

Online Resource 1 - Supplementary Information

Cross-Survey Analysis of Heterogeneous Aeromagnetic Data Reveals a Raw-Field Gradient-Reversal Anomaly at Uruana de Minas, Brazil

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Journal: Acta Geophysica | Article type: Research Article - Applied Geophysics

Purpose. This document summarizes the versioned computational, robustness, and falsification audits. Full machine-readable audit texts, derived CSV tables, and analysis scripts are supplied separately as Online Resource 2; they are not duplicated verbatim here.

S1. Evidential hierarchy and fixed claim boundary

The central direct claim is a localized reversal of the meridional spatial derivative of the measured scalar total magnetic field in the observed 2011 Uruana target relative to the positive main-field expectation. This is not a geomagnetic polarity reversal and is not a direct measured reversal of vector Z.

- Direct: minimally processed observations establishing the target phenomenon.
- Corroborative: another survey, support, operator, or independent structure reproduces a compatible feature without being equivalent to the direct observation.
- Interpretive: physically or geologically consistent with the direct result but not required for detection.
- FAIL: a robustness or independent test does not reproduce the target and remains visible in the audit trail.
- Retired/not retained: an exploratory observation or estimator is removed from evidential support after specificity or stability controls.

S2. Analytic known-truth benchmark

The analytic benchmark is deliberately dimensionless and is not fitted to Uruana. It uses $B_{\text{main}}(x)=x$ and $B_{\text{crust}}(x)=-A \exp(-x^2/2)$, $A=3.3$. A Gaussian observation kernel with support s gives a maximum descriptive competition ratio $R_s=A \exp(-1/2)/(1+s^2)$. It is an internal logic stress test and does not constitute independent empirical validation of CSMPPF.

Fine support $s=1/6$ gives $R \approx 1.95$ (>1), producing a finite negative total-gradient domain. Coarse support $s=2$ gives $R \approx 0.40$ (<1), so the total gradient remains positive. The underlying signed crustal transition remains exactly at $x=0$. After matching support, front distance is $D=0$ and signed-gradient agreement is $C=1$.

A fixed sensitivity family $A=\{3.0, 3.3, 3.6\}$, $s_{\text{fine}}=\{0.10, 1/6, 0.25\}$, $s_{\text{coarse}}=\{1.8, 2.0, 2.2\}$ yields 27/27 combinations in the same fine-reversal/coarse-nonreversal regime. A uniform single-sign comparison window can still give $C=1$ without containing a turnover, motivating the transition-existence criterion.

A	s_fine	s_coarse	R_fine	R_coarse
3.0	0.1	1.8	1.801576	0.429149
3.0	0.1	2.0	1.801576	0.363918
3.0	0.1	2.2	1.801576	0.311574
3.0	0.1667	1.8	1.770414	0.429149
3.0	0.1667	2.0	1.770414	0.363918
3.0	0.1667	2.2	1.770414	0.311574
3.0	0.25	1.8	1.712557	0.429149
3.0	0.25	2.0	1.712557	0.363918
3.0	0.25	2.2	1.712557	0.311574

The complete 27-row table and executable script are included in Online Resource 2.

S3. 2011 direct raw-field and acquisition-robustness audits

Fixed centre: -16.0593, -46.2585; fixed radius 8 km; only observed support is used. Fourteen lines meet the minimum spatial-support rule.

- Primary raw median northward gradient: -1.649644 nT/km; corresponding IGRF median +0.998354 nT/km; 14/14 line-wise inversion.
- Same-line self-control under the main-text operator: target median -1.554762 nT/km; 16-20 km north median +0.962614 nT/km; paired change positive in 14/14 (median +2.577798; minimum +0.549080 nT/km).
- Exact MAGMIC same-line check: 14/14 target-negative and 14/14 north-positive; medians -1.660952 and +1.164173 nT/km; all paired changes positive.
- Heading robustness: 7 northbound and 7 southbound lines retain the target-negative/north-positive relation; dates 27, 28, and 30 May 2011 preserve it.
- Unconstrained breakpoint screen: 14/14 select negative-to-positive topology; breakpoints ~ 16.25 -20.50 km, median ~ 18.50 km. Bin-width sensitivity from 125-1000 m at the original implementation preserves 14/14.
- Separate 250-m bin-origin sensitivity (0, 62.5, 125, 187.5 m) yields MAGBRU/MAGCOR target-negative counts [14,14,13,14]; the exceptional line is nearly flat at the 125-m phase. MAGCOM, MAGNIV, and MAGMIC remain 14/14 target-negative at all four phases, and all northern controls remain 14/14 positive.
- Flight-height/topography channels do not mimic the universal magnetic sign architecture: target positive counts are GPSALT 13/14, BARO 13/14, ALTURA 4/14, and MDT 10/14 across every tested phase. These are sign controls, not an altitude-adjusted replacement for the primary result.

