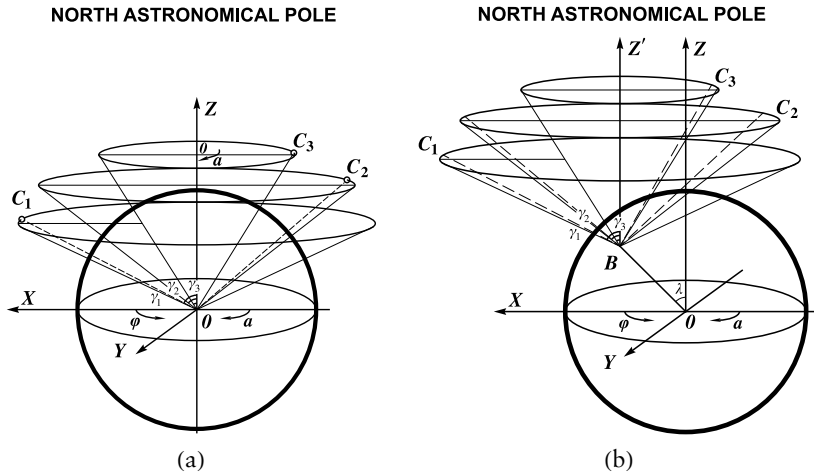
▍ 2.1 Three-Dimensional Model of the Earth

The 3D model of the Earth (Module 1) combines three coordinate systems: (I) spherical $P_0(\varphi, \lambda, R)$ (mathematics), (II) Cartesian $x\,y\,z$ to communicate with the cosmos, and (III) geographical $P_{0\,G}(\varphi_G, \lambda_G, R_G)$ (geography) in which all databases of the Earth's events are drawn upon.

All three systems of coordinates (I, II, III) are combined at the point 0 and the z axis so that the vector $r(90°, 0°)$ of (I) is combined with the negative x axis system (II). The origin and direction of the axes of all systems are individual:

> *System I. $P_0(\varphi, \lambda, R)$.* Latitude φ varies from $0°$ (z axis) down to $180°$ (negative z axis); longitude λ (clockwise for the right-handed system) varies from $0°$ (the negative end of the x axis) to $360°$ (same axis).

> *System II. $P_0(X, Y, Z)$.* Cartesian coordinate system with axes at $90°$ to one another.

Figure 1. Three-dimensional model of the Earth based on a motionless Earth 3D pattern in the system of spherical coordinates $P_0(\varphi, \lambda, R)$, where φ is latitude, λ is longitude, and R is radius. The coordinates are placed into the Cartesian system $x\,y\,z$ so that the rotation axis of the Earth is arranged in the positive Z direction toward the North astronomical pole (near the Polar Star) [9]. The X axis is arranged in the Greenwich Meridian. (a) Here all three sources are located in the highest position of their helical movement. (b) The circular moving source C relative to the observer on point B.

> *System III.* $P_{0\,G}(\varphi_G, \lambda_G, R)$. Latitude φ_G varies from $0°$ (equatorial plane $x\,y$) to the poles up and down to $90°$ N and $90°$ S; longitude λ_G varies from $0°$—the positive end of the x axis (Greenwich Meridian)—to the right and left, up to $180°$ and $-180°$.

It is known that the Earth is not a perfect sphere but instead is shaped like an ellipsoid of revolution and has R, the maximum radius of 6378.16 km, in which is inscribed the figure of the Earth (I), and R_G, the distance from the Earth's center at point B (III).

▌ 2.2 Method of Moving Source

In spatio-temporal technology, the idea of helical motion for n celestial bodies (C_n), is considered as n vectors around, up, and down in relation to the equatorial plane of the stationary Earth. This system is designated as Module 2 and presented in a 3D dynamical system called "the method of moving source" [6, 7].

Module 2 combines three coordinate systems: (IV) its own spherical $P_{0\,C}(\gamma, \alpha, S)$ (mathematics), (V) Cartesian $0_1\,X_1\,Y_1\,Z_1$, and (VI) a spherical system $P_{0\,A}(\delta, \alpha, S)$ (astrometry). These systems describe the motion of n vectors $r(\delta, \alpha)$ in relation to the n heavenly bodies with astronomical coordinates. n is the number of simultaneously considered multiple moving sources from the total (C_n).

Areas of the coordinates on the axes:

System IV. $P_{0\,C}(\gamma, \alpha, S)$. Latitude γ, the angle with the z axis varies as φ in system I; longitude (also known as the hour angle α) varies clockwise from $0°$ (the negative end of the x axis) to $360°$ or from 0 to 24 hours in solar time; S is the length of the vector of the Earth source.

