Use of Artificial Intelligence Methods in Processing Geophysical Data Related to Detection of the Shore Effect in Natural Variations of the Electric Field

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Abstract

A “shore effect” was discovered in the magnitude of the natural alternating electric field, which consists in an increase in the amplitude of variations in the horizontal component orthogonal to the coast near the coastline. While the "shore effect" in variations of the vertical component of the magnetic field arises due to a jump in the magnitude of the induction current flowing along the coastline, the effect in variations in the electric field is associated with a change in the density of electric charges on the coastline proportional to variations in the electric field strength.

Keywords

Paper template, paper formatting, CEUR-WS

1. Introduction

The shore effect in geomagnetic variations is a complex phenomenon associated with the impact of geoelectric heterogeneity in the form of a sea or ocean on the field of geomagnetic variations and telluric currents, and manifests itself at a relatively short distance from the coastline on land or at sea [1,2]. The first studies of the shore effect were performed by the scientists of the "Mirny" Observatory (Antarctica). It was noted that near the coast, namely on land, the current is directed at an angle of 45° to the coastline, and the normal and vertical components of the magnetic field are characterized by strong changes. The current in the sea is linearly polarized and flows along the coast, repeating the coastal configuration [3]. In the 70s of the twentieth century, a number of works appeared on the study of the coastal effect on the basis of experimental data from geomagnetic observatories and the method of magnetotelluric sounding (hereinafter referred to as the MT sounding method) [4]. In the second half of the 1960s, in order to study the effect of sea currents, special observations were made by a dense network of stations in the north and south of the Russian islands of Sakhalin and Iturup [5].

Analysis of previous studies revealed that the extinction of the coastal effect with distance from the water layer occurs at different rates in different regions. In addition, a large amount of experimental material made it possible to draw the following conclusions:

Local anomalous effects associated with the coast are attenuated at a distance of several kilometers. The magnitude of the coastal effect depends on the depth of the sea, the ratio of the conductivity of land and sea, and the configuration of the coastline. For example, on the Crimean coast, 40 km northeast of the city of Chernomorsk, no coastal effect was found due to the shallowness of the sea (the maximum depth reached 10 m), low electrical resistivity of the land (2.5-3 Ohm/m) and the straightness of the

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coastline. Whereas on the southern coast of Crimea, characterized by a high rate of increase in sea depth and a high-resistivity land section, the coastal effect was clearly expressed [6].

Since the coastal effect is observed in geomagnetic variations, this effect should also be present in variations of the electric field. However, no research in this direction has been done, which is probably due to the difficulties of studying the electric field in coastal zones, which leads to poor accuracy when using the method of MT sounding.

To fill this gap, we conducted a research of Ultra-low-frequency (hereinafter referred to in the text as ULF) variations of the electric and magnetic fields in the coastal zones of the White Sea (Umba village), the Barents Sea (Teriberka village), the Sea of Okhotsk (Sakhalin island) and the Pacific Ocean (Kamchatka Peninsula). Two multi-electrode experiments were performed in the village of Umba and on the Kamchatka Peninsula. Data registration in all experiments was performed by GI-MTS-1 geophysical stations located directly on the coast and at a point of 160 m from the coast in a forest tract.

Each station included 3 torsion-type three-component magnetic sensors (Bx, By, Bz) and two horizontal telluric lines ~ 50 m long (Ex, Ey). The Ex component was directed orthogonal to the coast, the Ey component was directed along the coast. The recorded data were recorded on a flash card with a resolution of 50 Hz. The root-mean-square sensitivity of the magnetic sensors was 2 pT at a frequency of 1 Hz, the sensitivity of the electrical sensors was 0.1 μV / m.

2. Experimental data processing results

During the processing of experimental data, using the methods of the theory of artificial intelligence and deep learning, the MATLAB system, a "coastal effect" was discovered in the magnitude of an alternating electric field. The results are presented below in various graphs [7,8].

In Figure 1 are shown the variations of the electric (horizontal components Ex and Ey) and magnetic fields of the Pc1 type (Bx and By) in the frequency range F = 0.1 - 0.2 Hz.

