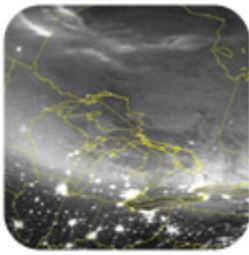


Space Weather: A Natural Hazard of the Technological Era



The Earth's magnetic field is influenced by the interplanetary magnetic field and charged particles in space that are mainly produced by the Sun. During active solar conditions (solar storms) more charged particles are released into space, affecting the normal conditions of the Earth's natural electromagnetic environment. This, in turn, affects normal operation of space and ground technologies, such as communication and navigation satellites, power grids and pipelines.

Variations in the interplanetary magnetic field and bursts of charged particles from solar flares disturb the Earth's magnetic field and ionosphere, initiating geomagnetic and ionospheric storms.

The varying geomagnetic field creates telluric currents which produce variations in natural geoelectric (telluric) field at the surface of the Earth. These variations are especially significant during geomagnetic storms, driving large currents in conductive structures, such as telegraph lines, power lines and pipelines, that stretch for hundreds of kilometres on the ground.

Changes in the stream of the charged particles from the Sun affect the conductivity of the ionosphere during ionospheric storms. This causes a decrease in the effectiveness of radio communications and in the precision of locations determined by the Global Positioning System.

High-energy particles affect electronics aboard satellites and expose humans in space to dangerous levels of radiation. The effect of space weather on technology is described in greater detail below.

Why is Canada affected by space weather?

The Earth's magnetic field has two poles, where the field is directed toward the Earth's surface at the North Pole and away from the Earth's surface at the South Pole. The North Magnetic Pole is located in the Arctic Ocean near the Canadian Arctic Archipelago. Interactions of the Earth's electromagnetic field with the interplanetary

disturbances are especially strong in the polar areas and in the surrounding 'auroral zones', where most auroras can be seen. Given its geographic location in northern latitudes, Canada is among the countries most affected by space weather, hence the need for close study and assessment of space weather conditions and their effects on technology (see Figure 1).

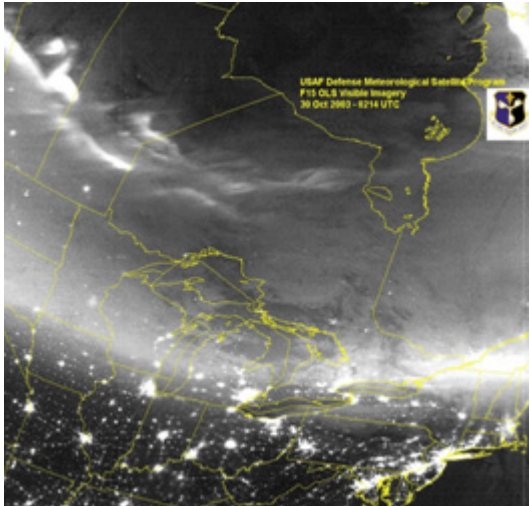


Figure 1. Auroral lights from Space. This image from a United States Air Force satellite shows that the auroral zone has moved south across the Great Lakes, bringing with it large magnetic disturbances that pose a threat to infrastructure.
Source: United States Air Force Weather Agency, Defence Meteorological Satellite Program F-15.

How does space weather affect vulnerable infrastructure?

1. How are communication cables affected?

The geoelectric (or telluric) field, associated with the variations of the Earth's magnetic field, drives electric currents in the Earth and in long conductive structures. These geomagnetically induced currents are especially large during disturbed space weather conditions and reduce the quality of transmitted signals.

Although modern cables use fibre-optics to carry the signals, there is still a conductor along the cable to carry power to the repeaters that periodically amplify or boost the signal. This means that cable systems are still vulnerable to the induced voltages produced by geomagnetic storms, although modern equipment is designed to automatically compensate for, and counteract, the voltages induced by geomagnetic storms.