System V. $P_{0\,C}(X_1, Y_1, Z_1)$ is similar to coordinate system II, and indices of 1 indicate the position of the coordinate system II if B is not located in the center of the Earth (Module 1).

System VI. $P_{0\,CA}(\delta_A, \alpha_A, S_A)$. Declination δ_C (astrometry) varies as φ in system III from $0°$ (the equatorial plane $x\,y$) up to $90°$ and down to $-90°$; α_A varies from $0°$ (coinciding with the negative end of the x axis) to $360°$; S is the length of the vector–Earth source. Each celestial body uses its own system of coordinates in forming VI.

Between the coordinates of VI, IV and III δ(VI), γ(IV) φ(III), there is a relationship: $\delta(\text{VI}) = \varphi(\text{III})$; $\delta(\text{VI}) + \gamma(\text{IV}) = 90°$.

3. Data Analysis

In this research, the databases of the seismic catalog (more than 180 000 events) and the astrometric data (more than 14 000 events) are used. Recent rapid development of computer equipment and technology has made it possible to solve some of the problems connected with processing large data arrays. However, while solving the problems associated with proving hypotheses and searching for new regularities, there is often incomplete or sub-definite information. Such problems can arise when working with catalogs on seismic data that contains information related to some regions and time lags not submitted in full.

It was necessary to solve the following problems: (*i*) how the data array related to each specific Earth science should be structured in order to facilitate ease of operation within each of these databases; (*ii*) which criteria must be established for selecting different base groups to find out the cause and effect relationship within those groups when conducting research in a cross-disciplinary field; and (*iii*) how to compare these data groups.

To address the issues of seismic event distribution in spacetime analysis, the following features of spatio-temporal technology were used:

1. Data was structured by the number of earthquakes per year, assuming unity (coincidence) of time of a seismic event and finding the brightness of a given height (angle of inclination) of Earth's equatorial plane.

2. To investigate the influence of the Moon relative to Earth from the astrometric data, such intervals Δt were chosen when the declination of the Moon (δ_{C2}) was equal to the value of $\delta_{C2} = \delta_k + \Delta\delta_{C2}$ (where accuracy $\Delta\delta$ is equal to plus or minus $1°$). For the study, data was used from 1982 to 2002, including a full 18.6 year cycle of lunar motion. For all the sums $\Sigma\Delta t$ of the given interval (where Δt represents each

year), the sum of the number of earthquakes ΔN that have occurred this year were selected from a catalog of seismic events $\Sigma \Delta N$.

3. As a result of analysis, because the task of comparing and analyzing heterogeneous (astronomical and geophysical) data included the use of both time and place of events, it was concluded that the overall structure and characteristics of the study database as a whole (or individual groups selected according to different criteria by classifying and sorting) is easiest to study using graphical techniques, including visualization of the statistical distribution.

To compare groups of data, analysis was conducted for periodic changes in the declination of the Moon's δ_{C2} in the test year and its extreme changes depending on the phase of the cycle. This information was used to analyze the 3D visualization of the latitudinal distribution of earthquakes throughout the lunar cycle. That is, the distribution of earthquakes φ_G occurred at $\delta_{C2} = \delta_k + \Delta\delta$, where δ_k is the selected constant. Research was carried out for $\delta_k = 0°$, $\delta_k = 15°$, and $\delta_k = -15°$.

In current geophysical surveys, the methods of applying visualization to the statistical distribution methods are as follows: analysis of complex systems; particularities revealing a system behavior in general without preliminary studies of the process-specific mechanisms, which are quite difficult to reveal by the computational procedural means; and comparison of geophysical, astronomical, and geological data arrays.

The use of visualization in the statistical distribution methods in the geophysical survey gives the following special advantages:

- allows general review of investigated phenomenon

- reveals hard-to-describe empiric regularities, such as intricate correlations, trends, exceptions, and anomalies by means of analytic mathematical methods, which cannot be detected only by means of the computational procedure

- often reveals effects (both estimated and unexpected) faster and sometimes better than can be revealed by means of numerical techniques

- provides unique possibilities for multidimensional analytic study or "data mining"

- allows obtaining of qualitative information on data groups of spatiotemporal allocation in 3D visualizations, which is impossible to represent by means of only one parameter; although the information is in the form of database (BD) geophysical events, whose number is currently very high (e.g., the number of earthquakes with magnitude 4.0 to 9.5 in 20 years is in the tens or hundreds of thousands), very accurate analysis is often still not enough

