Monitoring solar activity

Weather in Space

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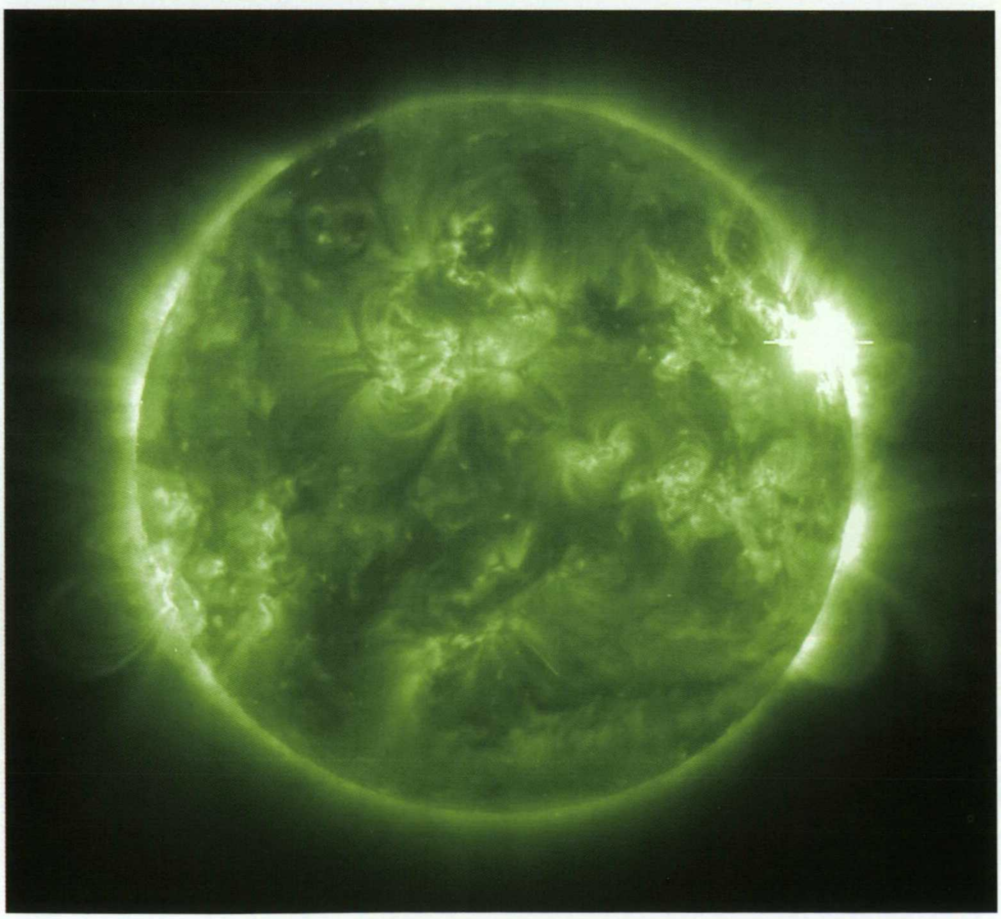
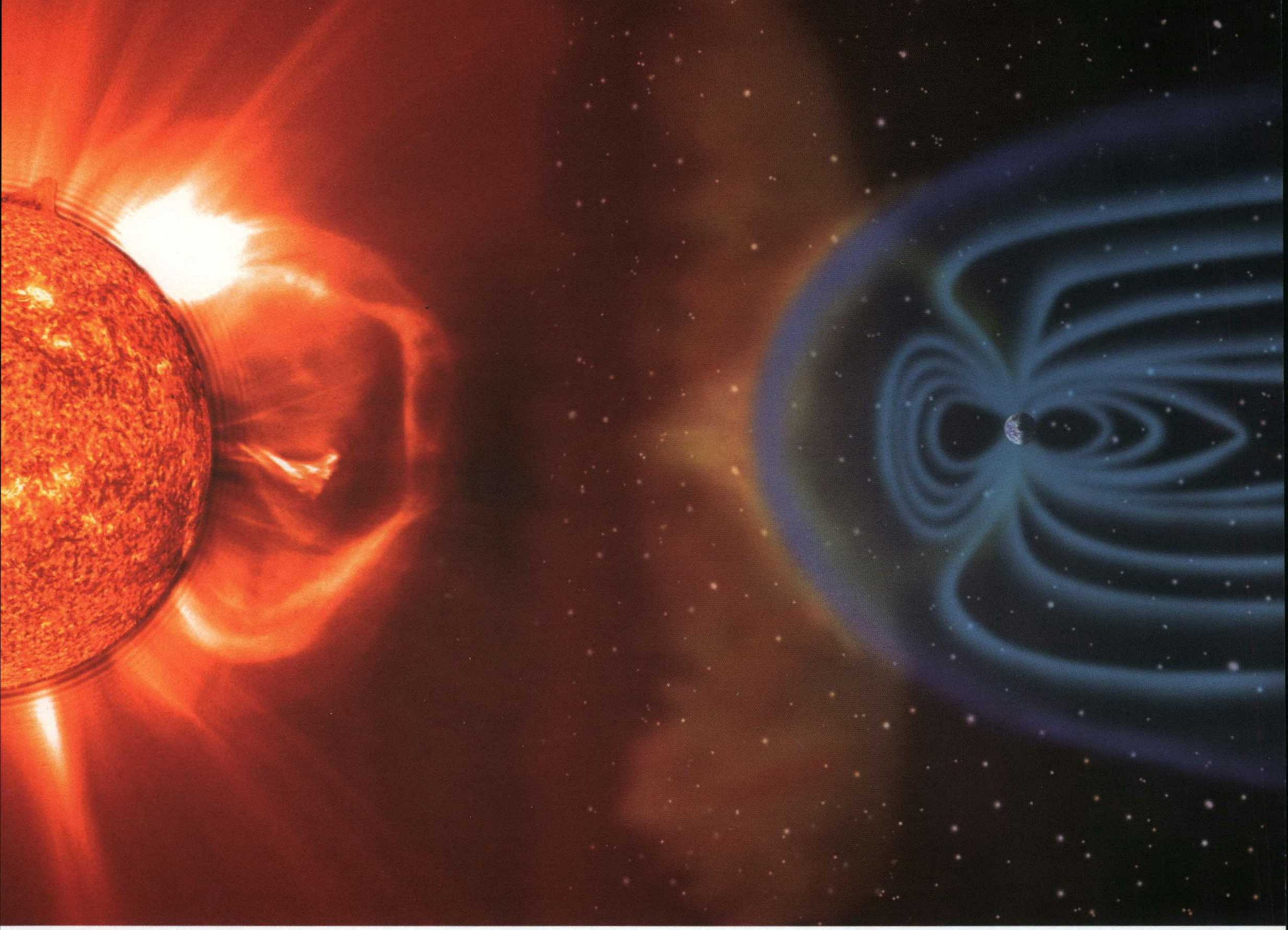
While the Sun energy is one of the main factors that supports terrestrial life, solar eruptions can sometimes wreak great havoc on Earth. One of the centers working to observe and forecast space weather is the Space Research Center of the Polish Academy of Sciences

