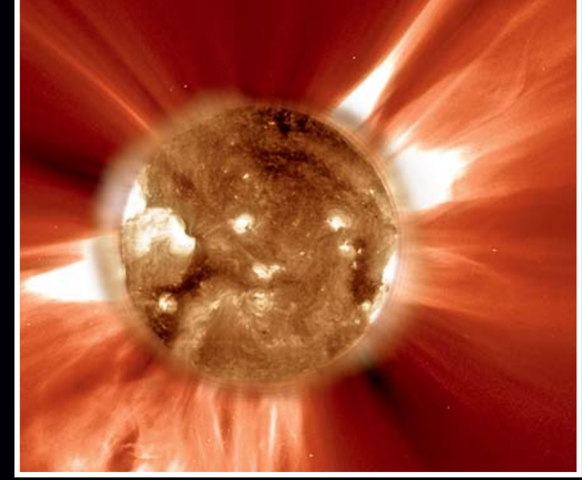
SPACE WEATHER

Much as the sky once gave the ancients warnings of danger, space activity today indicates risks for the modern world.

By Dr. Rudolf Kreutzer



This coronal mass ejection in 2002 photographed by sun-orbiting SOHO spacecraft reached the earth about two days later

Space weather is a very old phenomenon, as old as the sun and the stars that came before it. All life on earth is accustomed to its natural manifestations like the Aurora Borealis or enormous solar bursts of radiation that may have had profound effects on species extinction. Humans are also getting used to the newest kind of space weather, their own orbital debris.

Increasingly, risk managers are becoming aware of the effects that both natural phenomena and human debris can have on infrastructure like telephone networks and electricity grids. Experts debate what and how strong these effects are. However, some historic large losses seem to be directly linked to space weather, and the increasing dependence of society on electronics, especially wireless electronics, means a growing exposure to peak space weather events.

In general, space weather comes in four varieties (see box, p. 17). Solar elements like flares and storms, commonly called sunspots, affect earth most immediately. At the same time, we are constantly bombarded by interstellar elements like cosmic rays. Meteorites and other solid objects such as comets can also be classified as space weather or at least understood as elements in the space environment. Finally, the fourth group, space debris in our orbit is a man-made risk that increases every year. All of them affect the earth and our activity in different ways.

ALWAYS THERE

Solar and interstellar elements interact with the earth's atmosphere, with profound impacts on nature. The polar lights are certainly the most spectacular result of solar weather. They appear when solar wind interacts with charged particles in the ionosphere, the outermost part of the atmosphere, which concentrates these charged particles near the magnetic poles.

However, since the formation of the earth, natural space weather has affected its development. Careful studies of the climate, for example, indicate that solar activity has directly influenced atmospheric cooling and warming. This may in fact have played a role in the changes from ice ages to warmer periods.

The 11-year cycle in which sunspot activity increases and decreases seems to be linked to weather cycles as well (see table p. 16). Cosmic radiation ionizes the stratosphere, the part of the atmosphere just above the cloud layer. This ionization causes clouds to condense and generate more rain. The 11-year variation of the water level of the Nile corresponds closely to the solar activity cycle.

It is also thought that bursts of gamma rays from outside the galaxy can reduce the ozone concentration in the upper atmosphere, and therefore pose a risk to life on earth's surface. Some studies even indicate that geomagnetic storms caused by solar storms can be disorienting for the homing instincts of migratory birds, homing pigeons and whales.