The use of the statistical graphical method in this case provides additional information about the global phenomenon under study—the Earth's seismic processes that cannot be expressed as a single parameter. Figure 2 displays an overview of the events, where repetition of Earth's seismic activity both on the same latitude throughout the

study period (two decades) and short-term (over several years) shows the manifestation of some latitudes' activated epicenters, as well as anomalies in the form of a sharp increase in seismic activity in the form of peaks in certain years. The existence of stable minima at certain intervals of time and latitude can mean either the absence of seismic activity or lack of sufficiently detailed observations at high latitudes and in these intervals.
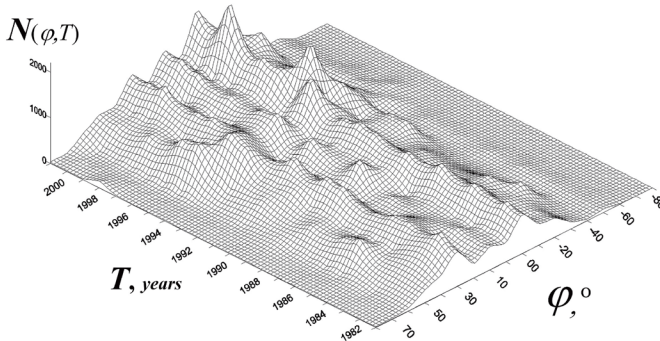
Figure 2. Visualization of the latitude-time statistical distribution of the sum total N of earthquakes on the z axis (180 000 with the value of magnitude ranging from 4.0 to 9.0). The time interval, from 1982 to 2002, is shown on the y axis (with an interval of 1 year) and the interval latitudes from 80–89 ° N to 80–89 ° S are shown on the x axis (with an interval of 10 °).

Processing statistics in the form of 3D visualization of the statistical distribution provides unique opportunities of multidimensional analytical study to test scientific hypotheses. The present study is an attempt by the example of the Moon's influence to get an answer to this question: does the position of heavenly bodies on the global distribution influence the number of earthquakes? It is known that this satellite affects the tides and biological processes on Earth.

3.1 Analysis of Seismic Data

Information about seismic events is placed in directories that include information about time, place, and magnitude of the event. This paper uses data from the U.S. Geological Survey's Earthquake Data Base directory on the distribution of earthquake epicenters in the world [10].

The presentation of this data in the format of geographic coordinates (latitude and longitude) shows that they are distributed unevenly in the Earth's surface and gravitate to specific lines, called plate boundaries (geology). The area of some slabs is comparable in size with areas of continents, but there are small slabs among them as well. Seismic and volcanic activities in these areas reflect the activity

of geologic processes within the Earth. Particularly highlighted is the activity of the sub-meridian course (location) on the border of the continental plates in the coastal zones of the Pacific Ocean. They account for about 90% of earthquakes. Also released is the sub-latitudinal zone of earthquake epicenters in Eurasia, located near 30° N to 40° N latitude.

Seismic activity continues in some areas and is constantly connected mainly with the passage of geological and geochemical processes in the Earth's interior.

It is clear that the probability of an earthquake is made up of many factors, most of which are geological, but astronomical effects can have an influence. We cannot express the probability of a distribution of global seismicity in the form of mathematical calculations, but we can try to test the hypothesis that celestial bodies influence it. Putting in the data structuring described here and using the interim guidelines for the appropriate astrometric data, we analyze the results of several tests. As a source in the form of latitude-time statistical distribution in Figure 2, all seismic events have occurred between 1982 and 2002 with a magnitude ranging from 4.0 to 9.0.

3.2 Astronomical Data Analysis

For the period under consideration (1982–2002), which includes an 18.6 year cycle of the Moon's relative motion to the Earth, the author analyzed time series variations in the astronomical data $\delta(T)$: declinations of the Sun, δ_{C1}, and the Moon, δ_{C2} [9]. Variations $\delta_{C1}(T)$ and $\delta_{C2}(T)$ are investigated step-by-step as the dynamics of relative motion in the Sun–Earth–Moon system and as changes in the angular distances of both bodies with respect to the Earth's equatorial plane. The 12 hourly time series of astronomical data (more than 14 500) was collected by the author over the 20-year period (1982–2002) and presented in the table [11].

Module 2 for each of the heavenly bodies will be unique, since the vertical and rotational velocity with respect to the equatorial plane of the Earth have individual characteristics. The time cycles and the maximum angle of deviation differ from the equatorial plane of the Earth. Fluctuations in the solar equatorial plane relative to a stable change occur in the δ_{C1} interval 23° to −23°. For the Moon, the δ_{C2} changes depend on the phase 18.6-year cycle and occur at intervals of 18° to −18° and 28° to −28°.

