GEOLOGICAL SURVEY OF CANADA
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Guide to the Space Weather Bulletin

R.A.D. Fiori

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Guide to the Space Weather Bulletin

R.A.D. Fiori

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Canada

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Abbreviations

ACE	Advanced Composition Explorer
CME	Coronal Mass Ejection
CSWFC	Canadian Space Weather Forecast Centre
DF	Duty Forecaster
ESA	European Space Agency
EST	Eastern Standard Time
GIC	Geomagnetically Induced Currents
GNSS	Global Navigation Satellite System
IMF	Interplanetary Magnetic Field
NASA	U.S. National Aeronautics and Space Administration
NRCan	Natural Resources Canada
SDO	Solar Dynamics Observatory
SOHO	Solar Heliospheric Observatory
UT	Universal Time

Introduction

Space weather consists of a variety of conditions and processes, largely originating from the Sun, that have the potential to affect the near-Earth environment, including human activities and technologies on Earth and in space. The Canadian Space Weather Forecast Centre (CSWFC) of Natural Resources Canada (NRCan) researches, monitors and forecasts the impacts of space weather on the Earth's own magnetic field, called the geomagnetic field, and provides a daily *Space Weather Bulletin* which summarizes observed space weather phenomena, current and predicted geomagnetic activity levels, and possible impacts to technology.

Space weather begins on the Sun. Whenever severe solar phenomena occur they have the potential to impact the geomagnetic field triggering geomagnetic storms. Geomagnetic storms are variations in the Earth's magnetic field, can last hours or days, and can directly affect operations that rely on the Earth's magnetic field, such as magnetic surveys done by mineral exploration companies, compass use for navigation, and directional drilling for oil and gas. These magnetic field variations can cause unexpected electric currents to flow in long conductors such as power systems, and pipelines. Such currents interfere with the proper operation of these systems, potentially causing power outages or reducing the lifespan of a pipeline. Space weather can also have effects on high frequency (HF) radio communications, the Global Navigation Satellite System (GNSS), and satellites. In the northern hemisphere, geomagnetic activity is strongest in a band called the auroral oval which surrounds the north magnetic pole and extends across Canada. Due to its location with respect to the north magnetic pole, Canada is the country MOST affected by space weather and geomagnetic storms.

The purpose of this document is to provide a basic understanding of the daily *Space Weather Bulletin* including general information about space weather and the crucial role of space weather experts in a world becoming increasingly dependent on technologies impacted by space weather. Section 1 provides an introduction to the *Space Weather Bulletin* including a basic description of its purpose and contents, and a complete description of all possible bulletin statements and their interpretation. In Section 2, tables for determining possible impacts to technology are provided based on geomagnetic and near-Earth conditions. Sample bulletins for varying periods of activity are found in Section 3.

For a general understanding of space weather processes, solar activity contributing to space weather, the Canadian Space Weather Forecast Centre, and for a glossary of terms and frequently asked questions see Appendices A-F.

1. Description of the Daily Space Weather Bulletin

1.1. Structure of the Space Weather Bulletin and major storm watch

The *Space Weather Bulletin* is generated by NRCan's CSWFC and provides recipients with a simple daily description of current and forecasted space weather conditions.

The bulletin is structured as follows:

- Summary of the most important observations, including *major storm watch*
- Description of the current geomagnetic activity levels and geostationary satellite environment
    - Potential impacts to power systems, HF radio communication, geostationary satellites, aeromagnetic surveys, and directional drilling
- 24 hour forecast of future geomagnetic activity levels and geostationary satellite environment
    - Potential impacts to power systems, HF radio communication, geostationary satellites, aeromagnetic surveys, and directional drilling
- Detailed information about solar conditions, interplanetary conditions, the geostationary satellite environment, and geomagnetic activity
    - observation of coronal mass ejections (CMEs), coronal holes, active regions, and solar flares on the Sun
    - solar wind speed, and the magnitude and polarity of the interplanetary magnetic field (IMF) in the north / south or *z* direction (IMF B_z)
    - observed and predicted values of the electron fluence at geostationary orbit for the previous and following day
    - geomagnetic activity levels for the previous and following 24 hours

Geomagnetic activity level is derived from measurements made at magnetic observatories located in the polar cap, auroral, and sub-auroral zones (see Figure 1). The data are processed to produce an hourly range index to characterize the range of magnetic field variations measured during one hour. Hourly range indices are divided into 5 activity levels classified as *quiet*, *unsettled*, *active*, *stormy*, and *major storm*[1]. The significance of each activity level is summarized by considering the possible impacts associated with power systems, aeromagnetic surveys, and directional drilling presented in Section 2 and Appendix B. Current geomagnetic activity levels and forecasted geomagnetic activity levels for the next 24 hours are provided individually for the polar cap, auroral, and sub-auroral zones in Canada.

Space Weather Bulletin users should pay particular attention to periods where geomagnetic activity levels are high enough to cause a *major storm watch*. A *major storm watch* is issued to indicate that *major storm* geomagnetic activity levels have been observed by multiple observatories during the same period. These conditions are likely to continue to be observed for at least the next few hours. The *major storm watch* is either limited to the auroral zone if such conditions have only been observed in that zone or applies to all of Canada if major storm conditions have been observed in both the auroral zone and the sub-auroral zone.

[1] Activity levels are assigned according to guidelines set by the CSWFC described at www.spaceweather.gc.ca.

Figure 1: Location of magnetic observatories and the polar cap, auroral, and sub-auroral zones.

For a *major storm watch* to be issued, one of three criteria must be met:

1. At least two sub-auroral magnetic observatories have exceeded their respective thresholds for *stormy* conditions and at least three magnetic observatories of any zone have exceeded their respective thresholds for issuing a *major storm watch*.
2. At least three sub-auroral magnetic observatories have exceeded their respective thresholds for *stormy* conditions and one or more sub-auroral magnetic observatory has exceeded its respective threshold for issuing a *major storm watch*.
3. Only auroral magnetic observatories have exceeded their respective thresholds for *stormy* conditions and at least three auroral magnetic observatories have exceeded their respective thresholds for issuing a *major storm watch*.

If criteria in 1 or 2 are met, then a *major storm watch* is issued in the polar cap, auroral, and sub-auroral zones. If criteria 3 is met, then a *major storm watch* is issued in the auroral zone only. A one-zone *major storm watch* is not issued for the sub-auroral or polar cap zone. **NOTE: It is possible for activity to rate a classification of *major storm* at one or more observatory, or even within an entire zone, without triggering a *major storm watch*.**

In the following pages a sample bulletin is provided with descriptions of the individual sections. This is followed by tables describing all possible bulletin statements. All descriptions are based on data products and links available at www.spaceweather.gc.ca. For additional examples see Section 3.

Space Weather Bulletin - 2013-05-08 issued at

Summary

- There is currently no major storm watch in effect.
- Stormy conditions are currently observed in the polar cap zo
- Stormy conditions are possible in the polar cap zone within
- See our website for current information: http://www.spacew
  minutes)

Current Conditions (12:30 UT)

Geomagnetic Activity:

- polar cap zone: stormy
- auroral zone: unsettled
- sub-auroral zone: quiet

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Power Systems: possibility of weak voltage fluctuations in t
- Aeromagnetic surveys: Potential for significant disruptions
- Directional Drilling: Potential for significant deviations in t

24 Hour Forecast

Geomagnetic Activity:

- polar cap zone: unsettled with stormy intervals
- auroral zone: quiet with unsettled intervals
- sub-auroral zone: quiet

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Power Systems: possibility of weak voltage fluctuations in t
- Aeromagnetic surveys: Potential for significant disruptions
- Directional Drilling: Potential for significant deviations in the polar cap zone.

All times in the bulletin are given in universal time (UT). The offset between UT and Eastern Standard Time (EST) can be used to convert times reported in the bulletin from UT to EST.

The *Summary* section provides a brief summary of solar or geomagnetic activity, including a listing of events that are likely to impact the Earth and the expected time of impact. Comments are listed in the order of importance. Information includes: (1) issuance, extension, and cancellation of a *major storm watch*, (2) observation or forecast of stormy conditions, (3) observation or expected observation of disturbed conditions due to solar activity, (4) ionospheric conditions, and (5) details about solar eruptions.

***Current Conditions* describe the current (at the time indicated) level of geomagnetic activity in the polar cap, auroral and sub-auroral zones and the level of energetic electron fluence at geostationary satellite orbit based on measurements of the geostationary satellite environment. Possible impacts to technology are provided based on activity level.**

***24 Hour Forecast* provides a forecast of the level of geomagnetic activity in the polar cap, auroral and sub-auroral zones and the level of energetic electron fluence at geostationary satellite orbit based on measurements of the geostationary satellite environment for the next 24 hours (as of the time indicated in *Current Conditions*). Possible impacts to technology are provided based on activity level.**

Detailed Information

Solar

- Solar activity has been low.
- A non-Earth-directed CME erupted on 07 MAY 2013 02:05 UT.
- One coronal hole is located near the edge of the solar disk.
- One coronal hole is located near the centre of the solar disk.

Interplanetary

- The solar wind speed is currently moderate (500-700 km/s).
- The interplanetary magnetic field has been fluctuating at low (|B
- Moderate solar wind speeds are due to high speed streams from

Environment at Geostationary orbit

- Energetic electron fluence at geostationary orbit was at a normal
  be at a normal level tomorrow.
- Visit http://www.spaceweather.gc.ca/sffl-eng.php for the electro

Geomagnetic

- Over the last 24 hours geomagnetic activity has been unsettled v
  zone, unsettled with active intervals in the auroral zone, and qui
  sub-auroral zone.
- Over the next 24 hours geomagnetic activity is forecast to be un
  polar zone, quiet with unsettled intervals in the auroral zone, and
- Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the mag

Detailed information **provides further descriptions of solar activity, interplanetary conditions, and the geostationary satellite environment. This information is intended for users with a greater understanding of space weather.**

The *Solar* section contains detailed information about activity on the sun including the location and number of solar active regions, the eruption of Earth-directed, partially Earth-directed, and non-Earth-directed coronal mass ejections and when they are expected to reach the Earth, the number and general location of coronal holes, and the eruption and magnitude of solar flares.

The *Interplanetary* section describes details about the solar wind speed, interplanetary magnetic field, interplanetary shocks, and solar energetic proton events.

The *Geostationary Satellite Environment* section provides a review and forecast of the energetic electron fluence at geostationary orbit for the day before and the day after the date of issue.

The *Geomagnetic* section provides a description of the 24 hour review and 24 hour forecast of geomagnetic activity levels in the polar cap, auroral, and sub-auroral regions and indicates when geomagnetic sudden impulses are observed.

1.2. Description of bulletin statements

This section provides a summary of the most recent version of the *Space Weather Bulletin* in tabular format. Tables are used to separate statements into common groupings. The description below represents a fill-in-the-blank style template completed by the duty forecaster (DF). Descriptions of each bulletin statement are provided.

Symbolic text hi-lighted in red represents dates and times in Universal Time (UT) using a 24-hour format. For example:

DD MMM YYYY	day month year	26 JUN 2012
HH:MM	hour:minute	21:19
xx	any number	5

In some instances the duty forecaster completing the form has a selection of terms. The words to be selected from are encased in parenthesis and hi-lighted in blue. Each possible term is separated by the '/' symbol. For example:

> (Stormy / Major storm) conditions are possible within the next 24 hours.
>
> Creates two possible sentences:
>
> Stormy conditions are possible within the next 24 hours.
> Major storm conditions are possible within the next 24 hours.

In some instances the duty forecaster completing the form may pick any number of entries hi-lighted in blue. In these cases, the last entry in the list is preceded by 'and' and the duty forecater is places 'and' wherever it is required in the list. For example:

> Stormy conditions are possible in the (polar cap / auroral / and sub-auroral) (zone / zones).
>
> Creates several possibilities, such as
>
> Stormy conditions are possible in the auroral zone.
> Stormy conditions are possible in the polar cap and auroral zones.
> Stormy conditions are possible in the polar cap, auroral, and sub-auroral zones.

Note that in some situations the selection may be left blank.

1.2.1. Summary

	Bulletin Statements	Statement Explanations
major storm watch	1. A major storm WATCH is in effect for the (auroral zone / polar cap, auroral, and sub-auroral zones) from DD MMM YYYY HH:MM UT to DD MMM YYYY HH:MM UT.	1. Indicates the start and end time of a currently observed *major storm watch* and the geomagnetic zone(s) affected.
	2. A major storm WATCH is in effect for the (auroral zone / polar cap, auroral, and sub-auroral zones), and is anticipated to end DD MMM YYYY HH:MM UT.	2. Indicates the start and expected end time of a currently observed *major storm watch* and the geomagnetic zone(s) affected.
	3. The major storm WATCH issued DD MMM YYYY HH:MM UT for the (auroral zone / polar cap, auroral, and sub-auroral zones) has been extended to DD MMM YYYY HH:MM UT.	3. Issued when the end time for a previously reported *major storm watch* is extended.
	4. The major storm WATCH issued DD MMM YYYY HH:MM UT for the (auroral zone / polar cap, auroral, and sub-auroral zones) ended DD MMM YYYY HH:MM UT.	4. Indicates a *major storm watch* has ended. Statement (4) will either be issued as an update to statement (1-3) or if a *major storm watch* was issued while the DF was not on duty to acknowledge the activity.
	5. There is currently no major storm watch in effect.	5. Indicates there is no *major storm watch* at the time of issue.
Stormy Conditions	1. (Stormy / Major storm) conditions are possible in the (polar cap / auroral / and sub-auroral) (zone / zones) within the next 24 hours.	1. Issued if the 24-hour forecast in any given zone indicates a possibility of stormy or major storm conditions.[2]
	2. (Stormy / Major storm) conditions are (possible / expected) from DD MMM YYYY HH:MM UT to DD MMM YYYY HH:MM for the (polar cap / auroral / and sub-auroral) zone(s).	2. Similar to (1), where the start and end of possible or expected activity is known.
	3. (Stormy / Major storm) conditions are currently observed in the (polar cap / auroral / and sub-auroral) (zone / zones).	3. Issued if the current conditions, at the time of issue, indicate *stormy* or *major storm* conditions in any zone.
	4. (Stormy / Major storm) conditions expected from DD MMM YYYY HH:MM UT to DD MMM YYYY HH:MM UT for the (auroral zone / polar cap, auroral, and sub-auroral zones) did not occur.	4. Issued if stormy or *major storm* conditions predicted in statement (1-2) or the ***24-Hour Forecast*** did not occur.

