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Assessing Microscale Dispersion of PM_{10} under Different Meteorological Conditions in Prague Street Canyons with GRAMM/GRAL: Impact of Model Setup

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Introduction

The current study aims to demonstrate the performance of the GRAMM/GRAL system simulating dispersion of PM_{10} in the vicinity of the Sokolská and Legerova boulevards in Prague, Czech Republic (Fig. 1). 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. Statistical metrics were implemented to compare the results of the model run with 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.

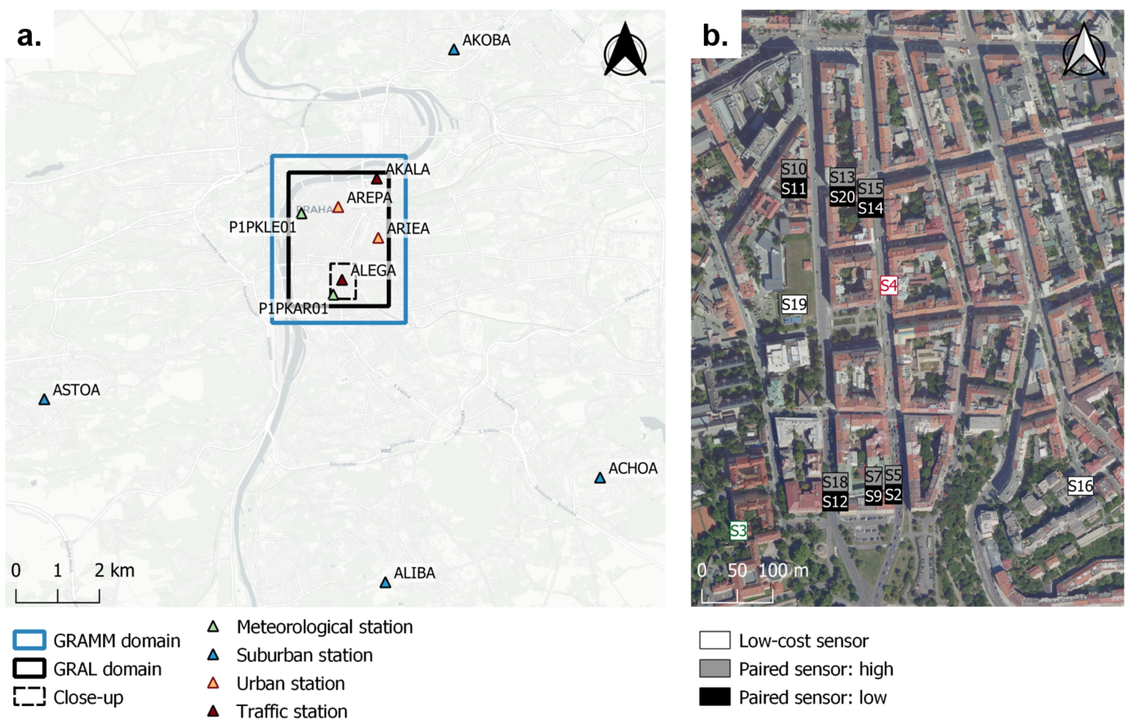

Fig. 1. (a) Extent of GRAMM and GRAL domains, location of meteorological and air quality stations. (b) Close-up area with the location of low-cost sensors.

Methodology

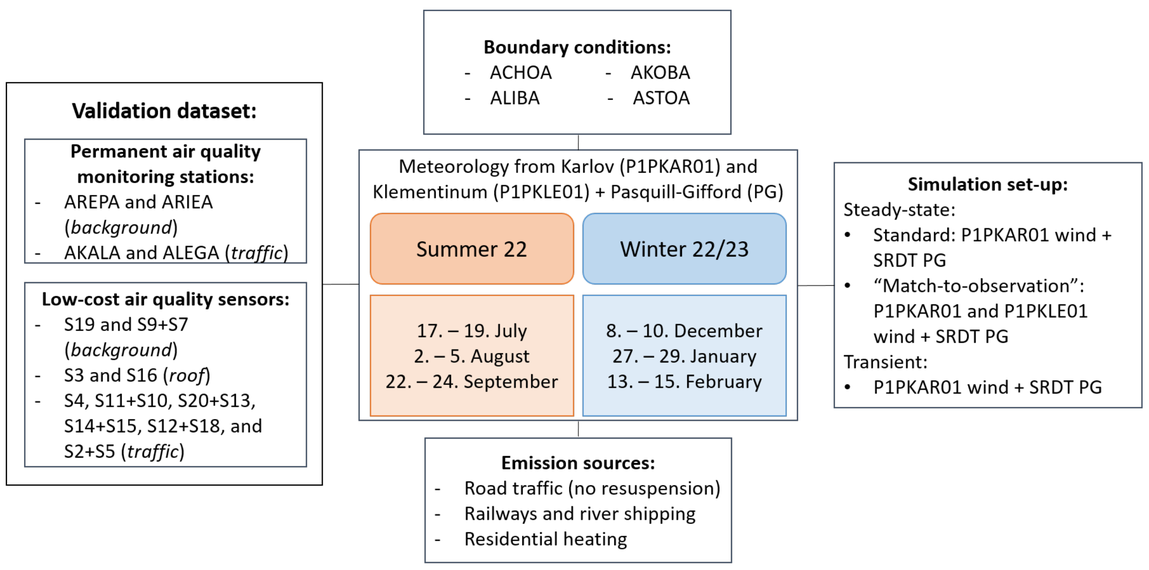

Fig. 2. Input parameters for the six episodes selected and simulation set-up.

The standard steady-state mode computes stationary concentration fields for classified weather situations, independent from the dispersion time. 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 within the model domain. On the other hand, in the transient mode particles are released and tracked together with newly emitted particles from following meteorological situations.

