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Study of the Possibility of Predicting Earthquakes

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Abstract

It is already well known that the "when, where and how strong" earthquake prediction problem cannot be solved by only analyzing the database from former earthquakes. A possible solution to this problem is proposed herein based on the analysis of the physicochemical processes as participants in earthquake preparation and on the characteristic rate of reflection of these processes on the Earth's surface. The proposed procedure includes monitoring of correlation of electromagnetic fields variations with tidal waves. This solution provides a way of selecting a complex of reliable earthquake precursors using the Inverse Problem Method for earthquakes which will occur in the region around the monitoring point (radial distance ≈ 700 km) in the next seven-day period [1].

Keywords

Earthquakes Prediction, Earth Degassing, Physical Chemistry, Explosions, Electromagnetic Field Monitoring

1. Introduction

In this article, tectonic earthquake and eruption processes are presented and discussed as a series of chemical explosions caused by physicochemical processes, which are partly reflected on Earth's surface. Energy accumulation in the hypocenter includes the latent energy of chemically active (explosive) substances which induce exothermic syntheses (explosions) depending on local changes of Pressure-Temperature (PT). Also discussed are chemical explosions which are presented here as branched chain reactions that form concentrations of highly explosive clusters whose explosions generate earthquake hypocenters. Those intermediate hypocenters (foreshocks - major shock - aftershocks) ascend along faults and fractures from a depth of about 700 km to the Earth's surface, becoming the complex of an earthquake.

Cold nuclear synthesis (fusion) and natural fission reactions are also presented as the major internal energy sources.

Whole assemblage of hypocenter preparation processes is accompanied by the generation of electromagnetic fields, which in contrast to other processes, are instantly reflected on the Earth's surface.

Presented are principles and results of forecasting of regional imminent seismic activity based on the analysis of one minute of INTERMAGNET geomagnetic field data and NASA codes for Sun-Moon tides—Geomagnetic Quake (GQ). Examples of prediction of the period, magnitude, depth, and coordinates of the hypocenter of an impending earthquake are based on the Inverse Problem Method for the analysis of monitoring data variations of geoelectromagnetic fields. The necessary and sufficient conditions for the existence of a solvable inverse problem are formulated based on the Dubna method for discovering the hidden dependences. The accuracy of prediction depends on the values of depth, coordinates, time, magnitude of the impending earthquake, number of monitoring points, geology of the region, and on the ill-posed quality of the received overdetermined non-linear algebraic system. Monitoring of additional data provides a way of selecting a complex of reliable earthquake precursors.

2. The Reason for Tectonic Earthquakes Is a Series of Chemical Explosions

The classical Reid's model [2] of "earthquake as a result of rock displacement under accumulated elastic stress" cannot explain the observed earthquake-cycle, foreshocks - main shock - aftershocks, of the strong earthquake, and from where comes its monstrous energy [3] [4]. There are clear demonstrations that the reasons for most of the "tectonic earthquakes" are underground natural explosions which cause the acceleration in the vertical direction exceeding the acceleration of gravity [5] and are shown in **Table 1**. Anomalous flow of the Earth's core lower mantle helium enriched by its light isotope ^{3}He, and hydrogen, which accompanies earthquakes and volcanic eruptions, provides evidence that volcanic eruption is a variety of "tectonic earthquake" wherein its hypocenter rises to the Earth's surface. Both events are a release of high density energy from the deep-rooted mantle-plumes through physicochemical reactions.

"There is evidence, which should be regarded less as established fact than as working hypothesis, that in the neighborhood of the epicenter the vertical component of motion is larger relative to the horizontal components than elsewhere" [6]. The elastic energy of "semi-solid mantle and lithosphere" breaks cannot

Table 1. Database of ground motion components in the neighborhoods of the epicenters.

Kathmandu, Nepal	International Seminar on				
November 29-30, 2009	**Hazard Management for Sustainable Development**				
Event	**Station (Mw)**	**Hor-1 (g)**	**Hor-2 (g)**	**Vert (g)**	**V/h**
Gazli, Uzbekistan 1976	Karakyr (6.8)	0.71	0.63	1.34	1.89
Imperial Valley, USA 1979	El centro array 6 (6.5)	0.41	0.44	1.66	3.77
Nahanni, Canada 1985	Site 1 (6.8)	0.98	1.1	2.09	1.9
Morgan Hill, USA 1989	Gilroy array#7 (6.2)	0.11	0.19	0.43	2.25
Loma Prieta, USA 1989	LGPC (6.9)	0.56	0.61	0.89	1.47
Northbridge, USA 1994	Arleta fire station (6.7)	0.34	0.31	0.55	1.61
Kobe, Japan 1995	Port Island (6.9)	0.31	0.28	0.56	1.79
Chi-Chi, Taiwan 1999	TCU 076 (6.3)	0.11	0.12	0.26	2.07

cause such motion and energy release in principle [7]. The energy release and the dominant vertical component of Earth's surface motion [6] [8] [9] support the claim that explosion is a basic mechanism of tectonic earthquakes.

Flow of H and He from the core and the lower mantle where pressure-temperature (PT) exceeds 1,000,000 atm. and 5000 K is undeniably a major energy source [3] [4]. This energy is:

1) Quasi-constantly released during billions of years of the Earth's existence and practically limitless;

2) Can be quickly concentrated and focused;

3) Is of very high density;

4) Offers very high velocities of energy release;

5) Has small losses during transportation over long distances.

