On-Land Detecting a Motionally Induced Electric Field:
Test Measurements in Northern Finland

N. A. PALSHIN, P. KAIKKONEN, L. L. VANYAN, J. TIIKKAINEN, and V. H. RUKOL

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Test measurements of the electric voltage in Kilpisjärvi, northern Finland during September 9—October 12, 1995 were made with the aim of studying the possibility of detecting a motionally induced electric field by means of a horizontal electric dipole 3800 meters in length located at a distance of about 50 km from the nearest fjord of the Norwegian Sea. In addition to the electric voltage we measured at Kilpisjärvi, the water level, magnetic field and meteorological data from Tromsø, Norway, the meteorological data from Kilpisjärvi and the magnetic field data from Sodankylä, Finland were used in analysis. Raw data were preprocessed to eliminate non-stationarities (remove outliers) and to remove solar daily variations, and were then smoothed. No significant influence of the local temperature, humidity and rainfall on the smoothed voltages was found. Probably due to a source effect the voltage was not coherent with the magnetic field from Tromsø and Sodankylä. The long-period anomaly with the period of about 16 days was observed in the smoothed voltage, water level and air pressure. More data are necessary to derive a definite conclusion about the nature of the observed phenomenon, which is probably associated with direct atmospheric forcing on the coastal zone of the Norwegian Sea.

1. Introduction

Natural EM fields in the oceans are induced by two principal types of the sources: external—the ionospheric and magnetospheric current systems and internal—the dynamo interaction of moving conducting seawater with the Earth’s magnetic field. Thus, EM field measurements in the oceans could potentially be used for studies of the solid earth beneath the oceans by the magnetotelluric and magnetovariational methods, and for monitoring the ocean variability. The signals at the solar-daily and tidal frequencies dominate in both electric and magnetic fields in the oceans. The continuum spectrum is generated by fluctuations of the ring current at the distances of 3–4 Earth radii, auroral phenomena and ocean variability over the wide spatial and frequency range. See Palshin (1996) for a review.

The most significant experiments using the motionally induced electric field were the long-term underwater cable measurement at Florida Current (Larsen, 1992) and the complex oceanic experiment along profile 26.5°N crossing the Antilles Current (Chave et al., 1997). These experiments have made it possible to evaluate water and heat transport, and to investigate synoptic, seasonal and annual variability of these currents. The first on-land measurements of the electric field induced by the oceanic tides were carried out almost fifty years ago (Longuet-Higgins, 1949). Since then measurements have been carried out by several researchers in the various coastal areas and have shown a possibility of measuring the electric field induced by the oceanic tides (Osgood et al., 1970; Harvey et al., 1977; Junge, 1988, 1996).

Numerical modelling of the motionally induced electric fields confirms the presence of the ocean-induced fields on land (Stephenson and Bryan, 1992; Vanyan et al., 1992; Flosadottir et al., 1997; Tyler et al., 1997). Thus, the motionally induced electric field can be detected and measured not only in seas and oceans but also on shores. To study the synoptic and other longer period variability of the sea with on-land measurements it is necessary to estimate a spatial distribution of the motionally induced electric field by means of numerical modelling in order to find the proper location, orientation and length of the receiving
Numerical simulation of the electric field for an idealized oceanographic model of the Norwegian Coastal Current (NCC) and a realistic conductivity structure of northern Scandinavia has shown that the amplitude of the field can reach 10 mV/km at a coastal zone about 50 km in width (Palshin et al., 1996). Coastal boundary currents and their synoptic variability, as well as tides, could be the sources of the field.

The present experiment was planned to study the possibility of detecting an electric field induced by the variability of the water velocity field at the coastal zone of the Norwegian Sea by the on-land voltage difference measured by a horizontal electric dipole.

2. Field Observations

Test measurements for voltages during September 9–October 12, 1995 were aimed to study the possibility of detecting a motionally induced electric field by means of a horizontal electric dipole. The dipole was installed nearby the Lake Kilpisjärvi in the most northwestern point of Finland at a distance of about 50 km from the nearest fjord of the Norwegian Sea (Fig. 1). The length of the dipole is about 3.8 kilometers, and the direction of the dipole is from NW to SE, so it is almost perpendicular to the sea coast. The location of the NW electrode is 69°02.700’ N, 20°48.174’ E and the location of the SE electrode is 69°01.158’ N, 20°51.797’ E. Geologically the dipole is situated over the Palaeozoic sedimentary rock in the margin of the Caledonides.

Fig. 1. Map showing northern Scandinavia and the locations of Kilpisjärvi (KIL), Tromsø (TRO) and Sodankylä (SOD).
Simple plastic coated multistrand wire of 0.75 mm² was used for connecting the electrodes to the recording unit. Such cable was used because it is available in 500 m reels to have fewer connections. The low-noise on-land electrodes applied to this experiment were specially designed and manufactured by Dr. M. M. Bogorodsky from the Institute of Geoelectromagnetic Research of the Russian Academy of Sciences. The electrodes are of Pb-PbCl₂-type, constructed inside a plastic tube measuring 140 mm in length and 35 mm in diameter. The top of the tube is hermetically covered and the electrical connection to the spiral shaped Pb-wire inside the electrode is through the cover. The PbCl₂ electrolyte is in gel form, and the bottom cover of the tube has small holes to have electrical connection to the ground. The electrodes were placed in a plastic bucket filled with salted wet sand and buried almost one meter underground.

