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PAPER CHECK · SPACE WEATHER

The May 2024 storm did little harm to grids; a 2026 paper's reason why is unconfirmed

Twelve researchers argue that some effects of the great storm of May 2024 were comparatively weak, and that a small jump in the solar wind's electric field at the storm's front is probably why [1 Abstract]. We could read only the abstract and the reference list: the indexes list the paper as free to read, but the site's owner met a paywall at the publisher [3][4]. For power grids "minor" holds, and the paper's −606 nT is, by our inference, a range in SYM-H, not a revised Dst; Kyoto's own index is unchanged [7][8]. On our own definitions, which may not be the paper's, one of the three outage storms clears its 15 mV/m, one misses it, and one has no solar-wind measurement at all.

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OUR ANALYSIS marks our own reasoning and calculations, including every number from our re-run of ΔIEFy, whose definitions are ours and may differ from the paper's, and the verdicts are our assessment. Everything else comes from the numbered sources. For the paper [1] we could read only the abstract its publisher deposited with Crossref [3], so Abstract is the only locator into it. Elsewhere p. gives a page and Abstract the part of a source we rely on.

A great storm that did little harm to grids; the paper's explanation is unconfirmed, and its −606 nT is, by our inference, a range on another scale

OUR ASSESSMENT

−606 nT

by our inference, SYM-H's low of −518 nT minus its +88 nT peak hours earlier [1 Abstract][8]. On that scale March 1989 is −792 nT [5 p. 4], and Kyoto's Dst for May 2024 is still −406 nT [7]

1 of 3

outage storms clears the abstract's 15 mV/m on our definition, which may not be the paper's: November 2001 does, unless our front moves by 5 minutes; October 2003 does not; and March 1989 has no solar-wind measurement [1 Abstract][34 p. 2]

321 nT/min

the field's fastest change at Eyrewell, New Zealand, in May 2024, against 191 in November 2001 [15 p. 8], when a transformer failed [21 Abstract]; in 2024 the country's electricity supply was unaffected [15 p. 1]

THE PAPER'S CLAIMS

PARTLY TRUE

"2nd most intense geomagnetic storm in space age with revised intensity −606 nT"

The paper's abstract [1 Abstract]

By our inference, which one sentence of the paper's text would settle, this is not a revised Dst or a slip for −406 but the group's own "revised intensity" [6 Abstract]: SYM-H's −518 nT minus its +88 nT peak [5 p. 4][8]. May 2024 is second on SYM-H and on that scale, which start in 1981 [8][10 p. 2], and, by our arithmetic, on the same subtraction on hourly Dst since 1957, though hourly means can hide short peaks [7]. Only plain Dst puts it lower, at sixth [7]. And the abstract names no index, so its "2nd" can't be pinned to one. Our analysis; see section 2.

PARTLY TRUE

"caused only minor technological problems"

The paper's abstract [1 Abstract]

It holds for grids: North America's stayed stable and served all load [13 p. 18], the UK's impacts were "relatively minor" [14 p. 1], and New Zealand's supply was unaffected [15 p. 1]. By our inference "minor" echoes the group's class of minor-system-damage events [5 p. 5][6 Abstract], which those grid effects fit. But the abstract's words are "technological problems", which is wider: GPS-guided planting stopped and thousands of satellites manoeuvred [14 p. 9][14 p. 13]. And whether the storm or the grids explain the contrast with earlier outages is a question the abstract doesn't address [1 Abstract]. See section 3.

PARTLY TRUE

"Prompt penetration electric field, F_3 layer, and ionosphere-thermosphere storms were also weak"

The paper's abstract [1 Abstract]

The frame is comparative: the title says "Comparatively Weak", and this sentence follows the contrast with the outage storms [1 Abstract]. But it doesn't name the comparator for these effects. Against October 2003 the record agrees: the interplanetary electric field [27 p. 6], the equatorial field changes [27 p. 7] and the largest rise in electron content [27 p. 13] all came in lower. Against November 2001, itself an outage storm, the field changes were close [27 p. 7]. The F_3 and thermosphere parts can't be rated from what we could read. See section 4.

UNCONFIRMED

A small jump in the solar wind's electric field at the ICME's front, and a lower average in its body, may explain the difference

The paper's abstract, paraphrased; its own words are "seem due to" and "probably" [1 Abstract]

On our definitions, which may not be the paper's, "similar to other ICMEs" is fair, November 2001 fits, and a main-phase mean separates the two testable outage storms from nine others, in the direction argued; and two of the three outages came within minutes of a sudden commencement. But March 1989 has no solar-wind measurement, October 2003 misses 15 mV/m at its shock, and May 2024's figure depends on the window and the spacecraft. Two events can't make the abstract's numbers a dividing line, and three couldn't either. Our analysis; see section 5.

OVERSTATED

"explains the weakness for the first time"

The paper's abstract [1 Abstract]

In 2025 Raj and colleagues, three of them authors here, wrote that the event caused no severe damage "probably because IEFy at the ICME front was small and fluctuating" [6 Abstract]. That year Astafyeva and colleagues also tied a weaker penetration effect to the interplanetary field's changing polarity [27 p. 6]. Both are on its reference list [3]. The new paper may go further; we can't read how. See section 6.

1 · WHAT WE COULD READ

Only the abstract and the reference list of a peer-reviewed paper

Twelve researchers argue in *JGR Space Physics* that some effects of the great storm of May 2024 were comparatively weak, and offer a reason [1 Abstract]. We could not reach the text, so every definition of ΔIEFy, front and body on this page is ours, and the paper's may differ. S0 News linked the paper on November 2, 2026 [2].

What the record shows

Received April 18, accepted October 7 and published October 27, 2026, as article e2026JA035527 in volume 131, issue 11; twelve authors, at Nagoya University's Institute for Space-Earth Environmental Research, Shandong University and institutes in the United States, Brazil, India and China; 102 references; no funder listed; Wiley's standard terms, not an open licence [3].

OUR ANALYSIS

What that means for this check

OpenAlex and Semantic Scholar list the paper as free to read at the publisher, with no licence [4]. The site's owner met a paywall there, and Wiley's site shows our tools and our browser a bot check, which we do not attempt. We found no preprint in Crossref, OpenAlex or a web search. So we rate only the abstract's words, we attribute no method, station or definition to the paper, and we redraw nothing from it. If you have the paper, tell us through the correction form below; with the text in hand we will revise this page.

The abstract's terms, in plain words

TERM	WHAT IT MEANS HERE
ICME	Interplanetary coronal mass ejection: what a coronal mass ejection seen leaving the Sun becomes out in the solar wind, here as it passes near Earth [36]
Dst and SYM-H	Indices of how far the field at low latitudes is depressed in a storm. Dst is hourly and starts in 1957; SYM-H is its one-minute counterpart and starts in 1981 [7][8]
IEFy	The solar wind's dawn-to-dusk electric field: its speed times the southward part of its magnetic field, as Astafyeva and colleagues compute it from OMNI [27 p. 6]; the abstract calls it the Y-component of the interplanetary electric field [1 Abstract]
ΔIEFy	The abstract's "impulsive change" in IEFy "at the ICME front" [1 Abstract]. Its definition is in the text we could not read
Prompt penetration field	An electric field from the magnetosphere that reaches low latitudes very rapidly, when the currents that normally shield them fail for a while [27 p. 1][27 p. 2]
F_3 layer	An extra layer that can form above the ionosphere's main F_2 peak [31 Abstract]

What we could not read, and so do not rate

QUESTION	STATUS
How ΔIEFy, the front and the body are defined; which monitors, windows and events are used	Unverified; section 5 gives our own stand-ins
What the paper does for March 1989, when no solar-wind measurement exists	Unverified
The comparator for "weak": which storms, stations and local times	Unverified; section 4 sets out what we could find
Whether the text weighs changes in grids, the rate of change of the field, local time or the ground	Unverified; the abstract does not mention them [1 Abstract]. Its reference list has titles on them: Viljanen and colleagues (2001) on the field's rate of change; Kappenman (2005), Lundstedt (2006), Stauning (2013) and Despirak and colleagues (2025) on grid effects; Boteler and Pirjola (2017) on modelling induced currents [3]. Titles don't show what the text says, but they do show the authors aren't unaware
Figures, tables, data statement, funding and interests	Unverified; no figure is redrawn
Journal, dates, licence terms, authors, references	Known [3]

How firmly the abstract speaks

The authors hedge in key places: "some aspects", "comparatively", "seem due to", "probably". The abstract also has firmer words: "This study shows", "explains", "have strong" [1 Abstract]. Keep both in mind in what follows.

