American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBP
ISSN: 2997-9331

Study of the Effect of Solar Activity on the Earth's Atmosphere

Sheikha Abdullah Jaber Ail, Ruqayya Kazem Khalifa Hanoun
University of Basra College of Science Department of Physics

Amna Jubair Ali Jebur, Zahraa Jaber Yasser Dhaif
University of Dhi Qar College of Science Department of Physics

Habeb Ahmed Habeb Zabn
University of Baghdad College of Science Department of Physics

Received: 2024 19, Sep
Accepted: 2024 28, Sep
Published: 2024 18, Oct

Annotation: Geomagnetic storms are severe disturbances in the Earth's magnetic field caused by interactions between the solar wind and the magnetosphere. These storms significantly affect the total electron content (TEC) of the ionosphere, which in turn affects communications, navigation, and radio signals. Geomagnetic storms affect the accuracy of GPS signals, resulting in position errors of up to several meters, a critical problem in precision applications such as aviation and maritime navigation. Geomagnetic storms cause distortions in data transmitted to and from satellites, affecting the accuracy of scientific measurements and ground-based observations.

Introduction:

the sun: the central star of the solar system and one of the stars of the milky way galaxy, which contains approximately 200 billion stars. the diameter of the sun is 1,392,684 kilometers, which is equivalent to 109 times the diameter of the earth, and its mass is 30*10^2 kilograms, which is equivalent to 330,000 times the mass of the earth.

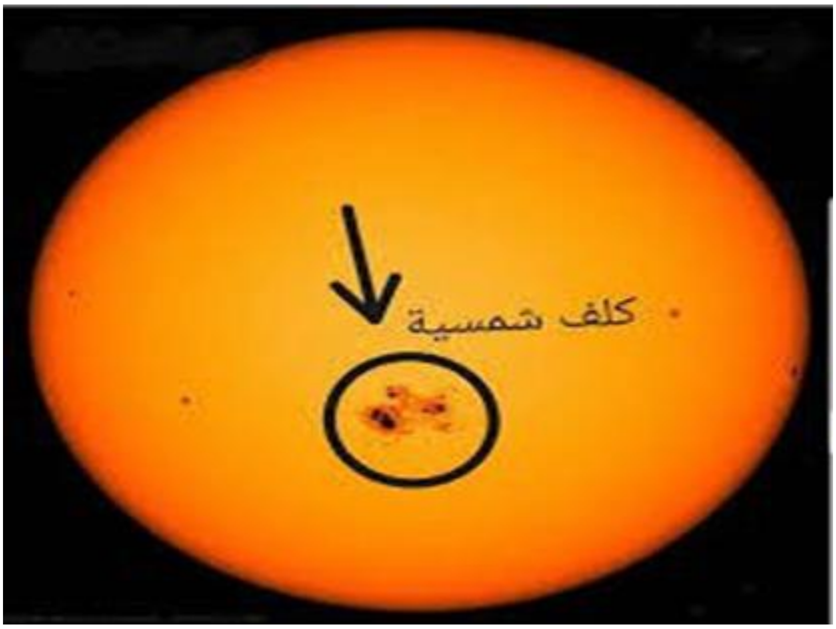
the sun: it is the primary source of energy as it provides heat and light to the earth. it is a huge ball of hot gases and produces huge amounts of energy by converting hydrogen into helium in its depths. due to the intensity of this radiation, it can damage the eyes, so it is not possible to look directly at the sun with the naked eye or through a telescope unless it is equipped with a solar filter.

the position of the sun: the sun is located at the center of the solar system and constitutes 99% of the mass of the system. its huge gravity pulls the planets, dwarf planets, asteroids, comets and other objects. the average distance between the sun and the earth is about 93 million miles (150 million kilograms). light travels through space at a speed of about 186,282 miles 299,792 kilometers per second, so it takes only 8 minutes for a ray of sunlight to reach earth, as light coming from the nearest star takes more than four years to reach earth. the basic properties of the sun: more than 90% of the sun's orbit is hydrogen, and most of the rest is made up of helium. there are small amounts of heavy elements such as carbon, nitrogen, oxygen, silicon, and iron. due to the hot atmosphere, there can be no solid or liquid material on the surface of the sun, but rather it consists of gas and plasma, which is a state in which gases are heated to a great degree so that electrons are stripped from their atomic nuclei. the heated gas is said to be ionized, i.e. it has turned into ions because it consists of a group of ions or electrically charged particles, and the free electrons carry a negative charge and the atomic nuclei carry a positive charge.

