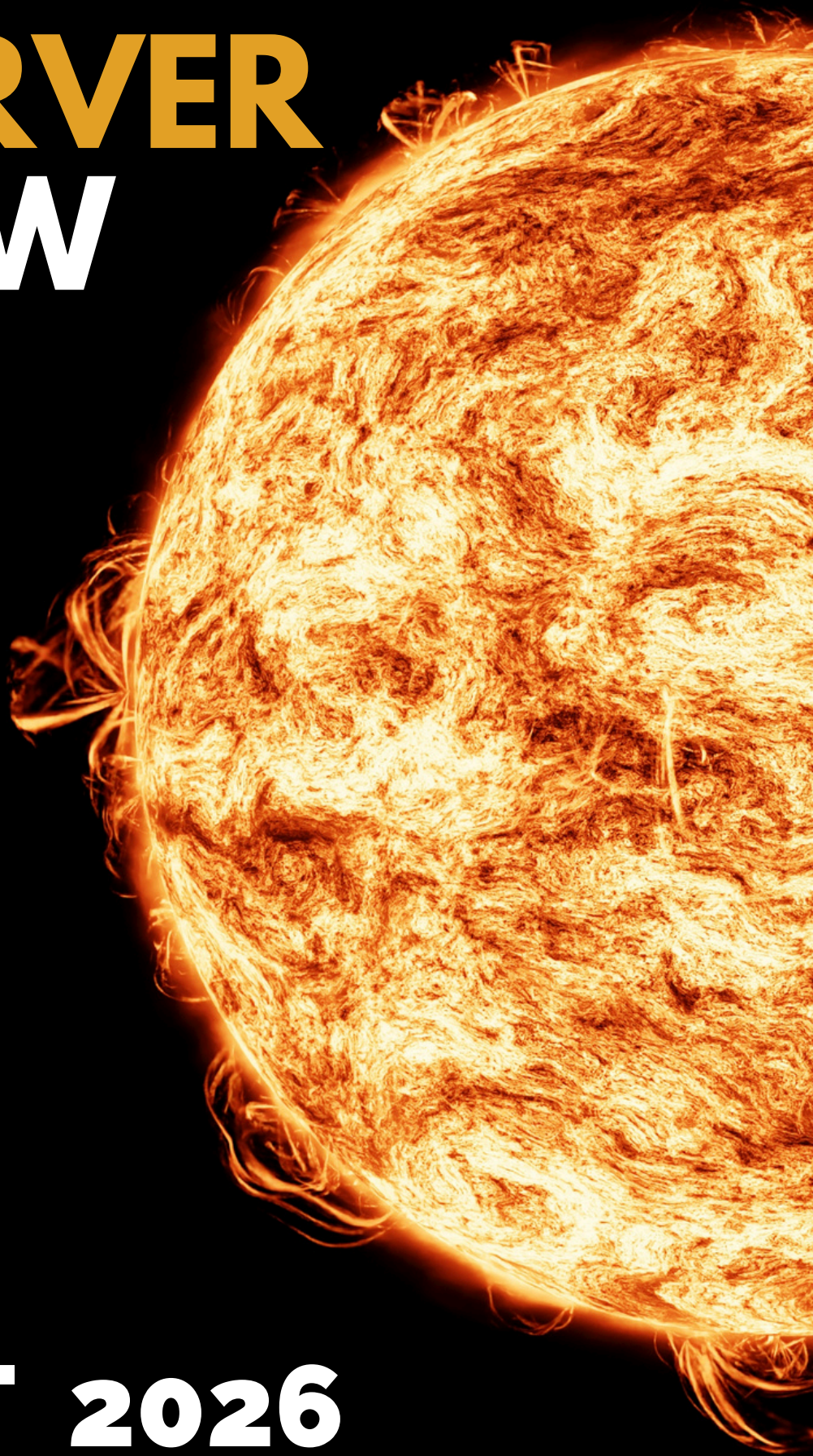


THE OBSERVER REVIEW



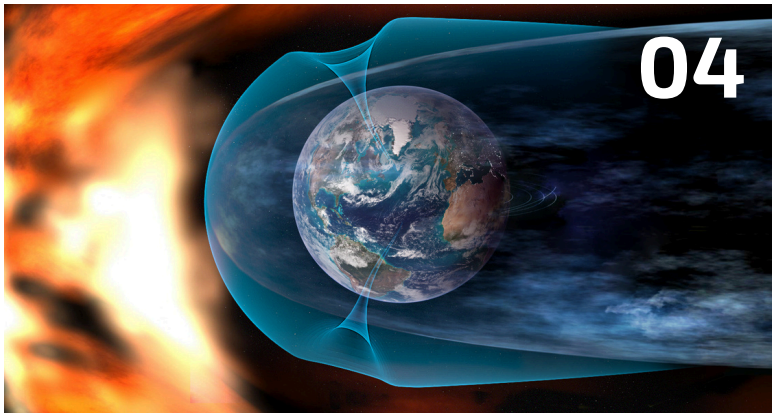
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THE MOLECULAR COMPASS

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

THE MOLECULAR COMPASS: EXPLORING THE BIOLOGICAL GPS IN HUMANS, BIRDS, AND OTHER ANIMALS

The Molecular Compass: Exploring the Biological GPS in Humans, Birds, and Other Animals examines the emerging science of magnetoreception, the biological ability to detect and respond to magnetic fields, and the molecular mechanisms that could allow living organisms to sense something humans cannot consciously see.