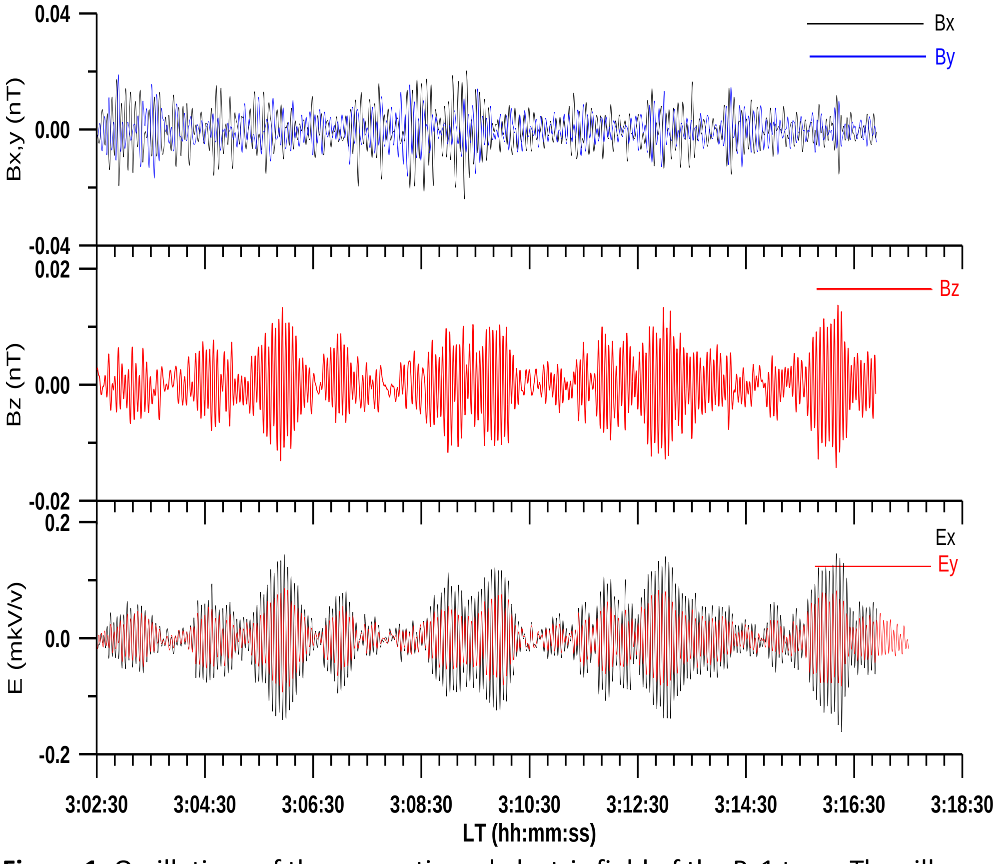

Figure 1: Oscillations of the magnetic and electric field of the Pc1 type. The village of Teriberka, 16.08.2018

In Figure 2. the ellipse of polarization of the electric field (Ex - Ey) is represented.

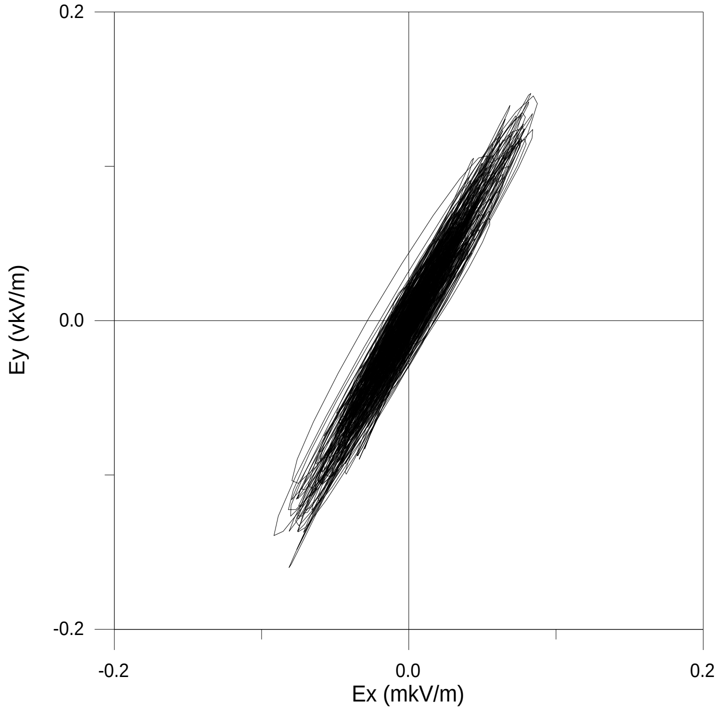

Figure 2: Polarization of the horizontal components of the electric field

The data on the electric and magnetic fields were obtained in an experiment on the Barents Sea (the village of Teriberka).

In Figure 3 it is clearly seen that in variations of the electric field the coastal effect is very weak, while in the magnetic field there is a serious increase in the vertical component of the field.

