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EMRP2.15 Measuring space weather condition with geomagnetic data

Geomagnetically Induced Currents over Kazakhstan during Large Geomagnetic Storms

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The main hypothesis. As studies have shown, extreme solar events, such as flares accompanied by the release of a powerful magnetic cloud (coronal mass ejections, CMEs), cause perturbation of the Earth's magnetic field and form fluctuating currents in the ionosphere and magnetosphere. One of the negative effects of extreme solar events on technological systems is appearance of geomagnetically induced currents, GIC, in conducting ground systems, power lines, and pipelines.

A brief description. Based on measurements of the parameters of the geomagnetic field, we investigated whether or not significant geomagnetically induced currents in the Kazakhstan region were manifested during emergency helio-geoeffective events.

***Relevance*.** Many countries in the world already have reliable ways to predict the appearance of geomagnetically induced currents in the electric power system, but Kazakhstan, which has many power transmission lines and pipelines, needs its own strategy to mitigate the effects of GIC, taking into account ionospheric currents, soil conductivity, and the spatial direction of main lines.

THE SIGNIFICANCE OF RESEARCH ON A NATIONAL SCALE

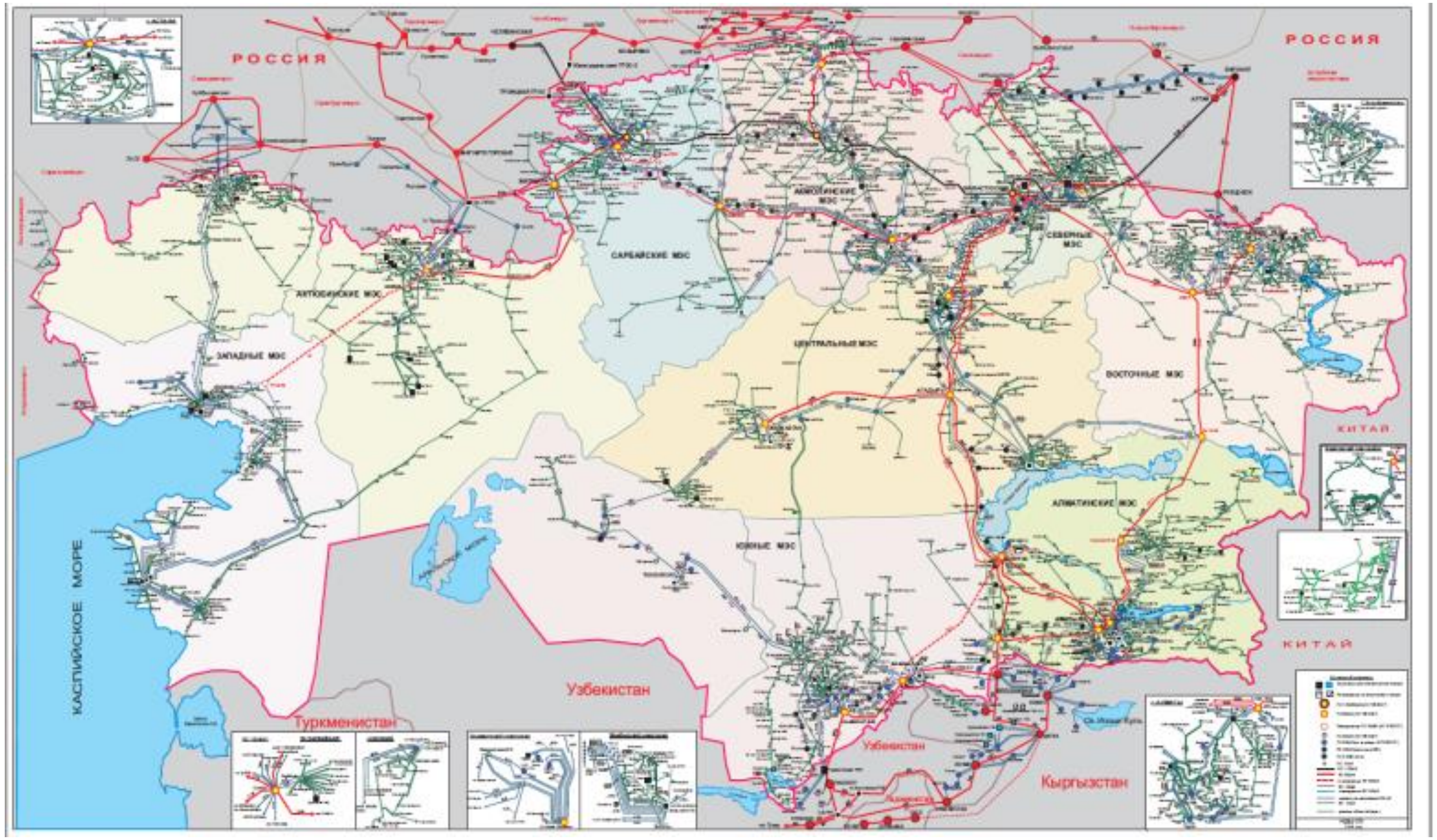


Figure 1. Schematic Map of Electric Networks of the Republic of Kazakhstan (1150-500-220-110 kV)

Extreme geomagnetic storms can lead to accidents in power transmission networks, oil and gas pipelines, telecommunication cables and railways. For Kazakhstan, which has a territory of 2 725 000 km^2, where the long trunk power lines, long pipelines, transit railway lines connecting Asia and Europe are located, it is extremely important to find a solution for these problems.

According to KEGOC Kazakhstan Electricity Grid Operating Company (Kazakhstan Electricity Grid Operating Company, http://www.kegoc.kz), the length of the National Public Electricity Grid in the Republic of Kazakhstan is 24 533 km.

KEGOC:

- a high-voltage power line (HVL) with a voltage of 1 150 kV – the length of the line is 1421.23 km;
- HVL with a voltage of 500 kV – length of the line 6483.04 km;
- HVL with a voltage of 330 kV – the length of the line is 1759.48 km;
- Overhead line with a voltage of 110 kV – the length of the line is 351.78 km; HVL with a voltage of 35 kV – the length of the line is 44.13 km.