2 · WHAT −606 NT IS

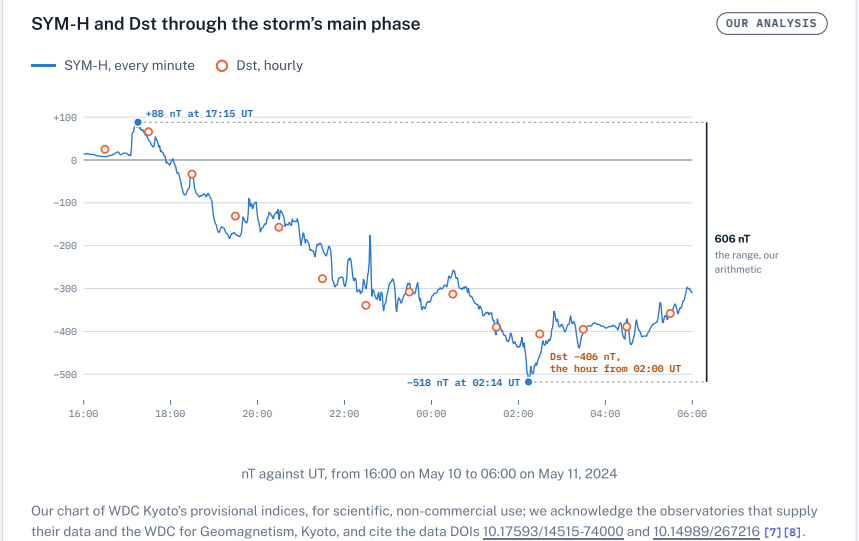
A fall in SYM-H, by our inference, not a revised Dst; Kyoto's own index has not changed

Readers of our other pages will wonder, so first: on November 2, 2026, Kyoto's Dst for May 2024 is still −406 nT, provisional, in the hour from 02:00 UT on May 11, and March 1989 is still −589 nT, final [7]. The real-time value of −412 nT is no longer served by Kyoto and rests on Hayakawa and colleagues [9 p. 2]. By our inference, what differs in this abstract is the yardstick.

THE PEAK (OUR ANALYSIS)	THE LOW (OUR ANALYSIS)	THE DIFFERENCE (OUR ANALYSIS)
+88 nT SYM-H at 17:15 UT on May 10, after the shock's arrival [8][10 p. 4]	**−518 nT** SYM-H at 02:14 UT on May 11 [8][10 p. 4]	**−606 nT** −518 − (+88), exactly the abstract's figure [1 Abstract]

SYM-H and Dst through the storm's main phase

OUR ANALYSIS



nT against UT, from 16:00 on May 10 to 06:00 on May 11, 2024

Our chart of WDC Kyoto's provisional indices, for scientific, non-commercial use; we acknowledge the observatories that supply their data and the WDC for Geomagnetism, Kyoto, and cite the data DOIs 10.17593/14515-74000 and 10.14989/267216 [7][8]. Not from the paper.

The group's own method

In 2024 Manu, Balan and colleagues proposed measuring a storm from the peak before its main phase rather than from zero, "raising the 0-level of SymH to the MPO-level", and they called the result the "corrected (revised) storm intensity" [5 p. 1]. MPO, the main-phase onset, is the largest initial-phase peak in the 8 hours before SYM-H turns negative or, under a further criterion, the next-largest [5 p. 3]. In 2025 Raj, Manu, Balan and colleagues applied a "revised intensity" to events of 1981–2024, May 2024 among them [6 Abstract].

OUR ANALYSIS

Why we infer this, and what would settle it

The abstract does not define its "revised intensity" [1 Abstract]. A simplified form of their rule, the largest peak only, run by us on Kyoto's SYM-H, gives exactly −606 nT. It also gives their worked example, −394 → −489 nT, which in our run is November 2004, and their largest value, −792 nT, which is March 1989 (−720 − 72) [5 p. 4]. Their further criterion can pick a later peak instead [5 p. 3]. On our reading it would give −537 for March 2001 and, on its letter, −572 for May 2024 (+54 at 17:39 UT, after a dip to +30). So the abstract's figure is the largest-peak value: either their program treats that short rise differently, or the criterion isn't applied here. May 2024 is second either way. We wrote the subtraction down before fetching any SYM-H. Both group papers are on this paper's reference list [3]. That is a close match, but it is our inference: one sentence of the paper's text would settle it.

If so:

OUR ANALYSIS

Not a revised Dst

Kyoto publishes no such index, and no version of Kyoto's Dst for May 2024 goes below −412 nT [7][9 p. 2]. The same subtraction on Dst gives −472 nT from the provisional values (−406 − 66), by our arithmetic; Hayakawa and colleagues report "peak-to-peak amplitudes of 474 nT" from the real-time ones, without calling that intensity [9 p. 25].

Not a slip for −406

The match to SYM-H is exact, and the phrase "revised intensity" is the group's own [6 Abstract].

Not comparable with Dst figures

−606 nT can't be set beside −589, −412 or −406 on our other pages, which are Dst. On the same scale 1989 would be −792 nT.

May 2024's rank depends on the index

OUR ANALYSIS

INDEX AND SPAN	MAY 2024	RANK	AHEAD OF IT
Dst, from 1957	−406 nT provisional (−412 real time)	6th	1989 −589; 1959 −429; 1957 −427; 1958 −426; Nov 2003 −422 [7][9 p. 2]
Dst, from 1981	−406 nT	3rd	1989; Nov 2003 [7]
The same subtraction on hourly Dst, from 1957	−472 nT (−406 − 66), by our arithmetic	2nd	1989 −589, with no positive hour to subtract; then 1957 −462; 1959 −446; 1967 −442; Nov 2004 −435; 1958 −426; Nov 2003 −422 [7]
SYM-H, from 1981 only	−518 nT	2nd	1989 −720 [8][10 p. 2]
Revised SYM-H, from 1981 only; by our inference, the abstract's measure	−606 nT	2nd	1989 −792 [5 p. 4]; third is March 2001 at −561 on a simplified form of their rule, or −537 on our reading of their further criterion [5 p. 3][8]

Our listing of Kyoto's hourly series, with storms less than 48 hours apart merged; the SYM-H rows cover the 24 storms since 1981 with Dst at or below −250 nT, and the subtraction row the 39 since 1957. Hourly means hide short peaks: March 1989's +72 nT in SYM-H leaves no positive hour in Dst, so the 10 nT margin over 1957, and 1958's place, are not firm. Daily Ap ranks May 11 second since 1932, as our guide shows.

OUR ANALYSIS

Is it fair to call it second in the space age?