[2] The DF may issue this statement if such conditions are possible based on past solar conditions; in this case the ***24-Hour Forecast*** may not indicate stormy conditions and the DF should be contacted if clarification is required.

Disturbed Conditions	1. Disturbed geomagnetic conditions due to solar activity observed on DD MMM YYYY are not expected. 2. Disturbed geomagnetic conditions due to solar activity are expected to be observed on the Earth between DD MMM YYYY and DD MMM YYYY. 3. Disturbed geomagnetic conditions due to solar activity are expected today. 4. Disturbed geomagnetic conditions due to solar activity are currently observed in the (polar cap / auroral / and sub-auroral) (zone / zones).	1. Indicates that solar activity listed in the ***Solar*** section is not expected to impact geomagnetic activity. 2. Provides the anticipated start and end date of geomagnetic effects due to solar activity.[3] 3. Similar to statement (2) when activity is expected the date of issue. 4. Indicates enhanced geomagnetic activity is currently (at the time of issue) observed in a specific zone(s).
Ionosphere	1. (An ionospheric / A polar cap) absorption event is currently in progress in the (polar cap/auroral/and sub-auroral) (zone/zones). 2. The (ionospheric / polar cap) absorption event reported yesterday has ended. 3. (An ionospheric / A polar cap) absorption event is currently not in effect. 4. (An ionospheric / A polar cap) absorption event is possible. 5. An (ionospheric / polar cap) absorption event is currently in progress for the (polar cap / auroral / and sub-auroral) zone(s) from DD MMM YYYY HH:MM UT to DD MMM YYYY HH:MM UT. 6. An (ionospheric / polar cap) absorption event is currently in progress for the (polar cap / auroral / and sub-auroral) zone(s), and is anticipated to end at DD MMM YYYY HH:MM UT. 7. The (ionospheric / polar cap) absorption event that began DD MMM YYYY HH:MM UT in the (polar cap/auroral/and sub-auroral) zone(s) has been extended to DD MMM YYYY HH:MM UT. 8. The (ionospheric / polar cap) absorption event that began DD MMM YYYY HH:MM UT in the (polar cap / auroral / and sub-auroral) zone(s) ended DD MMM YYYY HH:MM UT.	1. Indicates zones affected by an absorption event. 2. Indicates a previously reported absorption event has ended. 3. Indicates an absorption event is not in effect. 4. Indicates an absorption event is possible. 5. Issued if an absorption event is in progress at the time of issue. Indicates the zones affected, the start time, and the expected end time. 6. Similar to statement (5) when the event is already in progress. 7. Issued if a previously reported absorption event is extended beyond the reported end time. Indicates the zones affected and the new end time. 8. Issued if a previously reported absorption event has ended, or if an event occurred while the DF was not on duty. Indicates the zones affected and event start and end time.

[3] Solar activity expected to have geomagnetic effects will be reported in the ***Summary*** and ***Solar*** sections until the solar disturbance reaches the Earth.

Ionosphere	9. The (ionospheric / polar cap) absorption event expected from DD MMM YYYY HH:MM UT to DD MMM YYYY HH:MM UT for the (polar cap / auroral / and sub-auroral) zone(s) did not occur.	9. Issued if a previously reported absorption event did not occur. Indicates the zone(s) expected to be affected and the expected start and end time of the event.
Solar Activity	1. An Earth-directed CME has erupted over the past 24 hours. 2. (Two / Three / Several) Earth-directed CMEs have erupted over the past 24 hours. 3. A (medium / large / medium to large) (long duration) solar x-ray flare has erupted over the past 24 hours. 4. (Two / Three / Several) (medium / large / medium to large) (long duration) solar x-ray flares have erupted over the past 24 hours. 5. CMEs may be associated with these flares.	1. Issued when a CME ejected directly toward the Earth has erupted in the past 24 hours. 2. Similar to statement (1) for multiple events. 3. Issued when a solar x-ray flare has erupted in the past 24 hours. Flare magnitude and duration are indicated. 4. Similar to (3) for multiple events. 5. Indicates a CME may also have erupted, but must be investigated.[4]
Linking Statements	1. The major storm WATCH issued DD MMM YYYY HH:MM UT for the (auroral zone / polar cap, auroral, and sub-auroral zones) ended DD MMM YYYY HH:MM UT. 2. (Disturbed / Stormy / Major storm) conditions observed DD MMM YYYY in the (polar cap / auroral / and sub-auroral) (zone / zones) have ended. 3. An Earth-directed CME erupted on DD MMM YYYY HH:MM UT (and is expected to reach the Earth on DD MMM YYYY)(, resulting in increased / disturbed geomagnetic activity). 4. (Two/Three/Several) Earth-directed CMEs erupted on DD MMM YYYY at HH:MM UT, HH:MM UT, …, and HH:MM UT (and are expected to reach the Earth on DD MMM YYYY) (, resulting in increased/disturbed geomagnetic activity).	1. Indicates the start and end time of a *major storm watch* and the geomagnetic zone(s) affected. 2. Indicates that observed *major storm*, *stormy*, or disturbed geomagnetic activity levels have ended. The start time of activity and the zone(s) affected are provided. 3. Issued when a CME ejected directly toward the Earth has erupted. Indicates the time of eruption, and possibly the estimated time of arrival. 4. Similar to statement (3) when multiple CMEs have erupted.

[4] CME and flares often erupt near the same time from the same active region. If the DF suspects a CME has erupted, but is unable to confirm (for example, due to a lag in receiving data) they may issue this statement to indicate they are investigating the event.

Linking Statements	5. A CME was observed on DD MMM YYYY, and is expected to deliver a glancing blow to the Earth on DD MMM YYYY (, resulting in increased/disturbed geomagnetic activity). 6. (Two / Three / Several) CMEs were observed on DD MMM YYYY, and are expected to deliver a glancing blow to the Earth on DD MMM YYYY (, resulting in increased/disturbed geomagnetic activity). 7. Disturbed geomagnetic conditions are expected DD MMM YYYY to DD MMM YYYY due to high speed streams from coronal holes.	5. Issued when a CME is ejected at an angle away from a line directly connecting the Sun and Earth and will not fully impact the Earth.[5] 6. Similar to statement (5) when multiple CMEs have erupted. 7. Indicates the time range within which high speed streams from a coronal hole are expected to cause disturbed geomagnetic activity.[6]
Other	1. Possibility of impacts to (power systems / radio systems / satellites / aeromagnetic surveys / and directional drilling. 2. See our website for current geomagnetic conditions: http://www.spaceweather.gc.ca (updated every 15 minutes)	1. DF may issue this statement when possible impacts are noted under ***Current Conditions*** and ***24-Hour Forecast***. 2. Provides a link to the space weather webpage where current conditions are available at any time.

1.2.2. Current conditions (HH:MM UT)

Geomagnetic activity

	Bulletin Statement	Statement Explanation
	1. polar cap zone: (quiet / unsettled / active / stormy / major storm / unavailable) 2. auroral zone: (quiet / unsettled / active / stormy / major storm / unavailable) 3. sub-auroral zone: (quiet / unsettled / active / stormy / major storm / unavailable)	1. Current geomagnetic activity level in the polar cap zone. 2. Current geomagnetic activity level in the auroral zone. 3. Current geomagnetic activity level in the sub-auroral zone.

[5] In such a case the CME is only partially Earth-directed, and the full force of the CME will not be felt. Geomagnetic activity for a partially Earth-directed CME will be reduced compared to an equivalent Earth-directed CME.

[6] The level of impact a coronal hole will have on the geomagnetic field is dependent on the location, orientation, and size of the coronal hole and the speed of the high speed streams. Not all coronal holes reported in the ***Solar*** section will require this statement to be issued.

Environment at geostationary orbit

	Bulletin Statement	Statement Explanation
	1. energetic electron fluence at geostationary orbit: (Low / Normal / Moderate High / Very High / unavailable)	1. Current level of energetic electron fluence at the orbital altitude of geostationary satellites.

Possible impacts on technology

	Bulletin Statement	Statement Explanation
	1. Power Systems: (Possibility of weak voltage fluctuations / Geomagnetically induced currents may cause misoperation of protective relays and transformer heating) in the (polar cap / auroral / and sub-auroral) zone(s).	1. Possible impacts to power systems based on current level of ***Geomagnetic Activity***. See Section 2.1.
	2. HF radio: Ionospheric and polar cap absorption events may affect radio communications for transpolar flights and other arctic operations.	2. Possible impacts to HF radio communications based on ionospheric data (not reported). See Section 2.2.
	3. Geostationary satellites: (Moderate risk of internal charging / High risk of internal charging / Very high risk of internal charging).	3. Possible impacts to geostationary satellites based on the current ***Geostationary satellite environment***. See Section 2.3.
	4. Aeromagnetic surveys: (Potential for disruptions / Potential for significant disruptions / Potential for severe disruptions) in the (polar cap / auroral / and sub-auroral) zone(s).	4. Possible impacts to aeromagnetic surveys based on current level of ***Geomagnetic activity***. See Section 2.1.
	5. Directional Drilling: (Potential for deviations / Potential for significant deviations / Potential for severe deviations) in the (polar cap / auroral / and sub-auroral) zone(s).	5. Possible impacts to directional drilling based on current level of ***Geomagnetic activity***. See Section 2.1.
	6. Impacts are not expected.	6. Based on ***Current conditions***, impacts to above systems are not expected.

1.2.3. 24 hour forecast

Geomagnetic activity

	1. polar cap zone: (quiet / unsettled / active / stormy / major storm / unavailable) (with quiet / unsettled / active / stormy / major storm intervals)	1. 24-Hour forecast of geomagnetic activity level in the polar cap zone.
	2. auroral zone: (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) 3. sub-auroral zone: (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals)	2. 24-Hour forecast of geomagnetic activity level in the auroral zone. 3. 24-Hour forecast of geomagnetic activity level in the sub-auroral zone.

Environment at geostationary orbit

	Bulletin Statement	Statement Explanation
	1. energetic electron fluence at geostationary orbit: (Low / Normal / Moderate High / Very High / unavailable).	1. 24-Hour forecast of energetic electron fluence at the orbital altitude of geostationary satellites.

Possible impacts on technology

See Section 1.2.2.

1.2.4. Additional information

	Bulletin Statement	Statement Explanation
	1. Additional information at http://www.spaceweather.gc.ca 2. Updated conditions and forecast; Background information; FAQ, Glossary of terms, and potential impacts	1. Link to the website where additional information is available. 2. Provides links to the polar-cap, auroral, and sub-auroral zone review and forecast, background information on the CSWFC, frequently asked questions, a glossary of terms, and a listing of potential impacts.

1.2.5. Detailed information

Solar

	Bulletin Statements	Statement Explanations
General	1. Solar activity has been (very low / low / moderate / high / very high). 2. Data about solar conditions are currently unavailable.	1. Statement on the level of solar activity. Based on the presence of coronal holes and solar eruptive activity. 2. Issued if information describing solar conditions are not available to the DF.
Active Regions	1. (There is one active region / There are xx active regions / There are several active regions) visible on the solar disk. 2. The active region located near the (east limb / central region / west limb) of the solar disk has produced a (solar x-ray flare / long duration solar x-ray flare) (and an associated CME) (and has the potential to produce subsequent solar eruptions). 3. The active region located near the (east limb / central region / west limb) of the solar disk has produced (solar x-ray flares / long duration solar x-ray flares) (and an associated CME / and associated CMEs) (and has the potential to produce subsequent solar eruptions).	1. Indicates number of solar active regions visible on the solar disk. 2. Indicates a specific active region has produced solar x-ray flares, and possible CMEs, and may produce similar events in the future.[7] 3. Similar to statement (2) for multiple eruptive events.
CME	1. An Earth-directed CME erupted on DD MMM YYYY HH:MM UT (and is expected to reach the Earth on DD MMM YYYY)(, resulting in increased / disturbed geomagnetic activity).	1. Issued when a CME ejected directly toward the Earth has erupted in the past 24 hours. Indicates the eruption time and expected time of arrival at the Earth (i.e., when geomagnetic activity is expected to increase).

[7] An active region in the central region of the solar disk faces the Earth and any possible eruption will be Earth-directed. Any possible eruption from an active region in the east or west limb could possibly have an Earth-directed component (i.e., a CME from the east or west limb could potentially deliver a glancing blow). An active region near the east-limb will rotate over a period of ~3 days to the central region of the solar disk. An active region on the west-limb is rotating away from the central solar disk. NOTE: The DF cannot predict if further eruptions will occur, or what the potential impact on geomagnetic conditions will be prior to eruption. The DF is monitoring the active region for further activity.

CME	2. (Two / Three / Several) Earth-directed CMEs erupted on DD MMM YYYY at HH:MM UT, HH:MM UT, …, and HH:MM UT (and are expected to reach the Earth on DD MMM YYYY) (, resulting in increased / disturbed geomagnetic activity).	2. Similar to statement (1) for multiple events.
	3. A CME was observed on DD MMM YYYY, and is expected to deliver a glancing blow to the Earth on DD MMM YYYY (, resulting in increased/disturbed geomagnetic activity).	3. Issued when a CME is ejected at an angle away from a line directly connecting the Sun and Earth.[8]
	4. (Two / Three / Several) CMEs were observed on DD MMM YYYY, and are expected to deliver a glancing blow to the Earth on DD MMM YYYY (, resulting in increased/disturbed geomagnetic activity).	4. Similar to statement (3) for multiple events.
	5. A non-Earth-directed CME erupted on DD MMM YYYY HH:MM UT.	5. Issued when a CME ejected away from the Earth has erupted.[9]
	6. (Two / Three / Several) non-Earth-directed CMEs erupted on DD MMM YYYY at HH:MM UT, HH:MM UT, …, and HH:MM UT.	6. Similar to statement (5) for multiple events.
	7. A CME erupted on DD MMM YYYY HH:MM UT. It is not yet known if the CME will impact the Earth.	7. Issued to indicate a CME has erupted, but at the time of the bulletin, the trajectory of the CME is unknown.
	8. (Two / Three / Several) CMEs erupted on DD MMM YYYY at HH:MM UT, HH:MM UT, …, and HH:MM UT. It is not yet known if the CMEs will impact the Earth.	8. Similar to statement (7) for multiple events.
Coronal Hole	1. One (small / medium / large) coronal hole (elongated in longitude) is located near the (centre / edge) of the solar disk.	1. Indicates the size and location of a coronal hole.[10]
	2. (Two / Three / Four / Five / Six) (small / medium / large) coronal holes (elongated in longitude) are located near the (centre / edge) of the solar disk.	2. Similar to statement (1) for multiple events.

