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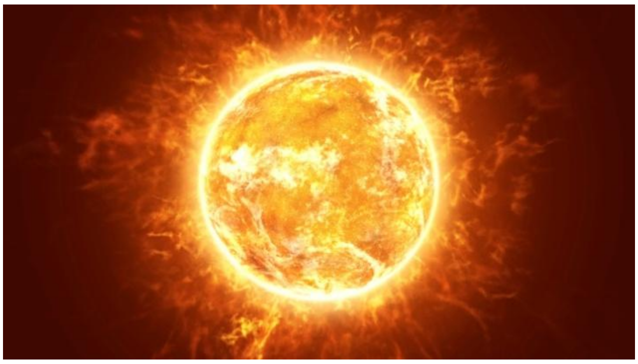
Space Weather



Overview

Space weather can affect space- and ground-based technological systems and cause harm to human health. Monitoring space weather is crucial in order to understand and mitigate its impacts. International collaboration, stimulated by the approaching peak in solar activity, has a key role to play in this area given the global nature of space weather.

Background

"Space weather" means changes in the near-Earth space environment. It is caused by varying conditions within the Sun's atmosphere. The Sun emits a continuous stream of particles, some highly energetic, and radiation of varying intensity. Solar activity changes according to an approximately 11-year cycle and the current consensus is that the next peak will occur in 2012-13.[1] Within the solar cycle, solar storms can occur. A solar flare (a rapid outburst of radiation and energetic particles) is one type of solar storm. Another is a coronal mass ejection or CME – a larger scale, violent ejection of material into space. If directed towards the Earth, CMEs can reach it within a few days, and cause disruptions of the Earth's magnetic field known as geomagnetic storms. Solar storms are more frequent near the peak of solar activity but can also occur at other times. On average, such events disrupt human activity once or twice per solar cycle.

Effects

Solar activity has long been known to have adverse effects on technological infrastructure (Box 1). Dependence on satellites is increasing, so future space weather events are likely to have more impact on society than in the past. The largest recorded geomagnetic storm occurred in 1859. It significantly disrupted telegraph systems around the world for as long as 8 hours. A recent study cited by the US National Academy of Sciences claims that a similar storm today could potentially cause $1-2 trillion damage.[2]

Effects on Space- and Air-based Systems

Space weather can affect satellites in a number of ways.

- Equipment (particularly sensitive electronics) can be damaged through exposure to highly energetic particles, particularly during solar storms. Long-term exposure can reduce a satellite's lifetime.
- The top layer of the Earth's atmosphere heats and expands at times of increased solar activity. The increased friction (atmospheric drag) slows down some satellites, which can drop to lower altitudes and sometimes be lost. Active satellites need to use up costly fuel to maintain orbit.
- Space weather disturbs the ionosphere (one of the upper layers of the atmosphere) which may temporarily degrade or disrupt communication and navigation signals. This can affect satellite-provided broadband and TV and satellite navigation (SatNav), on which society increasingly depends. For example, stock exchanges use GPS timing signals to record transactions accurately.

Box 1. Examples of Space Weather Effects

Quebec Blackout Storm of March 1989
A geomagnetic storm caused an electrical blackout in Canada affecting several million people for 9 hours. The Montreal metro was suspended during the morning rush hour and the Montreal-Dorval international airport temporarily paralysed.

Halloween Storms of October/November 2003
Solar storms caused an hour-long power outage in Sweden and a $640 million Japanese satellite was permanently damaged. Some aircraft were forced to re-route due to a communications blackout and excessive radiation exposure to air travellers. In the UK, the compass north changed temporarily by five degrees in just six minutes.

Aviation equipment can also be affected by energetic particles. Ionospheric disturbances can interfere with aircraft communications. These effects can be particularly significant on high-altitude and high-latitude flights. Although the Earth's atmosphere and magnetic field offer some protection, unexpected solar events may still cause damage.

Effects on Human Health

Space weather can expose air crews and passengers to ionising radiation. Astronauts could be subject to lethal doses of radiation during a single solar storm if inadequately shielded.

Effects on Ground- based Systems

Geomagnetic storms can affect ground-based systems by causing geomagnetically induced currents (GICs) in conducting networks electrically grounded in the Earth's surface (for example pipelines, power systems or railways). GICs affect high-voltage electricity transformers, often those near the extremities of electric grids. Power blackouts may occur if a transformer is damaged enough to require repair or replacement. Operations that use the Earth's magnetic field as a directional reference can also be affected.