On SYM-H, yes, and others say the same: Hajra and colleagues call it "the second strongest geomagnetic storm of the space age" [10 p. 2], as do Tulasi Ram and colleagues in other words [11 Abstract]. SYM-H starts in 1981 [8], some 23 years after the space age began, so the years before that have only Dst. On plain Dst May 2024 is sixth, behind three storms of 1957–1959 [7][9 p. 2]. Apply the same subtraction to hourly Dst, by our arithmetic, and it is second, behind only 1989: −472 nT against −462 nT for 1957, a margin hourly means can't make firm. So by our inference the claim holds on the group's measure, and on plain SYM-H, and holds on its revised or one-minute measure we can compute; only plain Dst puts it lower. We say Partly true because the abstract names no index, and an unlabelled "revised intensity" invites a comparison with Dst figures that it can't bear.

One slip, of no consequence to the science: the abstract places the G5 rating "in the American Geological Survey" [1 Abstract]. The G scale is that of NOAA's Space Weather Prediction Center [12].

3 · "ONLY MINOR"

For power grids "minor" holds; whether the storm or the grids explain it is a question the abstract doesn't address

The abstract says the May 2024 ICME "caused only minor technological problems", while those of March 13, 1989, November 6, 2001, and October 30, 2003, "caused power outages" [1 Abstract]. The reviews of the storm's effects agree on the first half, for grids.

NORTH AMERICA	UNITED KINGDOM	NEW ZEALAND
68th most impactful day of 2024 on NERC's severity index, with "minimal impact" on equipment [13 p. 12]. The bulk power system "remained stable" [13 p. 1] and served all load [13 p. 18]	**14 A** the largest induced current on the British grid, at three sites; a "low-level" G5 whose impacts were "relatively minor", though models put up to 68 A where nothing measures it [14 p. 1][14 p. 6]	**112.7 A** the largest induced current there since records began in 2001, and yet "There was no impact to New Zealand's electrical supply" [15 p. 1][15 p. 8]

What else happened: where "only" needs care

WHERE	WHAT THE RECORD SHOWS
North American generators and lines	Five generators affected, all in the Northeast, some tripped by their relays [13 p. 14]; one nuclear unit reduced output under its procedures [13 p. 4]; a surge arrester's failure took an AC substation out for 14 hours 35 minutes [13 p. 14]; a 2% voltage drop on part of the 500 kV system when a compensator tripped at peak current [13 p. 11]
Sweden	A disturbance in a transformer in the south, which the grid operator confirmed came from induced currents, caused a drop in supply on the line to Poland [17 Abstract]
Mexico	Significant induced currents at three sites; the authors see a potential threat to low-latitude grids [18 Abstract]
Farms	GPS-guided tractors had to stop during corn planting [14 p. 13]. One report, in which we found no sign of peer review, estimates $69.6 million to $1.7 billion in lost revenue across 12 Midwestern states, and also calls the risk across all US acres negligible, one to two bushels an acre [19 p. 2]; Horne and colleagues quote about $500 million [14 p. 13]
Satellites	Satellites manoeuvring rose from about 300 to almost 5,000 on May 11, most of them Starlink's; ICESat-2 lost six weeks of service; UK operators got 2,560 collision warnings in May, 35% more than in April [14 p. 9][20 p. 5]

Whether these add up to "minor" is a judgment. NERC's and the UK review's own words point that way for infrastructure [13 p. 12][14 p. 1], so the verdict is about "only", and about what the contrast with earlier outages can show.

OUR ANALYSIS

What "minor" may be measured against

By our inference, "minor" echoes a class the group has defined: minor-system-damage events, such as capacitor tripping in transformers and high voltage in grids, as against the outages of severe events [5 p. 5][6 Abstract]. By that yardstick NERC's list reads as minor, and GPS and satellites fall outside it. The abstract's own words, "technological problems", are wider than that class, which is part of why we say Partly true.

The earlier outages: two clear, one thin

March 13, 1989: clear

Hydro-Québec's grid collapsed at 2:44 a.m. local time (07:44 UT), leaving about six million people without power for more than nine hours [34 p. 2][25], about 17–18 hours before the Dst low [26]. See our review of the record.

October 30, 2003: clear

Malmö, Sweden: a blackout from 20:07 UT, for 20 to 50 minutes in one account and an hour in another, affecting about 50,000 customers [24 p. 1782][40 Abstract].

November 6, 2001: thin

The abstract of Marshall and colleagues, on this paper's reference list, describes "A transformer failure" in New Zealand's South Island [21 Abstract][3]. Halfway Bush's T4 tripped at about 01:53 UT, as did systems at Islington, and an inspection found it beyond repair [22 slide 3][15 p. 5]; a later paper says it "required repair" [16 p. 2]. Trichtchenko counts it among "two short power outages" of that solar cycle [23 p. 500], and the group's 2024 table calls it a power outage [5 p. 5]. We found no customer count.

Storm or grid?

OUR ANALYSIS

A question the abstract doesn't address

An outage depends on the storm and on the grid. NERC lists the storm's strength, duration and frequency content, the location, the equipment's design and the ground beneath [13 p. 1]; operators act too [13 p. 3]. The abstract's contrast between minor problems and outages mentions none of these [1 Abstract]. We cannot say whether the text does, so we don't say the paper ignores them, and its reference list has titles on induced currents and grid effects, as section 1 lists [3]. The group's 2024 paper did note that outages could be reduced over time by technological improvements [5 p. 6].

Whether May 2024 spared grids because of what it was, or because of what grids had become, can't be settled by counting outages.

What points to the storm itself

NERC notes that observers rate it less intense than March 1989 [13 p. 18]. The UK review calls it a "low-level" G5 whose individual eruptions were not particularly severe, its effects coming from five successive CMEs [14 p. 1][14 p. 2]. Elvidge and Themens's return-period estimate, as Mac Manus and colleagues report it, gives it 1 in 12.5 years by magnitude and 1 in 41 by duration [15 p. 14]. All of that is in keeping with the authors' point that some of its effects were comparatively weak.

What points to the grids, and what timing shows

FACT	THE RECORD
New Zealand's forcing was larger in 2024	At Eyrewell, 321 nT/min at about 08:50 UT on May 11, "the largest since digital records began", against 191 nT/min in November 2001 [15 p. 8][15 p. 9]
New Zealand's grid had changed	The vulnerable single-phase T4 was decommissioned in late 2017 [16 p. 2]; a national mitigation strategy became operational in mid-2023 and was used for the first time, with 113 A measured against about 200 A modelled without it [15 p. 1]
Québec's grid had changed too, by the utility's own account	Hydro-Québec says that after 1989 it recalibrated its protection systems and raised their trip level, added a real-time alert system, changed its operating procedures and installed series compensation, and that very intense storms since have caused it no problems [25]
North America's operators were warned and required to act	Six hours' notice from NOAA [13 p. 2]; procedures required since 2015 [13 p. 3]; cancelled maintenance, reconfigured lines and GIC blocking devices in the higher-risk areas [13 p. 3][13 p. 4]; a planning benchmark at least 2.5 times stronger than March 1989 [13 p. 18]
The currents were not small	The highest in NERC's database, which starts in 2013: 175.7 A in Wisconsin, and over 90 A in five of six regions [13 p. 6]
Sweden's 2003 outage had a grid side too	Pulkkinen and colleagues, on this paper's reference list, blame an abnormal switching state and a relay very sensitive to the third harmonic, and call the protective relays too sensitive; they name substorms, the sudden commencement and enhanced convection as the storm's part [40 Abstract][3]
Timing cuts both ways	Close to a front: Hydro-Québec's collapse at 07:44 UT [25] came within minutes of the second sudden commencement, put at 07:43 UT [26 Abstract] or 07:47 UT [34 p. 2], and New Zealand's T4 tripped at about 01:53 UT [22 slide 3], against a disturbance time of 01:52 UT [36]. Marshall and colleagues suggest that shocks and their sudden impulses may be as hazardous to mid-latitude grids as a large storm's main phase [21 Abstract]. Long after one: Malmö's outage, about 3 hours 48 minutes after ACE saw the shock of October 30, 2003 [24 p. 1782][36]; and, in May 2024, the highest US current at 02:03 UT on May 11, nine hours after the shock [13 p. 6], and New Zealand's largest change, 478 nT/min at Awarua, about 12:29 UT that day [15 p. 8]
The shock itself was not small	Our analysis: flow pressure rose from about 4 to about 30 nPa at ACE and from 6.5 to 38.5 at Wind [38], against "nearly 20 nPa" in the study of the 2001 failure [21 Abstract]. SYM-H rose 78 nT within minutes, against 86 in November 2001 and about 18 on October 30, 2003 [8]
IEFy's level is not a fast-changing field	Our analysis, with a rough lag from ACE: IEFy was about 21 mV/m near Eyrewell's 321 nT/min of 2024, and about 33 mV/m just after the 2001 shock, when Eyrewell saw 191 nT/min [15 p. 8][38]. So levels and the ground's rate of change don't map one to one. But the abstract's quantity is a change, and in 2024 IEFy also jumped at ACE, from about 3 to about 21 mV/m in 5-minute means between 07:50 and 08:05 UT, at the start of that lag window and long after the front [38]
Local time differed	By our arithmetic from longitude, the 2024 front reached Québec near noon and Dunedin near 04:30; Dunedin's failure of 2001 came near 13:30, Malmö's outage near 21:00 and Québec's collapse near 03:00, in solar time. How much that matters is open: for one storm and one grid, Wallner and colleagues find that most local-time sectors along the same latitude saw similar geoelectric fields, and that the Swedish disturbance would probably have happened with a different arrival time [17 Abstract]