One of the strongest examples comes from migratory birds. Behavioral experiments have established that many birds can orient themselves using Earth's geomagnetic field, helping them maintain direction across migrations spanning hundreds or thousands of miles. Unlike an ordinary compass that distinguishes magnetic north from south, the avian system appears to function largely as an inclination compass, detecting the angle at which magnetic field lines intersect Earth's surface.

This mechanism is particularly intriguing because it connects quantum-scale processes with animal behavior. Laboratory research has shown that Earth-strength magnetic fields can alter radical-pair chemistry, while experiments involving European robin cryptochrome 4, or CRY4, demonstrated that the protein itself is magnetically sensitive in vitro. Researchers also found that CRY4 from migratory European robins showed greater magnetic sensitivity than corresponding proteins from non-migratory chickens and pigeons.

The location of these proteins adds another piece to the puzzle. Cryptochromes have been identified in bird retinas, raising the possibility that magnetic information is integrated directly into the visual system. Rather than "feeling" north as a separate sensation, a bird could potentially perceive magnetic direction as a pattern or modulation layered onto normal vision. Neural experiments further support this connection: a vision-associated region of the migratory bird brain known as Cluster N becomes active during magnetic orientation, and disrupting this region interferes with the bird's ability to use its magnetic compass.

Evidence from pigeons strengthens the biological case. Research on pigeon CRY4 found that the protein forms long-lived, spin-correlated radical pairs and is widely expressed within the retina, including regions associated with signaling between retinal cells.

ELECTRIC FIELDS PUSHES SOUTH ATLANTIC ANOMALY RADIATION

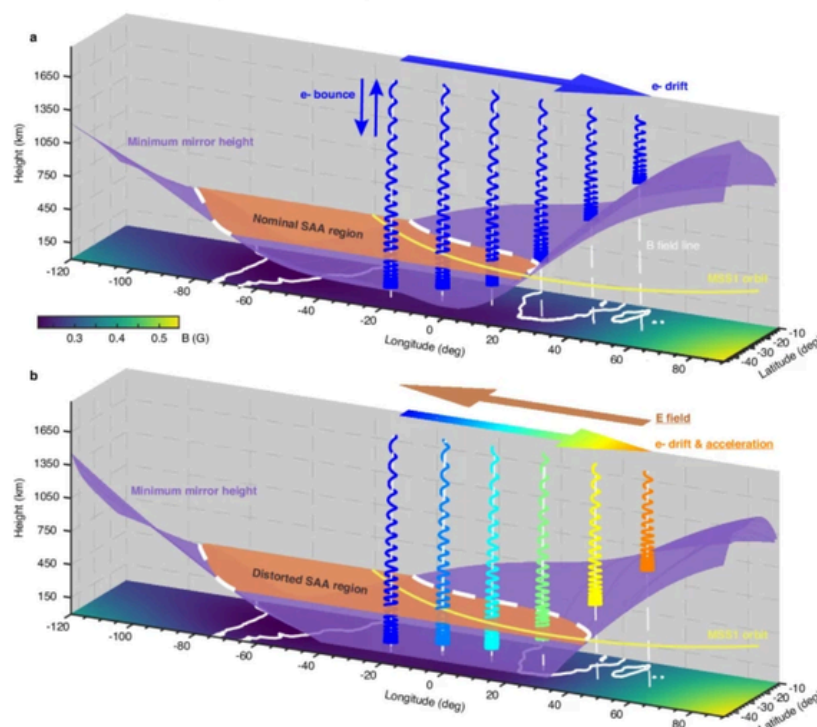
BY: BAILEY LAURISSA

ARTICLE REFERENCED:

[HTTPS://AGUPUBS.ONLINELIBRARY.WILEY.COM/DOI/FULL/10.1029/2026GL123119](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2026GL123119)

Using energetic-electron measurements from the Macau Science Satellite-1 mission, researchers identified unusual bursts of radiation outside the nominal South Atlantic Anomaly. These appeared in several forms, including isolated spikes or “vertical stripes,” repeated stripes, and continuous eastward expansions of the radiation region. In some observations, the distortion extended as much as 30 degrees in longitude beyond the expected boundary.

Fig. 1: Schematic illustration of the transient distortion of the SAA radiation environments driven by electric-field perturbations.



The researchers propose that large-scale electric-field disturbances are responsible. Normally, energetic electrons in the inner radiation belt follow trajectories controlled largely by Earth's magnetic field. When a westward-directed electric field develops, however, eastward-drifting electrons can gain energy. As their energy changes, their magnetic "mirror points," the locations where particles reverse direction along magnetic field lines, can move downward. Electrons that would normally remain above a low-orbiting satellite can therefore temporarily descend to spacecraft altitude outside the traditional South Atlantic Anomaly boundary.

The team analyzed three events recorded during 2024 and used test-particle simulations to reproduce the observed radiation patterns. Their modeling suggests that some of these disturbances involved electric fields with amplitudes of several millivolts per meter, lasting roughly 10 minutes. Weaker or shorter disturbances failed to reproduce the radiation enhancements, while stronger interactions could turn an isolated radiation stripe into a continuous expansion of the South Atlantic Anomaly.