LITERATURE REVIEW: STUDIES OF GEOMAGNETICALLY INDUCED CURRENTS

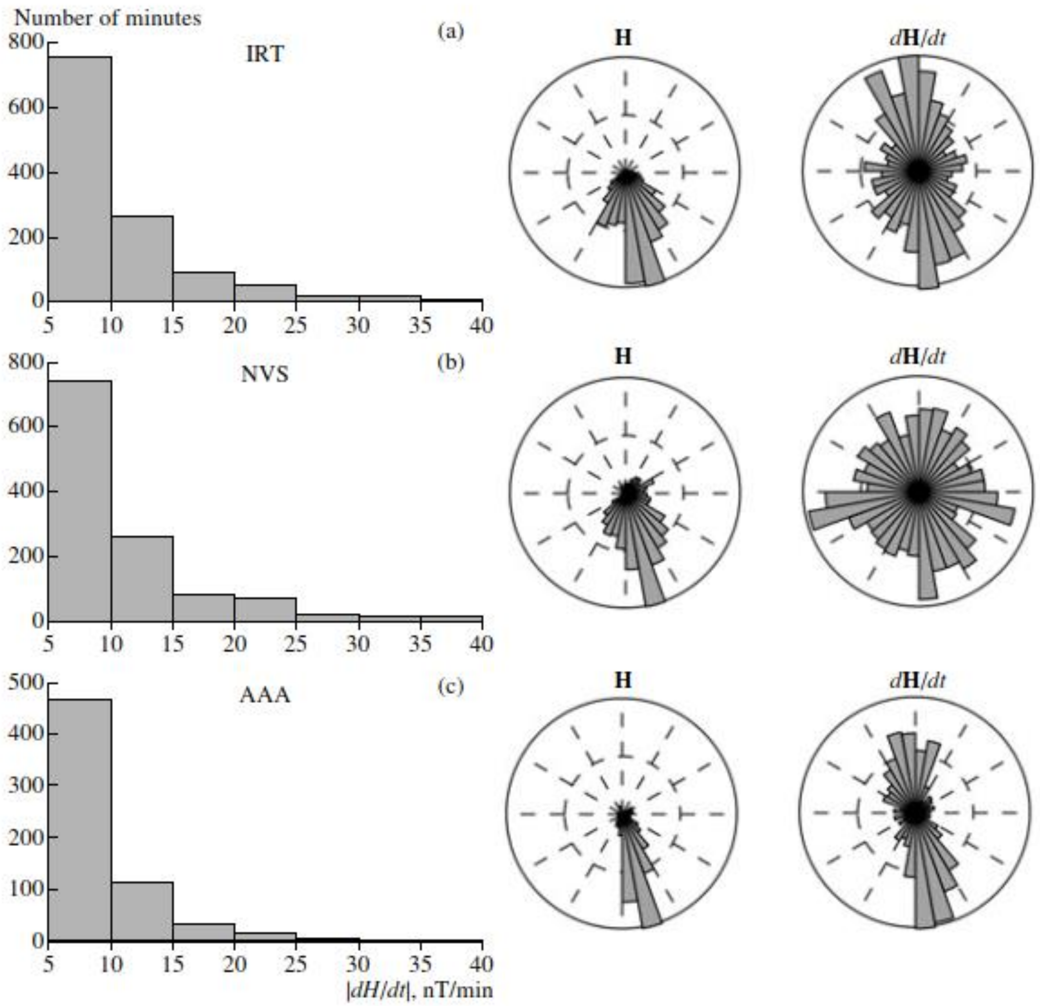
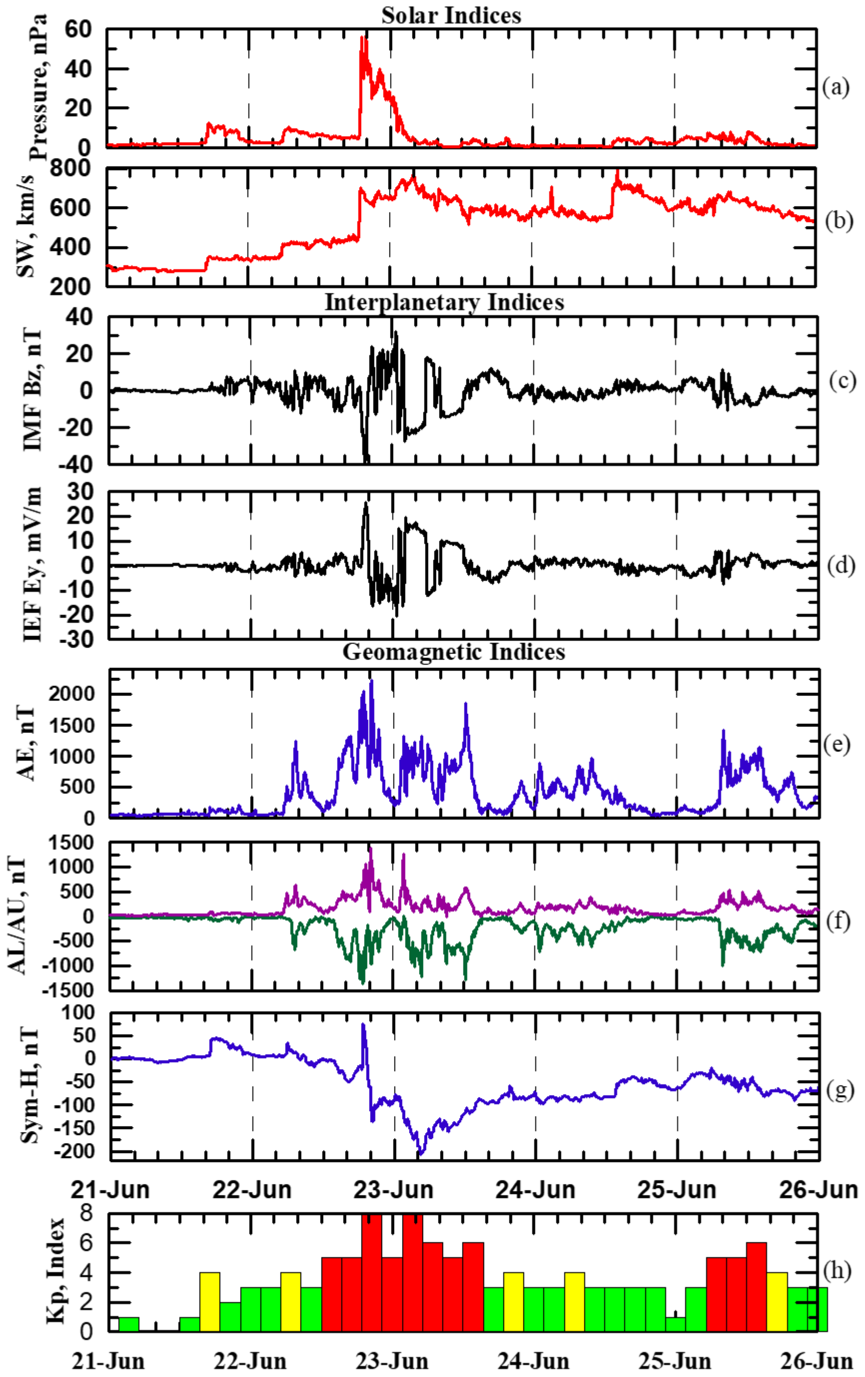