Authors have proposed [3] [4] a conceptual system of hypotheses, which explains that during Earth's accretion, primordial helium and hydrogen were trapped and stored in the planet's interior as He- and H-interstitial solutions and compounds, stable only under ultrahigh PT-conditions, which were discovered in recent experiments. The endothermic reactions of their generation provided effective cooling of the planet and prevented its evaporation, where the end-products of those reactions were more compact than the initial gases. Since the stabilization of our planet, exothermic processes of H and He degassing became dominant, releasing the energy invested in their generation. The specific energy of the core-mantle H and He was calculated with ^{3}He serving as a unique measuring transformer correlative to the internal heat flow. Multiplying its flow from the lower mantle by the highest coefficient of correlation results in 5.12 × 10^{20} J/year, an amount of energy five-fold greater than the entire energy loss involved in earthquake and volcanic activity [3] [4].

In distinction to other main sources of the Earth's internal energy (cold fusion and fission nuclear reactions, radioactive decomposition of U, Th and ^{40}K, gravitational differentiation in the Earth's liquid core and the energy of lunar tides) the chemical energy can be concentrated and focused in the mantle-plumes supplied hypocenters generating great earthquakes and volcanic eruptions [3] [4].

In summary: H- and He-sublimation from the solid and convection in the liquid core with flux-melting the solid mantle, generates gas-liquid scavenging plumes. H- and He-release are accompanied by an intense release of their stored specific (latent) energy, and their ionization and incorporation into different chemical compounds was followed by decomposition due to local and gradual PT changes. Ongoing compressions-decompressions (foreshocks - major shock - aftershocks) within upward moving hypocenters (magma chambers), accompanied by additional releases of energy, cause release of elemental H, O, C, S, Cl, F etc., and induce synthesis of H_2O, SO_2, H_2SO_4, CO_2, H_2S, HCL, HF and other compounds in accordance with local changes of PT and energy, in accordance with Principle Le Chatelier-Braun ("The Equilibrium Law": "whenever a system in equilibrium is disturbed the system will adjust itself in such a way that the effect of the change will be nullified").

3. Physics and Chemistry of the Hypocenter Preparation and Earthquake Prediction

The earthquake preparation includes a number of processes having different rates. Only the electromagnetic waves approach Earth's surface immediately. This difference in the rates allows us to use them as a reliable earthquake precursor. A possible solution of this problem is proposed herein based on the analysis of the physicochemical processes as participants in earthquake preparation and on the characteristic rate of reflection of these processes on the Earth's surface. This solution provides a way of selecting a complex of reliable earthquake precursors using the Inverse Problem Method for earthquakes which will occur in the region around the monitoring point (radial distance ≈ 700 km) in the next seven day period.

N.N. Semenov declared already in 1956 in his Nobel Prize lecture titled "Some problems relating to chain reactions and to the theory of combustion" that the trains of chemical explosions are chemical branched chain-reactions [10]. This declaration is supported by a comparison of seismograms from earthquakes and nuclear explosions where the complexity of natural events (earthquakes) is higher than that of artificial events (explosions). Micro- or macro-foreshocks are forerunners of the major shock. Natural earthquakes are more complex than nuclear explosions and at teleseismic distances the difference between them is clear. This difference is observed very clearly in the relationship of solids to surface-wave amplitudes [11]. The nuclear weapons test is just a point explosion, whereas earthquake is the superposition of the totality of explosions which are distributed in space and time.

Prerequisites for the chemical explosions are the critical concentrations of reactants and their ratio which depends on PT conditions [10] [12] [13]. The critical concentration of the reactants and critical size of the explosive substances cluster is the first necessary condition of the local explosion [14].

The possibility of explosion propagation (or detonation) to other clusters depends on the distance between clusters or on the cluster volume concentration. The critical or more than critical concentration of ready to detonate volume of explosive substances clusters is the second condition of earthquake. Too large a distance between clusters limits the propagation of detonation possibility due to the possibility of absorption of the local explosion's energy by surrounding matter. This absorption causes local heating of matter and the formation of the chemically active substances [15].

Relatively small concentrations of explosive clusters before an earthquake produce foreshocks, which is preparation for an earthquake's major shock. "Combustion" of most of the clusters during the earthquake process decreases their concentration and generates aftershocks, (which take part in the rising hypocenter) and cause the relaxation of the surrounding matter.

Formation and accumulation of the explosive substances cluster, and preparation of the earthquake, is a totality of process. A hypocenter is an open thermodynamic system which uses all the possible degrees of freedom. This system is non-linear due to a principally different rate of separate processes including diffusion and filtration of molten matter through porous rock and cracks, heating and cooling, and stress and strain flow. An earthquake may be described as a bifurcation which returns part of the mantle-lithospere system to their main trajectory of development and corresponds to minimal internal free energy of the system and maximal rate of entropy production in the macrosystem. The following possible reactants participate in an earthquake explosion: hydrogen - oxygen; hydrogen - halogens; hydrogen - sulfur; alkanes (methane, etc.) - oxygen; alkanes - halogens; alkanes - nitrates, etc.

Explosive substances are produced and accumulated due to the energy which is released in the Earth's core, mantle, and lithosphere, by five main sources:

1) Cold nuclear synthesis (fusion reactions), which are accompanied by a generation and release of energy, ^{3}He, ^{4}He, ^{3}H and Earth neutrinos [16]-[23].

2) The natural fission nuclear reactors with fast neutrons on the boundary of Earth's solid/liquid core, and possibly, liquid core/mantle [24] [25] [26]. The capacity of those reactors depends on the Sun-Axions flow-intensity [27].

3) Tidal waves cause dissipation of energy in the Earth's core, mantle, and lithosphere; tidal waves are the main source of energy on the Jupiter and Saturn moons [28].

4) Gravitational differentiation promotes the solid core formation and plume activity [29].