One event revealed an additional layer of complexity. Researchers detected recurring radiation stripes with a periodicity of roughly 175 seconds. At the same time, a ground magnetometer detected ultra-low-frequency activity near 6 millihertz, corresponding to a period of about 167 seconds. The close match suggested that ultra-low-frequency waves were modulating the electric fields and repeatedly moving electron mirror heights above and below satellite altitude. Simulations combining a pulsed electric field with ultra-low-frequency wave perturbations successfully reproduced the repeating radiation pattern.

The distortions could also become a new way of studying near-Earth electric fields. Because these fields are difficult to measure directly, scientists may be able to use changes along the South Atlantic Anomaly boundary as a kind of remote sensor. Satellite particle measurements combined with electron-trajectory simulations could help determine when an electric-field disturbance occurred, how strong it was, and how long it lasted.

Fig. 8: Measurements from ground-based magnetometer during Event III.

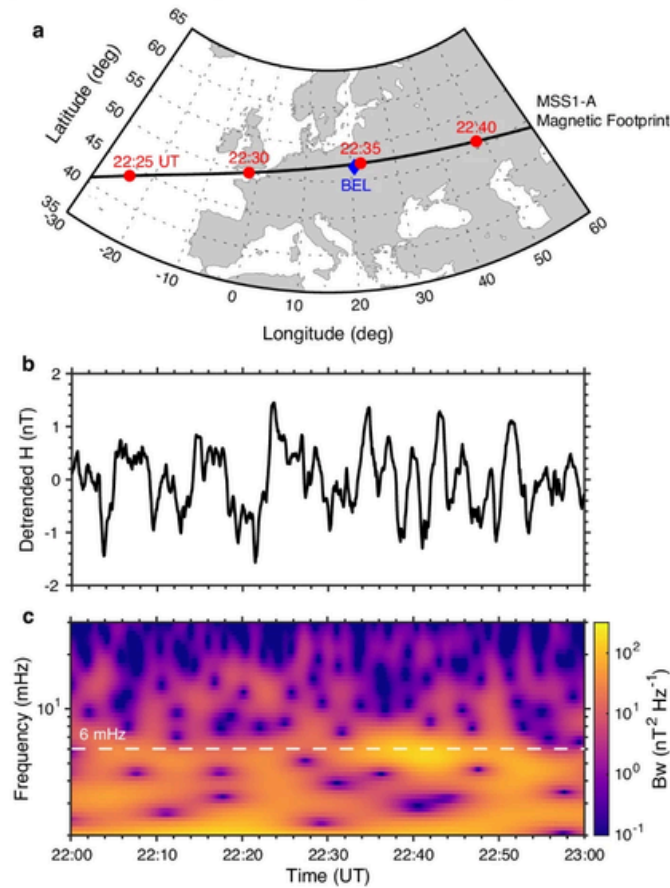
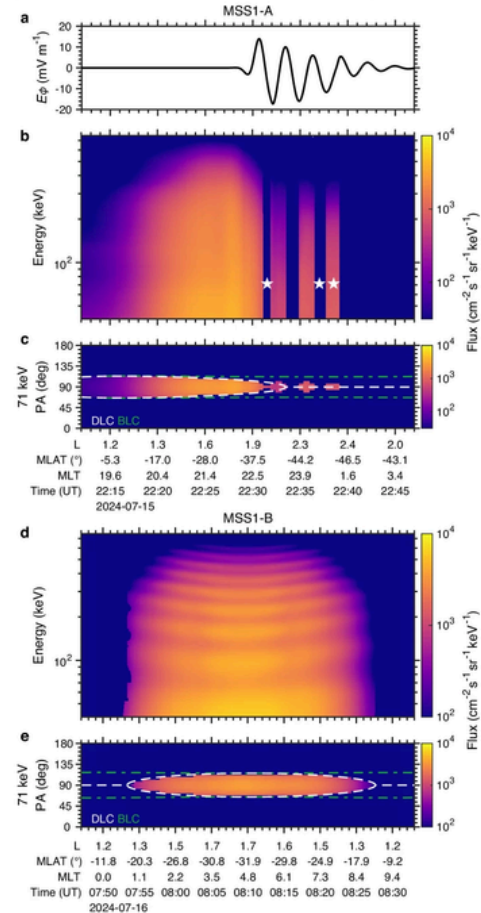


Fig. 9: Simulation results for Event III with recurrent vertical stripes.