Issues

Monitoring and Forecasting

Although solar activity can be predicted days or weeks in advance, it is difficult to say whether a given solar event will have harmful effects on Earth without substantial monitoring capability in space and on the ground. There is no extensive warning system in place for geomagnetic storms. Some warnings can be issued only an hour or less in advance. Solar missions such as STEREO (in which the UK played a key role) can help in tracking CMEs, but are designed to study the Sun rather than provide warning. There are about sixty ground-based ionospheric monitoring stations worldwide (three of which are UK-operated), a global network of geomagnetic observatories (three in the UK) and 15 space-based monitoring stations.

Space scientists say that a significantly better capability is required, particularly in space, to provide high-confidence forecasts. This could enable forecasts of geomagnetic storms and disturbances in the ionosphere 1 to 3 days in advance.[2] A US study estimates that a $100 million satellite warning system for geomagnetic storms could save the power industry $450 million over three years. Currently the main benefit of monitoring space weather is to study its impacts and help satellite operators understand the causes of system failure, rather than to issue warnings. International collaboration (including data sharing) is important for the provision of a reliable space weather service (see Box 2).

Mitigation and Resilience

Measures taken to protect satellites against other hazards can also provide some protection against space weather. For example material designed to withstand extreme temperatures in space, can also help shield a satellite against CMEs. In addition, specific measures can be taken, such as carrying more fuel to tackle increased atmospheric drag at times of increased solar activity. However, these measures are costly and there is wide variation in practice. It is generally agreed that more efforts are needed to educate providers of services which are vulnerable to space weather, as well as the end-user.

There is little public information available about the extent to which satellites are insured for space weather effects. A major US spacecraft insurance company has estimated that over $500m in insurance claims was disbursed from 1994 to 1999 due to "on-orbit failures related to space weather".[3]

Forecasting harmful space weather effects can allow preventative measures to be taken. For example, in the International Space Station, astronauts can retreat to the most shielded parts of the craft during solar storms to avoid excessive radiation exposure. This happened in 2003 (Box 1). Damage to aircraft, air crews and passengers during geomagnetic storms can be prevented by changing the flight path, provided warning of geomagnetic storms is received sufficiently in advance. This measure was applied to some high-latitude routes in 2003 (Box 1). In the UK National Grid, many transformers are designed to resist the effects of geomagnetically induced currents. The company also has procedures in place for when a geomagnetic storm warning is given. However, obtaining advance warning of such storms can be problematic as discussed previously.

Box 2. International Space Weather Initiatives

The **US National Oceanic and Atmospheric Administration Space Weather Prediction Centre (SPWC)** is currently the main source of space weather data, obtained from space-borne sensors. It provides free online alerts and warnings. Two other initiatives in planning are:

- The **European Space Agency Space Situational Awareness (SSA) programme.** This aims to monitor near-Earth space including near-Earth objects (comets, asteroids), space debris (see POSTnote 355) and space weather. SPWC is a key partner in this programme. The UK has valuable assets and human resources and could have an important role in the programme. However, its financial contribution to SSA is minimal and no UK funding is provided for the space weather part of the programme.
- The **World Meteorological Organisation**, through its member states, aims to play a role in international space weather collaboration in future. The UK will be involved in this initiative through the Meteorological Office.

Funding

Several UK universities and agencies, including the Met Office, are involved in space weather research activities. Some provide monitoring information and data, but the UK largely relies on international initiatives for forecasting capability (see Box 2). Responsibilities for funding of space weather research and services are spread amongst various research councils. The Science and Technology Facilities Council funds solar-terrestrial physics research activities which recently suffered budget cuts. Within the Natural Environment Research Council (NERC) space weather falls within natural hazards. NERC's British Geological Survey is a key source of data and space weather research. The new UK Space Agency is likely to be involved in space weather activities but its exact role is not yet clear.

Endnotes

1 Solar Cycle Progression, US National Oceanic and Atmospheric Administration, http://www.swpc.noaa.gov/SolarCycle/
2 *Severe space weather events—understanding societal and economic impacts: a workshop report*, The National Academies Press, 2008
3 http://www.swpc.noaa.gov/info/Satellites.html

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