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Research on the multidimensional impact of space environment disturbance on polar travel and technological response

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Abstract:
This study analyzes how space environment disturbances, such as geomagnetic variations and solar storms affect polar expeditions, focusing on GPS, auroras, health, and meteorology. It finds that geomagnetic storms disrupt GPS through ionospheric scintillations, solar wind influences auroras and the upper atmosphere, and geomagnetic activity is linked to cardiovascular changes. Meteorological data show geomagnetic anomalies are related to extreme weather. The study notes current limits in prediction and technology, calling for better GPS resilience and interdisciplinary methods to improve polar expedition safety and climate research.

Keywords: Polar area, geomagnetic variation, solar storms, GPS

1. Introduction

On December 14, 1911, Norwegian explorer Roald Amundsen led a team of five to successfully reach the South Pole, their means of transportation included around 100 sled dogs imported from Greenland and used the most advanced navigation equipment of the time, including a sextant, theodolite, and chronometer, relying solely on the positions of the sun and stars for celestial navigation. This marked humanity's first venture into the South Pole, opening the door to polar scientific research with curiosity and courage toward the unknown. Today, polar scientific expeditions have become increasingly specialized. Today, polar scientific exploration has become increasingly specialized, and the changes in the space environment that affect polar exploration activities cannot be ignored. The changes in the space environment can be divided into three aspects: geomagnetic variations, solar storms, and atmospheric electrical disturbances. Geomagnetic storms are intense global geomagnetic disturbances, regarded as one of the most critical events in hazardous space weather, which are ground-level effects caused by interactions between coronal mass ejections or high-speed solar wind streams and Earth's magnetosphere (Kang & Han, 2024). Ionospheric storms occur when the ionosphere is significantly disturbed due to geomagnetic storms, leading to irregularities in electron density. These disturbances cause rapid fluctuations in the amplitude and phase of radio signals, referred to as amplitude and phase scintillations (Yin, 2016). Solar storms or solar winds refer to streams of charged particles released from the sun into space (Gao, 2009).

These space environmental changes, geomagnetic variations, solar storms, and disturbances, affect polar expeditions in various ways and to differing de-

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grees. Unlike visible influencing factors such as extreme weather (e.g., snow accumulation, ice layers, or whiteout conditions), dynamic topographical changes, or phenomena like the aurora, the three factors discussed in this paper are invisible to the naked eye. They require precise instruments and equipment for observation, as their variations are subtle and difficult to predict. Additionally, some geomagnetic measurement indicators were only proposed in the 20th century, meaning human understanding and research in this area remain relatively limited. The significance of researching these aspects extends beyond ensuring the safety of expeditions. Investigating these effects can help teams better predict and respond to risks, reducing potential losses to personnel and equipment while improving efficiency by optimizing expedition plans. Moreover, it contributes to addressing global climate change, as polar space environments serve as critical observatories for monitoring global climate dynamics. Changes in this environment are closely tied to the global ecosystem, and studying them can help scientists gain a more comprehensive understanding of the potential threats climate change poses to human activities. Additionally, this research can improve polar navigation and communication technologies, supporting further polar research and development. The importance of these studies, although not widely recognized, holds significant value.

This paper will primarily utilize literature review, supplemented by interviews and data analysis as part of the original research. It will examine the impact of space environmental changes on Global positioning system (GPS), auroras, human health, and weather, and summarize potential strategies to address these challenges. The aim is to provide a relatively comprehensive review of less-organized aspects in previous research.

2. Literature review

2.1 Overview

This part explores the impact of space environmental changes on various aspects of polar scientific expeditions. It covers key areas such as GPS navigation, auroras, human health, and meteorology, discussing how these factors are affected by space weather phenomena like geomagnetic activity and solar flares. The article also identifies gaps in existing research, emphasizing the need for more comprehensive and accessible studies to help the public better understand and address the effects of space environmental changes on polar expeditions.

2.2 The Impact of Space Environmental Changes on Various Aspects of Polar Scientific Expeditions

2.2.1 GPS

For polar scientific expeditions, GPS is an important tool for navigation. Due to the mechanism of GPS, its performance can be affected by changes in the space environment, which is a risk that cannot be ignored. Figure 1 illustrates the working principle of GNSS, showing how satellites transmit signals to user devices via the control segment. This process is essential for accurate positioning in polar environments.

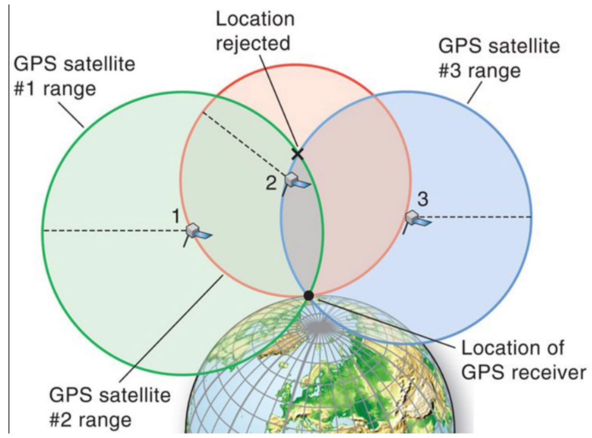

Fig 1 Schematic diagram of GPS working principle (Sharda, 2019)

Since the 21st century, foreign researchers have increased their studies on geomagnetic navigation and applied it to various fields. Through long-term observations of the geomagnetic field, it has been found that Earth's fundamental magnetic field is not constant but changes gradually over time. Specifically, the annual mean values of various geomagnetic parameters change year by year. The geomagnetic parameters not only change in value but also in direction (Xiao, 2023) .