EXTREME GEOMAGNETIC STORM EXPOSES HIDDEN RISKS TO POWER GRIDS

BY: BAILEY LAURISSA

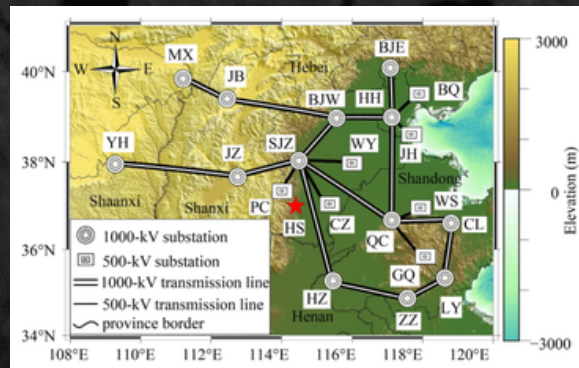
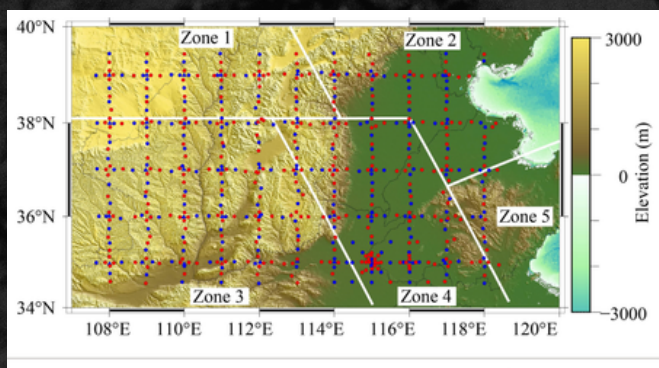
ARTICLE REFERENCED:

ESTIMATING THE GEOMAGNETICALLY INDUCED CURRENTS IN THE 1,000 KV POWER GRID OVER NORTH CHINA DURING THE MAY 2024 GEOMAGNETIC STORM: ACCOUNTING FOR ANISOTROPIC EARTH CONDUCTIVITY

The researchers focused on North China's ultra-high-voltage power grid during the geomagnetic storm of May 9–15, 2024. Geomagnetic storms disturb Earth's magnetic field, producing electric fields at the surface that can drive unwanted electrical currents through long conductors such as transmission lines. Known as geomagnetically induced currents, these currents can enter transformers and substations, interfere with grid operation, and in severe cases contribute to equipment damage or power disruptions.

A major challenge in estimating these currents is understanding the electrical conductivity of the ground beneath the grid. The researchers compared several approaches, including one-dimensional resistivity models, three-dimensional isotropic models, three-dimensional anisotropic models, and observed magnetotelluric impedance data. An isotropic model assumes electrical properties are essentially the same in every direction, while an anisotropic model accounts for the fact that underground rock formations may conduct electricity differently depending on direction. That distinction proved significant during the extreme May 2024 storm. At some substations, including the JB substation, incorporating anisotropy changed calculated geomagnetically induced currents by as much as 90 amperes compared with an isotropic three-dimensional model. Differences between some modeling approaches exceeded 300 amperes at individual substations.

Using magnetotelluric observations and the May 2024 storm conditions, researchers ultimately identified six high-risk substations, primarily situated in high-resistivity regions of the southern North China Plain, Lvliang Mountains, and Taihang Mountains. No substations reached the same high-risk classification during the more moderate March 2023 storm.



EARTH IS THE WORLD'S LARGEST NATURAL CAPACITOR

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

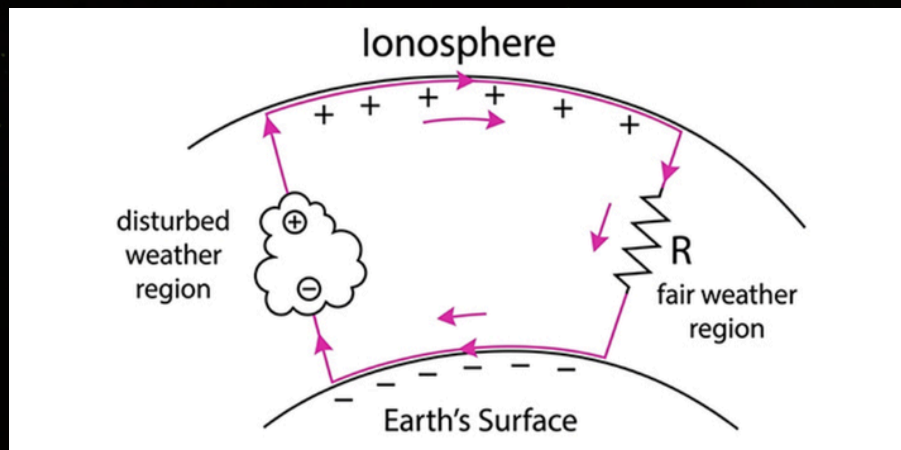
WHERE IS THE WORLD'S LARGEST CAPACITOR?

Published in Physics Education, researcher Ching-Chi Chu uses the global atmospheric electric circuit to demonstrate how the same electrical principles found in a small electronic component also operate across the entire planet. In this model, Earth's surface and the ionosphere act like the two conducting plates of a capacitor, while the atmosphere between them serves as a weakly conducting insulating layer.

THE SYSTEM IS CONTINUOUSLY ENERGIZED BY THUNDERSTORMS AND ELECTRIFIED CLOUDS, WHICH HELP MAINTAIN A POTENTIAL DIFFERENCE OF ROUGHLY 250,000 VOLTS BETWEEN EARTH'S SURFACE AND THE IONOSPHERE.

ELECTRICAL CHARGE SPREADS THROUGH THE CONDUCTIVE IONOSPHERE AND RETURNS TOWARD THE SURFACE THROUGH FAIR-WEATHER REGIONS, CREATING WHAT SCIENTISTS CALL THE GLOBAL ATMOSPHERIC ELECTRIC CIRCUIT.

