Fact-Checked Science

PAPER CHECK · SPACE WEATHER

May 2024's auroral oval did pass below 50°; we couldn't read the paper's case for why

Ten researchers report that the auroral oval's edge passed below 50° magnetic latitude in the postmidnight-to-dawn sector during the May 2024 storm, and that deep earthward convection caused it [1 Abstract]. We could read only the paper's public view, its Abstract, Plain Language Summary, data statement and references: every section, method and figure is unread, and the site's owner met a paywall, although OpenAlex lists it as free to read [1][4]. Open DMSP data support the latitude, on our own definitions, and old fits put it within the published relation, though Kp fits stop near 50°; the case for the cause is in text we couldn't read.

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OUR ANALYSIS marks our own reasoning and calculations: every number from our check of DMSP's open files, whose definitions are ours and may differ from the paper's, with "edge" meaning the edge at 1 keV and above; the old fits as we evaluate them; the comparison between storms; and what we infer from the reference list. The verdicts are our assessment. Everything else comes from the numbered sources. For the paper [1], read only in its public view, Abstract, Plain Language Summary, Availability Statement and References are those parts of it; every numbered section, method and figure is unread. Elsewhere p. gives a page and Abstract the part of a source we rely on.

The latitude holds up in public data, the case for the cause is in text we couldn't read, and the summary goes further than the abstract

OUR ASSESSMENT

below 50°

the only number in the paper's public view: the oval's equatorward edge, postmidnight to dawn [1 Abstract]. It is a ceiling, not a value, and doesn't conflict with the 29.8° and 35.5° on our earlier page

42–49°

how low electrons reach in that sector in DMSP's open files, by how we measure them: softer electrons about 42–43°; at 1 keV and above about 44–45°, at noise level; brighter electrons 47–49°. Before the storm, 66–71° at 1 keV and above (our analysis) [38]

about −140 nT

the Dst at which a 1998 fit puts the oval's edge at midnight at 50°. In this sector 50° means about 45–48° at midnight, or about −190 to −370 nT on its two lines, against −406 nT in this storm. So "below 50°" isn't beyond the published relation (our arithmetic) [9 p. 570][43]

THE PAPER'S CLAIMS

TRUE

"below 50° magnetic latitude"

The paper's abstract, on the oval's equatorward edge; its summary repeats it [1 Abstract]

Supported by public data, on our definitions; the paper's is unread. In DMSP's open files electrons stand above flat counts below 50° on all three satellites. At 1 keV and above they do so on 5 of 17 main-phase crossings in that sector, by inspection, with bright ones, about 1 erg/cm²/s, at 47.4° and 47.8°. Softer electrons reach below 50° on 12 of 17, lowest about 42°. Quiet orbits that day stay at 63° or higher (our analysis) [38]. Two routine products reach their own floor at 50° [38][39]. Others report the same picture: enhanced TEC in a narrow band at 45–55° on the nightside, read as the oval extended to lower latitudes [7 p. 37], and a burst near 45° [27 Abstract]. See section 3.

CONTEXT

"remains unresolved"

The paper's abstract, on what controls such expansion during extreme storms; its summary says "has remained poorly understood" [1 Abstract]

An introductory phrase, scoped to extreme storms, and there it stands: how much convection, the ring current and substorms each contribute at the extreme, and what lights the visible oval reconstructed near 30–36°, are still open [15 Abstract][7 p. 35]. The facts it leaves out: the basic link, from convection to the plasma sheet's inner edge to the oval's edge, is decades old, and they cite it [1 References]. We can't see how the text treats these. See section 5.

UNVERIFIED

"results from the deep earthward penetration of magnetospheric convection"

The paper's abstract, after "We show" [1 Abstract]

What this rests on is in text we couldn't read. We know the paper's data sources from its data statement, not how it used them, which passes it took or which coordinates [1 Availability Statement]. In DMSP's open files, fast ion flow sits within 2° of the 1 keV edge on 10 of 17 crossings, a figure that changes with the energy band (our analysis) [40]. That fits, and can't show cause. Others report the same picture for this storm: Zhang and colleagues have the Region 2 current at mid-latitudes and sunward convection at low latitudes [34 Abstract], and Hayakawa and colleagues an intense convective field from high to low latitudes [7 p. 40]. Unverified stands for what this paper shows. See section 3.

OVERSTATED

"the key mechanism responsible for substantial low-latitude auroras"

The paper's Plain Language Summary, whose words we rate here, not the abstract's [1 Plain Language Summary]

The abstract says "a key process", which has decades of support [1 Abstract]. The summary's "the key mechanism", hedged only by "Our results indicate", turns that into a general answer for low-latitude auroras, from one storm. That step from "a" to "the", and that generality, are what we rate. Its "shifting the entire auroral oval" we can't rate: the data statement's global data sets might bear on it, and we can't see how [1 Availability Statement]. See section 5.

UNCONFIRMED

"may also help explain"

The paper's abstract, on expansion in "previous superstorms" [1 Abstract]

A fair hedge on an untested extension. March 1989 fits: precipitation reached 40.1° and the electric field 35° [23 Abstract]. Before the space age nobody measured convection. In our coarse comparison, only 2024 had a satellite at 3–5 magnetic local time near its deepest hours, and at 5–6 its 47.8° sits 2–6° below the earlier storms, with different sensors (our analysis). See section 6.

1 · WHAT WE COULD READ

The paper's public view, not its sections

Ten researchers, eight at China's National Space Science Center, one at INPE in Brazil and one at ESA, published this peer-reviewed paper in *JGR Space Physics* on October 31, 2026 [3]. S0 News linked the paper on November 4, 2026 [2].

What we could read: the public view

The site's owner pasted Wiley's public view: the Abstract, the Plain Language Summary, the statements on interests and on data, and the 72 references [1]. The owner met a paywall for the rest, although OpenAlex lists the paper as free to read [4], as the indexes did for Balan and colleagues' paper. Every numbered section, method and figure is unread. We found no preprint or repository copy.

So we rate only words we can read, and we say nothing about how the paper used its data, which passes it took or which coordinates it means. No figure of the paper is redrawn. If you have the article, please tell us through the correction form, and we will revise the page.

What its data statement lists

Kyoto's Dst; NASA's OMNI solar-wind data; the MMS1 and THEMIS spacecraft; DMSP F18's auroral data and ion drift; DMSP's precipitating electrons, through Madrigal; Swarm's electrojet product; AMPERE's field-aligned currents; SuperMAG's indices; and SuperDARN convection maps, which the lead author deposited at Zenodo [1 Availability Statement][5]. That is a list of sources. How the paper used each, which passes it took and which coordinates it means, we can't say.

What else the record shows

No competing interests declared [1 Conflict of Interest]. Crossref lists the Chinese Academy of Sciences as funder; OpenAlex adds the National Natural Science Foundation of China [3][4]. Received July 20, accepted October 23 [3]. Wiley's standard terms apply, so we quote short phrases only.

Four of the authors also posted a conference abstract for EGU 2026, on the dusk side, which speaks of mid-latitude auroras and of brightest emissions reaching 50° [6 Abstract]. It is a separate document, not a preprint, and we infer nothing about this paper's methods from it.