5) Earth's degassing of hydrogen and helium [3] [4] [29] [30] [31], which generates anomalies of these gases in vicinities of active faults and forms a halo of hydrogen and helium surrounding our planet and comprising its exosphere.

Results of the analyses of the earthquake and volcanic eruption related gases clearly show that the mechanism of quake and eruption is a release of chemical energy. Physicochemical processes are the most effective way of transformation, transportation, and accumulation of energy into the hypocenter chamber.

Total heat losses of the Earth are 46 ± 3 TW [32] including about 20 TW of the released radiogenic heat. According to neutrino flow measurements radiogenic component in heat losses would be near 19.9 ± 9 TW [16] [26]. Heat from the core is about 8 TW ([32] table 11). Heat flow from the convective mantle including gravitational differentiation and degassing is about 39 TW [3] [4] [32].

The average annual energy of earthquakes is about 0.44 TW and energy of tidal wave dissipation is about 0.1 TW ([32] table 13). Heat and radiation produced by the nuclear reactions cause dissociation and an increase of reactants temperature, which create thermal currents due to the Seebeck effect. Partial or complete melting of solid matter generates electrochemical processes on phase boundaries and corresponding galvanic currents. Local heating increases local pressure and accelerates the movement of semi-melt or melt matter through porous rock and cracks creating the streaming potential, sedimentation potential, and corresponding currents. Temperature gradient of the heat flow causes electric gradient or electrode potentials on phase boundaries, which create electrophoresis and electroosmosis. Hydrogen, oxygen, sulfur, halogens, carbon, nitrogen, aluminum, and alkaline metals are possible participants in energy transport due to their chemical activity. The presence of helium increases flexibility and rate of stream of solids and melts [30] [33] [34]. Moreover, hydrogen, lithium, and boron may take part in nuclear fusion reactions [16]-[21] [35] [36]. Movement of the matter creates triboelectricity [37] due to friction between boundaries of the mantle-fragments and of gas-liquid plume and mantle, and also promotes electrokinetic phenomena (electrophoresis and electroosmosis).

4. Sun-Moon Tides as Earthquake Triggers

Tidal waves cause dissipation of energy in the mantle and lithosphere [28] [38] [39] [40] and periodic stress-strain waves create a peristaltic effect and increase the rate of rising of plume matter. Tidal waves have a very high velocity (more than 460 m/s in the lithosphere and more than 240 m/s on the liquid core boundary in the equatorial zone). This velocity is higher than the critical rate of propagation of brittle cracks. A high rate of loading promotes brittle behavior of the semi-solid viscose mantle and generates cracks. Cracks and cavities are filled by melt, steam, gas, suspension, etc. Coexistence of the liquid and solid phase provides “adiabatic” heat transport with maximal efficacy:

$$K = \frac{n\langle V\rangle * \lambda * C_V}{3 * N_A} \tag{1}$$

where: K is thermal conductivity; $n\langle V\rangle$ is number of particles per unit volume, which is close for liquid and solid phase near melting point; λ is mean concentration of free particles (electrons, for example); C_V is molar heat capacity; N_A is Avogadro’s number.

It is well known, that the specific heat capacity during phase transition is two orders of magnitude higher than for the mixed liquid and solid phase [41] [42] [43] [44] due to latent heat of the heat transition. It means that solid-liquid state is thermodynamically preferable for the mantle matter and for the earthquake-hypocenter heat-transport. Multiphase structure is preferable also for the matter-transport due to significantly higher flexibility and super-elasticity during phase transition [43] [44].

Thermal-current loops at the phase boundaries can enhance the local magnetic field created by the matter flows and by physicochemical processes.

$$B = \sum\nolimits_1^n \int_{-} \frac{\mu_0}{4\pi r_n^2} * \mathrm{d}l_n * \hat{r}_n \tag{2}$$

where: B is magnetic field intensity (a vector); $\mathrm{d}l_n$ is differential element of the current in the direction of the corresponding current (vector); r is distance from the current to the point of magnetic field measurement; $\hat{r}_n$ is the unit vector from the current element to the point of magnetic field measurement.

Tidal waves are a natural trigger of the totality of physicochemical processes, which comprise earthquake-preparation [45] [46] [47]. Most of these processes are accompanied by electromagnetic phenomena. The rate of the magnetic field propagation is 300,000 km/sec. This means that the geomagnetic signal approaches the Earth's surface without any delay. However, the time taken for the relaxation processes, for creating electrical currents, and for changing the local geomagnetic field is much longer than that of the magnetic field propagation. The rate of detonation at atmospheric pressure varies from 3 to 11 km/s (more than the velocity of sound) and the rate of the longitudinal and transverse waves in the solid mantle changes from 8 to 13.5 km/s for P-waves and from 4.5 to 7 km/s for S-waves. The time propagation of shock wave from hypocenter to epicenter is a function of depth and may vary between 1 to 90 seconds. The rate of all other processes may be much smaller. For example, the rate of plume matter movement, diffusion, or filtration through fractured or porous rock may be very low also.

So, processes of earthquake-hypocenter preparation comprise a multi-parametric non-linear system, which compensates differences in times of response or relaxation of different processes by bifurcation.

The monitoring system has to use parameters with a characteristic time of response equal or shorter than the duration of hypocenter matter relaxation. Moreover, the time it takes for the measurement of these parameters has to be shorter than the time of earthquake preparation. Time and rate of the processes involved are variable and may accelerate toward earthquake or bifurcation. It means that relatively short-time reliable predictions may be based only on monitoring the changes of the electromagnetic fields and viscous-elastic waves as a response to tides only.

