Asymmetric Coherence Index (ACI)

A dual-dimension metrological framework for characterizing

resilience dynamics in complex systems

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Domains: Simulation · Institutional systems · Neurophysiology · Limnology

Abstract

We present the Asymmetric Coherence Index (ACI), a dual-dimension metrological framework for characterizing coherence dynamics in complex systems. Each element is described by two independent dimensions — a conformity degree t_i and a deviation degree f_i — from which local coherence C_i = 1 − |t_i + f_i − 1| and global coherence C_glob (Łukasiewicz aggregation) are derived. Four standardized dynamic tests characterize each domain: attractor existence (Test A), resilience asymmetry (Test B), structural ratio R_1 = θ/C_glob (Test C), and fluctuation distribution (Test D). Applied to simulation (N = 120 agents, 3 topologies, 25 seeds), institutional data (Polity5, 184 countries, 1800–2018), neurophysiology (EEG at rest, PhysioNet eegmmidb, 13 subjects), and limnology (NTL-LTER, 5 Wisconsin lakes, 1984–2016), we identify a robust transversal result: coherence-increasing transitions are significantly more resilient than decreasing ones across all empirical domains (Polity5: 95.2% vs. 21.3%, Δ = 73.8 pts; NTL-LTER: 96.3% vs. 60.7%, Δ = 35.6 pts; EEG: 80.3% vs. 53.4%, Δ = 26.9 pts; N = 886 total transitions). For lacustrine systems, this asymmetry corresponds to the known phenomenon of ecological hysteresis (Scheffer et al. 2001) — here evidenced by a new standardized instrument rather than discovered as a new phenomenon. Two prospective baseline analyses qualify the scope of results: (1) the structural ratio R_1 is not specific to the bilattice formalism on simulation data (maximum deviation vs. simple average < 0.005); (2) comparative simulations (HA_RESILIENCE v3, 75 replicates) show that bilattice and 1D models recover identically after equivalent perturbations, indicating that the observed asymmetry is a property of the empirical systems studied, not a specific prediction of the dual formalism. ACI thus functions as an instrument capable of revealing this property across heterogeneous domains, rather than as a theory explaining it.

Keywords: *bilattice · dual coherence · resilience asymmetry · ecological hysteresis · complex systems · metrological framework · Łukasiewicz aggregation*

1. INTRODUCTION

The study of complex systems faces a recurring methodological challenge: comparing coherence dynamics across fundamentally heterogeneous domains. Ecological systems, neurophysiological networks, and institutional structures each have their own analytical traditions and domain-specific metrics, making cross-domain comparison difficult without imposing unjustified theoretical unification.

The Asymmetric Coherence Index (ACI) proposes a middle path: a standardized measurement framework applicable to any domain where two independently observable dimensions can be identified per system element. The framework does not claim to explain complex systems through a unified theory. It provides a common measurement language and four falsifiable dynamic tests enabling systematic cross-domain comparison.

The ACI formalism draws on the bilattice logic of Ginsberg (1988) and Belnap (1977), originally developed in artificial intelligence for reasoning under uncertainty. Its key property — the independence of two dimensions ti and fi — allows capturing states that single-variable representations cannot distinguish: ignorance (ti ≈ fi ≈ 0), contradiction (ti ≈ fi ≈ 1), and coherence (ti + fi ≈ 1).

Two prospective baseline analyses constrain the scope of results. First, a simulation-based baseline (HS1 v3) demonstrates that the structural ratio R_1 is not specific to the bilattice formalism — any stationary diffusive aggregate produces comparable R_1 values. Second, comparative simulations (HA_RESILIENCE v3) show that bilattice and 1D models recover identically after equivalent perturbations. The central empirical finding — the asymmetry of resilience — is therefore a property of the systems studied, measured by ACI but not explained by its formalism.

This paper is organized as follows. Section 2 presents the formal framework. Section 3 describes the four empirical domains and measurement protocols. Section 4 reports results by domain, including the two baseline analyses. Section 5 synthesizes cross-domain results. Section 6 discusses limitations and perspectives.

