Status Report: Dynamic Critical Richardson Number (Ri_c*)

For: R. McNider & A. Biazar
Date: November 19, 2025

Purpose

Summarize current understanding (Ri.md material received), and request focused contributions from McNider (physics, mixing-length path) and Biazar (operational K-path, model integration) to develop, calibrate and validate a practical dynamic Ri_c* for hybrid MOST/Ri closures.

Current status (brief)

- Ri curvature and neutral invariant Δ documented; Jensen bias (bulk vs point) identified and quantified.
- Proposed hybrid strategy: use Ri_c* as regime classifier with MOST below and Ri-based closures above; blend/hysteresis specified.
- Prototype formula and pseudocode exist in the repository (dynamic_Ric_strategy.md / dynamic critical notes).

Requested contributions (clear asks)

McNider (physics lead)

- Derive/justify physically motivated form(s) for Ri_c*(t) using inversion strength, shear and turbulence memory; propose candidate functional forms and plausible coefficient ranges.
- Develop mixing-length modification functions $l^*(Ri, Ri_c^*)$ (examples: $l/(1 + a_l(Ri/Ri_c^*)^n)$). Provide analytic limits to preserve neutral curvature 2Δ.
- Lead slope/terrain and intermittent turbulence tests (CASES-99, GABLS3-like LES); provide diagnostics and thresholds for hysteresis (Ri_suppress/Ri_restart).

Biazar (operational lead)

- Prototype a multiplicative diffusivity path $K^* = K \cdot g_K(Ri, Ri_c^*)$ (exponential or power-law), implement in a small test branch of CMAQ/WRF or in the provided Python prototype.
- Assess computational cost, backward compatibility, and namelist options; prepare guidance for WRF/CMAQ insertion points and necessary regression tests.
- Lead air-quality impact experiments (urban case studies) to quantify sensitivity of nocturnal pollutant trapping to Ri_c* tuning.

Data and benchmarks

- Tower: SHEBA, ARM SGP, Cabauw (recommended for tuning $\alpha_\Gamma, \alpha_S, \alpha_T$).
- LES: GABLS suite (GABLS1–3) for "truth" curvature and regime timing.
- Urban: Dallas/DFW remote-sensing + tower for air-quality metrics.

Algorithm sketch

1. Compute local diagnostics: $Ri_g(z_g)$, Ri_b, curvature $\partial^2 Ri_g/\partial\zeta^2$, TKE (or proxy).
2. Compute Ri_c*:
$$Ri_c^* = Ri_{c,0}\Big[1 + \alpha_\Gamma \frac{\Gamma}{\Gamma_{\text{ref}}} + \alpha_S \frac{S}{S_{\text{ref}}} + \alpha_T \frac{\text{TKE}_{\text{prev}}}{\text{TKE}_{\text{ref}}}\Big]$$
with optional curvature term $\alpha_{\text{curv}}|\partial^2 Ri_g/(2\Delta)|$.
3. Regime logic: MOST if $Ri < 0.7Ri_c^*$; blend if in band; Ri-closure if $Ri > 1.3Ri_c^*$; hysteresis on/off per prior state.
4. Choose intervention: mixing-length reduction (McNider) or K-multiplier (Biazar). Preserve 2Δ by enforcing $G(0) = 1$ and $G'(0) = 0$.

Validation metrics and targets

- Bias ratio B reduction: target 40%+ reduction at $\Delta z = 60$–$100\,\text{m}$.
- Surface flux RMSE reduction (tower/LES): target <10–15 W m^{-2} improvement.
- Regime classification accuracy vs manual/LES labels: >85%.
- Computational overhead: <5% for operational module.

Timeline (proposed)

- 0–2 weeks: diagnostic runs and compute Ri_c* statistics from archived WRF/LES outputs (Biazar assist with I/O).
- 2–8 weeks: McNider proposes candidate Ri_c* forms and l_mod functions; Biazar implements K-path prototype in Python/CMAQ branch.
- 8–20 weeks: calibration (Bayesian/optimization) on selected datasets; offline 1D column tests and LES comparisons.
- 20–36 weeks: integrate into WRF/CMAQ, regression tests and case studies; prepare manuscript and code release.

Deliverables

- Parameterized Ri_c* functional forms (analytic + code).
- Two intervention modules: (A) mixing-length updater; (B) K-multiplier — both with unit tests preserving 2Δ.
- Validation report: tower/LES/urban case studies and computational-cost assessment.
- Draft manuscript for BLM/MWR and GitHub release with examples and namelist options.

Immediate next steps for you (one-line)

Please confirm which intervention (mixing-length first vs K-multiplier first) you prefer to prototype; McNider to deliver physics forms, Biazar to prepare operational hooks — target diagnostic runs in 2 weeks.

Respectfully,
Project lead (contact in repo)