S4. 2008 x 2011 matched-support topology and controls

- 2008 raw-grid meridional gradients over successive northern 8-km intervals: +0.841790, -1.632000, +2.217333, +3.113029 nT/km; diurnal-corrected signs are unchanged.
- Matched 1.5-km support gives 2008 northern fronts ~ 15.58 , 15.50, 15.34 km and 2011 fronts ~ 14.34 , 13.99, 14.08 km for 3/5/7-cell windows.
- Uruana: median cross-survey front distance $D_{\text{med}}=1.254$ km; mean sign agreement $C_{\text{mean}}=0.908$. Strongest external competitor $k=+1$: $D_{\text{med}}=1.354$ km; $C_{\text{mean}}=0.881$.
- Uruana ranks 1/5 among transition-bearing tested blocks for both front proximity and signed-gradient agreement.
- False-positive safeguard: internal $k=-1$ can reach 100% sign agreement while raw 2011 transition recovery is 0/14. Similarity is therefore conditioned on transition existence.

S5. Historical 1971-72 and matched-resolution stress

- Historical IGRF northward gradient +1.356 to +1.373 nT/km; residual -0.356 to -0.233; reconstructed total +1.000 to +1.144. Direct historical scalar-gradient reversal: FAIL.
- All 450 first-vertical-derivative reconstruction variants retain a zero crossing within 8 km (min 0.005, median 2.375, max 6.864 km).
- The 25-50 km support family also passes a nearby +16-km centre and is not used as point-localizing proof.
- A 2-km low-pass plus 2.5-nT residual quantization leaves 2011 at 14/14 inverted; extreme 6-km low-pass plus quantization leaves 11/14. Resolution alone explaining the historical scalar FAIL: FAIL.
- Descriptive R values: 1971-72 ~ 0.17 -0.26; 2008 ~ 0.86 ; 2011 ~ 2.63 . These are observability regimes, not a temporal crustal-strength series.

S6. Modern model/operator sensitivity

- Coarse WMMHR total-field inversion at the available 2026 grid support: FAIL.

- Controlled WMMHR + static EMM2017 degrees 134-790 scale addition changes the modeled crustal scalar-gradient contribution from +0.179723 to -0.333653 nT/km while the total remains +0.808092 nT/km.
- Signed inclination-gradient perturbation changes from -2.354 to -4.542 arcsec/km while retaining direction.
- This experiment is model sensitivity only and is not a 2026 local measurement.

S7. Geological holdout, gravity FAIL, and claims not retained

- Magnetic-only anchor: 5.385 km from city, Pmax=0.937 km; GIS distance to the mapped Serra de Santa Helena/Lagoa do Jacare contact = 30.7 m. At the 1:750,000 source-map scale, this is treated only as a proximity statistic, not metric registration accuracy. One of 1195 non-overlapping controls matches/exceeds both thresholds; exploratory cross-domain rank only.
- Sao Domingos mapped exposure/concealment transition: ~8.113 km from Uruana. Independent 2008 E-W and N-S traverses acquired ~63 days apart record field increase toward the same NE side; qualitative structural corroboration.
- Bouguer gravity does not preserve the localized magnetic response: FAIL; no joint magnetic-gravity anomaly is claimed.
- Full coordinate-free 2-D gradient reversal is non-discriminating: FAIL. The meridional scalar derivative remains the direct result.
- ~43-degree directional specificity is not retained after the regional directional null; direct local vector Z/inclination reversal remains unresolved pending measured fX/fY/fZ.

S8. Exploratory source-depth sensitivity audit

This post-discovery audit tests whether the available public data support a stable quantitative source-depth estimate; it is not part of the direct anomaly claim.

Radially averaged logarithmic power spectra of the 2008 1.5-km grid, evaluated across local half-widths 20-50 km and first- versus second-degree detrending, recover a shallow apparent ensemble scale of 1.508-2.168 km (median 1.700 km). A deeper spectral component is much less stable (5.552-11.657 km). The shallow value is an ensemble scale under spectral assumptions, not a source-specific body depth.

Euler deconvolution sensitivity across structural index 0, 0.5, 1, and 2; 5/7/9-cell windows; and upward continuation 0/1.5/3 km produces materially different median depths. At native support alone, median solutions span approximately 1.78-7.00 km across the tested structural-index/window family and rise further under continuation. No unique Euler depth is retained.