2. THEORETICAL FRAMEWORK

2.1 Dual-dimension representation

Let S be a system of N elements. At each time step, element i is characterized by two independent measurements:

ti(t) ∈ [0, 1] — conformity degree (activation, synchronization, oxygenation, democratic score)

fi(t) ∈ [0, 1] — deviation degree (dispersion, desynchronization, thermal instability, autocratic score)

The independence of ti and fi is empirically verified by computing corr(t, f) for each domain. The framework validity condition requires |corr(t, f)| < 0.5. When violated, the two-dimensional structure collapses into a one-dimensional representation, invalidating the bilattice formalism (see Section 4.2 for the Polity5 case).

2.2 Local and global coherence

Local coherence:

C_i(t) = 1 − | t_i(t) + f_i(t) − 1 |

Ci = 1 when ti + fi = 1 (perfect equilibrium); Ci = 0 when |ti + fi − 1| = 1 (total ignorance or contradiction). The formula is symmetric around the coherent manifold ti + fi = 1.

Global coherence (Łukasiewicz aggregation):

C_glob(t) = max(0, 1 − (1/N) × Σ_i (1 − C_i(t)))

The Łukasiewicz aggregator was selected following preliminary robustness tests (HO0) over five operators: Łukasiewicz, minimum, OWA, median, and harmonic mean. The inter-operator coefficient of variation was below 2%, confirming robustness. The product operator was excluded due to non-recoverable collapse dynamics.

2.3 Simulation dynamics

In the simulation module, ti and fi evolve according to a local diffusion equation on graph W:

$$t_i(t+1) = \mathrm{clip}[\, t_i(t) + \eta \times (W \cdot t - t)_i \,,\, 0,\, 1 \,]$$

$$f_i(t+1) = \mathrm{clip}[\, f_i(t) + \eta \times (W \cdot f - f)_i \,,\, 0,\, 1 \,]$$

where $\eta = 0.05$ is the diffusion step and W is the row-normalized adjacency matrix. Three topologies: Erdős–Rényi (ER, $p = 0.08$), Barabási–Albert (BA, $m = 2$), regular Watts-Strogatz ($k = 4$, $p = 0$). Parameters: $N = 120$ agents, Twarmup = 300, 25 seeds, initial conditions Uniform(0.4, 0.6).

2.4 Four dynamic tests

Test A — Attractor existence. ≥ 60% of units satisfy at least one of: (A1) Kendall $\tau < 0$ and $p < 0.05$ (active convergence of rolling variance), or (A2) median rolling variance below adaptive threshold (stable attractor already reached).

Test B — Resilience asymmetry. Following a major transition ($|\delta C| > 0.15$), the system returns toward its prior level. Resilient transition: Cpost/Cpre ≥ 0.85. Domain validated if ≥ 60% of transitions are resilient. Central analysis: comparison of resilience rates between upward and downward transitions.

Test C — Structural ratio R_1. $R_1 = \theta/\mathrm{Cglob}$, where θ = median Cobs over the second half of the series (estimated attractor). Validated if the 95% bootstrap CI includes the synthetic reference R_1ref = 1.009. Reported as a descriptive metric; baseline analysis (Section 4.1.4) shows R_1 is not specific to the bilattice formalism.

Test D — Fluctuation distribution. Likelihood ratio LR = log(Lpower/Llognormal) following Clauset et al. (2009), xmin estimated by KS minimization. LR > 0: heavy tail (SOC-compatible); LR < 0: subcritical. Descriptive test — no claim to criticality in the strict physical sense.

3. DOMAINS AND MEASUREMENT PROTOCOLS

3.1 Simulation — Bilattice network dynamics (HS1 v3)

The simulation provides a controlled reference where all parameters are known. It also serves as the basis for the two prospective baseline analyses (Section 4.1.4 and Section 4.1.5). The synthetic reference sigma σbil is established from HS3 (30 sessions): θref = Cglob,ref = 0.972, R_1ref = 1.009 [0.990, 1.029].

3.2 Polity5 — Institutional systems (HA2)

Polity5 (Center for Systemic Peace, 2018): 165+ countries, 1800–2018. Intended bilattice construction: ti = democi/10, fi = autoci/10.

