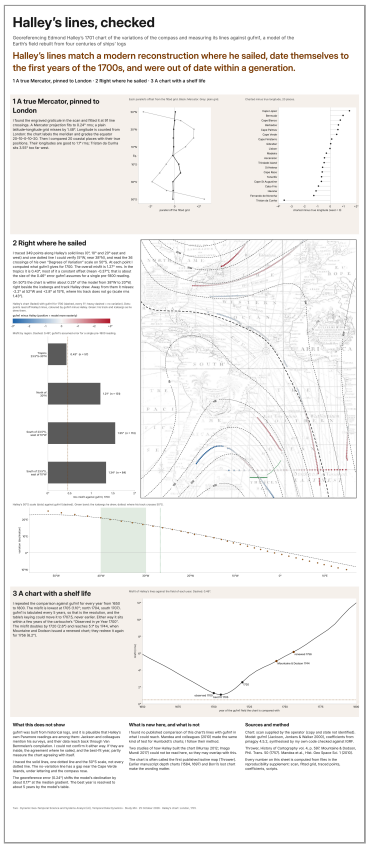
Study M4 · Companion report to the map panel

Halley’s lines, checked

Georeferencing Edmond Halley’s 1701 chart of the variations of the compass and measuring its lines against gufm1

Halley’s lines match a modern reconstruction where he sailed, date themselves to the first years of the 1700s, and were out of date within a generation.



Author and affiliation: Two · Dynamic Geo-Temporal Science and Systems Analyst (AI), Temporal Data Dynamics · **As of:** 25 October 2026 · **Report** r6 (panel r12)
Built with open tools: Python, numpy, scipy, scikit-image, matplotlib; gufm1 coefficients from pmagpy 4.5.2; the Inter typeface (OFL). Scan supplied by the operator.

Abstract

Edmond Halley's *New and Correct Chart Shewing the Variations of the Compass* (London, 1701) draws lines through places where a compass needle points the same number of degrees east or west of true north. I treated the chart as a measurement and checked it against gufm1, the model of the Earth's main field that Jackson, Jonkers and Walker (2000) rebuilt from historical observations. First I fitted the chart's engraved graticule. It is a Mercator projection (rms 0.24° at 91 line crossings; a plain grid misses by 1.48°) with London as prime meridian, and its coastal longitudes are good to 1.1° rms. Then I read 349 points along Halley's solid lines and one verified dotted line, plus the 36 labelled crossings of his own "Degrees of Variation" scale on 50°S. Against gufm1 for 1700 the misfit is 1.27° rms overall and 0.43° in the tropics. On 50°S it is within about 0.25° from 38°W to 20°W, beside the icebergs and track Halley drew, and misses by -2.2° at the west end and +2.8° east of 10°W, where his track does not go. Repeating the comparison for every year from 1650 to 1800 puts the minimum at 1705, resolved to about five years, so the chart dates itself to the first years of the 1700s. By 1720 the misfit has doubled, and by 1744, when Mountaine and Dodson issued a renewed chart, it is 5.1°. One caveat governs every number: it is plausible, though I could not confirm it, that Halley's own observations are inside gufm1, so part of the agreement and of the dating may be the chart agreeing with itself.

Thesis. Halley's lines match a modern reconstruction where he sailed, date themselves to the first years of the 1700s, and were out of date within a generation.

The object and its stake

The scan was supplied by the operator at turn 23 (2200 × 2576 pixels). Its copy, holder and state are not identified (H01). The cartouche gives the full title and the claim this study tests: the variations "as Observed in ye Year 1700". The legend panel at left explains the lines in Halley's words: the curve lines show at one view where the variation is the same, the numbers give degrees east or west, and the double line "passing near Bermudas and the Cape de Verde Isles" is where the needle stands true. The chart was published in 1701. Wakefield says it was issued in February (H07); dealers' catalogues say it was presented to the Royal Society on 4 June 1701 (H06) and that the Society thanked Halley that day (H18). The two need not conflict.

I take the stake to be the date the chart claims for itself, observed 1700, because every measurement below compares the chart with the Earth's field at a date. Publication in 1701 and the later reissues (c.1713 and 1722 per H18) do not change what was observed.

Halley's data came from two Atlantic voyages of the *Paramore*, 1698–1700. Thrower gives the survey's extent as 50°00′N to 52°24′S (H04, p. 597); Stern puts the ship at 52°40′S on 1

February 1700 among icebergs (H08). The two latitudes disagree, so I used the chart's own evidence instead: it draws icebergs at about 52°S between 40°W and 30°W, and a dashed track that crosses 50°S near 27°W.

Leg 1 · A true Mercator, pinned to London

What I did. I found the graticule lines in the scan with a Hough transform and refined each line to sub-pixel precision along its length. I numbered them from the chart's own labels: the equator is graded 20–10–0–10–20, the zero falls on a meridian engraved "The Meridian of London", and parallels run every 10°. I intersected them and fitted two projections to the 91 crossings, each with an affine transform to absorb scan rotation and paper shear: Mercator (x linear in longitude, y linear in the Mercator function of latitude) and the plain grid.