The terms, in plain words

TERM	WHAT IT MEANS HERE
Auroral oval, its equatorward edge	The ring of aurora around each magnetic pole, and its low-latitude side. A midnight index for March 1989 has that side at 55–65° when Dst is above −50 nT [9 p. 567]
Plasma sheet	The hot plasma of the magnetic tail. The oval's diffuse edge is usually taken as the map of its inner edge [9 p. 571]
Magnetospheric convection	The large-scale flow of plasma driven by the solar wind, with the electric field that goes with it [25 Abstract]
Region 1 and 2 currents	Large-scale field-aligned currents: Region 1 near the poleward side of the current region, Region 2 near its equatorward side [47 Abstract]
Magnetic latitude, CGM, ILAT	The public view says only "magnetic latitude" [1 Abstract]. DMSP's files give corrected geomagnetic latitude at 110 km [38]. Invariant latitude is the latitude of a field line's footprint [7 p. 35]
MLT	Magnetic local time: 00 is magnetic midnight and 06 is dawn
Kp, Hp30	Planetary activity indices. Kp is three-hourly and stops at 9. Hp30 is half-hourly and open-ended; it reached 11.33 in this storm [42]
Dst, SYM-H	How far the field at low latitudes is depressed: hourly and one-minute. May 2024 reached −406 nT and −518 nT [43][44]

What its 72 references cover, by title

OUR ANALYSIS

GROUP, OURS	COUNT	EXAMPLES
The oval and its boundaries	20	Feldstein and Starkov 1967; Horwitz and colleagues 1982; Gussenhoven and colleagues 1983; Carbary 2005; Milan 2009
Convection and solar-wind coupling	14	Cowley and Lockwood 1992; Thomsen 2004; Thomas and Shepherd 2018; Dai and colleagues 2024
Earlier great storms, historical aurora	13	Rich and Denig 1992; Huang and colleagues 2005; Heelis and Coley 2007; Silverman 2008; Love and colleagues 2025
Instruments, networks, data	8	Ruohoniemi and Baker 1998; McFadden and colleagues 2008; Gjerloev 2012; T. Wang 2026
May 2024	7	Hayakawa and colleagues 2025; Foster and colleagues 2024; Karan and colleagues 2024; Lockwood and colleagues 2025
Field-aligned currents, electrojets	7	Iijima and Potemra 1978; Anderson and colleagues 2014; Kepko and colleagues 2015
Space-weather impacts	3	Boteler 2003; Buzulukova and Tsurutani 2022; Xue and colleagues 2024

Inference, from titles alone [1 References][3]. Titles don't show what the text says. Eleven of the 72 come from the authors' own group, whose recent work treats convection as driven quickly from the dayside [45 Abstract]; we infer that the paper builds on it. Balan and colleagues and Prikryl and colleagues are not on the list. Of the 72, 65 of 66 DOIs resolve in Crossref and the other in DataCite; six entries have no DOI.

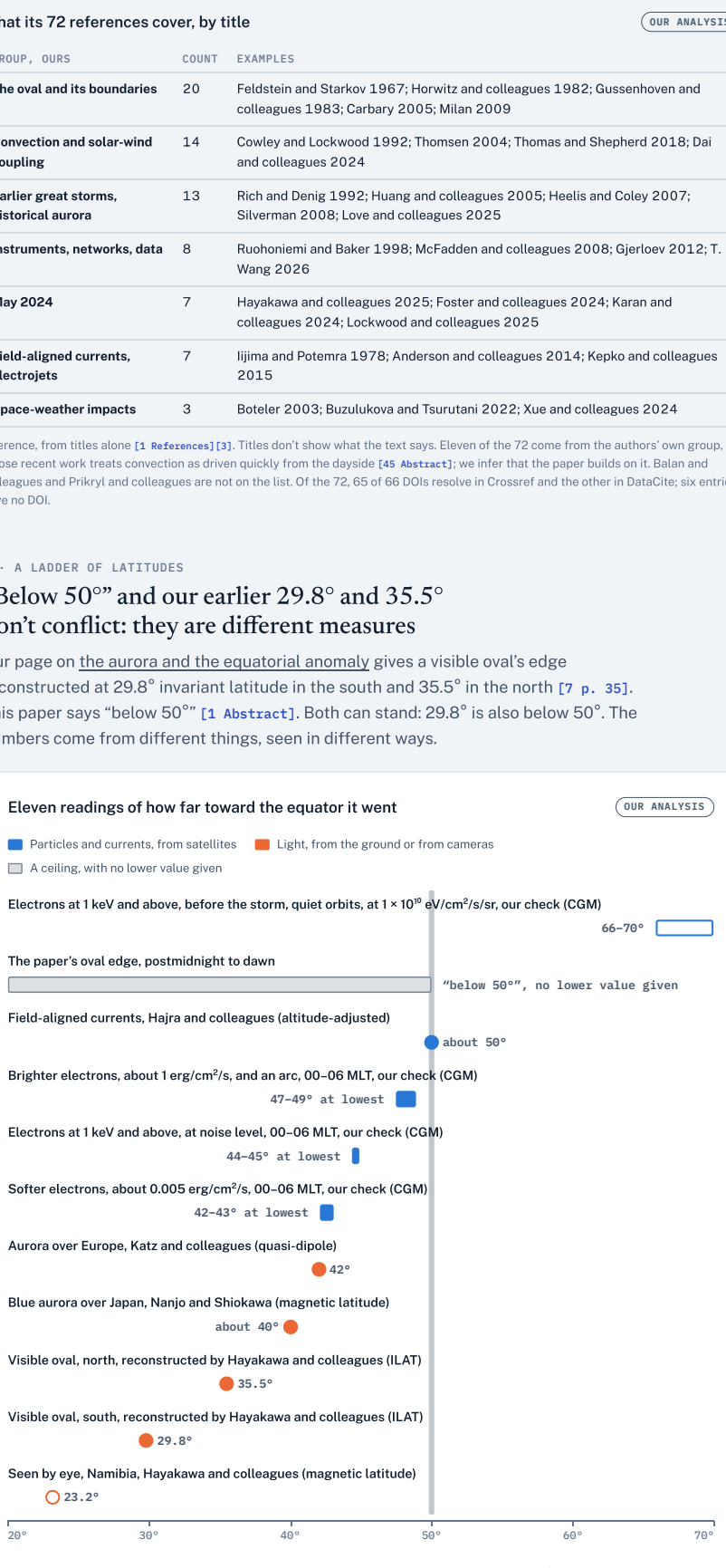
2 · A LADDER OF LATITUDES

"Below 50°" and our earlier 29.8° and 35.5° don't conflict: they are different measures

Our page on the aurora and the equatorial anomaly gives a visible oval's edge reconstructed at 29.8° invariant latitude in the south and 35.5° in the north [7 p. 35]. This paper says "below 50°" [1 Abstract]. Both can stand: 29.8° is also below 50°. The numbers come from different things, seen in different ways.

Eleven readings of how far toward the equator it went

OUR ANALYSIS



Drawn by us from numbers in the cited texts and from our own analysis; no figure is reproduced. The rows are not in one coordinate system, and the storm's reports come from different hours and sectors [1 Abstract][30 p. 1]. Katz and colleagues [31 Abstract]; Nanjo and Shiokawa [32 Abstract]; Hayakawa and colleagues [7 p. 34][7 p. 35]; ours [38]. In field-line terms, by our arithmetic, 50° is L = 2.42, 45° is L = 2.0, 35.5° is L = 1.51 and 29.8° is L = 1.33.

How to read 29.8° and 35.5° beside it

What was measured

Those two are reconstructed from where people saw light, how high it stood in the sky and an assumed emission height, then traced along the field line [7 p. 34][7 p. 35]. "Below 50°" is about the oval's edge and electron precipitation; how the paper finds it is unread [1 Abstract].

A ceiling, not a value

The public view gives no lower figure, so nothing in it can disagree with a lower one [1 Abstract].

The height assumed

About 400 km. For the Namibian camera limit, 300, 400, 500 and 800 km give 27.6°, 28.9°, 30.1° and 33.3° invariant latitude [7 p. 48].

Brightness

Naked eye and camera differ, and low-flux electrons may light emission too dim to see [7 p. 35][7 p. 48]. A satellite with a flux threshold sees only what passes it.

Coordinates

At 400 km, 29.8° and 35.5° invariant are about 26.5° and 32.9° magnetic latitude, by the formula on our earlier page (our arithmetic).

Sector and moment

The visual numbers take the lowest report anywhere, from different times in the storm [7 p. 47]. The paper's is one slice of local time in the main phase [1 Abstract].

What the red light may be

Hayakawa and colleagues weigh stable auroral red arcs, which reach farther toward the equator, and choose reports with structure or non-red colour to avoid them [7 p. 35][7 p. 36].

