ABOUT DETERMINATION OF COORDINATES OF SOURCES OF GEOMAGNETIC PERTURBATIONS ACCORDING TO THE WORLD NETWORK OF MAGNETIC OBSERVATORIES

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Abstract. A method for determining the coordinates of geomagnetic perturbation sources based on joint data processing of the world network of magnetic observatories is proposed. A large statistical material showed the relationship of large geomagnetic storms with the interaction of two or more magnetic clouds formed as a result of coronal mass ejections. To determine the coordinates of the sources of perturbations, it is proposed to use the data of magnetic observatories of the "INTERMAGNET" international network, which has more than 100 observation points distributed around the world and equipped with modern identical hardware. The results of geomagnetic field measurement obtained by magnetic observatories are brought to a single coordinate system. It was achieved by rotation of the axes of local stations which allows to determine the coordinates of the sources of perturbations and evaluate the accuracy of specifying the coordinate system of each local observatory.

The work is devoted to determining the coordinates of geomagnetic disturbance sources according to the INTERMAGNET global network of magnetic observatories. A method is proposed that improves the predictability of geomagnetic disturbances.

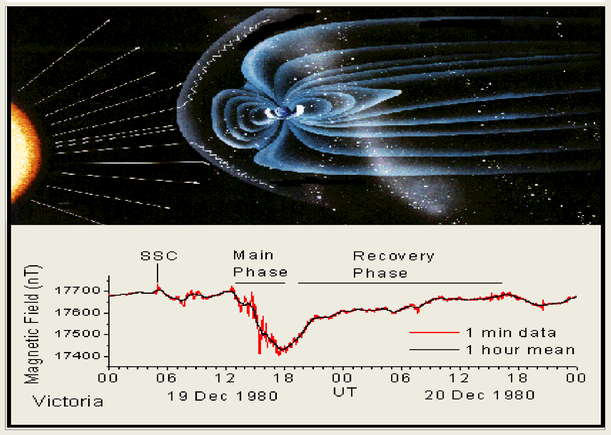
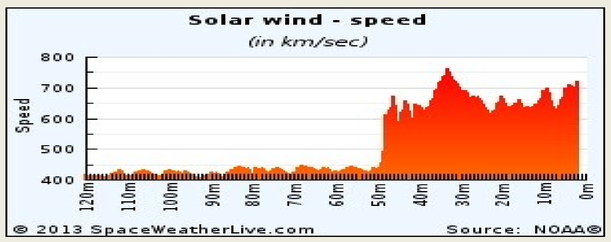


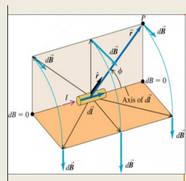
Figure 1

The main model of the occurrence of geomagnetic disturbances (magnetic storms) at present is the compression of the lines of force of the Earth's magnetic field under the influence of a shock wave of a solar flare (Figure 1).



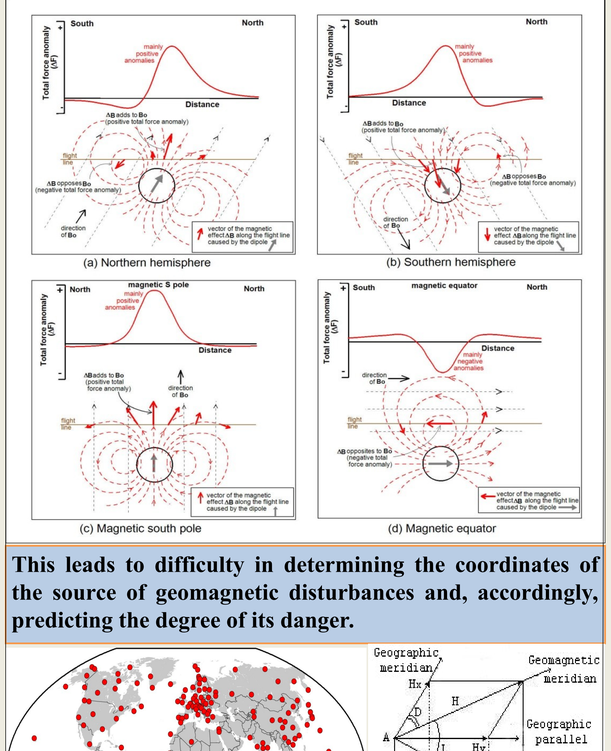
The size of a typical ejection of solar plasma at the intersection of the Earth's orbit is about 300,000 km; length of about 10,000,000 km, speed over 700 km / s. The probability of a direct hit of solar plasma on Earth is extremely small. Most likely, the "flying" of a cloud of solar plasma near the Earth.

