

**23rd International Conference on  
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**EXTENDED ABSTRACT**

***Assessing Microscale Dispersion of PM<sub>10</sub> under Different Meteorological Conditions in Prague Street Canyons with GRAMM/GRAL: Impact of Model Setup***

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**Abstract:** The dispersion of PM<sub>10</sub> was studied in an area enclosing part of the city centre of Prague, characterized by the presence of street canyons and congestion. Different configurations of the GRAMM/GRAL model were tested under selected episodes which covered summer and winter 2022–2023. It was observed that the implementation of advanced techniques such as the “match-to-observation” method and the transient mode increased the accuracy of the model. However, the correlation coefficient was moderately low, particularly during summer. The analysis of the time series of concentrations revealed a high influence of transitions from stable to neutral or unstable atmospheric conditions and low wind speeds.

**Keywords:** *Lagrangian modeling, microscale, air quality, urban pollution, particulate matter*

## **Introduction**

The hazardous effects of air pollution on human health remain a serious concern in many European cities. A considerable percentage of the population is exposed to harmful concentrations of particulate matter, especially in areas with high traffic density. Urban geometry is a critical factor in this issue as congested roads may be flanked by tall buildings on either side, causing a rise in pollutant accumulation at ground level. The large concentration gradients and temporal variability in these hotspots cause difficulties when estimating the exposure of pedestrians and cyclists. For this reason, reliable tools are needed to understand microscale phenomena appropriately.

The current study aims to demonstrate the performance of the GRAMM/GRAL system simulating dispersion of PM<sub>10</sub> in the vicinity of the Sokolská and Legerova boulevards in Prague, Czech Republic. Six episodes lasting 3 to 4 days within the period 2022–2023 were selected to represent summer and winter conditions according to the occurrence of extreme situations, such as: high concentration of pollutants, heat waves and temperature inversions. In this way, multiple configurations of the model could be tested with low computational demands. Statistical metrics were implemented to compare the results of the model applying the “match-to-observation” method and transient mode, against the standard steady-state simulation. The objective was to determine the sensitivity of the model to meteorological pre-processing and calculation approach.

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## **Methodology**

### **Data collection**

Meteorological parameters were acquired from Karlov (P1PKAR01) for the following episodes: 17–19.07.22, 2–5.08.22, 22–24.09.22, 8–10.12.22, 27–29.01.23, 13–15.02.23. Pollutant concentrations were obtained using a network of low-cost air quality sensor (LCS) units, most placed in pairs at different heights on the facades of the buildings, and measurements from permanent air quality monitoring stations: AREPA, ARIEA (urban), and AKALA, ALEGA (traffic). Measurements from suburban background air quality stations (ACHOA, AKOBA, ALIBA, ASTOA) located in the surroundings of the model domain (Figure 1) were processed to build a time series of the median value and set the boundary conditions for the calculation of the final concentrations.

The sources modelled include road traffic, railways, river shipping, and residential heating. Resuspension emissions were neglected given that the method implemented seemed unreliable according to the previous results (Patiño et al., 2024). A complete report on the acquisition of data and time disaggregation is available in Bauerova et al. (2025) and Resler et al. (2024).