For the longer time prognosis, other reliable precursors have to be included (see below).

5. Development of the "Geomagnetic Quake" Earthquake Prediction Method

- **The beginning** of this investigation dates back to the period of the International Scientific Group work in the framework of the "Clean and Peaceful Black Sea" program (1986-1991)—Crimea 1927 earthquakes. In 1989 INRNE-BAS started an investigation of the physics of the sea flames, observed at the time of the Crimea 1927 earthquake with the help of the magnetometer, with a relative accuracy of less than or equal to 1 nT, 2.4 samples per second (Boris Vasiliev, JINR, Dubna, private communication).
- **The second stage** of the research was carried out within the framework of the program "1998-2004 INRNE-BAS monitoring" and consisted of monitoring the geomagnetic field-Boris Vasiliev, JINR, Dubna, with a one component magnetometer.

These measurements were made with an interval of one minute and the obtained data allowed suggesting the following variables: the geomagnetic quake (GQ) of the field in the vicinity of a tidal wave maximum, the average daily magnitude of the magnetic field strength, and its hourly and minute average deviation [1]. This was the first statistical evidence that after a geomagnetic quake there is an increase of the seismic activity around a monitoring point estimated by the number of earthquakes with different magnitudes.

Further progress (2004-2010) was reached with the use of a three-component Danish fluxgate magnetometer, operated by the Skopje Seismological Observatory with the analysis of one minute INTERMAGNET data [48] [49] [50].

Introduction of the diurnal sum of earthquake energy as a numerical estimation of regional seismic activity.

The distributions for variable Day Diff of 874532 world earthquakes with magnitude M = 3.5, 5, 6, 7 which occurred in the period of 1981-2017 (International Seismological Center: http://www.isc.ac.uk/iscgem/overview.php) support the old hypothesis that the Sun-Moon tides are the earthquakes trigger. DayDiff is as follows:

$$\text{DayDiff} = \text{EqTime} - \text{NearTideExtreme},$$

where EqTime is the time of earthquake and NearTideExtreme is the time of nearest extreme of the diurnal mean of the Sun-Moon tide values and is presented in **Figure 1**.

As is seen from the graphs, 92% of all analyzed earthquakes occurred in the time period of +/− 2.23 days around the time of a tide extreme in the locality of their epicenter.

The value at Day Diff can be interpreted as a count of aftershocks.

Table 2 illustrates the cases of magnitude (M), the values of sigma (half wide), total number of earthquakes, number of earthquakes outside of sigma intervals (+, −), and percent of earthquakes that occurred in the sigma interval.

It is important to note that the daily estimation of regional (around monitoring point) seismic activity can be achieved by summing up the variable reflecting