Monitoring all the symptoms of space weather is a task of grave importance not just for our understanding of astronomic phenomena and how they interact, but also for our ability to forecast them and thus to stave off their negative consequences. Geomagnetic fluctuations touched off by solar eruptions can induce electric currents in the Earth and in all types of networks made of conducting material, such as high-voltage power lines, oil and gas pipelines, and even the old telephone cable running along the Atlantic floor. These geomagnetically induced currents (GICs) are strong enough to disturb the operation of such networks. Ever since the spectacular incident in 1989 when a transformer in the Quebec power system was burnt out by such currents, they have been kept under close watch. This has led space weather reporting services to gain new clients, alongside the traditional satellite owners and telecommunications operators. Using



SOHO (ESA & NASA)

Huge Solar X-Ray Flare. The big explosion, which took place near the Sun's northwest limb, hurled a coronal mass ejection (CME) into space - at a whopping speed of roughly 7.2 million km/h - but not directly towards Earth



NASA Marshall Space Flight Center (NASA-MSFC)

the information from such services, power network operators can also be properly prepared for any oncoming magnetic disturbances.

The kind of interference that can be caused by such extensive solar activity was recently experienced in late 2003, as a result of a series of solar eruptions. The two last weeks of October and early November 2003 brought on a series of large solar disturbances that caused an extraordinary increase in the intensity of the interplanetary particle stream. As a result, the Earth experienced a series of strong magnetic storms that followed close upon each other, and even overlapped. The disruptions recorded on the Earth were exceptionally intense, ranging from the destruction of satellite devices to the failure of power transmission lines.