One of the study's most surprising comparisons is the estimated capacitance of this enormous system. Depending on assumptions about the effective height of the ionosphere, the Earth-ionosphere system has a capacitance of approximately 0.1 to 1 farad. That means its capacitance can be roughly comparable to a small, handheld 1-farad supercapacitor.



ANCIENT LAVA FLOWS

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

LASCHAMP AND GREENLAND-NORWEGIAN SEA EXCURSIONS RECORDED IN NE IBERIA LAVA FLOWS: LATE QUATERNARY GEOMAGNETIC DATA FROM LA GARROTXA VOLCANIC FIELD

Ancient lava flows in northeastern Spain have preserved evidence of multiple periods when Earth's magnetic field became dramatically weaker and unstable, including the Laschamp and Greenland–Norwegian Sea geomagnetic excursions. The findings provide the first volcanic record of multiple Quaternary geomagnetic excursions from the Iberian Peninsula and add an important new dataset for reconstructing how Earth's magnetic field behaved during the Late Pleistocene.

Researchers studied basaltic lava flows from the La Garrotxa Volcanic Field in northeastern Iberia, spanning approximately 134,000 to 16,000 years ago. Volcanic rocks are particularly valuable for studying ancient magnetism because, as lava cools, magnetic minerals within the rock can lock into alignment with the surrounding geomagnetic field. This thermoremanent magnetization effectively creates a snapshot of both the field's direction and, under suitable conditions, its strength at the time of an eruption.

The researchers recovered paleomagnetic directions from 14 oriented sites and conducted extensive paleointensity experiments to determine how strong the magnetic field was when individual lava flows cooled. The resulting measurements revealed substantial changes in both magnetic direction and intensity. Most reconstructed virtual geomagnetic poles remained relatively close to geographic north, but one lava flow produced an exceptionally anomalous pole at a latitude of roughly 20 degrees, indicating a major departure from the field's normal configuration.

Even more striking were the changes in field strength. Reliable paleointensity measurements ranged from approximately 3.5 to 39.7 microteslas, while reconstructed Virtual Axial Dipole Moments ranged from about 0.59 to $6.69 \times 10^{22} \text{ A}\cdot\text{m}^2$.

Several lava flows therefore formed during periods when the global magnetic field was substantially weaker than its more stable states.

When the ages, magnetic directions and field strengths of the lava flows were compared with global geomagnetic models, the researchers found that the weak-field intervals corresponded with known episodes of geomagnetic instability.

Most notably, the record is consistent with the Laschamp excursion and the Greenland–Norwegian Sea excursion, along with another weak-field interval between the Blake and Post-Blake geomagnetic events.

During these periods, reconstructed dipole strength dropped to markedly low levels, with values around $2.5 \times 10^{22} \text{ A}\cdot\text{m}^2$ or lower in portions of the record.

The La Garrotxa record is important because volcanic rocks can preserve relatively rapid changes that may be blurred in sedimentary records. Sediments accumulate gradually and can smooth short-lived magnetic variations, while rapidly cooling lava can capture the field existing during a much narrower interval of time.

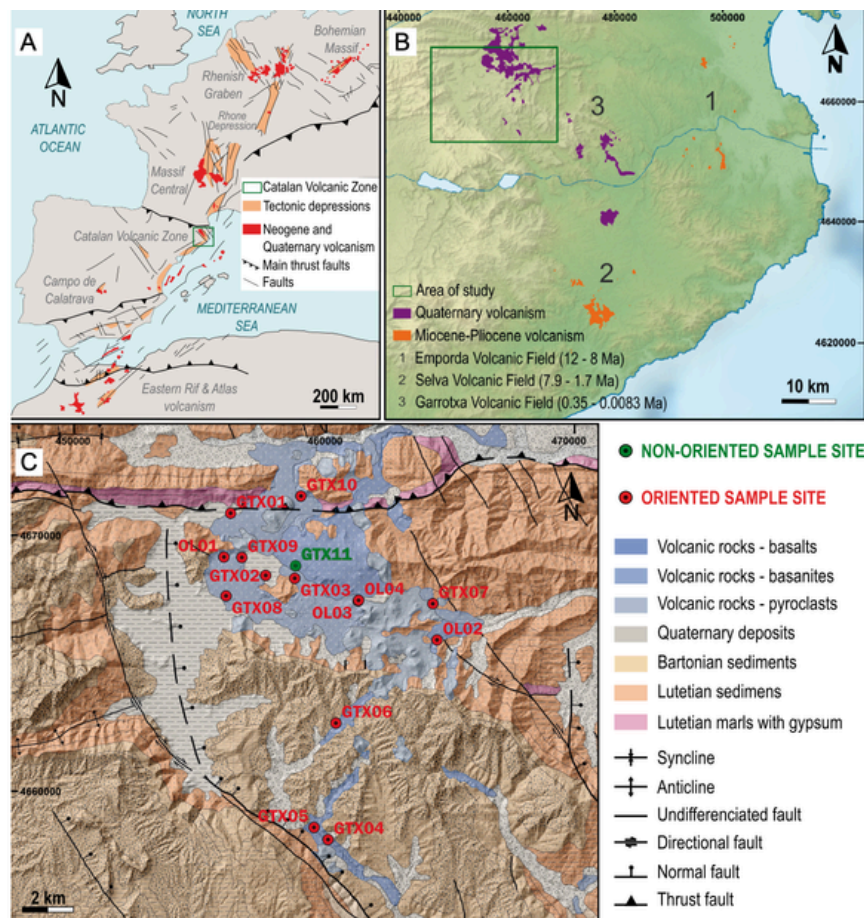


FIGURE 1. (A) European Cenozoic Rift System and its main alkaline volcanic provinces (modified from [Martí et al., 2017](#)). (B) Distribution of the main outcrops of the Catalan Volcanic Zone volcanism and location of the study area (modified from [Martí et al., 2025](#)). (C) Simplified geological map of the sampling area within the Garrotxa Volcanic Field (Ortophoto from ICGC Catalunya and Digital Elevation Model from IGN).

