

Revision Notice

Forward-Only Temporal-Coherence Occupancy Regimes in Atlantic Tropical Cyclone Intensity Evolution (1851–2024)

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Updated manuscript and supersession statement

This manuscript is a corrected and substantially revised version of the previously posted EarthArXiv preprint. **This version supersedes the earlier EarthArXiv version for scientific interpretation, reproduction, and citation of the current analysis.**

The revision preserves the central forward-only temporal-coherence construction while correcting its activation semantics and substantially narrowing the associated scientific claims. Under the revised V2 definition, the first coherent advisory is not counted as active or retrospectively backfilled. Confirmed activity begins only when the current and immediately preceding advisories share the same nonzero common direction across the 3-, 5-, and 9-advisory tendencies. A reversal resets confirmation and must itself be reconfirmed.

The revised analysis also distinguishes the **54,203-row frozen source-lineage collection** from the **54,174 unique-advisory analysis materialization**, obtained after deterministic resolution of 29 duplicate storm-time keys.

The interpretation has been correspondingly narrowed. Although cumulative V2 occupancy continues to descriptively stratify historical event-ever rapid intensification, the revised manuscript does **not** interpret that relationship as forecast skill or evidence of a physical storm-structure mechanism. A shared-sample comparison shows that a simpler five-advisory persistence measure provides stronger tested model fit than the three-window construction, so broad superiority of the multi-horizon state is not established.

The event-timing analysis also shows that confirmed activation was not generally an advance RI marker: among storms with both times observed, the median RI-onset-minus-activation offset was **−24 h**, meaning confirmation typically occurred after RI onset. Environmental-conditioning analyses likewise did not establish incremental association beyond the tested covariates.

Accordingly, the current manuscript presents the construct as a **reproducible, forward-only VMAX lifecycle-state reference and benchmark for future work using independent physical observations**, rather than as an operational early-warning system, superior predictor, or validation of a broader physical theory.

The accompanying corrected reproduction package is archived as Zenodo v4.0, DOI: 10.5281/zenodo.21911306.

**Forward-Only Temporal-Coherence Occupancy Regimes in Atlantic Tropical Cyclone
Intensity Evolution (1851–2024)**

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Abstract

We test whether a forward-only state derived solely from maximum sustained wind speed (VMAX) provides a reproducible description of tropical cyclone intensity persistence and historical rapid-intensification (RI) stratification. Atlantic HURDAT2 records for 1,991 storms during 1851–2024 were evaluated with causal 3-, 5-, and 9-advisory tendencies. A state was confirmed only when the current and previous advisory shared the same nonzero common direction; reversals and missing required lags interrupted confirmation, and the first coherent advisory received no retroactive occupancy. The V2 analysis dataset contains 54,174 advisories, of which 15,542 are confirmed active, totaling 93,252 h. Event-ever RI, defined as a VMAX increase of at least 30 kt over an exact 24-h interval, occurred in 525 storms. Among 524 storms with at least 72 h of occupancy, 277 underwent RI (52.86%), compared with 26.37% across the basin archive. This conditional difference is descriptive, not forecast skill. In a shared-sample duration-controlled comparison, simple five-advisory persistence had stronger tested model fit than the three-window state (AIC 1896.01 versus 1991.56), so broad superiority of the multihorizon construction was not established. For 496 storms with both times observed, RI onset minus confirmed activation had a median of –24 h (interquartile range –60 to 0 h); confirmed activation was therefore not generally an advance RI marker. Incremental association beyond the tested environmental covariates was also not established. The construct is a reproducible VMAX-only temporal baseline for testing whether independent physical observations add information beyond persistence and lifecycle history.

1. Introduction

Rapid intensification (RI), typically defined as an increase in maximum sustained wind speed of at least 30 kt within 24 h, remains one of the most consequential and difficult-to-forecast aspects of tropical cyclone evolution (Kaplan and DeMaria 2003; Kaplan et al. 2010; DeMaria et al. 2021). Environmental conditions, persistence, and recent intensity change are already central to operational and statistical RI guidance. Because recent intensity change and persistence are already used in operational RI guidance, determining whether additional temporal constructions provide information beyond simpler persistence is itself relevant to forecast-method development. A negative comparison is informative in this setting: it identifies complexity that should not be interpreted as added forecast information without independent evidence. A descriptive analysis of intensity history must therefore be separated carefully from prediction and from claims about physical storm structure.

Best-track intensity records extend much farther back than aircraft and satellite observations. HURDAT2 can support long-record analysis of intensity evolution, but VMAX alone cannot retrieve convective organization, vortex alignment, or an inner-core mechanism (Landsea and Franklin 2013). The bounded question here is whether the Atlantic VMAX record contains reproducible, persistence-qualified common-direction states, and whether cumulative occupancy of those states historically stratifies event-ever RI occurrence.