In early October 2003, there were no signs to portend the coming danger. In fact, solar activity was quite calm. Yet by the end of the second week of the month, the solar observatory in Sacramento Peak noted very strong emissions in the Sun's coronal lines (Fe XIV, Ca XV, Fe X), signaling that strong eruptions were underway on an invisible portion of the solar disc. Then the scenario continued to change drastically: hour after hour, day after day, solar activity increased up to a level that had not been seen for many years. Eleven strong bursts of X-ray radiation were observed, with an intensity that exceeded the range of the measuring apparatus. Satellites watched as a vast amount of solar material was slung out into interplanetary space, and streams of high-energy particles traversed through the Solar System. Unfortunately, the Earth stood in their path. GEOS satellites observed the three most geoeffectcive bursts on 22, 28, and 29 October, among the strongest eruptions ever witnessed by mankind.

The shock wave let loose on 28 October struck the Earth in a record time of 19 hours. On the way it deprived the ACE and Wind satellites of their plasma-observation capacity, and the measurement apparatus of the GOES satellites reached saturation point. Several satellites automatically shut down their operations, only to be recovered several days later. Other satellites automatically reset their computers. All of them, however, reoriented their solar panels so as to minimize their exposure to the forceful stream of solar particles. Communications with satellites was limited to the essential minimum, so as to limit the risk of such mes-

Filled by charged particles trapped in the Earth's magnetic field, the spherical comet-shaped magnetosphere extends out 66,000 km from Earth's surface in the sunward direction and more in other directions. When massive solar explosions, known as coronal mass ejections, blast through the Sun's outer atmosphere and plow toward Earth at speeds of thousands of kilometers per second, the resulting effects can be harmful to communication satellites and astronauts outside the Earth's magnetosphere

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ACE team, NASA

Earth aurora observed from the ACE spacecraft. Green auroras occur from about 100 km to 250 km altitude only in the auroral zones at polar latitudes

sages being misinterpreted, something highly likely under such circumstances. Most satellites were allowed to run adrift. All told, these eruptions caused complications of a larger or smaller degree for 28 satellites, both in terrestrial orbit and distantly positioned in space. The MARIE apparatus aboard Mars Odyssey in fact never resumed operation.

Yet the danger posed by these solar eruptions was not just limited to satellites: the associated extreme increase in radiation also threatened human beings. For safety, the astronauts at the International Space Station moved into the service module. And the danger stretched even further downwards than this, to the level of high-altitude plane flights: for the first time in its history, the FAA issued a warning for passengers and crews on planes traveling above 25,000 feet that there was a potential threat of receiving a large dose of radiation. On the ground, in turn, the most intense magnetic storm since 1932 was unleashed. The magnetic field fluctuations registered at both Boulder, Colorado and at the Geophysical Observatory of the Polish Academy of Sciences in Belsk looked highly unnatural: they showed a vertical line that ran off the edge of the recording scale. Mankind also witnessed spectacular auroras stretching to southern France and northern Texas (seen in Poland as well, even in the Bieszczady Mountains in the country's southeast). The entire terrestrial magnetosphere and ionosphere experienced radical changes. The change in the ionosphere's electron concentration was so great that amateur short-wave radio enthusiasts were surprised to note cases in which frequency bands 20 times beyond their usual frequency ranges could be used. In Sweden, geomagnetically induced currents were of such great intensity that they caused a high-voltage power transmission grid to fail on 30 October.

The damage done in October 2003 was undoubtedly an influential factor contributing to the fact that a second surge in solar activity seen in November 2004, only slightly weaker, did not cause such great destruction. Scientists and the respective agencies were already much better prepared. An ominous center of solar activity was first observed on the edge of the Sun's disc on 1 November, and developed

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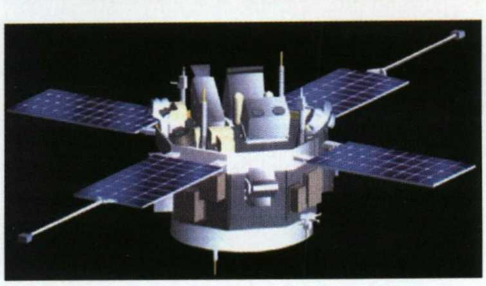
As the Sun's magnetic field rises up through the dense photopshere and chromosphere, it can form magnetic arches or loops constraining the coronal plasma like huge magnetic pipes

