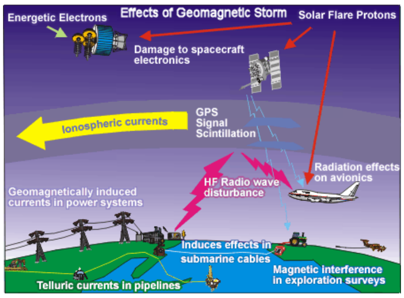
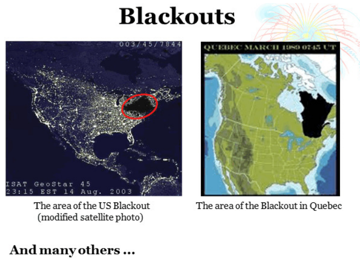
Sun – Part 27 - Geomagnetic storms



GMS effects


GMS – transformer burnout



1989 GMS – blackout areas

A geomagnetic storm (GMS) is a major disturbance of Earth's magnetic field that occurs 36-48 hours following violent activity on the Sun eg solar flares, coronal mass ejections (CME). The frequency of GMSs increases and decreases with the 11-year sunspot cycle. CME driven storms are more common during solar maximum. They last an average of 2-3 days.

The Prussian geographer Alexander von Humboldt was possibly the first to record a GMS, when, while recording bearings on a magnetic compass in Berlin in December 1806, he noticed erratic readings during a bright auroral event. The 1859 Carrington event was the largest recorded GMS, so far. A massive CME had been launched from the Sun, reaching Earth in 18 hours (usually 3-4 days). Ice cores show evidence of similar high intensity events once per 500 years, on average.

It is the solar wind which carries the ejected solar magnetic field and associated highly energised particles towards Earth. Increased wind pressure initially compresses the magnetosphere before transferring its increased energy into it. Both interactions increase plasma movement through the magnetosphere, driven by increased electric fields inside the magnetosphere and an increase in electric current in the magnetosphere and ionosphere. During a GMS, part of the ionosphere becomes unstable, it fragments and may even disappear, with consequences for organic safety and electrical functions on Earth.

GMSs are defined by changes in the Dst (disturbance storm time) index, which estimates globally averaged changes of the horizontal component of Earth's magnetic field at the magnetic equator, based on measurements from a few magnetometer stations.
The Dst is computed once an hour and reported in near real time. GMSs occur in phases. Normally, during the initial phase, also known as storm sudden commencement, there is a sudden increase in Dst value. However,, not all GMSs have an initial phase and not all sudden increases in Dst value are followed by a GMS. The main phase is characterised by a decrease in Dst value and usually lasts 2-8 hours. Finally, during the recovery phase, the Dst recovers to the normal quiet time values. This phase may last from 8 hours to 7 days. A GMS is classified as moderate, intense or super-storm, depending on Dst values.

GMSs can have many and widespread effects. Space weather phenomena associated with GMS include solar energetic particle events, geomagnetically induced currents, ionospheric disturbances that cause radio and radar scintillation, disruption of navigation by magnetic compass, and auroral displays at much lower latitudes than normal.

Hazards to humans include radiation poisoning in astronauts caused by the very high energy particles. This can cause chromosomal damage, cancer and other health problems, or immediate death if doses are large enough. Solar energetic particle (proton) events can also produce elevated radiation in aircraft at high altitudes. The risks are small, but need to be monitored. Fauna is also at risk, and some birds' navigational abilities have been found to be degraded. GMSs may also affect other migratory animals which demonstrate magneto-sensitive behaviour eg whales, dolphins.

Electrical and electronic systems are particularly vulnerable. GMSs can damage satellites, power grids and radio communications, and cause electrical blackouts. Ionospheric storms can affect radio communications at all latitudes. TV and commercial radio are little affected, but short-wave ship-tp-shore broadcasts and amateur radio frequently are easily disrupted. Some military detection and early warning systems which bounce signals off the ionoosphere are also affected by extreme solar activity. GMSs can also mask or distort the magnetic signatures of submarines as one input of their location detection. Long haul telephone lines and non-fibre optic undersea cables are also vulnerable while communication satellite damage can disrupt non-terrestrial telephone, TV, radio and internet links. Navigation systems which incl GPS are also susceptible.

Satellite hardware damage can result from GMS. Increasing solar ultraviolet emissions which heat the upper atmosphere cause it to expand. The resulting rising of heated air increases drag on satellites, causing them to slow and change orbit slightly. Within satellites, the more advanced and compact spacecraft and satellite components used currently have increased their sensitivity to more energetic solar particles. Microchip damage is possible, which can change software commands on satellite based computers. Differential charging can result from a satellite passing through the highly energised environment associated with an increase in number and energy of electrons and ions, discharge possibly damaging components

On Earth, mains electricity grids are susceptible to damage when geomagnetically induced currents are produced in long transmission lines eg in US, China, SA, and Australia, especially modern ones with high-voltage and low resistance. Transformers are particularly at risk. Pipelines can also be affected by geomagnetically induced currents, affecting eg flow meters and corrosion estimates

GMS prediction and warning systems are becoming increasing important to enable action to be taken, where possible, to avoid or minimise these effects. Magnetometers monitor the auroral zones and equatorial regions, while radar is used to probe the auroral ionosphere. Instruments on spacecraft include magnetometers, electric sensors to measure electric field strengths, radio sounders which bounce radio waves of varying frequencies off the ionosphere, their return times allowing determination of electric density profiles, particle detectors including Geiger counters, scintillation counters, and electron multipliers

Recent notable GMS events occurred in 1989 (when power outages in SE Canada affected millions of people), 2000 and 2003.

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org