The space weather, including solar activity, solar wind, and its effects on the Earth's magnetic field, leads to geomagnetic storms, which can affect navigation systems like GPS (Figure 1 shows how it works). Changes in electron density in the ionosphere alter the speed of radio wave propagation, causing delays in GPS signals, especially in polar and auroral regions, with these delays potentially lasting for hours (P. V. S. Rama Rao, 2009) .

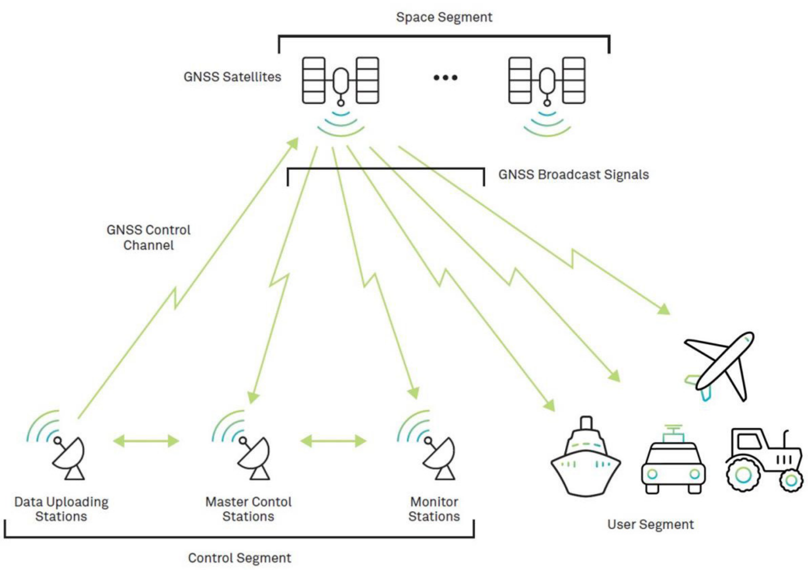

Fig 2 GNSS Positioning System Working Principle Diagram (HEXAGON, 2025)

2.2.2 Aurora

For polar expeditions, the observation of auroras is also a very important aspect. The changes in the space environment are deeply and closely related to the changes in auroras. As an important indicator of space weather, the auroral intensity and distribution on the auroral oval are closely linked with the solar wind-magnetosphere-ionosphere energy coupling, and change with the variations in space and geomagnetic environments (Hu, 2020).

Toward the end of the nineteenth century, and it has of course been accelerated during the past two decades with in situ measurements by means of rockets and satellites. Two significant findings were soon established: the auroras occur in two narrow bands, one around each geomagnetic pole, and auroral activity is highly correlated with sunspot activity. Stormer (1955) and other Norwegians concluded that the auroras are caused by streams of energetic charged particles emitted by the sun especially at times of solar disturbances. The earth's magnetic field deflects the particles toward the high latitudes, Figure 3 shows the principle of solar wind's mechanism. From the measured height sand other characteristics of it can be inferred that the primary auroral particles are electrons with rather low energies,100 to 10,000 ev. Protons with slightly higher energies are also present (W. J. Heikkila, n.d.).

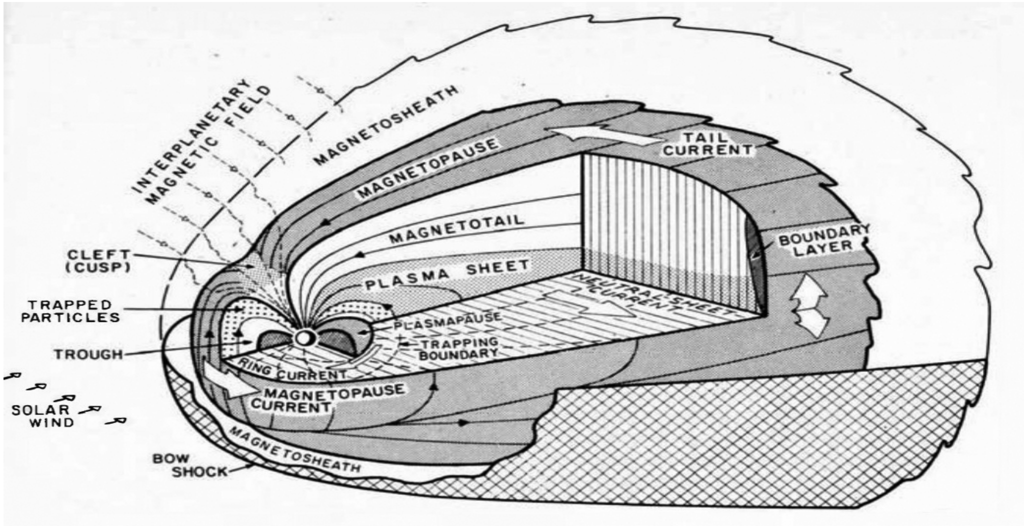

Fig 3 The principle of solar wind's mechanism (W. J. Heikkila, n.d.)

2.2.3 Human Health

The impact of space environment changes on human health is often overlooked, but for polar expeditions, the health of the expedition members is crucial. Even minor

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effects in this regard should not be ignored. The influence of space environment changes on human health exists in many aspects.