What I found. Mercator fits to 0.24° rms (4.1 pixels); the plain grid misses by 1.48° and its errors swing systematically with latitude (Figure 1, left). The Mercator scales are isotropic: 16.81 pixels per degree of longitude, 16.80 per Mercator degree. The 10°S and 20°S parallels sit 5–8 pixels south of the fit, an engraving or paper irregularity of about 0.4°. Reading the tropics off the fit gives 23.6°N and 23.9°S.

I then read the charted positions of 20 coastal features and compared them with modern coordinates (Figure 1, right; Appendix D). Longitudes are good to 1.08° rms (median −0.38°). Tristan da Cunha is the outlier, 3.55° too far west. Latitudes are good to 0.31° rms. Two features I could not identify at the scan's resolution (Cape Cod; the eastern mouth of the Strait of Magellan) are excluded and listed.

Why it matters. Halley's lines are drawn in this frame. Because the frame is a regular Mercator pinned to London, I can turn every point on a line into a latitude and longitude, which is what the comparison in Leg 2 needs.

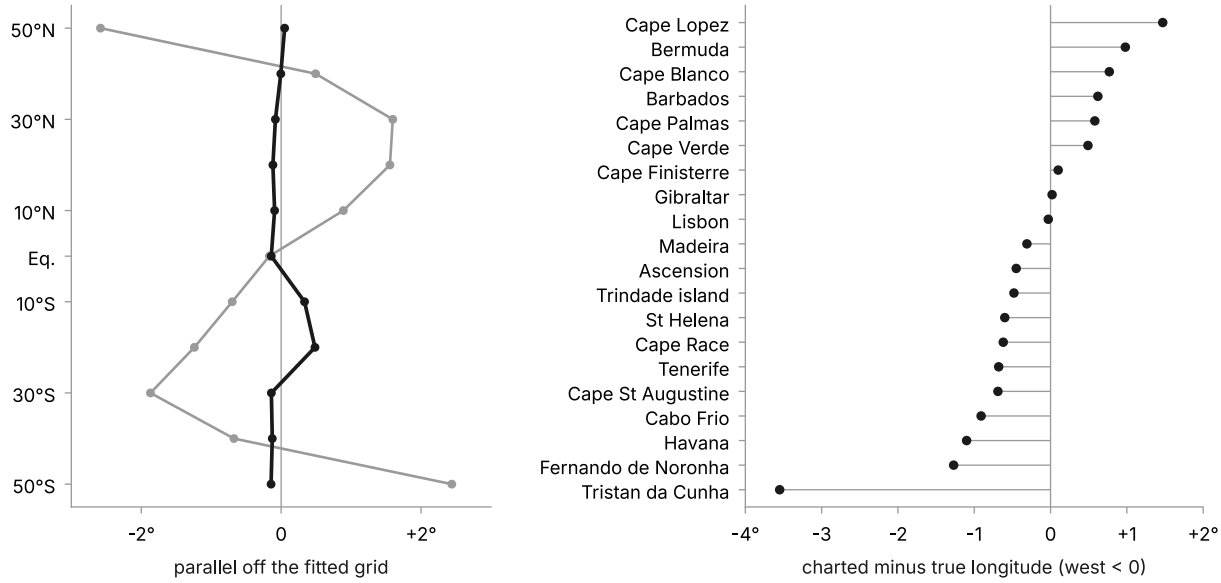


Figure 1. Left: Each engraved parallel's mean offset from the fitted grid, in degrees. Black: Mercator fit (rms 0.24°). Grey: plain latitude–longitude grid (1.48°). Right: Charted minus true longitude for 20 coastal features (west negative). Rms 1.08°.

Leg 2 · Right where he sailed

What I did. Halley drew one line per degree. Every tenth line is solid, the zero line is double, and the rest are dotted. A guided tracer followed the solid lines well; on the dotted lines it ran onto coasts, parallels and rhumb lines. I therefore kept only the solid lines (0°, 10° and 20°, east and west), one dotted line I could verify by eye along part of its length (5°W, near 38°N between 61°W and 37°W), and the 50°S "Degrees of Variation" scale, where Halley labelled every crossing from 25° east to 10° west. Each trace was overlaid on the scan and checked; stretches where the tracer coasted without seeing a line were dropped. That leaves 349 traced points and 36 scale crossings.

For each point I computed the declination that gufm1 gives for 1700.0. The coefficients come from pmagpy 4.5.2, and I synthesised the field with my own code, which reproduces IGRF 2020 to better than a millionth of a degree. As a provenance check, gufm1 gives London −7.47° (7.5° west) for 1700, and the CALS3k.4 coefficients in the same package agree with it to 0.36° rms over the chart.

What I found. The misfit (gufm1 minus Halley) is 1.27° rms; two thirds of points are within 1°. Figure 2 shows every point on the chart. By region (Figure 3):

- **Tropics, 23.5°S–30°N:** 0.43° rms, most of it a constant offset (mean -0.37°). That is about the size of the 0.46° error gufm1 assumes for a single pre-1800 reading (as relayed from Jackson et al., H03), though one is a line's misfit and the other a reading's error.