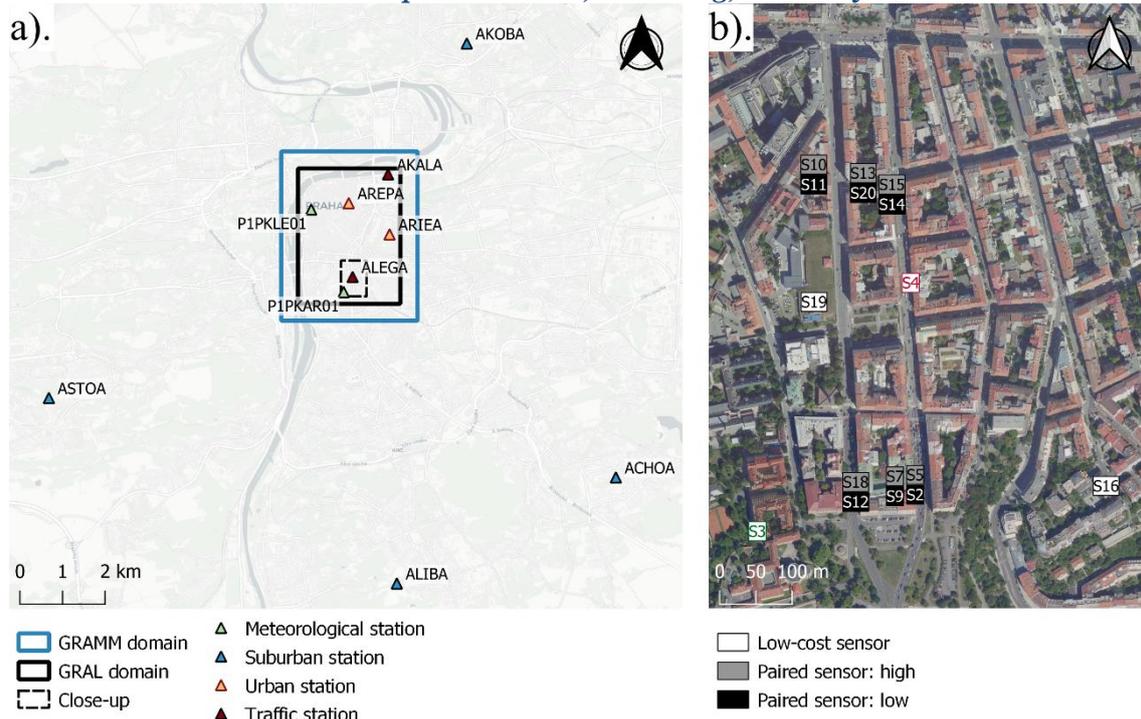
### **Model configuration**

The mesoscale model domain GRAMM had an extension of 3200 m × 4000 m, with a horizontal resolution of 50 m. The internal-flow field and concentration grids covered an extension of 2400 m × 3200 m with a horizontal resolution of 2 m for steady-state simulations and 4 m for transient simulations.

Meteorological input is composed of a time series of wind speed, wind direction, and Pasquill-Gifford stability class. Oettl et al. (2020) suggested a scheme based on the so-called SRDT method (solar radiation/delta-T) to derive the stability classes using the surface layer wind speed in combination with the total solar radiation during the day, and the temperature gradient at night. Daytime and nighttime were distinguished using a threshold of 20 W/m<sup>2</sup> for solar radiation.

The standard steady-state mode computes stationary concentration fields for classified weather situations, independent from the dispersion time. Nevertheless, the “match-to-observation” strategy is recommended to counter the large uncertainties in GRAMM computed flow fields. The application of this method consists in the calculation of every possible wind field using an artificial wind rose as input, so then, the procedure selects the best-fitting simulation to a set of observations at any location within the model domain. The current study implemented this algorithm using a catalogue of 1764 weather situations, matched to the observations at Karlov (P1PKAR01) and Klementinum (P1PKLE01). On the other hand, inaccuracies can be derived from assuming steady-state, therefore, the transient mode was also tested to improve the estimation of concentration time series. In this case, the particles are released and tracked together with newly emitted particles from following meteorological situations.

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**Figure 1.** (a) Extent of GRAMM and GRAL domains, location of meteorological and air quality stations. (b) Area of interest (black dashed-border) with the location of low-cost sensors (LCS).

## Results and discussion

The assessment of the different model configurations was carried out using statistical metrics such as the fraction of values within a factor of 2 of the observations (FAC2), fractional bias (FB), normalized mean square error (NMSE), root mean square error (RMSE), and correlation coefficient (R). Table 1 shows the results using the whole dataset, and also filtered by type of location and season. Boundary conditions were assessed as well to be able to compare against a reference value. Statistics proved a better performance of the model when the transient mode was implemented, especially for receptors located in traffic areas and during the winter episodes. On the other hand, the “match-to-observation” method generally provided improved values for mean squared errors and correlation coefficient compared to the standard steady-state mode. Every model setup demonstrated prediction capabilities that exceeded the use of boundary conditions, except in matters of correlation. This issue stemmed from irregular patterns in the hourly averaged time series, which were also identified in Patiño et al. (2024).