Table 1 Geomagnetic activity and its effects (Zi et al., 2023)

Aspect	Description
Formation of Earth's Magnetic Field	Generated by the liquid outer core's magnetic fluid dynamo, extending into space.
Definition of Geomagnetic Activity (GMA)	Changes in the Earth's magnetic field over time and space, including intensity, direction, and morphology.
Human Magnetic Field	The human body generates bioelectricity, which produces a weak magnetic field.
Interaction with Earth's Magnetic Field	Under stable conditions, the human magnetic field is balanced with the Earth's magnetic field.
Effects of Geomagnetic Activity on Humans	Disrupts the balance between the Earth's and human magnetic fields, potentially affecting health.
Possible Mechanism	Substances involved in physiological activities are sensitive to magnetic fields, and metabolic processes involve charged particles.
Reference	Zi et al., 2023

Geomagnetic activity (GMA) is associated with human health, with strong activity potentially leading to significant health issues or even death (Mavromichalaki et al., 2021). Geomagnetic disturbances (GMD), which include geomagnetic storms, substorms, and pulsations, involve changes in the Earth's magnetic field (Clarke et al., 2008). These disturbances are irregular, with complex patterns and both global and regional effects, primarily caused by solar mass ejections that disrupt the Earth's space environment (Jin Wei et al., 2017). GMA not only helps us explore space but can also impact human health (Kleimenova et al., 2007b; Jacobs and Westphal, 1964).

Table 2 Geomagnetic Activity and Cardiovascular Health

Aspect	Description
Systolic Blood Pressure (SBP)	Maximum force exerted on blood vessels during heartbeats.
Diastolic Blood Pressure (DBP)	Resting pressure when the heart relaxes.
Sensitivity of DBP	DBP is the most sensitive cardiovascular parameter to external changes (Khabarova & Dimitrova, 2009).
Correlation with Geomagnetic Field	Both SBP and DBP correlate with the horizontal components of the geomagnetic field, strongest at night.
Gender Differences	Women's SBP and DBP show more significant changes, especially during low and rising solar activity.
Magnetic Field Resonance Hypothesis	Earth's magnetic field frequencies align with cardiovascular and autonomic nervous system frequencies, potentially affecting heart health (Stoupel, 2002).
Contradictory Findings	Some research (e.g., Klein et al., 2015) suggests that geomagnetic effects on cardiovascular health are minor compared to environmental factors like temperature and air quality.

Regarding mental health, the skull's electrical conductivity is lower than the brain's, allowing geomagnetic fields to penetrate and affect brain activity, especially during geomagnetic storms, potentially altering synaptic potentials and making the brain more sensitive (de Assis et al., 2019). On the other hand, other studies (e.g., Jacobs and Westphal, 1964) emphasize that the brain's response is more likely due to the psychological stress brought on by external environmental conditions, such as isolation and pressure in extreme environments, rather than direct effects of geomagnetic activity.

Table 3 The supporting and opposing views on the impact of body health, according to (Yuan et al., 2024)

Topic	Pro (Supporting)	Con (Opposing)
Magnetic Field and Cardiovascular Health	Stoupel (2002): Geomagnetic field resonance affects cardiovascular system.	Klein et al. (2015): Temperature, air quality have more significant effects.
Geomagnetic Activity and Blood Pressure	Khabarova & Dimitrova (2009): Strong correlation with blood pressure, especially at night.	Mavromichalaki et al. (2021): Effects depend on climate and other factors.
Magnetic Fields and Brain Health	de Assis et al. (2019): Geomagnetic storms affect brain activity, increase brain sensitivity.	Jacobs & Westphal (1964): Brain response due to environmental stress, not magnetic activity.
Solar Activity and Mental Health	Kleimenova et al. (2007b): Solar activity causes mood disturbances via neurohormones.	Su et al. (2017): Psychological issues due to conditions in polar expeditions.
Geographical and Regional Differences	Clarke et al. (2008): Stronger geomagnetic activity near poles affects health.	Jin Wei et al. (2017): Cold, darkness, and pressure play a larger role in health issues.

2.2.4 Meteorology

Space weather involves conditions in the Sun, solar wind, magnetosphere, ionosphere, and thermosphere, which can affect the normal operation and reliability of space-based and ground-based technological systems, thereby endangering human life or health. The source of space weather disturbances mainly comes from the Sun, driven by various short-term solar activities and the associated longer-term variations in solar output. Modern high-tech societies are becoming increasingly vulnerable to disturbances originating from space, particularly those caused by solar eruptions. Adverse space weather conditions are primarily caused by solar flares and coronal mass ejections (CMEs), the majority of which are driven by the energy released by sunspot groups or the complex magnetic fields in active regions. Additionally, the Sun continuously produces outward-flowing plasma, known as the solar wind, which extends into the outer solar system. Solar flares are the largest energy release phenomena in the solar atmosphere. The types of radiation generated during flare events are one aspect of space weather that attracts attention.

The interaction between the solar wind and Earth's magnetic field is crucial for understanding near-Earth space weather. The solar wind not only controls the size of the magnetosphere through momentum flux or dynamic pressure but also determines the energy flow coupling into the magnetosphere through magnetic reconnection between the interplanetary magnetic field and Earth's geomagnetic field. Therefore, in space weather applications, researchers are most interested in the speed of the solar wind, its mass density, and the strength and direction of the interplanetary magnetic field.