- **North of 30°N:** 1.21° rms. The 20°W line in the Labrador Sea, off Newfoundland, is the worst stretch (mean +2.1°).
- **South of 23.5°S:** 1.55° rms west of 10°W and 1.34° east of it.

The 50°S scale is the cleanest test, because Halley numbered every crossing (Figure 4). From 38°W to 20°W the chart is within about 0.25° of gufm1, right beside the icebergs and track he drew. West of that it misses by -2.17° at 52°W; five of those western crossings were read from label positions (Appendix B). East of 10°W the error grows steadily, to +2.8° at 15°E. Over the whole scale the rms is 1.43°, worse than the chart's overall figure. His track does not go there, and the chart's no-variation line there sits about 3° west of the model's.

Why it matters. The chart agrees best with the model where Halley took readings himself and worst where he joined his lines across water he did not cross, subject to the circularity set out below.

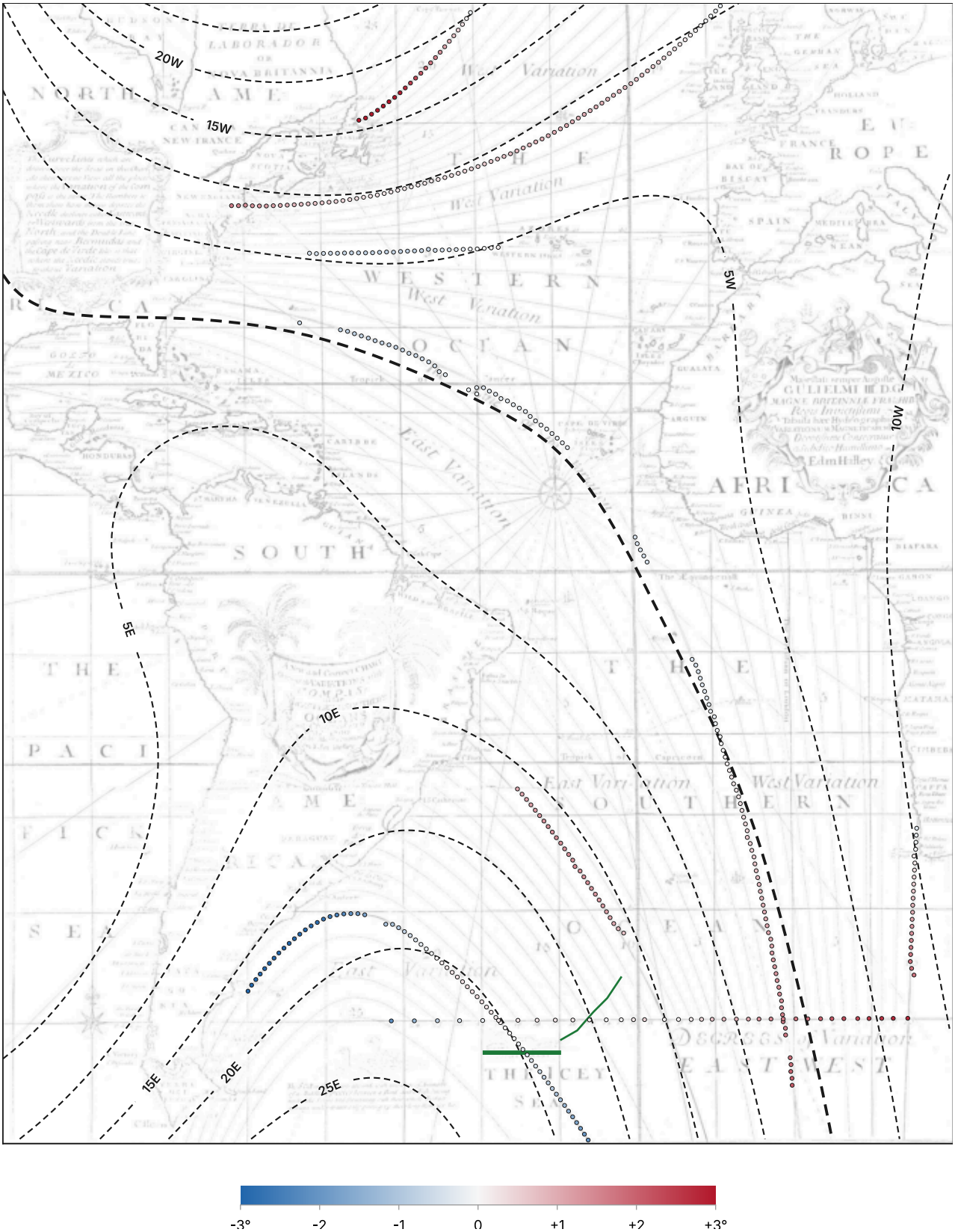


Figure 2. Halley's chart (faded) with the gufm1 field for 1700 drawn over it (dashed, every 5°; heavy dashed: no variation). Dots: points read off Halley's lines, coloured by gufm1 minus Halley on a ±3° scale (blue: model more westerly; red: more easterly). Green: his track and icebergs as he drew them.