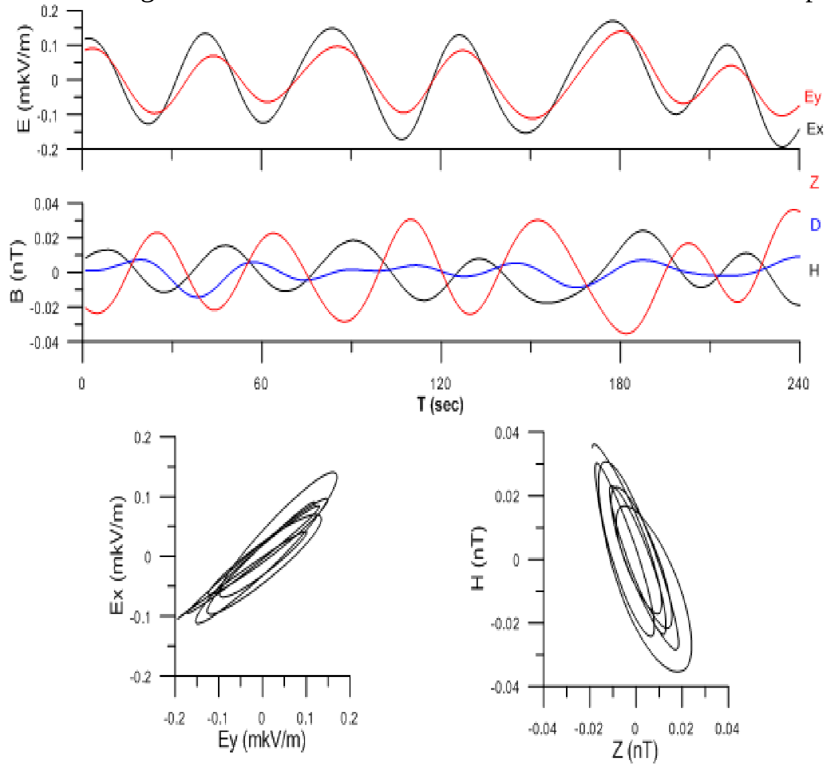

Figure 3: Components of electric and magnetic field variations (upper panels) of Pc3 type (F = 0.1 - 0.033 Hz) and polarization ellipses Ex - Ey and H - Z (lower panels). Teriberka, 15.08.2018

In Fig. 3, the two upper panels show the variations of the electric (horizontal components Ex and Ey) and magnetic fields of the Pc4 type (all three components) in the lower frequency range F = 0.01 - 0.033 Hz. The lower panels show the polarization ellipses of the electric field (Ex - Ey) and magnetic field (H - D) and (H - Z). In the area where the instruments were located, the coast was rocky and the tide reached 5 m.