Temporal coherence is defined operationally as common direction across three causal, nested representations of the same VMAX record. The horizons are correlated and are not treated as independent physical scales. RI is applied only after the state is constructed and is used as a downstream outcome. The method is evaluated first by its episode behavior, then by descriptive RI stratification, a fair simple-persistence comparator, signed event timing, distinct null families, and duration and environmental conditioning. Viewed narrowly, the V2 construct is a rule-based coarse-graining of one observed variable into persistence-qualified directional states. Regime-based descriptions of persistence, recurrence, and transition have a long history in nonlinear atmospheric dynamics (Ghil and Robertson 2002), but “regime” is used here descriptively and does not imply a metastable attractor, bifurcation, critical transition, or physical phase change. The intended contribution is deliberately limited: a transparent lifecycle-state reference that can be replayed on a fixed archive. It is not an operational early-warning system, predictive model, physical retrieval, or validation of a broader multimodal theory. A secondary purpose is to

establish a reproducible VMAX-only reference for later studies using independent physical observations. Such studies can evaluate whether microwave, precipitation, lightning, aircraft, radar, or surface-wind measurements contribute stable information beyond simple VMAX persistence and the three-window common-direction state on a common eligible sample.

2. Data and frozen analysis reference

The analysis uses Atlantic HURDAT2 best-track records for 1,991 tropical cyclones spanning 1851–2024 (Landsea and Franklin 2013). Records were restricted to the nominal 0000, 0600, 1200, and 1800 UTC synoptic times. The frozen source-lineage collection contains 54,203 rows; deterministic resolution of 29 duplicate storm-time keys yields 54,174 unique advisories in the V2 analysis dataset.

No storm-status, tropical-storm-genesis, VMAX, landfall, or terminal-stage gate was applied to the analysis timeline. Tendencies and confirmation were calculated within storm identity across the retained synoptic record, and status changes did not by themselves interrupt an otherwise qualifying state. RI opportunities were likewise defined from VMAX and elapsed time rather than storm-status class; consequently, qualifying intervals could span status transitions.

Event-ever RI was assigned when VMAX increased by at least 30 kt from an advisory to the fourth subsequent advisory within the same storm, provided that elapsed time was exactly 24 h. Multiple qualifying intervals were reduced to a storm-level event-ever label, with first RI onset defined by the earliest qualifying interval. All consecutive within-storm observations in the 54,174-row materialization were separated by 6 h; the V2 detector itself did not apply an additional elapsed-time gap test. HURDAT2 is not homogeneous across observing eras, especially before aircraft and satellite coverage, and retrospective best-track products are not equivalent to real-time operational inputs (Landsea and Franklin 2013; Vecchi and Knutson 2008, 2011).

116 3. Temporal-coherence V2 detector

117 3.1. Causal directional tendencies

118 Let $V(t)$ denote VMAX at advisory t . For each advisory window s in $\{3, 5, 9\}$, the one-step
119 change in the causal trailing mean reduces algebraically to

$$120 \quad D_s(t) = \text{mean}_s(t) - \text{mean}_s(t-1) = [V(t) - V(t-s)] / s, \quad s \in \{3, 5, 9\}.$$

121 Only $\text{sign}[D_s(t)]$ is retained. The positive factor $1/s$ does not change the sign. The trailing-mean
122 presentation and the lag-difference identity are therefore algebraically equivalent when applied
123 to the same historical active-state semantics.

124 3.2. Common direction, confirmation, and occupancy

125 The common-direction state $G(t)$ is defined as

$$126 \quad G(t) = +1 \text{ if all three signs are } +1; \quad G(t) = -1 \text{ if all three signs are } -1; \quad G(t) = 0 \text{ otherwise.}$$

127 The zero state includes a zero tendency, disagreement among horizons, or a missing required lag.

128 Confirmed activity is

$$129 \quad \text{active}(t) = 1 \text{ if } G(t) \neq 0 \text{ and } G(t) = G(t-1); \quad \text{active}(t) = 0 \text{ otherwise.}$$

130 The first coherent advisory is unconfirmed and receives neither a retroactive active label nor
131 backfilled occupancy. A reversal from $+1$ to -1 or from -1 to $+1$ resets confirmation even
132 though both advisories are coherent. Each confirmed active advisory contributes 6 h, so the
133 minimum recorded occupancy is 6 h. Storm-total occupancy is the sum of those confirmed
134 increments.