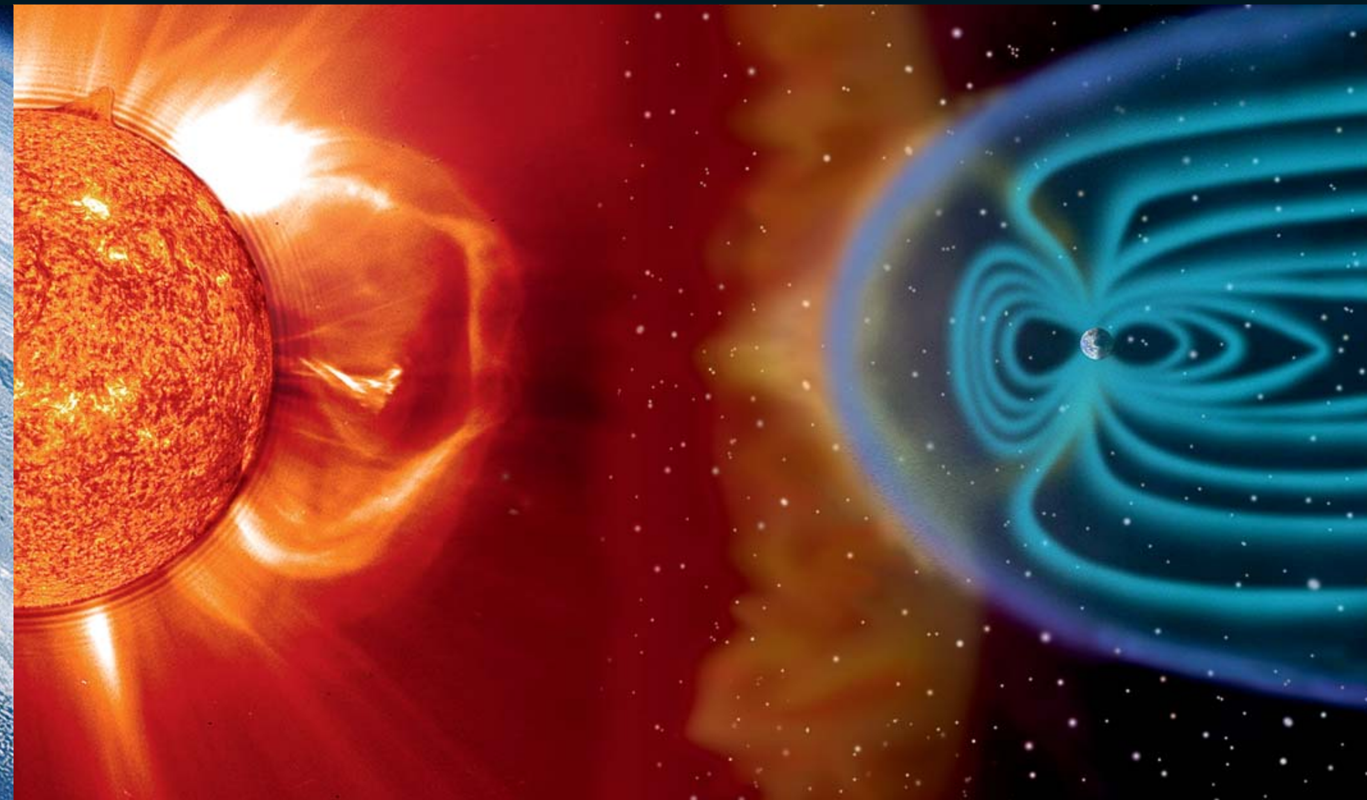
TECHNOLOGICAL BREAKDOWN

Our highly technological world is particularly exposed to the electromagnetic effects of space weather. Each solar storm, for example, generates intensive showers of particles and gigantic currents in the ionosphere which induce major alterations in the geomagnetic field. Electric conductors in the changing magnetic field, whether cables, pipes or seawater, run currents called "geomagnetically induced currents", or GICs. The bigger the sunspot and the longer the conductor, the higher the voltage and possibly the GIC. While there are natural electric currents running through the earth and sea known as "telluric currents", they vary wildly during coronal mass ejections.

The effects on electrical infrastructure can be profound. The first historical event when GICs appear to be

Photos: NASA (1), SOHO Consortium (1)

Skylab fell to earth in 1979 when solar radiation warmed the atmosphere.



This NASA image shows how a coronal mass ejection warps the earth's magnetic field.

linked to a large loss was a telegraph breakdown on September 2, 1859. The day before, scientists detected a spectacular solar flare, followed by the largest aurora ever reported. At the same time, the extreme geomagnetic storm overloaded telegraph lines worldwide, causing short circuits and fires in telegraph stations and ultimately a breakdown in service.

If an event of the same magnitude were to take place today, a recent report released by NASA ("Severe Space Weather Events") estimates that costs due to business interruption in the United States alone could reach over US$ 1 trillion - some ten times the cost of Hurricane Katrina.

During a similarly large magnetic storm accompanied by vivid auroras visible as far as Hawaii and Cuba on March 13, 1989, GICs hit power lines from the Hydro-Québec power network. This led to a blackout affecting 3 million people and losses of C$ 10 million. Though experts disagree as to whether GICs were related to the event, at the very same time, a transformer in New Jersey was destroyed in the US. In 2003, Europe experienced widespread power outages during heavy solar activity.