4 · "ALSO WEAK"

No comparator named in the abstract, and the literature points both ways

The abstract says "Prompt penetration electric field, F_3 layer, and ionosphere-thermosphere storms were also weak" [1 Abstract]. The frame is comparative: the title says "Comparatively Weak", this sentence follows the contrast with the three outage storms, and the next begins "The differences". But it doesn't name a comparator for these effects, or stations or local times, and a shock's sector matters. At 17:05 UT on May 10 it was about noon at Jicamarca, 22:00 at Thumba and midnight at Sanya, by our arithmetic.

Two later papers on the storm

Two papers published a few days after this one measure other effects: GPS scintillation at high latitudes (our check) and the auroral oval's edge (our check). Neither cites this paper, and neither tests what it calls weak.

What the literature says, by phenomenon

PHENOMENON	WHAT SUPPORTS "WEAK", MOSTLY AGAINST OCTOBER 2003	WHAT CUTS AGAINST IT, OR CAN'T DECIDE IT
Prompt penetration field	The interplanetary electric field swung between about ±33 mV/m, below 58.8 on July 15, 2000, and about 45 on October 30, 2003; because its polarity kept changing, its effect was most likely weaker than a long, steady field's [27 p. 6]. Equatorial field changes fell below those of October 2003's main phase [27 p. 7], and drifts were "comparable or smaller" than in earlier great storms [27 p. 9]. At Sanya and Jicamarca, shielding cancelled the penetration field quickly at the southward turnings of 17:45–18:25 and 19:30–22:30 UT, and the afternoon field barely responded [28 Abstract]	The same passage calls those ±33 mV/m very high, larger than or comparable with most earlier superstorms [27 p. 6]. "Strong unshielded" penetration fields for about 2.5 hours, with drifts up to 95 m/s [27 Abstract]; field changes close to those of other great storms of 2001–2004, November 2001 among them [27 p. 7]; drifts comparable with March 1989 [27 p. 9]. Over Jicamarca about 95 m/s and an electrojet near 275 nT, "extreme" perturbations [29 Abstract]. At Thumba, penetration fields mapped effectively onto the equatorial ionosphere [30 Abstract]
F_3 layer	Nothing we could read compares its strength with earlier storms	Nothing against "weak" either, since presence isn't strength. Present at Thumba, with the peak altitude beyond 500 km near noon, in a paper with one of this paper's authors [30 Abstract]. At Japanese and other mid-latitude stations, in a paper with two others, it stayed stronger than the F_2 layer for a considerable time after sunrise, but that F_2 layer was, in the abstract's account, new and weak [31 Abstract]
Ionospheric storm	The largest rise in electron content was about +100 TECU over South America, against more than +150 in July 2000 and more than +200 in October 2003, over the southwest coast of North America [27 p. 13]. It was not strong everywhere: over Asia and Australia it fell for about three hours while it rose for about nine over the Americas [41 Abstract]. The strongest super-fountain effects came in 2000–2004 [27 p. 2]	The same paper calls that the strongest in over 20 years, a span that stops at about October 2003, and the anomaly's crests at ±30–35° the strongest seen by Swarm, which wasn't flying then, so neither bears on that comparison [27 p. 3][27 p. 13]. "Unusually strong" at three local times, lasting about 12 hours in the afternoon sector [29 Abstract]; more than 100% over the dayside [11 Abstract]; a super-fountain to about 35° [42 Abstract]
Thermospheric storm	We found no like-for-like comparison with 2003. Swarm wasn't flying then; CHAMP and GRACE were, and the paper's references include CHAMP studies, so its text may make this comparison [3]. We found none we could read	Large effects, but none of these compares with an earlier storm. On its reference list: thermospheric heating and changes of composition, tied to strong negative ionospheric storm effects in East Asia [33 Abstract]. Off it: Swarm-A's density up by a factor of 4.5 at about 470 km, with Joule heating peaking at 1,822 GW [32 Abstract]; a model's factor of up to 6 at 400 km, and satellites manoeuvring "en masse" [20 p. 4][20 p. 5]

Astafyeva and colleagues' paper is CC BY-NC-ND, so we quote short phrases and redraw nothing [27]. TECU is a total-electron-content unit. These comparisons use different stations, instruments and local times, so none of them is a clean ranking.

OUR ANALYSIS

So is "weak" right?

In part. The abstract's frame is comparative, so "weak" isn't a plain word here, and it isn't contradicted when papers on its reference list call the same things "strong", "extreme" or "unusually strong"; being on that list isn't endorsement either way, and we can't see the paper's own evidence. But it names no comparator for these effects. Against October 2003 the record agrees: the interplanetary electric field, the equatorial field changes and the rise in electron content all came in lower [27 p. 6][27 p. 7], and the rise was about half as big [27 p. 13]. Against November 2001, itself an outage storm, the field changes were close [27 p. 7]. The F_3 and thermosphere parts can't be rated from what we could read: papers by some of its own authors report F_3 layers without a comparison, and we found no comparison for the thermosphere, which can't show that the claim goes beyond the evidence. So Partly true. The text could move that either way.

5 · OUR RE-RUN OF ΔIEFY

On our own definitions the direction has something to it; the abstract's numbers rest on too few storms, and one has no data

The abstract says May 2024's "ΔIEFy <4 mV/m", that of the outage ICMEs "ΔIEFy >15 mV/m", and that their body averages are "<20 and more than 20 mV/m" [1 Abstract]. Every definition below is ours, because the paper is unread; its own may differ and could change these numbers. We wrote rules before fetching any solar-wind data; the rules we set showed OMNI could not test the abstract's numbers, so what follows, built on ACE, came after seeing the data and is post hoc.

OUR ANALYSIS

What supports the authors

"Similar to other ICMEs" is fair: six of the eight other storms are under 4 mV/m at 10 minutes, and none is over 15. **November 6, 2001 fits:** +25.4 mV/m, from 8.0 to 33.3. The margin isn't wide: moving our front 2 minutes earlier or later gives +20.4 and +18.9, and 5 minutes +13.3 and +12.0, under 15. **Two of the three outages came within minutes of a sudden commencement,** Québec's [25][26 Abstract] and New Zealand's [22 slide 3][36], and Malmö's did not; see section 3. **The main-phase mean separates the two testable outage storms** from nine others, in the direction they argue: 39.7 and 20.7 mV/m from the front to SYM-H's low, and 15.5 or less for the rest, May 2024 at 15.4. October 2003's 20.7 is only just past the abstract's 20: speeds 3.2% lower would take it under, though it takes 25% lower to reach the others' 15.5. **Most IEFy-based quantities do better here than storm depth:** ten of our twelve, all but the two means over Richardson and Cane's ICME intervals; Dst, SYM-H and the sudden commencement's size don't pick these two out at all.