Module 2 is the most important for the study of the Sun because we live in solar diurnal time. Seasonal (annual) data on the position of the Sun relative to Earth is also important as it is actively influencing its geosphere (atmosphere, hydrosphere, etc.) and indirectly influencing the Earth's seismicity.

▍ 3.3 Practice Spacetime Technology

Figure 3 shows examples of spacetime technology as 3D visualizations of the statistical distributions of groups of seismic events that coincide with the Moon's presence in a plane of $15°$, $0°$ (equatorial), and $-15°$.

The complexity of the problem lies in the fact that it is necessary to establish a link between the motion parameter of the Moon (declination δ_{C2}) and pulse-temporal distribution of earthquakes, $N(\varphi, T)$. It is assumed that the appearance of maxima $N(\varphi)$ in the distributions of groups of earthquakes on the latitude φ, close in magnitude to δ_{C2}, can testify to the influence of astronomical factors on the distribution of seismic events on a global scale.

Figure 3 shows 3D visualization of the statistical distribution of seismic events selected from the database directory for the National Earthquake Information Center from 1982 to 2002 by sampling by the criterion (with constant value δ_k) [10].

An overall increase in the number of earthquakes $N(T)$ from time T can be observed in 1992, which can be explained by insufficient amounts of data, due to either a lower seismic activity or fewer seismic stations that recorded the event.

Changes in the distribution of the latitudes may depend on the selection criteria imposed by the number of earthquakes.

In the initial renderings, Figure 2 shows the distribution of 180 000 events. The ridge of the earthquakes is visible on the latitude ranges $30°$ to $39°$ and $0°$ to $10°$ in the Northern Hemisphere as well as $10°$ to $19°$ and $30°$ to $39°$ in the Southern Hemisphere, which corresponds to the constant seismic activity at these latitudes.

Comparing the visualizations from Figures 2 and 3 shows the change in the number of earthquakes in the latitudinal distributions if the sample number of imposed criteria $\delta = \delta_k$, δ_k remains constant.

In visualizing $\delta_k = 0$ in Figure 3(b), the height of the ratio of ridges changes in the initial distribution. The maxima are situated symmetrically at the latitudes of $30°$ to $39°$ N and S.

In visualizing $\delta = 15°$ in Figure 3(a), the highs are a little excessive at latitudes $50°$ to $39°$ N.

In the case of criterion $\delta_k = -15°$ in Figure 3(c), there is no pronounced trend of an increase of any of the ridges under the influence of the direction $\delta_{C2} = -15°$. Consider either that manifestation of the influence of the Moon is weak, that the absence of lesions is at the moment "ready" for an earthquake, or that the number of selected earthquakes of this criterion is so small that the sample is not representative.
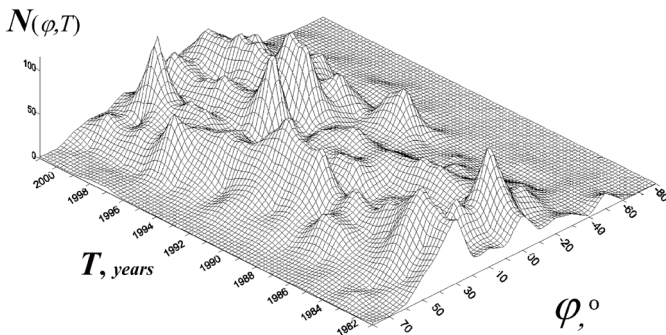
In addition, it is necessary to consider that the ridges in Figure 3(c) are defined weakly because in the Southern Hemisphere the length of deep faults and the boundaries of the lithosphere plates are shorter in latitude than in the Northern.
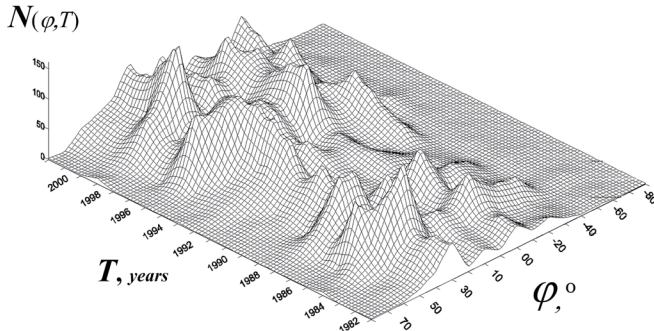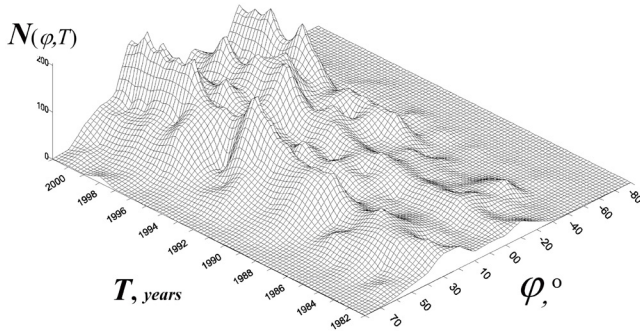
Figure 3. Latitudinal-temporal distribution of seismicity $N(\varphi, T)$ (z axis) is shown as a function of latitude φ (on the x axis with an interval of $10°$) and time T (on the y axis with an interval of 10 years) for the groups of earthquakes with magnitude factors between 4.0 and 9.5 for the years 1982–2002. The group N is selected by one criteria: the time when the Moon is located (a) at $\delta_{C2} = 15°$; (b) $\delta_{C2} = 0°$ (on the equatorial plate); and (c) at $\delta_{C2} = -15°$.

