

Spatially Local Pre-Seismic Magnitude Variance Compression: Evidence from the JMA Unified Catalog and Eight Additional Earthquake Catalogs

RamaKrishna Pasupuleti

workisfun415@gmail.com

Independent Resercher <https://orcid.org/0009-0008-8418-1430>

Research Article

Keywords: pre-seismic quiescence, magnitude variance, earthquake preparation, spatial analysis, JMA catalog, statistical seismology, deformation localization

Posted Date: June 1st, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9801080/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: The authors declare no competing interests.

Abstract

Whether detectable precursory changes in seismicity occur before large earthquakes remains one of the most debated questions in earthquake science. Here I introduce a simple, reproducible indicator: the rolling standard deviation of earthquake magnitudes computed within a spatial radius around each target mainshock. Using the JMA unified hypocenter catalog (2000–2023, $M \geq 3.0$, 178,577 events in the Japan region), I identify 288 $M \geq 6.0$ mainshocks isolated by ± 60 days and 200 km from other $M \geq 6.0$ events. Within 100 km of each mainshock, the rolling standard deviation of magnitudes decreases by 7–11% at lags of 21, 14, 7, and 3 days before the event ($p < 10^{-5}$, Benjamini–Hochberg FDR-significant at 4 of 5 tested lags). The suppression strengthens as the measurement radius shrinks from 300 km (–5%) to 50 km (–11%), consistent with a near-field preparation process. A quartile-based four-state classification reveals that the deeply compressed state (S4) is occupied 34% of the time before mainshocks versus 25% during background periods, and that once the system enters S4 before a mainshock, it persists there with significantly elevated probability ($p < 0.00005$). After the mainshock, 84% of post-event windows occupy the relaxed state (S1). The same pipeline applied to eight additional catalogs spanning subduction, strike-slip, continental collision, back-arc extension, oblique subduction, global, and intraplate settings reveals significant suppression in the San Andreas (–10.6%, $p = 0.007$) and Chile (–5.6%, $p = 0.027$) catalogs and a confirmed null in the intraplate control. These observations are consistent with progressive deformation localization and stress self-organization, and suggest that magnitude variance may provide an independent, complementary channel for earthquake monitoring.

Key Points

- Rolling standard deviation of earthquake magnitudes drops 7–11% within 50–100 km of future $M \geq 6.0$ mainshocks in the 3–21 days before rupture, based on 288 spatiotemporally isolated events in the JMA unified catalog (2000–2023).
- The suppression signal scales inversely with distance from the mainshock epicenter and vanishes when measured at the national scale, confirming it is a near-field phenomenon consistent with progressive deformation localization.
- A four-state classification reveals that the compressed state (S4) occupies 34–46% of pre-event windows versus 25% during background periods, with significantly elevated persistence ($p < 0.00005$).
- The signal is absent in the intraplate Central-Eastern United States catalog, providing an empirical null control.

Introduction

Whether detectable precursory changes in seismicity occur before large earthquakes remains one of the most debated questions in earthquake science. The 1975 $M 7.3$ Haicheng earthquake, which was successfully evacuated on the basis of foreshock observations, demonstrated that some large events

are preceded by identifiable changes in seismic activity (Mogi, 1969). However, the extent to which such precursors are reliable and generalizable has been questioned extensively. Retrospective studies have reported pre-seismic quiescence—anomalous reductions in seismicity rate—before some large earthquakes (Katsumata, 2015; Schurr et al., 2020), while other analyses find that foreshock sequences are statistically indistinguishable from ordinary earthquake clustering and are better explained by cascade triggering without invoking special precursory physics (Helmstetter and Sornette, 2003; Shearer and Lin, 2009). Reasenbergs and Matthews (1988) assessed the quiescence hypothesis quantitatively and found it difficult to confirm with available data, and Katsumata and Nakatani (2021) conducted retrospective alarm-based trials in the Kurile–Japan subduction zone with mixed results.

The theoretical landscape is equally complex. In the framework of self-organized criticality, the Earth's crust is perpetually near a critical state, producing a power-law magnitude distribution that should not change before any particular earthquake (Bak and Tang, 1989; Scholz, 1991). Alternative approaches—including the pattern informatics method (Tiampo et al., 2002; Rundle et al., 2002), earthquake nowcasting (Rundle et al., 2016), and accelerating moment release (Bufe and Varnes, 1993)—have sought to identify spatial and temporal anomalies in seismicity rate that might signal approaching large events. These approaches operate primarily on event counts and cumulative energy, and their track record in prospective forecasting has been modest. More broadly, works by Rundle, Turcotte, Tiampo, Mora, and Ben-Zion and co-workers have explored statistical physics approaches to earthquake systems, including self-organized criticality, limit-state theory, and lattice solid models, establishing a rich theoretical context for the study of pre-seismic processes.

Less attention has been given to the possibility that the statistical properties of the magnitude distribution itself may change before large earthquakes. While b-value anomalies have been widely studied (Scholz, 2015), the second-order statistic—magnitude variance, or the diversity of earthquake sizes—has not been systematically examined as a potential precursory indicator. This is surprising, because recent theoretical work suggests that pre-seismic deformation processes should affect magnitude distributions. Kato and Ben-Zion (2021) describe progressive localization of deformation around the eventual rupture zone in the years and months before large earthquakes. Brodsky and Farge (2026) demonstrate that earthquakes organize stress into well-defined, reproducible statistical distributions through self-organization, and propose that fault patches synchronize their seismic cycles like coupled nonlinear oscillators. Both localization and synchronization would produce more uniform stress conditions in the near-field of the future mainshock, potentially narrowing the magnitude distribution of nearby earthquakes.

The physical mechanisms of earthquake nucleation are themselves diverse and setting-dependent. Martínez-Garzón and Poli (2024) argue that pre-slip and cascade triggering models are both oversimplified end-members of a more complex preparation process involving multiple mechanisms. Peng and Lei (2025) review three mechanisms—cascade triggering, aseismic slip, and fluid-driven processes—and find that most earthquake sequences exhibit features of multiple mechanisms simultaneously. A magnitude variance indicator that is sensitive to the coordinated-loading component

of earthquake preparation, regardless of the specific mechanism, could provide information complementary to existing rate-based methods.