Figure 2. Distributions of |*dH/dt*|, **H** and d**H**/dt directions for the magnetically active period of July 24-28, 2004.

Recent studies of GIC in Europe [Viljanen et al., 2014], Austria [Bailey et al., 2017], Spain [Torta et al., 2014], Greece [Zois, 2013], Czech Republic [Hejda and Bochnícek, 2005], Brazil [Barbosa Barbosa et al., 2015], Japan [Watari et al., 2009], South Africa [Matandirotya et al., 2015], Australia [Marshall et al., 2011], New Zealand [Beland and Small, 2004] have shown that geomagnetically induced currents of more than tens of amperes appear at all latitudes. The results of a study by Liu et al. (2009) show that the topology and parameters of the power system are important factors for the GIC levels at medium and low latitudes, and large GICs can occur at these latitudes.

Vodyannikov et al. (2006) have shown that during severe storms (this applies especially to the storm of October 30-31, 2003) for a fairly long time from tens of minutes to several hours, the energy systems of the north of Kazakhstan were exposed to significant GIC.

In Figure 2: Magnetic observatories: Alma-Ata Observatory, Kazakhstan (code AAA, 43.25°N, 76.92°E); Novosibirsk Observatory, Russia (code NVS, 54.85N, 83.23E); Irkutsk Observatory, Russia (code IRT, 52.17°N, 104.45°E).



VERY LARGE GEOMAGNETIC STORMS

In this paper, we consider the minute values of the magnetic field vector B or its components Bx, By, Bz during four very large geomagnetic storms with a local geomagnetic activity K-index≥7. Following storms were used to calculate the values of geomagnetically induced currents:

- September 26-28, 2011, VLMS, Sc, duration 54 h 00 min, K-index =7;
- June 22-25, 2015, VLMS, Sc, duration 78 h 30 min, K-index =8;
- October 24-28, 2016, VLMS, duration 93 h 00 min, K-index =7;
- May 12-17, 2021, VLMS, Sc, duration 17 h 25 min, K-index =7.

Figure 3. Variation of solar, interplanetary & geomagnetic indices during 19–22 December 2015:

Temporal variations of (a) ram pressure;

(b) solar wind speed;

(c) IMF *Bz*; (d) IEF *Ey*;

(e) *AE* index; (*f*) *AL/AU* index;

(g) *Sym-H*;

(h) *Kp* index,

provided by OMNIWeb, NASA (omniweb.gsfc.nasa.gov) and the Kp index provided by WDC, Kyoto (wdc.kugi.kyoto-u.ac.jp)