the sun rotates like the planets, but because of its non-solid nature, different parts of it rotate at different rates. the surface parts near the equator rotate faster, completing one rotation every 25 earth days, while the surface parts near the poles take 36 days to complete a rotation.

The sun consists of several layers

1- The photosphere
2- The chromosphere
3- The corona



sunspots or sunspots: are spots on the surface of the sun (photosphere) that are characterized by a lower temperature than the surrounding areas and by intense magnetic activity that prevents heat transfer, forming areas with low surface temperatures. despite being very flat areas, the difference between their temperature, which is about 4000-4500 kelvin, and the general surface temperature of the sun (5700 kelvin), makes them appear as dark spots. if we look at these spots in isolation from the surrounding photosphere, they would appear brighter than an arc lamp. sunspots have reached a minimum during the sunspot cycle.

geomagnetic storms: are a natural phenomenon that occurs when the earth's magnetic field is disturbed by solar activity. these storms can cause a variety of effects, ranging from aurora borealis to power outages. they can also disrupt satellite and radio communications. they can even cause damage to electrical grids. understanding the causes and effects of geomagnetic storms is important to predicting their potential effects and preparing for them.

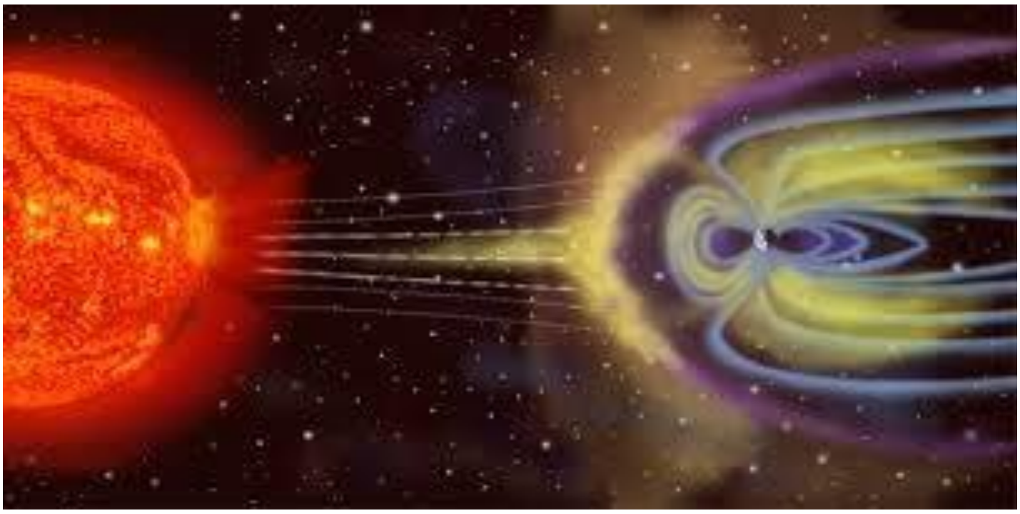
Recent Developments In Geomagnetic Storm Research

geomagnetic storms are a phenomenon that occurs when the earth's magnetic field is disturbed by solar activity. in recent years, research into geomagnetic storms has continued, with a focus on understanding the causes and effects of these events.

one of the latest developments in geomagnetic storm research is the use of satellite data to better understand the dynamics of these storms. by studying the data collected by satellites, scientists can gain a better understanding of the physical processes that occur during a geomagnetic storm. this data can then be used to develop models that can predict the intensity and duration of the storm.