Magnetic storms are the most significant disturbances in the magnetosphere and are associated with many space weather phenomena. Magnetic storms are characterized by the formation of strong electric currents that encircle the Earth, and they can last from 12 hours to several days (Lv, et al., 2011).

2.3 Research Gap

There is existing research on the impacts of space envi-

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ronmental changes on GPS, human health, and weather, but most studies are highly specialized and fragmented, making it difficult for the general public to access and understand. Although some technologies are being developed to address space weather challenges, current research still has limitations, especially in terms of integrating findings from multiple fields. For ordinary travelers in polar regions, it is hard to fully grasp the relevant professional literature. Therefore, while technology and theory are advancing, there is a lack of comprehensive and accessible research that can provide clear analysis and practical guidance for the public. This research aims to fill this gap by presenting the impacts of space environmental changes on polar expeditions in a more holistic and understandable way, offering a more universally applicable perspective

2.4 Existing Countermeasures and Research Gaps

2.4.1 GPS

To mitigate the impact of ionospheric scintillation on satellite navigation, proposed solutions include improving receiver design and using user positioning algorithms. However, these measures cannot completely eliminate positioning errors or anomalies caused by ionospheric disturbances. The current research lacks comprehensive strategies and has limited data samples (Liu et al., 2009).

2.4.2 Human Health

Key areas for future research on the effects of geomagnetic activity on human health include: First, developing a comprehensive theoretical framework that integrates various fields such as physiology, neuroscience, medicine, and electromagnetism to better understand the detailed impacts of geomagnetic activity on health. Second, creating prediction and early warning systems using smart Earth technologies to forecast geomagnetic events and provide timely alerts to healthcare professionals and patients to minimize health risks. Third, developing protective measures using materials science and electronics to reduce the harmful effects of geomagnetic activity on human health (Yuan et al., 2024).

2.4.3 Meteorology

Space weather forecasting still faces challenges, such as predicting the timing, location, and intensity of solar flares. Recent studies suggest a connection between galactic cosmic rays (GCR) and cloud formation, with a response time of a few days. However, satellite data on low cloud cover is often unreliable, making accurate predictions difficult (Zhao et al., 2011).

3. Methodology

3.1 Overview

The EPQ research focuses on how changes in the space environment affect GPS, auroras, human health, and weather. Specific data and information need to be collected to support the argument. The research primarily uses secondary research, with some primary research as a supplement.

The secondary research mainly involves reading literature to gather information. This method is necessary because studying geomagnetism and space environment changes requires specialized knowledge and equipment, which is difficult to access. Additionally, field research in polar regions is not possible, making it more practical to use secondary data. However, relying only on secondary research can make the content too complex and hard to understand due to the high level of specialized knowledge, and it might lack practical value.

To address this limitation, primary research was added through interviews with travelers who have been to the polar regions to gain their relevant experiences and insights. This method makes the research more connected to reality and helps to fill the gaps in the literature review. Besides reading literature, online resources and books were also consulted to further enrich the research foundation.

3.2 Literature research

During the research process, literature searches were conducted using keywords such as geomagnetism, GPS, auroras, the impact of space environment changes on human health, and the impact on weather. To ensure the timeliness of the research, literature from the 2010s to the present was prioritized, as studies from this period tend to be more comprehensive, with technological advancements leading to more accurate data and results. However, earlier high-quality literature also provides valuable references, especially in offering foundational knowledge that plays an important role in the research.

In addition to timeliness, relevance is also an important criterion when selecting literature. The goal is to find literature that is directly related to the research topic in order to obtain the necessary data and conclusions. Authority is another key factor to consider. Preference is given to articles from high-level authors or national research institutions, or those published in recognized journals, to ensure the accuracy and authority of the content. Additionally, theses from PhD and graduate students are also considered as reference sources. Furthermore, data from websites related to geomagnetism and geology are used to supplement the research.

3.3 Interview

In addition to literature research, interviews were conducted with travelers who have visited the polar regions, tourist A had been to Arctic and tourist B had been to Arctic and Antarctic. These interviews provided valuable practical perspectives and support for the research. Interviewee A had been to north pole in 2024, and interviewee B had been to south pole in 2024. Among the interviewees, some have traveled to Antarctica and the Arctic for scientific expeditions. However, because the most suitable time for exploration in these regions is during the summer, when temperatures rise, the climate is relatively stable, and small animals are more active, they have not observed the aurora.

The discussion mainly focused on the effects of space environment changes during polar travel. Specific questions included whether they noticed any impacts of space environment changes on GPS, such as signal instability or location errors; whether they observed any changes in auroras, such as changes in frequency, color, or range; and whether these changes were linked to weather conditions. Additionally, we asked whether they experienced any physical symptoms, such as dizziness, fatigue, or other health issues, during their polar travels. These questions were designed to gather firsthand information related to the research topic based on their personal experiences. During the interview, the interviewees were informed that their responses would be used for this research, and all data will remain anonymous and confidential. Participants voluntarily provided information, with no personal identities disclosed. All collected data will be used solely for academic purposes and will not be used for any other purpose. The interviewer ensures that the interviewees are aware of their rights and that their privacy is fully protected.

3.4 Data analysis

In my data analysis, I utilized various methods to present information more clearly. I transformed raw data into intuitive bar charts, making trends and comparisons more visually accessible. Additionally, I organized events into structured tables, allowing for a clearer understanding of relationships and patterns. By analyzing these visual representations, I derived meaningful conclusions from the data, ensuring that key insights were effectively communicated. These methods enhanced the clarity and interpretability of my findings, facilitating a more comprehensive understanding of the analyzed information.