OUR ANALYSIS

Our definitions

IEFy: speed times the southward field, in mV/m. **Front:** the step in the field's magnitude at the monitor, near Richardson and Cane's disturbance time [36]. **ΔIEFy:** the mean of the 10 minutes after the front minus the 10 minutes before; we also ran 5, 30 and 60 minutes and a first-peak form. **Body:** four windows, from the front to SYM-H's low; the 6 hours after the front; from the front to the end of Richardson and Cane's ICME; and that ICME alone. **ΔV × Bz:** one mean after, after the group's earlier product of the speed jump at the front and the southward field at that moment [43 Abstract]; in our form, the rise in the 10-minute mean speed times the mean Bz of the 10 minutes after the front. May 2024 stays small on it, at +0.2 mV/m, and November 2001 ranks first, at +13.7, but neither outage storm passes 15: October 30, 2003 is +0.8. We use the abstract's outage labels as given. The storms are the 11 with Dst at or below −250 nT since 2000 that have data at the front; before 2000 the records are too thin.

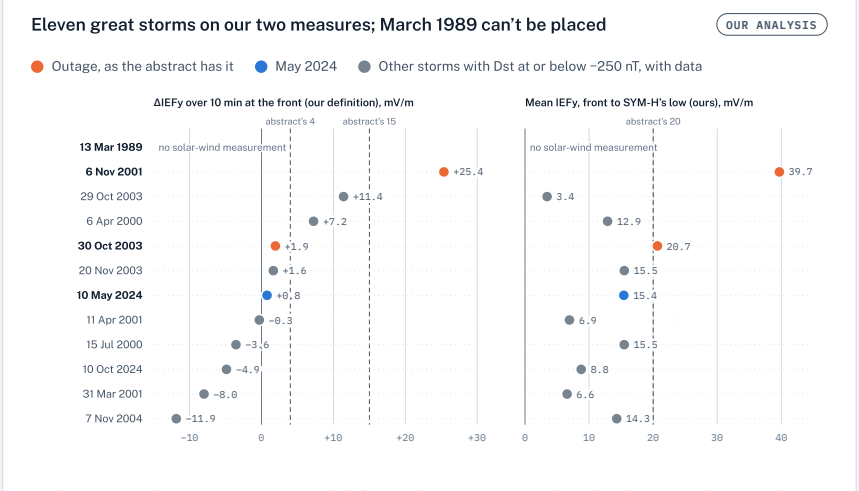
OUR ANALYSIS

The data we could use

OMNI, NASA's merged solar-wind record, has nothing at the fronts of 2001 and 2003 [37]: ACE's 64-second speeds stop at 00:56 UT on November 6, 2001, before the shock, and OMNI's gaps run from 05:49 to 18:43 UT on October 29, 2003, and from 23:51 UT that day to 11:14 UT on October 31. ACE's magnetometer kept working [38]. So for those storms we pair its field with ACE's about 33-minute speeds as listed in Raj (2025), a data set by one of this paper's authors: 409 to 693 km/s across the 2001 shock, 673 to 1,487 and 948 to 1,117 km/s across the two of 2003 [35]. An AI page reader copied those rows for us; they were not parsed, and they could not be checked against the files. One 2003 row is missing, at about 00:31 UT on October 30, apparently cut off at the reader's page limit, so we interpolate across 66 minutes there. Fourteen 2003 rows list no velocity components, the 1,487 km/s among them; the file's header, as the reader returned it, says those speeds came from one-dimensional fits, because the wind exceeded the instrument mode's range. Everything else comes from ACE or, for two storms, OMNI.

Eleven great storms on our two measures; March 1989 can't be placed

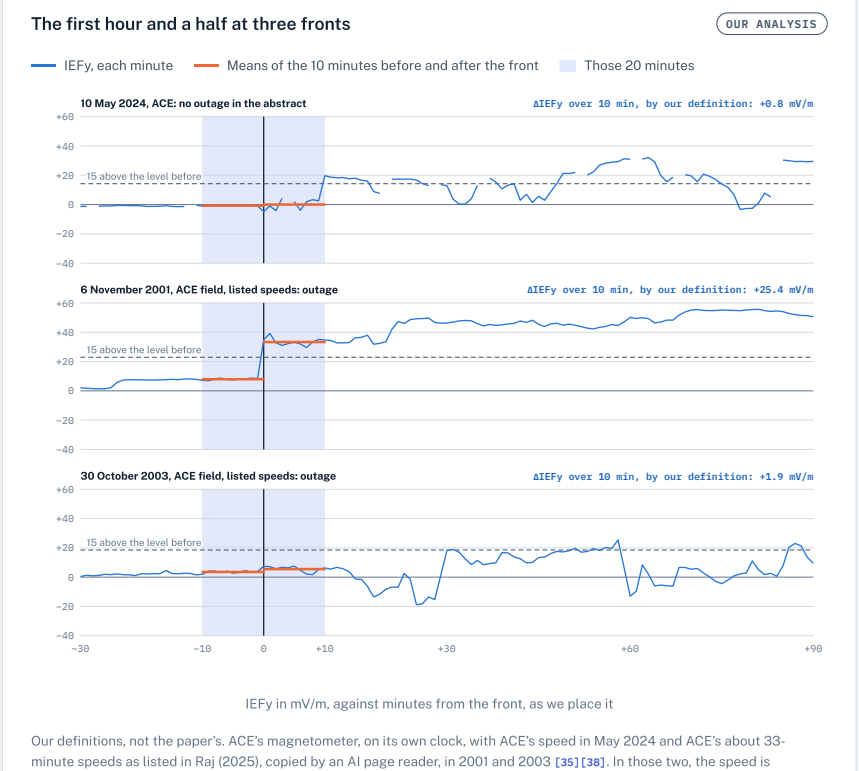
OUR ANALYSIS



Our definitions, not the paper's. ACE on its own clock (MAG and SWEPAM, via CDAWeb [38]), with OMNI for July 2000 and October 2024 [37]. The speeds for 2001 and 2003 are ACE's about 33-minute speeds as listed in Raj (2025), copied by an AI page reader; they could not be checked against the files [35]. Fronts located from Richardson and Cane's list [36]; SYM-H's low from Kyoto [8]. Dashed lines mark the abstract's numbers [1 Abstract].

The first hour and a half at three fronts

OUR ANALYSIS



Our definitions, not the paper's. ACE's magnetometer, on its own clock, with ACE's speed in May 2024 and ACE's about 33-minute speeds as listed in Raj (2025), copied by an AI page reader, in 2001 and 2003 [35][38]. In those two, the speed is interpolated between rows on each side of the front.

The limits

OUR ANALYSIS

March 13, 1989 has no solar-wind measurement

OMNI has no minute with both speed and field from 00:00 UT on March 13 to 22:00 UT on March 14 [37]. IMP 8's plasma records, at 16 to 36 Earth radii behind Earth, are flagged not solar wind until 22:54 UT on March 14 [38]. Nagatsuma and colleagues say "no solar wind coverage during its onset, main phase, and most of the recovery phase" [34 p. 2], and Hajra and colleagues "no interplanetary measurements" [10 p. 2]. Nagatsuma's estimates, a field of about −50 nT and a speed of about 960 km/s, imply about 48 mV/m by our arithmetic for the five hours after 20:00 UT, long after the sudden commencements at 01:28 and 07:47 UT [34 p. 1][34 p. 2]; Boteler's, 980 km/s and 40 to 60 nT [26 Abstract]. These are estimates, not measurements, and they say nothing of the front, but they lie in the direction the abstract argues for its body average. We don't know what the paper does with this storm.