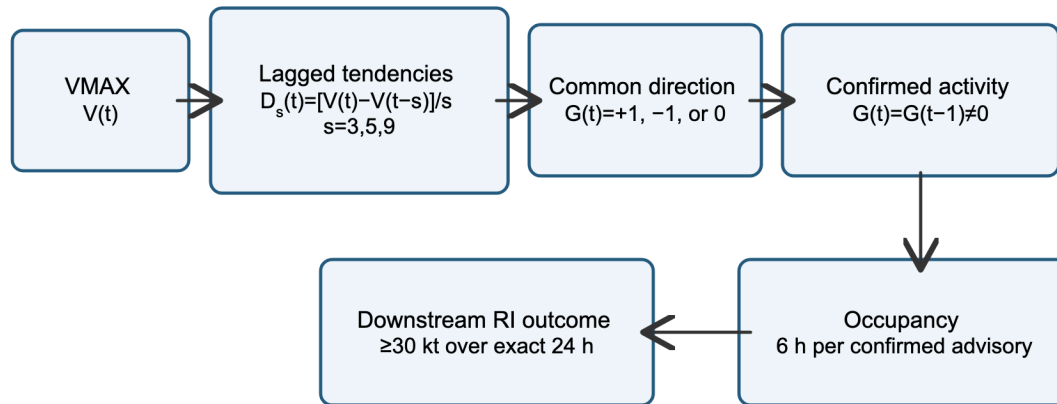
135

136 For storm i with n_i materialized advisories, storm-total occupancy is

$$137 \quad O_i = 6 \sum_{t=1}^{n_i} \text{active}_i(t)h$$

138 where $\text{active}_i(t)$ is the confirmed-activity indicator defined above. Advisories with missing
139 required lags have $\text{active}_i(t) = 0$, and no calculation crosses a storm boundary.

140



Zero tendencies, missing required lags, and reversals are inactive. The first coherent advisory is unconfirmed.

Figure 1. Literal V2 detector hierarchy. The state uses causal VMAX tendencies at 3, 5, and 9 advisories; only same-direction consecutive common states are confirmed. RI is a downstream outcome and is not used in construction.

Parameter	V2 definition
Temporal Windows	3,5,9 advisories
Direction criterion	Same nonzero tendency sign across all three windows
Confirmation	Same common direction at the current and immediately preceding advisory
First coherent advisory	Unconfirmed; contributes no occupancy
Direction reversal	Ends the confirmed state; the new direction must be reconfirmed
Missing required lag	Inactive
Analysis Cadence	6-h synoptic materialization; no separate elapsed-time gap test
Minimum positive occupancy	6 h

Table 1. V2 detector and downstream RI endpoint. Zero tendencies, missing required lags, and direction reversals interrupt confirmed activity.

4. Evaluation design

4.1. Instrument and episode behavior

Confirmed advisories were grouped into contiguous, same-direction episodes. Episode duration, the number of episodes per activated storm, isolated 6-h episodes, direction changes across separated episodes, and storm-level activation and RI outcome cohorts were summarized before considering RI. The declared perturbation grid was retained as a neighborhood description rather than used to select a new detector. The full prespecified parameter-neighborhood results are provided in Table S1.

4.2. Historical RI stratification

Storms were grouped by minimum accumulated V2 occupancy. For each threshold, the denominator is the number of storms reaching that threshold and the numerator is the subset meeting event-ever RI. The 72-h result is the principal descriptive checkpoint. Broader threshold estimates are shown with denominators and binomial 95% display intervals; upper-tail points are explicitly sample-limited and are not interpreted as forecast skill.

4.3. Shared-sample simple comparator

The comparator uses the **same 54,174-row analysis sample**, same RI labels, zero handling, confirmation semantics, accumulation, and duration scaling as V2. The intended method difference is that the comparator uses the nonzero sign of the 5-advisory tendency alone, whereas V2 requires common sign across 3, 5, and 9 advisories. Logistic models compare RI with occupancy and observed storm duration, each scaled per 24 h.

4.4. Signed event time

The retained timing estimand is the distribution among storms with both first confirmed activation and first RI onset under the same 24-h definition. Signed offset is RI onset time minus confirmed activation time: positive means activation occurred before RI onset, zero means the same advisory, and negative means activation occurred after RI onset. This is not a hazard estimand; storms without both times are not recoded as observed non-events. The legacy survival surface is not retained.

4.5. Null families

Null families are interpreted separately according to what each preserves and disrupts. Block shuffling retains within-block VMAX sequences and storm length while disrupting between-block order. Lifecycle-stratified reassignment preserves occupancy distributions within lifecycle-length strata but disrupts storm-specific pairing. Lifecycle randomization preserves recipient duration and source occupancy fractions; RI-label permutation preserves V2 occupancy and basin RI prevalence. Separate onset-alignment nulls use timing statistics in hours and are not pooled with 72-h lift statistics (Künsch 1989; Politis and Romano 1994; Theiler et al. 1992).

