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## SHORT ABSTRACT

***Abstract title: Improving Air-Pollution Dispersion Forecasts with a Hybrid Physical–Machine-Learning Approach***

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## Abstract text *(maximum 350 words.)*

FAPPS (Forecasting of Air-Pollution Propagation System), created at the Polish Institute of Meteorology and Water Management – National Research Institute, produces air-pollution forecasts for the Małopolskie voivodeship and, specifically, the city of Kraków in southern Poland. It predicts concentrations of PM10, PM2.5, $NO_2$ and $SO_2$.

FAPPS is based on the AROME/WRF/CALMET/CALPUFF model chain. Over the years the system has been improved, for example by updating the emission inventory and replacing the unsupported MM5 meteorological core with WRF (Weather Research and Forecasting Model).

Within FAPPS, AROME supplies initial and boundary conditions to WRF, a mesoscale weather-prediction model. CALMET adjusts wind speed and direction to the orography, while CALPUFF, a Lagrangian puff model, simulates pollutant dispersion. Modelling is carried out in three nested domains: central and southern Poland (resolution 50 km), Małopolska (5 km) and Kraków (1 km).

This work shows how machine-learning techniques can further improve physics-based dispersion modelling. In the proposed hybrid approach, CALPUFF output concentrations are combined with additional predictors (such as mixing-layer height and wind speed) and compared with air-quality measurements to detect and correct model bias. Ensemble methods, including Random-Forest and Gradient-Boosting regressors, are used for bias correction, while a Long Short-Term Memory (LSTM) recurrent neural network introduces time-series-based adjustments.

Data from 2021–2023 are used to train the models, and 2024 serves as the independent test year evaluated with the Delta-tool program.

The study highlights the benefits of a hybrid approach that integrates physical modelling with machine-learning methods for short-term air-pollution forecasts at both urban and regional scales.