4. Results and discussion

4.1 GPS

4.1.1 Geomagnetic Activity and Ionospheric Storms in Polar Environments

In the polar regions, there is a close relationship between geomagnetic activity and ionospheric storms. According to a geomagnetic storm case in September 2011, intense geomagnetic activity led to increased ionospheric disturbances, especially during the storm period, where significant ionospheric changes affected the quality of GPS signals. Although the two visitors did not how it works, they both know that it has impact.

4.1.2 Temporal Variations of Geomagnetic Activity and Ionospheric Disturbance

As the figure shown below, before the Storm (September 24-25): During this period, geomagnetic activity was relatively calm, with the Ap index and auroral electrojet index (AL) remaining stable. At this time, ionospheric disturbances were minimal, and the scintillation index remained at low levels.

During the Storm (September 26): Starting on September 26, geomagnetic activity underwent intense fluctuations, with a significant increase in the Ap index and a decrease in the AL index. The geomagnetic field shifted to a negative value. Ionospheric disturbances intensified, and scintillation strength significantly increased, especially between 18:00 and 23:00 UTC.

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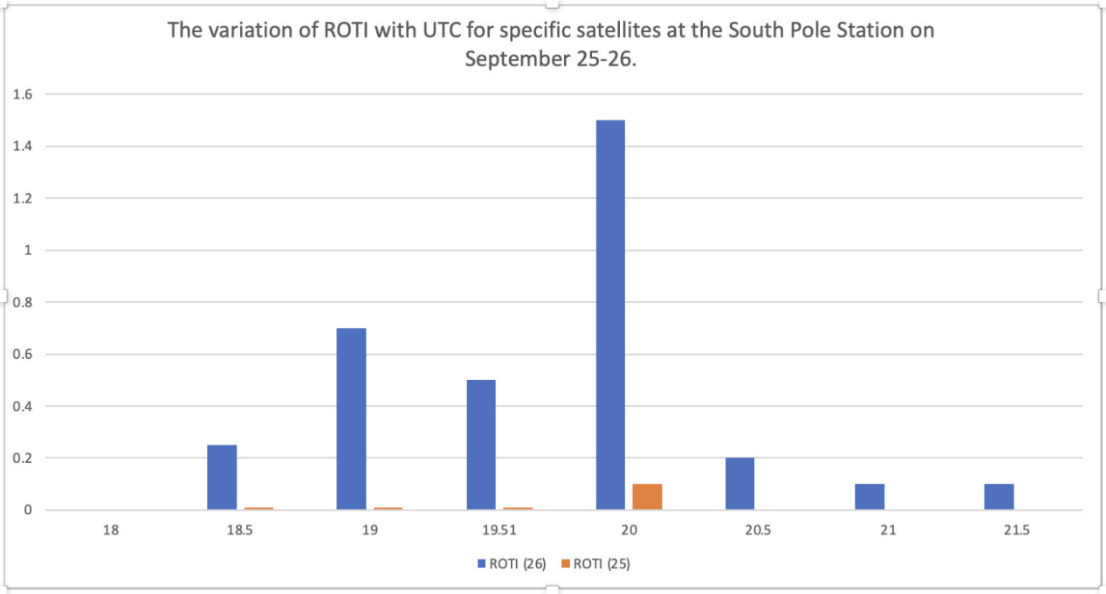

Fig 4 The variation of ROTI with UTC for specific satellites at the South Pole Station on September 25-26(Yin, et al, 2014)

After the Storm by September 27, geomagnetic activity and ionospheric scintillation gradually returned to a calm state, with scintillation intensity and spatial distribution decreasing and returning to a quiet condition.

4.1.3 Spatial and Temporal Variations of Ionospheric Scintillation and GPS TEC

Before the Storm (September 24-25): During these two days before the storm, the ionospheric scintillation intensity was low, primarily exhibiting localized disturbances. The scintillation activity did not expand to a larger range, and therefore, GPS signals were not significantly affected.
During the Storm (September 26): Ionospheric scintillation significantly intensified, with both scintillation intensity and spatial distribution expanding, affecting more GPS satellites. The scintillation activity was particularly active during the 18:00-23:00 UTC period.
After the Storm (September 27): After the storm, the intensity and spatial distribution of ionospheric scintillation gradually decreased, returning to a calmer state, with the affected area and intensity also reducing.

4.1.4 Effects of Spatial Variations on GPS Signals

Before and After the Storm: Before and after the storm, the scintillation index was low, with fewer GPS satellites affected, and the signal quality remained stable with minimal interference.
During the Storm: During the storm, ionospheric disturbances were severe, leading to more irregular structures, causing a significant increase in scintillation intensity and spatial range. This resulted in more substantial impacts on GPS signal quality. The signal fluctuations were prominent, potentially causing reduced positioning accuracy and signal. (Yin, et al, 2014)

4.1.5 Conclusion

Therefore, to enhance the effectiveness of GPS usage during polar expeditions, especially during storm events, it is recommended to adopt more precise positioning technologies or implement stronger anti-interference measures, such as optimizing GPS receiver design, adding redundant systems, and utilizing other space weather forecasting methods for early warning to minimize the negative effects of ionospheric disturbances on GPS signal quality.

