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Hybrid AI-Physics Calibration of a 1D Fog Model: Improving Near-Surface and Visibility Forecasts at a Moroccan Airport

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Fog and low stratus forecasting remains a challenge due to the high sensitivity of these phenomena to boundary layer processes. One-dimensional models, such as COBEL–ISBA, offer physical consistency but often lead to systematic errors in key surface variables. This work proposes a novel hybrid calibration framework combining physical modeling with machine learning (ML) to correct COBEL–ISBA forecasts at Nouasseur Airport, Morocco. Using two winter seasons of model outputs and SYNOP observations, we calibrate five variables (2-m temperature and humidity, 10-m wind components, visibility) for each forecast run and lead time (0–12 h).

Two ML architectures are tested: direct correction (ML–COBEL) and residual-learning approach (ML–Phys) using Random Forest and XGBoost. For visibility, a two-stage classification-regression model is implemented, and an oversampling technique is used to address class imbalance. Results are benchmarked against classical bias correction and quantile mapping.

The ML–Phys approach outperforms traditional methods across all variables and lead times, reducing errors (bias, RMSE) while preserving observed temporal variability. Furthermore, it improves also low-visibility event detection. In contrast, traditional methods show limited skill, often degrading beyond short lead times. This work demonstrates the potential of hybrid AI-physics strategies to mitigate 1D model limitations, providing a path toward more reliable operational fog and visibility forecasting.