[8] In such cases the CME is only partially Earth-directed, and the full force of the CME will not be felt. Geomagnetic activity for a partially Earth-directed CME will be reduced compared to an equivalent Earth-directed CME.
[9] Non-Earth-directed CMEs are not expected to impact the Earth.
[10] Coronal holes located at the centre of the solar disk are more likely to impact the Earth. High speed streams from coronal holes take several days to reach the Earth and affect the Earth for several days. Coronal holes elongated in longitude will affect the Earth for a longer period of time. The DF will report any expected periods of elevated geomagnetic activity due to coronal holes in the ***Summary***. NOTE: Not all coronal holes reported will cause (or will be expected to cause) increased geomagnetic activity.

Solar Flare	1. An (M (medium) / X (large)) solar x-ray flare erupted DD MMM YYYY HH:MM UT (near the (centre / edge) of the solar disk). 2. (Two / Three / Several) (medium / large / medium to large) (long duration) solar x-ray flares have erupted over the past 24 hours. 3. A long duration (C (low) / M (medium) / X (large)) solar x-ray flare erupted at DD MMM YYYY HH:MM UT near the (centre / edge) of the solar disk.	1. Issued when a solar x-ray flare has erupted. Indicates the size, time, and location of eruption (if available). 2. Similar to statement (1) for multiple events. 3. Issued when a long duration solar x-ray flare has erupted. Indicates the size, time, and location of eruption.[11]

Interplanetary

	Bulletin Statements	Statement Explanations
General	1. Interplanetary activity has been (very low / low / moderate / high / very high). 2. Data about interplanetary conditions are currently unavailable.	1. Indicates level of interplanetary activity. Based on the solar wind speed and variation of the IMF B_z. 2. Indicates data about solar wind conditions are not available, possibly due to an instrument malfunction.
Solar Wind Speed	1. The solar wind speed is currently (very slow (<400 km/s) / slow (400-500 km/s) / moderate (500-700 km/s) / fast 700-1000 km/s) / very fast (>1000 km/s)). 2. The solar wind speed has been (increasing / decreasing) over the last (hour / xx hours) (currently ~ xx km/s). 3. (Moderate / fast) solar wind speeds are due to (high speed streams from coronal holes / a CME observed at DD MMM YYYY HH:MM UT). 4. The solar wind speed has been at xx km/s since the passage of an interplanetary shock DD MMM YYYY at HH:MM UT.	1. Indicates solar wind speed over the last 1-hour interval. This statement is used when the solar wind speed is relatively steady. 2. Indicates trend in solar wind speed over a specified time period and provides the most recent value. 3. Attributes source of moderate and fast solar wind speed to the arrival of high speed streams from a coronal hole or the arrival of a specified CME. 4. Indicates an interplanetary shock occurred that was associated with a jump in the solar wind velocity to the specified level.
IMF	1. The interplanetary magnetic field has been fluctuating at (very low ($\|B_z\|$<2 nT) / low ($\|B_z\|$<5 nT) / moderate ($\|B_z\|$<10 nT) / high ($\|B_z\|$<20 nT) / very high ($\|B_z\|$>20 nT)) levels.	1. Indicates the range of the IMF B_z component over the last 1-hour interval. Statement is used when the IMF B_z fluctuates between positive and negative values.

[11] Long duration (30-180+ minutes) solar x-ray flares are associated with larger eruptions of particles and CMEs associated with such flares may have a stronger geomagnetic impact.

IMF	2. The interplanetary magnetic field has been primarily (positive / negative) at (very low ($\|B_z\|$<2 nT)/low (2<$\|B_z\|$<5 nT) /moderate (5<$\|B_z\|$<10 nT)/high (10<$\|B_z\|$ <20 nT) / very high ($\|B_z\|$>20 nT)) levels. 3. The interplanetary magnetic field currently has B_z=(+ / -) xx nT. 4. Prolonged periods of negative interplanetary magnetic field are often associated with increased geomagnetic activity.	2. Indicates the range of the IMF B_z component over the last 1-hour interval. Statement is used when the IMF B_z is steady and positive or negative. See statement (4) below. 3. Statement provides the most recent value of the z component of the IMF. 4. Indicates IMF B_z has been negative for a period of several hours.[12]
Shock	1. An interplanetary shock has been observed on DD MMM YYYY HH:MM UT.	1. Indicates that one or more solar wind parameters has undergone a sudden jump in value.[13]
Proton	1. A solar energetic proton event started on DD MMM YYYY at HH:MM UT. Current levels are (normal/moderate/high/very high).	1. Indicates the arrival of solar energetic protons preceding a CME.

Environment at Geostationary Orbit

	Bulletin Statements	**Statement Explanations**
General	1. Energetic electron fluence at geostationary orbit was at a (low / normal / moderate / high / very high) level yesterday and is expected to be at a (low / normal / moderate / high / very high) level tomorrow. 2. The 5-minute integral energetic electron flux is currently high. 3. Data about conditions in the environment at geostationary orbit are currently unavailable.	1. Indicates the energetic electron fluence for the previous day and the prediction for the following day. Current conditions are provided under ***Current Conditions***. 2. The current running average of the energetic electron flux is high. 3. Indicates data about the energetic electron fluence at geostationary orbit is not available, likely due to an instrument malfunction or a problematic data set.

[12] Notice should be taken when the IMF B_z is negative for a period of several hours, particularly at moderate, high, and very high levels as such intervals are associated with increased levels of geomagnetic activity; notably in the auroral and sub-auroral zones.

[13] Such activity indicates the arrival of high speed streams from a coronal hole or the arrival of a CME. Shocks are often followed within 30-90 minutes (depending on the solar wind speed) by a geomagnetic sudden impulse which may precede a period of enhanced geomagnetic activity. Enhancements in geomagnetic activity are dependent on solar wind parameters. DFs are aware when shocks are likely to happen and monitor conditions at that time. Shocks will only be reported as an update if the DF believes it is likely to cause a *major storm watch*. Otherwise, shocks will be reported in the next bulletin update, along with any resulting geomagnetic activity.

Geomagnetic

	Bulletin Statements	Statement Explanations
General	1. Over the last 24 hours geomagnetic activity has been (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the polar zone, (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the auroral zone, and (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the subauroral zone.	1. Review of the geomagnetic activity over the last 24 hours (as of the time indicated in ***Current Conditions***).
	2. Over the next 24 hours geomagnetic activity is forecast to be (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the polar zone, (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the auroral zone, and (quiet / unsettled / active / stormy / major storm / unavailable) (with unsettled / active / stormy / major storm intervals) in the subauroral zone.	2. Forecast of the geomagnetic activity over the next 24 hours (as of the time indicated in ***Current Conditions***).
	3. Enhanced geomagnetic activity (is / was) likely associated with a CME that erupted DD MMM YYYY HH:MM UT and reached the Earth at DD MMM YYYY HH:MM UT.	3. Indicates geomagnetic activity can be attributed to the arrival of the specified CME.
	4. Enhanced geomagnetic activity (is / was) likely due to the arrival of a high speed stream associated with coronal holes.	4. Indicates geomagnetic activity can be attributed to the arrival of high speed streams from a coronal hole.
	5. Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the magnetic forecast.	5. Current data is available from the space weather webpage.
	6. Data about geomagnetic conditions are currently unavailable in the (polar cap / auroral / and sub-auroral) zone(s).	6. Indicates data about the geomagnetic conditions are not available.
Impulse	1. A geomagnetic sudden impulse due to a shock in the solar wind was observed on DD MMM YYYY HH:MM UT.	1. A sudden enhancement has been observed by at least one magnetic observatory. Usually follows an interplanetary shock.[14]

[14] Depending on solar wind and IMF parameters, a geomagnetic sudden impulse due to a shock in the solar wind can be followed by increased levels of geomagnetic activity. DFs are aware when geomagnetic sudden impulses are likely to happen and monitor conditions at that time. A geomagnetic sudden impulse will only be reported as an update if the DF feels it is likely to cause a *major storm watch*.

1.2.6. Signature

	Signature Information	Explanation
	Space weather scientist DF name Canadian Space Weather Forecast Centre Canadian Hazard Information Service Natural Resources Canada 2617 Anderson Road, Ottawa ON K1A 0E7 DF email (preferred method of contact) Telephone: (613) 837-xxxx Government of Canada	The signature block indicates the contact information for the DF on duty. All questions regarding the bulletin and current space weather conditions should be directed toward the DF on duty. The DF on duty can be reached by phone during the business day and by email during the evenings and weekends. Note that DF is not a 24/7 position, and the DF is not required to respond outside of business hours.

1.3. Update notifications

During active conditions geomagnetic activity may rapidly change and it may become necessary to issue an update to the daily *Space Weather Bulletin* prior to sending the next day's bulletin. In such an event the subject line of the bulletin email will read

> Space Weather Bulletin – YYYY-MM-DD issued at HH:MM UT (HH:MM EST) – UPDATE

A bulletin update contains information about conditions that have changed since the last bulletin, or conditions that are related to the current level of activity. For example, geomagnetic activity changing from *active* level to *major storm* level will be reported, but the current conditions for the geostationary satellite environment may be omitted if *normal* activity levels remain *normal*.

Updates are only issued under the following conditions:

1. Issue a *major storm watch*.
2. Extend a *major storm watch*.
3. Cancel a *major storm watch*.
4. DF's discretion.

Updates will not be issued at the time of new solar eruptions (i.e., flare or CME). Such eruptions will NOT impact the Earth prior to the issuance of the next bulletin and an update is not required. If the bulletin user becomes aware of such an eruption, for example by the media, the user is encouraged to check the CSWFC website for forecast updates or contact the DF for any questions. Note that DFs monitor a variety of sources for solar events, but do not monitor media coverage.

DF is not a 24/7 position and events that occur outside of business hours will not necessarily receive updates until the issuance of the next scheduled bulletin.

2. Possible Impacts on Technology

This section lists possible impacts to ground-based and space-based technologies and infrastructure based on the geomagnetic activity level, ionospheric conditions, and the geostationary satellite environment. A more detailed description of the effects of space weather is provided in Appendix B.

Note that impacts are only possible, and not certain. Possible impacts are based on a limited data set and represents what is reasonable to expect based on current or forecasted conditions. Systems listed below may be impacted at times other than those indicated in the bulletin. Whether or not a system is impacted depends not only on the space weather conditions, but factors within the individual systems that are unknown to DFs and therefore cannot be factored into the impacts listed. In addition, space weather affects a wide spatial region and it is not possible to pinpoint the exact time or place impacts may be felt. The intention of including these impacts is to make the user aware of space weather conditions.

2.1. Impacts derived from geomagnetic activity level

Derived from

- Current Conditions, geomagnetic activity level
- 24 Hour Forecast, geomagnetic activity level

Regions affected

- polar cap zone
- auroral zone
- sub-auroral zone

Systems affected

- power systems
- aeromagnetic surveys
- directional drilling

Table 1: Possible impacts to power systems, aeromagnetic surveys, and directional drilling based on geomagnetic activity levels.

Activity Level	System	Possible Impact
Quiet	Power Systems:	Impacts are not expected
	Aeromagnetic surveys:	Impacts are not expected
	Directional Drilling:	Impacts are not expected
Unsettled	Power Systems:	Impacts are not expected
	Aeromagnetic surveys:	Impacts are not expected
	Directional Drilling:	Impacts are not expected
Active	Power Systems:	Impacts are not expected
	Aeromagnetic surveys:	Potential for disruptions
	Directional Drilling:	Potential for deviations
Stormy	Power Systems:	Possibility of weak voltage fluctuations[15]
	Aeromagnetic surveys:	Potential for significant disruptions
	Directional Drilling:	Potential for significant deviations
Major Storm	Power Systems:	Geomagnetically induced currents may cause misoperation of protective relays and transformer heating
	Aeromagnetic surveys:	Potential for severe disruptions
	Directional Drilling:	Potential for severe deviations

2.2. Impacts derived from ionospheric conditions

Derived from

- Internal measurements not reported in the bulletin. NOTE: Ionospheric absorption events are listed in the summary section of the bulletin.

Regions affected

- polar cap zone
- auroral zone
- sub-auroral zone

Systems affected

- HF radio communication

[15] Although these fluctuations are likely to be observed, they are in general within normal operating parameters and do not cause problems with the proper operation of the power system. However, it is possible that for some isolated cases, specific locations, or specific systems, fluctuations might move out of the range of what is acceptable.

Table 2: Possible impacts to HF radio communication based on ionospheric conditions.

Activity Level	System	Possible Impact
N/A	HF radio communication:	Ionospheric and polar cap absorption events may affect radio communications used for transpolar flights and other arctic operations.

2.3. Impacts derived from the geostationary satellite environment

Derived from

- Current Conditions, Geostationary Satellite Environment
- 24 Hour Forecast, Geostationary Satellite Environment

Regions affected

- geostationary satellite orbit (~35900 km altitude)

Systems affected

- satellites

Table 3: Possible impacts to geostationary satellites based on the geostationary satellite environment.

Activity Level	System	Possible Impact
Low	Geostationary satellites:	No risk of internal charging
Normal	Geostationary satellites:	No risk of internal charging
Moderate	Geostationary satellites:	Moderate risk of internal charging
High	Geostationary satellites:	High risk of internal charging
Very High	Geostationary satellites:	Very high risk of internal charging

3. Sample Bulletins

3.1. Example 1: Low activity

Email Subject: Space Weather Bulletin - 2013-06-13 issued at 19:46 UT (14:46 EST)

Space Weather Bulletin - 2013-06-13 issued at 19:46 UT (14:46 EST)

Summary

- There is currently no major storm watch in effect.
- A medium solar x-ray flare has erupted over the past 24 hours.
- See our website for current information: http://www.spaceweather.gc.ca (updated every 15 minutes)

Current Conditions (19:30 UT)

Geomagnetic Activity:

- polar cap zone: unsettled
- auroral zone: quiet
- sub-auroral zone: quiet

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Impacts are not expected.

