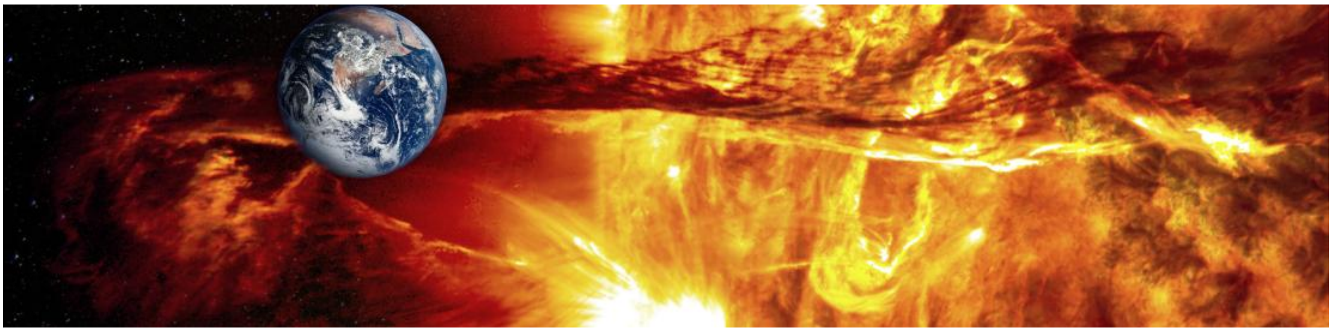
Horizon
The EU Research
& Innovation Magazine

European Commission



Space researchers build traffic light system to warn of dangerous solar storms

Researchers have created an improved traffic light system for predicting geomagnetic storms. They are now testing how well these algorithms can prepare us for incoming space storms that can wreak havoc by knocking out satellites in space and power grids on Earth.

23 January 2025 - By JONATHAN O'CALLAGHAN

Yuri Shprits, a space scientist at the German Research Centre for Geosciences in Potsdam, is on a mission to save our planet.

We have known for a long time that much of our modern way of life is threatened by the whims of the Sun. If our star suddenly enters a more active period, it can cause geomagnetic storms that knock out satellites or cause blackouts on Earth.

But can we predict when these storms will arrive, how they will affect the Earth's environment and infrastructure and ensure we are prepared? This is what Shprits has been working on, starting with an EU-funded project named PAGER that ran from 2020 until 2023.

Predicting space weather

The researchers' goal was to develop an algorithm that could pull data from Sun-observing telescopes and satellites together with data from Earth-orbiting satellites. Based on that, they could predict when a dangerous geomagnetic storm is heading in our direction and what the consequences would be for the infrastructure in space and on the ground.

To that end, the researchers connected different computer models of the solar environment and near-Earth space.

In a best-case scenario, said Shprits, it could "take us an hour or two to calculate what would arrive to Earth and what effects it would have in the near-Earth environment, but it would actually take two days for this disturbance to arrive".

As it can take another couple of days for the radiation that can be harmful to satellites to build up, this could allow some time to prepare.

The algorithm devised by the PAGER team is now being put through its paces to see how useful it can be.

"After decades of fundamental space research, that started with the first US satellite discovering harmful space radiation in 1958, we are finally at a point where we have reached predictive capabilities," said Shprits. "We're very excited."

Storm front

A geomagnetic storm occurs when a powerful eruption from the Sun interacts with our planet's magnetic field.

As solar wind travels from the Sun to Earth, it can carry charged particles that interact with Earth's protective magnetic field. These get further heated inside the magnetosphere, creating highly energised particles that can be harmful to satellites.

The collision of these particles with particles in Earth's atmosphere can produce the magnificent aurorae seen from Earth. But they also pose a danger as they can interfere with satellites' electronic systems. Such geomagnetic storms have hit our space installations quite recently.

In February 2022, the US company SpaceX lost 38 of its Starlink internet satellites when a powerful geomagnetic storm pulled them back into Earth's atmosphere after they had launched.