Critical methodological note. Direct calculation reveals corr(t, f) = −0.854, exceeding the validity threshold |corr| < 0.5. This reflects the structural empirical reality that democratic and autocratic scores are inversely related across countries — the two dimensions are not genuinely independent in this dataset. As a result, the bilattice construction Cbil = 1 − |democ/10 + autoc/10 − 1| yields R_1 = 0.974, while the original analysis based on Cpol2 = (polity2 + 10)/20 (composite score democ − autoc) yields R_1 = 1.164, violating the independence condition by construction. All R_1 results for Polity5 in this paper use the bilattice construction Cbil. Test B results (resilience asymmetry) are robust to this choice, as they depend on transition detection, not on the level of Cobs.

Analysis: 184 countries with ≥ 20 years of data (16,765 valid observations after exclusion of special scores −66/−77/−88).

3.3 EEG at rest — Neurophysiology (HA5)

PhysioNet eegmmidb (Power et al. 2011): 64-electrode EEG, 160 Hz, 13 valid subjects (2 excluded for null variance). Concatenated rest runs R01 + R02. Time windows: 1 s, 50% overlap. Construction: ti(w) = alpha power electrode i, window w / percentile95(alpha power electrode i); f(w) = std(alpha power across electrodes, window w) / max(std). Observed corr(t, f) = 0.15–0.25 per subject (< 0.5, validity condition satisfied). The two dimensions measure structurally different phenomena: local alpha level versus global network synchronization.

3.4 NTL-LTER — Lacustrine limnology (HA3b)

North Temperate Lakes LTER (knb-lter-ntl.352.4): 5 Wisconsin lakes (IDs: E, L, R, T, W), 1984–2016, 38,614 physico-chemical observations. Construction: ti(w) = dissolvedOxygeni(w) / percentile95(dissolvedOxygeni); f(w) = CV(temperature_C, 5-measure sliding window) normalized [0,1]. Annual aggregation eliminates sub-annual seasonal bias (V1b correction).

Interpretive framing. The resilience asymmetry observed in lacustrine data is not a new discovery. Ecological hysteresis — the asymmetric response of lake ecosystems to eutrophication and recovery — is a well-established phenomenon documented by Scheffer et al. (2001) and formalized in catastrophe theory applied to ecology (Holling 1973). The ACI framework provides here a new standardized instrument for evidencing this known phenomenon, demonstrating its capacity to detect established ecological dynamics without prior domain-specific calibration. This constitutes a validation of the instrument’s sensitivity, not a new finding about lacustrine systems.

4. RESULTS

4.1 Simulation (HS1 v3)

4.1.1 Test A — Topological impact on C_glob

ANOVA on three connected topologies (25 seeds) yields $\eta^2 = 0.2436$, F(2,72) = 11.59, $p = 4.3 \times 10^{-5}$. Means: ER = 0.9925 ± 0.0060, BA = 0.9905 ± 0.0060, regular = 0.9853 ± 0.0037. The effect is statistically robust, but the absolute difference is modest (Δmax = 0.0073 on [0,1]), reflecting the near-saturation regime of Cglob for these parameters. The four-topology analysis including 'independent' ($W = 0$) yields $\eta^2 = 0.9999$ — trivially inflated by mechanical decay and excluded from the verdict (A2 sub-test).

4.1.2 Test B — Structural invariance to renewal

After complete agent renewal ($r = 100\%$), Cglob ratios: ER = 0.998, BA = 1.001, regular = 1.000. All three topologies maintain Cglob above threshold THETA_FRAC = 0.90. Note: for a linear ergodic diffusion on a fixed graph, invariance to renewal of initial conditions is analytically expected (definition of ergodicity). Test B measures that Cglob bilattice inherits this property.

4.1.3 Test C — Spatial correlations

ΔAIC (exponential vs. power law): ER = −15.39, BA = +0.92. Exponential fit dominates in both cases, indicating a subcritical regime. This is consistent with the simulation parameters ($\eta = 0.05$, sparse graphs) and constitutes an internal model consistency check.

4.1.4 Baseline Analysis I — Specificity of R_1

To test whether $R_1 \approx 1$ is specific to the bilattice formalism, four conditions were compared on simulation data. Pre-registered criterion (before execution): distinctive if $|R_1A - R_1cond| > 0.05$ in ≥ 2/3 conditions and ≥ 2/3 topologies.

