**ASTY SPACE WEATHER** / *Since the wake-up call in 1989 when the last great solar storm almost cause a multibillion-dollar electrical disaster, scientists have been keeping their eyes on the sun*

# Watching the sun's every jolt

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On March 13, 1989, the phenomenon of space weather went from a curiosity to a world issue in the span of six seconds.

This transition began four days earlier and 150 million kilometres away when the surface of the sun, suddenly and without warning, exploded with atomic force and belched forth billions of tons of charged particles.

The strength of the blast was enough to send the behemoth cloud of solar material screaming across space at speeds as high as two thousand kilometres per second. It was headed straight for Earth.

Four days later in southern Quebec, everything appeared quiet. But no one was watching space. At 2:45 that morning, the cloud unleashed by the sun slammed into the Earth's magnetic field, compressing it and causing millions of amps worth of current to flow through the upper atmosphere.

This massive electrical charge channelled through rock formations all over the world, and then leaped into the power grids. The Hydro-Quebec electrical system, serving over three million people, collapsed in a mere six seconds under the strain, leaving the province without electricity for 17 hours.

The ferocity of this event shocked scientists. They had known about such "solar storms" since the launch of the first satellites in the late 1950s, but never before had they seen such a graphic illustration of the effects on Earth.

## *Attitudes changed quickly, and a new profession was born*

In the aftermath, power companies in the eastern United States reported that the entire coast had come perilously close to losing power — a shutdown which would have cost up to $6 billion. The event was dubbed the "Great Storm" — the day the weather in space turned nasty.

In the months following, researchers, industry, and government alike struggled to understand this newly discovered threat from space, and to figure out a way to defend themselves.

"Attitudes changed overnight," says David Boteler, a physicist with the Geological Survey of Canada's National Geomagnetism Program.

"People realized that they needed to do something about this."

It was agreed the best protection against the sun was to keep apprised of the outbursts that our star routinely throws our way. Thus came the mainstreaming of a new profession — space weather forecaster.

Physicists like Boteler, meteorologists and even engineers began to turn away from their previous professions to look toward the sun. And as they watched, the question on their minds was — could the Great Storm happen again?

The answer appears to be a resounding yes, and there is unsettling evidence to suggest that the next big one could come during 2001. The reason relates to an incredible observation first made during the 1800s when astronomers began to seriously study sun spots — dark patches which are constantly appearing on the face of the solar sphere.

### FLARES AND CMEs

■ A flare is a sudden, rapid, and intense variation in brightness. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time.

■ Coronal mass ejections are sometimes accompanied by solar flares, but it is now known that most CMEs are not associated with flares. If a CME collides with the Earth, it can excite a geomagnetic storm. Large geomagnetic storms have, among other things, caused power outages and damaged communications satellites.

*NASA/Goddard Space Flight Center*

Watching over decades, the early solar scientists found that sun spot numbers tended to increase according to a cycle, consistently reaching maximum concentrations every 11 years.

What seemed like an innocuous curiosity then turned out to be of critical importance two hundred years later when space weather workers studying solar storm data were shocked to find that storm activity follows the same pattern.

"Storm frequency seems to increase with increased solar activity," says Richard Coles, a forecaster with the Canadian Geomagnetism Program.

"Magnetic data has been correlated back 150 to 160 years." Indeed, looking at a chart of yearly storm activity, one sees a series of repeating peaks, roughly 11 years apart. Forecasters realized that the year of the Great Storm, 1989, had been one such peak. They predicted that the dawn of the new millennium would bring another.

Just as the hurricane season brings conditions that are right for the formation of tropical storms, the solar maximum appears to be a time when conditions within the sun are right for generating large explosions of charged particles. These events, known as coronal mass ejections (CMEs), are still poorly understood, but they appear to be related to the rotation of the sun's gaseous surface.

When a CME occurs, the Earth is in a cosmic shooting gallery — the outgoing cloud may well be aimed harmlessly off into space, but odds are that once in a while the explosion will point toward us. It is then only a matter of time until a storm hits.