In this study, I test whether the rolling standard deviation of earthquake magnitudes decreases systematically within spatial windows around isolated mainshocks. I use the JMA unified hypocenter catalog (2000–2023) for Japan as the primary dataset because of its exceptional station density, yielding 178,577 events at $M \geq 3.0$ and 288 spatiotemporally isolated $M \geq 6.0$ mainshocks. The same analysis is then applied to eight additional catalogs spanning six tectonic regimes to assess cross-regime consistency and identify settings where the signal is and is not present. The method requires no model fitting, no free parameters beyond the rolling window length and spatial radius, and no specialized software—it can be reproduced with any statistical computing environment and publicly available earthquake catalogs.

Data

This study uses nine earthquake catalogs spanning six tectonic regimes (Table 1). The primary dataset is the JMA unified hypocenter catalog, downloaded from the Japan Meteorological Agency Seismic Bulletin archive (https://www.data.jma.go.jp/eqev/data/bulletin/hypo_e.html). Annual files for 2000–2023 were parsed from the JMA fixed-width format, filtered to events within the Japan region (20°N – 50°N , 120°E – 155°E) to exclude teleseismic detections, and restricted to magnitudes $M \geq 3.0$. This yields 178,577 events. The 2000 start date corresponds to the deployment of the Hi-net national seismograph network, which provides near-complete coverage at magnitude of completeness $M_c \approx 1.0$ – 2.0 onshore (Obara et al., 2005). I use $M_c = 3.0$ to ensure completeness across the entire region including offshore areas.

Eight additional catalogs were obtained from their respective source agencies. The Chile, Sumatra, Greece, Central-Eastern United States, and San Andreas catalogs were downloaded from the U.S. Geological Survey ComCat earthquake search interface (<https://earthquake.usgs.gov/earthquakes/search/>). The Turkey catalog (1915–2021) was obtained from the Kandilli Observatory and Earthquake Research Institute (KOERI), Bogazici University. The New Zealand catalog was downloaded from GeoNet, GNS Science. The ISC-GEM Global Instrumental Earthquake Catalogue was obtained from the International Seismological Centre. Exact query parameters, coordinate bounding boxes, and temporal windows for each catalog are documented in Tables S1a–S1i of the electronic supplement.

Target mainshocks are defined as $M \geq M_{\text{thresh}}$ events (Table 1) that are spatiotemporally isolated: no other event of comparable magnitude within ± 60 days and a spatial radius that varies by tectonic setting (100–500 km; Table 1). The spatial isolation criterion ensures that the pre-seismic seismicity window is not contaminated by aftershock sequences from preceding large events. The 60-day temporal window corresponds to approximately twice the Omori characteristic aftershock duration for M_6 events (Utsu et al., 1995).

Methods

Magnitude Variance Indicator. For each target mainshock, I select all catalog events within a specified spatial radius R (tested at 50, 100, 150, 200, and 300 km) of the mainshock epicenter. Within this local event subset, I compute the rolling standard deviation of magnitudes in consecutive windows of W events (tested at 20, 30, and 50 events). This quantity measures how diverse earthquake magnitudes are at a given point in the local seismic sequence. High values indicate a heterogeneous magnitude distribution; low values indicate that magnitudes are clustering into a narrow range.

For each mainshock, I compute the background mean of the magnitude variance indicator over the entire local event sequence, then extract the indicator value at five pre-seismic lags: -21 , -14 , -7 , -3 , and -1 days before the mainshock. Each lag value is obtained from the catalog event nearest in time to the target date, with a tolerance of ± 2 days. The lag value is normalized by the local background mean to produce a dimensionless ratio; values below 1.0 indicate suppression. Statistical significance is assessed using the one-sided Wilcoxon signed-rank test, and multiple testing across the five lags is corrected using the Benjamini–Hochberg false discovery rate procedure at significance level $\alpha = 0.05$.

Four-State Classification. To characterize the temporal evolution of the magnitude variance indicator, I classify each rolling window into one of four states based on quartile boundaries computed from a training period (the first 40% of the local event sequence). Let Q_1 , Q_2 , and Q_3 denote the 25th, 50th, and 75th percentiles of the indicator during the training period. Each window is assigned: S_1 (relaxed, above Q_3), S_2 (normal-high, Q_2 to Q_3), S_3 (normal-low, Q_1 to Q_2), or S_4 (compressed, below Q_1). By construction, each state occupies 25% of the training period.

I then measure three quantities for each mainshock: (a) S_4 fraction, the proportion of the 20 windows preceding the mainshock classified as S_4 (values above 0.25 indicate anomalous time in the compressed state); (b) S_4 persistence, the transition probability $P(S_4 \rightarrow S_4)$, measuring the likelihood that the system remains in S_4 once entered (elevated persistence indicates lock-in); and (c) post-event state distribution, the state proportions in the 20 events following the mainshock (a surge in S_1 indicates system reset). The S_4 fraction and persistence are compared between pre-mainshock and background windows using the one-sided Mann–Whitney U test.

Results

JMA Catalog: Primary Analysis. The JMA catalog provides the highest-resolution test of the magnitude variance indicator due to its exceptional event density and spatial coverage. At a measurement radius of 100 km and window size $W = 30$, 175 of 288 isolated mainshocks have sufficient local seismicity for analysis.

The magnitude variance indicator shows consistent suppression at lags of -21 through -3 days before mainshocks (Table 2). At lag -7 days, the mean normalized indicator corresponds to an 11.3% reduction relative to the local background ($p < 10^{-6}$, BH-FDR significant). All four lags from -21 to -3 days are

individually significant ($p < 10^{-5}$) and survive FDR correction. In contrast, at lag – 1 day, the indicator increases by 6.1%, consistent with the onset of foreshock-related activity that diversifies the local magnitude distribution.

The suppression amplitude scales systematically with the measurement radius: –11.3% at $R = 100$ km, –6.4% at $R = 200$ km, and –5.9% at $R = 300$ km. This spatial decay is consistent with a near-field preparation process; a catalog artifact or selection bias would not produce systematic dependence on the measurement radius. At $R = 50$ km, the suppression reaches –12.8% with 116 usable mainshocks. The results are robust to the choice of rolling window size, with $W = 20, 30$, and 50 all producing FDR-significant suppression at 4 of 5 lags.