In [1, 2], it was shown that due to the ambipolar diffusion of charged particles in the clouds of the solar plasma, an excessive concentration of alpha particles is created along their axis of motion, leading to the appearance of a magnetic field with a similar structure in the field of a current conductor.



$$dB = \frac{\mu_0}{4\pi}\frac{|dQ|v_d \sin\phi}{r^2}$$

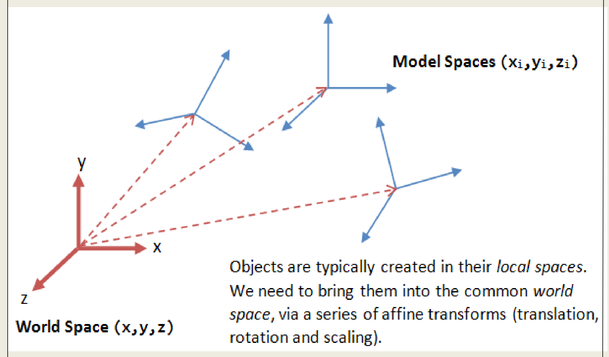
When the Earth's magnetic field and the cloud field of the solar plasma interact, these fields add up. Depending on the direction and intensity of the magnetic field of the plasma cloud at the surface of the Earth, variations of different magnitude and polarity are recorded at different observation points.



This leads to difficulty in determining the coordinates of the source of geomagnetic disturbances and, accordingly, predicting the degree of its danger.

There are many observatories in the world to observe the Earth's magnetic field, but they are all oriented differently. Each observatory has its own coordinate system depending on its geographical location. Due to the fact that each cloud of solar plasma is different in size, flies past the Earth along its unique trajectory, at different speeds and at different times of the day, it is very difficult to find a system in the results of observations.

Mathematical transformations allow you to rotate the Cartesian coordinate system around any of the axes.



$$R_z(\theta) = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}, R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix}, R_y(\theta) = \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix}$$

Bringing the results of observations at various observatories to a single coordinate system, you can get something like a planetary phased array antenna. At the same time, averaging the results of observations of many stations will increase the signal / (noise + interference) ratio of the results of the total observations and increase the accuracy of measurements of the magnetic field vector created by the solar plasma cloud.

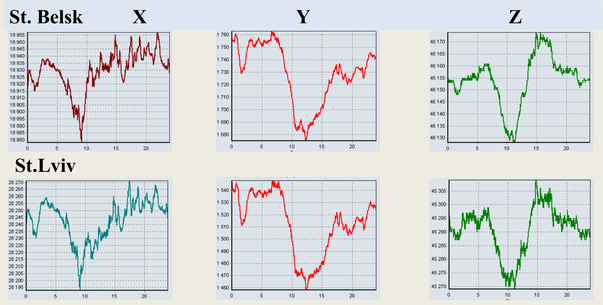
As a single planetary coordinate system, to simplify mathematical transformations, a coordinate system is proposed that is oriented like an observatory if it were located at 0 degrees latitude and 0 degrees longitude (the intersection of the Greenwich meridian with the equator).