The same pairing in 1989

Satellites had precipitation to 40.1° and the electric field to 35° [23 Abstract]. The 29° beside them is a visibility limit, where an observer stood, and the source warns that the relation with the visual oval isn't clear [8 p. 22]. For 2024 the same pairing is 44–45° against 23.2°, about 21°; against the reconstructed edges it is 9–15°.

OUR ANALYSIS

No conflict: the two pages agree.

Our earlier page already gives "below 50°" as where the auroral belt's edge at midnight moved in the March 1989 storm, once Dst passed −100 nT [9 p. 567]. What the gap does leave open is the reach of the explanation. The public view doesn't say how the mechanism reaches a visible oval reconstructed near 30–36°, some 15–20° beyond 50°, with sightings from 23° magnetic latitude, yet its summary opens on aurora visible at unusually low latitudes [1 Plain Language Summary]. The text may address that.

3 · OUR CHECK ON DMSP'S OPEN FILES

Open satellite files put electrons below 50° in that sector, on our definitions

Four things first. The definitions here are ours, and the paper's is unread. "Edge" means the edge at 1 keV and above unless we say softer electrons. This tests where electrons were, not why they were there. And it wasn't blind: the first run failed, a control forced the threshold up, the working threshold came after the data, and a fresh review of this page moved the window's end and added a test of softer electrons. The amendments are public with their hashes (section 9).

AT 1 KEV AND ABOVE

OUR ANALYSIS

5 of 17

crossings in 00–06 MLT, from the shock to SYM-H's low, with electrons below 50°, by inspection of the raw counts. The pipeline counts 7 at our working threshold; we set aside 18:56 and 00:04 UT [38]

HOW LOW, BY ENERGY

OUR ANALYSIS

42–49°

softer electrons about 42–43°; at 1 keV and above about 44–45°, at noise level, on F18 near 22:20–22:45 UT, MLT 4.8 and 3.3; brighter electrons 47–49°: about 1 erg/cm²/s, by a usual rule of thumb bright enough to see, at 47.4° and 47.8°, and an arc at 48.9° [38]

BEFORE THE STORM

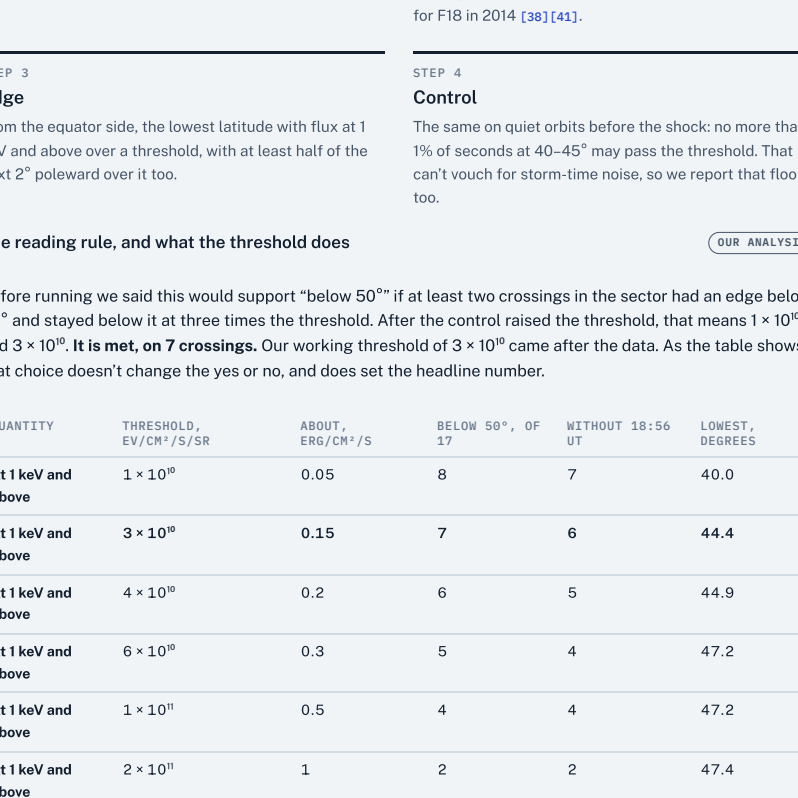
OUR ANALYSIS

66–71°

the edge at 3 × 10¹⁰ eV/cm²/s/sr on 14 quiet-orbit crossings in that sector earlier on May 10; 66–70° at 1 × 10¹⁰; softer electrons 63–75° [38]

How far DMSP saw electrons and fast flow, crossing by crossing

OUR ANALYSIS



Magnetic latitude (|CGM| at 110 km) against UT, 16:30 on May 10 to 02:30 on May 11, 2024; each crossing sits at the time of its edge at 1 × 10¹⁰, and each fast-flow mark just right of it

Our own analysis of public data, not from the paper: DMSP F16, F17 and F18 SSJ from NOAA NCEI [38], ion drift from NASA's CDAWeb [40], and Kyoto's provisional Dst, for scientific, non-commercial use, with acknowledgement of the observatories that supply it and of the WDC for Geomagnetism, Kyoto [43]. Our definitions; the paper's is unread.

STEP 1

Read

NOAA's SSJ text files for F16, F17 and F18 give electron counts each second in 19 energy channels, with position and magnetic local time [38]. The files stop near 40°, so we can't see lower.

STEP 2

Flux

Counts averaged over 11 s, a background from the 25th percentile across channels, flat counts and the South Atlantic masked, then the format guide's formula and pre-flight factors. Our flux runs about 1.27 times NASA's for F18 in 2014 [38][41].

STEP 3

Edge

From the equator side, the lowest latitude with flux at 1 keV and above over a threshold, with at least half of the next 2° poleward over it too.

STEP 4

Control

The same on quiet orbits before the shock: no more than 1% of seconds at 40–45° may pass the threshold. That can't vouch for storm-time noise, so we report that floor too.

The reading rule, and what the threshold does

OUR ANALYSIS

Before running we said this would support "below 50°" if at least two crossings in the sector had an edge below 50° and stayed below it at three times the threshold. After the control raised the threshold, that means 1 × 10¹⁰ and 3 × 10¹⁰. **It is met, on 7 crossings.** Our working threshold of 3 × 10¹⁰ came after the data. As the table shows, that choice doesn't change the yes or no, and does set the headline number.

QUANTITY	THRESHOLD, EV/CM²/S/SR	ABOUT, ERG/CM²/S	BELOW 50°, OF 17	WITHOUT 18:56 UT	LOWEST, DEGREES
At 1 keV and above	1 × 10¹⁰	0.05	8	7	40.0
At 1 keV and above	3 × 10¹⁰	0.15	7	6	44.4
At 1 keV and above	4 × 10¹⁰	0.2	6	5	44.9
At 1 keV and above	6 × 10¹⁰	0.3	5	4	47.2
At 1 keV and above	1 × 10¹¹	0.5	4	4	47.2
At 1 keV and above	2 × 10¹¹	1	2	2	47.4
Softer electrons	1 × 10⁹	0.005	13	12	42.1
Softer electrons	3 × 10⁹	0.015	9	9	42.3
Softer electrons	1 × 10¹⁰	0.05	5	5	43.3

These are the pipeline's counts, before the inspection below. At 1 × 10¹⁰ the lowest is the file's floor [38].

OUR ANALYSIS

What went wrong on the way

The first run failed. Under the rules as first written it found 0 of 12 crossings below 50°. Raw counts showed that to be our error: the contamination flag fired on real, intense precipitation, and the search started in polar-cap noise. Amendment 2 replaced both. We kept that run's table.

A control forced the threshold up. At the 2 × 10⁹ we took from Decotte and colleagues, 2.8% of F18's quiet seconds at 40–45° passed, against our 1% limit, and at 6 × 10⁹, 1.1% [37 Abstract]. By rule it rose to 1 × 10¹⁰, where 0.1% pass. F17's quiet seconds at 40–45° in 00–06 MLT all fall inside the South Atlantic box, so for F17 the control can't speak to that sector.

