Estimation of the Lithospheric Component Share in the Earth Natural Pulsed Electromagnetic Field Structure

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Abstract. Article describes the results of the atmosphere and Earth’s crust climatic and ecological parameters integrated monitoring. The estimation is made for lithospheric component share in the Earth natural pulsed electromagnetic field structure. To estimate lithospheric component we performed a round-the-clock monitoring of the Earth natural pulsed electromagnetic field background variations at the experiment location and measured the Earth natural pulsed electromagnetic field under electric shields. Natural materials in a natural environment were used for shielding, specifically lakes with varying parameters of water conductivity. Skin effect was used in the experiment – it is the tendency of electromagnetic waves amplitude to decrease with greater depths in the conductor. Atmospheric and lithospheric component the Earth natural pulsed electromagnetic field data recorded on terrain was compared against the recorded data with atmosphere component decayed by an electric shield. In summary we have demonstrated in the experiment that thunderstorm discharge originating electromagnetic field decay corresponds to the decay calculated using Maxwell equations. In the absence of close lightning strikes the ratio of field intensity recorded on terrain to shielded field intensity is inconsistent with the ratio calculated for atmospheric sources, that confirms there is a lithospheric component present to the Earth natural pulsed electromagnetic field.

1. Introduction

Though Earth natural pulsed electromagnetic fields (ENPEMF) are widely used in engineering and geophysical surveys, geodynamic forecasts and permafrost studies [1], the discussion about the nature and sources of those fields is still open in the scientific community.

A large number of researchers think that a vast majority of impulses in ENPEMF structure originates from thunder strikes in the atmosphere [2–4], and the proved efficiency of the methods based on those fields recording is explained by the fact that in very low frequency band electromagnetic waves propagate within the Earth-Ionosphere waveguide. Depending on geological framework and Earth’s crust stress-strained state, waves’ propagation conditions vary and the depth of waves’ penetration into geological substrate varies as well.
Another group of researchers, including the authors of this paper, while not denying the existence of the atmospheric component in ENPEMF, proves that lithospheric component takes considerable place in those fields overall structure [5–8]. Radio-wave methods applied are based on the phenomenon of electromagnetic emission - dielectric materials emissive ability when they are acted on. Electromagnetic emission emerges in the process of charges generation and relaxation on fracture planes during the stress state of the rocks. Pulses emerge both when dielectric uniformity changes and when electrolyte-filled capillars rift [9]. In rock formations there can be the following sources of natural electromagnetic fields: soil structure inconsistencies, unequally strained structures, fractures and microfractures. All those sources generate pulsed electromagnetic fields as a result of mechanic-to-electric energy conversion, strain waves from the mantle, tides, microseisms, winds, and technological loads thus creating a natural electromagnetic background of lithospheric nature. Observing electromagnetic emission allows to monitor stress-strained state of the rock formation [10, 11].

According to everything mentioned above it is necessary to create physical-mathematical models, describing electromagnetic processes and to confirm current understanding with an experiment. We carried out an integrated monitoring of climate and ecological parameters of the atmosphere and Earth’s crust to estimate lithosphere component share in ENPEMF structure. That is a fundamental research leading to acquiring new knowledge in Earth sciences, but it has a useful applied potential as well. ENPEMF based geophysical survey methods developed were successfully tested in the inland and proved most informative compared to other cost-effective methods.

Most promising locations for new natural deposit site explorations are continental shelves, especially in Extreme North region. If most of the pulses in the ENPEMF structure originate from the atmosphere then applying ENPEMF methods in shelf exploration would be impossible due to the fact that saltwater’s high conductivity would screen atmospheric pulsed fields.

The goal of the experiment is to prove the existence of lithospheric ENPEMF component, show the possibility of geophysical survey based on ENPEMF parameters while working on continental shelf. To achieve that goal a series of experiments were carried out recording ENPEMF at the location shielded from atmospheric discharges. Natural materials in a natural environment were used for shielding, specifically lakes with varying parameters of water conductivity. Time of the experiments in July was selected based on seasonal highest ENPEMF intensity with distinguishing extremums of daily trajectories.

2. Experiment
Field research took place in Khakassia republic, Russia. Lake Itkol is a large freshwater pond of 2300 hectares in area. Lake Shira is large water body with mineralization parameters close to seawater. Lake Tus is a bitter lake with a large bottom sludge layer.