4.2 Meteorology

4.2.1 Relationship Between Geomagnetic Activity and Weather Changes

Overall, geomagnetic activity and other space environmental changes can lead to weather variations, but there is no linear relationship. From November 1990 to January 1991, geomagnetic anomalies occurred in several regions of China, with a significant decrease in geomagnetic field values in many areas, and the range of anomalies was extensive. For example, in Anhui, Jiangsu, Zhejiang, and Guizhou, the anomaly values dropped from 20 to below 10, lasting for several months. The geomagnetic anomalies during this period had a clear correlation with subsequent meteorological disasters.
For instance, in May 1991, a heavy rainstorm occurred in Hunan and the Jianghan Plain, followed by floods and rainstorms in the middle and lower reaches of the Yangtze

River in June, and frequent heavy rainstorms in Guizhou in July. Guangdong, Hainan, and other areas also experienced typhoons and heavy rain disasters. Additionally, the Beijing-Tianjin region, Heilongjiang, and Jilin experienced similar geomagnetic anomalies, which correlated with rainstorms, mudslides, and other disasters from June to September 1991. The geomagnetic anomalies were temporally and spatially related to the occurrence of meteorological disasters, suggesting that geomagnetic changes may have an influence on climate and weather patterns.

Table 4 A table shows the geonagnetic anomaly associated with meteorology disasters (Zeng, et al, 1992)

Time Period	Geographic Area	Geomagnetic Anomaly Description	Associated Meteorological Disasters
Nov 1990 - Jan 1991	Anhui, Jiangsu, Zhejiang, Guizhou, Henan, Hubei, Hunan, Guangxi, Guangdong, Fujian coastal areas	Two large geomagnetic anomaly zones, r-value dropped from 20 to 10-40	May: heavy rain and hailstorm in Hunan, Jianghan Plain; Jun 29 - Jul 13: heavy rain and flooding in Yangtze River; Jul: heavy rain in Guizhou, Typhoons in Guangdong, Hainan, etc.
Dec 1990	Beijing-Tianjin area, Hebei, Shanxi, Northern Shaanxi, Inner Mongolia	Large geomagnetic anomaly, r-value dropped from 30 to 10	Jun 7-11: rare heavy rainstorm in Beijing, heavy floods in Tianjin, Inner Mongolia, Hebei, Shanxi, Ningxia in Jun, Jul, Sept
Dec 1990 - Jan 1991	Heilongjiang, Jilin, Liaoning provinces	Geomagnetic anomaly belt formed, r-value of 25	Jun 27-29: heavy rain in Heilongjiang; Jul 28-30: heavy rain in Liaoning and Jilin
Dec 1990 - Jan 1991	Sichuan, Yunnan regions	Elliptical geomagnetic anomaly zone, with a southwest anomaly in Tonghai, r-value=-15	May 23-26: heavy rain in Eastern Sichuan; Jun 12-14, 29-30, Aug 4-6, Aug 8-10: heavy rain in Sichuan; Jul: tornado and hailstorm in Tonghai

4.2.2 Geomagnetic Effects and Climate Change

The geomagnetic effect is the result of the interaction between Earth's internal and external magnetic fields. The Earth's inner and outer cores generate conductive flows due to gravitational forces from the sun and moon, the Coriolis force, and thermal buoyancy, forming the geomagnetic field. Solar wind and flare activities provide additional energy to the geomagnetic field, and intense solar activity can trigger geomagnetic storms, causing short-term disturbances in the Earth's magnetosphere. At the same time, there are heat convection and angular momentum exchanges in the Earth's internal layers (such as at the boundary between the inner and outer cores), and electromagnetic forces are an important driving force for the movement of the outer core. These processes not only affect the Earth's rotation speed and angular momentum distribution, but also modulate global climate and atmospheric activity through the magnetic field. This geomagnetic effect is particularly significant on long timescales, such as the solar cycle, and is an important mechanism for studying the interaction between Earth and the Sun. According to the answer of the two visitors, we can know that weather had a significant impact on the expendition, so we should figure out how it works, especially in polar regeins, where weather disasters are normal.

4.2.3 Outer Magnetic Field and Earth's Climate Regulation

Outer magnetic fields (such as the galactic arm magnetic field and solar magnetic field) → Magnetize the Earth (boundaries between the inner and outer cores, and the mantle).

The solar wind amplifies the energy of the Earth's internal current layers through transformer coupling.

The Earth's rotation is influenced by angular momentum

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modulation, heat convection, and energy transfer, regulating the global climate. (Yan, et al, 1999)
Significant Impact of Solar Flares on the Atmospheric Electric Field: In Beijing, the solar flare events caused notable changes in the atmospheric electric field, particularly on the second day after the flare. For example, after 25 instances of Class 3 solar flares, the electric field increased by about 10% on the second day; while after the massive Class 4 solar flare on February 4, 1986, the electric field increased by 61%.
Faster Response of Atmospheric Electric Field, Ionospheric Currents, and Ozone Compared to Meteorological Parameters: The response of the atmospheric electric field, ionospheric currents, and ozone to solar activity in Beijing occurred much faster than the response of meteorological parameters (such as temperature and humidity). These electrical parameters showed noticeable changes shortly after solar flares, whereas meteorological parameters lagged behind.
Possible Mechanism of Solar Activity's Influence on Meteorology: Since the atmospheric electric field, ionospheric currents, and ozone react more rapidly to solar activity, the changes in these electrical parameters may affect the electrical and chemical properties of the atmosphere, subsequently influencing meteorological parameters. Therefore, solar flares may indirectly affect meteorological changes by modulating these electrical parameters.