Spectral-slope estimates on the 14 high-resolution 2011 profiles also vary with spatial window and wavelength band. Source-specific transition-width fits at the mapped Sao Domingos crossing do not center stably on the crossing. Verdict: current data do not uniquely constrain causative-body depth or geometry; no precise depth is used in the manuscript inference.

S9. Claim/falsification matrix

ID	Claim	Class	Boundary
C1	Localized magnetic-gradient anomaly at Uruana de Minas	CORE	Direct 2011 raw scalar total-field meridional gradient reversal
C2	14/14 raw 2011 lines reverse relative to positive main-field gradient	DIRECT CORE	Fixed primary 250-m binned OLS operator; shifted bin-origin sensitivity explicitly reported
C3	14/14 unconstrained breakpoints recover - to + topology	DIRECT CORE	Breakpoint median ~18.5 km; bin-width sensitivity 125 m-1 km
C4	External tested controls do not reach 14/14	ADVERSARIAL	Maximum external 9/14; descriptive, not preregistered p-value
C5	2008 contains + to - to + architecture	CORROBORATIVE	Raw and diurnal-corrected grids
C6	Uruana ranks 1/5 among transition-bearing matched-support blocks	CORROBORATIVE STRONG	Dmed=1.254 km; Cmean=0.908
C7	Sign agreement alone can be a false positive	METHOD CORE	k=-1 can show 100% agreement but 0/14 transition
C8	1971-72 1DV boundary within target in 450/450 reconstructions	HISTORICAL CORROBORATIVE	Not raw-flight proof
C9	1971-72 total-field reversal	FAIL	Residual opposes main field but total remains positive
C10	Resolution alone explains historical FAIL	FAIL	2011 remains 14/14 after ~2 km low-pass + quantization
C11	Modern WMMHR total-field reversal	FAIL	Coarse model does not reproduce 2011 inversion
C12	Adding EMM degrees 134-790 makes modeled crustal F-gradient opposed	MODEL CORROBORATIVE	Hybrid total still positive; R=0.292
C13	Sao Domingos localized magnetic intensification	GEOLOGICAL CORROBORATIVE	Orthogonal 2008 traverses, separate dates
C14	Bouguer gravity independently replicates magnetic response	FAIL	Not a joint magnetic-gravity anomaly
C15	Full 2-D gradient reversal discriminates Uruana	FAIL	Meridional scalar derivative is the defensible direct result
C16	~43 degree directional axis is rare	RETIRED	Regional directional null did not support specificity
C17	Direct local Z/inclination reversal	UNRESOLVED	Requires local measured fX/fY/fZ
C18	2011 target-to-north turnover is confined to MAGBRU	FAIL / ROBUSTNESS	MAGMIC same-line 14/14; MAGCOM/MAGNIV/MAGMIC 14/14 across four shifted bin phases
C19	Simple flight-height/topography sign trend reproduces magnetic pattern	FAIL / NEGATIVE CONTROL	No supplied height/topography channel gives the universal magnetic sign architecture

S10. Online Resource 2 inventory and reproducibility map

The synchronized Online Resource 2 contains 60 regular files: 15 narrative audits, 31 machine-readable files in derived/, 4 executable scripts, 6 source-depth-sensitivity files, and 4 root-level README/run/checksum files. SHA256SUMS.txt enumerates and hashes every other package file, providing the authoritative complete inventory.

Key additions in the 18 August robustness layer are:

- audits/URUANA_2011_CHANNEL_HEIGHT_BINPHASE_SENSITIVITY_AUDIT.txt
- derived/URUANA_2011_BIN_PHASE_CHANNEL_HEIGHT_SENSITIVITY.csv
- derived/URUANA_2011_BIN_PHASE_CHANNEL_HEIGHT_SENSITIVITY_SUMMARY.csv
- derived/URUANA_2011_RAWPOINT_CHANNEL_HEIGHT_SENSITIVITY.csv
- scripts/verify_3087_channel_altitude_sensitivity.py
- UPSTREAM_3087_SENSITIVITY_RUN.txt

The principal verification entry point is scripts/verify_principal_claims.py. The upstream reconstruction script can stream the original public Mag-3087.XYZ file or its ZIP archive and regenerate the new channel/bin-origin/height sensitivity tables. Large third-party upstream survey files are not redistributed; they should be obtained from the original public SGB/ANP/NOAA archives under the identifiers reported in the manuscript and derived/SOURCE_DATA_MANIFEST.csv.