24 Hour Forecast

Geomagnetic Activity:

- polar cap zone: quiet
- auroral zone: unsettled with active intervals
- sub-auroral zone: quiet

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Aeromagnetic surveys: Potential for disruptions in the auroral zone.
- Directional Drilling: Potential for deviations in the auroral zone.

Detailed Information

Solar

- Solar activity has been low.
- One coronal hole is located near the centre of the solar disk.
- An M (medium) solar x-ray flare erupted 12 JUN 2013 20:05 UT near the centre of the solar disk.

Interplanetary

- The solar wind speed is currently slow (400-500 km/s).
- The interplanetary magnetic field has been fluctuating at very low (|Bz|<2 nT) levels.

Environment at Geostationary orbit

- Energetic electron fluence at geostationary orbit was at a normal level yesterday and is expected to be at a normal level tomorrow.
- Visit http://www.spaceweather.gc.ca/sffl-eng.php for the electron forecast.

Geomagnetic

- Over the last 24 hours geomagnetic activity has been unsettled with active intervals in the polar zone, unsettled with active intervals in the auroral zone, and quiet in the sub-auroral zone.
- Over the next 24 hours geomagnetic activity is forecast to be quiet in the polar zone, unsettled with active intervals in the auroral zone, and quiet in the sub-auroral zone.
- Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the magnetic forecast.

3.2. Example 2: Moderate activity

Email Subject: Space Weather Bulletin - 2013-06-07 issued at 19:59 UT (14:59 EST)

Space Weather Bulletin - 2013-06-07 issued at 19:59 UT (14:59 EST)

Summary

- There is currently no major storm watch in effect.
- Stormy conditions are currently observed in the polar cap zone.
- Stormy conditions are possible in the polar cap and auroral zones within the next 24 hours.
- Several medium solar x-ray flares have erupted over the past 24 hours.
- See our website for current information: http://www.spaceweather.gc.ca (updated every 15 minutes)

Current Conditions (19:45 UT)

Geomagnetic Activity:

- polar cap zone: active
- auroral zone: stormy
- sub-auroral zone: active

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: high

Possible Impacts on Technology:

- Power Systems: possibility of weak voltage fluctuations in the auroral zone.
- Aeromagnetic surveys: Potential for significant disruptions in the auroral zone.
- Aeromagnetic surveys: Potential for disruptions in the polar cap and sub-auroral zones.
- Directional Drilling: Potential for significant deviations in the auroral zone.
- Directional Drilling: Potential for deviations in the polar cap and sub-auroral zones.
- Geostationary satellites: high risk of internal charging.

24 Hour Forecast

Geomagnetic Activity:

- polar cap zone: active with stormy intervals
- auroral zone: active with stormy intervals
- sub-auroral zone: unsettled with active intervals

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: moderate

Possible Impacts on Technology:

- Power Systems: possibility of weak voltage fluctuations in the polar cap and auroral zones.
- Aeromagnetic surveys: Potential for significant disruptions in the polar cap and auroral zones.
- Aeromagnetic surveys: Potential for disruptions in the sub-auroral zone.
- Directional Drilling: Potential for significant deviations in the polar cap and auroral zones.
- Directional Drilling: Potential for deviations in the sub-auroral zone.
- Geostationary satellites: moderate risk of internal charging.

Detailed Information

Solar

- Solar activity has been moderate.
- The active region located near the east limb of the solar disk has produced a solar x-ray flare and an associated CME and has the potential to produce subsequent solar eruptions.
- A non-Earth-directed CME erupted on 06 JUN 2013 18:27 UT.
- One medium coronal hole elongated in longitude is located near the centre of the solar disk.
- Several medium solar x-ray flares have erupted over the past 24 hours.

Interplanetary

- The solar wind speed is currently moderate (500-700 km/s).
- Moderate solar wind speeds are due to high speed streams from coronal holes.
- The interplanetary magnetic field has been fluctuating at moderate ($|Bz|<10$ nT) levels.

Environment at Geostationary orbit

- Energetic electron fluence at geostationary orbit was at a high level yesterday and is expected to be at a moderate level tomorrow.
- Visit http://www.spaceweather.gc.ca/sffl-eng.php for the electron forecast.

Geomagnetic

- Over the last 24 hours geomagnetic activity has been active in the polar zone, active with stormy intervals in the auroral zone, and unsettled with active intervals in the sub-auroral zone.
- Over the next 24 hours geomagnetic activity is forecast to be active with stormy intervals in the polar zone, active with stormy intervals in the auroral zone, and unsettled with active intervals in the sub-auroral zone.
- Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the magnetic forecast.

3.3. Example 3: High activity

Email Subject: Space Weather Bulletin - 2013-06-17 issued at 20:23 UT (15:23 EST)

Space Weather Bulletin - 2013-06-17 issued at 20:23 UT (15:23 EST)

Summary

- There is currently no major storm watch in effect.
- Stormy conditions are possible in the polar cap and auroral zones within the next 24 hours.
- Disturbed geomagnetic conditions due to solar activity are expected today.
- An Earth-directed CME erupted on 14 JUN 2013 18:27 UT and is expected to reach the Earth on 17 JUN 2013, resulting in increased geomagnetic activity.
- An Earth-directed CME erupted on 15 JUN 2013 22:30 UT and is expected to reach the Earth on 17 JUN 2013, resulting in increased geomagnetic activity.
- Two medium solar x-ray flares have erupted over the past 24 hours.
- See our website for current information: http://www.spaceweather.gc.ca (updated every 15 minutes)

Current Conditions (20:15 UT)

Geomagnetic Activity:

- polar cap zone: unsettled
- auroral zone: unsettled
- sub-auroral zone: quiet

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Impacts are not expected.

24 Hour Forecast

Geomagnetic Activity:

- polar cap zone: unsettled with stormy intervals
- auroral zone: active with stormy intervals
- sub-auroral zone: unsettled with active intervals

Environment at Geostationary orbit:

- energetic electron fluence at geostationary orbit: normal

Possible Impacts on Technology:

- Power Systems: possibility of weak voltage fluctuations in the polar cap and auroral zones.
- Aeromagnetic surveys: Potential for significant disruptions in the polar cap and auroral zones.
- Aeromagnetic surveys: Potential for disruptions in the sub-auroral zone.
- Directional Drilling: Potential for significant deviations in the polar cap and auroral zones.
- Directional Drilling: Potential for deviations in the sub-auroral zone.

Detailed Information

Solar

- Solar activity has been moderate.
- The active region located near the central region of the solar disk has produced solar x-ray flares and associated CMEs and has the potential to produce subsequent solar eruptions.
- An Earth-directed CME erupted on 14 JUN 2013 18:27 UT and is expected to reach the Earth on 17 JUN 2013, resulting in increased geomagnetic activity.
- An Earth-directed CME erupted on 15 JUN 2013 22:30 UT and is expected to reach the Earth on 17 JUN 2013, resulting in increased geomagnetic activity.
- A non-Earth-directed CME erupted on 17 JUN 2013 00:53 UT.
- Two coronal holes are located near the centre of the solar disk.
- One coronal hole is located near the edge of the solar disk.
- Two medium solar x-ray flares have erupted over the past 24 hours.

Interplanetary

- The solar wind speed is currently slow (400-500 km/s).
- The interplanetary magnetic field has been fluctuating at low ($|Bz|<5$ nT) levels.

Environment at Geostationary orbit

- Energetic electron fluence at geostationary orbit was at a normal level yesterday and is expected to be at a normal level tomorrow.
- Visit http://www.spaceweather.gc.ca/sffl-eng.php for the electron forecast.

Geomagnetic

- Over the last 24 hours geomagnetic activity has been unsettled with active intervals in the polar zone, unsettled with active intervals in the auroral zone, and quiet in the sub-auroral zone.
- Over the next 24 hours geomagnetic activity is forecast to be unsettled with stormy intervals in the polar zone, active with stormy intervals in the auroral zone, and unsettled with active intervals in the sub-auroral zone.
- Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the magnetic forecast.

3.4. Example 4: Update for high activity

After issuing the bulletin presented as Example 3, the Duty Forecaster closely monitors interplanetary and geomagnetic conditions for the arrival of the coronal mass ejection. When conditions change, an update may be issued. Depending on the nature of the change, the updated bulletin will either present information for the entire bulletin, or changes of note. Updates should always be considered with the original bulletin.

Email Subject: Space Weather Bulletin - 2013-06-18 issued at 02:25 UT (22:25 EST) - UPDATE

Space Weather Bulletin - 2013-06-18 issued at 02:25 UT (22:25 EST)

Summary

- A major storm WATCH is in effect for the auroral zone from 18 JUN 2013 02:21 UT to 18 JUN 2013 05:21 UT.
- Major storm conditions are currently observed in the polar cap and auroral zones.
- See our website for current information: http://www.spaceweather.gc.ca (updated every 15 minutes)

Current Conditions (02:15 UT)

Geomagnetic Activity:

- polar cap zone: major storm
- auroral zone: major storm
- sub-auroral zone: stormy

Possible Impacts on Technology:

- Power Systems: geomagnetic induced currents may cause misoperation of protective relays and transformer heating in the polar cap and auroral zones.
- Power Systems: possibility of weak voltage fluctuations in the sub-auroral zone.
- Aeromagnetic surveys: Potential for severe disruptions in the polar cap and auroral zones.
- Aeromagnetic surveys: Potential for significant disruptions in the sub-auroral zone.
- Directional Drilling: Potential for severe deviations in the polar cap and auroral zones.
- Directional Drilling: Potential for significant deviations in the sub-auroral zone.

24 Hour Forecast

Geomagnetic Activity:

- polar cap zone: stormy
- auroral zone: stormy with major storm intervals
- sub-auroral zone: active with stormy intervals

Possible Impacts on Technology:

- Power Systems: geomagnetic induced currents may cause misoperation of protective relays and transformer heating in the auroral zone.
- Power Systems: geomagnetic induced currents may cause misoperation of protective relays and transformer heating in the polar cap and sub-auroral zones.
- Aeromagnetic surveys: Potential for severe disruptions in the auroral zone.
- Aeromagnetic surveys: Potential for significant disruptions in the polar cap and sub-auroral zones.
- Directional Drilling: Potential for severe deviations in the auroral zone.
- Directional Drilling: Potential for significant deviations in the polar cap and sub-auroral zones.

Detailed Information

Interplanetary

- The solar wind speed is currently fast (700-1000 km/s).
- Fast solar wind speeds are due to a CME observed at 14-15 JUN 2013.
- The interplanetary magnetic field has been primarily negative at high (|Bz|<20 nT) levels.
- An interplanetary shock has been observed on 18 JUN 2013 01:37 UT.

Geomagnetic

- A geomagnetic sudden impulse due to a shock in the solar wind was observed on 18 JUN 2013 02:15 UT.
- Visit http://www.spaceweather.gc.ca/sfst-1-eng.php for the magnetic forecast.

Appendices: Introduction to Space Weather

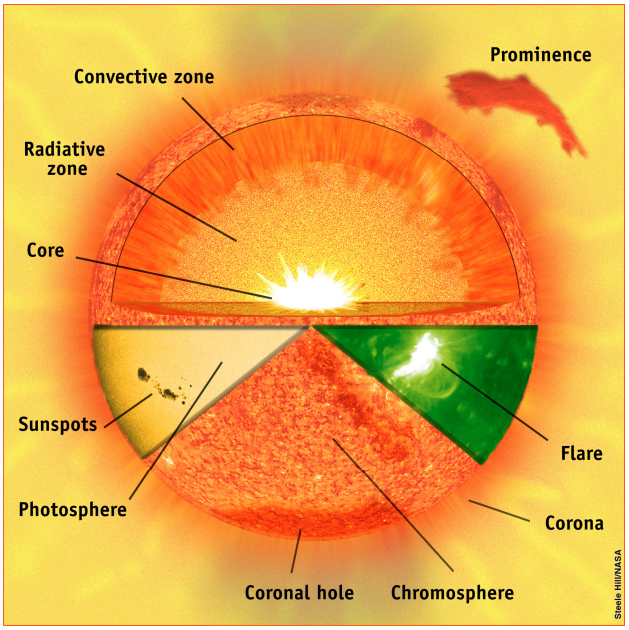


Figure 2: Parts of the Sun. Image courtesy of the Solar Heliospheric Observatory (SOHO). SOHO is a project of international cooperation between the U.S. National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA).

A. Space weather

To understand space weather processes it is first necessary to have a basic understanding of how the Sun, which is the major source of space weather, interacts with the Earth.

A.1. The Sun

Solar phenomenon can have a direct impact on the Earth through space weather. Figure 2 shows the features on the Sun. The source of the Sun's energy is a hydrogen core which contains about ½ of the Sun's mass. This energy comes from the conversion of hydrogen to helium through the process of nuclear fusion. Moving outwards is the radiation zone which emits radiation and diffuses it outwards over a period of millions of years. Next is the convection zone where plasma circulates in turbulent cells. The photosphere is the visible layer of the Sun. It is only a few 100 km thick. The outermost region of the Sun, called the corona, extends millions of kilometers, but cannot be seen by the naked eye. The corona and photosphere are separated by a relatively thin layer called the chromosphere.

Similar to the Earth, the Sun has a magnetic field. The solar magnetic field can be quite complicated, having loops and twists that vary on a wide range of time scales from seconds to hours. Figure 3a shows magnetic field lines looping out of the Sun from different active regions. These active regions appear as dark spots on the surface of the Sun called sunspots, see Figure 3b. Strong magnetic fields within the sunspot (~3000 time larger than the average solar magnetic field) cause plasma within the sunspot region to be about 2000K cooler than the surrounding solar photosphere. Sunspot groups are of interest because they are the source of solar eruptions and are used as an indication of solar activity.