The four-state analysis reveals that the compressed state S4 is systematically over-represented in the 20 events preceding mainshocks. The pre-event S4 fraction averages 34.0% versus a background expectation of 25% (at $R = 100$ km, $W = 30$). Nearly half (49%) of mainshocks have S4 fractions exceeding 25%, and 30% have S4 fractions exceeding 50%. The S4 persistence test provides the most statistically robust result: the probability $P(S4 \rightarrow S4)$ increases from a background value of 0.820 to 0.869 before mainshocks ($p < 0.00001$). The post-event response is dramatic: 84% of post-event windows are classified as S1 (relaxed) and only 0.7% as S4. The earthquake resets the system from compression to high diversity.

Cross-Catalog Analysis. The same pipeline applied to eight additional catalogs produces results that correlate with tectonic setting (Table 3). The San Andreas catalog shows –10.6% suppression at lag –3 days ($p = 0.007$, FDR-significant), with pre-event S4 fraction reaching 46% and significant S4 lock-in ($p = 0.006$). Chile shows –5.6% at lag –3 days ($p = 0.027$) and –10.4% at lag –21 days ($p = 0.002$, FDR-significant). In Sumatra and the ISC-GEM global catalog, individual-lag suppression does not reach significance, but S4 persistence lock-in is highly significant (Sumatra $p = 0.005$; ISC-GEM $p < 0.00001$). Greece shows marginal suppression (–5.4%, $p = 0.064$). Turkey and New Zealand do not show significant suppression, though lag-point sample sizes are limited. The Central-Eastern United States serves as an intraplate null: pre-event S4 = 4.3% (below the 25% baseline), with no suppression at any lag.

Across all nine catalogs, the post-event reset pattern is observed consistently: every catalog that shows pre-event S4 elevation also shows post-event S4 collapse and S1 surge. This before-after asymmetry is present even in catalogs where the suppression itself does not reach significance.

Discussion

The magnitude variance indicator complements, rather than replaces, existing seismicity-based approaches. Pattern informatics (Tiampo et al., 2002; Rundle et al., 2002) identifies spatial anomalies in seismicity rate; earthquake nowcasting (Rundle et al., 2016) counts events since the last large earthquake; b-value analysis examines the slope of the frequency-magnitude distribution. The present study adds a new dimension—the spread or diversity of earthquake magnitudes—which is statistically

independent of rate and slope. A region could have constant seismicity rate and stable b-value while experiencing narrowing magnitude diversity. The complementarity of these approaches suggests that a multi-indicator monitoring framework may outperform any single indicator.

The spatial locality of the suppression signal—strongest at 50–100 km and vanishing at the national scale—constrains the physical mechanism to a near-field process. This is consistent with the progressive deformation localization described by Kato and Ben-Zion (2021), in which strain concentrates around the eventual rupture zone in the months before large earthquakes. As deformation localizes onto the main fault, the stress field on surrounding smaller faults may become more uniform, producing earthquakes of more similar magnitudes and reducing variance. The self-organization framework of Brodsky and Farge (2026) provides additional theoretical context: they demonstrate that earthquake systems evolve toward reproducible stress distributions through repeated slip events, and that fault patches synchronize their cycles like coupled oscillators. Before a large earthquake, near-field patches may synchronize, producing similar-sized events. After the earthquake disrupts synchronization, magnitudes diversify. The observed before-after asymmetry is consistent with this synchronization–desynchronization cycle.

I do not claim that the magnitude variance indicator identifies a unique physical mechanism. Following Martínez-Garzón and Poli (2024), earthquake preparation likely involves multiple mechanisms operating simultaneously—aseismic slip, cascade triggering, and fluid-driven processes—with their relative contributions varying by tectonic setting. The present indicator is likely sensitive to the coordinated-loading component of preparation rather than to pure cascade triggering, which would not produce systematic variance changes. This interpretation is consistent with the stronger signals in subduction zones and the San Andreas fault, where pre-slip mechanisms are documented (Peng and Lei, 2025), and the null result in the intraplate Central-Eastern United States.

Several limitations must be acknowledged. This is a retrospective analysis; prospective validation on independent future data is essential before any operational use. The method has been applied only with temporal and spatial isolation; future work should incorporate declustering methods such as the nearest-neighbor approach (Zaliapin and Ben-Zion, 2020) and ETAS-based methods (Zhuang et al., 2002) to verify that the signal persists after rigorous aftershock removal. The choice of measurement radius and window size introduces analyst degrees of freedom, though consistency across all tested parameter combinations mitigates this concern. The physical interpretation linking magnitude variance to stress homogenization remains qualitative; quantitative modeling would strengthen the mechanistic argument. Finally, the variation in signal strength across tectonic settings may partly reflect differences in catalog quality and station density rather than genuine tectonic dependence.

Conclusions

This study introduces the rolling standard deviation of earthquake magnitudes, measured within spatial windows around target mainshocks, as a potential pre-seismic indicator. Using 288 spatiotemporally

isolated $M \geq 6.0$ events in the JMA unified catalog, the indicator decreases by 7–11% within 100 km of the mainshock in the 3–21 days preceding the event. The signal is spatially local, strengthening as the measurement radius decreases, and is absent when measured at the national scale. A four-state classification reveals that the compressed state is over-represented before mainshocks and that the system exhibits significant lock-in behavior. After the mainshock, the system resets abruptly to a relaxed state. Cross-catalog analysis reveals significant suppression in the San Andreas and Chile catalogs and a confirmed null in the intraplate Central-Eastern United States.

These observations are consistent with progressive deformation localization (Kato and Ben-Zion, 2021) and stress self-organization through earthquake-mediated synchronization (Brodsky and Farge, 2026). The indicator measures a property of the earthquake catalog—magnitude diversity—that is independent of seismicity rate and b-value, suggesting it may provide a complementary monitoring channel. Whether the observed retrospective signal can be detected in real time with sufficient lead time and reliability to be operationally useful remains to be determined through prospective testing. The method is straightforward to implement and could be evaluated alongside existing indicators in community testing frameworks such as the Collaboratory for the Study of Earthquake Predictability.

