New network is installed to investigate space weather over South America

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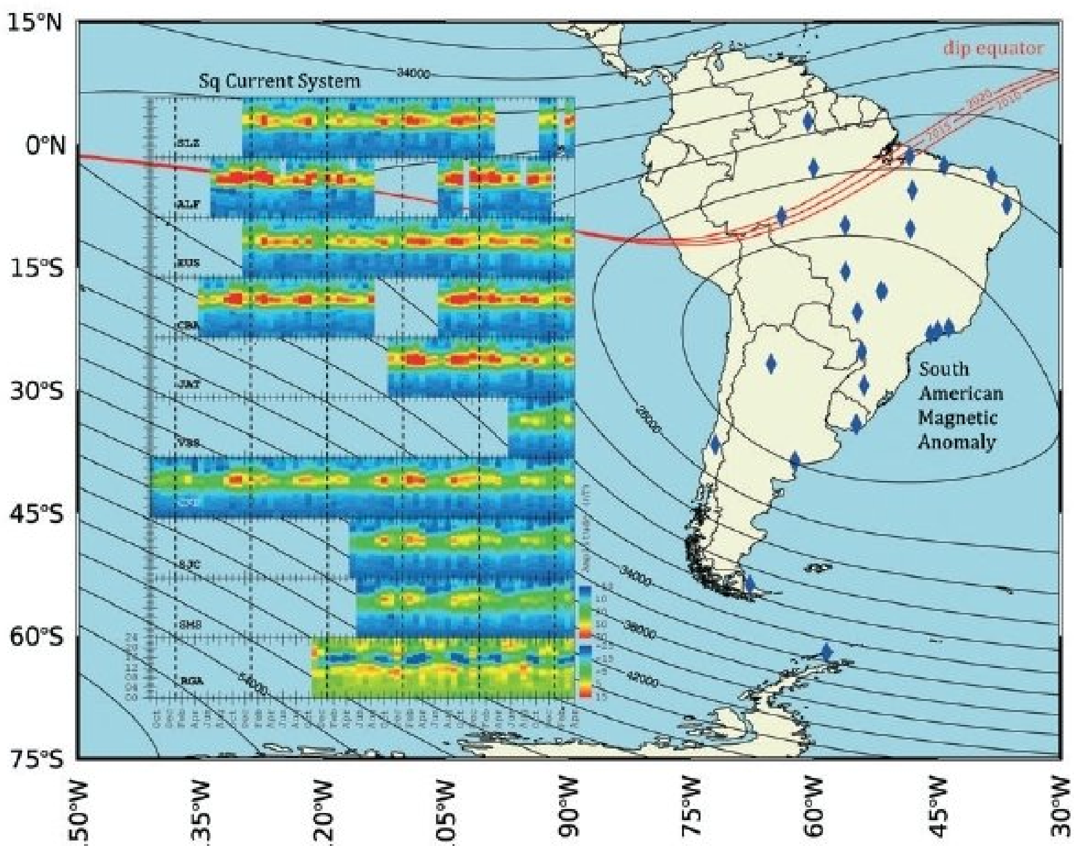

Magnetometer network identifies magnetic field disturbances that can cause interference in electronic appliances, power grids and satellite navigation systems . Credit: Radio Science

A group of Brazilian researchers affiliated with the National Space

Research Institute (INPE) is working to install a network comprised of magnetometers (instruments used to measure the intensity of a magnetic field) across South America.

The Embrace Magnetometer Network for South America (Embrace MagNet) involves joint efforts from other Latin American institutions with the aim of studying the specific characteristics of magnetic field disturbances over the continent and comparing their intensities with those occurring elsewhere in the world. The possible damage done by space weather to electronic appliances is also a primary subject.

Located in Sao Jose dos Campos, Brazil, at the headquarters of the National Space Research Institute (Inpe), Embrace MagNet already has 13 magnetometers up and running. When the network is complete, it will consist of 24 magnetometers installed in 16 Brazilian states and Argentina, Chile and Uruguay.

Before Embrace MagNet, South American researchers depended on data from institutions in the U.S., Europe and Japan to study magnetic field disturbances over South America, according to INPE's head of space and atmospheric sciences, Clezio Marcos De Nardin.

"Magnetic disturbances aren't equivalent in the northern and southern hemispheres. Several publications in the scientific literature show that the aurora borealis and aurora australis aren't symmetrical, either," says the researcher. "Based on their data, when we heard that the magnetic field was disturbed, we had no idea if the disturbance had reached Brazil or whether we could assume the disturbance occurred in this sector," he adds.