Condition	Description	ER	BA	regular	$\|\Delta R_1\|$ max
A — Bilattice	C_i = 1−|t_i+f_i−1|	1.0023	1.0016	1.0020	Reference
B — Simple mean	C_i = (t_i+f_i)/2	0.9982	1.0026	0.9971	0.0049
C — t/f permutation	Coupling destroyed	1.0023	1.0016	1.0015	0.0005
D — Random Beta(2,2)	No network structure	0.9919	0.9919	0.9919	0.0103

Table 1. Baseline I — R_1 under four conditions (25 seeds × 3 topologies). No deviation exceeds the pre-registered threshold of 0.05. Condition C (independent permutation of t_i and f_i, which destroys the per-agent coupling central to bilattice logic) yields R_1 values indistinguishable from the original.

Result: 0/3 distinctive topologies. $R_1 \approx 1$ is a property of stationary diffusive aggregates, not specific to the bilattice formalism. This result is reported as a principal finding: R_1 is a valid descriptive metric for comparing coherence regimes, but cannot be presented as evidence of a bilattice-specific invariant.

4.1.5 Baseline Analysis II — Bilattice vs. 1D recovery (HA_RESILIENCE v3)

To test whether the bilattice formalism specifically predicts the resilience asymmetry observed empirically, comparative simulations were run across 75 replicates (3 topologies × 25 seeds). The 1D reference model uses $C_{1D} = \text{mean}(x_i)$ with equivalent diffusion dynamics and perturbations of identical amplitude. Recovery was measured as the normalized rebound ratio $(C_{final} - C_{shock}) / (C_0 - C_{shock})$.

Result: bilattice and 1D recovery rates are indistinguishable (normalized difference = 0.000 across all 75 replicates and both topologies). This follows analytically from the shared linear diffusion dynamics: recovery speed is determined by the spectral gap of the Laplacian of W, identical for both models.

Implication: the resilience asymmetry observed in empirical data (Sections 4.2–4.4) is a property of the systems studied — institutional path dependence, neurodynamic stability, ecological hysteresis — not a prediction specific to the bilattice dual-dimension representation. ACI functions as a sensitive instrument for detecting this asymmetry; it does not generate it.

4.2 Polity5 — Institutional systems

4.2.1 Stationarity

175/184 countries (95.1%) satisfy the stationarity criterion (A1 OR A2). Breakdown: A1 (active convergence, Kendall $\tau < 0$ and $p < 0.05$) = 58/184 (31.5%); A2 (stable regime, median rolling variance < threshold) = 169/184 (91.8%). The high proportion of A2 over A1 reflects the dominance of long-stable regimes over those in active transition. The distribution of $\theta_{country}$ is bimodal, revealing two distinct attractors corresponding to democratic and autocratic regimes, consistent with institutional path dependence theory (North 1990).

4.2.2 Resilience asymmetry

308 major transitions ($|\delta C| > 0.15$) detected across 184 countries. Overall resilience: 65.9%.

Direction	N	Resilient	%	Asymmetry
Upward (↑)	186	177	95.2%	+73.8 pts vs. downward
Downward (↓)	122	26	21.3%	—
Total	308	203	65.9%	—

Table 2. Resilience asymmetry — Polity5. Upward coherence transitions (democratization) are 4.5× more resilient than downward transitions (autocratization). This is consistent with institutional lock-in theory (North 1990, Gurr 1974).

The 73.8-point asymmetry constitutes the strongest result across all empirical domains. It indicates that increases in institutional coherence are structurally more stable than decreases, in line with the institutional persistence literature. Test D: LR = −0.14, subcritical regime (lognormal dominates).

4.3 EEG at rest — Neurophysiology

4.3.1 Stationarity and R_1

12/13 subjects (92.3%) are stationary (ADF, $p < 0.05$). $R_1 = 0.990$, 95% bootstrap CI = [0.929, 1.138], including synthetic reference R_1ref = 1.009: Test C validated descriptively. θneuro = 0.479, Cglob = 0.492. Brute cosine (σneuro vs. σbil) = 0.985.

4.3.2 Resilience asymmetry

441 transitions detected across 13 subjects (33.9 per subject on average).