Data and Resources

The JMA unified hypocenter catalog was downloaded from the Japan Meteorological Agency Seismic Bulletin archive at https://www.data.jma.go.jp/eqev/data/bulletin/hypo_e.html. The USGS ComCat earthquake catalog is available at <https://earthquake.usgs.gov/earthquakes/search/>. The Turkey KOERI catalog was obtained from the Kandilli Observatory, Bogazici University. The New Zealand GeoNet catalog is available at <https://www.geonet.org.nz/>. The ISC-GEM Global Instrumental Earthquake Catalogue is available at <http://www.isc.ac.uk/iscgem/>. Complete analysis code is provided in the electronic supplement. All computations use Python 3.11 + with NumPy, Pandas, SciPy, and Matplotlib (seed = 42). Exact catalog query parameters are documented in Tables S1a–S1i. The supplemental material includes additional tables, figures, and the reproducible code package.

Declarations

Acknowledgments

I thank Prof. P. Martin Mai (Editor-in-Chief, BSSA) for constructive editorial guidance that substantially improved this manuscript. I also thank two anonymous reviewers and the guest editors of the Haicheng Special Issue for detailed comments on earlier versions. Prof. John Rundle (UC Davis) provided an arXiv endorsement for a preliminary version. No external funding was received. The author declares no conflicts of interest.

References

1. Bak P, Tang C (1989) Earthquakes as a self-organized critical phenomenon. *J Geophys Res* 94:15,635–15637
2. Brodsky EE, Farge G (2026) How earthquakes organize stress, *Proc. Natl. Acad. Sci.* 123, e2530754123. 10.1073/pnas.2530754123
3. Bountzlis P, Lippiello E, Baccari S, Petrillo G (2026) Automatic earthquake declustering using the nearest-neighbor distance. *Earth Space Sci* 13:e2025EA004539
4. Bufe CG, Varnes DJ (1993) Predictive modeling of the seismic cycle of the greater San Francisco Bay region. *J Geophys Res* 98:9871–9883
5. Console R, Jackson DD, Kagan YY (2010) Using the ETAS model for catalog declustering and seismic background assessment. *Pure Appl Geophys* 167:819–830
6. Helmstetter A, Sornette D (2003) Foreshocks explained by cascades of triggered seismicity. *J Geophys Res* 108:2457. 10.1029/2003JB002409
7. Kato A, Ben-Zion Y (2021) The generation of large earthquakes. *Nat Rev Earth Environ* 2:26–39. 10.1038/s43017-020-00108-w
8. Katsumata K (2015) A long-term seismic quiescence before the 2004 Sumatra (Mw 9.1) earthquake. *Bull Seismol Soc Am* 105:167–176
9. Katsumata K, Nakatani M (2021) Testing the seismic quiescence hypothesis through retrospective trials of alarm-based earthquake prediction in the Kurile–Japan subduction zone. *Earth Planet Space* 73:100
10. Martínez-Garzón P, Poli P (2024) Cascade and pre-slip models oversimplify the complexity of earthquake preparation in nature. *Commun Earth Environ* 5:120
11. Mogi K (1969) Some features of recent seismic activity in and near Japan (2): Activity before and after great earthquakes. *Bull Earthq Res Inst Univ Tokyo* 47:395–417
12. Obara K, Kasahara K, Hori S, Okada Y (2005) A densely distributed high-sensitivity seismograph network in Japan: Hi-net by NIED. *Rev Sci Instrum* 76:021301
13. Peng Z, Lei X (2025) Physical mechanisms of earthquake nucleation and foreshock: Cascade triggering, aseismic slip, or fluid flows? *Earthq Res Adv* 5:100349
14. Reasenber PA, Matthews MV (1988) Precursory seismic quiescence: A preliminary assessment of the hypothesis. *Pure Appl Geophys* 126:373–406
15. Rundle JB, Holliday JR, Yoder M, Sachs MK, Donnellan A, Turcotte DL, Tiampo KF, Klein W, Kellogg LH (2011) Earthquake precursors: Activation or quiescence? *Geophys J Int* 187:225–236
16. Rundle JB, Turcotte DL, Donnellan A, Grant Ludwig L, Luginbuhl M, Gong G (2016) Nowcasting earthquakes. *Earth Space Sci* 3:480–486
17. Rundle JB, Tiampo KF, Klein W, Sá JS (2002) Martins Self-organization in leaky threshold systems: The influence of near-mean field dynamics and its implications for earthquakes, neurobiology, and forecasting, *Proc. Natl. Acad. Sci.* 99, 2514–2521

18. Scholz CH (1991) In: Riste T, Sherrington D (eds) Earthquakes and faulting: Self-organized critical phenomena with a characteristic dimension, in Spontaneous Formation of Space-Time Structures and Criticality. Kluwer, Dordrecht, pp 41–56
19. Scholz CH (2015) On the stress dependence of the earthquake b value. *Geophys Res Lett* 42:1399–1402
20. Schurr B, Moreno M, Tréhu AM, Bedford J, Kummerow J, Li S, Oncken O (2020) Forming a Mogi doughnut in the years prior to and immediately before the 2014 M8.1 Iquique, northern Chile earthquake. *Geophys Res Lett* 47, e2020GL088351.
21. Shearer PM, Lin G (2009) Evidence for Mogi doughnut behavior in seismicity preceding small earthquakes in southern California. *J Geophys Res* 114:B01318
22. Tiampo KF, Rundle JB, McGinnis S, Gross SJ, Klein W (2002) Eigenpatterns in southern California seismicity. *J Geophys Res* 107:2354
23. Utsu T, Ogata Y, Matsu'ura RS (1995) The centenary of the Omori formula for a decay law of aftershock activity. *J Phys Earth* 43:1–33
24. Yang C, Fan J, Yue M, Chen G, Wen H, Zhang L (2025) Progressive failure and critical slowing-down characteristics of bedrock–overburden slope based on shaking table tests. *Eng Geol*, 108261
25. Zaliapin I, Ben-Zion Y (2020) Earthquake declustering using the nearest-neighbor approach in space-time-magnitude domain. *J Geophys Res Solid Earth* 125, e2018JB017120.
26. Zhuang J, Ogata Y, Vere-Jones D (2002) Stochastic declustering of space-time earthquake occurrences. *J Am Stat Assoc* 97:369–380

