

## Introduction — (State-Space Basis, Five-Minute-Ahead Prediction)

“Momentum” in soccer is often debated. We take an operational view and define flow as a latent state accumulated by events: when the team in possession produces events, the state updates; when the opponent has the ball, the state only predicts forward (natural decay). Because each team’s flow can diverge within the same match, we enforce a frame-level team-separated *Duel-stream* update so that updates/predicts are cleanly split by team. We regard flow as *measurable* if it yields additional out-of-sample predictive power *five minutes ahead* for xT/xG/possession.

## Methods —

Using public data (292 matches), we build multi-view features on attack (line-breaking passes, Zone-14/box entries, sequence metrics, etc.) and defense (gap/line-gap, defensive success, blocks/clearances, etc.). We fit a local linear state-space model with exogenous inputs and strictly apply the team-separated *Duel-stream* update at every frame to prevent cross-team leakage. OLS serves as the baseline. Our primary criterion is five-minute-ahead OOS RMSE. The split is a deterministic 80/20 rule by match id, and audit logging verifies the frame-level update/predict separation.

## Results —

Across six panels, the state-space model consistently reduces OOS error vs. OLS for five-minute-ahead forecasting (e.g., attack-xT 0.1386→0.1175 (−15.3%), attack-xG 0.1637→0.1497 (−8.6%), defense-xT 0.1273→0.0997 (−21.7%), defense-xG 0.1485→0.1359 (−8.5%)), while improvements for possession (hold) are small (~0.3%). Coefficient signs align with domain knowledge (e.g., positive for line breaks and deep-zone entries; negative for off-post misses). Audit snippets confirm the team-separated *Duel-stream* update on each frame.

## Conclusion —

This study models momentum as a measurable latent flow, prevents cross-team contamination via a team-separated *Duel-stream* update, and delivers practical five-minute-ahead gains on xT/xG using public data.

Limitations include modest signal sizes and limited gains for possession. We outline follow-ups—placebo and label-swap tests, window-length sensitivity, and integration of tracking-derived pressure/vision options.

In short, within a state-space framing, flow can be measured and it improves prediction.