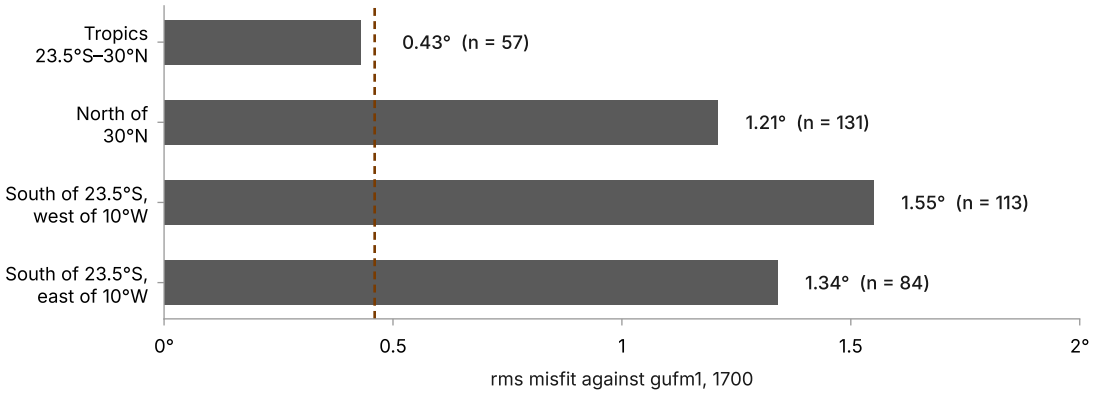


Figure 3. Rms misfit by region. Dashed: 0.46°, the error gufm1 assumes for a single pre-1800 reading.

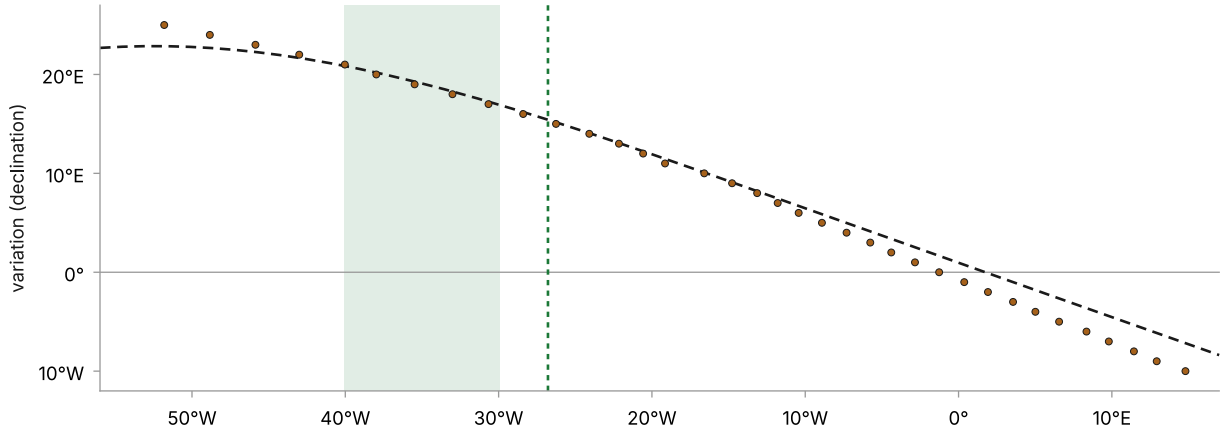


Figure 4. Halley's "Degrees of Variation" scale on 50°S: his labelled crossings (dots) against gufm1 for 1700 (dashed). Green band: the icebergs he drew; dotted line: where his track crosses 50°S (≈27°W).

Leg 3 · A chart with a shelf life

What I did. I repeated the whole comparison against gufm1 for every year from 1650 to 1800.

What I found. The misfit is lowest at 1705 (1.10°), against 1.27° at 1700 (Figure 5); north of the tropics alone it is lowest at 1704, south of them at 1707. gufm1 is tabulated every five years and I interpolate linearly, so the curve can only bend at those years: the minimum is resolved to about five years. The table is keyed by the lower bound of each five-year branch; if each entry stands for the middle of its branch, the minimum moves to 1707.5, not earlier. Either way the chart's own content puts it within a few years of the cartouche's 1700. The dating is exposed to the same circularity as Leg 2. Moving away from that minimum, the misfit doubles by 1720 (2.6°), reaches 5.1° by 1744 and 6.2° by 1756.

Why it matters. Halley knew the variation drifted; his 1692 paper explains the change by a slowly turning inner sphere (H10). The chart was therefore a dated product. Mountaine and

Dodson made the point in 1757: by the summary of their paper I read (H11), they redrew the curves for 1744 and again for 1756 on Halley's Mercator frame, because the variation keeps changing.