Direction	N	Resilient	%	Asymmetry
Upward (↑)	218	175	80.3%	+26.9 pts vs. downward
Downward (↓)	223	119	53.4%	—
Total	441	294	66.7%	—

Table 3. Resilience asymmetry — EEG at rest. 26.9-point asymmetry consistent across 13 subjects. Test D: LR = +43.15, α_Hill = 6.61 — heavy tail consistent with neuronal avalanche literature (Beggs & Plenz 2003).

Test D heavy tail (LR = +43.15) indicates a SOC-compatible fluctuation regime for resting EEG, diverging from the subcritical simulation model. This divergence is a documented feature pointing to a property of natural autonomous systems absent from the linear synthetic model.

4.4 NTL-LTER — Lacustrine limnology

4.4.1 Stationarity and R_1

5/5 lakes (100%) satisfy stationarity after annual aggregation (V1b). $R_1 = 0.980$, 95% CI [0.940, 1.050]: Test C validated descriptively. θeco = 0.708, Cglob = 0.722.

4.4.2 Resilience asymmetry and ecological hysteresis

137 transitions detected across 5 lakes.

Direction	N	Resilient	%	Asymmetry
Upward (↑)	81	78	96.3%	+35.6 pts vs. downward
Downward (↓)	56	34	60.7%	—
Total	137	112	81.8%	—

Table 4. Resilience asymmetry — NTL-LTER limnology. The 35.6-point asymmetry reflects ecological hysteresis (Scheffer et al. 2001): lake ecosystems transition rapidly toward degraded states but recover slowly, a known dynamic here detected by ACI without domain-specific calibration.

The asymmetry detected by ACI corresponds precisely to ecological hysteresis as described in the catastrophic shift literature (Scheffer et al. 2001; Holling 1973): oxic, thermally stable states are robust against perturbation, while degraded states persist once established. ACI does not discover this phenomenon — it provides a new generic instrument for its standardized detection, demonstrating the framework's sensitivity to known ecological dynamics.

Test D: LR = +89.63, α_{Hill} = 3.25. Heavy tail, consistent with regime shift literature. Together with EEG at rest (LR = +43.15), this suggests that autonomous natural systems present heavy-tailed fluctuation distributions, while institutional and synthetic systems are subcritical — a cross-domain discrimination emerging from the data (see Section 5.3).

5. CROSS-DOMAIN SYNTHESIS

5.1 Resilience asymmetry — transversal result

The principal finding of this study is the systematic and robust asymmetry of resilience across all validated empirical domains:

Domain	Upward (%)	Downward (%)	Asymmetry (pts)	N transitions	LR (Test D)
Polity5 (institutions)	95.2	21.3	73.8	308	−0.14 subcritical
NTL-LTER (limnology)	96.3	60.7	35.6	137	+89.63 heavy tail
EEG at rest (neuro)	80.3	53.4	26.9	441	+43.15 heavy tail
Simulation (HS1)	—	—	N/A	—	ΔAIC<0 subcritical

Table 5. Cross-domain resilience asymmetry. Upward transitions are systematically more resilient across 886 total empirical transitions. The asymmetry magnitudes differ substantially between domains, reflecting domain-specific mechanisms (institutional lock-in, ecological hysteresis, neurodynamic stability) rather than a universal quantitative invariant.

The asymmetry is robust across three independent empirical domains and 886 total transitions. It is not predicted by a symmetric attractor model: in a linear Ornstein-Uhlenbeck process, upward and downward transitions would be equally resilient. The domain-specific mechanisms — institutional path dependence (North 1990), ecological hysteresis (Scheffer 2001), neurodynamic stability (Kaplan 2005) — differ in nature, suggesting that ACI detects a generic measurement signature rather than a single universal mechanism.

Crucially, comparative simulations (HA_RESILIENCE v3) demonstrate that this asymmetry is not a prediction of the bilattice formalism specifically. Both bilattice and 1D models recover identically after equivalent perturbations. The asymmetry belongs to the empirical systems, not to the measurement instrument.

5.2 Structural ratio R_1 — descriptive validity, limited scope

Domain	R_1	95% CI bootstrap	R_1_ref = 1.009 included?
Synthetic (HS3)	1.009	[0.990, 1.029]	Reference
EEG at rest (HA5)	0.990	[0.929, 1.138]	✓
NTL-LTER (HA3b)	0.980	[0.940, 1.050]	✓
Polity5 C_bil (HA2, valid)	0.974	Not bootstrapped	Compatible (ratio 0.97)
Polity5 C_pol2 (HA2, invalid)	1.164	[1.020, 1.310]	Ambiguous (lower bound > ref)

Table 6. Structural ratio R_1 by domain. Results for Polity5 with invalid construction (corr = −0.854) are reported for transparency. Baseline analysis (Table 1) shows R_1 is not specific to the bilattice formalism.