Data were measured and recorded with a DATATAKER DT 50 data logger and stored on memory card. Because the electrodes allow only a very low current, about 2 nA maximum, input impedance of more than 100 MΩ was used in the input amplifier which has autoranging from +/-25 mV to +/-2500 mV with

![Graphs showing raw data, residuals, and smoothed residuals.](image)

Fig. 2. Voltage measured in Kilpisjärvi during September 9–October 12, 1995. Topmost panel shows the raw data measured at the sampling interval of 5 minutes, the middle one depicts residuals and the bottom one—smoothed residual values.
maximum resolution. The resolution of the recording is 16 bits corresponding to $1 \mu V$ in maximum input sensitivity range. The signal was sampled 10 times per second (full speed of the recorder) and preprocessed so that repetitive averages over the 5 minutes interval were stored in the data file to reduce a high frequency noise. The date and time information was also recorded in the data file. The recording instrumentation was comfortably situated in a laboratory of the Kilpisjärvi Biological Station of the University of Helsinki. The relatively stable room temperature resulted in a low temperature based drift in the recording instrument compared with the instrumentation installed outdoors.

In addition to the voltage data which we measured at Kilpisjärvi, the water level, magnetic field and meteorological data from Tromsø, Norway, the meteorological data from Kilpisjärvi and the magnetic field data from Sodankylä, Finland were used in the analysis (see Fig. 1).

3. Data Processing and Discussion

Northern Scandinavia is characterized by high intensity of geomagnetic disturbances due to its location under the polar electrojet. Spatial inhomogeneities and non-stationarities are typical for geomagnetic field variations in such areas. As the main aim of the test measurements was to study the long-term variability, the raw data were preprocessed using routine procedures (Larsen et al., 1996) to eliminate non-stationarities (to remove outliers) and remove the solar daily variations. After preprocessing the data were smoothed with a running average with a 48 hours wide window. It should be noted that a similar processing procedure was used for all time series considered in the analysis, including the meteorological

![Graphs showing humidity, temperature, and voltage data over time]

Fig. 3. Voltage (lower panel), temperature (middle panel), humidity and rainfall (upper panel) in Kilpisjärvi during September 9–October 12, 1995. Rainfall (thicker line) was measured every 6th hour.
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The residual values of all data sets were used to get the power spectral densities.

The Kilpisjärvi voltage vs. time data are presented in Fig. 2. Amplitudes of some outliers were more than 20 mV and are not included in the plot. Most of the outliers were removed by the preprocessing procedure, but several geomagnetic disturbances produce voltage peaks up to 10 mV. The situation changes after smoothing of the data. Note the different scales of the panels of Fig. 2. The long-period signal with the amplitude of about 1.2 mV is clearly seen in the smoothed data set.

The local meteorological conditions might be expected to influence the measured voltage. The temperature, humidity and rainfall measured at the Kilpisjärvi meteorological station are plotted in Fig.

![Graphs](image-url)

**Fig. 4.** Amplitude spectra of north magnetic fields in Tromsø and Sodankylä, seawater level in Tromsø (dashed line) and voltage in Kilpisjärvi. The S1, O1, S2, M2 and N2 vertical lines stand for the diurnal and semi-diurnal harmonics.
3 together with the smoothed voltage values. No significant correlation between the voltage and the temperature or the voltage and the humidity was found. The spectral analysis of the magnetic field from Tromsø and Sodankylä and the voltages in Kilpisjärvi shows that there are pronounced spectral peaks at the solar and lunar tidal frequencies (Fig. 4). The $S_1$, $O_1$, $S_2$, $M_2$ and $N_2$ vertical lines stand for the diurnal and semi-diurnal harmonics. The tidal signals from the Norwegian Sea in the Kilpisjärvi voltages are probably screened by the powerful ionospheric dynamo processes dominating in the auroral regions or due to different spatial scales of water flow fields for different tidal components.

The squared coherences of the voltage in Kilpisjärvi and the horizontal magnetic field in Tromsø and Sodankylä do not exceed the values of 0.2–0.3 which means that there is no statistically significant correlation between these processes, probably due to small spatial scales of magnetic fluctuations in this region. Thus, we use a low-pass filtering (running average smoothing) to remove (or at least to reduce) the influence of geomagnetic disturbances on the voltage data. So we consider the smoothed voltages to be more or less free from the geomagnetic disturbances and find out that they are not influenced by the local meteorological conditions. But they could probably contain information on the electric field motionally induced by the long-period variability of the Norwegian Sea. To find the correlation between the Norwegian Sea variability and the measured voltage, the air pressure, water level and southwestern wind speed at Tromsø were studied. The smoothed residual values of the parameters mentioned above together with the voltage at Kilpisjärvi are presented in Fig. 5. One can see that three of these processes are rather similar.

![Graphs showing correlation between smoothed voltage, air pressure, water level, and wind speed.](image-url)
4. Conclusions

The observed long period anomaly in smoothed voltages from Kilpisjärvi is clearly correlated with the water level at Tromsø (and essentially with the air pressure) and is probably associated with the passage of the atmospheric cyclone over northern Scandinavia (see Fig. 6) producing water flows in the coastal zone of the Norwegian Sea. The amount (length) of data obtained during the first test measurements is not enough to get statistically meaningful estimations and all the conclusions are preliminary. More accurate statistical analysis will be made when the amount of data collected in northern Finland will be large enough. The additional oceanographic data from the Norwegian Sea will be used as well. The measurements in Kilpisjärvi are continued and new data to be obtained will most likely give us a possibility to ensure the results concluded from these test measurements.

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