That level is still noisy. At 1 × 10¹⁰ four crossings reach the file's floor, where the raw counts look like noise. Before that run we said the edge should land near 43–44° on the 22:20 UT crossing at 1 × 10¹⁰. It doesn't: it lands there, at 44.4°, only at 3 × 10¹⁰.

Storm-time noise is higher than quiet-time noise. In the lowest 2° of F18's main-phase crossings, where the flux at 1 keV and above is noise in the top channels, its median is 0.8–2.6 × 10¹⁰, and on the 22:23 UT crossing 24% of those seconds pass 3 × 10¹⁰. In the quiet control none of F18's pass 2 × 10¹⁰. On F18 one count above background at 30 keV is 7.9 × 10⁹, and one in each of the nine channels is 2.3 × 10¹⁰, and near the floor the background sits under the channels that weigh most. So 44.4° sits on the noise floor on that crossing. Flat bands of about 8–18 counts also lie at 45–54° on all three satellites.

The South Atlantic. Flat counts over it gave false low edges at dusk, so amendment 4 masks a box. It changed nothing in this sector's table, and it also hides some real aurora.

A test against a published number failed. On March 1989 we get about 46–50° where Rich and Denig report 40.1° [23 Abstract]. So our 1 keV edges may run several degrees high of that number (section 6).

OUR ANALYSIS

What we count, and what the raw counts show

Not counted: 18:56 UT. The pipeline puts it at 49.6°, but below about 50.5° the raw counts are flat, like contamination.

Not counted at 1 keV and above: 00:04 UT. Channels at 13.9 keV and above give all the flux at its 49.2° edge. The electrons that stand above noise there are soft, about 0.1–0.5 keV, to about 46°.

Counted by its arc: 01:47 UT. Its 47.5° is the 30 keV channel, but the arc at 48.9° is real, with over 100 counts at 2–6 keV.

So the pipeline's 7, 6 and 2 of 17 at 3 × 10¹⁰, 4 × 10¹⁰ and 2 × 10¹¹ become 5, 5 and 2: F18 at 20:41, 22:23, 22:42 and 01:47 UT, and F17 at 02:12 UT. That is a judgment, and the counts are hosted so you can make your own.

A bright, clean case: F17, 02:12 UT, MLT 5.7. 47.8° on every rung to 2 × 10¹¹, with hundreds of counts in every channel from 1.4 to 30 keV near 48.7° and flux up to 4.7 × 10¹¹, about 24 erg/cm²/s. It lies 2 minutes before SYM-H's low; our first window closed before it, and amendment 6 moved the window after we had seen the data.

By eye, and that is a judgment, F18 stands above noise at about 20:38 UT, to about 47–49°; 22:21 UT, electrons of about 0.2–4 keV, to about 44°; 22:43 UT, to about 43–44°; 01:44 UT, soft to about 44.5°.

Two of the 17 rows, 17:09 and 17:43 UT, precede any fall in Dst.

OUR ANALYSIS

Softer electrons: a test the review prompted

Amendment 5 follows a fresh review of this page and isn't blind: the reviewer had seen the counts, and we re-derived the reviewer's test in our own code. Take the flat level from the channels at 9.45 keV and above, take the excess over it at 6.46 keV down to 139 eV, and walk as before.

It passes the quiet control at 1 × 10⁹, about 0.005 erg/cm²/s: 0.10%, 0.06% and 0.25% of quiet seconds at 40–45° on F16, F17 and F18. Quiet edges stay at 63–75°. In the main phase it reaches below 50° on 13 of 17 crossings, or 12 without 18:56 UT, with lowest 42.1° (table above) [38].

Not uniform, at 1 keV and above. In the same hours F16 and F17 near 5–6 MLT show 1 keV edges of 50–56°. But softer electrons reach about 43–47° on those satellites, apart from F17 at 00:32 UT, at 55°. So much of the spread about 1 keV and above, is a choice of energy band.

Is that the oval? Whether soft electrons at about 0.005 erg/cm²/s count as "the oval" is a matter of definition, and the paper's definition is unread.

OUR ANALYSIS

Fast flow beside electrons: it fits, and can't show cause

DMSP's drift meter shows cross-track ion flow of at least 300 m/s below 50° on 9 of 17 crossings, lowest 45.7°, with 66° or higher on quiet orbits [40]. Against the 1 keV edge at 3 × 10¹⁰ it sits within 2° on 10 of 17, lower by more than 2° on 5, mostly near dawn, and higher on 2. Against softer electrons at 1 × 10⁹ the split is 3, 3 and 11: electrons run 2–11° below the flow on 11 of 17. So the pairing depends on the band.

We use speed only and don't read direction, so fast flow equatorward of or beside electrons could also be subauroral ion drifts [28 Abstract]. Electrons and fast flow were at these latitudes at the same time, which fits the abstract's account. It cannot show that one caused the other.

In the authors' SuperDARN deposit, flows of at least 300 m/s reach 42.5–47.5° across all sectors from 18:00 UT on, where 42.5° is the deposit's coverage floor in the bins that reach it, and our test of its orientation was inconclusive, so we give no sector [5].

OUR ANALYSIS

Two routine products stop at 50°

NOAA's boundary marks in these SSJ files bottom out at 50.007°, the lowest of 113, on our reading of an undocumented format [38]. SSUSI's auroral maps stop at about 49.7–50.2° in this sector and its swath boundary at 49.84° [39]. Flux over SSUSI's 0.2 erg/cm²/s reaches that limit on most F18 passes from about 18:45 UT and on F17 in the south from about 23:00 UT. So they agree with SSJ as far as they can see, and can't by themselves show "below 50°". We say nothing about which products the paper used beyond its data statement.

OUR ANALYSIS

An early fall

On that 18:56 UT crossing, precipitation stood near 50.5° under two hours after the shock and about seven hours before the Dst low, with SYM-H at −92 nT [44]. That fits a convection account, but pressure effects muddy Dst then, and one crossing can't decide it. Yokoyama and colleagues' lead of about an hour doesn't bear on it: they put that lead down to substorms [9 p. 572].

4 · WHAT THE OLD FITS SAY

"Below 50°" isn't beyond the published relation

Fits of the oval's edge against activity go back decades, and several are on the paper's own list. Here are published formulae only, with their limits, at Kp 9 and at Dst near −406 nT. Extrapolating them to a superstorm is weak.

Against Kp and Hp30: the edge's latitude by magnetic local time, in degrees

OUR ANALYSIS

FIT, WITH ITS BASIS	00–01	01–02	02–03	03–04	04–05	05–06
Gussenhoven and colleagues 1983, Kp 9. DMSP F2 and F4 electrons; well ordered at night, with more scatter from dawn on [10 Abstract]. Bins 02–04 are absent, so interpolated	48.2	51.1	52.2	53.3	54.4	51.0
Troyer and colleagues 2025, median, Kp or Hp30 of 9. The 50th percentile from just under a million DMSP boundaries, 1986–2014 [11 Abstract]	50.0	50.4	51.1	52.1	53.4	54.9
The same, Hp30 of 11.33, the storm's peak, at 22:30 UT [42]	46.6	47.2	48.1	49.3	50.7	52.2

Coefficients for Gussenhoven and for Troyer are as transcribed in the ocbpy code, unchecked against the papers, whose tables we couldn't reach, and the Kp ranges behind both are unread [12]; ocbpy gives Troyer one formula for "Kp or Hp30". Carbary's table is out of reach too; the abstract says the fits are good below Kp 6 and worsen above [13 Abstract].

Against Dst: Yokoyama and colleagues 1998, the edge at midnight, in degrees

OUR ANALYSIS

DST, NT	−100	−143	−200	−300	−339	−406	−589
All 423 storms, 1983–1991, r = 0.8	52.5	50.0	47.4	43.8	42.6	40.7	36.3
March 1989's main phase alone	53.1	51.3	49.4	46.6	45.6	44.1	40.7

From their ring-current energy −4 × 10¹³ Dst (J, nT), field energy 8 × 10¹⁷ / L³ and the two regression lines 0.11 E − 4.7 × 10¹⁴ and 0.17 (E − 1.4 × 10¹⁵) [9 p. 568][9 p. 570], by our arithmetic. Read from the paper, whose symbols are mangled in the PDF's text layer. Check: zero Dst gives 65.3° against the paper's 65°. The 1989 line at −589 nT gives 40.7° beside Rich and Denig's 40.1° [23 Abstract], but that isn't independent: the line is fitted to that storm's same index.