4.6. Duration and environmental conditioning

Duration-controlled storm models use one row per storm and scale both occupancy and lifecycle duration per 24 h. Environmental models use a strict shared complete-case sample of 5,667 advisory rows from 422 storms (135 event storms) with storm-cluster-robust inference at the advisory level, and 422 storm-level rows for lifecycle summaries (Liang and Zeger 1986). The environmental covariates and model formulas were fixed for the analysis; coefficients from unlike aggregation levels are not compared directly. These restrictions are specific to the environmental-conditioning analyses: advisory rows were truncated after first RI onset, environmental records were matched exactly in time, and models used a shared complete-case sample. These filters are not part of the V2 detector or the storm-level RI definition.

5. Results

5.1. Canonical accounting and behavioral characterization

The V2 analysis dataset contains 54,174 advisories from 1,991 storms. Of these, 15,542 advisories are confirmed active, totaling 93,252 h. Strengthening states account for 7,719 advisories and 46,314 h; weakening states account for 7,823 advisories and 46,938 h. Directional balance is descriptive and does not define separate detectors.

The confirmed advisories form 3,847 episodes in 1,525 activated storms. Median episode duration is 18 h (interquartile range 12–30 h), and 90% of episodes end by 48 h. There are 642 isolated 6-h episodes (16.7%); 1,084 activated storms contain multiple episodes, with a median of two and a maximum of 11. Across separated episodes, 957 storms change direction at least

once. These results show a mixture of short, fragmented, and longer-lived behavior rather than uniformly clean, non-chattering transitions.

V2 temporal-coherence episode behavior

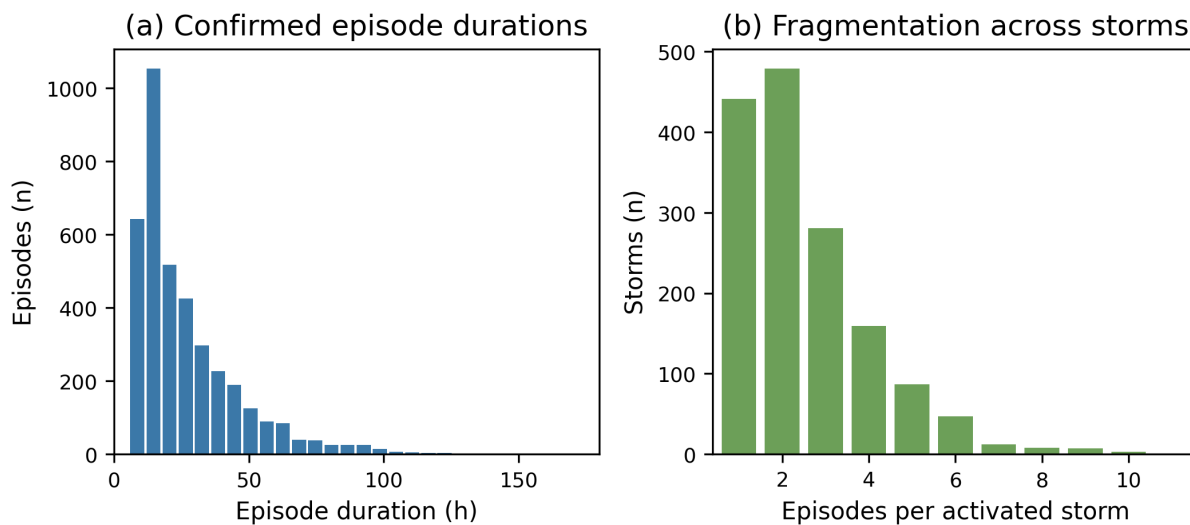


Figure 2. Confirmed V2 episode behavior. (a) Episode-duration counts on the 6-h grid. (b) Number of confirmed episodes per activated storm. The distributions show substantial short-duration behavior and fragmentation.

Cohort	Definition	Count	% basin	% relevant outcome
Active, no RI	any confirmed activation and no RI	1029	51.68	70.19
Active, RI	any confirmed activation and RI	496	24.91	94.48
Inactive, no RI	no confirmed activation and no RI	437	21.95	29.81
Inactive, RI	no confirmed activation and RI	29	1.46	5.52
High occupancy, no RI	V2 occupancy at least 72 h and no RI	247	12.41	16.85
Long coherent, weak	V2 occupancy at least 72 h and peak VMAX below 64 kt	32	1.61	3.2
RI, low occupancy	RI and full-lifecycle V2 occupancy below 24 h	74	3.72	14.1

Table 2. Descriptive activation and RI outcome cohorts. Categories may overlap and are not causal classifications.

Of 525 RI storms, 496 have at least one confirmed activation and 29 do not. Conversely, 1,029 storms activate without event-ever RI. This asymmetry reinforces that activation is a background lifecycle-state description rather than an RI trigger. The 1,525 activated storms comprise 1,029 storms without event-ever RI and 496 storms with RI.