Another recent development in geomagnetic storm research is the use of ground-based instruments to measure the effects of the storm. by measuring the strength and direction of the magnetic field at different locations, scientists can gain a better understanding of the storm's effect on the earth's magnetic field. this data can then be used to develop models that can predict the storm's effects on the earth's magnetic field.

finally, researchers are also exploring the possibility of using artificial intelligence to better understand geomagnetic storms. using machine learning algorithms, scientists can develop models that can accurately predict the intensity and duration of the storm. this could lead to improved prediction of geomagnetic storms, which could help reduce the potential for damage from these events. overall, research into geomagnetic storms is ongoing, and recent developments have allowed scientists to gain a better understanding of these events. using satellite data, ground-based instruments, and artificial intelligence, researchers can gain a better understanding of geomagnetic storms and develop models that can accurately predict their intensity and duration.



- ✓ **Benefits of geomagnetic storms:**

One of the most important benefits of geomagnetic storms is the increased availability of charged particles in the atmosphere. These particles, known as cosmic rays, can be used to study the composition of the universe and the effects of radiation on the Earth's atmosphere. Scientists have used cosmic rays to study the effects of radiation on astronauts, as well as to develop new technologies such as medical imaging and cancer treatment.

Geomagnetic storms can also be beneficial to the environment. The increased availability of charged particles can help break down pollutants in the atmosphere, reducing the amount of air pollution. Additionally, the increased activity of the aurora can help reduce light pollution in areas near the poles.

Finally, geomagnetic storms can be beneficial to the economy. Increased activity of the aurora can attract tourists to areas near the poles, providing a boost to local economies. Additionally, the increased availability of charged particles can be used to generate electricity, providing an alternative source of energy.

In general, geomagnetic storms can bring a variety of benefits, ranging from helping scientific research to providing economic opportunities. While these storms can be disruptive, they can also have a number of positive effects.

- ✓ **Long-term effects of geomagnetic storms:**

Geomagnetic storms are severe disturbances in the Earth’s magnetic field caused by solar activity. These storms can have a range of effects on the environment, both in the short and long term.

In the short term, geomagnetic storms can disrupt power grids, satellite communications, and navigation systems. They can also cause the aurora borealis, or northern and southern lights, to appear at lower latitudes than usual.

In the long term, geomagnetic storms can have a range of effects. One of the most significant is the potential for damage to satellites and other spacecraft. Geomagnetic storms can cause electrical charges to build up on the surface of a spacecraft, which can lead to short circuits and other malfunctions. This can cause significant damage to a spacecraft, and can even lead to its complete destruction.

Geomagnetic storms can also cause changes in the Earth’s atmosphere. These changes can affect the amount of radiation reaching the Earth’s surface, which can have an impact on human health. Additionally, geomagnetic storms can cause changes in the Earth’s climate, as they can affect the amount of energy absorbed and reflected by the atmosphere.

Finally, geomagnetic storms can cause changes in the Earth’s magnetic field. These changes can affect the accuracy of navigation systems, and can also cause disruptions to power grids.

In general, geomagnetic storms can have a range of long-term environmental impacts, from changes in the atmosphere to damage to spacecraft. It’s important to be aware of these potential impacts, and take steps to mitigate them.

- ✓ How to monitor geomagnetic storms:

You can monitor geomagnetic storms using websites such as the Space Weather Prediction Center or NOAA’s Space Weather Prediction Center. You can also use apps such as SOLAR MONITOR or SPACE WEATHER LIVE to monitor geomagnetic storms.

These storms occur once a month, but they can occur more or less frequently, depending on solar activity. These storms last from a few hours to several days, but they can last for a long time, depending on the severity of the storm. These storms do not pose a danger to humans, but they can cause disruption to networks and energy communications via satellite.

- ✓ **Results of previous studies**

The total electron content (TEC) of the ionosphere is significantly influenced by solar activities, especially coronal mass ejections (CMEs), which can induce geomagnetic storms. This review brings together the results from different studies to illustrate the impact of CMEs on TEC, covering different geographic regions and storm intensity. Ionospheric disturbances during geomagnetic storms have been extensively studied using Global Positioning System (GPS) data. Mannucci et al. (2005) studied the ionospheric effects of geomagnetic storms, including insights into TEC changes attributed to CME events. Their findings emphasize the foundational role of GPS observations in understanding TEC dynamics during space weather events.