R_1 is a useful descriptive metric for comparing coherence regimes across different scales and domains. Its convergence toward 1.009 in EEG and limnological domains suggests structural regularities in these systems. However, Baseline I demonstrates that R_1 is not specific to the bilattice formalism, appropriately limiting transdisciplinary invariance claims.

5.3 Autonomous vs. reactive systems — emergent discrimination

An emergent finding from Test D is the discrimination between two system classes:

Autonomous natural systems (EEG at rest LR = +43.15; NTL-LTER LR = +89.63): heavy-tailed distributions, consistent with neuronal avalanche (Beggs & Plenz 2003) and ecological regime shift literature (Scheffer 2001).

Non-autonomous systems (Polity5 LR = −0.14; simulation ΔAIC < 0): subcritical distributions, lognormal dominant.

This discrimination is not imposed a priori — it emerges from the data. It suggests that ACI can distinguish intrinsic self-organizing dynamics from exogenously driven dynamics. This constitutes an additional informative use of Test D, independent of the resilience asymmetry result. However, this observation requires dedicated replication on independent datasets before stronger claims can be made.

6. DISCUSSION

6.1 What ACI establishes

This study establishes results of three levels of epistemic strength:

Robust (Level 1): Coherence-increasing transitions are significantly more resilient than decreasing ones across three independent empirical domains (886 total transitions). The asymmetries are large

(26.9–73.8 points) and replicated. This constitutes the central empirical contribution of the framework.

Solid but instrument-dependent (Level 2): R_1 is descriptively consistent across EEG and limnological domains. However, Baseline I shows it is not specific to the bilattice formalism, limiting any claim of transdisciplinary bilattice invariance.

Emergent and preliminary (Level 3): The autonomous/reactive discrimination via Test D is an emergent finding without formal prior hypothesis. It has not been subjected to pre-registered hypothesis testing and requires replication.

6.2 Limitations

Independence condition. $|corr(t, f)| < 0.5$ must be verified for each domain before analysis. Violation occurs in Polity5 (−0.854) and genomic data (HA4, −0.717, not reported in this paper). The construction of genuinely independent dimensions remains the primary methodological challenge for domain extension.

Sample sizes. N = 13 EEG subjects and N = 5 lakes are limited. Replication on HCP (N > 100 subjects) and GLT (N > 500 lakes) is necessary before generalizing the resilience asymmetry in these domains.

Formalism specificity. The bilattice formalism is not demonstrated to specifically predict the resilience asymmetry. Baseline II (HA_RESILIENCE v3) shows that 1D and bilattice models recover identically under controlled perturbations. The asymmetry is a property of the empirical systems, detected but not generated by ACI.

Temporal granularity. Annual aggregation for NTL-LTER (V1b) eliminates sub-annual seasonal bias but may obscure intra-annual dynamics. The formal impact of this aggregation choice on resilience results has not been assessed.

Ecological result framing. The resilience asymmetry in lacustrine data corresponds to ecological hysteresis, a known phenomenon. The contribution of ACI here is instrumental (a new standardized detection tool), not substantive (a new empirical discovery). This distinction must be maintained clearly in any scientific communication of these results.

6.3 Perspectives

Three pre-registerable research hypotheses are stated before any new data collection:

HA_HCP (Priority 1): EEG replication on Human Connectome Project (N > 100). Pre-registered predictions: $R_1 \in [0.95, 1.05]$; asymmetry > 15 points; LR > 0. Conditioned on OSF pre-registration prior to data access.

HA_GLT (Priority 2): Limnological extension on Global Lake Temperatures dataset (N > 500 lakes). Pre-registered predictions: $R_1 \in [0.93, 1.07]$; asymmetry > 20 points. Conditioned on HA_HCP completion.

HA_MECHANISM (Priority 3): Identify which structural property of the empirical systems (institutional lock-in, ecological switching cost, neurodynamic energy landscape) generates the observed asymmetry magnitudes. This requires domain-specific theoretical modeling beyond the ACI measurement framework.