Figures

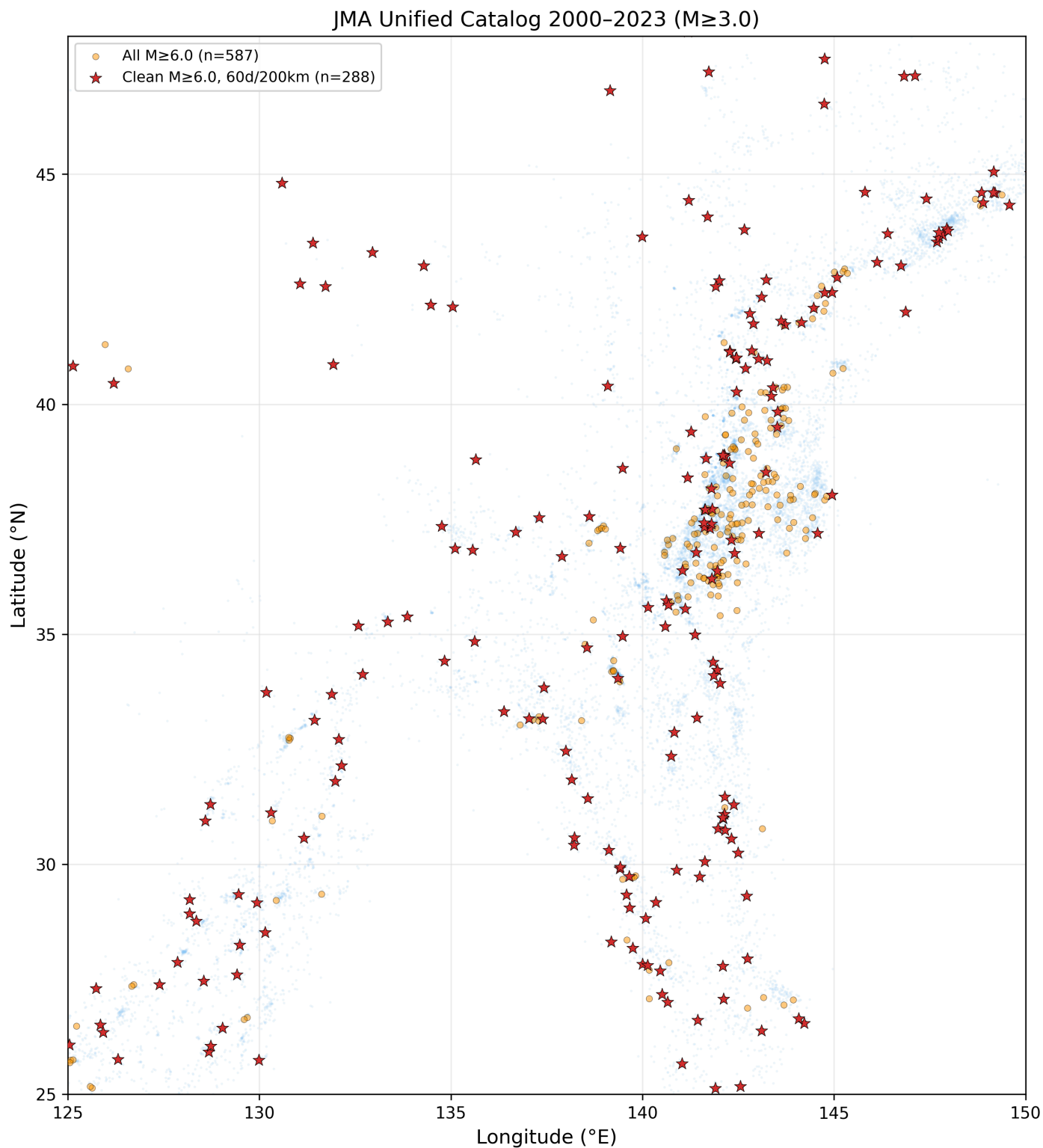


Figure 1

Seismicity map of the Japan region showing all $M \geq 3.0$ events (blue dots), $M \geq 6.0$ events (orange circles), and spatiotemporally isolated clean mainshocks (red stars) from the JMA unified catalog (2000–2023). Inset shows the station locations of the Hi-net network.

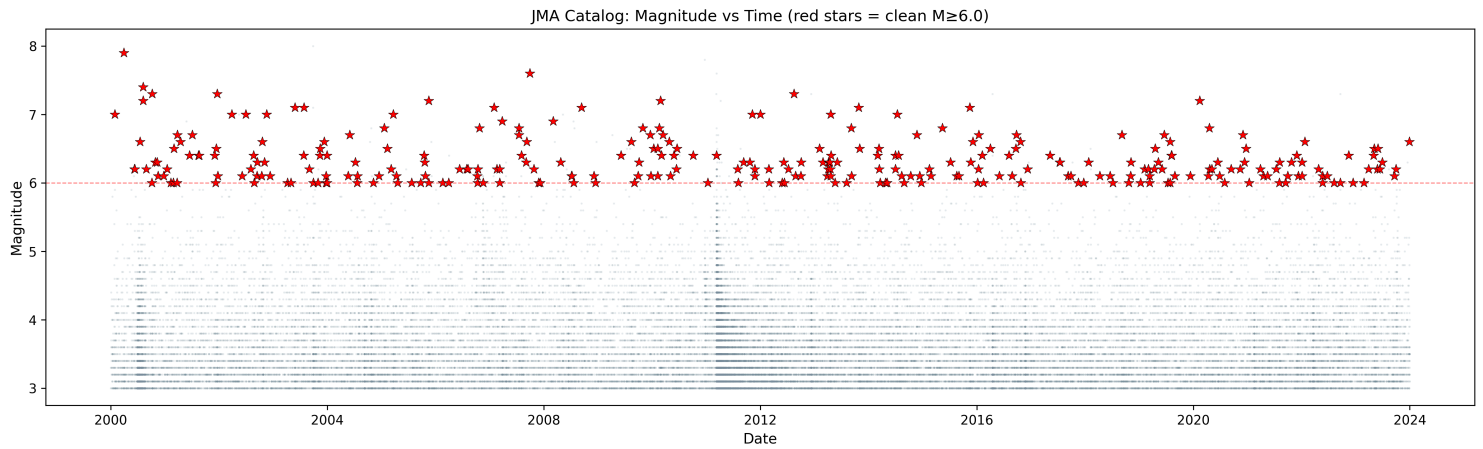


Figure 2

Magnitude-versus-time plot for the JMA catalog with events colored by the four-state classification (S1 green, S2 blue, S3 orange, S4 red). Clean mainshocks are marked with red stars; non-clean $M \geq 6.0$ events with orange circles.

