

# Earth's magnetic field – what is it good for?

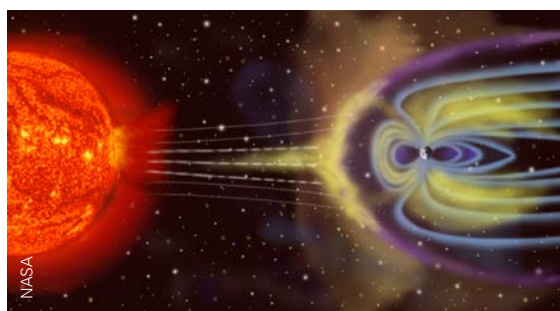
*Sunspots are evidence of magnetic activity on the surface of the Sun.*

*When Mars lost its magnetic field, its atmosphere was ripped away by the solar wind leaving it apparently uninhabitable. Does the same fate await Earth? Mike Follows looks at the latest thinking.*

In the previous issue of CATALYST (Volume 26, Issue 1) we saw that both the strength and direction of the Earth's magnetic field change, switching direction every 300 000 years or so. This article explores the impact these changes might have for us on Earth in terms of both geomagnetic storms and climate.

## Not-so-empty space

The Earth is exposed to the solar wind, a plasma composed mainly of electrons, protons and alpha particles which have enough energy to escape from the Sun's corona or surface layer. The solar wind typically travels at 400 kilometres per second. Fortunately for us, the Earth's magnetic field creates the magnetosphere (**Figure 1**), which acts like an umbrella, deflecting charged particles coming our way.



**Figure 1** The Earth's magnetosphere deflects the charged particles of the solar wind.

The solar wind fills a volume known as the heliosphere. Beyond the furthest planets, the particles of the solar wind gradually lose energy as they collide with the particles of the very low density interstellar medium. The region where they finally run out of energy to push back the interstellar medium is called the heliopause and this is accepted as the outer edge of the Solar System.

As well as the solar wind, the Sun also emits occasional solar flares. These are followed by a coronal mass ejection (CME), when a cloud of up to one billion tons of charged particles is ejected into the interplanetary medium (**Figure 2**). Most head off in the wrong direction to collide with Earth but, when a cloud heads our way, it usually takes between one and five days to reach us. Though our magnetosphere deflects most of these charged particles and the atmosphere protects us from the surge in ionising radiation, CMEs can cause geomagnetic storms on Earth.



**Figure 2** A coronal mass ejection: on 31 August 2012 a large bubble of solar material that had been hovering in the Sun's atmosphere, the corona, erupted out into space.