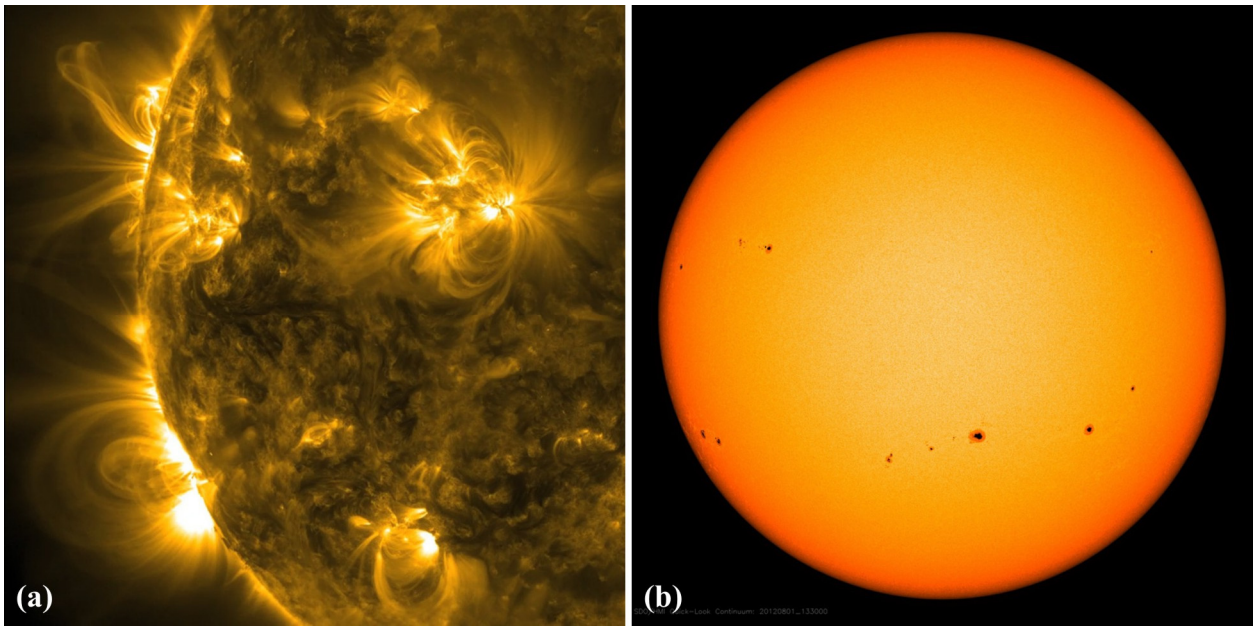


Figure 3: (a) Magnetic field lines looping out from active regions on the Sun viewed under ultraviolet light October, 2012. (b) Sunspots visible on the Sun August 1, 2012. Images courtesy of NASA and the Solar Dynamics Observatory (SDO).

Particles always drift outward from the Sun in a continuous stream called the solar wind carrying along parts of the Sun's magnetic field called the interplanetary magnetic field (IMF). Solar wind particles and the IMF both influence the Earth's magnetic field (see Appendix B.1). The nature of these effects is determined by the type and strength of activity on the Sun. Increased solar activity and solar eruptions can cause additional clouds of particles to travel to the Earth causing disturbances in the Earth's magnetic field.

A.2. Solar phenomena

There are three types of solar activity that have major impacts on the Earth. These are, in order of importance: coronal mass ejections, coronal holes, and solar flares.

A.2.1. Coronal mass ejections (CMEs)

CMEs involve huge ejections of plasma (sometimes ~10 billion tons of plasma) from the corona of the Sun which travel at speeds from ~400 to 2000 km/s, taking 1 to 4 days to reach the Earth. The arrival of a CME at Earth is the main cause for large geomagnetic disturbances.

CMEs can be ejected from any part of the Sun, but only those directed toward the Earth will affect the Earth. Earth-directed CMEs (also called halo CMEs) have the largest influence on the Earth (Figure 4a). Partially Earth-directed CMEs deliver a partial or 'glancing' blow to the Earth and have a lesser affect (Figure 4b). The speed of a CME is a rough indicator of how strong the effects on the Earth will be; a slow-moving CME moving close to the background solar wind speed (300-400 km/s) will have less influence than a fast moving CME (>700 km/s).

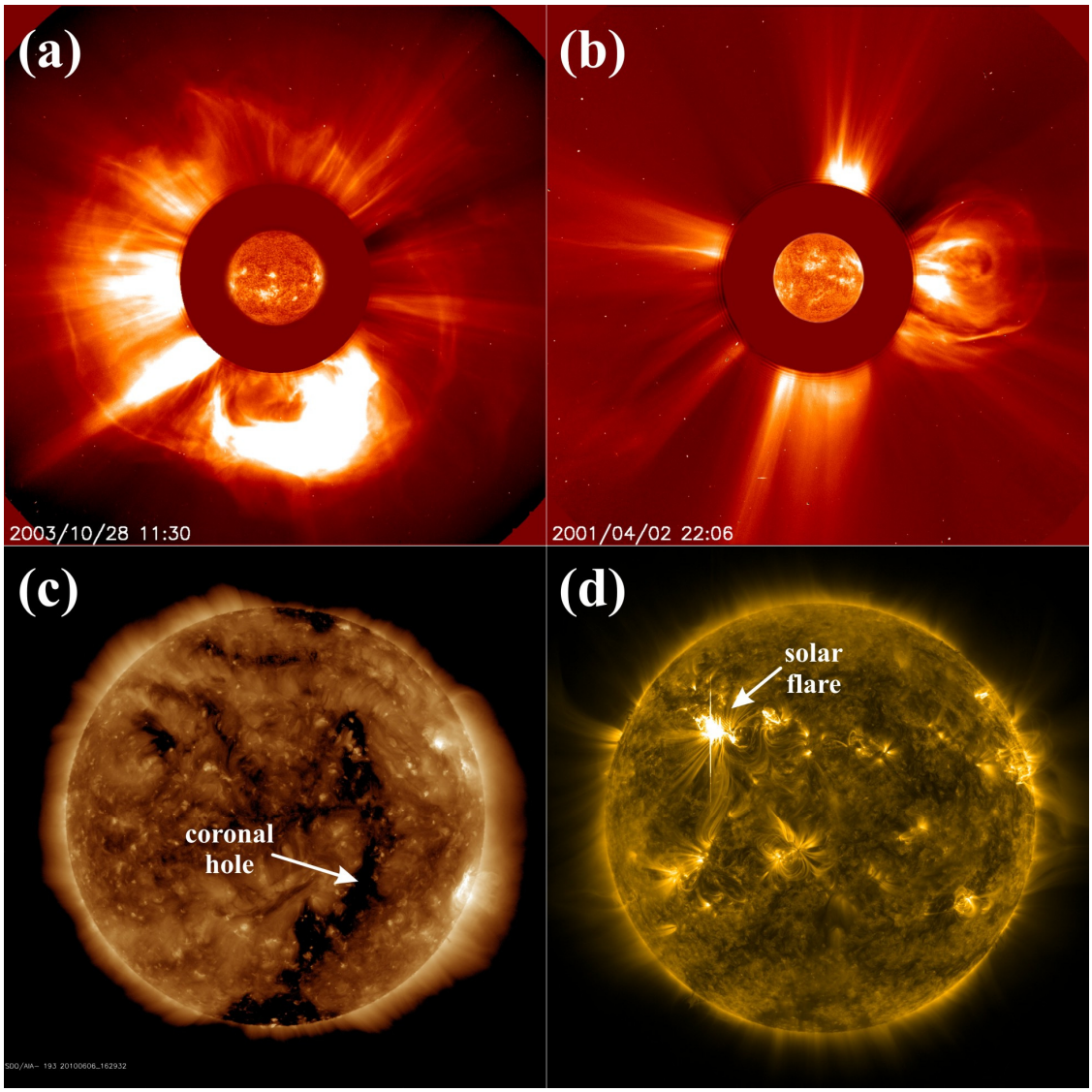


Figure 4: (a) Full halo CME having an Earth-directed trajectory. (b) CME ejected to the side of the Sun having a partially-Earth-directed trajectory. (c) Coronal hole. (d) Solar flare. Images courtesy of SOHO.

A.2.2. Coronal holes

Coronal holes are regions in the corona where magnetic field lines are open to space allowing high speed streams of plasma to escape from the Sun. When the high speed streams arrive at the Earth they can cause long lasting (3 or 4 days) periods of disturbed geomagnetic activity, particularly in the auroral zone. High speed streams from coronal holes that are extended in longitude can interact with the Earth for longer periods of time. Figure 4c shows a large coronal hole that extends vertically along the centre of the Sun.

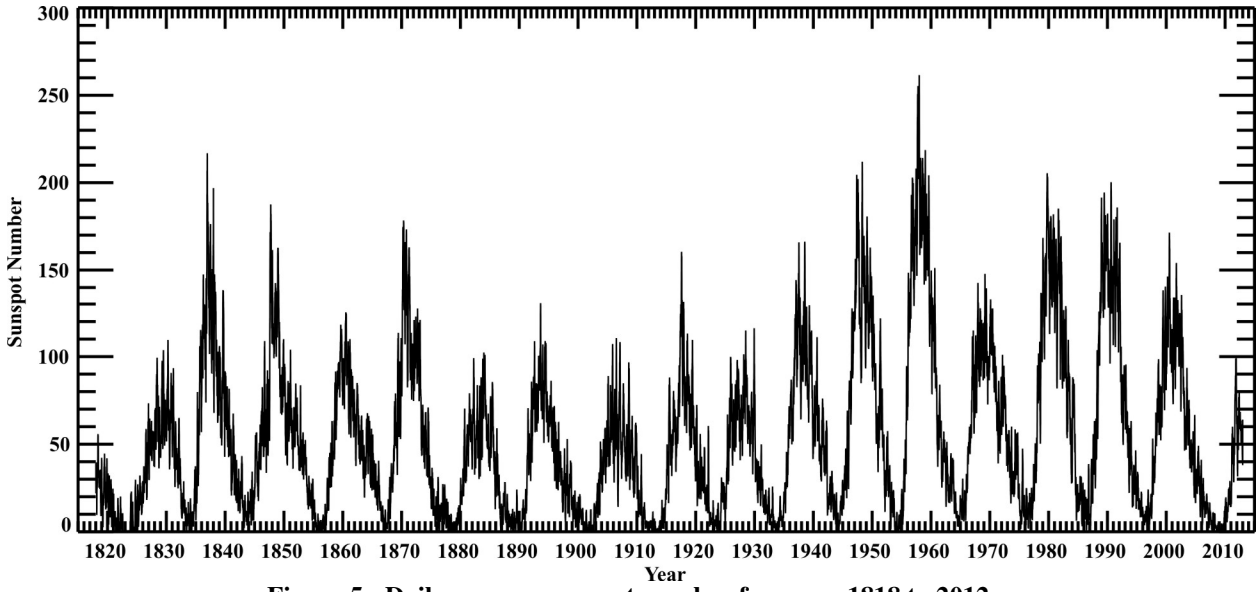


Figure 5: Daily average sunspot number for years 1818 to 2012.

A.2.3. Solar flares

A solar flare is a burst of electromagnetic radiation across the electromagnetic spectrum, notably in visible light, and x-rays that can last from a few minutes to a few hours. Long duration flares can last for more than 3 hours. Solar x-ray flares are one indicator of possible solar plasma eruptions, and can be classified according to x-ray intensities into 4 categories: B (very low), C (low), M (medium), and X (large). Each category (except X) has 9 subdivisions ranging from, e.g., M1 to M9. The scaling is defined so that an M2 x-ray flare is twice as powerful as an M1 flare. X class flares >9 are possible. Figure 4d shows a solar flare erupting. Solar flares can lead to ionospheric absorption.

A.3. Solar cycle

Observations over the last 300 years show the number of sunspots, and therefore the level of solar activity, has regularly varied over an approximately 11 year cycle. Figure 5 shows the sunspot number versus year for 1818 to 2012. During periods of solar maximum, geomagnetic activity is generally more disturbed compared to periods of solar minimum.

A.4. Earth and the geomagnetic field

The Earth's magnetic field, also called the geomagnetic field, can be approximated by a simple bar magnet that passes through the centre of the Earth at a slight inclination of 11° from the Earth's rotational axis (Figure 6a). The geomagnetic field is dipolar, meaning it has two poles where the magnetic field strength is a maximum. Magnetic field lines can be thought of as flowing out from the pole in the Earth's southern hemisphere, arcing around the Earth, and flowing into the pole in the Earth's northern hemisphere. In reality the geomagnetic field is more complex, but this description is convenient for basic understanding.

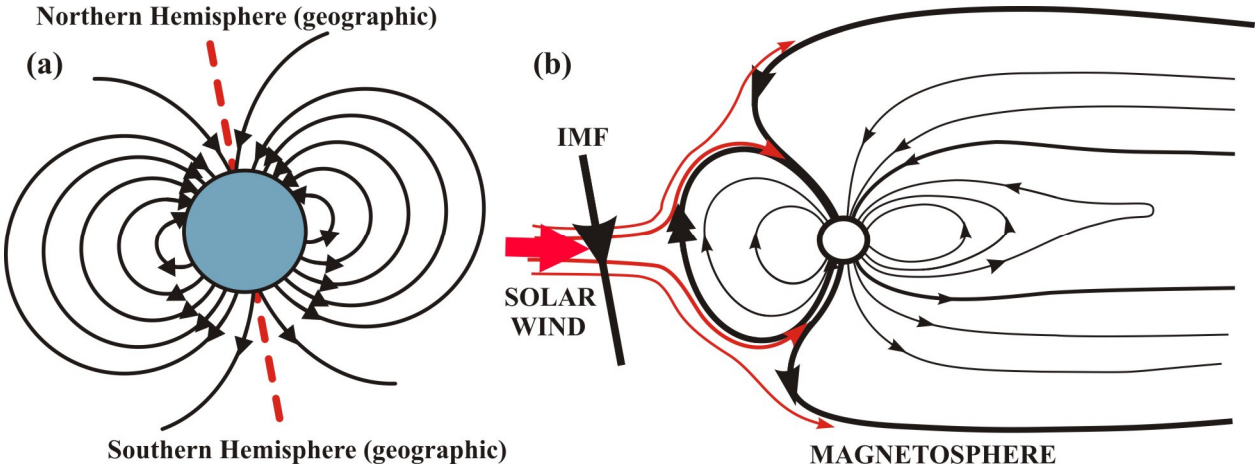


Figure 6: (a) The geomagnetic field can be approximated as a dipole field with magnetic field lines flowing into the Earth in the northern (geographic) hemisphere and out of the Earth in the southern (geographic) hemisphere. The dipole is offset 11° from the vertical spin axis (red dashed line). (b) Cross-section of the Earth's magnetosphere. Also shown are the solar wind flow (red) and a southward oriented IMF line.