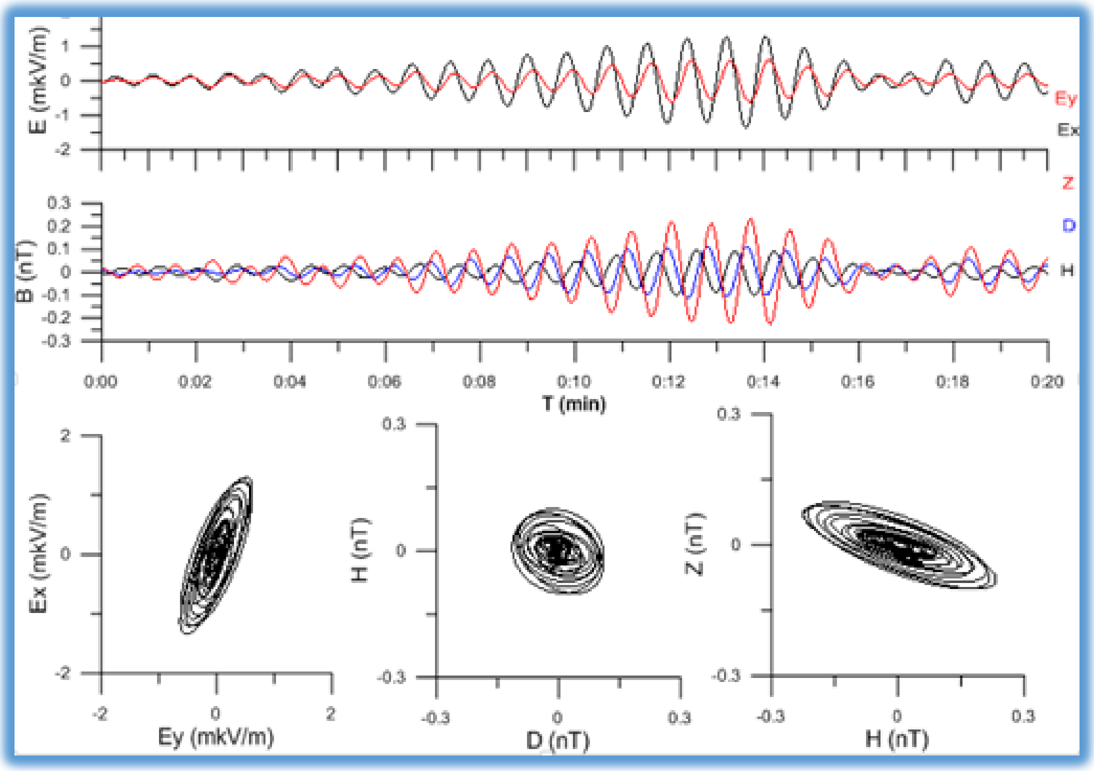

Figure 4: Components of electric and magnetic field variations (upper panels) of Pc4 type (F = 0.01 - 0.033 Hz) and polarization ellipses Ex - Ey, Y - D and H - Z (lower panels). Teriberka, 16.08.2018

In Figure 4, in contrast to Figure 1 - Figure 3, it can be noticed that the coastal effect is also observed in variations of the electric field - the Ex component is significantly larger than the Ey component, and in the variations of the magnetic field - the Z component is significantly larger than the H and D components. The effect is clearly seen in the records of the electric and magnetic fields and in the polarization ellipses.

In Figure 5, the two upper panels show the variations of the electric (horizontal components Ex and Ey) and magnetic fields of the Pc3 type (all three components) in the lower frequency range F = 0.03 - 0.1 Hz. The lower panels show the polarization ellipses of the electric field (Ex - Ey) and magnetic field (H - D) and (H - Z). The data on the electric and magnetic fields were obtained in an experiment on the White Sea (Umba village). In the area where the instruments were located, the coast was sandy and the tide was ~ 2 m.

In Figure 5, the coastal effect is clearly observed in the variations of the electric field - the Ex component is twice the Ey component, and in the variations of the magnetic field - the Z component is significantly larger than the H and D components. The effect is clearly visible in polarization ellipses.

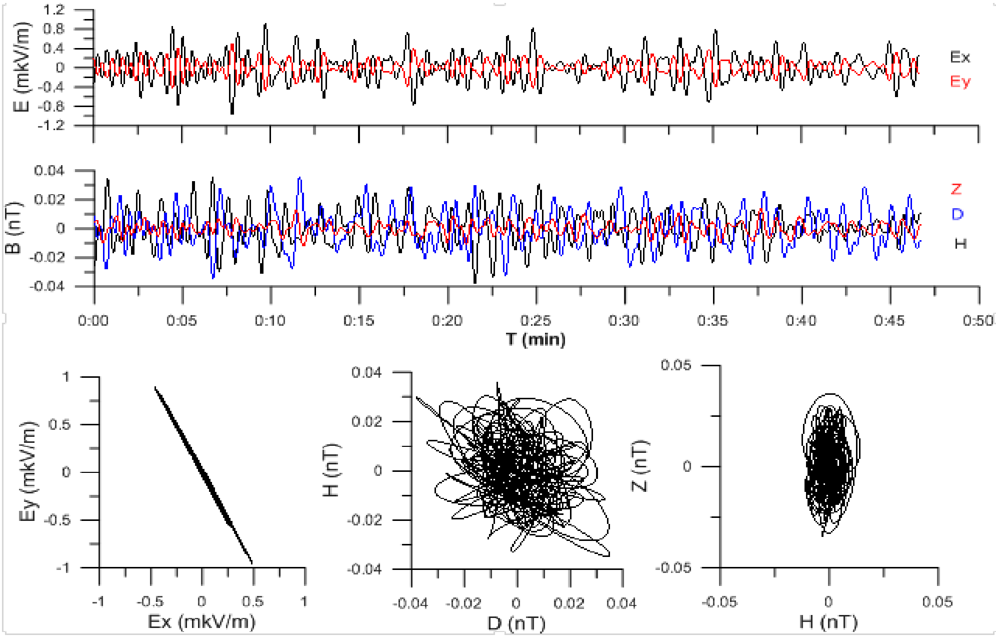

Figure 5: Components of electric and magnetic field variations (upper panels) of Pc3 type (0.03 - 0.1 Hz) and polarization ellipses Ex - Ey, H - D and H - Z (lower panels)