Across the declared grid, changing windows and the number of confirming advisories changes activation prevalence, median occupancy, and the size of the 72-h cohort. The reference 3/5/9, two-advisory confirmation configuration yields 524 storms and 277 RI storms at 72 h. The neighborhood does not establish a uniquely optimal configuration.

5.2. Descriptive RI stratification

Event-ever RI occurs in 525 of 1,991 storms (26.37%). A total of 524 storms reach at least 72 h of confirmed V2 occupancy; 277 of them meet RI, for conditional occurrence of 52.8626%. The corresponding descriptive lift is 2.00475 relative to the basin occurrence. This is historical conditional stratification, not a probability forecast or discrimination score.

Occupancy threshold (h)	Storms (n)	RI storms (n)	Conditional RI (%)	Wilson 95% interval (%)
0	1991	525	26.37	24.48–28.35
24	1123	451	40.16	37.33–43.06
48	753	355	47.14	43.60–50.72
72	524	277	52.86	48.58–57.10
96	360	208	57.78	52.62–62.77
120	231	137	59.31	52.87–65.44
168	75	50	66.67	55.42–76.29
270	6	4	66.67	30.00–90.32

Table 3. Event-ever RI occurrence across selected V2 occupancy thresholds. Intervals are Wilson 95% display intervals computed from the corresponding numerator and denominator; upper-tail estimates are sample-limited.

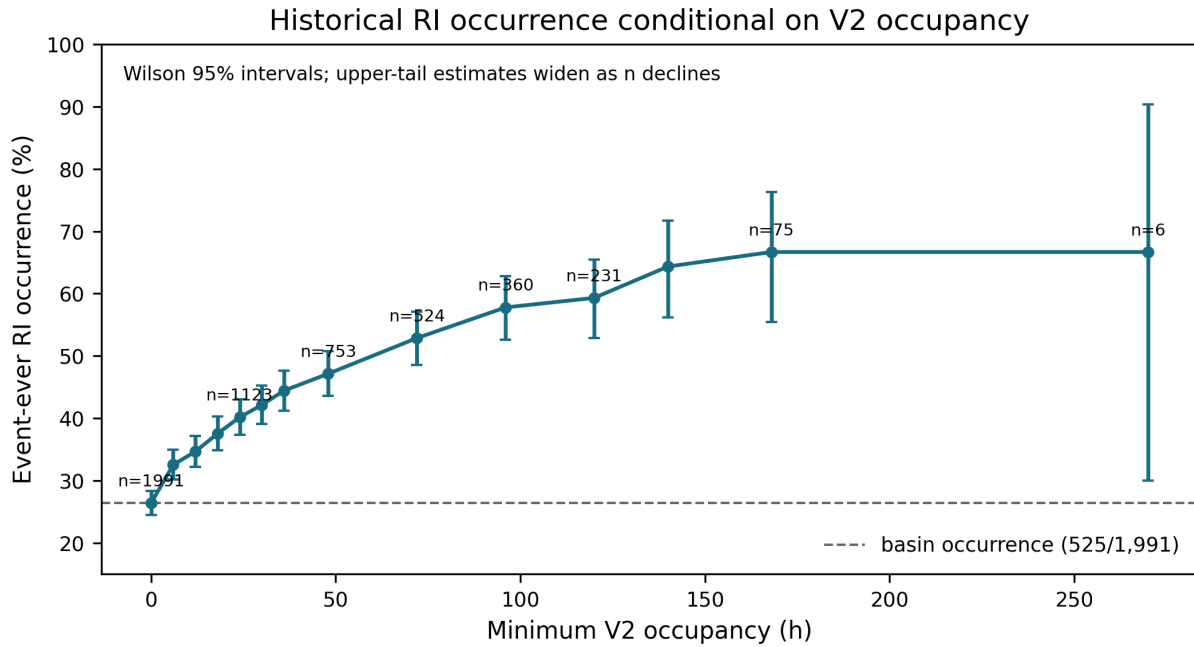


Figure 3. Historical event-ever RI occurrence conditional on V2 occupancy. Points use the V2 numerators and denominators; bars are Wilson 95% display intervals. The 168- and 270-h points are upper-tail cohorts with $n=75$ and $n=6$, respectively.

5.3. Comparator and duration

Simple five-advisory persistence also stratifies RI. In the duration-controlled shared-sample models, the five-advisory comparator has AIC 1896.0099, whereas the three-window occupancy model has AIC 1991.5624. The lower comparator AIC indicates stronger tested fit under these declared formulas. Broad superiority of the three-window construction is therefore not established. V2 is retained as an explicit multihorizon common-direction representation, not as a superior predictor.