The geomagnetic field protects the Earth from solar and interstellar particles. Unable to penetrate the geomagnetic field, the solar wind distorts it creating a protective magnetic cavity called the magnetosphere. The magnetosphere extends out ~10 Earth radii on the dayside of the Earth and >50 Earth radii on the nightside (Figure 6b). The IMF traveling from the Sun interacts with the geomagnetic field. Magnetic field lines pointing in opposite directions can interconnect in the front-side magnetosphere and be swept around into the magnetotail. When this happens, the solar wind particles associated with the IMF can make their way into the magnetosphere where they funnel down into the Earth's upper atmosphere to create the aurora.

Geomagnetic disturbances caused by sudden strong variations in the speed or density of the solar wind or the magnetic properties of the IMF are registered as variations of the geomagnetic field observed by magnetometers on the ground or onboard satellites orbiting the Earth.

A.5. Earth's ionosphere and the aurora

One final region important for understand space weather and its effects is the Earth's ionosphere. The ionosphere is the region of the atmosphere that extends from ~60 km to 1000 km (or more) in altitude. The ionosphere is made up of ions and electrons which form a neutral plasma. The ionosphere is broken into three distinct layers called the D, E, and F regions which are characterized by peaks in the electron density at about 90 km, 110 km, and 300 km.

The main source of the ions and electrons in the ionosphere is photoionization of oxygen and nitrogen in the atmosphere. In a photoionization reaction a photon reacts with a neutral particle to create a positive ion and electron pair. Ion and electron pairs are also formed when energetic particles originating from the Sun enter the ionosphere and collide with a neutral particle. When this happens, it's possible that a particle may be excited to a high energy state. When it decays back to the ground state, a photon is released which produces the light we see as spectacular auroral displays.

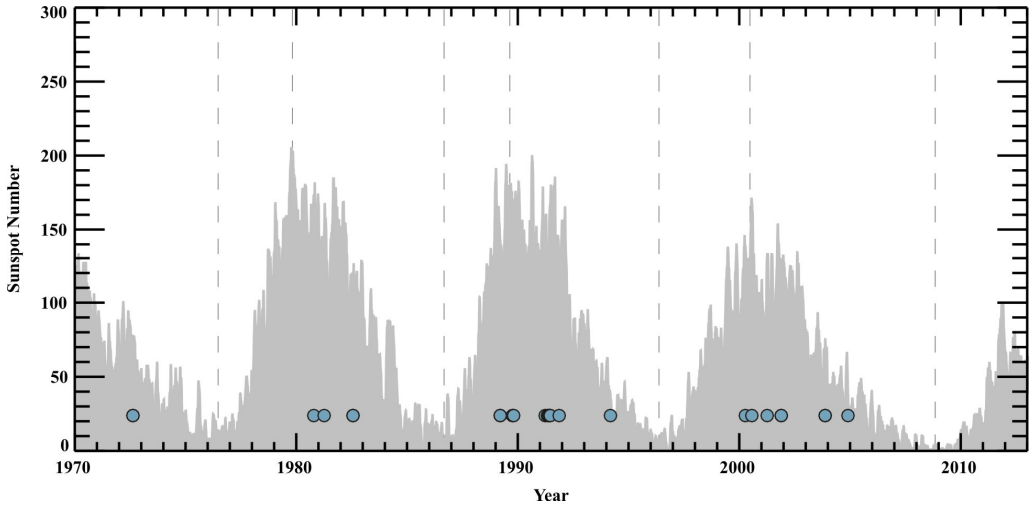


Figure 7: Sunspot number from 1970 to 2013. Vertical dashed lines indicate solar minimum and maximum. Blue filled circles indicate dates of notable space weather effects on technology and infrastructure.

B. Impacts of space weather

In this Section the impacts of space weather on both the geomagnetic field and on technology and infrastructure are discussed.

B.1. Impact due to solar wind and Interplanetary Magnetic Field (IMF)

Geomagnetic disturbances are caused by sudden variations in the solar wind and IMF parameters. Both the magnitude and polarity of the IMF influences the strength of the interaction between the IMF and the geomagnetic field and drives plasma flows both in the magnetosphere and closer to the Earth in the ionosphere. When the vertical component of the IMF (IMF B_z) is southward, there is a strong interaction with the geomagnetic field. Prolonged periods of southward IMF, and sudden transitions from positive to negative IMF are likely to cause geomagnetic disturbances. IMF magnitudes of $|B_z|<5$ nT are considered low. Moderate levels range from 5-10 nT, high levels range from 10-20 nT, and very high levels are >20 nT. The larger the magnitude of southward oriented IMF, the more likely geomagnetic activity will be enhanced. The background solar wind has a typical speed of 300-400 km/s. Moderate (500-700 km/s), fast (700-1000 km/s) and very fast (>1000 km/s) speeds indicate the arrival of CMEs or high speed streams from coronal holes. Geomagnetic disturbances are more likely when the solar wind speed is moderate, fast, or very fast.

B.2. Impacts due to solar disturbances

Figure 7 shows the level of solar activity characterized by sunspot number for 1970-2013. Blue circles indicate notable geomagnetic disturbances having marked effects on technology and infrastructure. Geomagnetic activity levels follow a similar curve, but notable events can occur at any time of the solar cycle. There are three kinds of solar phenomena which can have major influences on the Earth: CMEs, coronal holes, and solar flares. Each type of solar phenomena impacts different technological systems and infrastructure on a variety of time scales.

CMEs have the most impact on the Earth because they involve an ejection of particles from the Sun which carries with it a magnetic field. Immediately following the eruption, solar protons are accelerated by the CME shock front and reach the Earth after a few hours. These particles can affect satellite operation, HF radio communication, and navigation systems. When the CME reaches the Earth 1-4 days later the fast moving dense region of particles compress the Earth's magnetosphere and the magnetic field associated with the CME particles may interconnect with the geomagnetic field leading to increased particle precipitation into the ionosphere and the production of electric currents in the magnetosphere and ionosphere. These changes result in enhanced geomagnetic activity which can affect satellite operation, navigation, aeromagnetic surveys, power systems, pipelines, and directional drilling.

Coronal holes produce high speed streams of plasma which sweep through space as the coronal holes are carried around by the rotation of the Sun. When the high speed streams sweep past the Earth they cause geomagnetic disturbances, particularly in the auroral zone.

During a solar flare x-rays are emitted from the Sun, reaching the Earth in ~ 8 minutes. These x-rays increase ionization in the D-region of the ionosphere (altitude of ~90 km) on the sunlit side of the Earth, typically for 1-2 hours. The increased ionization can impact HF radio communication and navigation systems.

Geomagnetic disturbances are often incorrectly attributed to solar flares. This is a common misconception because solar flares and CMEs often erupt near the same time. However, when this happens it is the CME that causes the geomagnetic disturbance, not the solar flare. It used to be thought that solar flares cause CMEs, which might explain the misconception. We now know that CMEs and solar flares can erupt independently of each other. Solar flares do not involve a burst of particles or a changing magnetic field and do not cause geomagnetic disturbances. However, it might be noted that if a CME is associated with the eruption of the solar flare then, in general, a stronger CME will be associated with a larger solar flare.

B.3. Impacts on technology and critical infrastructure

Figure 8 illustrates some of the systems impacted by space weather, including power systems, pipelines, HF radio communications, satellites, navigation, directional drilling, and aeromagnetic surveys.

B.3.1. Power systems

A fluctuating geomagnetic field causes currents to be induced in long conductors like power systems. These geomagnetically induced currents (GIC) cause problems with the proper operation of these systems. GIC in transmission lines flow to ground through power transformers and interfere with transformer operation. This can cause transformer heating, tripping out of power lines, or even blackouts.

GIC are routinely observed during periods of heightened geomagnetic activity. For the most part, these fluctuations are within the range of normal operation. Problems only result when the

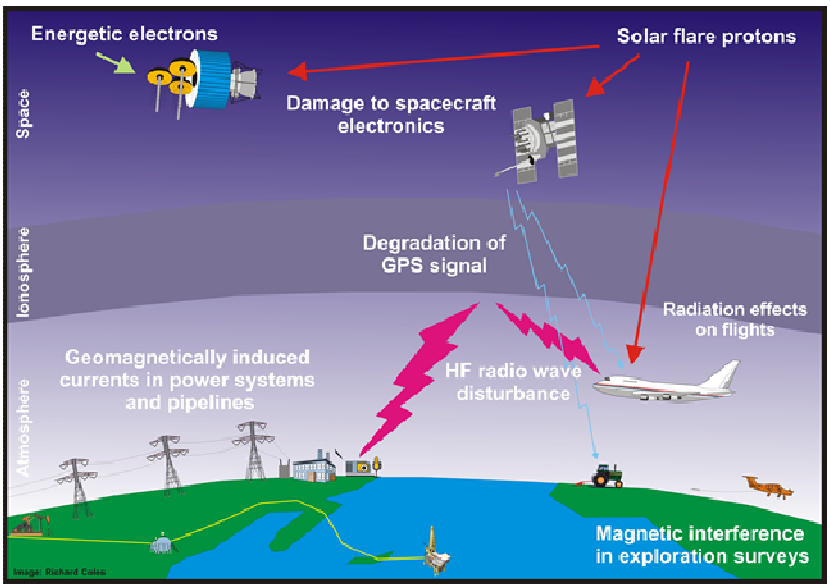


Figure 8: Illustration of the technologies and infrastructure potentially impacted by space weather.

size of the GIC moves out of the range of acceptable operation. One example is the 1989 Hydro-Québec blackout which left over 6 million people in Quebec without power for nine hours.

B.3.2. Pipelines

Geomagnetic disturbances can also cause GIC to flow in pipelines, creating conditions that can contribute to pipeline corrosion. Corrosion is an electrochemical reaction that occurs when iron in the pipeline comes into contact with oxygen in the soil, water, or moist air. Under normal conditions this reaction can be slowed or even prevented by keeping the pipeline steel at a negative potential with respect to the soil. However, during geomagnetic disturbances the GIC cause variations in the pipeline potential, taking it outside the optimum range for corrosion prevention. The effect on the pipeline is not immediate, but the cumulative effect of many geomagnetic disturbances can shorten the lifespan of the pipeline.

B.3.3. HF radio communication

Long-distance HF radio communication is possible because radio signals bounce between the Earth and the ionosphere (Figure 9). When there is increased solar activity, more particles from the Sun enter the Earth's ionosphere. The consequence is a disruption of the radio signals making radio communication difficult, or even impossible. HF radio communication is of particular importance for communication with transpolar flights (Figure 10). This is becoming of increasing importance as the number of cross-polar flights is dramatically increasing.

Three kinds of solar events interfere with the reflection and therefore transmission of radio signals: solar x-ray flares, solar proton events, and auroral precipitation. Each event increases the level of ionization in the D-region ionosphere causing D-region absorption, where radio signals are absorbed instead of reflected and communication is not possible. Solar x-ray flares cause D-region absorption to occur ~8 minutes following the eruption of the flare. The effect is

Figure 9: Radio waves bounce between the ionosphere and the Earth between transmission and receiving points.

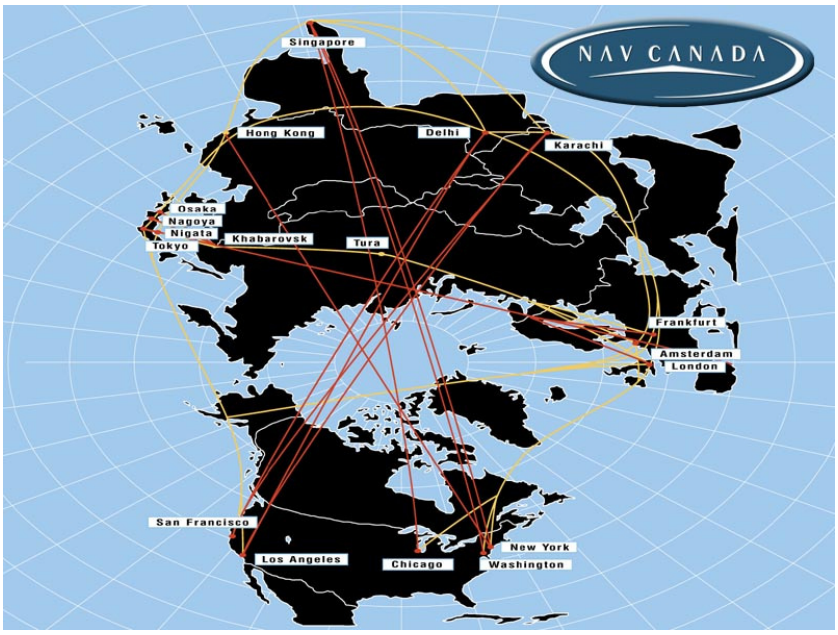


Figure 10: Typical routes for transpolar flights (courtesy of NavCanada).

stronger at low latitudes and more directly affects the United States than Canada. A solar proton event occurs when an Earth-directed CME erupts, causing a shock front to form ahead of the CME accelerating protons toward the Earth. After a few hours, the solar protons reach the Earth where they are directed into the high-latitude region causing D-region absorption. Such an event is called a polar cap absorption event, and can last for several days. Auroral precipitation occurs 1-4 days later when the electrons travelling with the bulk of the CME are injected into the Earth's ionosphere causing D-region absorption in the auroral zone.

B.3.4. Satellites

Charged particles can affect satellites in a variety of ways, either directly by penetrating into the satellite electronics or indirectly through spacecraft charging with the resultant discharge causing problems. These processes can result in radiation damage, phantom commands, damage to electronics, loss of control, and even satellite failure.

One example is the temporary loss of the Anik E-1 and E-2 satellites which began January 20, 1994. The temporary loss of Anik E-1 caused a loss of signal to 56 television channels and a loss of data and telephone services to north western Ontario, northern Quebec, the Northwest Territories, and the Yukon. Loss of signal from the Anik E-2 satellite caused a disruption in Canadian Press data transmission to >100 newspapers and >400 radio stations and prevented the TV and radio relay of CBC news broadcasts. Telesat Canada operators regained control of the Anik E-1 satellite after 8 hours, but the Anik E-2 satellite was not fully operational for 8 months.