OUR ANALYSIS

"Below 50°" isn't beyond the published relation. That doesn't make the paper trivial, and doesn't confirm its mechanism.

Dst fits at midnight: within reach, with a caveat. They put the edge at midnight at 50° at about −140 to −180 nT. But theirs is an index at midnight, extrapolated from the evening sector when no midnight pass exists [9 p. 567], and our 44–45° is at MLT 3.3–4.8. At Kp 9, Gussenhoven's and Troyer's shapes put 3.5–4.7 MLT 2–5° above midnight. So 50° in this sector means about 45–48° at midnight, which is −186 to −263 nT on the all-storm line and −246 to −366 nT on the 1989 line, and the storm's −406 nT lies beyond both. At −339 nT they give 42.6–45.6° at midnight, so the match with our 44–45° at that hour is partly coincidence. They miss by 5–10° elsewhere: −277 nT gives 44.5–47.1° at midnight, against 52–54° at 21:03 UT. And −406 nT interpolates between a few storms: the deepest in the fit is −589 nT, March 1989, and points are sparse out there.

Kp fits: they stop near 50°. At Kp 9 in this sector, one bin of twelve is below 50° (Gussenhoven at 00–01 MLT, 48.2°), and Troyer's median stops at 50.0°. Like with like, a median against a median: our 14 edges at 3 × 10¹⁰ from 19:21 UT have a median of 50.3°, 1.8–4.6° below Troyer at 3.3–4.8 MLT. Kp stops at 9, so it can't rank the extremes: March 1989 and May 2024 both hit its ceiling. Hp30 goes further and comes closer: at 11.33, four of six bins are below 50°.

Other yardsticks. Yokoyama and colleagues give 6–7° per 100 nT past −100 nT, though the lines above give 5.1 and 3.7° from −100 to −200 nT and 2.3–3.6° beyond; older work has 2.5° for quiet arcs and 2.3° at the polar-cap edge [9 p. 571][9 p. 572]. Milan and colleagues' oval radius, a proton-aurora peak and not an edge, grows from about 18° to close to 30° as SYM-H falls to −200 nT [14 p. 2918]. Hayakawa and colleagues say of the visual oval that its reach was as expected from the empirical correlation with storm intensity [7 p. 31].

These fits are statistics about one quantity. None says what moves the edge.

5 · "UNRESOLVED", "A KEY", "THE KEY"

"Remains unresolved" is scoped to extreme storms, and there it stands; the decades-old link it leaves out is on the authors' own list

The abstract says that during extreme storms the process controlling such expansion "remains unresolved", and the summary that it "has remained poorly understood" [1 Abstract]. We rate that Context, because it is an introductory phrase, and we add the facts it leaves out. We can't see how the unread text treats any of this.

The older work, as far as we could read it

YEAR, WORK	WHAT IT SAYS	ON THE PAPER'S LIST?
1967, Feldstein and Starkov	The auroral belt's dynamics; record only [21]	Yes
1968, Vasyliunas; 1970, Wolf	Inner-magnetosphere electrons, and convection with the ionosphere's conductivity; records only [18][19]	No
1969, Kennel	The auroral precipitation boundary can be computed by balancing convection with precipitation [17 Abstract]	No
1978, Southwood and Wolf	Shielding by the plasma sheet's electron boundary keeps the convection field from reaching low latitudes, to a degree that depends on precipitation [20 Abstract]	No
1982, Horwitz and colleagues	Plasmapause, plasma sheet inner edge and the oval's edge often coincide, from a few cases [22 Abstract]	Yes
1983, Gussenhoven and colleagues	Boundary fits are identified with the plasma sheet's inner edge and set against convection-field predictions; the boundary serves as an indicator of the field's strength [10 Abstract]	Yes
1992, Rich and Denig	March 1989: precipitation to 40.1°, auroral electric field to 35° [23 Abstract]	Yes
1998, Reddy and Mayr	Convection-driven ion flows penetrating as low as 30° in two storms: the word isn't new [24 Abstract]	No
1998, Yokoyama and colleagues	The diffuse edge taken as the plasma sheet's inner edge, controlled by tail pressure balance and the dawn-to-dusk electric field [9 p. 571]	No
2004, Thomsen	Kp tracks the convection field through the plasma sheet's inner edge [25 Abstract]	Yes
2007, Heelis and Coley	Drifts that "may be induced" by the convection pattern as it expands to about 40° in superstorms [26 Abstract]	Yes

What is still open, from the same literature

The shares. The ring current by itself stretches the field so as to enlarge the polar cap [16 Abstract]. Solar-wind coupling and ring current both matter [15 Abstract], and Milan and colleagues' main finding is that the oval's radius grows as the ring current intensifies [14 Abstract].

Substorms. Foster and colleagues tie a sudden burst of low-energy precipitation near 45° in this storm to a substorm breakup [27 Abstract]. In storms of 1989–1992, Shiokawa and colleagues find broadband electrons near the oval's edge, at 47–66° magnetic latitude, trace them to the inner plasma sheet, and link them to certain substorms and to red aurora at mid-latitudes [28 Abstract].

The lowest light. Whether it is aurora at all is still weighed [7 p. 35].

OUR ANALYSIS

Why Context, and what may be new

The sentence is scoped: "During extreme geomagnetic storms", it says [1 Abstract]. At that extreme the shares are still open, so it stands there. What it leaves out is the basic link at ordinary levels, which is decades old, and they cite it [1 References]: Feldstein and Starkov, Horwitz, Gussenhoven, Rich and Denig, Thomsen, and Heelis and Coley are on their list. Those papers report a relation, a proposed control or a "may", not a settled process for such storms. It is an introductory phrase, not a finding, and the text may set all this out.

What may be new, by inference from the public view alone: tying that reach to the oval's edge in this sector, in one superstorm, with that combination of data. The reach itself isn't new: flows to 30° [24 Abstract], a field to 35° [23 Abstract], and for this storm convection at low latitudes [34 Abstract]. Whether the text separates convection from the ring current, and how, we can't read.

The abstract and the summary, side by side

	ABSTRACT	PLAIN LANGUAGE SUMMARY	OUR READING
The gap	"remains unresolved"	"has remained poorly understood"; "solve this puzzle"	"Solve" goes furthest
Force	"a key process"	"the key mechanism responsible"	"A" to "the" is a real step up, in a general claim from one storm, though the summary keeps "indicate". This is what "Overstated" rests on
Cause	"We show"; "results from"	"Our results indicate"	Here the abstract is the firmer. The evidence is unread
Reach	The boundary below 50°, in one sector; "a coherent equatorward displacement of the auroral oval"	"shifting the entire auroral oval"	"Entire" goes a little further than "coherent". The data statement's AMPERE, SuperMAG and SuperDARN sets are hemispheric or global and might bear on it; we can't see how
What is explained	Low-latitude auroral expansion	Low-latitude auroras, opening on visibility at unusually low latitudes	People saw it at 23° magnetic latitude [7 p. 34]. The public view stops at below 50°

Wording from the public view [1 Abstract][1 Plain Language Summary]. The summary's "directly tracked" we don't rate: how the data were used is unread.

6 · PREVIOUS SUPERSTORMS

A fair hedge, and untested: our comparison is coarse, and only 2024 had a satellite at 3–5 MLT near its deepest hours

Given stronger convection expected at higher Kp and more negative Dst, the abstract says, the mechanism "may also help explain" expansion in "previous superstorms" [1 Abstract]. The public view gives no data on another storm. Its reference titles name 1859, 1872, 1989 and 2003 [1 References].

What supports it

In March 1989 DMSP saw both electrons and electric field low [23 Abstract]. One paper on superstorms of 2001–2004 says drifts "may be induced" by the convection pattern as it expands to about 40° [26 Abstract], and ion flows were seen as low as 30° in two earlier storms [24 Abstract].