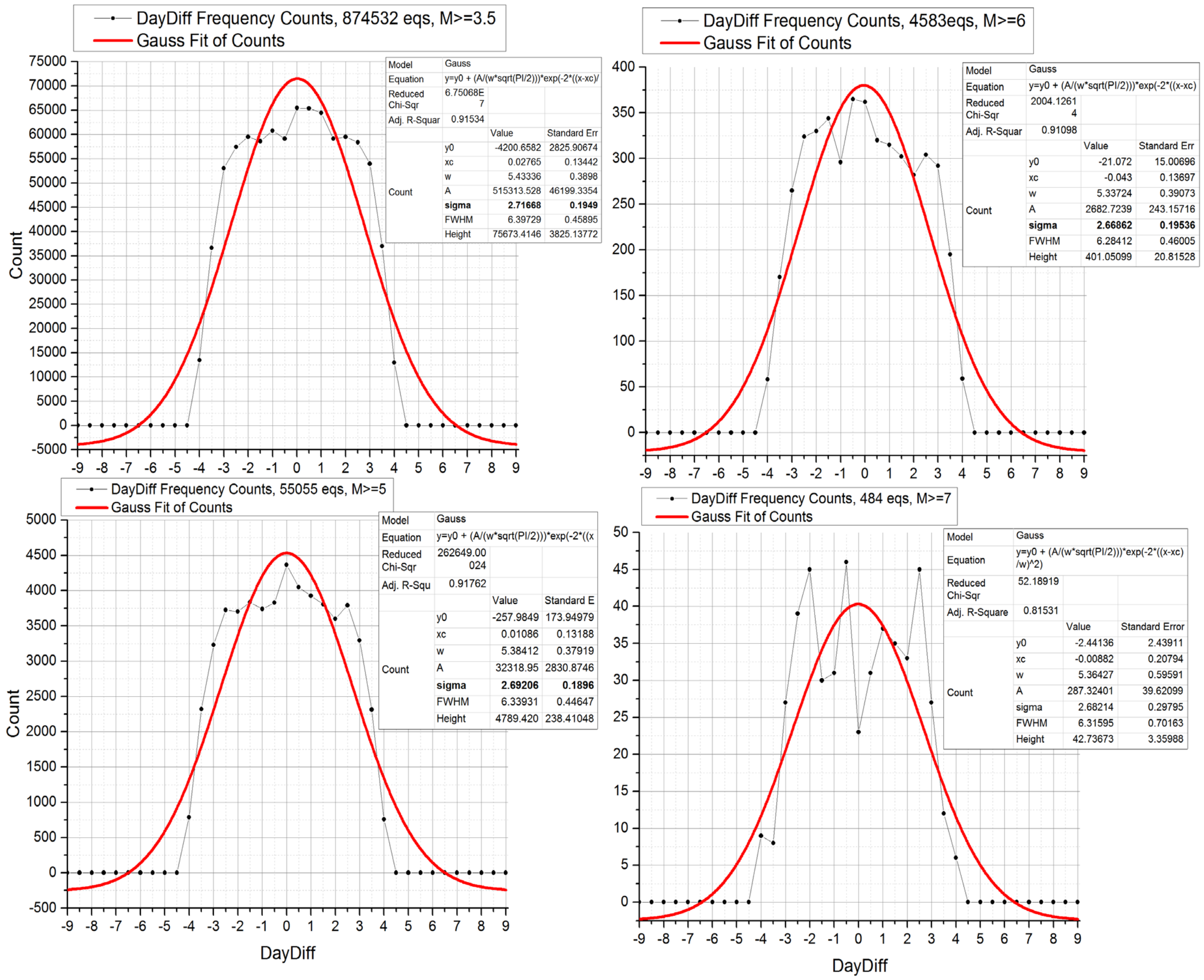

Figure 1. The Gauss fit of DayDiff distributions in case of different M.

Table 2. Distribution of earthquakes relative to tides maximum.

Magnitude	3.5	5	6	7
Sigma	2.72	2.69	2.67	2.68
TotalEqs	874,532	55,055	4583	484
MinSigmaEqs	106,772	6780	545	50
PluSigmaEqs	107,314	6821	601	48
SigmaEqs	214,086	13,601	1146	98
Percent	0.24	0.25	0.25	0.20

density of surface energy:

$$S_{Cht} = 10^{1.5M+4.8} \Big/ \left(D + Depth + Dist_{Mp}\right)^2 \quad \left[J/km^2\right] \qquad (3),$$

where D = 40 km for the Balkan region, for every earthquake that occurred. Probably this value is determined by average lithosphere thickness in the Balkans. The explicit form of function S_{Cht} was obtained using the Dubna inverse problem method [51]-[56] for estimation of the correlations between GmPrecSig and regional seismic activity in the tide's extreme period.

The inverse problem solution allowed selection of the following variables based on monitoring data:

The estimation of the variability of one experimental series of measurements - $T = \{T_i, i = 1, \ldots, n\}$ includes the calculation of the mean value mT:

$$mT = \frac{\sum_{i=1}^{n} T_i}{n} \tag{4}$$

and the value of its dimensionless standard deviation SdT:

$$\mathrm{Sd}T = \sqrt{\frac{\sum_{i=1}^{n}\left(1 - \frac{T_i}{mT}\right)^2}{n}} \tag{5}$$

Obviously, the biggest standard deviation value means the biggest variability of the series.

Therefore, the procedure of monitoring includes numerical comparison of two sequential series of measurements.

The data used:

- Japan one minute INTERMAGNET geomagnetic stations MMB (Memambetsu, Lat 43.907˚N, Lon 144.193˚E, Altitude = 42 m), KAK (Kakioka, Lat 36.232˚N, Lon 140.186˚E, Altitude = 36 m) KNY (Kanoya, Lat 31.42˚N, Lon 130.88˚E, Altitude = 107 m) minute data (http://www.intermagnet.org/),
- Software for calculation of the daily and minute Earth tide behaviour (Dennis Milbert, NASA, Solid Earth Tide Software updated 07 June, 2018, http://geodesyworld.github.io/SOFTS/solid.htm),
- Earth tide extremes (daily average maximum, minimum and inflexed point) as a trigger of earthquakes,
- Data for World A-indices (National Oceanic and Atmospheric Administration Space Weather Prediction Center (NOAA SWPC) https://www.swpc.noaa.gov/products-and-data).

The geomagnetic signal was calculated as a simple function of the relative standard deviations of the geomagnetic vector components. The precursor signal is the difference between today and yesterday's geomagnetic signal corrected by the A-indices values. An increase of the precursor signal means an increase of the geomagnetic field variability. Such a positive leap was named a geomagnetic quake in analogy with an earthquake. An analysis of the correlation between the earthquakes occurrences, and the time of Sun-Moon Earth tide extremes on the basis of the variable earthquake's surface energy density S_{ChtM} permits the forecast of an imminent regional seismic activity. Calculation of the day differences (DayDiff) between the time of the earthquakes occurrence and the time of the nearest tide extreme permits the building of the curve of DayDiff and its Gaussian fit. The comparison of Gauss widths for all the earthquake occurrences and those with the biggest S_{ChtM} permits the formulation of the hypothesis for "predictable" earthquakes.