Fuller-Rowell et al. (2006) presented a detailed analysis of the geomagnetic storms of 29–30 October 2003, highlighting the regional variability in TEC response across latitudes. Their study focused on the complex ionospheric interactions induced by CMEs, contributing valuable insights into storm-induced TEC variability.

B et al. (2010) focused on the December 2006 overturning storm, using GPS scintillation and TEC data to characterize the ionospheric disturbances induced by CMEs. Their research emphasized the importance of monitoring both TEC and scintillation parameters for a comprehensive assessment of ionospheric behavior during CME-driven events.

Bhattacharya et al. (2013) investigated TEC variations over the Indian region at low latitudes during multiple geomagnetic storms, highlighting the distinct effects of CMEs on ionospheric electron density. Their findings highlighted regional variations in TEC responses, influenced by geomagnetic storm intensity and local ionospheric conditions.

Kumjathi et al. (2015) analyzed ionospheric gradients and TEC variability during the 2015 St. Patrick's Day storm, a prominent event driven by multiple CMEs. Their study emphasized the role of large-scale ionospheric dynamics in shaping TEC responses to severe geomagnetic disturbances.

Astafieva et al. (2017) provided a global perspective on ionospheric responses to the September 2017 geomagnetic storm, integrating ionosonde and GNSS data to assess CME-induced TEC variations across the globe. Their comprehensive analysis highlighted the large-scale nature of ionospheric disturbances during intense coronal emission events.

Rama Rao et al. (2019) focused on TEC responses over the Indian region during the 2015 St. Patrick's Day storm, using ground-based and satellite-based GPS observations. Their study demonstrated the regional specificity of CME effects on TEC, emphasizing the importance of local observations in understanding ionospheric variability.

Ballan et al. (2020) investigated GPS-TEC responses over equatorial anomalies during geomagnetic storms, elucidating ionospheric irregularities caused by CME events. Their findings contributed valuable insights into the role of geomagnetic storms in shaping equatorial ionospheric dynamics and TEC variability.

Tsurutani et al. (2021) conducted a comprehensive review of the effects of coronal emission on the Earth's magnetosphere and ionosphere, highlighting TEC variations as critical indicators of storm intensity. Their synthesis emphasized the multifaceted effects of coronal emission on ionospheric electron density and geomagnetic storm dynamics. Abbey et al. (2022) explored the longitudinal variations in TEC responses to geomagnetic storms, focusing on the variations caused by coronal emission across different longitudes. Their study confirmed the existence of longitudinal variations in ionospheric responses, influenced by geomagnetic storm parameters and local ionospheric properties.

- ✓ **Data Observations**

The change in the ionosphere electron content (TEC) factor and its impact on solar activities, especially geomagnetic storms that recur during the year, were studied.

Data on geomagnetic storms were taken from the site to determine the change in TEC values for the period shown in Table 1

Year	The month	day
2012	3	9
2012	4	24
2012	7	15
2012	7	16
2015	3	17
2015	3	18
2015	6	22
2015	6	23

These dates were chosen for the frequency of geomagnetic storms and to understand the reason for the frequency of these storms and their source, it was decided to examine the solar activity during this period and its effect on the ionosphere.

- Coronal mass ejection (CME) data from the Sun were recorded from the LASCO site to determine the speed, direction and location of the CME relative to the surface of the Sun.
- Recording of (TEC) data through the site
- (TEC) data were taken from more than one site to find out if there is an effect of geomagnetic storms with the geographical location on Earth.