Electric field intensity measurement device “CS110” allowing to register a vertical component of electric field intensity in a band of ±22.3kW/m was used to analyze thunderstorm factor. By the operating concept that device is a field mill with a shuttling screening plate.

ENPEMF variation were measured by geophysical recorders. “GR-01” records the following parameters of ENPEMF:
• number of field’s magnetic component pulses in a specified time frame, with a pulse height over a specified threshold;
• pulse height of the first pulse exceeding a threshold for magnetic component;

Measurement resolution was 1 second. Meteorological data obtained was compared against the data of meteorological stations network. The closest meteorological station was Shira, situated in about 10km from the experiment site.

We have carried out a research on the particulars of atmospheric-electric and meteorological parameters changes during the passing of the frontal and air-mass convective clouds over the experiment site. To interpret the data, an additional analysis of synoptical maps, nephanalysis and
cloud evolution forecast maps and MODIS (KA Terra, Aqua) spectroradiometer data was used including resulting thermodynamical and optical cloud parameters.

To estimate lithospheric component we performed a round-the-clock monitoring of ENPEMF background variations at the experiment location and measured ENPEMF under electric shields. Terrain experiment site registering ENPEMF background variations, electric field intensity and meteorological parameters was located at north-east coastline of Lake Itkol. Recorders in hermetically sealed radio transparent containers were doused to different depths into lakes with different water conductivity (l. Itkol, l. Shira, l. Tus) in order to shield off atmospheric electricity. Skin effect was used in the experiment – it is the tendency of electromagnetic waves amplitude to decrease with greater depths in the conductor. Atmospheric and lithospheric component ENPEMF data recorded on terrain was compared against the recorded data with atmosphere component decayed by an electric shield. Table 1 shows experimentally measured electrical conductivity, skin-layer for that conductivity and calculated based on Maxwell equations atmosphere EM field decaying for different depths. Skin depth is a level inside of the conductor decaying EM field $e$ times.

**Table 1.** Calculated decay of atmospheric EM field depending on conductivity and dousing depth.

| Conductivity | 1. Itkol | 1. Shira | 1. Tus |
|--------------|---------|---------|-------|
| Skin depth for $f=14.5$ KHz, [m] | 11.6 [m] | 2.2 [m] | 0.9 [m] |
| Decay at 2m, [times] | 1.2 | 2.4 | 8.3 |
| Decay at 10m, [times] | 2.4 | 99.7 | - |
| Decay at 13m, [times] | 2.8 | 396.6 | - |

Figure 1 shows ENPEMF recorded data in two dominating directions of reception on terrain and atmospheric electric field intensity.

![Figure 1](image_url)

**Figure 1.** EM field parameters: a) ENPEMF pulse flow intensity in dominating reception direction North-South; b) ENPEMF pulse flow intensity in dominating reception direction West-East; c) Atmospheric electric field intensity.
It is clearly visible that ENPEMF intensity recorded in North-South direction correlates well with the intensity recorded in West-East direction. Anomalies appear on the electric field intensity chart when a thunderstorm cloud was passing over the recording equipment with high peaks during thunder strike discharges. It can be concluded based on Figure 1 that nearby thunderstorm manifest themselves in higher ENPEMF intensity values which is correct.

Let’s review the ENPEMF recorded data with non-anomaly electric field intensity values compared to general synoptic situation at the region, e. g. July the 10\textsuperscript{th} and July the 17\textsuperscript{th}.

There was a cold frontal passage over the recording site at July the 10\textsuperscript{th}. Many meteorological station indicated thunderstorm along the front line visually (red circles on the map in Figure. 2b), including the stations within 300 km distance of the ENPEMF recording site. Figure 2a shows ENPEMF intensity values for that day. Red line on the chart illustrates hourly running average value. Running average values do not exceed 5 pulses per second throughout the whole day.

On the July the 17\textsuperscript{th} none of the meteorological stations located within 400 km distance from the experiment site detected thunderstorms. The region was under the anticyclone influence. Despite the absence of nearby thunder strikes running average ENPEMF values exceed those recorded during the thunderstorm passage for over 4 times. That can be considered as one of the indirect proofs to the inconsistency of the theory stating atmospheric component predominance in ENPEMF structure.