What limits it

Before the space age nobody measured convection, so 1859, 1872 and 1921 can't be tested. The premise has support at ordinary levels [25 Abstract][36 Abstract], but Kp stops at 9, and the authors' group finds indices responding nonlinearly to stronger fields, in high-speed streams [35 Abstract].

The same kind of edge on earlier storms: lowest at 4 × 10¹⁰ / 2 × 10¹¹, at 1 keV and above, in degrees

OUR ANALYSIS

STORM	LOWEST HOURLY DST, NT	SATELLITES	DAWN SIDE, 5–6.6 MLT	18–24 MLT
March 13–14, 1989	−589	F08, F09	50.8 / 51.3	47.7 / 49.7
October 29–30, 2003	−353	F13, F15, F16	52.8 / 53.4	49.6 / 50.9
October 30, 2003	−383	F13, F15	none usable	49.2 / 50.9
November 20, 2003	−422	F13, F14, F15	50.1 / 51.3, at about 6.6	47.7 / 49.9
May 10–11, 2024	−406	F16, F17, F18	47.8 / 47.8, at 5.7	47.0 / 49.8, north only

March 1989 from NOAA's binary files by our pipeline [38], where F08 at 6.16 MLT gives 50.6° at 4 × 10¹⁰. 2003 from NASA's background-subtracted product, in AACGM latitude, whose flux scale is about 0.79 of ours [41]. Dst from Kyoto [43]. South Atlantic masked. Edges below 35° are set aside as suspect, up to 7 per storm at 4 × 10¹⁰, among them F13's near the Dst lows of October 2003: on October 30 it flew at 6.6 MLT with edges at about 20°, so that cell is empty. May 2024's window ends at SYM-H's low, 02:14 UT, a choice made after seeing the data (amendment 6), and its −406 nT is the mean for the hour holding 02:14 UT. Its dawn cell is F17 at 02:12 UT. In 2003, the dusk rows are left out because they sit beside the South Atlantic and look contaminated. Coarse: different sensors, backgrounds and local times.

OUR ANALYSIS

What this shows, and what it doesn't

On the dawn side, like for like, May 2024's 47.8° is 2.3–5.0° below the earlier storms at 4 × 10¹⁰, and 3.5–5.6° below at 2 × 10¹¹. **In the evening the storms sit together,** at about 47–50°, with no clear order by Dst. That is coarse, with different sensors, and two of 2024's 17 rows precede any fall in Dst, so it doesn't rank the storms.

Only 2024 had a satellite at 3–5 MLT near its deepest hours. F08 flew there in March 1989 only until about 19:10 UT, near −255 nT, and found 53–56° at 4 × 10¹⁰. So the 44–45° has nothing to be set against. In 2024 F16 and F17 also reach 44.8–45.4° at 3 × 10¹⁰ just past 06 MLT, near 22:30 UT, though 50.7–52.5° at 4 × 10¹⁰.

Our test against a published number failed. We set out to test our definition on Rich and Denig's 40.1° for March 1989 [23 Abstract], and said beforehand that a miss would make it less secure. The pass we read in raw counts, F09 south near 01:03 UT, MLT 20.5, lies inside our South Atlantic box, so the mask removes it: with the box off its edges sit at 1 × 10¹⁰ at about 46°, and its raw counts, now hosted, show soft electrons from about 43–44°. With the box on, F09 north at 00:35 UT, MLT 22.6, gives 47.3°, and 22:51 UT, MLT 22.8, gives 49.9°. On the softer test at 1 × 10⁹ those two give 42.9° and 43.2°, closer to their number. At Kp 9 Gussenhoven's fit puts the bin after midnight 1–4° below 22–24 MLT (51.9°, 49.2°, 48.2°), and Rich and Denig's abstract ties 40.1° to midnight boundary indices. So much of the miss may be energy band and projection. Our 1 keV edges may run several degrees high of that number, and shouldn't be pressed as absolutes. That doesn't set the sign of any error on F18 at dawn in 2024, where noise pushes the other way (section 3).

The hedge is reasonable, and unconfirmed. It needs convection measured in those storms, in the same sector, against the ring current's share.

7 · TWO KINDS OF PENETRATION

This paper's penetration of convection isn't the penetration field that Balan and colleagues called weak, though the two share a driver

This paper's mechanism is the "deep earthward penetration of magnetospheric convection" [1 Abstract]. Another paper on the storm, by Balan and colleagues, calls its prompt penetration electric field, F₃ layer and ionosphere-thermosphere storms "also weak", and its abstract has no aurora, oval or convection in it [33 Abstract] (our page on it). The shared word doesn't make them one thing, and neither paper tests the other.

The two, side by side: plainly different, with a shared driver

	THIS PAPER	BALAN AND COLLEAGUES
The words	"deep earthward penetration of magnetospheric convection" [1 Abstract]	"Prompt penetration electric field" [33 Abstract]
What it is	Plasma sheet particles and flow moving inward, so that the oval and its currents sit lower [1 Abstract]	An electric field reaching the low-latitude ionosphere very rapidly when shielding fails for a while (our page's terms)
Where the words put it	The inner magnetosphere, and the oval and its currents [1 Plain Language Summary]	The equatorial and low-latitude ionosphere [34 Abstract]

Matched by the word alone, the two would look like one thing. They aren't: neither measure tests the other. They do share a driver, and the authors' group sees inner-magnetosphere convection fields as "likely linked to low-latitude penetration electric fields" [35 Abstract], so "unrelated" would go too far. By our reading both can hold at once: deep convection at 45–50° is compatible with an equatorial field that shielding cancels quickly [34 Abstract].

8 · A CARRINGTON-CLASS STORM?

In auroral reach, close: one survey ranks May 2024 among the nights of 1859; its public view tests no earlier storm and names no harm

By one measure, close to one. Ranked by the lowest geomagnetic latitude from which aurora was observed, the storm's second night comes third in northern records since 1650, among the nights of the Carrington events of 1859 [29 Abstract]. The authors call it "a historic superstorm" [1 Plain Language Summary] and suggest their mechanism may also help explain expansion in earlier superstorms; their reference titles include the storms of 1859 and 1872 [1 Abstract][1 References]. But what it shows is the oval's edge below 50° in one storm. Its public view tests no earlier storm, and says nothing of what such a storm does to technology.

How May 2024 compares

In that survey, which allows for the secular change of Earth's field, the most extensive night is February 4, 1872; nights of the Carrington events of 1859 rank second, fourth and fifth, and May 2024's second night third [29 Abstract]. Satellites saw March 1989's precipitation reach 40.1° and its electric field 35° [23 Abstract]. And the paper's "below 50°" isn't beyond the published relation with storm strength (section 4).

OUR ANALYSIS

What it means, and where it stops

If the paper is right, a stronger storm's deeper convection would carry the oval farther toward the equator, and with it the Region 1/2 currents and the auroral electrojets, which the abstract says shifted too [1 Abstract]. In this storm strong GPS scintillation sat largely within the electrojets or at their edges, another paper finds [46 p. 1], so the mechanism bears on a Carrington-class storm's disturbances would reach. The public view names no effect on technology; three of its reference titles are on space weather's impacts and hazards [1 References], so the text may. Two limits remain. The mechanism is shown for the oval's edge, and the public view doesn't say how it reaches a visible oval reconstructed near 30–36°, some 15–20° beyond 50° (section 2). And before the space age nobody measured convection, so 1859 and 1872 can't be tested (section 6).

9 · REPEAT OUR NUMBERS

One script fetches the public data and recomputes every number of ours

The rules, with each failure and amendment, are here with their hashes. Raw files stay at their sources, and the script fetches them by URL. None of these files holds the paper's figures, or its text beyond the phrase "below 50° magnetic latitude", and the paste of its public view isn't hosted.