2. How are power systems affected?

In power transmission systems, electrical lines are connected to the Earth through transformers, which provide a path of least resistance to the current produced by geomagnetic storms. The geomagnetically induced currents flow through the transformer windings at transformer substations, producing extra magnetization that can saturate the core of the transformer. This results in overheating of the transformer and the malfunctioning of relays and other equipment in the system. The protection system perceives this abnormal signal and deactivates transmission equipment. This leads to problems ranging from the trip-out of individual lines (where one line is isolated or removed from the power grid to prevent damage to connected lines) to collapse of the whole system, leaving entire cities without power. The most severe example was the collapse of the Hydro-Québec power system due to a geomagnetic storm on March 13–14, 1989, which happened in just a few minutes and left hundreds of thousands of people without power.

In order to prevent damage to their power systems, power utilities establish special operating procedures during strong geomagnetic storms. They also monitor the severity of space weather activity and the magnitudes of geomagnetically induced currents to increase their preparedness and to take additional protective actions.

3. How are pipelines affected?

To prevent corrosion, steel pipelines are covered with an isolating coating and, using corrosion protection rectifiers, kept within a safe range of voltages that minimizes the corrosion process. Geomagnetic variations create voltage swings that take the pipeline voltage out of that safe 'protected' range. During geomagnetic storms, these variations can be large enough to keep portions of a pipeline in the unprotected regime for some time. This effect is cumulative and can result in increased corrosion and a significant reduction in the lifetime of the pipeline. Annual monitoring of the protection performance helps to reduce the risk of pipeline corrosion and resulting leaks that can damage the environment.

4. How are radio communication and navigation affected?

Streams of very energetic particles produced during solar storms enter the ionosphere in the regions near the magnetic poles. As a result, the polar ionosphere becomes very ionized, which cause severe absorption and fading of radio signals near the poles. Such an occurrence is known as a polar cap absorption event and can last from days to weeks (see Figure 2). High-frequency radios are very important in the polar region, where they are the only means of communicating with aircraft flying over the North Pole. This communication becomes very difficult or impossible during polar cap absorption events.



Figure. 2. Polar Cap Absorption Zone over Canada

Source: Natural Resources Canada

Ionospheric irregularities, especially significant during ionospheric storms, may produce fluctuating signals (a phenomenon known as scintillation) and distort the paths of radio waves. This affects navigational aids, such as the Global Positioning System. Constant monitoring of space weather conditions and forecasts, especially over the Arctic, are needed to correct for space weather effects on communication and navigation.

Personal Preparedness

Pipeline, power and communication utilities can prepare their systems to be more robust and resilient to the effects of space weather. Individual citizens can prepare themselves for the inconvenience of a power outage or communication breakdown by having an emergency plan and kit prepared. The Public Safety Canada Web site 'Is Your Family Prepared' (<http://www.getprepared.gc.ca/index-eng.aspx>) has excellent advice on what to include in both an emergency plan and an emergency kit, both of which can be put to good use in any natural disaster or emergency.

Definitions of underlined terms

Aurora: Temporary luminous phenomena in the high atmosphere occurring mainly in the Polar Regions. This phenomenon is produced by the impact of ionized particles resulting from the solar activity on neutral particles.

Auroral zone: Region situated about 10-15° from either geomagnetic pole, within which the aurora is most frequent and active. (International meteorological vocabulary, World Meteorological Organization, Geneva : Secretariat of World Meteorological Organization, 1966)

Geomagnetic storm: A major disturbance of the earth's magnetic field, usually lasting for one or more days, characterized by large departures from its normal value of at least one of the components of the field. This disturbance is caused by the solar activity.

Ionospheric storms: Turbulence in the ionosphere, usually due to a sudden burst of radiation from the Sun.

Magnetic field: Any space or region in which a magnetic force is exerted on moving electric charges.

Solar storm: Violent outburst of explosive activity on the Sun.

Telluric currents: Static or alternating electric current flowing through the ground and arising either in natural or artificial electric or magnetic fields. (Glossary of geology. Margaret Gary, Robert McAfee, Jr., and Carol L. Wolf, editors; Washington: American Geological Institute, 1972.)