The typical data and results of its analysis are shown in **Figure 2**

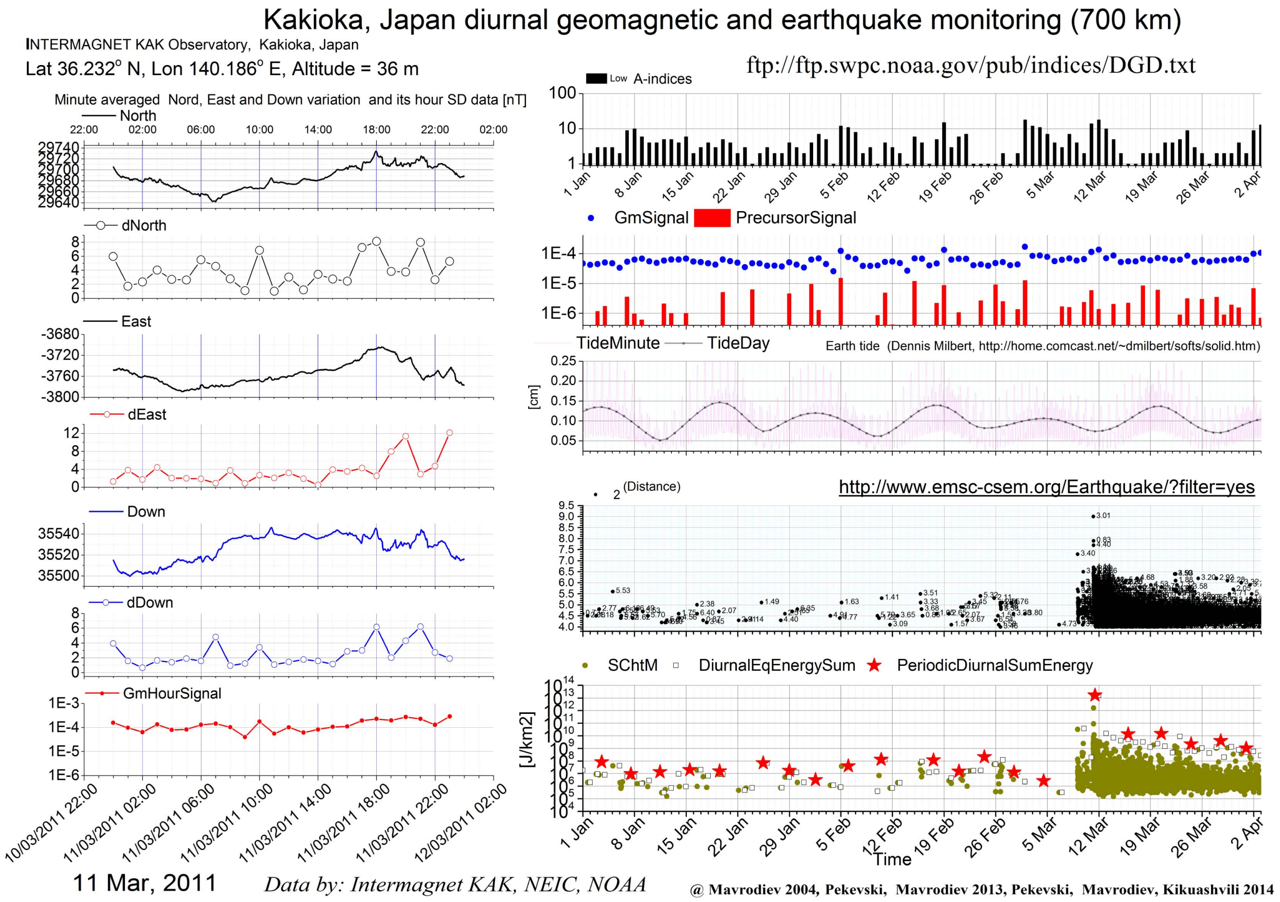

Figure 2. Kakioka diurnal geomagnetic and earthquakes monitoring in the time period around the Fukushima earthquake with geomagnetic field data on March 11, 2011.

The Geomagnetic field components North_m, East_m, Down_m, $m = 1440$, are the minute averaged values of the geomagnetic vector F, and the variables SdNorth_h, SdEast_h, dSDown_h are their standard deviation, calculated for 1 hour, $h = 1, \dots,$ 24:

$$\text{SdNorth}_h = \sqrt{\frac{\sum_{m=1}^{60}\left(1-\frac{\text{North}_m}{m\text{North}_h}\right)^2}{60n}} \tag{6}$$

where

$$m\text{North}_h = \frac{\sum_{m=1}^{60}\text{North}_m}{60} \tag{7}$$

The geomagnetic signal GeomHourSig_h is the geometrical sum of hour standard deviation normed by the module of hour geomagnetic vector:

$$\text{GmSig}_h = \sqrt{\frac{\text{SdNorth}_h + \text{SdEast}_h + \text{SdDown}_h}{m\text{North}_h + m\text{East}_h + m\text{Down}_h}} \tag{8}$$

The A indices are the Low, Medium and High indices, calculated by the NOAA, Space Weather Prediction Center: https://www.swpc.noaa.gov/products-and-data

In this paper we use A_{Low}.

The variable $\mathrm{GmSig}_{h\mathrm{Day}}$ is the diurnal mean value of GmSig_h:

$$\mathrm{GmSig}_{h\mathrm{Day}} = \frac{\sum_{m=1}^{60} \mathrm{GmSig}_h}{60} \tag{9}$$

and $\mathrm{PrecSig}_{\mathrm{Day}}$ is

$$\mathrm{PrecGmSig}_{\mathrm{Day}} = 2\frac{\mathrm{PrecGmSig}_{\mathrm{Day}} - \mathrm{PrecGmSig}_{\mathrm{YesterDay}}}{A_{\mathrm{Day}} + A_{\mathrm{YesterDay}}} \tag{10}$$

The indices of earthquake's magnitude value are the distance of one hundred km between the epicenter and the monitoring point.

The variable Periodic $\mathrm{S}_{\mathrm{Cht}}$Sum [J/km^2] is the sum of the variables $\mathrm{S}_{\mathrm{Cht}}$ for all earthquakes that occurred in the time period +/− 2.7 days before and after the tide extreme in the 700 km region around the monitoring point. Obviously, its value can serve as an estimation of the regional seismic activities for the time period around the tide's extreme.

The variable Diurnal $\mathrm{S}_{\mathrm{ChtM}}$Sum [J/km^2 per day] is the sum of the variable $\mathrm{S}_{\mathrm{Cht}}$, calculated for all earthquakes that occurred during the day in the 700 km region around the monitoring point. This variable can serve as a quantitative measure of diurnal regional seismicity.

It is worth noting that the explicit form of the variable $\mathrm{S}_{\mathrm{Cht}}$ was established in the framework of the inverse problem [48]-[54] in an effort to get a clearer correlation between the variables $\mathrm{PrecSig}_{\mathrm{Day}}$ and Periodic$\mathrm{S}_{\mathrm{Cht}}$Sum.