GICs are known to have led to severe problems with metal transatlantic phone cables, while the switch to fiber optic cables seems to have solved that problem. However, the metallic cables that deliver the power to boost fiber optic signals are still affected. Modern mobile phone users are familiar with the problem of sunspots interfering with transmission. This is especially severe at dawn or dusk, when the sun lies low in the sky, and solar radio bursts radiate horizontally into the antennas of cell site base stations.

HIGH ABOVE THE EARTH

Space travel is obviously an area where space weather poses a major concern. Space debris and planetary elements like asteroids are a constant worry for satellites and manned space travel, while solar storms represent a deadly danger for life forms. Astronauts outside their ships can suffer a lethal dose of radiation during solar storms. It was by pure luck that the Apollo 11 astronauts missed a massive solar flare, a phenomenon little understood at that time, which would have killed them or at least destroyed their electronics.

Satellites also face risks from increased UV radiation by extraordinary solar activity. The radiation makes the atmosphere expand, surrounding satellites at lower orbits and slowing them down so that they eventually fall to earth. The crash of the space station Skylab in 1979 is a famous example. In addition, solar storms can cause electro-static discharges which destroy electronic devices like solar panels. Solar storms, for example, probably caused the total loss of the Nozomi Mars Probe in 2002.

Photos: NASA (1), NASA - Steel Hill (1)

> "As our dependence on electricity and electronics increases, so does the potential impact of space weather."

Most critical are telecommunications signals. Solar storms change the properties of the ionosphere, disturbing signals or modifying them. This can mean GPS satellites have to be disconnected, as was the case in 2003 and 2005. It can also cause the failure of military radar systems and other shortwave transmission systems like TV broadcasting, mapping, land surveying and exploration.

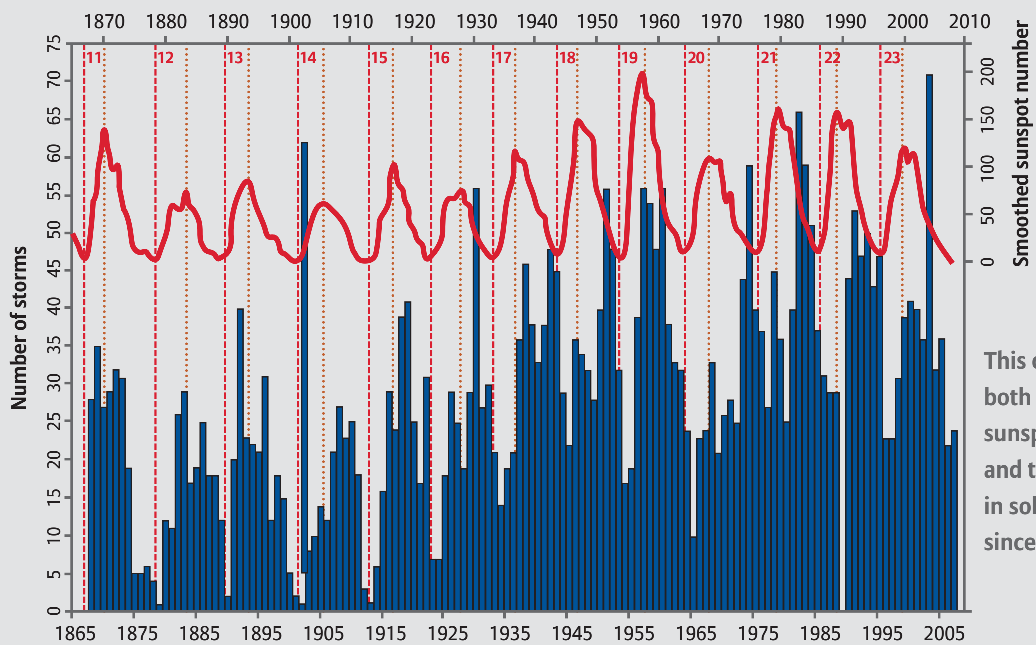
Closer to earth, air traffic is also affected. Especially on pole routes, flight personnel and passengers are exposed to higher radiation intensity, and they have to be monitored for compliance with safety rules. During solar storms, this radiation increases greatly, endangering not only people but also interfering with radio communication and the electronic equipment of the plans. For all these reasons, solar storms mean that planes have to deviate to routes at lower latitudes, which lengthens the flight and can raise its costs by more than US$100,000.