The initiative was the subject of two articles penned by De Nardin and colleagues, recently published in *Radio Science*, a journal of the American Geophysical Union. The first article describes the network's scientific objectives and details its design, equipment, and installation and the treatment of the data it produces. In the second article , the authors disclose the initiative's first scientific results.

Solar eruptions cause important phenomena in the magnetic field. They eject electromagnetic radiation (light) and massive amounts of highly energized particles into space. Traveling at more than 2 million kilometers per hour, the particles reach Earth in a few days, bombarding the magnetic field that surrounds and protects the planet.

Interactions among energized solar particles and Earth's magnetic field cause disturbances around the globe, producing auroras in the stratosphere over the North and South Poles.

"In the auroral regions, the interactions of magnetic clouds with the magnetic field creates a system of currents at an altitude of 100 km that can damage equipment on the ground," said co-author Paulo Roberto Fagundes. Fagundes is a professor at the Paraíba Valley University (UNIVAP) in São José dos Campos, São Paulo State.

The solar phenomena that reach Earth can cause interference in satellite navigation systems, such as the GPS used by motor vehicles, aircraft and ships, whose operation would be severely degraded. Solar eruptions can also induce electric currents in power line transformers and affect the protection of oil and gas pipelines.

In the case of power plants, the consequences can be even worse. When a solar magnetic cloud strikes Earth's magnetic field, auroras appear in the sky and electric currents in the ground. In the vicinity of a hydroelectric power plant, the currents can damage transformers and disrupt the grid, causing a blackout.

Such a scenario happened in North America on March 13, 1989, three and a half days after a huge solar storm and solar flare. The phenomena induced powerful currents in the ground at various locations in North America, causing a nine-hour outage in the Canadian province of Quebec and a major breakdown in satellite transmission, weather satellites and others.

"Recent studies published in the journal *Risk Analysis* estimate that, if a geomagnetic event like the 1989 solar storm were to occur today, it would cause damage amounting to between $2.4 trillion and $3.4 trillion globally," De Nardin said.

It doesn't take a huge solar storm to damage the power grid, however. Any solar storm causes ground currents that affect transformers. Additionally, hydroelectric power plants built next to large dams and reservoirs are especially vulnerable to the ground currents caused by solar storms. The water in reservoirs boosts current transmission. Worse still, as water flows through turbines in powerhouses, it transmits the current directly to the transformers.

Higher or lower frequencies of solar explosions are directly linked to the solar cycle (that is, the solar magnetic activity cycle), which lasts 11 years and is characterized by successive increases and decreases in the number and surface area of sunspots.

"At times of peak solar activity, transformer degradation worsens. Papers published by the IEEE [Institute of Electric and Electronics Engineers] based on research conducted in South Africa show that transformers can explode if proper maintenance is not done," said De Nardin, who is also Deputy Director of the International Space Environment Service (ISES), a collaborative network of space weather service organizations around the globe.

Based on their analysis of the mountain of data collected every day by

Embrace MagNet, Brazilian researchers are developing a specific magnetic K-index for South America called the Ksa index. K-indices quantify disturbances in the horizontal component of Earth's magnetic field and characterize the magnitudes of geomagnetic storms.

"Our aim is to produce a K-index specifically for South America, hence the 'sa' in the acronym. We already know that what happens in the rest of the world isn't the same as what happens here," De Nardin said. "In addition, we also managed to capture the variation in a solar explosion at the moment radiation from the sun reached Earth, before the storm."

In addition to studying the magnetic field using Embrace MagNet, the project has also produced an important scientific discovery, says Fagundes. "We detected the existence of a fourth layer in the ionosphere, the F4 layer."

The ionosphere is the portion of Earth's upper atmosphere that is found between approximately 60 km and 500 km above the surface. Solar radiation ionizes the atoms and molecules within this layer, creating a layer of electrons. "We knew about the F1, F2 and F3 layers. Now, we've discovered F4, the outermost layer, above 350 km in altitude. We're investigating the mechanism that creates this structure," Fagundes said.

More information: C. M. Denardini et al, The Embrace Magnetometer Network for South America: Network Description and Its Qualification, *Radio Science* (2018). DOI: 10.1002/2017RS006477

C. M. Denardini et al. The Embrace Magnetometer Network for South America: First Scientific Results, *Radio Science* (2018). DOI: 10.1002/2018RS006540

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