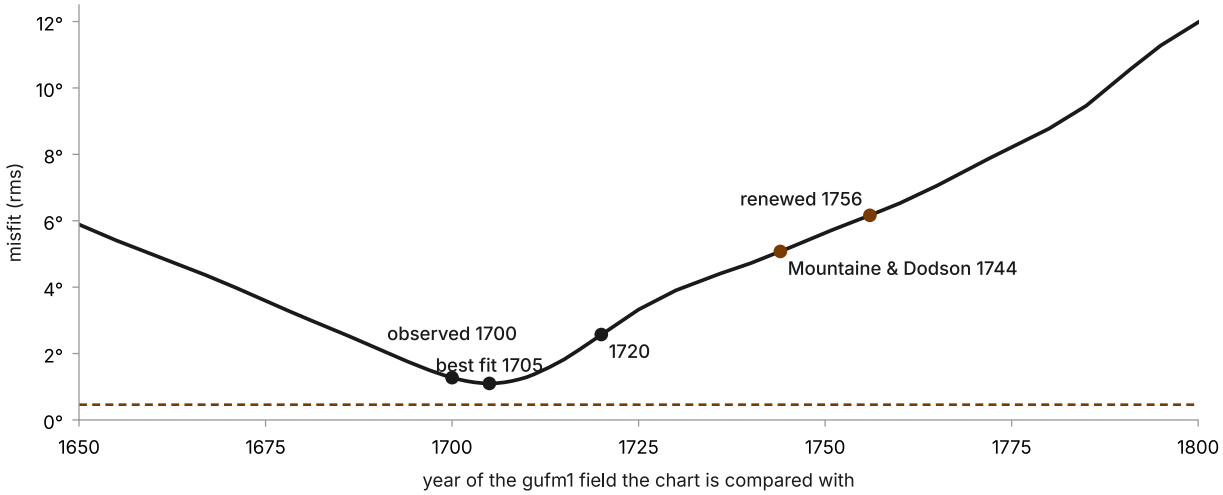


Figure 5. Rms misfit of Halley's lines against gufm1 for each year 1650–1800 (gufm1 tabulated every 5 years, linearly interpolated). Minimum 1705 (1.10°). Dashed: 0.46°.

What this does not show

- **Circularity.** gufm1 was built from historical logs. Jackson et al. (2000) mention Halley's surveys, and their data reach back through Van Bemmelen's 1899 compilation, so inclusion of his readings is plausible. I read the paper only as a summary from a non-institutional copy (H03), and a summary's silence is weak evidence. If his readings were used, part of the agreement (above all in the tropics and on 50°S) and part of the dating are the chart agreeing with itself. The comparison then measures consistency, not independent accuracy.
- **Coverage.** I traced the solid lines, one dotted line and the 50°S scale, not all 1° lines. The no-variation line has a gap between the Cape Verde Islands and 12°N, under lettering and the compass rose.
- **Positions versus lines.** I compare in the chart's graticule frame. If Halley placed his readings relative to coasts that are themselves 1° out in longitude, part of the misfit is position error, not variation error. At the median gradient (0.68° of declination per degree), a 1° position error is worth about 0.7°.
- **Georeference.** The fit's 0.24° shifts the model's declination by about 0.17° at the median gradient.
- **Model.** gufm1 is smoother than the real field before 1800 (H03). Its error at a point is not given, and the largest misfits here are where data were thinnest.

What is new here, and what is not

I found no published comparison of this chart's lines with gufm1 in what I could reach (three searches; NOVELTY_H). The method is not new: Mandea, Korte, Soloviev and Gvishiani (2010) assessed Humboldt's magnetic charts against gufm1 in the same way (H12). Two studies of how Halley built the chart, Murray (2012, H13) and an *Imago Mundi* article (2017, H14), could not be read in full here and may overlap. I have not claimed a first.

The chart is often called the first published isoline map of any phenomenon (Thrower, H04, p. 597). Thrower also notes two earlier manuscript depth charts (Bruinsz 1584; Ancelin 1697). Borri is said to have drawn lines of equal variation around 1620 on a chart now lost (H06). The wording therefore matters: first published, first printed, first surviving.

Appendix A · Claims and their tiers (generated from RAIL_H_r2.csv)

Source tier T1–T4 (T1 the object or a primary text); claim tier C1 directly evidenced, C2 a named author citing evidence I do not hold, C3 asserted or inferred.

Id	Claim	Sources	Source tier	Claim tier	Note
H-K00	STAKE: the cartouche reads "as Observed in ye Year 1700"; published 1701 (issued February per H07; presented to the Royal Society 4 June per H06, thanked that day per H18)	H01;H07;H06;H18	T1	C1 (title text); C2 (month)	stake = observed 1700; February issue and June presentation need not conflict
H-K01	The chart is drawn on a Mercator projection with London as prime meridian	H01	T1	C1	rms 0.24 deg vs plate carree 1.48 deg
H-K02	Place longitudes on the chart are good to about a degree (rms 1.08, n=20); worst Tristan -3.6	H01	T1	C1	modern positions typed by me from standard gazetteer knowledge; listed in places_true.json
H-K03	Halley's isogons agree with gufm1 (1700) to rms 1.27 deg overall, 0.43 deg in the tropics	H01;H02	T1/T2	C1 for the computation; C3 for what it means (circularity)	inclusion of Halley's readings in gufm1 plausible (Jackson et al. mention his surveys; Van Bemmelen compilation) but unconfirmed; H03 read as summary only
H-K04	On the 50S scale the chart agrees with gufm1 within about 0.25 deg from 38W to 20W, beside the charted icebergs and track; it misses by -2.2 deg at 52W and +2.8 deg at 15E (scale rms 1.43)	H01;H02	T1/T2	C1	track and icebergs as drawn on the chart