October 30, 2003 misses, on our front

+1.9 mV/m at 10 minutes, and −3.7 to +12.6 across our windows; the shock at ACE came at 16:19 UT [36][38]. A step of +21.6 mV/m follows 30 minutes later, so a different choice of front could change that. But May 2024 has a larger later step too, +25.7 mV/m at 85 minutes.

May 2024's figure depends on the window and the spacecraft

See the table below. IEFy passes 15 mV/m 5 minutes after the front at Wind and 10 minutes after it at ACE [38]. The "large and rapid fluctuations" are real at ACE, with the field swinging between +7.5 and −8.4 nT in the first 10 minutes. In OMNI, a further problem: 15 of the 29 minutes in 17:05–17:33 UT carry pre-shock speeds, because its time shift swings between 1,311 and 3,973 seconds [37]. We don't know which data the paper used.

Our numbers fit only if "body" means the main-phase driver

On Richardson and Cane's ICME intervals, every storm's mean is under 10 mV/m, and the outage storms are among the lowest, because most of the driving came before their ejecta arrived [36]. The mean can't be the whole story: May 2024 reached −406 nT at about 15 mV/m.

Two events, 16 comparisons

What separates here is a description, not a test: 2 positives among 11 storms, 16 quantities compared, definitions chosen after seeing the data. Two events can't make the abstract's numbers a dividing line, and three couldn't either. "Threshold" would be our word: the abstract doesn't use it [1 Abstract], though the group's 2017 abstract does, for ΔV × Bz [43 Abstract]. And the group has said of another index that its observed values "need not be thresholds" [5 p. 6].

May 2024's ΔIEFy, by monitor and window (mV/m)

OUR ANALYSIS

MONITOR, OWN FRONT	5 MIN	10 MIN	30 MIN	60 MIN
ACE, 16:37 UT	−0.7	+0.8	+11.5	+13.5
Wind, 16:38 UT	+0.2	+8.5	gaps	gaps
OMNI, 17:03 UT, short speed gaps filled before the front	+7.8	+7.0	+4.7	+5.5

Data: [37][38]. ACE's front 2 or 5 minutes later gives +6.1 and +10.9 at 10 minutes, and earlier about 0. On an about 33-minute sampling comb, the cadence of the listed speeds, May 2024 at ACE ranges from −2.1 to +19.6 by phase, so coarse sampling alone can carry it across both of the abstract's numbers. We don't know what sampling the paper uses.

6 · "FOR THE FIRST TIME"

Earlier explanations are on record, some in the paper's own reference list

The abstract says the study "explains the weakness for the first time" [1 Abstract]. It may well add something new; we can't read how much. But the idea was in print before.

Raj and colleagues, 2025

Three of this paper's authors, in a paper it cites: May 2024 caused no severe damage "probably because IEFy at the ICME front was small and fluctuating" [6 Abstract][3].

Astafyeva and colleagues, 2025

The interplanetary field changed polarity several times, so the penetration effect was most likely weaker than under a steady field [27 p. 6]; also cited by this paper [3].

Zhang and colleagues, 2025

Shielding cancelled the penetration field quickly and for a long time, at the southward turnings of 17:45–18:25 and 19:30–22:30 UT [28 Abstract]; also cited [3].

Reviews of the grids' effects

Operators' warning and procedures in North America [13 p. 3][13 p. 18]; a planned mitigation in New Zealand [15 p. 1]; and, in the UK's account, a storm of successive eruptions, none particularly severe alone [14 p. 1]. Explanations of a different kind, for the same small effects.

7 · A GRID-BREAKING SUPERSTORM?

By the paper's account a storm's intensity didn't settle its harm: no all-clear, and nothing beyond the space age's storms

Neither a warning nor an all-clear. The abstract says the second most intense storm of the space age caused only minor technological problems, while the ICMEs that caused power outages in 1989, 2001 and 2003 had, it says, a strong jump at the front [1 Abstract]. That cuts against the idea that harm simply grows with a storm's intensity. It leaves outages possible in a storm of this class; the one larger storm it names, March 1989, did break a grid; and it says nothing of a storm larger than any of the space age.

What the record shows

Grids came through May 2024 well: North America's bulk power system remained stable [13 p. 1], the UK's impacts were relatively minor [14 p. 1] and New Zealand's supply was unaffected [15 p. 1]. Its induced currents were still the highest in NERC's record, which starts in 2013 [13 p. 6], and beyond the grids GPS-guided planting stopped and thousands of satellites manoeuvred [14 p. 9][14 p. 13]. The outages the abstract names were regional: about six million people in Québec without power for more than nine hours [34 p. 2][25], about 50,000 customers in Malmö for up to an hour [24 p. 1782][40 Abstract], and a transformer in New Zealand [21 Abstract]. In between, grids changed: warnings and required procedures in North America [13 p. 2][13 p. 3], a mitigation strategy in New Zealand [15 p. 1], and Hydro-Québec's own changes [25] (section 3).

OUR ANALYSIS

What it means, and where it stops

If the paper is right, a storm no deeper than May 2024 but with a strong jump at its front could do more harm. If the grids explain the difference, May 2024 says more about defences than about storms, and the group's 2024 paper allowed that outages could fall with technological improvements [5 p. 6]. Either way, the abstract's numbers rest on two testable storms (section 5). Nor is May 2024 the extreme case: on the group's revised scale, by our inference the abstract's, March 1989 is larger, at −792 nT [5 p. 4]; one estimate puts a storm like May 2024 at 1 in 12.5 years by magnitude and 1 in 41 by duration [15 p. 14]; and NERC's planning benchmark is at least 2.5 times stronger than March 1989 [13 p. 18]. The abstract names no storm before 1989, and none larger than 1989's [1 Abstract], so it says nothing of how a storm beyond the space age's would go.

8 · REPEAT OUR NUMBERS

One script fetches the public data and recomputes our ranks and our re-run

The rules came first, then the logged failures and amendments, each with its hash; the amendments, the ACE-based run and everything in section 5 came after seeing the data, and the same subtraction on Dst, ΔV × Bz and the further criterion on revised SYM-H were added after a final review. Every definition of ΔIEFy, front and body in them is ours, and the paper's may differ. The checks on the copied rows use columns we don't host, so the script can't redo them.

PY **may2024_numbers.py**
Downloads the inputs and recomputes the indices, the data checks and the re-run; needs numpy and pandas · 37 KB

JSON **may2024-numbers.json**
Its output: Kyoto's minima and ranks, what data exist, May 2024 by monitor, the separation as a description · 14 KB

CSV **may2024-storms.csv**
Every storm, every window; derived numbers only · 3 KB

JSON **may2024-chart-series.json**
The charts' data: Kyoto's SYM-H and Dst for the window shown, under Kyoto's terms, and our IEFy around three fronts · 10 KB

CSV **raj2025-ace-speeds-transcribed.csv**
ACE's speeds for 2001 and 2003 as listed in Raj (2025), CC BY 4.0: a transcription by an AI page reader, not the files; its header gives the missing row and the fitted speeds · 5 KB

TXT **RULES_before_running.txt**
The rules written before any OMNI value was fetched · 7 KB

TXT **RULES_addendum_after_availability.txt**
The addendum, written after seeing OMNI's gaps · 3 KB

TXT **RULES_amendment_stage3.txt**
The amendment, with two rules that failed and a bug fix, all logged · 3 KB

TXT **rules_sha256.txt**
The SHA-256 of each rules file as it was recorded, two with their times; the amendment has three, as it was first written and twice extended, and notes say which · 1 KB

Run it

`python3 -I may2024_numbers.py <folder>` downloads about 105 MB into that folder, reads it as data, and writes its three outputs next to the script. It takes under a minute once the files are there. Kyoto's values for 2024 are provisional, so a later download may differ slightly.