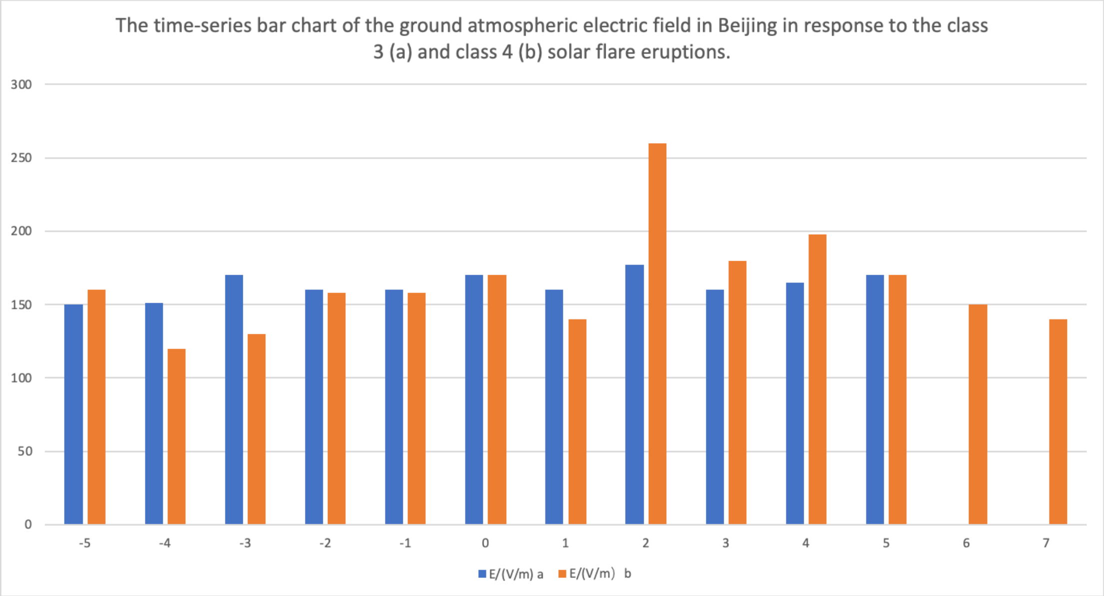

Fig 5 The time series bar chart of the ground atmospheric electric field in Beijing in response to the class 3(a) and class 4(b) solar flare eruptions.(Yan, et al 1999)

This aspect explores the correlation between geomagnetic activity and meteorological changes, highlighting how geomagnetic storms affect GPS signal quality and global climate. It provides insights into the impact of solar activity on weather patterns through ionospheric disturbances and geomagnetic effects. (Yan, et al 1999)

4.3 Aurora

4.3.1 Solar Wind Impact and Magnetic Field Changes

On May 15, 1997, the WIND satellite observed solar wind (charged particles ejected by the Sun) and magnetic field changes near Earth.
At 01:16 (1:16 AM), the WIND satellite detected a strong solar wind shock hitting Earth's magnetic field, similar to a strong wind hitting Earth's "magnetic bubble."
At 04:46 (4:46 AM), the direction of the magnetic field suddenly changed, indicating the arrival of a special magnetic cloud.
At 05:56 (5:56 AM), the magnetic field weakened significantly (-24.2nT), as if it were "flattened."
Between 07:30 - 08:00 (7:30 AM to 8:00 AM), the magnetic field briefly recovered and then reverted to its original direction.
At 10:34 (10:34 AM), the magnetic field weakened again (-24.7nT).
At 12:00 (12:00 PM), the WIND satellite measured a solar wind speed of 440 m/s (equivalent to 1584 km per hour), and the Earth's magnetic field index (Dst) reached a minimum value of -115nT, indicating that the magnetic field was strongly "compressed" by the solar wind.

4.3.2 Magnetic Storm and Ionospheric Impact in the Aurora Region

This entire process caused a magnetic storm (similar to a "storm" in Earth's magnetic field), which affected Earth, with the maximum intensity of the Kp index reaching 7 (the Kp index is used to measure the strength of a magnetic storm, with 7 indicating a very strong storm). Overall, on this day, the solar wind was particularly strong, severely impacting Earth's magnetic field, leading to significant changes, which could affect satellites, radio communications, and even cause beautiful auroras to appear on Earth.

4.3.3 Magnetic Storm's Impact on the Upper Atmosphere

The magnetic storm on May 15, 1997, affected the ionosphere above the aurora region. In altitudes above 200 km, the number of electrons decreased significantly, particularly in the 250-350 km range, where electron loss was most severe, with a reduction of up to 70%. This indicates that the magnetic storm had a significant impact on the upper atmosphere.