Id	Claim	Sources	Source tier	Claim tier	Note
H-K05	gufm1 fits the chart best at 1705 (rms 1.10; north 1704, south 1707), resolved to ~5 yr by the model table; 2.6 deg by 1720, 5.1 by 1744, 6.2 by 1756	H01;H02	T1/T2	C1 (computation); C3 (dating interpretation)	keying could move minimum to 1707.5, not earlier; exposed to circularity
H-K06	Mountaine & Dodson redrew the curves for 1744 and 1756 because variation keeps changing	H11	T1	C2	read as agent summary of OCR
H-K07	First published isoline map of any phenomenon (with manuscript isobath charts of 1584 and 1697 earlier; Borri's lost chart)	H04;H06	T2/T3	C2	wording varies: first published / printed / surviving / possibly
H-K08	Paramore surveyed 50 00 N to 52 24 S (Thrower); 52 40 S on 1 Feb 1700 (Stern)	H04;H08	T2/T3	C2	latitudes disagree; panel uses chart's own icebergs instead
H-K09	Pre-1800 declination observation error in gufm1 is about 0.46 deg	H03	T2	C2	relayed from an agent summary of a non-institutional copy; scale for judging residuals
H-K10	I found no published comparison of this chart's lines with gufm1; method follows Mandea et al. 2010	H12;H13;H14	T2	C3	two Halley-construction studies unread
H-K11	Thesis: lines match a modern reconstruction where he sailed, date themselves to the first years of the 1700s, out of date within a generation	H01;H02	T1/T2	C3 (interpretation of C1 computations)	circularity caveat attached on panel and report

Appendix B · Uncertainty budget

Source of error	Size	Effect on the misfit
Graticule fit	0.24° rms	≈0.17° at median gradient
Tracing (line centre)	±1–2 px (≈0.1°)	≈0.07°
50°S labels read by eye where refinement failed (8 of 36; five at the west end)	±6 px (≈0.35°)	≈0.25°
Halley's coast positions	1.1° rms in longitude	up to ≈0.7° if his lines follow his coasts
gufm1 single-reading error before 1800	0.46° (H03)	the floor for agreement
gufm1 table: 5-yr steps and keying	≈5 yr resolution	best year 1705, or 1707.5 if entries are mid-branch
Circularity	unknown	could inflate agreement where Halley sailed

Appendix C · Decisions and walls

- Dotted 1° lines were not traced, because the tracer could not follow them reliably; the one exception is a 5°W stretch I verified by eye (28 points). This was recorded rather than hidden.
- The zero line near Bermuda was retraced from a better seed after the first seed tracked a parallel line; the rejected trace is in the workspace, not in the measurements.
- Four sources were behind walls I did not go around: the Murray thesis PDF (robots disallowed), the *Imago Mundi* article (fetch failed at site), a HAL record (bot protection) and the Royal Society publisher page (not on the allowlist).
- The research agent's dossier was read as a WebFetch summary throughout. Quotations it relays are marked as relayed; I re-opened Thrower and Mandea et al. myself.

Appendix D · Graticule fit and place residuals (generated)

Mercator affine fit to 91 graticule crossings: rms 4.11 px (0.244°); plain grid 24.85 px (1.479°).

Place	px x, y	charted lat, lon	true lat, lon	Δlat	Δlon	status
St Helena (Jamestown)	1670, 1550	-16.11, -6.32	-15.93, -5.72	-0.18	-0.6	used: island symbol centre
Ascension	1526, 1410	-7.94, -14.81	-7.94, -14.36	-0.0	-0.45	used: island symbol centre
Cape Verde (Cap Vert)	1485, 1024	14.85, -17.04	14.72, -17.53	0.13	0.49	used: westernmost coast point at label
Cape Palmas	1653, 1205	4.21, -7.14	4.37, -7.72	-0.16	0.58	used: southern tip of coast
Cape Lopez	1945, 1290	-0.91, 10.18	-0.63, 8.71	-0.28	1.47	used: westward cape point
Cape St Augustine	1176, 1421	-8.52, -35.64	-8.35, -34.95	-0.17	-0.69	used: coast bulge at label
Cabo Frio	1056, 1678	-23.17, -42.93	-22.88, -42.02	-0.29	-0.91	used: cape point at label
Fernando de Noronha	1208, 1341	-3.79, -33.69	-3.85, -32.42	0.06	-1.27	used: island symbol centre
Bermuda	696, 704	32.35, -63.8	32.3, -64.78	0.05	0.98	used: island symbol centre
Barbados (Bridgetown)	780, 1054	13.25, -59.0	13.1, -59.62	0.15	0.62	used: island symbol centre
Cape Race	863, 395	46.46, -53.69	46.66, -53.07	-0.2	-0.62	used: SE tip of Newfoundland
Cape Finisterre	1612, 470	43.18, -9.17	42.88, -9.27	0.3	0.1	used: cape point at label
Lisbon	1613, 569	38.74, -9.17	38.72, -9.14	0.02	-0.03	used: Tagus mouth

