Real-time and Long-term magnetotelluric monitoring in North China Craton

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SUMMARY

Real-time long-term monitoring of the electric field and geomagnetic field can be used not only to study the induced currents generated by geomagnetic storms but also to investigate the electrical structure of the mantle. We developed ultra-stable non-polarizing electrodes and magnetotelluric instruments equipped with 4G data transmission. Since December 2023, we have been conducting magnetotelluric monitoring in the North China Craton region. Currently, 40 measurement sites have been operating stably for six months, measuring the G5 geomagnetic storm and induced electric field in May, 2024. We estimated the magnetotelluric impedance in the periods of 10-10^5 seconds, which is expected to invert a three-dimensional conductivity model of the deep mantle in the North China Craton.

Keywords: Real-time MT; Very long period MT; Magnetic Storm; Induced electric field.

INTRODUCTION

This year marks a peak in geomagnetic activity, with the magnetic storm in May , 2024, causing an Hx variation of nearly 700 nT. Such magnetic storms can induce dramatic changes in the electric field, potentially causing significant damage to power grids (Love & Finn, 2017). Therefore, long-term real-time monitoring of electric and magnetic fields has become essential. Additionally, long-term monitoring of electromagnetic data allows for the calculation of very-long period magnetotelluric impedance (~10^5 s), which is expected to reveal the electrical structure at the depth range of the mantle transition zone (Egbert and Booker, 1992; Wang et al., 2020). This has significant implications for studying water content in the mantle transition zone, deep structural, and earthquake prediction.

However, long-term magnetotelluric monitoring faces challenges such as electrode noise drift, data loss, and high costs. To address these issues, we developed ultra-stable non-polarizing electrodes and magnetotelluric instruments equipped with real-time 4G data transmission. We conducted experiments in North China, where the equipment has been operating stably for over six months. All collected data is publicly shared.

ULTRA-STABLE NON-POLARIZING ELECTRODES

Based on the Petiau electrode (Petiau,2000), by adding small channels at the bottom and extending length of the electrode. We developed the solid Pb-$PbCl_2$ non-polarized electrode by adding clay. The potential of the electrodes is very stable, with a monthly variation of less than 50 μV (Figure 1) and the temperature coefficient is less than 20 μV/degree (Figure 2). Field tests show that the electrodes can obtain smooth MT impedance with a period of 10^5 seconds over 5 month-long acquisition with only 20 m dipoles length (Fig. 6).

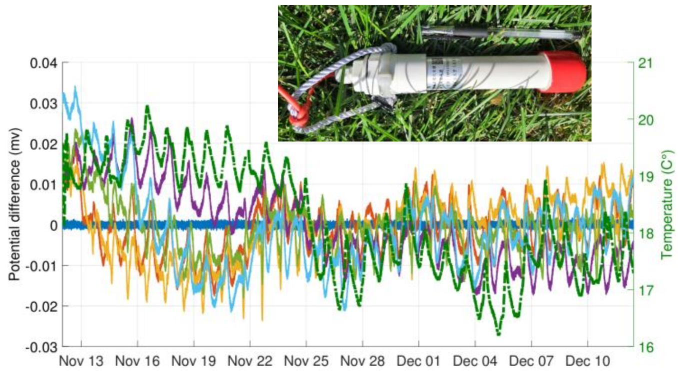

Figure 1 Electrode potential drift in a month, the dotted green line indicates temperature variation from ~16 to 20 degree Celsius.

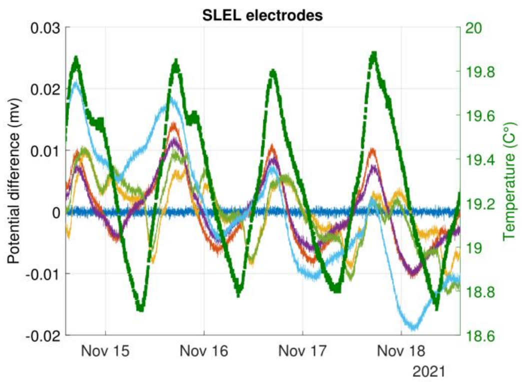

Figure 2. . Temperature coefficient of the electrodes. The daily temperature variation is approximately 1 degree Celsius, and the daily variation of electrode potential is less than 20 microvolts.

MT4G Magnetotelluric Instrument

We developed a long-period magnetotelluric instrument named MT4G with real-time 4G data transmission (Figure 3). It features a maximum sampling rate of 2 seconds, dependent on network conditions. The electric field range is 1000 mV with a resolution of 0.1 μV and an accuracy of 1 μV. The magnetic field range is 70000 nT with accuracy better than 20 pT, and temperature drift is less than 0.2 nT/℃. The instrument exhibits linearity <0.03%, operates within a temperature range of -20 to 50 ℃, has an input impedance of 100 MΩ, operates on a supply voltage of 8-24 V, and consumes less than 0.8 W of power.