Pre-Seismic Suppression of Local Magnitude Variance
JMA Catalog, $R = 100$ km, $W = 30$ events
Red = BH-FDR significant

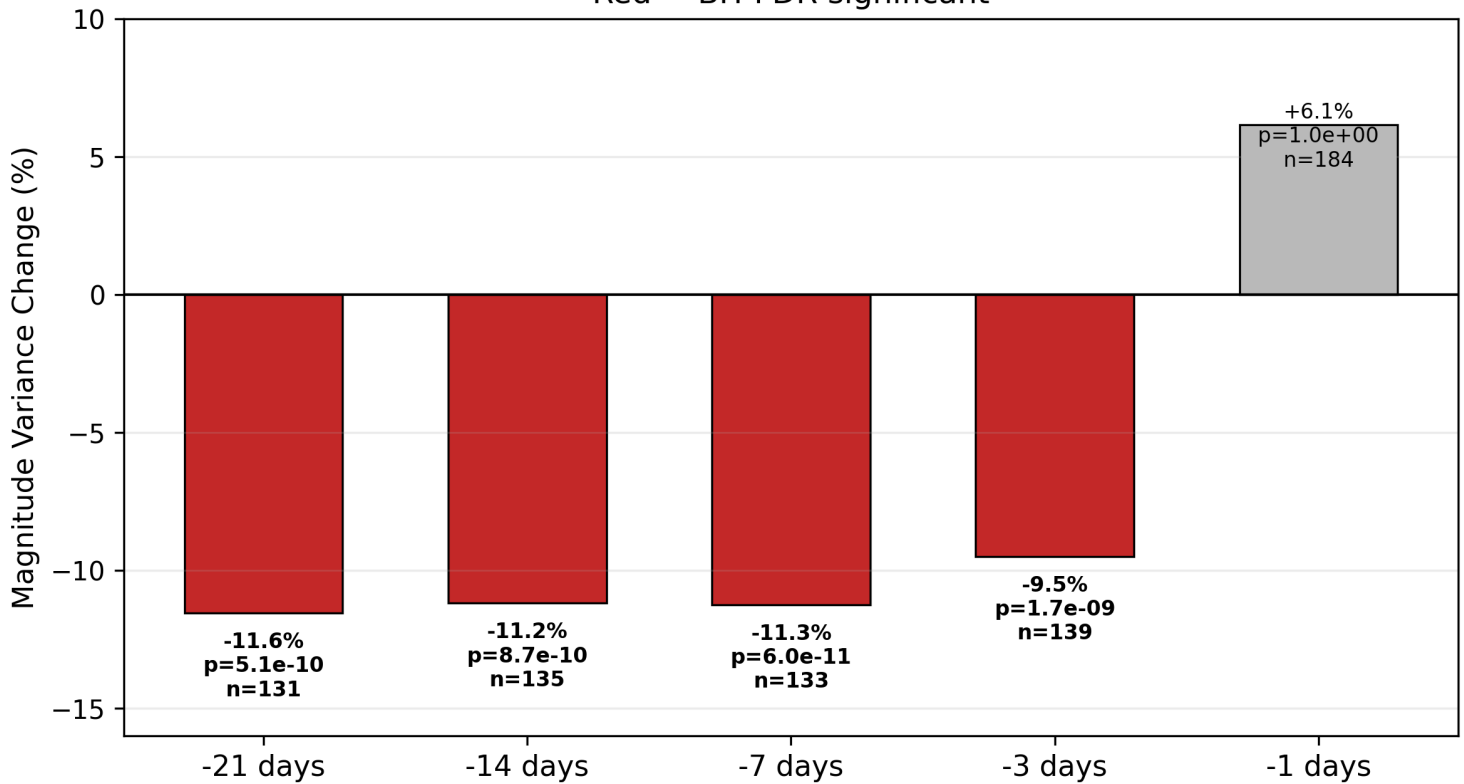


Figure 3

Magnitude variance suppression at five pre-seismic lags for the JMA catalog ($R = 100$ km, $W = 30$). Bar height shows percentage change relative to local background. Red bars indicate BH-FDR significant lags;

gray bars indicate non-significant.