The satellite failure has been linked to energetic particles streaming outward from a huge coronal hole[16]. The coronal hole was large and wide and bombarded the Earth with a high speed stream of particles for 7 days. The constant bombardment of energetic electrons was more than the satellites' shielding could withstand, and a charge built up inside the satellites. The subsequent discharge damaged a component of the satellites' momentum wheel electronics causing them to spin out of control, starting the satellites tumbling in space. This prevented communication with the ground and relaying of signals. The temporary loss of the satellites cost Telesat $50-70 million.

B.3.5. Navigation

Global navigation satellite system (GNSS) satellites rely on the transmission of radio wave signals between satellites and vehicles and ships at the Earth's surface, or planes in the air. Perturbations in the ionospheric electron density can change the path of the signal which in turn causes errors in determining the distance between the satellite and receiver causing a loss of accuracy in the GNSS measurement.

B.3.6. Directional drilling

To reach different regions from one drill head, a technique called directional drilling is used. In 3-dimensional drilling a digital compass is used to navigate the drill head. Strong variations in the geomagnetic field reduce navigational accuracy. Poor placement of the well within the target zone can result in reduced production, property boundary infringement, and, in the worst case, collision of the drill head with an active well.

B.3.7. Aeromagnetic surveys

An aeromagnetic survey is carried out using a magnetometer located onboard or towed behind an aircraft. The magnetometer measures the ambient magnetic field which is due to both the Earth's magnetic field and magnetic minerals in the Earth's crust. Aeromagnetic surveys are widely used to produce geological maps and during mineral exploration. During periods of elevated geomagnetic activity the accuracy and quality control of the survey are reduced and in some cases the survey has to be repeated.

[16] Lam, H.-L., D. H. Boteler, B. Burlton, and J. Evans (2012), Anik-E1 and E2 satellite failures of January 1994 revisited, Space Weather, 10, S10003, doi:10.1029/2012SW000811.

Figure 11: Images of the main building and compound for NRCan's Geomagnetic Laboratory.

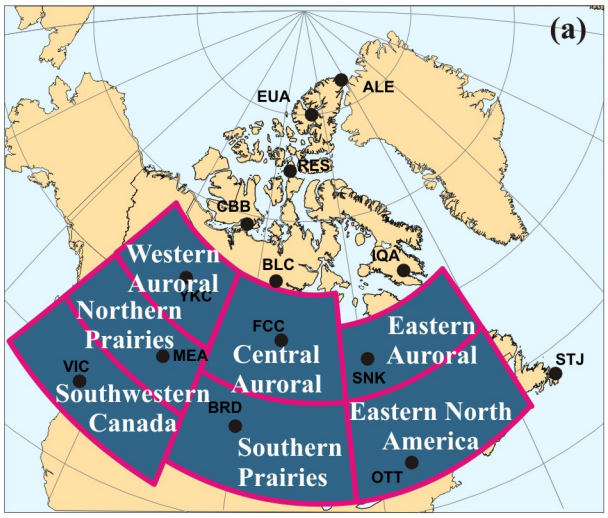
C. Canadian Space Weather Forecast Centre

The Canadian Space Weather Forecast Centre (CSWFC) is located at NRCan's Geomagnetic Laboratory at the edge of Ottawa. Laboratory staff operate the Canadian Magnetic Observatory network, including engineering, technical support, data processing, and data dissemination. The Laboratory also constitutes the National Authority for all magnetic declination information for Canada.

Research at the Geomagnetic Laboratory is conducted, often in conjunction with industrial or academic partners, on a variety of topics related to geomagnetic and space weather hazards to technological systems. These include: modelling of geomagnetically induced currents in power systems; effects of currents in the Earth on cathodic protection of pipelines; high energy particle effects on satellites; induction in submarine phone cables; the effects of ionospheric and geomagnetic disturbances on GNSS, and geophysical exploration techniques.

The CSWFC researches, monitors, analyzes and forecasts geomagnetic activity and dispatches warnings and alerts across Canada. Solar activity is monitored for the primary purpose of forecasting effects on the geomagnetic field. The CSWFC does not forecast solar activity levels, but instead uses observations of solar activity to forecast geomagnetic activity. Geomagnetic activity is monitored and forecast based on data from NRCan's network of magnetometers and data from instruments that monitor the Sun. Magnetometers, satellites and other instruments are used to give advanced notice of potentially harmful space weather periods. Scientists look at patterns and clues in the data collected to produce a forecast. The centre also contributes to the International Space Environment Service by providing geomagnetic data and space weather forecasts.

For the purpose of reporting and forecasting geomagnetic activity levels, Canadian territory has been divided into three zones: the polar cap zone; the auroral zone; and the sub-auroral zone (Figure 1). The auroral zone represents the typical location of the auroral oval. Geomagnetic disturbances are most frequent in the auroral region compared to the surrounding polar and sub-auroral regions. Note that for consistency these zones are geographically fixed, but the auroral oval itself expands (i.e., into the sub-auroral zone) during periods of higher than normal activity or contracts (i.e., into the polar cap zone) during periods of low activity.



Kr	(b)	Status last hour	Forecast 0 - 3 hours	Forecast 3 - 6 hours
9	major storm			
8	major storm			
7	major storm			
6	stormy			
5	stormy			
4	active			
3	unsettled			
2	quiet			
1	quiet			
0	quiet			

No storm watch in effect

Kr is approximately equivalent to the K index but is based on a one hour interval

Figure 12: (a)Location of the seven regions within which regional forecasts are available. (b) Example of regional conditions for the *Eastern North America* region.

D. Space weather webpage

The Government of Canada's space weather webpage can be found at www.spaceweather.gc.ca. Three different forecasts of the geomagnetic conditions are provided: Regional Conditions, Short Term Magnetic Forecast, and Long Term Magnetic Forecast. A forecast of the energetic electron fluence is also provided. This section provides a description of each available product.

D.1. Regional conditions

Address: http://www.spaceweather.gc.ca/current-actuelle/regional/sr-eng.php

Description: Geomagnetic activity level (*quiet*, *unsettled*, *active*, *stormy*, *major storm*) for the last hour and forecast for the next 0-3 hours and the subsequent 3-6 hours. Regional conditions are available for the following regions, as indicated on the map in Figure 12a: *Eastern North America*, *Southern Prairies*, *Southwestern Canada*, *Northern Prairies*, *Eastern Auroral*, *Central Auroral*, and *Western Auroral*. Figure 12b shows an example for the *Eastern North America* region.

D.2. Short term magnetic forecast

Address: http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-eng.php

Description: Geomagnetic activity level (*quiet*, *unsettled*, *active*, *stormy*, *major storm*) as a 24-hour review, 6-hour review, 6-hour forecast, 24-hour forecast, and following 24-hour (i.e., hour 24-48) forecast for the sub-auroral, auroral, and polar cap zones. Tabular and map formats are available. A review and forecast of the geomagnetic activity for the last 48 hours and following 24 hours is provided using a bar graph either by zone or by observatory.

Magnetic Activity Review and Forecast for Date: 2013-02-26 Time: 18:15 UT (Date: 2013-02-26 Time: 13:15 EST)			
	Sub-Auroral	**Auroral**	**Polar**
24 Hour Review	quiet	quiet + stormy intervals	quiet + active intervals
6 Hour Review	quiet	quiet + unsettled intervals	quiet
6 Hour Forecast	quiet	quiet	quiet
24 Hour Forecast	quiet	quiet + unsettled intervals	quiet
Following 24 Hour Forecast	quiet	quiet	quiet

Figure 13: Example of the tabular (by zone) short term magnetic forecast.

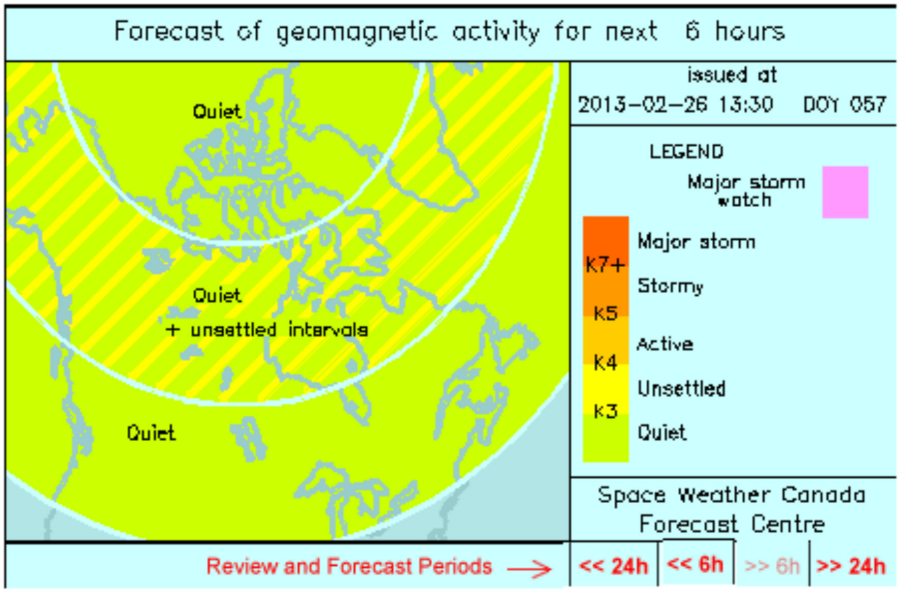


Figure 14: Example of the map (by zone) short term magnetic forecast.

Tabular (by zone)
See Figure 13.
http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-1-eng.php

Map (by zone)
See Figure 14.
http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-2-eng.php

Review and forecast (by zone)
See Figure 15
http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-4-eng.php

Review and forecast (by observatory)
See Figure 16.
http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-5-eng.php

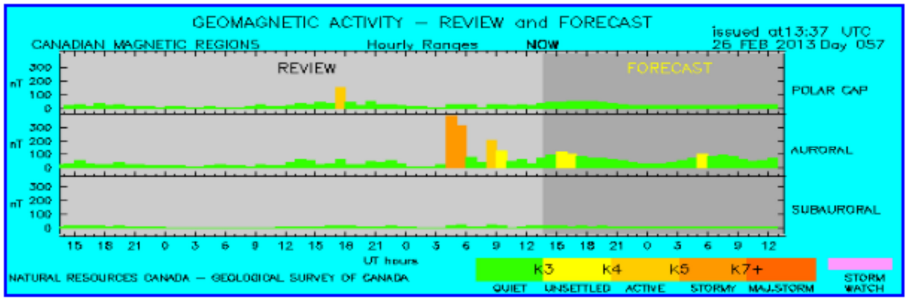


Figure 15: Example of the review and forecast (by zone) short term magnetic forecast.

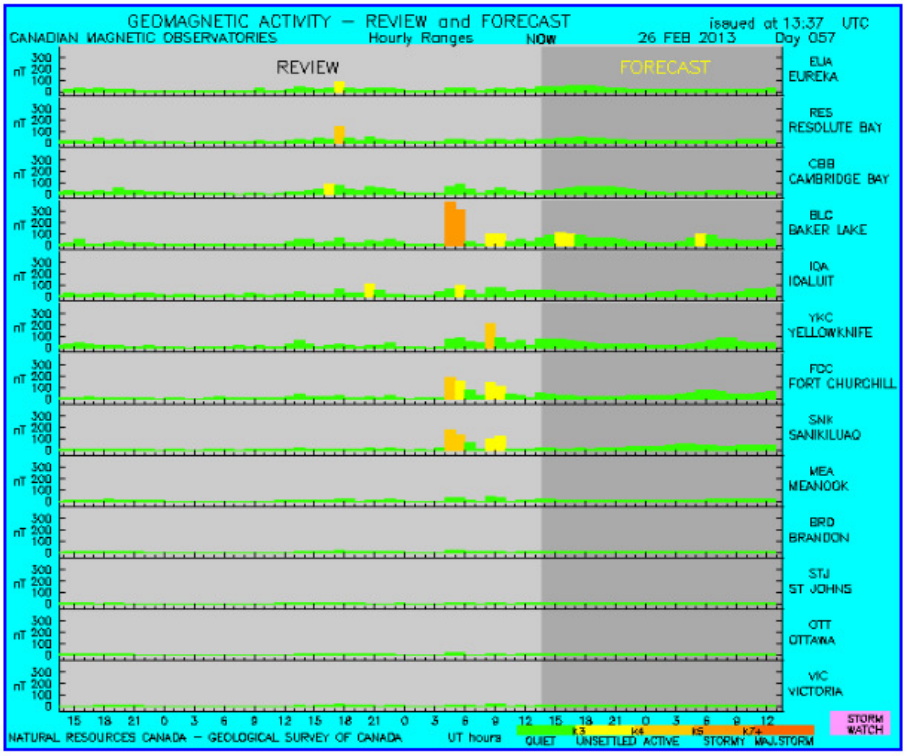


Figure 16: Example of the review and forecast (by observatory) short term magnetic forecast.

D.3. Long term magnetic forecast

Address: http://www.spaceweather.gc.ca/current-actuelle/long/sflt-eng.php

Description: Geomagnetic activity level (*quiet*, *unsettled*, *active*, *stormy*) for the polar cap, auroral, and sub-auroral zones. Review for the last 30 days and forecasts up to 27 days in advance.

