ARF • One-Pager (v1.6) — RI Nowcast & Preregistration

Core statement (one line). *Pre-resonant air volumes*—coincident **IR heating band (850–600 hPa)**, **nocturnal OLR minimum**, and elevated PCI⋆—increase **RI probability** beyond classical predictors.

Operational decision rule (Nowcast gate). Activate a **12–24 h RI window** in the **inflow sector** only if all three hold:

1. PCI⋆ $\geq$ Q90 (basin/season normalized),
2. **IR fingerprint** present: IRB $= \max_{p\in[850,600]\ \mathrm{hPa}} \left(\frac{\partial T}{\partial t}\right)_{\mathrm{rad}}$ [K/d],
3. **OLR minimum** during **nighttime (00–06 LT)**.

Post-ERC: Re-intensification is more likely when $\mathrm{AOD}_{\mathrm{IR}}$ persists in a 50–150 km inflow ring.

Inflow geometry (for diagnostics & skill tests).

$$\mathcal{S}_{\mathrm{inflow}}(t) = \{\mathbf{x}:\ r \in [100, 300]\ \mathrm{km},\ \angle(\mathbf{v}_{\mathrm{env}},\ \mathbf{x}-\mathbf{x}_{\mathrm{storm}}) \in [-60^\circ, 60^\circ],\ p \in [925, 700]\ \mathrm{hPa}\}, \quad \Delta t = 6\text{–}18\ \mathrm{h}.$$

Negative control (SAL "dust lid"). Flag *damping* if, within the inflow, **Dust-AOD > Q85** *and* **mid-level RH < Q25** (quantiles computed on *training only*). Expected ordering: BC/VOC > clean > SAL.

Preregistered tests (excerpt T1–T6).

- **T1 Added skill:** out-of-sample ΔAUC (ARF vs. strong baseline) ≥ 0.05; Brier↓, logLik↑.
- **T2 IR fingerprint:** IRB peak *leads* RI by 6–18 h (composites/lead–lag).
- **T3 Diurnality:** nocturnal OLR minimum co-located with heating-rate peak.
- **T4 ERC hazard:** Cox HR > 1 with persistent $\mathrm{AOD}_{\mathrm{IR}}$ in inflow.
- **T5 Negative control:** ordering BC/VOC > clean > SAL holds.
- **T6 Ablation (PLF):** *monotonic* skill gain from PCI → PCI⋆ across PLF quantiles.

Synergy criterion ("resonance").

$$S = \mathrm{AUC}(\mathrm{PCI}^\star + \mathrm{IRB} + \mathrm{OLR}) - \max\{\mathrm{AUC}(\text{any pair})\}, \qquad \text{expect } S > 0 \text{ with 95\% bootstrap CI.}$$

Minimal "offline test" package (for ops/modeling groups).

- **Inputs:** ERA5 (T, radiative heating tendency or proxy, RH, p), OLR (satellite/proxy), AOD (MODIS/VIIRS/TROPOMI), IBTrACS track. *Optional:* GLM/LIS lightning for the electrical facet.
- **Thresholds:** Q90 for PCI⋆; SAL mask Q85/Q25 (train-only); night window 00–06 LT.
- **Outputs:** ΔAUC, Brier change, reliability, Cox-HR, and S (synergy).

Definitions. $\mathrm{PCI}^\star = \mathrm{norm}_{[0,1]}(\mathrm{PCI}\cdot(1+\mathrm{PLF}_{\mathrm{total}}))$; $\mathrm{AOD}_{\mathrm{IR}}$: infrared-absorbing AOD (dimensionless).

Provenance & use. Hypothesis & design paper; **figures are illustrative/synthetic**. Drop-in hooks (WRF/ICON) and YAML configs via Zenodo: DOI. Preregistered protocol via OSF: DOI. AI used as synthesis tool, not as author.

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