Model	Term	β per 24 h	SE	p	AIC	Pseudo- R ²	Stor ms
Occupancy + duration	occupancy per 24h	0.351542	0.052903	3.03e-11	1991.562	0.1356	1991
Occupancy + duration	duration per 24h	0.034778	0.027435	0.205	1991.562	0.1356	1991
Five-advisory comparator + duration	single window per 24h	0.612986	0.058172	5.8e-26	1896.01	0.1772	1991
Five-advisory comparator + duration	duration per 24h	-0.236966	0.043479	5.03e-08	1896.01	0.1772	1991

245 *Table 4. Shared-sample duration-controlled logistic models. Coefficients are scaled per 24 h.*

246 Both models contain an intercept, one occupancy term, and storm duration and are fitted to the
247 same 1,991 storms.

248

249 The positive V2 occupancy coefficient in its duration-controlled model does not establish unique
250 information beyond correlated duration summaries, particularly because the simpler comparator
251 fits better. Nor do these results prove exact equivalence or complete mediation.

252 **5.4. Signed RI event time**

253 There are 496 storms with both first confirmed activation and first RI onset under the same RI
254 definition. Signed offset has a median of −24 h and an interquartile range of −60 to 0 h. Under
255 the declared sign, the typical negative value places confirmed activation after RI onset rather
256 than before it. Confirmed activation was therefore not generally an advance RI marker.

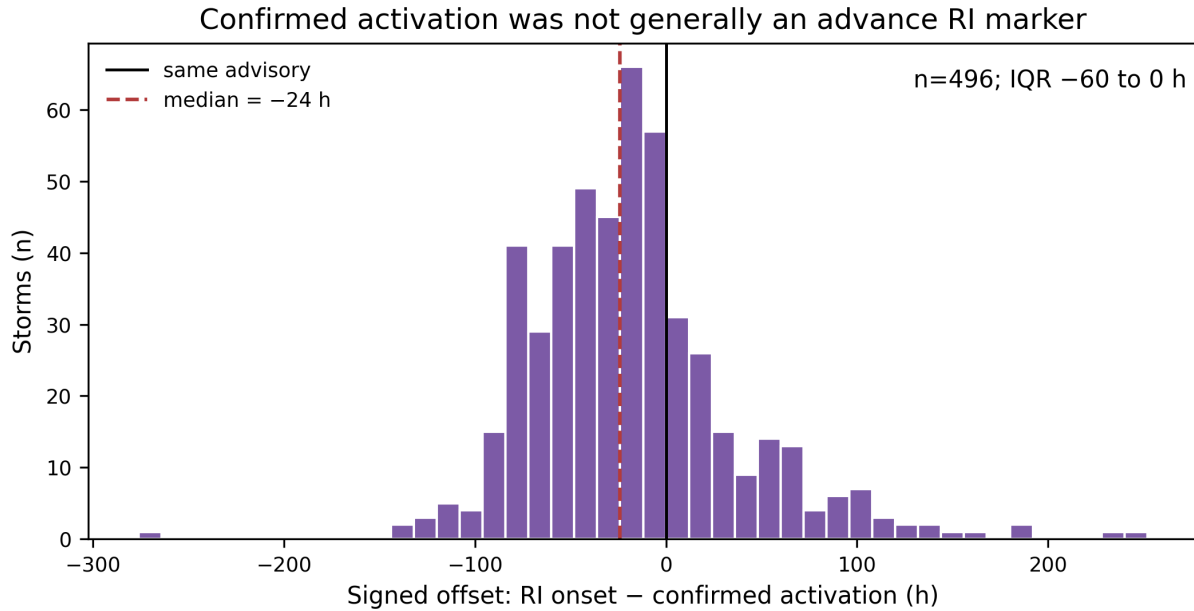


Figure 4. Distribution of RI onset minus confirmed activation for 496 storms with both times observed. Positive values indicate activation before RI; negative values indicate activation after RI. Median is -24 h and the interquartile range is -60 to 0 h. No survival or hazard interpretation is made.

5.5. Null-family results

The null results depend on the structure preserved. For 12-, 24-, 48-, and 72-h block shuffles, mean 72-h lifts are 2.5923, 2.3958, 2.2136, and 2.0965, respectively, compared with observed lift 2.00475. Thus, block-shuffle nulls reproduce or exceed the observed threshold enrichment. By contrast, lifecycle-stratified reassignment, lifecycle randomization, and RI-label permutation have lower null means. These outcomes cannot be pooled into a single claim that all nulls attenuate the result.