Magnetic activity review

See **Figure 17**a.

http://www.spaceweather.gc.ca/current-actuelle/long/sflt-2-eng.php

27 Day magnetic activity forecast

See **Figure 17**b.

http://www.spaceweather.gc.ca/current-actuelle/long/sflt-1-eng.php

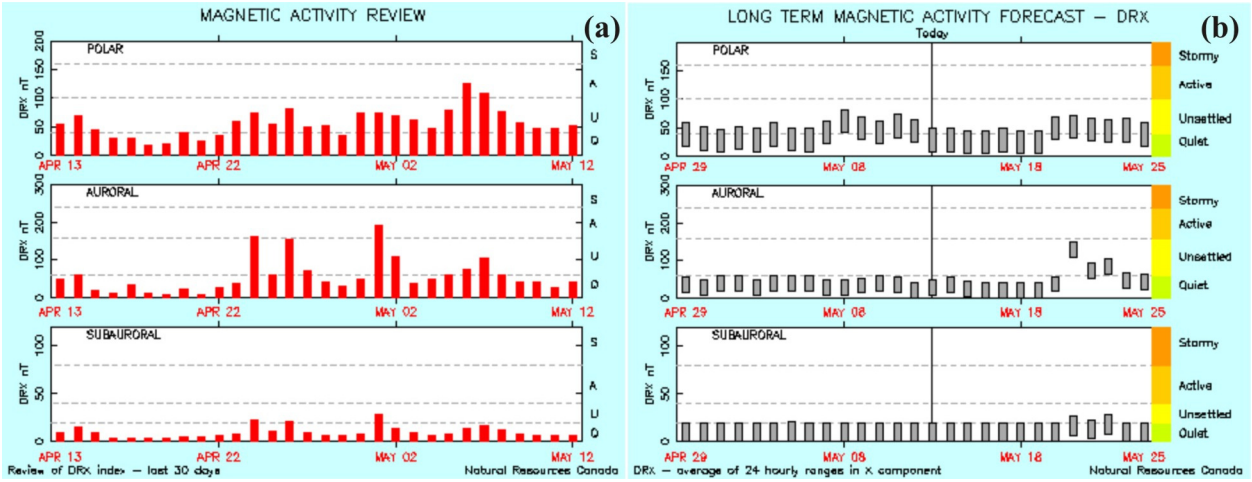


Figure 17: Example of the long term magnetic (a) review and (b) forecast.

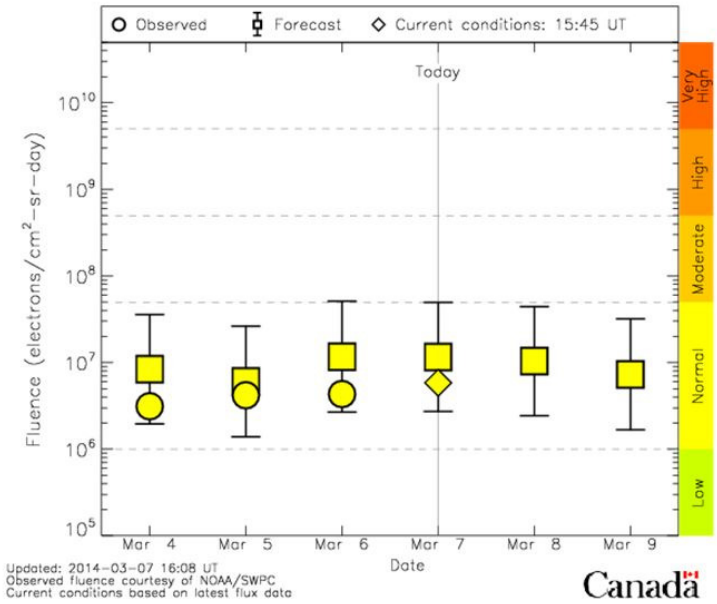


Figure 18: Example of the review and forecast of energetic electron fluence.

D.4. Forecast of energetic electron fluence

Address: http://www.spaceweather.gc.ca/current-actuelle/fluence/sffl-eng.php

Description: Electron fluence refers to the total number of energetic electrons with energies >2 MeV passing through a given area in a day. Electron fluence is measured in units of electrons per square centimeter per steradian per day (electrons / cm^2-sr-day). To determine electron fluence over 1 day, flux measurements made at a geosynchronous orbit of 6.6 Earth radii are taken at 5 minute intervals and summed over a 24 hour period. The fluence value of 5.0×10^7 electrons/cm^2-sr-day is considered as a threshold level for possible adverse space weather conditions hazardous to geostationary satellites. See example in Figure 18.

E. Glossary of terms

Auroral Zone: Canada has three zones of geomagnetic activity: the polar cap zone, the auroral zone, and the sub-auroral zone. The greatest geomagnetic disturbances and the aurora are observed in the auroral zone. Current and forecast conditions for the auroral zone apply to the region of Canadian territory extending between 63° and 77° north magnetic latitude.

Corona: The corona is the outermost region of the Sun's atmosphere that extends millions of kilometres out. The corona consists of ionized gas at a temperature of 1 million degrees Celsius. Because of its high temperature, the corona produces a continual flow of electrically charged particles called the solar wind.

Coronal Mass Ejections (CME): CMEs are ejections of plasma from the corona of the Sun. Their arrival at Earth is the main cause for large geomagnetic disturbances. CMEs travel at speeds from 400 to 2000 km/s and their travel time to Earth varies from 1 to 4 days. CMEs are often associated with solar x-ray flares.

Coronal Holes: Coronal holes are regions in the solar corona where magnetic field lines are open to space allowing high speed streams of plasma to escape from the Sun. High speed streams interacting with the Earth can be the cause of long lasting (3 or 4 days) periods of geomagnetic activity, particularly in the auroral zone. High speed streams from coronal holes that are extended in longitude can interact with the Earth for extended periods of time.

Electron Fluence: Electron fluence refers to the total number of energetic electrons with energies >2 MeV passing through a given area in a day. Electron fluence is measured in units of electrons per square centimetre per steradian per day (electrons / cm2-sr-day). To determine electron fluence over 1 day, flux measurements made at a geosynchronous orbit of 6.6 Earth radii are taken at 5 minute intervals and summed over a 24 hour period. The fluence value of 5.0 E10+07 electrons / cm^2-sr-day is considered as a threshold level for possible adverse space weather conditions hazardous to geostationary satellites. Possible impacts are provided in Section 2.

Geomagnetic: A geomagnetic property is a magnetic property of the Earth. For example, the geomagnetic field is the magnetic field of the Earth.

Geomagnetic Activity: Geomagnetic activity is derived from measurements made at magnetic observatories located in the polar cap, auroral, and sub-auroral zones. The data are processed to produce an hourly range index to characterize the range of magnetic field variations measured during one hour at ground level. Hourly range indices are divided into 5 activity levels: classified as *quiet*, *unsettled*, *active*, *stormy*, and *major storm*. Hourly range values corresponding to different activity levels depend on observatory locations and can be found at http://www.spaceweather.gc.ca/current-actuelle/short-court/sfst-5-eng.php by clicking on each observatory. For more information about the Earth's magnetic field, see http://www.geomag.nrcan.gc.ca/. Possible impacts for each activity level are provided in Section 2 and described in Appendix B.

Geomagnetic Disturbances: Geomagnetic disturbances are produced by electric currents in the ionosphere and magnetosphere. These currents are generated by the interaction of CMEs or high speed streams with the Earth's magnetic field. The strongest currents are associated with the aurora.

Geomagnetically Induced Currents (GIC): During a geomagnetic disturbance, magnetic field variations induce currents in the ground and in long conductors at the Earth's surface. These geomagnetically induced currents (GIC) can produce problems for the operation of pipelines and power systems.

Geostationary: A satellite in a geostationary orbit is located at an altitude of ~35900 km above the Earth at the equator and has an angular velocity equal to that of the Earth so that the position of the satellite is fixed with respect to the Earth.

Geostationary Satellite Environment: Geostationary satellite environment refers to energetic electron fluence measured at a geostationary orbit (~35900 km altitude) which influences the operation of satellites in this orbit.

Interplanetary Magnetic Field (IMF): The IMF is the solar magnetic field carried out into interplanetary space by the solar wind. The north-south component of the IMF (IMF B_z) has a strong influence on the occurrence of geomagnetic activity. Prolonged period of negative IMF B_z are often associated with increased levels of geomagnetic activity.

Ionosphere: The ionosphere is a layer of the upper atmosphere that is ionized by solar radiation. It is made up of several ionized layers and extends from about 70 to 1000 km above the Earth's surface.

Ionospheric Absorption: Ionospheric absorption is the loss in signal strength or attenuation of radio waves as they propagate through the ionosphere. Precipitating electrons and protons are the main causes of strong ionospheric absorption. During the daytime, ionization of the ionosphere by solar radiation is also a source of ionospheric absorption.

Ionospheric Disturbances: Ionospheric disturbances are produced by charged particles precipitating into the ionosphere. These particles create extra ionization that causes absorption of radio waves.

Major Storm Watch: A *major storm watch* is issued to indicate that major storm conditions have been observed by multiple observatories during the same period. These conditions are likely to continue to be observed by more than one observatory for at least the next few hours. The *major storm watch* is either limited to the auroral zone if such conditions have only been observed in that zone or applies to all of Canada if major storm conditions have been observed in both the auroral zone and the sub-auroral zone.

Magnetosphere: The magnetosphere is a region surrounding the Earth in which charged particles are trapped and their behaviour is dominated by the Earth's magnetic field. The

magnetosphere extends from one hundred to several thousand kilometres above the surface of the Earth.

Plasma: An ionized medium composed of positive ions and negative electrons. An ionized medium, unlike a neutral medium, responds to electric and magnetic fields.

Polar Cap Absorption: Polar Cap Absorption is a term given to a type of ionospheric absorption that is caused by the precipitation of energetic protons into the auroral and polar regions. The energetic protons react with the particles of the lower ionosphere and during sunlit conditions cause severe attenuation of radio waves for magnetic latitudes greater than 63°. During periods when the ionosphere is dark, the attenuation is substantially reduced.

Polar Cap Zone: The region poleward of the auroral oval. Current and forecast conditions for the polar cap zone apply to the region of Canadian territory extending between 77° and 90° north magnetic latitude.

Solar Flare: A solar flare is a burst of electromagnetic radiation across the electromagnetic spectrum, notably in visible light, and x-rays that can last from a few minutes to a few hours. Long duration flares can last for more than 3 hours. Solar x-ray flares are one indicator of possible solar plasma eruptions, and can be classified according to x-ray intensities into 4 categories: B (very low), C (low), M (medium), and X (large). Each category (except X) has 9 subdivisions ranging from, e.g., M1 to M9. The scaling is defined so that an M2 x-ray flare is twice as powerful as an M1 flare. X class flares >9 are possible.

Solar Wind: The solar wind is a continuous stream of charged particles flowing outward from the Sun. Typical speeds are 300 – 400 km/second.

Space Weather: Space weather refers to changes in the space environment and geomagnetic disturbances resulting from eruptions on the Sun. Space weather ultimately affects human activities and technologies on Earth and in space.

Sub-Auroral Zone: The region equatorward of the auroral oval. Current and forecast conditions for the sub-auroral zone apply to the region of Canadian territory extending between 49° and 63° north magnetic latitude.

F. Frequently asked questions about the Space Weather Bulletin

A CME erupted today. What will it's impact on technology be when it reaches the Earth?

It is not currently possible to exactly predict what impacts a given CME will have on technology at the time of eruption. When a CME erupts DFs use the time, location, trajectory, and speed of eruption to determine (1) if the CME is fully Earth-directed, partially Earth-directed, or non-Earth-directed, and (2) approximately when the CME will arrive at the Earth. If the CME is fully or partially Earth-directed it is possible that geomagnetic activity levels will become disturbed when the CME arrives, but the exact level of disturbance cannot be predicted until the orientation and magnitude of the IMF and exact speed of the solar wind associated with the CME is known. Such parameters are measured by a satellite located 1.5 million kilometers Sunward of the Earth (about $1/100^{th}$ of the way from the Earth to the Sun), providing a 30-90 minute lead-time on when the solar wind and IMF will arrive at the Earth and influence geomagnetic activity. DFs monitor solar wind and IMF parameters when CMEs are expected to arrive at the Earth to determine the significance of the event on geomagnetic activity levels. Possible impacts on technology are not clear until geomagnetic activity levels are known.

When is geomagnetic activity significant enough to merit reporting?

Possible impacts to technology including power systems, aeromagnetic surveys, directional drilling, and satellites are provided in the daily bulletin based on geomagnetic activity levels and conditions at geostationary satellite orbit. Impacts to systems of interest to the user merit reporting. For example, a power company would generally not be concerned if the energetic electron fluence at geostationary satellite orbit were *high*, but would be interested to know of *major storm* geomagnetic activity levels.

What does it mean when a CME is '*expected to deliver a glancing blow to the Earth*'?

The Sun is a 3-dimensional body and CMEs may be ejected from any part of the solar surface. CMEs ejected along an Earth-directed trajectory are referred to as Earth-directed CMEs. In such cases, the bulk of the CME will intercept the Earth and the geomagnetic field resulting in the maximum possible impact to the geomagnetic field. Note that the strength of the impact is dependent on the individual CME (size, magnetic field, speed of eruption). If the CME is ejected only partially toward the Earth, then the CME will not fully intercept the Earth and the impact on the geomagnetic field will be reduced compared to an equivalent Earth-directed CME. Partially Earth-directed CMEs deliver glancing or partial blows to the Earth opposed to a full and direct impact. Geomagnetic activity for a partially Earth-directed CME will be reduced compared to an equivalent Earth-directed CME.

***Major Storm* conditions are observed in the polar cap, but a *major storm watch* hasn't been issued. Why?**

Major Storm is a geomagnetic activity level used to classify the highest level of geomagnetic activity. A *major storm watch* is issued to indicate that *stormy* and *major storm* condition

thresholds have been exceeded by multiple observatories at the same time in the auroral zone (*major storm watch* issued for the auroral zone) or in the sub-auroral zone and possibly other zones (*major storm watch* issued for the polar cap, auroral, and sub-auroral zones). A *major storm watch* indicates a significant level of activity is present for multiple stations possibly in multiple zones. For a description of the criteria used to determine when a *major storm watch* is issued, see Section 1.1.

Note that issuance of a *major storm watch* is dependent on high levels of activity in the auroral or sub-auroral zones. If auroral and sub-auroral activity is below *stormy* geomagnetic activity levels, it is possible to observe *major storm* activity levels in the polar cap zone without the issuance of a *major storm watch*.

How far in advance can you forecast space weather?

Thanks to satellite observations we're able to detect solar activity within a matter of minutes-to-hours. Depending on the rate at which they are ejected, it takes between 1 and 3 days for particles ejected during these storms to reach the Earth. Based on observations of the solar eruptions, we can predict when they will reach the Earth, and forecast the expected geomagnetic activity that will result. Additional measurements are made at the Advanced Composition Explorer (ACE) satellite which provides information on solar wind plasma 30-90 minutes before reaching the Earth. We can't always predict when a solar storm will erupt on the Sun, but once it does, we can predict when it will affect the Earth.