PREDICTING THE WEATHER

What lies ahead? As far as solar activity is concerned, for centuries it has shown a very constant cycle that peaks every 11 years. In 2008, we hit a low point. The next peak is expected around 2011 and 2012. In addition, as the table on p. 16 shows, a general increase in geomagnetic storms has been observed since 1865. At the same time, the strength of the geomagnetic field has been decreasing slightly but continuously since it has been first measured. It provides important protection for life on earth against solar and interstellar elements, so that protection will slowly diminish.

Generally we have to expect an increase of "normal" solar related space weather events in the coming years. Beyond that, experts know that other unforeseeable events of great impact could very well happen in addition to those attributed to the 11-year solar cycle.

SUNSPOT CYCLE AND ANNUAL NUMBER OF MAGNETIC STORMS



This chart shows both the 11-year sunspot cycle and the increase in solar activity since 1865.

Source: British Geological Survey

Electronic elements are becoming more and more microscopic, pervasive and ubiquitous. Thus, the probability of space weather-related soft errors in manufacturing and application may increase. Similarly, critical infrastructures, whether they be power generation, telecoms, finance, fuel, food or water, are becoming ever more dependent on electricity and electronics. A specific trend can be observed in telecommunication, where wireless communication, satellite-based communication and the importance of long-distance communication cables is on the rise. They all are susceptible to space weather. This exposes them to business interruptions, especially in highly developed countries.

FUTURE DIALOGUE

As a future risk, space weather contains many unknowns and demands close risk dialogue with industry. For years, Allianz has been a leader in studying these risks and working with clients and brokers to develop insurance solutions and technical recommendations. As this critical area and its exposure emerge, AGCS will continue its research and knowledge-sharing with risk managers and experts in the insurance industry and beyond. ▮

Comets hitting the earth are rare but are known to have major impacts.

DR. MICHAEL BRUCH
Allianz Center for Technology
michael.bruch@allianz.com

http://esa-spaceweather.net/
http://www.swpc.noaa.gov/
http://www.spaceweather.com/
http://www.geomag.bgs.ac.uk/spweather.html

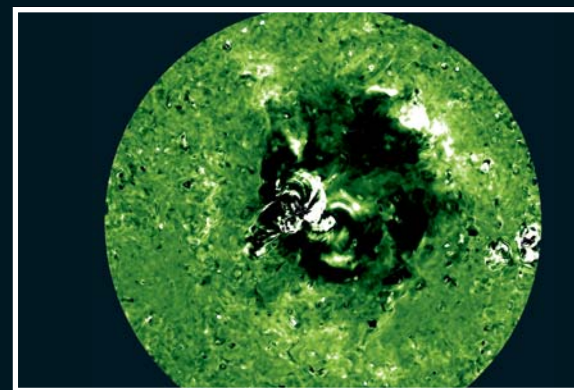
Photos: corbis (2), NASA (2), ESA (1)

THE MOST COMMON KINDS OF SPACE WEATHER

SOLAR ELEMENTS

Protuberances, flares
Violent explosions on the sun's surface produce extremely intensive bursts of radiation such as radio waves, X-rays and ultraviolet radiation. They reach the earth's surface with the speed of light in about eight minutes.

(Slow) solar wind
Constant outward flows of ionized gas or plasma (protons, electrons, alpha particles) leave the surface of the sun and expand into space with a speed of approx. 400 km/sec, reaching the earth in 4 - 5 days. There they deform the geomagnetic field and create the Aurora Borealis and Australis.



(Fast) solar storms
Commonly known as sunspots and called "coronal mass ejections" by experts, these are tremendous isolated ejections of plasma clouds. They expand into space with a speed of around 1000 km/sec. If one of them erupts in the direction to the earth, it can reach the earth in about 2 days. This so-called "bow shock" produces extreme variations of the earth's geomagnetic field.

INTERSTELLAR ELEMENTS

Cosmic rays, gamma ray bursts
This radiation and single particles may come from gigantic cosmic events billions of light-years away. In times of minimal solar activity, they can penetrate the earth's atmosphere and react with its gases.

Interstellar winds and storms
These are vast wandering plasma clouds caused by coronal mass ejections from outside our solar system.

INTERPLANETARY ELEMENTS

Meteorites, comets, asteroids
These common solid elements may collide with spaceflight and satellites or may impact on earth.

ORBITAL ELEMENTS

Space debris
There are innumerable man-made fragments, trash and dead satellites straying at various orbits. Over 18,000 objects larger than 10 cm have been tracked.