ELECTRON MICROBURSTS

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

ULTRA-LOW-L SUB-MEV ELECTRON MICROBURSTS DURING THE MAY 2024 SUPER STORM

The historic May 2024 geomagnetic superstorm did more than produce auroras at unusually low latitudes. New research shows that the extreme disturbance pushed radiation-belt processes much closer to Earth, allowing energetic electrons to plunge toward the atmosphere in intense bursts lasting less than a second.

Earth's magnetic field traps populations of energetic charged particles within the radiation belts. Occasionally, interactions within the magnetosphere scatter some of these electrons out of their trapped trajectories, sending them toward the atmosphere in extremely short events known as electron microbursts.

These events are normally associated with the outer radiation belt, typically at L-shells of roughly 3 to 8. During extreme geomagnetic storms, however, the structure of the radiation belts and surrounding plasma environment can be dramatically compressed toward Earth.

During the May 2024 storm, researchers identified sub-second electron microbursts at approximately $L = 2$, placing the activity unusually deep within the inner magnetosphere. The observations were made using the Gamma-ray Burst Monitor aboard the CALorimetric Electron Telescope on the International Space Station. Its time resolution of one-eighth of a second allowed researchers to see rapid variations that most radiation-belt instruments cannot resolve.

This is important because observations of microbursts below $L \approx 3$ are exceptionally rare. Normally, the inner boundary of the outer radiation belt does not extend this close to Earth. Extreme storms can fundamentally change that geometry, pushing the environment associated with the outer belt inward.

At nearly the same time, the Arase satellite detected enhanced whistler-mode chorus waves at approximately $L^* = 2$ to 4.

Chorus waves are electromagnetic plasma waves capable of interacting strongly with energetic electrons. These interactions can change an electron's motion relative to Earth's magnetic field, scattering particles into trajectories that carry them downward toward the atmosphere.

Under normal conditions, the plasmopause and inner boundary of the outer radiation belt remain considerably farther from Earth.

During the May 2024 event, however, previous observations confirmed that the plasmopause contracted inward to approximately $L = 1.5^*$. Such an extreme displacement created conditions in which processes normally associated with the outer radiation belt could occur at remarkably low L-shells.

THAT HELPS EXPLAIN WHY THE RESEARCHERS DETECTED MICROBURSTS AROUND $L \approx 2$.

THE RESEARCHERS ALSO CONSIDERED LIGHTNING-GENERATED ELECTRON PRECIPITATION AS AN ALTERNATIVE EXPLANATION.

THE FINDINGS COULD ALSO HELP EXPLAIN ANOTHER PHENOMENON SEEN AFTER MAJOR GEOMAGNETIC STORMS: SLOT FILLING.

Normally, a relatively depleted region separates Earth's inner and outer radiation belts. Powerful storms can inject energetic particles into this region and temporarily alter the familiar two-belt structure.

The researchers show that chorus waves play more than one role during these events. They can scatter electrons downward and produce the microbursts detected by the International Space Station, and chorus waves can also accelerate electrons near the magnetic equator.

That acceleration can contribute to filling low-L regions with relativistic electrons during superstorms.

NEW EXO MOON

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

[NEW 'EXOMOON' DETECTION CHALLENGES COSMIC LABELS](#)



Using the European Southern Observatory's Very Large Telescope in Chile, researchers detected evidence of a planetary-mass object orbiting a brown dwarf in the CD-35 2722 system. The findings, published in *Nature*, present a system that challenges the familiar categories astronomers use to distinguish stars, planets, and moons.

The system is centered on CD-35 2722, a young star with roughly half the mass of the Sun. Orbiting the star is a brown dwarf, an object that occupies the middle ground between planets and stars. Brown dwarfs are more massive than planets but generally lack enough mass to sustain the hydrogen fusion that powers ordinary stars.

Researchers estimate that the object is at least as massive as Jupiter, while its brown-dwarf host is more than 30 times Jupiter's mass. That makes the satellite massive enough to resemble a planet in its own right. Yet because it orbits another substellar object rather than the system's central star, its orbital role resembles that of a moon. The team used the CRRES+ instrument on the Very Large Telescope to search for the object using the radial velocity method, one of astronomy's most established techniques for finding unseen companions. An orbiting object does not simply travel around a perfectly stationary host. Both objects orbit their shared center of mass, producing a small back-and-forth motion in the larger body. Astronomers can measure this movement by examining shifts in the wavelengths of its light. In this case, researchers detected small wobbles in the brown dwarf consistent with the gravitational influence of another massive object orbiting it. The team considers the signal strong evidence for the presence of the exosatellite.