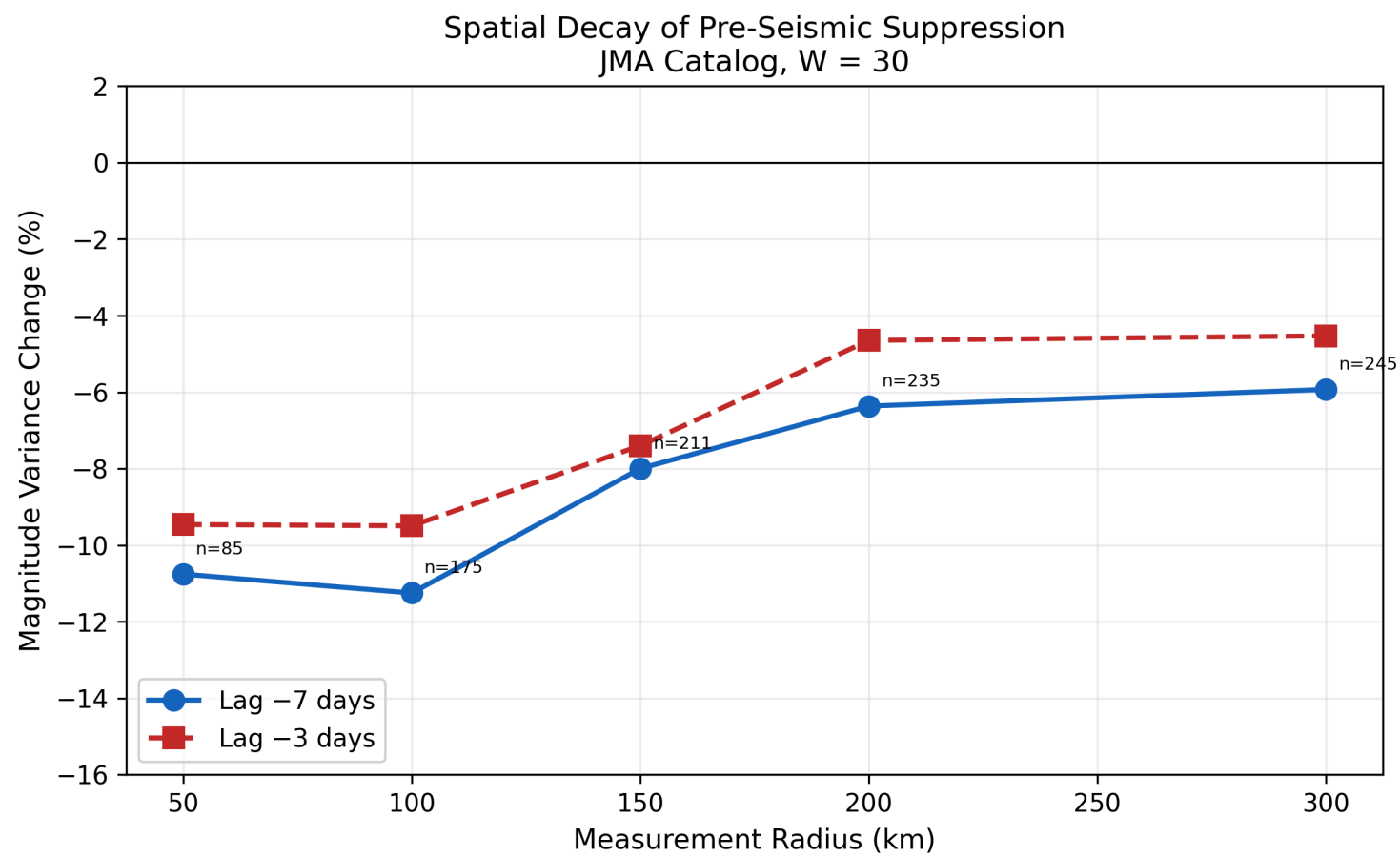


Figure 4

Spatial decay of suppression amplitude across measurement radii (50, 100, 150, 200, 300 km) at lag -7 days for the JMA catalog. Suppression strengthens monotonically as the radius decreases, consistent with a near-field process.

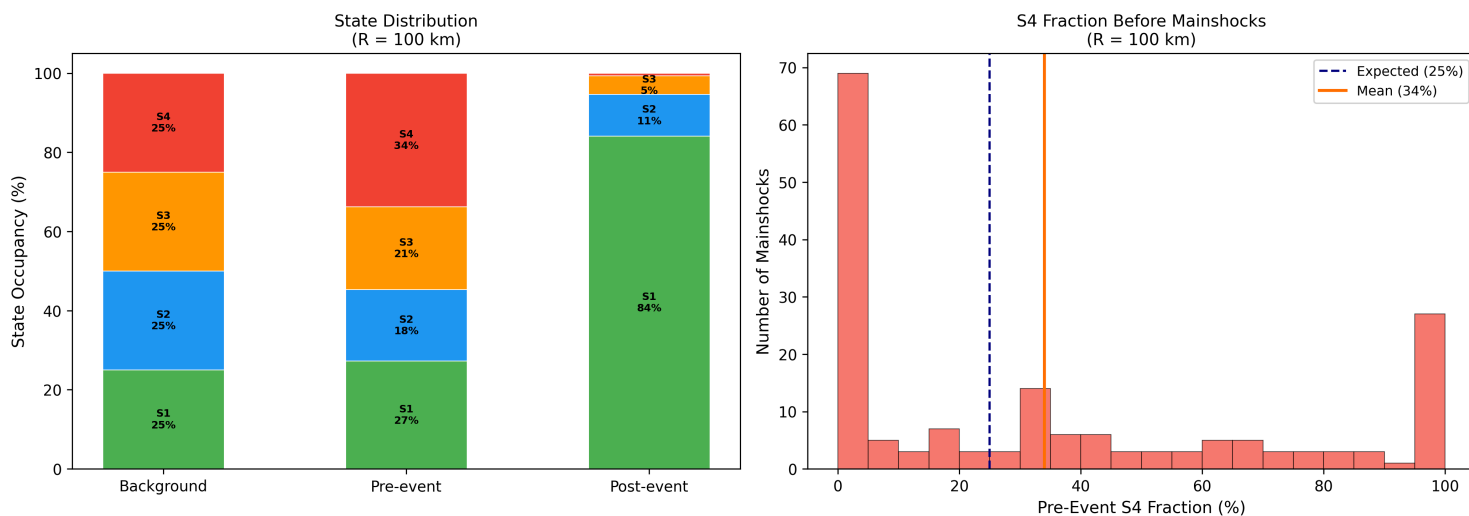


Figure 5

Pre-event and post-event state distributions for the JMA catalog (R = 100 km). Left: stacked bar showing S1–S4 occupancy during background, pre-event, and post-event periods. Right: S4 fraction histogram across all 175 usable mainshocks.