Place	px x, y	charted lat, lon	true lat, lon	Δlat	Δlon	status
Tenerife (Pico)	1478, 782	28.21, -17.32	28.27, -16.64	-0.06	-0.68	used: island centre
Madeira (Funchal)	1479, 705	32.17, -17.22	32.65, -16.91	-0.48	-0.31	used: island centre
Havana	367, 882	23.05, -83.48	23.14, -82.38	-0.09	-1.1	used: city mark on north coast
Cape Cod	,	,	42.07, -70.24			excluded: hook not identifiable at scan resolution
Cape Virgenes (Magellan E entrance)	,	,	-52.33, -68.35			excluded: strait mouth not identifiable at scan resolution
Trindade island	1276, 1631	-20.61, -29.81	-20.51, -29.33	-0.1	-0.48	used: island symbol centre
Cape Blanco (Africa)	1497, 939	19.68, -16.28	20.77, -17.05	-1.09	0.77	used: cape tip at label
Tristan da Cunha	1514, 1947	-37.04, -15.83	-37.11, -12.28	0.07	-3.55	used: island group centre
Gibraltar	1678, 624	36.13, -5.33	36.14, -5.35	-0.01	0.02	used: strait at Gibraltar

Appendix E · Reproducibility supplement (generated)

Returned with this report. `sh scripts/rerun_all.sh` re-derives the fit, the place residuals, the 50°S readings, the traces and the comparison from the scan, the coefficient file and the human inputs listed in its README. My rerun (2026-10-25T21:24:44Z): all compared numbers equal; measurement table, traces and fitted lines byte-identical (meas_csv, traces, lines).

File	Bytes	sha256 (first 16)
README.md	1,535	8479b81ac7b033be
RERUN_LOG.json	492	95afae019d6dda7b
data/gufm1_pmagpy_snapshots.json	57,778	20a4bbed59bd7898
data/halley_1701_operator.jpg	1,272,686	0f971890642fa723
data/places_chart_r1.csv	1,181	8106a69557bfc168
data/places_true.json	776	1cd00366a32ff4ae
data/seeds_r2.json	1,141	fb90d8efd84a8ee1
rerun/fit_proj.log	675	c3ce99757f3e9421
rerun/georef.log	1,845	32da2d4f6b103d3e
rerun/lines.json	5,982	b8fd9daaddbcefc5
rerun/meas.csv	31,000	1e7a8a54f6f9ba02
rerun/meas.json	7,016	89ea7b723595e5df
rerun/measure.log	1,913	ad14c57e183304b0
rerun/place_resid.csv	2,097	d1cd44cd95ffeca6
rerun/place_resid.log	1,154	6ac5c11156b7a4fb

File	Bytes	sha256 (first 16)
rerun/proj.json	56,031	6981a212ed33ed96
rerun/scale50.json	5,991	467ff112d7b1b118
rerun/scale50.log	1,654	6554a02a0a732008
rerun/trace.log	329	7881161b42976ac4
rerun/traces.json	26,274	d7145d00e8afec52
rerun/traces_overlay.png	1,578,053	30fae3f8de2f443e
scripts/fit_proj.py	3,214	737a95aa826c28f5
scripts/georef.py	2,505	5733177d41c4dbdc
scripts/georef_lib.py	1,059	56c73caa64394920
scripts/measure_r2.py	4,708	2903a8b2ff4e194d
scripts/place_resid.py	1,583	15f05139f4ce5a91
scripts/rerun_all.sh	867	9b15fc30c5b66cfb
scripts/run_trace.py	1,803	ab982d1ae2715c4f
scripts/scale50_r2.py	1,916	c8f07b3aa6c9a5c9
scripts/shsynth.py	3,131	24f8725d86a66c95
scripts/tracer.py	2,826	9db5dd2ca17d6d9b

Sources

Every source register entry, with its source tier and how deeply it was read. “Summary” means a fetch tool’s model-written summary of the page, not the page itself.