7. CONCLUSION

The Asymmetric Coherence Index (ACI) is a standardized metrological framework for characterizing coherence dynamics in complex systems. Applied to four domains — simulation, institutional systems, neurophysiology, and limnology — it identifies a robust and transversal empirical result: coherence-increasing transitions are systematically more resilient than decreasing ones, with asymmetries ranging from 26.9 to 73.8 percentage points across 886 total transitions.

For lacustrine systems, this asymmetry corresponds to ecological hysteresis as documented in the catastrophic shift literature (Scheffer et al. 2001). ACI provides a new standardized instrument for detecting this known dynamic, validating its sensitivity without claiming a new discovery about lake ecosystems.

Two prospective baseline analyses delimit the scope of results with precision. The structural ratio R_1 is not specific to the bilattice formalism on simulation data. The resilience asymmetry is not predicted by the bilattice model in controlled simulations — it belongs to the empirical systems, not to the measurement instrument.

ACI is not a unified theory of complex systems. It is a measurement instrument with documented properties, explicit validity conditions ($|corr(t, f)| < 0.5$), and falsifiable predictions. Its scientific value resides in its capacity to provide comparable metrics across heterogeneous domains, and in doing so, to reveal — as here — regularities that domain-specific tools would not detect in a single analytical framework.

REFERENCES

Beggs, J. M., & Plenz, D. (2003). Neuronal avalanches in neocortical circuits. Journal of Neuroscience, 23(35), 11167–11177.

Belnap, N. D. (1977). A useful four-valued logic. In J. M. Dunn & G. Epstein (Eds.), Modern Uses of Multiple-Valued Logic (pp. 8–37). Reidel.

Clauset, A., Shalizi, C. R., & Newman, M. E. J. (2009). Power-law distributions in empirical data. SIAM Review, 51(4), 661–703.

Fitting, M. (1991). Bilattices and the semantics of logic programming. Journal of Logic Programming, 11(1–2), 91–116.

Ginsberg, M. L. (1988). Multivalued logics: A uniform approach to inference in AI. Computational Intelligence, 4(3), 265–316.

Gurr, T. R. (1974). Persistence and change in political systems, 1800–1971. American Political Science Review, 68(4), 1482–1504.

Holling, C. S. (1973). Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4, 1–23.

Kaplan, A. Y., et al. (2005). Nonstationary nature of the brain activity as revealed by EEG/MEG. Signal Processing, 85(11), 2190–2212.

North, D. C. (1990). Institutions, Institutional Change and Economic Performance. Cambridge University Press.

Polity IV Project. (2018). Polity5 Annual Time-Series, 1800–2018. Center for Systemic Peace. https://www.systemicpeace.org/

Power, R. J., et al. (2011). EEG motor/imagery dataset eegmmidb. PhysioNet. https://physionet.org/content/eegmmidb/1.0.0/

Scheffer, M., Carpenter, S., Foley, J. A., Folke, C., & Walker, B. (2001). Catastrophic shifts in ecosystems. Nature, 413(6856), 591–596.

Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks. Nature, 393, 440–442.

APPENDIX — PARAMETERS AND CALIBRATION

Parameter	Value	Justification	Sensitivity
δ — transition threshold	0.15	75th pct. on O-U process (τ=2, σ=0.1)	Robust [0.10, 0.30]
ρ — resilience threshold	0.85	Calibrated on forced-return simulations	Robust [0.75, 0.95]
T_pre / T_post	5 / 6–10 pts	Sufficient for convergence estimate	Not systematically tested
Bootstrap N	1,000	Standard, stable beyond 500	—
x_min (Test D)	Clauset KS	Clauset et al. (2009)	vs. percentile 80: qualitatively stable
Annual aggregation (lakes)	Mean lake × year	Eliminates sub-annual seasonal bias	To be formally tested
η (simulation)	0.05	Subcritical diffusion regime	Not varied
N agents (simulation)	120	Computation-speed tradeoff	Effect of N not studied
HS3 reference (θ_ref)	0.972	30 sessions, HS3 module	—
R_1 reference	1.009	HS3 synthetic model	95% CI [0.990, 1.029]

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