Results and discussion

The assessment of the different model configurations was carried out using common statistics and Taylor diagrams. Boundary conditions were also included as a reference. Performance metrics in Tab. 1 proved a better performance of the model when the transient mode was implemented, especially for receptors located in traffic areas (Fig. 3). On the other hand, the "match-to-observation" method generally provided improved values for standard deviation, root mean squared error and correlation coefficient. 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.

Fig. 4 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. These anomalies were more frequent in the summer episodes and seemed to be associated with changes in the atmospheric stability to unstable conditions and sudden drops of wind speed below 0.5 m/s.

Tab. 1. Statistical performance metrics. Best results are highlighted in italics.

Simulation mode	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

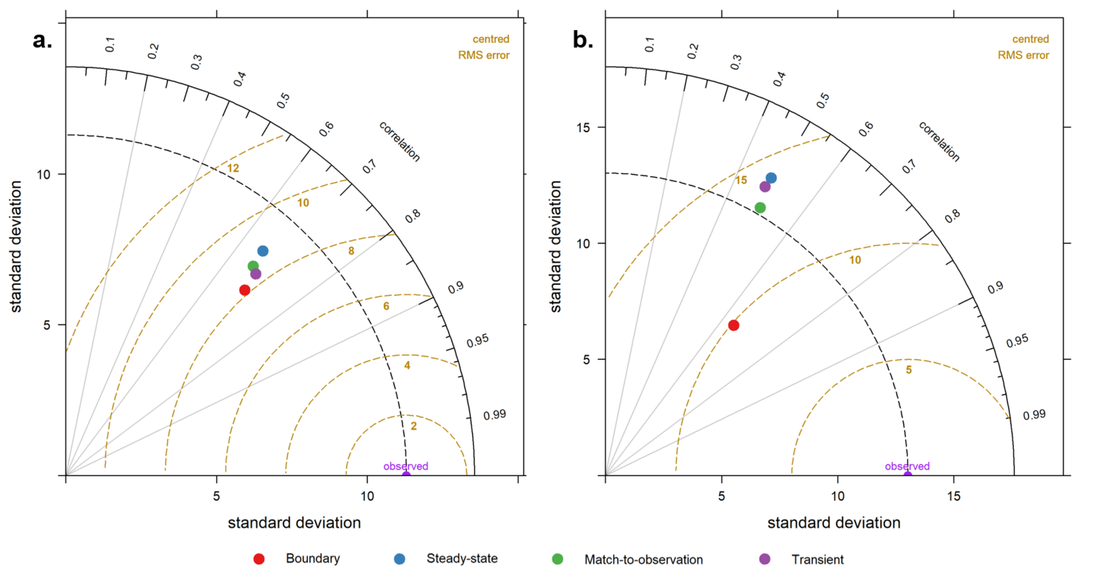

Fig. 3. Taylor diagram for (a) background and roof receptors, and (b) traffic receptors.

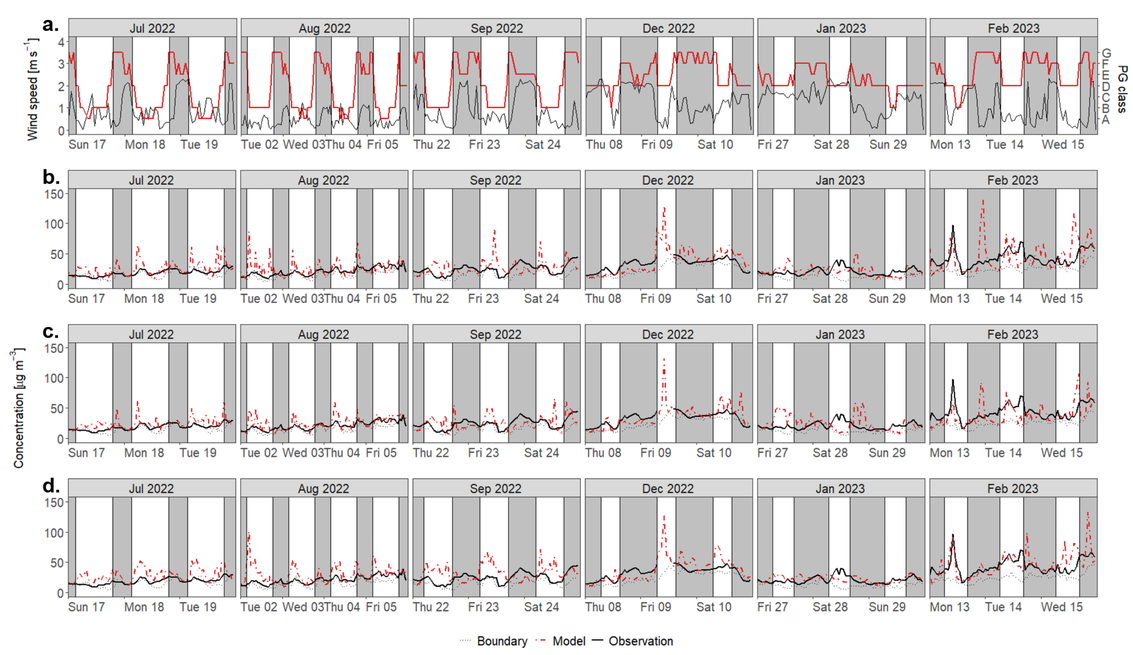

Fig. 4. (a) Time series of wind speed (black) and PG stability class (red), and predicted concentrations of PM_{10} using (b) steady-state mode, (c) match-to-observation method and (d) transient mode in ALEGA station.

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. 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.

Acknowledgements

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