Figure 3 MT4G Instrument and data monitoring interface

North China MT Monitoring

In December 2023, we deployed 40 magnetotelluric sites (Figure 4) in North China, where 17 sites synchronously record both electric and magnetic fields, while an additional 23 sites only measuring electric fields with typical electrode dipole length is 20 m. These stations are powered by solar panels. Currently, we have been continuously collecting data for six months, meticulously recording the G5-class geomagnetic storm up to 700 nT variation in May, 2024 (Figure 5. Figure 6 shows the apparent resistivity and phase curves with 5 month time series, demonstrating impedance calculations approaching 10^5 seconds despite low resistivity, using electrode dipole length of 20 meters. All data are available at http://em.mt4g.com/page/HuabeiEM

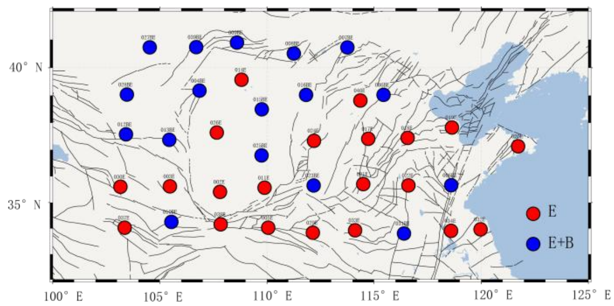

Figure 4. Distribution of MT monitoring sites in North China.The blue circles indicate sites where both electric and magnetic fields are collected, while the red circles indicate sites where only the electric field is collected."

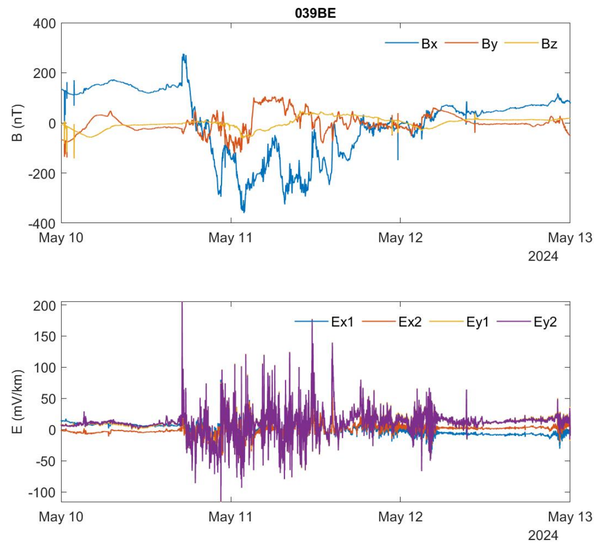

Figure 5. Time series of the G5 geomagnetic storm and induced electric field in May, 2024.

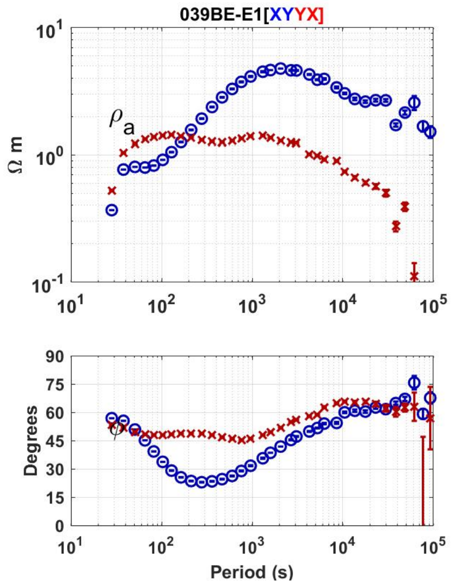

Figure 6. Apparent resistivity and phase of 039BE site by using data from 2024/01/01 to 2024/05/30.

CONCLUSIONS

We developed a very stable unpolarized electrode with a monthly drift of less than 50 μV and the temperature coefficient is less than 20 μV/degree. We also developed a long-period MT instrument for 4G data transmission with power consumption less than 0.8W and deployed 40 MT monitoring sites in North China, which have continuously operated for over 6 months and recorded data during G5 geomagnetic storms. Experimentation has confirmed that our instruments can be applied to real-time long-term EM monitoring, i.e., GIE, deep mantle exploration, earthquakes, volcanoes.

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REFERENCES

Egbert, G. D., & Booker, J. R. (1992). Very long period magnetotellurics at Tucson Observatory: Implications for Mantle Conductivity. Journal of Geophysical Research, 97(B11), 15113. https://doi.org/10.1029/92jb01252
Love, J. J., & Finn, C. A. (2017). Real-time geomagnetic monitoring for space weather-related applications: Opportunities and challenges. In Space Weather, 15(7), 82-827. https://doi.org/10.1002/2017SW001665
Petiau, G. (2000). Second generation of Lead-lead chloride electrodes for geophysical applications. Pure and Applied Geophysics, 157(3), 357 – 382. https://doi.org/10.1007/s000240050004
Wang, H., Egbert, G., Yao, Y., & Cheng, J. (2020). Array analysis of magnetic and electric field observatories in China: estimation of magnetotelluric impedances at very long periods. Geophysical Journal International, 222(1), 305 – 326. https://doi.org/10.1093/gji/ggaa169