The variable Tide Minute [cm] is the module of tide vector calculated every 15 minutes.

The variable Tide Day [cm] is the diurnal mean value in the time calculated in analogy of the *mass center* formulae

$$\mathrm{Time}_{\mathrm{TideDay}} = \frac{\sum_{m=1}^{360} m\mathrm{TideDay}_m}{\sum_{m=1}^{360} \mathrm{TideDay}_m} \tag{11}$$

Note: For the seconds and number of samples per second, the generalization has been to calculate geomagnetic field characteristics for every minute, and correspondingly the values of $\mathrm{GmSig}_{\mathrm{day}}$ have to be the average for 1440 minutes.

The positive value of the variable $\mathrm{PrecursorSig}_{\mathrm{day}}$ means that the geomagnetic field variability, which is calculated via standard deviations of geomagnetic field components, is increasing (formulae 1, 2).

In an analogy with an earthquake we call such an increase a *geomagnetic quake*.

As one can see from **Figure 2**, after the appearance of the geomagnetic quake, in nine of twelve cases (75%), the regional seismic activity is increasing (the bigger value of the Periodic $\mathrm{S}_{\mathrm{ChtM}}$Sum variable) in the time period around the following tide extreme. Therefore, the geomagnetic quake approach described herein can serve as a forecast of imminent regional seismic activity.

In **Figure 3** the values of the variable Periodic $\mathrm{S}_{\mathrm{ChtM}}$Sum are calculated not

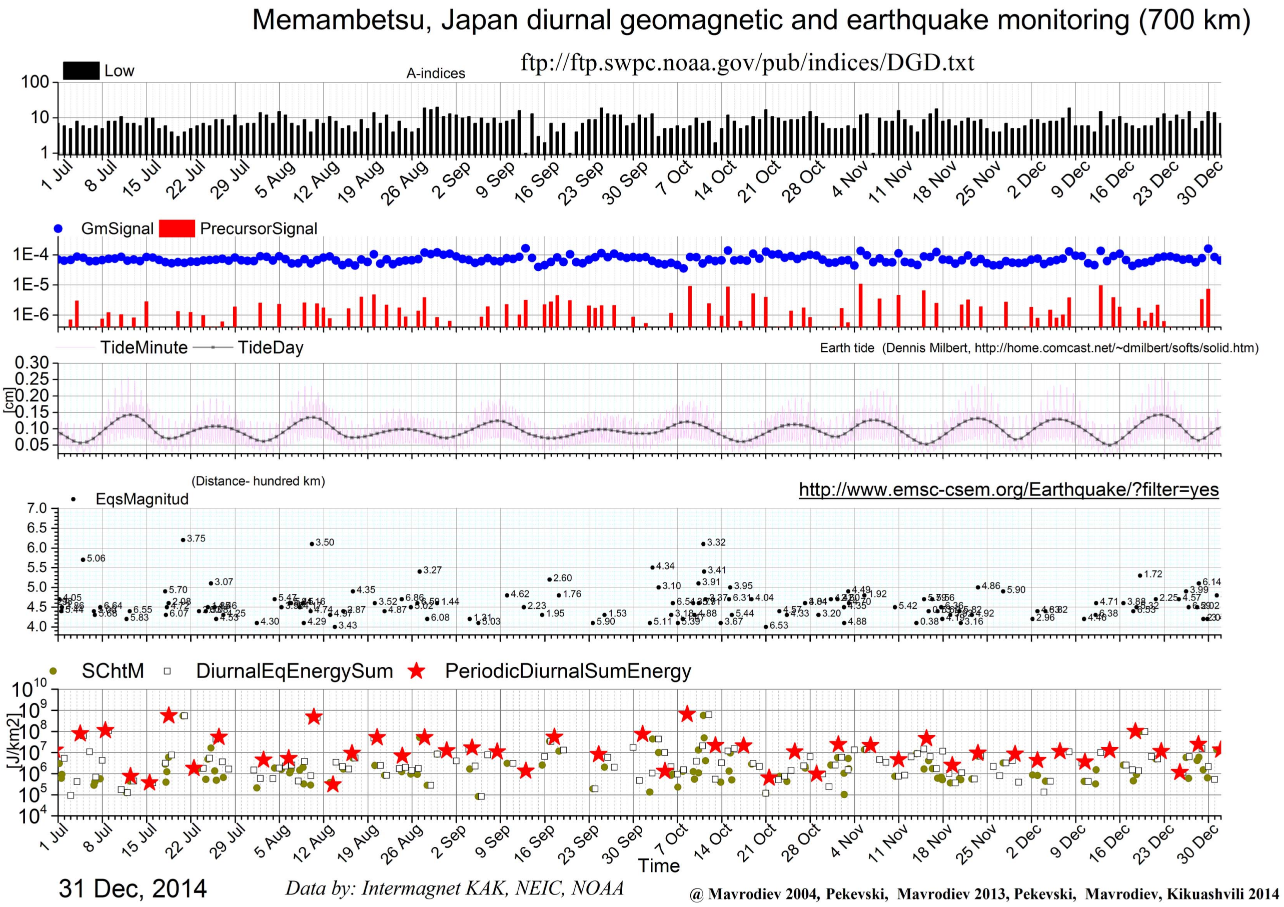

Figure 3. Memambetsu diurnal geomagnetic and earthquakes monitoring for the period Jul. 1, 2014 – Jan. 1, 2015.

only for the time periods around the extremes, but also for the time period between them. We can see that the values in almost every extreme period are higher.