THE DATA OF OBSERVATORIES OF THE INTERMAGNET NETWORK

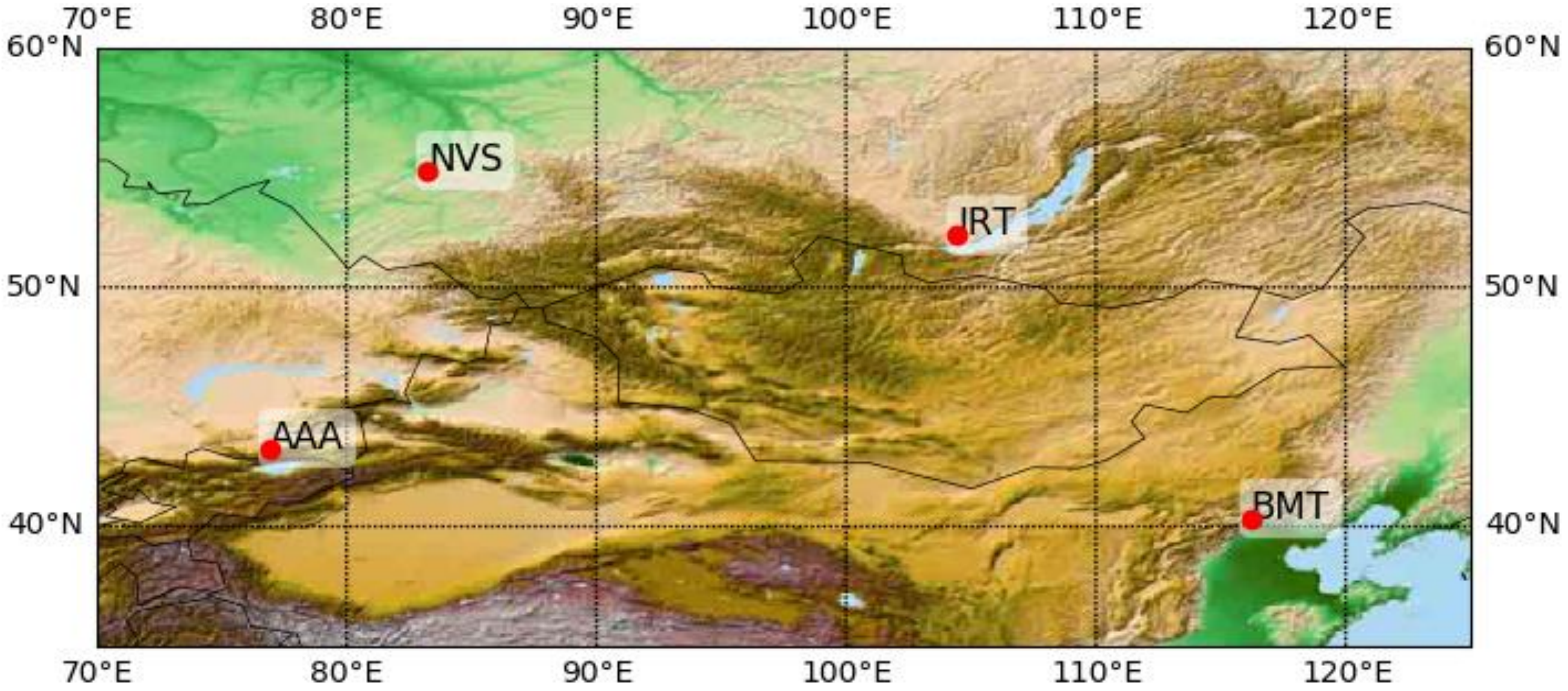
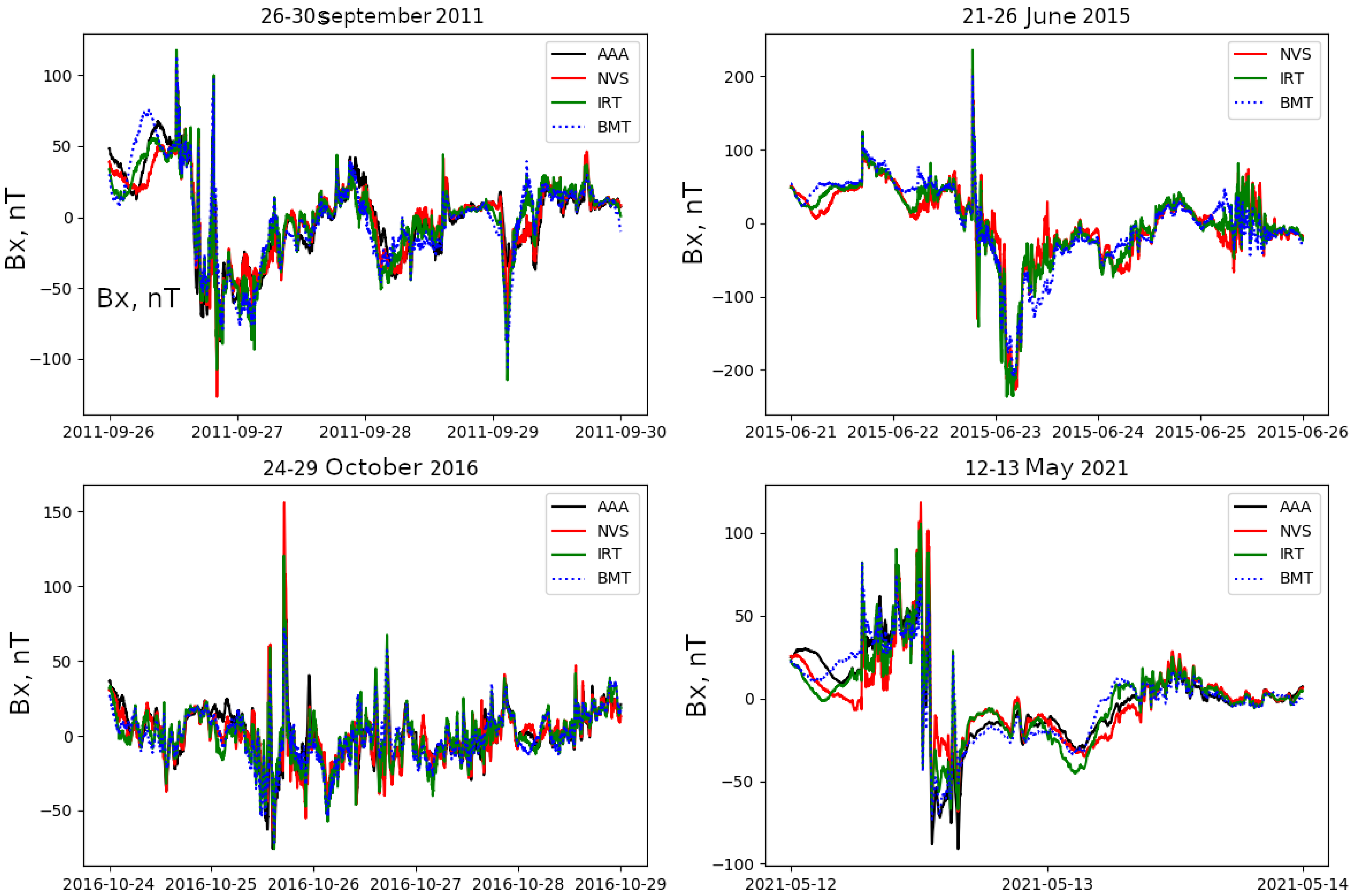