The data and their terms

Kyoto's Dst and SYM-H: for scientific use and no commercial use, with acknowledgement of the observatories that supply the data, of the WDC for Geomagnetism, Kyoto, and of the data DOIs; the condition carries over to our outputs [7][8]. **OMNI and CDAWeb:** NASA's public data, with credit to the OMNI authors and the instrument teams [37][38]. **Raj (2025):** CC BY 4.0; Zenodo refused direct downloads from our network, so an AI page reader answering a prompt, not a parser. Their speeds match their velocity components on the 88 rows that list them, their field magnitudes match ACE's magnetometer, and three of them match ACE's 64-second file, and they fit Skoug and colleagues' account of speeds above 1,850 km/s [39 Abstract], but they could not be checked against the files [35]. **Richardson and Cane's list:** credited by its DOI [36].

9 · LIMITS

What this check could and couldn't see

The abstract, not the paper

We rate its words, and the paper may qualify, define or support them in ways we can't see [1 Abstract]. Where a verdict leans on a definition or a comparator, it is one we had to supply.

Speeds in 2001 and 2003

ACE's about 33-minute speeds as listed in Raj (2025), from one of this paper's authors, copied by an AI page reader and interpolated between rows. One 2003 row is missing and 14 are fitted speeds. We could not check them against the files, and a coarse speed adds uncertainty near a shock [35].

One monitor upstream

A monitor samples one track through a structure that can vary over the width of Earth's magnetosphere and beyond. ACE and Wind differ by minutes and by mV/m at the May 2024 front [38].

Labels

We kept the abstract's outage labels, though 2001 is thin (section 3) and other storms had grid effects of their own, as May 2024 did. A measure such as the field's rate of change at the affected grid would be a better target than outage or no outage.

Sources read in part

Many are abstracts, marked in the list. Time lags from ACE to the ground are rough.

What would change these verdicts

01 The paper's text: its definitions of ΔIEFy, front and body, its value for March 1989, its comparator for "weak" and any discussion of grids. Any of these could move any of the five verdicts.

02 The Zenodo files themselves, if they show our transcribed speeds are wrong.

03 A test over many storms, with measured induced currents or rates of change as the target, in which a jump at the front predicts them better than chance. That would move "Small jump at front may explain" toward True.

OUR ANALYSIS

Bottom line: a great storm that grids came through well; a hedged idea with something to it; numbers that two testable storms can't settle as a dividing line; and a −606 nT that is, by our inference, a range on another scale.

The authors' observation that May 2024 did less harm than its size might suggest fits NERC's and the UK's reviews, on our definitions a main-phase mean of IEFy does pick out the two outage storms we can test, and two of the three outages came within minutes of a sudden commencement. But the abstract's sharper claims go further than what we could confirm: one outage storm has no solar-wind data, another misses the mark at its shock, May 2024's own figure moves with the window and the spacecraft, and grids had changed between the storms compared. We read only the abstract; the paper may answer some of this.

Related checks

FALSE More auroras from less solar input? The Disaster Cycle, Fact-Checked

Sources

Bracketed numbers refer to this list. For the paper [1] we could read only the abstract its publisher deposited with Crossref [3], so Abstract is the only locator into it; the same goes for every source marked "Abstract only". Elsewhere p. gives a page of the copy named in the entry, and slide a slide of a talk. nT is the nanotesla, mV/m the millivolt per metre, UT universal time; local times are solar. Publishers' hyphen characters are printed as ordinary hyphens. Links checked November 2, 2026.

1 Balan, N., Otsuka, Y., Shiokawa, K., Miyoshi, Y., Fejer, B. G., Batista, I. S., Pant, T. K., Lei, J., Navarro, L., Nakamura, K., Raj, J. K., and Manu, V. (2026). Insight Into the Comparatively Weak Geo-Effectiveness of the May 2024 ICME. *Journal of Geophysical Research: Space Physics* 131(11), e2026JA035527. Published October 27, 2026 (received April 18, accepted October 7). Peer reviewed; under Wiley's standard terms of use, not an open licence, so we quote only short parts of the sentences we rate and redraw nothing. We could not read it: the site's owner met a paywall at the publisher, and Wiley's site shows our tools and our browser a bot check, which we do not attempt. Abstract and reference list only, as the publisher deposited them with Crossref [3].

2 SpaceWeatherNews (S0) (November 2, 2026). Pole Shift Changes Reported, Solar Coronal Hole | S0 News Nov.2.2026. YouTube video, https://www.youtube.com/watch?v=bSJbUC5WIgU, published at 12:02 UT. No transcript was available.

3 Crossref. Metadata record for doi:10.1029/2026JA035527. Retrieved November 2, 2026: the abstract deposited by the publisher, which we quote; the received, accepted and published dates; the authors and their affiliations; volume 131, issue 11; 102 references, which we looked up one by one: 98 resolve in Crossref, one is the Zenodo data set [35], two have no DOI, and one DOI as deposited does not resolve; no funder; Wiley's terms of use for the version of record and its text-and-data-mining licence.

4 OpenAlex, record for doi:10.1029/2026ja035527, and Semantic Scholar, record for the same DOI, both read November 2, 2026: each lists the paper as open, "bronze", at the publisher's PDF link, with no licence, and OpenAlex lists no repository copy. That is what the indexes say; the site's owner met a paywall at the publisher.

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6 Raj, J. K., Manu, V., Balan, N., Zhang, Q.-H., and Xing, Z.-Y. (2025). Capability of Revised Intensity and Impulsive Strength of Geomagnetic Storms and Activities to Identify Severe Space Weather. *Space Weather* 23(7), e2025SW004399. CC BY-NC 4.0. Abstract only, as deposited with Crossref: Wiley's site showed us a bot check, and so did its preprint's host. On this paper's reference list.

7 Nose, M., Iyemori, T., Sugiura, M., Kamei, T., Matsuoka, A., Imajo, S., and Kotani, T. (2015). Geomagnetic Dst index (data set). World Data Center for Geomagnetism, Kyoto. Provisional hourly values for May 2024 (page updated January 28, 2025), final values for March 1989, and the whole series through the WDC's HAPI server, all read November 2, 2026, under the WDC's data usage rules: scientific use, no commercial use, with acknowledgement of the observatories, of the WDC and of the data DOI. The final index stops at 2020.

8 World Data Center for Geomagnetism, Kyoto, Imajo, S., Matsuoka, A., Toh, H., and Iyemori, T. (2022). Mid-latitude Geomagnetic Indices ASY and SYM (ASY/SYM Indices). Provisional one-minute SYM-H through the WDC's HAPI server, which starts in 1981, read November 2, 2026, under the same rules as [7].

9 Hayakawa, H., Ebihara, Y., Mishev, A., Koldobskiy, S., Kusano, K., Bechet, S., et al. (2025). The Solar and Geomagnetic Storms in 2024 May: A Flash Data Report. *The Astrophysical Journal* 979(1), 49. CC BY 4.0. We read the accepted version, arXiv:2407.07665; p. gives its page. On this paper's reference list.

10 Hajra, R., Tsurutani, B. T., Lakhina, G. S., Lu, Q., and Du, A. (2024). Interplanetary Causes and Impacts of the 2024 May Superstorm on the Geosphere: An Overview. *The Astrophysical Journal* 974(2), 264. CC BY 4.0. We read the accepted version, arXiv:2408.14799; p. gives its page.