- PY **auroral_edges.py** Downloads the inputs and recomputes the edges, softer electrons, fast flow, fits, product floors and earlier storms; needs numpy and netCDF4 · 60 KB
- JSON **auroral-numbers.json** Every summary number on this page: counts, ladder, controls, softer electrons, fits, floors, the deposit's all-sector reach, earlier storms · 22 KB
- CSV **auroral-main-phase.csv** The 17 crossings of the table above, with fits, fast flow, softer electrons, storm-time floor and flux shares · 5 KB
- CSV **auroral-crossings.csv** Every crossing, every sector and rung, with the sensitivity runs and softer electrons · 28 KB
- CSV **auroral-other-storms.csv** Every crossing of March 1989, October 2003 and November 2003; for 1989 also with the South Atlantic box off, and softer electrons, which on SSJ4 can run to low latitudes where counts are sparse · 26 KB
- TXT **auroral-raw-counts.txt** Raw electron counts on 15 stretches of 2024, so that you can judge the "by eye" calls · 42 KB
- TXT **auroral-raw-counts-1989.txt** Raw electron counts on the three F09 passes of March 1989 named in section 6 · 16 KB
- TXT **RULES_dmsp_before_running.txt** The rules, written before any storm-time file but one small probe was read, which it declares · 8 KB
- TXT **RULES_dmsp_amendment1.txt** After a look at the files' structure: coverage stops at 40° · 2 KB
- TXT **RULES_dmsp_amendment2.txt** After the first run failed: not blind; a new pipeline · 3 KB
- TXT **RULES_dmsp_amendment3.txt** After the control failed: the threshold goes up · 1 KB
- TXT **RULES_dmsp_amendment4.txt** After false edges over the South Atlantic: a mask · 2 KB
- TXT **RULES_dmsp_amendment5.txt** After a fresh review, not blind: the test of softer electrons · 2 KB
- TXT **RULES_dmsp_amendment6.txt** After the review, not blind: the window now ends at SYM-H's low · 2 KB
- TXT **RULES_dmsp_amendment7.txt** After the review, not blind: reports added, no edge changed, and which crossings count by inspection · 2 KB
- TXT **RULES_other_storms.txt** The rules for the earlier storms, including the test against 40.1° · 2 KB
- TXT **RULES_superdarn.txt** The rules for the look at the deposit, with the outcome of the orientation test as it was written then · 2 KB
- TXT **rules_sha256.txt** The SHA-256 of each rules file as recorded, with its time, and notes · 2 KB
- CSV **auroral-run0-failed.csv** The first run's table, kept as it came out. Don't use its edges: the hosted script no longer makes it · 17 KB

Run it

`python3 -I auroral_edges.py <folder>` downloads about 250 MB into that folder, reads it as data and writes its six outputs next to the script. Kyoto's values for 2024 are provisional, so a later download may differ slightly. If Zenodo refuses your network, the deposit's lines are left empty and the rest runs. A run in an empty folder on November 4, 2026, re-downloading everything, gave the same outputs byte for byte.

The data and their terms

DMSP SSJ: NOAA NCEI and AFRL [38]. **SSUSI:** NASA SPDF and JHU/APL [39]. **SSIES:** University of Texas at Dallas, through NASA's CDAWeb [40]. **NASA's SSJ product:** through CDAWeb [41]. **Kp and Hp30:** GFZ Potsdam, CC BY 4.0 [42]. **Dst and SYM-H:** for scientific and non-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 [43][44]. **SuperDARN CSV:** T. Wang 2026, CC BY 4.0 [5]. **Fit coefficients:** as transcribed in ocbpy, BSD 3-clause licence [12].

Departures with no amendment or hash

Most later changes have a hashed amendment. These four don't, so we list them here. **March 1989** comes from NOAA's binary files, not from NASA's product as RULES_other_storms.txt planned, because NASA's F08 and F09 don't cover 1989. **Ion drift** is |vy| as an 11-s median, where the rule said |vy − corvely| over about 12 s: on quiet orbits vy has by far the smaller scatter, and the cadence is 1 s. **The MLT test** missed its 0.3 h limit at the 95th percentile, 0.55 h, and we read it on the median, 0.05 h or less, because a centred dipole departs from CGM by that much with longitude. **The SSUSI map check** goes beyond the rule.

10 · LIMITS

What this check could and couldn't see

The public view, not the paper

We rate its words, and the text may qualify, define or support them in ways we can't see. Its coordinates, hemisphere, passes, thresholds and figures are unread [1].

Our definitions

An edge at 1 keV and above at a flux threshold, chosen and then raised by us, and a softer test taken from a review. Pre-flight factors, no ageing correction for 2024, a simple background. The by-eye and by-inspection calls are judgments. Against one published number our 1 keV edges run several degrees high, and noise can push them low (sections 3 and 6).

Where DMSP flies

The files stop near 40°. These orbits don't reach noon or midnight. In 2024, F18 sampled 3–5 MLT through the deepest hours, and F16 once, at 00:47 UT. Latitudes are CGM at 110 km; MLT is the files' own, a few tenths of an hour soft [38].

Fits we read at second hand

Gussenhoven's and Troyer's coefficients are as transcribed in ocbpy, unchecked, and their Kp ranges are unread. Their sources were out of our reach, and two report copies refused our client [12].

What we didn't test

Currents and electrojets: Swarm's, AMPERE's and SuperMAG's data weren't used, and we used no data behind a sign-in. Another paper reports currents reaching about 50° [30 p. 1]. Ion-drift direction wasn't interpreted.

Comparison between storms

Coarse: different sensors, backgrounds and local times, and a 2024 window set after seeing the data. It cannot rank the storms (section 6).

What would change these verdicts

01

The paper's text: its definition of the boundary, its passes, and how it separates convection from the ring current. Any of these could move any of the five verdicts.

02

Gussenhoven's and Troyer's own tables, if they differ from ocbpy's, or a better account of Rich and Denig's 40.1° against our edges.

03

Convection measured in earlier superstorms, in the same sector, against the ring current's share, which would move "May explain past superstorms" toward True or away from it.

OUR ANALYSIS

Bottom line: the oval's edge did pass below 50°, as a 1998 fit at midnight would put it, while Kp fits stop near 50°. The case that deep convection caused it is in text we couldn't read.

Open DMSP files support the latitude on our own definitions, and show fast flow beside the electrons, which fits and can't show cause. The link is decades old and on the authors' own list; what the unread text adds, we can't say. The abstract's "a key process" is well founded; its summary's "the key mechanism" goes further.

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 read only Wiley's public view, pasted by the site's owner: Abstract, Plain Language Summary, Conflict of Interest, Availability Statement and References are those parts of it, quoted in short phrases where words are rated; every numbered section, method and figure is unread, and no figure of the paper is redrawn. "On this paper's reference list" means [1]'s list. Elsewhere p. gives a page of the copy named in the entry, and Abstract the abstract as the entry says; when only an abstract or a record was read, the entry says so. CGM is corrected geomagnetic latitude, ILAT invariant latitude, MLT magnetic local time, UT universal time and nT the nanotesla; Kp is given in thirds, so 9− is 8.67. Publishers' hyphen characters are printed as ordinary hyphens. Links checked November 4, 2026.

1 Wang, T., Dai, L., Ren, Y., Gonzalez, W., Escoubet, C. P., Zhu, M., Wang, X., Wang, K., Wang, C., and Zhang, J. (2026). Substantial Equatorward Auroral Expansion Driven by Deep Penetration of Magnetospheric Convection During the May 2024 Superstorm. *Journal of Geophysical Research: Space Physics* 131(11), e2026JA035972. Peer reviewed; received July 20, accepted October 23, published October 31, 2026. Under Wiley's standard terms of use, not an open licence, so we quote only short phrases and redraw nothing. **Public view only:** the site's owner pasted its Abstract, Plain Language Summary, Conflict of Interest, Availability Statement and References from Wiley's public view on November 4, 2026, and we paid for none of the rest. Every numbered section, method and figure is unread.

2 SpaceWeatherNews (S0) (November 4, 2026). Uranus/Neptune Pole Shift, New Nova Type (Again) | S0 News Nov.4.2026. YouTube video, https://www.youtube.com/watch?v=6cKdVg0jY90. No transcript was available.