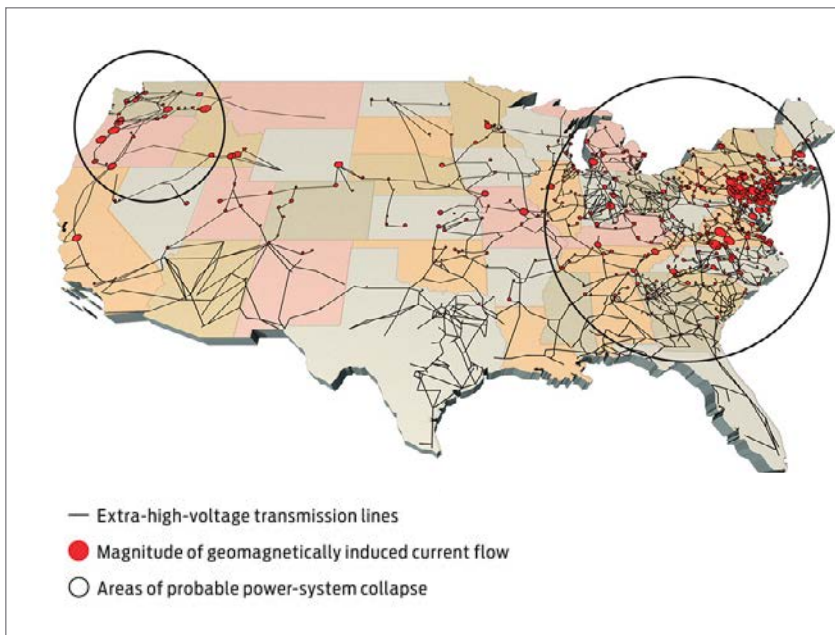
## Key words

magnetic field  
solar wind  
climate change  
correlation

On 6 March 1989, a very large X15-class solar flare was observed. A CME followed on 9 March and four days later a severe geomagnetic storm struck Earth. The storm began with extremely intense auroras at the poles which could be seen as far south as Florida and, because this happened during the Cold War, it is claimed that some people feared that the lights in the sky were due to the detonation of nuclear weapons. Within 92 seconds, the storm had knocked out the Hydro-Québec power grid causing an electrical blackout that left over 6 million people in North America without power for nine hours (**Figure 3**).

### Magnetic interaction

What causes geomagnetic storms? As the CME is a moving cloud of charged particles, it has an associated magnetic field that interacts with the Earth's field, causing it to vibrate. The changing field induces voltages, which drive geomagnetically induced currents (GICs) on the Earth's surface. These currents pass along paths of least resistance, which can include overhead power cables that make up the electrical distribution grid as well as the ground beneath our feet.



**Figure 3** The areas of the USA where power grid lines were seriously impacted by the 1989 geomagnetic storm.

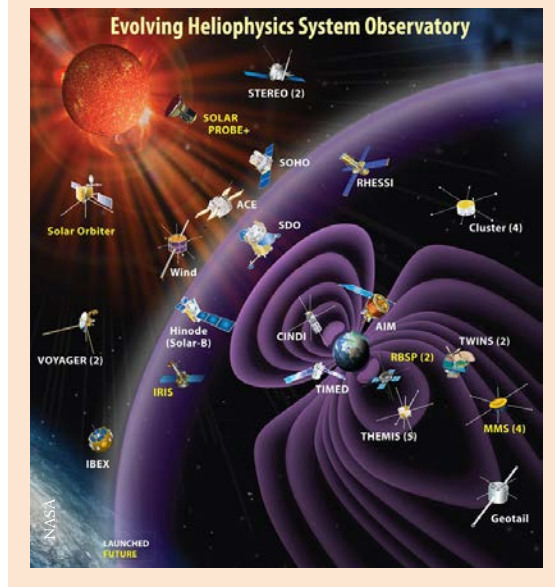
Most of Quebec stands on rock that has a high resistance, so the current took to the man-made alternative – the 735 kV power lines. This is one of the reasons why North America is so vulnerable to solar storms. In extreme cases GICs can melt the windings of heavy-duty transformers, which can take more than 12 months to manufacture. In the absence of spare transformers, this could have an impact on the long-term supply of electrical energy.

On a positive note, Dr Alan Thomson, Head of Geomagnetism at the British Geological Survey, believes that, while the frequency of solar storms will remain the same, GICs will probably weaken

in line with the Earth's diminishing magnetic field as we head towards a reversal. But, according to Scandinavian scientists, this may lead the Earth into a mini 'ice age'.

### Standing guard

Engineers need advanced warning of a geomagnetic storm so that they can disconnect transformers from the grid in order to protect them. This is where Solar Shield comes in. Images from SOHO and NASA's twin STEREO spacecraft will provide a 3D model of the CME and predict when it will reach Earth. A spacecraft called ACE is stationed 1.5 million km upstream of Earth; as the cloud of charged particles sweeps past, ACE will detect its speed, density and magnetic field and give people on the ground about half an hour to take evasive action.