ACE team, NASA

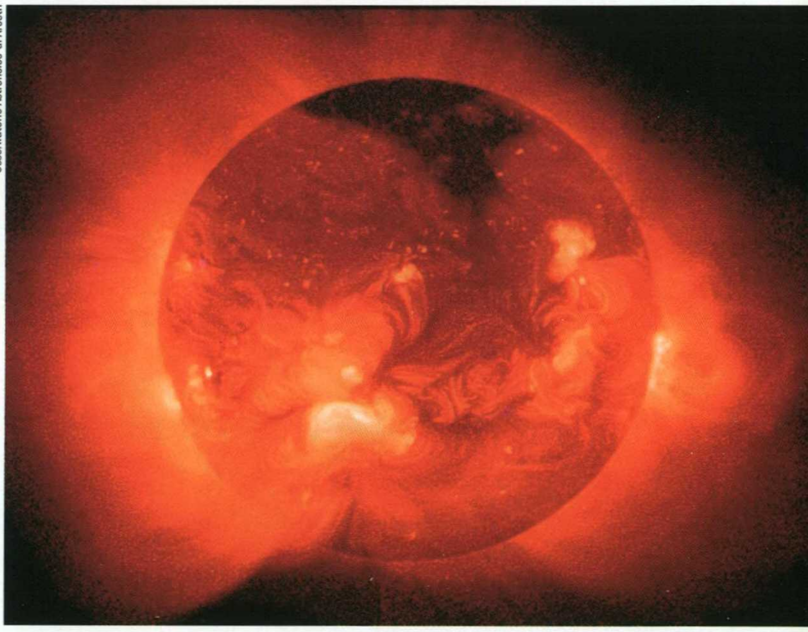


When reporting space weather, ACE can provide an advance warning (about one hour) of geomagnetic storms quickly. Between 2 and 10 November it produced 16 surges that were strong, albeit not as strong as in 2003. The shock waves touched off by these eruptions reinforced each other and reached the Earth in the form of exceptionally strong disturbances in the solar wind. The path of the first shock waves sent out into space did not in fact encompass the Earth or its close vicinity. But unfortunately, in subsequent days the rotation of the sun increasingly brought the ominous center nearer the threshold beyond which even weak eruptions could sweep through the Earth's magnetosphere and cause strong disturbances. The Earth remained exposed to strong variations in the solar wind through 17 November. By 7 November, a mighty magnetic storm had already begun on the Earth, and intense ionospheric disturbances were observed on every continent. The chemical composition of the ionosphere was transformed and its electron concentration drastically increased. Another disturbance started up before things could calm down, and the situation repeated itself after a few days. As a result, most of the previously available radio frequencies were rendered unusable. The transformation of the ionosphere changed the propagation properties not only for terrestrial waves, but for transionospheric waves as well.

Although solar eruptions cannot be prevented, it is possible to minimize their negative impact. Nevertheless, this requires accurate forecasting. Services that provide space weather news bulletins, including alerts and warnings about oncoming dangers, draw upon the real-time observations carried out using the SOHO and ACE satellites, the GOES series of satellites, and also terrestrial research. Such observations are performed by solar, magnetic, and ionospheric observatories.

One center working to keep an eye on and forecast the weather in space has been operational for many years at the Space Research Center of the Polish Academy of Sciences (http://www.cbk.waw.pl/rwc, ftp://www.cbk.waw.pl/rwc), which belongs to the ISES network (the International Space Environment Service). The Space Research Center receives measurement data from around the world, both directly from observatories and via the centers linked in the ISES network. It also hosts the Ionospheric Dispatch Centre in Europe (IDCE), which provides ongoing access to measurement data from 30 ionospheric stations, catalogs of ionospheric disturbances, and ionospherically calm and turbulent days. This makes it possible to keep close tabs on the condition of the ionophere and to make forecasts for the near future.

The releases issued by the ISES concern not just the condition of the ionosphere but also solar activity and the condition of the entire circumterrestrial vicinity. The Center also works to support operational communications services, providing essential surveys and forecasts for both the short and long term. The tools used in such work are also developed here, including models, algorithms, and forecasting techniques. The Center cooperates closely with scientists and similar services under many international and European organizations and research programs, and thus makes its own contribution to the integration of European science and technology, helping to boost the competitiveness of European science and the wider European economy. ■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Sun activity observed in the X-ray light

Further reading

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