3 Crossref. Metadata record for doi:10.1029/2026JA035972. Retrieved November 4, 2026: the authors and their affiliations; the received, accepted and published dates; volume 131, issue 11; the Chinese Academy of Sciences as funder, awards XDA15350201 and XDA15052500; Wiley's terms of use; and 72 references, which we looked up one by one: 65 of 66 DOIs resolve in Crossref, and the other, the Zenodo data set [5], in DataCite, and six entries have no DOI.

4 OpenAlex. Record for doi:10.1029/2026ja035972, read November 4, 2026: it lists the paper as open, "bronze", at the publisher's PDF link, with no licence and no repository copy, and adds National Natural Science Foundation of China funding. That is what the index says; the site's owner met a paywall at the publisher.

5 Wang, T. (2026). SuperDARN dataset during the 10 May 2024 superstorm [data set]. Zenodo, published May 21, 2026. CC BY 4.0. This paper's reference list. We read SuperDARN-csv.zip, 13,097,252 bytes, MD5 03712905c6f99fc1d8c451d2ec33865, as data; its .map2 file was not fetched. We host no copy, and how the deposit relates to the paper's figures is unread.

6 Wang, T., Dai, L., Ren, Y., and Zhu, M. (2026). Low Magnetic Latitude Auroral Oval Through a Convection-Driven Equatorward Shift of Auroral Currents. EGU General Assembly 2026, Vienna, EGU26-6087. CC BY 4.0. Conference abstract, on dusk-side aurora: a separate document, not a preprint of [1].

7 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.

8 Hayakawa, H., Ebihara, Y., Willis, D. M., Toriumi, S., Iju, T., Hattori, K., et al. (2019). Temporal and Spatial Evolutions of a Large Sunspot Group and Great Auroral Storms Around the Carrington Event in 1859. *Space Weather* 17(11), 1553–1569. As on our earlier page; we read the accepted version, arXiv:1908.10326; p. gives its page.

9 Yokoyama, N., Kamide, Y., and Miyaoka, H. (1998). The size of the auroral belt during magnetic storms. *Annales Geophysicae* 16(5), 566–573. Full text; p. gives the journal's page.

10 Gussenhoven, M. S., Hardy, D. A., and Heinemann, N. (1983). Systematics of the equatorward diffuse auroral boundary. *Journal of Geophysical Research: Space Physics* 88(A7), 5692–5708. Abstract only, as deposited with Crossref; its coefficients as transcribed in [12], unchecked against its table. On this paper's reference list.

11 Troyer, R. N., Landry, R., David, M., Eccles, J. V., and Acosta, A. E. (2025). A Probabilistic Kp and Hp Driven Auroral Boundary Model Using 28 Years of DMSP Data. *Journal of Geophysical Research: Space Physics* 130(5), e2024JA033497. Abstract only, as deposited with Crossref; its formula as transcribed in [12], unchecked against its text.

12 Burrell, A. G., Chisham, G., and Reistad, J. P. ocbpy [software]. BSD 3-clause licence. We read its models.py, develop branch, November 4, 2026, as data and did not run it, for the coefficients of [10] and [11] as it transcribes them.

13 Carbary, J. F. (2005). A Kp-based model of auroral boundaries. *Space Weather* 3(10), S10001. Abstract only, as deposited with Crossref. On this paper's reference list.

14 Milan, S. E., Hutchinson, J., Boakes, P. D., and Hubert, B. (2009). Influences on the radius of the auroral oval. *Annales Geophysicae* 27(7), 2913–2924. CC BY 3.0. Full text; p. gives the journal's page. On this paper's reference list.

15 Milan, S. E. (2009). Both solar wind-magnetosphere coupling and ring current intensity control of the size of the auroral oval. *Geophysical Research Letters* 36(18), L18101. Abstract only, as deposited with Crossref. On this paper's reference list.

16 Schulz, M. (1997). Direct influence of ring current on auroral oval diameter. *Journal of Geophysical Research: Space Physics* 102(A7), 14149–14154. Abstract only, as deposited with Crossref.

17 Kennel, C. F. (1969). Consequences of a magnetospheric plasma. *Reviews of Geophysics* 7(1–2), 379–419. Abstract only, as deposited with Crossref.

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METHOD

How this was checked

On November 4, 2026, we tried the routes the site allows to the paper's text: Crossref's record and title search, the prefix of ESS Open Archive, OpenAlex and a web search, which found no preprint or repository copy. We did not try Wiley's site. So the page rests on the paper's public view, pasted by the site's owner, who met a paywall for the rest; on its 72 references, looked up one by one; on the authors' Zenodo deposit and their EGU abstract, a separate document; on 33 other papers (four read in full or for the passages we cite, two through other pages, 24 by abstract and three by bibliographic record); on the ocbpy code; and on public records from NOAA, AFRL, NASA, the University of Texas at Dallas, GFZ and Kyoto: the 47 sources listed. Quotations from the paper were checked word for word against the paste and are limited to the words rated and short phrases.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. They cover every number from our DMSP check, including the test of softer electrons; the old fits as we evaluate them; the comparison between storms; our reading of what the public view's wording does and doesn't say; and what we infer from the reference list, which is marked as inference. The unread text could change any of the five verdicts, and section 10 says how. If you have the article, please tell us through the correction form.

One hosted script fetches its inputs and recomputes all our numbers, and a run in an empty folder, re-downloading everything, gave the same outputs byte for byte. We wrote rules before reading any storm-time file but one small probe, and logged most later changes with hashes; the others are listed in section 9. The check wasn't blind: the first run failed, a quiet-time control forced the threshold up, flat counts over the South Atlantic forced a mask, the working threshold came after the data, and a test against Rich and Denig's 40.1° for March 1989 did not reproduce it. We could not read Gussenhoven's or Troyer's own tables, so their coefficients are as transcribed in ocbpy, unchecked. No figure of the paper is redrawn; the charts are our own, of public data and of numbers in the texts. A fresh review, which rebuilt our table with its own code from NOAA's files and found it sound, then changed what the page concludes from: "edge" now means the edge at 1 keV and above; a test of softer electrons was added, following that review and not blind, and our code reproduces its table; the main-phase window now ends at SYM-H's low, which adds a bright crossing; the count below 50° and the headline became 5 of 17 and a range by energy; the claim that only 2024 sampled 3–5 MLT was narrowed; "remains unresolved" went from Partly true to Context; and "Overstated" now rests only on "a" against "the" and on generality.

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 was removed; section 7 keeps only its comparison of two kinds of penetration, and section 8, which was on the episode's title, now asks what the paper means for the idea of a Carrington-class storm. That section uses only sources already cited here, with more of Lockwood and colleagues' abstract, read in our saved copy. 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 limited section 8's heading to the public view, gave the citation of Prikryl and colleagues a page, replaced a gendered pronoun in section 4 and fixed smaller wordings.

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.
UNVERIFIED	We couldn't find the source or record it depends on.
TRUE	The evidence supports the claim.
CONTEXT	A question or aside rather than a claim. We add the facts it leaves out.

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, section 7 keeps only its comparison of two kinds of penetration, the section on the episode's title is replaced by one on what the paper means for the idea of a Carrington-class storm, the page's other mentions of the episode are removed, and the verdicts on the paper's claims are unchanged. A fresh review then limited section 8's heading to the public view and fixed smaller wordings.
Nov 4, 2026	Published on factchecked.science after a full check against the sources. Built from the paper's public view, pasted by the site's owner because the rest is paywalled; its 72 references; the episode's title and description, as no transcript existed; the literature on the point; and our own analysis of DMSP's open files, whose script, rules and hashes are hosted on the page. Six claims are rated on the site's scale, and no figure of the paper is redrawn. Before publication a fresh review rebuilt our numbers and changed what the page concludes from: "edge" became the edge at 1 keV and above, a test of softer electrons was added, the main-phase window now ends at SYM-H's low, the headline became a range by energy, "remains unresolved" went from Partly true to Context, the reasons for "Overstated" were narrowed, and the title now says "we couldn't read the paper's case for why".

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