Figure 4. Location of the geomagnetic observatories Alma-Ata (AAA), Novosibirsk (NVS), Irkutsk (IRT) and "Beijing Ming Tombs", Beijing (BMT)

The data of four observatories of the INTERMAGNET network, whose geomagnetic latitudes are close to the geomagnetic latitudes of the southern and northern borders of Kazakhstan were considered: Alma-Ata Observatory, Kazakhstan (code AAA, 43.25°N, 76.92°E); Novosibirsk Observatory, Russia (code NVS, 54.85N, 83.23E); Irkutsk Observatory, Russia (code IRT, 52.17°N, 104.45°E) and the Beijing Ming Tombs Observatory, Beijing, China (code BMT, 40.3°N, 116.2°E).

VARIATIONS OF THE Bx-COMPONENT OF THE GEOMAGNETIC FIELD



Variations of the Bx- component of the geomagnetic field during the four very large magnetic storms according to the observatories AAA, NVS, IRT, BMT showed variability from 50 nT to 150 nT for several hours. The close values of the time series of variations of the X-component (north-south orientation) of the geomagnetic field **B** during the four magnetic storms indicate the applicability of observatories in this latitude range for the analysis of geomagnetically induced currents in the Kazakhstan region.

Figure 5. Variations of the Bx-component of the geomagnetic field during the four magnetic storms considered according to the observatories AAA, NVS, IRT, BMT