11 Tulasi Ram, S., Veenadhari, B., Dimri, A. P., Bulusu, J., Bagiya, M., Gurubaran, S., et al. (2024). Super-Intense Geomagnetic Storm on 10–11 May 2024: Possible Mechanisms and Impacts. *Space Weather* 22(12), e2024SW004126. CC BY-NC-ND 4.0. Abstract only, as deposited with Crossref; paraphrased, not quoted. On this paper's reference list.

12 NOAA Space Weather Prediction Center. NOAA Space Weather Scales. Read November 2, 2026.

13 North American Electric Reliability Corporation (2026, January). May 2024 GMD Event Review. NERC staff report. Full text, as on our guide.

14 Horne, R. B., Angling, M. J., Attrill, G. D. R., Beggan, C., Bisi, M. M., Cannon, P. S., et al. (2026). The May 2024 geomagnetic storm: UK experience and perspective. *Royal Society Open Science* 13(4), 251943. CC BY 4.0. Full text, from the NERC Open Research Archive; p. gives a page of that PDF.

15 Mac Manus, D. H., Rodger, C. J., Renton, A., Lo, V., Malone-Leigh, J., Petersen, T., et al. (2025). Implementing Geomagnetically Induced Currents Mitigation During the May 2024 "Gannon" G5 Storm: Research Informed Response by the New Zealand Power Network. *Space Weather* 23(6), e2025SW004388. CC BY 4.0. Full text, from the NERC Open Research Archive; p. gives a page of that PDF. On this paper's reference list.

16 Feng, X., Rodger, C. J., Clilverd, M. A., Mac Manus, D. H., Lo, V., Dalzell, M., et al. (2026). Geomagnetically Induced Currents, Transformer Harmonics, and Reactive Power Impacts: Observed Response of a Single-Phase Transformer in New Zealand. *Space Weather* 24(6), e2026SW004966. CC BY 4.0. Full text, from the NERC Open Research Archive; p. gives a page of that PDF.

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34 Nagatsuma, T., Kataoka, R., and Kunitake, M. (2015). Estimating the solar wind conditions during an extreme geomagnetic storm: a case study of the event that occurred on March 13–14, 1989. *Earth, Planets and Space* 67, 78. CC BY 4.0. Full text. On this paper's reference list.

35 Raj, J. K. (2025). Missing ACE solar wind data for severe space weather events [data set]. Zenodo. CC BY 4.0. By one of this paper's authors, and on its reference list. Zenodo refused direct downloads from our network, so on November 2, 2026, an AI page reader copied rows of two of its files for us: ACE's about 33-minute speeds. A language model read them; they were not parsed, and they could not be checked against the files themselves. One 2003 row is missing, and 14 are fitted speeds, as section 5 says.

36 Richardson, I. G., and Cane, H. V. Near-Earth Interplanetary Coronal Mass Ejections Since January 1996, revised July 23, 2026, DOI 10.7910/DVN/C2MHTH. Disturbance times and ICME intervals; its footnote (a) says a time flagged "A" is the shock's passage at ACE.

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METHOD

How this was checked

On November 2, 2026, we tried the routes the site allows to the paper's text: the publisher's page and the DOI, Crossref's title search for a preprint, OpenAlex and Semantic Scholar. Wiley's site showed our tools and our browser a bot check, which we did not try to get past, and the site's owner met a paywall at the publisher, whatever the indexes say. So the page rests on the abstract and reference list the publisher deposited with Crossref, 102 references looked up one by one; 13 other papers, reports and talks whose full text we had, read for the passages we cite, and 18 read only as abstracts, as the source list marks; Kyoto's Dst and SYM-H; NASA's OMNI and CDAWeb; Richardson and Cane's list; and rows of Raj's data set. Every quotation was checked word for word against its saved source.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. They cover the arithmetic behind −606 nT and its link to this paper, which is our inference; the ranks by index; the storm-or-grid question; and every number of our re-run. Every definition of ΔIEFy, front and body in that re-run is ours, because the paper's could not be read, and the paper's may differ.

One hosted script fetches its inputs and recomputes all our numbers; it reproduces the stage-by-stage outputs behind this page to the rounding, and a run in an empty folder, re-downloading everything, gave the same outputs byte for byte. We wrote rules before fetching any solar-wind data and logged each later change: those rules showed OMNI could not test the abstract's numbers, two of our own rules for finding fronts failed and were replaced, and a bug was fixed, all after seeing the data, and the rules with their hashes are hosted. We could not read the paper; we could not check ACE's about 33-minute speeds as listed in Raj (2025), which an AI page reader copied for us, against the files, because Zenodo refused direct downloads from our network, though their internal checks and the checks against ACE's other files pass; and no solar-wind measurement exists for March 13, 1989. Nothing was recomputed for NERC's, the UK's or New Zealand's reported currents. A fresh reviewer then checked the finished page; that review moved the upper-atmosphere verdict from Overstated to Partly true, corrected our reason on "2nd most intense" and a count of shared authors, replaced our word "threshold" with the abstract's numbers, and added the outages' timing, the same subtraction on Dst and the group's ΔV × Bz.

On November 6, 2026, the page was revised to review the paper on its own: no transcript of the S0 News episode that linked it was available, and without one the site no longer comments on how an episode presented a paper. The verdict on the link's label and the section on the episode's title were removed, and section 7 now asks what the paper means for the idea of a grid-breaking superstorm, from sources already cited here. Nothing was fetched again and no number was recomputed; the verdicts on the paper's claims are unchanged. A fresh reviewer then checked the revision against the saved texts; it corrected section 7's heading and lead, which had said the paper says nothing of a larger storm though the abstract names March 1989, and put the grids back in the page's search title.

This page was researched and written with Claude, an AI assistant made by Anthropic, and then re-checked against its sources in a separate verification pass.

The verdicts on this page

OVERSTATED	Has some basis but claims much more than the evidence supports.
UNCONFIRMED	Rests on a preliminary result that hasn't been confirmed.
PARTLY TRUE	Part of the claim holds up and part doesn't.

All ten verdicts, and how we check

CORRECTIONS

Corrections and changes

If we get something wrong, we fix it and record the change below with the date. If a correction changes a verdict, the log says what the old verdict was.

Change log

Nov 6, 2026	Revised to review the paper on its own. No transcript of the S0 News episode that linked it was available, and without one the site no longer comments on how an episode presented a paper. The verdict on the link's label is removed, the section on the episode's title is replaced by one on what the paper means for the idea of a grid-breaking superstorm, the page's other mentions of S0 News's episodes are removed or reworded, and the verdicts on the paper's claims are unchanged. A fresh review of the revision then corrected section 7, which had said the paper says nothing of a larger storm, though the abstract names March 1989.
Nov 5, 2026	The hosted script, may2024_numbers.py, now fetches under a plain client name, factchecked-research/1.0, rather than a browser-like one. Nothing else on this page changes.
Nov 4, 2026	Added links to our checks of two later papers that S0 News linked on November 4 under "May 2024 Not Weak", on GPS scintillation and on the auroral oval's edge. Nothing else on this page changes.
Nov 2, 2026	Published on factchecked.science after a full check against the sources. Built from the paper's abstract and reference list, because the site's owner met a paywall at the publisher, together with Kyoto's indices, NASA's solar-wind records, the published reviews of the storm's effects and our own re-run, whose definitions are ours; nothing from the paper is reproduced beyond short quotations from its abstract. A fresh reviewer then checked the finished page; that review moved the upper-atmosphere verdict from Overstated to Partly true, corrected our reason on "2nd most intense" and a count of shared authors, replaced our word "threshold" with the abstract's numbers, and added the outages' timing, the same subtraction on Dst and the group's ΔV × Bz.

Fact-Checked Science is independent. It isn't affiliated with the channels, presenters or authors whose claims it checks.

Last updated Nov 6, 2026