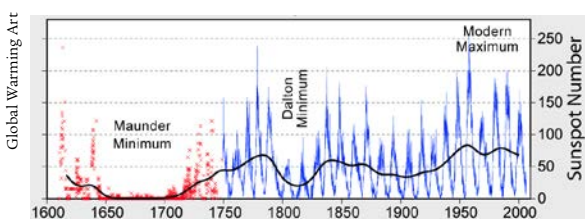


### Magnetic fields and climate

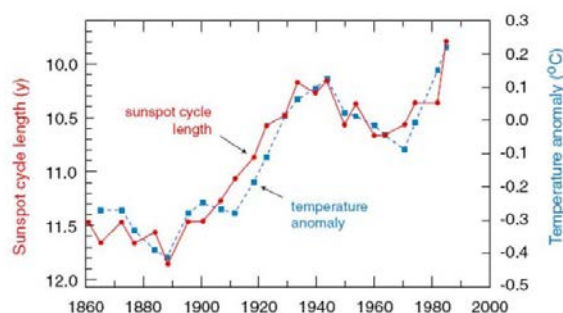
There is mounting evidence that the strength of both the Earth's and Sun's magnetic fields may influence our climate. The climate was changing long before humans started burning fossil fuels. Volcanic eruptions and cometary impacts are just two examples. The many causes of climate change make modelling the climate and predicting future climate tricky – there are so many variables to take into account.

In London, 'frost fairs' were held on the frozen River Thames during the 'Little Ice Age' between 1645 and 1715. This period is also known as the Maunder Minimum because the British astronomers Walter and Annie Maunder showed that the number of sunspots was at a minimum (**Figure 4**). Is there a connection? Well, a paper in 1991 by the Scandinavian scientists Eigil Friis-Christensen and Knud Lassen certainly suggests a remarkably strong correlation between the number of sunspots and the Earth's global mean surface temperature (**Figure 5**). But correlation is not the same as causation and their work was largely

dismissed because they failed to come up with a causal link. However, their colleague Henrik Svensmark has since suggested the galactic cosmic ray hypothesis.



**Figure 4** 400 years of counting sunspots: By combining older (red) and systematic modern (blue) observations, the Maunder discovered the period of low solar activity now associated with the Little Ice Age.



**Figure 5** As the length of the sunspot cycle increases, the Earth's temperature rises.

Galactic cosmic rays, produced by exploding stars called supernovae, are basically protons travelling close to the speed of light. The magnetic fields of the Earth and Sun shield us by deflecting these cosmic rays. The number of sunspots indicates the strength of the Sun's magnetic field. When there are more sunspots, we know that the Sun's magnetic field is stronger, deflecting more of the cosmic rays, leading to a warmer climate.

How does this work? When either or both magnetic fields is weak (as when the Sun sported fewer sunspots during the Maunder Minimum), more cosmic rays reach our atmosphere, creating muons (heavy electrons) that produce the condensation nuclei for cloud formation. An increase in cloudiness results in more sunlight being reflected back into space, making the Earth cooler.

## The CLOUD experiment

An experiment at CERN is being conducted to try to create the condensation nuclei hypothesised by Svensmark (**Figure 6**). The Proton Synchrotron is being used to mimic galactic cosmic rays by firing high-energy protons at the Cosmics Leaving Outdoor Droplets (CLOUD) experiment, which is basically a chamber of very clean air. Early results are positive.

Svensmark's hypothesis, though controversial, is gaining more advocates. But as Thomas Huxley once said, "Science is organised common sense where many a beautiful theory was killed by an ugly fact." While the theory underpinning geomagnetic

storms is understood and accepted, a lot of work still needs to be done in order to forecast when they will arrive and how their impact can be minimised.



**Figure 6** The CLOUD experiment at CERN. Will high-energy protons, fired into the tank, cause clouds to form?

If we were to lose our magnetic field completely, Earth would become uninhabitable as the solar wind would eventually blow away our atmosphere. As the Earth's field is weakening, engineers will need to develop ways of making satellites and aircraft communications less vulnerable to the solar wind and CMEs. A weakening field might also reduce the intensity (though not the frequency) of geomagnetic storms reducing the need for engineers to protect power grids from GICs. But we might also get global cooling, which would reduce or even reverse the predicted warming due to the enhanced greenhouse effect. The danger is that, if the Earth enters a cooling phase, people might stop believing that burning fossil fuels leads to warming. As we have seen, there is more than one source of climate change operating at any one time, clouding the issue.

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### Look here!

The Geomagnetic Storm of 1989:

<http://bit.ly/1kdqzQi>

Cosmic rays and the CLOUD experiment:

<http://bit.ly/1P7rEoB>