The effects of these storms on Earth are startling. The interaction of solar particles with our planet's own magnetic field creates an incredible amount of electricity. "If you've ever seen the northern lights," says Boteler, "flowing along that arc is a large current."

But what appears as a beautiful light show to many people, can pose great risk to utilities. During large storms, the extra current can be enough to overload transformers at power stations, damaging equipment and infrastructures. During a storm in 1992, workers for Alleghany power in the eastern U.S. were shocked to see the temperature of one of their transformers suddenly jump by more than one hundred degrees.

The effects of solar storms on space technology can be equally devastating, disrupting transmissions and even severing pieces from orbiting elec-

tronics. In 1994, television transmissions across Canada were cut off when the Anik E1 satellite was destroyed by a long-lasting storm event. A similar event in 1997 damaged the AT&T Telstar 401 satellite, disrupting calls around the world.

Ultraviolet radiation is another hazard of storms. Usually levels are insignificant, but during events such as in 1989, passengers on trans-Atlantic flights could receive the equivalent of as many as one hundred chest x-rays. The effects on astronauts could be even greater.

Spurred by the spectre of these dangers, space weather workers have been striving to prepare for the current solar maximum. In 1995, the U.S. government created the National Space Weather Program to co-ordinate forecasting efforts. Space agencies worldwide aided the program by launching more than ten satellites dedicated solely to observing the sun and the storms it creates.

## *Protective measures defend against each solar onslaught*

This new technology has made the jobs of forecasters a lot easier. In 1996, the forecasting success rate jumped from 30 to 50 per cent. The next five years saw accuracy increase more, with power utilities and other industries beginning to pay close attention to forecasters' daily reports. Everything appeared ready for the sun's maximal onslaught.

The first big test of the solar maximum came last July, when workers at the Space Environment Center in Boulder, Colo., spotted a large mass ejection coming off the sun.

Realizing this could be the moment they had been preparing for, forecasters issued a storm warning for July 14. When the day arrived, everyone waited breathlessly to see if they had accurately predicted the assault. Their estimate of the storm's onset time was correct almost to the hour.

These kinds of warnings allow power companies to initiate protective measures such as reducing the current flowing through their systems or using locally-generated power instead of current from distant sites, which is vulnerable to space weather as it travels along power lines.

"It was just a great job by the guy on duty," smiles Joe Kunches, a forecaster with the National Oceanic and Aeronautical Administration.

"I wish it had been me."

But as the dust settled it became apparent that the storm, although being classified as an S3 or "strong" event, was not the Great Storm II. Apart from some satellite interruptions, there had been very few effects felt on Earth. Indeed, the past year has been somewhat anticlimactic in terms of space weather, with other strong storms occurring only in February and April.

All of this has left forecasters wondering — are we out of danger from the sun? Not yet, cautions Kunches, observing that the solar maximum is "more of a season than a point."

Indeed, a panel convened in 1996 estimated that this "storm season" could last until 2005, meaning that space weather forecasters need to keep sharpening their skills.

And there's certainly still improvements to be made. The main problem with forecasting lies in what Kunches calls "Chicken Little experiences" — predicted storms that never materialize.

Such occurrences are common, owing mainly to a lack of understanding about what happens as a CME travels from the sun to the Earth.

As Kunches explains: "Not all of those things coming away from the sun have the right stuff to cause a storm, but based on the data we have right now, we can't tell. So you sit in your chair in the forecast centre with your knuckles turning white, hoping that things are going to play out the way you expected."

But things seem to be playing out well for forecasters, with the Space Environment Center realizing a two to three day forecast of most storms.

And this work is becoming ever more important as new research shows just how affected we are by the sun. A conference on space weather effects held by the NATO Advanced Science Institute last year featured presentations linking solar activity to climate change, the size of newborn babies, the spread of disease, and even the worldwide incidence of heart attacks.

And with the sun predicted to have another five billion years' worth of power left, it's likely that the need for space weather work is going to continue to grow proportionally to the advance of technology.

"It's a field with a lot of energy," says Kunches.

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