THE RATE OF CHANGE OF THE By- COMPONENT OF THE GEOMAGNETIC FIELD

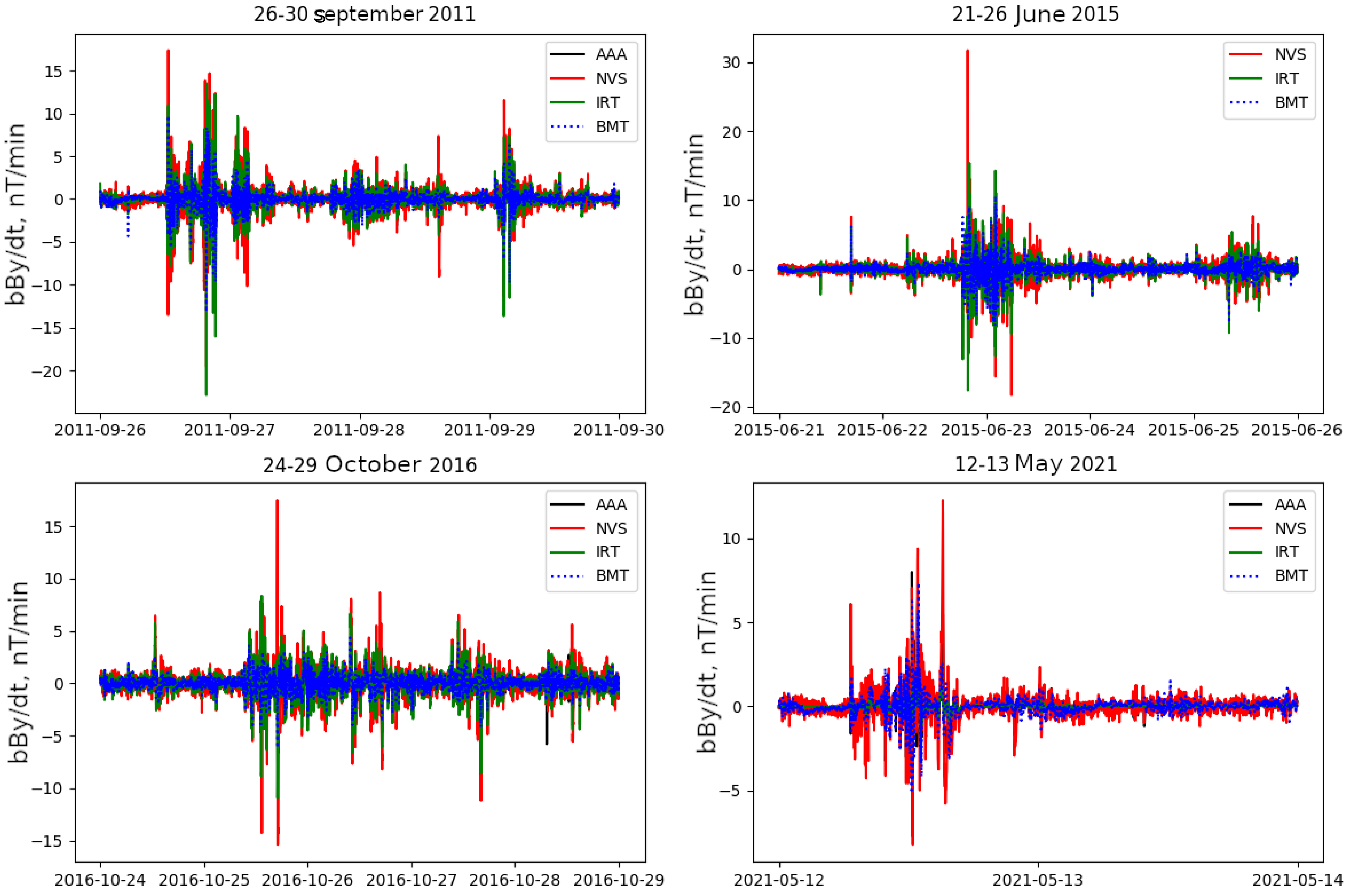


Figure 6. Variations of dBy/dt during the four considered magnetic storms according to observatories AAA, NVS, IRT, BMT

The rate of change of the By-component of the geomagnetic field during four very large magnetic storms according to the observatories AAA, NVS, IRT, BMT have peak values up to 15-30 nT/minute.

The highest values of the rate of change of the magnetic field are observed for the NVS observatory.