Family	Parameter	Preserves	Disrupts	Observed	Null mean	Null 95% range
block shuffle	12h_blocks	within-block VMAX sequence and storm length	between-block temporal order	2.0048	2.5923	2.3227–2.8549
block shuffle	24h_blocks	within-block VMAX sequence and storm length	between-block temporal order	2.0048	2.3958	2.2678–2.5269
block shuffle	48h_blocks	within-block VMAX sequence and storm length	between-block temporal order	2.0048	2.2136	2.0893–2.3114
block shuffle	72h_blocks	within-block VMAX sequence and storm length	between-block temporal order	2.0048	2.0965	2.0232–2.1737
Lifecycle-stratified reassignment	occupancy_reassigned_within_lifecycle_length_strata	occupancy distribution within lifecycle-length quartiles	storm-specific occupancy-to-RI pairing	2.0048	1.7247	1.6445–1.8005
lifecycle randomized	occupancy_fraction_reassigned_to_lifecycle	recipient storm lifecycle length and source occupancy fractions	storm-specific occupancy fraction	2.0048	1.7111	1.5681–1.8842
permutation	storm_ri_labels	canonical occupancies and RI prevalence	storm-specific RI labels	2.0048	1.0	0.8902–1.1129
onset alignment	peak_vmax	active-advisory set and milestone timing	which active advisory is treated as onset	6.0	-39.0	-42.0000–-36.0000
onset alignment	first_hurricane_intensity	active-advisory set and milestone timing	which active advisory is treated as onset	-6.0	-60.828	-66.0000–-60.0000

Table 5. Separate null-family results. Lift statistics and timing statistics have different units and estimands and must not be pooled.

Null-family and parameter-neighborhood behavior

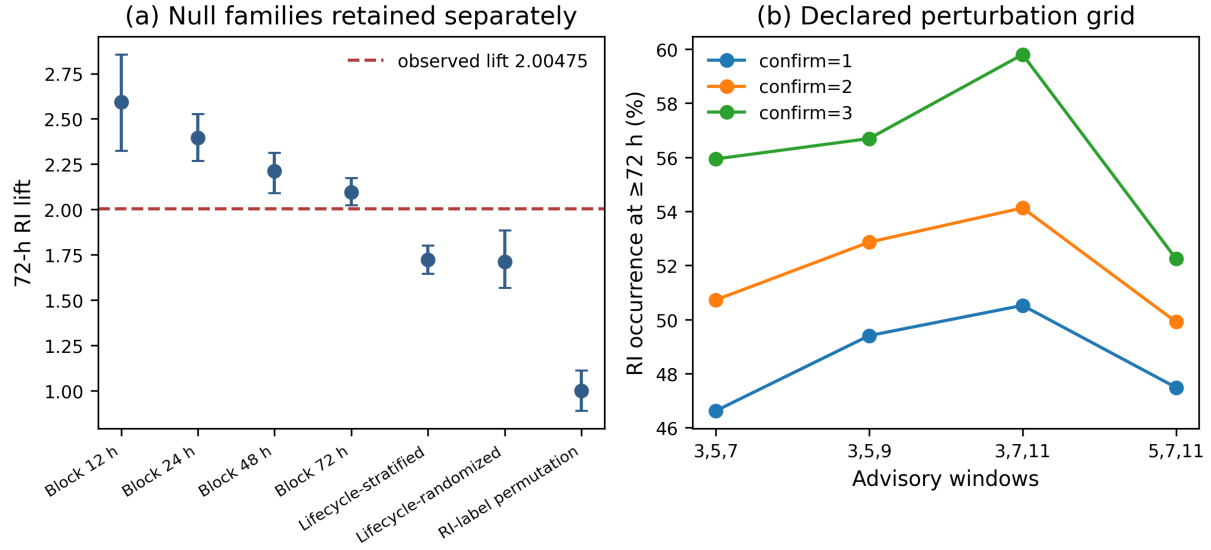


Figure 5. Separate null-family and declared perturbation behavior. (a) Null mean and 95% range for the 72-h lift statistic; onset-alignment families are excluded because their statistic is measured in hours. (b) RI occurrence at 72 h across the predeclared window and confirmation grid.

5.6. Environmental conditioning

At the advisory level, the cumulative-occupancy coefficient is 0.218925 per 24 h ($p=0.353379$), with $\Delta AIC=+1.027981$ relative to the environmental baseline. At the storm level, total occupancy conditional on maximum run has coefficient 0.403086 per 24 h ($p=0.334117$), with $\Delta AIC=-1.909024$ relative to the named environment-plus-duration baseline. The analyses differ in aggregation and dependence treatment; their coefficients are not compared as though they were on the same scale.