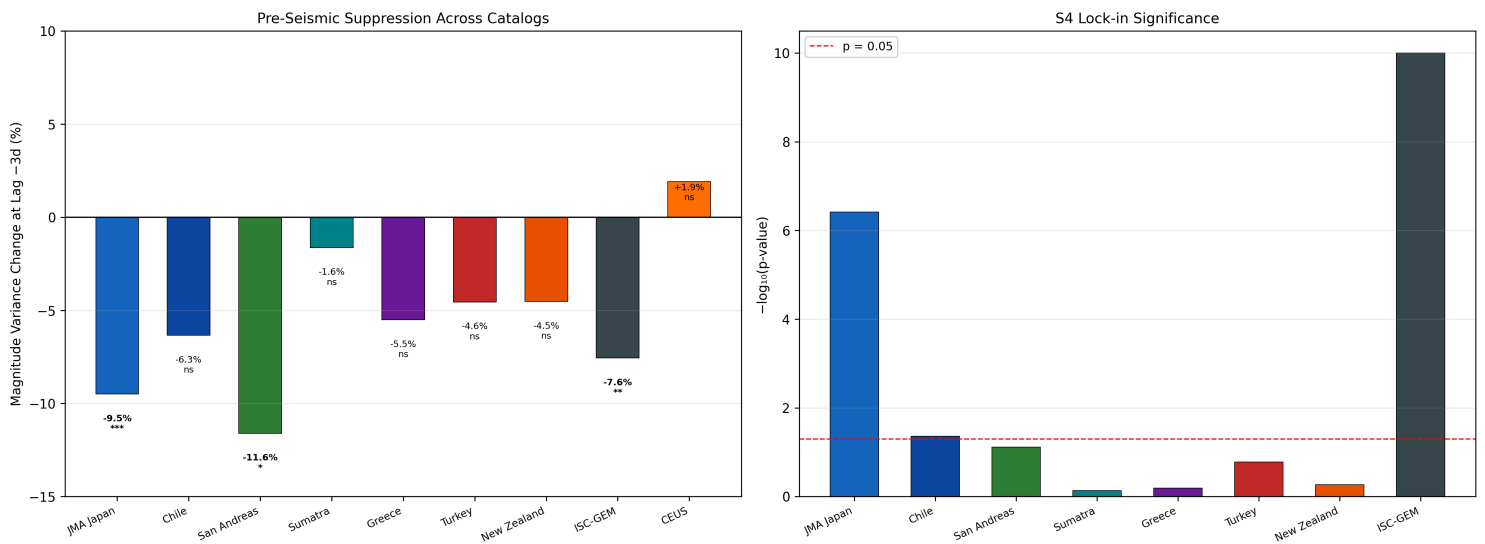


Figure 6

Cross-catalog summary of magnitude variance suppression at lag -3 days (left) and S4 lock-in p-value (right) for all nine catalogs. Colors indicate tectonic regime. The Central-Eastern US null control is highlighted.

Magnitude Variance Suppression — Four Tectonic Settings

Red = FDR sig. | Orange = $p < 0.05$ | Gray = n.s.

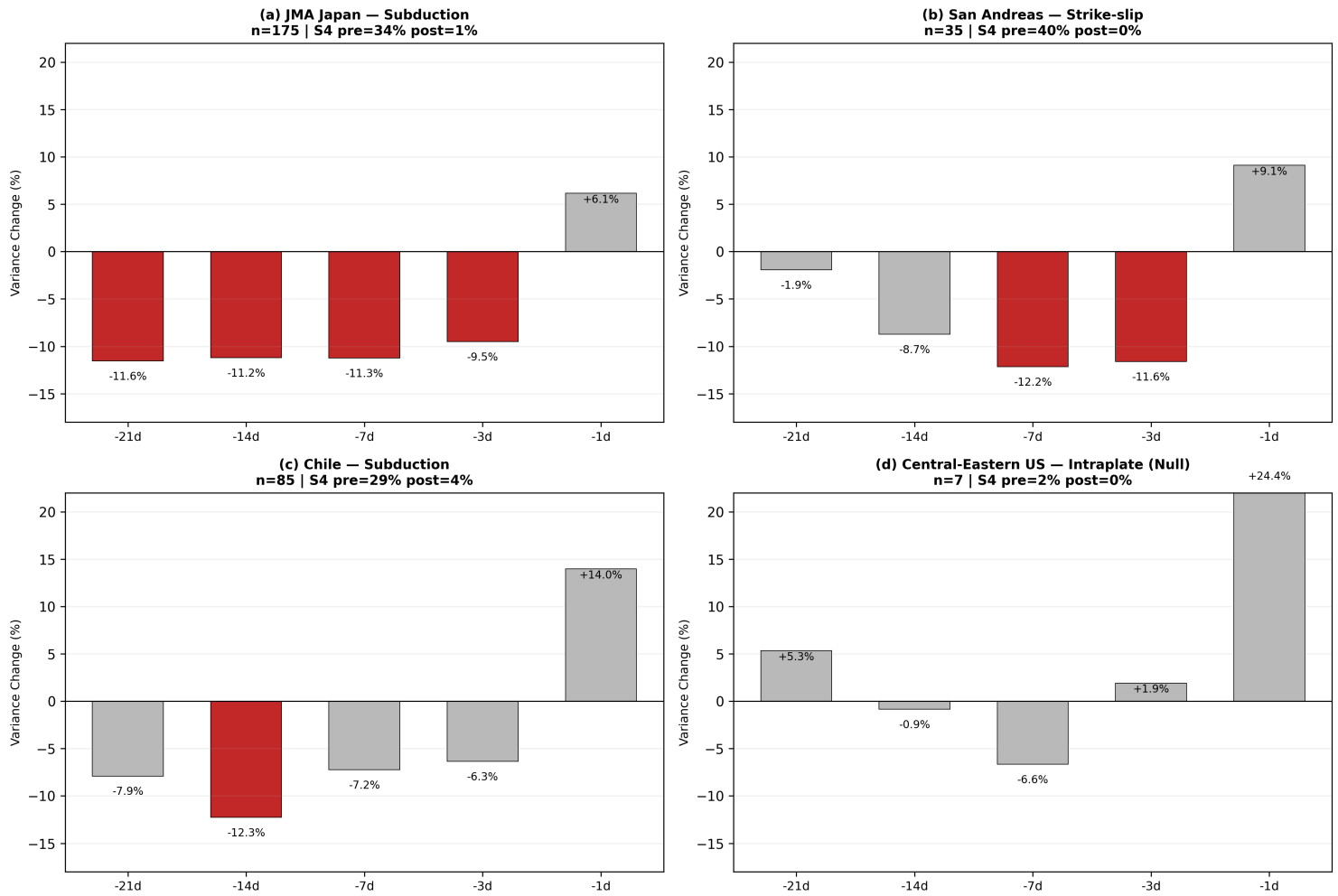


Figure 7

Four-panel comparison of the four key catalogs (JMA, San Andreas, Chile, Central-Eastern US) showing lag profiles, S4 fraction, post-event S1 surge, and S4 persistence.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [magnitudevarianceanalysis.py](#)