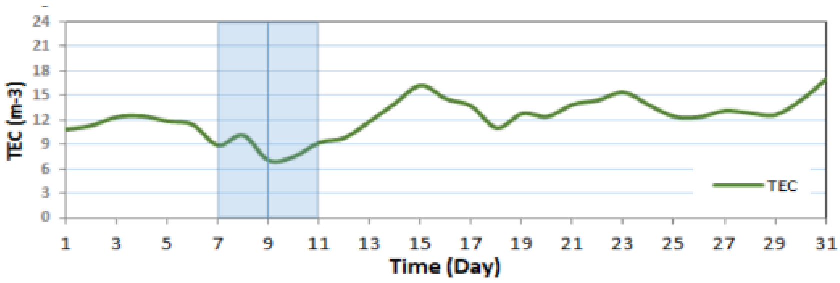
✓ Results and Discussion

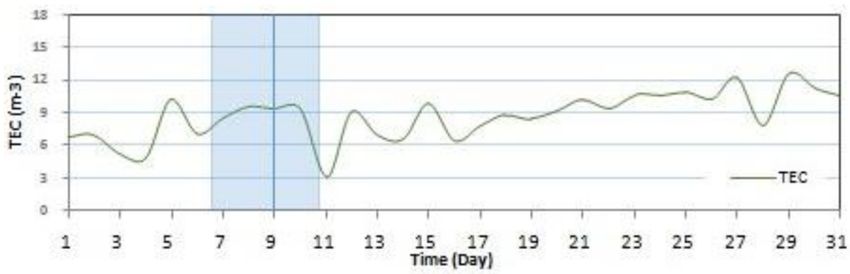
- CME data were taken from the website https://cdaw.gsfc.nasa.gov/CME_list. For the years 2012 and 2015 for the months (3,4,6,7,10) and arranged in Table No. 2.

Table 2 shows the data of the ejected coronal masses.

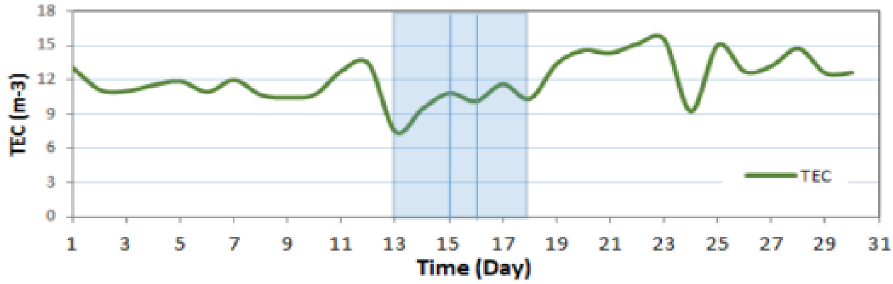
X-ray Importance	Source Location	Apparent Speed [km/s]	First C2 Appearance Date Time [UT]	
X5.4	N17E27	2684	00:24:06	07/03/2012
X1.3	N15E26	1825	01:30:24	07/03/2012
C2.0	N14W17	528	18:24:05	23/04/2012
---	S18W162	379	01:25:27	11/07/2012
X1.4	S15W01	885	16:48:05	12/07/2012
C9.1	S22W25	719	01:48:05	15/03/2015
---	S27E06	1305	17:24:24	18/06/2015
M2.6	N12E16	1366	02:36:05	21/06/2015

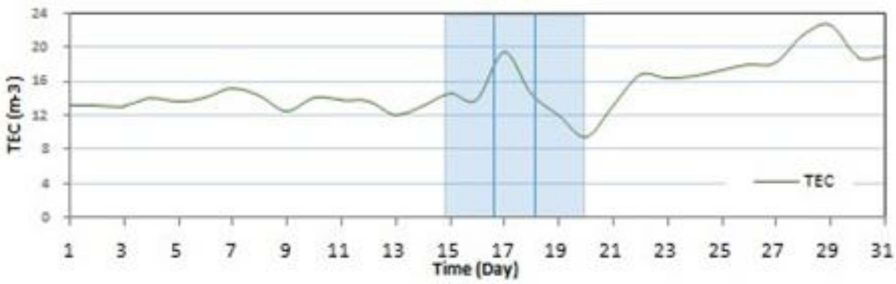
- The TEC data with the date for the selected events were plotted according to the figures below, especially for the double events and for the two stations ATHENS and PT ARGUELLO STATION, as in the following figures:





Event date : 9 March 2012





Event date : 17 march 2015
Event date : 18 march 2015

- From Table 2 we notice that the CMEs are produced from the same location on the surface of the sun for the double events.
- Two events were drawn for the month of March for the years 2012 and 2015 and for the stations ATHENS AND PT ARGUELLO STATIONS located as in the figure below.

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