WINTER STORMS ARE GROWING STRONGER IN ANTARCTICA'S

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

[INCREASING WINTER STORMINESS IN THE SOUTHERN ROSS SEA, ANTARCTICA, AND ITS IMPACT ON LAND-FAST SEA-ICE](#)

A new study of more than six decades of Antarctic weather observations has found that winter storms in the southern Ross Sea are becoming more frequent and more intense.

The analysis incorporated observations from 13 weather stations across the Ross Sea region. The longest record came from Scott Base, where daily weather observations extend back to 1964.

Winter storminess increased significantly at several stations in the southern Ross Sea and across the Ross Ice Shelf. Researchers also found increases in both the frequency and, at some locations, the strength of above-average winter storms.

One of the study's most striking findings involves the growing unpredictability of Antarctic winters.

At Scott Base, year-to-year variability in winter storminess began increasing around the mid-2000s and reached unprecedented levels after 2016. The average measure of winter variability after 2016 was approximately 2.5 times higher than the average before 2016.

The researchers also found that longer-term variations in storm activity correspond with the Southern Annular Mode, a major atmospheric circulation pattern surrounding Antarctica. Significant connections appeared on timescales longer than 10 years, although a shorter approximately five-year relationship disappeared after the mid-2000s.

The consequences are particularly visible in McMurdo Sound, where land-fast sea ice, or fast-ice, forms along the coastline each winter.

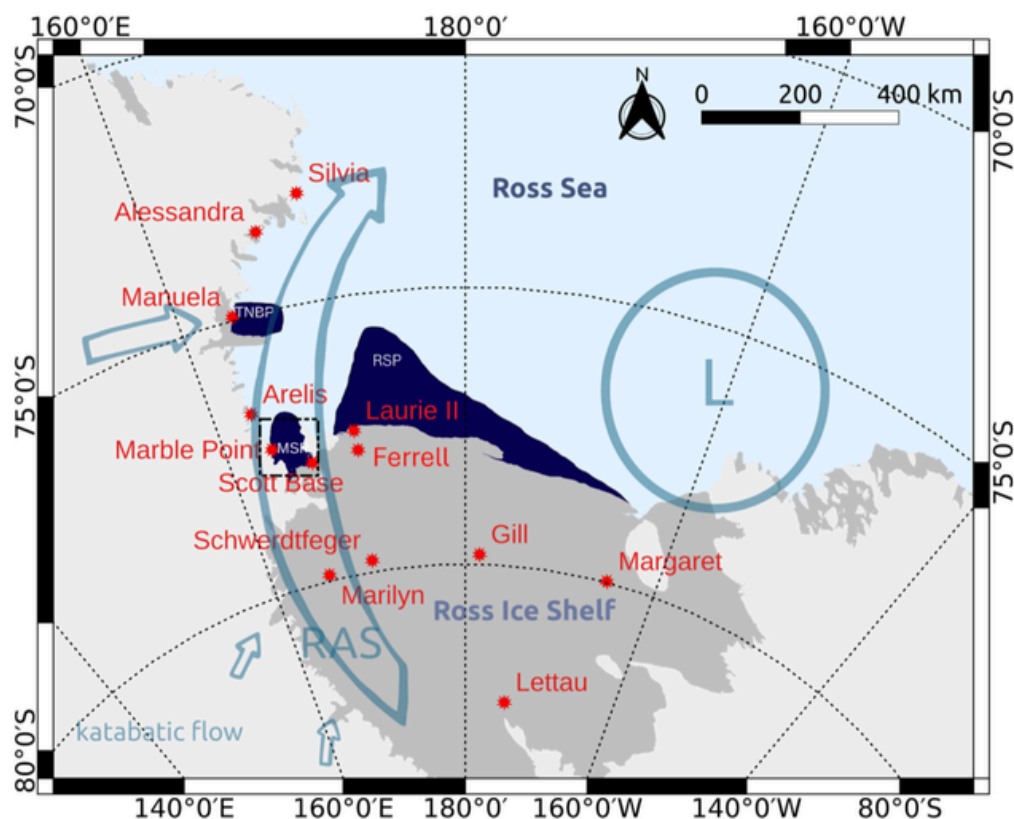
Unlike drifting pack ice, fast-ice remains attached to the coast, ice shelves, or grounded icebergs. Strong winds associated with storms can push newly forming ice away from the coast, causing it to break apart before it becomes established.