To bring to a single coordinate system, all local systems must: rotate around the Y axis by an angle equal to the latitude of the observation station, making the X axis parallel to each other (and parallel to the axis of rotation of the Earth) of all observation points; by the second transformation, rotate the coordinate system around the X axis by an angle equal to the longitude of the station to ensure that all the Y and Z axes of the local observatories are parallel to each other.

For the experiment, the event was selected on August 1, 2005, when a magnetic storm was observed, but at the same time there was not a sufficiently strong previous flash on the Sun. Observatories located at approximately the same latitude but significantly differing in longitude were selected as control stations.

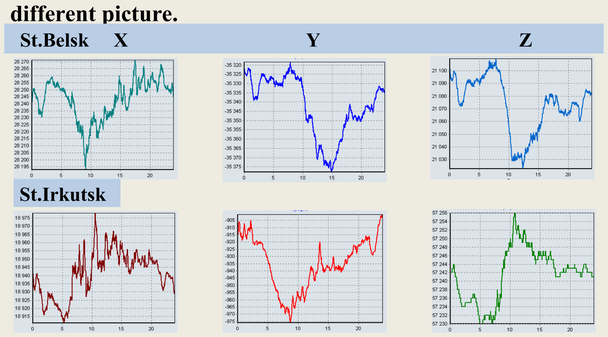
№№ п/п	Название обсерватории	Код	Широта	Долгота
1	Alma-Ata	AAA	43.25	76.62
2	Lviv	LVV	49.90	23.75
3	Belsk	BEL	51.84	30.79
4	Irkutsk	IRT	52.46	104.04

Observatories are located in 4 different countries and are independent of each other. The observatories Belsk (Poland) and Lviv (Ukraine) are located at a distance of about 200 km from each other and the results of their measurements could be used to verify the method. The results of magnetometric measurements at the selected observatories for August 1, 2005 before the coordinate conversion.

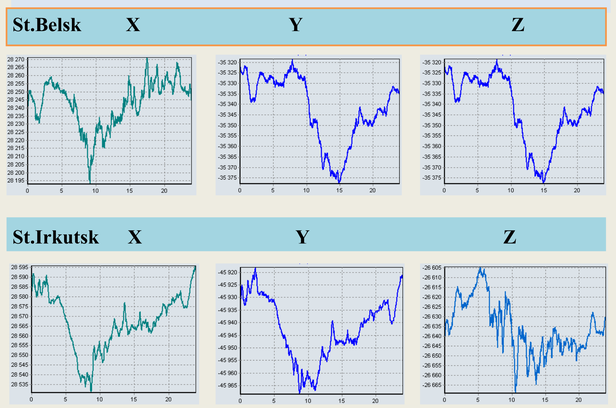


The nature of the graphs shows their high correlation with the difference in the amplitudes of the measured signals by 5-10%.

At the same time, measurements at the Irkutsk observatory, which is almost 90 longitude away, show a different picture.



As can be seen from the graphs, the time of observation of the maximum disturbances at the observatories located far relative to each other is significantly different.The results of magnetometric measurements at the same observatories after coordinate conversion:As can be seen from the graphs, the time of observation of the maximum disturbances at the observatories located far relative to each other is significantly different.The results of magnetometric measurements at the same observatories after coordinate conversion:



The nature of the graphs has changed significantly. After the transformations, the X axis became directed almost perpendicular to the ecliptic plane. This led to the fact that the nature of the variation of the magnetic field perpendicular to the plane of the ecliptic became identical in amplitude and time of occurrence of the extremum. What is typical of all observatories: They showed a decrease in the magnetic field vector directed parallel to the Earth's axis by about 55 nT, regardless of the coordinates of the measurement points.

Summary

- a plasma cloud did not hit the Earth, but passed by it at a sufficiently large distance;
- the average time the cloud passed through the Earth's orbit was about 6 hours, which at a cloud speed of 800 km / s gives an estimate of its length of 17.28 million km, which is close to theoretical values;
- the method can be used to estimate the coordinates of solar plasma emissions and their characteristics;

References

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