Single peaks indicate high seismic activity in a given period of time in these latitude zones.

4. Discussion of Results

Obviously, the influence of the Moon, located in the equatorial plane in both hemispheres of the Earth (North and South), should be symmetric. 3D visualization of the statistical distribution (presented in Figure 2) has confirmed this assumption. Figure 3(b) shows two distinct ridges located at a latitude of 30° to 39°, parallel to the equator for 10 years (the location is affirmed in [12]) and two below the ridge at the latitude of about 10° to 19° and 0° to 9° for 20 years. Thus, there is a transformation of the surface distribution for the total number of earthquakes. Figure 2 is in accordance with the expected influence of the Moon symmetrical to the Earth's surface.

In all cases in Figure 3, it can be assumed that either there is no manifestation of the influence of the Moon with this trend (up to 1990) or that the number of selected earthquakes is too small and the sample is not representative.

The asymmetrical pattern for the δ_{C2} criterion $\delta_k = 15°$ and $\delta_k = -15°$ leads us to believe that such an effect exists, but is not too pronounced and is near the sub-latitude boundary of the lithospheric plates.

Statistical analysis of the number of earthquakes (in %) has been conducted for the Northern and Southern Hemispheres. Figures 3(a), 3(b), and 3(c) correspond to the samples of earthquakes that occurred when the Moon was located above the equatorial plane ($\delta = 15°$), in the plane ($\delta = 0°$), and under the plane ($\delta = 15°$) respectively.

The difference for single amounts of earthquakes was estimated (in %) in the Northern and Southern Hemispheres for the sample represented in Figures 3(a) and 3(c). If the amounts (in %) for Figure 3(b) are set equal to zero, where the Moon replaces in the equatorial plane ($\delta = 0°$), deviation of amount for the Northern Hemisphere is equal to $+5\%$ in Figure 3(a) (where the Moon replaces in the North Hemisphere, $\delta = 15°$), and in Figure 3(c) (where the Moon replaces in the Southern Hemisphere $\delta = 15°$) equal to -5%.

The deviation for the Southern Hemisphere is equal to -5% in Figures 3(a) and 3(c). The total difference for the samples shown in Figures 3(a) and 3(c) is equal to only 10%. This deviation corresponds to the hypothesis of a weak influence manifesting from the Moon.

The group of factors: geological (related to the Earth's tectonic development, to the boundaries of lithosphere plates), astrophysical (related to the influence of the other celestial bodies), distribution of geophysical fields (as variations in the direction and values of the physical fields, gravitational anomalies, and others), concern the remaining 90%.

5. Summary

The aim of this paper was the study of the allocation of available seismic data and positions of celestial bodies in the case of the Moon. The three-dimensional (3D) spatio-temporal technology interdisciplinary research tool was developed as a means to understand the Earth and celestial coordinates. The structure of the statistic distribution of the sum total of the National Earthquake Information Center/U.S. Geological Survey seismic data directory for earthquakes with magnitudes ranging from 4.0 to 9.5 between the years 1982 and 2002 was presented with their 3D visualizations [10].

Spatio-temporal analysis was conducted on the 3D visualization of the statistical distribution of seismic events if their time had coincided with the presence of the Moon ($\delta_k = 0$) in the equatorial plane ($\varphi_G = 0$), which can be interpreted as the existence of a lunar influence on the global seismicity. It is symmetric for both hemispheres in the case of $\delta_k = 0$. For $\delta_k = 15\,°$ and $\delta_k = -15\,°$, the highs are a little excessive at latitudes in the Northern Hemisphere for $\delta_k = 15\,°$ and in the Southern Hemisphere for $\delta_k = -15\,°$.

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