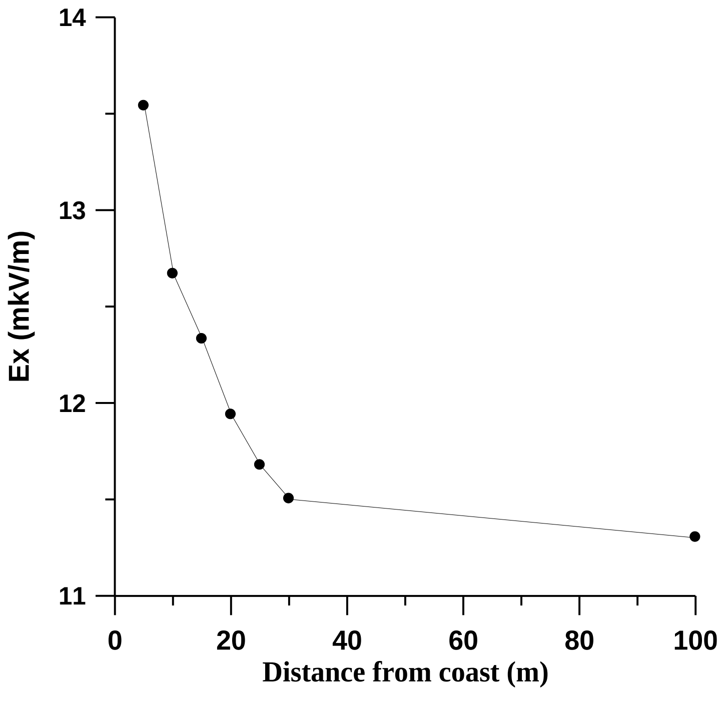

Figure 6: Dependence of the root-mean-square value of the horizontal component of the natural alternating electric field on the distance to the water's edge. Umba, 04.07.2019

In Figure 6 shows the dependence of the root-mean-square value of the horizontal component of the natural alternating electric field (pulsations of the Pc4 range) on the distance to the water's edge.

The dependence was built based on the results of a multi-electrode experiment on the White Sea on July 05, 2019. It can be seen from the figure that at a distance of 30 m from the water edge, the amplitude of variations in the electric field decreased by 1.2 times; at a greater distance, the amplitude decreases more slowly, which means a strong locality of the source of variations.

As seen in Figure 1 - 6, the magnitude of the coastal effect depends on the ratio of the conductivity of land and sea and the frequency of variations - in longer-period variations, the coastal effect is stronger.

In Figure 7 shows a diagram of the change in the concentration of negative electric charges near the coastline when the direction of the horizontal component of the alternating electric field is changed. When the direction of the horizontal component of the electric field of the orthogonal coastline changes, the concentration of negative electric charges changes accordingly.

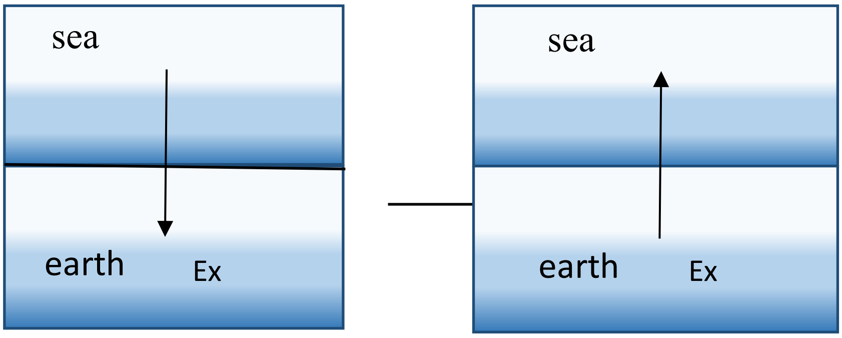

Figure 7: Change in the concentration of negative electric charges near the coastline when the direction of the horizontal component of the alternating electric field changes.

A saturated blue color means an increased concentration of negative charges.

3. Conclusion

Applying the methods of the artificial intelligence theory and of deep learning, a "shore effect" was discovered in the magnitude of an alternating electric field, which consists in an increase in the amplitude of variations in the horizontal component (orthogonal to the coast) near the coastline. The effect diminishes with increasing distance from the sea. The "shore effect" in magnetic field variations is associated with a current step in the induction current on the coastline when an electromagnetic wave falls on the Earth's surface. The effect in variations in the electric field is associated with a change in the density of electric charges on the coastline proportional to the variations in the electric field strength.

A change in the charge density arises due to a change in the magnitude of the horizontal component of the electric field of an orthogonal coastline undergoing a current step on the coastline, while the tangent component is continuous.

4. References

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