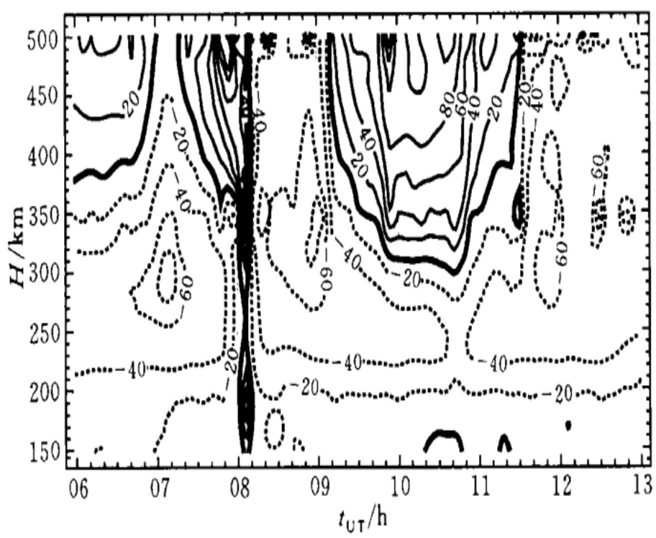

Fig 6 Variation in electron density observed by the EISCAT radar between the geomagnetic storm day on May 15, 1997, and the quiet reference day on June 26, 1997.(Ma, et al, 2002)

The geomagnetic storm on May 15, 1997, had a significant impact on Earth's magnetic field and the ionosphere over the auroral regions. The intense solar wind caused drastic changes in the magnetic field, leading to a substantial decrease in electron density, particularly between 250-350 kilometers in altitude. This geomagnetic storm not only affected satellites and communication systems but also enhanced auroral activity, highlighting the profound influence of solar wind and geomagnetic storms on Earth's space environment. (Ma, et al, 2002)

4.4.1 Research Overview

Study Subjects: A total of 162 patients with chest tightness and chest pain who were hospitalized were selected, including 85 cases in the stable angina group and 77 cases in the non-coronary heart disease group. Patients with positive ECG stress tests, abnormal myocardial enzyme levels, etc., were excluded from the study.

Methods:

Hematorheology Testing: Venous blood samples were collected after fasting to measure low shear and high shear whole blood viscosity, as well as plasma viscosity.

Geomagnetic Activity Monitoring: The geomagnetic index (Dst) was used to monitor geomagnetic activity and distinguish between geomagnetic quiet and geomagnetic active conditions.

Meteorological Monitoring: Meteorological data from Kunming, including temperature and humidity, were collected.

Statistical Analysis: Data were analyzed using SPSS software. T-tests, paired t-tests, and chi-square tests were used for intergroup differences, and multiple linear regression analysis was conducted to assess factors affecting hematorheology indicators.

4.4.2 Main Results

Comparison of General Data between the Two Groups: There were no significant differences between the two groups in terms of gender and medical history, but differences were found in age and smoking history with statistical significance.

Geomagnetic Activity: The number of geomagnetic activity days in Yunnan Province in 2014 was recorded and analyzed.

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Effects of Geomagnetic Activity on Hematorheology:

During geomagnetic quiet conditions, significant differences were found in the low shear whole blood viscosity between the stable angina group and the non-coronary heart disease group.

During geomagnetic activity, low shear whole blood viscosity significantly increased in the non-coronary heart disease group, and also increased in the stable angina group, though no significant differences were found in high shear whole blood viscosity and plasma viscosity.

Multiple Regression Analysis: Hyperlipidemia and geomagnetic activity significantly affected low shear and high shear whole blood viscosity, while hyperlipidemia was a significant factor affecting plasma viscosity.

The study shows that geomagnetic activity has a significant relationship with blood rheology, particularly with whole blood viscosity under low shear conditions. This suggests that geomagnetic changes may have an impact on cardiovascular health, especially during periods of strong geomagnetic activity. (Yuan, et al)

5. Evaluation

Highlights:

The author explores the impact of space environmental changes on polar expeditions from multiple perspectives like geomagnetism, meteorology, and human health, demonstrating a comprehensive approach to complex issues. This interdisciplinary research provides valuable insights, particularly for polar science.

By combining existing literature with interviews of polar travelers, the author adds practical, first-hand data, making the research more grounded and relevant.

The focus on "invisible" factors like space environmental changes, which are often overlooked, fills an important gap in the field of polar expeditions.

The research not only offers theoretical analysis but also provides practical strategies for future polar expeditions, with real-world relevance.

Limitations:

The sample size of interviews is small, and the interviewees' expeditions were limited to the summer, affecting data representativeness. For instance, the lack of aurora-related data limits the analysis of its impact on expeditions.

Space environmental changes are influenced by many complex factors, and the mechanisms behind them are still unclear. This makes it difficult to provide definitive conclusions.

Although the author suggests solutions like optimizing GPS systems, the practical feasibility in polar conditions is not deeply explored, particularly regarding technology stability in extreme cold.

The study mainly relies on existing literature and technologies, which may be outdated or limited in scope.

6. Conclusion

This paper investigates the impact of polar space environmental changes on polar scientific expeditions, focusing on four key factors: GPS, aurora, physical health, and weather. By reviewing existing literature and analyzing relevant research data, the author identifies the specific effects of these environmental changes on polar expeditions. Through a detailed study of the impact of aurora activity on equipment performance, changes in GPS signal quality, and the challenges to physical health in polar environments, this research provides valuable insights into the difficulties encountered during expeditions. At the same time, the author offers practical recommendations to improve expedition planning, such as adopting advanced GPS technologies and adjusting health management strategies to address the risks posed by extreme weather conditions.

The findings of this study are of significant importance for future polar expeditions, and the author hopes this research will serve as an important reference for future researchers, explorers, and polar engineers. The study also suggests that future research should further explore other variables, such as the long-term impact of space weather on human health and the effects of climate change on polar expeditions.

In conclusion, this study provides a comprehensive perspective on the impact of polar space environmental changes on polar expeditions, offering valuable insights that can serve as useful references for future polar research. The author calls for continued attention to this field in future studies to enhance the safety and efficiency of polar exploration, contributing to the scientific advancement and practical applications of polar research.

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