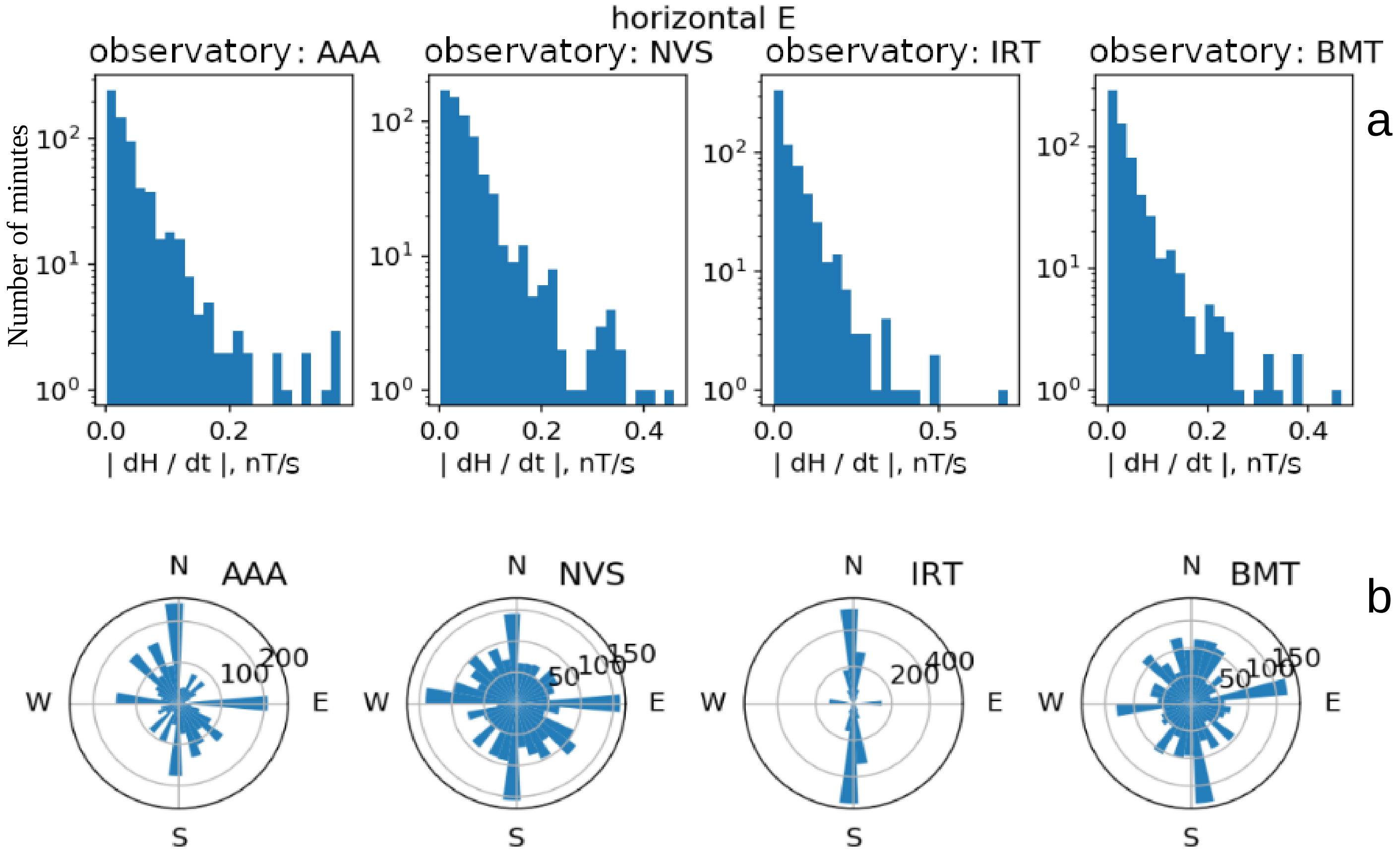


Figure 7. Histograms of the distribution of the time derivative |*d**H**/dt*| (a) and the directions of the time derivative *d**H**/dt* (b) during May 12-13, 2021

MAIN CONCLUSIONS

The geomagnetic-induced current was estimated based on the calculation that the electromotive force of self-induction is proportional to the change in the magnetic field strength [Nakamura et al., 2018].

The variations of the horizontal component **H** of the magnetic field vector and its time derivative (d**H**/dt) were analyzed on the basis of measurements of geomagnetic observatories AAA, NVS, IRT, BMT . Histograms of the distribution |*d**H**/dt*| and histograms of the distribution of the directions **H** and d**H**/dt were constructed.

We have shown that the energy systems of Kazakhstan are exposed to geomagnetically induced currents when d**H**/dt/ varies from 17 nT/min and more. The geomagnetic-induced current is estimated based on the calculation that the electromotive force of self-induction is proportional to the rate of change in the magnetic field strength. According to preliminary calculations, the values of geomagnetic-induced currents are fractions of 1,0 mA.

For more accurate calculations, it is necessary to take into account the topology of the electrical system, the composition of the underlying surface and other factors that determine the degree of susceptibility of individual elements of the power system.

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