The use of the above described analysis for a longer time period with the calculation of distribution of day difference between the "predicted" earthquakes (earthquakes with the highest value S_{ChtM}) demonstrates the reliability of this approach for forecasting imminent regional seismic activity for regions with seismic risk (**Figure 4**).

The correspondence between GmPrecSig and the predicted increase of regional seismic activity permits the formulation of the hypothesis that the "predicted" earthquake is defined as the quake with the bigger value of function S_{Cht}. The GQ analysis of one minute INTERMAGNET data of Kakioka, Memambetsu and Kanoya, Japan stations demonstrated that such earthquakes are "predicted" in the same time from two stations, which permits the formulation of the overdetermined algebraic system for the explicit form of function

$$\text{GmPrecSig}\ (M_i,\ Dept_i,\ Lat_i,\ Long_i),\ i = 1,\ \ldots,\ \text{number of “predicted” earthquakes} \quad (12)$$

Using (12), with the number of monitoring points, number of reliable precursors one can formulate the conditions for existence of overdetermined algebraic

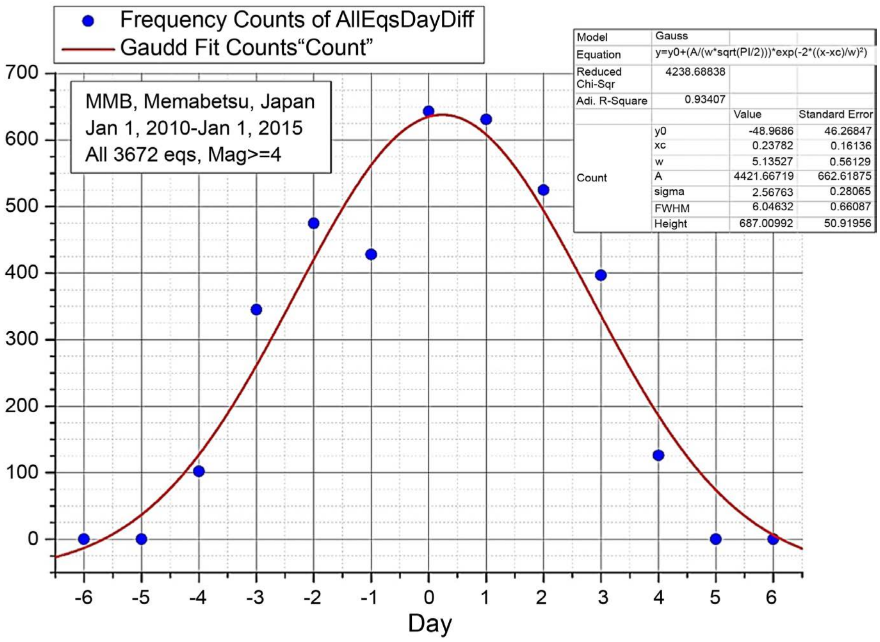

Figure 4. The distribution and its Gauss fit of DayDiff for all earthquakes occurred in Memambetsu (700 km radial distance) region [56].

system, solution of which are the values of M_i, $Dept_i$, Lat_i, $Long_i$), $i = 1, \ldots,$ number of predicted earthquakes in the time period on the next tide extreme.

At the end is a brief presentation of the real time data acquisition system for researching the reliability of earthquakes precursors, formulation and solution of the overdetermined inverse problem for the magnitude, depth, and coordinates of epicentre of impending earthquake.

The other precursor of earthquakes is the bore-hall water level. The preliminary results of such findings were positive (Georgia, Armenia, BlackSeaHazNet proceedings) http://theo.inrne.bas.bg/~mavrodi/11%20ArmeniaBoreHole/WlEqMoembMonitoring.png, but for its reliability, more statistical analysis is needed.

6. Conclusions

The approach proposed for solving the problem of the “how, where and when” of earthquake prediction does not decrease the importance of commonly accepted investigations based on seismology, geology, geoelectromagnetism and JPS data.

Presented herein is a new approach for forecasting of the regional weekly seismic and volcanic activity based on the analysis of the INTERMAGNET geomagnetic field and NASA code for Sun-Moon tides data and is a Geomagnetic Quake approach. The results are based on the inverse problem method for analysis of the geomagnetic field which instantaneously reflects terrestrial currents in hypocenter. The necessary and sufficient conditions for the existence of a solvable inverse problem are formulated on the basis of the existence of reliable precursors.

A real time data acquisition system for researching the reliability of earthquake precursors, formulation, and solution of the overdetermined inverse problem for the magnitude, depth, and coordinates of the epicentre of impending earthquake must include the following additional types of monitoring:

1) Increase of helium 3, 4 and radon surface concentration;

2) Increase of the local heat flows through the Earth's surface;

3) The water-level in boreholes and steam release into atmosphere;

4) Change of the ionosphere height, conductivity for the radio waves and meteorological conditions;

5) Appearance of low frequency waves in the atmosphere and the Earth's crusts which are not observed by nuclear test monitoring;

6) Variations in Schumann resonance.

An inverse problem could be solved for prediction time (±2.7 days), magnitude, depth and epicenter coordinates of an upcoming earthquake—with 4 parameters, which means that at least 4 monitoring points in a region of a radial distance of 700 km are necessary for formulation of the solvable overdetermined algebraic system.

The combination of the geomagnetic measurements and the above-listed additional reliable precursors is bound to make feasible an overdetermined algebraic system.

The solution of such a multi-parametric system will provide the possibility for estimating an earthquake's magnitude and epifocal coordinates' prediction accuracy and will be very useful in the further research of the nature of the tectonic processes.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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