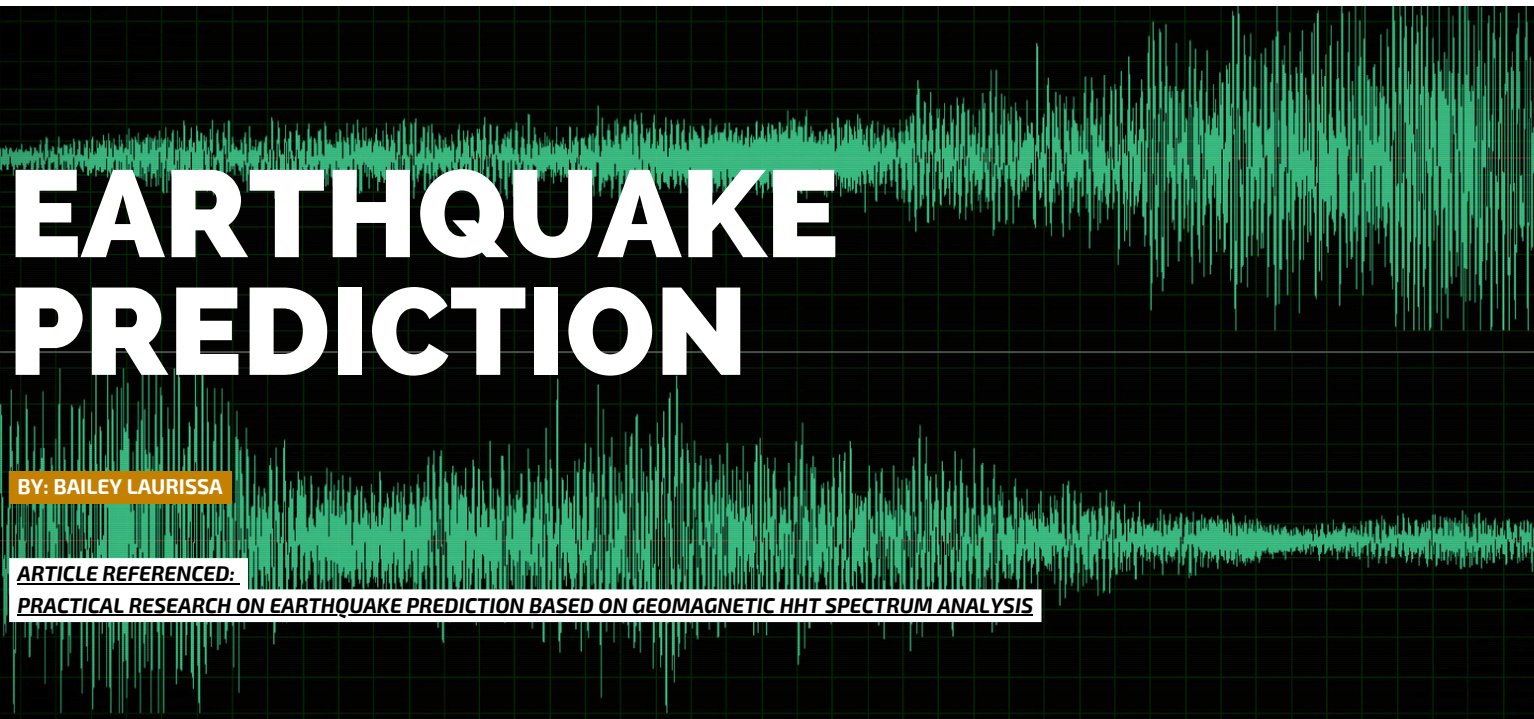
Satellite observations from 2019 through 2024 showed that particularly stormy winters, including 2019, 2022, and 2024, experienced noticeably delayed formation of the main fast-ice cover in southern McMurdo Sound.

Across the longer record analyzed by the researchers, 2000, 2012, 2019, 2022, and 2024 experienced fast-ice formation delays of as much as four months comparatively.

Strong winds help create coastal polynyas, areas of open water surrounded by sea ice despite freezing conditions. These areas act as important sites of sea-ice production and contribute to the formation of Antarctic Bottom Water, a dense water mass involved in global ocean circulation. Polynya conditions also provide open water, nutrients, and light that support Antarctic marine ecosystems.

Increasing winter storm activity could therefore alter polynya activity, pack-ice production, Antarctic Bottom Water formation and, potentially, aspects of global ocean circulation. At the same time, greater variability in fast-ice formation could affect ecosystems that depend on stable coastal ice, including seals, penguins and microalgae communities.





EARTHQUAKE PREDICTION

BY: BAILEY LAURISSA

ARTICLE REFERENCED:

PRACTICAL RESEARCH ON EARTHQUAKE PREDICTION BASED ON GEOMAGNETIC HHT SPECTRUM ANALYSIS

The study used a signal-processing technique known as the Hilbert-Huang Transform, which is designed to analyze complex signals that change over time. Researchers focused on an improved method called Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN). This approach helps separate overlapping signals and reduce a problem known as “mode mixing,” allowing scientists to identify subtle changes that might otherwise be hidden within noisy geomagnetic observations.

Tests using synthetic signals showed that CEEMDAN produced a clearer separation of different frequencies and a more concentrated distribution of signal energy. This allowed researchers to identify when specific frequencies became stronger and how those frequencies changed over time.

The researchers then applied the method to geomagnetic observations associated with the magnitude 8.0 Wenchuan earthquake and its aftershocks, analyzing measurements from stations including Chengdu, Chongqing, and Lhasa. Their analysis revealed evidence of increased geomagnetic energy before the earthquake. In particular, disturbances around a dominant frequency of approximately 0.01 Hz appeared in the magnetic declination component recorded at Chengdu and the total magnetic field component recorded at Lhasa.

The findings suggest that Hilbert-Huang spectrum analysis can capture short-lived and evolving characteristics within geomagnetic signals, including changes occurring around the time of an earthquake.

THANK YOU!

**WE HOPE YOU ENJOYED OUR AUGUST ISSUE!
WE APPRECIATE YOUR QUEST AND LOVE FOR KNOWLEDGE
ABOUT SPACE AND OUR GREATER COSMOS.**

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