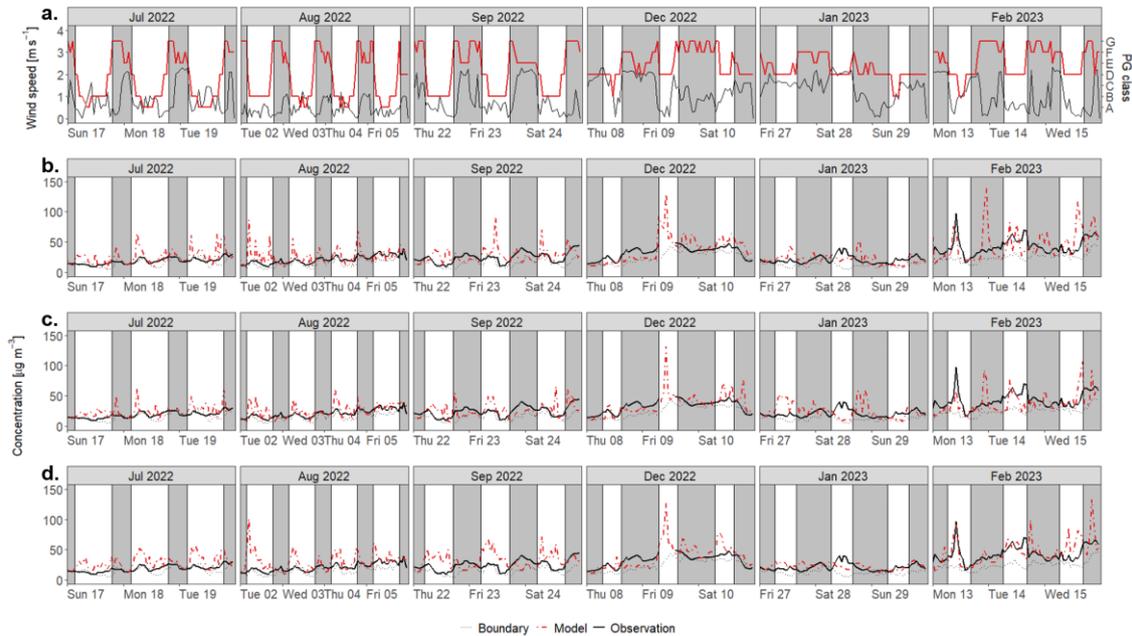
Thus, Figure 2 illustrates a comparison of the different simulation strategies including the time series of wind speed and stability class for ALEGA station, which is located within the bounds of Legerova street canyon. The plots of the advanced techniques show a slight improvement in the adjustment of hourly averages to the observation patterns, reducing the concentration peaks that appeared in the standard steady-state mode. These anomalies were more frequent in the summer episodes and seemed to be associated with changes in the atmospheric stability from stable to unstable conditions and sudden drops of wind speed below 0.5 m/s.

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**Table 1.** Statistical performance metrics. The best results for each group are highlighted in blue.

Class*	Model	FAC2	FB	NMSE	RMSE	R
Boundary		0.745	0.376	0.344	12.764	0.649
Steady-state		0.846	0.083	0.254	12.716	0.547
“Match-to-observation”		0.843	0.125	0.243	12.192	0.559
Transient		0.857	0.059	0.236	12.406	0.551
Background	Boundary	0.838	0.284	0.229	9.932	0.719
	Steady-state	0.863	0.181	0.203	9.859	0.658
	“Match-to-observation”	0.855	0.208	0.205	9.776	0.671
	Transient	0.868	0.195	0.185	9.352	0.695
Roof	Boundary	0.832	0.134	0.194	8.484	0.656
	Steady-state	0.840	0.110	0.184	8.350	0.662
	“Match-to-observation”	0.834	0.113	0.186	8.399	0.658
	Transient	0.840	0.109	0.184	8.361	0.658
Traffic	Boundary	0.696	0.439	0.399	14.217	0.650
	Steady-state	0.839	0.050	0.268	14.183	0.487
	“Match-to-observation”	0.840	0.101	0.254	13.471	0.500
	Transient	0.855	0.013	0.247	13.890	0.483
Summer	Boundary	0.761	0.299	0.315	10.245	0.392
	Steady-state	0.834	0.002	0.285	11.317	0.318
	“Match-to-observation”	0.840	0.048	0.255	10.453	0.337
	Transient	0.842	-0.041	0.280	11.463	0.308
Winter	Boundary	0.727	0.442	0.347	15.166	0.713
	Steady-state	0.859	0.155	0.226	14.164	0.603
	“Match-to-observation”	0.848	0.193	0.227	13.937	0.601
	Transient	0.875	0.148	0.201	13.415	0.633

\*The stations were grouped as follows: AREPA, ARIEA, S19 and S9+S7 (background); S3 and S16 (roof); and AKALA, ALEGA, S4, S11+S10, S20+S13, S14+S15, S12+S18, and S2+S5 (traffic). Sensor pairs are denoted by a plus sign, the lower one is indicated first. Summer: 17–19.07.22, 2–5.08.22, 22–24.09.22. Winter: 8–10.12.22, 27–29.01.23, 13–15.02.23.



**Figure 2.** (a) Times series of wind speed (black) and PG stability class (red), and predicted concentrations of PM<sub>10</sub> using (b) steady-state mode, (c) “match-to-observation” method and (d) transient mode in ALEGA station.

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The most noticeable peak, common in the three setups evaluated, was registered on 9.12.2022 before noon. Unfortunately, there were no available measurements from the monitoring station at the time, but S4 which was located right next to the station did not perceive such an increase, so it could be assumed that the peak was caused from a drastic decrease of wind speed, at the same time that the stability changed from extremely stable to neutral.

### **Conclusions**

The statistical evaluation of the model performance using different setups gave satisfactory results over the distinct types of receptor and seasons, complying with FAC2 above 0.8, FB below 0.2 and NMSE under 0.3. The implementation of transient mode showed better statistics in general. Although, there was a clear flaw in the summer episodes, where overestimation was evident and the correlation coefficient was the lowest. The analysis of the time series revealed that this behavior corresponded to the presence of extreme peaks originated from changes of the stability class and low wind speeds.

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