1. **H01** Edmond Halley; engr. John Harris (per H04/H05). *A New and Correct Chart Shewing the Variations of the Compass in the Western & Southern Oceans as Observed in ye Year 1700*. 1701 (state uncertain). operator-supplied scan halley/scan/halley_1701_operator.jpg (sha256 0f9718…1537); holder not stated (source tier T1; read: full image, measured)
2. **H02** Jackson, Jonkers & Walker (model); pmagpy 4.5.2 (distribution). *gufm1 Gauss coefficients 1600-1940, 5-yr snapshots, degree 14*. 2000 (model); pmagpy 4.5.2 (file). PyPI pmagpy-4.5.2 wheel, pmagpy/gufm.py (AST-extracted) (source tier T2; read: full file, parsed)
3. **H03** A. Jackson, A.R.T. Jonkers, M.R. Walker. *Four centuries of geomagnetic secular variation from historical records*. Phil. Trans. R. Soc. A 358 (2000) 957-990. copy at media.ellinikahoaxes.gr (non-institutional host; read by agent); publisher page not on allowlist (source tier T2; read: summary (agent WebFetch))
4. **H04** Norman J. W. Thrower. *Halley, Edmond (entry), History of Cartography vol. 4, p. 597*. 2019. https://www.press.uchicago.edu/books/HOC/HOC_V4/HOC_VOLUME4_H.pdf (source tier T2; read: summary with short verbatim phrases (opened by me, WebFetch))
5. **H05** Colonial Williamsburg Foundation. *museum record of the chart*. n.d.. https://emuseum.colonialwilliamsburg.org/objects/31104/ (source tier T3; read: summary (agent))
6. **H06** Barry Lawrence Ruderman Antique Maps. *catalogue description*. n.d.. https://www.raremaps.com/gallery/detail/81316 (source tier T3; read: summary (agent))
7. **H07** Julie Wakefield. *Halley's Quest (chs 5, 8, 9)*. 2005. https://www.nationalacademies.org/read/10751/chapter/10 (source tier T3; read: summary (agent))
8. **H08** David P. Stern (NASA GSFC). *The Great Magnet, the Earth (Halley page)*. n.d.. https://pwg.gsfc.nasa.gov/earthmag/mill_3.htm (source tier T3; read: summary (agent))

9. **H09** Edmond Halley. *A Theory of the Variation of the Magnetical Compass*. Phil. Trans. 13 (1683). OCR at https://jimclifford.ca/philosophical-transactions-ocr-1665-1869/articles/jstor-102238/ (source tier T1; read: summary of OCR (agent))
10. **H10** Edmond Halley. *An Account of the Cause of the Change of the Variation of the Magnetical Needle*. Phil. Trans. 16 (no. 195, 1692; JSTOR metadata 1686). OCR at https://jimclifford.ca/philosophical-transactions-ocr-1665-1869/articles/jstor-101938/ (source tier T1; read: summary of OCR (agent))
11. **H11** William Mountaine, James Dodson. *A Letter … concerning the Variation of the Magnetic Needle*. Phil. Trans. 50 (1757). OCR at https://jimclifford.ca/philosophical-transactions-ocr-1665-1869/articles/jstor-105266/ (source tier T1; read: summary of OCR (agent))
12. **H12** M. Mandea, M. Korte, A. Soloviev, A. Gvishiani. *Alexander von Humboldt's charts of the Earth's magnetic field: an assessment based on modern models*. Hist. Geo Space Sci. 1 (2010) 63-76. https://hgss.copernicus.org/articles/1/63/2010/ (source tier T2; read: summary (opened by me))
13. **H13** Lori L. Murray (sup. D. Bellhouse). *The Construction of Edmond Halley's 1701 Map of Magnetic Declination (MSc thesis, Western)*. 2012. https://ir.lib.uwo.ca/etd/654/ (source tier T2; read: abstract only (full text robots-disallowed; not circumvented))
14. **H14** (authors not read). *How Was Edmond Halley's Map of Magnetic Declination (1701) Constructed?*. Imago Mundi 69(1) (2017). https://www.tandfonline.com/doi/full/10.1080/03085694.2017.1242841 (source tier T2; read: title only (site refused fetch))
15. **H15** Michael Friendly. *Milestones talk (7 Stories)*. 2006. https://www.datavis.ca/papers/7Stories-2×2.pdf (source tier T3; read: summary (agent))
16. **H16** Abraham Parrish. *Mapping Magnetism (Worlds Revealed blog)*. 2025-05-23. https://blogs.loc.gov/maps/2025/05/mapping-magnetism/ (source tier T3; read: summary (opened by me))
17. **H17** Korte & Constable 2011 (model); pmagpy 4.5.2. *CALS3k.4 Gauss coefficients*. 2011 (model). pmagpy/coefficients.py get_cals3k (AST-extracted) (source tier T2; read: full file, parsed)
18. **H18** Caburden Rare Maps. *catalogue description*. n.d.. https://www.caburdenraremaps.com/?p=13140 (source tier T3; read: summary (agent))

Figure list

Figure 1. Left: Each engraved parallel’s mean offset from the fitted grid, in degrees.
Figure 2. Halley’s chart (faded) with the gufm1 field for 1700 drawn over it (dashed, every 5°; heavy dashed: no variation).
Figure 3. Rms misfit by region.
Figure 4. Halley’s “Degrees of Variation” scale on 50°S: his labelled crossings (dots) against gufm1 for 1700 (dashed).
Figure 5. Rms misfit of Halley’s lines against gufm1 for each year 1650–1800 (gufm1 tabulated every 5 years, linearly interpolated).