CSL — A Compact Guardrail for Time■Series Instability

What it is

The Coherence Shift Law (CSL) is a simple, interpretable detector for regime instability in univariate time series. It flags windows where multiple properties change together—variance ↑, short■term persistence ↑, and spectral entropy ↓—which are the periods where forecasts, controls, and heuristics are most brittle.

What it is not

CSL does not predict exact event dates (e.g., precise troughs). Use it as an early■warning and governance signal, not as a point■forecasting model.

Minimal recipe (replicate in <50 lines)

1. Input: a regularly sampled univariate series x(t) (e.g., monthly).
2. Sliding window (e.g., 48 samples). For each window: compute an instability proxy $\alpha(t)$ via a simple, robust transform (see below).
3. Form two components on $\alpha(t)$: Level $L(t) = [\alpha(t) - \text{median\_13m}(\alpha)]$■, Slope $S(t) = [\alpha(t) - \alpha(t-12)]$■ (positive parts).
4. Composite score: $CSL(t) = L(t) \times S(t)$.
5. Online thresholding (budgeted): set the alert threshold to the $(1 - p)$ quantile of past CSL values, with $p \approx 12/60$ for monthly data (≈12 alerts per 5 years). Emit alert when CSL(t) exceeds this threshold.

A simple $\alpha(t)$ (instability proxy)

Any proxy that strengthens under non■stationarity works. Two easy options:

- Variance■ratio proxy: α■(t) = rankpct[Var(x, 6) / Var(x, 24)], computed per window.
- Coherence■tilt proxy (the version used in our tests): within the window, split into equal sub■segments of length $L \in \{6,12\}$; compute $\kappa(L) = \text{Var}(\Delta x)$ per sub■segment; fit $\log \kappa(L) \approx a + b \log L$; set α■(t) = 1 – b. Intuition: when short■horizon variability inflates relative to long■horizon structure, α■ rises.

Interpretability probes (attach to each alert)

Probe	How to compute (rolling)	Alert■side expectation
Var(6m)	Variance over 6 samples	↑ (elevated short■horizon variance)
VarRatio(6/24)	Var(6) / Var(24)	↑ (short over long variance)
AC(1)	Lag■1 autocorrelation	↑ (stronger persistence)
Ljung–Box proxy	–log10 p■value at small lags	↑ (rejects whiteness)
Spectral entropy	Shannon entropy of normalized periodogram	↓ (spectrum concentrates)
Band power	Power in 6–14m and/or 14–36m bands	↑ (band emphasis)

How to threshold (budgeted alerts)

Maintain a rolling quantile of past CSL values. For monthly data, p ≈ 12/60 produces ≈12 alerts per 5 years. Warm■up with ~36 months of history before triggering alerts. This keeps alerts sparse and avoids alert floods.

Where CSL shines

- Risk gating & governance: widen CIs, require human sign■off, or switch to robust losses during alerts.
- Adaptive retraining: trigger retrains or hyper■param refresh only when CSL stays elevated.
- Observability triage: send analysts to ‘why now?’ with the probes above for each alert.
- Scientific ‘change hunting’: flag likely regime transitions (ENSO, solar, hydrology) for study.

Validation (summary of evidence)

Across Sunspots and ENSO, CSL alerts consistently align with non■stationary windows where VarRatio rises, AC(1) increases, spectral entropy dips, and mid/long band power increases. CSL is best treated as an early■warning guardrail; it is not a precise trough■date predictor.

Limits & good practice

- Not a point■event forecaster. Don’t use CSL to call exact tops/bottoms.
- Pair with a simple variance alarm (Var(6), VarRatio) for best coverage at equal alert budget.
- Calibrate by domain: window size, bands, and alert budget should match the sampling and dynamics.

Quickstart checklist (for adopters)

1. Pick a cadence (e.g., monthly) and a window (e.g., 48 samples).
2. Compute $\alpha(t)$ (variance■ratio or coherence■tilt).
3. Build CSL(t) = Level × Slope on $\alpha(t)$.
4. Use online rolling quantile to set the alert threshold (budgeted).
5. For every alert, record the probes (Var(6), VarRatio, AC(1), Ljung–Box, entropy, band power).
6. Act conservatively during alerts; evaluate downstream wins (fewer bad deploys, better calibration).

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