![Figure 2](image1.png)

**Figure 2.** Comparison of ENPEMF pulse flow intensity recorded during atmospheric frontal passage at July the 10\textsuperscript{th} (a) against intensity during anticyclone at July the 17\textsuperscript{th} (b) synoptic map at July the 10\textsuperscript{th}; (c) synoptic map at July the 17\textsuperscript{th}.

Figure 3 shows ENPEMF intensity values, measured by two recorders one of which was on the bank terrain and another one 13 m underwater of lake Itkol. For better visibility underwater measured values are multiplied by -1. The gap in the lake Itkol underwater measurements is a result of thunderstorm weather floating craft watering ban. Battery elements in the equipment weren’t changed in time and it caused a stop in recording. Based on the calculated values for water conductivity of 0.065 cm/m in the case of only atmospheric ENPEMF component present, the field decay recorded underwater should be 2.8 times. However throughout the whole measurements time the observed experimental value was 1.6 times, which confirms the hypothesis of a lithospheric ENPEMF component.
component present. Decay value close to a calculated one was recorded one time during a strong thunderstorm at July the 11\textsuperscript{th}. There was a frontal passage of local cumulonimbus cluster, developing at a rear of a cyclone behind a katafront. According to MODIS cumulonimbus at that cluster developed at a limited local area but had a large size and vertical thickness.

Lets review EM parameters during a thunderstorm of July the 11\textsuperscript{th} in more detail. Figure 4a) shows a segment of ENPEMF recording corresponding to that event.

For better visibility there are EM field intensity values measured close to terrain geophysical recorder overlaid on the chart. Sharp peaks of intensity are caused by a thunderstorm. Sharp peaks in intensity are induced by the close lightning strikes. Plot indicates that ENPEMF atmospheric component decay by the water layer corresponds with a calculated one, but between the lightning strikes there are impulses that are not decayed. That is a lithospheric component. At that time there was a passing of local cumulonimbus cluster, developing at a rear of a cyclone behind a katafront. One of the clouds of that cluster passing over the experiment site, should have reach a mature stage, as indicated by high values of EM field intensity near the surface and intense thunderstorm activity (peaks in EM field intensity at Figure 4a), and anvil form observed at passing.

Figure 3. ENPEMF intensity on terrain and 13 m underwater of lake Itkol. Underwater values multiplied by -1.

Figure 4b shows segments of ENPEMF recorded on terrain and 13 m underwater of lake Itkol after the thunderstorm. It follows from the charts that in the absence of nearby lightning strikes there is no decay to ENPEMF intensity by water layer electric shield neither considering pulse flow intensity nor pulse amplitude. That is another proof of the lithospheric component existence in those fields structure.

Figure 4. A segment of ENPEMF intensity recording and EM field intensity recording. Underwater intensity values multiplied by – 1, where a) during a thunderstorm; b) in the absence of thunderstorms.

In addition to the results of ENPEMF measurements in a freshwater lake presented above, there was also a simultaneous fields recording done underwater of salted lake Shira and on terrain,
underwater of bitter lake Tus and on terrain. On lakes Shira and Tus at 2m underwater the decay value was 1.5 times higher than a calculated value. Those lakes have a sludge layers with mineralization higher than water mineralization, so the equipment was in fact shielded from both atmospheric and lithospheric electricity. Experiment program didn’t include sludge layers’ depth and conductivity; therefore it wasn’t possible to calculate the decay for those conditions using known formulae. At 13 m underwater of lake Shira the decay recorded was 1380 times while calculated decay was 380 times for conductivity of 1.85 S/m. According to Malakhov’s plan of sludge deposit the thickness of deposits at measurement site is around 1m

3. Summary
In summary we have demonstrated in the experiment that thunderstorm discharge originating electromagnetic field decay corresponds to the decay calculated using Maxwell equations. In the absence of close lightning strikes the ratio of field intensity recorded on terrain to shielded field intensity is inconsistent with the ratio calculated for atmospheric sources; that confirms there is a lithospheric component present to ENPEMF. Bottom sludge deposits of high conductivity apparently set practical limitation to ENPEMF method applications for geophysical survey on inland shelves.

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