The US firm Intelsat, meanwhile, lost control of its Galaxy 15 satellite in April 2010 because of a geomagnetic storm. "It started drifting, threatening other spacecraft, due to frequency interference," said Shprits. "This could be very costly because the price of a spacecraft can be over a billion euros."

Geomagnetic storms also cause problems on Earth. The electric currents they create can overload power plants and cause temporary blackouts. This occurred in Quebec, Canada, in 1989, when a geomagnetic storm caused a widespread nine-hour blackout.

Very strong storms in October and November 2003 caused a disruption of satellite services, anomalies on numerous satellites, and disruption of communication, power grids, and GPS navigation in many regions around the globe.

Radiation belts

Most near-Earth satellites also operate in Earth's radiation belts, a region of space up to almost 58 000 kilometres above our planet where many charged particles become trapped by Earth's magnetic field. These belts can dramatically intensify during storms.

"GPS satellites operate in the heart of these belts where the radiation is the most damaging," said Shprits. Even though these spacecraft are well protected, the most energetic particles can penetrate their shielding and still damage them.

To protect against solar events, countries in Europe and the US have space weather prediction centres that can forecast when bad storms will arrive on Earth. However, until recently, these predictions were not connected to models able to predict radiation in space, how this radiation would penetrate spacecraft or the potential effects on Earth.

In the PAGER project, scientists from Europe and the US combined the models from the Sun and solar environment with those for the Earth environment to develop a comprehensive predictive system.

Shprits pointed out that “some of the space weather predictions are really complex and convoluted and stakeholders sometimes do not have PhDs in space physics. They just want to know if it’s going to be safe or not.”

Space traffic light

The PAGER team’s goal was therefore to create a simple traffic light system based on predictions. It tells a satellite operator if conditions in space are likely to be safe or not.

Using PAGER, an operator will immediately know if the situation is red and they should consider temporarily switching satellites into protective mode or if power grid operators need to take preventive measures. Yellow means they need to be wary of potential effects, while green signals that everything is fine.

“Green means ‘don’t worry, nothing is happening’,” said Shprits. “Sometimes that’s actually the most useful for them because with storms, they want a clear sign they can go back to normal operations.”

To make these calculations, PAGER is constantly running on powerful machines at a computer centre at the German Research Centre for Geosciences.

“Usually the most difficult predictions are done in the middle of the night so that it doesn’t overload the computers,” said Shprits.

He said his team has moved to predicting probabilities, explaining that it is virtually impossible to make very precise long-term predictions of the effects of the storm.

“If we say that, with a certainty of 80%, there will be very harsh conditions in space, it’s the same as terrestrial weather, when we are told there is an 80% chance of rain.”

“That gives us an idea that it’s better to take an umbrella. It’s the same with satellites.”

Refining models

Shprits is currently in discussions with the European Space Agency (ESA) for a new project that would allow ESA to adopt some of the PAGER models in its operation.

The goal is to continue improving the prediction services and make the analysis of incoming space weather events better and better.

“We’re trying to use machine learning in many places and blend it into this infrastructure. We are also trying to use all the available real-time data and blend it with our predictions so that the measurements can refine our models.”

Another thing that could help is more satellite data. Shprits explained that an upcoming ESA project to monitor the near-Earth radiation environment will provide “real-time measurements of the harsh radiation in the magnetosphere that would be really useful for us”. It will do so by flying through the radiation belts and taking measurements.

“There are also proposals to put radiation detectors on all commercial spacecraft,” he said. “That would certainly help us get a much better and bigger picture of what’s going on in space. We have now developed tools to use all this data and improve our predictions.”

Research in this article was funded by the EU's Horizon Programme. The views of the interviewees don't necessarily reflect those of the European Commission. If you liked this article, please consider sharing it on social media.

More info

- PAGER
- PAGER project website
- EU research and innovation for space