Level	Sample	Occupancy unit	β	p	ΔAIC	Inference
advisory	5667 rows; 422 storms	24 cumulative occupancy hours	0.218925	0.353379	1.027981	storm-cluster- robust SEs
storm	422 rows; 422 storms	24 storm-total occupancy hours conditional on max run	0.403086	0.334117	-1.909024	model-based standard errors

287 *Table 6. Strict shared-sample environmental-conditioning checkpoints. ΔAIC is extended minus*
288 *the named baseline; negative values favor the extended fit.*

289 Neither occupancy term is statistically distinguished from zero at conventional levels in the
290 specified model. Incremental association beyond the tested environmental covariates was not
291 established. This does not prove exact equivalence, complete mediation, or absence of all
292 possible information.

293 6. Discussion

294 Atlantic best-track VMAX contains reproducible, persistence-qualified common-direction states.
295 Accumulating time in those states historically stratifies event-ever RI occurrence: the principal
296 72-h cohort has approximately twice the basin RI occurrence. This result is descriptive and is
297 bounded by the fact that the detector and outcome both derive from intensity evolution.

298 The comparator materially changes the interpretation. Simple five-advisory persistence also
299 stratifies RI and produces stronger tested fit in the shared-sample duration-controlled model. The
300 three-window state is therefore useful as a selective common-direction consensus reference, but
301 the evidence does not support broad claims of improved discrimination, additional information
302 beyond persistence, or superior upper-tail behavior.

303 From a forecasting-method perspective, the comparison provides a cautionary result: descriptive
304 enrichment from an intensity-history diagnostic should not be interpreted as added predictive
305 information unless it improves on simpler persistence under common samples and appropriate
306 controls.

307 The signed timing result also narrows the contribution. Confirmed activation was not generally
308 an advance RI marker; among storms with both times, the median confirmation followed RI
309 onset by 24 h. The state can still describe lifecycle state behavior and episodes, but it should not
310 be presented as early warning.

Block shuffling shows how much apparent enrichment can be retained or increased when autocorrelated intensity sequences are preserved locally while their broader order is changed. Other null families attenuate the statistic because they disrupt different relationships. Family-specific results, rather than a global significance narrative, are the appropriate interpretation. Environmental and duration conditioning further indicate overlap with persistence, storm lifetime, and the tested environmental covariates. The analyses reported here do not establish incremental environmental association or information uniquely attributable to occupancy beyond duration. Independent physical observations could later test whether this VMAX reference aligns with storm structure, but such modalities do not inherit validation from the present analysis. Taken together, these negative and restricted findings define the role of the VMAX-only reference. Simple five-advisory persistence produced stronger tested fit, V2 confirmation was not generally early relative to RI onset, and incremental association beyond the tested environmental formulation was not established. Future studies using microwave, precipitation, lightning, wind-field, or other independent observations should therefore evaluate whether those measurements provide stable, causally available, held-out information beyond VMAX persistence and lifecycle history on a common eligible sample. The present analysis supplies that temporal-only control; it does not imply that any physical modality will necessarily add information.

7. Limitations

- VMAX and the RI label both derive from best-track intensity evolution, limiting claims of independence.
- HURDAT2 contains observing-era inhomogeneity, especially before aircraft and satellite coverage.
- The horizons are nested and correlated; they are not independent physical scales.
- The analysis materialization contains 6-h within-storm transitions; V2 does not apply a separate elapsed-time gap test.
- Episodes include isolated and fragmented behavior rather than uniformly clean state changes.
- The simple five-advisory comparator has stronger tested model fit than the three-window state.

- Confirmed activation is not generally an advance RI marker.
- Upper-tail threshold cohorts lose sample rapidly, widening uncertainty.
- Duration and environmental covariates overlap with occupancy, and incremental association was not established in the analyses reported here.
- All relationships are observational and do not establish causation or direct physical-structure retrieval.
- Retrospective best-track products are not equivalent to real-time operational inputs.

8. Conclusion

The V2 temporal-coherence construct provides one reproducible, forward-only VMAX lifecycle-state reference with explicit same-direction confirmation, reversal reset, and no retrospective first-advisory backfill. Its cumulative occupancy descriptively stratifies historical Atlantic event-ever RI occurrence and supports controlled episode, comparator, timing, null, and conditioning analyses.

The evidence does not establish superiority to simple persistence, a physical mechanism, predictive skill, environmental independence, or general RI lead time. The appropriate use is as a bounded benchmark for future studies using independent observational information.

9. Data availability and reproducibility

The Atlantic hurricane database (HURDAT2) is publicly available from the National Hurricane Center (<https://www.nhc.noaa.gov/data/>). Code, reproducibility materials, and derived data supporting the temporal-coherence diagnostic are archived at Zenodo (DOI: <https://doi.org/10.5281/zenodo.21911306>). All detector operations proceed sequentially using current and prior observations. The V2 reproducibility package fixes the construct definition, 54,174-row analysis sample, RI definition, and table and figure source data. Reproducibility materials include machine-readable data, receipts, and a clean-room replay (Peng 2011).

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